LN_2–free HPGe detector for low background studies

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Introduction

Background minimization is critical for rare event studies like $0\nu\beta\beta$ decay measurement where $T_{1/2} > 10^{20}$ years or dark matter search. These experiments are housed in underground locations for reducing cosmogenic background together with auxiliary low background setups for material qualifications and trace impurity measurement. Cryogen free HPGe detectors, which have recently become available, are ideal choice for underground locations. With this motivation, a liquid nitrogen (LN_2) free low background HPGe detector has been successfully tested at TIFR. This paper reports a comparison of the cryogen free HPGe with a conventional LN_2 cooled HPGe detector.

Experimental Details

Ortec make cryogen free low background detector (GEM30P4-83-RB) with 30% relative efficiency and having a carbon fiber body has been successfully installed at TIFR. The detector (D1) is cooled to $\sim$ 100K with a Ortec make cryocooler, X-Cooler III, which is a electrically powered mechanical cooler employing refrigerant. Special features have been incorporated by the manufacturer [1] for reducing the vibrations, which can affect the detector resolution. Typical cooldown time required by the system is found to be 16 – 20 hrs. Additional UPS has been installed in the setup to take care of short power outrages. Figure 1 shows a picture of the detector and the cryocooler. The resolution of the detector D1 was studied with ^{152}Eu source and was compared with a conventional LN_2–based HPGe (D2 Bruker Baltic) detector of similar relative efficiency. In addition, the ambient background spectrum was recorded in the D1 detector without any shielding. Data were recorded with a commercial FPGA based 100 MHz digitizer (CAEN-N6724) [2] and analyzed using LAMPS.

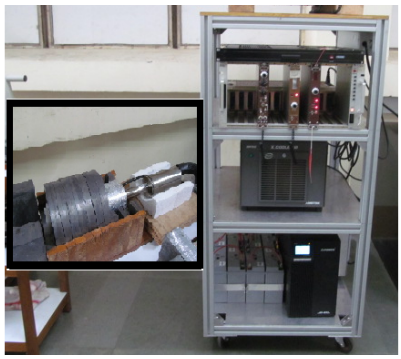

FIG. 1: The setup with the detector (shown in inset), cryocooler and UPS system.

Analysis and Results

Fig. 2 shows the gamma ray spectra of both the D1 and D2 detectors with a ^{152}Eu source, kept at a arbitrary distance from the detector face. The resolutions of D1 and D2 at different energies are compared in the Table I. Although the resolution of the cryo-free detector (D1) is only slightly worse ($\sim$ 10%) compared to the D2, overall quality of the spectra in both detectors is very similar and is evident in Fig. 2(b) where a 1085.9–1089.7 keV doublet is well resolved.

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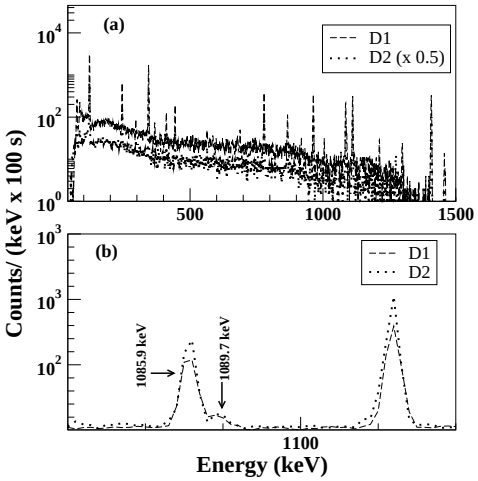

FIG. 2: γ-ray spectra with a ^{152}Eu source in (a) D1 (dashed black lines) and D2 (dotted black lines) detectors. The spectra in D2 has been scaled by 0.5 for better visualization and (b) D1 and D2 detectors in the expanded region. The D2 spectra has been scaled to the intensity of 1089.7 keV γ-ray in the D1 detector for comparison.

TABLE I: Energy Resolution (FWHM) of the D1 and D2 detectors with a ^{152}Eu source.

Energy (keV)	D1 (keV)	D2 (keV)
121.7	2.00(2)	1.88(3)
344.3	2.09(2)	1.84(5)
778.9	2.25(7)	2.17(6)
1085.9	2.34(11)	2.16(11)
1408.0	2.64(4)	2.41(6)

The energy resolution of D1 is found to be stable with the thermal cycles. The room background γ-ray spectrum of the detector D1 without any shielding is shown in Fig. 3. The background spectrum taken in a different site (different floors of same building) with the low background, high efficiency (relative efficiency $\sim$ 70%) Ortec HPGe detector (D3) [3] is also shown for comparison. No additional gamma-rays from room background have been found in the D1 detector as compared the D3 detector. On normalizing the spectra in both

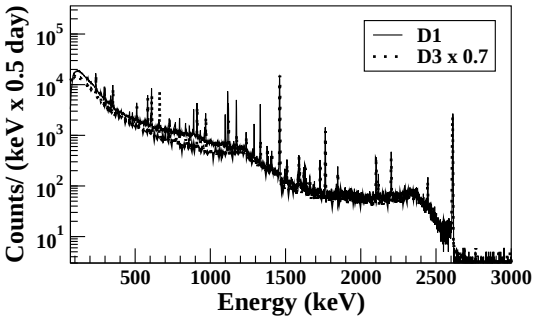

FIG. 3: γ-ray spectra of room background in D1 (dotted black lines) and D3 (solid black lines) detectors. The spectra of the D3 detector has been normalized to the intensity of 2614.5 keV γ-ray in the D1 detector for comparison.

the detectors to the intensity of 2614.5 keV γ-ray, the level of 1460.8 keV (^{40}K) is also found to be similar. The compton continuum (below 1000 keV) is higher in D1 than D3, as expected due to the smaller size of the D1 detector.

Summary

A cryo-free HPGe detector was successfully installed and tested at TIFR for the first time in India. The performance of the detector was found to be satisfactory as compared to the conventional LN_2-based HPGe detectors. With a UPS support, the cryo-free detector system is well suited for measurements in remote locations. This detector will be part of the low background counting setup for the TIN.TIN detector (The INdia–based TIN detector) [4].

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References

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