ND2016

11-16 / 09

BRUGES BELGIUM

PROGRAMME & ABSTRACT BOOK

www.nd2016.eu

Welcome

Dear colleagues,

Thank you very much for the enthusiasm you have shown to contribute to the ND2016 conference.

Together with our co-organizers the OECD-NEA and the IAEA, we from the European Commission's DG Joint Research Centre welcome you to ND2016.

On Sunday 11 September we kick-off in the historical provincial court "Het Provinciaal Hof" on De Grote Markt in Brugge (Bruges) with registration from 16:00 to 19:00 and a welcome drink with your partner at the reception from 17:00-19:00.

On Monday 12 September we start the conference with the keynote opening session in the concert hall "Het Concertgebouw" on 't Zand in Brugge. A stimulating view on future needs and main developments of interest to our field will be provided by the DDG of the European Commission's Joint Research Centre, Maive Rute, the DG of the OECD Nuclear Energy Agency, William Magwood, the DDG of the IAEA and Head of the Department of Nuclear Sciences and Applications, Aldo Malavasi, the Scientific Director of the Nuclear Energy Division at the French Commission for Atomic and Alternative Energies (CEA), Frank Carré, the DG of the JAEA, Nuclear Science and Engineering Center, Shigeaki Okajima, the DDG of SCK•CEN, the Belgian Nuclear Research Centre, Hamid Aït Abderrahim and Enrico Chiaveri representing the DG of CERN. Registration will be open from 08:00 and the keynote session will start at 09:30.

Still at the Concertgebouw we will start the technical sessions on Monday 12 September at 14:00. On Monday evening at 18:00 you can enjoy a guided tour of Bruges, which is open to accompanying persons as well.

Technical sessions continue on Tuesday Morning 13 September at 08:30 at the Site Oud St Jan, Zonnekemeers in Bruges, at just a two minutes' walk from the Concertgebouw. Technical sessions continue at this venue until Friday 16 September 13:00. For those who missed the guided tour of Bruges on Monday evening a second opportunity is given Wednesday evening at 18:15.

You and your partner are kindly invited to the conference banquet at the Stadshallen under the Belfort on De Grote Markt, Thursday evening 15 September starting at 20:00. The conference photo will be taken at the start of this event in the court of this historic landmark.

We wish you a pleasant journey to Bruges and hope to see you there from Sunday onwards. For suggestions on how to reach Bruges please remember to consult the travel directions at our website www.nd2016.eu.

Enjoy the conference.

Arjan Plompen
Chair of the ND2016
organising committee.

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Organized by

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General and Practical Information

Venue and Dates

The ND2016 Conference will take place at the following locations:

Monday 12 September 2016
Keynote opening Session
Concertgebouw Brugge
Address: 't Zand 34, 8000 Brugge

Tuesday 13 September till Friday 16 September 2016
Technical Sessions
Conference Site Oud Sint-Jan
Address: (pedestrian) Mariastraat 38, 8000 Brugge
(vehicle) Zonnekemeers, 8000 Brugge

Registration and Information desk

The registration and information desk will be open during the whole congress as follows:

Opening hours:

Sunday, 11 September	16.00-19.00hrs
Monday, 12 September	08.00-17.30hrs
Tuesday, 13 September	08.00-18.30hrs
Wednesday, 14 September	08.00-18.30hrs
Thursday, 15 September	08.00-18.30hrs
Friday, 16 September	08.00-13.00hrs

Special Information Point

During the meeting:
Phone: +32 (0)9 233 86 60
Fax: +32 (0)9 233 85 97

House Rules

- The venue is a public non-smoking building. Those who need nicotine from time to time will find ashtrays in front of the main entrance.
- Switch off your mobile during sessions.
- When you take a cup, glass or plate into a room, please take it out as well.

Use of Internet

Wireless internet is available.
password: ND2016
network: Bruges

Lost and Found

For lost and found personal belongings, please contact the Information desk.

First Aid

In case of emergency, please contact the Information Desk.

Name badge

Your personal badge is your entrance ticket to all sessions and the exhibition. Please, remember to wear your badge at the congress center and the social events. If you lose your badge, a new one can be purchased against proof of your original registration, at a cost of 4.00 Euros.

Coffee breaks

Coffee/tea are included in the registration fee and will be served daily in the different levels and the poster exhibition area.

Banks and Post office

Most banks open at 09.00hrs and close around 16.00hrs Monday through Friday. They are generally closed for lunch between 12.00-14.00hrs. Post offices are open between 09.00 and 16.00hrs. Please, note that there will be no exchange facilities at the congress venue.

Climate and Dress

The Belgian climate is distinctly maritime and usually mild, and the city of Bruges is no exception to this. At this time of the year temperatures will be around 18-20°C. An umbrella might be useful as the most precipitation on average occurs in September. Dress will be business casual throughout the conference.

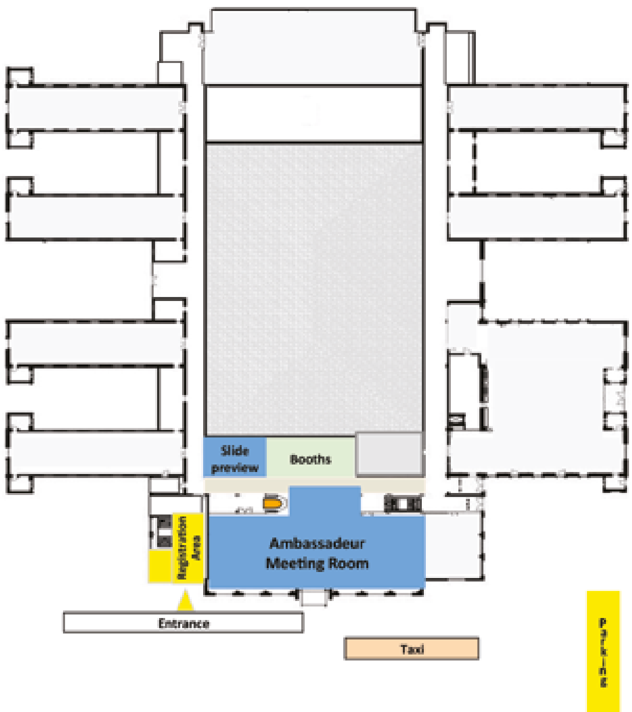
Electrical supply

Electricity is supplied at 220 volts, 50 Hz. Some hotels provide 110 volts AC sockets for electric razors only. For all other equipment, an adaptor/converter is necessary.

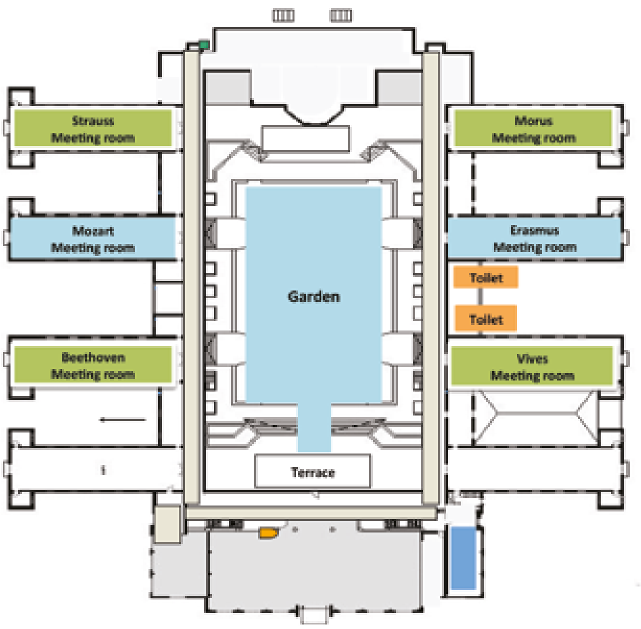
Insurance and Liability

The ND2016 Organization committees and Semico n.v. do not accept liability for personal medical expenses/ travel expenses/losses of whatever nature incurred by delegate

Level 0



Level 1



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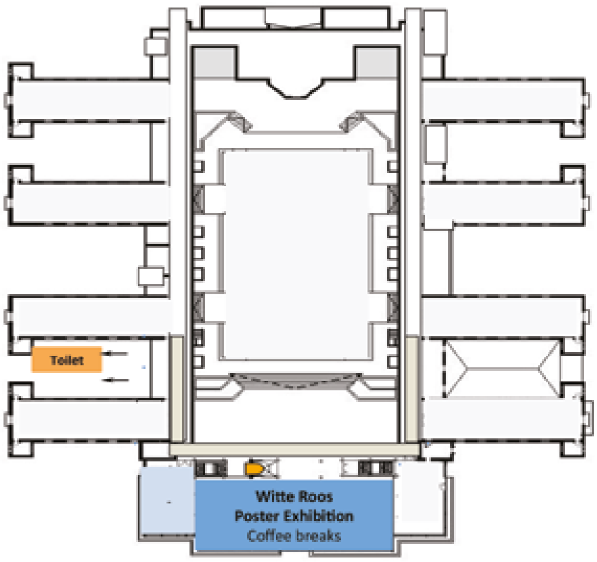

Social Programme

Welcome Reception (17.00 until 19.00 hrs)

Sunday, 11 September
Provinciaal Hof
Address: Markt 3, 8000 Brugge

Opportunity for every participant to pick-up registration materials and meet old friends and make new ones.

Guided Walk of Bruges (17.30 until 19.00 hrs)

Bruges, the Venice of the North
Monday, 12 September 2016
Following the Keynote Opening session.
Start: Concert Gebouw Brugge
Address: 't Zand 34, 8000 Brugge

Conference Dinner (20.00 until 23.00hrs)

Thursday 15 September 2016
Stadshallen in the Belfry of Bruges
Address: Markt 7, 8000 Brugge

Scientific Information

Invited, Regular and Short Oral Contributions

Parallel sessions will take place in the Ambassadeur, Beethoven, Mozart, Strauss, Morus, Erasmus and Vives rooms.

Instructions for Oral Contributors

- The slide preview room is located at the ground floor and will be open from half an hour before the first session until half an hour after the last session of the day;
- Please, hand in your presentation on (USB-stick) at the slide preview room at least two hours before your presentation is scheduled;
- Speakers are requested to come to the meeting room at least 5 minutes prior to the start of the session and identify them to the chair;
- Microphones will be under control of the technician all the time. There is no need to switch them on;
- Presenters must take place at seats in front of the room for the duration of the session. The chair will call you to the lectern in sequence. Delegates will be seated in theatre style.

Allocated Presentation Time for Oral Contributions

- **Invited Contribution**
  Invited Contributions are indicated as 'I' in the programme and abstract book.
  The slot allocated to an invited contribution is 30 minutes: 25 minutes for presentation and 5 minutes for questions.
- **Regular Contribution**
  Regular Contributions are indicated as 'R' in the programme and abstract book.
  The slot allocated to a regular contribution is 20 minutes: 15 minutes for presentation and 5 minutes for questions.
- **Short Contribution**
  Short Contributions are indicated as 'S' in the programme and abstract book.
  The slot allocated to a short contribution is 5 minutes (maximum of 4 slides). In addition short contributions have a poster for discussion and further presentation.
  The poster will be on display for the whole day, on the same day of the oral presentation.

Instructions for Poster Presenters

- Poster boards will be located in the room 'Witte Roos' on the second floor. Posters will only be displayed for **ONE (1) day** on the day of your short contribution.
- Posters should be mounted before 09:00 and left on display till 18:00 (posters must be removed at 18:30 at the latest).
- Please ensure that your poster is displayed on the correct poster board. Posters left behind at the conclusion of the conference will be discarded. Please ensure that you collect your poster at the conclusion of the day your poster was on display.
- Mounting materials will be available onsite
- **Presenting authors are asked to attend their poster during the coffee breaks.**

Poster Display

Posters will be displayed in the Witte Roos Room.

Tuesday 12 September	(P001-P052)	Short contributions: S007-S162
Wednesday 13 September(	P053-P099)	Short contributions: S172-S328
Thursday 14 September	(P100-P142)	Short contributions: S338-S491

Programme Overview

Sunday 11 September 2016

Site	**Provincial Hof** (Markt 3, 8000 Brugge)
16:00-19:00	Registration
17:00-19:00	*Welcome Reception*

Monday 12 September 2016

Site	**Concertgebouw** ('t Zand 34, 8000 Brugge) Concert Hall
08:00-17:30	Registration / Information desk
	Keynote Opening Session
09:30-09:40	**Welcome**
09:40-10:00	**Keynote: Nuclear Science and the challenges of the European Union**
10:00-10:20	**Keynote: Nuclear Science: Meeting the Challenges of the Future**
10:20-10:40	**Keynote: Nuclear data and its impact on the IAEA programme**
10:40-11:00	**Keynote: Nuclear Science, nuclear data and advanced nuclear energy solutions**
11:00-11:20	**Keynote: Perspectives of nuclear data activities from past to future**
11:20-11:40	**Keynote: MYRRHA – A new large infrastructure for R&D on fuel cycle. Needs for new nuclear data**
11.40-12.00	**Keynote: Nuclear data @ CERN: fundamental physics and applications**
12:00-12:30	**Discussion and summary**
12:30-14:00	*Lunch break*

Site	**Concertgebouw** ('t Zand 34, 8000 Brugge) Concert Hall
	Plenary Session
14:00-14:45	From science to applications, the role of measurements, evaluations, databases and validation
14:45-15:30	Systematic approach to nuclear data evaluation
15:30-16:00	Coffee break
16:00-16:45	Towards more accurate and reliable predictions for nuclear applications
16:45-17:30	Considerations on the direction of nuclear data as a database
17:30	Closing of day 1 of the conference
17:30 -19:00	*Guided Walk of Bruges*

Tuesday 13 September 2016

08:30-12:20	Parallel Sessions	
10:20-10:40	Coffee break	
Room	**Ambassadeur**	Topic track: Fission physics and observables Session title: Fission theory and experiments I
	Beethoven	Topic track: Evaluation Session title: Evaluation I
	Mozart	Topic track: Nuclear reaction measurements Session title: Thermal and resonance neutrons I
	Strauss	Topic track: Astro nuclear physics Session title: Astro nuclear physics I
	Morus	Topic track: Experimental facilities, equipment, techniques and methods Session title: Experimental facilities, equipment, techniques and methods I
	Erasmus	Topic track: Thermal scattering laws and libraries Session title: Thermal scattering laws and libraries
	Vives	Topic track: Medical applications Session title: Medical applications I
	Witte Roos	Poster display

14:00-18:10	Parallel Sessions	
16:00-16:20	Coffee break	
Room	**Ambassadeur**	Topic track: Fission physics and observables Session title: Fission theory and experiments II
	Beethoven	Topic track: Evaluation Session title: CIELO
	Mozart	Topic track: Nuclear reaction measurements Session title: Thermal and resonance neutrons II
	Strauss	Topic track: Astro nuclear physics Session title: Astro nuclear physics II
	Morus	Topic track: Experimental facilities, equipment, techniques and methods Session title: Experimental facilities, equipment, techniques and methods II
	Erasmus	Topic track: Integral experiments, benchmarks and data validation Session title: Integral experiments, benchmarks and data validation I
	Vives	Topic track: Theory of nuclear reactions and structure, models and codes Session title: Theory of nuclear reactions and structure, models and codes I
	Witte Roos	Poster display
18:10	Closing of day 2 of the conference	

Wednesday 14 September 2016

08:30-12:20	Parallel Sessions	
10:20-10:40	Coffee break	
Room	**Ambassadeur**	Topic track: Fission physics and observables Session title: Prompt fission gamma-ray emission
	Beethoven	Topic track: Evaluation Session title: Evaluation II
	Mozart	Topic track: Nuclear reaction measurements Session title: Fast neutrons I
	Strauss	Topic track: Nuclear data for applications Session title: ADS and spallation reactions
	Morus	Topic track: Experimental facilities, equipment, techniques and methods Session title: Experimental facilities, equipment, techniques and methods III
	Erasmus	Topic track: Integral experiments, benchmarks and data validation Session title: Integral experiments, benchmarks and data validation II
	Vives	Topic track: Medical applications Session title: Medical applications II
	Witte Roos	Poster display

14:00-18:10	Parallel Sessions	
16:00-16:20	Coffee break	
Room	**Ambassadeur**	Topic track: Fission physics and observables Session title: Prompt fission neutron emission
	Beethoven	Topic track: Evaluation Session title: Evaluation III
	Mozart	Topic track: Nuclear reaction measurements Session title: Fast neutrons II
	Strauss	Topic track: Nuclear data for applications Session title: Non-Destructive Assay
	Morus	Topic track: Experimental facilities, equipment, techniques and methods Session title: Experimental facilities, equipment, techniques and methods IV
	Erasmus	Topic track: Integral experiments, benchmarks and data validation Session title: Integral experiments, benchmarks and data validation III
	Vives	Topic track: Theory of nuclear reactions and structure, models and codes Session title: Theory of nuclear reactions and structure, models and codes II
	Witte Roos	Poster display
18:10	Closing of day 3 of the conference	

Thursday 15 September 2016

08:30-12:20	Parallel Sessions	
10:20-10:40	Coffee break	
Room	**Ambassadeur**	Topic track: Fission physics and observables Session title: Fission theory and experiments III
	Beethoven	Topic track: Evaluation Session title: Evaluation IV
	Mozart	Topic track: Nuclear reaction measurements Session title: Fast neutrons III / Charged particles I
	Strauss	Topic track: Nuclear data for applications Session title: Fusion
	Morus	Topic track: Nuclear masses, structure and decay data measurements Session title: Nuclear masses, structure and decay data measurements I
	Erasmus	Topic track: Gamma-ray strength functions Session title: Gamma-ray strength functions I
	Vives	Topic track: Theory of nuclear reactions and structure, models and codes Session title: Theory of nuclear reactions and structure, models and codes III
	Witte Roos	Poster display

14:00-18:10	Parallel Sessions	
16:00-16:20	Coffee break	
Room	**Ambassadeur**	Topic track: Fission physics and observables Session title: Prompt fission neutron emission IV
	Beethoven	Topic track: Evaluation Session title: Evaluation V
	Mozart	Topic track: Nuclear reaction measurements Session title: Charged particles II
	Strauss	Topic track: Nuclear data for applications Session title: Reactors and fuel
	Morus	Topic track: Nuclear masses, structure and decay data measurements Session title: Nuclear masses, structure and decay data measurements II
	Erasmus	Topic track: Gamma-ray strength functions Session title: Gamma-ray strength functions II
	Vives	Topic track: Knowledge Transfer Session title: Knowledge Transfer
	Witte Roos	Poster display
18:10	Closing of day 4 of the conference	
20:00-23:00	***Conference DInner***	

Friday 16 September 2016

Room	Ambassadeur
	Plenary Session
08:30-09:15	Knowledge management of Nuclear Data at the NEA
09:15-10:00	General description of fission observables: the GEF code
10:00-10:45	Reactor simulations using JEFF-3 nuclear data: assessing performance and needs
10:45-11:00	Coffee break
11:00-11:45	CIELO collaboration advances in evaluating cross sections for 239Pu, 238U, 235U, 56Fe, 16O and 1H
11:45-12:30	CENDL project, the Chinese Evaluated Nuclear Data Library
12:30	Award ceremony, announcement of ND2019 and conference closing

Programme in detail

Monday 12 September 08:30-12:00 Concert Hall

Keynote opening Session

08:00 Registration + Welcome coffee

09:30 Welcome
by Arjan Plompen, Chairman of the ND2016 organising committee

09:40 Nuclear Science and the challenges of the European Union
Maive Rute, Deputy Director General of the Joint Research Centre, European Commission

10:00 Nuclear Science: Meeting the Challenges of the Future
William D. Magwood IV, Director-General of the Nuclear Energy Agency, Organisation for Economic Co-operation and Development

10:20 Nuclear data and its impact on the IAEA programme
Aldo Malavasi, Deputy Director General of the International Atomic Energy Agency, Department for Nuclear Sciences and Applications.

10:40 Nuclear Science, nuclear data and advanced nuclear energy solutions
Franck Carré, Scientific Director of Nuclear Energy at the Commissariat à l'Energie Atomique, France

11:00 Perspectives of nuclear data activities from past to future
Shigeaki Okajima, Director General of the Nuclear Science and Engineering Center, Japan Atomic Energy Agency

11:20 MYRRHA – A new large infrastructure for R&D on fuel cycle. Needs for new nuclear data
Hamid Aït Abderrahim, Deputy Director General SCK•CEN, Chairman SNETP, Belgium

11:40 Nuclear data @ CERN: fundamental physics and applications
Enrico Chiaveri, CERN, European Organisation for Nuclear Research, on behalf of the CERN DG

12:00 Discussion and summary
by the co-organizers Maive Rute (JRC), William D. Magwood IV (OECD-NEA) and Aldo Malavasi (IAEA)

12:30-14:00 Lunch break

Monday 12 September 14:00-17:30 Concert Hall

Plenary Session

Chair: M. Betti, Director of JRC Directorate G 'Nuclear Safety and Security'

14:00		**From science to applications, the role of measurements, evaluations, databases and validation** Arjan Plompen, Joint Research Centre, Geel, Belgium
14:45	**PL001**	**Systematic approach to nuclear data evaluation** Arjan Koning, Nuclear Data Section, International Atomic Energy Agency
15:30		**Break**
16:00	**PL002**	**Towards more accurate and reliable predictions for nuclear applications** Stéphane Goriely, Université Libre de Bruxelles, Brussels, Belgium
16:45		**Considerations on the direction of nuclear data as a database** Tokio Fukahori, Japan Atomic Energy Agency,
17:30		**Closing of day 1 of the conference**

Tuesday 13 September 08:30-12:20 Ambassadeur

Ambassadeur

Topic track: Fission physics and observables
Session Title: Fission theory and experiments I

Chair: P. Talou, Theoretical Division, Los Alamos National Laboratory, Los Alamos, USA

08:30	**I003**	**Parallel theoretical study of the two components of the prompt fission neutrons: dynamically released at scission and evaporated from fully accelerated fragments** Carjan N. (National Institute for Physics and Nuclear Engineering, Bucharest-Magurele, Romania and Joint Institute for Nuclear Research, Dubna, Russia)
09:00	**R004**	**Validation of delayed neutron group parameters for 235U by critical experiment** Yin Y. (Institute of Nuclear Physics and Chemistry, Mian Yang, P.R.China)
09:20	**R005**	**Angular correlations in the prompt neutron emission in spontaneous fission of 252Cf** Kopatch Y. (Joint Institute for Nuclear Research (JINR), Dubna, Russia)
09:40	**R006**	**Angular distributions and anisotropy of fission fragments from neutron-induced fission in intermediate energy range 1-200 MeV** Vorobyev AS. (NRC "Kurchatov Institute", Gatchina, Russia)
10:00	**S007**	**Neutron-multiplicity experiments for enhanced fission modelling** Al-Adili A. (Uppsala University, Uppsala, Sweden)
10:05	**S008**	**Digital spectrometer for fission prompt neutron spectra measurement** Khryachkov V. (Institute for Physics and Power Engineering (IPPE), Obninsk, Russia)
10:10	**S009**	**Measuring PFNS at the Chi-Nu Experiment** Gomez JA. (Los Alamos National Laboratory, Los Alamos, USA)
10:15	**S010**	**Prompt fission gamma-ray data from spontaneous fission and the mechanism of fission-fragment de-excitation** Oberstedt S. (European Commission, IRMM, Geel, Belgium)
10:20	**S414**	**MCNP6 updated fission cross section calculations at intermediate energies** Kerby L. (Idaho State University, Nuclear Engineering and Health Physics, Pocatello, Idaho, USA and Los Alamos National Laboratory, Los Alamos, NM, USA)
10:25		**Break**
10:50	**I011**	**Sensitivity of 252CF(SF) neutron observables to FREYA input distributions** Randrup J. (Lawrence Berkeley National Laboratory, Berkeley, CA, USA)
11:20	**R012**	**Influence of scission neutrons on the prompt fission neutron spectrum calculations** Serot O. (Cadarache center, Saint Paul lez Durance, France)
11:40	**R013**	**Experimental programme on absolute fission fragment yields with the Lohengrin spectrometer at ILL: new optical and statistical methodologies** Kessedjian G. (Université Grenoble-Alpes, CNRS/IN2P3, Grenoble Cedex, France)
12:00	**R014**	**Effects of microscopic transport coefficients on fission observables calculated by Langevin equation and its systematics** Usang MD. (Tokyo Institute of Technology, Tokyo and Malaysian Nuclear Agency, Bangi, Malaysia)

Tuesday 13 September 08:30-12:20 Beethoven

Beethoven

Topic track: Evaluation
Session Title: Evaluation I

Chair: R. Capote, NAPC-Nuclear Data Section, IAEA, Vienna, Austria

08:30	**I015**	**From cutting-edge pointwise cross-section to groupwise reaction rate: a primer** Sublet J.-Ch. (United Kingdom Atomic Energy Authority, Culham Science Centre, UK)
09:00	**R016**	**Current status of the verification and processing system GALILÉE-1** Jouanne C. (CEA Saclay, LLPR, Gif-sur-Yvette, France)
09:20	**R017**	**Evaluated displacement and gas production cross-sections for materials irradiated with intermediate energy nucleons** Konobeyev AY. (Karlsruhe Institute of Technology, Eggenstein-Leopoldshafen, Germany)
09:40	**R018**	**Important comments on kerma factors and DPA cross-section data in ace files of JENDL-4.0, JEFF-3.2 and ENDF/B-VII.1** Konno C. (Japan Atomic Energy Agency, Japan)
10:00	**S020**	**PyNjoy 2012: a system for producing cross-section libraries for the DRAGON lattice code** Hébert A. (Institut de Génie Nucléaire, Montreal Canada)
10:05	**S021**	**Development of a new nuclear data library based on ROOT** Park TS. (Sungkyunkwan University, Suwon, Korea)
10:10	**S022**	**Encoded physics knowledge in checking codes for nuclear cross section libraries at Los Alamos** Parsons DK. (Los Alamos National Laboratory, Los Alamos, USA)
10:15	**S023**	**NJOY21: Next generation nuclear data processing capabilities** Conlin JY. (Los Alamos National Laboratory, Los Alamos, USA)
10:20		**Break**
10:50	**I024**	**Progress on China nuclear data processing code system** Liu P. (China Institute of Atomic Energy, Beijing, P.R.China)
11:20	**R025**	**Frendy: the new nuclear data processing system for JENDL** Tada K. (Japan Atomic Energy Agency, Tokai, Japan)
11:40	**R026**	**NDEC: An NEA platform for nuclear data testing, verification and benchmarking** Diez CJ. (OECD NEA, Data Bank, Paris, France)

Tuesday 13 September 08:30-12:20 Mozart

Mozart

Topic track: Nuclear reaction measurements
Session Title: Thermal and resonance neutrons I

Chair: F. Gunsing, IRFU, CEA Saclay, Gif-sur-Yvette, France

08:30	I027	**Methods, setups and measurements for determining resonance parameters at the time-of-flight facility GELINA** Kopecky S. (European Commission, IRMM, Geel, Belgium)
09:00	R028	**Measurement of the neutron capture cross section of the fissile isotope 235U with the CERN n_TOF total absorption calorimeter and a fission tagging based on micromegas detectors** Balibrea J. (CIEMAT, Madrid, Spain)
09:20	R029	**Bismuth activation with thermal neutrons and with Maxwellian neutrons at kT 30 keV** Shor A. (Soreq Nuclear Research Center, Yavne, Israel)
09:40	R030	**Measurement of the neutron capture resonances for platinum using the Ge spectrometer and pulsed neutron beam at the J-PARC/MLF/ANNRI** Kino K. (Hokkaido University, Sapporo, Japan)
10:00	S031	**The 236U neutron capture cross-section measured at the n_TOF CERN facility** Mastromarco M. (Istituto Nazionale di Fisisa Nucleare, Bari, Italy)
10:05	S032	**New measurement of the Pu-242(n,γ) cross section at n_TOF-ear1 for MOX fuels** Lerendegui-Marco J. (Universidad de Sevilla, Sevilla, Spain)
10:10	S033	**Experimental verification of neutron capture cross section of 237Np in variable neutron field at KURRI-LINAC** Yashima H. (Kyoto University Research Reactor Institute, Osaka, Japan)
10:15		**Break**
10:50	I034	**Research and development for accuracy improvement of neutron nuclear data on minor actinides** Harada H. (Japan Atomic Energy Agency, Nuclear Science and Engineering Center, Ibaraki, Japan)
11:20	R035	**Absolute measurement of the 242Pu neutron-capture cross section** Buckner MQ. (Lawrence Livermore National Laboratory, Livermore CA, USA)
11:40	R036	**Measurement of the Am241 neutron capture cross section at the n_TOF facility at CERN** Mendoza E. (CIEMAT, Madrid, Spain)
12:00	R037	**Measurements of neutron capture cross sections for 238U at GELINA** Kim HI. (Korea Atomic Energy Research Institute, Nuclear Data Center, Daejeon, Republic of Korea)

Tuesday 13 September 08:30-12:20 Strauss

Strauss

Topic track: Astro nuclear physics
Session Title: Astro nuclear physics I

Chair: J.L. Tain, Instituto de Fisica Corpuscular, C.S.I.C. and University of Valencia, Paterna, Spain

08:30	**I038**	**Radiative capture reactions for the p process** Harissopulos S. (Inst. of Nuclear and Particle Physics, NCSR “Demokritos”, Athens, Greece)
09:00	**R039**	**Reactor neutrons in nuclear astrophysics** Reifarth R. (Goethe University Frankfurt, Frankfurt,Germany)
09:20	**R040**	**New accurate measurements of neutron emission probabilities for relevant fission products** Agramunt J. (Instituto de Fisica Corpuscular, Valencia, Spain)
09:40	**R041**	**Time-of-flight and activation experiments on 147Pm and 171Tm for astrophysics** Guerrero C. (Universidad de Sevilla, Sevilla, Spain)
10:00	**R042**	**A nuclear data approach for the Hubble Constant measurements** Herman M.W. (NNDC, Brookhaven National Laboratory, Upton, USA
10:20	**S043**	**Neutron capture cross sections of 69,71Ga and 63,65Cu at 25 and 90 keV** Göbel K. (Goethe University, Frankfurt, Germany)
10:25		**Break**
10:50	**I044**	**A new model for beta-delayed neutron emission and applications to the astrophysical r-process of nucleosynthesis** Mumpower M. (Los Alamos National Lab, Theory Division, Los Alamos, USA)
11:20	**R045**	**Nuclear data from cosmological observations: neutrino energy transport and big bang nucleosynthesis** Paris M. (Los Alamos National Lab, Theory Division, Los Alamos, USA)
11:40	**R046**	**7Be(n,α) and 7Be(n,p) Cross section measurement for the cosmological lithium problem at the n_TOF facility at CERN** Colonna N. (Istituto Nazionale di Fisica Nucleare, Bari, Italy)

Tuesday 13 September 08:30-12:20 Morus

Morus

Topic track: Experimental facilities, equipment, techniques and methods
Session Title: Experimental facilities, equipment, techniques and methods I

Chair: E. Chiaveri, CERN, Geneva, Switzerland

08:30	I048	**Experimental facilities supporting nuclear data measurements at the Los Alamos neutron science center** Mocko M. (Los Alamos National Laboratory, Los Alamos, USA)
09:00	R049	**Redesign of the target-moderator-reflector-shield assembly for optimization of the neutron flux in the epithermal and medium energy ranges at the Los Alamos Neutron Science Center** Nowicki S. (Los Alamos National Laboratory, Los Alamos, USA)
09:20	R050	**TANGRA - an experimental setup for basic and applied nuclear research by means of 14.1 MeV neutrons** Ruskov I. (Joint Institute for Nuclear Research, Dubna, Russia and Institute for Nuclear Research and Nuclear Physics of Bulgarian Academy of Sciences, Sofia, Bulgaria)
09:40	R051	**A development of photo-neutron source for time-of-flight measurement at KAERI** Kim JW. (Korea Atomic Energy Research Institute, Daejeon, Korea)
10:00	S052	**ASP neutron source: future capabilities** Woolhead V. (Science Group, Aldermaston, UK)
10:05	S053	**Preliminary decommissioning plan of European spallation source** Ene D. (European Spallation Source ERIC, Lund, Sweden)
10:10	S054	**92,94Zirconium irradiation for 1 keV - 1 MeV neutron flux determination by means of (n, gamma) reaction** Sergeyeva V. (CEA, DEN, DER, Cadarache, St Paul Lez Durance, France)
10:15	S055	**Analysis of energy resolution in the KURRI-LINAC pulsed neutron facility** Sano T. (Kyoto University Research Reactor Institute,Osaka, Japan)
10:25		**Break**
10:50	I056	**Nuclear data measurement activities at China Institute of Atomic Energy** Ruan X. (Institute of Atomic Energy, Beijing, P.R.China)
11:20	R057	**Nuclear astrophysics and measurements of deuteron-induced reactions at Soreq applied research accelerator facility** Halfon S. (Soreq NRC, Yavne, Israel)
11:40	R058	**Induced radioactivity studies of the shielding and beamline equipment of the high intensity proton accelerator facility at PSI** Otiougova P. (Paul Scherrer Insitite (PSI), Villigen, Switzerland)
12:00	I059	**Solving challenges in nuclear data for the safety of European nuclear facilities - the CHANDA Euratom project** González-Romero EM. (Medioambientales y Tecnológicas CIEMAT, Madrid, Spain)

Tuesday 13 September 08:30-12:20 Erasmus

Erasmus

Topic track: Thermal scattering laws and libraries
Session Title: Thermal scattering laws and libraries

Chair: G. Noguere, SPRC/LEPh, CEA Cadarache, Saint Paul Les Durance, France

08:30	**I060**	**New evaluation of thermal neutron scattering libraries for light and heavy water** Márquez Dámian JI. (Centro Atómico Bariloche, Bariloche, Argentina)
09:00	**R061**	**Important integral parameters in thermal neutron scattering in liquids** Roubtsov D. (Canadian Nuclear Laboratories, Chalk River, ON, Canada)
09:20	**R062**	**New scattering kernels for ethane and triphenylmethane at cryogenic temperatures** Cantargi F. (Centro Atómico Bariloche (CNEA), Bariloche, Argentina)
09:40	**S065**	**Measurement of double differential cross section of light water at high temperature and pressure to generate S(alpha,beta)** Jaiswal V. (Institut de Radioprotection et de Sûreté Nucléaire, Fontenay-aux-Roses, France)
10:00	**S064**	**Thermal neutron scattering evaluation framework** Chapman C. (Georgia Institute of Technology, Atlanta, USA)
10:05	**S066**	**Study of thermal scattering nuclear data for organic tissue through molecular dynamics** Cantargi F. (Centro Atómico Bariloche, Bariloche, Argentina)
10:10	**S067**	**Thermal neutron scattering data for LiF and BeF2** Wang J. (Institute of Applied Physics and Computational Mathematics, Beijing, P.R. China)
10:15		**Break**
10:50	**I069**	**Thermal neutron scattering law calculations using ab initio molecular dynamics** Hawari AI. (North Carolina State University, Raleigh, NC, USA)
11:20	**R070**	**Production of the thermal neutron scattering law for water ice with density functional theory and lattice dynamics** Holmes JC. (Bettis Atomic Power Laboratory, West Mifflin, PA, USA)
11:40	**R071**	**A thermal neutron scattering law for yttrium hydride** Zerkle ML. (Atomic Power Laboratory, West Mifflin, PA, USA)
12:00	**R072**	**Neutron thermalization in uranium mononitride as a potential fuel candidate for light water reactors** Al-Qaisr I. (University of Sharjah, Sharjah, United Arab Emirates)

Tuesday 13 September 08:30-12:20 Vives

Vives

Topic track: Medical applications
Session Title: Medical applications I

Chair: S. Smith, Idaho Accelerator Center, Idaho State University, Pocatello, USA

08:30 I073 High-precision gamma-ray spectroscopy for enhancing application of medical isotopes
McCutchan EA. (National Nuclear Data Center, Brookhaven National Laboratory, New York, USA)

09:00 R074 Measurement of the half-life of 177Lu
Ferreira K. (National Physical Laboratory, Middlesex, United Kingdom)

09:20 R075 Production of isotopes with linear accelerators
Arias de Saavedra F. (Universidad de Granada, Granada, Spain)

09:40 R076 New theoretical atomic radiation library for basic science and applications
Lee BQ. (Australian National University, Acton, Australia)

10:00 S077 New cross sections for the nat-Al(p,x)7-Be nuclear process: monitoring proton beam energy via the 22-Na/7-Be cross-section ratio between 45 and 200 MeV
Szelecsény F. (Institute for Nuclear Research of the Hungarian Academy of Sciences, ATOMKI, Debrecen, Hungary)

10:05 Break

10:50 I078 Nuclear data for medical applications: an overview of present status and future needs
Qaim SM. (Forschungszentrum Jülich, Jülich, Germany)

11:20 R079 Decay data evaluation project: evaluation of 52Mn and 52mMn nuclear decay data
Luca A. (Horia Hulubei National Institute for R&D in Physics and Nuclear Engineering, Magurele, Romania)

11:40 R047 The 33S(n,α)30Si cross section measured at n_TOF Experimental Area 2 (CERN): from thermal to the resolved resonance region
Sabaté-Gilarte M. (CERN, Geneva, Switzerland and 2 University of Seville, Seville, Spain)

Tuesday 13 September 14:00-18:10 Ambassadeur

Ambassadeur

Topic track: Fission physics and observables
Session Title: Fission theory and experiments II

Chair: J. Randrup, Nuclear Science Division, Lawrence Berkeley National Laboratory, Berkeley, USA

14:00	**I080**	**Dynamical approach to low-energy nuclear fission in terms of Langevin equation** Chiba S. (Tokyo Institute of Technology, Tokyo, Japan)
14:30	**R081**	**High-fidelity evaluation of the 235U prompt fission neutron spectrum including new experimental and improved model information** White MC. (Los Alamos National Laboratory, Los Alamos, USA)
14:50	**R082**	**Fission fragment total kinetic energy and mass yields for neutron-induced fission of 235-Uranium and 238-Uranium with En = 200 keV - 30 MeV** Duke DL. (Los Alamos National Laboratory, Los Alamos, USA)
15:10	**R083**	**Neutron-induced fission cross-section measurement of 234U with (quasi-) monoenergetic beams in the keV and MeV range using Micromegas detectors** Tsinganis A. (National Technical University of Athens, Greece and European Organisation for Nuclear Research (CERN), Geneva, Switzerland)
15:30	**S084**	**Measurement of selected IRDFF materials cross section in 235U and 252Cf fission spectra** Jánský B. (Research Center Rez, Husinec-Rez, Czech Republic)
15:35	**S085**	**Fission yields data generation and benchmarks for decay heat estimation of a nuclear fuel** Gil C.S. (Korea Atomic Energy Research Institute, Yuseong, Daejeon, Korea)
15:40	**S086**	**Validating nuclear fission codes with integral nuclear observables** Mattera A. (Uppsala University, Uppsala, Sweden)
15:45	**S087**	**Monte Carlo calculations of nucleon-induced fission in the GeV energy range** Tarrio D. (Univ Santiago de Compostela, Santiago De Compostela, Spain and Uppsala Univ,, Uppsala, Sweden)
15:50	**S088**	**Dissipative effects in fission investigated in complete kinematic measurements** Ramos D. (University of Santiago de Compostela, Santiago de Compostela, Spain) and Taieb J. (CEA/DAM/DIF, Arpajon, France)
15:55		**Break**
16:20	**I089**	**Point-by-point model calculation of the prompt neutron distribution ν(A) for 238U(n,F) at incident neutron energies ranging from 1 MeV to 80 MeV** Tudora A. (University of Bucharest, Bucharest-Magurele, Romania)
16:50	**R090**	**Fission fragment deexcitation study by gamma-ray spectrometry with the EXILL experiment** Materna T. (SPhN, IRFU, DRF, CEA Saclay, Gif-sur-Yvette, France)
17:10	**R091**	**Monte Carlo simulation of gamma and fission transfer reactions using extended R-matrix theory: application to U-237* system** Bouland OH. (CEA/DER/SPRC/LEPh, Saint-Paul-lez-Durance, France)
17:30	**R092**	**Studies on fission with Aladin: precise measurement of 236U isotopic yields in inverse kinematics** Grente L. (CEA, DAM, DIF, Arpajon, France)
17:50	**R093**	**Measurement of the 240Pu(n,f) cross-section at the cern n_TOF facility: first results from experimental area ii (ear-2)** Stamatopoulos A. (National Technical University of Athens, Athens, Greece)

Tuesday 13 September 14:00-18:10 Beethoven

Beethoven

Topic track: Evaluation
Session Title: CIELO

Chair: J.-C. Sublet, Technology Department, United Kingdom Atomic Energy Authority, Abingdon, United Kingdom

14:00	**I094**	**Criticality data testing of collaborative international evaluated library organization evaluated nuclear data files** Kahler AC. (Los Alamos National Laboratory, Los Alamos, USA)
14:30	**R095**	**Neutron cross sections for carbon and oxygen from new R-matrix analyses of the 13,14C and 17O systems** Hale GM. (Group T-2, Los Alamos National Laboratory, Los Alamos, USA)
14:50	**R096**	**Status of CIELO evaluation for iron** Herman M. (Brookhaven National Laboratory, Upton, USA)
15:10	**R097**	**The evaluation of experimental data in the fast range for n+56Fe** Qian J. (China Nuclear Data Center (CNDC), Beijing, P.R.China)
15:30	**S098**	**Fast benchmarking of CIELO test files** Cornock M. (Physics, AWE.plc, Aldermaston, United Kingdom)
15:35	**S099**	**Use of integral experiments for the assessment of a new 235U evaluation** Ichou R. (PSN-EXP/SNC/LNR, IRSN, Fontenay-aux-roses, France)
15:40	**S100**	**New fit of neutron thermal constants for U-233,235,Pu-239,241 and Cf-252: microscopic vs integral data** Capote R. (International Atomic Energy Agency, NAPC-Nuclear Data Section, Vienna, Austria)
15:45	**S101**	**Preparing for ENDF/B-VIII** Brown DA. (Brookhaven National Laboratory, National Nuclear Data Center, NY, USA)
15:50		**Break**
16:20	**I102**	**U-238 evaluation and validation of the neutron induced reactions up to 20 MeV** Capote R. (International Atomic Energy Agency, NAPC-Nuclear Data Section, Vienna, Austria)
16:50	**R103**	**Evaluation of neutron induced reactions for 238U in the resonance region** Schillebeeckx P. (Joint Research Centre, Institute for Reference Materials and Measurements, Geel, Belgium)
17:10	**R104**	**U-235 Evaluation of the neutron induced reactions up to 20 MeV** Koning A. (IAEA, Nuclear Sciences and Applications, Vienna, Austria)
17:30	**R105**	**Re-evaluation of the 235U resonance parameters to fit the standard recommended values** Leal L. (PSN-EXP/SNC/LNR, IRSN, Fontenay-aux-Roses, France)
17:50	**R106**	**235U resonance parameters and neutron multiplicities in the neutron energy region below 100 eV** Pigni MT. (Oak Ridge National Laboratory, Oak Ridge, USA)

Tuesday 13 September 14:00-18:10 Mozart

Mozart

Topic track: Nuclear reaction measurements
Session Title: Thermal and resonance neutrons II

Chair: H. Harada, Nuclear Science and Engineering Center, Japan Atomic Energy Agency, Ibaraki, Japan

14:00	**I107**	**The measurement programme at the neutron time-of-flight facility n-TOF at CERN** Gunsing F. (Irfu, CEA Saclay, Gif-sur-Yvette, France)
14:30	**R108**	**Neutron nuclear data measurements for criticality safety** Guber K. (Oak Ridge National Laboratory, Oak Ridge, USA)
14:50	**R109**	**Iron-56 capture cross section experiments at the RPI LINAC center** Danon Y. (Rensselaer Polytechnic Institute, Troy, NY, USA)
15:10	**R110**	**Neutron inelastic cross section measurements for natural titanium** Olacel A. (Horia Hulubei National Institute for Physics and Nuclear Engineering, Bucharest-Magurele, Romania)
15:30	**S111**	**Measurement of the neutron capture cross section of 99Tc using ANNRI at J-PARC** Katabuchi T. (Tokyo Institute of Technology, Research Laboratory for Nuclear Reactors, Tokyo, Japan)
15:35	**S112**	**Measurements of the total and capture cross sections of natural silver in the resonance range with the time of flight technique** Šalamon L. (DER, DEN, CEA Cadarache, Saint-Paul-lez-Durance, France and EC-JRC-IRMM, Geel, Belgium)
15:40	**S113**	**New measurement on 16O(n,alpha) reaction at Los Alamos Neutron Science Center (LANSCE)** Lee HY. (Los Alamos National Lab., Los Alamos, USA)
15:45	**S114**	**Application of modified REFIT code for J-PARC/MLF to evaluation of neutron capture cross section on 155,157Gd** Mizuyama K. (Japan Atomic Energy Agency, Nuclear Science and Engineering Center, Japan)
15:50	**S504**	**Resonance parameters from neutron capture measurements of dysprosium isotopes in the energy range 10 - 1000 eV** Kim G. (Department of Physics, Kyungpook National University, Daegu, Republic of Korea)
15:55		**Break**
16:20	**I115**	**Resonance region measurements of dysprosium and rhenium** Leinweber G. (Bechtel Marine Propulsion Corp., Knolls Atomic Power Laboratory, Schenectady, NY, USA)
16:50	**R116**	**Neutron capture cross section measurements of Sn-120, Sn-122 and Sn-124 with the array of germanium spectrometer at the J-PARC/MLF/ANNRI** Kimura A. (Japan Atomic Energy Agency, Nuclear Science and Engineering Center, Tokai-mura, Japan)
17:10	**R117**	**Measurement of the keV-neutron capture cross sections and capture gamma-ray spectra of CS-133 and I-127** Umezawa S. (Tokyo Institute of Technology, Tokyo, Japan)
17:30	**R118**	**High precision measurement of the radiative capture cross section of 238U at the n_TOF CERN facility** Mingrone F. (European Organization for Nuclear Research, Geneva, Switzerland)
17:50	**R119**	**Interpretation of cross section data in cold and thermal neutron spectra** Žerovnik G. (EC-JRC Institute for Reference Materials and Measurements, Geel, Belgium)

Tuesday 13 September 14:00-18:10 Strauss

Strauss

Topic track: Astro nuclear physics
Session Title: Astro nuclear physics II

Chair: S. Harissopulos, Institute of Nuclear and Particle Physics, NCSR "Demokritos", Athens, Greece

14:00	**I120**	**Strong gamma-ray emission from neutron-unbound states populated in beta-decay: impact on neutron capture cross-section estimates** Tain JL. (Instituto de Fisica Corpuscular, CSIC - U. Valencia, Valencia, Spain)
14:30	**R121**	**Measurement of the heaviest beta-delayed 2-neutron emitter 136Sb** Caballero-Folch R. (TRIUMF, Vancouver, Canada and 2 UPC, Barcelona, Spain)
14:50	**R122**	**Isomeric ratio measurements for the radiative neutron capture 176Lu(n,) at DANCE** Denis-Petit D. (CEA, DAM, DIF, Arpajon, France)
15:10	**R123**	**Nuclear level densities and gamma-ray strength functions of 180,181Ta and nucleo-synthesis of 180Ta** Malatji KL. (Department of Physics, University of the Western Cape, Bellville, South Africa)
15:30	**R124**	**Empirical estimation of astrophysical photodisintegration rates of 106Cd and 108Cd** Stopani KA. (Skobeltsyn Institute of Nuclear Physics, Lomonosov Moscow State University, Moscow, Russia)
15:50	**S125**	**Experimental cross sections for alpha particle induced reactions on p-nuclei** Oprea A. (Department of Nuclear Physics, Horia Hulubei National Institute for R&D in Physics and Nuclear Engineering (IFIN-HH), Magurele, Romania)
15:55	**S126**	**Cross section and astrophysical reaction rate of photodisintegration reaction in p-process: systematic calculation and future experiment based on ELI-NP** Xu Y. (RA4, Extreme Light Infrastructure - Nuclear Physics , Magurele, jud. Ilfov, Romania)
16:00		**Break**

Tuesday 13 September 14:00-18:10 Morus

Morus

Topic track: Experimental facilities, equipment, techniques and methods
Session Title: Experimental facilities, equipment, techniques and methods II

Chair: E. Gonzalez, Department of Energy, Nuclear Fission Division, CIEMAT, Madrid, Spain

14:00 I127 The neutrons for science facility at SPIRAL-2
Ledoux X. (GANIL, Caen, France)

14:30 R128 Simulations and experimental verification of neutron fields at IGISOL for neutron induced fission yield studies
Lantz M. (Uppsala University, Uppsala, Sweden)

14:50 R129 Characterization of the medley setup for measurements of neutron-induced cross-sections at the GANIL-NFS facility
Tarrio D. (Uppsala University, Uppsala, Sweden)

15:10 R130 Developments of a new data acquisition system at ANNRI
Nakao T. (Nuclear Science and Engineering Center (NSEC), Japan Atomic Energy Agency (JAEA), Ibaraki, Japan)

15:30 S131 Development and test of a compact multi-plate fission chamber for the simultaneous measurement of uranium-233 capture and fission cross-sections
Bacak M. (CEA, CERN, Geneva, Switzerland, CEA, Irfu/SPhN, Gif-sur-Yvette, France and TUW Atominstitut, Vienna, Austria)

15:35 S133 Scalp: scintillating ionization chamber for alpha particle production in neutron induced reactions
Galhaut B. (EAMEA, Cherbourg-en-Cotentin, France)

15:40 S134 Digital pulse shape analysis and gamma-ray energy dependent prompt-timing response functions for the UK national nuclear array
Shearman R. (National Physical Laboratory, Teddington, UK and University of Surrey, Guildford, UK)

15:45 S135 Neutron-gamma discrimination using non-negative matrix factorization blind sources separation algorithms
Arahmane H. (Mohammed V, Rabat, Morocco)

15:50 Break

16:20 I136 Selective data analysis for diamond detectors in neutron fields
Weiss C. (European Organization for Nuclear Research (CERN), Geneva, Switzerland)

16:50 R137 Progress of a 4πBaF2 System at CIAE
He GZ. (China Institute of Atomic Energy, Beijing, R.P. China)

17:10 R138 Accurate measurement of an ionization chamber efficiency using prompt fission neutron detection method
Mathieu L. (CENBG, CNRS/IN2P3-Université de Bordeaux, Gradignan, France

17:30 R139 Development of a gaseous proton-recoil detector for neutron flux measurements between 0.1 and 2 MeV neutron energy
Marini P. (Centre d'Etudes Nucléaires de Bordeaux Gradignan, Gradignan, France)

17:50 R140 Application of minor actinides as neutron fluency and average neutron energy detectors in the place of their location
Szuta M. (National Centre for Nuclear Research, Otwock- wierk, Poland)

Tuesday 13 September 14:00-18:10 Erasmus

Erasmus

Topic track: Integral experiments, benchmarks and data validation
Session Title: Integral experiments, benchmarks and data validation I

Chair: M. White, XCP Computational Physics Division, Los Alamos National Laboratory, Los Alamos, USA

14:00 I141 Contributions to integral nuclear data in ICSBEP and IRPhEP since ND2013
Bess J. (Idaho National Laboratory, Idaho Falls, USA)

14:30 R142 Summary of ORSphere critical and reactor physics measurements
Marshall MA. (Idaho National Laboratory, Idaho Falls, ID, USA)

14:50 R143 SFCOMPO-2.0: an NEA database of spent fuel assay data for integral benchmarking
Michel-Sendis F. (OECD Nuclear Energy Agency, Boulogne-Billancourt, France)

15:10 R144 Nuclear data processing capabilities in OpenMC
Romano PK. (Argonne National Laboratory, Lemont, IL, USA)

15:30 S145 New functions for improved uncertainty analysis in the NEA Nuclear Data Sensitivity Tool (NDaST)
Dyrda J. (Nuclear Science, OECD NEA, Boulogne-billancourt, France)

15:35 S146 Benchmarking of HEU mental annuli critical assemblies with internally reflected graphite cylinder
Marshal lMA. (Institute of Nuclear Physics and Chemistry, CAEP, Mianyang, P.R. China)

15:40 S147 Examination of total cross section resonance structure of niobium and silicon in neutron transmission experiments
Khryachkov V. (Institute for Physics and Power Engineering - IPPE, Obninsk, Russia)

15:45 S148 Integral cross section measurement of the 235U(n,n')235mU reaction in a pulsed reactor
Belier G. (CEA/DAM/DIF, Arpajon, France)

15:50 S149 Measurement and calculation of neutron leakage spectra from slab samples of beryllium, gallium and tungsten irradiated with 14.8 MeV neutrons
Ruan XC. (China Nuclear Data Center, China Institute of Atomic Energy, Beijing, P.R. China)

15:55 Break

16:20 I150 Methodology and issues of integral experiments selection for nuclear data validation
Ivanova T. (OECD-NEA, Nuclear Science Division, Boulogne-Billancourt, France)

16:50 R151 Americium-241 integral radiative capture cross section measurement in thermal domain using the oscillation technique in the minerve reactor
Geslot B. (CEA, DEN, DER/SPEx, Cadarache, St Paul Lez Durance, France)

17:10 R152 Neutron spectra measurement and calculations using data libraries CIELO and JEFF-3.2 in Iron benchmark assemblies
Jansky B. (Department of Neutron Physics, Research Centre, Rez, Czech Republic)

17:30 R153 Integral experiments on thorium assemblies with D-T neutron source
Liu R. (Institute of Nuclear Physics and Chemistry, China Academy of Engineering Physics, Mianyang, R.P. China)

17:50 R154 Validation of the U238 inelastic scattering cross section through the excalibur dedicated experiment
Leconte P. (CEA Cadarache, DER/SPRC/LEPh, Saint Paul Lez Durance, France)

Tuesday 13 September 14:00-18:10 Vives

Vives

Topic track: Theory of nuclear reactions and structure, models and codes
Session Title: Theory of nuclear reactions and structure, models and codes I

Chair: A. Ferrari, CERN, Meyrin, Switzerland

14:00	**I155**	**A theoretical study of deuteron-induced surrogate reactions** Carlson B.V. (Instituto Tecnológico de Aeronáutica, São José dos Campos SP, Brazil)
14:30	**R156**	**Some evaluations of the deuteron induced reactions by using a semi-microscopic approach relying on the Continuum discretized coupled channels formalism** Chau HTP. (DAM/DIF CEA, Arpajon, France)
14:50	**R157**	**The neutron and proton microscopic optical potentials based on the Skyrme interaction** Xu Y. (College of Physics and Electronic Science, Shanxi Datong University, Datong, P.R. China)
15:10	**R158**	**Microscopic optical model potential based on Dirac-Brueckner-Hartree-Fock theory and the relevant covariance analysis** Xu R. (China Institute of Atomic Energy, Beijing, P.R. China)
15:30	**S159**	**The study of structure in 224-234 Thorium nuclei within the framework IBM** Lee SY. (Dong-Eui University, Department of Physics, Busan, South Korea)
15:35	**S160**	**Optical model with multiple band coupling using a soft rotator model and taking account of volume conservation** Martyanov D. (Nuclear Evaluation Lab, Joint Institute for Energy and Nuclear Research, Minsk, Belarus)
15:40	**S161**	**Nuclear data evaluation by microscopic optical potential** Minato F. (Japan Atomic Energy Agency, Tokai, Japan)
15:45	**S162**	**Non-local microscopic potentials for calculation of scattering observables of nucleons on deformed nuclei** Nasri A. (CEA DAM, Arpajon, France)
15:50		**Break**
16:20	**I163**	**Microscopic description of direct nucleon emission for neutron scattering off even and odd actinides** Dupuis M. (CEA, DAM, DIF, France; 2 IPHC, Strasbourg, France)
16:50	**R164**	**Compound-nuclear reactions with unstable isotopes: Constraining capture cross sections with indirect data and theory** Escher JE. (Lawrence Livermore National Laboratory, Livermore, CA, USA)
17:10	**R165**	**State density formalism of the Iwamoto-Harada model: a suitable tool to treat cluster emission from heavy-ion collisions with account for spin variables** Běták E. (Dept. Nuclear Physics, Inst. of Physics SAS, Bratislava, Slovakia)
17:30	**R166**	**Role of different nuclear charge radii parameterizations on the thermal equilibrium in nuclear reactions** Sangeeta A. (School of Physics and Materials Science, Thapar University, Punjab, India)

Tuesday 13 September 08:30-18:10 Witte Roos

Witte Roos

Session Title: Poster Session

Poster number

P001	S007	Neutron-multiplicity experiments for enhanced fission modelling
P002	S008	Digital spectrometer for fission prompt neutron spectra measurement
P003	S009	Measuring PFNS at the Chi-Nu Experiment
P004	S010	Prompt fission gamma-ray data from spontaneous fission and the mechanism of fission-fragment de-excitation
P006	S020	PyNjoy 2012: a system for producing cross-section libraries for the DRAGON lattice code
P007	S021	Development of a new nuclear data library based on ROOT
P008	S022	Encoded physics knowledge in checking codes for nuclear cross section libraries at Los Alamos
P009	S023	NJOY21: Next generation nuclear data processing capabilities
P010	S031	The 236U neutron capture cross-section measured at the n_TOF CERN facility
P011	S032	New measurement of the Pu-242(n,g) cross section at n_TOF-ear1 for MOX fuels
P012	S033	Experimental verification of neutron capture cross section of 237Np in variable neutron field at KURRI-LINAC
P013	S043	Neutron capture cross sections of 69,71Ga and 63,65Cu at 25 and 90 keV
P014	S052	ASP neutron source: future capabilities
P015	S053	Preliminary decommissioning plan of European spallation source
P016	S054	92,94Zirconium irradiation for 1 keV - 1 MeV neutron flux determination by means of (n, gamma) reaction
P017	S055	Analysis of energy resolution in the KURRI-LINAC pulsed neutron facility
P018	S064	Thermal neutron scattering evaluation framework
P019	S065	Measurement of double differential cross section of light water at high temperature and pressure to generate S(alpha,beta)
P020	S066	Study of thermal scattering nuclear data for organic tissue through molecular dynamics
P021	S067	Thermal neutron scattering data for LiF and BeF2
P022	S068	Covariance matrix for light water thermal scattering law
P023	S077	New cross sections for the nat-Al(p,x)7-Be nuclear process: monitoring proton beam energy via the 22-Na/7-Be cross-section ratio between 45 and 200 MeV
P024	S084	Measurement of selected IRDFF materials cross section in 235U and 252Cf fission spectra
P025	S085	Fission yields data generation and benchmarks for decay heat estimation of a nuclear fuel
P026	S086	Validating nuclear fission codes with integral nuclear observables
P027	S087	Monte Carlo calculations of nucleon-induced fission in the GeV energy range
P028	S088	Dissipative effects in fission investigated in complete kinematic measurements
P029	S098	Fast benchmarking of CIELO test files
P030	S099	Use of integral experiments for the assessment of a new 235U evaluation
P031	S100	New fit of neutron thermal constants for U-233,235,Pu-239,241 and Cf-252: microscopic vs integral data

P032	S101	Preparing for ENDF/B-VIII
P033	S111	Measurement of the neutron capture cross section of 99Tc using ANNRI at J-PARC
P034	S112	Measurements of the total and capture cross sections of natural silver in the resonance range with the time of flight technique
P035	S113	New measurement on 16O(n,alpha) reaction at Los Alamos Neutron Science Center (LANSCE)
P036	S114	Application of modified REFIT code for J-PARC/MLF to evaluation of neutron capture cross section on 155,157Gd
P037	S125	Experimental cross sections for alpha particle induced reactions on p-nuclei
P038	S126	Cross section and astrophysical reaction rate of photodisintegration reaction in p-process: systematic calculation and future experiment based on ELI-NP
P039	S131	Development and test of a compact multi-plate fission chamber for the simultaneous measurement of uranium-233 capture and fission cross-sections
P041	S133	Scalp : scintillating ionization chamber for alpha particle production in neutron induced reactions
P042	S134	Digital pulse shape analysis and gamma-ray energy dependent prompt-timing response functions for the UK national nuclear array
P043	S135	Neutron-gamma discrimination using non-negative matrix factorization blind sources separation algorithms
P044	S145	New functions for improved uncertainty analysis in the NEA Nuclear Data Sensitivity Tool (NDaST)
P045	S146	Benchmarking of HEU mental annuli critical assemblies with internally reflected graphite cylinder
P046	S147	Examination of total cross section resonance structure of niobium and silicon in neutron transmission experiments
P047	S148	Integral cross section measurement of the 235U(n,n’)235mU reaction in a pulsed reactor
P048	S149	Measurement and calculation of neutron leakage spectra from slab samples of beryllium, gallium and tungsten irradiated with 14.8 MeV neutrons
P049	S159	The study of structure in 224-234 Thorium nuclei within the framework IBM
P050	S160	Optical model with multiple band coupling using a soft rotator model and taking account of volume conservation
P051	S161	Nuclear data evaluation by microscopic optical potential
P052	S162	Non-local microscopic potentials for calculation of scattering observables of nucleons on deformed nuclei
P119	S414	MCNP6 updated fission cross section calculations at intermediate energies
P147	S504	Resonance parameters from neutron capture measurements of dysprosium isotopes in the energy range 10 - 1000 eV

Wednesday 14 September 08:30-12:20 Ambassadeur

Ambassadeur

Topic track: Fission physics and observables
Session Title: Promt fission neutron emission

Chair: K. Nishio, Advanced Science Research Center, Japan Atomic Energy Agency, Tokai, Japan

08:30 I168 Prompt emission in fission induced with fast directional neutrons
Wilson J.N. (Institut de Physique Nucléaire d'Orsay, Orsay cedex, France)

09:00 R169 Prompt fission gamma ray emission from the (d,p)-induced fission of 233U
Rose SJ. (University of Oslo, department of physics, Oslo, Norway)

09:20 R170 Correlations in prompt neutrons and gamma-rays from Cf-252 spontaneous fission
Marcath MJ. (University of Michigan, Ann Arbor, Michigan, USA)

09:40 R171 Measurement of prompt fission gamma rays from Uranium-235 using spectrometer for exotic fission fragments at the neutron time of flight facility CERN
Wright T. (University of Manchester, Manchester, U.K.)

10:00 S172 Neutron-neutron and neutron-photon correlations with FREYA
Vogt R. (Lawrence Livermore National Laboratory, Livermore, CA, USA and University of California at Davis, Davis, CA, USA)

10:05 S173 Theoretical investigation of fission fragment observables in the symmetric mass region for thermal neutron induced fissions of 233U and 241Pu
Serot O. (CEA, DEN, DER, SPRC, LEPh, Cadarache center, Saint Paul lez Durance, France)

10:10 S174 Total prompt gamma-ray emission in fission
Wu CY. (Lawrence Livermore National Laboratory, Livermore, CA, USA)

10:15 S175 Precision requirement of the photofission cross section for the nondestructive assay technique
Kimura R. (Tokyo Institute of Technology, Tokyo, Japan)

10:20 Break

10:50 I176 Prompt particle emission in fission - news on systematics and predictions for fission induced by fast neutrons
Oberstedt A. (Horia Hulubei National Institute for Physics and Nuclear Engineering (IFIN-HH), Bucharest-Magurele, Romania)

11:20 R177 New prompt fission gamma-ray spectral data from 239Pu(nth,f) in response to a high priority request from OECD Nuclear Energy Agency
Gatera A. (European Commission, Joint-Research Centre, Institute for Reference Materials and Measurements (IRMM), Geel, Belgium and Ghent University, Ghent, Belgium)

11:40 R178 First experimental prompt gamma-ray spectra in fast neutron-induced fission
Bélier G. (CEA/DAM/DIF, Arpajon, France)

12:00 R179 Measurement of high-energy prompt gamma-rays from neutron induced fission of U-235
Makii H. (Japan Atomic Energy Agency (JAEA), Tokai, Japan)

Wednesday 14 September 08:30-12:20 Beethoven

Beethoven

Topic track: Evaluation
Session Title: Evaluation II

Chair: C. De Saint Jean, CEN Cadarache, Saint Paul Lez Durance, France

08:30	**I180**	**Status of the JENDL Project** Iwamoto O. (Data Center, Japan Atomic Energy Agency, Tokai-mura, Japan)
09:00	**R181**	**A new evaluation of the neutron data standards** Carlson AD. (National Institute of Standards and Technology, Gaithersburg, MD, USA)
09:20	**R182**	**On the search for a (n,f) cross-section reference at intermediate energies** Duran I. (Universidad de Santiago de Compostela, Spain)
09:40	**R183**	**An analytic approach to probability tables for the unresolved resonance region** Brown DA. (Brookhaven National Laboratory, National Nuclear Data Center, NY, USA)
10:00	**S503**	**Inter-comparison of Hauser-Feshbach model codes toward better actinide evaluations** Kawano T. (LANL, Los Alamos, NM, USA)
10:05	**S185**	**Evaluation of neutron total and capture cross sections on Tc-99 in the unresolved resonance region** Iwamoto N. (Nuclear Data Center, Nuclear Science and Engineering Center, Japan Atomic Energy Agency, Tokai, Ibaraki, Japan)
10:10	**S186**	**Improving activation cross section data with TALYS** Dzysiuk N. (NRG, Petten, the Netherlands)
10:15	**S187**	**Updated and revised neutron reaction data for n+236,238Np** Chen G. (China Institute of Atomic Energy, Beijing, P.R. China)
10:20	**S188**	**Comparison evaluation for neutron cross section of 250Cf** AbuSaleem K. (Jordan Atomic Energy Commission and Department of the University of Jordan, Amman, Jordan)
10:25		**Break**
10:50	**I189**	**The TENDL library: hope, reality and future** Rochman D. (Reactor Physics and Systems Behaviour Laboratory, Paul Scherrer Institut, Switzerland)
11:20	**R190**	**TALYS/TENDL-2014 verification and validation processes: outcomes and recommendations** Fleming M. (UK Atomic Energy Authority, Abingdon, Oxon, UK)
11:40	**R191**	**Development and application of hybrid evaluated nuclear data library HENDL for advanced nuclear energy systems** Zou J. (Institute of Nuclear Energy Safety Technology, Chinese Academy of Sciences, Hefei, Anhui, P.R.China)
12:00	**R192**	**Nuclear data infrastructure and API for the new nuclear data format defined by WPEC subgroup 38** Beck BR. (Lawrence Livermore National Laboratory, Livermore, CA, USA)

Wednesday 14 September 08:30-12:20 Mozart

Mozart

Topic track: Nuclear reaction measurements
Session Title: Fast neutrons I

Chair: C. Borcea, DFN, IFIN-HH, Magurele, Romania

08:30	**I193**	**Activation and AMS for studying neutron-induced reactions on 232Th and 235,238U in the keV to MeV energy range** Wallner A. (Australian National University, Canberra, Australia)
09:00	**R194**	**Measurement of the 89Y(n,2n)88Y reaction cross section at AWE's ASP neutron source** Bunce M. (Radiation Science Group, AWE, Aldermaston, UK)
09:20	**R195**	**Preliminary determination of cross sections of 39K(n,p)39Ar induced by D-neutrons** Changlin L. (School of Nuclear Science and Technology, Lanzhou University, Lanzhou , R.P.China and Key Laboratory of Special Function Materials and Structure Design, Ministry of Education, R.P.China)
09:40	**R196**	**The cross section functions for neutron reactions with Rhenium in the energy range 13.0 -19.5 MeV** Oberstedt S. (European Commission, Joint Research Centre, Institute for Reference Materials and Measurements, Geel, Belgium)
10:00	**S197**	**Measurements of the 6Li(n,α)t standard cross-section at the GELINA facility** Jansson K. (Department of Physics and Astronomy, Uppsala University, Uppsala, Sweden)
10:05	**S198**	**Cross section of the 197Au (n,2n) 197Aug+m1,m2 reaction** Kalamara A. (Department of Physics, National Technical University of Athens, Athens, Greece)
10:10	**S199**	**Cross sections of the 144Sm(n,α)141Nd and 66Zn(n,α)63Ni reactions at 4.0, 5.0 and 6.0 MeV** Gledenov Y. (Frank Laboratory of Neutron Physics, Joint Institute for Nuclear Research, Dubna, Russia)
10:15	**S200**	**Measurements of neutron capture cross-section on 70Zinc** Pachuau R. (Mizoram University, Department of Physics, Tanhril, India)
10:20		**Break**
10:50	**I201**	**Recent cross-section measurements of neutron-induced reactions of importance for background estimates in neutrino-less double-beta decay searches** Tornow W. (Duke University and Triangle Universities Nuclear Laboratory, Durham, USA)
11:20	**R202**	**10B(n,α0) and 10B(n,α1) cross section data up to 3 MeV incident neutrons** Hambsch F.-J. (European Commission, Joint Research Centre, Institute for Reference Materials and Measurements, Geel, Belgium)
11:40	**R203**	**Study of (n,2n) reaction on 191,193Ir isotopes and isomeric cross section ratios** Vlastou R. (Department of Physics, National Technical University of Athens, Greece)
12:00	**R204**	**Inelastic neutron scattering cross-section measurements on 7Li and 63,65Cu** Nyman M. (European Commission, Joint Research Centre, Institute for Reference Materials and Measurements, Geel, Belgium)

Wednesday 14 September 08:30-12:20 Strauss

Strauss

Topic track: Nuclear data for applications
Session Title: ADS and spallation reactions

Chair: C. Romano, Nuclear Security and Isotope Technology Division, Oak Ridge National Laboratory, Oak Ridge, USA

08:30	**I205**	**Impact of intermediate and high-energy nuclear data on the neutronic safetyparameters of MYRRHA accelerator driven system** Stankovskiy A. (SCK•CEN, Institute for Advanced Nuclear Systems, Mol, Belgium)
09:00	**R206**	**Nuclear data sensitivity analysis and evaluated data library comparison for MYRRHA relevant quantities** Romojaro P. (Energy Engineering Department, Universidad Politécnica de Madrid, Madrid, Spain)
09:20	**R207**	**Decay heat uncertainty quantification of MYRRHA** Fiorito L. (SCK-CEN, Mol, Belgium and ULB, Université Libre de Bruxelles, Brussels, Belgium)
09:40	**R208**	**On prediction accuracy of neutronics parameters of accelerator-driven sub-critical system** Chiba G. (Hokkaido Universy, Faculty of Engineering, Sapporo, Japan)
10:00	**S209**	**The evaluated nuclear data library for ADS in China** Han Y. (China Institute of Atomic Energy, R.P.China)
10:05	**S210**	**Comparative analysis of the non-destructive methods to control fissile materials in large containers** Sklyarov S. (All-Russia Research Institute of Automatics (VNIIA), Moscow, Russia)
10:10	**S211**	**Cross-sections from deuteron irradiation of thin thorium target at energy 7 GeV** Vespalec R. (Joint Institute for Nuclear Research, Dubna, Russian Federation and Czech Technical University, Prague, Czech Republic)
10:15	**S212**	**Work plan for improving the DARWIN2.3 depleted material balance calculation concerning some important isotopes for fuel cycle** Noguere G. (CEA, DEN, DER, SPRC, Cadarache, Saint-Paul-Lez-Durance, France)
10:20		**Break**
10:50	**I213**	**Systematic investigation of the energy dependence in 136Xe on proton spallation reactions** Paradela C. (Universidade de Santiago de Compostela, Santiago de Compostela, Spain)
11:20	**R214**	**Measurement of Al(p,x)Be-7, Al(p,x)Na-22, 24, C(p,x)T+He-3 and C(p,x)He-4 cross section for 3-GeV proton** Meigo S. (JAEA/J-PARC, Tokai, Ibaraki, Japan)
11:40	**R215**	**Spallation reaction study for fission products in nuclear waste: cross section measurements for 137Cs, 90Sr, and 107Pd on proton and deuteron at different reaction energy** Wang H. (RIKEN Nishina Center, Wako, Saitama, Japan)
12:00	**R216**	**Measurement of 430-MeV/u carbon, nitrogen and oxygen incident neutron production cross sections for carbon** Shigyo N. (Department of Applied Quantum Physics and Nuclear Engineering, Kyushu University, Fukuoka, Japan)

Wednesday 14 September 08:30-12:20 Morus

Morus

Topic track: Experimental facilities, equipment, techniques and methods
Session Title: Experimental facilities, equipment, techniques and methods III

Chair: X. Ledoux, GANIL, Caen, France

08:30 I217 The n_TOF facility: neutron beams for challenging future measurements at CERN
Chiaveri E. (Department EN/STI, CERN, Geneva, Switzerland)

09:00 R218 New deuterium-deuterium (D-D) neutron generator developed for medical, industry and home land security application
Bergaou K. (National Center of Nuclear Sciences and Technologies. Technopole Sidi Thabet, Tunisia)

09:20 R219 Development of compact accelerator neutron source
Letourneau A. (Irfu, DRF, CEA Saclay, Gif-sur-Yvette, France)

09:40 R220 Characterisation of the n_TOF EAR2 neutron beam
Chen YH. (Institut de Physique Nucléaire, IN2P3-CNRS, Orsay, France and Université Paris-Sud, Université Paris-Saclay Orsay, France)

10:00 R221 On the possible use of the MASURCA reactor as a flexible, high-intensity, fast neutron beam facility
Dioni L. (Aix-Marseille University, Institut Fresnel, Marseille, France)

10:20 S222 Monte Carlo simulations of the n_TOF lead spallation target with the Geant4 toolkit: a benchmark study
Lerendegui-Marco J. (Universidad de Sevilla, Dep. of Atomic, Molecular and Nuclear Physics, Seville, Spain)

10:25 Break

10:50 I223 White neutron source and nuclear data measurement platform at CSNS
Tang JY. (Institute of High Energy Physics, CAS, Dongguan Branch, Dongguan, Guangdong, China)

11:20 R224 p+thin 9Be as a source of quasi-monoenergetic neutrons
Novak J. (Nuclear Physics Institute, department of Nuclear Reactions, Rez, Czech Republic)

11:40 R225 Proton and neutron test facilities at 1 GeV synchrocyclotron of PNPI for radiation resistance testing of avionic and space electronics
Vorobyev AS. (B.P. Konstantinov Petersburg Nuclear Physics Institute of National Research Centre “Kurchatov Institute”, Gatchina, Russia)

12:00 R226 Cross section measurement of residues produced in proton- and deuteron-induced spallation reactions on 93Zr at 100 MeV/u using the inverse kinematics method
Kawase S. (Faculty of Engineering Sciences, Kyushu University, Kasuga, Japan)

Wednesday 13 September 08:30-12:20 Erasmus

Erasmus

Topic track: Integral experiments, benchmarks and data validation
Session Title: Integral experiments, benchmarks and data validation II

Chair: E. Ivanov, SAG, Institut de Radioprotection et de Sûrete Nucléaire, Fontenay-aux-Roses, France

08:30 I227 New approaches to provide feedback from nuclear and covariance data adjustment for effective improvement of evaluated nuclear data files
Palmiotti G. (Idaho National Laboratory, Idaho Falls, USA)

09:00 R229 Determining the nuclear data uncertainty on MONK10 and WIMS10 criticality calculations
Ware TC. (Reactor Services, Amec Foster Wheeler, Dorchester, UK)

09:20 R230 Validation of tungsten cross sections in the neutron energy region up to 100 kev
Pigni MT. (Oak Ridge National Laboratory, USA)

09:40 S231 Impact of implicit effects on uncertainties and sensitivities of the Doppler coefficient of a LWR pin cell
Leray O. (Paul Scherrer Institut, Villigen, Switzerland)

09:45 S232 A stress test on 235U(n, f) in adjustment with HCI and HMI benchmarks
Wu H. (China Institute of Atomic Energy, China Nuclear Data Center, Beijing, R.P.China)

09:50 S501 Testing of the ABBN-RF multigroup data library in photon transport calculations
Khryachkov V. (Institute for Physics and Power Engineering (IPPE), Obninsk, Russia)

09:55 R228 Impact of uncertainties in the uranium 235 cross section resonance structure on characteristics measured in the BFS-79 critical assemblies
Khryachkov V. (Institute for Physics and Power Engineering (IPPE), Obninsk, Russia)

10:00 S502 Verification of the databases EXFOR and ENDF
Cabellos O. (NEA, OECD, Paris, France)

10:05 Break

10:50 I233 Benchmarking and validation activities within JEFF project
Cabellos O. (NEA, OECD, Paris, France)

11:20 R234 Analyses of criticality benchmark experiments with beryllium reflector
Hu Z. (Institute of Applied Physics and Computational Mathematics, Beijing, R.P.China)

11:40 R235 Plutonium effect in fuel bundles of pressure-tube heavy water reactors
Roubtsov D. (Canadian Nuclear Laboratories, Chalk River, ON, Canada)

12:00 R236 Analysis of C/E results of fission rate ratio measurements in several fast lead VENUS-F cores
Kochetkov A. (SCK-CEN, Advanced Nuclear Systems Institute, Mol, Belgium)

Wednesday 14 September 08:30-12:20 Vives

Vives

Topic track: Medical applications
Session Title: Medical applications II

Chair: S. Qaim, INM-5: Nuklearchemie, Forschungszentrum Jülich, Jülich, Germany

08:30 I237 Production of platinum radioisotopes at Brookhaven Linac Isotope Producer (BLIP)
Smith S.V. (Collider Accelerator Department, Brookhaven National Laboratory, Upton NY, USA)

09:00 R238 Production of medically useful bromine isotopes via alpha-particle induced nuclear reactions
Scholten B. (Forschungszentrum Jülich, Institute of Neuroscience and Medicine, Nuclear Chemistry, Jülich, Germany)

09:20 R239 IAEA CRP on nuclear data for charged-particle monitor reactions and medical isotope production
Capote R. (International Atomic Energy Agency, NAPC-Nuclear Data Section, Vienna, Austria)

09:40 R240 The new CERN-MEDICIS facility for the production of new innovative radioisotopes for medical research
Cocolios TE. (KU Leuven, Instituut voor Kern- en Stralingsfysica, Leuven, Belgium)

10:00 Break

10:50 I241 Differential cross sections measurements for hadrontherapy: 50MeV/n 12C reactions on H, C, Al, O and Ti targets
Divay C. (LPC Caen, France; 2 IPHC Strasbourg, France)

11:20 R242 How nuclear data collected for medical radionuclides production could constrain nuclear codes
Guertin A. (Laboratoire SUBATECH, Ecoles des Mines de Nantes, Université de Nantes, CNRS/IN2P3, France)

11:40 R243 Production of 92Y via the 92Zr(n,p) reaction using the C(d,n) accelerator neutron source
Kin T. (Kyushu University, department of Engineering Science, Fukuoka, Japan)

12:00 R244 In-flight annihilation correction for spectrometry based on the 511 keV photopeak
Steyn GF. (Department of Nuclear Physics, iThemba LABS, Somerset West, South Africa)

Wednesday 14 September 14:00-18:10 Ambassadeur

Ambassadeur

Topic track: Fission physics and observables
Session Title: Prompt fission gamma-ray emission

Chair: N. Carjan, Flerov Laboratory for Nuclear Reactions, Joint Institute for Nuclear Research, Dubna, Russia

14:00	**I245**	**Prompt particle emission in correlation with fission fragments** Litaize O. (CEA, DEN, DER, SPRC, Cadarache, Saint Paul-lez-Durance, France)
14:30	**R246**	**Prompt fission neutron spectra for energetic neutron-induced fission of 235U** Devlin M. (Los Alamos National Laboratory, Los Alamos, USA)
14:50	**R247**	**New prompt fission neutron spectra measurement in 238U(N,F) reaction with a dedicated setup at Lansce/WNR** Laurent B. (CEA, DAM, DIF, Arpajon, France; 2 CENBG, Bordeaux, France)
15:10	**R248**	**Local and global even-odd effects in the fragment distributions and the prompt emission of 234U(n,f)** Giubega G. (University of Bucharest, Faculty of Physics, Bucharest-Magurele, Romania)
15:30	**S249**	**Estimates of fission barrier heights for neutron-deficient Po to Th nuclei produced in fusion reactions** Sagaidak R. (Flerov Laboratory of Nuclear Reactions, Joint Institute for Nuclear Research, Dubna, Moscow region, Russia)
15:40	**S251**	**Measurements of isomeric yield ratios of fission products from proton-induced fission on nat-U and 232-Th** Rakopoulos V. (Department of Physics and Astronomy, Uppsala University, Uppsala, Sweden)
15:45		**Break**
16:20	**I252**	**Prompt neutron emission and the energy balance in the reaction 235U(n,f)** Göök A. (European Commission, Joint Research Centre, Institute for Reference Materials and Measurements (IRMM), Belgium)
16:50	**R253**	**Comprehensive modeling of prompt fission neutrons and gamma rays in the spontaneous fission of Cf-252** Talou P. (Theoretical Division, Los Alamos National Laboratory, Los Alamos, New Mexico, USA)
17:10	**R254**	**Prompt neutron multiplicity in thermal neutron induced fission of 235U** Zeinalov Sh. (Laboratory of Neutron Physics, Joint Institute for Nuclear Research, Dubna Moscow region, Russia)
17:30	**R255**	**237Np absolute delayed neutron yield measurements** Doré D. (Irfu/SPhN, CEA/Saclay, Gif-sur-Yvette, France)
17:50	**R256**	**Prompt fission neutron and gamma properties as a function of incident neutron energy** Stetcu I. (Theoretical Division, Los Alamos National Laboratory, Los Alamos, USA)

Wednesday 14 September 14:00-18:10 Beethoven

Beethoven

Topic track: Evaluation
Session Title: Evaluation III

Chair: D. Rochman, Reactor Physics and Systems Behaviour Laboratory, Paul Scherrer Institut, Villigen PSI, Switzerland

14:00	**I257**	**The calculation and evaluation for n+54,56,57,58Fe reactions** Han Y. (China Institute of Atomic Energy, Beijing, R.P.China)
14:30	**R258**	**New evaluations of n+Cu and n+Zr nuclear data for neutron energies up to 200 MeV** Pereslavtsev P. (Karlsruhe Institute of Technology (KIT), Institut für Neutronenphysik u. Reaktortechnik, Eggenstein-Leopoldshafen, Karlsruhe, Germany)
14:50	**R259**	**Application of the samint methodology to the new cross section evaluations of 63cu and 65cu** Sobes V. (Ridge National Laboratory, Reactor and Nuclear Systems Division, Oak Ridge, USA)
15:10	**R260**	**On the use of the generalized SPRT method in the equivalent hard sphere approximation for nuclear data evaluation** Noguere G. (CEA, DEN, DER, SPRC, Cadarache, Saint-Paul-lez-Durance, France)
15:30	**S261**	**Analysis on CEA93 library** Guo F. (Nuclear Power Institute of China, Cheng du, R.P.China)
15:35	**S262**	**Method of self-consistent evaluation of absolute emission probabilities of particles and gamma rays** Badikov SA. (National Research Nuclear University “MEPhI”, Moscow, Russia)
15:40	**S263**	**Application and research of 281 group cross section library to lattice physics code of COSINE software package** Yan Y. (State Nuclear Power Software Development Center, SPIC, Beijing, P.R.China)
15:45		**Break**
16:20	**I265**	**Towards JEFF-3.3: goals, status and perspectives** Plompen AJM. (EC-JRC-IRMM, Geel, Belgium)
16:50	**R266**	**Implementation of a new energy-angular distribution of particles emitted by deuteron induced nuclear reaction in transport simulations** Ogando F. (UNED, Departamento de Ingenieria Energetica, Madrid, Spain)
17:10	**R267**	**Evaluation of deuteron-induced excitation functions for 186W(d, p)187W and 186W(d, 2n)186Re** Wang J. (China Institute of Atomic Energy, Beijing, R.P. China)
17:30	**R268**	**Theoretical calculations and analysis for n+6Li reaction** Tao X. (China Institute of Atomic Energy, Beijing, R.P. China)
17:50	**R269**	**Updated and revised neutron reaction data for n+237Np** Chen G. (China Institute of Atomic Energy, Beijing, R.P. China)

Wednesday 14 September 14:00-18:10 Mozart

Mozart

Topic track: Nuclear reaction measurements
Session Title: Fast neutrons II

Chair: M. Pillon, Fusion, ENEA, Frascati, Italy

14:00	**I270**	**Investigations of the inelastic scattering of fast neutrons on iron-56** Junghans AR. (Helmholtz-Zentrum Dresden - Rossendorf, Institute of Radiation Physics, Nuclear Physics Department, Dresden, Germany)
14:30	**R271**	**Measurements of 89Y(n,2n)88Y and 89Y(n,3n)87Y cross sections for fast neutrons by using the Korea Institute of Radiological and Medical Science MC-50 cyclotron** Hong SW. (Sungkyunkwan University, Department of Physics, Suwon, South Korea)
14:50	**R272**	**Measurement of (N, XN gamma) reaction cross section in W isotopes** Henning G. (Université de Strasbourg, IPHC, Strasbourg, France and CNRS, UMR7178, Strasbourg, France)
15:10	**R273**	**Fast neutron-induced fission at the time-of-flight facility nELBE** Kögler T. (Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany and Technical University Dresden, Dresden, Germany)
15:30	**S274**	**Measurements of cross sections for 209Bi (n, 4n) reactions with high energy neutrons produced by 30, 35, and 40 MeV protons** Hong S. (Department of Physics, Sungkyunkwan University, Suwon, Korea; 3 Department of Physics, S.P. Pune University, India)
15:35	**S275**	**Neutron transmission measurement for natural W at nELBE** Song TY. (Korea Atomic Energy Research Institute, Daejeon, Korea)
15:40	**S277**	**Angular distribution measurement of gamma rays from inelastic neutron scattering on iron-56 at nELBE time-of-flight facility** Dietz M. (Helmholtz-Zentrum Dresden Rossendorf (HZDR), Institute of Radiation Physics, Dresden, Germany)
15:45	**S278**	**Inspection of 56Fe g-ray angular distributions as a function of incident neutron energy using optical model approaches** Vanhoy JR. (Department of Physics, United States Naval Academy, Annapolis, USA)
15:50		**Break**
16:20	**I279**	**Inelastic neutron scattering with GAINS@GELINA: an overview of the last decade** Borcea C. (Horia Hulubei National Institute for Physics and Nuclear Engineering, Romania)
16:50	**R280**	**(n,xn gamma) Cross sections on actinides versus reaction code calculations** Kerveno M. (Université de Strasbourg, IPHC, Strasbourg, France, CNRS, UMR7178, Strasbourg, France)
17:10	**R281**	**(n,xn) cross sections on 56,57Fe** Negret A. (Horia Hulubei National Institute for Physics and Nuclear Engineering, Bucharest - Magurele, Romania)
17:30	**R282**	**Measurements of neutron scattering angular distributions with a new scintillator setup at GELINA** Pirovano E. (Institute for Reference Materials and Measurements, Joint Research Center, Geel, Belgium)
17:50	**R283**	**Measurement of (n,α) cross section for set of structural material isotopes** Khryachkov V. (Institute for Physics and Power Engineering (IPPE), Obninsk, Russia)

Wednesday 14 September 14:00-18:10 Strauss

Strauss

Topic track: Nuclear data for applications
Session Title: Non-Destructive Assay

Chair: A. Stankovskiy, Institute for Advanced Nuclear Systems, SCK•CEN, Mol, Belgium

14:00	**I284**	**Update on the nuclear data working group in the United States** Romano CE. (Oak Ridge National Laboratory, Tennessee, USA)
14:30	**R285**	**Nuclear data for ion beam analysis applications** Capote R. (NAPC-Nuclear Data Section, IAEA, Vienna, Austria) Nuclear Data Section, International Atomic Energy Agency, Vienna, Austria
14:50	**R286**	**Developments in capture-gamma libraries for nonproliferation applications** Firestone RB. (Lawrence Berkeley National Laboratory, Berkeley, California)
15:10	**R287**	**Delayed gamma-ray spectroscopy technique for nuclear security and safeguards in a project of active neutron non-destructive analysis (NDA) developments** Koizumi M. (Integrated Support Center for Nuclear Security and Nuclear Nonproliferation)
15:30	**S288**	**Influence of the neutron transport tube for neutron resonance densitometry** Kitatani F. (JAEA Nuclear Science and Engineering Center, Ibaraki, Japan)
15:35	**S289**	**Elemental composition and sedimentation rates in a marine system influenced with the tide action using INAA and Plomb-210 method: example of the Gabes Gulf (Tunisia)** Hassen NH. (National Center of Nuclear Sciences and Technologies, Technopole Sidi Thabet, Tunisia)
15:40	**S290**	**Designing tools for oil exploration using nuclear modeling** Mauborgne ML. (Schlumberger Riboud Product Center, Clamart, France)
15:45	**S291**	**Non-destructive assay of nuclear materials using a self-indication method** Hori J. (Department of Nuclear Science and Engineering, Kyoto University, Research Reactor Institute, Osaka, Japan)
15:50		**Break**
16:20	**I292**	**Exploring for oil with nuclear physics** Mauborgne ML. (Schlumberger Riboud Product Center, Clamart, France)
16:50	**R293**	**Neutron resonance analysis for nuclear safeguards and security applications** Paradela C. (Standards for Nuclear Safety, Security and Safeguards Unit, EC-JRC-IRMM, Geel, Belgium)
17:10	**R294**	**Experiments at the GELINA facility for the validation of the self-indication neutron resonance densitometry** Rossa R. (Belgian nuclear research centre SCK-CEN, Society and Policy Support expert group, and Universite' Libre de Bruxelles ULB, Ecole polytechnique de Bruxelles - Service de Métrologie Nucléaire, Brussels, Belgium)
17:30	**R295**	**Applications of gamma spectrometry and particle accelerators in the field of nuclear forensics** Apostol AI. (Horia Hulubei National Institute for Physics and Nuclear Engineering, department of Nuclear Physics and University of Bucharest, Bucharest, Romania)
17:50	**R296**	**134mTe, 135mTe,136mXe (ratio) production yield measurements for SNM detection and identification at border control points** Etilé A. (Commissariat à l'énergie Atomique et aux énergie alternativers, DAM, DIF, Arpajon, France)

Wednesday 14 September 14:00-18:10 Morus

Morus

Topic track: Experimental facilities, equipment, techniques and methods
Session Title: Experimental facilities, equipment, techniques and methods IV

Chair: C. Weiss, CIVIDEC instrumentation, Vienna, Austria

14:00	**I297**	**Isotope production and target preparation for nuclear astrophysics data** Schumann D. (Energy and Safety Research Department, Paul Scherrer Institute, Villigen, Switzerland)
14:30	**R298**	**Targets for production of research quantities of the medical radioisotopes with α and p/d beams** Stolarz A. (Heavy Ion Laboratory, University of Warsaw, Warsaw, Poland)
14:50	**R299**	**Overview of the nuclear targets produced at the Institute for Reference Materials and Measurements within the project of solving challenges in nuclear data** Sibbens G. (EC-JRC Institute for Reference Materials and Measurements, Geel, Belgium)
15:10	**R300**	**Technical developments for accurate determination of amount of samples used for TOF measurements** Terada K. (Japan Atomic Energy Agency (JAEA), Nuclear Science and Engineering Center (NSEC), Ibaraki, Japan)
15:30	**S301**	**High precision analysis of isotopic composition for samples used for nuclear cross-section measurements** Shibahara Y. (Kyoto University / Research Reactor Institute, Osaka, Japan)
15:35	**S302**	**Measurement and simulation for a complementary imaging with the neutron and X-ray beams** Hara KY. (Faculty of engineering, Hokkaido University, Sapporo, Japan)
15:40	**S303**	**Neutron beamline design of a white neutron source at CSNS** Jing H. (Institute of High Energy Physics, Chinese Academy of Sciences (CAS) Beijing, P.R. China)
15:45		**Break**
16:20	**I304**	**Deuteron nuclear data for the design of accelerator-based neutron sources – measurement, model analysis, evaluation and application** Watanabe Y. (Kyushu University, Department of Advanced Energy Engineering Science, Kasuga, Japan)
16:50	**R305**	**Neutron field of accelerator-driven p(35)+Be fast neutron source at NPI Rez** Stefanik M. (Nuclear Physics Institute of The Academy of Sciences of the Czech Republic, Rez, Czech Republic and Czech Technical University in Prague, Faculty of Nuclear Sciences and Physical Engineering, Prague, Czech Republic)
17:10	**R306**	**Simulations of the stopping efficiencies of fission ion guides** Solders A. (Department of Physics and Astronomy, Uppsala University, Uppsala, Sweden)
17:30	**R307**	**Nuclear and reaction data programme at the AWE's ASP neutron source** Simons A. (Radiation Science Group, Physics, AWE, Aldermaston, UK)
17:50	**R308**	**Extended methods using thick-targets for nuclear reaction data of radioactive isotopes** Ebata S. (Nuclear Reaction Data Centre, Faculty of Science, Hokkaido University, Sapporo, Japan)

Wednesday 14 September 14:00-18:10 Erasmus

Erasmus

Topic track: Integral experiments, benchmarks and data validation
Session Title: Integral experiments, benchmarks and data validation III

Chair: O. Cabellos, Data Bank, OECD-NEA, Boulogne-Billancourt, France

14:00	I309	**High fidelity Monte Carlo program SuperMC and its on-the-fly temperature-dependent cross section generation method** Zou J. (Institute of Nuclear Energy Safety Technology, Chinese Academy of Sciences, Hefei, P.R. China)
14:30	R310	**Experimental validation of depletion calculations with VESTA 2.1.5 using JEFF-3.2** Haeck W. (IRSN - PSN-EXP/SNC/LNR, Fontenay aux Roses, France)
14:50	R311	**Criticality benchmark simulations with ENDF/B-VIII.beta structural material evaluations in GND format** Descalle MA. (Lawrence Livermore National Laboratory, Livermore, CA, USA)
15:10	R312	**Use of integral experiments in support to the validation of JEFF-3.2 nuclear data evaluation** Leclaire N. (IRSN/PSN-EXP/SNC, Fontenay-aux-Roses, France)
15:30	S313	**Birth-death model for description of transient processes in multiplying medium with MOX-Fuel** Korbut T. (The Joint Institute for Power and Nuclear Research - Sosny, Minsk, Belarus)
15:35	S314	**Use the results of measurements on COBRA facility for testing of neutron data of main structural materials for fast reactors** Khryachkov V. (Institute for Physics and Power Engineering (IPPE), Obninsk, Russia)
15:40	S315	**Re-interpretation of the ERMINE-V experiment: validation of fission product integral cross section in the fast energy range** Leconte P. (CEA Cadarache, Saint Paul les Durance, France)
15:45	S316	**Comparison and validation of MCNP photon interaction data against computational examples and SINBAD benchmark experiments** Colling B. (Culham Centre for Fusion Energy, Culham Science Centre, Oxon, UK)
15:50		**Break**
16:20	I317	**Validation of dosimetry data using historic and recent measurements on the flattop critical assembly** White MC. (Los Alamos National Laboratory, Los Alamos, USA)
16:50	R318	**Combined use of K-effective and beta-effective measurements for nuclear data validation and improvement** Kodeli IA. (Jožef Stefan Institute, Ljubljana, Slovenia)
17:10	R319	**Comparative study of nuclear data libraries on Monte Carlo modelling of MYRRHA mockup critical cores in the VENUS-F reactor** Krasa A. (Advanced Nuclear Systems Institute, Belgian Nuclear Research Centre SCK-CEN, Mol, Belgium)
17:30	R320	**Reliability assessment of MVP-BURN code and JENDL-4.0 library related to the nuclear transmutation of light platinum-group elements** Terashima A. (Tokyo Institute of Technology, Tokyo, Japan and University of California, Irvine, CA, USA)
17:50	R505	**A test blanket module mock-up experiment at high intensity deuteron triton neutron generator experimental platform** Liu C. (Institute of Nuclear Energy Safety Technology, Chinese Academy of Sciences, Hefei, Anhui, P.R. China)

Wednesday 14 September 14:00-18:10 Vives

Vives

Topic track: Theory of nuclear reactions and structure, models and codes
Session Title: Theory of nuclear reactions and structure, models and codes II

Chair: A. Carlson, NIST, Frederick, USA

14:00 I321 Improvement of gross theory of beta-decay for application to nuclear data
Koura H. (Advanced Science Research Center, Japan Atomic Energy Agency, Ibaraki, Japan)

14:30 R322 Exclusive data-based modeling of neutron-nuclear reactions below 20 MeV
Savin D. (Dukhov Research Institute of Automatics (VNIIA), The Center for Fundamental and Applied Research, Moscow, Russia)

14:50 R323 R-matrix approach at the intersection with the statistical model regime
Srdinko Th. (Technische Universität Wien, Atominstitut, Vienna, Austria)

15:10 R324 The first unbound states of mirror 9B and 9Be nuclei
Odsuren M. (School of Engineering and Applied Sciences, National University of Mongolia, Ulaanbaatar, Mongolia)

15:30 S325 An approach to adjustment of relativistic mean field model parameters
Bayram T. (Department of Nuclear Energy Engineering, Sinop University, Sinop, Turkey)

15:35 S326 A tool for calculation of the 7Li(p,n)7Be neutron spectra below the three-body break up reaction threshold
Pachuau R. (Department of Physics, Mizoram University, Tanhril, Aizawl, Mizoram, India)

15:40 S327 Description of nucleon scattering on 208Pb and 209Bi by a fully lane-consistent dispersive coupled-channel optical model potential
Sun WL. (Institute of Applied Physics and Compuational Mathematics, Beijing, P.R. China)

15:45 S328 Role of rotational energy component in the dynamics of 16O+198Pt reaction
Sangeeta A. (School of Physics and Materials Science, Thapar University, Patiala, India)

15:50 Break

16:20 I329 Advances in nuclear reaction calculations by incorporating information from nuclear mean-field theories
Kawano T. (Theoretical Division, Los Alamos National Laboratory, Los Alamos, USA)

16:50 R331 Ab initio calculations of light-nucleus reactions
Hupin G. (CEA/DAM/DIF, Service the Physique Nuclèaire, Arpajon, France)

17:10 R332 Statistical theory of light-nucleus reactions with 1p-shell light nuclei involved
Sun X. (Guangxi Normal University, College of Physics, Guilin, P.R.China)

17:30 R333 Global phenomenological and microscopic optical model potentials for alpha
Xu Y. (Shanxi Datong University, School of Physics and Electronic Science, Datong, P.R.China)

17:50 R167 Anomalous coupling of high spin collective levels in coupled channels optical model calculations for even-even actinides
Quesada JM. (Departamento de Fisica Atomica, Molecular y Nuclear, Universidad de Sevilla, Sevilla, Spain)

Wednesday 14 September 08:30-18:10 Witte Roos

Witte Roos

Session Title: Poster Session

Poster number

P053	S172	Neutron-neutron and neutron-photon correlations with FREYA
R054	S173	Theoretical investigation of fission fragment observables in the symmetric mass region for thermal neutron induced fissions of 233U and 241Pu
P055	S174	Total prompt gamma-ray emission in fission
P056	S175	Precision requirement of the photofission cross section for the nondestructive assay technique
P058	S185	Evaluation of neutron total and capture cross sections on Tc-99 in the unresolved resonance region
P059	S186	Improving activation cross section data with TALYS
P060	S187	Updated and revised neutron reaction data for n+236,238Np
P061	S188	Comparison evaluation for neutron cross section of 250Cf
P062	S197	Measurements of the 6Li(n,α)t standard cross-section at the GELINA facility
P063	S198	Cross section of the 197Au (n,2n) 197Aug+m1,m2 reaction
P064	S199	Cross sections of the 144Sm(n,α)141Nd and 66Zn(n,α)63Ni reactions at 4.0, 5.0 and 6.0 MeV
P065	S200	Measurements of neutron capture cross-section on 70Zinc
P066	S209	The evaluated nuclear data library for ADS in China
P067	S210	Comparative analysis of the non-destructive methods to control fissile materials in large containers
P068	S211	Cross-sections from deuteron irradiation of thin thorium target at energy 7 GeV
P069	S212	Work plan for improving the DARWIN2.3 depleted material balance calculation concerning a some important isotopes for fuel cycle
P070	S222	Monte Carlo simulations of the n_TOF lead spallation target with the Geant4 toolkit: a benchmark study
P071	S231	Impact of implicit effects on uncertainties and sensitivities of the Doppler coefficient of a LWR pin cell
P072	S232	A stress test on 235U(n, f) in adjustment with HCI and HMI benchmarks
P073	S249	Estimates of fission barrier heights for neutron-deficient Po to Th nuclei produced in fusion reactions
P075	S251	Measurements of isomeric yield ratios of fission products from proton-induced fission on nat-U and 232-Th
P076	S261	Analysis on CEA93 library
P077	S262	Method of self-consistent evaluation of absolute emission probabilities of particles and gamma rays
P078	S263	Application and research of 281 group cross section library to lattice physics code of COSINE software package
P080	S274	Measurements of cross sections for 209Bi (n, 4n) reactions with high energy neutrons produced by 30, 35, and 40 MeV protons
P081	S275	Neutron transmission measurement for natural W at nELBE

P083	S277	Angular distribution measurement of gamma rays from inelastic neutron scattering on iron-56 at nELBE time-of-flight facility
P084	S278	Inspection of 56Fe g-ray angular distributions as a function of incident neutron energy using optical model approaches
P085	S288	Influence of the neutron transport tube for neutron resonance densitometry
P086	S289	Elemental composition and sedimentation rates in a marine system influenced with the tide action using INAA and Plomb-210 method: example of the Gabes Gulf (Tunisia)
P087	S290	Designing tools for oil exploration using nuclear modeling
P088	S291	Non-destructive assay of nuclear materials using a self-indication method
P089	S301	High precision analysis of isotopic composition for samples used for nuclear cross-section measurements
P090	S302	Measurement and simulation for a complementary imaging with the neutron and X-ray beams
P091	S303	Neutron beamline design of a white neutron source at CSNS
P092	S313	Birth-death model for description of transient processes in multiplying medium with MOX-Fuel
P093	S314	Use the results of measurements on COBRA facility for testing of neutron data of main structural materials for fast reactors
P094	S315	Re-interpretation of the ERMINE-V experiment: validation of fission product integral cross section in the fast energy range
P095	S316	Comparison and validation of MCNP photon interaction data against computational examples and SINBAD benchmark experiments
P096	S325	An approach to adjustment of relativistic mean field model parameters
P097	S326	A tool for calculation of the 7Li(p,n)7Be neutron spectra below the three-body break up reaction threshold
P098	S327	Description of nucleon scattering on 208Pb and 209Bi by a fully lane-consistent dispersive coupled-channel optical model potential
P099	S328	Role of rotational energy component in the dynamics of 16O+198Pt reaction
P144	S501	Testing of the ABBN-RF multigroup data library in photon transport calculations
P145	S502	Verification of the databases EXFOR and ENDF
P146	S503	Inter-comparison of Hauser-Feshbach model codes toward better actinide evaluations

Thursday 15 September 08:30-12:20 Ambassadeur

Ambassadeur

Topic track: Fission physics and observables
Session Title: Fission theory and experiments III

Chair: G. Belier, CEA-DIF, Arpajon, France

08:30 I334 Nuclear fission: from more phenomenology and adjusted parameters to more fundamental theory and increased predictive power
Magierski P. (Faculty of Physics, Warsaw University of Technology, Warsaw, Poland)

09:00 R335 Study of five-dimensional potential-energy surfaces for actinide isotopes by the macroscopic-microscopic method
Fan TS. (State Key Laboratory of Nuclear Physics and Technology, Institute for Heavy ion Physics, School of Physics, Peking University, Beijing, P.R. China)

09:20 R336 Odd-even effect dependence on the excitation energy in low energy fission
Mirea M. (Theoretical Physics, Horia Hulubei National Institute of Physics and Nuclear Engineering, Bucharest-Magurele, Romania)

09:40 R337 Microscopic description of fission dynamics: toward a 3D computation of the time dependent GCM equation
Regnier D. (CEA, DAM, DIF, Arpajon, France)

10:00 S338 Neutron induced fission cross section measurements of 240-Pu and 242-Pu
Belloni F. (EC/JRC/IRMM, Geel, Belgium)

10:05 S339 Energy dependence of time parameters of delayed neutrons for neutron induced fission of the Np-237 in energy range from 14.23 to 17.98 MeV
Khryachkov V. (Institute for Physics and Power Engineering (IPPE), Obninsk, Russia)

10:10 S340 The fission time projection chamber
Snyder L. (Lawrence Livermore National Lab, Livermore, USA)

10:15 S342 Potential-driving model study on neutron-induced actinide nuclei fission
Wei Z. (Lanzhou University, School of Nuclear Science and Technology and Ministry of Education, Engineering Research Center for Neutron Application, Lanzhou, P.R.China)

10:20 Break

10:50 I343 A new UK fission yield evaluation
Mills RW. (UK National Nuclear Laboratory, Sellafield, UK)

11:20 R344 Excitation energy influence at the scission configuration
Ramos D. (Dept. de Física de Partículas, USC, Santiago de Compostela, Spain)

11:40 R345 Macroscopic-microscopic models of nuclear potential energy - implementation in CONRAD
Tamagno P. (CEA, DEN/DER/SPRC, Saint-Paul-lez-Durance, France)

12:00 R346 Fission description: first steps towards a full resolution of the time-dependent hill-wheeler equation
Verrière M. (CEA, DAM, DIF, Arpajon, France)

Thursday 15 September 08:30-12:20 Beethoven

Beethoven

Topic track: Evaluation
Session Title: Evaluation IV

Chair: W. Sun, Institute of Applied Physics and Compuational Mathematics, Beijing, P.R.China

08:30	I347	**On the use of Bayesian Monte-Carlo in evaluation of nuclear data** De Saint Jean C. (CEA, DEN-Cadarache, Saint-Paul-lez-Durance, France)
09:00	R348	**A variational Bayesian approach to accelerate Monte Carlo evaluation methods** Schnabel G. (CEA Saclay, Irfu/SPhN, Gif-sur-Yvette, France)
09:20	R349	**Novel evaluation concept including model defects** Leeb H. (Technische Universität Wien, Atominstitut, Vienna, Austria)
09:40	R350	**Fission yield covariances for JEFF: a Bayesian Monte Carlo method** Leray O. (Reactor Physics and Systems Behaviour Laboratory, Paul Scherrer Institut, Villigen, Switzerland)
10:00	S351	**Bootstrap method for constructing covariance matrices of optical-model parameters in the study of the threshold anomaly** Abriola D. (Department of Physics, CNEA, Buenos Aires, Argentina)
10:05	S352	**Uncertainty of the delayed neutron fraction in fuel assembly depletion calculations** Aures A. (Gesellschaft für Anlagen- und Reaktorsicherheit (GRS) gGmbH, Core Behaviour Department, Garching, Germany)
10:10	S353	**The impact of the retroactive method for resonance parameter uncertainties, in particular propagated to helium production due to Ni-59 in stainless steel** Helgesson P. (Division of applied nuclear physics, Uppsala University, Uppsala, Sweden)
10:15	S354	**Emerging capabilities for charged-particle induced reactions with the R-matrix SAMMY code** Pigni MT. (Oak Ridge National Laboratory, Oak Ridge, USA)
10:20		**Break**
10:50	I355	**Characterization of the energy-dependent uncertainty and correlation in the neutron displacement kerma** Griffin PJ. (Sandia National Laboratories, Albuquerque, NM, USA)
11:20	R356	**Understanding total Monte Carlo uncertainty propagation in burn up calculations with generalized perturbation theory** Bidaud A. (Laboratoire de Physique Subatomique, LPSC/IN2P3/CNRS, Univ. Grenoble-Alpes, Grenoble, France)
11:40	R357	**Nuclear data uncertainty propagation by the XSUSA method in the HELIOS2 lattice code** Wemple C. (Studsvik Scandpower, Inc., Idaho Falls, ID USA)
12:00	R358	**Covariances for the 56Fe radiation damage cross sections** Simakov S. (Department of Nuclear Sciences and Applications, IAEA, Vienna, Austria and Institute of Neutron Physics and Reactor Technology, KIT, Karlsruhe, Germany)

Thursday 15 September 08:30-12:20 Mozart

Mozart

Topic track: Nuclear reaction measurements
Session Title: Fast neutrons III/Charged particles IV

