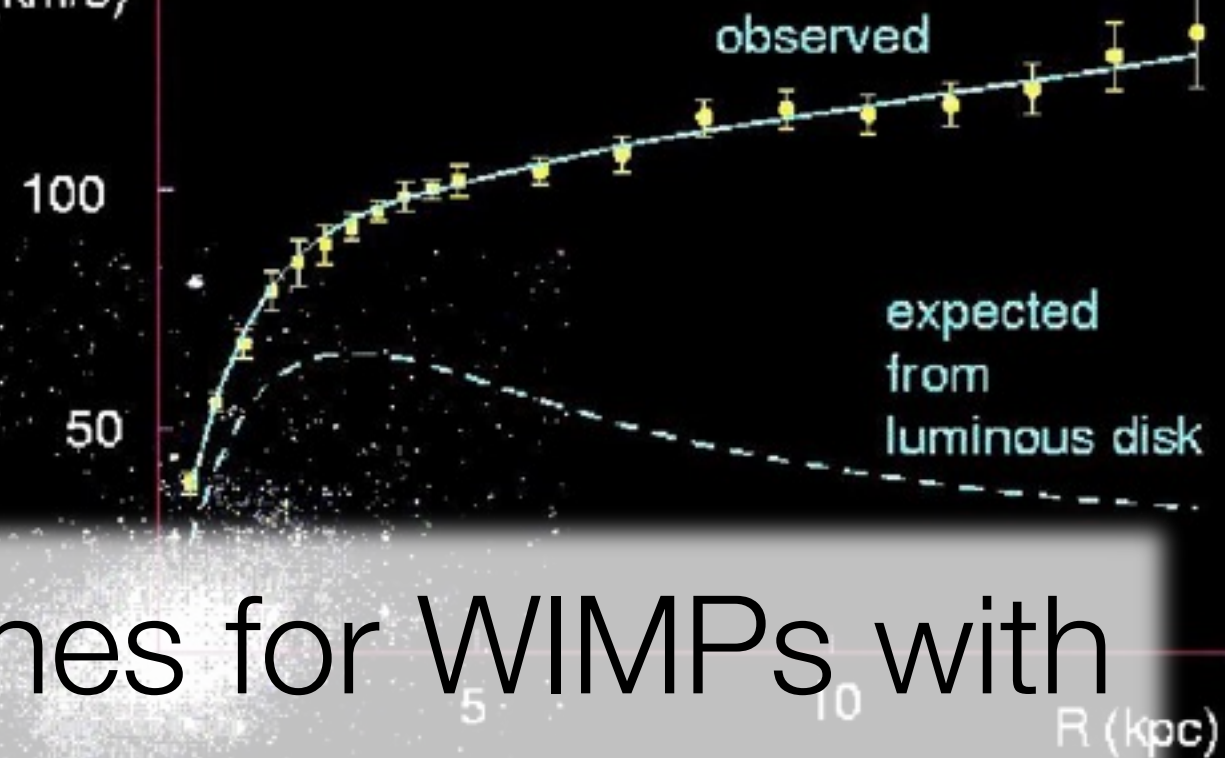


Multimessenger searches for WIMPs with suppressed interactions

M33 rotation curve



Thomas Jacques
with A. De Simone, A. Riotto,
E. Morgante, D. Racco and others

2015-12-17
Texas Symposium

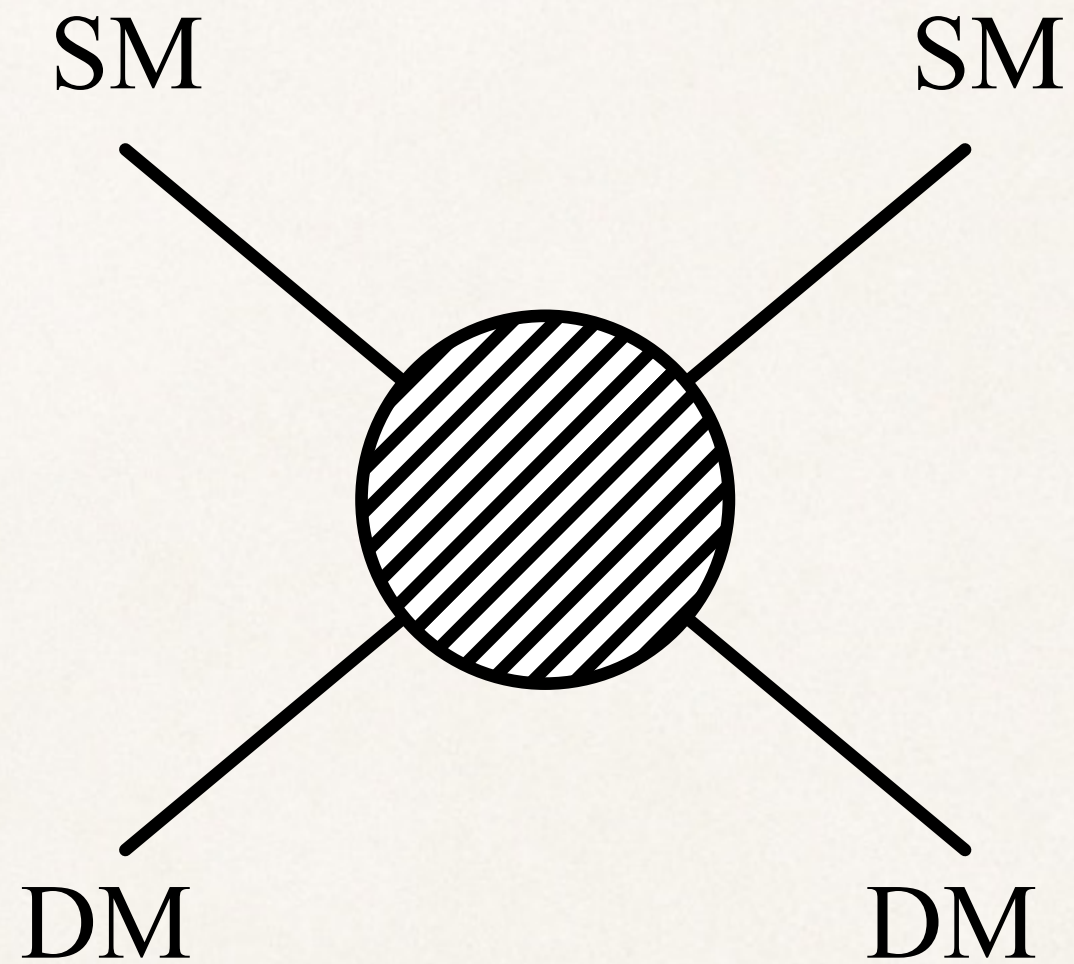


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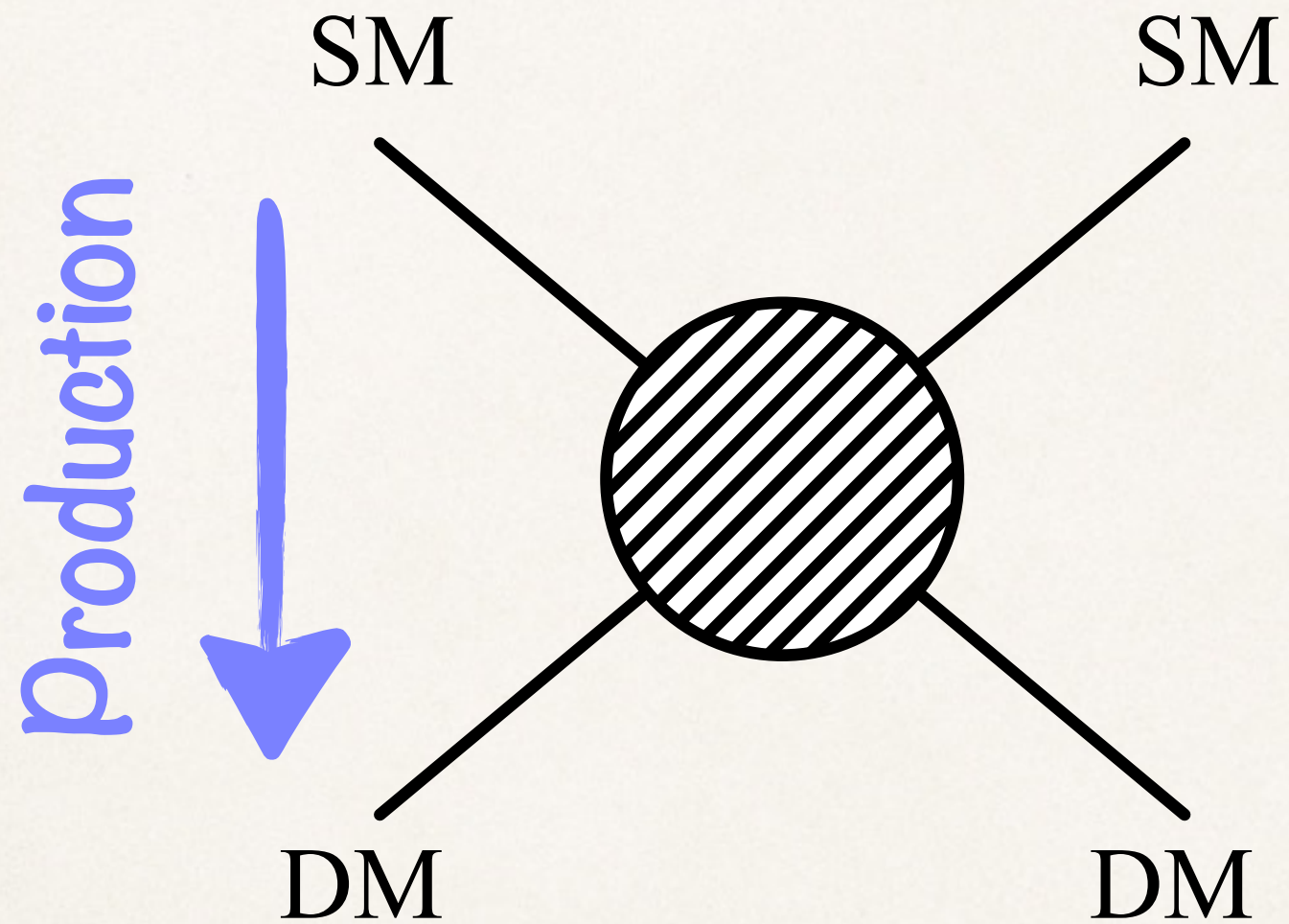


