Advancement of germanium detector technology in rare event search

V. Kumar[1], M. K. Singh[1],* and H. T. Wong[2]

[1] *Department of Physics, Institute of Applied Sciences and Humanities, GLA University, Mathura - 281406, India and*

[2] *Institute of Physics, Academia Sinica, Taipei - 11529, Taiwan*

Germanium (Ge) has went through significant advancement from initial use in early technology to its current applications in rare event searches. With progression in technology, Ge detectors can detect energy levels as low as 100 eV_{ee} are advancement in research for neutrino, dark matter physics and CEνNS. These highly sensitive detectors are enabling scientists to detect these low energy particles. The TEXONO collaboration has established a cutting-edge detection system at the Kuo-Sheng Nuclear Power Plant, utilizing an ultra-low energy, high-purity Ge detector.

Introduction

Since the discovery, Ge detector technology has been used in shaping the advancement and growth of semiconductor devices. During mid of 1980s, the Heidelberg-Moscow (HM) collaboration found a new ground by using Ge detectors. They implimented germanium detector for neutrinoless double-beta decay. This process opened many branches for developing the unknown facts about neutrinos and mystery of Universe. Later, Ge detectors had been modified for rare event searches and used by many of collaboration across the world. In recent upgrades the Ge detectors had undergone several significant improvements involving advanced cryogenic technology, point contact (PC) detectors, integrated detector array, surface passivation and enrichment.

By operating these detectors at cryogenic temperatures also results in reduction of thermal noise and improve sensitivity. By this several collaborations are investigating different physics such as neutrino oscillations, CEνNS, neutrino magnetic moment, double beta decay. In this article we will be giving overview of different achievements in advancing Ge detector for rare event searches in TEXONO at KSNL.

*Electronic address: singhmanoj59@gmail.com

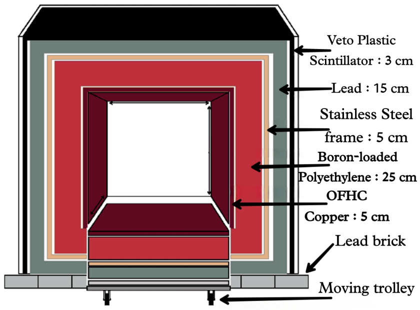

FIG. 1: Layout of inner target of passive shieldings [2].

Experimental Overview

TEXONO is a collaborative research experiment in Taiwan which focuses on understanding different neutrino physics, particularly neutrino oscillations and CEνNS, using a variety of experimental features. While looking for rare events, TEXONO encountered the signals contains various kinds of backgrounds which suppress the sensitivity and reduce impact of required signal. In order to achieve these targets, TEXONO in its initial stages used coaxial Ge (CoaxGe) (FIG 2 (a)) and different types of shielding such as passive (FIG. 1) and active shielding which is well defined in previous published works [1,2].

By utilizing a range of detector types in recent modifications including ultra low energy (ULE), p-type point contact (pPC)

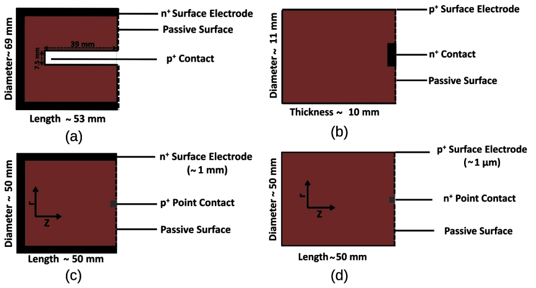

FIG. 2: Schematic configuration of Ge detector: (a)CoaxGe (b)ULEGe (c)pPCGe (d)nPCGe [1].

and n-type point contact (nPC) (FIG. 2), TEXONO optimizes its experimental setups for rare events searches such as dark matter interactions and neutrinoless double beta decay. CoaxGe detectors are cylindrical with a central borehole, forming a U-shaped coaxial structure. ULEGe detector are designed for extremely low energy thresholds and are optimized for low electronic noise. pPCGe detectors have a small PC electrode, which rejects electronic noise and allows for the detection of low-energy events [3]. nPCGe detectors are similar to pPCGe detectors but are made from n-type Ge crystals. Also there is an incorporation of NaI(Tl) detectors with PMTs for active background rejection and anti-coincidence detection, improves signal-to-noise ratio.

Table 1 shows the comparative analysis of various Ge detector used in rare event searches by TEXONO collaboration. From using CoaxGe to PC with modular mass of 1000g and 500g in TEXONO experiment, exhibits a massive improvement in noise edge from around 5.6 keV to 300 eV. From the Table 1 even in PCGe of modular mass 500g, the nPCGe and pPCGe presented much lower noise edge values of 373 to 311 eV [1,3]. Currently TEXONO collaboration is using 1.4 kg pPCGe and achieved the noise edge around 200 eV. Further reduction in noise edge and optimisation of Ge detector by improving hardwares and softwares are their future goal. Soon TEXONO collaboation will update their limits by using current data for 1.4 kg pPCGe.

Items	**CoaxGe**	**pPCGe**	**nPCGe**	**pPCGe**
Modular Mass (g)	1000	900	500	500
Pedestal Noise RMS (eV)	812	56	49	41
Pulser FWHM (eV)	1566	124	133	110
Noise Edge (eV)	5600	400	373	311

TABLE I: Comparison of different detector parameters

Conclusion

The TEXONO collaboration commitment to advancing our understanding of neutrino physics and rare nuclear processes through innovative experimental designs and international collaboration. The current goal of TEXONO is to harness the capabilities of Ge detectors and conducting experiments near the Kuo-Sheng Nuclear Power Plant and unravel the mysteries of neutrinos and their fundamental role in the Universe.

Acknowledgments

The experimental setup discussed in this article is collective efforts of the TEXONO Collaboration. The authors are grateful for the contributions of every team member.

References

[1] A. K. Soma et al., NIM-A, **836**, 67 (2016).
[2] M. K. Singh et al., Ind. J Phys, **91(10)**, 1277 (2017).
[3] H. B. Li et al., Astro. Phys. **56**, 1 (2014).