Chair: M. Kerveno, IPHC - CNRS, Strasbourg, France

08:30	**I359**	**High resolution measurements of the exited states (n,pn), (n,dn) C-12 cross sections** Pillon M. (ENEA C.R. Frascati, Rome, Italy)
09:00	**R360**	**The 13C(n,a0)10Be cross section at 14.3 MeV and 17 MeV neutron energy** Kavrigin P. (CIVIDEC Instrumentation, Vienna, Austria)
09:20	**R361**	**Neutron production in deuteron-induced reactions on Li, Be, and C at an incident energy of 100 MeV** Araki S. (Department of Advanced Energy Engineering Science, Kyushu University, Fukuoka, Japan)
09:40	**R063**	**Assessment of beryllium and molybdenum nuclear data files with the RPI neutron scattering system in the energy region from 0.5 to 20 MeV** Danon Y. (Gaerttner LINAC Center, Rensselaer Polytechnic Institute, Troy, New York)
10:00	**S363**	**(n,xn) Cross section measurements for Y-89 foils used as detectors for high energy neutron measurements in deeply subcritical assembly "QUINTA"** Bielewicz M. (National Centre for Nuclear Research, Swierk, Poland)
10:05	**S364**	**A high precision tagged neutron n-p scattering measurement at 14.9 MeV** Carlson AD. (National Institute of Standards and Technology, Gaithersburg, USA)
10:10	**S365**	**Measurement of the angular and energy distributions of neutrons from 7Li(d,n)8Be reaction at deuteron energy 2.9 MeV by activation method** Khryachkov V. (Institute for Physics and Power Engineering (IPPE), Obninsk, Russia)
10:15		**Break**
10:50	**I366**	**Investigating the surrogate-reaction method via the simultaneous measurement of fission and gamma-decay probabilities** Jurado B. (Centre d'Études Nucléaires de Bordeaux-Gradignan, Gradignan, France)
11:20	**R367**	**The cross sections and energy spectra of the particle emission in proton induced reactions on 204,206,207,208Pb and 209Bi** Zhang ZJ. (Department of Physics, Northwest University, Xi'an, P.R.China)
11:40	**R368**	**Proton inelastic cross-sections on 16O and 28Si** Boromiza M. (Horia Hulubei National Institute for Physics and Nuclear Engineering, Bucharest-Magurele, Romania and University of Bucharest, Faculty of Physics, Bucharest, Romania)
12:00	**R362**	**Measurements of gamma-ray emission cross section for 14N(d,p)15N from 0.6-2.0 MeV** Kakuee O. (Physics & Accelerators Research School, NSTRI, Tehran, Iran)

Thursday 15 September 08:30-12:20 Strauss

Strauss

Topic track: Nuclear data for applications
Session Title: Fusion

Chair: P. Leconte, DEN/DER/SPRC/LEPh, CEA, Saint Paul Lez Durance Cedex, France

08:30	**I369**	**Nuclear data for fusion technology - The European approach** Fischer U. (Institute for Neutron Physics and Reactor Technology, Karlsruhe Institute of Technology (KIT), Eggenstein-Leopoldshafen, Germany)
09:00	**R370**	**Scoping the material response landscape with automatic simulation tools – activation, transmutation, and primary damage functions** Gilbert MR. (T&M department, United Kingdom Atomic Energy Authority, UK)
09:20	**R371**	**Reliability of activation cross sections for estimation of shutdown dose rate in the ITER port cell and port interspace** Ogando F. (Power Engineering Department, UNED. Madrid, Spain)
09:40	**R372**	**Double differential light charged particle emission cross sections and stopping power calculations for some structural fusion materials** Sarpün IH. (Afyon Kocatepe Uni., Physics Dept., Afyonkarahisar, Turkey)
10:00	**S373**	**Study of concrete activation with IFMIF-like neutron irradiation: status of EAF and TENDL neutron activation cross-sections** Ogando F. (Power Engineering Department, UNED. Madrid, Spain)
10:05		**Break**
10:50	**I374**	**Copper benchmark experiment for the testing of JEFF-3.2 nuclear data for fusion applications** Angelone M. (ENEA UT-FUS, C.R. Frascati, Rome, Italy)
11:20	**R375**	**natCu and natV cross-sections measured by quasimonoenergetic neutrons from p+7Li reaction in the energy range of 18-34 MeV** Majerle M. (Department of Nuclear Reactions, Nuclear Physics Institute of the CAS, Řež, Czech Republic)
11:40	**R376**	**Sensitivity and uncertainty analysis for the tritium breeding ratio of a DEMO fusion reactor with a helium cooled pebble bed blanket** Nunnenmann E. (Karlsruhe Institute of Technology, Institute of Neutron Physics and Reactor Technology, Karlsruhe, Germany)
12:00	**R377**	**On the synergy of nuclear data for fusion and model assumptions** Avrigeanu V. (Horia Hulubei National Institute for Physics and Nuclear Engineering, Bucharest-Magurele, Romaniaf)

Thursday 15 September 08:30-12:20 Morus

Morus

Topic track: Nuclear masses, structure and decay data measurements
Session Title: Nuclear masses, structure and decay data measurements I

Chair: M. Fallot, SUBATECH - University of Nantes - CNRS/IN2P3 - EMN, Nantes, France

08:30	**I378**	**Measurement and interpretation of nuclear structure data in heavy mass region** Mukherjee G. (Variable Energy Cyclotron Centre, Kolkata, India)
09:00	**R379**	**Structure of single particle states in 75,77Cu** Hadynska-Klek K. (INFN Laboratori Nazionali di Legnaro, Legnaro, Italy)
09:20	**R380**	**Corrections of alpha- and proton-decay energies in implantation experiments** Huang WJ. (CSNSM-IN2P3/CNRS, Universitvé de Paris Sud, Orsay, France)
09:40	**R381**	**Investigation of beta spectral shapes with a PIPS-Detector-Setup** Domula AR. (Technische Universität Dresden, Institut für Kern- und Teilchenphysik, Dresden, Germany)
10:00	**R382**	**Isomers close to the 170Dy valence maximum: first spectroscopy of 168,170Tb** Gurgi LA. (Department of Physics, University of Surrey, Guildford, UK)
10:20		**Break**
10:50	**I383**	**The 2016 atomic mass evaluation and the mass tables** Audi G. (CSNSM, Univ Paris-Sud, CNRS/IN2P3, Université Paris-Saclay, Orsay, France)
11:20	**R384**	**Multipolarity measurement of the main ground-state transition 2- to 1- in 210Bi** Cieplicka-Orynczak N. (INFN sezione di Milano, Milano, Italy and Institute of Nuclear Physics, Polish Academy of Sciences, Krakow, Poland)
11:40	**R385**	**Gamma-decay in light nuclei. Halo isomers** Izosimov IN. (Joint Institute for Nuclear Research, Dubna, Russia)
12:00	**R386**	**Study of isomers and their decays in 193,195Bi** Mukherjee G. (Variable Energy Cyclotron Centre, Kolkata, India)

Thursday 15 September 08:30-12:20 Erasmus

Erasmus

Topic track: Gamma-ray strength functions
Session Title: Gamma-ray strength functions I

Chair: H. Utsunomiya, Department of Physics, Konan University, Higashinada, Japan

08:30	**I387**	**Quasiparticle random phase approximation systematics of gamma-ray strength functions based on the Gogny finite range effective interaction** Goriely S. (Institut d'Astronomie et d'Astrophysique, Université Libre de Bruxelles, Brussels, Belgium)
09:00	**R388**	**Microscopic calculations of radiative nuclear reaction characteristics for double-magic nuclei** Achakovskiy O. (Institute for Physics and Power Engineering, Obninsk, Russia)
09:20	**R389**	**Dipole strength functions from large scale shell model for light and medium-mass nuclei** Sieja K. (IPHC/CNRS Strasbourg, France)
09:40	**R390**	**Improvements and testing practical expressions for photon strength functions of E1 gamma-transitions** Kadenko I. (Nuclear Physics Department, Taras Shevchenko National University, Kyiv, Ukraine)
10:00	**S391**	**Determination of the effects of nuclear level density parameters on photofission cross sections of 235U up to 20 MeV** Sarpun IH. (Kırıkkale University, Faculty of Arts and Science, Department of Physics, 1 Kırıkkale, Turkey)
10:05	**S392**	**Axial asymmetry breaking in excited heavy nuclei as essential feature for the prediction of level densities** Junghans AR. (Institute of Radiation Physics, Helmholtz-Zentrum Dresden-Rossendorf)
10:10	**S393**	**Photon strength functions of 78Se from the two-step gamma cascades measurement** Krticka M. (Faculty of Mathematics and Physics, Charles University, Prague, Czech Republic)
10:20		**Break**
10:50	**I394**	**E1 and M1 strength functions at low energy** Schwengner R. (Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany)
11:20	**R395**	**Photoneutron reaction cross sections from various experiments - analysis and evaluation using physical criteria of data reliability** Varlamov VV. (Lomonosov Moscow State University, Skobeltsyn Institute of Nuclear Physics, Moscow, Russia)
11:40	**R396**	**Gamma strength functions measurements at the Oslo Cyclotron** Siem S. (Dept. of Physics, University of Oslo, Oslo, Norway)
12:00	**R397**	**Statistical gamma-ray decay studies at iThemba LABS** Wiedeking M. (Department of Nuclear Physics, iThemba LABS, Faure, South Africa)

Thursday 15 September 08:30-12:20 Vives

Vives

Topic track: Theory of nuclear reactions and structure, models and codes
Session Title: Theory of nuclear reactions and structure, models and codes III

Chair: T. Kawano, Theoretical Division, Los Alamos National Laboratory, Los Alamos, USA

08:30 I398 Nuclear model developments in FLUKA for present and future applications
Ferrari A. (CERN, Geneva, Switzerland)

09:00 R399 Update on FLUKA prompt-gamma emission and residual activity calculations
Schoofs P. (EN, CERN, Geneva, Switzerland)

09:20 R400 Influence of secondary pions on neutron and prompt photon production in spallation neutron sources
Colonna N. (INFN, Section of Bari, Bari, Italy)

09:40 R401 BetaShape: A new code for improved analytical calculations of beta spectra
Mougeot X. (CEA, LIST, Laboratoire National Henri Becquerel (LNE-LNHB), Gif-sur-Yvette, France)

10:00 R402 Role of the direct processes in deuteron interactions with structural materials
Avrigeanu M. (Horia Hulubei National Institute for Physics and Nuclear Engineering, Bucharest-Magurele, Romania)

10:20 S403 Calculation of pre-equilibrium effects in neutron-induced cross section on 65Cu
Yettou L. (University of Bab Ezzouar, Faculty of physics, Algiers, Algeria)

10:25 Break

10:50 I404 Generalized Reich-Moore R-matrix approximation
Arbanas G. (Reactor and Nuclear Systems Division, Oak Ridge National Laboratory, Oak Ridge, TN, USA)

11:20 R405 Status of the R-matrix code AMUR toward a consistent cross-sections evaluation and covariance analysis for the light nuclei
Kunieda S. (Japan Atomic Energy Agency, Nuclear Data Center, Tokai-mura, Naka-gun, Ibaraki, Japan)

11:50 R406 Development of a code system DEURACS for theoretical analysis and prediction of deuteron-induced reactions
Nakayama S. (Nuclear Data Center, Japan Atomic Energy Agency, Tokai, Japan)

12:00 R407 Multi-criteria comparative evaluation of spallation reaction models
Korovin YA. (General and special physics, Obninsk Institute for Nuclear Power Engineering of NNRU MEPhI, Obninsk, Russia)

Thursday 15 September 14:00-18:10 Ambassadeur

Ambassadeur

Topic track: Fission physics and observables
Session Title: Fission theory and experiments IV

Chair: P. Magierski, Faculty of Physics, Warsaw University of Technology, Warsaw, Poland

14:00	I408	**Experimental fission study using multi-nucleon transfer reactions** Nishio K. (Advanced Science Research Center, Japan Atomic Energy Agency, Tokai, Ibaraki, Japan)
14:30	R409	**Fission product yield measurements using mono-energetic photon beams** Tornow W. (Triangle Universities Nuclear Laboratory and Department of Physics, Duke University, Durham, NC, USA)
14:50	R410	**Energy dependence of fission product yields for 235U,238U and 239Pu with monoenergetic neutrons between thermal and 14.8 MeV** Gooden ME. (Los Alamos National Laboratory, Los Alamos, NM, USA)
15:10	R411	**Fission fragment angular distributions in neutron-induced fission of U-235 measured with a time projection chamber** Geppert-Kleinrath V. (Vienna University of Technology, Atominstitut, Vienna, Austria)
15:30	S412	**Comparison between absolute and relative neutron-induced fission cross section measurements of 237Np and 238U at NPL and IRMM** Salvador-Castiñeira P. (Neutron Metrology Group, National Physical Laboratory (NPL), Teddington, UK)
15:35	S413	**Neutron-induced fission cross section of 242Pu from 15 MeV to 20 MeV** Hambsch F.-J. (European Commission, Joint Research Centre, Institute for Reference Materials and Measurements, Geel, Belgium)
15:40	S415	**Thorium-232 fission induced by light charged particles up to 70 MeV** Métivier V. (Laboratoire SUBATECH, Ecole des Mines de Nantes, Université de Nantes, CNRS/IN2P3, Nantes, France)
15:45	S416	**High accuracy 234U(n,f) cross-section in the resonance energy region** Leal-Cidoncha E. (Universidad de Santiago de Compostela, Santiago de Compostela, Spain)
15:50		**Break**
16:20	I417	**Studies of fission fragment properties at the Los Alamos Neutron Science Center (LANSCE)** Tovesson F. (Los Alamos National Laboratory, Los Alamos, NM, USA)
16:50	R418	**The new double energy-velocity spectrometer verdi** Jansson K. (Uppsala University, , Uppsala, Sweden)
17:10	R419	**New developments of the FALSTAFF experimental setup** Thulliez L. (CEA, DSM, IRFU, SPhN, Gif-sur-Yvette, France)
17:30	R420	**Detailed examination of neutron-induced fission cross section systematic uncertainties using a time projection chamber** Manning B. (Los Alamos National Laboratory, Physics Department, Los Alamos, USA)
17:50	R421	**High-resolution measurements of thermal neutron-induced fission fragment yields with the SPIDER 2V-2E spectrometer at LANSCE** Mayorov DA. (Los Alamos National Laboratory, Los Alamos, NM, USA)

Thursday 15 September 14:00-18:10 Beethoven

Beethoven

Topic track: Evaluation
Session Title: Evaluation V

Chair: P. Griffin, Radiation and Electrical Sciences, Sandia National Laboratories, Albuquerque, USA

14:00 I422 The Decay Data Evaluation Project (DDEP): an international collaboration providing evaluated decay scheme data
Kellett MA. (CEA, LIST, Laboratoire National Henri Becquerel, Gif-sur-Yvette, France)

14:30 R424 Nuclear data for nuclear reactor antineutrino flux calculations
Sonzogni AA. (National Nuclear Data Center, Brookhaven National Laboratory, Upton, NY, USA)

14:50 R425 233U data evaluation for criticality study
Alrwashdeh M. (Jordan Atomic Energy Commission, Irbid, Jordan)

15:10 S426 Decay data evaluation project (DDEP): updated evaluation of the Ba-140, La-140 and Ce-141 decay characteristics
Chechev VP. (Applied Nuclear Researches, Khlopin Radium Institute, Saint Petersburg, Russia)

15:15 S427 The XUNDL database at www.nndc.bnl.gov
McCutchan EA. (National Nuclear Data Center, Brookhaven National Laboratory, New York, USA)

15:20 S428 Nuclear structure and decay data evaluation in Europe
Negret A. (Nuclear Physics Department, 2 ELI-NP, Horia Hulubei National Institute for Physics and Nuclear Engineering, Romania)

15:25 S429 A new online database of nuclear electromagnetic moments
Mertzimekis TJ. (University of Athens, Faculty of Physics, Athens, Greece)

15:30 S430 Latest user-related radionuclide-handbook as a link between laboratory needs and international databases
Wahl W. (ISuS, Inst. f. Spectrometry and Radiation Protection, Schliersee, Germany)

15:35 Break

16:20 I431 Evaluated Nuclear Structure Data Base (ENSDF) and related services at National Nuclear Data Center (NNDC)
Tuli J. (National Nuclear Data Center, Brookhaven National Laboratory, NY, USA)

16:50 R432 Random sampling and validation of covariance matrices of resonance parameters
Plevnik L. (Jožef Stefan Institute, Reactor physics department, Ljubljana, Slovenia)

17:10 R433 Covariance generation and uncertainty propagation for thermal and fast neutron induced fission yields
Terranova N. University of Bologna, Bologna, Italy and Cadarache Center, St. Paul-lez-Durance, France)

17:30 R434 Propagation of nuclear data uncertainties for fusion power measurements
Sjöstrand H. (Division of applied nuclear physics, Uppsala University, Uppsala, Sweden)

17:50 R435 Propagation of neutron-reaction uncertainties through multi-physics models of novel light water reactors
Hernandez-Solis A. (Uppsala University, Ångströmlaboratoriet, Uppsala, Sweden)

Thursday 15 September 14:00-18:10 Mozart

Mozart

Topic track: Nuclear reaction measurements
Session Title: Charged particles II

Chair: B. Jurado, CENBG, CNRS, Gradignan, France

14:00 I436 Double differential cross section for light mass fragment production on tens of MeV proton, deuteron, helium and carbon induced reactions
Sanami T. (High Energy Accelerator Research Organization (KEK), Tsukuba, Ibaraki, Japan and The Graduate University for Advanced Studies (SOKENDAI) Japan

14:30 R437 Investigations of the 27Al(d,x)24Na nuclear reaction for deuteron beam monitoring purpose
Khandaker MU. (Department of Physics, University of Malaya, Kuala Lumpur, Malaysia)

14:50 R438 Measurements of neutron and charged particle production cross sections on beryllium, carbon and iron bombarded with 13MeV/nucleon neon beam
Hagiwara M. (High Energy Accelerator Research Organization (KEK), Radiation Science Center, Tsukuba, Japan)

15:10 R439 Dispersive and deflective effect in transverse momentum distribution of fragments at intermediate energies
Momota S. (Kochi University of Technology, Kochi, Japan)

15:30 S440 The activation of W and Zr by deuterons at energies up to 20 MeV
Simeckova E. (Nuclear Physics Institute, Řež, Czech Republic)

15:35 S441 Cross sections for nuclide production in proton- and deuteron-induced reactions on niobium-93 measured using the inverse kinematics method
Nakano K. (Kyushu University, Department of Advanced Energy Engineering Science, Fukuoka, Japan)

15:40 Break

16:20 I443 Measurement of production cross sections for the proton induced reactions on yttrium with proton energy of 69 MeV
Kim GN. (Department of Physics and Center for High Energy Physics, Kyungpook National University, Daegu, Republic of Korea)

16:50 R444 Proton and deuteron activation measurements on the NPI and future plants at SPIRAL2/NFS
Simeckova E. (Nuclear Physics Institute, Řež, Czech Republic)

17:10 R445 Cross sections for the proton-induced production of long-lived radionuclides in heavy metal targets
Talip Z. (Laboratory of Radiochemistry, Paul Scherrer Institut, Villigen, Switzerland)

17:30 R446 Integral measurements of the residue nuclide production induced by protons in heavy metal targets
Schumann D. (Nuclear Energy and Safety Research Department, Paul Scherrer Institute, Villigen, Switzerland)

17:50 R447 New measurement of the 19F(α,n)22Na cross section
Smith MS. (Oak Ridge National Laboratory, Oak Ridge, Tennessee, USA)

Thursday 15 September 14:00-18:10 Strauss

Strauss

Topic track: Nuclear data for applications
Session Title: Reactors and fuel

Chair: U. Fischer, Institute for Neutron Physics and Reactor Technology, Karlsruhe Institute of Technology (KIT), Eggenstein-Leopoldshafen, Germany

14:00	I448	**Nuclear data sensitivity and uncertainty assessment of sodium voiding reactivity coefficients of an ASTRID-like Sodium Fast Reactor** Garcia-Herranz N. (Department of Energy Engineering, Universidad Politécnica de Madrid, Madrid, Spain)
14:30	R449	**Sensitivity and uncertainty analysis of keff to nuclear data in a pressurized water reactor** Qiang S. (Design and Research Sub-Institute, Nuclear Power Institute of China, Cheng Du, P.R.China)
14:50	R450	**Comparison of ENDF/B-VII.1 and JEFF-3.2 in VVER-1000 operational data calculation** Frybort J. (Czech Technical University in Prague, Department of Nuclear Reactors, Prague, Czech Republic)
15:10	R451	**Impact of nuclear data uncertainty on criticality safety calculations for spent nuclear fuel geological disposal** Rochman D. (Nuclear Energy and Safety Research Department, Paul Scherrer Institut (PSI), Villigen PSI, Switzerland)
15:30	S452	**Anisotropic scattering cross section treatment for reactor pressure vessel fast neutron fluence calculations** Zhang B. (School of Nuclear Science and Engineering, North China Electric Power University, Beijing, P.R. China)
15:35	S453	**Distribution of 14C in neutron irradiated graphite from RBMK-1500 reactor** Lagzdina E. (State Research Institute Center for Physical Sciences and Technology, Vilnius, Lithuania)
15:40	S454	**Multigroup cross section library for gas cooled fast reactor applications** Čerba Š. (Slovak University of Technology in Bratislava, Institute of Nuclear and Physical Engineering, Bratislava, Slovakia)
15:45		**Break**
16:20	I455	**The use of nuclear data in the field of nuclear fuel recycling** Martin JF. (AREVA NC La Défence, Paris, France; 2 AREVA NC La Hague, Beaumont-Hague, France)
16:50	R456	**An in-depth analysis of MA fission chambers measurements in the FCA IX experimental programme** Leconte P. (CEA Cadarache, DER/SPRC/LEPh, Saint Paul Lez Durance, France)
17:10	R457	**Update and evaluation of decay data for spent nuclear fuel analyses** Simeonov T. (Studsvik Scandpower, Inc., Waltham, Massachusetts, USA)
17:30	R458	**Antineutrino emission and gamma background characteristics from a thermal research reactor** Giot L. (SUBATECH, CNRS/IN2P3, Univ. de Nantes, EMN, Nantes, France)

Thursday 15 September | 14:00-18:10 | Morus

Morus

Topic track: Nuclear masses, structure and decay data measurements
Session Title: Nuclear masses, structure and decay data measurements II

Chair: G. Audi, CSNSM, Univ Paris-Sud, CNRS/IN2P3, Université Paris-Saclay, Orsay, France

14:00 I459 Test of internal-conversion theory with a measurement in 111mCd
Nica N. (Texas A&M University, Cyclotron Institute, College Station, Texas, USA)

14:30 R460 A metallic magnetic calorimeter dedicated to X-ray spectrometry of radionuclides
Rodrigues M. (CEA, LIST, Laboratoire National Henri Becquerel (LNE-LNHB), Gif-sur-Yvette Cedex, France)

14:50 R461 Measurement of the relative gamma ray emission probabilities from the electron capture decay of 153Gd
Shearman R. (Radioactivity Group, National Physical Laboratory, Teddington, UK and Department of Physics, University of Surrey, Guildford, UK)

15:10 R462 A low background ionisation chamber for alpha-spectroscopy
Wilsenach H. (Institut für Kern- und Teilchenphysik, Technische Universität Dresden, Dresden, Germany; 2 Helmholtz-Zentrum Dresden-Rossendorf (HZDR), Dresden, Germany

15:30 S463 Beta-strength and anti-neutrino spectra from Total Absorption Spectroscopy of a decay chain 142Cs->142Ba->142La
Wolińska-Cichocka M. (Heavy Ion Laboratory, University of Warsaw, Warsaw, Poland, Physics Oak Ridge National Laboratory and Joint Institute for Nuclear Physics and Applications, Oak Ridge, TN, USA)

15:35 S464 Determination of the gamma emission probabilities of 239Np
Shang J. (Northwest Institute of Nuclear Technology, Xi'an, P.R.China)

15:40 S465 The measurements of the decay data of Lu-173 and Lu-174g
Shi Q. (Northwest Institute of Nuclear Technology, Xi'an, P.R.China)

15:45 S466 Beta feeding anomaly in 43K(β)43Ca
Mukherjee G. (Variable Energy Cyclotron Centre, Bidhan Nagar, Kolkata, India)

15:50 Break

16:20 I467 Total absorption spectroscopy of fission fragments relevant for reactor antineutrino spectra and decay heat calculation
Fallot M. (SUBATECH, CNRS/IN2P3, Univ. de Nantes, EMN, Nantes, France)

16:50 R468 Analysis of reactor-neutrino spectra fully based on the gross theory of beta-decay emphasizing the special role of odd-odd fission-product nuclides
Yoshida T. (Tokyo Institute of Technology, Research Laboratory for Nuclear Reactors, Tokyo, Japan)

17:10 R469 Tags measurements of 100nb ground and isomeric states for neutrino physics with the new DTAS detector
Guadilla V. (Intituto de Física Corpuscular, CSIC-Universidad de Valencia, Valencia, Spain)

17:30 R471 Total absorption studies of high priority decays for the reactor decay heat problem
Algora A. (Instituto de Fisica Corpuscular (CSIC-Universitat de Valencia), Valencia, Spain)

Thursday 15 September 14:00-18:10 Erasmus

Erasmus

Topic track: Gamma-ray strength functions
Session Title: Gamma-ray strength functions II

Chair: S. Goriely, Institut d'Astronomie et d'Astrophysique, Université Libre de Bruxelles, Brussels, Belgium

14:00	**I472**	**Neutron capture cross sections with unstable nuclei** Tonchev AP. (Lawrence Livermore National Laboratory, Livermore, CA, USA)
14:30	**R473**	**Systematics of photon strengths from discrete nuclear data** Firestone RB. (University of California, Department of Nuclear Engineering, and Lawrence Berkeley National Laboratory, Berkeley, CA, USA)
14:50	**R474**	**Breaking of axial symmetry in excited heavy nuclei as identified in experimental data** Junghans AR. (Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany)
15:10	**R475**	**Gamma strength functions and level densities from high-resolution inelastic proton scattering at very forward angles** Bassauer S. (Institut für Kernphysik, Technische Universität Darmstadt, Darmstadt, Germany)
15:30	**S476**	**Dipole strength in 80Se below the neutron separation energy for the nuclear transmutation of 79Se** Schwengner R. (Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany)
15:35	**S477**	**Isomer ratios for products of photonuclear reactions on 121Sb** Kadenko M. (Taras Shevchenko National University of Kyiv, Kyiv, Ukraine)
15:40	**S478**	**Partial photoneutron cross section measurements on 209Bi** Gheorghe I. (ELI-NP, "Horia Hulubei" National Institute for Physics and Nuclear Engineering (IFIN-HH), and University of Bucharest, Bucharest-Magurele, Romania)
15:45	**S479**	**Resonances in odd-odd 182Ta** Brits CP. (Department of Physics, University of Stellenbosch, Stellenbosch, South Africa)
15:50		**Break**
16:20	**I480**	**A unified understanding of (G,N) and (N,G) reaction cross sections with the gamma-ray strength function method** Utsunomiya H. (Department of Physics, Konan University, Kobe, Japan)
16:50	**R481**	**Studying the photon strength function of 97Zr using the 96Zr(n,g) and 96Zr(d,p) reactions** Winkelbauer JR. (Los Alamos National Laboratory, Los Alamos, New Mexico, USA)
17:10	**R482**	**Nuclear level density, gamma-ray strength function of 240Pu and 239Pu(n,g) cross-section** Zeiser F. (Department of Physics, University of Oslo, Oslo, Norway)
17:30	**R483**	**High-resolution study of the ^{113}Cd(n,γ) spectrum by statistical decay model with discrete levels and transitions** Belgya T. (Institute for Energy Security and Environmental Safety, Centre for Energy Research, Hungarian Academy of Sciences, Budapest, Hungary)
17:50	**R484**	**Isospin splitting of the GDR and photoproton reactions on isotopes of molybdenum** Stopani KA. (Skobeltsyn Institute of Nuclear Physics, Lomonosov Moscow State University, Moscow, Russia)

Thursday 15 September 14:00-18:10 Vives

Vives

Topic track: Knowledge Transfer
Session Title: Knowledge Transfer

Chair: M. Herman, NNDC, Brookhaven National Laboratory, Upton, USA

14:00	**I485**	**Good practices in provision of nuclear safeguards and security training course at integrated support center for nuclear nonproliferation and nuclear security** Kobayashi N. (Japan Atomic Energy Agency, Japan)
14:30	**R486**	**The GENTLE project: graduate and executive nuclear training and lifelong education** Heyse J. (Joint Research Centre, Institute for Reference Materials and Measurements, Geel, Belgium)
14:50	**R487**	**Knowledge management: role of the radiation safety information computational center (RSICC)** Valentine TE. (Radiation Safety Information Computational Center, Oak Ridge National Laboratory, Oak Ridge, USA)
15:10	**R488**	**Education and training in nuclear data by the Belgian SCK•CEN academy for nuclear science and technology** Van den Eynde G. (Nuclear Systems Physics Group, Technology, SCK•CEN, Mol, Belgium)
15:30	**S489**	**Decay Data Evaluation Project (DDEP): dissemination and visualisation of reference decay data** Dulieu C. (CEA, LIST, Laboratoire National Henri Becquerel, Gif-sur-Yvette Cedex, France)
15:35	**S490**	**Experiments in the EXFOR library for evaluation of thermal neutron constants** Capote R. (Nuclear Data Section, International Atomic Energy Agency, Wien, Austria)
15:40	**S491**	**JANIS: NEA java-based nuclear data information system** Cabellos O. (OECD Nuclear Energy Agency, Boulogne-Billancourt, France)
15:45		**Break**
16:20	**I492**	**'Euratom success stories' in facilitating pan-European E&T collaborative efforts** Garbil R. (Research and Innovation, Euratom Fission Unit, European Commission, Brussels, Belgium)
16:50	**R493**	**Dissemination of data measured at the CERN n_TOF facility** Dupont E. (Irfu/SPhN, CEA Saclay, Gif-sur-Yvette, France)
17:10	**R494**	**EXFOR - a global experimental nuclear reaction data repository: status and new developments** Semkova V. (Nuclear Data Section, International Atomic Energy Agency, Vienna, Austria)
17:30	**R495**	**Progress towards a new international standard for storing nuclear data** Mattoon CM. (Lawrence Livermore National Laboratory, Nuclear and Analytic Chemistry Division, Livermore CA, USA)
17:50	**R496**	**Nuclear data web dissemination efforts at the NNDC** Sonzogni AA. (National Nuclear Data Center, Brookhaven National Laboratory, Upton, NY, USA)

Thursday 14 September 08:30-18:10 Witte Roos

Witte Roos

Session Title: Poster Session

Poster number

P100	S338	Neutron induced fission cross section measurements of 240-Pu and 242-Pu
P101	S339	Energy dependence of time parameters of delayed neutrons for neutron induced fission of the Np-237 in energy range from 14.23 to 17.98 MeV
P102	S340	The fission time projection chamber
P104	S342	Potential-driving model study on neutron-induced actinide nuclei fission
P105	S351	Bootstrap method for constructing covariance matrices of optical-model parameters in the study of the threshold anomaly
P106	S352	Uncertainty of the delayed neutron fraction in fuel assembly depletion calculations
P107	S353	The impact of the retroactive method for resonance parameter uncertainties, in particular propagated to helium production due to Ni-59 in stainless steel
P108	S354	Emerging capabilities for charged-particle induced reactions with the R-matrix SAMMY code
P109	S363	(n,xn) Cross section measurements for Y-89 foils used as detectors for high energy neutron measurements in deeply subcritical assembly “QUINTA”
P110	S364	A high precision tagged neutron n-p scattering measurement at 14.9 MeV
P111	S365	Measurement of the angular and energy distributions of neutrons from 7Li(d,n)8Be reaction at deuteron energy 2.9 MeV by activation method
P112	S373	Study of concrete activation with IFMIF-like neutron irradiation: status of EAF and TENDL neutron activation cross-sections
P113	S391	Determination of the effects of nuclear level density parameters on photofission cross sections of 235U up to 20 MeV
P114	S392	Axial asymmetry breaking in excited heavy nuclei as essential feature for the prediction of level densities
P115	S393	Photon strength functions of 78Se from the two-step gamma cascades measurement
P116	S403	Calculation of pre-equilibrium effects in neutron-induced cross section on 65Cu
P117	S412	Comparison between absolute and relative neutron-induced fission cross section measurements of 237Np and 238U at NPL and IRMM
P118	S413	Neutron-induced fission cross section of 242Pu from 15 MeV to 20 MeV
P120	S415	Thorium-232 fission induced by light charged particles up to 70 MeV
P121	S416	High accuracy 234U(n,f) cross-section in the resonance energy region
P122	S426	Decay data evaluation project (DDEP): updated evaluation of the Ba-140, La-140 and Ce-141 decay characteristics
P123	S427	The XUNDL database at www.nndc.bnl.gov
P124	S428	Nuclear structure and decay data evaluation in Europe
P125	S429	A new online database of nuclear electromagnetic moments
P126	S430	Latest user-related radionuclide-handbook as a link between laboratory needs and international databases
P127	S440	The activation of W and Zr by deuterons at energies up to 20 MeV
P128	S441	Cross sections for nuclide production in proton- and deuteron-induced reactions on niobium-93

		measured using the inverse kinematics method
P129	S442	Measurement of production cross sections for the proton induced reactions on 89Y with proton energy of 69 MeV
P130	S452	Anisotropic scattering cross section treatment for reactor pressure vessel fast neutron fluence calculations
P131	S453	Distribution of 14C in neutron irradiated graphite from RBMK-1500 reactor
P132	S454	Multigroup cross section library for gas cooled fast reactor applications
P133	S463	Beta-strength and anti-neutrino spectra from Total Absorption Spectroscopy of a decay chain 142Cs->142Ba->142La
P134	S464	Determination of the gamma emission probabilities of 239Np
P135	S465	The measurements of the decay data of Lu-173 and Lu-174g
P136	S466	Beta feeding anomaly in 43K(ß)43Ca
P137	S476	Dipole strength in 80Se below the neutron separation energy for the nuclear transmutation of 79Se
P138	S477	Isomer ratios for products of photonuclear reactions on 121Sb
P139	S478	Partial photoneutron cross section measurements on 209Bi
P140	S479	Resonances in odd-odd 182Ta
P141	S489	Decay Data Evaluation Project (DDEP): dissemination and visualisation of reference decay data
P142	S490	Experiments in the EXFOR library for evaluation of thermal neutron constants
P143	S491	JANIS: NEA java-based nuclear data information system

Friday 16 September 08:30-12:00 Ambassadeur

Ambassadeur

Plenary Session

08:30 **Knowledge management of Nuclear Data at the NEA**
Jim Gulliford, OECD-NEA

09:15 PL497 **General description of fission observables: the GEF code**
Karl-Heinz Schmidt, CENBG, Gradignan, France

10:00 PL498 **Reactor simulations using JEFF-3 nuclear data: assessing performance and needs**
Robert Jacqmin, CEA, Saint-Paul-lez-Durance, France

10:45 **Break**

11:00 PL499 **CIELO collaboration advances in evaluating cross sections for 239Pu, 238U, 235U, 56Fe, 16O and 1H**
Mark Chadwick, ADX, Associate Directorate, Los Alamos National Laboratory, Los Alamos, USA

11:45 PL500 **CENDL project, the Chinese Evaluated Nuclear Data Library**
Zhigang Ge, China Nuclear Data Center, China Committee of Nuclear Data, China Institute of Atomic Energy, P.R. China

12:30 **Award ceremony, announcement of ND2019 and conference closing**
Arjan Plompen, Chairman of the ND2016 organising committee

Abstracts

PL001 Systematic approach to nuclear data evaluation

Koning A.
Nuclear Data Section, International Atomic Energy Agency, Vienna, Austria

Only with a fully systematic approach to nuclear data evaluation we can make maximal use of experimental and theoretical knowledge of nuclear physics. This is needed since nuclear technology requires this. For too long, the field of nuclear data has remained a "research-only" activity without attention for quality-assured aspects such as reproducibility and uncertainty estimation. This means a waste of money and efficiency in an already sparsely populated field.
Besides all required experimental and theoretical research, the following is essential:

- All evaluated nuclear data should be derived, in a reproducible manner, from the most basic information possible. In the nuclear data world this currently means the EXFOR database for experimental nuclear reactions and basic nuclear structure databases for input libraries (such as RIPL) of nuclear model codes.
- Open source, readable and robust software for nuclear model simulations.
- An automated system in which nuclear data library production (in ENDF-6 or newer formats) and uncertainty estimation becomes close to trivial, so that all the effort of the evaluators can go into the assessment of the quality of the basic experimental data and the physics of nuclear models and their parameters.
- No hesitation to unleash the full power of current day computers

There is currently one initiative which aims for this ideal situation of incorporating the whole nuclear data world in one reproducible process, and it revolves around the TALYS nuclear code system.
Once accomplished, the possibilities are endless, and include the TENDL nuclear data library, Total Monte Carlo for uncertainty propagation and the associated safety limit estimates for nuclear reactors, a systematic quality assessment of the entire EXFOR database, complete databases with astrophysical reaction rates, large-scale comparison of optimal production routes for medical isotopes, and much more.
In 2017, the above possibilities will be provided to all nuclear data users with the release of TALYS-2.0 which, next to the "usual" nuclear models, will also include all statistical information resulting from parameter and model randomization (uncertainties, covariances, sensitivities, Total Monte Carlo) and complete ENDF-6 formatting.

PL002 Towards more accurate and reliable predictions for nuclear applications

Goriely S.
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The need for nuclear data far from the valley of stability, for applications such as nuclear astrophysics or future nuclear facilities, challenges the robustness as well as the predictive power of present nuclear models. Most of the nuclear data evaluation and prediction are still performed on the basis of phenomenological nuclear models. For the last decades, important progress has been achieved in fundamental nuclear physics, making it now feasible to use more reliable, but also more complex microscopic or semi-microscopic models in the evaluation and prediction of nuclear data for practical applications. In the present contribution, the reliability and accuracy of recent nuclear theories are detailed and compared for most of the relevant quantities needed to estimate reaction cross sections and beta-decay rates, namely nuclear masses, nuclear level densities, gamma-ray strength, fission properties and beta-strength functions. It is shown that nowadays, mean-field models can be tuned at the same level of accuracy as the phenomenological models, renormalized on experimental data if needed, and therefore can replace the phenomenological inputs little by little in the prediction of nuclear data. The latest achievements obtained in our HFB mass models, including the related uncertainties in the model predictions, will be discussed. Similarly, recent efforts to determine fission observables within the mean-field approach will be described and compared with more traditional existing models. Finally, recent achievements to determine gamma-ray strength and beta-decay rates in deformed QRPA calculations will be mentioned. The impact of such newly-determined microscopic inputs on nuclear reaction cross sections, but also on some nuclear astrophysics applications, such as the r-process nucleosynthesis, will be discussed.

I003 Parallel theoretical study of the two components of the prompt fission neutrons: dynamically released at scission and evaporated from fully accelerated fragments

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Prompt fission neutrons (PFN) angular and energy distributions for the reaction 235U(nth, f) are calculated as a function of the mass asymmetry of the fission fragments using two extreme assumptions:

1) PFN are released during the neck rupture due to the diabatic coupling between the neutron degree of freedom and the rapidly changing neutron-nucleus potential. These unbound neutrons are faster than the separation of the nascent fragments and most of them leave the fissioning system in few 10−21 sec. i.e., at the begining of the accel- eration phase [1]. Surrounding the fissioning nucleus by a sphere one can calculate the radial component of the neutron current density. Its time integral gives the angular distribution with respect to the fission axis [2]. The average energy of each emitted neutron is also calculated using the unbound part of each neutron wave packet. The distribution of these average energies gives the general trends of the PFN spectrum: the slope, the range and the average value.
2) PFN are evaporated from fully accelerated, fully equilibrated fis- sion fragments. To follow the de-excitation of these fragments via neu- tron and °-ray sequential emissions, a Monte Carlo sampling of the initial conditions and a Hauser-Feshbach statistical approach is used [3, 4]. Recording at each step the emission probability, the energy and the angle of each evaporated neutron one can construct the PFN energy and the PFN angular distribution in the laboratory system. The predictions of the two methods are finally compared with recent experimental results obtained for given fragment mass ratio [5].

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R004 Validation of delayed neutron group parameters for 235U by critical experiment

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Delayed neutron group parameters including decay constant and relative fraction are important data of fissile isotopes in nuclear database, such as ENDF, JEFF, JENDL, etc. , used to describe precursor's decay, and are helpful for research of fission model. What's more, the delayed neutron data are also key parameters for reactor kinetic equation and are crucial for safety control of nuclear reactor. So a lot of work has been done to obtain accurate delayed-neutron group parameters for the past seventy years . ^{235}U is the most important fissile isotope and has many sets of delayed-neutron group parameters from different sources. Many researchers have pointed out huge difference in calculation of reactor's reactivity in literature. For example, The delayed-neutron group data for ^{235}U in ENDF/B-VII.1 are quite different from the data in ENDF/B-VII.0, the Keepin's data, etc. It is necessary to answer that which set of delayed-neutron group parameters are more accurate and what is the criterion. Integral experiments have been done on a HEU critical assembly in China to validate the delayed neutron group parameters. Two independent methods are introduced: one on subcritical, the other on prompt supercritical. The results suggest that Keepin's 6-group delayed neutron parameters estimated reactivity biased by approximately 2%, ENDF/B-VII.0's delayed neutron parameters overestimated subcritical reactivity by approximately 20%, ENDF/B-VII.1's delayed neutron parameters underestimated subcritical reactivity by approximately 20%.

R005 Angular correlations in the prompt neutron emission in spontaneous fission of 252Cf

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It is well known that the prompt neutrons in nuclear fission are emitted anisotropically with respect to the fission axis. Various attempts to analyze the experimental data on neutron emission anisotropy lead to the conclusion that the anisotropy cannot be fully described only by the kinematic focusing of the neutrons emitted by the moving fragments. There are two possible reasons which can explain these discrepancies: either the existence of scission neutrons or the anisotropic emission of neutrons in the centre-of-mass system (CMS) of the fragments. The latter anisotropy is expected with respect to the fragment spin orientation (alignment) due to the emission of neutrons with non-zero angular momentum.
An experiment aimed at the detailed investigation of angular correlations in the neutron emission from spontaneous fission of ^{252}Cf has been performed at IPHC Strasbourg using the angle-sensitive double ionization chamber CODIS for measuring fission fragments and a set of 60 DEMON scintillator counters for neutron detection. The CODIS chamber allows determining with reasonable accuracy energies, masses and the direction of emission of the fission fragments. The DEMON detectors are placed in a quasi-spherical arrangement around the chamber and make it possible to determine the neutron emission direction. Neutrons could be clearly separated from the gamma-rays by the pulse-shape discrimination of the signals, as well as by the time-of-flight method.
Both, the existence of the scission neutrons, and the anisotropy of the neutron emission in the centre-of-mass system of the fragments has been tested in the experiment. The results of the data analysis and the Full Monte-Carlo simulations of the experiment will be reported in the present paper.

R006 Angular distributions and anisotropy of fission fragments from neutron-induced fission in intermediate energy range 1-200 MeV

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Angular distributions of fission fragments from the neutron-induced fission of ^{232}Th, ^{233}U, ^{235}U and ^{238}U have been measured in the energy range 1-200 MeV at the neutron TOF spectrometer GNEIS based on the spallation neutron source at 1 GeV proton synchrocyclotron of the PNPI (Gatchina, Russia). The multiwire proportional counters have been used as a position sensitive fission fragment detector. A description of the experimental equipment and measurement procedure is given. The anisotropy of fission fragments deduced from the data on measured angular distributions is presented in comparison with experimental data of other authors, first of all, the recent data from LANSCE (Los Alamos) and n_TOF(CERN).

S007 Neutron-multiplicity experiments for enhanced fission modelling

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The nuclear de-excitation process of fission fragments (FF) provides fundamental information for the understanding of nuclear fission and nuclear structure in neutron-rich isotopes. Improved determination of fission yields in correlation with particle-emission characteristics (prompt- neutrons and γ-rays) enhances the modelling of fission**,** provides input for nuclear structure studies and nuclear astrophysical processes, and could lead to efficient and safe use of nuclear reactors.
Presently, nuclear data libraries lack data on many of those areas, especially on the evolution of fission observables as a function of excitation energy (E*). The variation of the prompt-neutron multiplicity, ν(A), as a function of the incident neutron energy (E_n) is one of many open questions, leading to significantly different treatments in various fission models, implying that experimental data are analysed based on contradicting assumptions. One critical question is whether the additional E* is manifested through an increase of ν(A) for all fragments or for the heavy ones only. The few existing experimental data supports the latter but are surprisingly ignored in contemporary fission calculation codes. This will be emphasized in the first part of the paper.
The second part of the paper deals with the experimental efforts to solve the above-mentioned issue. Systematic investigation of (A) as a function of E_n has been initiated. Correlations between prompt-fission neutrons and fission fragment are obtained by using liquid scintillators in conjunction with a Twin Frisch-grid ionization chamber. The proof-of-principle has been achieved on the reaction $^{235}U(n_{th},f)$ at the Van De Graaff accelerator of the JRC-IRMM using a fully digital data acquisition system. Neutrons from $^{252}Cf(sf)$ were measured separately to quantify the neutron-scattering component due to surrounding shielding material and to determine the intrinsic detector efficiency. Results on ν(A) and spectrum in correlation with FF properties will be presented.
In comparison, a second experiment is foreseen for $^{235}U(n,f)$ at E_n = 5.5 MeV allowing to compare ν (A) at a different E*. Simulations will be briefly reviewed, as the main problem will be to disentangle relevant fission neutrons from room-scattered beam neutrons. Simulations are benchmarked experimentally against measurements with dedicated shielding configurations.

S008 Digital spectrometer for fission prompt neutron spectra measurement

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Prompt neutron spectra are very important for criticality calculation for different reactor types. The most precise method for neutron spectra measurement is the time of flight method. Organic scintillators, which often used for fast neutron registration, have significant registration efficiency of gamma-ray accompanied nuclear fission process. The n/ discrimination for low energy region is very difficult to perform. In order to get good timing resolution for prompt neutron spectra both fission and neutron data have to be measured precisely.
Present work describes the spectrometer based on digitization of organic scintillator and fission fragments signals. This gives the possibility for amplitude and timing analysis, gamma-ray suppression and pile-up rejection. Algorithms based on correlation analysis are used for processing of digitized signal. We have achieved efficient n/ discrimination down to energy of 40 keVee. Energy calibration and registration efficiency was carried out using standard gamma sources and Cf-252 neutron source. It was shown that digital signal processing method allows to reach significant improving of detector response function, energy resolution and reliability of the final result. Energy dependence of scintillation light output for gamma-rays and neutrons was measured. Obtained prompt neutron energy spectrum for Cf-252 is presented.

S009 Measuring PFNS at the Chi-Nu Experiment

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Accurate data on the spectrum of neutrons emitted in energetic neutron-induced fission are needed for various nuclear applications. At LANSCE, the Chi-Nu collaboration is measuring prompt fission neutron spectra (PFNS) for fission of ^{235}U and ^{239}Pu induced by neutrons from 0.7 to over 30 MeV using the WNR neutron facility, and for spontaneous fission of ^{252}Cf. The goal is to obtain better data than those in the literature and especially to understand and quantify systematic uncertainties to a deeper level than was possible before.
This poster will describe the technical details involved in these measurements. We use a double time-of-flight (TOF) technique to determine energies of the incoming and outgoing neutrons. We use parallel plate avalanche detectors to register the fission event. Fission neutrons are detected either by a high-energy array made of 54-liquid-organic scintillators, or, a low-energy array made of 22-^{6}Li-glass scintillators. A more detailed technical discussion and the phase space probed by each array will be presented.
CAEN waveform digitizers are used to process the data, and using a new method developed by the Chi-Nu collaboration, accidental coincidences between the fission chamber and the neutron detectors are also measured to high statistical accuracy and then subtracted from measured events. Data taking and background subtraction will be discussed in more detail.
In addition to the apparatus and experimental significance, a discussion of the systematic errors routinely encountered will be presented. In particular, the challenge of accurately measuring the low-energy regime of the PFNS due to down-scattered neutrons contaminating the observed spectra will be addressed. Monte Carlo simulations have proven invaluable to the design and understanding of this background. These simulations, as well as tests of their accuracy, will also be described.

S010 Prompt fission gamma-ray data from spontaneous fission and the mechanism of fission-fragment de-excitation

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The investigation of prompt γ-ray emission in nuclear fission has a great relevance for the assessment of prompt heat generation in a reactor core and for the better understanding of the de-excitation mechanism of fission fragments. Some years ago experimental data was scarce and available only from a few fission reactions, ^{233,235}U(n_{th}, f), ^{239}Pu(n_{th}, f), and ^{252}Cf(SF). Initiated by a high priority data request published by the OECD/NEA a dedicated prompt fission γ-ray measurement programme is being conducted at the EC-JRC IRMM. In recent years we obtained new and accurate prompt fission γ-ray spectrum (PFGS) characteristics (average number of photons per fission, average total energy per fission and mean photon energy) from ^{252}Cf(SF) [1], ^{235}U(n_{th},f) [2] and ^{239,241}Pu(n_{th},f) [3,4] within 2% of uncertainty. In order to understand the dependence of prompt fission γ-ray emission on the compound nuclear mass and excitation energy we started a first measurement campaign on spontaneously fissioning plutonium and curium isotopes.
Results on PFGS characteristics from ^{240,242}Pu(SF) [5] and ^{246,248}Cm(SF) show a dependence on the fragment mass distribution rather than on the average prompt neutron multiplicity, pointing to a more complex competition between prompt fission γ-ray and neutron emission.

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I011 Sensitivity of 252CF(SF) neutron observables to FREYA input distributions

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Within the framework of the fission event generator FREYA, (Fission Reaction Event Yield Algorithm) we have studied the sensitivity of various neutron observables to the yield distribution Y(A,Z,TKE) used as input to the code. Concentrating on the spontaneous fission of 252Cf, we generate a large number of different input yield distributions by performing simultaneous variations in the mass and charge yields as well as the kinetic energy distribution, governed by yield covariance matrices established from experimental data sets. For each of these input yield distributions, we then use FREYA to generate a large sample of complete fission events from which we extract various neutron observables, in particular the neutron multiplicity distribution, and the neutron spectrum associated with each multiplicity.
On this basis, we are able to determine the sensitivity of those observables to the uncertainties in the input yield distribution obtained experimentally.
This kind of study can be applied to any other case of interest and the information obtained can help to establish any needs and target accuraciesrequired for further measurements to ensure reliable data validation.

R012 Influence of scission neutrons on the prompt fission neutron spectrum calculations

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The calculation of the Prompt Fission Neutron Spectrum (PFNS) was performed using a Monte Carlo code (called 'FIFRELIN') simulating the de-excitation of the whole fission fragments. This de-excitation is governed by the Hauser-Feshbach statistical model, which has the advantage to take into account the conservation laws for the energy, spin and parity of the initial and final states. In this way, the competition between prompt neutron and prompt gamma emission can be properly accounted for. Assuming that the prompt neutron emission comes only from an evaporation process of the fully accelerated fission fragments, then our calculations are not able to reproduce satisfactorily the experimental data. We have shown that this failure is not due to the level density or strength function models used for the de-excitation calculations. In this context, we have added in the FIFRELIN code an additional source of neutrons that may arise during the sudden rupture of the neck (the so-called scission neutrons). Recently, the existence of these scission neutrons has been experimentally confirmed for the ^{252}Cf spontaneous fission [1]. Two free parameters have been introduced in the code: the contribution of the scission neutrons (b_{sc}) and the energy required for their emission (E_{sc}), which has been estimated theoretically [2]. The impact of these parameters on the PFNS calculation will be presented and discussed.

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R013 Experimental programme on absolute fission fragment yields with the Lohengrin spectrometer at ILL: new optical and statistical methodologies

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The study of fission yields has a major impact on the characterization and understanding of the fission process and is mandatory for reactor applications. The mass and isotopic yields of the fission fragments have a direct influence on the amount of neutron poisons that limit the fuel burnup and on the evaluation of the residual power of the reactor after shutdown. The fission yields of the plutonium nuclides are also mandatory for the studies on the fuel multi-recycling. In order to significantly improve the precision of nuclear data, more and more fundamental fission models are used in the evaluation processing. Therefore, tests of fission models become a central issue to achieve a coherent libraries of nuclear data. In this framework, an important investigation in the experimental limits of facilities is required to provide complete sets of data with their coherent variance-covariance matrices. In the past with the LOHENGRIN spectrometer of the ILL, priority has been given for the studies in the light fission fragment mass range. The LPSC in collaboration with ILL and CEA has developed a measurement program on symmetric and heavy mass fission fragment distributions. The combination of measurements with ionisation chamber and Ge detectors is necessary to describe precisely the heavy fission fragment region in mass and charge. Recently, new measurements of fission yields and kinetic energy distributions, with different fissioning systems, were performed with this facility. The focus has been done on the self-normalization of the data to provide new absolute measurements, independently of any libraries, and the experimental covariance matrix. To reach precise measurements, a new experimental procedure was developed along with a new analysis method based on metadata. Because of the complex correction scheme from count rates to yields, a classical propagation uncertainty is not possible. The new analysis path gives the mean value of mass yields, its probability density function and the associated experimental variance-covariance matrices. All this information is a first step to bring nuclear data into statistical tests of the underlying hypothesis of fission models.

R014 Effects of microscopic transport coefficients on fission observables calculated by Langevin equation and its systematics

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The Langevin dynamical description of fission observables is inspired by the random evolution of shape parameters across the potential surface. In these work, we shall use mass and friction tensors inspired from Linear Response Theory [1] [2] [3] [4] (microscopic transport coefficients) and obtain the fission observables associated with these calculations. We compare these microscopic results with calculations using hydrodynamical mass tensor [5] and wall-window friction tensor [6] (macro-scopic transport coefficients). In linear response theory, the mass tensor and friction tensor can be calculated at several different temperature which we denote here as the transport temperature, Ttr. Meanwhile, by interpolating the microscopic transport coefficients into the temperature we desired, enabled our Langevin equation to use transport coefficients equal to the local temperature of the dynamical evolution. This allow us to directly compare the fission observables of both macroscopic and microscopic calculation. Calculation of the microscopic transport coefficients at specific finite temperature shows the friction increases along with the increase of temperature, meanwhile the mass decreases with temperature. In terms of fission yield, we see an additional peak reveal itself in the valley between the two peaks of 236U compound nucleus as we probe the lower temperatures. We do this by calculating the Langevin equation using microscopic mass and friction tensor calculated by linear response theory at very low temperature. We also shows that by calculating the Langevin equation using the microscopic mass and friction tensor at the local temperature of the deformation, we are able to approximate the fission yield, Coulomb kinetic energy and prescission kinetic energy of macroscopic calculation. We also seek to establish the systematic of average light and heavy mass fission product yield calculated using both microscopic and macroscopic calculations. Results of macroscopic shows a very good agreement for actinides up to 242Am in comparison with the systematics for average light and heavy mass fission product yield of JENDL's 14 MeV incident neutron data. We compare these results with our microscopic calculations. We also compare the results of microscopic and macroscopic calculation with Viola's total kinetic energy systematics[7]

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I015 From cutting-edge pointwise cross-section to groupwise reaction rate: a primer

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The nuclear research and development community has a history of using both integral and differential experiments to support accurate lattice-reactor, criticality and shielding simulations, as well as verification and validation efforts of cross sections and emitted particle spectra. An important aspect to this type of analysis is the proper consideration of the contribution of the neutron spectrum in its entirety, with correct propagation of uncertainties and standard deviations derived from Monte Carlo simulations, to the local and total uncertainty in the simulated reactions rates (RRs), which usually only apply to one application at a time. This paper identifies deficiencies in the traditional treatment, and discusses correct handling of the RR uncertainty quantification and propagation, including details of the cross section components in the RR uncertainty estimates, which are verified for relevant applications. The methodology that rigorously captures the spectral shift and cross section contributions to the uncertainty in the RR are discussed with quantified examples that demonstrate the importance of the proper treatment of the spectrum profile and cross section contributions to the uncertainty in the RR and subsequent response functions.
The recently developed inventory code FISPACT-II [1], when connected to the processed nuclear data libraries TENDL-2014, ENDF/B-VII.1, JENDL-4.0u or JEFF-3.2, forms an enhanced multi-physics platform providing a wide variety of advanced simulation methods for modeling activation, transmutation, burnup protocols and simulating radiation damage sources terms. The system has extended cutting-edge nuclear data forms, uncertainty quantification and propagation methods, which have been the subject of recent integral and differential, fission, fusion and accelerators validation efforts [2]. The platform is used to probe, understand and underpin a modern and sustainable understanding of the nuclear physics that is so important for many areas of science and technology; advanced fission and fuel systems, magnetic and inertial confinement fusion, high energy, accelerator physics, medical application, isotope production, earth exploration, astrophysics and homeland security.
This work was funded by the RCUK Energy Programme under grant EP/I501045.
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R016 Current status of the verification and processing system GALILÉE-1

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GALILÉE-1 is the new verification and processing system for evaluated data, developed at CEA. This paper describes the current status of GALILÉE-1. Three main components are under development.

- GALION component (GALilée Input Output for Nuclear data) is dedicated to read (resp. write) input (resp. produced) data. Input format can be ENDF-6 or GND format while output format is GND format.
- GALVANE component (GALilée Verification of the Accuracy of Nuclear Evaluations) is dedicated to verify nuclear evaluations that are GALILÉE-1 input data. This verification is achieved by comparin structure data found in the evaluations with reference ones given in NUBASE or ENSDF for instance.
- TREND component (Treatment and Representation of Evaluated Nuclear Data) is dedicated to provide continuous-energy and multigroup data as well as probability tables.

A fourth component which development will begin later is an automated chain for producing consistent libraries for transport and depletion codes. All these components are written in C++ language and share the same objects which hierarchy is very close to the GND object hierarchy.
At the present time, GALION can read evaluated data in ENDF-6 or GND format as well as structure data in ENSDF or NUBASE format. All the physical data are stored in C++ objects, named GBASE objects, independent of the evaluation format. GALVANE and TREND components only work on these GBASE objects, which allows the same verification and processing stages, whatever the evaluation format is. GALVANE can diagnose inconsistencies in general information, resonance parameters, Q reaction values, thresholds, excited level schemes, kinetic data of emitted particles, thermal scattering laws. TREND can reconstruct continuous energy cross-sections in the resolved resonance range, provide a linearization grid, broaden exact or linearized cross-sections and calculate moment based probability tables. At each processing step cross-comparisons are made with NJOY, CALENDF or PREPRO codes. Some results of such comparisons are provided.

R017 Evaluated displacement and gas production cross-sections for materials irradiated with intermediate energy nucleons

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The evaluation of atomic displacement and gas production cross-sections for irradiated materials is a challenging task combining the modelling of the various underlying nuclear reaction processes, the simulation of the material behavior, and taking into account, as far as possible, experimental data.
The report describes methods of evaluation and evaluated data recently obtained in KIT for a number of materials.
Atomic displacement cross-sections were obtained for Be, Al, Ti, V, Cr, Fe, Ni, Cu, Zr, and W for nucleon incident energies concerning the irradiation in nuclear- and fusion reactors. The NRT model [1] and an advanced atomistic modelling approach combining the use of binary collision approximation model and results of molecular dynamics simulations [2] were utilized for calculations of the number of stable displacements in materials. Proton-, deuteron-, triton-, ^{3}He, and -particle production cross-sections were evaluated for nucleon induced reactions for 278 stable target nuclei from Li to Bi for incident energies up to 1.2 GeV using available experimental data and results of model calculations. The data obtained were processed into ENDF and ACE formatted data and tested by means of MCNP calculations.

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R018 Important comments on kerma factors and DPA cross-section data in ace files of JENDL-4.0, JEFF-3.2 and ENDF/B-VII.1

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KERMA factors and DPA cross-section data which are used for calculating nuclear heating and damage are not included in nuclear data libraries but estimated from nuclear data libraries with the NJOY code and so on and stored to ACE files for nuclear analyses. So far we pointed out that a lot of the KERMA factors and DPA cross-section data had problems, which were not known by users, for the following reasons.
1) No secondary gamma data.
2) Huge gas production data in low neutron energy.
3) NJOY code bugs.
Now we compare the KERMA factors and DPA cross section data included in the official ACE files of JENDL-4.0, ENDF/B-VII.1 and JEFF-3.2 in detail. As a result, we find out new differences among the three nuclear data libraries for a lot of nuclei. We specify that reasons of the differences are the followings.
1) It seems that NJOY cannot adequately process capture reaction data in File 6 of the nuclear data libraries, not Files 12-15 of the nuclear data libraries.
2) It seems that NJOY produces incorrect KERMA factors and DPA cross-section data for nuclei without secondary gamma data or with Files 12-15, MT3, where it is difficult to keep energy-balance.
The ACE files of JENDL-4.0, ENDF/B-VII.1 and JEFF-3.2 with these problems should be revised based on this study.

S020 PyNjoy 2012: a system for producing cross-section libraries for the DRAGON lattice code

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The PyNjoy 2012 system is a set of components dedicated to the production of cross-section libraries in Draglib format for the DRAGON lattice code. These libraries can be used with Version3, Version4 and Version5 distributions. The PyNjoy 2012 system produces a Draglib in ASCII format that can be converted in binary XSM format by the equality module (:=) available in DRAGON. PyNjoy 2012 also offers limited support for producing libraries in Wimslib or Acelib format.
The PyNjoy 2012 is based on Njoy-2012. It differs from the version previously reported because of the change to Fortran-90 style and storage allocation. The previous PyNjoy system was based on Njoy-99 and was included with the DRAGON/DONJON Version4 distribution. The PyNjoy 2012 system is made of the following components: (1) The Njoy 2012.0 distribution, as released by LANL. (2) New Njoy 2012 updates from EPM. These updates contain bug fixes and additional energy meshes for the groupr module (3) A generic Python script named PyNjoy.py for automating the preparation of datasets for Njoy. (4) A collection of Python datasets, each of them corresponding to a specific evaluation processed wit a specific multigroup energy mesh. A preliminary verification of our new PyNjoy 2012 implementation was based on effective multiplication factor benchmark calculations comparisons with respect to PyNjoy 99. The first benchmark is the well-known Rowlands benchmark. The effective multiplication factors obtained for the UOX and MOX cases are shown in Tables 1 and 2, respectively. The discrepancies are computed with respect to the collision estimator kcoll in TRIPOLI. Tables 1 and 2 are also reporting fission (kstep), track-length (ktrack), and macrocollision (macro kcoll) estimated values of the effective multiplication factor. The numerical results show the excellent accuracy of our self-shielding model, provided that the distributed selfshielding effects are correctly taken into account (using many rings in fuel) and that the correlation effects between resonant isotopes and shells of different temperatures in the fuel are accounted for. In this case, the discrepancies on the effective multiplication factors obtained in the lattice calculations are less than two standard deviations of the corresponding TRIPOLI calculations. The discrepancy between Njoy-99 and Njoy-2012 is of the order of 2 pcm on all benchmarks.
The transition from Njoy-99 to Njoy-2012 is a significant achievement from the computer language and quality assurance (QA) points of view. Njoy-2012 is a solid foundation for implementing advances in nuclear data representations. We have successfully upgraded our cross-section production system to this new system and we do not have observed any significant regression related to the existing cross-section ENDF evaluations.

S021 Development of a new nuclear data library based on ROOT

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We develop a new C++ nuclear data library for the Evaluated Nuclear Data Format (ENDF) data, which we refer to as TNudy. Main motivation of the development is to provide powerful, versatile and intuitive interfaces and functionalities for browsing, visualizing and manipulating the detailed information embodied in the ENDF. To achieve this aim efficiently, the TNudy project uses a powerful, open system called the ROOT (http://root.cern.ch), which has been developed to treat and analyze a vast amount of data in nuclear and particle physics experiments. The huge amount of well-tested and well-organized ROOT functionalities strengthens and enhances the power of TNudy. For example, the ENDF data can be navigated intuitively by the TBrowser, and can also be accessed and handled in a short macro files thanks to the C++ interpret of the ROOT, cint, which increases the flexibility enormously in addressing diverse needs. So far, emphasis has been made to provide methods of accessing and visualizing faithfully the details of ENDF. TNudy is still in the stage of active development, and the current status and future plans will be presented.

S022 Encoded physics knowledge in checking codes for nuclear cross section libraries at Los Alamos

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Nuclear data libraries used by transport codes are produced by nuclear data processing codes like NJOY from evaluated nuclear data files. Quality assurance (or verification) of the nuclear data is performed by checking codes at several points during the generation of the evaluated data and the processing of the data. The last stage of nuclear data checking performed at Los Alamos is the subject of this paper.
Nuclear cross section libraries produced by NJOY and maintained by the Nuclear Data Team at Los Alamos are either in ACE (continuous energy) or NDI (multi-group) format. The final check of ACE files at Los Alamos is performed by the locally developed and maintained CHECKACE code. The final check of NDI tables at Los Alamos is performed by the locally developed and maintained CHECKMG code. Both of these programs encode basic physics knowledge to check the data in nuclear cross section libraries.
Checking of Continuous Energy ACE Files at Los Alamos
CHECKACE is a collection of FORTRAN and PERL routines which uses common sense physics-based rules and known MCNP limitations to check the data in ACE files. The intent of CHECKACE is to identify errors in the ACE data and or to document unusual data values which might be indications of other problems. CHECKACE is a brain-dead but very useful tool which is used by the nuclear data team to verify ACE files. It does not -- and indeed cannot -- catch every conceivable ACE file error, but it quickly checks for many possible errors.
The capabilities of CHECKACE have recently been extended by the addition of new rules and the modification of previous rules. Since the rules are logical expression of physics knowledge, they are the real core capability of CHECKACE. In fact, many of the rules of CHECKACE were developed in the aftermath of and as a consequence of nuclear data problems which have been encountered. Hence, over time, the rule checking becomes more comprehensive and effective.
Summary
Physics-based common sense rules undergird the nuclear data library checking codes used at Los Alamos. Checking codes like CHECKACE and CHECKMG are now officially a part of the standard nuclear data processing and verification procedures used by the nuclear data team.

S023 NJOY21: Next generation nuclear data processing capabilities

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NJOY is a well respected code for nuclear data processing throughout the world. It was first publicly released in 1977 as a successor to MINX and has continuously improved its capabilities ever since.
The latest release of NJOY is NJOY2012 and was released in December 2012 with its latest update coming in February 2015.
A new effort has begun at Los Alamos National Laboratory to ensure that NJOY remains a useful nuclear data processing code for the next generation of data processing needs. The result of this effort will be NJOY21,a new code for processing nuclear data and interacting with a variety of nuclear data_files.
Much has changed in the nuclear data world since NJOY was_first re-leased. Perhaps the biggest change is the increase in the amount of data -both in the number of available materials and the richness of the data for each material. While more and better nuclear data greatly improves the quality of simulations and calculations that rely on that data, it creates significant challenges for the individual who processes and verifies the nuclear data. NJOY2012 is well vetted and capable, but when processing many_files/materials, it is cumbersome and slow.
NJOY21 will build on the success of many previous major releases of NJOY made during the previous four decades. In addition, NJOY21 will facilitate the processing, verifying,and validating of many nuclear data_files.

I024 Progress on China nuclear data processing code system

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China Nuclear Data Center has developed the Ruler nuclear data processing system recently. Ruler is a computer code package for producing multi-group cross sections and related quantities from evaluated nuclear data in the ENDF format.
The Ruler uses modern code design, with an independent ENDF I/O system. The Ruler is written in a modern subset of Fortran-90, and it consists of 11 modules, they are main driver, ENDF I/O, mathematics subroutines, public subroutines of system, module for reconstructing resonance cross sections, module for generating Doppler-broadened cross sections, module for producing effective self-shielded cross sections in unresolved energy range, module for generating scattering cross sections in the thermal energy range, module for producing multi-group cross sections and group-to-group scattering matrices, module for preparing libraries for the reactor physics code WIMS, etc.
Ruler can only work with neutrons currently, and it can be used for generating WIMS-D format data files and continues energy point format cross sections.
The WIMS-D format data files have been generated with Ruler, and the multi-group cross sections are compared with the results of NJOY99.396. It can be seen that the average results of Ruler show agreement with NJOY99 in the ranges of 0.1%.
Because of the independent ENDF I/O system in the Ruler, Ruler is faster, and more maintainable and extendable.

R025 Frendy: the new nuclear data processing system for JENDL

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Japan Atomic Energy Agency (JAEA) provides the nuclear data and nuclear calculation systems, e.g., evaluated nuclear data library JENDL, general purpose Monte Carlo code MVP, and particle and heavy-ion transport code system PHITS. Several decades ago, the nuclear data processing system was developed in JAERI, but data libraries for these computer codes of JAEA were prepared by NJOY and PREPRO. When JENDL-4.0 was released, we found several problems in data processing systems especially in NJOY. In that case, they should be modified by ourselves quickly. Furthermore, recently, the introduction of the Generalized Nuclear Data (GND) utilizing XML format has been considered. Since XML is completely different from the current ENDF-6 format, the current nuclear data processing systems can't treat the GND format without extremely large revision.
To overcome such problems, JAEA has started to develop new nuclear data processing system FRENDY (FRom Evaluated Nuclear Data libralY to any application). FRENDY is designed to deal with the new nuclear data format, immediately. Therefore, we consider the maintainability, modularity, portability and flexibility in this development.
To achieve these requirements, FRENDY is written in the object-oriented language C++. Since all classes in FRENDY were encapsulated, the maintainability and modularity are highly improved than current nuclear data processing systems written in FORTRAN. Furthermore, to improve the portability and flexibility, each class was designed to minimize the function and to maintain the independence of each module.
Because functions of FRENDY such as the reconstruction of resonance are encapsulated, these can be used by other calculation codes by adding only a few lines. Furthermore, each function of FRENDY can be easily revised and extended for the future needs.
In this presentation, the outline of the development of FRENDY is presented. And functions and performances of FRENDY are demonstrated by generation and validation of the continuous energy cross section data libraries for MVP, PHITS and MCNP codes.

R026 NDEC: An NEA platform for nuclear data testing, verification and benchmarking

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The selection, testing, verification and benchmarking of evaluated nuclear data consists, in practice, in putting an evaluated file through a number of checking steps where different computational codes verify that the file and the data it contains complies with different requirements. These requirements range from format requirements to good performance in application cases, while also addressing verifications of physical constraints, compliance with experimental data, consistence and completeness of the file and its good usability in simulation tools. Different tools and codes are available for performing these tasks.
A platform that automatizes and sequences the execution of these codes upon submission of an evaluated file, while compiling and parsing all outputs, is being built at NEA. This platform aims at providing, in a user-friendly interface, a thorough diagnose of the quality of evaluated nuclear data, based on the requirements mentioned above. This is the objective of the NDEC (Nuclear Data Evaluation Cycle) platform being developed, which is aimed at both users and evaluators of nuclear data and, in particular, members of the Joint Evaluated Fission and Fussion (JEFF) Nuclear Data Library project.
By design, NDEC takes advantage of other existing NEA tools and databases (JANIS, ICSBEP, IRPHE, NDaST) which are built and maintained at the NEA Data Bank, providing lasting support with its features. In this paper the NDEC platform is presented, showing the current development status. A first application of it use into selecting neutron cross-section candidate files for the next release of JEFF Nuclear Data Library is given.

I027 Methods, setups and measurements for determining resonance parameters at the time-of-flight facility GELINA

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For more than five decades the electron linear accelerator at the Joint Research Centre in Geel has been operating for nuclear data measurements. The designs of accelerator, moderator and flight paths, flight distances ranging from 10 to 400 m are available, make high resolution time-of-flight measurements in a wide range of neutron energies possible.
This contribution will describe the existing setups and methods that allow for precise and accurate measurements of the capture and total cross sections. For most non-fissile elements capture yields can be consistently derived with accuracies of order 1-2 %, and for measured transmissions uncertainties are even smaller.
The purpose of these measurements is twofold. Firstly the testing and validation of new or existing evaluated data files. Especially transmission measurements of thick samples are very sensitive to imperfection in these files, and some recent examples of such measurements e.g. Cu and W will be presented.
Secondly, these measurements are at the base of new evaluations, for analysis done either in the resolved or the unresolved resonance range, some recent examples e.g. W, U-238, Am-241 will be given.

R028 Measurement of the neutron capture cross section of the fissile isotope 235U with the CERN n_TOF total absorption calorimeter and a fission tagging based on micromegas detectors

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The accuracy on neutron-induced capture cross section of fissile isotopes must be improved for the design of future nuclear systems such as Gen-IV reactors and Accelerator Driven Systems [1]. The High Priority Request List of the Nuclear Energy Agency [2] summarize the most important nuclear data requirements. In the list are included the neutron-induced capture cross section of fissile isotopes such as ^{235}U.The measurement of this cross section presents several difficulties, mainly due to the strong fission γ-ray background competing with the weak capture γ-ray cascades used as signature of (n,γ) events.
A specific experimental setup [3] has been used at the CERN n_TOF facility for the measurement of the neutron-induced capture cross section of fissile isotopes and particularized to the case of the ^{235}U. This setup consists a set of micromegas fission detectors [4] placed inside a segmented BaF2 Total Absorption Calorimeter [5].
In the conference we will present the details of the measurement, the methodology used for the data analysis and the results obtained from the measurement.

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R029 Bismuth activation with thermal neutrons and with Maxwellian neutrons at kT 30 keV

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We report on new measurements of bismuth activation with thermal neutrons and also activation with Maxwellian neutrons at kT~30 keV. Bismuth activation with thermal neutrons was performed at the Soreq research reactor [1], where measurements of -particle from the ^{210}Bi->^{210}Po->^{206}Pb decay and the 803keV gamma line from the ^{210}Po->^{206}*Pb decay provide measurements of neutron activation to the 210gBi ground state. Detection of the 265 keV and 305 keV gamma lines provide measurements of activation to the metastable Bi state via the reaction ^{209}Bi(n, g)210mBi->206Tl.
A new measurement was performed for bismuth activation with high flux Maxwellian neutrons at kT~30 keV using the SARAF-LiLiT high intensity linac and high power liquid lithium target facility at Soreq. Details of this new facility are presented elsewhere in these proceedings[2]. Activation to the ground state ^{209}Bi(n, g)^{210}gBi was measured via ‘s from the 210gBi decay, ‘s from the ^{210}Po decay, and gammas from the ^{210}Po->^{206}*Pb decay. Accurate measurement of bismuth activation is important for better design considerations of coolants using eutectic Pb-Bi. Neutron activation of bismuth is also of importance in nuclear astro-physics since it signifies the end of the cycle of the s-process reactions in stellar nucleo-synthesis.

[1] Soreq Nuclear Research Center IRR1 Reactor; [2] S. Halfon, these proceedings

R030 Measurement of the neutron capture resonances for platinum using the Ge spectrometer and pulsed neutron beam at the J-PARC/MLF/ANNRI

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Platinum is one of the useful atoms in our society as catalyst. For example, platinum is used in mufflers of cars and the key material for saving the environment. However, the catalytic activity in mufflers deteriorates by coupling of sulfur compound in car exhaust with platinum at high temperature. In-situ observation of platinum in mufflers without destruction could help improving clarification performance of car exhaust. On the other hand, the pulsed neutron imaging using resonance transmission spectroscopy was developed recently [1,2], which can provide three-dimensional distributions of nuclei and temperature. However, the experimental data of neutron resonances for platinum is poor.
Therefore, we conducted measurement of the neutron capture reaction for platinum at the Neutron-Nucleus Reaction measurement Instrument (ANNRI) of Materials and Life science experimental Facility (MLF) in Japan Proton Accelerator Research Complex (J-PARC). Intense pulsed neutron beam that is provided by the Japan Spallation Neutron Source (JSNS) was bombarded on a natural platinum foil sample at a distance of 21.5 m from the JSNS. Prompt gamma rays following the neutron capture reaction at the sample were observed by the Ge spectrometer that surrounds the sample. Neutron energy of each event was determined by the Time of Flight (TOF) method between the JSNS and sample.
We observed many resonance peaks on the TOF spectrum and the most intense one at 453 microseconds, which corresponds to 11.8 eV. In order to clarify the isotope that provides this 11.8 eV resonance, we applied a gate of selecting this resonance on the gamma ray spectrum. The gamma ray spectrum showed intense peak that corresponds to the separation energy of a neutron from Pt-196 nucleus. This result means that Pt-195 has the 11.8 eV resonance.
In this presentation, we show the experimental result and analysis of the observed resonances aiming at providing the nuclear data of platinum.

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S031 The 236U neutron capture cross-section measured at the n_TOF CERN facility

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The 236U isotope plays an important role in nuclear systems, both for future and currently operating ones. In the current reactors based on the U/Pu fuel, it contributes to the neutron balance in the reactor core and to the fuel composition at equilibrium, where it is produced mainly in neutron capture reactions on 235U. For future reactors based on the Th/U cycle, 236U plays the same role as 242Pu in the traditional fuel cycle, with a relevant contribution to neutron absorption. The actual knowledge of the capture reaction of this isotope is satisfactory in the thermal region, but it is considered insufficient for Fast Reactor and ADS applications. For this reason the 236U(n, γ) reaction cross-section has been measured for the first time in the whole energy region from thermal energy up to 1 MeV at the n_TOF facility with two different detection systems: an array of C6D6 detectors, employing the total energy deposited method, and a 4π total absorption calorimeter (TAC), made of 40 BaF2 crystals. The two n_TOF data sets agree with each other within the systematic uncertainty (≈ 3%) in the Resolved Resonance Region up to 800 eV, while sizable differences (up to ≈ 20%) are found relative to the current evaluated data libraries. Moreover two new resonances have been found in the n_TOF data. In the Unresolved Resonance Region, the n_TOF results show a reasonable agreement with previous measurements and evaluated data. In this talk, the n_TOF results on the 236U(n, γ) cross-section will be presented.

S032 New measurement of the Pu-242(n,γ) cross section at n_TOF-ear1 for MOX fuels

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The use of MOX fuel (mixed-oxide fuel made of UO_2 and PuO_2) in nuclear reactors allows substituting a significant fraction of the enriched uranium by plutonium reprocessed from spent fuel. Indeed, around 66% of the plutonium from spent fuel is made of ^{239}Pu and ^{241}Pu, which are fissile in thermal reactors. A typical reactor of this type uses a fuel with 7% reprocessed Pu and 93% depleted U, thus profiting from both the spent fuel and the remaining ^{238}U following the ^{235}U enrichment. With the use of such new fuel compositions rich in Pu a better knowledge of the capture and fission cross sections of the Pu isotopes becomes very important. This is clearly stated in the recent OECD NEA "*High Priority Request List*" and in the WPEC-26 report "*Uncertainty and target accuracy assessment for innovative systems using recent covariance data evaluations*". In particular, a new series of cross section evaluations has been recently carried out jointly by the European (JEFF) and United States (ENDF) nuclear data agencies. For the case of ^{242}Pu, there are only two TOF measurements from 1973 and 1976 available and there are sizeable differences between them, which calls for a new time-of flight capture cross section measurement, the first in 40 years.
In collaboration with JGU Mainz and HZ Dresden-Rossendorf, we have produced a sample consisting of a stack of seven relatively thick targets (~1 mg/cm2) making a total of 108 mg of $^{242}PuO_2$ deposited (via molecular plating) as a circular sample 45 mm in diameter spot. In the summer of 2015 the corresponding cross section has been measured at the n_TOF-EAR1 (185 m flight path) beam line at CERN using a set of four C_6D_6 detectors by means of the Total Energy Detection technique. The data reduction process and the final capture yield for this new experimental data will be presented. The experimental limitations and uncertainties associated to statistics, background subtraction, normalization and other experimental effects will be discussed, taking into account that the aimed accuracy of the measurements ranges between 7% and 12% depending on the energy region.

S033 Experimental verification of neutron capture cross section of 237Np in variable neutron field at KURRI-LINAC

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To improve the accuracy of nuclear data on minor actinides (MAs) and long-lived fission products (LLFPs), the project entitled as "Research and development for Accuracy Improvement of neutron nuclear data on Minor ACtinides (AIMAC)" has been started in Japan from October 2013. In this study, we proposed the thermal capture cross section measurement methods using variable neutron fields, developed in the Kyoto University Research Reactor Institute - Linear Accelerator (KURRI-LINAC), and investigated neutron spectra in these fields using TOF and activation methods.
In this study, the variable neutron field for the measurements of neutron capture reaction rate of MAs was developed with the moderator activated boric-acid solution at KURRI-LINAC. The measurement of neutron capture reaction rate of ^{237}Np was carried out in the variable neutron spectrum field. The 3 cases of boric-acid concentration of the light water moderator, namely 0, 850 and 2740 ppm, were used for the experiment. As a result, the reaction rate of Np^{237} was 2.78×10^3 [/s] within 2% statistical error in the condition of 850 ppm boric-acid concentration. In the conference, the detail of the experiment will be reported.
Present study includes the result of "Research and Development for accuracy improvement of neutron nuclear data on minor actinides" entrusted to the Japan Atomic Energy Agency by the Ministry of Education, Culture, Sports, Science and Technology of Japan (MEXT).

I034 Research and development for accuracy improvement of neutron nuclear data on minor actinides

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A nuclear data project entitled as “Research and development for Accuracy Improvement of neutron nuclear data on Minor ACtinides (AIMAC)” is being performed in Japan. The objective of the project is to improve accuracy of neutron nuclear data for minor actinides and some fission products, which is required for developing innovative nuclear system transmuting these nuclei. The AIMAC project team is composed of researchers in four different fields: differential nuclear data measurement, integral nuclear data measurement, nuclear chemistry, and nuclear data evaluation. By integrating all of the forefront knowledge and independent techniques in these fields, the team aims at improving the accuracy of the data.

Following research items have been performed to achieve the objective:
1) Measurements of thermal neutron capture cross-sections by activation methods
2) High-precision quantifications of shielded sample amounts used for TOF measurement
3) Resonance parameter determinations at J-PARC/ANNRI and KURRI/LINAC
4) Extension of capture cross sections to high energy neutrons at J-PARC/ANNRI
5) High quality evaluation based on iterative communication with experimenters
This contribution presents the outline of the achievements, and individual results are presented by other contributions.
Present study includes the result of “Research and Development for accuracy improvement of neutron nuclear data on minor actinides” entrusted to the Japan Atomic Energy Agency by the Ministry of Education, Culture, Sports, Science and Technology of Japan (MEXT).

R035 Absolute measurement of the 242Pu neutron-capture cross section

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Precision (n,f), (n,γ), and (n,2n) cross sections are important for the network calculations of the radiochemical diagnostic chain for the U.S. DOE’s Stockpile Stewardship Program. The ^{242}Pu(n,) cross section is relevant to the network calculations of Pu and Am. Additionally, new reactor concepts have catalyzed considerable interest in the measurement of improved cross sections for neutron-induced reactions on key actinides. To date, little or no experimental data has been reported on ^{242}Pu(n,γ) for incident neutron energy below 50 keV. A new measurement of the ^{242}Pu(n,γ) reaction was performed with the DANCE together with an improved PPAC for fission-fragment detection at LANSCE during FY14. The relative scale of the ^{242}Pu(n,γ) cross section spans four orders of magnitude for incident neutron energies from thermal to ≈ 30 keV. The absolute scale of the ^{242}Pu(n,γ) cross section is set according to the measured ^{239}Pu(n,f) resonance at 7.8 eV; the target was spiked with ^{239}Pu for this measurement. Latest results to be reported.
This measurement was performed under the auspices of the US Department of Energy by Lawrence Livermore National Security, LLC under contract DE-AC52-07NA27344 and by Los Alamos National Security, LLC under contract DE-AC52-06NA25396. Additional funding was provided by the U.S. DOE/NNSA Office of Defense Nuclear Nonproliferation Research and Development. The isotopes used in the measurement were obtained from Oak Ridge National Laboratory.

R036 Measurement of the Am241 neutron capture cross section at the n_TOF facility at CERN

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New neutron cross section measurements of minor actinides have been performed recently in order to reduce the uncertainties in the evaluated data, which is important for the design of advanced nuclear reactors and, in particular, for determining their performance in the transmutation of nuclear waste.
We have measured the ^{241}Am(n,γ) cross section at the n_TOF facility [1] between 0.2 eV and 10 keV with a BaF_2 Total Absorption Calorimeter [2], and the analysis of the measurement has been recently concluded. Our results are in reasonable agreement below 20 eV with the ones published by C. Lampoudis et al. [3] in 2013, who reported a 22 % larger capture cross section up to 110 eV compared to experimental and evaluated data published before. Our results also indicate that the ^{241}Am(n,γ) cross section is underestimated in the present evaluated libraries between 20 eV and 2 keV by 25%, on average, and up to 45% for certain evaluations and energy ranges.

[1] C. Guerrero et al., Eur. Phys. J. A 48, 29 (2012).; [2] C. Guerrero et al., Nucl. Instr. Meth. A 608, 424 (2009).; [3] C. Lampoudis et al., Eur. Phys. J. Plus 128, 86 (2013).

R037 Measurements of neutron capture cross sections for 238U at GELINA

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Measurements have been performed at the time-of-flight facility GELINA to determine the ^{238}U(n,γ) cross section in the resonance region below 1.2 keV and between 3.5 keV and 90 keV. Experiments were carried out at a 12.5 and 60 m measurement station. The total energy detection principle in combination with the pulse height weighting technique was applied using C_6D_6 liquid scintillators as prompt gamma-ray detectors. The energy dependence of the neutron flux was measured with an ionization chamber based on the ^{10}B(n,α) reaction. The data have been normalized to the isolated and saturated ^{238}U resonance at 6.67 eV. Special procedures have been applied to reduce bias effects due to the weighting function, normalization, dead time and background corrections. The total uncertainty due to normalization, neutron flux and weighting function is about 1.5%. The parameters of resonances below 500 eV are in good agreement with those resulting from the evaluation carried out by Derrien et al., which have been adopted in the main data libraries. Average cross section data were derived from the experimental capture yield in the energy region between 3.5 keV and 90 keV. The data are in very good agreement with an evaluated cross section resulting from a least squares fit to experimental data available in the literature prior to this work.

I038 Radiative capture reactions for the p process

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The p process of nucleosynthesis is responsible for the production of the stable neutron-deficient nuclei heavier than iron observed in the solar system. The most favoured scenarios proposed for the p process involve the photodisintegration through a series of (γ,n), (γ,p), and (γ,α) reactions of intermediate and heavy elements at high temperatures (2–3 billion degrees Kelvin) that can be achieved only during the explosive burning phases of massive stars. The relevant abundance calculations involve extended networks of about 20000 reactions on 2000 nuclei, a very small fraction of which can or have been measured in the laboratory. As a result, the calculations rely largely on predictions of the statistical model which have shown to depend strongly on the α-nucleus optical model potential (α-OMP).
Considerable effort has been devoted in recent years to improve our knowledge of the behaviour of the α-nucleus OMP at low energies relevant to explosive stellar environments. Recently, the so-called 4π γ-summing method was developed by the groups of "Demokritos" and Bochum that is based on the use of a large volume NaI(Tl) detector covering a solid angle of almost 4π for photons emitted by a target placed at its center. Using this new method, angle integrated cross sections of more than 20 (p,γ) and (α, γ) reactions were determined at energies well-below the Coulomb barrier. The present paper presents a review of recent experimental and theoretical developments.
Apart from the α-capture reaction cross sections, α-elastic scattering data and other α-related reaction cross sections will be compared with the predictions of the most recent global α OMP available. Finally, the question of whether there is sufficient experimental information to put constraints on the theory and draw final conclusions will be discussed.

R039 Reactor neutrons in nuclear astrophysics

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The neutron-induced nucleosynthesis in stars occurs typically at temperatures between kT=5 keV and kT=200 keV. The neutron-energy distribution in reactors is centered around 25 meV. The reaction cross sections at 25 meV are therefore usually not a strong constraint for the reaction cross sections in the keV-regime.
However, the huge neutron fluxes offer the possibility to use research reactors to produce isotopes of interest, which can be investigated afterwards. Examples are half-lives of long-lived isotopes like ^{129}I. This isotope is a branch point in the nucleosynthesis path of the stellar slow neutron capture process. Using reactors, it is possible to irradiate ^{128}Te and measure the activity ratio of ^{129}Te to ^{129}I, which results in an independent determination of the half-life of ^{129}I.
As already discussed, the traditional method of determining the (n,g) cross sections in reactors doesn't constrain the astrophysical rates significantly. However, since typically the direct capture component can be determined, it can help to improve the extrapolation of measurements in the keV-regime to temperatures not investigated so far. Examples for such measurements are the radioactive isotopes ^{10}Be, ^{60}Fe, and ^{171}Tm.
A direct usage of reactor neutrons in the astrophysical energy regime is only possible, if the corresponding ions are not at rest in the laboratory frame. Ions with energies between 0.1 AMeV and 10 AMeV can be efficiently stored in ion storage rings. The combination of such a ring with a reactor could open the path to direct measurements of neutron-induced cross sections on short-lived radioactive isotopes in the astrophysically interesting energy regime. The interaction zone could be the reactor core or long neutron guides.

R040 New accurate measurements of neutron emission probabilities for relevant fission products

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The fraction of delayed neutrons in nuclear reactors is an important parameter influencing reactor control and dynamics [1]. This parameter is obtained from measurements of specific fissioning systems (integral measurements). It can be obtained also from summation calculations which require the knowledge of fission yields *Y* and *β*-delayed neutron emission probabilities P_n of individual precursors. The advantage of the latter method is that it can be applied to systems for which no integral data exits (unconventional fuel compositions). However summation calculations do not attain currently the level of accuracy necessary to replace the conventional method. Although this is mainly due to uncertainties in the yields *Y*, the improvement of the current knowledge of P_n values for selected isotopes can have an impact on the calculations. Moreover, from comparison of summation calculations and integral measurements, constraints on uncertain fission yields could be established. We have performed a sensitivity study to select precursors that contribute appreciably to the delayed neutron fraction and have a relatively uncertain P_n value, for an improved measurement. The selection was completed with isotopes that are relatively close to the astrophysical r-process path. The *β*-delayed neutron emission of very neutron-rich nuclei produced during the rapid neutron capture process modifies the final element abundance [2]. P_n values for very neutron-rich nuclei either have a direct impact on r-process calculations or help to improve beta-strength based P_n theoretical estimations for those isotopes that are out of experimental reach.
The measurements were performed with the BELEN neutron counter [3] using an improved version with 48 ^{3}He proportional tubes, and a new beta detector with a reduced noise discrimination level. Furthermore, to enhance the quality of the data, radioactive beams for the isotopes of interest were produced without isobaric contamination at the IGISOL Mass Separator of JYFL with the help of the double Penning Trap system [4]. Data was taken for a total of ten isotopes of the elements Y, Sb, Te and I. Preliminary results will be presented and discussed.

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R041 Time-of-flight and activation experiments on 147Pm and 171Tm for astrophysics

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The neutron capture cross section of several key unstable isotopes acting as branching points in the s-process are crucial for stellar nucleosynthesis studies, but they are very challenging to measure due to the difficult production of sufficient sample material, the high activity of the resulting samples, and the actual (n,γ) measurement, for which high neutron fluxes and effective background rejection capabilities are required.
As part of a new program to measure some of these important branching points, radioactive targets of ^{147}Pm and ^{171}Tm have been produced by irradiation of stable isotopes at the ILL high flux reactor. Neutron capture on ^{146}Nd and ^{170}Er at the reactor was followed by beta decay and the resulting matrix was purified via radiochemical separation at PSI. The radioactive targets have been used for time-of-flight measurements at the CERN n_TOF facility using the 19 and 185 m beam lines during 2014 and 2015. The capture cascades were detected using a set of four C_6D_6 scintillators, allowing to observe the associated neutron capture resonances. The results presented in this work are the first ever determination of the resonance capture cross section of ^{147}Pm and ^{171}Tm.
Activation experiments on the same ^{147}Pm and ^{171}Tm targets with a high-intensity 30 keV quasi-Maxwellian flux of neutrons will be performed using the SARAF accelerator and the Liquid-Lithium Target (LiLiT) in order to extract the corresponding Maxwellian Average Cross Section (MACS). The status of these experiments and preliminary results will be presented and discussed as well.

R042 A nuclear data approach for the Hubble Constant measurements

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An extraordinary number of Hubble constant measurements challenges physicists with selection of the best numerical value. The standard U.S. Nuclear Data Program (USNDP) codes and procedures have been applied to resolve this issue. The nuclear data approach has produced the most probable or recommended Hubble constant value of 66.2(77) (km/sec)/Mpc. This recommended value is based on the last 25 years of experimental research and includes contributions from different types of measurements. The present result implies $(14.78\pm1.72)\times10^9$ years as a rough estimate for the age of the Universe. The complete list of recommended results is given and possible implications are discussed.

S043 Neutron capture cross sections of 69,71Ga and 63,65Cu at 25 and 90 keV

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The elements from iron to lead are mainly produced by the rapid (r) and the slow (s) neutron capture processes. The s-process takes place during stellar helium and carbon burning phases. The reaction path closely follows the valley of stability since neutron capture times of typically ten years are much slower than most of the β-decay times of the involved nuclei. The main and the weak component contribute to the s-process. The main differences are the neutron-to-seed ratio, the temperature, as well as the neutron densities.

The weak component of the s-process takes place in massive stars of more than eight solar masses during convective helium burning at temperatures of about 30 keV and during convective shell carbon burning at about 90 keV. It produces most of the isotopes between iron and strontium due to the comparably low time-integrated neutron flux. The flux is too low to achieve reaction flow equilibrium. Therefore, a particular neutron capture cross section not only determines the abundance of the respective isotope, but affects the abundances of all heavier isotopes as well. Hence, Maxwellian averaged cross sections (MACS) for energies of 30 and 90 keV are highly desired in the mass region A=60-90.

We measured the neutron capture cross sections of ^{69,71}Ga and ^{63,65}Cu at 25 and 90 keV by the activation technique at the Institute for Reference Materials and Measurement (IRMM) in Geel, Belgium. Protons were provided by an electrostatic Van de Graaff accelerator to produce neutrons via the reaction ^{7}Li(p,n). The produced activity was measured via the γ emission of the product nuclei by high-purity germanium detectors. We present the results and show their effect on the s-process abundances.

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I044 A new model for beta-delayed neutron emission and applications to the astrophysical r-process of nucleosynthesis

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β-delayed neutron emission probabilities (Pn-values) are important inputs for a broad range of nuclear physics applications. We present a new model of β-delayed neutron emission which combines QRPA and statistical decay calculations. This approach uses microscopic nuclear structure information which starts with Gamow-Teller strength distributions in the daughter nucleus, and then follows the statistical decay until the initial available excitation energy is exhausted. Explicitly included at each neutron emission stage is γ-ray competition. One consequence of this formalism is a prediction of more neutrons on average being emitted after β-decay for neutron-rich nuclei towards the neutron dripline. The framework presented here also enables us to extend our calculations to β-delayed fission and pre-scission neutron emission. We show that larger neutron emission and new β-delayed fission rates can substantially impact the observed abundances for the astrophysical rapid neutron capture or r-process of nucleosynthesis.

R045 Nuclear data from cosmological observations: neutrino energy transport and big bang nucleosynthesis

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We introduce a new computational capability that moves toward a self-consistent calculation of neutrino transport and nuclear reactions for big bang nucleosynthesis (BBN). Such a self-consistent approach is needed to be able to extract detailed information about nuclear reactions and physics beyond the standard model from Precision cosmological observations of primordial nuclides and the cosmic microwave background radiation. We calculate the evolution of the early universe through the epochs of weak decoupling, weak freeze-out and big bang nucleosynthesis (BBN) by simultaneously coupling a full strong, electromagnetic, and weak nuclear reaction network with a multi-energy group Boltzmann neutrino energy transport scheme. The modular structure of our approach allows the dissection of the relative contributions of each process responsible for evolving the dynamics of the early universe. Such an approach allows a detailed accounting of the evolution of the active neutrino energy distribution functions alongside and self-consistently with the nuclear reactions and entropy/heat generation and flow between the neutrino and photon/electron/positron/baryon plasma components. Our calculations reveal nonlinear feedback in the time evolution of neutrino distribution functions and plasma thermodynamic conditions. We discuss the time development of neutrino spectral distortions and concomitant entropy production and extraction from the plasma. These effects result in changes in the computed values of the BBN deuterium and helium-4 yields that are on the order of a half-percent relative to a baseline standard BBN calculation with no neutrino transport. This is an order of magnitude larger effect than in previous estimates. For particular implementations of quantum corrections in plasma thermodynamics, our calculations show a 0.4% increase in deuterium and a 0.6% decrease in 4He over our baseline. The magnitude of these changes are on the order of uncertainties in the nuclear physics for the case of deuterium and are potentially significant for the error budget of helium in upcoming cosmological observations.

R046 7Be(n,a) and 7Be(n,p) Cross section measurement for the cosmological lithium problem at the n_TOF facility at CERN

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One of the most important unresolved problems in Nuclear Astrophysics is the so-called "Cosmological Lithium problem" (CLiP). It refers to the large discrepancy (factor 3-5) between the abundance of primordial ^{7}Li predicted by the standard theory of Big Bang Nucleosynthesis (BBN) and the value inferred from the so-called "Spite plateau" in halo stars.
In the framework of Standard Model, a possible explanation for this longstanding puzzle is related to the incorrect estimation of the destruction rate of ^{7}Be. Indeed in the standard theory of BBN, 95% of primordial ^{7}Li is produced by the decay of ^{7}Be ($t_{1/2}$=53.2 days), relatively late after the Big Bang, when lower temperature of Universe allows electrons and nuclei to combine into atoms. Therefore, the abundance of ^{7}Li is essentially determined by the production and destruction of ^{7}Be.
While charged-particle induced reactions responsible for the destruction of ^{7}Be have mostly been ruled out by recent measurements, data on the ^{7}Be(n,α) and ^{7}Be(n,p) reactions have been so far scarce or completely missing, mainly due to unsurmountable experimental difficulties arising from ^{7}Be specific activity.
Recently, (n,α) reaction cross-section has been measured at n_TOF (CERN) while (n,p) reaction cross-section measurement is in progress, taking advantage of state-of-art techniques for the production of high-purity radioactive samples, of high performance detection systems and, especially, of the innovative features of the new measuring station (EAR2) particularly suited for challenging measurements on short-lived radioisotopes.
The two measurements, performed with two different silicon detection systems, provide for the first time nuclear data on ^{7}Be(n,α) and ^{7}Be(n,p) cross-section in a wide neutron energy range, namely in the energy range of interest for Nuclear Astrophysics.
The experimental setups and the results of the measurements will be here presented, together with the implications of the measurements in standard BBN theory.

R047 The 33S(n,α)30Si cross section measured at n_TOF Experimental Area 2 (CERN): from thermal to the resolved resonance region

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We present the results of the ^{33}S(n,a)^{30}Si cross section measurement using ^{10}B(n,a)^{7}Li as reference at the n_TOF Experimental Area 2 (EAR-2) facility at CERN, providing data below 10 keV for the first time. This reaction is of interest in astrophysics due to the still open question about the origin of ^{36}S, but also in medical physics since ^{33}S is being studied as a possible cooperative target to boron in Neutron Capture Therapy. The ^{33}S(n,a)^{30}Si cross section data are scarce, with only one high energy resolution measurement available in literature [1], that shows a factor of two discrepancy in the resonance parameters in comparison to the sole existing transmission measurement [2]. In addition to this, and being the main motivation for the present work, there are no data below 10 keV except at the thermal point which show important discrepancies. Therefore, the expected 1/v behaviour has not been confirmed with experimental data and low energy resonances, below 10 keV, may be possible in view of the experimental work in inverse kinematics [3]. Moreover, evaluated nuclear data files diverge not only in the value of the cross section at the known resonances but also drastically in its behaviour above the thermal point. Only EAF-2010 includes the resonances empirically observed. Moreover, ENDF/B-VII, JENDL-4.0, JEFF-3.2 and ROSFOND-2010 predict a constant and unrealistic behaviour from the thermal point up to 10 keV while JEFF-3.2, EAF-2010 and FENDL-3.0 show the known 1/v behaviour, but the value of this last library is almost four orders of magnitude higher than the rest of them.
In this work we present the result of the ^{33}S(n,a)^{30}Si cross section using ^{10}B(n,a)^{7}Li as reference in the energy range from thermal to 100 keV. For the first time data below 10 keV are provided allowing the study of the cross section at energies below the resonance region. This has been possible because of the outstanding features of the n_TOF neutron beam at EAR-2, especially the high instantaneous flux at low energies, and the optimization of the experimental set-up consisted of a set of micro-megas detectors and a low level noise electronics [4].

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I048 Experimental facilities supporting nuclear data measurements at the Los Alamos neutron science center

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At the heart of the Los Alamos Neutron Science Center is a powerful linear proton accelerator (linac) that accelerates protons up to 800 MeV. The high-energy proton beams are utilized at 5 experimental facilities simultaneously. The experimental facilities located on the south side of the linac contain two spallation neutron sources. These two target stations are designed and optimized to provide neutron beams with very different characteristics to accommodate a variety of experimental techniques. The Weapons Neutron Research (WNR) facility is centered around a bare tungsten production target serving six instrumented neutron flight paths (FPs). The neutron spectra at different FPs vary with the angle under which they view the target. The WNR facility offers fast neutrons up to the energy of hundreds of MeV. The second neutron spallation target serves sixteen neutron FPs in the Lujan Neutron Scattering Center (Lujan Center). The Lujan Center neutron source is optimized to deliver high intensity thermal and cold neutron beams to the experimental end stations. Together these two spallation neutron sources offer neutron beams in over eleven orders of magnitude in neutron energy. Recently, we have started exploring design options for the next-generation spallation target at the Lujan Center with focus on supporting more nuclear physics experiments. The goal of the new design is to increase the epithermal neutron flux and improve the energy resolution. These upgrades will benefit many new experiments relevant to the nuclear data community.

R049 Redesign of the target-moderator-reflector-shield assembly for optimization of the neutron flux in the epithermal and medium energy ranges at the Los Alamos Neutron Science Center

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The powerful linear proton accelerator at the Los Alamos Neutron Science Center (LANSCE) generates pulses of 800 MeV protons, which after compression in the proton storage ring, impinge on a tungsten target producing spallation neutrons. This spallation neutron source, called the Lujan Neutron Scattering Center, operates as a user facility that serves a wide community of international users. Currently, the primary high-energy neutrons are further slowed down and moderated in a moderator-reflector-shield assembly to provide thermal and cold neutrons that are then available at 16 neutron Flight Paths (FPs). The current generation Target-Moderator-Reflector-Shield (TMRS) was optimized to deliver cold and thermal neutrons to neutron-scattering experiments. As the current TMRS approaches the end of its life, we are working on the conceptual physics design of the next generation TMRS. Four neutron FPs will provide higher intensity in the epithermal and medium energy ranges while the other 12 FPs will preserve most of the thermal and cold neutron capabilities to support neutron-scattering experiments. This new design will enable many new nuclear physics experiments that are currently limited by neutron intensity or energy resolution available at existing neutron FPs at LANSCE.
Monte Carlo N-Particle eXtended (MCNPX) was used to model the complex Mark III TMRS design and compare it to various arrangements of the moderator/reflector/filter materials. Both neutron energy and time emission spectra were extracted from the simulation results and are presented in this paper.

R050 TANGRA - an experimental setup for basic and applied nuclear research by means of 14.1 MeV neutrons

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For investigation of the basic characteristics of 14.1 MeV neutron induced nuclear reactions on a number of important for nuclear science and engineering isotopes, a new experimental setup TANGRA has been constructed and tested at the Frank Laboratory of Neutron Physics of the Joint Institute for Nuclear Research in Dubna, Russian Federation.
The TANGRA setup consists of: a portable neutron generator ING-27 as a source of 14.1 MeV steady-state neutron radiation with an intensity of $\sim 5x10^7$n/s (a 64-pixel Si charge-particle detector is incorporated into its vacuum chamber for registering the α-particles from D(T,α)n reaction); a compact iron shielding-collimator; a reconfigurable γ-ray (and neutron) multi-detector system; a computerized data-acquisition system on the base of a fast personal computer loaded with 2x16 channels 100 MHz ADC PCI-E cards for signal processing; Linux ROOT software for data acquisition, storing, visualization and analysis.
The existence of the α-particle detector is giving the possibility to apply the associated particle technique the main advantage of which are: (a) - removal of uncertainties in the determination of the neutron flux (important when measure the reaction cross-sections) and (b) - reduction in the background arising from direct γ-rays (and neutrons) from the neutron source and setup surroundings. This way the signals from the α-particle detector are 'tagging' the neutrons. By counting the coincidences between the α-particle and the reaction-product detectors in a 20 ns time interval the effect/background-ratio is improved by a factor of $\sim$200.
In order to investigate the performance of TANGRA-setup, the angular distribution of gamma-rays (and neutrons) from the inelastic scattering of 14.1 MeV neutrons from high-purity carbon,^{12}C(n, n'γ)^{12}C - reaction, was measured and the angular anisotropy was determined. This reaction was chosen because of its importance from fundamental (differential cross-sections) and practical (nondestructive elemental analysis of materials containing carbon) point of view.
The preliminary results for the anisotropy of the γ-ray emission from the inelastic scattering of 14.1 MeV neutrons on carbon are compared with already published by the other authors data. A detailed data analysis for determining the correlations between scattered neutron and γ-ray emissions is ongoing.

R051 A development of photo-neutron source for time-of-flight measurement at KAERI

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The project for building a neutron time-of-flight facility is still progressing. The construction itself has been delayed because the licensing process is still under way.
Meanwhile, a photo-neutron source will be manufactured by May 2016 and tested. By stopping the incident electrons in a heavy material target, neutrons are produced by bremsstrahlung photons through (,n) reactions.
For this, electron beam will be produced by the KAERI super conducting accelerator. The expected electron beam conditions are 17 MeV, average current 0.08mA, and 20ps pulse width with 200 kHz.
Our photo-neutron source also uses liquid lead as a target material. Liquid lead target has merits on the following two points. To have a good time resolution in the neutron data measurement with time-of-flight method, the smaller size of target will be better. On the contrary, if the target size is getting smaller, the heat produced by a focused electron beam is getting higher, so that the target could be melted. Liquid lead target can manage these issues. The same kind of the liquid lead target photo-neutron source already had been realized for the measurement of neutron cross sections at Helmholtz-Zentrum Dresden-Rossendorf (HZDR).
We refer to the photo-neutron source of HZDR in view that Mo-tube is used for radiator channel and liquid lead is circulated by an electromagnetic pump. However, we modified it to fit our conditions that the electron beam is incident from the top to the bottom, using coil type electromagnetic pump since we have experience of it, and omitting a heat exchanger due to a low heating power (1.36kW).
A photo-neutron source and its control system will be tested through the operating scenario by applying heating coil on the radiator channel instead of electron beam until the time-of-flight facility will be ready.
In this presentation, our photo-neutron source, its control system, and test results will be introduced.

S052 ASP neutron source: future capabilities

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The reinvigoration of the AWE's experimental nuclear physics programme at the ASP neutron facility (D-T neutron source) has increased demand for new diagnostics and capabilities. A key aspect of measuring nuclear data is to understand the radiation field. New diagnostics will be installed to improve gamma-ray and neutron spectral measurements. GEANT4 modelling has been used to develop a ~14 MeV neutron shielded, Compton suppressed HPGe system to measure prompt gamma rays from neutron activation in the ASP irradiation cell. Together these new capabilities will enable the measurement of short lived activation products, and radioactive isotope cross sections. An overview of these diagnostics and highlights of the likely future programme of work will be displayed.

S053 Preliminary decommissioning plan of European spallation source

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This paper is a survey of the European Spallation Source, ESS preliminary decommissioning plan (DP) developed in compliance with Swedish Regulatory Authority requirements defined for non-nuclear facilities, and following also the guidance provided by Swedish Nuclear Fuel and Waste Management Company (SKB).
ESS selected as referenced decommissioning strategy: immediate dismantling (ID) option. The desirable final goal of decommissioning activities will be to return the site to green field status.
The baseline plan for decommissioning consists of removing the components in a sequence starting with the most radioactive parts and ending with the least radioactive ones. Main tasks and time-scaling are discussed in the paper.
The approach to be used involves the dismantling, segmenting and decontamination techniques that are expected to be effective for the ESS facility. A summary of the methodologies and types of equipment recommended for application in each of the area of the facility is provided.
Types and quantities of radioactive waste estimated to be generated at the final shut-down of the facility are further outlined. The amounts of ESS radioactive waste and classifications were derived using: i) precise Monte Carlo calculations ii) scaling the activity from the operation experience of the existing spallation source installations for waste such it is difficult to predict level of activation or for components of the facility in stage of the pre-conceptual model.
Emphasis is given upon the calculations of the radioactivity of the components of the machine and earth underneath the facility using the computer code MCNPX6 coupled with activation code CINDER'90. Obtained results are discussed in detail in relation with decommissioning activities.
The paper ends up with the recommendations to the ESS management team of actions that can be taken during the design phase for efficient dismantling and disposal and thus reducing any exposure levels of the personnel and decommissioning costs.

