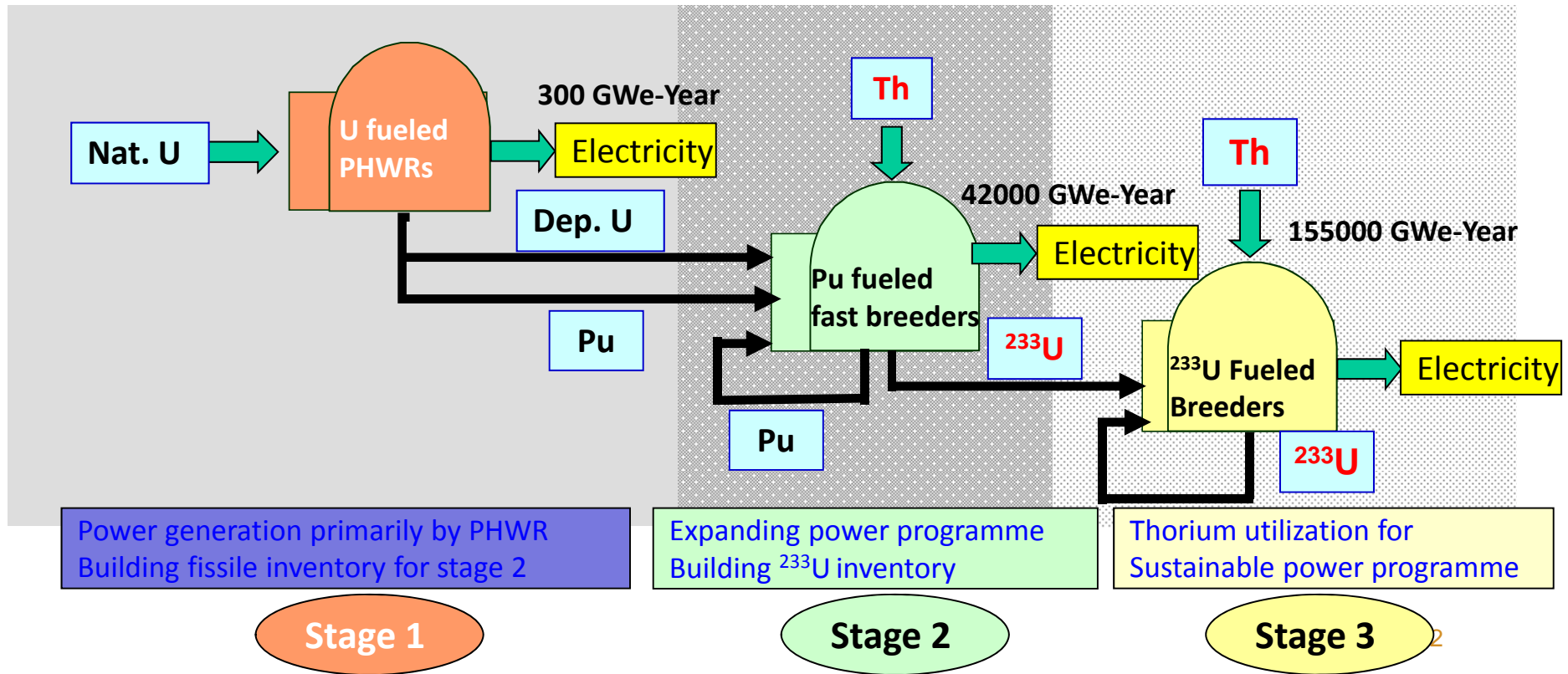


**An Overview of activities of Nuclear Data Physics Centre of India  
2012-2014**

Alok Saxena  
Nuclear Physics Division, BARC, Mumbai-400 085  
India

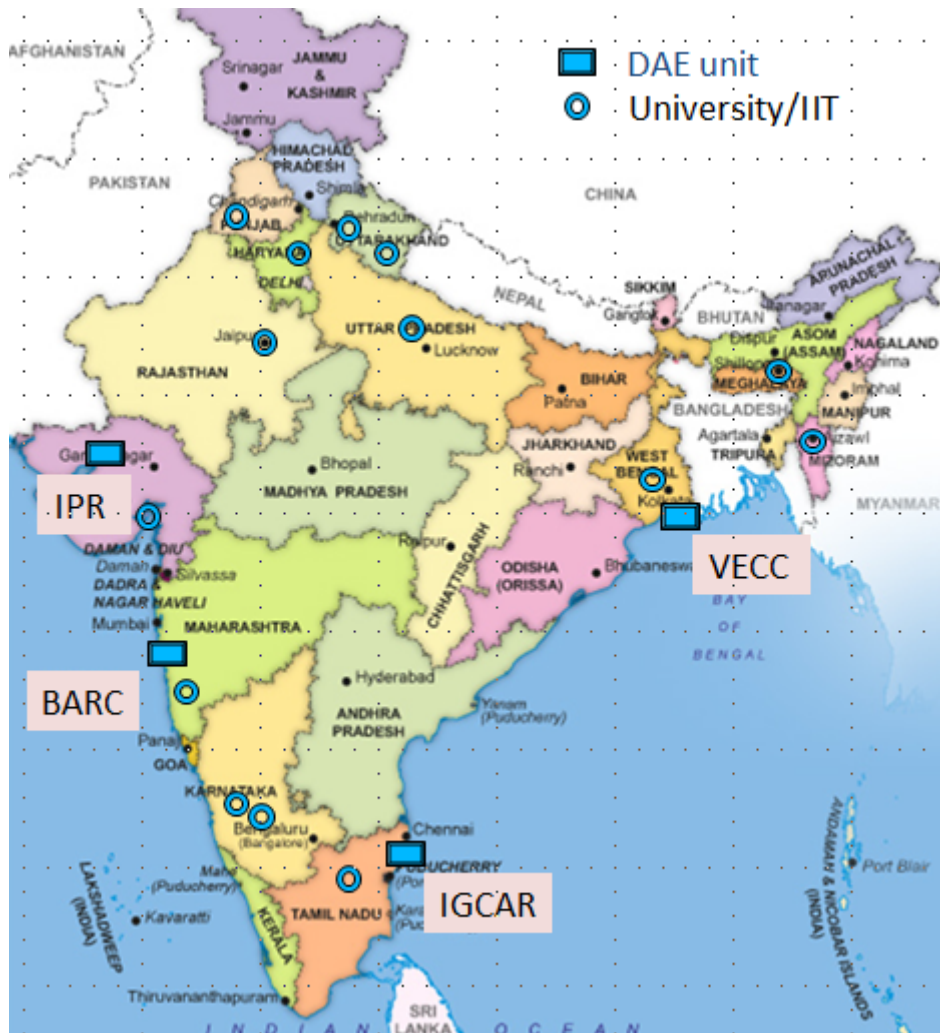
# Three-Stage Indian Nuclear Programme



## Nuclear Data Physics Centre of India (NDPCI)

- ❖ To cater to various needs of department, the Nuclear Data Physics Centre of India (NDPCI) was formed in 2010-11 to provide a platform for coordinated efforts in all aspects of nuclear data, viz., measurements, analysis, compilation and evaluation involving national laboratories and universities in India

# Linkages of NDPCI with DAE Units and Univ./IIT



NDPCI has projects / collaborations with universities/DAE units across India.

Examples of highly successful DAE-BRNS projects funded by the NDPCI /DAE-BRNS included the following:

- 14MeV neutron data physics project in **Pune University**. Closed.
- Nuclear data physics activities at Jaipur, **University of Rajasthan**. (V. Kumar, ADSS- DUBNA). Closed.
- Measurements using the Microtron facility in **Mangalore University**.
- Covariance error matrix in nuclear data physics at the Department of Statistics, **Manipal University, Karnataka**. A new initiative. Closed.
- “Nuclear model based calculations of particle-nuclear interaction cross sections,” at the Department of Physics, **G.B. Pant University, Pantnagar**. Closed.
- “Studies for 14 MeV and fast neutron induced fission/reaction for AHWR and ADS applications”, at the **Maharaja Sayajirao University of Baroda, Vadodara**. Closed.
- Nuclear data physics project at **Bharathiar University, Coimbatore**, Tamilnadu. Project in progress.
- Nucl. Data Physics Project in **University of Mizoram** ((In progress).
- Project on EXFOR compilation in **NEHU, Shillong, Meghalaya** (In progress).
- Project on EXFOR compilations, **Vishva Bharati University, Shantiniketan** (In progress).
- Project on nuclear model based predictions, Hisar (In progress). etc.
- Project

- The NDPCI project by **Prof. A.K. Jain (IIT-R)** “Improved Nuclear Structure and Decay Data for Nuclear Models in the Heavy Nuclides Region” is under progress.

**A=224,222, 150,112,95**

- **Development of a modern computer code with up-to-date databases to estimate the inventory and radioactivity of actinides and fission products during various stages of nuclear fuel cycle.**

**R. Srivenkatesan, Manipal University**

- **Continuing EXFOR compilations and participation in the Measurement of High Energy Photon and Neutron induced reaction cross-sections of structural materials (e. g. Fe, Co, Ni, Cr, Zr etc.) and materials related to medical isotopes ( e.g. Mo)**

**B Jyrwa, NEHU**



# NUCLEAR DATA PHYSICS CENTRE OF INDIA (NDPCI)

- Home
- About Us
- Our Work
- Publications
- Contact Us
- User Registration

## NDPCI EVENTS

- [DAE-BRNS Theme Meeting on EXFOR Compilation of Nuclear Data](#)
- [DAE-BRNS Workshop on Covariance in Nuclear Data](#)

## ANNOUNCEMENT/DOCUMENTS



### NDPCI ACTIVITIES

- Provide support for joint experiments and development of computer programs 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.
- Organize theme meetings and national conferences on nuclear data physics
- Coordinate experimental and theoretical programs 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.

## NUCLEAR DATA PHYSICS SERVICES

Do you want to send your query to expert group in NDPCI? [Register.](#)

Already registered? [Post your query](#)

This is discussion forum. You can post your query to a concerned expert group in NDPCI. Expert group will answer your posted query to your registered email address. Keep posting.

## EXFOR/EN SDF

- [EXFOR Procedure \(2012\)](#)
- [EXFOR Compilation](#)
- [International Network of Nuclear Reaction Data Centres \(NRDC\)](#)

## IMAGE BANK/GALLERY



## LINK TO OTHER SITES

[IAEA Nuclear Data Service](#)

# Domestic EXFOR Compilation Workshop

- No such an attempt of domestic compilation workshop before India.
- The Department of Atomic Energy(DAE) conducted five domestic EXFOR workshops (2006, 2007, 2009, 2011, 2013).
- The organizers successfully collected many young and senior participants from Indian universities and institutes.
- Participation of NDPCI to NRDC (International Network of Nuclear Reaction Data Centres) was officially approved in 2008 NRDC Meeting (Obninsk, Russia).



