Narrowing down DM with the help of colliders

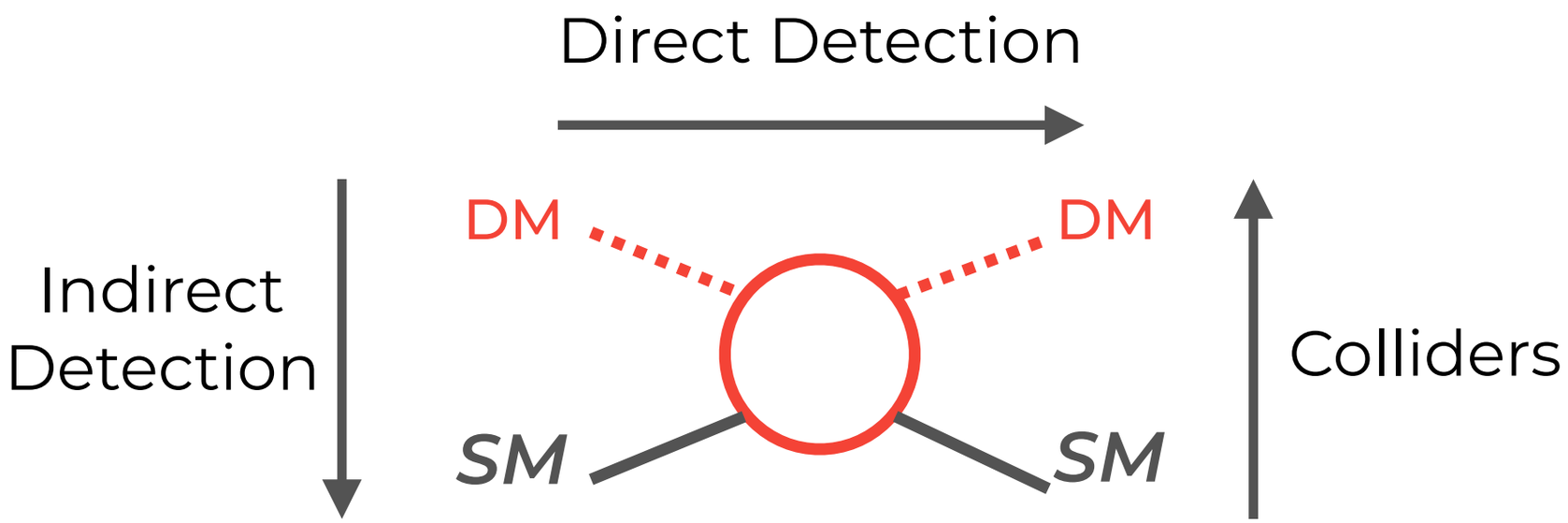
André Lessa
(UFABC)

New Trends in Dark Matter

ICTP-SAIFR
December 9, 2020

Universidade Federal do ABC

Dark Matter @ Colliders



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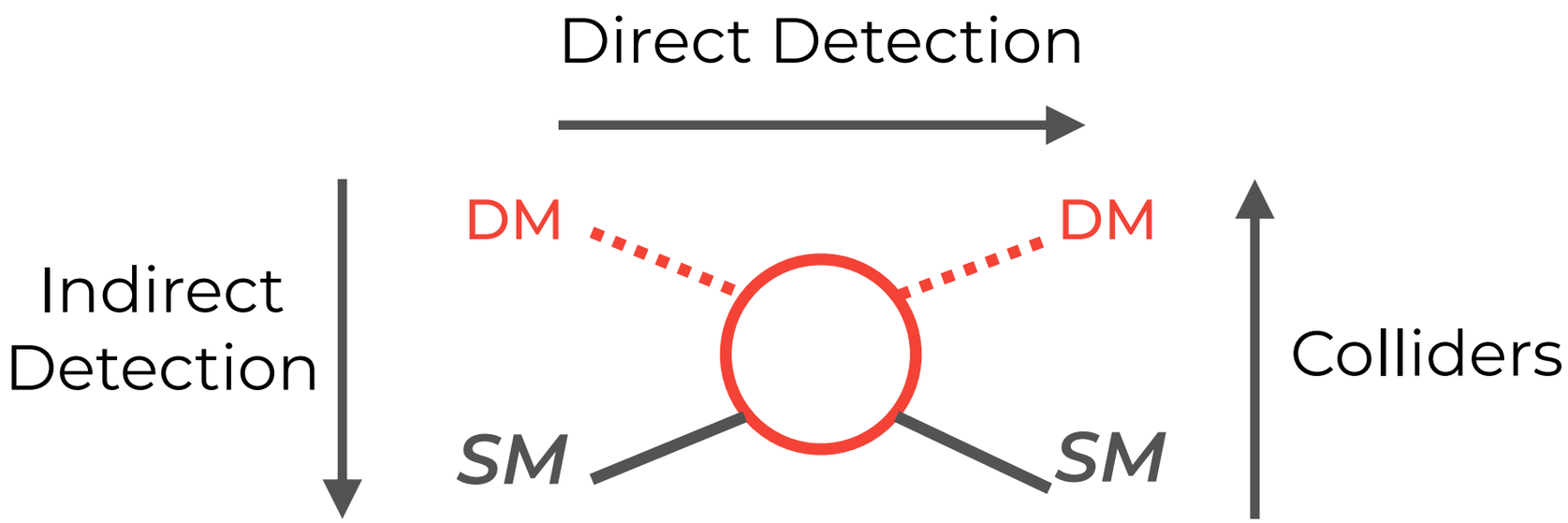

- *The complementarity is highly model dependent!*

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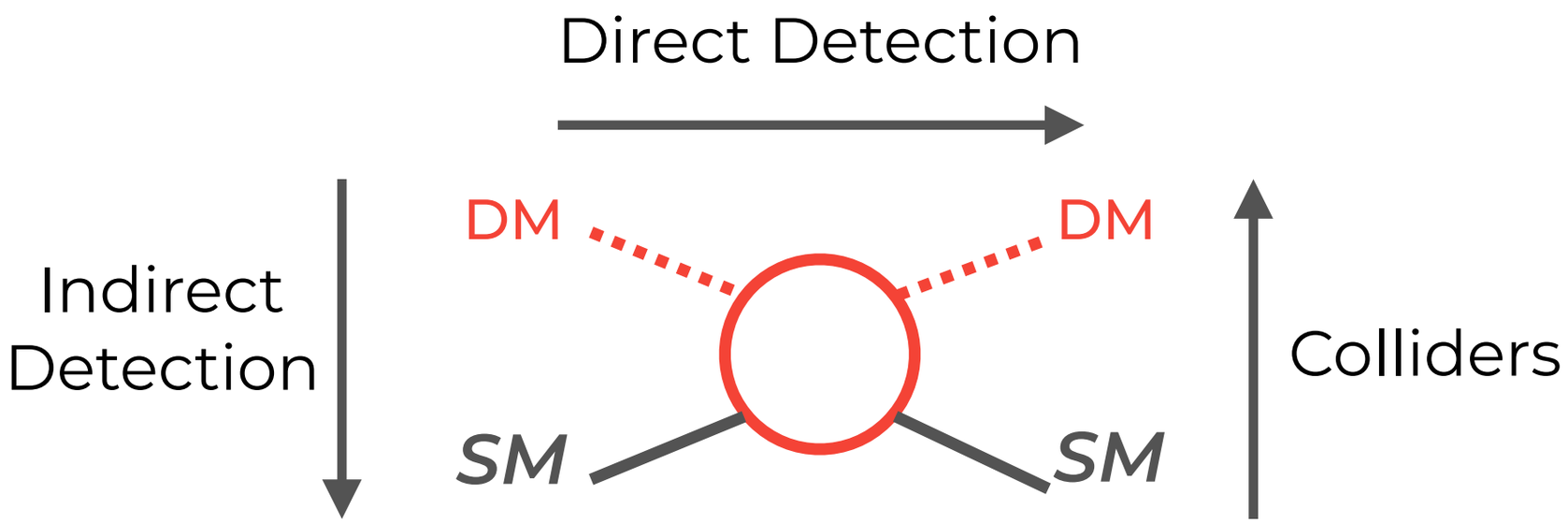

- *The complementarity is highly model dependent!*
- What is the role of colliders in the hunt for DM?

Dark Matter @LHC

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$$\lambda\, g \sim 1 - 10^{-2}$$

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$$\lambda\, g \sim 1 - 10^{-2} \longrightarrow \text{WIMPs}$$

- Direct Detection:

$$\sim \lambda\, g$$

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- Collider searches (minimal scenarios)

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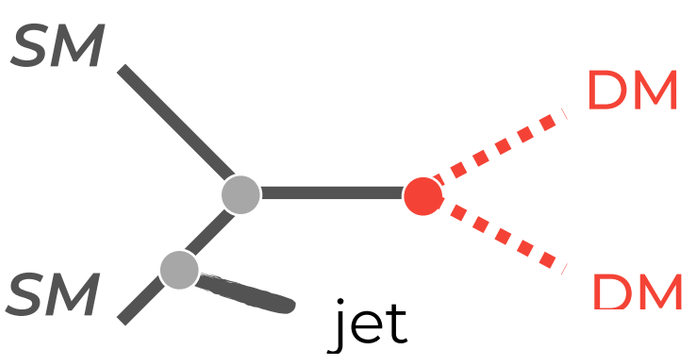

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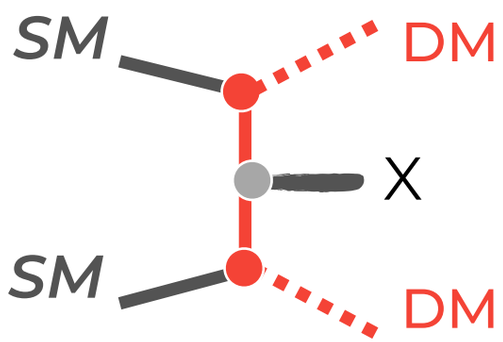

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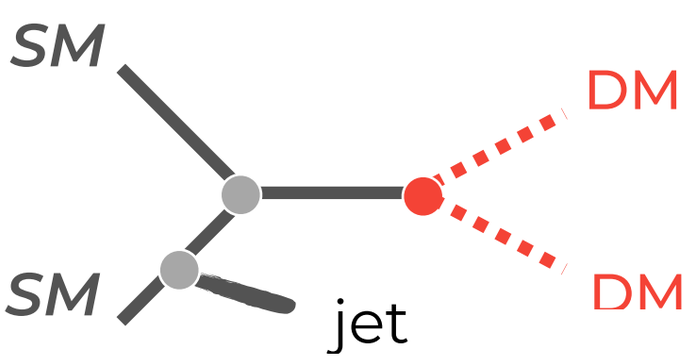

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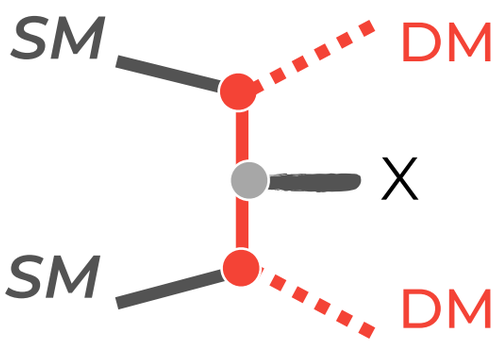

- Large BG (Z/X+jets)
- Large signal ($\lambda \gg g_{SM}$)

WIMPs @LHC

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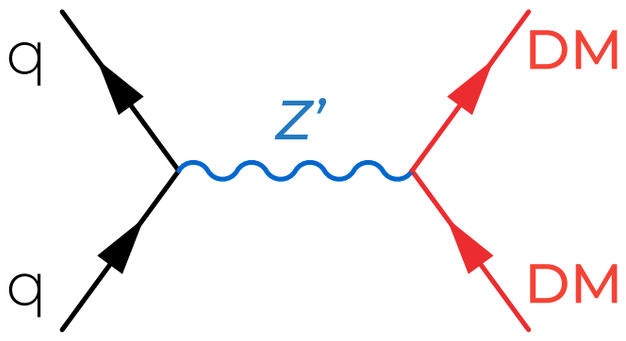

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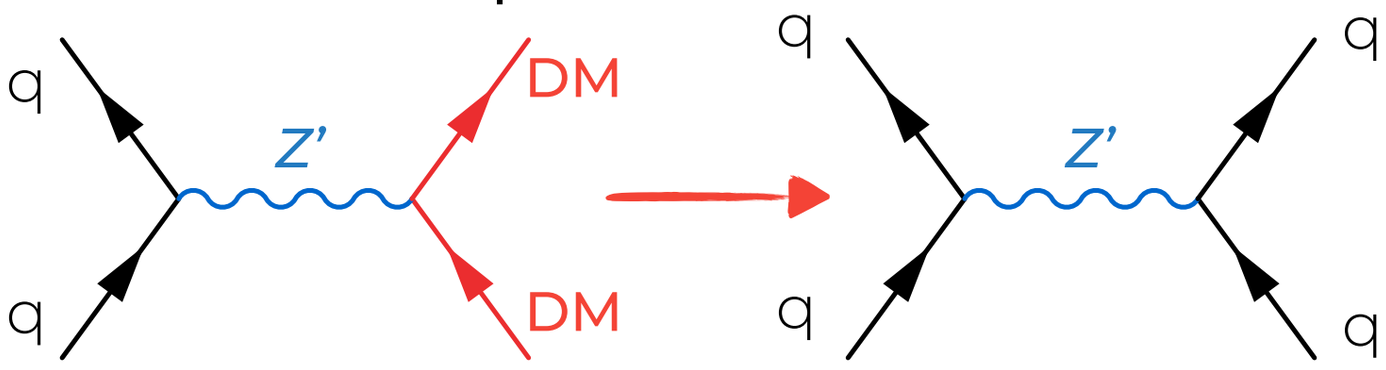

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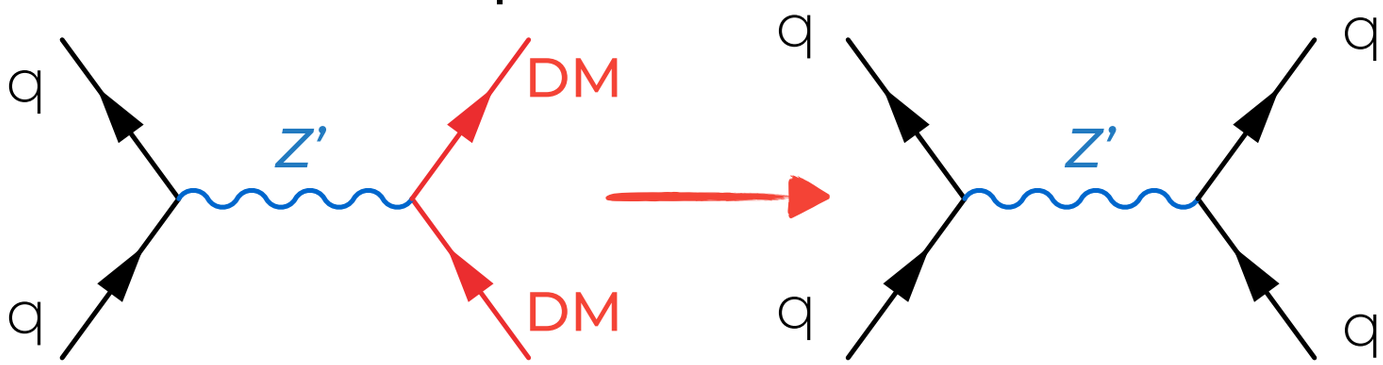

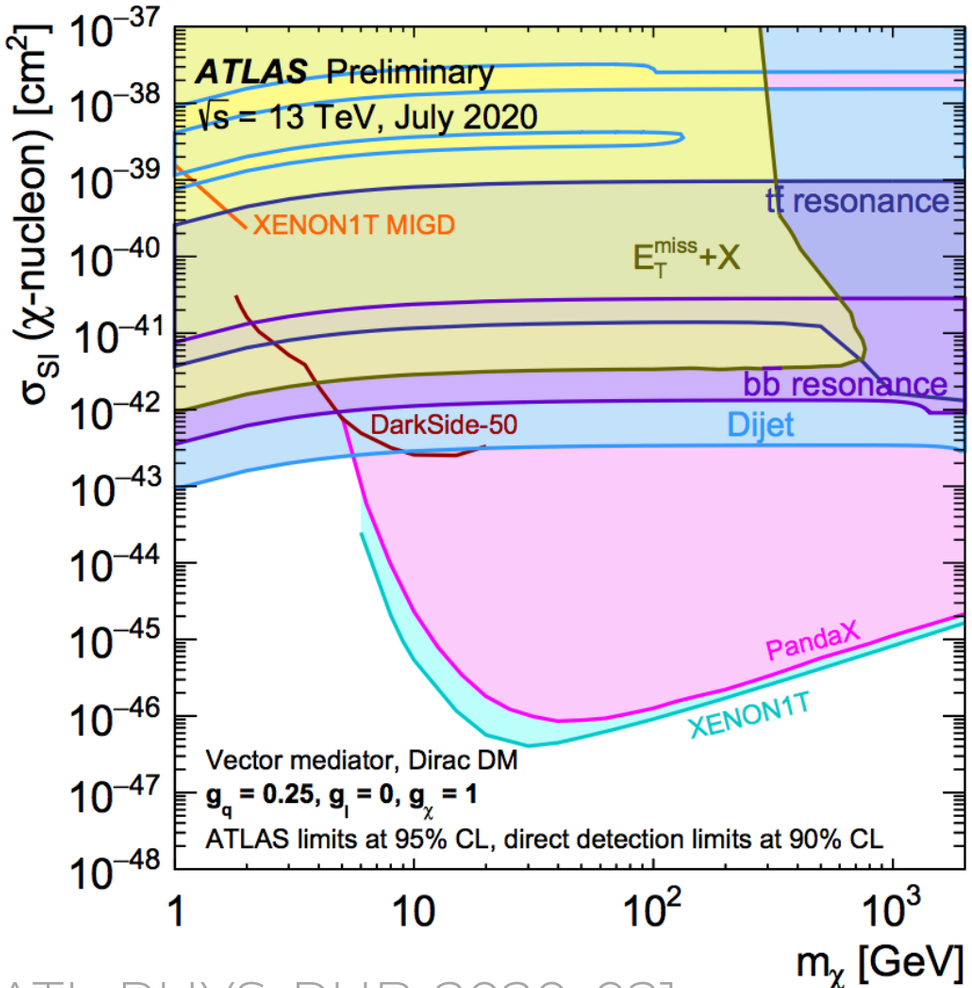

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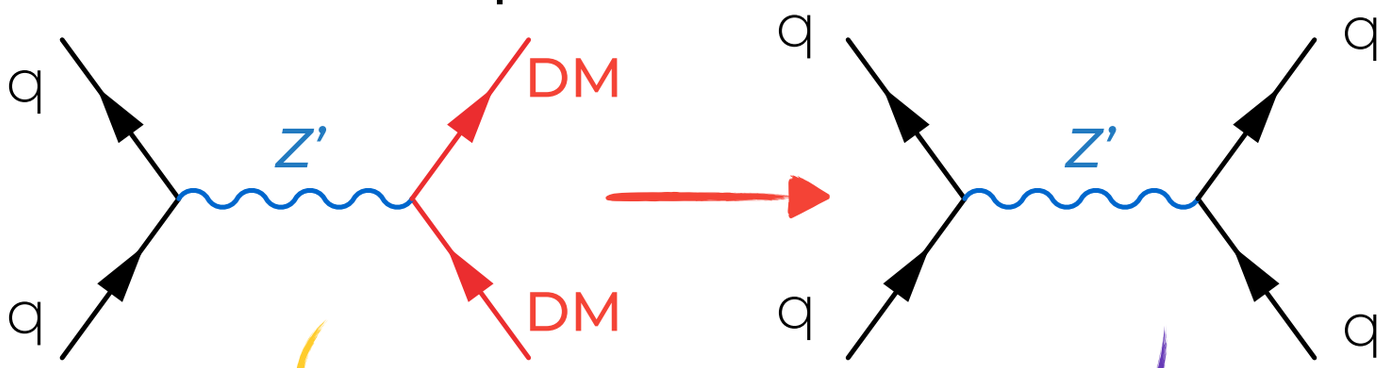

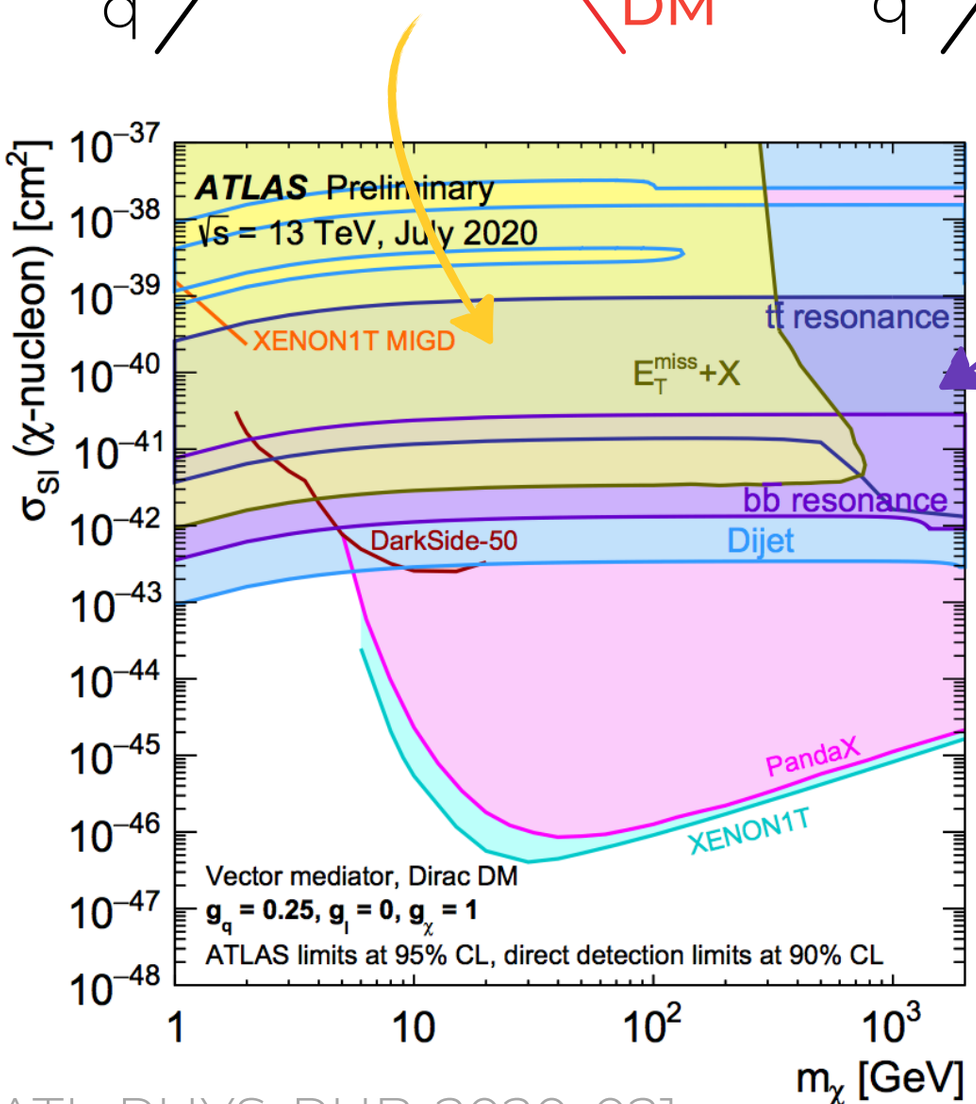

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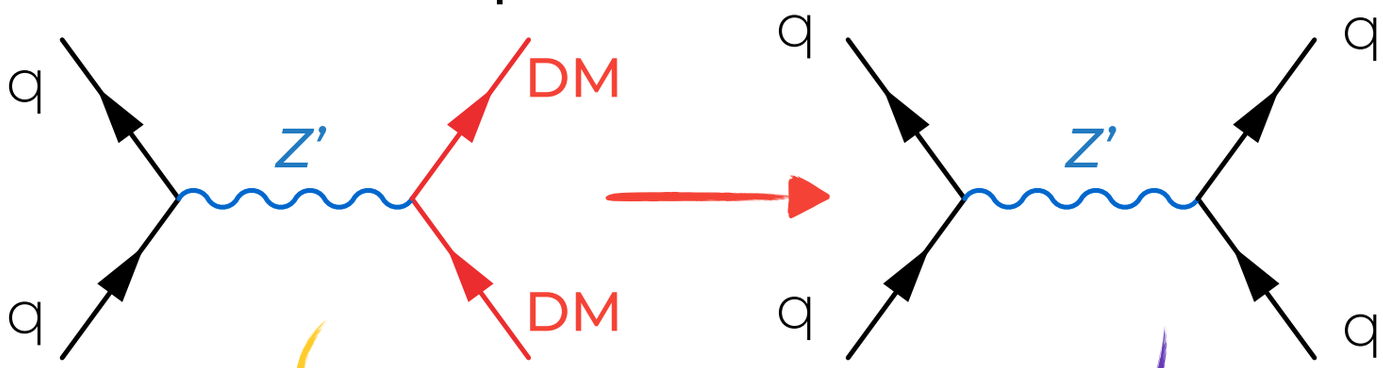

