Relevant Models on low mass dark matter and our results

- **WIMP standard models**
- **Axion-like model**
- **WIMP with Magnetic moment**
- **Leptophillic Dark Matter**
  (χ-e scattering)
- **Some models on low mass dark matter**

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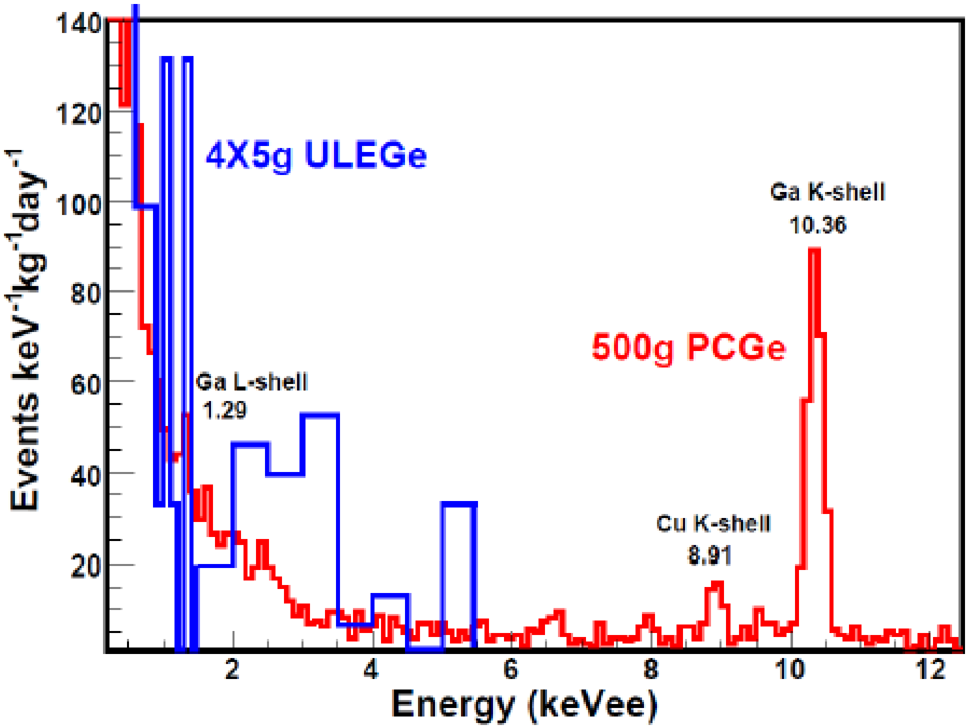
@Academia Sinca . MHEP Journal Club 11April 2011

Low Energy background at KSNL

- Background Understanding & Subtraction
  - generic γ-like source
  - residues of cosmic–induced
  - surface events at low energy
- Threshold reduction by software



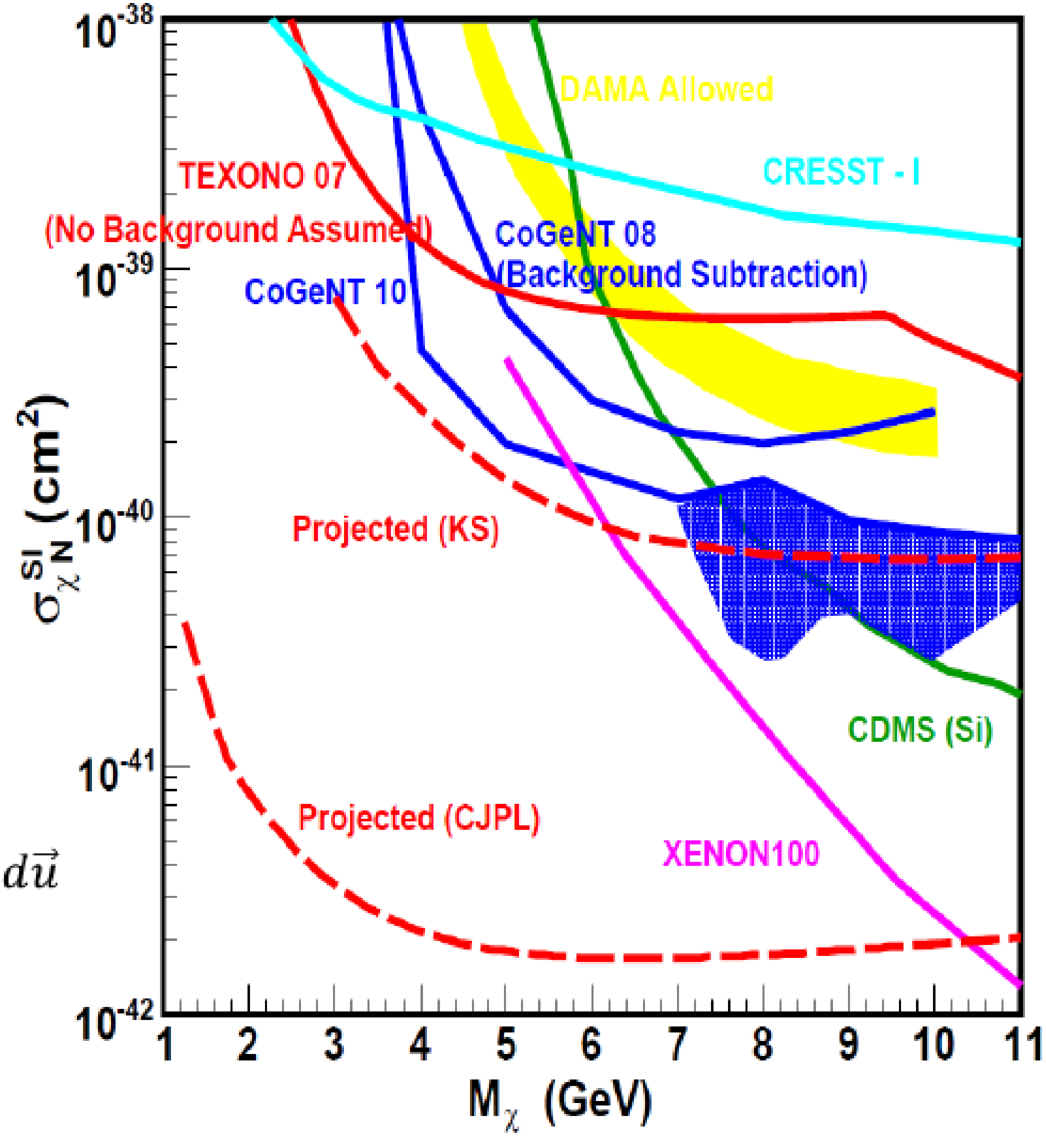
Spin independent with standard halo model

