5th AASPP Workshop on

Asian Nuclear Reaction Database Development

September 22 – 24, 2014

Seminar Hall, Nabhikiya Urja Bhawan, Anushaktinagar

Mumbai, India

Organized in Co-operation with IAEA, Vienna and DAE-BRNS, Mumbai

Abstract Booklet

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Compiled by:

Devesh Raj
Alok Saxena

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(Presentations by Participants shall be Uploaded for Open Access)

5^{th} AASPP Workshop on
Asian Nuclear Reaction Database Development

September, 22-24, 2014.

Seminar Hall, NUB, Anushaktinagar, Mumbai 400 094

(Lecture time includes time for questions &answers)

Day 1 (Monday, 22nd September, 2014), Session 1

9.30 – 10.00 **Inaugural Session:**

Welcome address	***P.D. Krishnani,*** Chairman, Organizing Committee
Introductory Remarks	***S. Kailas***, Chairman, Nuclear Data Physics Centre of India
Theme of the workshop	***Alok Saxena***, Technical Convener
Inaugural Address	***P.K. Vijayan***, Director, Reactor Design and Development Group
Vote of Thanks	***Devesh Raj***, Co-convener

10:00 -10:30 ***Mayasuki Aikawa, Hokkaido University, JAPAN***
"Compilation Status and Research Topics in Hokkaido University Nuclear Reaction Data Centre"

10:30-10:50 ***Alok Saxena, Nuclear Physics Division, BARC, Mumbai***
"Overview of Nuclear Data Activities of Nuclear Data Physics Centre of India (NDPCI)"

10:50 – 11:15 High Tea

11:15 – 11:45 ***Ge Zhigang, China Nuclear Data Center, China Institute of Atomic Energy, Beijing, P.R. China***
"Recent Nuclear Data Work in China"

11:45-12:05 ***B.K. Nayak, Nuclear Physics Division, BARC, Mumbai***
"Surrogate Reaction Methods for Neutron Induced Cross-sections"

12:05-12:25 ***P.C. Rout, Nuclear Physics Division, BARC Mumbai***
"Experimental Studies on Nuclear Level Density"

12:25-12:55 ***V. Semkova, Nuclear Data Section, International Atomic Energy Agency, Vienna***
"Neutron-Induced Activation Measurements and EXFOR Compilations in the Energy Range up to 20 Mev"

12:55-13:15 ***Lalremruata Bawitlung, Mizoram University*, Mizoram**
"Overview of EXFOR Activities in India"

13:15 – 14:15 Lunch

Day 1, Session 2

14:15 – 14:45 ***Pham Ngoc Son, Nuclear Research Institute, Dalat, Vietnam***
"Filtered Thermal Neutron Captured Cross Sections Measurements and Decay Heat Calculations"

14:45-15:05 ***Devesh Raj, Reactor Physics Design Division, BARC, Mumbai***
"Decay Heat Calculations for Reactors"

15:05-15:25 ***Gopal Mukherjee, Variable Energy Cyclotron Centre, Calcutta***
"Overview of ENSDF Activities in India"

15:25-15:55 ***T. T. Anh' Nuclear Research Institute, Dalat, Vietnam***
"Total Cross Section Measurements of Nb, In and Pr on Filtered Neutron Beams at Dalat Research Reactor"

15:55 – 16:15 Tea

Day 1, Session 3

16:15-16:35 ***S. Ganesan, Reactor Physics Design Division, BARC, Mumbai***
"Nuclear Data Covariances in the Indian Context"

16:35-16:55 ***E. Radha, Indira Gandhi Centre for Atomic Research, Kalpakkam***
"ICSBEP Criticality Benchmarking for Nuclear Data Validations, KAMINI, PURNIMA-II and PURNIMA-I"

16:55-17:25 ***Wang Jimin, China Nuclear Data Center, China Institute of Atomic Energy, Beijing, P.R. China***
"Evaluation of the D(n,2n)p Reaction Cross Section"

Day 2, Session 4 (Tuesday, 23rd September, 2014)

10:00-10:30 **Jong Woon KIM** ***Korea Atomic Energy Research Institute*, *Daejeon, Korea***
"Current Status of n_TOF Facility Construction at KAERI"

10:30-10:50 ***S. Acharya, BARC, Mumbai***
"RF Electron Linacs for Neutron Time-of-Flight Facilities"

10:50-11:10 ***V.M. Datar, Nuclear Physics Division, BARC, Mumbai***
"Overview of Upcoming INO Facility"

11:10-11:30 Tea

Day 2, Session 5

11:30-11:50 ***Saila Bhattacharya, VECC, Calcutta***
"Nuclear Physics using VECC Cyclotrons: Scopes and Possibilities"

11:50 -12:10 ***Amar Sinha, BARC , Mumbai***
"Physics Study of D-D/D-T Neutron Driven Experimental Subcritical Assembly "

12:10-12:30 ***P. Singh, BARC Mumbai***
"An Overview of FOTIA and LEHIPA"

12:30-12:50 ***S. Sugathan, IUAC, New Delhi***
"Overview of Nuclear Experimental Facilities and the Accelerator Facilities at IUAC"

12:50-13:10 ***A.K. Gupta, BARC, Mumbai***
"An Overview of BARC-TIFR Pelletron-Linac Facility"

13:10 – 14:15 Lunch

Day 2, Session 6

14:15-14:45 ***Sung-Chul Yang, Nuclear Data Center, KAERI, Korea***
"EXFOR Compilation and Nuclear Data Measurement at KAERI/NDC"

14:45-15:05 ***H. Naik, Radio Chemistry Division, BARC, Mumbai***
"Studies on High Energy Photon (Bremsstrahlung) and Neutron Induced Fission of Actinides and Pre-Actinides"
15:05-15:25 ***A.K. Jain, Indian Institute of Technology, Roorkee,***
"Atlas of Nuclear Isomers and their Systematics"

15:25-15:55 ***Tao Xi, China Nuclear Data Center, China Institute of Atomic Energy, Beijing, P.R. China***
" R-matrix Analysis of n+^{6}Li Reaction"

15.55 – 16.15 Tea

16:30-17:00 ***GN Kim, Kyungpook National University, Daegu, Korea***
"Activities for Nuclear Data Measurement using Charged particle-, Neutron-, and Photon Induced Reactions in Korea"

17: 00-17:30 ***Guochang Chen, China Nuclear Data Center, China Institute of Atomic Energy, Beijing, P.R. China***
"Update of Neutron Nuclear Data Evaluation for ^{236,238}Np"

Day 3, Session 7 (Wednesday, 24th September, 2014

10:00-10:30 ***M. Odsuren, Nuclear Research Center, National University of Mongolia, Ulaanbaatar, Mongolia***
"Applications of the Photo-Nuclear Reaction Data for Activation Analysis"

10:30-11:00 ***Guochang Chen, China Nuclear Data Center, China Institute of Atomic Energy, Beijing, P.R. China***
"Recent EXFOR Compilation in CNDC"

11:00-11:20 ***G. Pandikumar, Indira Gandhi Centre for Atomic Research, Kalpakkam***
"Nuclear Data Needs for Fast Reactor"

11:20-11:40 Tea

Day 3, Session 8

11:40-12:00 **M. P. S. Fernando, Nuclear Power Corporation of India Ltd, Mumbai**
"Nuclear Data Needs for Indian Nuclear Power Program"

12:00-12:20 ***Umasankari Kannan, Reactor Physics Design Division, BARC, Mumbai***
"Sensitivity Studies on Nuclear Data for Thorium Fuelled Advanced Heavy water Reactor (AHWR)"

12:20-12:*40* ***S.V. Suryanarayana, Nuclear Physics Division, BARC, Mumbai***
"Statistical Model Calculations using TALYS code for the Study of Neutron and γ Induced Reactions "

12:40-13:00 ***Ajay Kumar, BHU, Varanasi***
"Study of Elastic and Inelastic Neutron Cross sections using Time of Flight Technique"

13:00-14:00 Lunch

Day 3, Session 9

14:00-14:30 ***F. Ergashev, S. Artemov, R. Yarmukhamedov, Institute of Nuclear Physics, Uzbekistan, Academy of Sciences, 702132 Tashkent,***
"Inclusion of nuclear data of Uzbekistan authors to the NRDC during year 2013-2014"

14:30-15:00 ***N.Takibayev , Al-Farabi Kazakh National University, Almaty, Kazakhstan***
"Joint Activities with IAEA on Uploading of Scientific Papers from Kazakhstan and Uzbekistan into the EXFOR Database"

15:00-15:20 ***Yongli Jin, China Nuclear Data Center, China Institute of Atomic Energy, Beijing, P.R. China***
"Introduction on the Digitization Software GDgraph"

15:20-15:45 Tea

15:45 - 16:30 - PANEL DISCUSSION

Compilation Status and Research Topics in Hokkaido University Nuclear Reaction Data Centre

M. Aikawa[1], S. Ebata[2], N. Furutachi[3], D. Ichinkhorloo[2], S. Imai[2], K. Katō[1], A. Sarsembayeva[4],
M. Takibayeva[3], B. Zhou[2]

[1]*Faculty of Science, Hokkaido University, Sapporo 060-0810, Japan*
[2]*Meme Media Laboratory, Hokkaido University, Sapporo 060-8628, Japan*
[3]*Faculty of Engineering, Hokkaido University, Sapporo 060-8628, Japan*
[4]*Graduate School of Science, Hokkaido University, Sapporo 060-0810, Japan*

Abstract

The Hokkaido University Nuclear Reaction Data Centre (JCPRG) is a member of the International Network of Nuclear Reaction Data Centres (NRDC) under the auspices of the International Atomic Energy Agency (IAEA). JCPRG contributes about 10 percent of the data on charged-particle nuclear reactions in the EXFOR.