# 5<sup>th</sup> Workshop in Varanasi (Feb. 2013)



Each participant is responsible for compilation of an assigned article.

Progress is monitored and recorded by Technical Convener.



**Very efficient to compile new articles.  
IAEA NDS strongly supports this workshop.**

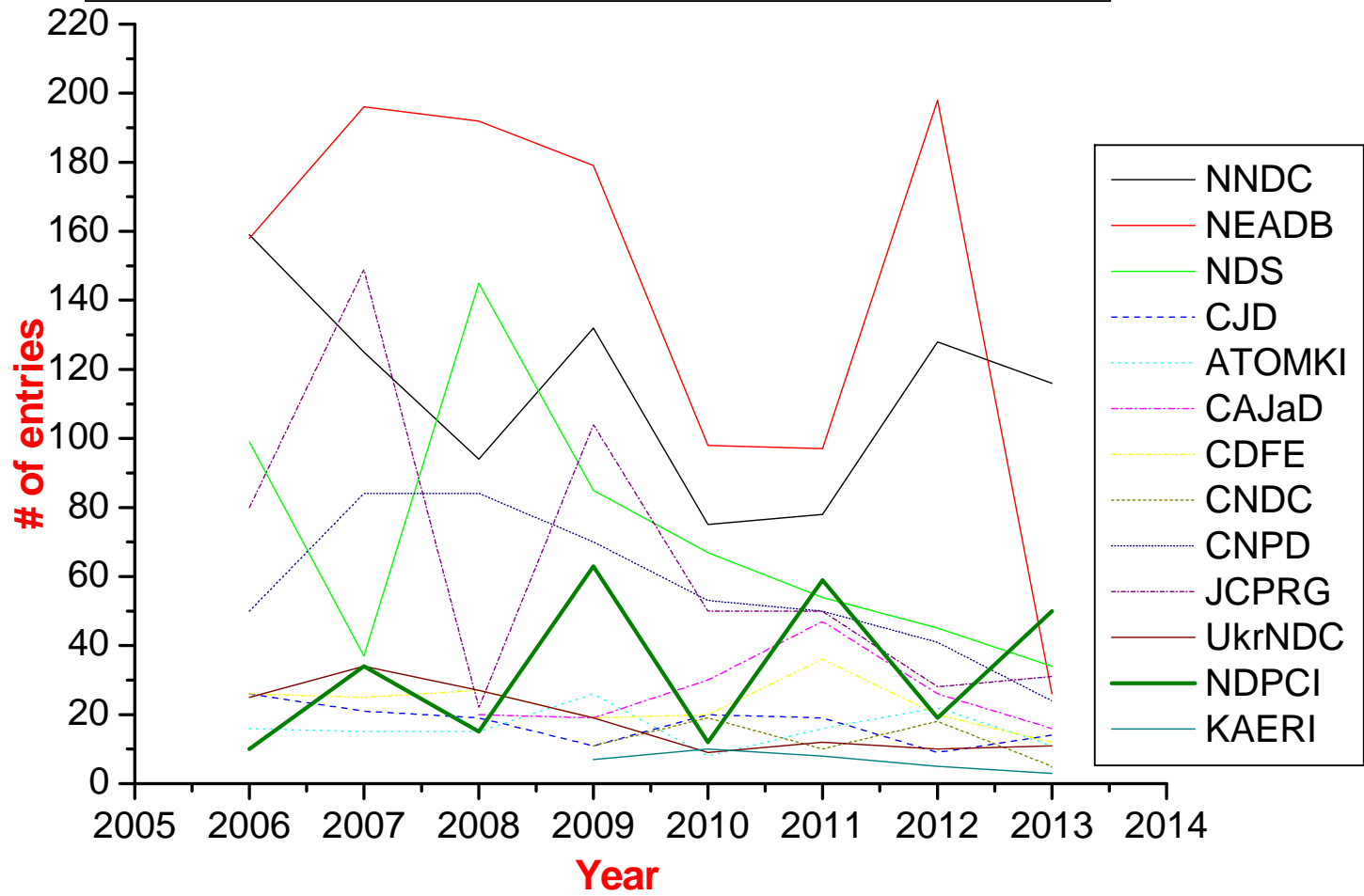


## NDPCI Projects on EXFOR:

Sl.No	Title of the Project	PI/CI	PCs	Amount (Rupees)	Period	Staff	Institute
1	EXFOR compilation of nuclear Data	B.Jyrwa	S.Ganesan, A.Saxena, H.Naik (BARC)	8.15 lakhs	2011- 2013	R. Ghosh S.Badwar (Project Assistant)	NEHU
2	EXFOR Compilation of Nuclear Reaction Data	S.N.Roy	G.Mukherje e (VECC), A.Saxena (BARC)	9.11 lakhs	2012- 2014	U.S.Ghosh K.Mondal (Project Assistant)	Vishva-Bha rati University
3	Measurements, EXFOR compilation and theoretical study of nuclear data	B.Lalremruata H.H.Thanga	S.V.Suryanar ayana, A.Saxena, H.Naik (BARC)	24.69 Lakhs	2012- 2015	L.Punte(JRF) Postdoc position yet to be filled	Mizoram University

We are evolving a mechanism to coordinate the EXFOR compilation activities with IAEA-NDS

# of EXFOR compilations by different nuclear data centres



Indian EXFOR CoCoS (sinc x

https://www-nds.iaea.org/nrdc/india/

## Indian EXFOR CoCoS - Compilation Control System (Last updated:2014-04-22)

- All [ZCHEX](#) and [JANIS Trans Checker](#) error messages must be discussed with the coordinator before submission.
- Entries must be submitted within 1 month since reservation. **Reservation is cancelled if the entry is not submitted within 1 month.**

**Status**

- Compile!: The entry must be compiled.
- Accepted: The entry was compiled.
- PRELIM: The entry was transmitted to other centres for comments.
- EXFOR: The entry was entered into the database.

**Source**

- Curve: Digitized data exist. Ask authors numerical data if the article is not old.
- Table: All data are from authors.

ZCHEX and JANIS Trans Checker are developed and maintained by IAEA Nuclear Data Section and NEA Data Bank, respectively. Thanks.

Entry	Compiler	Reference	Lab	Status	Source	Booked	Finalized	Remark
33044	A.Chakraborty	J,PRM,79,249,2012	TRM	<a href="#">EXFOR</a>	Table	2013-02-18	2013-05-09	
33045	V.K.Mulik	J,JRN,296,1321,2013	TRM	<a href="#">EXFOR</a>	Table	2013-05-22	2013-06-12	
33046	S.Badwar+R.Ghosh	J,EPJ/A,16,495,2003	TRM	<a href="#">EXFOR</a>	Table	2013-06-12	2013-09-03	
33047	P.M.Prajapati	J,NSE,176,106,2014	TRM	Expired!	Table	2014-02-25		Will be compiled by the end of April
33048	S.Badwar	J,JRN,82,263,1984	TRM	Compile!	Table	2014-04-17		
33049	R.Ghosh	J,JRN,91,291,1985	TRM	Compile!	Table	2014-04-17		
33050	B.Lalremurata	J,JRN,125,85,1988	TRM	Accepted	Table	2014-04-17	2014-04-22	
33061	B.Lalremurata	J,NP,83,407,1966	TRM	Compile!	Curve	2014-04-22		
D6170	S.Shivashankar	J,JRN/L,119,303,1987	VEC	<a href="#">EXFOR</a>	Table	2011-04-18	2011-04-19	
D6171		J,CHP,49,884,2011	VEC	<a href="#">EXFOR</a>	Table			
D6172		J,EPJ/A,47,118,2011	TRM	<a href="#">EXFOR</a>	Table			Clarify relation with AIP-1423,122,2012 (Fig.1)
D6173		J,EPJ/A,47,156,2011	NSD	<a href="#">EXFOR</a>	Table			Clarify relation with IMP/E,20,645,2011, IMP/E,17,393,2008 (D6023), Skip 12C+56Cr (D6190)
D6174		J,EPJ/CS,17,03004,2011	TRM	<a href="#">EXFOR</a>	Table			Fig.1-2 incl. previous exps?
D6175		J,EPJ/CS,17,03006,2011	NSD	<a href="#">EXFOR</a>	Table			Fusion data are for D6118.
D6176		J,EPJ/CS,21,10009,2012	NSD	<a href="#">EXFOR</a>	Table			
D6177		J,IMP/E,20,645,2011	NSD	<a href="#">EXFOR</a>	Table			

5:28 PM  
4/25/2014

About 45 entries require redigitization

All papers published in 2013 and 2014 to be compiled in the upcoming workshop on EXFOR compilation, collection of numerical data for those articles are being done

## 35 articles are missing in EXFOR database

Vidya Thakur

Reference	Year	Author	Quantity	Remark
J,IJ,28,396	1954	Nandi+	CS	Cross section ratio
J,IJ,30,80	1956	Saha+	CS	
J,IPA,12,640	1974	Rama Prasad+	CS	
J,JIN,31,1217	1969	Prakash+	KE	
J,JIN,34,2685	1972	Prakash+	KE	
J,JRN,82,263	1984	Nair+	FY	in compilation (33048)
J,JRN,91,291	1985	Tomar+	FY	in compilation (33049)
J,JRN,125,85	1988	Ramaswami+	FY	
J,NIM,205,145	1983	Ajitanand+	KE	
J,NP,55,127	1964	Koul.	DA	
J,NP,83,407	1966	Bharathi+	DA	
J,NP/A,133,625	1969	Ajitanand	FY	
J,NP/A,213,35	1973	Murty+	CS	Some data are in EXFOR
J,NP/A,235,307	1974	Alam+	CS	
J,NP/A,346,473	1980	Choudhury+	KE	
J,NP/A,355,13	1981	Sharma+	KE	
J,NP/A,502,307	1989	Manohar+	FY	Conf. Proc.
J,PHY,28,1011	1962	Machwe	DA	
J,PR,131,283	1963	Kapoor+	MFQ	PFNS
J,PR,166,1190	1968	Kapoor+	FY	X-ray
J,PR,177,1776	1969	Kapoor+	FY	X-ray
J,PR/C,21,1411	1980	Datta+	FY	
J,PR/C,51,3127	1995	Samant+	NU	
J,PRM,24,131	1985	Sharma+	DA	
J,PS,24,935	1981	Srinivasa Rao+	CS	
J,RCA,31,65	1982	Raghuraman+	FY	
J,RCA,35,15	1984	Srivastava+	FY	
J,RCA,46,177	1989	Bhargava+	FY	

