# On the Validity of Effective Operators in WIMP Searches

**Thomas Jacques**

1405.3101 G. Busoni, A. De Simone, TDJ, E. Morgante, A. Riotto
1402.1275 Busoni, De Simone, Gramling, Morgante, Riotto
1307.2253 Busoni, De Simone, Morgante, Riotto

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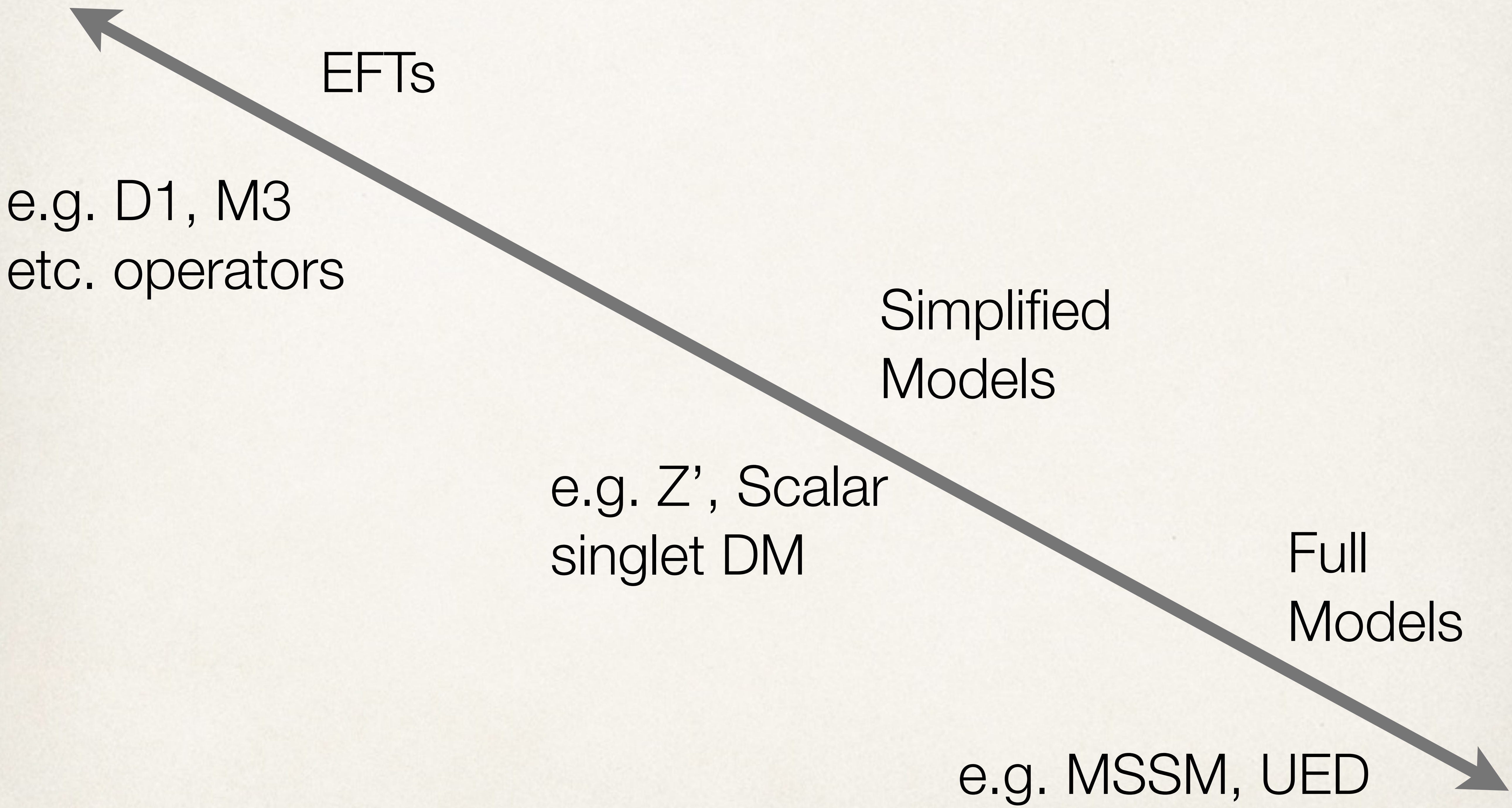
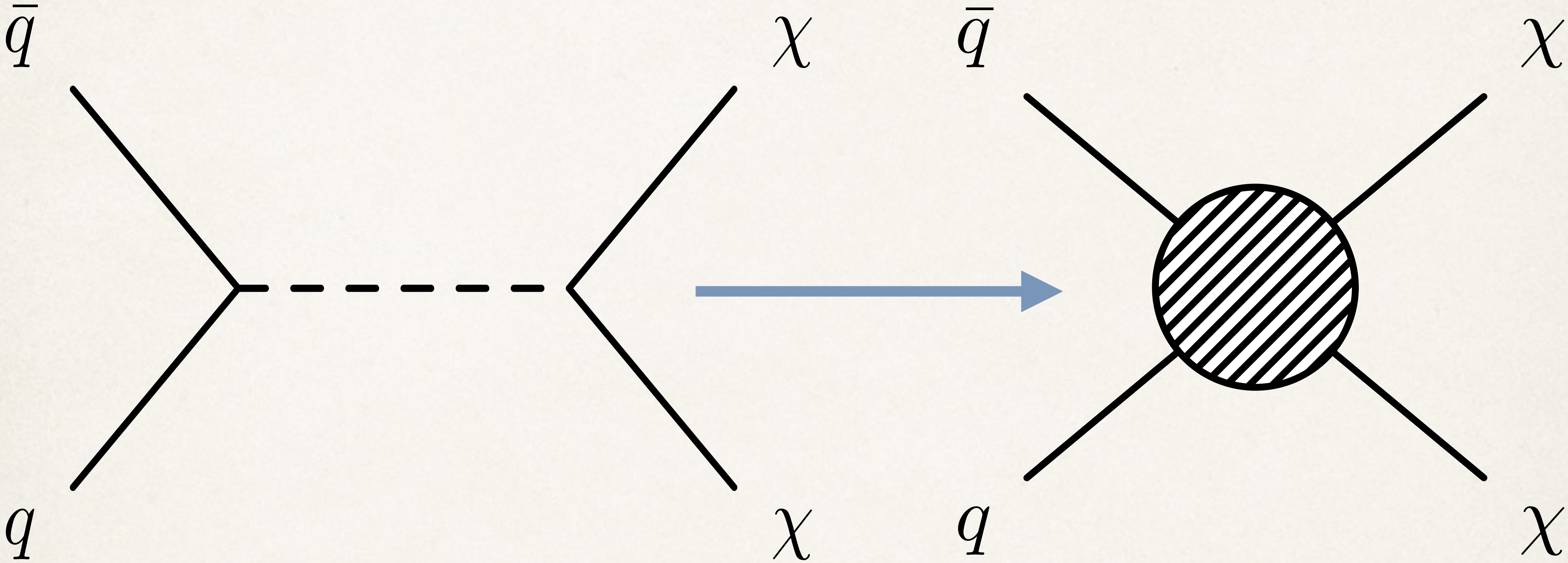
Center for Astroparticle Physics GENEVA

2014-07-03
Geneva

# What to constrain?



# Effective Operators

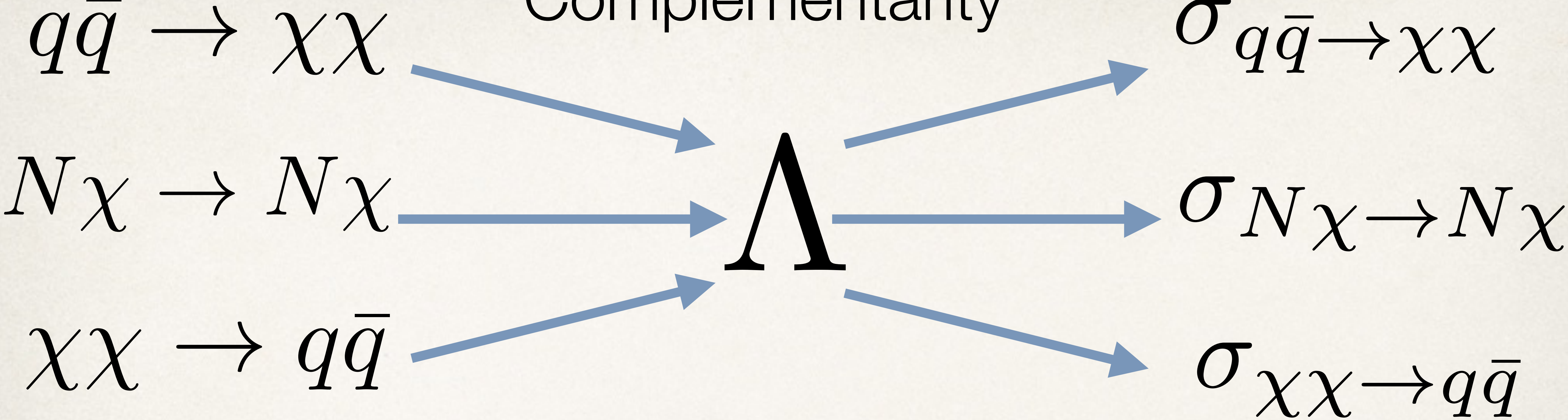


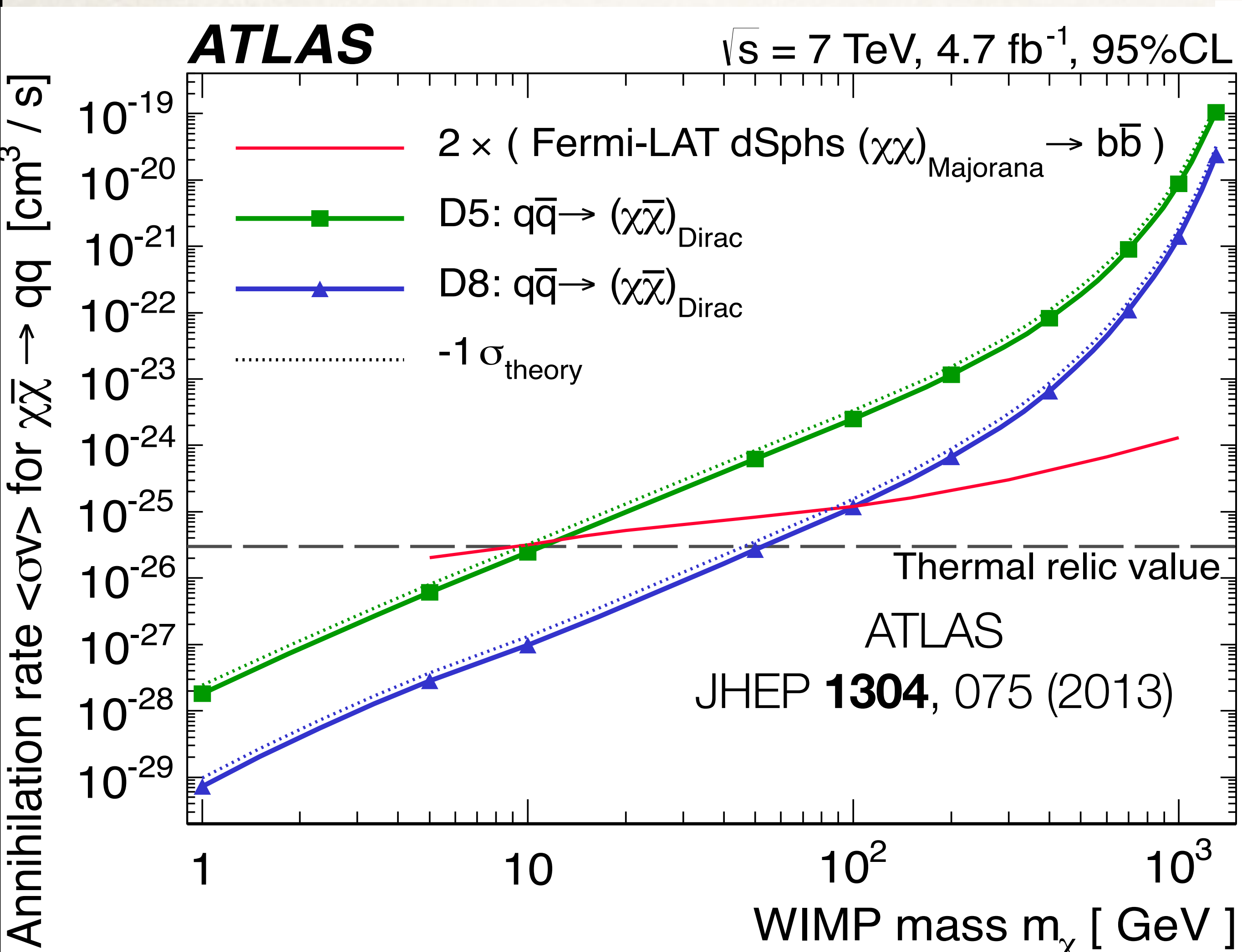

$$\frac{g_a g_b}{Q_{\rm tr}^2 - M^2} = -\frac{g_a g_b}{M^2}\left(1 + \frac{Q_{\rm tr}^2}{M^2} + \mathcal{O}\left(\frac{Q_{\rm tr}^4}{M^4}\right)\right) \simeq -\frac{1}{\Lambda^2}$$

