**P6 (Rev.)**

# A brief summary report on selected Indian nuclear data physics activities: A status report submitted to the NRDC Meeting-2008[1]

S. Ganesan, Scientific Officer (H+), Head, Nuclear Data Section,
Reactor Physics Design Division, 5th Floor, Central Complex,
Bhabha Atomic Research Centre, Trombay,
Mumbai-400085 India

## *1. Introductory Remarks*

The current status of the Indian nuclear programme for energy and non-energy applications is well described in the official websites. See, for instance, a document on vision: http://www.dae.gov.in/publ/vision.pdf

Until 2004, both at BARC and IGCAR, the Indian nuclear data activities were confined to processing of ENDF/B files and thus generically encompassed the user-oriented reactor physics approach starting from the basic evaluated nuclear data files available from the IAEA. The nuclear data physics activities in the last 4 years have expanded considerably beyond this perspective to initiate and include R & D activities on our own nuclear data evaluation, processing and integral testing. Experimental basic neutron data measurements using accelerator and reactor based neutron sources and also a programme of critical facility for integral validation of reactor physics data of Advanced Heavy Water Reactor at BARC have been initiated.

This document provides a brief account of Indian nuclear data physics activities in the last 2 years with stress on aspects of interest to this Meeting of International Network of Nuclear Reaction Data Centres (NRDC), which India is attending for the first time.

All the reactor physics applications oriented processing tasks at BARC and IGCAR have been covered in the INDC report presented in the 27th International Nuclear Data Committee (INDC) Meeting, April 21-25, 2008, IAEA, Vienna, Austria, Europe and are not repeated here to save space.

## *2. Indian EXFOR compilation activities*

India successfully contributed 10 new entries in 2006 and 31 new entries in 2007 and many more new EXFOR entries are continuing to be made. Thus far, in all more than 50

[1] *IAEA Technical Committee Meeting of International Network of Nuclear Reaction Data Centres (NRDC) from 22 to 25 September 2008 at the Institute of Physics and Power Engineering in Obninsk, Russian Federation*

new Indian EXFOR entries based upon experimental data generated in Indian nuclear physics experiments have been successfully made into the IAEA-EXFOR database. The identification for coding into EXFOR of all the suitable Indian articles published in the literature was done by the IAEA-NDS staff.

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/exfor_input.htm

The EXFOR activity in India got a boost with BARC successfully organizing two EXFOR national training workshops sponsored by the DAE-BRNS (department of Atomic Energy-Board of Research in Nuclear Sciences) mechanism, one in 2006 and another in 2007. In each of these two workshops, more than 40 delegates (experimental nuclear scientists, University faculty, Ph. D. and M.Sc., students) took active part and got a "first time" exposure to a classical nuclear data physics activity of EXFOR compilation culture. India appreciates the initiative by the IAEA-NDS in deputing Dr. Otto Schwerer during September 4-8, 2006 period and Dr. Ms. Svetlana DUNAEVA during October 29-November 2, 2007 period as faculty in these Indian training workshops on EXFOR. 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, BARC plans to continue the EXFOR compilation activity and take up more responsibilities. After the two IAEA-EXFOR training workshops, a Ph. D. student (Paresh Prajapati from MS University, Vadodara) is continuing to work with us. Thus far, he has made nine new Indian EXFOR entries (Reference: EXFOR entry with no: 33003, D6007, 33011, 33016, 33017, 33018, 33019, G0014 and D6016 and accepted by the IAEA).

### *3. Efforts towards evolving a strong and sustainable Indian nuclear data centre.*

BARC is in the process of initiating the formation of a strong and sustainable Indian nuclear data centre. The nuclear data physics activities have significantly been enlarged in scope in the last 4 years in India.

Presently the nuclear data physics activities in India encompass already the following activities:

- Basic nuclear data physics measurements.
- EXFOR compilations.
- Nuclear model based calculations.
- Processing of evaluated nuclear data files to produce plug-in libraries for discrete ordinates and Monte Carlo codes.
- Efforts to digest the status of covariance error methodology in nuclear data and its applications
- Preparation of integral Indian experimental criticality benchmarks for integral nuclear data validation studies

In the last four years, as a result of increased nuclear data physics activities in India, several professional meetings on nuclear data physics were encouraged and successfully conducted by BARC/DAE. See Appendix-1.

In India, we are locating interested faculty in the Universities 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. See Appendix-2.

Recruitment of permanent manpower to compile and co-ordinate EXFOR activity in India and with network of centres abroad will be one of the urgent tasks under the proposed Indian nuclear data centre

### *4. The online nuclear data services*

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).

