# Geant4 Monte-Carlo simulation for the response of INGA at TIFR-BARC Pelletron Linac Facility

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## Introduction

The Indian National Gamma detector Array (INGA)[1] at Tata Institute of Fundamental Research (TIFR) consists of twenty four Compton suppressed high purity germanium detectors (HPGe). This is a powerful spectrometer used for the study of nuclear structure and dynamics by measuring $\gamma$-rays from an excited atomic nuclei produced in different nuclear reactions. A detailed knowledge of the efficiency of the array up to high energy is necessary to study high spin excitation near the shell closure and low mass nuclei which often produce high energy gamma rays of 4 to 5 MeV. A Geant4 simulation has been carried out to study the response of the array for various energies of $\gamma$-rays[2]. Investigation of the simultaneous hit efficiency of a gamma ray in clover and its BGO shield will validate the usage of the Compton suppressed clover for high energy gamma ray measurement with increased efficiency. The array has been simulated with the clover having 4-crystals arranged on a copper tray inside an aluminum housing, BGO anti-Compton shield, heavy metal collimator, target chamber and the beam line. The present INGA geometry at TIFR has the provision of placing 24 Compton suppressed clover detectors with 3 detectors each in 157°, 140°, 115°, 65°, 40° and 23° and 6 detectors at 90° with respect to the beam axis [3].

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## Geometry

The Clover detector consists of 4 high purity germanium crystals cut along their flat edges to have a efficient closed pack square geometry. These crystals also have tapered edges to avoid trapping of charges for longer time due to low field gradients at the edges. Each crystal of the clover has been simulated by subtracting from a cylindrical shape of 2.5 cm radius and 7 cm length two wedge shapes from the two adjacent sides and two parallelepiped from the other two adjacent edges to form closed packing of the crystals within the clover and square cut edge at front. A bore hole of 0.5 cm radius and 5 cm length has also been cut through each crystals axis in the simulated crystals. The crystals were placed on a copper tray of 1 cm thickness and 4.55 cm x 4.55 cm base station to simulate the back scattering events in case of an actual clover detector. The outer aluminum envelop of the clover detector has been simulated by adding a trapezoid with the x and y dimensions varying along z axis in such a way that the base and the front face of the trapezoid is 5.05 cm x 5.05 cm and 4.35 cm x 4.35 cm squares respectively. The trapezoidal part of the envelop is 5.7 cm long while the box part is 4.1 cm long with a 5.05 cm x 5.05 cm square base. The thickness of the envelop was kept at 0.1 cm. Similarly, a trapezoidal plus box shape arrangement has been made to create Compton suppression shield of BGO material and its aluminum housing. Heavy metal collimator composed of tungsten material was also simulated according to its shape as used in front of the INGA clover and BGO assembly. The sole purpose of using the shield is to prevent direct hit of gamma rays to the BGO shield

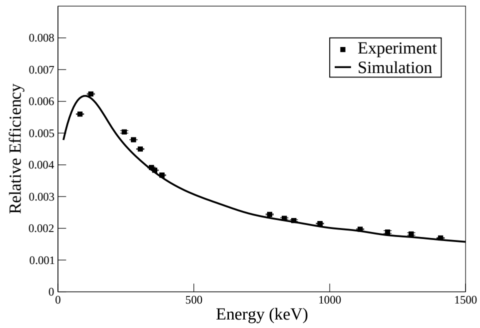


FIG. 1: Comparison between experimental and simulated efficiency.

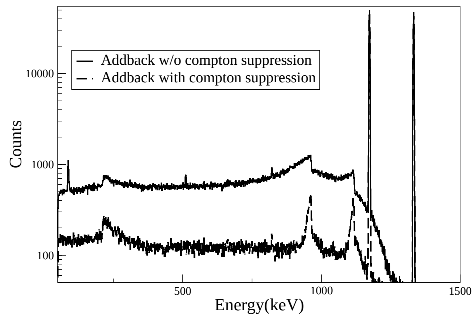


FIG. 2: Simulated spectrum of $^{60}$Co with and without compton suppression.

leading to reduction in coincident events hitting both clover and BGO shields. The BGO and clover geometry so designed is replicated into 24 compton suppressed heavy metal collimated clover detector assembly and each assembly is positioned and rotated according to the actual physical INGA geometry.

## Physics Process

In the present simulation, three kinds of particles considered to be generated are gamma, electrons and positrons. For the $\gamma$-rays, three possible physics processes considered are photoelectric effect, Compton scattering and pair production. Charge particles, like electrons and positrons generated from a pair production event can undergo multiple scattering, electron ionization and produce bremsstrahlung radiation in material. Positrons, in addition can undergo $e^+$-$e^-$ annihilation.

## Results and Summary

The recently developed Geant4 general particle source class has been used to simulate radioactive source. Isotropic sources of $^{60}$Co, $^{152}$Eu and $^{133}$Ba are simulated following their natural branching ratios and decay pattern. Monoenergetic isotropic sources of different gamma ray energies were simulated to obtain efficiency of the array at different energies. Total photopeak efficiency of the array from 50 keV up to 1.5 MeV has been simulated and compared with experimental result. The simulation shows good agreement with the experimental spectrum as shown in Fig.1. Simulation has been carried out with and without Compton suppression for $^{60}$Co source and spectra of individual crystals as well as the addback spectrum was generated. Good agreement has been observed in simulated and experimental spectrum. In Fig.2, simulated $^{60}$Co addback spectrum was plotted with and without compton suppression. The peak-to-total ratio for the addback spectrum with suppression in the simulation is found to be 40% which is similar to the measured value with same energy threshold in the BGO shield.

## References

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