Charge transport Simulations for Pulse Shape Analysis in segmented Planar HPGe Detector

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Recent advancements in γ-ray detection systems have steered us toward the use of highly segmented germanium detectors, which offer excellent energy resolution and improved position accuracy. These improvements are achieved through novel techniques such as Pulse Shape Analysis and Gamma Ray Tracking.

The primary goal of charge transport simulations is to create a theoretical database of waveforms corresponding to all possible interaction positions within the detector volume. This database enables accurate Pulse Shape Analysis, which enhances position resolution beyond the physical or electrical segmentation of the detectors.

Detector Configuration

A p-type double sided orthogonal strip detector (Mirion Technologies) with active volume of $60 \times 60 \times 20mm^3$ having 10X + 10Y strips arranged in orthogonal directions has been simulated. Two guard rings on each side of the strips are used for minimizing the leakage current. The impurity concentration for both type of strips has been taken of the order of $10^{10}cm^{-3}$ which will be optimised after comparing the pulse shapes with the measured ones. The parameters used for Geant4 simulation and SSD.jl package are given in the Table1.

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TABLE I: Variables used to define the Detector Geometry in Geant4 and SSD.jl

Variable	Value
Physical Dimensions	$60mm \times 60mm \times 20mm$
Al window thickness	0.5mm
no. of AC strips	10
AC strip width	6 mm
no. of DC strips	10
DC strip width	6 mm
Guard ring width	7.5 mm
Operating Voltage	-1900V

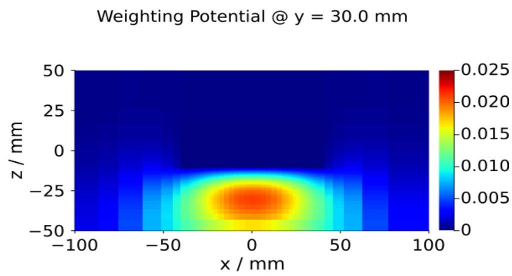

FIG. 1: Calculated weighting Potential for a strip (DC04) present in the centre of detector volume

Detector Simulation framework

Two simulation packages have been utilized to simulate the database. Firstly, Geant4[2] has been used to get the location of interaction in the detector volume and the corresponding energy deposited. When gamma ray interacts with the matter, the resulting charge carriers move under the influence of Electric field, gen-

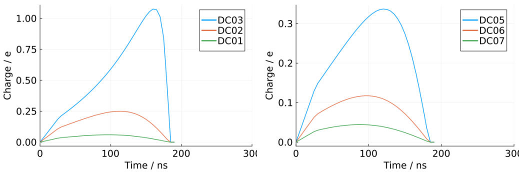

FIG. 2: Mirror charges in all the neighbouring electrodes for an interaction in strip (DC04).

erating net charge on the collecting electrode and mirror charges on the neighbouring ones.

The transport of charge carriers and the generation of waveforms has been done using SSD.jl package developed by the GeDet group at the Max- Planck-Institut fur Physik, Munich[3]. Calculation of Electric Potential and Electric Field is the first step towards pulse shape simulation. The Electric Field has been calculated numerically as the gradient of Electric Potential. While the electric potential is determined by solving Guass's law via successive over relaxation algorithm on a 3D adaptive grid. The adaptive grid is defined coarsely first and refined in the regions where potential values between adjacent grid points transcend specific threshold. Further, Weighting potential is also calculated for each electrode by applying unit potential at the sensing electrode and zero potentials at all others contacts. The weighting potential for a strip (DC04) is shown in the Fig.1.

Pulse Shape Generation

The parameters required for pulse generation like drift velocity and mobilities has been provided by Agata Detector Library (ADL)[4]. By taking the values of Energy deposition and its location, the drift paths of electrons and holes have been simulated. The mirror charges in the neighbouring strips have been examined for an interaction in (DC04) strip as shown in Fig.2. The mirror charges have higher amplitude if the interaction is happening close to the strip of interaction and it further reduces as we move away from the interaction position.

The pulses at various depths in strip (DC04) have been analyzed to gain a clearer understanding of the waveform shapes. The drift paths are shown in the Fig.3(a) while the corresponding pulses for each interaction location is shown in Fig.3(b). The variation in pulse shapes at different depths is due to the differing collection of electrons and holes as they move toward their respective collecting electrodes. It is observed that rise-time of the pulses increases with the increase in depth. Further analysis is in progress and comprehensive results will be presented at the conference.

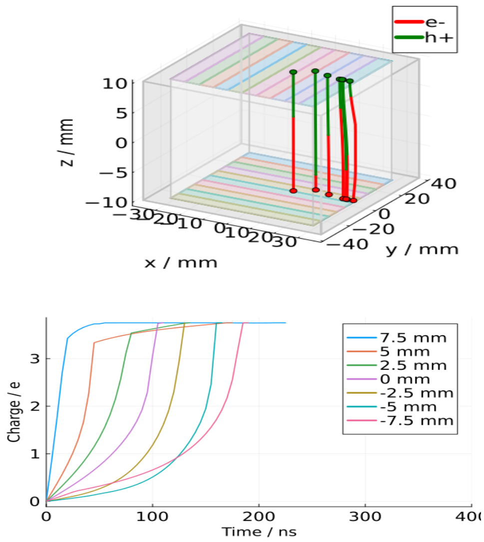

FIG. 3: (a) Drift paths for electrons and holes for interactions at different depths and (b) the corresponding pulse shapes.

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