THEORIES OF LIGHT DARK MATTER

Neal Weiner
CCPP NYU

THE TYRANNY OF ONE-SCALE DARK MATTER

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- Historically: Weakly Interacting Massive Particle

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Applies to **everything**: mass, interaction, etc

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the χ-SM

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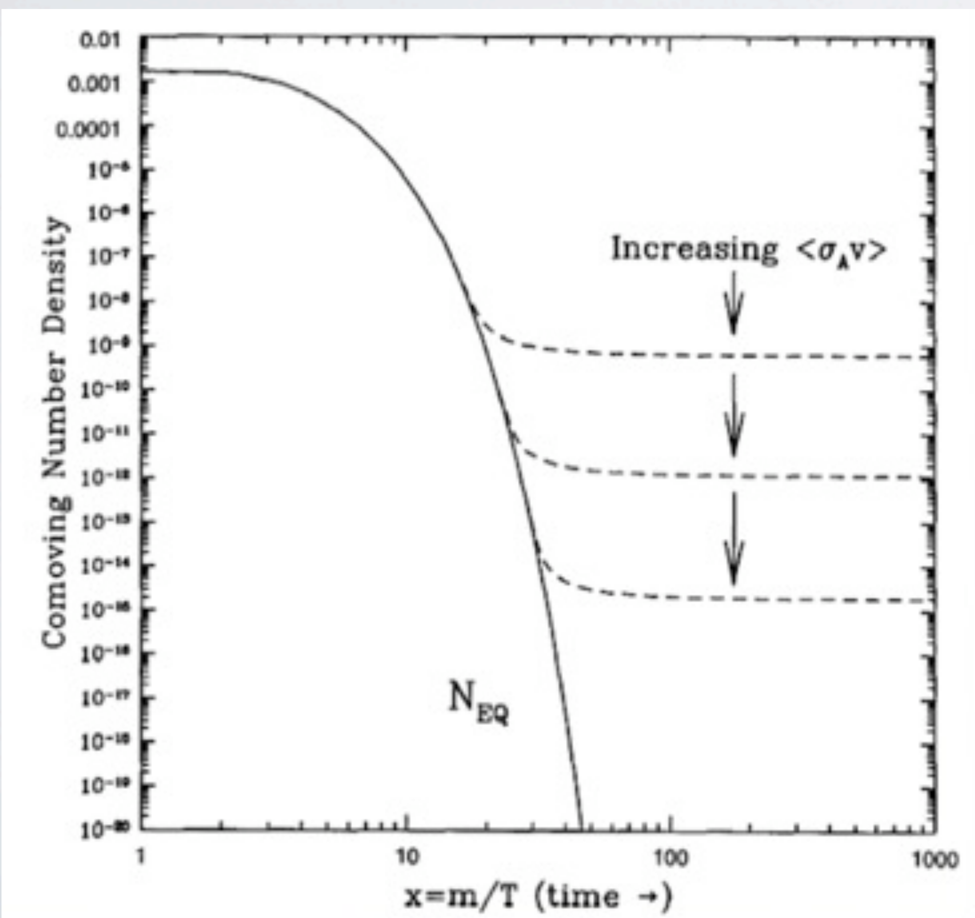
The **one** thing we know about WIMPs



$$\Omega h^2 \approx 0.1 \times \left(\frac{3 \times 10^{-26} cm^3 s^{-1}}{\langle \sigma v \rangle} \right)$$

$$\approx 0.1 \times \left(\frac{\alpha^2/(100\mathrm{GeV})^2}{\langle \sigma v \rangle} \right)$$

THE OVERLORDS OF THE SINGLE SCALE

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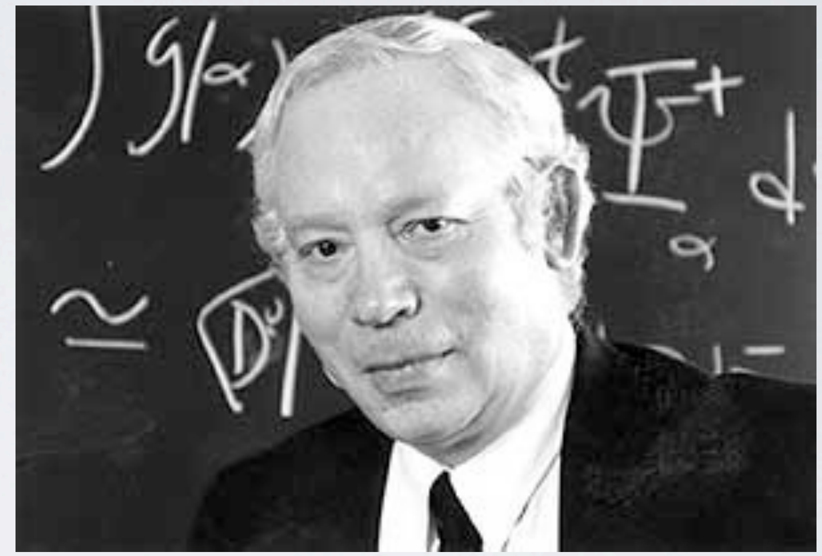

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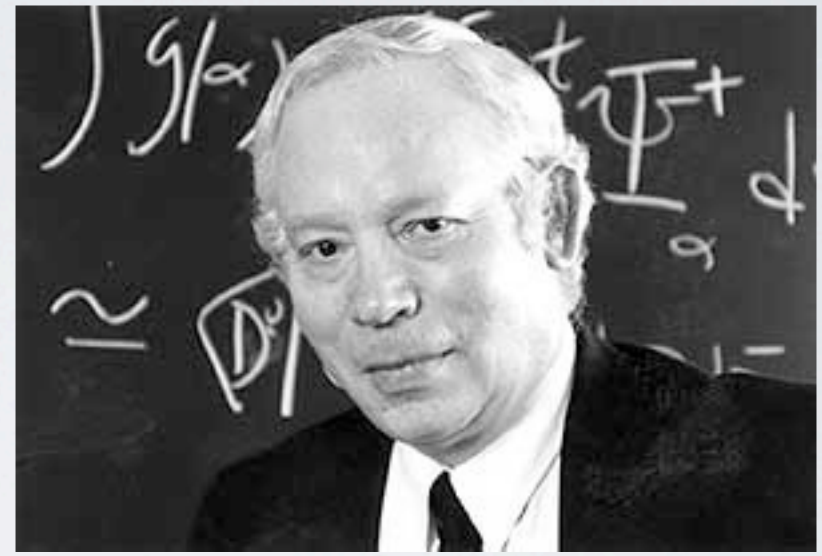

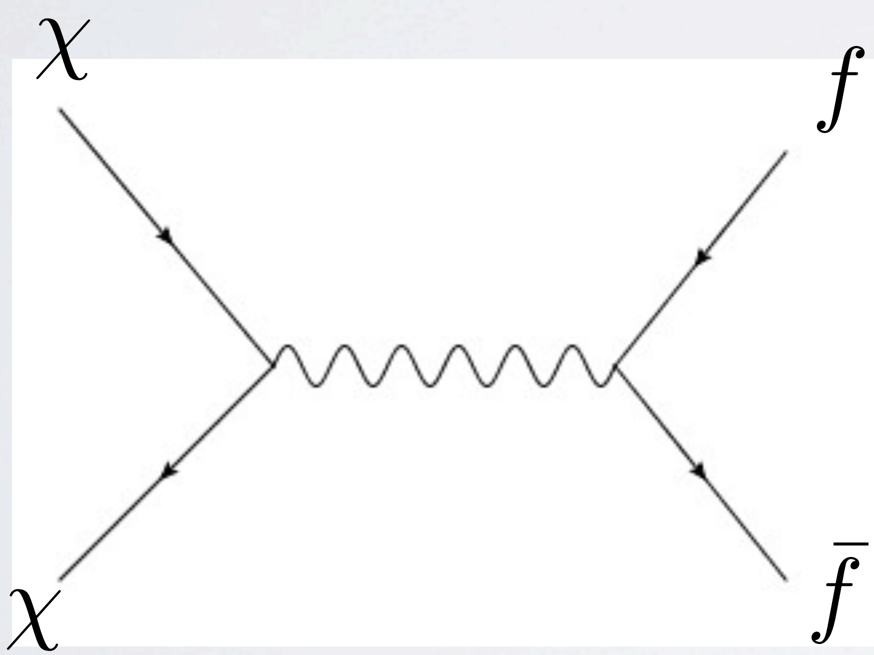

$$\sigma \approx G_f^2 m_\chi^2$$

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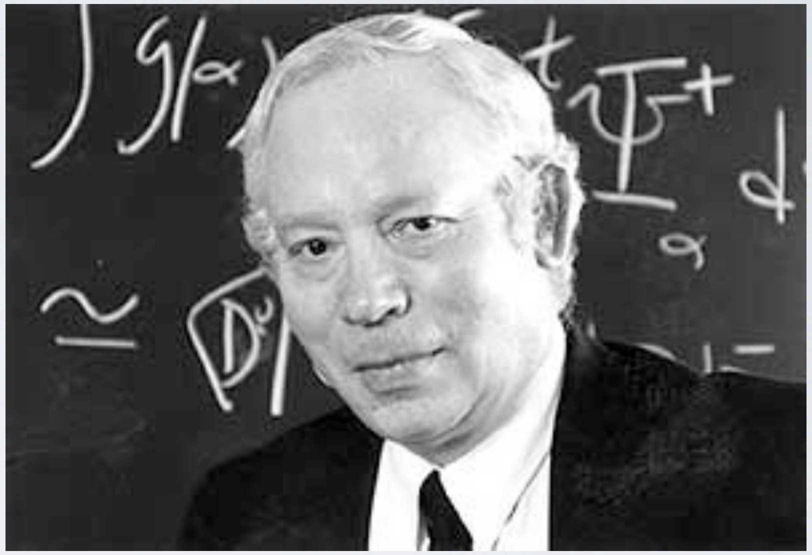

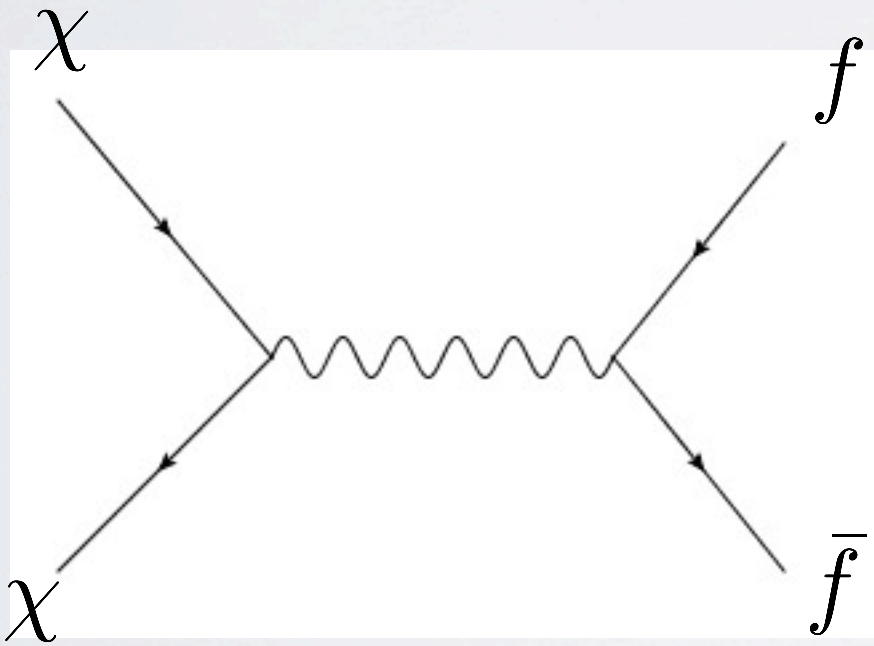

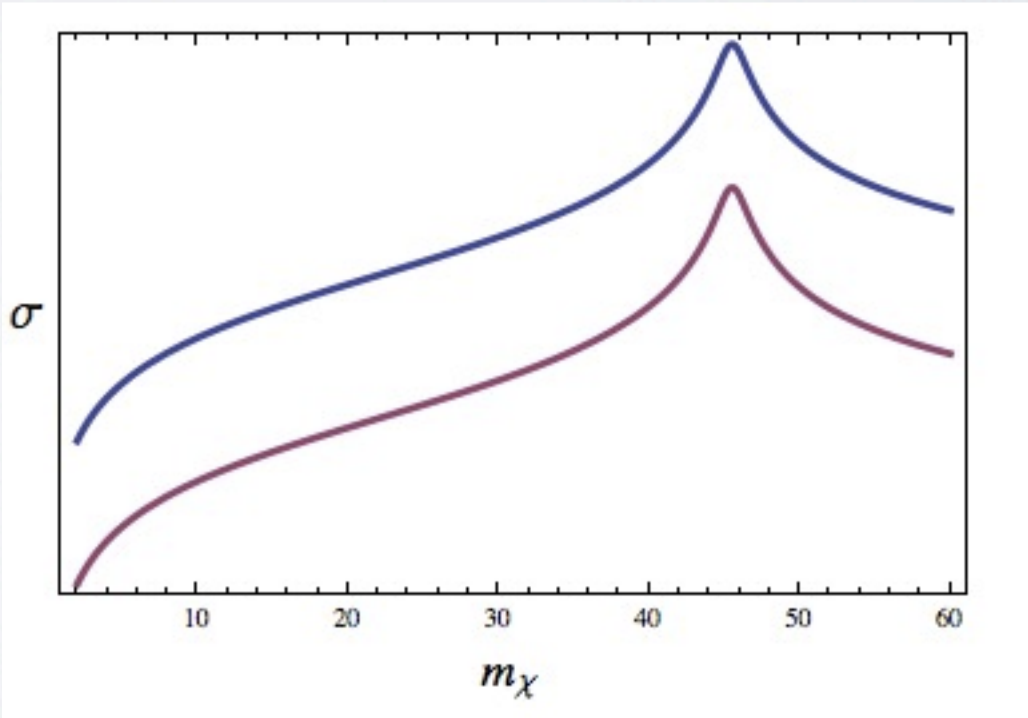

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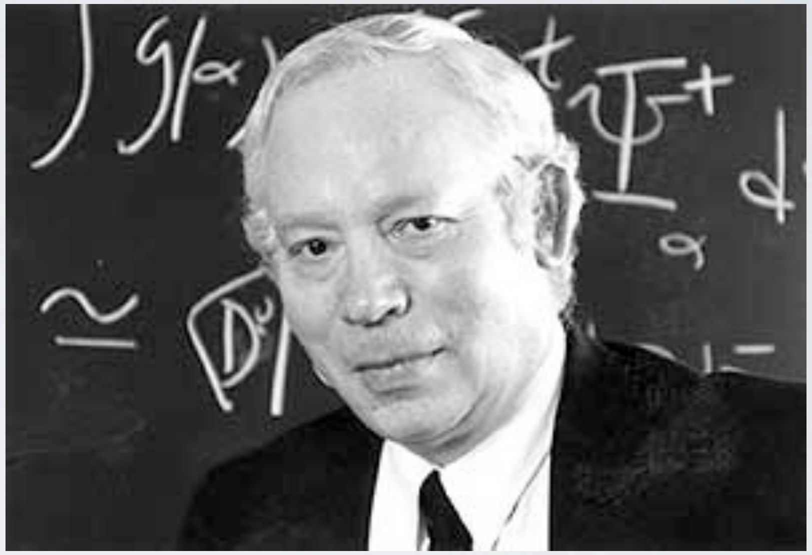

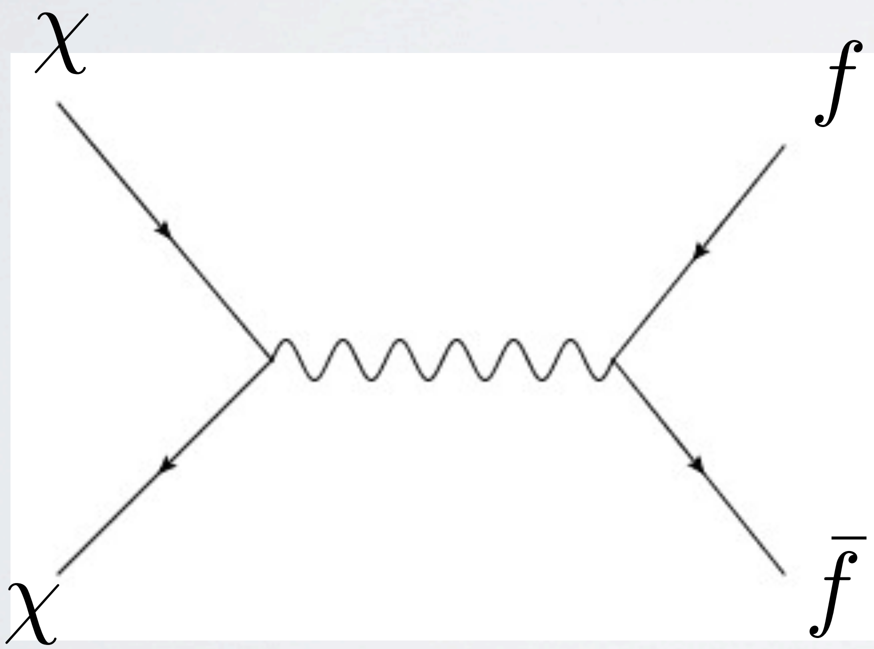

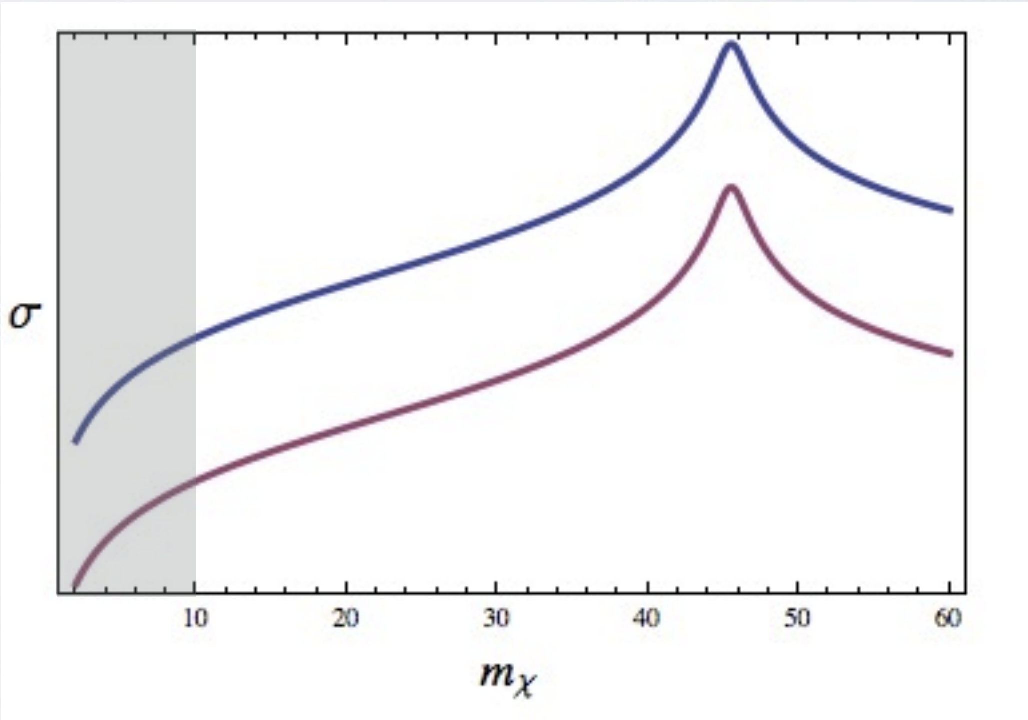

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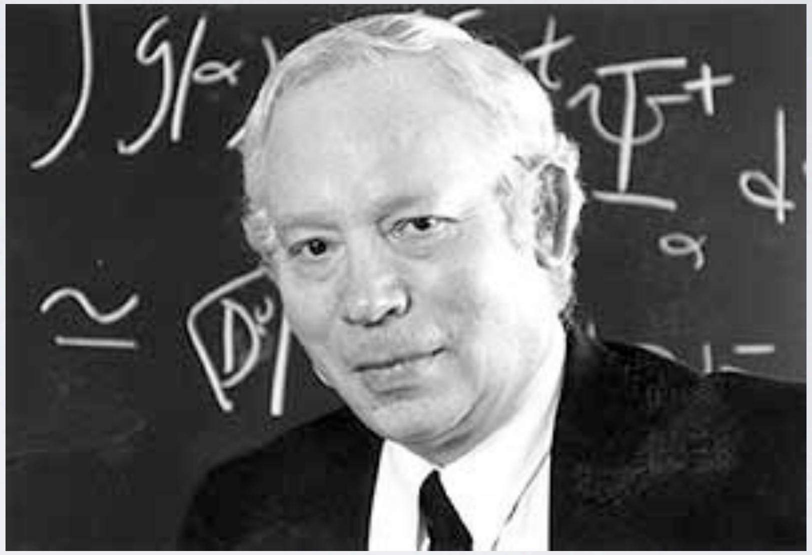

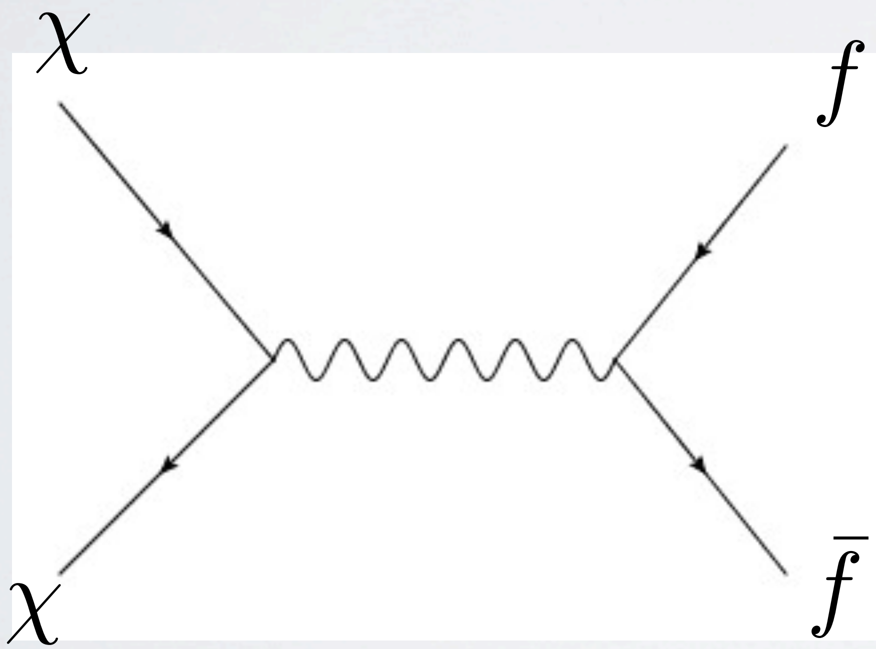

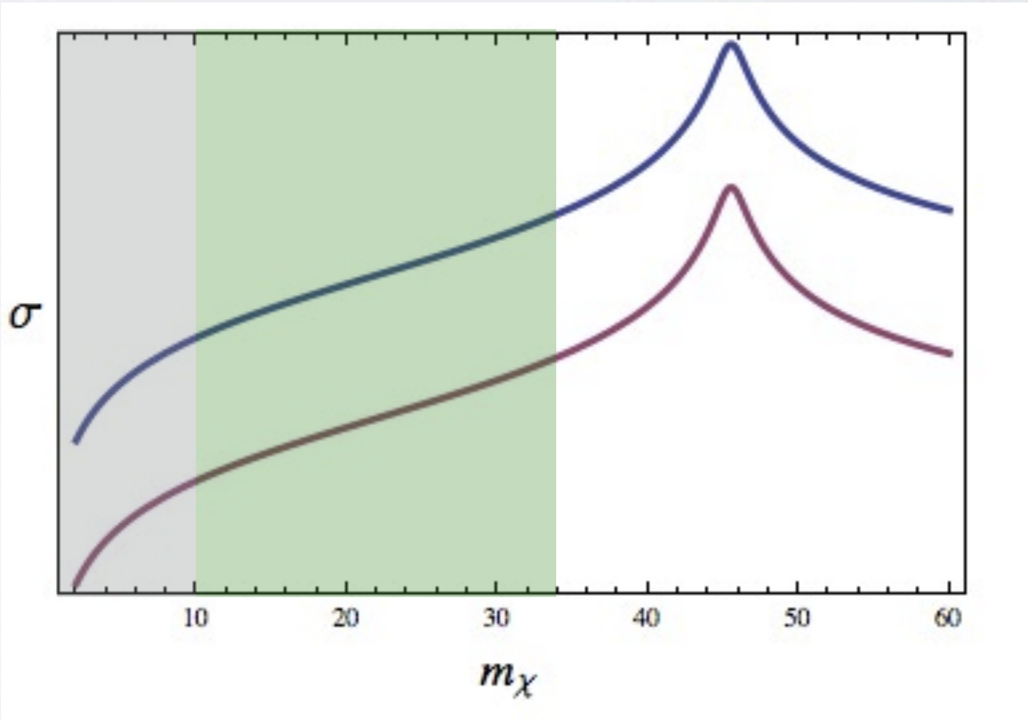

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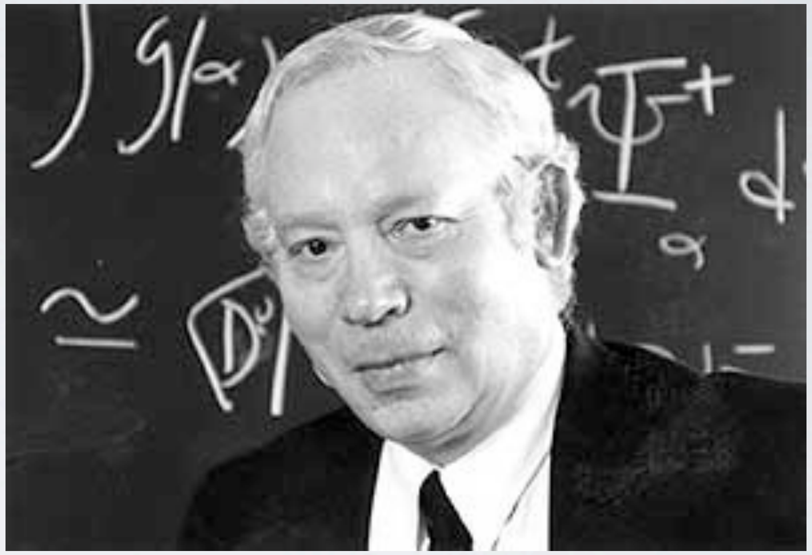

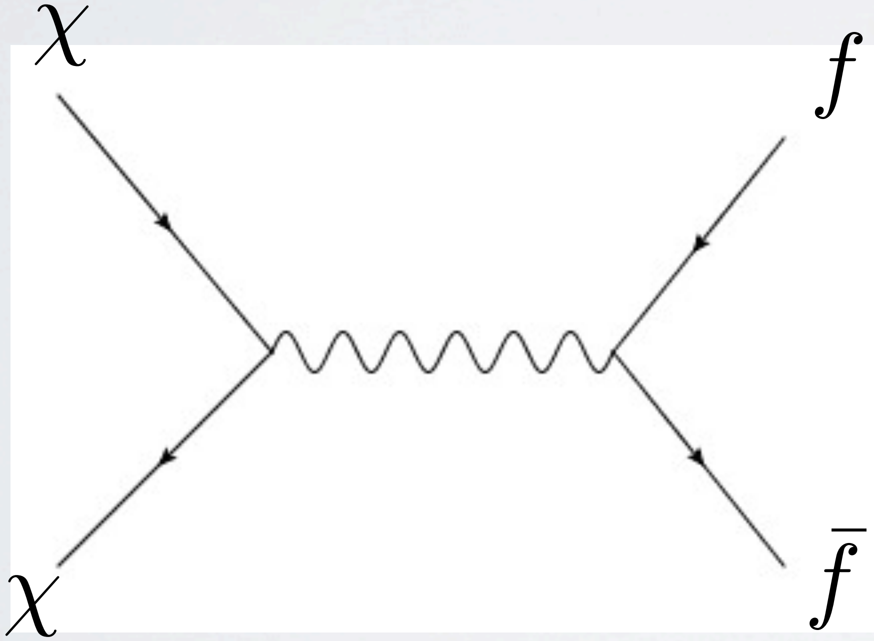

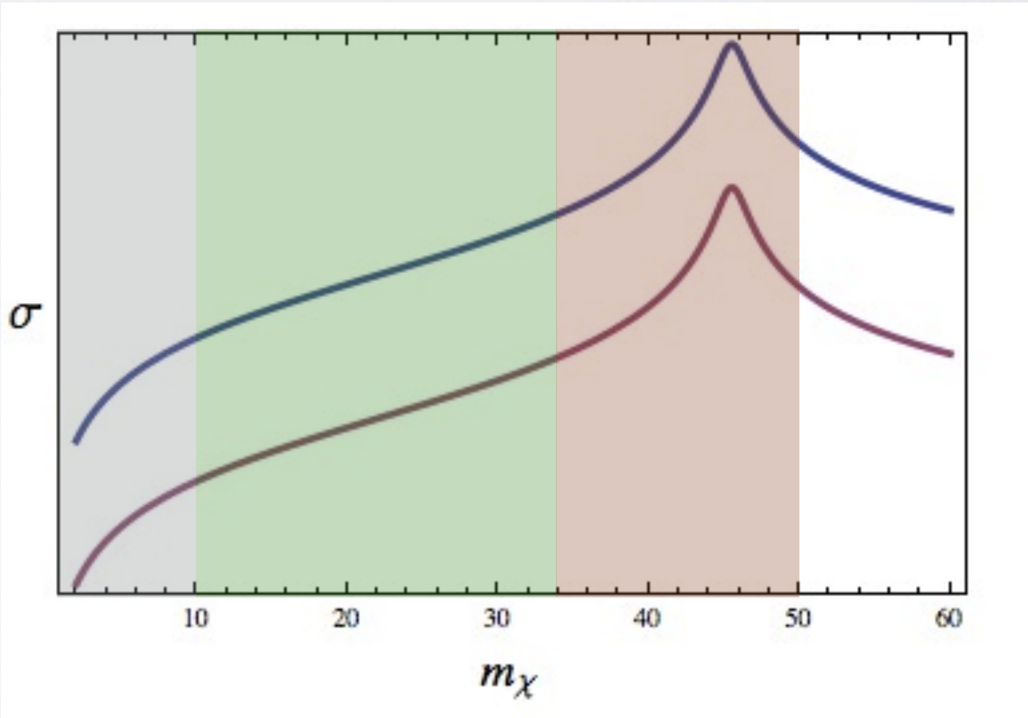

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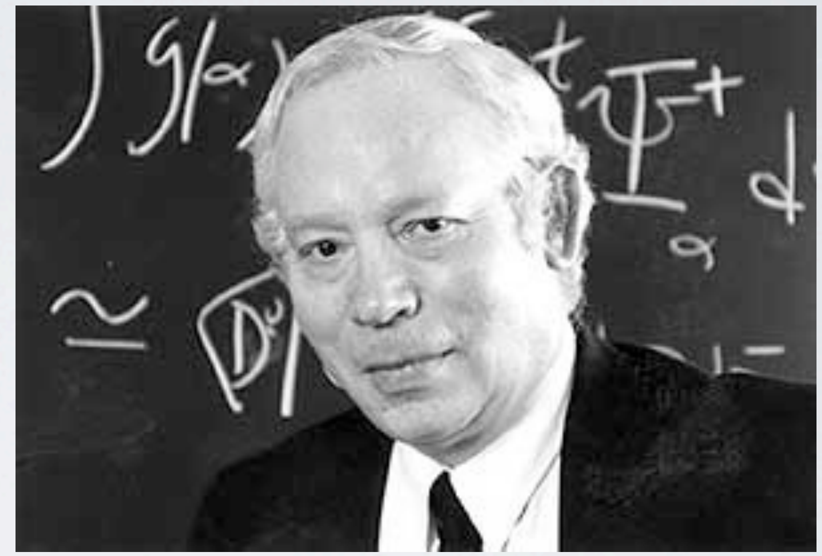

