Isospin Violating Dark Matter and Neutrinos From the Sun

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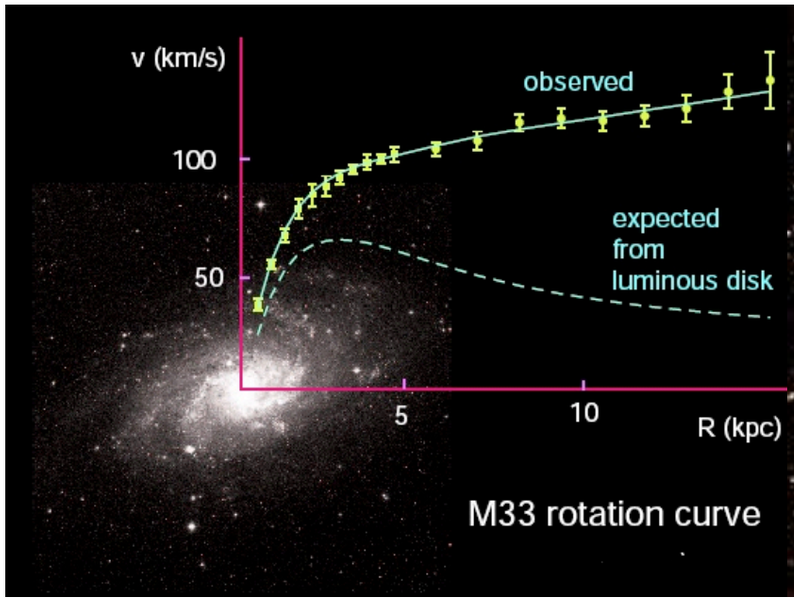
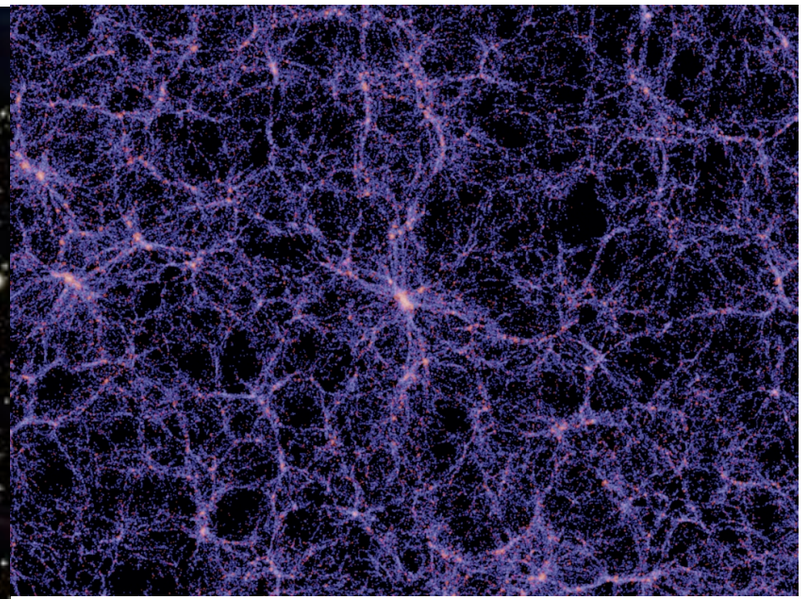
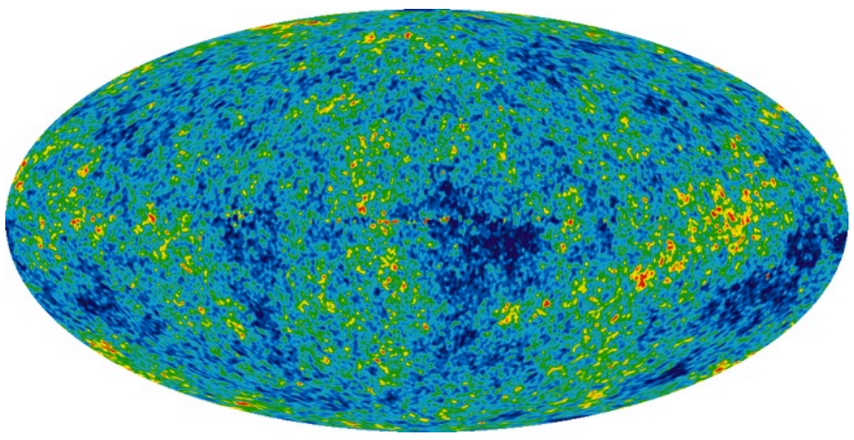
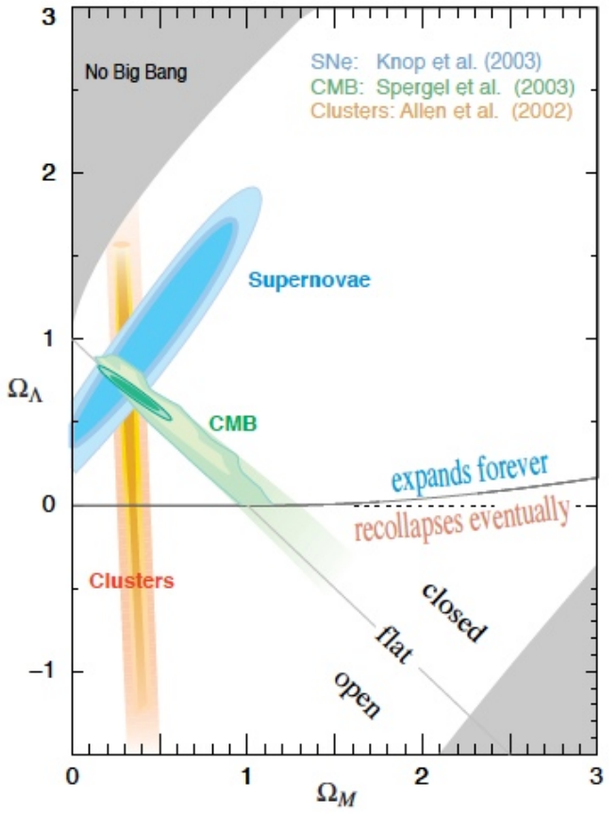
两岸粒子物理与宇宙学研讨会，重庆，2012年5月

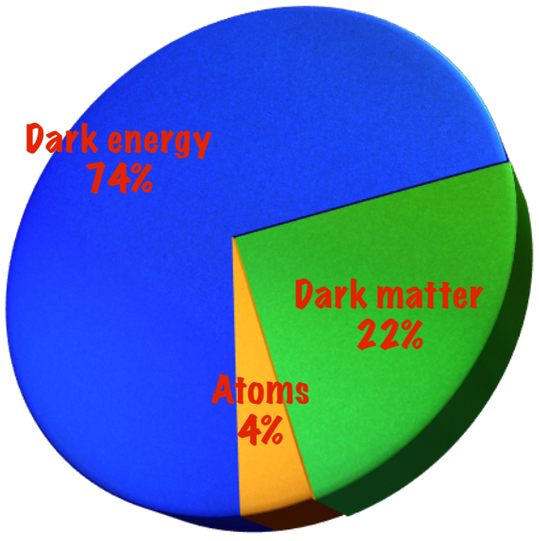
Evidence for DM (?)