S054 92,94Zirconium irradiation for 1 keV - 1 MeV neutron flux determination by means of (n, gamma) reaction

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Reactor dosimetry is based on the isotope irradiation and γ/X-ray spectrometry. The neutron spectra characterization is well performed for the thermal and fast energies. The lack of a proper detector for the intermediate neutron energy from 1 keV to 1 MeV encourages the research for a new target-isotope and nuclear reaction.
The purpose of this paper is to show the possible ^{92,94}Zr application, to prove its feasibility and to motivate new studies in zirconium nuclear data evaluation.
We irradiated ^{92,94}Zr under a boron nitride filter to eliminate the thermal neutrons contribution. The radiative capture produces during the irradiation two new isotopes: ^{93}Zr, ^{95}Zr. ^{95}Zr is measured by γ spectrometry whereas ^{93}Zr is measured by accelerator mass spectrometry. The experimental values obtained are ^{95}Zr activity and ^{93}Zr/^{92}Zr ratio.
The irradiation simulations were performed. ^{92,94}Zr (n, γ) cross section contributes the most to the global uncertainty of the calculation results. Zirconium isotopes are not enough studied and they are not included in IRDFF library that is traditionally used for dosimetry. Radiative capture information for ^{92,94}Zr was taken from JEFF 3.2 and ENDF/B VII.1. The C/E comparison is being performed.
ENDF provides the uncertainties values for the whole energy range from 10^{-5} eV to 20 MeV. Uncertainties for ^{92}Zr (n, γ) (resp. ^{94}Zr (n, γ)) cross sections for 1 keV - 1 MeV energy range vary from 7% to 19% (resp. from 7% to 13%). JEFF provides high uncertainty values for incident neutron energy from 161 keV to 27 MeV. We also noticed a lack of recent experimental data concerning Zr (n, γ) cross sections. The most complete information is given by experiments from 1976 that were partially completed in 2010. This work provides C/E values for ^{95}Zr activity and ^{93}Zr/^{92}Zr ratio. Uncertainties are based on available nuclear data. Experimental uncertainty for ^{95}Zr activity is inferior to the cross section uncertainty. Experimental uncertainty for ^{93}Zr/^{92}Zr has still to be improved; nevertheless it is similar to the cross section uncertainty. Thus, it is shown here that more precise evaluation of ^{92,94}Zr (n, γ) cross section is required in order to improve the C/E values.

S055 Analysis of energy resolution in the KURRI-LINAC pulsed neutron facility

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In order to improve accuracy of minor actinides (MAs) and long life fission products (LLFPs), the project entitled as “Research and development for Accuracy Improvement of neutron nuclear data on Minor Actinides (AIMAC)” is being performed in Japan. In this project, differential experiments of MAs and LLFPs nuclear data with pulsed neutron source are carried out. To supply independent and accurate cross section data by time-of-flight (TOF) technique, we measure total and capture cross sections of MAs by in the Kyoto University Research Reactor Institute - Linear Accelerator (KURRI-LINAC).
In this study, we carried out Monte Carlo calculation to provide energy resolution of neutron flux for TOF measurements in the KURRI-LINAC pulsed neutron facility.
The calculations were performed for moderated neutron flux at the energy range from 0.01 eV to 20 MeV. As the result, we obtained the energy resolutions (ΔE/E) in the epi-thermal region. For example, the energy resolutions were 1.0% in the neutron energy of 1.0 eV, 1.1% in 100.0 eV and 1.7% in 1.0 keV.
Present study includes the result of “Research and Development for accuracy improvement of neutron nuclear data on minor actinides” entrusted to the Japan Atomic Energy Agency by the Ministry of Education, Culture, Sports, Science and Technology of Japan (MEXT).

I056 Nuclear data measurement activities at China Institute of Atomic Energy

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China Institute of Atomic Energy (CIAE) is one of the most important bases for nuclear data measurement in China. In this talk, the nuclear data measurement activities at CIAE in recent years will be presented. The secondary neutron emission DX and DDX measurement, the integral experiment for nuclear data benchmarking, the excitation function measurement, the neuron induced fission yields measurement and the gamma production yields measurement carried out in recent years will be introduced. Furthermore, the progress of some new facilities and proposed plans (e.g. A Gamma ray Total Absorption Facility (GTAF) for (n,g) reaction cross section measurement, A 3He detector array for (n,2n) reaction cross section measurement, the back streaming white neutron beam for nuclear data measurement at China Spallation Neutron Source (CSNS)) will also be presented.

R057 Nuclear astrophysics and measurements of deuteron-induced reactions at Soreq applied research accelerator facility

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Phase 1 of the Soreq Applied Research Accelerator Facility (SARAF) is based on a proton/deuteron RF superconducting Linac with variable energy (1.5-6 MeV) and a high ion intensity (0.01-2 mA). A high-power free-surface Liquid-Lithium Target (LiLiT) is operated routinely for neutron production via the thick-target ^{7}Li(p,n)^{7}Be reaction and used for quantitative determination of neutron capture cross sections. Bombarded with a 1-2 mA proton beam at ~1.92 MeV from SARAF, LiLiT yields a 30-keV quasi-Maxwellian neutron spectrum with an intensity of 3-5×10^{10} n/s, more than one order of magnitude larger than present near-threshold ^{7}Li(p,n) neutron sources. First experiments were dedicated to benchmark the experimental system by measuring the Maxwellian Averaged Cross Section (MACS) of several targets. The MACS of ^{94}Zr and ^{96}Zr, important isotopes for the understanding of s-process evolution, were determined as 28.0 ± 0.6 mb and 12.4 ± 0.5 mb, respectively, based on activation measurements and detailed analysis, in good agreement with previous measurements and with lower uncertainties [1]. We are extending our experimental studies to several targets of current astrophysical interest: the ^{36,38}Ar(n,γ) reactions are being investigated for the first time with 30-keV quasi-Maxwellian neutrons as well as neutron capture reactions on important nuclides such as ^{nat}Ga and ^{nat}Se in the weak s-process and ^{209}Bi in s-process termination. The high neutron intensity enables the MACS measurements of low abundance or radioactive targets: neutron-induced reactions on ^{7}Be, for Big Bang Nucleosynthesis, and on s-process branching points ^{147}Pm, ^{171}Tm [2] are investigated. The status of these experiments and preliminary results will be presented and discussed. The SARAF Phase I variable energy linac also enables accurate measurements of deuteron-induced reaction cross sections in the range 2-6 MeV. While much of the available deuteron cross section data were obtained from stack technique measurements which result in large uncertainties in energy in the 2-6 MeV range, the SARAF setup allows for single thin target irradiations with an energy resolution smaller than 50 keV. We will present here published results for ^{63}Cu(d,p)^{64}Cu, ^{nat}Cu(d,x)^{65}Zn and ^{23}Na(d,p)^{24}Na cross sections measured at SARAF [3].

[1] M. Tessler et al., Phys. Lett. B 751 (2015) 418.; [2] C. Guerrero et al., These Conference Proceedings.; [3] L. Weissman et al., Nucl. Inst. and Meth. in Phys. Res. B 342 (2015) 7–12

R058 Induced radioactivity studies of the shielding and beamline equipment of the high intensity proton accelerator facility at PSI

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The Paul Scherrer Institute (PSI) is the largest national research center in Switzerland. Its multidisciplinary research is dedicated to a wide field in
natural science and technology as well as particle physics. The High Intensity Proton Accelerator Facility (HIPA) has been in operation at PSI since 1974. It includes 870 keV Cocroft-Walton pre-accelerator, a 72 MeV cyclotron injector as well as a 590 MeV ring cyclotron. The experimental facilities, the meson production graphite targets, Target E and Target M, and the spallation targets (SINQ and UCN) are used for material research and particle physics. In order to fulfill the request of the regulatory authorities and to be reported to the regulators, the expected radioactive waste and nuclide inventory after an anticipated final shutdown in the far future must be estimated. In this contribution, calculations for the 20 m long beamline between Target E and the 590 MeV beam dump of HIPA are presented. The first step in the calculations was determining the particle distributions around the beamlines using the MCNPX 2.7.0 Monte-Carlo particle transport code [1]. To perform the analysis of the MCNPX output and to determine the radionuclide inventory as well as the specific activity of the nuclides, an activation script [2] using the FISPACT10 code with the cross sections from the European Activation File (EAF2010) [3] was applied. The specific activity values were compared to the currently existing Swiss exemption limits (LE) [4] as well as to the future Swiss liberation limits (LL). The obtained results were used to estimate the total volume of the radioactive waste produced at the facility and have to be reported to the Swiss regulatory authorities. The comparison of the performed calculations to measurements is also discussed.

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I059 Solving challenges in nuclear data for the safety of European nuclear facilities - the CHANDA Euratom project

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The CHANDA FP7-EURATOM project, Solving Challenges in Nuclear Data for the Safety of European Nuclear Facilities, brings together the majority of the European nuclear data community (35 partners from 16 countries), infrastructures and resources to prepare the methodologies, detectors, facilities, interpretation and tools to produce and use nuclear data with the quality required to comply with the needs for the safety standards that are mandatory for present and future European nuclear reactors and other installations using radioactive materials. The project covers the whole energy field for the needs of thermal and fast neutron reactors, as well as the high energy data (up to a few GeV) needed for the subcritical Accelerator Driven Systems (ADS). Significant technical, methodological and organizational challenges have previously prevented the achievement of this goal for a number of relevant isotopes and nuclear reactions and CHANDA focus its effort on overcoming those challenges.

The progress and selected preliminary results of the project will be presented in this paper, including:

- Progress on new methodologies addressing challenging data needs including: fission and capture cross sections for very radioactive and rare isotopes, detector setups for more complete characterization of elastic, inelastic and (n, xn) reactions, high efficiency and accurate decay data and fission yield measurements,
- Contributions to commissioning new facilities (NFS@GANIL and N_TOF_Area_2@CERN), facilitating access to best existing nuclear data facilities at Europe, and helping to coordinate the preparation of radioactive targets,
- Developments on data evaluation tools, particularly to include uncertainty and covariance matrices, as well as updates of simulation tools to facilitate the regular use of these covariances in standard problems,
- Nuclear data needs and applicability for nuclear reactor safety and fuel cycle analysis, in general and in particular for the MYRRHA prototype of ADS and of Generation IV reactor.

Finally an outlook of the additional results expected by the end of the project will also be included.
More information on CHANDA can be found at http://www.chanda-nd.eu/.

I060 New evaluation of thermal neutron scattering libraries for light and heavy water

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In order to improve the design and safety of thermal nuclear reactors and for verification of criticality safety conditions on systems with significant amount of fissile materials and water, it is necessary to perform high-precision neutron transport calculations and estimate uncertainties of the results. These calculations are based on neutron interaction data distributed in evaluated nuclear data libraries. To improve the evaluations of thermal scattering sub-libraries, we developed a set of thermal neutron scattering cross sections (scattering kernels) for hydrogen bound in light water, and deuterium and oxygen bound in heavy water, in the ENDF-6 format from room temperature up to the critical temperatures of molecular liquids. The new evaluations were generated and processable with NJOY99 and also with NJOY-2012 with minor modifications (updates). The new TSL libraries are based on molecular dynamics simulations with GROMACS and recent experimental data, and result in an improvement of the calculation of single neutron scattering quantities. In this work, we discuss the importance of taking into account self-diffusion in liquids to accurately describe the neutron scattering at low neutron energies (quasi-elastic peak problem). To improve modeling of heavy water, it is important to take into account temperature-dependent static structure factors and apply Sköld approximation to the coherent inelastic components of the scattering matrix. The usage of the new set of scattering matrices and cross-sections improves the calculation of thermal critical systems moderated and/or reflected with light/heavy water obtained from the International Criticality Safety Benchmark Evaluation Project (ICSBEP) handbook. For example, the use of the new thermal scattering library for heavy water, combined with the ROSFOND-2010 evaluation of the cross sections for deuterium, results in an improvement of the C/E ratio in 48 out of 65 international benchmark cases calculated with the Monte Carlo code MCNP5, in comparison with the existing library based on the ENDF/B-VII.0 evaluation. Impacts on benchmarks from the recent edition of the International Reactor Physics Experiment Evaluation Project (IRPhEP) handbook will also be discussed.

R061 Important integral parameters in thermal neutron scattering in liquids

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In order to improve the design and safety of thermal nuclear reactors and for the verification of criticality safety conditions on systems with a significant amount of fissile material and water, it is necessary to perform high-precision neutron transport calculations and estimate uncertainties of the results. These calculations are based on neutron interaction data distributed in evaluated nuclear data (ND) libraries, where additional complexity is introduced by the fact that different evaluations of the same nuclide/material can be found in different ND releases. In the case of thermal scattering sub-libraries (TSL), the question that arises is how to compare different evaluations (S(a,b) tables) of the same material in a fast and efficient manner. Here, we focus on light and heavy water used as coolant/moderator/reflector in many nuclear systems. A comparison of different TSL evaluations of the same material commonly starts with the scattering cross sections vs. incident neutron energy. Other parameters useful for comparison are the average scattering cosine, the average energy of out-scattered neutrons, as well as the effective temperature and Debye-Waller coefficient. The scattering cross-sections, average cosine and average energy should satisfy certain asymptotic conditions at neutron energies near the upper energy cut off (~ 10 eV) and at very low incident neutron energy (cold and ultra-cold neutrons). We propose to add the second moments of energy and scattering cosine distributions to this list, estimate the standard deviations of the average parameters, and calculate the corresponding scattering fractions. All these integral parameters can be calculated based on standard TSL evaluations in ENDF-6 format and NJOY-2012 output files. The effective temperature of a liquid (water) can be calculated using the results of molecular dynamics simulations directly as well as by NJOY. The effective temperatures estimated from different TSL evaluations of water are then compared with available experimental results obtained where deep inelastic scattering techniques are applied to light-heavy water mixtures at room temperature.

R062 New scattering kernels for ethane and triphenylmethane at cryogenic temperatures

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Both in nuclear reactors and particle accelerators, neutrons are born with energies close to 1 MeV. For scattering experiments, these neutrons have to be thermalized. For that purpose, in the vast majority of traditional neutron sources, moderator materials such as light or heavy water are used at room temperature to produce thermal neutrons and H2 or D2 at cryogenic temperatures to produce cold neutrons.
In particular, in a pulsed source, where the pulse-width is an important parameter to be considered, hydrogenated materials are often used because of its high energy transfer in each collision.
In this work we present two potential cold moderator materials: ethane and triphenylmethane. The first one, ethane (C2H6), is an organic compound which is very interesting from the neutronic point of view, better than liquid methane to produce subthermal neutrons, not only because it remains in liquid phase through a wider temperature range (Tf = 90.4 K, Tb = 184.6 K), also because its high protonic density together with its frequency spectrum which has a low rotational energy band. Triphenylmethane is an hydrocarbon with formula C19H16 which has already been proposed as a good candidate as a cold moderator material.
Following one of the main research topics of the Neutron Physics Department of Centro Atómico Bariloche, we present here two ways to estimate the frequency spectrum which is needed to feed the NJOY nuclear data processing system in order to generate the scattering law of each desired material. For ethane, computer simulations of molecular dynamics were done, while for triphenylmethane existing experimental and calculated data were used to produce a new scattering kernel. With these models, cross section libraries were generated, and applied in neutron spectra calculation.

R063 Assessment of beryllium and molybdenum nuclear data files with the RPI neutron scattering system in the energy region from 0.5 to 20 MeV

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A series of neutron scattering benchmark measurements were performed on beryllium and molybdenum with the Rensselaer Polytechnic Institute's Neutron Scattering System. The pulsed neutron source was produced by the Rensselaer Polytechnic Institute Linear Accelerator and a well-collimated neutron beam was incident onto the samples located at a distance of 30.07 m. Neutrons that scattered from the sample were measured using the time-of-flight by eight EJ-301 liquid scintillator detectors positioned 0.5 m from the sample of interest. A total of eight experiments were performed with two sample thicknesses each measured by detectors placed at two sets of angles. All data were processed using pulse shape analysis that separated the neutron and gamma-ray events and included a gamma misclassification correction to account for erroneously classified gamma-rays. A detailed model of the neutron scattering system simulated each experiment with several current evaluated nuclear data libraries and their predecessors. Results for each evaluation were compared to the experimental data using a figure-of-merit. The neutron scattering system has been used as a means to quantify a library's performance.

S064 Thermal neutron scattering evaluation framework

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A neutron scattering kernel data evaluation framework for computation of model-dependent predictions and their uncertainties is outlined. In this framework, model parameters are fitted to double-differential cross section measurements and their uncertainties. For convenience, the initial implementation of this framework uses the molecular dynamics (MD) model implemented in the NAMD code. It is applied to light and heavy water using the TIP3P and TIP4P interaction models. The MD trajectories computed by the NAMD simulation are then processed using the nMOLDYN code to compute the thermal neutron scattering kernel. Double-differential cross sections computed from the scattering kernel are then fitted to double-differential scattering data measured at the Spallation Neutron Source detector at Oak Ridge National Laboratory. The fitting procedure is designed to yield optimized model-parameters and their uncertainties in the form of a covariance matrix, from which new evaluations of thermal neutron scattering kernel will be generated. Two complementary fitting procedures will be considered: Generalized Least Squares and Monte-Carlo. We show how the computation of sensitivities of the scattering kernel with respect to model parameters could be computed by a novel application of the adjoint method to MD simulations.

S065 Measurement of double differential cross section of light water at high temperature and pressure to generate S(alpha,beta)

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Nuclear cross section libraries use derived thermal neutron scattering represented by scattering kernel S(α,β) where α and β stand for the unit-less momentum and energy transfers respectively. The availableS(α,β)of light water in the evaluated data libraries are based on physics models [1] and experimental data measured in the 1960s with a low accuracy due to the limitations of the experimental and computational capabilities. S(q,ω) is analogous to the scattering function S(q,ω) which describes the microscopic dynamics of a scattering system, where q is the neutron momentum transfer and ω is the neutron energy transfer. S(q,ω) for light water can be directly measured by performing time-of-flight inelastic thermal neutron scattering experiment in order to avoid approximations and thus possibly enhance the reliability of S(α,β)and the accuracy of the thermal scattering cross sections.

The *Institut de Radioprotection et de Sûreté Nucléaire* (IRSN) is working on the improvement of thermal scattering cross section data of light water for criticality safety studies and reactor physics. Improved S(q,ω) and neutron scattering cross section of light water at ambient temperature and pressure have been successfully carried out at Institut Laue-Langevin (ILL) [2]. The present work aims at extending the previous measurements beyond room temperature and pressure to more realistic operating conditions in connection with nuclear power reactors. The full paper will introduce the results of the two consecutive inelastic thermal neutron scattering experiments for light water performed using high resolution time-of-flight spectrometers (IN4c and IN6) at ILL in 2015. Measurements have been carried out for several high temperatures and pressures. A detailed data reduction of the raw data [3] is done to obtain S(q,ω) which is then transformed into S(q,ω) in order to calculate the double differential thermal neutron scattering cross section. The paper will focus on the effect of temperature and pressure on the thermal scattering kernel S(q,ω) of light water and its impact on integral experiments. Further, the evaluation of the experimental data will provide grounds to obtain the uncertainties associated with the experimental conditions in connection with the measurements, namely the systematic and the statistical uncertainties.

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S066 Study of thermal scattering nuclear data for organic tissue through molecular dynamics

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The Boron Neutron Capture Therapy (BNCT) is an experimental therapy for tumors which is based on the nuclear reaction that occurs when ^{10}B is irradiated with thermal neutrons. It has been applied to the tumors which have had a poor response to traditional therapies such as surgery, conventional radiotherapy and chemotherapy. Nowadays, feasibility studies and clinical trials are being carried out all over the world. BNCT is applied to a number of other tumors, using neutrons in wide energy ranges. In order to plan the treatment for this therapy, numerical dosimetry calculations must be performed.
Calculations for BNCT with Monte Carlo N-Particle (MCNP) take into account the thermal scattering treatment for hydrogen bound in bulk water for any organic tissue. However, in these tissues, hydrogen is also present in macromolecules (protein, lipids, etc.) and in confined water. We have determined that the differences in thermal neutron flux calculations using libraries for hydrogen in polyethylene or hydrogen in water, in phantoms of adipose tissue, can reach values of 9%, depending on the type of source and irradiated geometry. These results, have showed the importance of utilizing the appropriate thermal scattering treatment for each organic tissues in dosimetry calculations.
Thermal scattering cross section for hydrogen in an organic tissue can be determined by calculating the scattering law $S(\alpha,\beta)$. This function can be obtained with the nuclear data processing system NJOY from the vibrational frequency spectrum of an atom in a molecular system. We performed calculations of the frequency spectrum from molecular dynamics simulations using the program GROMACS. This technique was selected because it allows to obtain the velocity autocorrelation function and then, applying the Fourier Transform, the frequency spectrum. Systems composed of a peptide in a water box were considered, with different proportion of water molecules. All-atom potentials for modeling these molecules were used in order to represent the internal vibrational normal modes for the atoms of hydrogen. The results showed several internal normal modes that in the case of hydrogen bound in bulk water do not appear. With this information, and NJOY, thermal scattering libraries for hydrogen in different tissues were generated.

S067 Thermal neutron scattering data for LiF and BeF2

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Thermal neutron scattering data are widely used in nuclear engineering applications, such as reactor design, radiation shielding, long-lived nuclear waste transmutation, Boron Neutron Capture Therapy (BNCT) . Although the sub-libraries of some moderator materials are given in the available evaluated nuclear data libraries, the data for more materials are needed for the molten salt reactor.

A code, SIRIUS, is developed to describe thermal neutron scattering process and produce data in ENDF-6 format. This code considered coherent elastic, incoherent elastic, coherent inelastic and incoherent inelastic scattering processes. The phonon band structures and projected phonon densities of states (DOS) were calculated by Hellman-Feynman Theorem combined with a lattice dynamics direct method. The thermal neutron scattering data for LiF and BeF2 are given and expected to be used for molten salt reactor.

nce matrix for light water thermal scattering law

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The correct understanding of the thermalization process in light water reactors is important for safety applications. Efforts are underway to improve the neutron thermal cross sections of light water down to the cold neutron energy range, where the evaluated cross sections in the nuclear data libraries JEFF-3.1.1 and ENDF/B-VII.1 show sizeable disagreements from measurements.
The current thermal scattering laws (TSL) of hydrogen in light water in the cited nuclear data libraries derive from IKE model [1], which is based on experimental measures carried out in the late sixties. Recent publications have shown the feasibility of using molecular dynamics simulations for calculating the frequency spectrum of hydrogen in light water and obtaining TSL with the LEAPR module of the processing tool NJOY. This approach, namely "CAB model" [2], relies on the GROMACS code [3] in association with the water potential TIP4P/2005f [4].
New measurements of the double-differential cross sections of light water were done at Laue-Langevin institute (Grenoble, France) as a function of the temperature and pressure [5]. Such new data are essential for producing reliable covariance matrices for light water that account for discrepancies with the CAB model. The covariance matrices will be produced with the CONRAD code, developed at the CEA Cadarache, by combining retroactive analysis technique, marginalization method and defect model. The originality of the work is to produce a covariance matrix between the model parameters involved in the LEAPR model and in the GROMACS code.
The posterior covariances will be used for propagating the TSL uncertainties on integral benchmark calculations in "cold conditions" (room temperature and atmospheric pressure) and "hot full power conditions" (T=600 K and P=150 bars).

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I069 Thermal neutron scattering law calculations using ab initio molecular dynamics

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In recent years, methods for the calculation of the thermal neutron scattering law (i.e., S(α,β), where α and β are the dimensionless momentum and energy transfer variables, respectively) were developed based on ab initio lattice dynamics (AILD) and/or classical molecular dynamics (CMD). While these methods are now mature and efficient, further advancement in the application of such atomistic techniques is possible using ab initio molecular dynamics (AIMD) methods. In this case, temperature effects are inherently included in the calculation of, e.g., phonon spectra while using ab initio force fields that eliminate the need for parametrized semi-empirical force fields. In this work, AIMD simulations were performed to predict the phonon spectra as a function of temperature for beryllium and graphite, which are representative nuclear reactor moderator and reflector materials. Subsequently, the calculated phonon spectra were utilized to predict S(α,β) using the LEAPR module of the NJOY code. The AIMD models of beryllium and graphite were 5x5x5 crystal unit cells (250 atoms) and 4x4x4 crystal unit cells (256 atoms), respectively. Electronic structure calculations for the prediction of Hellman-Feynman forces were performed using density functional theory with a GGA exchange correlation functional and corresponding Perdew-Burke-Ernzenhof core electron pseudopotentials. AIMD simulations of 10,000 time-steps were performed within the micro-canonical ensemble (NVE thermostat) for several temperatures between 300 K and 1200 K. The phonon spectra were calculated as the power spectrum of the AIMD predicted velocity auto-correlation functions. The resulting AIMD phonon spectra and corresponding inelastic thermal neutron scattering cross sections at 300 K, where anharmonic effects are expected to be small, were found to be in reasonable agreement with the results generated using traditional AILD analysis for both materials. This illustrated the validity of the AIMD approach. However, since the impact of temperature on the phonon spectra (e.g. broadening of spectral peaks) was observed in AIMD analysis, this technique may be envisioned as the approach for deriving the needed atomistic data for thermal scattering law calculations under realistic temperature and structural conditions for a given material.

R070 Production of the thermal neutron scattering law for water ice with density functional theory and lattice dynamics

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Water ice has more crystalline structures than any other material due to the wide range of geometric configurations possible for the hydrogen bonds between H_2O molecules. Ice Ih forms below 273 K at normal atmospheric pressure and is the most common form. The primitive unit cell for ice Ih contains four H_2O molecules for which particular orientations are allowable. Although the hydrogen bonds have local order, they exhibit disordered geometry over the global structure. The VASP a*b initio* density functional theory code is used to simulate the hexagonal structure of ice Ih. To improve capturing the random distribution of molecular alignments, a twelve-molecule unit cell model is incorporated. The PHONON lattice dynamics code is used with VASP to calculate Hellmann-Feynman forces for a 2×2×2 supercell, allowing the production of the phonon density of states for hydrogen and oxygen. Translational, librational, bending, and stretching modes are produced with high resolution and are consistent with experimental Raman, infrared, and inelastic neutron scattering results [Renker et al. (1969), Li (1996)]. The theoretical phonon spectra are used to calculate the thermal neutron scattering law for ice Ih. This is compared to experimental at 268 K [Harling (1967)] and found to be consistent within the limited experimental resolution. Next, total cross sections are calculated by integrating over to determine the incoherent inelastic scattering cross sections and then separately adding the incoherent elastic scattering and absorption components. This is compared to experimental total cross sections for ice Ih at 115 K over a range of incident energies [Torres et al. (2006)] and found to provide excellent agreement. Finally, the ice Ih scattering kernel is tested in a benchmark model using the LLNL COG Monte Carlo transport code against measured results from a pulsed-neutron die-away experiment for cylinders of ice at 188, 208, 228 and 253 K [Silver (1965), Salaita (1971)]. Incorporation of the scattering kernel for ice Ih results in a significant improvement of results compared to a conventional free-gas scattering treatment.

R071 A thermal neutron scattering law for yttrium hydride

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Yttrium hydride (YH_2) is of interest as a potential high temperature moderator material because of its superior ability to retain hydrogen at elevated temperatures. Thermal neutron scattering laws for hydrogen bound in yttrium hydride (H-YH_2) and yttrium bound in yttrium hydride (Y-YH_2) prepared using an *ab initio* approach are presented. Density functional theory, incorporating the generalized gradient approximation (GGA) for the exchange-correlation energy, is used to simulate the face-centered cubic structure of YH_2 and calculate the interatomic Hellmann-Feynman forces for a 2×2×2 supercell containing 96 atoms. Lattice dynamics calculations using PHONON are then used to determine the phonon dispersion relations and density of states. The two calculated phonon density of states for H and Y are used to prepare H-YH_2 and Y-YH_2 thermal scattering laws using the LEAPR module of NJOY2012. Analysis of the resulting integral and differential scattering cross sections demonstrates adequate resolution of the $S(\alpha,\beta)$ function. Comparison of experimental lattice constant, heat capacity, total phonon density of states and integral scattering cross section measurements to calculated values are used to validate the thermal scattering laws.

R072 Neutron thermalization in uranium mononitride as a potential fuel candidate for light water reactors

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There has been a renewed interest in uranium mononitride (UN) fuel for power reactors. UN has higher thermal conductivity, higher uranium density and smaller linear thermal expansion coefficient than uranium dioxide. Neutronic and thermal-hydraulic performance of UN and associated composite fuels have been studied recently for several types of light water reactors (LWRs), such as, the boiling water reactor [1], the pressurized water reactor [2] and the super critical water reactor [3], which is the only concept of Generation IV nuclear reactors cooled and moderated by light water. However, for a complete analysis of the LWRs performance using nitride fuels, thermal neutron scattering libraries of UN is a necessity. To date, no ENDF library for UN is available. In this work, the thermal neutron scattering law and inelastic scattering cross section of UN will be calculated at different temperatures. The calculation of the thermal neutron scattering cross sections requires a detailed knowledge of the lattice dynamics of the scattering medium. The vibrational properties of UN is studied using ab initio lattice dynamics direct method. Excellent agreement between the calculated phonon dispersion relations and the experimental data have been obtained. The optical modes are well separated from the acoustic modes due to the large mass ratio between the masses of U and N atoms. Recent inelastic neutron scattering measurements of UN scattering law showed that it is composed of a set of equally-spaced and well-defined modes in multiples of 50 meV [4] and that each N atom represents an ideal isotropic three-dimensional quantum harmonic oscillator with a fundamental energy of 50 meV [4]- unlike the behavior of the hydrogen atom in zirconium hydrides which showed a significant anisotropy [5]. Because N-14 has a large absorption cross section in the thermal energy range and results in production of C-14, the scattering law and inelastic scattering cross sections are also under investigation using N-15 in UN compound.

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I073 High-precision gamma-ray spectroscopy for enhancing application of medical isotopes

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Precise knowledge of the radiation emitted by medical isotopes is needed to determine the total dose received by the patient, the specific dose to targeted tissue, the cost of infrastructure in production facilities (i.e. shielding requirements) and the background in imaging technologies. A number of either well-established or emerging medical isotopes were last studied more than 30 years ago using very primitive detection setups. Since then, the field of gamma-ray spectroscopy has made tremendous advances, now often using multiple high-purity germanium (HPGe) detectors employing Compton-suppression technology. In the present work, we make use of these new techniques to significantly improve the knowledge of decay schemes of both traditional and emerging radionuclides used for medical imaging.
Sources of medical isotopes were produced and purified at the Brookhaven Linear Isotope Producer (BLIP) then shipped to Argonne National Laboratory where high-precision, gamma-ray measurements were performed using the state-of-the-art gamma-ray spectrometer, Gammasphere, consisting of 100 Compton-suppressed HPGe detectors. An overview of results on a number of medical isotopes will be presented including studies of ^{82}Rb, a very common Positron Emission Tomography (PET) radioisotope used in cardiac imaging, and ^{72}As a longer-lived positron emitter which allows for imaging of biochemical and physiological processes and receptor mapping. In all nuclides studied, significant revisions were made to the decay schemes, including the observation of many new levels and gamma-ray transitions. The high-sensitivity of Gammasphere allowed for a significant reduction in the uncertainty of gamma-ray intensities and the deduced beta-feedings. The new decay schemes will be presented and their impact on dose estimates discussed.

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R074 Measurement of the half-life of 177Lu

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^{177}Lu is a medium energy beta-emitter with a maximum tissue penetration of approximately 1-2 mm and a maximum beta energy of 498.3 (8) keV. This radionuclide is used in Nuclear Medicine for therapy procedures such as treatment of neuroendocrine tumours and relapsed non-Hodgkin Lymphoma. ^{177}Lu is also characterised by gamma emission with the most abundant peaks being 112.9 keV and 208.4 keV which allows image acquisition for treatment planning and after treatment, becoming a big advantage for dosimetry calculations. In the current literature, measurements of the half-life of ^{177}Lu contained quantities of ^{177m}Lu impurity. These required corrections to determine an accurate half-life affecting the accuracy and precision of the values. In this work, the half-life of ^{177}Lu has been measured using a re-entrant ionisation chamber over a period of approximately 80 days (~ 12 half-lives). The material used in this work was produced via the ^{176}Yb(n,γ)^{177}Yb reaction followed by the β-decay to ^{177}Lu, resulting in no ^{177m}Lu being produced. The absence of ^{177m}Lu was checked by high purity germanium (HPGe) gamma ray spectrometry and by the extended measurement of the source over a period of 12 half-lives; no ^{177m}Lu was measured in the gamma-ray spectra and no deviation in the exponential decay curve was observed. The half-life was determined using the initial 38.1 days (~ 5.8 half-lives) to provide the best balance in the uncertainty budget. A precise half-life of 6.6430 (11) days was determined, which is in agreement with the recommended half-life of 6.6463 (15) days that has been evaluated by the Decay Data Evaluation Project (DDEP). An updated evaluation has been performed and a recommended half-life of 6.6443 (10) days has been determined by the power-moderated mean method.

R075 Production of isotopes with linear accelerators

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Recent advances in accelerator science are opening new possibilities in different fields of physics. In particular, the development of compact linear accelerators that can provide charged particles of low-medium energy (few MeV) with high current (above mA) allows the study of new possibilities in neutron production for different applications and new routes for the production of radioisotopes.

Keeping in mind the actual production in the dedicated facilities for radioisotope production, we perform a study of reactions to produce PET isotopes as, for example, ^{10}B(d,n)^{11}C, ^{20}Ne(d,α)^{18}F and ^{14}N(d,n)^{15}O. We have fitted the EXFOR cross sections data, used the fitted values of the stopping power by Ziegler and have calculated by numerical integration the yield considering that the charged particles can have energies up to 20 MeV. These results in the energies up to 3 MeV are compared with the ones provided by cyclotrons which are able to provide higher energies to the charged projectiles but with lower intensities. Following this philosophy, we have also analyzed the reaction ^{51}V(p,n)^{51}Cr. Our results indicate that the use of linear accelerators may be a good possibility for producing medical radioisotopes reducing drastically the problem of neutron activation.

R076 New theoretical atomic radiation library for basic science and applications

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Unstable atomic nuclei release excess energy through various radioactive decay processes. In some cases, including internal conversion and electron capture, the atom remains ionised after the nuclear decay event. Atomic relaxation back to the ground state occurs rapidly via radiative and non-radiative processes, often referred to collectively as atomic radiations. Non-radiative processes include emission of Auger, Coster-Kronig and super Coster-Kronig electrons.
While these atomic radiations usually carry a small fraction of the available nuclear decay energy, because of their high cross sections to interact with matter, they are important for nuclear dosimetry and a range of applications [1]. In contrast to nuclear radiations, the experimental data on low-energy atomic radiations are scarce, therefore, in most cases, theoretical transition energies and rates are used to evaluate the absorbed energy dose. Unfortunately, the currently available calculations are based on several different physical assumptions and approximations, resulting veryifdferent emission rates [2].
Recently, we have proposed an Auger-cascade model [2, 3] to provide more realistic theoretical descriptions of atomic radiations. The model is based on a full Monte Carlo approach to treat the stochastic nature of the creation of the initial vacancy in the nuclear decay process and the subsequent propagation of vacancies. To achieve reasonable accuracy, a large number of decays need to be calculated. While for a simple system, like 40K, it takes less than 30 minutes to simulate 1 M events, the same calculation for 99mTc could take more than 24 hours. To reduce the CPU time drastically we are developing a new data base, which will contain pre-calculated atomic radiation spectra for Z=6 to 100 systems, allowing quick (< 1 s) evaluation of the full energy spectrum.
In this talk we will review the recent progress in the development of the Auger-cascade model and its application for basic nuclear science [4], and the development of a data base of nuclear and atomic radiations of medical isotopes in the framework of the IAEA Coordinated Research Project [1]. The new atomic radiation data base will also allow the inclusion of the mean energy and intensity of the various X-ray and Auger-electron groups into ENSDF (Evaluated Nuclear Structure Data File).

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S077 New cross sections for the nat-Al(p,x)7-Be nuclear process: monitoring proton beam energy via the 22-Na/7-Be cross-section ratio between 45 and 200 MeV

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Two proton-induced nuclear processes on natural Al, ^{nat}Al(p,X)^{22}Na and ^{nat}Al(p,X)^{24}Na, not only have well-measured cross-section databases (<100 MeV) but the activities of their products (^{22}Na: $T_{1/2}$ = 2.6027 a, E_γ = 1274.54 keV; ^{24}Na: $T_{1/2}$ = 14.997 h, E_γ = 1368.63 and 2754.01 keV) are well established for monitoring purposes via off-line γ-ray spectrometry. Additionally, since both radioisotopes are formed simultaneously above effective thresholds near 30 MeV, and the ^{22}Na/^{24}Na cross-section ratio has a unique functional relationship with proton energy, this ratio can be conveniently used to determine the proton beam energy. These processes therefore are frequently employed in different laboratories.
In our experiments we have often used Al as target backings, separation foils and/or dedicated monitor foils, utilizing the produced ^{22}Na and ^{24}Na activities for monitoring purposes. In some cases, however, the extracted ^{22}Na/^{24}Na cross-section ratios obtained in different experiments showed clear deviations in common (i.e. overlapping) energy regions. This can be attributed to the formation of ^{22}Na and ^{24}Na via activation by secondary neutrons, mainly via the ^{nat}Al(n,α2n)^{22}Na and ^{nat}Al(n,α)^{24}Na reactions. These neutrons originate from all materials in the experimental set-up that intercept the beam, e.g. the collimators, target foils, etc.
It was found, however, that besides the above-mentioned Na radioisotopes, ^{7}Be ($T_{1/2}$ = 53.22 d) was also present in the activated samples above 40 MeV. Since it has a conveniently measurable gamma-ray at 477.60 keV (I_g =10.44%) and has a half-life closer to ^{22}Na (than that of ^{24}Na), its activity can be measured during the same counting session as the ^{22}Na. Compared to the ^{22}Na/^{24}Na cross-section ratios, the ^{22}Na/^{7}Be ratios show better agreement in the overlapping energy regions. Consequently, it is concluded that the ^{22}Na/^{7}Be ratio is superior as an energy monitor for proton beams above about 45 MeV.
In this work, we present cross-section data for the ^{nat}Al(p,X)^{7}Be process that have not hitherto been reported. In addition, ^{22}Na/^{7}Be cross-section ratios are presented in the energy region 40−200 MeV. In this region it exhibits a monotonically decreasing trend with increasing energy and a range spanned by a factor of about 20, making it a sensitive monitor of the proton energy.

I078 Nuclear data for medical applications: an overview of present status and future needs

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Medically-oriented nuclear data research has the basic aim to provide fundamental high-quality database for external radiation therapy as well as for internal radionuclide applications. External radiation therapy is commonly carried out using γ-rays from a 60Co source or harder photons from a linear accelerator. Another modality was fast neutron therapy. However, due to its unspecific nature, in recent years it has been mostly abandoned. A newer fast developing modality involves the use of 70 to 250 MeV protons, or in some special cases, heavy-ion beams. In this presentation a brief overview of the radiation-therapy related nuclear data needs is given.
With regard to internal radionuclide applications, the major deciding factors are the suitability of the emitted radiation for organ imaging from outside the body and the dose it causes to the patient. Diagnosis is routinely performed using emission tomography, i.e. Single Photon Emission Computed Tomography (SPECT) or Positron Emission Tomography (PET). The radionuclides needed for those studies are short-lived single γ-ray emitters (e.g. 99mTc, 123I, 201Tl, etc.) and positron emitters (such as 11C, 18F, etc.), respectively. In contrast, internal radionuclide therapy is a developing area and it entails use of longer lived radionuclides emitting low-range but highly ionising radiation (e.g. 90Y, 103Pd, 125I, etc.). The importance of nuclear data in the choice of a radionuclide for a particular application as well as for its production in a highly pure form is discussed. The status of the decay and production data of the commonly used radionuclides is briefly mentioned. Nuclear model calculations performed to reproduce the experimental data are outlined.
The radionuclide production technology is well established, both at reactors and accelerators. Yet there are some areas where novel radionuclides are needed. Their development demands interdisciplinary work, involving nuclear data measurements, target development for irradiations, devising chemical separation schemes to obtain high purity products, and finally elaborating quality assurance tests for human use. The emphasis in this presentation is on nuclear data studies, with particular reference to development of cyclotron production methods of non-standard positron emitters like 64Cu, 86Y and 124I; low-energy β- emitters like 67Cu and 186Re; Auger electron emitters like 193mPt and 195mPt; and the α-emitter 225Ac. Whereas many of those radionuclides can be produced using a commonly available medical cyclotron (with E ≈ 18 MeV), or a medium sized cyclotron (E ≤ 30 MeV), for obtaining some radionuclides an intermediate energy proton accelerator (with Ep up to 150 MeV) is required. Furthermore, for producing some low-lying high-spin isomeric states, which release an avalanche of Auger electrons in their decay, an α-particle beam appears to be very advantageous.
Research work related to internal radionuclide applications has made considerable progress in recent years. In particular the significance of metallic radionuclides in medical research has been increasing. Some special demands regarding the quality of a desired metallic radionuclide are outlined and the role of nuclear data in meeting those demands is discussed. Furthermore, the prospects of combining PET with MRI (Magnetic Resonance Imaging) for enhanced quality imaging, and of radioactivity with nanotechnology for effective internal radiotherapy, are mentioned. The emerging demands for nuclear data are briefly enumerated.

R079 Decay data evaluation project: evaluation of 52Mn and 52mMn nuclear decay data

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In the frame of the Decay Data Evaluation Project (DDEP) international collaboration (http://www.nucleide.org/DDEP.htm) and the IAEA Coordinated Research Project code F41029, "Nuclear data for Charged-particle monitor reactions and medical isotope production" (2012-2016), the nuclear decay data for the decay chain ^{52}Fe-^{52,52m}Mn-^{52}Cr were evaluated at IFIN-HH, Romania. ^{52}Fe and its daughter ^{52}Mn are two promising radionuclides for nuclear medicine as they can be used to produce radiopharmaceuticals for PET and SPECT imaging, in particular for PET bone marrow imaging. The results for ^{52}Fe (half-life ($T_{1/2}$) of 8.273 (8) hours) were previously reported at IAEA and will be published in the journal Appl. Radiat. Isot., doi:10.1016/j.apradiso.2015.11.098. ^{52}Mn (ground state, $T_{1/2}$ =5.591 (3) days) decays 100% by electron capture/positron emission transitions (EC/beta plus). ^{52m}Mn (isomeric state, with an excitation energy of 377.749 (5) keV and half-life of 21.1 (2) minutes) decays by EC/beta plus transitions and by a small (but important) branch, consisting in the gamma-ray isomeric transition of 377.748 (5) keV (1.64 (4) %). This paper presents the first DDEP evaluation of the nuclear decay data for ^{52}Mn and ^{52m}Mn using the DDEP procedures and tools, including computer codes available from BNL/NNDC (USA) and IAEA. The main nuclear decay data evaluated were: the half-life $T_{1/2}$, the decay energy Q, the energies and probabilities of the electron capture and β+ transitions, the internal conversion coefficients and the gamma-ray energies and emission intensities; some important atomic data were also evaluated: energies and emission intensities of the Cr X-rays (K and L components) and fluorescence yields. The cut-off date of the references used for the evaluations was 2015, October 31st. The improved recommended decay data sets obtained will be reported to the IAEA and will be very useful, especially in nuclear medicine for dose rate computations, but also in other applications of nuclear science and technology.

I080 Dynamical approach to low-energy nuclear fission in terms of Langevin equation

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Nuclear fission is the most basic phenomenon in many application of nuclear technology. The nuclear fission, on the other hand, continues to be an interesting subject for basic research point of views. It is interesting since it involves large-scale collective motion leading to violent rearrangement of nucleons, exhibiting quantum nature (shell effects) in low-energy region. Furthermore, there are many observables associated with fission; excitation function, angular distribution of fission fragments, mass and charge (or isotopic) distribution of fission fragments and their kinetic energies, pre- and post-fission particle emissions, and so on. All these observables are correlated to each other, and hence should be considered or treated in a consistent manner. It will require a deep understanding of nuclear fission.

We treat the nuclear fission as a fluctuation-dissipation process, and describe the fission in terms of multi-dimensional Langevin equation. So far, we have been using 3 collective coordinates, the elongation, fragment deformation and mass asymmetry. The potential energy surface is calculated by the liquid-drop model plus Strutinski's prescription by using the two-center shell model parametrization of nuclear shape. The transport coefficients are calculated by macroscopic method, namely, Werner-Wheeler method for the inertial tensor, and wall-and-window formula for the friction tensor.

In the present work, we will describe the current improvements of our method. Firstly, we have introduced a linear response theory with locally-harmonic approximation to calculate the transport coefficients in a microscopic way. In this manner, effects of the shell and pairing interaction to the transport coefficients are included, and dependence of the results on nuclear temperature will be shown. Next, we will extend the 3-dimensional calculation to a 4-dimensional one. Here, we will set the deformation of the 2 fragments as independent variables. It will make the potential energy surface to more realistic, and excitation energy of the each fragment due to deformation can be calculated independently, which will lead to accurate prediction of the number of prompt neutrons.

R081 High-fidelity evaluation of the 235U prompt fission neutron spectrum including new experimental and improved model information

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Reliable evaluated data of the prompt fission neutron spectrum (PFNS) of ^{235}U and associated covariances are of high interest for nuclear data application areas such as reactor physics and global security. They are studied within the international "Neutron Cross-section Standards and References" and "CIELO" high-fidelity evaluation projects. The resulting evaluated data will feed back into upcoming national nuclear data libraries such as ENDF/B-VIII.0 in the U.S.

Here, we present an evaluation of the ^{235}U PFNS and associated covariances for incident neutron energies from thermal to 20 MeV. To this end, experimental data were carefully analyzed and associated covariances were estimated in detail. Also, new experimental information of currently ongoing measurements (e.g., of the Chi-Nu project of LANL/LLNL) will be included in this evaluation, once it is available. The incident energy dependence of the PFNS was modeled carefully by including an extended Los Alamos model for compound nucleus neutron evaporation processes and the exciton model for pre-equilibrium neutron emission processes. Also, the incident energy dependence and uncertainties of model parameters were assessed in detail and included in this evaluation. The obtained evaluated results are compared to experimental data and selected evaluations. First benchmark calculations using these data are discussed as well."

R082 Fission fragment total kinetic energy and mass yields for neutron-induced fission of 235-Uranium and 238-Uranium with En = 200 keV - 30 MeV

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Understanding neutron-induced fission of major actinides is vital for advancing fission theory as well as modeling and simulations of energy and defense applications. Key nuclear data of interest include the average Total Kinetic Energy (TKE) release and mass distributions of fission fragments. Previous measurements of average TKE from neutron-induced fission of 235U and 238U were largely restricted to incident neutron energies below 9 MeV. Mass yields were available only in the thermal, fission neutron, and 14 MeV range for 235U and few measurements existed for 238U. This work examined the excitation energy dependence of fission fragment properties, using a neutron spectrum covering from several hundred keV to 100 MeV at the Los Alamos Neutron Science Center (LANSCE) - Weapons Neutron Research (WNR) facility. A twin Frisch-gridded ionization chamber and digital data acquisition system were used to measure TKE for both 235U and 238U(n,f) reactions. The results of the TKE and yield distributions, from En = 200 keV – 30 MeV (for 235U) and En = 1.3 – 30 MeV (for 238U) will be presented. The resulting structure in the neutron-energy dependent average TKE at multi-chance fission thresholds and the ratio of the symmetric to asymmetric mass yield components as a function of incident neutron energy will be discussed. LA-UR-16-20199

R083 Neutron-induced fission cross-section measurement of 234U with (quasi-) monoenergetic beams in the keV and MeV range using Micromegas detectors

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Accurate data on neutron-induced fission cross-sections of actinides are essential for the design of advanced nuclear reactors based either on fast neutron spectra or alternative fuel cycles, as well as for the reduction of safety margins of existing and future conventional facilities. The fission cross-section of ^{234}U was measured at incident neutron energies between 300 and 500 keV and 4 and 10 MeV with a setup based on “microbulk” Micromegas detectors and the same samples previously used for the measurement performed at the CERN n_TOF facility (Karadimos et al., 2014). The standard ^{235,238}U fission cross-sections were used as reference. The (quasi-)monoenergetic neutron beams were produced via the ^{7}Li(p,n) and the ^{2}H(d,n) reactions at the neutron beam facility of the Institute of Nuclear and Particle Physics at the “Demokritos” National Centre for Scientific Research. An exhaustive study of the neutron spectra produced in the targets and intercepted by the samples was performed coupling the NeuSDesc and MCNP codes, taking into account the energy spread, energy loss and angular straggling of the beam ions in the target assemblies, as well as contributions from competing reactions (e.g. deuteron break-up) and neutron scattering in the detector chamber and surrounding material. Auxiliary Monte-Carlo simulations were performed with the FLUKA code to study the behaviour of the detectors, focusing particularly on the reproduction of the pulse height spectra of α-particles and fission fragments (using distributions produced with the GEF code) for the evaluation of the detector efficiency. The developed methodology and preliminary results are presented.

S084 Measurement of selected IRDFF materials cross section in 235U and 252Cf fission spectra

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An ongoing process of evaluation, reevaluation and measurement of selected dosimetry cross sections is covered by the Nuclear Data Section of IAEA. Many reactions in the International Reactor Dosimetry and Fusion File (IRDFF library) were already evaluated, but substantial portion of them have not been validated yet. One of the mentioned is 23Na(n,2n) reaction. As essential cross section data have been obtained by direct measurement, therefore there is considerable interest in irradiation experiments on available neutron fields. The LR-0 is multipurpose experimental reactor operated by Research Center Rez. It is commonly known for VVER-1000 mock up used for reactor dosimetry experiments. But there can be also assembled specials cores for other types of experiments, like those intended for study of neutronic parameters of new reactor systems coolants or measurement of spatial distribution of fission density in special arrangements. These special arrangements have also advantage, that there are well defined neutron spectra, which are in higher energies identical with 235U fission spectra. Well defined neutron spectrum can also obtain from 252Cf neutron source which is available at Research Center Rez (neutron emission 1E9 n/s). IRDF community has a strong interest in the implementation of radiation experiments to obtain spectrum average cross section in Cf-252(s.f.) and U-235 (nth, f) fields of (n,2n) reaction on 23Na. Both available neutron fields have been used for determination of spectral average 23Na(n,2n) cross-section. The influence of different shape of 235U and 252Cf fission spectra can be observed in comparison of cross section averaged over the (n,2n) threshold to 20 MeV. The presented neutron cross section of 23Na(n,2n) reaction in both reactor and 252Cf spectrum is derived from the experimentally determined reaction rates. Those are derived from Net Peak Areas (NPA) measured using the semiconductor HPGe spectroscopy. 22Na can origin not only by (n,2n) reaction but also by (γ,n) reaction. The gamma background is more significant in the reactor spectrum. It was proven that in the reactor the (γ,n) reaction does not contribute to 22Na production rate because this reaction has threshold higher than the most upper part of the photon spectrum in core. The correction to spectral shift caused by relatively thick target is also employed and is evaluated by means of calculation. The experimental reaction rates are compared with reaction rates calculated using various nuclear data library.

S085 Fission yields data generation and benchmarks for decay heat estimation of a nuclear fuel

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Nuclear fission yields data are indispensable in assessments of decay heats and nuclear material compositions of spent fuels. Fukushima nuclear accident clearly shows that the most important first step should be an accurate appraisal of the source terms of radioactivities and decay heats from radioactive materials in spent fuels. The primary datasets for accurate assessments of the source terms are the fission product yields and nuclear structure/decay datasets. Decay modes of very short-lived ($T_{1/2}$ < 1,000 sec) nuclides among fission products need to be re-evaluated with new experimental data.
The fission yields data with ENDF-6 format of ^{235}U, ^{238}U, ^{239}Pu and several actinides dependent on incident neutron energies have been generated with GEF code, which is implemented with recent theoretical model for evaluation of fission yields data. Also, fission yields data libraries of ORIGEN-S, -ARP modules in SCALE code, which is world-widely used for burnup calculation of nuclear fuel, have been developed with the new data. The calculated results using the new fission yields data have been compared with the measured data for validation in this study. With analysis of fission product yields data in ORIGEN-S, -ARP modules of SCALE code, the fission yields data libraries based on ENDF/B-VII.1, JEFF-3.1.1, JENDL/FPY-2011 and JENDL-4.0 have been generated for comparisons and validations.

S086 Validating nuclear fission codes with integral nuclear observables

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Several reaction codes are available for the calculation of fission observables (notable examples are CGMF, FIFRELIN, Freya and GEF). In the latest years, their importance has increased both as a way to assist experimental nuclear physicists in data analysis and in the interpretation of their results. The codes are also useful in nuclear applications to provide quantities that are not directly available as evaluated data. Assumptions in the models and tuning of parameters behind the codes provide, in many cases, a good reproduction of experimental data. However, from the user's point of view, it is often difficult to establish the trustworthiness of a code's output in cases where measured nuclear data are scarce,that is, when the calculations would be mostly interesting.

In this work, a systematic and reproducible approach was attempted to compare some of the well known available fission codes in order to obtain information on where and how these codes differ in, e.g., the treatment of excitation energy of the fragments. This was carried out by calculating some basic information on the fission fragments (pre-neutron emission yields, excitation energies, spin distributions, etc.), before corrections could be applied in the codes to fit the results to experimental data.

The fragments in their excited states were then coupled to Talys, a well-known and widely tested nuclear reaction program, to calculated the fragments de-excitation and to extract measurable quantities (such as total ν, ν(A), but also ground/isomeric-yield distributions, etc.) that could be compared with generally well-known experimental observables. The method we propose provides a way to benchmark different codes against each-other and with data, in terms of the fission fragments observables right after scission, by handling the de-excitation process in an independent and consistent fashion, using the Hauser-Feshbach model built into Talys.

First results of this study show significant discrepancies of integral nuclear observables (such as the ν (A) distribution) both between codes and in the comparison with experimental data. Ongoing work is focusing on trying to identify the source of these discrepancies, either in the fission codes (that could shed light on the different approaches that the various codes use in assigning the fission fragments excitation energies) or in the subsequent treatment with Talys.

S087 Monte Carlo calculations of nucleon-induced fission in the GeV energy range

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In the present work we extend up to an incident energy of 5 GeV the Monte Carlo calculations of nucleon-induced fission on actinides and pre-actinides from 100 MeV to 1 GeV described in a recent paper of ours[1]. Use is made of Version 5.2 of the Liège Intranuclear Cascade Model INCL++[2] , including multiple pion production as described in Ref.[3], and of different evaporation-fission models. Our calculated (p,f) cross sections are compared with available experimental data in the energy range from 100 MeV to 5 GeV; the same model parameters are used to predict (n,f) cross sections, which compare reasonably well with experimental data present in the literature.

[1] S. Lo Meo, D. Mancusi, C. Massimi, G. Vannini and A. Ventura, Nucl. Phys.A 933 (2015) 43.; [2] D. Mancusi, A. Boudard, J. Cugnon, J.-C. David, P. Kaitaniemi and S.Leray, Phys. Rev. C 90 (2014) 054602.; [3] S. Pedoux and J. Cugnon, Nucl. Phys. A 866 (2011) 16.

S088 Dissipative effects in fission investigated in complete kinematic measurements

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A complete description of the fission process still represents a challenge, despite the recent progress based on time-dependent Hartree-Fock models [1]. Statistical models provide a tool to describe fission probabilities at excitation energies around the fission barrier. This approach is justified because, under such conditions, statistical times dominate over the typical timescales for the coupling between intrinsic and collective degrees of freedom (~10-21s). At high excitation energies, pre- and postscission particle emission and fission probabilities [2,3] indicate that simple statistical approaches are not valid and models, describing the dynamics of the process, are required. These models are based on transport equations, e.g. Fokker-Planck or Langevin, where the main ingredients are the potential landscape and the friction and inertia tensors [4]. The friction parameter is particularly interesting because it quantifies the magnitude of the coupling between collective and intrinsic degrees of freedom in fission.
In this work, we propose to investigate these effects by taking advantage of proton-induced fission reactions at relativistic energies for producing highly-excited fissioning nuclei with low angular momentum, where dissipative effects should manifest in a clear way. The SOFIA setup together with the inverse kinematics technique were used for the first time to measure in coincidence the mass and atomic number of the two fission fragments with good resolution [5]. These high-quality data allowed us to obtain new observables in fission. In particular, total and partial fission cross sections and the charge distribution of the fission fragments will be used to characterize the fission dynamics at small deformation [6]. Moreover, we will also present the results concerning the neutron excess, the isotopic widths of the fission fragments, and the average pre- and postneutron multiplicities, which should help us to investigate the postsaddle dynamics.

[1] G. Scamps et al., Phys. Rev. C 91, 044606 (2015); [2] J.P. Lestone et al., Phys. Rev. C 79, 044611 (2009); [3] J. Benlliure et al., Phys. Rev. C 74, 014609 (2008); [4] P.N. Nadtochy et al., Phys. Rev. C 65, 064615 (2002); [5] J.L. Rodríguez-Sánchez et al., Phys. Rev. C 91, 064616 (2015); [6] J.L. Rodríguez-Sánchez et al., Phys. Rev. C 92, 044612 (2015)

I089 Point-by-point model calculation of the prompt neutron distribution ν(A) for 238U(n,F) at incident neutron energies ranging from 1 MeV to 80 MeV

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The prompt emission in fission is responsible for an intrinsic even-odd effect. Consequently the total *Z* and *N* even-odd effect in different prompt emission quantities is the result of two contributions: the intrinsic effect due to the even-odd nuclear character of fragments reflected in their properties (and consequently in the emitted prompt neutrons and gamma-rays) and the even-odd effect caused by the fragment distributions.
The primary result of prompt emission calculations consists in multi-parametric matrices of different quantities, *q(A,Z,TKE)*, characterizing both the fragments and the prompt emission. Different average quantities (as a function of *A*, of *Z*, of *TKE* and total average quantities) are obtained by averaging these matrices in different ways over the *Y(A,Z,TKE)* distributions. Consequently the even-odd effect in different average quantities is the combined result of two effects, one due to the nuclear properties of fragments and the other one due to the fragment distributions.
The charge polarization *ΔZ(A)* (and the *rms(A)* of the Gaussian functions fitted to the isobaric charge distributions) exhibit oscillations with a periodicity of about 5 mass units. The amplitude of these oscillations reflects the magnitude of the even-odd effect (zero amplitudes meaning no oscillations, i.e. no even-odd effect).
Different quantities as a function of *A*, e.g. the energy release *Q(A)*, the total excitation energy *TXE(A)*, the prompt neutron multiplicity *ν(A)*, of even-*Z* and odd-*Z* fragmentations exhibit oscillations with a periodicity of about 5 mass units. We demonstrate that these oscillations are the consequence of the periodicity of nuclear properties of fragments, being independent of the existence of even-odd effects in the fragment distributions. In the case of *Q* this fact is also proven experimentally.
The intrinsic even-odd effect of the prompt emission is emphasized by comparing the global even-odd effects in different total average quantities by using distributions with and without even-odd effects and by the very weak variation of these global even-odd effects with incident neutron energy (ranging from 0.2 MeV to 5 MeV in the case of ^{234}U(n,f)), knowing that the *Z* even-odd effect in fragment distributions visibly decreases with increasing incident neutron energy.

R090 Fission fragment deexcitation study by gamma-ray spectrometry with the EXILL experiment

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Nuclear fission is a complex process, still not yet well described by microscopic models, and its main observables are difficult to measure with accuracy. Following the capture of a thermal neutron the compound nucleus fissions in two fragments. Most of the energy of the process is transferred in kinetic energy, whereas the nuclei are let in few tens of MeV excited states. This excitation energy is then released, the majority of it within less than some nanoseconds, by the evaporation of a few neutrons and the emission of -rays in cascade.
To overcome the low accuracy of microscopic models in the prediction of fission observables, nuclear technology relies on libraries of evaluated data and semi-empirical models, like the GEF model for fission yield evaluations. Such a strategy requests systematic and accurate experimental data on the few possible observables. Here we will present the advantages of studying yields of fragment correlated pairs and their de-excitations using an array of high-resolution -ray detectors directly placed around an actinide target irradiated by a thermal or cold neutron beam. Such a setup was installed at ILL in 2012 and 2013 (EXILL) and campaigns were performed with ^{235}U and ^{241}Pu targets. This study is largely motivated by the future installation of a permanent -ray detector array at the ILL, which will be coupled to fission fragment detectors in a first construction phase and a fragment separator in a second phase (FIPPS).
An important outcome of EXILL data is the observation of the -ray cascade occurring in both fission fragments with an unambiguous determination of the fragments. The cascade is directly linked with the angular momentum of the fragments after scission, which is one of the less precise and less understood properties. With the development of new simulation codes for the neutron evaporation and the -ray cascade like FIFRELIN or KEWPIE, systematic studies and comparisons with the large amount of experimental data resulting from double and triple gamma-ray coincidence analysis become possible. Preliminary results on the gamma–ray cascades measured in the well produced Kr and Ba fragments and comparisons with FIFRELIN simulations will be presented.

R091 Monte Carlo simulation of gamma and fission transfer reactions using extended R-matrix theory: application to U-237* system

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The idea to supplement neutron-induced fission cross-section database with particle-transfer-induced reactions has been raised a long time ago. Analytical simulations of these measured direct-reaction induced fission probabilities were performed under several simplifications from which is stated the Weisskopf-Ewing (WE) frame of Hauser-Feshbach theory. Major limitations in surrogate data conversion were promptly noticed with the difficulty to estimate compound nucleus formation cross section, possible differences of angular momentum distribution between neutron capture and direct reactions and the assumption of fission decay probability spin-parity independence. Referring to the WE frame was justified in the seventies because of computer restrictions, lack of precise information on nuclear level densities across deformation and difficulties for achieving confident optical model calculations over a large range of nuclides. Nowadays the bulk of those approximations can be left aside even if difficulties remain. A recent *R*-matrix analysis [PRC.88.054612 (2013)] of low-energy neutron-induced fission cross sections over the whole Pu isotope family has enlightened the actual possibility to carry extended *R*-matrix fission barrier calculations accurate enough to make predictions of neutron-induced cross sections for the family isotopes for which no neutron spectroscopy measurements exist. This conference presentation is willing to show how well extended *R*-matrix fits low nuclear excitation energy (from 4 to S_n+2 *MeV*) fission decay probabilities without referring to WE. Fission decay probability analyses were essential in the determination of neutron sub-threshold double fission barrier heights for fissile target isotopes of the Pu family. The second part of the presentation will indeed focus on the U-237* system for which high-quality decay probabilities have been recently measured (DOI: 10.1051/epjconf/34201003), offering the opportunity to validate our model against simultaneously fission and gamma experimental decay probabilities. The final good agreement opens a new era for neutron cross section evaluation of heavy isotopes on the ground of combined experimental cross section and decay probability databases.

R092 Studies on fission with Aladin: precise measurement of 236U isotopic yields in inverse kinematics

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The SOFIA (Studies On Fission with Aladin) experiment is a novel technique for fission studies, based on the inverse kinematics approach at relativistic energies. Following pioneering work in the nineties, the SOFIA collaboration has designed and built an experimental set-up dedicated to the simultaneous measurement of isotopic yields, total kinetic energies and total prompt neutron multiplicities, by fully identifying both fission fragments in coincidence, for the very first time. This experiment, performed at GSI, permits to study low-energy fission of a wide variety of fissioning systems, and to reach unprecedented uncertainty on the fission yields, thus providing very good quality data for the applications.
A first experiment, performed in 2012, successfully measured, among others, fission yields of ^{234,235,238}U. In 2014 a second measurement was performed with an upgraded set-up in order to obtain high statistics data for the low-energy fission of ^{236}U, a reaction of great interest for the nuclear data community, but for which uncertainties on evaluated isotopic yields remain mainly above 30%.
Results from this recent experiment will be presented, including nuclear charge yields as well as isotopic yields and total neutron multiplicities.

R093 Measurement of the 240pu(n,f) cross-section at the cern n_TOF facility: first results from experimental area ii (ear-2)

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The accurate knowledge of the neutron-induced fission cross-sections of actinides and other isotopes involved in the nuclear fuel cycle are essential for the design of advanced nuclear systems, such as Generation-IV nuclear reactors. These experimental data can also provide feedback for the adjustment of nuclear model parameters used in the evaluation process, resulting in further developments of nuclear fission models.
In the present work, the ^{240}Pu(n,f) cross-section was measured at CERN's n_TOF facility over a wide range of neutron energies, from a few meV to several MeV, using the time-of-flight technique and a set-up based on MicroMegas detectors. This measurement was the first experiment to be performed in n_TOF's new experimental area (EAR-2), which offers a significantly higher neutron flux compared to the existing experimental area.
Preliminary results as well as the experimental procedure, including a description of the facility, the sample mounting, the readout process and the data handling and analysis, are presented.

I094 Criticality data testing of collaborative international evaluated library organization evaluated nuclear data files

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The Collaborative International Evaluated Library Organization (CIELO) Pilot Project is a Working Party for Evaluation Cooperation (WPEC) Sub-Group whose goal is to develop new evaluated nuclear data files for ^{1}H, ^{16}O, ^{56}Fe, ^{235,238}U and ^{239}Pu that represent a fundamental improvement over those available in existing regional evaluated nuclear data libraries (e.g., ENDF/B, JEFF, JENDL).
Candidate CIELO files were downloaded from https://www-nds.iaea.org/CIELO/ and were processed with NJOY2012 to produce MCNP "ACE" files. Eigenvalues from MCNP models for a suite of International Criticality Safety Benchmark Evaluation Project (ICSBEP) benchmarks were calculated. We assess the accuracy of candidate CIELO files by looking for the presence (or absence) of biases and trends in calculated eigenvalues versus various benchmark parameters. In the simplest case we perform a linear regression analysis of k_{eff} C/E versus a specific parameter with the expectation that the intercept term will be unity and the slope term will be zero (to within statistical 95% confidence intervals). Deviation from either condition indicates a deficiency in the underlying nuclear data (most likely) or in the underlying MCNP models (also possible but unlikely when the test suite includes benchmarks from various laboratories worldwide).
Categories of ICSBEP benchmarks tested include (i) bare, unmoderated HEU and Pu (i.e., LANL's Godiva and Jezebel) assemblies; (ii) unmoderated but reflected uranium and Pu (i.e., LANL Flattop and Big-10) assemblies; (iii) HEU thermal solution assemblies; (iv) Pu thermal solution assemblies; (v) LEU lattice assemblies with varying H/U (i.e., varying rod pitch), and (vi) critical benchmark assemblies with ^{depl}U or steel (i.e., primarily iron) reflectors. Comparison of calculated eigenvalues from the CIELO files versus those obtained with ENDF/B-VII.1 nuclear data suggest improved criticality predictions are often obtained but additional work in needed. For example, the tendency toward softer prompt fission neutron spectra (pfns) in the new actinide files has a large impact on calculated thermal solution assembly reactivity. Calculated eigenvalues for these assemblies are generally quite accurate with existing nuclear data. As such these pfns revisions may be eliminating part of a compensating error while the remaining error is yet to be identified.

R095 Neutron cross sections for carbon and oxygen from new R-matrix analyses of the 13,14C and 17O systems

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We report the latest results from *R*-matrix analyses of reactions in the ^{13,14}C and ^{17}O systems that are of interest in reactor applications and nuclear astrophysics. These were done in order to provide separate cross sections for the stable isotopes (^{12,13}C) of natural carbon, and to contribute improved cross sections for ^{16}O to the CIELO project. The ^{13}C system analysis included reactions among the channels n+^{12}C, n+^{12}C*, and γ+^{13}C, while the ^{14}C system analysis included only n+^{13}C elastic scattering. The ^{17}O system analysis included reactions among the channels n+^{16}O, α+^{13}C, and γ+^{17}O. Particular attention was paid to the data in the standards region (< ~2 MeV) for the carbon isotopes, and to the low-energy region for n+^{16}O. However, the analyses extend to several MeV neutron energy for all the systems. The types of data used are mostly differential and integrated (total) cross sections, but some analyzing-power measurements are also included. The fits to the data are generally quite good, and have the following characteristics: The cross sections for ^{12,13}C give results for natural carbon that are very close to the previous evaluation by Fu *et al.* in the standards range. Above 2 MeV, the deviations become larger, especially near the narrow resonances. The thermal cross section for ^{16}O is at the upper end of the range of recommended values, in excellent agreement with a high-precision measurement by Schneider. At higher energies, the ^{17}O analysis follows in great detail the total cross section measurements of Ohkubo, Johnson, Fowler, and Cierjacks with reasonable re-normalizations. It also agrees quite well with the ^{13}C(α,n)^{16}O cross section measurement of Bair and Haas at roughly their original normalization scale, a consequence of the unitarity imposed by an *R*-matrix description. We will discuss how these results differ from those of other analyses, and what the implications are for various applications, including nuclear astrophysics.

R096 Status of CIELO evaluation for iron

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Iron is one of the five materials selected to be evaluated within the pilot international evaluation project CIELO. Among these five, all of primary importance for applications, iron is the only structural material. It has been chosen since it is a component appearing in consistent quantities in many nuclear systems. From the neutronics point of view the most important are scattering properties of iron and therefore the new CIELO evaluation puts emphasis on elastic angular distributions and inelastic scattering. Three major isotopes of iron ^{54}Fe, ^{56}Fe, and ^{57}Fe were evaluated. In the case of ^{56}Fe the file is composed of the resolved resonance range evaluated initially at ORNL and continued at IRSN and the fast neutron range, which has been produced by BNL-IAEA collaboration using the EMPIRE code. EMPIRE has been upgraded to address specific requirements of the iron evaluation. In particular, explicit l-j coupling has been implemented to produce angular distributions, and width fluctuation correction has been updated with Kawano expression for number of degrees of freedom. New implementation of coupled-channel calculations and coding of Engelbrecht-Weidenmueller transformation are beeing advanced. Analysis of the vast amount of data which were used to constrain EMPIRE calculations had been performed by CNDC. BNL, IAEA, and RPI contributed validation of the new file. In the present contribution we shall focus on the evaluation procedure in the fast neutron region, file assembly, and testing. If possible, first results of the combined validation, involving other CIELO materials will also be presented.

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R097 The evaluation of experimental data in the fast range for n+56Fe

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Iron is one of the five materials selected for evaluation within the pilot international evaluation project CIELO. Critical analysis of experimental data for n+56Fe is the bases for constraining theoretical calculations and eventual creation of the evaluated file. The analysis was performed for all cross sections of neutron induced reactions with 56Fe in the fast range up to 20MeV. In particular, more detail analysis was performed for inelastic scattering cross section where there are significant differences among the main evaluated libraries, mainly caused by using different experimental data. Gamma-ray production cross sections provide one of the ways to gain experimental information about the inelastic cross section. Large discrepancies between experimental data for the 847-keV gamma ray produced in the 56Fe(n,n1′γ) reaction were analyzed. In addition, experimental data for elastic scattering cross section between 9.41-11MeV were used to deduce the inelastic cross section from the unitarity constrain.

S098 Fast benchmarking of CIELO test files

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The benchmarking of new evaluated data files is a key step in the release process; the provision of benchmarked, validated nuclear data libraries by data centres plays an important role in hastening the adoption of new data by user communities.
This paper will show results from a number of ICSBEP[1] integral benchmarks calculated using the currently available CIELO[2] test files. The benchmark systems will focus on the Fast energy regime and pay particular attention to bare spheres such as JEZEBEL and GODIVA.
K-effectives are calculated and compared to published benchmark values. A number of "goodness of fit" metrics are also calculated to facilitate the comparison of the whole ensemble of results with benchmark results.
As a means of checking the performance of the new CIELO files; calculated k-effectives will be compared to those calculated using a number of available evaluated data libraries such as ENDF/B-VII.1[3].
Calculations will be performed with a proprietary 1D Sn neutron transport code and compared with those performed using LANL's MNCP[4] code.

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S099 Use of integral experiments for the assessment of a new 235U evaluation

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Over the last couple of years, evaluation work has been done to improve data for several isotopes, namely ^{1}H, ^{16}O, ^{56}Fe, $^{235-238}$U, and ^{239}Pu. The Working Party on International Nuclear Data Evaluation Co-operation (WPEC) subgroup 29 (SG 29) was established to investigate an issue with the ^{235}U capture cross-section in the energy range from 0.1 to 2.25 keV, [1] due to a possible overestimation of 10 % or more.
To improve the ^{235}U capture cross-section, a new ^{235}U evaluation has been proposed by the Institut de Radioprotection et de Sûreté Nucléaire (IRSN) and the CEA Bruyères-le-Châtel (BRC). This new evaluation is based on new time-of-flight ^{235}U capture cross-section measurements, done at the Rensselaer Polytechnic Institute (RPI) [2] and at the Los Alamos National Laboratory (LANL). [3] Furthermore, recent fission cross-section measurements have been performed at the n_TOF experiment [4] from CERN. The n_TOF fission measurement was normalized in the [7.8 – 11] eV energy range according to the recommended standard values [5] and used in the re-evaluation process. A set of resonance parameters was derived with the SAMMY code [6] in the energy range from 10^{-5} eV to 2.25 keV. CEA/BRC was responsible for the re-evaluation in the fast energy region.
IRSN has also carried out calculations for testing the new ^{235}U evaluation using benchmarks extracted from the ICSBEP database. The benchmarks have been selected using the DICE database, associated with the ICSBEP Handbook, [7] by privileging the experiments showing small experimental uncertainties and a sensitivity to ^{235}U capture cross-section covering the entire energy range.
The k_{eff} calculations were performed with both the MCNP6 code [8] and the 5.C.1 release [9] of the MORET 5 code, developed at IRSN, using the JEFF3.2 library and the new ^{235}U evaluation. The benchmark selection allowed highlighting a significant effect on k_{eff} due to the new ^{235}U evaluation. The results of this data testing, provided as input for the evaluators, will be presented and discussed in the paper.

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S100 New fit of neutron thermal constants for U-233,235,Pu-239,241 and Cf-252: microscopic vs integral data

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An IAEA project to update the Neutron Standards [1] is on-going. Traditionally, the Thermal Neutron Constants (TNC) for the fissile nuclei and Cf-252(sf) have been evaluated separately and released within the updated standards. The TNC fit goes back to initial IAEA efforts led by Westcott [2,3], and later by Lemmel [4]. Lemmel already pointed out in 1975 an existing discrepancy between results of the fit using microscopic data only, and the overall result that employs both microscopic and integral data, especially for the U-235 thermal constants [4]. A new least-squares fit of the Thermal Neutron Constants using a GMA code is undertaken. Additional experimental data have been compiled that include a recently published direct measurement of the U-235 thermal capture done by the AMS method [5]. This microscopic measurement is shown to have a great impact on fitted results of the U-235 constants. We recommend using the newly derived TNCs that correspond to the use of microscopic data only. We discarded the integral data in the fit to avoid the impact of the prompt fission neutron spectra on fitted results, as Maxwellian fission spectra with an average energy close to 2.03 MeV were used to interpret the bulk of integral data. New TNC are recommended and their impact on selected thermal solutions and fast benchmarks is shown.

[1] A. D. Carlson, V.G. Pronyaev, D.L. Smith, et al., *Nucl. Data Sheets* **110** (2009) 3215.; [2] C. H. Westcott, K. Ekberg, G.C. Hanna, et al., *Atom. Energy Rev.* **3** (1965) 3. Available online as www-nds.iaea.org/publications/indc/indc-iae-asteris k009U .pdf ; [3] G. C. Hanna, C. H. Westcott, H. D. Lemmel, et al., *Atom. Energy Rev.* 7 (1969) 3. Available online as www-nds.iaea.org/publications/indc/ indc-nds-0012.pdf ; [4] H. D. Lemmel, Proc. Conf. on Nuclear Cross Sections and Technology, Washington, D.C., 3-7 March, *NBS Spec. Publ.* **425** (1975) 286.; [5] A. Wallner, T. Belgya, M. Bichler, et al., *Phys. Rev. Lett.* **112** (2014) 192501.

S101 Preparing for ENDF/B-VIII

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Preparing for ENDF/B-VIII: Cross Section Evaluation Working Group
Although the next major release of the ENDF/B library is not due until the 2017-2018 time frame, ENDF/B-VIII is already positioned to become the most important release of the library in some time. ENDF/B-VIII will be built around the Neutron Reaction Standards as well as the ^{1}H, ^{16}O, ^{56}Fe, ^{235}U, ^{238}U and ^{239}Pu evaluations developed as part of the Coordinated International Evaluation Library Organization (CIELO) pilot project. In this talk, we summarize these improvements as well as the many other improvements to ENDF that have already been made or are scheduled to be made in the next year.
Improvements already included in the ENDF/B-VIII beta:

1) Aggressive use of the flexible and physically correct LRF=7 resolved resonance format in 9 evaluations (^{35,37}Cl, ^{56}Fe, ^{63,65}Cu and ^{182,183,184,186}W)
2) Thermal capture gammas from the EGAF project (^{6,7}Li, ^{11}B, ^{19}F, ^{23}Na, ^{27}Al, ^{28}Si, ^{35,37}Cl)
3) Thermal Scattering Law evaluations from NCSU (SiO_2-alpha, SiO_2-beta, CinSiC, SiinSiC, Hin$C_5O_2H_8$ (Lucite)) and from the CAB-AECL collaboration (OinD_2O, DinD_2O, HinH_2O)
4) Many new evaluations in the neutron sublibrary (^{1}n, ^{236m1}Np, ^{40}Ar, ^{58,59,60,61,62,64}Ni, ^{120}Sn, ^{63,65}Cu)
5) Inclusion of Red Cullen's EPICS2014 library, updating the photo-atomic, electron and atomic-relaxation sublibraries
6) Many bug fixes

Improvements planned in the next year

7) Isotopic carbon evaluations (^{12,13}C)
8) Many more new neutron evaluations (^{86}Kr, ^{90,91,92,94,96}Zr)
9) Many charged particle evaluations from LLNL's ECPL
10) Adding anti-neutrino spectra to the decay sublibrary
11) Many more bug fixes

In addition to these major changes, ENDF/B-VIII will be the first official library released simultaneously in the legacy ENDF-6 and the newly developed GND formats.

I102 U-238 evaluation and validation of the neutron induced reactions up to 20 MeV

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Advanced modelling and new measurements of neutron induced reactions on ^{238}U nucleus are aimed at improving our knowledge of the neutron scattering on a nucleus which is critical for fission reactor technology. In the resonance range we rely on the latest evaluation coordinated by IRMM to define a new set of resonance parameters. Capture and fission channels of U-238 in the fast neutron range are well constrained by available experimental data and Neutron Standard evaluation [1]. Therefore, a focus of this evaluation in the fast neutron range is on elastic and inelastic scattering and multiple neutron emission cross sections. New experimental data on multiple neutron emission have been critically reviewed and combined with existing data to provide a constraint on reaction modelling result [2]. The employed nuclear reaction model includes – a dispersive optical model with multiple band coupling; – the Engelbrecht-Weidenmüller transformation allowing for inclusion of compound-direct interference effects; – and a double humped fission barrier with absorption in the secondary well described within the optical model for fission [3,4]. Impact of the advanced modelling on scattering cross sections including angular distribution and emission spectra is being assessed both by comparison with selected microscopic experimental data and integral criticality benchmarks including measured reaction rates, as well as with quasi-differential data measured at RPI [5]. Benchmark calculations provided feedback to improve the reaction modelling. The current status of the U-238 IAEA evaluated file is reviewed and the impact of possible changes in U-235 data will be discussed.

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R103 Evaluation of neutron induced reactions for 238U in the resonance region

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Cross sections for neutron induced reactions on ^{238}U are important for a performance assessment and for safety calculations of present and innovative nuclear reactor systems. Due to the role of these cross sections for nuclear energy and criticality safety applications, ^{238}U is one of the key nuclides of the CIELO (Collaborative International Evaluated Library Organization) project.
Experimental as well as evaluated library data related to neutron induced reaction cross sections for ^{238}U in the resonance region were reviewed. Based on this review a new evaluation was carried out in the resolved and unresolved resonance region. Resonance parameters were derived from a simultaneous analysis of high resolution capture and transmission time-of-flight cross section data. Experimental data available in the literature were included in a least squares analysis using the GMA code to determine a recommended average capture and total cross section for the unresolved resonance region. These cross sections were parameterised in terms of average resonance parameters applying the Hauser-Feshbach theory with width fluctuations. In this analysis consistency with the fast region was ensured by including results of optical model calculations [1] and in-elastic cross section data of Capote et al. [2].
Based on the evaluation results a set of test files was produced to study systematic effects such as the contribution of bound states, the impact of the upper boundary of the resolved resonance region and the representation of the infinitely dilute capture and inelastic cross section in the unresolved resonance region. A set of benchmark experiments was selected and used to verify the test files. Based on these studies recommendations for a new evaluation were defined.

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R104 U-235 Evaluation of the neutron induced reactions up to 20 MeV

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The primary fissile material in commercial reactor systems is ^{235}U. This places a high demand on the accuracy of its nuclear data. Furthermore, the fission cross section at thermal and in the energy range from 0.15 MeV to 200 MeV is a standard. The proposal to adopt the thermal-neutron induced prompt fission spectrum of ^{235}U as a reference spectrum led to an IAEA evaluation effort that resulted in consensus that the average neutron energy is 2.0 MeV, which is lower than the commonly adopted 2.03 MeV. This small change has severe implications on some high-leakage critical solution benchmark assemblies. An extensive search for compensating effects was undertaken. The basic principle was to use the best physics in nuclear model calculations, respect the microscopic experimental data and limit the adjustments only to parameters that are poorly known. In addition to the prompt fission spectrum, a new simultaneous evaluation of the thermal constants for the "Standards" was recently undertaken, and updated values were used to refine the resolved resonance evaluation. Above the resonance range a new dispersive coupled-channel optical model and a triple-humped fission barrier were employed to update the fast neutron cross sections. A good fit of the standard fission cross section was obtained, which is extremely important for the correct prediction of the competing channels. The focus of the evaluation was in the energy region below 20 MeV, but extension to higher energies is foreseen. The evaluation is being extensively tested in a large number of criticality benchmarks from the Handbook of International Criticality Safety Benchmark Experiments. Compensating effects with other nuclides are investigated in parallel. Current performance of the evaluation is comparable to the ENDF/B-VII.1 library, with the goal to achieve significantly enhanced performance without compromising the consistency with measured microscopic data.

R105 Re-evaluation of the 235U resonance parameters to fit the standard recommended values

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Recently a great deal of effort has been dedicated to the revision of the standard values in connection with the neutron interaction for some actinides. While standard data compilation are available for decades nuclear data evaluations included in existing nuclear data libraries (ENDF, JEFF, JENDL, etc.) do not follow the standard recommended values. Indeed, the majority of evaluations for major actinides do not conform to the standards whatsoever. In Particular, for the n + ^{235}U interaction the only value in compliance with the standard is the thermal fission cross section.
A resonance re-evaluation of the n + ^{235}U interaction has been carried to address the issues regarding the standard values in the energy range from 10^{-5} eV to 2250 eV. Recently, ^{235}U fission cross-section measurements have been performed at the CERN Neutron Time-of-Flight facility, known as N_TOF, in the energy range from 0.7 eV to 10 keV. The data were normalized according to the recommended standard of the fission integral in the energy range 7.8 eV to 11 eV. As a result, the N_TOF averaged fission cross sections above 100 eV are in good agreement with the standard recommended values. The N_TOF data were included in the ^{235}U resonance analysis that was performed with the code SAMMY. In addition to the average standard values related to the fission cross section, standard thermal values for fission, capture, and elastic cross sections were also included in the evaluation. The intent of the full paper is to describe the procedure used for re-evaluating the ^{235}U resonance parameters including the recommended standard values as well as new cross section measurements.

R106 235U resonance parameters and neutron multiplicities in the neutron energy region below 100 eV

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A new set of Thermal Neutron Constants (TNCs) have been recently evaluated using direct measurements at the thermal energy [1]. The new TNCs feature a reduced thermal neutron multiplicity, namely $\bar{\nu}$ computed at the thermal energy. Additionally, new thermal prompt fission neutron spectra (PFNS) have been recently evaluated [2]; these new PFNS result in a lower PFNS average energy than that one used in existing evaluated data libraries.
The use of new TNCs and thermal PFNS of ^{235}U in thermal solution benchmark simulations yields k_{eff} values that are larger than measurements by an increasing margin as the above-thermal-leakage-fraction (ATLF) increases. Current libraries achieved an almost independent k_{eff} vs the ATLF for ^{235}U solution benchmarks, and such performance is considered an important constrain for the evaluated physical quantities.
The goal of this work is to restore the benchmark performance for ^{235}U solutions by combining changes to the resonance parameters as well as to the prompt resonance $\bar{\nu}$ below 100 eV. This new set of physical quantities should restore the agreement for high-leakage solution benchmarks while keeping the good performance of large thermal solution assemblies. Additionally, the new RPs should yield cross sections in agreement with all available TOF measured data for thermal neutron induced fission of ^{235}U.

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I107 The measurement programme at the neutron time-of-flight facility n-TOF at CERN

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Neutron-induced reaction cross sections are important for a wide variety of research fields ranging from the study of nuclear level densities and stellar nucleosynthesis to applications of nuclear technology like the safety and criticality assessment of existing and future nuclear reactors, radiation dosimetry, medical applications, nuclear waste transmutation, accelerator-driven systems and fuel cycle investigations. Simulations and calculations of nuclear technology applications largely rely on evaluated nuclear data libraries. The evaluations in these libraries are ased both on experimental data and theoretical models.
CERN's neutron time-of-flight facility n_TOF has produced a considerable amount of experimental data since it has become fully operational with the start of its scientific measurement programme in 2002. While for a long period a single measurement station (EAR1) located at 185 m from the neutron production target was available, the construction of a second beam line at 20 m (EAR2) in 2014 has substantially increased the measurement capabilities of the facility. An outline of the experimental nuclear data activities at CERN's neutron time-of-flight facility n_TOF will be presented.

R108 Neutron nuclear data measurements for criticality safety

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The US Department of Energy Nuclear Criticality Safety Program (NCSP) has a number of tasks requiring effective nuclear criticality safety calculations of fissionable material storage from former operations. Pertinent to these criticality calculations are improved neutron cross sections for nuclides involved in fissionable material conditioning and long-term storage. New data and evaluations including covariances are required for several stable fission products as well as for materials found in mixtures with uranium. Identified deficiencies in nuclear data libraries have been outlined in the five-year plan of the NCSP. To respond to these needs, new neutron-induced cross section measurements have been initiated for cerium and vanadium.
The Geel Electron Linear Accelerator (GELINA) of the Institute for Reference Material and Measurements of the Joint Research Centers of the European Union was used to perform two types of experiments. Firstly, a metallic natural Ce target was placed in Flight Path 14 at a distance of 60 m from the neutron production target to measure neutron capture with 4 C6D6 detectors. Due to its reactivity with air, the metallic Ce sample was encapsulated in a thin-wall aluminum container. To correct for the effect of the aluminum, an empty container of the exact same dimensions was also measured. Secondly, the same sample and a similar thicker sample were used in a transmission experiment to determine the total cross section. The sample was placed in Flight Path 4 and at a distance of 50 m from the neutron target a 1.27-cm thick 6Li glass detector was used to detect the sample-transmitted neutrons. Empty aluminum containers served in the open beam as a compensator for the aluminum in the sample. Similar experiments were performed for vanadium samples of different thickness, which were not encapsulated in a container. The final paper will provide the experimental details and compare the measured cross-section data for cerium and vanadium with cross sections calculated from the latest evaluated data files.

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R109 Iron-56 capture cross section experiments at the RPI LINAC center

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Iron's role as a structural material in a wide variety of nuclear systems make it a high priority for new and better cross section measurements. The upper energy limit for existing capture cross section evaluations of its major isotope, iron-56, has historically been constrained by the first inelastic threshold at 847 keV. Little experimental capture data for iron-56 exists above this threshold, as inelastic photons tend to obscure the much smaller capture signal.
A new array of C_6D_6 detectors installed at the RPI LINAC Center has enabled the capability to measure capture cross section measurements above the inelastic threshold through the use of digital post-processing filters and pulse-integral discriminators, without sacrificing the statistical quality of data at lower incident neutron energies where such filtering is unnecessary.
The C_6D_6 detectors were used to perform time-of-flight capture cross section measurements on a sample 99.87% enriched iron-56 at a flight path of 45 meters and using an electron pulse width of 10 ns. The total-energy method combined with the pulse height weighting technique were then applied to the raw data to determine the energy-dependent capture yield. Above the inelastic threshold, the data was reanalyzed with a pulse-integral filter to reveal the capture signal. Resolved resonance structure is observed in the keV region, and partially resolved structure is observable up to 2.5 MeV.

R110 Neutron inelastic cross section measurements for natural titanium

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A neutron inelastic scattering experiment was performed at the GELINA (Geel Electron LINear Accelerator) neutron source of the EC-JRC-IRMM (European Commission-Joint Research Center-Institute for Reference Materials and Measurements) with the aim of determining the reaction cross sections for the stable isotopes of a natural titanium sample. A ^{235}U fission chamber was used to monitor neutrons with energies up to 20 MeV. The GAINS (Gamma Array for Inelastic Neutron Scattering) spectrometer was employed to detect the gamma rays resulting from the decay of the excited nuclei. We determined the γ-production cross sections, the level cross sections and the total inelastic cross sections for the $^{46-50}$Ti isotopes. The experimental values were compared with previous reported results and also with the theoretical calculations performed with the TALYS 1.6 code. An uncertainty of less than 5% was obtained for the strongest transition in the most abundant isotope ^{48}Ti.

S111 Measurement of the neutron capture cross section of 99Tc using ANNRI at J-PARC

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Long-lived fission products (LLFP) in nuclear spent fuel have been an issue to deal with in nuclear power industry. Currently-planned geological disposal of nuclear waste has been disputed in public. To solve this long-standing issue, nuclear transmutation, in which LLFPs are transmuted into shorter-life or stable isotopes through neutron-induced reactions, has been suggested. Among LLFPs, technetium-99 has the highest priory to transmute due to its high fission yield and radiotoxicity. In order to design a nuclear transmutation system for ^{99}Tc, reliable neutron nuclear data of ^{99}Tc in a wide range of neutron energy are necessary. In the present work, we carried out time-of-flight (TOF) experiments to measure the neutron capture cross section of ^{99}Tc with the Accurate Neutron-Nucleus Reaction Measurement Instrument (ANNRI) at the Japan Proton Accelerator Research Complex (J-PARC). ANNRI has been built for nuclear data measurement utilizing a high-intensity pulsed neutron beam from a spallation neutron source of J-PARC. NaI(Tl) detectors of ANNRI, located at a flight distance of 27.9 m from the spallation neutron source, were used in the present measurements. The TOF method was employed to determine the incident neutron energy. The neutron capture cross section of ^{99}Tc were measured from thermal to keV neutron energy region. In particular, an effort was made to extend the high energy limit of measurement to more than 100 keV. In this contribution, comparison of the present data with previous measurements and evaluated cross sections will be given and discussed.
Present study includes the result of “Research and Development for accuracy improvement of neutron nuclear data on minor actinides” entrusted to the Japan Atomic Energy Agency by the Ministry of Education, Culture, Sports, Science and Technology of Japan (MEXT).

S112 Measurements of the total and capture cross sections of natural silver in the resonance range with the time of flight technique

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Natural silver is composed of two stable isotopes ^{107}Ag and ^{109}Ag with ^{107}Ag being the more abundant (51.8%). Silver is often used together with cadmium and indium to produce an alloy used for the production of control rods in water moderated power reactors. Such an alloy, referred to as AIC, provides good mechanical properties and results in an uniform absorption spectrum. Recently an evaluation of the resonance parameters for cadmium isotopes was performed by Volev et al. [1]. This evaluation, which was strongly based on results of experiment at the GELINA facility of JRC-IRMM, was included in the JEFF-3.2 neutron library. In this contribution experiments to improve the nuclear data for ^{107}Ag and ^{109}Ag are described. The results of these experiments will be used to produce new evaluated data for ^{107}Ag and ^{109}Ag in the resonance region. This should result in a better prediction of the reactivity worth of AIC control rods.
A multi-year program plan was defined for measuring the total and capture cross sections of silver at the GELINA facility with the time of flight technique. The first experimental phase consists in measuring thin and thick metallic samples. The second experimental phase consists in studying the technical feasibility of transmission measurements using long cylindrical samples which were initially designed for oscillation measurements in the MINERVE reactor (CEA Cadarache).
The data obtained during the first experimental phase will be analysed with the REFIT and CONRAD resonance shape analysis codes. The REFIT code is routinely used at JRC-IRMM. It provides several experimental corrections suitable for the analysis of time of flight data. The CONRAD code is developed at the CEA of Cadarache. It was specifically designed for producing Resonance Parameter Covariance Data by using analytic and Monte-Carlo marginalization techniques. Preliminary values for energy resonance parameters in the low energy region will be compared with the resonance parameters available in the main neutron cross sections libraries (JEFF, ENDF/B, JENDL) and compiled in the Atlas of Neutron Resonances. Results from JRC-IRMM will be also tested with results of integral measurements in the MINERVE reactor (Credit Burn Up and MAESTRO programs).

[1] Volev K. et al., "Evaluation of resonance parameters for neutron induced reactions in cadmium", NUCLEAR INSTRUMENTS AND METHODS IN PHYSICS RESEARCH B 300 (2013) 11-29

S113 New measurement on 16O(n,alpha) reaction at Los Alamos Neutron Science Center (LANSCE)

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Oxygen is present in many materials - water, oxides, concrete and elsewhere - and the uncertainties in its nuclear data can have a significant impact on many applications including neutron reactivity in light water reactors. In particular, neutron-absorption reactions cause reduction of available neutrons in applications. This has been recognized and is the motivation for improving the nuclear data for key isotopes. At the heart of the questions on the oxygen-16 data is a 30-50% discrepancy between various (n,alpha) cross section measurements. Reconciling these discrepancies and settling on a best value requires new measurements for confirmation.
The Los Alamos Neutron Science Center (LANSCE) produces a white neutron spectrum ranging from thermal to several hundreds of MeV energies. We have recently developed the LENZ (Low Energy NZ-neutron induced charged particle detection) capability to measure (n,alpha) cross sections. The LENZ is composed of a twin Frisch-gridded ionization chamber, which is coupled with several double-sided silicon strip detectors at forward and backward angles. In order to provide more reliable data, we have enhanced solid angle coverage, and improved signal-to-noise ratio and time-of-flight resolution by implementing digitizer waveform analysis.
For the 16O(n,alpha) reaction, we investigate an oxygen solid target by anodizing highly-pure water on tantalum backing and make a relative measurement to a better known cross section, such as the 6Li(n,alpha) reaction in order to further reduce systematic uncertainty. We will present the progress of the (n,alpha) study at LANSCE to discuss the current status of data taking, beam-induced backgrounds and analysis path. We will discuss neutron-induced proton reactions in terms of enhancing the predictive power of Hauser-Feshbach formalism as a part of the nuclear data activity at LANSCE.

S114 Application of modified REFIT code for J-PARC/MLF to evaluation of neutron capture cross section on 155,157Gd

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There are mainly two difficulties for the evaluation of the data in neutron time-of-flight (TOF) measurement in the J-PARC/MLF/ANNRI, the double-bunch structure and the resolution function of the pulsed neutron beam. The former is caused by an incident proton delivered by a double-bunch scheme. This makes the structure of resonance split into two peaks. The latter gives the energy spread of pulsed neutron mainly from source and moderator. This affects the resonance shape.
The least-squares multilevel R-matrix code REFIT was widely used for the nuclear data analysis.
In order to overcome the difficulties mentioned above, REFIT was modified to include the function of describing the double bunch structure and the resolution function for the ANNRI. The parameters of resolution function based on the formulation of Ikeda-Carpenter were obtained at certain operational conditions of J-PARC/MLF. Nevertheless, this code has not been applied to the actual evaluation of nuclear data.
Gadolinium has been used as neutron-absorbing material in a thermal reactor since Gd-155,157 have large thermal neutron capture cross sections. However, there is a discrepancy between the previous measured data and JENDL-4.0 data for Gd-157. For example, the data measured at the RPI make the criticality of Gd-loaded thermal systems in ICSBEP overestimated.
Recently, the neutron capture cross sections of Gd-155,157 were measured with good accuracy by the TOF method using the ANNRI in the J-PARC/MLF. In this study, we applied the modified REFIT code to the analysis of the capture cross sections of Gd-155,157, and demonstrated the applicability of the code. We derive the resonance parameters for some low-lying resonances of the two Gd isotopes, and discuss the difference between the new resonance parameters and previous ones.
Present study includes the result of “Research and Development for accuracy improvement of neutron nuclear data on minor actinides” entrusted to the Japan Atomic Energy Agency by the Ministry of Education, Culture, Sports, Science and Technology of Japan (MEXT).

I115 Resonance region measurements of dysprosium and rhenium

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Neutron capture and transmission measurements have been performed, and resonance parameter analysis has been completed for dysprosium, Dy, and rhenium, Re. The 60 MeV electron accelerator at RPI Gaerttner LINAC Center produced neutrons in the thermal and epithermal energy regions for these measurements. Transmission measurements were made using 6Li glass scintillation detectors. The neutron capture measurements were made with a 16-segment NaI multiplicity detector. The detectors for all experiments were located at ≈25 m except for thermal transmission, which was done at ≈15 m. The dysprosium samples included one highly enriched 164Dy metal, 6 liquid solutions of enriched 164Dy, and one elemental Dy metal. The Re samples were elemental metals. Their capture yield normalizations were affected by their very high gamma attenuation. The multi-level R-matrix Bayesian computer code SAMMY was used to extract the resonance parameters from the data. 164Dy resonance data were analyzed up to 550 eV, other Dy resonances up to 17 eV, and Re resonance data up to 1 keV. Uncertainties due to resolution function, flight path, burst width, sample thickness, normalization, background, and zero time were estimated and propagated using SAMMY. An additional check of sample-to-sample consistency is presented as an estimate of uncertainty. The thermal total cross sections and neutron capture resonance integrals of 164Dy and Re were determined from the resonance parameters. The NJOY and INTER codes were used to generate these values. Plots of the data, fits, and calculations using ENDF/B-VII.1 resonance parameters are presented.

R116 Neutron capture cross section measurements of Sn-120, Sn-122 and Sn-124 with the array of germanium spectrometer at the J-PARC/MLF/ANNRI

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Accurate neutron capture cross section data for long-lived fission products (LLFPs) are required in the study of transmutation of radioactive waste. Tin-126, which is included in spent-fuels of light water reactors with relatively large yields, is one of the most important LLFPs. However, there is only one experimental data at the thermal energy[1], and accurate cross section measurements of Sn-126 are strongly required.
It is expected that a 126Sn sample for a nuclear data experiment is contaminated with a large amount of tin stable isotopes, Sn-117, 118, 119, 120, 122, 124, because these stable isotopes also have fission yields. These isotopes have large effects on neutron capture cross section measurements for Sn-126. Therefore, to obtain accurate cross section data for Sn-126, a series of neutron capture cross section measurements of all the stable tin isotopes are required, and the measurements of all tin stable isotopes had been started with Accurate Neutron-Nucleus Reaction measurement Instrument (ANNRI) of Materials and Life science experimental Facility (MLF) in Japan Proton Accelerator Research Complex (J-PARC). The results of the neutron capture cross sections for Sn-112 and Sn-118 have been reported in ND2013[2]. In this presentation, preliminary results of the neutron capture cross section measurements of Sn-120, Sn-122 and Sn-124 are reported in the neutron energy region from 10 meV to 2 keV.

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The author would like to thank the accelerator and technical staff at J-PARC for operation of the accelerator and the neutron production target and for the other experimental supports.

[1] S. Zhang, et al., Radiochimica Acta 94, 385, (2006).; [2] A. Kimura, et al., Nuclear Data Sheets., 119, 150, (2014).

R117 Measurement of the keV-neutron capture cross sections and capture gamma-ray spectra of CS-133 and I-127

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Management of radioactive waste from nuclear power plants is a key issue to continue nuclear energy production in the future. In order to solve the issue, researchers have suggested nuclear transmutation systems that transmute long-lived nuclides to shorter or stable species via neutron-induced reactions. Accurate nuclear data such as reaction cross sections of long-lived fission products (LLFP) are necessary for the design of a nuclear transmutation system.
In the present work, we measured the neutron capture cross sections of ^{133}Cs and ^{127}I. These neutron capture cross sections are needed to design a system to transmute the LLFP nuclides ^{135}Cs ($T_{1/2}$ = 2.3 M year) and ^{129}I ($T_{1/2}$ = 15.7 M year) because LLFPs exist together with their stable isotopes in spent nuclear fuel. The neutron capture cross sections of both LLFPs and their stable isotopes are required unless isotope separation is carried out. In addition, we measured the neutron capture γ-ray spectra of ^{133}Cs and ^{127}I, which give more information on reaction mechanism of the neutron capture process.
Experiments were carried out in the Tokyo Institute of Technology. A pulsed proton beam from a Pelletron accelerator was used to produce neutrons. Neutrons were produced through the ^{7}Li(p,n)^{7}Be reaction. The time-of-flight method was employed to measure the incident neutron energy. The energy of the incident neutrons distributed up to 100 keV. The flight path length from the neutron source to the sample was 12 cm. The natural isotope abundance of ^{133}Cs and ^{127}I is 100%. Isotopically-enriched samples were not needed. Samples in chemical forms CsI, PbI_2 and Pb were used. Combing results from three samples, contributions from Cs, I and Pb to neutron capture yields can be separated. After background subtraction, a pulse-height weighting technique was applied to derive capture yields. The absolute cross sections were determined from standard measurements of a gold sample, based on the well-known cross section of ^{197}Au(n,γ)^{198}Au. The derived cross sections of ^{133}Cs and ^{127}I were compared with previous measurements and the evaluated cross sections in nuclear data libraries. Detailed discussion on the present results will be given in this contribution.

R118 High precision measurement of the radiative capture cross section of 238U at the n_TOF CERN facility

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Nuclear energy represents one of a limited number of options available at scale to reduce greenhouse-gas emissions, and the development of new-generation technologies of nuclear reactors could be the decisive step towards an unquestioned nuclear energy production in matters of intrinsic safety and nuclear waste disposal. The design of these new reactors rests its foundations upon accurate and precise nuclear data, a list of the most urgent requirements of which has been compiled by the Nuclear Energy Agency. Among them, the measurement of ^{238}U(n,γ) reaction cross-section is included because of its key role in the design calculations of nuclear reactors, governing the behaviour of the reactor core. In particular, fast neutron reactors, which are experiencing a growing interest for their ability to burn radioactive waste, operate in the high energy region of the neutron spectrum. In this energy region inconsistencies between the existing measurements are present up to 15%, and the most recent evaluations disagree between each other. The assessment of nuclear data uncertainty performed for innovative reactor systems shows that the uncertainty in the radiative capture cross-section of ^{238}U should be further reduced to 1-3% in the energy region from 20 eV to 25 keV. The final results of the ^{238}U(n,γ) measurement performed at the n_TOF CERN facility will be presented. It was carried out with a detection system constituted of two liquid scintillators. In the analysis, special attention was devoted to the identification of all sources of background and to the accurate determination of the various systematic uncertainties. Particular emphasis will be given to the high energy region ($3<E_n<700$ keV), where the detection technique used together with the characteristics of the n_TOF facility provide a very accurate determination of the cross section.

R119 Interpretation of cross section data in cold and thermal neutron spectra

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Accurate thermal cross sections can be obtained from activation measurements in cold neutron spectrum. However, for nuclides where deviation of the capture cross section from the expected $1/v$ shape reaches below the thermal energy point, a correct assumption about the cross section shape below the thermal point has to be made. Furthermore, the neutron spectra in cold beam facilities are usually cleaner compared to thermal reactor spectra in a sense that they more closely resemble the Maxwellian distribution and that the epi-thermal component is (almost) negligible.
On the other hand, activation measurements in reactor neutron spectra also have several advantages compared to cold neutron measurements. Due to the epi-thermal neutron spectrum component, determination of the resonance integral is also possible. The intensity of the neutron flux in reactor irradiation channels can be several orders of magnitude higher than in cold neutron beams, thereby enabling shorter irradiation times, increased counting statistics, and detection of materials present in lower quantities and/or with lower cross section values.
The main purpose of this paper is to study the possible bias effects when deriving integral cross section parameters from activation measurements in typical cold and reactor neutron spectra. The analysis in this paper is limited to reaction rates, i.e. uncertainties due to branching ratios, half-lives etc. are not included. The methodology addressed in this paper is general and can be applied to any nuclide. However, this study is focused on the capture cross sections in strong non-actinide absorbers: ^{113,nat}Cd, ^{155,157,nat}Gd, ^{149}Sm, ^{151}Eu, ^{167}Er and ^{176}Lu. The selection criterion was the lowest energy resonance below 0.5 eV while only naturally existing isotopes with significant abundances (> 1%) were considered. Additionally, the (n,γ) reactions of two actinides, ^{241}Am and ^{237}Np, have been considered within the framework of the NEA WPEC SG41 project.

I120 Strong gamma-ray emission from neutron-unbound states populated in beta-decay: impact on neutron capture cross-section estimates

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As it is well known from neutron capture measurements, radiative widths $\Gamma\gamma$ are orders-of-magnitude smaller than neutron widths Γ_n. In a similar way γ-ray emission from neutron-unbound states populated in β-decay is hindered in favor of neutron emission. Experimentally, γ-ray emission from states above the neutron separation energy S_n has been observed only for a small fraction of the known β-delayed neutron emitters. The difficulty lies with the weakness of the emission and the limited sensitivity of high-resolution HPGe γ-ray spectroscopy employed in those studies. It is expected that a large fraction of the actual intensity at high excitation energy goes undetected (Pandemonium effect).
We have recently applied the total absorption gamma-ray spectroscopy (TAGS) technique and obtained for the first time [1] accurate information for three known delayed neutron emitters. For two of them, ^{87}Br and ^{88}Br, a surprisingly large fraction of the decay intensity above S_n proceeds by gamma emission, 57% and 20% respectively, and could be explained from nuclear structure considerations. A similar effect can be expected for other delayed neutron emitters and should be taken into account when comparing β-strength based theoretical calculations of delayed neutron emission probabilities with experiment. In the third case ^{94}Rb that is 5n away from stability, the gamma branching, 4.5%, although weak is more than one order-of-magnitude larger than Hauser-Feshbach (HF) calculations with standard parameters. This information can be used to constraint HF calculations of neutron capture cross-section for experimentally inaccessible neutron-rich nuclei, which is also based on Γ_γ and Γ_n. Capture (n,γ) cross-sections for those nuclei are a key ingredient in element abundance calculations of the *r* process. Our result could be explained as the result of a large relative increase of the radiative width away from stability. If confirmed and generalized it will have a significant impact on *r* process calculations. Preliminary results for newly measured isotopes seem to confirm an enhancement of the γ-branching above S_n. Results will be presented and discussed.

[1] J.L. Tain et al., Phys. Rev. Lett. 115 (2015) 062502.

R121 Measurement of the heaviest beta-delayed 2-neutron emitter 136Sb

Caballero-Folch R. 1,2, Dillmann I. 1,3, Agramunt J. 4, Tain JL. 4, Calvino F. 2, Cortes G. 2, Ganioglu E. 5, Gelletly B. 6, Marta M. 3, Mendoza E. 7, Rubio B. 4, IGISOL group, 8, et al.
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The β-delayed neutron emission probability, Pn, of very exotic nuclei is crucial for the understanding of nuclear structure properties of many isotopes, and astrophysical processes such as the rapid neutron capture process (r-process). The production of neutron-rich isotopes in the present RIB facilities allowed to measure β-delayed one-neutron emitters (β1n) up to regions around the A~150, and recently up to isotopes of masses heavier than A=200, beyond N=126 [1], the latter by using a 4pi neutron detector based on ^{3}He counters named BELEN [2]. With this detector, an experiment performed at the RIB facility of the University of Jyväskylä (Finland), using the IGISOL penning trap, allowed to produce ^{136}Sb, and thanks to an innovative self-triggered digital data acquisition system, specifically developed for BELEN, it was possible to register multiple neutron emission (β2n) events. This means the heaviest multiple neutron emitter measured so far. The ^{136}Sb is present in the freeze-out of the r-process and contributes to the second abundance peak around N~82 in the A=130 mass region. It was measured previously as β1n [3], when it was considered as double emitter candidate. This contribution will report the results of the aforementioned experiment together with an overview of recent Pn values measured for isotopes of Hg and Tl (N>126), and the new plans for β-delayed neutron emitter measurements at RIKEN. In particular the BRIKEN campaign which aims to set the limits for the next decade by the measurement of dozens of β1n emitters, several β2n emitters and also for the first time the heaviest β3n emitters, many of them for the first time.

