Collider probes of real triplet scalar dark matter

Yong Du

based on arXiv: 2003.07867

email: yongdu at umass dot edu

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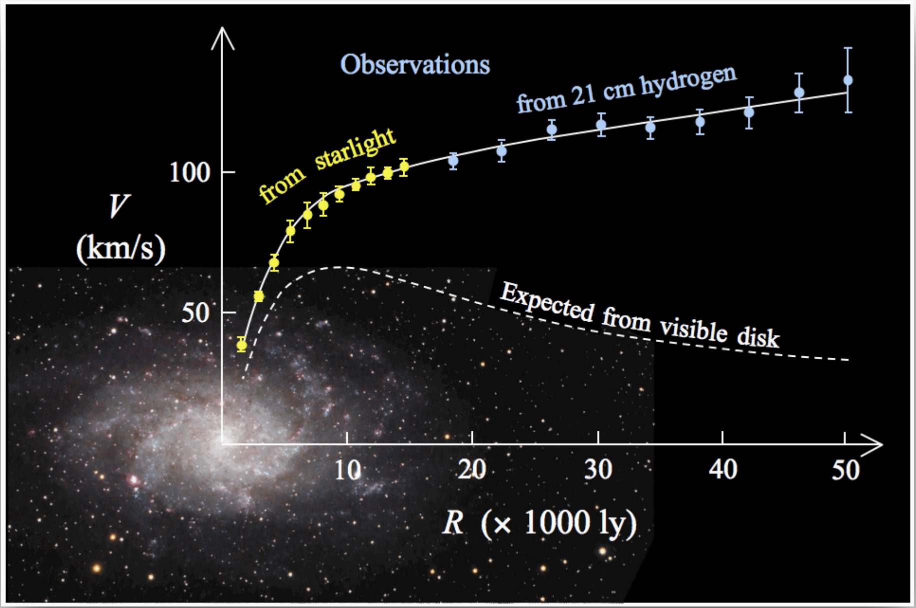
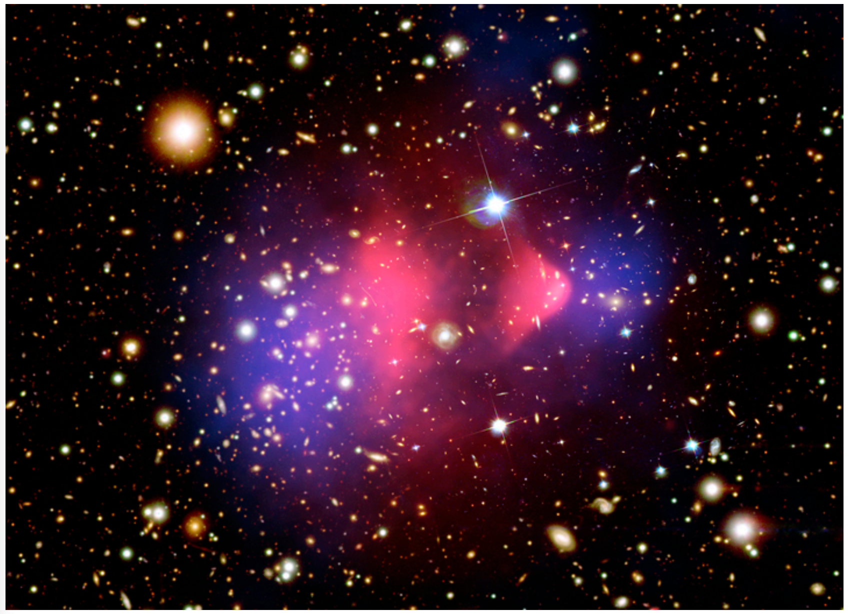
In collaboration with Cheng-Wei Chiang, Giovanna Cottin, Kaori Fuyuto, Michael Ramsey-Musolf

AMHERST CENTER FOR FUNDAMENTAL INTERACTIONS
Physics at the interface: Energy, Intensity, and Cosmic frontiers
University of Massachusetts Amherst