**workshop on covariance in nuclear data during Dec. 16-19, 2013**





## 5<sup>th</sup> Asian Workshop on **Nuclear Reaction Database Development** 22-24 September, 2014, HBNI, Anushaktinagar, Bhabha Atomic Research Centre (BARC), Mumbai, INDIA

*Asian Nuclear Reaction Database Development Workshops is held every year in different countries for discussing current status and possible future collaborations in Asian nuclear data activities.*

### **Topics:**

- *Nuclear Data Activities in Asian Nuclear Data Centers*
- *Progress in EXFOR Compilation*
- *Development of the Asian Nuclear Reaction Database Network*
- *Nuclear Data Measurement and Experimental Facilities.*
- *Computational Nuclear Reaction and Nuclear Data Evaluation*

### **Programme Advisory Committee**

S. Kailas, DAE, India  
Masayuki AIKAWA, JCPRG, JAPAN  
Naohiko OTSUKA, IAEA, Vienna  
Ge Zhigang, China Institute of Atomic Energy, China  
Young-Ouk Lee, KAERI, South Korea  
Nurgali Takibayev, Kazakhstan  
S. Ganesan, DAE, India  
V. Kain, BARC, India

### **Organizing Committee**

P. D. Krishnani, RPDD, Chairman  
V.M. Datar, NPD  
Alok Saxena, NPD (Technical Convener)  
Debanik Roy, BRNS, DAE

B. K. Nayak, NPD  
S.V.Suryanarayana, NPD  
Anek Kumar, RPDD  
Vishal Bharati, RPDD  
Arindam Chakravarti, RPDD  
Devesh Raj, RPDD (Co-convener)

H. Naik, RCD  
Sadhana Mukerji, RPDD  
Kapil Deo, RPDD  
Ahsish Srivastava, RPDD  
Raman Sehgal, NPD

### **Contact:**

aloks@barc.gov.in, aloks279@gmail.com, draj@barc.gov.in, deveshraj@gmail.com

**About Mumbai** (also known as **Bombay**) is the capital city of the Indian state of Maharashtra. It is the financial, commercial and entertainment capital of India. The distance of workshop venue from Mumbai international airport is about 25 km. Prepaid taxi can be booked at the airport. (<http://www.barc.gov.in/visitor/index.html#point1>) Mumbai has a tropical climate. During the workshop the temperature is expected to vary between ~30°C (86°F) to ~24.0°C (75°F) with humidity ~80%. Rain is also likely as ~12 inches (15% of the yearly rain fall) takes place during the month of September. (<http://en.wikipedia.org/wiki/Mumbai>)

Mumbai is a well known city in the world tourist map. There are many tourist attractions around one should not miss. Elephanta caves, Gateway of India, Kanheri caves are some of them. ([http://en.wikipedia.org/wiki/List\\_of\\_tourist\\_attractions\\_in\\_Mumbai](http://en.wikipedia.org/wiki/List_of_tourist_attractions_in_Mumbai))



# Nuclear Reaction Experiments in India

There are many experimental activity in India performed at

## BARC (Mumbai, Navi Mumbai)

TIFR Pelletron (14 MV), FOTIA at BARC (6 MV)

Research Reactor “APSARA” , “CIRUS” and “DHRUVA”

Electron linacs (3 MeV/30 kW and 10 MeV/10 kW) at Khargarh

14 MeV neutron generator at BARC, PUNE University

## VECC (Kolkata)

cyclotron

## IUAC (New Delhi)

15 MV Pelletron

## Mangalore Univ. (Mangalagangothri)

Microtron

**About 35 papers published in various journals in two years**

## Typical results from neutron activation measurements

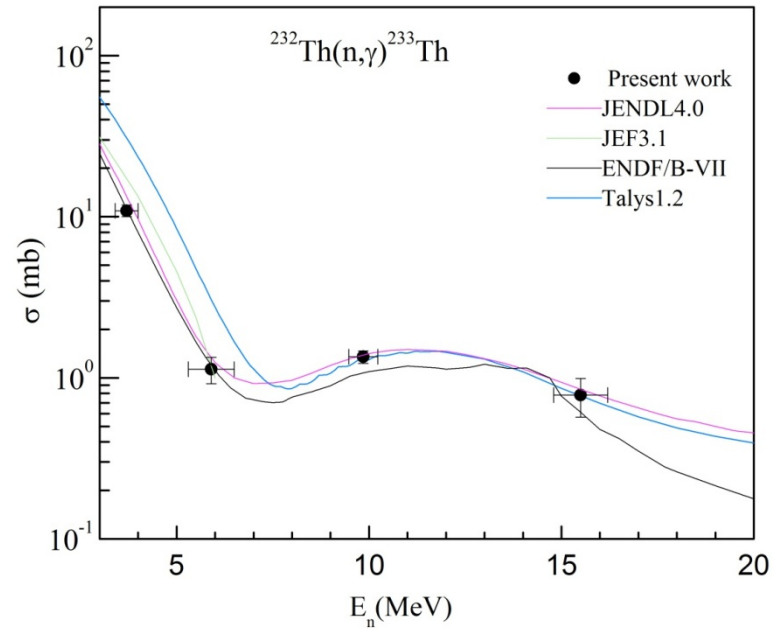
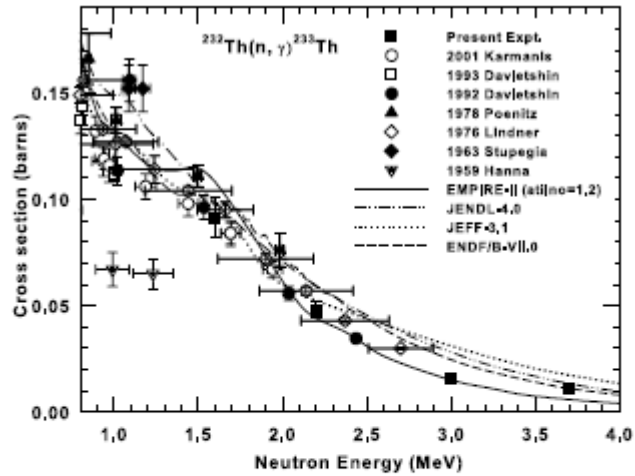


TABLE IV

The Cross-Section Values for the Reactions  $^{98}\text{Mo}(n, \gamma)^{99}\text{Mo}$ ,  $^{186}\text{W}(n, \gamma)^{187}\text{W}$ ,  $^{115}\text{In}(n, \gamma)^{116m1}\text{In}$ , and  $^{92}\text{Mo}(n, p)^{92m}\text{Nb}$  Deduced in the Present Measurements\*

Reactions	$\sigma$ (mb) $E_n = 3.2 \text{ MeV}$
$^{98}\text{Mo}(n, \gamma)^{99}\text{Mo}$	$11.5 \pm 1.2$
$^{186}\text{W}(n, \gamma)^{187}\text{W}$	$13.8 \pm 1.1$
$^{115}\text{In}(n, \gamma)^{116m1}\text{In}$	$40.2 \pm 2.9$
$^{92}\text{Mo}(n, p)^{92m}\text{Nb}$	$7.7 \pm 0.7$

\*The cross-section values are in units of millibarns.

**NUCLEAR SCIENCE AND ENGINEERING:  
170, 1–10 (2012)**

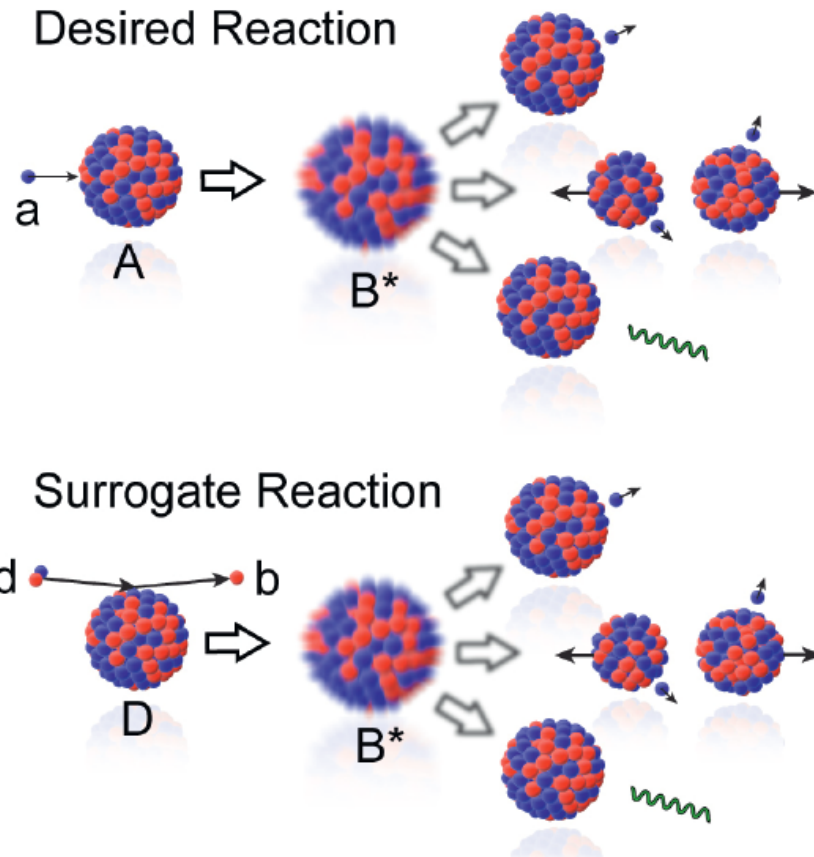
# 1<sup>st</sup> Measurement: $^{70}\text{Zn}(n,\gamma)^{71\text{m}}\text{Zn}$ (4 hour)

- $^{70}\text{Zn}(n,\gamma)$  is a potential dosimetry reaction to determine epithermal flux with other Zn neutron capture reactions.
- No experimental data in EXFOR except for the thermal neutron.
- An enriched (72.4%)  $^{70}\text{Zn}$  sample was irradiated at  $E_p = 2.25, 2.6, 2.8$  and  $3.5$  MeV in July 2013 at BARC FOTIA facility.  
(6 MV Folded Tandem Ion Accelerator)