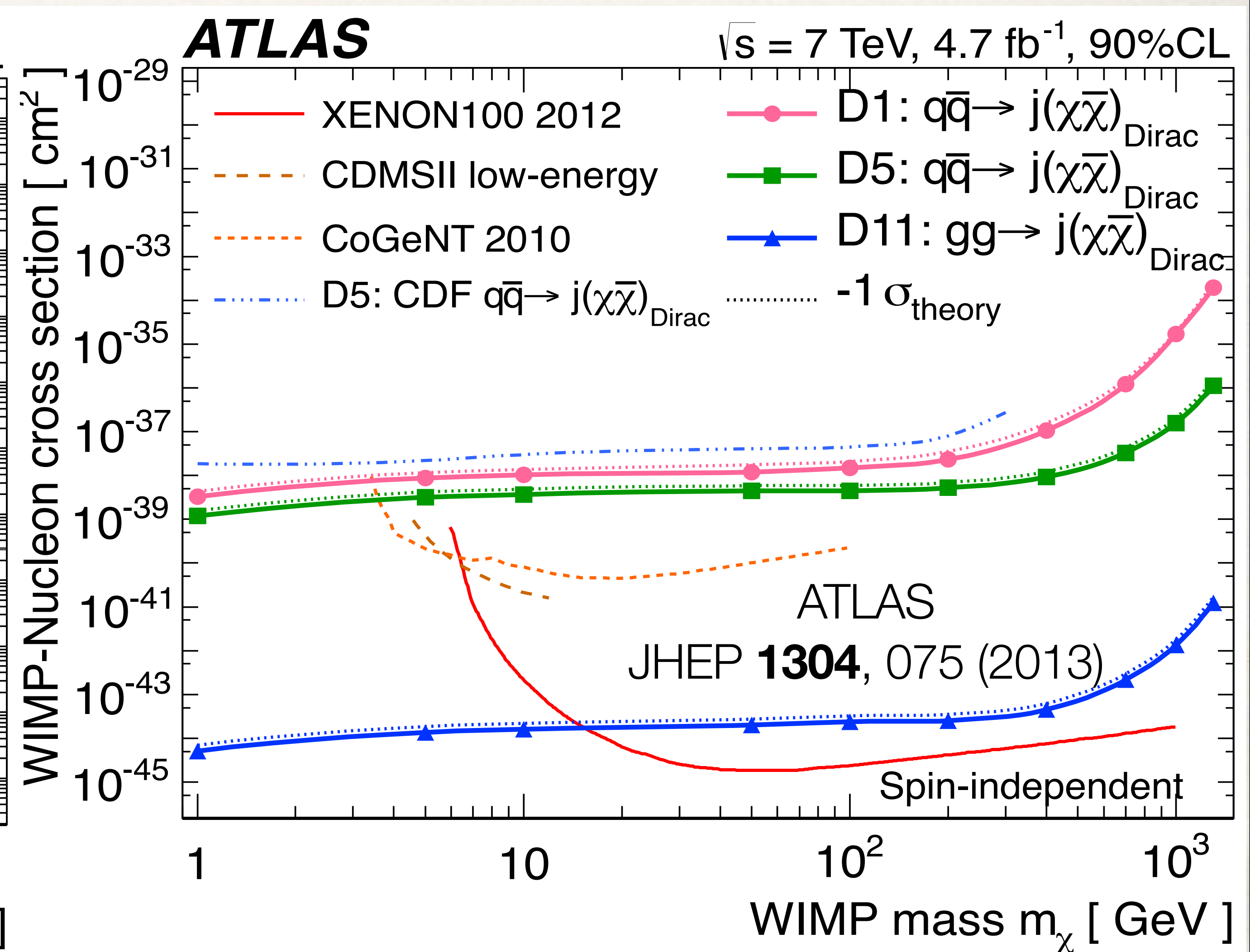
$$\mathrm{D1} = (\bar{\chi}\chi)(\bar{q}q) \qquad \mathrm{M1} = (\chi\chi)(\bar{q}q)$$

$$\mathrm{D5} = (\bar{\chi}\gamma^\mu\chi)(\bar{q}\gamma_\mu q) \qquad \mathrm{C1} = (\chi^\dagger\chi)(\bar{q}q)$$