[1] R.Caballero-Folch, C.Domingo-Pardo et al. First measurement of several β-delayed neutron emitting isotopes beyond N=126. Submitted to Phys. Rev Lett. (arXiv:1511.01296).; [2] J.Agramunt et al. 2016 Nucl. Instr. Meth. A 807 69–78.; [3] D.Testov et al, online at: http://icc.ub.edu/congress/ESPRUS2011/Talks_Presentations/Parallel_Sessions/Seminar_S214/09-11-11/ Testov.pdf

R122 Isomeric ratio measurements for the radiative neutron capture 176Lu(n,) at DANCE

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Neutron capture cross sections are of high interest in nuclear astrophysics to investigate the s-process in which the synthesis of heavy elements is dominated by neutron induced reactions. In this context, partial cross sections feeding the ground states or isomers are particularly crucial in certain cases of the s-process nucleosynthesis. From first studies on isomeric states, the isomeric ratio, defined as the ratio of isomeric over total cross sections, was always seen as a pertinent parameter to characterize the gamma-ray cascade following the decay of the compound nucleus state. Parameters required to evaluate the neutron capture cross sections as the spin distribution of the compound nucleus, the level density, the gamma strength function can be set by means of isomeric ratio measurements.
The isomeric ratios for the neutron capture reaction ^{176}Lu(n,γ) on the the $J^{\pi}=5/2^{-}$, 761.7 keV, $T_{1/2}$=32.8 ns and the $J^{\pi}=15/2^{+}$, 1356.9 keV, $T_{1/2}$=11.1 ns levels have been measured using the DANCE array at LANL. The detection efficiencies were determined with GEANT4 simulations and γ-cascades obtained with the Hauser-Feshbach code EVITA, based on the TALYS code and developed at CEA. To reproduce the experimental γ-ray spectra, it was needed to add a resonance at low energy in the photon strength function using in EVITA. The experimental isomeric ratios are compared with calculated ones with the TALYS and EVITA codes. In these calculations, we have tested several models of nuclear level density and optical potential in order to reproduce the data.

R123 Nuclear level densities and gamma-ray strength functions of 180,181Ta and nucleosynthesis of 180Ta

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Most stable and extremely low abundance proton-rich nuclei with A>110 are thought to be produced by the photodisintegration of s- and r- process seed nuclei. However, this so-called p-process is insufficient to explain the observed low abundance (0.012%) of the 180Ta isotope. Hence combinations of several processes are considered to reproduce the observed abundance of 180Ta in the cosmos, provoking debates and making it a unique case study. Significant uncertainties in the predicted reaction rates in p-nuclei arise due to large uncertainties in nuclear properties such as the nuclear level densities (NLD) and gamma-ray strength functions (γSF) [1], as well as the actual astrophysical environments.
An experiment was performed to extract the γSF and NLD below the neutron threshold in 180,181Ta isotopes which provide important input parameters for nuclear reaction models. In the present case study, these parameters were measured using the 181Ta(3He, 3He'γ)181Ta and 181Ta(3He, 4Heγ)180Ta reactions with 34MeV beam energy at the Oslo Cyclotron Laboratory. Using the SiRi array at backward angles (64 silicon particle telescopes) and the CACTUS array (26 NaI(Tl) detectors), the NLD and γSF were simultaneously extracted from particle-γ coincidence matrices through iterative procedures using the Oslo method [2].
The experimental results have been used to determine the corresponding neutron capture cross sections, which in turn were utilized to extract Maxwellian averaged cross sections. The latter can be used in astrophysical network calculations to investigate the galactic production mechanism of 180Ta. In this talk I will present results of this investigation of statistical properties for 180Ta and 181Ta and the corresponding (n,γ) cross sections.

[1] S. Goriely et al., A & A 375, L35 (2001). ; [2] A. Schiller et al., Nucl. Instrum. Methods Phys. Res. A 447, 498 (2000).

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R124 Empirical estimation of astrophysical photodisintegration rates of 106Cd and 108Cd

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The β-delayed neutron emission probability, Pn, of very exotic nuclei is crucial for the understanding of nuclear structure properties of many isotopes, and astrophysical processes such as the rapid neutron capture process (r-process). The production of neutron-rich isotopes in the present RIB facilities allowed to measure beta-delayed one-neutron emitters (b1n) up to regions around the A~150, and recently up to isotopes of masses heavier than A=200, beyond N=126 [1], the latter by using a 4pi neutron detector based on 3He counters named BELEN [2]. With this detector, an experiment performed at the RIB facility of the University of Jyvaskyla (Finland), using the IGISOL penning trap, allowed to produce 136Sb, and thanks to an innovative self-triggered digital data acquisition system, specifically developed for BELEN, it was possible to register multiple neutron emission (b2n) events. This means the heaviest multiple neutron emitter measured so far. The 136Sb is present in the freeze-out of the r-process and contributes to the second abundance peak around N~82 in the A=130 mass region. It was measured previously as b1n [3], when was considered as double emitter candidate. This contribution will report the results of the aforementioned experiment together with an overview of recent Pn values measured for isotopes of Hg and Tl (N>126) and the new plans for beta-delayed neutron emitter measurements at RIKEN. In particular the BRIKEN campaign which aims to set the limits for the next decade by the measurement of dozens of b1n emitters, several b2n emitters and also for the first time the heaviest b3n emitters, many of them for the first time.

[1] R.Caballero-Folch, C.Domingo-Pardo et al.First measurement of several β-delayed neutron emitting isotopes beyond N=126. Submitted to Phys. Rev Lett. (arXiv:1511.01296); [2] J.Agramunt et al. 2016 Nucl. Instr. Meth. A 807 69–78; [3] D.Testov et al, online at http://icc.ub.edu/congress/ESPRUS2011/Talks_Presentations/ Parallel_Sessions/Seminar_S214/09-11-11/Testov.pdf

S125 Experimental cross sections for alpha particle induced reactions on p-nuclei

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Preliminary alpha capture cross sections on p-nuclei at energies close to the Gamow window will be presented. The cross sections were measured by means of the activation method using an alpha beam delivered by the Bucharest IFIN-HH 9MV tandem accelerator. The induced activities were measured with two large volume HPGe detectors in close geometry placed in a low background passive shielding. The experimental results are compared with theoretical predictions obtained in the framework of the statistical model, using the latest version of Talys1.8 and the alpha OMP potential by V. Avrigeanu et al [1].

S126 Cross section and astrophysical reaction rate of photodisintegration reaction in p-process: systematic calculation and future experiment based on ELI-NP

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The astrophysical p-process is an important way of nucleosynthesis to produce the proton-rich, stable nuclides beyond Fe which can not be reached by the s- and r-process. The common picture is that these nuclides are synthesized by photodisintegration of pre-existing s- and r-process nuclei. In the present study, the (γ,n), (γ,p), and (γ,α) photodisintegration cross sections and astrophysical reaction rates are computed within the modern reaction code TALYS for about 3000 stable and proton-rich nuclei with $12 \le Z \le 110$. The nuclear-structure ingredients involved in the calculation are determined from experimental data whenever available and, if not, from global microscopic nuclear models. Furthermore, sensitivity studies of the photodisintegration reaction rates to photon strength function, optical potential and nuclear level density are also conducted, which indicates that the better determination of photon strength function would be in particular essential to reduce the uncertainties of photodisintegration reaction rate. Recently, the ELI-NP facility is being developed, and it will provide the great opportunity to experimentally study the photodisintegration reactions in p-process. Measurements of (γ,p) and (γ,α) reactions for the p-isotopes of Mo, Ru, Sm and Gd have been proposed. Preliminary results of experimental simulations are presented.

I127 The neutrons for science facility at SPIRAL-2

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Numerous domains, in fundamental research as well as in applications, require the study of reactions induced by neutrons with energies between a few MeV and a few tens of MeV. Reliable measurements are necessary to improve the evaluated databases used by nuclear transport codes. It concerns a large number of topics like transmutation of nuclear waste, design of future fission and fusion reactors, nuclear medicine or test and development of new detectors. A new facility called Neutrons For Science (NFS) has been built for this purpose on the GANIL site at Caen (France). NFS is composed of a pulsed neutron beam for time-of-flight measurements and irradiation stations for cross-section measurements. Neutrons will be produced by the interaction of deuteron and proton beams, delivered by the SPIRAL-2 linear accelerator, with thick or thin converters made of beryllium or lithium. Continuous and quasi-mono-energetic spectra will be available at NFS up to 40 MeV. In this fast energy region, the neutron flux is expected to be up to 2 orders of magnitude higher than the one of the others existing time-of-flight facilities. In addition, irradiation stations for neutron-, proton- and deuteron-induced reactions will allow performing cross-section measurements by the activation technique. After a description of the facility and of its characteristics, the experiments to be performed in the short and medium term will be presented.

R128 Simulations and experimental verification of neutron fields at IGISOL for neutron induced fission yield studies

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A proton-neutron converter for measurements of neutron-induced independent fission yields has been designed for the IGISOL-JYFLTRAP facility at University of Jyväskylä (IGISOL = Ion Guide Isotope Separation On-Line, JYFLTRAP = Jyväskylä Physics Laboratory Penning Trap). Different geometries and materials were considered and tested in simulations in order to optimize the neutron field (1) in view of measurements of fission yield data of importance for nuclear power applications, and (2) for measurements of physical properties of unstable neutron-rich nuclei.
Desirable objectives are flexibility of design, the possibility to vary the neutron field, and a flux sufficiently high to enable measurements of fission products with low yields. The proposed approach is to use 30 MeV protons from a MCC30/15 cyclotron, where the protons impinge on a water-cooled beryllium plate. The resulting neutron field irradiates thin ^{238}U foils arranged in a barrel shaped ion guide, placed sufficiently close to allow 10^{12} fast neutrons on the foils. The thickness of the beryllium plate can be varied, the proton energy can be modified, and deuteron beams can be used, in order to obtain different neutron fields. A thick moderator material can also be inserted between the converter and the ion guide, enabling measurements with thermal neutrons, although with a significantly reduced flux.
Simulations for the design have been performed with the Monte Carlo codes FLUKA and MCNPX. A mock-up of the selected design was used in a test measurement at The Svedberg Laboratory, where the neutron flux was determined with Time-of-Flight and Bonner Sphere Spectrometry methods. Thereafter a prototype has been installed in Jyväskylä and used for the first online extraction of neutron-induced fission products with IGISOL. The neutron flux has been measured with activation plates and Thin Film Breakdown Counters.
This paper summarizes the results of the different measurements and compare them with the simulations. The Monte Carlo codes display some discrepancies, both compared to the experiments and each other. An outlook for the capabilities of the converter for obtaining valuable fission yield data, taking the uncertainties from experiments and simulations into account, will also be reported.

R129 Characterization of the medley setup for measurements of neutron-induced cross-sections at the GANIL-NFS facility

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Neutron-induced fission cross sections of ^{235}U and ^{238}U are widely used as standards for monitoring of neutron beams and fields [1]. Nevertheless, there are few measurements above 20 MeV at an absolute scale, i.e., versus the H(n,n) scattering cross section (see [2,3] and references therein), which is regarded as the primary neutron standard . Taking advantage of the high-intense white neutron beam under construction at the NFS (Neutrons For Science) facility at GANIL [4], we will measure the $^{235}U(n,f)$ and $^{238}U(n,f)$ cross sections relative to each other and to H(n,n) in a continuous energy range, from 1 to 40 MeV, and in a single measurement, thus cancelling out systematic effects due to variations in the beam characteristics, and aiming at a final accuracy below 2%. Angular distributions of fission fragments, of interest for studying the states of the fissioning nuclei, will also be measured.
An upgraded version of the Medley setup will be used. It consisted originally [5,6] of eight ΔE-ΔE-E telescopes, each composed of two Si detectors and one CsI(Tl) crystal, to detect and identify light ions. The new version [7] will also include PPACs (Parallel Plate Avalanche Counter). Each PPAC will produce a fast signal originating from a fission fragment, before its arrival to a front Si detector in a telescope. The energy of the incident neutron will be measured by the time-of-flight technique.
The first prototypes of the PPACs have already been built. The detection efficiency and the time and energy resolution of the PPACs and of the telescopes are being studied using spontaneous fission events from a ^{252}Cf sample. In addition, the performance of the entire setup for fission fragment detection is being characterized. The results will be presented at the conference.
The original version of Medley will also be used in a different experiment at the NFS facility: measurements of neutron-induced double-differential cross-sections for light ion production on nuclei of interest for different applications, such as Si for radiation effects, Fe for reactor applications, Pb and Bi for spallation sources, Au and others for neutron dosimetry, etc.

References:
[1] A. D. Carlson, Metrologia 48, S328 (2011).; [2] R. Nolte, Nucl. Sci. and Eng. 156, 197-210 (2007).; [3] A. V. Prokofiev et al., AIP Conference Proceedings No. 769, 800-803 (2005).; [4] X. Ledoux et al., Nuclear Data Sheets, 119, 353-356 (2014) .; [5] U. Tippawan, et al., Phys. Rev. C 79, 064611 (2009).; [6] R. Bevilacqua, et al., Nucl. Inst. Meth. A 646, 100-107 (2011).; [7] K. Jansson et al., Nucl. Inst. Meth. A 794, 141-150 (2015).

R130 Developments of a new data acquisition system at ANNRI

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The Accurate Neutron-Nucleus Reaction Measurement Instrument (ANNRI) has been built for nuclear data measurement utilizing a pulsed neutron beam from a spallation neutron source in the Materials and Life Science Experimental Facility (MLF) of the Japan Proton Accelerator Research Complex (J-PARC). Neutron capture experiments using a large Ge detector array and NaI(Tl) detectors have been conducted in ANNRI. In addition, a new Li glass detector system to measure total cross sections was recently installed.
Increasing beam power of J-PARC in recent years allows beam line users to obtain high quantity experimental data yields. Compared to 2009, more than 20 times beam current is achieved in 2015. For the purpose to correspond a high counting rate, a new data acquisition system (DAQ system) for the Ge detector arrays in ANNRI is developed. CAEN v1724 100MHz 14bit peak sensitive ADCs are prepared to correspond high energy resolution of the Ge detector arrays. For fast response pulse signals of Li glass detector system, CAEN v1720 250MHz 12bit charge sensitive ADCs are selected.
Commissioning experiment of a new DAQ system at ANNRI was performed by using 0.1mm thickness gold sample with 500kW J-PARC proton beam power. An applicability of time-of-flight method for both neutron capture and total cross-sections measurements was checked. For the Ge detectors array, system performance such as digital conversion nonlinearity, energy resolution, multi-channel coincidence and dead time was evaluated. The dead time value for Ge detectors was successfully decreased by a factor of four compared with the previous DAQ system with minor deterioration on energy resolution.
The author would like to thank the accelerator and technical staff at J-PARC for operation of the accelerator and the neutron production target and for the other experimental supports.
Present study includes the result of “Research and Development for accuracy improvement of neutron nuclear data on minor actinides” entrusted to the Japan Atomic Energy Agency by the Ministry of Education, Culture, Sports, Science and Technology of Japan (MEXT).

S131 Development and test of a compact multi-plate fission chamber for the simultaneous measurement of uranium-233 capture and fission cross-sections

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A particularity of uranium-233 used in the thorium fuel cycle is its small capture-over-fission cross-sections alpha ratio, since the capture cross-section is about one order of magnitude lower than the fission cross-section. Therefore the accuracy in the measurement of the uranium-233 capture cross-section essentially relies on efficient capture-fission discrimination. A new measurement campaign of the uranium-233 capture cross-section and alpha ratio is planned at JRC-IRMM with C6D6 detectors, and at the CERN n_TOF facility, where the Total Absorption Calorimeter (TAC) made of 40 BaF2 detectors will be equipped with a compact multi-plate fission chamber acting as an active target. Thus one can easily distinguish between capture and fission events. The present contribution describes the compact multi-plate fission chamber developed for this experiment: compact design, fast ionising gas, optimised electronics, simulation of the signals and optimisation of the alpha-fragment separation, preparation and characterisation of uranium-233 samples, Monte Carlo simulation of the detector and the neutron-induced background, along with preliminary results of the first tests with neutron beam.

S132 Study of a proton recoil telescope for the measurement of the 235U(n, f) fission cross section relative to n-p scattering, at n_TOF

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The 235U(n, f) fission cross section is a reference cross section for fission studies. In the energy region between thermal neutron energy and 20 MeV, a large number of experimental data measured relative to the differential np scattering cross section is present in literature. In contrast, only one set of data measured relative to np scattering with good energy coverage at a 'white' source and a few measurements at selected neutron energies are available in the energy range between 20 MeV and 200 MeV. Above 200 MeV, no measurements of the ^{235}U(n,f) cross section relative to np scattering were carried out so far.
The n_TOF facility [1] offers the unique opportunity to collect long-needed dataon the ^{235}U(n, f) cross section, relative to the n-p elastic scattering, from 200 MeV to about 1 GeV, as well as to improve its knowledge down to a few MeV. To this aim, the n_TOF Collaboration has already successfully employed at n_TOF a fission detector based on Parallel Plate Avalanche Counters, capable of reaching neutron energies up to 1 GeV, while a proton recoil telescope is now being developed for the measurement of the n-p elastic scattering.
In this contribution we present the conceptual design of the proton recoil telescope, and the Monte Carlo simulations of the device. The detector is based on a design used so far for this kind of measurements [2] with some sizable modifications for extending the extending the energy range to neutron energies above 200 MeV. In addition the result of a test under neutron beam of a prototype detector consisting of fast scintillators will be presented.

[1] C. Guerrero, et al. (The n_TOF Collaboration), Eur. Phys. J. A 49 (2013) 27.; [2] V. Dangendorf, R. Nolte, F. Roos, H. Schuhmacher, B.R.L. Siebert, M. Weyrauch, Nuclear Instruments and Methods A 469 (2001) 205

S133 Scalp: scintillating ionization chamber for alpha particle production in neutron induced reactions

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In a nuclear reactor, alpha production due to neutron induced reactions on the oxygen of the uranium oxide is a sizable contribution (roughly 25% of the overall production of alpha particles in fast and thermal nuclear reactor). This contribution affects the installation physical parameters. Thus, it leads to 7% uncertainty on the alpha production in oxide fuel reactors and to a 100 pcm uncertainty on the k_{eff} (effective neutron multiplication factor). Many cross section's evaluations were performed and great discrepancies were found among these measurements and also among the nuclear model predictions.
From 2005 (High Priority Request List by the Nuclear Energy Agency (NEA)) efforts have been done to improve these values especially in the energy domain of the reactor physics. Therefore, the situation is still unclear and needs to be improved.
The aim of the SCALP project is to perform several measurements of the $^{16}O(n,\alpha)^{13}C$ cross section in the range from threshold (2.36 MeV) to 20 MeV. The experiment is based on the detection of the alpha-particles produced in the reaction. SCALP is an ionization chamber filled with a mixture of CF_4 and a few percent of CO_2 with four photomultiplier tubes in order to collect light emission associated with neutron induced reactions in the gas. Using the scintillating properties of the CF_4, the incident neutron energy will be obtained by time-of-flight measurements. Knowledge of both deposited energy and incident neutron energy is crucial to separate and identify all the nuclear reactions. Finally, by an accurate estimation of the oxygen-targets in the active volume, the calculus of the cross section will be possible.
SCALP will be tested in spring 2016 using neutron sources at LPC and LPSC laboratory at Grenoble, France, using pure CF4. Cross section measurements using the gas mixture will be done at the Neutron For Science (NFS) facility at GANIL, Caen, France. This will be also the occasion to perform measurements of $^{19}F(n,\alpha)^{16}N$ cross section reaction (interest in reactor physics via molten salt reactors).
SCALP project's motivation and set-up will be introduced during the oral presentation. Some preliminary results and perspective will be also presented.

S134 Digital pulse shape analysis and gamma-ray energy dependent prompt-timing response functions for the UK national nuclear array

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The lifetime of isomeric states is one of the best observables for use as a probe to understand the underlying structure of atomic nuclei. The NAtional Nuclear Array (NANA) is a 12 module $LaBr_3$(Ce) scintillation detector coincidence gamma-ray spectrometer array which can be used to measure the lifetimes of excited nuclear states of the order of 10 ns down to tens of picoseconds. In recent years significant progress has been made in the analogue implementation of the centroid shift method for timing measurements (Regis2012), specifically for γ-γ energy-time coincidence measurements using two or more $LaBr_3$ detectors. Using a similar analysis procedure to these analogue measurements, a full characterisation of the digital timing profile for the CAEN digitizer (V1751C, 1 GHz sampling frequency) and NANA has been conducted, using the reference source ^{152}Eu to provide near prompt and delayed γ-ray coincident cascades. This includes the implementation of pulse shape analysis algorithms for more precise timing responses. The different discrete energy gamma-ray emissions has allowed for the creation of a prompt response function and prompt response differences of the system over a considerable range of primary gating energies and energy pairs. The presentation will show the results of this detailed characterisation together with example lifetime measurements of excited states from radioactive sources in the sub-100ps regime which showcase the power of the digital system.

S135 Neutron-gamma discrimination using non-negative matrix factorization blind sources separation algorithms

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In this study, we apply blind sources separation methods (BSS) based on non-negative matrix factorization techniques (NMF) to extract independent components from signals recorded at the output of fission chamber detectors. Since these modern signal processing methods require no hypothesis on the way that the signal and the noise are mixed, encouraged us to apply these methods to reach neutron-gamma discrimination in a soft way. For that reason, we use Geant4 as nuclear simulator, to model the neutron detection system installed inside the TRIGA MARK II Reactor (Nuclear facility of the Moroccan National Center for Nuclear Energy, Sciences and Techniques). The fission chamber is used in a research nuclear and a flux-mapping experiment is performed. We use the simulated fission chamber's output signals as time series mixtures that will be analysed through non-negative and blind sources separation algorithms. The computation of performance index of each blind separation method will allow us to select the most efficient NMF algorithm that permit to achieve the best neutron-gamma discrimination. In addition, the computation of the auto and cross-correlation functions, the power spectral densities and time-frequency decomposition of the resulting independent components will provide a better characterization of these nuclear signals with very high precision.

I136 Selective data analysis for diamond detectors in neutron fields

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Detectors based on synthetic chemical vapor deposition (CVD) diamond materials gain importance in various neutron applications. The superior thermal robustness and the excellent radiation hardness of diamond as well as its excellent electronic properties make this material uniquely suited for rough environments, such as nuclear fission and fusion reactors.
The intrinsic electronic properties of diamond detectors allow distinguishing various interactions in the detector. This can be used to successfully suppress background of gammas and charged particles in different neutron experiments, such as neutron flux measurements in thermal nuclear reactors or cross-section measurements in fast neutron fields.
A novel technique of distinguishing background reactions in neutron experiments with diamond detectors will be presented. A proof of principle will be given on the basis of the results of experiments in thermal and fast neutron fields.

R137 Progress of a 4πBaF2 System at CIAE

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A gamma ray total absorption facility (GTAF) made of barium fluoride is developed at China Institute of Atomic Energy (CIAE). Modules of BaF2 crystal were manufactured by Bei Jing Institute of Glass. Flash analogue-to-digital convert cards (FADC, Acqiris DC 271) and photomultiplier tubes of PHOTONIS XP4508B were selected.
Advantages of GTAF to be used in accurate measurement of neutron capture cross-sections is attributed to such characteristics of BaF2 scintillator as high efficiency, quick response, lower neutron sensitivity and so on. Prompt -ray cascades, emitted due to deexcitation of the excited compound nucleus promptly after the (n,) reactions, can be detected with total energy and be used to register the capture events efficiently. In the total energy spectrum of the prompt ray cascades, capture events will fall in energy range from 5 to 8 MeV of the neutron separation energy and well separated from backgrounds as presented in Fig 1.
Digital pulse shape data acquisition method based on FADC is applied. Scheme of the signal measurement is shown in figure 2. Technologies about signal detection, pulse shape digitization, data transmission and storage, off line data analysis have been studied. By pulse shape technique, particle can be clearly discriminated as presented in Fig 3 a. By measuring the characteristic -ray cascades radiated from a 60Co source the Esum spectrum was obtained and the key experimental technique for the (n,) reaction cross section measurement is tested. Most of the backgrounds were clearly suppressed in the Esum spectrum, as presented in Fig 3 b.
Different samples of Cd, C and blank, switched to the center of the GTAF, were respectively bombarded by the collimated neutron beam of an Am-Li isotopic neutron source that was located behind the shield and the collimator. Neutron capture events occurring in the samples of cadmium were measured. The plan of the experiment is schemed in Fig 4 a.
A comparison of Esum spectrums for the three samples is presented in fig 4 b. Net counts of neutron capture events occurred in Cd sample are displayed.
Works included are the perfection of the detector module so as to increase energy resolution, the optimization of the data acquisition system to raise data transmission rate, the construction of the neutron absorber to suppress interferences from sample scattered neutrons, the experimental preparation at the China Spallation Neutron Source and so on.

R138 Accurate measurement of an ionization chamber efficiency using prompt fission neutron detection method

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Ionization Chambers (IC) are often used either to determine fission cross sections or to measure neutron beam flux via standard neutron-induced fission reactions. Thus, the fission fragments detection efficiency is a key parameter. Depending on the studied samples (nuclear properties such as half-life and spontaneous-fission half-life, knowledge of its fission cross section) and the IC design (presence of a Frisch grid), several methods can be used to measure the fission fragments detection efficiency. They always rely on known nuclear data or fission fragments spectrum extrapolation, and the obtained accuracy is not better than 1%. The detection of prompt fission neutrons allows to tag events related to the fission process. The efficiency of the IC is directly given by the ratio between the number of detected neutrons in coincidence with fission fragments and the total detected neutrons respectively. It is therefore an efficiency value which is directly extractable from the experimental data. The achieved accuracy is of the order of few 0.1%.
This method is very robust since it is independent in first order of several factors like geometry, used materials or neutron detection thresholds. To obtain the best accuracy, few corrections have still to be taken into account. In particular, the neutron detectors have to cover several detection angles with respect to the normal direction to the target surface. In addition, the presence of the natural neutron background created by primary cosmic ray particles incident on the atmosphere has to be estimated and undertaken. Several experiments based on the use of a ^{252}Cf source are presented to detail all these points.

R139 Development of a gaseous proton-recoil detector for neutron flux measurements between 0.1 and 2 MeV neutron energy

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Absolute measurements of neutron fluence are an essential prerequisite of neutron-induced cross section measurements, neutron beam lines characterisation and dosimetric investigations.
The H(n,p) elastic scattering cross section is a very well known standard used to perform precise neutron flux measurements in high precision measurements.
The use of this technique, with proton recoil detectors, is not straightforward below incident neutron energy of 1 MeV, due to a high background in the detected proton spectrum. Experiments have been carried out at the AIFIRA facility to investigate such background and to determine its origin and components. Based on these investigations, a gaseous proton-recoil detector has been designed, with a reduced low energy background.

R140 Application of minor actinides as neutron fluency and average neutron energy detectors in the place of their location

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It is a feasibility study for utilizing neutron-irradiated actinide samples for estimating average neutron fluence and neutron energy inside the volume of samples. The idea is to search the neutron energy for the ratio of fission cross section to capture cross section of the selected actinide isotope from the nuclear data base that is equal to the measured ratio of fissioned and captured actinide isotopes.
^{237}Np samples were placed inside a subcritical assembly (the Quinta assembly at the Joint Institute for Nuclear Research, Russia). The assembly was irradiated by a pulsed deuteron beam (the energy was 2 and 4 GeV, and irradiation times were 6-10 h). After the irradiation, gamma-rays of ^{133}I, ^{97}Zr, ^{135}I, and ^{238}Np from the samples were measured for evaluating the fission/capture rates of ^{237}Np. In the research, the average neutron energy and fluence were estimated to be about 0.4 MeV and in the order of 10^{12} n/cm^2, respectively.
It is concluded that minor actinide samples can be used as average neutron flux detectors especially in the high neutron energy range that is difficult to measure.
Given the importance of high energy neutron measurement the actinide neutron fluence and average neutron energy detectors could be

I141 Contributions to integral nuclear data in ICSBEP and IRPhEP since ND2013

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The status of the International Criticality Safety Benchmark Evaluation Project (ICSBEP) and the International Reactor Physics Experiment Evaluation Project (IRPhEP) was last discussed directly with the international nuclear data community at ND2013. Since ND2013, integral benchmark data that are available for nuclear data testing has continued to increase. The status of the international benchmark efforts and the latest contributions to integral nuclear data for testing is discussed. Select benchmark configurations that have been added to the ICSBEP and IRPhEP Handbooks since ND2013 are highlighted. The 2015 edition of the ICSBEP Handbook now contains 567 evaluations with benchmark specifications for 4,874 critical, near-critical, or subcritical configurations, 31 criticality alarm placement/shielding configuration with multiple dose points apiece, and 207 configurations that have been categorized as fundamental physics measurements that are relevant to criticality safety applications. The 2015 edition of the IRPhEP Handbook contains data from 143 different experimental series that were performed at 50 different nuclear facilities. Currently 139 of the 143 evaluations are published as approved benchmarks with the remaining four evaluations published in draft format only. Measurements found in the IRPhEP Handbook include criticality, buckling and extrapolation length, spectral characteristics, reactivity effects, reactivity coefficients, kinetics, reaction-rate distributions, power distributions, isotopic compositions, and/or other miscellaneous types of measurements for various types of reactor systems. Annual technical review meetings for both projects were held in April 2016; additional approved benchmark evaluations will be included in the 2016 editions of these handbooks.

R142 Summary of ORSphere critical and reactor physics measurements

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In the early 1970s Dr. John T. Mihalczo (team leader), J. J. Lynn, and J. R. Taylor performed experiments at the Oak Ridge Critical Experiments Facility (ORCEF) with highly enriched uranium (HEU) metal (called Oak Ridge Alloy or ORALLOY) to recreate GODIVA I results with greater accuracy than those performed at Los Alamos National Laboratory in the 1950s. The purpose of the Oak Ridge ORALLOY Sphere (ORSphere) experiments was to estimate the unreflected and unmoderated critical mass of an idealized sphere of uranium metal corrected to a density, purity, and enrichment such that it could be compared with the GODIVA I experiments. This critical configuration has been evaluated. Preliminary results were presented at ND2013. Since then, the evaluation was finalized and judged to be an acceptable benchmark experiment for the International Criticality Safety Benchmark Experiment Project (ICSBEP). Additionally, reactor physics measurements were performed to determine surface button worths, central void worth, delayed neutron fraction, prompt neutron decay constant, fission density and neutron importance. These measurements have been evaluated and found to be acceptable experiments and are discussed in full detail in the International Handbook of Evaluated Reactor Physics Benchmark Experiments. The purpose of this paper is summary summarize all the critical and reactor physics measurements evaluations and, when possible, to compare them to GODIVA experiment results.

R143 SFCOMPO-2.0: an NEA database of spent fuel assay data for integral benchmarking

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SFCOMPO is a database of spent fuel assay data hosted by the OECD Nuclear Energy Agency (NEA). Assay data are radio-chemically determined nuclide densities of spent fuel samples complemented with corresponding reactor design data, operational data and irradiation conditions of the samples. The database is today under the supervision of the NEA Expert Group on Assay Data of Spent Nuclear Fuel of the NEA Working Party on Nuclear Criticality Safety.
In recent years, a collaborative effort led by Oak Ridge National Laboratory (ORNL) and the NEA Data Bank has focused in populating and restructuring this database into an expanded and documented modern relational database with standardized assay data entries taken from the open literature. Today, SFCOMPO-2.0 contains experimental data from over 500 samples from over 40 reactors representing 8 different reactor types. SFCOMPO-2.0 is available as a Java application downloadable from the NEA website. SFCOMPO is a unique integral experiment database that can be used to benchmark nuclear data and depletion models.

R144 Nuclear data processing capabilities in OpenMC

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Validation and testing of nuclear data evaluations relies heavily on the use of critical benchmark results as a measure of the integral quality of the data. Critical benchmark calculations are typically carried out using Monte Carlo methods due to the lack of physical approximations and ability to easily handle complex geometries. However, these calculations often require large-scale computational resources which are not always available to those in the evaluation community. In this work, we describe newly-developed capabilties for automated critical benchmark calculations using the OpenMC Monte Carlo code [1] using Amazon's Elastic Compute Cloud (EC2). These capabilities make it easy to perform hundreds or thousands of benchmark calculations in a timely manner and/or carry out perturbation studies which require large computational studies.
Amazon EC2 offers multiple instance types with tradeoffs in performance/memory/cost. An analysis of benchmark calculations on the various instances was carried out to assess the process/thread parallel scalability and to determine which instance type is most cost-effective. The c4.large instance was found to provide the highest performance per dollar due to suboptimal OpenMP thread scaling when using larger C4 instances.

[1] P. K. Romano et al., "OpenMC: A State-of-the-Art Monte Carlo Code for Research and Development", Proc. SNA+MC, Paris, France, Oct. 27-31, 2013.

S145 New functions for improved uncertainty analysis in the NEA Nuclear Data Sensitivity Tool (NDaST)

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Following the release and initial testing period of the NEA's Nuclear Data Sensitivity Tool, new features have been designed and implemented in order to expand its uncertainty analysis capabilities. The aim is to provide a free online tool for integral benchmark testing, that is both efficient and comprehensive, meeting the needs of the nuclear data and benchmark testing communities.
New features include access to P1 sensitivities for neutron scattering angular distribution and constrained Chi sensitivities for the prompt fission neutron energy sampling. Both of these are compatible with covariance data accessed via the JANIS nuclear data software, enabling propagation of the resultant uncertainties in keff to a large series of integral experiment benchmarks. These capabilities are demonstrated using a number of different covariance libraries e.g. ENDF-B, JEFF, JENDL and TENDL, comparing the broad range of results it is possible to obtain.
The IRPhEP database of reactor physics measurements is now also accessible within the tool in addition to the criticality benchmarks from ICSBEP. Other improvements include the ability to determine and visualise the energy dependence of a given calculated result in order to better identify specific regions of importance or high uncertainty contribution. Sorting and statistical analysis of the selected benchmark suite is now also provided. Examples of the plots generated by the software are included to illustrate such capabilities.
Finally, a number of analytical expressions, for example Maxwellian and Watt fission spectra will be included. This will allow the analyst to determine the impact of varying such distributions within the data evaluation, either through adjustment of parameters within the expressions, or by comparison to a more general probability distribution fitted to measured data. The impact of such changes is shown through several calculations which are compared to a "direct" measurement found by adjustment of the original ENDF format file.

S146 Benchmarking of HEU mental annuli critical assemblies with internally reflected graphite cylinder

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Three experimental configurations of critical assemblies, performed in 1963 at the Oak Ridge Critical Experiment Facility, which are assembled using three different diameter HEU annuli (15-9 inches, 15-7 inches and 13-7 inches) metal annuli with internally reflected graphite cylinder are evaluated and benchmarked. The experimental uncertainties which are 0.00055, 0.00055 and 0.00055 respectively, and biases to the detailed benchmark models which are -0.00179, -0.00189 and -0.00114 respectively, were determined, and the experimental benchmark keff results were obtained for both detailed and simplified model. The calculation results for both detailed and simplified models using MCNP6-1.0 and ENDF VII.1 agree well to the benchmark experimental results with a difference of less than 0.2%. These are acceptable benchmark experiments for inclusion in the ICSBEP Handbook.

S147 Examination of total cross section resonance structure of niobium and silicon in neutron transmission experiments

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One of the main sources of information about the structure and effects of neutron cross section resonance self-shielding are experiments measuring neutron beam transmission through different material samples. The experiments presented in this report are part of an extensive experimental program aimed at studying the neutron cross section resonance effects of structural materials (including a few score of materials) were carried out in the Van de Graaff accelerator at the SSC RF – IPPE. In these experiments rather a coarse energy grid was used which did not allow defining the detailed cross section dependence on the energy but was sufficient enough for describing the total cross section resonance structure.
The average cross-section values estimated based on these experimental data were published in the EXFOR library (EXFOR No. 40082.005, 40883.006). Based on the experimental analysis calculations, estimates for the description of the cross section resonance region parameters were formed for the ABBN group neutron data library.
Revision and reassessment of the experiments measuring the functional dependencies of neutron transmission through iron, chrome, and nickel samples were included in the ICSBEP Handbook of Benchmark Experiments (FUND-IPPE-VdG-MULT-TRANS-001).
As part of the study, a calculation analysis and revaluation of the existing experimental data were carried out in order to obtain previously unrecorded information related to refining the neutron cross sections of structural materials (niobium and silicon) within the resonance energy region.
A titan-tritium target was used as a neutron source, the neutron energy varied from 7 keV to 3 MeV for niobium and 300 keV to 3 MeV for silicon. The energy range varied from 15 – 40 keV in the 7 – 600 keV energy region measurements up to 150 – 300 keV in the 0.3 – 3.0 MeV energy region measurements. The maximum sample thickness reached 50.5 cm for niobium and 35.8 cm due to which it was possible to obtain information on cross section self-shielding in a wide range of cross section dilution variation within the resonance energy region. The calculation analysis was performed using the MCNP transport code and recent versions of the evaluated neutron data libraries (ROSFOND, ENDF/B-7.1, JEFF-3.2, JENDL-4.0, TENDL-2014).
A comparison of the calculated and experimental dependencies of the total cross section of niobium made it possible to prove and justify the extension of the unresolved resonance region up to 0.6 MeV. Based on the results of the analysis of the calculated and experimental discrepancies in the total neutron transmission functions of silicon, this study has revealed inaccuracies in the description of the total cross section resonance structure within the energy range of 0.4 – 0.7 MeV in the current evaluated nuclear data libraries. Due to the identified discrepancies, it became possible to improve the ROSFOND evaluated nuclear data files.

S148 Integral cross section measurement of the 235U(n,n')235mU reaction in a pulsed reactor

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The integral measurement of the neutron inelastic cross section leading to the 26 minutes ^{235m}U isomer in a fission-like neutron spectrum is presented. The experiment has been performed at a pulsed reactor, where the internal conversion decay of the isomer was measured using a dedicated electron detector after activation. The sample preparation, efficiency measurement, irradiation, radiochemistry purification and isomer decay measurement will be presented. We determined the integral cross section for the $^{235}U(n,n')^{235m}U$ reaction to be 1.00±0.13 b. This result supports an evaluation performed with TALYS-1.4 code with respect to the isomer excitation as well as the total neutron inelastic scattering cross section.

S149 Measurement and calculation of neutron leakage spectra from slab samples of beryllium, gallium and tungsten irradiated with 14.8 MeV neutrons

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In order to make benchmark validation of the nuclear data for Gallium (Ga), Tungsten (W) and Beryllium (Be) in existing modern evaluated nuclear data files, neutron leakage spectra in the range from 0.8 to 15MeV from slab samples were measured by time-of-flight technique with a BC501 scintillation detector. The measurements were performed at China Institute of Atomic Energy (CIAE) using a D-T neutron source. The thicknesses of the slabs were 0.5 to 2.5 mean free path for 14.8 MeV neutrons, and the measured angles were chosen to be 60° and 120°. The measured spectra were compared with those calculated by the continuous energy Monte-Carlo transport code MCNP-4B, using the data in the CENDL-3.1, ENDF/B-VII.1 and JENDL-4.0 nuclear data files, the comparison between the experimental and calculational results showed that: for Ga, the results from all three libraries significantly underestimated the cross section in energy range of 10-13MeV; for W, ENDF/B-VII.1 gave good agreements with the experiments in the whole energy regions at 60°, the calculated spectra using data from CENDL-3.1 and JENDL-4.0 libraries showed larger discrepancies with the measured ones, especially around 8.5–13.5 MeV, and for Be, the calculation results based on CENDL-3.1 were larger than measurements in the energy range from 3 to 12 MeV at 60°, while at 120°, all the libraries led to underestimation below 3 MeV. By checking the data from different evaluated files, it is considered that these disagreements were caused by improper evaluation of cross section values, and/or angular distribution of cross section, and/or energy distribution of secondary neutrons.

I150 Methodology and issues of integral experiments selection for nuclear data validation

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Nuclear data validation involves a large suite of Integral Experiments (IEs) for criticality, reactor physics and dosimetry applications. [1] The benchmarks are available, for instance, in Handbooks. [2, 3] The IEs have different neutronic status and usually the use of a single benchmark in the validation is not advised. Indeed, it may lead to erroneous interpretation and results. [1] Although IEs have correlated uncertainties [4] many practitioners neglect them [5] compromising the nuclear data comparison. Objective of this work is to quantify the importance of benchmarks for cross sections validation. The approach is based on novel application of General Linear Least Squared Method (GLLSM) using IRSN in-house developed BERING code system [6]. Generally tools like BERING are used to establish biases and uncertainties for design or criticality parameters. Novel approach in the BERING code is used to establish biases and uncertainties for given cross sections (within given energy interval). The statistical treatments result in weighting factors associated with benchmarks. These factors characterize the value added by a benchmark to nuclear data validation in the field of interest. It should be noted that the approach is a statistical one and it can provide credible values if the set of the benchmarks is reliable and statistically significant.
The full paper will describe the theoretical substantiation of the methodology and will provide one example on the selection of benchmarks for validation of 239Pu fission and capture cross sections.
The studies were performed in the frame of Subgroup 39 (Methods and approaches to provide feedback from nuclear and covariance data adjustment for improvement of nuclear data files) established at the Working Party on International Nuclear Data Evaluation Cooperation (WPEC) of the Nuclear Science Committee under the Nuclear Energy Agency (NEA/OECD).

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R151 Americium-241 integral radiative capture cross section measurement in thermal domain using the oscillation technique in the minerve reactor

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For nearly 10 years, several experiments have been conducted to improve the knowledge of americium 241 radiative capture cross section. Indeed, evaluated cross sections from major libraries differ from 10 % to 15 %, especially in the thermal domain [1][2]. A 9 % discrepancy is for instance observed on the thermal point between JEFF3.2 and ENDF-B.VII.1 nuclear data libraries. An international collaborative working group (WPEC/SG-41) started in 2015 with the aim of explaining such discrepancies [3].
In this context, an experimental program (called AMSTRAMGRAM) was recently conducted by the CEA in the MINERVE reactor. Its objective is to measure the integral capture cross section of americium 241 in a very thermal neutron spectrum. A new core configuration was designed in order to maximize the thermal neutron flux in its centre. The target accuracy on the thermal point is 3 % (k=1).
The AMSTRAMGRAM program makes use of 7 americium samples manufactured by ITE Karlsruhe in the framework of a previous collaboration between IRMM and CEA [4]. The experiment is based on the reactivity oscillator technique commonly implemented in MINERVE [5]. This technique allows measuring the reactivity of small worth samples (typically of a few pcm) with a very good accuracy. However, it is a relative measurement that requires well characterized samples taken as reactivity reference. Gold and lithium samples with the same geometry as the americium samples were used for that purpose.
In this paper, the reactor configuration and the experiment setup are presented. First results on the integral cross section of americium 241 are discussed and compared to the calculations.

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R152 Neutron spectra measurement and calculations using data libraries CIELO and JEFF-3.2 in Iron benchmark assemblies

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The leakage neutron spectra measurements have been done on benchmark spherical assemblies - iron spheres with diameter of 50 and 100 cm. The Cf-252 neutron source was placed into the centre of iron sphere. The proton recoil method was used for neutron spectra measurement using spherical hydrogen proportional counters with pressure of 400 and 1000 kPa. Diameter of detectors is 4 cm. The neutron energy range of spectrometer is from 0.1 to 1.3 MeV. This energy interval represents about 85 % of all leakage neutrons from Fe sphere of diameter 50 cm and about of 74% for Fe sphere of diameter 100 cm. The adequate MCNP neutron spectra calculations based on data libraries CIELO and JEFF-3.2 were done. The neutron energy structure used for calculations and measurements was 40 groups per decade (gpd) and 200 gpd. Structure 200 gpd represents lethargy step about of 1%. This relatively fine energy structure enables to analyze the Iron resonance neutron energy structure. The evaluated cross section data of iron were validated on comparisons between the calculated and experimental spectra.

R153 Integral experiments on thorium assemblies with D-T neutron source

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In Th-U fuel cycle, accuracy of nuclear data for Th nuclide is crucial to the physical design of a hybrid reactor with thorium. To validate nuclear data and code of calculation for the neutronics design, neutronics integral experiments in two kinds of benchmark thorium assemblies have being performed. The one kind of 1D assembly consists of depleted uranium shells. The other kind of 2D assembly is combined with one depleted uranium cylinder and three thorium oxide cylinders. A D-T fusion neutron source is located at the center of the 1D assembly, as at one side of a 2D assembly. On the assemblies, the capture reaction rates, fission reaction rates, ratios of capture to fission and (n, 2n) reaction rates for ^{232}Th are measured by ThO_2 foils and an HPGe gamma spectrometer. The leakage neutron spectra from the thorium oxide cylinders are measured by a liquid scintillation detector. The experimental results among assemblies are compared and discussed. The experimental uncertainties in all the results are analyzed. The measured results are compared to the calculated ones with MCNP code and ENDF/B-VII library data.

R154 Validation of the U238 inelastic scattering cross section through the excalibur dedicated experiment

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This paper presents the first interpretation of the EXCALIBUR experiment which was specially designed to validate the inelastic scattering cross section of ^{238}U in the 1-8 MeV energy range which is relevant for both thermal and fast reactor applications. EXCALIBUR is an integral transmission experiment based on the fast neutron source produce by the highly enriched critical facility CALIBAN, located in Valduc (France). Two experimental campaigns have been performed, one using a sphere of diameter 17cm and one using two cylinders of 17cm diameter 9cm height, both made of pure Uranium 238. A set of 15 different dosimeters with specific threshold energies have been employed to provide information on the neutron flux attenuation as a function of incident energy. Measurements uncertainties are typically in the range of 0.5-3% (1sigma).
The analysis of these experiments is performed with the TRIPOLI4 continuous energy Monte Carlo code. A calculation benchmark with validated simplifications of the geometry is defined in order to improve the statistical convergence under 3%. Various nuclear data libraries are tested, e.g. JEFF-3.1.1, JEFF-3.2, ENDF/B-VII.0 and the IB36 evaluation from AIEA. Sensitivity calculations are performed with the correlated sampling method to identify the contribution of scattering and fission cross sections. Finally, an integral data assimilation technique was used to derive trends on the multigroup inelastic scattering cross section, in order to provide selected constraints for the evaluation process. This feedback may be of interest for the international effort on U238, through the CIELO project.

I155 A theoretical study of deuteron-induced surrogate reactions

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Deuteron-induced reactions have long been studied as surrogates for neutron-induced reactions [1-2]. They have gained interest in recent years as a possible means of inferring neutron-induced cross sections on unstable nuclei. In a deuteron-induced reaction, competition between elastic and inelastic breakup, absorption of only a neutron or a proton and absorption of the deuteron must be taken into account to determine the formation or not of a compound nucleus. The breakup-fusion reactions – those in which either only a neutron or a proton is absorbed – are particularly complex, forming compound nuclei with a wide range of excitation energies and angular momenta, but are the cross sections of interest as surrogates. We present a theoretical study of recently measured ^{238}U(d,p) breakup-fusion cross sections [3-5]. We use the zero-range post-form DWBA approximation to calculate the elastic and nonelastic breakup cross sections [6-8] and estimate the breakup-fusion cross section. We compare the energy and angular momentum dependence of the breakup-fusion compound nucleus formation cross section with the corresponding neutron-induced cross sections and calculate the differential ^{238}U(d,pg) and ^{238}U(d,pf) cross sections using the EMPIRE-3 nuclear model code [9].

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R156 Some evaluations of the deuteron induced reactions by using a semi-microscopic approach relying on the Continuum discretized coupled channels formalism

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We have used the Continuum Discretized Coupled Channel (CDCC) formalism to study deuteron induced reactions. Combined with a Distorded Wave Born Approximation (DWBA), we have computed the (d,p) cross sections and for a large set of nuclei, we have obtained a good agreement with the experimental data for both the differential cross sections and the excitation functions. We have then extracted a global parameterization of our calculations for these cross sections and we have included this new way of computing the (d,n) and (d,p) cross sections into the reaction code Talys which are usually underestimated. We will show the effects of these calculations on the other reaction cross sections such as the (d,2n), (d,3n)...We propose to build some new evaluations for deuteron induced reactions by this way. We will present some of these results.

R157 The neutron and proton microscopic optical potentials based on the Skyrme interaction

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The neutron microscopic optical potential (MOP) can be equivalent to the mass operator of the one-particle Green function. The real part of the MOP is obtained by the first-order mass operator. The imaginary part of the MOP is given by the imaginary part of second-order mass operator because the second order diagrams are the lowest order diagrams to contribute to the imaginary part of the MOP. The neutron MOP with Skyrme interaction are obtained by the nuclear matter approximation and given for finite nuclei by the local density approximation (LDA). The spin-orbit potential is further amended by the results of relativistic microscopic optical potential in Skyrme-Hartree-Fock approach to consider the correlation with incident energy. Similarly, the proton MOP is also derived by this approach. Up to now, there have been many sets of Skyrme interaction parameters. Most of them were obtained by considering some properties of nuclear matter and ground state for finite nuclei, while the neutron induced reaction data were not considered. We obtain a set of effective Skyrme interaction parameters SkC by fitting not only nuclear matter properties and ground state properties, but also the neutron induced scattering data for (near) spherical targets in the mass range of $24 \leq A \leq 209$ below 100 MeV. On this basis, we adopt the Skyrme interaction parameters SkC to obtain the neutron MOP for those data without involving in their fittings and show the prediction power. The total cross sections, nonelastic cross sections, elastic scattering angular distributions, and analyzing powers are predicted by the obtained neutron MOP for some light nuclei and actinide nuclei, as well as those targets in the mass range of $148 \leq A \leq 194$ which are too deformed and have rich nuclear structure properties. In addition, the proton induced reaction data for different targets below 100 MeV are also predicted by the proton MOP based on the Skyrme interaction parameters SkC. All of the predicted results are satisfactory agreements with experimental data. Therefore, the obtained neutron and proton microscopic optical potentials in this present work has a good prediction power and can provide a reasonable theoretical basis for the experimental research of far from β stability nuclide.

R158 Microscopic optical model potential based on Dirac-Brueckner-Hartree-Fock theory and the relevant covariance analysis

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Investigations of optical model potential (OMP) based on a fundamental microscopic theory provide a reliable basis to explore nuclear reaction mechanisms. In recent years, microscopic OMPs such as the JLMB model become popular in the nuclear data study of unstable nuclei. Considering the spin-orbit potential can be naturally involved with other potentials in the relativistic framework, we develop an isospin-dependent microscopic OMP (MOP) based on the latest Dirac-Brueckner-Hartree-Fock (DBHF) theory for the scatterings of neutron and proton on ^{12}C-^{208}Pb at incident energy $0.1 \leq E \leq 200$MeV.
We firstly construct the Dirac potentials using the calculated self-energies from DBHF theory, and then the potentials of equivalent Schrödinger equation for finite nuclei are determined correspondingly through an improved local density approximation (ILDA) method. In order to build the MOP on more fundamental bases, we adopt the nuclear matter density of finite nuclei based on the microscopic Hartree Fock Bogoliubov approach with Gogny D1S force. There are two uncertain components in this MOP development, namely the potentials in the nuclear density region $0<\rho<0.08$ fm^{-3} and a finite range correction parameter in ILDA to obtain the better prediction of scattering observables. In this work, a χ^2 assessment system based on the global simulated annealing algorithm is specially developed to optimize these two components. The scatterings on ^{40}Ca and ^{208}Pb are adopted in the process of optimization, and scatterings on other nuclei are predicted based on the optimized results. The scattering observables including the total neutron cross sections, nonelastic cross sections, differential elastic scattering cross sections, etc. are calculated and compared with the experimental data, as well as with results derived from the widely used phenomenological Koning-Delaroche global potential. The satisfying agreements are obtained. In addition, we develop an executable file to derive this MOP for any nuclides, which makes this MOP accessible to more researchers.
In order to determine the uncertainties of the predictions of MOP, the deterministic simple least square (SLS) approach is employed in a covariance analysis in this work. Some discussions on SLS are included, and a reasonable covariance of the calculated scattering observables using this MOP is obtained.

S159 The study of structure in 224-234 Thorium nuclei within the framework IBM

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This work makes an investigation into how nuclear structure behaves under the increase in neutron number with constituent parts of $^{224\text{-}234}$Th. Thorium nuclei with the mass number 232 is a typical rotor nucleus which can be explained by SU(3) limit of IBM in algebraic nuclear model. Also $^{224\text{-}230}$Th lies on the path of symmetry breaking phase transition. And the nuclear structure ^{224}Th is possible to explain using by X(5) symmetry. But $^{226\text{-}230}$Th nuclei are not fully symmetry nuclei so these can be represented by adding of perturbed term to express symmetry breaking.
We calculated by next three ways to identify the tendency about nuclear structure change. Firstly, the structure of ^{232}Th is described by using the matrix elements of the Hamiltonian and the electric quadrupole operator between basis states of SU(3) limit in IBM. Secondly, low-lying energy level and E2 transition ratio corresponding to the observable physical values are calculated by adding perturbed term with first-order Casimir operator of U(5) limit to SU(3) Hamiltonian in IBM. We compared the results with experimental data of $^{224\text{-}234}$Th. Lastly, the potential of Bohr Hamiltonian is represented by harmonic oscillator, and then the structure of $^{224\text{-}234}$Th can be expressed by closed form from an approximate separation of variables.
The results of theoretical prediction will be able to understand the tendency of nuclear structure changes in Thorium nuclei of relevant to the region of mass numbers.

S160 Optical model with multiple band coupling using a soft rotator model and taking account of volume conservation

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Recently we have proposed a model [1] which allows interband coupling in optical model calculations for strongly deformed nuclei, of special interest for actinides. Coupling to bands other than GS band appears due to small dynamic departures from axiality and symmetric quadrupole and octupole equilibrium deformations. In such approach, the canonical axial rigid rotator model proposed by Tamura [2] appears to be its zero approximation.
Interband coupling is determined by appropriate “effective” deformations, while intraband coupling strength is the one determined in [2], with small correction terms arising from the nuclear softness.
For even-even nuclides the necessary “effective” deformations can be determined from the ground state deformations using a soft rotator model [3]; model also includes the “effective” zero order multipole deformations, introduced to account of nuclear volume conservation while shape oscillations.
We incorporated such approach in OPTMAN optical model code and managed to get a self-consistent description of the available optical observables up to 200 MeV incident energies, which include S_0 and S_1 strength functions, total cross section, angular distributions of scattered nucleons, neutrons in (p,n) reaction with excitation of isobar analog states and the figure of merit – the ratio of ^{238}U and ^{232}Th total cross sections. The developed regional Lane-consistent dispersive optical potential couples all the observed collective levels of five rotational bands, including a negative parity one, with excitation energies up to about 1 MeV.
It’s necessary to mention, that the number of adjusted parameters was the same as in the case of axial rigid rotator coupled channels calculations, since the additional “effective” deformations have been built over rigid rotator (equilibrium) axial deformations using appropriate soft rotator nuclear Hamilton parameters, which in turn had been adjusted to reproduce the experimental collective levels scheme.

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S161 Nuclear data evaluation by microscopic optical potential

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Phenomenological optical potential is known to be able to describe the nuclear scattering process well. The advantage of the potential is that it can calculate the total and elastic scattering cross sections on nuclei, and the analyzing power successfully without considering complicated process inside target nuclei. Therefore, it is applied widely to the nuclear data evaluation of medium to heavy nuclei. Many kinds of the optical potential parameterized both in local and global forms have been studied so far.
However, the parameters in the phenomenological optical potentials are determined so as to reproduce existing experimental data, so that use of it for unmeasured nuclei such as neutron-rich nuclei including fission fragment and r-process nuclei is not necessarily reliable. Recently, a new optical potential derived from the microscopic effective reaction theory (MERT) was proposed [1]. It has been shown that it can reproduce elastic scattering cross sections from light to heavy nuclei successfully if the density distribution is correctly given. Since the formulation of MERT is based on the NN effective interaction (g-matrix), no parameterizations in the optical potential are needed. Therefore, it is also capable of calculating nuclei whose scattering cross section isn’t measured.
We incorporated the optical potentials of MERT in the nuclear reaction simulation code CCONE [2] recently and start nuclear data evaluation of several nuclei. In this work, we present and discuss difference of cross sections evaluated by MERT’s optical potentials and conventional phenomenological ones.

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S162 Non-local microscopic potentials for calculation of scattering observables of nucleons on deformed nuclei

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Recent developments in various areas like 4th generation reactors, waste management, neutron-therapy etc. have stressed the need for more accurate nuclear data on a wider range. A good understanding and prediction capacity of neutron scattering cross sections on minor actinides is crucial to all kinds of reactors based on fission process. For deformed nuclei, the determination of such observable for the elastic channel and the firsts, low energy excited states requires coupled channel calculations. Local, phenomenological optical and transition potentials are the most commonly used in coupled channel analyses, and extrapolating them brings forth the question of their accuracy outside of their fitting range. Microscopic approches are being developped in order to improve prediction power and solve the extrapolation issue[1]. Potentials obtained microscopically are nonlocal, and recent studies [2,3,4] have emphasized the importance of treating explicitely this nonlocality.
Our study aims at developping a code that can solve coupled channel equations with nonlocal microscopic optical potentials, while treating explicitely the nonlocality. We lead our study on ^{208}Pb, with potentials derived from Melbourne G-matrix and ground state and transition densities stemming from the Random Phase Approximation nuclear structure model, considering the couplings between the elastic channel and the inelastic channel for the 3^- excitation. Extensive experimental data for both elastic and inelastic scattering of neutrons is available on ^{208}Pb, and we use this target to validate our code and investigate effetcs of nonlocality before focusing on deformed nuclei.

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I163 Microscopic description of direct nucleon emission for neutron scattering off even and odd actinides

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Microscopic models for nuclear reaction are key ingredients to obtain reliable nuclear data in the mass and/or energy range for which measurements are lacking. To correctly predict observables for neutron induced reaction on actinides, one has to consider four reaction processes: direct elastic and inelastic scattering, compound nucleus formation and evaporation, pre-equilibrium emission and fission follo-wed by evaporation from the fission fragments. We focus here on improving the description of the direct inelastic scattering mechanism. We developed a microscopic model based on an in-medium two-body interaction between the incident nucleon and one target's nucleon, and on the quasi-particle random phase approximation (QRPA) to describe the target ground and excited states. All one-phonon excitations predicted by the QRPA model, implemented with the Gogny D1S interaction, are considered. Our approach provides a consistent description of direct inelastic scattering to discrete states, to giant resonances and to the continuum. Our model has been recently showed to improve the description of neutron induced reaction on ^{238}U [1]. We present further application of this approach to neutron scattering off both even and odd actinides for energies below 20 MeV. Inelastic cross sections are obtained coupling the ground state rotational band to the rotational band built on an intrinsic exci-tation. This calculation is performed for each one-phonon excitation predicted by the QRPA model to provide the double differential direct neutron emission cross section. In this calculation, we account for the rearrangement correction that arises from the density-dependent part of the effective two-body interaction used in the JLM folding model and that cannot be neglected at these incident energies [2]. We will first depict our model's predictions considering inclusive (n,xn) cross sections as well as (n,n'), (n,n'γ) and (n,2n) cross sections for n+^{238}U, n+^{232}Th and n+^{239}Pu. We will then detailed how our microscopic approach can be used to deduce (n,2n) cross sections from (n,2nγ) measurements and present preliminary results of this study.

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R164 Compound-nuclear reactions with unstable isotopes: Constraining capture cross sections with indirect data and theory

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Cross sections for compound-nuclear reactions involving unstable targets are important for many applications, but can often not be measured directly. Several indirect methods have recently been proposed to determine neutron capture cross sections for unstable isotopes. These methods aim at constraining statistical calculations of capture cross sections with data obtained from the decay of the compound nucleus relevant to the desired reaction. Each method produces this compound nucleus in a different manner (via a light-ion reaction, a photon-induced reaction, or beta decay) and requires additional ingredients to yield the sought-after cross section. This contribution focuses on the process of determining capture cross sections from inelastic scattering and transfer experiments. Specifically, theoretical descriptions of the (p,d) transfer reaction have been developed to complement recent measurements in the Zr-Y region. The procedure for obtaining constraints for unknown capture cross sections is illustrated. The main advantages and challenges of this approach are compared to those of the proposed alternatives.

R165 State density formalism of the Iwamoto-Harada model: a suitable tool to treat cluster emission from heavy-ion collisions with account for spin variables

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The Iwamoto-Harada(-Bisplinghoff) model [1-3] became considered as an universal recipe to handle statistical nuclear reactions at low energies with cluster emission. Its level-density (state-density in the case of angular momentum variables) formulation [2] is open to generalization to other types of ejectiles [4] and – using the general formulation of Obložinský et al. [5] – also for inclusion of angular momentum variables. This was done soon for γ's and nucleons [6], but the cluster emission had to wait for another two decades, and even that was only for nucleon- and α-induced reactions without spin variables [7].

Modification of the exciton model to reactions induced by heavy ions means to start with correct initial exciton configuration. To this aim, we use the approach of Cindro et al. [8]. The formation of clusters has been combined with heavy ions, for the initial stage yet without spin variables [9].
Recent progress in theory of super- and hyperdeformed nuclei (see, e.g. [10]) indicated as a possibly feasible way to use the heavy ion reactions to populate nuclei with tendency to extremely high deformations, and therefore it raised the interest in calculations of the involved reactions. Better understanding of the process, however, needs to have all three components: i) heavy-ion collisions (at not too high excitation energy), ii) angular momentum variables, and iii) clusterization process. The inclusion of spin variables for reactions of colliding heavy ion (using the idea of J.J. Griffin [11]) has been done according to [12]. We present here some results of our approach.

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R166 Role of different nuclear charge radii parameterizations on the thermal equilibrium in nuclear reactions

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The different reaction outcome in mass symmetric and asymmetric nuclear reactions provides qualitative understanding of the different processes and nuclear dynamics involved [1]. A phenomenologist study of these reactions can provide the information about the energy dissipation and nuclear equation of state (NEOS) of asymmetric nuclear matter. Also, the reaction dynamics is sensitive towards the structural effects via different nuclear charge radii parameterizations [2]. These declared facts have motivated us to emphasize the role of nuclear charge radii parameterizations on the thermalization by studying the average temperature and average density achieved in highly interacting nuclear matter for mass symmetric and asymmetric reactions. The simulations have been carried out for the reactions of ${}^{50}_{20}Ca + {}^{50}_{20}Ca$, ${}^{14}_{7}N + {}^{86}_{36}Kr$, ${}^{124}_{50}Sn + {}^{124}_{50}Sn$ and ${}^{38}_{18}Ar + {}^{210}_{82}Pb$ over the entire collision geometry within the framework of isospin-dependent quantum molecular dynamics (IQMD) model [3]. Our study reveals that the small change in available phase space at initial stage through different nuclear radii, enhance the temperature of nuclear system at time span between 10-20 fm/c which is expected to alter the outcome of reaction at saturation time i.e. 200 fm/c. Further studies in this direction are under consideration.

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R167 Saturation of coupling of collective levels in optical model calculations for even-even actinides

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Since their origins, it had been widely believed that in coupled channels optical model (OM) calculations, the axial rigid rotator coupling scheme would quickly saturate after including a few first levels. By saturation we understand the situation in which the addition of higher energy levels in the coupling scheme changes the predicted OM observables by less than their experimental or computational errors, depending on the goals of such calculations. For many years and even now OM calculations including the coupling of the three first levels [1] and some others have been considered adequate for describing nucleon scattering and have been widely used for nuclear data analysis and evaluation .
Afterwards it had been understood that saturation requires the inclusion of more levels [2] and recently [3] it had been pointed out that in axial rigid rotator calculations, adequate predictions of the reaction cross-section in the 0.1-1.0 MeV neutron incident region request that all levels of the ground state (GS) rotational band with spin at least 10h should be included, despite the fact that the predicted inelastic scattering cross sections on the higher spin levels are very small, in any case much smaller than the accuracy of the calculations.
We have developed a model [4] which allows the coupling of collective levels belonging to the other rotational bands in OM calculations for strongly deformed nuclei (particularly actinides), which has already been incorporated in OPTMAN code It allowed us to check whether high spin levels from non-GS rotational bands have similar impact.
Our calculations have shown the same behavior while including the first octupole band. Though cross sections for excitation of levels of this band are much smaller, than the ones for GS band; nevertheless we need to include negative parity levels with spin up to 7h, while their predicted excitations are significantly smaller than the excitation of 10h-spin level of the GS band. Our presentation discusses the found phenomena.

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I168 Prompt emission in fission induced with fast directional neutrons

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Prompt gamma-ray and neutron emission data in fission integrates a large amount of information on the fission process and can provide a useful test of state of the art fission models and shed light on angular momentum generation and the partition of energy. Measured emission spectra, average energies and multiplicities also provide important information for energy applications. While current reactors mostly use thermal neutron spectra, most future reactors of Generation IV will use fast neutron spectra for which little experimental prompt emission data exist.
Initial investigations on prompt emission in fast neutron induced fission have recently been carried out at the LICORNE facility at the IPN Orsay a new and unique type of neutron source which exploits the p(^{7}Li,n) reaction to produce naturally collimated, intense beams of fast neutrons. We report on recent results with LICORNE to measure both prompt gamma ray and prompt neutron emission in fast neutron induced fission of ^{238}U and ^{235}U at different incident neutron energies. The recent extension of the LICORNE energy range from 4MeV to 7 MeV by using the p(^{11}B,n) inverse reaction will also be presented along with the coupling with the Miniball high efficiency Ge spectrometer to study the gamma emission from individual fission fragments to obtain post neutron emission fragment yield information.

R169 Prompt fission gamma ray emission from the (d,p)-induced fission of 233U

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Prompt fission gamma-ray spectra have been measured in an experiment at the Oslo Cyclotron Laboratory (OCL), using a 12.5 MeV deuteron beam on a 233U target. Charged particle ejectiles were recorded with the SiRi particle telescope, in coincidence with γ-radiation in the CACTUS γ-detector system, and fission fragments were recorded with the NIFF PPAC-detectors. CACTUS consists of 28 5"5" NaI(Tl) crystals, mounted on a spherical frame; with a total efficiency of 15%.
The (d,pf) reaction has been used as a "surrogate" reaction for the (n,f) reaction, and characteristics such as the prompt fission gamma ray spectra, and the γ multiplicity have been studied. Both characteristics have been extracted as functions of excitation energy, in the energy range 5-10 MeV, in the fissioning nucleus. The results are compared to a similar experiment from the OCL on the 239Pu isotope.
In addition, the setup enables us to study the nuclear level density and the gamma ray strength function, and these properties have been extracted for the 234U isotope, from the same experiment. These results will also be presented.

R170 Correlations in prompt neutrons and gamma-rays from Cf-252 spontaneous fission

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New event-by-event fission models have prompt neutrons and gamma-rays that are correlated in time, energy, and multiplicity, however there is limited measurement data available to validate these models. Measurement of high-order fission neutron and gamma-ray coincidences is difficult and there has previously been little motivation to measure properties of both particle types simultaneously. High-order Cf-252 spontaneous fission neutron and gamma-ray coincidences were measured with a cylindrical array of 22 liquid organic and 8 NaI(Tl) scintillation detectors, 50 cm from a central axis. Waveforms were acquired and saved for post-processing using four time-synchronized CAEN V1720 digitizers. Liquid organic scintillator waveforms were analyzed with off-line pulse shape discrimination techniques to categorize neutron and gamma-ray detections. Detected multiplicity was compared with MCNPX-PoliMi simulation results, where built-in fission models and event-by-event fission models, CGMF and FREYA, have been implemented. Additionally, measured neutron energy by time-of-flight and gamma-ray energy correlated by detected multiplicity were compared to simulated results.

R171 Measurement of prompt fission gamma rays from Uranium-235 using spectrometer for exotic fission fragments at the neutron time of flight facility CERN

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The Nuclear Energy Agency (NEA) High Priority Request List[1] is a compilation of nuclear data improvement requests deemed most important to the nuclear energy community, designed to
help guide nuclear data research. Present on this list is a request for more accurate knowledge of the energy spectrum and multiplicity of prompt γ-rays produced during 235 U fission, due to the heating
effects these γ-rays have on reactors[2]. Previous works have studied this phenomenon and these nuclear data are being improved, however the majority of this work has been performed using thermal neutrons to induce fission, while the submitted request has expressed an interest in improving the quality of data in neutron energies across the whole energy spectrum. Previous work also ex-
hibits discrepancies up to approximately 15%, whereas the target uncertainty for this measurement is 7.5%; demonstrating the need for a more accurate measurement.
In response to this, the 'SpecTrometer for Exotic Fission Fragments' (STEFF), a detector designed at the University of Manchester, has performed experiments at the neutron Time-Of-Flight (n_TOF) facility at CERN. This facility uses a beam of 20 GeV/c protons impinging upon a lead spallation target to produce a white spectrum of neutrons, with energies ranging from thermal to above 1 GeV.
The neutrons are emitted almost isotropically from the target and the facility has two beamlines leading to experimental halls: one is horizontal and approximately 185 m in length (n_TOF EAR1),
the other is vertical and approximately 20 m (n_TOF EAR2). STEFF was situated in EAR2 containing a thin (100 μg cm -2) sample of 235 U. Using a system of gas ion chambers and fast timing
multi-channel plates, in conjunction with an array of NaI γ-ray scintillators of approximately 7.6% total efficiency, STEFF can measure very accurately the fission fragments and γ-rays released in (n,f) reactions. Using a time-of-flight technique to determine neutron energies, measurements of the prompt γ-rays have been recorded from thermal energies up into the keV energy region. The preliminary results from this experimental work will be presented.

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S172 Neutron-neutron and neutron-photon correlations with FREYA

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For many years, the state of the art for handling fission in radiation transport codes has involved sampling from average distributions. However, such “average” fission models have limited interaction- by-interaction capabilities. Energy is not explicitly conserved and no correlations are available because all particles are emitted isotropically and independently. However, in a true fission event, the energies, momenta and multiplicities of emitted particles are correlated. The **FREYA** (Fission Reaction Event Yield Algorithm) code generates complete fission events. Event-by-event techniques such as those of **FREYA** are particularly useful because it is possible to obtain complete kinematic information on the prompt neutrons and photons emitted during the fission process. It is therefore possible to extract any desired correlation observables. We describe **FREYA** and compare our results with neutron-neutron, neutron-light fragment and neutron-photon correlation data.
The work of R.V. was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344. The work of J.R. was performed under the auspices of the U.S. Department of Energy by Lawrence Berkeley National Laboratory under Contract DE-AC02-05CH11231. R.V. and J.R. also gratefully acknowledge support of the Office of Defense Nuclear Nonproliferation Research and Development in DOE/NNSA.

S173 Theoretical investigation of fission fragment observables in the symmetric mass region for thermal neutron induced fissions of 233U and 241Pu

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Fission yields are essential for nuclear reactor studies (decay heat, fuel inventory calculations,…) and constitute also one of the main observables needed to improve our understanding of the fission process. The symmetric mass region is of particular interest due to various intriguing properties of the Fission Fragments (FF) already reported in the literature: inversion of the nuclear charge polarization, large width of the FF kinetic energy distribution for some masses, strong change of the prompt neutron multiplicity, etc. Recently, in the frame of our collaboration between several French laboratories, new measurements of fission yields and kinetic energy distributions in the symmetric mass region were carried out at the mass spectrometer LOHENGRIN of the Institut Laue Langevin (Grenoble, France). Two neutron-induced fission reactions were investigated: $^{233}U(n_{th},f)$ and $^{241}Pu(n_{th},f)$. This experimental work is challenging due to the low counting rate in this region, but also due to the appearance of contaminant masses, leading to pronounced components in the FF kinetic energy distributions. In order to properly remove these undesirable contributions, a new data analysis procedure has been developed. For some masses of the symmetry region, the corrected kinetic energy distribution still shows two components, indicating that the fission process could be modal. Indeed, these structures can be seen as the reminiscence, after prompt neutron emission, of the two distinct valleys followed by the nucleus during the fission process. At the scission point, both valleys lead to the same mass split but with different shape elongations and therefore different kinetic energies. For a given mass, the low kinetic energy component could correspond to the so-called symmetric ‘Super-Long’ fission mode (according to the Brosa’s terminology), while the higher component could be attributed to the asymmetric ‘Standard’ fission mode. A comparison between our experimental data and the results obtained from Monte Carlo calculations (FIFRELIN code) simulating the deexcitation of the fission fragments will be presented and discussed.

S174 Total prompt gamma-ray emission in fission

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In response to the needed of the improved data on the prompt fission gamma rays endorsed by OECD/NEA, we have undertaken measurements of the total prompt gamma-ray energy distributions for the neutron-induced fission of 235U and 239,241Pu for the incident neutron energy range of 0.025 eV – 100 keV and the spontaneous fission of 252Cf using the Detector for Advanced Neutron Capture Experiments (DANCE) in coincidence with the detection of fission fragments by a parallel-plate avalanche counter. DANCE is a highly segmented, highly efficient 4pi gamma-ray calorimeter and consists of 160 equal-volume, equal-solid-angle BaF2 detectors. Corrections were made to the measured distribution by unfolding the two-dimensional spectrum of total gamma-ray energy vs. multiplicity using a simulated DANCE response matrix generated with a geometrical model of the detector arrays and validated with the gamma-ray calibrated sources. The mean values of the total prompt gamma-ray energy, determined from the unfolded distributions and given in the table below, are ~ 20% higher than those of early measurements for all the fissile nuclei studied. The current measurements enable one to evaluate the variance in addition to the average value of the energy deposit in medium by the prompt gamma rays. This would improve our understanding of the gamma heating in many applications involving nuclear fission. Details of the experimental measurements, analyses, and results will be presented.

Isotope	2-D	Ref. 1	ENDF/B-VII.1	Ref. 2	Refs. 3, 4, 5
235U	8.35		6.60	6.53(20)	6.92(9)
239Pu	7.94	7.46	6.74	6.78(10)	
241Pu	8.01		7.26		6.41(6)
252Cf	8.52			6.95(30)	6.64(8)

1.J.L. Ullmann et al. Phys. Rev. C 87, 044607 (2013).; 2.T.E. Valentine, Ann. Nucl. Energy 28, 191 (2001) and references therein.; 3.R. Billnert, F.-J. Hambsch, A. Oberstedt, and S. Oberstedt, Phys. Rev. C 87, 024601 (2013).; 4.A. Oberstedt et al., Phys. Rev. C 87, 051602(R) (2013).; 5.A. Oberstedt et al., Phys. Rev. C 90, 024618 (2014).
This work was performed under the auspices of the US Department of Energy by Lawrence Livermore National Security, LLC, under contract No. DE-AC52-07NA27344 and by Los Alamos National Security, LLC, under Contract No. DE-AC52-06NA25396. Partial funding is greatly acknowledged from the US DOE/NNSA Office of Defense Nuclear Nonproliferation Research and Development.

S175 Precision requirement of the photofission cross section for the nondestructive assay technique

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The development of the compact and quasi-monochromatic photon (X-ray) source generator has proceeded, which is expected to be realized as portable photon generator device with higher energy than the photonuclear threshold energy. Its application is expected to be one of the nondestructive assay (NDA) techniques for non-proliferation. In the present study, the sensitivity of a new NDA technique based on the photofission reaction to photonuclear cross sections of ^{235}U and ^{238}U have been investigated to prioritize their precision requirement.
The new NDA technique is aiming for uranium enrichment measurement, characterized by mathematical process which represents the correlation of the target enrichment and relative measured counts of neutron produced by the photofission reactions of ^{235}U and ^{238}U at different specific incident photon energies of 6MeV and 11 MeV. Principle of the technology was confirmed by small scale numerical simulation with good reproducibility of within 2% difference of predicted uranium enrichment and reported to [Kimura, JNST, 2016]. The results, however, also revealed the importance of the photofission cross section precision to evaluate the overall uncertainty.
The sensitivity of the NDA to photonuclear cross section has been investigated by MCNP6 and ENDF/B-VII.1 as a Monte Carlo code and photonuclear reaction data library. Simple geometry as same as the reference [Kimura, JNST, 2016] was considered in the simulation consisting of 1mm metallic enriched uranium slab target with 6/11 MeV photon injection on the target, causing the photofission reaction in the target. The tally of the fission reaction was evaluated to examine the number of fission reaction at the target caused by both photofission and neutron-fission.
Assuming 10% uncertainty of the photofission cross section of ^{235}U and ^{238}U in the range of 6 to 11 MeV, predicted uranium enrichment had a 16% uncertainty as a result. The maximum uncertainty of the uranium enrichment were highly depending on the uncertainty of the photofission cross sections to be reduced to less than 5% by selecting 3% uncertainty of the photofission cross section. Improvement of precision of the photofission cross section would contribute to the reliability of the new NDA technique.

I176 Prompt particle emission in fission - news on systematics and predictions for fission induced by fast neutrons

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During the last years prompt-fission particle emission has been measured, motivated by OECD/NEA requests for new values especially for gamma-ray multiplicities and mean photon energies, in particular for ^{235}U and ^{239}Pu. Both isotopes are considered the most important ones with respect to the modelling of innovative cores for fast Generation-IV reactors.
These results are investigated in terms of a revised version of systematics for prompt fission gamma-ray spectra (PFGS) characteristics as function of both atomic and mass number of the compound system [1], which allows estimating average gamma-ray multiplicity, mean and total photon energy in cases, where target nuclei are not available or not accessible experimentally. While this previously had been applied to thermal-neutron induced and spontaneous fission only, we show how PFGS characteristics may be predicted for fission induced also by fast neutrons. So far, calculations were performed for the target nuclei ^{238}U [2], ^{235}U and ^{239}Pu. Our results are compared to existing experimental and theoretical values.

[1]T.E. Valentine, *Ann. Nucl. Energy* **28, 191** (2001); [2]A. Oberstedt, R. Billnert, S. Oberstedt, *Physics Procedia* **59, 24** (2014)

R177 New prompt fission gamma-ray spectral data from 239Pu(nth,f) in response to a high priority request from OECD Nuclear Energy Agency

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Present knowledge on the released heat during fission states that around 10% of all energy released comes from gamma-rays, and about 40% of these are prompt. Hence a good evaluation of prompt fission gamma-rays characteristics for major isotopes (^{235}U,^{239}Pu) is crucial for modelling new nuclear reactors. Since currently evaluated data from the 1970s show a deviation from benchmark calculations of up to 28%, an urgent request for new prompt fission gamma -ray spectra (PFGS) measurements was put high on the OECD Nuclear Energy Agency (OECD/NEA) Nuclear Data High Priority Request List targeting at an uncertainty of 7.5%.
In recent years we executed a dedicated measurement program on prompt fission gamma-rays employing state-of-the-art lanthanum bromide ($LaBr_3$) detectors with superior timing and good energy resolution. Our new results from ^{252}Cf(SF), ^{235}U(n_{th},f) and ^{241}Pu(n_{th},f) provide PFGS characteristics (average number of photons per fission, average total energy per fission and mean photon energy) within 2% of uncertainty.
We will be presenting the latest results on ^{239}Pu(n_{th},f), measured at the Budapest Neutron Centre and supported by the CHANDA project in response to the OECD/NEA High Priority Request List, as well as discussing our different published results in comparison to the historical data and what it tells us about the discrepancy observed from the benchmark calculations.

R178 First experimental prompt gamma-ray spectra in fast neutron-induced fission

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The knowledge of prompt fission gamma-ray emission has been of major interest in reactor physics for a few years. Since no experimental spectra were ever published until now for fast neutron-induced fission, measurements would be also valuable to improve our understanding of the fission process. A simple experimental method was used to measure the prompt fission gamma-ray spectrum up to 10 MeV. In this approach, the gamma-rays are measured with a bismuth germanate (BGO) detector which offers two significant advantages with respect to other gamma-ray detectors: a high peak-to-total ratio and a high efficiency. The prompt fission neutrons are rejected by the time-of-flight technique between the BGO detector and a fission trigger given by a fission chamber. Prompt fission gamma-ray spectra were measured for 1.7, 5.2 and 15.6 MeV neutron-induced fission on 238U at the CEA, DAM, DIF Van de Graaff accelerator; average multiplicity and mean photon energy per fission were deduced from the spectra.

R179 Measurement of high-energy prompt gamma-rays from neutron induced fission of U-235

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The measurement of the prompt fission gamma-ray spectrum (PFGS) is quite important to study the de-excitation process of neutron-rich fission fragments as well as to generate data required to design a generation-IV reactors. The PFGS measured for spontaneous fission of Cf-252 [1] shows a broad bump at energies more than 8 MeV. This is interpreted as a giant dipole resonance (GDR) of the fragments centered around 15 MeV. In addition to the study of the GDR, the PFGS include information on sharing the total excitation energy between two fragments, and quantities such as level density parameters to describe de-excitation process of the fragments. For neutron induced fission, the measurements of PFGS is limited up to about 7 MeV even in the recent experiment for U-235 [2]. Hence we have designed new setup to take data up to energies high enough to observe GDR for neutron induced fission of U-235 using newly developed large volume LaBr3(Ce) scintillators and a digital data acquisition system. The measurement has been carried out at the PF1b beam line of the Institut Laue Langevin. An enriched U-235 target is mounted in the vacuum chamber. Fission fragments were detected with two multi-wired proportional counters and prompt gamma-rays from the fragments were observed by two large volume LaBr3(Ce) scintillators placed on both sides of the vacuum chamber. The intense cold neutron beam available at the PF1b beam line and the high efficiency LaBr3(Ce) scintillators enable us to increase the detection sensitivity for prompt gamma-rays by about 5 order of magnitude compared with recent measurement [2], which is high enough to take data at energies more than 15 MeV. In this contribution, we will present the details of the experimental method and results obtained the measurement

[1] H. van der Ploeg et al., Phys. Rev. C 52 (1995) 1915.; [2] A. Oberstedt et al., Phys. Rev. C 87 (2013) 051602.

I180 Status of the JENDL Project

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The latest version of the general purpose file JENDL-4.0 was released in 2010 by improving fission-product and minor-actinide data as well as covariance data to meet needs of innovative reactors. After that, the neutron energy range of JENDL-4.0 was extended up to 200 MeV for 130 nuclides, and the proton-induced reaction data for 133 nuclides were incorporated in order to meet needs from various accelerator applications such as accelerator driven system (ADS). They were compiled as JENDL-4.0/HE and released in 2015.
An activation cross section file for decommission of light-water reactors (LWRs) is under development and will be released in FY2016. It will contain neutron reaction data for approximately 300 nuclides in energy range of 10-5 eV to 20 MeV including isomer production cross sections. The JENDL Decay Data File 2015 was released in 2015. It would be used in estimation of radio-isotope production by radioactive decay in materials for the decommissioning. As the next step, the activation file will be upgraded by including important nuclides for applications other than the decommissioning of LWRs.
Evaluation of nuclear data for the next version of the general purpose file is also in progress. It is planned to be released by 2022. Several new evaluations mainly for fission products that had not been updated in JENDL-4.0 were already done. Data for light nuclei and structure material will be updated. Minor actinides data are still important to develop transmutation system of nuclear waste, and so they will be updated using new measurements especially done in J-PARC.Status of the JENDL project in developing the general and special purpose files will be presented.
This work was partly supported by the coordinated research on “The development of the data base for radiological characterization for nuclear facilities” with The Japan Atomic Power Company and The Institute of Applied Energy.

R181 A new evaluation of the neutron data standards

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A number of national cross section libraries are planning new versions of their libraries including ENDF/B. Updated standards evaluations will be needed for those libraries. Improvements have been made in the databases and evaluation techniques for the standards that have been included in a new standards evaluation that was recently completed. The evaluation resulted from a collaboration supported by an IAEA Data Development Project.
Measurements have been made for all the standard cross sections since the last evaluation of the standards. The database includes the cross sections for the H(n,n), ^{3}He(n,p), ^{6}Li(n,t), ^{10}B(n,αγ), ^{10}B(n,α), C(n,n), Au(n,γ), ^{235}U(n,f) and ^{238}U(n,f) standard reactions and ratios among them. The database also includes the ^{238}U(n,γ) and ^{239}Pu(n,f) cross sections in addition to the standard cross sections. Those data were included since there are many ratio measurements of those cross sections with the standards and absolute data are available on them. Thus they will have an impact on the standards in the evaluation process that includes ratio data. Work has been done recently to improve the ^{238}U(n,γ) and ^{239}Pu(n,f) cross sections. Work has also been done on the thermal constants.

Evaluations for reactions that are not traditional standards have also been made. Work was done on the gold cross section at energies below where it is considered a standard. This has resulted in improvements in this cross section particularly in the energy region where it is used as a reference in astrophysics applications. Reference cross sections for prompt gamma-ray production in fast neutron-induced reactions have been studied and the best candidates have been suggested. Also reference cross sections for very high energy fission cross sections have been evaluated.
An effort was directed at improvements in the evaluations of the ^{252}Cf spontaneous fission neutron spectrum and the ^{235}U thermal neutron fission spectrum.
The results obtained from the work on this project will be given at this meeting.

R182 On the search for a (n,f) cross-section reference at intermediate energies

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Accurate data on the fission of heavy nuclei at intermediate energies are of a renewed interest for both fundamental and applied nuclear physics. While for the energy range from 20 to 200 MeV there are experimental data good enough to get accurate evaluations, in the energy range from 200 MeV to 1 GeV there are not. The only evaluated information coming from the JENDL/HE-2007 nuclear data library has been seriously criticized by the work of Lo Meo et al. [NPA 933, 2015]. On the other hand, the IAEA has recently issued a document [Marcinkevicius et al., IAEA INDC(NDS)-0681, 2015] on the recommended references to be used in nuclear-fission applications in the intermediate energy region. The case of ^{235}U, ^{238}U, ^{209}Bi and ^{nat}Pb are there studied being clearly stated the lack of an experimental reference point, accurate enough to calibrate the experimental apparatuses used at different laboratories. In this work we will discuss on the (n,f) cross-section proposed as references by the IAEA for ^{235}U, ^{238}U and ^{209}Bi, comparing it with a new analysis that combines the measurements performed at CERN-nTOF of their cross-section ratios [Tarrío et al. PRC 83, 2011][Paradela et al. PRC 91, 2015] with new calculations done using MC codes based on phenomenological models INCL++, GEMINI++, and ABLA07. The calculations are cross-checked with those calculated for the (p,f) reactions, where experimental values are available.

We have so evaluated the (n,f) cross sections for ^{238}U, ^{235}U and ^{209}Bi, in the intermediate energy region going from 200 MeV to 3 GeV. For these Uranium isotopes, our results definitively discard the JENDL/HE evaluations above 300 MeV, falling inside the confidence corridor proposed by IAEA but for the points around 300 – 400 MeV where a discrepancy is to be noticed. For Bismuth, our new parametrization falls inside the uncertainties associated to the IAEA recommended values.

R183 An analytic approach to probability tables for the unresolved resonance region

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For neutron induced reactions below 20 MeV incident energy, the Unresolved Resonance Region (URR) connects the fast neutron region with the Resolved Resonance Region (RRR). The URR is problematic since resonances are not resolvable experimentally yet the fluctuations in the neutron cross sections play an discernible and technologically important role: the URR in a typical nucleus is in the 100 keV -- 2 MeV window where the typical fission spectrum peaks. The URR also represents the transition between R-matrix theory used to described isolated resonances and Hauser-Feshbach theory which accurately describes the average cross sections. In practice, only average or systematic features of the resonances in the URR are known and are tabulated in evaluations in a nuclear data library such as ENDF/B-VII.1. Codes such as AMPX and NJOY can compute the probability distribution of the cross section in the URR under some assumptions using Monte Carlo realizations of sets of resonances. These probability distributions are stored in the so-called PURR tables. In our work, we develop a scheme for computing the covariance of the cross section probability distribution using the Gaussian Orthogonal Ensemble triple integral. Under the assumption that the cross sections' probability distributions are normal or log-normal, we can compute the PURR tables analytically. We test our approach with an improvement to the Gaussian Orthogonal Ensemble inspired approach of Kawano, Talou and Weidenmueller. Our approach defines the limits of applicability of Hauser-Feshbach theory and suggests a way to calculate PURR tables directly from systematics for nuclei whose RRR is unknown.

S185 Evaluation of neutron total and capture cross sections on Tc-99 in the unresolved resonance region

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A nuclear data project entitled as “Research and development for Accuracy Improvement of neutron nuclear data on Minor ACtinides (AIMAC)” is being performed in Japan. The present study aims at high quality evaluation based on iterative communication with experimenters.
Technetium-99 is one of the most important radioisotopes for nuclear transmutation in long-lived fission products. The reliable nuclear data are indispensable for wide energy range up to a few MeV, in order to develop environmental load reducing technology. Nevertheless, it is found that the total cross sections of evaluated libraries, JENDL-4.0, ENDF/B-VII.1, JEFF-3.2 and CENDL-3.1 show large difference in the energies above the resolved resonance to 1 MeV due to no available experimental data. The total cross section of Tc-99 was calculated by the coupled-channels optical model. In order to constrain the total cross section in the unresolved resonance region, we adopted neutron strength function derived from the resolved resonance data of JENDL-4.0, together with experimental data above 1 MeV. The calculation of capture cross section was done by using the CCONE code. The resonance spacing was derived from the resonance data and used to fix the level density parameter. The present evaluation suggests that the total cross section is different from that of JENDL-4.0. In this presentation, the obtained total and capture cross sections will be compared and discussed with those of evaluated libraries.
Present study includes the result of “Research and Development for accuracy improvement of neutron nuclear data on minor actinides” entrusted to the Japan Atomic Energy Agency by the Ministry of Education, Culture, Sports, Science and Technology of Japan (MEXT).

S186 Improving activation cross section data with TALYS

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Nowadays Nuclear Data are expanding the area of their application and are acquiring more fundamental importance as well as more specific precision needs in various studies. The major part of available data is stored in computer readable formats in data libraries and includes general purpose files used for neutronic calculations. Unfortunately the problem with inconsistency between different data libraries still remains which demands additional efforts and approaches. The current work is focused on improving activation cross section data in the TENDL-2016 library. The nuclear reaction cross sections relevant for fusion and astrophysical needs were considered. The fits have been performed with the TALYS-1.8 code by means of nuclear model parameter variation. Mostly for the optical model and level densities, followed by comparison to the recent experimental data taken from EXFOR and other evaluated nuclear databases. The updated cross section data are going to be adopted to the new version of TENDL. The improvements have been performed both for differential as well as integral data sets.

S187 Updated and revised neutron reaction data for n+236,238Np

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The nuclear data with high accuracy for minor actinides play an important role in nuclear technology applications, including reactor design and operation, fuel cycle, estimation of the amount of minor actinides in high burn-up reactors and the minor actinides transmutation. Base on a new set of neutron optical model parameter and the reaction cross section systematic of Np isotopes reaction, a full set of ^{236,238}Np neutron nuclear data from 10^{-5} ~ 20 MeV were updated and improved through theoretical calculation. The mainly revised quantities include the total, elastic, inelastic, fission, (n, 2n) and (n, g) cross sections as well as angular distribution etc. The promising results were obtained when the renewal evaluated data of ^{236,238}Np will be used to instead of the evaluated data in CENDL-3.1 database.

S188 Comparison evaluation for neutron cross section of 250Cf

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The purpose of this study is to analyze the time-of-flight cross section data in the resolved and unresolved resonance regions, where the incident particle is either a neutron or a charged particle (p, alpha, d, ...). Energy-differential cross sections and angular-distribution data are treated, as are certain forms of energy-integrated data. In the Resolved Resonance Region (RRR), theoretical cross sections are generated using the Reich-Moore approximation to R-matrix theory (and extensions thereof). Sophisticated models are used to describe the experimental situation: Data-reduction parameters (e.g. normalization, background, sample thickness) are included. Several options are available for both resolution and Doppler broadening, including a crystal-lattice model for Doppler broadening. Self-shielding and multiple-scattering correction options are available for analysis of capture cross sections. Multiple isotopes and impurities within a sample are handled accurately. Cross sections in the Unresolved Resonance Region (URR) can also be analyzed using SAMMY. The capability was borrowed from Froehner's FITACS code; SAMMY modifications for the URR include more exact calculation of partial derivatives, normalization options for the experimental data, increased flexibility for input of experimental data, introduction of user-friendly input options. Nuclear data of Cf-250 have been evaluated in the energy range from 0.00001 eV to 20 MeV. There exist only a few experimental data for the cross sections of both the, isotopes, which is, the cross sections at the thermal neutron energy and the resonance integrals. Therefore, the present evaluation was based on systematic trends of the data and the calculation with the optical, statistical and evaporation models. The evaluted cross sections in this work are the total, elastic and inelastic scattering, fission, radiative capture, (n,2n), (n,3n) and (n,4n) reaction cross sections. In the energy range below 150 eV, hypothetical resonance levels were generated so as to reproduce the measure! thermal cross sections and resonance integrals. Other evaluated quantities are the angular distributions of elastically and inelastically scattered neutrons and those of neutrons emitted from the (n,2n), (n,3n), (n,4n) and fission reactions, their energy distributions, and average numbers of neutrons emitted per fission.

I189 The TENDL library: hope, reality and future

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The TALYS Evaluated Nuclear Data Library (TENDL) has now 8 releases since 2008. Considerable experience has been acquired for the production of such general-purpose nuclear data library based on the feedbacks from users, evaluators and processing experts. The backbone of this achievement is simple and robust: completeness, quality and reproducibility.

If TENDL is extensively used in many fields of applications, it is necessary to understand its strong points and remaining weaknesses. Alternatively, the essential knowledge is not the TENDL library itself, but rather the necessary method and tools, making the library a side product and focusing the efforts on the evaluation knowledge. The future of such approach will be discussed with the hope of nearby greater success.

R190 TALYS/TENDL-2014 verification and validation processes: outcomes and recommendations

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The TALYS-generated Evaluated Nuclear Data Libraries (TENDL) provide truly general-purpose nuclear data files assembled from the outputs of the T6 nuclear model codes system for direct use in both basic physics and engineering applications. The most recent TENDL-2014 version is based on both default and adjusted parameters of the most recent TALYS, TAFIS, TANES, TARES, TEFAL, TASMAN codes wrapped into a Total Monte Carlo loop for uncertainty quantification. TENDL-2014 contains complete neutron-incident evaluations for all target nuclides with Z < 116 with half-life longer than 1 second (2632 isotopes), up to 200 MeV, with covariances and all reaction daughter products including isomers of half-life greater than 0.1 second. With the added High Fidelity Resonance (HFR) approach, all resonances are unique, following statistical rules.

The validation of the TENDL-2014 neutron-induced library against standard, evaluated, microscopic and integral cross sections has been performed against a newly compiled UKAEA database of thermal, resonance integral, Maxwellian averages, 14 MeV and various accelerator-driven neutron source spectra. This has been assembled using the most up-to-date, internationally-recognised data sources including the Atlas of Resonances, CRC, evaluated EXFOR, activation databases, fusion, fission and astrophysics experiments. Excellent agreement with TENDL-2014 values is found with a small set of errors within the reference databases andTENDL-2014 predictions.

This work surveys the set of UKAEA validation efforts [1,2,3,4], summarising the overall findings and identifying errors and areas for model or input improvement. These should be re-examined and, where appropriate, lead to re-evaluations for future TENDL distributions. These can be generally broken down as: (1) updating input parameter databases, (2) modification of resolved resonance formalism, (3) improving the automated use of CALENDF to generate statistically resolved/extended resonance regions, (4) re-examination of pre-equilibrium mechanisms for specific channels/energies (5) extension of man-made model limits/restrictions and (6) harmonisation of equivalent yield/partial channels using finer detail and improved processing.

R191 Development and application of hybrid evaluated nuclear data library HENDL for advanced nuclear energy systems

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The nuclear data library used for the traditional fission reactor is relatively perfect and mature. But there is no mature applied nuclear data library for the advanced nuclear energy systems in the research phase, for example Accelerator-Driven Subcritical System, Fusion-driven Subcritical System, et al. For ADS nuclear design and analysis, there have some preliminary applied nuclear data including ADS.lib, La150 and JENDL/HE. But these nuclear data libraries had some defects, such as energy range can't cover ADS spectral range, too little nuclide and insufficient physical effect correction. In addition, there is lack of specialized applied nuclear data library for fusion-driven subcritical system.
FDS Team have developed Hybrid Evaluated Nuclear Data Library HENDL[1-5] according the need of design and analysis for advanced nuclear energy systems. HENDL has been developed based on the latest nuclear evaluation files optimized by simulation results of criticality safety experiments and neutron shielding integral experiments. The HENDL had 420 kinds of nuclide, the neutron cross section of HENDL had energy range from 10^{-5}eV to 150 MeV, which covered the major energy range for the advanced nuclear energy system.
The group structure, weighting function design, as well as the correction for physical effect has been deeply studied in the design for HENDL. For the research of energy structure, first, the high-energy new reaction channel energy points of key nuclides, high energy nuclear reaction threshold and cross section change energy points were gotten. Second, the optimized group structure was design according to the comprehensive analysis above. And appropriate weighting function distribution of advanced nuclear power system was obtained by using the least square method to high energy spectrum analysis in the research for typical advanced nuclear energy systems. A optimizing background section method[5] was developed for the correction of strong resonance self-shielding effect and this method overcame effect the influence of resonance interference.
To validate and qualify the reliability of HENDL, more than 2000 benchmark models and experiments, such as ICSBEP, SINBAD, IRPhEP, BEAVR, ITER C-lite etc, have been performed. And the testing results indicated that the nuclear system had accuracy and reliability. Now HENDL has been successfully applied in the nuclear design and analysis for the international thermonuclear experimental reactor, Experimental Advanced Superconducting Tokamak EAST, FDS series reactor and the China Lead-Alloy Cooled Reactor CLEAR.

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R192 Nuclear data infrastructure and API for the new nuclear data format defined by WPEC subgroup 38

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Subgroup 38 of the Working Party on Evaluation Co-operation (WPEC SG38) has been working since 2012 to define a modern, flexible nuclear data format to eventually replace the Evaluated Nuclear Data Format (currently ENDF-6). With SG38 nearing completion, supporting infrastructure for processing and manipulating data in the new nuclear data format is required. LLNL is working both to implement a version of the new format called Generalized Nuclear Data (GND), and to extend its nuclear data infrastructure code FUDGE and its low-level nuclear data access library GIDI to handle GND-formatted data in deterministic and Monte Carlo transport codes.
FUDGE (For Updating Data and Generating Evaluations) is a set of python modules that: 1) convert ENDF-6 files to and from GND, 2) read/write GND formatted data, 3) reconstruct cross sections and angular distribution data from resonance parameters, 4) heat cross sections, 5) support modification of data, 6) visualize GND data, 7) perform physics checking, and 8) support deterministic and Monte Carlo processing (e.g., creating multi-group cross sections and transfer matrices).
GIDI (General Interaction Data Interface) is a C++ API that reads GND formatted data for use in Monte Carlo and deterministic transport codes. It also samples data for Monte Carlo transport codes.
In this talk, we describe the current status of FUDGE with a focus on processing evaluated nuclear data for deterministic and Monte Carlo transport codes. We also describe GIDI and demonstrate results from integrating GIDI into LLNL's Monte Carlo simulation code called Mercury.

I193 Activation and AMS for studying neutron-induced reactions on 232Th and 235,238U in the keV to MeV energy range

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Major nuclear data libraries show discrepancies at keV and MeV energies for ^{235,238}U(n,γ), ^{232}Th(n,γ) but also for (n,xn) reactions. Similarly, differences were found for the cross-section ratio ^{238}U(n,γ)/^{197}Au(n,γ) at keV energies between data based on TOF and prompt γ-detection and accelerator mass spectrometry (AMS). A major difficulty in such experiments is the discrimination against a strong γ-background (e.g. from the competing fission channel) or unfavourable decay schemes. Only recently measurements have been performed for such reactions applying AMS. This method, based on direct atom-counting of the reaction products, has the advantage that the involved systematic uncertainties are in no way correlated with the uncertainties inherent e.g. to the TOF technique. Therefore, such data provide important and independent information for key reactions of reactor physics.
We have extended our previous (n,γ) measurements on ^{235,238}U using AMS to higher neutron energies and to additional reaction channels. Within the EUFRAT programme natural uranium and thorium samples were exposed to neutrons of energies between 0.5 and 23 MeV at IRMM. After the activation, the production of longer-lived nuclides was quantified by AMS. The radionuclides counted via AMS were either the direct product of a reaction or a decay-product of a directly produced short-lived nuclide. A particular feature of the U and Th isotopes are their low (n,2n) and (n,3n) thresholds; even the ^{232}Th(n,4n) reaction could be studied.
We will present new data for ^{232}Th(n,γ), ^{232}Th(n,2n), ^{232}Th(n,4n) and ^{232}Th(n,α), as well as for ^{238}U(n,γ) and ^{235,238}U(n,3n).

R194 Measurement of the 89Y(n,2n)88Y reaction cross section at AWE's ASP neutron source

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The ASP accelerator (DT neutron generator) was used to measure the ^{89}Y(n,2n)^{88}Y cross section for the first time at the AWE. Foils of ^{89}Y were irradiated for a period of approximately 25 hours and measured over a period of 4 months. The activation of the experimental foils were extrapolated to time t=0 and from this the number of activated nuclei was determined. The number of activated nuclei was used in conjunction with fission chamber data, published evaluations and a simulated neutron spectrum to calculate a scaling factor for each evaluated cross section curve. The results are consistent with published data with scaling factors close to unity. The results are also shown as a single point by averaging the energy and the cross section. The half life of ^{88}Y was also assessed as part of this work and all of these results shows good self-consistent agreement with published data.

R195 Preliminary determination of cross sections of 39K(n,p)39Ar induced by D-neutrons

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The cross section of the ^{39}K(n,p)^{39}Ar induced by neutron with energy around 2.5 MeV is important for ^{40}Ar/^{39}Ar geochronology. From the literatures, all the published values were measured before 1967s and with big uncertainties. Meanwhile, there are large discrepancies between the measured and evaluation results. By taking advantage of the high sensitivity and high resolution rare gas mass spectrometry at Institute of Geology and Geophysics, Chinese Academy of Sciences.
Natural Nickel foil and standard potassium samples were irradiated by neutrons produce by a ^{2}H(d,n)^{3}He neutron generator at China Institute of Atomic Energy (CIAE). The neutron fluence was determined using the monitor reactions ^{58}Ni(n,p)^{58}Co via measured the gamma-ray activities using a low background gamma ray spectrometer equipped with a coaxial HPGe γ-ray detector. Then the argon isotopes were determined by the mass spectrometry. As a result, the cross sections of ^{39}K(n,p)^{39}Ar for the average neutron energy of 2.50 ± 0.40 MeV and 3.10 ± 0.40 MeV were obtained. The results were compared with previously reported measured corss sections and evaluation data.
Our results are useful for verifying the accuracy of nuclear models used in the calculation of cross sections and nuclear data evaluations, especially to improve the data accuracy in ^{40}Ar/^{39}Ar geochronology.

R196 The cross section functions for neutron reactions with Rhenium in the energy range 13.0 -19.5 MeV

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The technique for measuring neutron activation cross-sections using wide energy neutron beams (NAXSUN) was recently developed at IRMM [1-3]. This method is based on the detection of the gamma activity induced by the activation of the samples in different but overlapping neutron fields and following an unfolding procedure. In the present work, measurements of the cross-section functions by the NAXSUN technique for the (n,a), (n,2n), (n,p) and (n,3n) reactions on rhenium istopes ^{185}Re and ^{187}Re were performed. The results are the first experimental data for the mentioned reaction cross-sections in the energy range 13.0-19.5 MeV. The obtained data are of interest for possible applications of Re in nuclear technology and medicine.

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S197 Measurements of the 6Li(n,α)t standard cross-section at the GELINA facility

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The ^{6}Li(n,α) reaction cross-section is an established standard because of its relatively high cross-section as well as its high Q-value. However, it is only considered a neutron standard up to 1 MeV. In order to extend and establish ^{6}Li(n,α) as a neutron standard above 1 MeV some issues must be resolved. In the neutron energy region 1–3 MeV there are discrepancies of several per cents between recent measurements [1, 2] and evaluated data files [3].
It has been speculated [4] that negligence of the particle leaking effect might be part of the explanation why there is a disagreement in this region. In the region around 2 MeV one also expects, based on R-matrix calculations, three excitation levels of ^{7}Li to significantly influence the cross section. These levels are much broader than the level responsible for the large resonance observed at 240 keV, therefore, their contribution to the cross section will be more smeared out.
Our measurement at the GELINA facility at JRC-IRMM in Geel, Belgium is ongoing. Previously, a double twin Frisch-grid setup was used to detect the α-particles from the ^{6}Li(n,α) reaction as well as the fission products from the ^{235}U(n,f) reaction, i.e., a single chamber for both reactions. Even though our targets have thick backings, they are employed in pairs in a back-to-back configuration, allowing us to cover, in principle, a solid angle of 4π. Preliminary results, from 2014, using this setup showed that the existing cross-section data could be well reproduced around the resonance at 240keV. However, several problems were identified which are now fixed in an updated setup.
The old chamber is being split into two separate chambers in order to accommodate for different gas pressures. A chamber with higher gas pressure allows us to detect not only the α-particles but also tritons from the lithium reaction. For the detection of the fission products we use a chamber with lower pressure, due to the much higher stopping power of heavy ions. Here, we review the current situation for the measurement and report on new results from the data taken during 2016 with the modified setup.

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S198 Cross section of the 197Au (n,2n) 197Aug+m1,m2 reaction

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Neutron reactions on ^{197}Au are very important as reference/monitor reactions as well as for testing nuclear models. The need, especially at high energies, of accurate reference/monitor reactions for advanced reactor system studies and other applications, has been emphasized in several IAEA meetings. The available reaction data present many discrepancies, thus more complete and reliable data are necessary.
The cross section of the reaction ^{197}Au(n,2n) has been experimentally determined relative to the ^{27}Al(n,α)^{24}Na reaction in the neutron energy range 15.3 – 20.9 MeV by means of the activation technique. The monoenergetic neutron beam was produced at the 5.5 MV Tandem accelerator of NCSR “Demokritos”, by means of the ^{3}H(d,n)^{4}He reaction implementing a new Ti- tritiated target consisted of 2.1 mg/cm^{2} Ti-t layer on a 1 mm thick Cu backing for good heat conduction. After the end of the irradiations, the activity induced by the neutron beams at the targets and reference foils, has been measured by HPGe detectors. The cross sections for the population of the second isomeric (12^{-}) state m2 of ^{196}Au and the sum of the ground (2^{-}) and first isomeric (5^{-}) state g+m1 population cross sections were independently determined. Theoretical calculations of the above cross sections were carried out with the use of the EMPIRE code.

S199 Cross sections of the 144Sm(n,α)141Nd and 66Zn(n,α)63Ni reactions at 4.0, 5.0 and 6.0 MeV

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Cross sections of the ^{144}Sm(n,α)^{141}Nd and ^{66}Zn(n,α)^{63}Ni reactions were measured at E_n = 4.0, 5.0 and 6.0 MeV performed at the 4.5-MV Van de Graaff Accelerator of Peking University, China. A double-section gridded ionization chamber was used to detect the alpha particles. The enriched samples of $^{144}Sm_2O_3$ and ^{66}Zn were placed at the common cathode plate of the chamber. Monoenergetic neutrons were produced by a deuterium gas target through the ^{2}H(d,n)^{3}He reaction. The neutron flux was monitored by a BF_3 long counter. Cross sections of the ^{238}U(n,f) reaction were used as the standard to perform the (n,α) reaction measurement. Present results are compared with existing measurements, evaluations and TALYS-1.6 code calculations.

