

Dark Matter at the ILC



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Outline

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- Dark matter evidences

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- Effective operator approach

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- Microscopic models approach

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- Specific example
- Comparison with other experiments

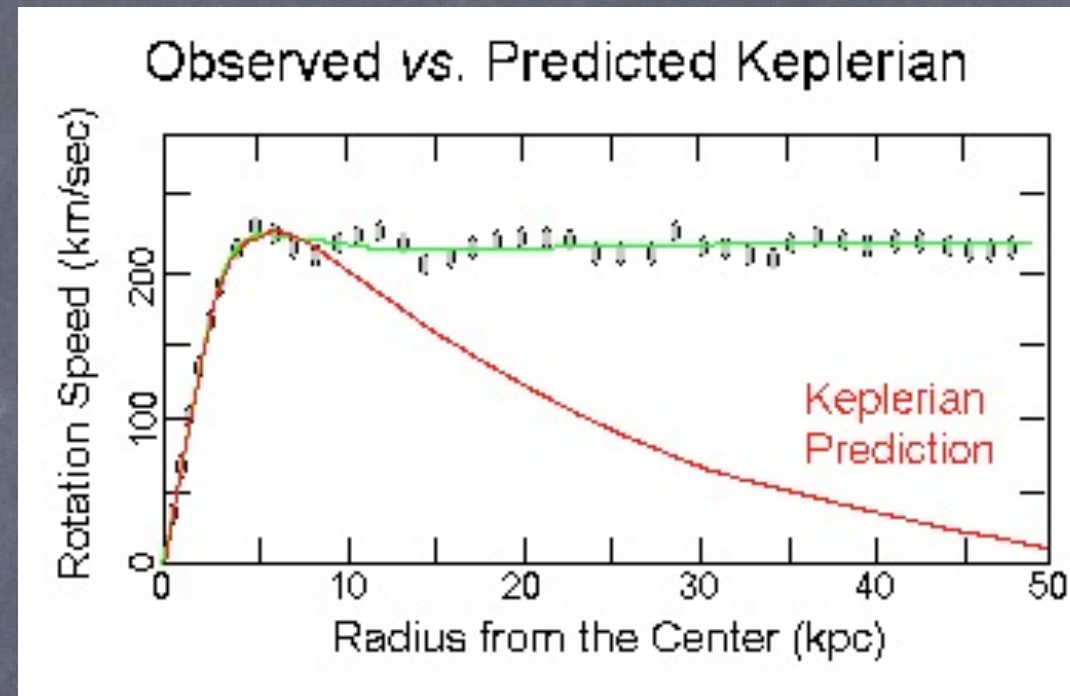
Outline

- Dark matter evidences
- Effective operator approach
- Microscopic models approach
- Specific example
- Comparison with other experiments
- Conclusions and perspective

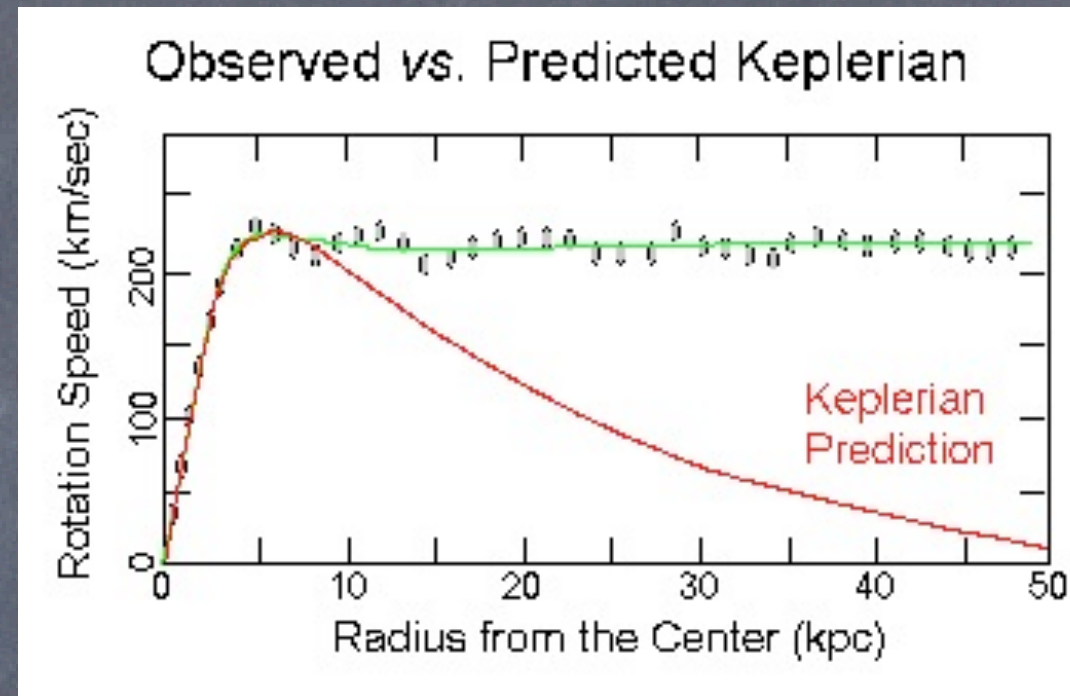
Dark matter evidence : Galactic scale



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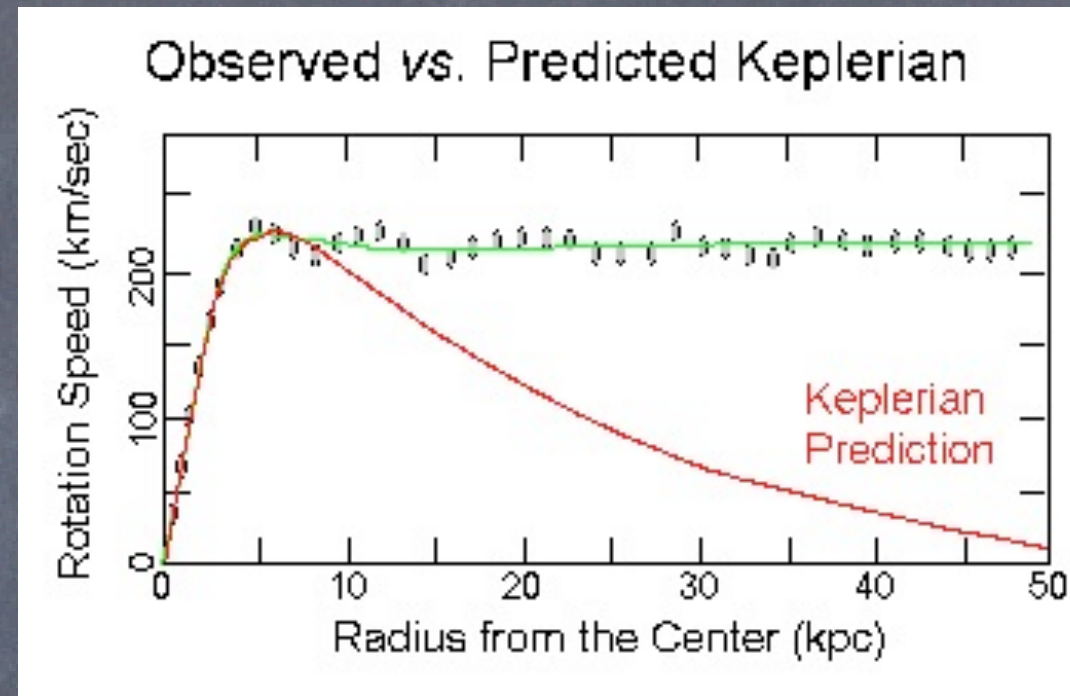


Dark matter evidence : Galactic scale



$$\frac{GmM_{gal}}{r} = mv^2 \rightarrow v \propto \frac{1}{\sqrt{r}}$$

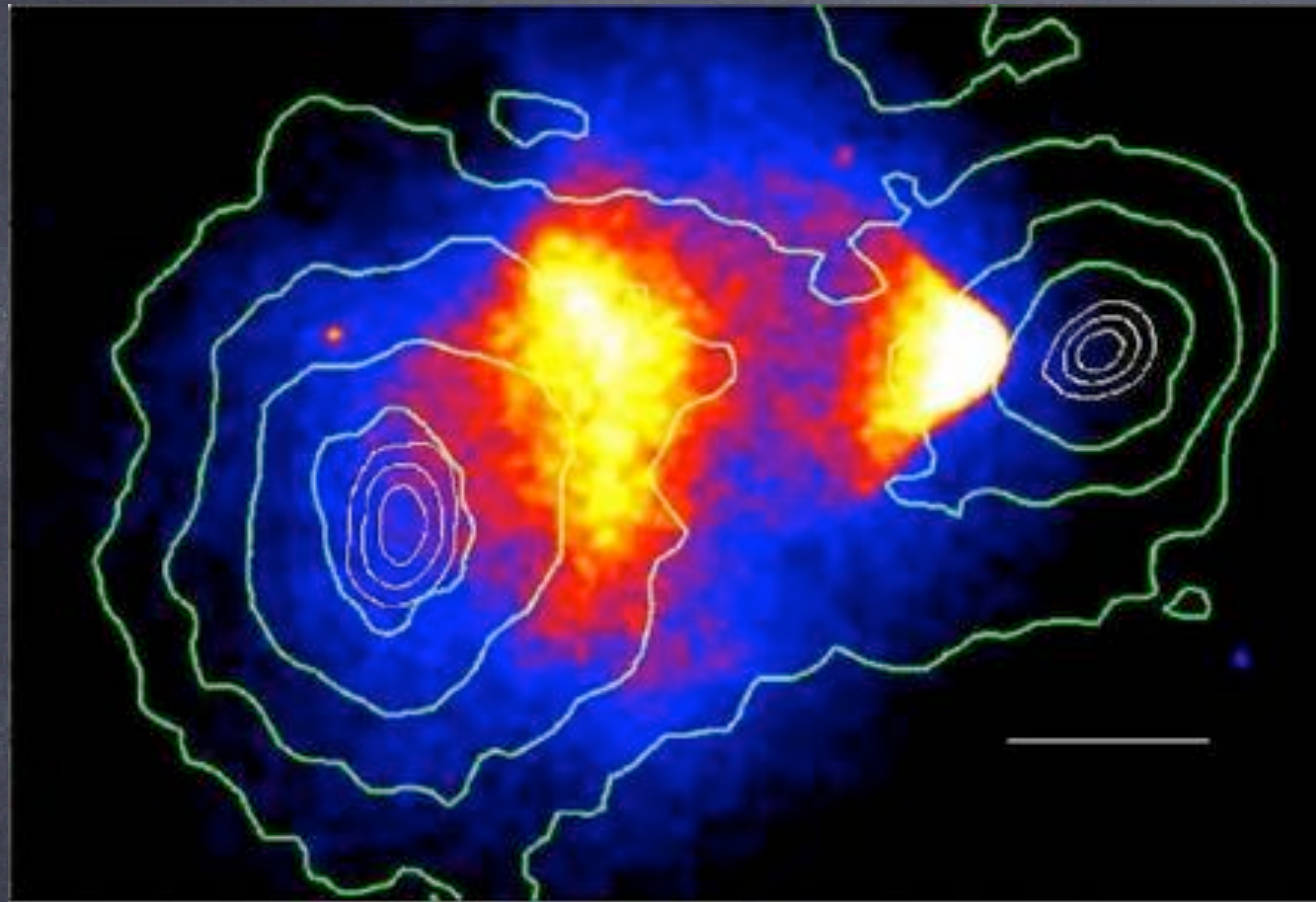
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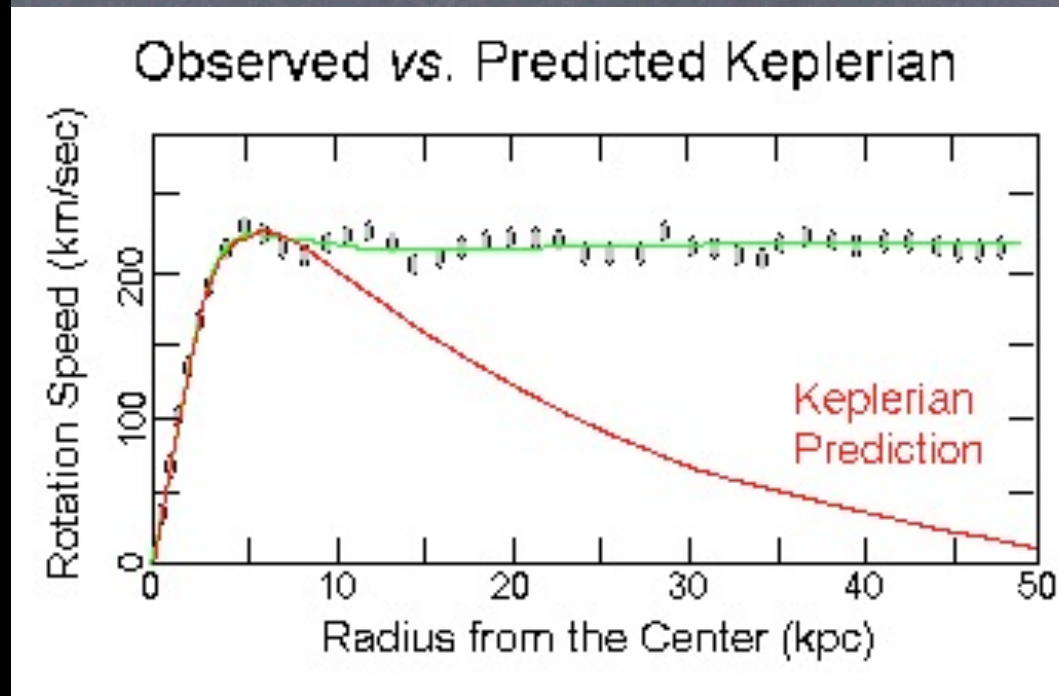
$$\rho_{DM} \propto \frac{1}{r^2} \rightarrow M_{gal} = Volume * \rho \propto r \rightarrow v \sim cte$$

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Dark matter evidence : Galactic scale



Bullet cluster



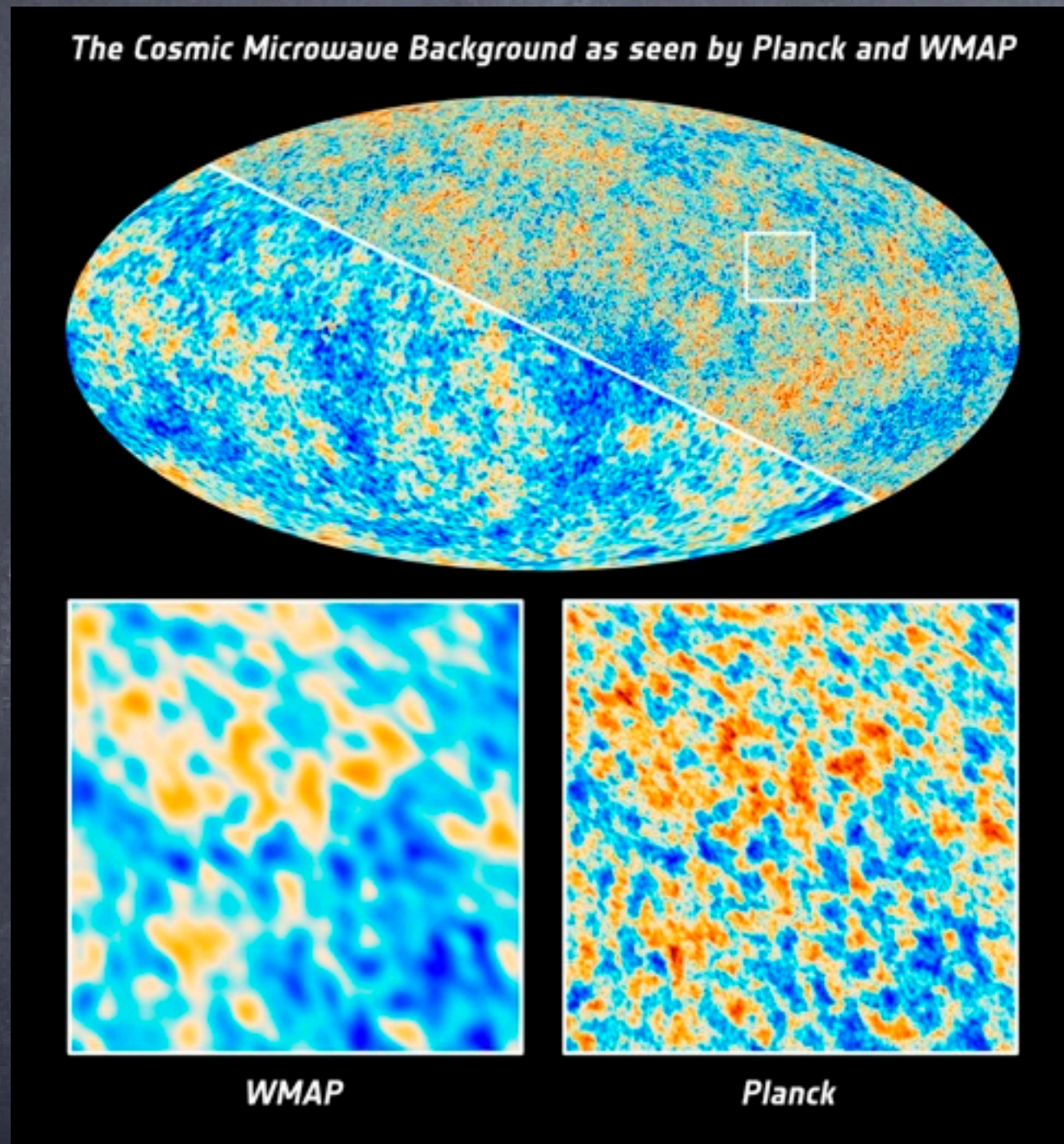
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Cosmological scale (PLANCK results March 19th)

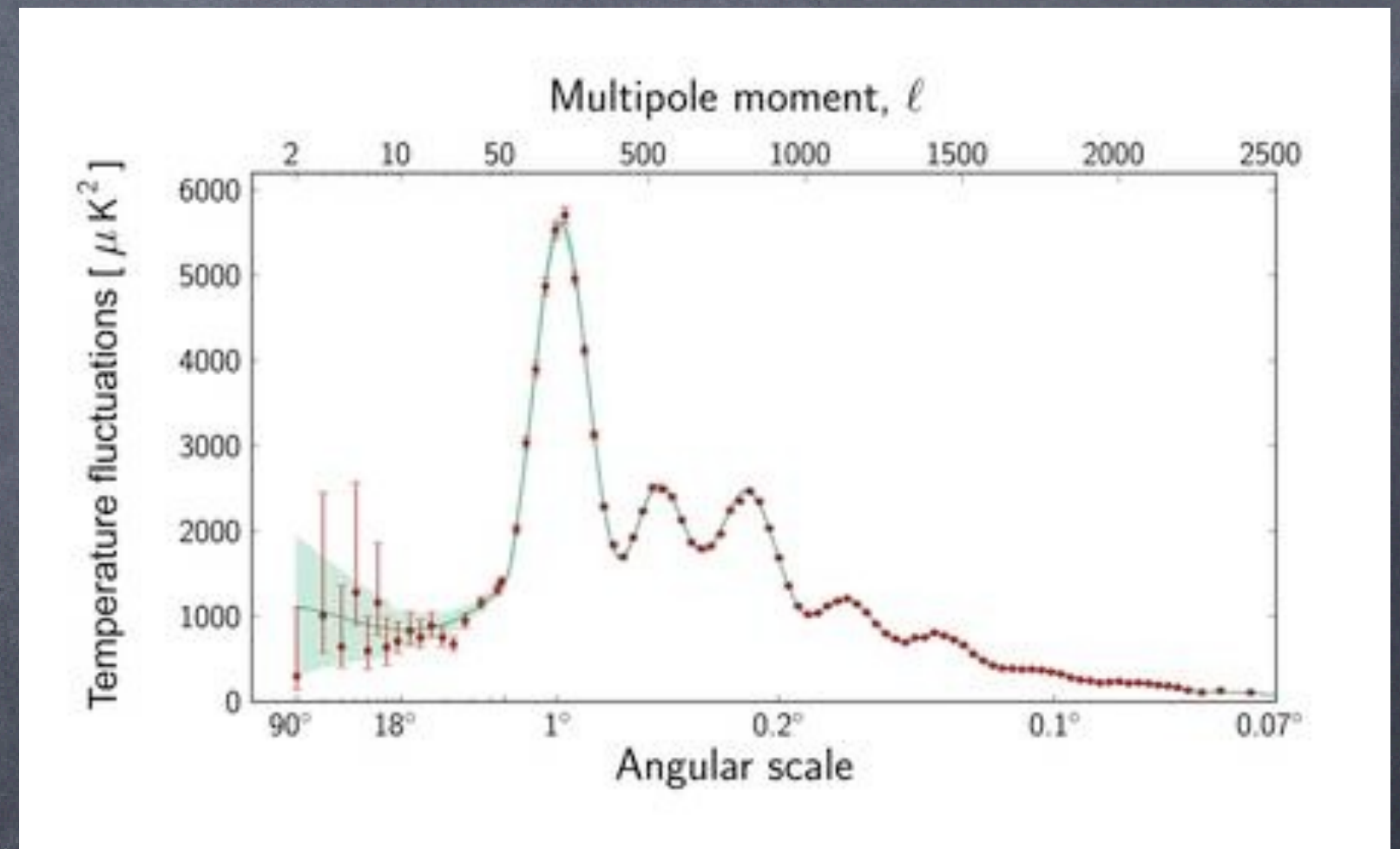
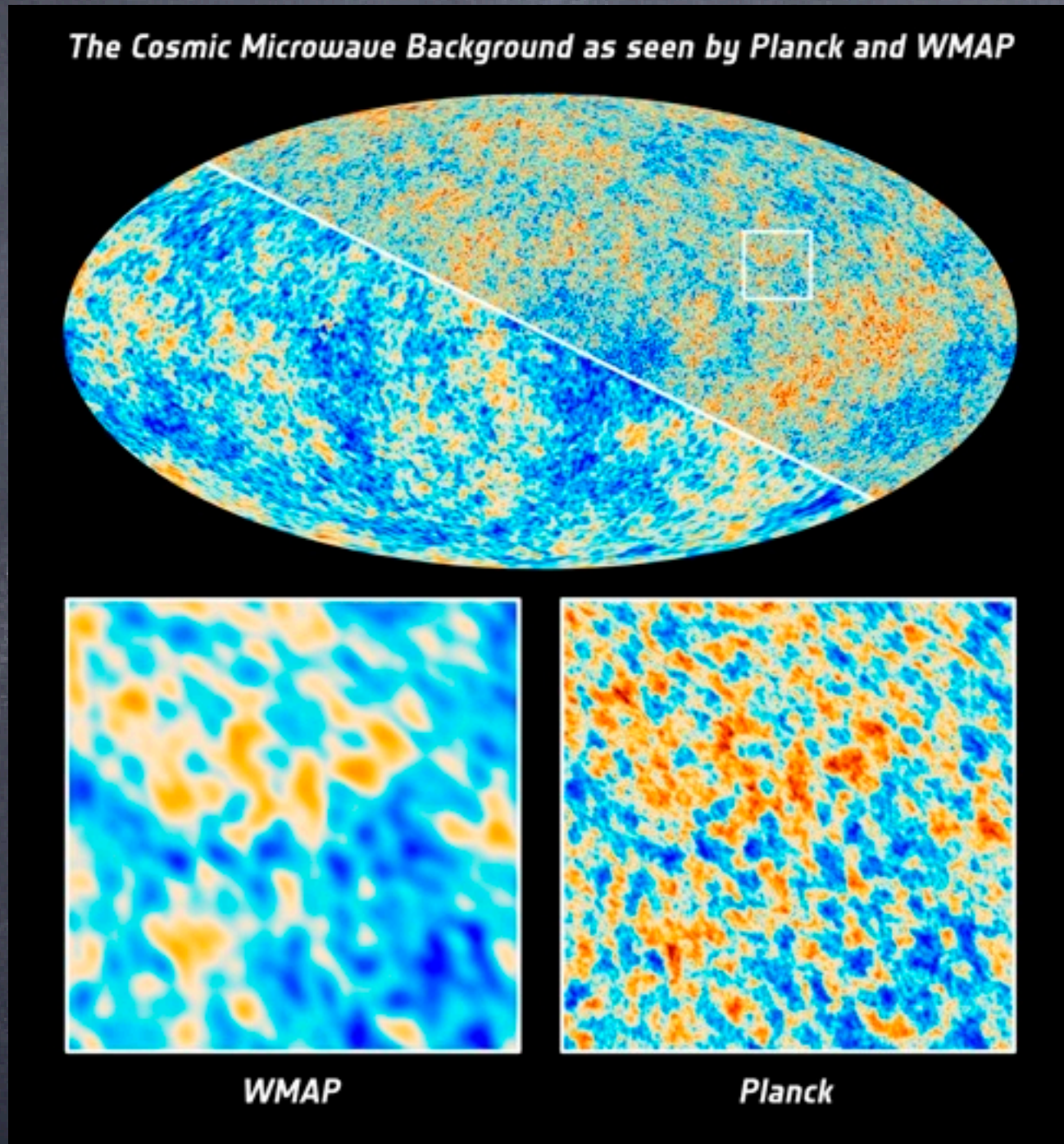
Cosmological scale (PLANCK results March 19th)

