A STATUS REPORT ON EXFOR COMPILATION ACTIVITIES IN INDIA AND ON FORMATION OF NUCLEAR DATA PHYSICS CENTRE OF INDIA (NDPCI)

Presented by
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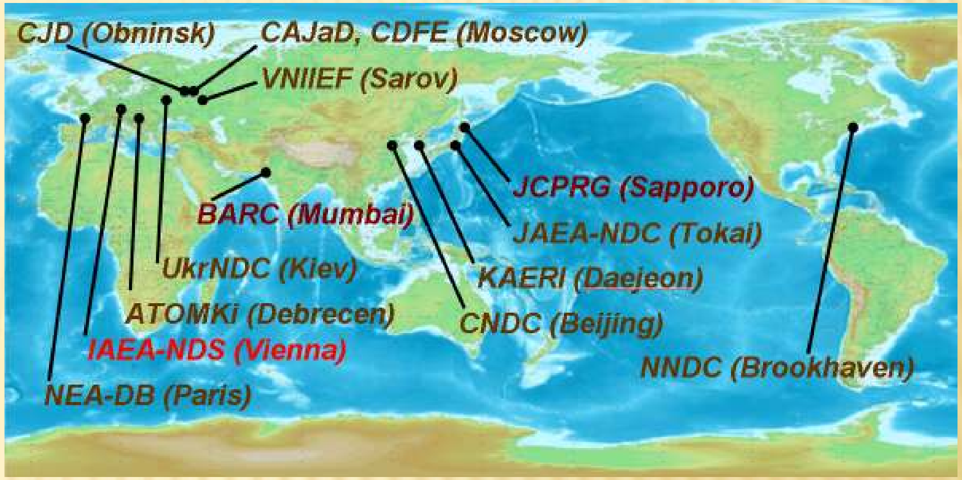
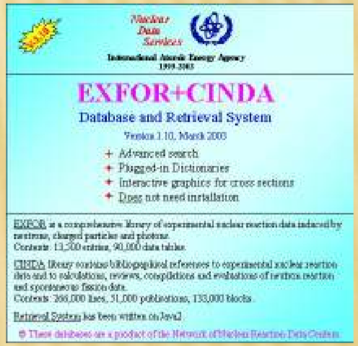
NUCLEAR DATA ACTIVITIES IN INDIA

- ***Basic nuclear data physics measurements. FOTIA (BARC), BARC-TIFR Pelletron, PURNIMA (BARC) D-D, D-T sources),*** **Photon induced reactions (Electron accelerator based bremstrahlung at Kharghar); Pune 14 MeV facility. IPR 14 MeV facility**
- **New facilities for data measurements (being discussed)**
- ***EXFOR compilations. Three successful workshops thus far: 2006 (Mumbai) , 2007 (Mumbai) , 2009 (Jaipur)***
- ***Nuclear model based calculations. E.g., EMPIRE, TALYS***
- ***Processing of evaluated nuclear data files to produce plug-in libraries for discrete ordinates and Monte Carlo codes. NJOY (USA) equivalent to be developed***
- ***Efforts to digest the status of covariance error methodology in nuclear data and its applications. A beginning with a DAE-BRNS Project at Manipal***
- ***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 in progress. Reactor sensitivity studies –AHWR, CHTR (RPDD, BARC)***

INTERNATIONAL NETWORK OF NUCLEAR REACTION DATA CENTRES (NRDC)

- NNDC
- NEA-DB
- IAEA-NDS
- CJD, CAJaD, CDFE, CNPD
- ATOMKI
- CNDC
- JCPRG, JAEA
- KAERI
- UkrNDC
- BARC





4 neutron centres (NNDC, NEA-DB, NDS, CJD) are responsible to compilation of PFNS data measured in their (geographic) areas.

Three Successful EXFOR workshops

Increased visibility to India's work in nuclear physics data generation

Introduction of a new Experimental Nuclear Physics Database culture in India- A challenge.

International community (NRDC) took note of India contributing more than 125 Indian EXFOR entries based upon Indian nuclear physics experiments since 2006.

Sustainability by, for instance, by recruitment of RAs.

India successfully contributed more than 120 EXFOR entries:

•10 new entries in 2006 Workshop (Faculty: Otto Schwerer Manual entries)

•31 new entries in 2007 Workshop (Faculty: Svetlana DUNAEVA, EXFOR editor)

• 55 new entries in 2009 Workshop (Faculty: Svetlana DUNAEVA, EXFOR editor software used)

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

•Thus far, since 2006, in all more than 120 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.

Over 70 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.





Indian Compilation Group: BARC and others, India.
Data compiled in India

Entries:

1 entry in photonuclear data
(Zone: G0014 - G0014 [India])

25 entries in neutron data
(Zone: 33001 - 34000 [India])

94 entries in Charged-Particle Nuclear Data
(Zone: D6001 - D7000 [India])

See more details in links such as :
http://www-nds.iaea.org/exfor-master/working/x4map/last_x4map.htm#3300134000

Zone: D6001 - D7000 [India] Indian Compilation Group: BARC and others, India
Entries: 94 Charged-particle nuclear data

