2015 CERN Theory Retreat

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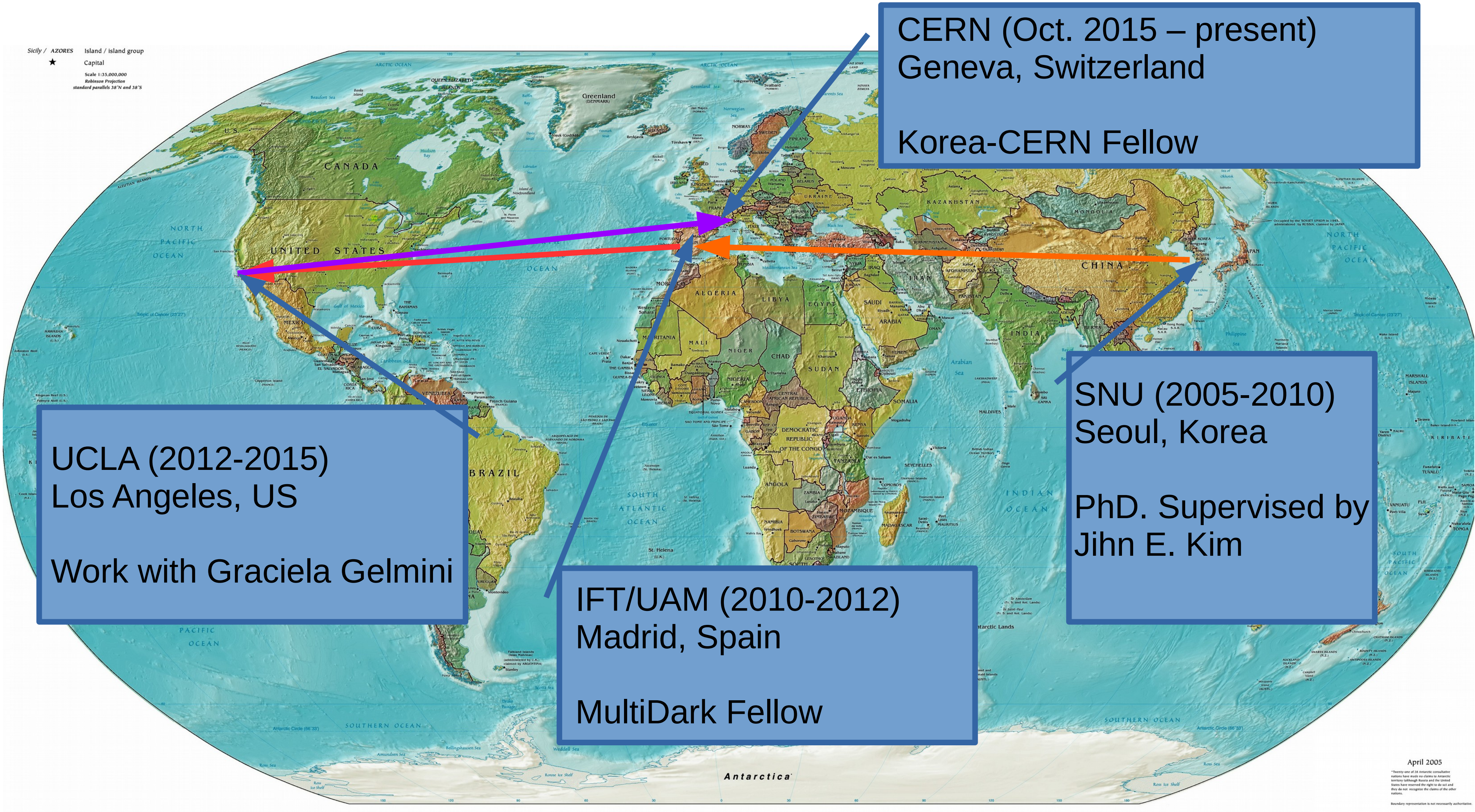
06.11.2015 Les Houches

How did I get to CERN?