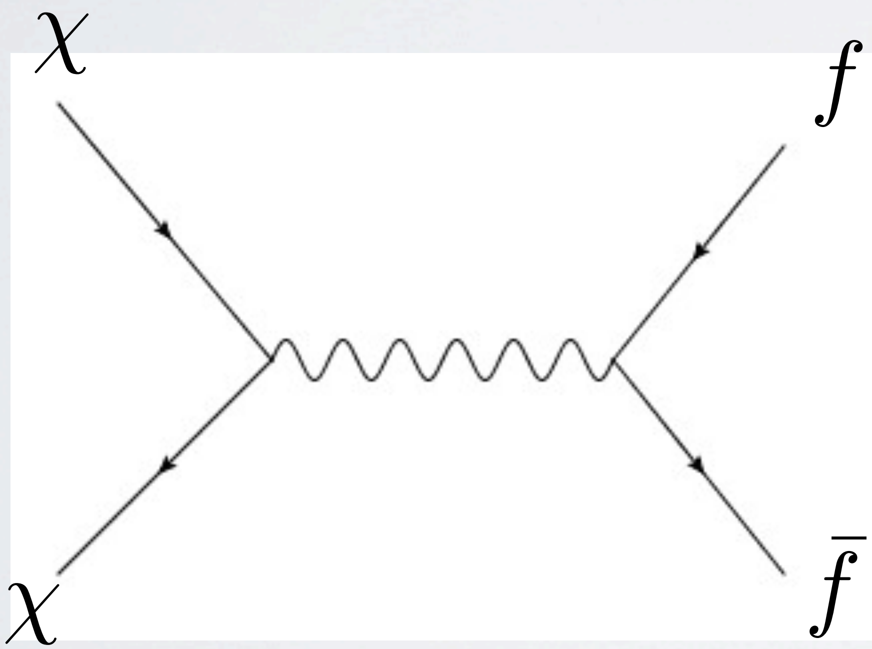

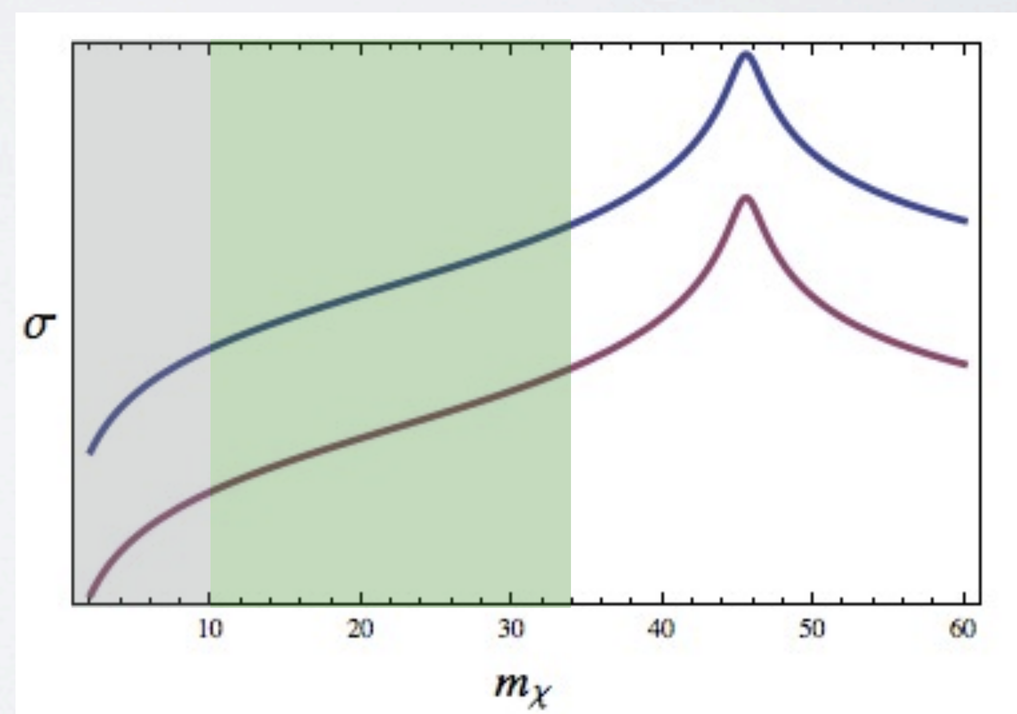

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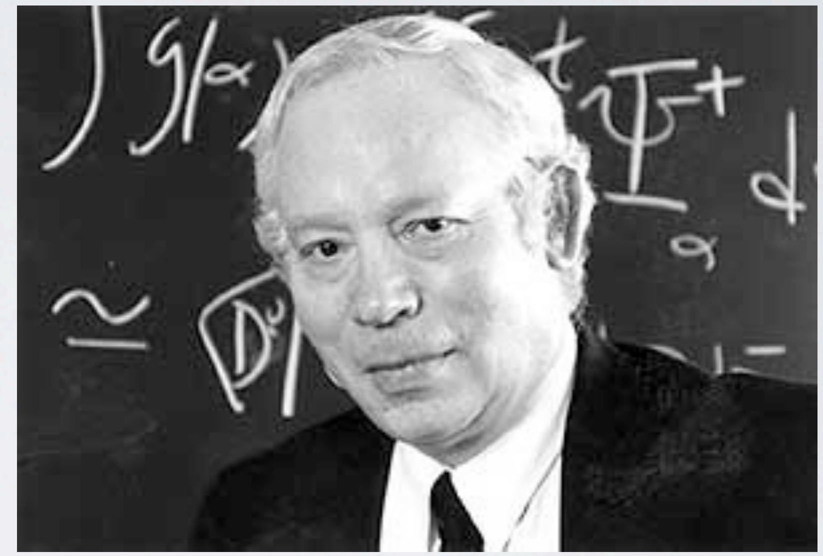

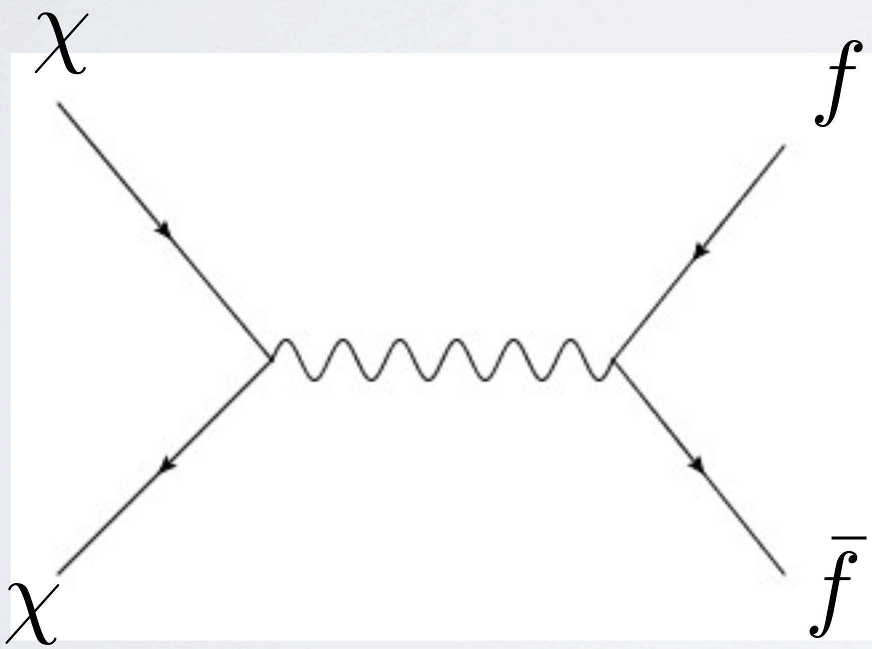

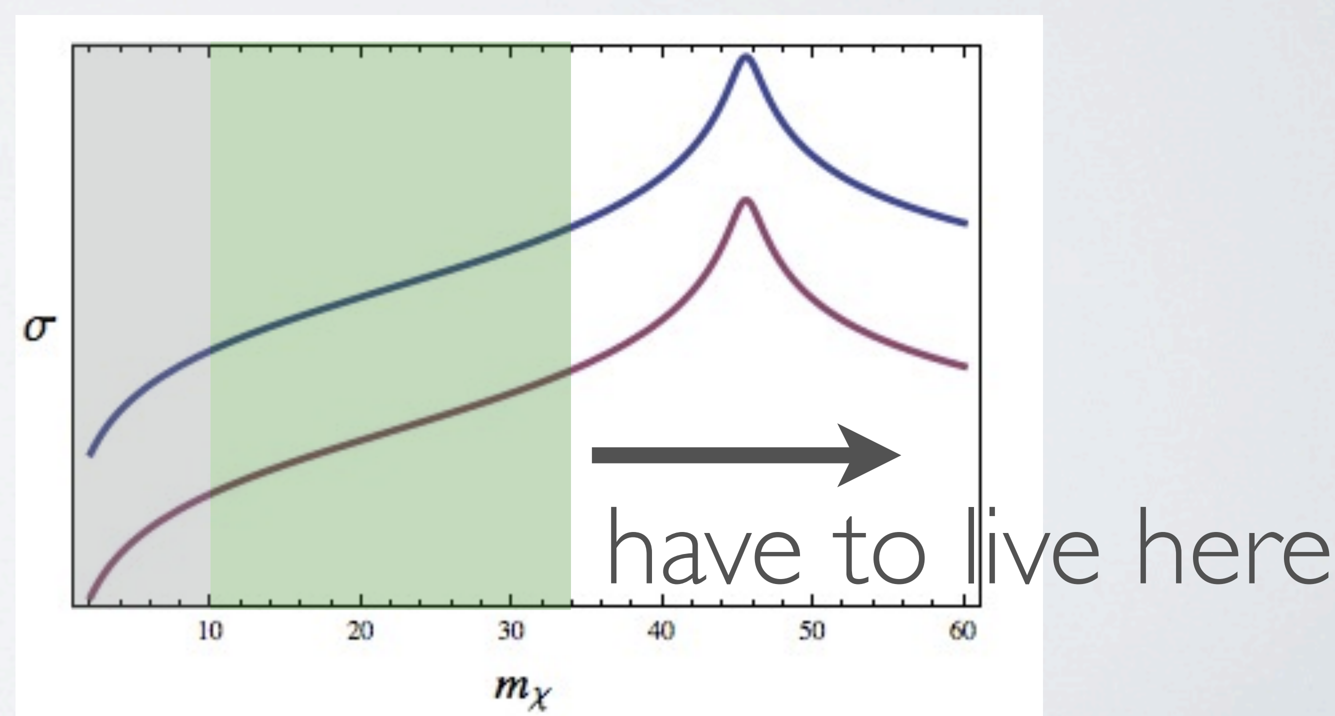

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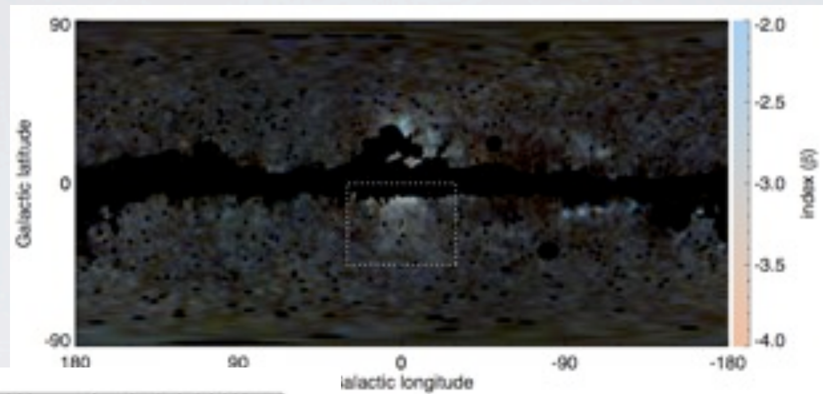
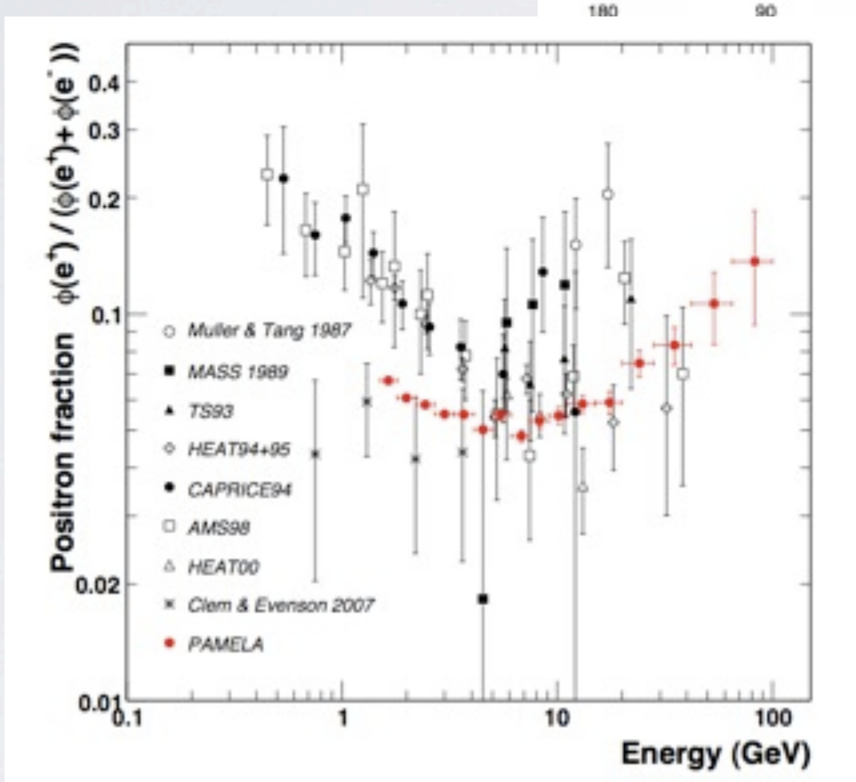
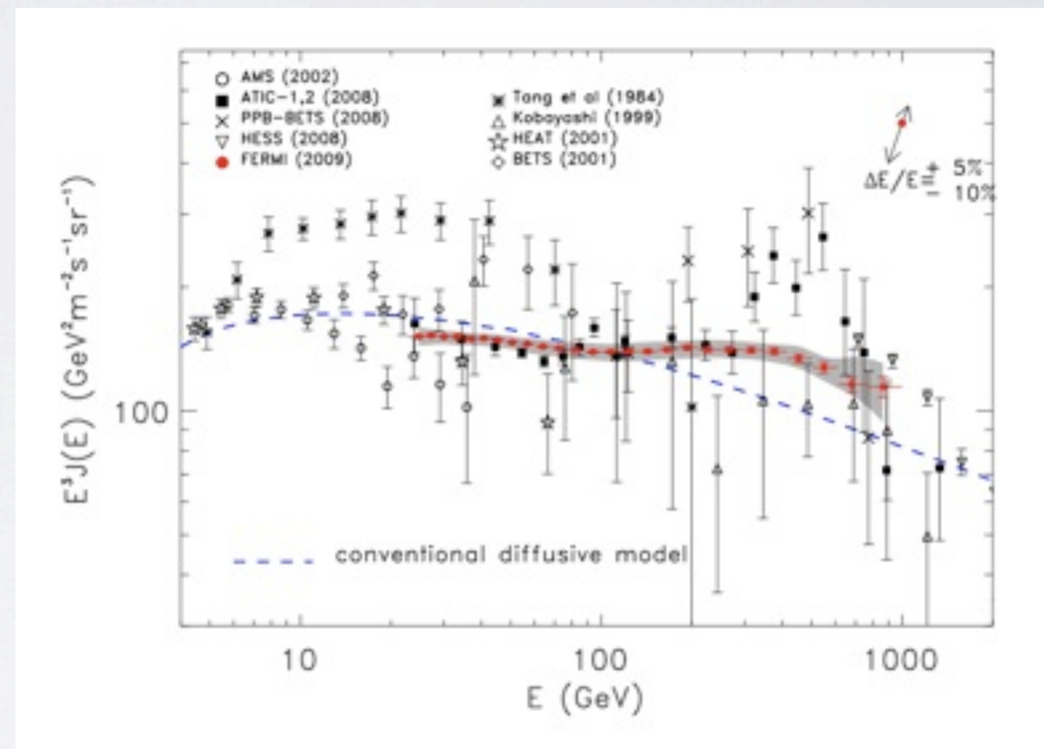
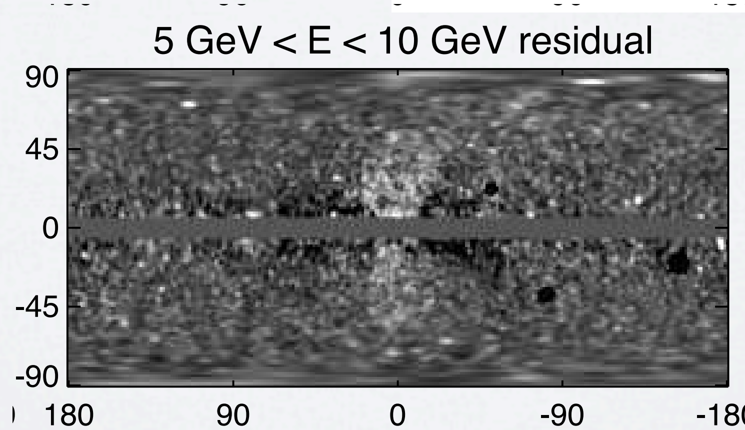
WHY GO AGAINST THE GRAIN?









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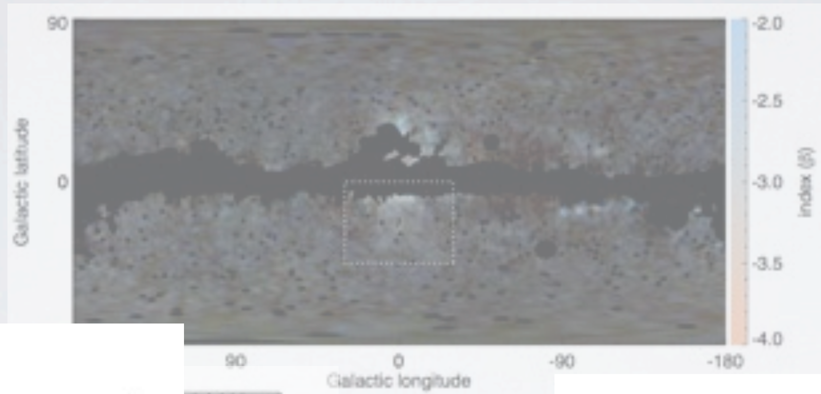

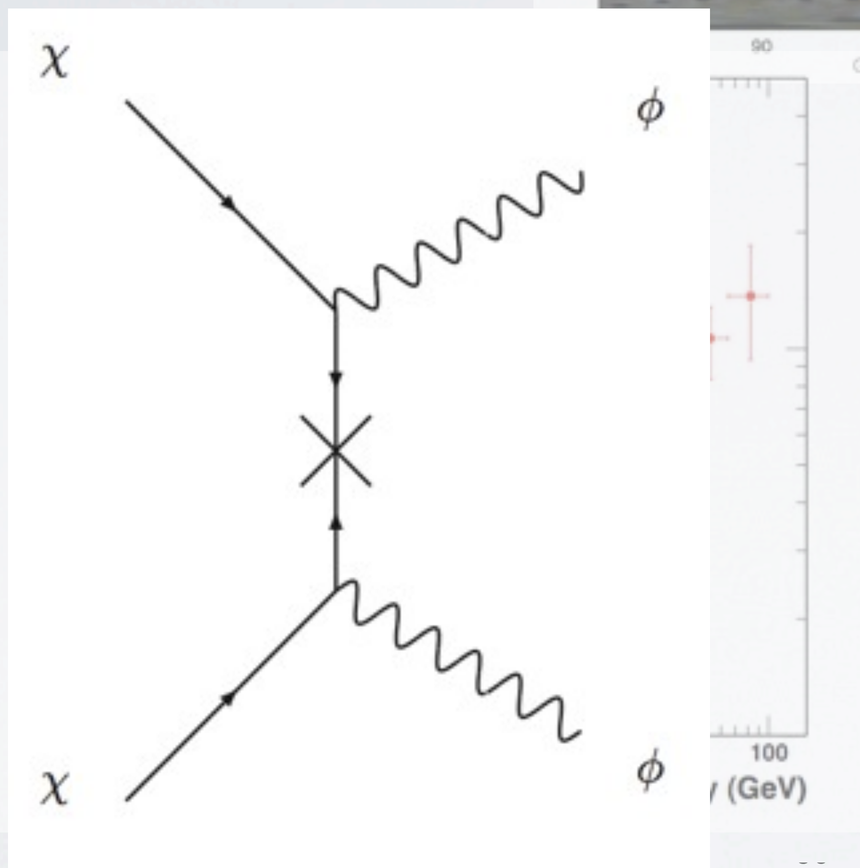

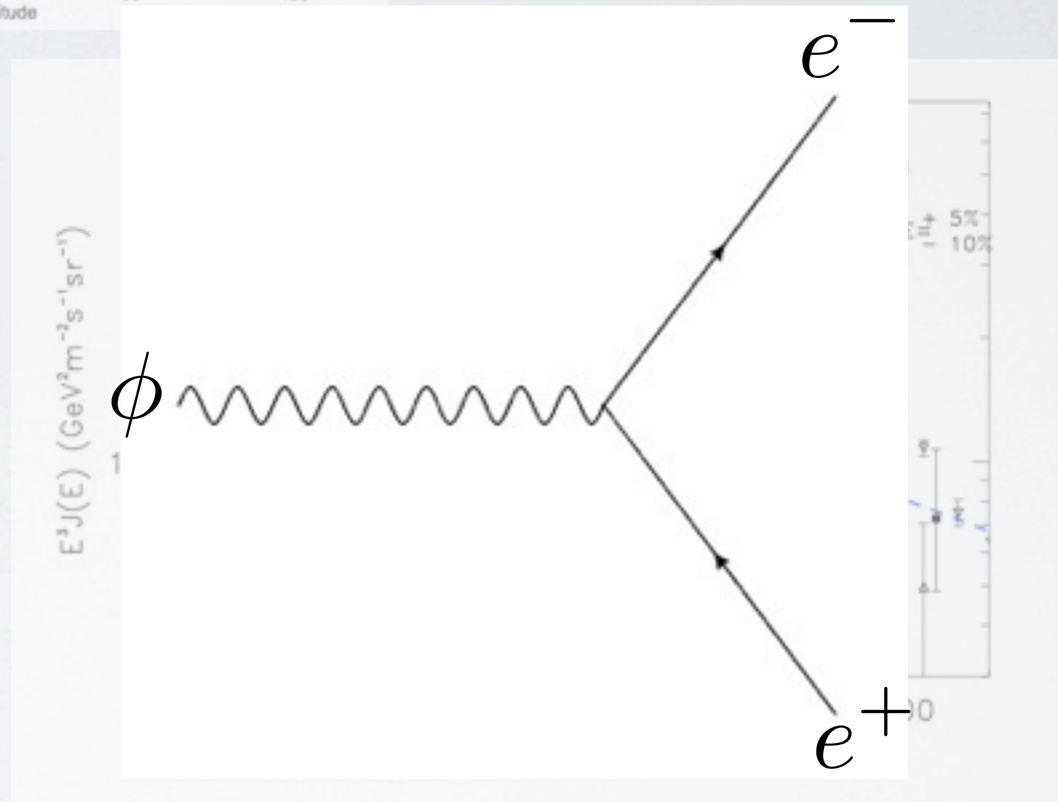

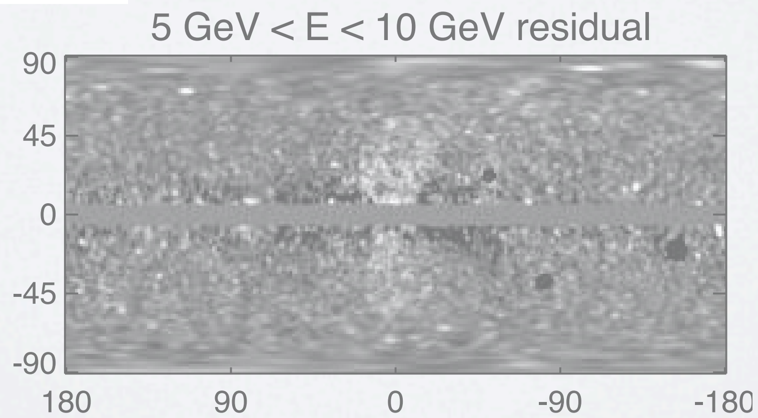

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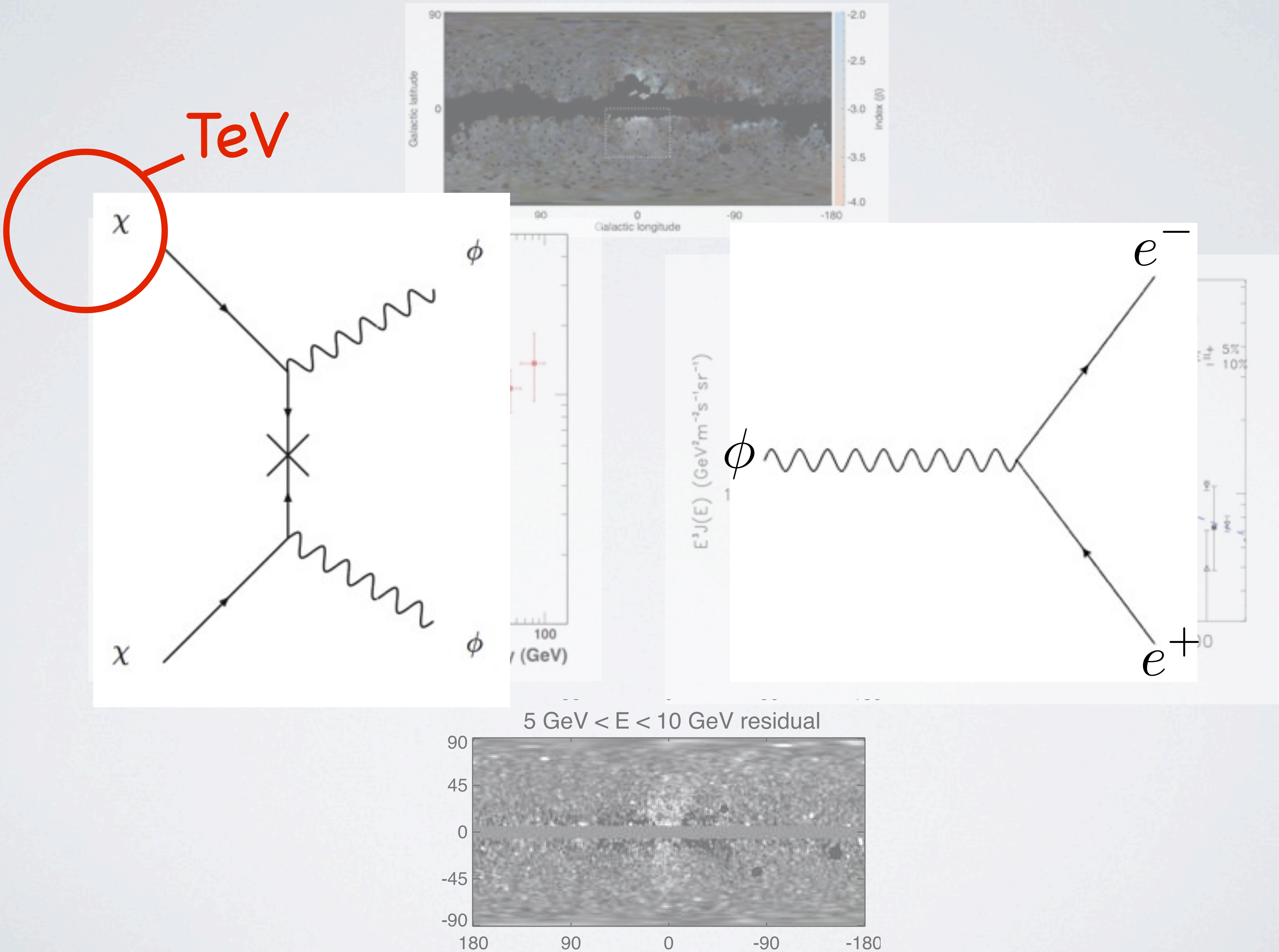

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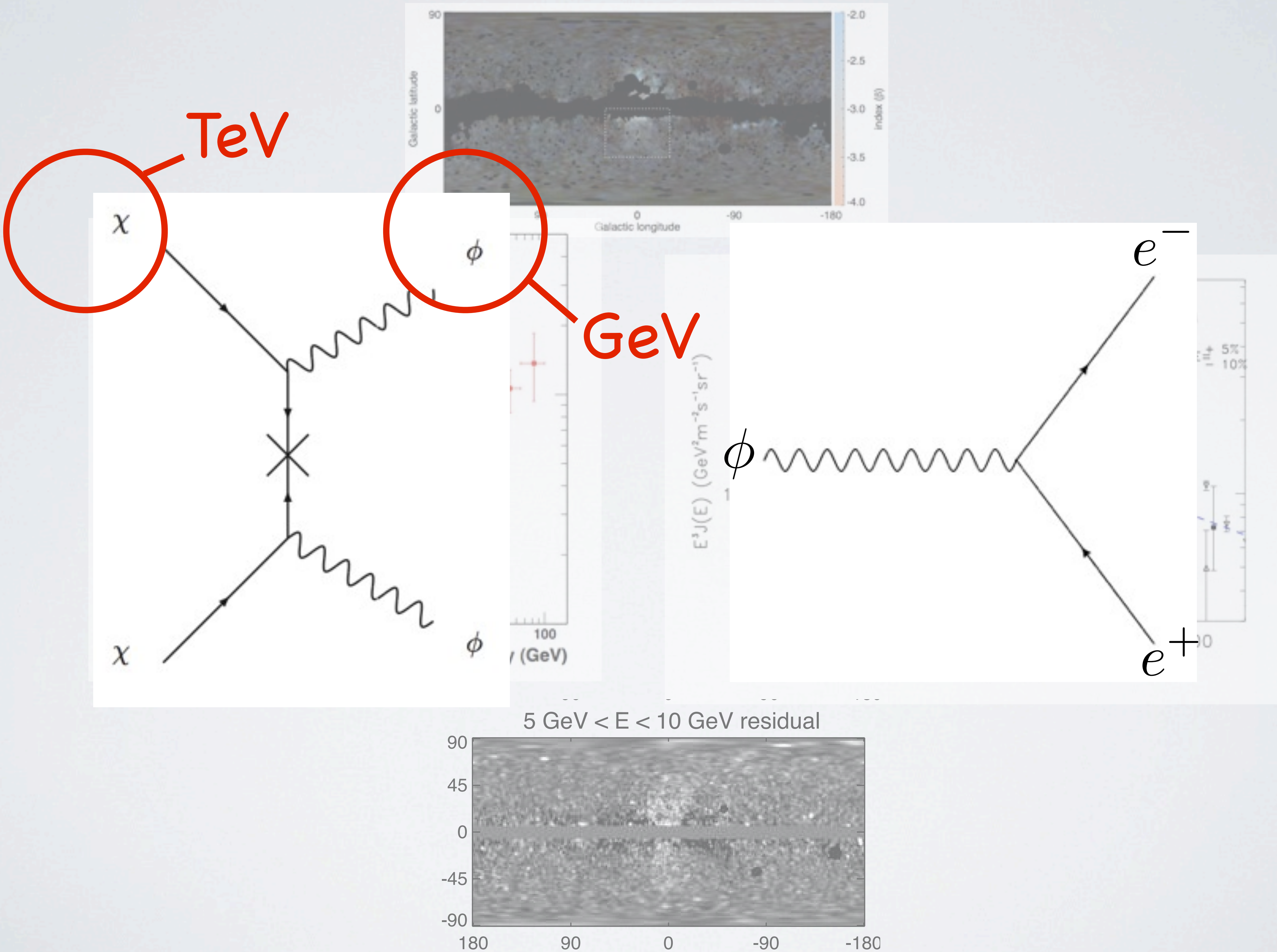

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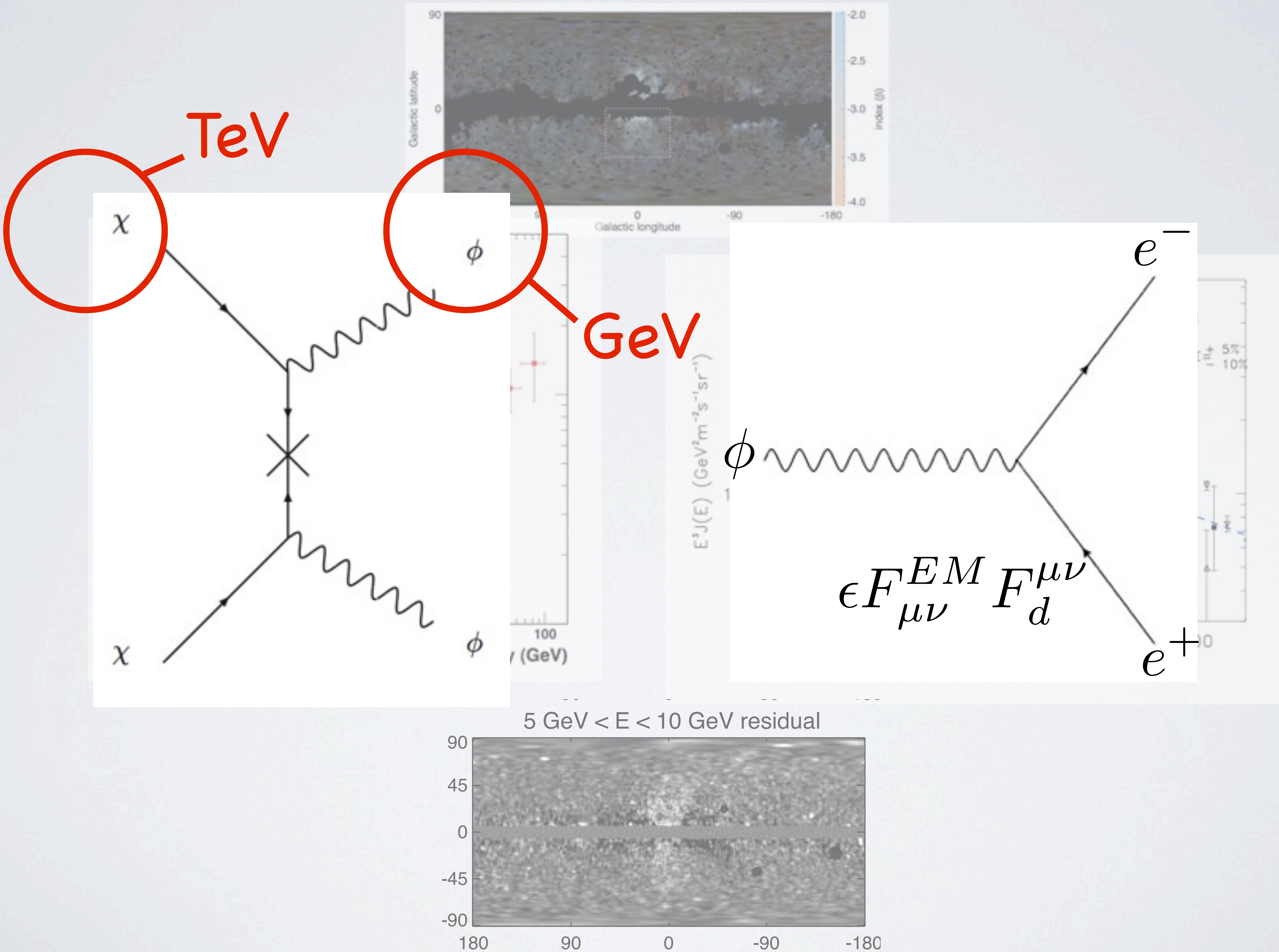