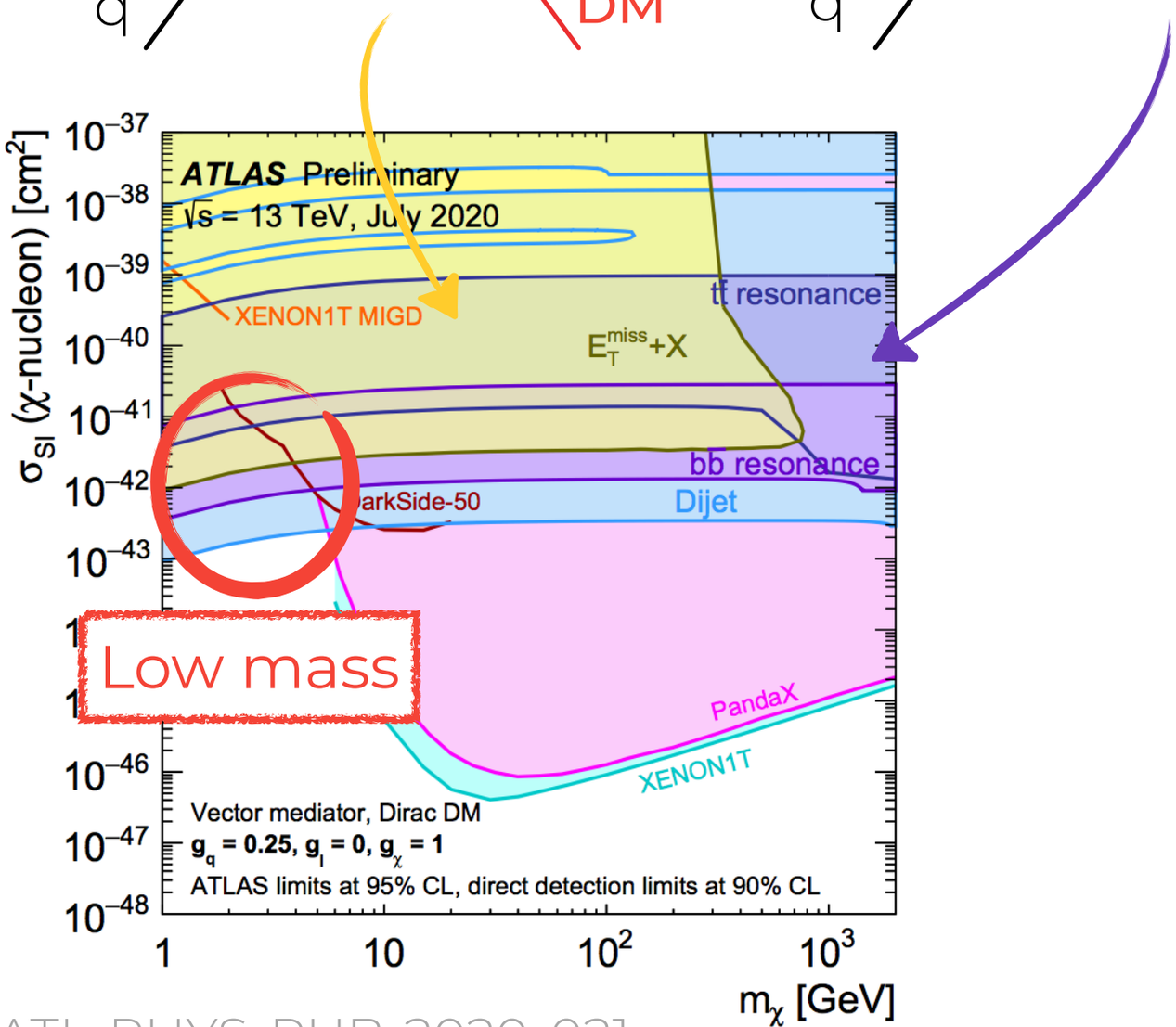

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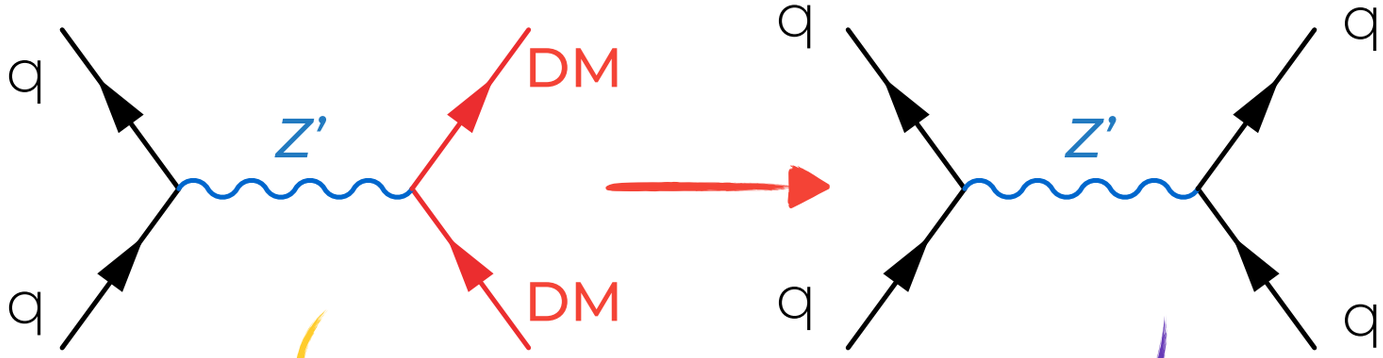

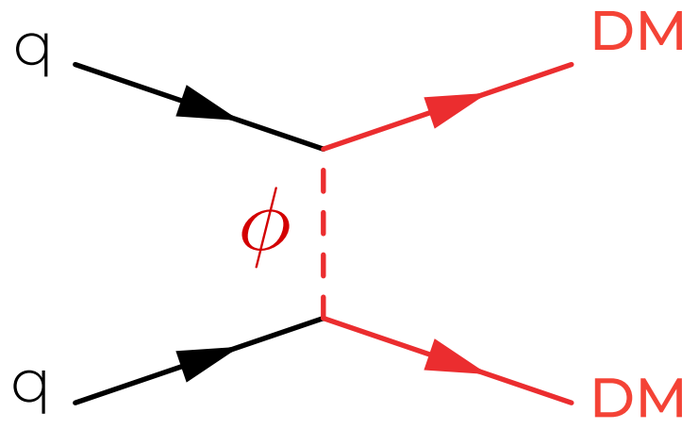

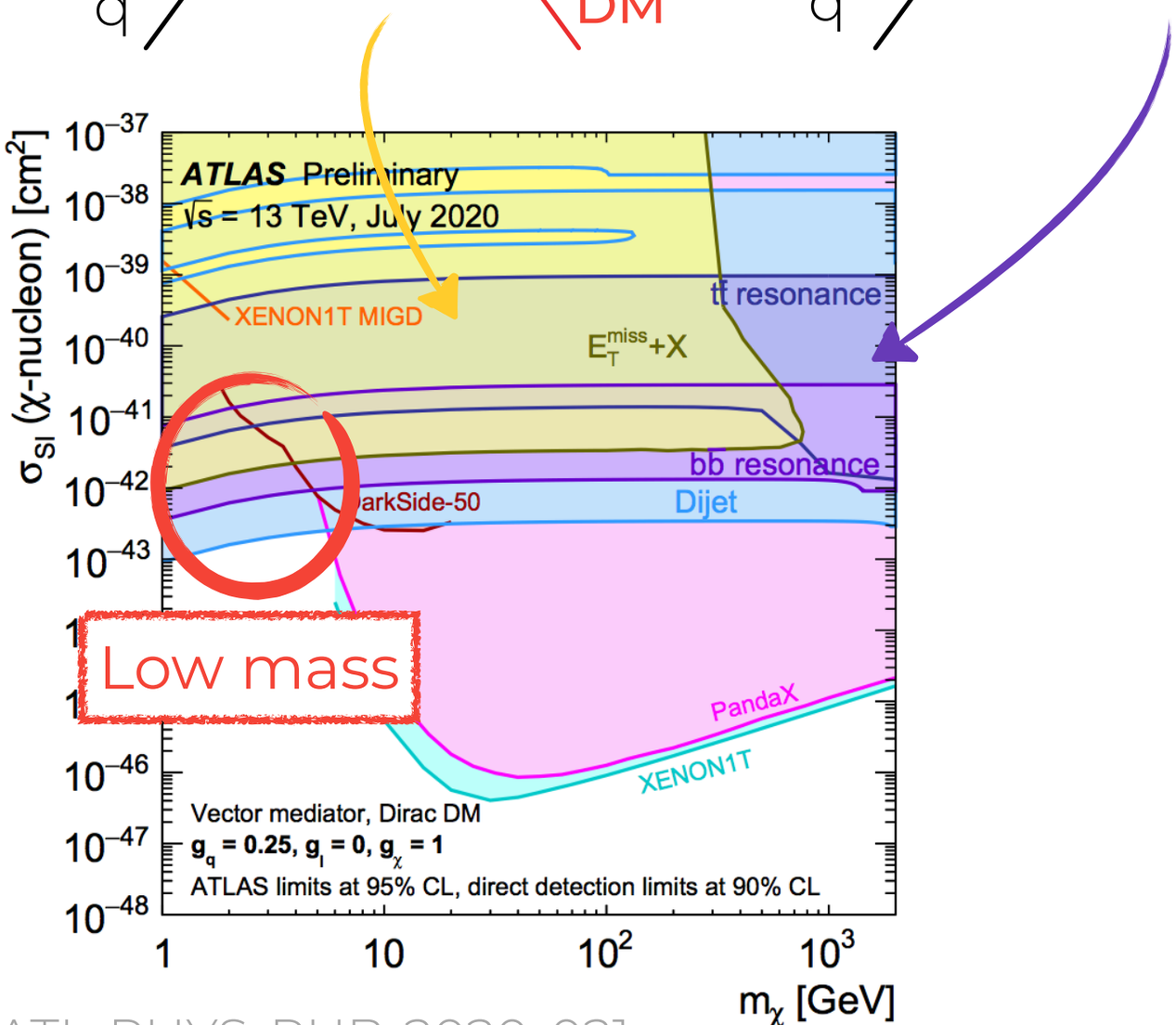

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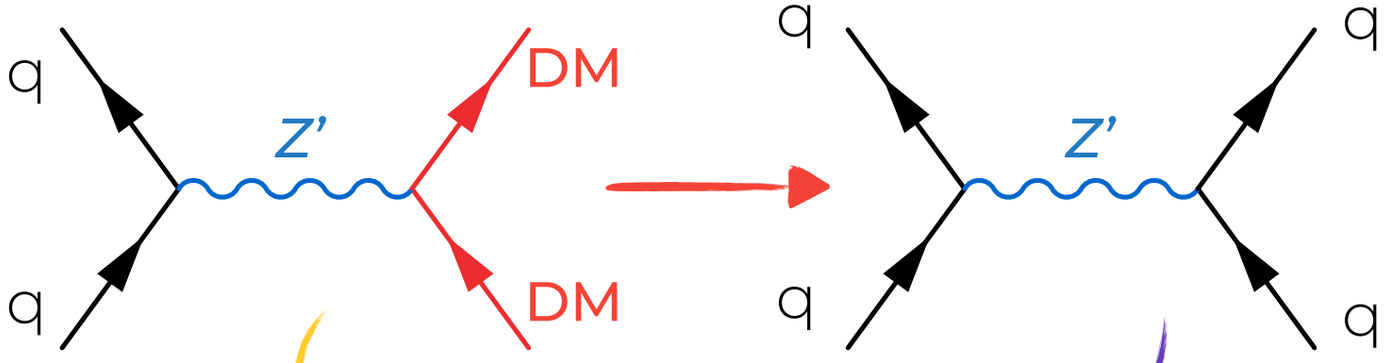

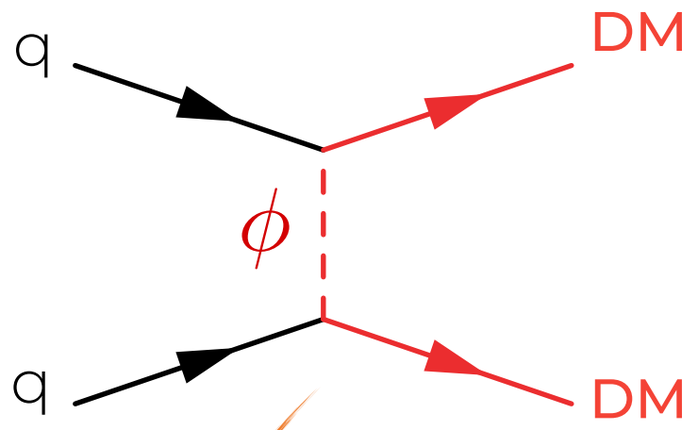

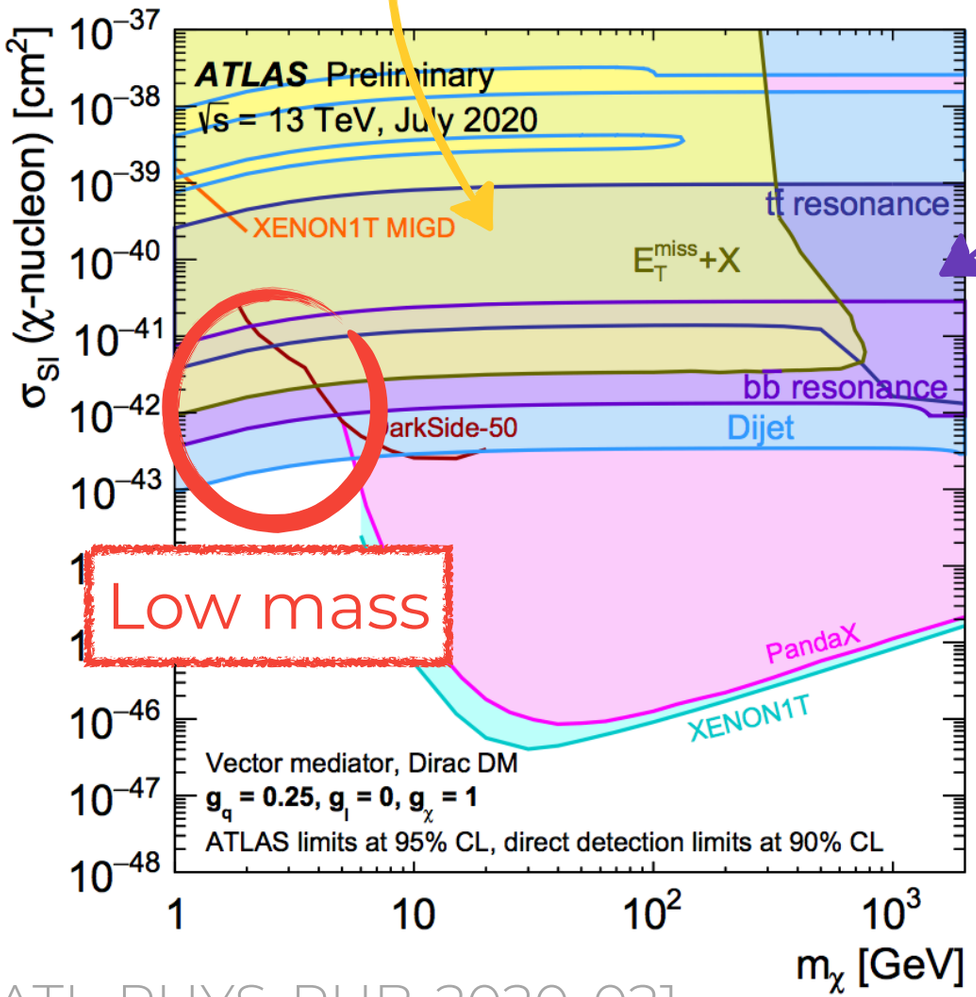

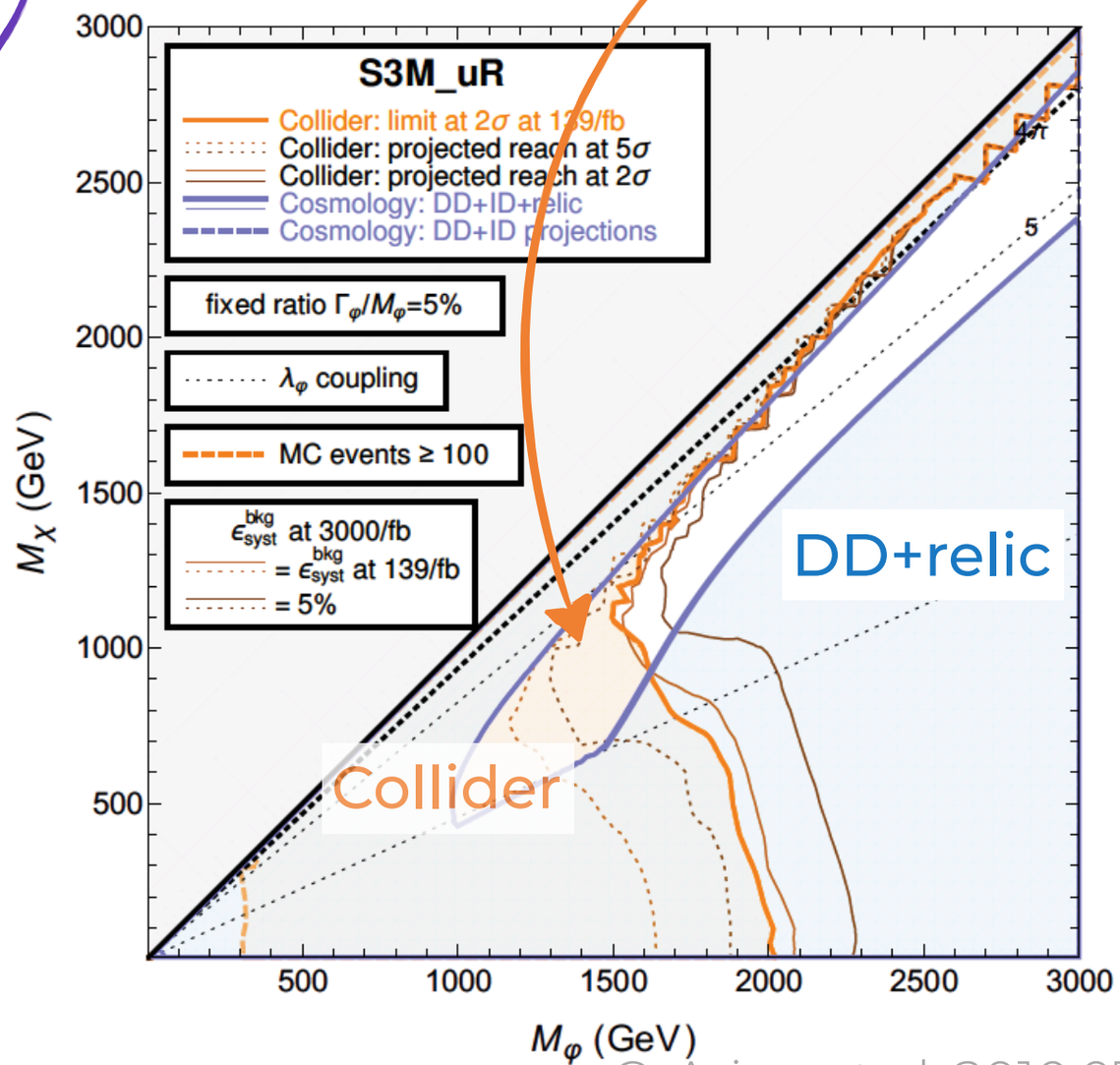

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C. Arina et al, 2010.07559

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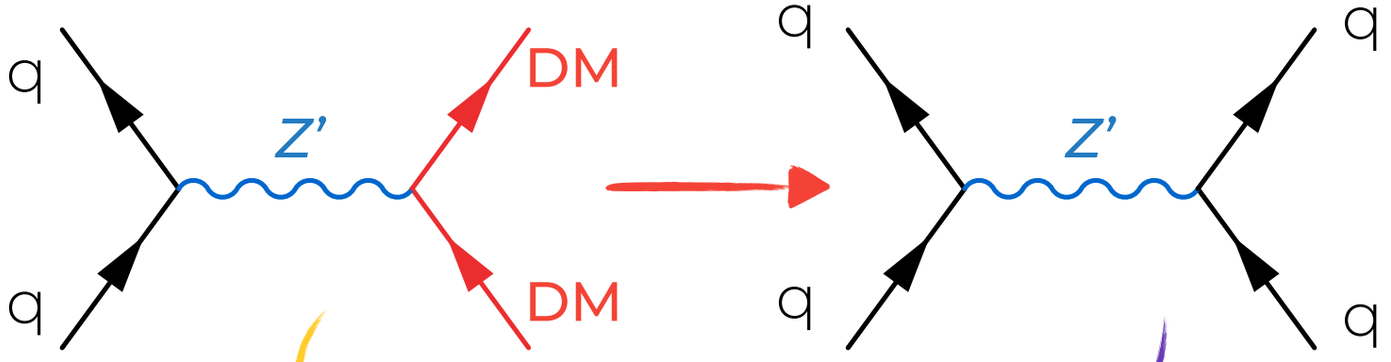

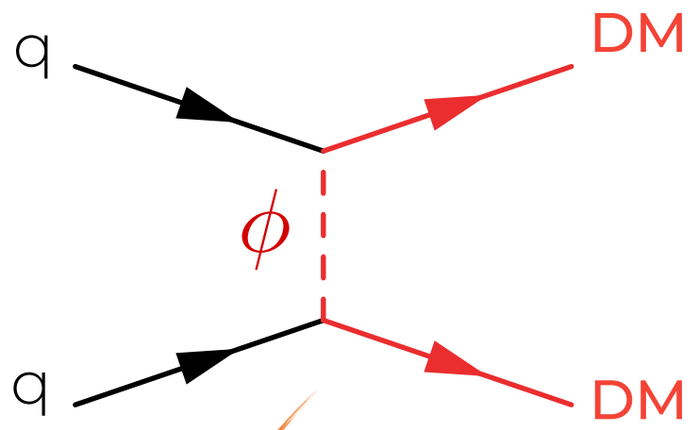

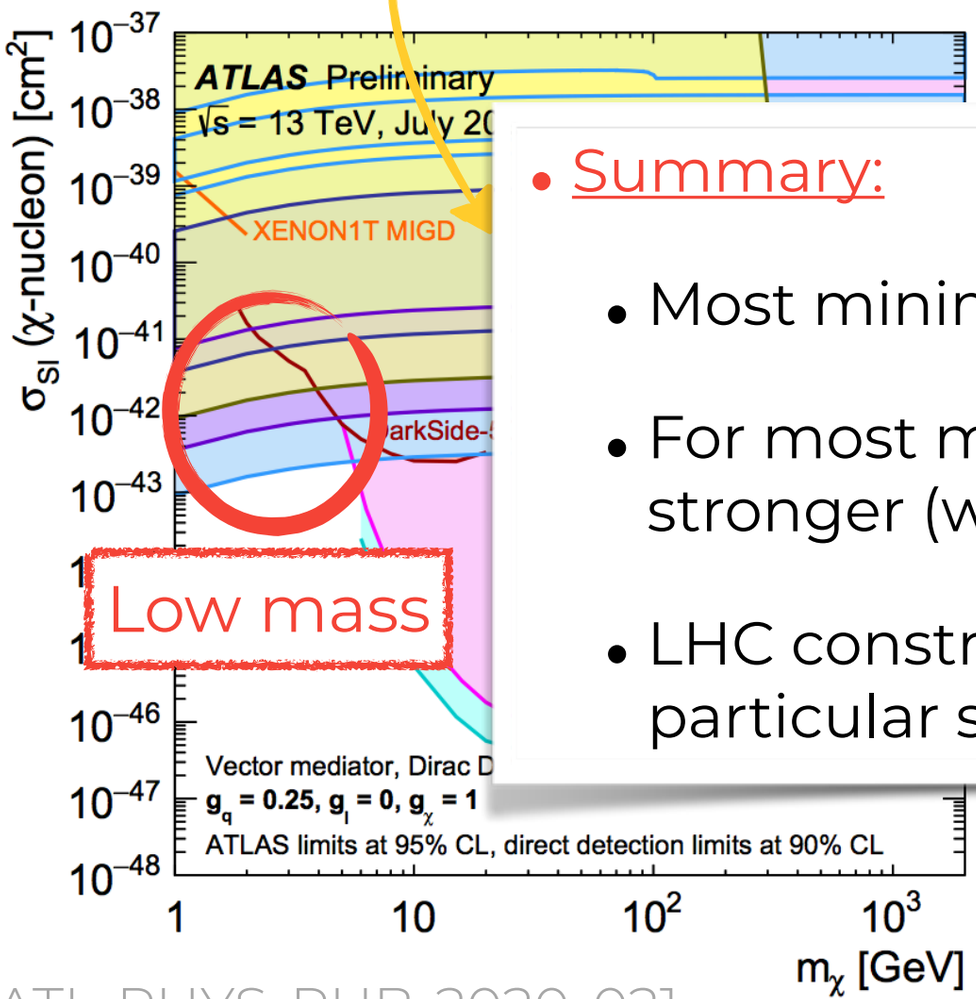

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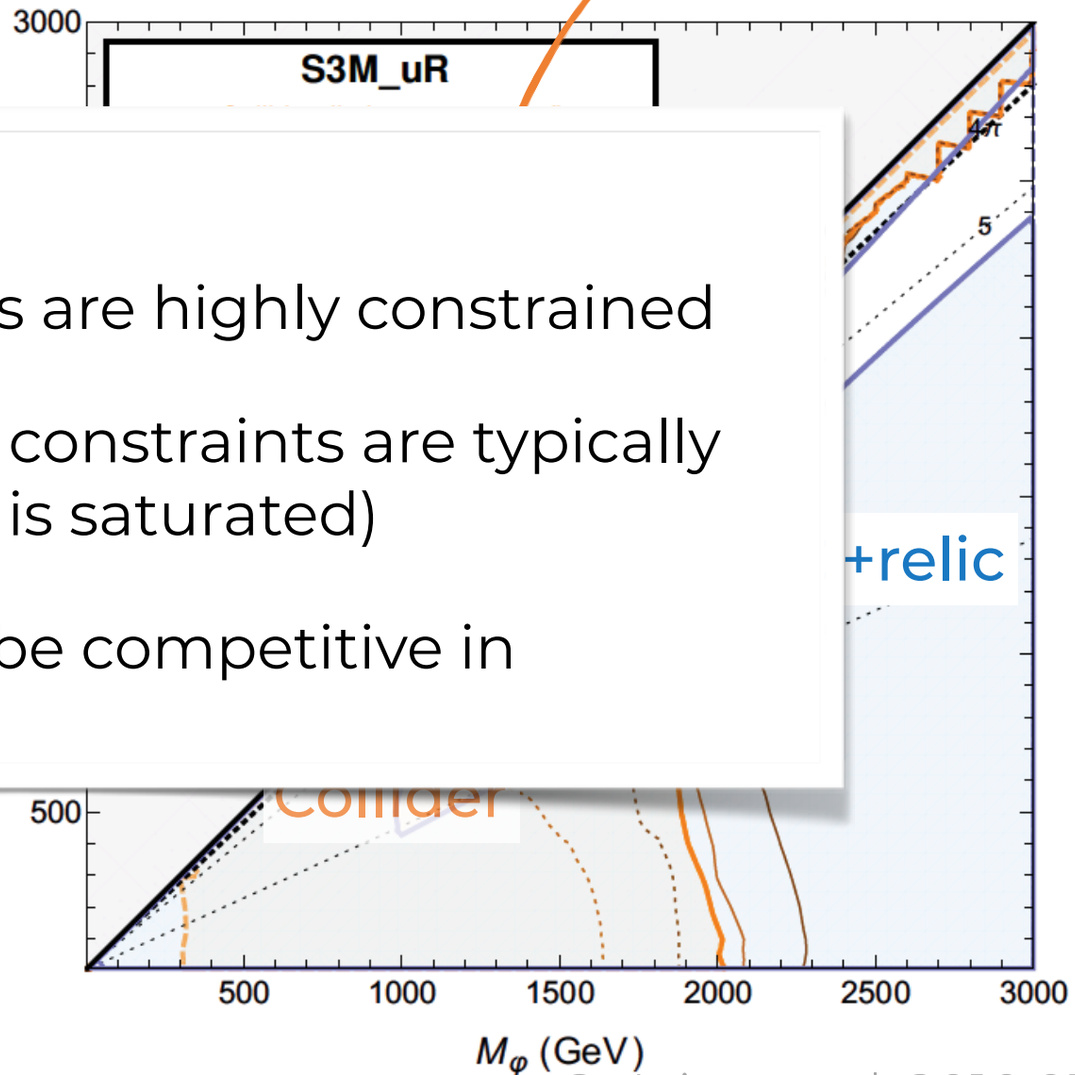
- Summary:
  - Most minimal models are highly constrained
  - For most models DD constraints are typically stronger (where relic is saturated)
  - LHC constraints can be competitive in particular scenarios



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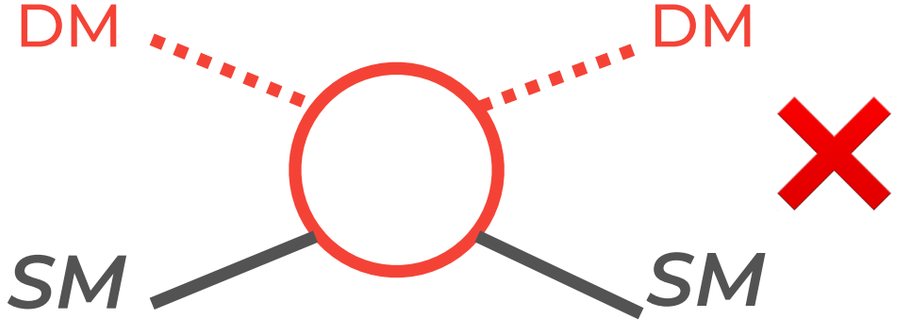

some exceptions: resonant scattering, low mass mediator,...