S200 Measurements of neutron capture cross-section on 70Zinc

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The cross sections of the ^{70}Zn(n,γ)^{71}Zn^m ($T_{1/2}$ = 3.96±0.05 hrs) reaction have been measured relative to the ^{197}Au(n,γ)^{198}Au cross sections. The neutrons are obtained by the ^{7}Li(p,n)^{7}Be reaction at incident proton energies 2.8 MeV and 3.5 MeV. The experiment was carried out at the Folded Tandem Ion Accelerator (FOTIA) Facility, Nuclear Physics Division, Bhabha Atomic Research Centre (BARC), Mumbai. The neutron spectra at these incident proton energies are obtained by ^{7}Li(p,n)^{7}Be neutron spectrum code EPEN (Energy of Proton-Energy of Neutron) developed by our group. The activation technique was employed where the **γ**-ray activities of the product nuclei ^{71}Zn^m and ^{198}Au were measured using a pre-calibrated lead-shielded 185 cc high purity germanium (HPGe) detector having 30% relative efficiency, and 1.8 keV energy resolution at 1.33 MeV **γ**-energy. The data acquisition was carried out using CAMAC based LAMPS (Linux Advanced Multi Parameter System) software (TCAMCON-95/CC 2000 crates controller and CM-48 ADCs). The cross section of this reaction has been measured for the first time in the MeV region. The data analysis is carried out using the latest decay data, and by applying the various corrections such as low energy neutron backgrounds from ^{7}Li(p,n_1)^{7}Be* reaction, sample as well as room scattered background neutrons, neutron beam fluctuation and gamma self-attenuation. The measured cross sections are compared with theoretical prediction by TALYS-1.6 with various level density models as well as TENDL-2014. The ^{70}Zn(n,γ)^{71}Zn^{g+m} total capture cross-sections have also been derived by applying the evaluated isomeric ratios in the TENDL-2014 library. The covariance information for ^{70}Zn(n,γ)^{71}Zn^m reaction cross-sections are also obtained.

I201 Recent cross-section measurements of neutron-induced reactions of importance for background estimates in neutrino-less double-beta decay searches

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A program is underway at Triangle Universities Nuclear Laboratory (TUNL) to measure neutron capture, (n,2n), and partial γ-ray cross sections on nuclei important to ongoing searches for neutrino-less double-beta ($0\nu\beta\beta$) decay. Although these searches take place deep underground in mines, so-called spallation neutrons and neutrons from (μ,n) reactions created in the detector itself and/or in the surrounding shielding and cooling materials are of great concern. These neurons could induce signals in the detectors which are indistinguishable from the signals of interest. At TUNL we are focusing on the important neutron energy range between 1 and 15 MeV.
Currently large-scale $0\nu\beta\beta$ searches involve the isotopes ^{76}Ge, ^{130}Te and ^{136}Xe as $0\nu\beta\beta$ source. In the GERDA (^{76}Ge), Majorana (^{76}Ge), CUORE (^{130}Te) and EXO (^{136}Xe) experiments these isotopes are also the main detector medium, while the KamLAND-Zen experiment uses ^{136}Xe dissolved in liquid scintillator. Because the detectors are not enriched to 100% in the isotopes of interest for $0\nu\beta\beta$ decay, neutron induced reactions on ^{74}Ge, ^{128}Te and ^{134}Xe are also of importance, in addition to reactions involving shielding and cooling materials like lead, copper and liquid argon.
We will present data for the reactions ^{40}Ar(n, γ), ^{63,65}Cu(n,γ), ^{74,76}Ge(n, γ), ^{128,130}Te(n, γ), ^{124,136}Xe(n, γ), and ^{63,65}Cu(n,2n), ^{76}Ge(n,2n), ^{128,130}Te(n,2n), ^{124,136}Xe(n,2n), and ^{40}Ar(n,n′ γ), ^{74,76}Ge(n,n′ γ), ^{134,136}Xe(n,n′ γ) and ^{76}Ge(n,p).

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R202 10B(n,α0) and 10B(n,α1) cross section data up to 3 MeV incident neutrons

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The ^{10}B(n,α) reaction cross-section is a well-established neutron cross-section standard for incident neutron energies up to 1 MeV. However, above this energy limit there are scarce direct (n,α) measurements available and these few experimental data are showing large inconsistencies with each other [1]. These discrepancies are reflected in the evaluated data libraries: ENDF/B-VII.1, JEFF-3.1.2 and JENDL-4.0 are in excellent agreement up to 100 keV incident neutrons, whereas the ^{10}B(n,α) data in the different libraries show large differences in the MeV region. To address these inconsistencies, we have measured the cross section of the two branches of the ^{10}B(n,α) reaction for incident neutron energies up to 3 MeV. We present here the ^{10}B(n,α_0) and the ^{10}B(n,$\alpha_1\gamma$) reactions cross section data, their branching ratio and the total ^{10}B(n,α) reaction cross section. The measurements were conducted with a dedicated Frisch-grid ionization chamber installed at the GELINA pulsed neutron source of the EC-JRC-IRMM. We compare our results with the existing experimental data and evaluations.

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R203 Study of (n,2n) reaction on 191,193Ir isotopes and isomeric cross section ratios

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The study of neutron induced reactions and, whenever it is possible, of their isomeric cross section ratios, is of considerable importance for testing nuclear models. The probability of forming isomeric states, is sensitive to the spin state values of the levels involved and to the spin distribution in the continuum of the compound nucleus. The high spin value 11^- of the second isomeric state (m2) of ^{190}Ir relative to the corresponding 4^- value of its ground state (g), offers this opportunity to study the spin distribution of the residual nucleus.
The cross section of ^{191}Ir(n,2n)^{190}Ir^{g+m1} and ^{191}Ir(n,2n)^{190}Ir^{m2} reactions has been measured at 17.1 and 20.9 MeV neutron energies at the 5.5 MV tandem T11/25 Accelerator Laboratory of NCSR "Demokritos", using the activation technique. The neutron beams were produced by means of the ^{3}H(d,n)^{4}He reaction at a flux of the order of 10^5-10^6n/cm^2 s. The neutron flux has been deduced implementing the ^{27}Al(n,α) reference reaction, while the flux variation of the neutron beam was monitored by using a BF_3 detector. The ^{193}Ir(n,2n)^{192}Ir reaction cross section has also been determined, taking into account the contribution from the contaminant ^{191}Ir(n,γ)^{192}Ir reaction. The correction method is based on the existing in ENDF data of the contaminant reaction, convoluted with the neutron spectra which have been extensively studied by means of simulations using the NeusDesc and MCNP codes. Statistical model calculations using the code EMPIRE 3.1 and taking into account pre-equilibrium emission have been performed on the data measured in this work as well as on data reported in literature.

R204 Inelastic neutron scattering cross-section measurements on 7Li and 63,65Cu

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The γ-ray production cross section for the 477.6-keV transition in ^{7}Li following inelastic neutron scattering has been measured from the reaction threshold up to 18 MeV. This cross section is interesting as a possible standard for other inelastic scattering measurements. The experiment was conducted at the Geel Electron LINear Accelerator (GELINA) pulsed white neutron source with the Gamma Array for Inelastic Neutron Scattering (GAINS) spectrometer. Previous measurements of this cross section are reviewed and compared with our results. Recently, this cross section has also been calculated using the continuum-discretized coupled-channels (CDCC) method.
Experiments for studying neutrinoless double-β decay (0νββ) or other very rare processes require greatly reducing the background radiation level (both intrinsic and external). Copper is a common shielding and structural material, used extensively in experiments such as COBRA, CUORE, EXO, GERDA, and MAJORANA. Understanding the background contribution arising from neutron interactions in Cu is important when searching for very weak experimental signals. Neutron inelastic scattering on ^{nat}Cu was investigated with GAINS. The results are compared with previous experimental data, model calculations using the TALYS 1.8 code, and evaluated nuclear data libraries.

I205 Impact of intermediate and high-energy nuclear data on the neutronic safety parameters of MYRRHA accelerator driven system

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Along with the advantages of safe operation of an Accelerator Driven System, the coupling of a charged particle accelerator to a sub-critical core brings many challenges in the design. Various abnormal situations with the beam impinging on the spallation target may occur. The beam may deviate from its axial direction and hit the fuel assemblies or the beam shape may be disrupted. This study evaluates such situations for the MYRRHA Accelerator Driven System. A linear accelerator will deliver a 600 MeV doughnut-like proton beam swept around central axis onto a Lead-Bismuth Eutectic (LBE) spallation target located in the central sub-assembly of a sub-critical core. The core will be loaded with MOX fuel and cooled by LBE.
Various situations of beam distortion are considered and their influence on the core neutronic characteristics is studied. The local heating of the fuel pins is most crucial parameter determining the safety of the sub-critical core operation in case of abnormal situation. Other important parameters are neutron source multiplication which in large extent determines the heating, and radiation damage of structural materials, even if the misalignment is assumed to be quickly detected.
The sensitivity of these safety parameters to the variations of physics models describing interactions of intermediate and high energy (above 20 MeV) primary protons and secondary neutrons is assessed. The combinations of intranuclear cascade, pre-equilibrium and equilibrium models incorporated in the general purpose radiation transport code MCNPX are compared. The JENDL-HE neutron and proton transport library is also considered. The sensitivities to the nuclear data evaluations of major general purpose libraries ENDF/B, JEFF, JENDL and TENDL are also provided.
The ranking of the isotopes of fuel, LBE and structural materials regarding the influence of their intermediate and high-energy data on the discussed safety parameters is given.
The analysis is performed in two steps. Firstly, the variance of the considered neutronic characteristics is studied for normal operation conditions. Secondly, an additional spread due to the misaligned beam is evaluated.

R206 Nuclear data sensitivity analysis and evaluated data library comparison for MYRRHA relevant quantities

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The uncertainty in nuclear data is one of the most important sources of uncertainty in reactor physics simulations; however, scientists using nuclear data generally consider the uncertainty information contained in the evaluated data libraries to be insufficiently reliable. The CHANDA European project (solving CHAllenges in Nuclear Data) aims to solve the challenges present in the field of nuclear data for nuclear applications, allowing European scientists and institutions to upgrade the nuclear data needed for simulation tools, improving the accuracy of code assessments and getting better estimations of the safety and economic margins of nuclear systems.
In particular, the work package 10 of CHANDA is focused on the analysis of the nuclear data required for the development, safety assessment and licensing of the lead-cooled fast neutron spectrum MYRRHA experimental reactor being designed at SCK-CEN. Within the work package 10, the first task included the nuclear data Sensitivity and Uncertainty analysis of the current MYRRHA design using different codes and methodologies.
In this paper, results of the sensitivity analysis carried out with the MCNP6.1.1b code are presented, providing the sensitivity of the effective neutron multiplication factor of MYRRHA critical core to changes in the energy dependent cross sections contained in different versions of JEFF, ENDF/B and JENDL evaluated nuclear data libraries for key reactions and nuclides. Furthermore, a comparison between the results obtained using the state-of-the-art nuclear data libraries is performed. The results of this study, along with additional results obtained in this task, will allow an in-depth analysis of the current nuclear data libraries and to identify experimental data that can be used to improve the present evaluations, with the objective of reducing the uncertainties of nuclear data relevant for MYRRHA.

R207 Decay heat uncertainty quantification of MYRRHA

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MYRRHA (Multi-purpose hybrid research reactor for high-tech applications) is a lead-bismuth cooled MOX-fueled accelerated driven system (ADS) currently in the designing phase at SCK•CEN in Belgium. The correct evaluation of the decay heat and of its uncertainty level is very important in the safety demonstration. In this work we assessed the decay heat released by the MYRRHA core after one irradiation cycle using ALEPH, the SCK•CEN burnup code. ALEPH was previously validated for such calculations against the experimental decay heat measurements of ^{239}Pu and ^{238}U fission pulses.

ALEPH effectively predicted the decay heat curves. Differences in between calculations and measurements are compatible with nuclear data input uncertainties. On top of that, with the new ALEPH routine for adjoint perturbation theory along depletion we were able to calculate the decay heat uncertainty and its sensitivity to nuclear data, such as decay constants, decay energy and fission yields.

The second part of the study focused on the nuclear data uncertainty and covariance propagation to the MYRRHA decay heat. We propagated radioactive decay data and fission yield uncertainties with the ALEPH adjoint routine. Cross section covariances for ^{238}U, ^{239}Pu, and the most important fission products were propagated with the NUDUNA code, developed by AREVA GmbH, which performs nuclear data random sampling.

According to the results, ^{238}U cross sections and fission yields are prominent contributors to the MYRRHA decay heat uncertainty, although the effect of the latter can be strongly reduced by the introduction of fission yield covariances.

Finally, uncertainties on the fission pulse decay heat values were used to improve the estimate of the MYRRHA decay heat uncertainty by Bayesian inference.

R208 On prediction accuracy of neutronics parameters of accelerator-driven sub-critical system

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ADS is one of promising nuclear systems, which has a potential to drastically reduce the burden of nuclear waste disposal. Since accurate prediction of neutronics parameters of ADS is essential and important, so many efforts have been devoted to uncertainty quantifications and reductions of the ADS neutronics parameters. In the present work, we evaluate nuclear data-induced uncertainty of neutronics parameters of one specific ADS design. It is notable that this is conducted with combined information of microscopic data and macroscopic data: covariance data provided in the evaluated nuclear data files and presently available integral data. This combination is realized by application of the so-called nuclear data adjustment method. For ADS neutronics parameters predictions, several integral data provided in the ICSBEP handbook, such as the SPEC-MET-FAST (SMF) data, are useful. When we utilize the SMF-2, -8, -11 and -14 data, which are sensitive to nuclear data of neptunium-237 and plutonium-238, nuclear data-induced uncertainties of the ADS neutronics parameters are reduced in comparison with those estimated only with the microscopic data. For example, the uncertainties of effective neutron multiplication factors at the initial burnup cycle and at the end of cycle 3 are reduced from 0.95% to 0.87% and from 1.44% to 1.26%, respectively. Actually these uncertainties are higher than those required by the ADS designers, so we plan to add other integral data such as sample reactivity worth measurement data conducted at FCA in JAEA and other data in the ICSBEP handbook, and attempt to further reduce nuclear data-induced uncertainties. We intend to make it clear whether new microscopic/macroscopic measurements are required for the ADS development or not through this study.

S209 The evaluated nuclear data library for ADS in China

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The Aaccelerator-Driven System (ADS) is defined as a system driven by energetic particles of GeV range accelerated by a so-called high power accelerator incorporated normally with a target of a heavy element, which generates intense secondary particles, e.g., neutron, proton, etc., via the spallation nuclear process. The application of the scheme involves the nuclear transmutation for high level nuclear waste (HLW), plutonium burner for proliferation resistance, the energy production, fissile or tritium fuel breeding, neutron sources for material irradiation, neutron scattering science, industrial applications, and so on. To address these needs, a program is under way to develop new evaluated nuclear data libraries for incident protons and neutrons up to 200 MeV for a range of high-priority elements in the ENDF/B format. These evaluations are based on a combination of nuclear model calculations and measured data to evaluate cross sections.
The theoretical model code UNF has been made based on the frame of the optical model, the unified Hauser-Feshbach and exciton model which includes Iwamoto-Harada model at incident neutron energies below 20 MeV. To keep the energy balance, the recoil effects are taken into account for all of the reaction processes. The nuclear reaction models code MEND which can give all kinds of reaction cross sections and energy spectra for six outgoing light particles (neutron, proton, alpha, deuteron, triton, and helium) and various residual nuclei in the energy range up to 250 MeV, has been developed. Fission is included as a decay channel, that is, a fission competitive width can be estimated at every step of the cascades. The uncoupled fission barrier is used to represent the fission system and describe different channels, respectively.
All cross sections of neutron induced reactions, angular distributions, energy spectra and double differential cross sections are consistent calculated and evaluated for 23Na 24,25,26Mg, 27Al, 28,29,30Si, 31P, 32,33,34,36S, 40,42,43,44,46,48Ca, 50,51V, 50,52,53,54Cr, 54,56,57,58Fe, 59Co, 58,60,61,62,64Ni, 63,65Cu, 90,91,92,93,94,95,96Zr, 93Nb, 92,94,95,96,97,98,100Mo, 107,109Ag, 113,115In, 181Ta, 180,182,183,184, 186W, 197Au, 204,206,207,208Pb, 209Bi, 232Th, 237Np, 232,233,234,235,236,237,238,239,240U, 236,237, 238,239,240,241,242,243,244,246Pu, 241,242m,242,243Am and 243,244,245,246,247,248Cm at incident neutron energies below 200 MeV, based on the nuclear theoretical models. All cross sections of proton induced reactions, angular distributions, energy spectra and double differential cross sections are consistent calculated and evaluated for 27Al, 28,29,30Si, 40,42,43,44,46,48Ca, 54,56,57,58Fe, 59Co, 58,60,61,62,64Ni, 63,65Cu, 90,91,92,94,96Zr, 92,94,95,96,97,98,100Mo, 180,182,183,184,186W, 204,206,207,208Pb, 209Bi, 232Th, and 235,238U at incident proton energies below 200 MeV.
Theoretical calculated results are compared with the existing experimental data, and ENDF/B7 and JENDL-4. Good agreement is generally observed between the calculated results and the experimental data. Since the improved Iwamoto-Harada model has been included in the exciton model for the light composite particle emissions, the theoretical models provide the good description of the shapes and magnitude of the energy spectra and double differential cross section of emission deuteron, triton, helium and alpha. The evaluated data is stored using ENDF/B high-energy format.

S210 Comparative analysis of the non-destructive methods to control fissile materials in large containers

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One of the most important characteristic that confirms the “closed” type of a nuclear fuel cycle is the non-proliferation of nuclear materials and therefore preventing the actinide loss above ~ 0,1% over the all stages of the cycle. Thereby the task is to detect tiny amounts (tens of milligrams per kilogram of high level waste (HLW)) of fissile material in HLW that contains fission products with a dose rate of up to kSv/h. This task can be solve by using active neutron interrogation equipped with detectors that are not sensible to gammas, but effectively detect neutrons.
Our previous work showed the ability to detect ~ 1 mg of unshielded uranium-235 inside an empty 70 liter container irradiated with $5{\cdot}10^8$ n/s flux from the ING-07T neutron generator during 8 min [1]. Now we start to explore the sensitivity of the used helium-3 counters to high γ-background. The effects of pulses overlay on the count rates of helium-3 counters were simulated at different gamma-backgrounds and counters operation modes. The simulated effects are confirmed by measuring the counting rate of helium-3 counters exposed to Co-60 γ-source of 4 Ci activity. Also various kinds of shielding are proposed to protect the helium-3 counter to reduce its gamma response. Different types of other detectors are compared if used in the task. The probable scheme of active neutron assembly is outlined for industrial control of HLW.

[1] VIACHESLAV F. BATYAEV, SERGEY S. SKLYAROV., Potential of active neutron interrogation to control fissile materials in “closed” fuel cycle. International Conference on Management of Spent Fuel from Nuclear Power Reactors: An Integrated Approach to the Back End of the Fuel Cycle, IAEA, Vienna, 2015.

S211 Cross-sections from deuteron irradiation of thin thorium target at energy 7 GeV

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The residual nuclei yields are of great importance for the estimation of basic radiation-technology characteristics (like a total target activity, production of long-lived nuclides etc.) of accelerator driven systems planned for transmutation of spent nuclear fuel and for a design of radioisotopes production facilities. Experimental data are also essential for validation of nuclear codes describing various stages of a spallation reaction. Therefore, the main aim of this work is to add new experimental data in high-energy deuteron region. The sample made of thin natural thorium foil was irradiated at JINR Nuclotron accelerator with a direct deuteron beam. Deuteron flux density was determined with the use of aluminum activation detectors. Products of deuteron induced spallation reaction were qualified and quantified by means of activation measurement and gamma-ray spectroscopy methods. Several important spectroscopic corrections were applied to obtain high precision results. Experimental cumulative and independent cross-sections were determined for more than 80 isotopes including meta-stable isomers. Non-symmetrical mass yield fission curve was reconstructed. The systematic error of results was estimated to 13 %. Experimental results were compared with MCNP6 Monte-Carlo code predictions. Several high-energy event generators and nuclear models were used (LAQGSM.03.03, INCL). Generally, experimental and calculated cross-sections are in a reasonably good agreement, with the exception of a few light isotopes in fragmentation region, where the calculations are highly under-estimated. Measured data can be used for future development of high-energy nuclear codes and will supplement rare data in EXFOR database.

S212 Work plan for improving the DARWIN2.3 depleted material balance calculation concerning some important isotopes for fuel cycle

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DARWIN2.3 [1] is the French reference package used for fuel cycle applications. It solves the Boltzmann and Bateman equations in a coupling way, with the European JEFF3.1.1 nuclear data library, to compute the fuel cycle parameters. It integrates both the deterministic transport APOLLO2 [2] (for light water reactors) or ERANOS2 [3] (for fast reactors) code and the depletion DARWIN/PEPIN2 [4] code developed by CEA.

The DARWIN2.3 package has been experimentally validated for pressurized and boiling water reactors, but also for sodium fast reactors for the material balance of the main actinides and the fission products involved in burnup credit criticality calculations and in decay heat calculation; this experimental validation relies on the analysis of post-irradiated experiments (PIE). The DARWIN2.3 experimental validation work points out some isotopes for which the depleted concentration calculation is not completely satisfactory, such as for instance ^{244}Cm. Some other isotopes have no available experimental validation, and the accuracy associated with the calculation of their concentration is provided by the propagation of a priori nuclear data uncertainties.
This paper describes the studies which are launched today to improve the accuracy of the DARWIN2.3 depleted material balance calculation concerning some isotopes important for cycle.
The DARWIN2.3 calculation biases and uncertainties are defined with the C/E values brought by the experimental validation. The C/E values can have several origins:
- the calculation methods (all the approximations of the calculation scheme)
- the nuclear data used for the transport and depletion calculations (cross sections, fission yields, radioactive periods, branching ratios).
The uncertainties associated with C/E values gather the uncertainty due to the control of the irradiation history modelling and the experimental uncertainties.
Elements for the quantification of the DARWIN2.3 calculation method biases will be handled; first, the impact of the up-scattering treatment for heavy nuclides in the resonance energy range will be studied for an APOLLO2 depletion calculation. Besides, comparisons between DARWIN2.3 and TRIPOLI4®-D [5] calculations (code for the coupling of the Boltzmann and the Bateman equations; at each time step, the neutron flux is calculated in Monte Carlo) will be performed. These results will be provided in the full paper.

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I213 Systematic investigation of the energy dependence in 136Xe on proton spallation reactions

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The energy dependence of 136Xe on proton spallation reactions was investigated at the Fragment Separator at GSI by measuring the isotopic distributions of the production cross sections of the residual nuclei produced. The combined used of the inverse kinematics and a high-resolving power magnetic spectrometer allow to fully identify in atomic and mass number all the residual nuclei produce in those reactions at 1000, 500 and 200 A MeV.
The measurement at the lowest energy was particularly challenging because of the non negligible presence of charge states at that energy. This measurement was also interesting because this energy represents the limit of validity for intra-nuclear cascade codes. Moreover in that case nucleon-nucleon collisions are governed only by elastic interactions.
Measurements around 500 MeV are representative for many of the applications of spallation reactions. At this energy level one should also consider the role of inelastic nucleon-nucleon collisions.

Finally the comparison of the isotopic distributions of the production cross sections of the residual nuclei produced in these reactions at different energies provides relevant information on the spallation process and represents an important data set for the validation of intra-nuclear cascade codes.

R214 Measurement of Al(p,x)Be-7, Al(p,x)Na-22, 24, C(p,x)T+He-3 and C(p,x)He-4 cross section for 3-GeV proton

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At the spallation neutron source in J-PARC, aluminum alloy is employed as the proton beam window, which plays role of the boundary between vacuum and helium region around at mercury target vessel. In order to estimate lifetime and the residual dose of the proton beam window, it is necessary to understand the accuracy of the production cross section for 3-GeV protons. Although many activation data of Al were observed up to 2.6 GeV at many facilities, the data at 3-GeV was, however, scares. To obtain the data of aluminum, the reaction cross section for aluminum was measured at the entrance of beam dump placed 3-GeV proton synchrotron. By using well-calibrated current transformers and the well-collimated beam, the present data has good accuracy. After irradiation, Al(p,x)Be-7, Al(p,x)Na-22 and Al(p,x)Na-24 cross section was obtained by the gamma ray spectroscopy using Ge detector. It is found that the present cross sections show good agreement with the extrapolation of the existing experimental data as energy function. The evaluated data of JENDL/HE 2007 shows good agreement with the present data. Also the gas production, such as T and He, cross section for carbon, which was utilized as muon production target in J-PARC, was measured. The muon production target is rotating target, which is cooled by only the heat radiation, and has high temperature about 500 C during beam exposure so that gas such as T and He is released to the vacuum regiont. The experiment was performed for 0.5 MW beam power of 3-GeV proton with reputation rate of 25 Hz and the amount of gas was observed by quadrupole mass spectrometer in the vacuum line at beam transport to the mercury target. The sensitivity of the mass spectrometer was calibrated by the standard leak source of He. The JENDL/HE 2007 shows good agreement with the present data.

R215 Spallation reaction study for fission products in nuclear waste: cross section measurements for 137Cs, 90Sr, and 107Pd on proton and deuteron at different reaction energy

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Reduction in the quantity of high-level radioactive waste in the spent fuel is one of the major issues for the use of a nuclear power plant. Research and development into the reduction of radioactive waste using partitioning and transmutation technology has been performed over recent decades. In particular, the transmutation on the long-lived fission products (LLFPs) has received much attention. The LLFP nuclei have large radiotoxicities and long lifetimes, and they can be produced continuously in the accelerator driven systems and next-generation nuclear reactors in addition. It is essential to find effective reactions for the LLFP transmutation. However, experimental reaction data are currently lacking.
Aiming at bringing a new invention to the nuclear transmutation on LLFP, we have studied the proton- and deuteron-induced spallation reactions for the long-lived fission products ^{137}Cs, ^{90}Sr, and ^{107}Pd. Our study on ^{137}Cs and ^{90}Sr [1] is the first attempt in the history of nuclear physics to solve the problem of the LLFP transmutation and has triggered the reaction studies for other long-lived fission products.
The experiments were performed at the RIKEN Radioactive Isotope Beam Factory. The inverse kinematics was applied in order to study systematically the target dependence of reactions, and to avoid the difficulties associated with using a highly radioactive target. The LLFP beams were produced by in-flight fission of a ^{238}U primary beam at 345 MeV/nucleon in the BigRIPS separator. The reaction residues were analyzed by the ZeroDegree spectrometer. Both the LLFP beams and reaction products were unambiguously identified event-by-event. The proton- and deuteron-induced spallation cross sections were obtained by using the polyethylene (CH_2), deuterated polyethylene (CD_2), and natural carbon targets at reaction energies around both 200 and 100 MeV/nucleon. The new results were compared with the spallation model with intra-nuclear cascade and evaporation processes.
In the presentation, the results on the spallation of ^{137}Cs, ^{90}Sr, and ^{107}Pd as well as the potential of spallation reaction on the LLFP transmutation will be discussed.

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R216 Measurement of 430-MeV/u carbon, nitrogen and oxygen incident neutron production cross sections for carbon

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Heavy ion cancer therapy has been increased by reason of its clinical advantages. The secondary particles such as neutron and gamma-ray are produced by nuclear reactions of a heavy ion incidence in a patient body. The neutron cross section data is essential for assessment of secondary cancer risk of patients. Accurate data in neutron energy around 1 MeV is required because neutron in that energy region has large relative biological effectiveness. We have measured the neutron double differential cross sections from carbon, nitrogen and oxygen ion incidences on a carbon target of neutron energy above 1 MeV with 430-MeV/u.
The experiment was performed at Heavy Ion Medical Accelerator in Chiba (HIMAC), National Institute of Radiological Sciences. The 430-MeV/u heavy ion beams were delivered via a plastic scintillator to a target. Average beam intensity was about 1E5 ions/3.3sec. The thicknesses of graphite targets were chosen for an incident ion to deposit its energy of about 10 % in the targets. Two sizes of NE213 scintillators were applied for wide energy range neutrons. Both size detectors were placed at 15, 30, 45, 60, 75 and 90 degrees. The neutron energy was measured by the time-of-flight (TOF) technique.
In data analysis, charged particle, gamma-ray events were eliminated using light output spectra of veto counters and pulse shape discrimination for light output of NE213 scintillators, respectively. The SCINFUL-QMD code was used to obtain the detection efficiencies of NE213 scintillators.
Experimental results of neutron double differential cross sections were obtained in energy range from 1 MeV to 600 MeV. The measured data have some fluctuations below 10 MeV because background the number of neutrons was relatively higher than that above 10 MeV. It was found that PHITS reproduces the measured cross sections of carbon incident case below 100 MeV and slightly overestimates above the energy. The quantum molecular dynamics model, which is adopted in PHITS as a theoretical one for dynamical process of heavy ion induced nuclear reaction, would cause this disagreement. The present work data will help to improve of the model. Data for nitrogen and oxygen incidences will be discussed.

I217 The n_TOF facility: neutron beams for challenging future measurements at CERN

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The CERN n_TOF neutron beam facility is characterized by a very high instantaneous neutron flux, excellent TOF resolution at the 185 m long flight path (EAR1), low intrinsic background and coverage of a wide range of neutron energies, from thermal to a few GeV. These characteristics provide a unique possibility to perform high-accuracy measurements of neutron-induced reaction cross-sections and angular distributions of interest for fundamental and applied Nuclear Physics. Since 2001, the n_TOF Collaboration has collected a wealth of high quality nuclear data relevant for nuclear astrophysics, nuclear reactor technology, nuclear medicine, etc.
The overall efficiency of the experimental program and the range of possible measurements have been expanded with the construction of a second experimental area (EAR-2), located 20 m on the vertical above the n_TOF spallation target. This upgrade, which benefits from a neutron flux 30 times higher than in EAR1, provides a substantial improvement in measurement capabilities, opening the possibility to collect data on neutron cross-sections of isotopes with short half-lives or only available in very small amounts.
This contribution will outline the main characteristics of the n_TOF facility, with special emphasis on the new experimental area. In particular, we will discuss the innovative features of the EAR2 neutron beam that open possibilities for very challenging measurements on short-lived radioisotopes or sub-mg samples, out of reach up to now at other neutron facilities around the world. Finally, the future perspectives of the facility will discussed.

R218 New deuterium-deuterium (D-D) neutron generator developed for medical, industry and home land security application

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A new deuterium-deuterium (D-D) neutron generator has been developed for wide range of applications. These applications include medical (i.e., Boron Neutron Capture Therapy, BNCT), homeland security (i.e., Prompt Gamma Activation Analysis, PGAA and Fast Neutron Activation Analysis, FNAA) and industry (PGAA and Neutron Radiography). The plausibility of BNCT treatment of the cancer using neutrons from a DD-110 is assessed by calculating the distribution of photon equivalent dose on a breast phantom using Monte-Carlo (MCNP6) simulations. Beam Shaping Assemblies (BSA) is investigated and an optimized configuration is proposed. The radiography facility used in the measurements and simulations employs a fully high-voltage-shielded, D-D neutron generator. Both fast and thermal neutron images were acquired with the generator and a Charge Coupled Devices camera. To shorten the imaging time and decrease the noise from gamma radiation, various collimator designs were proposed and simulated using MCNP6. Design considerations included the choice of material, thickness, position and aperture for the collimator. Optimization of a D-D neutron generator based Explosive Detection System (EDS) was performed using Monte-Carlo simulation. The shape and the thickness of the moderators and shields are optimised to produce the highest thermal neutron flux at explosive position and the minimum total dose at the outer surfaces of the explosive detection system walls. In addition simulation of the response functions of NaI, BGO, and LaBr3-based -ray detectors to pure chemical elements is described.

R219 Development of compact accelerator neutron source

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With the development of high-intensity accelerators it is now envisage to build compact high-intensity neutron sources for applications which are up to now only devoted to nuclear research reactors. The most symbolic project is the International Fusion Materials Irradiation Facility IFMIF using high-energy neutrons produced by the primary interaction between a deuteron beam and the Lithium target for the qualification of materials which might be used in future nuclear fusion reactors. However, other applications leading to major industrial or societal challenges can be expected such as nuclear data measurements for nuclear industry, fundamental solid state physics studies with neutron scattering experiments, neutron radiography especially for industry materials qualification and also medical purposes like isotope production, neutron-capture therapy.

Compact accelerator-based neutron sources are currently fast-growing leading to the founding in 2009 of the community UCANS (Union for Compact Accelerator-driven Neutron Sources) for promotion and stimulation in development of such sources especially for medical perspectives. They are attractive alternative solutions to nuclear research reactors especially in term of public acceptance as well as for nuclear non-proliferation. Many facilities around the world have already chosen this option but these concern accelerators with few mA of continuous current.

In CEA we have started a work to promote such technology based on the existing 100 mA IPHI proton injector developed at IRFU/SACM. To provide an economical way of neutron production, low energy proton-induced reactions are considered. In our case less than 20 MeV protons on thin Beryllium-target are envisaged. As most of applications need moderated neutrons a lot of work has to be done to optimize the target-moderator assembly in order to maximize the neutron rate for the measurements. This work is mainly done by simulation using validated simulation tools

After a short review of CANS developments in the world, I will present the development status of the GEANT4-based simulation tool and the already calculated performances for some configurations showing good competitiveness with existing facilities. The key technological issues will be addressed in particular in terms of nuclear data and model point of views as well as the development plan of a prototype in Saclay.

R220 Characterisation of the n_TOF EAR2 neutron beam

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CERN's neutron time-of-flight facility (n_TOF) experimental area 2 (EAR-2), which has been constructed and is operational since 2014, is designed and built as a short-distance complementary to experimental area 1 (EAR-1). The parallel plate avalanche counter (PPAC) beam profile measurement was performed at EAR-2 on July of 2015. The experiment setup including the n_TOF facility and detector system is presented. Some basic characteristics of this new neutron beam line (EAR2), such as beam profile and neutron flux, are obtained. The prompt γ-flash which is used for calibrating the neutrons' time-of-flight at EAR-1 is not seen by PPAC at EAR-2, shedding light on the physical origin of this γ-flash, which will be discussed.

R221 On the possible use of the MASURCA reactor as a flexible, high-intensity, fast neutron beam facility

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In recent work [1], we have shown that the MASURCA research reactor could be used to deliver a fairly-intense continuous fast neutron beam to an experimental room located next to the reactor core. We report here new results of this feasibility study in which we demonstrate that, by optimizing the geometrical setup of the core and radial channel, in combination with filters, beam intensities of up to 1.3×10^8 neutrons cm^{-2} s^{-1} can be reached, with 96% of the neutrons having energies above 10 keV. As a consequence of the MASURCA favorable characteristics and diverse material inventories, the neutron beam intensity and spectrum can be further tailored to meet the users' needs, which could be of interest for several applications. Monte Carlo simulations have been performed to characterize in detail the extracted neutron (and photon) beam entering the experimental room. These numerical simulations were done for two different bare cores: A uranium metallic core (~30% ^{235}U enriched) and a plutonium oxide core (~25% Pu fraction, ~78% ^{239}Pu). The results show that the distinctive resonance energy structures of the two core leakage spectra are preserved at the channel exit. As the experimental room is large enough to house a dedicated set of neutron spectrometry instruments, we have investigated several candidate neutron spectrum measurement techniques, which could be implemented to guarantee well-defined a repeatable beam conditions to users. Our investigation also includes considerations regarding the photons in the beams.

[1] L. Dioni, R. Jacqmin, M. Sumini, B. Stout, "A Multipurpose Fast Neutron Beam Capability at the MASURCA Facility", *ANIMMA 2015*, Lisbon (2015)

S222 Monte Carlo simulations of the n_TOF lead spallation target with the Geant4 toolkit: a benchmark study

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We present Monte Carlo simulations, carried out with the Geant4 toolkit, of the lead target of the n_TOF facility at CERN, for neutron production by spallation reactions with 20 GeV/c protons. The main goal was the validation of the intra-nuclear cascade models implemented in the code (Binary, Bertini and INCL++ cascade models) using, as benchmark, the characteristics of the neutron beam measured at the first experimental area (EAR1), especially the neutron flux and energy distribution, and the time distribution of neutrons of equal kinetic energy (the so-called "resolution function"). The second goal was the development of a Monte Carlo tool to provide useful calculations for both the analysis and planning of the upcoming measurements at the new experimental area (EAR2) of the facility. The geometry model was developed quite thoroughly, following the technical drawings as accurately as possible, since details of the geometry and materials of the surrounding structures (such as cooling and moderator circuits, target vessel, beginning of beam lines and concrete walls) have a significant impact on the neutron energy distribution and resolution function scored at both experimental areas, especially for delayed thermal neutrons. Our calculations show that the shape of the energy distribution is remarkably well reproduced by all sets of models recommended by the Geant4 collaboration (known as "reference physics lists"), especially below 10 MeV. The choice of a certain intra-nuclear cascade model showed a significant impact on the calculated integral flux of neutrons as well as on the shape of the neutron energy distribution above 10 MeV in both experimental areas. Among the physics lists considered in this work, those using the INCL++ cascade model gave the best overall agreement with respect to the experimental data, showing differences not larger than 20%.

I223 White neutron source and nuclear data measurement platform at CSNS

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CSNS (China Spallation Neutron Source) is a large scientific facility under construction, aiming for multidisciplinary research, which will be completed in early 2018. Taking the high proton power of 100 kW at Phase-I and 500 kW at Phase-II, it is also advantageous to add a white neutron beamline for nuclear data measurements in the facility. Study shows that the back-streaming neutrons at the spallation target have the typical characteristics as a white neutron beam, very intense flux of 10^7 n/cm^2/s at a flight distance of 50 m, very wide energy spectrum of ev to 100 MeV, good time resolution of 1 ns to tens ns. A project (CSNS Back-n) to use the back-streaming neutrons for nuclear data measurements has been proposed and gets supported by a consortium of five institutions. The CSNS Back-n beamline has two endstations, at 50 m and 80 m from the target, respectively. The time resolution at 80 m can reach a few per mille in most cases, and special CSNS operation modes have been designed to obtain a best resolution of 1.5 per mille for the whole energy range. Six spectrometers including multi-layer fission chamber, BaF2 array for neutron capture, HPGe array, Light-particle emission measurement spectrometer, Prompt-fission neutron spectrum measurement spectrometer and total cross-section measurement spectrometer have been designed and will be built. Among them, four spectrometers will be available for experiments in late 2017 when the CSNS spallation target receices the first proton beam.

R224 p+thin 9Be as a source of quasi-monoenergetic neutrons

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The cyclotron driven fast quasi-monoenergetic neutron source based on the p+thin ^{9}Be reaction was studied in the Department of Nuclear Reactions of the NPI Řež. Isochronous cyclotron U-120M provides protons in the energy range of 20-38 MeV and currents up to 20 μA.
The aim is to replace the most used p+thin Li neutron source with the p+thin ^{9}Be, for neutron cross section measurements. The p+thin ^{9}Be provides a similar quasi-monoenergetic neutron spectrum as the p+thin Li source, but with significantly higher neutron output due to higher melting point of Be.
There are only few measurements of the neutron spectra from thin Be. Therefore, the experimental measurement of the p+thin ^{9}Be spectrum at the proton energy around 30 MeV was performed. The time-of-flight method at three distances with NE 213 scintillator and 10 bit digitizer with 1 GHz sampling frequency was used.
The measured neutron spectrum was compared with predictions based on experimental data and databases. The results from our measurements agree with other experimental data and indicate only two peaks, separated by some 2-3 MeV, in the p+thin ^{9}Be neutron spectrum.

R225 Proton and neutron test facilities at 1 GeV synchrocyclotron of PNPI for radiation resistance testing of avionic and space electronics

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A description of the proton and neutron test facilities based on the 1 GeV synchrocyclotron SC-1000 at the PNPI and used for radiation resistance testing of electronic components and systems intended for avionic and space research is presented. A unique conjunction of proton and neutron beams enables to perform complex testing of the semiconductor electronic devices within a single testing cycle.
At present, two proton beam lines are used for radiation resistance testing. The IS SC-1000 testing facility provides proton beam with fixed energy of 1000 MeV, while at the IS OP-1000 facility the proton energy might be varied from 100 to 1000 MeV with a 100 MeV increment by means of a set of copper degraders. Both beam lines provide variable intensity from 10^{5} to 10^{8} p/cm^{2}·s, beam diameter ≥ 25 mm and uniformity better than 10%. The beam lines are equipped with a remotely controlled system intended for device under test positioning and heating in a 20°-125°C temperature range.
The testing facility IS NP/GNEIS with a neutron spectrum resembling that of cosmic-ray neutrons is based on the high-energy beam of neutron time-of-flight spectrometer GNEIS. A broad energy range (1-1000 MeV) spectrum of the spallation neutron source providing neutron flux of $4 \cdot 10^{5}$ n/cm^{2}·s is used for accelerated SEE-testing of semiconductor electronic components. A high quality collimation of the neutron beam 50-100 mm of diameter in conjunction with the TOF-technique enables to carry out precise and reliable monitoring of the neutron beam which is carried out by means of a fission ionization chamber (FIC) as beam monitor and a position sensitive multiwire proportional counter as beam profile meter.
Today, a number of Russian research organizations specialized in radiation testing of the electronics conduct their research on the SC-1000 beams under direct agreements with the PNPI or with the Branch of JSC "United Rocket and Space Corporation" - "Institute of Space Device Engineering" (Moscow), a Head Organization of the ROSCOSMOS Interagency Testing Center. A convenient location of the PNPI close to St. Petersburg with its highly developed transportation system makes it very attractive for potential users both from Russia and abroad.

R226 Cross section measurement of residues produced in proton- and deuteron-induced spallation reactions on 93Zr at 100 MeV/u using the inverse kinematics method

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The long-lived fission products (LLFPs) which are produced in nuclear reactors have been an important issue because of the difficulty of disposal due to their remarkably long lifetimes. Therefore some sort of treatment method to transform the LLFPs into short-lived and/or low-toxic materials is strongly desired and the nuclear transmutation technology is expected to be one of the promising candidates. However, the reaction data of LLFPs required for the design of an optimum pathway of the transmutation process are quite scarce at this moment. One of the reasons is that there is considerable difficulty in both manufacturing and handling of LLFP targets which are needed for the conventional measurement in normal kinematics such as the activation method.
In this study, we employed the inverse-kinematics method, in which the nuclide to be measured and the probe are the projectile and the target, respectively, and hence there is no need to handle the radioactive targets. In addition, this method has a crucial advantage that one can measure the production yield over a wide range of isotopes regardless of their lifetimes.
We performed an experiment for the measurements of isotopic production cross section on ^{93}Zr, which is an LLFP nuclide with the half-life of 1.53 Myear, through the proton- and deuteron-induced spallation reactions at RIKEN RI Beam Factory (RIBF). A beam including ^{93}Zr at 100 MeV/u was produced by in-flight fission of a ^{238}U beam at 345 MeV/u and separated by using the BigRIPS in-flight separator. Then the beam bombarded CH_2, CD_2, and pure C targets and the fragments produced through the spallation reaction were identified event-by-event by using the ZeroDegree spectrometer. The obtained cross sections corresponding to proton, deuteron, and ^{12}C injection were compared with the calculations using some dynamical and statistical decay models. The detail of the experiment and the result of the analysis will be discussed.

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I227 New approaches to provide feedback from nuclear and covariance data adjustment for effective improvement of evaluated nuclear data files

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A critical examination of data adjustments methods is underway since several years in the frame of successive OECD-NEA WPEC subgroups. Subgroup 33 has succeeded in providing a deeper understanding of nuclear data and associated covariance adjustment methods, the role of integral experiment uncertainties and of their application. The new WPEC subgroup 39 is intended to provide criteria and practical approaches to use effectively the results of sensitivity analyses and cross section adjustments for feedback to evaluators and differential measurement experimentalists in order to improve without ambiguities the knowledge of neutron cross sections, uncertainties, and correlations to be used in a wide range of applications.
An approach has been envisaged that expands as much as possible the use in the adjustment procedure of selected integral experiments that provide information on "elementary" phenomena, on separated individual physics effects related to specific isotopes or on specific energy ranges. In practice in the present work, in order to complement the "classical" set of integral experiments (criticality, reaction rates, reactivity coefficients) used e.g. in Subgroup 33 in the fast energy range, new more focused experiments have been used, in particular βeff experiments that detailed sensitivity analysis have shown to provide, beside information on delayed neutron parameters, new selective information on e.g. the U-238 inelastic, elastic, fission and prompt fission spectrum data, while epithermal high accuracy under-moderated LWR experiments (k_∞, reaction rates, void reactivity effects) performed in the past in the PROTEUS facility have been used to enhance the otherwise scarce sensitivity to the actinide cross sections in the energy range ≤ 1 keV. Moreover, the ASPIS-88 experiment provides specific feedbacks on iron scattering (elastic and inelastic) cross sections, and the MANTRA irradiation experiments are sensitive to actinides and fission products capture cross sections in the range from few hundred eV to 1 eV.
The full paper will show the impact of these new experiments, in terms of robustness of the adjustment and their added value in order to provide credible indications on major actinides and structural materials cross section nominal values, their energy behavior and associated uncertainties that could be used in the most advanced new nuclear data evaluations.

R228 Impact of uncertainties in the uranium 235 cross section resonance structure on characteristics measured in the BFS-79 critical assemblies

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The report presents the results of an analysis of benchmark experiments form the international ICSBEP Handbook (HEU-MET-INTER-005) carried out at the the SSC RF – IPPE in cooperation with the Idaho National Laboratory (INL, USA) applicable to the verification of calculations of a wide range of tasks related to safe storage of vitrified radioactive waste. Experiments on the BFS critical assemblies make it possible to perform a large series of studies needed for neutron data refinement, including measurements of reactivity effects which allow testing the neutron cross section resonance structure. These measurements are rather sensitive to the resonance region peculiarities and may supplement the measurements of neutron transmission functions. The results of integral experiments on measuring the reactivity effects have been actively used in recent years for the resonance energy region analysis of different isotopes.
The report analyzes an impact of uncertainties in ^{235}U neutron capture and fission cross sections within the fast-intermediate energy range on characteristics measured in the BFS-79 critical assemblies. The authors provide an overview of current works aimed at refining ^{235}U nuclear cross sections based on the revision of experimental measurements of resonance effects within the intermediate energy region of 500-2500 eV.
The calculation analysis of the BFS assemblies was performed using the MCNP transport code and recent versions of the evaluated neutron data libraries (ROSFOND, ENDF/B-7.1, JEFF-3.2, JENDL-4.0, TENDL-2014). The calculated benchmark models of BFS-79 assemblies from the ICSBEP Handbook have been supplemented with the calculation of measured reaction rates and reactivity introduced by the enriched uranium samples of various sizes into the BFS-79 central area. Based on the analysis of uncertainties in the ^{235}U resonance region within the energy range of 500-2500 eV, it became possible to justify the calculated experimental discrepancies in reactivity measurements.
Thus, it is shown that despite the wide range of available experimental data, in so far as it relates to the resonance region refinement, the experiments on reactivity measurement make it possible to more subtly reflect the resonance structure peculiarities in addition to the time-of-flight measurement method.

R229 Determining the nuclear data uncertainty on MONK10 and WIMS10 criticality calculations

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The criticality safety assessment of a system containing fissile material requires a demonstration that the calculated neutron multiplication factor, k-effective, is sufficiently low to ensure that the risk of criticality under normal and accident conditions is tolerable. The required difference between k-effective and unity depends upon the accepted sub-critical limit and allowances for the uncertainty on the calculated value of k-effective. This uncertainty arises from a number of sources, including nuclear data uncertainties, manufacturing tolerances on input data, modelling approximations/errors and, for Monte Carlo simulation, stochastic uncertainty.

The ANSWERS Software Service is developing a number of techniques to better understand and quantify uncertainty on the calculated values of k-effective. For determining the uncertainties due to nuclear data, a set of application libraries have been generated for use with the MONK10 stochastic criticality and reactor physics code and the WIMS10 deterministic reactor physics code. This paper overviews the generation of these nuclear data libraries by Latin Hypercube Sampling of JEFF3.1.2 evaluated data based upon a covariance library constructed from covariance data taken from JEFF, ENDF/B, JENDL and TENDL evaluations. Criticality calculations have been performed with MONK10 and WIMS10 using these sampled libraries for a number of benchmark models of fissile systems. Results are presented which show the uncertainty on k-effective for these systems arising from the uncertainty on the input nuclear data.

R230 Validation of tungsten cross sections in the neutron energy region up to 100 kev

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Following the series of recent cross section evaluations on tungsten isotopes performed by Pigni and Leal[1][2][3] at Oak Ridge National Laboratory (ORNL), the aim of this paper is to present the validation work carried out to test the performance of the calculated cross sections based on Lead Slowing-Down (LSD) benchmarks[4].
Performed with support from the US Nuclear Criticality Safety Program (NCSP) in an effort to provide improved tungsten cross section and covariance data for criticality safety analyses, ORNL completed the resonance parameter evaluation of four tungsten isotopes in August 2014. The ^{182,183,184,186}W resonance evaluations were submitted as ENDF-compatible file to be part of the next release of the ENDF/B nuclear data library.
In view of the interest in tungsten metal for several distinct types of nuclear applications and in order to maintain and guarantee the consolidated performance of the ENDF/B library in nuclear science and technology, the performance of the calculated cross sections needs to be tested. In the current ENDF/B-VII.1 nuclear data library[5], the tungsten isotope evaluations were performed and tested by Trkov[6] by the use of benchmark models taken from the SINBAD[7] and the ICSBEP[8] compilation. The number of benchmarks used in that analysis involved neutron flux spectra in the intermediate and fast energy range. Since this energy range is only slightly sensitive to the extended resonance ^{182,183,184,186}W

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S231 Impact of implicit effects on uncertainties and sensitivities of the Doppler coefficient of a LWR pin cell

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One major part of input uncertainty in nuclear safety analyses is coming from nuclear data. In established uncertainty evaluation methods, these input uncertainties are propagated through the calculation chain to uncertainties of output quantities.
In the present work, PSI and GRS sensitivity analysis and uncertainty quantification methods, SHARK-X and XSUSA respectively, are compared for reactivity coefficient calculation. SHARK-X is a set of Perl-based scripts build around the lattice code CASMO-5. The XSUSA methodology provides tools for statistical analysis of relevant output quantities, as well as sensitivity analyses. It is built around the neutron transport codes (T-NEWT in this study) and nuclear covariance data of the SCALE 6.1 code package. Since both CASMO-5 and NEWT utilize multi-group cross section data, self-shielding calculations need to be performed prior to the transport calculation. In case of XSUSA, cross sections are perturbed after the self-shielding. The so-called implicit effects are therefore not taken into account. With SHARK-X, it is possible to perturb the cross sections either before or after the self-shielding calculation.
Analyses are done for a Light Water Reactor (LWR) pin cell based on Phase I of the UAM LWR benchmark. In direct perturbation calculations (DP), the U-238 capture cross sections of the individual energy groups are one after another increased and decreased by 5% in several consecutive calculations. In addition to the Doppler reactivity coefficient and the corresponding uncertainty, sensitivity profiles of the Doppler coefficients are thereby obtained.
For further comparisons, the TSUNAMI and SAMPLER modules of the SCALE code package are used. TSUNAMI is based on first order perturbation theory. Sensitivity profiles are obtained both with and without consideration of implicit effects. With SAMPLER, a sequence of the beta release of SCALE 6.2, implicit effects are considered in direct perturbation calculations.
The negligence of implicit effects leads to deviations of a few percent between the sensitivity profiles predicted by XSUSA and SAMPLER, and between the two TSUNAMI calculations. With SHARK-X, however, the impact of the implicit is much larger especially in the resonance region. The Doppler coefficient uncertainties obtained with XSUSA and SAMPLER are in agreement when using DP.

S232 A stress test on 235U(n, f) in adjustment with HCI and HMI benchmarks

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To understand how compensation error occurs in a nuclear data adjustment mostly devoted to U-Pu fuelled fast critical experiments and with only limited information on U-235 data, a stress test on $^{235}U(n,f)$ was suggested, using critical benchmarks sensitive to $^{235}U(n,f)$ in 1~10keV region. The adjustment benchmark exercise with 20 integral data suggested by WPEC/SG33 was used as the reference, where practically only one experiment did give information on U-235 data. The k_{eff} of HCI4.1 and HCI6.2 experimental benchmarks were used as the 21^{st} and 22^{nd} integral data separately to perform stress test. The adjusted integral values and cross sections based on 20, 21 and 22 integral data and the same nuclear data and covariance data sets were compared. The results that will be fully reported in the final paper confirm that the compensation errors are created by missing essential constraints.

I233 Benchmarking and validation activities within JEFF project

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The challenge for any nuclear data Evaluation Project is to periodically release a revised, fully consistent and complete library, with all needed data and covariances, and ensure that it is robust and reliable for a variety of applications. Within an evaluation effort, benchmarking activities play an important role in validating proposed libraries. The Joint Evaluated Fission and Fusion (JEFF) Nuclear Data Library [1] aims to provide such a library, and thus, requires a coherent and efficient benchmarking process. In the past, JEFF participants have used different benchmarking suites, for different JEFF library versions and hence, benchmarking consisted of summing isolated validation results, which resulted in poor coverage of application space. In order to centralize, streamline and strengthen the benchmarking process, the JEFF Benchmarking and Validation Working Group (JEFF-B&V WG) has been created.
The main goals of this WG are to exchange ideas on best practices in benchmarking and to perform inter-comparisons among methodologies used by JEFF-B&V WG's members. The working group will exchange and cross-check benchmark input decks, discuss benchmarking suites to be used, selection of pertinent validation cases for all nuclides in the library, and provide as complete as possible a multi-purpose validation suite. This paper shows the status of benchmarking selection and preliminary results for next JEFF candidate cross-section file for release.
The centralization of these tasks relies on the NEA Data Bank to implement and co-ordinate a comprehensive process involving verification, testing and benchmarking tasks according to well-defined criteria, while assessing the needs for benchmarking efforts in participating institutions. Here, the NDEC application [2], under development by NEA, performs the automated testing and diagnosis in human-readable outputs, aiding the selection of better JEFF files. At the same time, DICE/IDAT benchmark databases [3, 4] are used through NDaST [5] to provide a means to easily select benchmarks due to sensitivity coefficients and quickly assessing the impact on benchmark calculations due to nuclear data library changes.

[1] "JEFF Co-ordination Group meeting", JEF/DOC-1730. December 2015; [2] "JEFF and horizontal Nuclear Data activities at NEA", F. Michel-Sendis, JEF/DOC-1625, April 2015; [3] https://www.oecd-nea.org/science/wpncs/icsbep/dice.html; [4] https://www.oecd-nea.org/science/wprs/irphe/irphe-handbook/; [5] http://www.oecd-nea.org/ndast/

R234 Analyses of criticality benchmark experiments with beryllium reflector

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Beryllium is an important nuclear material, and the reliability of the data for neutron-induced nuclear reactions of beryllium is of significant importance to nuclear engineering. The criticality benchmark experiment calculations are the basic means to test the reliability of nuclear data and indicate the direction of the improvement of nuclear data. In nuclear data test, the calculations of two series of benchmark experiments (HMF058 and HMF066) with beryllium reflector give apparently contradictory conclusions, so the quality of nuclear data of beryllium cannot be evaluated and the direction for improvement cannot be pointed out too. The similarity theory based on the use of sensitivity coefficients and uncertainty data is used to analyze the similarity of two series of experiments. The experiments are grouped into "five similarity suites" by similarity index. The experiments in the same similarity suite are highly similar to each other. In a similarity suite, for experiments of different series the deviations of calculated results and experimental value are disagreed, however for experiments of the same series the deviations are agreed with each other. This shows that there may be careless mistakes in the measurements or evaluations of HMF058 and (or) HMF066 benchmarks. It is necessary to carry out detailed reevaluation of the benchmark experiments, or to develop reliable new integral experiments to exclude unreliable experiments, in order to avoid the misleading of the nuclear data test.

R235 Plutonium effect in fuel bundles of pressure-tube heavy water reactors

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In typical heavy water cooled / heavy water moderated power reactors (PT-HWR), the contribution of ^{239}Pu in the fission power is significant near the typical design conditions, roughly 40% of fissions in the equilibrium reactor core can be attributed to ^{239}Pu. This means that ^{239}Pu generated in the fuel pins is as important for nuclear power generation as is ^{235}U that is initially present in the uranium dioxide fuel (UO_2), and the reactor physics (neutronics) properties of the fuel bundles near the middle of burn-up or end-of-life can significantly differ from those at the beginning of the bundle life-cycle. This Pu effect in the fuel pins manifest itself in the form of peculiarities in the behaviour of k_∞ *vs*. average fuel temperature in single cell models as the burn-up progresses and ^{239}Pu builds up.
In this study, we introduce a simple computational model that captures all important physics of the UO_2 fuel bundle of the typical PT-HWR near the middle of burn-up, and we show how the modern evaluations of ^{239}Pu cross-sections perform in the reactor physics analysis of this model. We estimate the differences in k_∞, changes in coolant-void reactivity (CVR) and fuel temperature coefficient (FTC) near the typical design conditions due to the differences in the modern evaluations of ^{239}Pu data. Using nuclear data processing tools, such as NJOY, we perform reactor physics analysis employing modern Monte Carlo methods and different multiple-temperature nuclear data library patches for ^{239}Pu and compare the results. Since the goal of more recent evaluations is to improve the performance of ^{239}Pu data, a recently posed question regarding the relevance of C/E bias in evaluating the performance of ^{239}Pu in thermal critical benchmarks for the PT-HWR physics analysis (at high fuel temperatures) can be partially addressed by testing the new and improved evaluations using our simple models. Meanwhile, observed difference in k_∞ and other reactor physics parameters of interest, such as CVR and FTC, (which depend on the usage of different released and trial evaluations of ^{239}Pu data) can give a quick and rough estimate of the possible bias and uncertainty in those same parameters due to the uncertainty in microscopic nuclear data of ^{239}Pu in the evaluated nuclear data libraries and application of the Doppler broadening rejection correction (DBRC) in the Monte Carlo neutron transport solver.

R236 Analysis of C/E results of fission rate ratio measurements in several fast lead VENUS-F cores

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During the GUINEVERE FP6 European project (2006-2011), the zero-power VENUS water-moderated reactor was modified into VENUS-F, a mockup of lead cooled fast spectrum system with solid components that can be operated in both critical and subcritical mode.
The Fast Reactor Experiments for hybrid Applications (FREYA) FP7 project was launched in 2011 to support the designs of the MYRRHA Accelerator Driven System (ADS) and the ALFRED Lead Fast Reactor (LFR). Three VENUS-F critical core configurations, simulating the complex MYRRHA core design and one configuration devoted to the LFR ALFRED core conditions were investigated in 2015. The MYRRHA related cores simulated step by step design peculiarities like the BeO reflector and in pile sections. For all of these cores the fuel assemblies were of a simple design consisting of 30 % enriched metallic uranium, lead rodlets to simulate the coolant and Al2O3 rodlets to simulate the oxide fuel.
Fission rate ratios of minor actinides such as Np-237, Am-241 as well as Pu-239, Pu-240, Pu-242 and U-238 to U-235 were measured in these VENUS-F critical assemblies with small fission chambers in specially designed locations, to determine the spectral indices in the different neutron spectrum conditions.
The measurements have been analyzed using advanced computational tools including deterministic and stochastic codes and different nuclear data sets like JEFF-3.1, JEFF-3.2, ENDF/B7.1, ENDF/B6.8, JENDL-4.0 and TENDL-2014. The analysis of the C/E discrepancies will help to improve the nuclear data in the specific energy region of fast neutron reactor spectra.

I237 Production of platinum radioisotopes at Brookhaven Linac Isotope Producer (BLIP)

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Currently 25% of cancer patients receive platinum agents. They are used to treat a wide range of cancers, either alone or in combination with other chemotherapeutic agents or antibodies. Recent drug approvals, clinical trials and scientific findings on mechanisms of resistance against these agents have renewed interest in research into platinum agents. Monitoring the pharmacokinetics of emerging and established agents using ^{195m}Pt ($t_{1/2}$= 4.02 d), ^{191}Pt($t_{1/2}$=2.802 d), ^{188}Pt ($t_{1/2}$=10.2 d) or ^{189}Pt ($t_{1/2}$=10.87 hr) *in vitro*, preclinical and clinical trials would be an invaluable theranostic agents to improve understanding of their delivery and resistance.[1] Additionally, ^{195m}Pt, and ^{193m}Pt ($t_{1/2}$=4.33d), emit Auger and/or conversion electrons, which at the appropriate dose could be used to kill the cancer cells.
Cross sections of proton-induced nuclear reactions on natural platinum metal have been reported (2004) and data is available up to 70 MeV.[2] We were interested to investigate the feasibility of accelerator production of a range of platinum isotopes at BLIP using protons energies up to 200 MeV. Six platinum targets were irradiated at energies ranging from 50 – 195 MeV (current 115 µA) in parasitic mode with Thorium and RbCl targets for up to 3 hours. The platinum targets were digested in aqua regia, and then converted to the chloride salt with a series of concentration HCl digestion. The resultant residue was dissolved in 0.1 M HCl and analysed by conventional gamma spectrometry and Compton-suppressed coincidence gamma-ray spectroscopy. Two software programs were used for the gamma-ray spectrum analysis. In addition, theoretical cross sections for the production of a range of platinum isotopes using the EMPIRE code were determined for protons of 10 to 200 MeV. The effective cross sections of the range of platinum isotopes produced at BLIP were determined and compared with literature values and those predicted using the EMPIRE code. Overall the results were in good agreement and production of ^{191}Pt, ^{195m}Pt and ^{188}Pt was demonstrated. Co-production of Ir and Au isotopes are significant. However initial chemical separation work shows potential for effective separation of the platinum isotopes. The use of isotopically enriched target material suggests accelerator production of selected platinum isotopes is feasible over a wide proton energy range.

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R238 Production of medically useful bromine isotopes via alpha-particle induced nuclear reactions

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Objectives: Radiobromine is of special interest for labelling of biomolecules since different radioisotopes of radiobromine are available which can be used for diagnostic or therapeutic purposes. Furthermore, labeling methods already known for radioiodine can be also easily applied for labeling with radiobromine. Owing to the longer half-life of ^{76}Br ($T_{½}$ = 16.2 h), this "non-standard" PET nuclide can be used to image slow metabolic processes in the timescale of several hours. Limitations, concerning spatial resolution and image quality may be reduced by corrections in the image reconstruction. The other radioisotope ^{77}Br ($T_{½}$ = 57 h) decays almost exclusively via electron capture (99.3%) to its stable daughter ^{77}Se. The emitted Auger electrons make it an attractive nuclide for internal radiotherapy. Due to the emitted 239 keV γ-ray (I_g = 23 %) ^{77}Br is additionally suited for SPECT, hence representing a so called *theragnostic* radionuclide. In this work the production of radiobromine via α-particle induced reactions was studied.
Methods: For production of ^{76}Br and ^{77}Br, cross sections of α-particle induced reactions on arsenic, leading to the formation of ^{76,77,78}Br as well as to the non-isotopic impurity ^{74}As, were measured from their thresholds up to 37 MeV using the established stacked-foil technique. Sediments of elemental arsenic were used as targets for irradiation. Furthermore, in order to clarify the cross section discrepancies between different authors in the literature, the cross section ratios of the monitor nuclides ^{67}Ga/^{66}Ga were used for the determination of the α-particle energy. Using these monitor nuclides the effective beam current through all the stacks could be reliable determined.
Results and conclusion: The new experimental cross section data were assessed and compared with the available excitation functions. Here, the new data indicate slightly divergent curve shapes. In the case of ^{76}Br the excitation function seems to be shifted to lower α-particle energies, and also the maximum cross sections of the formation of ^{77}Br tends to be slightly lower compared to the currently recommended excitation function. In the case of a re-evaluation, these new data should be taken into account, as they may contribute to enhance the accuracy of the existing excitation functions.

R239 IAEA CRP on nuclear data for charged-particle monitor reactions and medical isotope production

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A review of activities within the IAEA research project on "Nuclear Data for Charged-particle Monitor Reactions and Medical Isotope Production" is given. New values with uncertainties are proposed for charged-particle induced reactions suitable as beam monitors for the subsequent determination of activation cross sections of radionuclides of interest for medical and other applications. Production cross sections of various existing and potential diagnostic and therapeutic radionuclides have been measured, evaluated and recommended for a wide range of targets and projectiles, along with new decay-data evaluations for some of these medical radionuclides.

R240 The new CERN-MEDICIS facility for the production of new innovative radioisotopes for medical research

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Objective: CERN-MEDICIS (MEDical Isotope Collected from ISolde) is a new facility currently being commissioned at CERN for the production of radioisotopes for medical research [1].
Material & method: It builds upon 50 years of experience at CERN-ISOLDE (Isotope Separation On-Line DEvice) in the production of radioisotopes by spallation of thick targets with high-energy protons [2]. Two irradiation points have been commissioned between the existing ISOLDE target stations and the proton beam dumps, making use of the 80% of the proton beam that passes through the ISOLDE target unaffected. A radiation-hard rail system and a robotic arm are used to extract the target modules from the high-radiation area and manipulate them to storage, to a hot cell, or to an off-line mass separator. The mass separator relies on a dipole magnet previously used at the LISOL facility (Louvain-La-Neuve, Belgium) which allows the collection of three samples of different mass at the same time [3].
Results & conclusions: The civil construction of the facility is now complete and the commissioning of the different components is progressing. The first collections are expected before the end of 2016. The research programme at CERN-MEDICIS builds upon the existing medical research at CERN-ISOLDE, including the theranostic quadruplet of terbium isotopes [4] or the optimisation of 213Bi generators [5]. In this contribution, I shall introduce the new facility and present its current state of operation.

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I241 Differential cross sections measurements for hadrontherapy: 50 MeV/n 12C reactions on H, C, Al, O and Ti targets

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To keep the benefits of carbon ions in radiotherapy, a very high accuracy on the dose location is required. The dose deposition is affected by the fragmentation of the incident ions that leads to: (i) the consumption of the projectiles with their penetration depth in the tissues, (ii) the creation of lighter fragments having a different biological effectiveness (RBE), (iii) the apparition of a fragmentation tail behind the tumor. The constraints on nuclear models and/or fragmentation cross sections in the energy range used in hadrontherapy (up to 400 MeV/n) are not yet sufficient to reproduce the local dose deposition with the accuracy required in a clinical treatment.
In this context, three experiments have been performed at GANIL by our collaboration to measure the energy and angular differential fragmentation cross sections on thin targets of medical interest (H, C, Al, O and ^{nat}Ti). Two were done with 95 MeV/n ^{12}C beams in 2011 and 2013 and one with a 50 MeV/n ^{12}C beam in March 2015. The experimental set-up was made of five three stages telescopes, each composed of two Si detectors and one CsI scintillator mounted on rotating stages to cover angles from 3° to 39°.
The analysis of this new experiment shows that the angular cross sections for light fragments are less forward-focused at 50 MeV/n compared to 95 MeV/n, resulting in “flatter” distributions. Protons and ^{4}He fragments are dominant on the entire angular distribution. At this beam energy, the production of alpha particles is higher than protons for angles up to 20° compared to 10° at 95 MeV/n.
The energy distributions of the fragments at forward angles are peaked close to the beam energy showing an emission dominated by the quasi-projectile. Comparisons between experimental data and Geant4 simulations using different inelastic models (BIC, QMD and INCL++) show important discrepancies.
Final data as well as comparisons with simulations and the previous experiments will be presented during the conference.

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R242 How nuclear data collected for medical radionuclides production could constrain nuclear codes

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Objectives: Nuclear medicine is a specialty that uses unsealed radioactive sources for therapy or diagnosis of diseases such as different types of cancer. These radionuclides are most of the time coupled to a carrier molecule to target cells of interest. Currently, only few radionuclides are used in clinical practice but many others may be of medical interest due to their emitted radiation and/or their half-life. They can be adapted to the carrier molecule transit time and to the pathology.
The aim of this presentation is to give the status of nuclear data collected in the framework of the production of innovative radionuclides for therapy and diagnosis applications in collaboration with the GIP ARRONAX, which possesses a multi-particle high energy cyclotron and to show constrains that can be put on nuclear codes.
Material and Methods: In order to assess the cross section of a given production route, experiments have been carried out using the stacked foils technique and gamma-spectroscopy for a set of radionuclides of medical interest: photon (Tc-99m) and positon (Sc-44g) emitters for diagnosis, electron (Re-186, Tb-155, Sn117m) and alpha particles (Th-226, Ra-233, Bi-213) emitters for therapeutic applications. A systematic comparison has been made between the results from the last version of the TALYS code (1.6) and the large set of data collected using different projectiles (proton, deuteron and alpha particle) from few MeV up to 70 MeV and covering a wide range of target masses.
Results and Conclusion: We first used the code with its default models. Then, three main phenomena have been found to have a great influence on the calculated production cross section values: the optical model, the pre-equilibrium model and the level density model. Finally, a better overall agreement with our experimental data has been obtained with a different combination of models already included in the TALYS code.

R243 Production of 92Y via the 92Zr(n,p) reaction using the C(d,n) accelerator neutron source

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Medical radioisotopes are widely applied not only for diagnostic but also therapeutic purposes. In particular, radioimmunotherapy (RIT) plays an important role in cancer therapy in recent years. Yttrium-90-ibritumomab tiuxetan is the first RIT agent approved by the U.S. Food and Drug Administration (FDA). After that it has been approved in more than 40 countries. Until Nov. 2011, assessment of biodistribution by using ^{111}In-ibritumomab tiuxetan before administration of ^{90}Y-ibritumomab tiuxetan (called "bioscan") was required in United States, Japan and Switzerland. The FDA removed the bioscan at Nov. 2011 and the first reason was "analysis of data in 253 patients showed that the In-111 imaging dose and bioscan was not a reliable predictor of altered Y-90 ZEVALIN (the trade name of ibritumomab tiuxetan) bio-distribution". If ibritumomab tiuxetan is labeled with an Yttrium isotope, it has to be a reliable predictor. Since gamma-ray imaging is used for the bioscan, gamma-ray emitter has to be used as the labelling nuclide. There are a few Yttrium isotopes which emit gamma ray. Among all we focus on ^{92}Y, because it has relatively-long half-life (3.5 h) and decays to a stable isotope (^{92}Zr).
We propose a new method to produce ^{92}Y using accelerator neutrons. Yttrium-92 is produced via the (n,p) reaction on ^{92}Zr. A feasibility experiment was performed at Cyclotron and Radioisotope Center in Tohoku University. A carbon thick target was irradiated by 20 MeV deuterons to produce accelerator neutrons. The thick target neutron yield (TTNY) was measured by using the multiple foils activation method. The foils were made of Al, Fe, Co, Ni, Zn, Zr, Nb, and Au. The amount of ^{92}Y production and induced impurities were estimated by simulation with the measured TTNY. The details of the data analysis and the results are shown in the presentation.

R244 In-flight annihilation correction for spectrometry based on the 511 keV photopeak

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An important requirement in the spectrometry of positron emitters, based on the 511 keV photopeak, is complete annihilation within the materials that constitute the source. Such spectrometry is often performed in cases where a particular radionuclide has significant β^+ emissions but lacks other characteristic γ-lines suitable for quantitative radioactivity assessment.
Spectrometry based on the 511 keV annihilation photopeak usually requires the positron source to be surrounded by an additional absorber material. While this method is well established in the literature, correction for in-flight annihilation losses from the 511 keV photopeak is often found to be neglected. With these issues in mind, application to volume sources, such as typically employed in a radionuclide production environment for yield determination and quality control (QC) purposes, is presented is this work.
The main aims of this paper are to briefly revisit the reasons for in-flight annihilation losses, to present a method for performing simple 511 keV spectrometry suitable for any radionuclide production counting room equipped with a good HPGe detector, to apply the method to volume sources (in this case standard serum vials containing a small sample of a product solution for purposes of performing a γ-ray assessment of the product) and lastly to present in-flight annihilation probabilities suitable for correcting the 511 keV photopeak area, for a number of different non-conventional/non-pure positron emitters. Sources of ^{22}Na, ^{64}Cu, ^{65}Zn, ^{66}Ga, ^{68}Ga and ^{82}Rb were selected for this purpose. The absorber materials investigated are water, Plexiglass, borosilicate glass, Cu and Pb. Results obtained by analysing the 511 keV photopeak are compared with activity values extracted from other characteristic γ-lines. It is shown that a better overall agreement is obtained when in-flight annihilation loss corrections are explicitly performed.

I245 Prompt particle emission in correlation with fission fragments

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The de-excitation process of primary fission fragments can be simulated with the FIFRELIN Monte Carlo code leading to an estimation of prompt fission observables such as neutron and gamma multiplicities, and spectra in correlation with fission fragments. De-excitation cascades are simulated using the notion of nuclear realization following Beckvar terminology. A nuclear realization is a random set of nuclear levels (energy, spin, parity) in association with partial widths for neutron, gamma or electron emission. Experimental data related to electromagnetic transitions in the discrete level region are taken from RIPL-3 database. When nuclear level structure is completely unknown (in the continuum region), level density and strength function models are used. In between these regions, our partial knowledge of nuclear structure is completed by models up to a fixed maximum level density. In this way the whole available experimental information is accounted for.
FIFRELIN is ruled by five free input parameters driving the excitation energy repartition, the rotational energy and the spin distribution of primary fission fragments. These five free parameters are determined to match a target observable such as the total average prompt neutron multiplicity (nu-bar). Once this procedure is completed, the whole set of fission observables can be compared with experimental results. Obviously the number of observables obtained within this code is higher than what is available from measurements. This code can therefore provide useful insights into the compatibility between models and a whole set of fission observables.
In the present work the influence of several models or model parameters is estimated on important observables. For instance the impact of the primary fission fragment total angular momentum or fragment kinetic energy distributions on the average prompt neutron multiplicity is addressed. This crucial observable is also decomposed in mass, charge or energy range.
Average gamma multiplicity and spectrum are also directly decomposed in mass and charge split but also in radiation type (electric or magnetic nature and multipolarity) or expressed as a function of detection threshold and time coincidence window.

R246 Prompt fission neutron spectra for energetic neutron-induced fission of 235U

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Accurate data on the spectrum of neutrons emitted in energetic neutron-induced fission are needed for a better understanding of nuclear applications. At LANSCE we are measuring prompt fission neutron spectra (PFNS) for fission of ^{235}U and ^{239}Pu induced by neutrons from 0.7 to over 30 MeV using the WNR neutron facility, and for spontaneous fission of ^{252}Cf. The goal is to obtain better data than those in the literature and especially to understand and quantify systematic uncertainties to a deeper level than was possible before.
We use a double time-of-flight (TOF) technique to determine energies of the incoming and outgoing neutrons. We use parallel plate avalanche detectors to register the fission event, and one or the other of two arrays of neutron detectors to detect the fission neutrons. With data acquisition via waveform digitizers, accidental coincidences between fission chamber and neutron detector are also measured to high statistical accuracy and then subtracted from measured events.
Neutrons are detected either by a 54-detector array of liquid scintillators for neutrons above 0.5 MeV or by a 22-detector array of ^{6}Li-glass scintillators for neutrons below 1 MeV. Measuring the low-energy part of the PFNS is particularly challenging because down-scattered neutrons contribute significantly to the observed spectra. Monte Carlo simulations have proven to be essential in the experimental design to minimize neutron scattering, and are central to the analysis of the observed spectra.
Current results from both arrays will be presented for ^{235}U(n,f) and ^{252}Cf(sf); in addition, we will discuss our plan for measuring the PFNS for ^{239}Pu(n,f).

R247 New prompt fission neutron spectra measurement in 238U(N,F) reaction with a dedicated setup at Lansce/WNR

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A new prompt fission neutron spectra (PFNS) measurement in ^{238}U(n,f) reaction was performed at LANSCE/WNR facility.
For PFNS, evaluated data show discrepancies on the low (below 1 MeV) and high (above 5 MeV) energy parts for different major and minor actinides. The goal is to improve these measurements, in a wide range of incident energy.
The incoming neutron energy, inducing the fission, and prompt neutron energy are measured by time-of-flight method.
A dedicated fission chamber was developed, in order to improve alpha-fission discrimination, timing resolution, actinide mass, and to reduce the amount of neutron scattering.
The fission chamber contains 72 deposits of ^{238}U (0.6 mg/cm² for a total mass of 360 mg). The alpha-fission discrimination is very good: fission detection efficiency is better than 95%. Moreover, the timing resolution of the chamber is less than 0.8 ns FWHM, resulting in a timing resolution of the time-of-flight measurement of about 2 ns FWHM.
To detect neutrons, the 54 Chi-Nu scintillator cells array were surrounding the fission chamber.
By using lead shielding, the amount of low energy gamma rays detected in the cells was reduced, improving the neutron-gamma discrimination. Added to the digital acquisition system, the threshold of the neutron detection was reduced by at least a factor two, compared to previous experiments.
To correct the background component in the measured spectra, due to incoming or prompt neutron scattering in the experimental room, MCNPX simulations of the whole setup are performed.
High statistics were recorded during this experiment, allowing a precise study of PFNS behavior as a function of incident neutron energy, from 1 MeV to 200 MeV.
This experiment also showed that all the new tools developed to improve PFNS measurements are performing. Therefore, others PFNS measurements with others actinides, such as ^{239}Pu, are planned.

R248 Local and global even-odd effects in the fragment distributions and the prompt emission of 234U(n,f)

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The paper demonstrates the dominance of the intrinsic even-odd effect in prompt emission (due to the nuclear properties of fragments) for the case of an even-odd fissioning nucleus, 234U(n,f) at 14 incident neutron energies ranging from 0.2 MeV to 5 MeV. For this demonstration three fragment distributions Y(A,Z,TKE) are used. These are based on the experimental Y(A,TKE) data measured at JRC-IRMM and isobaric charge distributions with different Zp model parameter prescriptions. The global even-odd effects in the Y(Z) projections, exhibiting pronounced decreases with increasing incident neutron energy (En), are different as magnitude and decreasing slope.
The multi-parametric matrices of different prompt emission quantities, as primary results of the Point-by-Point model are averaged over these Y(A,Z,TKE) distributions.
Small differences between the global Z even-odd effects in prompt neutron multiplicity <ν>, total excitation energy of fragments <TXE> and prompt γ-ray energy <Eγ> and between the N global even-odd effects in the average neutron separation energy from fragments <Sn> are obtained. The global even-odd effects in different prompt emission quantities exhibit a very slow variation with En, compared to the pronounced decrease of the global even-odd effect in the Y(Z) distributions.
A local even-odd effect is calculated for ^{234}U(n,f) on the basis of the number of configurations of pre-formed and completely formed fragmentations in an even-odd fissioning nucleus.

S249 Estimates of fission barrier heights for neutron-deficient Po to Th nuclei produced in fusion reactions

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Despite a significant progress in nuclear fission studies, the variations of fission barrier heights (FBH) still remain an open problem. Fission model parameters, which provide a reasonable description of FBH for nuclei close to the stability line, are tuned by using the experimental data obtained for such nuclei [1]. However, large deviations are observed between predictions of different models for FBH of neutron-deficient nuclei and of very neutron-rich ones. In the last case discrepancies (up to 20–30 MeV [2]) become important in the r-process calculations for extremely neutron-rich nuclei whose FBH determine the termination of the r-process by fission [3]. Unfortunately, such neutron-rich nuclei are not accessible for the study in present-day experiments. At the same time, fission properties of the neutron-deficient nuclei can be investigated with fusion reactions. Fusion-fission and fusion-evaporation cross sections obtained in reactions with heavy ions provide the data for the estimates of FBH for these nuclei. In calculations, the cross section values are mainly determined by statistical properties of decaying nuclei, particularly by FBH of nuclei involved in the compound nucleus (CN) de-excitation chains leading to observable evaporation residues (ER) and fission fragments. The cross section data for heavy nuclei from Po to Th produced in fusion reactions has been considered in a systematic way within the framework of the conventional barrier-passing (fusion) model coupled with the standard statistical model (SSM) [4]. The data for fission and ER excitation functions obtained in very asymmetric projectile-target combinations can be described within these models rather well and allow one to set the model parameters unambiguously. In particular, one can scale and fix macroscopic (liquid-drop) FBH for nuclei involved in the CN de-excitation. In nearly symmetric combinations one has empirically to introduce the quantity of a fusion probability (Pfus < 1) and to increase the height of the fusion barrier in order to reproduce ER excitation functions using SSM parameters obtained in the analysis of very asymmetric combinations [5–7]. The macroscopic FBH for nuclei from Po to Th have been derived in the framework of the analysis and compared with the predictions of various theoretical models.

1. RIPL-2, Reference Input Library 2, http://www-nds.iaea.org/ripl-2/. ; 2. A. Mamdouh et al., Nucl. Phys., A679, 337 (2001).; 3. I.V. Panov et al., Nucl. Phys., A747, 633 (2005).; 4. W. Reisdorf, Z. Phys. A 300, 227 (1981); W. Reisdorf and M. Schädel, ibid 343, 47 (1992).; 5. R.N. Sagaidak and A.N. Andreyev, Phys. Rev. C 79, 054613 (2009).; 6. Roman N. Sagaidak, EPJ Web of Conferences 21, 06001 (2012).; 7. Roman Sagaidak, Journal of Physics: Conference Series 580, 012039 (2015).

Study on the yield energy dependence for the n+238U fission with semi-impirical model

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A semi-empirical model is used to calculate the yield mass distributions and energy dependence for 238U neutron-induced fission. Macro energy and the shell effect correction were considered, the later one was assumed to weaken with the nuclear temperature. The yield could be expressed with a five-Gaussian-like equation with 13 parameters, which were determined by fitting to the experimental data. The results could well describe the yield mass distributions and the yield energy-dependence of fission fragments in the incident energy range 0-20 MeV. The mass distributions at different incident energies were very close at A~133, that meant the yield of A~132 would change little with the incident energy of 0-20MeV, and agreed with earlier results for ^{233,235}U and ^{239}Pu study.

S251 Measurements of isomeric yield ratios of fission products from proton-induced fission on nat-U and 232-Th

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The angular momentum of fission fragments is regarded as an important quantity in order to understand the fission mechanism because it can provide information on the scission configuration. One of the means to deduce the angular momentum of highly excited nuclei is by determining the yield ratio of low lying isomeric states. Furthermore, the knowledge of the population of the isomeric states for simulation of processes such as the r-process, which is believed to be terminated by the fission of very rich neutron heavy nuclei, and the neutronics and decay heat of nuclear reactors, makes the experimental determination of isomeric yield ratios important by itself.

We report on the measurements of isomeric yield ratios of fission products from proton induced fission on ^{nat}U and ^{232}Th, performed at the Ion Guide Isotope Separator On-Line (IGISOL) facility at the University of Jyväskylä. With the IGISOL method, short-lived fission products can be measured, and by employing the high resolving power of the Penning trap JYFLTRAP, isomeric states separated down to a few hundreds keV from the ground state can be resolved. Thus, a direct measurement of the isomeric fission yield ratios by means of counting the fission product ions can be accomplished, registering the fission products in less than a second after their production.

Isomeric yield ratios of fission products were measured in a wide mass range (A = 81 to 130) for the 25 MeV protons on ^{nat}U and ^{232}Th. The obtained isomeric yield ratios, in conjunction with a statistical model analysis, were converted to the root mean square angular momentum (J_{rms}) of the primary fragments. Specifically six isomeric pairs (^{81}Ge, ^{96}Y, ^{97}Y, ^{97}Nb, ^{128}Sn and ^{130}Sn) with suitable half-lives were measured in which we see indications for a dependence of the production rate on the fissioning system. In addition, the isomeric yield ratios of ^{nat}U, were measured by means of γ-spectroscopy in order to verify the consistency of the experimental set up.

I252 Prompt neutron emission and the energy balance in the reaction 235U(n,f)

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Investigations of prompt fission neutron (PFN) emission are of importance in understanding the fission process in general and the sharing of excitation energy among the fission fragments in particular. Experimental activities at IRMM on PFN emission in response to OECD/NEA nuclear data requests is presented in this contribution. The focus lies on on-going investigations of PFN emission from the reaction ^{235}U(n,f) in the region of the resolved resonances taking place at the GELINA facility. For this reaction strong fluctuations of fission fragment mass distributions and mean total kinetic energy have been observed [1] as a function of incident neutron energy in the resonance region. In addition, fluctuations of prompt neutron multiplicities were also observed [2]. The goal of the present study is to verify the current knowledge of PFN multiplicity fluctuations and to study correlations with fission fragment properties. The Experiment employs a scintillation detector array for neutron detection. Fission fragment properties are determined via the double kinetic energy technique using a position sensitive twin ionization chamber.
Results on PFN multiplicity correlations with fission fragment properties from the present study show significant differences compared to earlier studies on this reaction, induced by thermal neutrons. Specifically, the total kinetic energy dependence of the number of neutrons emitted per fission shows an inverse slope $dE_k/d\nu_T$ ~ 35% weaker than observed in earlier studies [3-6]. The inverse slope is related to the energy carried away per emitted neutron and, thereby, closely connected to the energy balance of the fission reaction. The present result should have strong impact on the modelling of both prompt neutron and prompt γ-ray emission in fission of the ^{236}U compound nucleus.

[1] F.-J. Hambsch et al., *Nucl. Phys. A* **491** (1989) 56; [2] R. E. Howe et al., *Phys. Rev. C* **13** (1976) 195; [3] E. E. Maslin et al., *Phys. Rev.* **164** (1967) 1520; [4] J. W. Boldeman et al., *Aust. J. Phys.* **24** (1971) 821; [5] K. Nishio et al., *Nucl. Phys. A* **632** (1998) 540; [6] A. S. Vorobyev, *EPJ Web of Conf.* **8** (2010) 03004

R253 Comprehensive modeling of prompt fission neutrons and gamma rays in the spontaneous fission of Cf-252

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Recent developments in the experimental and theoretical study of prompt fission neutrons and γ rays are providing a rather comprehensive and coherent picture of the later stages in the fission process. For mostly practical reasons, the spontaneous fission of ^{252}Cf constitutes a reaction of choice for the study of a wide range of prompt fission data. Over the years, numerous experiments have provided- and still provide, quality data on the average neutron spectrum, the average neutron multiplicity, the neutron multiplicity distribution, as well as more exclusive information about the neutron energies and multiplicities as a function of the fragment characteristics in mass, charge and kinetic energy. Data on neutron-neutron and neutron-fragment angular distributions also exist, providing further constraints on modern fission models. Similar data have been obtained for the prompt γ rays, completing a long list of separate views of this post-scission event.
A comprehensive modeling of these data is crucial for a fundamental understanding of the fission process but also for placing physical constraints on models used for nuclear data evaluation purposes.
In this talk, I will review the progress made in this direction, in the light of recent experimental efforts and with the development of event-by-event fission codes. CGMF is such a code, developed at LANL, which implements a Monte Carlo version of the Hauser-Feshbach statistical nuclear reaction theory applied to the de-excitation of the primary fission fragments. CGMF calculations are compared to the existing large body of experimental data on ^{252}Cf (sf). In particular, *n-n*, *n-γ*, and *γ-γ* correlations are discussed. Also, recent experimental data obtained at IRMM, CEA, LANL, LLNL and PNPI on ^{252}Cf (sf) prompt fission neutron and γ spectra will be reviewed in detail.
Finally, I will briefly discuss the ongoing integration of CGMF, as well as other fission event generators, into the MCNP6 transport code.

R254 Prompt neutron multiplicity in thermal neutron induced fission of 235U

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The prompt neutron emission in thermal neutron induced fission of ^{235}U has been investigated applying digital signal electronics. The goal was to compare the results of this digital data acquisition and digital signal processing analysis to the results of the pioneering work of Apalin et al. Using a twin Frisch grid ionization chamber for the fission fragment detection and a NE213 equivalent neutron detector in total about 10^6 neutron coincidences have been registered. The fission fragment kinetic energy, mass and angular distribution has been investigated along with prompt neutron time of flight and pulse shape using a six channel synchronous waveform digitizer with sampling frequency of 250 MHz and 12 bit resolution. The signals have been analyzed using digital pulse processing algorithms, developed by authors.

R255 237Np absolute delayed neutron yield measurements

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The delayed neutrons (DN) emitted by some fission fragments have an important role for the control of nuclear reactors. DN absolute yields and parameters of the different groups of DN precursors were measured in the past for major actinides and for few incident neutron energies. Many innovative studies for transmutation reactors or different fuel cycles were proposed during the last 15 years. This has motivated measurements of DN yields for different actinides and different incident neutron energies. In this context the absolute DN yields of ^{237}Np has been measured over a large domain in energy. The experiment, funded by the European contract ERINDA, has been performed at the Physikalisch-Technische Bundesanstalt facility.
The PTB Van de Graaff accelerator and the cyclotron CV28 have delivered 9 different neutron beams between 1.5 and 16 MeV using p+T, d+D and d+T reactions. Twelve ^{3}He tubes inserted in a polyethylene cylinder composed the detection system with a total efficiency of ~15 %. For each beam energy, the absolute DN yields have been determined taking into account the background, the corrections for scattered neutrons in the polyethylene, the non mono-energetic part of the beam, etc…
In this paper, the experimental setup and the data analysis method will be described. The evolution of the absolute DN yields as a function of the neutron incident beam energies will be presented and compared to previous results on ^{232}Th obtained with the same apparatus.

R256 Prompt fission neutron and gamma properties as a function of incident neutron energy

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The CGMF code, developed in the Nuclear Data Group at Los Alamos National Laboratory, provides a complete description of the properties of the prompt neutrons and gamma rays, emitted before beta decays. It is based on a Monte-Carlo implementation of the Hauser-Feshbach statistical model, which provides an accurate phenomenological description of the de-excitation of the fission fragments toward stable configurations via particle (neutrons and gamma rays) emissions. This approach allows a more detailed description of a large number of observables previously not calculated in the simpler yet successful Los Alamos model, such as multiplicity probabilities and correlations between the emitted particles, in addition to information about gamma-ray observables. Originally implemented for the spontaneous fission of ^{252}Cf and the neutron-induced fission of ^{235}U and ^{239}Pu at thermal neutron energy, the formalism has been extended to incident neutron energies up to 20 MeV. For the emission of pre-fission neutrons, at incident energies beyond second-chance fission, we take into account both the pre-equilibrium and statistical components. By sampling the neutron spectra and subtracting the pre-fission neutron energy from the total energy of the system, we obtain the available excitation energy for fission. The yields in mass, charge, and TKE, together with energy conservation rules, are used in order to obtain a collection of fission fragments, whose de-excitation to a ground or isomeric state we follow. In this contribution, we will investigate the sensitivity of neutron and gamma observables (multiplicity distributions, spectra) to the different input, which are either non-observable (multi-chance fission probabilities), or possibly are limited due to experimental resolution (e.g., mass yields). In particular, we will apply this formalism to the neutron-induced fission of ^{235}U and ^{239}Pu.

I257 The calculation and evaluation for n+54,56,57,58Fe reactions

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All cross sections of neutron-induced reactions, angular distributions, double differential cross sections, angle-integrated spectra, γ-ray production cross sections and energy spectra are calculated by using theoretical models for 54,56,57,58Fe at incident neutron energies from 0.1 to 200 MeV. The optical model, the unified Hauser-Feshbach and exciton model which included the improved Iwamoto-Harada model, the linear angular momentum dependent exciton density model, the distorted wave Born approximation, the intranuclear cascade model and recent experimental data are used. The theoretical calculated results are analysis and compared with the new experimental data for (n, n'γ), (n, 2n'γ), (n, n') and (n, 2n) reactions. The present consistent theoretical calculated results are in good agreement with recent experimental data. The theoretical models provide the good description of the shapes and magnitude of the energy spectra and double differential cross sections of emission neutron, proton, deuteron, triton, helium and alpha. The present evaluated data are compared with the existing experimental data and evaluated results from ENDF/B-VII, JENDL-4, and present results are given in ENDF/B format.

R258 New evaluations of n+Cu and n+Zr nuclear data for neutron energies up to 200 MeV

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High energy neutron cross section data have been evaluated for the stable copper isotopes ^{63,65}Cu in the energy range from $1{\cdot}10^{-11}$ up to 200 MeV. This evaluation provides a complete and consistent set of data as required for the particle transport, heating, shielding and radiation damage simulations in the fission and fusion reactor applications.
The TALYS-1.8 computer code is used to generate a full set of nuclear reaction data for neutron energies from 0.001 to 200 MeV. The statistical Hauser-Feshbach theory is applied for the compound nuclear reactions and geometry dependent hybrid model is used for the description of the pre-equilibrium reactions. The optical model calculations are performed in TALYS internally making use of default optical model potentials (OMPs) for neutrons and protons and external OMPs for other charged particles. The reaction cross sections obtained with TALYS calculations were compared against available experimental data. Validated reaction cross-section data from other data libraries were adopted as far as suitable for the evaluation in case of the nuclear models deficiency.
New resonance parameters evaluations for n+63,65Cu including covariance data were done with the SAMMY code. This evaluation is based on the new measurements performed at GELINA on enriched isotopic copper samples for the capture cross sections and on old measurements preformed at the Oak Ridge Electron Linear Accelerator (ORELA) on highly enriched isotopic copper samples for the neutron transmission.
The new evaluations provide covariance matrices for all reaction cross sections up to 200 MeV to enable uncertainty analyses with the data files. This covariance data are based on the nuclear model results in combination with relevant experimental data using the Unified Monte Carlo Approach as implemented in the BEKED computer code of KIT.
General purpose data files for n+^{63,65}Cu for neutron energies from $1{\cdot}10^{-11}$ to 200 MeV were generated in accordance with ENDF-6 format rules. Intensive testing of the files was then performed by analyses of integral experiments as available in the benchmark data base for fission and fusion technology applications. These data files, produced in the frame of the European fusion program, finally will be made available for inclusion in the JEFF nuclear data library.

R259 Application of the samint methodology to the new cross section evaluations of 63cu and 65cu

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The SAMINT methodology allows coupling of differential and integral data evaluation in a continuous-energy framework [1]. Prior to the SAMINT code, integral experimental data, such as in the International Criticality Safety Benchmark Experiments Project, remained a tool for validation of completed nuclear data evaluations. Now, SAMINT extracts information from integral benchmarks in the form of calculated sensitivity coefficients by Monte Carlo codes such as CE TSUNAMI-3D or MCNP6 and combines it with the results of experimental cross-section measurements to produce an updated cross-section evaluation based on both sets of data. The use of the generalized linear least squares methodology ensures that proper weight is given to both the differential and integral data. Near the end of a traditional evaluation process, integral data can be used to resolve remaining ambiguity between differential data sets, highlight troublesome energy regions, determine key nuclear data parameters for integral benchmark calculations, and improve the nuclear data covariance matrix evaluation. However, SAMINT is not intended to bias nuclear data toward specific integral experiments but should be used to supplement evaluation of differential experimental data. At the conference the results of the application of the SAMINT methodology to the new ORNL evaluations of the two isotopes of copper, ^{63}Cu and ^{65}Cu will be presented.

[1] V. Sobes, L. Leal, G. Arbanas, Nuclear Data Adjustment with SAMMY Based on Integral Experiments, Trans. Am. Nucl. Soc., 111, Nov. 2014.

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R260 On the use of the generalized SPRT method in the equivalent hard sphere approximation for nuclear data evaluation

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A consistent description of neutron cross sections from thermal energy up to the to MeV region is challenging. One of the first steps consists in optimizing the optical model parameters using average resonance parameters. Average parameters, such as neutron strength functions, can be derived from an analysis of resolved resonance based on their statistical properties. Neutron strength functions can also be derived from the scattering matrix elements provided by optical model calculations. The generalized form of the SPRT method is used in this work. One of the difficulties is to establish the contributions of the direct and compound nucleus reactions. This problem was solved by using a slightly modified average R-Matrix formula with an equivalent hard sphere radius deduced from the phase shift originating from the potential.
Empirical rules suggest that the neutron strength functions for even angular momentum =0,2,4… are similar, and also those for odd . For the nuclear system ^{238}U+n, an SPRT analysis in the equivalent hard sphere approximation seems to confirm such an empirical rule for =0 and =2. The reasonable agreement between S_0 and S_2 was achieved thanks to the complex coupling scheme proposed with the latest set of optical model parameters established with the OPTMAN code.
This result could become an attractive property for the determination of optical model parameters. Indeed, a set of parameters could be optimized in order to reach a d-wave strength function as close as possible to the s-wave neutron strength function. Inversely, this constraint could help for detecting spurious S_0 values. The validity of such a property was investigated on a wider set of nuclear systems by using the coupled-channel optical models of the OPTMAN, ECIS and CONRAD code.

S261 Analysis on CEA93 library

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In this paper, CEA93 library was studied, which provides the basic nuclear data for APOLLO2-F program of SCIENCE system. The properties of structure for CEA93 library and the methods of maintenance were introduced. By comparing with the WIMS library, the results show that CEA93 library can be readed more quickly than WIMS library because of the index table and be maintained easily by job command stream.

S262 Method of self-consistent evaluation of absolute emission probabilities of particles and gamma rays

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Method of self-consistent evaluation of absolute emission probabilities of particles and gamma rays is described in detail. The method provides an exact taking the intensity balance relationships into account. The covariances of the experimental data are estimated and processed. Technically the evaluation problem has been reduced to a recurrent solution of the systems of linear algebraic equations with the number of equations exceeding the number of unknown variables.
The method enables: 1) to decrease the uncertainties of the evaluated absolute emission probabilities of particles and gamma-rays compared to the traditional methods, 2) to get a balanced decay scheme, 3) in some cases to estimate the unmeasured intensities of weak gamma-rays.
The method was successfully applied for an evaluation of absolute alpha and gamma emission probabilities in decay of ^{242}Cm and ^{244}Cm [1].
Direct inclusion of the exact intensity balance relationships into evaluation procedure leads to a strong correlation and lower uncertainty of the evaluated emission probabilities for the most intense lines compared to the traditional methods. In particular, the uncertainties of the most intense gamma transition probabilities are decreased in few times.
We pay attention to an incomplete and incorrect representation of the correlated emission spectrum values in reference books, publications, evaluated data libraries (ENDF/B-VII.1, JEFF-3.1, etc) as a set of pairs: a recommended value and its uncertainty. Such the representation distorts the uncertainty information of the evaluation because the confidence regions for correlated and uncorrelated evaluated values differ by a form and an orientation in multidimensional space. Moreover, in case of any two strongly correlated (close to 100%) evaluated values one of the variables degenerates. As a result the confidence region for strongly correlated evaluated values has lower dimension.
For the same reason, the ENDF-6 options [2] must be expanded to get an opportunity for a representation of the covariances of the evaluated emission spectra.

1. Badikov S.A., Chechev V.P., New evaluation of the alpha and gamma emission intensities in the decay of ^{244}Cm, Applied Radiation and Isotopes, **109**, pp.164-168 (2015).; 2. ENDF-6, 2011. ENDF-6 Formats Manual. Ed. Trkov A., Herman M., Brown D.A., Report BNL-90365-2009 Rev.2.

S263 Application and research of 281 group cross section library to lattice physics code of COSINE software package

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Lattice physics code develop toward to the exactly calculation direction , including the group structure refining as well as an accurately description of the geometry in transport calculation . The number of energy groups in a cross section library has a significant impact on lattice physics computations ,new developed multigroup cross section library is the SHEM 281 group structure, which is from point wise data treatment tools processing ,had more nuclides information , especially designed to avoid the resonance overlap effect among different nuclides. lattice physics code of COSINE project core and system integrated engine for design and analysis has used this multigroup library to calculation . This paper describes the procedures used to cross section library of the verification process and energy group structure optimization for 281 groups, through the critical benchmark experiments, lattice burnup calculations. The results indicate that the our lattice physics code uses 281 groups can be effectively improved the accuracy and acceptable computation time .

I265 Towards JEFF-3.3: goals, status and perspectives

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Since the release of the JEFF-3.2 nuclear data library, on March 5, 2014, considerable benchmarking and experience has been acquired. JEFF-3.2 generally performs well for a wide range of criticality benchmarks. On the other hand, it falls short of users' expectations as it is missing features that are increasingly expected of a modern nuclear data file. Two main expected, missing features are first, general applicability: best predictions for a wide range of applications beyond the well-tested criticality and simple benchmarks and second, uncertainty propagation and analyses requiring a complete set of covariance matrices. Improved quality assurance of the file is a main goal for which improvements in information technology are increasingly employed for file-production and in particular covariance generation, processing and verification, and benchmarking and validation. An overview will be presented of the improvements undertaken to mitigate against the above problems for the release of JEFF-3.3, foreseen January 2017, referring to recent contributions by the JEFF working groups on evaluations, covariances, decay-data and fission yields, fusion, processing and verification, benchmarking and testing, and thermal scattering data.

R266 Implementation of a new energy-angular distribution of particles emitted by deuteron induced nuclear reaction in transport simulations

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The ability of reproducing the correct energy-angular distribution of neutron (and proton) emitted by deuteron induced nuclear reaction is an essential feature of coupled deuteron/neutron transport simulations. MCUNED (extension of MCNPX) and MCNP6.1 codes are able to perform deuteron transport simulations using evaluated nuclear data libraries to reproduce deuteron induced nuclear reactions. Current TENDL deuteron libraries are built using Kalbach formulation to store data of secondary particle energy-angular distributions. Unfortunately, this formulation is not able to reproduce the forward peaked angular distributions of emitted neutrons and protons, observed in experimental measurement. This forward peaked distribution is the result of deuteron breakup mechanism, which emits neutron and proton in almost the same direction as the incident deuteron. In this work we introduce a new formulation for energy-angular distribution of particles emitted by deuteron induced nuclear reactions. In this formulation the energy-angular distribution of particles produced by deuteron breakup channel is treated differently with respect to the other reaction channels. The angular distribution of particles emitted by breakup reaction is fitted by an exponential law while the angular distribution of particles produced by the other reaction channels is described by the Kalbach formulation. This new formulation only requires two additional parameters to original Kalbach parameters and can be easily stored in ENDF-6 formatted library with very small changes.
This novel approach has been fully implemented from deuteron library generation to deuteron transport simulation. Transport simulations using this methodology show a significant improvement, compared to the former methodology, in the reproduction of integral experiments.

R267 Evaluation of deuteron-induced excitation functions for 186W(d, p)187W and 186W(d, 2n)186Re

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The excitation functions of $^{186}W(d,p)^{187}W$ and $^{186}W(d,2n)^{186}Re$ reactions have been evaluated with the correction of γ-ray branch ratio, radioactive decay constant and standard cross sections. The experimental data of $^{186}W(d,p)^{187}W$ and $^{186}W(d,2n)^{186}Re$ reactions are available in EXFOR library and literature. Analysis and fitting were done from threshold to 50 MeV. The evaluation of excitation functions for $^{186}W(d,p)^{187}W$ and $^{186}W(d,2n)^{186}Re$ reactions were recommended below 50 MeV.

R268 Theoretical calculations and analysis for n+6Li reaction

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R-matrix theory is an important theory of light, medium and heavy mass nuclides nuclear reaction in the resonance energy range. Full R-matrix formalism contains the un-diagonal elements of energy levels matrix and it is rigorous in theory. Because of different assumptions and approximations, many kinds of R-matrix methods are obtained. The new R-matrix code FDRR is presented and includes 4 kinds of R-matrix methods. It can be used for calculating integral cross sections and angular distributions of 2-bodies reactions. The cross sections and angular distributions of $n+^{6}Li$ reaction are calculated and analyzed by FDRR code. The results are in good agreement with experimental data below 20MeV.

R269 Updated and revised neutron reaction data for n+237Np

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The updated and revised evaluation of a complete set of n+^{237}Np nuclear data from 10^{-5} ~ 20 MeV were carried out and recommended based on the evaluated experimental data. The mainly revised quantities are the fission cross sections, inelastic, (n, 2n) and (n, g) cross sections as well as angular distribution etc. The promising results were obtained when the renewal evaluated data of ^{237}Np will be used to instead of the evaluated data in CENDL-3.1 database.

I270 Investigations of the inelastic scattering of fast neutrons on iron-56

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At the neutron time-of-flight facility nELBE [1] of the Helmholtz-Zentrum Dresden – Rossendorf, Germany, investigations of the inelastic neutron scattering on ^{56}Fe have been performed. As indicated by the NEA/WPEC Subgroup 26 report [2], the NEA High Priority Request list [3] and CIELO project [4] ^{56}Fe is of great interest for the development of novel nuclear facilities and for the improvement of the basic knowledge about nuclear reaction mechanisms. New evaluations are ongoing.
At nELBE neutrons in the energy range from 100 keV to 10 MeV are available and two different experimental techniques were utilized to study inelastic scattering: a double time-of-flight technique and the measurement of photon production.
The double-time-of-flight setup consists of a set of long plastic scintillators for neutron detection and an array of BaF_2 scintillators for photon detection. By coincident registration of the de-excitation photons and scattered neutrons the triple differential inelastic scattering cross section, i.e. dependent on the energy of the incoming neutron and the emission angles of the neutron and the photon, can be determined. The photon production cross section and the photon angular distribution was determined using an array of HPGe- and $LaBr_3$-detectors detecting only the emitted photons. Both techniques were applied to deduce the angle integrated inelastic neutron scattering cross section of the first excited state of ^{56}Fe. A deviation of the cross section determined by double-time-of-flight from the result of the photon production measurement and values from the literature gives indication to an angular correlation effect between the emitted neutron and photon.

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R271 Measurements of 89Y(n,2n)88Y and 89Y(n,3n)87Y cross sections for fast neutrons by using the Korea Institute of Radiological and Medical Science MC-50 cyclotron

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In the study of fast neutron systems such as accelerator driven systems, nuclear data for neutron induced reactions at energies above 20 MeV are required, but they are not well known. For instance, it is known that content of Yttrium can improve the corrosion resistance of Zirconium-base alloy, but the data on 89Y (n, 2n) cross sections at neutron energies above 30 MeV do not exist. Also, the data on 89Y (n, 3n) reactions are only scarcely measured with large uncertainties. In this work, we thus consider the neutron induced reactions of Yttrium for fast neutrons. The reaction products 88Y and 87Y emit gamma-rays, and their half-lives are long enough to measure. By using the neutron activation analysis method, we measured 89Y (n, 2n) and (n, 3n) cross-sections.

A proton cyclotron MC-50 in Korea Institute of Radiological & Medical Science (KIRAMS) is used to carry out neutron activation experiments with Y2O3 targets irradiated with neutron beams of a continuous spectrum produced by proton beams on a thick beryllium target. Neutrons are generated by 9Be (p, n) reaction with incident protons of 20 A. The continuous neutron spectra generated by proton beams of 30, 35, and 40 MeV are calculated by GEANT4 simulations and are experimentally tested against the integrated neutron flux by extracting the cross sections of 56Fe(n, p)56Mn and 27Al(n,)24Na, which are found to be in good agreement with the existing experimental cross sections. The gamma-rays emitted by the reaction products 87Y and 88Y are measured with HPGe detectors. From the measured gamma-ray activities induced in Yttrium, the gamma-ray disintegration rate in each sample was deduced. By using a subtraction method, the average cross section of 89Y (n, 2n) and (n, 3n) reactions in the neutron energy ranges of 28 ~ 33 MeV and 33 ~ 38 MeV are obtained and are found to be close to the cross sections from TALYS and the existing EXFOR data. The present study shows that continuous energy neutron spectra can be used to obtain the average cross section of (n, xn) reactions by using a subtraction method.

R272 Measurement of (N, XN gamma) reaction cross section in W isotopes

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Most nuclear reactor developments use evaluated databases for numerical simulations to optimize performance and reactor control parameters. However, the considered databases present still large uncertainties, preventing calculations from reaching the required precision. The necessary improvement of evaluated databases entails new measurements and a better theoretical description of involved reactions. Among those, (n, xn) reactions are of great importance for the operation of a reactor as they modify the neutron spectrum, the neutron population, and produce radioactive species.

The IPHC group started an experimental program with the GRAPhEME setup installed at the neutron beam facility GELINA (Geel, Belgium) to measure (n, xn gamma) reaction cross sections using prompt gamma spectroscopy and neutron energy determination by time-of-flight [1-3]. The obtained experimental data provide constraints on nuclear reaction mechanisms models. Measurements of (n, xn gamma) cross section have been performed for ^{nat,182,183,184,186}W, which will be discussed in this contribution, and also for ^{232}Th, ^{235,238}U and ^{nat}Zr.

Tungsten is not an active element in nuclear reactors, but, because of its chemical and mechanical properties, it is used in many alloys. The interaction of neutrons with tungsten is therefore of importance for reactor physics, in particular for fusion reactors in which tungsten is one of the most exposed material to high energy neutrons. From a theoretical point of view, a better description of (n, xn) reactions on tungsten nuclei allows an improvement of models for other key nuclei in reactors fuel. Indeed, tungsten isotopes are deformed like actinides, but also easier to describe as they do not present a neutron-induced fission channel. Still, there are only a few measurements available today to test evaluations. Our new experimental data will provide a constraining test to the predictability of models.