Research Interests

- BSM
- Dark Matter Phenomenology

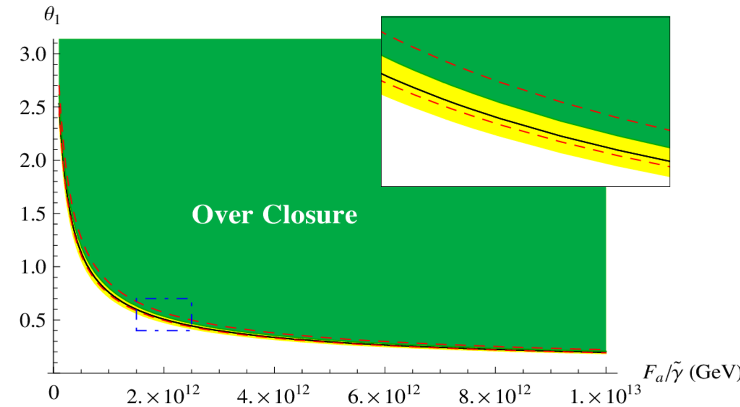
  - Model building (SUSY, Non-SUSY, WIMP, axion...)

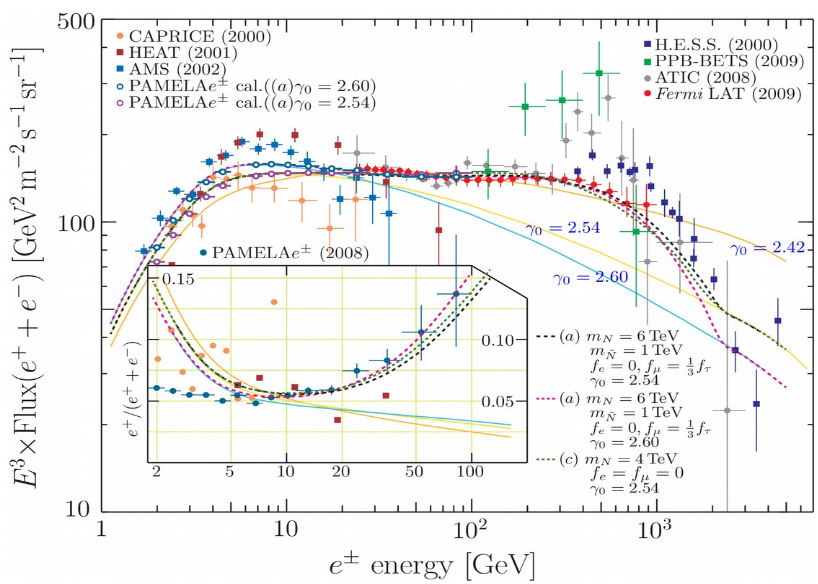
  - Indirect Detection

  - Direct Detection

At Seoul National University (2005~2010)

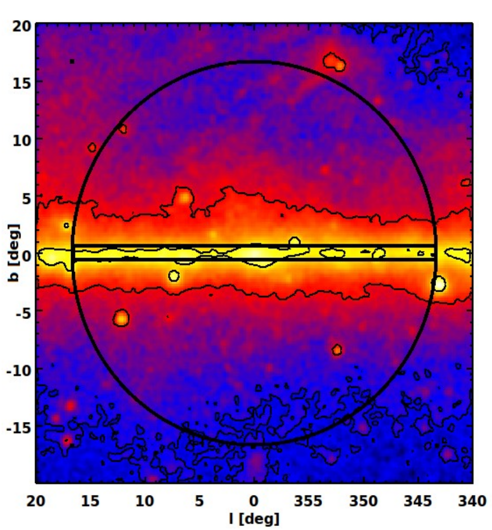
- With Jihn E. Kim
- 511 keV gamma-ray
- Axion CDM
- Positron CR anomaly
- SUSY leptophilic dark matter (annihilating or decaying DM)
- Magnetic Dipole DM
- Dark Star (with Paolo Gondolo)