In addition to the worldwide collaboration of compilation, Asian collaboration on compilation and evaluation was also promoted. As a result of this promotion, a research on the ^{9}Be+n reaction was launched between Hokkaido University and Al-Farabi Kazakh National University. Beryllium is one of essential materials as a target window and a reflector for a spallation neutron source. The theoretical study and evaluation of the ^{9}Be+n reaction are indispensable for nuclear engineering.

We report current status of our activity and collaboration on compilation and evaluation of nuclear reaction data.

Overview of Nuclear Data Activities of Nuclear Data Physics Centre of India (NDPCI)

Alok Saxena

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Abstract

The NDPCI has been pursuing all aspects of nuclear data viz, measurements, analysis, compilation and evaluation involving national laboratories and universities in India. The NDPCI is evolving a streamlined and coherent activities of all nuclear data activities in India by bringing people in various fields (e.g., Nuclear Physics, Reactor and Radiochemistry Divisions of Bhabha Atomic Research Centre, Mumbai, Indira Gandhi Centre of Atomic Research, Kalapakkam, Variable Energy Cyclotron, Calcutta, etc.) and students and staff from various Universities across India covering both experimentalists and theoreticians. Our scientists are involved in nuclear data measurements using pelletron/FOTIA accelerator facility. They have carried out a number of cross-section studies using 7Li(p,n) reaction as mono-energetic neutron source, surrogate technique for unstable targets also using 14 MeV neutron generator both at Pune university and at Purnima, BARC for cross-section measurement. Our scientists have also used electron accelerators at Khargarh and Pohang for photon induced cross-section studies. BARC has a formal MOU with CERN where our scientists have participated in n_TOF experiments on cross-sections relevant to nuclear applications. Our scientists have also carried out extensive measurements of charged particle induce reactions, the results are reported in the symposium proceedings of DAE symposium of nuclear Physics. We have carried out measurement of prompt neutron spectra in neutron induced fission reaction for ^{238}U under CRP of IAEA. VECC is setting up facility for TAGS studies for decay heat data using BaF2 detectors. Our scientists are also involved in nuclear theory and simulation related to nuclear data for AHWR, and other advanced reactors. They are also involved in criticality bench-mark studies for various reactors. NDPCI has involved some of the universities in EXFOR compilations and has organized a series of theme meetings on EXFOR compilations. NDPCI has also organized a meeting on nuclear data evaluations, covariances in nuclear data, ENSDF etc. The NDPCI has awarded many projects to PIs of various universities on topics relevant to nuclear data.

Recent Nuclear Data Work in China

Ge Zhigang

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Abstract

A brief of introduction about China nuclear activities will be introduced in this presentation, which including the view of nuclear data measurement, evaluation activity system of China and the progress of the nuclear data measurements and evaluations during recently years. As the main output of China Nuclear Data Center, The scheme of the new Chinese Evaluated Nuclear Data Library (CENDL) will be introduced also in this article. The new version of CENDL is general purpose evaluated nuclear data file which consists of the neutron reaction sub-library, the activation sub-library, decay data sub-library and fission yield sub-library. CENDL-3.2 can be used for the nuclear engineering, nuclear medicine and nuclear science etc. fields. The CENDL-3.2 is based on the previous version of CENDL and other special purpose libraries established by CNDC, the updated experimental information and new nuclear data evaluation methodologies. The progress of the evaluation methodologies during recently years in China will be introduced in this presentation.

Surrogate Reaction Methods for Neutron Induced Cross-Sections

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Abstract

Compound nuclear cross sections for reactions of neutrons and light charged particles with target nuclei across the isotopic chart, taking place at energies from several KeV to tens of MeV, are required for nuclear astrophysics, national security, and nuclear-energy applications [1]. The trans-uranium nuclide produced in the nuclear fuel cycles by successive neutron capture, play prominent role in modeling processes that are relevant to generate energy. The fast-neutron induced reactions have also been proposed for the incineration of actinide materials, notably minor actinide isotopes which are produced in Th-U or U-Pu fuel cycles. Unfortunately, for a large number of reactions the relevant data cannot be directly measured in the laboratory, since the relevant nuclei are often too difficult to produce with currently available experimental techniques or too short-lived to serve as target in present day setups. The Surrogate reaction methods provide access to such nuclear data indirectly.

In recent years, the surrogate reaction methods in various forms have been employed to get indirect estimate of the neutron induced fission reaction cross sections of many compound nuclear systems in actinide region, which are not accessible for direct experimental measurements. We have developed a new experimental technique known as hybrid surrogate ratio method[2] and successfully employed to determine ^{233}Pa(*n,f*), ^{234}Pa(*n,f*), ^{239}Np(*n,f*), and ^{240}Np(*n,f*) compound nuclear cross sections in the equivalent neutron energy range 10.0 to 16.0 MeV by measuring the ratio of fission decay probabilities in [^{232}Th(^{6}Li,α)^{234}Pa/ ^{232}Th(^{6}Li,d)^{236}U], [^{232}Th(^{7}Li,α)^{235}Pa/ ^{232}Th(^{7}Li,t)^{236}U], [^{238}U(^{6}Li,α)^{240}Np /^{238}U(^{6}Li,d)^{242}Pu], and [^{238}U(^{7}Li,α)^{241}Np / ^{238}U(^{7}Li,t)^{242}Pu] transfer reactions respectively[2-4]. We have also determined ^{241}Pu(n,f) cross section in the equivalent neutron energy range 11.0 MeV to 18.0 MeV using ^{238}U(^{6}Li,d)^{242}Pu and ^{232}Th(^{6}Li,d)^{236}U transfer reactions employing surrogate ratio method[5].

In this talk, we start with a brief discussion on surrogate reaction methods and present some of the recent results on neutron induced fission cross section measurements carried out by our group and the possibility of extending the measurements for determining (n,γ), (n,2n) and (n,p) reaction cross-sections by surrogate reaction method will also be discussed.

References:

1. J.E. Escher *et al.,* Rev. of Mod. Phys. **84**, 354 (2012).
2. B.K. Nayak *et al.,* Phys. Rev. **C78**, 061602 (R) (2008).
3. V. V. Desai, B. K. Nayak, A. Saxena, and E. T. Mirgule, Phys. Rev. **C89**, 024606 (2014).
4. V. V. Desai, B. K. Nayak, A. Saxena, E. T. Mirgule, and S.V. Suryanarayan, Phys. Rev. **C88**, 014613 (2013).
5. V. V. Desai *et al.* ,Phys. Rev. **C87**, 034604 (2013).

Experimental Studies on Nuclear Level Density

Prakash Chandra Rout

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Bhabha Atomic Research Centre, Mumbai, 400085

Abstract

The nuclear level density (NLD) is a fundamental property of the atomic nucleus. The NLD is an indispensable input to the statistical calculation of compound nuclear decay and thus an important physical quantity for many practical applications, such as the calculations of reaction rates relevant to nuclear astrophysics, nuclear reactors, and spallation neutron sources. It is also an essential quantity for obtaining the thermodynamical properties of an excited atomic nucleus, namely entropy, temperature and specific heat. The analytic form of the level density deduced by Bethe using Fermi gas model has been used as the basis for building the most of the phenomenological formula for the fitting of the experimental data or calculating reaction cross section. The level density increase rapidly with the excitation energy and with mass number. In general, the level density depends on excitation energy, angular momentum, parity, isospin, shell effect, paring etc. There are many experimental methods such as direct counting of levels, particle resonance spectroscopy, Ericson fluctuation and analysis of evaporation spectra have been used for the extraction of the NLD parameters. The recent development of the state of the art experimental techniques, namely CERN n-TOF experiment through neutron resonance spectroscopy, Oslo method for study of continuum gamma rays in coincidence with the particles in transfer induced reactions, Mumbai method for the study of continuum particle spectra in coincidence with the particles (ejectiles) in the breakup-fusion reaction, provide opportunities to study many important problems pertaining to the level density. In this talk, the recent progress in the measurements highlighting various aspect of the nuclear level density and open problems in the level density will be discussed.