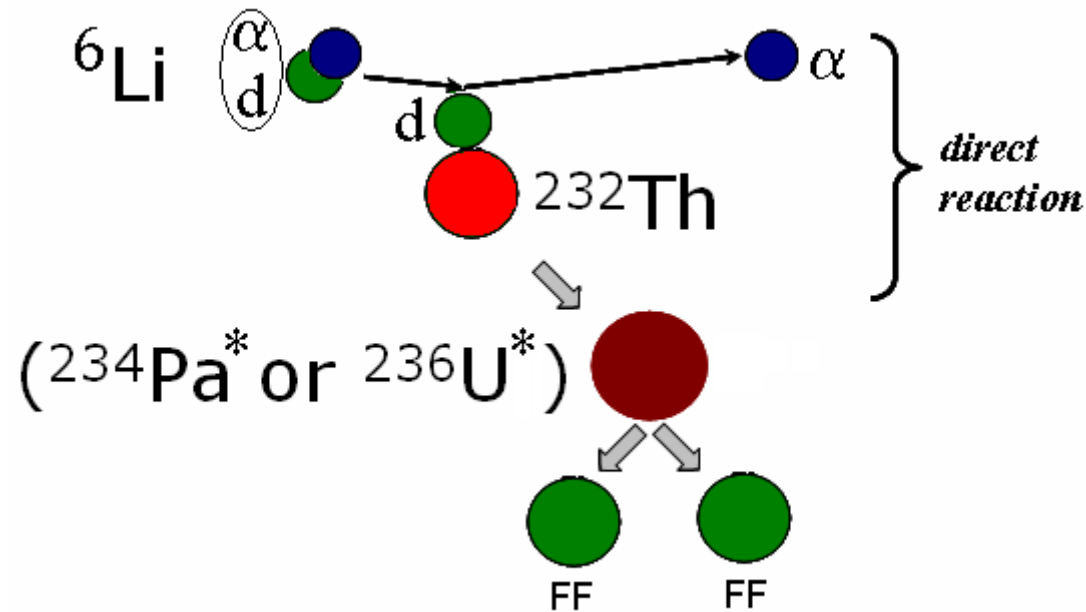


You do not have neutron beam.  
You do not have a target of an unstable nuclei. How do you get the cross section data for interaction of neutrons with unstable target nuclide?

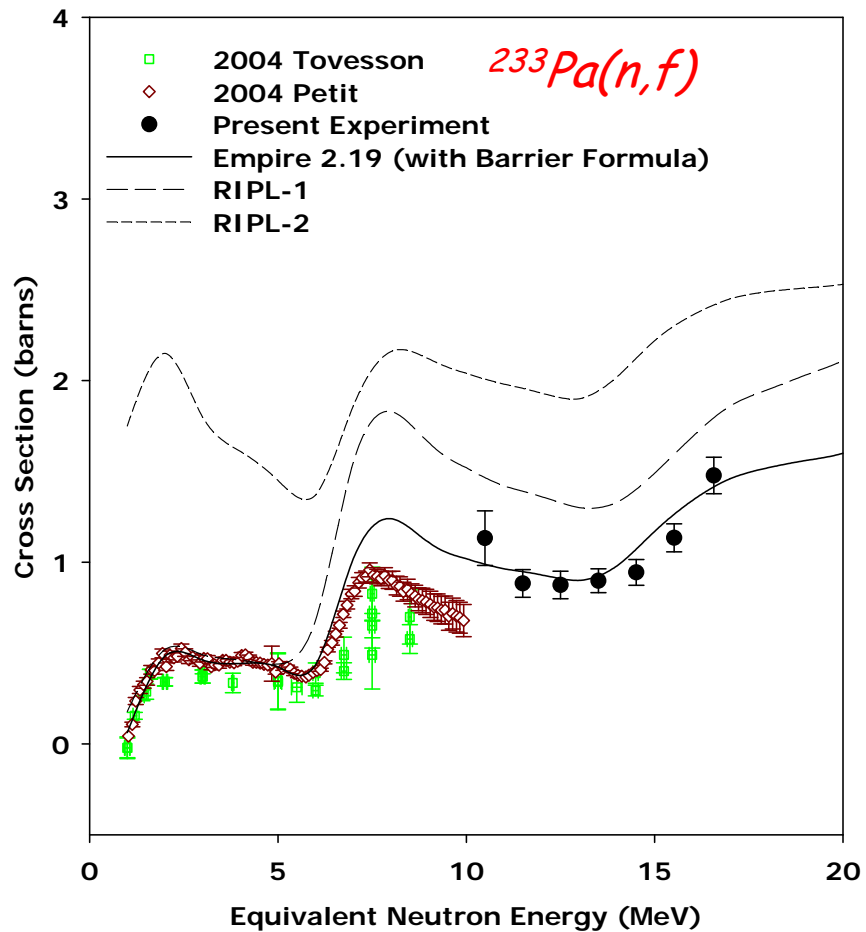
Use of **surrogate nuclear reactions**



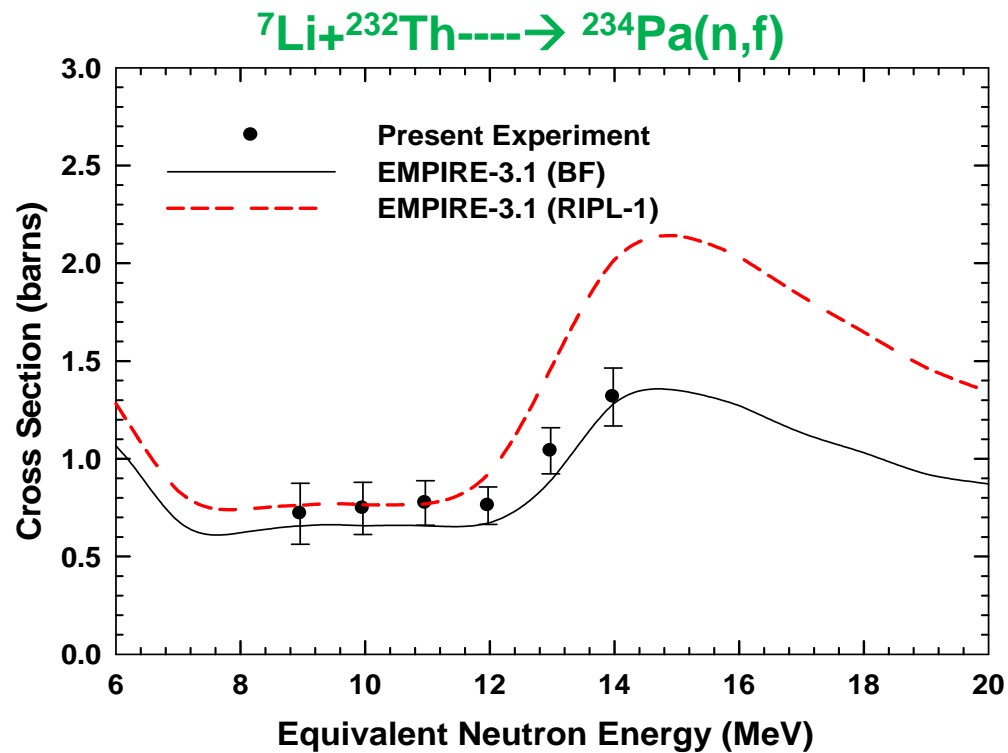
# ${}^6\text{Li} + {}^{232}\text{Th}$ transfer reaction (as the Surrogate reaction)



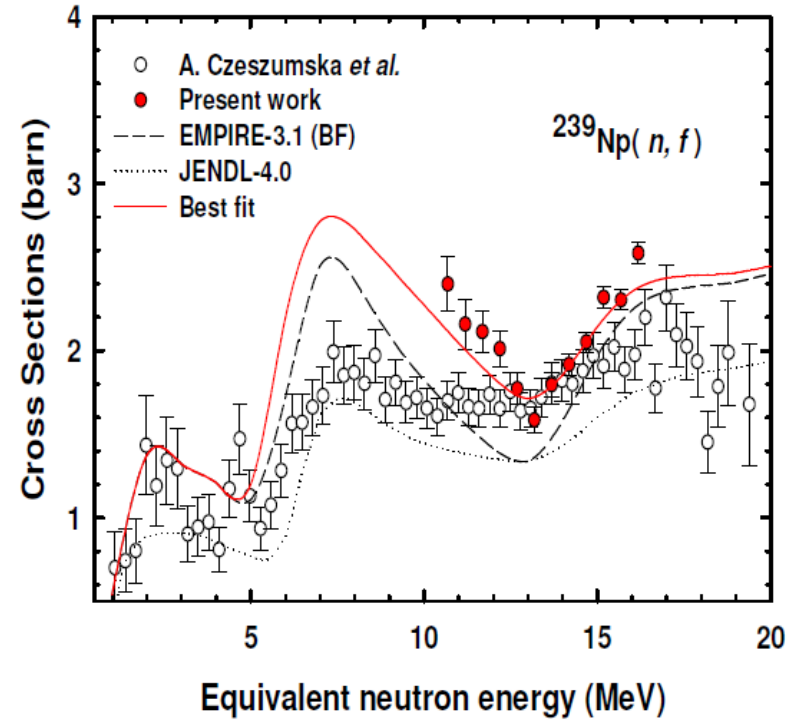
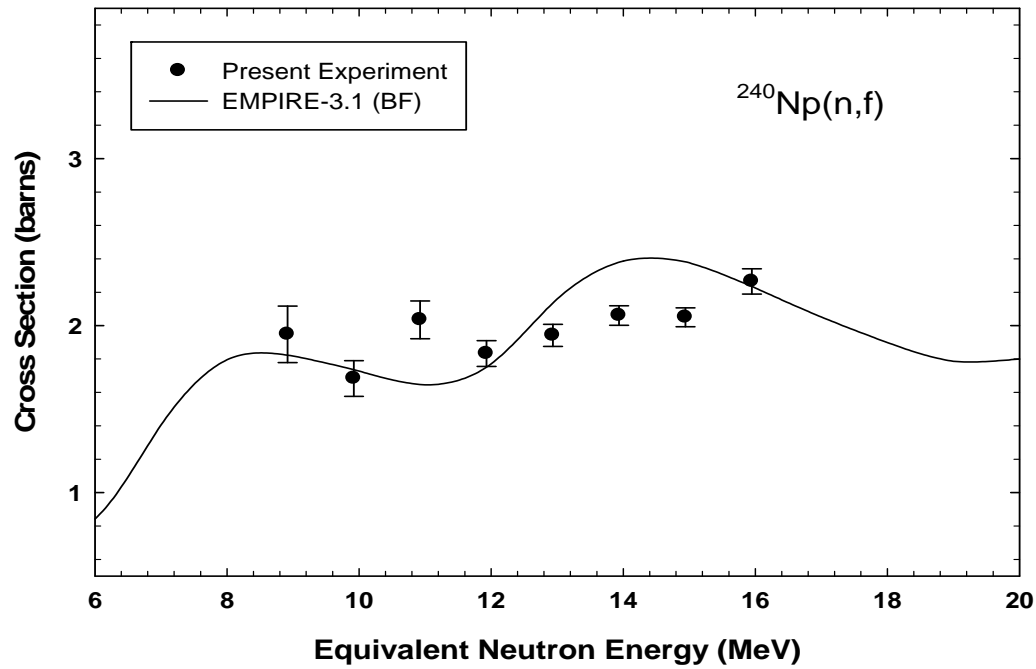
By carrying out PLF-FF coincidence measurement, we can determine the decay probability of the compound residues.