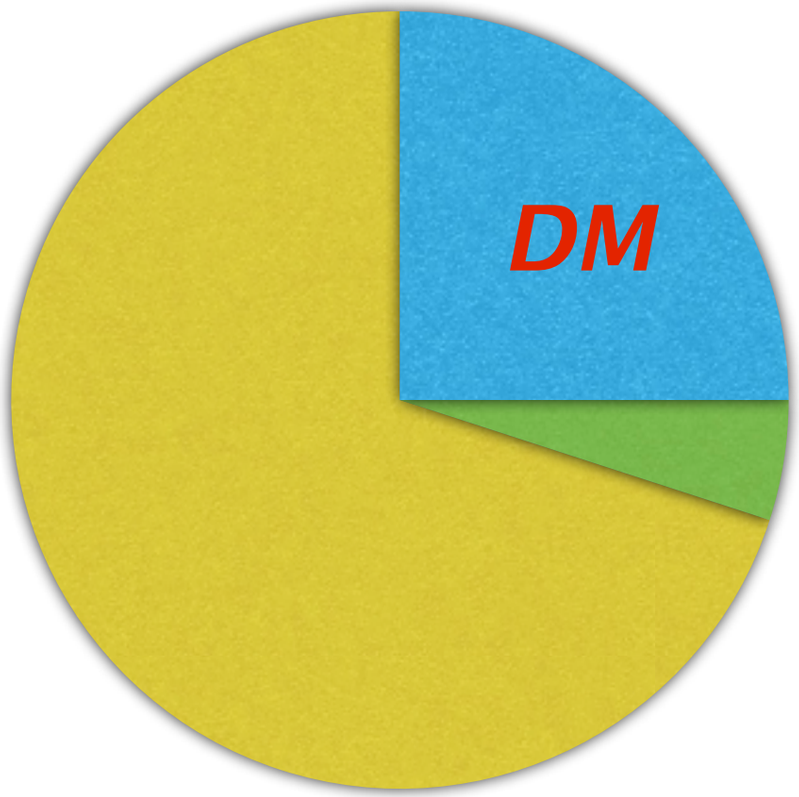








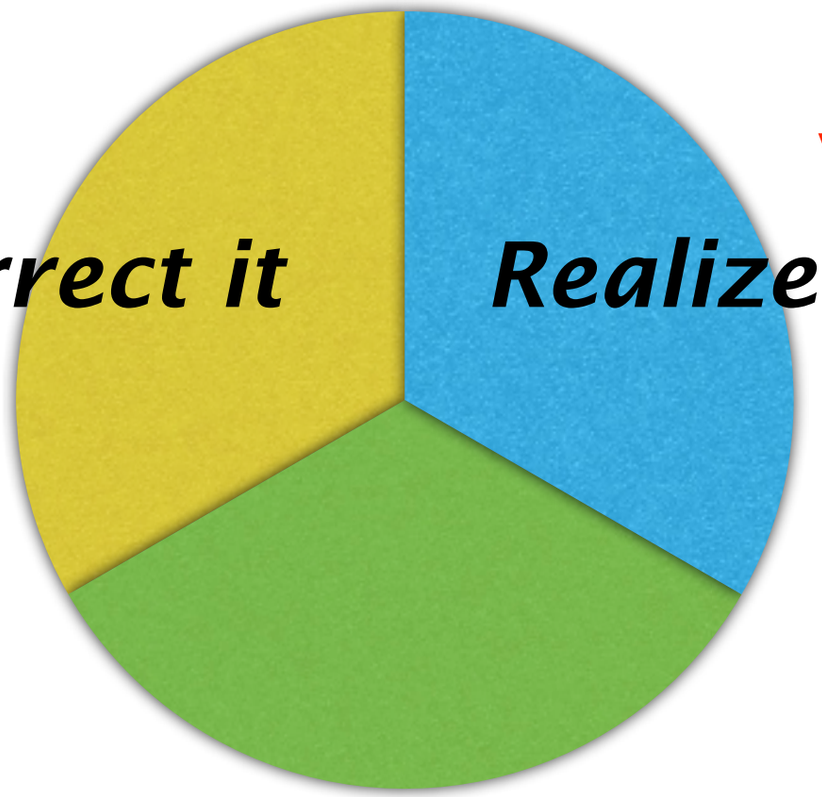
Question: Do you believe in Dark Matter?



Question: Do you believe in Dark Matter?

No!

Leave it / correct it



Yes!

Realize it / find it

No comments.

Particle Dark Matter

- **Basic properties:** **Neutral, Massive, Non-Baryonic, Weakly interacting, Stable/long-lived.**

- **Popular Candidates:** **Weakly interacting Massive Particles (WIMPs).**

- **Predicted (Embedded) in many models Beyond the SM addressing the hierarchy problem. (TeV/weak scale DM)**

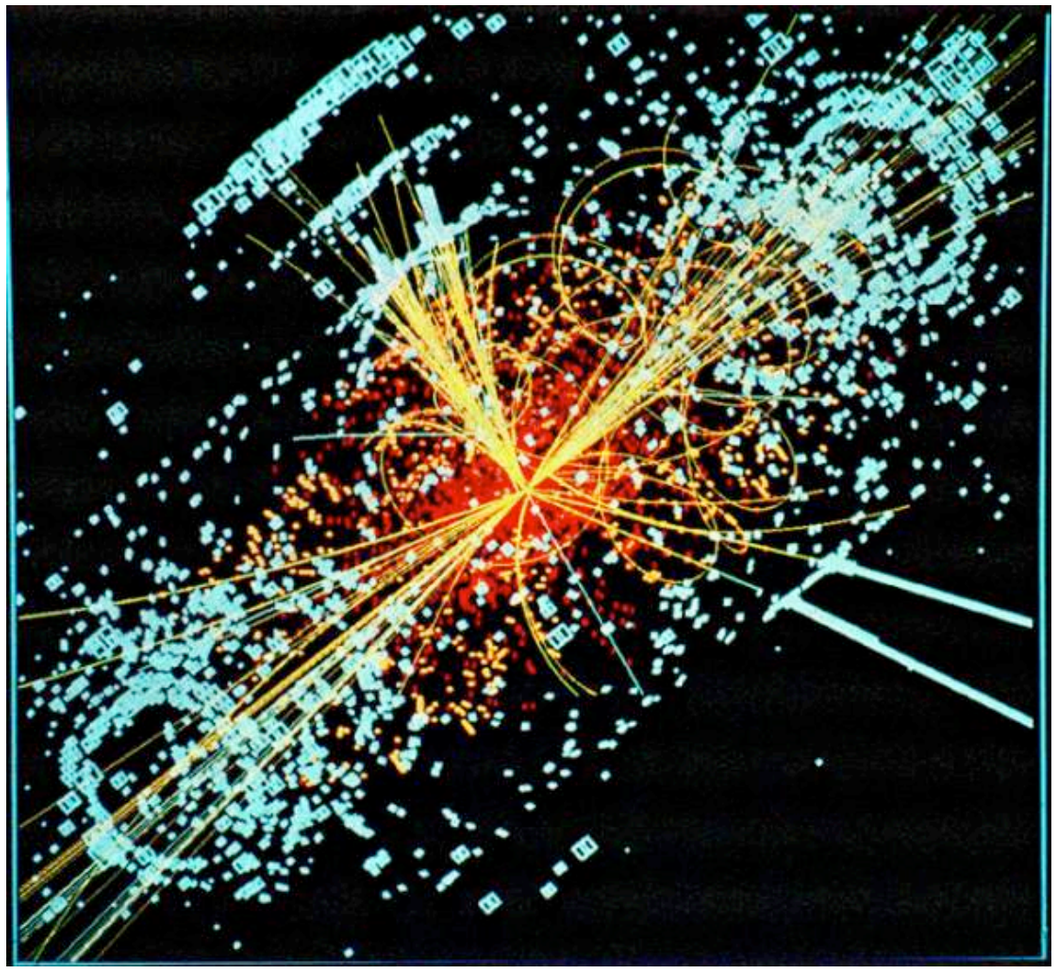
- **WIMP miracle**:

$$\Omega_\chi h^2 \simeq \frac{3\times 10^{-27}\mathrm{cm}^3/\mathrm{sec}}{\langle\sigma v\rangle} \sim 0.11 \quad \Leftrightarrow \quad \sigma \sim \frac{g^4}{M^2_{weak}} \sim 1\mathrm{pb}$$