Neutron-Induced Activation Measurements and EXFOR Compilations in the Energy Range up to 20 Mev

V. Semkova

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Abstract

Neutron-induced reaction cross sections are important for many fields of science and applications. Activation and transmutation analyses for the high intensity neutron sources require a full set of cross section data comprising all target nuclides that may be present in the materials to be irradiated. Material damage is largely governed by helium and hydrogen production, radiation hazards and decay heat are associated with the activation products and neutron transport is related to the (in)elastic scattering and (n, xn) cross sections. Accurate knowledge on neutron-induced activation cross sections is of interest for testing nuclear models as well.

Activation cross sections measurements on reactions induced by neutrons with quasi-monoenergetic or spectral energy distributions in the energy range up to 20 MeV will be presented. Examples of cases where correction, such as: sample isotopic composition; coincidence summing; background neutrons; bean intensity fluctuation etc., were applied will be given. Peculiarities of uncertainty propagation in activation measurements will be discussed.

Large part of EXFOR database contains data obtained by activation techniques. An overview of the compilation of activation measurements will be presented.

Overview of EXFOR Activities in India

Lalremruata Bawitlung

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Abstract

To meet various needs of the department, the Nuclear Data Physics Centre of India (NDPCI) was formed which has been successful in pursuing all aspects of nuclear data, viz., measurements, analysis, compilation and evaluation involving national laboratories and universities in India. One of the most important activities of NDPCI is EXFOR compilation with the help of Nuclear Data Section, IAEA, of articles for research work performed in India. EXFOR compilation has been carried out in India since 2006 mainly through theme meeting on EXFOR compilation organized by NDPCI. So far five successful workshops have been conducted and more than 200 EXFOR entries have been submitted from such workshops. The Sixth is planned next January, at Bangalore University, Bangalore. At the same time, EXFOR compilation on a regular basis has also been going on for the last few years, through funds given by NDPCI to Universities. As a result, NDPCI has also submitted quite a large number of entries to NDS, IAEA though such activities.

NDPCI is now one of the most active data centres and produced higher EXFOR entries compared to most of other data centres. For example, between 2013 and 2014 NRDC meetings, NDPCI transmitted 55 entries. This is larger than NDS, ATOMKI, CNDC, KNDC and UkrNDC (see P2014-06) and also CAJaD and JCPRG (WP2014-02). The 30th INDC meeting (2-6 June 2014) recognizes this achievement very well as we see in the draft of the recommendation from INDC WG2 the following statement: "We appreciate the significant compilation effort by India by organising a training workshop on a regular basis and suggest continuous support by the NDS".

Due to the continuous efforts of NDPCI and with the continuous support from NDS, IAEA , EXFOR entries for articles published by Indian researchers in the country (old as well as new articles) are expected to be complete by the next Indian EXFOR workshop.

Filtered Thermal Neutron Captured Cross Sections Measurements and Decay Heat Calculations

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2) Vietnam Agency for Radiation and Nuclear Safety, 113-Tran Duy Hung, Hanoi, Vietnam

Abstract

Recently, a pure thermal neutron beam has been developed for neutron capture measurements based on the horizontal channel No.2 of the research reactor at the Nuclear Research Institute, Dalat. The original reactor neutron spectrum is transmitted through an optimal composition of Bi and Si single crystals for delivering a thermal neutron beam with Cadmium ratio (R_{cd}) of 420 and neutron flux (Φ_{th}) of 1.6×10^6 n/cm^2.s. This thermal neutron beam has been applied for measurements of capture cross sections for nuclide of V-51, Mn-55, Hf-180 and W-186 by the activation method relative to the standard reaction Au-197(n,γ)Au-198. In addition to the activities of neutron capture cross sections measurements, the study on nuclear decay heat calculations has been also considered to be developed at the Institute. Some results on calculation procedure and decay heat values calculated with update nuclear database for U-235, U-238, Pu-239 and Th-232 are introduced in this report.

Decay Heat Calculations for Reactors

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Abstract

Estimation of release of energy (decay heat) over an extended period of time after termination of neutron induced fission is necessary for determining the heat removal requirements when the reactor is shutdown, and for fuel storage and transport facilities as well as for accident studies.

The method of decay heat estimation relies on the measurements over practical time intervals as well as on calculation for predictions over very long time intervals. Neutron cross sections, fission yields and decay data together with operational history are the basic inputs to such. A code used to calculate decay heat would require to generate isotopic inventory that would be present at the shutdown based on operational history of the reactor and follow up the decay over an extended period of time.

Aspects of decay heat estimation based on standards like ANS 5.1 and by fuel cycle analysis codes shall be discussed. A Fuel Cycle Analysis Code, ADWITA (Activation, Decay, Waste Incineration and Transmutation Analysis) which can generate inventory based on irradiation history and calculate radioactivity and decay heat for extended period of cooling, has been written. The method and data involved in Fuel Cycle Analysis Code ADWITA and some results obtained shall also be presented.

References:

1. Review of Decay Heat Predictions and Standards, Draft Report, JEF/DOC-473.
2. Nuclear Data Requirements for Decay Heat Calculations, A.L. Nichols, Nuclear Data Section, IAEA, Vienna. (Lectures at Trieste, 25 February 28 March 2002
3. Technical Support for a Proposed Decay Heat Guide Using AS2H/ORIGEN-S Data, O. W. Hermann et. al., NUREG/CR-5625, ORNL-6698
4. ORIGEN - The ORNL Isotope Generation And Depletion Code, M. J. Bell, ORNL-4628, 1973
5. ORIGEN2-A Revised and Updated Version of the Oak Ridge Isotope Generation and Depletion Code, A. G. Croff, ORNL-5621, 1980.

Overview of ENSDF Activities in India

Gopal Mukherjee

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Abstract

Nuclear Structure and Decay Data (NSDD) evaluation in the ENSDF (Evaluated Nuclear Structure and Decay Data File) format is considered as one of the important activities worldwide under the aegis of International Atomic Energy Agency (IAEA) which is maintained and coordinated by the National Nuclear Data Centre (NNDC), USA. In the ENSDF evaluation, the experimental nuclear structure data on nuclear level energy, level lifetime, spin and parity of a level, gamma transition energy, multipolarity and conversion coefficient of the transition and some other related parameters are evaluated for each nucleus and are grouped as isobars i.e all the nuclei under the same mass number and a set of this evaluation is called a mass chain evaluation. India has now become one of the active members in the NSDD network and has contributed regularly and significantly for more than 10 years. Before that the Indian contribution to this activity was sparse and irregular. It has really geared up since the year 2003 when an Indian contingent had participated in the IAEA organized workshops at Vienna, Austria and Trieste, Italy. The Indian ENSDF activity, since then, has significantly strengthened the international data evaluation network by adding more than 12 mass chain evaluations and several horizontal evaluations. All these have been published in peer reviewed journals. A center at I.I.T., Roorkee on ENSDF evaluation has been established and recognized by the NSDD network and has formally been assigned the responsibility of evaluating the mass chains A = 218 – 219. One of the aims of the Indian NSDD network is also to train new persons and induct them into the fold of international network of data evaluations. There have been workshops organized and collaborative efforts among participants from various Universities and Institutions have been undertaken for the mass chain evaluations. The Indian community has active collaboration with the National Nuclear Data Centre (NNDC), USA; McMaster University, Canada; Argonne National Laboratory, USA; International Atomic Energy Agency (IAEA), Austria etc. Apart from this, the Indian physicists were also collaborated in the IAEA CRP on Decay data evaluation and have published decay data evaluation of ^{233}U and ^{229}Th which are important for the Th-U fuel cycle. The details of the ENSDF activities in India and some of the results will be discussed in the workshop.

