Identification of bulk and surface events in p-type point contact germanium detectors

M. K. Singh[1],* V. Singh[2,3], and H. T. Wong[4]
[1]*Department of Physics, Institute of Applied Sciences and Humanities, G. L. A. University, Mathura - 281406, INDIA*
[2]*Department of Physics, Institute of Science, Banaras Hindu University, Varanasi - 221005, INDIA*
[3]*Department of Physics, School of Physical and Chemical Sciences, Central University of South Bihar, Gaya-824236, INDIA and*
[4]*Institute of Physics, Academia Sinica, Taipei - 11529, Taiwan*

Introduction

One fourth of the total energy density of the Universe can be attributed to cold dark matter whose nature and properties are still unknown [1]. Weakly Interacting Massive Particles (WIMP) are the leading candidates of cold dark matter [1]. The understanding of background sources as well as their contribution in the energy spectrum are the key factors for all the experiments involved dark matter searches [2]. The p-type point contact germanium (pGe) detectors have excellent energy threshold in the sub-keV energy range and the low intrinsic radioactivity background, which enhance its importance in rare-event detection experiments [3]. The pGe detector is a novel technology offering kg-scale radiation sensors with sub-keV sensitivities. However, there are anomalous surface behaviour in pGe detectors which we needs to understand [4].
Taiwan EXperiment On NeutrinO (TEXONO) is one of the leading experiment in low energy nuclear reactor neutrino and dark matter physics at KuoSheng Reactor Neutrino Laboratory in Taiwan [2, 5]. The TEXONO Collaboration has developed and used several HPGe detectors to acheive different physics goals [5]. The generic benchmark goals of TEXONO in terms of detector performance are; (i) modular target mass of the order of 1 kg, (ii) detector sensitivities in terms of energy threshold reaching the range of 100 eVee, and (iii) background level at the range of 1 $kg^{-1}keV_{ee}^{-1}day^{-1}$ (cpkkd) [2, 5].The surface events in pGe detectors exhibit anomalous behaviour [4]. It may limit the physics sensitivities and can lead to false interpretation of the data [4]. Therefore the analysis of the surface events is an important experimental challenge before the full potentials of pGe detector technique at sub-keV energy [4]. In this report, we present the highlights on our study for the identification and differentiation of bulk and surface events based on their pulse shape behaviour [3, 4].

Experimental Details

The KuoSheng Neutrino Laboratory (KSNL) is situated at Kuo-Sheng Nuclear Power Station-II (KSNPS-II) which is located at the Jinshan district on the northern shore of Taiwan [2]. KSNPS-II consists of 2 boiling water reactor cores, each of them having an average thermal power output of 2.9 Giga Watt (GW). The KSNL is located at a distance of 28 m from the first core of KSNPS-II [2]. To reduce the background TEXONO experiment using different types of shielding which is mainly divided into two main categories, one of them is passive shielding and other one is the active shielding well described in Ref. [2]. The physics signals from the pGe detector are supplied through a reset preamplifier. The output of the preamplifier is distributed to a fast timing amplifier and shaping amplifiers which keeps the rise-time information and energy information respectively [2]. The fast-timing

*Electronic address: singhmanoj59@gmail.com

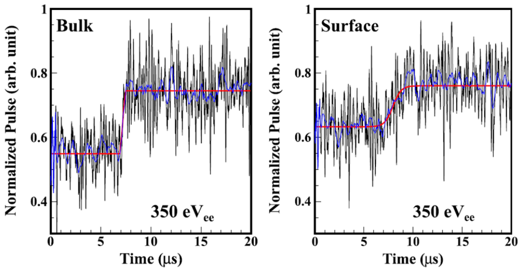

FIG. 1: Typical pulse shape of Bulk (left side) and Surface events (right side) both having $350eV_{ee}$ energy are shown along with raw pulses in black, the smoothed (blue) pulses, together with the best-fit functions (red) are also superimposed [2].

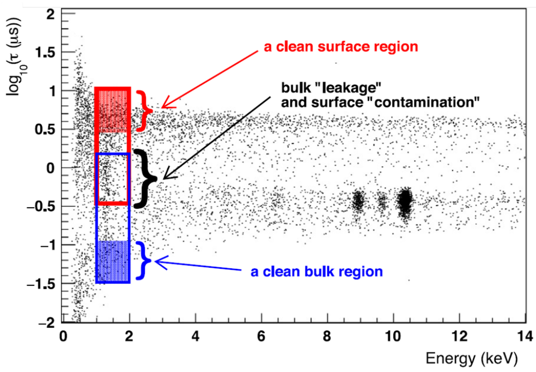

FIG. 2: The τ distribution at low background configuration for pGe detector [2].

and slow-shaping output were digitized by the flash analog-to-digital converters at 200 and 60 MHz, respectively. The energy calibration was achieved by the internal X-ray peaks and the zero energy was defined with the pedestals provided by the random events [2].

Result and Discussions

To study the effects of the surface events, the Canberra 2111 timing amplifier processes the signal from the preamplifier. The output of the timing amplifier are recorded by the 200 MHz FADC for further process. The typical pulse shape of the timing amplifier corresponding to the energy 350 eV_{ee} is shown in figure 1 [2]. The rise-time of the timing amplifier signal τ, parameterized by the hyperbolic tangent function [2],

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

where, A_0 , P_0 and t_0 are amplitude, pedestal offset and timing offset, respectively. The scattered 2d plot for the variation of rise time (τ) versus the measured energy (T) for the physics interest event ($AC^{-} \otimes CR^{-}$) are shown in figure 2 [2]. From figure 2 it is cear that the bulk and surface events are well separated for energy more than 1.5 keV while below 1.5 keV there is leackage between bulk and surface events. The TEXONO experiment have devepoled several techniques to differentiate the bulk and surface events in sub-keV region, which is well described in Ref. [3, 4]. Despite the advances in the BS-selection and their efficiency measurements [3, 4] there are still fundamental challenges to further boost the sensitivities on the studies of subkeV events in pGe detectors [3, 4].

Acknowledgments

The research programs and results presented in this article are from the efforts of the TEXONO Collaboration. TEXONO Collaboration consisting of groups from Taiwan (Academia Sinica), China (Tsinghua University, Institute of Atomic Energy, Nankai University, Sichuan University), India (Banaras Hindu University, GLA University) and Turkey (Middle East Technical University, Dokuz Eyll University).

References

[1] H.B. Li et al., Phys. Rev. Lett. 110 261301 (2013).
[2] M. K. Singh et al., Indian J.Phys. 91(10), 1277 (2017).
[3] L. T. Yang et al., Nucl. Instrum. Meth., A 886, 13 (2018).
[4] H. B. Li et al., Astroparticle Physics, 56, 1 (2014).
[5] A. K. Soma et al., Nucl. Instrum. Meth., A 836, 67 (2016).