- **Scalar Coherent scattering**

$$\sigma_{0,SI} = \frac{4\mu^2}{\pi}\{Zf_p + (A-Z)f_n\}^2$$

$$f_p \approx f_n, \sigma_{0,SI} = \sigma_p\left(\frac{\mu}{\mu_p}\right)A^2$$

$$\frac{dR}{dE_{rec}} = \frac{\sigma_{0,SI}\mid F(E)\mid^2}{2m\mu^2}\rho\int_{u>v_{min}}^{u<v_{esc}}\frac{f(\vec{u},t)}{u}d\vec{u}$$



Spin dependent (χn) with standard halo model

- χ-n scattering due to $_{73}$Ge

$$\sigma_{SD}(q) = \frac{32\mu^2 G_f^2}{2J+1}\left(a_p^2 S_{pp} + a_p a_n S_{pn} + a_n^2 S_{nn}\right)$$

- $_{73}$Ge matrix element adopted

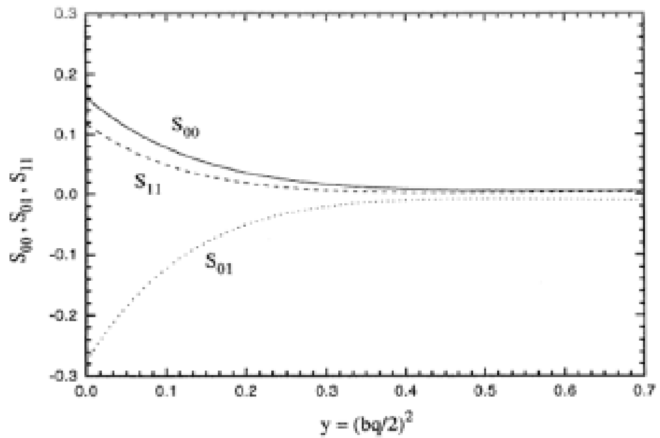
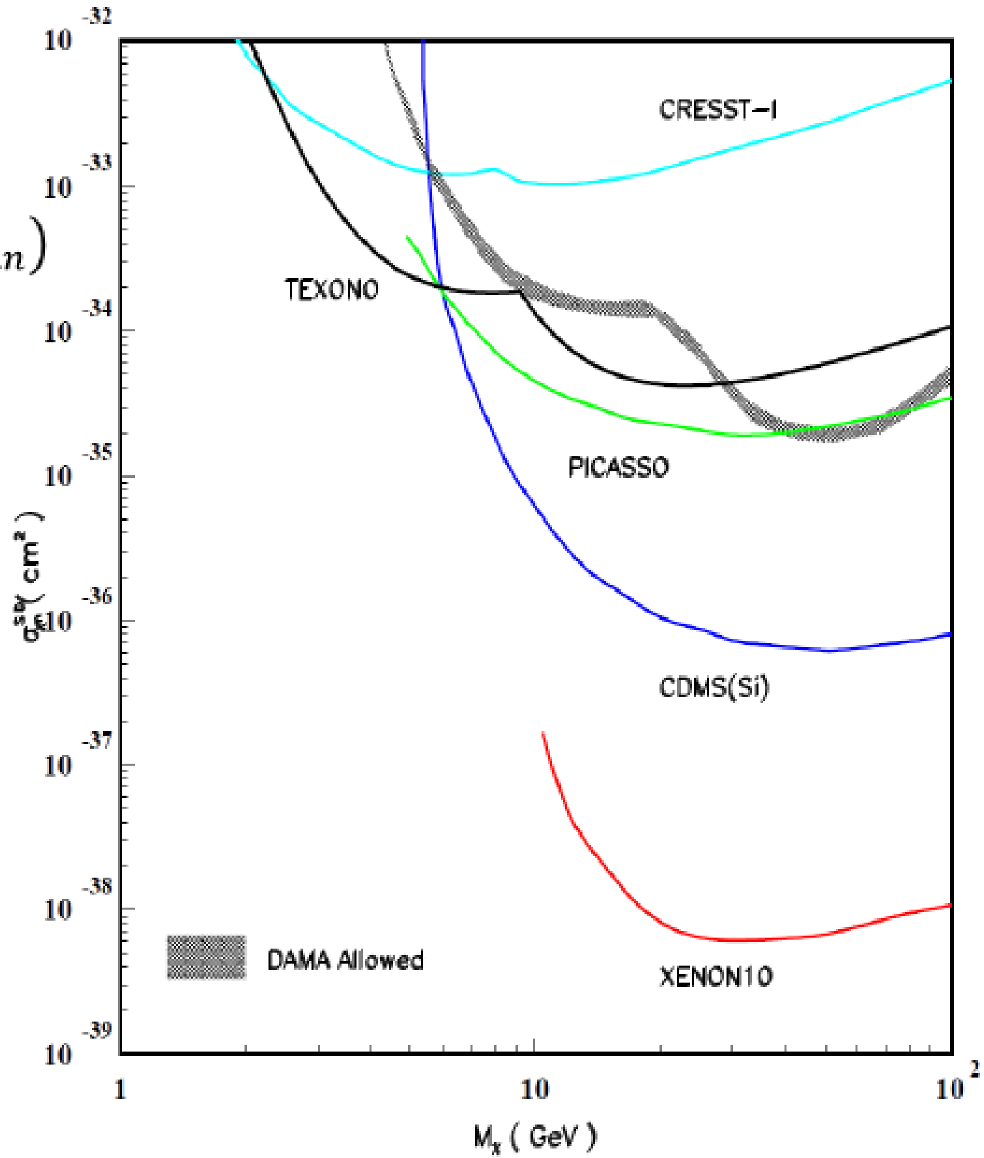


FIG. 1. The calculated functions S_{00}, S_{01}, and S_{11} for ^{73}Ge, as a function of $y=(bq/2)^2$ (b is the harmonic-oscillator length parameter). The solid line is S_{00}, the dashed line is S_{11}, and the dotted line is S_{01}. These functions are defined in Refs. [6,21].