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GENEVA

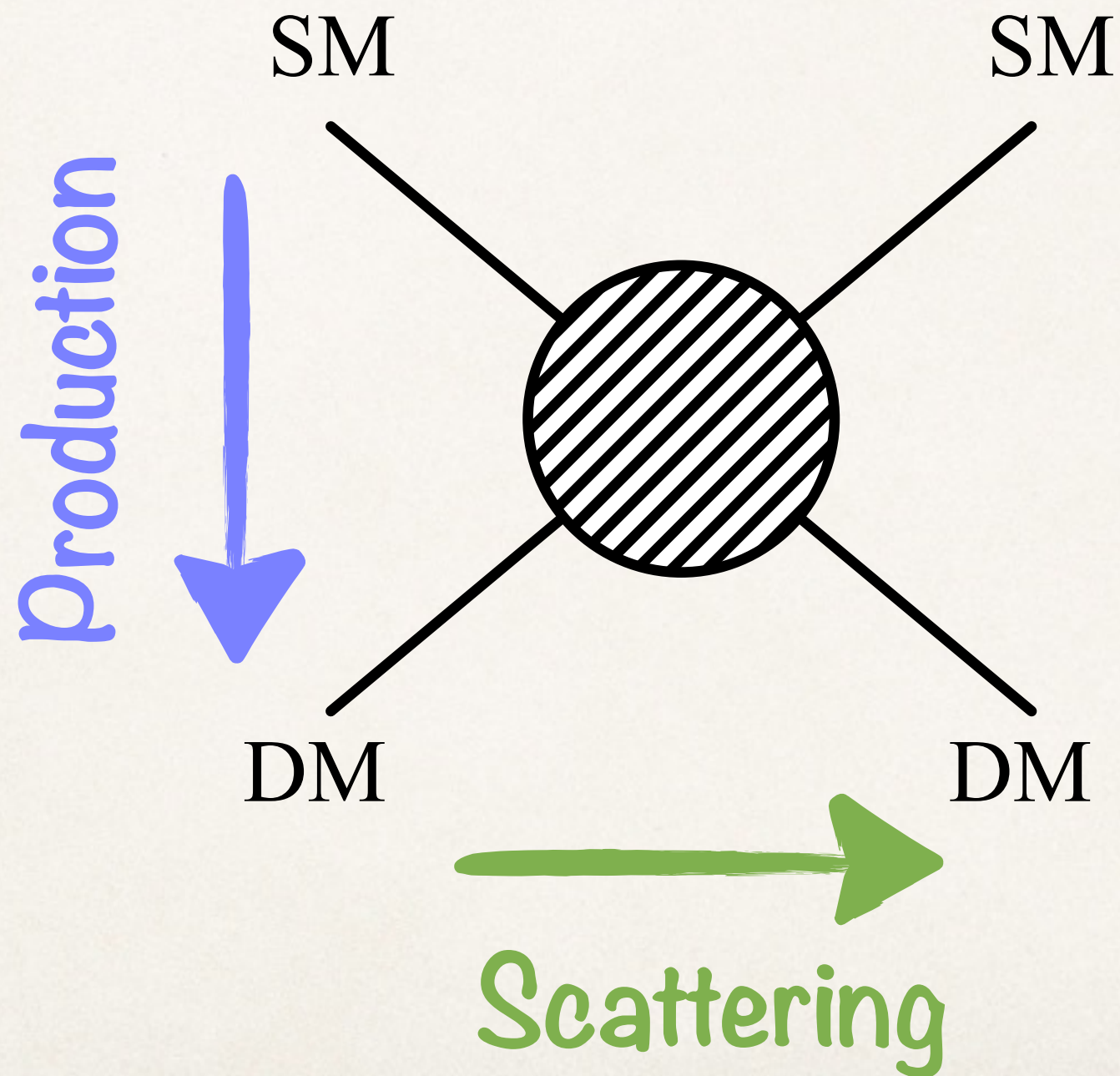
Dark matter searches



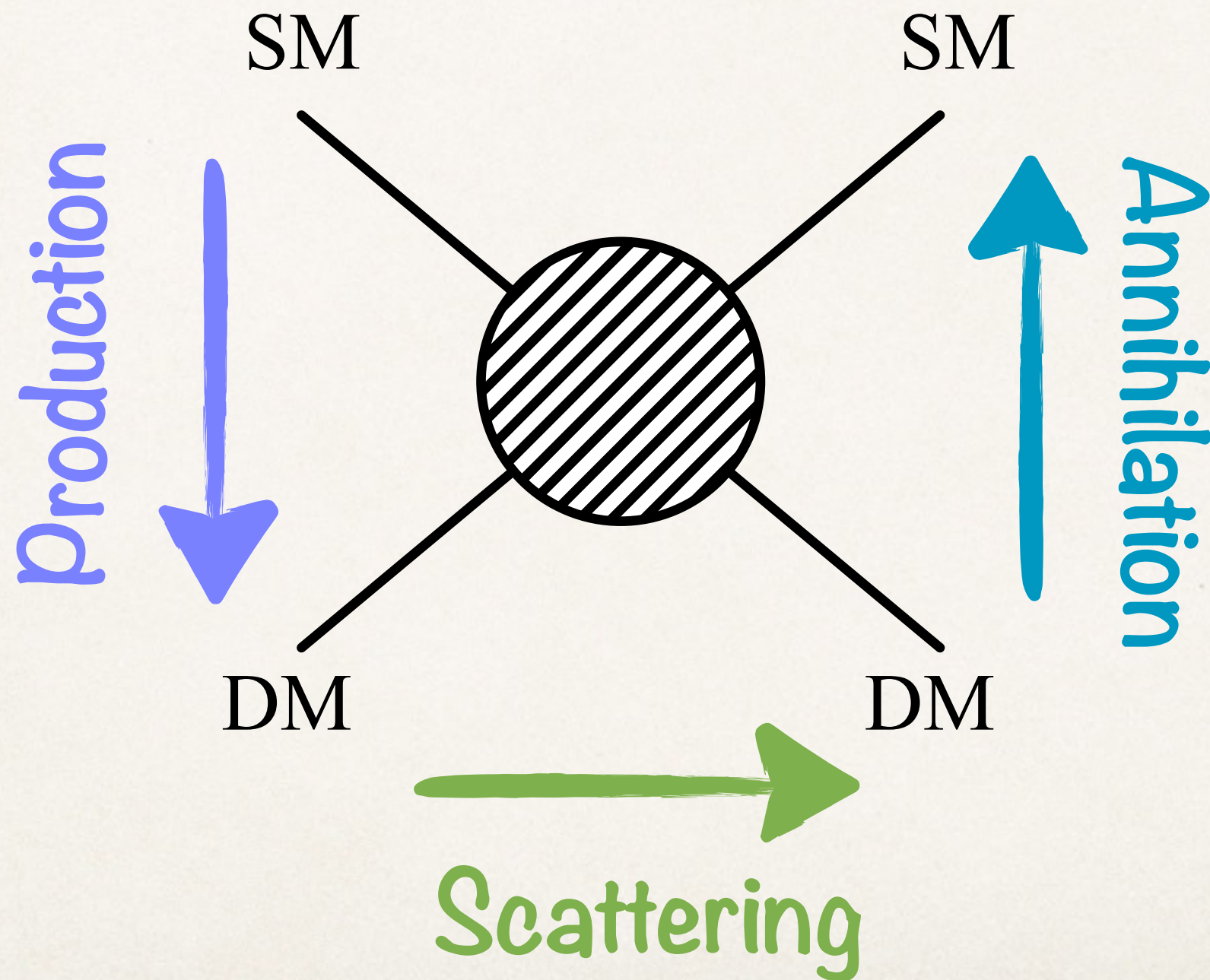
Dark matter searches



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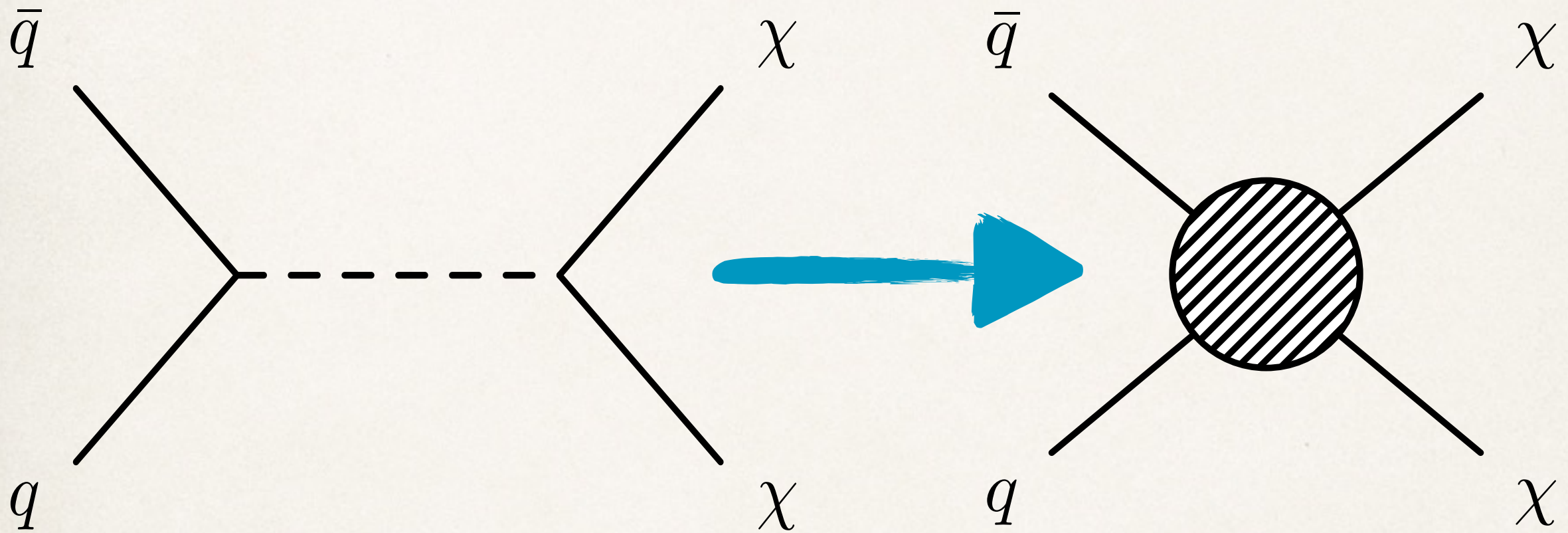


Dark matter searches



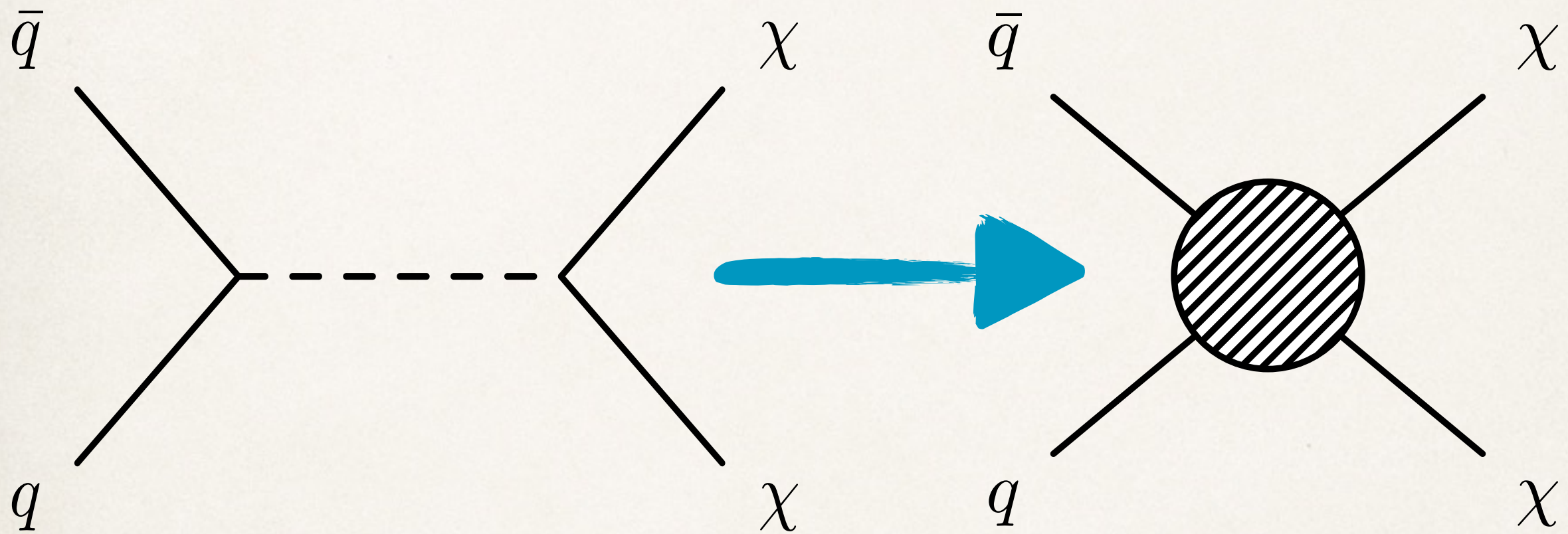
Effective Field Theories

- Integrate out the mediator, reducing parameters to m_{DM} , M^* for each operator
- Easy to scan wide range of models, easy comparison between searches



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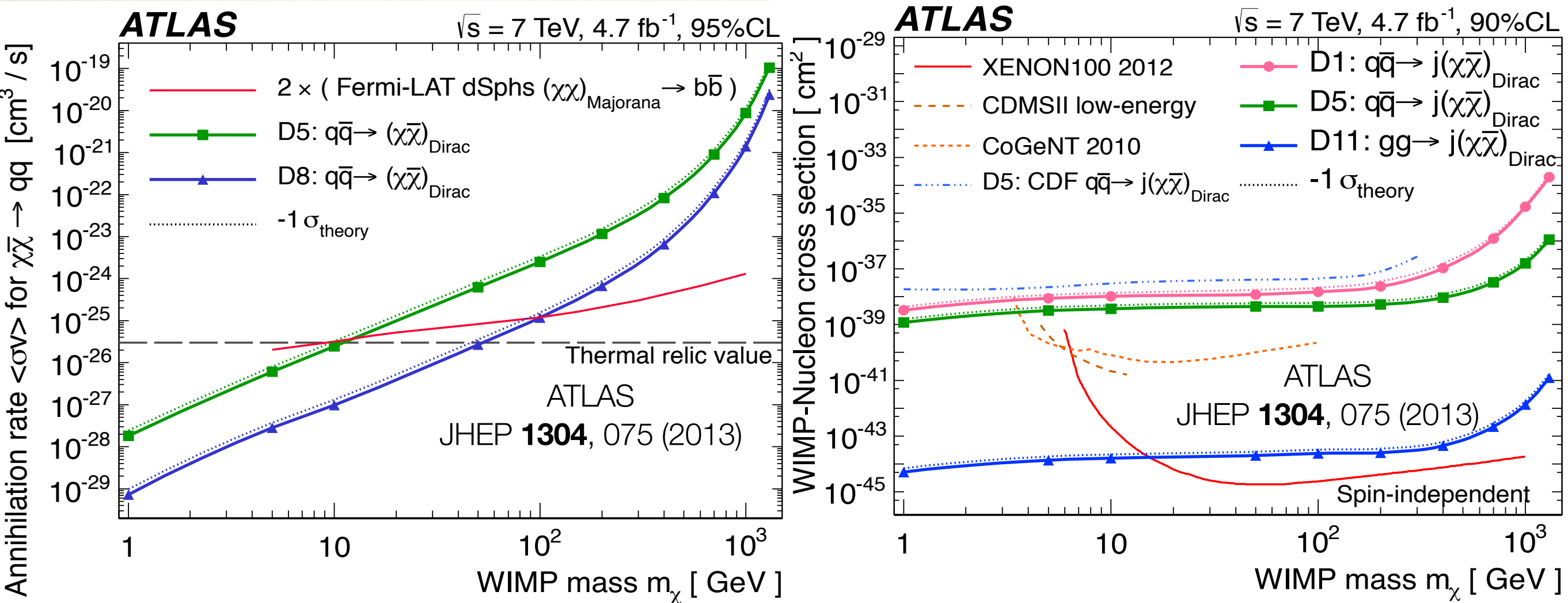
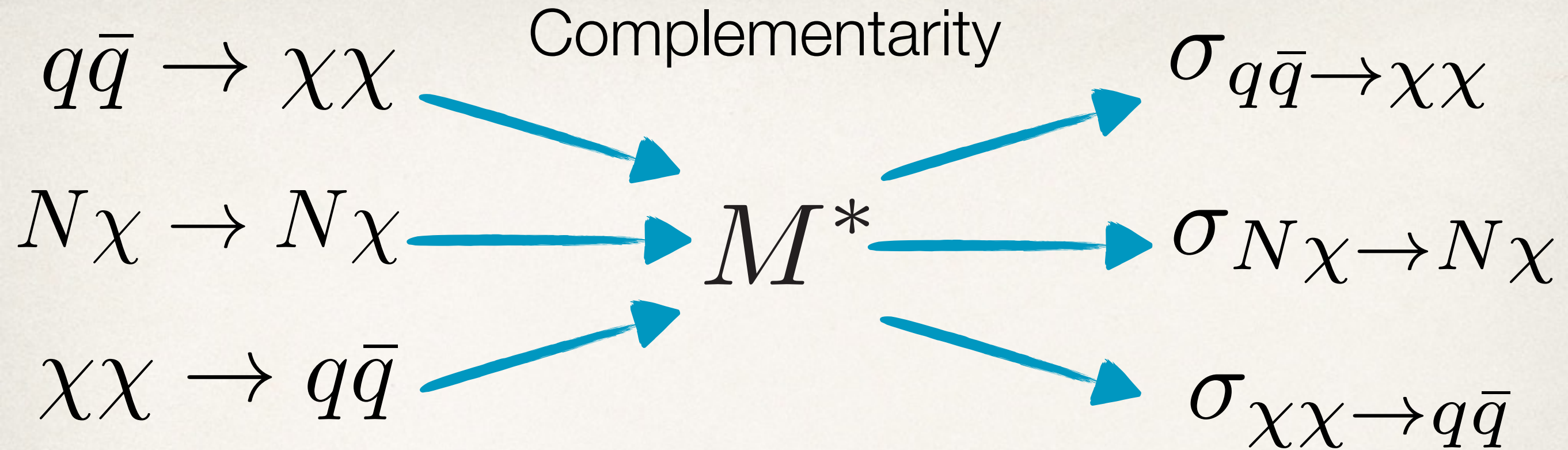


$$\text{D5} = (\bar{\chi}\gamma^\mu\chi)(\bar{q}\gamma_\mu q)$$

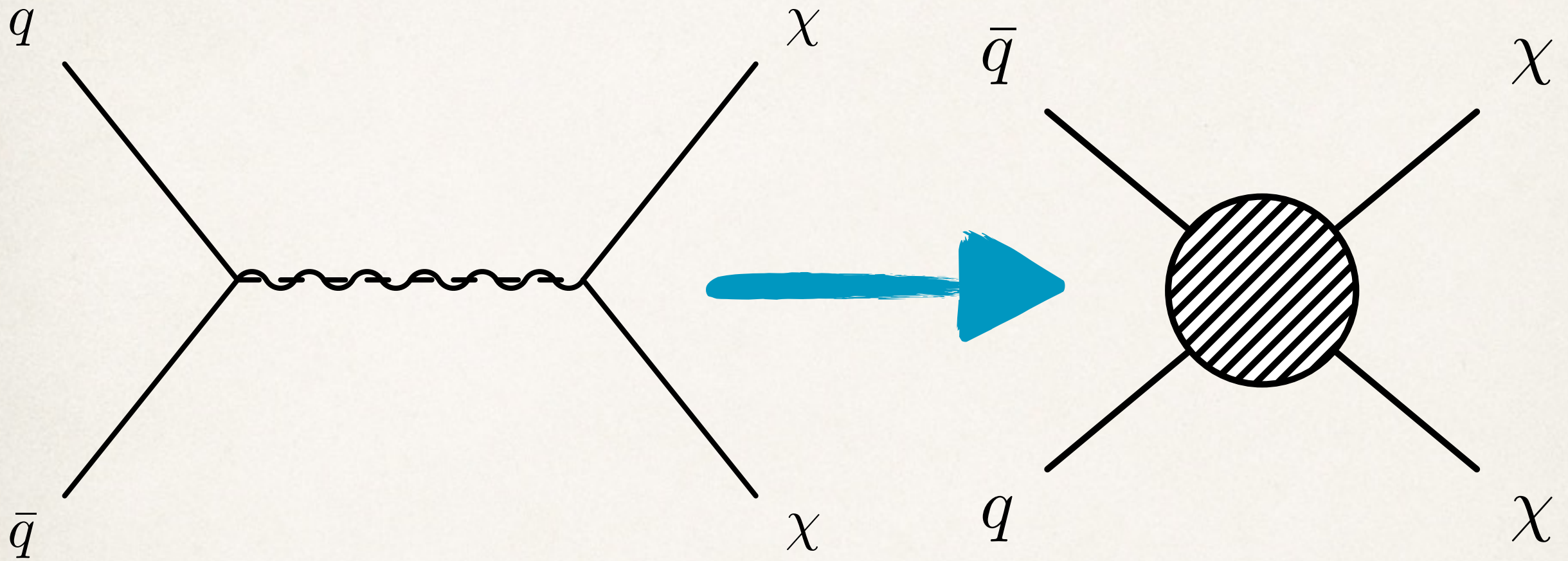
$$\text{D8} = (\bar{\chi}\gamma^\mu\gamma^5\chi)(\bar{q}\gamma_\mu\gamma^5 q)$$