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



PHYSICAL REVIEW C, **C89**, 024606  
 (2014)

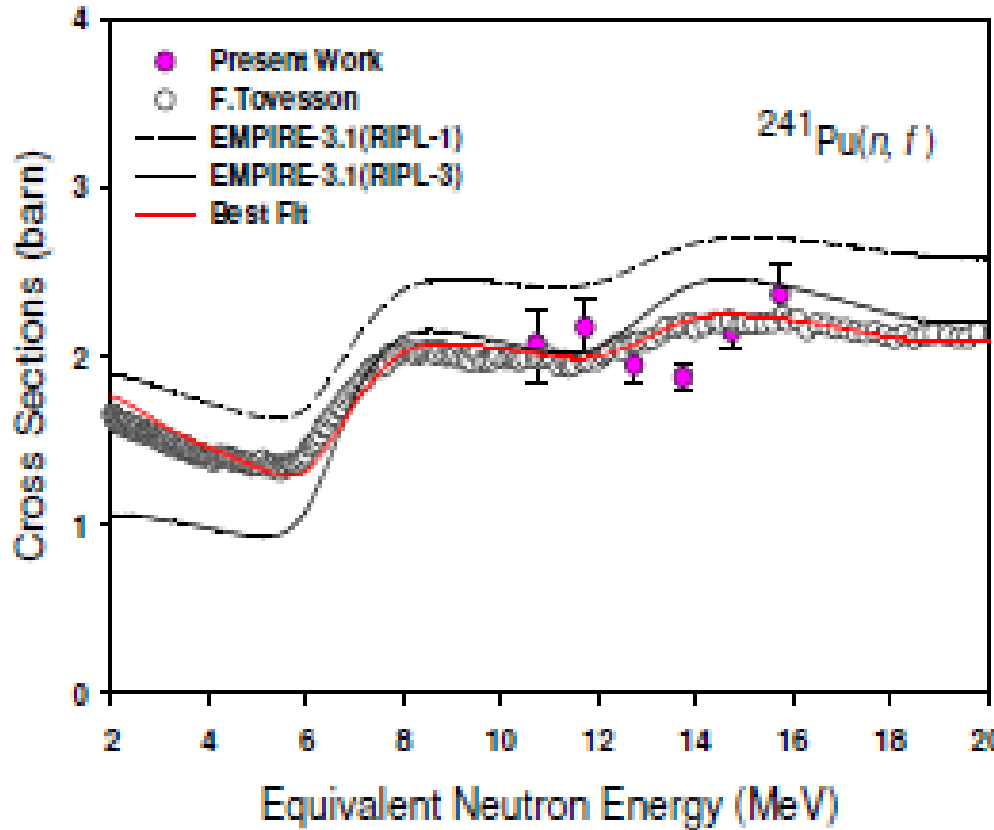


Experiment  ${}^{240}\text{Np}(n,f)$  cross sections and EMPIRE-3.1 code predictions.

PHYSICAL REVIEW C 88, 014613 (2013)



Phys. Rev. C 87, 034604 (2013)



System	Inner barrier		Outer barrier	
	RIPL-3	Best Fit	RIPL-3	Best Fit
${}^{242}\text{Pu}$	6.02	5.35	5.61	5.40
${}^{241}\text{Pu}$	5.85	6.22	5.81	5.85
${}^{240}\text{Pu}$	5.89	6.30	5.73	5.82
${}^{239}\text{Pu}$	5.96	6.30	5.86	5.96

National Workshop on Surrogate Reactions and its Applications (Surrogate-2013), MSU, Vadodara  
(24-25 January 2013)



*Name of the Chairman and Convener :*

**1) Chairman Organizing Committee:**

**Dr. Alok Saxena**, Head, Nuclear Data Physics Section, Nuclear Physics Division, BARC, Trombay, Mumbai and Member Secretary, Nuclear Data Physics Centre of India.

**2) Technical Convener:**

**Dr. B.K. Nayak**, Scientific Officer (H), Nuclear Physics Division, BARC, Trombay, Mumbai

**3) Local Convener:**

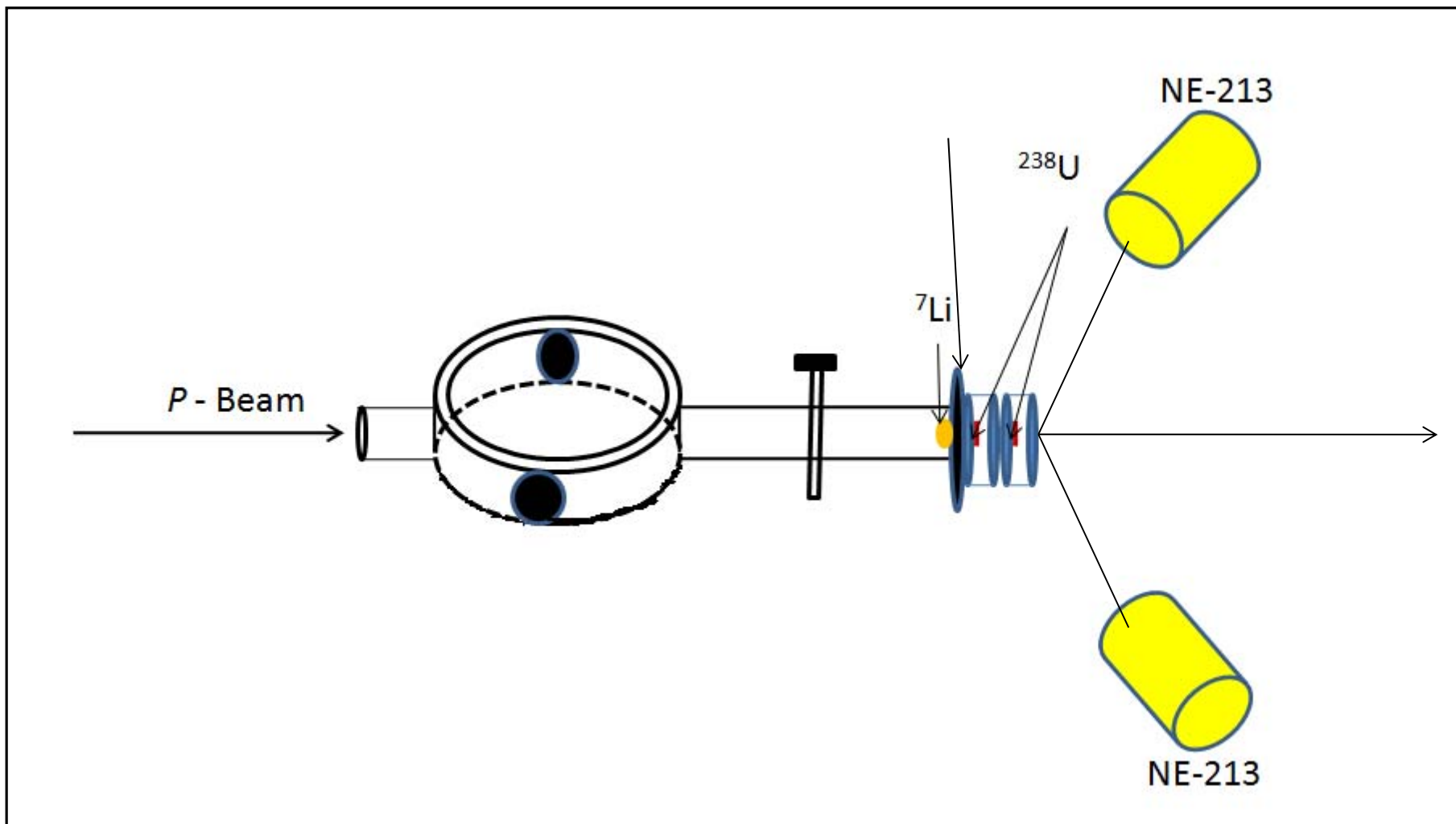
**Dr. S. Mukherjee**, Physics Department, Faculty of Science, M.S. University of Baroda, Vadodara