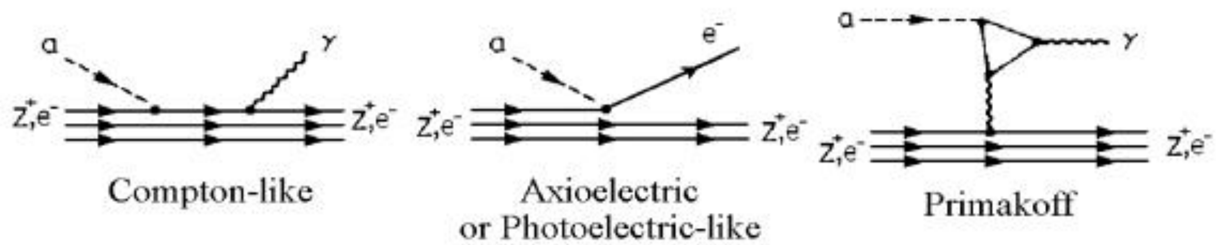


Our results is particular unique in

(a) Low threshold (to ~100 eV)

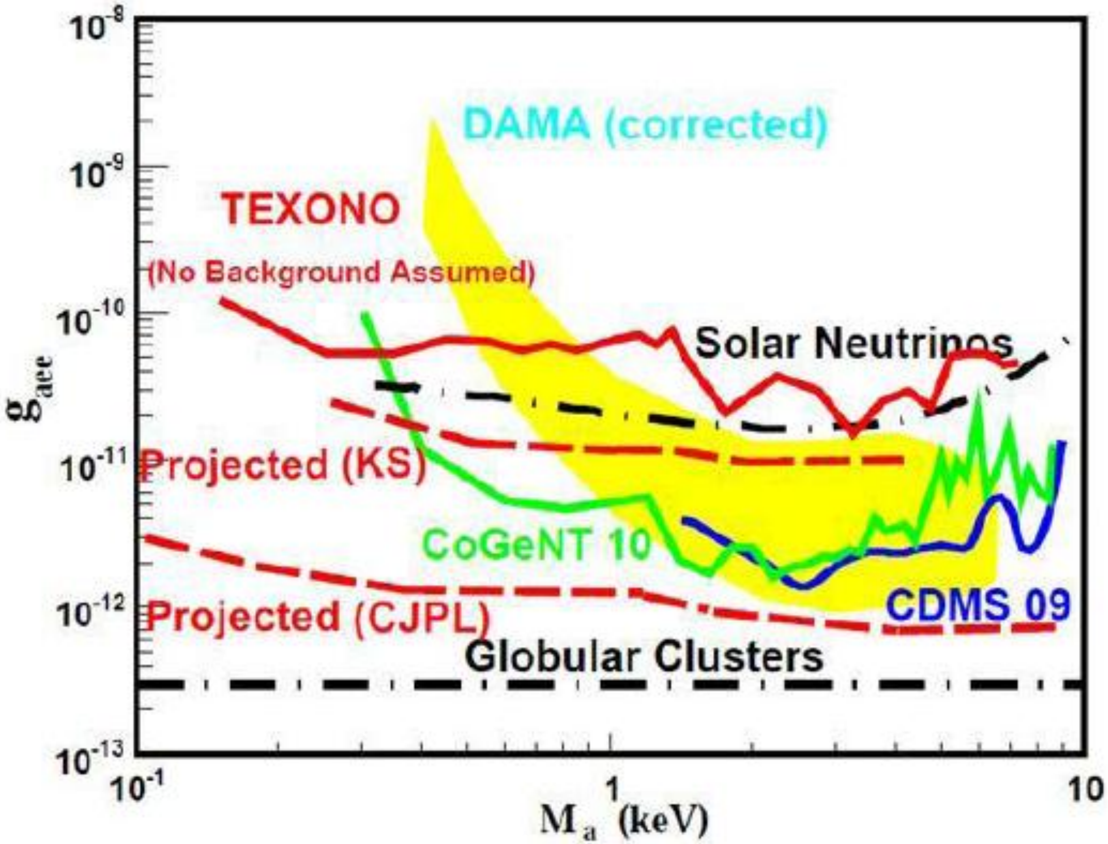
(b) Sensitive to electromagnetic final-states (unlike CDMS, XENON)

Dark Matter as axion-like particle (*pseudo -scalar*)