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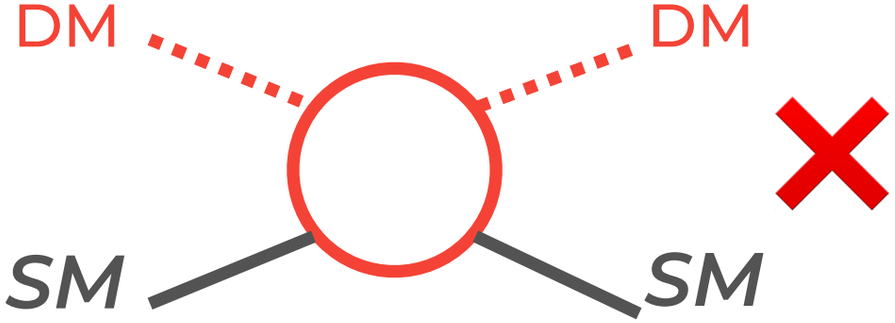

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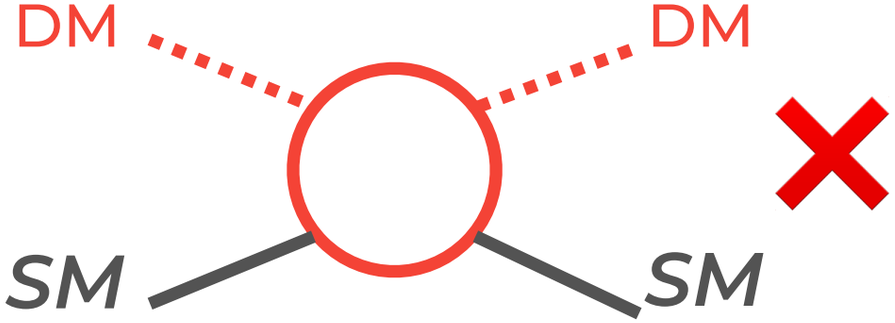

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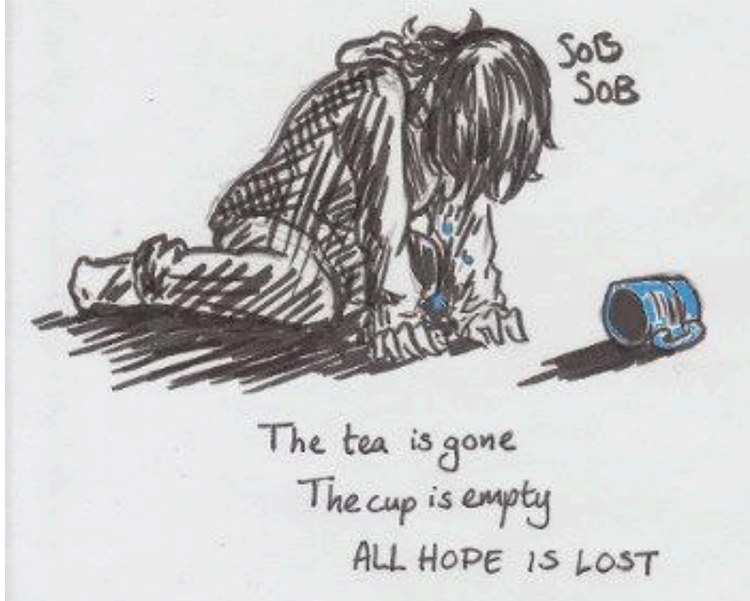

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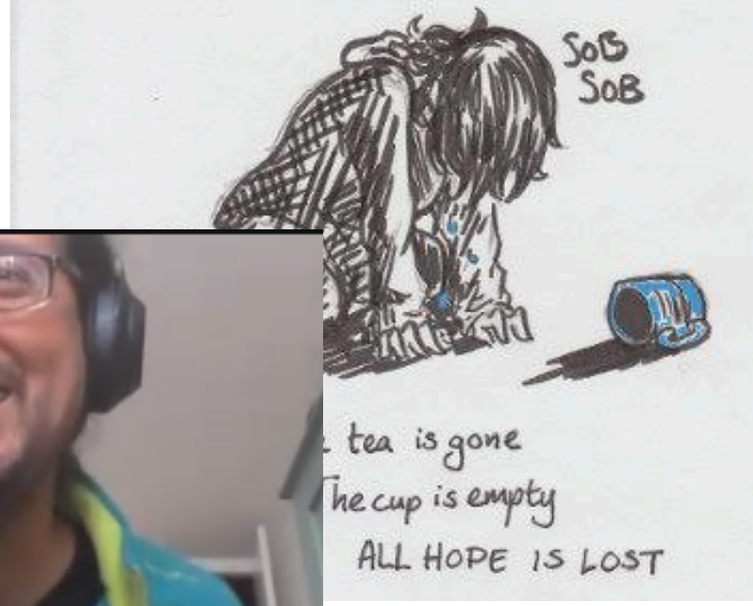

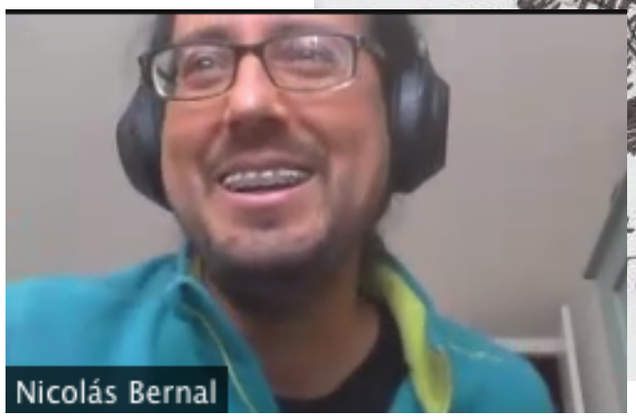

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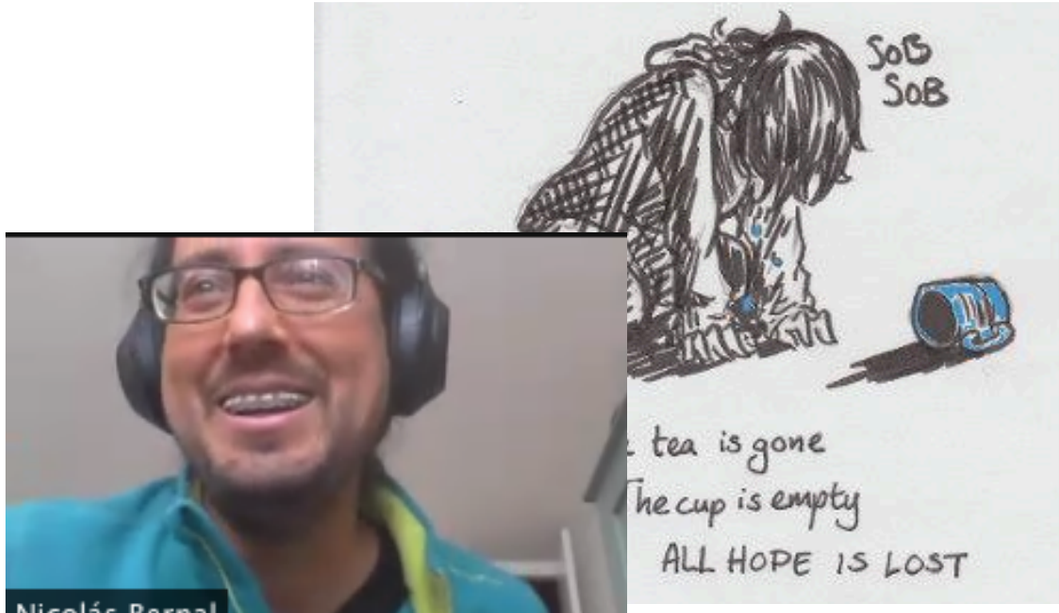

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Camilos' talk (Inelastic DM)
Laura's talk (FIMPs)

Minimal Framework

$$\lambda \ll 1,\ g \sim 1$$

- "Minimal scenario" G. Bélanger et al, *JHEP* 02 (2019) 186
  - Mediator: vector-like fermion (F)
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S. Junius, L. Lopez-Honorez, A. Mariotti, *JHEP* 07 (2019) 136

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$$\mathcal{L} = \mathcal{L}_{SM} + \frac{1}{2}\partial_\mu s\,\partial^\mu s - V(s) + \bar{F}\left(i\not{D} - m_F\right)F - \lambda\left(s\bar{F}f_R^{SM} + h.c.\right)$$

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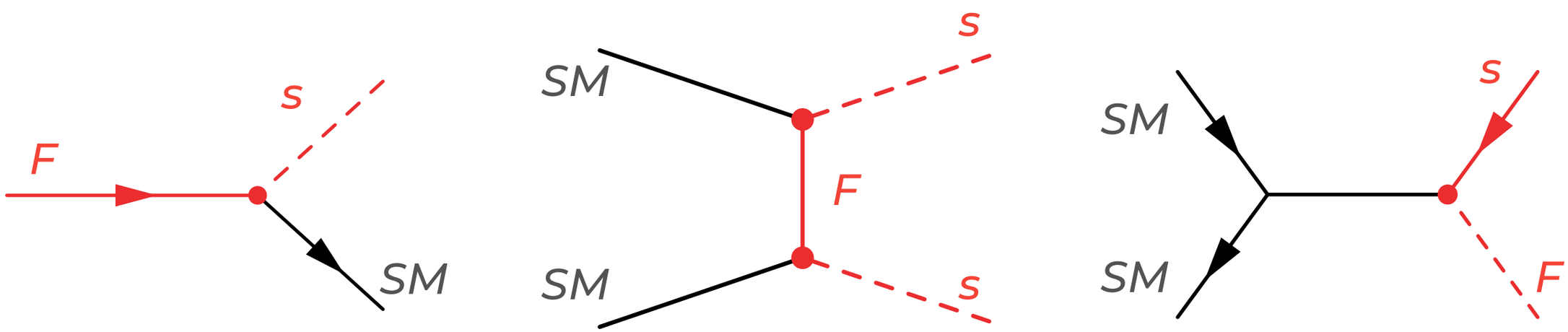

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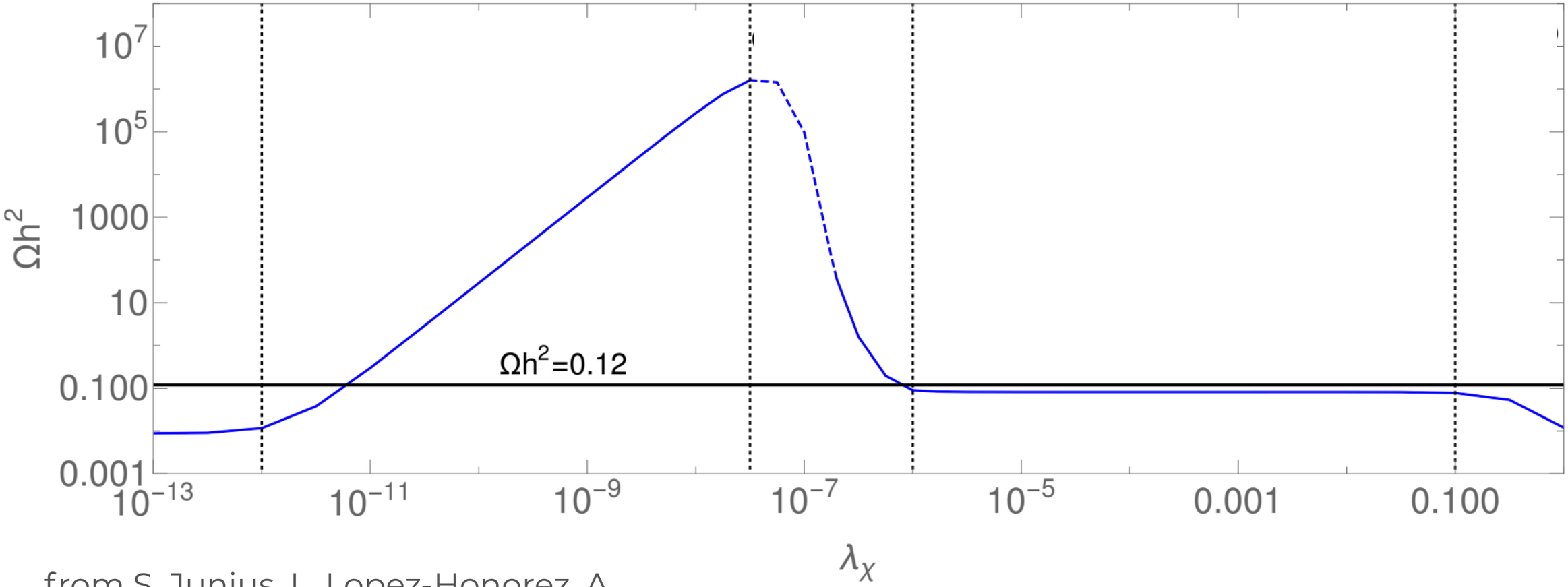

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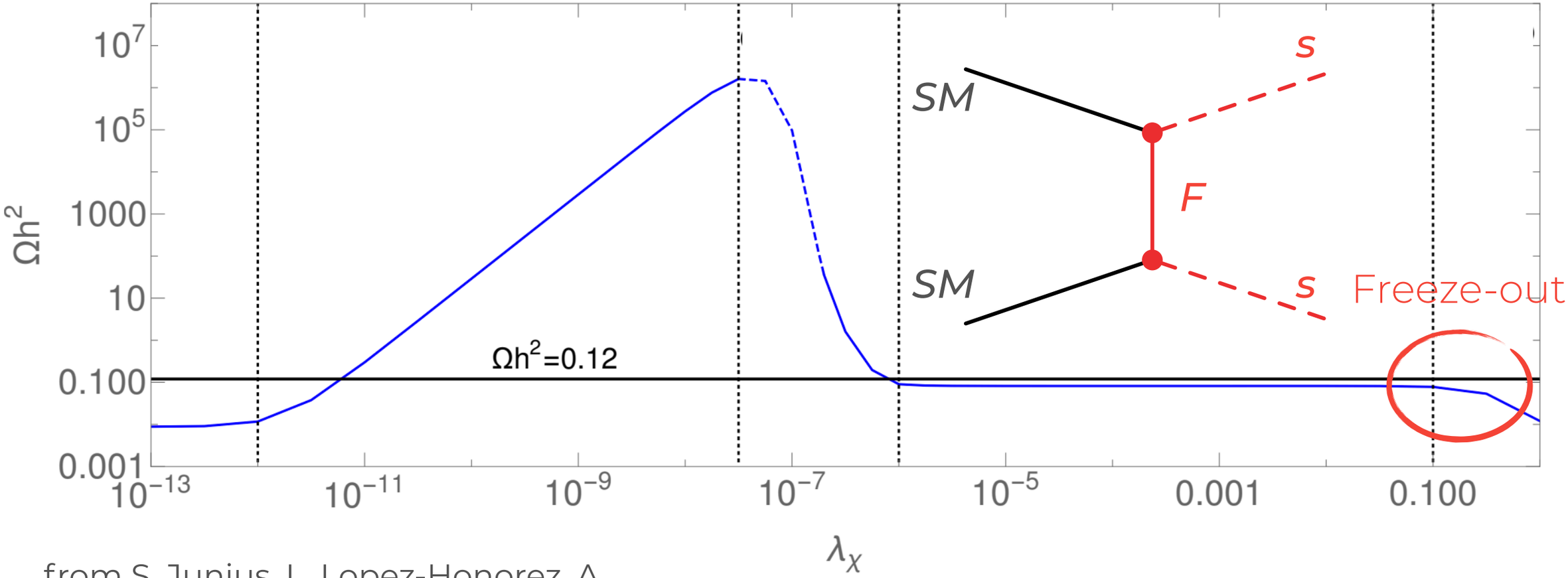

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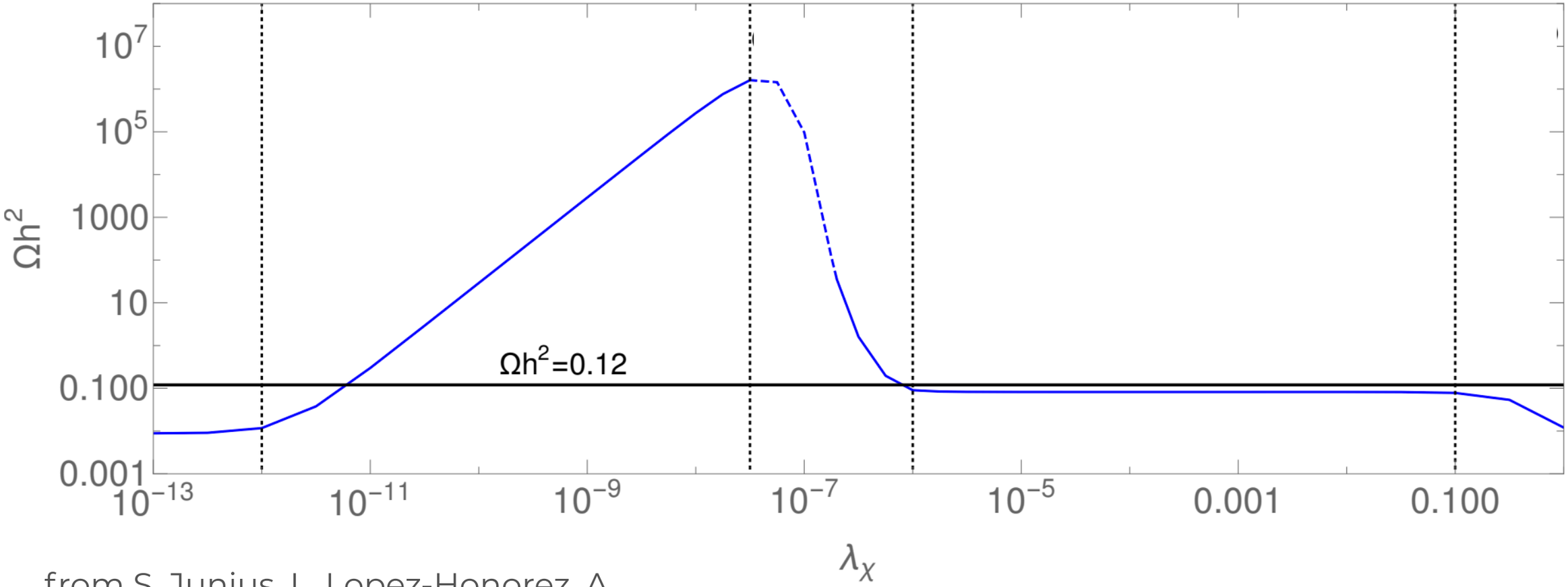

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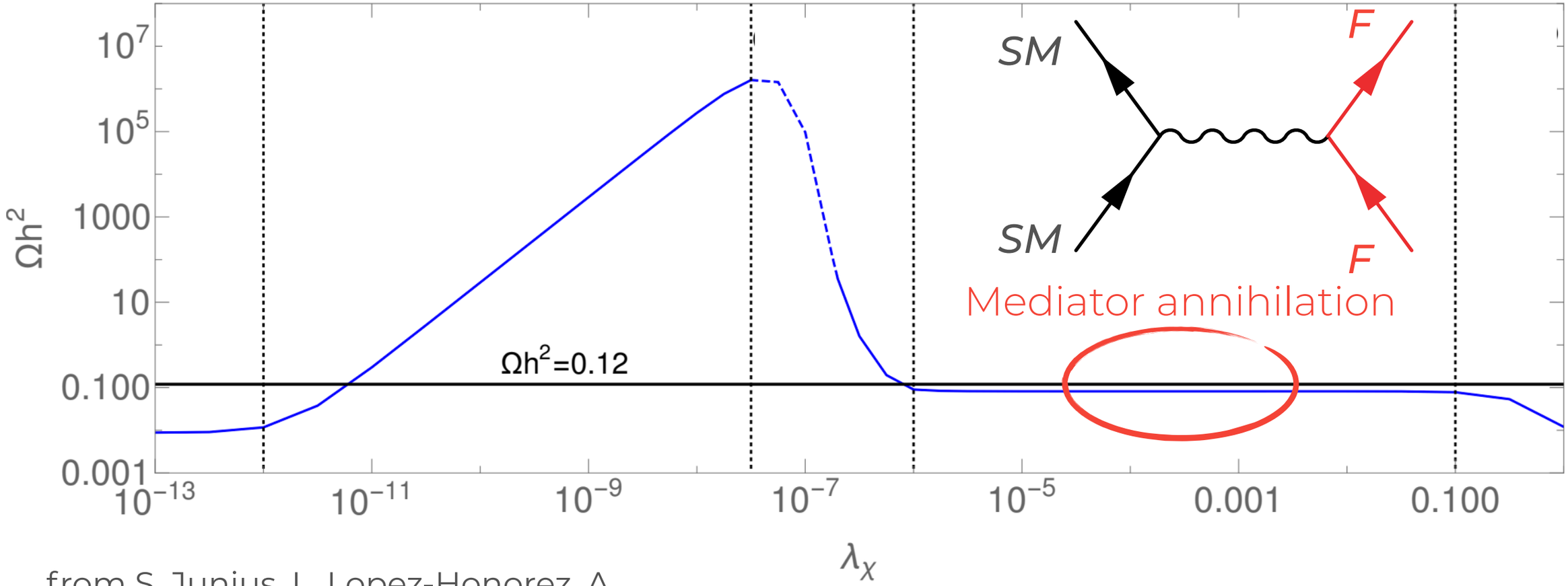

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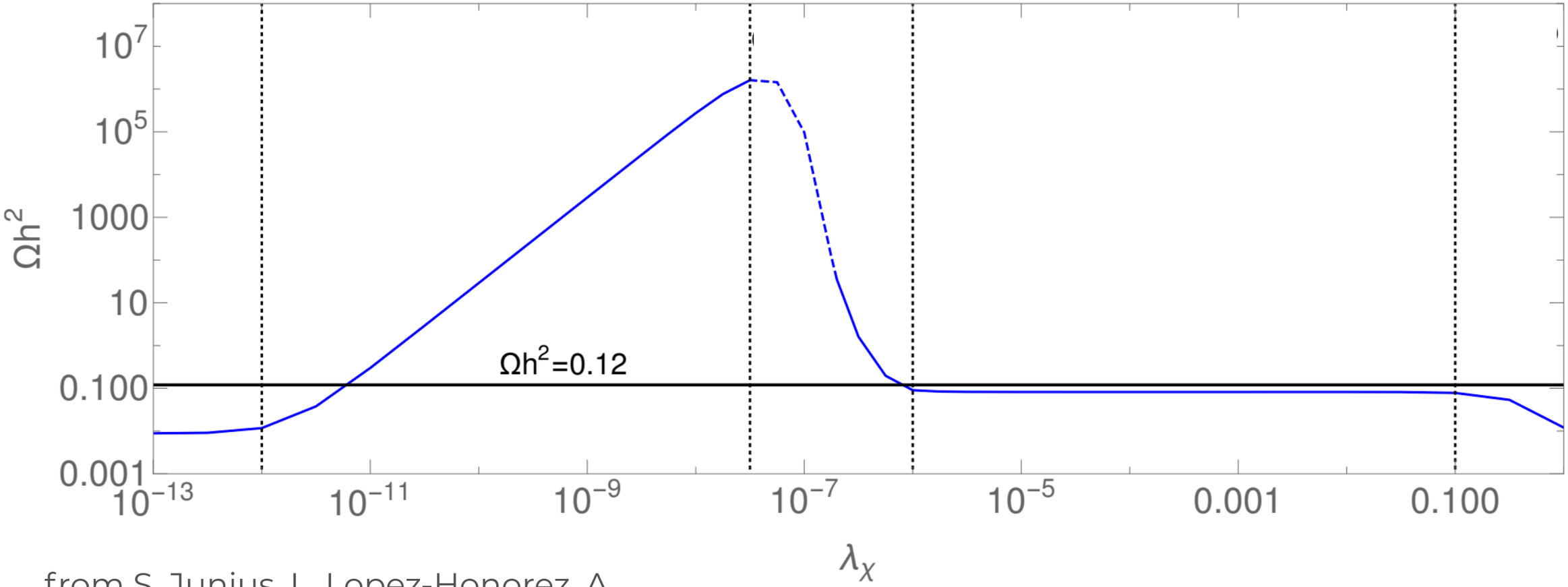

