HPGe detector simulation using SIMSPEC-G

S. S. Nayak[1]* and G. Mukherjee[1,2]
[1]Variable Energy Cyclotron Centre, 1/AF Bidhannagar, Kolkata -700064, INDIA
[2]HBNI, Training School Complex, Anushaktinagar, Mumbai-400094, INDIA
*ss.nayak@vecc.gov.in

Introduction

HPGe detectors in different variants of geometry (e.g. single-crystal, Clover, segmented clover, etc.) are widely used for γ spectroscopy in nuclear physics experiments. Simulation of these detectors helps in understanding the events leading to peak formation and other aspects. They also provide reasonable estimate for various parameters like addback factor, efficiency, etc. for different geometrical setup.

A new code SIMSPEC-G has been developed to simulate simple clover and segmented clover like geometries and provide an estimate for various parameters. The probability of highest energy deposition in the first interaction itself is evaluated. A comparison of segmented clover with normal clover in polarization measurements is also studied.

In the present version, the SIMSPEC-G is for γ energies up to 1 MeV and only Compton scattering (CS) and photoelectric effect (PE) are considered with no pair production processes. This greatly simplifies the algorithm. The cross section data has been taken from photon cross section database at NIST [1].

Algorithm and Simulated Geometry

γ – photons are initially distributed on the surface of detectors. The next point of interaction is determined using total cross section data of the material and the mean free path is calculated using Beer-Lambert's law. The type of interaction is determined using the respective cross section data (CS or PE). The photon propagation stops if the photon undergoes PE or it goes out of the detector volume or the scattered energy is below the threshold (1 keV). At all points of interaction, the photon energy, electron energy and the coordinates of the point of interaction are recorded.

Three different geometries (Fig. 1) have been evaluated in this work. A cylinder of Ge of diameter 5 cm and length 7 cm with a 1 cm thick Al casing at the back (Fig 1(b)), a clover geometry with 4 Ge crystals of dimensions 6cm x 6 cm x 9 cm (Fig.1(c)) and a segmented clover (Fig. 1(d)) with same crystal dimensions as the clover but with each of its crystal divided into 4 identical segments. An isotropic γ-source of 1 MeV is assumed at 5 cm from the detector.

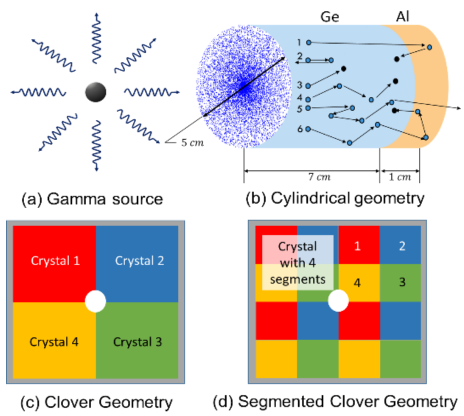

Fig. 1 The source & detector geometries. Photon distribution on detector surface is shown in (b).

Results and Discussion

A simulated spectrum for 1-MeV γ ray is shown in Fig. 2a. The back scattering peak, Compton edge and the full energy peak (FEP) in the spectrum are clearly visible. The events between the Compton edge and photo peak are due to multiple Compton scattering. This can also be seen from Fig. 2b which is a 2-dimensional plot of deposited energy and no. of scatterings. The contribution of different scattering processes to the full-energy peak for 1-MeV γ is shown in Fig. 2c. It is seen that the two CS followed by a PE (c^2p) process has the maximum contribution to FEP. The contribution of only PE in FEP is only about 3%.