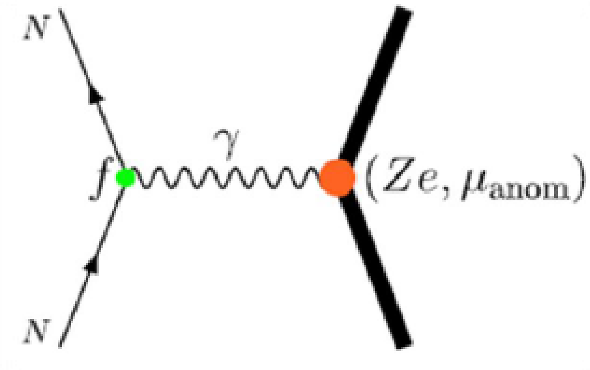


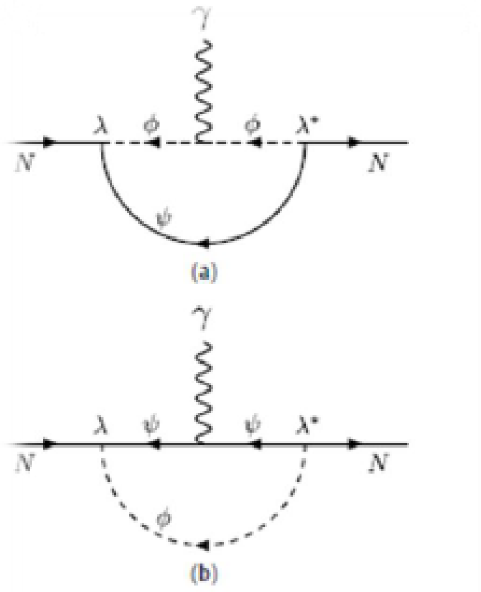
$$R \simeq \frac{1.2 \times 10^{19}}{A} g_{aee}^2 \left(\frac{m_a}{\text{keV}}\right)\left(\frac{\sigma_{photo}}{\text{bn}}\right) \text{ kg}^{-1}\text{day}^{-1}$$

Formula: Pospelov et al. PRD 78, 115012 (2008)



WIMP with magnetic moment





ne-loop diagrams for the magnetic moment of N.

$$\frac{ef}{2m_N}\bar{N} i\sigma^{\mu\nu} N F_{\mu}$$

- **Magnetic Moment of WIMP**

$$f = \frac{|\lambda|^2 m_N^2}{16\pi^2}\int_0^1 dx \left\{ \frac{q_\phi (x^2 - x^3)}{m_N^2 x^2 + (m_\psi^2 - m_N^2)x + m_\phi^2(1-x)} - \frac{q_\psi (x^2 - x^3)}{m_N^2 x^2 + (m_\phi^2 - m_N^2)x + m_\psi^2(1-x)} \right\}$$

$$\frac{d\sigma}{dE_{\rm rec}} = \frac{2\pi\alpha_{\rm em}^2 f^2}{M m_N^2 |\vec{p}|^2}\left[Z^2 \left\{ \frac{\Lambda_-(s, m_N^2, M^2)}{2ME_{\rm rec}} + (2m_N^2 + M^2 - s) \right\} + 2ZF_2(4m_N^2 - ME_{\rm rec}) + F_2^2 \left\{ \frac{\Lambda_+(s, m_N^2, M^2)}{M^2} - \frac{2sE_{\rm rec}}{M} + E_{\rm rec}^2 \right\} \right],$$

WIMP with magnetic moment

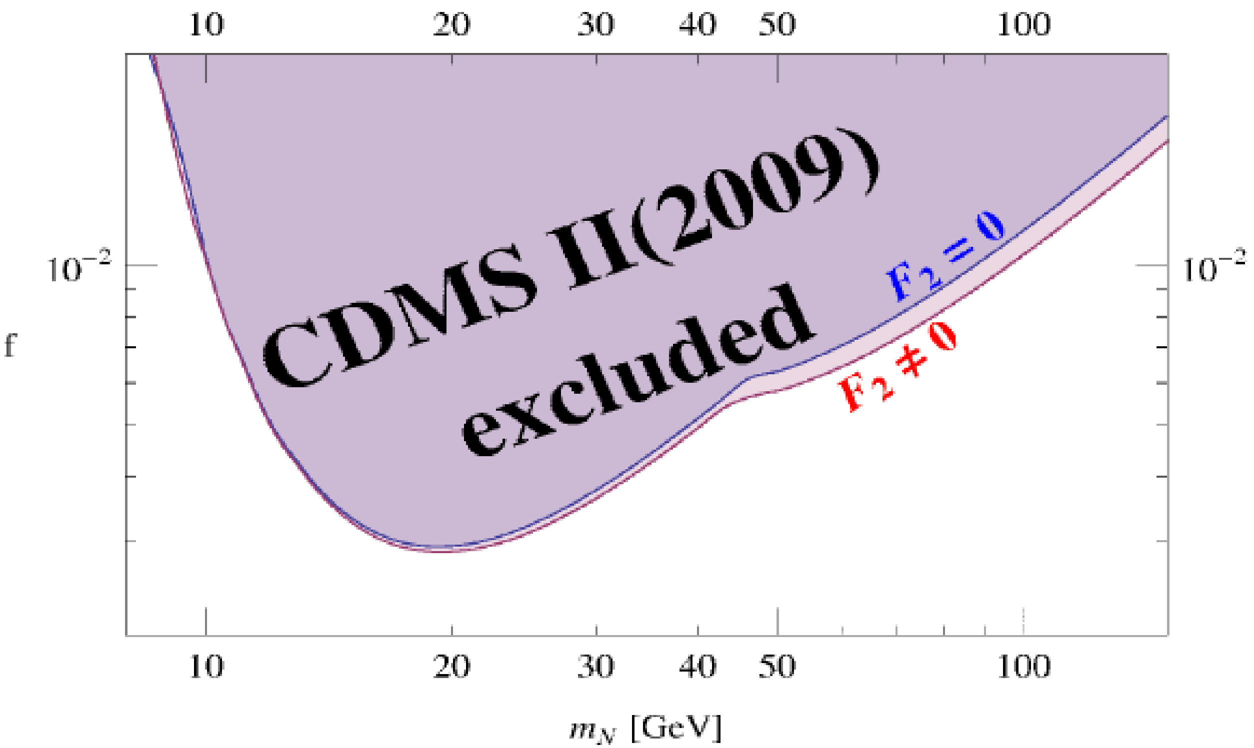


FIG. 5: The allowed region of the DM magnetic moment f vs. the DM mass m_N. The upper colored regions are excluded for $F_2 = 0$ and $F_2 \neq 0$, respectively, with the 90 % confidence level for the CDMS II data [6].