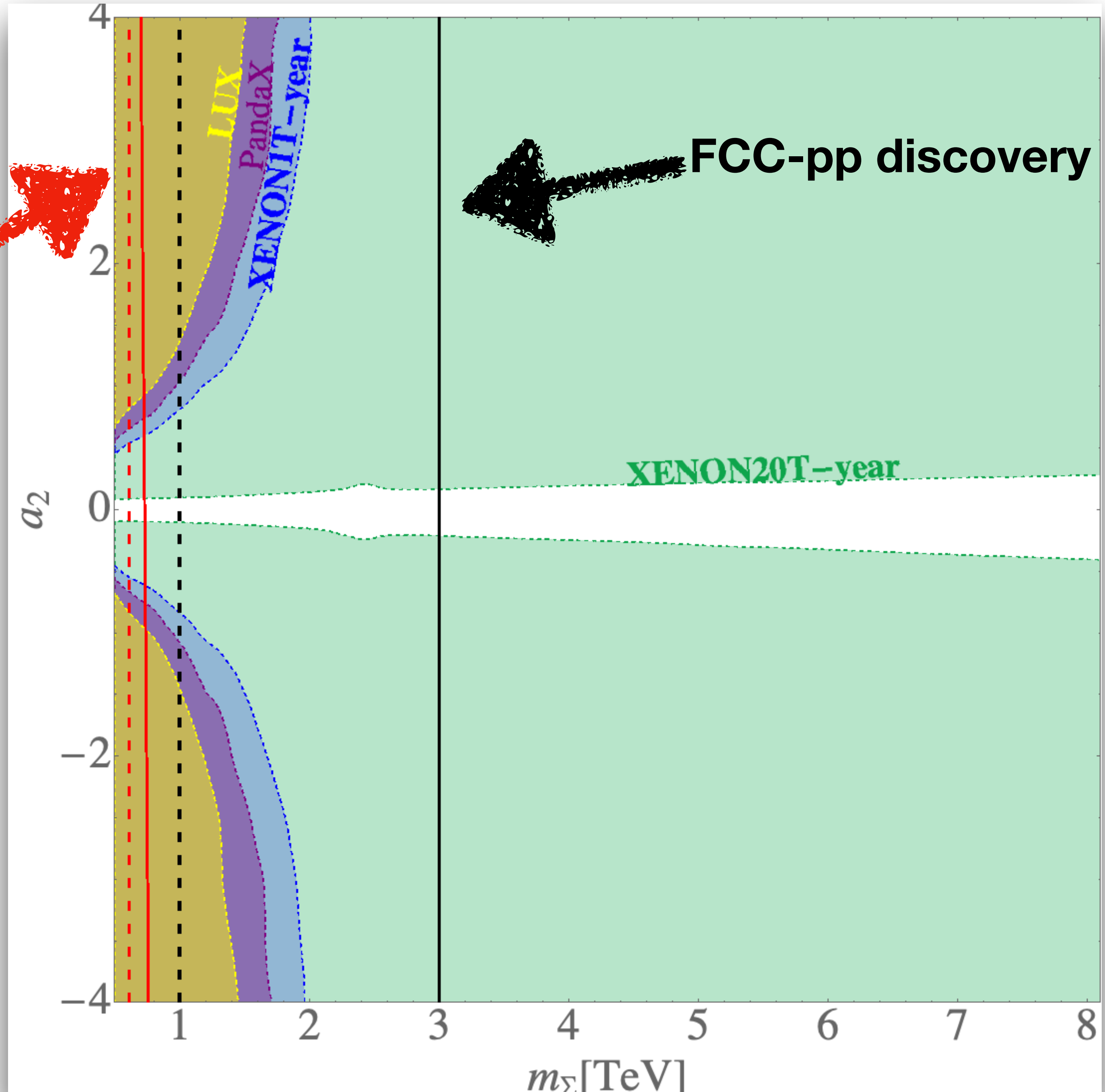
Our focus...