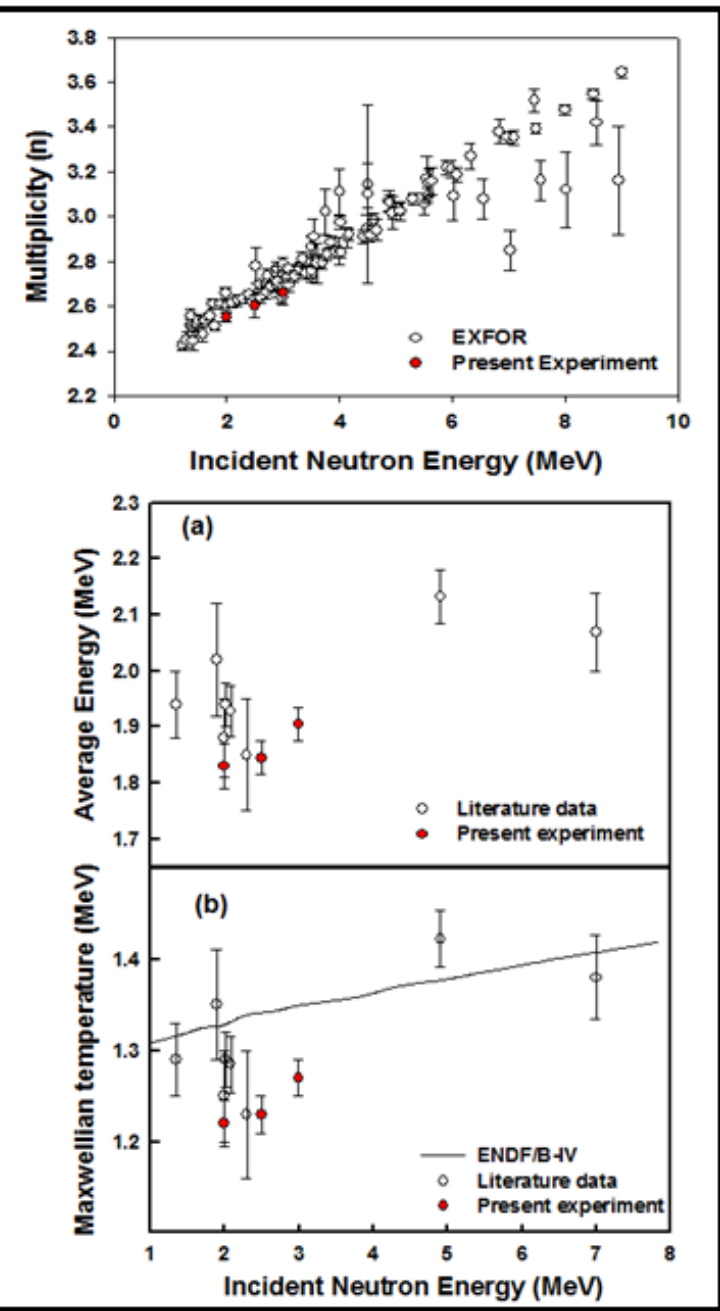
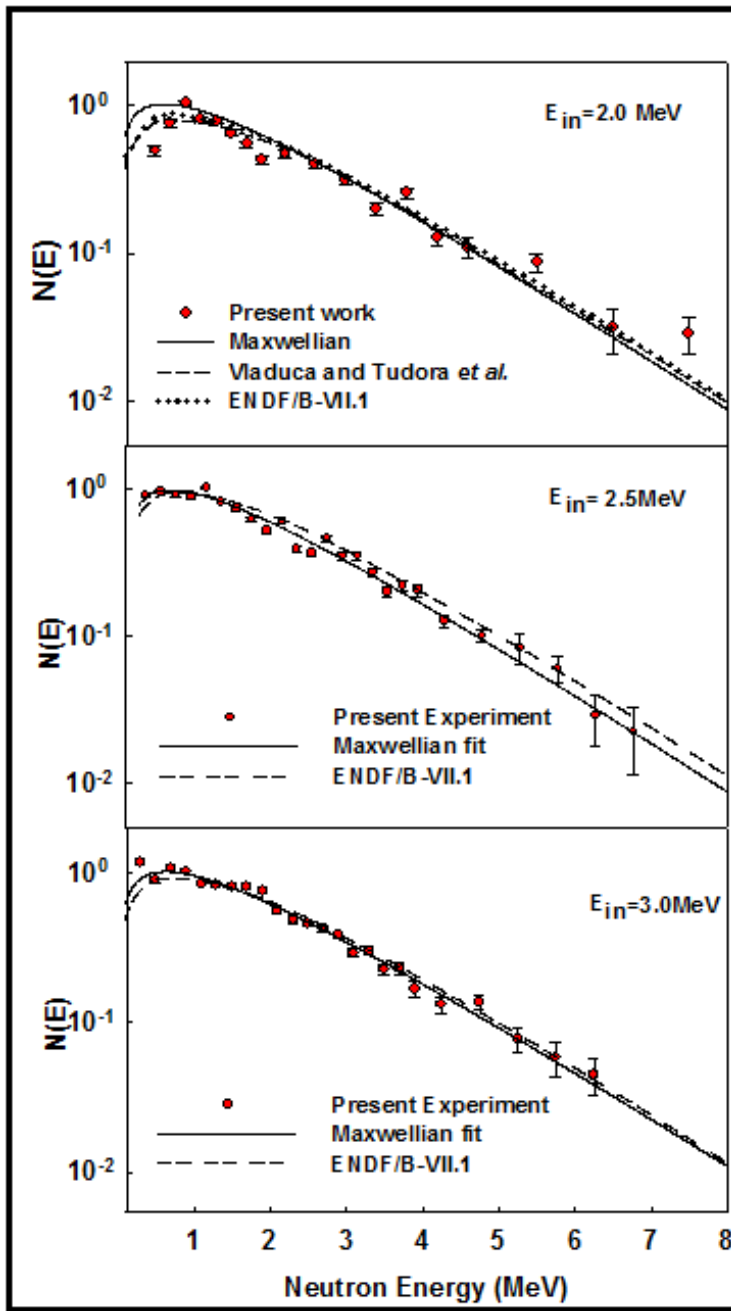
The workshop began with a brief Inaugural session in the presence of Chief Guest Dr. S.Kailas, Director Physics Group, BARC . Dr. V.M. Datar, Head, Nuclear Physics Division, BARC, was the Special Guest. Prof. A.C. Sharma, Dean, Faculty of Science, M.S. University of Baroda, presided over the function, and Prof. T.K. Das, Vice Dean, Faculty of Science, M.S. University of Baroda, welcomed the guests, followed by a Vote of Thanks by Dr. S. Mukherjee, Local Convener.

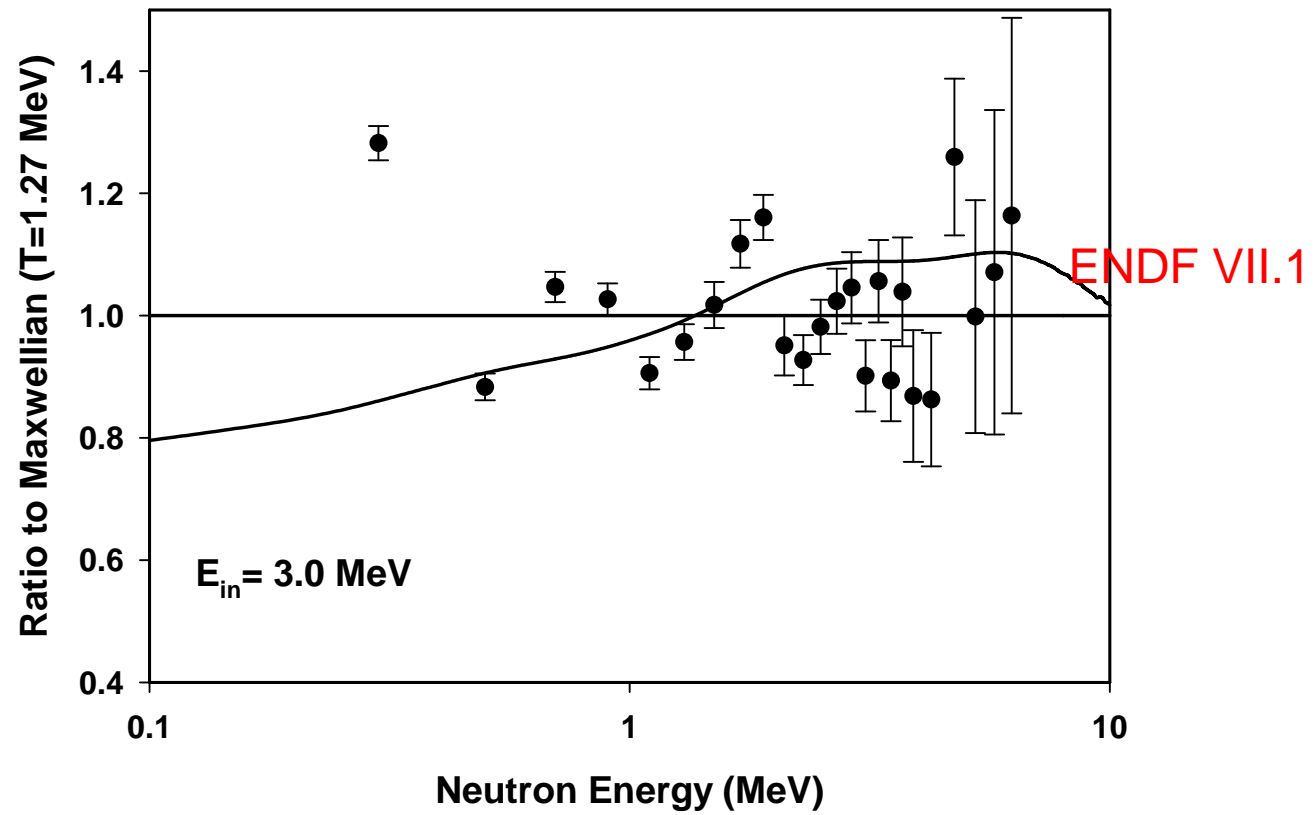
# Study of Prompt Neutron energy spectra in fast neutron induced fission of $^{238}\text{U}$ , $^{232}\text{Th}$

- 1 Study of prompt neutron emission spectra in fast neutron induced fission reaction is of topical interest because of its importance in engineering and design of new reactors for nuclear energy production, based on fast neutron induced fission .
- 2 The uncertainties affect the design parameters of thermal, fast, fusion-fission hybrids and accelerator driven systems reactor designs.

# Schematic of Experimental Setup at FOTIA







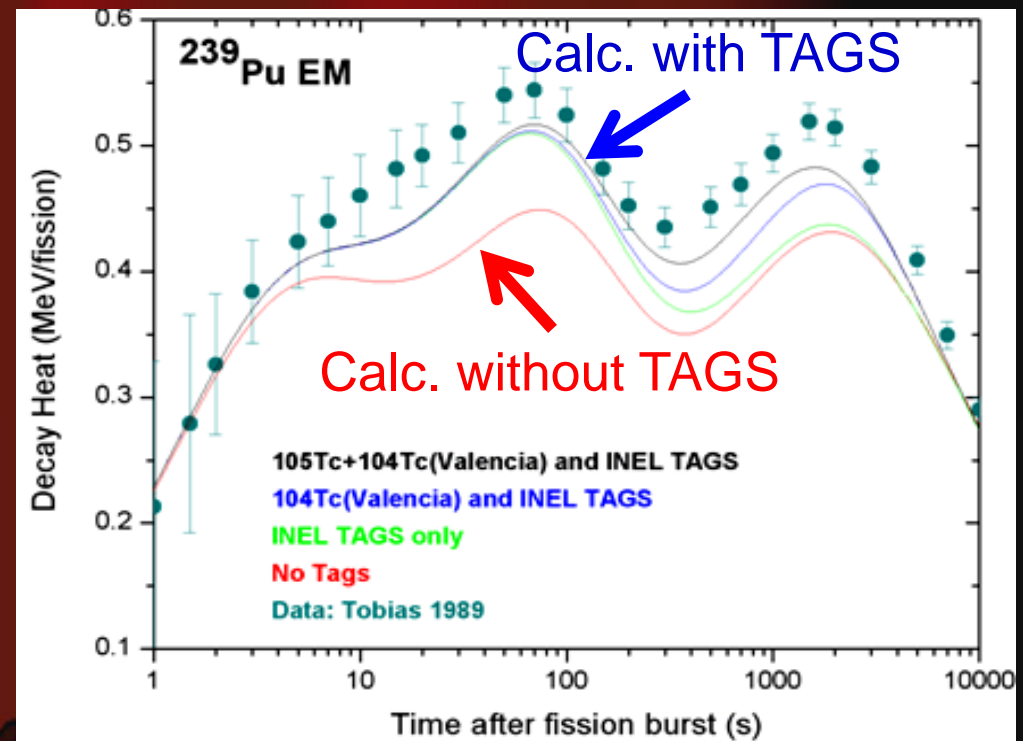
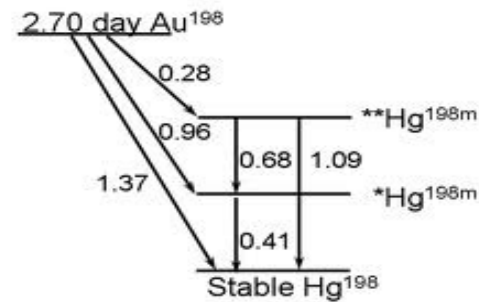
# A modular Setup at VECC for TAGS Measurement



TAGS measurements provides accurate beta decay feeding intensities free from Pandemonium effect.