Leptophilic Dark Matter *PRD 80, 083502(2009)*

- ***Hypothesis***: *DM has tree-level interaction only with leptons*

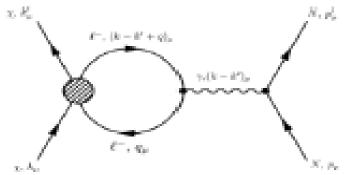
$$\mathcal{L}_{\text{eff}} = \sum_i G(\bar{\chi}\Gamma^i_\chi \chi)(\bar{\ell}\Gamma^i_\ell \ell) \quad \text{with} \quad G = \frac{1}{\Lambda^2}$$

- ***Signal in detection***

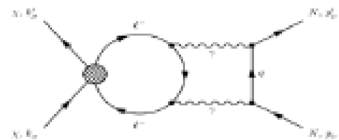
– *WIMP-electron scattering* : The whole recoil is absorbed by the electron that is then kicked out of the atom

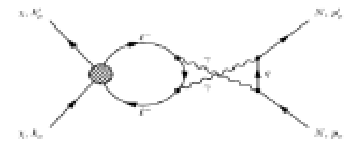
–*WIMP-atom scattering* : The electron on which the DM particle scatters remains bound and the recoil is taken up the whole atom

– *Loop induced WIMP-nucleus*



- ***For scalar, vector, tensor types***



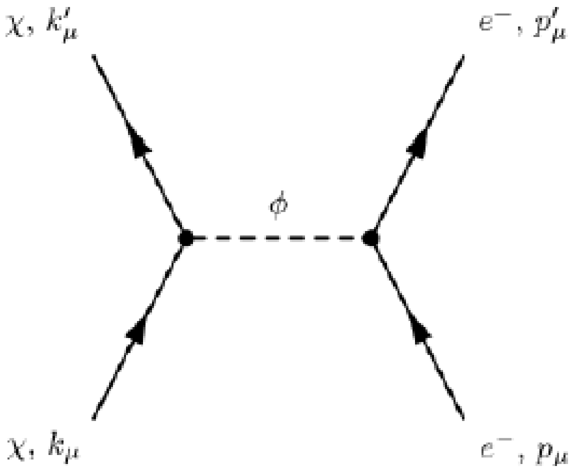


$$R^{\text{WAS}}:R^{\text{WES}}:R^{\text{WNS}} \sim 10^{-17}:10^{-10}:1$$

WIMP-electron scattering

- **Energy conservation :** $E'_e = m_e + E_d - E_B.$
- **Assume** $E_d \ll m_e \leq E_e \ll m_\chi$ and $v \sim 10^{-3}$

$$E_d \approx -\frac{p^2}{2m_\chi} - pv\cos\theta,$$



- **Event Rate**

$$\frac{dR^{\rm WES}}{dE_d} \simeq \frac{3\rho_0 m_e G^2}{4\pi(m_{\rm I} + m_{\rm Na})m_\chi} \sum_{nl} \sqrt{2m_e(E_d - E_{B,nl})}(2l+1) \int \frac{dp\,p}{(2\pi)^3} |\chi_{nl}(p)|^2 I(v_{\rm min}^{\rm WES})$$

$$I(v_{\rm min}) \equiv \int d^3v \frac{f_\odot(\mathbf{v})}{v} \theta(v - v_{\rm min})$$

$\chi_{nl}(p)$ is the momentum wave function

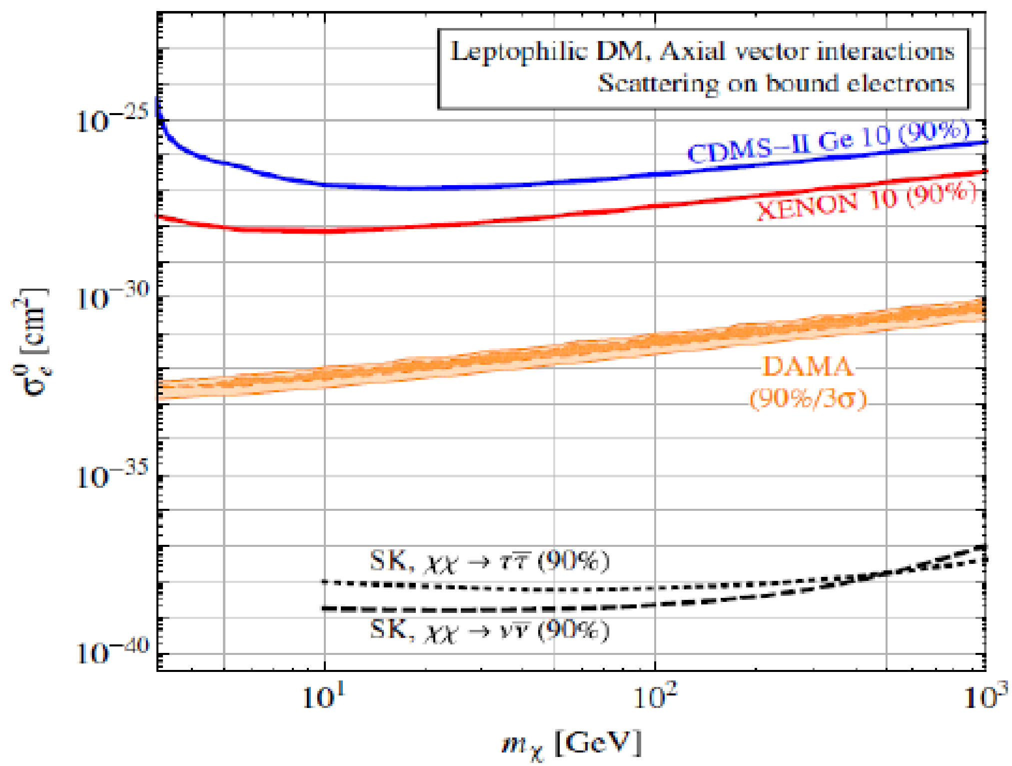
- **The minimal velocity required to get detectable energy**