- **WIMP** ← in the real triplet model
- **FIMP**
- **SIDM**
- **Axion/ALPs**
- **Sterile neutrinos**
- **LSPs**
- **PBHs**
- **...**

What we find… the spoiler



FCC-pp discovery

LHC exclusion

$$\sigma_{\rm SI}^{\rm scaled} \equiv \frac{\sigma_{\rm SI}\Omega h^2}{(\Omega h^2)_{\rm Planck}}$$

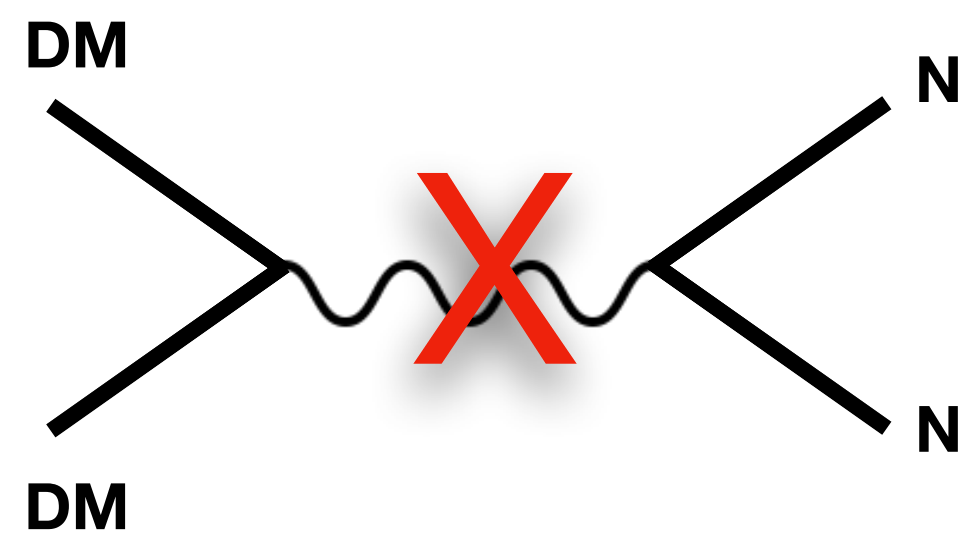
Brief model introduction

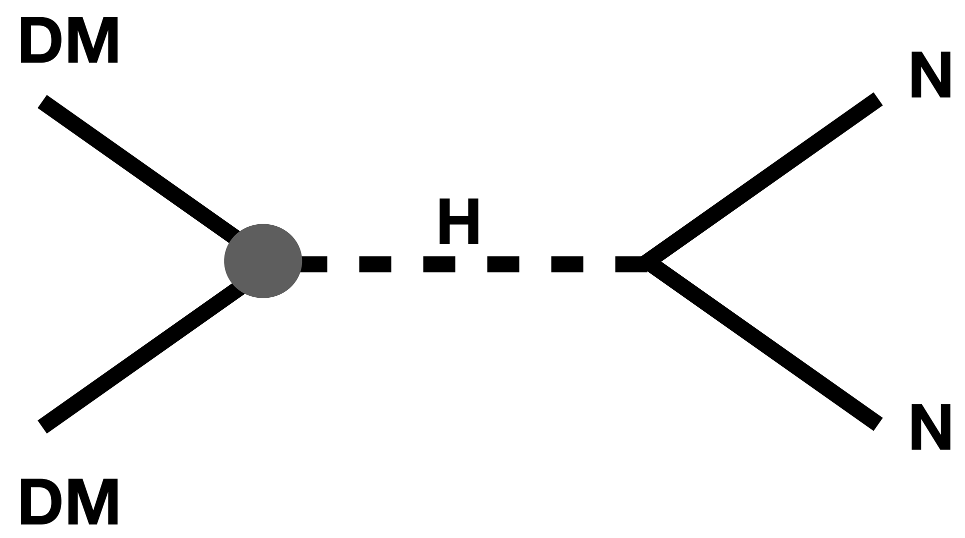
Σ := Real triplet (1, 3, 0)

$$\Sigma = \frac{1}{2}\begin{pmatrix} \Sigma^0 & \sqrt{2}\Sigma^+ \\ \sqrt{2}\Sigma^- & -\Sigma^0 \end{pmatrix}$$

$$\mathbf{V(H,\Sigma) = -\mu^2 H^\dagger H + \lambda_0 (H^\dagger H)^2 - \frac{1}{2} M_\Sigma^2 F + \frac{b_4}{4} F^2 + \frac{a_2}{2} H^\dagger H F}$$

