BARC–TIFR Pelletron Linac Facility Beam Time Request @2024

Title of the Experiment: Study of neutron induced reaction cross section of different structural materials with covariance analysis

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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. Shivani Sharma (NSUT, Delhi).

Motivation of the experiment: As per Annexure attached.

Beam details: Proton beam of energy range 10 to 22 MeV with current ~300nA

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

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

Objective of Experiment:

Systematic study of neutron induced reaction cross sections for isotopes Te, Mo, Ti, Mn, Ag, and Zr in neutron energy region threshold to 20 MeV

Nuclear data hold paramount significance in the examination of nuclear phenomena such as fission, reaction cross-sections, and structural/decay properties, playing a crucial role in diverse applications spanning from the design of novel reactors, fusion devices, to accelerators(Forrest 2006). Precise nuclear data, encompassing cross-sections and decay properties, pertaining to all pertinent materials within the devices, are indispensable for simulation investigations(Bernstein et al. 2019). These nuclear data, along with their associated uncertainties, are requisite for a myriad of calculations, encompassing:

1. Reactor core and fuel design

2. criticality safety

3. material damage in structures

In design of reactors of this nature, nuclear data pertaining to reaction and fission cross-sections of structural materials, alongside the yield of fission products generated during neutron-induced fission of select elements at medium to fast neutron energies, hold significant importance.

The investigation of reaction cross-sections for materials employed in fission-fusion reactors stands as a paramount endeavor for validating nuclear models within a practical framework. Numerous reactions exhibit deficiencies and discrepancies in cross-section data particularly at low neutron energies, issues which can be addressed through improved and precise measurements. Consequently, there exists a considerable level of interest in this area of research.

i) to measure accurate cross sections of neutron induced reactions both in the low and high energy regions.

ii) to improve nuclear models at incident energies below 20 MeV, where the statistical model (SM) calculations are most sensitive to parameters related to residual nuclei and emitted particles as well as around 20 MeV, where the pre-equilibrium emission (PE) becomes important for the particle emission.

With the development of new advanced reactors and micro-reactors utilizing diverse fuels, coolants, and moderators compared to the existing reactor fleet, there arises a potential necessity for enhanced nuclear data(Kolos et al. 2022) . Current target selections are contingent upon the available nuclear data and their intended applications. Ensuring the precision of nuclear data for isotopes such as Tellurium (Te), Molybdenum (Mo), Titanium (Ti), Manganese (Mn), Silver (Ag), and Zirconium (Zr) is imperative for their utilization as structural materials as given in Table 1.

It is important to quantify the significant discrepancies between the experimental and theoretical data of nuclear reaction cross sections and thereby, increase the predictive power of theoretical models like TALYS, EMPIRE. etc. In the present proposal, covariance analysis will be used to analyze the experimental results with maximum accuracy.

Table 1: Proposed reactions for the experimental measurement.

Isotopic Abundance (%)	Target isotope	Nuclear reaction	Threshold Energy (MeV)	Half-life $(\tau_{\frac{1}{2}})$	E_γ (keV)	I_γ (%)
34.1	$^{130}Te_{52}$	$^{130}Te(n, p)\,^{130}Sb$	4.318	39.5 m	839.49	100
		$^{130}Te(n, 2n)^{129}Te$	8.484	69.6 m	27.81	16.3
		$^{130}Te(n, \alpha)^{127}Sn$	0.00	2.1 h	1114.3	39
24.3	$^{98}Mo_{42}$	$^{98}Mo(n, \alpha)^{95}Zr$	0.00	64.02 d	756.729	54
73.7	$^{48}Ti_{22}$	$^{48}Ti(n, p)\,^{48}Sc$	3.274	43.67 h	983.517 1312.096	100.1 100.1
100	$^{55}Mn_{25}$	$^{55}Mn(n,2n)^{54}Mn$	10.413	312.3 d	834.848	99.976
51.8	$^{107}Ag_{47}$	$^{107}Ag(n,2n)^{106}Ag$	9.626	23.96m	511.842	17
51.5	$^{90}Zr_{40}$	$^{90}Zr(n,p)\,^{90}Y$	1.510	64 h	2186.242	1.4E-6
		$^{90}Zr(n,2n)\,^{89}Zr$	12.100	78.41 h	908.96	100

Description of Experiment:

The mono-energetic fast neutron can be generated from ^{7}Li(p,n) reaction (E_{th}=1.88MeV)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.

The current proposal will measure the neutrons induced cross sections for different materials and provide excitation functions with high precision. In this study, the selected targets are structural/reactor materials such as Te, Mo, Ti, Mn, Ag and Zr etc. 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. The gamma ray activities of the reaction products will be measured by using HPGe detector connected to digital acquisition system. Measured photo peaks will be used for analysis and determination of the cross sections at various neutron energies.

The following steps will be follow:

- Theoretical study of the selected nuclear reactions.
- Experimental measurements of the nuclear cross sections.
- Validation of theoretical prediction with the measured data.

References

Forrest, R. A. 2006. "Data Requirements for Neutron Activation. Part I: Cross Sections." *Fusion Engineering and Design* 81(18): 2143–56.

Bernstein, Lee A. et al. 2019. "Our Future Nuclear Data Needs." *Annual Review of Nuclear and Particle Science* 69: 109–36.

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

- **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