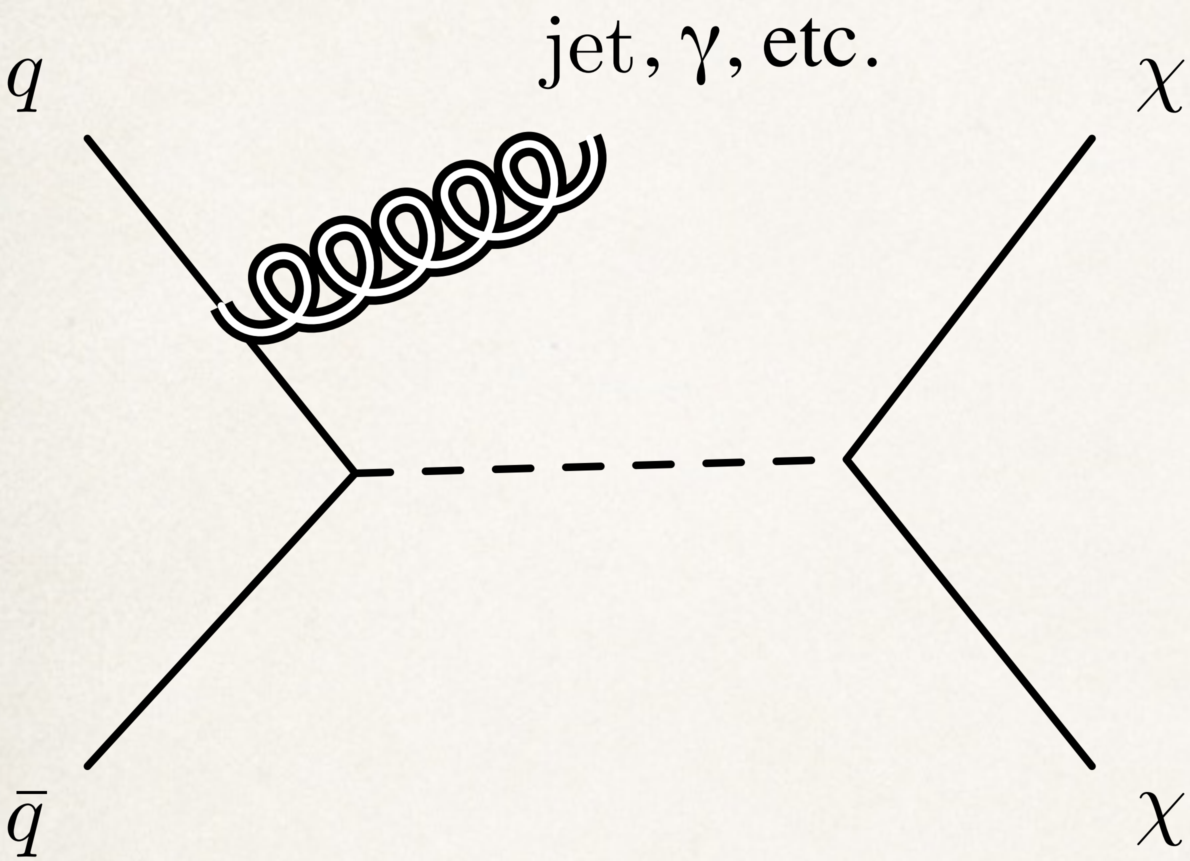
# Complementarity

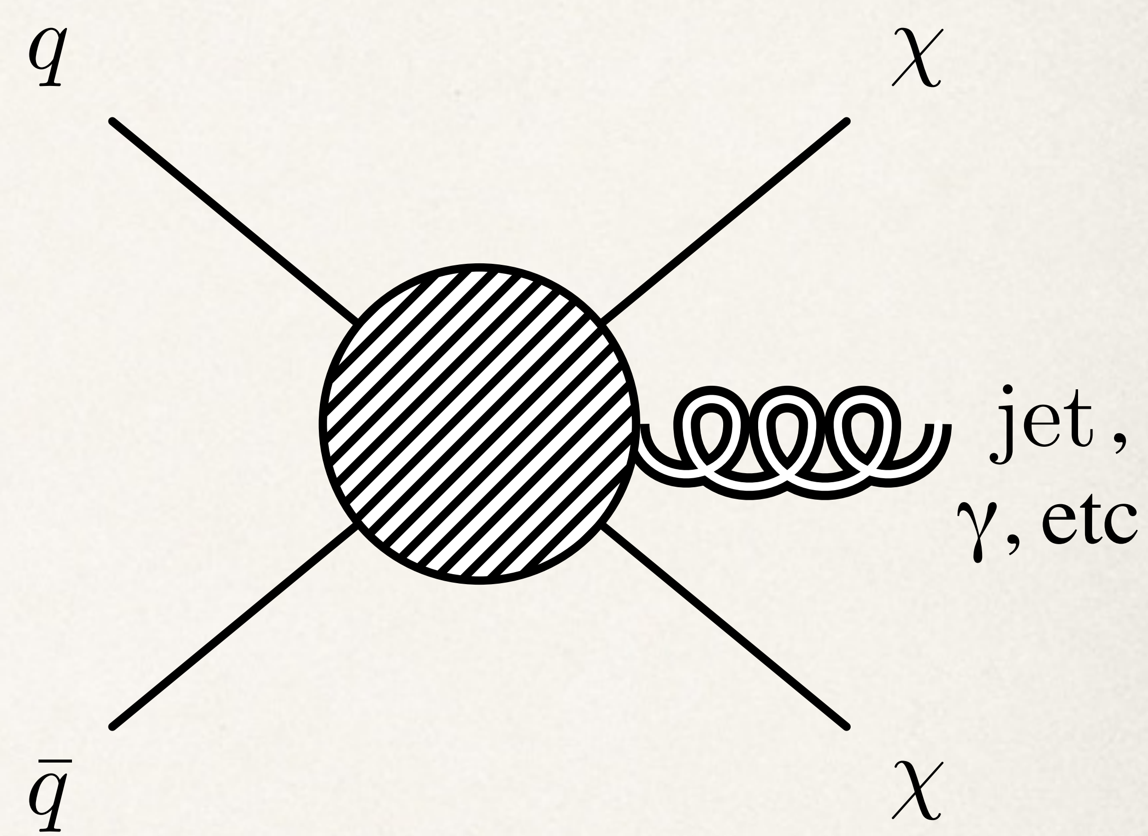


# Measuring the Validity

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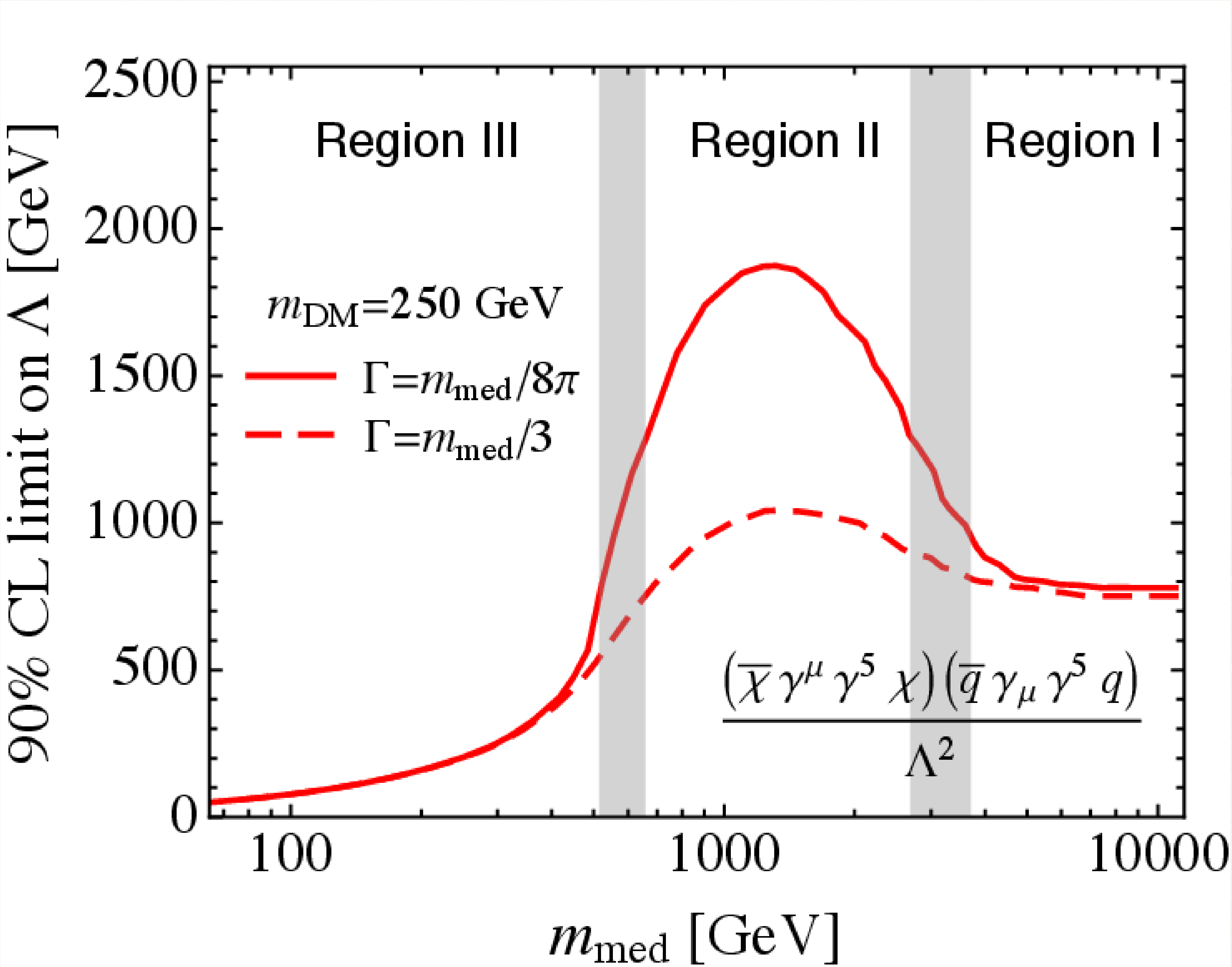


Buchmueller, Dolan, McCabe, arXiv: 1308.6799

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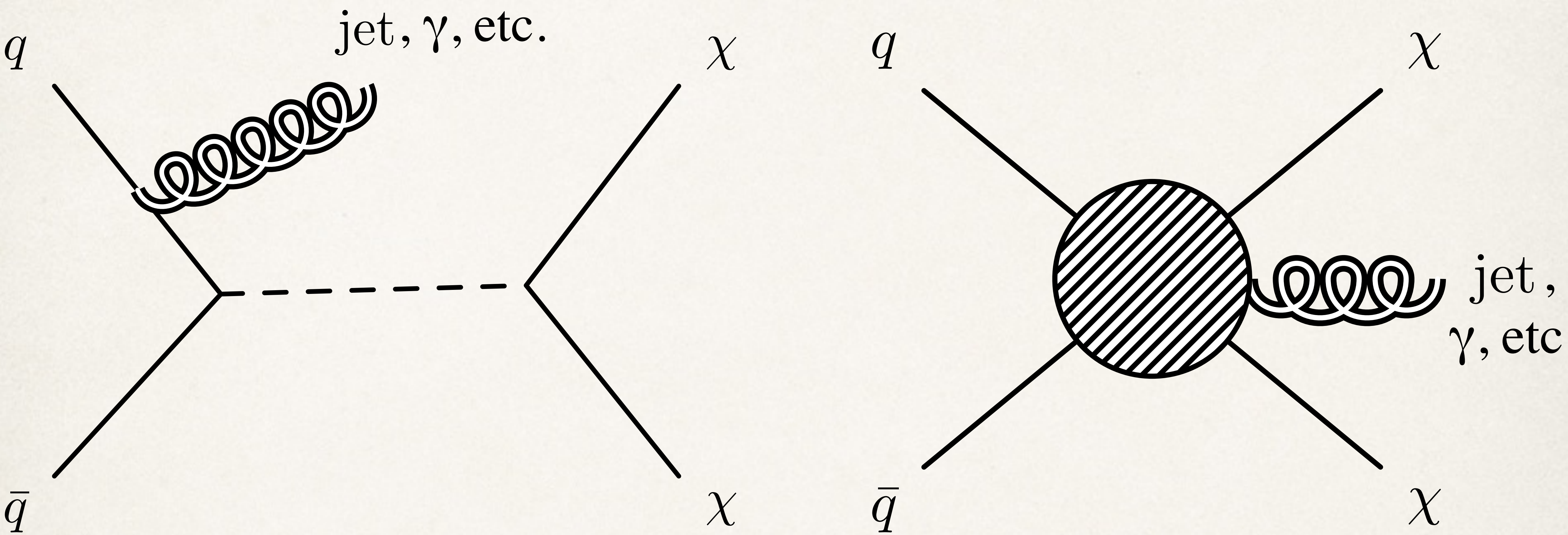


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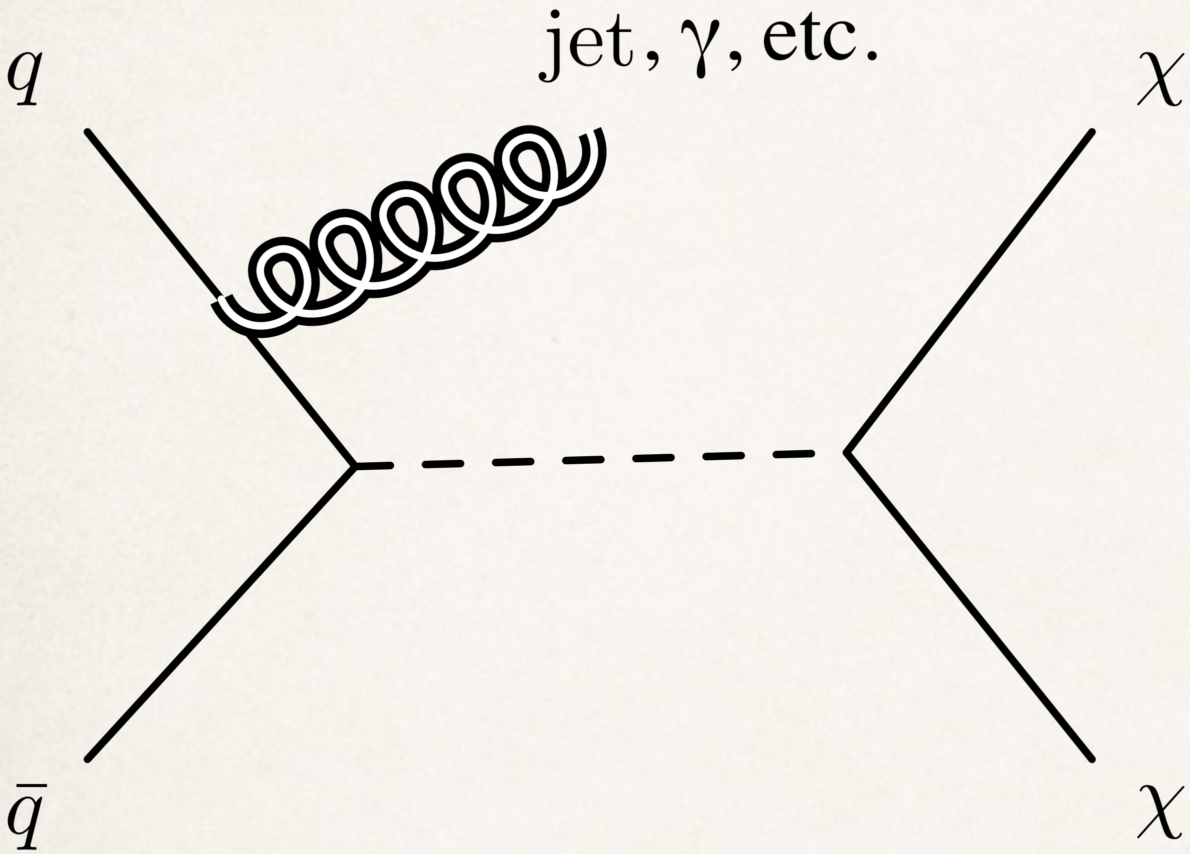


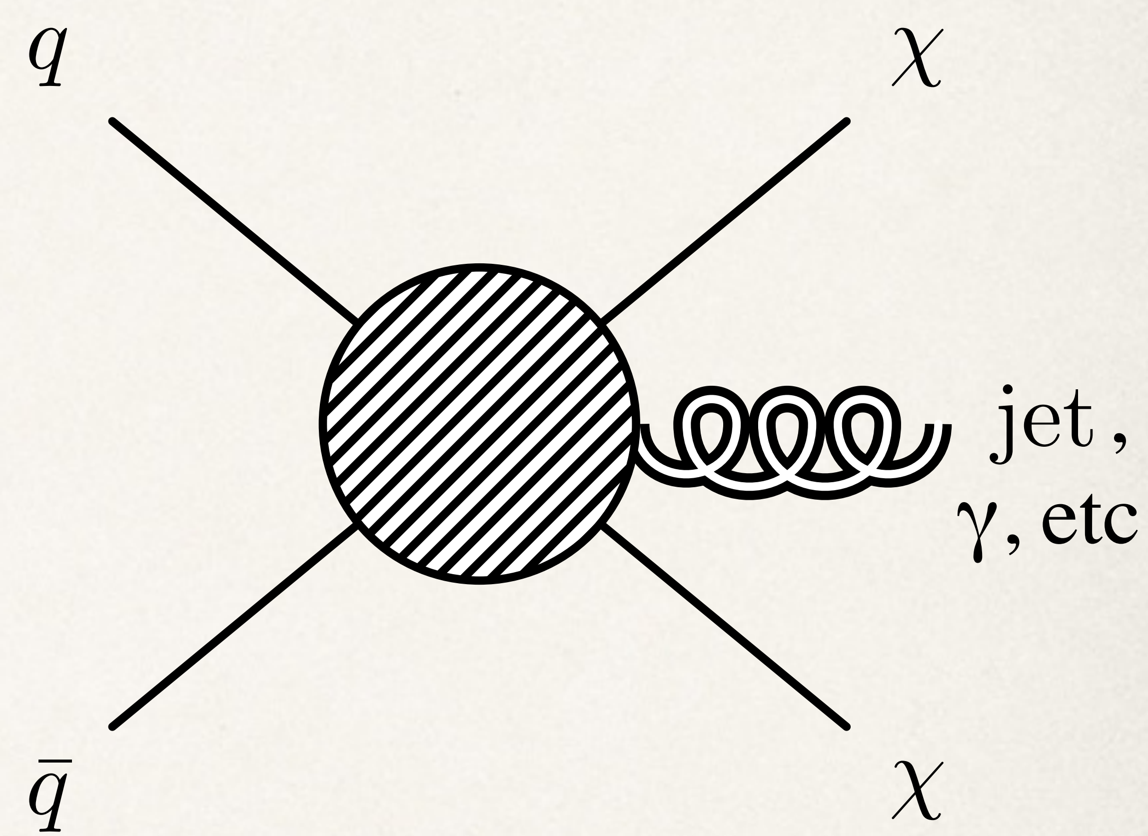


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$$\Lambda \gtrsim \frac{m_{\rm DM}}{2\pi}$$

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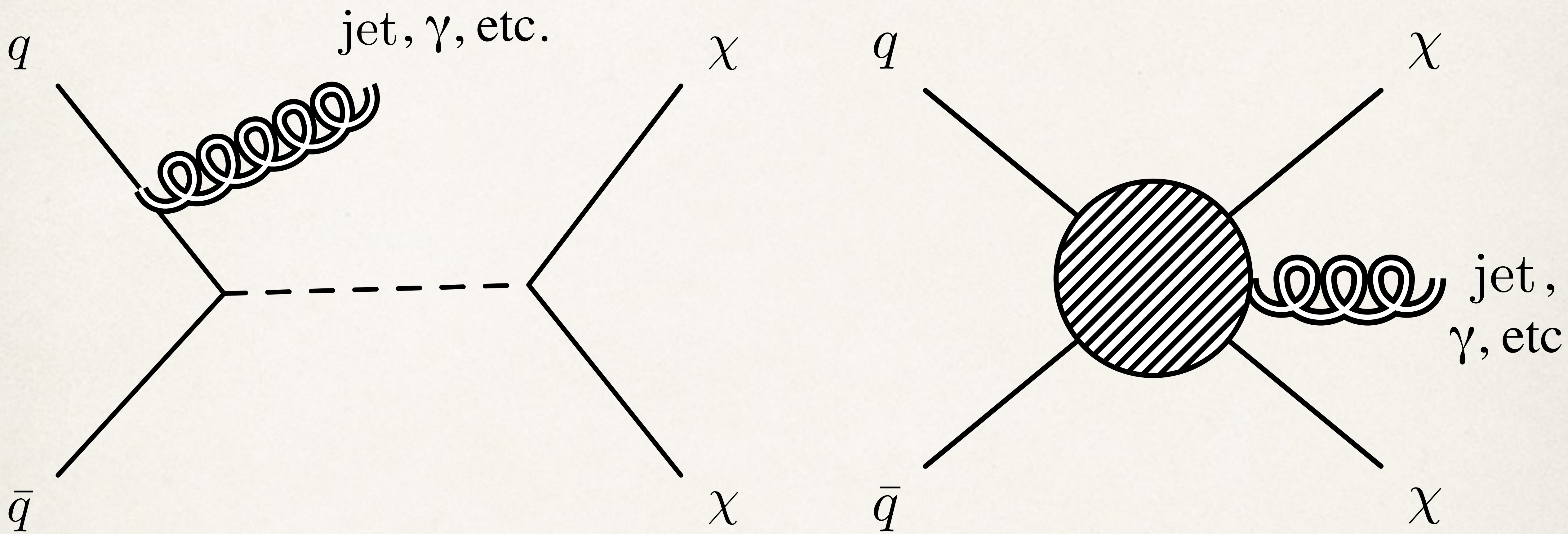