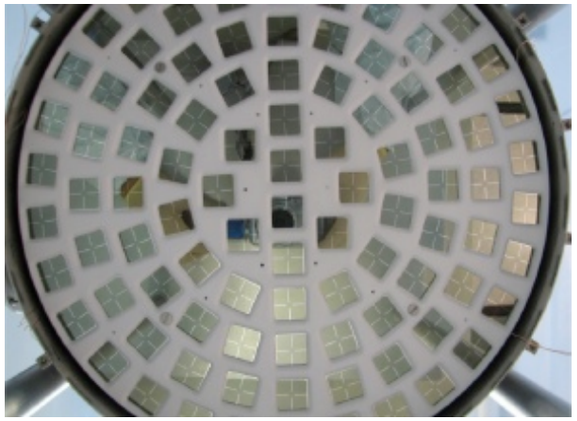
- **Direct detection era:**

$$\sigma_{DM_N} \lesssim (\sim) 10^{-44}\mathrm{cm}^2$$

Efforts for DM detections



对撞机产生



直接探测

间接探测

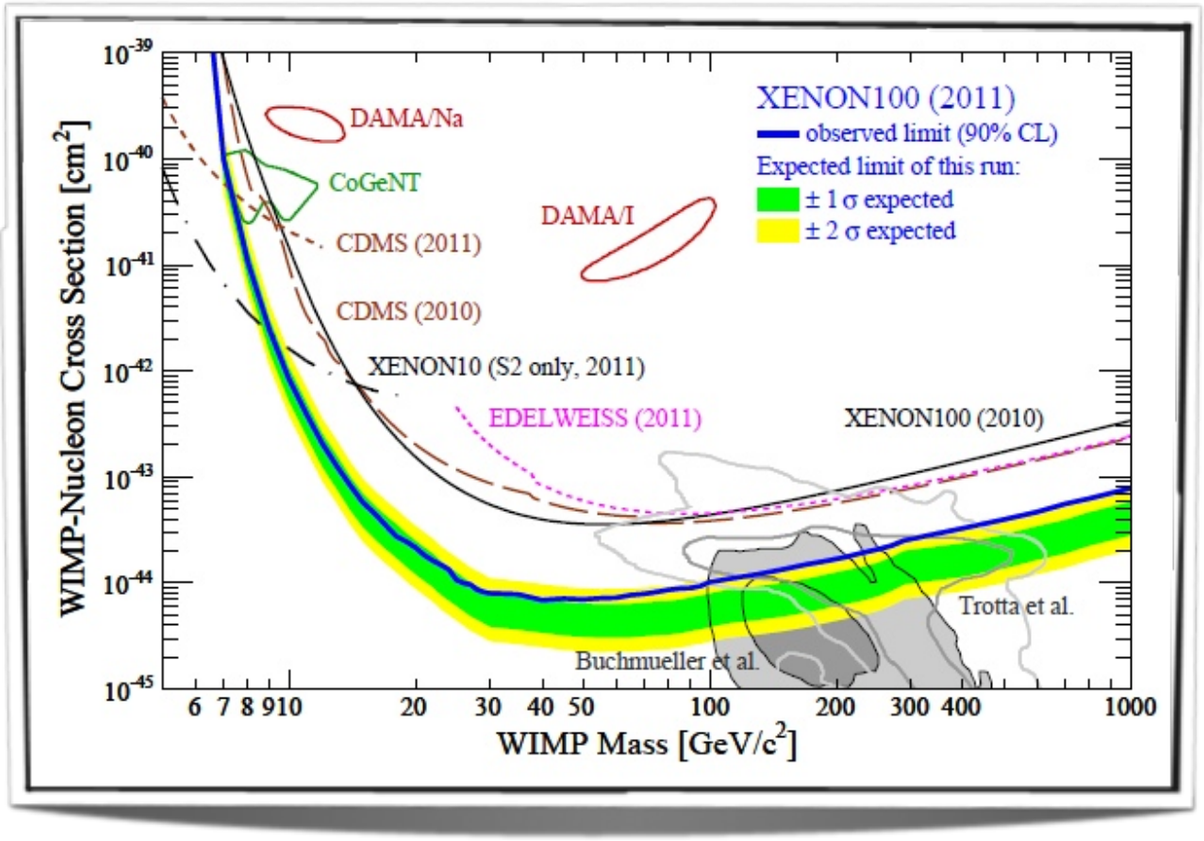
Messages from DM Expt's

- **Indirect detection (ATIC, FERMI, HESS, PAMELA, ...)**
  Positron and electron excess

  ⇒ **TeV/weak scale Dark matter explanation**

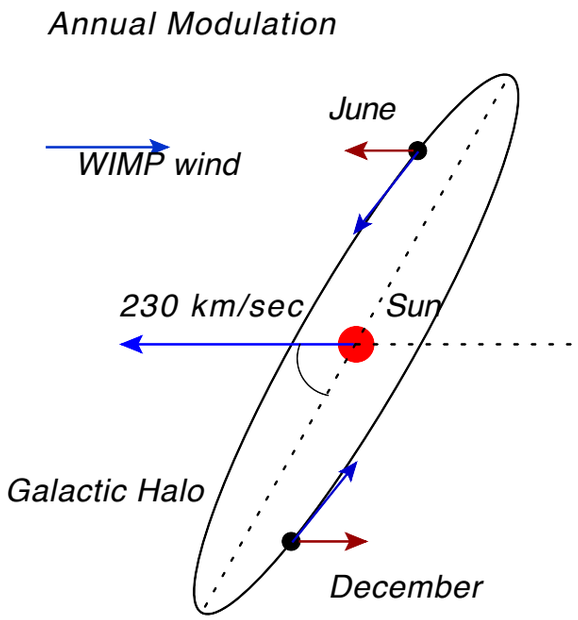
- **Direct detection:**

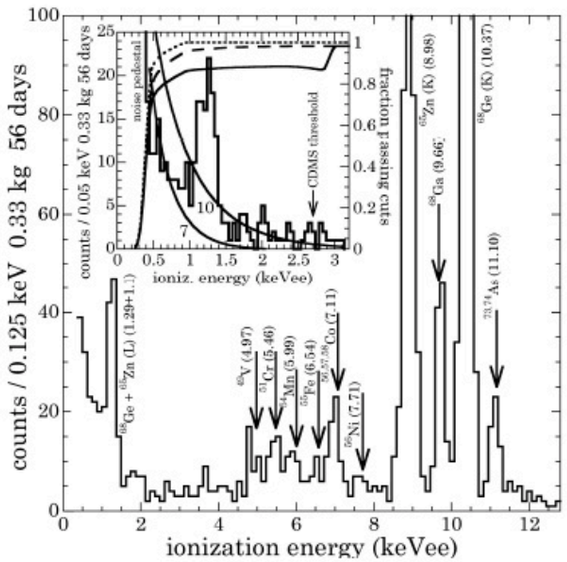
  Null Experiments (CDMS, XENON 10/100, etc)



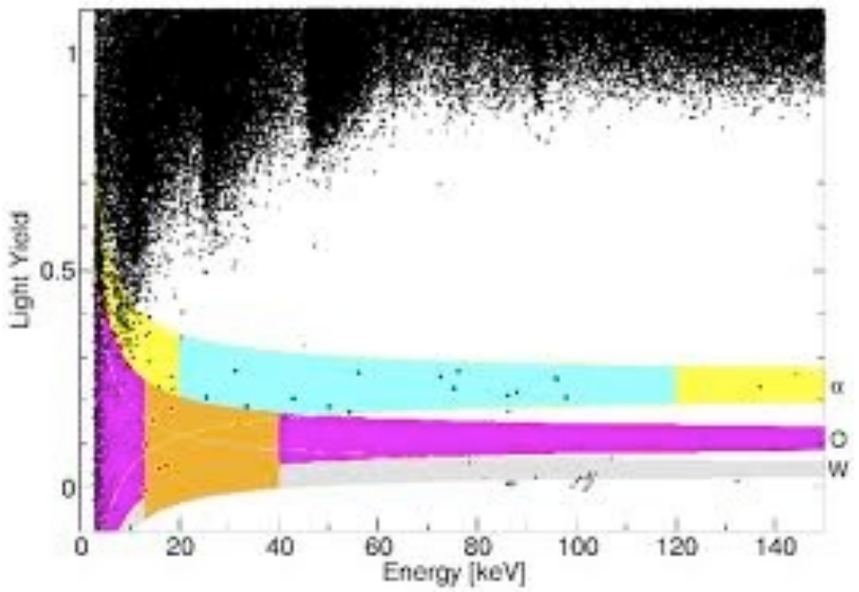
Hints for Light WIMPs

- **DAMA/LIBRA (NaI):** annual modulation effect at 8.9σ C.L.
- **CoGeNT (Ge):** excesses of events(2010), annual modulation effect at 2.8σ C.L. (2010).
- **CRESST II (CaWO4):** excesses of events (2011).



