Constraints on Spin-Independent Nucleus Scattering with WIMP Dark Matter for CDEX and TEXONO Experiments under the Earth Attenuation Effect

C.-H . Yeh[1]*, H. B. Li[1], and H. T. Wong[1]

[1]*Institute of Physics, Academia Sinica, Taipei 11529*
**email of Corresponding author: a95101303@gate.sinica.edu.tw.*

Abstract: In our research, we investigate limits on spin-independent WIMP-nucleus scattering cross-section, considering both earth and shielding effects. Beyond the extreme cross-sections for dark matter with different masses could be blocked from reaching detectors. Our results using (1)nuclear recoil, incorporating (2)Midgal effect, (3)Bremsstrahlung, and (4)Electron recoil are presented with CDEX(underground experiment)and latest TEXONO(Surface experiment) data. In particular, the very low mass region, which is between 0.06GeV and 0.16 GeV, can be excluded by TEXONO data with the higher cross-sections that underground experiments cannot probe.
Keywords: WIMP, Direct-Detection Experiment, TEXONO, CDEX

1. Introduction

Weakly interacting massive particle (WIMP, denoted as χ)[1], which is the most popular candidate among the models of dark matter, catches many direct-detection experiments' eyes, such as TEXONO, CDEX, SuperCDMS, etcetera. Traditionally, WIMP-nucleus (χ-N) elastic scattering[1], also known as nuclear recoil (NR), through spin-independent(SI) and spin-dependent interactions are supposed to be the model exploited to set limits on the sensitivity of WIMP. Unfortunately, the experimental observable rapidly diminishes with lowering masses. How to accomplish the measurements on the lower masses of WIMPs is a crucial issue for all direct-detection experiments.

Recently, the theorists have come up with useful models of electro-magnetic final states based on the (χ-N) inelastic scattering, such as Migdal effect(MD)[2] for electronic final states as well as bremsstrahlung(BR)[2] for the photonic final states in search of low-mass dark matter(DM). In addition to that, the WIMP-electron (χ-e) inelastic scattering[3], also known as electron recoil(ER), is also the prominent model for discovering the low-mass DM. In our studies, those processes are used to set limits on the lower mass region of WIMPs with TEXONO and CDEX data. To aim at calculating the more precise counts for WIMPs reaching the detector, the attenuation effect is taken into account as the material on their ways to the detector could block them outside.

2. Technical Work

In our research, we exploit spectrums from four channels, encompassing NR, MD, BR, and ER, to set limits on WIMPs. The distributions of differential rates (recoil spectrums) from three of them are demonstrated in Fig. 1[2]: (ER is under-investigated)

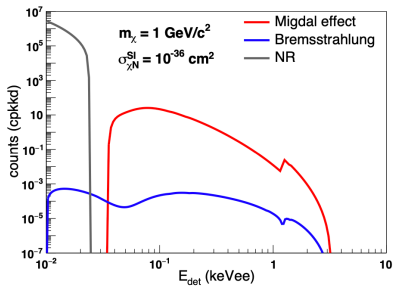

Fig. 1 The example of the differential rates from three channels at M_χ=1GeV and σ_{SI} =$10^{-36} c\,m^2$

We apply the Binned Possion method[4] to obtain the lower boundaries of cross-sections of WIMPs with TEXONO and CDEX data as well as the original flux(HALO model) of WIMPs. Fig. 2 shows setting limits at two mass points as instances from both experiments.

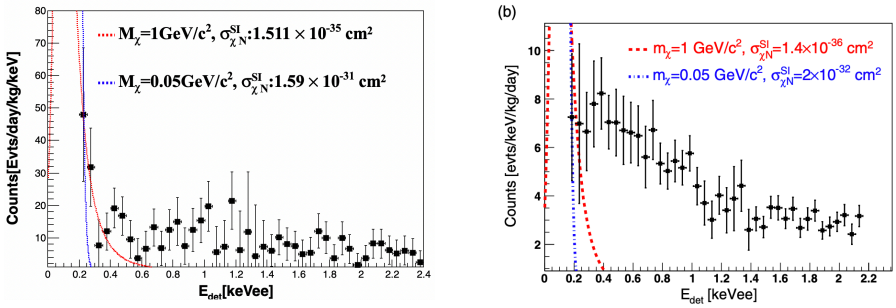

Fig. 2: The measured spectrums from TEXONO(left) and CDEX(right)[2] are demonstrated. With the Binned Possion method associated with the recoil spectrums of MD at 1GeV(red) and 0.05GeV(blue) WIMP masses, the cross-sections for both masses are shown in these two plots.

When the mass is getting lower, the higher cross-section can be observed. Under this circumstance, the attenuation effect on the flux of WIMPs can't be ignored. We use the real structure of the earth and the settings of both experiments to calculate the authentic flux. With the changing flux, we can recalculate the recoil spectrums again for the different masses and use the same method to figure out the true cross-sections. The exclusion plot we have done for now is in Fig.3. We will present the latest results in the talk.

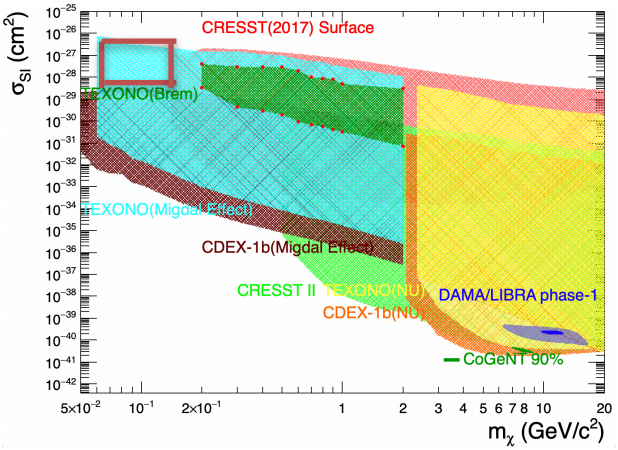

Fig.3 The exclusion plot for WIMPs from various experiments. The brown region is for CDEX with MD[2] and the shadow blue one is for TEXONO with MD. The deep green one is for TEXONO with BR. The most intriguing thing is that between 0.06GeV and 0.16 GeV, the region within σ_{SI} from 10^{-29} to 10^{-26} can be excluded by TEXONO data, which is not excluded by other experiments.

3. Conclusions

In conclusion, the lower mass region can be achieved with MD as well as BR using CDEX and TEXONO data. The higher cross-section region within the mass region between 0.06 and 0.16 GeV/c2 can be explored with TEXONO data, which cannot be probed by other experiments.

References

1. Richard W. Schnee, Physics of the Large and the Small, pp. 775-829 (2011)
2. Z. Z. Liu *et al.* (CDEX Collaboration), Phys. Rev. Lett. **123**, 161301(2019)
3. Mukesh K. Pandey *et al.,* Phys.Rev.D 102,123025(2020)
4. C. Savage et al., J. of Cosmol. Astropart. Phys. 04, 010 (2009)