Characterization of the Point Contact Germanium Detector

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Introduction

Taiwan EXperiment On NeutrinO (TEXONO) is one of the leading experiments in low energy nuclear reactor neutrino and dark matter physics. The principal objectives of TEXONO collaboration are to pursue experimental studies on low energy neutrino physics such as neutrino nucleus coherent scattering (NNCS), neutrino millicharge, neutrino charge radius, neutrino magnetic moments and dark matter search at KuoSheng Reactor Neutrino Laboratory (KSNL) in Taiwan [1].

Germanium detectors with sub-keV sensitivities have been demonstrated as efficient means to probe Weakly Interacting Massive Particles [1]. This novel detector technique is also adopted in the study of neutrino-nucleus coherent scattering with reactor neutrinos [1]. This motivates the development of point-contact germanium detectors. The generic benchmark goals in terms of detector performance are: (I) modular target mass of order of 1 kg; (II) detector sensitivities reaching the range of 100 eV; and (III) background at the range of 1 count $kg^{-1}keV^{-1}day^{-1}$ (cpkkd).

Germanium detector study

There are several configurations of Germanium detectors with variable volumes available, such as Standard Electrode Coaxial Germanium Detector (SEGe), Broad Energy Germanium Detector (BEGe), Reverse Electrode Coaxial Germanium Detector (REGe), Ultra Low Energy Germanium Detector, Point Contact Germanium Detector (PCGe) etc. The capacitance of SEGe detector is typically 20pF, whereas the PCGe detector has capacitance less than a pF, which is the big advantage in the Germanium detector technology [1]. The lower capacitance of the PCGe detector provides several benefits such as: (I) Noise fluctuation is reduced. (II) Energy resolution is improved because of the reduction in the noise fluctuation. (III) Timing resolution is improved, which allows distinguishing single and double-sited events in a crystal. (IV) Energy threshold is improved. The threshold is around 2-5 keV_{ee}

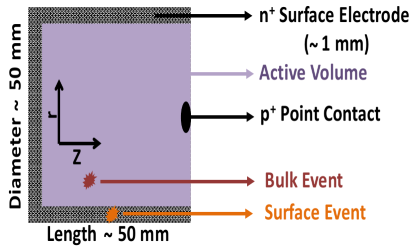

FIG. 1: Schematic crystal configurations of the pGe detector

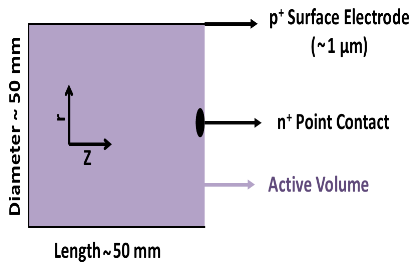

FIG. 2: Schematic crystal configurations of the nGe detector.

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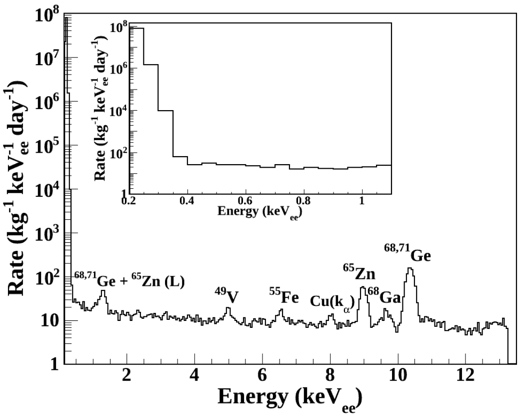

FIG. 3: Energy spectrum for pGe detector, having electronic noise edge 300 eV_{ee}.

for SEGe detector whereas for the PCGe detector it is 300-400 eV_{ee} .

The outer surface electrode of the p-type point contact Germanium detector (pGe) fabricated by lithium diffusion, having a finite thickness. Electron-hole pairs produced by the radiations at the surface (S) layer subjected to a weaker drift field than those in the crystal bulk region (B). The S-events have only partial charge collection and slower rise-time [1]. The thickness of the S layer is derived to be 1.16±0.09 mm, via the comparison of simulated and observed intensity ratios of γ-ray peaks from a ^{133}Ba source. While for the n-type point contact Germanium detector (nGe), the outer surface is boron-implanted electrode of submicron thickness, due to which nGe has no anomalous surface effect. Figure 1&2 shows the schematic crystal configuration of the pGe and nGe.

Results and discussion

In this article, we focus on the data taken at KSNL with 500g pGe and 500g nGe detectors having identical circumstances. The calibration techniques used in this study are described in Ref. [2], and data analysis to reject the background are well described in Ref. [1]. We found that pGe detector have

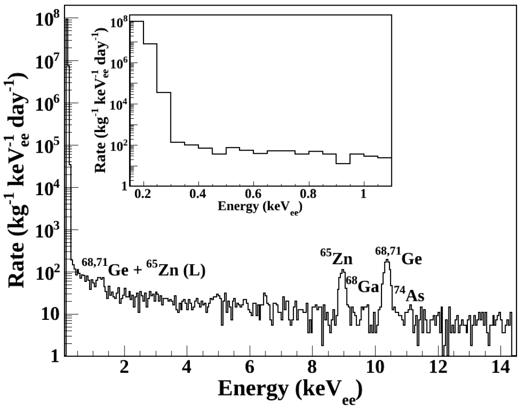

FIG. 4: Energy spectrum for nGe detector, having electronic noise edge 350 eV_{ee}.

better energy resolution compared to the nGe detector. Electronic noise of nGe detector is 350 eV_{ee} as shown in Figure 3 while pGe detector have electronic noise 300 eV_{ee} as shown in Figure 4. Which reveals that pGe detector is better in energy resolution as well as electronic noise edge as compared to nGe detector.

The understanding about the sub-keV background and optimization of the energy resolution of nGe detector as comparable to the pGe detector is our ongoing research program.

Acknowledgments

M. K. Singh thanks the University Grants Commission (UGC), Govt. of India, for the funding through UGC D. S. Kothari Post-Doctoral Fellowship (DSKPDF) scheme. The authors are grateful to the contributions from all collaborators.

References

[1] M. K. Singh et al., INJP, DOI 10.1007/s12648-017-1004-4 (2017) and references theirin.

[2] M. K. Singh et al., INJP (In Press), (2017) and references theirin.