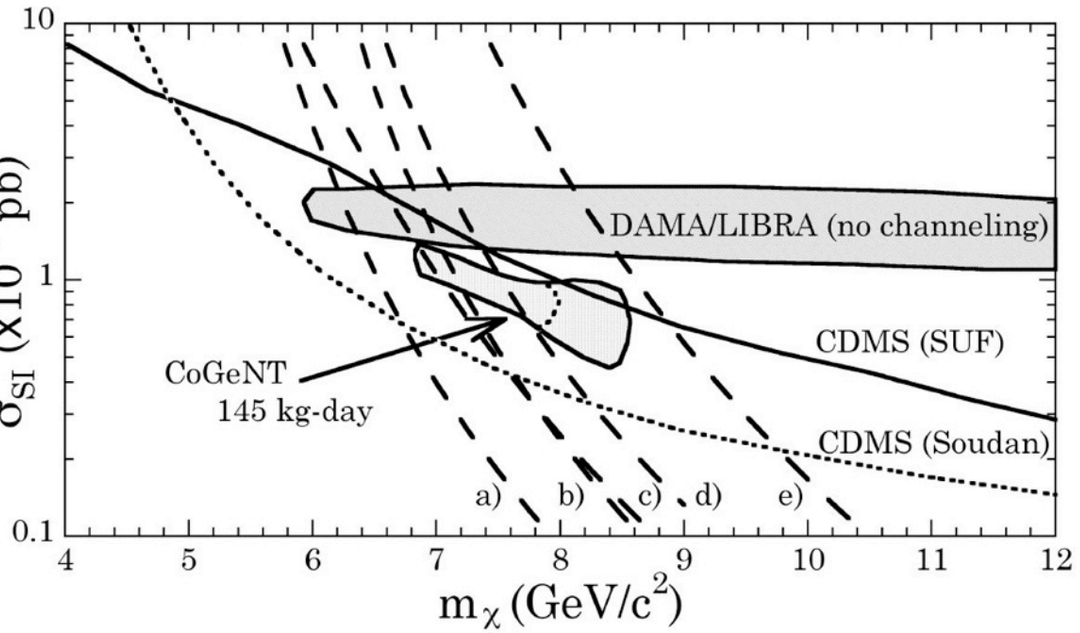


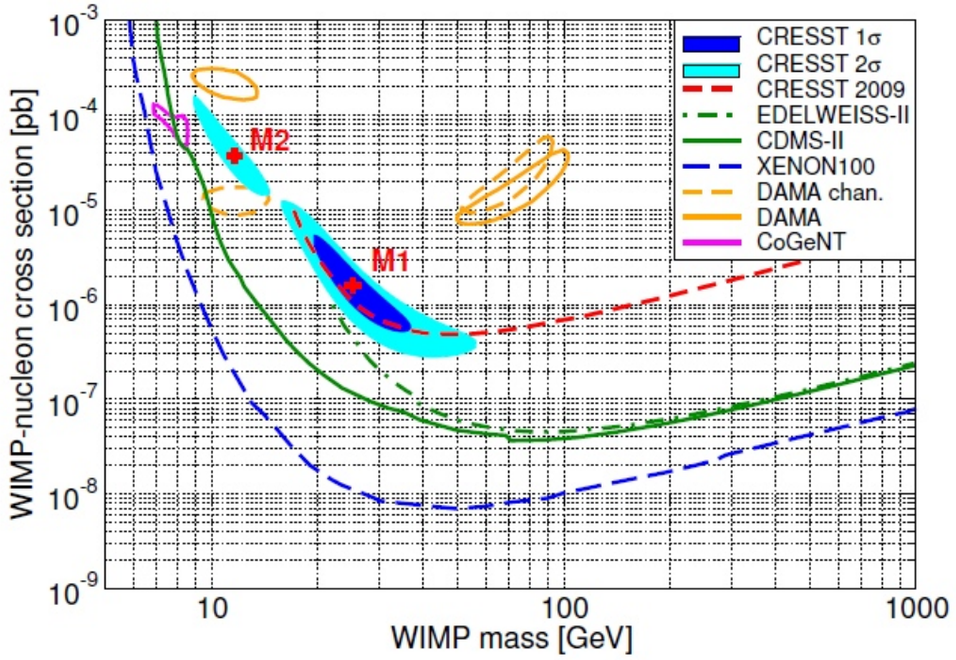
CoGeNT



CRESST II

Tensions exist





- **Tracks of low mass WIMPs?**
- **Tension with the constraints from null expts, XENON10/100, CDMS, ...**
- **No simultaneous explanation of CoGeNT, DAMA and CRESST-II.**

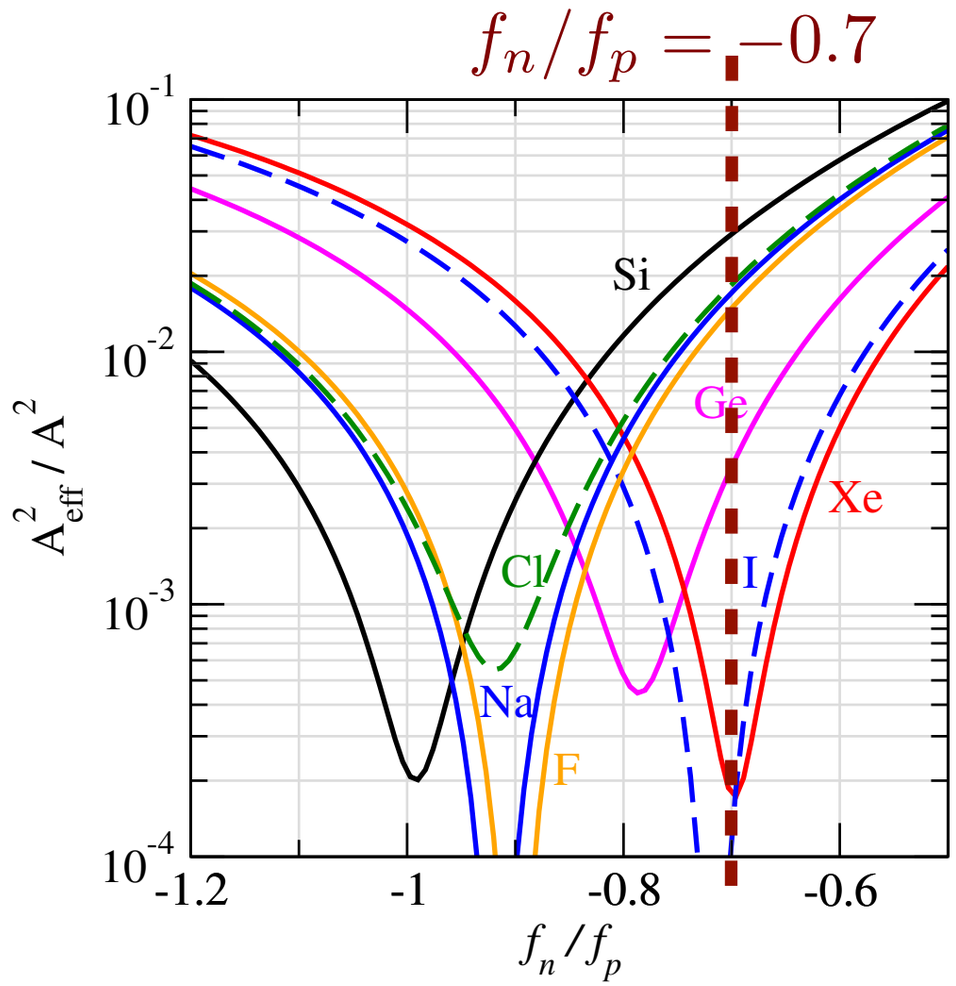
Isospin-Violating DM

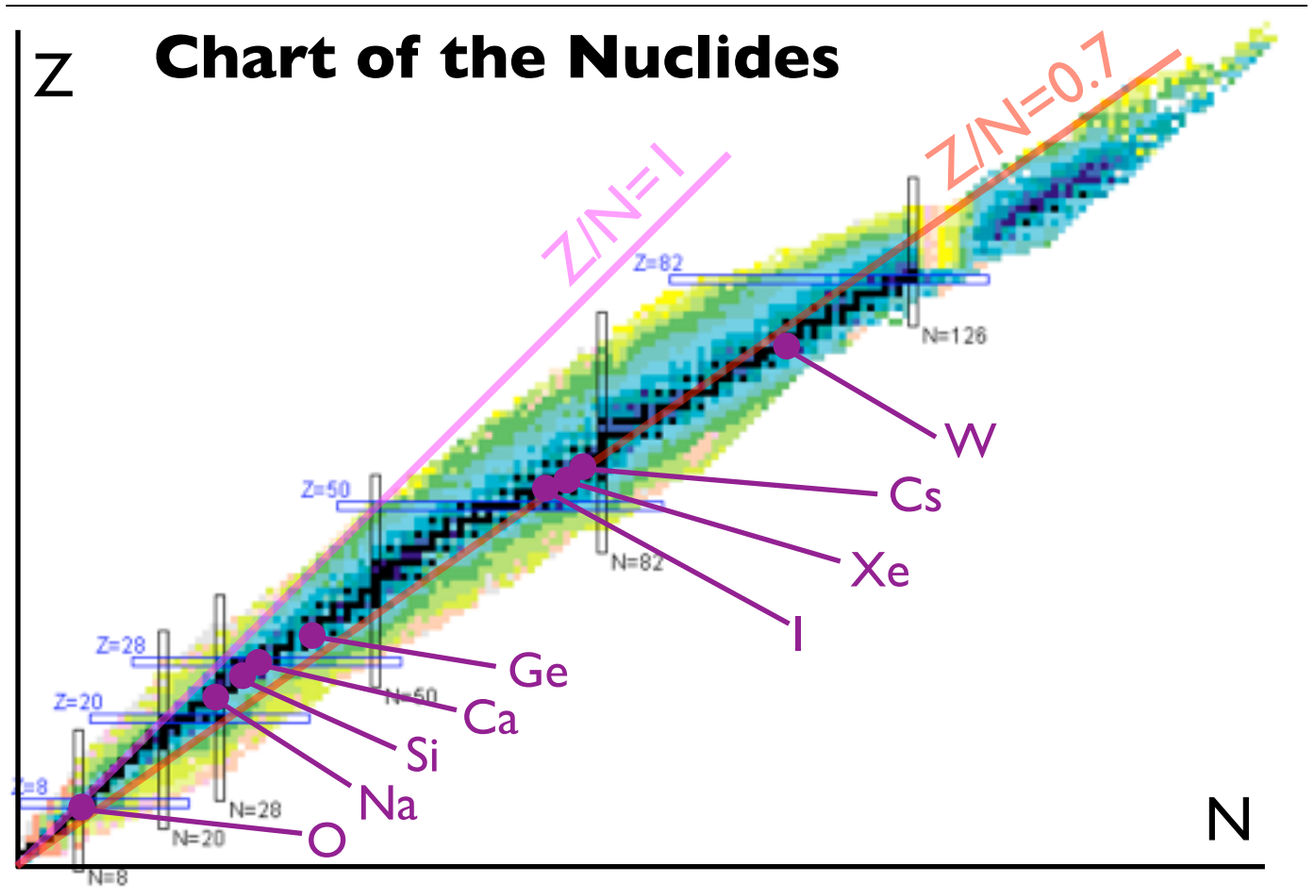
Kurylov, Kamionkowski(2004);Giuliani (2005);
Chang, Liu, Pierce, Weiner, Yavin(2010);Feng, Kumar, Marfatia, Sanford (2011), ...

