# Simulation and Characterization of a Ge detector using Monte-Carlo Methods

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## Introduction

The Monte Carlo simulations are a broad class of computing methods that rely on repeated random sampling to get numerical results. GEANT4 [1] is one of the toolkit that uses such methods to simulation of the passage of particles through matter. In the present work, the Monte-Carlo simulations has been performed for a Compton suppressed HPGe Clover of INGA (Indian National Gamma array) facility at IUAC (Inter University Accelerator Centre) using GEANT4. A Clover detector consists of four n–type coaxial HPGe crystals. The Anti Compton Shield (ACS) made up Bismuth germanium oxide **(**BGO) surrounding the Clover detector are used to reduce the Compton background of the γ-rays. The results of the simulation are compared with the experimental data collected from INGA array with various γ- sources utilizing the ROOT based data acquisition [2].

## Detector Construction

An HPGe crystal is a tapered cylinder with diameter of 50 mm and height of 70 mm [3]. Each crystal has a square front face after tapering it by ~ 7 degrees on two adjacent faces as shown in Fig 1. Such four identical crystals are created for a Clover detector. The distance between cap and front face of the crystals is kept 20 mm with a gap of 5 mm between the tapered edge of the crystal and the tapered part. The Al window is 0.3 mm thick and is placed at 6 mm away from the front face of the crystal. To generate a realistic detector a simple BGO Compton shield has also been considered for simulation. The ACS has dimension of 20 mm thick, 250 mm long, and width of 44 mm [1]. Dead layer of the crystal is not included in the geometry.

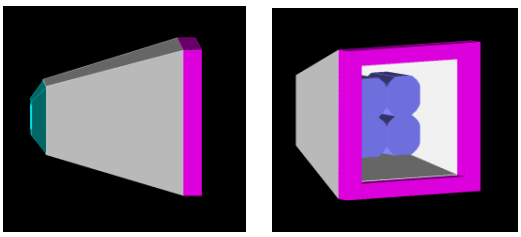

**Fig 1:** (a) Lateral and (b) Cross sectional view of simulated Clover detector with an ACS shield.

## Physics Processes

In our simulation the interaction of γ-rays with HPGe detector uses all the known physical processes using a physics list stored in the GEANT4 library. The three major process, the Photoelectric effect, Compton scattering, and Pair production were extracted from Geant4 libraries for primary interaction of γ-rays with the matter [3]. The secondary electrons produced will interact with the Ge crystal using electron ionization, multiple scattering, bremsstrahlung radiation and positron annihilation processes. These process were also incorporated for the complete simulation of γ-rays interaction with the detector.

## Results and Discussions

The detector characterization and simulations were performed using radioactive sources $^{60}$Co and $^{152}$Eu and $^{16}$N from the library of GEANT4. The simulated spectrum obtained from a $^{152}$Eu source kept at 25 cm from the detector along the axis perpendicular to the front face of the detector as shown in Fig. 2. A good agreement between experimental and simulated spectrum is achieved. In the experimental

spectrum of $^{152}$Eu there were eight major peaks and all of them were generated in the simulation with good statistics. The calculated relative efficiency is not sensitive to the thickness of germanium dead layer detection, and hence the energy spectrum in the Fig. 2 does not contain certain peaks [4].

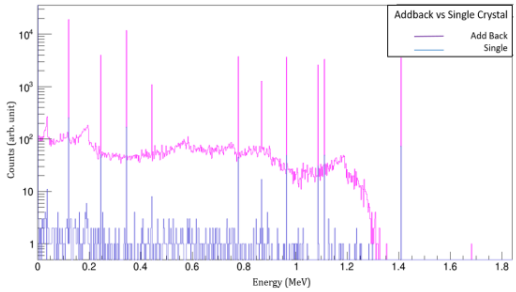


**Fig. 2** Addback vs Single crystal spectra using $^{152}$Eu source

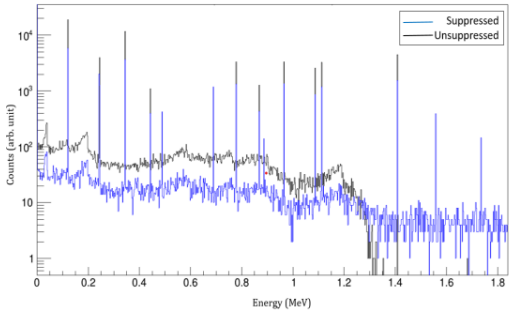


**Fig. 3** Spectrum for $^{152}$Eu source with and without Compton suppression in add-back mode

Total 100000 events were recorded in the ROOT based format data file and analyzed by the same. The simulated $^{152}$Eu spectra with and without Compton suppression have been generated and are shown in Fig 3. Peak to-total ratio for unsuppressed spectrum is 35 %, whereas for the Compton suppressed spectrum the ratio is 45 %. The results of efficiencies in add-back mode obtained using simulations and from the experiment for $^{152}$Eu source using Clover detector are shown in Fig. 4.

Measured value of detector in the addback mode using $^{152}$Eu source. Relative efficiency at 1.33 MeV for the $^{60}$Co source kept at 25 cm in the total add back mode is approximately 120%. The efficiencies of the detector using other various other gamma sources were also calculated for references and all of them matched the experimental results very well.

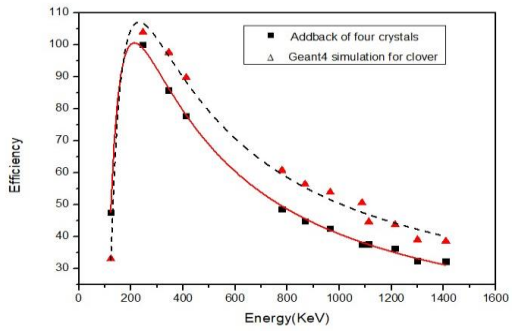


**Fig. 4** Comparison of simulated and experimental relative efficiency of a Clover

## Conclusion

The simulation results match very well with the experimental ones. The experimental and simulated $^{60}$Co spectrum have also been compared and a good agreement has been achieved. The $^{152}$Eu spectra with and without Compton suppression have been simulated and the corresponding peak-to-total ratios have been obtained. Simulation using GEANT4 has proven to be very efficient tool to understand and visualize the interaction of radiation with matter. Based on the results from the simulations, the Monte-Carlo methods can be further extended to simulate the complete INGA facility.

## References

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