The experimental setup and the data analysis method will be presented. The experimental results for natural tungsten isotopes will be compared to the latest predictions from the usual nuclear reaction codes. From this we will investigate the consequences for reaction mechanism models.

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R273 Fast neutron-induced fission at the time-of-flight facility nELBE

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Neutron induced fission cross sections of actinides like the Pu-isotopes are of relevance for the development of nuclear transmutation technologies. For ^{242}Pu current uncertainties are of around 21 %, the target uncertainties in the order of 7 %. Sensitivity studies [1], [2] show that the total uncertainty has to be reduced below 5 %, to allow for reliable neutron physics simulations. This challenging task will be performed at the neutron time-of-flight facility of the new German National Center for High Power Radiation Sources at HZDR, Dresden. Improved experimental conditions (low scattering environment) and beam power, paired with the right spectral shape of the *n*ELBE neutron source provide excellent conditions to achieve this aim [3].
Within the TRAKULA project, large and homogeneous deposits of ^{235}U and ^{242}Pu have been produced successfully. Using two consecutively placed fission chambers [4] allows the determination of the neutron induced fission cross section of ^{242}Pu relative to ^{235}U. The areal density of the Plutonium targets was calculated from the measured spontaneous fission rate.
First experimental results of the fast neutron induced fission of ^{242}Pu acquired at *n*ELBE will be presented and compared to recent experiments (e.g. [5]) and evaluated data. Corrections addressing the neutron scattering are discussed by using results of different neutron transport simulations (Geant 4, MCNP 6 and FLUKA).

This work is supported by the EURATOM FP7 project CHANDA and by the German Federal Ministry of Education and Research (03NUK13A).

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S274 Measurements of cross sections for 209Bi (n, 4n) reactions with high energy neutrons produced by 30, 35, and 40 MeV protons

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Experimental cross sections on ^{209}Bi (n, 2n), (n, 3n), (n, 4n) have been measured only at a few neutron energies, while such nuclear data are needed for the development of Accelerator Driven Systems with Pb-Bi coolants. We have thus measured (n, xn) cross sections of ^{209}Bi at neutron energies in the range of E_n (28 ~ 38) MeV. Bismuth oxide and gold samples were irradiated with the neutrons produced by proton beams on a thick beryllium target, where the gold sample is used for monitoring the neutron flux. The proton beams of 30, 35 and 40 MeV are available at the MC-50 Cyclotron of Korea Institute of Radiological Medical Sciences (KIRAMS). By measuring the gamma-rays from the irradiated samples with HP-Ge detectors, we analyzed the activities of ^{208}Bi, ^{207}Bi and ^{206}Bi and extracted the (n, xn) cross sections.
The neutron flux $\Phi(E_n, E_p)$ generated by the proton beams impinging on the beryllium target with proton energies of E_p were obtained by GEANT4 Monte-Carlo simulations. We first tested the validity of the simulated neutron flux $\Phi(E_n, E_p)$ by extracting the experimental cross sections of ^{56}Fe (n, p) ^{56}Mn and ^{27}Al (n,α) ^{24}Na and found good agreement between our cross sections with other existing data. While $\Phi(E_n, E_p)$ is not mono-energetic, the differences in the neutron fluxes obtained by the proton beams with neighboring E_p, i.e., $\Phi(E_n$, 40 MeV) - $\Phi(E_n$, 35 MeV) and $\Phi(E_n$, 35 MeV) - $\Phi(E_n$, 30 MeV) can be used to extract the average cross sections. Using this method, we could obtain the (n, xn) cross sections at E_n =(28~33) and (33~38) MeV and compared our results with those from TALYS and the EAF-2010 library.

S275 Neutron transmission measurement for natural W at nELBE

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Korea has developed a Helium Cooled Ceramic Reflector Test Blanket Module (Ko HCCR TBM) related to the ITER project. Tungsten is considered as a prime candidate of plasma facing materials in fusion reactors and/or a structure material of Ko HCCR TBM. Recently, KAERI (Korea Atomic Energy Research Institute) evaluated neutron total and elastic scattering cross sections of tungsten isotopes for neutron energy up to 150 MeV based on nuclear reaction codes and available measurement data. New experimental data were measured at nELBE of HZDR (Helmholtz-Zentrum Dresden-Rossendorf) for the comparison with the evaluated and existing measurement data. The neutron source nELBE adopts a 40 MeV superconducting electron linac and a liquid Pb target for time-of-flight measurements. The nELBE neutron source uses no moderator and provides fast neutrons. An electron bunch length of 5 ps and a compact target provide a good neutron energy resolution with a relatively short flight length compared to other time-of-flight neutron sources. Transmission data of a natural tungsten sample were measured with a flight path length of 851.1 cm and repetition rate of 101.6 kHz . The neutron total cross section of natural tungsten was obtained in the energy range between 100 keV and 10 MeV.

S277 Angular distribution measurement of gamma rays from inelastic neutron scattering on iron-56 at nELBE time-of-flight facility

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The inelastic neutron scattering reaction on ^{56}Fe was studied at the nELBE time-of-flight facility[1], the only photo-neutron source at a superconducting electron accelerator worldwide. The incoming neutron energy ranges in the fast neutron spectrum from 100 keV to 10 MeV, where high precision nuclear data is needed[2].
Regarding the new CIELO[3] evaluation on ^{56}Fe, there is a great interest on improving the knowledge of inelastic scattering angular distribution and increasing the accuracy on the partly very diverse data in literature.
To investigate angular distribution of the emitted particles a new detector setup has been installed. It contains five HPGe detectors and five $LaBr_3$ scintillation detectors, which can be set under different angles. For this measurement they were positioned under 30, 55, 90, 125 and 150 degrees, relative to the beam axis.
By cyclical measurement with and without the natural Fe-target the intrinsic and the neutron induced background from the setup except for the target has been subtracted. Correction for gamma-self-absorption inside the target and extended source efficiency were done using GEANT4 simulations.
The angular distribution data measured with the HPGe detectors are compared with data from D. L. Smith[4]. Due to the much better time resolution in $LaBr_3$ detectors high resolution data have been obtained.

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S278 Inspection of 56Fe g-ray angular distributions as a function of incident neutron energy using optical model approaches

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Inelastic neutron scattering differential cross sections, (n,n') and (n,n γ), are measured at the University of Kentucky Accelerator Lab (www.pa.uky.edu/accelerator) for both basic and applied research. The g-ray angular distributions are generally discussed using Legendre polynomial expansions. For nuclear data purposes, angle-integrated cross sections are desired over a wide range of fast neutron energies. Three to four days of experimental beam time are required for a data set at each incident neutron energy, which limits the number energies that can be measured in a reasonable amount of time. Approximations are employed to generate cross sections on a finer energy grid. At 125°, the a_2P_2 term of the Legendre expansion is identically zero and the a_4P_4 is assumed to be very small. Provided this assumption is true, a single measurement at 125° will return A_o and the cross section is deduced. The a_2 and a_4 coefficients are determined by the relative m_J substate populations of each excited state, which in turn are controlled by an angular momentum analysis of the scattering process with the mixing ratios, and the transmission coefficients which are energy dependent.
This project tests these assumptions and energy dependences using the codes CINDY/SCAT and TALYS/EMPIRE/ECIS06. The energy dependence of transmission coefficients and the resulting substate alignment are examined as a function of incident neutron energy. A better understanding of our experiment's uncertainties for the angle-integrated γ-ray production cross sections and a better understanding of the reaction mechanisms involved in the process are gleaned from this analysis and will be presented.
This research was supported by a grant from the U.S. Department of Energy - Nuclear Energy Universities Program: NU-12-KY-UK-0201-05. The isotopes used in this research were supplied by the United States Department of Energy Office of Science by the Isotope Program in the Office of Nuclear Physics.

I279 Inelastic neutron scattering with GAINS@GELINA: an overview of the last decade

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Measurements of neutron inelastic cross sections started at IRMM-JRC in 2001 with two Ge detectors on a table at the end of a 200 m flight path of GELINA neutron source. Since then, the number of detectors was increased to 12 100% HPGe placed in the backward hemisphere on a dedicated "ball" support structure. The acquisition is digitized. The efficiency of the installation is modeled with MCNP and the data processing is largely automatized. Data has been collected for numerous isotopes, most of the results being published. The data precision is better than 5% complying with the highest quality standards and the most severe requirements. The problems arising during this activity inspired further developments like an ancillary detector for electrons and the possibility of performing coincidence measurements which are currently under study.

R280 (n,xn gamma) Cross sections on actinides versus reaction code calculations

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(n,xn) and especially inelastic reactions (slowing down processes), are of importance in a reactor core as the cross sections impact for example the radial power or some neutronic parameters like k_{eff}. This impact has been demonstrated in sensitivity studies

, and has been highlighted by the introduction of requests in the High Priority list of the Nuclear Energy Agency. The target accuracy demand is very tight (few percent) and represents a real challenge from the experimental point of view. Our collaboration has chosen the prompt gamma-ray spectroscopy coupled to time of flight measurements to face this challenge and provides complete sets of (n,xn g) cross sections on various nuclei.
One part of the measurement campaigns concerns actinides samples and is performed at GELINA, a multiuser neutron time-of-flight facility operated by EC-JRC-IRMM, in Geel, Belgium. The experimental setup GRAPhEME (GeRmanium array for Actinides PrEcise MEasurements) has been especially designed to take into account the specific difficulties generated by the use of actinides samples. Special care has been also paid to quantify as accurately as possible all the uncertainties from the instruments and the analysis procedure. Once accurate (n,xn g) cross sections are produced with GRAPhEME, the way to obtain (n,xn) cross sections is not straightforward and the use of model calculations is required.
In this paper, we will present some recent results obtained on different actinides - ^{238}U, ^{232}Th -compared to the state of the art of modeling with reaction codes. A new measurement campaign on ^{233}U has started recently, a first assessment of the recorded data will be presented and conclusion and outlooks for future measurement programs will be discussed.

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R281 (n,xn) cross sections on 56,57Fe

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Iron is undoubtedly an essential structural material for any nuclear facility and therefore extremely precise knowledge of the neutron cross sections are highly important.
We employed the GAINS spectrometer [1] operated at the GELINA neutron source [2] in order to measure (*n*, *xn*) cross sections on ^{56,57}Fe using γ spectroscopy techniques reaching a level of uncertainty of the order of 5%.
The results obtained for the ^{56}Fe isotope were already reported in Ref. [3]. In case of more recent experiment on the ^{57}Fe isotope, serious difficulties arise from the fact that the first excited level has an excitation energy of only 14 keV and its decay could not be observed. Therefore a delicate combination of experimental and theoretical approaches have to be used to infer the inelastic cross section.
We will present the particularities of the two measurements concentrating on the approaches allowing us to overcome specific problems in each case.

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R282 Measurements of neutron scattering angular distributions with a new scintillator setup at GELINA

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A new measurement setup for the investigation of neutron scattering angular distributions is being developed at GELINA, the neutron time-of-flight facility operated by the EC-JRC Institute for Reference Materials and Measurements. With this setup, the secondary particles emitted by the neutron scatter are detected directly using up to 32 organic liquid scintillators. The contribution of elastic scattering is separated from the inelastic by deconvoluting the scintillators pulse-height spectra. Both the differential and the total angle integrated cross-sections are obtained by measuring the incident flux with a U-235 fission chamber and applying the Gauss-Legendre quadrature technique. For verification, the elastic scattering cross section of natural carbon was measured, testing limits and possibilities of the method. The final purpose is its application with nuclides of interest for criticality calculations, and thus iron was chosen as first study case. The first experiment with natural iron was carried out in collaboration with the Helmholtz-Zentrum Dresden-Rossendorf at the nELBE facility, using a sample of 3 mm thickness and employing 16 detectors. The calibration of the detectors, 8 EJ301 hydrogen-based and 8 EJ315 per-deuterated benzene scintillators, their response function, necessary for the proper unfolding of the spectra, and the detection efficiency were determined at the Physikalisch-Technische Bundesanstalt of Braunschweig.

R283 Measurement of (n,a) cross section for set of structural material isotopes

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In spite of the fact that structural material is widely used in nuclear power engineering, the data for (n, α) reaction cross section given in different libraries are significantly discrepant. Therefore new experimental efforts are necessary to resolve the problem. Unfortunately the (n,α) reaction for many structural material elements produced nonradioactive residual nuclei in output channel and classical activation technique can not be used. A novel spectrometer was developed and used to measure the cross section for the (n,α) reaction at IPPE. The basic parts of the new instrument are an ionisation chamber with Frisch grid, a solid target, and signal digitisation. It is shown that simultaneous digitisation of the anode and cathode signals allows realising effective background suppression. Monoenergetic neutrons were generated in (d, d) reaction. The reaction of ^{238}U fission was used as a neutron flux monitor. Direct measurements of the α-particles yield from solid isotopic pure targets of 50, 52 and 53 chromium 54 and 57 iron and 60 nickel were carried out. Measurements in a neutron energy range from 4.7 to 7.2 MeV were carried out. For some isotopes the (n, α) reaction cross-sections for neutron energies less than 14 MeV were measured for the first time. The result of comparison of new experimental data with the evaluated data libraries ENDF/B VII, JENDL 4.0, JEFF 3.1, ROSFOND 2010 and BROND 3 and the experimental data of other authors is present.

I284 Update on the nuclear data working group in the United States

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As a result of a Nuclear Data Needs and Capabilities for Applications (NDNCA) Workshop at Lawrence Berkeley National Laboratory in May 2015, program managers from a wide range of U.S. government agencies (DOE-Office of Science, DOE-Nuclear Energy, National Nuclear Security Agency, Department of Homeland Security) interested in nuclear data activities decided that it would be useful to meet periodically to exchange updates on efforts and investments in Nuclear Data occurring in their different program areas. A working group of representatives chosen by these program managers was organized to identify and prioritize opportunities to enhance and magnify the fidelity and impact of a variety of nuclear data activities. This Nuclear Data Working Group (NDWG) intends to identify nuclear data activities where enhanced collaboration and coordination amongst the various program offices with mission critical nuclear data needs would be broadly beneficial. The NDWG also intends to recommend topics for experimental research and data compilation relevant to nuclear data for applications and report their findings to DOE-Nuclear Physics and the participating federal program offices. This paper summarizes the progress of the NDWG to date.

R285 Nuclear data for ion beam analysis applications

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Ion Beam Analysis is a suite of non-destructive analytical techniques that provide information on the bulk composition and/or depth profile of surface layers of materials. As such they are used in applications ranging from materials analysis to cultural heritage, environmental studies, fusion technologies, biomedical and forensic applications.
For over 10 years, the Nuclear Data Section (NDS) of the IAEA has been serving as the international centre for the collection and dissemination of nuclear data for Ion Beam Analysis. Through a series of Coordinated Research Projects (CRP) [1,2], collaborations with expert scientists and staff efforts, it has created and maintained the Ion Beam Analysis Data Library (IBANDL) [3] that contains over 6000 datasets of differential and total cross sections in the low energy region below several MeV.
The most recent CRP on Particle-Induced Gamma-ray Emission spectroscopy (PIGE) [2] from 2011 to 2015 has resulted in augmenting the data library by over 300 new datasets of gamma-ray production cross sections needed in the implementation of the PIGE technique in bulk analysis and depth profiling.
Since 2013, the NDS is fully responsible for compilation of data and for maintenance of the retrieval system of IBANDL. Recently, it has also initiated a coordinated effort to evaluate data for charged-particle-induced reactions in the resolved-resonance region in response to emerging needs for such data in a broad spectrum of applications including Ion Beam Analysis.
In this paper we present the current status of the content of IBANDL, as well as the new retrieval features that have been introduced to facilitate the user in searching, retrieving and plotting data. We report on the progress made in the coordinated evaluation effort and finally, we discuss the perspectives for further development in the future.

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R286 Developments in capture-gamma libraries for nonproliferation applications

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The neutron-capture reaction is of fundamental use in identifying and analyzing the gamma-ray spectrum from an unknown assembly because it provides unambiguous information on the neutron-absorbing isotopes. Nondestructive-assay applications may exploit this phenomenon passively, for example, in the presence of spontaneous-fission neutrons, or actively where an external neutron source is used to probe the unknown assembly. There are known gaps in the Evaluated Nuclear Data File (ENDF) libraries corresponding to capture-gamma data that otherwise limit transport-modeling applications. In this work, we describe how new thermal-neutron capture data are being used to improve information in the ENDF libraries for isotopes relevant to nonproliferation applications. We address this problem by providing new experimentally-deduced partial and total neutron-capture reaction cross sections and then evaluate these data by comparison with statistical-model calculations.
This work was performed under the auspices of the University of California, supported by the Director, Office of Science, Office of Basic Energy Sciences, of the U.~S. Department of Energy at Lawrence Berkeley National Laboratory under Contract DE-AC02-05CH11231, the U.~S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344, and by NAP VENEUS OMFB 00184/2006.

R287 Delayed gamma-ray spectroscopy technique for nuclear security and safeguards in a project of active neutron non-destructive analysis (NDA) developments

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For nuclear security and safeguards in the global increase of nuclear applications and their industries, requirements on effective detection, qualification, and quantification technology of nuclear material (NM) are growing. Total gross mass monitoring of NM with low radiative emission is performed using passive non-destructive analysis (NDA) techniques, while destructive analysis (DA) techniques are applied for precise analysis of nuclide composition. In addition to the passive NDA techniques, active NDA techniques would acquire different information from sample objects. Using particles (such as photons and neutrons) to induce nuclear reactions, the quality and/or quantity of NM in a sample is deduced from the measured emitted particles. Such an active interrogation method would be also useful for detection of hidden NM. An active neutron NDA system equipped with a pulsed neutron generator is currently under development for technological study of Differential Die-Away Analysis (DDA), Delayed Gamma-ray Spectroscopy (DGS), Neutron Resonance Transmission Analysis (NRTA), and Prompt Gamma-ray Analysis (PGA) techniques. Of these, DGS measures decay gamma-rays from fission products (FP) proportional to each fission yield distribution of fissile material, enabling the isotope ratio of a sample to be deduced. In order to evaluate a spectrum, integration of nuclear data of fission cross-sections, fission yields, half-lives, decay chain patterns, and decay gamma ray yields are required. The development of the DGS technique includes experimental checks (or precise re-measurements) of nuclear data of fissile materials as well as development of the system. The studies are being carried out in a collaboration between the JAEA and the JRC. This presentation will be a brief introduction of this active neutron NDA project and an explanation of the DGS development program. Some preliminary results of DGS carried out at JRC-ITU (Ispra) are also presented.

S288 Influence of the neutron transport tube for neutron resonance densitometry

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Neutron Resonance Densitometry (NRD) is an assay technique of nuclear materials in particle-formed debris that contains various nuclides, such as of structural materials and the others. It is a combination of two techniques: Neutron Resonance Transmission Analysis (NRTA) , and Neutron Resonance Capture Analysis (NRCA) or Prompt Gamma-ray Analysis (PGA). Containing nuclides in a sample are identified by NRCA/PGA. The information of NRCA/PGA is used in NRTA analysis to quantify nuclear material isotopes. A neutron time of flight (TOF) method is used in NRD measurements. A facility consisting of a neutron source, neutron flight paths, and detectors, is required. One of the distinctive features is utilization of a short flight path; this increases the neutron beam strength, and reduces construction cost in a practical applications. On the other hand, that
reduces resolving power in TOF measurements, and increases neutron background. In order to investigate the effect of neutron flight length, we carried out NRTA experiments with a short neutron flight path constructed at the Kyoto University Research Reactor Institute - Linear Accelerator (KURRI-LINAC).
In measurements of NRD, the quantity of the nuclear materials is determined from NRTA spectra in the neutron energy range of less than 30 eV. At KURRI-LINAC, we have examined NRTA with a 7-m flight path. The resonance dips of 183W at 27 eV was successfully observed with an electron pulse width less than 2 μs. This indicates the applicability of short-flight-path TOF system to nuclear material quantification. The importance of the pulse width of neutron beam should be noted. Both simulation studies and experiments

S289 Elemental composition and sedimentation rates in a marine system influenced with the tide action using INAA and Plomb-210 method: example of the Gabes Gulf (Tunisia)

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The revelation of primary composition, digenetic and geochemical process affecting the sedimentary records in marine environment is necessary to answer origin and dynamics of pollution especially in area with variable hydrodynamic. Using nuclear tools as a complementary approach to conventional methods of quantification of pollution appears very interesting in such active areas. This study was carried out to assess elemental composition in relation with sedimentary dynamics of sediments from the Gabes Gulf of Tunisia.
For this purpose two sediment cores were collected from two settings in the Gabes Gulf (G-1 and G-2) in 2013.
Isotopic method based on measurements of the natural radionuclide ^{210}Pb ($t_{1/2}$ = 22.3 yr) associated with the artificial radionuclide ^{137}Cs ($t_{1/2}$ = 30 yr) were applied to determine sequences of sediment deposition and rates of sediment accumulation and mixing. Activities were determined respectively with alpha and gamma spectrometry.
Mercury (Hg) was analyzed with DMA-80 Analyzer. The concentrations of 27 elements (Al, Fe, K, Na, Ti, V, Mn, Sc, Co, Cr, Rb, Cs, Ce, As, Sm, Tb, Yb, Lu, Hf, Ta, Th La, Eu, Sb, Br and La) only in the G-1 core were determined by instrumental neutron activation analysis (INAA).
The results support multiple conclusions: (1) Sedimentation rates obtained range from 0.5 gcm^{-2}year^{-1} to 1 gcm^{-2}year^{-1} along the depth, and are consistent with previous work developed in the Mediterranean Sea. (2) Down core concentration of Hg profile show significant variation that could be due to the variable sedimentation rate and the tide action specifics of the region, values range between 0.2 to 30μg/g for G-1 and from 0.3 to 10 μg/g for G-2 (3) Traces metals values show an increase in the concentrations of Al, Mn, Br, Cr, Co, Rb, V, Ce and Hf with the depth. Cluster and Enrichment Factor (EF) values were discussed; data are used to acquire a general image of the primary composition of the sediments and the sedimentary processes. However, it can be used as a base background level for a future marine monitoring program of the Gabes Gulf.

S290 Designing tools for oil exploration using nuclear modeling

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In the oilfield, exploration of the subsurface is essential to answer questions regarding location, quantity and type of hydrocarbon and its producibility. Well logging provides measurements of the rock formation characteristics and the fluids in their pore space. Downhole nuclear measurements focus on formation properties such as natural radioactivity, formation density and hydrogen content as well as the identification of the elemental and mineralogical composition of the rock. They rely on a multitude of nuclear properties and interactions.
The downhole drilling environment in which Logging While Drilling (LWD) nuclear tools are used can be severe. These tools have to work at temperatures that may exceed 175˚C, while being exposed to repeated shocks of 100 g and more, and they must be protected by pressure housings withstanding downhole pressures of 2000 atmospheres or more, while delivering accurate and reliable measurements. Modeling is essential in defining promising tool concepts, tool geometries and materials, while respecting mechanical constraints of the tool construction.
Tool concept evaluation and detailed tool characterization requires accurate modeling. The better the model, the closer the final tool will be to the predictions and thus we can be more confident in the results. It is therefore essential to evaluate tool concepts through modeling before launching an often expensive development project. Not only does modeling provide an excellent starting point for the tool design, it will also reduce the number of design iterations that may be required as the design evolves. As the tool matures, modeling is used to complement experimental data and to expand the database to include situations, which are difficult or impossible to reproduce in the lab.
The presentation will focus on the importance of good knowledge of nuclear cross sections of the elements found in tool, borehole and subsurface formation. For neutron induced inelastic and capture gamma ray spectroscopy, major obstacles may come from a lack of or inaccuracies of cross sections for essential materials. We will also show examples for the benchmarking of the modeling results against experimental data obtained during tool characterization and discuss discrepancies encountered in the process.

S291 Non-destructive assay of nuclear materials using a self-indication method

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A fast reactor system with trans-uranium (TRU) fuels including minor-actinide (MA) is expected to be effective for the incineration of high-level radioactive wastes. In order to realize the fast reactor system, integrity evaluation of the fuels with high activity is required for the safety operation. Therefore, the project entitled as “Development of Non-destructive Methods Adopted for Integrity Test of Next Generation Nuclear Fuels (N-DeMAIN)” has been started in Japan from October 2014. In this project, the neutron resonance transmission analysis (NRTA) is adapted for the identification and quantification of nuclides in the fuels by neutron time-of-flight (TOF) measurement.
We propose a new concept of “self-indication method” combined with neutron resonance densitometry. In the method, the indicator made of the target isotope is set after the sample. Then, the neutrons transmitted through the sample can be indirectly measured by detecting the reaction products such as neutron capture gamma rays with a TOF method. The self-indicator is a transmission neutron detector that has high efficiency around the objective neutron resonance energies of the target nuclide, enabling us to quantify the target area-density easily from the difference of the counts with or without the sample. We performed the numerical and experimental verification. The results of numerical verification showed that the area density of fuel material can be determined in the range from 10-6 to 10-2 (/b) using multi resonances. Moreover, the experimental verification performed at the Kyoto University Research Reactor Institute – Linear Accelerator (KURRI-LINAC) indicated that the contribution from the impurities in the sample such as MAs can be remarkably suppressed by applying the self-indication method.
Present study includes the result of “Development of Non-destructive Methods Adopted for Integrity Test of Next Generation Nuclear Fuels” entrusted to Kyoto University by the Ministry of Education, Culture, Sports, Science and Technology of Japan (MEXT).

I292 Exploring for oil with nuclear physics

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Oilfield service companies, like Schlumberger provide a large variety of services to oil companies to help them identify and assess oil reservoirs and to allow them to optimize their production. A large part of Schlumberger's business is to provide petrophysical information on rock formations in particular on those containing hydrocarbons, i.e. oil and gas. Some parameters of interest are the amount of pore space in the rock, the quantity of oil or gas contained in the rock, the composition of the rock matrix, its permeability etc. Many physical measurements to obtain electromagnetic, acoustic, magnetic resonance and nuclear properties of the formation surrounding the wellbore are used for this purpose. This talk will give an introduction to the application of nuclear physics in this oil industry with the most advanced nuclear measurements (Capture and Inelastic Gamma Ray Spectroscopy, Neutron-Gamma Density, Thermal Neutron Capture Cross Section, Natural Gamma Ray, Gamma-Gamma Density, Neutron Porosity) that are currently employed, for the development of which the use of accurate nuclear scattering and reaction cross sections is crucial. A brief description of the technical challenges associated with putting nuclear technology (pulsed neutron generators, Detectors,…) in the extreme conditions of an oil well (temperature, shocks, pressure) will also be given.

R293 Neutron resonance analysis for nuclear safeguards and security applications

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Neutron-induced reactions can be used to study the properties of nuclear materials in the field of nuclear safeguards and security. The elemental and isotopic composition of these materials can be determined by using the presence of resonance structures in the reaction cross sections as fingerprints. This idea is the basis of two non-destructive analytical techniques which have been developed at the GELINA neutron time-of-flight facility of the JRC-IRMM: Neutron Resonance Capture Analysis (NRCA) and Neutron Resonance Transmission Analysis (NRTA). In particular, NRTA is an absolute analysis method which does not require sample preparation or any calibration using representative reference materials. A full quantitative validation of the NRTA technique was obtained by determining the areal densities of enriched reference samples used for safeguards applications with an accuracy better than 1 %.
Moreover, a combination of NRTA and NRCA has been proposed for the characterisation of particle-like debris of melted fuel formed in severe nuclear accidents. In order to deal with the problems due to the diversity in shape and size of these samples and the presence of strong absorbing matrix materials, new capabilities have been implemented in the resonance shape analysis code REFIT. They have been validated by performing a blind test in which the elemental abundance of a combined sample composed of unknown quantities of materials such as cobalt, tungsten, rhodium or gold was determined with accuracies better than 2%.

R294 Experiments at the GELINA facility for the validation of the self-indication neutron resonance densitometry

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Self-Indication Neutron Resonance Densitometry (SINRD) is a passive non-destructive method that is being investigated to quantify the ^{239}Pu content in a spent fuel assembly. The technique relies on the energy dependence of total cross sections for neutron induced reaction. The cross sections show resonance structures that can be used to quantify the presence of materials in objects, e.g. the total cross-section of ^{239}Pu shows a strong resonance close to 0.3 eV. This resonance will cause a reduction of the number of neutrons emitted from spent fuel when ^{239}Pu is present. Hence such a reduction can be used to quantify the amount of ^{239}Pu present in the fuel. A neutron detector with a high sensitivity to neutrons in this energy region is used to enhance the sensitivity to ^{239}Pu. This principle is similar to self-indication cross section measurements. An appropriate detector can be realized by surrounding a 239Pu-loaded fission chamber with appropriate neutron absorbing material. The latter are mostly referred to as SINRD filters.
The present concept of SINRD is strongly based on Monte Carlo simulations. In this contribution experiments performed at the GELINA time-of-flight facility of the JRC at Geel (Belgium) to validate the simulations are discussed. Two types of measurements were performed: transmission and self-indication measurements. The former were carried out to verify the quality of the nuclear data used in the simulations and to verify the optimum thickness of the SINRD filters derived from Monte Carlo simulations. The results of the self-indication experiments are used to test the performance of different neutron detectors and to validate the SINRD concept. Foils of Cd were used to mimic the absorption due to ^{239}Pu, whereas the detection system consisted in a thin Cd foil and a set of C6D6 detectors to mimic the response of a ^{239}Pu fission chamber. A ^{235}U fission chamber and a 10B ionization chamber were also used to compare the response of different detector types. The results confirm that the strongest sensitivity to the target material was achieved with the self-indication technique, highlighting the importance of using a ^{239}Pu fission chamber for the SINRD measurements.

R295 Applications of gamma spectrometry and particle accelerators in the field of nuclear forensics

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This work presents the applications of gamma spectrometry and charged particles accelerators in nuclear forensic science at IFIN-HH. The investigated samples consisted of fuel cycle uranium of different enrichments and fuel grade plutonium. Isotopic composition analysis needed for the fast categorization of the nuclear material seized in illicit trafficking was performed using MGAU code for uranium and MGA code for plutonium. Elemental signatures of the uranium samples (minor and trace elements) were investigated by Particles Induced X-ray Emission (PIXE), Particles Induced Gamma-Ray Emission (PIGE), and Nuclear Reaction Analysis (NRA) techniques at the 3 MV Tandetron particles accelerator. GUPIX software was used to determine elemental concentrations from the X-ray spectra. Methodological triangulation was applied for age dating of the studied nuclear materials by gamma spectrometry. The two chronometers used for the age dating of the analyzed samples are ^{214}Bi/^{234}U for uranium and ^{241}Am/^{241}Pu for plutonium. The GAMMAW software was used for gamma-ray spectra analysis, while GESPECOR code was used for full energy peak efficiency calculations by Monte Carlo simulations. Characteristic gamma rays of the radionuclides from uranium and plutonium decay series, as well as particle induced gamma and X-rays were measured using small and large volume high purity germanium detectors, placed in the low background laboratory and Ion Beam Analysis (IBA) reaction chamber. The potential of Accelerator Mass Spectrometry (AMS) facility for precise age dating of actinides is presented as well.

R296 134mTe, 135mTe,136mXe (ratio) production yield measurements for SNM detection and identification at border control points

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Nowadays, border security is a matter of utmost importance for all European Union. It is therefor essential to control Special Nuclear Matter (SNM) flux at border control points. In particular, to prevent illicit trafficking, potentially involved in the conception of a nuclear device. In order to do so, in the frame of the H2020 European project C-BORD, a new method for SNM detection & identification on-board of a container is being developed.
This inspection technique is non-intrusive and active. The principle is a two-step procedure: first, produce photofission reactions in nuclear material using a commercial 9 MeV LINAC, and second, detect delayed gamma rays emitted by three specific isomers of interest: ^{134m}Te, ^{135m}Te & ^{136m}Xe. The energies and half-lives of these γ-rays (164 ns < $T_{1/2}$ < 2.95 µs) present advantageous measurement conditions: the reduction of the photo-absorption in different material (Eγ> 1 MeV)and a better signal over background ratio (due to stronger activity compared to longer-living isotopes). Moreover, using gating-technique, measurements take place 100 ns after γ-irradiation, avoiding prompt γ-background.
Use of these isomeric states for the detection of SNM leads to the identification of fissile and fertile actinides. Indeed the ratio of production yields of these isomers (Y(^{134m}Te)/Y(^{135m}Te), Y(^{134m}Te)/Y(^{136m}Xe), Y(^{135m}Te)/Y(^{136m}Xe)) will give a specific signature of the nuclear material that underwent the photofission reaction.
Will be presented in this talk, the innovative method allowing SNM identification in containers at border control points as well as the first results of production yields and/or ratio for ^{134m}Te, ^{135m}Te & ^{136m}Xe for spontaneous fission in ^{252}Cf and in photofission in the region of energy of ~ 9 MeV for different actinides (^{235}U, ^{238}U, ^{239}Pu).

I297 Isotope production and target preparation for nuclear astrophysics data

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High-energetic protons and secondary particles induce in matter the production of a big variety of radionuclides, some of them being very rare, exotic, and, in several cases, difficult to obtain by complementary reactions. Some of these isotopes are of high importance in nuclear astrophysics, and sufficient sample material for scientific experiments is urgently needed.
Highly-activated components stemming from the surroundings or parts of a high-power particle accelerator are a unique possibility to gain such valuable isotopes. The advantage of "mining" isotopes from waste materials consists in their principal availability, not requiring "extra" beam time. The challenge is their radiochemical isolation from the matrix.
PSI operates the Spallation Neutron Source SINQ, which is driven by one of the most powerful proton accelerators world-wide (590 MeV, 2.4 mA), and is therefore best-suited as a producer of such rare exotic radionuclides. In the frame of the ERAWAST (Exotic Radionuclides from Accelerator Waste for Science and Technology) initiative a complex program for isotope separation from different matrices has been established at PSI within the past decade. In particular, the following sources for isotope extraction are available:
• Beam dumps, targets, shielding components (copper, lead, graphite and others) [1]
• Samples from the material research program STIP (stainless steels and other metals) [2]
• SINQ cooling water [3]
• Special irradiation positions in the SINQ target for dedicated irradiations
The paper presents an overview on the isotope resources at PSI, the methods for isolation and sample preparation as well as some of the highlights in scientific application.

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R298 Targets for production of research quantities of the medical radioisotopes with α and p/d beams

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The production of research quantities of medically interested radioisotopes is carried at the HIL UW with two charged particle accelerators. The heavy ion cyclotron U200P operating since 1994 K=160 and recently installed medical p/d high current 16/8 MeV PETtrace cyclotron.
The medical radioisotopes are produced by irradiation of the ^{100}Mo, ^{nat,40,42}Ca, ^{nat}Ge, ^{nat}Bi targets.
The α-particle beam delivered by the U200P machine is used for the production of ^{211}At on ^{nat}Bi target as well as for the production of medically atractive ^{43,44g,m}Sc isotopes with natural and enriched Ca targets. The ^{72}Se/^{72}As pair is produced also with α-particle beam by bombardment of the ^{nat}Ge targets.
Samples are irradiated by the internal α-particle beam what requires special shape of targets. The procedure used for their preparation will be presented.
The radioactive purity of the accelerator produced ^{99m}Tc is investigated using ^{100}Mo(p,2n) reaction performed with the p beam from the PETtrace cyclotron.
The produced radioisotopes extraction from irradiated targets is performed at the Institute of the Nuclear Chemistry and Technology, where research on the synthesis of radiopharmaceuticals based on the produced radioelements is conducted.

R299 Overview of the nuclear targets produced at the Institute for Reference Materials and Measurements within the project of solving challenges in nuclear data

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In the frame of the EC-funded integrated project CHANDA (solving CHAllenges in Nuclear DAta) the importance of nuclear target preparation for the accurateness and reliability of experimental nuclear data is set in a dedicated work package (WP3). The global aim of WP3 is the development of a network for nuclear target preparation and characterization, enabling to coordinate the target production corresponding to the experimental requirements. Therefore, a set of tasks within the work package needs to be followed. Primarily, an inventory of target related facilities and radioisotope providers was created. In the next step a priority list of target requests was made in agreement with the target user considering the technical specification, the scheduled experiments and the availability of the target laboratories.
A set of target requests has been assigned to the JRC-IRMM. This contribution gives an overview of the nuclear targets that are produced at the JRC-IRMM within the CHANDA project. The equipment and techniques available for the preparation and characterization of uranium, plutonium and neptunium layers with an areal density ranging from 50 to 300 µg/cm2 will be emphasized.

R300 Technical developments for accurate determination of amount of samples used for TOF measurements

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Accurate neutron capture cross sections of Minor Actinides (MAs) are required for the R&D of innovative nuclear systems and environmental load reduction from the disposal of nuclear wastes. However, there are gaps between required accuracies and current accuracies on relevant neutron capture cross sections. The research project entitled "Research and development for Accuracy Improvement of neutron nuclear data on Minor ACtinides (AIMAC)" has been started to improve the reliability of the neutron cross section data of MAs. In order to obtain accurate cross section data, it is indispensable to determine amount of MA sample accurately and non-destructively. Therefore, as a part of the AIMAC project, we have developed the techniques accurately determining the amount of of samples by two different methods: gamma-ray spectroscopic method, and calorimetric method. In the spectroscopic method, gamma-ray emission probabilities of ^{241,243}Am and ^{237,239}Np were determined with high precision for accurately quantifying the amounts of the samples, by direct detection of emitted gamma-rays from the samples, with a planar type High-Purity Germanium (HPGe) detector. An efficiency curve of the HPGe detector was derived by combining measured efficiencies and Monte Carlo simulation. The gamma-ray emission probabilities for the major gamma-rays of these nuclides were determined with uncertainties less than 2%, and radioactivity measurements of the samples were performed. As for the calorimetric method, decay heat of the samples was measured accurately by using a calorimeter (TAM-IV) manufactured by TA Instruments. Since Q values associated with radioactive decays of MAs are well known, activities of the samples can be obtained accurately. This contribution presents the developed techniques together with results obtained by two independent techniques.

The author would like to thank the accelerator and technical staff at J-PARC for operation of the accelerator and the neutron production target and for the other experimental supports. Present study includes the result of "Research and Development for accuracy improvement of neutron nuclear data on minor actinides" entrusted to the Japan Atomic Energy Agency by the Ministry of Education, Culture, Sports, Science and Technology of Japan (MEXT).

S301 High precision analysis of isotopic composition for samples used for nuclear cross-section measurements

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For the accuracy improvement of nuclear data of minor actinides and long-lived fission products in the AIMAC project, high quality data of the isotopic composition of samples are indispensable. The objective of our team is to obtain the isotopic composition data of samples contributing to the analysis of nuclear cross-section measurement data by mass spectrometry etc. In this study, we analyzed the isotopic composition of two Am samples of ^{241}Am and ^{243}Am by thermal ionization mass spectrometry (TIMS).

In the analysis by TIMS, a thermal ionization mass spectrometer (TRITON-T1^{TM}, Thermo Fisher Scientific) with a rhenium double filament system was applied. The loading amount on the evaporation filament was 1.5 ng. Isotopic analysis of Am was conducted with a secondary electron multiplier detector and the peak jump method because of the limited amount of Am on the filament: the measurement procedure is based on our previous study on U and Pu [1]. The Am samples were also analyzed by α-spectrometry.

A pure ^{241}Am ion beam was observed for the ^{241}Am sample. In the analysis of ^{243}Am, on the other hand, the ion beams of ^{243}Am, ^{241}Am, and ^{242m}Am were detected. From the results, it was concluded that the ^{241}Am sample is a product of pure ^{241}Am and the ^{243}Am sample is a mixture of ^{243}Am, ^{241}Am, and ^{242m}Am whose abundances are *ca*. 99.7%, 2.3%, and 0.04%, respectively. In both analyses, trace amounts of ^{239}Pu, ^{240}Pu, ^{242}Cm, and ^{244}Cm were found as impurities. The results of these analyses will be presented together with the developed high precision analytical method.

Present study includes the result of "Research and Development for accuracy improvement of neutron nuclear data on minor actinides (AIMAC)" entrusted to the Japan Atomic Energy Agency by the Ministry of Education, Culture, Sports, Science and Technology of Japan (MEXT).

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S302 Measurement and simulation for a complementary imaging with the neutron and X-ray beams

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For a complementary imaging, we have installed a composite source system of thermal neutron and keV X-ray at the 45-MeV electron linear accelerator facility in Hokkaido University. The source system provides the alternative beam of neutron and X-ray by switching the production target onto the electron beam axis. Both transmission images were measured using the neutron and X-ray beams without change of a sample and detector setup. In the measurement, the detector based on a vacuum-tube type neutron color image intensifier was applied to the beams for dual-use purpose. A flashlight, battery, or metallic plates were used as the sample. The measured transmission images were directly compared by calculating the ratio of the neutron to X-ray transmission at each pixel. As the result, an enhanced contrast image obtained from the dataset. On the other hand, the simulations of the neutron and X-ray transmissions for various substances were performed using the PHITS code, where JENDL4.0 was used to the neutron cross section data. A data analysis procedure for estimating the substance of sample was investigated through the simulations.

S303 Neutron beamline design of a white neutron source at CSNS

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China Spallation Neutron Source (CSNS) is a large scientific facility dedicated mainly for multidisciplinary research on material characterization using neutron scattering techniques. The CSNS Phase-I is under construction and expected to complete in early 2008. The CSNS accelerator complex is designed to deliver proton beam with an energy of 1.6 GeV and a pulse repetition rate of 25 Hz to a tungsten target, and the beam power at Phase-I is 100 kW. A white neutron source using the back-streaming neutrons through the incoming proton beam channel was proposed and is under construction. The back-streaming neutrons that are modestly moderated by the cooling water passing through the target slices have a very wide energy spectrum (so-called white neutrons) and also a good time structure, are very suitable for nuclear data measurements. The white neutron source includes an 80 m neutron beam line and two experimental halls. With different operation modes for the accelerator, the time resolution of neutron beam can be in the range of a few per mille in the whole energy range of eV to tens MeV. The physics design of the beamline is presented in this paper, with the emphasis on obtaining extremely low background. Key components includes neutron beam window, shutter, collimators and beam dump. The first-batch experiments on nuclear data measurements are expected to be conducted in late 2017.

I304 Deuteron nuclear data for the design of accelerator-based neutron sources – measurement, model analysis, evaluation and application

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In recent years, research and development of intensive accelerator-based neutron sources has led to renewed needs of the study of deuteron-induced reactions. The neutron sources using deuteron-induced reactions on light elements such as Li, Be, and C are proposed for various neutron beam applications, e.g., production of radioisotopes for medical use, boron neutron capture therapy, irradiation testing of fusion reactor materials, and transmutation of long-lived radioactive nuclear waste. The design of such (d,xn) neutron sources requires reliable knowledge about not only the interaction of deuterons with neutron converter material but also various nuclear reactions due to deuteron beam loss in the beam transport system. Therefore, comprehensive nuclear data of deuteron-induced reactions are indispensable over wide ranges of incident energy and target mass number for accurate estimation of neutron yields from the converter and induced radioactivity in materials.
The current status of deuteron nuclear data is as follows. There are no available experimental data of double differential (d,xn) cross sections (DDXs) above 20 MeV except for the Li(d,xn) data at 25 and 40 MeV, although thick target neutron yield (TTNY) data exist for deuteron energies up to 54 MeV. The evaluated nuclear data library FENDL-3 includes deuteron data up to 200 MeV. However, the data have been provided by TALYS model calculations and have not yet been well-validated for available experimental data.
Taking into consideration these circumstances, we have launched a comprehensive and systematic research project on deuteron nuclear data, which is composed of measurements of neutron production DDXs and TTYs at the RCNP in Osaka University and the Kyushu University Tandem Laboratory, theoretical model code development and analyses of the measured data, cross section evaluation and benchmark test, and application to production of radioisotopes for medical use. Our goal is to develop a state-of-the-art deuteron nuclear data library up to 200 MeV necessary for the design of deuteron accelerator neutron sources. The present status is reviewed in the presentation.

R305 Neutron field of accelerator-driven p(35)+Be fast neutron source at NPI Rez

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The accelerator driven fast neutron sources of the white- and quasi-monoenergetic spectra are operated at the NPI Rez Fast Neutron Facility utilizing the Be(thick), D_2O(thick), and ^{7}Li(C) target stations and the variable energy proton beam (up to 37 MeV) from the isochronous cyclotron U-120M. Recently, the design of beryllium target station was upgraded in order to provide the higher neutron flux at the modified positions of irradiated samples. Afterwards, the thick target neutron field of the p+Be source reaction was investigated for proton energy of 35 MeV. The spectral neutron flux for several target-to-sample distances was determined by using the multi-foil activation technique. From measured reaction rates, new neutron spectra were reconstructed by using the SAND-II unfolding code and validated against the MCNPX predictions. The spectral characteristics and uncertainty of the validation are discussed in details. The IFMIF-like (International Fusion Material Irradiation Facility) neutron field obtained from the p(35)+Be source is suitable for the neutron cross-sections validation within the IFMIF research program, radiation hardness tests of electronics, and neutron activation analysis experiments.

R306 Simulations of the stopping efficiencies of fission ion guides

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With the Ion Guide Isotope Separator On-Line (IGISOL), located at at the University of Jyväskylä, products of nuclear reactions are separated by mass. The high resolving power of the JYFLTRAP Penning trap, with full separation of individual nuclides, capacitates the study of nuclides far from the line of stability. For the production of neutron-rich medium-heavy nuclides, fissioning of actinides is a feasible reaction. This can be achieved with protons from an in-house accelerator or, alternatively, with neutrons through the addition of a newly developed Be(p,xn)-converter. The hereby-obtained fission products are used in nuclear data measurements, for example fission yields, nuclear masses, Q-values and decay spectroscopy.
Prior to separation, the ionized reaction products are stopped in a helium-filled gas cell, referred to as the ion-guide. In order to achieve high enough production rates, also for nuclides with low yields, the design of the ion-guides has to be optimized with regard to the number of extracted fission products. For independent fission-yield measurements the method heavily relies on an unbiased production rate. It is therefore necessary to evaluate any systematic dependence on mass or nuclear charge in the stopping efficiency of the ion-guide.
In this work we present simulations of the stopping of fission products for different ion-guide geometries, for both proton- and neutron-induced fission. The production-rates are evaluated, in absolute numbers as well as with respect to systematic effects, and the results are benchmarked against experimental data. MCNPX has been used to simulate the neutron production and transportation while the fission fragment yields and kinetic energies were calculated using GEF. For the transportation and stopping of fission products a model of the ion-guide has been developed using the GEANT4 toolkit

R307 Nuclear and reaction data programme at the AWE's ASP neutron source

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For the past few years the AWE has been running a neutron physics programme to acquire, evaluate and understand reactions and nuclear properties data. The programme has utilised, and increased the capabilities of, the ASP facility, a D-T neutron source capable of delivering ~$1E^{10}$-$1E^{11}$ 14 MeV neutrons per second. To date the programme has concentrated on rare-Earth materials with a particular focus on yttrium. This presentation discusses the current capabilities of the ASP facility and an overview of the experimental results obtained for the $^{89}Y(n, n')^{89}Y^{m}$, $^{89}Y(n,a)^{86}Rb^{m}$ and $^{89}Y(n,2n)^{88}Y$ reaction cross sections and half lives of the daughter products.

R308 Extended methods using thick-targets for nuclear reaction data of radioactive isotopes

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To dispose of a radioactive waste ejected from a nuclear power plant is an important subject for nuclear engineering and also nuclear physics.
A nuclear transmutation especially for a long-lived fission product (LLFP) is a much required technology. However, the basic data to study and to establish the technology are not enough because the experiments to measure them are difficult to handle the radioactive target. To obtain the LLFP reaction data, we therefore propose two methods using thick-targets and radioactive beams.
The thick-target yield (TTY) of the transmutation reaction is essential data to reduce a large amount of the waste, practically. We suggest a conversion method to estimate the TTY based on inverse kinematics to avoid the direct experiment of a LLFP target. Furthermore we propose the thick-target transmission (T3) method to obtain the excitation function of an interaction cross section which corresponds to one of the objective transmutation reaction if we choose the LLFP beam.
In conclusion, we found that the energy-dependent conversion-coefficient between TTYs of an original system and its inverse kinematics can be replaced to the constant value in the high energy region. And we show the usefulness of the T3 method to measure the excitation function of an interaction cross section, which is estimated in the simulation of 12C+27Al.
Our results reproduce the experimental data well, and can also describe the behavior in a low-energy region. If we combine these methods, the nuclear data can be effectively accumulated.

I309 High fidelity Monte Carlo program SuperMC and its on-the-fly temperature-dependent cross section generation method

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The Monte Carlo (MC) methods have been broadly adopted in nuclear design and analysis of advanced nuclear system. However, there are still great challenges in the current MC methods including the calculation modeling of complex geometries, simulation of deep penetration problem in radiation shielding, slow convergence of complex calculation, lack of experimental validation for new physical features, etc.
Super Monte Carlo Simulation Program for Nuclear and Radiation Process (SuperMC), a general, intelligent, accurate and precise simulation software system for the design and radiation safety evaluation of nuclear systems, is designated to support the comprehensive neutronics calculation, taking the radiation transport as the core and including the depletion, radiation source term/dose/biohazard, material activation and transmutation, etc. The latest version of SuperMC, based on the transport calculation of n, γ, developed depletion calculation, which support the whole process nertronics simulation of fission power plant.
In the nuclear reactor simulation, considering the neutronics-thermal hydraulics coupling calculation, the system temperature will be constantly changed, which will cause the variation of cross section due to the Doppler effect. In order to do nuclear simulation more precise, the temperature-dependent cross section should be generated. Due to the different physical characteristic, three regions were divided by the incoming particle energy. In resolved resonance region, a parallel on-the–fly Doppler broadening method with Gauss-Hermite quadrature and union energy grid is proposed to improve cross section process efficiency. In unresolved resonance region, however, cross section is represented by probability table and cannot use Doppler broadening method directly. A fast stochastic sampling method is used in this region. In the range of few eV, the thermal motion cannot be ignored for certain moderation materials. A method combination with stochastic sampling and linear interpolation is proposed in order to reduce time consumption.
SuperMC has been verified and validated by more than 2000 benchmark models and experiments, such as ICSBEP, SINBAD, IRPhEP, BEAVR, ITER C-lite etc. The benchmarking results have been compared with MCNP, demonstrating higher accuracy and efficiency of SuperMC, and also significant enhancement of work efficiency due to functions of automatic modeling and visualized analysis.

R310 Experimental validation of depletion calculations with VESTA 2.1.5 using JEFF-3.2

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Depletion codes such as VESTA [1] are used to calculate the time evolution of a material subjected to radiation for a wide variety of applications in the fields of nuclear safety, radiation protection and environmental health safety. For these applications, experimental validation is paramount. Over the last couple of years, IRSN has established an important experimental validation database of VESTA 2.1.5 using a set of 76 samples of radiochemical assay data and decay heat measurements [2] for a wide variety of reactor and fuel types (PWR, VVER, MOX, UO2, UO2-Gd2O3 fuel). This experimental validation work has been performed for two different nuclear data libraries, namely JEFF-3.1 and ENDF/B-VII.1 [3, 4].
A new VESTA depletion library has been recently produced based on the JEFF-3.2 nuclear data library and work is currently underway to calculate several experiments from the experimental validation database using this new JEFF-3.2 library. The experiments that have been selected for this work are the MALIBU PWR samples (radiochemical assay data for one MOX sample and four UO2 samples) [5] as well as the CLAB, [6] GE Morris and HEDL [7] assembly decay heat measurements.
In this paper, we will first provide an overview of the nuclear data processing applied for VESTA libraries using the GAIA tool, [8] a tool developed at IRSN to automate the NJOY processing [9] and provide an additional level of quality assurance. This will be followed by an overview of the selected experiments from the experimental validation database and the presentation of the new experimental validation results using the JEFF-3.2 library. Finally, a comparison of these results with the JEFF-3.1 and ENDF/B-VII.1 results obtained in the past will be performed.

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R311 Criticality benchmark simulations with ENDF/B-VIII.beta structural material evaluations in GND format

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Over the past three years subgroup 38 of the Working Party on Evaluation Co-operation (WPEC) has been defining a new, flexible nuclear data format called Generalized Nuclear Data (GND) to replace the half-century-old Evaluated Nuclear Data Format (ENDF6). At Lawrence Livermore National Laboratory three codes (FUDGE, GIDI and Mercury) have been updated or added to handle GND formatted data, allowing for Verification and Validation of GND formatted data.
The nuclear data infrastructure code FUDGE (For Updating Data and Generating Evaluations) supports translation of ENDF6 formatted data to and from GND. It also processes GND data for use in Monte Carlo and deterministic transport codes, including reconstructing cross sections and angular distributions from resonance parameters. FUDGE can also translate data from GND into the ACE format, for use with the MCNP6 Monte Carlo transport code.
The GND access library called GIDI (the ‘General Interaction Data Interface’) has been developed to read and perform Monte Carlo sampling from GND-formatted data, and was implemented in LLNL’s Monte Carlo particle transport code Mercury.
In this talk, we present results from criticality benchmark simulations run with ENDF/B-VIII.beta candidate evaluations. Most assemblies had reflectors made of structural materials such as Al, Ni, Cu, Zn, W and Pb, where angular distributions can be generated using the FUDGE angular distribution reconstruction capability. We compare k-effective values obtained with the Mercury/GIDI code and data in the GND format to those calculated using MCNP6 and ACE files. We demonstrate the new processing and simulation capabilities of GND/GIDI, as well as exploring the impact of detailed angular distributions on criticality benchmark simulations.

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R312 Use of integral experiments in support to the validation of JEFF-3.2 nuclear data evaluation

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For many years now, the “Institut de Radioprotection et de Sûreté Nucléaire” (IRSN) has developed MORET, a Monte-Carlo calculation code dedicated to criticality calculations. Since its 5th release, the MORET code embeds both continuous energy capabilities, allowing the use of various nuclear data libraries, and multigroup calculations capabilities, using macroscopic cross sections calculated by various neutronic cell codes. To support French criticality safety practitioners, a large validation database was established based on the selection of critical experiments covering most operations of the fuel cycle. Currently, the validation database of the multi-group APOLLO2-MORET 5 calculation route, which is part of CRISTAL V2.0 package, consists in more than 2500 benchmarks and the continuous energy MORET 5 validation suite comprises about 1200 experiments. This allowed contributing to nuclear data validation and promoting interactions with OECD groups such as the JEFF project and with related groups such as the Collaborative international Evaluated Library Organization Pilot Project (CIELO). In that frame, new evaluations of ^{235}U capture, ^{56}Fe, ^{16}O, ^{1}H cross sections were tested using the MORET 5 code on a selection of benchmarks for which k_{eff} is sensitive to these cross sections.
In this paper, the JEFF-3.2 library, processed with the IRSN GAIA tool (using NJOY), is tested in the MORET 5 continuous energy validation suite on a selection of more than 200 benchmarks taken from the 1200 available. The benchmarks selection aims at covering the whole neutron spectrum from fast energies (metallic systems) to thermal energies (solutions, lattices and powders) and to be sensitive to different materials of interest. The trending analysis will also focus on the presence of various structural materials (reflectors, absorbing canisters…).
The MORET 5.C.1 release, which allows k_{eff} sensitivity calculations to nuclear data, is used. Comparisons between the benchmark k_{eff} and the results obtained with the former JEFF-3.1.1 library will be presented. The first results show that the differences against benchmark k_{eff} results have been reduced, as for example BIG TEN experiment and HEU systems in fast spectrum. However, some nuclear data improvements are still needed. Special attention will be paid on benchmarks for which the results have been deteriorated.

S313 Birth-death model for description of transient processes in multiplying medium with MOX-Fuel

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Description of the processes occurring during the interaction of a neutron with the multiplying medium usually involves estimation of mean values and dispersions of random quantities within a stochastic process. In a number of cases, birth-death model based on forward Kolmogorov equations allows accurate or approximate solution of such problems in analytical form. At the continuous time analysis, mean number of neutrons M(t) and the criticality coefficient α(t) are defined by the difference of the instantaneous intensities of death λ(t) and birth μ(t) [1]. The proposed method is applied for analysis of the unsteady transient processes taking place in a thermal reactor at its power control during start-up or shutdown, as well as at accidental power variations around the nominal one [2].
Calculation results of the reactivity ρ for the subcritical assembly MASURCA are presented in this work. Experimental data from the paper [3] were used for the calculations.

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S314 Use the results of measurements on COBRA facility for testing of neutron data of main structural materials for fast reactors

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Several experiments were performed on the COBRA critical facility at the Institute of Physics and Power Engineering (IPPE), Obninsk, Russian Federation during the 1970s and 80s for researching of neutron absorption properties of the main structural materials for fast reactors.

The experiments were carried out at the special conditions simulating an infinite multiplication media with kin_{∞}~1.
The evaluation of five COBRA experiments was done at 2002 in the accordance with the ICSBEP procedures (HCI-005 series).
Since then, numerous attempts have been undertaken to reproduce the results of these evaluated benchmarks by using different libraries of evaluated neutron cross sections. However, the use of any data sets from modern libraries does not allow to obtain agreement between calculated and benchmark data within the limits of their uncertainties. It was shown in many papers presented at the international conferences on nuclear data.
This paper presents re-evaluations of capture cross sections, mainly in the resolved resonance region, for isotopes of Cr, Fe, Ni and Mn obtained based on new measurements of microscopic cross sections and the benchmark experiment results of HCI-005 series. The largest changes have been introduced in the parameters of the first resonances for odd isotopes Cr and Fe.
The calculations with the use of modified files for basic structural materials as well as for Zr file show encouraging agreement with the results of HCI-005 series benchmark experiments.
A further verification of modified files was done at the ICSBEP benchmarks having perceptible sensitivity of the effective multiplication factor to the cross sections of these materials.

S315 Re-interpretation of the ERMINE-V experiment: validation of fission product integral cross section in the fast energy range

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The current knowledge of nuclear data in the fast neutron energy range is not as good as in the thermal range, resulting in larger uncertainties. This situation makes it difficult to get the full benefit from recent advances in modeling and simulation. Zero power facilities such as the French ZPR MINERVE have already demonstrated that they can contribute to significantly reduce those uncertainties thanks to dedicated experiments. Historically, MINERVE has been mainly dedicated to thermal spectrum studies. However, experiments involving fast-thermal coupled cores were also performed in MINERVE as part of the ERMINE program, in order to improve nuclear data in fast spectra for the two French SFRs: PHENIX and SUPERPHENIX. Some of those experiments have been recently revisited. In particular, a full characterization of ZONA-1 and ZONA-3, two different cores loaded in the ERMINE V campaign, has been done, with much attention paid to possible sources of errors. It includes detailed geometric descriptions, energy profiles of the direct and adjoint flux and spectral indices obtained thanks to Monte Carlo calculations and compared to a fast reference. Sample oscillation experiments of separated fission products such as Rh-103 or Tc-99, which were part of the ERMINE V program, have been simulated using recently-developed options in the TRIPOLI-4 code and compared to the experimental values. The present paper describes the corresponding results. The findings motivate in-depth studies for designing optimized coupled-core conditions in ZEPHYR, a new ZPR which will replace MINERVE and will provide integral data to meet the needs of Gen-III and Gen-IV reactors.

S316 Comparison and validation of MCNP photon interaction data against computational examples and SINBAD benchmark experiments

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Several photon libraries are available for use with the MCNP-X, MCNP-5 and MCNP-6 code packages, such as the p04, p84, p05t and p12 data. Their performances were investigated both using computational and experimental fusion relevant benchmark cases. Doppler broadening treatment also differs among the MCNP code versions. Differences in the photon flux calculated using these libraries were evaluated for the following test cases:

- A simple sphere model composed of different elements available in the libraries (100 in total). Treatment of the Doppler broadening in MCNP-5, MCNP-6 and MCNPX codes was also compared;
- A computational DEMO benchmark sector model, used to assess the difference in photon flux and heating;
- Photon Leakage Spectra benchmark experiments performed at RFNC-VNIITF, Snezhinsk, using 14-MeV D-T neutron source placed in the centre of spherical samples of different materials. In the scope of this activity the measured and calculated photon flux from the water and iron spheres of inner diameter of 10 cm and outer diameter of 20 cm were compared.

Differences observed among the above photon libraries will be presented and discussed in the paper.
This work was part-funded by the RCUK Energy Programme [grant number EP/1501045] and the European Union's Horizon 2020 research and innovation programme. The views and opinions expressed herein do not necessarily reflect those of the European Commission.

I317 Validation of dosimetry data using historic and recent measurements on the flattop critical assembly

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First assembled in March 1958, the Flattop critical assembly remains one of the mainstays of critical assembly experiments today. As such, it is likely the longest running suite of critical experiments ever fielded on the same machine. A nearly infinitely thick, spherical natural uranium reflector surrounds a central cavity where various fissile cores can be placed. Flattop-25 (or just Flattop) is the most well-known configuration using a highly enriched uranium-235 core; Flattop-Pu and Flattop-23 use plutonium (6% Pu-240) and uranium-233 cores. Three large control rods and multiple mass adjustment buttons allow for substantial variation in reactivity control. A glory hole traversing one side of the reflector and the full width of each core enables access to many neutron spectra. One of its primary roles of this assembly has been to provide standard neutron fields for activation irradiations. The first irradiation performed using Flattop, similar to many recent measurements, was a set of actinide irradiations to study cumulative fission product yields. Activation measurements of standard dosimetry reactions have also been taken at many times over the years. These measurements have influenced decades of nuclear data evaluations, particularly the ENDF/B libraries, and have been used for validation of, among others, the IRDFF international dosimetry libraries. In this study we explore the rich history of the measurements and modeling of this assembly to see what new lessons we can learn from this unique resource. In particular, we examine the consistency of measurement results over the years and aspects of the uncertainties of the measurement and modeling techniques used for these comparisons.

R318 Combined use of K-effective and beta-effective measurements for nuclear data validation and improvement

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Nuclear data sensitivity and uncertainty methodology based on the first order perturbation theory, combined with the benchmark experiment analysis, play an essential role in assuring the accuracy and reliability of the nuclear reactor computations and provide an insight in the physical phenomena involved in the neutron transport. Critical benchmarks have been traditionally used to validate and improve nuclear data. However, keff is only one of the important reactor safety factors requiring accurate nuclear data. Other reactor quantities can likewise provide information relevant for the improvement of nuclear data, such as reaction rate and spectra measurements, or kinetic parameters (effective delayed neutron fraction - beta-eff). In this paper the potential of using beta-eff measurements for improving nuclear data is investigated based on several examples of fast reactors (such as FLATTOP-Pu, Big ten, SNEAK-7a & -7b, etc.) and Accelerator Driven Systems (ADS). The study makes use of k-eff and beta-eff sensitivity and uncertainty computations performed by means of the SUSD3D code. The sensitivity coefficients of beta-eff with respect to the basic nuclear data were calculated by deriving the Bretscher's k-ratio formula as initially proposed in 2010 in the scope of the Uncertainty Analysis in Modeling (UAM) project of the OECD/Nuclear Energy Agency. Sensitivities of k-eff and beta-eff with respect to nuclear data are compared in view of exploiting the differences among them for a physically more complete, comprehensive and consistent nuclear data validation and improvement procedure.
An important conclusion of these studies is that due to their high sensitivity and different shapes of sensitivity profiles some beta-eff experiments can provide a complementary information to critical experiments. These measurements can thus be used to validate other quantities than delayed nu-bar already done in the past. Inelastic and elastic scattering cross sections of 238U are particularly interesting examples where beta-eff measurements could contribute to improve nuclear data evaluations.
Furthermore, the above method allows estimating the uncertainty in the calculated beta-eff, which will be particularly important for the future reactor systems that are likely to use wider range of actinide isotopes with lower values of beta-eff (Pu isotopes), making the reactor control of MOX fueled cores more challenging.
The above two conclusions are relevant for the nuclear data evaluation activity within the CHANDA project and the MYRRHA reactor studies. In the scope of this activity, the SUSD3D code was used to evaluate the sensitivity and uncertainty in beta-effective due to the basic nuclear data for fast reactors and MYRRHA ADS project. The accuracy needed for the k-eff and beta-eff measurements in order to be able to provide information useful for improving modern nuclear data will be discussed.

R319 Comparative study of nuclear data libraries on Monte Carlo modelling of MYRRHA mockup critical cores in the VENUS-F reactor

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VENUS-F is a fast, zero-power reactor assembled within the GUINEVERE program in 2009 and loaded with 30% wt. metallic uranium as fuel and solid lead as reflector and coolant simulator. Within the currently ongoing FREYA project the reactor was coupled to an accelerator with a neutron producing target, making up an Accelerator Driven System (ADS). The main aim is to validate the optimal combination of online reactivity monitoring techniques for MYRRHA, which will be an ADS demonstrator with the option to be also operated in a critical mode.
During 2015 several new critical cores representative for a MYRRHA critical core were loaded. As MYRRHA will use MOX fuel, oxygen needed to be added into the VENUS-F core, which was done by introducing Al_2O_3 into the fuel assemblies. First, a simple core without any perturbations in the active zone was loaded and characterized. As MYRRHA will be a rather complex system using a number of in-pile sections and heterogeneous elements inside and around the active zone, the VENUS-F core was step by step modified by loading new materials and perturbations simulating reflector and in-pile sections of MYRRHA.
Monte Carlo calculations using MCNP5-1.60 code with JEFF-3.1.2, JEFF-3.2, JENDL-4.0, and ENDF-B-VII.1 nuclear data libraries are compared with experiments. Discrepancies between calculations of global parameters (k_{eff}, β_{eff}) and local parameters (fission rate spatial distributions, coolant void effects) depending on a nuclear data library used will be presented. The impact of S(α,β) data for thermal scattering (the General Atomics model re-evaluated in ENDF/B-VII and the IKE model in JEFF 3.2) in a fast reactor with thermal islands will be shown. Point-kinetics parameters calculated using a prompt method (TOTNU card) will be compared with a newly introduced criticality calculation options (KOPTS card) in MCNP.

R320 Reliability assessment of MVP-BURN code and JENDL-4.0 library related to the nuclear transmutation of light platinum-group elements

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The Aprés ORIENT research program, which is a new concept of advanced nuclear fuel cycle, was initiated in FY2011 aiming at creating stable, highly-valuable elements by nuclear transmutation from fission products contained in spent nuclear fuels [1,2]. In order to simulate creation of such elements by (n, γ) reaction succeeded by β^- decay in reactors, a continuous-energy Monte Carlo burnup code MVP-BURN [3] was employed. Then, to confirm the reliability of MVP-BURN code and neutron cross section library is one of the most important tasks. In this study, both burnup calculation by MVP-BURN code and neutron activation analysis in TRIGA® Mark I reactor at University of California, Irvine were performed for validation of the simulation on transmutation of light platinum-group elements (Ru, Rh, Pd). Especially, some neutron capture reactions such as ^{96}Ru(n, γ)^{97}Ru, ^{102}Ru(n, γ)^{103}Ru, ^{104}Ru(n, γ)^{105}Ru, ^{103}Rh(n, γ)^{104,104m}Rh, and ^{108}Pd(n, γ)^{109}Pd were dealt with in this study. From a comparison between the simulation and the experiment about ^{102}Ru(n, γ)^{103}Ru, the result of simulation significantly overestimated more than results of other isotopes. This cause is considered to be due to not MVP-BURN code but the neutron capture cross section of ^{102}Ru belonging to JENDL-4.0 library used in this simulation.

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I321 Improvement of gross theory of beta-decay for application to nuclear data

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A theoretical study of beta decay and delayed neutron has been carried out with a global beta-decay model, the gross theory. In a fissioning nucleus, neutrons are produced by the beta decay of neutron-rich fission fragments. This is known as delayed neutrons. The average number of delayed neutrons is estimated based on the sum of the beta-delayed neutron-emission probabilities multiplied by the cumulative fission yield for each nucleus. The behavior of these phenomena is important to manipulate nuclear reactors safely, and when we adopt some new high burn-up reactors, properties of minor actinides will play an important roll in the system, but these data have been insufficient. The gross theory of the beta decay [1,2] is based on a consideration of the sum rule of the beta-strength function, and gives reasonable results of beta-decay rates and delayed neutron in the entire nuclear mass region. We re-analyze and improve the theory on the strength functions and one-particle level densities [3]. For example, we considered shell effects of nuclei in the level density, which was originally estimated from the Fermi-gas model. By using the improved gross theory, the ability of theoretically reproduction (and also prediction) on beta-decay rates, delayed-neutron emission probabilities, decay heat, will be discussed. In the process, we make a new code of the gross theory of beta-decay including the improved parts. We will show the code, which can be distributed for the nuclear data community.

The present paper reports the results of 'Comprehensive study of delayed-neutron yields for accurate evaluation of kinetics of high-burn up reactors' entrusted to Tokyo Institute of Technology by the Ministry of Education, Culture, Sports, Science and Technology of Japan (MEXT) in the 2011-2015 fiscal year.

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R322 Exclusive data-based modeling of neutron-nuclear reactions below 20 MeV

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We are developing CHIPS-TPT [1] physics library for exclusive simulation of neutron-nuclear reactions below 20 MeV. Exclusive modeling reproduces each separate scattering and thus requires conservation of energy, momentum and quantum numbers in each reaction. Inclusive modeling reproduces only selected values while averaging over the others and imposes no such constraints. Therefore the exclusive modeling allows to simulate additional quantities like secondary particle correlations and gamma-lines broadening and avoid artificial fluctuations.
CHIPS-TPT is based on the formerly included in Geant4 [2] CHIPS library, which follows the exclusive approach, and extends it to incident neutrons with the energy below 20 MeV. The NeutronHP [3] model for neutrons below 20 MeV included in Geant4 follows the inclusive approach like the well known MCNP code. Unfortunately, the available data in this energy region is mostly presented in ENDF-6 format and semi-inclusive. Imposing additional constraints on secondary particles complicates modeling but also allows to detect inconsistencies in the input data and to avoid errors that may remain unnoticed in inclusive modeling. In this paper we discuss the development of exclusive modeling of inelastic neutron scattering with continuous secondary distribution.

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R323 R-matrix approach at the intersection with the statistical model regime

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The generation of modern evaluated nuclear data files requires the use of nuclear model calculations to compensate for the lack of experimental data especially at higher energies. In general standard reaction models yield fair descriptions of nucleon-induced reaction cross sections of most nuclei. The situation is less satisfactory in the resonance regime for which microscopically based predictions of the positions and widths of resonances are not available. Therefore the resolved resonance regime is usually described by adjusting the phenomenological R-matrix representation via fits to experimental data. However, the consistent transition to higher energies with an almost continuous level density of the compound nucleus represents a difficulty because of the conceptual differences between R-matrix theory and the statistical model.
In this contribution we focus on the development of a method which guarantees a continuous transition between the resonance regime and standard reaction calculations in terms of the statistical model. Our approach is based on the R-matrix concept which represents not only an excellent phenomenological tool for the description of the resonance region, but also an efficient method for the solution of coupled-channel equations. Exploiting the latter feature of the R-matrix theory a representation of the transition regime towards statistical model calculations is proposed which provides a smooth matching of the resonance regime with the energy region described by statistical model calculations. One challenge is the required completeness of channels in the R-matrix representation up to the transition regime. Therefore, the method is particularly well adapted for nuclear data evaluation of nucleon-induced reaction cross sections of light nuclei with A<20, for which the number of open channels is limited up to relatively high energies. An application to neutron-induced reaction data on O-16 is discussed.

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R324 The first unbound states of mirror 9B and 9Be nuclei

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A study of mirror nuclei plays an important role in understanding of the nuclear structure. Considerable experimental and theoretical efforts have been done to determine the location of the low-lying states of ^{9}Be and ^{9}B, specially the first unbound 1/2^{+} state. However, there exists a long-standing controversy concerning the properties of the ^{9}Be first excited state. Furthermore, ^{9}B has no bound states and all states are resonances above the α+α+p three-body threshold.
Theoretical model calculations can help to analyze the data and also guide future experiments. Recently, we investigated the photodisintegration cross section of ^{9}Be(γ,n) and also discussed the structure of the excited 1/2^{+} state of ^{9}Be by applying the complex scaling method (CSM) [1,2] to the α+α+n three-body model. From the decomposition of the photodisintegration cross section, it was found that the 1/2^{+} state decays into the ^{8}Be(0^{+})+n continuum states dominantly, indicating the possibility of the virtual-state nature of the first excited 1/2^{+} state in ^{9}Be [3].
Although the 1/2^{+} peak of the photodisintegration cross section can be reproduced and agrees well with the newly measured data [4], we cannot find a resonant state of 1/2^{+} in the CSM calculation of the α+α+n three-body model for ^{9}Be. Then, it is particularly interest to compare the structure of the ^{9}Be(1/2^{+}) state with the same spin parity state of the mirror nucleus ^{9}B. Its analog ^{9}B(1/2^{+}) state energy has been determined experimentally in the ^{8}Be+p channel of the ^{6}Li(^{6}Li,t) reaction [5] and a special attention must be paid on the determination of the state properties by the theoretical model. In this report, we discuss our recent CSM calculations of the resonance energy (MeV) with decay width (MeV) for the ^{9}B(1/2^{+}) state.

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S325 An approach to adjustment of relativistic mean field model parameters

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Objective: Relativistic Mean Field (RMF) model with a small number of adjusted parameters is powerful tool for correct predictions of various nuclear properties of nuclei. To improve RMF model parameters, Artificial Neural Network (ANN) method which mimics human brain functionality is employed and a new parameter set called DEFNE is introduced.
Methods: RMF model is a phenomenological model and nucleons interacts each other via exchange of various mesons in this model. Its starting point is lagrangian density. Equations of motion for nucleons and mesons are obtained by using variation principle. Dirac and Klein-Gordon like equations are solved iteratively for calculations of properties of nuclei. In this stage model parameters such as masses of considered mesons, nucleon-meson coupling constants and self-couplings of mesons are needed and they are fitted from experimental data. A different approach to optimizing of RMF model parameters is considered in the present study. ANN method has been employed to check its understanding capability of relations between RMF model parameters and predicted ground state properties of considered nuclei (Binding energy and charge radii) within the framework of RMF model. After this stage, same process has been done for selected some spherical nuclei to obtain adjusted parameters of RMF model to improve predictive power of RMF model on chart of nuclides. Finally new RMF model parameters called DEFNE has been carried out.
Results and Conclusion: Understanding capability of ANN method for relations between RMF model parameters and RMF predictions of ground state properties of considered some spherical nuclei is found well. RMF model predictions with new adjusted parameter set DEFNE for binding energies and charge radii of some nuclei are in agreement with experimental data. By expanding calculations on chart of nuclides and considering other ground-state observables of nuclei such as neutron skin thickness, two-proton and two-neutron separation energy, validity of the new parameters could be checked.

S326 A tool for calculation of the 7Li(p,n)7Be neutron spectra below the three-body break up reaction threshold

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The ^{7}Li(p,n)^{7}Be reaction is widely used as quasi-monoenergetic neutron source because of the rapid rise of cross section in the near-threshold region which provides a large amount of relatively low energy neutrons. Many researchers face problems while performing data reduction process at research facilities where it is impossible to employ the time-of-flight and multiple foil activation techniques. To serve these needs, we have developed a new deterministic neutron energy spectrum code EPEN – Energy of Proton Energy of Neutron – for a given lithium thickness, sample angular coverage and proton energy from the reaction threshold to the three-body break up threshold. EPEN reads two large data files tabulating the neutron energy and double differential neutron yields for various proton energy and angle for the ^{7}Li(p,n$_0$)^{7}Be and ^{7}Li(p,n$_1$)^{7}Be reactions in 1 keV - 1 degree bin. The angular differential cross sections of the ^{7}Li(p,n$_0$)^{7}Be and ^{7}Li(p,n$_1$)^{7}Be reactions evaluated by Liskien and Paulsen were adopted above 1.950 MeV while those for the (p,n$_0$) reaction parameterized by Lee and Zhou were adopted near the threshold energy. The ^{7}Li(p,n$_0$)^{7}Be differential cross section between 1.925 MeV and 1.950 MeV were obtained by linear-interpolation. The code is written in C++ language. For a given initial proton energy and lithium target thickness, the code determines the exit proton energy and then selects the double differential neutron yields from the database that satisfies the input conditions in terms of maximum neutron emission angle and the proton energies that fall within the initial and exit proton energies, and integrate them over the proton energy ranges corresponding to the beam stopping length and also over the angular range covered by the sample irradiated by the neutron beam. The neutron spectra predicted by EPEN were validated by the experimental neutron spectra at E_p=1.912 MeV and 2.3 MeV. EPEN results are also compared with the results of the existing code PINO. EPEN will be accessible online through the web link http://mzu.edu.in/index.php/physics-epen

S327 Description of nucleon scattering on 208Pb and 209Bi by a fully lane-consistent dispersive coupled-channel optical model potential

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The coupled channels optical model is applied to describe nucleon scattering interaction with doubly magic ^{208}Pb up to 200 MeV incident energies. Coupling with excited levels of ^{208}Pb had been built based on recently proposed model [1] which allows inter-band coupling. Necessary for calculations appropriate “effective” deformations determining coupling of excited levels had been fixed as allowing best-fit description of observed experimental angular distributions of nucleons scattered by these levels, while experimental total neutron cross-section, elastically scattered nucleon angular distributions and (p,n) data, had been used simultaneously to search the parameters of ^{208}Pb Lane-consistent dispersive optical model potential. Good agreement between experiment and calculation with this potential is observed. Meanwhile, the application of the determined optical potential with the same parameters to neighboring odd nuclei ^{209}Bi is also examined.

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S328 Role of rotational energy component in the dynamics of 16O+198Pt reaction

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In heavy ion induced reactions, the evaporation residues (ER) are formed as the outcome of competition between fission and other decay channels of the compound nucleus (CN). In theoretical study of heavy ion induced reactions, the long range (Coulomb and centrifugal) and the short range (proximity) interactions play a very crucial and important role. Over the past few years, significant amount of work has been done to understand the specific contribution of various interaction potentials in the heavy ion induced dynamics studies. In the present work, we have emphasised on centrifugal part of interaction potential via the sticking (I_S) and non-sticking (I_{NS}) limits of moment of inertia within the framework of dynamical cluster decay model (DCM) [1]. We have calculated the ER and fission cross-sections in the decay of $^{214}Rn^*$ compound nucleus formed in the $^{16}O+^{198}Pt$ reaction [2]. It is important to mention here that, this is the first time that we have studied both the evaporation residue and fusion-fission (ff) cross-sections simultaneously within I_S and I_{NS} limit, earlier it was accounted either for evaporation or ff channel. It is worth noting that, both ER and ff cross-sections are nicely addressed by I_S approach, although I_{NS} approach provides feasible addressal of data only for ER channel. It is evident from the literature that, ER process arises at lower angular momentum, whereas ff occurs corresponding to higher angular momentum range. Which inturns seem to suggest that I_S works better for ff channel as magnitude of angular momentum is much higher for this choice of moment of inertia. In this study, we have also explored the effect of spherical, static and dynamic deformation on centrifugal part of total interaction potential. We are in the process to analyze the effect of I_S and I_{NS} approaches on different isotopes of Rn, which we intend to complete by the time of conference presentation.

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I329 Advances in nuclear reaction calculations by incorporating information from nuclear mean-field theories

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Calculations of the statistical Hauser-Feshbach theory with the pre-equilibrium process require a lot of model inputs such as optical potentials, level densities, photon strength functions, fission barriers, and so on. In the nuclear data evaluations, we often employ model parameters that are estimated phenomenologically, or sometimes we derive them semi-microscopically with nuclear structure theories. We envision combining nuclear structure models with the nuclear reaction calculations will be very attractive for further development of nuclear reaction codes. An example is the mean-field model calculation for the neutron direct/semi-direct capture model developed at Los Alamos, where the Hartree-Fock (HF) BCS theory is used for calculating bound-neutron wave-functions. Recently this technique was extended to the Finite-Range Droplet Model (FRDM) and the model was unified with the statistical Hauser-Feshbach code CoH3 at LANL. In this paper we discuss possible connections between the nuclearreaction and structure models. Since fully-microscopic calculations still have some issues in practical applications, we limit ourselvesto a semi-microscopic approach so that we can perform calculations of the nuclear structure and reaction models simultaneously. For example, the single-particle states calculated with FRDM or HF-BCS are the basis for nuclear level density calculations. We apply the Gaussian Orthogonal Ensemble (GOE) to average the particle-hole level density, from which local fluctuation in the parity distribution can be inferred. Since these calculations are reasonably fast, we are able to fine-tune the calculation to available observables in a particular mass region of interest.

R331 Ab initio calculations of light-nucleus reactions

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An ab initio (i.e., from first principles) theoretical framework capable of providing a unified description of the structure and low-energy reaction properties of light nuclei is desirable to arrive at accurate evaluations of crucial reaction data for nuclear astrophysics, fusion-energy research, and other applications. In this talk, we will briefly present an efficient many-body approach to nuclear bound and scattering states alike, known as the ab initio no-core shell model with continuum [1]. In this approach, square-integrable energy eigenstates of the A-nucleon system are coupled to (A-a)+a target-plus-projectile wave functions in the spirit of the resonating group method [2] to obtain an efficient description of the many-body nuclear dynamics both at short and medium distances and at long ranges. Compound, target and projectile energy eigenstates are all described within the ab initio no-core shell model [3]. We will show that predictive results for nucleon [4] and deuterium [5] scattering on 4He nuclei can be obtained from the direct solution of the Schroedinger equation with modern nuclear potentials.
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R332 Statistical theory of light-nucleus reactions with 1p-shell light nuclei involved

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The 1p-shell light elements (Li, Be, B, C, N, and O) had long been selected as the most important materials for improving neutron economy in thermal and fast fission reactors and in the design of accelerator-driven spallation neutron sources. A statistical theory of light nucleus reactions (STLN) is proposed to describe the double-differential cross sections for both neutron and light charged particle induced nuclear reactions with 1p-shell light nuclei involved. The dynamics of STLN is described by the unified Hauser-Feshbach and exciton model, in which the angular momentum and parity conservations are strictly considered in equilibrium and pre-equilibrium processes. The Coulomb barriers of the incoming and outgoing charged particles, which significantly influence the open channels of the reaction, can be reasonably considered in the incident channel and different outgoing channels. In kinematics, the recoiling effects in various emission processes are strictly taken into account. The analytical double-differential cross sections of the reaction products in sequential and simultaneous emission processes are obtained in terms of the new integral formula proposed in our recent paper [Phys. Rev. C 92, 061601(R) (2015)]. Taking the 9Be(p,xn) reaction as an example, we calculate the double-differential cross sections of outgoing neutrons and charged particles using the PUNF code in the frame of STLN. The existing experimental double-differential cross sections of neutrons at Ep=18 MeV can be remarkably well reproduced, which indicates that the PUNF code is a powerful tool to set up “file-6” in the reaction data library for light charged particle induced nuclear reactions with 1p-shell light nuclei involved.

R333 Global phenomenological and microscopic optical model potentials for alpha

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The optical model has a significant impact on many branches of nuclear reaction physics. The central assumption of that model is that the complicated interaction between an incident particle and a nucleus can be represented by a complex mean-field potential. An important feature of a good optical model potential is that it can be used to reliably predict the observables for energies and nuclides for which no experimental data exist, meanwhile the ingredients of the model, either microscopic or phenomenological, are physically well-behaved.
A set of global phenomenological optical model potential parameters has been obtained for alpha projectile, by simultaneously fitting the experimental data of total reaction cross sections and elastic scattering angular distributions in the mass range of target nuclei 20≤A≤209 at incident energies below 400 MeV. The calculated results of total reaction cross sections and elastic scattering angular distributions are compared with the experimental data.
The microscopic optical potential for alpha is obtained by the Green function method through nuclear matter approximation and local density approximation based on the effective Skyrme nucleon-nucleon interaction. The radial dependence, the volume integral per nucleon and the root mean square radii of the microscopic optical potential are calculated. The total reaction cross sections and elastic scattering angular distributions for nuclides in the mass range 12≤A≤209 with incident alpha energies below 400 MeV are calculated, and the calculated results are compared with the experimental data.
The potential depth, shape, relative contribution of the surface and volume parts, as well as the energy dependence of the microscopic optical potential for certain energy regions are in reasonable agreement with those of the global phenomenological optical potential. Moreover, the calculated results of the total reaction cross sections and elastic scattering angular distributions with the microscopic optical potential reproduce the experimental data fairly well, and to certain extent are comparable with those calculated with the phenomenological optical potential up to 400 MeV.

I334 Nuclear fission: from more phenomenology and adjusted parameters to more fundamental theory and increased predictive power

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The wave function of a fissioning nucleus depends on 3A-coordinates and time, has $2^A \approx 10^{72}$-spin components and the Schrödinger equation solution is a forever elusive goal on classical computers. Being thus forced to rely on phenomenology and simplified models instead, one gave up on establishing a connection between a microscopic description of the nuclear dynamics and experiment. However, instead of computing the full many-body wave function, one can determine only the one-body density within the Density Functional Theory (DFT), the highly successful approach pioneered by Kohn (Nobel prize, 1998), Hohenberg, and Sham (1964-1965) for many-electron systems in chemistry and condensed matter physics. Within DFT fission dynamics becomes computationally manageable and a microscopic description feasible. To study quantum dynamics we developed a real-time DFT extension, explicitly including the dynamics of the crucial pairing correlations, used existing reasonably accurate energy density functionals (EDF), and implemented it on leadership class computers. These EDFs satisfy all required symmetries, the solutions are allowed to break all symmetries, and we take advantage of GPU (graphic processing unit) accelerators, which provide an enormous speedup with respect to a CPU (central processing unit) code. A single GPU on Titan (Oak Ridge National Laboratory) performs the same number of operations per second as approximately 160 CPUs, and the GPUs alone provide 90% of the theoretical peak speed. Currently we are able to simulate the fission dynamics (saddle-to-scission) in real-time and gain an unparalleled insight on many observables: the pre-neutron emission, total kinetic energy (TKE) of the fission fragments, charge and mass yields, the sharing of the excitation energy between fission fragments, and their initial angular momentum distributions. Even if no complete process description can be achieved yet (e.g. no neutron and gamma-ray emissions from fission fragments, which require very long times), the information provided by the dynamics can be used as input into Hauser-Feshbach codes that treat the de-excitation of fission fragments. TKE and mass/charge yields are directly compared with experimental data with unexpectedly good agreement and with no fitting parameters, see Bulgac et al. arXiv:1511.00738 and videos at http://www.faculty.washington.edu/bulgac/Pu240

R335 Study of five-dimensional potential-energy surfaces for actinide isotopes by the macroscopic-microscopic method

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To reveal the characteristic observables of the fission process, one must calculate a multi-dimensional potential-energy surface that guides the nuclear shape evolution from the ground state to the session point. It is generally accepted that the macroscopic-microscopic method is a powerful tool in the large-scale calculation of nuclear potential energies.
In this work, the nuclear potential-energy of the deformed nuclei as a function of shape coordinates is calculated in a five-dimensional (5D) parameter space of the axially symmetric generalized Lawrence shapes, on the basis of the macroscopic-microscopic method. The liquid-drop part of the nuclear energy is calculated according to the Myers-Swiatecki model and the Lublin-Strasbourg-drop (LSD) formula, respectively. Also, the folded-Yukawa and the Woods-Saxson formula for deformed nuclei are used for the shell and pairing corrections of the Strutinsky-type. The pairing corrections are calculated at zero temperature, *T*, related to the excitation energy. The eigenvalues of Hamiltonians for protons and neutrons are found by expanding the eigensolutions in terms of harmonic oscillator function for a spheroid. Then the BCS pair is applied on the smeared-out single-particle spectrum. By comparing the results obtained by different models, the most favorable combination of the macroscopic-microscopic model is known as the LSD formula with the foled-Yukawa potential.
Potential-energy landscapes for actinide isotopes are investigated based on a grid of 4,000,000 deformation points and the heights of static fission barriers are obtained in terms of a double-humped structure. In order to locate the ground state shape, saddle points, session points and optimal fission path on the calculated 5D potential-energy surface, two algorithms are designed and implemented, both of which are derived from the basic idea of watershed algorithm. The comparison of our results with available experimental data and others' theoretical results confirms the reliability of our calculations.
This work would provide the basis for fully dynamical calculations of adequate precision in five shape parameters description of the fission process. Studies directed towards this goal are presently under way.

R336 Odd-even effect dependence on the excitation energy in low energy fission

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A peculiar phenomenon was observed in the cold fission experimental data: the odd yields are favored over the even ones for excitations energies of the fragments smaller than 4 MeV. In this contribution, a microscopic model is proposed for the explanation of the odd-even yield distributions dependence on the excitation energy of the fragments in cold fission [1]. This explanation is based on a mixing configuration mechanism that behaves similarly to the Landau-Zener effect and it is produced during the fission process. This configuration mixing mechanism (or pair breaking mechanism) is introduced in the time dependent pairing equations by means of the quasiparticle creation and annihilation operators. The time dependent equations of motion for the pair breaking effect were also corroborated with a condition that fixes dynamically the number of particles on the two fission fragment. The single particle level scheme was calculated with the Woods-Saxon superasymmetric two center shell model, providing a continuous variation of the single particle energies and of the wave functions from one nucleus up to two separated fragments. A first rule can be extracted from this model. The even-even fission products cannot be obtained at zero excitation energies because of the existence of inherent excitations produced in the avoided level-crossing regions when the nuclear system deforms slowly. The magnitudes of the interactions and the location of the the avoided level crossing regions are fixed along the fission path and can be considered independent of the velocity of passage through these regions. In an avoided level crossing region, an interaction always exists. If this velocity of passage through this region is large (the nucleus deforms rapidly), the perturbation will act on the Cooper pair in a small duration of time. So, the chance to break a pair will be small. If the velocity is low, the pairs will traverse the regions in larger time durations. So, the probability to break a pair increases. On another hand, high velocities lead to large dissipation energies.

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R337 Microscopic description of fission dynamics: toward a 3D computation of the time dependent GCM equation

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Accurate knowledge of fission fragment yields is an essential ingredient of numerous applications ranging from the formation of elements in the r-process to fuel cycle optimization in nuclear energy. The need for a predictive theory applicable where no data is available, together with the variety of potential applications, is an incentive to develop a fully microscopic approach to fission dynamics. One of the most promising theoretical frameworks is the time dependent generator coordinate method (TDGCM) applied under the Gaussian overlap approximation (GOA). However, the computational cost of this method makes it difficult to perform calculations with more than two collective degrees of freedom. Meanwhile, it is well-known from both semi-phenomenological and fully microscopic approaches that at least four or five dimensions may play a role in the dynamics of fission. To overcome this limitation, we develop the code FELIX aiming to solve the TDGCM+GOA equation for an arbitrary number of collective variables. In this talk, we re-port the recent progress toward this enriched description of fission dynamics. We will briefly present the numerical methods adopted as well as the status of the latest version of FELIX. Finally, we will discuss the fragment yields obtained within this approach for the low energy fission of major actinides.

S338 Neutron induced fission cross section measurements of 240-Pu and 242-Pu

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Accurate neutron induced fission cross section of ^{240}Pu and ^{242}Pu are required in view of making nuclear technology safer and more efficient to meet the upcoming needs for the future generation of nuclear power plants (GEN-IV). The probability for a neutron to undergo such reactions figures in the
NEA Nuclear Data High Priority Request List [1,2].
A measurement campaign to determine neutron induced fission cross sections of ^{240}Pu and ^{242}Pu at 2.51 MeV and 14.83 MeV has been carried out at the 3.7 MV Van De Graaff linear accelerator at Physikalisch-Technische Bundesanstalt (PTB) in Braunschweig. Two identical Frisch Grid fission chambers, housing back to back a ^{238}U and a ^{A}Pu target (A = 240 or A = 242), were employed to detect the total fission yield. The targets were electrodeposited on 25 mm aluminium foils kept at ground potential and the employed gas was P10. The neutron fluence was measured with the proton recoil telescope (T1), which is the German primary standard for neutron fluence measurements. The two measurements were related using a de Pangher long counter and the charge as monitors. The experimental results have an average uncertainty of 5% and have been compared to the data available in literature.

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S339 Energy dependence of time parameters of delayed neutrons for neutron induced fission of the Np-237 in energy range from 14.23 to 17.98 MeV

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Analysis of existing database on the relative abundances of delayed neutrons and half-lives of their precursors measured for neutron induced fission of heavy nuclei in the energy range after 14 MeV shows, that such data are not available for many important nuclides of nuclear fuel cycle.
In the present work, for the first time the time dependence of delayed neutron activity for neutron-induced fission of ^{237}Np in the energy range from 14.23 to 17.98 MeV was obtained using T(*d,n*)^{4}He reaction on the electrostatic accelerator CG-2.5 at the SSC RF-IPPE. The basic experimental method employed in these experiments is based on cyclic irradiations of the fissionable sample in a well defined neutron flux followed by the measurement of the time dependence of delayed neutron activity. The measured data were corrected for effects inevitably arising when T(*d,n*)^{4}He reaction is used as a neutron source. The first one is associated with the concurrent neutron source from D(*d,n*)^{3}He reaction, originated due to the implantation of deuteron ions in the backing of tritium target. The second effect is related to distortions of response function of the neutron detector placed in high intensity neutron flux. After introduction of these corrections, the decay curves were analyzed with the help of the iterative least-squares method. The relative abundances and periods of their precursors in 6-group model presentation were obtained for incident neutron energies 14.23, 15.84, 16.70, 17.98 MeV. There was performed the comparison of obtained data with data obtained using summation method.

S340 The fission time projection chamber

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The Neutron Induced Fission Fragment Tracking Experiment (NIFFTE) has developed the fission Time Projection Chamber (TPC) in an effort to thoroughly understand and reduce the uncertainties of (n,f) cross section measurements. The fully operational fissionTPC has been deployed and collecting data at the Los Alamos National Laboratory's LANSCE-WNR facility for the past several years. This presentation will discuss the design and performance characteristics of a compact MICROMEGAS TPC tailored for fission fragment tracking and operation in a high fluence, high energy neutron beam.

S342 Potential-driving model study on neutron-induced actinide nuclei fission

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The potential-driving model with more well-determined parameters is proposed by uniting symmetric fission potential and asymmetric fission potential, which can precisely calculate pre-neutron-emission mass distributions for neutron-induced actinide nuclei fission for incident-neutron-energy up to 160 MeV, including of ^{232}Th, ^{235}U, ^{238}U, ^{237}Np and ^{239}Pu. Taking explicit account of shell-correction terms and energy-dependence evaporation neutrons for reaction , the potential-driving model can reproduce the experimental data reasonably well by observing the appearance of the calculated results in this work show a good agreement with the experimental data, which can also predict the mass distributions of fission fragments for unmeasured energies regions with a good accuracy. The potential-driving model can well depict the driving potential for neutron-induced excited nucleus, which presents strong evidence that the previous systematic model are fitted the experimental mass distributions with several Gaussian functions. Most importantly, the potential-driving model will be replace the fission model in Geant4 to depict fission process and calculate fission yields, kinetic energy, fission neutron spectrum and decay γ-ray spectrum for neutron-induced actinide fission.

I343 A new UK fission yield evaluation

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The JEFF neutron induced fission product yield evaluation is currently unchanged from JEFF-3.1.1 [1], also known by its UK designation UKFY3.6A [2]. It is based upon experimental data combined with empirically fitted mass, charge and isomeric state models which are then adjusted within the experimental and model uncertainties to conform to the physical constraints of the fission process.
A new evaluation has been prepared UKFY3.7 that incorporates new experimental data and replaces the current empirical models (multi-Gaussian fits of mass distribution, Wahl Zp model for charge distribution and the Madland and England model of Isomeric splitting) by a single semi-empirical model, GEF [3]. The GEF model has the advantage that one set of parameters allows the fitting and prediction of many different fissioning systems unlike previous systems where each system had to be fitted individually. This model also allows prediction of fission yields with the energy of the fission inducing neutron.
The new UKFY3.7 evaluation, submitted for testing as part of JEFF-3.3, is described alongside initial results of testing. In addition, initial ideas for future developments allowing inclusion of new measurements types and changing from any neutron spectrum type to true neutron energy dependence are discussed.

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R344 Excitation energy influence at the scission configuration

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Transfer-induced fission in inverse kinematics was proven to be a very powerful tool to investigate nuclear fission, widening the information of the fission fragments and the exoticity of the fissioning systems with respect to other experimental approaches. An experimental campaign for fission investigation is being carried out in GANIL with this technique since 2008. In these experiments, a beam of 238-U, accelerated to 6.1 MeV/u, impinges on a carbon target. Fissioning systems from U to Am are populated by transfer reactions, with excitation energies that range from few MeV up to 20 MeV, and fussion reactions that reach higher excitation energy.

The use of inverse kinematics and the VAMOS spectrometer permits the measurement of isotopic yields of the fission fragments over the complete fragment distribution in the produced fissioning systems, most of them exotic nuclei, as a function of the induced excitation energy. In addition, this technique gives us the opportunity to measure the kinematic properties of the fragments, such as velocities and kinetic energies. With this information, it is possible to obtain the neutron excess of the fragments before they emit neutrons, as well as the neutron multiplicity and the total kinetic energy at scission. These observables allow the investigation of the role of nuclear structure, the sharing of excitation energy, and the scission configuration along the full fragment distribution.

This contribution intends to present the evolution of isotopic fission yields as a function of the fission excitation energy; and, for first time, the evolution of the scission configuration, in terms of charge polarization and total kinetic energy, also as a function of the excitation energy of the measured fissioning systems.

These new results help to determine the features of the fission process, which is of importance for the design of new-generation nuclear power plants and for the incineration of nuclear waste. In addition, the measured yields can also be useful for RIB production for their use on future experiments.

R345 Macroscopic-microscopic models of nuclear potential energy - implementation in CONRAD

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To improve the evaluation of nuclear observables, refined models are to be used more and more as the underlying analysis tools of evaluation. Fission is a complex process and is the less accurately described with current models used in the evaluation methods. One of the first quantities involved in the fission process is the potential energy “felt” by the nucleus that undergoes fission. This potential energy – the fission barrier – is then used to determine the probability that the compound nucleus deforms from its ground-state shape to scission shapes. The potential energy varies with the shape of the nucleus; the latter is thus characterized with “macroscopic” shape coordinates, which yields Potential Energy Surface (PES).

Two main approaches are used to obtain this PES: the microscopic approach, for instance Hartree- Fock-Bogoliubov, and the macroscopic-microscopic approach. As models are rarely exact, evaluators are often compelled to “tune” model parameters so that observables are properly reproduced. The related computation time can thus be a limiting factor for the use of advance models in evaluation. The macroscopic-microscopic approach has thus been selected to replace the current phenomenological description of the fission barrier.

Two macroscopic-microscopic models, the Finite-Range Liquid-Drop Model (FRLDM) and the Finite-Range Drop Model (FRDM) have been implemented in the CONRAD evaluation code. As speed is a key requirement of evaluation models, insights will be given on the numerical and computation choices that have been used in the present implementation. The verification of the model on benchmarked data will be presented, as well as the results of the model in the prediction of atomic masses. The CONRAD code provides expectation values of the models but also related uncertainties and covariance data. Evaluated uncertainties and related correlation matrices will be presented for the model parameters and also for the calculated masses.

R346 Fission description: first steps towards a full resolution of the time-dependent hill-wheeler equation

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Dynamical description of low energy fission is, in our full microscopic approach, decomposed in two steps. In the first step we generate the potential energy surface (PES) of the compound system we want to describe with the Hartree-Fock-Bogoliubov (HFB) method with a Gogny interaction. The second step uses the time dependent generator coordinate method (TDGCM) with the gaussian overlap approximation (GOA). The GOA holds in two assumptions: the overlap matrix between HFB states has a gaussian shape (with respect to the difference between coordinates of states in deformation space); and the expectation value of the collective hamiltonian between these states can be expanded up to order two, leading in this case to a Schrödinger-like equation.
In this work we replace TDGCM+GOA in the second step of our approach by an exact treatment of the TDGCM. The main equation of this method is the time-dependent Hill-Wheeler equation and involves two objects: the overlap matrix and the collective hamiltonian. We first calculate these matrices on a PES. Then, we build an "exact TDGCM" solver using a finite element method and a Crank-Nicolson scheme.
In this talk, we will present the time-dependent Hill-Wheeler equation and discretization schemes (in time and deformation space). The analytic calculation of overlap matrix and collective hamiltonian will be detailed. Finally, first results with an exact treatment of the TDGCM will be discussed.

I347 On the use of Bayesian Monte-Carlo in evaluation of nuclear data

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As model parameters, necessary ingredients of theoretical models, are not always predicted by theory, a formal mathematical framework associated to the evaluation work is to obtain the best set of parameters (resonance parameters, optical models, fission barrier, average width, multigroup cross sections) by Bayesian statistical inference by comparing theory to experiment. The formal rule related to this methodology is to estimate the posterior density probability function of a set of parameters by solving an equation of the following type: pdf(posterior) proportional to pdf(prior) times a likelihood function. A fitting procedure can be seen as an estimation of the posterior density probability of a set of parameters {x} knowing an a-priori information on these parameters and a likelihood which gives the probability density function of observing a data set knowing {x}. To solve this problem, two majors path could be taken: add approximations and hypothesis and obtain an equation to be solved numerically (minimum of a cost function or Generalized least Square methods, referred as GLS) or use Monte-Carlo sampling of all a priori distribution and estimate the final posterior distribution. Monte Carlo methods are natural solution for Bayesian inference problems. They avoid approximations (existing in traditional adjustment procedure base on chi-square minimization) and propose alternative in the choice of probability density distribution for priors and likelihoods. The use of this kind of methods was first proposed by D. Smith and R. Capote for the evaluation of cross section in the continuum energy range.
This paper will exposed and proposed the use of what we are calling Bayesian Monte Carlo (referred as BMC in the rest of the manuscript) in the whole energy range from thermal, resonance and continuum range for all nuclear reaction models at these energies. Algorithms will be presented based on Monte-Carlo sampling and Markov chain. The objectives of BMC are to propose a reference calculation for validating the GLS calculations and approximations, to test probability density distributions effects and to provide the framework of finding global minimum if multi local minimum exists.
Application to resolved resonance, unresolved resonance and continuum evaluation as well as multigroup cross section data assimilation will be presented.

R348 A variational Bayesian approach to accelerate Monte Carlo evaluation methods

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Nuclear data evaluation deals with the determination of best estimates and uncertainties of cross sections and related quantities of the atomic nuclei. These quantities are compiled into nuclear data files, which are required for the development of nuclear technologies such as advanced reactors, nuclear waste transmutation, and nuclear medicine. Most evaluation methods rely on Bayesian statistics to combine experimental data and nuclear models in order to obtain the so-called posterior distribution. Best estimates, uncertainties and other quantities of interest can be extracted from this distribution. However, the posterior distribution is in general not available in closed form due to the complexity of the nuclear models. The simplification (e.g. linearization) of the nuclear models or the use of Monte Carlo sampling techniques are two common ways to address this issue. The benefit of using the exact model in Monte Carlo techniques is counter-balanced by their computational demands. It may take days or even weeks to obtain a sufficient sample size to produce reliable estimates. For instance, the Total Monte Carlo (TMC) approach of A. Koning et al. performs the complete chain of applications from the nuclear model code to the transport code for each sampled set of model parameters. Thus an efficient sampling scheme is paramount to the successful application of Monte Carlo evaluation methods.

In this contribution, an adaptive sampling scheme based on a variational Bayesian approach is presented, which aims at improving the sampling efficiency in the course of the sampling process. Noteworthy, the presented sampling scheme is designed for parallel computation in order to exploit the joint performance of computer clusters. Properties of the method are investigated and case studies are made to compare its performance against other sampling schemes.

R349 Novel evaluation concept including model defects

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Nuclear data evaluation provides consistent sets of nuclear reaction data which are essential prerequisites for the development of nuclear technologies such as advanced reactors, nuclear fusion devices, waste transmutation, medical radiation facilities, materials research and corresponding questions concerning radiation safety. Envisaged technological advances require an extension of the available nuclear data files to higher energies up to 200 MeV. Because of the scarcity of experimental data at higher energies, nuclear data evaluations rely more heavily on nuclear model calculations. In general nuclear models depend on a set of parameters whose values are known only with uncertainties. Despite this flexibility the models cannot yield a perfect description of data giving rise to a model deficiency which cannot be extracted from theory. In standard Bayesian evaluations only parameter uncertainties together with the experimental ones are taken into account. Model defects are ignored giving rise to unphysical distortions of the evaluated values.

In this contribution a novel Bayesian evaluation concept including model defects is presented. This extended method is statistically consistent and is based on Gaussian processes for the formulation of model defects. In addition uncertainties of the experiment and in the parameters are included in the evaluation. The evaluation process follows similar steps as standard techniques, but yields in addition an estimate of model defects, their uncertainty and correlations with other quantities. The extended method has been successfully applied to realistic examples, which clearly show the impact of the inclusion of model defects on the final evaluation result and covariance matrices.

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R350 Fission yield covariances for JEFF: a Bayesian Monte Carlo method

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The JEFF library does not contain fission yield covariances, but simply best estimates and uncertainties. This situation is not unique as all libraries are facing this deficiency, principally due to the lack of a defined format but also due to the challenges in generating these essential data.
With the increasing sophistication of model-based fission yield simulation tools (such as GEF) an alternative approach is to provide a set of fission yield files through intelligent sampling of physical parameters. Statistical analysis of repeated simulations provides complete uncertainty quantification and propagation. Therefore, this Total Monte Carlo (TMC) approach fulfills the need of the evaluations by providing full correlated fission yields.
In this work, random fission yield file sets are generated through parameter sampling that is updated to converge on JEFF-3.1.1 (JEFF-3.3 if available) fission yields and uncertainties. This methodology marries the theoretical knowledge of GEF with the evaluated data to produce the correlated TMC uncertainty. Examples of the major actinides are presented with applications in burn-up and decay heat simulations.

S351 Bootstrap method for constructing covariance matrices of optical-model parameters in the study of the threshold anomaly

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The parameters of optical-model potentials are usually obtained by adjusting theoretical calculations to the corresponding experimental elastic-scattering data. It has been observed that the use of conventional covariance matrices for the evaluation of the uncertainties of the parameters obtained in this way, leads in general to unrealistically small values. This underestimation may be caused by either a) an incorrect use of the statistical recipes, namely the prescription of determining the uncertainty by requiring a variation of just one unit in the value of χ^2 or b) the lack of a systematic study of the influence of excluding or including data points or different sets of data points, on the calculated uncertainties. In the present contribution we explore both factors. Regarding point a), we use a renormalization for χ^2, similar to the one proposed by Birge[1]. For point b) we use the Bootstrap method to create synthetic sets based on all the available experimental data in order to derive an effective covariance matrix. We have previously discussed the effect of a) and a version of the Bootstrap method on the error ellipses of strongly correlated parameters[2].
As case studies, these procedures were applied to the re-analysis of detailed elastic-scattering data for several heavy-ion systems at energies close to the Coulomb barrier. The experimental data in digital form were extracted from the EXFOR library[3]. We will present here the results of our study of the ^{12}C + ^{208}Pb, ^{16}O + ^{64}Zn, ^{6,7}Li + ^{27}Al, ^{6,7}Li + ^{80}Se, ^{6}Li + ^{64}Zn, ^{6}Li + ^{90}Zr and the ^{6,7}Li + ^{144}Sm systems. The use of the present method allows a more realistic and robust determination of the parameter´s uncertainties.

1. Phys. Rev. **40** (1932) 207; 2. Journal of Physics: Conference Series **630** (2015) 012021; 3. Nuclear Data Sheets **120** (2014) 272

S352 Uncertainty of the delayed neutron fraction in fuel assembly depletion calculations

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Delayed neutrons affect the reactor dynamic behaviour of a nuclear reactor. Therefore, an accurate determination of the delayed neutron fraction and its uncertainty is of crucial importance for the purpose of reactor transient and safety analyses. This study presents uncertainty and sensitivity (U/S) analyses of the delayed neutron fraction of a light water reactor fuel assembly (UAM-LWR) and a sodium-cooled fast reactor fuel assembly (SFR-FT, large oxide core). For these analyses, the sampling-based XSUSA methodology is used to propagate cross section uncertainties in neutron transport and depletion calculations. Cross section data is varied according to the SCALE-6.1 covariance library. Uncertainties of the numbers of both the prompt and delayed neutrons released per fission event are not individually included, but only of the total number. Since the delayed nu-bar uncertainties affect the uncertainty of the delayed neutron fraction, these uncertainties have additionally been taken into account from the covariance data of the JENDL-4.0 nuclear data library. The neutron transport and depletion calculations are performed with the TRITON/NEWT sequence of the SCALE-6.1 code package. The evolution of the delayed neutron fraction uncertainty as a function of burn-up is analysed with and without the consideration of delayed nu-bar uncertainties. Moreover, the main contributors to the result uncertainty are investigated for the beginning of life (BOL) and the end of life (EOL). For both arrangements, evidently, the delayed nu-bar uncertainties increase the delayed neutron fraction uncertainty. At BOL, for example, the uncertainty for the LWR case is increased from about 0.4 to 2.9 %. In the SFR case, the uncertainty is increased from about 3.4 to 4.4 %. The main contributors to the delayed neutron fraction uncertainty for the LWR fuel assembly are delayed nu-bar values, namely of U-235 at BOL and of Pu-239 at EOL. On the contrary, for the SFR case, the uncertainty of the scattering cross section of U-238 makes the main contribution at BOL and EOL. Since the isotopic composition changes only slightly over burnup, the delayed neutron fraction uncertainty is almost constant and the main contributors remain the same.

