Geant4 simulation of a large volume segmented clover detector

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Introduction

The simulation for the energy spectra, efficiency and addback factor for the large volume segmented clover detector at VECC has been performed in the Geant4 platform. The details about the segmented clover detector and its comparison of measured efficiency with a INGA clover detector has been reported earlier [1].

Geometry construction

The size of each crystal in this detector is 9 cm (length) x 6 cm (diameter), which is larger than a normal clover detector used in INGA array, having typical size of 7 cm (length) x 5 cm (diameter). The detector is housed inside an aluminium vacuum chamber.

Geant4 simulation for the segmented clover has been started by considering four crystals of cylindrical shape, each having 3 cm radius and 9 cm length. Exact shape of a crystal, as supplied by the manufacturer (Canberra Inc.) has been obtained by subtracting different geometrical shapes from the cylindrical one. Each crystal has two cuts along its length on two adjacent sides by subtracting two parallelepiped shapes to place the four crystal closely to each other while the other adjacent sides have been tapered at 22.5 degree to make square front of four crystal combination. A bore hole of 0.5 cm radius and 0.7 cm length has also been cut along crystal axis from behind for each crystal. The outer aluminium envelope of 0.15 cm thickness has been obtained by considering it as a rectangular box and the distance between the end cap and the crystal face is 0.55 cm. There is a copper plate of 1 cm thickness on the back side of the four crystals to simulate back scattering events. A simple BGO Compton suppression shield (closely packed from all sides except on the front face and back side of the detector) has also been considered for simulation.

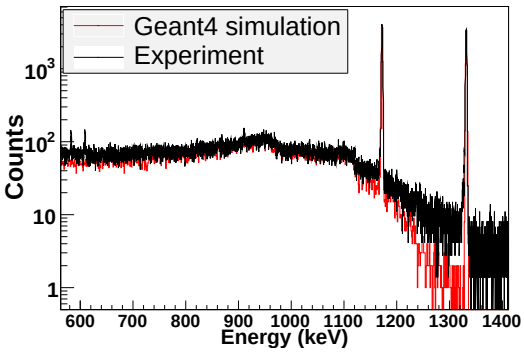

FIG. 1: Measured and simulated γ-ray energy spectra of ^{60}Co from one of the crystals of the segmented clover.

Physics processes

In the Geant4 simulation, for interaction of gamma ray with detector material photoelectric effect, Compton scattering and pair production processes have been used. Charged particles like electrons and positrons are produced by pair production and lose energy through electron ionization, multiple scattering and bremsstrahlung radiation in material. In addition, positrons can undergo e+ - e- annihilation.

Results and discussion

Characterization of the detector was done using radioactive sources ^{60}Co, ^{133}Ba and ^{152}Eu. The experimental spectrum obtained from a ^{60}Co source has been compared with the simulated spectrum which is shown in

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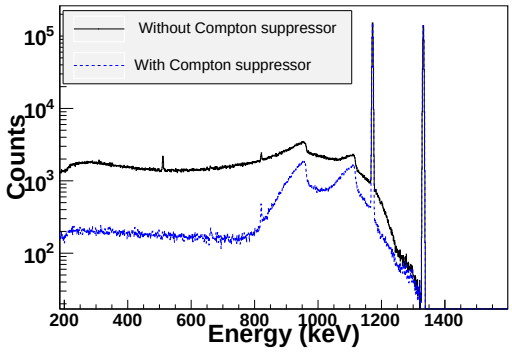

FIG. 2: Simulated ^{60}Co spectra with and without Compton suppressor in add-back mode.

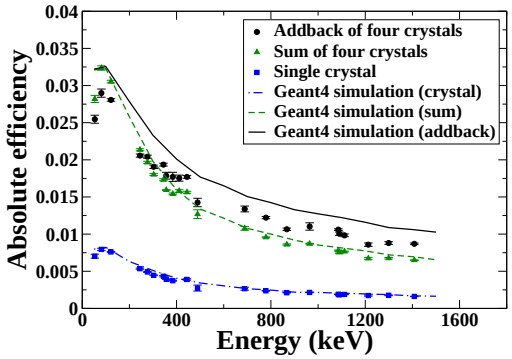

FIG. 3: Measured absolute efficiencies in crystal, sum and add-back modes are compared with simulation.

Fig.1. A good agreement between experimental and simulated spectrum is acheived. In the experimental spectrum, the extra counts between the 1172 keV and 1332 keV γ-lines of ^{60}Co is due to Compton scattering from background γ-lines (for example 1460 keV γ-line from ^{40}K) which are not considered in the simulation. Simulated ^{60}Co spectra with and without Compton suppressor have been generated and are shown in Fig. 2. Peak-to-total ratio for unsuppressed spectrum is 35 % whereas for the Compton suppressed spectrum the ratio is 53 %.

Absolute efficiencies in crystal mode, sum mode and add-back mode are obtained from the detector at a distance of 11 cm from the

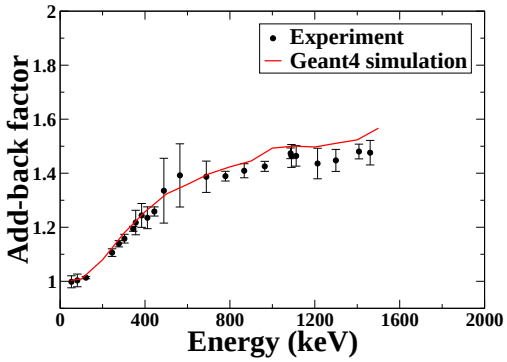

FIG. 4: Measured add-back factor is compared with simulation.

source and compared with the simulation as shown in Fig 3. Measured add-back factors as a function of γ-ray energy are also compared in Fig. 4.

It can be seen that the measured efficiencies in the crystal and sum mode could be well reproduced in the simulation, but in case of add-back efficiency, the agreement is not well which is attributed to the summing effect which is not included in the simulation. The add-back factor could be well reproduced in the simulation.

Conclusion

The experimental and simulated ^{60}Co spectrum have been compared and a good agreement has been acheived. The ^{60}Co spectra with and without Compton suppression have been simulated and the corresponding peak-to-total ratios have been obtained. The comparison between experimental and simulated efficiencies in crystal, sum, and add-back modes has been done. Similarly, experimental and simulated add-back factor have also been compared.

References

[1] Md. A. Asgar, et al., Proc. of DAE-BRNS Symposium on Nuclear Physics, 59, 882 (2014).