BARC–TIFR Pelletron Linac Facility Beam Time Request @2024

Title of the Experiment: Study of Neutron induced reaction cross section measurement up to 20 MeV relevant to nuclear data generation and covariance analysis.

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Local Collaborator / Spokesperson: Prof.Vandana Nanal
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Note: **Local collaborator is mandatory for non-BARC (NPD) / TIFR (DNAP) user**

Collaborators Name: Dr. Pargin Bangotra (Research Supervisor, Netaji Subhas University Of technology, Delhi),
Prof. N.L. Singh (Co-Supervisor, NSUT, Delhi),
Dr. Rajnikant Makwana, Dr. Ratan K. Singh (MSU, Baroda),
Mr. Mayur Mehta, (IPR, Gandhinagar)
Ms. Vandana (NSUT, Delhi).

Motivation of the experiment: As per Annexure attached.

Beam details: Proton beam of energy range of 8 to 20 MeV with current ~300nA.

Buncher requirement: ~~**Yes**~~**/ No:** No

Number of shifts (1 shifts=8 hr.) required: 3-6 shifts

Objective of Experiment:

A comprehensive understanding of nuclear phenomena, encompassing fission, reaction cross-sections along with their associated uncertainties, and structural/decay properties, is indispensable for various applications such as the development of novel reactor designs, reactor core and fuel configurations, as well as the selection of shielding and structural/cladding materials for future nuclear reactor systems. However, the lack of a well-quantified, predictive theoretical capability means that most nuclear observables must be measured directly and used to calibrate empirical models, which in turn provide the data needed for these applications. In many cases, either there is a lack of data needed to guide the models or the results of the different measurements are discrepant.

The available nuclear reaction cross section data for few elements are scarce, hence precise experimental data seems necessary for energies other than 14 MeV. The present work focuses on irradiating few pre-decided elements with neutron beam irradiation and using activation analysis technique for further analysis. The activities of the reaction products will be measured using a high-resolution high purity germanium spectrometry system. It is necessary to improve nuclear data and assess the availability of benchmark experiments that could be applied for testing and validation.

Further, the measured data set will allow to predict data with the nuclear modular codes such as TALYS, EMPIRE. Etc. This is useful to validate the data as well as to get the appropriate data set which can complete the data for the entire energy range for the reactor application. This also helps to understand the nuclear reaction models. In the current proposal, we have identified specific isotopes deemed significant for their utility as structural and shielding materials. Within a reactor environment, materials are subjected to intense neutron flux, potentially yielding substantial quantities of reaction byproducts. Additionally, we have opted to include Tin (Sn), characterized by its proton magic number, which predicts a comparatively diminished reaction cross-section. Nevertheless, the investigation of its behavior remains of notable interest.

The objective of the present work: **Neutron Activation Cross Section Measurement from threshold energy to 20 MeV for isotopes of Ta, In, Sn and Y (Table 1).**

Table1: Proposed reactions for the experimental measurement.

Isotopic Abundance (%)	Target isotope	Nuclear reaction	Threshold energy (MeV)	Half-life ($\tau_{1/2}$)	E_γ (keV)	I_γ (%)
99.98	$^{181}Ta_{73}$	$^{181}Ta(n,2n)\,^{180}Ta$	7.618	8.152 h	93.326	4.5
		$^{181}Ta(n, p)\,^{181}Hf$	0.255	42.39 d	482.182 133.024	80.50 43.3
		$^{181}Ta(n, \alpha)^{178}Lu$	0.00	28.4 m	93.180 1340.8	6.0 3.22
95.7	$^{115}In_{49}$	$^{115}In(n,\alpha)^{112}Ag$	0.00	3.130 h	617.516	43
		$^{115}In(n, p)\,^{115}Cd$	0.675	53.46 h	336.240 527.900	45.9 27.45
32.6	$^{120}Sn_{50}$	$^{120}Sn(n,\alpha)^{117}Cd$	0.00	2.49 h	273.349	28
100	$^{89}Y_{39}$	$^{89}Y(n, p)\,^{89}Sr$	0.728	50.53 d	908.96	0.010
		$^{89}Y(n,2n)\,^{88}Y$	11.612	106.65 d	1836.063	99.2
		$^{89}Y(n,\alpha)^{86}Rb$	0.000	18.631 d	1076.64	9