1) D6001/20 pt:36 1991, S.S.Rattan J,RCA,55,169,1991 TRANS.D050:20070306	2) D6002/4 pt:190 1999, S.Santra J,PR/C,60,034611,1999 TRANS.D050:20070306	3) D6003/12 pt:116 2006, D.Singh J,JPJ,75,(10),104201,2006 TRANS.D058:20080124	4) D6004/2 pt:19 2005, R.Tripathi J,EPJ/A,26,271,2005 TRANS.D058:20080124	5) D6005/8 pt:14 1990, S.S.Rattan J,RCA,51,55,1990 TRANS.D050:20070306
6) D6006/33 pt:106 1999, S.S.Rattan J,JRN,242,(2),551,1999 TRANS.D056:20070920	7) D6007/9 pt:283 2006, K.Kalita J,PR/C,73,(2),024609,2006 TRANS.D070:20100208	8) D6008/7 pt:55 2007, M.K.Sharma J,EPJ/A,31,43,2007 TRANS.D058:20080124	9) D6009/3 pt:103 2005, S.Adhikari J,EPJ/AS,25,299,2005 TRANS.D058:20080124	10) D6010/12 pt:72 2006, S.Mukherjee J,IMP/E,15,237,2006 TRANS.D058:20080124
11) D6011/5 pt:16 2005, T.Datta J,JRN,266,(1),79,2005 TRANS.D058:20080124	12) D6012/13 pt:112 2006, B.P.Singh J,NIM/A,562,717,2006 TRANS.D070:20100208	13) D6013/7 pt:183 1998, A.Shrivastava J,NP/A,635,411,1998 TRANS.D059:20080407	14) D6014/4 pt:243 1975, M.Balakrishnan J,PR/C,11,(1),54,1975 TRANS.D070:20100208	15) D6015/7 pt:523 2007, V.V.Parkar J,NP/A,792,187,2007 TRANS.D058:20080124
16) D6016/11 pt:54 2008, J,PR/C,77,014607,2008 TRANS.D061:20080729	17) D6017/4 pt:67 1975, S.Kailas J,PR/C,12,1789,1975 TRANS.D070:20100208	18) D6018/2 nodata 2008, P.D.Shidling J,PL/B,670,99,2008 TRANS.D070:20100208	19) D6019/3 pt:784 1976, L.V.Namjoshi J,PR/C,13,(3),915,197603 TRANS.D070:20100208	20) D6020/7 pt:134 1976, P.P.Singh J,PR/C,14,1655,1976 TRANS.D058:20080124
21) D6021/36 pt:151 2004, A.Navin J,PR/C,70,(4),044601,2004 TRANS.D070:20100208	22) D6022/8 pt:69 2007, H.Majumdar C,2007TOKYO,2,425,2007 TRANS.D070:20100208	23) D6023/8 pt:32 2008, A.Agarwal J,IMP/E,17,(2),393,2008 TRANS.D070:20100208	24) D6024/3 pt:32 1982, S.Kailas J,PR/C,26,(4),1733,1982 TRANS.D058:20080124	25) D6025/3 pt:145 1988, A.Chatterjee J,PR/C,37,(4),1420,1988 TRANS.D058:20080124
26) D6026/4 pt:481 1991, P.Singh J,PR/C,43,1867,1991 TRANS.D070:20100208	27) D6027/6 pt:38 1996, A.Navin J,PR/C,54,767,1996 TRANS.D058:20080124	28) D6028/4 pt:19 1998, G.V.Ravi Prasad J,PR/C,57,971,1998 TRANS.D058:20080124	29) D6029/8 pt:303 2001, S.Santra J,PR/C,64,024602,20010625 TRANS.D070:20100208	30) D6030/5 pt:55 2002, R.G.Thomas J,PR/C,65,057601,2002 TRANS.D058:20080124
31) D6031/6 pt:1358 2002, C.Bhattacharya J,PR/C,66,047601,2002 TRANS.D070:20100208	32) D6032/2 pt:6 2008, B.P.Ajitkumar J,PR/C,77,21601,2008 TRANS.D060:20080603	33) D6033/9 pt:943 2008, Ajay Kumar J,NP/A,798,1,2008 TRANS.D070:20100208	34) D6034/5 nodata 2007, Aparajita Dey J,PR/C,75,064606,2007 TRANS.D070:20100208	35) D6035/7 pt:18 2003, P.K.Sahu J,PR/C,68,054612,2003 TRANS.D058:20080124
36) D6036/5 pt:18 2004, C.Bhattacharya J,PR/C,69,024607,2004 TRANS.D069:20091222	37) D6037/3 pt:155 2008, M.Biswas J,NP/A,802,67,2008 TRANS.D070:20100208	38) D6038/10 pt:63 2004, M.K.Sharma J,PR/C,70,044606,2004 TRANS.D059:20080407	39) D6039/9 pt:64 2008, R.Gun J,IMP/E,17,(2),407,2008 TRANS.D070:20100208	40) D6040/11 pt:636 2009, R.Tripathi J,EPJ/A,42,25,2009 TRANS.D070:20100208
41) D6041/47 pt:46 2008, J,IMP/E,17,(3),549,2008 TRANS.D070:20100208	42) D6042/3 pt:64 2005, B.P.Ajith Kumar J,PR/C,72,067601,2005 TRANS.D058:20080124	43) D6043/3 pt:20 2005, S.Mukherjee J,PR/C,72,067602,2005 TRANS.D058:20080124	44) D6044/2 pt:1 1987, B.S.Tomar J,ZP/A,327,225,1987 TRANS.D066:20090508	45) D6045/3 pt:2 2008, R.Tripathi J,IMP/E,17,419,2008 TRANS.D070:20100208
46) D6046/40 pt:76 2006, R.Tripathi	47) D6047/28 pt:1365 2006, S.Adhikari	48) D6048/4 pt:379 2006, Aparajita Dey	49) D6049/2 pt:6 2006, P.D.Shidling	50) D6050/3 pt:53 2007, R.Tripathi

http://www-nds.iaea.org/exfor-master/working/x4map/last_x4map.htm#3300134000

Zone: 33001 - 34000 [India] Indian Compilation Group: BARC and others, India
Entries: 25 neutron data compiled in India

