Performance of a Hybrid Fast and Thermal Neutron Detector

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Introduction

Experiments in neutrino physics [1] and dark matter searches [1] often involve very small interaction rates, and therefore desire a good detection sensitivity with low count rates of background signals. The elimination of known background signals from the physical ones constitutes a major challenge to these experiments. A complete reduction of background signals, especially the neutron induced events, is not possible even in very deep underground laboratories. Therefore, direct measurement and elimination of neutron background signals are very crucial for such experiments [2].

The neutron detector used in this study has a hybrid structure, bringing two different types of target materials to operate at the same time; Bicron BC-501A liquid scintillator having 0.113 liter cell volume and BC-702 type scintillator enriched to 95% ^6Li in a fine ZnS(Ag) phosphor powder. The scintillation light output is readout by Hamamatsu photomultiplier tube (PMT). The schematic diagram of the detector is shown in Figure 1.

BC-501A is sensitive to fast neutrons detection while BC-702 has high efficiency of detection of thermal neutrons. Both scintillator detectors have, in addition to a good fast time response, a pulse shape discrimination property, which enables the isolation of γ ray events (due to different signal characteristics for proton and electron recoil events, enabling to distinguish neutron hit events from those

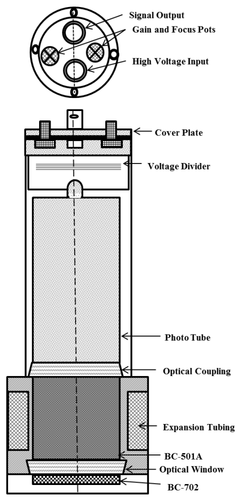

FIG. 1: Schematic diagram of the hybrid neutron detector.

of gamma ray). Therefore this hybrid neutron detector provides good discrimination against γ ray background [2].

Neutron Detector Response

With this hybrid neutron detector we are able to categorize the events into three groups: γ ray events, fast neutron events from BC-501A, and slow neutron events from BC-702 by pulse shape analysis (i.e., rise and decay time of the pulses). Slow neutron events have the most characteristic signal output since ZnS(Ag) scintillation light output is dominated by a very slow decaying component for recoil α particles and other heavier ions contrary to the fast response of the organic scintillator detectors. Fast neutron signals differ from that of γ events slightly in their tail behavior, as seen in

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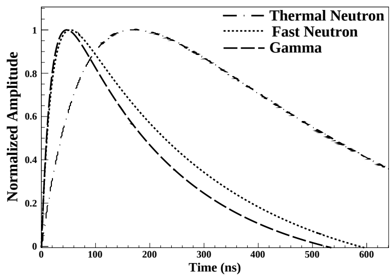

FIG. 2: Reference pulses for gamma, fast and slow neutron events.

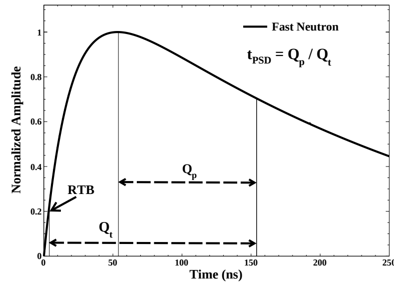

FIG. 3: Integral ranges for the calculation of PSD variable.

Figure 2.

In this study, a PSD technique is developed to identify the events orginated from different source particles. In this PSD technique the pulses are integrated within two different time intervals and the ratio between them is taken. The initial point of integration is taken to be the time-bin at which the pulses reach 20% of their maximum amplitude defined as Rise Time-Bin (RTB). For the PSD study, a parameter named t_{PSD}, which depends on RTB, is used as given in equation 1, since it yields better distinction between the pulses. The first integration region, denoted by Q_p, is defined as an integration region between 50 ns and 150 ns delays from the RTB. The second integration region, denoted by Q_t, is defined as an integration region from RTB to 150 ns delay from RTB, as shown in figure 3. Therefore t_{PSD} can be defined as simply taking the ratio of Q_p and Q_t.

$$t_{PSD} = \frac{Q_p}{Q_t} = \frac{I[(RTB + 50) : (RTB + 150)]}{I[(RTB) : (RTB + 150)]}. \quad (1)$$

^{241}AmBe(α,n) is used as a reference source for gamma, fast neutrons and slow neutrons. Adopting the PSD technique given in equation 1, we can see three spectral bands clearly appeared in figure 4. These three different bands corresponding to γ, fast neutron and slow neutron events from bottom to top, respectively. Figure 4 reveals that the thermal neutron events are well separated from both fast neutrons and γ ray events. On the other

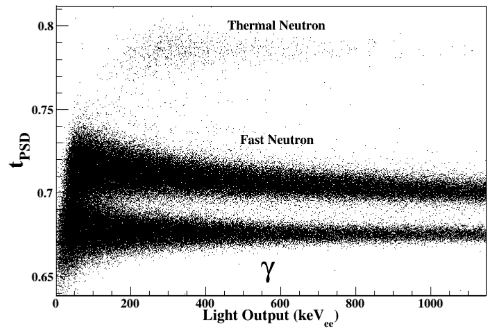

FIG. 4: Energy Distribution of the PSD variable for ^{241}AmBe(α,n) source.

hand, fast neutron events are only well separated from γ ray events starting from 150 keV_{ee}. There are some leackage between them bellow 150 keV_{ee}.

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References

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