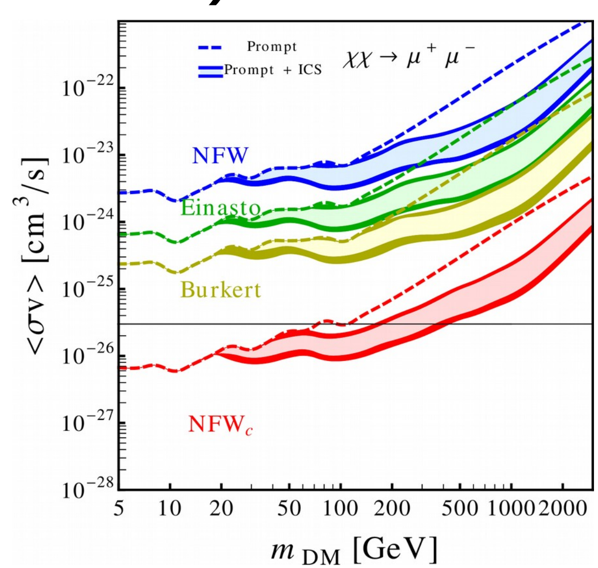


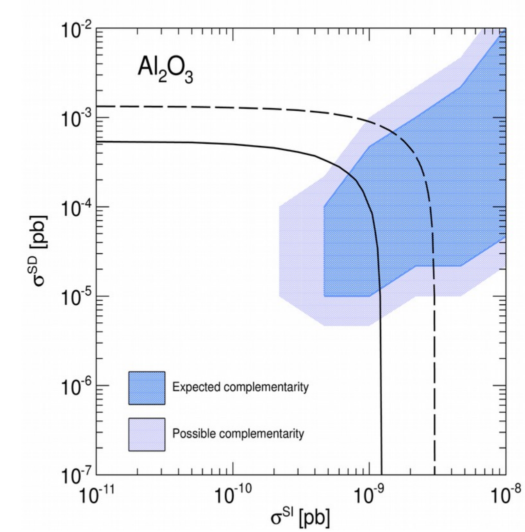


IFT/UAM Madrid
MultiDark fellow (2010~2012)

- Right handed neutrino in NMSSM
- Complementary target study of Direct Detection experiment (ROSEBUD)
- DM constraint inner Galactic gamma-ray in adiabatically contracted DM halo scenario (FERMI collaboration)

