Investigating response of liquid scintillator detector EJ301 to fast neutrons using Am-Be source

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Introduction

Organic liquid scintillator detectors have superior time response and because of this, they are widely used in neutron time of flight experiments. For these measurements efficiency of the detector, which is function of neutron energy and detector threshold must be determined accurately. In the present work, Monte Carlo simulation has been carried out using GEANT4 [1] for obtaining the efficiency at different energy and threshold values. For estimating detector efficiency the detector response has to be well reproduced by the simulation. In this study we have measured energy of γ-ray tagged neutrons emitted from ^{241}Am-^{9}Be source and investigated the response of the detector to fast neutrons using GEANT4 simulation package.

Experiment

Experiment was carried out at BARC using a ^{241}Am-^{9}Be source. Neutrons upto energy of 11 MeV are emitted from the reaction but only upto 7 MeV neutrons can be observed in coincidence with γ-ray. Two $CeBr_3$ detectors were placed at a distance of 3 cm from the source for detecting the γ-rays. Neutrons were detected using a EJ301 detector placed at a distance of 94.5 cm from the source. Data was collected using a 8 channel digitizer with sampling rate of 500MS/s. Threshold for the EJ301 was set at 220 keVee. EJ301 is sensitive to neutrons as well as γ-rays. Pulse shape discrimination (PSD) method was used to separate neutrons and γ-rays where signal from EJ301 was integrated over two different time intervals of 150ns (long gate) and 32ns (short gate). PSD was defined as $(E_{long} - E_{short})/E_{long}$ where E_{long} and E_{short} are pulse heights integrated over long and short gate.

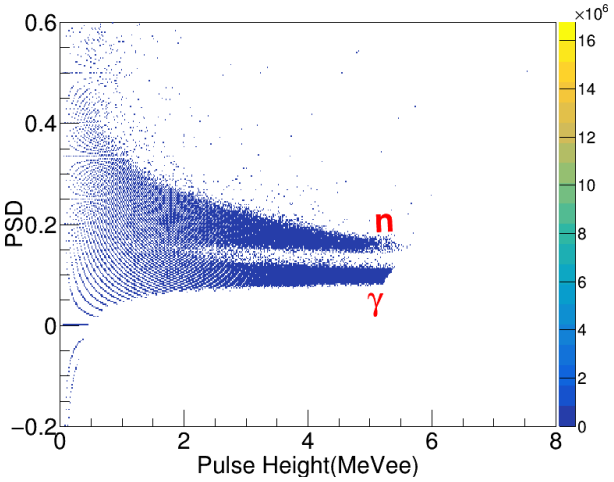

FIG. 1: Pulse height vs PSD for EJ301.

Result

Figure 1 shows the pulse height vs PSD for EJ301. Neutrons have higher PSD values and can be seen to be well separated from γ-rays. Detected γ-ray spectrum in one of the $CeBr_3$ detectors is shown in figure 2. The γ-ray at energy of 4.4 MeV which is emitted in ^{4}He+^{9}Be reaction can be observed clearly. Time of flight of neutron was extracted with respect to the $CeBr_3$ detectors and after applying a gate on high energy γ-rays, neutron energy was extracted which is shown in figure 3. As expected, only neutrons of energy $E_n < 7$ MeV were observed in coincidence with high energy γ-rays. The extracted neutron energy spectrum shows good agreement with previously

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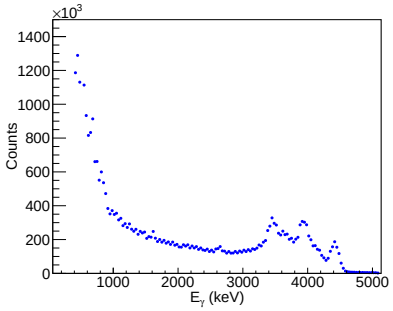

FIG. 2: γ-ray spectra detected by $CeBr_3$.

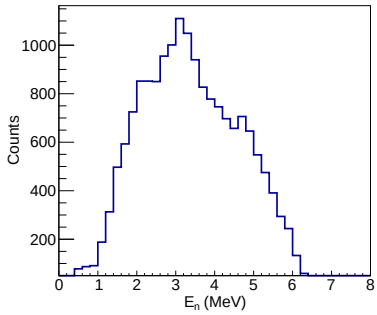

FIG. 3: Energy spectrum of neutrons detected in coincidence with γ-ray.

reported neutron spectra from Am-Be [2, 3]. Pulse heights for different incident neutron energies were obtained by applying gates of neutron energies extracted from time of flight.

Simulation of neutron detector was carried out using Monte Carlo based simulation package GEANT4. Energy deposited by neutron (E_{dep}) was converted into light output using equation $PH = a_1E_{dep}+a_2E_{dep}^2+a_3E_{dep}^3$. Parameters a_1, a_2 and a_3 were adjusted to reproduce the pulse height for different neutron energies simultaneously. Simulated pulse heights were compared with experimental pulse height as shown in figure 4. Good agreement was obtained between the simulated and experimental pulse height. Further analysis is going on to estimate the efficiency of the detector with these parameters at various energies.

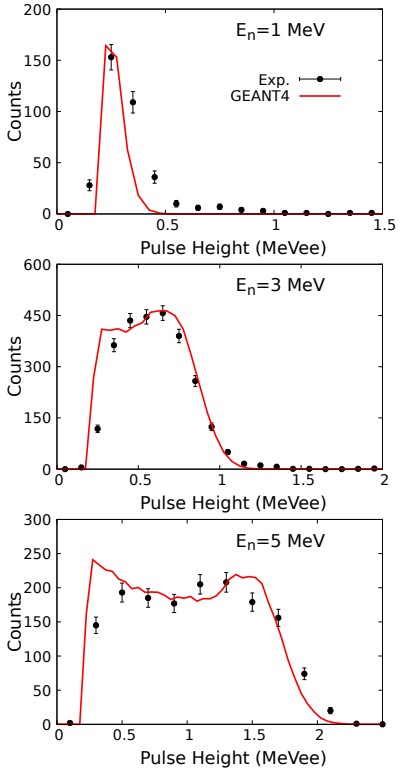

FIG. 4: Pulse height vs. counts for neutrons of energies 1, 3 and 5 MeV. Symbols represent experimental data and GEANT4 simulated pulse heights are shown by lines.

References

[1] Geant4, https://geant4.web.cern.ch
[2] Applied Radiation and Isotopes 193(2023)110655
[3] Appl. Radiat. Isot. 98 (2015) 7479