Ultra Low Energy-Ultra Low Background High Purity Germanium Detectors for studies on Dark Matter

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Introduction

Weakly Interacting Massive Particles (WIMP, denoted by χ) are the leading DM candidates. Super symmetric particles (SUSY) are one of the leading WIMP candidates. The popular SUSY models prefer WIMP mass m_χ in (10 – 100) GeV range. The simple extension of standard model with a singlet scalar favours light WIMPs. Most of the experimental programs optimize their design in the higher mass region and exhibit diminishing sensitivities for $m_\chi < 10$ GeV. To probe this least explored region **T**aiwan **EX**periments **O**n **N**eutrin**O** collaboration is pursuing research and development program by using **H**igh **P**urity **Ge**rmanium detectors (**HPGe**). These detectors offer a matured technology to scale up the detectors and achieve sub-keV level threshold i.e. few hundreds of eV, economically. The various detectors developed by the collaboration is shown in the below figure. The current goal of the collaboration is to develop detectors of kg-scale target mass, ~100 eV threshold and low-background specification for the studies on WIMPs, μ_ν and neutrino - nucleus coherent scattering.

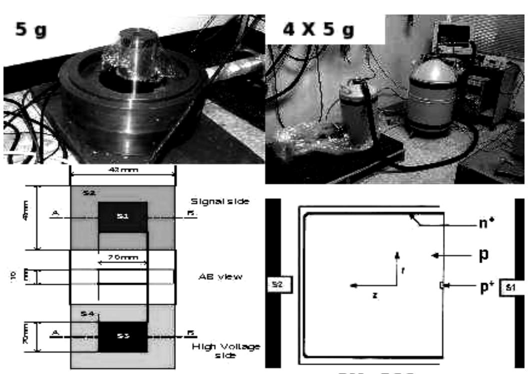

Fig. 1: In clock wise from top left 5g, 4 x 5g, 500g point contact and 180g ULE-HPGe detectors.

In this article we will present the new limits set on the spin-independent WIMP-nucleon ($\sigma^{SI}_{\chi N}$) and spin-dependent WIMP-neutron ($\sigma^{SD}_{\chi N}$) cross-section for WIMP mass between 3-6 GeV by using a four channel ULE-HPGe detector each with an active mass of 5g. We will also project in detail about the point contact germanium detector and its physics potential.

($\sigma^{SI}_{\chi N}$) and ($\sigma^{SD}_{\chi N}$) studies by using 4X5 ULE HPGe

Constrains on WIMP in the galactic halo were derived by using data acquired by 4X5 g ULE-HPGe at Kuo-Sheng laboratory. The energy threshold of the detector is (220±10) eV was achieved at an efficiency of 50% and the data acquisition live time was 0.338 kg-day. The details of the detector design; shielding configuration, data acquisition, and electronics are in ref. [1, 2] and for the detailed analysis procedure and event selection are in ref. [1].

Exclusion plots on both plans at 90% confidence level for galactic bound WIMP's were then derived and are depicted in the figure 2(a & b), respectively. The constraints on effective axial four fermions χ–proton and χ–neutron spin dependent coupling at $m_\chi = 5$ GeV are displayed in figure 2(c). It can be seen that the work extends the bounds on WIMPs by making measurements in a new energy region of 100eV–1keV in a low background environment. Understanding and suppressing of the background in this energy region is crucial for further improvement.

Point Contact Germanium Detector

This detector technology is not only offering scaling up the detector mass and sub-keV threshold but also showing ability to distinguish single and multi-hit events. This phenomenon will help in a better study on the background suppression and effective enhancement in signal to noise ratio. Preliminary