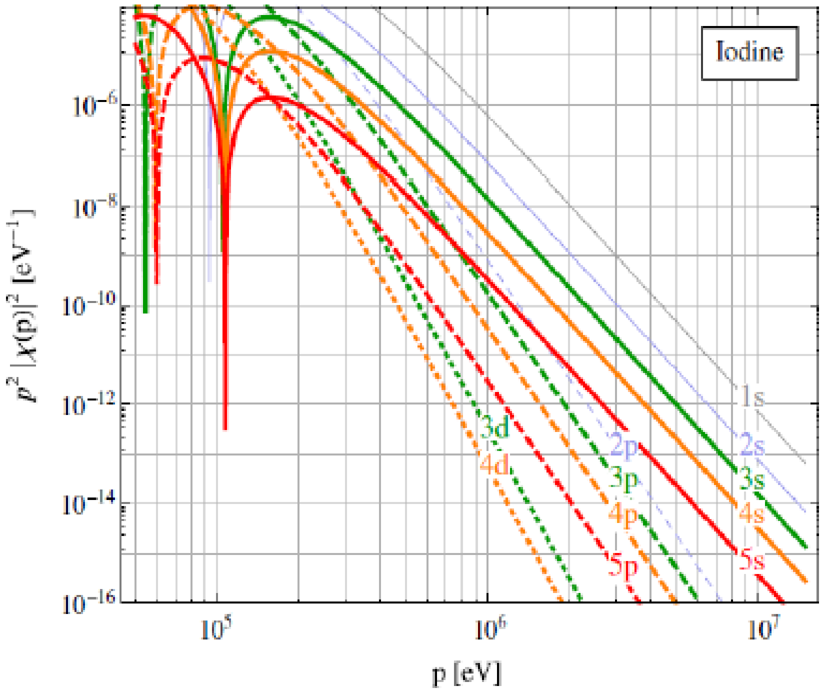
$$v_{\rm min}^{\rm WES} \approx \frac{E_d}{p} + \frac{p}{2m_\chi}. \qquad E_d \geq E_{B,nl}.$$

WIMP-electron scattering

- Maximal detectable energy from DM on electron at rest is
- Assume $v \sim 10^{-3}c$
- $p \sim \text{MeV}$ is required to obtain

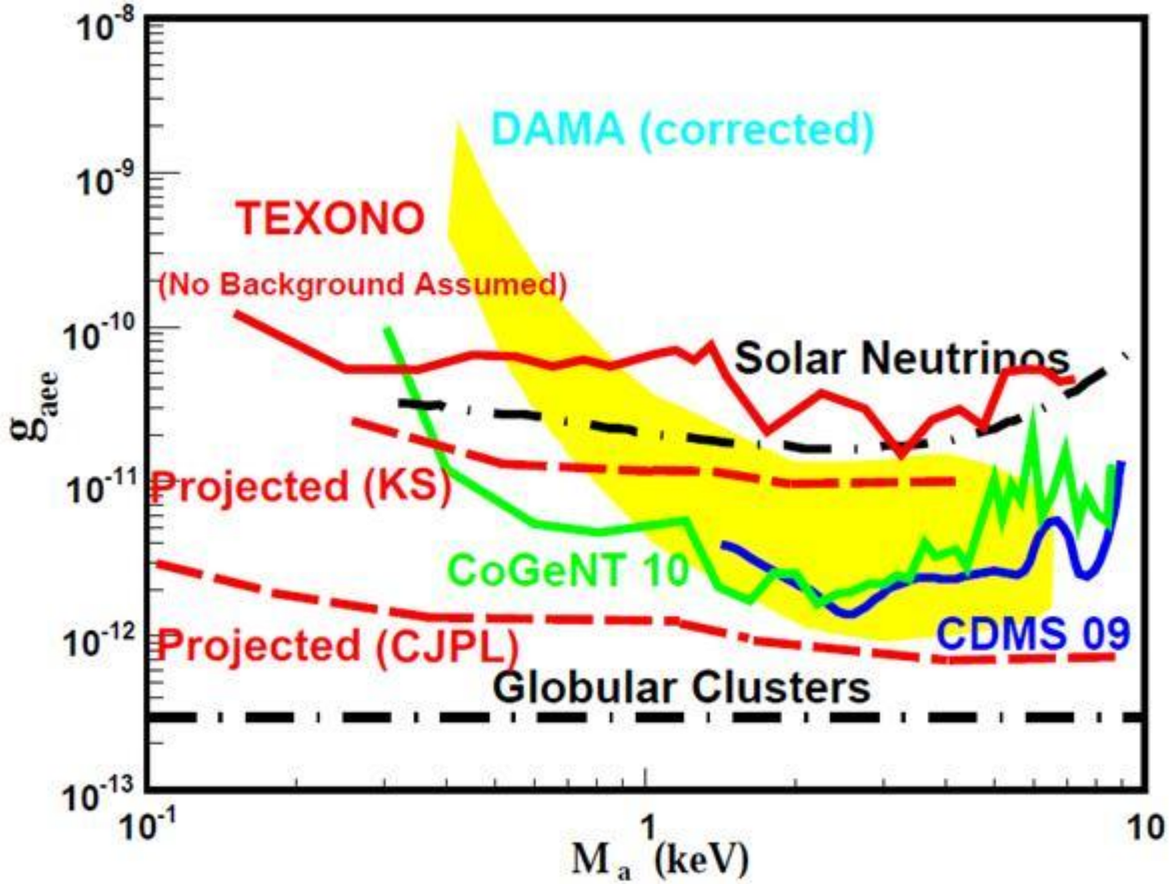
  $E_d \sim \text{keV}$





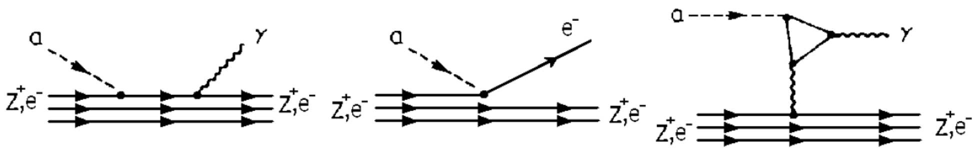
Toward to sub-GeV mass scale

Pseudoscalar Candidates (*axionlike*)



$$R \simeq \frac{1.2 \times 10^{19}}{A} g_{aee}^2 \left(\frac{m_a}{\mathrm{keV}}\right)\left(\frac{\sigma_{photo}}{\mathrm{bn}}\right) \ \mathrm{kg^{-1} day^{-1}}$$