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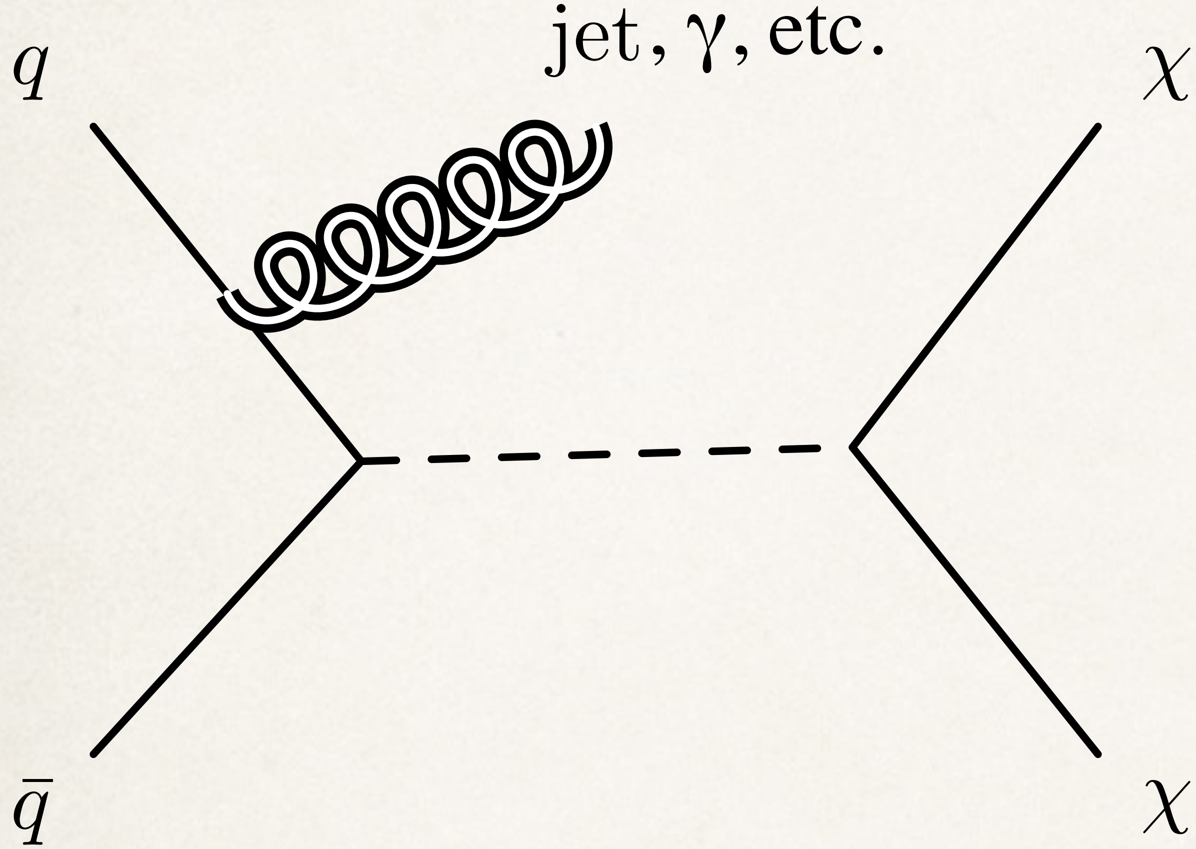


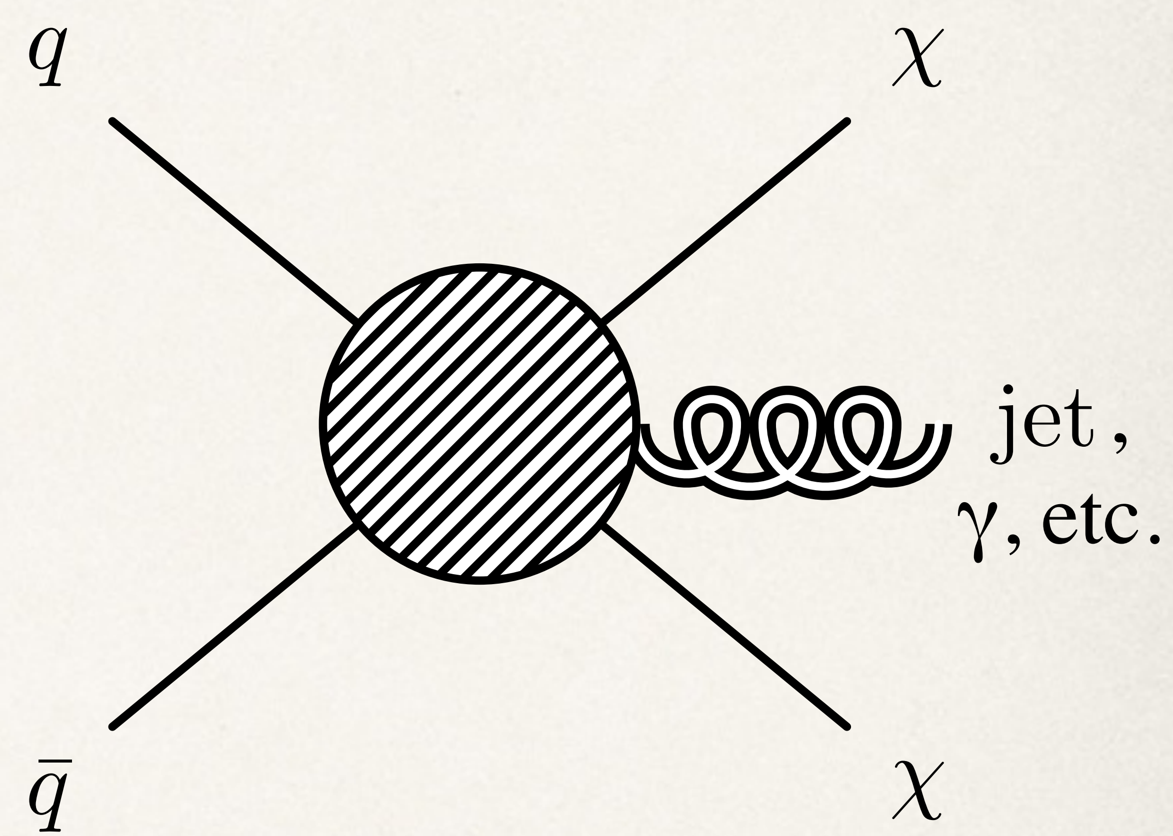


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$$Q_{\rm tr} < M$$

# Measuring the Validity

- EFT approximation:

$$\frac{M^2}{g_a g_b} \equiv \Lambda^2$$

- Best case scenario:

$$\sqrt{g_a g_b} \simeq 4\pi,\ Q_{\rm tr} \lesssim 4\pi\Lambda$$

- Reasonably robust scenario:

$$g_a g_b \simeq 1,\ Q_{\rm tr} \lesssim \Lambda$$

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Calculate or measure the fraction of events that pass the condition $Q_{tr} < \Lambda$, for a given choice of $\Lambda$ and $m_{DM}$

$$R_{\Lambda}^{\rm tot} = \frac{\sigma_{\rm eff}\big|_{\Lambda > Q_{\rm tr}}}{\sigma_{\rm eff}}$$

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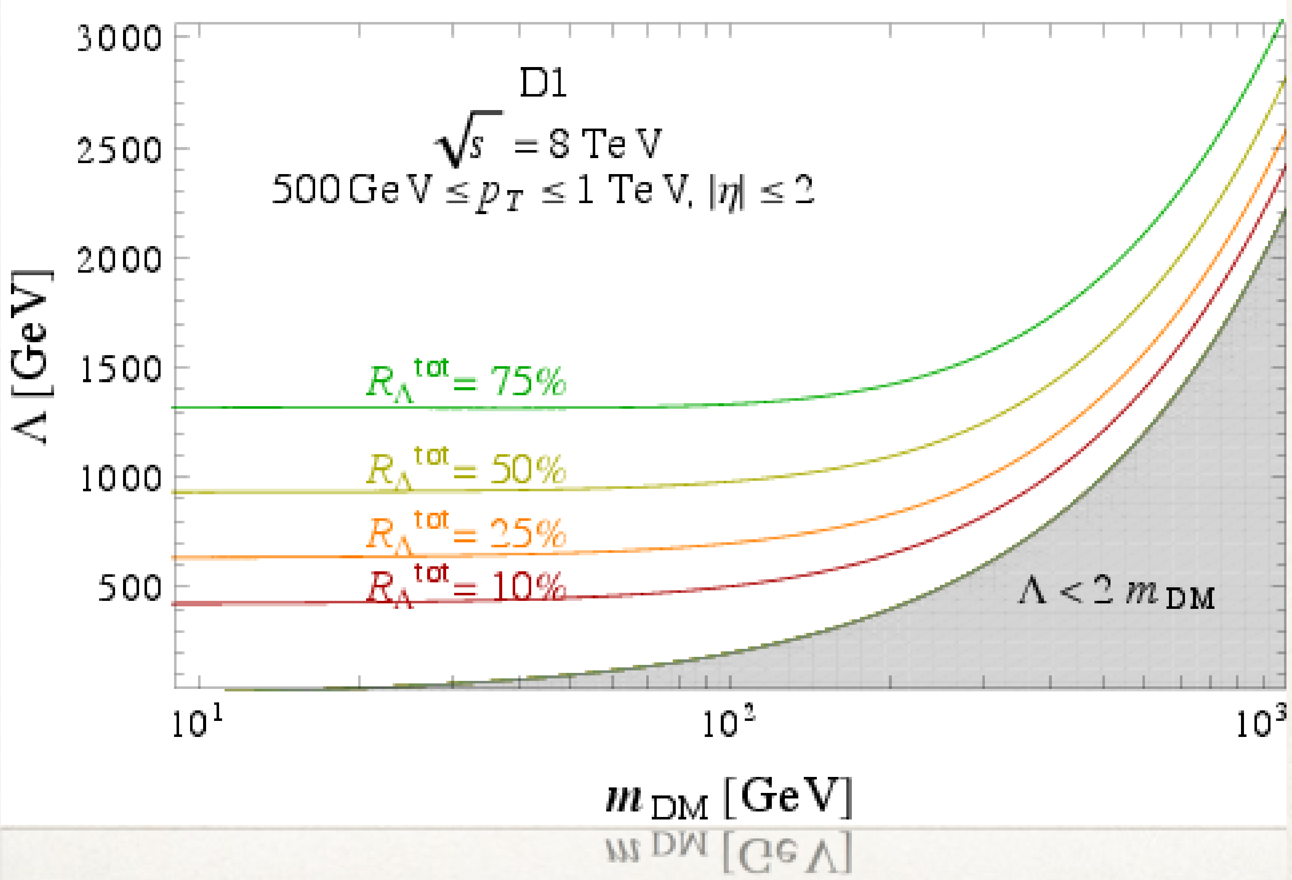