Cosmic Microwave Background (CMB)



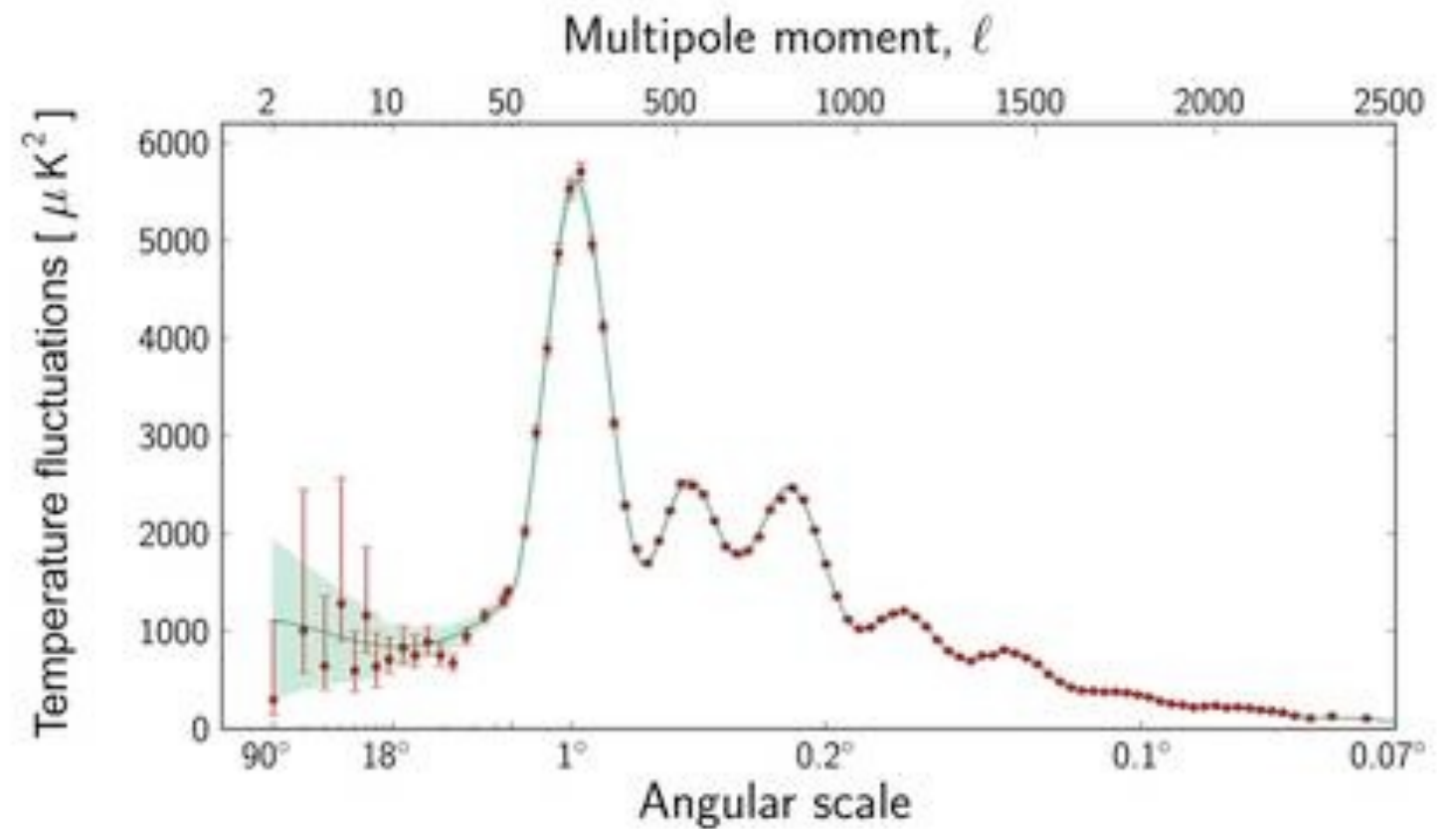
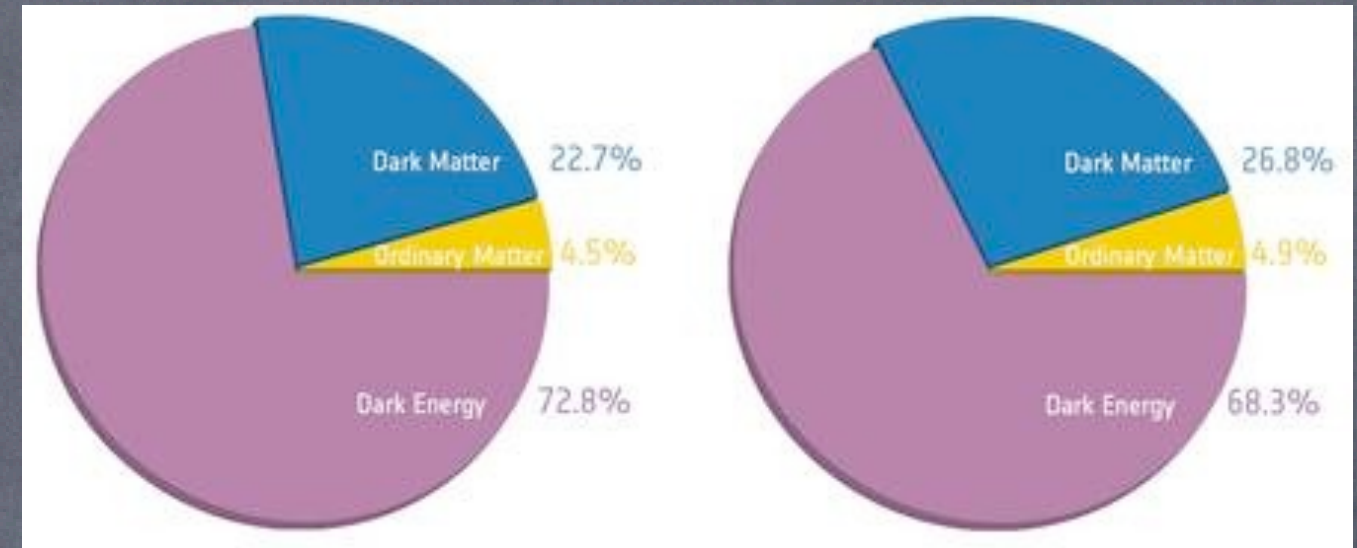
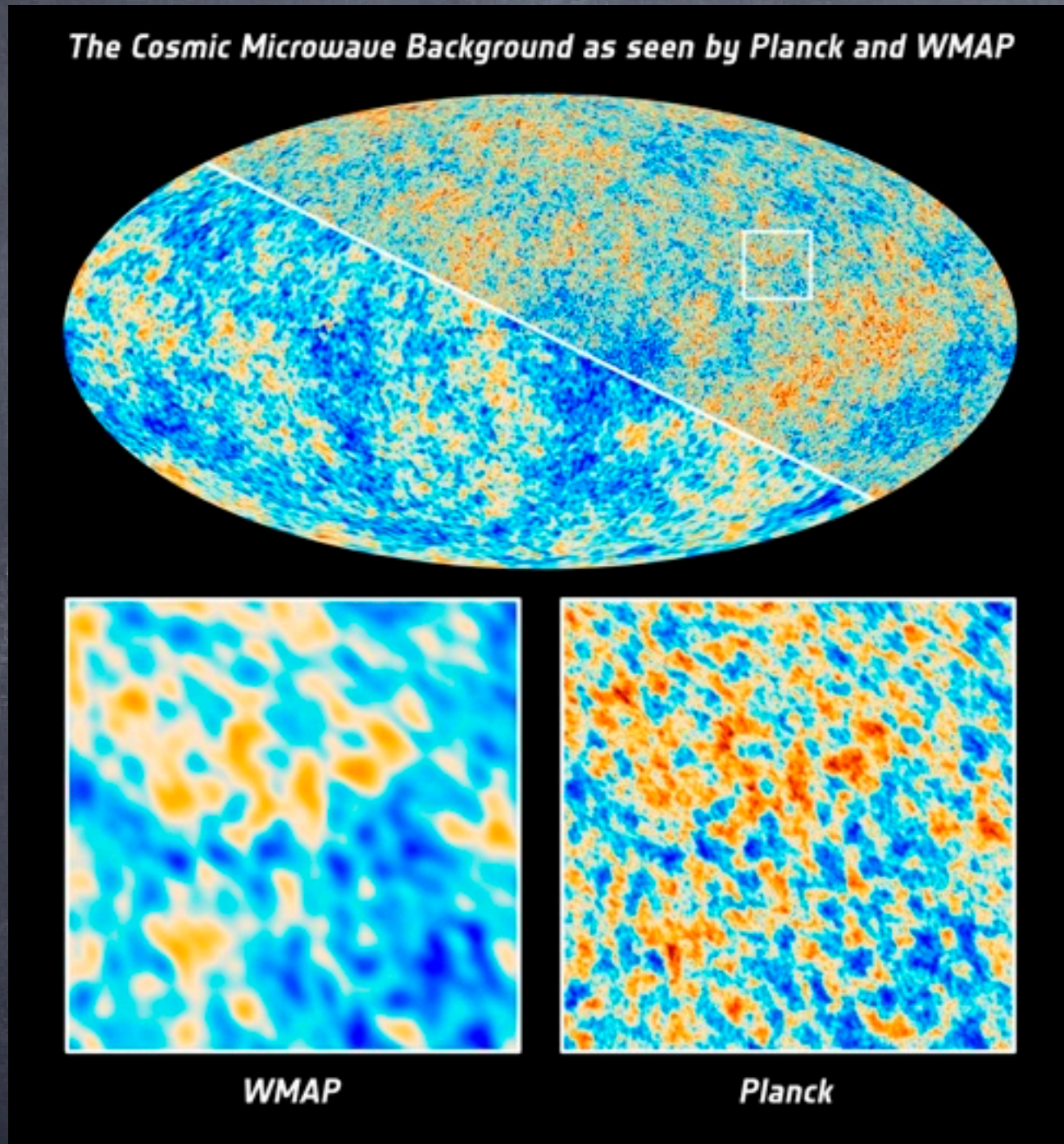
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Detection of Dark Matter



Detection of Dark Matter

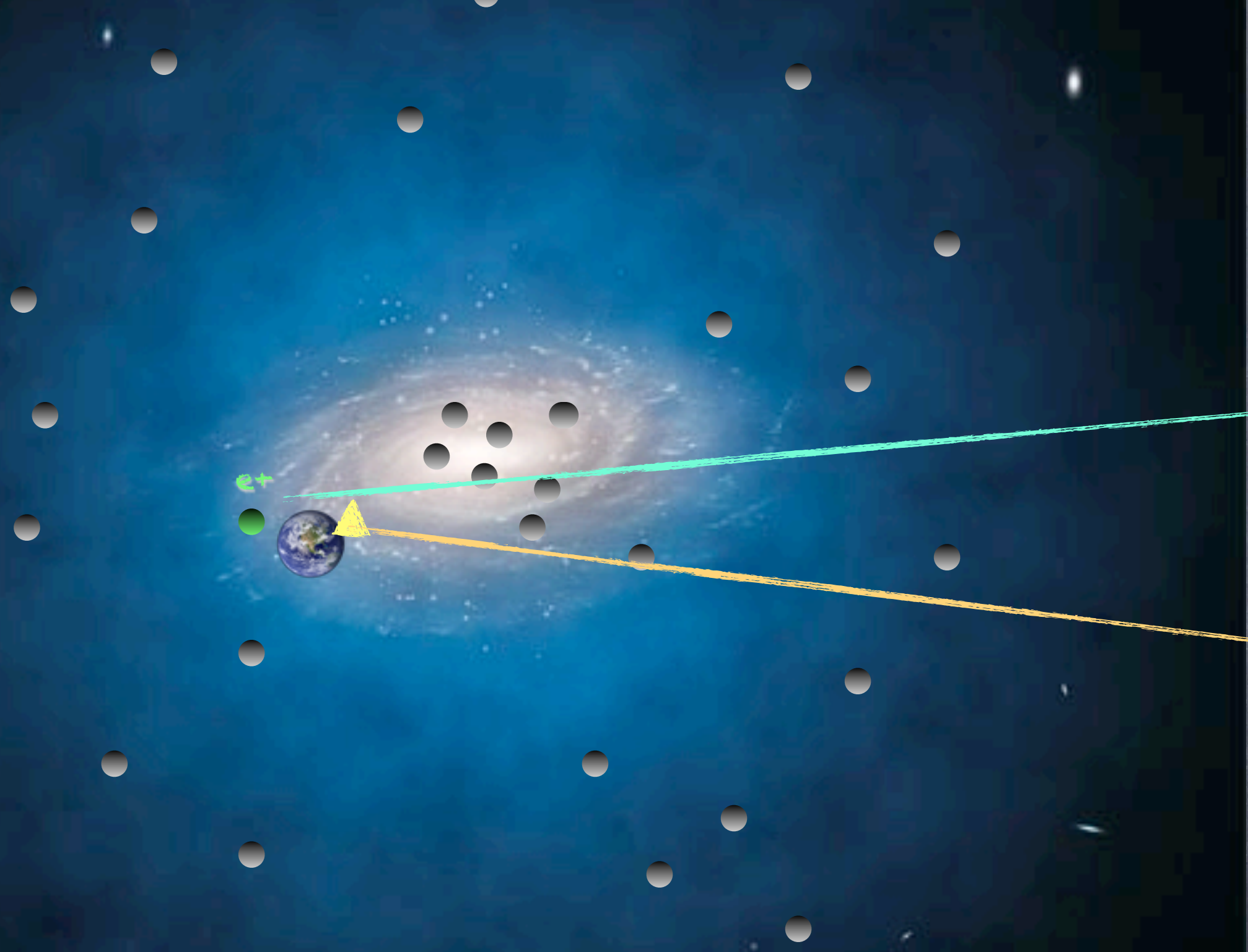


Detection of Dark Matter



Indirect gamma
(FERMI, HESS)

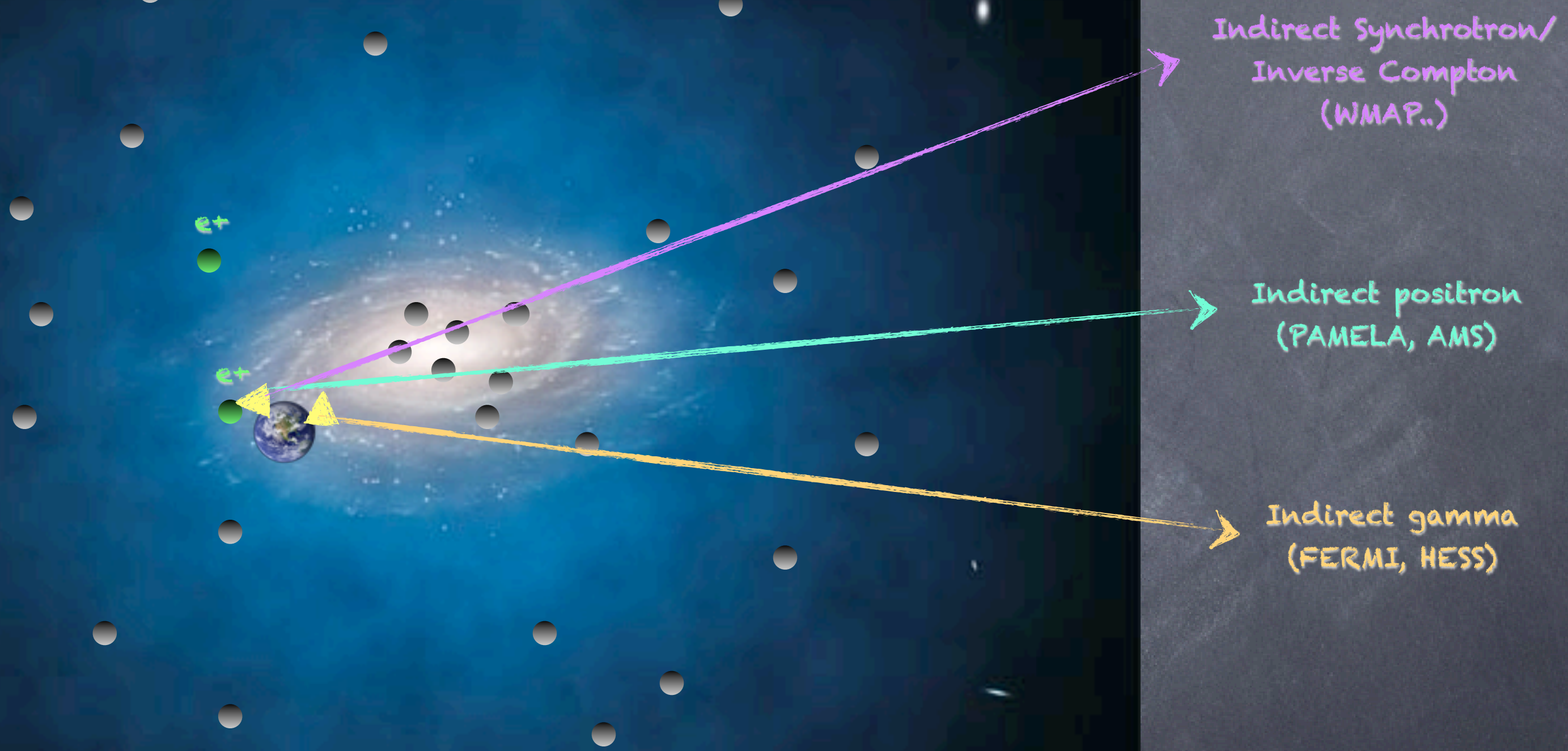
Detection of Dark Matter



Indirect positron
(PAMELA, AMS)

Indirect gamma
(FERMI, HESS)

Detection of Dark Matter

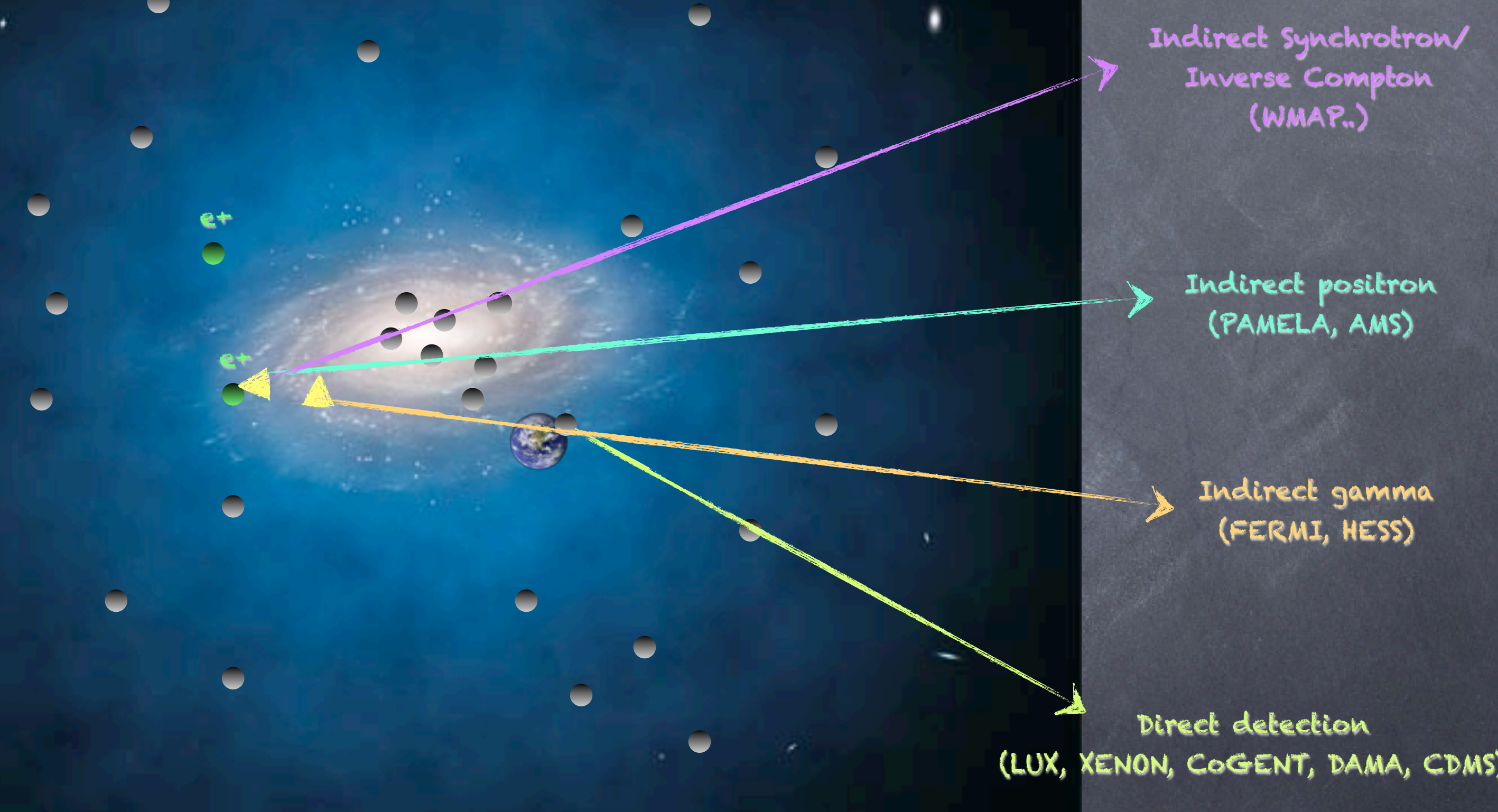


Indirect Synchrotron/
Inverse Compton
(WMAP..)

Indirect positron
(PAMELA, AMS)

Indirect gamma
(FERMI, HESS)

Detection of Dark Matter

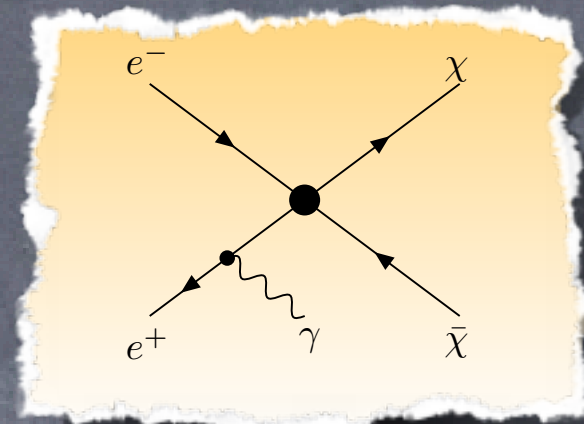


Particle physics modelization

Particle physics modelization

- Effective operator approach (COM energy < BSM physics)

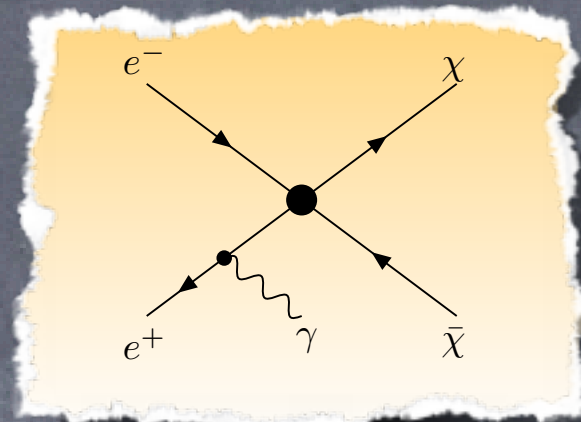
$$\frac{1}{\Lambda^2}$$



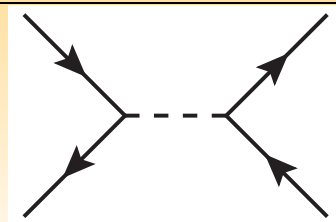
Particle physics modelization

- Effective operator approach (COM energy < BSM physics)

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- Generic microscopic constructions

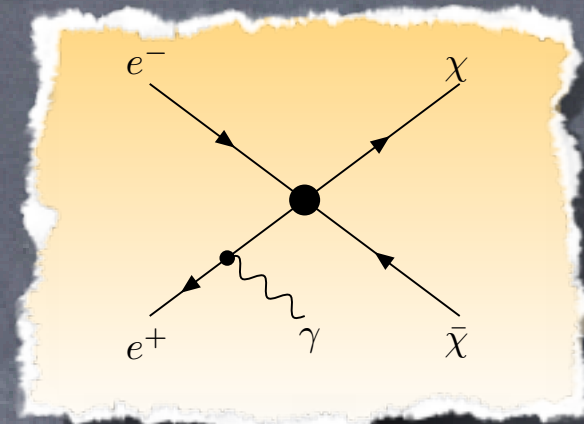


$$\bar{\chi} (g_s + g_p \gamma^5) \chi \phi + \bar{\psi} (g_s + g_p \gamma^5) \psi \phi$$
$$\frac{1}{M_\Omega^2} \bar{\chi} (g_s + i g_p \gamma^5) \chi \bar{\psi} (g_s + i g_p \gamma^5) \psi$$

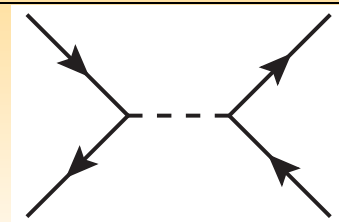
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$$\bar{\chi} (g_s + g_p \gamma^5) \chi \phi + \bar{\psi} (g_s + g_p \gamma^5) \psi \phi$$

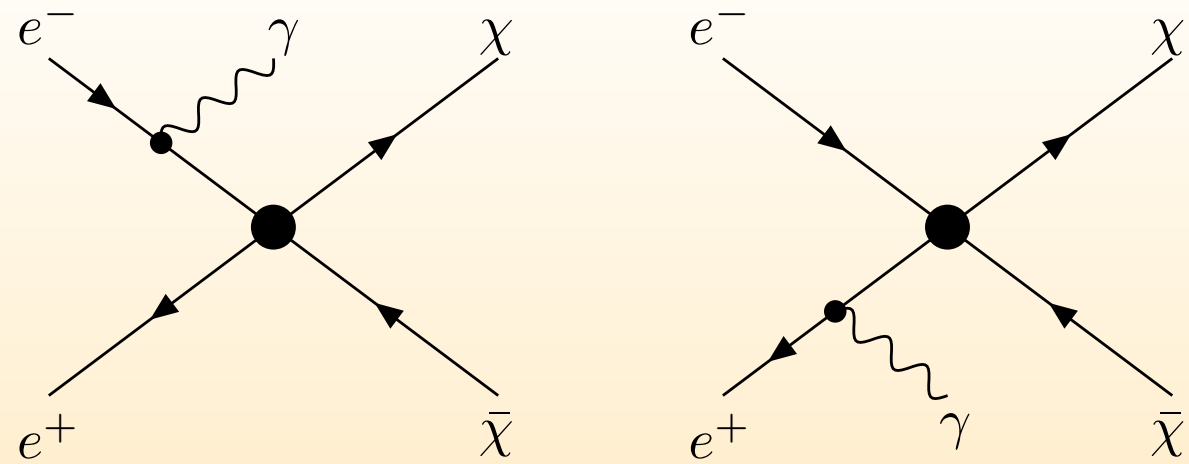
$$\frac{1}{M_\Omega^2} \bar{\chi} (g_s + i g_p \gamma^5) \chi \bar{\psi} (g_s + i g_p \gamma^5) \psi$$

$$\frac{g}{M_\phi^2} + \text{WMAP} + \phi \rightarrow f\bar{f}..$$

- Explicit UV constructions : Higgs portal, Z', ...

