Performance study of low background co-axial HPGe detector

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Introduction

The gamma-ray spectroscopy using high-purity germanium (HPGe) detector is a useful tool for nuclear structure studies. In rare decay studies like neutrinoless double beta decay or search for dark matter, the minimization of background is essential. Hence, identification of the radiative impurities in the detector as well as surrounding elements and elimination of the same to the extent possible, is highly desirable. In such low background measurements, samples often need to be counted in a close geometry to maximise the counting efficiency [1]. Therefore, it is necessary to understand the detector performance over a range of energies and for different counting geometries. A dedicated low background HPGe detector is being setup at IIT Ropar. This setup aims to perform measurements relevant for rare decay studies like *Tin.Tin* [2]. This paper reports the preliminary results of the characterization of the cryocooled HPGe detector installed at NuStaR Lab of IIT Ropar.

Experimental details and Setup

The HPGe detector is ORTEC make, GEM Series (GEM30P4-83-RB), coaxial, p-type, low-background crystal with a carbon fibre body. The detector is electrically cooled, making it suitable for usage at remote underground locations. The nominal dimensions of the detector, given by the manufacturer are : diameter -62 mm, length - 46 mm and carbon window thickness 0.9 mm. The detector is designed for relative efficiency of 35%. In order to make an equivalent detector model, it is essential to determine the detailed detector geometry including dead layers. A scanning table has been designed and fabricated to facilitate the radial, lateral and distance scans with collimated sources. A picture of the setup is shown in Fig 1. The sealed disk type gamma-ray sources ^{109}Cd, ^{57}Co, ^{60}Co, ^{54}Mn, ^{133}Ba and ^{137}Cs have been used for initial measurements.

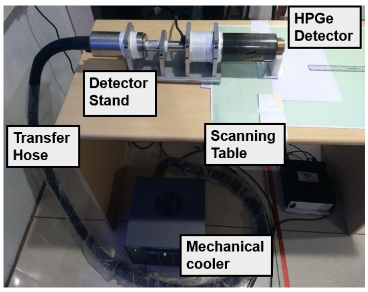

FIG. 1: IIT Ropar Low-background Measurement Infrastructure (ILMI)

The data was acquired using MAESTRO (ORTEC) software and analyzed in ROOT[3] and LAMPS [4].

Data Analysis and Results

A typical gamma-ray spectrum with ^{60}Co source is shown in Fig. 2 (top panel). The figure also shows efficiency as a function of energy (bottom panel) at d=25 cm. For 1332 keV, the measured resolution of 1.81 keV and the Relative efficiency of 33% at 25 cm distance are consistent with manufacturer's values.

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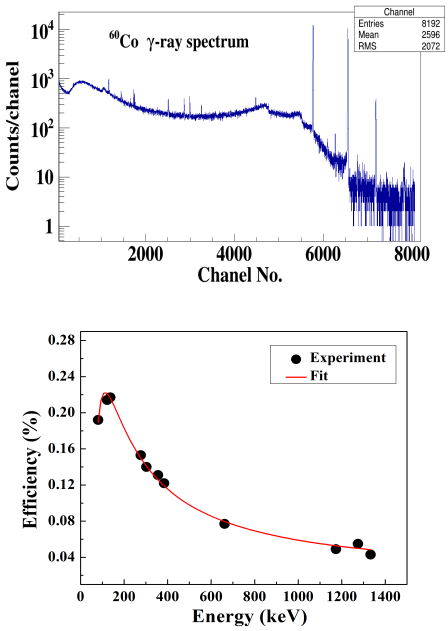

FIG. 2: Energy resolution and photopeak efficiency at d=25 cm.

The distance scan has been done with multiple sources in the range of 5-30 cm, in 5 cm steps and data are shown in Fig. 3. measured data are also compared with the efficiency obtained from simulations using GEANT4 [5]. The detector geometry is taken from the manufacturer's values. The simulated efficiency data is also shown in Fig. 3 (solid line). It can be seen that the simulations somewhat overestimates the data, particularly at low energy. The simulated relative efficiency for 1332 keV at 25 cm is 40%, which is about 10% higher than the measured value.

In the low energy region, the detection efficiency is strongly affected by the presence of the dead layer. For the front dead layer thickness (t) estimation, spectra with ^{57}Co (122 keV) was recorded with two collimators : one with ∼ 1 mm straight through hole (C_0) and the other with ∼ 1 mm through hole at 30^0 angle (C_{30}). A horizontal scan was also made on the top surface of detector in steps of ±5 mm using both these collimators. From the measured photopeak yields $Y(C_0)$ and $Y(C_{30})$ of 122 keV gamma ray with collimator C_0 and C_{30}, respectively, the front dead layer thickness is evaluated as

$$\frac{Y(C_0)}{Y(C_{30})} = \frac{e^{(-\sum_i \mu_i x_i)} e^{(-\mu_{Ge} t)}}{e^{(-\sum_i 1.15 \mu_i x_i)} e^{(-1.15 \mu_{Ge} t)}} \quad (1)$$

where μ_i and x_i are the attenuation coefficient and path length of absorber windows (Al and C). In the central region of the detector t is found to be 0.090±0.003 mm.

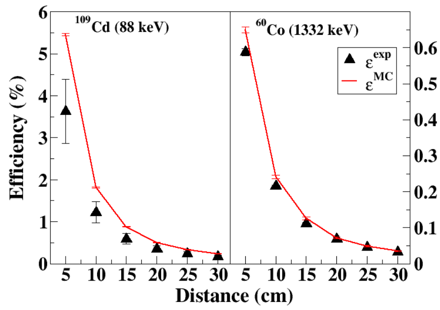

FIG. 3: Efficiency data (experiment and simulation) for distance scan using 88 keV and 1332 keV gamma rays.

Summary

An electrically cooled HPGe detector is setup at IIT Ropar for low background measurements. Simulations are carried out with Geant4 using manufacturer supplied geometry and results are found to be about 10% higher than the data. Further optimization of the detector geometry is in progress and results will be reported.

Acknowledgments

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