- **DM elastic scattering off nucleus: coherent effect!**

$$\mathbf{f_n = f_p \Rightarrow \sigma_{\chi N} \propto (Z f_p + (A - Z) f_n)^2 \propto A^2}$$

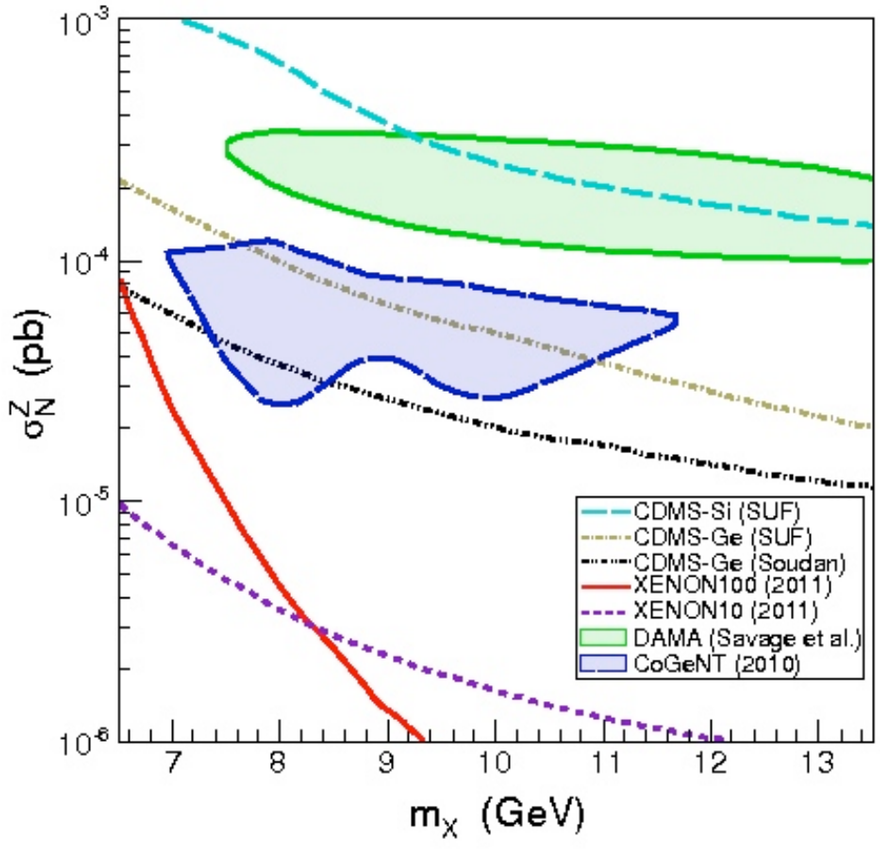
- **Breaking this assumption (isospin-violation): release one additional parameter: f_n/f_p**



