Extracting Physics from P^+ PCGe Detector near Noise Edge

V. Singh[1,] M.K. Singh[1,2], L. Singh[1,2], V. Sharma[1], N.S. Chouhan[1],
K. Saraswat[1], V.S. Subrahmanyam[1], H. T. Wong[2]
1. Department of Physics, Banaras Hindu University, Varanasi - 221005, INDIA
2. Institute of Physics, Academia Sinica, Nankang, Taipei 11529, TAIWAN
**Email: venktesh@bhu.ac.in*

Introduction

There is compelling evidence from cosmological and astrophysical observations that about one quarter of the energy density of the universe can be attributed to cold dark matter (CDM), whose nature and properties are still unknown [1]. Weakly interacting massive particles (WIMP) are the leading candidates for CDM. The popular SUSY models prefer WIMP mass in the range of >100 GeV, though light neutralinos remain a possibility [2]. Most experimental programs optimize their design in the high-mass region and exhibit diminishing sensitivities for m_ν <10 GeV.

The current goal is to develop detectors with kg scale target mass, 100 eV-range threshold and low background specifications for the studies of WIMPs, μ_ν, and ν-N coherent scatterings [3]. We are exploiting use of p+ type, point contact germanium detector with a few mm thick end-cap of OFHC Cu acting as dead layer around the crystal and mass of 500g. Surface and core parts of the detector are readout by two pre-amplifiers S1 and S0, respectively as shown in Fig. 1.

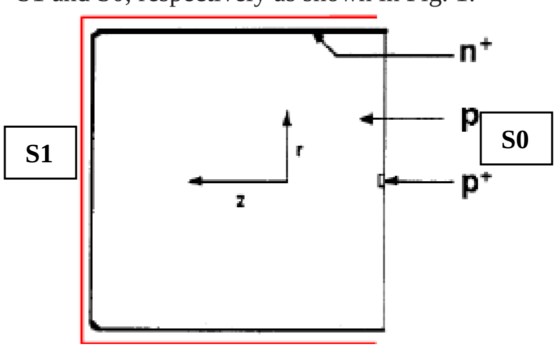

Fig. 1: Schematic layout of PPCGe detector.

Results and Discussion

Data were collected at the Kuo-Sheng Neutrino Laboratory in Taiwan [4] with 6 and 12 μs shaping time. To get zero energy scale a random trigger event is recorded at 0.1 Hz, which also helped us in calculating dead time. Random trigger also helped us in defining pedestals. To fix the energy scale, various X-ray sources up to 60 keV and internal gamma ray lines of the range of 1-12 keV from in situ data and precision pulser for low energy interpolation were used. Near noise edge or low energy region, energy scale is linear in area or Q mode but shows slight non-linear relation in amplitude mode. Noise edge, random trigger events and discriminator trigger threshold are shown in Fig.2 in terms of charge and amplitude mode.

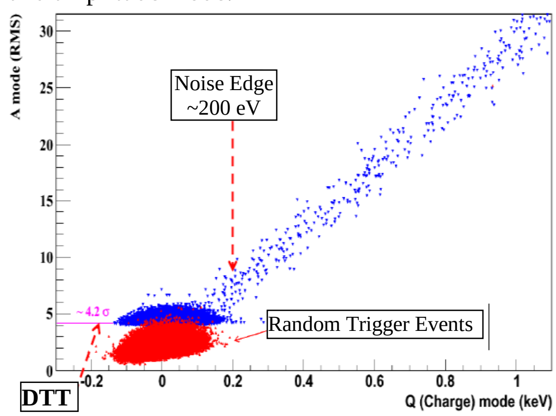

Fig. 2: Scatter plot of events.

When gamma rays are incident on the detector they lose their partial energy due to dead layer of the surface and then deposit rest of energy into the detector. The pulse shape of such event has slower rise time than the event which hit the detector directly such as neutron or neutrino as shown in Fig. 3.

Cosmic ray events have been tagged by plastic scintillators. Non-neutrino and non-dark matter events hit anti-Compton detector i.e. all anti-Compton events are physics events and not noise.

Events that survive all rejection criteria are those events that are either in situ, noise or neutrino and dark matter events i.e. either back ground or events in region of interest. A low energy spectrum of final events is shown in Fig. 4.

A pulse shape discrimination method has been devised to distinguish surface and bulk events on the basis of rise time as shown in Fig. 5. A clear-cut band of surface and bulk events are well separated below to 4 keV with 100% efficiency. In situ peaks are shown in bulk band of spectrum.

