Low Energy Neutrino and Astroparticle Physics with sub-KeV Germanium Detector

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Introduction

We present an overview of the current research program TEXONO Experiment to develop ultra-low energy germanium detectors to achive better than 100 eV sensitivities for Neutrino and Dark Matter experiments.The novel design of Point-Contact Germanium (PCGe) detectors offers the potential merits of sub-keV sensitivities with kg-scale target mass. The low threshold provides unique probe to low-mass Weakly interacting massive particle (WIMP) and neutrino-nucleus coherent scattering, as well as neutrino magnetic moments. A PCGe of mass 500 g was constructed and has been collecting data at the Kuo-Sheng Reactor in Taiwan.Latest results will be presented. A four-channel Ultra-Low-Energy Germanium (ULEGe) prototype detector with a total active mass of 20 g has collected low-background data at KSNL [1]. An energy threshold of (220±10) eV was achieved at an efficiency of 50%. The background spectrum with 0.338 kg-day of exposure is observed, The Constraints on WIMP-nucleon spin independent and spin dependent couplings as a function of WIMP-mass were derived. Status on the construction and installation of a new underground facility in Sichuan, China, for a dedicated dark matter experiment will be reported.

RESULTS ON DARK MATTER SEARCHES

WIMPs are the leading Dark Matter candidates. Super symmertic particle(SUSY) are one of the leading WIMP candidtes. The

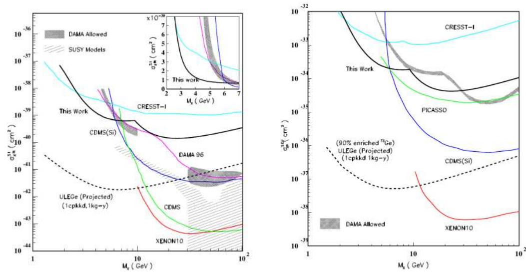

FIG. 1: Exclusion plot of the spin-independent $\chi-$neutron cross-section versus WIMP-mass (b)Exclusion plot of the spin-independent χN cross-section versus WIMP-mass.

popular SUSY models prefer WIMP mass m_χ in 10 to 100 GeV range. The simple extension of the standard model with singlet scalar favours of light WIMPs. Most of the experimental programs optimize their design in the higher mass region and exhibit diminishing sensitivities for $m_\chi < 10$ GeV A scientific goal is to develop advanced detectors with kg-size target mass, 100 eV-range threshold and lowbackground specifications for WIMP searches as well as for the studies of neutrino-nucleuscoherent scatterings and neutrino magnetic moments (μ_ν). The KS laboratory is located 28 m from a 2.9 GW reactor core and has an overburden of about 30 meter-water-equivalence (mwe). Its facilities are described in Ref.[1], where 500g germanium detector (HPGe) at a hardware threshold of 500 eV has been collecting data since 2009. The experimental procedures were well-established and the background above 12 keV about ~ 1 event $kg^{-1}keV^{-1}day^{-1}$(cpd)

A four-channel Ultra-Low-Energy Germanium (ULEGe) prototype detector with a to-

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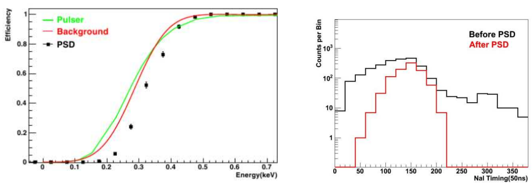

FIG. 2: (a) The trigger and analysis efficiency of the 500 g PCGe detector.(b)Events as a function of relative timing between NaI(Tl) and PCGe systems, before and after PSD selection.

tal active mass of 20 g has collected low-background data at KSNL [2]. Constraints on WIMP-nucleon spin-independent [σ_N^{SI}] and spin-dependent($\sigma_N^{SD}(n)$) couplings as functions of WIMP-mass (m) were derived as depicted in Figs. 1&2,The KSNL limits improve over previous results at $m \sim 3$ to 6 GeV. Sensitivities for full-scale experiments at 1 cpd background level are projected as dotted lines. The observable nuclear recoils at $m = 5$ GeV and $\sigma_N^{SI} = 0.5 \times 10^{-39}$ cm^2(allowed) and $1.5 \times 10^{-39} cm^2$ (excluded) are superimposed with the measured spectrum.

PERFORMANCE OF POINT-CONTACT GERMANIUM DETECTORS

The design of Point-Contact Germanium (PCGe) detectors was first proposed in the 1980s [3], offering the potential merits of sub-keV sensitivities with kg-scale target mass.There are successful realization and demonstration of the detector technique [4]. In KS laboratory where the experimental study with 500g PCGe at hardware threshold of 500eV are reported.

The trigger efficiencies were measured with two methods. The trigger efficiencies depicted in Figure 4 correspond to the fractions of the distributions above the discriminator threshold level, while the studies on the amplitude distributions of in situ data contributed to the other. Events in coincidence with ACV-tags are mostly physics-induced. The relative timing between the PCGe and anti-Compton (ACV) NaI(Tl)detectors is shown in Fig. 3,The fraction of these events surviving the PSD cuts was taken to be the PSD efficiency. This assignment is conservative since the actual efficiency corresponds to the survival fraction of samples after electronic noise events in accidental coincidence were subtracted,and therefore should be higher.

Events in coincidence with ACV at the 50 to 200 ns window are due to multiple Compton scatterings, which are actual physical processes having similar pulse shapes as the neutrino and WIMP signals. It can be seen that only these events have substantial probabilities of surviving the cuts, and the fractions constitute to the PSD efficiencies. The threshold at $\sim$50% combined efficiencies is $\sim$300 eV. Intensive background and optimization studies with the PCGe at KSNL are underway.

CHINA JIN-PING UNDERGROUND LABORATORY

The dark matter limits of Ref. [2] are by-product results of an experimental configuration optimized for neutrino physics. It is essential that the program will evolve into a dedicated dark matter search experiment in an underground location. An excellent candidate site for a deep underground laboratory was recently identified in Sichuan, China where the China Jin-Ping Laboratory (CJPL) is being constructed . The laboratory has more than 2500 m of rock overburden, is accessible by a road tunnel built for public traffic, and is supported by excellent infrastructures already available near the entrance. The first cavern of size 6 m(height) $\times$ 6 m(width) $\times$ 40 m(depth) has been completed.

References

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