Description of Experiment:

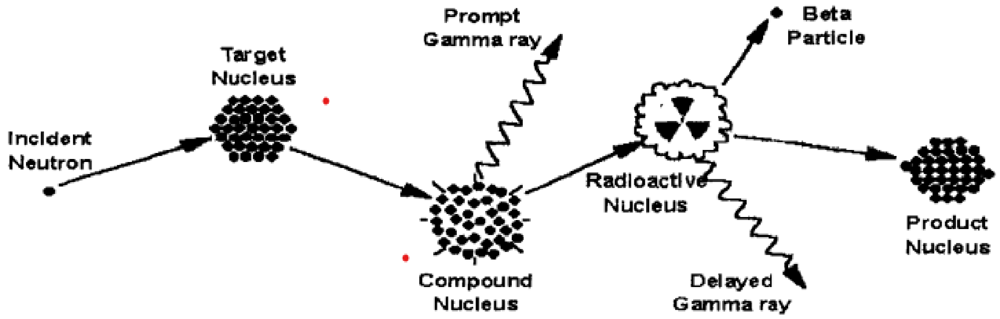
The present measurements will be performed by using 14UD Bhabha Atomic Research Center-Tata Institute of Fundamental Research (BARC-TIFR) Pelletron accelerator, Mumbai, India. It is aimed for taking together results of the systematic activation cross section measurement for the reactions of importance for fusion and other applications.

The studies of reactions cross-section of materials used in fission-fusion reactors are of prime importance for the validation of nuclear models in the context of a practical approach. As suggested in (Kolos et al. 2022) ,there are many reactions that have deficiencies and discrepancies in cross section data at low and high neutron energies. These can be resolved by performing better accurate measurements.

The experimental procedure includes:

1. Production of Quasi-mono energetic Neutron beam using ^{7}Li(p,n) reaction.
2. Irradiation of sample elements.
3. Detection of Gamma rays counts using HPGe.
4. Experimental calculations for cross section measurements
5. Validation of theoretical prediction with the measured data.

The mono-energetic fast neutron can be generated from ^{7}Li(p,n) reaction using the 14 UD Pelletron accelerator at TIFR, Mumbai. The neutron beam will be obtained from the ^{7}Li(p,n) reaction by using the proton beam main line at 6 m above the analyzing magnet of the BARC-TIFR Pelletron facility to utilize the maximum proton current from the accelerator. The proton beam energies will be selected between 5 to 20 MeV.



Neutron Activation Analysis

The present proposal will measure the neutron induced cross sections for different materials with high precision. The selected targets will be irradiated with different neutron energies. The irradiated samples will be taken for offline induced activity measurements and the cross sections will be measured by Neutron Activation Analysis method(Ali 1999).The gamma ray activities of the reaction products will be measured by using HPGe detector connected to a digital acquisition system. Measured photo peaks will be used for analysis and determination of the cross sections at various neutron energies. Using suitable reference reactions, accurate cross section measurements with uncertainty can be performed.

During the cross-section calculation, to reduce the effects of coincidence summing effect, inclusion of correction factor is necessary, which further depends upon the geometry of the HPGe detector. The tailing correction method, which removes low energy neutron from primary neutron group given by D. L. Smith (Koning n.d.) is essential part of experimental calculations.

References

Ali, M A. 1999. “A Brief Overview of Neutron Activation Analyses Methodology and Applications Nuclear Research Center , Atomic Energy Authority , Egypt.” : 13–17.

Kolos, Karolina et al. 2022. “Current Nuclear Data Needs for Applications.” *Physical Review Research* 4(2): 1–34.

Koning, A J. “NEA/WPEC-XX International Evaluation Co-Operation Volume XX N.” XX.

- **Whether the experiment is part of PhD Work:** Yes
- **Details of Beam time availed of in recent past on this experiment and / or by the PI:** NA
- **Details of papers published / presented in journals / symposia, etc. based on recent experiments:** NA