Effective operator approach

Effective operator approach



Initial State Radiation (ISR)

$$\mathcal{L}_{\text{int}} = \frac{1}{\Lambda^2} \mathcal{O}_i,$$

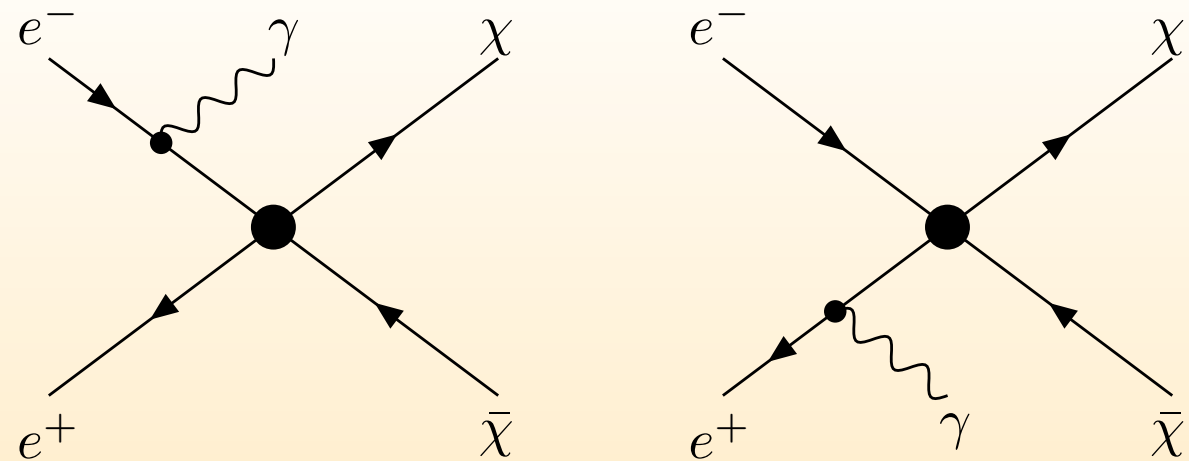
$$\mathcal{O}_V = (\bar{\chi}\gamma_\mu\chi)(\bar{l}\gamma^\mu l), \quad (\text{vector})$$

$$\mathcal{O}_S = (\bar{\chi}\chi)(\bar{l}l), \quad (\text{scalar, } s\text{-channel})$$

$$\mathcal{O}_A = (\bar{\chi}\gamma_\mu\gamma_5\chi)(\bar{l}\gamma^\mu\gamma^5 l), \quad (\text{axial-vector})$$

$$\mathcal{O}_t = (\bar{\chi}l)(\bar{l}\chi), \quad (\text{scalar, } t\text{-channel}).$$

Effective ope



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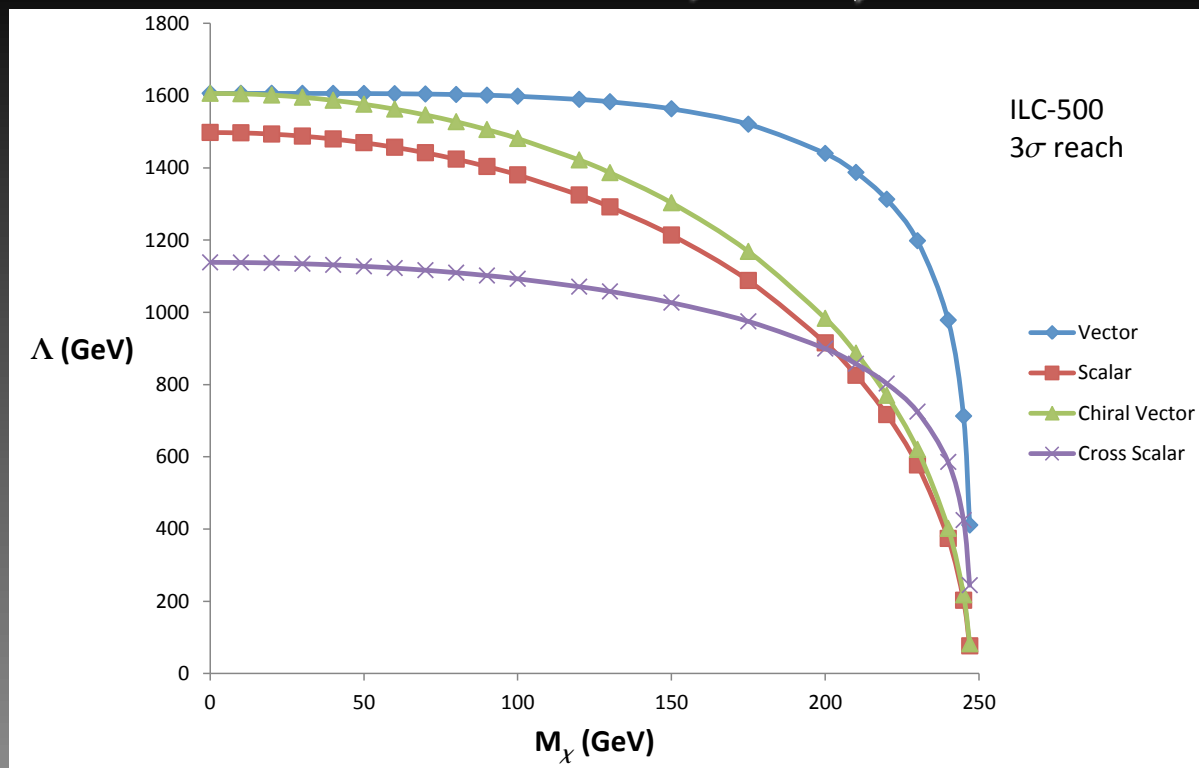
$$\mathcal{O}_V = (\bar{\chi}\gamma_\mu\chi)(\bar{\ell}\gamma^\mu\ell), \quad (\text{vector})$$

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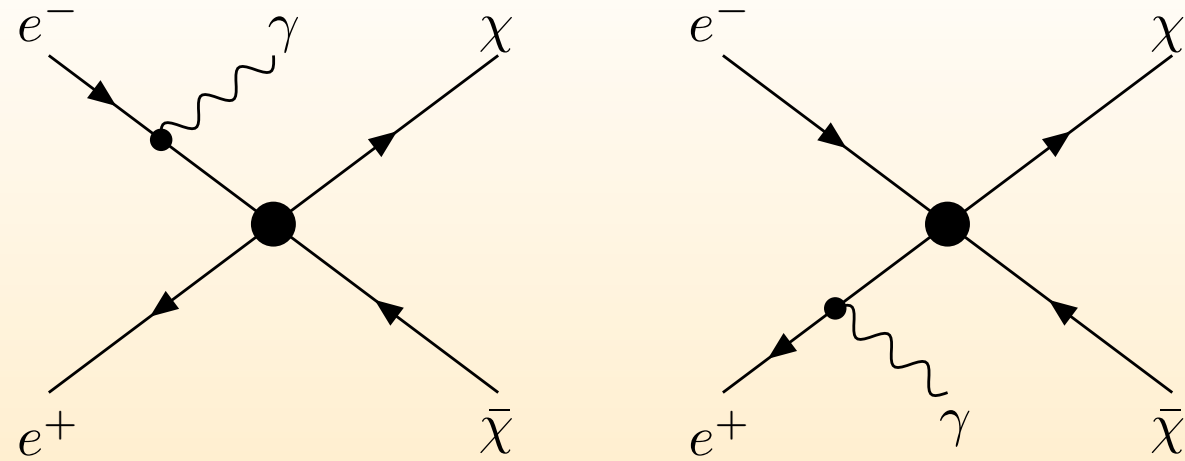
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ILC 500 GeV, 500 fb⁻¹



Effective ope

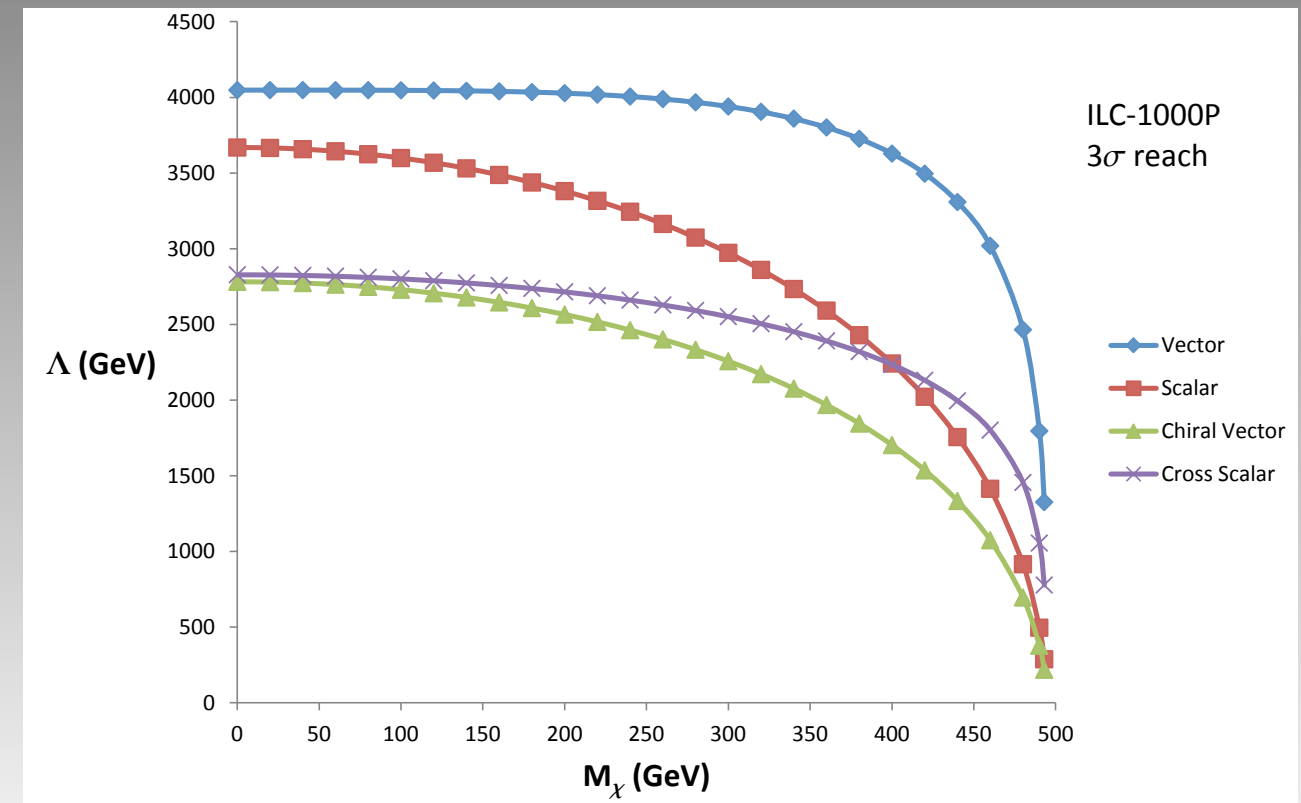
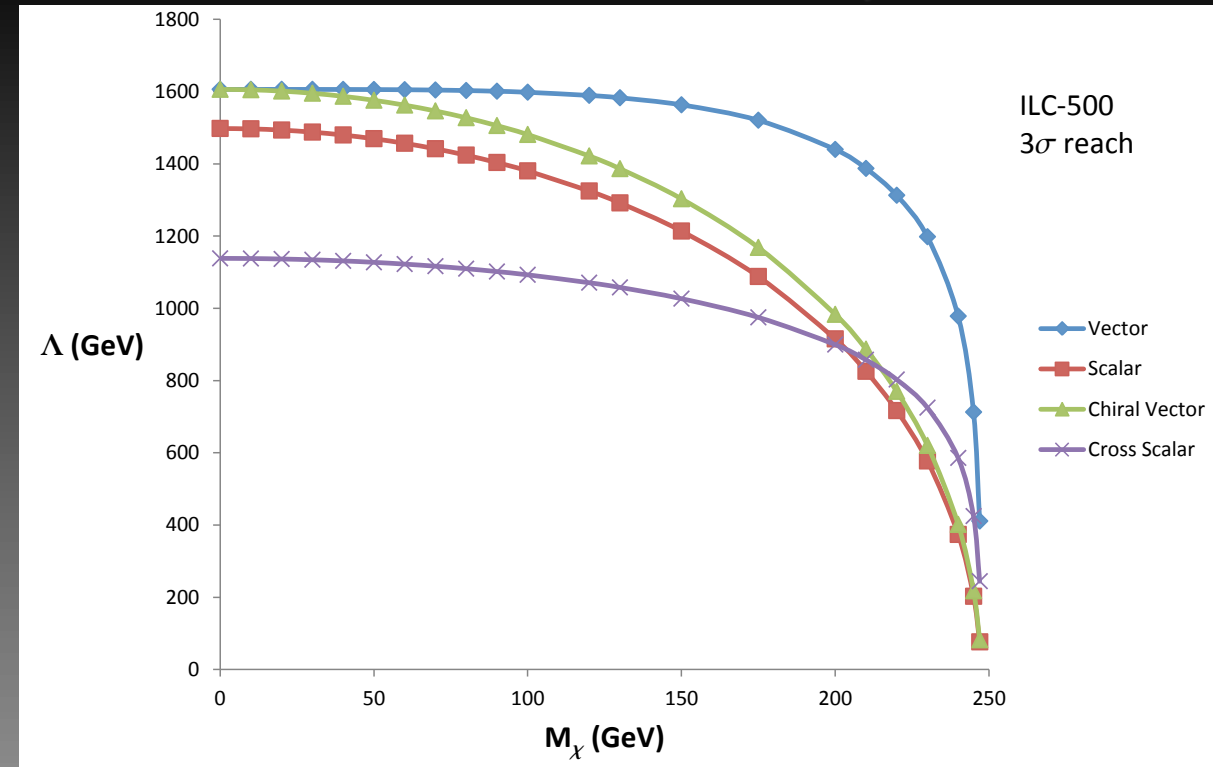


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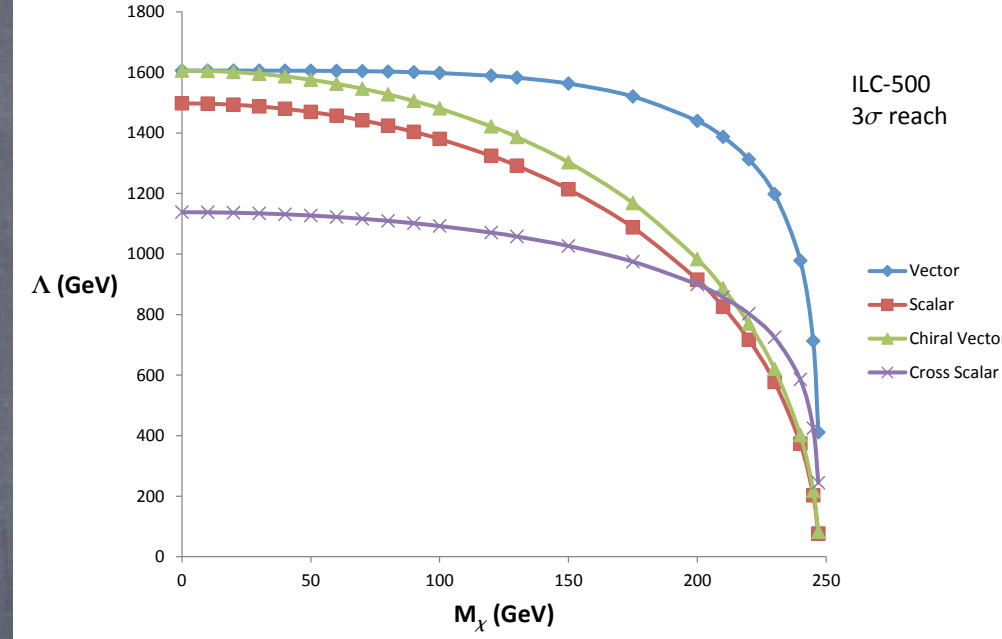
- $\mathcal{O}_V = (\bar{\chi}\gamma_\mu\chi)(\bar{\ell}\gamma^\mu\ell),$ (vector)
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- $\mathcal{O}_t = (\bar{\chi}\ell)(\bar{\ell}\chi),$ (scalar, t -channel).

ILC 500 GeV, 500 fb⁻¹

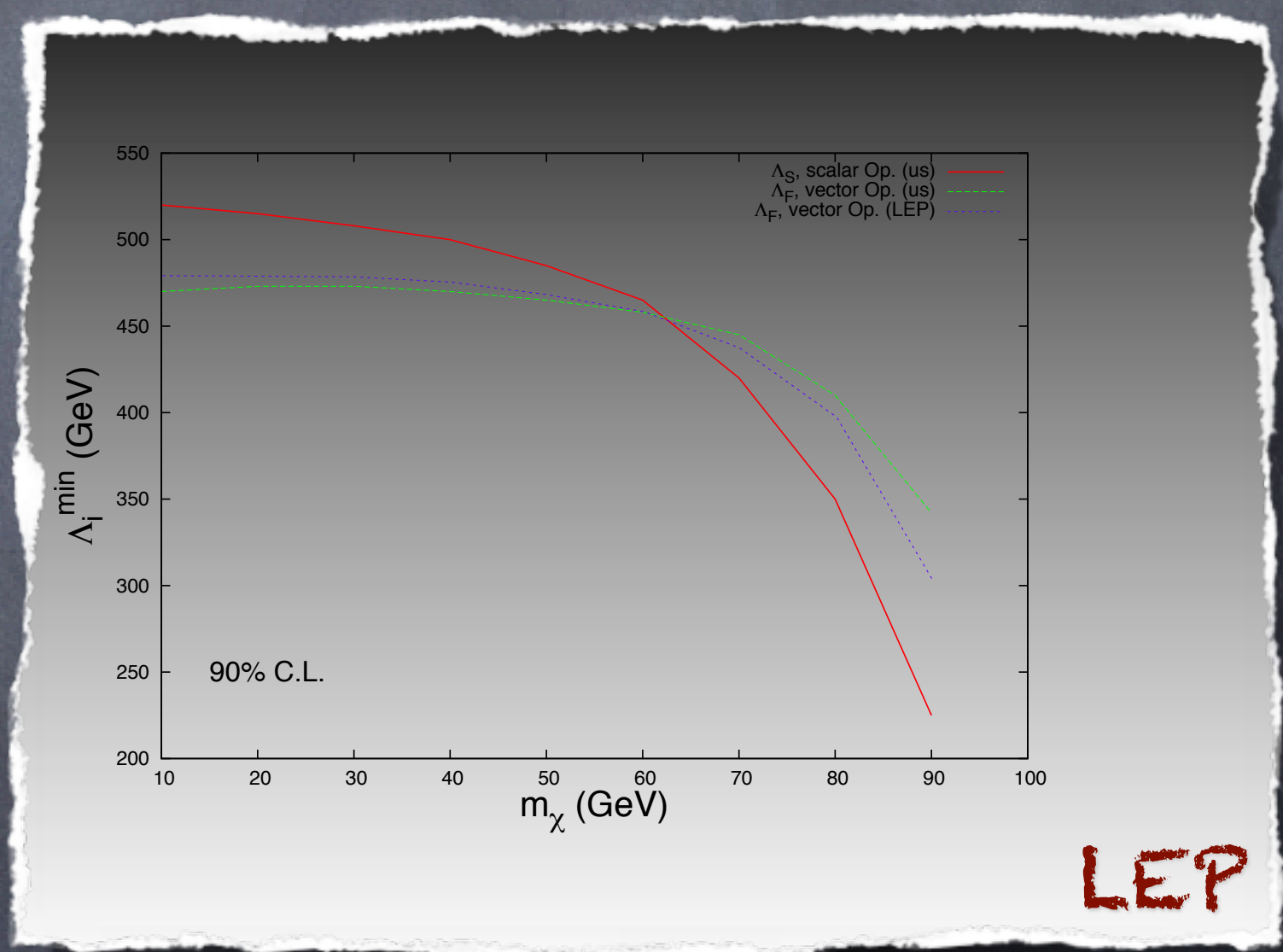
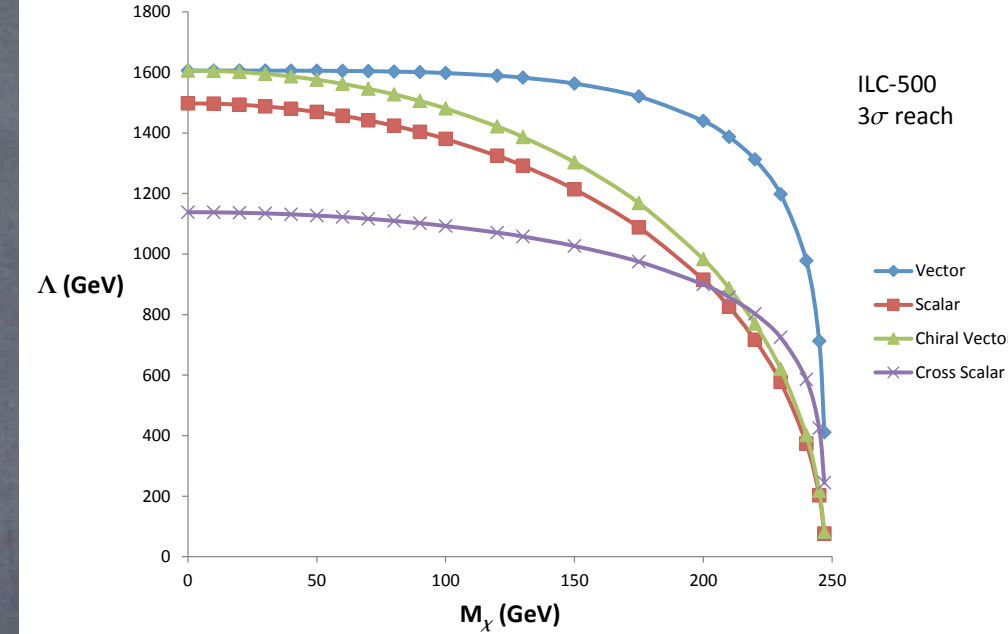


