Determination of intrinsic efficiency for a plastic scintillator bar for Prompt Fission Neutron Spectra Measurements

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1. Introduction

Plastic scintillator bars, due to their large effective solid angle and position sensitivity, can be used for Prompt Fission Neutron Spectra (PFNS) measurements. However, precise determination of PFNS depends on the accuracy of the intrinsic efficiency of the bar. Though the Monte Carlo simulations can give approximate behaviour, experimental determination of intrinsic efficiency is important as it depends on a number of factors unlike liquid scintillation detectors. In the present work, we have measured the intrinsic efficiency of a plastic scintillation bar by carrying out PFNS measurement of a standard ^{252}Cf spontaneous fission source and comparing it with the Manhart evaluated neutron spectra corresponding to Maxwellian temperature of 1.42 MeV.

2. Experiment

Fission fragments obtained from the spontaneous fission of ^{252}Cf were detected using a trigger ionisation chamber with circular electrodes of 4.5 cm diameter each, separated by a 3 mm teflon spacer. A ^{252}Cf spontaneous fission source was placed on the cathode of the fission chamber. The energy loss signal obtained due to the ionization produced by the fragments was processed to provide trigger to the data acquisition system. A plastic scintillator bar of dimensions 6 cm x 6 cm x 100 cm and coupled to two 5 cm diameter XP2020 PMTs [1], one at each end were used to detect the neutrons from the ^{252}Cf source. Negative bias of 2 kV was applied to both the PMTs. The distance betwen the source and the detector was kept ∼100 cm. The experimental set-up is shown in Fig.1.

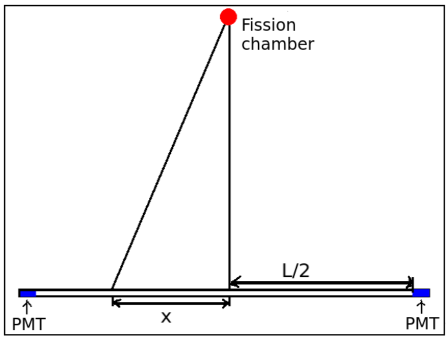

FIG. 1: Experimental setup.

3. Analysis

The time recorded at the left and right ends of the detector is given as:

$$T_L = T_0 + (\frac{L}{2} - x)/v + \rho \quad (1)$$

$$T_R = T_0 + (\frac{L}{2} + x)/v + \rho^{'} \quad (2)$$

$$T_L - T_R = -2x/v + \rho - \rho^{'} + nL/v \quad (3)$$

where ρ and $\rho^{'}$ are the electronic processing time, v is the velocity of light within the bar and n is the mean number of reflections in the detector. T_0 is the time required by the neutrons or gammas to reach the detector. In a separate measurement using collimated

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gamma sources of (^{137}Cs, ^{60}Co and ^{22}Na), the position resolution of the detector is observed to be 20 cm. Therefore, each detector was divided into five segments of 20 cm length for the subsequent analysis. The geometrical mean of the pulse heights of the two signals recorded in the left and right PMTs of the bar is observed to be proportional to the energy deposited in the detector [2] and roughly independent of position of the source. The threshold was also set to be $\sim$ 100 keVee and approximately 3x10^7 fission events for a ^{252}Cf source are recorded. Absolute time for each segment was obtained using the gamma peak. The Time-of-Flight (TOF) spectra of the prompt fission neutrons and gammas measured in coincidence with fission trigger is shown in Fig.2.

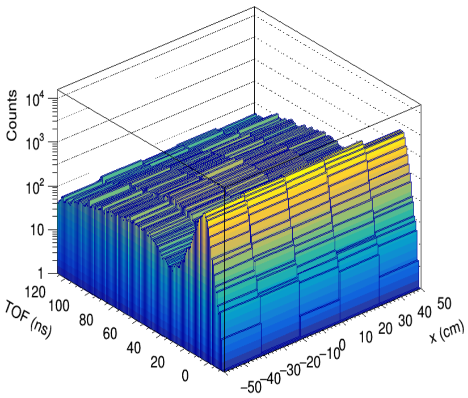

FIG. 2: TOF spectrum of prompt fission neutrons and gammas for the five regions of the bar.

To obtain the geometric efficiency of each of the sections, we have performed a Monte Carlo simulation and the solid angle for each of the sections are shown in Fig.3. The measured spectrum normalised per fission was then compared with the Manhart evaluated spectrum of ^{252}Cf to obtain the intrinsic efficiency of the plastic bar as shown in Fig.4. The GEANT4 simulation including optical transport is being performed to obtain the light output as a function of E_p, where E_p is the proton recoil energy deposited.

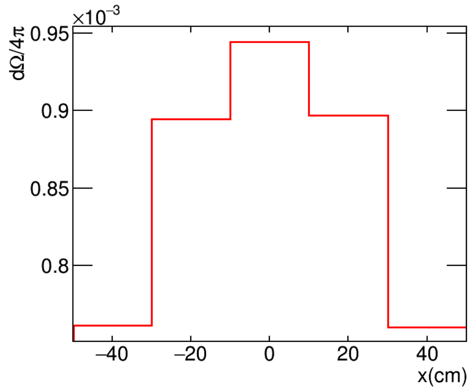

FIG. 3: Solid angles for the five sections of the bar.

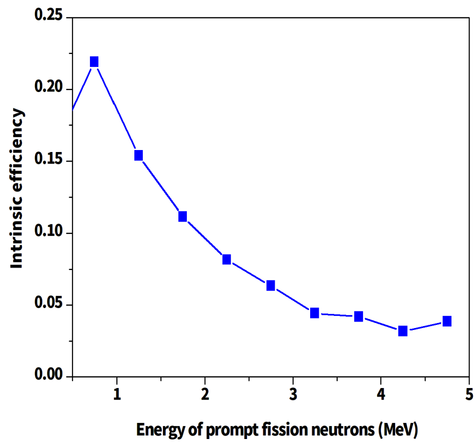

FIG. 4: Intrinsic efficiency of the plastic scintillation detector.

References

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