$$\text{M1} = (\chi\chi)(\bar{q}q)$$

$$\text{C3} = (\chi^\dagger\partial_\mu\chi)(\bar{q}\gamma^\mu q)$$

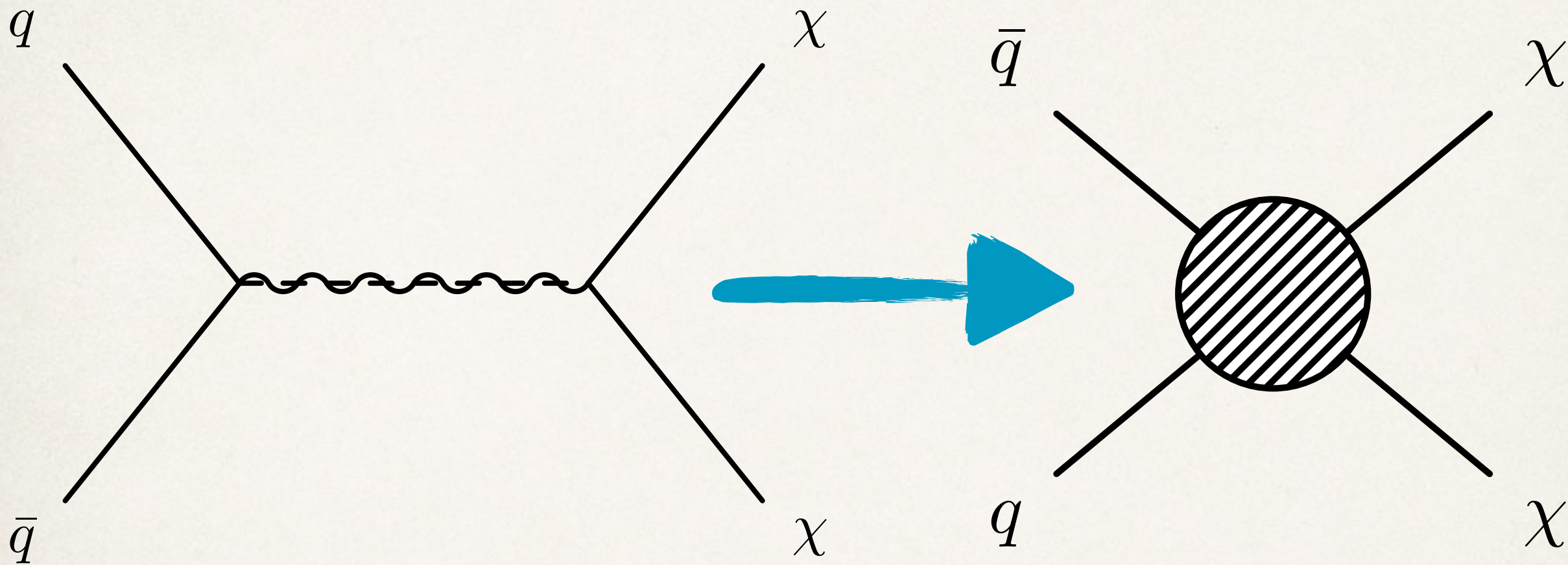


Effective field theories



$$\frac{g_q g_{\text{DM}}}{M^2 - Q_{\text{tr}}^2} \simeq \frac{g_q g_{\text{DM}}}{M^2} \equiv \frac{1}{M^{*2}}$$

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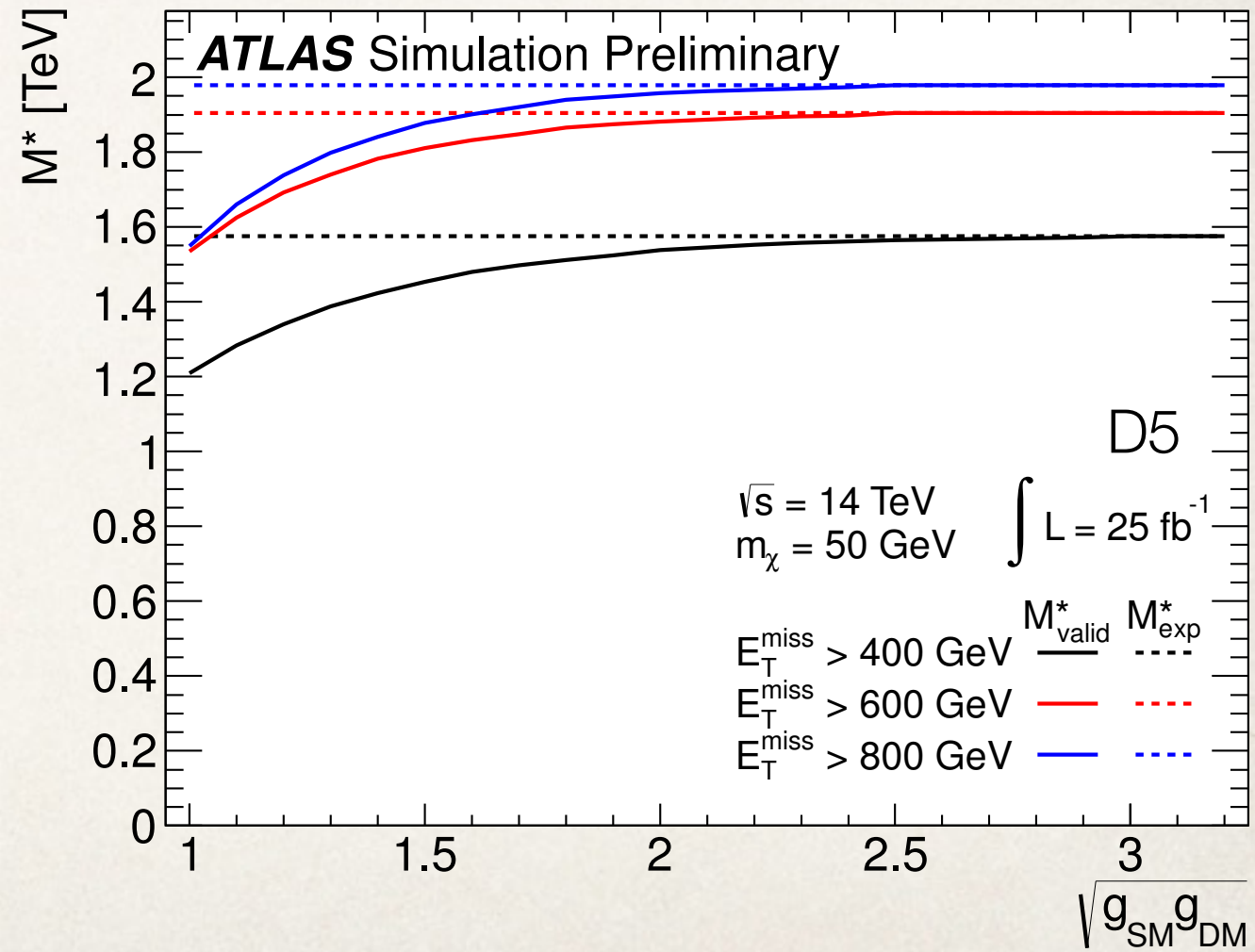
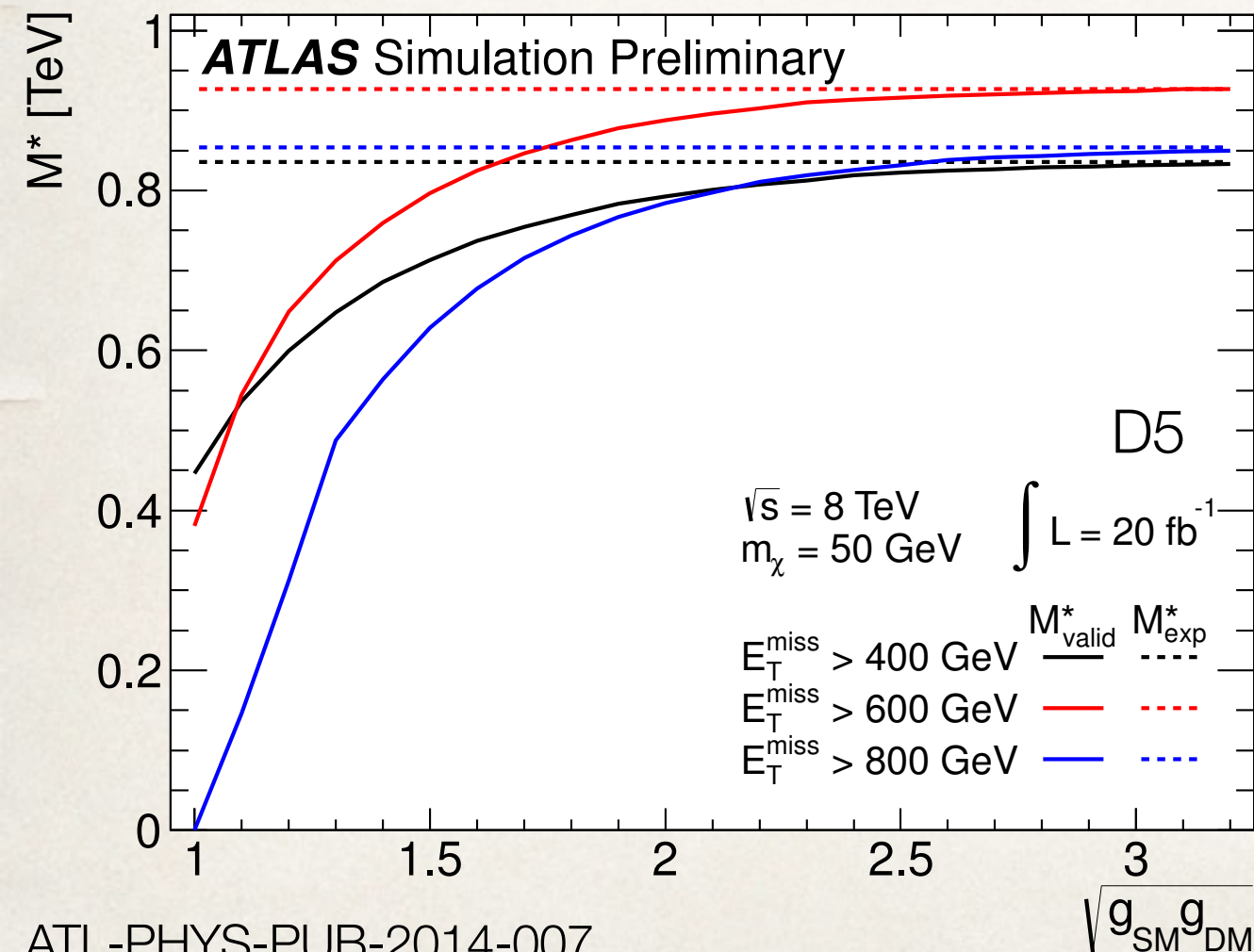
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$$Q_{\text{tr}}^2 \ll M^2 \equiv (g M^*)^2$$

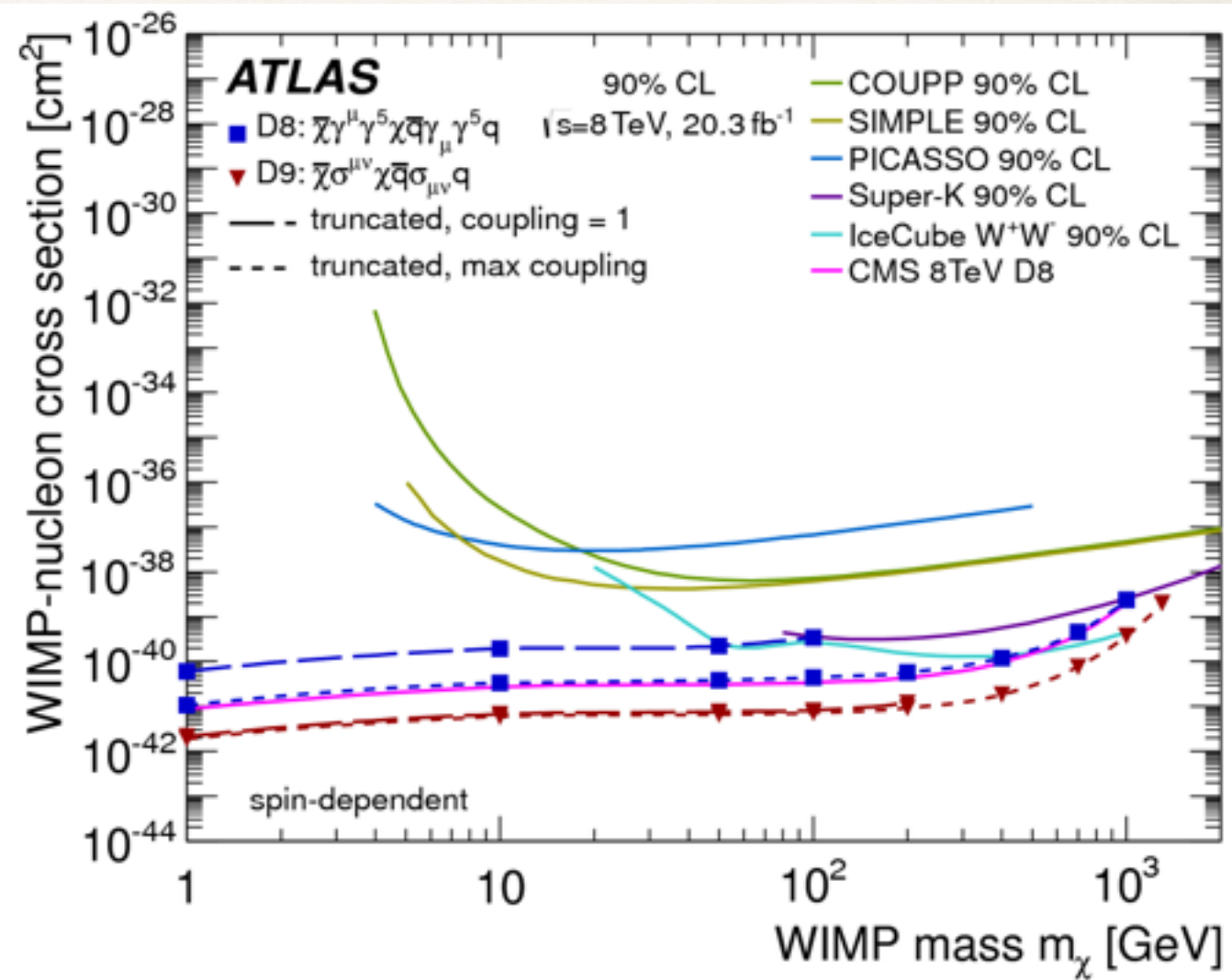
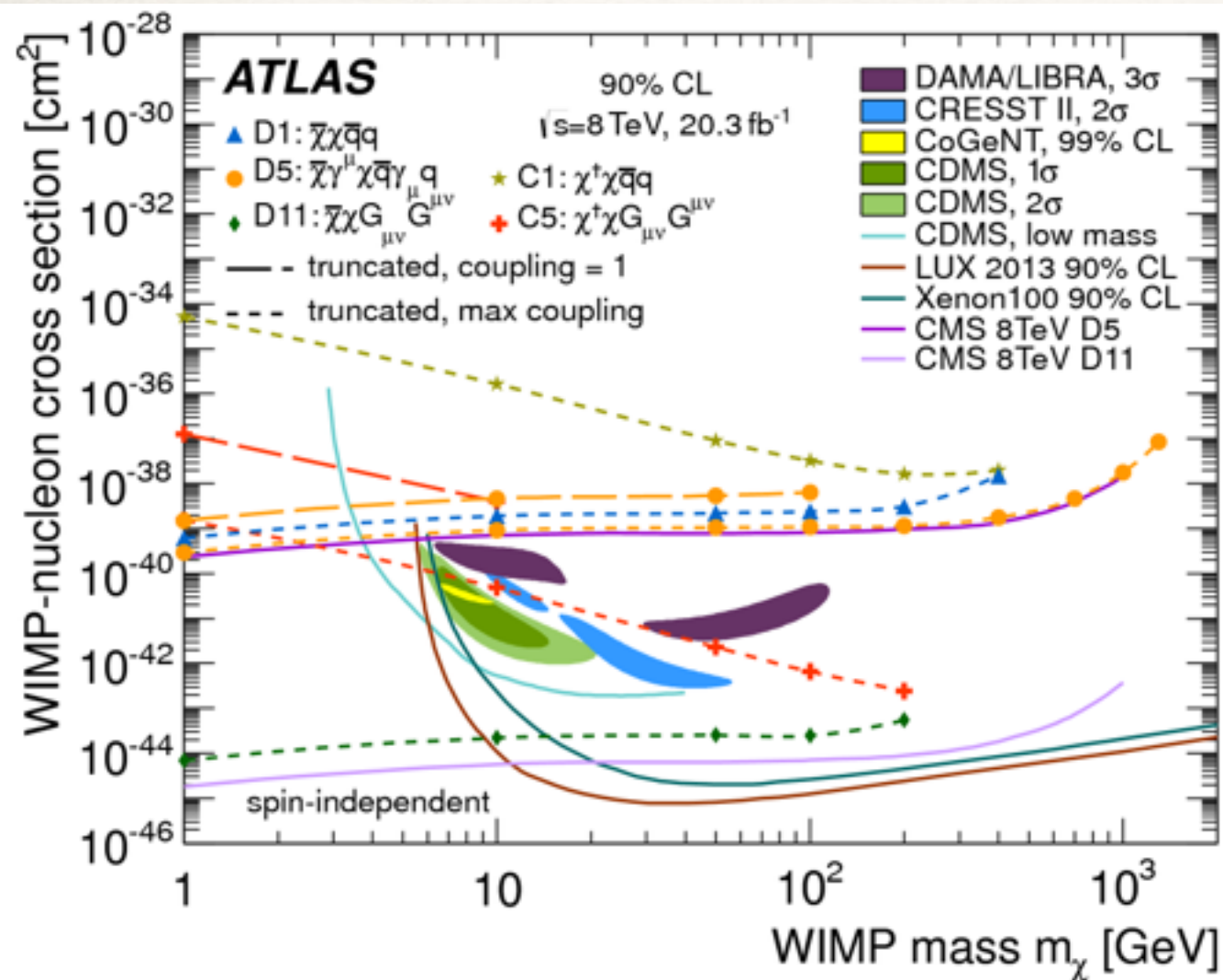
Rescaling EFT constraints