G. Busoni, A. De Simone, J. Gramling, E. Morgante, A. Riotto
arXiv:1402.1275

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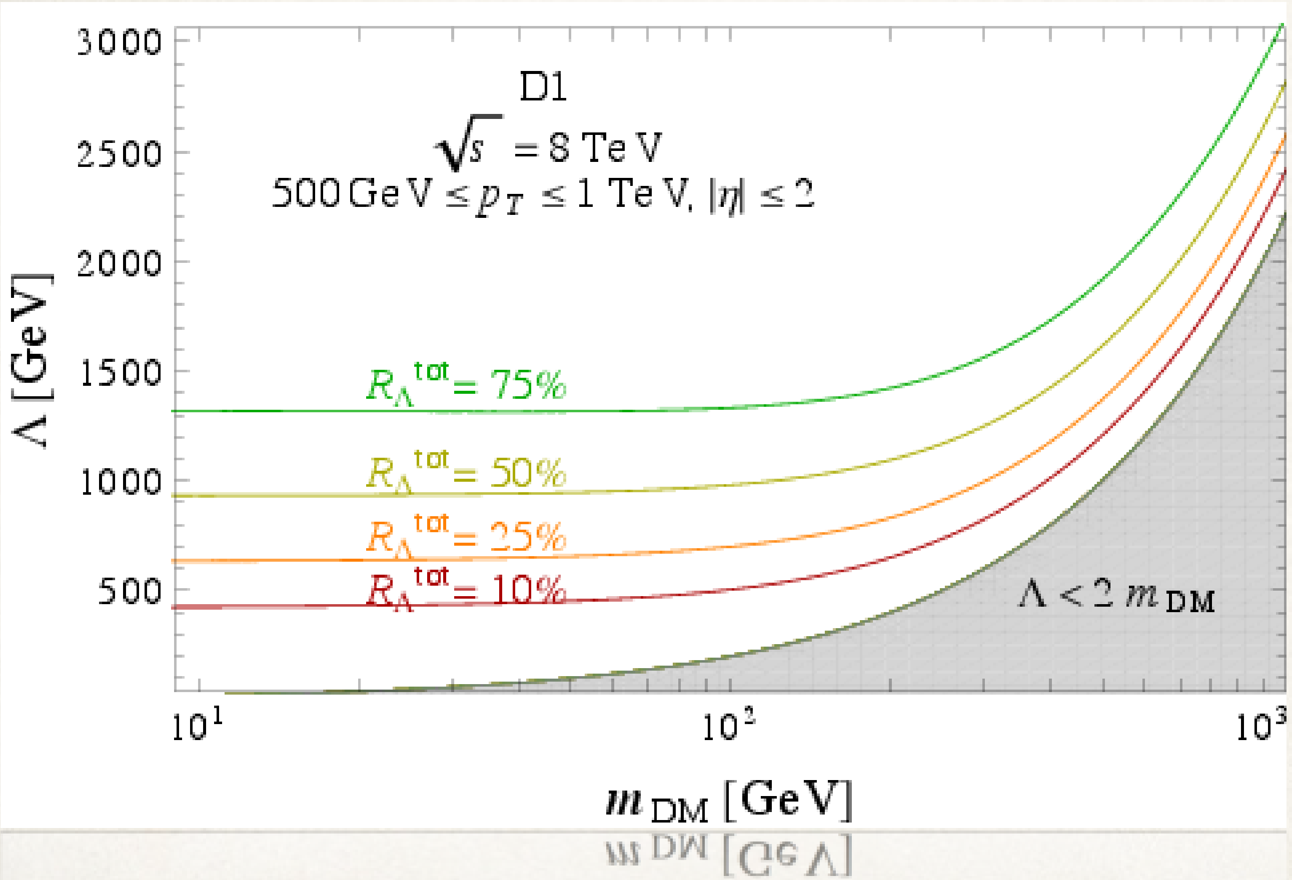


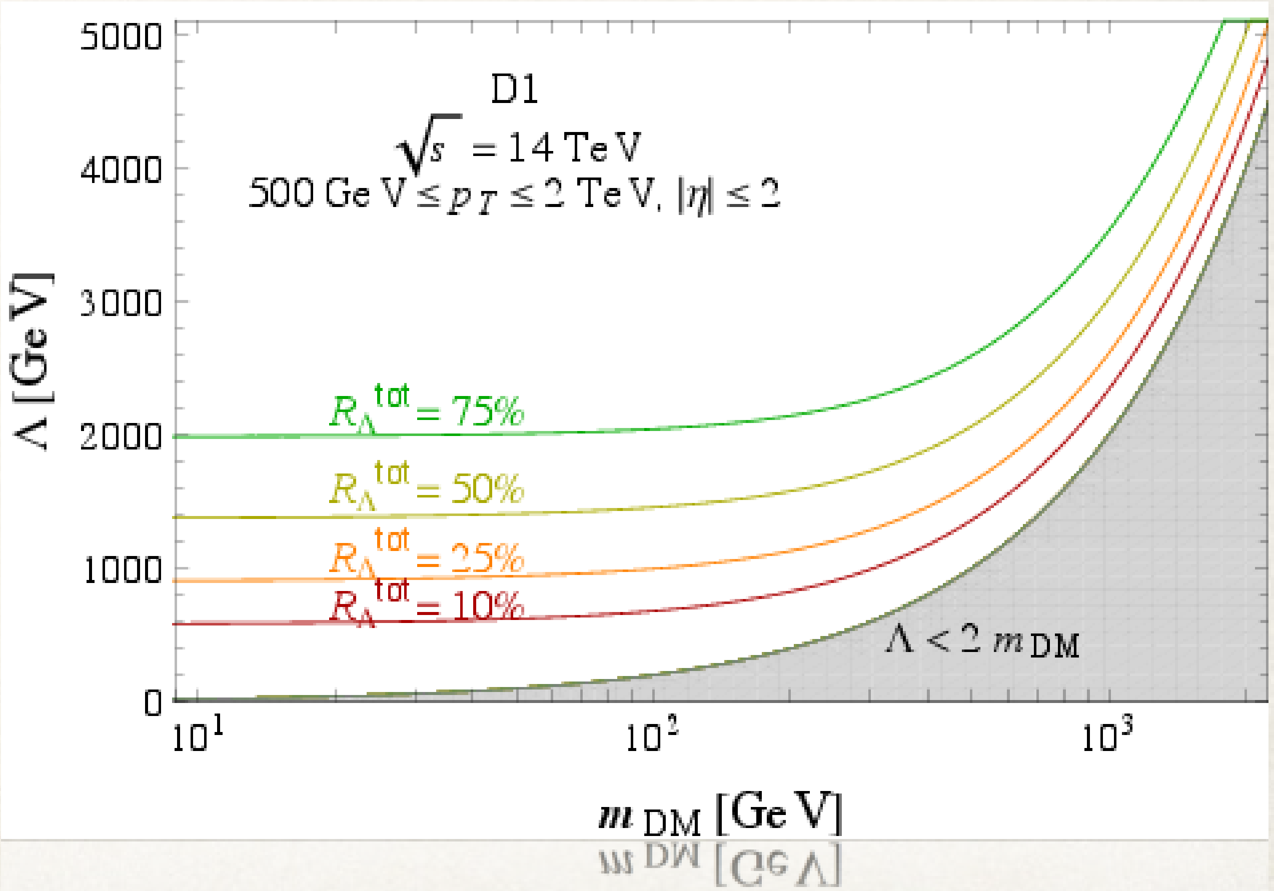


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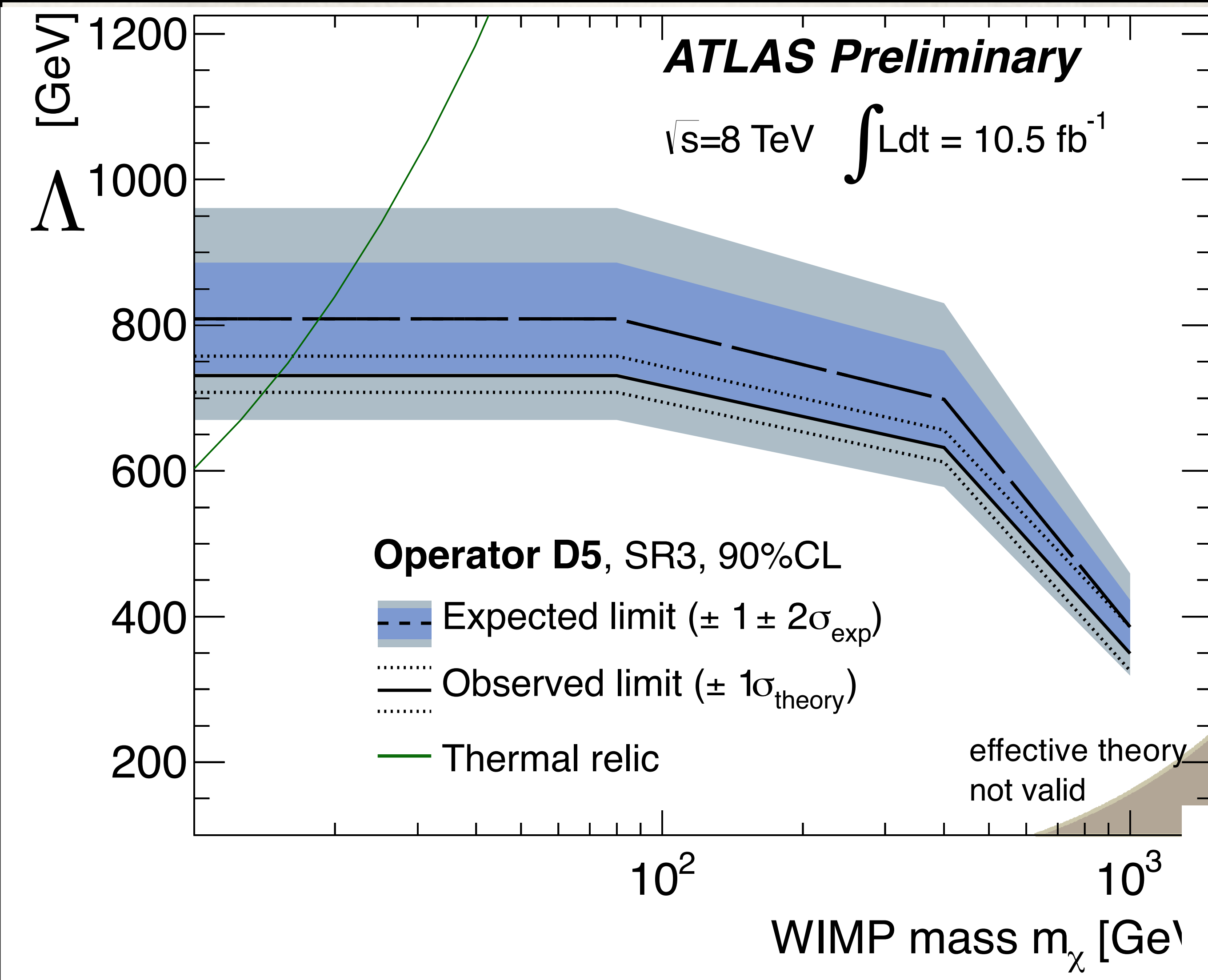


# Measuring the Validity

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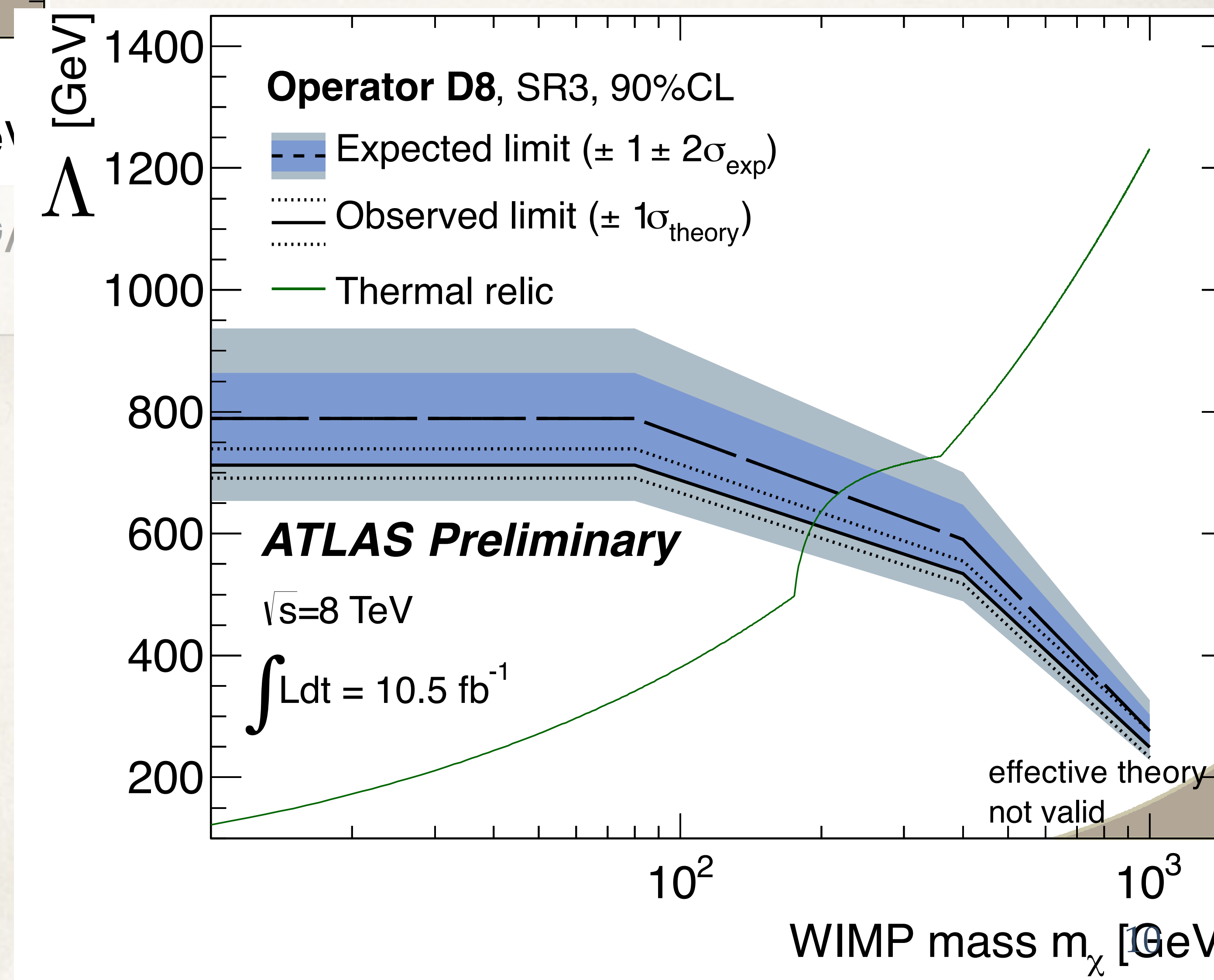

