Simulations for Segmented Germanium Detectors

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Introduction

The Clover detectors provide several unique advantages over the single crystal HPGe detectors, especially in their efficiency, when used in the add-back mode. The characteristics of these detectors have been experimentally established up to $E\gamma \leq 11$ MeV. The Indian National Gamma Array [INGA] [1] being extensively been used for more than a decade consists of Clover detectors [2] and efforts are in progress to upgrade the array. Simulation of detector characteristics can help predicting their performance at higher energy regime and contribute towards optimizing and upgrading the array.

Here we report the results of simulations carried out with the GEANT4 [3] toolkit. One of the salient features of these simulations is that the complex construction of Clovers, ordinary and segmented (two-fold) [4] has been approximated by simple geometry, which yields results of excellent agreement to the available data.

The chosen geometry of the Clover detector for the current simulations was as follows : The four crystals, each of diameter 51 mm and length 71 mm, were housed in an Al casing of thickness of 1.5 mm. The front face of the crystals was positioned at a distance of ≈ 4 mm inside the casing. The inter crystal spacing was ≈4-5 mm. The target-to-detector distance in INGA [5] is ≈ 21cm, and hence all the simulations have been performed with an isotropic source at a distance of 25 cm from the front face of the detectors..

The value of the normalised solid angle for the source at 25 cm is 8.079×10^{-3}. The individual crystal was modeled following a Boolean operation on a trapezoid, box and a cylinder to produce a shape of volume ≈117 cc. The volume of the entire assembly was ≈ 468 cc.

The response of a Clover to a ^{60}Co source is depicted in the Fig.1.

The absolute full-energy peak efficiency ε_p at 1332 keV for the Clover in the add-back mode was obtained as $\varepsilon_p = 2.54 \times 10^{-4}$, and the add-back factor is 1.51, which are in excellent agreement with the reported values. The variation of the absolute full-energy (photo-peak) efficiency with the simulated gamma-ray (80 keV ≤ Eγ ≤ 11640 keV) is presented in Fig. 2. for a single crystal and the Clover (in the add-back mode), which are in reasonable agreement with the measured values.

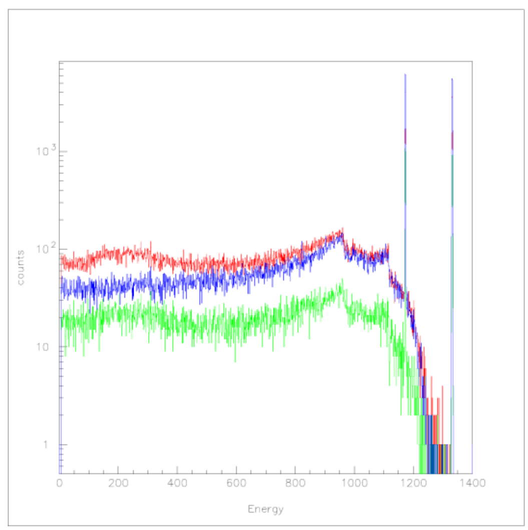

Fig.1 : simulated response of the Clover to ^{60}Co, the green colour corresponds to a single crystal, the add-back spectrum is depicted in blue and the red colour depicts the sum spectra

The major advantage of the Clover detector in the add-back mode is the ability to retrieve the Compton events into the full energy peak, and a substantial reduction in the opening angle of the detector. Further, reduction is achieved by electronic segmentation of the individual crystals. As an extension to our aforesaid efforts, we have carried out the simulation exercise for a two fold segmented Clover [4].

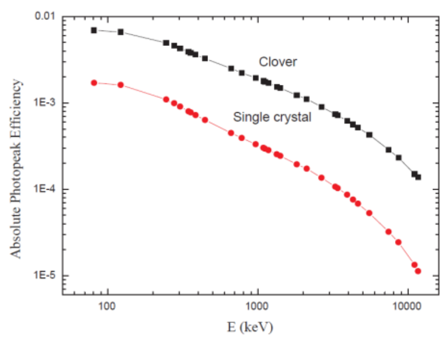

Fig:2 Variation of absolute photo-peak efficiency as a function of gamma-ray energy.

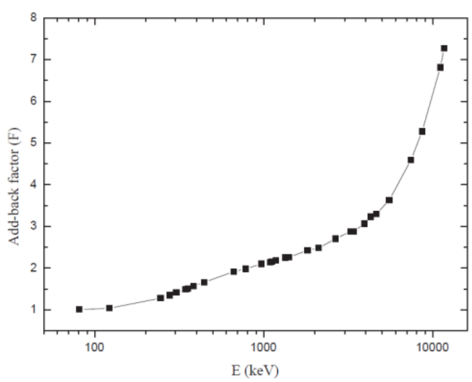

Fig:3: Variation of the add-back factor as function of the incident gamma-ray energy

We depict our modelled add-back factor for the 2-fold segmented Clover in Fig. 3.The behavior of the add-back is almost identical to the Clover, with three distinct energy regimes originating due to the dominance of the Photo-peak, Compton & Pair-Production interactions as a function of Eγ.

Scattering between the two crystal segments was simulated for events wherein we had two segments firing. Certain discrepancies were observed between our modeled and experimental observations. These warrant a revisit of the corresponding experimental data.

Since the INGA would be augmented with segmented LEPS detectors, we have extended our simulations for these detectors.

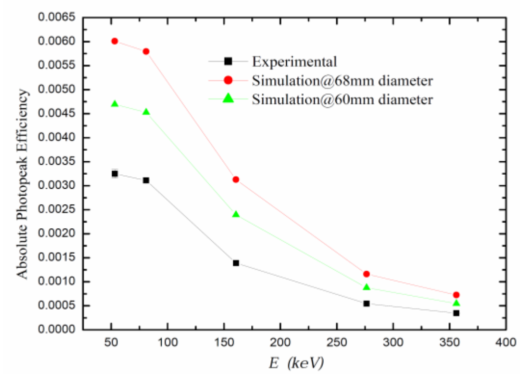

Fig.4 : Comparison of the experimental and simulated full-energy peak efficiency for LEPS.

The detector was modeled wherein the length of the length of the crystal was 11.5 mm and the external diameter was 68.00 mm. The front Be window was also included in the simulations. The simulated results over predicted the measured absolute photo-peak efficiency. Although the trend was reproduced with reasonable accuracy. Then the simulations were performed wherein we reduced the external diameter of the crystal to approximately 60 mm the results were in a better agreement with the simulations. It was then confirmed that the active area of the detector has a diameter of about 60 mm. The detailed simulations are in progress and to the best of our knowledge these are the first of it's kind for such detectors.

Hence, the simplistic geometrical approximations can efficiently and reliably model the performance of the detectors over a wide energy range.

References

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