Formula: Pospelov et al. PRD 78, 115012 (2008)



Highlights on Low Mass Dark Matter Models

- *WIMPless*
- *Mirror Dark Matter*
- *Asymmetric Dark Matter*
- *Single Fermion Dark Matter*
- *MSSM with MeV Dark Matter*

WIMPless Dark Matter

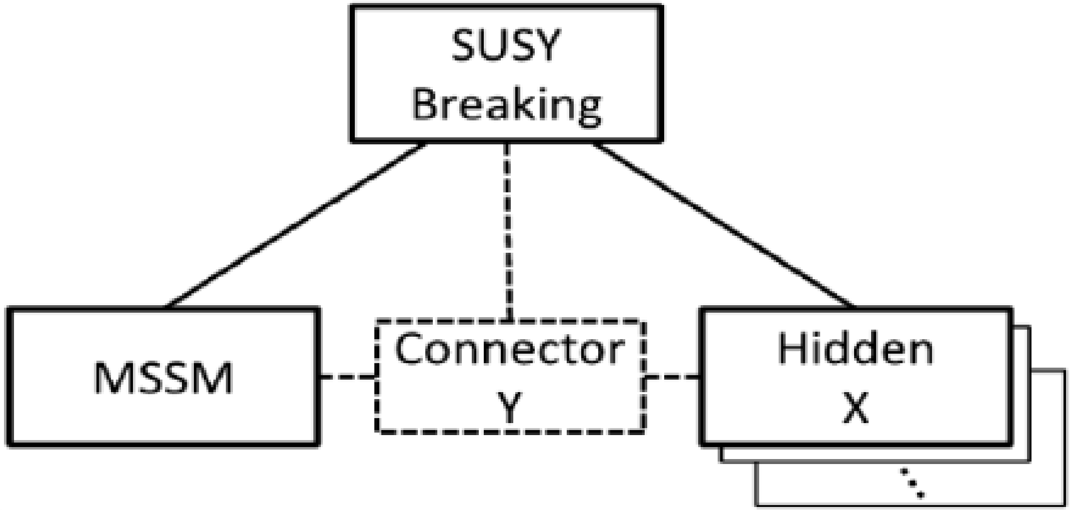
PLB, 670 37 (2008); PRL 101 231301(2008)

- *WIMPless DM provides a framework in which dark matter candidates with a wide range of masses naturally have thermal relic density*

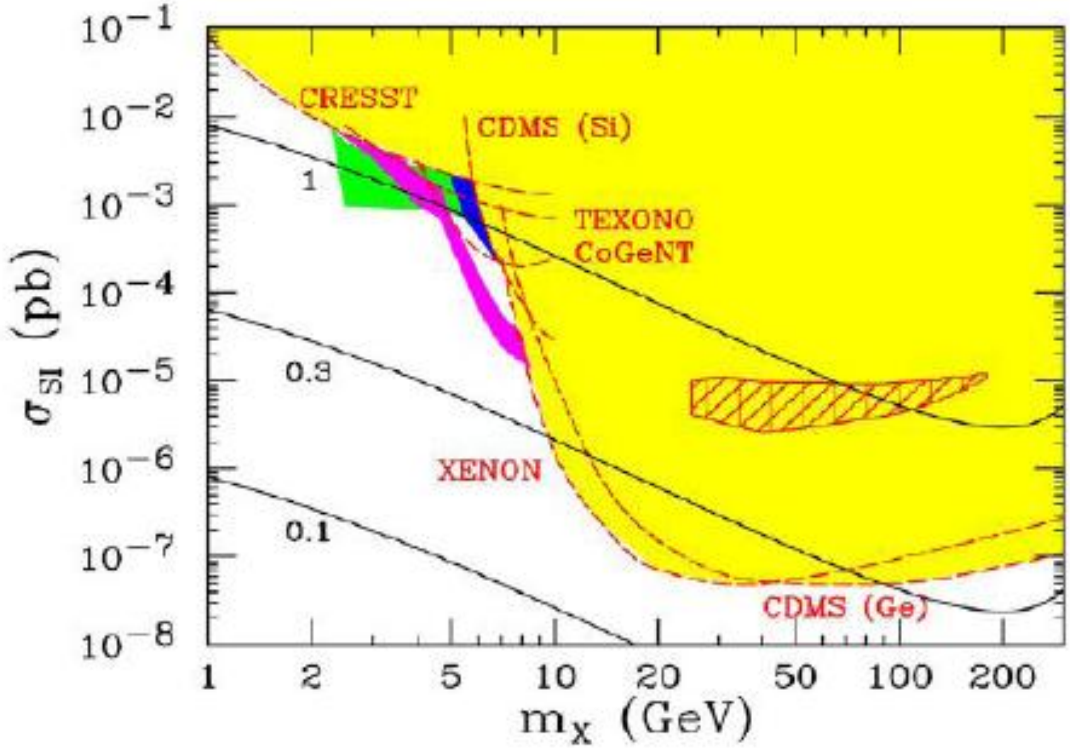
$$\frac{m_X}{g_X^2} \sim \frac{m_W}{g_W^2} \qquad \Omega \propto \frac{1}{\langle \sigma v \rangle} \sim \frac{m^2}{g^4},$$

where $m_W \sim 100$ GeV–1 TeV and $g_W \simeq 0.65$

- *Introduce hidden section X and connector particle Y*



WIMPless Dark Matter



- *Blue* : DAMA interpreted as WIMPless
- *Green* : DAMA includes *Magenta:* DAMA with channeling
- M_y= 400 GeV and Yukawa coupling indicated consistent with DAMA at low mass region