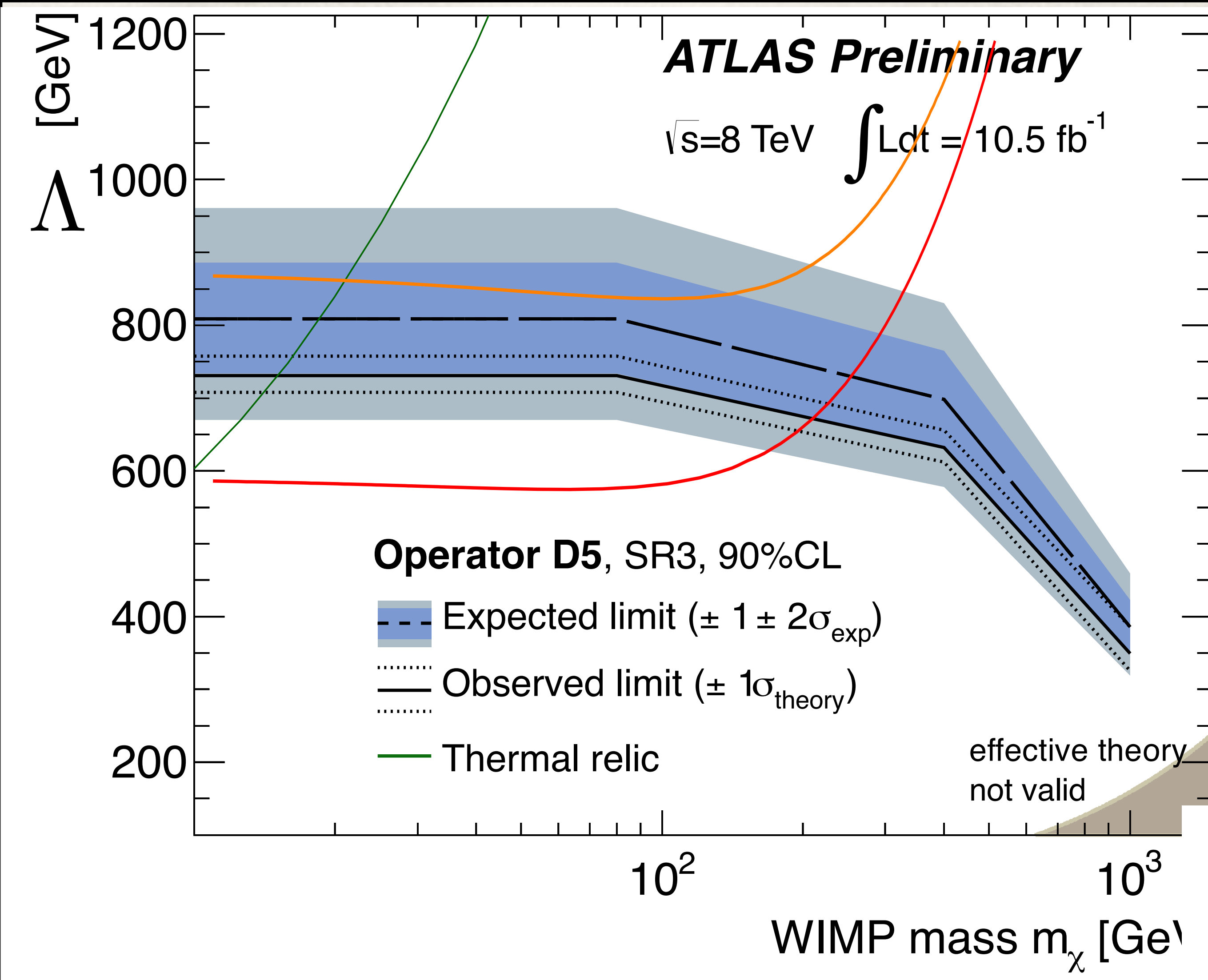


# Measuring the Validity

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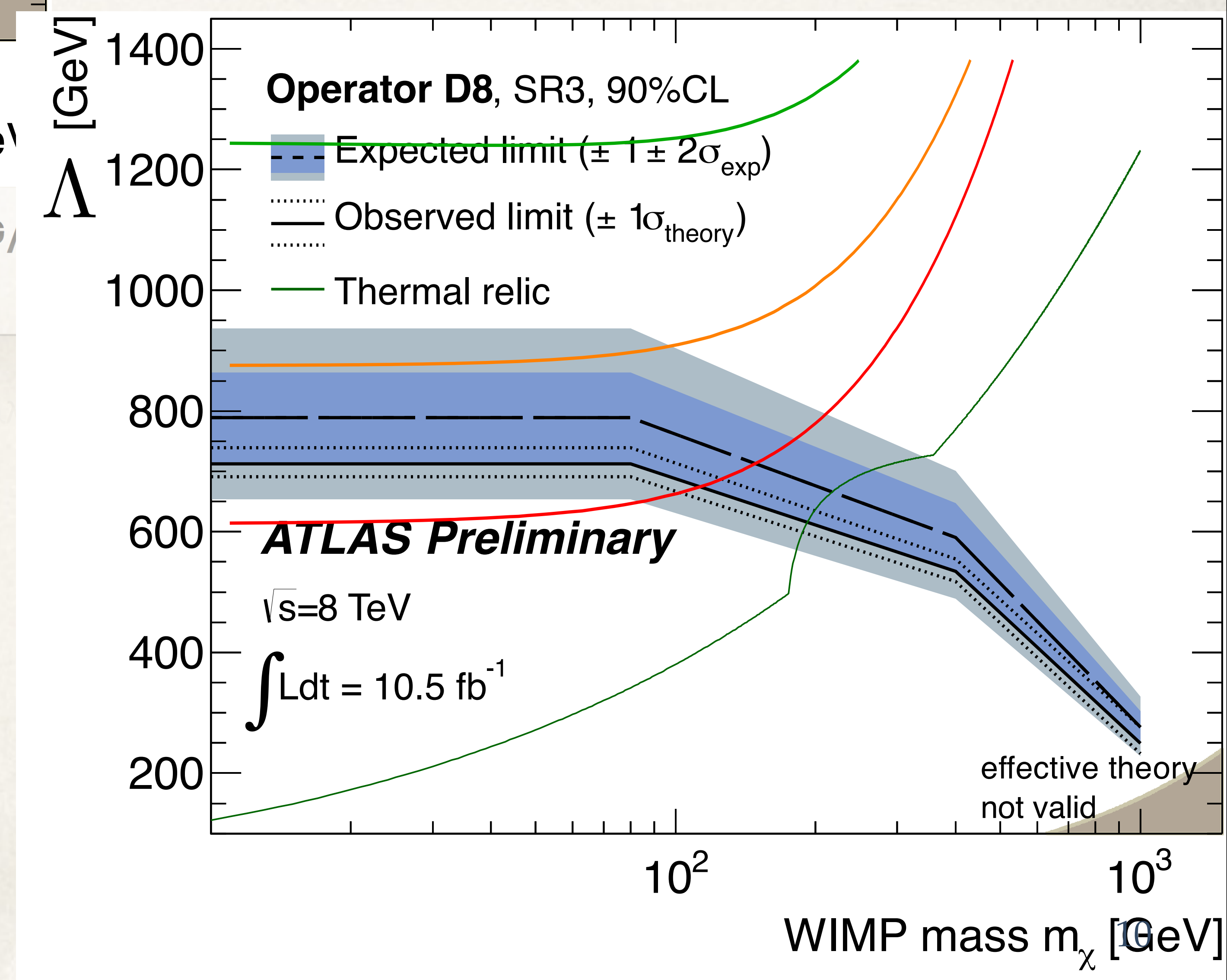
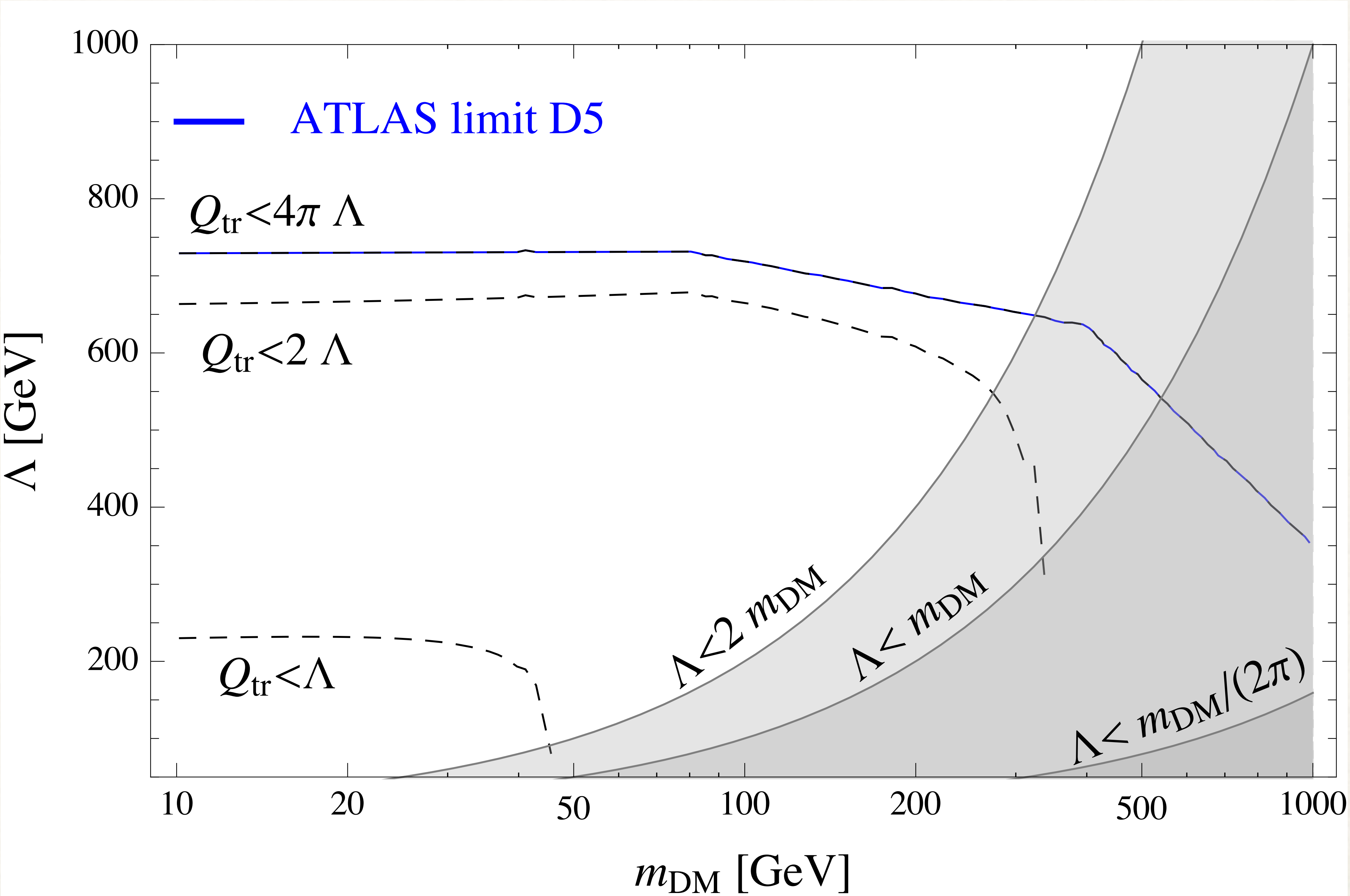