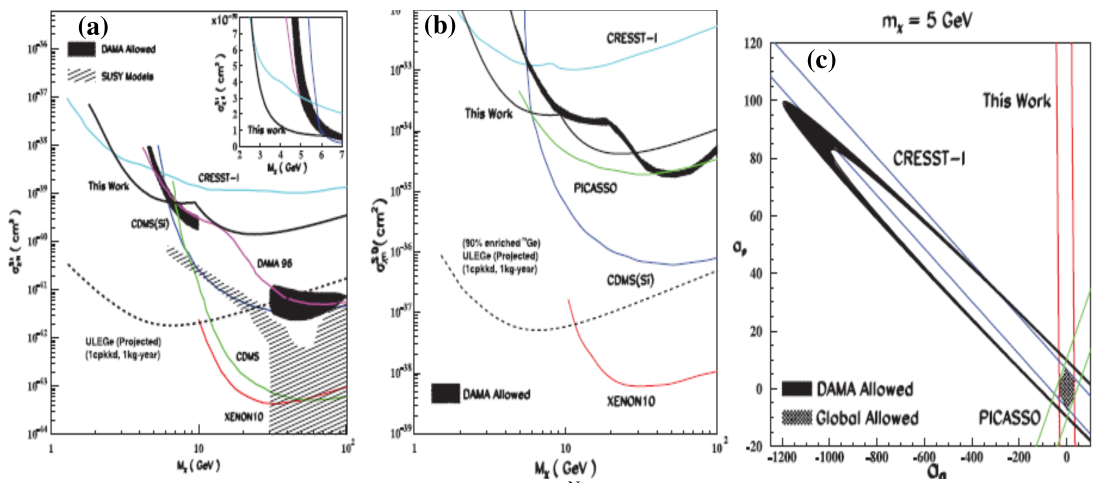

Fig. 2: Exclusion plots of (a) the spin independent χ^N (b) the spin dependent χ– neutron cross-section Vs WIMP mass, displaying the KS-ULEGe limit and those defining the current boundaries. The DAMA allowed region is superimposed. The striped regions are those favoured by SUSY models. Projected sensitivities of full scale experiment are indicated as dotted lines. (c) Constraints at m_χ = 5 GeV on the effective axial four fermion χ–proton (a_p) and χ–neutron (a_n) spin dependent couplings in units of $2\sqrt{2}G_F$. The shaded area at the origin is the combined allowed region.

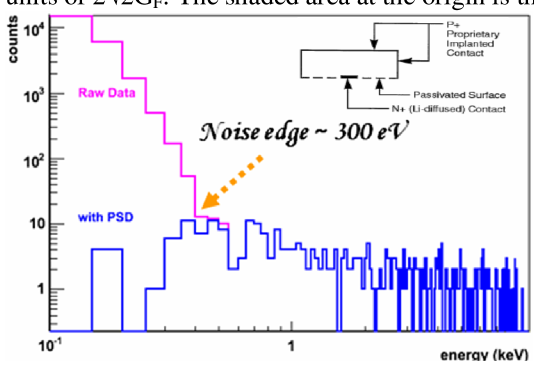

Fig. 3: Spectrum displaying the low energy threshold of Point Contact Germanium detector.

results in dark matter searches are under progress. The mass-normalized external background will be reduced in massive detectors because of self-attenuation. A further reduction in threshold may be possible with improved junction field-effect transistors and by correlating signals from both electrodes. This will enable the detector's applications in the area of neutrinoless double beta decay experiments.

Channeling effect in Crystals

Motion of an ion in inorganic scintillators differs substantially in many respects from that in amorphous solids. The ordered arrangement of nuclei in crystals makes possible the so-called channeling of ions propagating along certain directions. The deep penetration of 4 keV ions into a Ge crystal to a depth λ_c~10^3 Ă has been explained by the ion stopping power decreasing strongly along some directions in a

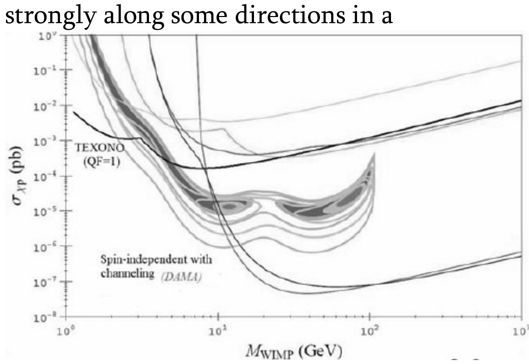

Fig. 4: Exclusion plots of WIPM's mass for different experiments after including channeling.

crystal. We expect that channeling should play a dominant role in measurement of low energy recoil ions with crystal detectors. The making and breaking of quasi-molecular bonds of channeled ions with ions in the channel walls, impurity of crystals etc. may influences the value of quenching factor. Cross section of WIMP with respect to WIMP mass is shown in figure 4.

References

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