ILC 1000 GeV, 1000 fb⁻¹, polarization

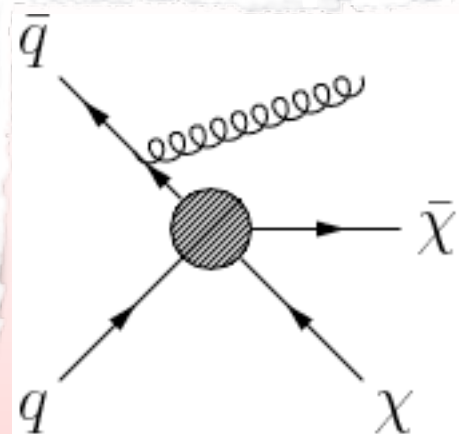
Comparison with other colliders



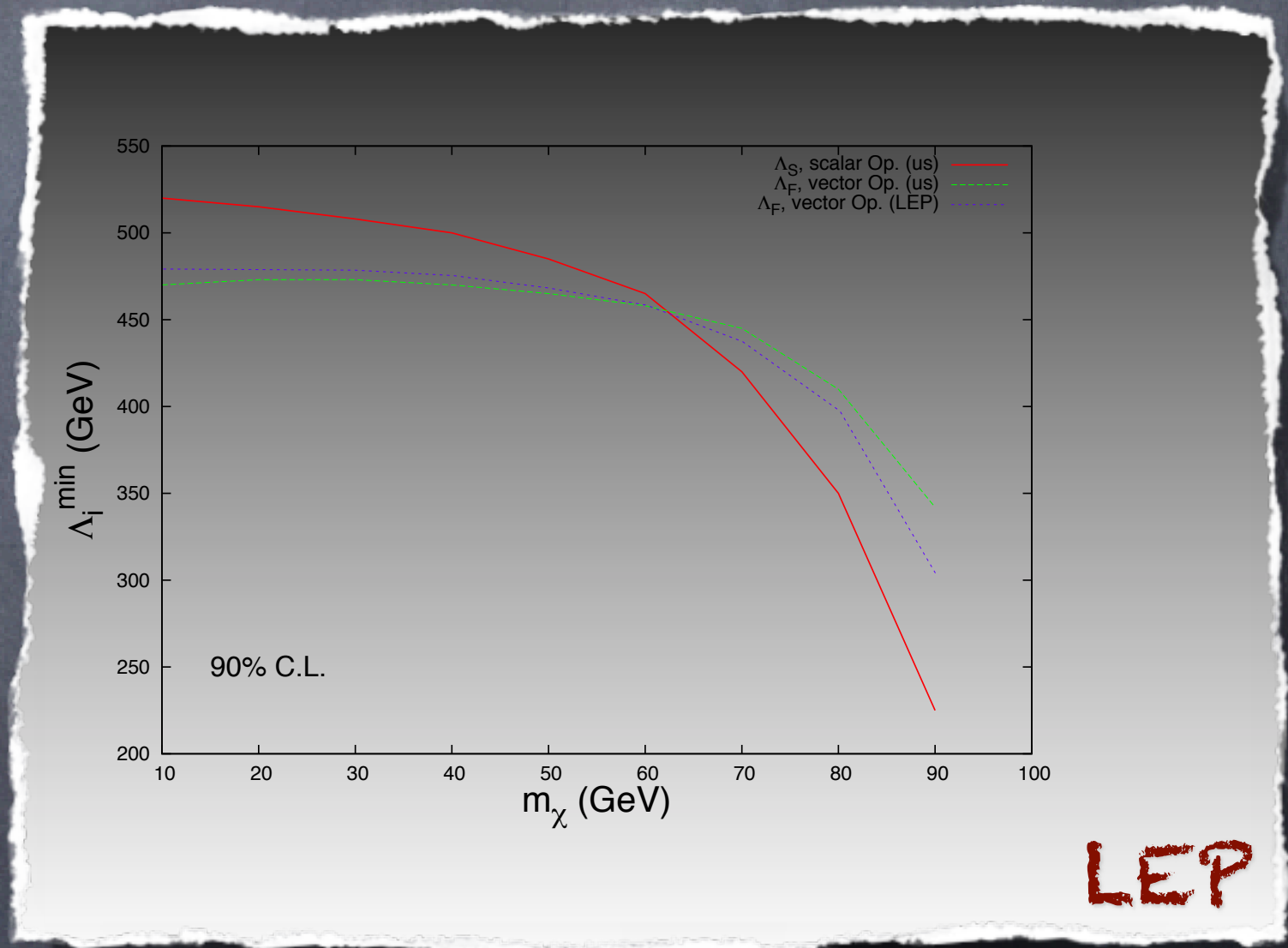
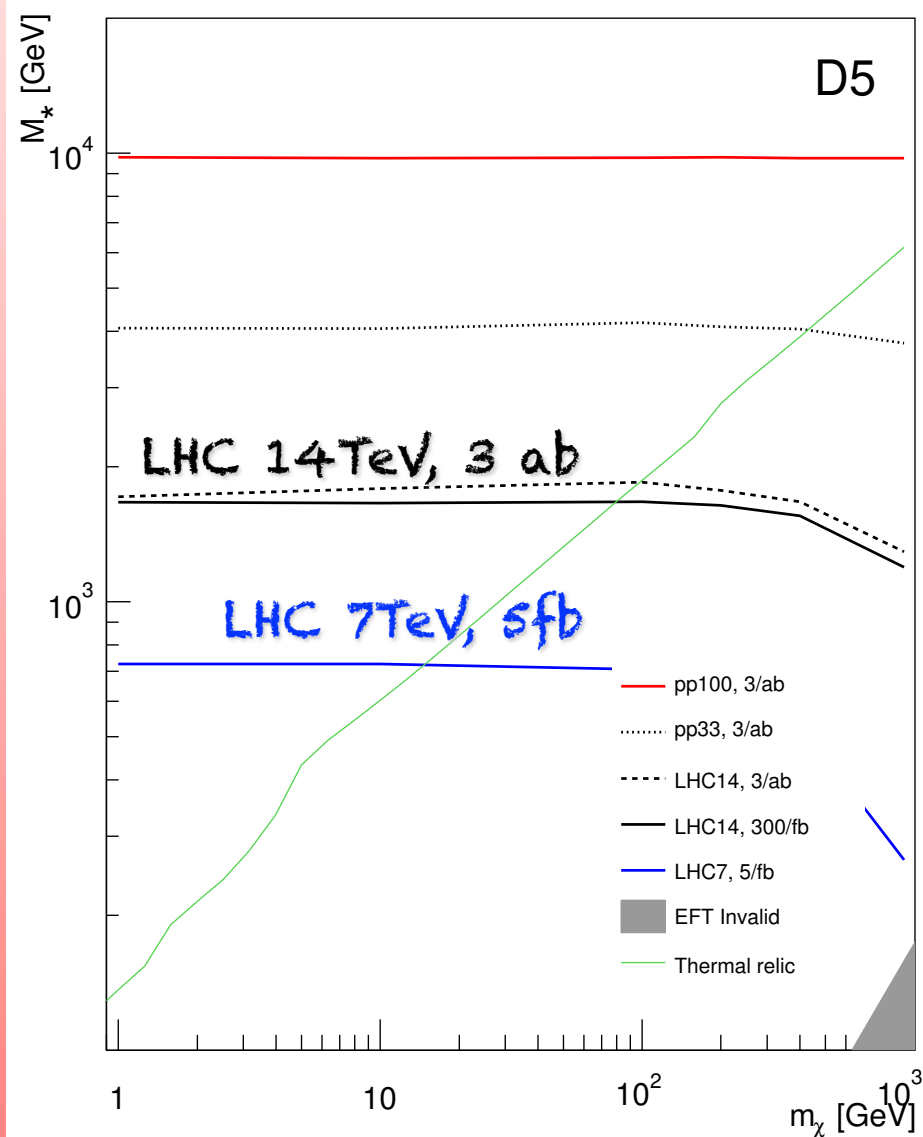
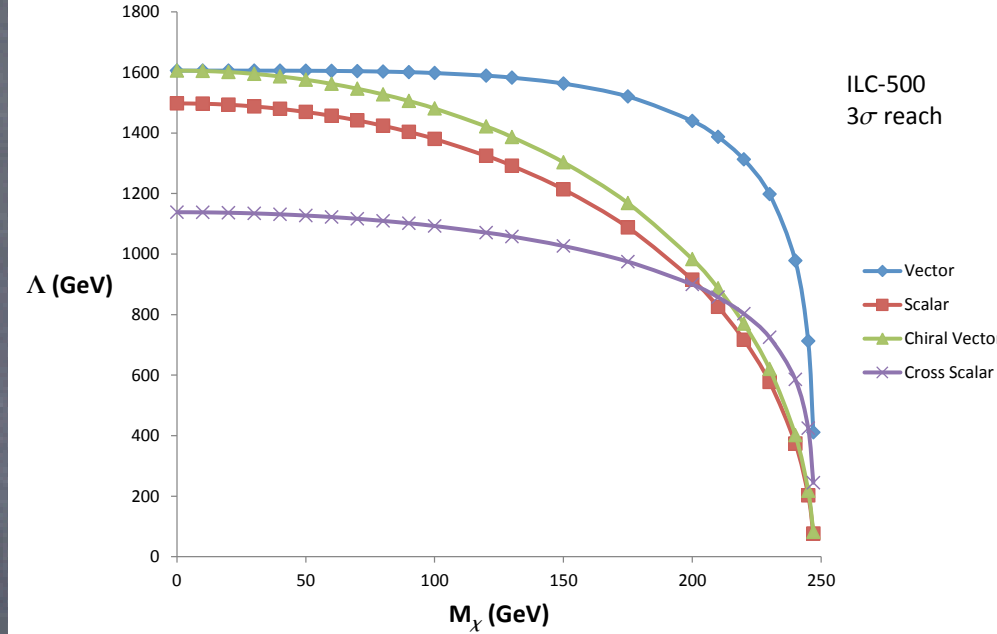
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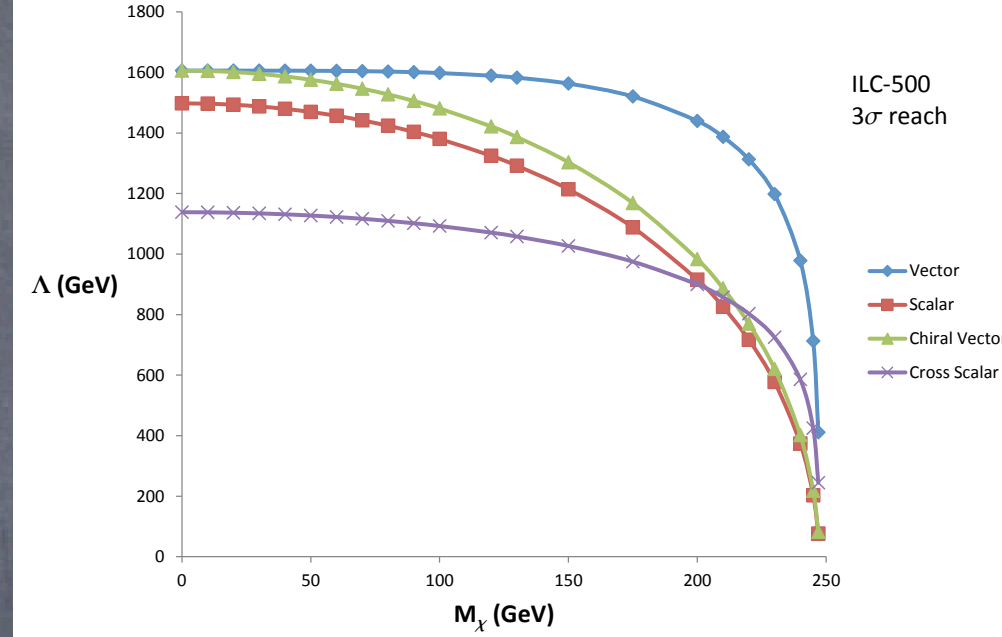


Monojet ATLAS/CMS
Vector coupling

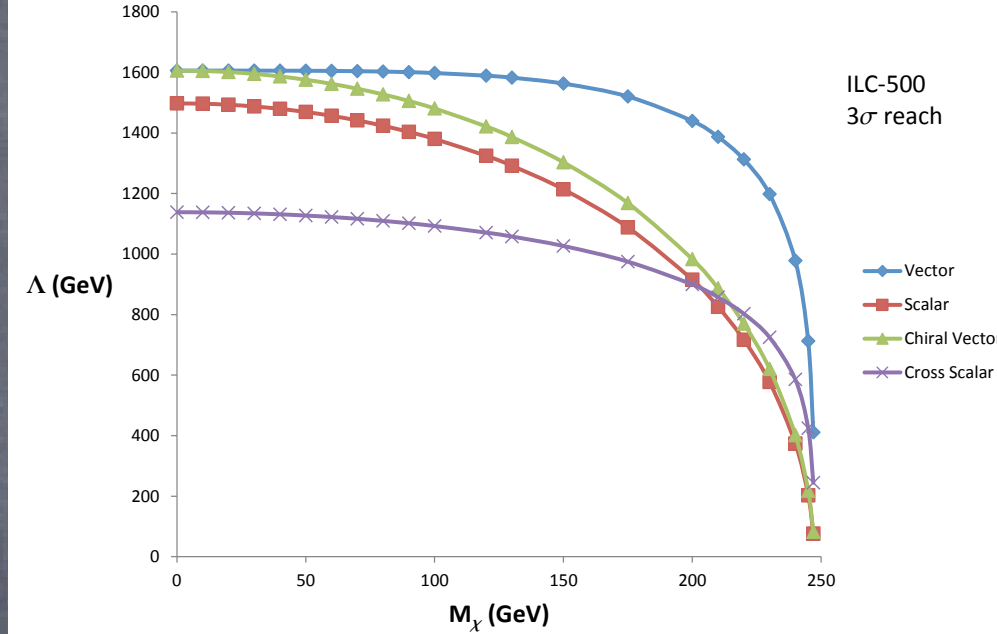


LEP

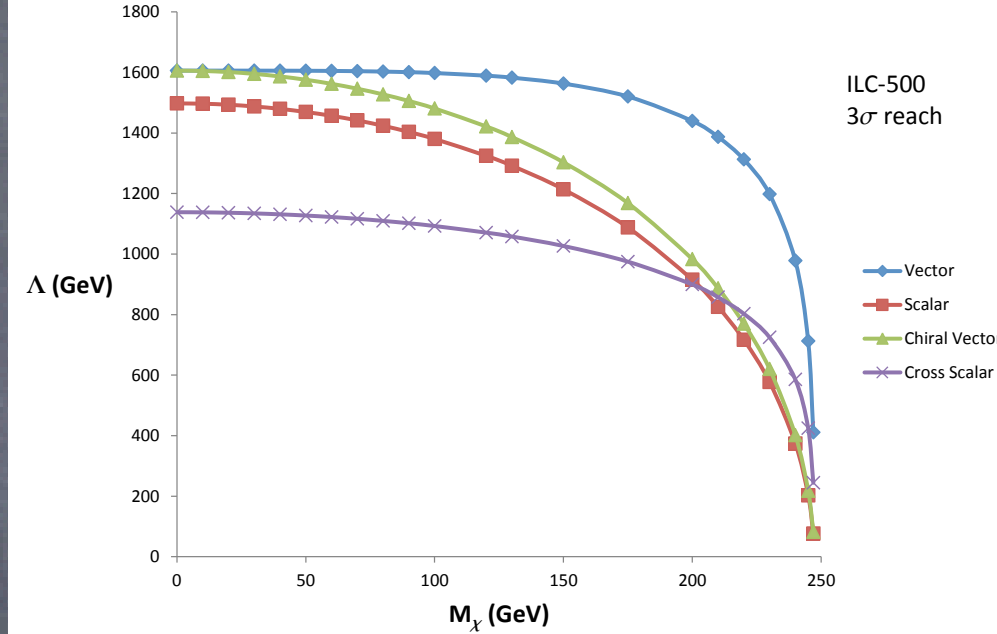
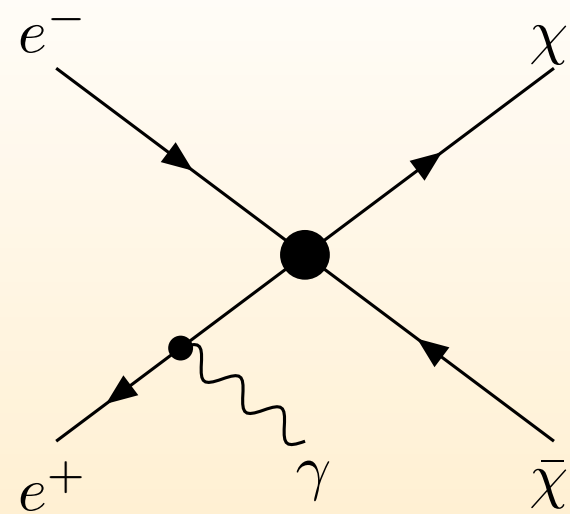
Comparison with synchrotron



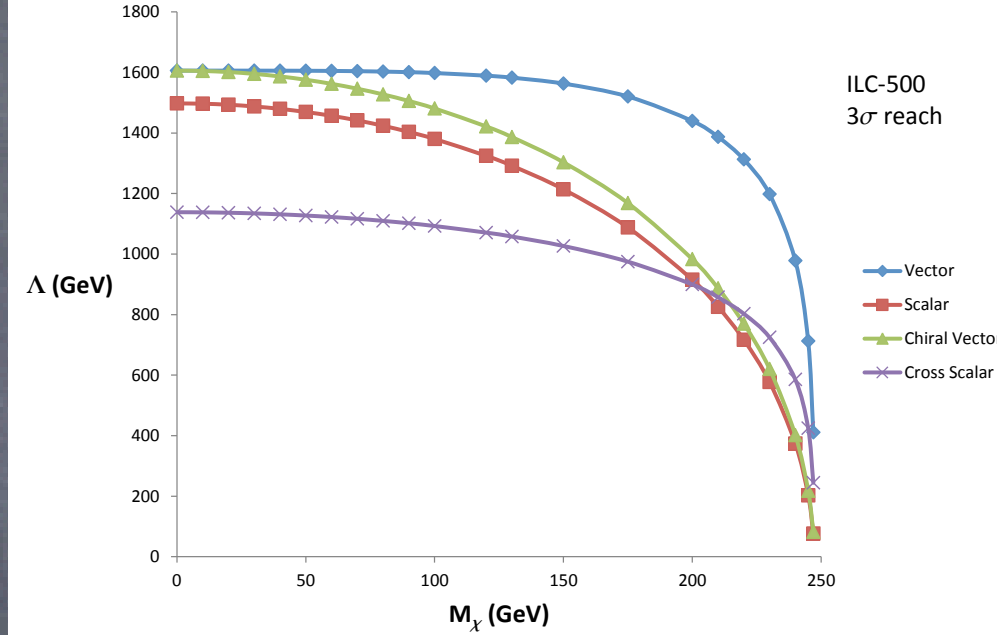
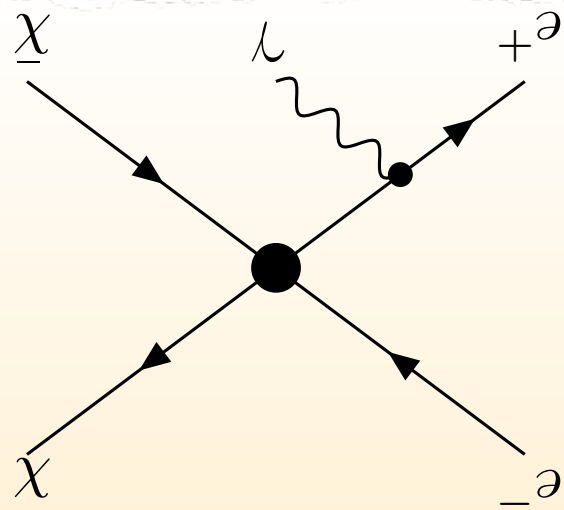
Comparison with synchrotron



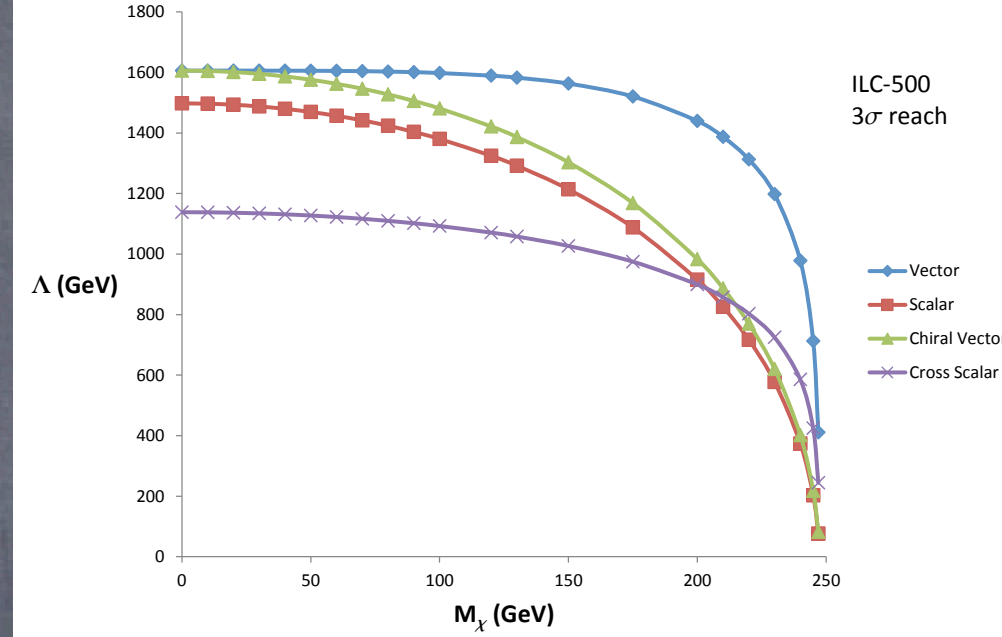
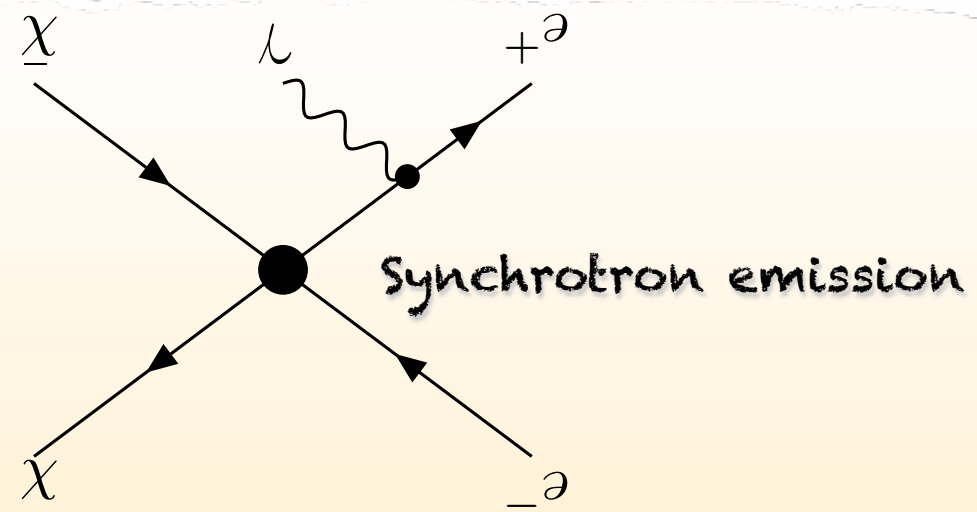
Comparison with synchrotron



