Study of prompt fission neutron energy spectra in fast neutron induced fission of ^{232}Th at 2.5 MeV

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Introduction

Measurement of prompt fission neutron spectra (PFNS) for fast neutron induced fission of actinides has gained renewed interest due to its importance in the development of upcoming Generation IV reactors and accelerator driven systems for the transmutation of nuclear waste [1]. Knowledge of the prompt neutron spectra and multiplicity enables us to gain deep insight about fission dynamics, particularly the energy partitioning in fission processes. Only limited experimental studies in this field are available because of the following major difficulties: non-availability of intense mono-energetic fast neutron sources, extremely small fission cross-section of actinides in the region of interest and the huge background due to the scattering of incoming neutrons having energies in the same range as that of fission neutrons. We have initiated a program to measure the PFNS obtained in the fast neutron induced fission of different actinides at varying neutron energies [2]. In this work, we report the measurements done for the PFNS obtained from the fast neutron induced fission of ^{232}Th at 2.5 MeV neutron energy.

Experimental set-up

The experiment was carried out at the Folded Tandem Ion Accelerator Facility (FOTIA), BARC. The primary quasi mono-energetic neutrons were obtained using the ^{7}Li(p,n)^{7}Be reaction by bombarding the proton beam on a natural Li metallic target of thickness ~ 4.0 mg/cm^2 [3]. A double sided ionization chamber operating in air was used to generate the fission trigger. The cathode and the anode diameter were 7.0 cm and were separated from each other by 2.0 mm Teflon spacer rings. Two 1.0 cm x 1.0 cm foils of ^{232}Th of thickness ~ 2.0 mg/cm^2 were placed on either side of the cathode of the ionization chamber. The fission fragments produced in the ^{232}Th(n,f) reaction were detected in the fission chamber covering a solid angle of nearly 4π. The anode plates were biased to +450 V and the cathode plate was kept at ground potential. The fission fragments deposit a fraction of their energies within the ionization chamber by generating electron-ion pairs which give rise to an electrical signal as shown in Fig. 1. This is used as the trigger for the time-of-flight (TOF) measurement. A certain threshold was set to cut down the events due to alpha particles.

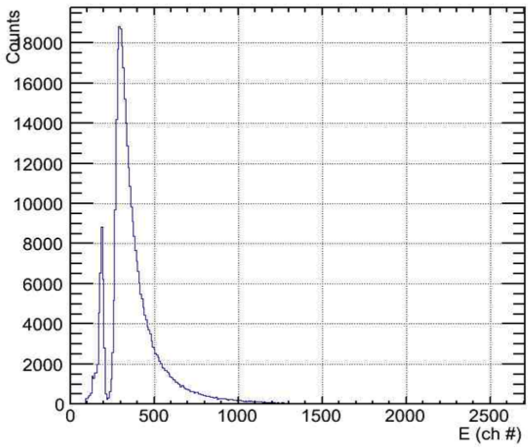

Fig. 1: Energy loss spectrum of fission fragments generated in the ionization chamber.

Two EJ301 liquid scintillator detectors (12.7 cm in diameter and 5.0 cm thick) were placed at a distance of 1.0 m from the ionization chamber. Three standard sources: ^{137}Cs, ^{60}Co, and ^{22}Na were used for energy calibration of the detectors. Both neutron detectors were kept at a threshold of ~ 113 keV. Pulse shape discrimination (PSD) technique was used to separate the neutrons and the gammas. Fig. 2 shows the schematic diagram of the experimental setup.

Analysis of experimental data

The TOF spectra were converted into energies after appropriate calibrations of the TDCs. In order to extract the true neutron events from the strong background, an artificial background (red line) which replicates the experimental background (green line) was generated in the prompt neutron coincidence region (blue line) using a Monte Carlo simulation as shown in Fig. 3. In order to obtain the genuine neutron spectrum, the energy spectrum of the artificially generated background of width similar to the prompt neutron coincidence region in the TOF spectrum was subtracted from the measured prompt neutron energy spectrum.

