Identification of physics signal-events near threshold in *p*-type point-contact Germanium detectors

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Introduction

Germanium detectors provides state-of-the-art technology for rare event searches. There is vast use of these detectors in the search for physics beyond the Standard Model as well as the Standard Model itself. There is a wide range of geometrical configurations for these detectors and are available in two types: n- and p-types. The electrical contact on Germanium detectors are made by adding a much higher impurity concentration over the surface. The n-type detectors (nPCGe [500g]: with 50 mm length & 50 mm diameter dimensions) has a p^+ outer layer electrode of thickness 100s of nm, formed by Boron implementation technique. While, for p-type detectors, n^+ outer layer electrode is formed by Lithium evaporation and diffusion technique of thickness typically $\sim$1 mm.

The p-type Germanium (pPCGe: with 50 mm length & 50 mm diameter [500g] and 70 mm length & 70 mm diameter [1500g] dimensions) detectors provides a region in which (near the surface−S) electron-hole pairs produced by radiations are subjected to a weaker drift field than those in the crystal's inner volume called as bulk (B) (Fig. 1). A portion of the pairs will recombine while the residual will induce signals which are weaker & slower than those originated in B (Near point-contact events are faster than B). That is, the S-events have only partial charge collection & slower rise-time (Fig. 2). Events with complete charge collection are considered as B signal-events [1].

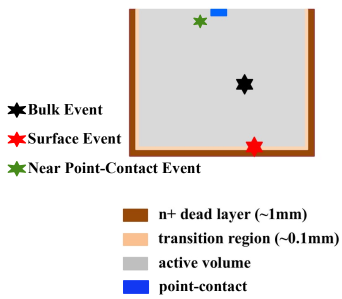

FIG. 1: Schematic diagram of pPCGe detector.

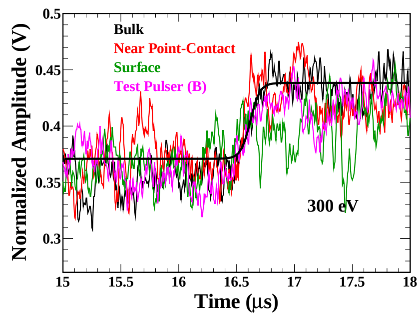

FIG. 2: Pulses from data and pulser in low energy region. Pulser, Bulk, Near point-contact events are well fitted with Tan$h$ (Eq. 1) function. Their pedestal noise-level in terms of RMS (σ) are 30 eV for data & 51 eV for pulser (nPCGe).

Thick electrode of pPCGe detector provides slower pulses (in rise-time) in comparison to those obtained in the active volume (bulk). Therefore this layer helps in the suppression of ambient γ-background. In high energy re-

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gions, S- & B-events can be differentiated by their rise-time distribution. However, in the sub-keV region S- and B-events starts have overlaps [2]. In order to get the energy spectra for actual B-events, it is essential to correct this region by including B-S leakage fraction.

B-S correction in sub-keV region

The electronic signals in Germanium detector are induced by the drifting charges. The signal rise-time (τ) can be parametrized by the following hyperbolic tangent function:

$$f(t) \;=\; \frac{1}{2}A_0 \times \left[\tanh\left(\frac{t-t_0}{\tau}\right)\right] + P_0 \quad (1)$$

where A_0, P_0 and t_0 represents the amplitude, pedestal offset and timing offset of the pulse, respectively. Illustrated in Fig. 2 are typical examples of B, S and Near point-contact events, showing both their raw pulses and the fitted-profiles, at 300 eV.

The B-S leakage correction requires the radioactive source & in situ ambient background data. Performance of the "ratio method" [2] currently used by the TEXONO & CDEX experiments can be enhanced by calibration data with an external programmable Pulse Generator. This can provide a high-statistics sample for B- and S-like events with all input parameters completely known and controlled.

Optimized test pulser events which mimic B-like events are shown in Fig. 2. Pulser events are generated by certain input voltages that can be calibrated into corresponding energy (with the help of real data). While there are fine differences between pulse shapes between B & Near point-contact events with those of test pulser at high energy, they are washed out by the pedestal electronic noise at near-threshold energy ($\sim$ 300 eV), & can be described by Eq. 1. S-events can be differentiated by pulse shape analysis at this energy.

Summary and prospects

The rise-time ($\log_{10}[\tau]$) 1D-distribution of events near detection threshold (7-9)σ [210-270 eV for pPCGe & 360-460 eV for nPCGe] in different detectors along with pulser is shown in the top of Fig. 3. It is explicit that the pulser resembles closely like B-events. Even, their FWHM of distribution are quite similar.

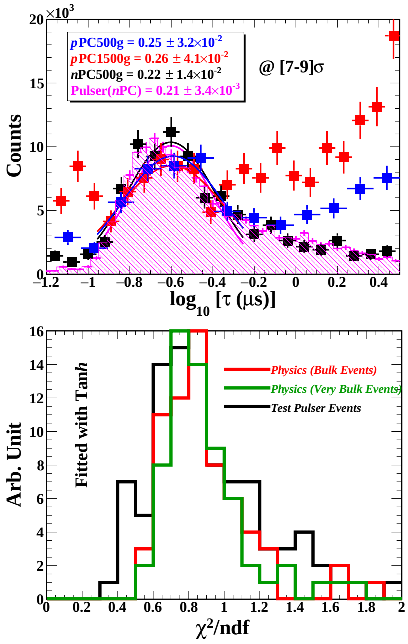

FIG. 3: (Top) Rise-time 1D-distribution of events near the detection threshold (7-9)σ along with pulser in three detectors. (Bottom) χ^2 distribution of fitting to the B, Near point-contact and pulser events with Tan$h$ function.

Furthermore, we have fitted the three Pulser, B, Near point-contact events with hyperbolic tangent function and their χ^2-distribution is shown in the bottom of Fig. 3. It shows that the pulser is good to mimic physics pulses. Although pulser is very close to the physics pulses, not identical. The hyperbolic tangent function is good enough to give accurate rise-time. Therefore an optimized pulser can be used as a good tool for the correction of B-S leakage and identification of B signal-events in sub-keV region.

References

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