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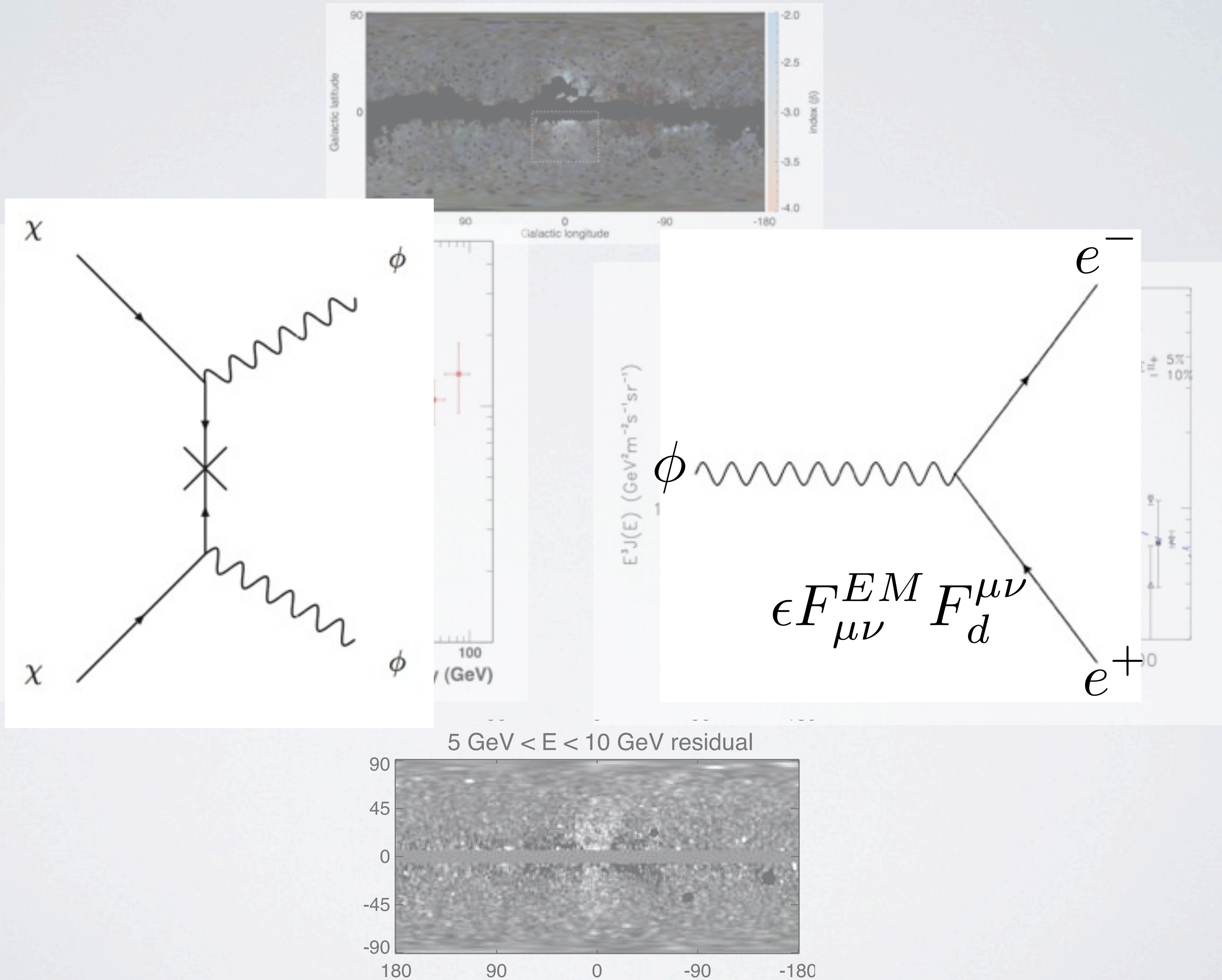

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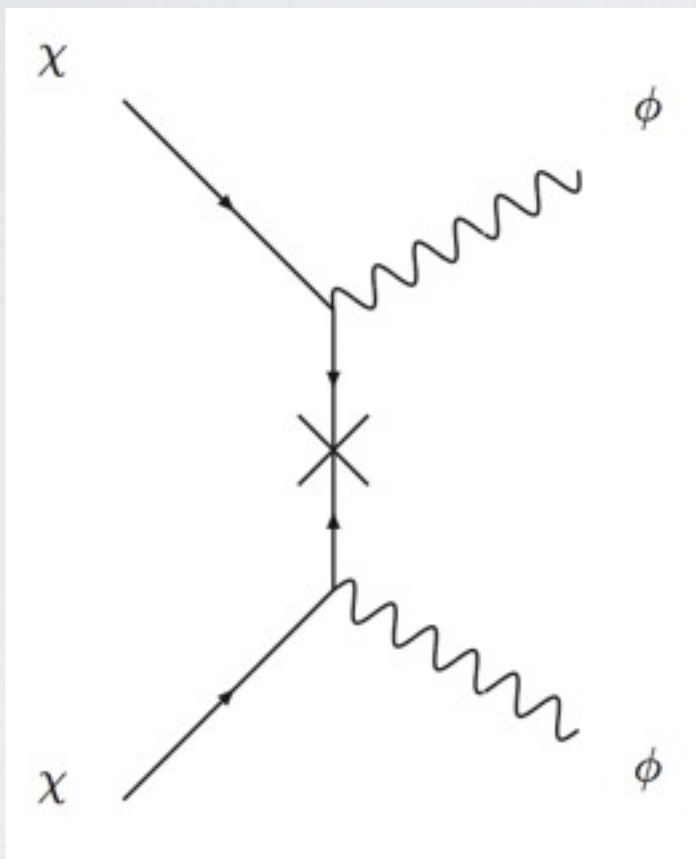

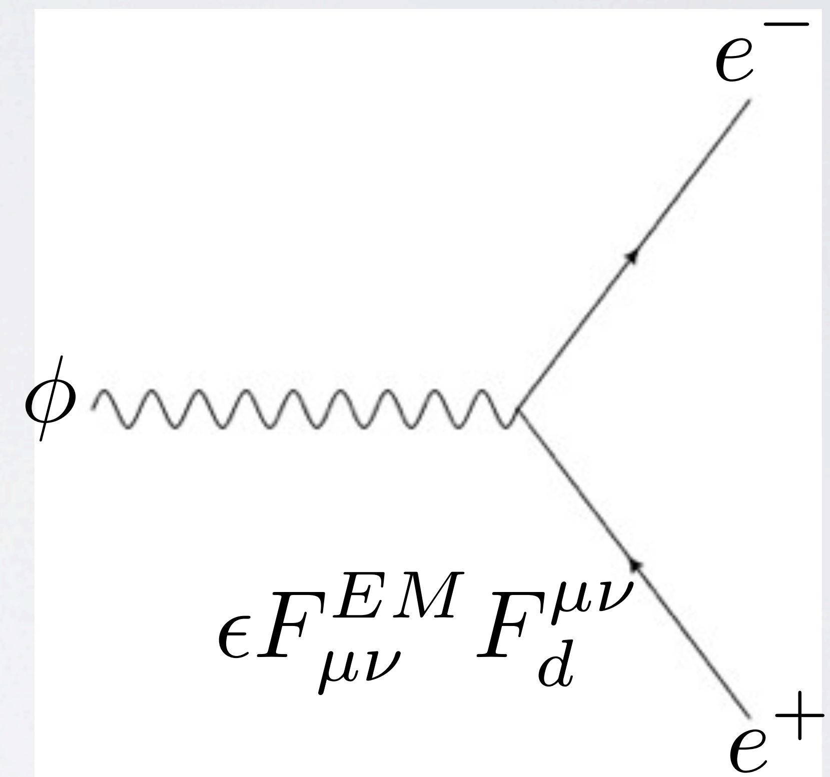

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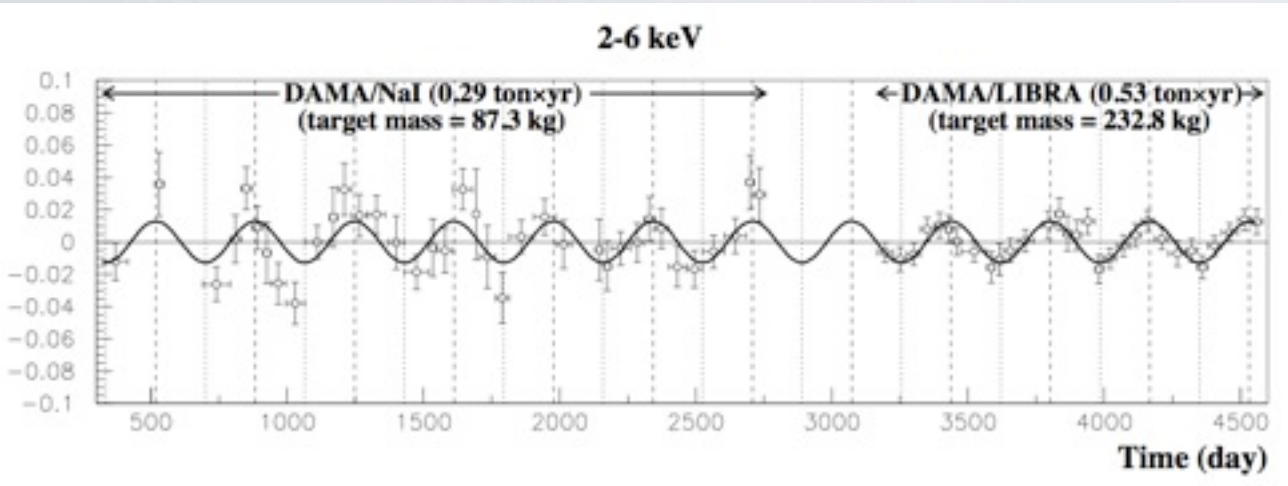

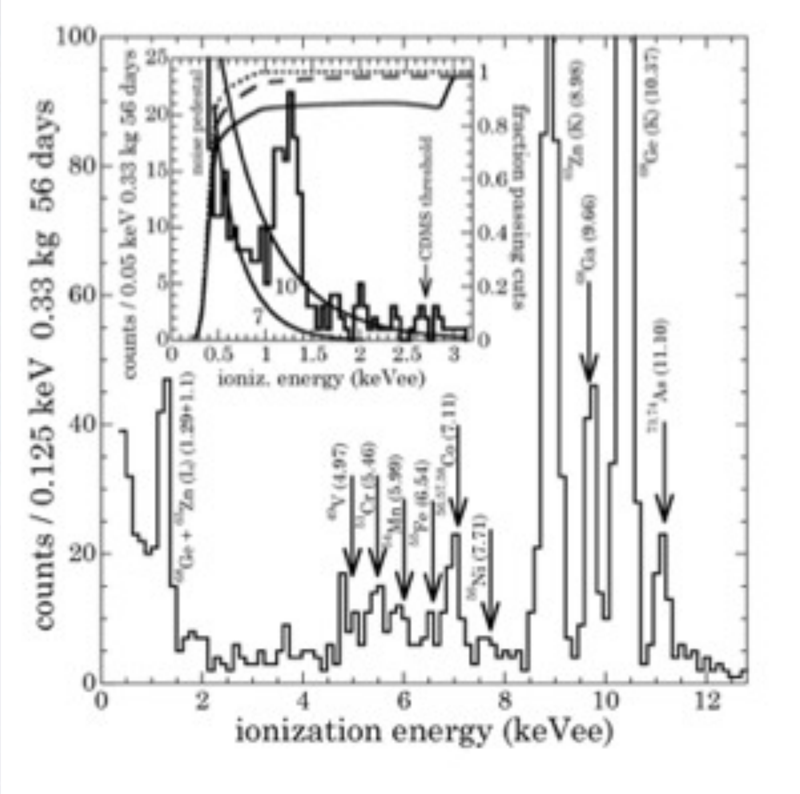

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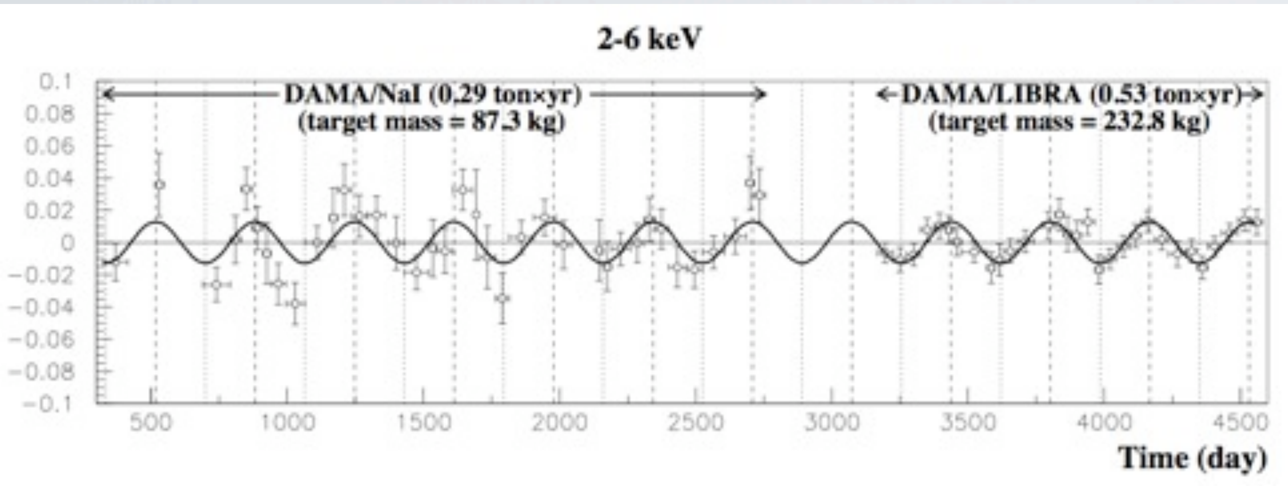

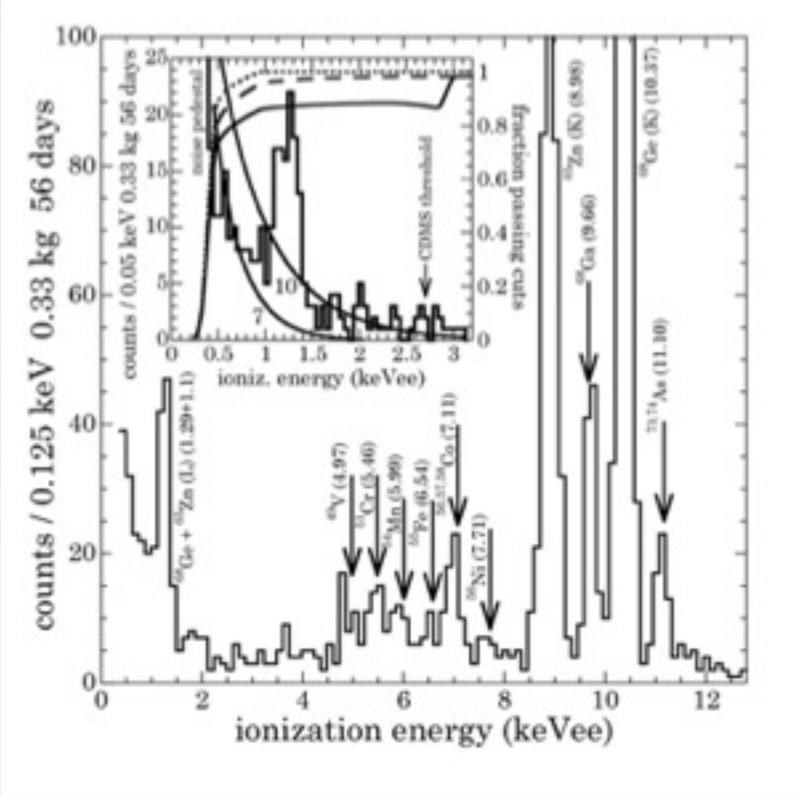

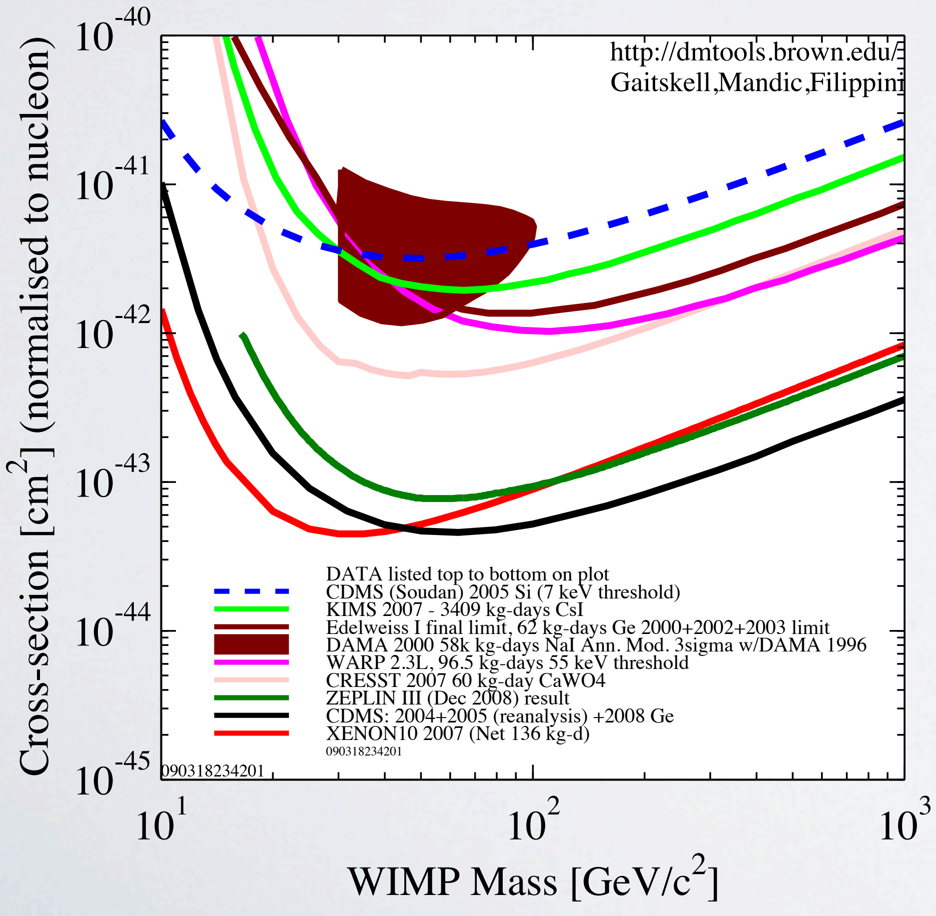

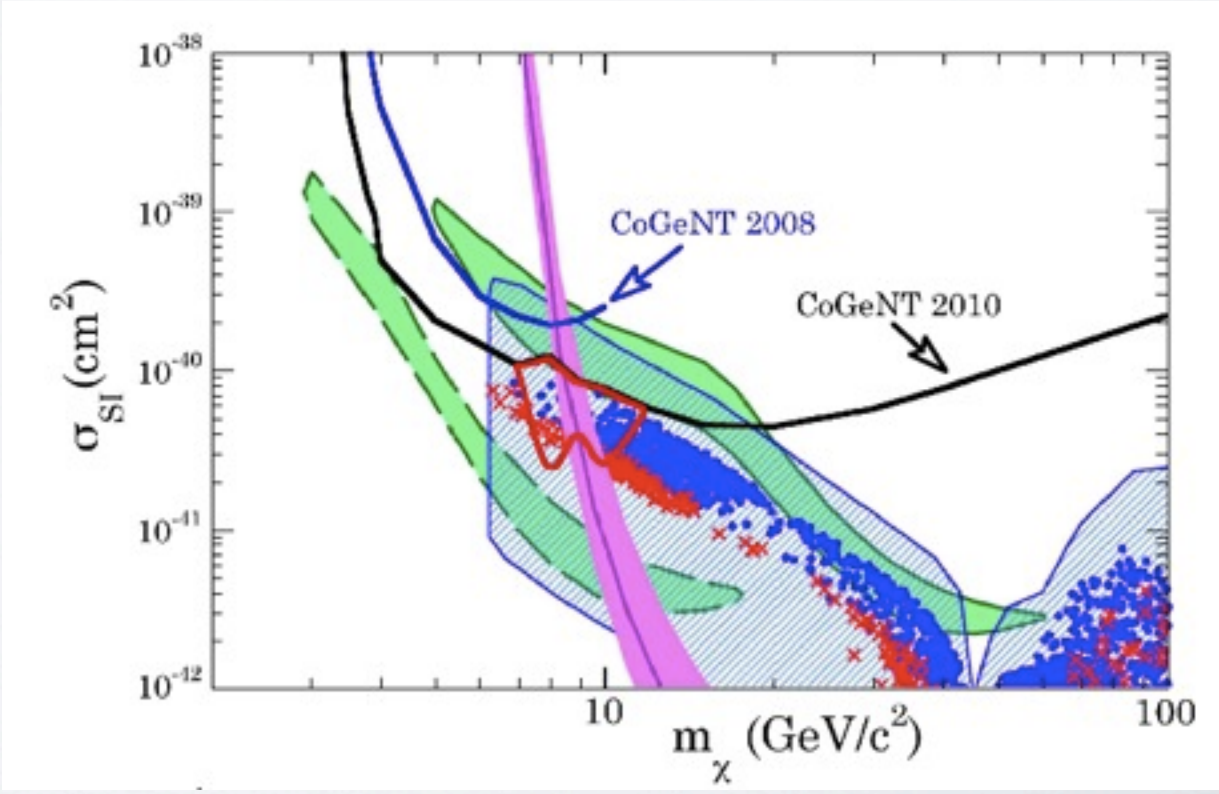

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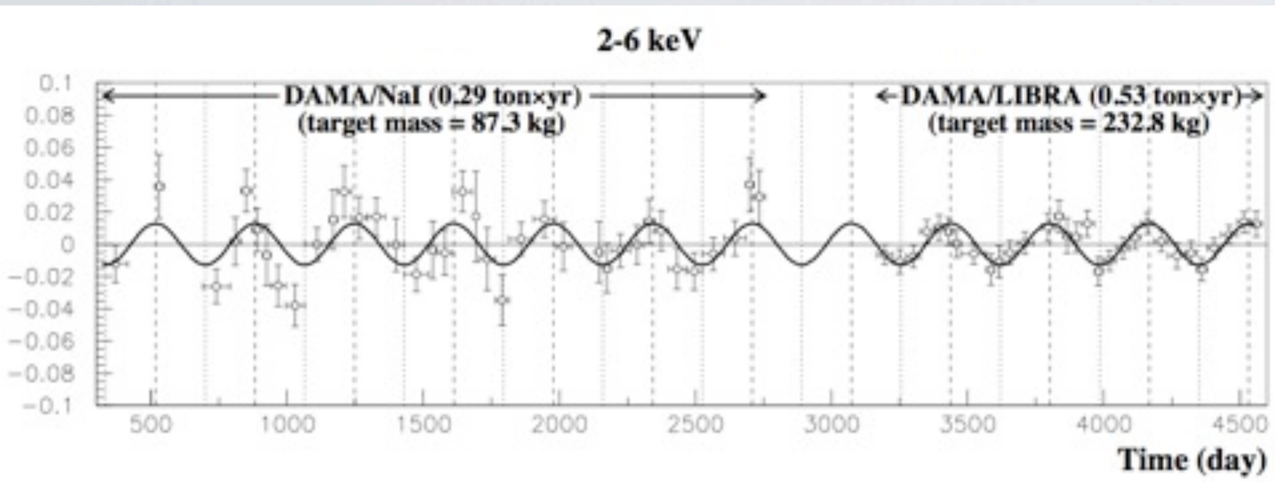

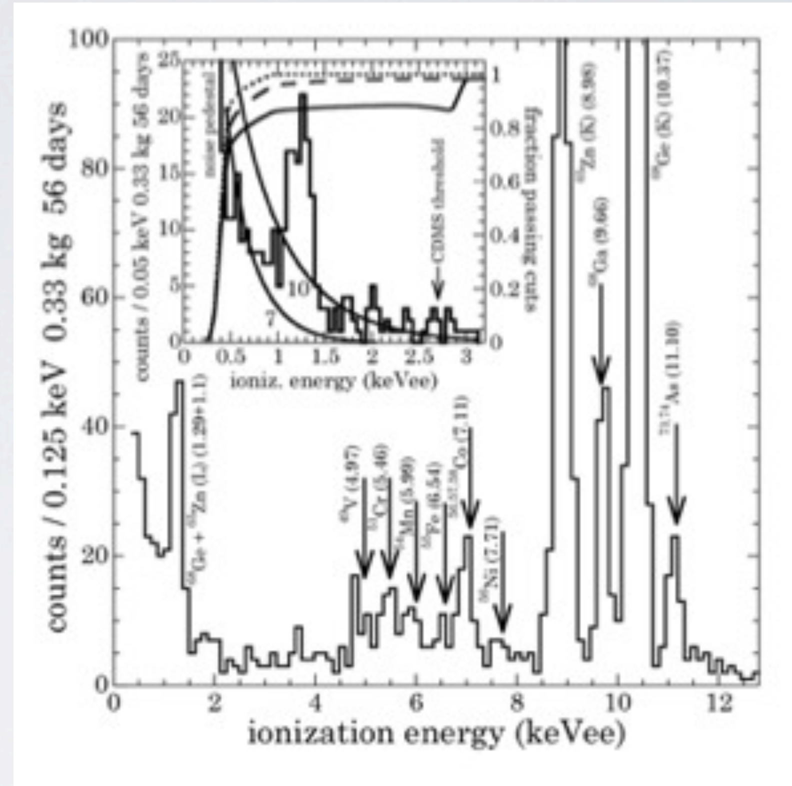

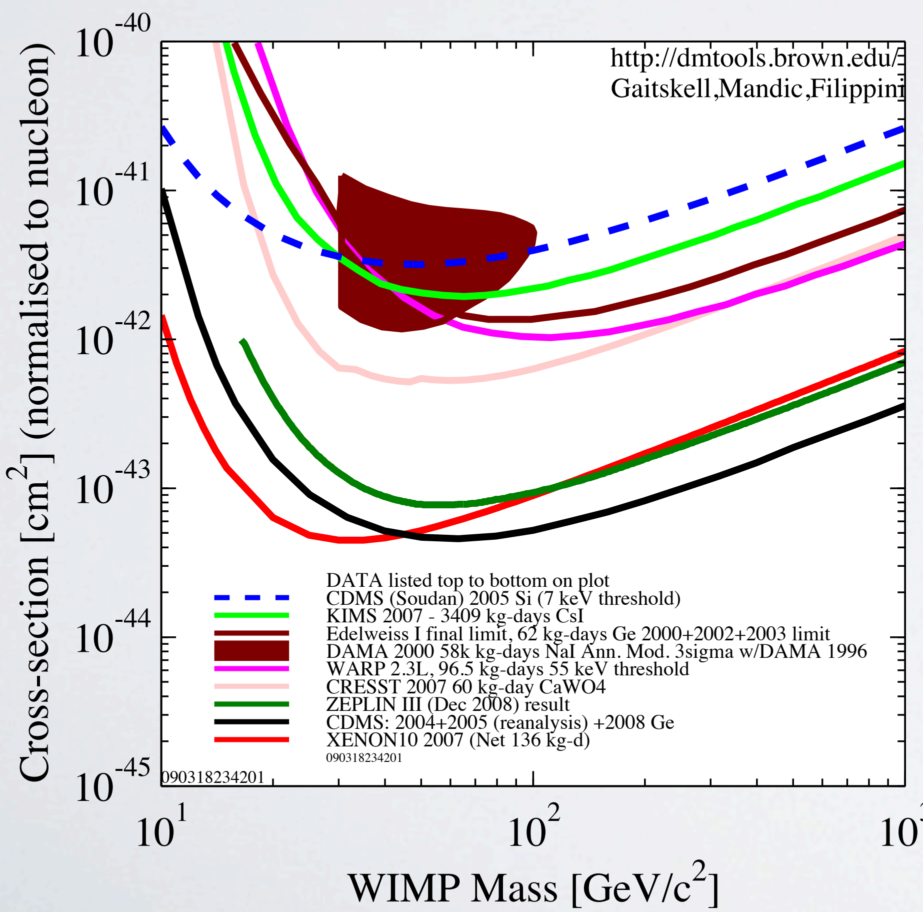

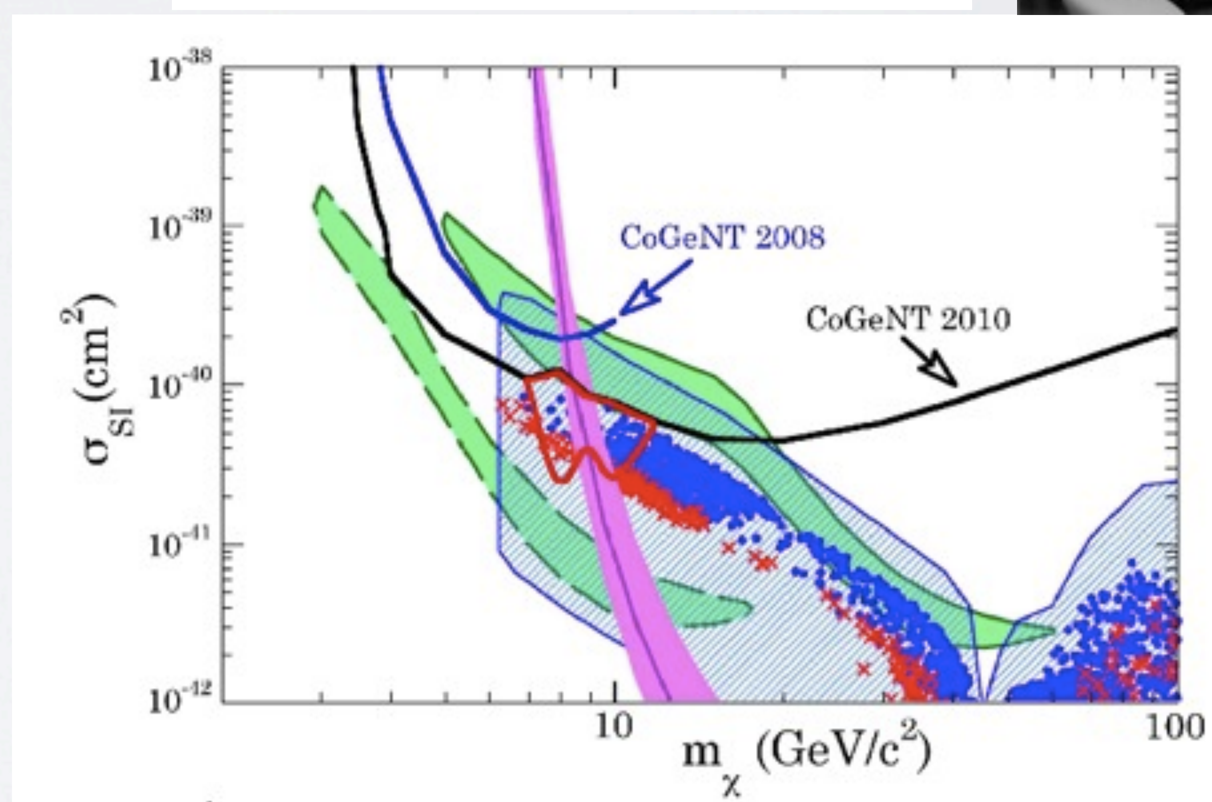

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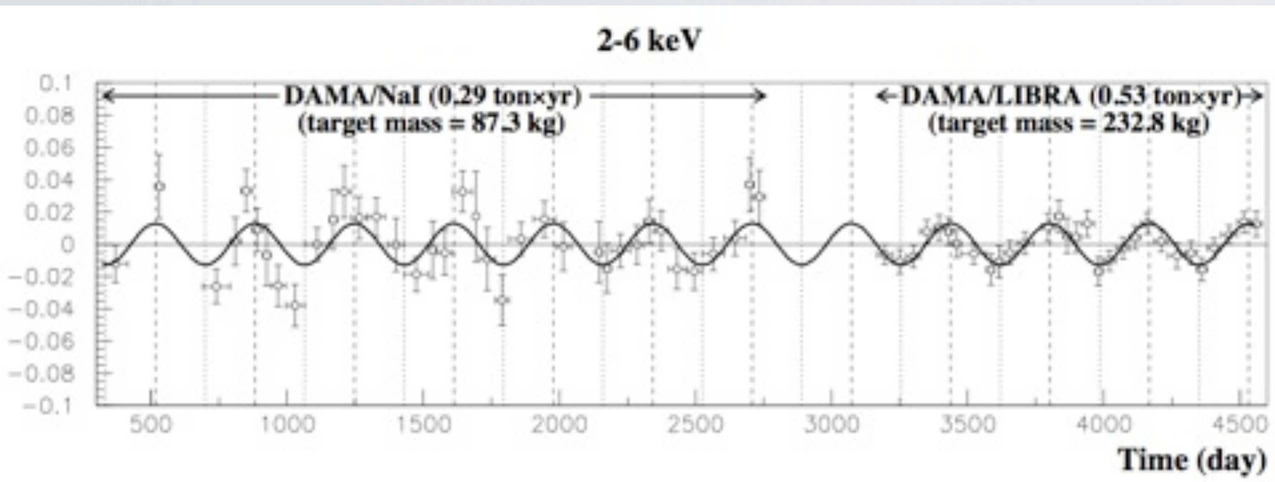