This has importance in the decay heat calculations

Beta Decay scheme



# The TAGS Setup at VECC

- ✓ 50 BaF<sub>2</sub> detectors: 25 on each side
- ✓ An array of 5 x 5 in each side
- ✓ Dimension of each BaF<sub>2</sub> :  
3.5 x 3.5 x 5 cm<sup>3</sup>
- ✓ Compact geometry with 4 pi coverage
- ✓ Array efficiency = 86% for 662 keV (<sup>137</sup>Cs)



## Uniqueness of the setup

Use of BaF<sub>2</sub> detectors: Excellent timing resolution

**Large Granularity: Multiplicity fold gate can be used to distinguish “sum Peak” from “single peak” of similar energy.**

The set up has been successfully tested with  $\beta$ -decay data from

<sup>137</sup>Cs (one  $\gamma$ -ray)                      <sup>22</sup>Na (three  $\gamma$ -rays)

<sup>60</sup>Co (two  $\gamma$ -rays)                      <sup>152</sup>Eu (many  $\gamma$ -rays)

## Results from the Workshop

The **activity** of the evaluation of mass chain **A=215** that was started at the workshop has been **pursued and monitored by the NDPCI after the workshop** The work has been completed successfully referee review is completed and the **56 page article** is ready for **publication** reputed nuclear data journal “**Nuclear Data Sheets**”.

# Nuclear Data Sheets for $A = 215$

**Principal Author and Coordinator:**

Balraj Singh (McMaster Univ, Hamilton, Canada)

**Author and Coordinator:**

Gopal Mukherjee (VECC, Kolkata, India)

**Authors:**

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Swapan Kumar Basu (Variable Energy Cyclotron Centre (VECC), Kolkata, India)

Pareskevi Demetriou (IAEA, Vienna, Austria)

Ashok Jain (Indian Institute of Technology (IIT), Roorkee, India)

Suresh Kumar (Delhi University, Delhi, India)

Sukhjeet Singh (M.M. University, Mullana, Ambala, India)

Jagdish Tuli (Brookhaven National Laboratory (NNDC,BNL), Upton, NY, USA)

**Reviewer:**

Edgardo Browne (NNDC,BNL), Upton, NY, USA)

**Trainees:**

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Sudeb Bhattacharya (Saha Institute of Nuclear Physics, Kolkata, India)

Shinjinee Dasgupta (VECC, Kolkata, India)

A. De (Raniganj Girls' College, Burdwan, India)

R. Gowrishankar (S.S. Institute of Higher Learning (SSIHL), Prasanthi Nilayam, India)

Navneet Kaur (Panjab University, Chandigarh, India)

S. Lakshmi (IIT, Roorkee, India)

Jeong-Yeon Lee (Sejong Univ, Seoul, Korea)

Bhoomika Maheshwari (IIT, Roorkee, India)

Debashis Mondal (VECC, Kolkata, India)

Aman Rohilla (Delhi University, Delhi, India)

K. Rojeeta Devi (Delhi University, Delhi, India)

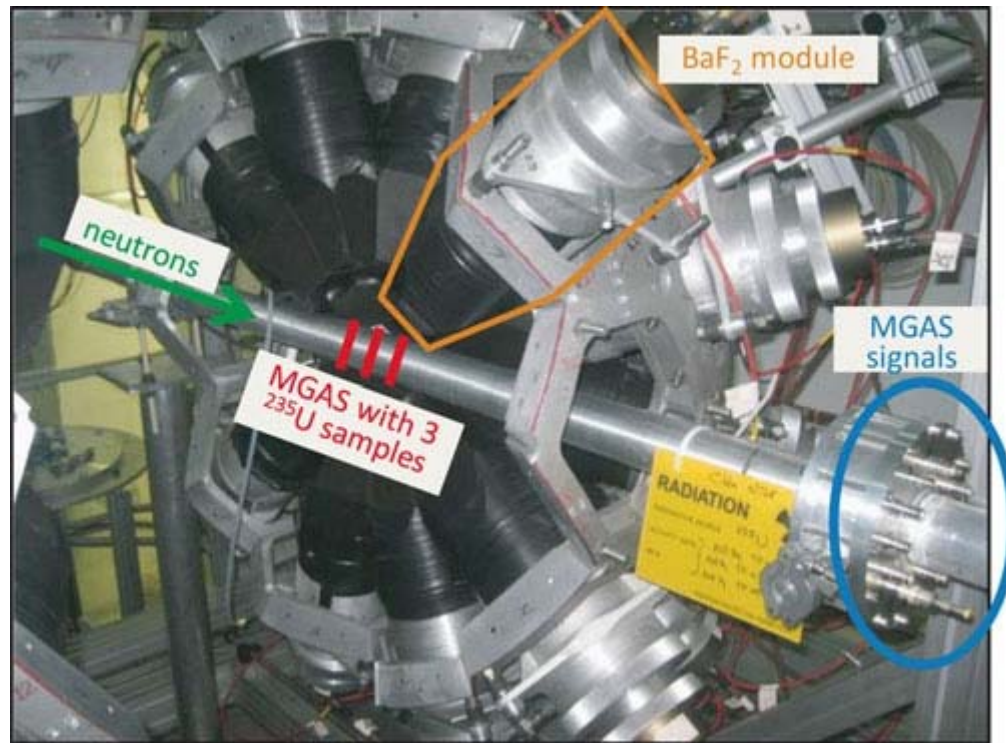
K. Vijay Sai (SSIHL, Prasanthi Nilayam, India)

**New group of interested ENSDF evaluators have emerged in India and new mass chains  $A = 219$  and  $A = 223$  is being taken up by the NDPCI for evaluation**



## CERN n\_TOF collaboration (Geneva)

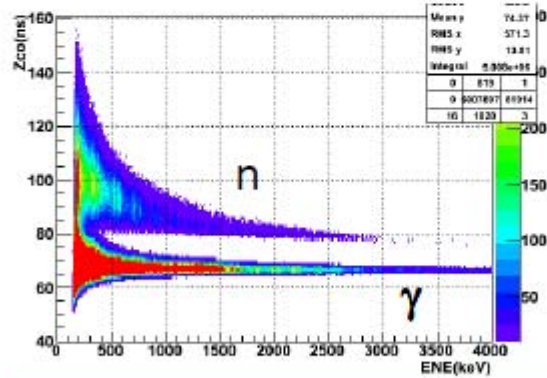
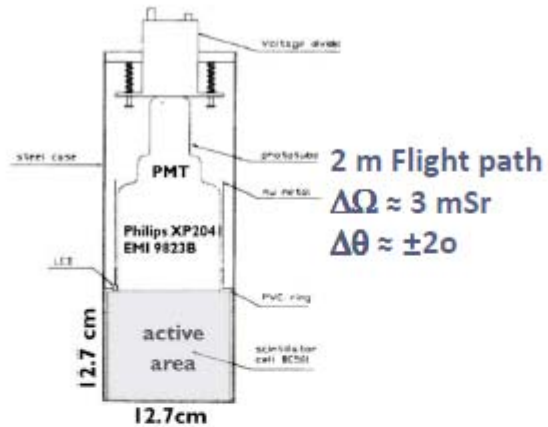
- MOU was signed in Nov., 2008 for Indian participation n\_tof experiments in phase II
- The annual O & M fee being paid from the NDPCI funds
- Mr. Devesh Raj of RPDD participated in the n\_tof experiments in 2010 and Mr. Pandikumar of IGCAR participated in 2011.
- Dr. Alok Saxena and Mr. AK Mallick have participated in experiments on September 1-15, 2012
- **Main Objectives:**
- (1) neutron cross section measurements for nuclear astrophysics, (2) nuclear data measurements for advanced nuclear technologies and nuclear waste transmutation, and (3) neutron cross section measurements for basic nuclear physics.



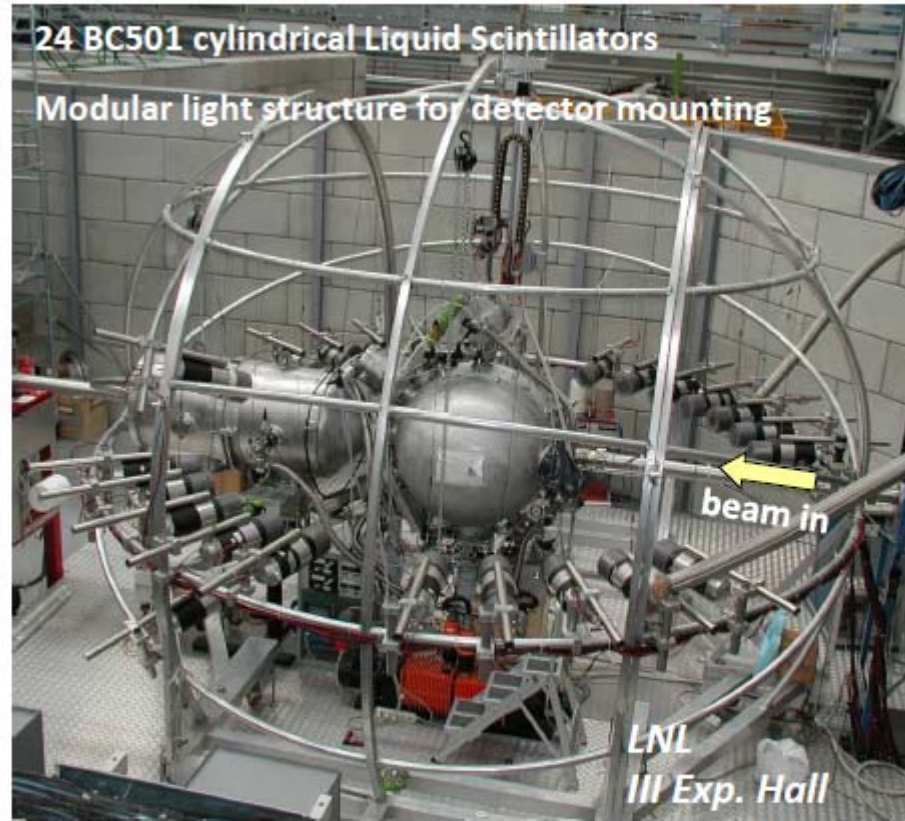
TAC consists of 40 BaF<sub>2</sub> each 15 cm thick to detect capture gamma with 5-10 MeV total Energies and multiplicities upto 6-8.  
Connected to 8 bit Flash ADCs ( memory of 8 Mb/channel) sampling at 250 MHz.  
32 ms data buffer allows neutron energies to 0.3 eV to 30 keV ( limited by gamma flash).