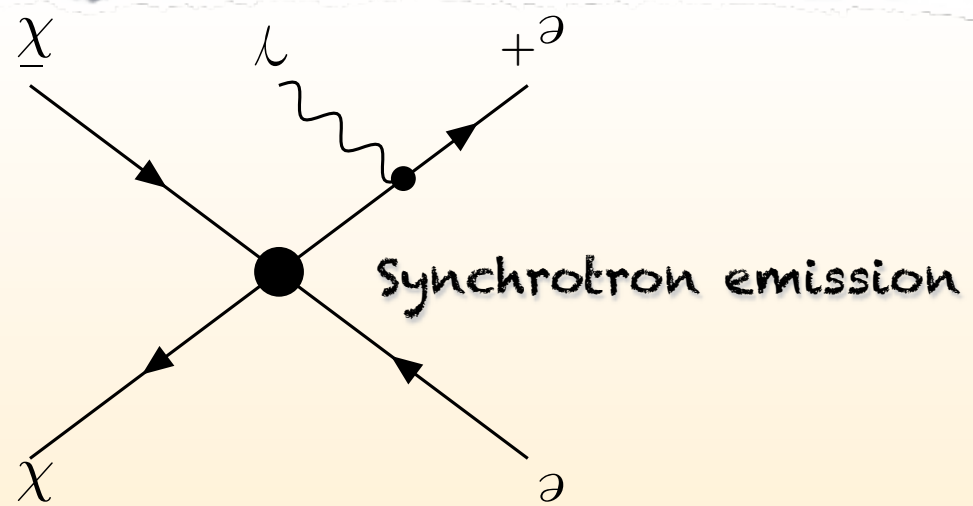
Comparison with synchrotron



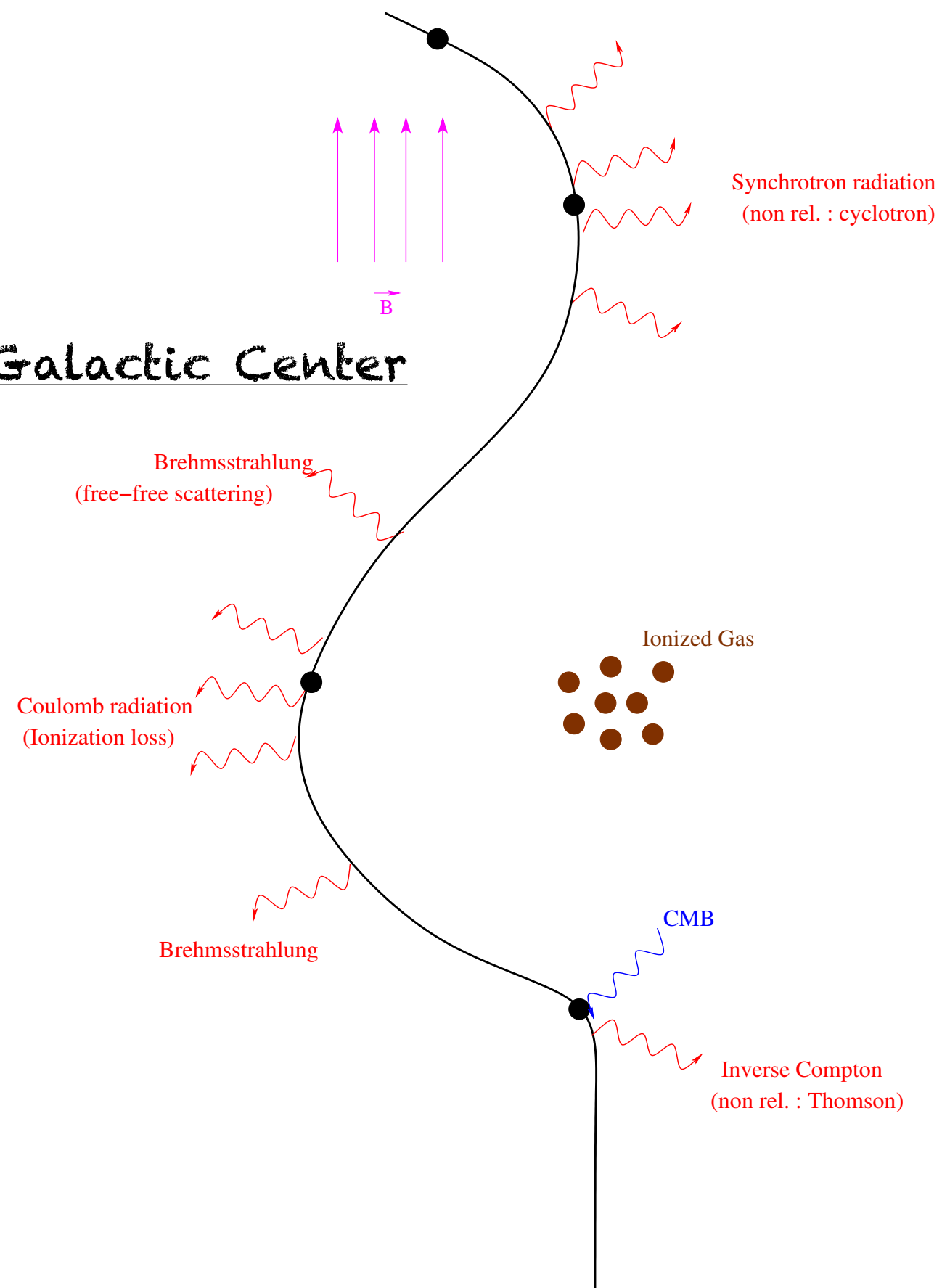
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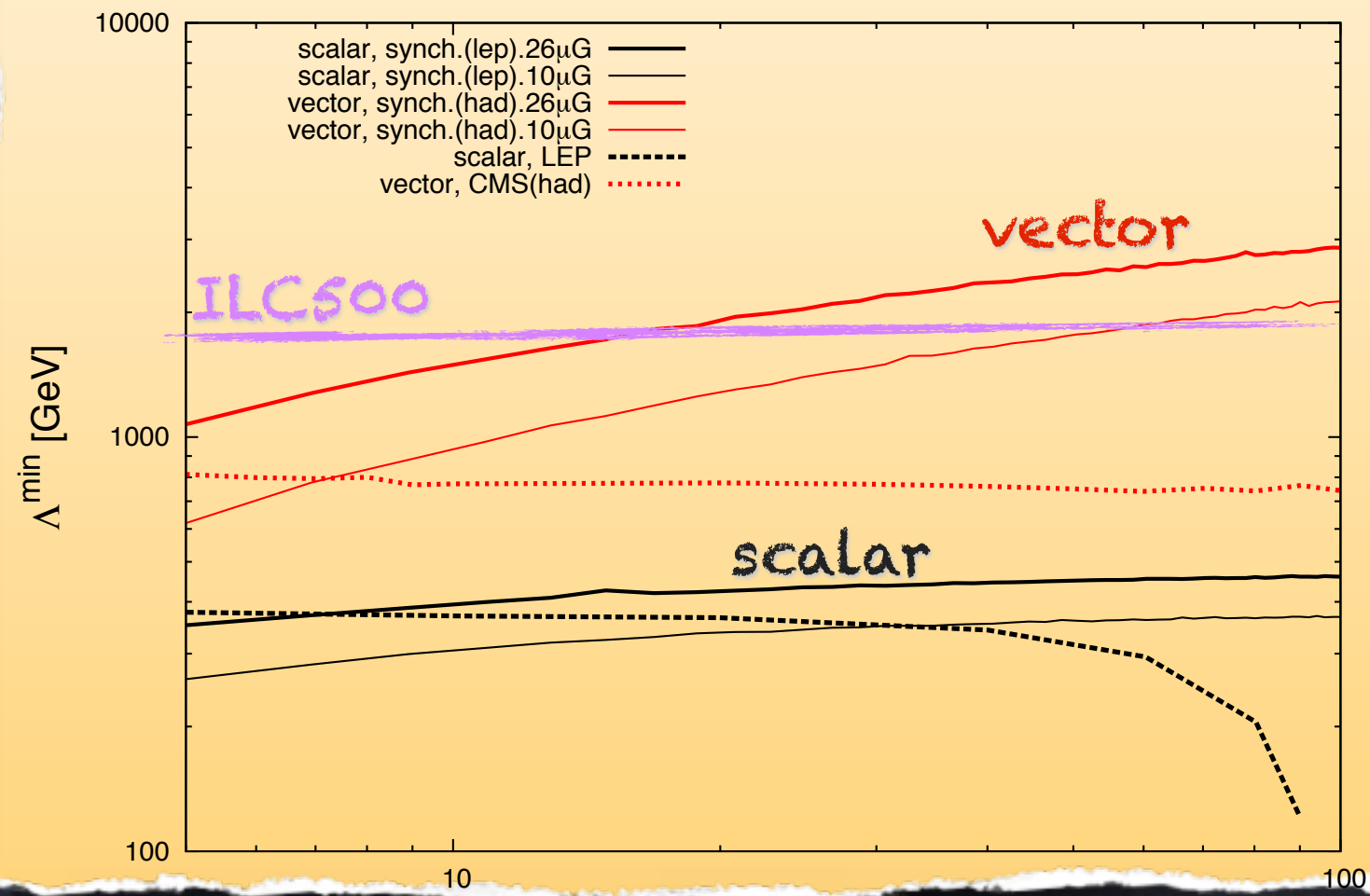
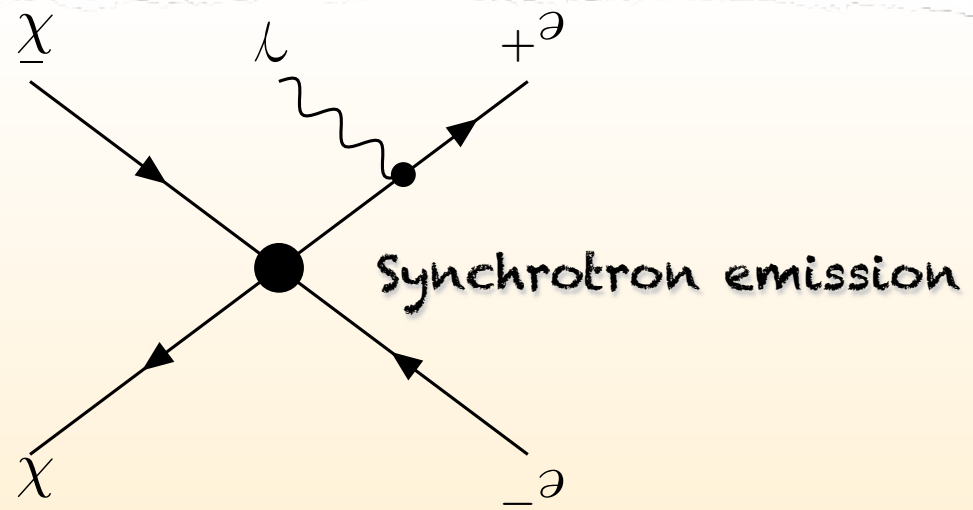
Comparison with synchro



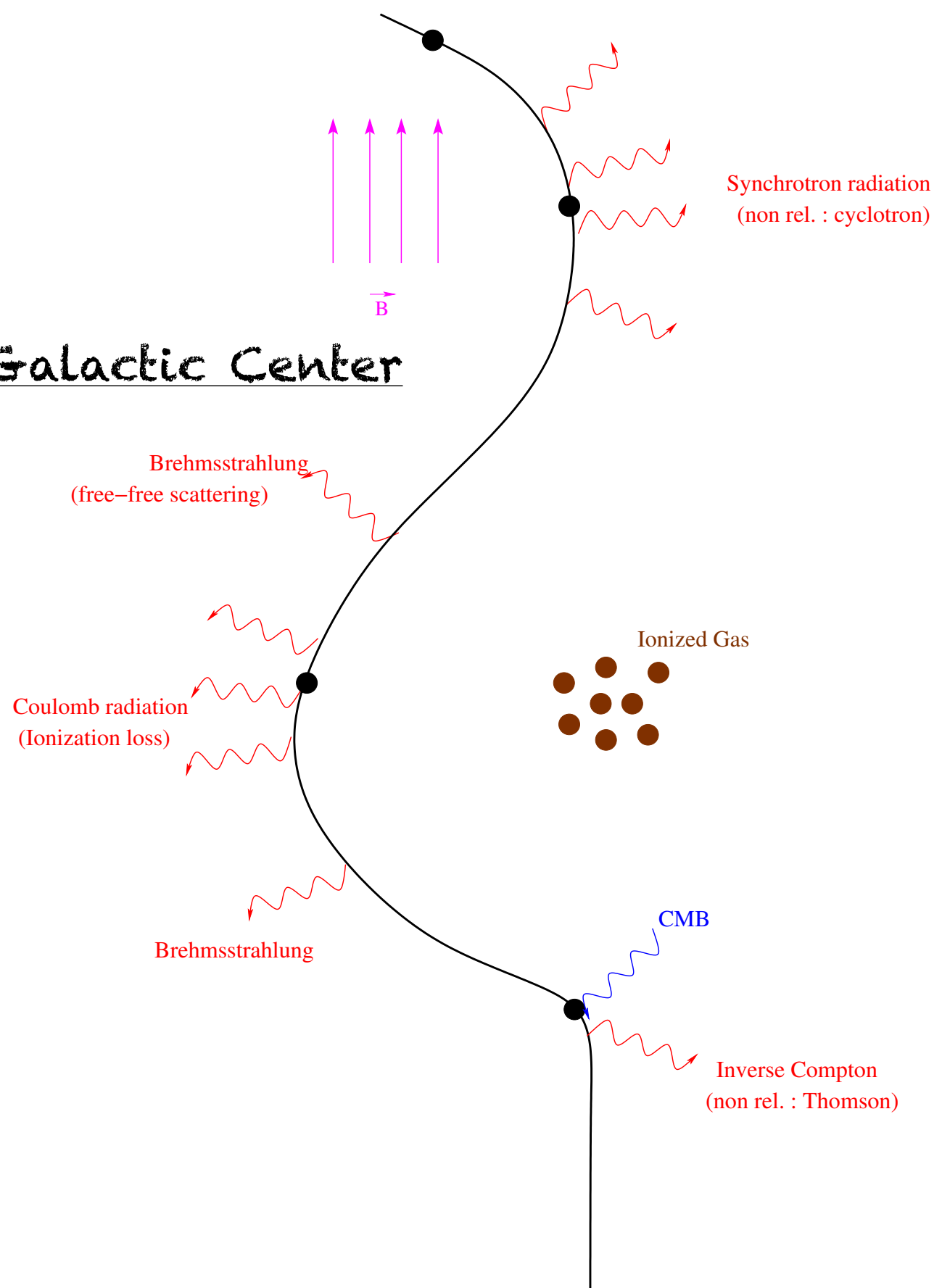
Galactic Center



Comparison with synchro

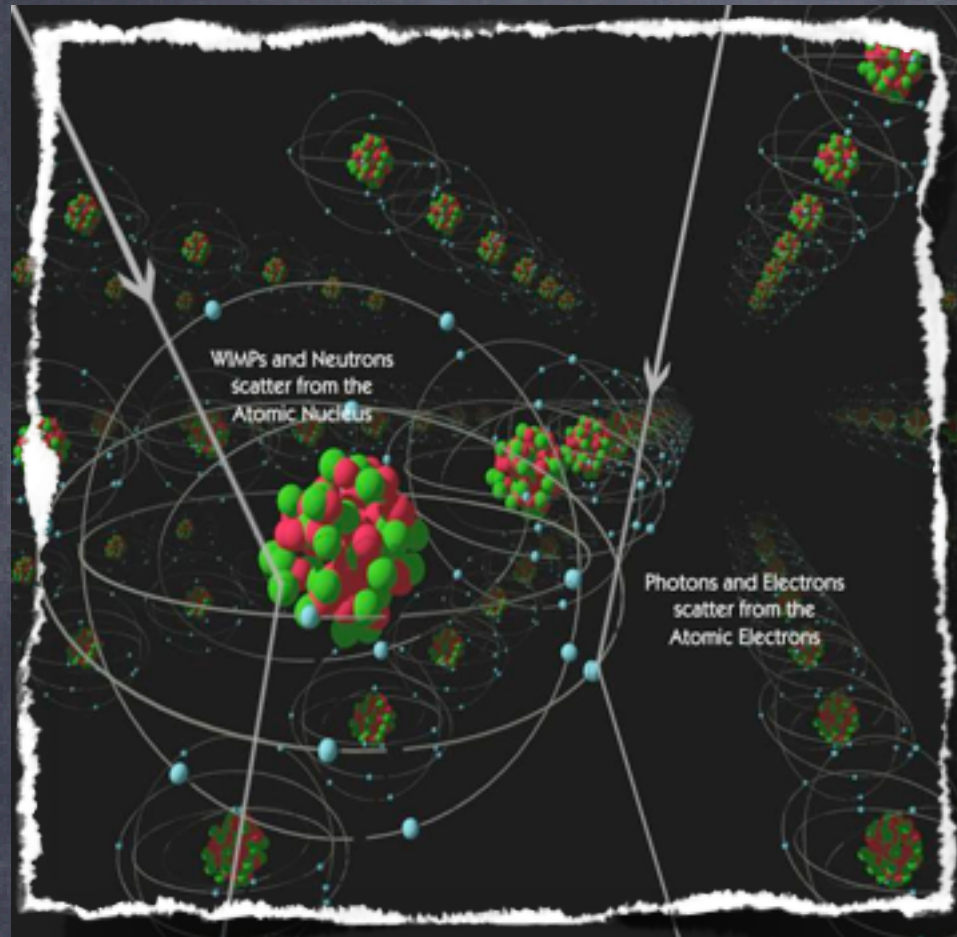


Galactic Center

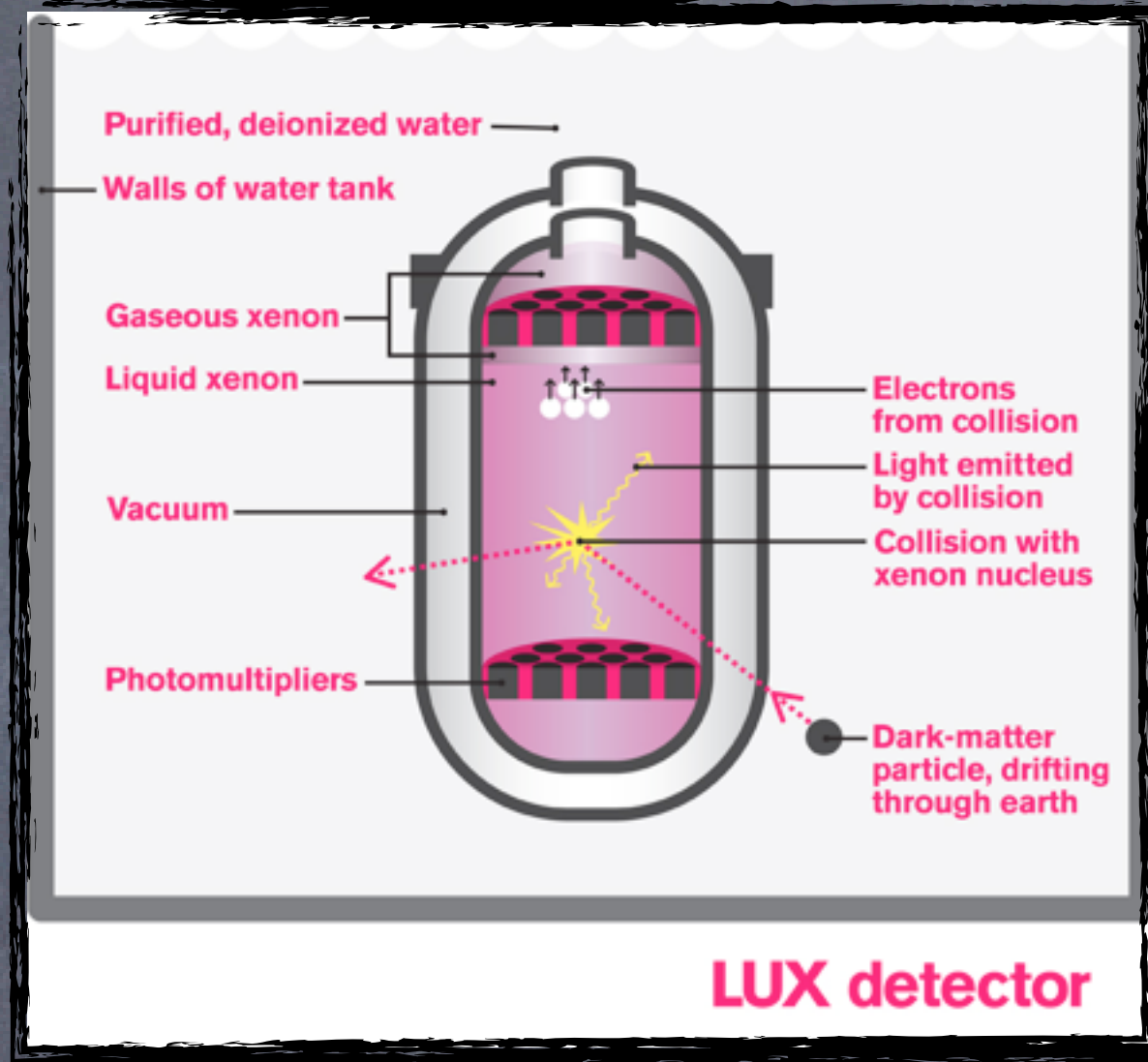
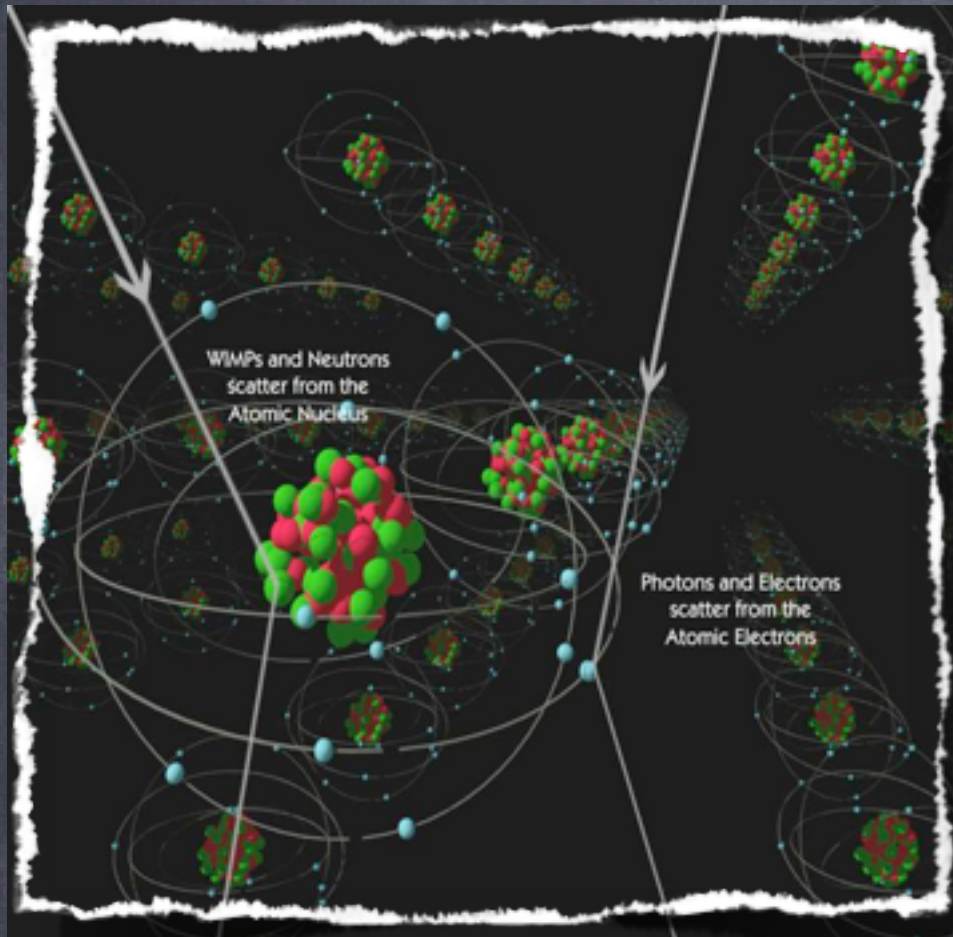


Direct detection of Dark Matter : LUX (10/2013)