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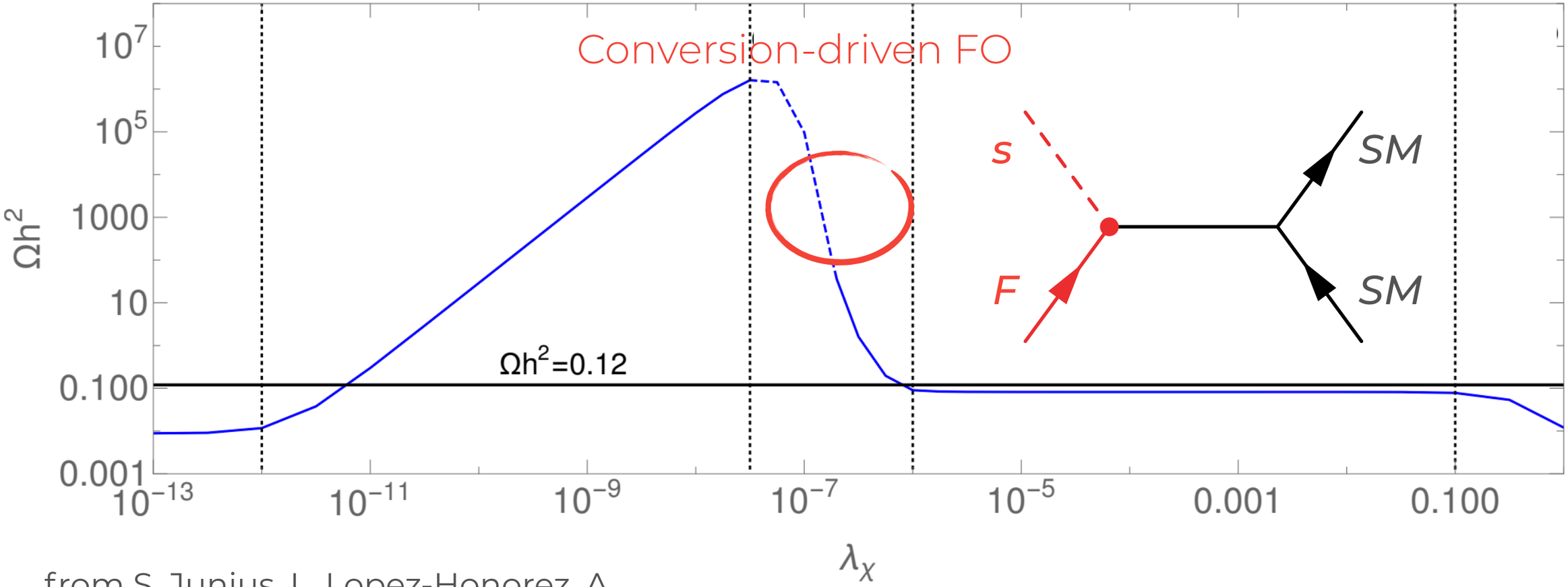

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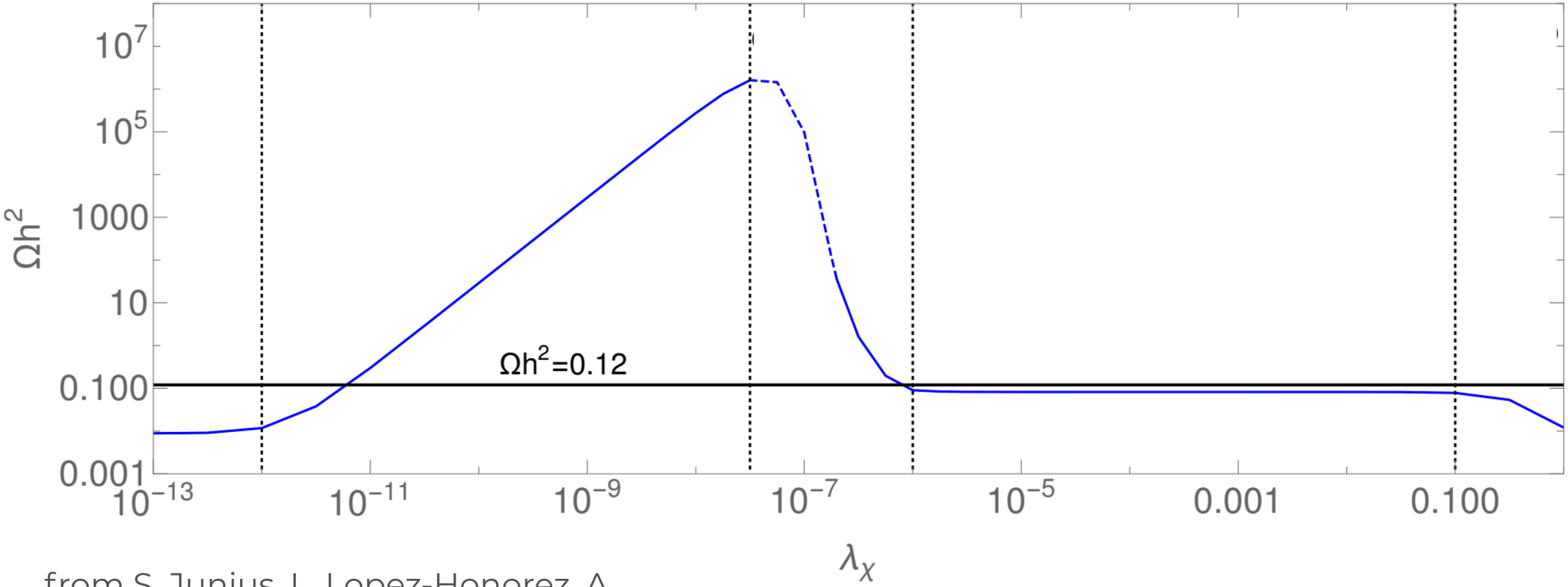

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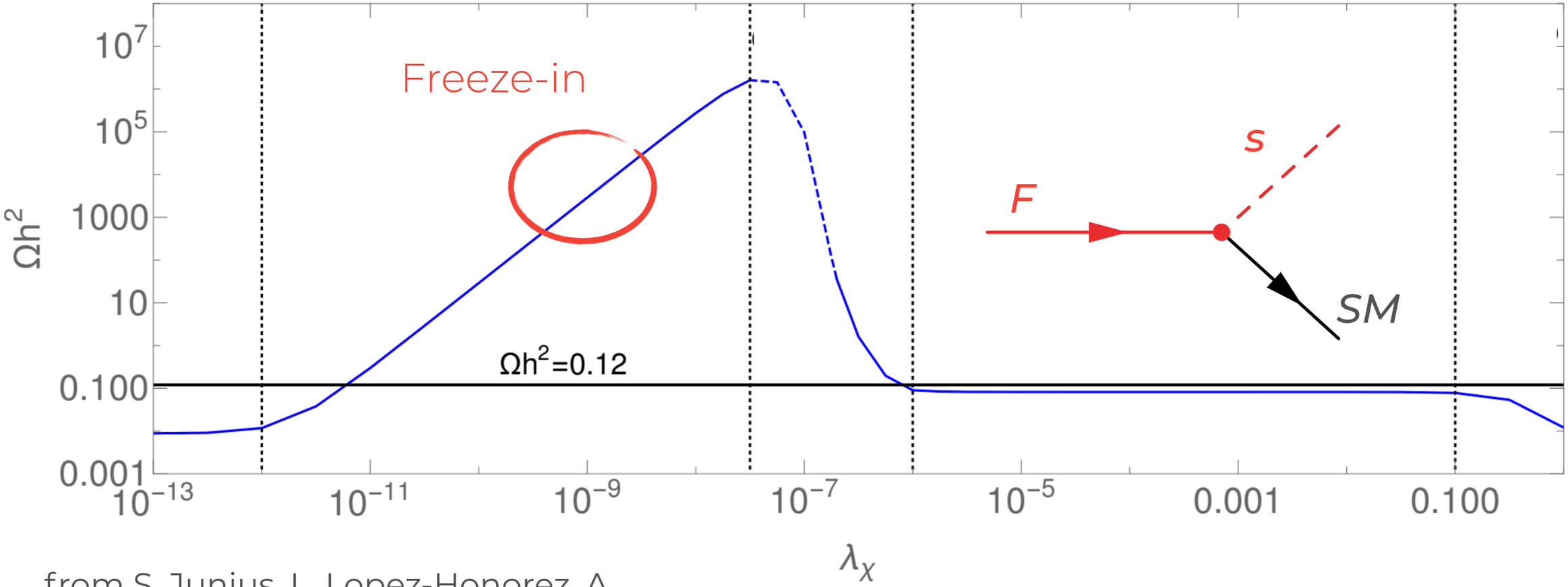

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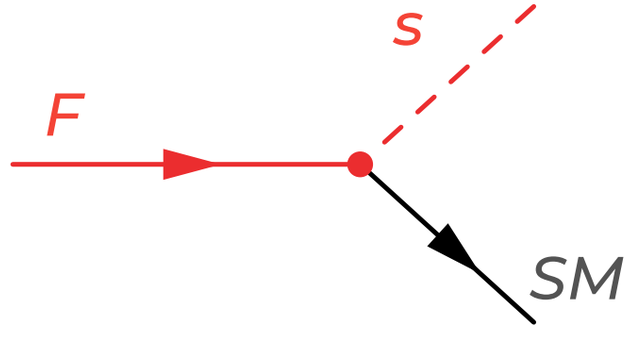

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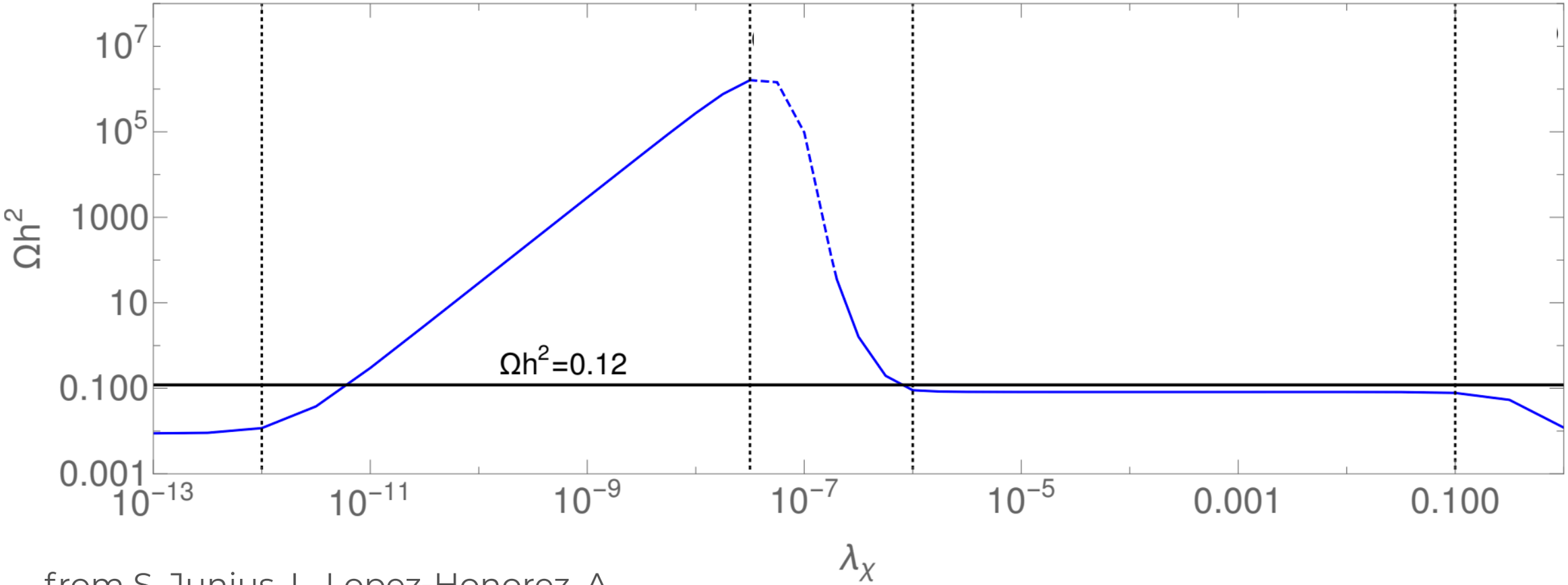

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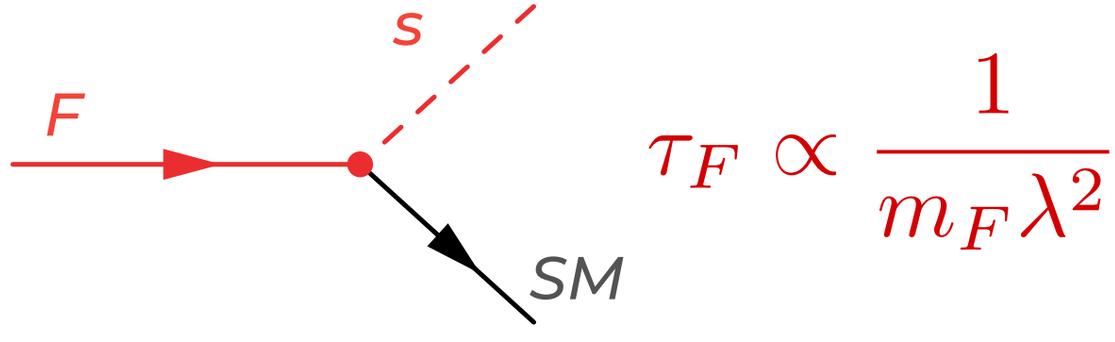

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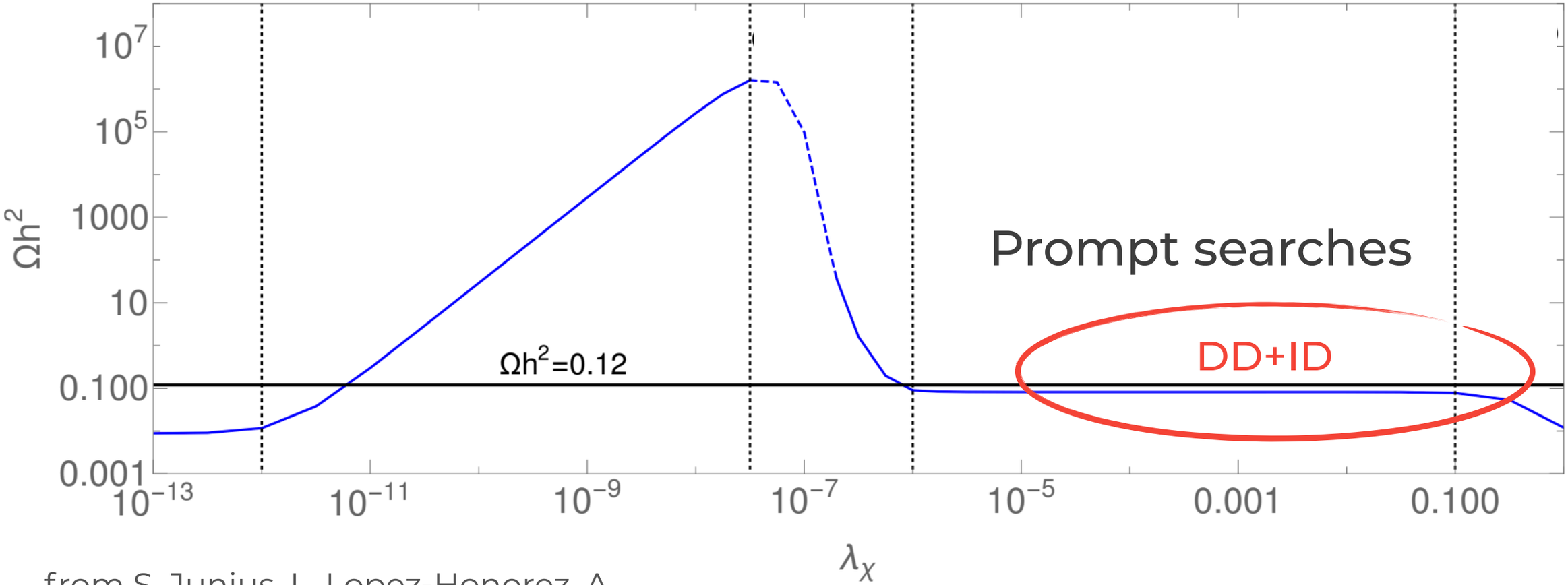

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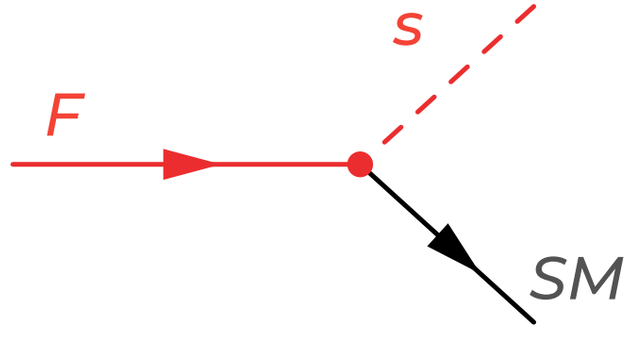
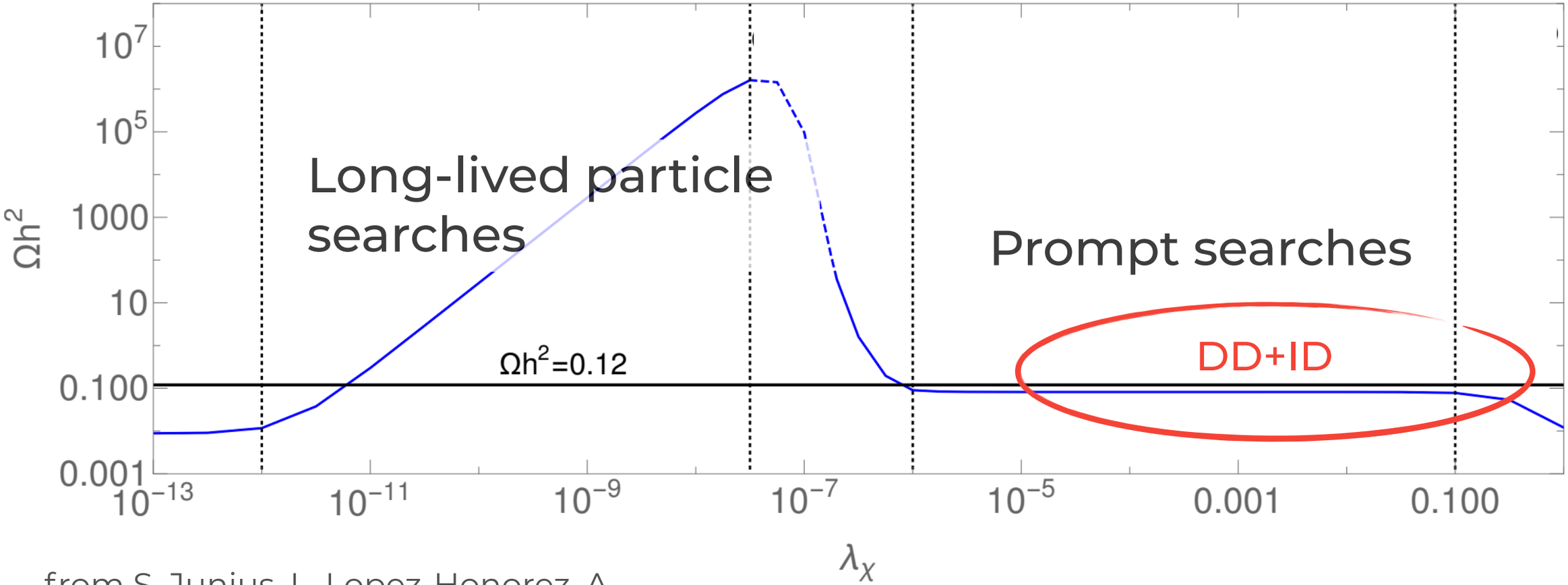


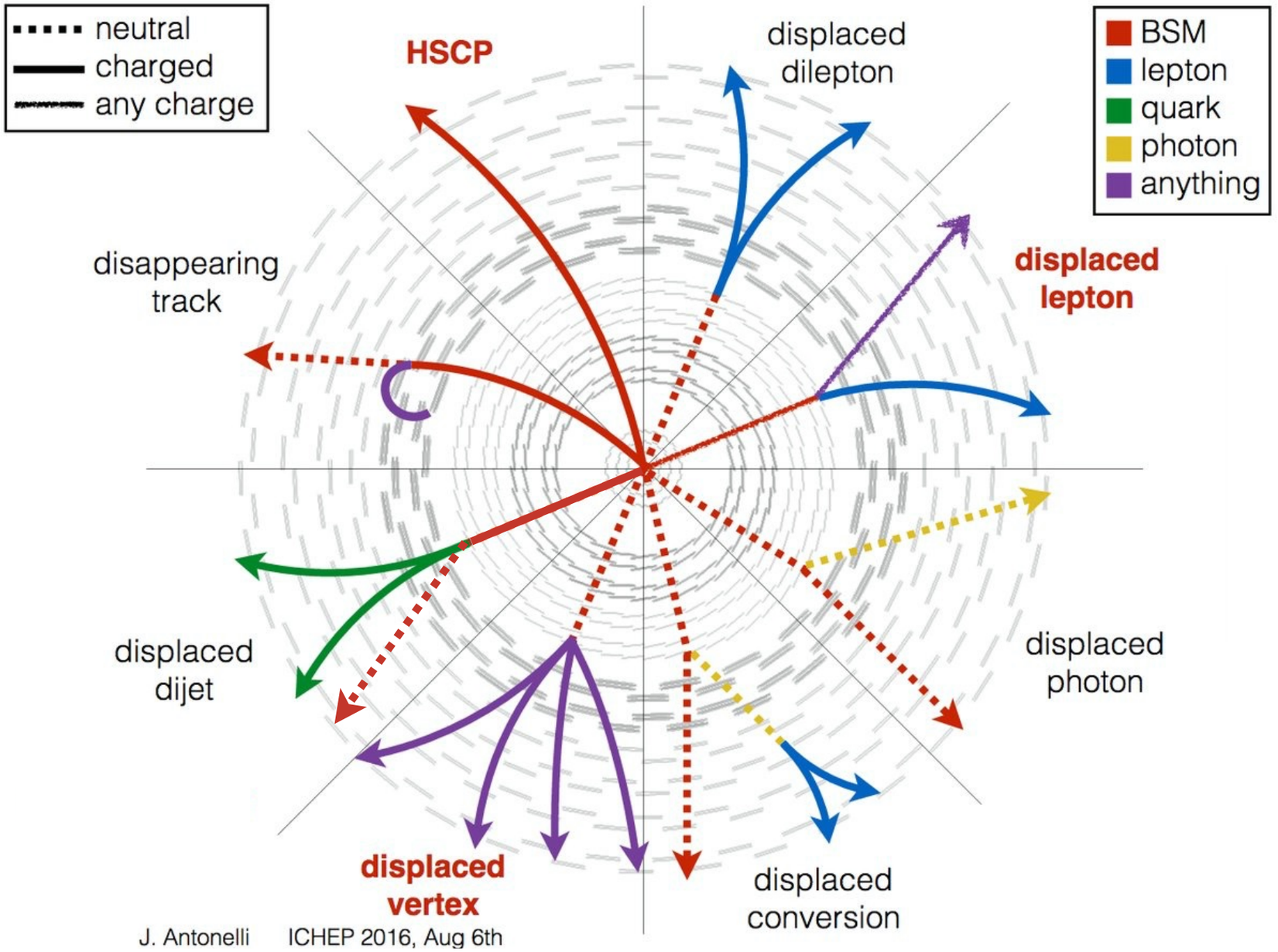
$$\tau_F \propto \frac{1}{m_F \lambda^2}$$



from S. Junius, L. Lopez-Honorez, A. Mariotti, *JHEP* 07 (2019) 136

LLPs @ LHC

- Long-lived signatures:



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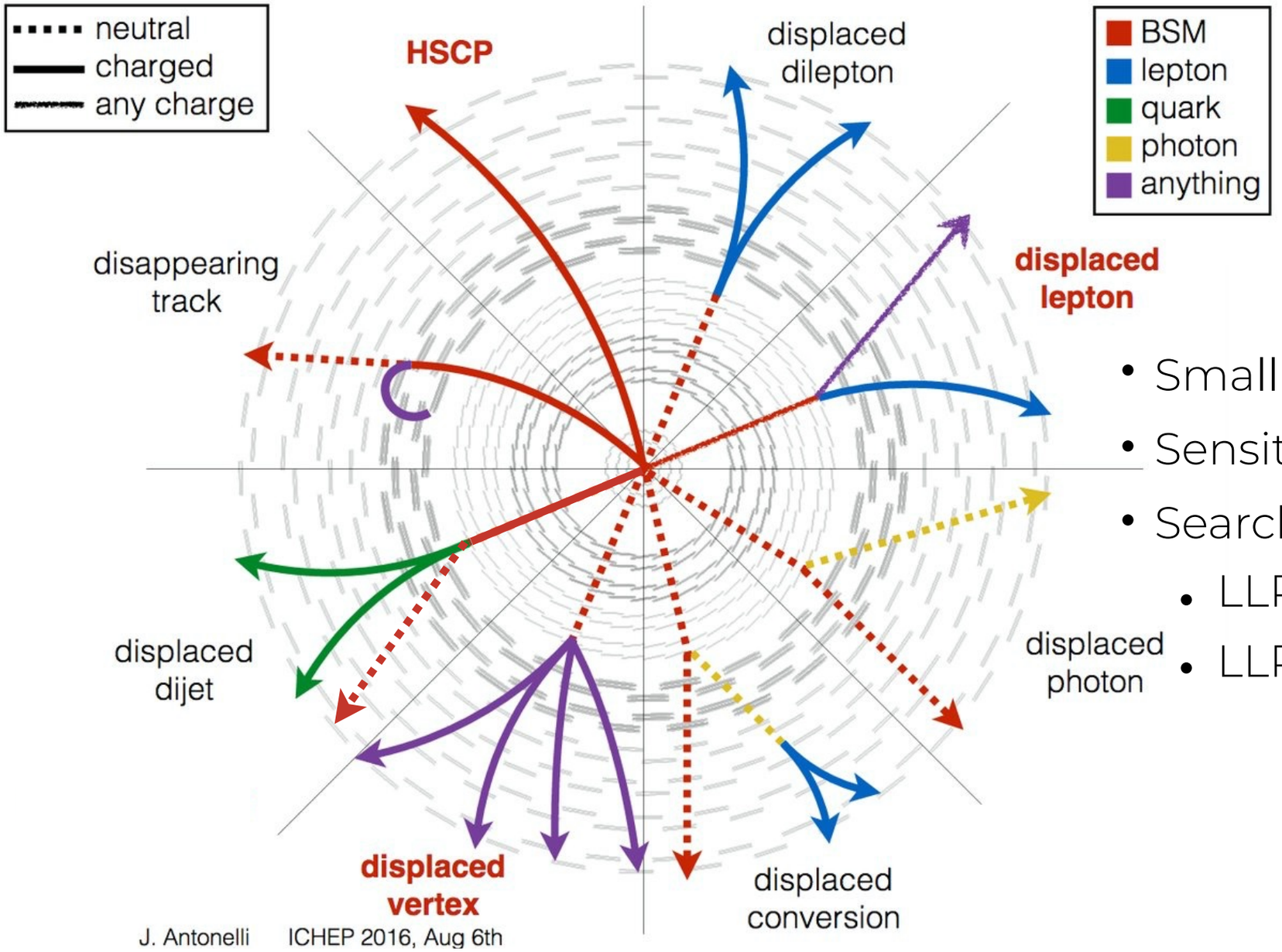

