Sub-keV Germanium Detectors for Neutrino and Dark Matter Experiments

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Introduction

Germanium detectors with sub-keV sensitivities have been demonstrated as efficient means to probe Weakly Interacting Massive Particles. This novel detector technique is also adopted in the studies of neutrino-nucleus coherent scattering with reactor neutrinos. The theme of TEXONO-CDEX Collaboration (Taiwan experiment on neutrino-China dark matter experiment) is to explores high-purity germanium (HPGe) detection technology to develop a sub-keV threshold detector for pursuing studies on low energy neutrino and dark matter physics.

The generic benchmark goals in terms of detector performance are: (1) modular target mass of order of 1 kg; (2) detector sensitivities reaching the range of 100 eV; (3) background at the range of 1 kg^{-1} keV^{-1} day^{-1}

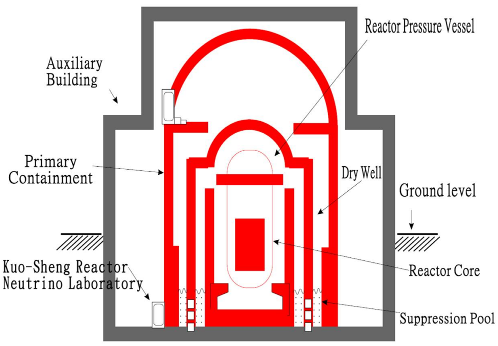

FIG. 1: Schematic diagram of Kuo-Sheng Reactor Neutrino Laboratory (KSNL).

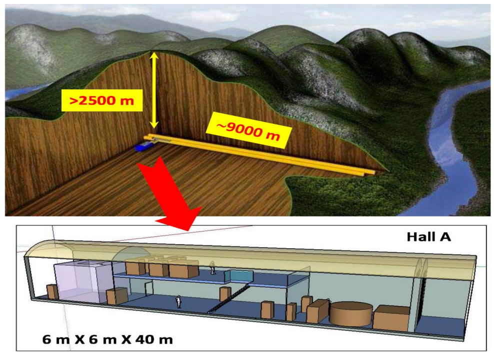

FIG. 2: Schematic diagram of China Jin-Ping Underground Laboratory (CJPL).

(cpkkd). The neutrino physics program is being pursued at the established Kuo-Sheng Reactor Neutrino Laboratory (KSNL), while dark matter searches will be conducted at the new China Jin-Ping Underground Laboratory (CJPL). The two facilities are depicted schematically in Figure 1 and Figure 2. The collaboration has developed and used several HPGe detectors like commercially available 1 kg coaxial HPGe, partially customized 4 x 5 g ultralow background (ULB) HPGe, 500 g and 900 g point contact germanium detectors (PCGe).

Neutrino Physics at KSNL

The physical origin and experimental consequences of finite neutrino masses and mixings are not fully understood. Investigations on anomalous neutrino properties and interactions are crucial to address these fundamental questions and may provide hints or constraints to new physics beyond the Standard Model (SM)[1]. The TEXONO program has contributed to the studies of neutrino magnetic moments with a 1-kg high-purity ger-

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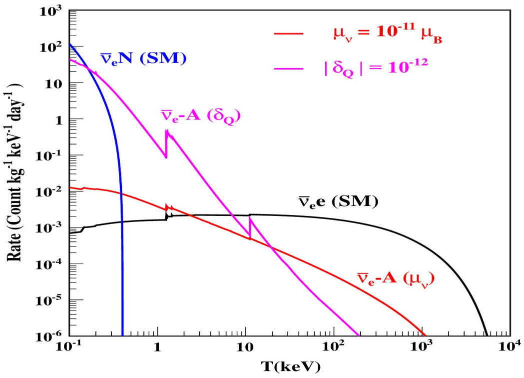

FIG. 3: The differential cross-section of the various neutrino interaction channels at KSNL with Ge as target, where $\phi(\nu_e^-) = 10^{13} cm^{-2} s^{-1}$ and $\mu_\nu = 10^{-11} \mu B$.

manium detector (HPGe), neutrino-electron cross-section with a 200-kg CsI(Tl) scintillator array. With the advent of detectors with sub-keV sensitivities, atomic ionization has been identified as a promising avenue to probe possible neutrino electromagnetic properties. The interaction cross sections induced by millicharged neutrinos are evaluated with the ab initio multiconfiguration relativistic random-phase approximation[1].

Based on reactor neutrino data taken at KSNL with 500-g n-type point contact germanium detector at an analysis threshold as low as 300 eV are studied. No such signatures are observed, and a combined limit on the neutrino charge fraction of $\delta_Q < 1.0$ x 10^{-12} at 90% confidence level is derived[1]. The various neutrino-induced interactions at KSNL are shown in Figure 3.

Cold Dark Matter Searches at KSNL and CJPL

The WIMPs interact with matter predominantly via the same coherent scattering mechanism like the neutrinos: $\chi + N \rightarrow \chi + N$. There are both spin-independent and spin-dependent interactions between WIMP and matter. Supersymmetric (SUSY) particles are the leading WIMP candidates. The popular

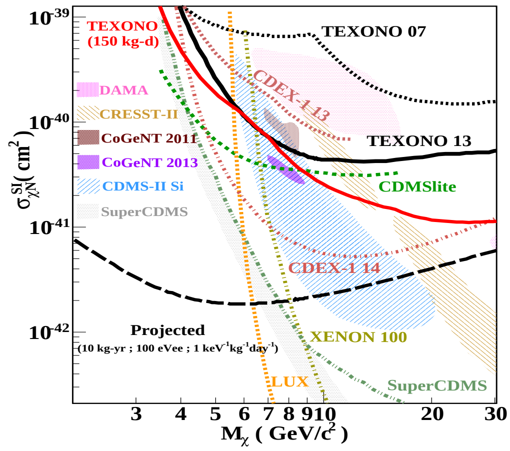

FIG. 4: Exclusion plot of spin-independent coupling, superimposed with the results from other benchmark experiments.

SUSY models prefer WIMP mass (m_χ) of the range of ~100 GeV. There are several experiment exploring < 10 GeV WIMP mass region such as DAMA, CDMS-II(Si), CDMS-II(Ge-Low), CoGent, CRESET-I, CRESET-II, XENON100, LUX. There are increasing theoretical interest in this light-WIMP region, which include models on light neutralinos, non-pointlike SUSY candidates like Q-balls, as well as WIMPless, mirror, asymmetric, and singlet fermionic dark matter. To probe the low-mass region, detector with sub-keV threshold is necessary [2].

Based on data taken at the KSNL and CJPL with p-type point-contact germanium detector having fiducial mass 840 g and 994 g respectively, We report new limits on a spin-independent weakly interacting massive particle (WIMP)-nucleon interaction cross section as shown on figure 4 [2].

References

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[2] H. B. Li et al., Phys. Rev. Lett. 110, 261301 (2013), H. B. Li et al., Astroparticle phys. 56, 1-8 (2014), Q. Yue et al., arXiv:1404.4946 (2014).