1) 33001/7 pt:6 1993, G.R.Pansare J,IMP/E,2,(01),259,199303 TRANS.3119:20060809	2) 33002/2 pt:28 1982, R.J.Singh J,RCA,31,69,1982 TRANS.3130:20081023	3) 33003/5 pt:191 1987, S.A.Chitambar J,RCA,42,169,1987 TRANS.3130:20081023	4) 33004/20 pt:19 2007, Manish Sharma J,PRM,68,307,2007 TRANS.3122:20070821	5) 33005/5 pt:4 2005, J.Adam J,KT,70,127,200503 TRANS.3121:20070209
6) 33006/2 pt:21 1999, A.K.Pandy J,RCA,87,1,199908 TRANS.3121:20070209	7) 33007/5 pt:4 1983, S.S.Rattan J,RCA,33,189,1983 TRANS.3130:20081023	8) 33008/2 pt:34 1969, S.P.Dange S,IAEA-SM-122,741,1969 TRANS.3136:20090720	Empty: 33009	9) 33010/2 pt:17 1981, A.Ramaswami J,JIN,43,3067,1981 TRANS.3130:20081023
10) 33011/59 pt:104 2005, H.Naik J,PR/C,71,014304,2005 TRANS.3129:20080904	11) 33012/7 pt:6 2007, V.Kumar W,KUMAR,2007 TRANS.3124:20080124	12) 33013/2 pt:18 1977, V.S.Ramamurthy J,PRM,9,(6),623,1977 TRANS.3127:20080710	13) 33014/3 pt:54 2008, C.Agarwal J,JRN,275,445,2008 TRANS.3130:20081023	14) 33015/2 pt:5 2008, F.M.D.Attar J,NP/A,802,1,200801 TRANS.3127:20080710
15) 33016/12 pt:20 2007, H.Naik J,EPJ/A,31,195,2007 TRANS.3129:20080904	16) 33017/21 pt:20 2000, H.Naik J,EPJ/A,7,377,2000 TRANS.3129:20080904	17) 33018/41 pt:40 1995, H.Naik J,NP/A,587,273,1995 TRANS.3130:20081023	18) 33019/5 pt:4 1988, H.Naik J,ZP/A,331,335,1988 TRANS.3129:20080904	19) 33020/2 pt:1 1987, B.S.Tomar J,ZP/A,327,225,1987 TRANS.3136:20090720
20) 33021/4 pt:3 1986, S.P.Dange J,JRN/L,108,269,1986 TRANS.3136:20090720	21) 33022/10 pt:9 2004, H.Naik J,RCA,92,1,2004 TRANS.3136:20090720	Empty: 33023	22) 33024/3 pt:2 2006, M.Bhike C,2006MANGAL,,(TP15),2006 TRANS.3143:20100126	23) 33025/11 pt:83 2009, B.Lalremruata J,NP/A,821,23,2009 TRANS.3143:20100126
24) 33026/16 pt:329 2007, H.Naik J,NP/A,781,1,2007 TRANS.3143:20100126	25) 33027/7 pt:18 2009, F.M.D.Attar J,NP/A,828,253,2009 TRANS.3143:20100126			

http://www-nds.iaea.org/exfor-master/working/x4map/last_x4map.htm#3300134000

Zone: G0014 - G0014 [India] Indian Compilation Group: BARC and others, India
Entries: 1 photonuclear data compiled at India

1) G0014/4 pt:25
2008, Haladhara Naik
J,KPS,52,934,2008
TRANS.G017:20080530

http://www-nds.iaea.org/exfor-master/working/x4map/last_x4map.htm#D6001D7000

The International Network of Nuclear Reaction Data Centres (NRDC) constitutes a worldwide cooperation of nuclear data centres under the auspices of the International Atomic Energy Agency.

The Network was established in the early sixties to coordinate the world-wide collection, compilation and dissemination of nuclear reaction data.

India was invited and admitted as a full member of NRDC in 2008.

INDIA WILL ACTIVELY PARTICIPATE IN PFNS COMPILATIONS IN EXFOR, RELEVANT FORE THIS CRP, IN CO-ORDINATION WITH AND ASSISTANCE BY THE IAEA-NDS

AN EXAMPLE OF NEW REQUIREMENTS TO MAKE EXFOR ENTRIES IN INDIA BECAUSE OF PROGRAMMTIC INTERESTS

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

This EXFOR compilation activity is triggered by BARC, India being a participant in the IAEA Co-ordinated Research Project (CRP) on "Prompt fission neutron spectra of actinide nuclei”

Under this CRP, BARC will carryout measurements of Prompt Fission Neutrons at 3 MeV energy. PFNS measurements are recommended to be carried out as ratio measurements respect to the well established PFN standard of Cf-252.