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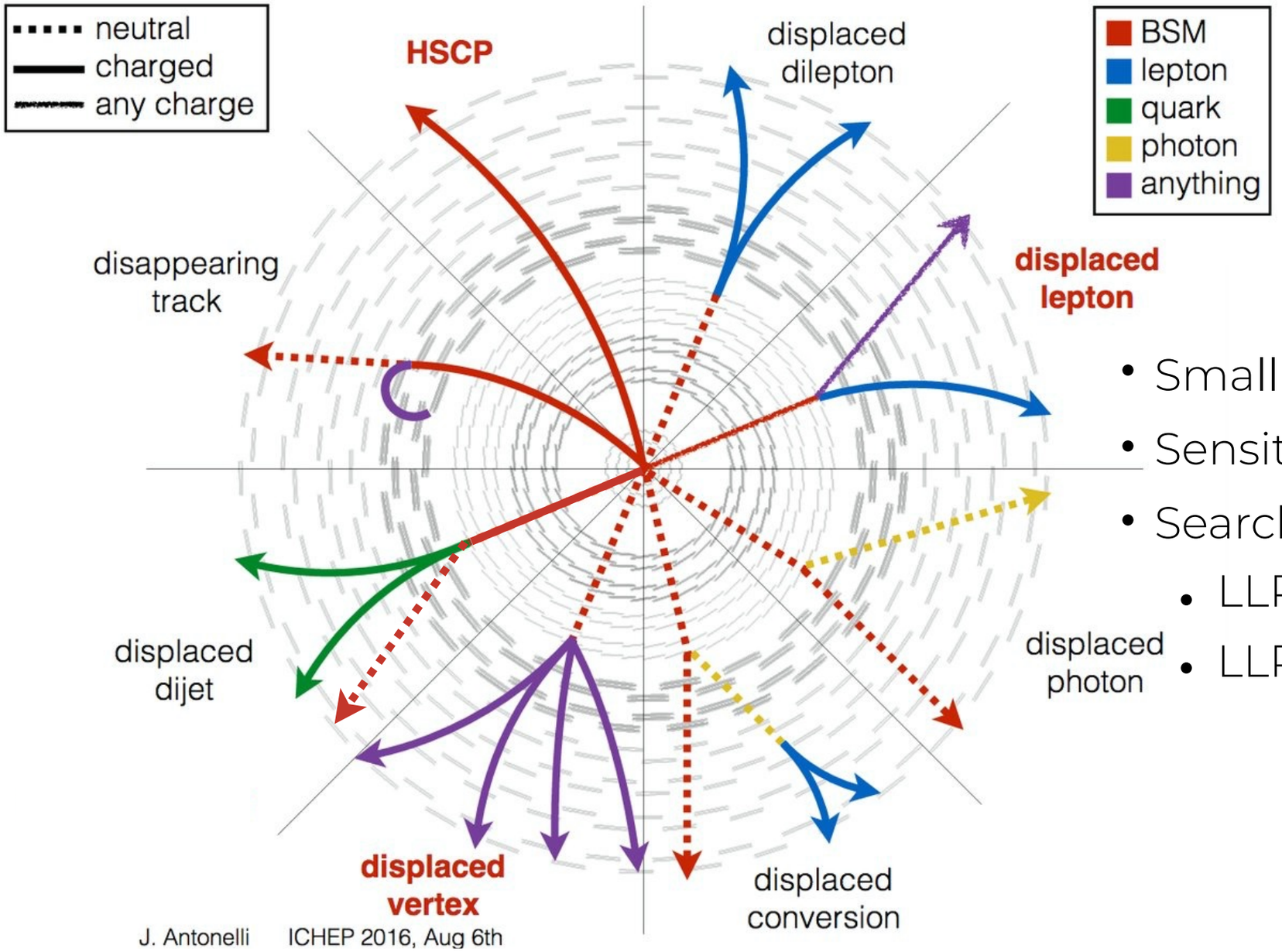

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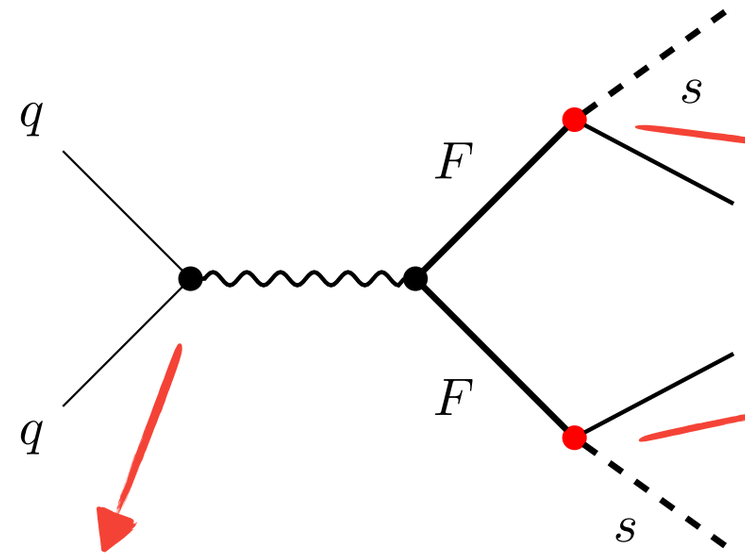
Many searches do not target DM motivated scenarios

"Minimal FIMP" DM @ LHC



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QCD-like (hadronic) or
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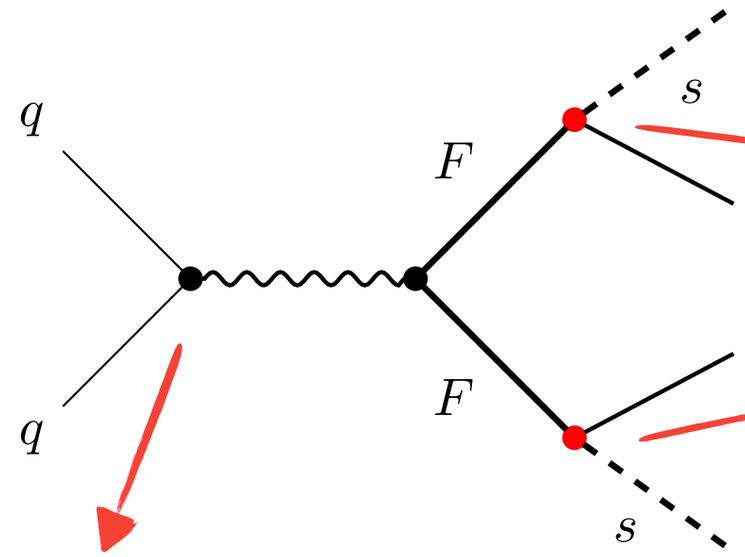

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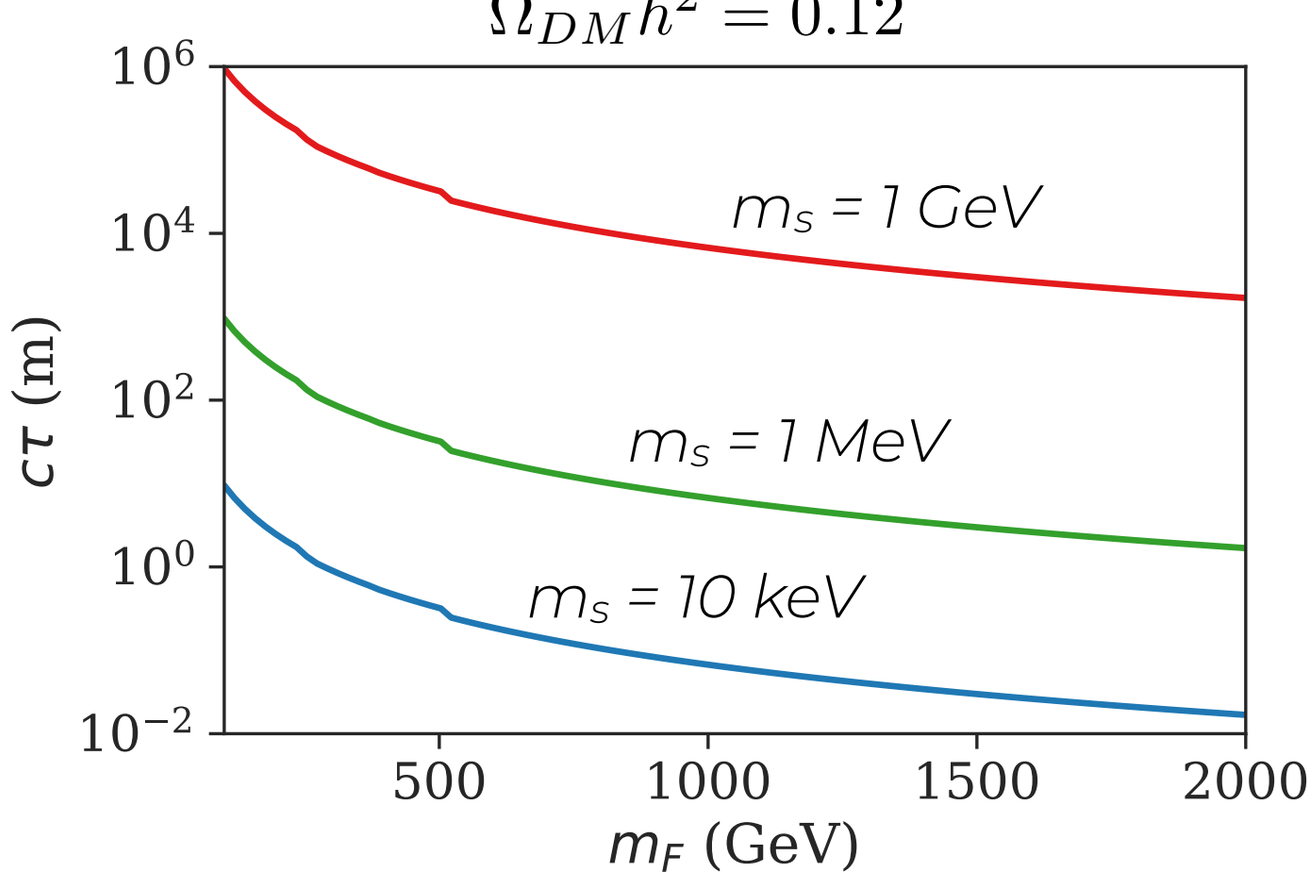

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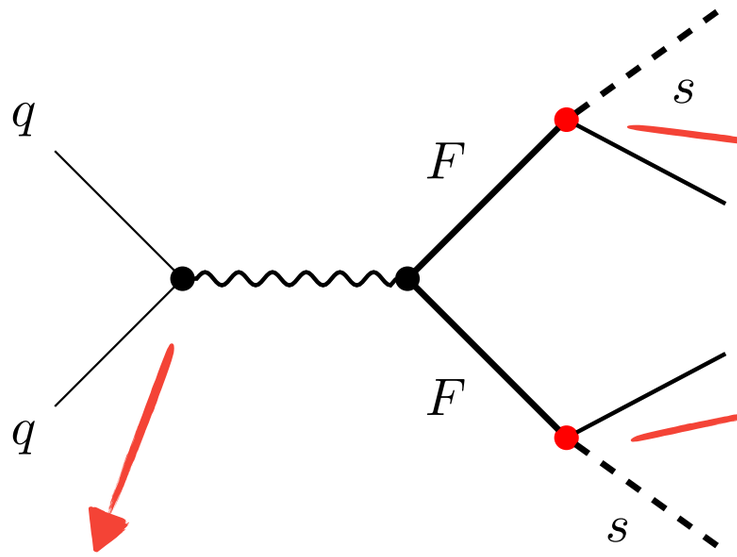

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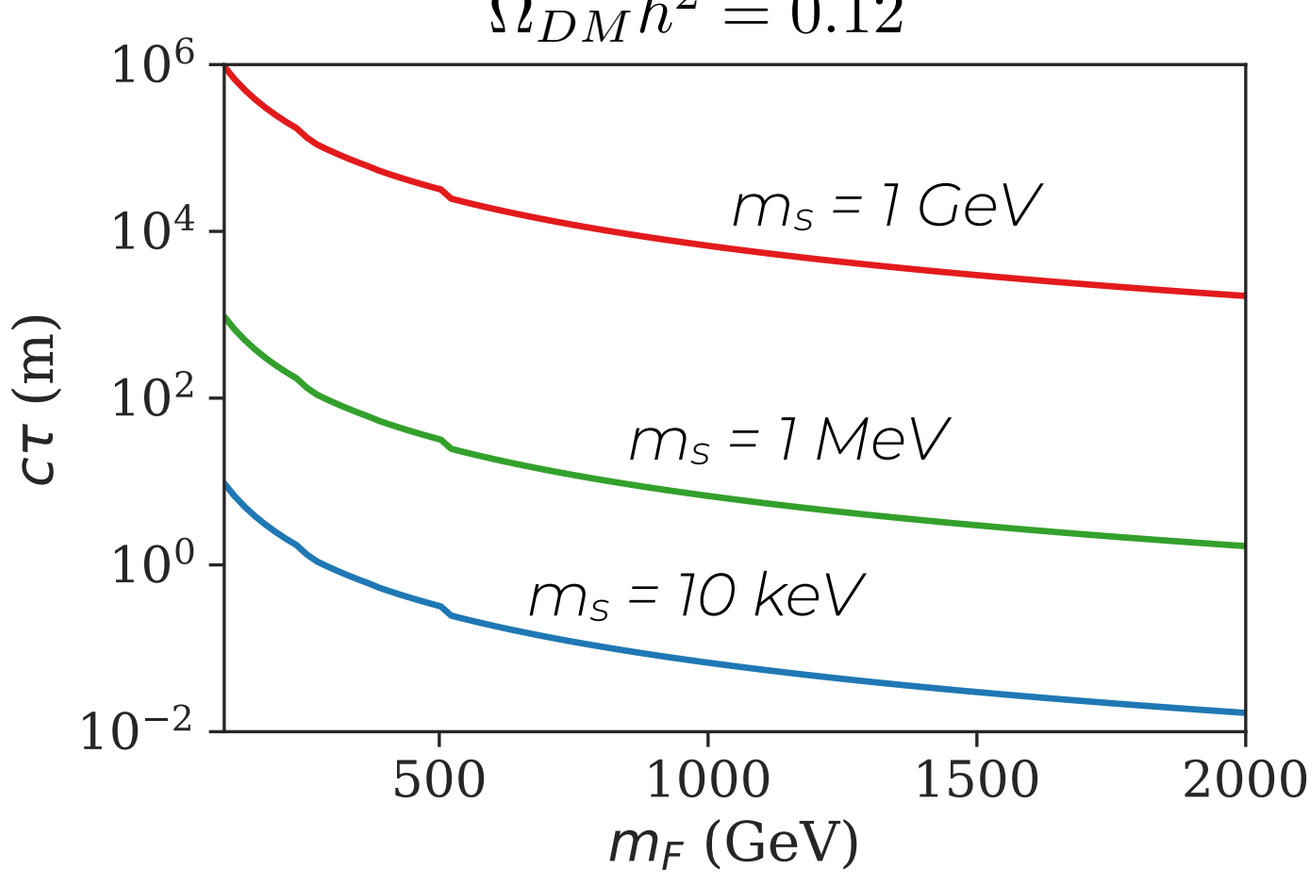
QCD-like (hadronic) or EW-like (leptonic) cross-sections

- Stable mediator (at collider scales)
- No direct connection to DM



Minimal FIMP DM @ LHC

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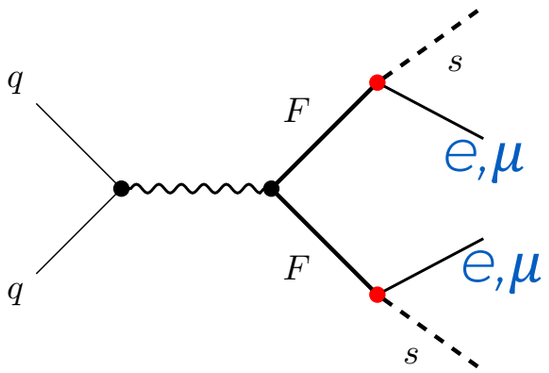

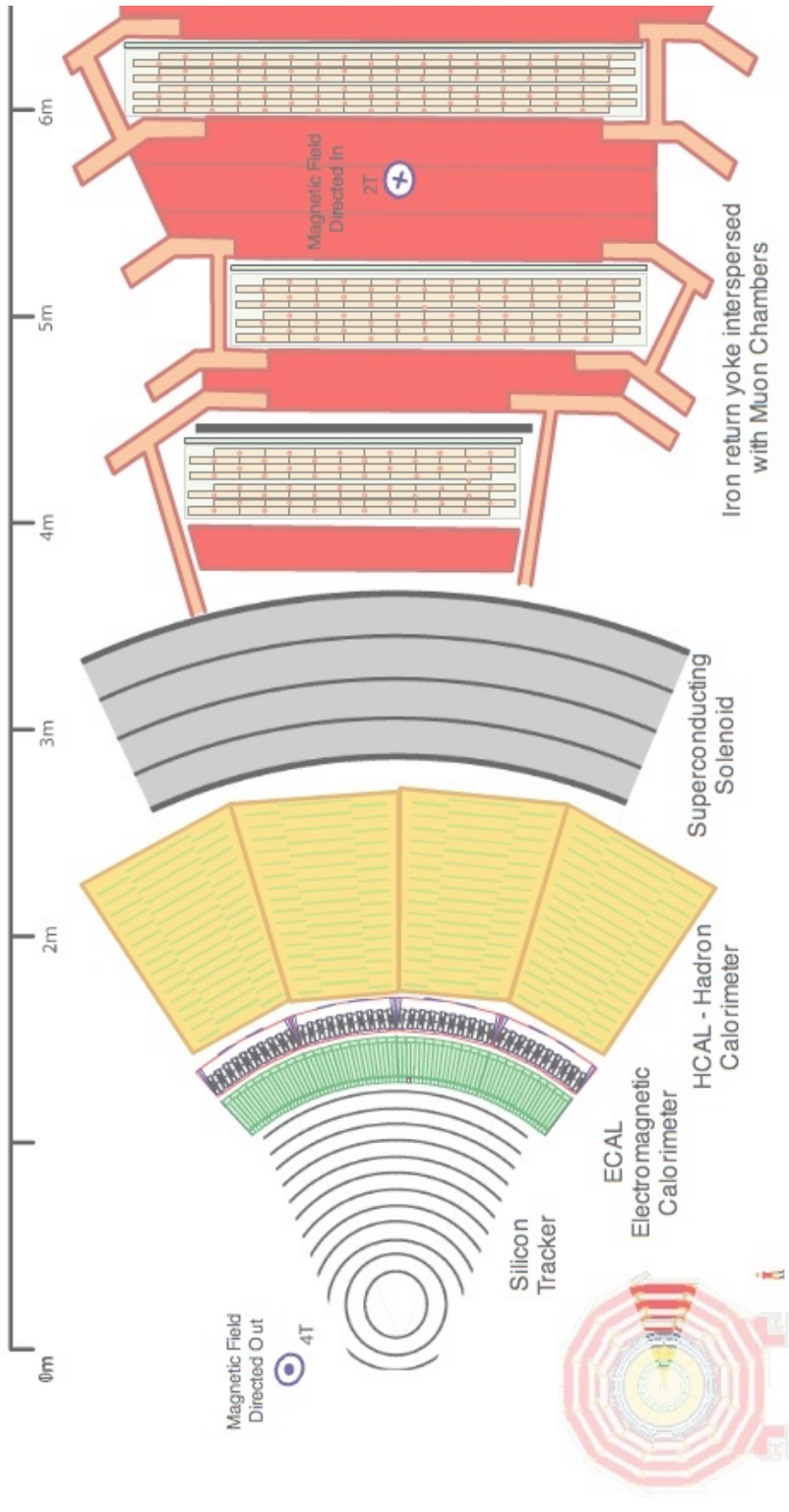

G. Bélanger et al, *JHEP* 02 (2019) 186

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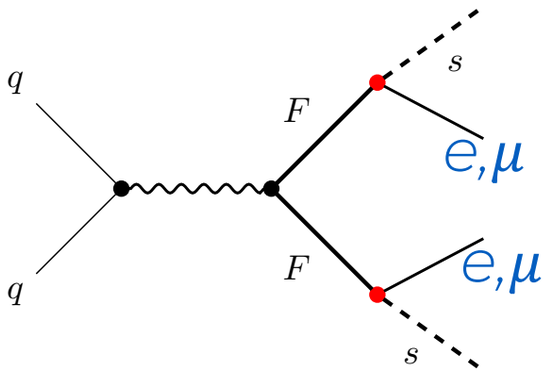

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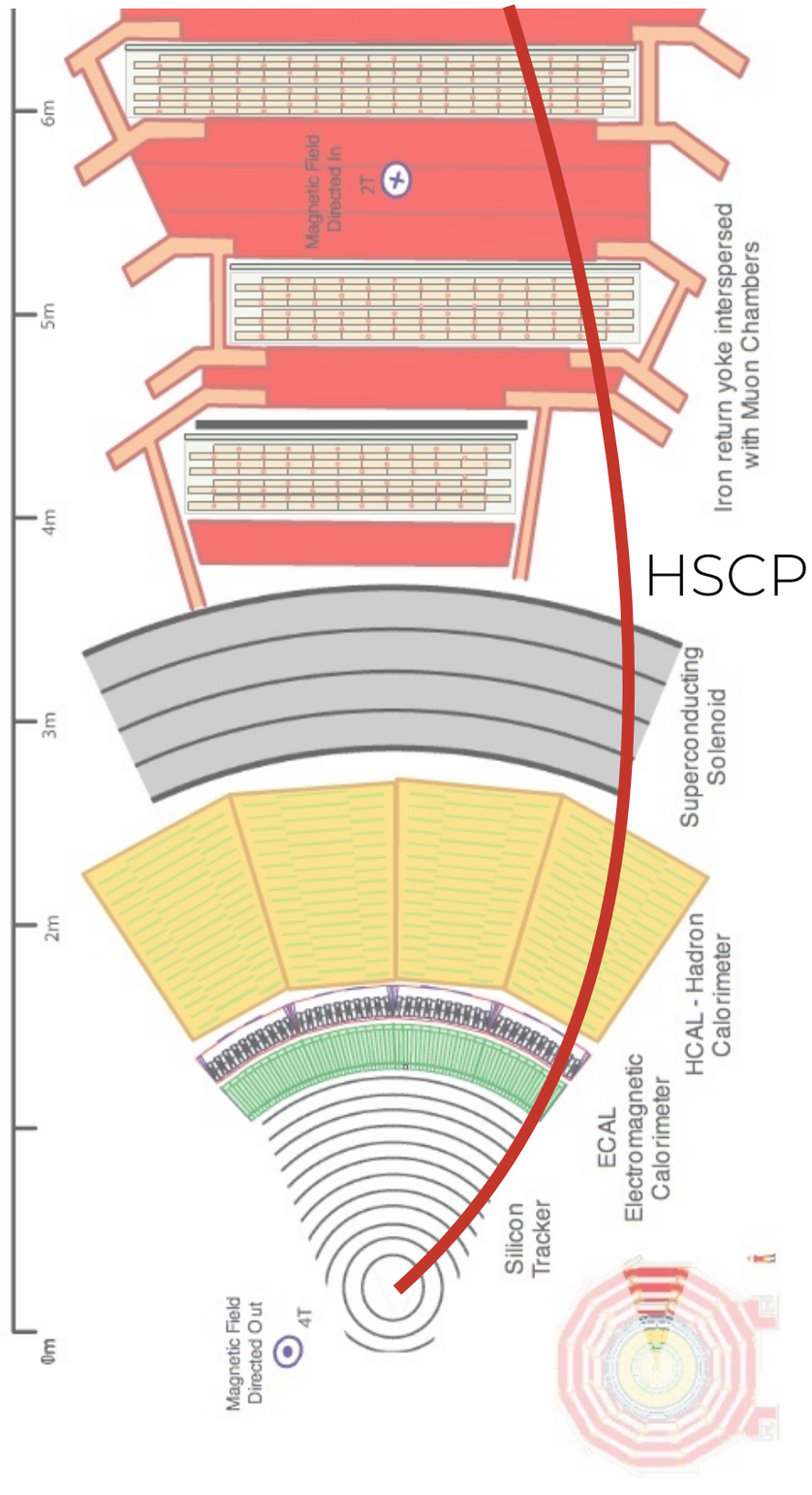

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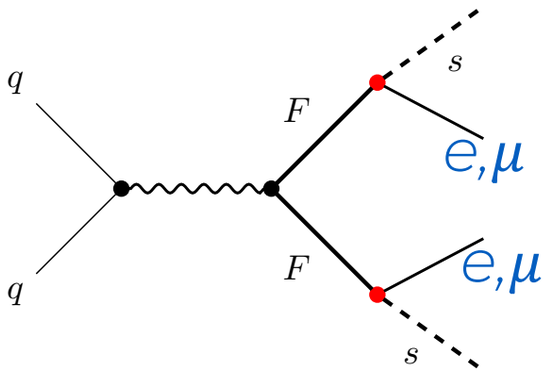

