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A Status report on EXFOR compilation activities in India and on formation of Nuclear Data Physics Centre of India (NDPCI)[1]

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Abstract: This progress report presents an overview of progress and the current status of NDPCI within the perspectives of NRDC. India became a member of NRDC in September 2008. The 3rd EXFOR Meeting was held in Jaipur during November 3-7, 2009. Since 2006, more than 125 new Indian EXFOR entries have been made and accepted by the IAEA.

On formation of Nuclear Data Physics Centre of India (NDPCI)

This center, NDPCI, will serve as the main hub for overall coordination of nuclear data activities in India with members drawn from national labs and universities. The centre will promote use of accurate nuclear data and its physics usage in all applications including in development of indigenous software for Monte Carlo codes and discrete ordinate cores for advanced reactor applications.

Activities and mandate of the NDPCI

The roadmap in nuclear data physics will cover the wide range of power and non-power applications in the Indian context, with a balance of nuclear data physics activities by a well-defined team of nuclear physicists, engineers, mathematicians, radiochemists and software information management:

- Experimental generation of basic physics data. Indian leadership recognizes that experimental studies require good quality research facilities to determine nuclear cross sections covering neutron and charged-particle reactions, and nuclear structure and decay data (all with well-defined uncertainties and to high accuracy), with the ability to

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cover the nuclear data physics needs for advanced fission and fusion systems (that also has thorium fuel and closed fuel cycle), analytical science and nuclear medicine. This involves significant costs and capital outlay, and all nuclear physicists by default would provide the expertise to undertake equipment development tailored to nuclear data physics measurements.

- Compilations of nuclear physics data generated by experiments in India and training workshops in EXFOR
- computerized visualizations
- large nuclear data files information management, IAEA mirror website (http://www-nds.indcentre.org.in) at Mumbai and India NDPCI website (to be created soon)
- evaluations which include nuclear model based predictions and covariances
- creating of computerized Indian evaluated nuclear data files in ENDF/B format
- physics laws based nuclear data processing for multi-group and Monte Carlo applications,
- Integral measurements and validations by use of experimental benchmarks and critical facilities.

The NDPCI will

- ❖ Organize theme meetings and national conferences on nuclear data physics
- ❖ Provide support for joint experiments and development of computer programmes interfacing with nuclear databases.
- ❖ Provide support to advanced reactor applications to enable use of updated nuclear data
- ❖ Provide fellowships to visiting research students and internships to summer students of Post Graduate and Undergraduate level.
- ❖ Coordinate experimental and theoretical programmes on nuclear data physics involving IAEA Nuclear data Section and be a single window from India for all its nuclear data physics activities as required by the IAEA-NDS.
- ❖ Coordinate experimental and theoretical programmes on nuclear data physics involving international informal collaborations.
- ❖ NDPCI can help to form useful local neutron data centres in Universities and Institutes on a coordinated programme mode.

NDPCI, a new Initiative in BARC

Director, BARC proposed, in early 2009, the formation of a strong and sustainable Indian Nuclear Data Centre. In-principle approval was accorded by Chairman, Indian Atomic Energy Commission August 2009. In view of the significant progress made in the last five years in nuclear data physics activities in a coordinated manner and in order to take this programme forward, BARC has proposed that the Nuclear Data Physics Centre of India (NDPCI) be formed with BARC serving as the nodal agency.

DAE-BRNS funding agency is just allocated the funds and a mechanism to release the funds to meet the stated objectives of the NDPCI is being evolved. It is proposed that there will be two committees, one with members drawn from working level for formulation of programmes and implementation and one for monitoring the progress. The Nuclear Data Physics Centre of India will function, to start with as a virtual centre. As of now there is no permanent and full time staff but the situation is expected to change to establish permanent and part-time faculty. The NDPCI will be formally announced during this year any time. Upon formal formation of the NDPCI, Director, BARC will be requested to communicate to the IAEA the formation of Nuclear Data Physics Centre of India. A separate user email ID with co-ordinator/s with a website for NDPCI will be established. This center will act as the window for IAEA and other international forums.

NDPCI and scope of interaction in nuclear data physics topics with Indian Universities

A number of students and staff from the Universities have expressed a desire to have training workshops on nuclear model codes and evaluation science of nuclear data. These will be planned by NDPC which will help in making proposals and recruiting Junior Research Fellows within the scope of functionality of the DAE-BRNS mechanisms. NDPCI will also conduct brain-storming sessions to propose new facilities for data measurements, new proposals in the Indian context such as, for instance, 15 MeV to 60 MeV electron accelerator based neutron sources.

Some the activities are briefly stated below.

