Simulation Studies Relevant for Background of Double Beta Decay Experiment

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Introduction

Underground experiments specially relevant for neutrino oscillation, neutrinoless double beta decay and dark matter have acquired status of mega projects globally for their potential to explore fundamental problems in physics, astrophysics and cosmology. This has seen enhanced growth of labs at LNGS Gran Sasso, SNO Sadbury and Kamiokande during last few decades with bigger experimental proposals [1]. One very important aspect of such experiments is the simulation studies of backgrounds relevant for these experiments [2]. Here some attempts have been made for such studies essential in context with double beta decay experiment.

Gamma-ray spectroscopy using HPGe detector is the most widely used technique because of its high energy resolution. The sensitivity of HPGe depends mainly on efficiency of germanium diode and on its background level [2]. Due to cosmic radiations continuously bombarding on earth's atmosphere and presence of natural radioactivity, all radiation detectors record some background signal. The nature of this background varies with the size of the detector and with the extent of shielding surrounding the detector. Underground location helps in reducing cosmic background as well as background caused by ambient sources of gamma rays [3].

Monte Carlo simulations were carried out with the Geant4 toolkit [4]. It is a free software package composed of tools which can be used to simulate the passage of particles through matter. Geant4 provides a complete set of tools to simulate geometry and material involved in the detector, fundamental particles of interest, generation of primary events, traking of particles through material and electromagnetic field, physics processes governing particle interactions and detector response. Generation of decay events for natural radioactive isotopes were carried out with DECAY0 [5]. An external code, JAS3, was used to analyse the simulated detector outputs [6].

Detector Description

The typical HPGe detector used here was a cylindrical absorber of volume 200 cc. It was surrounded by copper shield of dimension $1m \times 1m \times 1m$ and then lead shield of dimension $2m \times 2m \times 2m$ with thicknesses 20 cm each. Different cylindrical sources were chosen for simulations.

Result and Discussion

Anthropogenic contaminations like, ^{60}Co, ^{90}Sr,^{137}Cs etc. contribute to background signal [2]. Figs 1-3 show simulated spectra for ^{60}Co, ^{137}Cs and ^{90}Sr sources, respectively. The 1173 keV and 1332 keV gamma lines, sum peak at 2505 keV and Compton continum for ^{60}Co and 662 keV photopeak for ^{137}Cs are produced in Figs 1 and 2, respectively as per expectation. The simulated β-decay spectrum for $^{90}\text{Sr}\rightarrow^{90}\text{Y}$ decay with Q value 546 keV is shown in Fig 3.

The background from surrounding such as rock and construction is due to natural radioactive elements like, uranium(^{238}U/^{226}Ra) and thorium(^{232}Th) and the β/EC decaying ^{40}K. Thorium and uranium decay chains involve daughter products that emit a mixed spectrum of alpha, beta and gamma rays [3]. The decay of natural radioactive nuclei had been simulated using the HPGe detector and a soil sample of 1 Kg mass. The average

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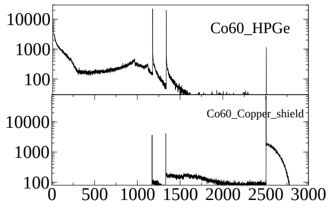

FIG. 1: Decay spectra of ^{60}Co source placed 1cm away from detector. Spectra as observed in HPGe and Copper shield, respectively.

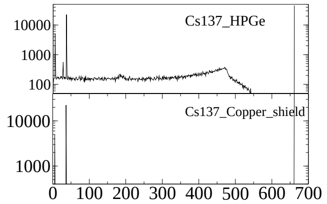

FIG. 2: Decay spectra of ^{137}Cs source placed 1cm away from detector. Spectra as observed in HPGe and Copper shield, respectively.

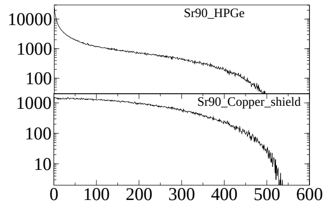

FIG. 3: Decay spectra of ^{90}Sr source placed on the detector. Spectra as observed in HPGe and Copper shield, respectively

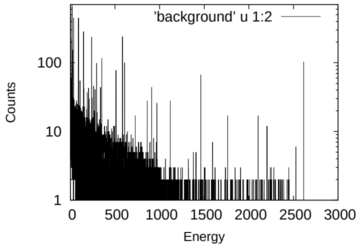

FIG. 4: Decay spectrum of natural radioactivity.

radioactivities present in the soil sample are given in Table 1. The simulated spectrum for one hour activity is shown in Fig 4. The following daughter activities can be identified: 238.6 keV, 295.2 keV and 352 keV of ^{214}Pb; 934 keV, 1120 keV, 1764 keV and 2204 keV of ^{214}Bi from ^{238}U series and 911 keV of ^{228}Ac and 2614 keV of ^{208}Tl from ^{232}Th series and 1460 keV of ^{40}K. As Q-value for neutrinoless double beta decay from ^{124}Sn is 2283 keV, So, 2204 keV and 2614 keV peaks are of interest for neutrinoless DBD experiment of ^{124}Sn.

TABLE I: The background radiation activity [7].

Radioactive substance	Order of Half life in years	Activity in Bq/Kg	Average activity in Bq/Kg
^{226}Ra	10^9	8.2–68.4	30.6
^{232}Th	10^{10}	5.9–77.2	38.2
^{40}K	10^9	14.6–344.9	152.2

Conclusion

Initial steps for exploring the relevant simulation for background studies for lab systems, detectors, shield etc. have been tested and shall be use for the planned experiments on DBD specially for ^{124}Sn, after incorporating bolometric aspects into it.

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