PHYSICAL REVIEW VOLUME 137, NUMBER 3B 8 FEBRUARY 1965

Kinetic-Energy Distributions and the Correlation of Anisotropy and Asymmetry in the 4-MeV Neutron-Induced Fission of U^{235}

S. S. KAPOOR, D. M. NADKARNI, R. RAMANNA, AND P. N. RAMA RAO
Atomic Energy Establishment Trombay, Bombay, India

(Received 22 May 1964; revised manuscript received 6 August 1964)

The kinetic-energy distributions and the correlation of the angular anisotropy and the mass asymmetry of the fission fragments have been determined in the fission of U^{235} induced by 4-MeV neutrons. The kinetic energies of the pair of fragments emitted parallel and perpendicular to the incident beam direction are measured by solid-state detectors and recorded by a three-dimensional analog-to-digital converter incorporating a printout arrangement. The observed variation of the total kinetic energy $\bar{E}_k$ and the mean-square deviation σ_{Ek}^2 are found to be different from that observed for the case of thermal fission. For the near-symmetric fragments the total-kinetic-energy distributions show a small peak at an energy of about 125 MeV in addition to the main peak at 163 MeV. The anisotropy has been found to increase with the asymmetry in the region of mass ratios 1.2 to 1.7. The different possibilities leading to the observed dependence of the anisotropy on the asymmetry are discussed.

I. INTRODUCTION

TO understand the mechanism of the mass division in fission, it is important to know whether the mass division depends on the quantum state of the fissioning nucleus at the saddle point. This dependence can be determined by a study of the correlation of the angular anisotropy and the mass asymmetry of the fission fragments, since the work of many authors[1–5]

between the anisotropy and the asymmetry has been studied in the fission of U^{235} induced by 4-MeV neutrons. The kinetic energies of the pair of fragments emitted nearly along and perpendicular to the direction of the incident beam are measured by back-to-back solid-state detector systems and recorded by a three-dimensional analog-to-digital converter. The data have been analyzed to obtain the distributions in the mass and the

Efforts to enter the the experimental data into the IAEA-EXFOR database will be made in BARC . This is an important task.
For EXFOR coding issues of PFNS, see for example: N. Otsuka, V. Pronyaev, R. capote Noy, WP2010-39, Memo CP-D/635 dated 14 April 2010

PHYSICAL REVIEW VOLUME 131, NUMBER 1 1 JULY 1963

Emission of Prompt Neutrons in the Thermal Neutron Fission of U^{235}

S. S. KAPOOR, R. RAMANNA, AND P. N. RAMA RAO
Atomic Energy Establishment, Trombay, Bombay, India
(Received 11 February 1963)

The energy distributions of the prompt neutrons emitted along the direction of motion of the light and heavy fragments have been measured in the laboratory system by the time-of-flight method. A gridded ionization chamber is used to measure the kinetic energies of the fission fragments and their directions of motion with the electric field direction of the ion chamber. A photomultiplier associated with the chamber detects the scintillations in the gas by the passage of a fragment and gives the zero-time pulse. A fast neutron detector placed along the electric field direction of the ion chamber determines the time-of-flight of the prompt neutrons in coincidence with the selected fission events. From the energy distributions in the laboratory system, the emission spectra of the prompt neutrons from the selected light and heavy fragments have been obtained. It is found that for the selected region, the light fragments emit about 30% more neutrons than the heavy fragments and also the average emission energy from the light fragments is about 32% more than that from the heavy fragments. The average nuclear temperatures of the fragments determined from the emission spectra are consistent with the average excitation energies expected from the number of neutrons and gamma rays emitted from the fragments. It is established that the emission spectrum from each fragment is a superposition of the various evaporation spectra corresponding to a distribution of nuclear temperatures. A linear distribution of temperatures up to a certain maximum temperature is found to fit the observed emission spectra. The angular correlations of the prompt neutrons of four different average energies and the light fission fragments have also been determined experimentally. The analysis shows that about 10% of the prompt neutrons are not emitted from the moving fragments. These prescission neutrons have an evaporation-like spectrum and an average energy of about 3.2 MeV. It is proposed that these neutrons are evaporated from the excited fissioning nucleus at stages between the saddle point and the scission.

Efforts to enter the the experimental data into the IAEA-EXFOR database will be made in BARC . This is an important task.
For EXFOR coding issues of PFNS, see for example: N. Otsuka, V. Pronyaev, R. capote Noy, WP2010-39, Memo CP-D/635 dated 14 April 2010

1st RCM Prompt Fission Neutron Spectra of Actinides, 6-9 April 2010, IAEA, Vienna

EXCITING SURROGATE TECHNIQUE

RAPID COMMUNICATIONS

PHYSICAL REVIEW C **78**, 061602(R) (2008)

Determination of the ^{233}Pa(n, f) reaction cross section from 11.5 to 16.5 MeV neutron en hybrid surrogate ratio approach

B. K. Nayak,[1] A. Saxena,[1] D. C. Biswas,[1] E. T. Mirgule,[1] B.V. John,[1] S. Santra,[1]
R. P. Vind,[1] R. K. Choudhury,[1] and S. Ganesan[2]
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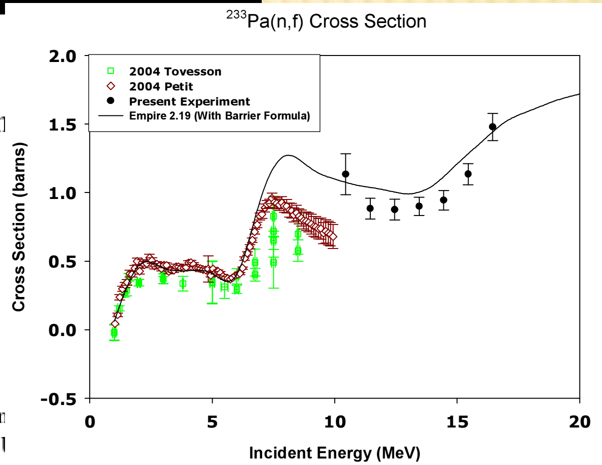
(Received 5 August 2008; published 12 December 2008)