Total Cross Section Measurements of Nb, In and Pr on Filtered Neutron Beams at Dalat Research Reactor

T. T. Anh[1*], P. N. Son[1], V. H. Tan[2], P. D. Khang[3]

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Abstract

The quasi-monoenergetic neutrons of 24 keV, 54 keV, 59 keV, 133 keV and 148 keV have been developed at the horizontal channel of N_0. 4 of Dalat Research Reactor by neutron filter technique. The neutron fluxes of the beams are $6.2x10^5$, $6.9x10^5$, $5.3x10^5$, $3.3x10^5$ and $4.05x10^6$ $n.cm^{-1}.s^{-1}$, respectively. Filtered neutron beams are being utilized for the measurements of the total and capture cross sections in keV region. In this work, the transmission method was applied for measuring total cross sections of ^{93}Nb, ^{115}In and ^{141}Pr on the beams. The obtained results with the accuracy less than 2% are compared with data of previous works and evaluated data from ENDF/B-VII.

Keyword: filtered neutron beams, total cross sections, Dalat Research Reactor.

Nuclear Data Covariances in the Indian Context

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Abstract

The topic of covariances is recognized as an important part of several ongoing nuclear data science activities, since 2007, in the Nuclear Data Physics Centre of India (NDPCI).

A Phase-1 project in collaboration with the Statistics department in Manipal University, Karnataka (Prof. K.M. Prasad and Prof. S. Nair) on nuclear data covariances was executed successfully during 2007-2011 period.

In Phase-I, the NDPCI has conducted three national Theme meetings sponsored by the DAE-BRNS in 2008, 2010 and 2013 on nuclear data covariances. In Phase-1, the emphasis was on a thorough basic understanding of the concept of covariances including assigning uncertainties to experimental data in terms of partial errors and micro correlations, thorough a study and a detailed discussion of open literature.

Towards the end of Phase-1, measurements and a first time covariance analysis of cross-sections for ^{58}Ni (n, p) ^{58}Co reaction measured in Mumbai Pelletron accelerator using ^{7}Li (p,n) reactions as neutron source in the MeV energy region were performed under a PhD programme on nuclear data covariances in which enrolled are two students, Shri. B. S. Shivashankar and Ms. Shanti Sheela.

India is also successfully evolving a team of young researchers to code nuclear data of uncertainties, with the perspectives on covariances, in the IAEA-EXFOR format.

A Phase-II DAE-BRNS-NDPCI proposal of project at Manipal has been submitted and the proposal is undergoing a peer-review at this time. In Phase-2, modern nuclear data evaluation techniques that including covariances will be further studied as a research and development effort, as a first time effort. These efforts include the use of techniques such as that of the Kalman filter.

Presently, a 48 hours lecture series on treatment of errors and their propagation is being formulated under auspices of the Homi Bhabha National Institute.

The talk describes the progress achieved thus far in the learning curve of the above-mentioned and exciting efforts in the subject area of nuclear data covariances.

ICSBEP Criticality Benchmarking for Nuclear Data Validations, KAMINI, PURNIMA-II and PURNIMA-I

E. Radha,

Reactor Physics Section, Technical Services Division, ROMG,
Indira Gandhi Centre for Atomic Research, Kalpakkam.

Abstract

India has contributed three experimental benchmarks to the International handbook of the International Criticality safety Benchmark Evaluation Project (ICSBEP) of the US-DOE/NEA-DB. This presentation describes the interesting experience in creating these three Indian experimental benchmarks for nuclear data and code validation studies. The concept of definition of benchmark is also reviewed for convenience. Series of sensitivity studies are performed to assess the various uncertainties that arise in knowledge of the description of the actual system.

KAMINI (2005): The KAlpakkam MINI (KAMINI) reactor is a ^{233}U fuelled light water moderated and beryllium oxide reflected research reactor, in operation at Kalpakkam. Benchmarking essentially involves quality description of the core, which results in characterization of the errors, and uncertainties that in total effect together will not affect k_{eff} by more than 1000 pcm (10 mk). The k_{eff} and the uncertainty in benchmark of KAMINI in the characterization of the predicted k_{eff} was found to be 0.99119± 0.00025 (Monte Carlo)± 0.00744 (benchmarking). This differs significantly from values of k_{eff} reported in earlier publications by two different IGCAR teams that were 1.03 and 1.017. The reasons are explained.

PURNIMA-II (2008): Purnima-II was a ^{233}U uranyl nitrate solution fuelled, beryllium oxide (BeO) reflected, homogeneous experimental setup at BARC during 1984-86. The experiments carried out with this system included measurement of critical mass as a function of solution concentration, reactivity worth of various safety devices, and the measurement of void and temperature coefficients of reactivity. The fissile solution was contained in a cylindrical zircaloy core and was surrounded by 30 cm thick BeO reflector. A pair of cadmium absorber plates operating on opposite sides of the core-vessel screen off reflector returned neutrons for rapid shut-down. The k_{eff} and the uncertainty in benchmark of PURNIMA-II in the characterization of the predicted k_{eff} for uranium concentration of 116.6 g/l was found to be 0.9935± 0.0003 (Monte Carlo)± 0.00772 (benchmarking).

PURNIMA-I (2012): Plutonium Reactor for Neutronic Investigations in Multiplying Assemblies was designed, built and operated at BARC, Trombay as India's first zero-energy fast reactor in the early seventies. It was fuelled by plutonium oxide and reflected by 17 cm thick copper followed by shielding of 23 cm mild steel in radial direction. The fuel pins were contained in an asymmetric hexagon core-vessel of 52 cm height made of 7 mm thick stainless steel. The 4 cm thick top grid plate had tapered holes into which the fuel pins fitted snugly and were held in position by retaining nuts. Six safety rods and three control rods made of molybdenum located in vertical channels in the copper reflector close to the core. To shut-down the reactor, the core was driven out of the reflector. The k_{eff} and the uncertainty in benchmark of PURNIMA-I in the characterization of the predicted k_{eff} was found to be 1.01009± 0.00019 (Monte Carlo)± 0.00437 (benchmarking).

Evaluation of the D(n,2n)p Reaction Cross Section

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Abstract

D(n,2n)p is one of the simplest three nucleons reactions without Coulomb interaction, it is very significant for searching after nuclear force and nuclear theory. Deuterium is one of the important fusion fuels, therefore D(n,2n)p reaction cross sections are useful for nuclear power development. It is difficult to measure the D(n,2n)p reaction cross sections, up to now all the measured data of 13 sets have been collected from threshold to 25MeV. The original data and errors of all the experiments were analyzed. The recommended values of D(n,2n)p reaction cross sections were obtained on basis of least-squares fit with orthogonal polynomial, and were compared with the theoretical calculation and the ENDF/B-VII.1, JEFF-3.2, JENDL-4.0 and CENDL-3.1.

Key words: D(n,2n)p, least-squares fit, evaluation

Current Status of nTOF Facility Construction at KAERI

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Abstract

Building Neutron TOF (Time of Flight) experimental facility has been in progress at KAERI, where neutrons are produced by stopping primary electrons from the KAERI super conducting electron accelerator in a liquid lead target. While incident electrons are stopped in the liquid lead target, bremsstrahlung photons are produced. These bremsstrahlung photons produce neutrons through (γ, n) reactions within the target.

This project is being proceeded by two tracks. One is building an nTOF facility and the other is manufacturing a liquid lead photo-neutron source.

Currently, the direction of incident electron beam to the liquid lead target is changed from horizontal to 90^o downward direction for easy construction. The simulation results with new configuration give 8% decrease in neutron /photon ratio at collimator direction. However, we can reduce shielding thickness by 80cm in +x and 30cm in +z directions and the neutron flux along the TOF line is slightly higher than before.

In this year, the final version of blueprint for the nTOF facility construction will be ready and some components of the revised photo-neutron source will be manufactured.

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RF Electron Linacs for Neutron Time-of-Flight Facilities

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Abstract

Cross-section measurement of the interaction of neutrons with matter is of fundamental interest for physicists working on nuclear physics, astrophysics and condensed matter. The wish-list of the experimenter in this data-gathering exercise primarily includes a source of high neutron flux with a mechanism to obtain high energy resolution and large signal-to-noise ratio for data reliability. In the Neutron Time of Flight (n-TOF) technique, neutrons from a short-pulse source with a rich energy spectrum are allowed to propagate a certain distance so that the pulse is elongated. Choosing a particular time-slice in the elongated pulse amounts to selection of energy for the experiments.