Presented below for May 2008, as an illustration, is the monthly statistics of the use of online services, as retrieved by C. S. R. C. Murthy, Computer Division, BARC. Total hits were 113437 with a 10144068 Kbytes with more than 3600 hits per day during this month.

**Table-1: Monthly Statistics for May 2008**
(http://www-nds.indcentre.org.in/)

| | | |
|---|---|---|
| Total Hits | **113437** | |
| Total Files | **108189** | |
| Total Pages | **99936** | |
| Total Visits | **2268** | |
| Total KBytes | **10144068** | |
| Total Unique Sites | **1741** | |
| Total Unique URLs | **9955** | |
| Total Unique Referrers | **231** | |
| Total Unique User Agents | **253** | |
| | **Avg** | **Max** |
| Hits per Hour | **152** | **594** |
| Hits per Day | **3659** | **9509** |
| Files per Day | **3489** | **9269** |
| Pages per Day | **3223** | **8576** |
| Visits per Day | **73** | **127** |
| KBytes per Day | **327228** | **1067693** |

The Mumbai mirror nuclear data website is fully functional since Nov. 2004 when a 5 year MOU arrangement was made. 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.*

India offers to collaborate with other network of reaction data centres and help in promoting the online nuclear data services in the coming years.

### *5. Experimental generation of nuclear data*

- Determination of the $^{233}$Pa (n, f) reaction cross-section from 11.5 to 16.5 MeV neutron energy by surrogate ratio method.
- Experimental 14MeV nuclear activation data generation at the University of Pune, Pune, India.
- Experimental Studies on fast neutron and bremsstrahlung induced reaction and fission of actinides and preactinides.
- Measurements of MeV range neutron activation cross-sections using 14 MV BARC-TIFR Pelletron machine.

### *6. CERN n_TOF international collaboration-Phase-2*

After a Letter of Intent was signed by all member teams in the n_TOF Collaboration participating in Phase-1, the CERN management and the n_TOF Collaboration started in 2005 a negotiation for the definition of the Memorandum of Understanding (MoU) for the execution of experiments at the CERN n_TOF facility for Phase-2. CERN has accepted the LoI signed by the Director of BARC.

A. Mengoni (IAEA-NDS) visited BARC during May 30 – June 2, 2007 and delivered a lecture on "Experimental activities at the CERN neutron time-of-flight facility (n_TOF): Results and perspective for the future". The lecture and discussions were all well received. Soon, in 2008, a formal MOU between BARC and CERN is expected to be signed.

### *7. The informal collaboration with the Pohang 100MeV electron LINAC*

The informal collaboration with the Pohang 100MeV electron LINAC facility is continuing since 2003 for nuclear resonance data measurements. For instance, Dr. H. Naik, BARC will be visiting Pohang as a visiting scientist for 3 months during the last quarter of 2008 to continue generation experimental data of photo-fission yields and photon induced neutron emission cross sections.

### *8. ENSDF Evaluation Activities.*

The ENSDF evaluation activities are being continued by Ashok Jain (IIT Rourkee), M. Gupta (Manipal), Gopal Mukherjee (VECC, Kolkata) and others. For the interested reader, details are available in the INDC report presented in the 27$^{th}$ International Nuclear Data Committee (INDC) Meeting, April 21-25, 2008, IAEA, Vienna, Austria, Europe.

### *9. Integral nuclear data validation studies*

India is formally listed as a contributor since 2005 in the International Handbook of Evaluated Criticality Safety Benchmark (ICSBEP) Experiments published by the USDOE-NEA for integral nuclear data validation studies (hhtp://icsbep.inl.gov). India was admitted to this project in the year 2005 following our submission of the KAMINI experimental bench mark. A document on PURNIMA-II (the $^{233}U$ nitrate solution) criticality experimental Indian benchmark was prepared by T. K. Basu. C. P. Reddy, E.Radha, K. K. Rasheed and S. Ganesan. This document has successfully gone through a critical international peer-review in the last 2 years by the ICSBEP and accepted for publication in the 2008 ICSBEP DVD handbook for nuclear data validation studies.