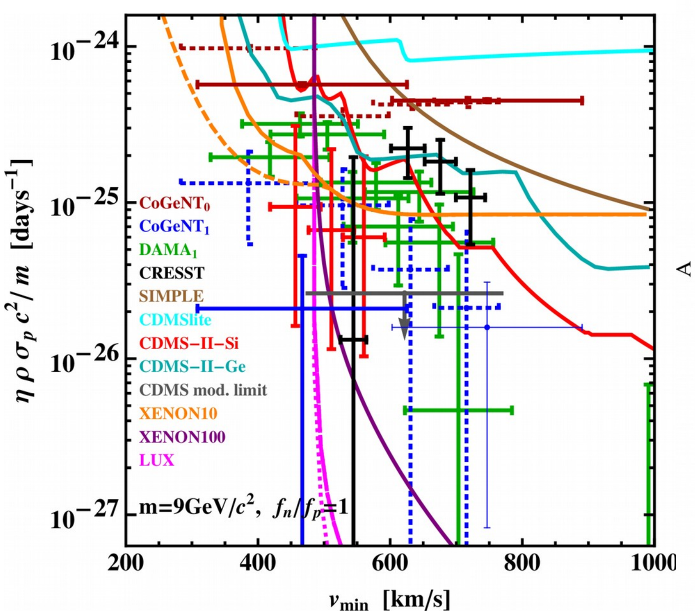


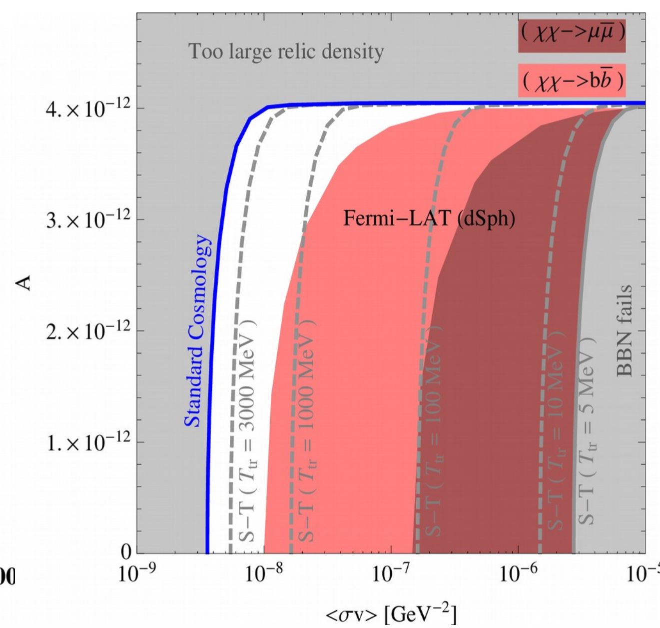


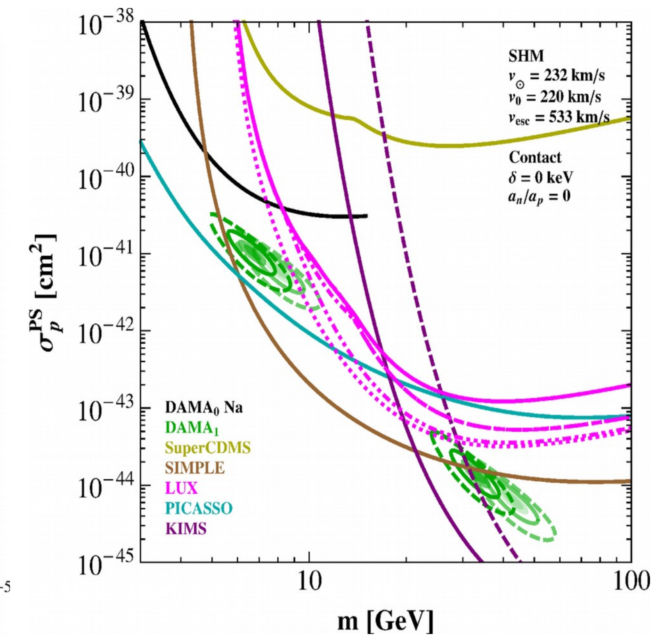


UCLA (2012-2015)

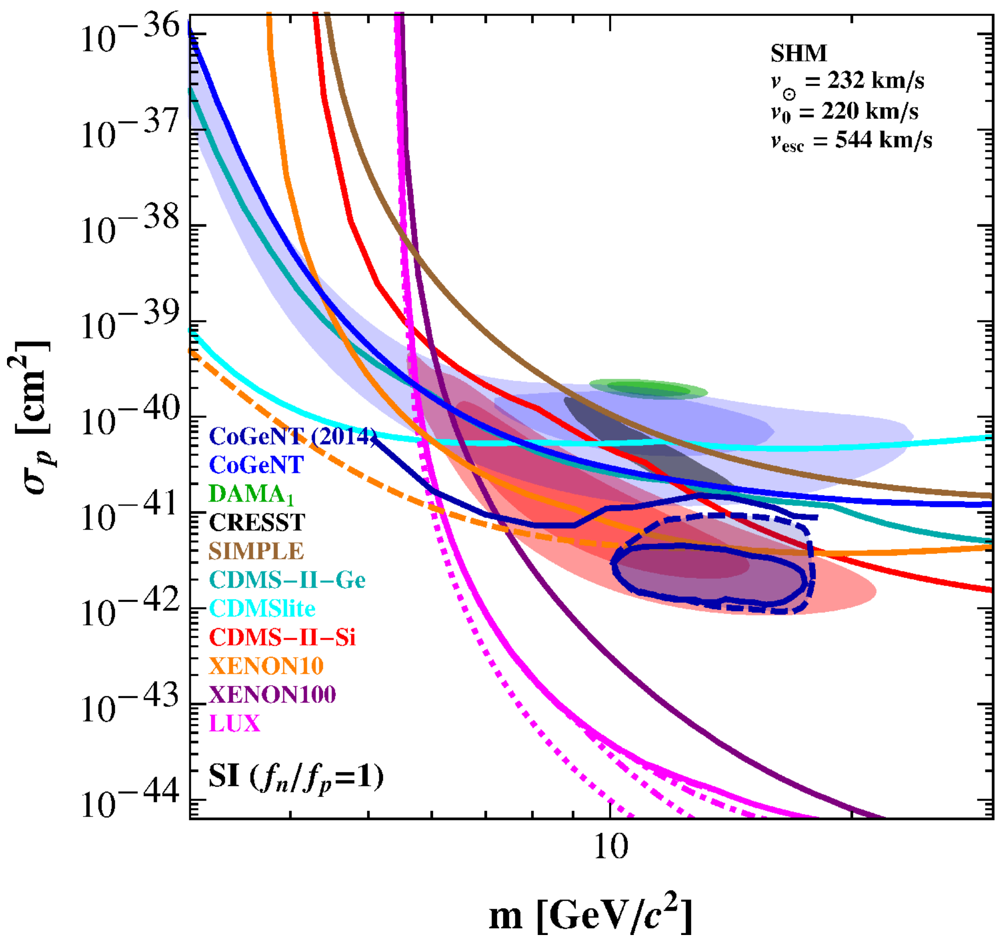
- With G. Gelmini, P. Gondolo, and E. Del Nobile
- Halo-independent Direct Detection (details in the next slides)
- Indirect Detection of ADM
- Ge-phobic inelastic Dark matter
- (not-so) Coy Dark matter (light DM with pseudo-scalar interaction)