Electron beams with energy higher than 10 MeV from an RF Linac can be incident on a high Z target like tantalum or uranium to produce an intense neutron source, thanks to the giant resonance mechanism. The Accelerator & Pulse Power Division of BARC is developing a 30 MeV indigenous RF Linac for IGCAR, Kalpakkam for radiation streaming studies in sodium in the context of FBTR technology. It is envisaged that the same linac can be used for n-TOF studies when radiation streaming studies are not in progress.

In the RF Linac, 50keV, 10ns electron pulses of a few amperes current will be first injected into a 1.5 meter long 15 MeV on-axis coupled cavity accelerating structure of standing wave type. Each accelerating structure will be sourced by a 2856 MHz, 7 μs pulsed Klystron at 7.5 MW power. A similar second stage structure will boost the energy to 30 MeV. Suitable optics will be incorporated at the injection end to enable effective beam-transmission at such high current. In the 10ns pulse, the output from the linac will be 30 micro electron pulses of varying energy, the first pulse having the maximum energy of 30 MeV with energy decreasing in subsequent pulses till it becomes 18 MeV in the last one. After emerging from the accelerating structure, the 10 ns pulse will be compressed to 1 ns to obtain a ten-fold enhancement in current. The compression in time will be achieved by taking advantage of different travel time of electrons of different energy in a suitably designed magnetic-field configuration. This beam will impinge on a Ta/U-238 target to result in a neutron source emitting 10^{13} neutrons/s. Design studies are in the initial stage at the moment and an out-line will be presented.

Overview of upcoming INO Facility

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Abstract

The India based Neutrino Observatory (INO) will be an underground laboratory, at the Bodi Hills in the Theni district of Tamilnadu, housing experiments that will benefit from the low cosmic ray background there. The flagship experiment will make measurements on atmospheric muon neutrinos and antineutrinos using a 50 kiloton Iron Calorimetric (ICAL) detector. As ICAL will be magnetised, with an average B-field of about 1.3 Tesla, it will be able to clearly identify the charge of the muons produced in charged current interaction of muon neutrinos and hence the identity of the primary muon neutrino or antineutrino. One of the key goals of ICAL at INO is to identify the neutrino mass hierarchy, normal or inverted. It will also make precise measurements of some of the parameters in the neutrino mass matrix. Apart from ICAL, the underground laboratory will also house other experiments such as a search for neutrinoless double beta decay using a cryogenic tin bolometer and a cryogenic silicon bolometer for dark matter particles in the low mass (few GeV) range. The current status of the R&D effort including that of the prototype ICAL to be housed at the Inter Institutional Centre for High Energy Physics at Madurai will be presented.

Nuclear Physics using VECC cyclotrons: Scopes and Possibilities

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Abstract

. The energetic ion beams (typically, ~10-60 MeV/nucleon) from K500 superconducting cyclotron (SCC) at the Variable Energy Cyclotron Centre (VECC), Kolkata, is going to open up unique opportunity of working in the frontier areas of intermediate energy nuclear physics, particularly around the Fermi energy domain. New, extensive experimental facilities are being built at VECC to facilitate proper utilisation of the superconducting cyclotron. In recent times, the room temperature cyclotron (VEC) has also been operating very steadily and delivering light ion (up to 4He) beams to the users. In this talk, the scope of research with the upcoming facilities and some highlights of the recent VEC experiments will be presented.

Physics study of D-D/D-T Neutron Driven Experimental Subcritical Assembly

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Abstract

An experimental program to design and study external source driven subcritical assembly has been initiated at BARC. This program is aimed at understanding neutronic characteristics of accelerator driven system at low power level. In this series, a zero-power, sub-critical assembly driven by a D-D/D-T neutron generator has been developed. This system is modular in design and it is first in the series of subcritical assemblies being designed. The subcritical core consists of natural uranium fuel with high density polyethylene as moderator and beryllium oxide as reflector. The fuel pins are made of metallic uranium with aluminum clad. A total of 160 fuel elements are arranged in a 13 X 13 square lattice. The central 3 X 3 positions form the central cavity for inserting the neutron source. The fuel is embedded in high density polyethylene moderator matrix. One of the unique features of subcritical core is the use of Beryllium oxide (BeO) as reflector and HDPE as moderator making the assembly a compact modular system. The core and reflector assembly is surrounded by an outer layer of borated polyethylene and cadmium. The subcritical core is coupled to Purnima Neutron Generator which works in D-D and D-T mode with both DC and pulsed operation. It has facility for online source strength monitoring using neutron tagging and programmable source modulation. Preliminary experiments have been carried out for spatial flux measurement and reactivity estimation using pulsed neutron source (PNS) techniques. Further experiments are being planned to measure the reactivity and other kinetic parameters using noise methods. This facility would also be used for carrying out studies on effect of source importance and measurement of source multiplication factor k_s and external neutron source efficiency in great details. Some Experiments with D-D and D-T neutrons will be presented. The plan for upgradation of this facility to higher Keff value and design of next generation of zero power fast experimental ADS facility will be discussed.

An Overview of FOTIA and LEHIPA

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Abstract

A 6 MV Folded Tandem Ion Accelerator (FOTIA) was commissioned in 2000 at BARC. Since then it is in operation and has been used both for basic and applied research. In FOTIA, negative ions extracted from a SNICS-II ion source at 150 keV are injected into low energy accelerating tube where they can be accelerated upto 6 MeV. In the high voltage terminal negative ions are stripped off their electrons to become positive ions and these positive ions are bent by an 180^0 magnet located inside the high voltage terminal. The beam is then injected into the second accelerating tube mounted in the same column section. In the second accelerating tube ions get additional energy gain of neV leading to total energy of (1+n) eV MeV. Here V is the terminal voltage and 'n' is the charge state of the ions. The beam energy analysis is then done using a 90^0 magnet. An energy resolution of 2 keV is achieved. At present, experiments are done using setups such as General Purpose Scattering Chamber, PIXE and external PIXE systems, Rutherford Back scattering and PIGE. All the nuclear physics experiments are done with 0^0 line using scattering chamber which has two movable platforms for mounting the detectors. The FOTIA is used very extensively for biology experiments where effects of radiation on live cells are studied. For this, beam is taken out in air through a 40 μ thick kapton foil.

We are also building a Low Energy High Intensity Proton Accelerator (LEHIPA) at BARC. It consists of a 50 keV ECR ion source, a 3 MeV CW Radio Frequency Quadrupole (RFQ) and a 20 MeV Drift Tube Linac (DTL). The LEHIPA is designed for 30 mA proton beam. The beam dynamics studies were done carefully and a transmission of > 97% is achieved. At these currents and low energies space charge forces become important and beam halo are formed and therefore apertures will be mounted at appropriate locations. A beam dump cum neutron target is being fabricated to handle beam power of 600 kW. A neutron yield in the range of 10^{15} n/sec is expected for 30 mA at 20 MeV and hence proper shielding etc have been planned. The first beam from LEHIPA is expected by end of 2015. Both FOTIA and LEHIPA will be excellent facilities for nuclear data generation at low energies.

In this talk, salient features of these systems and their present status will be discussed.

Overview of Nuclear Experimental Facilities and the Accelerator Facilities at IUAC

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Abstract

IUAC is a national user facility for accelerator based research programs in India. The accelerator facility consists of 15UD Pelletron tandem accelerator and a superconducting LINAC providing wide range of stable beams for nuclear physics and material science research. Nuclear physics research at IUAC focuses on heavy ion fusion reactions around Coulomb barrier energies to study a wide range of phenomena, namely, decay of excited states in nuclei, shapes and structure of nuclei, dynamics of fusion-fission reactions etc. Existing experimental facilities for nuclear research experiments consists of a 1.5 m diameter general purpose scattering chamber, recoil separators, gamma detector array and neutron detector array. Scattering chamber has been extensively used for elastic/inelastic scattering and fission fragment angular and mass distribution measurements. Dedicated detector setup made of multi wire proportional counters, time of flight detectors and charged particle array provide unique identification of charged particles and position & energy information. The recoil separator facilities HIRA and HYRA spectrometers have been used for measurement of evaporation residues in heavy ion induced reactions and for transfer reaction studies. Using the the clover/HpGe gamma detector array, a large number of experiments on nuclear structure studies has been performed by user community especially in the area of research in high spin studies and life time measurements. The recent addition of new facility consisting 100 neutron detectors coupled with fission fragment detectors can provide fresh opportunities for experimental study of dynamics of nuclear fission induced by heavy ions by exploiting the availability of high energy heavier beams from the LINAC accelerator. To further enhance the intensity and availability of new beams, accelerator facility is being augmented by addition of a high current injector in near future. An overview of the facilities and nuclear physics research programs will be presented here.