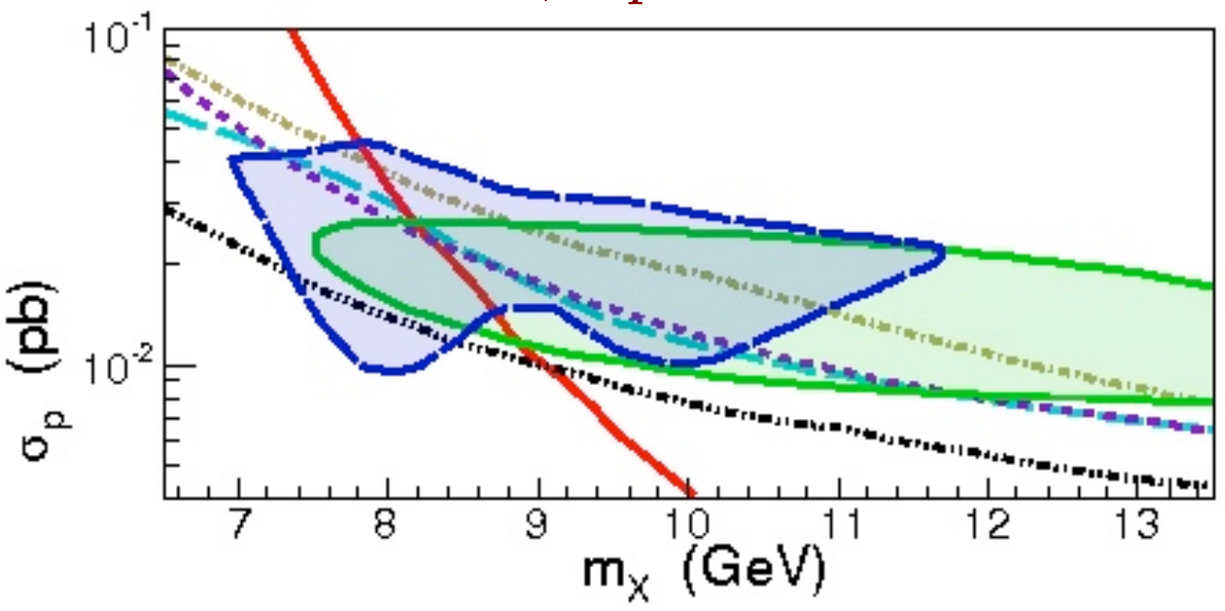


Isospin-Violating DM

$f_n/f_p = 1$

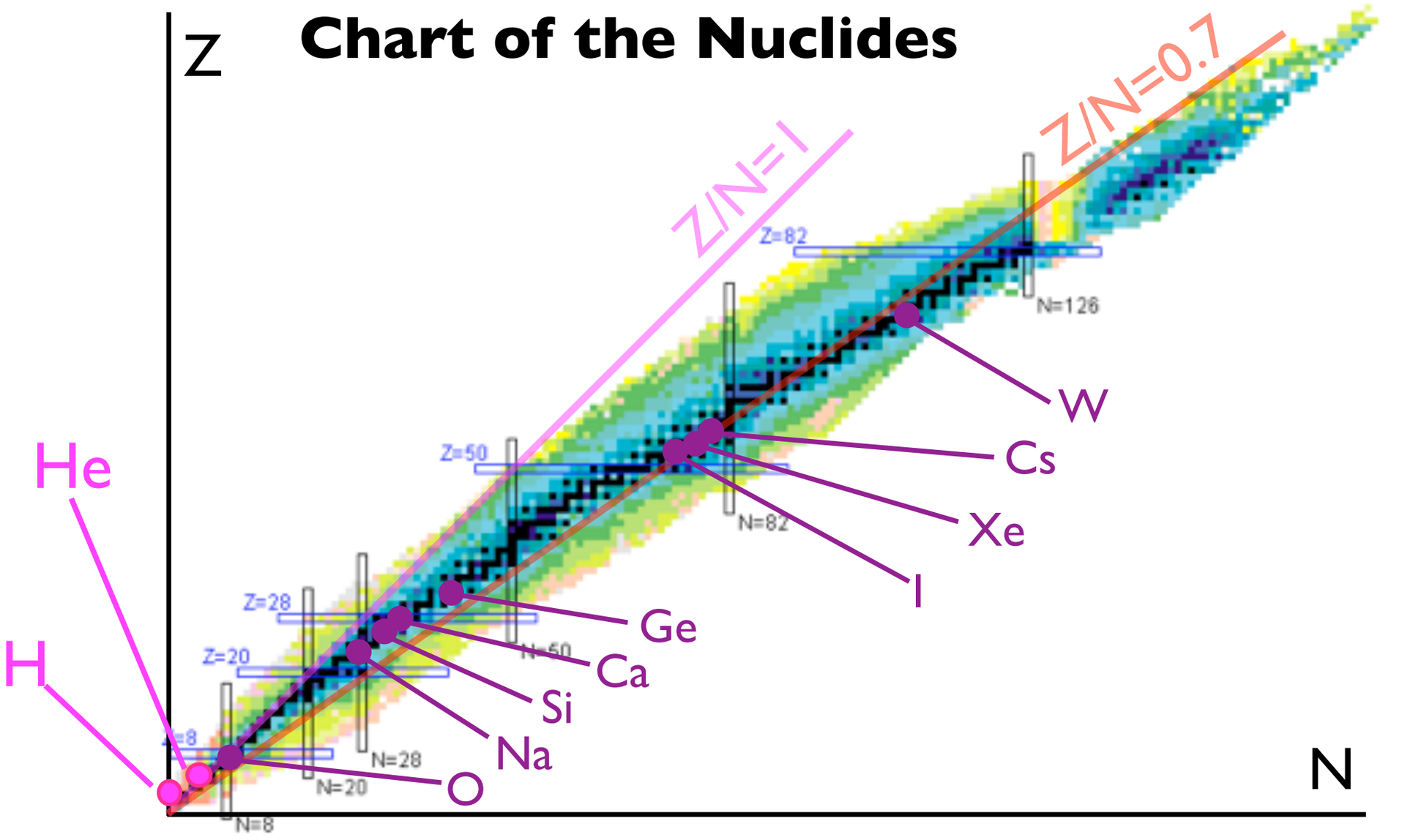


$f_n/f_p = -0.7$



tension alleviated

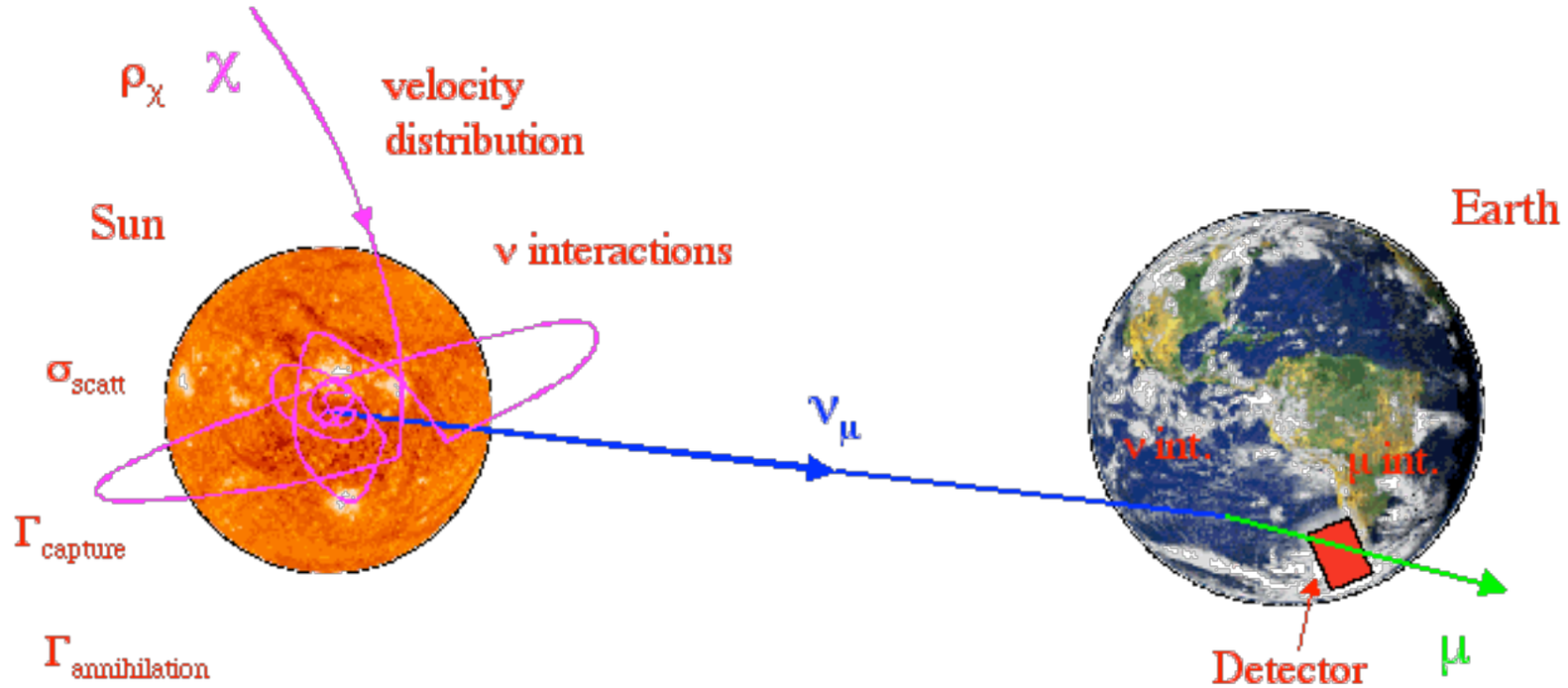
Isospin-Violating DM

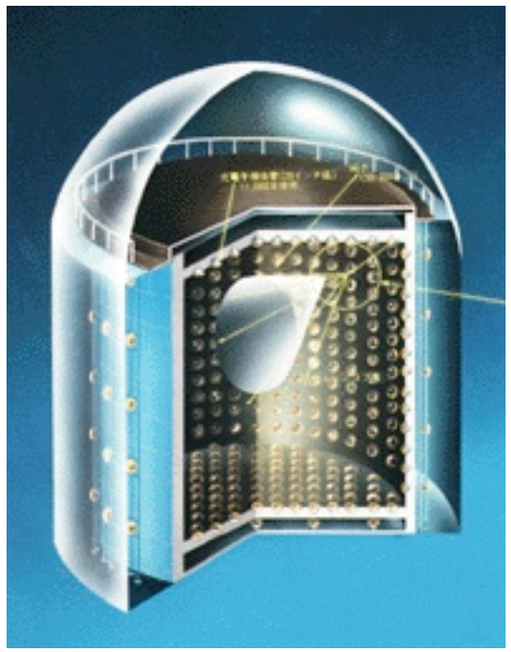


Light isotopes in the Sun: H, He, O **(Z/N=1)**

The Sun is a better detector for low mass IVDM!

DM capture in the Sun





- **DM capture and self-annihilation in the Sun**

$$\frac{dN}{dt} = C_\odot - C_A N^2 \longrightarrow N(t) = \sqrt{\frac{C_\odot}{C_A}} \tanh\left(\sqrt{C_\odot C_A} \cdot t\right)$$

- **Capture and self-annihilation are in equilibrium**

$$\Gamma_A = \frac{C_\odot}{2}$$

- **The Sun is a natural detector for DM direct detection.**

IVDM capture in the Sun

SL Chen & Yue Zhang, PRD(2011)

- **The capture rate**

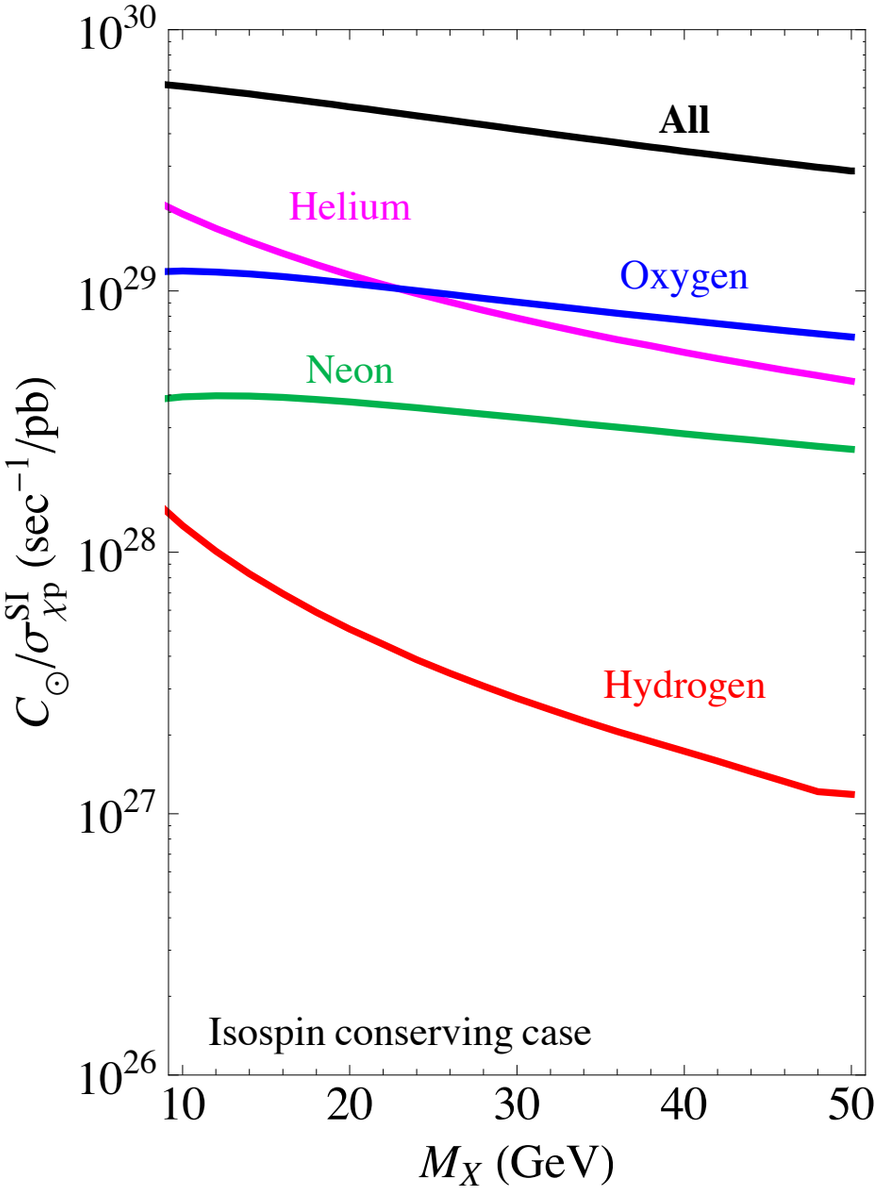
$$C_{\odot,i} = \sum_i 4\pi \int_0^{R_\odot} r^2 dr \frac{\rho_\chi \rho_{\odot,i}(r)}{2 m_\chi \mu_i^2} \sigma_i \times \int_0^\infty du \frac{f(u)}{u} \theta(E_{R,\max} - E_{R,\mathrm{cap}}) \int_{E_{R,\mathrm{cap}}}^{E_{R,\max}} dE_R F^2(E_R),$$