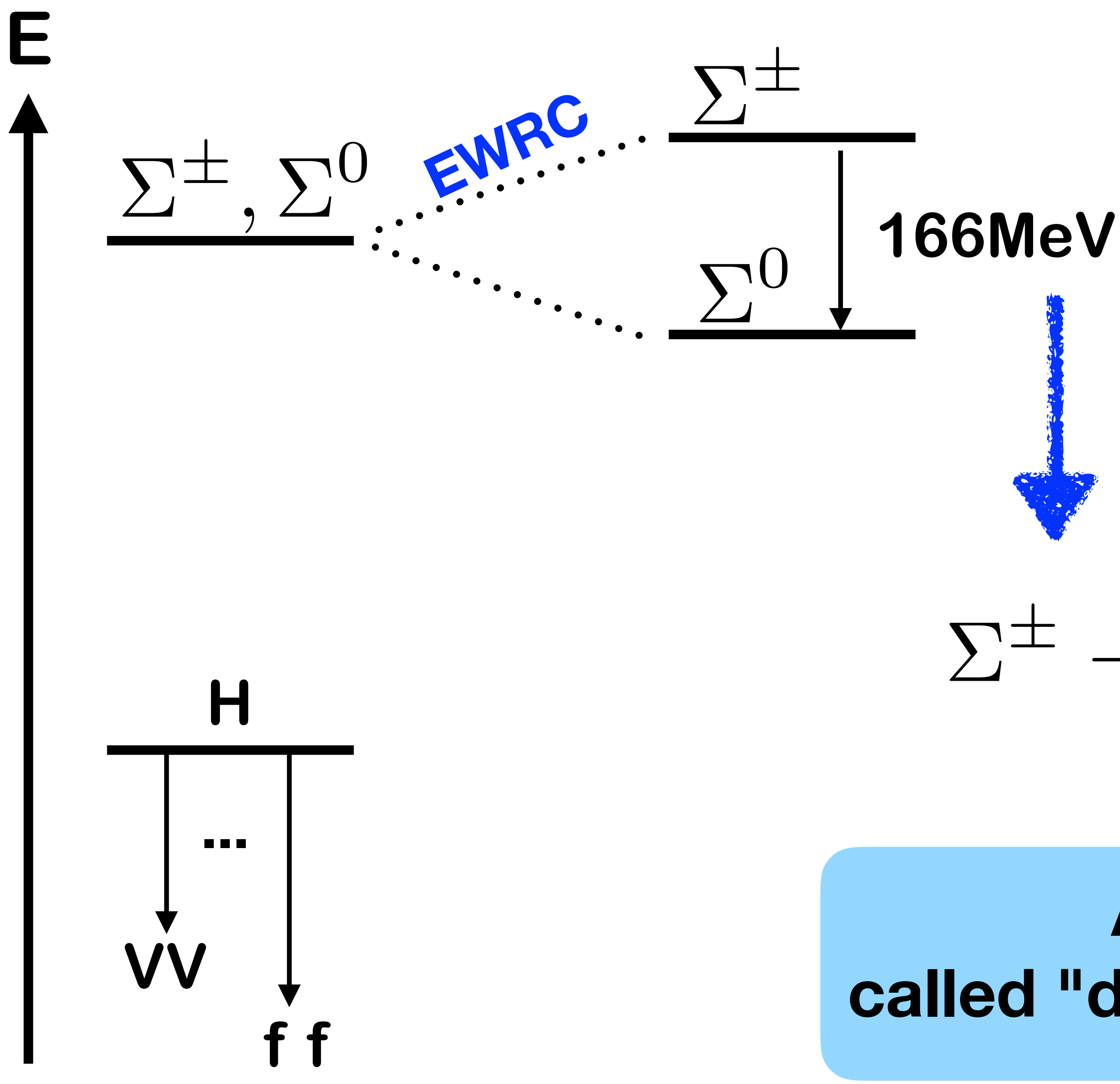
$$\mathbf{F = (\Sigma^0)^2 + 2\Sigma^+\Sigma^-}$$





Brief model introduction

$$\mathbf{\Sigma} = \frac{\mathbf{1}}{\mathbf{2}} \begin{pmatrix} \Sigma^0 & \sqrt{2}\Sigma^+ \\ \sqrt{2}\Sigma^- & -\Sigma^0 \end{pmatrix}$$