- For a given $\sqrt{g_q g_\chi}$, cut all events that don't pass

$$M \equiv \sqrt{g_q g_\chi} M^* \geq Q_{\text{tr}}$$



Rescaling EFT constraints



Eur. Phys. J. C (2015) 75:299

ATLAS + Busoni, De Simone, TDJ, Morgante, Riotto

Using simplified models

- Minimum particle content necessary to describe new physics;
Usually one DM candidate and one mediator
- Enlarged parameter space: Minimum of 4 parameters
- Even the simplest models
have more unless you start
making *choices* and *assumptions*

m_{DM}	M_{med}
g_{DM}	g_q
- Given that it is necessary to choose benchmark points and models,
we should use all of the information available from other DM
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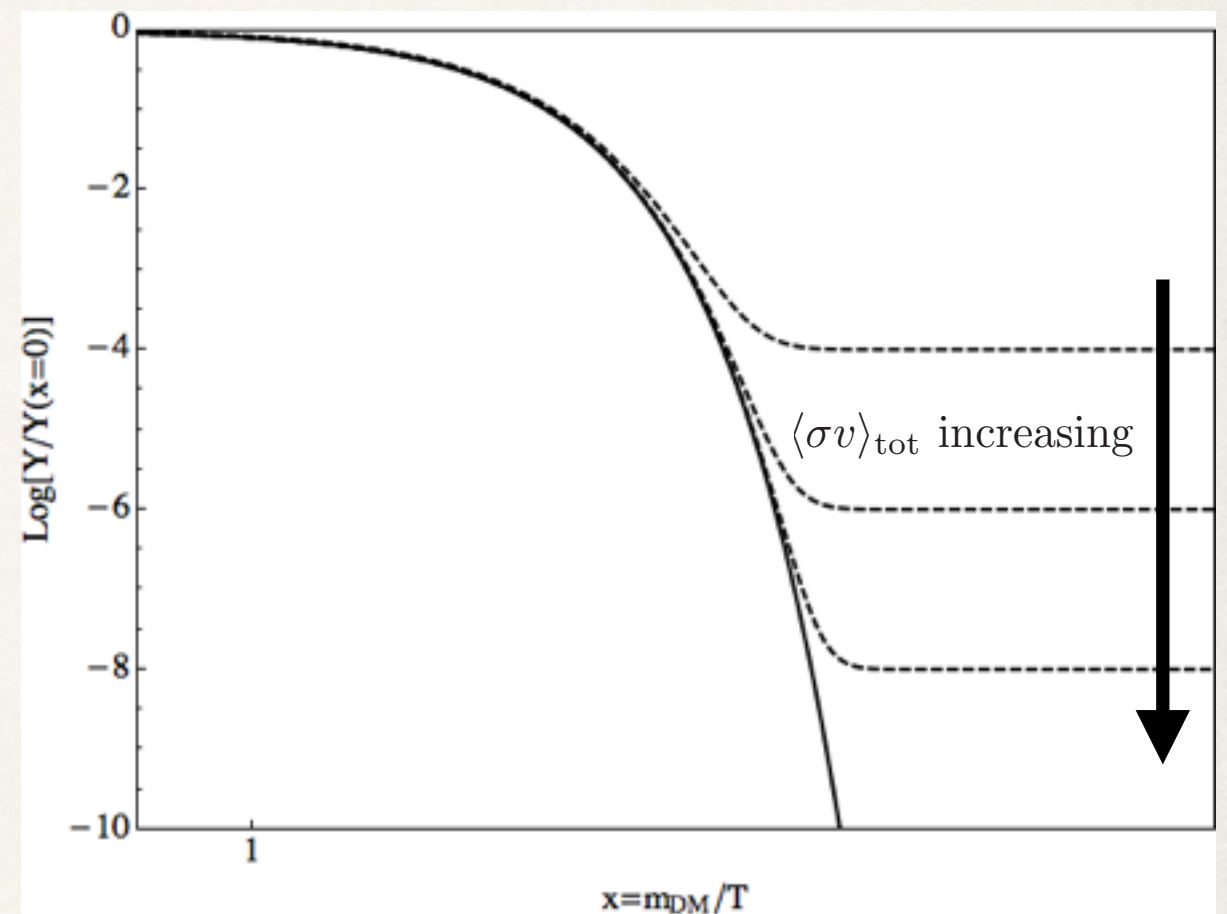
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Thermal relic dark matter

- Dark matter in thermal equilibrium at large T
- When $m_{\text{DM}} > T$, comoving abundance drops exponentially
- As universe expands, abundance freezes out
- Annihilation rate controls abundance at freezeout



$$\langle\sigma v\rangle_{\text{tot}} \simeq \frac{4.8 \times 10^{-10} \text{ GeV}^{-2}}{\Omega_{\text{DM}} h^2}$$

Annihilation range

- Relic density is sensitive to the annihilation channels of the model
- Collider searches assume minimal channels:
Mediator couples to quarks only, with equal coupling to each flavour
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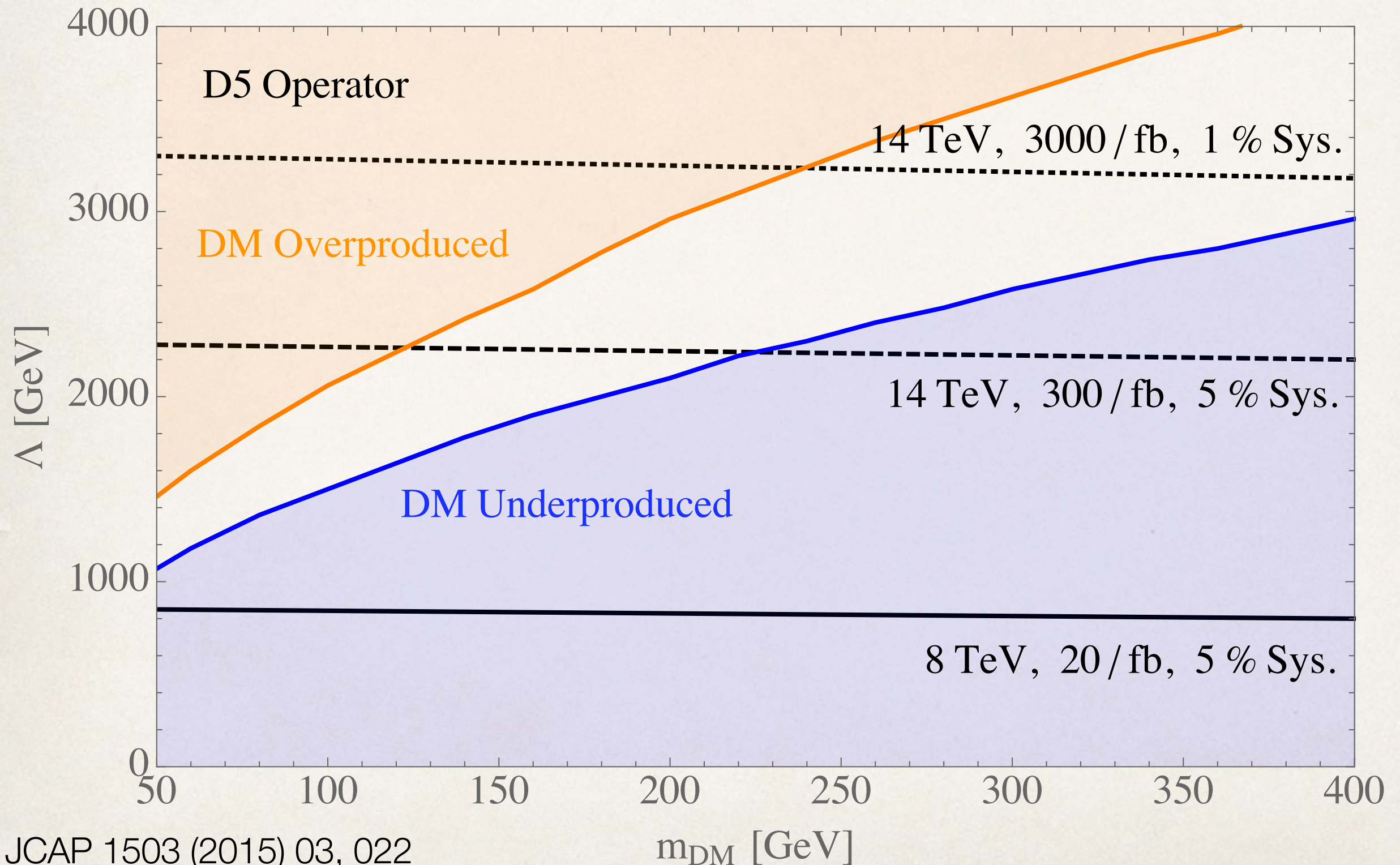
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$$1.0 \times 10^{-9} \text{ GeV}^{-2} \lesssim \langle\sigma v\rangle_{\text{min}} \lesssim 4.0 \times 10^{-9} \text{ GeV}^{-2}$$