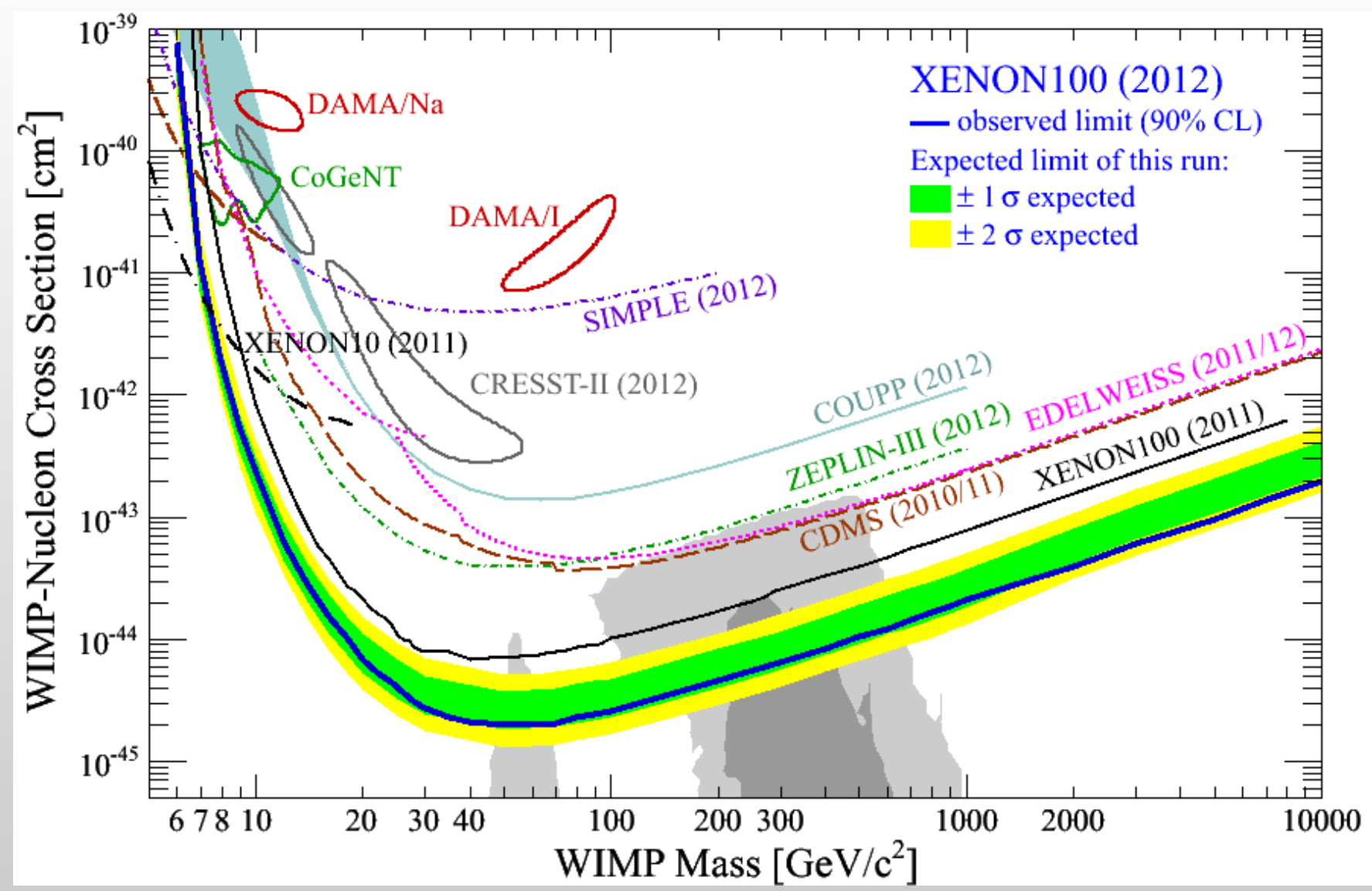
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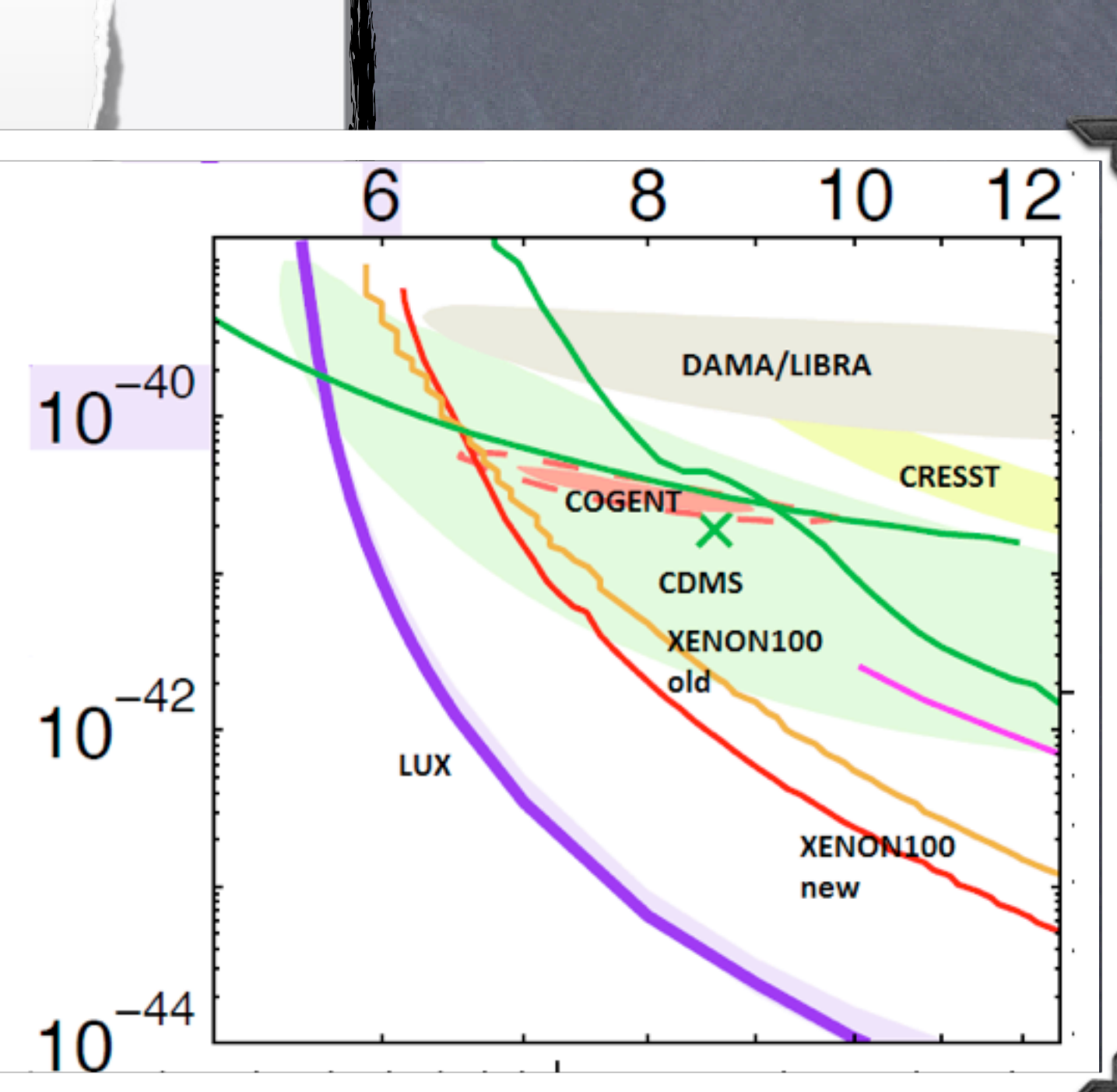
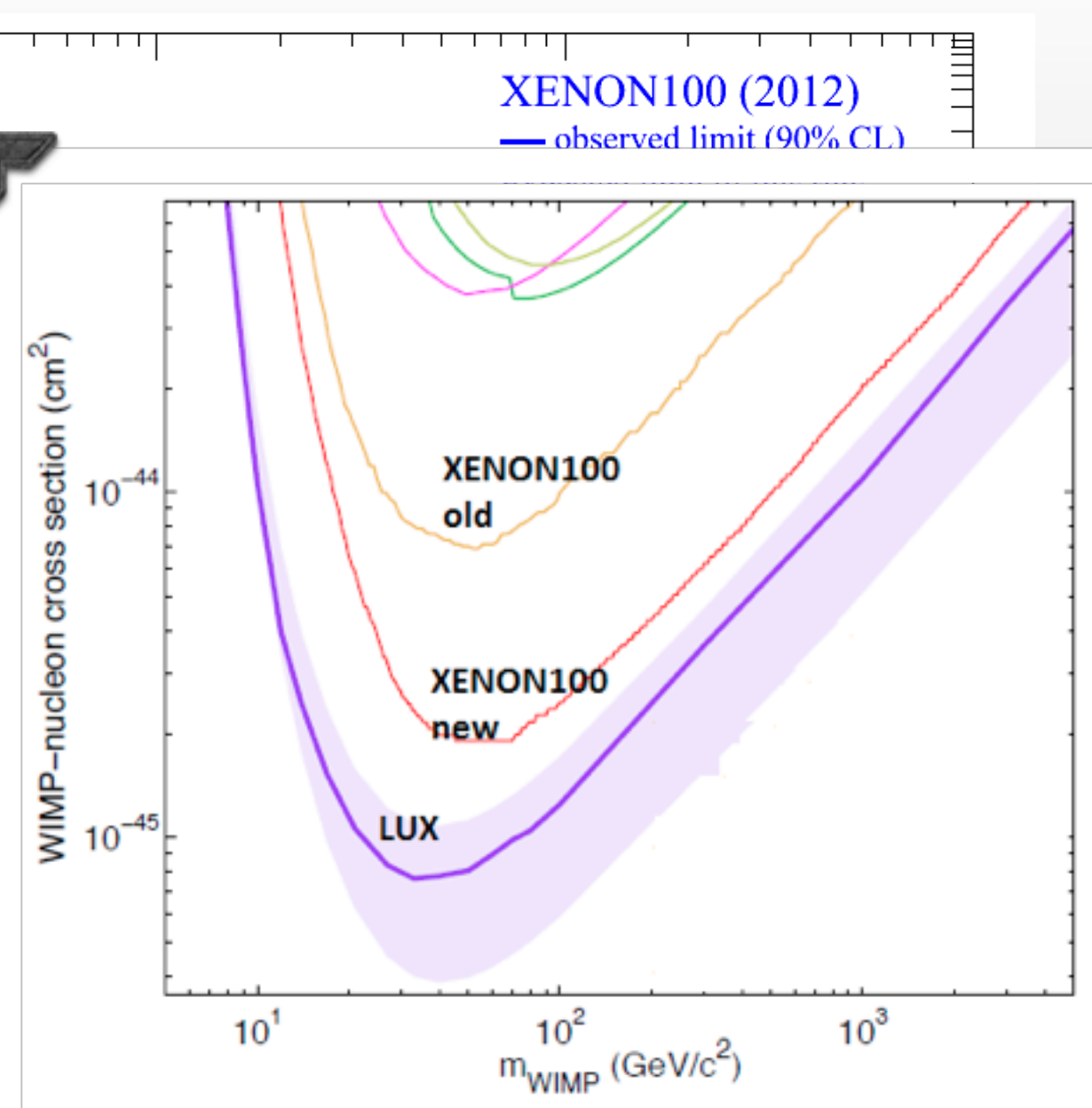
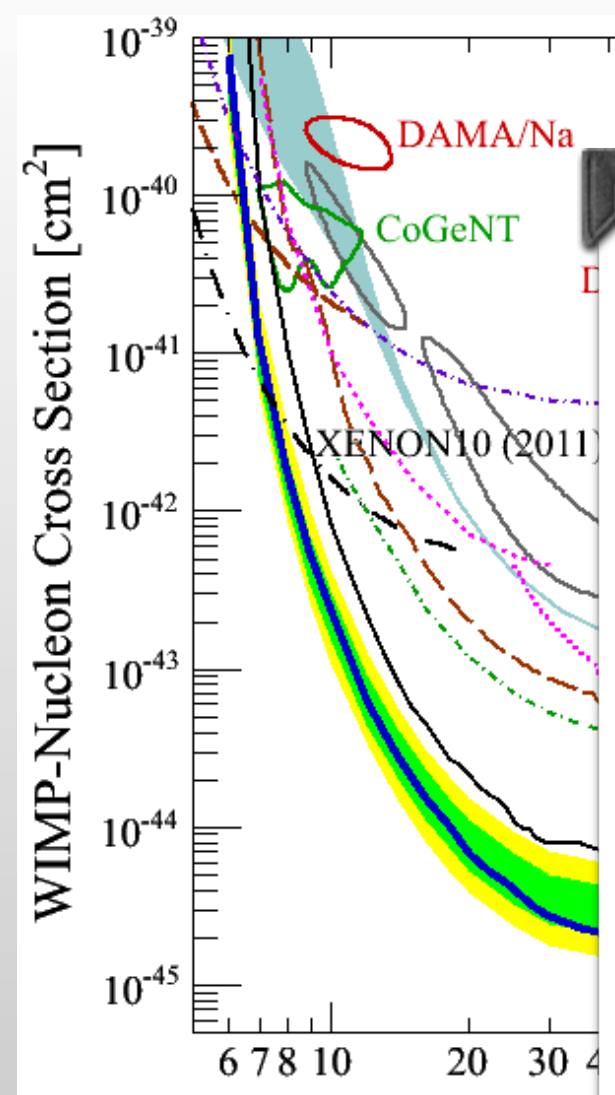
Direct detection of Dark Matter : LUX (10/2013)



- Electrons from collision
 - Light emitted by collision
 - Collision with xenon nucleus
 - Dark-matter particle, drifting through earth
- detector**

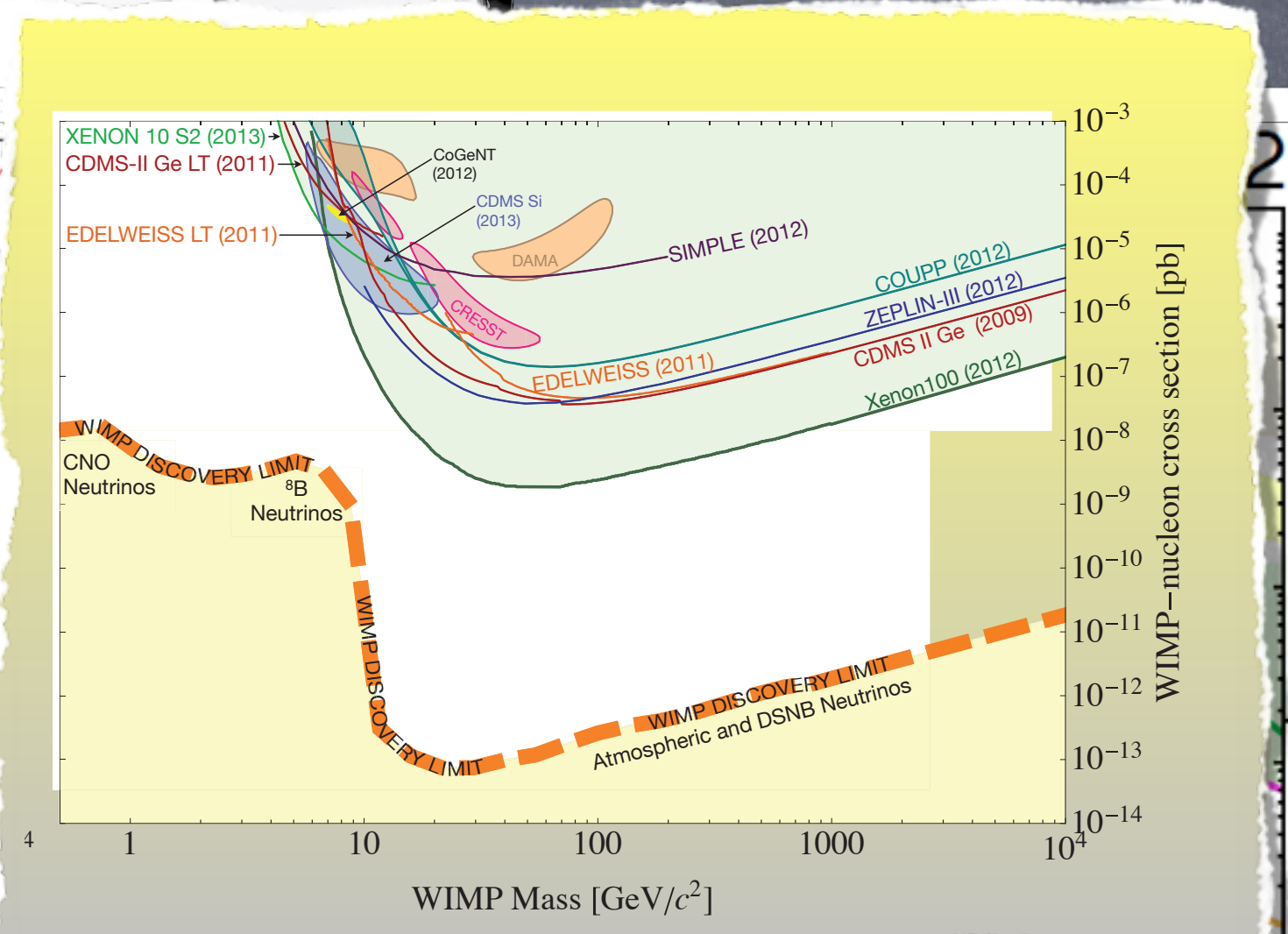
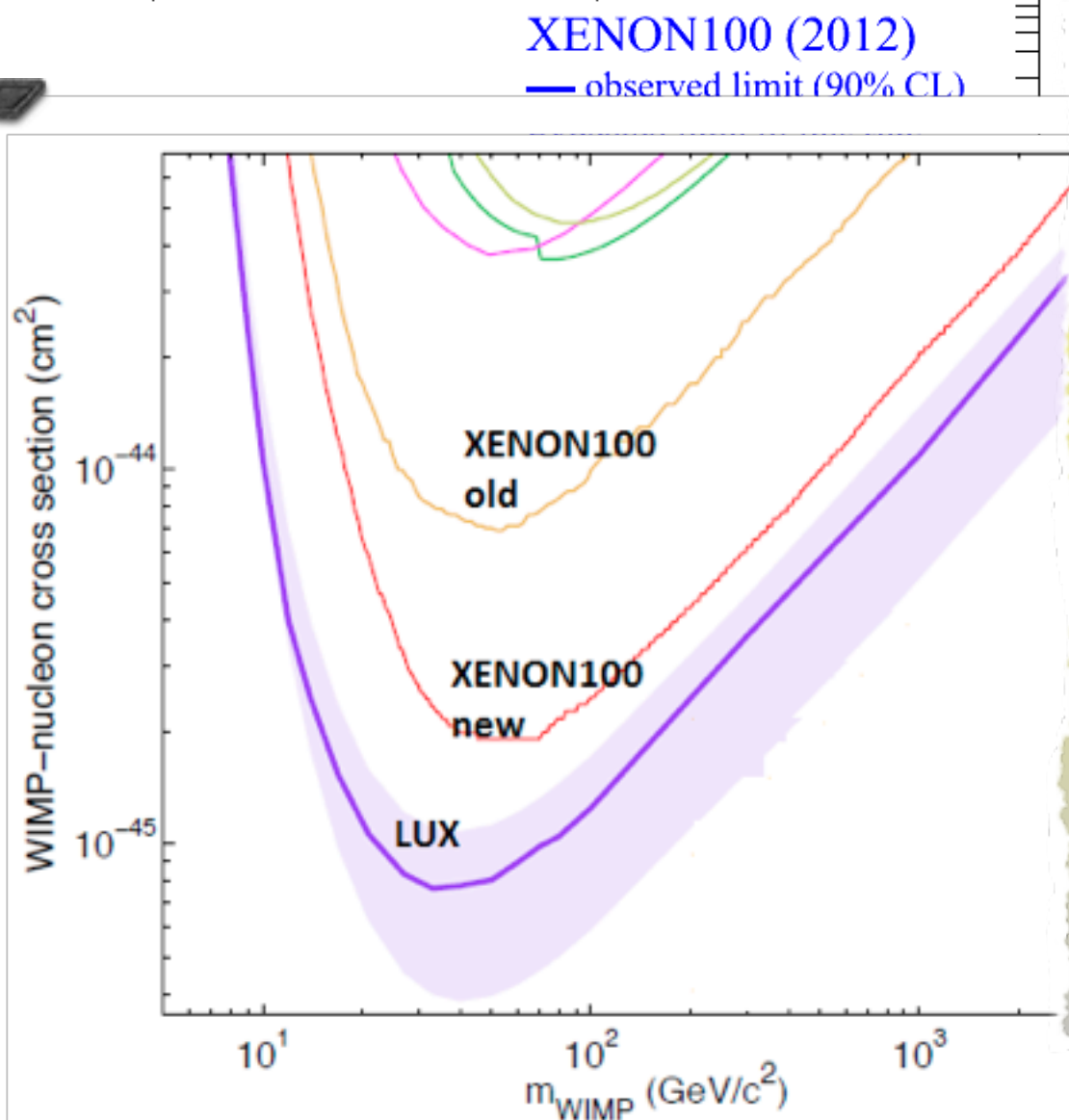
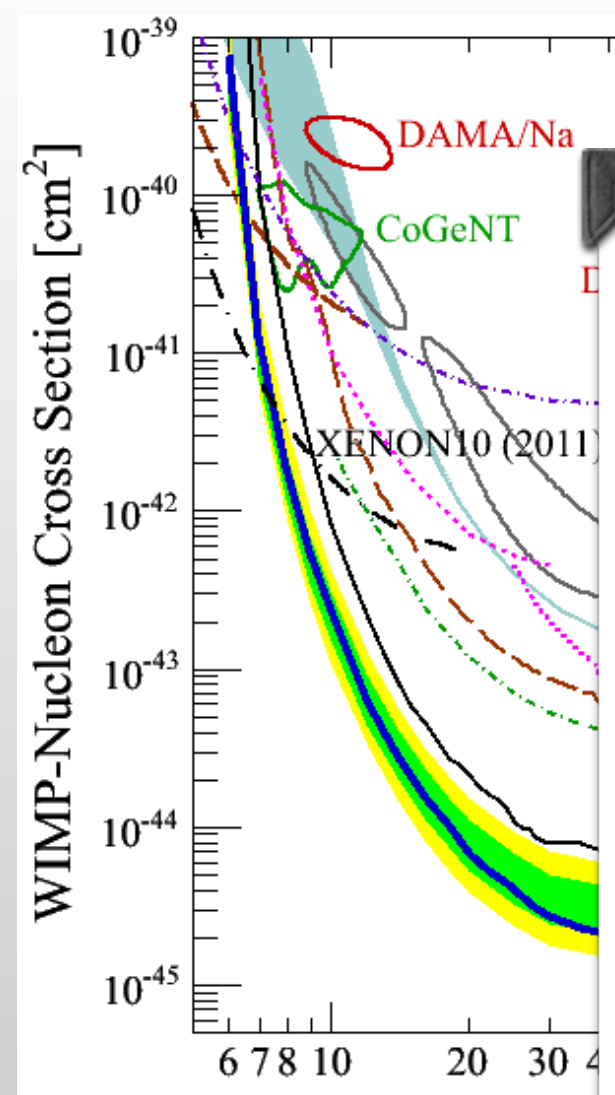
XENON100 (07/12)

Direct detection of Dark Matter : LUX (10/2013)



XE

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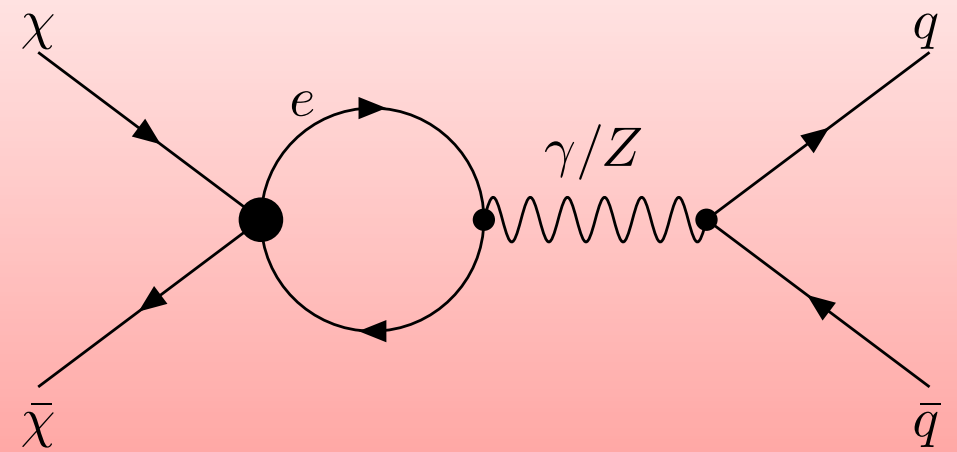