A new hybrid surrogate ratio approach has been employed to determine neutron-induced fission cross section of ^{233}Pa in the energy range of 11.5 to 16.5 MeV for the first time. The fission probability of ^{234}Pa and ^{236}U compound nuclei produced in ^{232}Th(^{6}Li, α)^{234}Pa and ^{232}Th(^{6}Li, d)^{236}U transfer reaction channels has been measured at E_{lab} = 38.0 MeV in the excitation energy range of 17.0 to 22.0 MeV within the framework of the absolute surrogate method. The ^{233}Pa(n, f) cross sections are then deduced from the measured fission decay probability ratios of ^{234}Pa and ^{236}U compound nuclei using the surrogate ratio method. The ^{233}Pa(n, f) cross section data from the present experiment along with the data from the literature, covering the neutron energy range of 1.0 to 16.5 MeV have been compared with the predictions of statistical model code EMPIRE-2.19. While the present data are consistent with the model predictions, there is a discrepancy between the earlier experimental data and EMPIRE-2.19 predictions in the neutron energy range of 7.0 to 10.0 MeV.

DOI: 10.1103/PhysRevC.78.061602 PACS number(s): 24.50.+g, 24.75.+i, 25.85.Ec, 28.20.−v

Determination of the neutron-induced fission cross sections of short-lived actinide nuclei is a major challenge for nuclear physics and nuclear astrophysics. Often indirect methods

27 day half-life of the ^{233}Pa isotope. As this isotope is produced in an intermediate step during the formation of the fissile ^{233}U nucleus, reactions competing with its natural decay affect the



EXFOR ENTRY IN PROGRESS

EXFOR ENTRY NOS:33023 and D6075

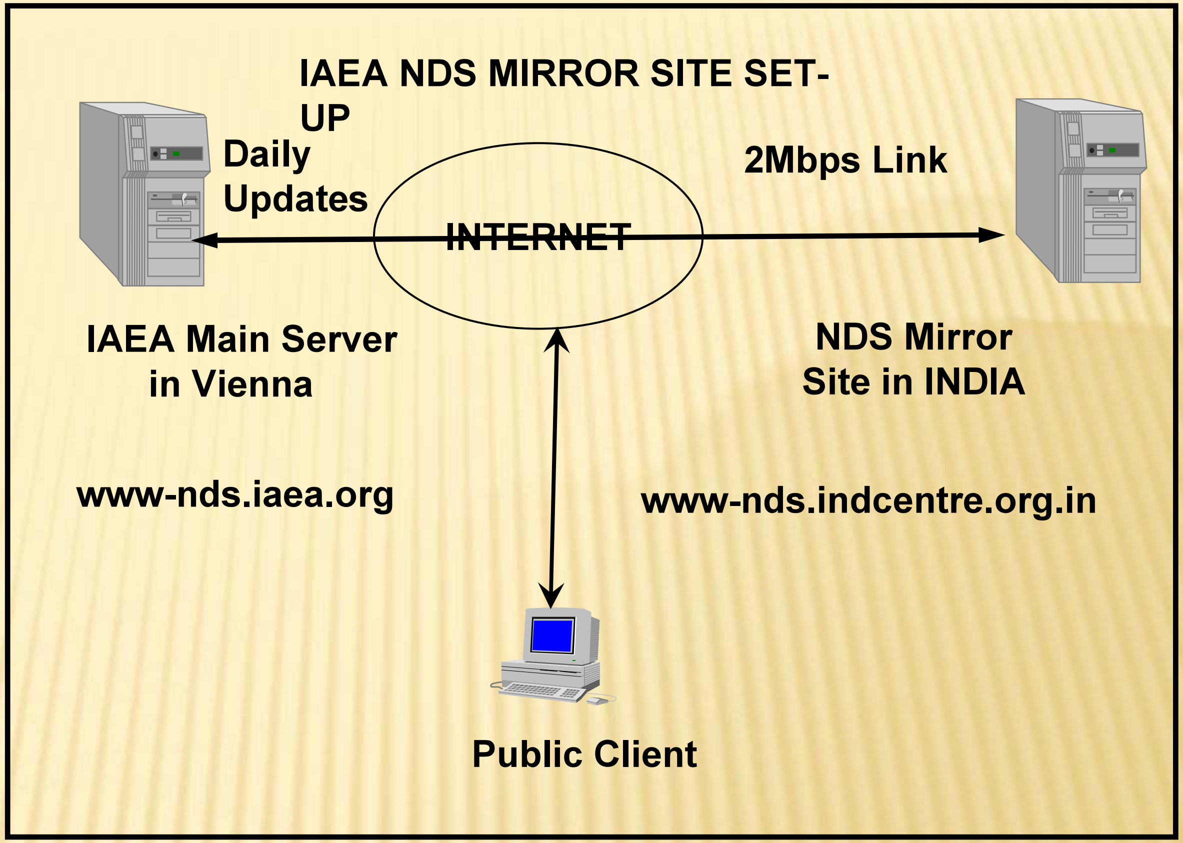
Examples of other experiments and analysis in Progress:

BARC (B. K. Nayak et al.,) working on using Li-7+^{232}Th to measure ^{234}Pa(n,f) reaction data.