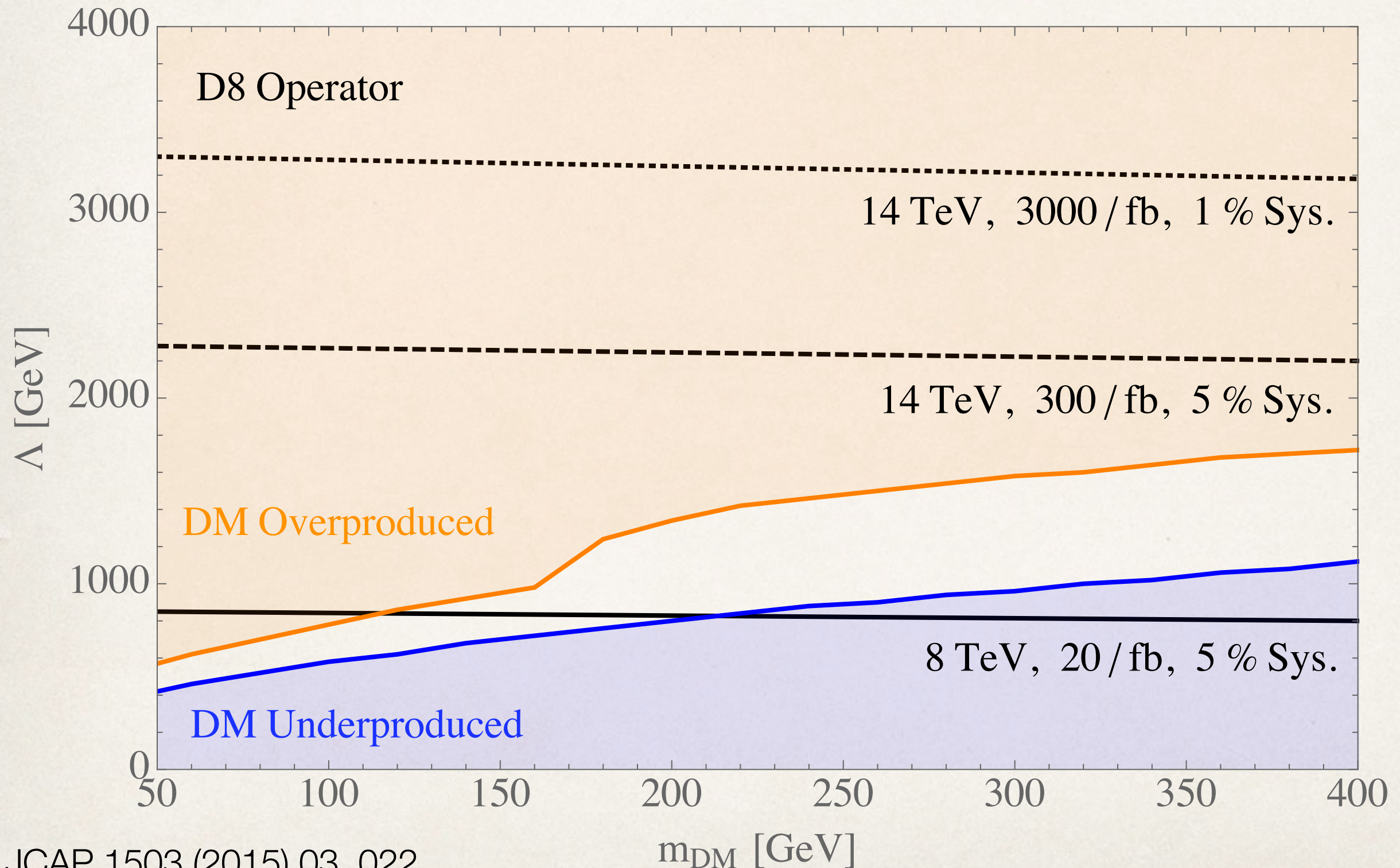
Effective operator results

$$D5 = \frac{1}{\Lambda^4} (\bar{\chi} \gamma^\mu \chi) (\bar{q} \gamma_\mu q)$$



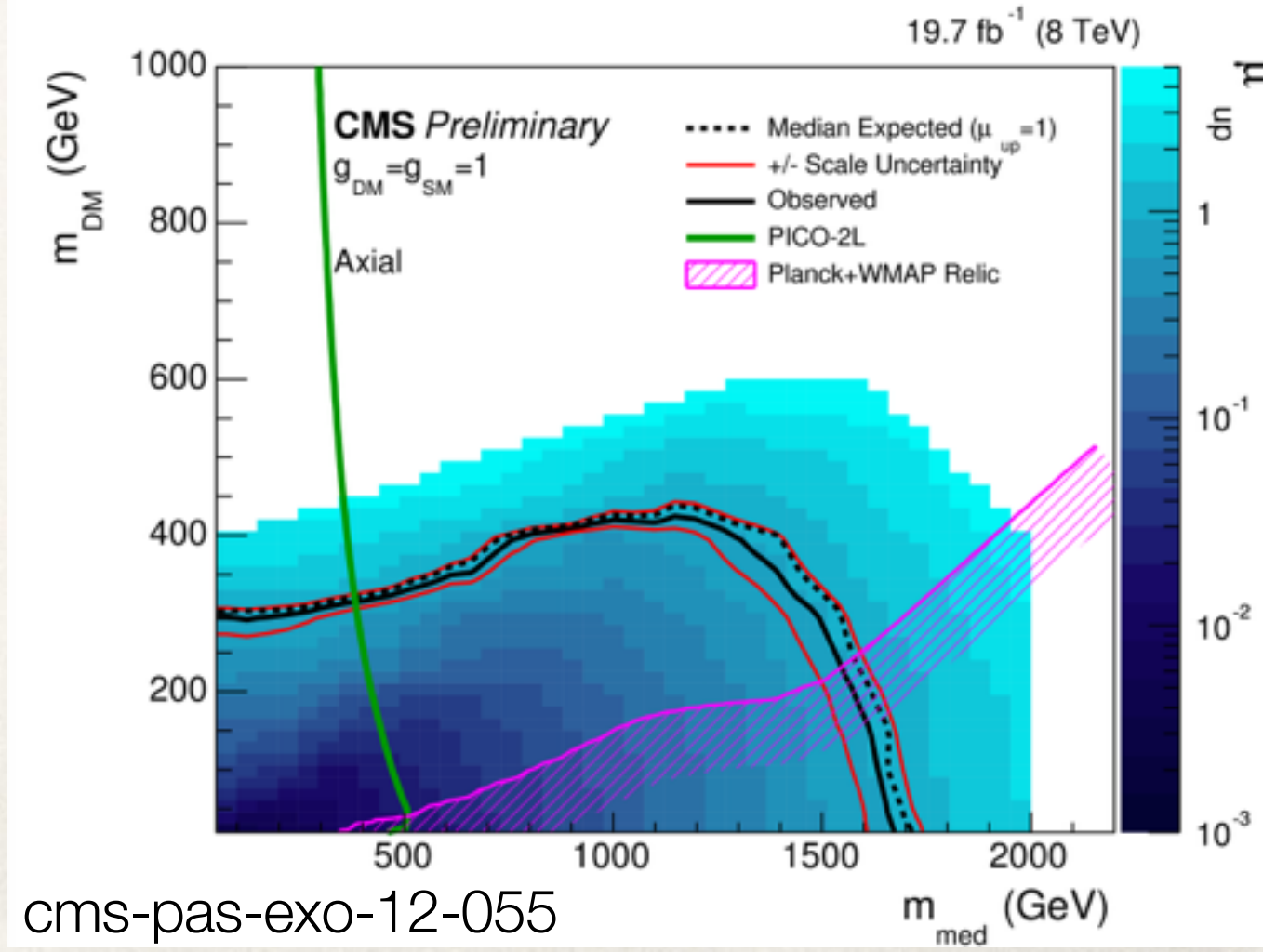
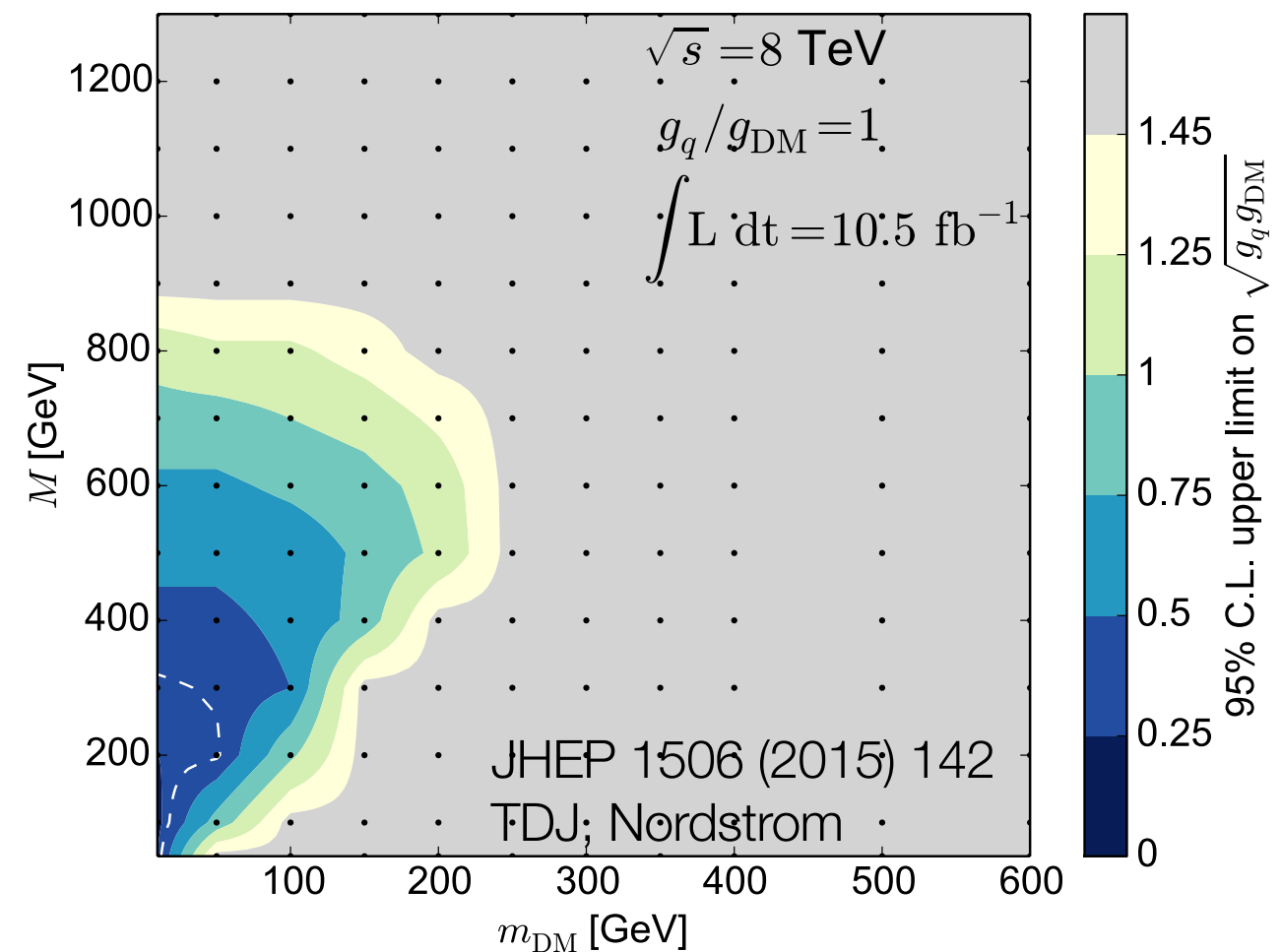
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Simplified models

- We can prioritize the model space - e.g. direct detection is better for vector models, LHC for axial-vector
- The parameter space is still large!
2 choices:
 - Scan over coupling, or
 - fixed benchmark
- Scan is more comprehensive and intuitive but technically difficult:
Width changes at each point in 4D parameter space
- Benchmarks allow comparison between experiments