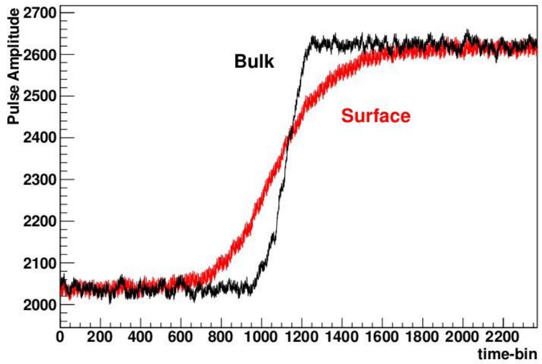

Fig. 3: Average pulse shapes of surface and bulk events.

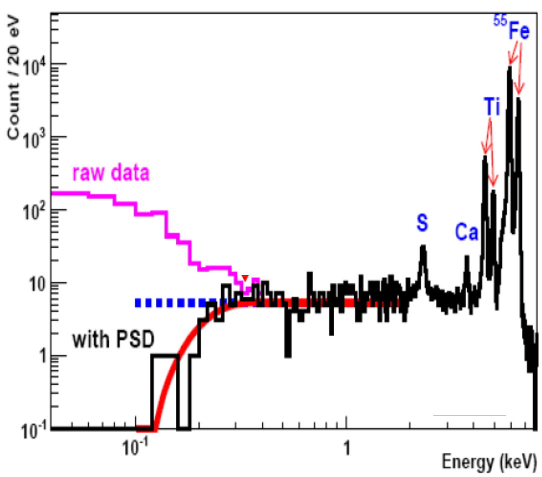

Fig. 4: A low energy region spectrum of final events.

To check the validity of devised PSD and surface, and bulk events concept, various data sets have been taken with ^{137}Cs and ^{241}Am sources. Cosmic-ray veto and anti-Compton triggered events are gamma ray rich background and cosmic-ray triggered and anti-Compton veto set of events are neutron rich background for this experiment.

Typical detector performance is tabulated in Table 1. It shows that with this detector around 300 eV detection thresholds has been achieved with 50% pulse shape discrimination efficiency which is not better than 4x5g ULE-HPGe detector [4].

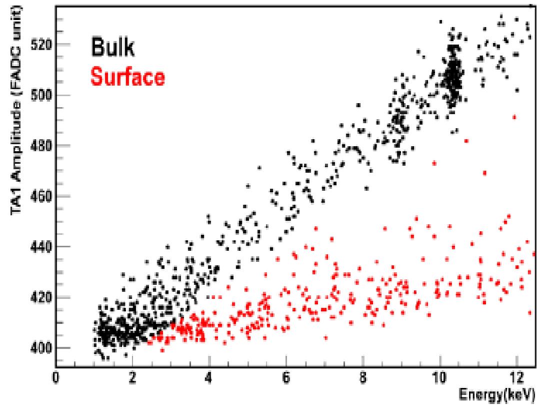

Fig. 5: Amplitude distribution of physics events with respect to energy.

Table 1: Typical performance of PPCGe detector.

Measurements	PPC Ge
Detector Mass	500 gram
Pedestal Q-RMS	~80 eV
Noise Edge	~500 eV
50% trigger efficiency @ Discriminator threshold	~180 eV @ 3.1 σ
50% selection efficiency (PSD)	~ 300 eV

Conclusion and prospects

PPCGe detector shows better energy resolution in low energy region with amplitude mode. Small dead layer i.e. end cap of the detector provides extra anti-Compton support in rejecting background. We are working on heavier (900g) mass detector of similar configuration. Kg scale detector is taking data in underground lab under Jing-Ping Mountain. Cosmic ray muon background of 6 events per month per m2 has been measured that is similar to the expected one. Further background measurements are ongoing.

References:

[1] M. Drees and G. Gerbier, J. Phys. G **33**, 233 (2006)

[2] A. Bottino et al., Phys. Rev. D **72**, 083521 (2005)

[3] H. T. Wong et al., J. Phys. Conf. Ser. **39**, 266 (2006); H. T. Wong and H. B. Li, Mod. Phys. Lett. A **20**, 1103 (2005); H. B. Li et al., Phys. Rev. Lett. **90**, 131802 (2003); H. T. Wong et al., Phys. Rev. D **75**, 012001 (2007)

[4] S. T. Lin et al., Phys. Rev. D **79**, 061101(R) (2009)