Pulse Shape Discrimination Performance of a meter-long Liquid Scintillator Bar

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Introduction

The organic scintillators (both Plastic and Liquid forms) are widely used as large area detectors in high energy physics. The response of oragnic scintillators is quite fast with the decay time of few ns or less. Scintillation in such compounds arises from transitions made by the free valance electrons of the molecules. In Liquid scintillators, the ionisation energy is absorbed mainly by the solvent and then passed on to the scintillation solute. Along with this, liquid scintillator has different pulse shapes for energy deposition for different particles which gives us a unique handle of Pulse Shape Discrimination. Here, we study the properties of meter long liquid scintillators (EJ301) using AmBe source and tune the Pulse Shape Discriminant (PSD) parameter. A setup of four such Liquid Scintillator bars is being used for styding cosmogenic particles [1].

Measurement and Analysis

We use four liquid Scintillator bars placed in two horizontal planes with detector no. 0 and 3 in lower plane and 2 and 1 on top of them respectively. Each detector bar is 1.02 metres long with cross section 4.9 cm × 5.6 cm of liquid material (EJ301). Each bar is connected with a PMT at each end, to detect the signal. An 8-Channel Digitiser is used to digitalise the analog signal. AmBe is used as a radiation source (cylindrical shape with diameter = 5.9 cm), which is kept between the bottom two detectors, in touch with detector no. 3. AmBe emits both, the neutrons as well as the γ-rays, with the average energies of 4.0 MeV and 4.44 MeV respectively. It gives Compton Edge at 4.198 MeV. The activity of AmBe source is 10 mCi and it emits 70 neutrons per 10^6 α-particles [2]. Thus this scouce emits 25900 neutrons per second.

PSD parameter is defined as the ratio of difference of energy depositions by a particle in the detector integrated in the Long Gate (E_{Long}) and Short gate (E_{Short}) to E_{Long} as

$$\mathrm{PSD} = \frac{E_{\mathrm{Long}} - E_{\mathrm{Short}}}{E_{\mathrm{Long}}}. \quad (1)$$

The PSDs from the two ends of the bar is combined as

$$\mathrm{PSD} = \sqrt{\mathrm{PSD}_1 \times \mathrm{PSD}_2}. \quad (2)$$

Figure 1 and 2 show histograms of PSD versus Energy for Detector 1 (in singles mode), without and with AmBe source respectively. Both the spectra are built over same acquisition time of 911 seconds. One can clearly see in figure 2 that the neutrons have higher PSD peaking around 0.38 as compared to that of photons which peaks at 0.28. PSD for Muon has similar value as that for photons. The Figure of Merit (FoM) is calculated by,

$$\mathrm{FoM} = \frac{\text{Separation of peaks } (\mu_2 - \mu_1)}{\text{Sum of peak widths } (\sigma_1 + \sigma_2)}. \quad (3)$$

Results and Discussions

Many different combinations of Long and Short gates were tried to obtain the best value for FoM. Table I shows the data for the Figure of Merit for the Detecter 1 for different short gates and for fixed Long gate = 400 ns. Figure 3 shows an example of PSD plot for Short Gate = 38 ns and Long Gate = 400 ns, the setting which is having the highest Figure of

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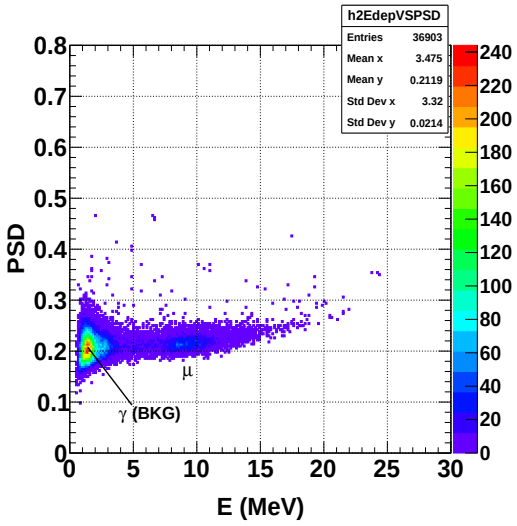

FIG. 1: PSD versus energy for Detector 1 without AmBe source

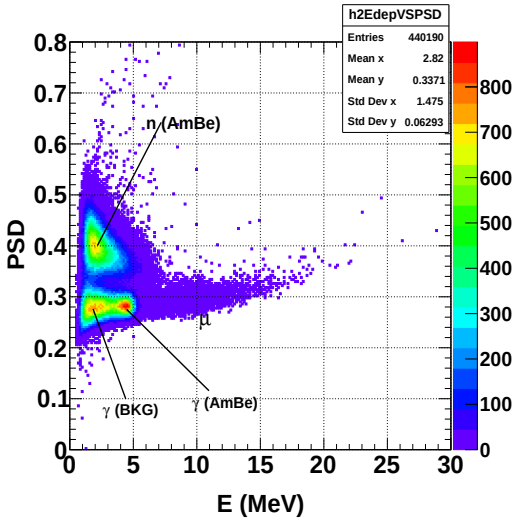

FIG. 2: PSD versus energy for Detector 1 with AmBe source

Merit (see Table I). The lower value of PSD corresponds to that of γ-particles while higher one is for the neutrons from AmBe source.

TABLE I: FoM for Detecter 1 for Long Gate of 400 ns.

S.No.	Acq. time	Short Gate(ns)	Det1 FoM
1	14 m 13 s	30	1.81
2	15 m 11 s	38	1.98
3	14 m 32 s	44	1.97
4	10 m 49 s	50	1.94

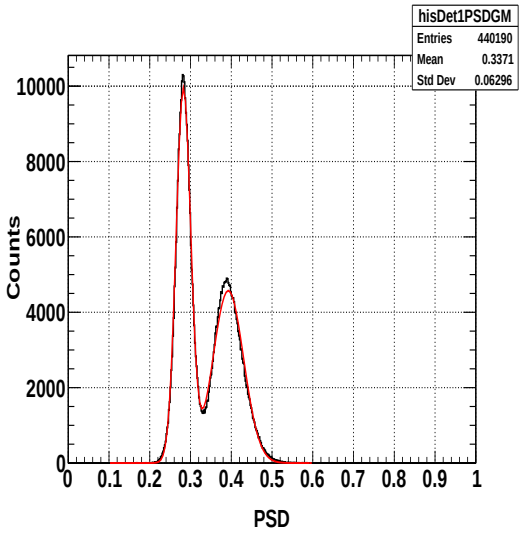

FIG. 3: PSD plot for Short Gate = 38 ns and Long Gate = 400 ns.

Conclusions

In this work, we have studied the performance of PSD for liquid scintillator bars. The PSD tuning has been done to obtain the best FoM among different combinations of Long and Short gates. The study concluded that the optimal values for Short Gate = 38 ns and Long Gate = 400 ns for these liquid scintillator bars, which can be further used in the future to understand the composition of cosmogenic particles.

References

[1] H. Sogarwal and P. Shukla, JCAP**07**, 11 (2022)

[2] Murata et al Progress in Nuclear Science and Technology 4, 345 (2014)