- *Basic nuclear data physics measurements. FOTIA (BARC), BARC-TIFR Pelletron, IUPAC (Delhi, VECC (Kolkata) PURMIA (BARC) D-D, D-T sources),* Photon induced reactions (Electron accelerator based bremstrahlung at Kharghar); Pune 14 MeV facility. IPR 14 MeV facility etc.
- *Basic nuclear data compilations; IAEA-EXFOR compilations.*
- *Co-ordinate activities with NRDC.*
- *Nuclear model based calculations and theoretical* predictions obtained using codes such as the European state-of-the-art software TALYS package and the USA package,, *EMPIRE. Encouragement will be given to develop our indigenous codes.*
- *Processing of evaluated nuclear data files to produce plug-in libraries for discrete ordinates and Monte Carlo codes. Development of indigenous processing codes will be encouraged*
- *NDPCI will serve as a catalyzing agent to indigenously process and generate nuclear data libraries for Indian software and applications*
- *Efforts to digest the status of covariance error methodology in nuclear data and its applications. A beginning with Manipal University DAE-BRNS Project has been made.*
- *Preparation of integral Indian experimental criticality benchmarks for integral nuclear data validation studies. (KAMINI, PURNIMA-II benchmarks completed and accepted by the US-DOE). PURNIMA-I benchmarking has been performed and critical internal peer-review in progress.*
- *Advanced Indian reactor sensitivity studies to assess the impact of using different evaluated nuclear data files such as ENDF/B-VII.0 and JENDL-3.3 for Advanced Heavy*

Water Reactor and Compact high temperature Reactors (Being performed in RPDD, BARC)

DAE-BRNS projects in neutron data physics

In India, we are including all the national laboratories and university teams using the DAE-BRNS mechanisms in order to evolve a streamlined and coherent activity of nuclear data for all our applications that will be sustainable. Examples of such DAE-BRNS projects under active implementation include the following:

- 14MeV neutron data physics project in Pune University.
- Nuclear data physics activities at Jaipur University. (ADSS- DUBNA)
- Measurements using the Microtron facility in Mangalore University.
- Ongoing project: Covariance error matrix in nuclear data physics at the Department of Statistics, Manipal University, Karnataka.
- "Nuclear model based calculations of particle-nuclear interaction cross sections," at the Department of Physics, G.B. Pant University, Pantnagar, India.
- "Studies for 14 MeV and fast neutron induced fission/reaction for AHWR and ADS applications", at the Maharaja Sayajirao University of Baroda, Vadodara.
- Nuclear data physics project at Bharathiar University, Coimbatore, Tamilnadu. The project is entitled, Studies on nuclear fission reaction process with orientation to nuclear data needs of India's advanced reactor programme". Project recently sanctioned by DAE-BRNS after a critical review:
- IIT-Rourkee, Proposal by Prof. Ashok K. Jain on Evaluated Nuclear Structure Data File (ENSDF). A new nuclear data physics activity to be initiated also in BARC. DAE-BRNS critical review-- in Progress.

Indian nuclear data mirror website at Mumbai

The online nuclear data services (http://www-nds.indcentre.org.in/) mirror the nuclear data website of the Nuclear Data Section of the International Atomic Energy Agency (IAEA), Vienna (http://www-nds.iaea.org).

The India mirror site is getting increased usage. For instance, the monthly statistics retrieved by the Computer Division of BARC (Courtesy A. G. Apte, C.S. R. C. Murthy and Rohitashva Sharma) is presented below as an example for the period of December 2009.

The Mumbai mirror nuclear data website has been fully functional since Nov. 2004 when a 5 year MOU arrangement was made between BARC and IAEA. Under this arrangement, online-updating every 12 hours is performed in the mirror with the IAEA website through a 2MB direct link. The server is being maintained by BARC Computer Division - with manpower and machinery. *The MOU between DAE/BARC and the IAEA is expected to be continued beyond 2010. This will be co-ordinated by NDPCI.*

Monthly Statistics for December 2009		
Total Hits		**25614**
Total Files		**7319**
Total Pages		**8677**
Total Visits		**250**
Total KBytes		**4644250**
Total Unique Sites		**18**
Total Unique URLs		**3962**
Total Unique Referrers		**68**
Total Unique Usernames		**3681**
Total Unique User Agents		**80**
	Avg	**Max**
Hits per Hour	**56**	**15438**
Hits per Day	**1348**	**20750**
Files per Day	**385**	**2934**
Pages per Day	**456**	**8325**
Visits per Day	**13**	**124**
KBytes per Day	**244434**	**1167982**

India offers to host regional IAEA Training workshops on nuclear data online services on the pattern of the highly successful IAEA-ICTP Workshops on nuclear data physics, if requested by the Agency. NDPCI will co-ordinate the same.

Required staff for online ND services: Under the NDPCI, a full time staff (1 SO and one SA) will be assigned to take care of interfacing with the IAEA mirror site. Right now the computer Division and RPDD are co-ordinating this activity.