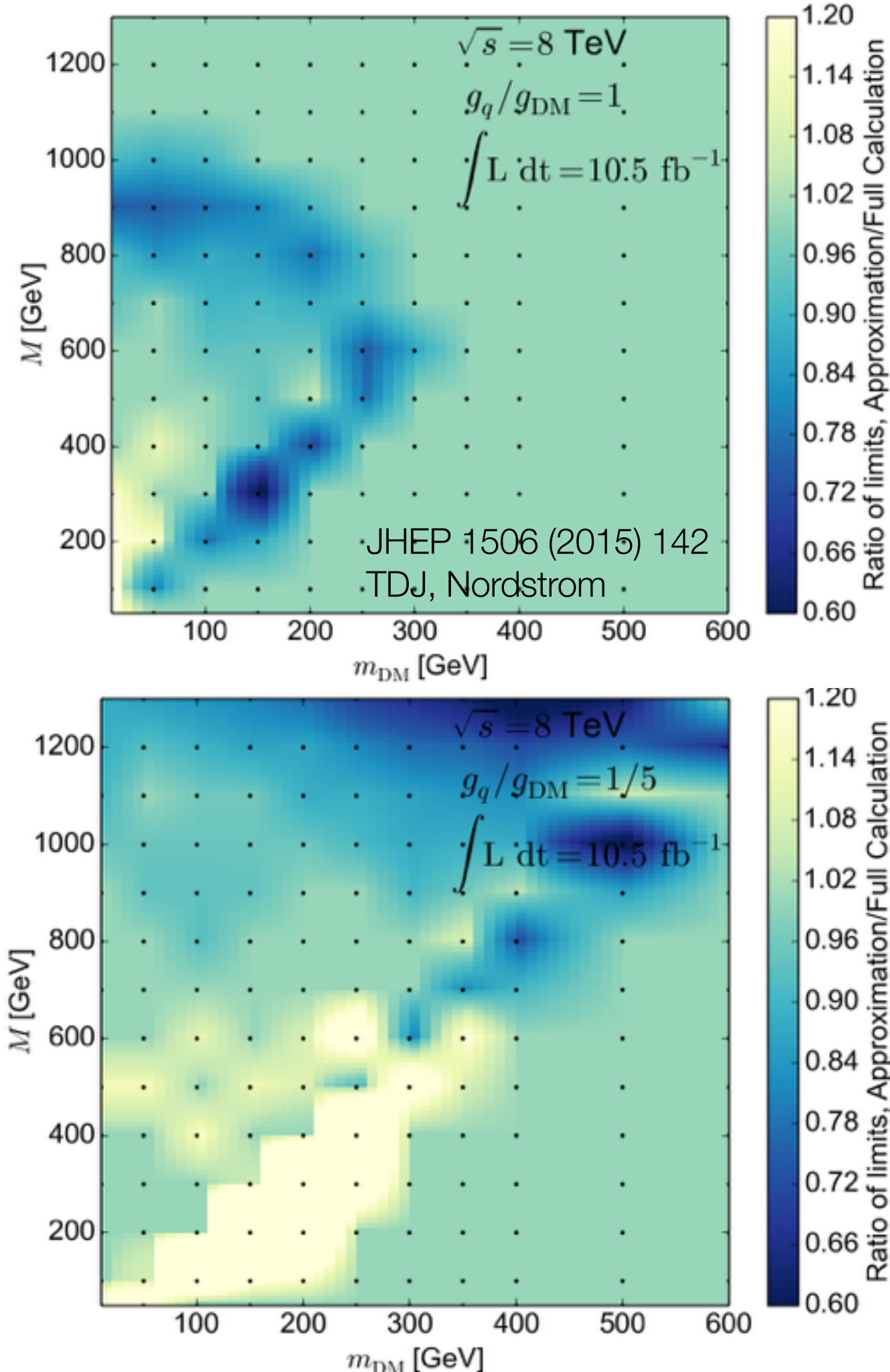


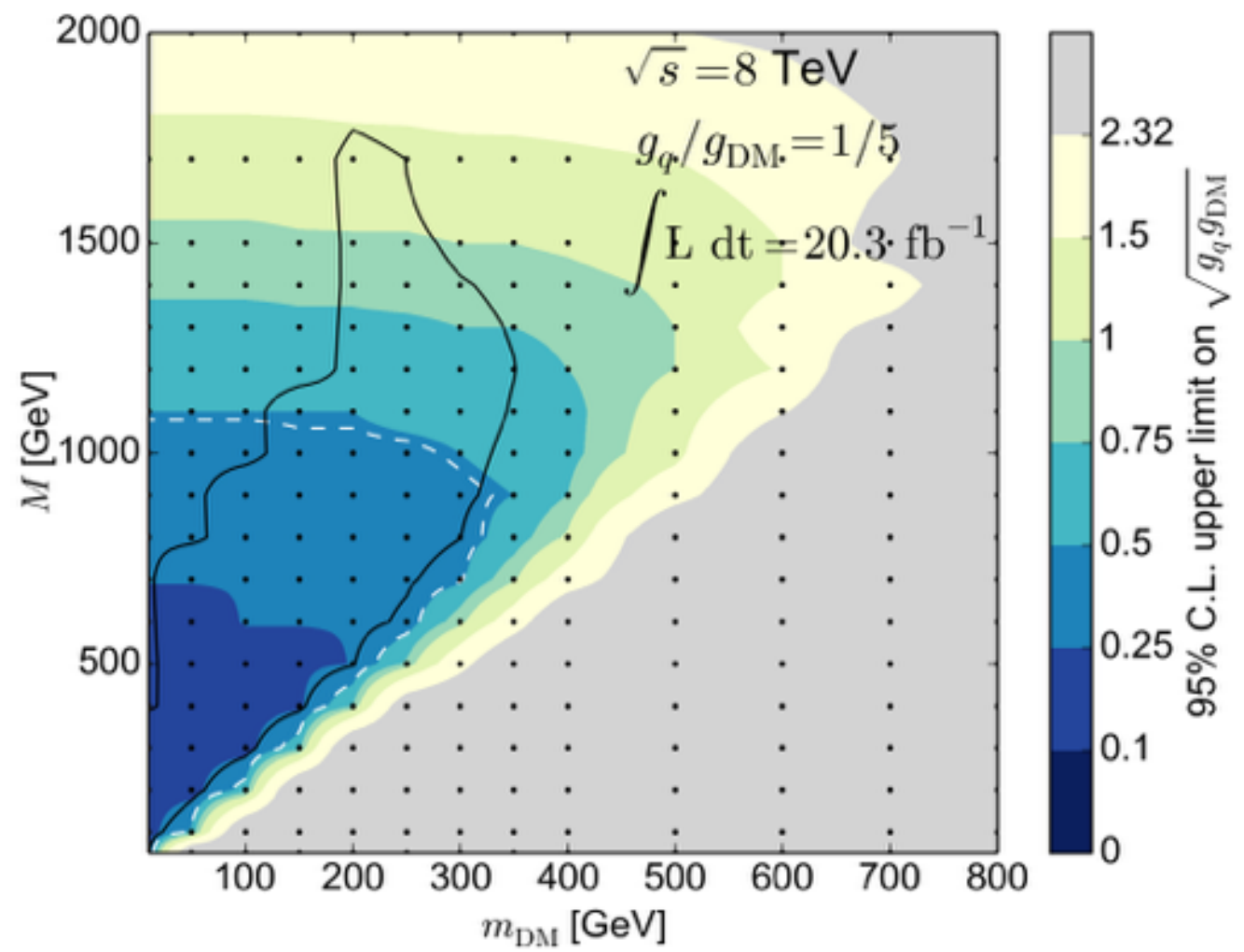
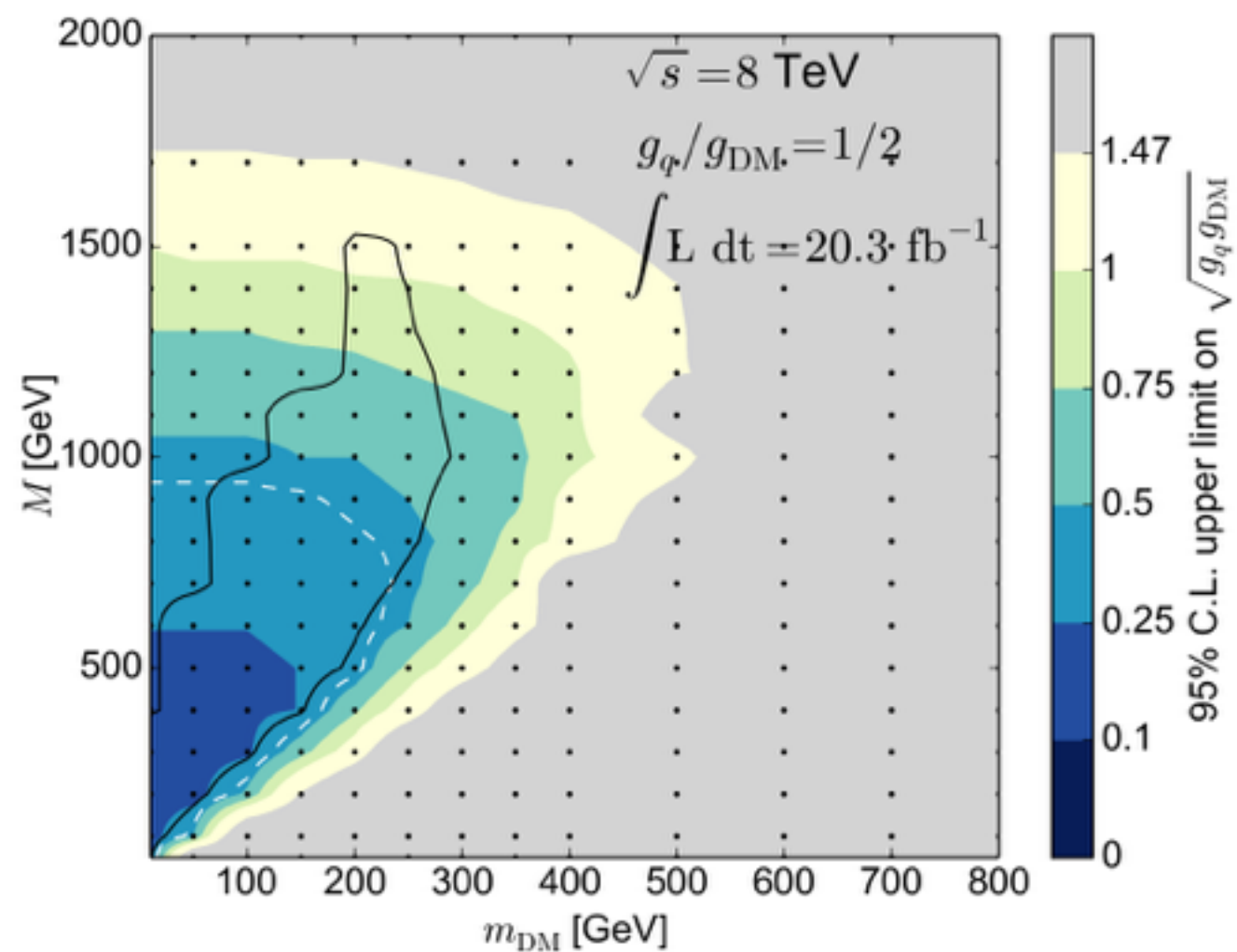
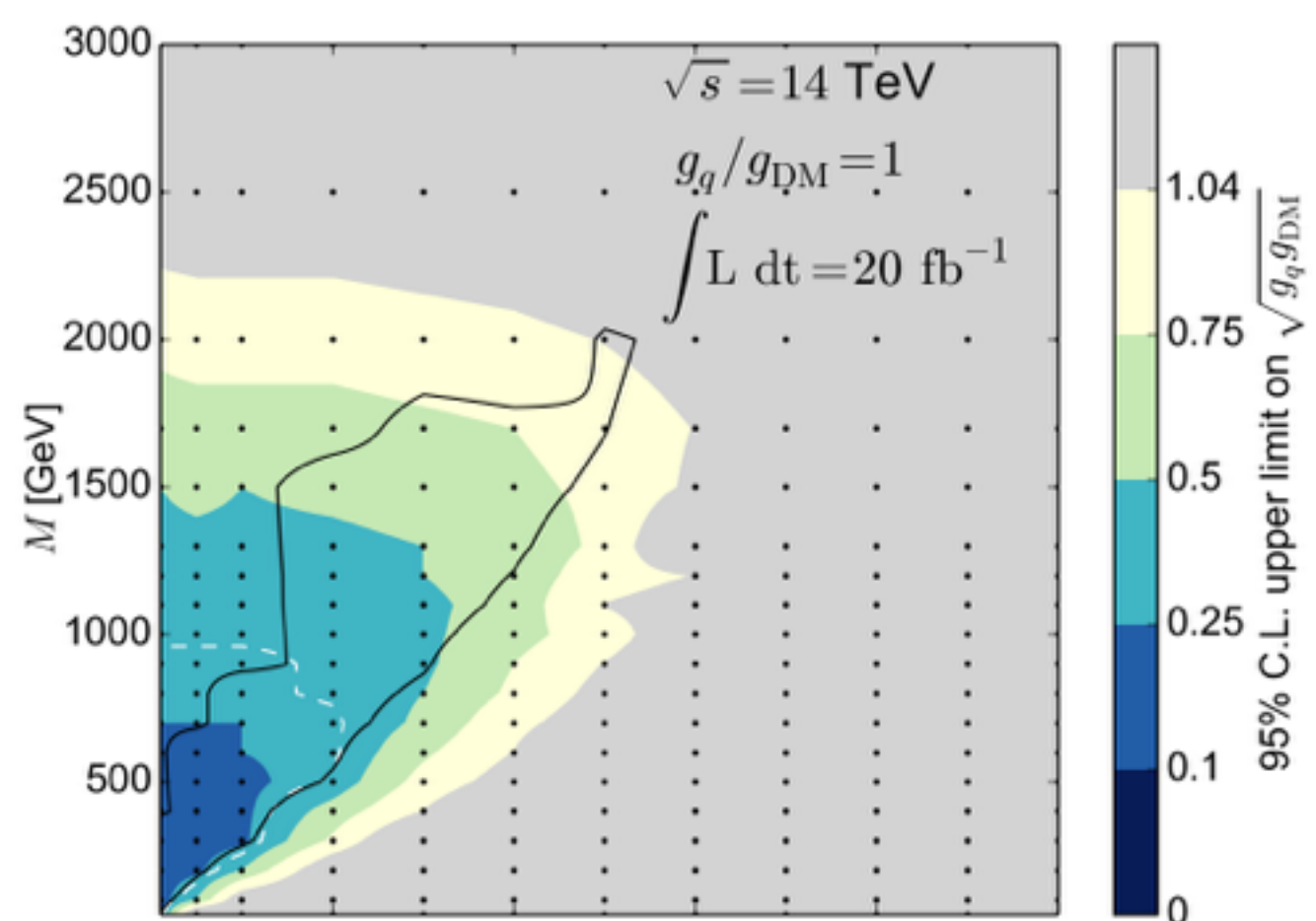
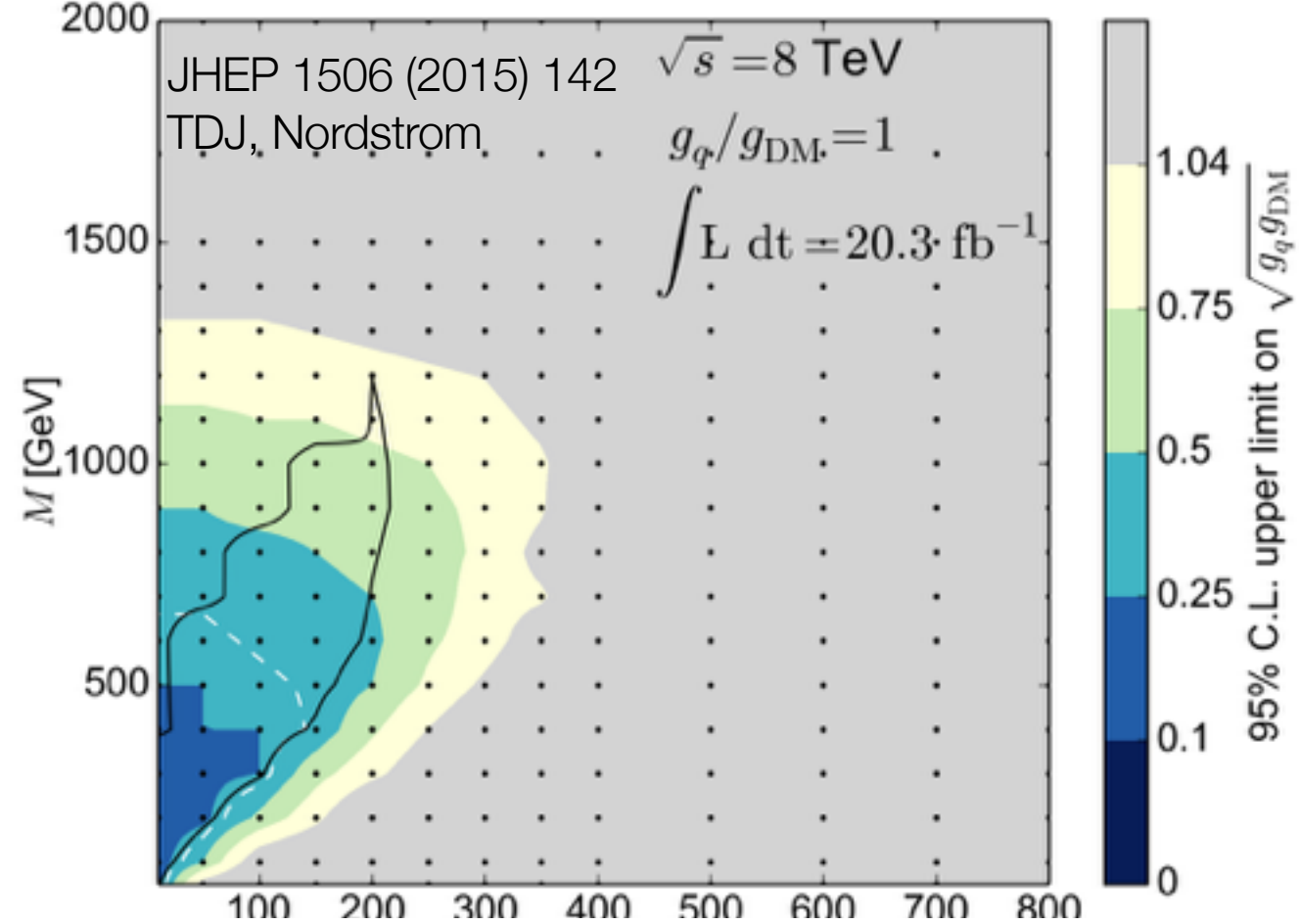
Simplified models

- Some approximations can help

$$\sigma \propto \begin{cases} g_q^2 g_{\text{DM}}^2 / \Gamma_{\text{OS}} & \text{if } M > 2m_{\text{DM}} \\ g_q^2 g_{\text{DM}}^2 & \text{if } M < 2m_{\text{DM}} \end{cases}$$

- Avoids scan over g_q , g_{DM}





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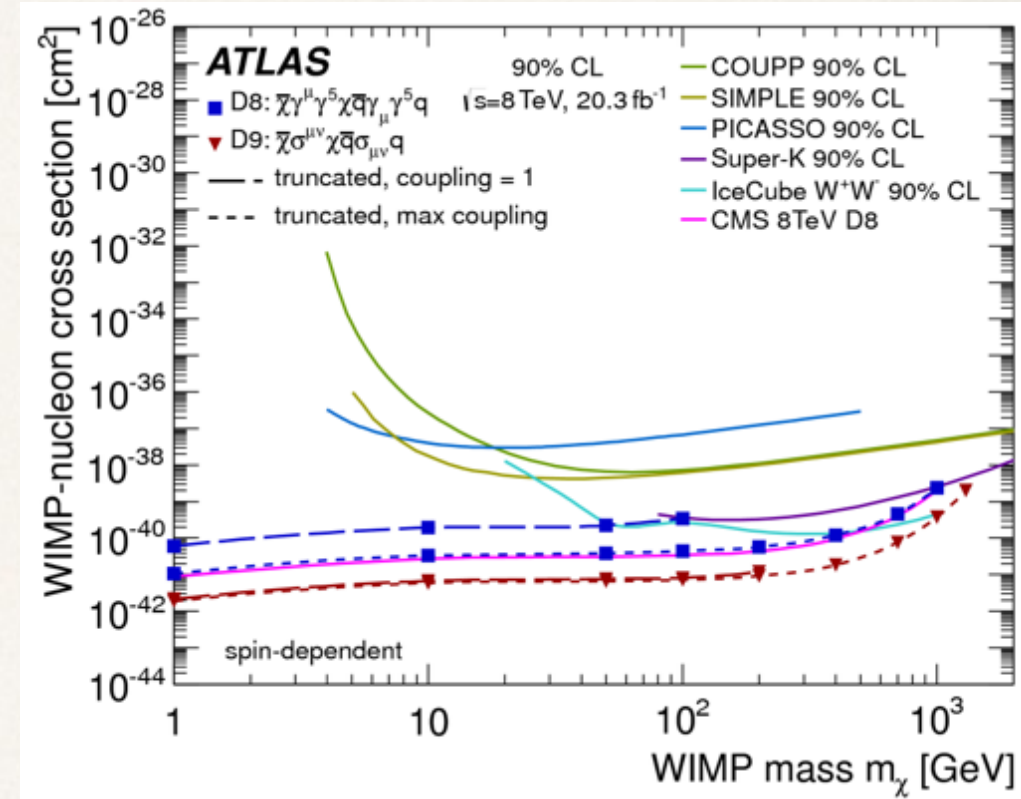
$$\begin{aligned}
 & \bar{\chi} \gamma_\mu \gamma_5 \chi \bar{f} \gamma^\mu f, \quad \bar{\chi} \gamma_\mu \gamma_5 \chi \bar{f} \gamma^\mu \gamma_5 f \\
 \longrightarrow & \underbrace{\vec{s}_\chi \cdot \vec{s}_N}_{\sigma_{SD}}, \quad \underbrace{i \vec{s}_\chi \cdot (\vec{s}_N \times \vec{q})}_{\text{Suppressed}}, \quad \vec{s}_\chi \cdot \vec{v}^\perp
 \end{aligned}$$