# Rescaling the Limits

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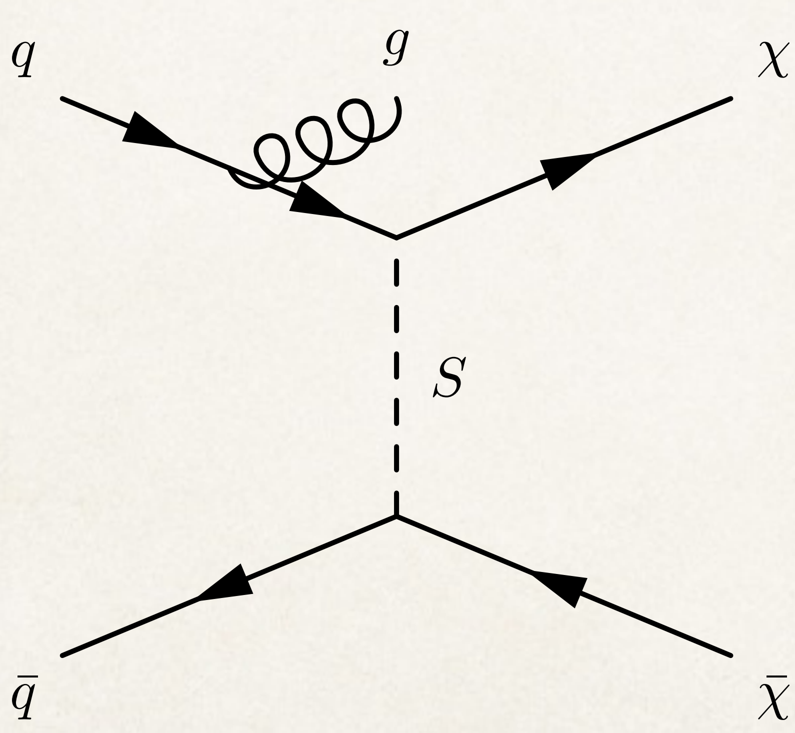
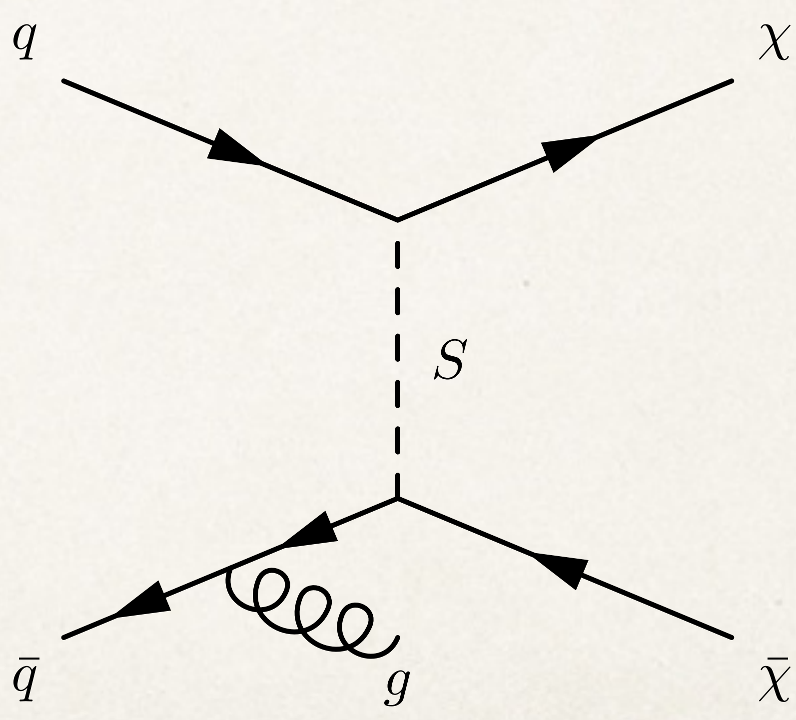
# Final piece of the puzzle

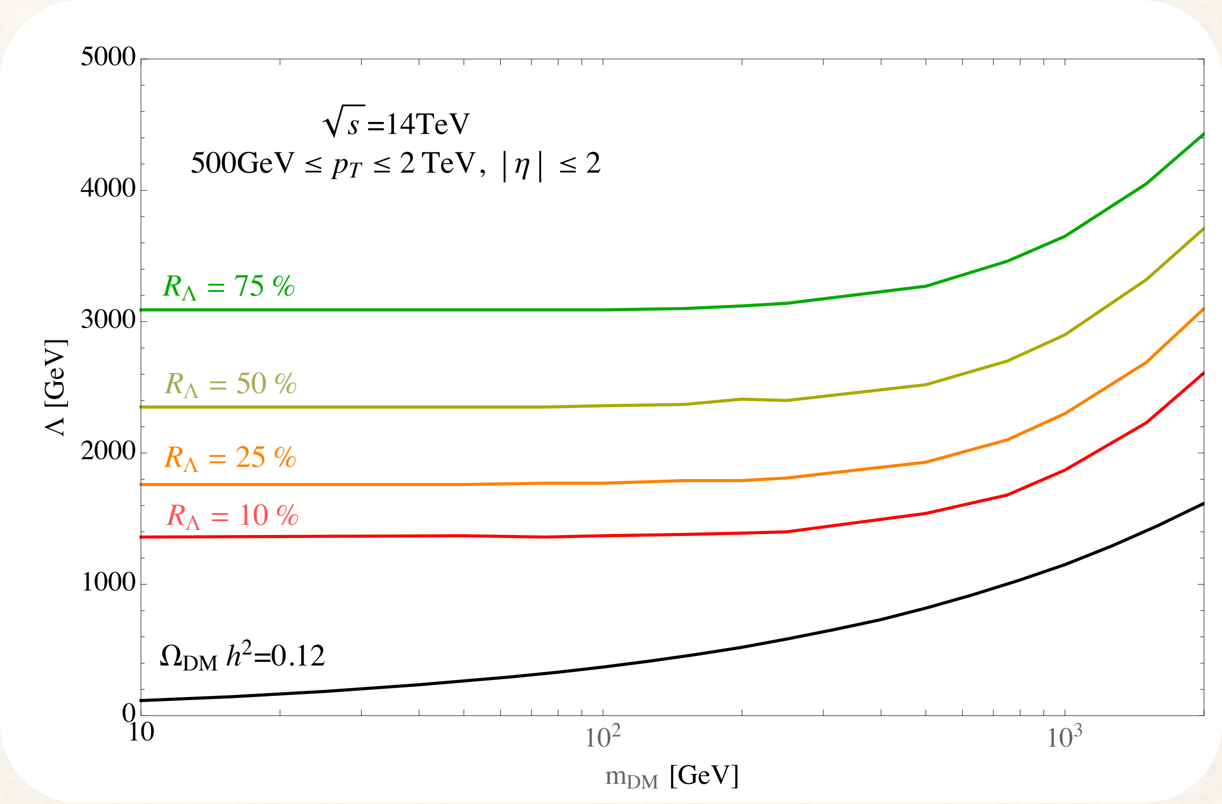
$$\frac{1}{\Lambda^2}\,(\bar{\chi}\mathrm{P_L}q)\,(\bar{q}\mathrm{P_R}\chi) = \frac{1}{2\Lambda^2}\,(\bar{\chi}\gamma^{\mu}P_R\chi)\;\;(\bar{q}\gamma_{\mu}P_Lq)$$