- **The suppression factors**

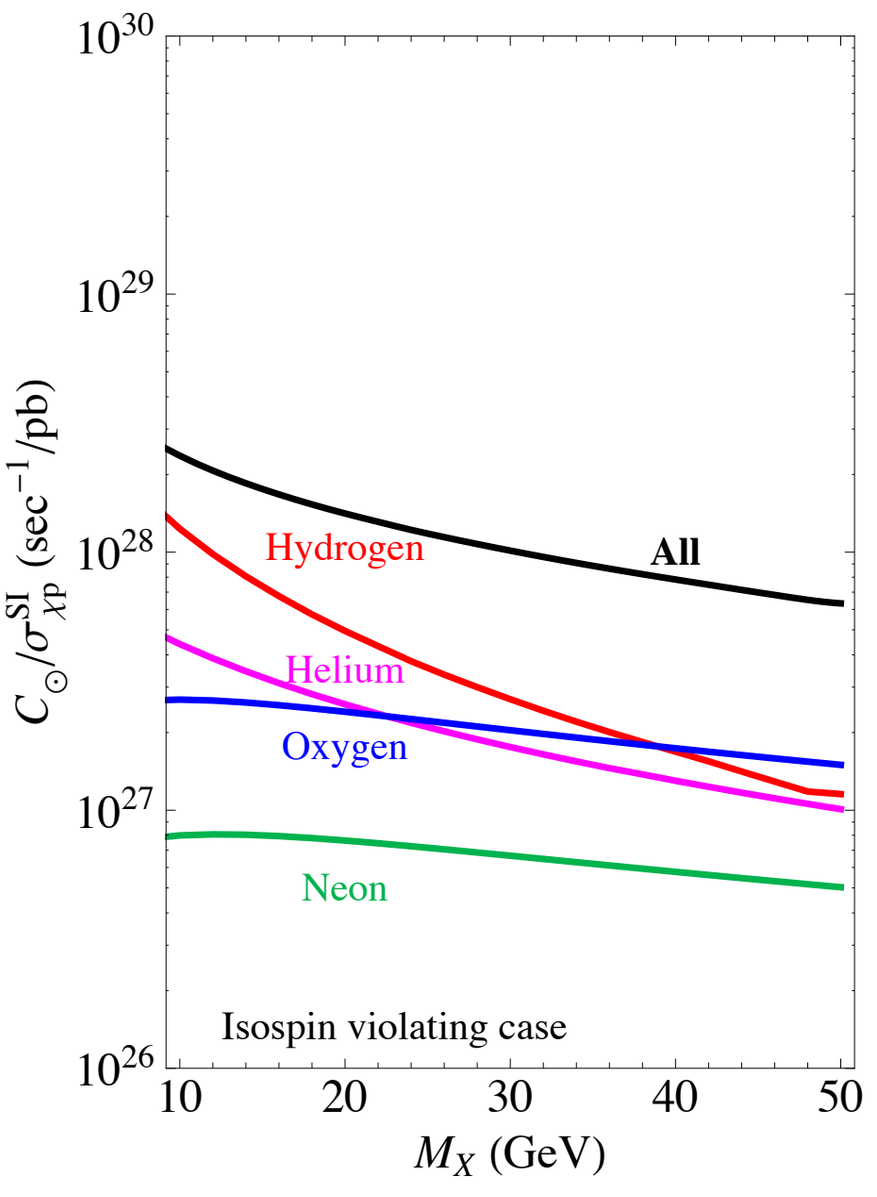
Element	Xe	Ge	Na	Solar capture
Suppression	1.3×10^{-4}	2.6×10^{-3}	1.3×10^{-2}	4.0×10^{-2}

$f_n/f_p = -0.7$ and $m_\chi = 10\,\mathrm{GeV}$.