An Overview of BARC-TIFR Pelletron Linac Facility

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Abstract

The 14UD Pelletron Accelerator at Mumbai has recently completed twenty five years of successful operation. The accelerator is primarily used for basic research in the fields of nuclear, atomic, condensed matter and material science. The superconducting Linac booster provides additional acceleration to the ions from Pelletron injector up to A~60 region with E~5 MeV/A. Further, an alternate injector system to the Superconducting LINAC booster is planned as an augmentation programme, comprising of a superconducting ECR ion source, room temperature RFQ and superconducting low-beta cavity resonators. This talk will provide an overview of the recent developmental activities carried out at the Pelletron Accelerator Facility, resulting in enhanced overall performance and uptime of the accelerator. The application oriented programs initiated at Pelletron Accelerator and the current status of the alternate injector system at the Pelletron-Linac facility will also be discussed.

EXFOR Compilation and Nuclear Data Measurement at KAERI/NDC

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Abstract

KAERI/NDC has compiled domestic nuclear reaction data to construct the EXFOR database under the guidance of IAEA/NDS. The produced entries for EXFOR database are a total of 38 and these entries include mainly an experimental data for neutron total cross section, isomeric yield ratio and photo-fission yields by bremsstrahlung beam, the cross section production by charged particle. Since AASPP workshop in 2013, 2 of the total 38 entries entered at the EXFOR DB and one entry was reserved to enter the EXFOR as Compile status.

The production cross-sections of radionuclides from natural yttrium samples were determined by the activation method with the proton beam of 57 MeV at the Korea Multi-purpose Accelerator Complex (KOMAC). The photo-neutron cross-sections for ^{59}Co were measured by using the end-point bremsstrahlung energies of 55, 60 and 65 MeV at the Pohang Accelerator Laboratory (PAL). The induced activities in the irradiated samples were measured by the HPGe detector and the γ–ray spectrum was analyzed by the Gamma vision program.

The activities for EXFOR compilation and measurement will be presented on the 5th AASPP workshop.

Studies on High Energy Photon (Bremsstrahlung) and Neutron Induced Fission of Actinides and Pre-Actinides

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Abstract

In the present talk, study of the fission products yields in the photon (bremsstrahlung) induced fission of pre-actinides (e.g. ^{nat}Pb and ^{209}Bi) and actinides (e.g. ^{232}Th, ^{238}U and ^{240}Pu) with 8-80 MeV and 2.5 GeV, based on the experimental work using microtron (Mangalore), Khraghar (Navi-Mumbai), ELEBE (Germany), SAPHIR (France) and PAL (South Korea) will be discussed. The yields of fission products in the 3.7-18.1 MeV neutron induced fission of actinides (e.g. ^{232}Th and ^{238}U), based on the work using neutron generator of Physics department (PUNE), PURNIMA (BARC) and Pelletron (TIFR) will also be described. The experimental techniques and the importance of fission products yields data in the high energy photon and neutron induced fission of actinides and pre-actinides relevance to conventional reactors, AHWR and ADSs application as well as the basic understanding of fission phenomenon will be discussed.

Atlas of Nuclear Isomers and their Systematics

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Abstract

Isomers can be viewed as a separate class of nuclei and offer interesting possibilities to study the behavior of nuclei under varied conditions of excitation energy, spin, life-time, and particle configuration. We have completed a horizontal evaluation of nuclear isomers [1] and the resulting data set contains a wealth of information which offers new insights in the nuclear structure of a wide range of configurations, nuclei approaching the drip lines etc. We now have reliable data on approximately 2450 isomers having a half-life up to 10 ns. A systematics of the properties of nuclear isomers like excitation energy, half-life, spin, abundance etc. will be presented. The data set of semi-magic isomers strongly supports the existence of seniority isomers originating from the higher spin orbitals [2].

References:

1. A.K. Jain et al., Atlas of Nuclear Isomers, to be published.
2. B. Maheshwari, A.K. Jain and P.C. Srivastava, Phys. Rev. C, submitted.

R-matrix Analysis of n+^{6}Li Reaction

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Abstract

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.

Keywords: R-matrix ; FDRR ; ^{6}Li

Activities for Nuclear Data Measurement using Charged particle-, Neutron-, and Photon-induced Reactions in Korea

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Abstract

We report the activities for nuclear data measurements using charged particle-, neutron-, and photon-induced reactions in Korea. Charged particle-induced reaction cross-sections are determined by using the stacked-foil activation technique at the MC-50 cyclotron facility in the Korean Institute of Radiological and Medical Science. Neutron-induced nuclear data were measured by using the pulsed neutron facility, which consists of an electron linear accelerator, a water-cooled Ta target with a water moderator, and a 12 m time-of-flight path. It can be possible to measure the neutron total cross-sections in the neutron energy range from 0.01 eV to few hundreds eV by using the neutron time-of-flight method and also measured the photo-neutron cross-sections by using the bremsstrahlung from the electron linac.

We collaborated with foreign researchers in India, Japan, Russia, China, and Vietnam. We also utilized foreign facilities in India, Japan, Rusia, and USA.

Update Neutron Nuclear Data Evaluation for $^{236,238}Np$

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Abstract

The nuclear data with high accuracy for 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 burnup reactors and its transmutation. According to the systematic trend of the total cross section and elastic cross section etc. of different Np isotopes, and based on the neutron optical model parameters of ^{237}Np, a new set of neutron optical model parameters were obtained for $^{236,238}Np$. Based on the new set OMP and the systematic trend of the cross sections of different Np isotopes, a full set of $^{236,238}Np$ neutron nuclear data has been updated and improved by theoretical calculation. The present result has significant improvements over the data in CENDL-3.1.

Applications of the Photo-Nuclear Reaction Data for Activation Analysis

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Abstract

In the activation analysis the photo-peak area of the activated sample is usually caused by factors: nuclear reaction cross section, irradiation beam flux and energy spectrum. In the relative method of activation analysis by continuum wide spectrum gamma-rays the same isotope is usually used for standard reference material and sample element in connection with different dependence of the reaction cross sections on the irradiation beam energy. Besides, in practice suitable isotopes for reference element are not always available.

In this paper, we suggest a new method for photo-activation analysis in which is used the correction factor. This factor takes into account the difference in the photo-nuclear reaction cross section dependence on the gamma-ray energy for standard reference isotope and sample elements. The correction factor is determined by three methods of experimental, theoretical and TALYS evaluation.

In the experimental correction factor the experimental data of photo-nuclear reaction cross sections for the reference and sample isotopes are used. In connection with difficulty of exact measurement of flux for wide continuum energy spectrum gamma-rays we were forced to use the Schiff formula of the bremsstrahlung gamma-ray spectrum.

In the theoretical correction factor the Lorentz formula for the giant resonance cross section and the Schiff formula for the bremsstrahlung gamma-ray spectrum are used.

The evaluation by TALYS code is used in the correction factor calculation as a third method.

Pure metal foils of Au, Cu and Mo were irradiated by bremsstrahlung gamma-rays on the electron cyclic accelerator Microtron MT-22 at the Nuclear Research Center, National University of Mongolia. Gamma spectra of the activated metal samples were measured by HP-Ge detector to obtain element contents in the samples. It was shown that experimental results with correction factors are satisfactorily in agreement with real values of the element contents in the samples.

Recent EXFOR Compilation in CNDC

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Abstract

Since China joined IAEA, China Nuclear Data Center (CNDC) takes part in scanning Chinese journals and compiling EXFOR entries for IAEA. Which the experiments were carried out by Chinese researcher and the experiments were measured in China, CNDC need to scan and collect measured results and compile these data and information as EXFOR format including neutron and charge particle induced reactions. CNDC are respond more than 9 Chinese journals and IAEA assigns EXFOR compilation task. During 2010-2013, we have compiled 21 entries on charge particle and 39 entries on neutron induced measurements, and cooperate with IAEA to correct 1 entries. Up to now, we still have more than 40 articles should be compiled in 2014.

Nuclear Data Needs for Fast Reactors

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Abstract

The nuclear data, i.e., the numerical information about every nuclide - especially those representing the probabilities of various nuclear interactions and of radioactivity - of interest in a nuclear fission reactor are among the most essential inputs to be known a priori, to the best possible accuracy, for the design of nuclear reactor. The nuclides of interest cover not just (1) the fuel nuclides, the containers, the coolant, the moderator (if any), etc., that are initially inserted, but also (2) the actinides, the fission products, etc. that would be produced from the moment the reactor goes into operation and (3) the decay products that are produced even while the reactor is shutdown. The nuclide-list is known to cover a few hundreds. The neutron-nuclear interaction cross-section data, required for a few tens of reactions, very sensitively depend on the nuclide species and the neutron energy. Hence the data requirement significantly varies between thermal and fast reactors. The present talk is intended to touch upon the kinds and forms of nuclear data needed in the design and analysis of fast reactors. The recent variants available in the databases and some inter-comparison results will also be presented.