σ_{SD} Suppressed, but neither σ_{SI} nor σ_{SD}

IceCube: Using annihilation to probe scattering

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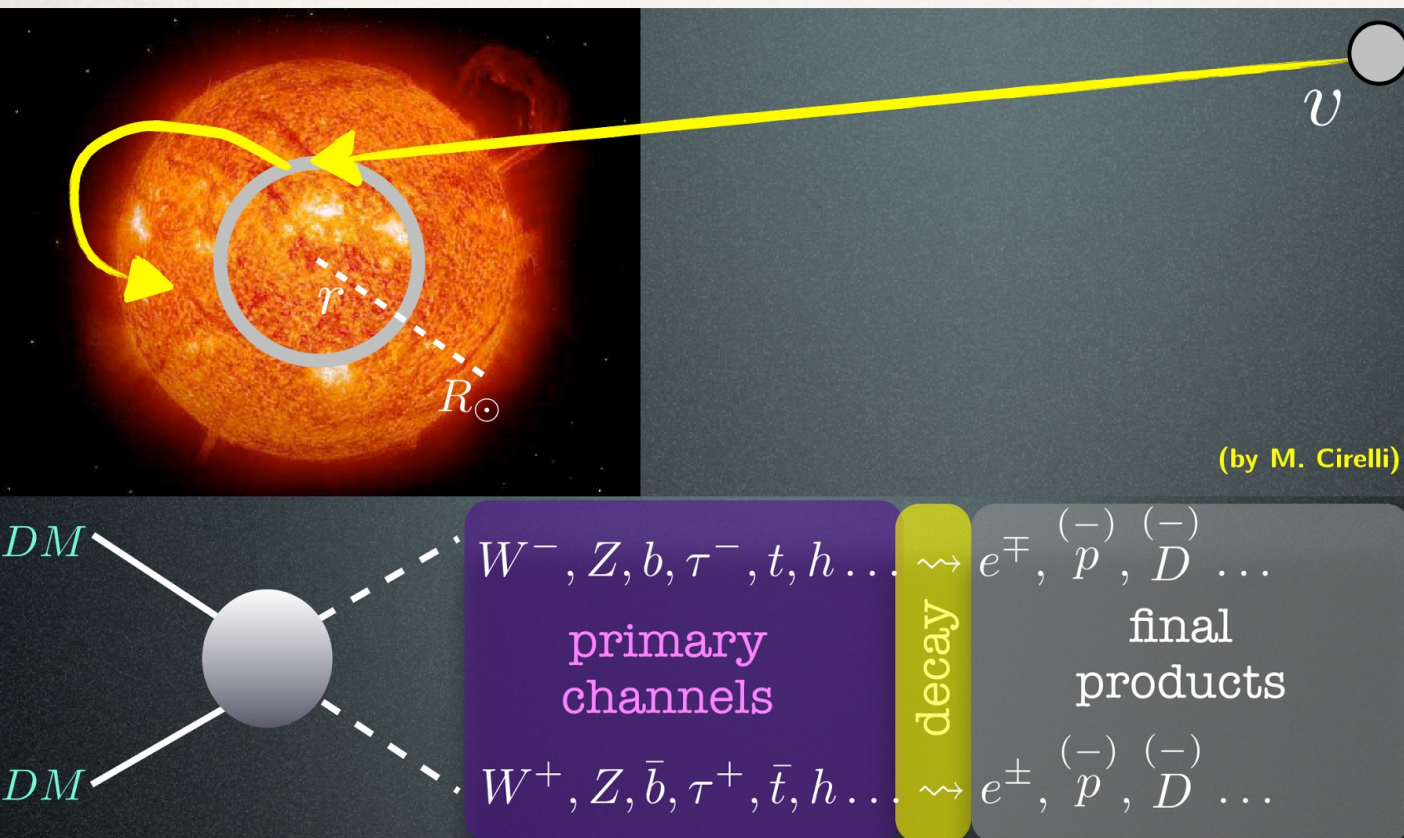
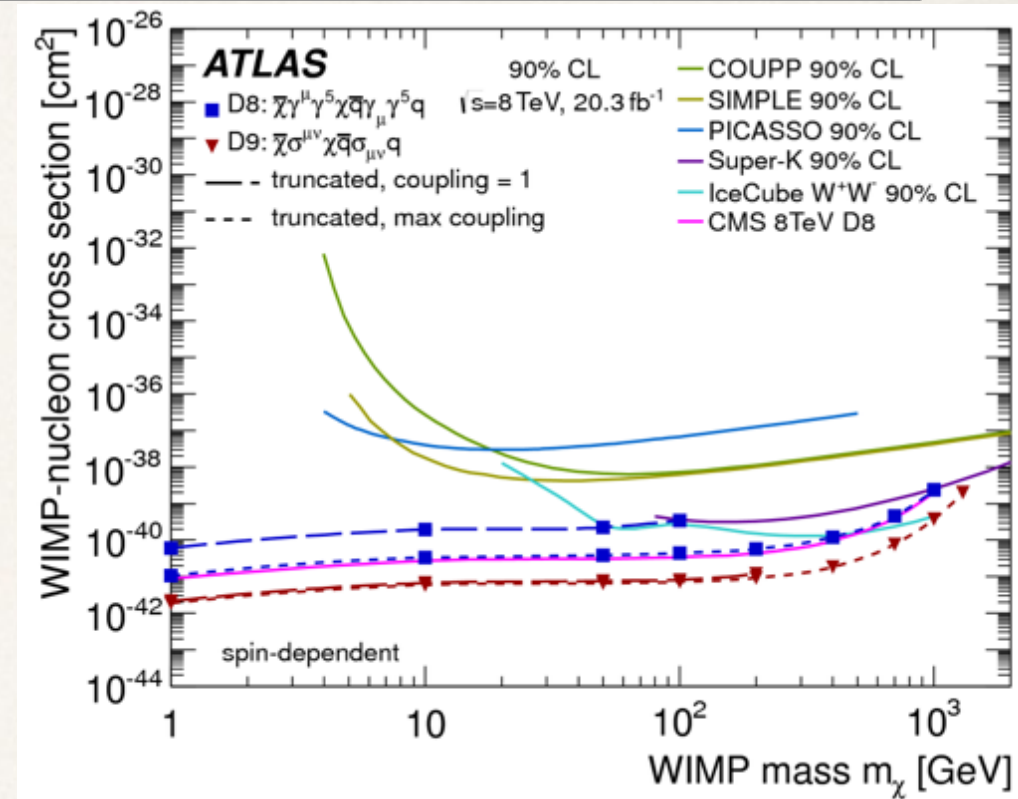
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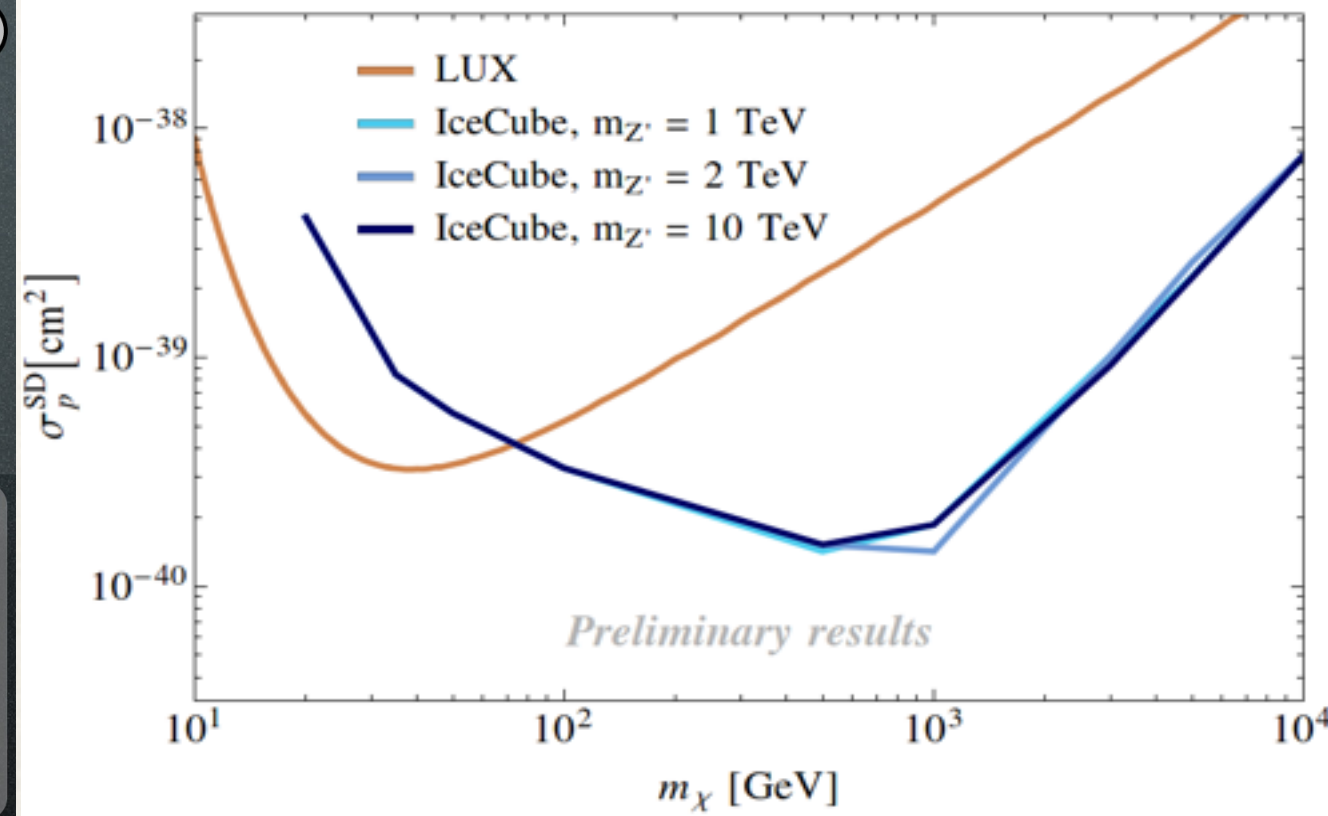
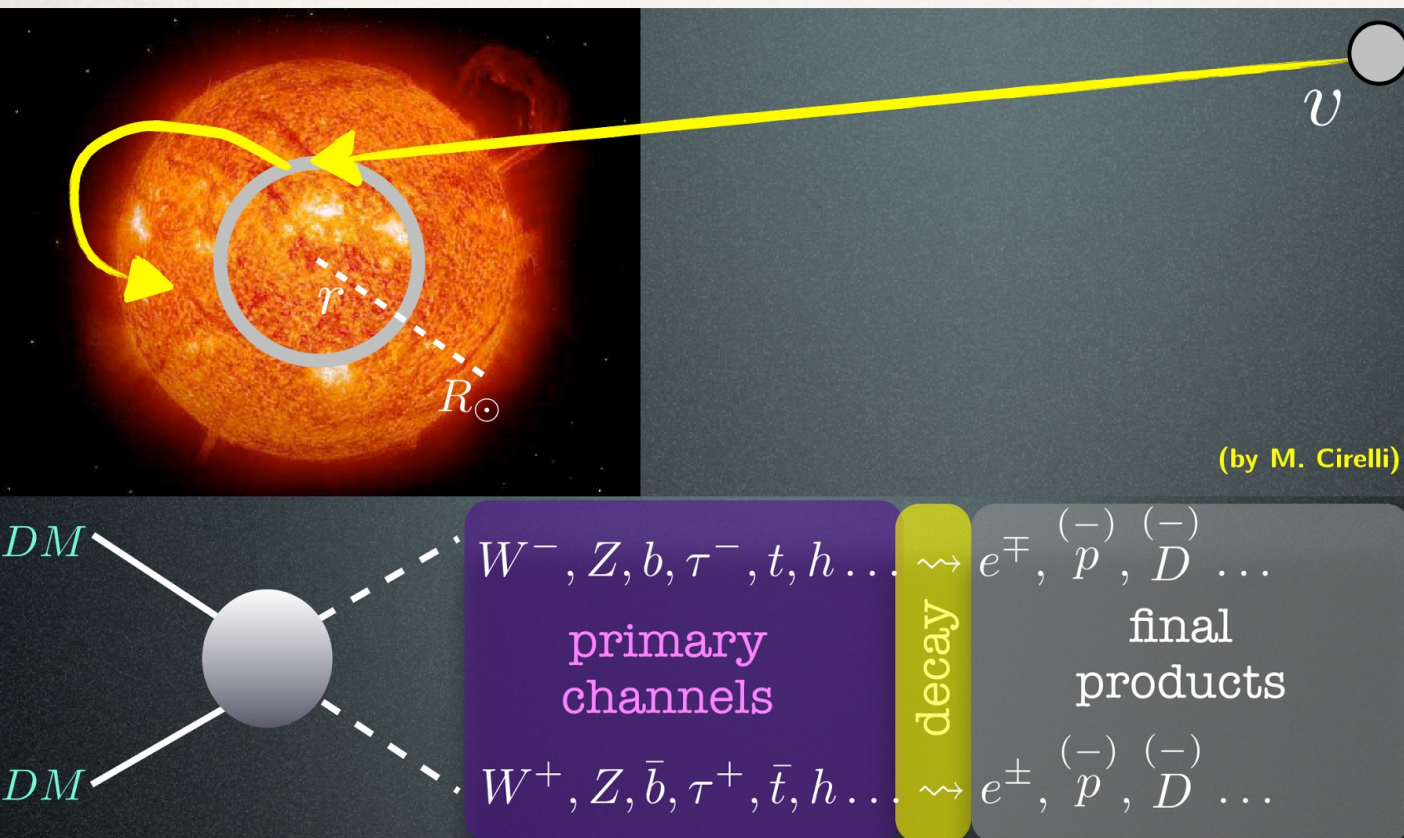
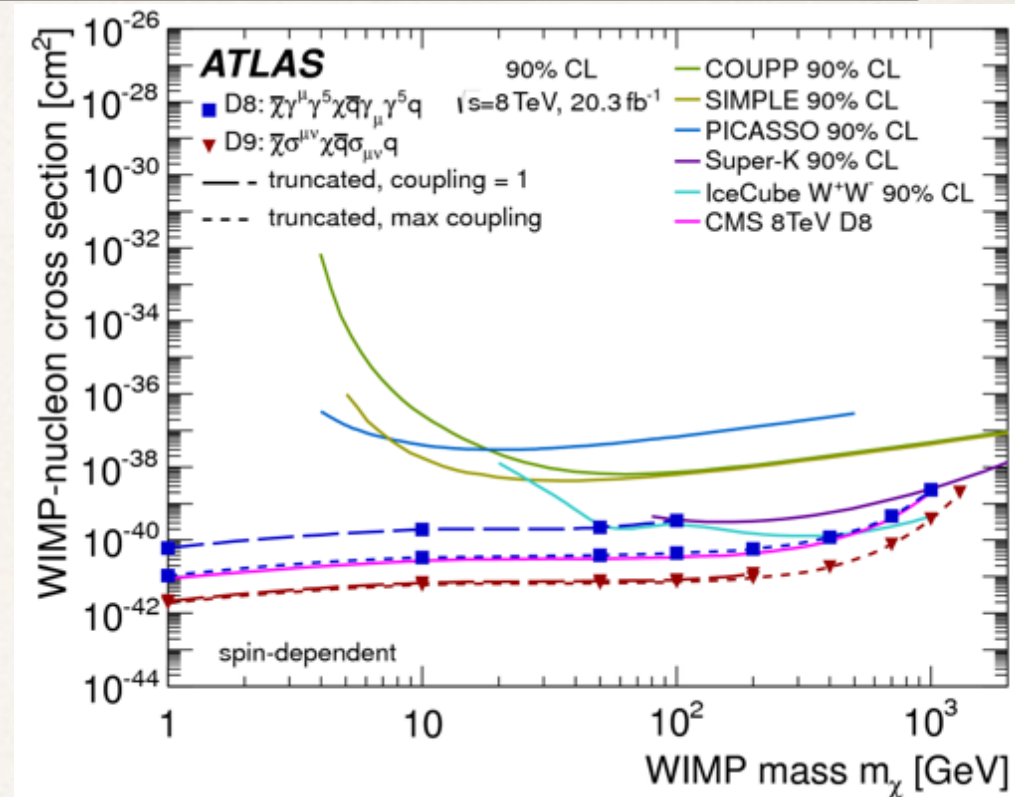
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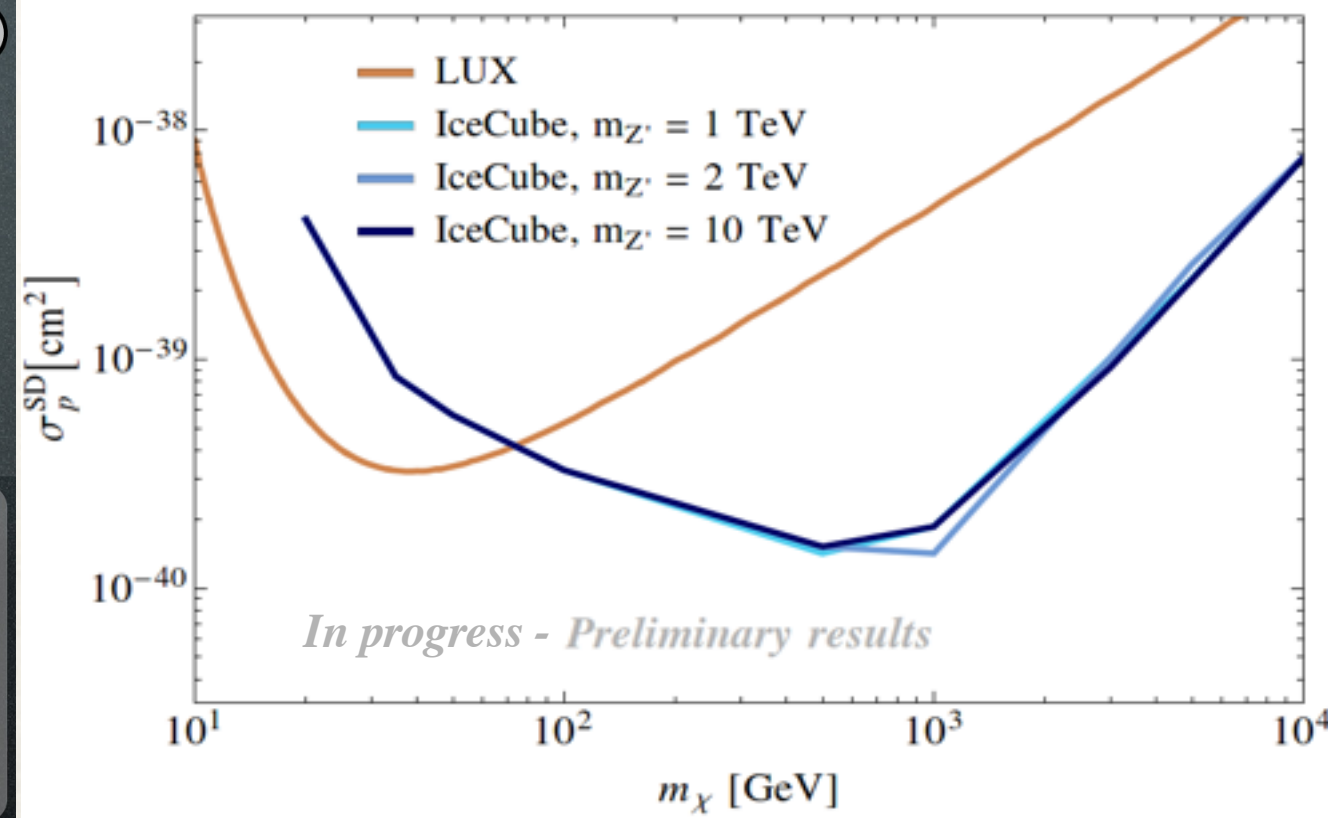
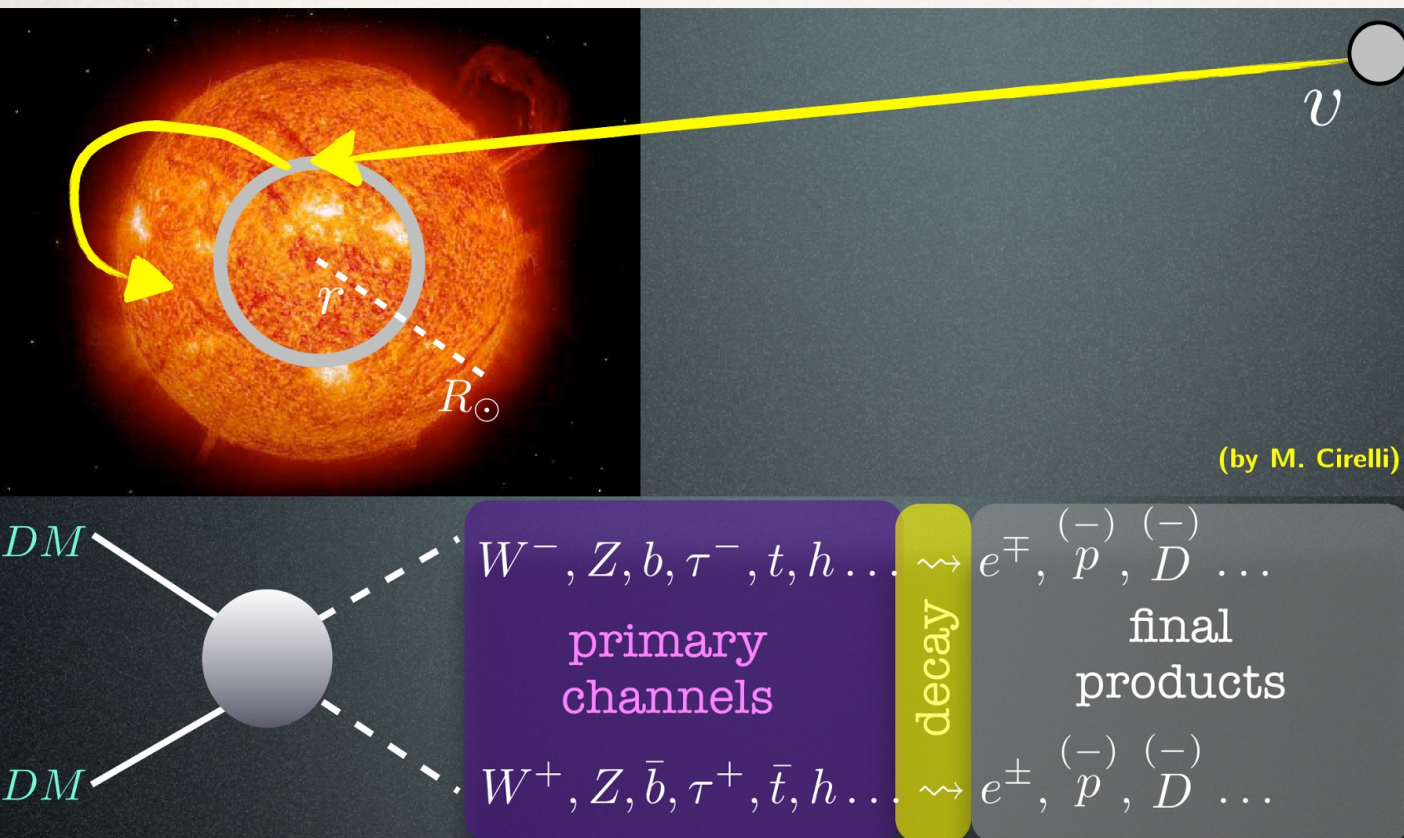
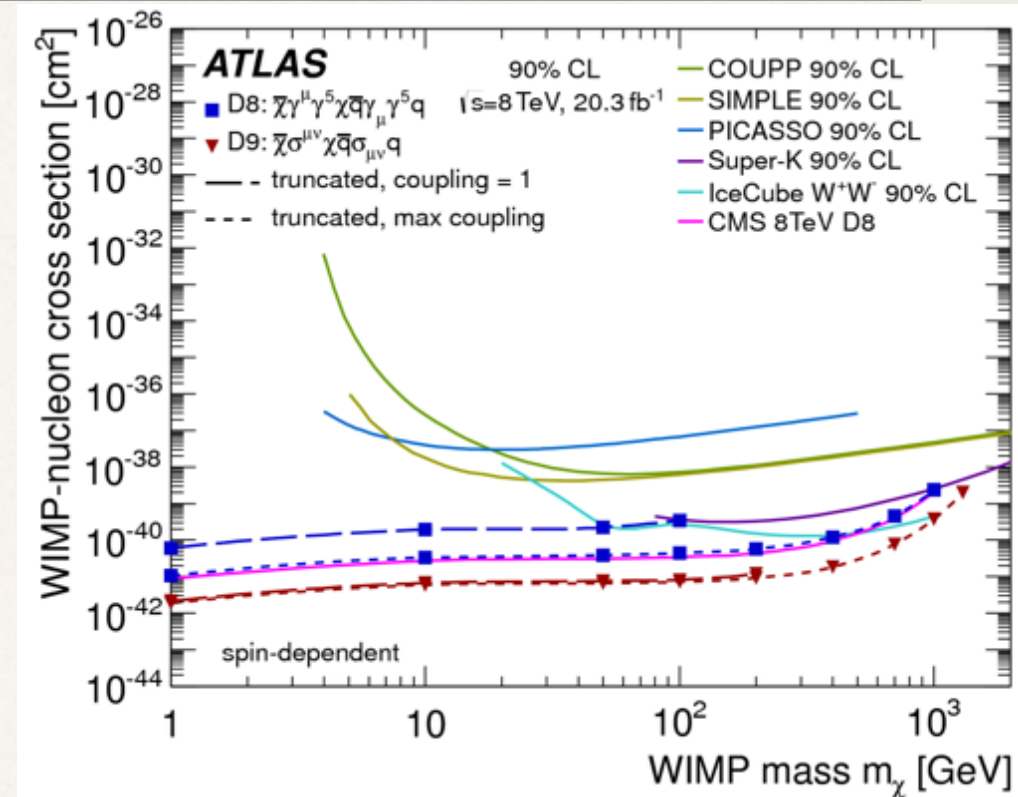
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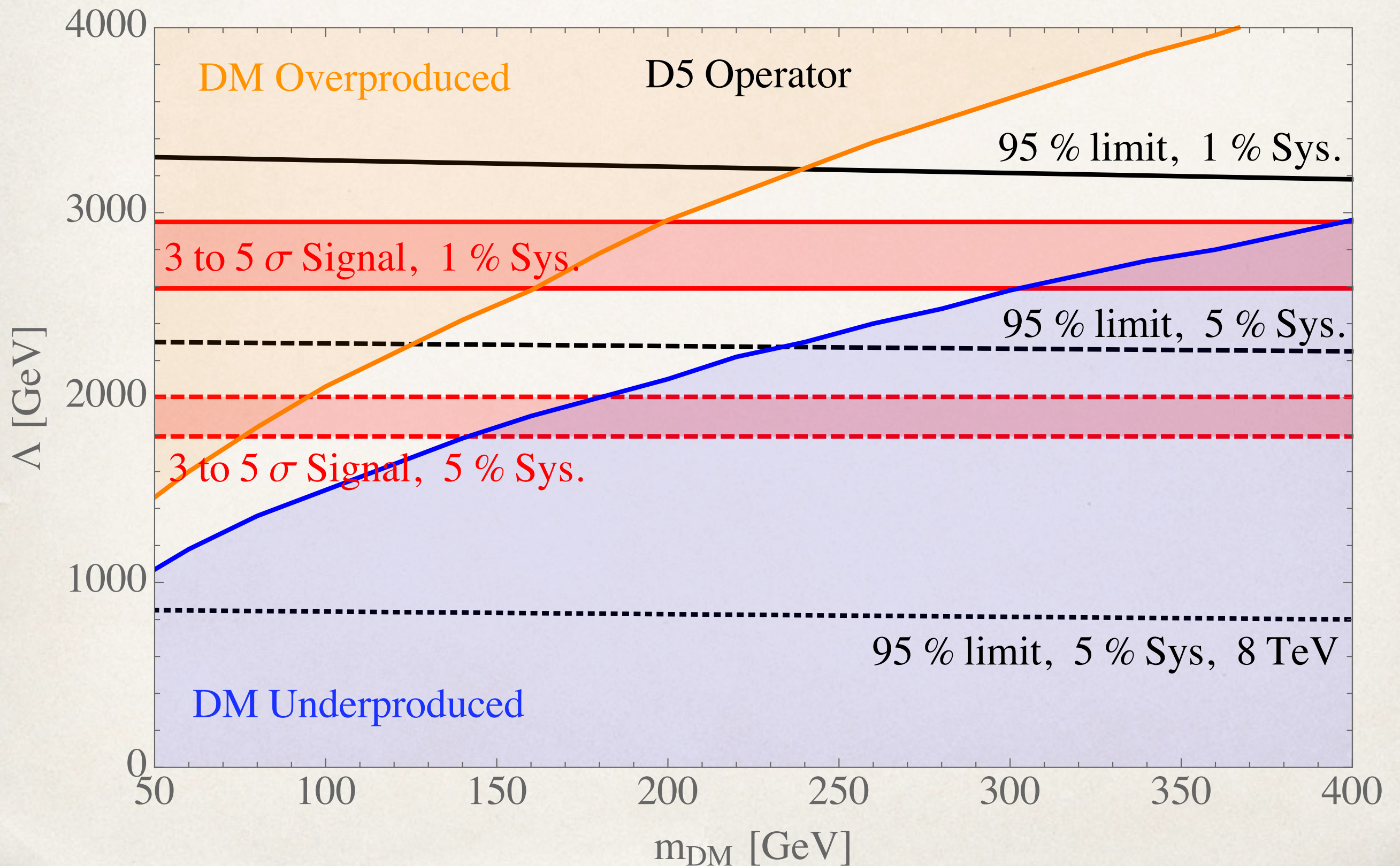