$$= \frac{1}{8\Lambda^2}\,(\mathrm{D5}+\mathrm{D6}-\mathrm{D7}-\mathrm{D8})$$



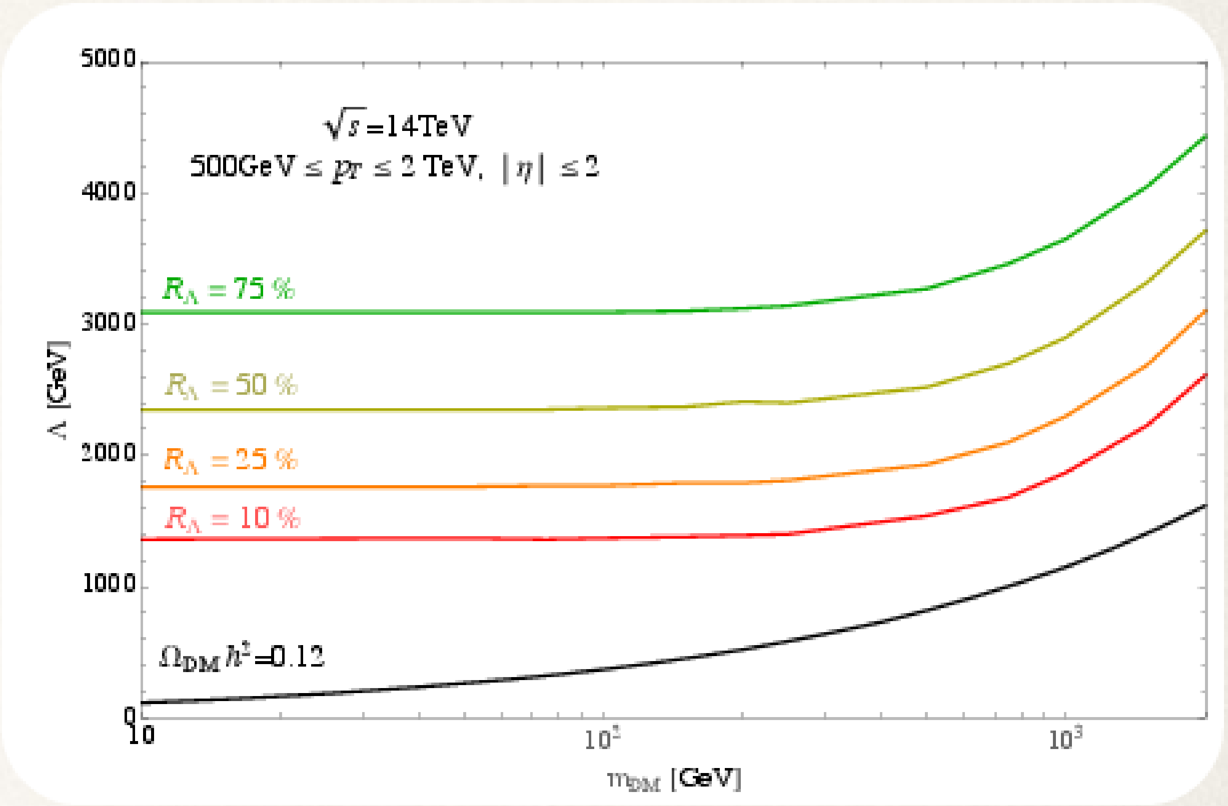
# Extension to t-channel

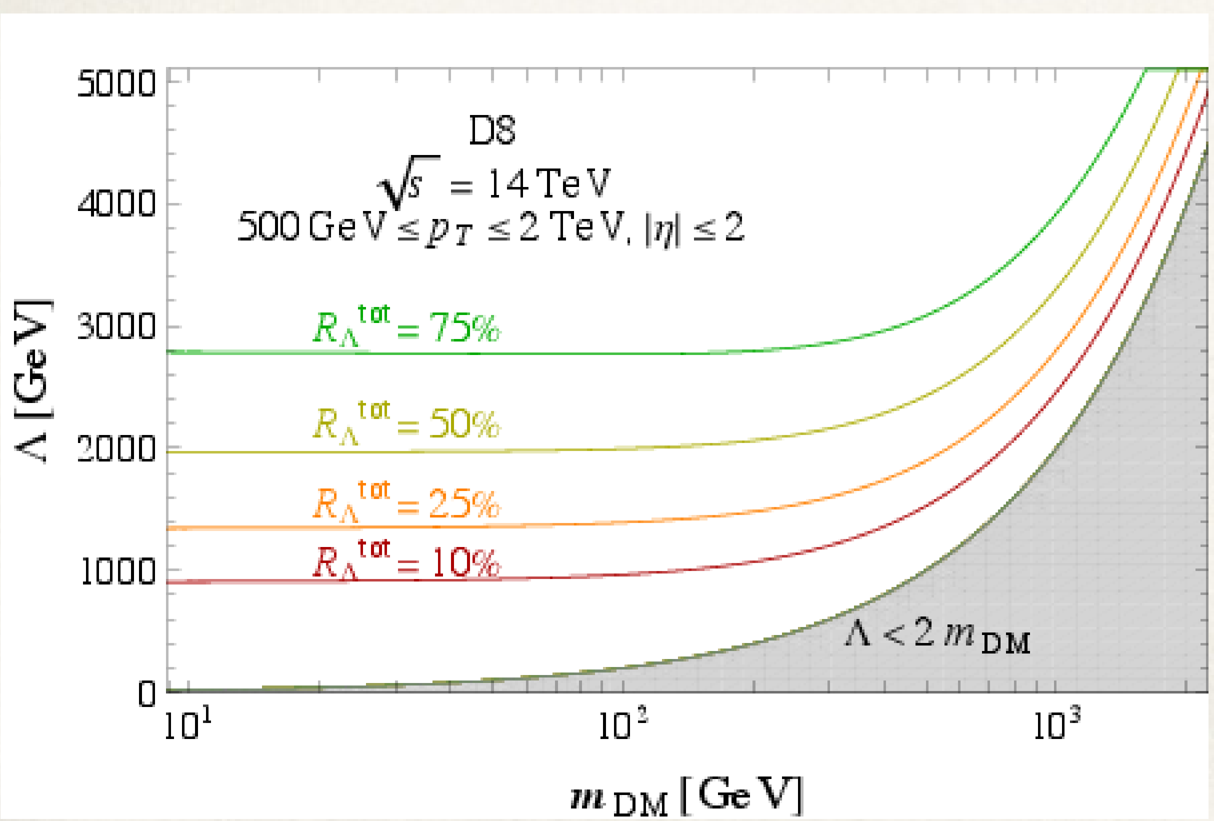


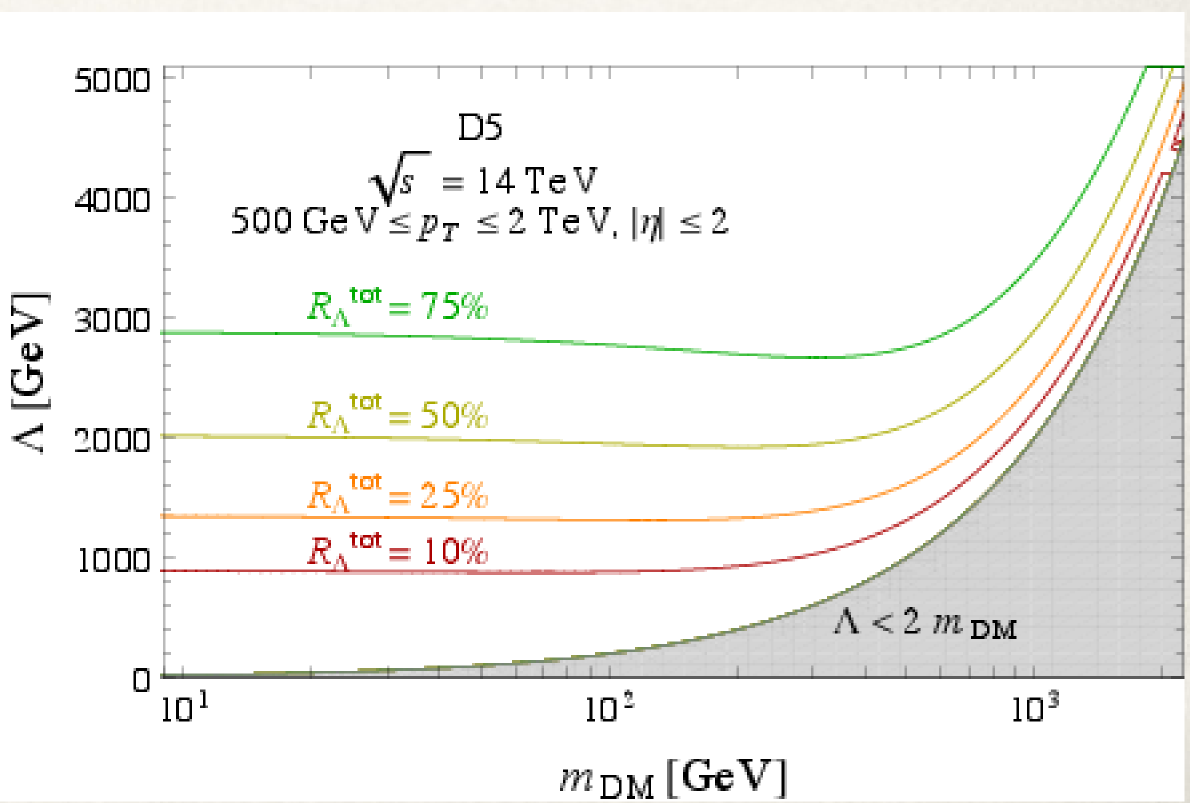
# Extension to t-channel

$$\frac{1}{\Lambda^2}\left(\bar{\chi}\mathrm{P_L}q\right)\left(\bar{q}\mathrm{P_R}\chi\right)$$

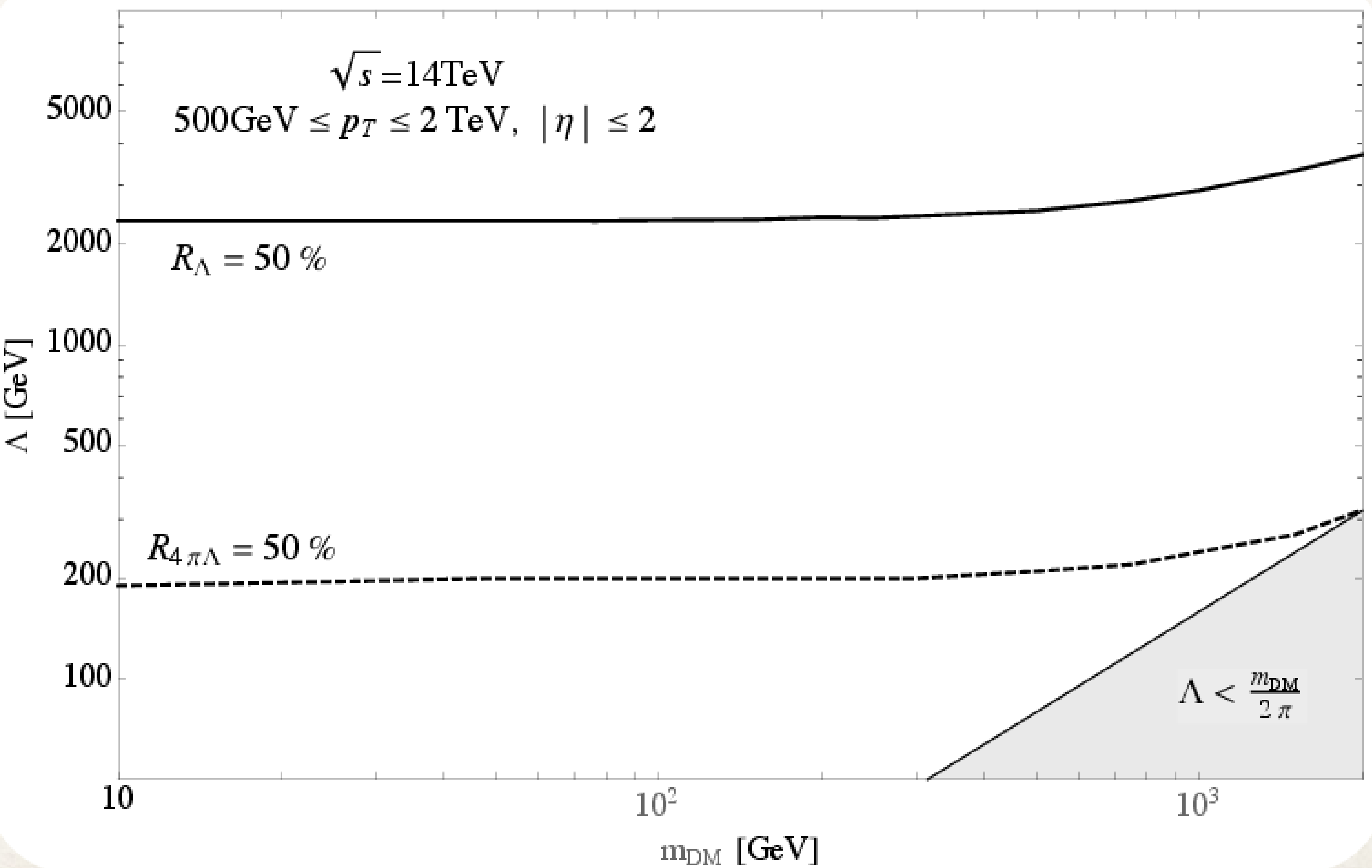
$$= \frac{1}{2\Lambda^2}\left(\bar{\chi}\gamma^{\mu}P_R\chi\right)\ \left(\bar{q}\gamma_{\mu}P_L q\right)$$



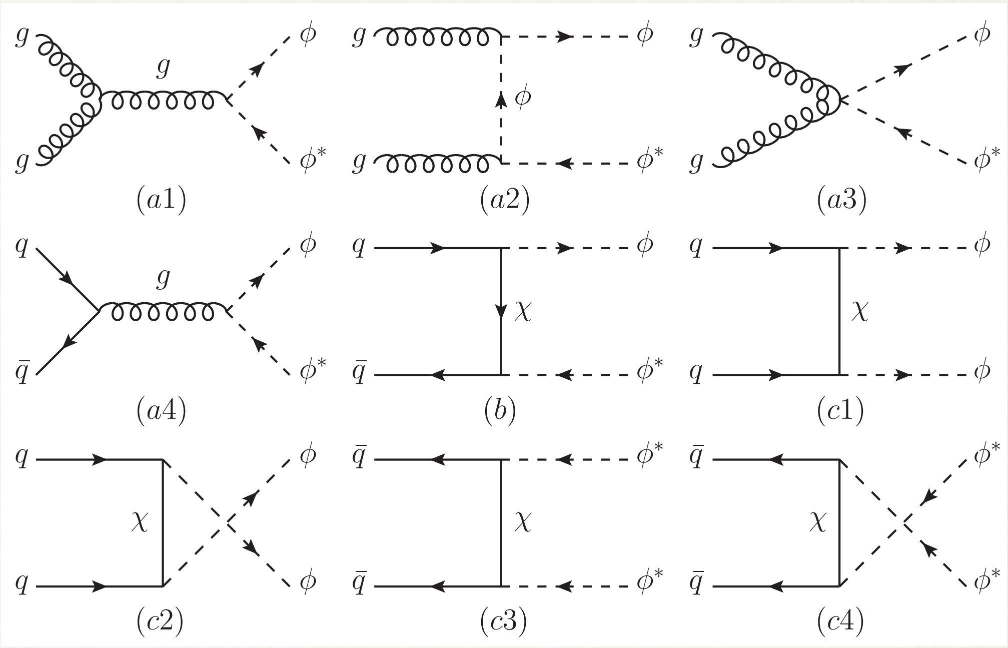



# Effect of coupling choice

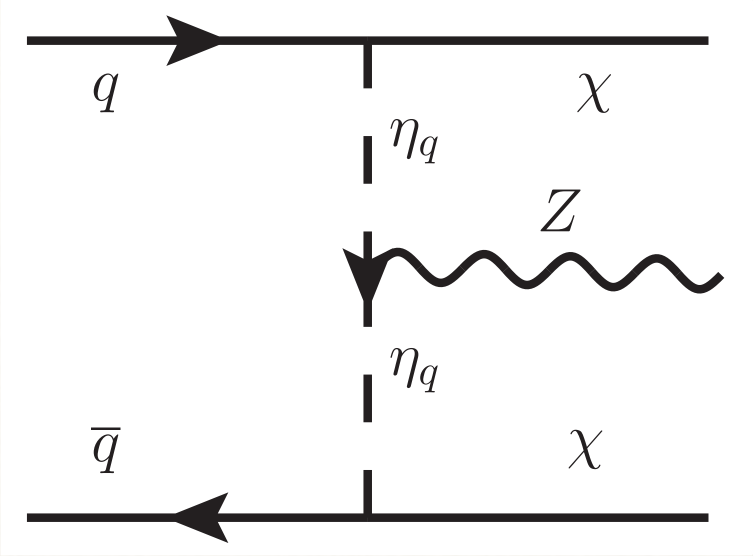


# Moving to Simplified Models

- Painful but necessary to add new parameters
- Direct mediator production leads to SM particles, and is a promising search channel
- Opens up emission from the propagator, can be a useful search channel when the mediator mass is low




An, Wang, Zhang, arXiv:1308.0592




e.g. Bell, Galea, Dent, TJ, Krauss, Weiler, arXiv:1209.0231

# Summary

- Independent of operator or channel, the effective operator approximation is not valid at LHC energies for all but the largest coupling strengths

- t-channel independent of s-channel, even in EFT scenario

- Moving from EFTs to simplified models is a necessity for the 14TeV run

- Effective operators still play a benchmark and comparison role, as long as the region of validity is well understood