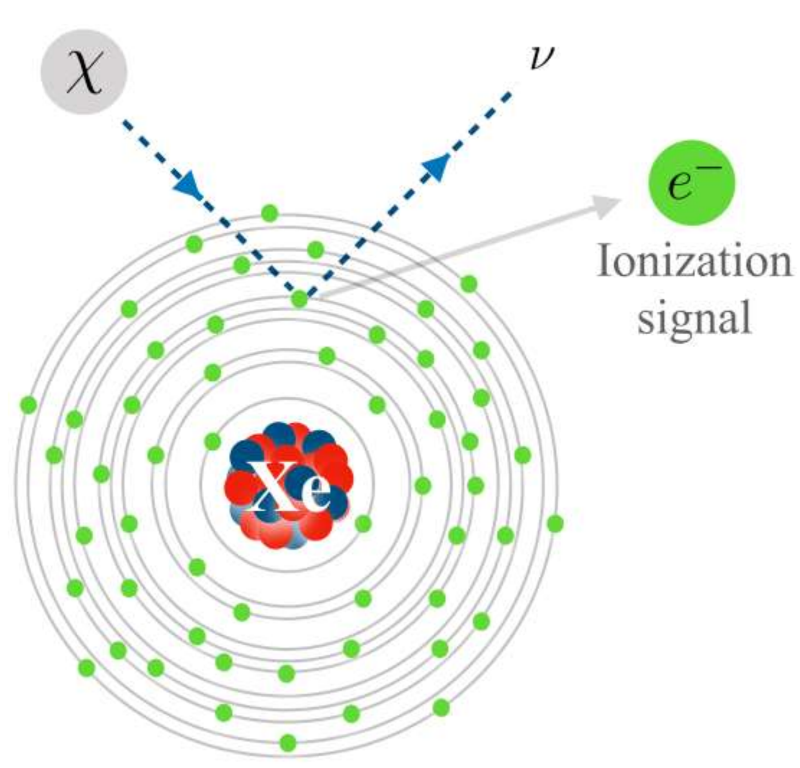
Light Fermionic Dark Matter Absorption on Electron Targets

Jie Sheng (盛杰) *[shengjie04@sjtu.edu.cn]*
2016-2020 Scholarship, Jilin University.
2020-Now PhD, Tusng-Dao Lee Institute, Shanghai Jiao Tong University.

Research Interests:
High Energy Physics, Dark Matter Phenomenology

Fermionic DM Absorption on Electron Target with EFT Approach

$$\chi + e^- \to \nu + e^-$$



$$\mathcal{O}^S_{e\nu\chi} \equiv (\bar{e}e)(\bar{\nu}_L \chi_R),$$
$$\mathcal{O}^P_{e\nu\chi} \equiv (\bar{e}i\gamma_5 e)(\bar{\nu}_L \chi_R),$$
$$\mathcal{O}^V_{e\nu\chi} \equiv (\bar{e}\gamma_\mu e)(\bar{\nu}_L \gamma^\mu \chi_L),$$
$$\mathcal{O}^A_{e\nu\chi} \equiv (\bar{e}\gamma_\mu\gamma_5 e)(\bar{\nu}_L \gamma^\mu \chi_L),$$
$$\mathcal{O}^T_{e\nu\chi} \equiv (\bar{e}\sigma_{\mu\nu} e)(\bar{\nu}_L \sigma^{\mu\nu} \chi_R),$$

1. Efficient Energy Transfer

Energy Conservation:

$$m_\chi = E_R + |p_\nu|, \quad E_R = \frac{|p_e|^2}{2m_e}.$$

Momentum Conservation:

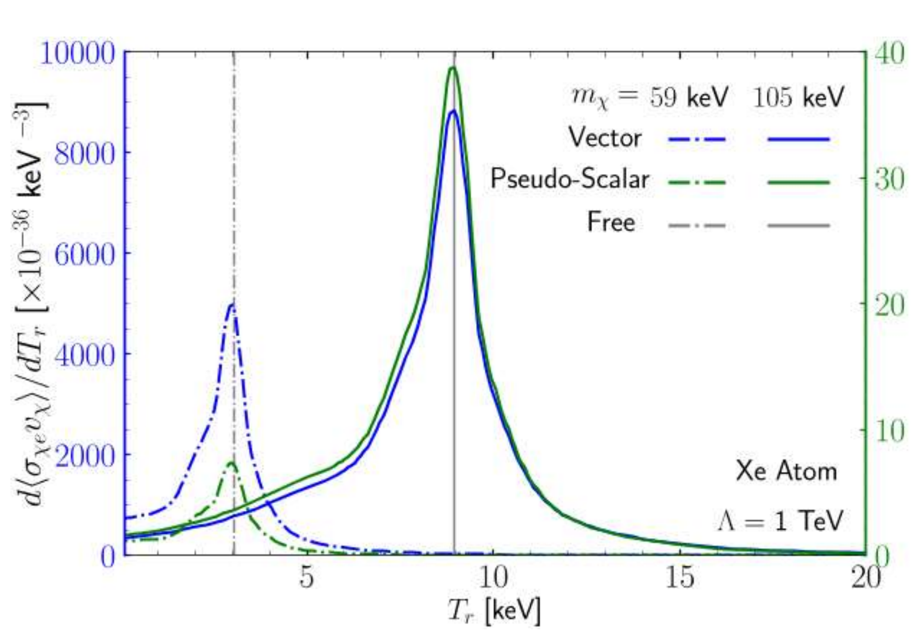
$$|p_e| = |p_\nu|.$$

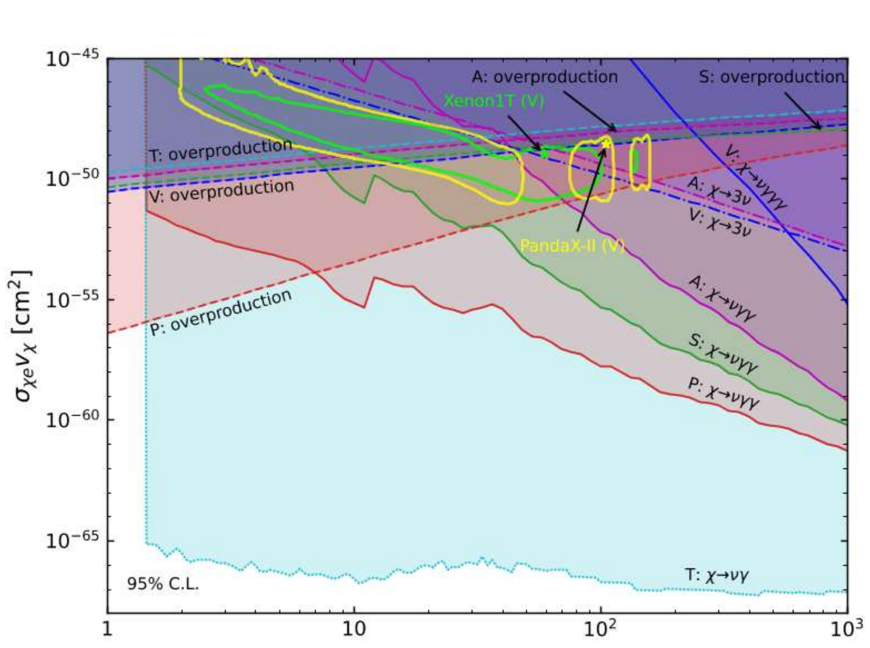
Recoil Energy:

$$E_R \simeq \frac{m_\chi^2}{2(m_T + m_\chi)} \sim \text{keV} \rightarrow m_\chi \sim 100\text{keV}.$$

DM absorption has the largest energy transfer efficiency for all the energy of DM can participant into the scattering process. This makes a 100 keV DM detectable in direct detection experiments.

