Dead layer thickness measurement in p-type point contact Germanium detector

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Introduction

P-type point-contact Germanium (pGe) detectors have excellent properties for the studies of low energy neutrino physics, WIMP dark matter search and other physics searches beyond the standard model at the Kuo-Sheng Reactor Neutrino Laboratory (KSNL)[1–3]. A small area of the point-contact electrode, which can significantly reduce the internal capacitance, results in reduction of low electronic noise and energy threshold [1–3]. The p-type point-contact Ge (pGe) detectors have an inactive layer at the surface caused by lithium diffusion [1–3].

The pGe detector can be distinguished into two parts, one of them is the surface part (dead layer), the events generated in the dead layer region will lead to a slow rise time pulse and an incomplete charge collection because of the very weak electric field in this region [1, 3] and other one is the bulk part, in which all charge produced is fully collected by the electrodes. The signals generated in the dead layer have a much slower rise time while in bulk region have fast rise time as shown in figure 1. The events interacting in this dead layer region are not providing the primary energies that are deposited in the detector therefore we should discriminate these events from the bulk events with using proper efficiency corrections [1, 3]. After calculating the thickness of the inactive layer we can precisely measure the fiducial mass of the detectors [1, 3].

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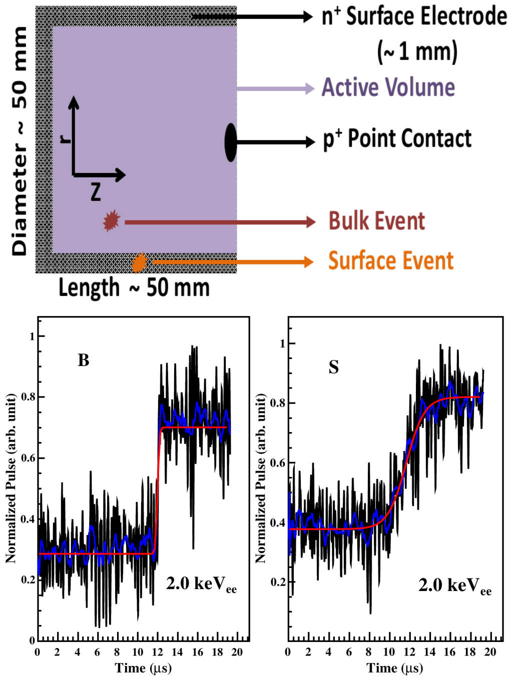

FIG. 1: Schematic crystal configurations of the pGe detectors and typical signals at 2 keV from surface and bulk region.

Dead layer thickness measurement

^{133}Ba source is an excellent source to measure the dead layer thickness of pGe detector because it has several photoelectron peaks. The photoelectron peaks of ^{133}Ba source with their intensities is shown in table 1. The basic idea behind this is for different energy gamma rays, they have different attenuation lengths in a Ge crystal. Lower energy photons are more likely to interact in the dead layer com-

TABLE I: Gamma-ray energies with their intensities of ^{133}Ba source [4]

Energy (keV)	53.2	79.6	81.0	160.6	223.2
Intensity (%)	2.1	2.7	33	0.64	0.45
Energy (keV)	276.4	302.9	356.0	383.8	
Intensity (%)	7.2	18.3	62	8.9	

pared to higher energy photons. Therefore, the thickness of the dead layer can be derived by comparing a higher energy photoelectron peak to the 81 keV photoelectron peak of the ^{133}Ba source. A Gaussian function and a linear function are used to describe the peak region. The peak areas are calculated by using following equation (1),

$$A = \sqrt{2\pi\sigma H/W}. \tag{1}$$

Where, A represents the peak area, σ refers to the FWHM of the Gaussian fitting function, H refers to the peak height and W represents the width of the energy bins.

Geant4 version 9.5 was used to simulate the initial interaction of the gamma rays from ^{133}Ba source with the pGe detector. In the simulation, the inactive layer thickness was scanned from 0.2 mm to 2.0 mm to get different simulated results of the ^{133}Ba source. The simulated energy spectrum of the ^{133}Ba isotope is shown in figure 2 with superimposed measured data.

Figure 3, showing the ratio of the number of events in the 356 keV photoelectron peak to that in the 81 keV photoelectron peak for different dead layer thickness. A quadratic fitting function provides a good description to the simulation data. The calculated thickness value of the dead layer for 900g pGe detector is 1.16 mm. And the calculated value of the fiducial mass of 900g pGe TEXONO detector is 840g.

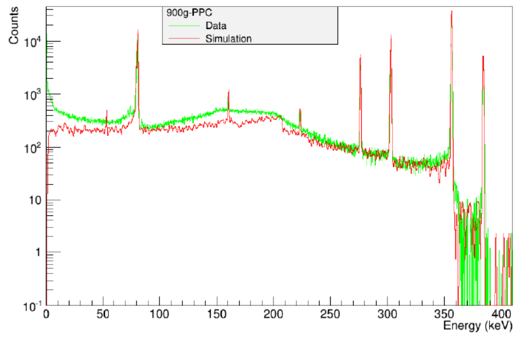

FIG. 2: The simulated spectrum superimposed with measured data of the ^{133}Ba source.

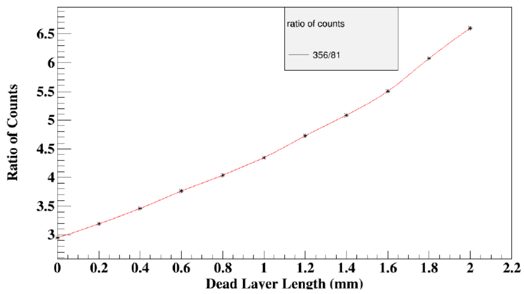

FIG. 3: Ratio of the area under 356 keV and the 81 keV peaks with dead layer thickness.

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