H. Naik et al., (neutron+ ^{234}Pa) fission cross section in thermal spectrum

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).

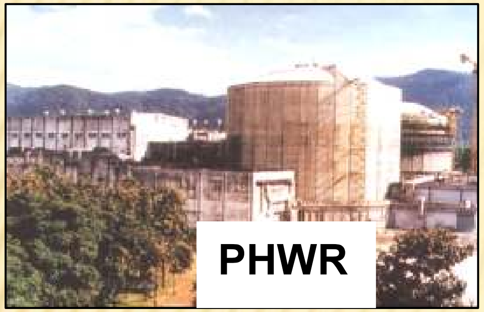
The MOU between DAE/BARC and the IAEA is expected to be continued beyond 2010.

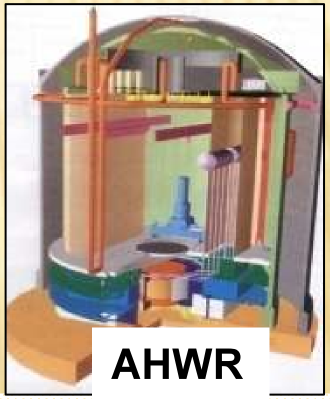


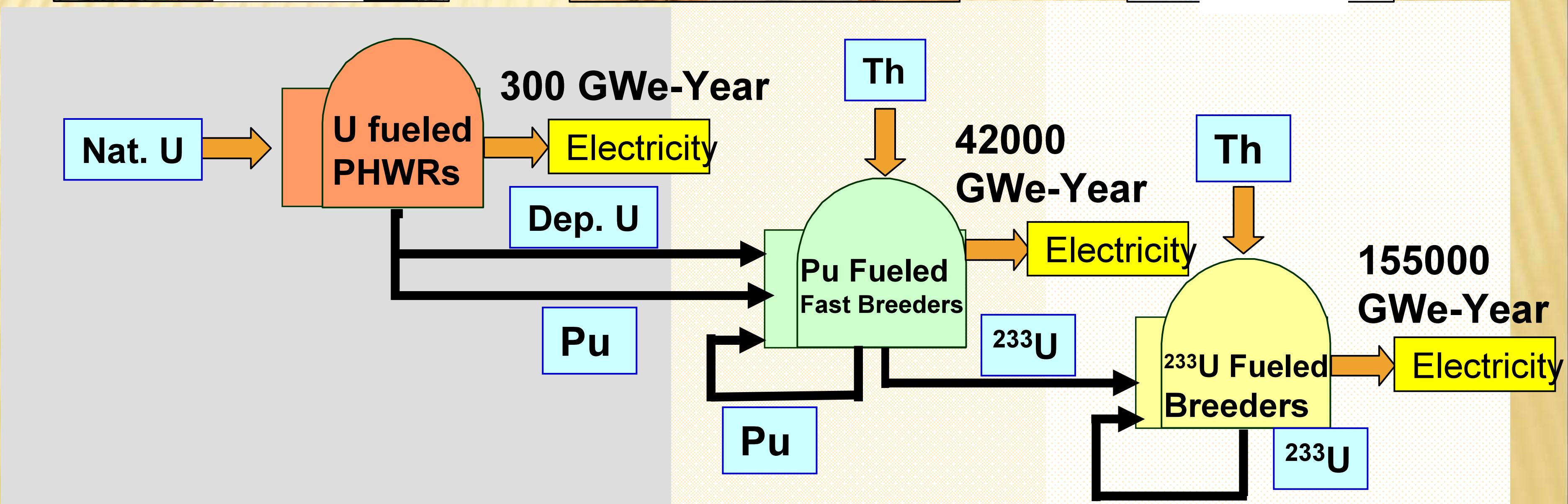
Under this arrangement, online-updating every 12 hours is performed in the mirror with the IAEA website through a 2MB direct link. The server is being maintained by BARC Computer Division - with manpower and machinery. It offers 2-3 times faster downloads in BARC compared to the Vienna site. India offers to collaborate with other network of reaction data centres and help in promoting the online nuclear data services in the coming years.

THREE-STAGE INDIAN NUCLEAR PROGRAMME

Thorium in the centre stage







Power generation primarily by PHWR
Building fissile inventory for stage 2

Stage 1

Expanding power programme
Building ^{233}U inventory

Stage 2

Thorium utilization for
Sustainable power programme

Stage 3

Three Stage Nuclear Power Programme- Present Status

Stage – I PHWRs

- 17 - Operating
- 3 - Under construction
- Several others planned
- Scaling to 700 MWe
- Gestation period has been reduced
- POWER POTENTIAL ≅ 10,000 MWe

LWRs

- 2 BWRs Operating
- 2 VVERs under construction

Stage - II

Fast Breeder Reactors

- 40 MWth FBTR - Operating since 1985, Technology Objectives realized.
- 500 MWe PFBR- Under Construction , likley operation in 2011.
- Stage-II POWER POTENTIAL : ≅ 530,000 MWe