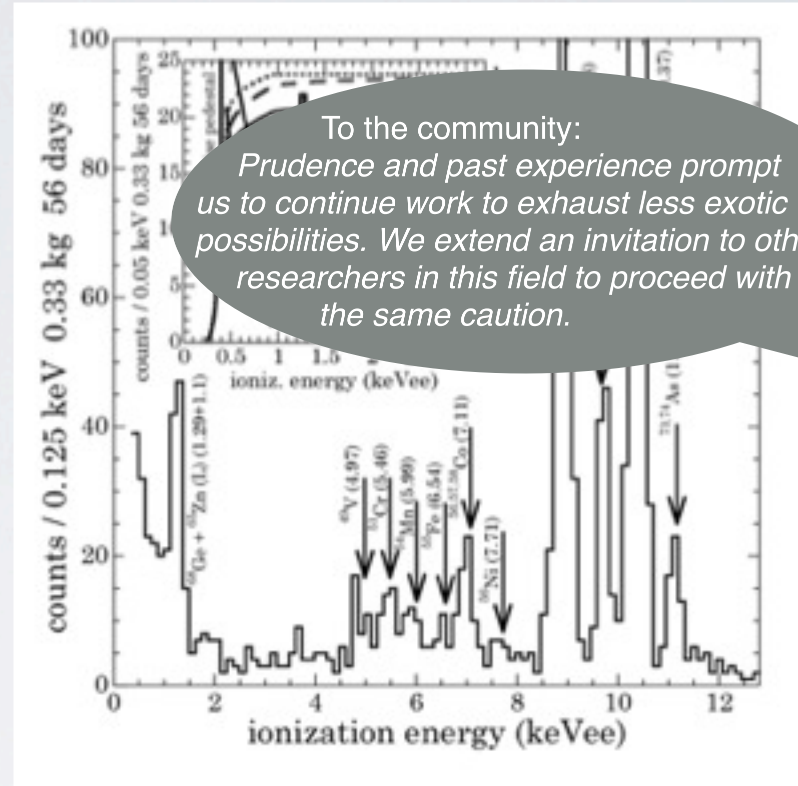

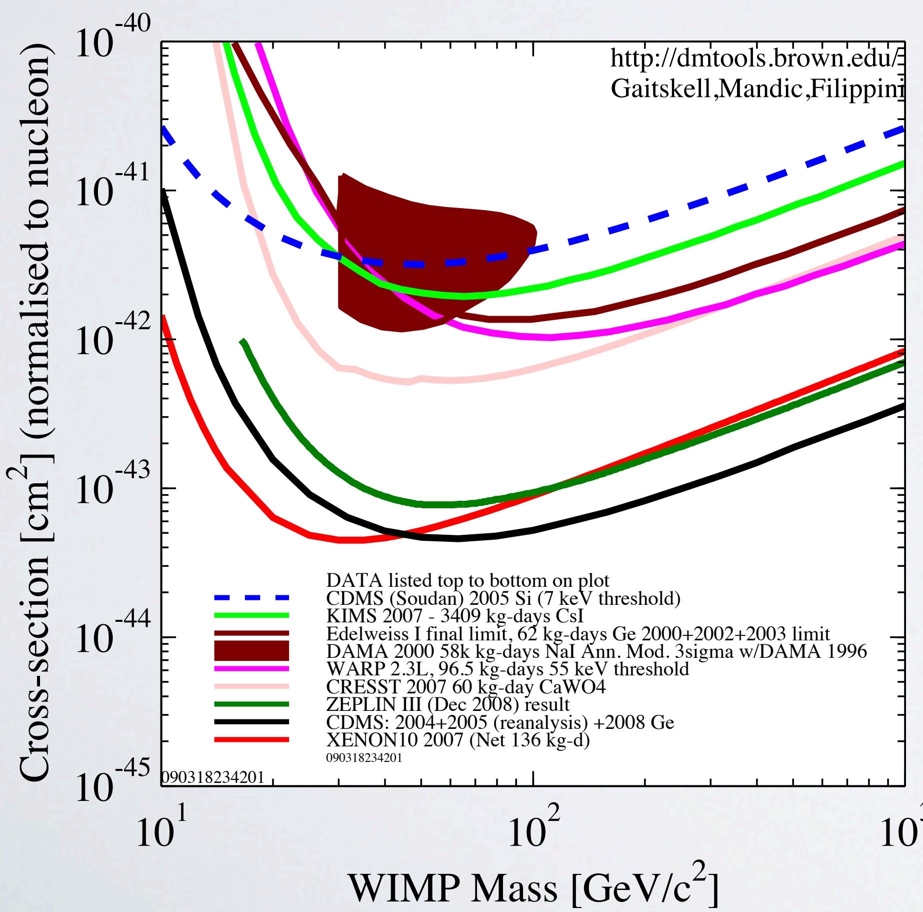

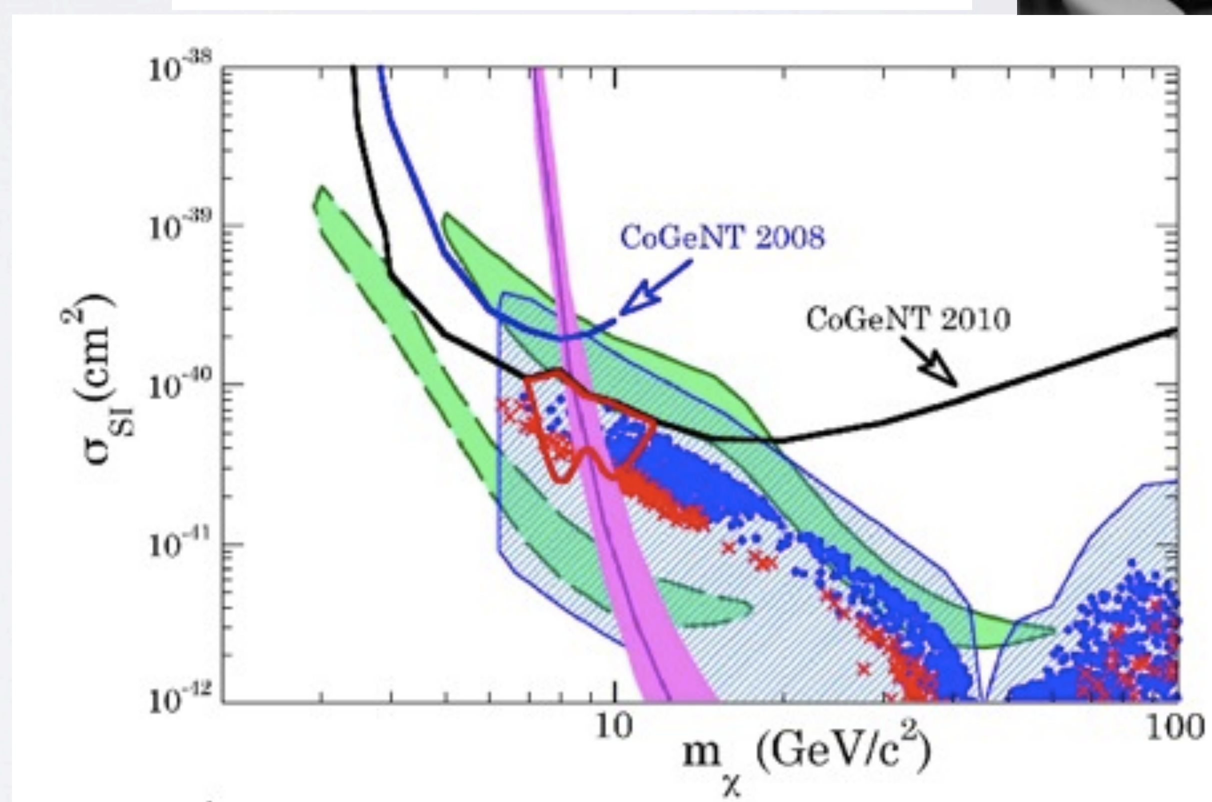

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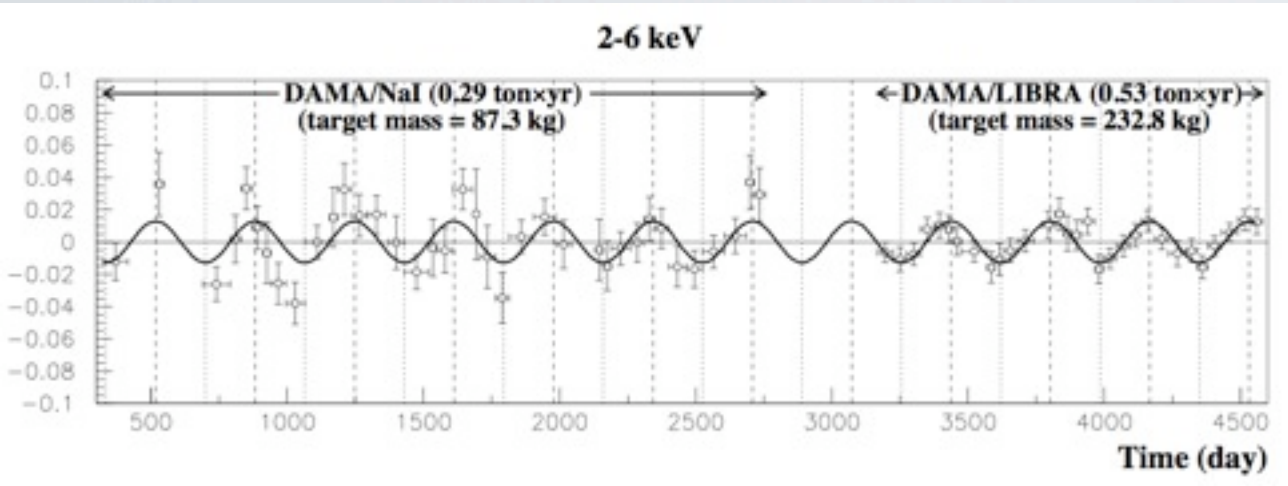
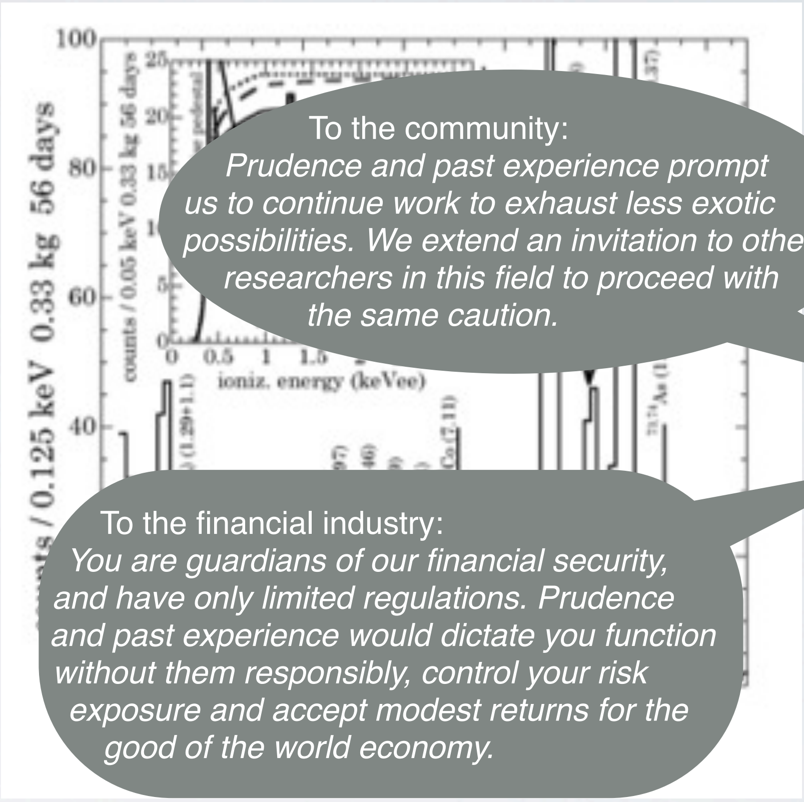
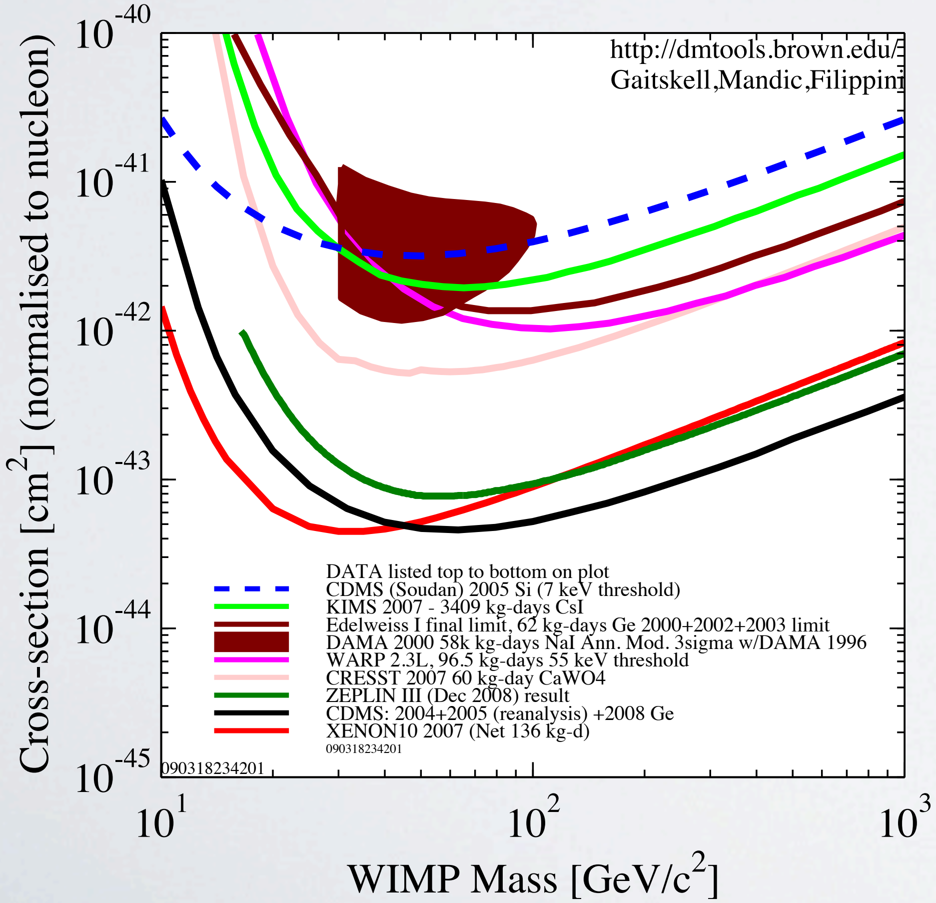
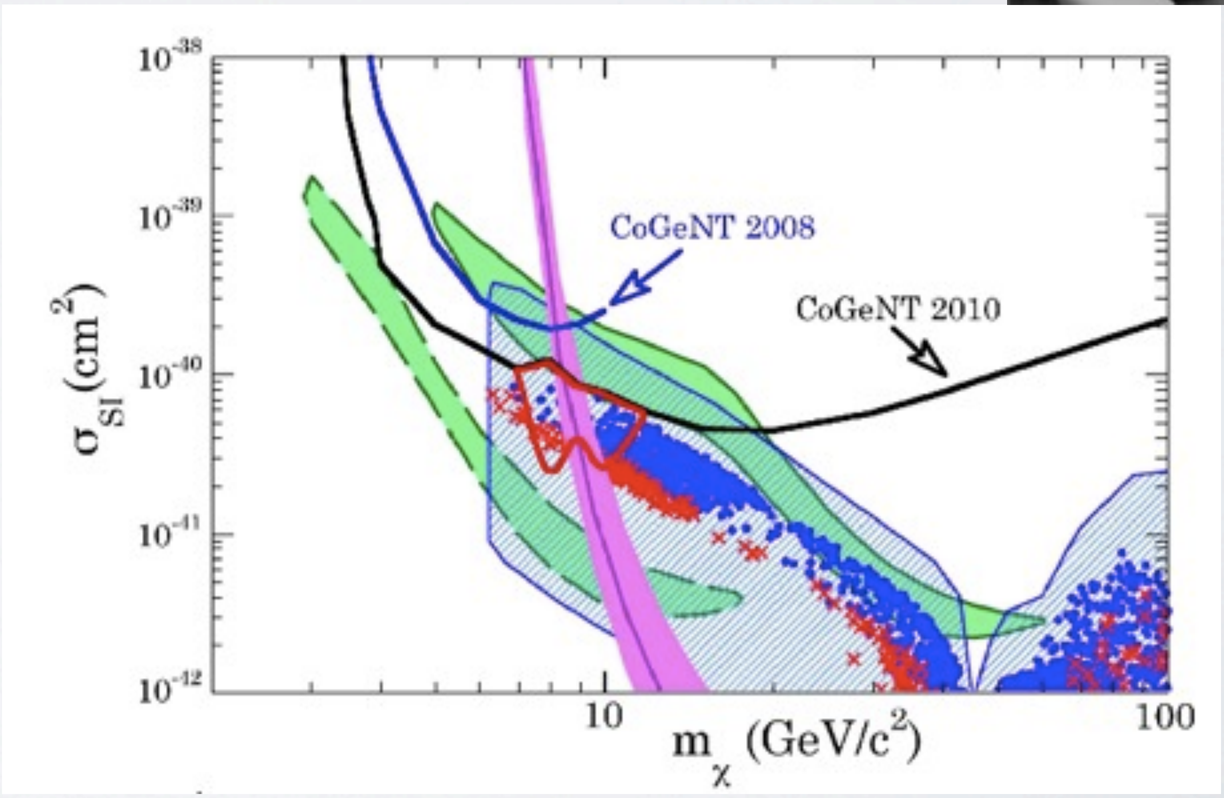


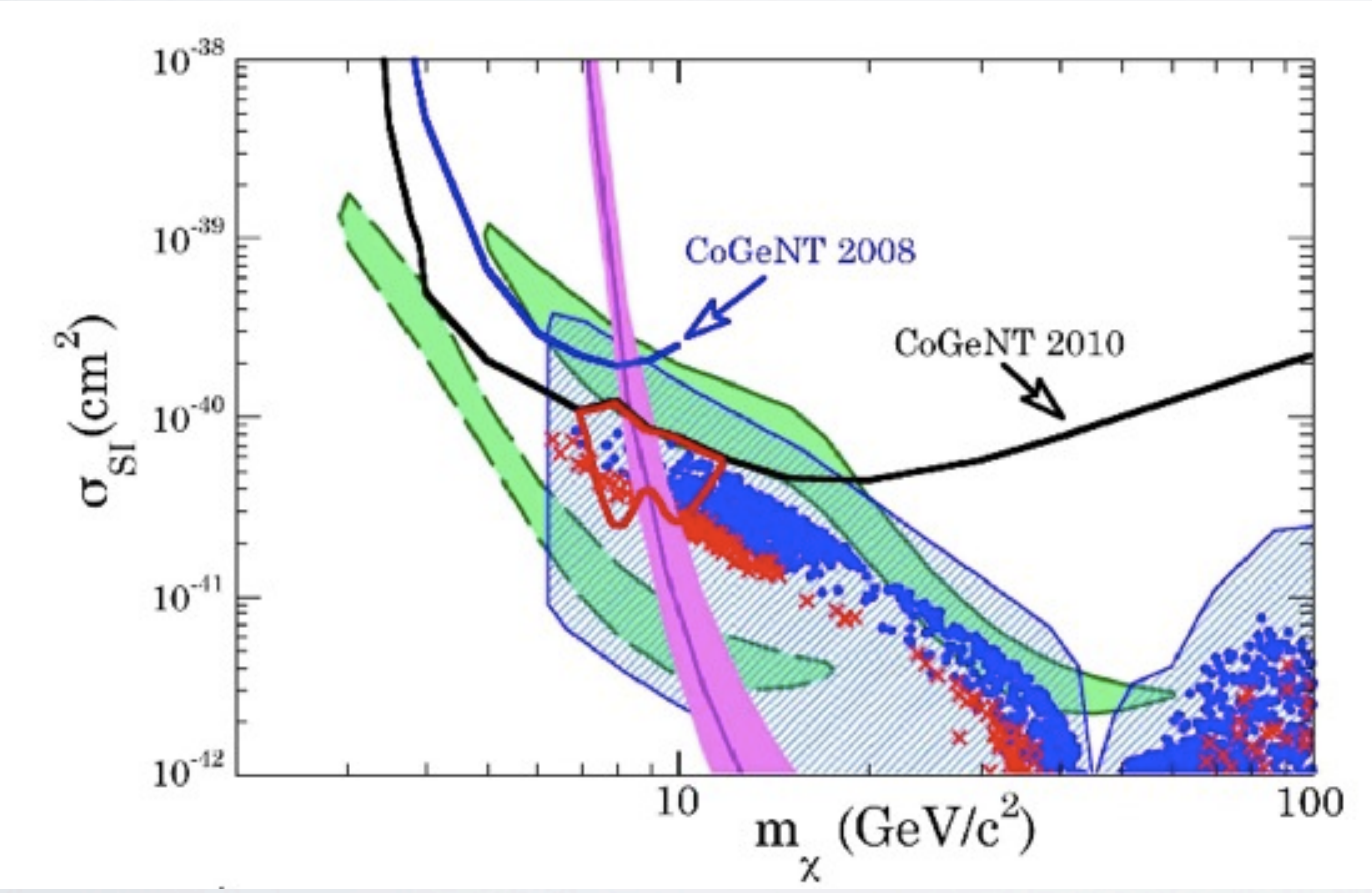


To the community:
Prudence and past experience prompt us to continue work to exhaust less exotic possibilities. We extend an invitation to other researchers in this field to proceed with the same caution.

To the financial industry:
You are guardians of our financial security, and have only limited regulations. Prudence and past experience would dictate you function without them responsibly, control your risk exposure and accept modest returns for the good of the world economy.

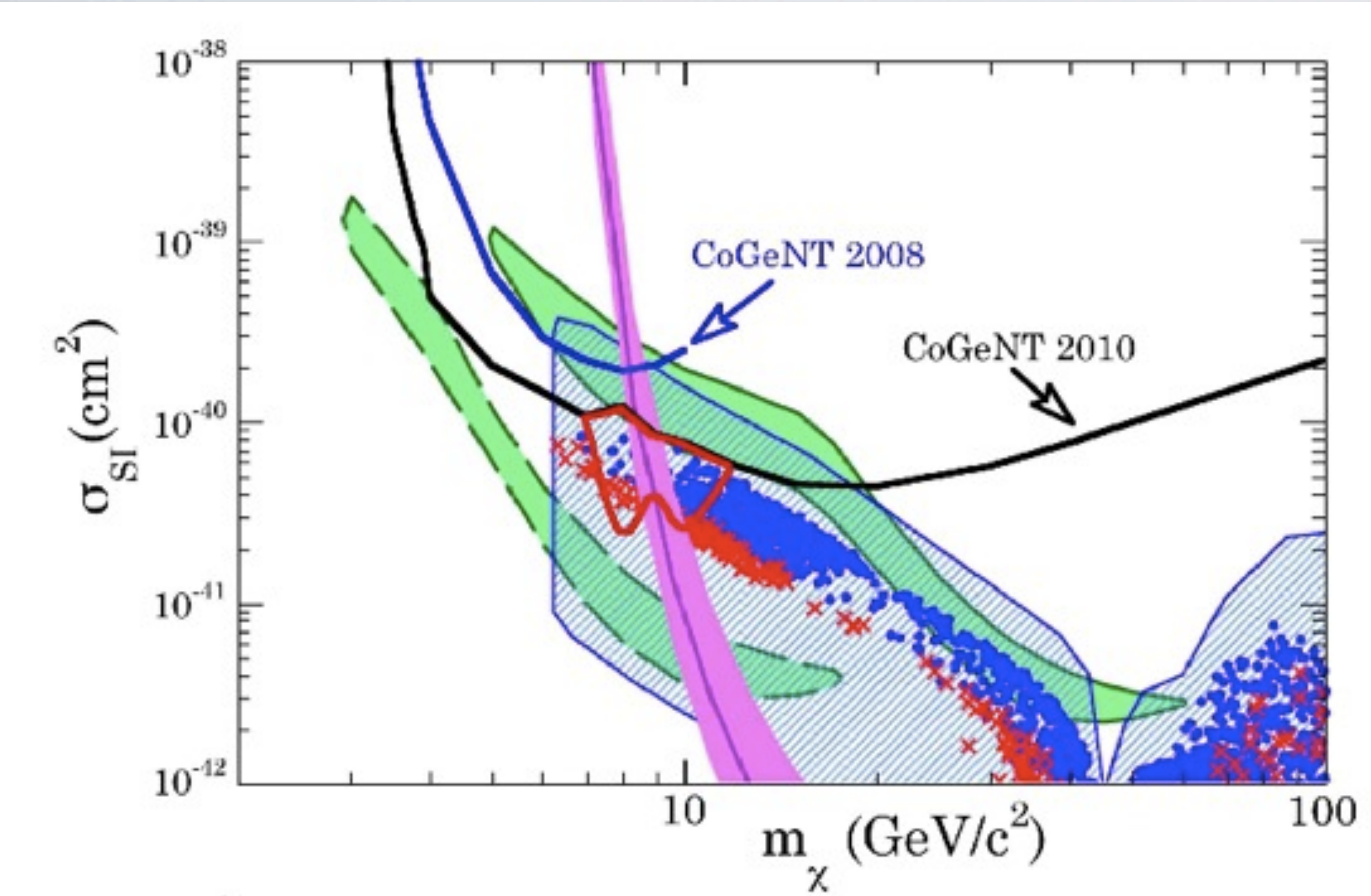






Big cross section?

Relic abundance?



Big cross section?

Relic abundance?

Light WIMPs: Largest Detection Scattering Cross Sections in the MSSM

Eric Kuflik, Aaron Pierce, and Kathryn M. Zurek
Michigan Center for Theoretical Physics, University of Michigan, Ann Arbor, MI 48109
(Dated: March 16, 2010)

Motivated by recent data from CoGeNT and the DAMA annual modulation signal, we discuss collider constraints on MSSM neutralino dark matter with mass in the 5-15 GeV range. Such an LSP would be a Bino with a small Higgsino admixture. Maximization of the DM-nucleon scattering cross section for such a WIMP requires a light Higgs boson with $\tan\beta$ enhanced couplings. Limits on the invisible width of the Z boson, when combined with Tevatron constraints on Higgs bosons at large $\tan\beta$, and the rare decay $B^{\pm} \to \tau\nu$, constrain cross sections to be below $\sigma_n \lesssim 2 \times 10^{-41}$ cm^2. This indicates a slightly higher local Dark Matter density than is usually assumed would be necessary to explain the CoGeNT excess. This scenario also requires a light charged Higgs boson, which can give substantial contributions to rare decays such as $b \to s\gamma$ and $t \to bH^+$.

LIBERATION FROM A LIGHT SECTOR

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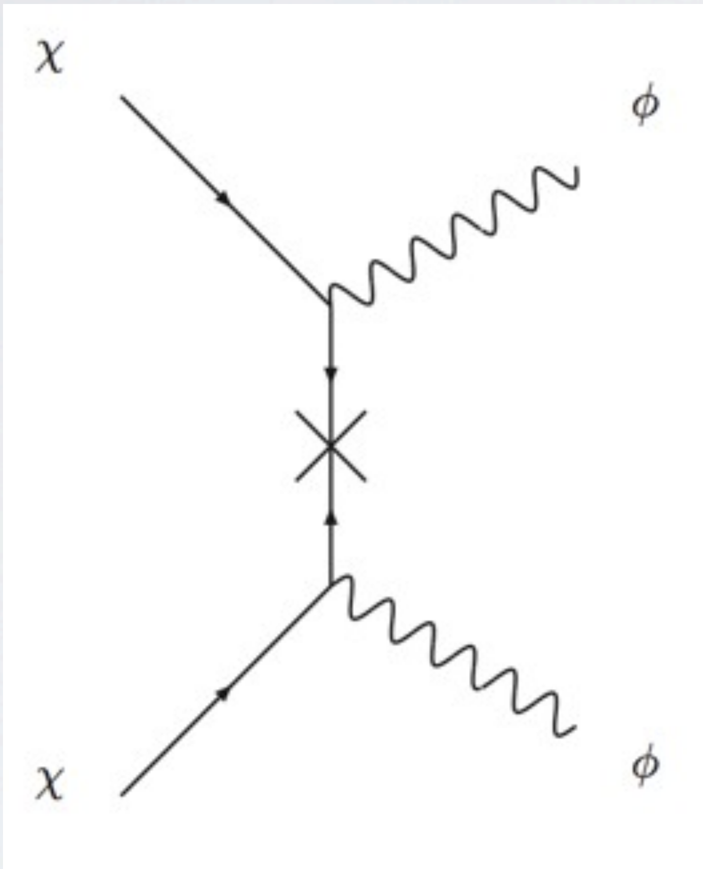

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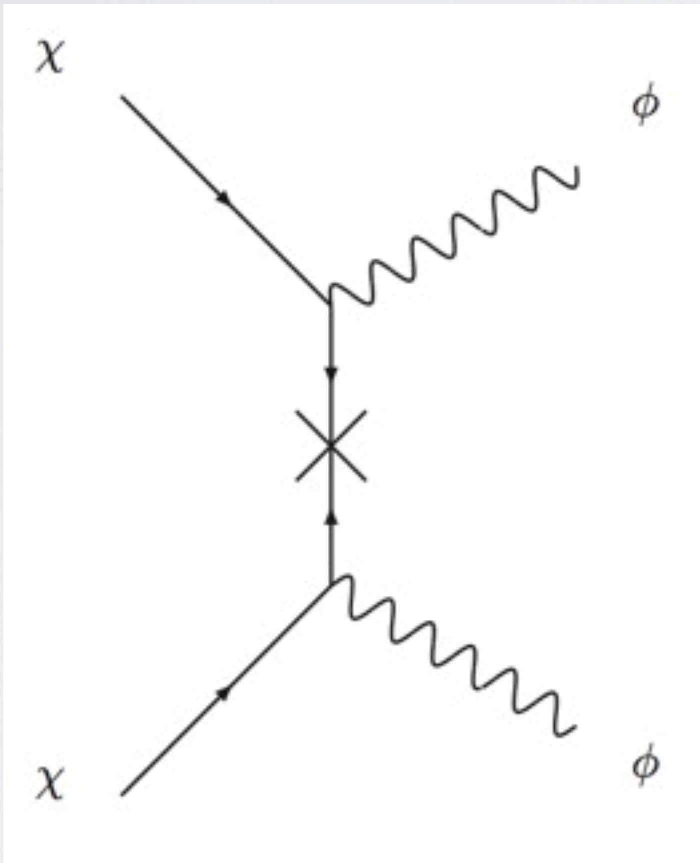

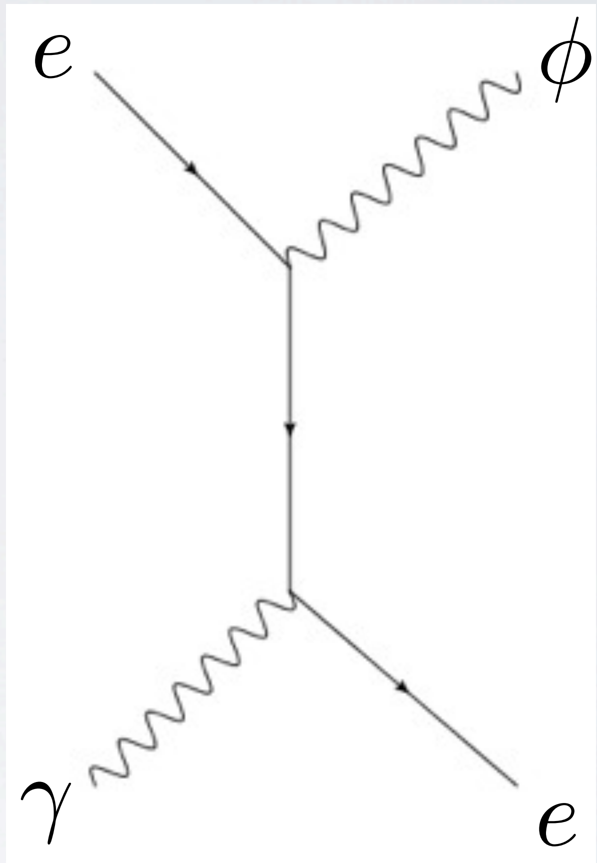

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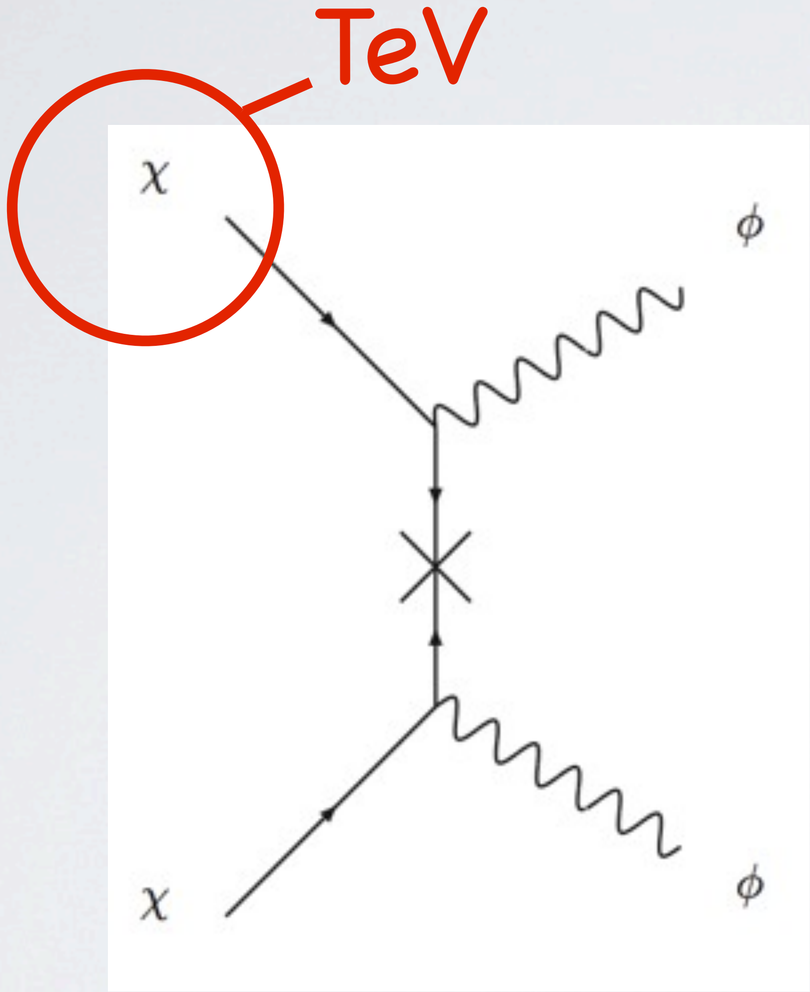