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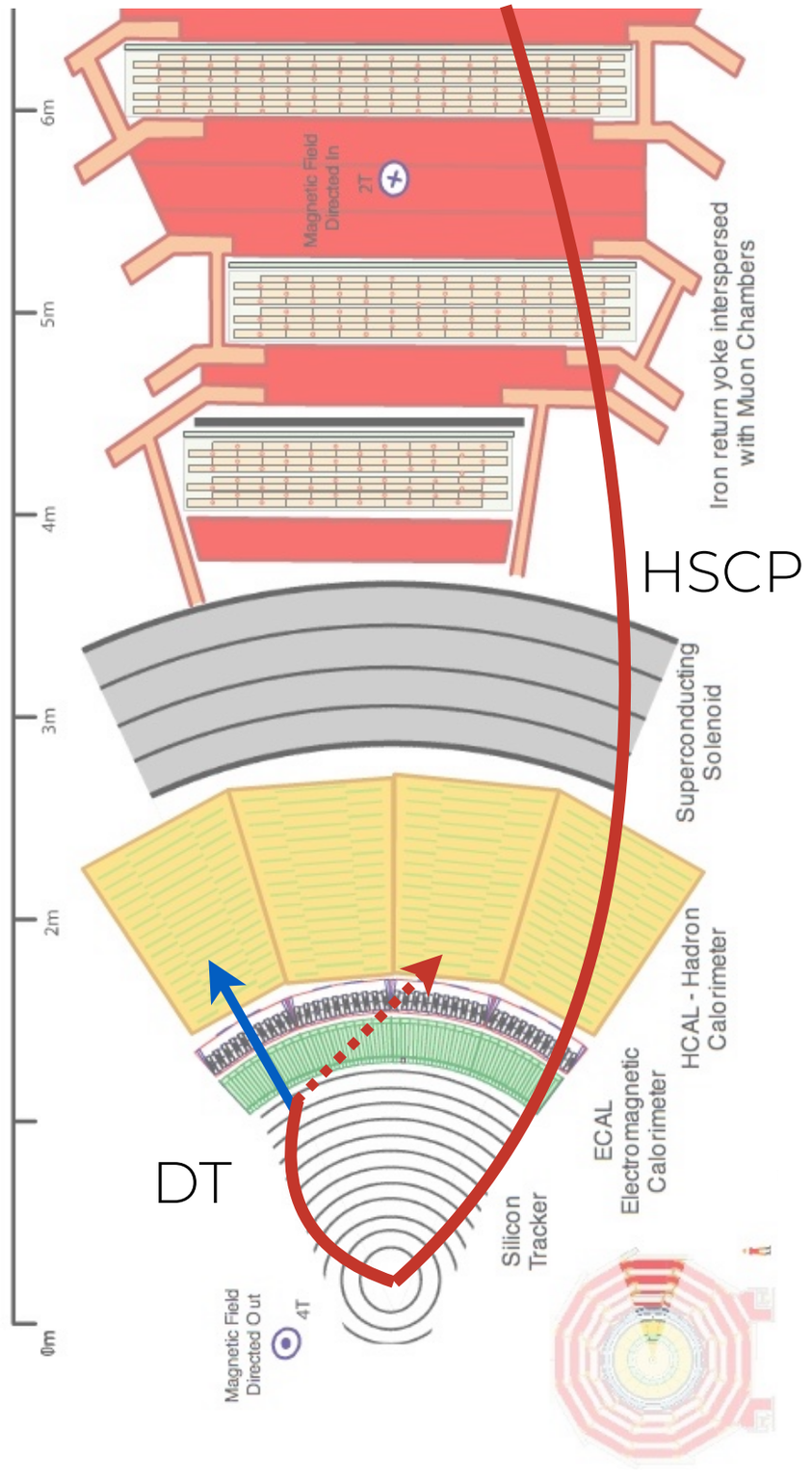

G. Bélanger et al, *JHEP* 02 (2019) 186

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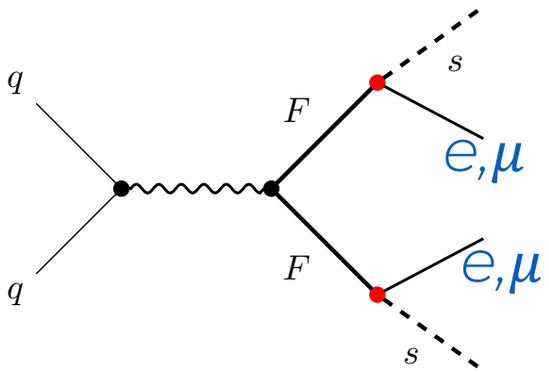

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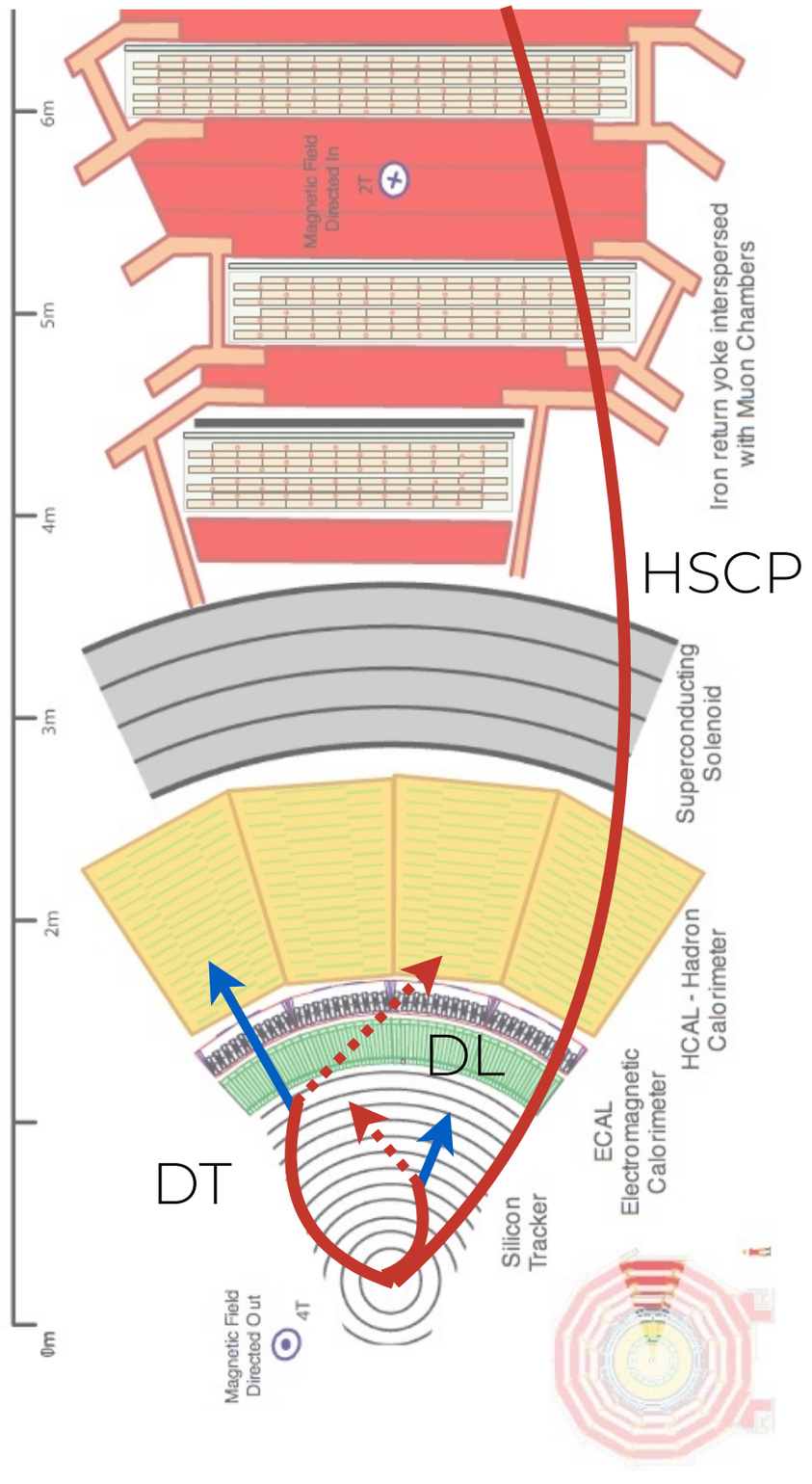

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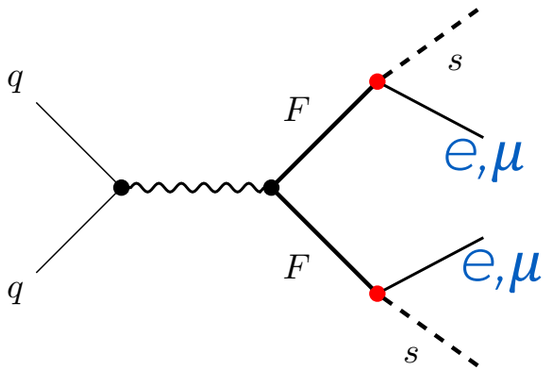

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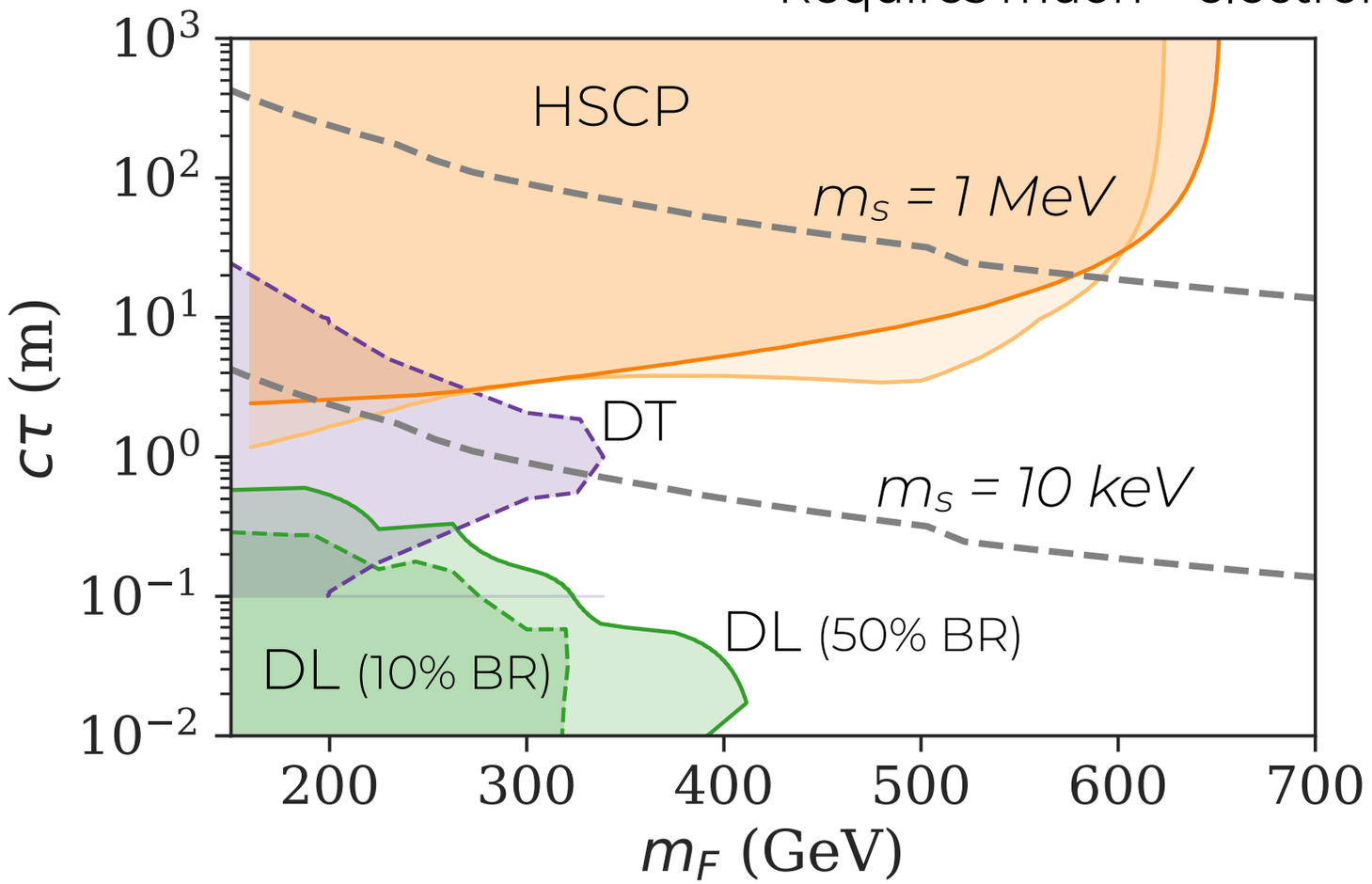

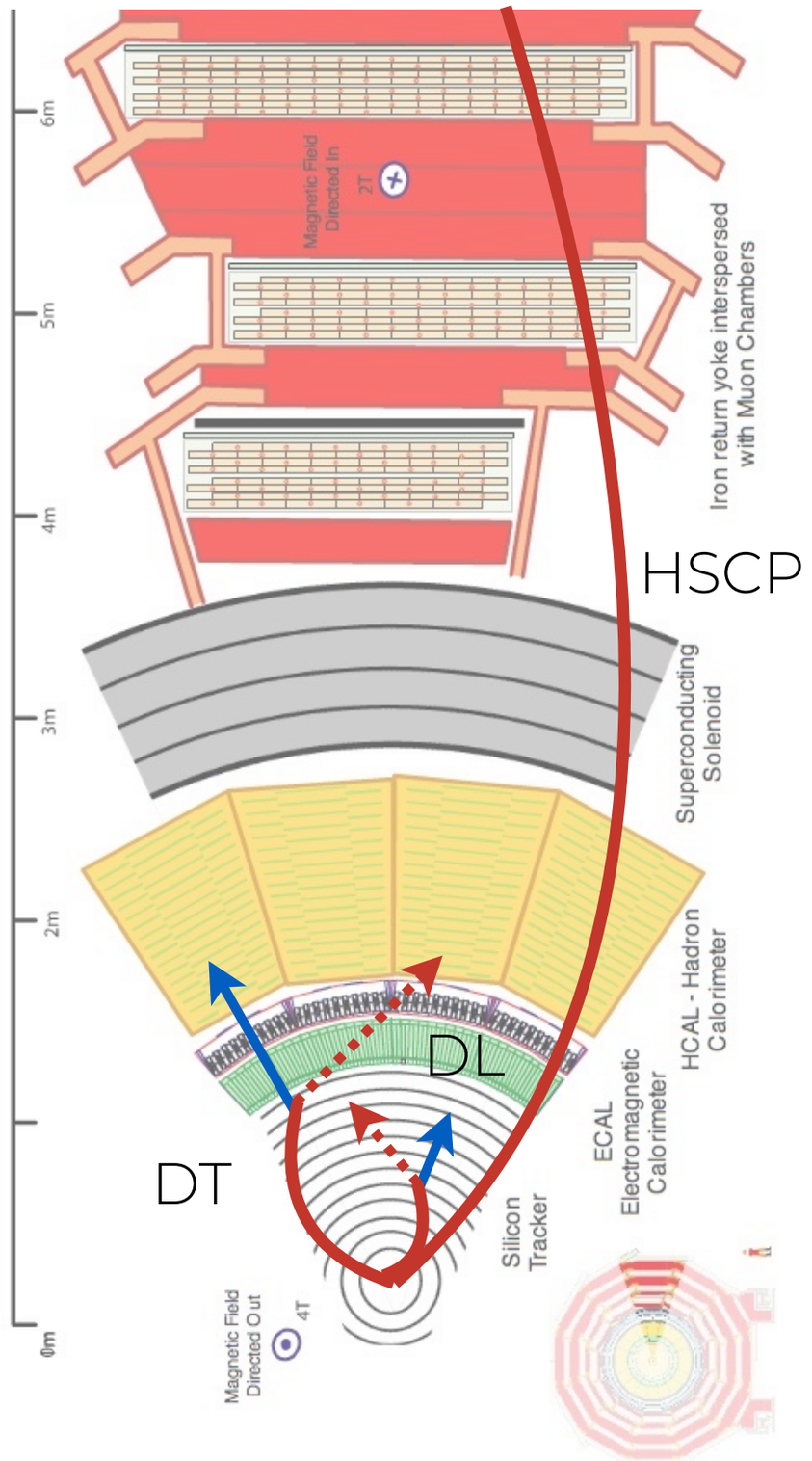

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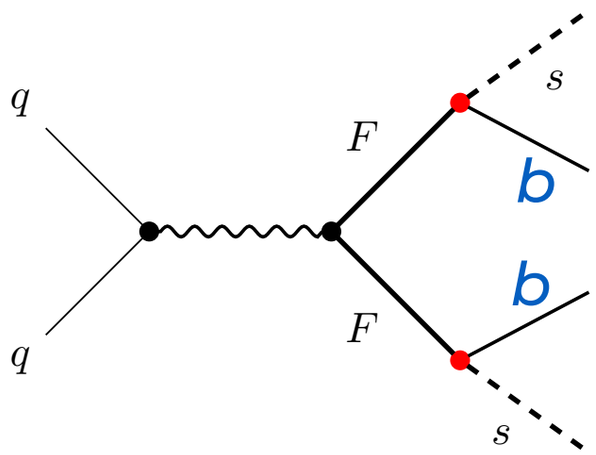
Conversion driven freeze-out

$$\Delta m \ll m_{DM},\ \lambda \sim 10^{-6}$$



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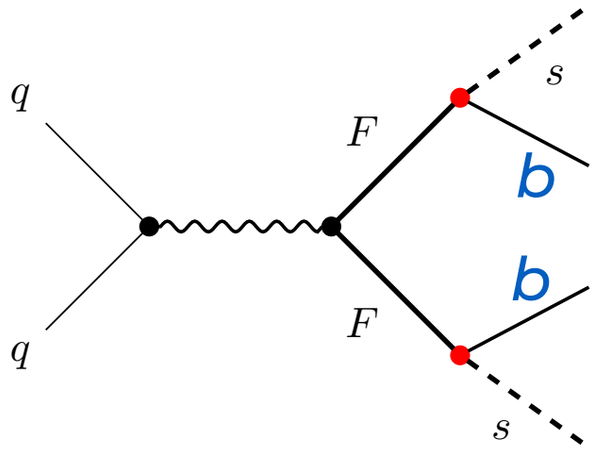

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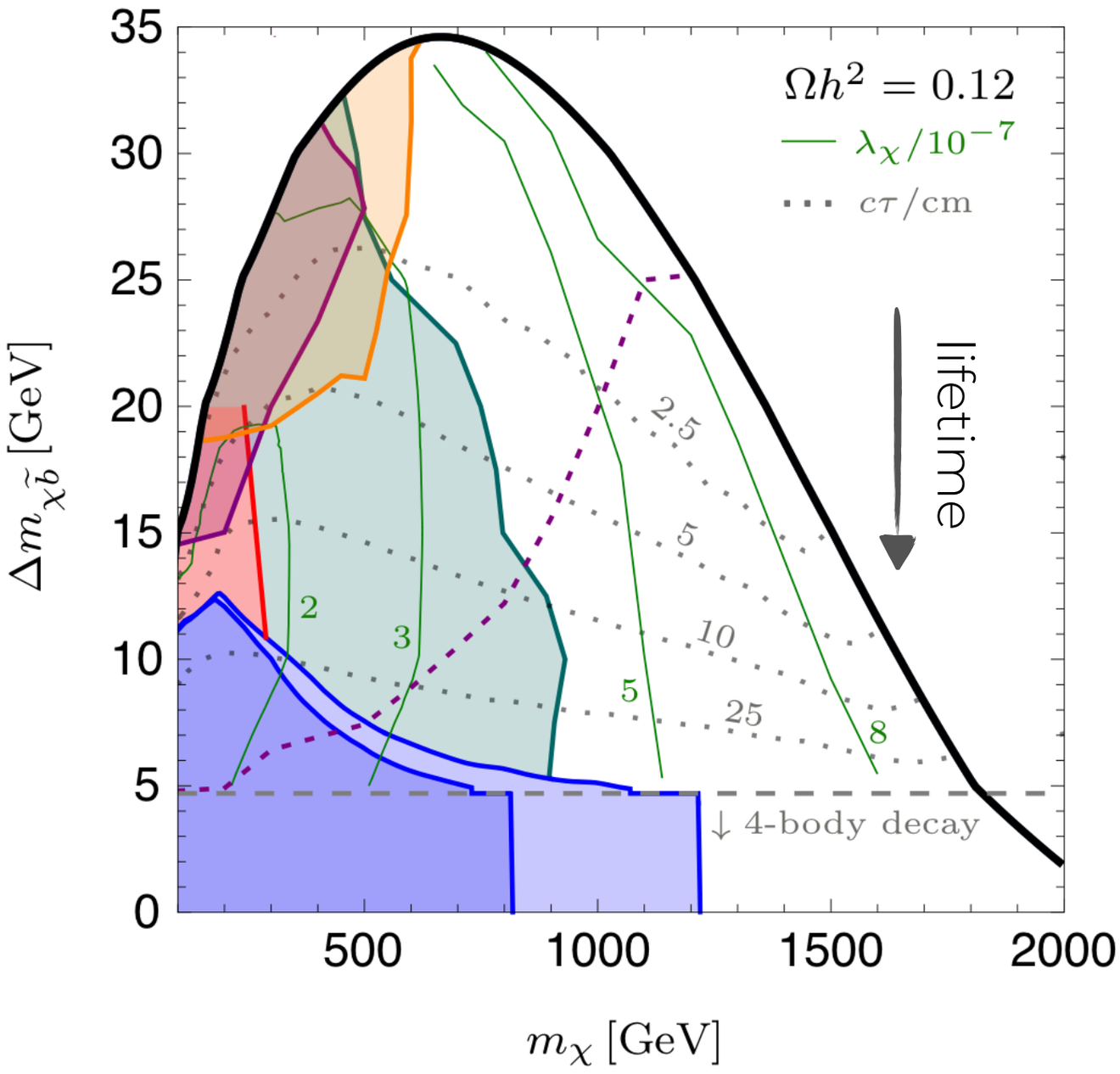

B. Fuks et al, 2002.12220

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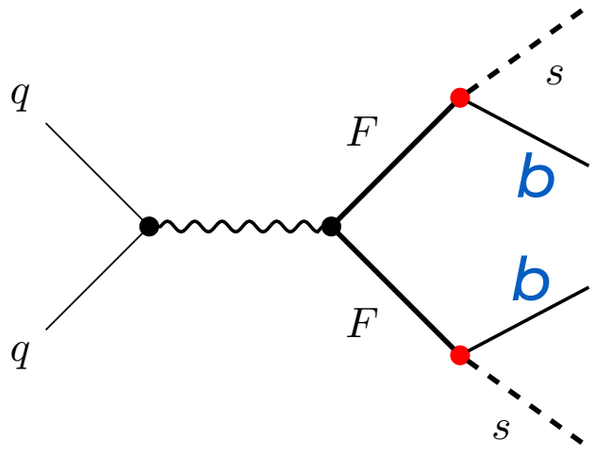

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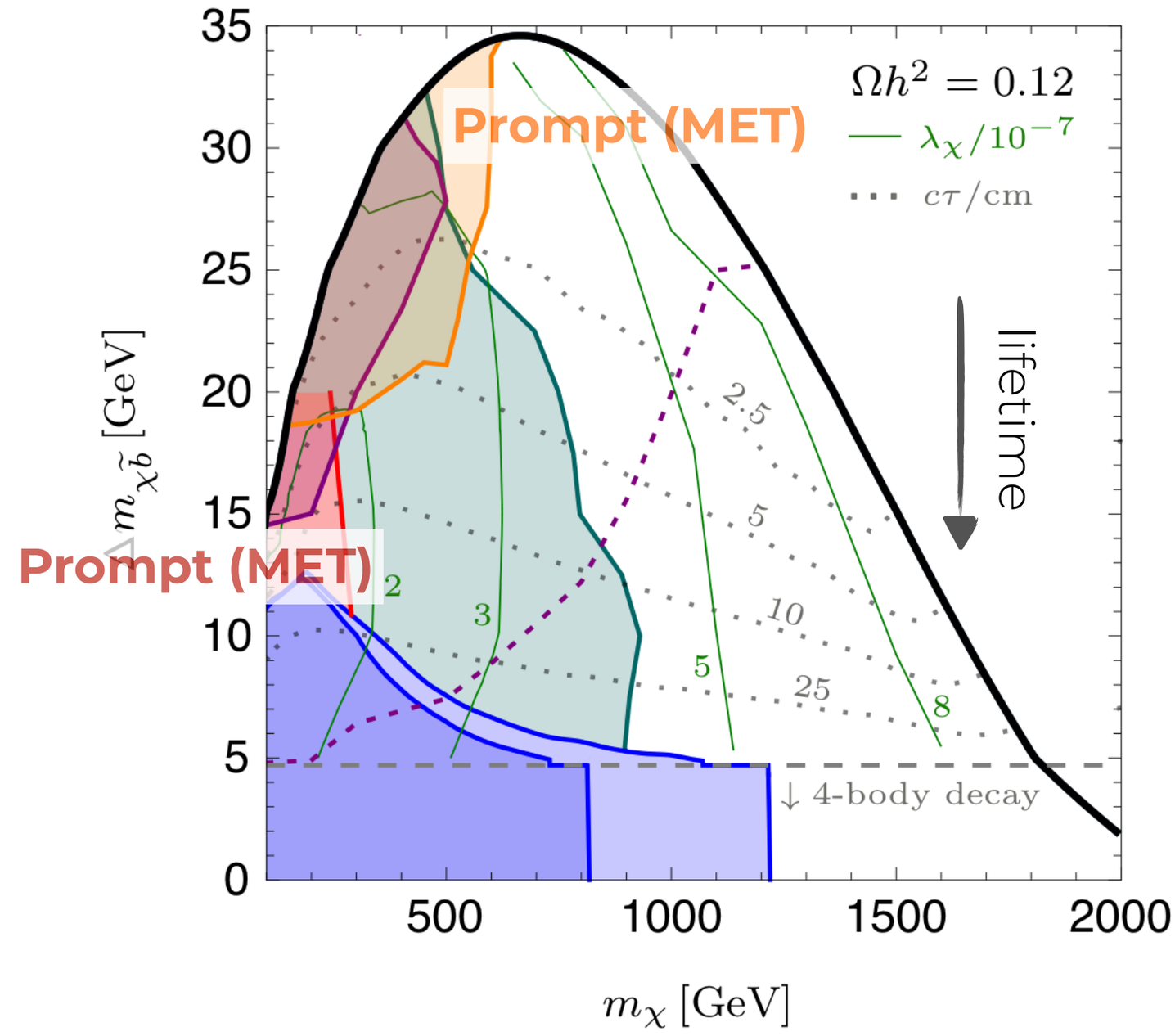

