Detector response in plastic scintillator detector using radioactive sources for ISMRAN experiment

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Introduction:

In this report, we present the measurements of the detector response of Plastic Scintillator Bars(PSBs) in a non-reactor environment.These measurements are useful in context of the ISMRAN(Indian Scintillator Matrix for Reactor Anti-Neutrinos) setup, which will be used to measure reactor antineutrinos, through inverse beta decay(IBD) process. ISMRAN detector is an above ground setup and situated in close proximity to the Dhruva reactor core(∼13 m). The ISMRAN setup is shielded by a 10 cm of Lead and 10 cm of Borated Polyethylene to reduce the reactor related background. The schematic diagram of the experimental setup is shown in Fig. 1 [1, 2]. Characterization of PS detectors with known radioactive sources is an essential prerequisite for energy, timing and position measurements of IBD events. Our approach is based on Geant4 Monte Carlo(MC) simulation of energy deposited spectrum of known radioactive sources in a single PSB. Then measured and simulated spectra are compared to determine the energy dependent resolution function for PSB.

Experimental Details:

The ISMRAN setup consists of 90 PSBs, arranged in the form of a matrix in an array of 10×9. Each PSB is wrapped with Gadolinium Oxide (Gd_2O_3 ; areal density: 4.8 mg/cm^2) coated on aluminized mylar foils. Each PSB is 100 cm long with a cross-section of $10\times10cm^2$.

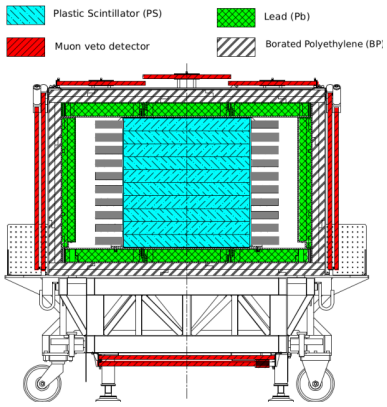

FIG. 1: Schematic of $100cm\times10cm\times10cm$ plastic scintillators array with shielding materials.

Three inch diameter, PMTs are coupled at the both ends of each PSB. The data acquisition system, CAEN V1730 16 channel 500MS/s frequency VME based waveform digitizers has been used for pulse processing and event triggering.

Results and Discussion:

Plastic scintillator is a low-Z material, the dominant feature in the gamma energy spectrum is the compton edge. In order to understand the energy and timing characteristics of each PSB across ISMRAN, it is important to do a gain matching along with the energy and time calibrations of individual bars for uniform response across ISMRAN setup.The energy calibration for each PSB is done using known γ-rays radioactive sources such as Cs^{137},Na^{22} and AmBe in the laboratory. The radioactive source is placed on top of the PSB and the spectra are recorded without any col-

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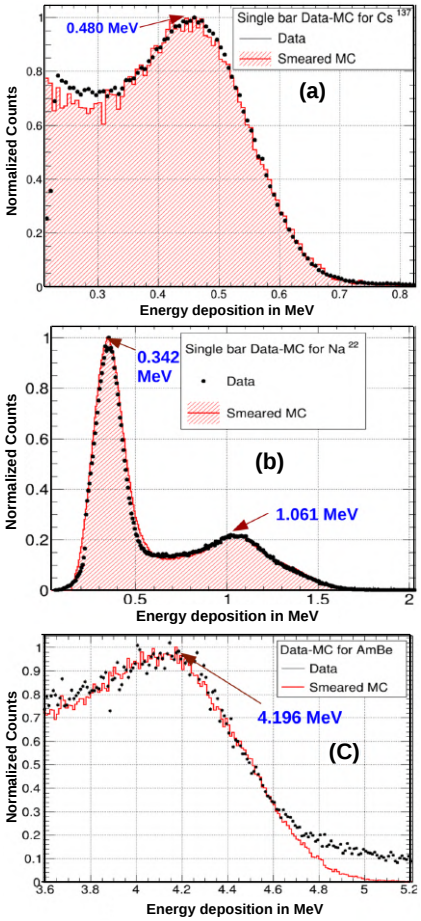

FIG. 2: Comparison between data and MC for energy deposition in a PS bar for a)Cs^{137},b)Na^{22} and c)γ from AmBe radioactive sources respectively.

limation of the emitted γ-rays. This method introduces additional spread in the timing and the position resolution of the PSB.

The simulation results are smeared with a empirical energy dependent resolution function to get a reasonable agreement with the measured data. Figure 2 (a),(b) and (c) show the data and MC comparison for three radioactive sources Cs^{137},Na^{22} and AmBe, respectively. The disagreement between data and simulation results below 0.25 MeV are mainly due to lack of modeling of natural

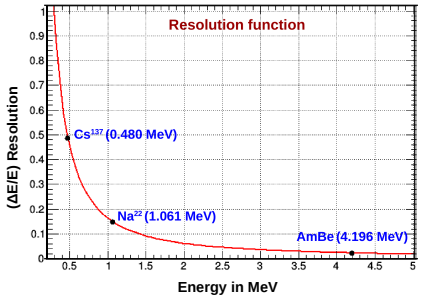

FIG. 3: Energy dependent resolution function in PSB.

background component in the MC simulation results. The energy resolutions ΔE/E are derived by dividing the FWHM(ΔE) with the Compton electron maximum energies(E). The parameters acquired by matching the spectra are the components of the following empirical equations:

$$\Delta E/E = \sqrt{A^2 + B^2/E + C^2/E^2}.$$

Through the acquired energy resolutions corresponding to Compton electron maximum energy, the energy resolution was best fitted by the empirical function and the parameters are A = 2.75%, B = 9.2%, C = 18%. A is a value for optimizing the experimental setup, B is a value that mainly determines the resolution and is very sensitive to light output of a scintillator, and C is determined by the dark current and electronic noise parameter.

Conclusions:

In this study,γ response in PSB has been studied by comparing the experimental data with MC simulation.We will study on the positions of Compton edge depending on the energy resolutions which are obtained from this study.

References

[1] D.Mulmule et al. Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment,**911** (2018).

[2] R.Dey et al. Journal of Instrumentation,**16** (2021).