XE

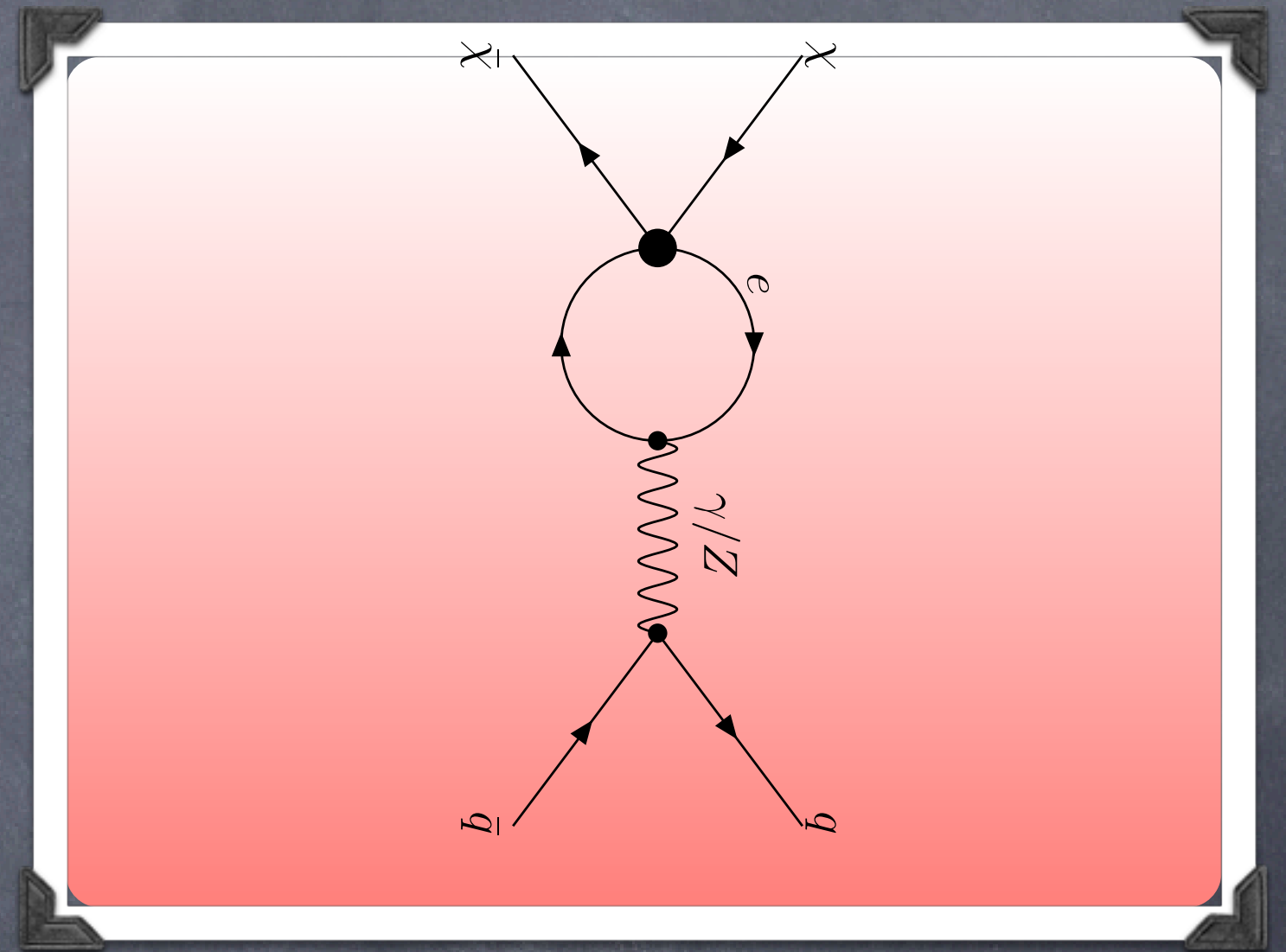
10⁻⁴⁴

Direct detection constraints

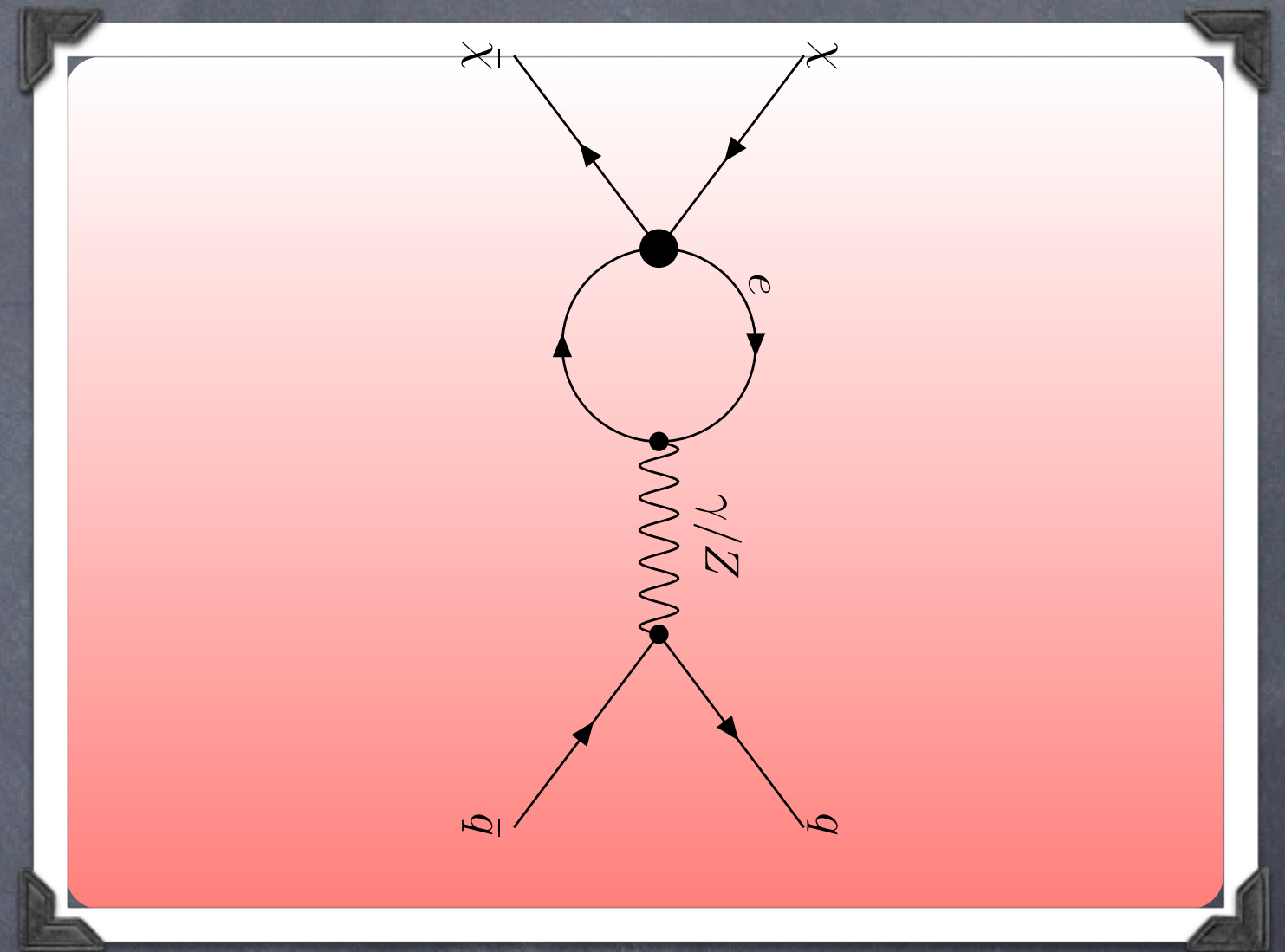
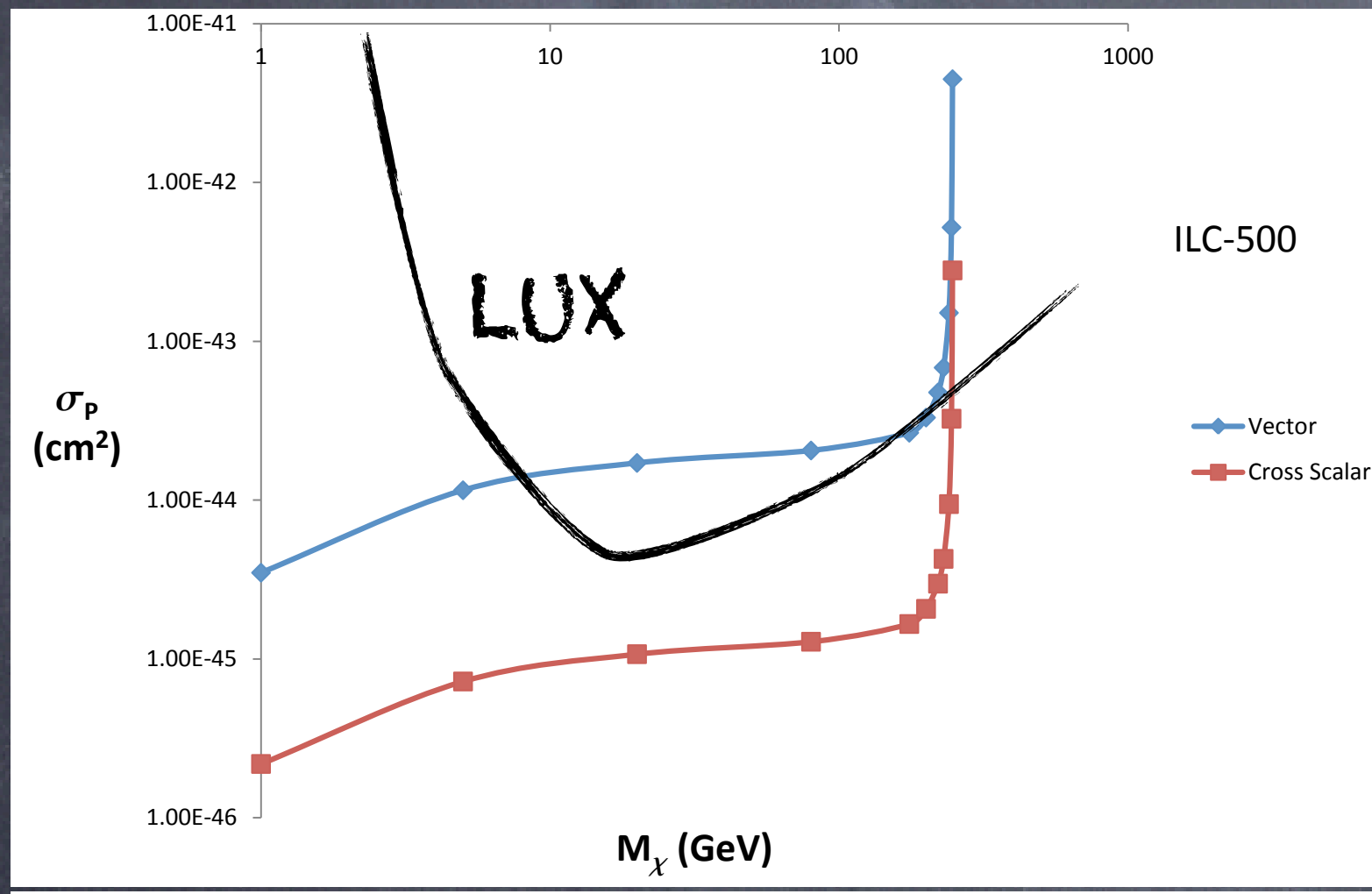
Direct detection constraints



Direct detection constraints



Direct detection constraints



Indirect detection constraints



Indirect detection constraints

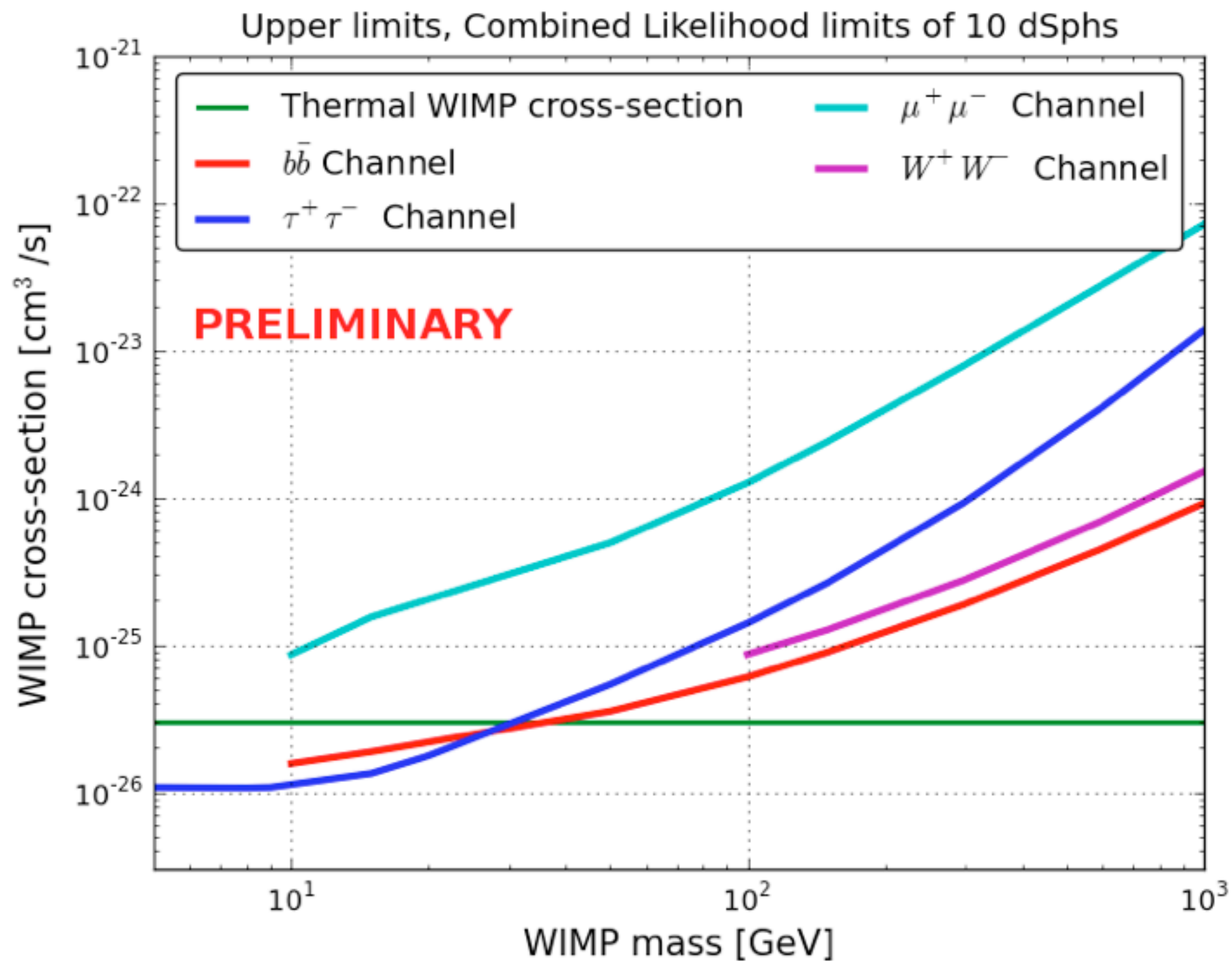


Indirect detection constraints

→ Limit on σv
(FERMI dwarf)

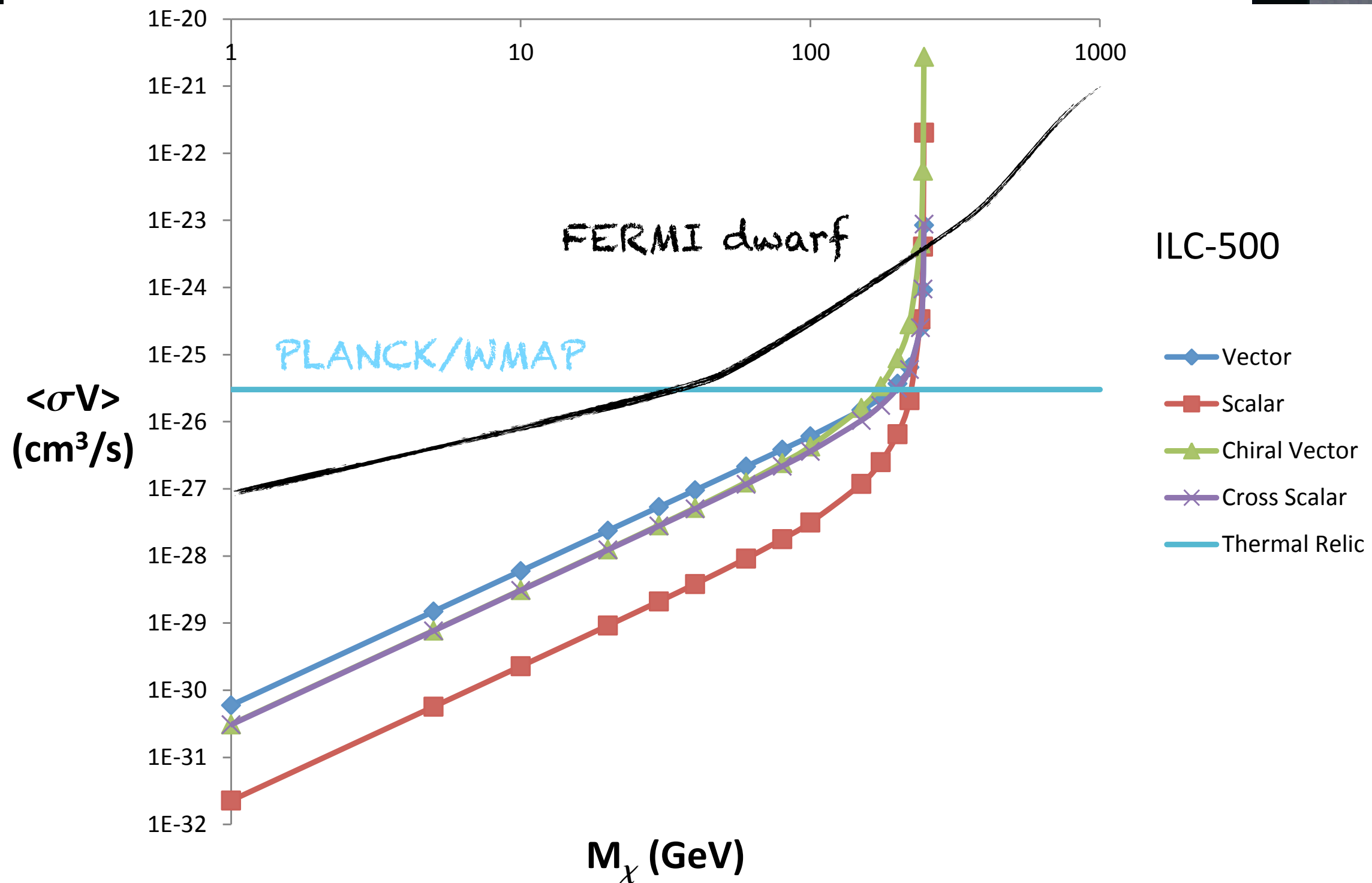


Indirect detection constraints



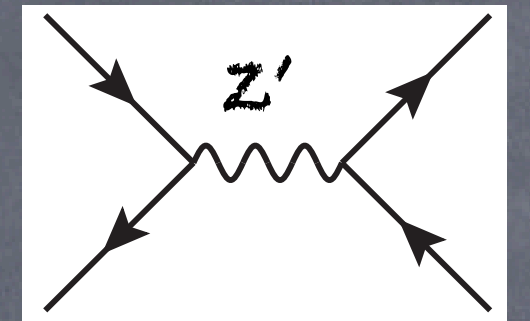
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Indirect detection constraints

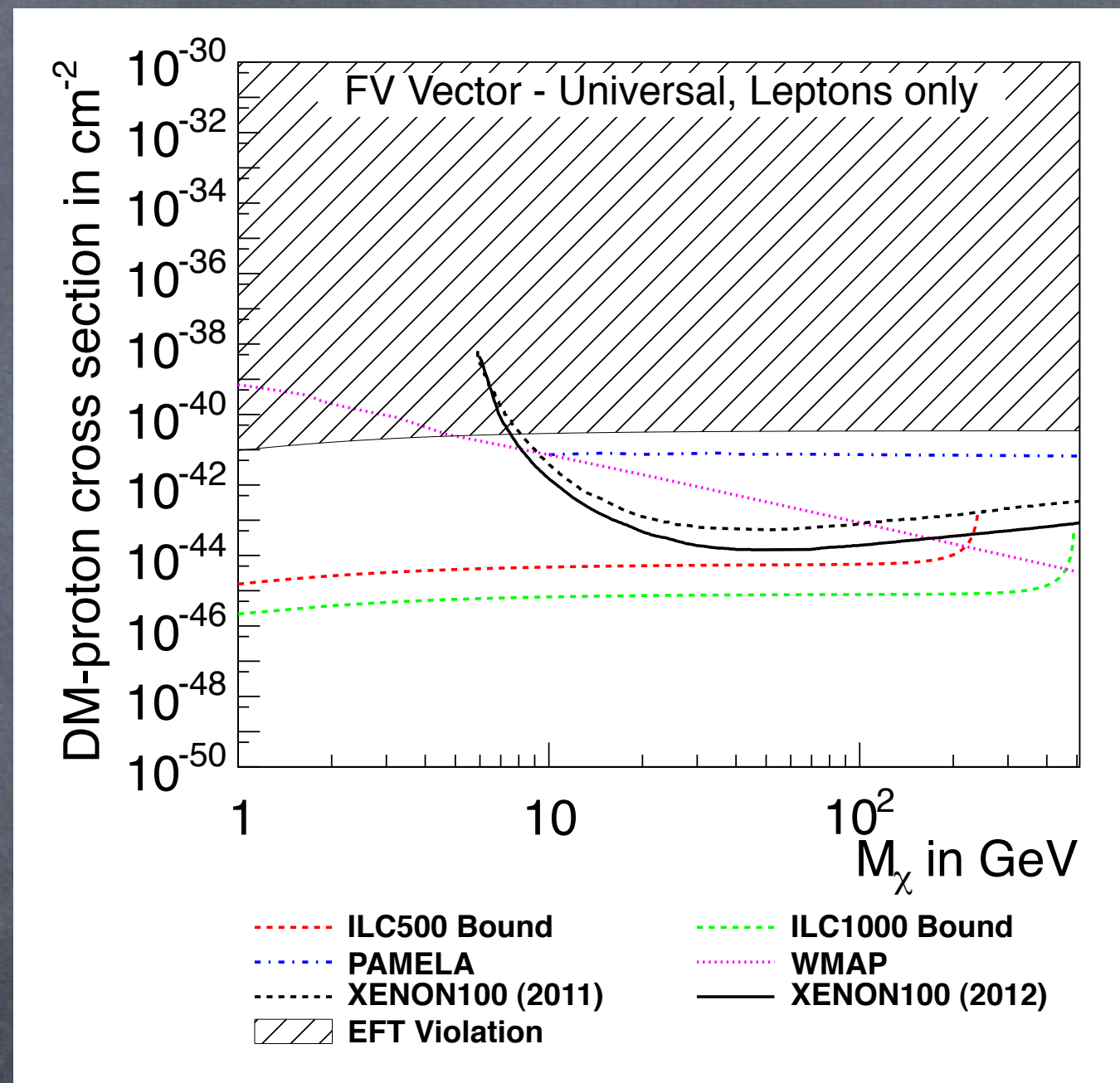
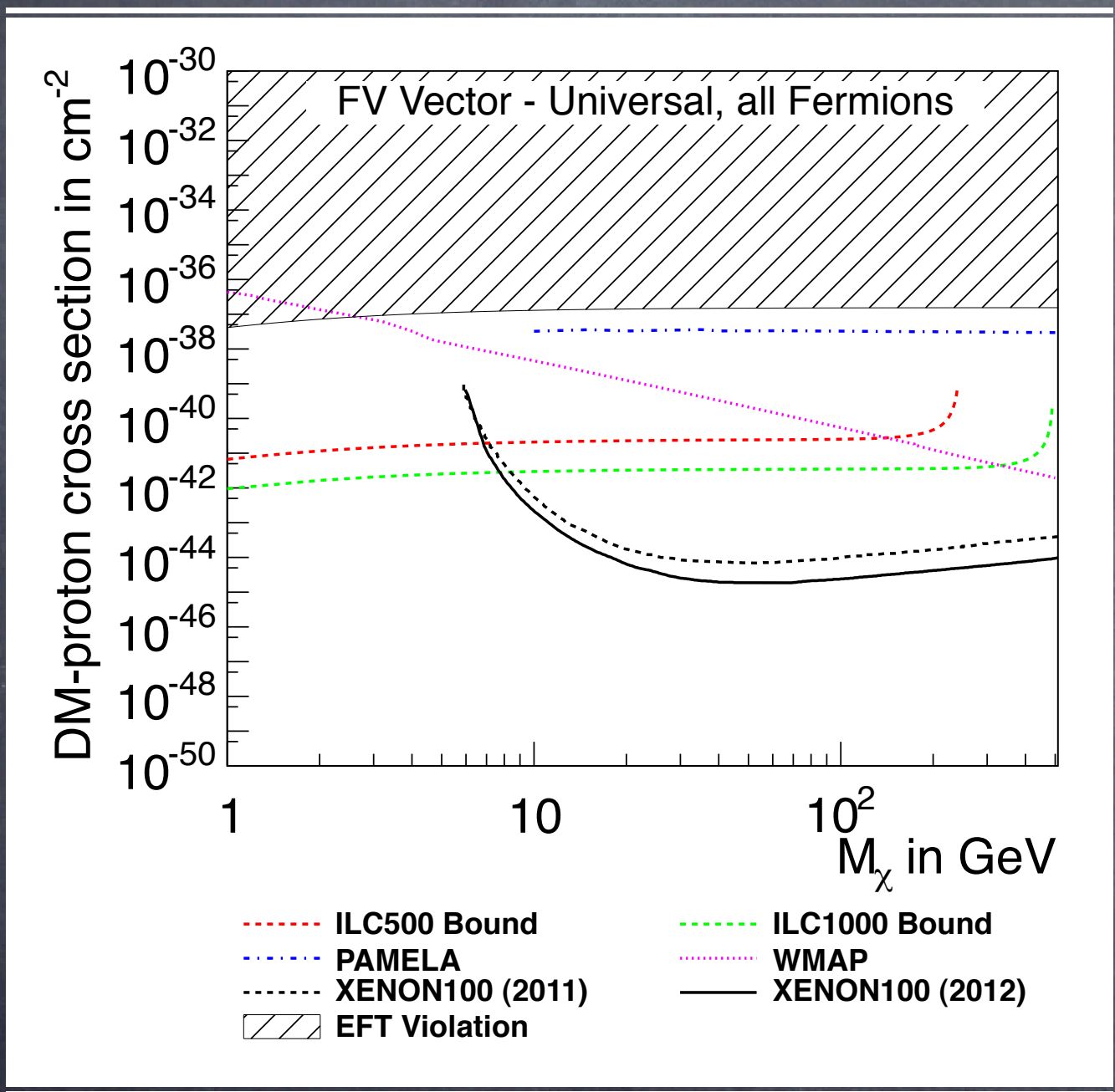
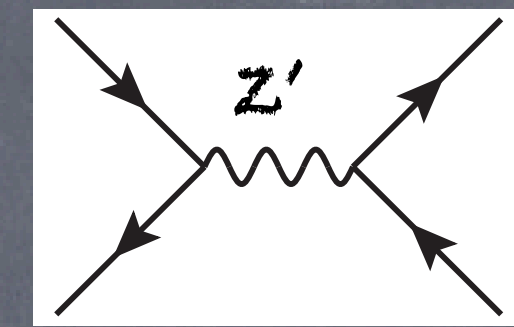