In order to check the energy deposition in different parts of the crystals, it has been divided in to 4 equal segments. The probability of energy deposition corresponding to FEP in one and multiple segments is shown in Fig. 3a as a

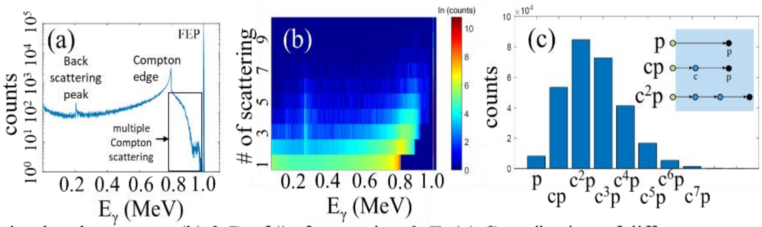

Fig. 2 (a) simulated spectrum (b) 2-D of # of scattering & E_γ (c) Contribution of different processes to FEP

function of incident γ-ray energy (E_γ). Considering the FEP, the fraction of events only in the first segment goes from about 100% for 0.1 MeV γ down to 52% for 1-MeV. That is 48% of the 1-MeV γ-rays hit multiple segments before depositing their full energy. Out of these multi-hit 1-MeV gammas, ~83% deposit highest energy in the first segment they hit (Fig. 3b). So, for ~92% of the events, the segment with FEP or maximum energy deposition may be taken as the first-hit segment for a 1-MeV γ for better angular resolution.

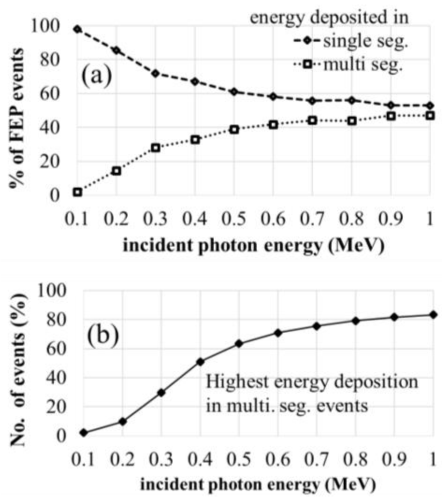

Fig. 3 (a) Energy deposition in single and in multiple segments (b) Highest energy deposition in multiple segment events

The calculated addback factor as a function E_γ for a clover detector (geometry of Fig. 1(c)) is shown in Fig. 4. The value of ~1.4 at 1 MeV agrees well with the measured value [2].

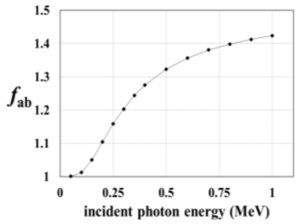

Fig. 4 Addback factor for different γ energies

In segmented geometry of Fig.1(d), CS from segments may be gainfully used to measure polarization asymmetry. The present work shows a gain of up to ~70% in parallel / perpendicularly scattered events over normal clover (Fig.5). Moreover, the low-energy limit of polarization measurement can be brought down by using the segments of segmented clover.

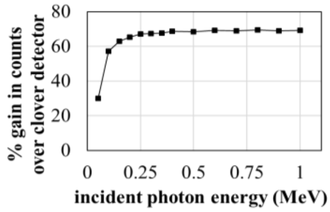

Fig. 5 Gain in counts in parallel scattering compared to a normal clover

Conclusion and future outlook

SIMSPEC-G is a simple simulation code, developed to understand the detection of γ rays up to 1 MeV in different geometries of HPGe detector. The measured spectra in HPGe crystal and addback factor for clover detector are well reproduced. It is seen that 2 CS followed by a PE has maximum contribution to FEP. This work shows that the angular information may be taken from segment with maximum energy deposition or full energy deposition to get better angular resolution for Doppler correction, etc. About 92% of the events have this characteristic for 1 MeV γ. It is also shown that the use of segments of a segmented clover detector is advantageous for measuring polarization asymmetry.

In future, more γ-ray interactions will be incorporated to use this code for a wide range of E_γ. More realistic geometries with Compton shields and for other detector materials, like scintillators, will be incorporated. This code may also be used for γ-ray tracking in future.

References

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[2] Md. A. Asgar et al., Proc. DAE-BRNS Symp. on Nucl. Phys. **61**, 950 (2016)