Improvements to background level of the Low Background HPGe setup

Neha Dokania[1],* K.V. Anoop[2], M.S. Pose[2], C. Ghosh[2], V. Singh[1], S. Mathimalar[1], S. Pal[2], V. Nanal[2], and R.G. Pillay[2]
[1]INO, Tata Institute of Fundamental Research, Mumbai, INDIA and
[2]DNAP, Tata Institute of Fundamental Research, Mumbai, INDIA

Introduction

A low background HPGe counting setup has been installed at TIFR. The detector, shielded with low activity Pb and Cu shield, has been extensively used for material screening for the TIN.TIN detector (The INdia-based TIN detector) [1, 2]. It is proposed to use this setup for the search of rare decay processes like double beta decay (DBD) to the excited states of the daughter nuclei where $T_{1/2} > 10^{18}$ years. To enhance the sensitivity of measurement, the background levels of the detector has been further improved by an addition of an active cosmic muon veto system in the FPGA based DAQ system.

Experimental Details

The low background Ortec HPGe detector, (with relative efficiency $\sim$ 70%), is shielded against the background γ-rays using an outer 10 cm low activity Pb (^{210}Pb $<$ 0.3 Bq/kg) and an inner 5 cm low activity OFHC Cu shield. Plastic scintillators (50 cm $\times$ 50 cm $\times$ 1 cm), assembled at TIFR, were tested in different configurations for best rejection. Each scintillator was coupled through a light guide to a single PMT (Photonis XP2262/B) operated at a voltage -1800 V. Data were recorded with a commercial FPGA based 100 MHz digitizer (CAEN-N6724). The fast signal of the plastic scintillator was fed through a custom-designed amplifier to the input of the digitizer. The data was saved in list mode on event-by-event basis with a time stamp. A program has been written for the implementation of anti-coincidence between the detector and plastic scintillator. The anti-coincidence window can be adjusted in the program and is defined to be $\pm 2.5\ \mu s$. Hence, if the Ge and plastic scintillator events fall within the window, the corresponding Ge events were rejected. The program generates the coincident, anti-coincident and time spectra which can be analyzed with LAMPS.

Analysis and Results

The region of interest (ROI) for DBD studies to the excited state is 511-2300 keV. The background of the detector installed at sea-level will be dominated by the muon-induced interactions in the surrounding high-Z shield materials (Pb + Cu). The background arising due to it can be reduced by vetoing the muon-induced events using a plastic scintillator. The reduction ratio (R) is defined as,

$$R = (1 - \frac{N_{Ge}\ .\ \bar{N}_{Plastic}}{N_{Ge}}) \times 100\% \quad (1)$$

where N_{Ge} and $N_{Plastic}$ are the events in the Ge detector and plastic scintillator respectively. The reduction factor R depends on the solid angle coverage of the muon flux and hence the geometry between both the detectors. Fig. 1 shows the schematic of the low background setup with the plastic scintillators. The incoming muon may interact in the Pb/Cu shield and the gamma produced can deposit energy in the Ge crystal, as shown in Fig. 1. It should be noted that due to higher attenuation of gamma rays in Pb (Z = 82) than Cu (Z = 29) and Cu being in the detector vicinity, the interactions originating in Cu will contribute more to the muon-induced background in the detector.

*Electronic address: neha@tifr.res.in

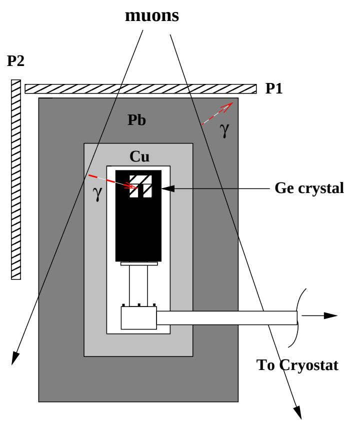

FIG. 1: Schematic of the low background setup with the plastic scintillators P1 and P2 arranged in configuration I. The drawing is to the scale.

It was ensured that the threshold of the scintillator was set above the noise level and the genuine Ge events were not lost. A total gamma background reduction of $\sim 50\%$ in the region of 0.2–3.0 MeV had been obtained by the addition of cosmic veto shielding to the setup (see Figure 2).

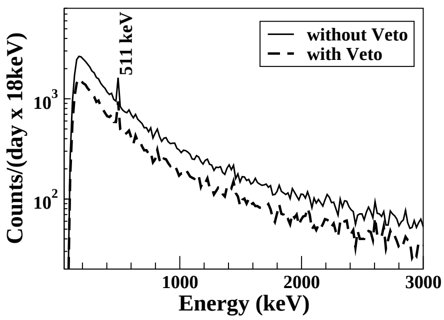

FIG. 2: γ-ray spectra of room background in the the detector with veto (black dotted lines) and without veto (black soild lines) in the energy range of 0.2 – 3.0 MeV.

Due to the saturation of the Ge preamplifier, the γ-ray spectra had a cutoff at $E_\gamma = 55$ MeV and the events corresponding to the muons traversing the entire length of the Ge crystal (~ 6 cm) could not be observed. It should be mentioned that another configuration (II) was used with the plastic scintillator (P2) on the bottom of the shield, at a distance of 71 cm from the center of the detector and gave 10% lower reduction factor in the range of 0.2–3 MeV. Table I shows reduction ratio (R) for different energy ranges in the background gamma-ray spectra.

TABLE I: Reduction ratio (R) for different energy regions for the two configurations of the setup geometry.

Energy Range (MeV)	R (I) (%)	R (II) (%)
0.2–3.0	52.1(0.4)	40.5(0.3)
3.0–5.0	54.7(1.5)	40.8(1.0)
5.0–25.0	61.2(0.5)	41.4(0.5)

Additional plastic scintillators will be added to the setup to achieve higher background reduction. The setup will be used for the search of DBD to the first excited state in ^{94}Zr [3]. Since the background in the ROI, i.e. $E_\gamma = 871 \pm 3$ keV is reduced by $\sim 50\%$, the sensitivity of $T_{1/2}$ has increased by a factor of ~ 1.45. Dry N_2 flushing system will be further added to reduce the ^{222}Rn contamination around the detector.

Summary

A reduction of $\sim 50\%$ in the overall γ background level was obtained by the addition of an active cosmic-veto system (plastic scintillators) to the low background HPGe setup.

Acknowledgements

We thank Mr. K.V. Divekar and Mr. A. Bhatt for help during the measurements and Prof. S.K. Gupta from TIFR for the plastic scintillators.

References

[1] V. Nanal, EPJ Web of Conferences, **66**, 08005 (2014).
[2] N. Dokania *et al.*, Nucl. Inst. Meth. A, **745**, 119 (2014).
[3] Eric B. Norman and Dawn M. Meekhof, Phys. Lett. B, **195**, 126 (1987).