Z=116,124 and more recently Z=104

The Experimental Set-up: The RipeN array



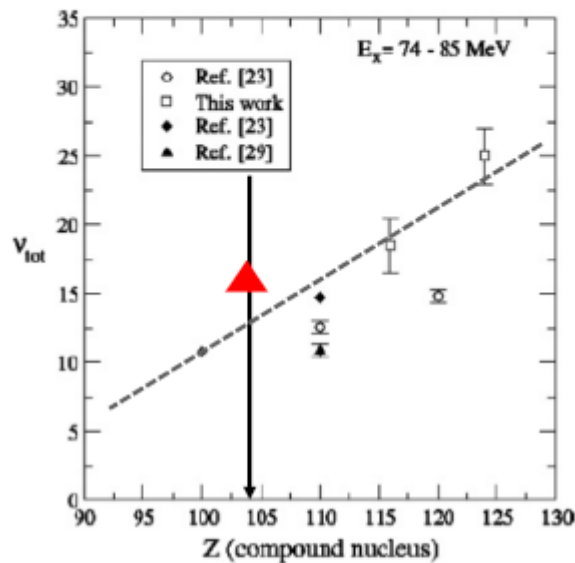
n/γ discrimination:  
 PSA with the Zero Crossing Method  
 V1720 CAEN digitizer (250 Ms/s, 12 bit)



*N. Colonna et al., NIM A 381 (1996) 472*

Threshold for neutron detection  $\cong 200 \text{ KeVee}$   
 Intrinsic time resolution for ToF measurement  $\sim 700 \text{ ps}$

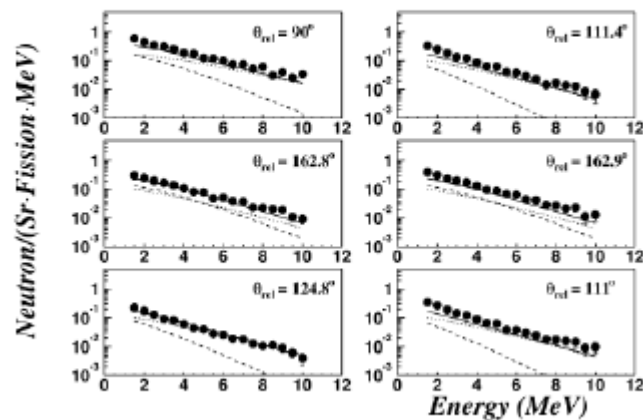
## Average total neutron multiplicity: A tentative comparison with earlier data



R.G. Thomas et al., Phys. Rev. C 75, 024604 (2007)

A. Saxena et al., Nucl. Phys. A 730 299 (2004)

$340 \text{ MeV } ^{28}\text{Si} + ^{232}\text{Th} \rightarrow ^{260}\text{Rf} (E_x=186 \text{ MeV})$



$$M_{\text{pre}}^n = 8.7 \pm 2$$

$$M_{\text{post}}^n = 8.6 \pm 2$$

PACE2 Calculations

Fission delay	$M_{\text{pre}}^n$	$\langle \epsilon^v \rangle$ (MeV)
$1 \times 10^{-20} \text{ s}$	5.0	4.8
$2 \times 10^{-20} \text{ s}$	6.5	4.7
$4 \times 10^{-20} \text{ s}$	8.1	4.5
$6 \times 10^{-20} \text{ s}$	9.2	4.3
$8 \times 10^{-20} \text{ s}$	9.8	4.3
$10 \times 10^{-20} \text{ s}$	10.3	4.2
$12 \times 10^{-20} \text{ s}$	10.6	4.2

## NUCLEAR DATA THEORY AND SIMULATIONS

- **Review of the fission spectrum for use in thorium fuelled systems like AHWR**

The fission spectra for AHWR has been computed by averaging over isotopes spectra of  $^{233}\text{U}$ ,  $^{239}\text{Pu}$  and  $^{241}\text{Pu}$  with weights 65%, 27% and 8%, respectively.

- **Spectrum average one-group cross section for fission fragment gas monitoring of AHWR**

A special procedure has been used to estimate the spectrum averaged capture reaction rates for the volatile fission products like xenon and krypton isotopes, namely,  $^{133}\text{Xe}$ ,  $^{135}\text{Xe}$ ,  $^{138}\text{Xe}$ ,  $^{85\text{m}}\text{Kr}$ ,  $^{87}\text{Kr}$ ,  $^{88}\text{Kr}$  and  $^{89}\text{Kr}$  for the fission gas monitoring system of AHWR.

- **Simulations:**

For the development of various neutron detection systems for measurement of the ambient dose equivalent of high energy neutrons a simulation of several  $(n, xn)$  reactions was carried out using the FLUKA Monte Carlo code for sensitivity analysis, optimization and detection efficiency.

- **Validation of PFBR database created for ORIGEN2:**

The ORIGEN2 results for decay powers were compared with those given by the decay power standards viz. ANS-5.1 (U.S. 1994) and AESJ (Japan 1991).

# Indigenous Development of a Monte Carlo Reactor Physics Code

A continuous energy general geometry Monte Carlo code is developed for the first time in India.

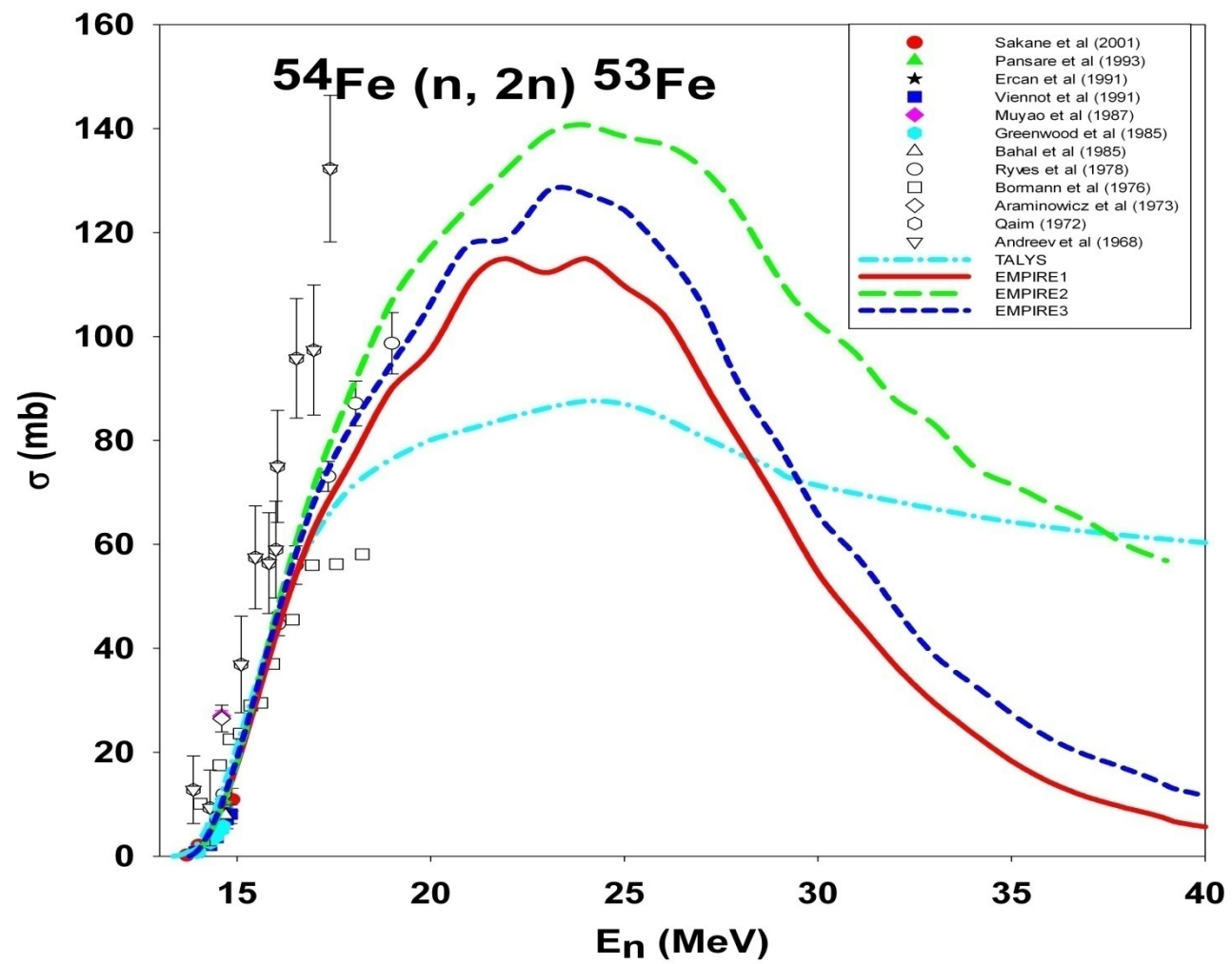
This code has all advance capabilities to incorporate each and every effect which are required to do exact simulation in reactor physics.

## Some of the important features of this code are mentioned below

Accept the continuous energy nuclear data in ACE format

- Use of probability table treatment in the unresolved resonance range
- Explicit sampling of a delayed-neutron spectrum
- Thermal scattering treatment for accounting the effects of chemical binding and crystal for incident neutron energies below about 4 eV

The developed code has been verified for its accuracy against more than 60 sample problems. These sample problems cover the wide range of simple (like spherical) to complex geometry problem (PHWR lattice, CHTR).



*(Sneh Lata Goel, Maitreyee Nandy, P. K. Sarkar, Prabhat Saran)*

Thank you.