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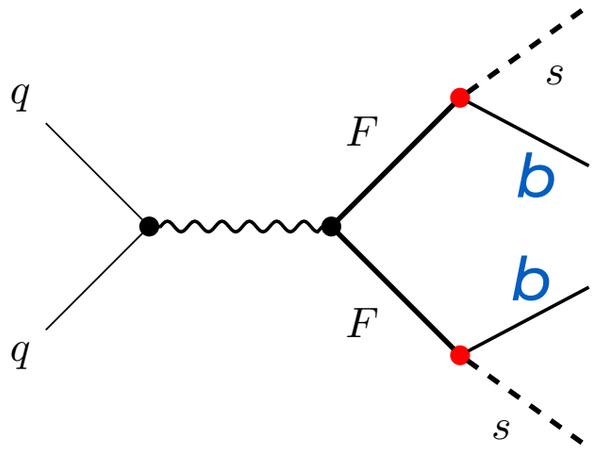

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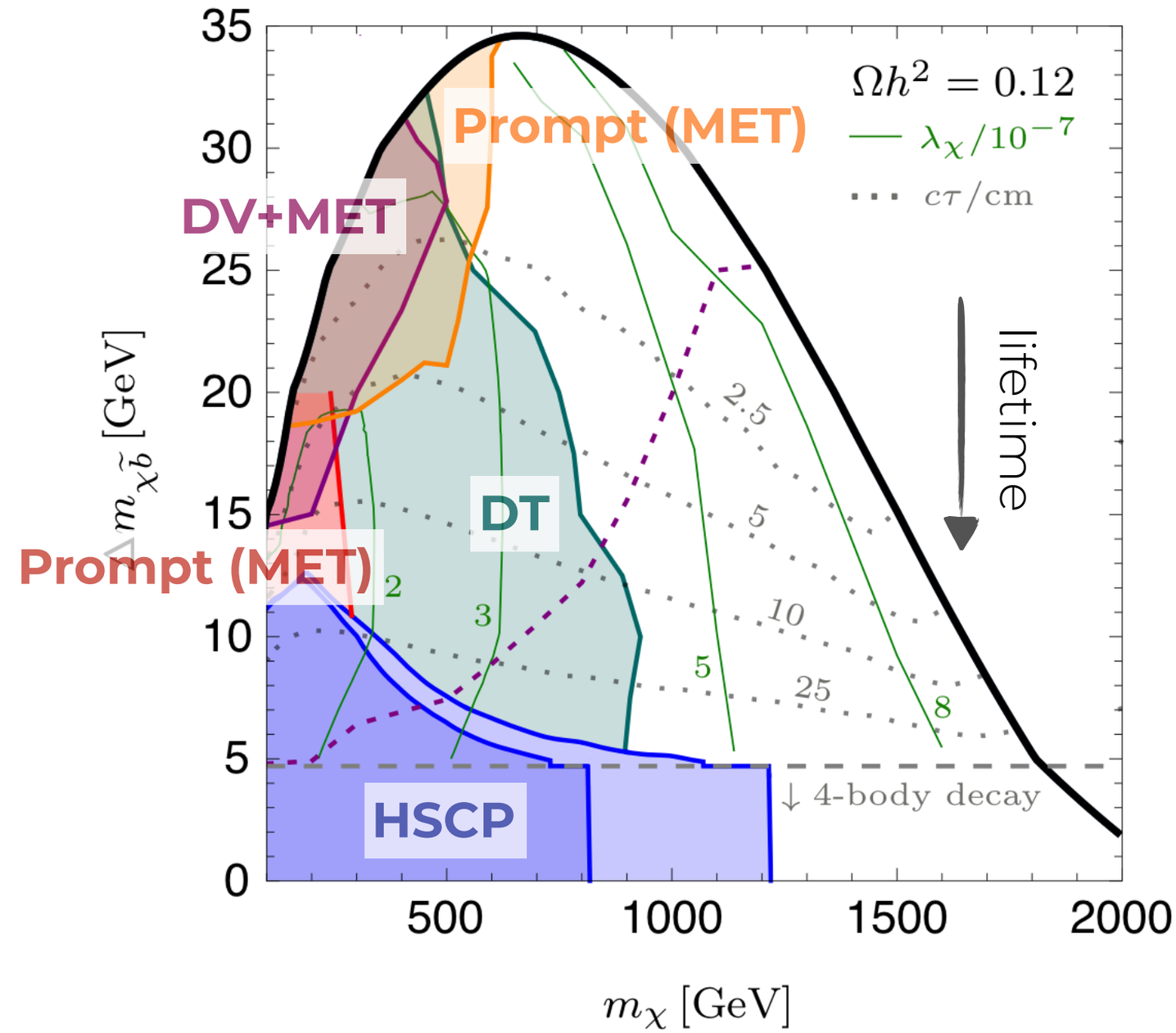

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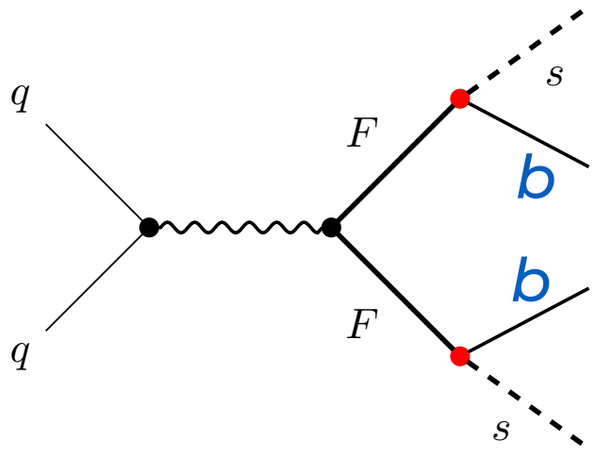

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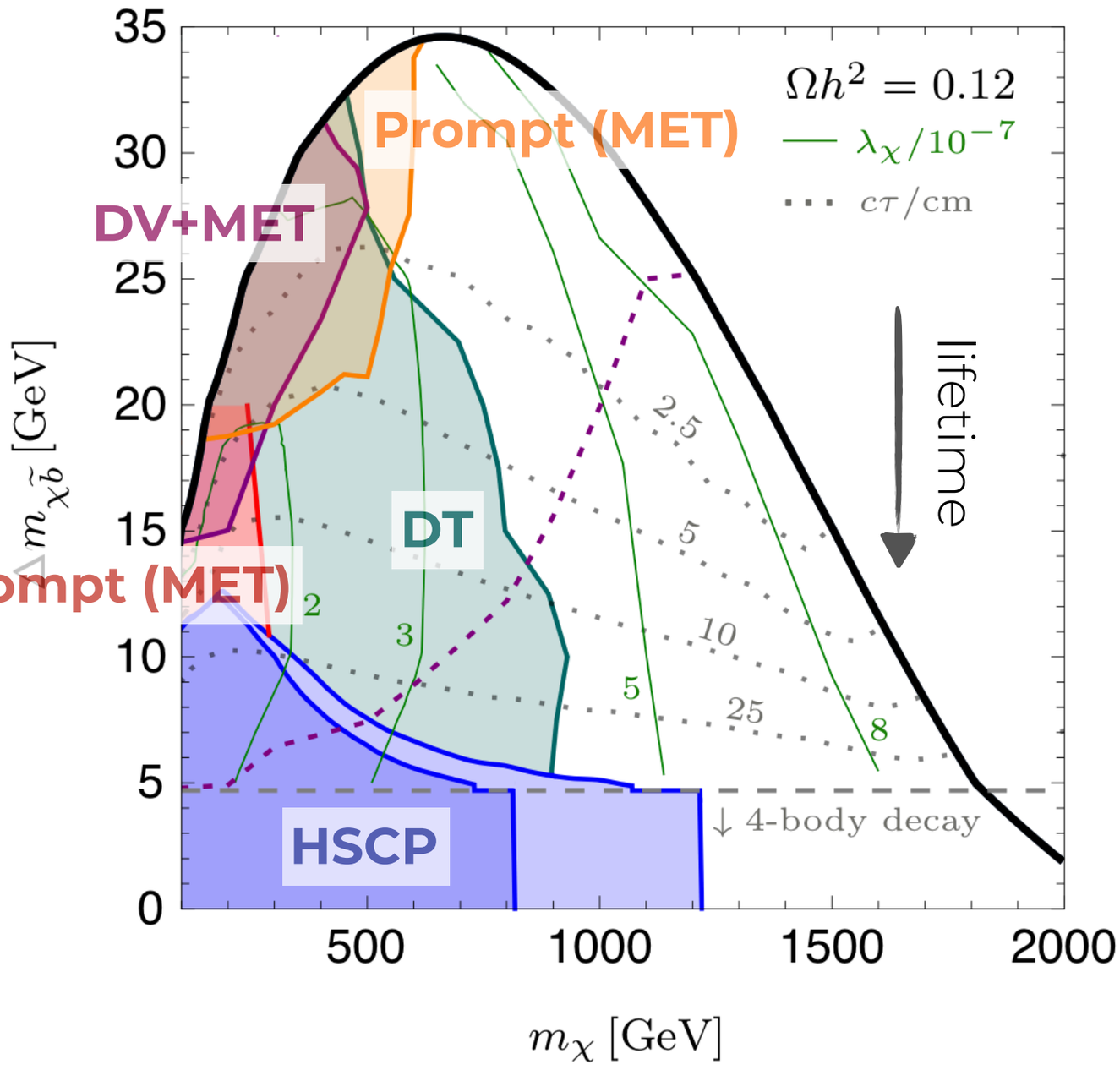

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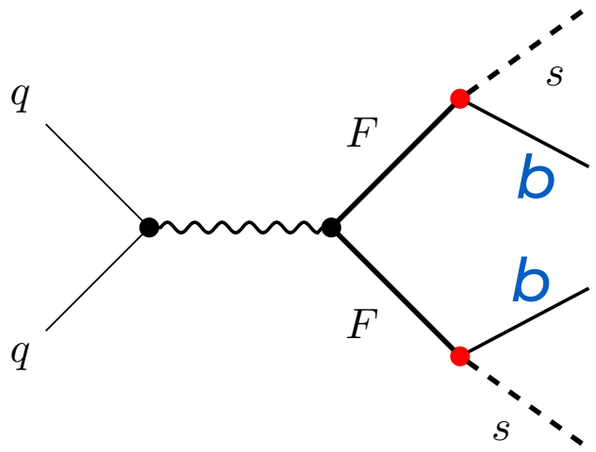

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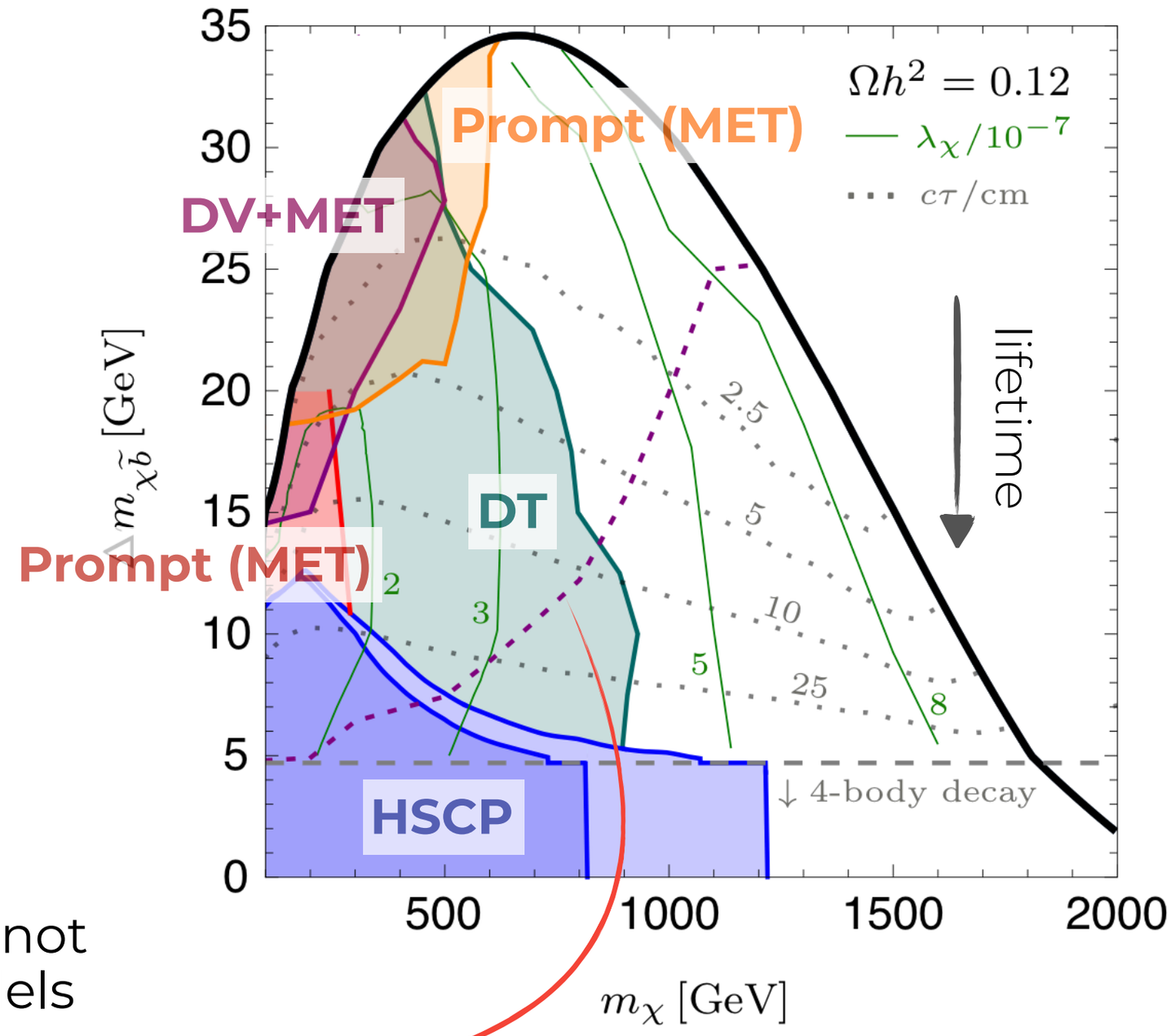

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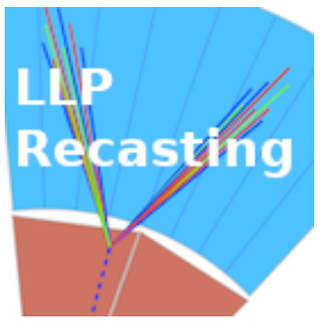

- Recasting repo @ GitHub:
  github.com/llprecasting/recastingCodes

"Measuring the relic density"

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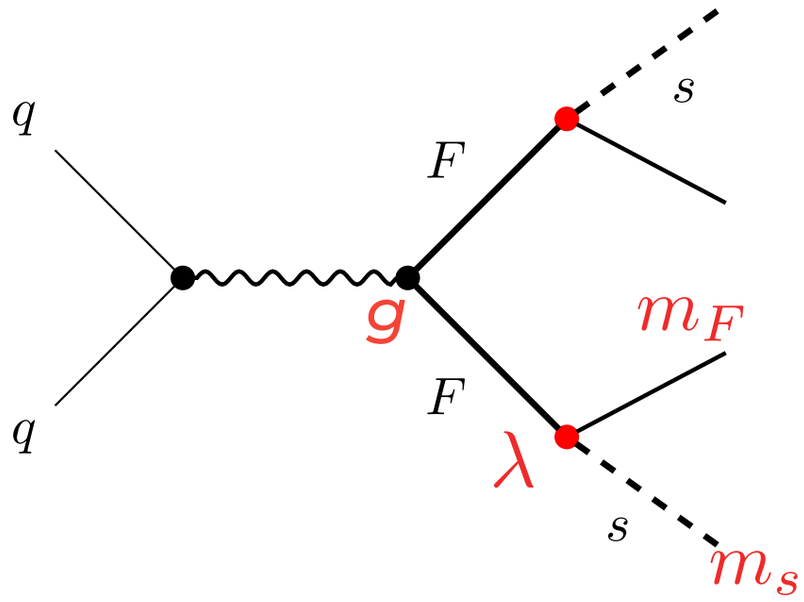

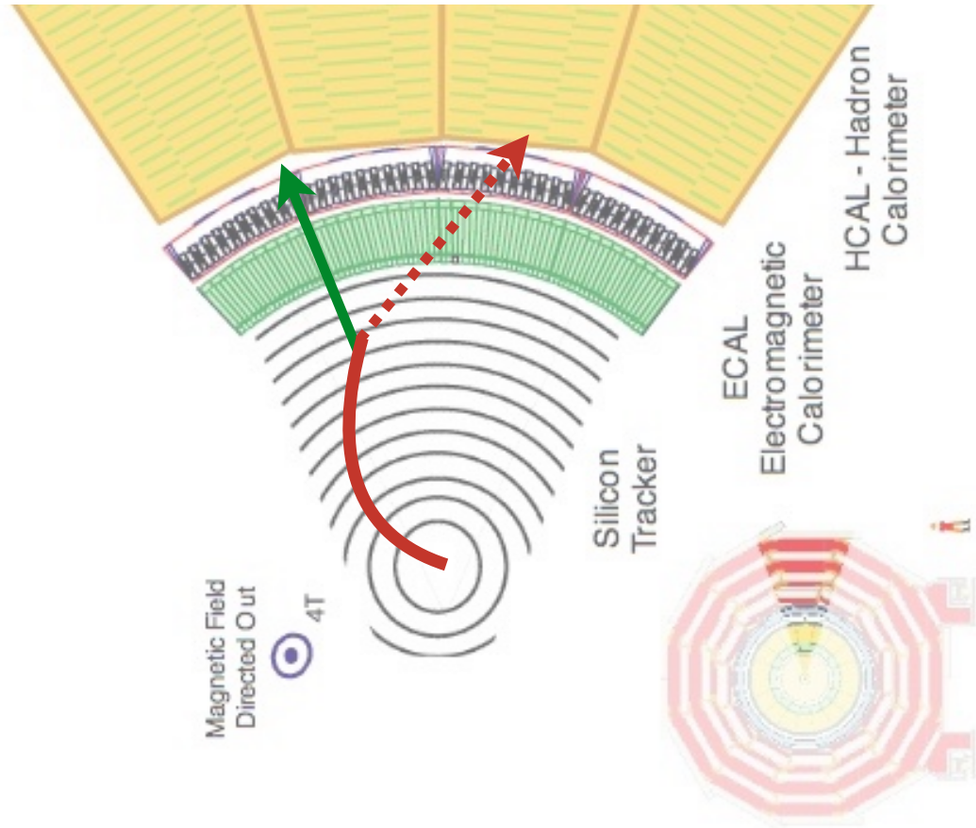

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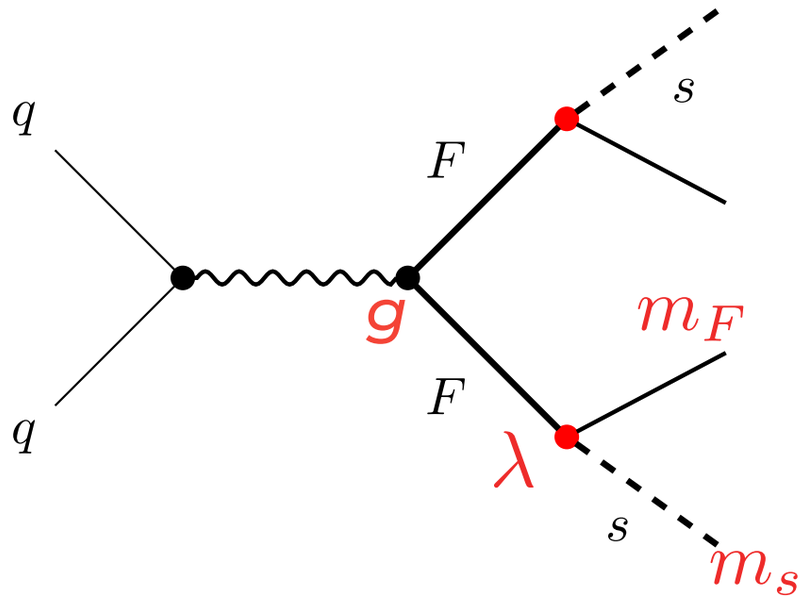

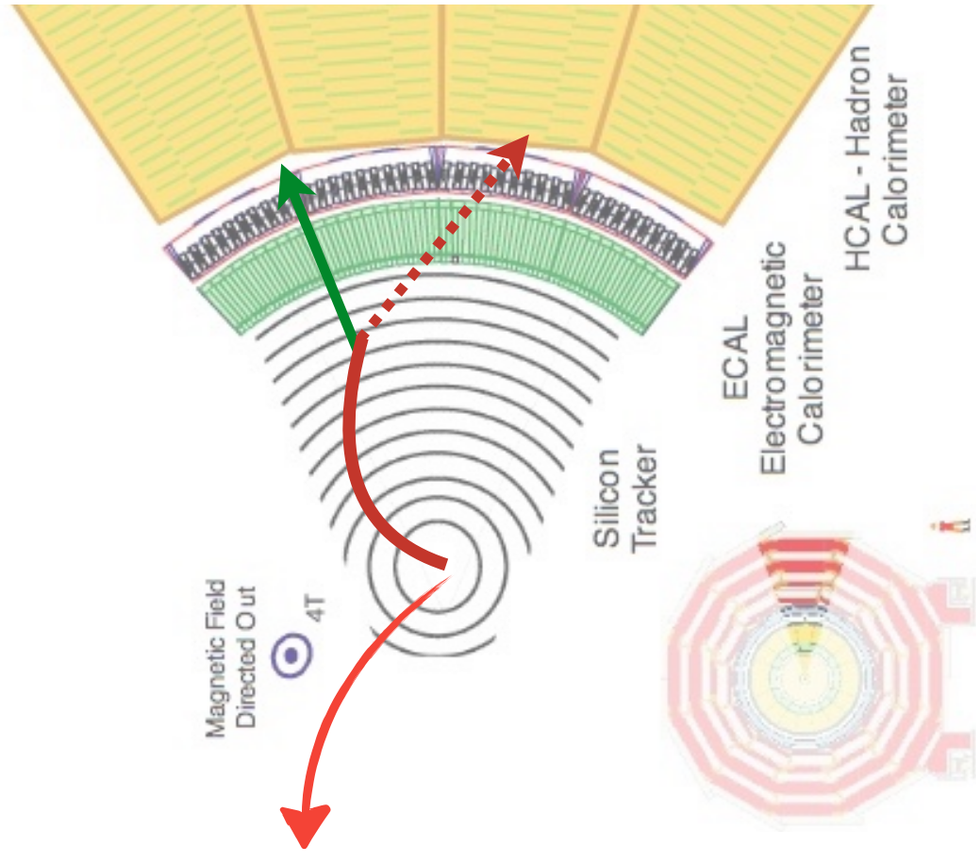

LLP cross-section → SM coupling → g

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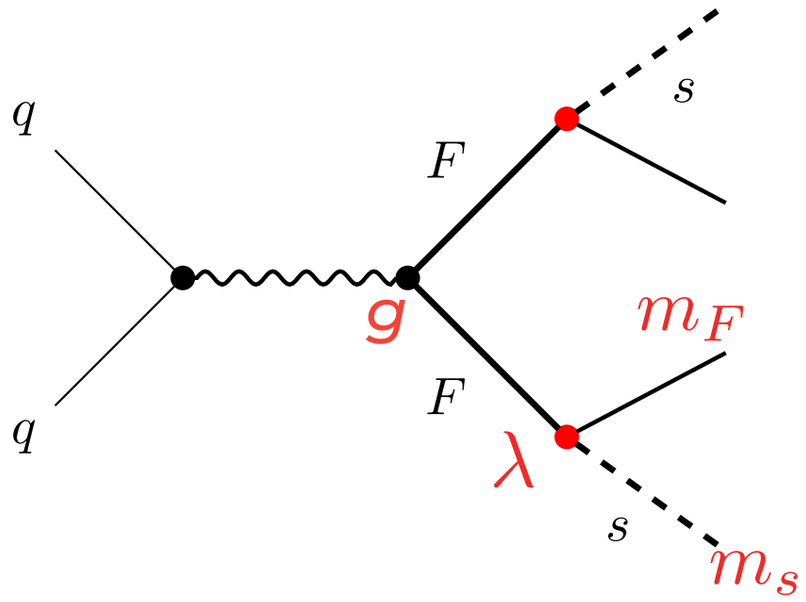

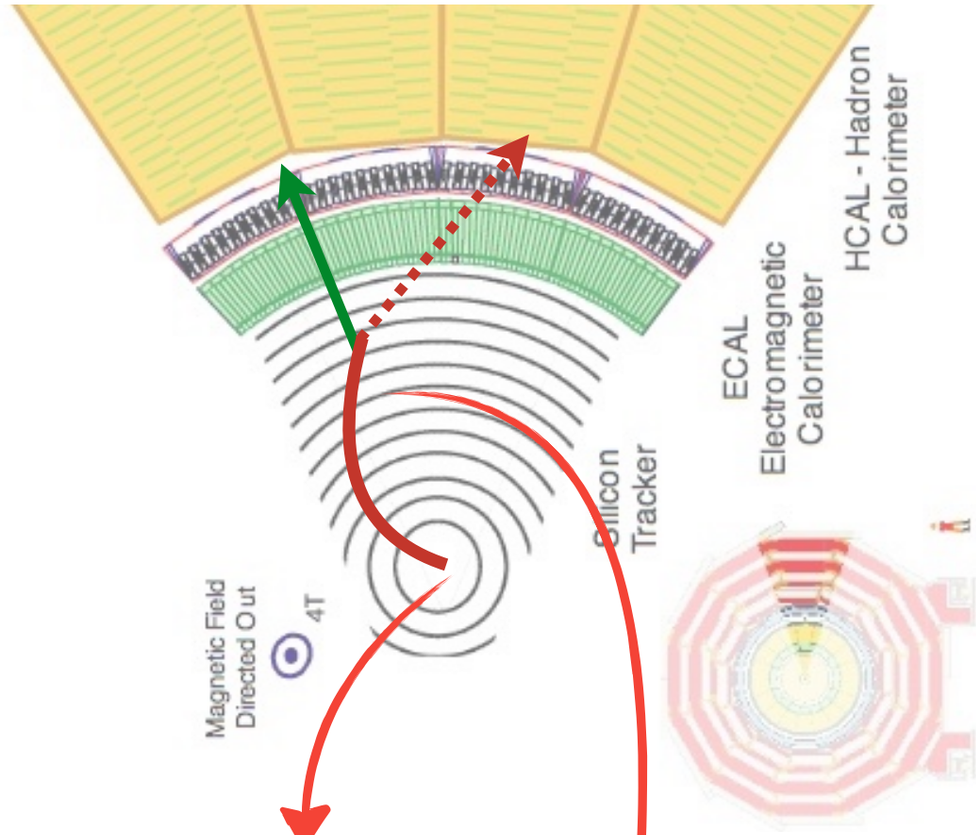

LLP cross-section → SM coupling → g

LLP track → mass → m_F

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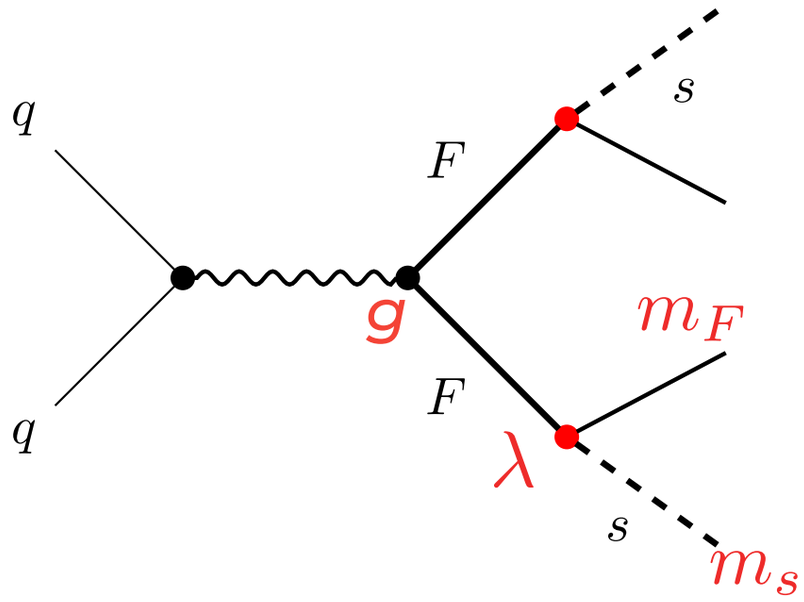