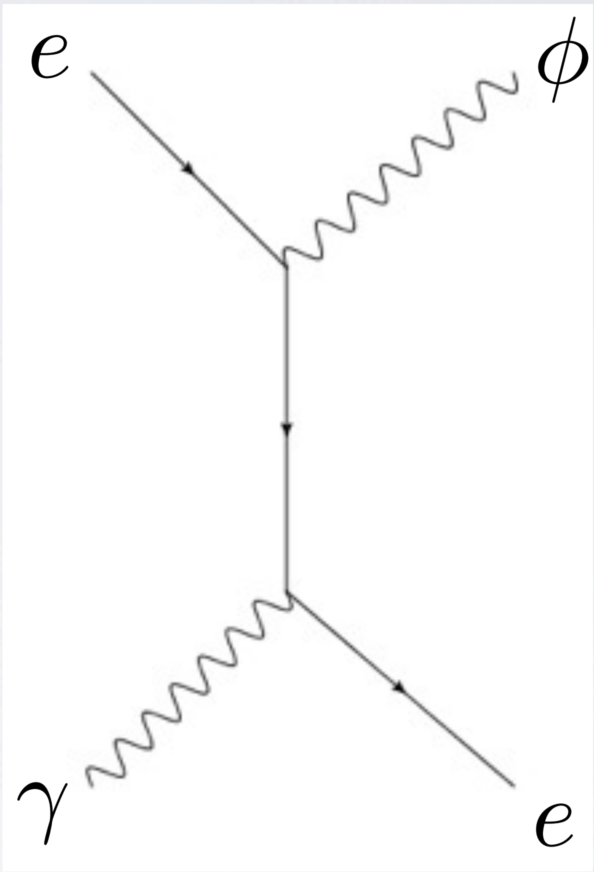

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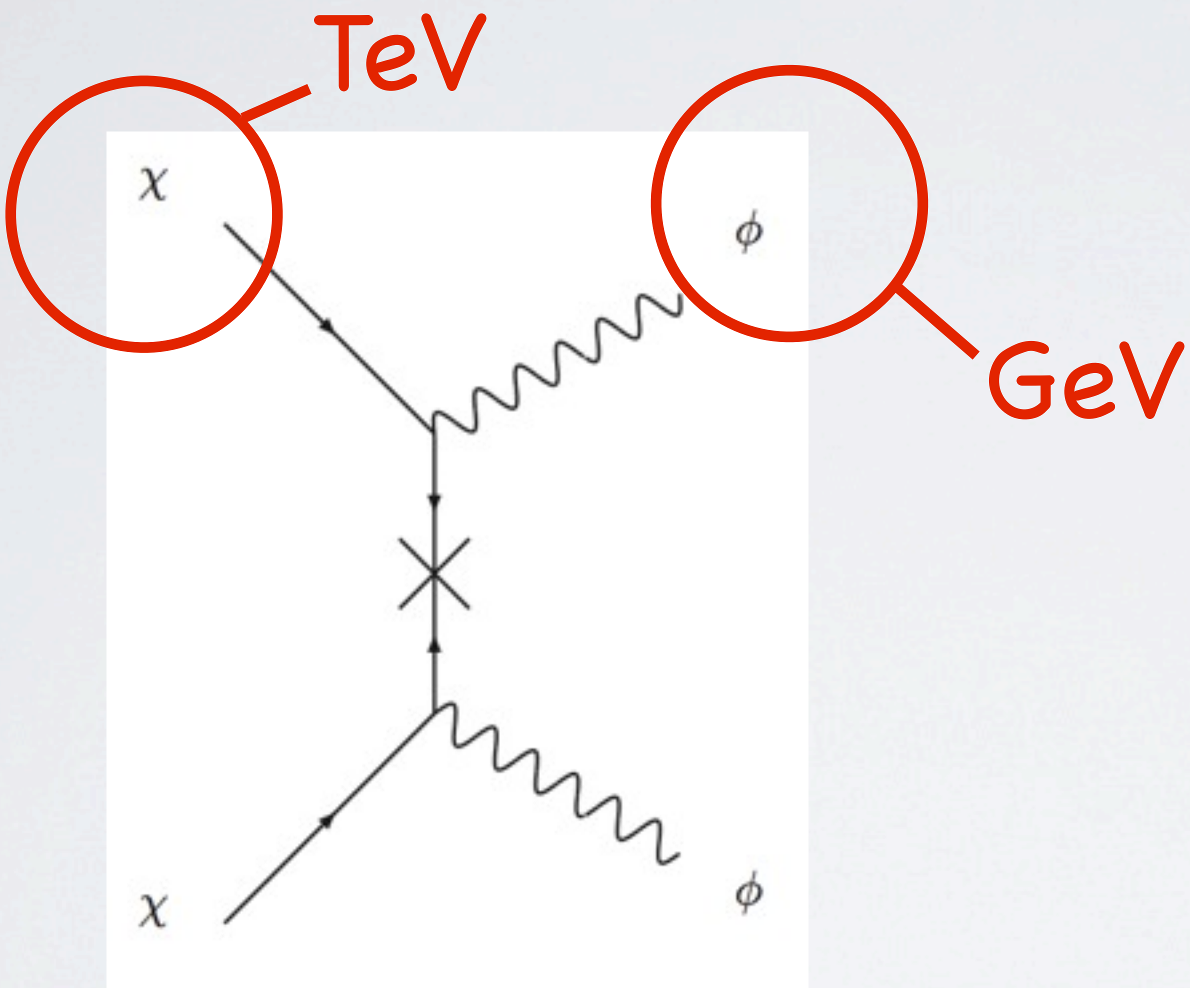

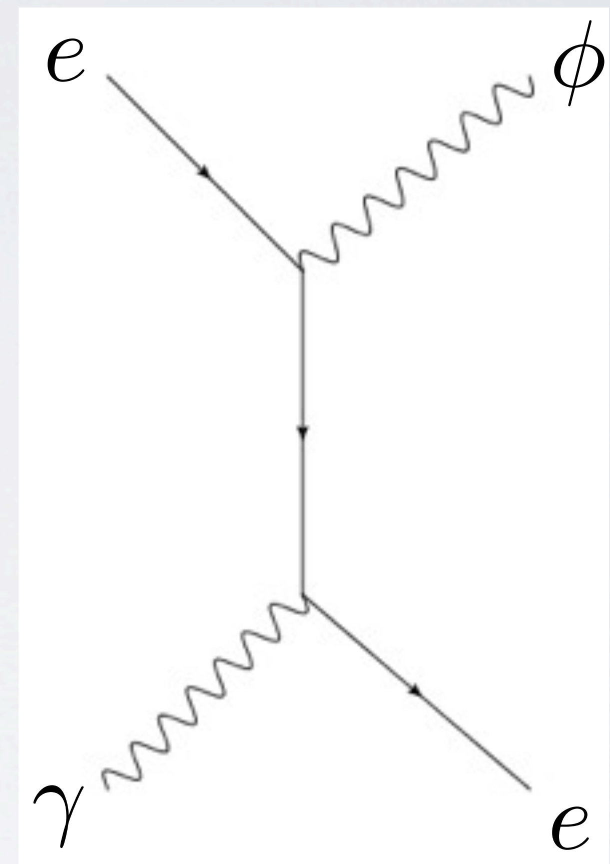

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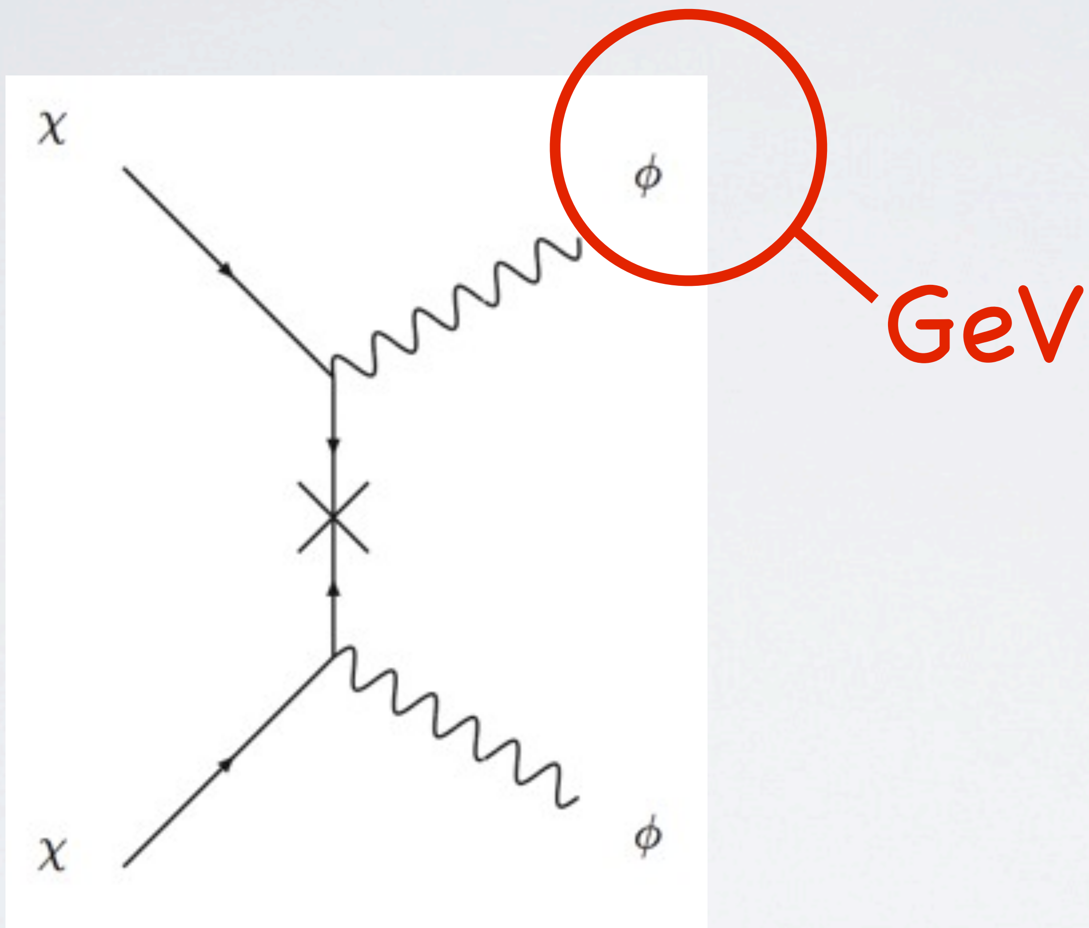

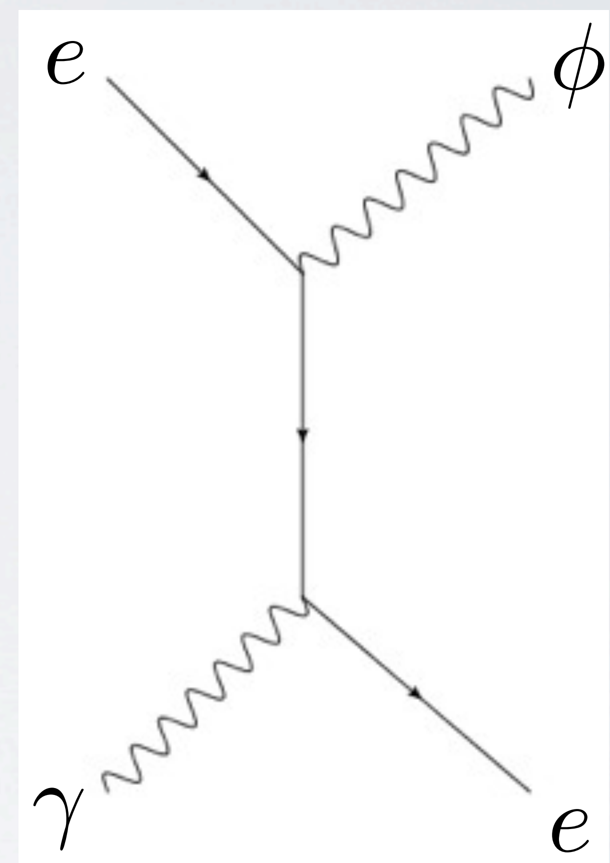

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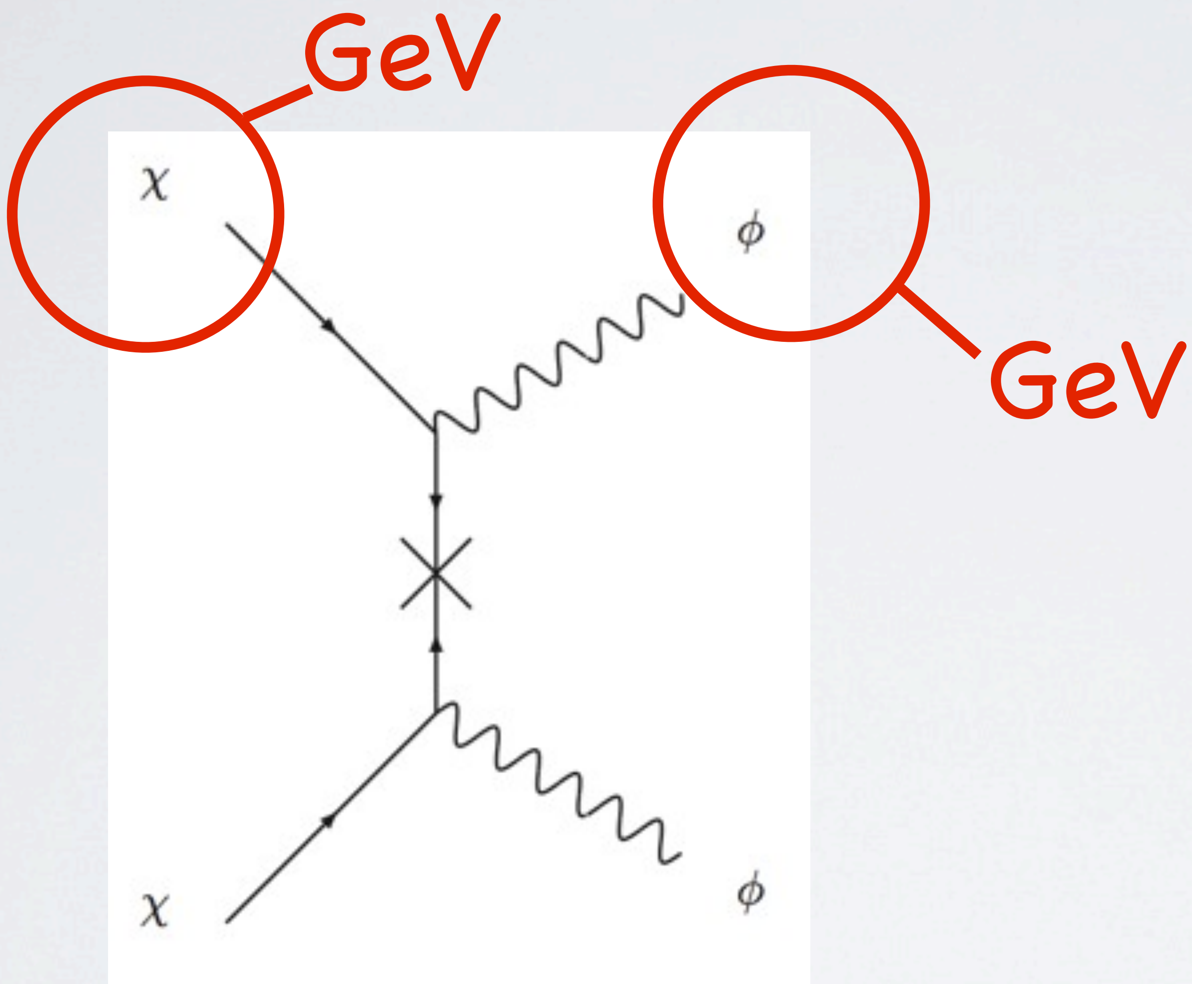

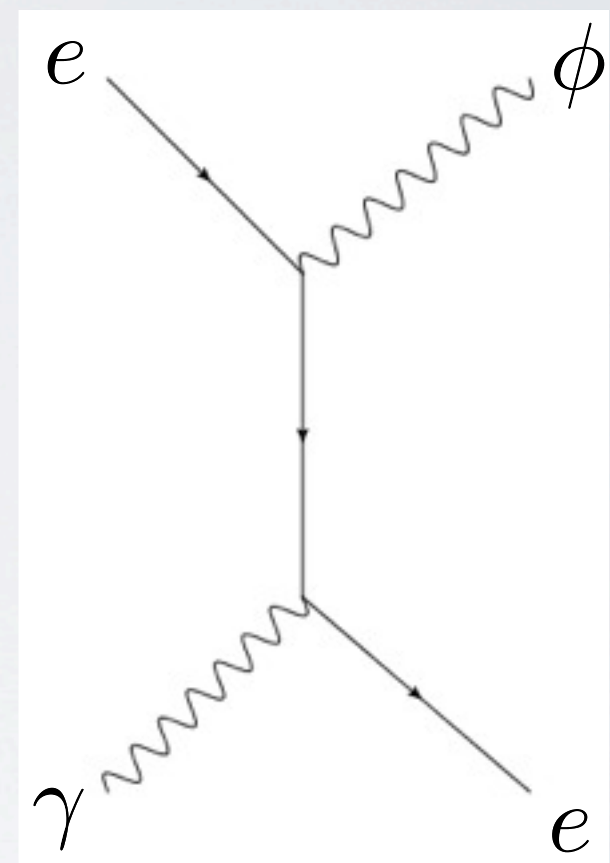

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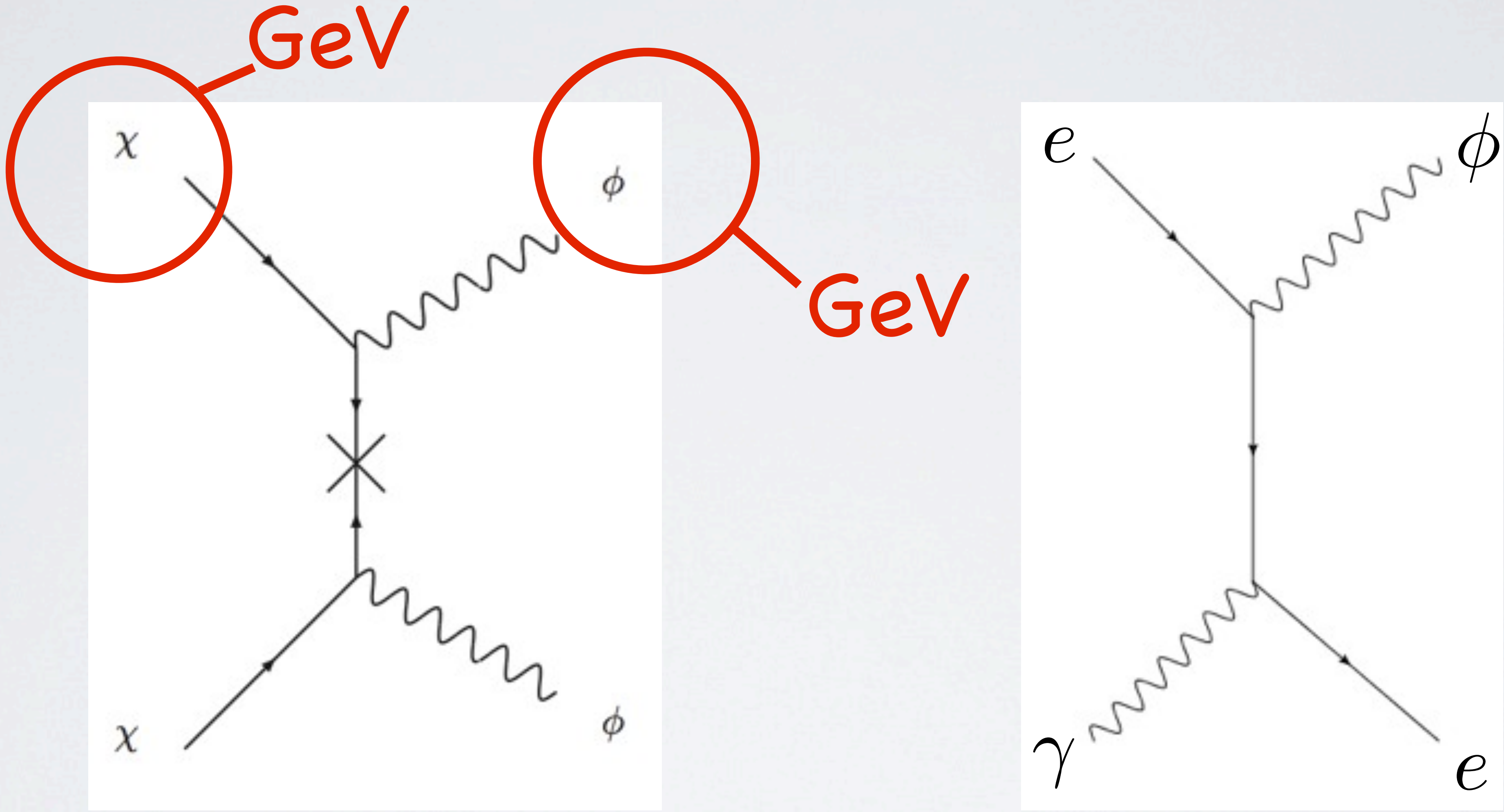
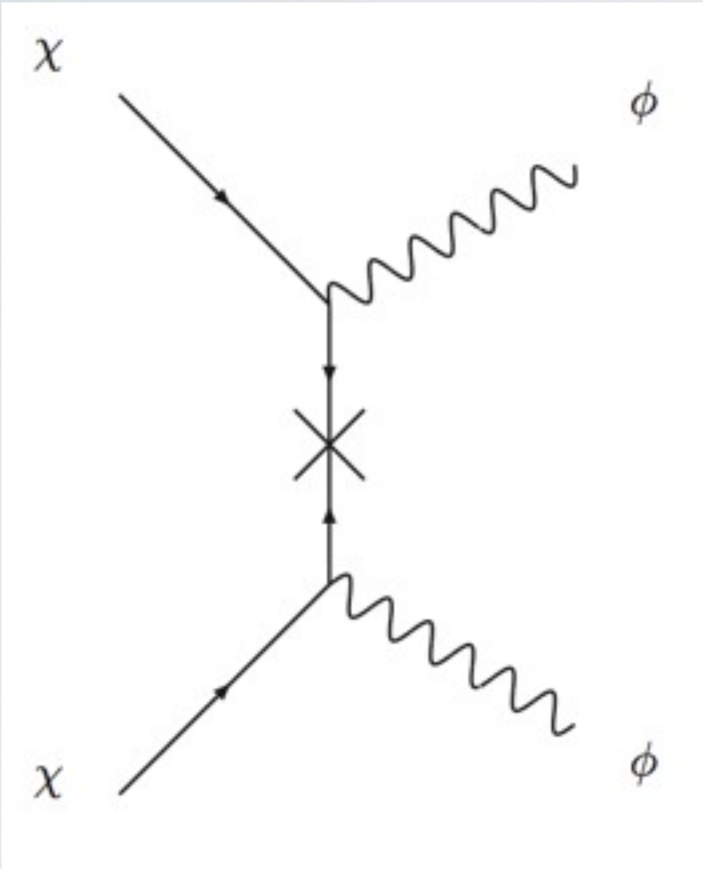


Even with interaction strengths ~ 10^{-8} x SM can maintain equilibrium

INTERACTIONS THROUGH A LIGHT SECTOR



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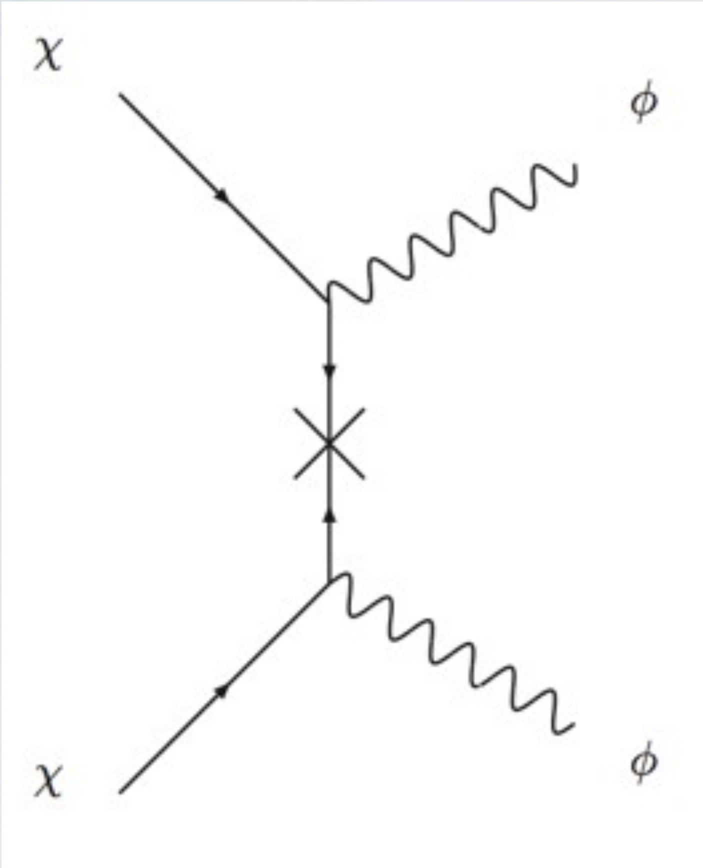

$$\sigma \approx \frac{\alpha_d^2}{m_\chi^2}$$

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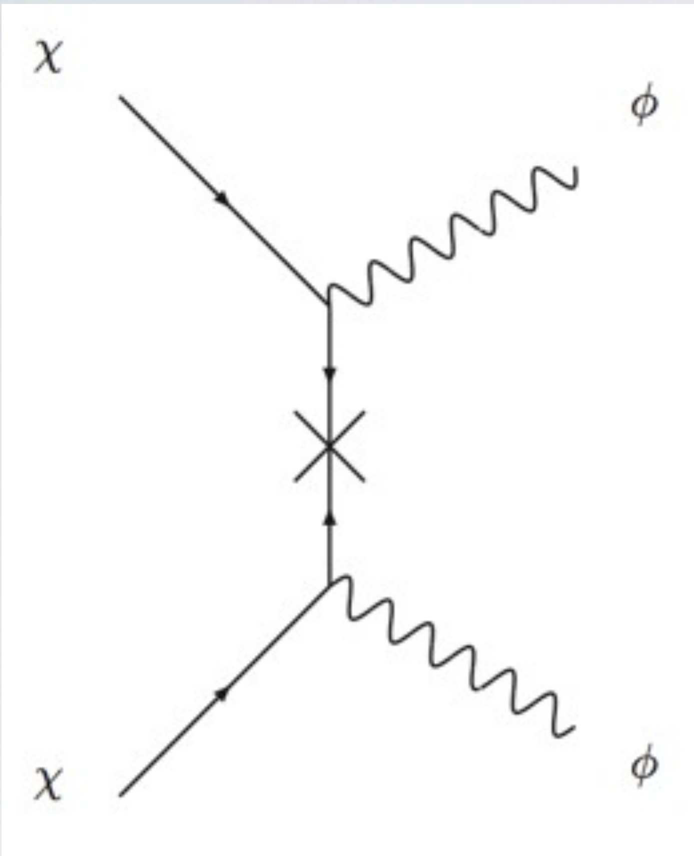

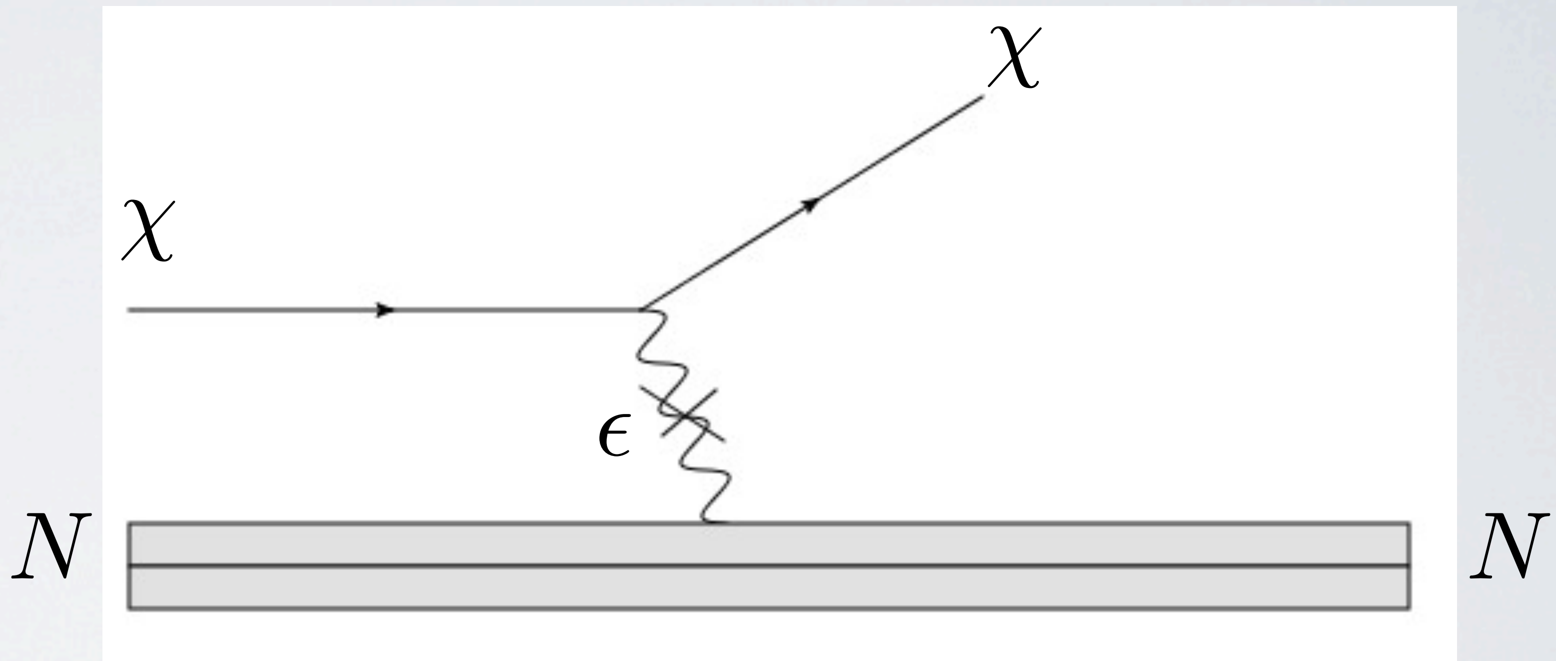

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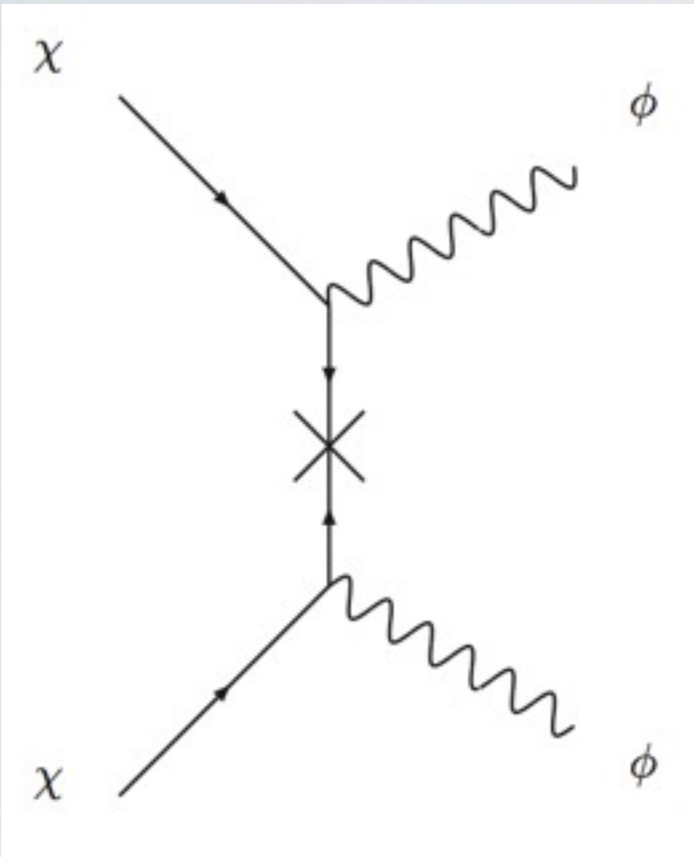