Limit on σV
(FERMI dwarf)

A microscopic model

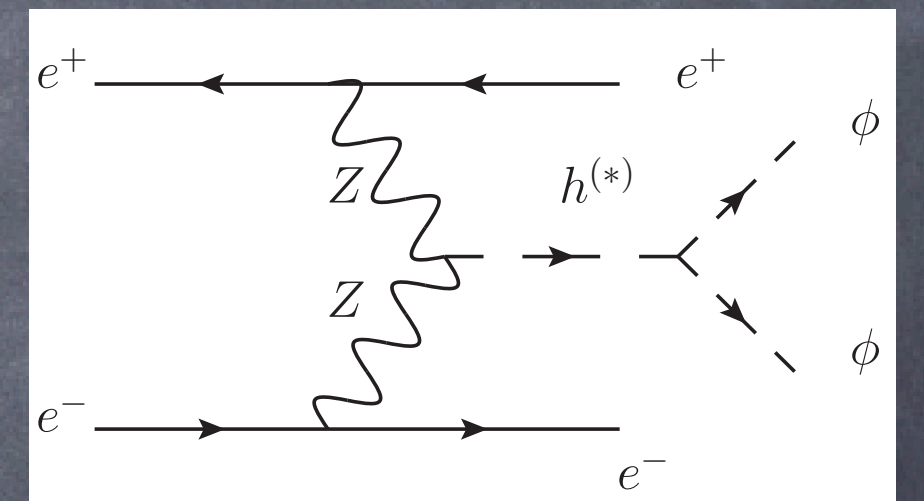
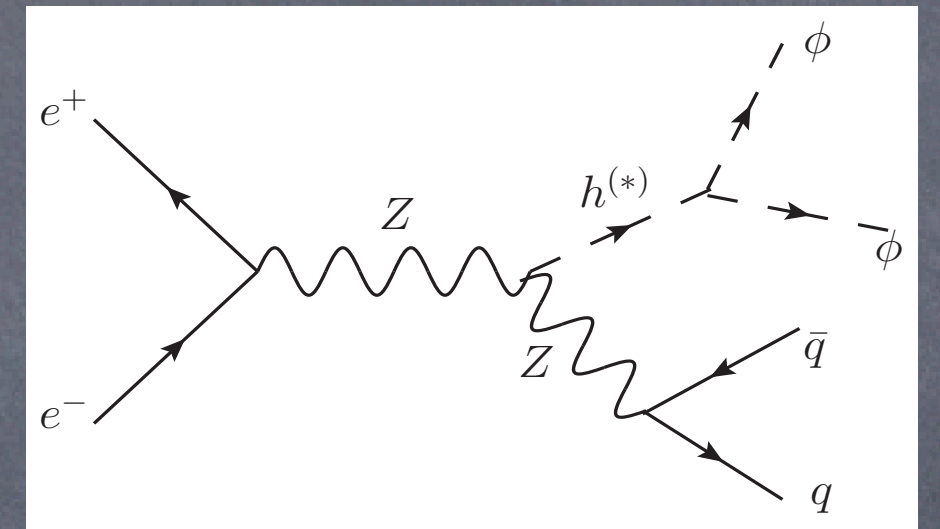


A microscopic model

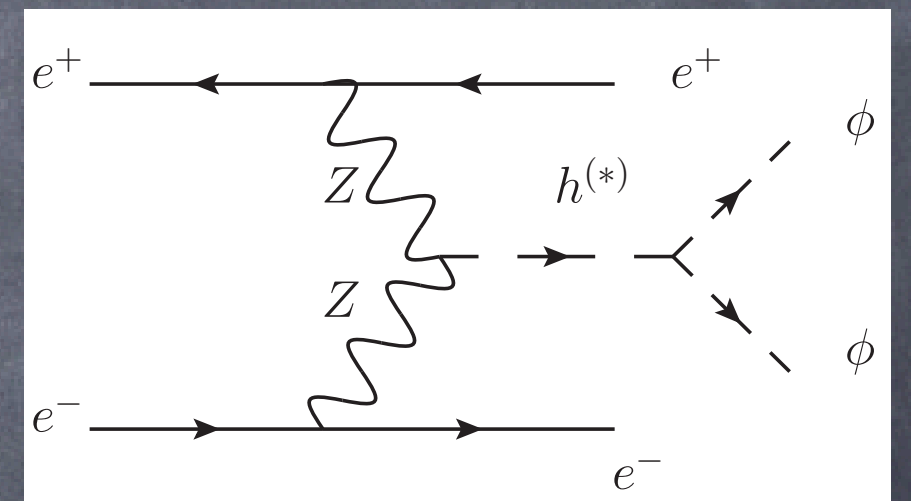
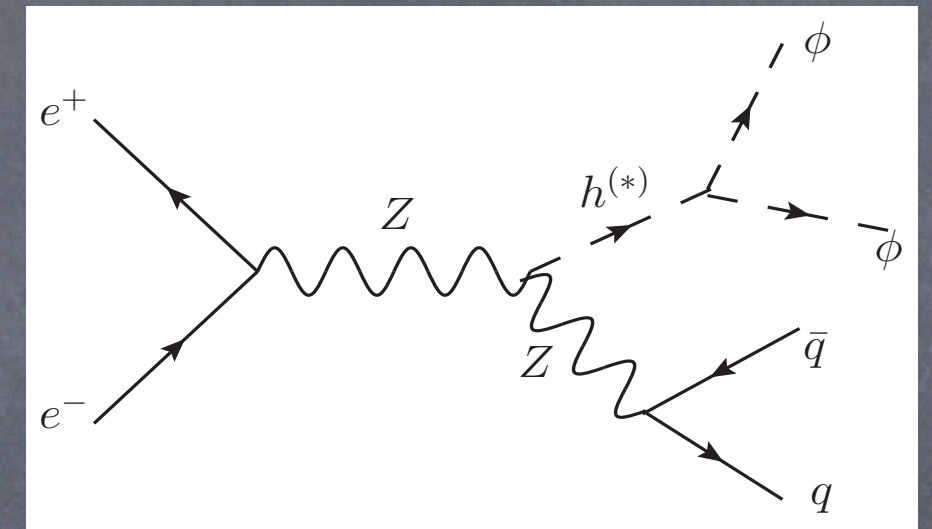
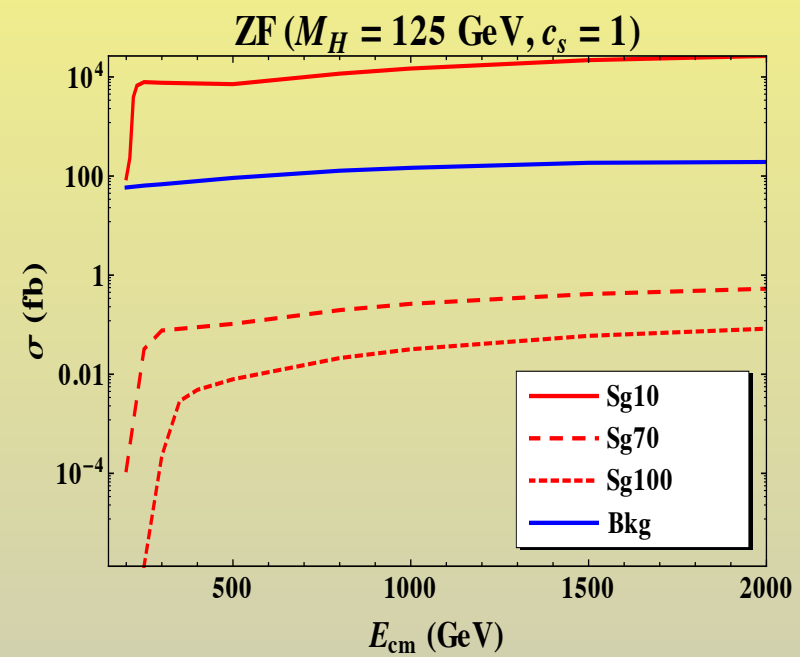
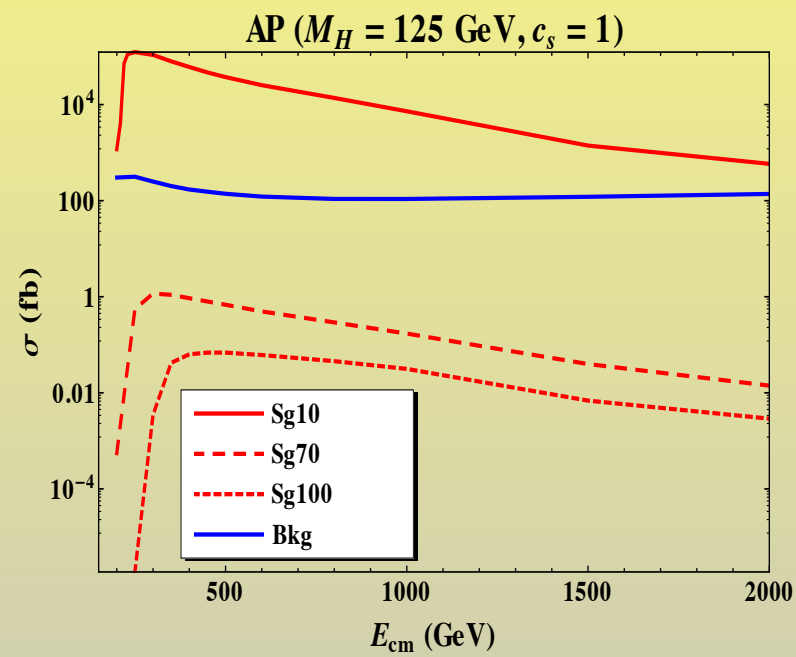


Invisible Higgs?

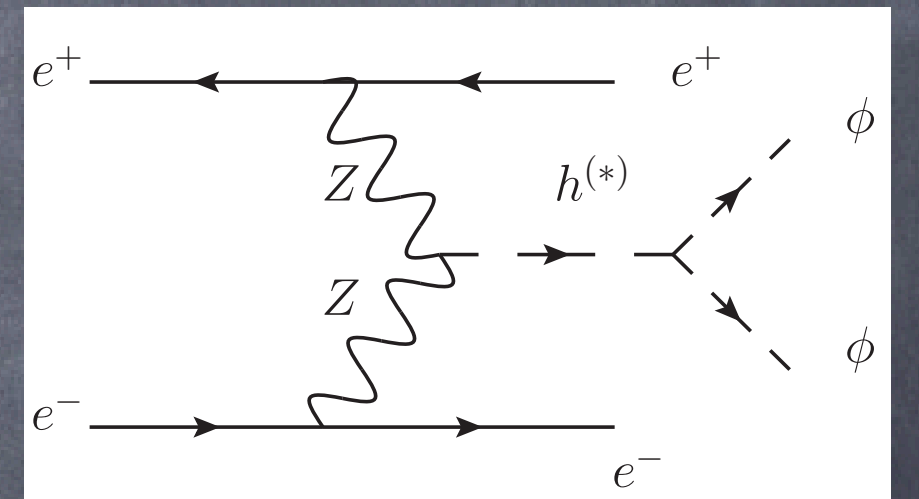
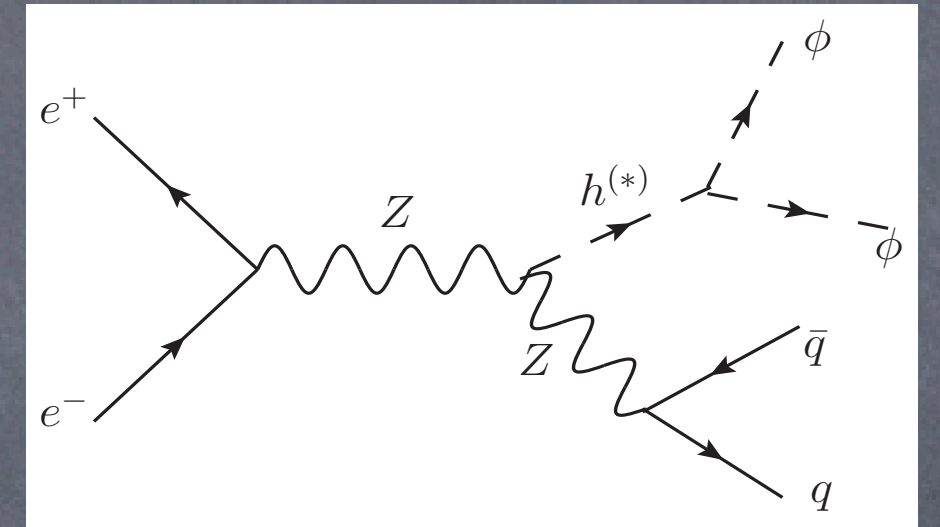
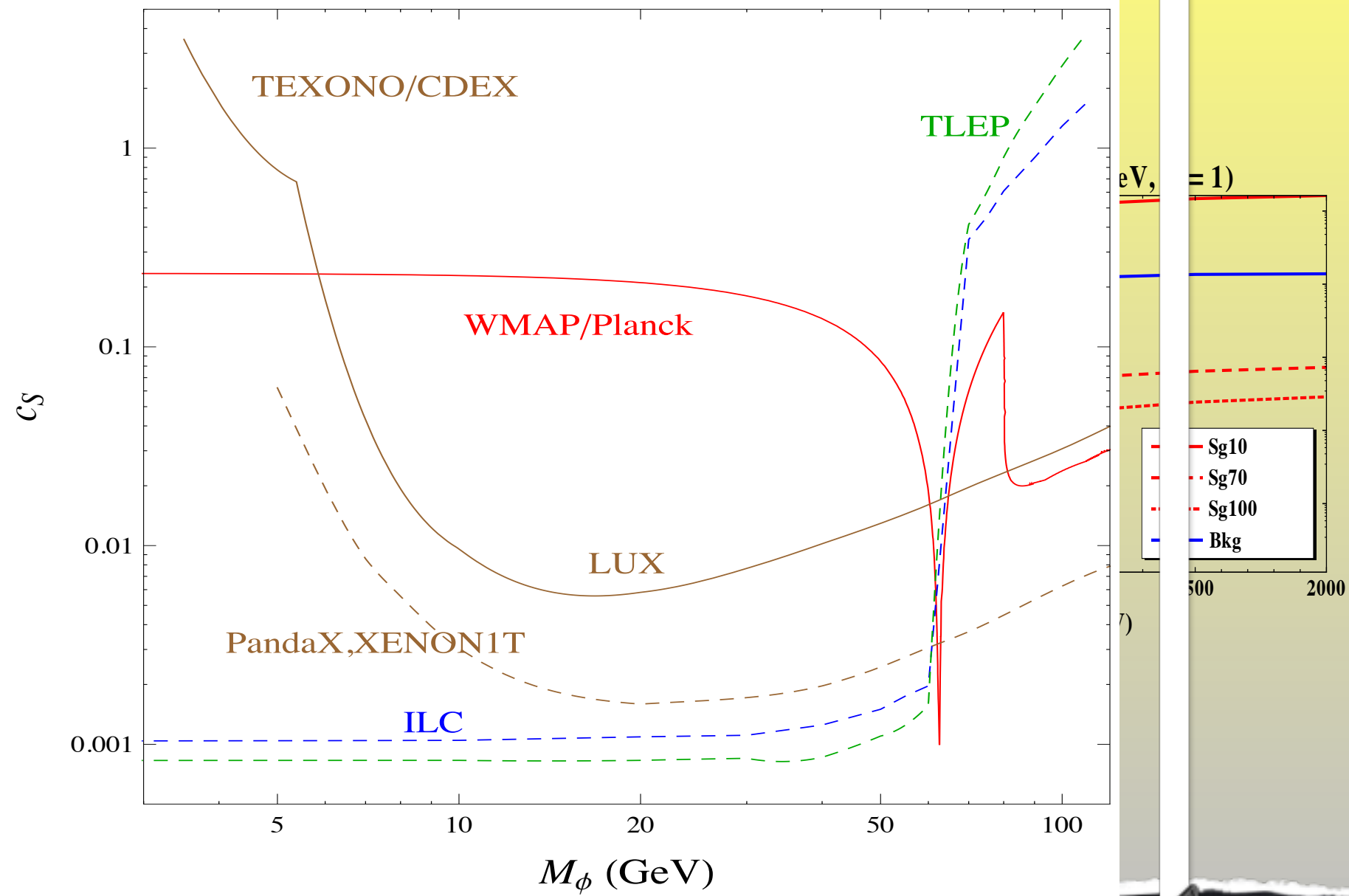
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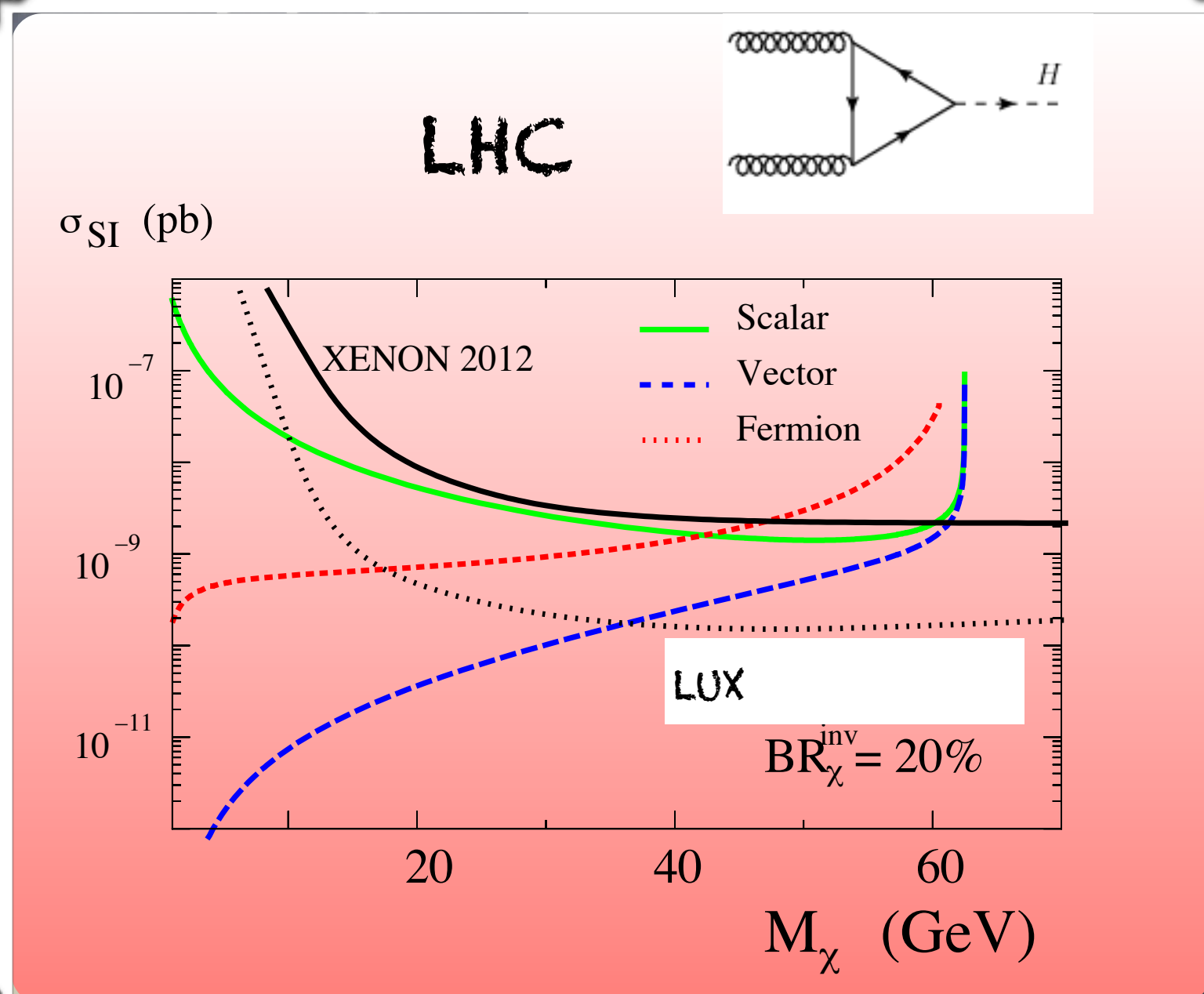
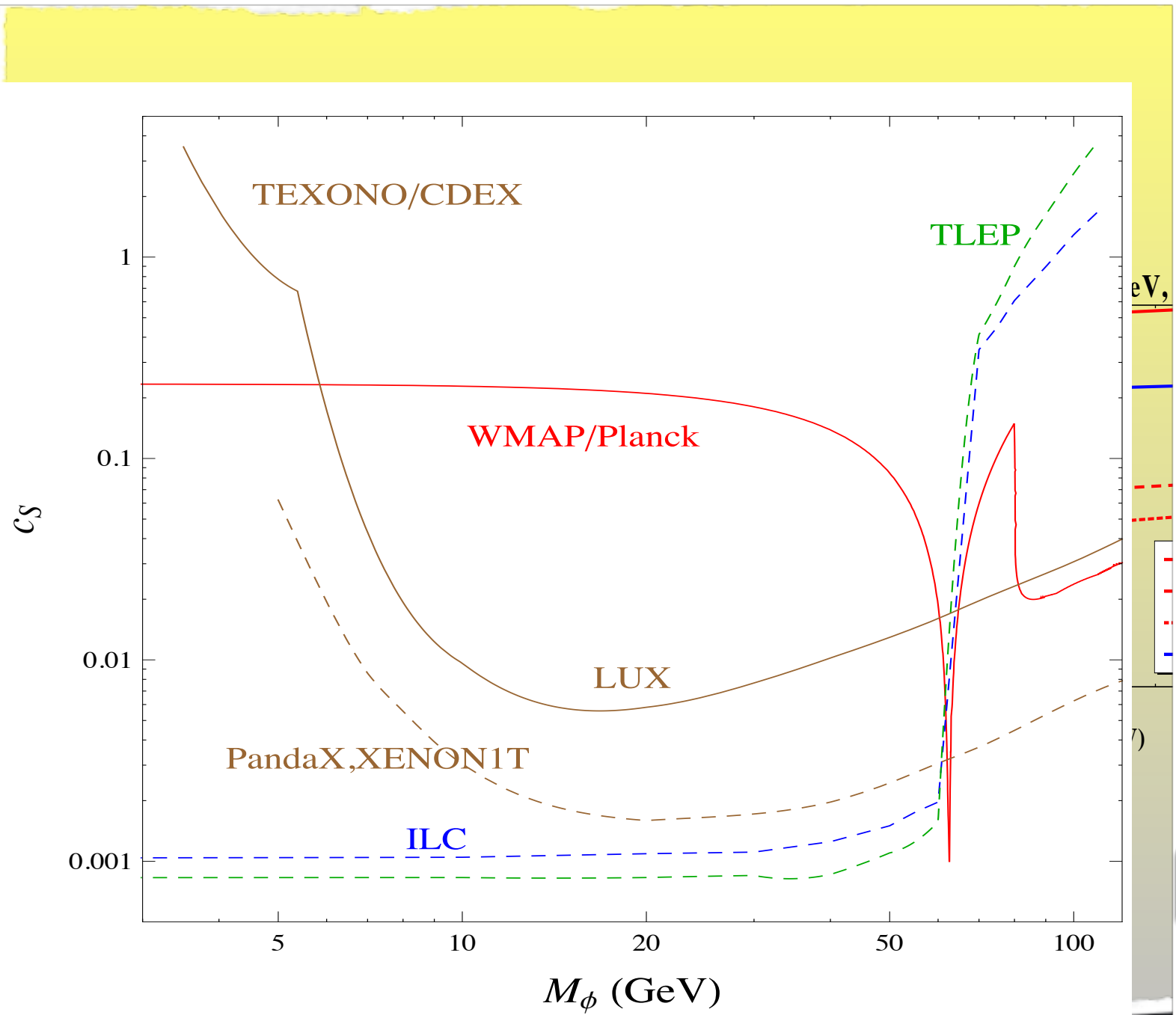
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