Direct Detection (DD) of DM



- DM candidate claim (light WIMP)

  - DAMA, CDMSII-Si, etc

- Strong Constraint

  - XENON,LUX, SuperCDMS, etc

- Apparent Conflict !

Two Usual assumption in DD analysis

$$\frac{dR}{dE'} = \epsilon(E')\frac{\rho}{m}\sum_T \xi_T G_T(E_R, E')\int_0^\infty dE_R \int_{v_{\min}(E_R)}^\infty dv \frac{f(v)}{v} v^2 \frac{d\sigma_T}{dE_R}$$

$$= \epsilon(E')\frac{\rho}{m}\sum_T \xi_T G_T(E_R, E')\int_0^\infty dE_R v^2 \frac{d\sigma_T}{dE_R}\eta(E_R)$$

1. Conventional WIMP

$$\frac{d\sigma_T}{dE_R} \sim \frac{1}{v^2}$$

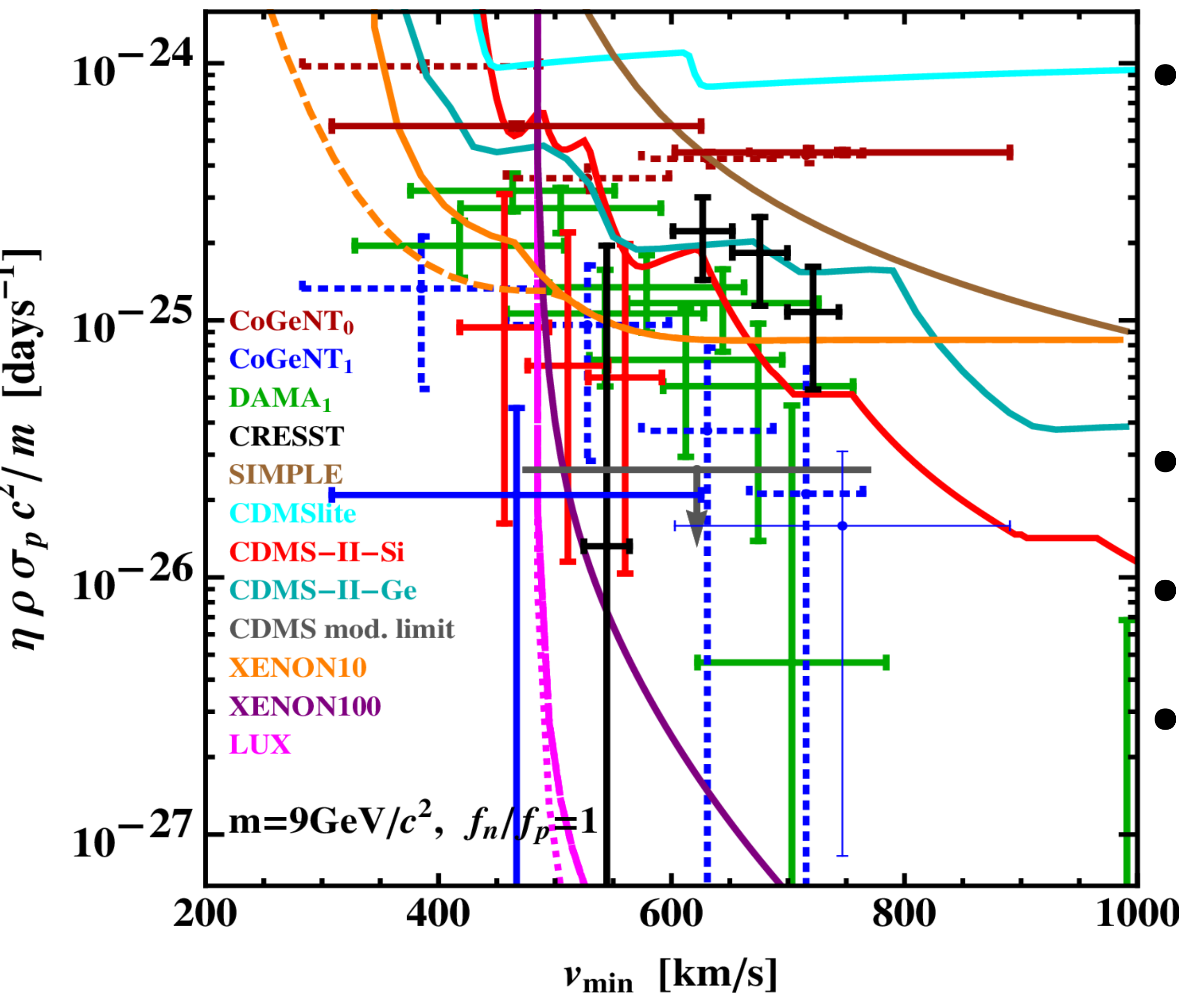
- Magnetic/Electric Dipole DM
- Anapole DM
- Pseudo-scalar interaction
- Model independent classification