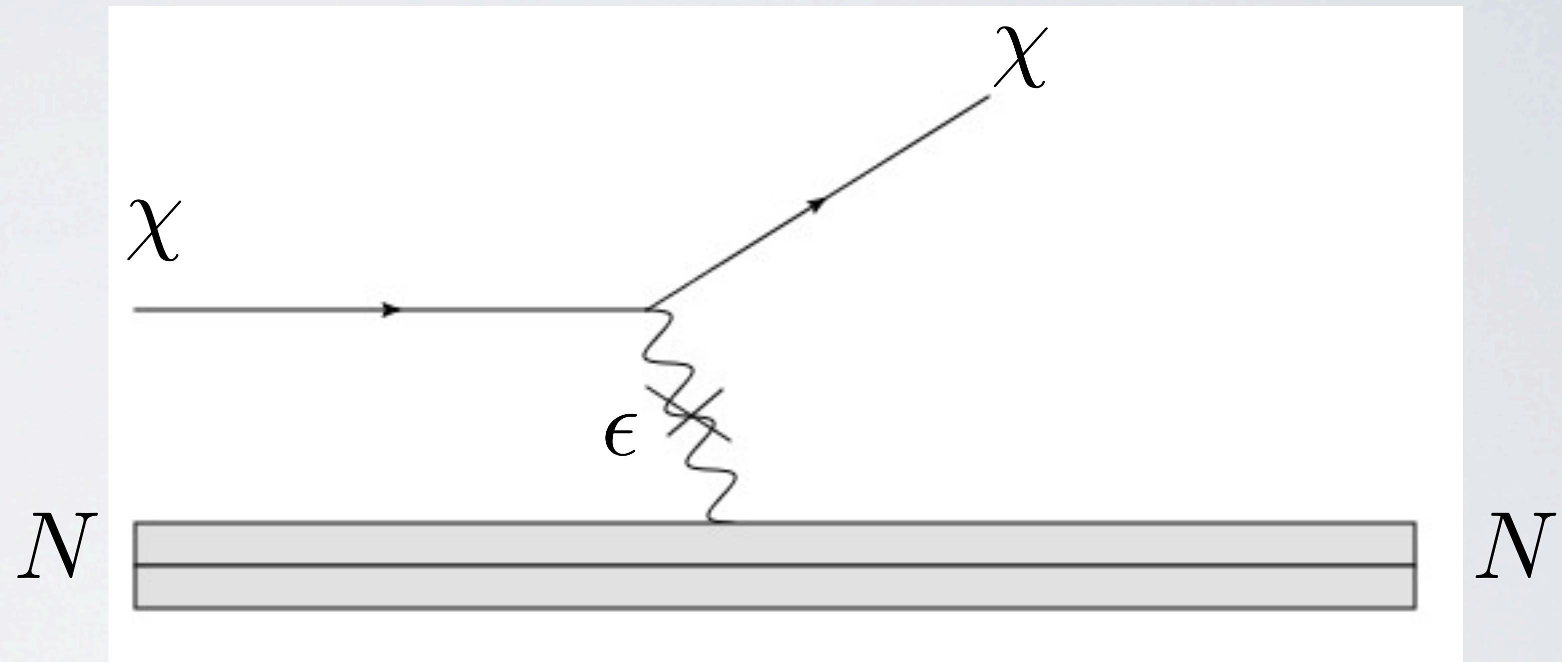

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$$\sigma \approx \frac{\alpha_d \alpha_{EM} \epsilon^2}{m_\phi^4}$$

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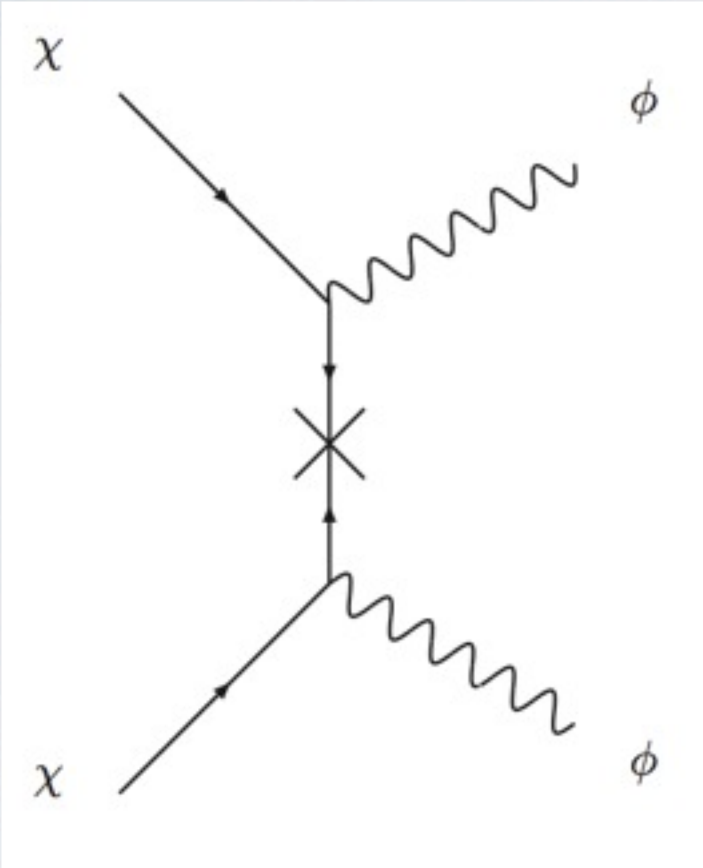
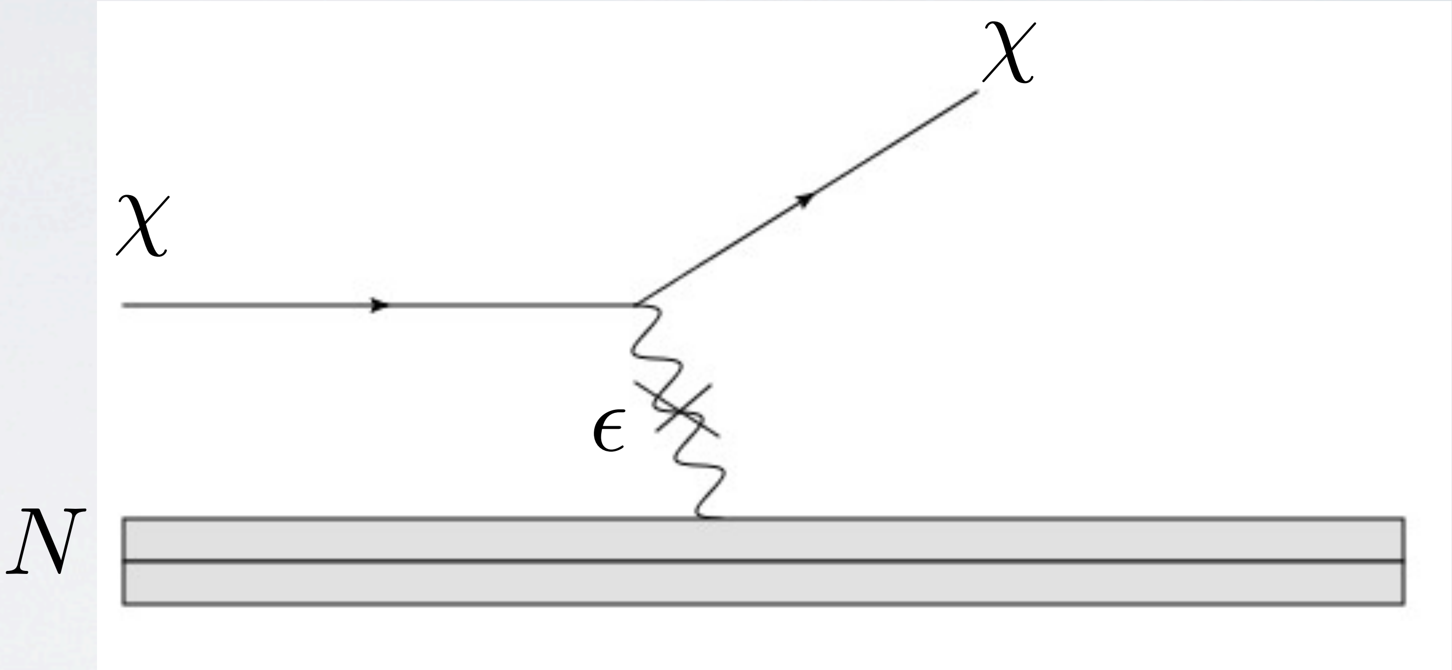




$$\sigma \approx \frac{\alpha_d^2}{m_\chi^2}$$

$$\sigma \approx \frac{\alpha_d \alpha_{EM} \epsilon^2}{m_\phi^4}$$

Significant parametric differences - can avoid overclosure *and* have large cross section

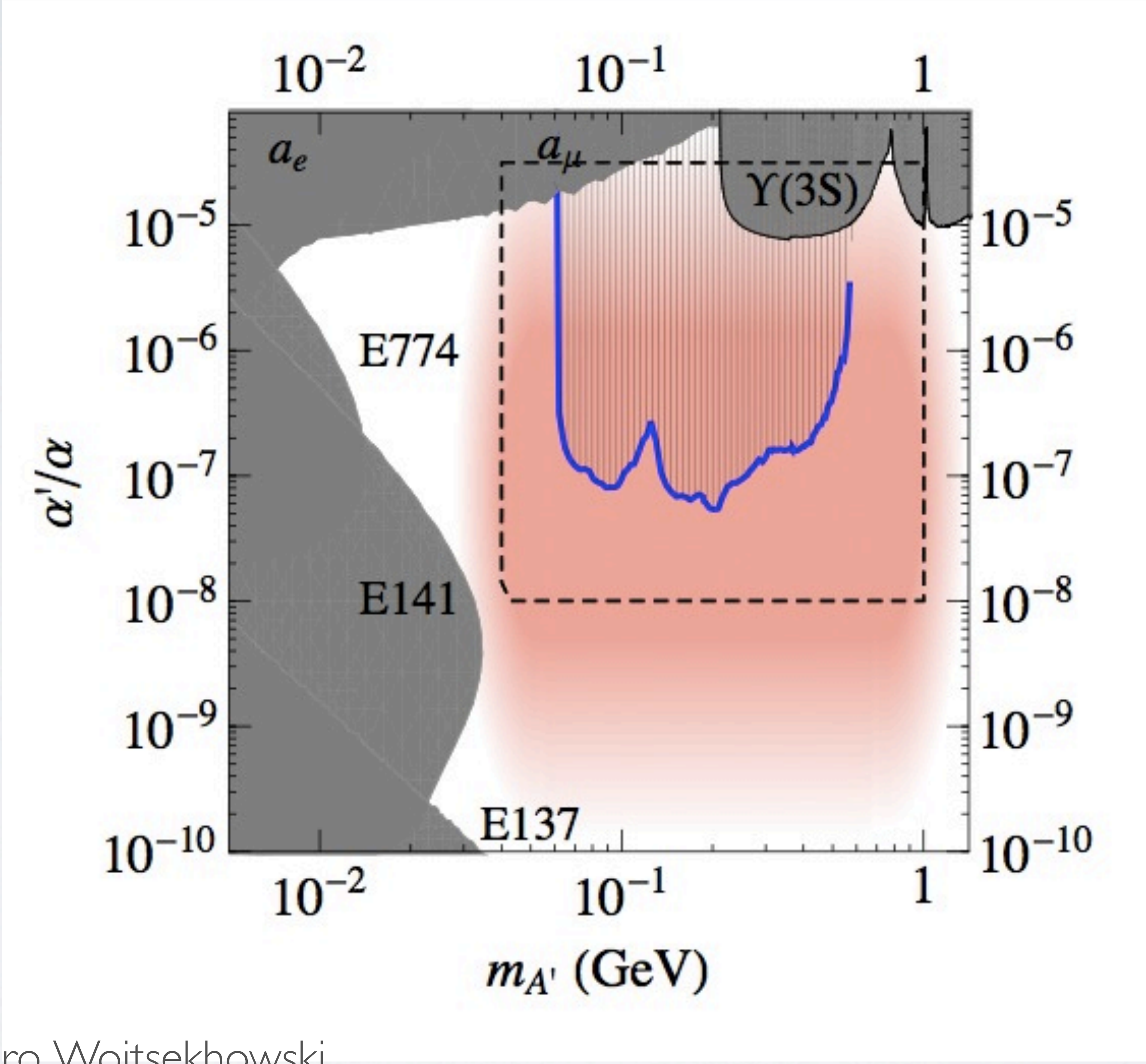
A DIFFERENT KIND OF SCALE INVARIANCE

$$\epsilon F_{\mu\nu}^{EM} F_d^{\mu\nu} \Rightarrow \epsilon W_\alpha^Y W_d^\alpha \Rightarrow \epsilon D_Y D_d$$

$$\sigma \sim \frac{\epsilon^2 \alpha_d \alpha_{EM}}{m_\phi^4} \rightarrow \frac{\epsilon^2 \alpha_d \alpha_{EM}}{\epsilon^2 D_Y^2} \rightarrow \frac{\alpha_d \alpha_{EM}}{D_Y^2} \sim \frac{\alpha_d \alpha_{EM}}{m_Z^4}$$

$$\sigma_n \sim 10^{-39} \mathrm{cm}^2$$

(Cheung, Ruderman, Wang, Yavin, '09)

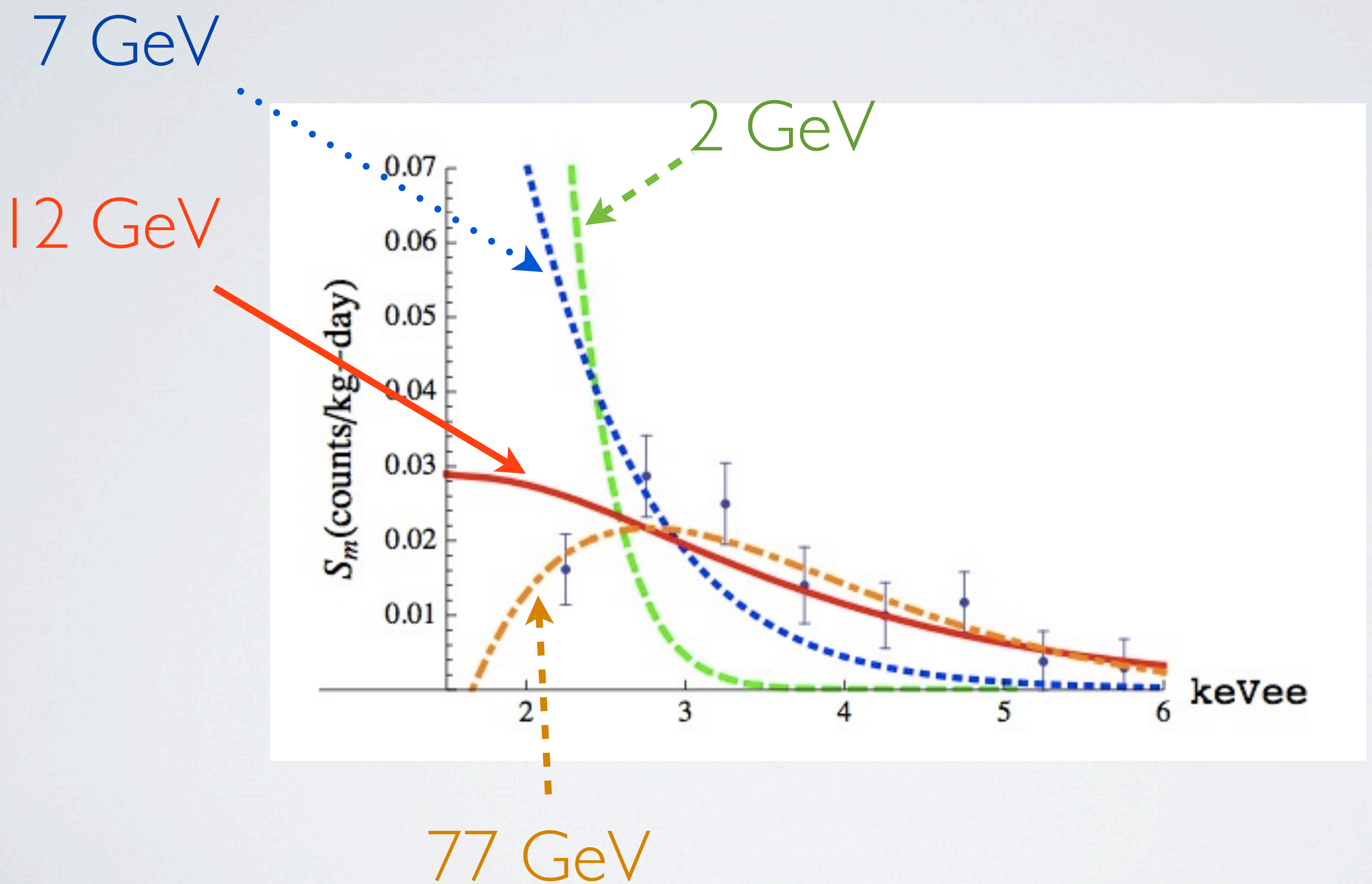


Essig, Schuster, Toro, Wojtsekhowski,
arxiv:1001.2557

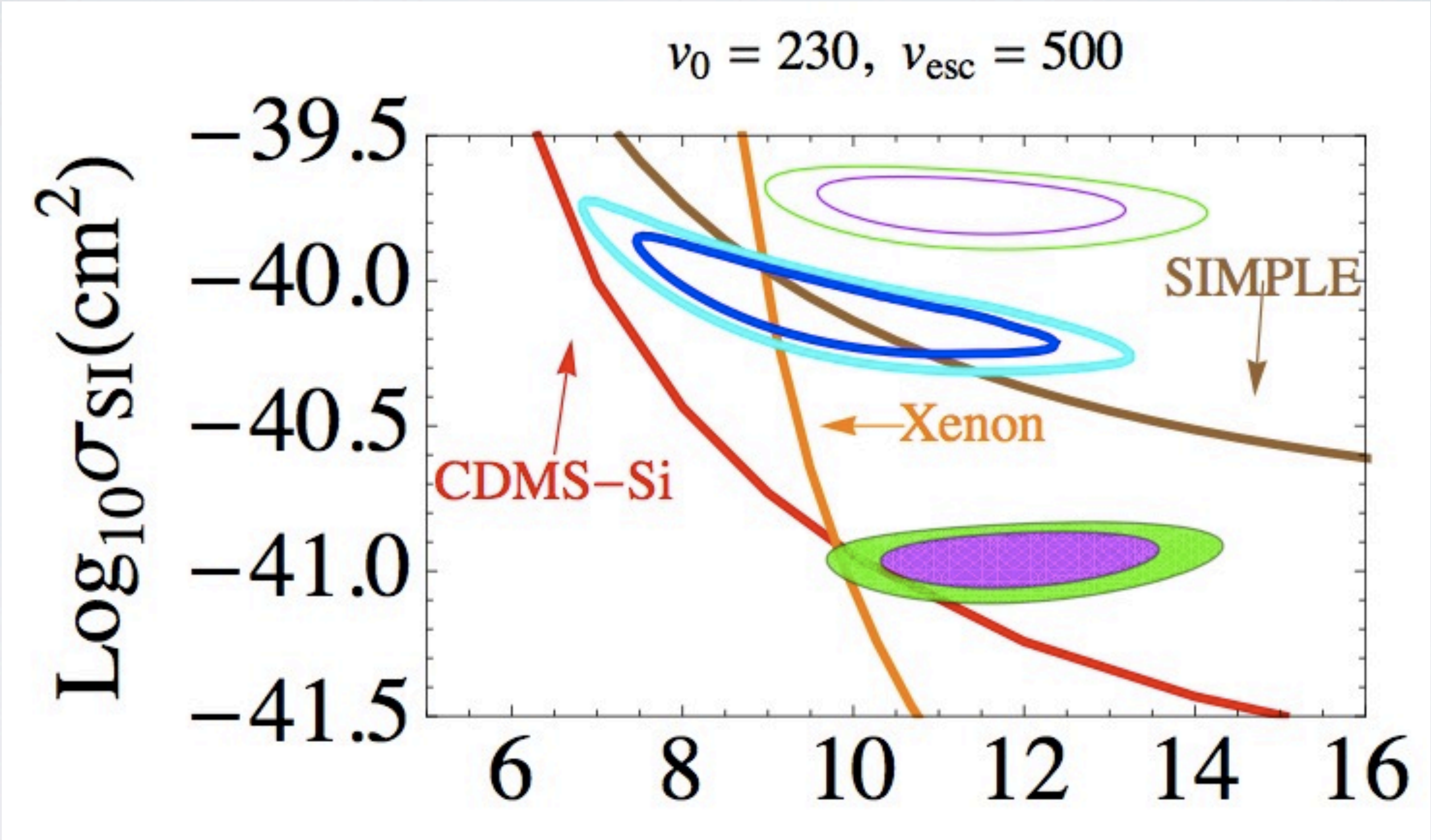
SUPER! HAVE WE EXPLAINED DAMA/COGENT YET?

- As it turns out, there are other experiments

DAMA

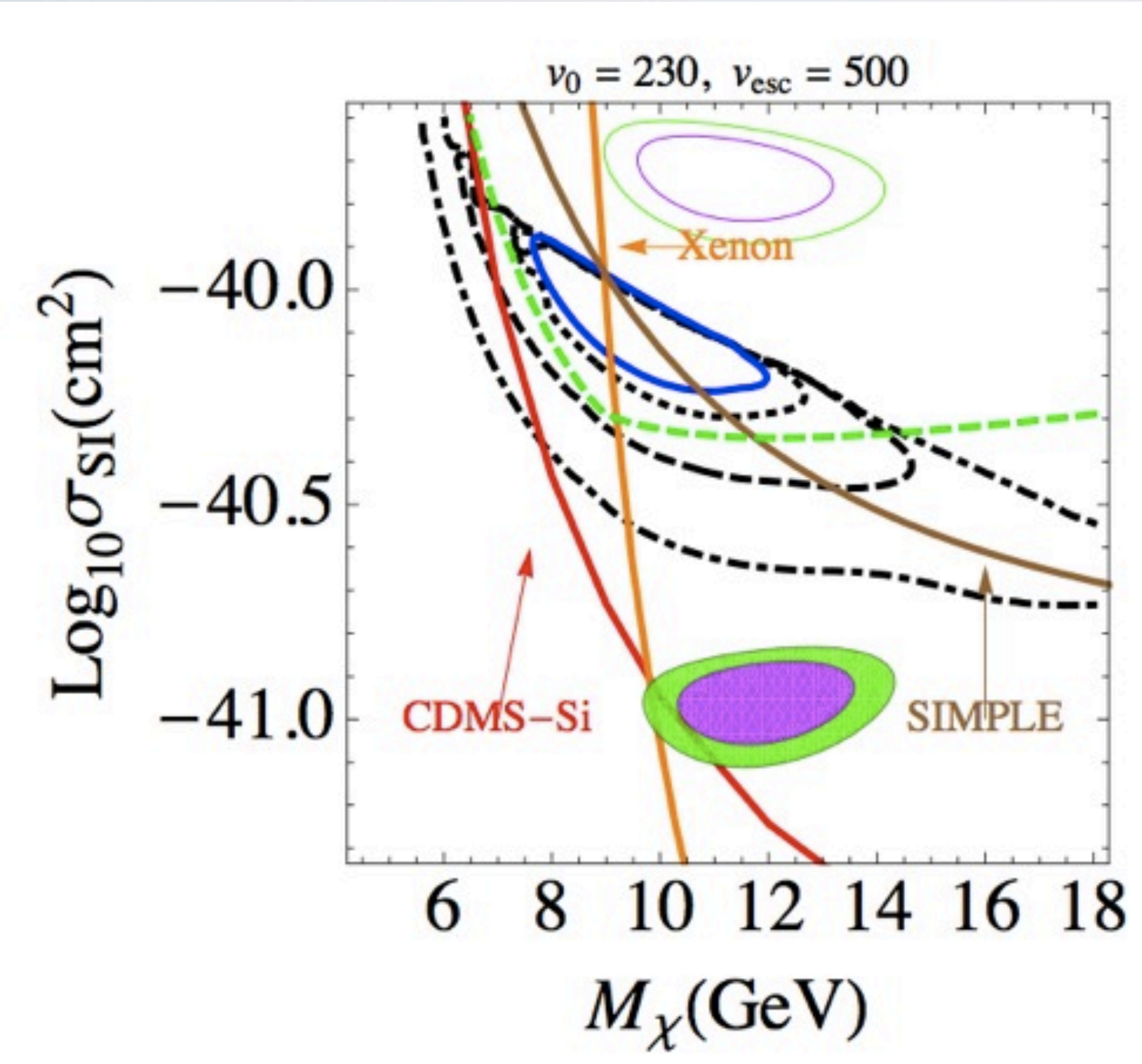

7 GeV
2 GeV
12 GeV
77 GeV
0.07
0.06
0.05
0.04
0.03
0.02
0.01
S_m(counts/kg-day)
2
3
4
5
6
keVee

WHAT DOES IT ALL LOOK LIKE TOGETHER



Can't do with Z or SM Higgs

INCLUDING BACKGROUNDS



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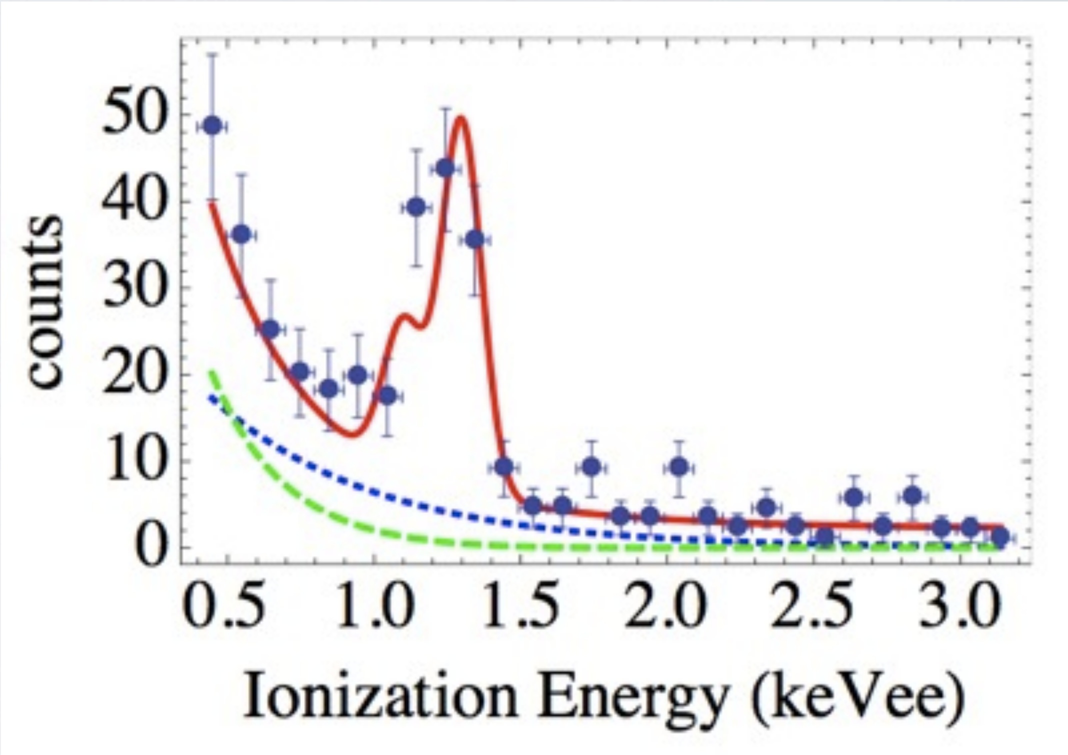

