Exploring the light response of a 5″ × 5″ BC501A detector using ^{252}Cf source

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Light response function of a 5″ × 5″ BC501A liquid scintillator, coupled with R4144 PMT type is explored using ^{252}Cf source. An experiment was conducted with a pair of proportional counters placed at 11 cm apart. Neutron time of flight (TOF) spectra was collected in conjunction to fission TOF spectra. Their energy distribution is obtained under PSD-TOF gate, being utilized to extract the light response at various neutron energy window values.

Introduction

Neutrons from the fissioning nuclei are the eyewitness of the process. They carries inclusive information about the nuclear viscosity and level densities of fission barrier. The viscosity is connected to the average number of neutrons (M_n) emitted in pre and post fission process [1]. To understand the fission dynamics in great details, one has to detect these neutrons in a efficient manner. Assisted by hundred liquid scintillator based BC501A detectors, NAND facility at IUAC, New Delhi, addresses accurately the measurement of M_n with high precision [2].

The objective of this study is to understand and characterize the BC501A light production function, under the flux of mono-energetic neutrons. Outcome of the study would be useful for the complete array simulation in terms of efficiency and neutron cross talk. Thereby, further making the correction in the measured M_n values.

Experimental Details

An experiment was performed at NAND facility, IUAC New Delhi, using ^{252}Cf source. In order to detect the fission fragments, a pair of proportional counters were used, placed in the NAND chamber of 1 m diameter. One of the detector (D_{start}) faces the source had the dimensions of 4 cm × 4 cm × 3.2 cm, provides start signal, being followed by a 16 cm × 11 cm × 3.4 cm position sensitive multiwire proportional counter (MWPC) [3] at 11 cm flight path. Both the detectors were operated with isobutae gas at a pressure of 3.5 mbar. Typical count rates were observed to be ≈ 3 kHz, and ≈ 2.6 kHz for D_{start} and MWPC detectors respectively. Data was collected under the master trigger of D_{start} anode CFD signal. We have recorded fission TOF spectra with four MWPC position signals, along with light output, TOF, and pulse shape discrimination spectra of fifty neutron detectors.

Analysis and Results

The present analysis focuses on the 7^{th} ring BC501A detector, placed at 90^o with respect to the beam direction. A distribution of pulse shape discriminator parameter versus time of flight is depicted in Fig. 1 (left). Total 541k neutrons were collected in 44 hours under PSD-TOF gate, shown in the same figure. These neutrons were emitted by ^{252}Cf fission fragments having average masses 109 a.m.u. and 143 a.m.u. [4]. In the analysis their temporal separation is found to be ∼ 4.5 ns. The average average number of gammas and neutrons emitted per fission is about ≈10 and 3.75 respectively [5]. Thus, the measured γ-ray TOF width is a result of two fragments convolution, provides a width of 3.34 ns. Their individual width is found to be of 1.78 ns and 1.87 ns for heavier and lighter fragment respectively. In order to get the accurate γ-ray peak position, event-by-event correction

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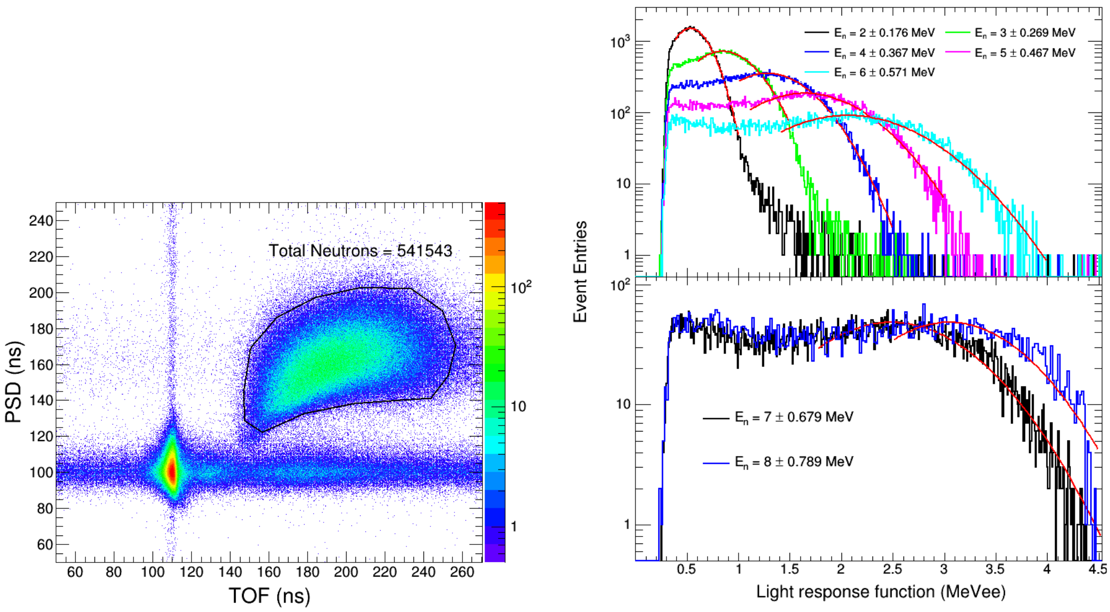

FIG. 1: Left : A pulse shape discrimination versus time of flight distribution plot along with graphical cut, used for the neutron energy calculation. Right : Neutron light response function of a BC501A detector from 1-8 MeV neutrons. Higher light edge is fitted with a Gaussian distribution whose half height reflects the maximum neutron energy transport [6].

is performed, compensating the temporal separation of γ-rays emitted from the two fission fragments. The corrected peak centroid is found to be at 109 ns, encompasses all the electronic delays, with a reduced broadening of 2.47 ns. Using γ-ray reference peak, neutron TOF is calculated and converted to their kinetic energy, given as :

$$E_n(MeV) = \left(\frac{d\,(cm)}{1.38\,TOF(ns)}\right)^2 \qquad (1)$$

$$d = Flight\ distance + Detector\ half\ depth$$

Total flight distance of 175 cm + 6.35 cm is used in the calculation. Obtained spectra is sliced at various neutron energy window : ΔE_n, to obtained the neutron response function. Here, ΔE_n is decided by the following equation :

$$\left(\frac{\Delta E_n}{E_n}\right)^2 = \left(\frac{2\Delta\tau}{TOF}\right)^2 + \left(\frac{2\Delta L}{L}\right)^2 \qquad (2)$$

$$\tau : Timing\ resolution,\ \Delta L : Depth\ resolution$$

While adopting the mentioned procedure, we have extracted the light response function of a BC501A detector as depicted in Fig. 1 (right). The distribution higher edge is fitted with a Gaussian function to obtain the connection between light response and neutron energy [6]. Experimental results and analysis would be presented during the symposium.

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