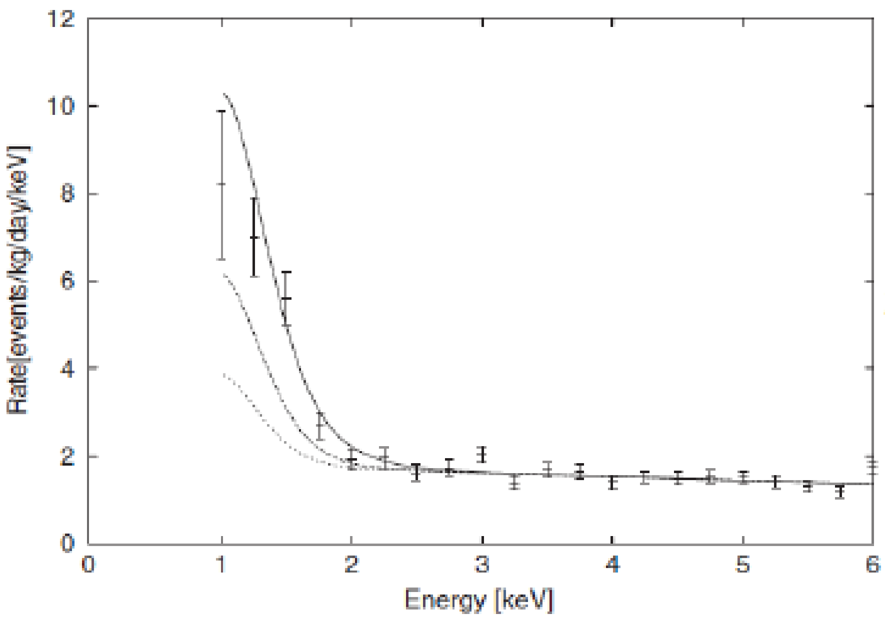
Mirror Dark Matter

PRD, 80 091701(2009)

- ***Assume the existence of a sector which is an exact duplicate of the ordinary matter sector***

$$\mathcal{L} = \mathcal{L}_{SM}(e, u, d, \gamma, \ldots) + \mathcal{L}_{SM}(e', u', d', \gamma', \ldots).$$

- ***The extra sector includes space-time parity symmetry.***



Mirror dark matter induced electron recoil recoils +background model

Asymmetric Dark Matter

PRD 79 115016 (2009)

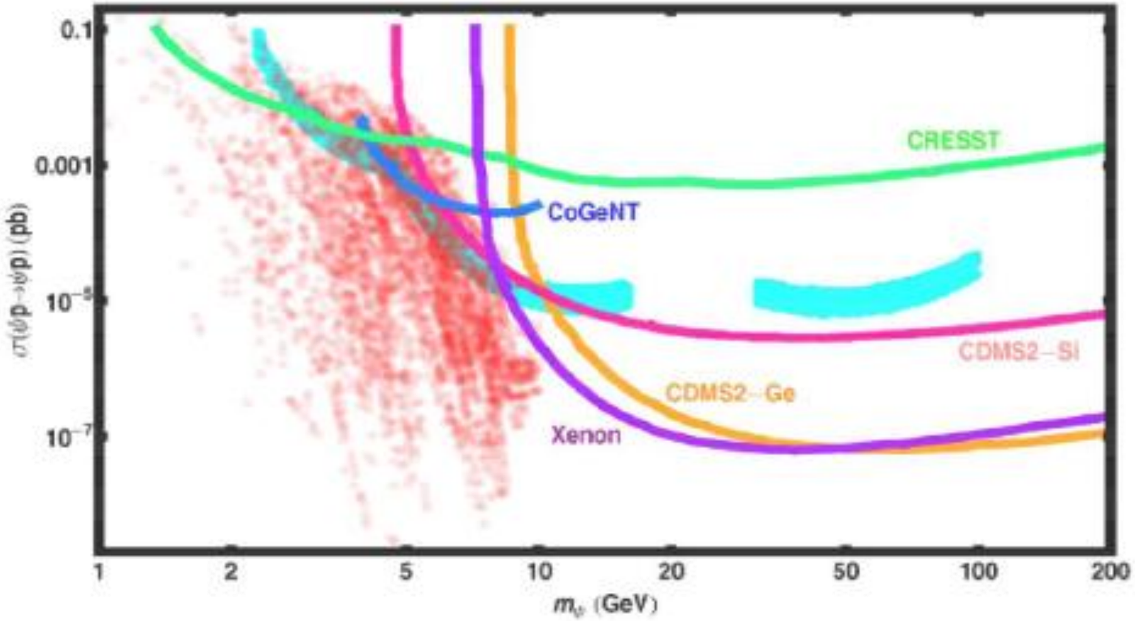
- *Assume the dark matter density arises from a dark matter particle-antiparticle asymmetry related to the B-L asymmetry*
- *Explain* $\rho_{DM} \sim \rho_{baryon}$ *in light of Dark matter and antiDark Matter asymmetry with the mass of* $5–15$ GeV.
- *However, in the standard paradigm, the densities of Dark Matter and Baryon arise by different mechanisms*

Single Fermion Dark Matter

JHEP 0905, 036(2009)

- *A standard model gauge singlet sector is introduced, which consists a real scalar filed and a singlet DM fermion*

- *The scalar field couples to the SM only through the SM Higgs Boson* $\mathcal{L} = \mathcal{L}_{SM} + \mathcal{L}_{hid} + \mathcal{L}_{int},$



MSSM with MeV Dark Matter

PRD 77, 087302(2008)

- *Motivation: Explain 511 keV photons from Galactic Bulge*

- *Due to the observed narrow width of 511 keV line, the annihilating (decaying or exciting) DM must have MeV mass*

- *Ratio between masses of DM and weak scale is 5 order of magnitude less.*

Status Plans

- **TEXONO-CDEX is particular unique in (a) Low threshold**

  (b) Sensitive to electromagnetic final-states
- **Survey and identify which particle or astrophysics models and detection channels in the market**
- ***Facility* : Dark Matter searches with *ULEGe* in *CJPL***
- ***Goals* : Find the nature of the Dark Matter particle(s) and the related astrophysical, nuclear and particle physics scenarios.**