### *10. Software Packages developed by BARC and contributed to the IAEA*

- **The XnWlup software:** The XnWLUP developed at BARC has been designed to view the histogram of 69/172 multi-group cross sections as a function of neutron energy is used by WIMS-D users / thermal reactor physicists extensively around the world. Thiyagarajan et al., successfully developed this software for MS-WINDOWS environment. This program has been designed using Microsoft Visual C++. Microsoft Internet Explorer is required to view the online help topics. The XnWLUP code that has been tested with several WIMSD libraries in 2008 is available:
    - http://www-nds.indcentre.org.in/wimsd/downloads.htm
    -
- **The SIGACE software**: Collaboration between the Institute for Plasma Research, BARC and the IAEA NDS resulted in the successful development of the SIGACE software for use in the Monte Carlo simulations of nuclear systems. In this software, a new recipe has been evolved for generating high-temperature ACE files for use with the MCNP code. The SIGACE code that has been tested with several FENDL/MC files (endorsed for ITER and fusion reactor applications) is available:
    - http://www-nds.indcentre.org.in/fendl21/downloads/

***Acknowledgements:***

The author thanks all the colleagues from various Divisions in BARC, IGCAR and other units of the DAE and colleagues in the Universities for having provided valuable input to make this report possible. The professional interactions with the IAEA-NDS are gratefully acknowledged with sincere thanks.

# Appendix-1: Professional Meetings in India (2006-2008) on nuclear data physics

1. DAE-BRNS Theme Meeting on EXFOR Compilation for Indian Scientists during September 4-8, 2006 (IAEA Faculty: Dr. Otto Schwerer, NDS)
2. BARC Golden Jubilee DAE-BRNS National Workshop on Nuclear Data for Advanced Nuclear Systems, Nuclear Databases and Applications, 8-11 November 2006, NWND-2006, hosted by Mangalore University. (Dr. Alan Nichols, Head, NDS, IAEA, Dr. Georges Audi (France), Prof. A. Takahashi (Japan) and Prof. G. N. Kim (Republic of South Korea) were among those who delivered invited talks on ND Activities)
3. Manipal (M. Gupta) hosted discussion Meeting, 12-13 November 2006, following NWND-2006, Mangalore, 8-11 November 2006, on "Atomic and Nuclear Data for Next Generation Medicine and Technologies," MAHE, Manipal, Karnataka (Dr. Alan Nichols, Head, NDS, IAEA, Dr. G. Audi and Prof. G. N. KIM and DAE scientists, S. Kailas, R. Srivenkatesan and S. Ganesan) gave special invited talks on ND Activities)
4. Supplementary Meeting to the DAE-BRNS Theme Meeting on EXFOR Compilation for Indian Scientists, December 7, 2006
5. DAE-BRNS Theme Meeting on EXFOR Compilation for Indian Scientists during Oct. 29 – Nov. 2, 2007. (IAEA Faculty: Dr. Svetlana Dunaeva, NDS).
6. DAE-BRNS Nuclear Data Meeting on Accelerator Driven System at VECC, Kolkata, November 13, 2007.
7. DAE-BRNS Theme Meeting on "Covariance Error Matrix and its Applications in Reactor Fuel Cycle and Technology," February 25 – 28, 2008, hosted by Manipal University, Manipal – 576104, India. (Prof. Dr. H. Leeb, Technical University, Vienna delivered a series of lectures on fundamentals of covariance error matrix, features and nuclear data evaluations. Prof. Sreekumaran Nair and Prof. K. Manjunatha Prasad, Manipal University served as local conveners with S. Ganesan as the Technical convener).

# Appendix-2: DAE-BRNS projects on nuclear data physics topics in Indian Universities

The roadmap in nuclear data for the wide range of power and non-power applications in the Indian context encompasses a wide range of activities in the field of experimental generation of basic physics data, compilations, computerized visualizations and large data files information management, evaluations which include nuclear model based predictions, creating of computerized ENDF/B files, physics laws based nuclear data processing for multi-group and Monte Carlo applications, integral measurements and validations by use of experimental critical facilities. These voluminous numerical databases and activities include not only interactions with neutrons but also with gammas and charged particles as incident beams.

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:

a. Ongoing 14MeV neutron data physics project in Pune University.
b. Ongoing nuclear data physics activities at Jaipur University.
c. Ongoing measurements using the Microtron facility in Mangalore University.
d. Covariance error matrix in nuclear data physics, a project that has been initiated in 2007 at Manipal University.
e. Ongoing project, “Nuclear model based calculations of particle-nuclear interaction cross sections,” at the Department of Physics, G.B. Pant University, Pantnagar, India.
f. The Maharaja Sayajirao University of Baroda, Vadodara proposed DAE-BRNS Project on nuclear data physics entitled, “Studies for 14 MeV and fast neutron induced fission/reaction for AHWR and ADS applications”.
g. Nuclear data physics project proposal from Bharathiar University, Coimbatore, Tamilnadu.