Nuclear Data Needs for Indian Nuclear Power Program

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Abstract

Currently 17 Pressurised Heavy water Reactors (PHWRs), 2 Boiling water reactors (BWRs) and 1 Pressurised water reactor (PWR) are being operated for power production by Nuclear Power Corporation India Limited (NPCIL). For PHWRs, different types of fuel bundles are simulated by the integral transport theory code, CLUB using a combination of collision probability method and interface current technique and employing IAEA supplied 69 /172 group WIMS cross section library based on ENDF-BVI, BVII. Ring power factors are calculated at different burnups and are used to estimate linear heat rating. The two group neutron cross sections of different type of lattices at different core irradiations are also generated by lattice code CLUB. Wherever reactivity devices are present, supercell approach is adopted and the suitable incremental absorption cross sections are obtained using BOXER which is based on 3-D integral transport theory considering two neutron energy groups. Using the appropriate properties for normal lattices and ones affected by reactivity devices, fuel management and core follow up studies are carried out using 3-D diffusion theory based TRIVENI code.

The KAPS-1 power rise transient on March 10, 2004 brought to focus the importance of accurate nuclear data for reactor physics estimation in Indian PHWRs. With IAEA supplied libraries in WIMS format we could satisfactorily resolve the rate of power increase. Stability analysis and sensitivity analysis was carried out for different incore burnup situations resulting from peak flux operation. The quantification of output uncertainties is necessary to adequately establish safety margins of nuclear facilities. The uncertainties in the integral parameters such as reactivity worth and coefficients due to cross section can be assessed using cross section covariance data produced directly from the uncertainties of measurements. Covariance data processing codes and sensitivity analysis tools have to be developed. The part of the uncertainty associated with the nuclear data is estimated by the adjustment method using different covariance evaluations using data sets such as ENDF B/VI, ENDF B/VII, JEF, JENDL etc. Other uncertainties are due to material dimension, density, isotopic composition measurements etc and the sensitivity matrix have to be developed based on measurements.

For shielding design, nuclear heat generation rate, activity calculation, neutron flux related studies, doses in operating and accident conditions, decay heat, radioactivity release, photo neutron estimations accurate nuclear data and processing tools are needed to be augmented.

References:-

1. P.D. Krishnani, "CLUB, A Multigroup Integral Transport theory code for analysis of cluster lattices", Annals of Nuclear Energy, Vol. 9, pp 255 to 260, 1982.
2. S.B. Degwekar, "BOXER-3, A 3D Integral Transport theory code for PHWR supercell", Report No. BARC-1295 (1985)

Sensitivity Studies on Nuclear Data for Thorium Fuelled Advanced Heavy Water Reactor (AHWR)

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Abstract

Sensitivity studies and uncertainty analyses on safety parameters for reactors are an important analysis tool for qualifying the basic nuclear cross section data. It is also helpful in providing adequate margins at the design stage. In India, the design on Advanced Heavy water Reactor (AHWR) based on thorium is in its advanced stage of development. It is a first-of-a-kind reactor designed with many passive safety features which required tobe qualified. In this paper, we discuss several types of sensitivity studies taken up for the integral parameters and reactivity coefficients for the AHWR-reference and the AHWR-LEU variant.

From isotopic and energy-wise breakdown of coolant void reactivity (CVR) in the AHWR-Ref lattice, it has been established that the major contributors are H, ^{232}Th, ^{233}U, ^{239}Pu and ^{240}Pu. ^{239}Pu has a positive contribution and a negative slope with burnup. ^{232}Th and ^{233}U have a negative contribution and a positive slope with burnup. H has a positive contribution to the CVR and a positive slope. The sensitivity to channel temperature reactivity (CTR) shows that the major contributors are H and ^{233}U which have positive components and ^{232}Th, ^{239}Pu and ^{240}Pu which have negative components. The ratio of the Maxwellian averaged capture to fission cross section of ^{233}U and ^{239}Pu has been used to explain the difference in the sign of the contribution to CTR from these isotopes.

Uncertainty analysis has been taken up for the newer version of AHWR lattice fuelled with (Th,LEU)MOX fuel with respect to processed multi-group data, manufacturing tolerances such as fuel density and enrichment variations. Variations in the multi-group nuclear data set accounts for 10% deviation in the calculated coolant void reactivity. The modelling uncertainties are as high as 25% in the coolant void coefficient. The sensitivities are larger with the use of a larger number of neutron energy groups. The Doppler coefficient of reactivity is uncertain by about 4%. The most sensitive parameter in the uncertainties in manufacturing tolerances is the variations in fuel pellet diameter which amounts to about 11%. Uncertainties in fuel density give rise to a sensitivity of about 7%.

The uncertainty studies are required to be taken to level higher where covariances can be established. It is important to analyse the uncertainties in a more rigorous manner.

Statistical Model Calculations Using TALYS Code for the Study of Neutron and γ Induced Reactions

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Abstract

TALYS-1.4 and EMPIRE are nuclear reaction codes and are essential for advanced modeling of nuclear reactions such as direct, compound, pre-equilibrium, fission reactions and to estimate their cross sections. These codes incorporate various nuclear models for the optical model, level densities, direct reactions, compound reactions, pre-equilibrium reactions, fission. They incorporate a large nuclear structure database, phenomenological expressions for parameters of these models depending on projectile energy and target mass. These codes simulate nuclear reactions involving projectiles such as neutrons, photons, protons, deuterons, tritons, ^{3}He and alpha-particles. TALYS code is useful for projectiles in the 1 keV - 200 MeV energy range and for target nuclides of mass $A \geq 12$. Cross sections can be calculated using default values of input parameters for a gross estimation, through a simplified input file listing only the projectile, target element symbols, their mass numbers, and incident projectile energy. However, detailed calculations can be done by using keywords in the input file for selecting several options for various physical models and their parameters in order to fit the experimental data. The keywords enable to select various quantities in output such as total and partial cross sections, energy spectra, angular distributions, double differential spectra, excitation functions for residual nuclide production, including isomeric cross sections.

Nuclear data of neutron and gamma induced reactions are of academic interest and also essential for many important applications. Especially, precision measurements of cross section data are needed for validating the nuclear reaction model codes and are of vital need for applications in reactor, dosimetry, medical and other fields. In this talk we discuss TALYS calculations for nuclear data applications. We present calculations for a few cases of neutron and gamma induced reactions and some of the experimental measurements performed by our group, such as $^{96}Zr(\gamma, n)^{95}Zr$, $^{93}Nb(\gamma, n)^{92}Nb$, $^{100}Mo(\gamma, n)^{99}Mo$, $^{238}U(\gamma, n)^{237}U$ at Eγ (bremsstrahlung) =10 and 12.5 MeV and the neutron capture reactions $^{238}U(n,\gamma)^{239}U$, $^{232}Th(n,\gamma)^{233}Th$ at various neutron energies. The experimentally determined cross-sections are compared with the TALYS calculations and also the evaluated data of ENDF-VIIB and JENDL-4.0 libraries, these details will be discussed.

Our collaborators covering many experiments and calculations, include Drs. Paresh Prajapati, Rita Crasta, Vikas Mullik, B.S. Shiva Shankar, K.S. Jagadeesan, S.V. Thackery, S. Ganesan and A. Goswami

Study of Elastic and Inelastic Neutron Cross sections using Time of Flight Technique

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Abstract

High precision neutron scattering data has become increasingly important in the development of nuclear reactors and accelerator systems, astrophysics and space system design, radiation therapy and isotope production, and for shielding considerations [1]. Previous evaluations of the neutron cross section standards were completed in 1987 and disseminated as NEANDC/INDC and other databases. R-matrix model fits for the light elements and non-model least-squares fits for the heavy elements were the basis of the combined fits for all of the data. Some important reactions and constants are not considered standards, but assist greatly in the determination of the standard cross sections and reduce their uncertainties.

Elastic and inelastic neutron cross sections are especially important for use in transport codes and energy-loss calculations; for the inelastic neutron channel, the resulting γ-rays can lead to heating of surrounding materials. Knowledge of the (n,n) and (n,n') channels are important for deducing the magnitude of other difficult or impossible to measure reaction channels which impact reactor operation. For ^{23}Na, the existing inelastic neutron scattering cross sections are known to approximately 30% in the 2-6 MeV region and the desired uncertainties are of the order of 12-13% [2].

