Characterization of NaI(Tl) SUM spectrometer

Sathi Sharma[1*]
[1] *Manipal Institute of Technology, MAHE, Manipal - 576 104, Karnataka, INDIA*

Introduction

SUM spectrometers are basically used to measure the β-decay branching ratios, half-lives of neutron rich nuclei which can be either artificially produced in the nuclear fission reactor or neutron capture reactions during stellar nucleosynthesis. To reduce the chances of missing transitions and weak β-feeding branches in β-decay studies, this kind of SUM spectrometer or γ-summing detector plays a significant role. These kinds of detectors can also be used for the total decay heat measurements. But the spectrum of the detector is really complex to analyze. Due to that one has to rely largely upon Monte Carlo simulations to interpret the experimental data [1]. So, proper characterization of the SUM spectrometer is necessary before the actual measurements.

Here, I have characterized the NaI(Tl) SUM spectrometer using lab standard sources (like, ^{137}Cs, ^{60}Co etc.). Different properties of the SUM spectrometer have been checked both via experiment and simulation (wherever needed).

SUM spectrometer

There is a SUM spectrometer at SINP laboratory which has been used as a passive shielding in a previous work (see Ref. [2]). It is basically a cylindrical shaped detector with six sectors of NaI(Tl) detectors. The SUM spectrometer has a length of 46 cm and a diameter of 30 cm. But, only one PMT is attached with each of the six sectors at one end of the detector. There is borehole at the centre of the cylindrical assembly which has a diameter of 8 cm. The SUM spectrometer has been shown in Fig. 1 (a).

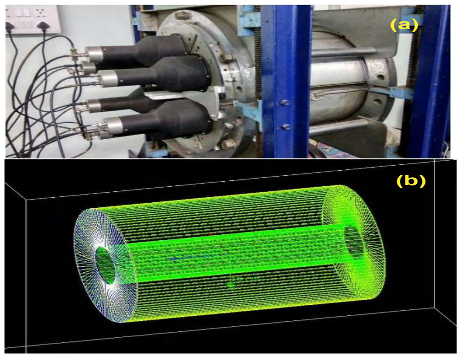

FIG. 1: (a) The SUM spectrometer facility at SINP, Kolkata, (b) A schematic of the SUM spectrometer geometry which have been used in the GEANT4 simulation.

Observed characteristics

Here, we have used CAEN DT5780M desktop digitizer to give the bias voltage to the individual crystal and to acquire the energy spectra with ^{60}Co and ^{137}Cs sources.

1. **Resolution** : The resolution (=FWHM/E_γ) has been plotted as a function of source position from the PMT. The data has been taken by changing the source position along the axis of the detector, and by changing the source position along the surface of the detector. The resolution of the detector is almost the same around 15% at 662 keV, but gradually increases when the source's position is varied from 20 cm to 30 cm. The resolution is poorer at 25 to 27 cm. However, the resolution beyond 30 cm, decreases gradually and behaves in a same manner as it does before 20 cm.

2. **Photopeak position** : As the PMT are only at one end of the big SUM spectrometer,

*Electronic address: `sathi.sharma@manipal.edu`

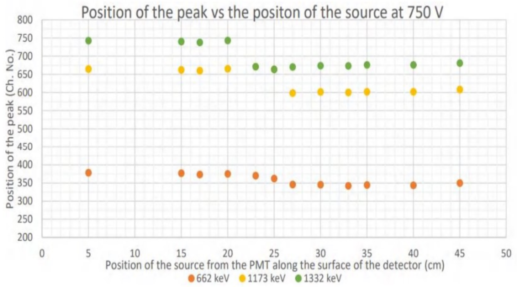

FIG. 2: Position of the photopeak for different energies vs. the distance of source from the PMT.

the light collection to the PMT varies largely as a function of the source position. Thus, the photopeak position varies depending on the source position. We have fixed the bias voltage to 750 V for this measurement. The photopeak positions of 662 keV from ^{137}Cs source and 1173 and 1332 keV from ^{60}Co have been plotted as a function of the position of the source from PMT. The photopeak shifts towards left side, i.e., at lower channel number with the increase in the distance of the source from the PMT, especially after 25 cm (see Fig. 2). The behaviour of the SUM spectrometer is not completely clear at certain positions of the source. So, to resolve this anomalous behaviour or better understanding of the SUM spectrometer characteristics at certain length interval of the detector, we take the help of Monte Carlo simulation.

Simulation model

The GEANT4 simulation toolkit [3] has been used to simulate the response of the SUM spectrometer as accurately as possible. Here, the bulk of the detector volume is consists of NaI material. Then, we have a MgO reflector, a quartz window at one end of the detector, a bialkali photocathode has been attached with the quartz PMT window. All the necessary optical, yield properties of the NaI crystal have been included in the code to directly simulate the optical photons from scintillation light. A schematic GEANT4 SUM spectrometer geometry has been given in Fig. 1 (b). The Detector Construction class is followed by PhysicsList, PrimaryGenerationAction class, SteppingAction and EventAction classes and finally in the RunAction class, the data has been collected and written to an output file.

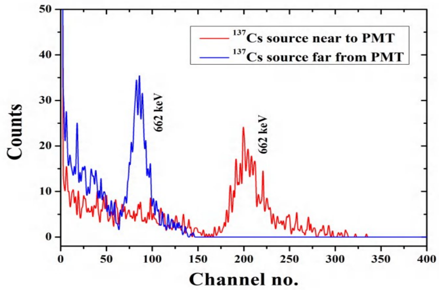

FIG. 3: The shifting of the photopeak positions as a function of source position has been simulated using the optical photon model in GEANT4 [3] using the ^{137}Cs source. The source has been placed at two positions near and far from the PMT.

The observed characteristic, i.e., the shifting of the photopeak positions as a function of source position has been simulated using the optical photon model (see Fig. 3).

Summary and future plan

Different properties of the SUM spectrometer have been checked through experiment as well as simulation and few of them needs more attention. Next work is to obtain the efficiency information using well known sources and in-beam reactions, and aftrerthat used it to study the β-decays for the total decay heat measurements and also for the astrophysical r-process nuclei.

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References

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