2. Standard Halo Model (SHM)

$$\eta(E_R) = \int_{v_{\min}(E_R)}^\infty dv \frac{f(v)}{v}$$

- Important for light WIMP
- Non-SHM
- Halo-Independent Analysis!

Halo-Independent (HI) analysis



- Common factor

$$\frac{\rho\sigma}{m}\eta(v_{\min})$$

- Crosses ; DM Signal
- Curves ; Constraints
- No way to resolve the conflict by altering Halo model

Generalized Halo-independent (HI) method

Obstacles

- If the differential cross section has multiple terms having different velocity dependence, we cannot apply the original halo-independent method. For example,

$$\frac{d\sigma_T}{dE_R} \sim Av^m + Bv^n$$ requires two different halo-functions

$$\eta^{(m)}(v_{\rm min}) \equiv \int_{v_{\rm min}} dv \frac{f(v)}{v^{1-m}}$$

$$\eta^{(n)}(v_{\rm min}) \equiv \int_{v_{\rm min}} dv \frac{f(v)}{v^{1-n}}$$

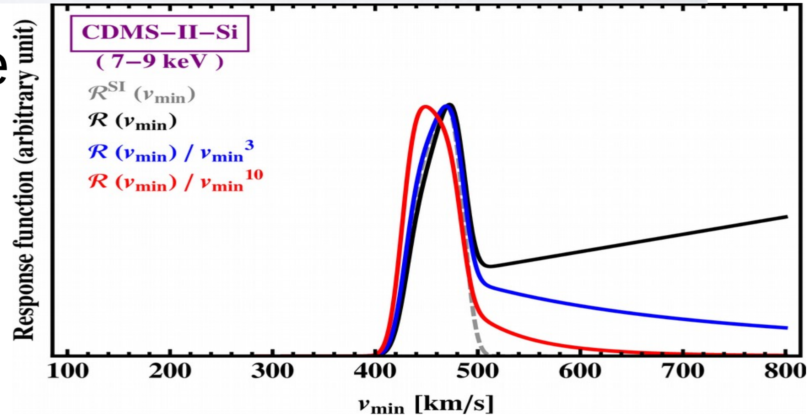
With a simple trick (for any int.), we can write

$$R_{[E_1',E_2']}(t) = \int_0^\infty \mathrm{d}v_{\rm min}\, \tilde{\eta}(v_{\rm min}, t)\, \mathcal{R}_{[E_1',E_2']}(v_{\rm min})$$

In many case,

(change of integration order) ~ (partial integration)

, but not the same, always.