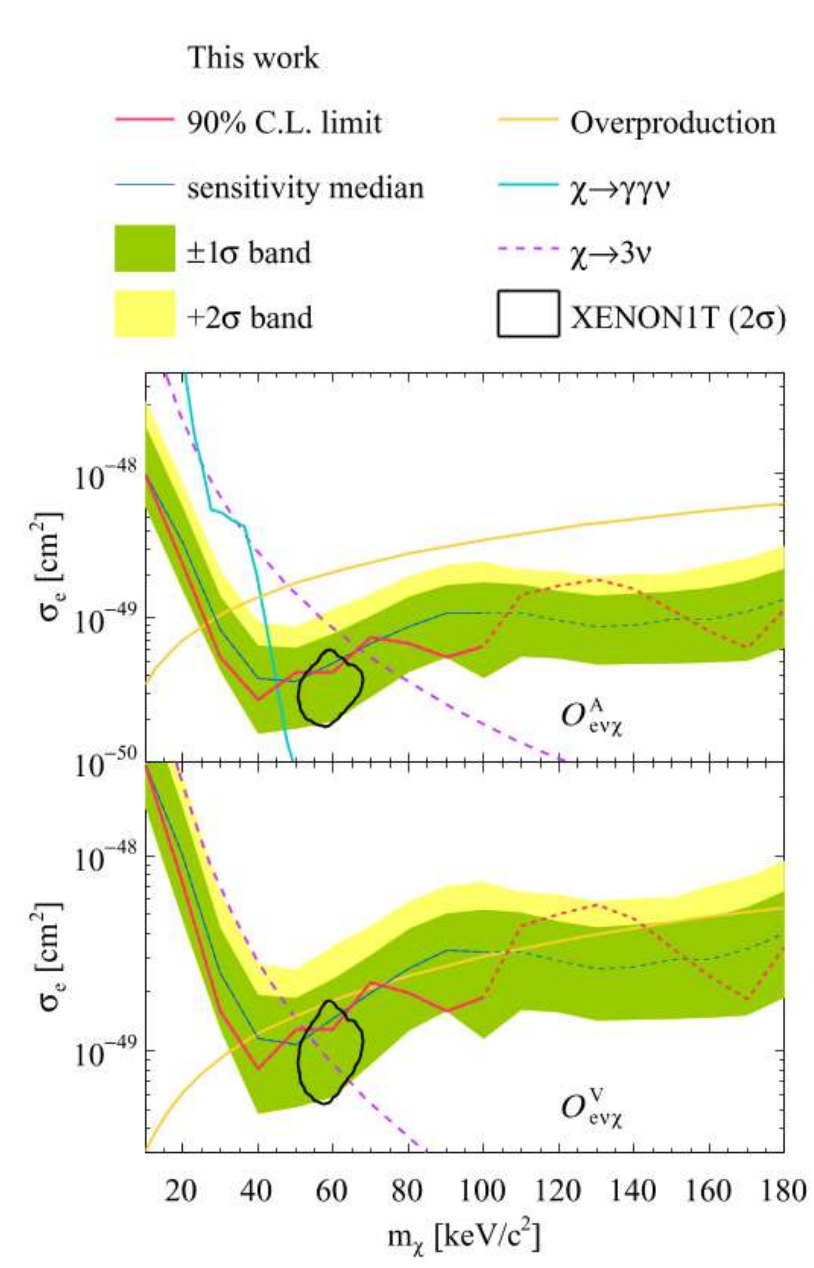
2. Spectrum with Atomic Effects





The upper panel shows the DM absorption on free electron target generates a fixed recoil energy as the gray lines. However, the electron inside an atom is bound by Coulomb potential and described by wave function with momentum distribution. The atomic effects enlarge the phase space and make the energy spectrum expand to a special finite peak. Fit it with Xenon-1T and PandaX-II data, we can get the sensitivity contour in the lower-panel. We find the parameter space for vector interaction still survive after considering all the Astro- and Cosmo-limits. [1]

3. Constraints From PandaX-4T



The first run of PandaX-4T data does not announce any definite events of fermionic DM absorption scenario. It gives the 90% C.L. limits shown in the plot. Because of the large energy efficiency, we can constrain the DM with mass down to keV scale in Xenon-based detector for the first time. Furthermore, the peaked-like spectrum makes data easy to distinguish. So this direct detection constraint is stronger than the limits from astrophysics and cosmology in some mass range. [2]

[1] Shao-Feng Ge, Xiao-Gang He, Xiao-Dong Ma, **JS** [JHEP 05 (2022) 191]
[2] PandaX + Shao-Feng Ge, Xiao-Gang He, Xiao-Dong Ma, **JS** [Phys.Rev.Lett. 129 (2022) 16, 161804]

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