GEANT4 simulation of Silicon Drift Detector

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Introduction

The Silicon Drift Detectors (SDDs) are frequently used in X-ray spectroscopy due to their outstanding properties of higher count-rate handling capacity, better resolution and ability to work at room temperature [1]. Consequently, SDDs are widely used in many applications including characterization of materials using various techniques such as electron microscopy, X-ray fluorescence (XRF), proton-induced X-ray emission (PIXE) etc. [2].

In the present work, the interests were to demonstrate the capability and robustness of an optimal GEANT4 [3] model on predicting detection efficiencies for low energy photons viz. in the energy range of 1-20 keV. The simulation code has been developed based on GEANT4 framework for simulating the geometry of SDD and its response to incident radiation. The overall performance of SDD has been studied based on spectrum simulation and efficiency calculations.

Geometrical description

The geometry of cylinderical shaped SDD (AXAS-A(VITUS H30); KETEK, GmbH) was simulated using the dimensions provided by the manufacturer. It has total circular active area of 30 mm^2 and cylindrical active volume of 450 μm. The crystal was protected by a Beryllium window of 8 μm thickness. The geometry also includes a collimator with a mylar window of thickness 2 μm at a distance of 42 mm from the Beryllium window. The geometrical arrangement of the source and detector is shown schematically in Fig. 1. The total distance (D) between the radioactive source and the detector crystal was D = 182.5 mm, out of which 42 mm is air gap.

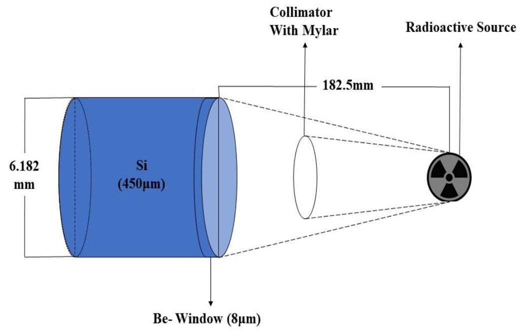

FIG. 1: Schematic diagram of the SDD.

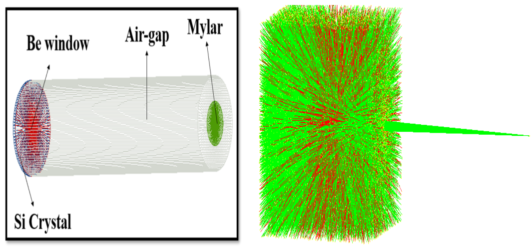

FIG. 2: (a) Simulated geometry of the SDD (b) Track structure produced by X-rays irradiating SDD.

GEANT4 code development

The GEANT4 [3] version 4.10.07 has been used for the code development in this work. The geometrical structure of SDD was con-

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structed using the necessary libraries from G4VUserDetectorConstruction class. The environment same as the experimental chamber has been simulated as used during experiments with SDD [4]. The Physics list uses sophisticated low energy Electromagnetic (EM) models to simulate the required energy range. An event generator program has been developed in order to produce input for the simulation. The standard G4ParticleGun option is used to generate the primary vertex for radioactive sources used in the simulation. Different X-ray energies from radioactive sources ^{241}Am and ^{55}Fe along with the K X-rays from ^{59}Ni have been used with their corresponding branching ratios to reconstruct the intensity pattern similar to the radioactive sources. A solid angle was calculated using detector dimensions and included in the code for appropriate momentum direction. The computing time for one source ranged typically from 20-25 min. on a intel pentium(R) - G4560 3.50 GHz CPU computer in linux operational environment for 10^6 events.

In order to collect the event-by-event information the ROOT libraries are invoked during run-time within the simulation. The information about the scattering of incident radiation such as energy deposition information are recorded in root Tree on event by event basis in a standard ".root" file format which was used for further analysis.

Results and Discussion

The tracks of different energy of photons irradiating SDD using GEANT4 for 10^6 events are shown in Fig. 2(b). The simulated X-ray spectra of radioactive sources ^{241}Am and ^{55}Fe are shown in Fig. 3(a) and 3(b) respectively. These spectra were simulated without taking any contribution of the background. The efficiency values were extracted for all the low energy photons by finding the areas under the curve. The studies have shown that simulated results are in good agreement with the results given by the manufacturer. However these results can be improved by including the background. Further analysis for accurate efficiency values (inclusion of background) is in progress.

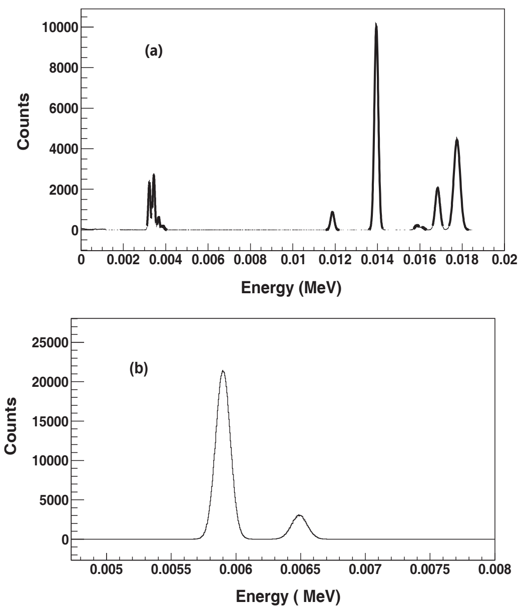

FIG. 3: Simulated spectrum for (a) ^{241}Am and (b) ^{55}Fe.

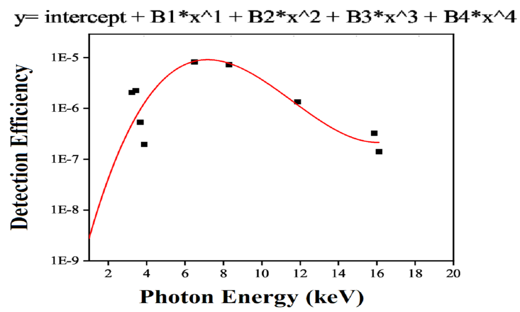

FIG. 4: Fitted efficiency curve for SDD.

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