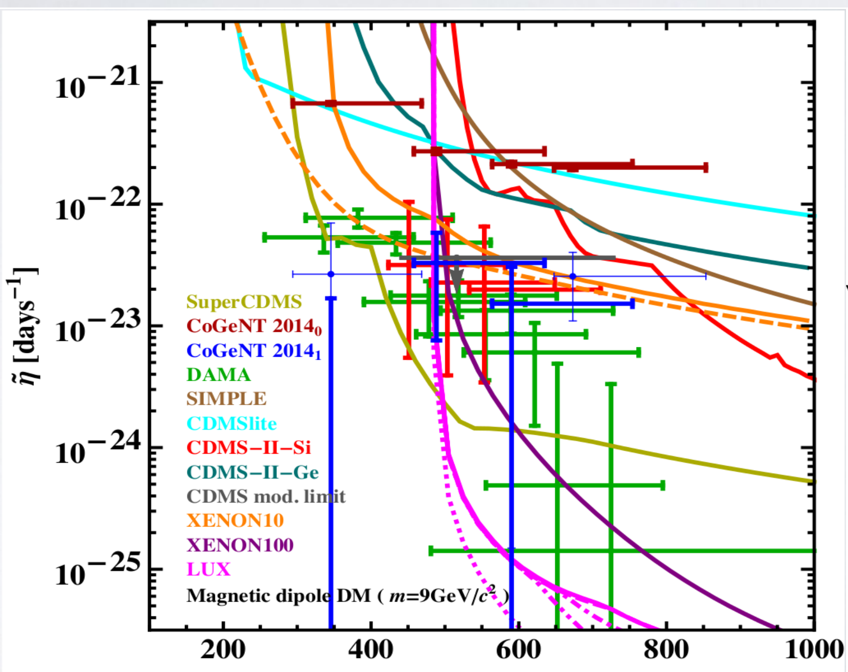
Exemple of Generalized HI analysis

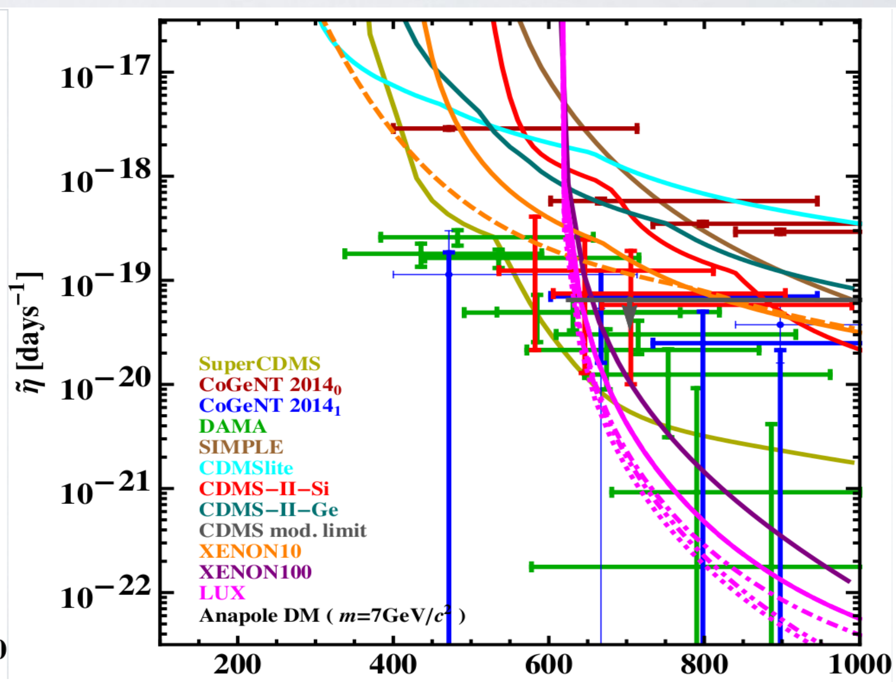
- Magnetic Dipole DM

$$\frac{d\sigma_T}{dE_R} = \sigma^M_{\rm ref}\frac{m_T}{\mu_T^2}\frac{1}{v^2}\left[Z^2\left(\frac{v^2}{v^2_{\rm min}} - 1 + \frac{\mu_T^2}{m^2}\right)F^2_{{\rm E},T}(\mathbf{q}^2) + 2\frac{\lambda_T^2}{\lambda_N^2}\frac{\mu_T^2}{m_N^2}\left(\frac{J_T+1}{3J_T}\right)F^2_{{\rm M},T}(\mathbf{q}^2)\right]$$

- Anapole DM

$$\frac{d\sigma_T}{dE_R} = \sigma^A_{\rm ref}\frac{m_T}{\mu_N^2}\frac{v^2_{\rm min}}{v^2}\left[Z^2\left(\frac{v^2}{v^2_{\rm min}} - 1\right)F^2_{{\rm E},T}(\mathbf{q}^2) + 2\frac{\lambda_T^2}{\lambda_N^2}\frac{\mu_T^2}{m_N^2}\left(\frac{J_T+1}{3J_T}\right)F^2_{{\rm M},T}(\mathbf{q}^2)\right]$$