Nuclear Data activities for the Indian fast reactor programme

With the construction of the PFBR, and with the efforts for enhancing the capacity of the FBTR, a lot of *nuclear data processing activities* have been devoted to meet the needs of India's fast reactor programme at IGCAR, Kalpakkam. There are 3 scientists in the Nuclear Data Section of Reactor Physics Design Division at IGCAR, Kalpakkam. Their scientific efforts involve QA assured physics processing of nuclear data files supplied by international sources such as the IAEA. *These applied physics efforts at IGCAR can be networked by NDPCI with other units and educational institutes for enhancing these activities.*

Professional Meetings in India on nuclear data physics

Since 2004, as a result of recognition of the importance of nuclear data physics research (following signals from reactor operations and fuel cycle studies), increased nuclear data physics activities in India resulted in several (more than 12) professional meetings on nuclear data physics. These were encouraged and successfully conducted under the auspices of DAE-BRNS in the last four years by BARC/DAE.

INDIA's EXFOR nuclear data compilation activities in collaboration with NRDC-IAEA.

The details of new Indian EXFOR entries are, for instance, available in "Full EXFOR Compilation Statistics", in the IAEA-NDS site: http://www-nds.iaea.org/exfor-master/x4compil/progress_India.htm

Three successful workshops on EXFOR have been held thus far: 2006 (Mumbai), 2007 (Mumbai), 2009 (Jaipur). *This EXFOR activity represents introduction of a new Experimental Nuclear Physics Database culture in India and a challenge.* The importance of such highly-focused training courses on EXFOR is well recognized and they are not deliberately combined with national nuclear physics conferences as there is a need to decouple and hold conferences and training workshops on EXFOR separately to sharpen and maintain the aims and objectives of EXFOR compilations.

The 3rd DAE-BRNS Theme Meeting on EXFOR Compilation of nuclear data, 3-7, November, 2009, Department of Physics, University of Rajasthan, Jaipur, 302004 was indeed a great success. We had over 70 delegates from various leading Academic and Research Institutions across India. The delegates are from across India from various Institutes that include BARC, IGCAR, NPCIL, University of Pune, MS University, Vadodara, BHU, Varanasi, NEHU, Shillong, NIIT-Jhalandhar, Panjab University, Chandigarh, Bharathiar University, Coimbatore, Tamilnadu, Mangalore University, University of Rajasthan, and several other colleges in the country. The delegates worked from 9:30 AM to up to 8PM every day. There were in use 20 desktop computers and another 20 individual laptops brought by delegates. This Theme Meeting was not in the nature of a seminar or conference. During the Theme Meeting, the delegates had a lot of specialist discussions and EXFOR coding tasks in a focused manner for placing the Indian experimental nuclear physics data into the IAEA EXFOR database. Participants were all in praise and full of excitement for this new and unique activity and initiative of BARC/DAE-BRNS.

The IAEA-NDS Co-ordinated Research Project (CRP) on "Prompt fission neutron spectra of actinide nuclei" (2010-2013).

India is a participant in this IAEA-CRP. The main proposed goal would be to determine the prompt fission neutron spectra and covariance matrices for actinides in the energy range from thermal to 20 MeV, including validation against integral critical assembly (k-eff) and dosimetry data. India will consider carrying out measurements of Prompt Fission Neutrons for Th-232 (and perhaps U-235 or U-238) to compare with available data at 3 MeV energy. This would complement other proposed programmes of various other countries, where extensive measurements of U-235 have been undertaken. PFNS measurements are recommended to be carried out as ratio measurements respect to the well established PFN standard of Cf-252.

BARC has accelerator facilities (e.g., Pelletron and FOTIA). We thus have accelerator facilities providing Li (p,n) based neutron source. We also have thermal and fast research reactors for

neutron irradiation. Research reactors based (e.g., DHURUVA) neutron source facilities are in use for several applications. Presently BARC is in final stages of setting up a new and advanced experimental facility for PFNS studies. This facility includes advanced neutron detectors and fission fragment detectors for carrying out high resolution neutron spectrum measurements using NE213 type detectors and silicon strip detectors. We have expertise indigenous electronics modules and time-of-flight methodology.

BARC has initiated EXFOR compilation of neutron induced fission physics data of actinides already measured and published by BARC in journals of repute since the early sixties but not yet coded into EXFOR.

Concluding remarks

BARC/DAE recognizes that the field of nuclear data physics is a thrust area to implement and is initiating the formation of a strong and sustainable Nuclear Data Physics Centre of India (NDPCI). In India, the nuclear data physics activities have been significantly enlarged in scope in the last 5 years due to the requirements of advanced reactor systems and the thorium fuel cycle. *More than 125 Indian EXFOR entries based upon Indian nuclear physics experiments since 2006 have been made and accepted by the IAEA. The Indian EXFOR data compilation activity has increased international visibility to India's work in nuclear physics data generation.* India appreciates the initiative by the IAEA-NDS in deputing its faculty (for instance, Dr. Ms. Svetlana DUNAEVA during November 3-7, 2009 period). India offers to collaborate with other network of reaction data centres and help host more such training workshops on international co-ordination of EXFOR compilation activity in the coming years. Presently, as a member of NRDC, BARC (NDPCI) plans to continue the EXFOR compilation activity and take up more responsibilities in co-ordination with the IAEA and NRDC network.