S353 The impact of the retroactive method for resonance parameter uncertainties, in particular propagated to helium production due to Ni-59 in stainless steel

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For older neutron cross section experiments in the thermal and resonance range, the only reasonably accessible documentation may be the experimenters estimates of thermal cross sections, resonance parameters and their respective uncertainties. Thus, it is difficult to judge which uncertainties that were included in the analysis, and there is no information on correlations between the thermal cross sections and resonance parameters. Disregarding the correlations can have severe consequences when propagating the uncertainties to applications. Further, the resonance parameters and thermal cross sections need not be compatible.
In this work, thermal experimental information is analyzed based on typical equations for obtaining cross sections from counts. The different components of the equations are assigned with uncertainties, either from the available documentation or using default values; and the correlations between different systematic components are estimated, even across different experiments. Then, the errors of the different components are sampled, yielding a full multivariate distribution for the thermal cross sections. The resonance parameters are sampled, too, including approximations of the same systematic errors. The two sets are then combined by adjusting bound resonances, making use of TALYS information in a way which takes the uncertainties of TALYS parameters into account. Higher energy cross sections are also obtained from TALYS, and the correlations this infers are kept track of. Therefore, the resulting cross sections includes correlations over the whole energy range.
In particular, the method is applied to the cross sections of Ni-59. This is interesting in reactor applications because of the nuclides buildup through capture in Ni-58 and its extraordinarily high (n,α) cross section, giving a dominating contribution to the helium production and damage energy in stainless steel components in thermal reactors.

S354 Emerging capabilities for charged-particle induced reactions with the R-matrix SAMMY code

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The most recent version of the *R*-matrix code SAMMY [1] allows the study of the ingoing and outgoing charged-particle channels in the low-energy interaction range. Although the SAMMY code system is mainly used in nuclear data evaluations for incident *neutrons* in the resolved resonance region (RRR), built-in capabilities also allow the code to describe the resonance structure produced by other incident particles, including charged particles.
ENDF/B-VII.1 nuclear data library [2] contains no evaluated data for α-induced reactions. However, (α,n) data provide fundamental information that underpins nuclear modeling and simulation software, such as ORIGEN [3] and SOURCES4C [4], used for the analysis of neutron emission and source emission processes. The ultimate goal of this work is to carry out evaluations of charged-particle-induced reaction cross sections in the RRR. The SAMMY code was recently used in this regard to generate a Reich-Moore parameterization of the $^{17,18}O(\alpha,n)$ available experimental cross sections in order to estimate the uncertainty in the neutron generation rates for uranium oxide fuel types [5]. This paper provides a detailed description of the SAMMY evaluation procedure for the treatment of (α,n) reaction cross sections applied to $^{17,18}O$ isotopes and describes further applications of these procedures to ^{19}F.

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I355 Characterization of the energy-dependent uncertainty and correlation in the neutron displacement kerma

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This work provides a characterization of the energy-dependent uncertainty in the silicon displacement kerma. We pioneered an approach for deriving a covariance matrix for a nuclear physics based energy-dependent response using a Total Monte Carlo (TMC) analysis. This analysis was rigorous in addressing model-defect in this type of uncertainty analysis.
Initial work captured the importance of considering contributions from all of the naturally occurring isotopes when extracting the displacement damage function. Collaborators (A. Koning and D. Rochman) at NRG in Petten, The Netherlands, used the TALYS nuclear reaction modeling code to generate a 101-element statistical sample of cross sections for all three naturally occurring silicon isotopes. This statistical sample was derived by varying the input parameters for the underlying nuclear models in TALYS, e.g. the optical model parameters and the resonance parameters. The effect of the uncertainty in the cross section and recoil spectra for different reaction channels were assessed using this statistical sample. While the effect of cross reaction channel correlations in the cross sections and in the recoil spectra were expected to be small, analysis indicated that, at high energy, there is a strong correlation and that the total displacement kerma uncertainty is much smaller than the uncertainty in any of the individual displacement kerma components. While this complicated our analysis of model defect, it clearly validates the use/necessity of the TMC approach, an approach that is capable of addressing the cross correlation between reaction channels.
After the TMC analysis, a detailed study was made on "model defect" associated with the methodology. This study addressed uncertainty arising from the damage partition function and the underlying potential used to separate ionization from displacement energy loss mechanisms. The distinction between a displacement kerma and a dpa is addressed and the uncertainty associated with the threshold displacement energy is discussed.
The paper characterizes the uncertainty of the silicon displacement kerma in the form of an energy-dependent covariance matrix that can be used to assess various material damage studies as support the use of silicon transistors as a neutron dosimeter in accordance with ASTM standards E1855 and E722.

R356 Understanding total Monte Carlo uncertainty propagation in burn up calculations with generalized perturbation theory

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The last few years has seen Total Monte Carlo becoming the most used method for uncertainty propagation in burn up calculations. This straightfoward approach allows for the direct observation of output uncertainties (keff, isotopic concentrations etc…) of the coupled Bateman equation (fuel depletion) and Boltzmann equation (neutron transport). The application of GPT in this coupled case implies not only the calculation of nuclide adjoint functions but also the calculation of a number of importance functions. The coupling is thus almost never done.
In this paper, we compare the propagation of Pu239 fission, capture and (n,2n) cross sections' uncertainties with both TMC and GPT methods in a simple Na-cooled fast reactor assembly. In such a case, the change of spectrum due to the change in in one nuclide's cross sections is expected to be smaller than in a thermal spectrum where the importance of individual resonances is high. We will see that it can't be negligeted. Thanks to the combined use of TMC and GPT we can separate the effects of uncertainties on a selection of other heavy nuclide densitities.
The power normalisation gives minor, but important contributions. The sensitivities to depletion terms are the dominant terms for Pu239 and its direct daughters' evolution. The minor actinide density uncertainties are dominated by the impact of Pu239 on neutron spectrum and then on minor actinides' average cross sections. The results of uncertainty analyses could therefore be very different if basic uncertainties with complete energy and cross nuclide correlations were available.

R357 Nuclear data uncertainty propagation by the XSUSA method in the HELIOS2 lattice code

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Uncertainty quantification has been extensively applied to nuclear criticality analyses for many years and has recently begun to be applied to depletion calculations. However, regulatory bodies worldwide are trending toward requiring such analyses for reactor fuel cycle calculations, which also requires uncertainty propagation for isotopics and nuclear reaction rates. XSUSA is a proven methodology for cross section uncertainty propagation based on random sampling of the nuclear data according to covariance data in multi-group representation; HELIOS2 is a very fast lattice code widely used for commercial and research reactor fuel cycle calculations. This work describes a technique to automatically propagate the nuclear data uncertainties via the XSUSA approach through fuel lattice calculations in HELIOS2. Application of the XSUSA methodology in HELIOS2 presented some unusual challenges because of the highly-processed multi-group cross section data used in commercial lattice codes. Currently, uncertainties based on the SCALE 6.1 covariance data file are being used, but the implementation can be adapted to other covariance data in multi-group structure. Pin-cell and assembly depletion calculations, based on models described in the UAM-LWR Phase I and II benchmarks, are performed and uncertainties in multiplication factor, reaction rates, isotope concentrations, and delayed-neutron data will be presented. With this extension, it will be possible for HELIOS2 users to propagate nuclear data uncertainties directly from the microscopic cross sections to subsequent core simulations.

R358 Covariances for the 56Fe radiation damage cross sections

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The goal is a calculation of the covariance matrices for the physical quantities used to characterize the neutron induced radiation damage in the materials. Such quantities encompass: the total kinetic energy deposition KERMA (nuclear heating), damage energy (to calculate then the atom displacement cross sections) and gas production cross sections ((n,xα), (n,xt), (n,xp) …). The uncertainties and energy-energy or reaction-reaction correlations were not assessed so far, in spite that covariances for many other cross sections are already available in the evaluated libraries. This research was also motivated by the IAEA Coordinated Research Project "Primary Radiation Damage Cross Sections" [1].
In this paper we report the results for the neutron interaction with ^{56}Fe in the energy range from thermal up to 20 MeV. The method is based on idea of Total Monte Carlo application to the Nuclear Data [2]. We used 1 unperturbed and 500 perturbed ^{56}Fe evaluated files from TENDL-2013, every one being generated in the ENDFB-6 format by TALYS with randomly varied nuclear reaction model parameters [3].
To propagate the random cross sections to the damage quantities, all 501 files were processed by NJOY-2012.50: the HEATR module was used to calculate KERMA and damage energy, whereas GASPR - gas production cross sections (n,x^{4}He), (n,x^{3}He), (n,xt), (n,xd) and (n,xp). Then the GROUPR module generated the desired data in the grouped-wise format *gendf* to reduce the rank of covariance matrices. The Fortran code was written to read *gendf* files and calculate the mean quantities, standard deviations and energy-energy or reaction-reaction correlation matrices.
The results obtained for KERMA and damage energy qualify the uncertainties within 6% corridor for low neutron energies (0.1 to 500 eV), 25% - fast resonance region (500 eV - 1 MeV) and 10% or 2% - at higher energies (1 - 20 MeV). The energy-energy correlation matrices show strong correlations within these energy intervals but weak ones between them. For ^{4}He production cross section we receive 20-30% uncertainty between the reaction threshold and 20 MeV. The strong energy-energy correlations are observed for energy pairs differing by factor less than 2.

1. The IAEA CRP "Primary Radiation Damage Cross Sections", https://www-nds.iaea.org/CRPdpa/ ; 2. D. Rochman, A.J. Koning et al., Ann. Nucl. Energy 38 (2011) 942; 3. A.J. Koning and D. Rochman, Random nuclear data files TENDL-2013: ftp://ftp.nrg.eu/pub/www/talys/tendl2013/random.html

I359 High resolution measurements of the exited states (n,pn), (n,dn) C-12 cross sections

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Measurements of C-12 cross-sections for several excited states (n,p_n), (n,d_n), n=1,2… have been carried out using the Van de Graaff neutron generator of the EC-JRC-IRMM. A very thin tritiated target
(263 μg/cm^2) was employed with deuteron beams energies impinging on the target in the range 2.5-3.75 MeV. Neutrons in the range 18.9-20.5 MeV were produced with an intrinsic energy spread of 0.2-0.25% FWHM. With such narrow neutron energies spread, using an high energy resolution device such as a single crystal diamond detector, several peaks from the outgoing charged particles produced by the (n,p_n), (n,d_n) and also (n,α) reactions appear in the pulse height spectrum. The peaks were identified using the reaction Q-values. The used diamond detector showed an intrinsic energy resolution lower than 0.9% FWHM for the measured deposited energies.
The analysis of the peaks allows to derive several partial carbon reaction cross sections produced by different excited states. The results are presented in the paper together with the analysis of the associated uncertainties. A comparison to the available compilations (e.g. TENDL) is also addressed.
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The analysis of the peaks allows to derive several partial carbon reaction cross sections produced by different excited states. The results are presented in the paper together with the analysis of the associated uncertainties. A comparison to the available compilations (e.g. TENDL) is also addressed.

R360 The 13C(n,a0)10Be cross section at 14.3 MeV and 17 MeV neutron energy

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At nuclear fusion reactors, CVD diamond detectors are considered an advantageous solution for neutron flux monitoring. For such applications the knowledge of the cross section of neutron-induced nuclear reactions on natural carbon are of high importance. Especially the (n,a_0) reactions, yielding the highest energy reaction products, are of relevance as they can be clearly distinguished in the spectrum.
The $^{13}C(n,a_0)^{10}Be$ cross section was measured relative to $^{12}C(n,a_0)^{9}Be$ at the Van de Graaff facility of JRC-IRMM, at 14.3 MeV and 17.0 MeV neutron energies. The measurement was performed with an sCVD (single-crystal Chemical Vapor Deposition) diamond detector, where the detector material acted as sample and as sensor. A novel data analysis technique, based on pulse-shape discrimination, allowed an efficient reduction of background events. The results of the measurement will be presented and compared to previously published values for this cross-section.

R361 Neutron production in deuteron-induced reactions on Li, Be, and C at an incident energy of 100 MeV

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In recent years, deuteron-induced reaction is considered as one of the effective reactions to produce high intensity neutron beam for neutron application fields such as radiation damage evaluation for fusion materials, boron neutron capture therapy and medical radioisotope production. Neutron production data from neutron converter materials such as Li, Be and C are essentially important. However, the experimental data are not sufficient, especially at incident energies above 60 MeV, therefore the theoretical models are not validated. Under this situation, we measured the double differential (d, xn) cross sections (DDXs) for Li, Be and C at 100 MeV and analyzed them with theoretical models.The experiment was performed using the Time of Fight course at the Research Center for Nuclear Physics in Osaka University. A deuteron beam accelerated to 102 MeV was transported to the neutron experimental hall and focused on the thin lithium, beryllium and carbon targets in natural compositions. The targets were placed on a beam swinger magnet. The DDXs were measured at six angles (0, 5, 10, 15, 20 and 25 degrees) by changing the target position in the swinger magnet. NE213 liquid organic scintillators were adopted as neutron detectors. The detected neutrons were recorded event by event as a function of their time of flight.
In the measured DDXs, a broad peak due to deuteron breakup process is observed at approximately half of the deuteron incident energy. The experimental results are compared with the calculations by PHITS. The calculated DDXs have the broad peak structure, but the shape and magnitude do not necessarily reproduce the experimental ones. Detailed analysis with an alternative theoretical model calculation is also presented. In the calculation, elastic breakup and continuum stripping reactions are described by the Continuum Discretized Coupled Channels (CDCC) theory and the Glauber model, respectively. In addition, the DWBA is employed for the stripping reaction to bound state. The Hauser-Feshbach theory and exciton model are adopted for statistical decay process.

R362 Measurements of gamma-ray emission cross section for 14N(d,p)15N from 0.6-2.0 MeV

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Deuteron Induced Gamma-ray Emission (DIGE) is a powerful analytical technique which measures prompt gamma-rays emitted from the nuclei that are in an excited state during bombardment of the solid samples. The ^{15}N as the reaction product of $^{14}N(d,p\gamma)^{15}N$ reaction with a Q-value of 8.609 MeV, decays from highly excited states, have a very intensive gamma-ray yields even at lower deuteron energies. Hence, the emitted high energy -rays (E= 7298 & 8310 keV) have enough yields in the low energy region. Unfortunately, no practical method exists for accurate calculation of DIGE cross sections at low energy for analytical porpuses and they can only be obtained from experiment with some limited margin of error and confidence.
In this research work, measured differential cross sections for gamma-ray emission from the nuclear reactions $^{14}N(d,p_{4-1})^{15}N$ (E= 1885keV), $^{14}N(d,p_{6-1})^{15}N$ (E= 2297 keV) and $^{14}N(d,p_{7-0})^{15}N$ (E= 8310 keV) were reported. The experimental work was carried out on the 45 right beamline of the 3MV Van de Graaff electrostatic accelerator of Nuclear Science and Technology Research Institute (NSTRI) in Tehran. A thin silicon-nitride film and a thick BN disk was applied for mesurements of differential cross sections and thick target yields, repectively. The gamma-rays and backscattered deuterons were detected simultaneously. A P-type HPGe coaxial detector with crystal size of 6.58 cm × 6.58 cm and an active volume of 213 cm^3 placed at an angle of 90 with respect to the beam direction was employed to collect gamma-rays while an ion implanted Si detector placed at a scattering angle of 165 was used to detect backscattered deuterons. The validity of the obtained differential cross sections was verified through a thick target benchmarking experiment. The overall systematic uncertainty of the cross section values was estimated and reported.

S363 (n,xn) Cross section measurements for Y-89 foils used as detectors for high energy neutron measurements in deeply subcritical assembly "QUINTA"

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Study of deep subcritical systems (QUINTA) using relativistic beams are performed within the project „Energy and Transmutation of Radioactive Wastes" (E&T – RAW). The experiment assembly was irradiated by deuteron/proton beam (Dubna NUCLOTRON). We calculated neutron energy spectrum inside the whole assembly by using threshold energy (n,xn) reaction in yttrium (Y-89) foils. Experimental cross section data for those reaction are poor. New experiments for Y-89 cross section measurements was made in Uppsala laboratory in 2015 y. In this paper we present our results from those experiments.

S364 A high precision tagged neutron n-p scattering measurement at 14.9 MeV

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The n-p scattering angular distribution was measured with 14.9 MeV incident neutrons produced at the neutron facility of Ohio University. The traditional time-of-flight (TOF) technique with neutron-gamma discrimination was applied for the measurement of the number and energy of scattered neutrons. The scattering angle varied from 20-deg to 65-deg in 5-degrees incremental step corresponding to an ejectile energy range from 13.16 MeV to 2.66 MeV.
The "scatter-detector" (plastic scintillator EJ-200, D=1.5 cm, H= 4.5 cm, Photo Multiplier Tube (PMT) XP2900) was applied for recoil protons counting. It was located at ~20 cm from a solid tritium target generated incident neutrons from T(d,n) reaction. Two liquid scintillation detectors (NE213, D=12.7 cm, H=5.08 cm, PMT RCA 4522) were used for counting of scattered neutrons. These detectors were placed in the time-of-flight tunnel at a flight path of 4.108 m. Pulses from these detectors were applied as "start" signals, and "scatter-detector" pulses as "stop" signals. The duration of each run was ~6 h.
The efficiency of the neutron detectors was measured in the energy range 2-9 MeV relative to a ^{252}Cf-standard, and was simulated using Monte Carlo methods in the 2-14 MeV energy range. Two methods of analysis were applied for experimental and simulated data: a traditional approach with a fixed threshold ~0.1MeVee, and a dynamic threshold approach. The efficiencies estimated by both methods are in excellent agreement for simulated and experimental results within the energy interval 2-9 MeV. The experimental (<9 MeV) and calculated efficiencies (>9 MeV) were applied for evaluation of the n-p scattering experimental result. The correction for neutron attenuation in the "scatter-detector" was calculated with analytical formulas, and by the Monte Carlo method. The detailed analysis of random and systematical uncertainties will also be given. The new experimental data confirm the ENDF/B-VII evaluation for the n-p angular distribution with an accuracy ~1.5%. The current state-of-the-art of experimental uncertainties which can be realized for a neutron counting experiment was reached in this investigation.

S365 Measurement of the angular and energy distributions of neutrons from 7Li(d,n)8Be reaction at deuteron energy 2.9 MeV by activation method

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The neutron beams generated at the electrostatic accelerators using nuclear reactions T(p,n)^{3}He, D(d,n)^{3}He, ^{7}Li(p,n)^{7}Be, T(d,n)^{4}He, ^{7}Li(d,n)^{8}Be, ^{9}Be(d,n)^{10}B are widely used in neutron physics and in many practical applications. Among these reactions the least studied reactions are ^{7}Li(d,n)^{8}Be and ^{9}Be(d,n)^{10}B. The present work is devoted to the measurement of the neutron spectrum from ^{7}Li(d,n)^{8}Be reaction at 0°, 45° and 90° angles to the deuteron beam axis on the electrostatic accelerator EG-1 (JSC "SSC RF – IPPE") using activation method and a stilbene crystal scintillation detector. The target was a thick lithium layer on metallic backing. The energy of the incident deuteron was 2.9 MeV. As activation detectors a wide range of nuclear reactions were used: ^{27}Al(n,p)^{27}Mg, ^{27}Al(n,α)^{24}Na, ^{113}In(n,n')^{113m}In, ^{115}In(n,n')^{115m}In, ^{115}In(n,γ)^{116m}In, ^{58}Ni(n,p)^{58m}Co, ^{58}Ni(n,2n)^{57}Ni, ^{60}Ni(n,p)$^{60m+g}$Co, ^{197}Au(n,γ)^{198}Au, ^{197}Au(n,2n)^{196}Au, ^{197}Au(n,γ)^{198m}Au, ^{59}Co(n,p)^{59}Fe, ^{59}Co(n,2n)$^{58m+g}$Co, ^{59}Co(n,α)^{56}Mn, ^{59}Co(n,γ)$^{60m+g}$Co. Measurement of the induced gamma-activity was carried out using HPGe-detector Canberra GX5019. The up-to-date evaluations of the cross sections for these reactions were used in processing of the data. The program STAYSL was used to unfold the energy spectra. The neutron spectra obtained by activation detectors is consistent within uncertainties with the corresponding data measured by a stilbene crystal scintillation detector. The present data were compared with appropriate data by other authors.

I366 Investigating the surrogate-reaction method via the simultaneous measurement of fission and gamma-decay probabilities

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Neutron-induced cross sections of short-lived nuclei are important for fundamental physics, nuclear astrophysics and applications in nuclear technology. However, in many cases the measurement of these cross sections is very difficult or even impossible due to the radioactivity of the targets involved. The surrogate-reaction method can help to overcome these difficulties. This indirect method consists in using an alternative (or surrogate) reaction to produce the same decaying nucleus as the one formed in the desired neutron-induced reaction. The decay probability induced by the surrogate reaction is measured and the desired neutron-induced reaction is "simulated" by multiplying the measured decay probability by the calculated cross section for the formation of a compound nucleus after neutron absorption. The advantage of the surrogate method is that in some cases it is possible to find a surrogate reaction where the target needed is stable or less radioactive than the target of the corresponding neutron-induced reaction. However, the angular-momentum and parity differences between the neutron-induced and the surrogate reactions might lead to significant differences between the results obtained with the two types of reactions.
In this contribution we will present the first results of an experiment where we have measured for the first time simultaneously the fission and gamma-decay probabilities induced by different surrogate reactions. In particular, we have investigated the $^{238}U(^{3}He,d)$, $^{238}U(^{3}He,t)$ and $^{238}U(^{3}He,^{4}He)$ reactions as surrogates for the neutron-induced ^{238}Np+n, ^{237}Np+n and ^{236}U+n reactions, respectively. Our results for the fission probabilities agree fairly well with the neutron-induced data, whereas our gamma-decay probabilities are a factor 3 to 10 higher than the neutron-induced data. These results are surprising and cannot be currently explained by calculations based on the statistical model, which predict a strong variation of the fission probabilities with angular momentum. Therefore, our data represent a stringent test to the statistical model.
In this contribution we will describe the experimental methodology and discuss the first results. We will also present future plans for surrogate-reaction studies in inverse kinematics with radioactive-ion beams inside storage rings.

R367 The cross sections and energy spectra of the particle emission in proton induced reactions on 204,206,207,208Pb and 209Bi

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All cross sections of proton induced reactions, angular distributions, energy spectra and double differential cross sections of neutron, proton, deuteron, triton, helium and alpha-particle emissions for p+$^{204,206,207,208}Pb$, ^{209}Bi reactions are consistently calculated and analyzed at incident proton energies below 250 MeV. The optical model, the intra-nuclear cascade model, direct reaction theories, the unified Hauser-Feshbach and exciton model which includes the improved Iwamoto-Harada model are used. Theoretically calculated results are compared with the existing experimental data. Good agreement is generally observed between the calculated results and the experimental data. Since the improved Iwamoto-Harada model has been included in the exciton model for the light composite particle emissions, the theoretical models provide the good description of the shapes and magnitude of the energy spectra and double differential cross section of emission deuteron, triton, helium and alpha. The evaluated data are given in the format of LA150 library. Therefore, these data can be effectively used in different practical applications.

R368 Proton inelastic cross-sections on 16O and 28Si

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A (p, p' gamma) experiment was performed at the Tandem accelerator of IFIN-HH (Bucharest) with the purpose of measuring the proton inelastic cross-sections on 16O and 28Si. The goal was to investigate to which extent the neutron cross-sections on these nuclei can be inferred from those obtained with charged particles. In doing so, we are trying to exploit the isospin symmetry by taking under consideration that the chosen targets are N=Z nuclei and, consequently, two mirror nuclei are formed in the (p,p') and (n,n') reactions. The experimental setup consisted of two HPGe detectors with 100% relative efficiency placed at 110 deg. and 150 deg. relatively to the direction of the incident proton beam. The incident protons, with energies ranging from 7 up to 17 MeV, were scattered on a thick quartz (SiO2) target. Also, a Faraday Cup was used to integrate the beam current, thus allowing an absolute determination of the gamma-production cross sections. We will shortly present the data analysis procedure, the experimental particularities and difficulties of the experiment and some preliminary results.

I369 Nuclear data for fusion technology - The European approach

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The European Fusion Programme aims at the realisation of fusion as energy source for the production of electricity by the year 2050. The Strategic Energy Technology (SET) Plan of the European Commission thus assumes the construction and operation of a Fusion Power Plant (FPP) which can provide electricity to the grid. Three major facilities are considered to be required to achieve this ambitious goal: (1) ITER, as a key physics and technology facility for the "next step", (2) a dedicated Elementary Neutron Source (ENS) for the material development, and (3) an early Demonstration Power Plant (DEMO) to enable a smooth extrapolation to FPP conditions. Accordingly the European Fusion Roadmap, implemented in the frame of the "Horizon 2020" programme, assumes that all know-how, required to start the construction of DEMO around 2030, can be acquired in time. A central element of this approach is the design of DEMO which is conducted in the a dedicated Power Plant Physics and Technology (PPPT) programme of the EUROfusion consortium.
This approach builds on the availability of qualified computational tools and nuclear data as pre-requisites for the nuclear design, optimization and performance evaluation of the key facilities, ITER, ENS and DEMO including safety, licensing, waste management and decommissioning issues. To satisfy the needs for high quality nuclear data, a Consortium on Nuclear Data Development and Analysis was formed which provides the relevant services on the generation, maintenance, and validation of relevant nuclear data evaluations and data files. The related activities include the development/extension of codes and software tools which are required for nuclear model calculations and sensitivity/uncertainty assessments. Supplementary experimental activities are conducted to provide the data which are required for the validation of the nuclear data in neutronics design and activation calculations.
The paper provides an overview of the related Nuclear Data Development (NDD) activities with focus on the recent achievements in the area of nuclear data evaluations, benchmarking and validation, nuclear model improvements, and uncertainty assessments.

R370 Scoping the material response landscape with automatic simulation tools – activation, transmutation, and primary damage functions

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The selection of materials for nuclear applications, such as for planned fusion research reactors and future fusion power plants, or for advanced next-generation fission systems, is a complex process with many factors to consider. Not only must a material withstand extreme mechanical and thermal conditions, but it must do this while being bombarded by high-energy neutrons that displace the constituent atoms and alter the properties of the material. Furthermore, some of the nuclear interactions cause the very nature of the atoms to change, via transmutation, with potential additional impacts on performance. As a final barrier (to material selection), these transmutations must not produce too many highly-active radioactive nuclides, because reactors must be approachable by personnel during maintenance operations and the cost of waste disposal from used components is a strong determining factor in both the political and commercial feasibility of nuclear reactors.
Whilst these activation, transmutation and damage responses can be calculated accurately for a given material in a detailed reactor design, there is often an additional need, at the material selection stage, to understand the general response of pure materials. Scoping calculations, across all pure elements, have been performed using the FISPACT-II [1] inventory simulator and SPECTRA-PKA [2] primary damage response evaluator, combined with the latest libraries of nuclear cross section libraries, for both fusion and fission neutron irradiation environments. An automated simulation infrastructure has been developed to run the necessary simulations, process the results, and to collate them into a handbook of nuclear responses for pure elements. This allows calculations to be readily repeated for multiple irradiation scenarios, and, more importantly, provides the platform to take advantage of the latest, advanced nuclear data libraries, which are more complete than their predecessors and are constantly being updated.
This paper presents typical results from the scoping calculations; discusses global trends in important responses, including gas production, post-irradiation activation, and dpa (displacements per atom) estimates; and considers the impact of selecting different nuclear data libraries (TENDL-2014, ENDF/B-VII.1, JEFF-3.2, JENDL-4.0) on the scoped responses.

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R371 Reliability of activation cross sections for estimation of shutdown dose rate in the ITER port cell and port interspace

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An accurate Shutdown Dose Rate (SDDR) prediction in ITER is essential to determine feasibility for manual maintenance activities. The reliability of the SDDR calculation strongly depends on the quality of the activation cross section data used.
This paper provides relevant information about the quality of available activation cross sections data for maintenance activities in ITER, specifically in the Port Cell (PC) and Port Interspace (PI) areas. For this purpose the EAF library (both 2007 and 2010 versions) has been explored, as it is typically used by the ITER community.
Taking into account both recent reports/papers about SDDR in ITER and own calculations, dominant radionuclides for SDDR, coming from the activation of relevant materials placed in ITER, are listed. In addition to these materials, some others that are being considered to be part of the bioshield, as L2N and barite concretes are also studied. Relevant production pathways for all major radionuclides are identified.
The quality of the EAF cross sections for the identified pathways is assessed following the procedure used in validating and testing the successive EAF versions. In addition to this, for those cross sections not validated, possible improvements in the TENDL library (2013, 2014 and 2015 versions) are assessed by comparing EAF and TENDL cross sections with available experimental data from EXFOR database.
Preliminary results point out that most of the activation cross sections involved in the problem are reliable and only a few need improvement, especially those related to the barite concrete. Finally, recommendations about the activation library to be used for the prediction of SDDR in ITER are provided.

R372 Double differential light charged particle emission cross sections and stopping power calculations for some structural fusion materials

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In fusion reactors, neutron induced radioactivity strongly depends on the irradiated material. So, a proper selection of structural materials will has been limited the radioactive inventory in a fusion reactor. First-wall and blanket components have high radioactivity concentration due to being the most flux-exposed structures. The main objective of fusion structural material research is the development and selection of materials for reactor components with good thermo-mechanical and physical properties, coupled with low-activation characteristics.
Double differential light charged particle emission cross section, which is a fundamental data to determine nuclear heating and material damages in structural fusion material research, for some elements target nuclei have been calculated by the TALYS 1.6 nuclear reaction code at 14-15 MeV neutron incident energy and compared with available experimental data in EXFOR library. Direct, compound and pre-equilibrium reaction contribution have been theoretically calculated and dominant contribution have been determined for each emission of proton, deuteron and alpha particle. Penetrating distance and stopping powers also have been calculated for the alphas, deuterons and protons using GEANT4 code and compared each other.

S373 Study of concrete activation with IFMIF-like neutron irradiation: status of EAF and TENDL neutron activation cross-sections

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The aim of this paper is to check the performance of EAF and TENDL libraries in the prediction of concrete activation under the neutron irradiation environment expected in IFMIF, an accelerator-based neutron source conceived for fusion materials testing. For this purpose activity and dose rate responses of 3 types of concrete (ITER-Bioshield kind, barite and magnetite concretes) have been studied. For these quantities, dominant nuclides and production pathways have been determined and, then, a qualitative analysis of the relevant activation cross sections has been performed by comparing with experimental data.
Concrete activation studies have been carried out with IFMIF-like neutron irradiation conditions using ACAB code and EAF and TENDL libraries. The cooling times assessed are related to safety and maintenance operations, specifically 1 hour, 1 day and 12 days.
Final conclusions are focused on the recommendations for the activation library to be used among those analyzed and cross-section data to be improved.

I374 Copper benchmark experiment for the testing of JEFF-3.2 nuclear data for fusion applications

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A neutronics benchmark experiment on a pure Copper block (dimensions 60x70x70 cm3), aimed at testing and validating the recent nuclear data libraries for fusion applications, was performed in the frame of the European Fusion Program at the 14-MeV ENEA Frascati Neutron Generator (FNG). Reaction rates, neutron flux spectra and doses were measured using different experimental techniques (e.g. activation foils techniques, thermoluminescent detectors and NE213 scintillator) to get the nuclear quantities of interest. The results were compared to the calculated quantities using fusion relevant nuclear data libraries. This paper reports on the analyses of the experiment carried-out using the MCNP5 Monte Carlo code and the European JEFF-3.2 nuclear cross-section data for neutron transport simulations and the IRDFF library for the calculation of reaction rates in the activation foils. The calculated (C) reaction rates in activation foils and neutron flux spectra were compared to the experimental quantities (E) and the C/E ratios with associated uncertainties were assessed. Large discrepancies were found for the reaction rates both in the high energy (up to 15%) and low energy range rates (up to 60%).
The analysis was complemented by sensitivity/uncertainty analyses using deterministic and Monte Carlo based approaches with the SUSD3D and MCSEN codes, respectively. The sensitivity/uncertainty analyses enabled to identify the cross sections and energy ranges which are mostly affecting the calculated responses. It is worth to note that the largest discrepancy among the C/E values was observed for the thermal (capture) reactions indicating severe deficiencies in the 63,65Cu capture and elastic cross sections at lower rather than at high energy. The results were further corroborated by the fact that deterministic and MC codes produced similar results.
The 14 MeV copper experiment and its analysis thus call for a revision of the JEFF-3.2 copper cross section and covariance data evaluation.

R375 natCu and natV cross-sections measured by quasimonoenergetic neutrons from p+7Li reaction in the energy range of 18-34 MeV

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^{nat}Cu and ^{nat}V samples were irradiated several times with quasi-monoenergetic neutrons from p+^{7}Li reaction in the energy range of 18-34 MeV. The activities of the samples were measured with the HPGe detector and the reaction rates were calculated. Time-of-flight measurements of the produced neutron spectra and the measurements of the residual ^{7}Be activity in the Li target were performed to improve the knowledge of the neutron spectra. The cross-sections were extracted using the SAND-II and STAYSL-PNNL codes with the reference cross-sections from the EAF-2010 database. The uncertainties of the final results are discussed.

R376 Sensitivity and uncertainty analysis for the tritium breeding ratio of a DEMO fusionreactor with a helium cooled pebble bed blanket

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The capability of a fusion reactor to breed enough tritium to reach self-sufficiency is described by the Tritium Breeding Ratio (TBR) which is estimated by means of Monte Carlo neutron transport calculations using codes like MCNP. These calculations utilize nuclear cross-section data which are associated with uncertainties. To propagate these uncertainties from the nuclear cross-section data to the final TBR uncertainty, sensitivity and uncertainty analysis is required. MCSEN, a patch to the MCNP code, employs such a method to the Monte Carlo transport technique. MCSEN has the capability to calculate the sensitivity of a specified nuclear response such as the TBR to multiple reaction cross-sections of an isotope in a single run. The sensitivity profiles provided in such a calculation and available covariance data are then used to calculate the TBR uncertainty with the Sandwich code.

For the Helium Cooled Pebble Bed (HCPB) concept, currently under development in the European Fusion programme as breeder blanket for DEMO, uncertainty analyses have already been performed for the tritium production in a mock-up of a single breeding blanket and a test blanket module designed for ITER. In this work, a TBR uncertainty assessment was performed for an entire fusion power plant of the European DEMO type.

To this end, a suitable 3D model of the DEMO reactor with HCPB blanket modules, as routinely used for blanket design calculations, was employed. The nuclear cross-section data were taken from the JEFF-3.2 data library. For the uncertainty analysis, the isotopes H-1, Li-6, Li-7, Be-9, O-16, Si-28, Si-29, Si-30, Cr-52, Fe-54, Fe-56, Ni-58, W-182, W-183, W-184 and W-186 were considered. The related covariance data were taken from JEFF-3.2 where available, and from FENDL-2.1 for Li-7, from EFF-3 for Be-9 and from JENDL-3.2 for O-16. For comparison purposes, covariance data from the TENDL-2014 library were used.

The analyses show an overall uncertainty of ±3.2% for the TBR when using JEFF-3.2 covariance data with the mentioned additions. The uncertainty is dominated by the uncertainties coming from the O-16, Li-6 and Li-7 cross-sections. When using TENDL-2014 covariance data, the uncertainty increases to ca. ±10%.

R377 On the synergy of nuclear data for fusion and model assumptions

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The basic role of the improvement of nuclear data for fusion has recently been pointed out with respect to the overall uncertainties on the measured yield of reaction-in-flight (RIF) neutrons with energies up to 30 MeV produced in warm, dense deuterium-tritium plasma [1]. While the ultimate aim has been the improved cross sections for the reactions with thresholds above 15 MeV in order to determine the RIF neutrons yield, a detailed analysis has been proved necessary for the quasimonoenergetic neutrons produced by the ^{2}H*(d,n)*^{3}He reaction at deuteron energies from 15 to 19 MeV. Beyond the usual neutron energy spread, the deuteron breakup (BU) has been proved significant at these energies and a related fractional contribution (FC) had to be carefully determined from neutron time-of-flight (NTOF) spectra. Finally, on the basis of the ^{90}Zr*(n,2n)*^{89}Zr monitor reaction cross-section evaluation with assumed uncertainties below 3.5% in the energy range studied, well-improved cross sections have been obtained for certain reactions but less confidence for the ^{94}Zr(n,α)^{91}Sr reaction data.

Several issues of this pioneering work [1] are considered in the present work, looking also for making use of their synergy within fusion physics. First, a BU empirical parametrization [2] is involved within the BU analysis of the NTOF spectrum. Second, the open questions underlined by an widespread study of the fast-neutron induced reaction on Zr isotopes [3], subsequent to the evaluation used formerly [1], are addressed in a consistent way (e.g., [4]). Third, a recent optical potential for α-particles [5] is used to understand the large discrepancy between the measured [1,3] and calculated [3] cross sections of the ^{94}Zr(n,α)^{91}Sr reaction. An improved physics modeling is thus leading to smaller uncertainties of the nuclear data for fusion while the RIF neutron spectra may also be used to support nuclear model assumptions.

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I378 Measurement and interpretation of nuclear structure data in heavy mass region

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Objective: The knowledge of high-spin level structures in nuclei are very crucial for the study of the single particle states in nuclei. The nuclei in the heavy mass region of A ~200 involves high-j proton and neutron orbitals near the proton and neutron Fermi levels. These orbitals have large shape driving effect and thereby, play important roles in the high-spin structure in nuclei and show interesting phenomena, like shape evolution, shape coexistence, doubly degenerate bands, magnetic rotational bands etc. Moreover, the involvement of high-j orbitals gives rise to many high-spin isomers in these nuclei.
We have performed several γ-ray spectroscopic measurements for the high spin states in the neutron deficient odd-A and odd-odd Tl (Z = 81) and Bi (Z = 83) isotopes in order to study the effect of the high-j $h_{9/2}$ and $i_{13/2}$ orbitals in nuclei around Z = 82 magic number. The proton-particle and neutron-hole configurations in these nuclei also provide important information on particle-hole interaction in these region.

Materials and Methods: The fusion evaporation reaction with light (α) and heavy-ion beams were used to populate the high spin states in $^{194\text{-}197}$Tl, ^{195,198}Bi and ^{197}Po nuclei using the K130 cyclotron at VECC, Kolkata and Pelletron-LINAC accelerators at TIFR, Mumbai and IUAC, New Delhi. The Indian National Gamma Array (INGA) with up to 19 clover HPGe detectors were used to detect the g-rays. For the study of high spin isomers and their decays, the gas filled Hybrid Recoil Analyser (HYRA) at IUAC, New Delhi was also used.
Results and Conclusions: Several new and interesting band structures were identified, the existing band structures have been extended in the above nuclei and a new high-spin isomer ($T_{1/2}$ = 1.6(1) ms) and its decays have been identified for the first time in ^{195}Bi. The systematic investigation of the high spin states and the isomers indicate a crucial phase change around neutron number N ≤ 112, which signifies the opening up of $\nu i_{13/2}$ orbital, for the nuclei around Z = 82. The results also show the relative importance of $\pi h_{9/2}$ and $\pi i_{13/2}$ orbitals on the high-spin states in these nuclei.

R379 Structure of single particle states in 75,77Cu

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Neutron-rich Cu nuclei with one proton outside the Z=28 shell and lying between N=40 and N=50 shell closures provide the experimental probe of the structure changes in ^{78}Ni mass region.
Previous studies indicated complicated level sequences in the neutron-rich $^{69–73}$Cu isotopes [1–6]. The low-lying $5/2^-$ and $7/2^-$ states were identified as of predominantly single-particle character based on $1f_{5/2}$ and $1f_{7/2}$ orbitals, respectively, while the lowest-lying $1/2^-$ state was found rather collective. Another type of excitation observed for the remaining low-lying $7/2^-$ states was explained as a proton-core coupling of $1f_{5/2}$ or $2p_{3/2}$ to the 2^+ state in corresponding $^{(68–72)}$Ni nuclei [3, 6].
Excited states in ^{75,77}Cu isotopes were populated in beta decay of ^{75,77}Ni nuclei (RIKEN, 2013). The results were compared with the shell model calculations. The absence of pure single-particle states in the range of around 2.5 MeV might indicate that such states appear in higher excitation energy (3 MeV) [7]. The identification of $\pi f_{7/2}$ particle-hole excitations in Cu isotopes will provide essential information on the evolution of size of Z=28 shell-gap.
A wide range of isotopes in the vicinity of ^{78}Ni, including ^{75,77}Cu isotopes, were produced in the first SEASTAR experiment performed at RIKEN in 2014. BigRIPS-ZeroDegree spectrometers were used to select and identify reaction products of interest populated at the secondary MINOS LH_2 reaction target [8] surrounded by DALI2 gamma-array consisted of 186 NaI detectors [9].
Recent results of the data analysis of ^{75,77}Cu isotopes from (p,2p) reactions will be presented.

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R380 Corrections of alpha- and proton-decay energies in implantation experiments

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Energies from alpha and proton decays yield information of capital importance for deriving mass values of exotic nuclides. Associated with the evaluation work for the 2016 AME, we present a method for correcting decay energies that takes into account stopping power and relativistic effects. Implantation of a decaying radioactive species in a solid state detector will give a light particle (e.g. proton
or alpha) and a recoiling ion. Both will lose their energies two ways: by excitation and ionization of electrons in the target (electronic process), or by collision with nuclei of the target atoms (nuclear process). The electronic process will produce a signal in the detector, while the nuclear process will not. Knowledge of both processes is important for implantation α-decay and p-decay experiments where the heavy recoil is detected at the same time. For alpha-decay spectroscopy, the experimentalist often makes the simple assumption that only the alpha energy is measured in the detector while in proton-decay experiments it is often assumed that both the proton and the heavy recoil are detected at the same time.
Neither of these statements is correct: protons and alphas of a few MeV do have almost 100% signal efficiency, but this is neither true for heavy species nor for low energies.
In this contribution, we present a concept for calibration and correction of these effects, using Lindhard's formula [1], which accurately predicts the energy deposition of heavy atomic projectiles in matter. In addition, a relativistic formula taking into account atomic effects [2] is derived to convert the particle kinetic energy into particle decay energy. Its comparison with non-relativistic treatment will be presented. The result shows that such a correction is indispensable for precision alpha-decay measurements aiming at uncertainties better than 0.1 keV.

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R381 Investigation of beta spectral shapes with a PIPS-Detector-Setup

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Several applications in modern nuclear physics, research and engineering are limited by a lack of precise knowledge in spectral shape data for beta-decays. Specifically the interest aims to study spectral data for forbidden decays with respectively long half-lives, which is one of the central activities of our group.
For the investigation of those rare beta-decays the group operates a setup of six PIPS detectors in a vacuum chamber built out of low-radioactivity materials. In the long term the setup will be used as low-background-detector for the investigation of rare beta-decays. In order to reduce the measuring-background a muon veto was installed.
The talk will describe the characterization of the setup in the energy-range from 20..1000 keV using conversion-electrons. A set of useful calibration-nuclides was established to determine energy calibration and efficiencies. First studies to explore the background of the setup and the effect of its reduction due to the muon will be presented. Finally first measurements of spectral shapes will be shown.

R382 Isomers close to the 170Dy valence maximum: first spectroscopy of 168,170Tb

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In-flight fission of a $^{238}U^{85+}$ primary beam of energy 345 MeV/nucleon on thick (2mm) beryllium target has been used to produce and study the decays of a range of neutron-rich nuclei around the valence maximum nucleus ^{170}Dy [1] at the RIBF Facility, RIKEN, Japan. The produced secondary fragments of interest were identified event-by-event using the BigRIPS separator with a decay spectroscopy set-up at the focal plane of the separator used to identify and correlate decays following both beta decay (in the milliseconds to seconds range) and isomeric decay in the nano-to-microsecond range. Discrete γ-ray lines emitted following decays from either metastable states or excited states populated following beta decay were identified using the 84 HPGe detectors of the EURICA spectrometer [2] which was complemented by 18 additional $LaBr_3$ fast-timing scintillation detectors from the FATIMA collaboration [3]. The fragments were implanted into the WAS3ABi position sensitive silicon active stopper which allowed pixelated correlations between implants and their subsequent beta-decay. This presentation will discuss the range of nuclei produced and identified in the experiment, with particular focus on previous unreported isomeric decays in the odd-odd nuclei ^{168,170}Tb. These data represent the first information on excited states in these nuclei, which are the most neutron-rich isotopes of terbium (Z=65) studied to date. Possible configurations for the observed isomeric states will be presented by comparison with Blocked BCS-Nilsson calculations for these axially symmetric, highly deformed nuclear systems which can give information on the proton and neutron orbits which reside close to the Fermi surface at the valence maximum.

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I383 The 2016 atomic mass evaluation and the mass tables

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The atomic mass gives access to the binding energy of the nuclides, it is therefore one of their most fundamental property : it plays an essential role in basic nuclear physics and astrophysics research and in many practical applications, such as nuclear energy and waste management.

The Atomic Mass Evaluation (AME) is the most reliable source for comprehensive information related to the atomic masses and binding energies. By evaluating all available experimental data worldwide, from nuclear reactions, radioactive decays and direct mass measurements and by using a weighted, least-squares method approach, it provides the best values for the atomic masses and their associated uncertainties.

Since the last AME publication in December 2012, the experimental knowledge of atomic masses has been continuously expanding along two main directions, including: measurements aimed at high-precision mass values and at the most exotic nuclei far from the stability line. It has also gained accuracy and/or precision. The next AME version is envisioned to be published at the end of 2016 where all experimental data appearing in the main nuclear physics journals by the end of May 2016 will be included.

R384 Multipolarity measurement of the main ground-state transition 2- to 1- in 210Bi

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The cold-neutron capture reaction on ^{209}Bi was used to investigate the low-lying structure of the ^{210}Bi nucleus. The experiment was performed at ILL Grenoble at the PF1B cold-neutron facility. The EXILL array, consisting of 8 EXOGAM clovers, 6 GASP detectors and two clovers from the ILL LOHENGRIN collaboration, was used for measuring coincidences between γ rays. The collected data were sorted offline into $\gamma\gamma$-coincidence matrix and $\gamma\gamma\gamma$- coincidence cube with a time window of 200 ns. As the neutron energy was very low (~5 meV) only the state at neutron binding energy in ^{210}Bi (at 4605.2(1) keV) was populated. This state decays by a great number of paths: 64 primary γ rays were identified, including 40 newly found branches. They feed the lower-lying states populating the

complex level structure: a total number of 70 discrete states were observed.

As the detectors of EXOGAM were placed in one ring, double $\gamma\gamma$-coincidence data could be sorted into three matrices corresponding to average angles between detectors of 0º, 45º and 90º. The analysis of γ-ray angular correlations provided information about transitions multipolarities, which allowed to confirm previously known values of spins as well as helped with new assignments. In particular, a very small mixing ratio was obtained for the main transition feeding the ground state, the 320-keV line, which confirmed its expected almost pure M1 multipolarity. The importance of this result is related to the application of Pb-Bi in Accelerator Driven Systems. The unknown multipolarity (pure M1, pure E2 or 50% M1 + 50% E2) of the 320-keV transition introduced rather large uncertainties in measurements of the capture cross section to the ground state in ^{210}Bi [1], β-decaying with $T_{1/2}$ = 5 d. On the other hand, the decay from the binding energy state feeds also the long lived ($T_{1/2}$ = 3.04 $\cdot 10^6$ y), α-emitting isomer at 271 keV. As Pb-Bi may be used as coolant or target material in Accelerator Driven Systems the values of neutron-capture cross sections to both these states are of particular interest, because this reaction will contribute significantly to the short and long-term radiotoxicity of the used material.

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R385 Gamma-decay in light nuclei. Halo isomers

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It has been shown that isobar-analog (IAS), double isobar-analog (DIAS), configuration (CS), and double configuration states (DCS) can simultaneously have *n-n*, *n-p*, and *p-p* halo components in their wave functions [1]. Both the Borromean and "tango" halo types can be observed for *n-p* configurations of atomic nuclei [2-4]. In atomic nucleus whose ground state does not exhibit halo structure, but the excited state may have one, the γ-transition from the excited state to the ground state can be essentially hindered, i.e. the formation of a specific type of isomers (halo isomers) becomes possible [2,3]. The radial factor r^{λ} for the electric and $r^{\lambda-1}$ for the magnetic multipole γ-transition operator of order λ may compensate the differences in the large-distance parts of halo and no halo wave functions. The most sensitive for detection of the γ-transition hindrance between halo-no halo states will be *M1* (or may be *E1* and *M2*) γ-transitions.
$B(M\lambda)$ and $B(E\lambda)$ for γ-transitions in $^{6-8}$Li, $^{8-10}$Be, ^{8,10,11}B, $^{10-14}$C, $^{13-17}$N, $^{15-17,19}$O, and ^{17}F are analyzed and systematics are presented. For *A*=6-17 nuclei the hindrance factor of *M1* γ-transitions is up to 10^4, of *E1* γ-transitions is up to $5\cdot10^4$, of *E2* γ-transitions is up to 10^2 for halo → no halo in comparison with halo → halo γ-transitions. On the contrary, observed halo → halo γ-transitions are enhanced. The IAS (3.56 MeV) in ^{6}Li has the Borromian *n-p* halo structure [2-6]. A large value of the reduced probability of *M1* γ-transition from IAS to the ground state is the evidence for the existence of "tango" *n-p* halo structure [2,3] in the ^{6}Li ground state.
The structure of the ground and excited states with different isospin quantum number in halo-like nuclei is discussed.

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R386 Study of isomers and their decays in 193,195Bi

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Objective: Presence of high-j proton ($h_{9/2}$, $i_{13/2}$) and neutron ($i_{13/2}$) orbitals near the Fermi level gives rise to high-spin isomers in Bi nuclei in A ~ 190 region. The half-life, excitation energy and decay properties of such isomers are crucial aspects in nuclear structure physics. The nuclear shape corresponding to these isomers depend on their configuration. Recently, the level scheme of ^{193}Bi has been extensively extended with several isomers but the information about the high-spin states in ^{195}Bi is very limited (only up to J = 29/2). This can be attributed to the presence of hitherto-unknown isomeric state at higher excitation energy.
Methods: In order to study the high spin isomer in ^{193,195}Bi, an experiment has been performed at the focal plane of Hybrid Recoil mass Analyser (HYRA) in gas filled mode at 15-UD Pelletron superconducting–LINAC facility at IUAC, New Delhi using the fusion evaporation reaction ^{30}Si (^{169}Tm, 6n/4n)^{193,195}Bi at 169/146 MeV of beam energies. The evaporation residues (ER) separated from the fission product and their decay gamma-rays have been detected using an MWPC, 3 Si-pad and clover HPGe detectors.
Results: An ER-gated E_1-ΔT matrix (ΔT = time difference between MWPC and clover) was formed and the E_1-gated ΔT spectrum was used to determine the half-life of the isomeric states. The half-lives of the known isomers in ^{193,195}Bi were well reproduced and a new high-spin isomer with $T_{1/2}$ = 1.6(1) μs has been identified in ^{195}Bi which is placed above the 750-ns isomer as the highest known level in this nucleus. Three new gamma-rays (238, 175 and 702 keV) have also been identified to decay from the new isomer and an excitation energy of 3336 keV with most-likely spin-parity as $31/2^-$ have been proposed. A configuration of a $i_{13/2}$-proton coupled to the 9^- state in ^{194}Pb core has been proposed for the new isomer in ^{195}Bi. The Total Rothian Surface calculations suggest an oblate shape with deformation β_2=0.12 for this configuration. The systematics of high spin isomers in neighboring nuclei and the effect of the high-j proton and neutron orbitals on the shape of these isomers will be discussed.

I387 Quasiparticle random phase approximation systematics of gamma-ray strength functions based on the Gogny finite range effective interaction

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Dipole excitations of nuclei are crucial since they play an important role in nuclear reaction modeling in connection with the photoabsorption and the radiative capture processes. We present here results for the gamma-ray strength function obtained in large-scale axially-symmetric deformed quasiparticle random phase approximations approach using the finite-range Gogny force, with a particular emphasis on the E1 mode.
The convergence with respect to the number of harmonic oscillator shells adopted and the cut-off introduced in the 2-quasi-particle (qp) excitation energy space is analyzed. The calculations performed with two parameters sets of the Gogny force are compared.
The microscopic nature of our self-consistent Hartree-Fock-Bogoliubov plus QRPA (HFB+QRPA) calculation has unfortunately to be broken, some phenomenological corrections being needed to take into account effects beyond the standard 2 qp QRPA excitations and the coupling between the single-particle and low-lying collective phonon degrees of freedom. The corresponding phenomenological parameters are adjusted on experimental photoabsorption data. In such a procedure, a rather satisfactory description of experimental data is obtained. To study the sensitivity of these phenomenological corrections on the extrapolation, both at low energies and towards exotic neutron-rich nuclei, three different prescriptions are considered. They are shown to lead to rather similar predictions of the $E1$ strength at low energies as well as for exotic neutron-rich nuclei. The Gogny-HFB+QRPA strength is finally applied to the calculation of radiative neutron capture cross sections and the predictions compared with those obtained with more traditional Lorentzian-type approaches.

R388 Microscopic calculations of radiative nuclear reaction characteristics for double-magic nuclei

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The microscopic approach in the nuclear theory accounts for specificity of each nucleus through its single-particle and collective (phonon) spectra. Therefore, it allows "some irregular changes" obtained in the global phenomenological models for nuclear reactions data [1] to be seen and checked. In order to check this statement we have calculated the following nuclear reaction characteristics for three double-magic nuclei, ^{56}Ni, ^{132}Sn and ^{208}Pb: 1) neutron capture cross sections, 2) corresponding neutron capture gamma-spectra, 3) average radiative widths of neutron resonances. For photon strength function (PSF), the selfconsistent version of the microscopic extended theory of finite Fermi systems (ETFFS) in the time blocking approximation (TBA) has been used in [2] (^{132}Sn) and [3] (^{208}Pb) and for the first time for ^{56}Ni. The approach includes phonon coupling (PC) effects in addition to the standard QRPA approach. The known Skyrme force SLy4 has been used. The calculations of characteristics of radiative nuclear reaction have been performed with the EMPIRE3.1 and TALYS nuclear reaction codes using our microscopic PSFs. Two nuclear level density (NLD) models have been used: the phenomenological so-called GSM [2] and microscopical combinatorial HFB model [4].
For all the considered characteristics, we found a significant disagreement between the results obtained with the GSM and HFB NLD models. For example, this disagreement for (n,γ) cross sections is about one order of magnitude practically in all the neutron energy interval up to 2 MeV and 10 MeV for the compound ^{132}Sn and ^{208}Pb, respectively. Unfortunately, the experimental data are very scarce for double-magic nuclei. However, for ^{208}Pb we found a very good agreement with systematics [5] for the Γ_γ values with HFB NLD and with the experimental data [5] for the HFB NLD average resonance spacing D_0, while for these two quantities the differences between values obtained with GSM and HFB NLD are of several orders of magnitude. The results confirm the necessity of using consistent microscopic approaches for calculations of radiative nuclear characteristics in double-magic nuclei.

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R389 Dipole strength functions from large scale shell model for light and medium-mass nuclei

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Gamma absorption and decay properties of atomic nuclei are of crucial importance in fundamental and applied nuclear physics research. They are indispensable for calculations of cross sections for a broad range of applications and the description of nucleosynthesis in explosive stellar environments.
In this paper, the calculations of dipole gamma strength functions are performed using the most advanced large scale shell model techniques, in several mass regions. The low energy enhancement of the M1 strength functions is observed, which is consistent with the previous works.
For the first time, also E1 dipole strength functions are evaluated in the same theoretical framework. We discuss these results in the case of Ti44-Ti45 nuclei, suggesting a different behavior of low energy part of M1 and E1 strengths.

R390 Improvements and testing practical expressions for photon strength functions of E1 gamma-transitions

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Photon (radiative, gamma-ray) strength functions (PSF) are important constituents of the compound nucleus model calculations of capture cross sections, γ-ray production spectra, isomeric state populations, and competition between gamma-ray and particle emission. The most important strength functions in these studies are related to the electric dipole (E1), magnetic dipole and electric quadrupole multipolarities.
The present contribution discusses the semiphenomenological approaches for descriptions of the PSF for the E1 transitions in hot nuclei. The PSF models [1,2] based on excitation of the isovector giant dipole resonance (GDR) are overviewed. New closed-form description of the E1 PSF is developed with allowance for response of the two nuclear states - low-energy state (LSE) and GDR. In spherical nuclei the LSE corresponds to the pigmy dipole resonance. Analytical expression for the nuclear response functions on E1 field is based on a model of two coupled damped-oscillators. The energy behaviour of this response function is compared with that for microscopic response functions.
All input parameters for PSF calculations are fixed by the use of the experimental data for gamma-decay and photoabsorption and their systematics are given.

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S391 Determination of the effects of nuclear level density parameters on photofission cross sections of 235U up to 20 MeV

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The level density models and level density parameters are two of important quantities for describing the properties of nuclei. Especially, the level density parameter has an important role as input in calculation of reaction cross sections. In this study, the cross sections on $^{235}U(\gamma,f)$ reaction were calculated for different level density models using the TALYS 1.6 code up to 20 MeV photon incident energies. First, it was determined the level density model that was the closest to the experimental data. Secondly, cross sections obtained for different level density parameters of this model were compared with experimental data from the EXFOR database. Thus it was determined the best level density parameter fit to experimental data.

S392 Axial asymmetry breaking in excited heavy nuclei as essential feature for the prediction of level densities

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In comparisons to various experimental data a considerable improvement of predictions for neutron capture resonance spacings by a modified back-shifted Fermi-gas model (BSFM) was found.
The modifications proposed by us closely follow the basic principles for a gas of weakly bound Fermions as given in text books of statistical physics:
(1) Phase transition at a temperature defined by theory,
(2) pairing condensation quasi-independent of nucleon number A, and
(3) proportionality of entropy to temperature (and thus the level density parameter) fixed by the Fermi energy.
For the application to finite nuclei we add:
(4) the back-shift energy is defined by liquid drop model shell correction and
(5) the projection onto fixed angular momentum allowing for a broken axial symmetry and thus the collective enhancement is considerably enlarged.
Nearly no parameter fitting is needed to arrive at a good reproduction of level density information obtained by various methods for a number of nuclei
in a wide range of nuclear mass number A and excitation energy Ex. To that end the modified BSFM is complemented by a constant temperature approximation below the phase transition point. The axial symmetry breaking (5), which is an evidently essential feature, will also be regarded with respect to other observables for heavy nuclei.

S393 Photon strength functions of 78Se from the two-step gamma cascades measurement

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Two-step gamma cascades (TSC) [1] following the radiative capture of thermal neutrons in ^{77}Se were measured at 15 MW light-water research reactor at Řež near Prague. Along with the description of the sum-coincidence TSC technique which uses two Ge detectors for detection of emitted gamma rays, results on photon strength functions (PSFs) and level density (LD) of ^{78}Se will be presented. The results were obtained by comparing experimental spectra with outcomes of simulations obtained under different assumptions about LD and PSFs using the DICEBOX algorithm [2] . The important advantage of DICEBOX algorithm is that it allows correct treatment of fluctuations of intensities of individual gamma ray transitions (Porter-Thomas fluctuations) which are expected at higher excitation energies. During the presentation of results, the main attention will be paid to possible manifestation of the pygmy resonance - observed recently in this nucleus in nuclear resonance fluorescence measurement [3] - in (n,gamma) reaction. In addition, limitations of applicability of statistical approach due to relatively low LD in this nucleus will be thoroughly discussed.

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I394 E1 and M1 strength functions at low energy

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We present photon-scattering experiments using bremsstrahlung at the gELBE facility of Helmholtz-Zentrum Dresden-Rossendorf (HZDR) and using quasi-monoenergetic, polarized gamma beams at the HIgS facility of the Triangle Universities Nuclear Laboratory (TUNL) in Durham. To deduce the photoabsorption cross sections at high excitation energy and high level density, unresolved strength in the quasicontinuum of nuclear states has been taken into account. In the analysis of the spectra measured by using bremsstrahlung at gELBE, we perform simulations of statistical gamma-ray cascades using the code gDEX to estimate intensities of inelastic transitions to low-lying excited states [1]. Simulated average branching ratios are compared with model-independent branching ratios obtained from spectra measured by using monoenergetic gamma beams at HIgS [1,2].
E1 strength in the energy region of the pygmy dipole resonance (PDR) is discussed in nuclei around mass 80 [3] and in xenon isotopes [4]. M1 strength in the region of the spin-flip resonance is also considered for xenon isotopes [2]. The dipole strength function of 74Ge [5] is compared with the one deduced from experiments in Oslo [6]. The low-energy upbend seen in the Oslo data is interpreted as M1 strength on the basis of calculations as described in Ref. [7].

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R395 Photoneutron reaction cross sections from various experiments - analysis and evaluation using physical criteria of data reliability

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Photonuclear reactions cross sections important for many fields of science and technology and data files (EXFOR, RIPL, ENDF, etc.) supported by the IAEA were obtained in various experiments primarily using quasimonoenergetic annihilation photons [1] and bremsstrahlung [2]. There are well–known systematic discrepancies between the results, first of all cross sections of partial reactions (g, 1n), (g, 2n), (g, 3n) + ... That was a reason for generating the IAEA Photonuclear Data Library [3]. For analysis of data reliability the objective physical criteria were proposed – ratios Fi(g, in) = sigma(g, in)/sigma(g, Sn), where (g, Sn) = (g, 1n) + 2(g, 2n) + 3(g, 3n) + ... is photoneutron yield reaction. Follow definitions Fi could not have values higher than 1.00, 0.50, 0.33, ..., correspondingly for i = 1, 2, 3, ….. Higher values mean definite incorrectness of neutron multiplicity sorting and therefore non–reliability of data. Systematic analysis of experimental data (for example, [4, 5]) revealed that for many nuclei partial photoneutron reaction cross sections as a rule are not reliable because of large systematic uncertainties of the method for determination of neutron multiplicity. The experimentally–theoretical method was proposed [4, 5] for evaluation of reaction cross sections satisfied physical data reliability criteria. It is based on using only (g, Sn) reaction experimental data in combination with the results of calculations in the frame of well–tested combined model [6] of photonuclear reactions: sigma-eval(g, in) = Ftheori(g, in) x σ-exp(g, Sn). Evaluated partial and total reactions cross sections for nuclei 63,65Cu, 80Se, 90–94Zr, 115In, 112–124Sn, 133Cs, 138Ba, 159Tb, 165Ho, 181Ta, 186–192Os, 181W, 197Au, 207,208Pb, 209Bi satisfy proposed criteria and in many cases differ noticeably from experimental data and data evaluated before [3]. Therefore it became evident that IAEA Library needs to be revised and updated. Correspondent researches are partially supported by the Russia RFBR project 13–02–00124 and will be supported by the upcoming IAEA CRP F41032. 1. S. S. Dietrich et al., Atom. Data and Nucl. Data Tables, 38, 199 (1988). 2. A. V. Varlamov et al., INDC(NDS)–394, IAEA, Austria, Vienna, 1999. 3. IAEA CRP TECDOC–1178, 2000. 4. B. S. Ishkhanov et al., EPJ Web of Conferences, 38, 12003 (2012). 5. V. V. Varlamov et al., Eur. Phys. J., A 50, 114 (2014). 6. B. S. Ishkhanov et al., Phys. Atom. Nucl., 71, 493 (2008).

R396 Gamma strength functions measurements at the Oslo Cyclotron

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The nuclear physics group in Oslo has developed a unique technique to extract simultaneously the level density and γ-strength function from primary γ-ray spectra [1]. These are important input parameters in reaction cross-section calculations, used in simulations of nuclear reactors and in astrophysics, in large network calculation of formation of heavy elements. An unexpected low energy enhancement of the γ-strength function has been observed for several nuclei measured at the Oslo Cyclotron [2-4]. Recently, the enhancement has been proven to be of dipole nature for 56Fe [5]. In 2013 appeared the first two theory papers on this enhancement, one explaining it as electric (E1) and the other magnetic (M1) character of the low energy gamma-rays, but we have still to measure the electromagnetic character experimentally. If it is also present in very neutron rich nuclei. the increased probability to decay by low-energy gamma rays can have a huge effect on the (n,γ) reaction rates. Therefor we are developing the Oslo method to study exotic neutron rich nuclei. As a first step in testing the Oslo method for inverse kinematics, we ran an experiment using stable 86Kr beam on a deuterated target at iThemba LABS. This is a preparation for later experiments with exotic beams at ISOLDE. Preliminary result from this experiment will be presented together with other recent results from experiments in Oslo.
I will also give an update on OSCAR (Oslo Scintillator Array), a new gamma-detector array we are building in Oslo, which will consist of 30 large volume LaBr3 detectors. OSCAR will open up possibilities not just for better, but also for new types of experiments in Oslo.

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R397 Statistical gamma-ray decay studies at iThemba LABS

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An incredible wealth of information can be obtained from investigations of the low-energy tail of the Giant Electric Dipole Resonance. The Radiative Strength Function (RSF), which represents the ability of nuclear matter to absorb and emit photons, is one of the quantities that is used successfully to extract resonance features in the region of the quasi-continuum. The RSF is one of the input parameters for calculations of nuclear cross sections and reaction rates relevant to astrophysical processes which are invoked to explain the origin of elements heavier than iron.

Significant experimental effort to study the gamma-ray decay from the region of high-level density is conducted at iThemba LABS, where high-resolution gamma-ray detector arrays are used in conjunction with silicon particle-telescopes or the K600 magnetic spectrometer.
In this talk I will present an overview of these experimental efforts and put our work into the context of the IAEA Coordinated Research Project "Updating the Photonuclear Data Library and Generating a Reference Database for Photon Strength Functions". In particular I will focus on results from two recent projects:
1) The ^{74}Ge(α,α'γ) reaction was used to investigate the Pygmy Dipole Resonance and these results were compared to (γ,γ') data, indicating that the dipole states adhere to the scenario of the splitting into two separated parts [1].
2) Data from the ^{95}Mo(d,p) reaction was used to develop a novel method for the determination of spins for low-lying discrete levels which utilizes the statistical gamma-ray decay in the vicinity of the neutron separation energy [2].

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I398 Nuclear model developments in FLUKA for present and future applications

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The FLUKA code is used all around the world for challenging applications spanning a very wide range of energies, projectiles and targets. In many cases studies carried out with the code are at heart of the design of new projects or experiment in domains where little or no data are available, adding particular emphasis on predictive power. In particular the high energy beams made recently available at the CERN LHC (6.5 + 6.5 TeV) and the even higher energy ones (50 + 50 TeV) envisaged for the future FCC project currently under study required a careful analysis and improvement of the high energy models embedded into FLUKA in order to make physics driven extrapolations into uncharted territory.
At the opposite end of the energy range, the widespread use of FLUKA in hadrontherapy research studies and clinical planning systems demands extreme accuracy, with predictions on 3D dose distributions in patient expected to be accurate within a couple of percent, and reliable information about fragment composition and secondary radiations required for biological effectiveness assessments and online monitoring respectively.
In both cases little or no data are available and the onus is on the development of accurate atomic and nuclear models in order to fulfill the tasks.
The talk will present the latest developments and addition to the FLUKA code models suite, including examples and benchmarking.

R399 Update on FLUKA prompt-gamma emission and residual activity calculations Schoofs P., on behalf of the FLUKA Collaboration EN, CERN, Geneva, Switzerland

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The Monte Carlo code FLUKA provides a detailed description of particle interaction with matter, radiation transport and particle decay. In FLUKA, nuclear properties such as masses, level structure and decay modes are based on information provided in the Evaluated Nuclear Structure Data File (ENSDF) [1] and the Reference Input Parameter Library (RIPL) made available by IAEA [2]. A modernization of the algorithm used to convert these databases into FLUKA-readable objects, combined with updates of these databases themselves, has led to an increase of a factor 2 in the amount of considered metastable states. This process has been complemented by the implementation of further sanity checks to ensure proper use of data of the highest standard. The impact such modifications have on the code is highlighted in this paper, in the framework of prompt- production for various proton and ion beams. Examples of residual activity calculations will also be reported.

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R400 Influence of secondary pions on neutron and prompt photon production in spallation neutron sources

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In a recent paper on the benchmarking of GEANT4 simulations of the n_TOF spallation target [1], whose results will also be the subject of a presentation at this Conference [2], it was shown that different intra-nuclear cascade models implemented in the code lead to sensibly different neutron production. In particular, large differences are observed between INCL++, which overestimate the measured neutron flux in the first experimental area of n_TOF by 20%, and the BERTINI model, which predicts a neutron flux more than 70% higher than measured. The results using the Binary Intra-Nuclear Cascade Model (BIC) are intermediate between the other two. In the same work, it was shown that those models predicting a higher neutron flux predict a lower flux of prompt γ-rays (i.e. emitted within a few nanoseconds from the start of the spallation reactions). This observation indicated a non-negligible role of secondary pions in the neutron and γ-ray production in spallation neutron sources, and triggered a further investigation of the subject.
In this talk, we present a thorough analysis of thin- and thick-target pion production in spallation reactions induced by high-energy protons. A comparison is performed between the predictions of different models, with particular emphasis on the differences between the old INCL version and the new multipion extension. The predictions of the various models are compared with the data on double-differential pion production cross section from the HARP collaboration [3]. It will be shown that while in thin-target interactions all pions play an important role in determining neutron and γ-ray production, in large volume spallation targets a crucial role is played only by the π^0, that divert part of the energy available in the reaction from the hadronic cascade to an electromagnetic one, so leading to an anti-correlation between neutron and prompt γ-ray production, as observed in the GEANT4 simulations of the n_TOF spallation target. The results here shown call for new data on pion production in high-energy proton-induced reaction and for further refinement in pion production modeling in intra-nuclear cascade codes.

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R401 BetaShape: A new code for improved analytical calculations of beta spectra

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Beta emission properties are crucial features when evaluating the decay schemes of radionuclides. Within the international collaboration of the Decay Data Evaluation Project (DDEP), a more precise knowledge of beta spectral shapes is sought by our users, especially in the field of radionuclide metrology. Thus the Laboratoire National Henri Becquerel (LNE-LNHB) has developed a computer code, BetaShape, dedicated to the calculation of beta spectra. To ensure fast computation times and ease-of-use, improved analytical models were preferred against more realistic numerical calculations, already described elsewhere [1]. In addition, the neutrino spectrum that corresponds to the beta spectrum is also calculated.
The calculations are performed using the Behrens and Bühring formalism [2]. Allowed and forbidden unique transitions are calculated explicitly and no limitation exists on the transition order, while forbidden non-unique transitions are determined using the approximation. The Fermi function and the parameters, involved in the definition of the theoretical shape factor, are determined from the Coulomb amplitudes of the relativistic electron wave functions. These wave functions are calculated for the Coulomb potential of a uniformly charged sphere, which means that the finite nuclear size effect is intrinsically accounted for. As no analytical solution exists for such a potential, Dirac equations are solved numerically according to "the fast but complicated method" from Behrens and Bühring [2]. A screening correction adapted from Bühring [4] was also implemented, as it exhibits no breakdown at low energy and is theoretically more refined compared with the usual Rose screening correction. The BetaShape code also includes a database of experimental shape factors, described and compared with improved calculations in [3].
Following the interest expressed by the IAEA Nuclear Data Section (NDS) in disseminating this code within the international network of Nuclear Structure and Decay Data Evaluators (NSDD), the calculation of multiple beta transitions from the decay of a specific radionuclide, using input from an ENSDF file, is being developed. The total beta and neutrino spectra are built by normalizing each single spectrum by its branching ratio. The calculation of log *ft* values, and the propagation of uncertainties from the input parameters, have also been implemented.

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R402 Role of the direct processes in deuteron interactions with structural materials

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At present, increased deuteron-data needs follow the demands of on-going strategic research programs (ITER, IFMIF, SPIRAL2-NFS) that involve deuteron beams, while the corresponding experimental and evaluated data are less extensive and accurate than for neutrons. Moreover, the analysis of low-energy deuteron reactions in terms of usual reaction models is challenging due to the deuteron breakup (BU) as a result of its weak binding energy. Thus, the BU leakage of the initial deuteron flux reduces the total-reaction cross section that is shared among different outgoing channels. At the same time, unlike the elastic breakup (EB) in which the target nucleus stays in its ground state, a subsequent interaction between one of the deuteron BU nucleons and the target nucleus, which represents an inelastic BU or breakup fusion (BF) process, may finally lead through a secondary compound nucleus (CN) to enhancement of various reaction channels.
There are currently many efforts to improve the description of deuteron reactions (e.g., [1–3]) also due to the use of *(d,pf)* surrogate reactions for neutron capture *(n,γ)* and induced fission *(n,f)* studies. Their common two-step approach endorses the BU and direct reactions (DR) phenomenological account of all available activation data for several structural materials ([4] and Refs. therein) and including fission competition [5]. However, recent studies [6] inferred that numerical calculations for deuteron reactions are beyond current capabilities. Conversely, the consistent account of the deuteron BU, DR, and CN mechanisms, following the explicit consideration of the former two, has recently been proved [7] and forms the object of this work for nuclei from ^{27}Al to ^{93}Nb.

[1] S. Nakayama *et al.*, Energy Proc. **71**, 219 (2015).; [2] J. Lei and A.M. Moro, Phys. Rev. C **92**, 044616 (2015); *ibid.* **92**, 061602(R) (2015).; [3] G. Potel *et al.*, Phys. Rev. C **92**, 034611 (2015).; [4] M. Avrigeanu *et al.*, Phys. Rev. C **89**, 044613 (2014). ; [5] M. Avrigeanu, V. Avrigeanu, and A. J. Koning, Phys. Rev. C **85**, 034603 (2012). ; [6] A.P.D. Ramirez *et al.*, Phys. Rev. C **88**, 064324 (2013); *ibid.* **92**, 014303 (2015).; [7] M. Avrigeanu and V. Avrigeanu, Phys. Rev. C **92**, 021601(R) (2015).

S403 Calculation of pre-equilibrium effects in neutron-induced cross section on 65Cu

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Copper is one of the constituents of alloys for structural components and a dosimetry material. In this study, we calculated the proton emission spectra and the excitation function produced by (n, xp) and (n, p) reactions respectively by using the Exciton model predictions combined with the Kalbach angular distribution systematics and the Hybrid Monte-Carlo Simulation (HMS). The sensitivity studies on the input parameters from optical model, level density, spin cut-off parameter and mean free path have been investigated for our calculation with the code EMPIRE and the code TALYS. The proton emission spectra and the excitation function for ^{65}Cu nucleus were discussed and found in good agreement with the available experimental data.

I404 Generalized Reich-Moore R-matrix approximation

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A conventional Reich-Moore approximation (RMA) of *R*-matrix is generalized into a manifestly unitary form by introducing a set of resonant capture channels that are treated explicitly in a generalized reduced *R*-matrix. A dramatic reduction of channel space witnessed in conventional RMA, from $N_c \times N_c$ full R-matrix to $N_p \times N_p$ reduced *R*-matrix, where $N_c = N_p + N_\gamma$, N_p and N_γ denoting the number of particle and *g*-ray channels, respectively, is due to $N_p << N_\gamma$.
A corresponding reduction of channel space in generalized RMA is from $N_c \times N_c$ full *R*-matrix to $N_{c'} \times N_{c'}$, where $N_{c'} = N_p + N_\lambda$ and N_λ is the number of *R*-matrix levels. This reduction, although not as dramatic as in the conventional RMA, could nonetheless be significant for medium and heavy nuclides where $N_\lambda << N_\gamma$. The resonant capture channels introduced by generalized RMA are a consequence of retaining level-level interference via capture channels neglected in conventional RMA. It is shown that the expression for total capture cross section in generalized RMA is formally equal to that of the full $N_c \times N_c$ *R*-matrix. This suggests that generalized RMA could yield improved nuclear data evaluations in the resolved resonance range. However, this would come at a cost of introducing $N_\lambda (N_\lambda - 1)/2$ resonant capture width parameters.
It is shown that manifest unitarity of generalized RMA may provide a formal basis for a method advocated by Froehner and implemented in a nuclear data evaluation code SAMMY for restoring unitarity of conventional RMA. A welcome byproduct of generalized RMA is that its capture widths are exactly convertible into alternative *R*-matrix parameters via Brune tranform. Application of idealized statistical methods to generalized RMA shows that variance among RMA capture widths could be used to estimate variance among off-diagonal elements neglected in conventional RMA. Finally, it is shown that significant departure of capture widths distribution from an idealized one may indicate presence of underlying doorway states.

R405 Status of the R-matrix code AMUR toward a consistent cross-sections evaluation and covariance analysis for the light nuclei

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The cross-sections on the light-nuclei are essential for the nuclear science and engineering. The cross-sections are also drawing attention for the ion-beam analysis, the astrophysics and the medical applications. However, there still exist inconsistencies between the measured and evaluated data, which could bring a large uncertainty in the practical applications. The R-matrix formalism is rigorous and straightforward to the quantum mechanics, in which the S-matrix is deduced from the measured cross-sections in the resonance energy region. Furthermore, physical constraint from the theory is known as a big tool to understand the differences among experimental data.

AMUR is a multi-level and multi-channel R-matrix code which is being in progress toward a consistent cross-sections evaluation for the light nuclei. We present the status of the code with new features on the theoretical calculation and the correction for the measurements. Some example evaluations are also presented for the p+^{7}Li reaction. Especially, we focus on the covariance analysis on the resonance parameters and the cross-sections. This is relevant not only to the estimation of the cross-sections uncertainty but also to visualizing natures in the resonant reactions.

R406 Development of a code system DEURACS for theoretical analysis and prediction of deuteron-induced reactions

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Recently, intensive neutron sources using deuteron accelerator have been proposed for various applications. In these facilities, the (*d*,*xn*) reactions on light elements (Li, Be, C, etc.) are considered as promising reactions to generate intensive neutron beams. Deuteron accelerator components consist of not only neutron converter materials but also various structure materials including Fe, Cr, Ni, etc. Thus, accurate and comprehensive deuteron nuclear data library over wide ranges of target mass number and incident energy are indispensable for the design of deuteron accelerator neutron sources. Since experimental data of deuteron-induced reactions are not necessarily enough, theoretical model calculation plays an important role in nuclear data evaluation.

Thus, we have developed an integrated code system dedicated for analysis and prediction of deuteron-induced reactions, which is called DEUteron-induced Reaction Analysis Code System (DEURACS). In the DEURACS, some calculation codes are integrated. Elastic breakup and stripping reactions to continuum are calculated using the codes based on the Continuum-Discretized Coupled-Channels (CDCC) theory and the Glauber model, respectively. In addition, the DWUCK4, which is the calculation code based on a conventional zero-range distorted wave Born approximation (DWBA) is used to calculate stripping reaction to bound states in the residual nuclei. Statistical decay components from compound nuclei are calculated using the Hauser-Feshbach and exciton models implemented in the CCONE code, which was successfully applied to neutron nuclear data evaluation for JENDL-4.0. Finally, neutron emission from the low-lying states of light nuclei is treated by the sequential decay model.

Calculations using the DEURACS are compared with available experimental data up to 100 MeV such as double-differential cross sections (DDXs) for light charged particle emission, double-differential thick target neutron yields (TTNYs), and deuteron activation cross sections. Validation of the present modelling for deuteron-induced reactions is discussed through comparison with the experimental data.

R407 Multi-criteria comparative evaluation of spallation reaction models

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In the last decade, high energy nuclear reactions have attracted increasing interest which is due to scientific problems and numerous applications, such as: creation of high-energy neutron sources, production of medical radioisotopes, radiation protection of space vehicles and accelerators.
Solving these problems requires a large amount of nuclear data for a wide range of nuclides and energies up to several tens of GeV. To obtain all data experimentally is not possible; therefore it is necessary to develop analytical methods the accuracy of which should be verified by measurements performed under certain conditions.
There is a growing number of models and programs designed to simulate nuclear reactions in different energy ranges and mass numbers as well as criteria and algorithms to verify the adequacy of simulated nuclear reactions to full-scale experimental data. It should be noted that currently there is no universally accepted theoretical concepts and models that could satisfactorily explain the entire spectrum of the considered nuclear reactions.
An evaluation of the predictive ability of calculation tools is based on the goodness-of-fit test. Due to lack of consensus among experts in the subject area on goodness measures and assessment procedures, the evaluation results generally vary enormously. Among other things, uncertainties of different nature have a significant impact on data evaluations.
This paper presents an alternative approach to evaluating the predictive ability of models based on the widely used, proven methods for discrete decision analysis (MAVT, AHP, TOPSIS, PROMETHEE, MAUT) and the results of such assessments for modern spallation reaction models (Bertini/Dresner, Bertini/ABLA, ISABEL/Dresner, ISABEL/ABLA, INCL4/Dresner, INCL4/ABLA, CEM2k, CASCADE, CASCADE/ASF, CASCADEX-1.2) in the presence of interaction of high-energy protons with ^{nat}Pb, ^{59}Co and ^{184}W.
The study has shown that if the multi-criteria decision analysis methods are applied to evaluating the predictive ability of spallation reaction models, despite some differences in model ranking, the results obtained by using different methods turn out to give good fit. A multi-criteria approach to the comparative evaluation of high-energy nuclear reaction models makes it possible to more finely differentiate various models with due account for experts' opinions, which provides an additional contribution to both the understanding of nuclear reaction mechanisms and preparation of a reliable nuclear data set.
The report demonstrates that taking into account the sensitivity analysis results, an additional alternative analysis using experts' judgments and the whole set of graphical and attributive information, the best models may be selected. Also the report gives recommendations on the use of multi-criteria decision analysis methods in order to prepare activation nuclear data.

I408 Experimental fission study using multi-nucleon transfer reactions

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The objective of this work is to extend fission data for actinide nuclei not investigated so far in order to understand the fission mechanism, especially for neutron-rich nuclei. Multi-nucleon transfer reactions were used to populate the compound nuclei which cannot be accessed by particle capture or fusion reactions. The experiment was carried out at the tandem facility of Japan Atomic Energy Agency. In the multi-nucleon transfer reactions using ^{18}O beam, a wide variety of nuclei around a target nucleus was produced. By identifying transfer channels, fission data of nuclei more than fifteen compound nuclei were generated in one experiment. Another feature of transfer reaction is that the excitation energies of a compound nucleus can be populated continuously from the ground state up to several tens MeV, allowing us to study the excitation energy dependence of fission properties. From the excitation function of fission probabilities, fission-barrier heights of neutron-rich actinide nuclei can be obtained. Experiments were carried out in the reactions of ^{18}O + ^{238}U, ^{232}Th, ^{248}Cm, ^{237}Np. The obtained fission fragment mass distributions were compared with a model calculation based on a fluctuation dissipation model. The data were reproduced with a shell damping energy of 20 MeV. In the experiment, fission fragment angular distributions relative to the direction of recoiled nucleus were also obtained. The data showed the increasing trend of spin of compound nuclei with transferred number of nucleons. We also started a campaign to measure the prompt neutrons in fission and their energy spectra, and the preliminary data will be discussed.

R409 Fission product yield measurements using mono-energetic photon beams

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Measurements of the fission products yields (FPY) are an important source of information on the fission process. During the past couple of years, a TUNL-LANL-LLNL collaboration has provided data on the FPYs from mono-energetic neutron-induced fission on ^{235}U, ^{238}U, and ^{239}Pu [1].
In an effort to understand and compare the effect of the incoming probe on the FPYs distribution, we have carried out, mono-energetic photon-induced fission on ^{235}U, ^{238}U, and ^{239}Pu. Mono-energetic photon-beams of E_γ = 13.0 MeV were provided by the HIγS facility, the world's most intense γ-ray source. In order to determine the total number of fission events, a dual-fission chamber was used during the irradiation of the actinides samples. These samples were counted at a low-background γ-ray counting facility using high efficient HPGe detectors over a period of 10 weeks. Results of the first mono-energetic photon-induced FPY measurements on ^{235}U, ^{238}U, and ^{239}Pu will be presented. These results will be compared with the neutron-induced FPY data [1].

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R410 Energy dependence of fission product yields for 235U,238U and 239Pu with monoenergetic neutrons between thermal and 14.8 MeV

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Under a joint collaboration between TUNL-LANL-LLNL, a set of absolute fission product yield measurements has been performed. The energy dependence of a number of cumulative fission product yields (FPY) have been measured using quasi-mono-energetic neutron beams for three actinide targets, ^{235}U, ^{238}U and ^{239}Pu, between 0.5 and 14.8 MeV. The FPYs were measured by a combination of fission counting using specially designed dual-fission chambers and γ-ray counting. Each dual-fission chamber is a back-to-back ionization chamber encasing an activation target in the center with thin deposits of the same target isotope in each chamber. This method allows for the direct measurement of the total number of fissions in the activation target with no reference to the fission cross-section, thus reducing uncertainties. γ-ray counting of the activation target was performed on well-shielded HPGe detectors over a period of two months post irradiation to properly identify fission products. Reported are absolute cumulative fission product yields for incident neutron energies of 0.5, 1.37, 2.4, 3.6, 4.6, 5.5, 7.5, 8.9 and 14.8 MeV. Preliminary results from thermal irradiations at the MIT research reactor will also be presented and compared to present data and evaluations. This work was performed under the auspices of the U.S. Department of Energy by Los Alamos National Security, LLC under contract DE-AC52-06NA25396, Lawrence Livermore National Laboratory under contract DE-AC52-07NA27344 and by Duke University and Triangle Universities Nuclear Laboratory through NNSA Stewardship Science Academic Alliance grant No. DE-FG52-09NA29465, DE-FG52-09NA29448 and Office of Nuclear Physics Grant No. DE-FG02-97ER41033.

R411 Fission fragment angular distributions in neutron-induced fission of U-235 measured with a time projection chamber

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The nuclear applications community heavily relies on simulations and modeling, and therefore on available data and their uncertainties. Fission fragment angular distributions in neutron-induced fission can provide insights into the quantum mechanical state of the transition nucleus at the saddle point, an important nuclear data quantity that can be used for fission theory developments. In addition, fragment emission anisotropies are valuable for precision cross section ratio measurements, since the distributions typically are different for the two isotopes used in the ratio. Available angular data is sparse, especially at neutron energies above 5 MeV. The Neutron Induced Fission Fragment Tracking Experiment (NIFFTE) collaboration employs a fission time projection chamber (fissionTPC) to measure fundamental nuclear data with unprecedented precision. The novel instrument enables complete three-dimensional tracking of charged particles providing a direct measurement of angular distributions and emission anisotropies of fission fragments in neutron-induced fission. Analysis of in-beam data collected at the Los Alamos Neutron Science Center provides angular distributions for ^{235}U(n,f) as a function of incident neutron energy from 160 keV to 230 MeV. The anisotropy result delivers new insights into the changes in anisotropy between 1 and 20 MeV. These changes seem to track the fission cross section closely in that energy range, consistent with theoretical considerations within the statistical model of nuclear fission. The presented measurement result will not only stimulate further fission theory development but also confirms the fissionTPC's suitability to investigate fundamental properties of nuclear fission.

S412 Comparison between absolute and relative neutron-induced fission cross section measurements of 237Np and 238U at NPL and IRMM

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In recent years several studies have highlighted the importance of improved cross section values for improved modelling of Generation-IV nuclear power plants. Primary standard experiments on fission cross sections are generally performed relative to ^{235}U(n,f). At fast neutron energies fission threshold isotopes (i.e. ^{238}U, ^{237}Np) might be more suitable for benchmarking. However, even though the ^{238}U is considered a secondary standard above 2 MeV the related uncertainties are not negligible. Different libraries (i.e. ENDF/B-VI.1 and JEFF-3.2) show discrepancies for ^{238}U(n,f) of 7% in the range of 1.5 MeV < E_n < 5 MeV and, for ^{237}Np(n,f) recent experiments [1] measured a higher cross section in the fast energy region.
To study the ^{237}Np(n,f) and ^{238}U(n,f) cross sections in a comprehensive manner, two experiments were performed at two different Van de Graaff (VDG) facilities: IRMM and NPL. The experiment at IRMM was supported by the EUFRAT project, and the one at NPL by the CHANDA project. The twin Frisch-grid ionization chamber and the samples used were common to both experiments. The samples, produced at IRMM, were placed back-to-back for a relative measurement of these cross sections. The two samples were also benchmarked using ^{235}U(n,f). At NPL, an absolute measurement was performed using a well-characterized long counter to measure the fluence [2]. The signals from each electrode were digitized for offline analysis. Another difference at NPL was the neutron-producing target cooling. At IRMM water was used, at NPL it was air cooled. The later method allows better neutron energy determination.
Analysis of both experiments is in progress. It is hoped to solve the fission cross sections issues. The results aim to provide an overview of different techniques to deliver neutrons and measure the neutron fluence, and provide guidelines for improved cross section measurements at VDG facilities.

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S413 Neutron-induced fission cross section of 242Pu from 15 MeV to 20 MeV

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Accurate nuclear-data needs in the fast-neutron-energy region have been recently addressed for the development of next generation nuclear power plants (GEN-IV) [1]. Of particular interest is the ^{242}Pu(n,f) cross section data. At the Van de Graaff accelerator of the Institute for Reference Materials and Measurements an experiment has been performed with quasi-monoenergetic neutrons in the energy range from 15 MeV to 20 MeV. A twin Frisch-grid ionization chamber has been used in a back-to-back configuration as fission fragment detector [2]. The ^{242}Pu(n,f) cross section has been normalized to the ^{238}U(n,f) cross section data. The results were compared with existing data and show acceptable agreement within 5% [3].

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S414 MCNP6 updated fission cross section calculations at intermediate energies

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MCNP6 has been Validated and Verified (V&V) against intermediate- and high-energy fission cross-section experimental data. Recent improvements contained in CEM03.03F and MCNP6-F to consider precompound emission of heavy clusters up to ^{28}Mg has necessitated a re-calculation of fission cross sections. With our re-calculation, we find that MCNP6-F using CEM03.03F predicts fission cross sections in good agreement with available experimental data for reactions induced by nucleons, pions, and photons on both subactinide and actinide nuclei at incident energies from several tens of MeV to several GeV.

S415 Thorium-232 fission induced by light charged particles up to 70 MeV

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Objectives: The fission phenomenon of thorium-232 has been investigated at the ARRONAX cyclotron (Nantes, France) at the same time as the production of heavy radionuclides of medical interest (Ra-223, Ac-225 and U-230) that occurs when such target is irradiated with light charged particles. This presentation focuses on fission fragments production cross section measurements and their comparison with TALYS simulations.
Material and methods: These new data have been measured as a function of the incident proton and deuteron energy using the stacked foil technique and gamma spectroscopy. These cross section measurements have been limited to fission fragments with associated gamma emission and long enough half-live due to experimental constraints associated to the chosen methodology.
Results: From these experiments, the mass distribution of the fission products has been obtained from 8 to 34 MeV with deuterons, and 11 to 70 MeV with protons. Independent and/or cumulative cross section data have been extracted, depending on the physical characteristic of the 25 radioactive nuclei detected, from Zn-72 to Pm-151. These results have been systematically compared with simulation using the last version of the TALYS code (1.6). A combination of models, based on those already included in the code, has been found to better describe the experimental values than the default models. The description of the optical, preequilibrium and level density models have been found to have a great influence on the calculated production cross section values.
Conclusions: Our new experimental results obtained on fission fragments production cross section induced by light charged particles show that it is possible to improve our knowledge on fission, based on relatively simple experimental set-up and measurement method. In addition, the large set of data obtained helps to constrain TALYS nuclear code.

S416 High accuracy 234U(n,f) cross-section in the resonance energy region

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The ^{234}U isotope is present in the uranium-enriched fuel of current reactors and is also formed during the thorium-fuel cycle. Because of its relatively low (n,f) cross section, the records existing in current nuclear databases could be sufficient for a first evaluation of critical reactors as well as for Accelerator Driven Systems. Nevertheless, a detailed assessment of relevant integral reactor quantities requires for this important isotope a more precise and complete set of basic nuclear data. Both experimental datasets available in EXFOR and data present in the evaluated libraries (ENDF/B-VII, JEFF3.1, BROND-2.2, JENDL-3.3, etc.) show discrepancies, thus motivating a new experiment during the Phase2 of the CERN – n_TOF facility. An improved detection setup based on Parallel Plate Avalanche Counters has been used to study neutron-induced fission reactions of ^{234}U in the whole energy range from eV up to 1 GeV.
In this contribution, we present new results on the fission cross section of ^{234}U, obtained with high accuracy in the resonance region, and relative to ^{235}U(n,f) as reference. The recent evaluation of ^{235}U(n,f) obtained with SAMMY by Leal et al. [Submitted to this Conference], based on previous n_TOF data [Paradela et al., WONDER2015 Proceedings], has been used for characterising the neutron fluence, and is here compared with the results obtained by using the official n_TOF flux.

I417 Studies of fission fragment properties at the Los Alamos Neutron Science Center (LANSCE)

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Nuclear data related to the fission process are needed for a wide variety of research areas, including fundamental science, nuclear energy and non-proliferation. While some of the relevant data have been measured to the required accuracies there are still many aspects of fission that need further investigation. One such aspect is how Total Kinetic Energy (TKE), fragment yields, angular distributions and other fission observables depend on excitation energy of the fissioning system. Another is the correlation between mass, charge and energy of fission fragments. At the Los Alamos Neutron Science Center (LANSCE) we are studying neutron-induced fission at incident energies from thermal up to hundreds of MeV using the Lujan Center and Weapons Neutron Research (WNR) facilities. Advanced instruments such as SPIDER (time-of-flight and kinetic energy spectrometer), the NIFFTE Time Projection
Chamber (TPC), and Frisch-gridded Ionization Chambers are used to investigate the properties of fission fragments, while other instruments such as Chi-Nu and DANCE are measuring neutron and gamma outputs in fission. Recent results on fission fragment properties will be presented, together with a discussion of future research directions and developments.

R418 The new double energy-velocity spectrometer verdi

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VERDI (VElocity foR Direct particle Identification) is a fission-fragment spectrometer recently put in operation at the Joint Research Centre IRMM. It allows measuring the kinetic energy and the velocity of both fission fragments simultaneously. The velocity provides information about the pre-neutron mass of each fission fragment when isotropic prompt-neutron emission from the fragments is assumed. The kinetic energy, in complement of the velocity, provides the post-neutron mass. From the difference between pre- and post-neutron masses the number of neutrons emitted by each fragment may be determined. Multiplicity and average spectral energy as a function of fragment mass and total kinetic energy are essential for understanding the sharing of excitation energy between fission fragments at scission and may be used to benchmark nuclear de-excitation models. The VERDI spectrometer provides the best compromise between geometrical efficiency and mass resolution, superseding Così-Fan-Tutte by a factor 100. The spectrometer consists of an electron detector located very close to the fissionable target and a double array of silicon detectors, each located 50 cm away from the target. The silicon detectors have an area of 450 mm2 and are made from neutron-transmutation doped (NTD) silicon to minimize rise-time variation and to reduce pulse height defect as well as plasma delay time. In the present configuration pre-neutron and post- neutron mass distributions in very good agreement with reference data were obtained.
First measurements performed with spontaneously fissioning 252Cf will be presented along with the established calibration procedure to obtain pulse height defect and plasma delay time corrections. Further improvements to the VERDI spectrometer will be discussed.

R419 New developments of the FALSTAFF experimental setup

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Most of the innovative nuclear reactors are based on fast reactor technologies. In this fast energy domain more precise and complete nuclear data are needed. In this context an experimental setup called FALSTAFF is under development. It will provide new data for the study of actinide nucleus fission at incident neutron energies between hundred of keV and several MeV.
FALSTAFF experimental setup will provide the full characterization of the fission fragments, i.e. their masses before and after neutron evaporation process, their kinetic energies and their nuclear charges. The deduced neutron multiplicity as a function of mass will provide information on the energy sharing at scission between both fragments.
The mass before neutron evaporation is obtained via the 2V (double velocity) method. It requires the measurement of both fragment velocities in coincidence. The velocity is determined with two Secondary Electron Detector (SED) time-of-flight (ToF) detectors, which respectively give the start and stop times and the positions. The mass after neutron evaporation is obtained with the EV (Energy-Velocity) method. In addition to the velocity information, the kinetic energy of the fragment is then required. This information is obtained with an axial ionization chamber. This type of ionization chamber also permits to measure the energy loss of the fragment along its track. This energy loss profile is useful for the nuclear charge determination.
This paper will focus on FALSTAFF experimental setup recent developments. The developments performed on the ToF detectors and on the axial ionization chamber will be presented. Tests performed with one arm of the setup will be compared to simulations. We will pay special attention to the fission fragment nuclear charge determination from the energy loss profile along the track in the ionization chamber.

R420 Detailed examination of neutron-induced fission cross section systematic uncertainties using a time projection chamber

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Nuclear data such as neutron-induced fission cross sections have long been of great interest for nuclear energy and defense applications. Advanced simulation and modeling play a critical role in understanding these systems, propagating uncertainties in nuclear data into final design criteria. Therefore, it is necessary to both minimize and fully quantify uncertainties in nuclear data. Furthermore, precise data provides an excellent test of modern nuclear theory which continues to strive for a complete model of nuclear fission. Recently, the Neutron Induced Fission Fragment Tracking Experiment (NIFFTE) has developed the fission Time Projection Chamber (fissionTPC) to measure fission cross sections to unprecedented precision by providing 3D tracking of charged particles. An-
alyzing track parameters provides a wealth of information not previously available with standard fission chambers. The presentation will highlight capabilities of the NIFFTE fissionTPC that provide a direct measurement of systematic uncertainties in fission cross sections, namely particle identification, and target and beam uniformity.

R421 High-resolution measurements of thermal neutron-induced fission fragment yields with the SPIDER 2V-2E spectrometer at LANSCE

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An accurate description of the fission process is important for the advancement of a number of disciplines, e.g. nuclear engineering and forensics. To aid this effort, a high-resolution, moderate-efficiency, dual-arm mass spectrometer was developed at the Los Alamos Neutron Science Center (LANSCE) with the goal of reaching 1 atomic mass unit resolution. The SPectrometer for Ion DEtermination in fission Research (SPIDER) uses the 2V-2E method to imultaneously measure the velocity and kinetic energy of coincident fission products. Each spectrometer arm is comprised of a time-of-flight system employing two position-sensitive micro-channel plate detector assemblies and an axial ionization chamber as an endpoint energy detector. SPIDER is well-positioned to collect valuable data on fission product yields (FPYs), neutron multiplicity (v), and total kinetic energy (TKE) release, all as a function of the excitation energy of the fissioning system. This contribution will present the first SPIDER measurements of thermal neutron-induced fission at the Lujan Center at LANSCE for the systems 235U(nth,f) and 239Pu(nth,f).

I422 The Decay Data Evaluation Project (DDEP): an international collaboration providing evaluated decay scheme data

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The Decay Data Evaluation Project (DDEP), is an international collaboration originally founded in 1994 between the Laboratoire National Henri Becquerel (LNE-LNHB), France, and the Physikalisch-Technische Bundesanstalt (PTB), Germany, both of which are the recognised National Metrology Institutes (NMIs) for ionising radiation in their respective countries. The collaboration was soon joined by other groups from the US, and subsequently by groups from China, Romania, Russia, Spain and the UK.
At present the collaboration undertakes the evaluation of decay scheme data for well-chosen radionuclides in the area of radionuclide metrology, detector calibration, nuclear medicine, both diagnostic and pharmaceutical, as well as in response to user requests from the wider community, and in cooperation with activities of the International Atomic Energy Agency (IAEA). Currently the DDEP members have evaluated over 220 radionuclides, following an agreed upon methodology, which includes a peer-review. These evaluations include all parameters relating to the nuclear decay; radiation energies and intensities, half-life, branching fractions, etc., as well as the associated atomic data; X-rays, Auger electrons, conversion electrons, etc. Examples are given of recommendations for new measurements, an inherent output of the evaluation process, which can serve as a basis for future measurement programmes. Recently evaluated radionuclides include: 18F, 59Fe, 82Rb, 82Sr, 88Y, 90Y, 89Zr, 94mTc, 109Cd, 133Ba, 140Ba, 140La, 151Sm, 169Er.
Recommended decay data and plots of the decay schemes are disseminated through a dedicated website, http://www.nucleide.org/NucData.htm, hosted at the LNE-LNHB, and are also published through a dedicated Monographie series of the Bureau International des Poids et Mesures (BIPM).
The current status of the collaboration will be presented, along with plans for the future.

R424 Nuclear data for nuclear reactor antineutrino flux calculations

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The current generation of nuclear reactor antineutrino experiments, Daya Bay, Double Chooz and RENO, have yielded a very precise value of the oscillation parameter Θ_{13}, but have also revealed an unexpected excess of antineutrinos in the spectrum at around 5 MeV. Additionally, a new analysis of previous short distance experiments point to a deficit of antineutrinos, the so-called reactor neutrino anomaly, which could be caused by one or more types of sterile neutrinos, triggering a new set of short baseline experiments. Both issues arise when the latest conversion method is used to obtain the antineutrino spectra for ^{235}U and ^{239,241}Pu. To improve the predictive capabilities of the alternate summation method, we have updated the ENDF/B decay data sub-library to include beta intensities from TAGS measurements and used it with JEFF fission yields to calculate antineutrino spectra. This allowed us to identify the nuclides that contribute the most at different energy regions in order to assess the quality and reliability of the decay and fission data. Additionally, we derived a systematic of the cross-section integrated antineutrino spectra as a function of the Z and A of the target, analogous to that for beta-delayed neutrons. On another front, the thermal ^{235}U ENDF/B fission yields were critically reviewed and corrections were applied to account for a) erroneous values, b) newly measured and better estimates of isomeric ratios, and c) consistency with far more recent decay data. The thermal ^{235}U antineutrino spectrum calculated with the corrected yields is in much better agreement with the spectrum calculated with the JEFF yields. Moreover, an excess of electrons observed using the original ENDF/B yields disappears once the corrected yields are used. In order to continue improving the data used in summation calculations, we have identified the ^{96}Y isomeric ratio as an important quantity that would merit a measurement. Currently, only estimates are available, which do not agree, leading to a peak uncertainty of about 5 % in the antineutrino spectrum. Finally, we have explored the possibility that the contributions from epithermal and fast neutrons in a power reactor are causing the excess of antineutrinos at 5 MeV.

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R425 233U data evaluation for criticality study

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To meet the development needs of thorium-based nuclear energy systems for nuclear data evaluation, the aim of this study was to investigate the availability and accuracy of cross-section data for U-233 to perform calculations of the critical system for the thorium - uranium fuel cycle. By utilising the method of weighted least squares and using nonlinear regression with high-order polynomials to meet the growing demands of nuclear data, a computer programme FITWR was developed and applied to the experimental total cross-sections for MEV incident energy particles, e.g., neutrons and protons.
The FITWR programme can handle variance and covariance data provided with experimental data and yield those statistical measures for evaluated data. Two evaluated data libraries are available, the U.S. data bank ENDF and the Japanese data bank JENDL. Pre-calculations were performed using the SAMMY code in conjunction with two fitting methods: the Bayes method, which is available through the SAMMY code, and the weighted least squares method with nonlinear regression. In addition, the programme was developed to investigate the available U-233 cross-section data for the suitable calculation of critical benchmark experiments and for the calculation of the multiplication factor Keff for several benchmarks in both the fast and thermal energy range.

S426 Decay data evaluation project (DDEP): updated evaluation of the Ba-140, La-140 and Ce-141 decay characteristics

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The Decay Data Evaluation Project (DDEP) collaboration is aimed at producing high-quality comprehensive nuclear decay data evaluations for important applications-oriented radionuclides, for example, gamma ray standards, dosimetry reaction residuals, medical isotopes, etc. Such evaluations should be based on a total set of published experimental and theoretical data accumulated to the current moment.
The current evaluation of Ba-133, Ba-140, La-140 and Ce-141 decay data takes into account experimental data and other information (compilations, calculations, analyses) published by 2016 including the recent works [1, 2]. The evaluated (recommended) data for the above radionuclides have been obtained using the approaches, programs and procedures adopted by the DDEP working group.
The following decay characteristics of Ba-133, Ba-140, La-140 and Ce-141 have been evaluated: half-life, decay energy, energies and probabilities of nuclear transitions, energies and emission probabilities of all the radiations accompanying decay. This work includes a collection, selection and statistical processing of the available experimental data and checking for consistency of the obtained data within a decay scheme.
The updated evaluated data obtained have been placed on the DDEP web site: (http://www.nucleide.org/DDEP_WG/DDEP-data.htm) maintained by CEA/LNE-LNHB and recommended for improving the IAEA International Dosimetry Library for Fission and Fusion (IRDFF) and other libraries of evaluated data.
This work was partly funded through the IAEA Research Contract 17762, which is gratefully acknowledged.

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S427 The XUNDL database at www.nndc.bnl.gov

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The eXperimental Unevaluated Nuclear Data List (XUNDL) compiles recently published articles on experimental nuclear structure physics and makes the data available through a web interface maintained at the National Nuclear Data Center at Brookhaven National Laboratory. A single XUNDL dataset consists of data and information from a single journal article, or closely related articles from the same experimental group. Supplemental material provided by authors and associated with published papers can also be incorporated into XUNDL. Several data centers at U.S. National Laboratories and Universities operating under the auspices of the DOE's US-NDP contribute to the XUNDL compilation effort In addition to providing a database of current nuclear structure measurements, the frequent interaction between the data compilers and authors provides additional information beyond that available in the original publication, and also helps in resolving data-related issues. The XUNDL database is updated on a weekly basis, usually taking less than 1-2 month from publication of the article to incorporation into the database.
A general description of XUNDL will be given, including its scope, methods and procedures. Examples of the benefit of such a database to nuclear structure researchers and use of the web interface will be shown. Possible extensions in coverage and compilation policies will also be presented.

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S428 Nuclear structure and decay data evaluation in Europe

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Nuclear Structure and Decay Data (NSDD) activities in Europe include mass-chain and individual nuclei evaluations as well as horizontal evaluations and compilations, data dissemination and educational activities. As such they are essential for a large range of applications from energy, environmental, and medical to basic research in nuclear structure and reactions, all of which are intensively pursued in Europe. Although the NSDD evaluation groups in Europe form part of the international network of NSDD evaluators, which is coordinated by the International Atomic Energy Agency, they are faced with some very distinct challenges. We will shortly present the NSDD Data Centre at IFIN-HH, Bucharest with an emphasis on the specific challenging conditions under which we perform our activities and discuss possible actions to improve the situation for the entire European NSDD evaluation effort.

S429 A new online database of nuclear electromagnetic moments

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Nuclear electromagnetic (EM) moments, i.e. the magnetic dipole and the electric quadrupole moments, provide important information of nuclear structure. As in other types of experimental data available to the community, measurements of nuclear EM moments have been organized in compilations already since the dawn of nuclear science. However, the wealth of recent moments data produced in experiments with radioactive beams, as well as earlier existing measurements, lack an online, easy-to-access, systematically organized presence to disseminate information to researchers. In addition, available printed compilations suffer a rather long life cycle, being left behind experimental measurements published in journals or elsewhere.
A new, online database focusing on nuclear EM moments has been recently developed to disseminate experimental data to the community. The database includes non-evaluated experimental data of nuclear EM moments, giving strong emphasis on frequent updates (life cycle is 3 months) and direct connection to the sources via DOI and NSR hyperlinks. The database has been recently integrated in IAEA's LiveChart [1], but can also be found as a standalone webapp [2]. A detailed review of the database features, as well as plans for further development and expansion in the near future will be discussed.