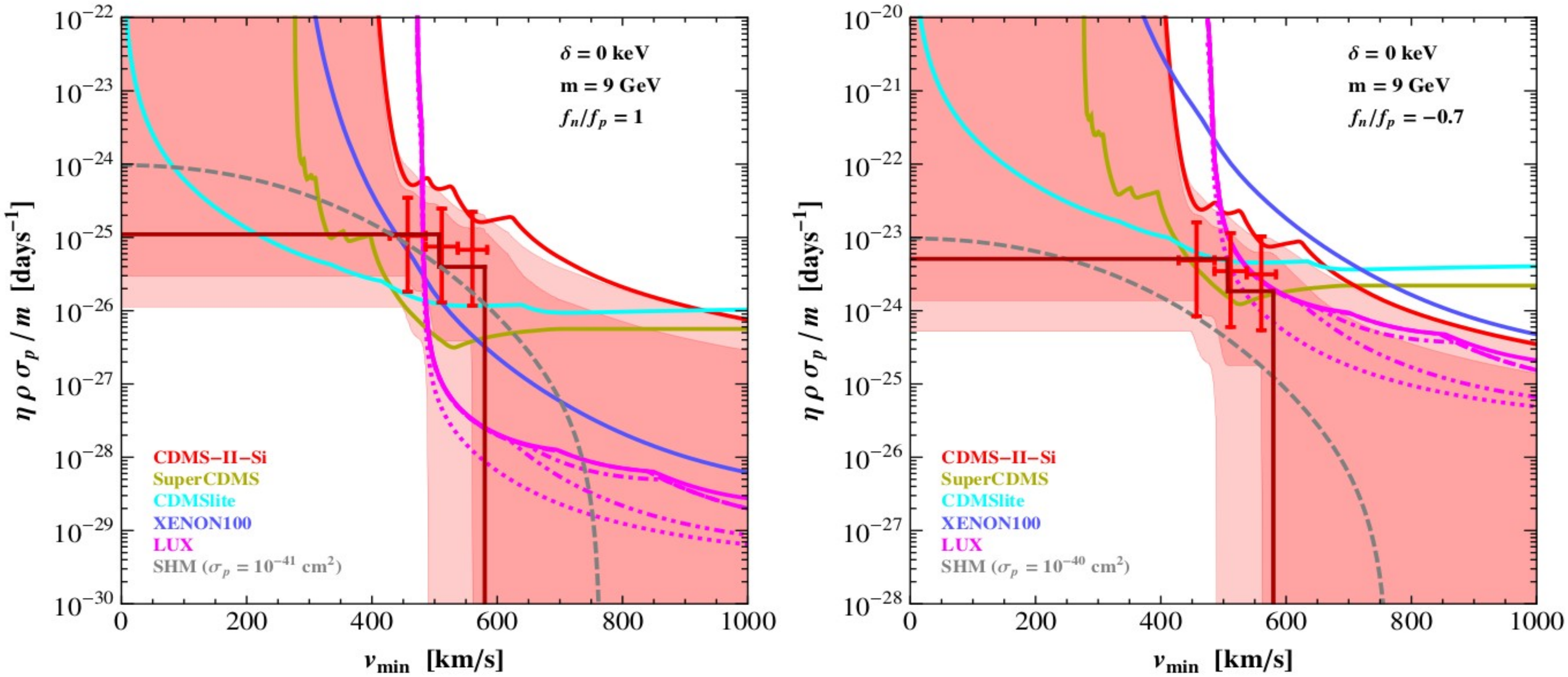




Band method in HI analysis

(Extended Maximum likelihood HI analysis)

- With crosses and curves, it is difficult to assess compatibility, quantitatively.
- Instead of crosses, a reconstructed band is much more useful. *Fox,Kahn&McCullough(2014), Gelmini, Georgescu&JHH(2015)*



Summary

- So far

  - Various approaches to find DM except LHC

- From now on

  - Various approaches to find DM including LHC

  - More developments in HI DD analysis

  - More crazy ideas to resolve the conflicts among DD experiments, e.g., 2 → 3

경청해 주셔서 감사합니다

Thank you for your attention!