Conclusion

- EFTs remain a useful tool for comparison between experiments, but have limited validity for LHC searches. Move to simplified models is necessary
- The difficulties associated with simplified models are eased by considering all available information and taking a different approach to relic density constraints
- LHC is strongest in searches for models which have suppressed scattering and annihilation rates, but building consistent models is important

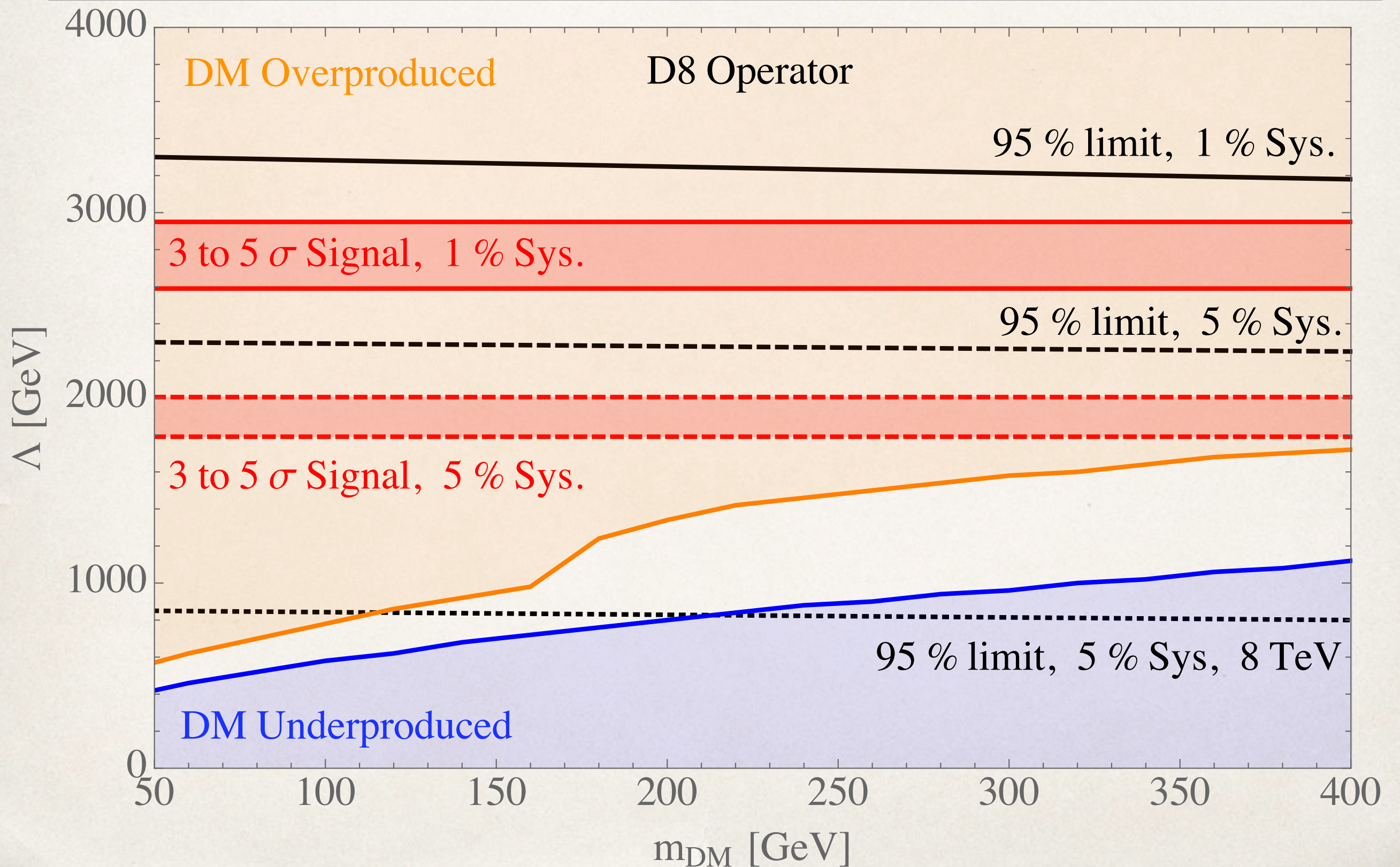
Backup

Effective operator results



Effective operator results

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Simplified model results