Stage - III

Thorium Based Reactors

- 30 kWth KAMINI- Operating
- 300 MWe AHWR- Under Development

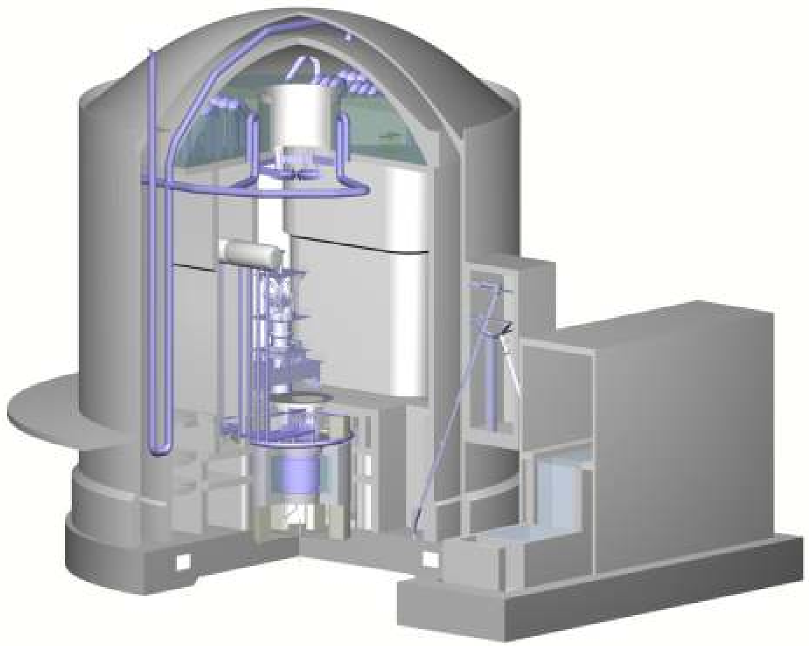
POWER POTENTIAL FOR STAGE-III IS VERY LARGE

Availability of ADS can enable early introduction of Thorium and enhance capacity growth rate.

ADVANCED HEAVY WATER REACTOR (AHWR)

- Vertical pressure tube.
- Boiling light water cooled.
- Heavy water moderated.
- Fuelled by ^{233}U-Th MOX and Pu-Th MOX.

Technology demonstration for large-scale thorium utilization

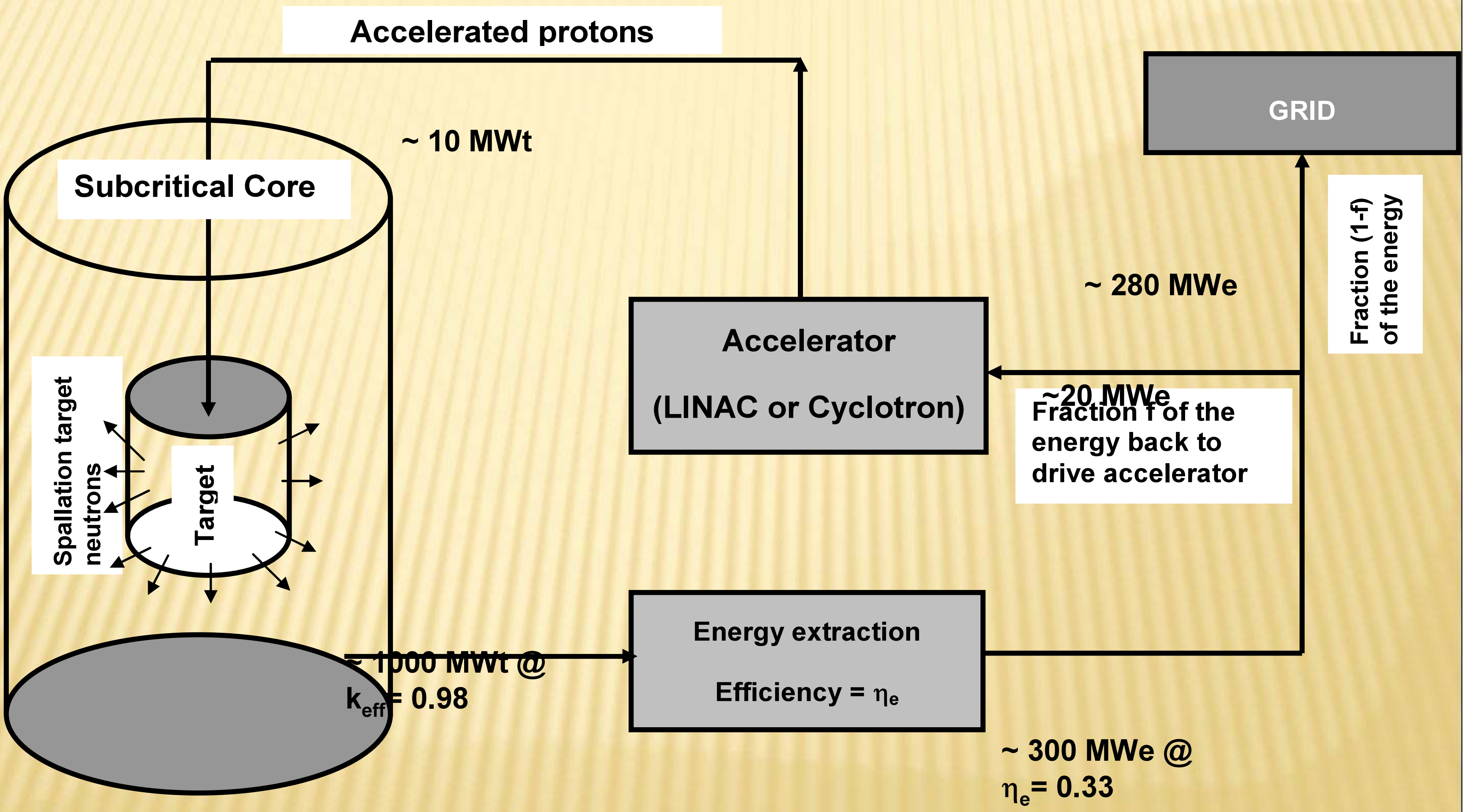


- Currently under Pre-Licensing Safety Appraisal by AERB.
- International recognition as an innovative design.

