Neutrino and Dark Matter physics with point contact sub-keV Germanium detector

M. K. Singh[1,2], V. Singh[1,*] and H. T. Wong[2]
[1] *Department of Physics, Institute of Science, Banaras Hindu University, Varanasi 221005, India.* and
[2] *Institute of Physics, Academia Sinica, Taipei 11529, Taiwan.*

Introduction

Experimental searches for low energy neutrino properties and their interactions such as neutrino-electron elastic scattering, neutrino-nucleus coherent scattering and neutrino electromagnetic interactions can lead to reveal physics within the **S**tandard **M**odel as well as to probe the physics **B**eyond **S**tandard **M**odel [1]. Eventually, it leads to make potentially enrich in the search of an important field of Dark Matter physics. The theme of **T**aiwan **EX**periment **O**n **N**eutrin**O** (TEXONO) Collaboration is based on these research programs. These objectives imposes requirement to develop detectors with sub-keV threshold $O(100\ \mathrm{eV}_{ee})$ and background $O(1\ \mathrm{kg}^{-1}\mathrm{keV}_{ee}^{-1}\mathrm{day}^{-1})$ (CPKKD) [2]. The point contact high purity Germanium ionization detectors (HPGe) are efficient to achieve such benchmark specifications.

The TEXONO collaboration is using HPGe detectors placed inside the KSNL, which has almost 30 m.w.e. overburden and located at a distance of 28 meter from the core-1 of Kuo-Sheng Nuclear Power Station. The target Ge detector is covered by NaI(Tl) anti-Compton (AC) detector inside a space of (100×85×75) cm^3 which is enclosed by 4π passive shielding of almost 50 ton. The outer space is further covered by the CR veto scintillator array as shown in Fig. 1.

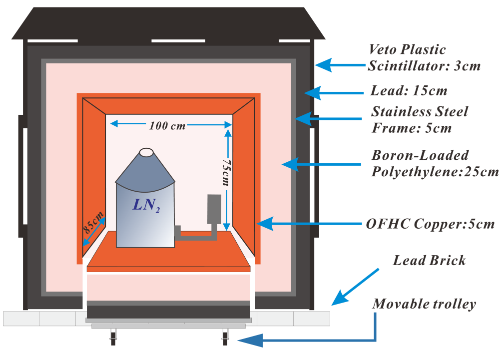

FIG. 1: Schematic diagram of the Kuo-Sheng Reactor Neutrino Laboratory (KSNL) with detectors placed inside the inner space and enclosed by the passive shielding which is further covered by the cosmic ray (CR) veto scintillator panels.

Data filtration

We have recorded the data with 900 g mass positive point contact Ge detector (pPCGe) in conjunction with NaI and CR veto scintillator array. The symbol of superscript (-) and (+) represents anti-coincidence and coincidence of CR and AC veto system with the pPCGe events. Therefore, the residual combination of $AC^- \otimes CR^-$ have uncorrelated desired signal events for the physics study [3].

The pPCGe detector faces anomalous surface charge collection effect because, its surface is fabricated by Li-diffused n^+ electrode, which is of the order of 1 mm thickness [4]. The Electron-hole pairs produced at the surface (S) faces weaker drift electric field in comparison to those which are produced in the bulk volume (B). Therefore, S events would exhibit slower rise time (τ) and have partial charge collection in comparison to B events as depicted in Fig. 2. The τ of events recorded by timing amplifier can be parameterized by

*Electronic address: venkaz@yahoo.com

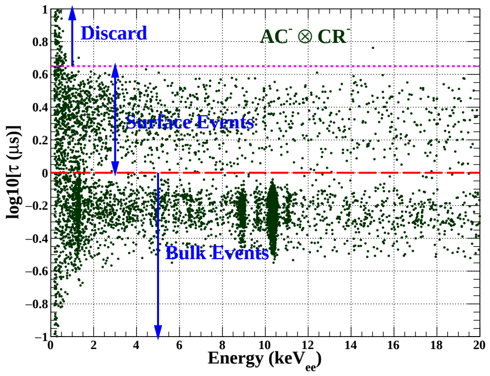

FIG. 2: Rise time distribution with energy of the residual AC$^-$ $\otimes$ CR$^-$ events.

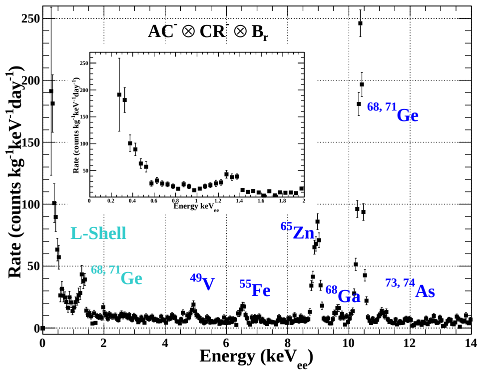

FIG. 3: Residual AC$^-$ $\otimes$ CR$^-$ $\otimes$ B$_r$ spectrum along with the natural X-rays lines.

the hyperbolic tangent function

$$\frac{1}{2}A_0 \times \left(\tanh\left(\frac{t-t_0}{\tau}\right)\right) + P_0 \qquad (1)$$

where, A$_0$, P$_0$ and t$_0$ are the amplitude, pedestal offset and timing offset, respectively [4]. With this parameterized τ one can see that the B and S events bands are well discriminated above 2 keV. A small fraction (<8%) of events in sub-keV region exhibit large value of τ, due to the failure of this procedure at these events which are excluded from the analysis. Events for which log 10[τ] < 0 are the accepted B events in AC$^-$ $\otimes$ CR$^-$. However, in low energy this criteria is not fully acceptable. Identification of S and B events have been performed with criteria that the ratio of B and S events is independent of τ distribution. After making all basic cuts as discussed in Ref. [5], incorporating corresponding efficiencies and using τ-independent ratio method the residual AC$^-$ $\otimes$ CR$^-$ $\otimes$ B$_r$ spectrum have been shown in Fig. 3 (B$_r$ stands for bulk cut correction efficiency). After all these gymnastics of data filtration we reached to the threshold of 275 eV$_{ee}$ and background 190 CPKKD. To be more potentially enrich in physics, we need to further improve them.

Summary and prospects

Present work dealt with ratio method to assign correctly B and S events and obtained results are in support of better results in future.

To cool the Ge crystal, we have used LN$_2$. Now we are focus to use the newly developed electrocool system which leads the Ge crystal at cryogenic temperatures. It will be helpful in reducing the ambient background with better equipped electronics. Making use of electrocool device will reduce the inner space which is covered by the LN$_2$ dewar. Filling this space with the Oxygen Free High Conductivity copper bricks will be helpful in reducing further the ambient background. Incorporating this, we can gain better threshold and background.

Acknowledgments

Author M. K. Singh acknowledges University Grant Commission (UGC), India for providing financial support and the TEXONO Collaboration.

References

[1] H. T. Wong *Int. J. Mod. Phys.* ***A 33***, 1830014 (2018).
[2] A. K. Soma et al. *Nucl. Inst. Meth.* ***A* 836**, 67 (2016).
[3] M. K. Singh et al. *Indian J. Phys.* ***91***, 1277 (2017).
[4] L. T. Yang et al. *Nucl. Inst. Meth.* ***A* 886**, 13 (2018).
[5] L. T. Yang et al. *Chinese Physics* ***C* 42**, 023002 (2018).