References

[1] IAEA LiveChart https://www-nds.iaea.org/livechart; [2] http://magneticmoments.info

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S430 Latest user-related radionuclide-handbook as a link between laboratory needs and international databases

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This radionuclide handbook is closing a gap between the metrology databases and the daily work of laboratory users in the handling of radio-isotopic data. Considering the actual "Version 5.1.5 (August 2015) about 250 radio-isotopes are included and subdivided into separate chapters: natural (incl. decay chains), man-made (activation & fission), calibration (incl. coincidence correction) and nuclear-medicine (therapy, diagnostic, PET, bone-seeking, body-composition), actinides (transuranic incl. (n,γ)-(n,2n)-activation & decay-series), low-background application (neutron scattering & capture), lists of isotope- and material properties and last but not least references & isotope index. Particular emphasis are placed on the methodical combination of the normative fundament of isotope decay-scheme with the decay structure in a clearly laid-out list-mode with all the branches, energies & intensities, half-lives & q-values, detailed energy lists & a catalogue all together with uncertainties of course. In case of gamma spectrometry, e.g., to reconstruct the activity as best as possible indicated are photon-interferences, cascade transitions and crossover decays with marked reference photon-transitions including advices regarding disturbance along with information such as coincidence corrections. For transuranic isotopes a new complete statement of the production via neutron activation and the decay processes are elaborated and inserted. Particular effects from the practice in gamma-spectrometry as asymmetric peaks, e.g., through neutron scattering with germanium crystal as well as line broadening, e.g., during $^{7}Li^{*}$ decay are – if known – described. Taking all the detailed information into consideration the handbook considerably facilitates the daily-life of laboratory users in the handling of radio-isotopic data and therefore improves quality assurance.

I431 Evaluated Nuclear Structure Data Base (ENSDF) and related services at National Nuclear Data Center (NNDC)

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The primary mission of the National Nuclear Data Center at Brookhaven National Laboratory, USA, is to compile, evaluate, and disseminate nuclear structure and nuclear reaction data. Evaluated Nuclear Structure Data File (ENSDF) is the primary source of nuclear structure information used both in pure and applied research. The file, used universally, is maintained by the NNDC on behalf of the international community under the auspice of the IAEA/DS. Its supplemental, but more up-to-date, experimental (unevaluated) nuclear data file (XUNDL) is also maintained at the NNDC. The NNDC provides web-based retrievals for these and many other databases and their related analysis and utility codes. Many of the retrieval services, uses in many diverse fields, and publication products, mainly focusing on ENSDF, will be presented here.

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R432 Random sampling and validation of covariance matrices of resonance parameters

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Analytically exact methods for random sampling of arbitrary correlated parameters are presented. Emphasis is given on one hand on the possible inconsistencies in the covariance data, concentrating on the positive semi-definiteness and consistent sampling of correlated inherently positive parameters, and on the other hand on optimization of the implementation of the methods itself. The methods have been applied in the program ENDSAM, written in the Fortran language, which from a file from a nuclear data library of a chosen isotope in ENDF-6 format produces an arbitrary number of new files in ENDF-6 format which contain values of random samples of resonance parameters (in accordance with corresponding covariance matrices) in places of original values. The source code for the program ENDSAM is available online at: https://www-nds.iaea.org/index-meeting-crp/CM_Data_Processing_2015/. The program works in the following steps: reads resonance parameters and their covariance data from nuclear data library, checks whether the covariance data is consistent, and produces random samples of resonance parameters. The code has been validated with both realistic and artificial data to show that the produced samples are statistically consistent. Additionally, the code was used to validate covariance data in existing nuclear data libraries. A list of inconsistencies, observed in covariance data of resonance parameters in ENDF-VII.1, JEFF-3.2 and JENDL-4.0 is presented. For now, the work has been limited to resonance parameters, however the methods presented are general and can in principle be extended to sampling and validation of any nuclear data.

R433 Covariance generation and uncertainty propagation for thermal and fast neutron induced fission yields

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Fission product yields (FY) are fundamental nuclear data for several applications, including decay heat, shielding, dosimetry, burn-up calculations. To be safe and sustainable, modern and future nuclear systems require accurate knowledge on reactor parameters, with reduced margins of uncertainty. Present nuclear data libraries for FY do not provide consistent and complete uncertainty information which are limited, in many cases, to only variances. In the present work we propose a methodology to evaluate covariance matrices for thermal and fast neutron induced fission yields. The semi-empirical models adopted to evaluate the JEFF-3.1.1 FY library have been used in the Generalized Least Square Method available in CONRAD (COde for Nuclear Reaction Analysis and Data assimilation) to generate covariance matrices for several fissioning systems such as the thermal fission of U235, Pu239 and Pu241 and the fast fission of U238, Pu239, Pu240 and U235. The impact of such covariances on nuclear applications has been estimated using deterministic and Monte Carlo uncertainty propagation techniques. We studied the effects on decay heat and reactivity loss uncertainty estimation for simplified test case geometries, such as PWR and SFR pin-cells. The impact on existing nuclear reactors, such as the Jules Horowitz Reactor under construction at CEA-Cadarache, has also been considered.

R434 Propagation of nuclear data uncertainties for fusion power measurements

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Analytically exact methods for random sampling of arbitrary correlated parameters are presented. Emphasis is given on one hand on the possible inconsistencies in the covariance data, concentrating on the positive semi-definiteness and consistent sampling of correlated inherently positive parameters, and on the other hand on optimization of the implementation of the methods itself. The methods have been applied in the program ENDSAM, written in the Fortran language, which from a file from a nuclear data library of a chosen isotope in ENDF-6 format produces an arbitrary number of new files in ENDF-6 format which contain values of random samples of resonance parameters (in accordance with corresponding covariance matrices) in places of original values. The source code for the program ENDSAM is available online at: https://www-nds.iaea.org/index-meeting-crp/CM_Data_Processing_2015/. The program works in the following steps: reads resonance parameters and their covariance data from nuclear data library, checks whether the covariance data is consistent, and produces random samples of resonance parameters. The code has been validated with both realistic and artificial data to show that the produced samples are statistically consistent. Additionally, the code was used to validate covariance data in existing nuclear data libraries. A list of inconsistencies, observed in covariance data of resonance parameters in ENDF-VII.1, JEFF-3.2 and JENDL-4.0 is presented. For now, the work has been limited to resonance parameters, however the methods presented are general and can in principle be extended to sampling and validation of any nuclear data.

R435 Propagation of neutron-reaction uncertainties through multi-physics models of novel light water reactors

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Fission product yields (FY) are fundamental nuclear data for several applications, including decay heat, shielding, dosimetry, burn-up calculations. To be safe and sustainable, modern and future nuclear systems require accurate knowledge on reactor parameters, with reduced margins of uncertainty. Present nuclear data libraries for FY do not provide consistent and complete uncertainty information which are limited, in many cases, to only variances. In the present work we propose a methodology to evaluate covariance matrices for thermal and fast neutron induced fission yields. The semi-empirical models adopted to evaluate the JEFF-3.1.1 FY library have been used in the Generalized Least Square Method available in CONRAD (COde for Nuclear Reaction Analysis and Data assimilation) to generate covariance matrices for several fissioning systems such as the thermal fission of U235, Pu239 and Pu241 and the fast fission of U238, Pu239, Pu240 and U235. The impact of such covariances on nuclear applications has been estimated using deterministic and Monte Carlo uncertainty propagation techniques. We studied the effects on decay heat and reactivity loss uncertainty estimation for simplified test case geometries, such as PWR and SFR pin-cells. The impact on existing nuclear reactors, such as the Jules Horowitz Reactor under construction at CEA-Cadarache, has also been considered.

I436 Double differential cross section for light mass fragment production on tens of MeV proton, deuteron, helium and carbon induced reactions

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Double differential cross sections (DDXs) for light mass fragment production should be modeled properly to evaluate amount of energy deposition in a finite volume due to single ion incidence. Systematic experimental data are desired to evaluate nuclear reaction models not only for various energy but also incident particles. The DDXs were measured for tens of MeV proton, deuteron helium and carbon induced reactions. The experiments were performed using Cyclotron facility of National Institute of Radiological Sciences, Japan. Protons with energies of 24, 50 and 70 MeV, deuteron with 24 and 50 MeV, helium with 50, 70 and 100 MeV, and carbon with energies 50, 72 and 144 MeV were prepared as incident particles. The data for the energies allow us the comparison of DDXs with same energy, 50 MeV, with different particles (p, d, He and C) and 70 MeV (p,He,C), and, the comparison of DDXs with same energy per nucleon, 12 MeV/n with different particles (d, He, C), 24 MeV/n (p, d, He). Targets were C, Al, Ti and Cu self-supported foils with thicknesses less than 1 µm. The targets were set on a target changer ladder at the center of a scattering chamber. Bragg curve counters placed at 30, 60 and 90 degrees of the scattering chamber are employed to measure light mass fragments. DDXs for Li, Be, B, C, N, O, F and Ne production were obtained for the targets. Evaporation like energy spectra are observed except for the fragment the mass of which is close to the incident ion. The results are summarized to study incident particle type dependency on DDX for each target nuclei.

R437 Investigations of the 27Al(d,x)24Na nuclear reaction for deuteron beam monitoring purpose

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Activation cross-sections for the $^{27}Al(d,x)^{24}Na$ nuclear reaction was measured by using a stacked-foil activation technique combined with high purity germanium (HPGe) γ-ray spectrometry over deuteron energy range of 2-24 MeV. Measured data were critically compared with the available literature data and also with the theoretical data extracted from the TENDL data base. Accuracy of the $^{27}Al(d,x)^{24}Na$ cross-sections were confirmed by the simultaneous measurements of the $^{nat}Ti(d,x)^{48}V$ monitor reaction cross-sections. Present results perfectly reproduced the IAEA recommended $^{nat}Ti(d,x)^{48}V$ reaction cross-sections, but provide slight deviation with the IAEA recommended $^{27}Al(d,x)^{24}Na$ cross-sections. It may be concluded that the use of $^{27}Al(d,x)^{24}Na$ in deuteron beam monitoring should not be a perfect choice if one has the scope to use the $^{nat}Ti(d,x)^{48}V$ reaction.

R438 Measurements of neutron and charged particle production cross sections on beryllium, carbon and iron bombarded with 13MeV/nucleon neon beam

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A new accelerator technology of intense and low-energy rare isotope beams developed at some organizations such as Michigan State University (MSU) opens new science fields, and brings on an interest in low-energy heavy ion reactions. The Particle and Heavy Ion Transport code System (PHITS) has been typically used to estimate radiation dose levels at heavy-ion accelerator facilities. However, the accuracy of PHITS has not yet been investigated for low-energy (10 MeV/nucleon) heavy-ion reactions due to lack of experimental data. In this study, we measured neutron and charged particle production double differential cross sections (DDXs) from ^{9}Be, ^{nat}C and ^{nat}Fe targets bombarded with 13 MeV/nucleon ^{20}Ne and made comparison between the measured data and calculated results by PHITS.
The experiments were carried out at the HB-1 beam line of the AVF cyclotron at the TIARA facility of JAEA. The targets were installed in a vacuum chamber with a diameter of 60 cm. Neutrons were measured using NE213 organic liquid scintillators (5.08 cm in diameter and 5.08 cm in length) placed in directions of 15, 30, 60, 90 and 120 degrees at a distance of 2.0 m from the targets. The events of neutrons and gamma-rays were separated by using a pulse shape discrimination technique, and neutron energy spectra were measured by the TOF method. On the other hand, charged particles were measured using the counter telescope system composed of three fully-depleted silicon solid-state detectors (SSDs) with different thickness (40 µm, 250 µm and 1000 µm) and a 2 cm thick lutetium yttrium orthosilicate (LYSO) scintillator placed in directions of 30, 60, and 90 degrees in the vacuum chamber. Each charged particle was identified by the two dimension plot with the pulse heights of the neighboring two detectors.
The calculation results with the R-JQMD coupled with GEM model implemented in PHITS version 2.82 were compared with the measured data. For production of hydrogen isotopes, calculated results give good agreement with the measured data, while that for production of heavier particles gives large underestimation. Our data will be used for the model improvement of the nuclear reaction and the fragmentation production reaction.

R439 Dispersive and deflective effect in transverse momentum distribution of fragments at intermediate energies

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In this study, transverse momentum (P_T) distribution of projectile-like fragments (PLFs), produced at intermediate energies E=95 and 290 MeV/u, are investigated based on systematic experimental results. At relativistic energies, the fragment momentum distribution shows an isotropic Gaussian shape, and the width can be successfully reproduced on the basis of the contribution of the Fermi momentum of nucleons in the fragmentation process. At intermediate energies, additional dispersion and deflection effects have been observed in P_T distribution of PLFs in previous experimental results. However, fragmentary measurements have prevented from disclosing further information on reaction processes and formulating the P_T distribution.
The obvious velocity dependence is observed in the width of P_T distribution of PLFs produced from Ar-beam and Be-target at E=95 MeV/u and the dependence is successfully reproduced by a simple formulation. According to a microscopic model calculation, observed velocity dependence is explained on the basis of the contribution of the impact parameter. At E=290 MeV/u, no significant velocity dependences are observed in P_T distribution. This result indicates that the collective process, which would cause the velocity dependence, is suppressed at higher energy. An orbital deflection effect has been observed in P_T distribution of PLFs, which were produced through few-nucleon removal reactions with heavy targets at E~100 MeV/u in earlier measurements. In our measurements with Ar- and Kr-beams and various targets (C, Al, Nb, Tb, and Au) at E=290 MeV/u, the deflection effect is successfully observed and the effect grows with target mass. In the case of 1-nucleon removal and exchange reactions, the evolutional behavior is consistently described by the orbital deflection with Coulomb potential and nuclear potential. In the case of multinucleon-removal reactions, P_T distribution is reproduced by practical formulation. Formulation, obtained in this study, enables a reliable characterization of the fragments, which would be applicable to various research fields involving, for example, radioactive nuclear beams.

S440 The activation of W and Zr by deuterons at energies up to 20 MeV

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The proton and deuteron induced reactions are of a great interest for the assessment of induced radioactivity of accelerator components, targets and beam stoppers. In order to investigate the important nuclides, we have carried up the irradiation experiments with the variable-energy cyclotron U-120M of the Nuclear Physics Institute Řež. The production cross sections of the nuclides ^{179,181,182m,182,183,184m,184,186}Re and ^{187}W from reaction on natural W, further – the nuclides ^{89m,90,91m,92m,94m,95m,95,96,97}Nb, ^{89,89m,95,97}Zr and ^{90m,91}Y from reaction on natural Zr were investigated by deuteron beams of 20 MeV energy. The stacked-foil technique was utilized. The comparison of present results to data of other authors and to predictions of evaluated data libraries is discussed.

S441 Cross sections for nuclide production in proton- and deuteron-induced reactions on niobium-93 measured using the inverse kinematics method

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The disposal of radioactive waste is one of the issues concerning nuclear power generation. Radioactivity of long-lived fission products (LLFPs) is a big factor of the issue. Accelerator-driven nuclear transmutation is proposed to resolve this problem. However, there is little experimental nuclear reaction data of LLFPs to find an optimum pathway of the nuclear transmutation. Recently, a new research project has been started for cross section measurement of residues produced in proton and deuteron induced spallation reactions on LLFPs (^{79}Se, ^{93}Zr, ^{107}Pd, and ^{135}Cs) using the inverse kinematics method in Japan. In the experiment for ^{93}Zr, the cross sections for a stable isobar, ^{93}Nb, were measured as well. Since there are systematic experimental data for the p+^{93}Nb reaction by the activation method, a comparison between the data measured with the two methods is of special interest to verify the inverse kinematics method used in our project.
The experiment was performed at RIKEN RI Beam Factory (RIBF). The cocktail beam containing both ^{93}Nb and ^{93}Zr at around 100 MeV/u was produced by in-flight fission of ^{238}U at 345 MeV/u. The cocktail beam was separated and identified by using the BigRIPS in-flight separator. Particle was separated by using energy degraders and slits placed at focal planes. Particle identification was performed by the TOF method. Then the beam particles irradiated CH_2, CD_2, and C targets placed at the entrance of ZeroDegree Spectrometer (ZDS). The residual nuclei produced by nuclear reactions were identified event-by-event using ZDS. The cross sections for nuclide production in proton-induced reaction on ^{93}Nb at 130 MeV/u measured using the inverse kinematics method were compared with the data measured using the activation method and the model calculations using the PHITS code and the CCONE code. The detail of the results will be discussed in the presentation.
This work was funded by ImPACT Program of Council for Science, Technology and Innovation (Cabinet Office, Government of Japan).

I443 Measurement of production cross sections for the proton induced reactions on yttrium with proton energy of 69 MeV

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The cross sections of radionuclides produced from the 89Y(p,x) reactions were measured by the stacked-foil activation technique with the proton energy of 69 MeV at the 100 MeV proton linac of Korea multi-purpose accelerator complex (KOMAC). A HPGe detector was used to measure the induced activities of irradiated samples. The proton beam energy at each foil was calculated by SRIM code and the beam flux was determined using the Cu monitor foil with known cross sections. The measured cross sections were compared with other available experimental data and the data from the TENDL-2014 library. The thick target integral yields of the investigated radionuclides were calculated from the measured cross sections.

R444 Proton and deuteron activation measurements on the NPI and future plants at SPIRAL2/NFS

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The proton and deuteron induced reactions are of a great interest for the assessment of induced radioactivity of accelerator components, targets and beam stoppers as well as isotope production for medicine. In present work, the proton induced reaction cross sections on iron were investigated by stacked-foil activation technique with proton beam of 20 MeV energy from the cyclotron U-120M of the Nuclear Physics Institute ASCR Řež. Also the deuteron activation cross section measurement of zinc is presented. The comparison of present results to data of other authors and to predictions of evaluated data libraries is discussed. The excitation function of the reaction $^{54}Fe(p,\alpha^{+})^{51}Mn$ is determined for the first time.
The investigation shall continue for higher proton and deuteron energy interval 20-35 MeV at SPIRAL2/NFS facility using a charged-particle irradiation chamber (under construction presently at NPI) equipped with pneumatic transport system from KIT – to measure isotopes and isomers with half-lives in minutes-regions.

R445 Cross sections for the proton-induced production of long-lived radionuclides in heavy metal targets

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Heavy metal targets are used for accelerator driven systems (ADS) and spallation neutron sources (SNS) to produce neutrons by spallation reactions. The knowledge of the radionuclide inventory is one of the key issues for the construction, decommissioning and disposal of ADS and SNS. This work aims to determine the production cross sections of long-lived gamma and alpha emitting radionuclides in Pb, W and Ta targets, irradiated by 220-2600 MeV protons.
Proton irradiations of Pb, Ta and W targets were performed with a special stacked foil technique between 1993-96 at the Lab National Saturne (LNS) Saclay and at TSL Uppsala (the details of the irradiation technique can be found in [1]). Now, after 20 years of decay, gamma spectrometry measurements on several of these Ta and W samples were performed (without prior chemical separation) to calculate the cross sections for the production of residual gamma emitting radionuclides.
Radiochemical separations of several long-lived radionuclides from irradiated Pb targets were reported in previous works [2, 3]. In the present study, the remaining LnF_3 fractions of the previous studies [2,3] were used to separate long lived alpha emitting lanthanides. Lanthanide separations were performed with gradient elution of α-hydroxyisobutyric acid (α-HIB) on DOWEX 50WX8 cation exchange resin. In order to remove the complexing agent from the Ln fractions, commercially available Ln-specific ion exchange resin (TRISKEM) was used with conc. HNO_3 as eluent in a following purification step. After the separation, molecular plating was used to prepare thin layers of the lanthanide fractions for alpha-counting. For the first time, it was possible to calculate cross sections for the production of alpha emitting lanthanides, in particular ^{148}Gd (half-life 75 yrs), in proton-irradiated lead targets.

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R446 Integral measurements of the residue nuclide production induced by protons in heavy metal targets

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Neutron spallation sources on the MegaWatt level are currently operational only at a few places worldwide, e.g. the pulsed facilities SNS (USA) and J-PARC (Japan), both using mercury as target material, as well as the continuously working neutron spallation source SINQ (Switzerland), normally equipped with a solid lead target. Only in 2006, a liquid metal target, consisting of Lead-Bismuth Eutectic (LBE), has been operated for 5 months in the frame of the MEGAPIE test experiment. We had the unique opportunity to extract both lead samples from one of the irradiated SINQ targets and from the MEGAPIE LBE target in order to determine the total radionuclide inventory of the most relevant longer lived radionuclides and their spatial distribution within the target. For the first time, it was possible to experimentally investigate the radionuclide production within a high-power spallation target, corresponding to the dimensions of a real Accelerator Driven System (ADS) concerning energy, irradiation time and power. The radionuclide content within the entire target was calculated by implementing the experimentally obtained results into the Kriging algorithm and integrating over the total volume.
Very unexpectedly, we found that the content of ^{210}Po, one of the most safety-relevant radionuclides, is several orders of magnitude higher than predicted. Furthermore, we have performed model calculations for the solid lead target using advanced simulation codes to increase the reliability of the theoretical predictions. Essential improvements were achieved by the implementation of an advanced physics model, INCL4.6/ABLA07, which, in particular, provides advantageous features concerning the consideration of secondary particles and light fragments for nuclear reactions.
The results serve as benchmarks for further estimations and triggered the improvement for nuclear reaction codes and Monte-Carlo models, thus, contributing to nuclear safety in general.

R447 New measurement of the 19F(α,n)22Na cross section

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The $^{19}F(\gamma,n)^{22}Na$ reaction cross section has an uncertainty of approximately 25% in the range of 3 - 8 MeV. Previous measurements are discrepant and have issues including large systematic uncertainties, poor energy resolution, and limited energy ranges. Higher precision for this cross section is needed because it is the foundation of a self-interrogating non-destructive assay (NDA) technique used to determine the enriched Uranium content in UF6 storage cylinders. The cross section uncertainty, however, limits the accuracy of this NDA technique to approximately 40%. To address this, we have made two new, complementary measurements of this cross section. In the first, we bombarded LaF3 targets with 4He beams and measured over 4000 neutron time-of-flight spectra at 135 different alpha energies ranging from 3.9 – 6.7 MeV at the University of Notre Dame. In the second, we bombarded a helium gas target with 19F beams at Oak Ridge National Laboratory and measured the resulting neutrons and ^{22}Na recoils in time coincidence. From these data sets, we have determined an absolute cross section for $^{19}F(\gamma,n)^{22}Na$ to an average precision of 7.6%. The new cross section enables improved interpretations of NDAs of containers of fluorinated actinide compounds of any size, configuration, and enrichment. The impact of our results on an NDA simulation of a standard UF6 container will be shown.

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I448 Nuclear data sensitivity and uncertainty assessment of sodium voiding reactivity coefficients of an ASTRID-like Sodium Fast Reactor

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The EU 7th Framework ESNII+ project was launched in 2013 with the strategic
orientation of preparing ESNII for Horizon 2020. ESNII stands for the European Industrial Initiative on Nuclear Energy, created by the European Commission in 2010 to promote the development of a new generation of nuclear systems in order to provide a sustainable solution to cope with Europe's growing energy needs while meeting the greenhouse gas emissions reduction target [1].
The designs selected by the ESNII+ project are technological demonstrators of Generation-IV systems. The prototype for the sodium cooled fast reactor technology is ASTRID (standing for Advanced Sodium Technological Reactor for Industrial Demonstration), which building phase is foreseen to be initiated in 2019.
The ASTRID core has a peculiar design which was created in order to tackle the main neutronic challenge of sodium cooled fast reactors: the inherent overall positive reactivity feedback in case of sodium boiling occurring in the core. Indeed, the core is claimed by its designers to have an overall negative reactivity feedback in this scenario. This feature was demonstrated for an ASTRID-like core within the ESNII+ framework studies performed by nine European institutions [2].
In order to shift the paradigm towards best-estimate plus uncertainties, the nuclear data sensitivity analysis and uncertainty propagation on reactivity coefficients has to be carried out.
The goal of this work is to assess the impact of nuclear data uncertainties on sodium boiling reactivity feedback coefficients in order to get a more complete picture of the actual safety margins of the ASTRID low void-core design.
The nuclear data sensitivity analysis is performed in parallel using SCALE-TSUNAMI 3D and the newly developed GPT SERPENT 2 module. A comparison is carried out between both methodologies. Uncertainty on the sodium boiling reactivity feedbacks is then calculated using TSAR module of SCALE and the necessary safety margins conclusions are drawn.

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R449 Sensitivity and uncertainty analysis of keff to nuclear data in a pressurized water reactor

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Sensitivity and uncertainty analysis of keff to nuclear data will be done in a pressurized water reactor(PWR) . First, we will create a full PWR model by a Monte Carlo code RMC which developed by Tsinghua University. Then, critical analysis will be studied with continuous energy cross section library, while using iterated fission probability method to calculate sensitivity coefficient of keff respect to important nuclear reaction cross-section data. Further, the covariance data will be used for uncertainty analysis of keff in PWR. At last through the study of the calculation results, we can screen out the important nuclear data which affect the accuracy of the keff calculation in PWR.

R450 Comparison of ENDF/B-VII.1 and JEFF-3.2 in VVER-1000 operational data calculation

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Safe operation of a nuclear reactor requires an extensive calculational support. Operational data are determined by full-core calculations during the design phase of a fuel loading. Loading pattern and design of fuel assemblies are adjusted to meet safety requirements and optimize reactor operation. Nodal diffusion code ANDREA is used for this task in case of Czech VVER-1000 reactors. Nuclear data for this diffusion code are prepared regularly by lattice code HELIOS. These calculations are conducted in 2D on fuel assembly level. There is also possibility to calculate these diffusion data by Monte-Carlo Serpent code. It can make use of alternative evaluated libraries.

All calculations are affected by inherent uncertainties in nuclear data. It is useful to see results of full-core calculations based on two sets of diffusion data obtained by Serpent code calculations with ENDF/B-VII.1 and JEFF-3.2 nuclear data including also decay data library and fission yields data.

Design of current TVSA-T fuel assemblies for Czech VVER-1000 reactors is shortly summarized together with the reactor core. Nuclear data required by ANDREA code are shown and the procedure to obtain them by Serpent code is described.

Comparison is based directly on fuel assembly level data. The greatest differences are identified and the reasons are found in the evaluated data. The analysis is focused on fuel mixture data and gadolinium burnable absorbers.

The next step is comparison of operational data. These include especially boric acid concentration in moderator and assembly power distribution during reactor operation.

This study illustrates effect of evaluated nuclear data library on full-core calculations of a large VVER-1000 reactor core. The level of difference which results exclusively from nuclear data selection can help to understand the level of inherent uncertainties of such full-core calculations.

R451 Impact of nuclear data uncertainty on criticality safety calculations for spent nuclear fuel geological disposal

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In the design of a spent nuclear fuel disposal system, one important condition is to show that the configuration remains subcritical during long periods ranging from 10,000 to 1,000,000 years depending on the regulations. K-eff eigenvalue calculations are affected by nuclear data uncertainty mainly in the burn-up calculation following reactor operation and in the criticality calculation for the canister loaded with the spent fuel assemblies.
Estimations of the uncertainty in the discharge compositions from the CASMO5 burn-up calculation phase are employed latter in the final MCNP6 criticality computations for the intact canister configuration; in between SERPENT2 is employed to get the spent fuel composition along the decay period.
The impact of nuclear data uncertainty in the k-eff value should be included in the subcriticality estimation to enforce safety. Nuclear data uncertainty is propagated by Monte Carlo sampling in the burn-up, decay and criticality calculation phases and representative values for fuel operated in a Swiss PWR plant will be presented as an estimation of this impact.

S452 Anisotropic scattering cross section treatment for reactor pressure vessel fast neutron fluence calculations

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Maintaining the structural integrity of the reactor pressure vessel (RPV) is a critical concern related to the safe operation of nuclear power plants. An accurate calculation of the fast neutron fluence (E > 1.0 MeV or E>0.1MeV) at the RPV is necessary to estimate the structural integrity over the designed lifetime and to support analyses for a potential plant life extension. The analysis of the effects of different treatments for anisotropic scattering cross section on the AP1000 RPV fast neutron fluence is not elaborated at present. In this paper, the corresponding influence factors have been studied, which are based on the discrete ordinates method.
Differential scattering cross sections may contain strong coupled energy-angle dependence, especially when the continuous energy variable of the transport equation is approximated by the multi-group approximation. The angular dependence of the differential scattering cross section is typically represented as a truncated Legendre series expansion. If the scattering cross section is highly anisotropic, these expansions may result in negative regions in the interval. These negative regions are likely to cause negative components in the discrete ordinates scattering source, which is non-physical and may adversely affect the iterative convergence and accuracy. To minimize the effects, transport approximation, which requires data from the (N+l)th Legendre moments of the cross sections to prepare a corrected N-table set, has been employed. Currently, the most frequently applied diagonal and Bell-Hansen-Sandmeier (BHS) methods, making an attempt to correct for anisotropy in the scattering matrix, are especially effective for forward-peaked scattering. The effects of truncated Legendre expansion and transport corrections based on RPV fluence calculations for pressurized water reactor are examined. The analysis shows that the different order of Legendre expansion ($l \geq 3$) introduces a deviation within 4% and the fixup is not necessary for the negative scattering source. Furthermore, whether to adopt the transport correction has a great impact on the results, the maximum bias of which can reach to 10%. The discrepancy between diagonal and BHS methods is smaller, less than 2%.

S453 Distribution of 14C in neutron irradiated graphite from RBMK-1500 reactor

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Graphite is widely used as a moderator, reflector in gas-cooled, RMBK and is planned in new generation Gen-IV nuclear reactors. Large quantities of irradiated graphite waste from graphite-moderated nuclear reactors existing up to now in the future indicates the need for a graphite waste management strategy. The greatest long-term radiological concern of contamination is ^{14}C with a half-life of 5730 years. For graphite treatment, disposal or recycling, concentration of radioactive contaminants in spent graphite should be identified and for proper evaluation the microscopic cross sections of their production reactions should be improved (for instance $^{12}C(n,\gamma)^{13}C$, $^{13}C(n,\gamma)^{14}C$, $^{13}C(n,\alpha)^{10}Be$ and $^{14}N(n,p)^{14}C$). Since the 1960s much effort has been made to understand the processes in the irradiated graphite. Despite the wide knowledge there are still gaps in understanding of graphite damage at the atomic level. Nowadays it is believed that significant concentration of radiological contamination exists in the surface layers of irradiated graphite. This work aims to characterize nuclear graphite of RBMK-1500 concerning ^{14}C formation in N environment and it distribution on the graphite surface layer and in the volume. The experimentally observed ^{14}C activity in the RBMK-1500 graphite samples is about 130 kBq/g, the calculated part form $^{13}C(n,\gamma)^{14}C$ is about 37%. This demonstrates the importance of nitrogen activation path and demands comprehensive investigation. Characterization of the chemical nature of ^{14}C in irradiated graphite would help in optimizing the chemical and physical processes for nuclear graphite utilization as well as decommissioning process of Ignalina NPP and other RBMK type reactors.

S454 Multigroup cross section library for gas cooled fast reactor applications

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The Gas Cooled Fast (GFR) reactor is one of the most promising concepts in GEN IV strategy, while GFR2400 is the pre-conceptual design incorporating the most challenging technical solutions for utilization of all features of high temperature and fast neutron spectrum. The special design of the fuel cladding, where composite materials and metallic liners are considered, UPuC fuel, Zr_3Si_2 reflector and He coolant create a unique system which however lacks any previous experimental and operational experience. Deterministic approach is an inseparable part of the design process but is strongly dependent on the quality of multigroup cross-section data. This paper presents the development process of such multigroup cross section library for GFR applications where an influence of neutron spectra from continuous energy Monte Carlo calculation and various fine and coarse group energy structures are investigated. The optimization procedure is based on key parameters, like reactivity effects, reaction rates of resonance materials as well as kinetic parameters. As reference the results from CE Monte Carlo calculations are considered. The expected applicability of the developed library will cover the area of sensitivity and uncertainty calculations; similarity assessments; static design and validation calculations; and for core simulators.

I455 The use of nuclear data in the field of nuclear fuel recycling

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The AREVA NC-La Hague facility in Manche, France, has been the first industrial facility for nuclear fuel recycling. From the received used fuel assemblies, the depleted uranium and the plutonium are extracted for further use for energy production purposes. Furthermore, the fission products and minor actinides on the one side, and the hulls and end-pieces on the other side, are adequately packaged for disposal. The used fuel is therefore separated into four very different materials.
The processing of the used fuel is governed by quantities such as specific activity, thermal heat, energy potential of the end-products, as well as by high standards of criticality-safety. Ahead of the reception and reprocessing, all these quantities are assessed from the radionuclides inventory of the used fuel, calculated with CESAR [1]. The latter is a fast and accurate depletion code, developed by CEA in partnership with AREVA NC, which uses the European nuclear data library JEFF3.1.1. [2]. Furthermore, some physical quantities of interest (such as radionuclides inventory, activity, specific thermal power) are measured on-line with the recycling process, through a large array of detectors, which may rely on particular radionuclides [3].
Given the variety, and particularity of the handled nuclear materials (used fuel as an input, and depleted uranium, plutonium, vitrified fission products and minor actinides and compacted waste as an output), the use of nuclear data on the La Hague plant is specific, and paramount nuclear data for the recycling may differ from the most important nuclear data for the field of reactors, for example. Indeed, a radionuclide which would bear a minor role in the used fuel may become prominent once the materials are separated, regarding the physical properties of the new mixture.
The La Hague plant has therefore worked to identify a list of the most important radionuclides for its application, relying on the process monitoring methods, and the end-products expectations.
The current use of nuclear data at the La Hague plant will be presented, according to the role they play in the inventory calculation of the most important radionuclides.

[1] Jean-Marc Vidal, Romain Eschbach, Agnès Launay, Christophe Binet, and Jean-François Thro. "CESAR5.3: An Industrial Tool for Nuclear Fuel and Waste Characterization with Associated Qualification-12067." Waste Management (2012).; [2] Alain Santamarina, and David Bernard. "The recommended JEFF3.1.1 file and CEA2005V4 library for accurate neutronic Calculations." JEFF Report, OECD/NEA (2009). ; [3] Cyrille Eleon, Christian Passard, Nicolas Hupont, Nicolas Estre, Benjamin Battel, Philippe Doumerc, Thierry Dupuy, Marc Batifol, Gabriele Grassi, "Status of the nuclear measurement stations for the process control of spent fuel reprocessing at AREVA NC/La Hague". ANIMMA (2015)

R456 An in-depth analysis of MA fission chambers measurements in the FCA IX experimental programme

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FCA is a zero power facility located at Tokai in Japan. The FCA-IX experimental programme exhibits 7 different cores with a variety of different neutron spectra. This has been achieved through the use of different moderators and different Uranium enrichments (93% for most of them except FCA-IX-7 where it is 20%).
Fission Chambers of seven different nuclides: ^{237}Np, ^{238}Pu, ^{239}Pu, ^{242}Pu, ^{241}Am, ^{243}Am and ^{244}Cm were used to measure ratios of fission reaction rate. Mass quantitative determinations of the electrodeposited nuclides were carried out through spectral analysis using a surface barrier silicon detector and a pulse height analyzer. The quantitative determination errors for electrodeposited nuclides were 3% for ^{244}Cm and 1.5% for the other.
Uncertainties are calculated with COMAC V0 covariances associated for the JEFF3.1.1 library, with COMAC V1 covariances associated for the JEFF32 library, with their own covariances for ENDFB71 and for JENDL40. The critical mass uncertainties are dominated by U235 capture contribution for JEFF3.1.1, JEFF3.2 and ENDFB71. However, uncertainties with JENDL4.0 are much lower due to a much reduced ^{235}U capture contribution.
In this work, we analyze in detail the Minor Actinide fission chambers being measured during the FCA-IX programme. Using covariance matrices associated to JEFF3.2 libraries (COMAC V1.0), ENDFB VII-1 and JENDL4.0 helps tracking the origin of nuclear data uncertainty in the calculation of measured fission rate ratios. The fact that these cores are all enriched Uranium introduce an indirect effect due to the capture cross section of ^{235}U and that limits the possible feedback on the cross sections of minor actinides that have been measured through fission chambers. However, the fission rates of ^{237}Np, of ^{243}Am and ^{244}Cm have a direct effect on significantly higher than those of the ^{235}U and ^{239}Pu in contrast to the ^{238}Pu, ^{242}Pu and the ^{241}Am. In the full paper, indications concerning Minor Actinide fission cross sections as a consequence of these analyses will be drawn.

Reference Document: Establishment of Benchmark Problems for TRU Fission Rate Ratios of FCA-IX Assemblies, M. Fukushima, A. Oizumi, H. Iwamoto, Y. Kitamura, Ref. JAEA-Data/Code/2014-030

R457 Update and evaluation of decay data for spent nuclear fuel analyses

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Studsvik's approach to spent nuclear fuel analyses combines isotopic concentrations and multi-group cross-sections, calculated by the CASMO5 or HELIOS2 lattice transport codes, with core irradiation history data from the SIMULATE5 reactor core simulator and tabulated isotopic decay data. These data sources are used and processed by the code SNF to predict spent nuclear fuel characteristics. Recent advances in the generation procedure for the SNF decay data are presented. The SNF decay data includes basic data, such as decay constants, atomic masses and nuclide transmutation chains; radiation emission spectra for photons from radioactive decay, alpha-n reactions, bremsstrahlung, and spontaneous fission, electrons and alpha particles from radioactive decay, and neutrons from radioactive decay, spontaneous fission, and alpha-n reactions; decay heat production; and electro-atomic interaction data for bremsstrahlung production. These data are compiled from fundamental (ENDF, ENSDF, TENDL) and processed (ESTAR) sources for nearly 3700 nuclides. A rigorous evaluation procedure of internal consistency checks and comparisons to measurements and benchmarks, and code-to-code verifications is performed at the individual isotope level and using integral characteristics on a fuel assembly level (e.g., decay heat, radioactivity, neutron and gamma sources). Significant challenges are presented by the scope and complexity of the data processing, a dearth of relevant detailed measurements, and reliance on theoretical models for some data.

R458 Antineutrino emission and gamma background characteristics from a thermal research reactor

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For the first time the summation method has been coupled with a complete reactor model, in order to predict the antineutrino emission of the OSIRIS research reactor in Saclay, France.
This modelling allows us predicting the low energy part of the antineutrino spectrum, below the inverse beta decay detection threshold, and evidencing the important contribution of actinides to the antineutrino emission. The obtained antineutrino energy spectra span an energy range beyond the one of the measured ILL and Garching integral beta spectra, which is the energy range of the converted spectra, making of the summation method spectra the only available predictions in these energy regions (below 1.8MeV and beyond 7-8MeV). In addition, we provide the corresponding off-equilibrium corrections, deduced for the first time from the simulation of a complete reactor core, that can only be computed with the summation method.
Experimental conditions at short distance from research reactors are challenging, because the reactor itself produces huge gamma and neutron backgrounds that induce accidental and correlated backgrounds in an antineutrino target. The understanding of these backgrounds is of utmost importance and triggered the second part of the work to be presented at this conference.

I459 Test of internal-conversion theory with a measurement in 111mCd

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Internal conversion is a general property of the atomic nucleus by which atomic electrons can compete with photons in the emissions from a nuclear electromagnetic transition. The internal conversion coefficient (ICC) for such a transition is the ratio of its electron to gamma-ray emission. ICCs are essential to the construction of most nuclear decay schemes and, because ICCs are not easy to measure precisely, scientists have relied for many decades on ICC tables for the purpose. However there are some ambiguities in the theory that can only be settled by comparison with actual measurements. One in particular was the treatment of the atomic vacancy created in the wake of the emitted electron: Some calculations ignored the effect of the atomic vacancy, while others did not. If anything, world data appeared to favor the former even though the lifetime of the atomic vacancy was known to exceed the time required for the electron the leave the vicinity of the atom.

Thus building a standard experimental ICC dataset became an obvious goal but before 2002, when we started our work, only 20 out of hundreds of measured values in the literature had a reported precision of 2% or better. Since that time we have exploited a precise method to measure ICCs using, instead of electrons, the x rays that follow the filling of the atomic vacancy. These x rays are detected in the same precisely efficiency calibrated HPGe detector ($\pm$0.15%) as are the γ rays from the transition of interest. We have by now added six critical cases to the most precise set of ICCs, of which we report here our most recently measured one, the 151-keV *E*3 transition in ^{111m}Cd. Like all our previously measured cases this result agrees with the version of the theory that includes the presence of the atomic vacancy. Collectively, our results decisively reject the version that ignores the vacancy.

Our ICC measurements are of significance for the nuclear data community because, on account of them, the Evaluated Nuclear Structure Data File – ENSDF – several years ago adopted the ICC calculations that included the atomic vacancy.

R460 A metallic magnetic calorimeter dedicated to X-ray spectrometry of radionuclides

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Many radionuclides emit relatively intense X-rays consecutively to their decay. The X-ray intensities depend mainly on the internal conversion coefficient of the associated gamma transition. Thus, measuring precisely the X-ray intensity indirectly provides information on the balance of the gamma levels and their internal conversion coefficients (ICCs). In addition, when the X-ray intensities of a given radionuclide are observed, their presence in a particular material can be quantified, but only if these emission intensities are well known. The main problem is a lack of accurate intensity measurements in the low energy range below 25 keV that can be solved using metallic magnetic spectrometers.

Actinides are especially concerned by this problem because the majority emit intense L X-rays in the range of 10 – 25 keV. Moreover, problems exist for some of their ICCs due to anomalous electric dipole transitions, meaning their ICCs cannot be calculated and are therefore based on nuclear and atomic data measurements.

The difficulty of accurately measuring L X-ray intensities is related to the complexity of the spectra which is unresolvable with the energy resolution of semiconductor spectrometers. A spectrometer based on the technology of metallic magnetic calorimeters (MMCs) has been developed. MMCs are cryogenic detectors, i.e. they measure the absorbed X-ray energy as a temperature elevation and by working at very low temperature (few tens of mK) they can achieve energy resolutions one order of magnitude better than semiconductor spectrometers.

The performance of the developed MMC has been derived from measurements of the L X-ray spectra of ^{210}Pb and ^{241}Am. An energy resolution of ~26 eV has been obtained between 10 – 26 keV. Moreover, the MMC has a special absorber that offers a constant efficiency, thus minimizing the efficiency correction in the determination of the relative L X-ray intensities.

Recent results will be presented and compared to available data and calculations, along with perspectives for the future.

R461 Measurement of the relative gamma ray emission probabilities from the electron capture decay of 153Gd

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^{153}Gd has a recommended half-life of 240.4 d and decays by 100% electron capture to the ground state (*I* = 4%) and four identified excited levels of ^{153}Eu, which is the stable A=153 isobar. Nine characteristic -ray emissions have been identified from the de-excitation of these four levels to the ground state with the two most intense emissions from the spin/parity 5/2$^-$ (I (97.4 keV) = 29.0 %) and 3/2$^+$ (I (103.2 keV) = 21.1 %) nanosecond isomeric levels. The nuclear data evaluation conducted by the Decay Data Evaluation Project (DDEP) reported inconsistencies in the measured emission probabilities in the published literature, with a number of identified rays that could not be placed in the level scheme. In the current work two HPGe -ray spectrometers were utilised, both with full-energy peak efficiency curves determined using a suite of radioactive sources that were traceable to primary standards of radioactivity. Three aliquots of radiochemically pure ^{153}Gd were measured multiple times in matching geometries. The -ray emission probabilities of seven rays (including the previously unplaced 151 keV ray emission) have been determined relative to the 97.4 keV ray emission. These have been determined with an approximately factor of two improvement in the precision than previously quoted e.g. . The determined values for the rays with energies less than 100 keV show discrepancies with the recommended values.

R462 A low background ionisation chamber for alpha-spectroscopy

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The goal of designing a low background ionisation chamber is to measure long lived alpha-decay half-lives which might interfere with rare event searches. Such decays play a part in many fields in nuclear physics and are difficult to measure. A lot of Geiger-Nutall studies also depend on them. Among others the research is specifically aimed at the precision measurements of alpha emitters within the Lanthanide region. Obviously any short living or other alpha emitter can be explored as well. The excellent energy resolution would also allow to search for excited states in alpha-decays.

To achieve this goal a gridded ionisation chamber was constructed using the Frisch-Grid design. The design is optimised for low energy alpha decays in two ways. The first one is the reduction of background from cosmic muons, radioactive decay chains and noise through the use of a secondary chamber that acts as a veto and dedicated materials. The second is a DAQ system that allows the recording and storage of each FADC pulse. Through further pulse shape analysis we are able to determine not only the energy of the alpha event, but also the position. Comparing this data to Monte Carlo simulation allows us to reach unprecedented levels of precision.

In this talk the design and performance of the chamber will be presented. A background rate of only (10.9\pm0.6) counts per day has been achieved in the energy region of 1 MeV to 9 MeV and improvements are possible. This low background rate and size of the chamber allow precision measurements of long living alpha decays with half-lives in the region of 1x1015 years. A re-measurement of the $_{147}$Sm half-life will be presented and compared with existing measurements and options for future measurements are discussed.

S463 Beta-strength and anti-neutrino spectra from Total Absorption Spectroscopy of a decay chain 142Cs->142Ba->142La

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Understanding beta strength function and resulting pattern of energy release in the decay of fission products is crucial for the analysis of processes occurring in nuclear fuel in power reactors, for the transportation and storage of radioactive waste [1-4] as well as for the analysis of processes involving reactor anti-neutrinos [5-7]. In particular, based on earlier existing data in the Evaluated Nuclear Structure Data Files (ENSDF), the decay of ^{142}Cs was expected to provide an important contribution to the high energy part of reactor anti-neutrino spectra [8,9].
The activities in the mass A=142 decay chain have been investigated by means of the 6-ton, Modular Total Absorption Spectrometer (MTAS) [10] at the ORNL's Tandem-ISOL facility. MTAS efficiency for full gamma energy absorption is about 78 % and 70% for 0.3 MeV and 5 MeV single γ-rays, respectively. MTAS results obtained for the decay of ^{142}Cs, ^{142}Ba and ^{142}La will be presented and discussed with respect to the beta-strength and antineutrino energy spectra. In particular, the observed shift of ^{142}Cs-emitted anti-neutrinos towards lower energies will be addressed during my presentation.

1] A. L. Nichols, "Nuclear Data Requirements for Decay Heat Calculations", Lectures given at the Workshop on Nuclear Reaction Data and Nuclear Reactors: Physics, Design and Safety", Trieste, Italy, 25 February - 28 March 2002, http://users.ictp.it/~pub_off/lectures/lns020/Nichols/Nichols.pdf ; [2] "Assessment of fission product decay data for decay heat calculations" OECD 2007, NEA No 6284, vol. 25, ISBN 978-92-64-99034-0 ; [3] A. Algora et al., PRL 105, 202501, 2010; [4] K. P. Rykaczewski, Physics 3, 94, 2010; [5] G. Mention et al., Phys. Rev., D 83, 073006, 2011; [6] Th. A. Mueller et al., Phys. Rev., C 83, 054615, 2011; [7] M. Fallot et al., PRL 109, 202504, 2012; [8] D. A. Dwyer et al., Phys. Rev. Lett. 114, 012502, 2015; [9] A.A. Sonzogni et al., Phys. Rev. C 91, 011301(R), 2015; [10] M. Wolińska-Cichocka et al., Nuclear Data Sheets 120, 22, 2014

S464 Determination of the gamma emission probabilities of 239Np

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^{239}Np is an important nuclide as the decay daughter of ^{239}U and it decays to ^{239}Pu by emitting beta particles and gamma rays with a half life of 2.356 days. The data of the emission probabilities of its gamma-rays in the open references are consistent except that the main gamma-ray of 106.1 keV, the emission probability of which varies from 25.9% to 27.2%. To verify the emission probability of 106.1 keV gamma-ray of ^{239}Np, a N-type coaxial HPGe detector was calibrated using ^{241}Am、^{133}Ba、^{60}Co、^{152}Eu and ^{155}Eu reference gamma sources to get the accurate efficiency of 106.1 keV gamma-ray. ^{239}Np was purified from solution containing ^{243}Am, where ^{239}Np is the alpha decay daughter of ^{243}Am. The specific activity of ^{239}Np solution was determined by a 4πβ(PC)-γ coincidence counting device. There were 6 gamma sources prepared to measure with the HPGe detector, and the activity of ^{239}Np in each gamma source was calculated with the weights of the solution contained in it. The emission probability of 106.1 keV of ^{239}Np is measured to be 25.4%(1±0.8%), which is consistent with 25.9%, the value measured by BIPM.

S465 The measurements of the decay data of Lu-173 and Lu-174g

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^{175}Lu(n,2n)$^{174m, g}$Lu(n,2n)^{173}Lu are important neutron reactions to monitor the high energy neutron fluxes and the residual nuclei, $^{174m, g}$Lu and ^{173}Lu, are usually measured by a HPGe spectrometer conviniently so that the decay data such as half lives and gamma-ray emission probabilities of $^{174m, g}$Lu and ^{173}Lu are indispensable. There are evaluated decay data only in ENDF/B 7.1 and JEFF 3.1.1 among the major evaluated nuclear data libraries, where the most data are almost same besides the gamma-ray emission probabilities of ^{173}Lu are higher in ENDF/B 7.1 than that in JEFF 3.1.1. Yb metal as a target was irradiated by 20 MeV proton beams on a tandem accelerator in CIAE to produce $^{174m, g}$Lu and ^{173}Lu, and ^{176}Lu isotopic dilution methods based upon a laser resonance ionization mass spectrometer (LRIMS) and a thermal surface ionization mass spectrometer (TIMS) were employed to determine the numbers of nuclides of ^{174}Lu and ^{173}Lu in a solution containing the irradiated target. Several radioactive sources made from the solution had been measured by a HPGe detector during the past 7 years and the peak intensities of the characteristic gamma-rays from ^{174g}Lu and ^{173}Lu were analyzed to determine the half lives and gamma-ray emission probabilities. According to the measurements, the half life of ^{173}Lu is 1.45y, which is about 6.1% longer than the evaluated 1.37y, and the gamma-ray emission probabilities of ^{173}Lu is also different from the evaluated data, especially the emission probability of 636.1 keV gamma-ray of ^{173}Lu is 10.3% higher than the value in ENDF/B 7.1. The half life of ^{174g}Lu is 3.43y, about 3.6% longer than the evaluated 3.31y, and the emission probabilities of 76.5 keV and 1241.8 keV gamma-rays of ^{174}Lu are 4.4% lower and 12.1% higher than the evaluated data in ENDF/B 7.1, respectively.

S466 Beta feeding anomaly in 43K(ß)43Ca

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Decay spectroscopy of neutron-rich ^{43}K were performed with primary aim to deduce the beta-feeding intensities of each level in the daughter ^{43}Ca, in particular, the first-forbidden (ΔJ = 2) beta transition of ^{43}K(3/2$^+$) to ^{43}Ca(7/2$^-$) ground state which has, reported to have, high value of feeding intensity [E.K. Warburton *et al*., Phys. Rev. **C38**, 2822 (1988)] relative to the (ΔJ = 1) ^{43}K(3/2$^+$) to ^{43}Ca(5/2$^-$) first excited state.

Radioactive ion beam (RIB) of ^{43}K ($t_{1/2}$ = 22.3 h) have been produced by the RIB facility at Variable Energy Cyclotron Centre (VECC), Kolkata, India [A. Chakrabarti, Nucl. Instr. and Meth. **B261**, (2007) 1018], utilizing the Isotope Separator On-Line (ISOL) technique. The radioactive ^{43}K were produced by the nuclear reaction of ^{40}Ar(^{4}He, p)^{43}K with the primary alpha (^{4}He) beam of 18 MeV of energy and up to 1 μA of beam current, delivered from the K130 cyclotron. The required ions of interest (^{43}K) were implanted on a 'Al' catcher foil. Off-line decay measurements were done by placing the 'Al' catcher foil in front of a Clover HPGe detector at a distance of 5 cm. The ^{43}K decay lines could be clearly observed in the spectrum. No other gamma lines from any possible contaminants are observed except for the standard identified room background lines. The time decay of each of the gamma rays from ^{43}K was followed in 1-hour step and the half-life corresponding to each gamma-line was measured. The measured decay half-life of ^{43}K was found to be consistent with the reported value (22.3 h). The beta–feeding intensity in each level of ^{43}Ca has been estimated from the difference in gamma ray intensities and some deviations have been observed with the previous measurements.

Coincidence measurements using clover HPGe detectors and a total absorption gamma spectroscopy (TAGS) measurement using the modular TAGS facility at VECC with BaF_2 detectors [G. Mukherjee *et al*., EPJ Web of Conferences **66**, 11026 (2014)] are being set up for a detailed understanding of the beta-feeding branching ratios of ^{43}K to the levels in ^{43}Ca. The experimental details and the results will be discussed during the presentation.

I467 Total absorption spectroscopy of fission fragments relevant for reactor antineutrino spectra and decay heat calculation

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The accurate determination of reactor antineutrino spectra remains a very actual research topic for which new interrogations have emerged in the latest years. Indeed, after the "reactor anomaly"[1] – a deficit of measured antineutrinos at short baseline reactor experiments with respect to spectral predictions – the three international reactor neutrino experiments Double Chooz, Daya Bay and Reno have evidenced lately spectral distortions in their measurements w.r.t the same spectral predictions[2]. The latter predictions were obtained through the conversion of integral beta energy spectra obtained at the ILL research reactor[3]. Several studies have shown that the underlying nuclear physics required for the conversion of these spectra into antineutrino spectra is not totally under control[4]. The unique alternative to converted spectra is a complementary approach consisting in determining the antineutrino spectrum through nuclear data[5,6]. It was shown that beta properties of some key fission products suffer from the pandemonium effect[7] which can be circumvented through the use of the Total Absorption gamma-ray Spectroscopy technique (TAS). The two main contributors to the PWR antineutrino spectrum in the region where the spectral distortion has been observed, ^{92}Rb and ^{96}Y, have been measured at the radioactive beam facility of the university of Jyväskylä in two TAS experiments[8,9]. At this conference, we will present the results of the analysis of the TAS measurements of the β-decay properties of ^{92}Rb and ^{96}Y.

[1] G. Mention et al. , Phys. Rev. D 83 , 073006 (2011); [2] Double Chooz and Reno Collaborations in Proceedings of the Neutrino 2014 Conference, http://neutrino2014.bu.edu/; Daya Bay Collaboration in Proceedings of the ICHEP 2014 Conference, http://ichep2014.es/.; [3] P. Huber, Phys. Rev. C 84, 024617 (2011). ; [4] A. C. Hayes et al., Phys. Rev. Lett. 112, 202501 (2014).; [5] M. Fallot et al., Phys. Rev. Lett. 109 , 202504 (2012). ; [6] A A. Sonzogni et al. , Phys. Rev. C 91 , 011301 (R) (2015). ; [7] J.C. Hardy et al. , Phys. Lett. B 71 , 307 (1977).; [8] A.-A. Zakari-Issoufou, Phys. Rev. Lett. 115 , 102503 (2015).; [9] V. Guadilla et al., to be published in Nuclear Instruments and Methods in Physics Research B (2016).

R468 Analysis of reactor-neutrino spectra fully based on the gross theory of beta-decay emphasizing the special role of odd-odd fission-product nuclides

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The gross theory of beta-decay (GT) had successfully been applied to describe the aggregate behavior of fission products (FPs) in reactors and it paved a way to recent drastic improvement of the prediction accuracy of the FP decay-heat on the firm basis of the modern total gamma-ray spectroscopy overcoming the pandemonium problem. In this background, here we applied the generation-2 GT (GT2) to calculate the reactor electron and antineutrino (leptons) spectra emitted from U and Pu samples by summing up all the contributions from decaying FPs. We made it clear what types of beta-transition and which short-lived FP nuclides are important to shape the lepton spectra. The calculation well reproduced the experimental lepton spectra within 25% for U-235 and Pu isotopes and within 10% for the most recent data of U-238 in the energy range below 8 MeV on the absolute-value basis without any tuning of parameters in the theory. In the energy range above 8MeV, however, we were confronted with a serious overestimation and concluded that it comes from the limit of the conventional GT treatment of odd-odd nuclides which dominate the shaping of the lepton spectra above 8 MeV. In order to overcome this difficulty, the effect of the beta-transition selection rules to low-lying levels was introduced into the framework of GT2 and it remarkably remedied the disagreement in the very high energy region of the reactor lepton spectra. Throughout the present arguments, however, we could not exclude a possibility that the lepton spectra by Schreckenbach *et al.* (practically the only one extensive series of measurements) are not free from any systematic bias. This work do not only provide us with a basis of calculating the reactor neutrino spectra for applications both in nuclear technology (*e.g.*, monitoring of operating reactors) and in basic physics (*e.g.*, θ_{13} determination or quest for sterile neutrinos), but also constitutes an essential part of the efforts toward more comprehensive and accurate description of the aggregate behaviors of FPs in nuclear reactors for a wide-range of technological applications.

R469 Tags measurements of 100nb ground and isomeric states for neutrino physics with the new DTAS detector

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The ground and isomeric states in 100Nb have been measured using TAGS technique for the first time. This nucleus is an important contributor to the antineutrino reactor spectrum (a 5.5% contribution to the antineutrino spectrum from 235U at energies around 4 MeV [1]), and it is priority one nucleus to the decay heat problem [2], since it is suspected to suffer from *Pandemonium* effect [3]. Furthermore, strong transitions from spherical to deformed nuclear shapes are predicted near A=100 [4], and TAGS technique has been proved to be a good tool to shed light on this problem [5].
The experiment was carried out in Jyväskylä with beams provided by the mass separator of the upgraded IGISOL IV facility [6]. Due to the small energy difference between the two states (314 keV), a precision trap-assisted separation was needed, and the JYFLTRAP double Penning trap system [7] was used in order to distinguish experimentally between the two decay paths. The 100Nb low spin isomer was populated selecting the 100Zr, whereas the 100mNb was obtained by using the high precision Ramsey cleaning purification technique [8]. Moreover, a combined measurement with the two isomers was performed.
The nuclei were implanted on a tape placed in vacuum at the centre of the new Decay Total Absorption γ-ray Spectrometer (DTAS) [9], that was commissioned with radioactive beams in this experiment [10], and in front of a β detector. The first TAGS analysis of the β-γ coincidences of these measurements will be reported on this work, and they show a large amount of new β intensity to high energy excited states close to the Q-value for both isomers, which means that indeed they are affected by *Pandemonium*.
In addition, a measurement of 140Cs, also purified by means of JYFLTRAP, was carried out. This nucleus contributes with a 3.4% to the antineutrino spectrum from 235U at energies around 4 MeV [1]. Although it was already measured with TAGS technique [11], it is an important measurement due to the large ground state feeding of this decay, and it represents a good benchmark for comparison.

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R471 Total absorption studies of high priority decays for the reactor decay heat problem

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Beta decay is an important source of nuclear structure information and can be used as a tool to study fundamental interactions. In addition, the study of beta decays, is also very relevant for practical and fundamental physics applications, like the prediction of the decay heat from nuclear fuel and the prediction of the neutrino spectrum from a working reactor [1,2]. For those last applications it is crucial to obtain experimental data that does not suffer from the Pandemonium effect [3], a systematic error associated with the use of conventional high-resolution spectroscopy techniques.
In this contribution we will present recently analyzed high priority beta decays [4] using the total absorption technique and discuss their impact in the prediction of the reactor decay heat. The measurements have been performed at the IGISOL IV facility of the University of Jyväskylä (Finland) using the high purity beams provided by the JYFL Penning trap. When possible, comparisons will be given with earlier measurements [5] and with results obtained using different analysis techniques [6], which will allow us to compare the correctness of the different methods, and validate their use. Nuclear structure aspects of the different studied decays will be also addressed.

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I472 Neutron capture cross sections with unstable nuclei

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Accurate neutron-capture cross sections for radioactive nuclei near the line of beta stability are crucial for understanding the *s*-process nucleosynthesis. However, neutron-capture cross sections for short-lived radionuclides are difficult to measure due to the fact that the measurements require both highly radioactive samples and intense neutron sources. Essential ingredients for describing the γ decays following neutron capture are the γ-ray strength function and level densities. We will compare different indirect approaches for obtaining the most relevant observables that can constrain Hauser-Feshbach statistical model calculations of capture cross sections. Specifically, we will consider photon scattering using monoenergetic and 100% linearly polarized photon beams [1,2]. Challenges that exist on the path to obtaining neutron-capture cross sections for reactions on isotopes near and far from stability will be discussed [3,4].

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R473 Systematics of photon strengths from discrete nuclear data

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Much of our knowledge of photon strengths comes from average properties measured primarily in photonuclear and charged particle reaction studies. These data are typically modeled using variations of Brink-Axel theory, based on the strength of the Giant Dipole Resonance (GDR), and generally require assumptions about level densities, spin distributions, and statistical strength variations. The models often fail at lower gamma-ray energies. Brink-Axel theory refers only to E1 multipolarity transitions so it cannot be entirely correct to model photon strengths at any energy without including models for M1 and E2 multipolarities. Level densities appear to increase exponentially but spin distributions are still poorly known and parity distributions are typically ignored by most models. The transition strengths are widely believed to follow a Porter-Thomas (PT) distribution yet there is little experimental evidence to support this hypothesis and the maximum allowed strengths are limited by the shell model yet unlimited by the PT model. Nuclear data from the Evaluated Gamma-ray Activation File (EGAF), the Evaluated Nuclear Structure Data File (ENSDF), and the Atlas of Neutron Resonances provide a wealth of microscopic information that can help us tease out the individual M1, E1, and E2 photon strengths and their statistical distributions. In this talk I will discuss our nearly complete measurement of the thermal ^{56}Fe(n,γ) reaction and other (n,γ) data from the EGAF file, systematics of photon strengths for low-excitation levels from the ENSDF file, spin distributions in the resonance region from the Atlas, and compare the statistical distribution of photon and neutron widths with the PT model.

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R474 Breaking of axial symmetry in excited heavy nuclei as identified in experimental data

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A phenomenological prediction for radiative neutron capture is presented and compared to recent compilations of Maxwellian averaged cross sections and average radiative widths. The basic parameters for it, photon strength functions and nuclear level densities near the neutron separation energy are extracted from data without an ad-hoc assumption about axial symmetry - at variance to common usage. A satisfactory description is reached with a small number of global parameters when theoretical predictions on triaxiality (from constrained HFB calculations with the Gogny D1S interaction) are inserted into conventional calculations of radiative neutron capture. The photon strength is parametrized using the sum of three Lorentzians (TLO) in accordance to the dipole sum rule. The positions and widths are accounted for by the droplet model with surface dissipation without locally adjusted parameters [1]. Level densities are influenced strongly by the significant collective enhancement based on the breaking of axiality.
The replacement of axial symmetry by the less stringent requirement of invariance against rotation by 180° leads to a global set of parameters which allows to describe the photon strength function and the level densities in the nuclear mass range from mass number A 50-250 [2]. The impact of non-GDR modes adding to the low energy slope of photon strength is shown to be of minor importance for a comparison with experimental cross sections for neutron capture by even target nuclei from Cr to Cm. A reliable prediction for compound nuclear reactions also outside the valley of stability is expected.

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R475 Gamma strength functions and level densities from high-resolution inelastic proton scattering at very forward angles

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Inelastic proton scattering at energies of a few 100 MeV and forward angles including 0° provides a novel method to measure the Gamma strength functions (GSF) in nuclei in an energy range of about 5 – 25 MeV [1-4]. The experiments provide not only the E1 but also the M1 part of the GSF [5]. The latter is poorly known in heavy nuclei. A case study of ^{208}Pb indicates that the systematics proposed for the M1 GSF in RIPL-3 needs to be substantially revised. Comparison with γ decay data (e.g. from the Oslo method) allows to test the generalized Axel-Brink hypothesis in the energy region of the pygmy dipole resonance (PDR) well below the giant dipole resonance (GDR) crucial for the modeling of (n,γ) and (γ,n) reactions in astrophysical reaction networks. A fluctuation analysis of the high-resolution data also provides a direct measure of level densities in the energy region well above the neutron threshold [6], where hardly any experimental information is available.

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S476 Dipole strength in 80Se below the neutron separation energy for the nuclear transmutation of 79Se

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The gamma-ray strength function (GSF) in 80Se is an important parameter for the estimate of the neutron capture cross section on 79Se, which is one of the long-lived fission products (LLFPs). Until now, the so-called GSF method for 80Se was applied only above the neutron separation energy (Sn), and the evaluated 79Se(n,gamma) cross section has uncertainties caused by the GSF below Sn. We studied the dipole strength distribution of 80Se with a photon-scattering experiment using bremsstrahlung produced by an electron beam of an energy of 11.5 MeV at the linear accelerator ELBE at HZDR.
We identified about 220 gamma transitions below 9.6 MeV. The measured gamma spectrum was corrected for detector response and the atomic background was subtracted. We performed simulations of statistical gamma-ray cascades to obtain the intensities of inelastic transitions and to correct the intensities of the ground-state transitions for their branching ratios. The photoabsorption cross section of 80Se below Sn obtained from this analysis is combined with the (gamma,n) cross section and compared with results of calculations using TALYS. We also calculated the 79Se(n,gamma) cross section using the present experimental GSF as an input and compared it with TALYS results using standard GSFs, with data from JENDL4.0 and earlier work by other groups. In this report the results on the newly evaluated 79Se (n,gamma) cross section obtained with the GSF method are presented. This work was partly supported by a collaboration project of RIKEN and Hokkaido University Nuclear Data Centre.

S477 Isomer ratios for products of photonuclear reactions on 121Sb

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Using of high energy gamma-quanta as projectiles in nuclear reactions has some essential advantages for study of nuclear structure and nuclear reaction mechanisms. Indeed, gamma-quanta do not introduce large angular momentum and do not cause an additional contribution to excitation energy of compound nucleus due to absence of projectile’s binding energy. In addition, the precise non-discrete control of the incident gamma-quanta energy is possible. Very limited experimental data for the photonuclear reactions in the energy range (30-100) MeV for testing newly developed and available theoretical models was the major motivation for the present work.
Experimental measurements and deriving the isomer ratios for products of photonuclear reactions with multiple particle escape on antimony have been performed with bremsstrahlung of end point energies 38, 43 and 53 MeV. We used metallic antimony targets with natural isotopic abundance to study the reactions $^{121}Sb(\gamma,3n)^{118m,g}Sb$ and $^{121}Sb(\gamma,5n)^{116m,g}Sb$. For products of (γ,5n) reaction the interfering contribution of $^{116m,g}In$ nucleus from reaction $^{121}Sb(\gamma,n\alpha)^{116m,g}In$ was taken into account. The method of the induced activity measurement was used and for acquisition of gamma spectra we used HPGe spectrometer with GC 2019 detector. Linear accelerator of electrons LU-40 served as a source of bremsstrahlung. Energy resolution of electron beam was about 1% and mean current was within (3.8 – 5.3) μA. For the reaction $^{121}Sb(\gamma,3n)^{118m,g}Sb$ isomer ratios of yields were obtained as follows: 0.14 ± 0.04 (for endpoint energy of the bremsstrahlung spectrum $E_{\gamma max}$=38 MeV) and 0.15± 0.01 ($E_{\gamma max}$=43 MeV). For the $^{121}Sb(\gamma,5n)^{116m,g}Sb$ reaction the isomer ratio of yields was 0.25 ± 0.03 ($E_{\gamma max}$=53 MeV).

S478 Partial photoneutron cross section measurements on 209Bi

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The majority of partial reactions (γ,n), (γ,2n), (γ,3n) cross sections were obtained using quasi-monoenergetic annihilation photon beams at the Lawrence Livermore National Laboratory (USA) and France Centre d'Etudes Nucleaires de Saclay. There are significant discrepancies between the cross sections measured at the two facilities that cannot be resolved in a systematic manner. To solve this long standing problem, a direct neutron multiplicity sorting technique of obtaining (γ,xn) cross sections, where x=1,2,3, has been developed [1]. The neutron sorting method relies on the constant neutron detection efficiency relative to the energy of reaction neutrons. For this, we use a flat efficiency neutron detector recently designed for neutron multiplicity sorting measurements. The method has been applied for the first time for the case of ^{209}Bi at the experimental hutch GACKO (Gamma Collaboration Hutch of Konan University) of the gamma-ray beam line of the NewSUBARU synchrotron radiation facility [2], where laser Compton scattered quasi-monochromatic gamma-ray beams with energies up to 45 MeV were used to irradiate the target. This is the first of a series of experiments dedicated to partial photoneutron cross section measurements for the IAEA-CRP F41032 which make use of the new neutron multiplicity sorting method. We report here on the experimental technique, data analysis and results.

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S479 Resonances in odd-odd 182Ta

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Relatively small resonances on the low-energy tail of the giant electric dipole resonance such as the scissors or pygmy resonances can have significant impact on reaction rates. These rates are important input for modelling processes that take place in astrophysical environments and nuclear reactors. Recent results from the University of Oslo indicate the existence of a significant enhancement in the photon strength function for nuclei in the actinide region due to the scissors resonance [1]. Further, the M1 strength distribution of scissors resonances in rare earth nuclei has been studied extensively over the years [2]. In order to investigate the extent and persistence of the scissor resonance in other mass regions, an experiment was performed utilizing the NaI(Tl) gamma-ray detector array (CACTUS) and silicon particle telescopes (SiRi) at the cyclotron laboratory at the University of Oslo. Particle-gamma coincidences from the 181Ta(d,p)182Ta reaction were used to measure the nuclear level density and photon strength function of the well-deformed 182Ta system, to investigate the existence of resonances below the neutron separation energy. In this talk I will present and discuss the results of this investigation and place our findings in the context of previous work.

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I480 A unified understanding of (G,N) and (N,G) reaction cross sections with the gamma-ray strength function method

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The γ-ray strength function (γSF) is a nuclear statistical quantity that governs electromagnetic processes in radiative neutron capture and photoneutron emission. Since the (γ,n) and (n,γ) reaction cross sections are interconnected through the γSF in the Hauser-Feshbach model, an indirect method called the γ-ray strength function method was devised for constraining radiative neutron capture cross sections for unstable nuclei of direct relevance to nuclear astrophysics and nuclear engineering [1]. In this method, the γSF is tested against and justified by reproducing known (n,γ) cross sections. Thus, this method requires a unified understanding of (γ,n) and (n,γ) reaction cross sections over an isotopic chain. Recently, we applied the γSF method to Nd [2] and Sm [3] isotopic chains. Furthermore, based on this method, we plan to perform a series of (γ,n) cross section measurements for 18 nuclei from ^{205}Tl to ^{58}Ni for the IAEA-CRP F41032. We have so far performed measurements for ^{205}Tl, ^{203}Tl, and ^{89}Y in collaboration with the University of Oslo and the ELI-NP. I review applications of the γSF method.

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R481 Studying the photon strength function of 97Zr using the 96Zr(n,g) and 96Zr(d,p) reactions

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A major barrier in the study of neutron-induced nuclear reactions, which play a critical role in stockpile stewardship and astrophysics, is the impossibility of direct measurements with short-lived radioactive isotopes. Theoretical models can be used to describe these reactions, although the nuclear structure inputs such as the Photon Strength Function (PSF) for these exotic nuclei are often poorly constrained. Recently, a program to investigate the PSF for medium-mass nuclei has begun as a collaboration between Los Alamos National Laboratory (LANL) and Argonne National Laboratory (ANL), combining unique experimental capabilities from both laboratories. At the Manuel J. Lujan Neutron Scattering Center at LANL, The Detector for Advanced Neutron Capture Experiments (DANCE) provides direct measurements of gamma ray cascades from neutron capture reactions on stable or long-lived radioactive nuclei. At the Argonne Tandem Linear Accelerator System (ATLAS) facility at ANL, single neutron transfer reactions in inverse-kinematics provide complementary data on short-lived radioactive nuclei. The Helical Orbit Spectrometer (HELIOS) is a device that was designed to study transfer reactions in inverse kinematics by detecting the charged ejectiles inside of a large-bore solenoidal magnet. The APOLLO array was designed and built at LANL to be placed inside the magnetic field of HELIOS to measure gamma ray cascades from the nuclear states populated in neutron transfer reactions. As a test case for this research program, the ^{96}Zr(n,γ) reaction was measured using DANCE and the ^{96}Zr(d,p) reaction was measured using HELIOS+APOLLO. ^{96}Zr lies near the light mass peak in the ^{239}Pu fission spectrum, so neutron capture rates on the neutron-rich Zr isotopes are important for fission applications. While DANCE provides Multi-Step Cascade spectra from ^{97}Zr as well as cross section information, HELIOS+APOLLO will provide more detailed nuclear structure information about the intermediate states in ^{97}Zr. Initial results from the ^{96}Zr(d,p) and ^{96}Zr(n,γ) measurements will presented. This work benefited from the use of the LANSCE accelerator facility. Work was performed under the auspices of the US Department of Energy by Los Alamos National Security, LLC under contract DE-AC52-06NA25396.

R482 Nuclear level density, gamma-ray strength function of 240Pu and 239Pu(n,g) cross-section

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The level density and strength function of 240Pu below the particle separation threshold have been extracted from the (d,p) reaction with the Oslo Method [1,2]. The resulting level density and gamma-ray strength function of 240 are essential inputs to calculations of the (n,g) cross-section of 239 within a statistical framework [3] between several keV and MeV. Although there is accurate knowledge of the cross-section for thermal and low-energy neutrons, there is little reliable experimental information on fast neutrons. Without this constrain, predictions from major nuclear data libraries like ENDFB/VII.1 [4] and JENDL-4.0 [5] reveal discrepancies of up to about half an order of magnitude for incident neutron energies above 0.5 MeV. Thus the reference article to ENDFB/VII.1 states that "[t]hese reactions are so important that should new assessments, based on new measured data, lead to significant changes in these evaluated cross sections, there will be significant implications for nuclear applications, for example in our criticality calculations." [4]
In addition, recent studies the actinide isotopes 231-233Th, 232-233Pa, 237-239U, 238Np [6-8] have shown the occurrence of an increase in the gamma-ray strength function at about 2-3 MeV, which is interpreted as a low-energy M1 scissor mode. This work investigates the presence and strength of the scissors resonance in 240Pu and it's impact on the (n,g) cross-sections for 239Pu.

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R483 High-resolution study of the 113Cd(n,γ) spectrum by statistical decay model with discrete levels and transitions

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A new statistical decay code has been developed to study (n,γ) spectra in details. Our first case study is the ^{113}Cd(n,γ) spectrum which has been measured at the Budapest PGAA facility. A combined interpretation of ^{113}Cd(n,γ) and ^{114}Cd(γ,γ') reactions (latter measured at Dresden-Rossendorf) has just been published [1], but yet with a limited energy-resolution.
Here a study with ten-times improved energy-resolution for the low-energy (n,γ) spectrum will be presented. The goal is to understand whether this model can be used to improve the low-energy decay scheme and simultaneously maintain a good description of the discrete and continuum part of the spectrum of this important nucleus. The natural ^{NAT}Cd(n,γ) spectrum is very similar to the ^{113}Cd(n,γ) spectrum due to the dominant thermal neutron capture cross section of ^{113}Cd isotope, which has already been confirmed by comparing measurements on natural and enriched samples under identical conditions. For this study new measurements were made with no Compton suppression on natural Cd metal sample. This was necessary because the modeling of the Compton suppressed response function with GEANT4 was not satisfactory compared in quality to the modeling of the unsuppressed spectra. The simulated unsuppressed spectra were then used to unfold the unsuppressed ^{114}Cd spectrum. In the comparison of the results from the simulation code and the obtained full energy spectrum was used.
With the help of the comparison of the experimental and simulated spectra, the radiative neutron capture decay-scheme of ^{114}Cd is being extended and improved up to 3.2-MeV critical energy, using a combination of the extreme statistical-decay model and consideration of discrete primary transitions directly fed the levels below the critical energy from the capture state. An attempt is made to obtain the mixing ratio of the 1^+ and 0^+ capture states for the ^{114}Cd compound system.
In the long-term prospective more prompt-gamma spectra of nuclei excited with (n,γ) reactions will be studied.
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R484 Isospin splitting of the GDR and photoproton reactions on isotopes of molybdenum

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Photon activation technique is used to measure yields and cross sections of multinucleon photonuclear reactions on isotopes of natural molybdenum ^{92}Mo, ^{94}Mo, ^{95}Mo, ^{96}Mo, ^{97}Mo, ^{98}Mo, and ^{100}Mo. The obtained results are compared with photoneutron data available from literature and with predictions of nuclear reaction simulation packages. An improved method of equivalent photon normalization which is used to compare data from experiments using bremsstrahlung and quasimonochromatic gamma-ray beams in a unified way is described. The photoproton reaction yields reveal a strong dependence on the isospin splitting effect of the giant dipole resonance. Since it is currently not possible to take isospin effects into account with the widely used simulation packages a simple method of inclusion of these effects into a TALYS calculation is described. Calculated photoproton cross sections corrected in this way are in a good agreement with the experimental results.

I485 Good practices in provision of nuclear safeguards and security training course at integrated support center for nuclear nonproliferation and nuclear security

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More than five years have passed since the Integrated Support Center for Nuclear Nonproliferation and Nuclear Security (ISCN) was established under the Japan Atomic Energy Agency (JAEA) in December 2010 and started its activities, in response to the commitment of Japan at the Nuclear Security Summit in Washington D.C.. ISCN has been vigorously involved in the capacity building assistance on nuclear nonproliferation (safeguards) and nuclear security, mainly in the Asian region. It has provided 98 training courses with 2,720 participants in total up to January 2016. ISCN has been playing a major role in strengthening nuclear nonproliferation and nuclear security in this region, and this can be considered as one of the great results of the Nuclear Security Summit process. Particularly, ISCN's nuclear security training courses, primarily two-week course on physical protection of nuclear material and nuclear facilities, have been building up its own instructors in cooperation with the U.S. Department of Energy/National Nuclear Security Administration and Sandia National Laboratories. It has also been providing the courses with emphasis on universalization of the IAEA INFCIRC/225/Rev.5 and nuclear security culture. Furthermore, ISCN has provided the training courses for the experts in Japan making the best use of our knowledge and experience of organizing international training courses. The total number of the Japanese experts participating in ISCN courses reached to more than 1000. In addition to that ISCN conducted a special lecture on nuclear security culture at the thirteen nuclear power plant (NPP) sites in Japan, and two thousands worker at NPP joined the lecture. This shows that the ISCN has been recognized as an expert organization of nuclear security training support in Japan. In addition to that ISCN started the joint synchronized training with EC/JRC on nuclear safeguards. ISCN offered two week SSAC training at Tokai-mura, after that EC/JRC offered NDA training for some of the participants to ISCN training using actual nuclear materials at ISPRA site. This paper will describe the good practices at ISCN through five years activities mainly the progress in our nuclear safeguards and nuclear security training.

R486 The GENTLE project: graduate and executive nuclear training and lifelong education

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The continued interest in nuclear power in several EU Member States and the increasing interest in emerging and developing economies create a growing demand for highly educated nuclear engineers and scientists in industry, research, technical safety and governmental organisations. A highly skilled and well informed workforce is essential to safely maintain the current civil nuclear reactor fleet, decommission obsolete plants, be involved in new build where policy dictates, and deal with legacy and future spent fuel. In view of this, education and training (E&T) in the field of Nuclear Science and Technology is a key component of the nuclear infrastructure worldwide.
Because of the specific infrastructure needed for opportunities for working with radioactive materials in practical quantities, over the past decades nuclear education and training have been the combined effort of universities and (inter)national laboratories in many countries.
In the light of this the members of the GENTLE consortium, a joint effort by leading academic and research institutions in Europe, contribute to a sustainable lifelong E&T programme in the field of nuclear fission technology that meets the needs of the European stakeholders from industry, research and technical safety organisations.
Specifically, the GENTLE project aims at the successful implementation of the following joint E&T tools:
- Student research experience (SRE) to facilitate students from the participating universities to get hands-on experience in Europe's unique and specialised laboratories and participate in cutting-edge research.
- Intersemester courses (ISC) for graduate and post graduate students on specific industry related topics.
- A Massive Open Online Course (MOOC) on Nuclear Energy to train students and professionals in all theoretical and practical aspects involved in nuclear engineering.
The uniqueness of the GENTLE project lies in the facts that it offers high level education and training through a combination of top class teachers with Europe's unique nuclear infrastructure, thus providing an exceptionally well informed holistic approach, that will help Europe to maintain its leading position in the nuclear fission field, and attract high quality students and young professionals from all over the world.

R487 Knowledge management: role of the radiation safety information computational center (RSICC)

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The Radiation Safety Information Computational Center (RSICC) at Oak Ridge National Laboratory (ORNL) is an information analysis center that collects, archives, evaluates, synthesizes and distributes information, data and codes that are used in various nuclear technology applications. RSICC retains more than 2,000 software packages that have been provided by code developers from various federal and international agencies. RSICC's customers (scientists, engineers, and students from around the world) obtain access to such computing codes (source and/or executable versions) and processed nuclear data files to promote on-going research, to help ensure nuclear and radiological safety, and to advance nuclear technology. The role of such information analysis centers is critical for supporting and sustaining nuclear education and training programs both domestically and internationally, as the majority of RSICC's customers are students attending U.S. universities. Additionally, RSICC operates a secure CLOUD computing system to provide access to sensitive export-controlled modeling and simulation (M&S) tools that support both domestic and international activities. This presentation will provide a general review of RSICC's activities, services, and systems that support knowledge management and education and training in the nuclear field.

R488 Education and training in nuclear data by the Belgian SCK•CEN academy for nuclear science and technology

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Preserving and extending nuclear knowledge on peaceful applications of ionising radiation is a key function of the Belgian Nuclear Research Centre. It is the specific task of the SCK•CEN Academy to foster the transfer of nuclear knowledge, skills and attitudes towards students and professionals who are active in the nuclear field. To this end, the SCK•CEN Academy works on 4 tracks: (i) providing guidance to students, (ii) delivering courses, (iii) providing policy support in education and training matters and (iv) caring for critical-intellectual capacities for society. All nuclear themes that are subject of the R&D performed at SCK•CEN are also treated within the Academy.
In the domain of nuclear data and modelling of nuclear systems, the SCK•CEN Academy and the Expert Group on Nuclear Systems Physics have joined forces and have developed several training initiatives. University students from bachelor to PhD level can perform their thesis work or an internship at SCK•CEN, supervised and guided by our experts.
Often in close collaboration with the EC-JRC-IRMM in Geel (Belgium), the SCK•CEN academy provides academic courses on the handling and use of nuclear data for nuclear energy applications. By means of these courses, we actively try to bridge the worlds of “nuclear data generators” and “nuclear data users”, enforcing each other’s understanding of wishes and limits in both domains. Lately, the propagation of uncertainties using covariance data is point of strong common interest.

S489 Decay Data Evaluation Project (DDEP): dissemination and visualisation of reference decay data

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As a primary laboratory in the field of ionising radiation metrology, the Laboratoire National Henri Becquerel (LNE-LNHB), CEA Saclay, is involved in measurement, evaluation and dissemination of radioactive decay data.
Data measurements, obtained by various laboratories, are evaluated by an international commission of experts (Decay Data Evaluation Project) in order to establish a set of recommended decay scheme data. These data are subsequently distributed to users via various tools developed by the LNE-LNHB, which are well suited to each application domain.
New nuclide evaluations are regularly added to our database “NUCLEIDE” and periodically published in the BIPM-5 Monographie series, as the Mini Table of Radionuclides, and the alpha & gamma emissions library. They are also systematically added to our website (http://www.nucleide.org/NucData.htm) and uploaded to our web application “Laraweb” (http://laraweb.free.fr), dedicated to alpha and gamma spectrometry. “Laraweb” has been significantly improved and now proposes decay scheme visualisation and enhanced search criteria (energy, intensity, half-life, atomic mass, disintegration mode). Users may specify energy and intensity thresholds in order to easily obtain a synthetic view of the disintegration scheme of a given radionuclide. These new features of “Laraweb”, as well as the various publications and future developments, will be discussed in this paper.

S490 Experiments in the EXFOR library for evaluation of thermal neutron constants

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Cross sections for thermal (2200 m/s) neutrons are fundamental neutron-induced reaction data, which have been evaluated at the IAEA since the pioneering works by Westcott [1], Hanna [2] and Lemmel [3]. Experimentally measured cross sections by TOF method are often normalized to those thermal cross sections; and evaluated nuclear data files rely on the same evaluated values as the best representation of available experimental data. The International Network of Nuclear Reaction Data Centres (NRDC) emphasized to ensure completeness of experimental thermal cross sections in EXFOR in the NRDC 2013 meeting; those measured data are used as a key input for the Thermal Neutron Constant (TNC) evaluation. In a typical evaluation of the Thermal Neutron Constants within the IAEA Neutron Standards [4] 25 thermal constants (elastic, fission and capture cross sections, absorption and fission g-factors, and total fission neutron multiplicities of U-233, U-235, Pu-239 and Pu-241 at the thermal energy as well as Cf-252 spontaneous fission neutron multiplicity) measured both in differential and integral (assemblies) experiments are included in a simultaneous generalized least-squares analysis by the GMA code [4]. Recent TNC evaluations were based on the comprehensive work by Axton [5]. However, Axton experimental database contains many untraceable corrections as well as data which are not available in EXFOR. NDS has been reviewing Axton experimental database to identify missing EXFOR entries and possible experimental corrections. Progress on compilation and assessment of the available experimental data will be reported.

[1] C. H. Westcott, K. Ekberg, G.C. Hanna, et al., *Atom. Energy Rev.* **3** (1965) 3. Available online as www-nds.iaea.org/publications/indc/indc-iae-asterisk009U.pdf ; [2] G. C. Hanna, C. H. Westcott, H. D. Lemmel, et al., *Atom. Energy Rev.* 7 (1969) 3. Available online as www-nds.iaea.org/publications/indc/indc-nds-0012.pdf ; [3] H. D. Lemmel, Proc. Conf. on Nuclear Cross Sections and Technology, Washington, D.C., 3-7 March, *NBS Spec. Publ.* **425** (1975) 286.; [4] A. D. Carlson, V.G. Pronyaev, D.L. Smith, et al., *Nucl. Data Sheets* **110** (2009) 3215; [5] E.J. Axton, Central Bureau for Nuclear Measurement, Geel, Belgium, June 1986, technical report GE/PH/01/86 (1986).
Available online at www-nds.iaea.org/standards/Reports/Axton-GE-PH-01-86.pdf

S491 JANIS: NEA java-based nuclear data information system

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JANIS (JAva-based Nuclear Information Software) is a software developed by the OECD Nuclear energy Agency (NEA) Data Bank to facilitate the visualization and manipulation of nuclear data, giving access to evaluated data libraries, such as ENDF/B, JEFF, JENDL, TENDL etc., and also the EXFOR experimental and CINDA bibliographical databases.
It is available as a standalone Java program, downloadable and distributed on DVD and also a web application available on the NEA Data bank website.
Recent NEA developments rely on JANIS features to access nuclear data, for example the Nuclear Data Sensitivity Tool (NDaST) makes use of BOXER and COVERX formats support and the NEA central database to retrieve covariances. The features added in the latest version of the software, notably automated plots generation through scripting via the command line and improvement of covariance data support are described, along with some examples of the use of JANIS.

I492 'Euratom success stories' in facilitating pan-European E&T collaborative efforts

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The European Atomic Energy Community (Euratom) Research and Training framework programmes are benefitting from a consistent success in pursuing excellence in research and facilitating Pan-European collaborative efforts across a broad range of nuclear science and technologies, nuclear fission and radiation protection.
To fulfil Euratom R&D programmes keys objectives of maintaining high levels of nuclear knowledge and building a more dynamic and competitive European industry, promotion of Pan-European mobility of researchers are implemented by co-financing transnational access to research infrastructures and joint research activities through to Research and Innovation and Coordination and Support Actions funding schemes.
Establishment by the research community of European technology platforms are being capitalised. Mapping of research infrastructures and E&T capabilities is allowing a closer cooperation within the European Union and beyond, benefiting from multilateral international agreements and from closer cooperation between Euratom, OECD/NEA and IAEA and international fora.
'Euratom success stories' in facilitating Pan-European E&T collaborative efforts through Research and Training framework programs show the benefits of research efforts in key fields, of building an effective 'critical mass', of promoting the creation of 'centres of excellence' with an increased support for 'open access to key research infrastructures', exploitation of research results, management of knowledge, dissemination and sharing of learning outcomes.

R493 Dissemination of data measured at the CERN n_TOF facility

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The n_TOF neutron source at CERN is measuring high quality nuclear data from thermal energy up to hundreds of MeV since 2002. A considerable amount of valuable experimental results have been obtained and published, and new measurements are ongoing. However, these results have not been fully exploited yet for the benefits of the end-users of nuclear data, e.g., through the improvement of evaluated nuclear data libraries. There are various reasons for this, but there is definitely room for improvements in the n_TOF data dissemination policy. In line with global standards in data preservation and Open Science, the n_TOF collaboration now takes additional actions to preserve its unique data, facilitate access to them in standardised format, and allow their re-use by a wide community in the fields of nuclear physics, nuclear astrophysics and various nuclear technologies for medical and energy applications. In the latter fields, all evaluated nuclear reaction libraries (for particle transport, activation, dosimetry, standards, etc.) are built on the international EXFOR database, which is successfully maintained for decades by a worldwide network of Nuclear Reaction Data Centres (NRDC), under the auspices of the IAEA. Accordingly, the n_TOF collaboration strengthened the links with the IAEA Nuclear Data Section and the NEA Data Bank to improve the dissemination and preservation of its data through the EXFOR database. The present contribution describes the objectives, progress and status of the n_TOF data dissemination activities, as well as the ongoing efforts to meet the needs for the preservation of more comprehensive experimental datasets for further use by expert users.

R494 EXFOR - a global experimental nuclear reaction data repository: status and new developments

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The EXFOR library [1] is a global repository of experimental nuclear reaction data and associated information that has been systematically collected expanded and developed as a product of the international collaboration of Nuclear Reaction Data Centres (NRDC) [2] under the auspices of the International Atomic Energy Agency Nuclear Data Section for data exchange since 1970. The efforts of the NRDC community to provide completeness and the high quality of the compilations made the EXFOR library a valuable source for information and analysis. The open literature (journals, conference proceedings, report etc.) is regularly scanned to identify publications reporting nuclear reaction data and keep the library up-to-date. In addition the EXFOR completeness is periodically checked and missing publications are compiled. Retroactive scanning of the "Symposia on Reactor Dosimetry" conference proceedings and articles reporting neutron Kerma factors were recently performed.
Different experimental techniques were discussed with experts at Consultants' Meetings (CM) [3,4] in order to improve the EXFOR quality and provide the necessary information for the proper analysis of the experimental data. Guidelines for compilation of the time-of-flight measurements and the thermal neutron scattering experiments were prepared and supplementary data (spectrometers' response function, phonon spectrum, structural parameters etc.) will be provided to users.
The feedback received from users contributes essentially to the improvement of the EXFOR library. In addition to the individual users' reports, verification, organized by NEA Data Bank, has performed systematic comparison of the EXFOR data with model calculations [5]. The data with significant deviations were further analysed and consequently the library contents have been revised.
The paper describes the status of the EXFOR library and the new developments in the compilation of the experimental nuclear reaction data.

[1] N. Otuka et al., Nucl. Data Sheets, **120**, 272–276 (2014) ; [2] International Network of Nuclear Reaction Data Centres www-nds.iaea.org/nrdc/ ; [3] CM on EXFOR Data in Resonance Region and Spectrometer Response Function, Report INDC(NDS)-0647, https://www-nds.iaea.org/index-meeting-crp/CM-RF-2013/ ; [4] CM on the EXFOR Compilation of Thermal Neutron Scattering Data, https://www-nds.iaea.org/index-meeting-crp/CM-THSC-2015/ ; [5] A.Koning, NEA/DB/DOC(2014)3

R495 Progress towards a new international standard for storing nuclear data

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For over 50 years, the Evaluated Nuclear Data Format (ENDF) has served as the principal interface between scientists who generate and use nuclear data. ENDF has been adopted as a standard, so ENDF-formatted files can be easily shared between institutions and can be used in a wide range of computer codes for visualization, data testing and simulations.
While the ENDF standard (currently on version 6) continues to be a valuable tool for the nuclear data community, it has not kept up with rapid changes in computing capabilities over the past decades. The format puts limits on the precision of numeric data (reflecting its punch-card origins with 11 characters reserved for each number). It restricts the types of reactions that can be stored, and is slow to add support for new types of data. These limitations sometimes force evaluators to store data in non-standard ways that require special handling by user codes and break the goal of computer readability.
To address these shortcomings, a new subgroup of the Working Party on Evaluation Co-operation (WPEC subgroup 38) was formed in 2012 to define a new, flexible standard to eventually replace ENDF-6. Since its inception, the subgroup has met twice a year, drafting requirements and specifications for the new standard, currently called Generalized Nuclear Data or GND.
GND is a hierarchical structure that is both human- and machine-readable. While the hierarchy was designed in XML, it can be easily stored in any hierarchical representation, including binary formats like HDF5.
The draft GND structure has been implemented in the code FUDGE ('For Updating Data and Generating Evaluations'). FUDGE, which was developed at Lawrence Livermore National Lab, supports translating ENDF-6 files to and from GND, visualizing data, physics checking and processing.
In this talk, we present the progress at WPEC towards defining the new standard, as well as progress towards implementing GND and building up a robust infrastructure of codes capable of handling GND-formatted data. We also discuss the proposed transition of the nuclear data community from ENDF-6 to the new GND standard.
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R496 Nuclear data web dissemination efforts at the NNDC

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The National Nuclear Data Center located in Brookhaven National Laboratory offers a wide variety of online services. Included are nuclear data dissemination via products such as NuDat 2.0, Wallet Cards, ENSDF/XUNDL search and file retrievals for obtaining detailed nuclear structure information, and ENDF/EXFOR searches for nuclear reaction cross section information. One of the most heavily used services, NuDat 2.0 presents a rich and easy-to-use interface to explore many aspects of nuclear and decay properties. The Evaluated Nuclear
Structure (ENSDF) files upon which this interface is based are available from the ENSDF database using an online search and retrieval web interface. From here it is possible to quickly locate supporting literature and to determine the latest dates on which evaluations are based. Complementary to this is the web interface for searching and retrieving experimental unevaluated nuclear data (XUNDL), representing the latest experimental results for nuclear structure measurements. Nuclear reaction data, including fission yields, can be accessed through Sigma or ENDF/EXFOR search and retrieval interfaces. Behind all this, the Nuclear Science References (NSR) interface enables finely tuned searches for research papers. Users may also avail themselves of online tools to calculate important quantities such as logft values or Q values, and are able to download analysis and utility codes.
The nuclear data available online has been put together through years of collaborative efforts of those in the nuclear data community and, in addition to the services mentioned, the National Nuclear Data Center hosts the GForge server to facilitate these efforts. GForge provides file versioning, bug tracking, and Wiki documents and the new ADVANCE system interfaces with GForge to provide real time quality control and checking of both codes and ENDF data. Although not exhaustive, presented here are a few of the online services available along with effective, sometimes not well-known, ways to utilize these resources.
Work at BNL was supported by the Office of Nuclear Physics, Office of Science of the U.S. Department of Energy under contract No. DE-AC02-98CH10886

PL497 General description of fission observables: the GEF code

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The semi-empirical GEneral Fission model GEF treats spontaneous fission and fission up to an excitation energy of about 100 MeV of a wide range of nuclei from Z = 80 to Z = 112. GEF is based on the observation of a number of regularities in fission observables, revealed by systematic experimental studies, combined with general laws of statistical and quantum mechanics. It is unique in providing a general description of essentially all fission observables (isotopic fission-fragment yields, fission-fragment kinetic energies, prompt fission gamma and neutron spectra,…) in a consistent way while preserving the correlations between all of them. In contrast to most of the other existing fission codes, GEF can be used to obtain reliable predictions for nuclei for which no experimental data exists. GEF is continuously improved and has become a useful tool for fundamental physics and applications in nuclear technology in the last years. GEF is also very often used for simulating nuclear-physics experiments. A detailed description of GEF including a thorough comparison between GEF results and experimental data can be found in [1].
In this contribution we will illustrate the quality of GEF by comparing its results with existing data. We will also demonstrate its usefulness for the evaluation of nuclear data and for applications in reactor physics. Finally, we will discuss possible future improvements and developments of the code.

[1] K.-H. Schmidt, B. Jurado, Ch. Amouroux, C. Schmitt, Nuclear Data Sheets 131 (2016) 107

PL498 Reactor simulations using JEFF-3 nuclear data: assessing performance and needs

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Although there exist well-established methodologies for deriving nuclear data uncertainties from reactor design, operation or safety parameters, in practice, there is often no systematic and well-substantiated quantitative evaluation of the nuclear data improvements needed to achieve a given reactor performance. As a result, nuclear physicists sometimes argue that they lack proper justification for prioritizing their work, especially when faced with the collective challenge of updating many nuclear data for a wide range of applications.
The difficulties associated with a rigorous assessment of nuclear data improvements for achieving a given reactor performance are presented and the underlying reasons are discussed. Examples taken from the recent use of JEFF-3 nuclear data for specific LWR, SFR and MTR applications illustrate these difficulties and some related pitfalls. In particular, it is shown that, if the assessment is not done with due care, in a consistent and global approach, the reactor performance objectives can result in needlessly demanding requirements on some nuclear data. Conversely, using unrealistic estimates of nuclear data covariances in reactor simulations can lead to unreliable and possibly misleading conclusions, even when the estimates are bias-free. A balanced approach is suggested as an appropriate way of performing such an assessment.

PL499 CIELO collaboration advances in evaluating cross sections for 239Pu, 238U, 235U, 56Fe, 16O and 1H

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For three years the Collaborative International Evaluated Library Organization (CIELO), under the auspices of the NEA/OECD and the IAEA, has been working to advance our understanding of neutron cross sections up to 20 MeV for a suite of high-priority isotopes: 1H, 16O, 56Fe, 235U, 238U, 239Pu. The researchers contributing to this effort come from laboratories around the world, and bring expertise in nuclear reaction theory and modeling, measurement, evaluation, and validation data testing.This paper will summarize the progress to date, discuss "lessons-learned", and identify future work that is needed.
The overview will highlight nuclear reaction data measurements made during the course of this collaboration, for fission cross sections, prompt fission neutron spectra, neutron capture, and neutron inelastic scattering, and (n,2n), in both the resonance and the higher energy range. Some of the nuclear reaction theory and modeling advances will also be described, as will the database work to represent, and perform integral validation testing on, the developmental CIELO evaluated databases.

During the course of this collaboration, certain findings, and tentative conclusions, have been reached by the teams (examples here include the the magnitude of the 16O(n,a) cross section; the thermal 235U prompt fission neutron spectrum (PFNS) with an average energy of about 2.00 MeV; and updates needed to the 235U(n,g) capture cross section near a keV). In other cases, there remain disparate opinions on less well understood quantities (examples include the magnitude of inelastic scattering in actinides, and the average energy of the 239Pu PFNS). These findings will be summarized, together with ongoing work that has been initiated with the aim to resolve these discrepancies. The present status of the CIELO starter files will be described.

PL500 CENDL project, the Chinese Evaluated Nuclear Data Library

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As a major project of nuclear data in China, CENDL project contains the nuclear data measurements, evaluations and related methodologies studies. More than 10 universities and institutions in China are involved in to the project. The main output of the project is the general purpose evaluated nuclear data file: China Evaluated Nuclear Data Library (CENDL), which contained evaluated neutron data files for several hundred nuclei. The fission yield data, activation data and decay data sub-libraries will be included in CENDL.
Recent years, most neutron files of the updated CENDL are evaluated by using the recently experimental information and the updated methodology, which contain the nuclear data model code UNF series (the updated vision is UNF2015), the cross section covariance evaluation system COVAC and SEMAW, et al. The most important neutron reaction data for the light, structure, actinide nuclei etc have been validated by the system of the ENDITS which contains more than 1200 integral benchmarks, and compared with other evaluated data files, and some of them predict the experiments well compared with other files. The updated CENDL files have been used for the CEFR, TMSR, ADS projects, etc. and very good feedback received.
New nuclear data measurements also are performed with the reactors and accelerators in China, some of the new measurements are used for the updated CENDL evaluation activities. Several facilities are under construction in China which can be used for the nuclear data measurements in future. The related methodologies of the measurements are carried out by the CENDL project support.

S501 Testing of the ABBN-RF multigroup data library in photon transport calculations

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Accurate knowledge about ionization radiation is very important for nuclear safety study. It may be produced in shield materials, transport containers, nuclear fuel storage, during operation of nuclear facility. The main component of this radiation is photon flux, because the neutron flux is reduced within shield in the most cases. Gamma radiation is produced via both of nuclear fuel and shielding materials. Photon interaction is known with appropriate accuracy, but gamma ray production known with less accuracy.
The purpose of this work is studying photon production data from neutron induced reactions in iron and lead. We tested this data through calculations of spheres of iron (ICSBEP ALARM-CF-FE-SHIELD-001) and lead (ALARM-CF-PB-SHIELD-001) using MCNP code. Neutron and photon spectra will be calculated using the ROSFOND, ENDF/B-7.1, JEFF-3.2 and JENDL-4.0 nuclear data libraries. Results of calculations show that all of these nuclear data have different photon production data from neutron induced reactions and have poor agreement with evaluated benchmark experiment.
The ABBN-RF multigroup cross-section library is based on the ROSFOND data and it has two formats of micro cross sections: ABBN and MATXS. We compared calculations using both this data to calculations using ROSFOND point-wise libraries, it shows good agreement. Calculated and experimental C/E discrepancies in neutron spectra are in limit of experimental errors but for the photon spectrum are out of experimental errors. Contribution of primary gamma rays becomes smaller with increasing diameter of spheres. Results of calculations using group-wise and point-wise representation of cross sections show a good agreement both for photon and neutron spectra.

S067 Thermal neutron scattering data for LiF and BeF2

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Thermal neutron scattering data are widely used in nuclear engineering applications, such as reactor design, radiation shielding, long-lived nuclear waste transmutation, Boron Neutron Capture Therapy (BNCT) . Although the sub-libraries of some moderator materials are given in the available evaluated nuclear data libraries, the data for more materials are needed for the molten salt reactor.
A code, SIRIUS, is developed to describe thermal neutron scattering process and produce data in ENDF-6 format. This code considered coherent elastic, incoherent elastic, coherent inelastic and incoherent inelastic scattering processes. The phonon band structures and projected phonon densities of states (DOS) were calculated by Hellman-Feynman Theorem combined with a lattice dynamics direct method. The thermal neutron scattering data for LiF and BeF2 are given and expected to be used for molten salt reactor.

S502 Verification of the databases EXFOR and ENDF

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The objective of this work is for the verification of large experimental (EXFOR) and evaluated nuclear reaction databases (JEFF, ENDF, JENDL, TENDL…). The work is applied to neutron reactions in EXFOR data, including threshold reactions, isomeric transitions, angular distributions and data in the resonance region. It is applied for isotopes and natural elements.
A methodology is developed for classification and ranking to assess the quality of EXFOR data. This method uses a statistical approach taking into account the uncertainties of both experimental and evaluated data. For each reaction, the experimental and evaluated data are compared in order to check if they are in good agreement. This is done by computing the distance between a curve (the evaluated data) and a set of points (the experimental data). For a given EXFOR data, the distance is computed as the gap between the two vertical confidence intervals of EXFOR and ENDF. The uncertainty in abscissa of the EXFOR point is taken into account by computing the minimal distance over the horizontal confidence interval. An indicator is computed as the ratio of the distance and the maximum between the standard deviation of ENDF and EXFOR. The greater the indicator, the lower is the agreement between EXFOR and ENDF. Finally, the average of all the indicators for all the EXFOR point is computed. Using this algorithm, 8 617 reactions were compared, with a total of 200 458 EXFOR data. Only 2% of these EXFOR data are classified in the lower ranking, and 247 reactions have been identified to be revised.
As a part of the resonance analysis, a comparison of the resonance integrals (790) compiled in EXFOR database with those derived from the evaluated libraries is also performed. In some cases, large differences between current evaluations have been found. The analysis of these data has been also used to correct few deficiencies in EXFOR entries.

S503 Inter-comparison of Hauser-Feshbach model codes toward better actinide evaluations

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The Hauser-Feshbach codes that include a pre-equilibrium model have been playing for years a central role in producing evaluated nuclear
reaction data files. The codes, such as Empire, TALYS, CCONE, and CoH3, have been and are still actively upgraded in order to better understand nuclear reaction mechanisms by sharing and exchanging theoretical knowledge as well as computational techniques between actors involved in their development. Albeit the framework of the model codes aforementioned is quite similar, implementation of the reaction models as well as computational techniques adopted may produce some differences in the calculated results. The IAEA Nuclear Data Section conducts one of such inter-organizational collaborations, and defined some exercises to compare the Hauser-Feshbach codes developed for nuclear data evaluations, with a particular focus on the actinide evaluations. We report here the results of Hauser-Feshbach calculations for neutron induced reactions on actinide nuclei using the input parameters defined in the IAEA report [Capote et al., INDC-NDS-0654 (2014)], and discuss the differences among these codes.

S504 Resonance parameters from neutron capture measurements of dysprosium isotopes in the energy range 10 - 1000 eV

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We measured resonance parameters of dysprosium using isotopically enriched dysprosium samples (Dy-161, Dy-162, Dy-163, and Dy-164) and natural dysprosium sample from the neutron capture yield in the energy region from 10 eV to 1 keV at the Gaerttner LINAC Center at Rensselaer Polytechnic Institute. The neutron capture measurements were performed at a flight path of 25 m with a 16-segment sodium iodide multiplicity detector. Resonance parameters were extracted from the capture yield and transmission using the multilevel R-matrix Bayesian code SAMMY. Transmission data from a previous measurement of a 10 mil natural dysprosium was used for determining the normalization factor and was included in the fit with the capture yield data.
We observed new resonances not listed in ENDF/B-VII.1; 7 in Dy-160, 40 in Dy-161, and 22 in Dy-163 isotopes. Resonances in the ENDF/B-VII.1 evaluation that were not observed in the current experiment and could not be traced to a literature reference were removed. This includes 6 resonances from Dy-161 isotope, 2 resonances from Dy-163, and 4 resonances from Dy-164.
The resulting resonance parameters were used to calculate the capture resonance integrals in the energy region from 0.5 eV to 20 MeV. The capture resonance integrals from the present resonance parameters were compared to calculations obtained by the resonance parameters from ENDF/B-VII1.1. The new parameters gave a resonance integral value of 1410 ± 3 barn for natural dysprosium, which is ~0.7% higher than that obtained with the ENDF/B-VII.1 parameters.
The average level spacing, D0, was determined by staircase-plotting the present resonance parameters and assuming the level spacing is theoretically a constant. The D0 for Dy-160, Dy-161, Dy-162, Dy-163, and Dy-164 were 16.54 ± 0.66, 2.59 ± 0.01, 55.7 ± 1.03, 6.85 ± 0.07, and 142.16 ± 7.34, respectively.

R505 A test blanket module mock-up experiment at high intensity deuteron triton neutron generator experimental platform

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To study the tritium production ratio of the Dual Functional Lithium-Lead (DFLL) Test Blanket Module (TBM)[1], which is developed by Institute of Nuclear Energy Safety Technology (INEST) for International Thermonuclear Experimental Reactor (ITER) as a typical liquid TBM concept, a mock-up has been constructed based on the DFLL TBM design. The TBM mock-up together with extra shielding component and duct structure are used to study deep penetration effect and other neutronics performance.
Its tritium breeding block is made of China Low Activity Martensitic(CLAM) steel[2] and Pb-Li coolant. The shielding block is made of stainless steel and water. The experimental mock-up will be irradiated with 14 MeV neutrons on High Intensity Deuteron Triton NEutron Generator (HINEG) experimental platform[3]. Tritium production rates and reaction rates will be measured in different places through the mock-up. 6Li detectors will be set in positions along the experimental central channel located in the mock-up mid-plane. Activation foils will be set along the duct in shielding structure. Reaction rates will be determined by several sets of activation foils of Au, Al, Nb, and leaked neutrons will be measured by a liquid scintillator detector. Boron-doping Polyethylene plates will surround the mock-up to reduce the neutron background in the shielding component.
The measured leakage spectra and reaction rates will compare with the calculated ones using Super Monte Carlo Simulation Program for Nuclear and Radiation Process (SuperMC) [4] with the evaluated point-wise data processed from main data libraries including ENDF/B-VII.1, JEFF-3.1 and JENDL-4.0 etc. The comparison of simulation and measurement will be used to validate the precision of the data library and TBM design.

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