Major Design Objectives

- Power output – 300 MWe with 500 m^3/d of desalinated water.
- Core heat removal by natural circulation
- A large fraction (65%) of power from thorium.
- Extensive deployment of passive safety features – 3 days grace period, and no need for planning off-site emergency measures.
- Design life of 100 years.
- Easily replaceable coolant channels.

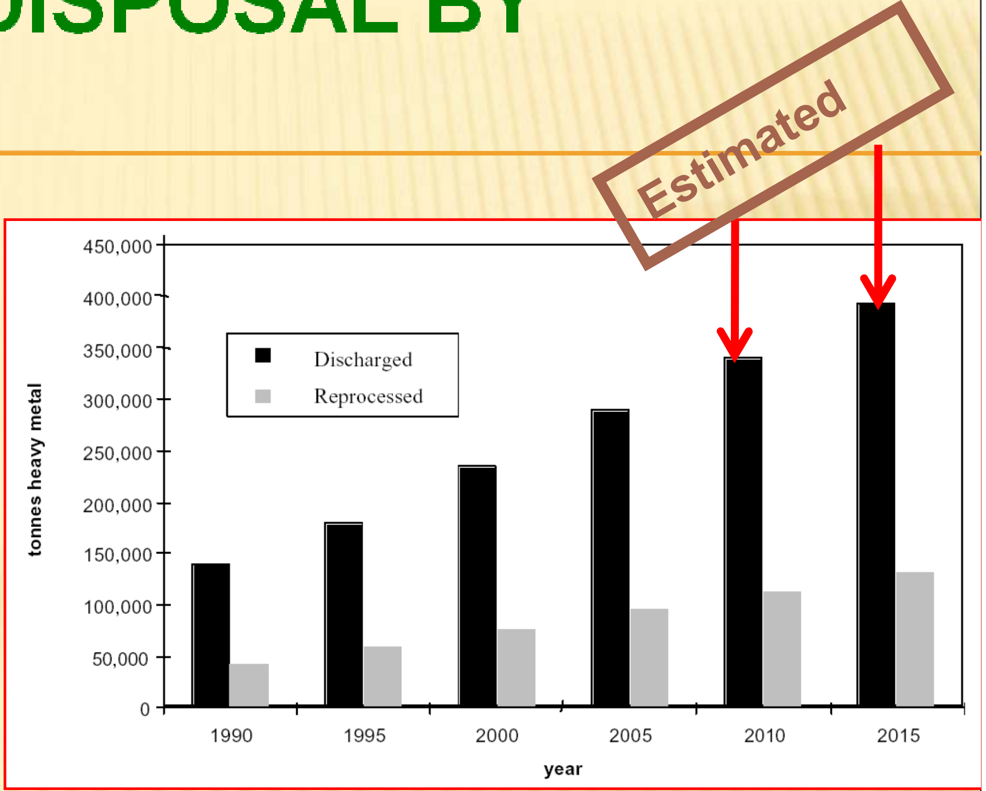
SCHEMATIC OF ADS- ENERGY BALANCE

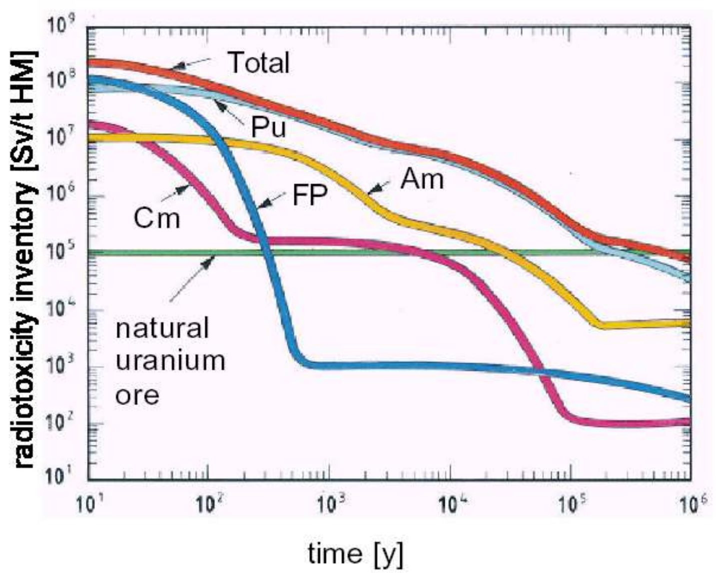


Uncertainties in PFNS will affect the design of ADSS.

NUCLEAR WASTE DISPOSAL BY *TRANSMUTATION*

- Accumulation of spent fuel: a global issue.
- Spent fuel requires > 100,000 years to decay.
- Transuranic elements (TRUs: **Np, Pu, Am & Cm**) + a few long-lived fission products (FPs): decay very slowly.
- Bulk of FPs decay to safe disposal levels in 3-5 centuries.
- If TRUs transmuted into FPs by fission: bulk of FPs decay very fast.





THANK YOU