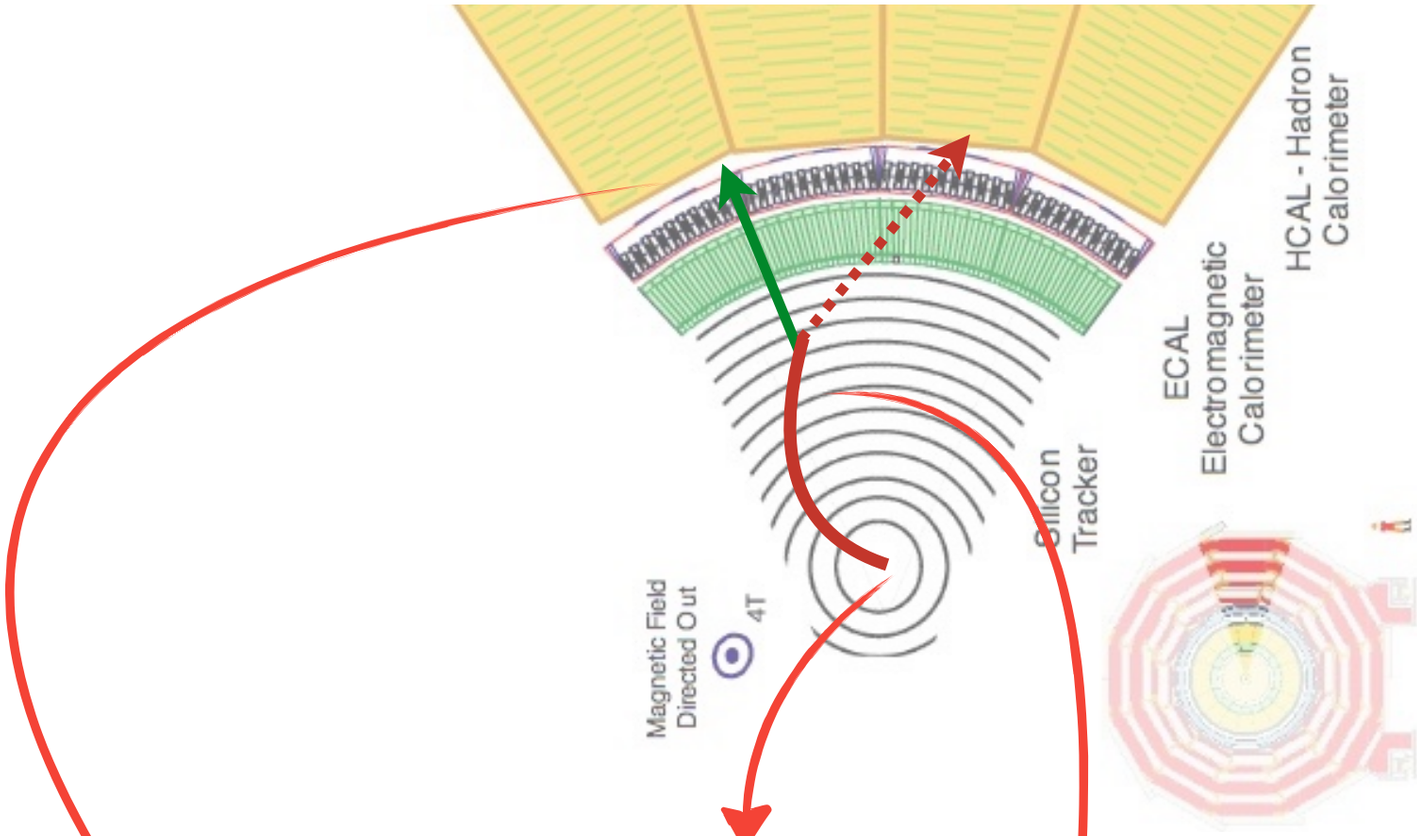

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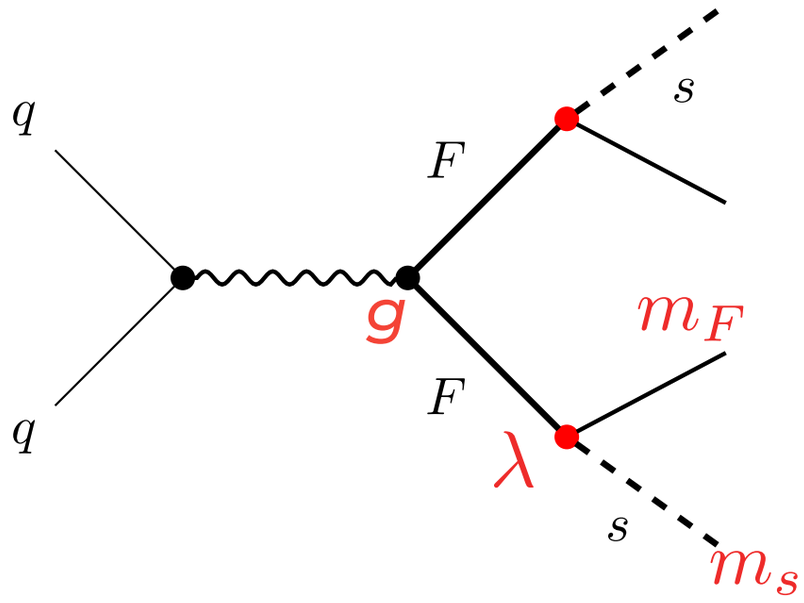

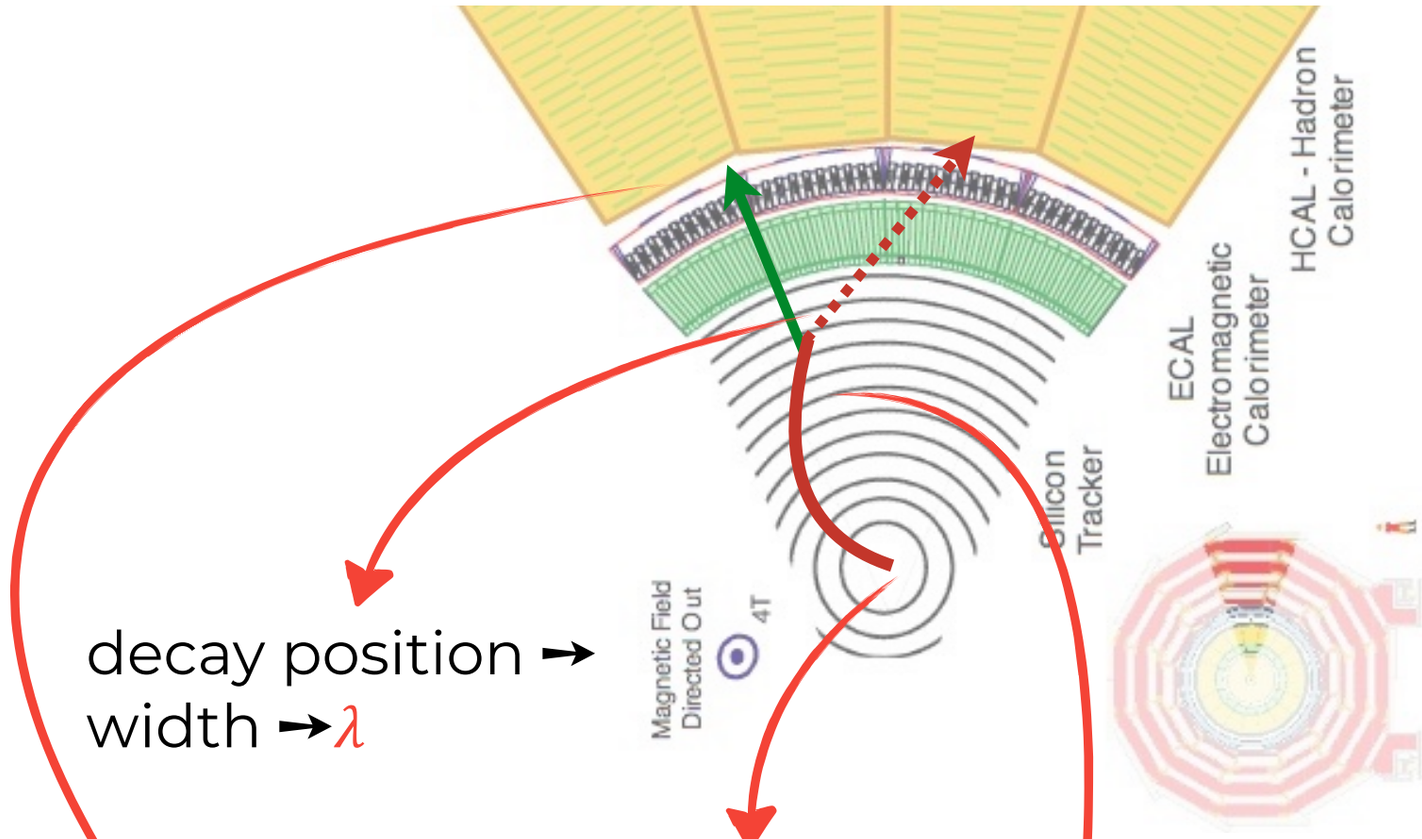

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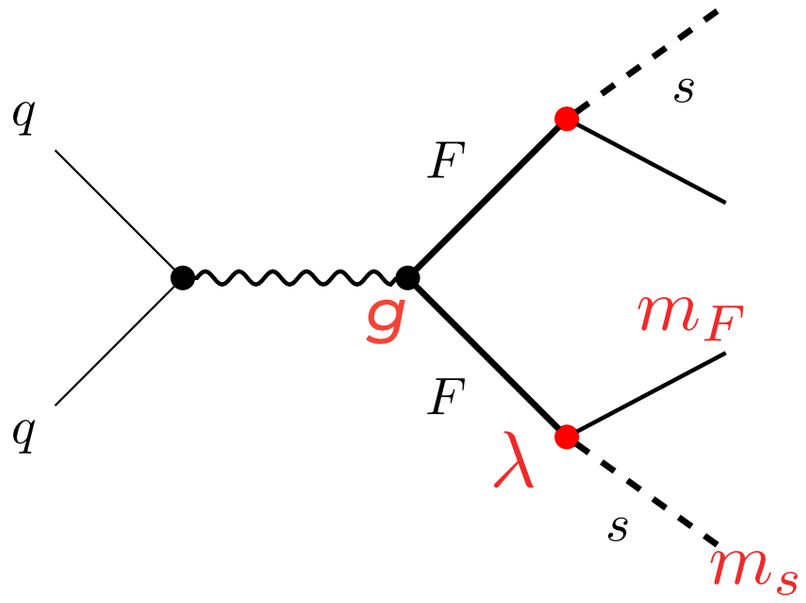
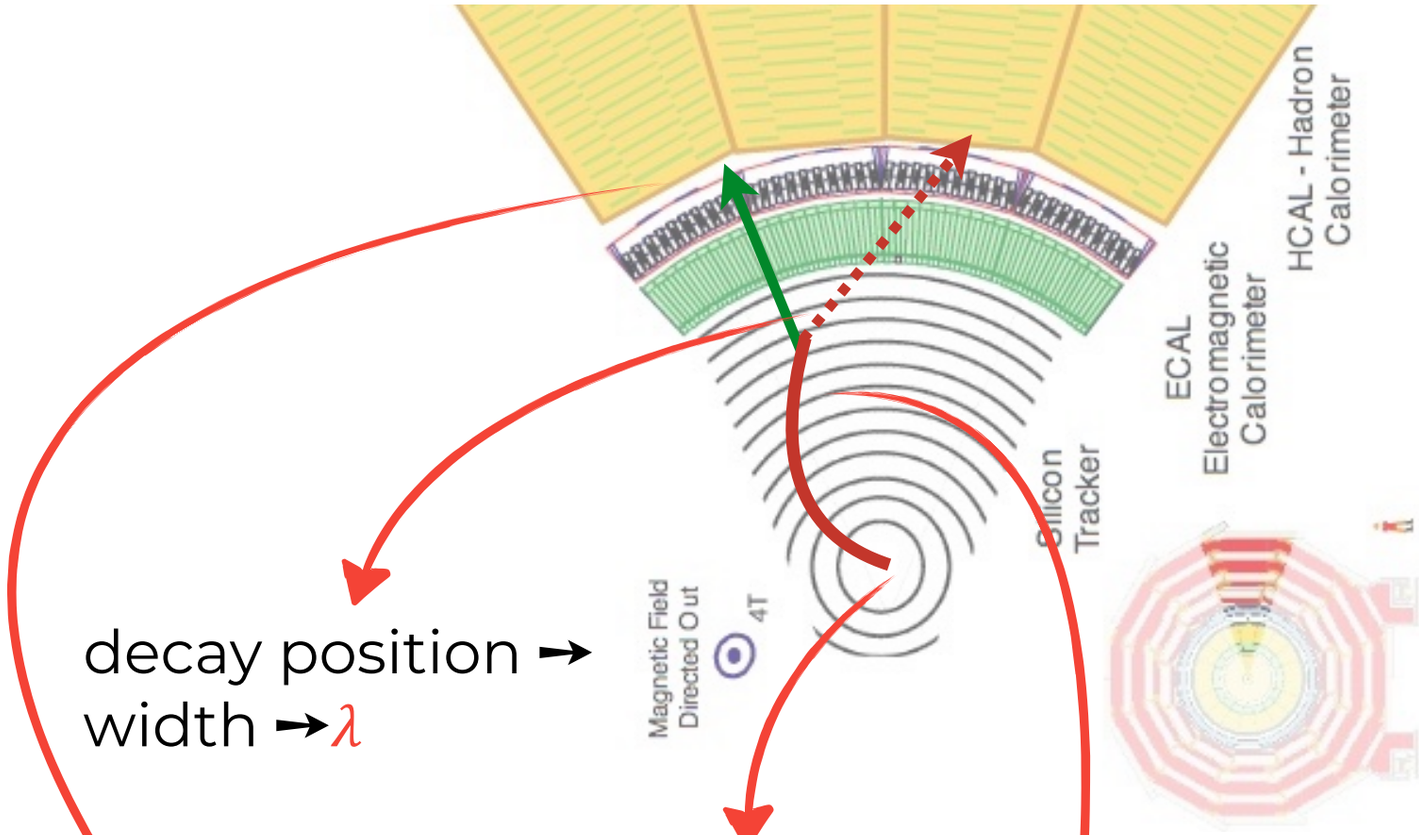
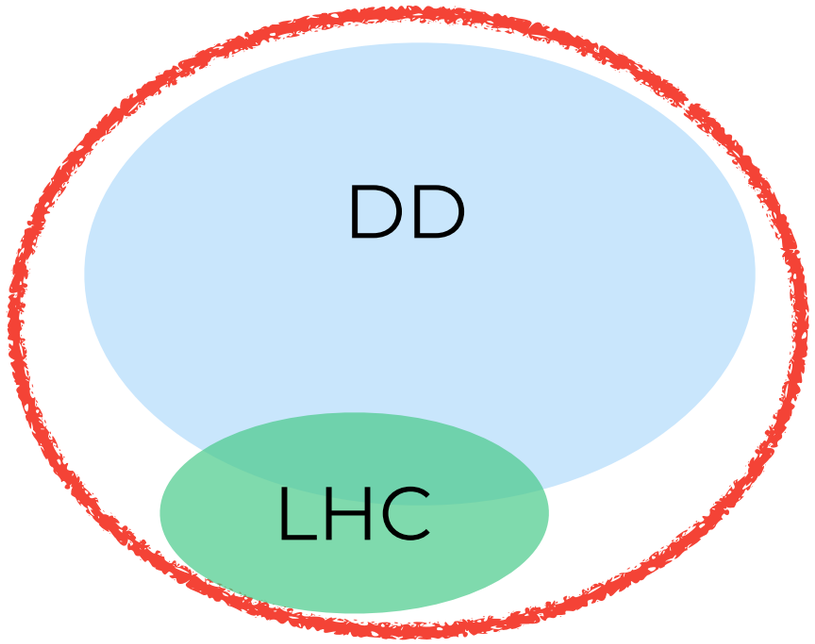




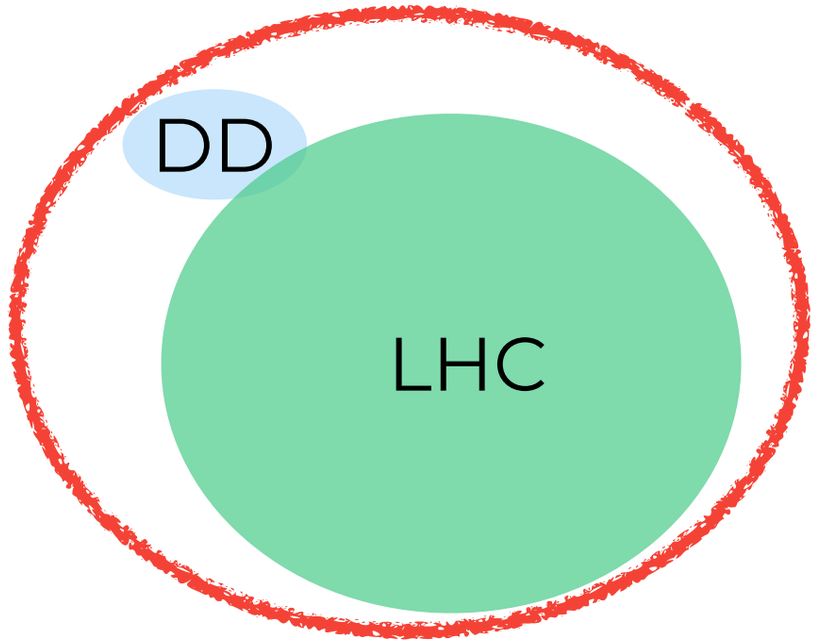
- It is possible to measure all relevant parameters!
- Verify the consistency with relic abundance

Conclusions

WIMP Models



“Feebly coupled” Models



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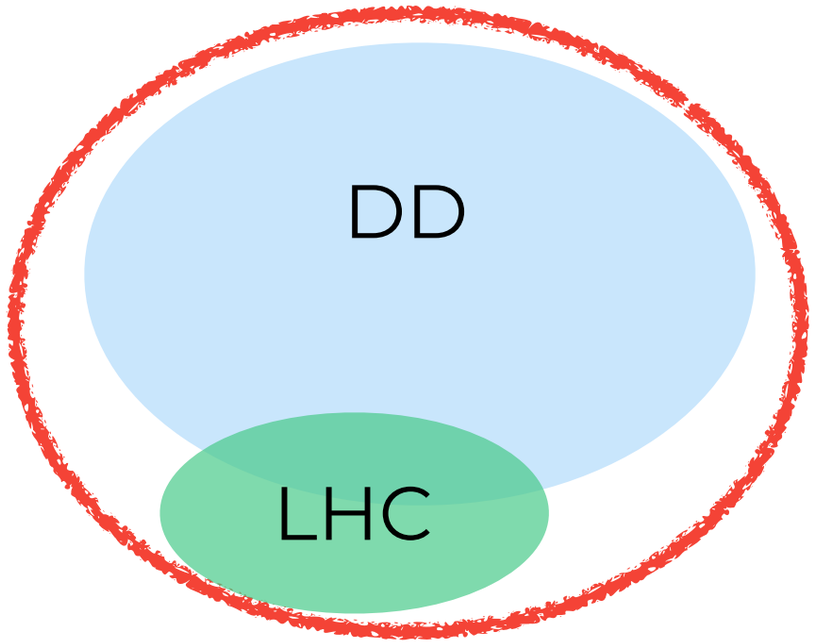

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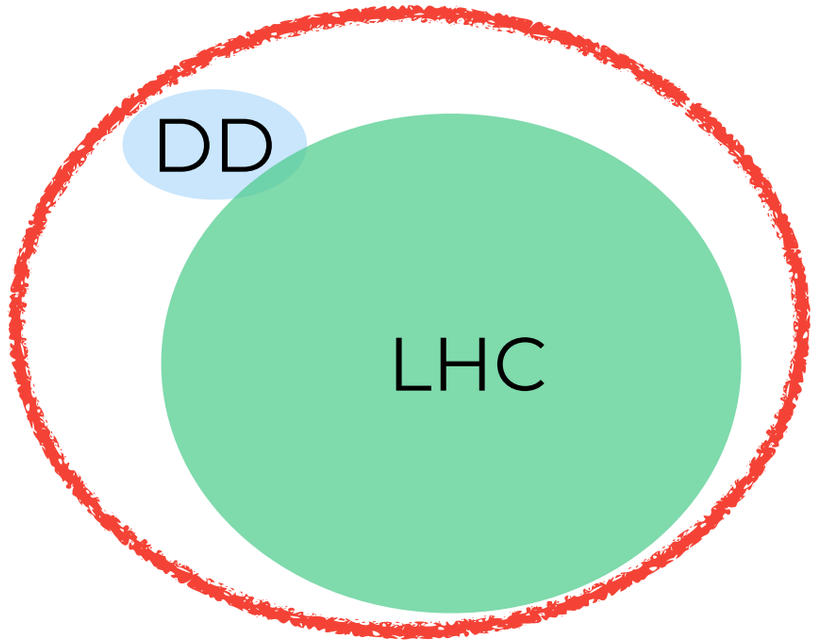
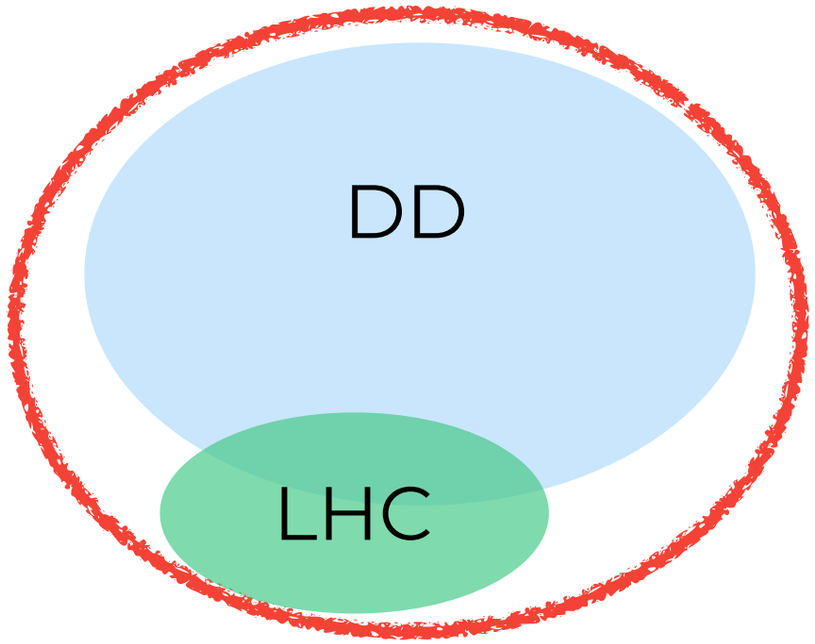


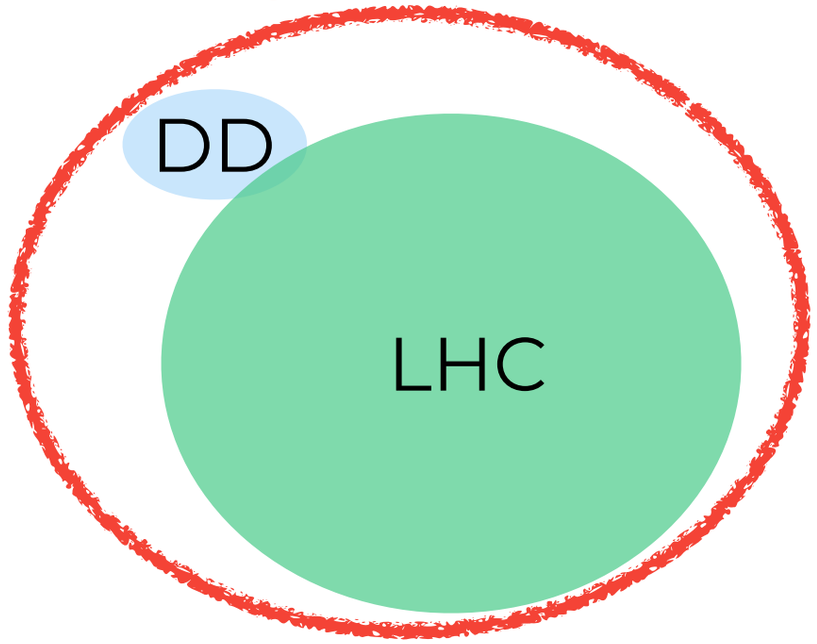
- *Colliders could play the main role if DM is feebly coupled (or highly compressed)*
- *LLP searches are not yet strongly motivated by DM models*
- *Still a lot of unexplored potential*
- *New ideas from the DM community are welcome!*

Conclusions

WIMP Models



"Feebly coupled" Models



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Thanks!