DM capture in the Sun

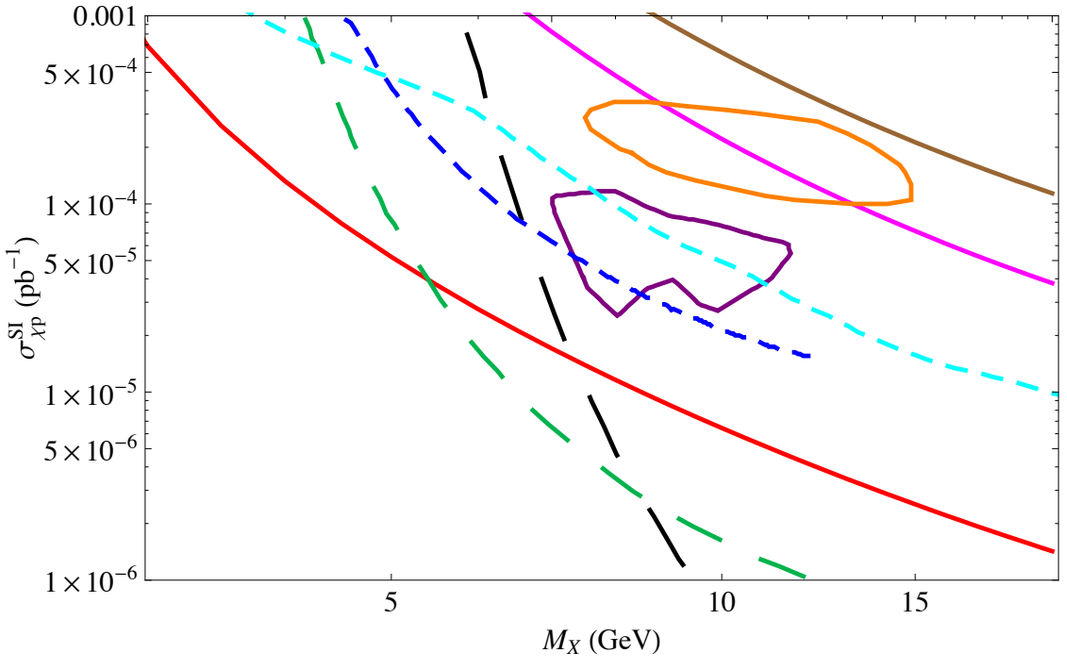


Isospin-conserving DM



Isospin-violating DM

The constraints from Super-Kamiokande data 16



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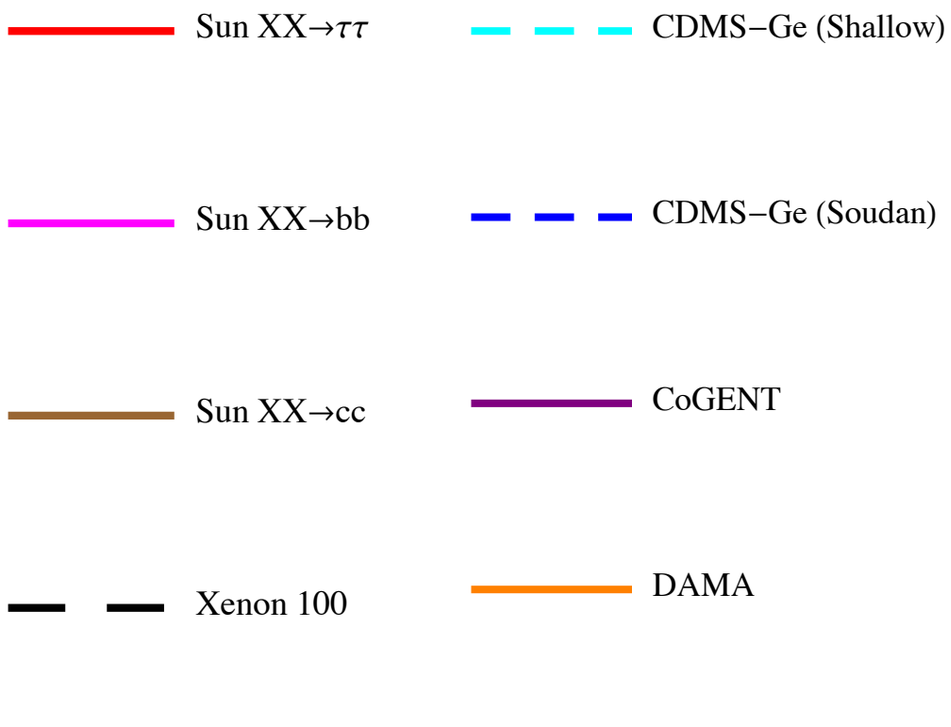
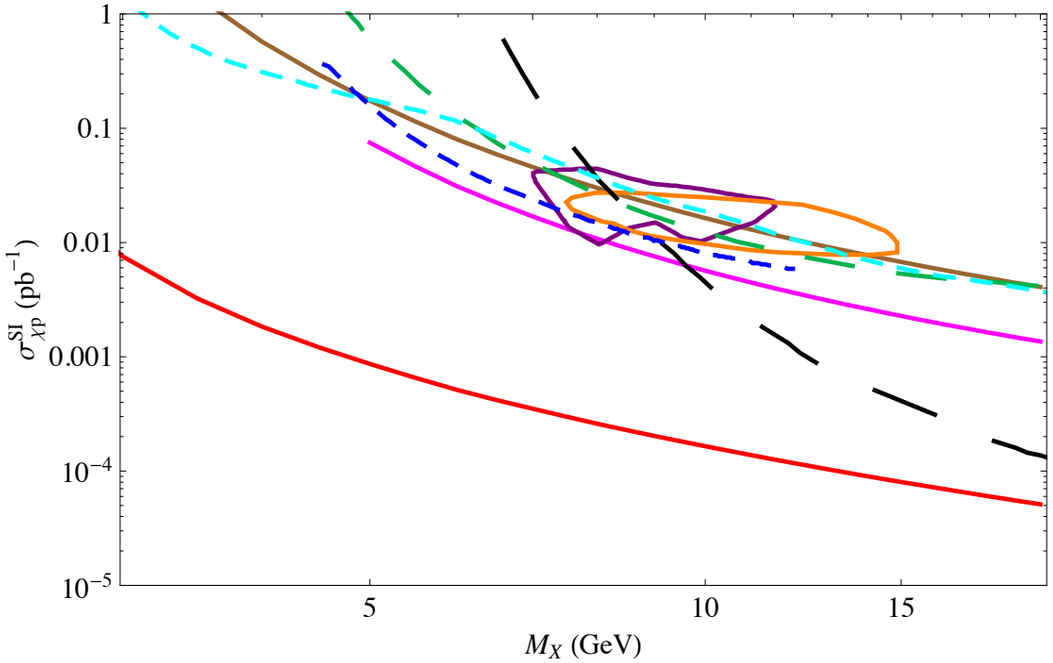
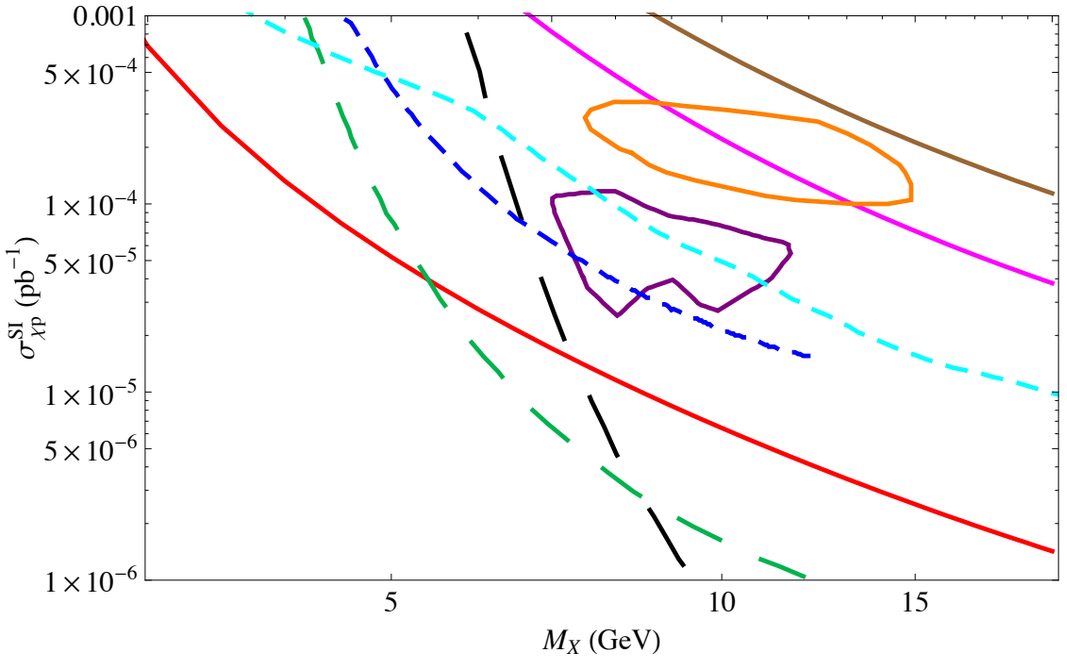




Isospin-violating DM

The constraints from Super-Kamiokande data 16



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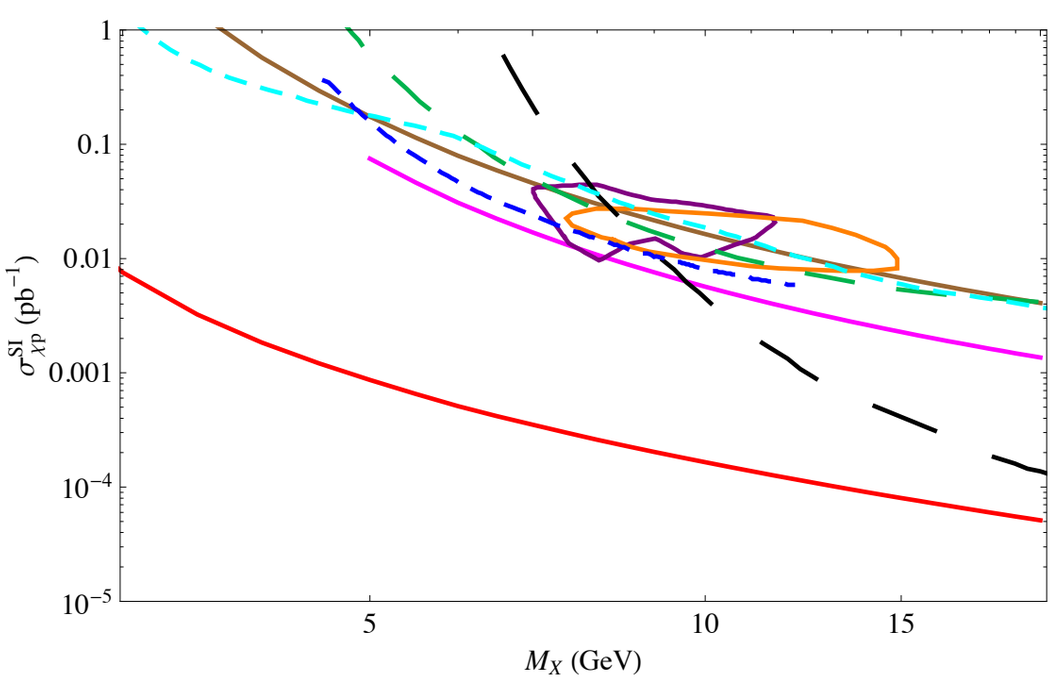

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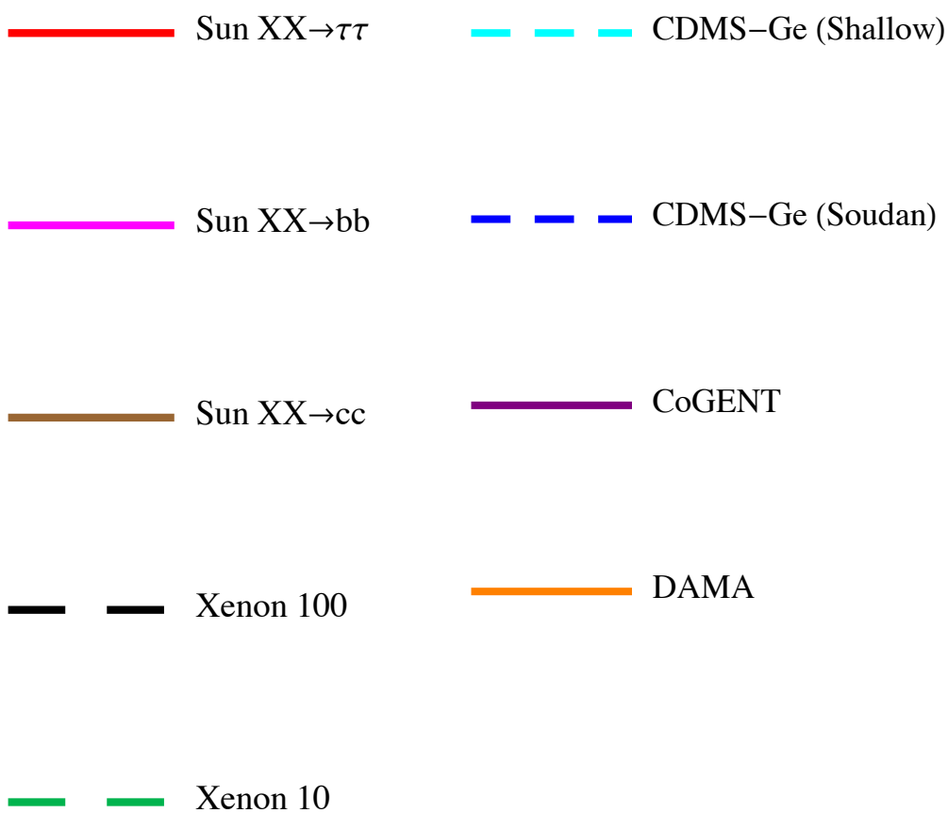

Challenge to the IVDM model building

Summary

- Low mass DM explanation for direct detection expt's: in tension with constraints
- IVDM: a phenomenological way proposed model is helpful to alleviate the tension.
- The neutrino flux from the Sun puts severe constraint to the IVDM.