The focus of the present work is to measure elastic and inelastic neutron differential scattering cross sections for ^{23}Na using Time of Flight Technique for a range of energies with a high accuracy level.

References:

1. P. Archier et al. (2011), ^{23}Na evaluation with CONRAD for fast reactor applications, Journal of the Korean Society **59(2),** 915-918.
2. *G. Aliberti, G. Palmiotti, M. Salvatores*, T. K. Kim, T. A. Taiwo, M. Anitescu, I. Kodeli, E. Sartori, JC Bosq, and J. Tommasi (2006), Nuclear data sensitivity, uncertainty and target accuracy assessment for future nuclear systems, Ann. Nucl. Energy **33,** 700-733.

Inclusion of nuclear data of Uzbekistan authors to the NRDC during 2013-2014 year

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Abstract

Uzbekistan's first step to join to IAEA was made in 1995 by International Nuclear Information System (INIS) and after that Uzbekistan became a member of INIS. The group organized in INP AS RUz (Tashkent) was called "Uzbekistan national INIS center". Liaison officer of this group is Dr. Makhtuba Kadirova and deputy liaison officer is Dr. M. Salimov. Uzbekistan national INIS center provides a comprehensive information reference service for the specialists in nuclear science and technology, including scientific publication in Uzbekistan (http://www.inp.uz/node/306).

Since the time INP was founded, a number of nuclear experiments have been made and the nuclear reaction data, induced by charged-particle reactions obtained. During the years, the obtained experimental data have been published in domestic and international journals. In order to save those data for future needs, they needed to be added to some database. Those works have been performed by members of Nuclear Reaction Data Centres (NRDC) of the world. At the time of those works were carrying out, some problems appeared related to the correspondence with domestic authors of the articles. To solve those problems, the members of the centers decided to contact with scientists of domestic institutes and request them to contact with authors, collect experimental data from them.

The next step toward to join to IAEA was participation in the 4th Asian Nuclear Reaction Database Development Workshop (ANRDDW) which was held in Almaty, Kazakhstan (23-25 October, 2013). Researchers from Uzbekistan participated in this workshop and set active collaboration with members of CA-NRDB (Central Asian Nuclear Reaction Data Base). The new EXFOR entries prepared by the Kazakhstan and Uzbekistan compile group are shown in Table 1.

The nuclear scientists of Uzbekistan suggested including the data on astrophysical S-factor obtained for the nuclear astrophysical reactions at low energies in the future.

Table 1. New EXFOR entries prepared by the Kazakhstan + Uzbekistan group

Entry #	**First author**	**Article**	**Lab.**	**Status**
31737	S.R.Palvanov	J,PAN,77,35,2014	4UZ UZB	PRELIM.3163
31738	Yu.N.Koblik	J,PAN,77,39,2014	4UZ UZB	PRELIM.3163
31741	G.A.Abdullaeva	J,NESE,3,72,2013	4UZ UZB	Compiled.
D0712	N.Burtebayev	J,NP/A,909,20,2013	4KASKAZ	TRANS.D093
D0726	A.Vasidov	J,IZU,1981,(3),93,1981	4UZ UZB	in EXFOR
G0041	S.R.Palvanov	J,PAN,77,35,2014	4UZ UZB	PRELIM.G029

Joint Activities with IAEA on uploading of Scientific Papers from Kazakhstan and Uzbekistan into the EXFOR Database

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Abstract

More than a year passed since Kazakhstan joined the international network of nuclear reactions data centers (NRDC). A Central Asian centre for nuclear reactions (CANRDB, Central Asia Nuclear Reaction Database) has been established at al-Farabi Kazakh National University, and a group of experts there is actively working on expansion of the database, further development of the specialized software, and fostering partnership with international nuclear physicists. There are also on-going activities aimed on training, searching of the published nuclear data obtained earlier by scientists from Central Asia to incorporate their results in the database. The main objective of CA-NRDB is the development and formation in Kazakhstan of open and user-friendly database on nuclear reactions with further incorporation of this database in the international network of nuclear databases under the International Atomic Energy Agency (IAEA). We note that such a database is created in the entire Central Asian region for the first time.

The CANRDB team started its work from compilation of research article in November 2013 and since then eleven articles were downloaded into the EXFOR database. All the articles were published in 2013-2014 and relate to experiments on nuclear reactions; the authors are from Kazakhstan and Uzbekistan. Below we present a list of the articles incorporated in the database by the CANRDB team.

Entry #	First author	Article	Lab.	Status
31737	S.R.Palvanov	J,PAN,77,35,2014	4UZ UZB	PRELIM.3163
31738	Yu.N.Koblik	J,PAN,77,39,2014	4UZ UZB	PRELIM.3163
31741	G.A.Abdullaeva	J,NESE,3,72,2013	4UZ UZB	Compiled.
D0711	Sh.Hamada	J,PR/C,87,024311,2013	4KASKAZ	in EXFOR
D0712	N.Burtebayev	J,NP/A,909,20,2013	4KASKAZ	TRANS.D093
D0723	V.T.Gkadun	J,IZK,1980,(4),82,1980	4KASKAZ	in EXFOR
D0725	I.N.Khaustov	J,IZK,1990,(2),3,1990	4KASKAZ	in EXFOR
D0726	A.Vasidov	J,IZU,1981,(3),93,1981	4UZ UZB	in EXFOR
D0727	S.Muhammedov	J,IZU,1985,(5),81,1985	4UZ UZB	in EXFOR
D0728	V.V. Dyachkov	IET,56,521,2013	4KASKAZ	in EXFOR
G0041	S.R.Palvanov	J,PAN,77,35,2014	4UZ TSK	PRELIM.G029

As one can see from the table above, six articles have already been posted and are available at the related IAEA web-site. Such uploading process takes from one to four months. Several articles published in previous years in local journals are now processed for incorporation in the EXFOR database.

CANRDB team has participated in the technical meeting of NRDC under the auspices of the IAEA held in Smolenice (Slovakia) on May 6-9, 2014. Participation in this meeting was of particular importance for the CANRDB team and allowed to present our activities among experienced colleagues from other centers with nuclear data bases. This was the first step towards joining the NRDC network. Important issues related to preparation of some valuable articles published in local journals in the past, digitization of data and data incorporation to the EXFOR database were discussed at the meeting. We plan to continue such work together with Dr. Naohiko Otsuka during his visit to Almaty. There will also be arranged a training for the CANRDB team members on how to upload articles into the EXFOR database.

Our center maintains friendly cooperative relations with many data centers in different countries. We are planning to officially incorporate the CANRDB into the International Network of NRDC. In this regard, the team is planning to upload all the noticeable domestic papers into the EXFOR by the next technical meeting to be held in Vienna on April 2015.

Introduction on the Digitization Software GDgraph

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Abstract

For 30 years, China Nuclear Data Center (CNDC) has been accumulating neutron and charged particles induced reaction data as EXchange FORmat (EXFOR) data files.

The evaluators and experimenters always desire to have full and latest experimental data sets. However, the data are often published as figures without numerical values for some publications or journals. Furthermore, the quality of figures is not always good enough, especially for some figures scanned from the hard copy of old publications. In the other hand, the researchers would like to retrieve the data directly from EXFOR database. Digitization of figures is only one method to obtain the numerical data and correlative uncertainty, when there are only figures available from publications. Therefore need a digitization software to fit the requirements from evaluation, measurement and EXFOR compilation in CNDC.

Before 2000, there was no common software to digitize experimental and evaluated data. And the quality of digitization results can not fit the requirements of evaluation and measurement using the traditional coordinate paper (plotting paper) or rule. The end of twenty century, the personal computer was developed so quickly that to develop a software for digitization purpose become possible. Since 1997, CNDC devotes to develop a software for digitization. The first version of digitization software GDGraph was developed and released in 2000 using VC++ language. Although, the functions of the 1st version of GDGraph is fit the basic requirements of digitization only, in which can digitize one group data excluding data error, BMP image format only, and it can not randomly delete digitizing points. However, the mold of GDGraph software can obtain higher quality digitizing results and high efficiency than the traditional way.

Five years late, collected much feedback information on update and bugs of this software. The 2nd version of GDGraph software was released at 2006, in which the whole software was re-written using Perl computer language to obtain more comfortable conditions for programming and updating. The version 3.0, 4.0 and 5.0 of GDGraph is released at 2011, 2012 and 2013, respectively.