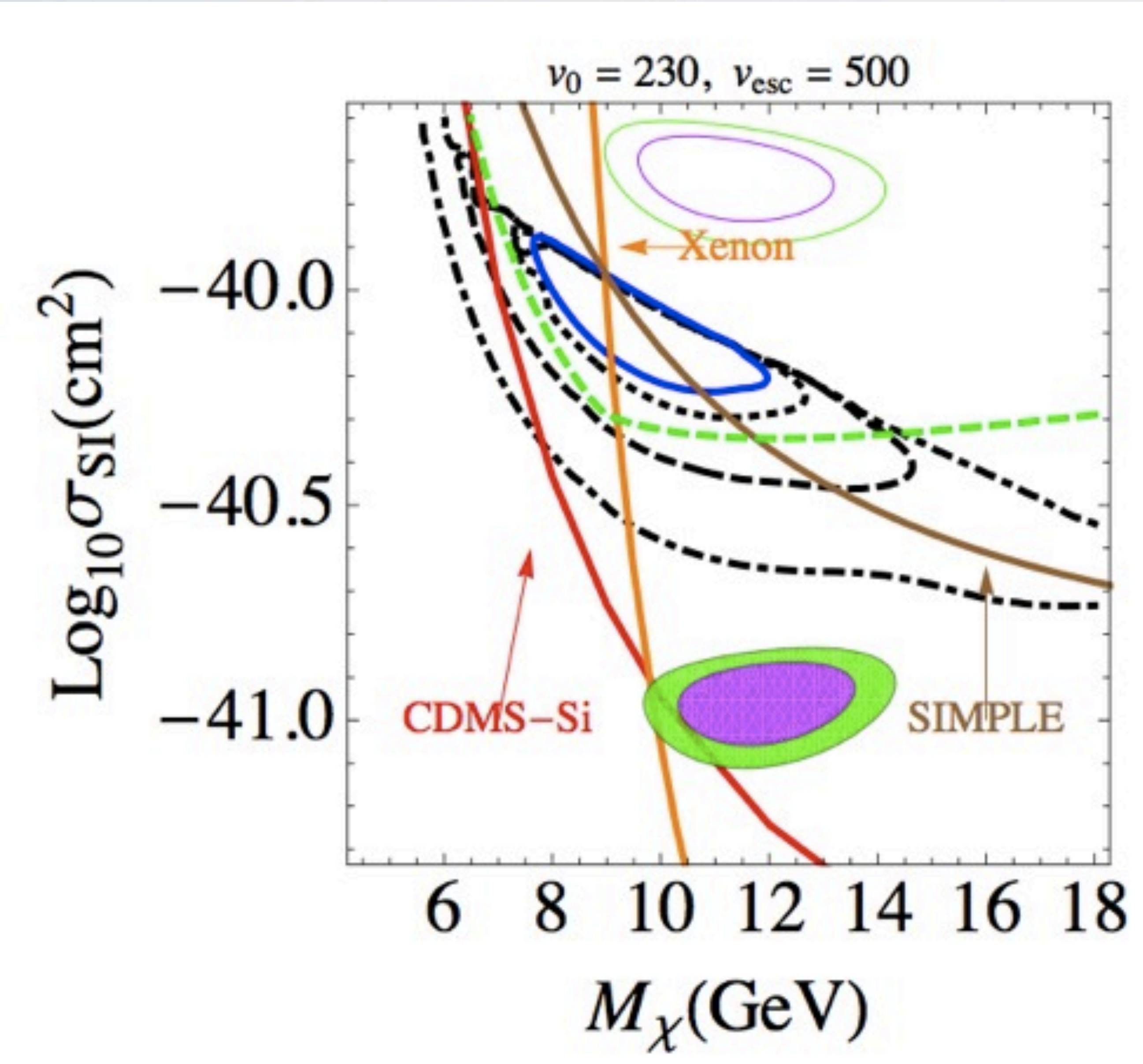

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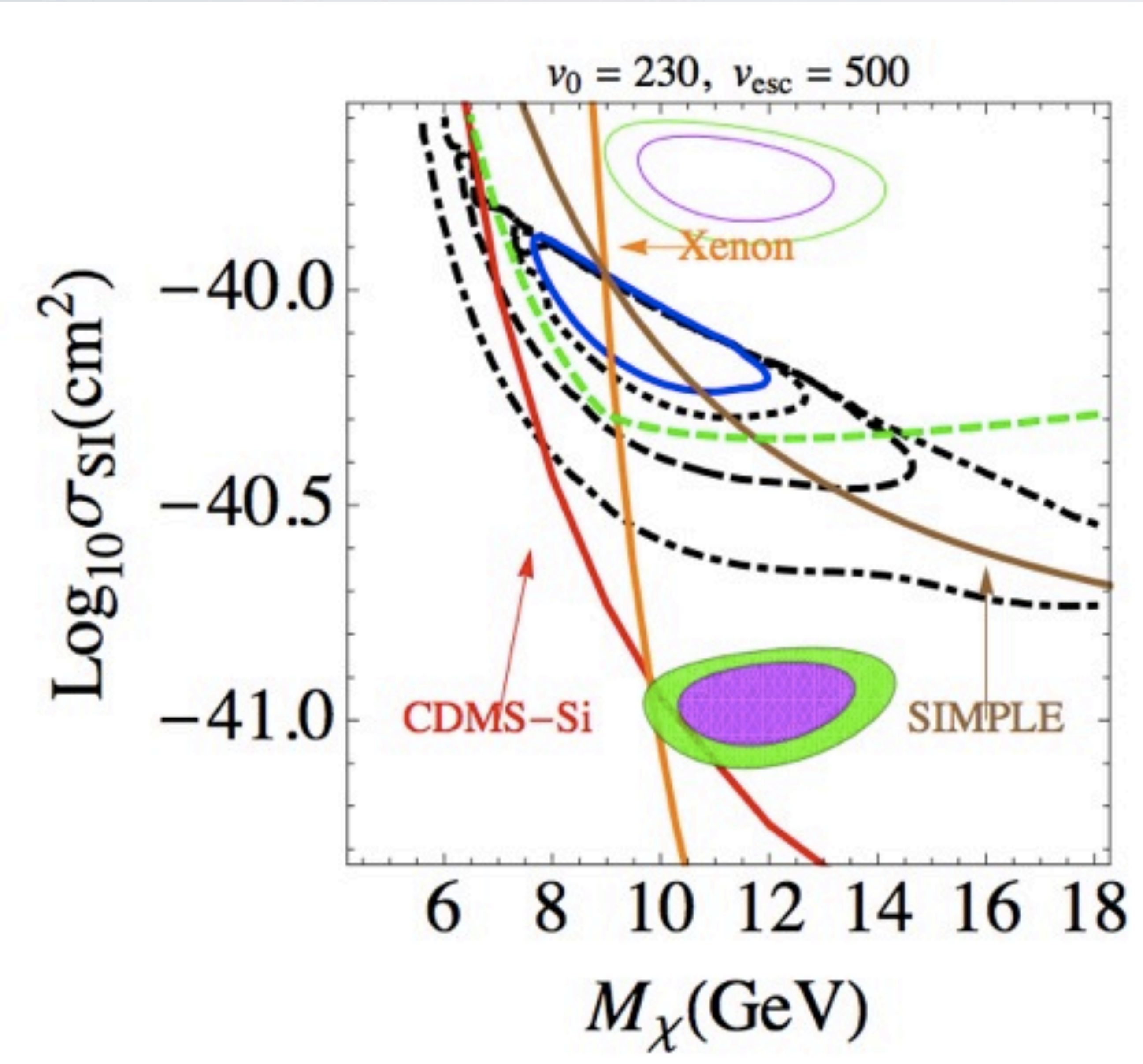
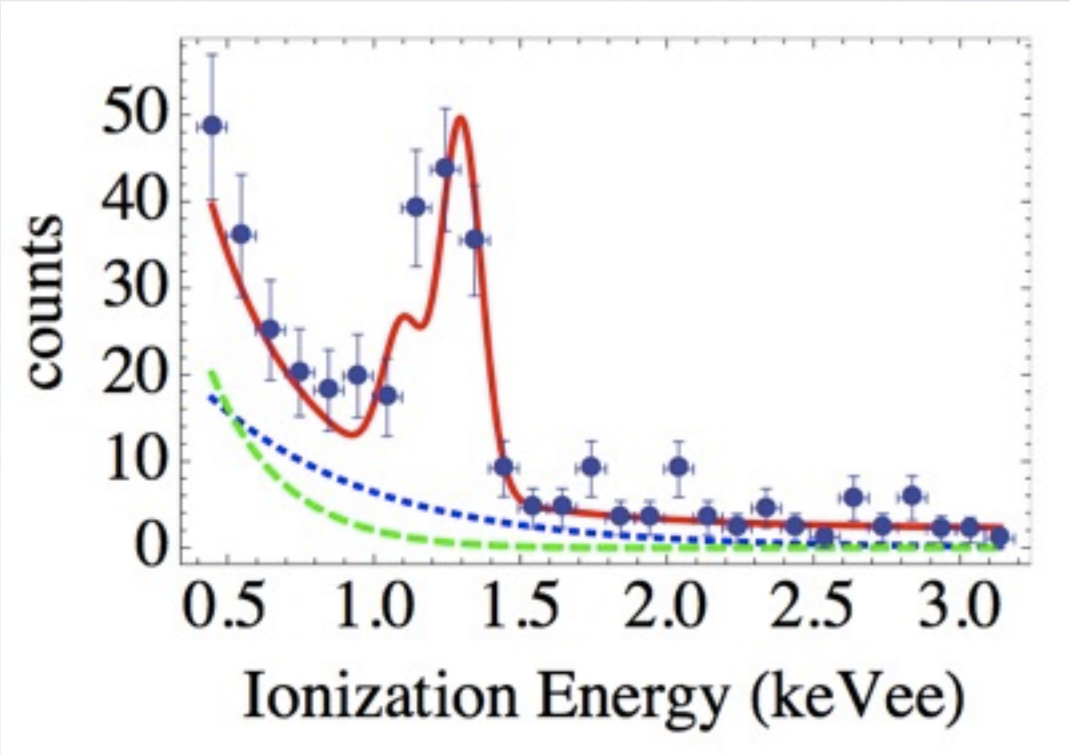
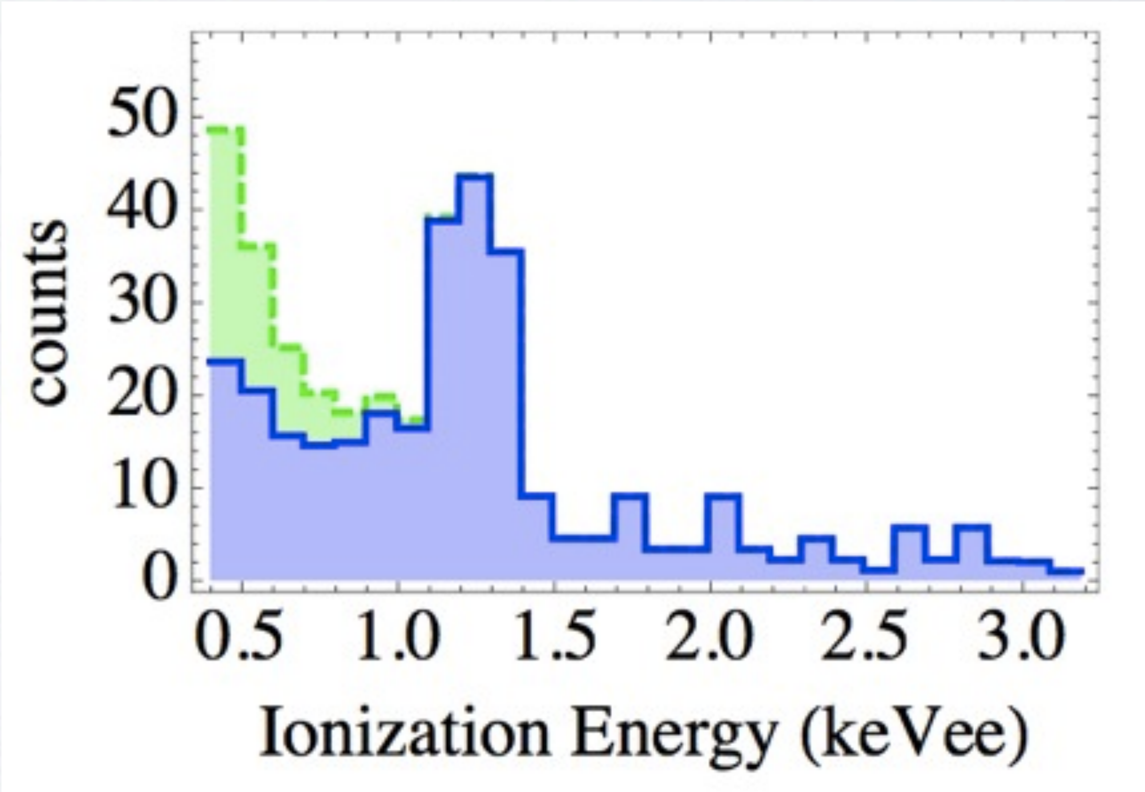
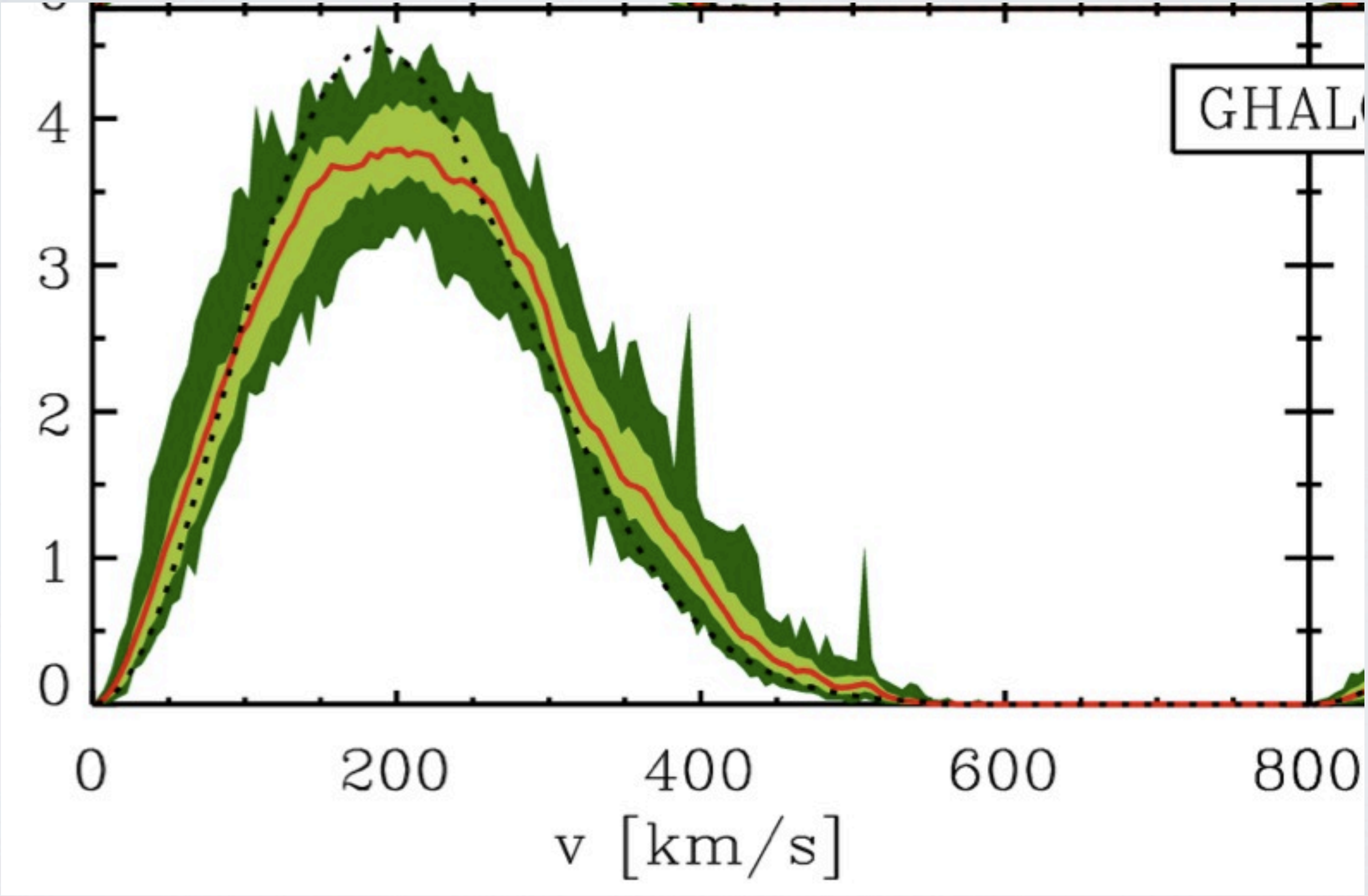






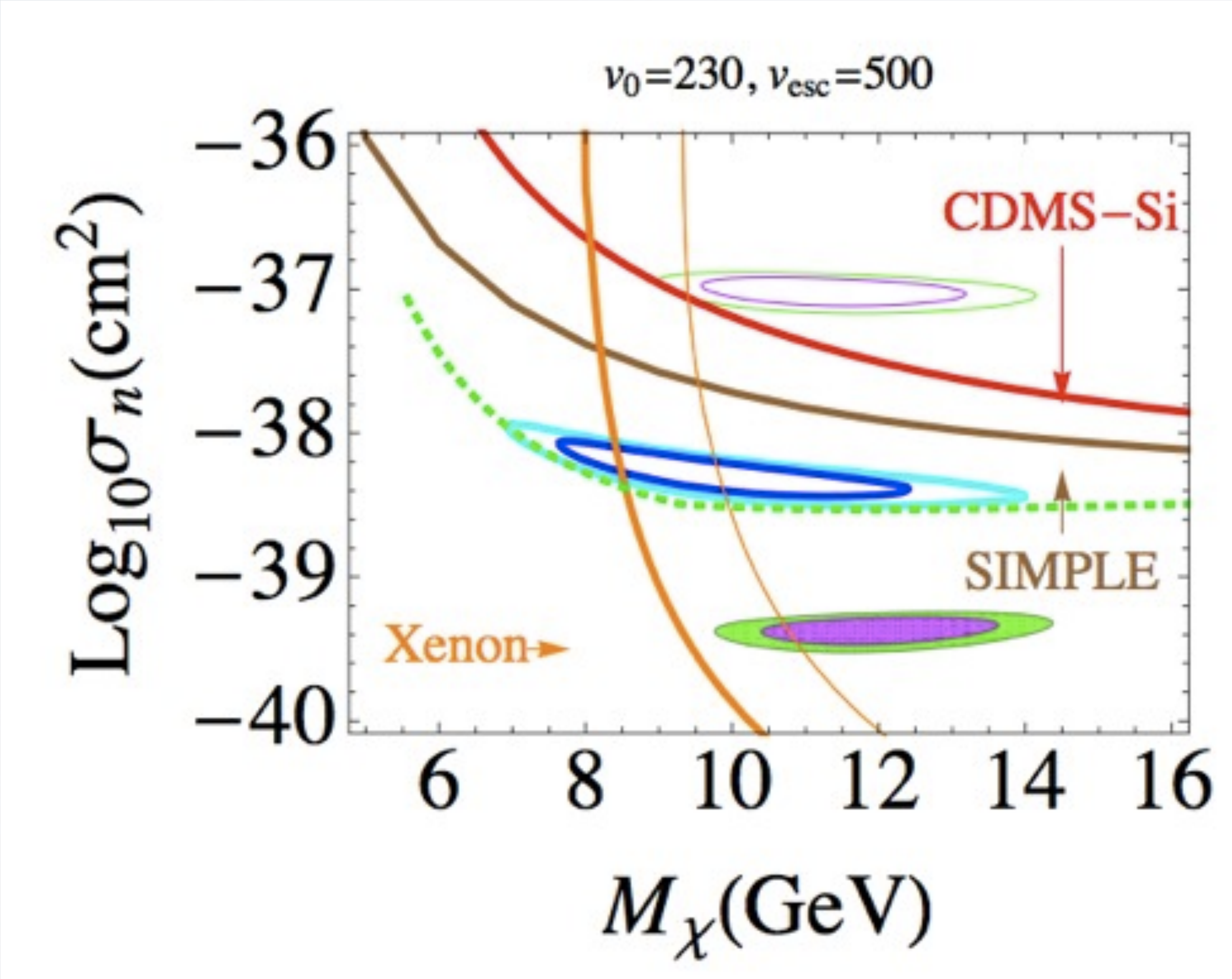
ROBUSTNESS OF ANALYSIS?



NEW VARIATIONS IN WIMP INTERACTIONS

Old	New
Spin independent	SI p/n
Spin dependent (p/n)	form factors / q^2 dependence
	kinematics (inelastic scattering)

NOT YOUR ADVISOR'S T-CHANNEL BOSON



$$f_p = -f_n$$

Couples like isospin - but I don't know how to build this model right now

NOT YOUR ADVISOR'S T-CHANNEL BOSON

$$\frac{q^2}{m_Z^2} \approx \frac{\text{small}}{\text{big}} \sim \text{very small}$$

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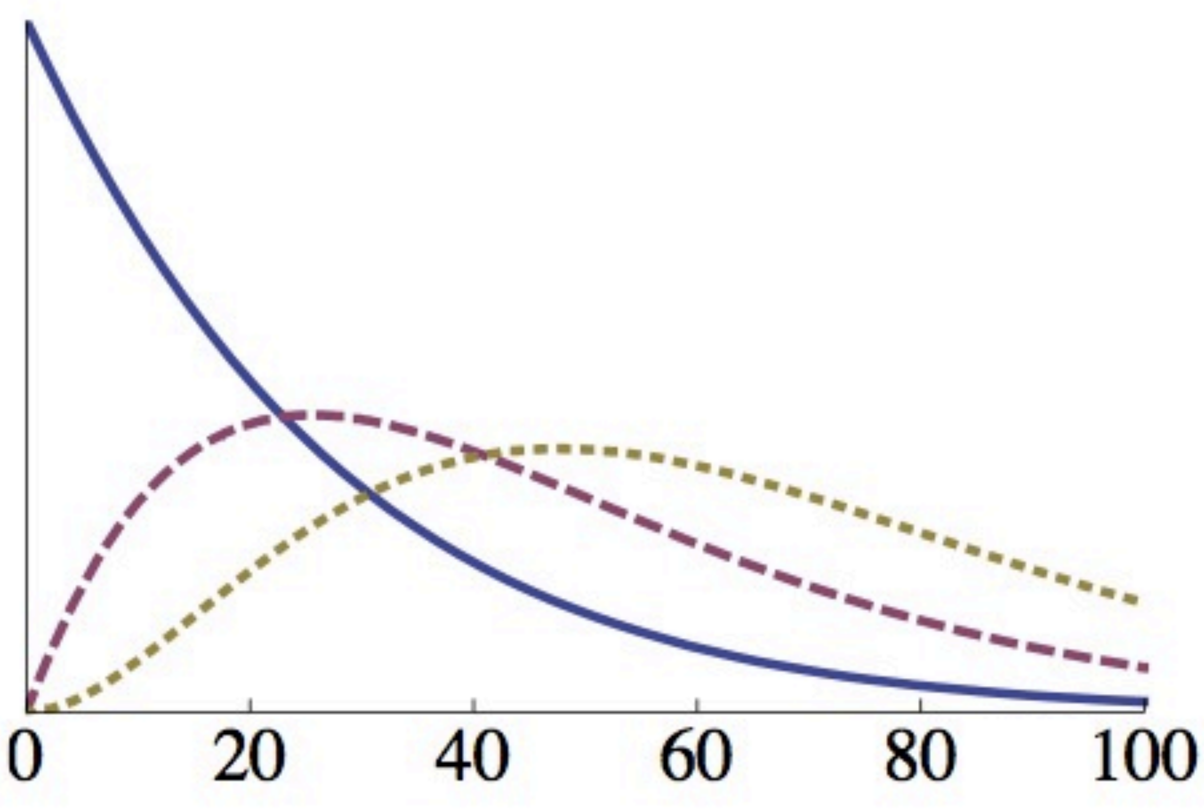
$$\frac{q^2}{m_\phi^2} \approx \frac{\text{small}}{\text{also small}} \sim ?$$

$$\begin{aligned}
\mathcal{O}_1 &= (\bar{\chi}\gamma_5\chi)(\bar{q}q), \\
\mathcal{O}_2 &= (\bar{\chi}\chi)(\bar{q}\gamma_5 q), \\
\mathcal{O}_3 &= (\bar{\chi}\gamma_5\chi)(\bar{q}\gamma_5 q), \\
\mathcal{O}_4 &= (\bar{\chi}\gamma_\mu\gamma_5\chi)(\bar{q}\gamma^\mu q)
\end{aligned}$$

NOT YOUR ADVISOR'S T-CHANNEL BOSON

$$\frac{q^2}{m_Z^2} \approx \frac{\text{small}}{\text{big}} \sim \text{very small} \qquad \frac{q^2}{m_\phi^2} \approx \frac{\text{small}}{\text{also small}} \sim ?$$



a)

$$\begin{aligned} \mathcal{O}_1 &= (\bar{\chi}\gamma_5\chi)(\bar{q}q), \\ \mathcal{O}_2 &= (\bar{\chi}\chi)(\bar{q}\gamma_5 q), \\ \mathcal{O}_3 &= (\bar{\chi}\gamma_5\chi)(\bar{q}\gamma_5 q), \\ \mathcal{O}_4 &= (\bar{\chi}\gamma_\mu\gamma_5\chi)(\bar{q}\gamma^\mu q) \end{aligned}$$

NOT YOUR ADVISOR'S T-CHANNEL BOSON

$\sigma \propto q^4$

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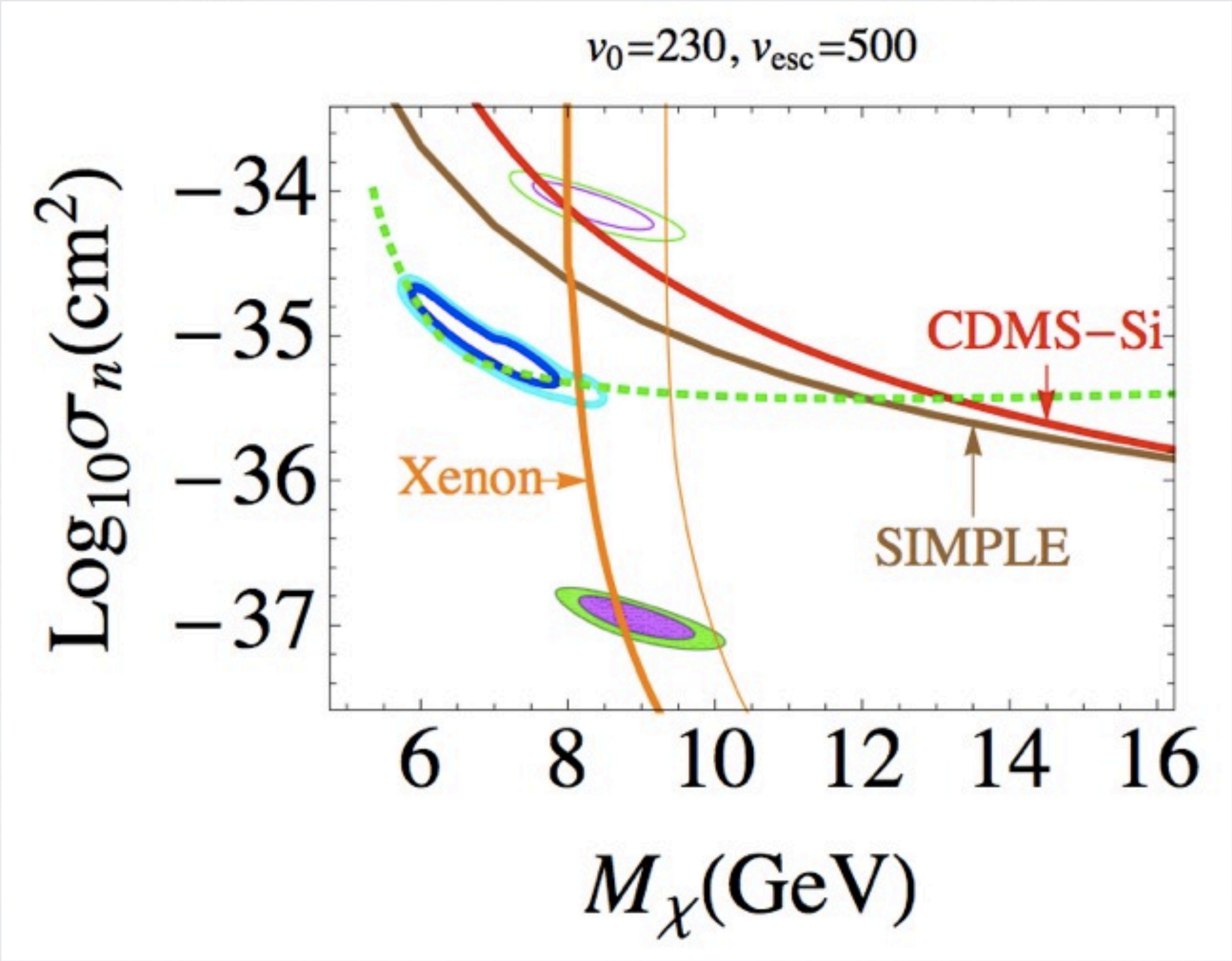

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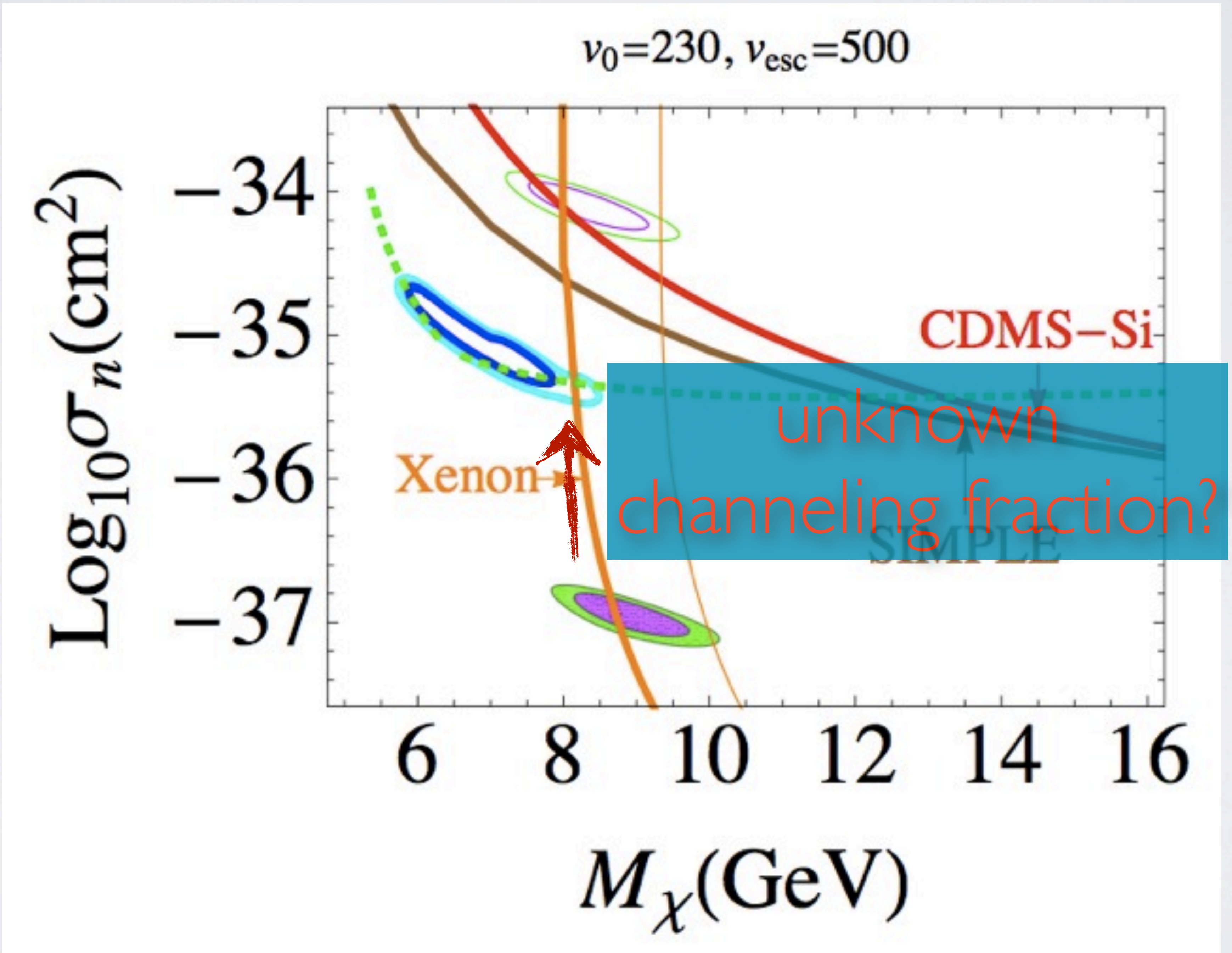
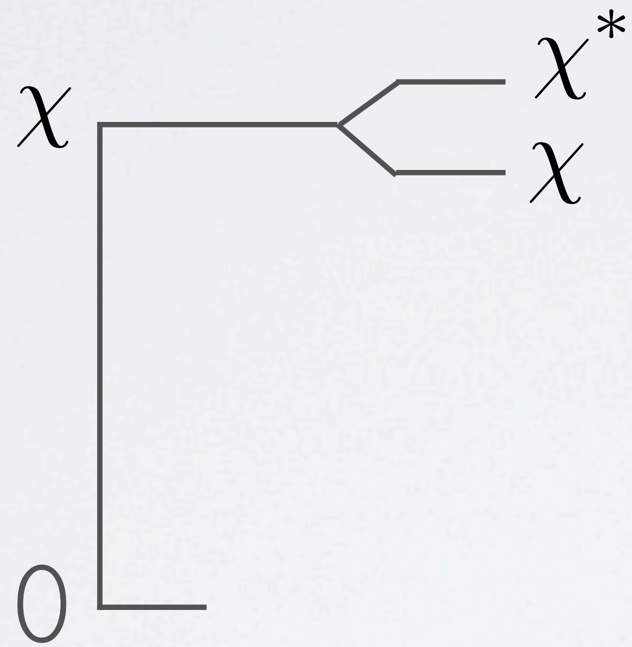
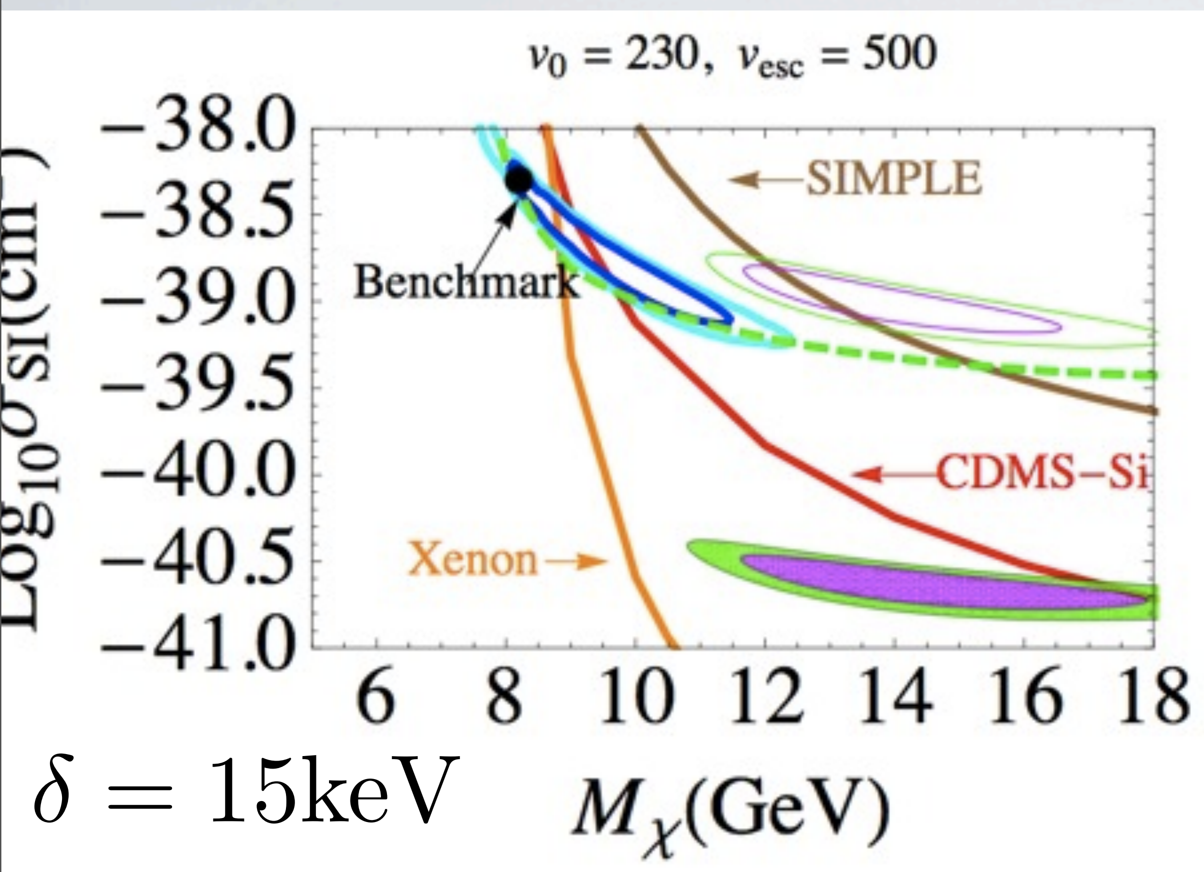
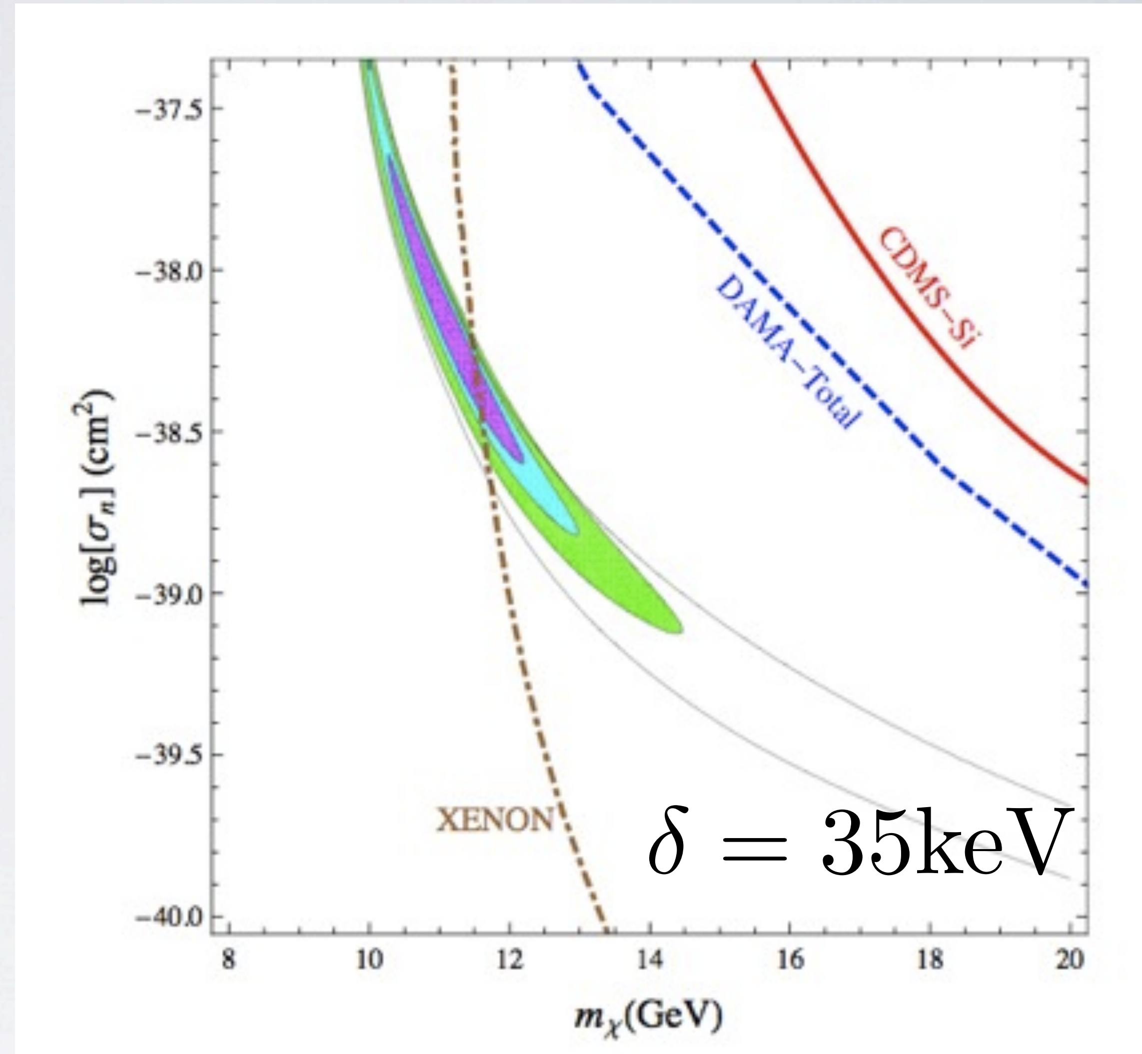


