Light output functions and γ-ray response of neutron detector

M. K. Singh[1],* V. S. Subrahmanyam[1], V. Singh[1], and H. T. Wong[2]
[1]*Department of Physics, Institute of Science, Banaras Hindu University, Varanasi - 221005, INDIA and*
[2]*Institute of Physics, Academia Sinica, Taipei - 11529, Taiwan*

Introduction

Experiments in neutrino physics and dark matter searches often involve very small interaction rates and therefore desire good detection sensitivity with low count rates of background signals [1, 2]. Fast neutrons are a particular problem for the dark matter search experiments [1, 2]. Fast neutrons can mimic signatures of these rare events, often with significantly higher frequency than the desired events. Thus, it is important to know the fast neutron background in the laboratory so that it can be minimized using proper shielding. Neutron detector used in this study has a hybrid structure, bringing together two different types of target material to operate at the same time. These are the widely used scintillators, namely a Bicron, BC501A, which is sensitive to fast neutrons, and BC702, sensitive to thermal neutrons [1, 2]. The simulated schematic diagram of the hybrid neutron detector using GEANT4 is shown in figure 1.

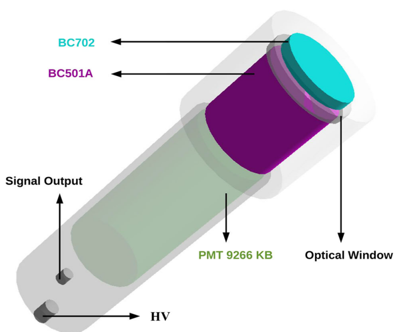

FIG. 1: The simulated schematic diagram of the hybrid neutron detector using GEANT4 [1].

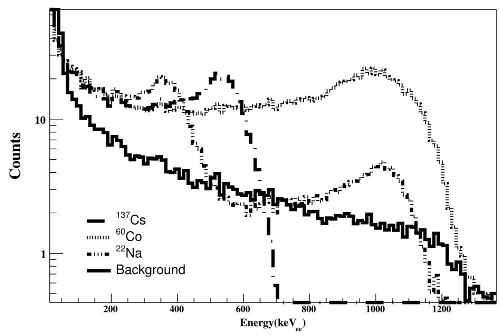

FIG. 2: The energy spectra of various gamma sources including background (BKG) spectrum [1].

BC501A is an organic liquid scintillator containing 4.82×10^{22} and 3.98×10^{22} atoms of hydrogen and carbon per cm^3. High density of hydrogen atoms in this compound makes it a very good target material for neutron detection through neutron-proton elastic scattering for the fast neutrons in the MeV range [1–3]. BC702 material is composed of 11 mg of ^6Li per cm^3 with 95% purity, which is dispersed in ZnS(Ag) phosphor powder. Detection mechanism that the neutron absorption by ^6Li resulting, particle and triton with recoil kinetic energies that interact with the phosphor powder. The excited ZnS(Ag) molecules emit scintillation light inducing detector signal output [1–3].

*Electronic address: singhmanoj59@gmail.com

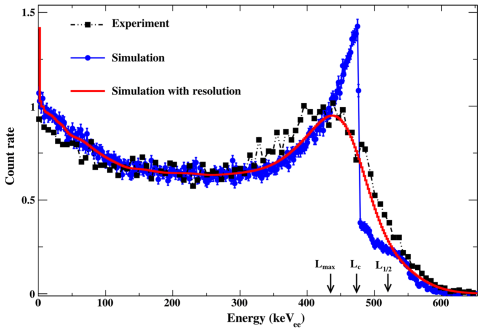

FIG. 3: Light output resolution function of BC501A. L_C, L_{max} and $L_{1/2}$ correspond to the positions of the Compton edge the maximum probability and the location of halfmaximum intensity, respectively [1].

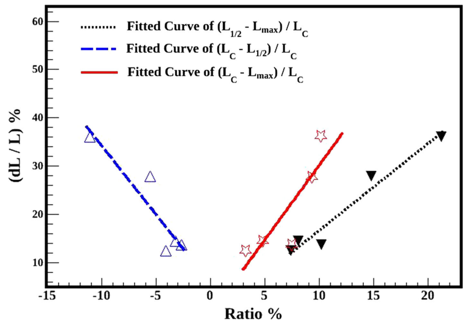

FIG. 4: Light output resolution of BC501A versus ratios of (L_C - L_{max})/L_C, (L_C - $L_{1/2}$)/L_C and ($L_{1/2C}$ - L_{max})/L_C [1].

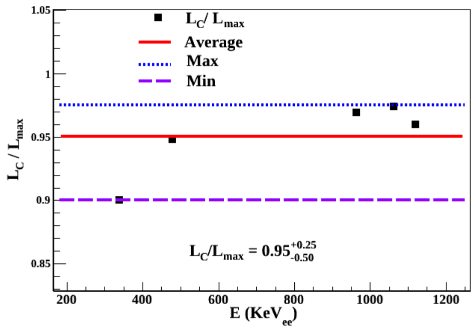

FIG. 5: The ratios of L_C / L_{max} of the BC501A detector [1].

Results and Discussion

The calibration of the hybrid neutron detector adopted in this measurement was described in detail in Ref.[1,2]. The light output response functions of the hybrid neutron detector determined by gamma rays using ^{22}Na, ^{137}Cs and ^{60}Co sources [1, 2] are shown in figure 2 including the background spectrum [1]. The experimental and simulated spectra of 662 keV photons emitted by ^{137}Cs radionuclide source with their Compton energy [1] is shown in figure 3. Figure 3 reveals that the measured recoil electron spectrum is wider than the simulated spectrum, this happens due to noise and statistical fluctuations [1]. After including the energy resolution obtained from the observed spectrum in simulation, the simulated spectra are almost matching with the measured data spectrum, which can be seen in figure 3.

The relationship between the light output resolution and the ratios of (L_C - L_{max})/L_C, (L_C - $L_{1/2}$)/L_C and ($L_{1/2C}$ - L_{max})/L_C are shown in figure 4 [1]. Figure 5 shows the ratio of L_C to L_{max} of the BC501A liquid scintillator detector, which is ($0.95^{+0.25}_{-0.50}$) [1]. This study show that the hybrid neutron detector is suitable for use in mixed fields of neutron and γ with an energy range around hundreds of keV to few MeV [1].

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