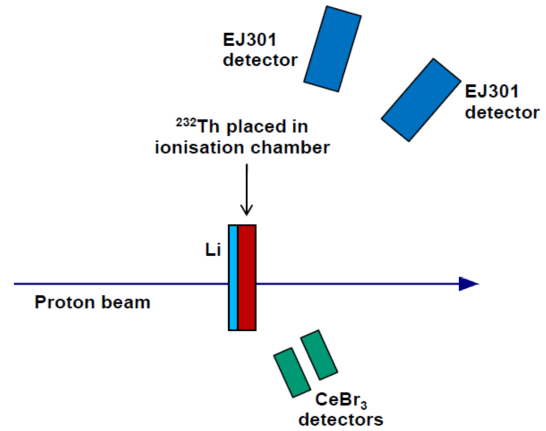

Fig. 2: Schematic diagram of the experimental setup.

A commonly used approximation for prompt fission neutron spectra is the Normalized Maxwellian distribution given as:

$$N_M(E) = \frac{2\sqrt{E}}{\sqrt{\pi}\,T_M^{\;3/2}}\, e^{-(\frac{E}{T_M})}$$

where T_M is the Maxwellian temperature [2]. The efficiency corrected neutron energy spectra for both the detectors were added in order to get better statistics. It was then fitted with the Maxwellian distribution (red line) as shown in Fig. 4.

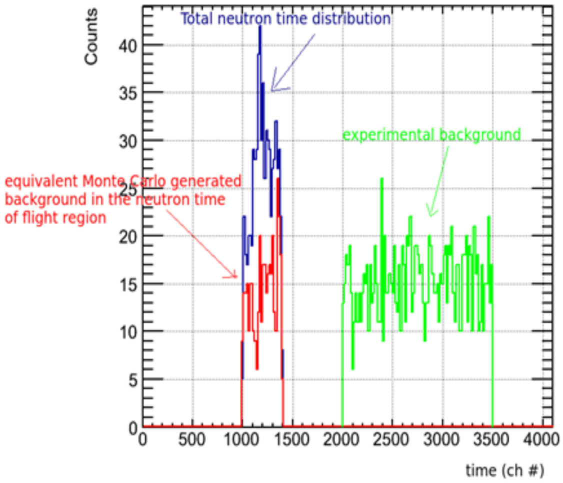

Fig. 3: Measured TOF spectra along with the artificially generated background.

The error bars along the y-axis are because of the statistical uncertainties in the measurement of neutron counts. The systematic uncertainties in the present data mainly come from the background subtraction. A neutron spectrum for ^{252}Cf having the same signal-to-noise ratio as that in our experiment was artificially generated using a GEANT4-FREYA [4] simulation. Similar background subtraction technique was applied and the difference in the actual T_M and the T_M obtained using our background subtraction technique helps us to estimate the error in our experimental case for ^{232}Th. In present work, the Maxwellian temperature was obtained to be 1.32±0.07 MeV. In an earlier measurement by Takako Miura *et al*[5], T_M=1.28±0.08 MeV was obtained for the fast neutron induced fission of ^{232}Th at 4.1 MeV neutron energy. Further systematic investigation about the PFNS obtained in the fast neutron induced fission of different actinides at different incident neutron energies are being planned to be carried out in the future.

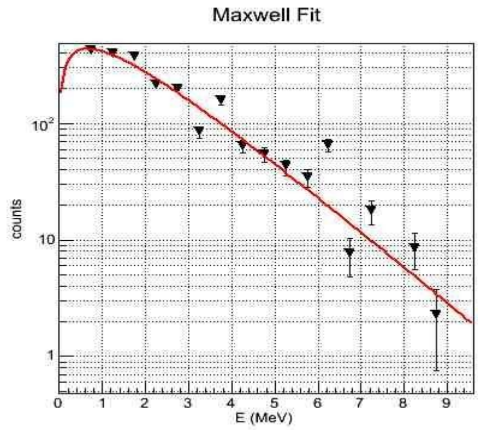

Fig. 4: Prompt fission neutron spectra fitted with a Maxwellian distribution.

Acknowledgements

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