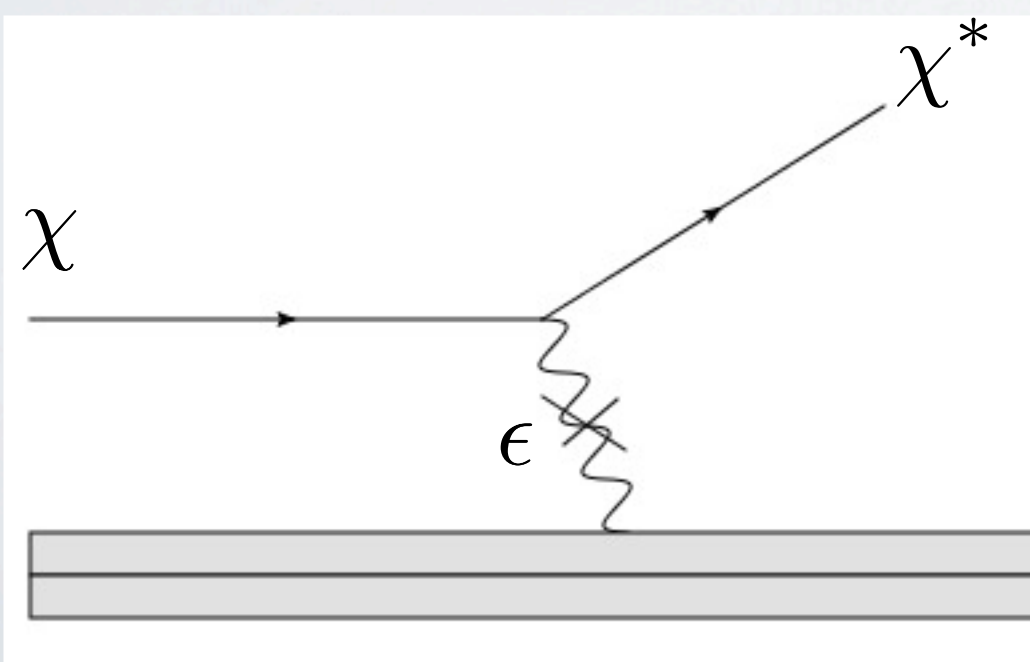
THE FINE STRUCTURE OF NEW PHYSICS



UPSCATTERING (AKA IDM)



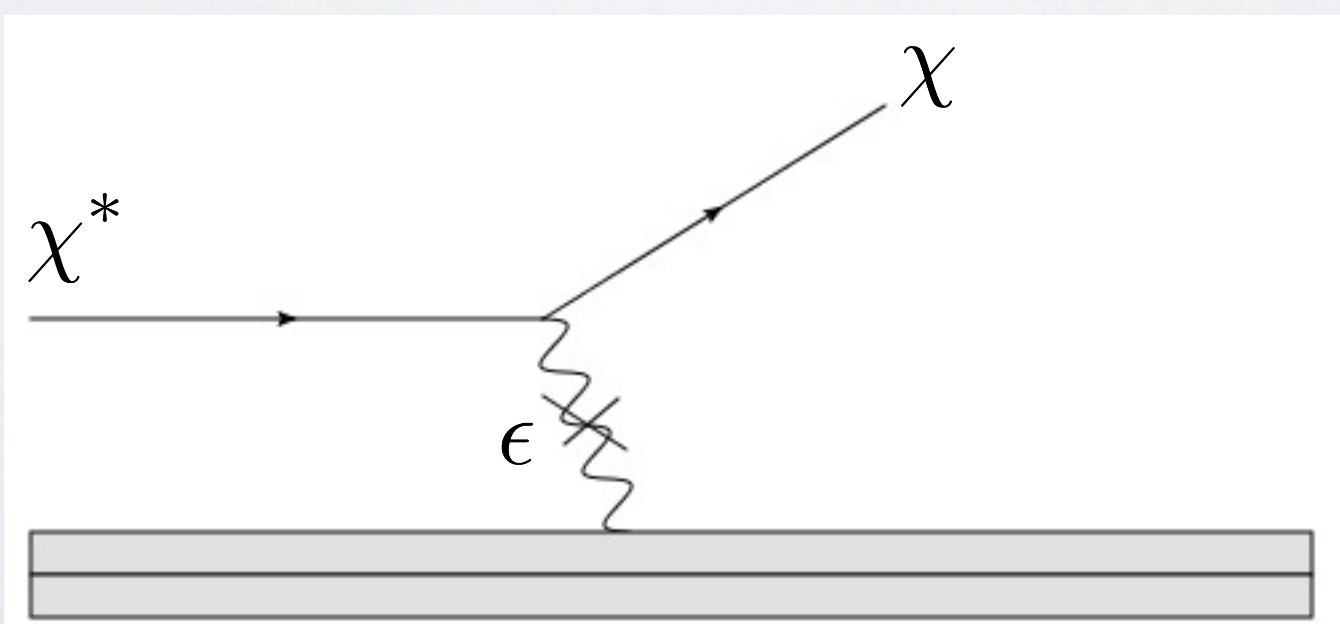




$$v_{min} = \sqrt{\frac{1}{2m_N E_R}}\left(\frac{m_N E_R}{\mu} + \delta\right)$$

DOWNSCATTERING

(plot from Essig et al)



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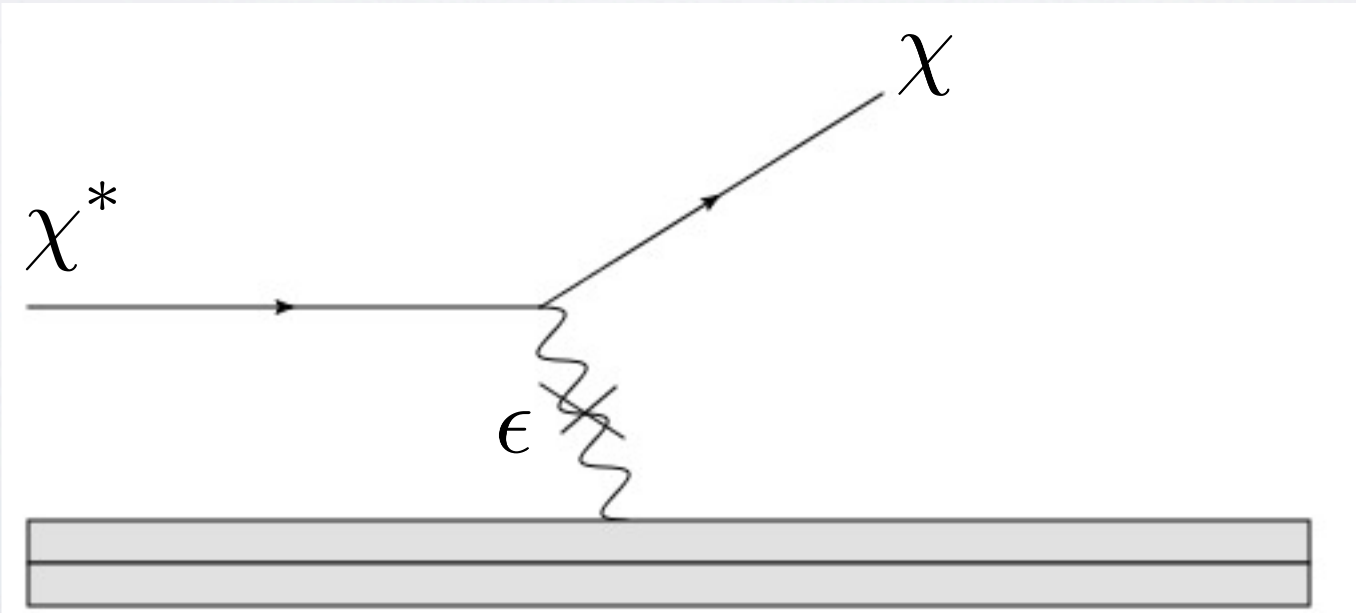

$$E_R \approx \frac{\delta \mu}{m_N}$$

$$\Delta E_R \approx 4\sqrt{\frac{\mu v^2}{2\delta}}$$

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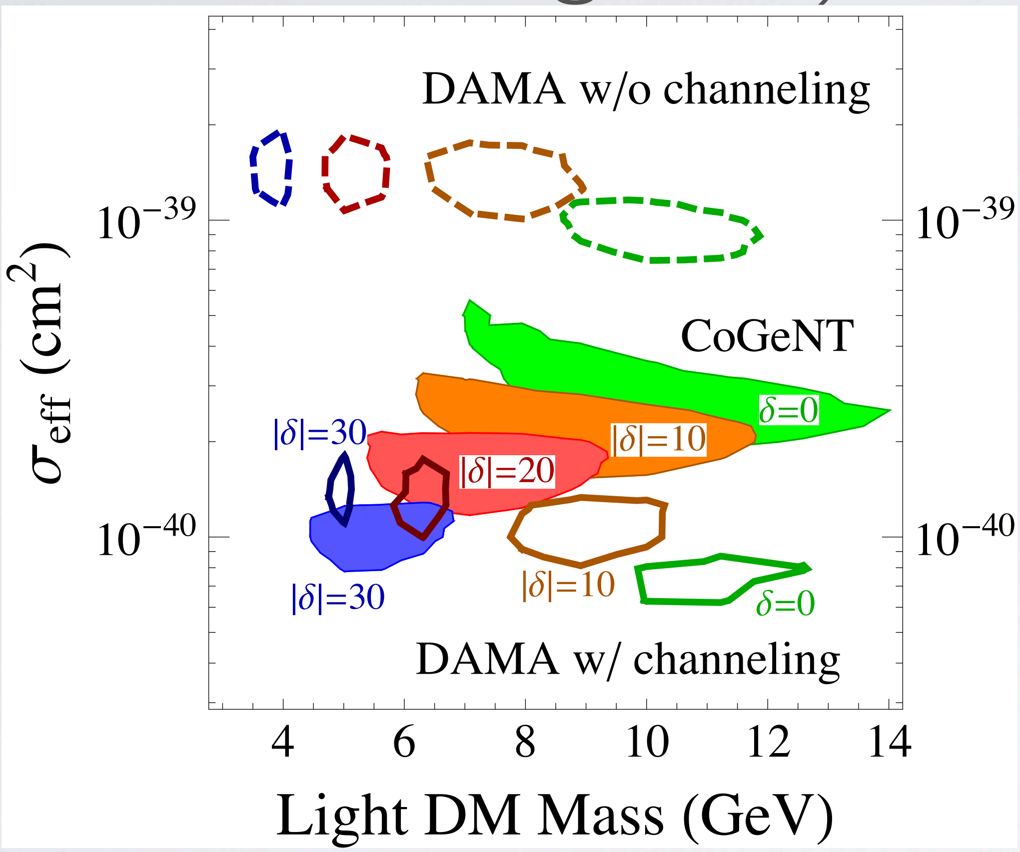

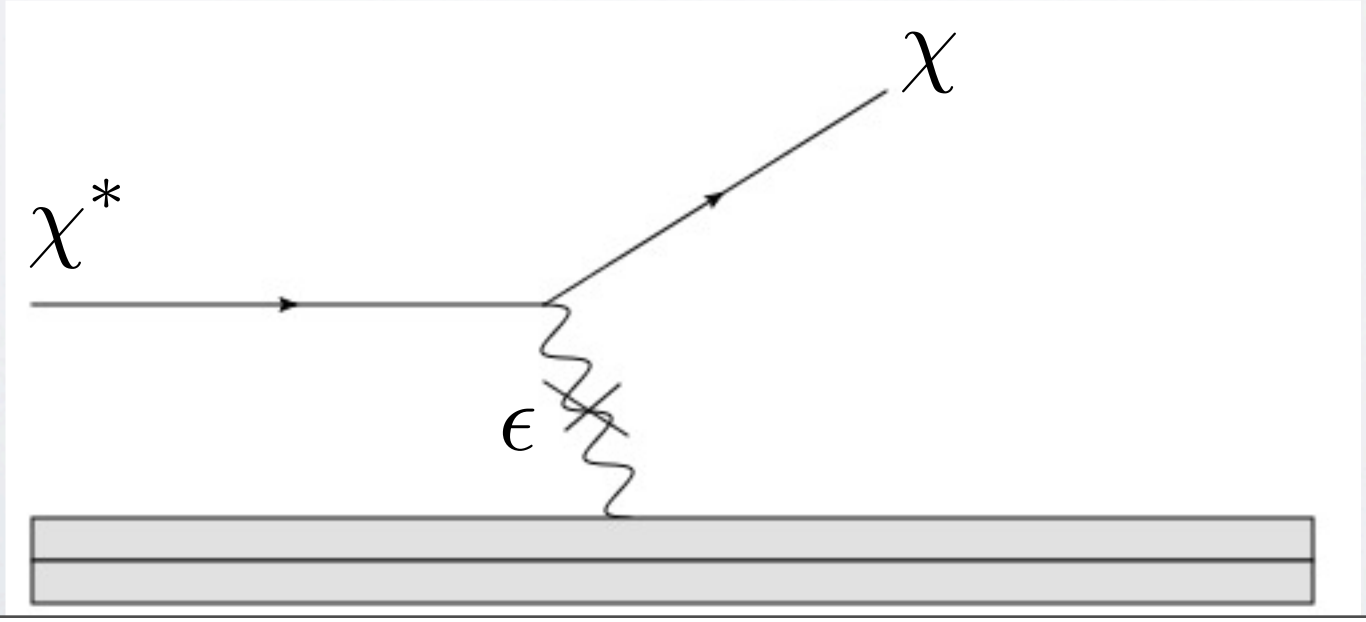

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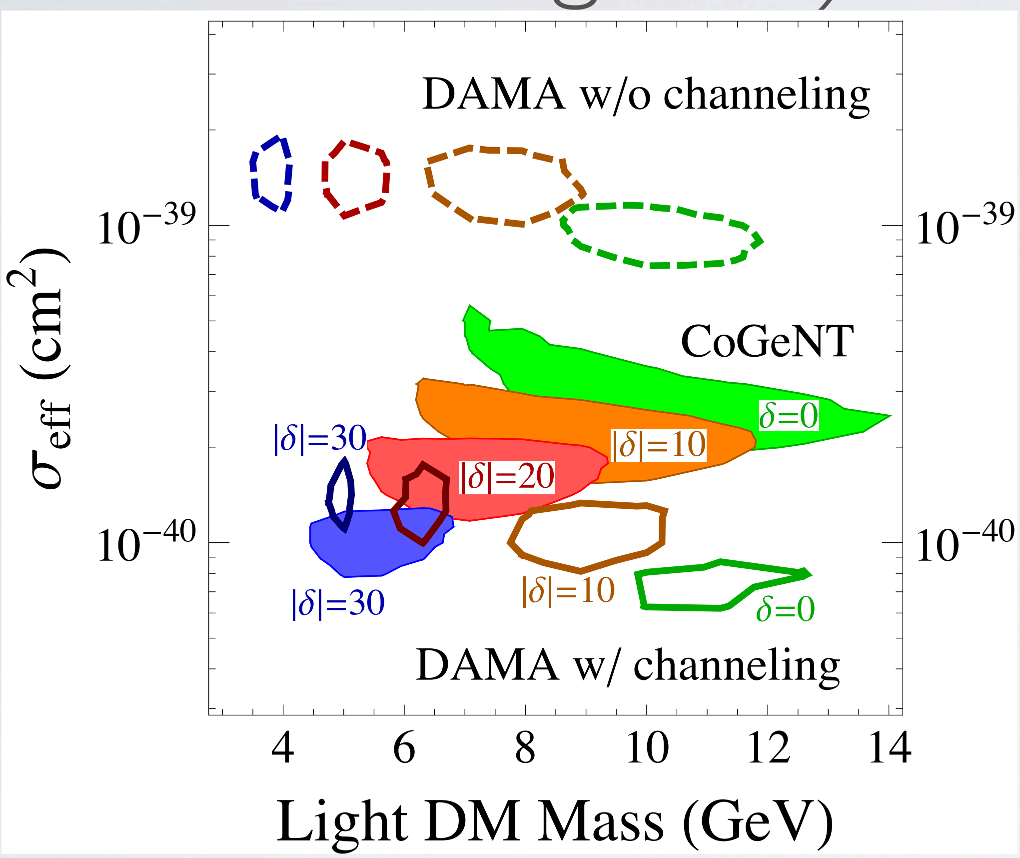

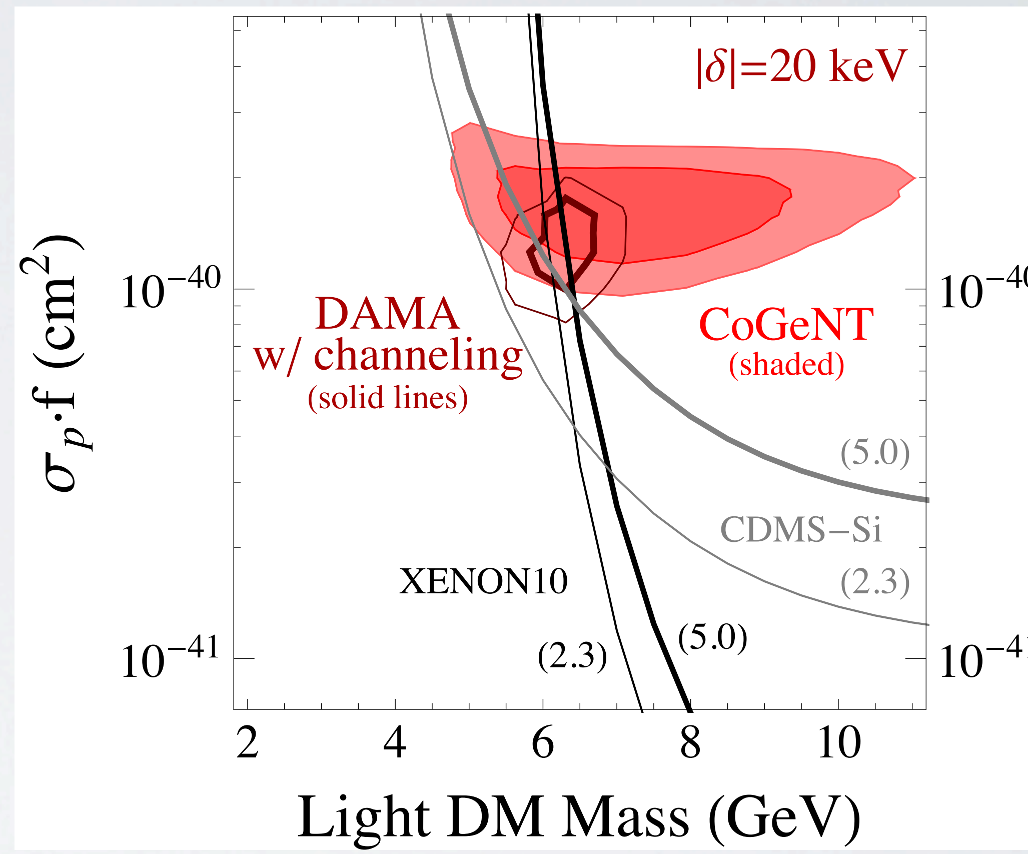

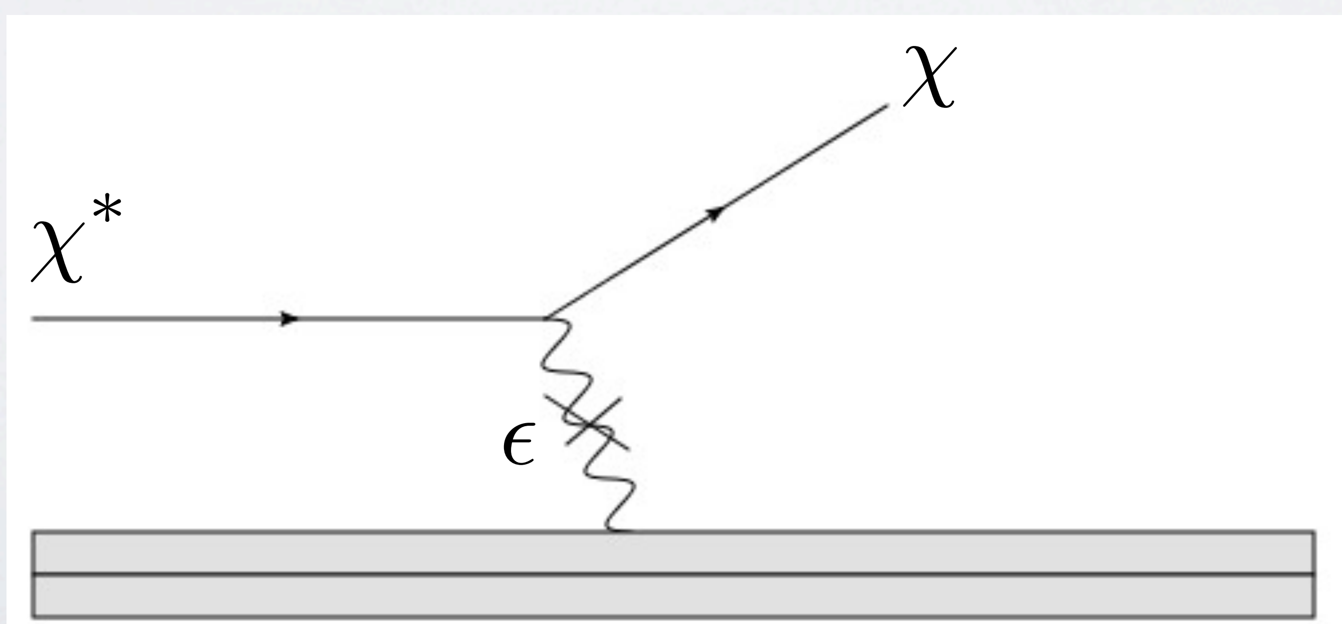

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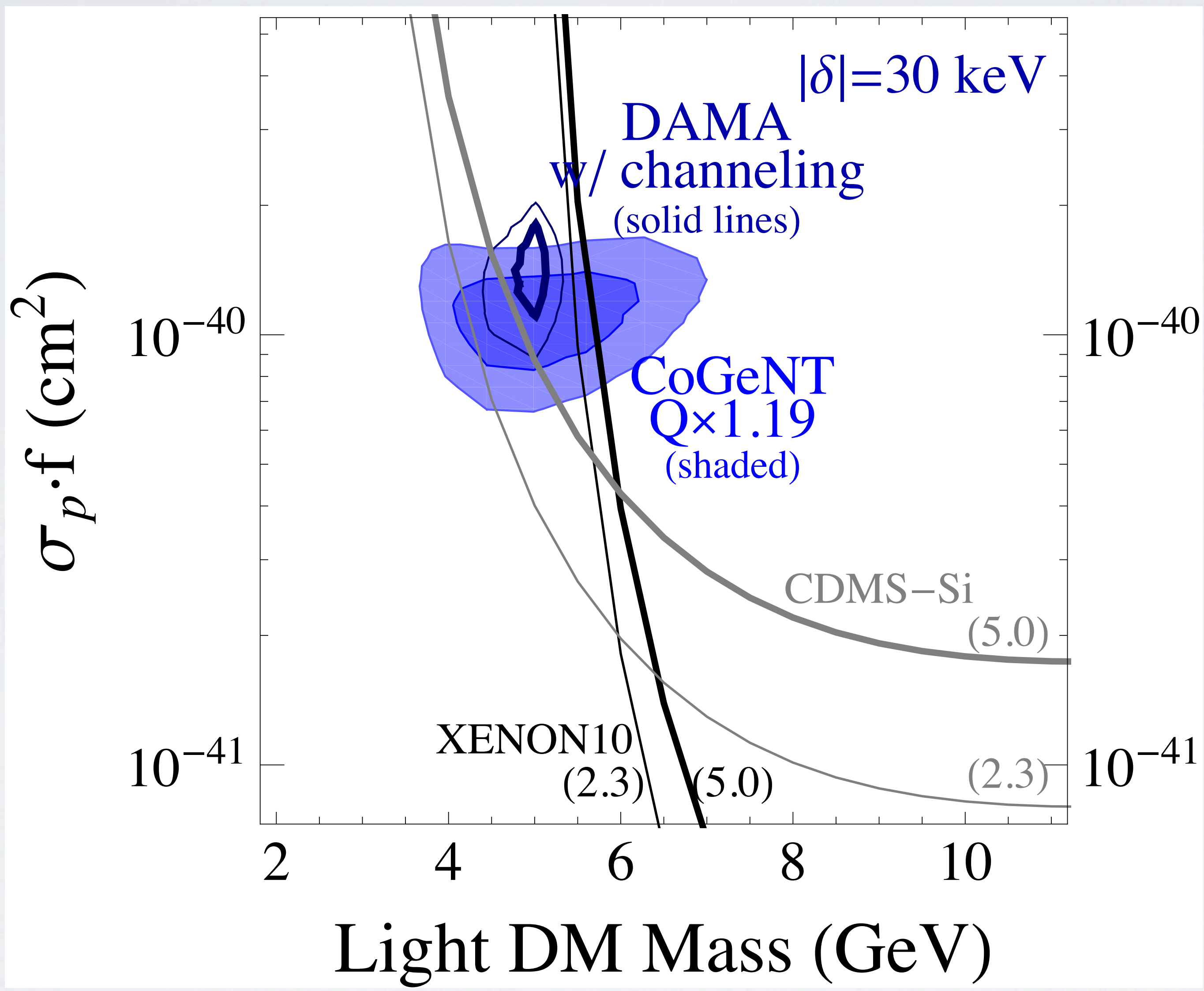
WITH MOUNTAIN-WEST UNCERTAINTIES



WHAT ARE THE SENSITIVITIES?

- Assume we really know what energies we're talking about
  - If the CoGeNT region is lower / CDMS-Si is higher - easy to evade limits
  - For elastic or down-scattering processes, halo models not important
- For up-scattering, halo is everything


ONE RESOLVE.

WE ARE THE ONES WE'VE BEEN WAITING FOR

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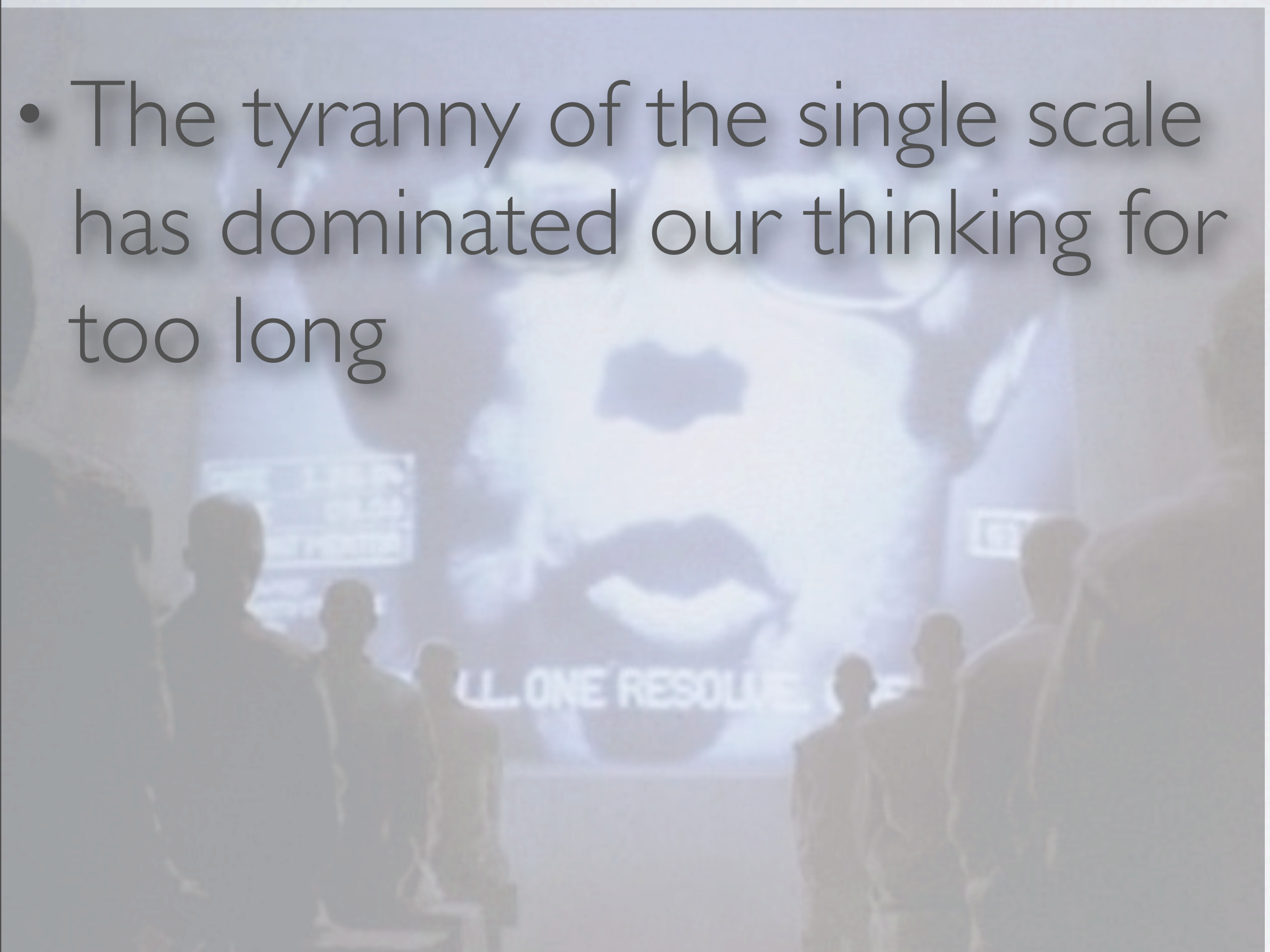

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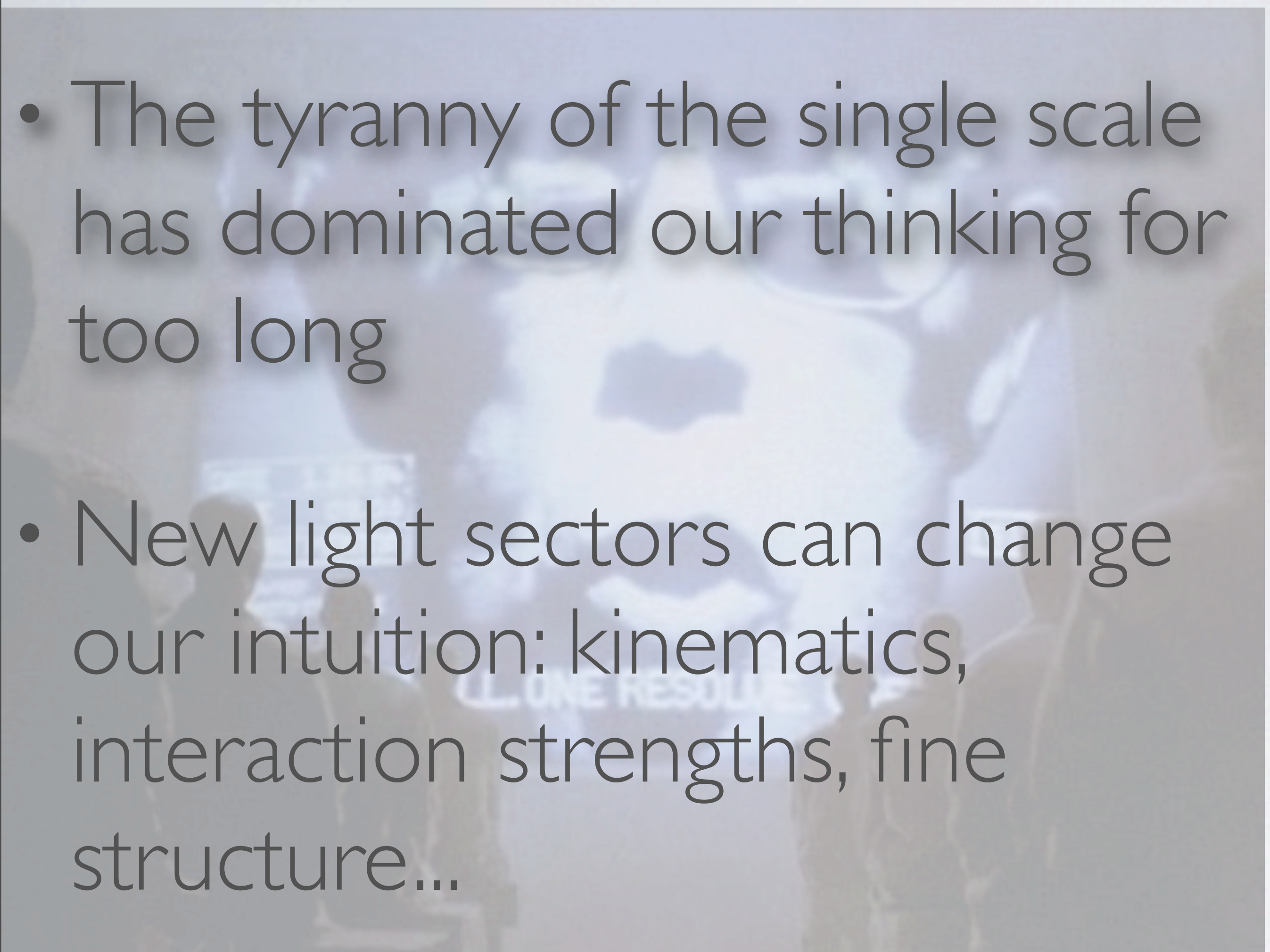

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Exciting times ahead!