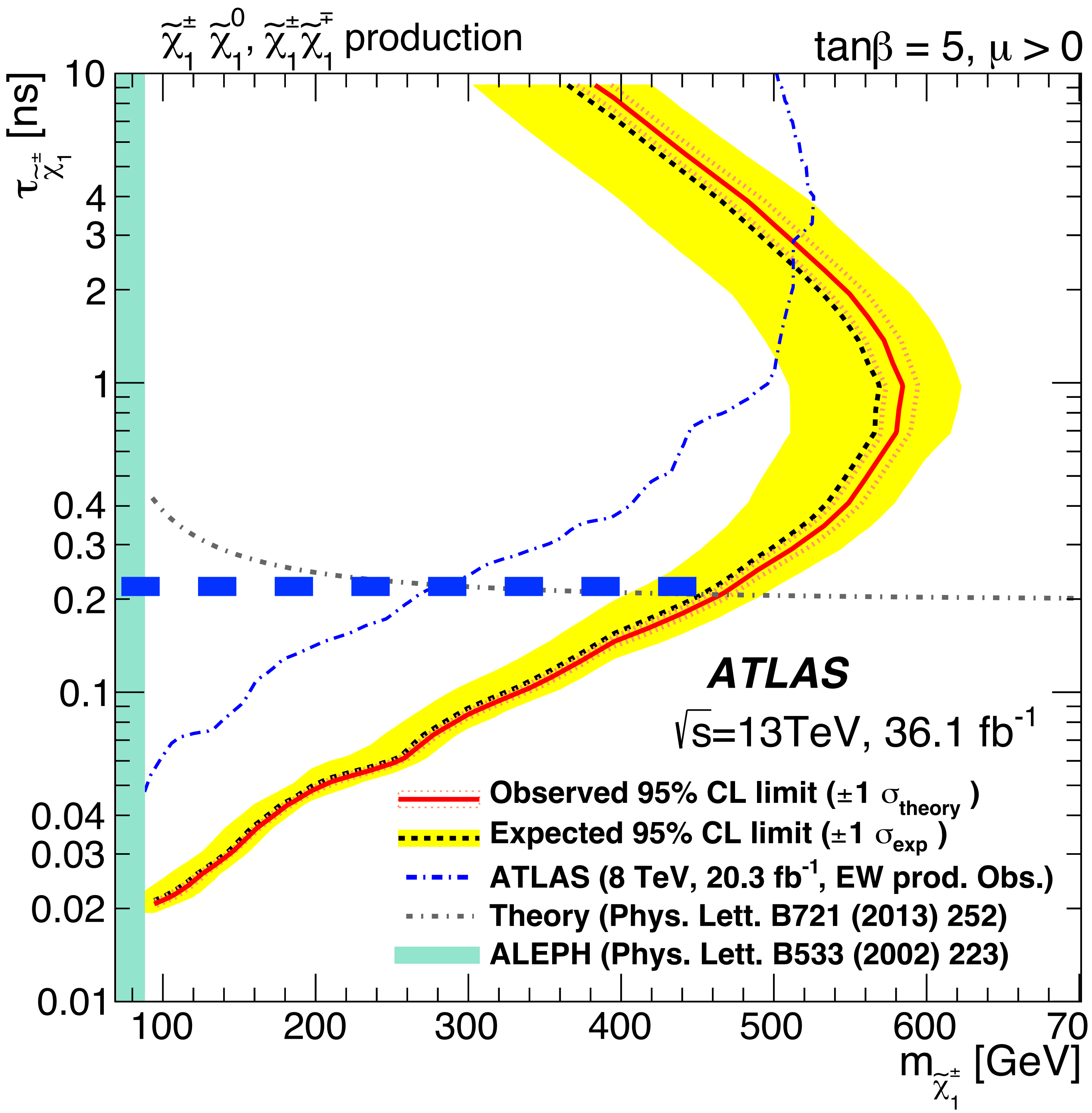
$\Sigma^\pm$ **is long lived (0.2ns)**

$$\Sigma^\pm \to \Sigma^0 \pi^\pm (97\%)$$

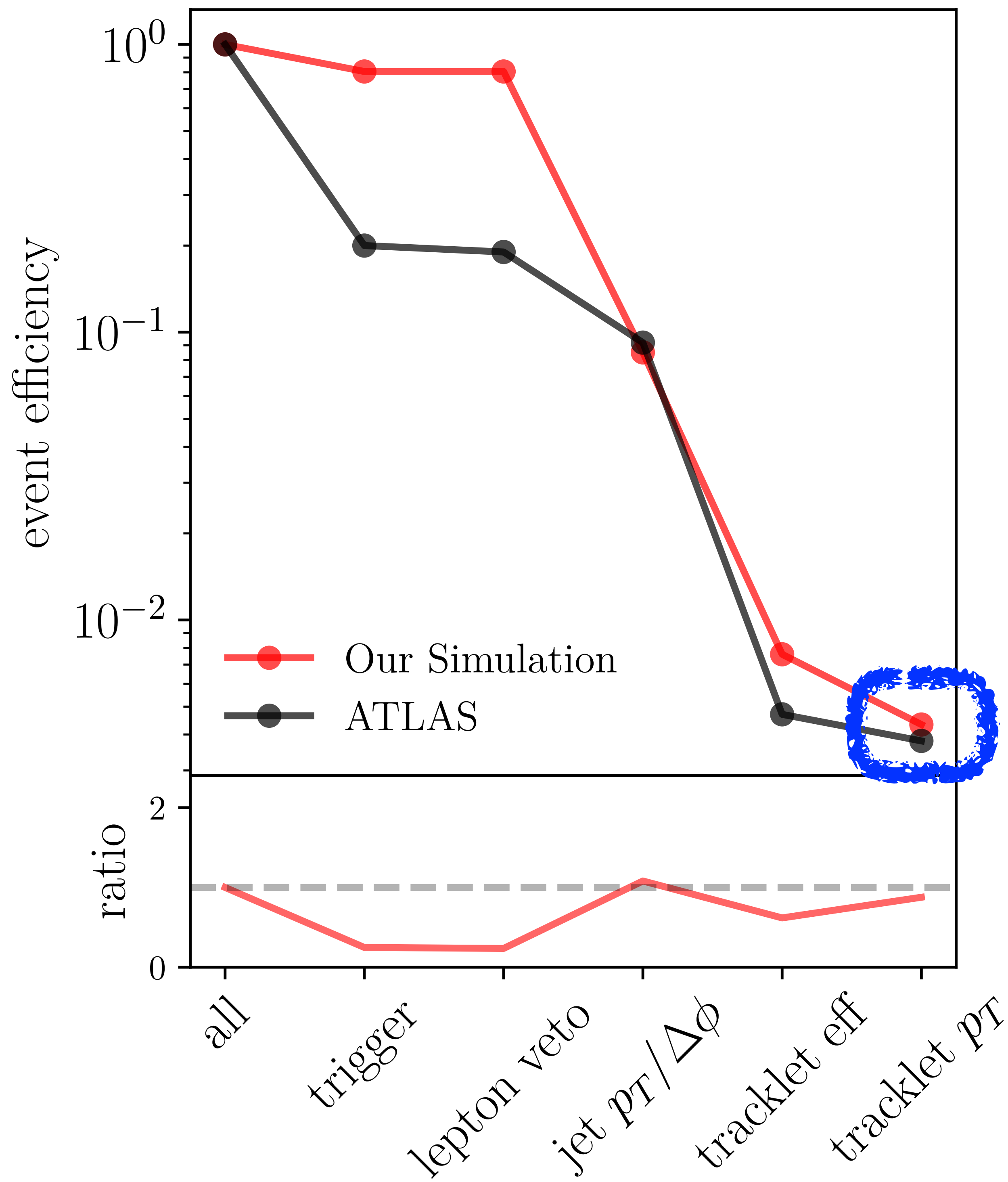
A distinct signature called "disappearing charged track"

Reproduction of ATLAS result

C.W. Chiang, G. Cottin, Yong Du,
K. Fuyuto, M.J. Ramsey-Musolf
arXiv: 2003.07867



ATLAS collaboration,
arXiv:1712.02118



What we find…Collider part

C.W. Chiang, G. Cottin, Yong Du,
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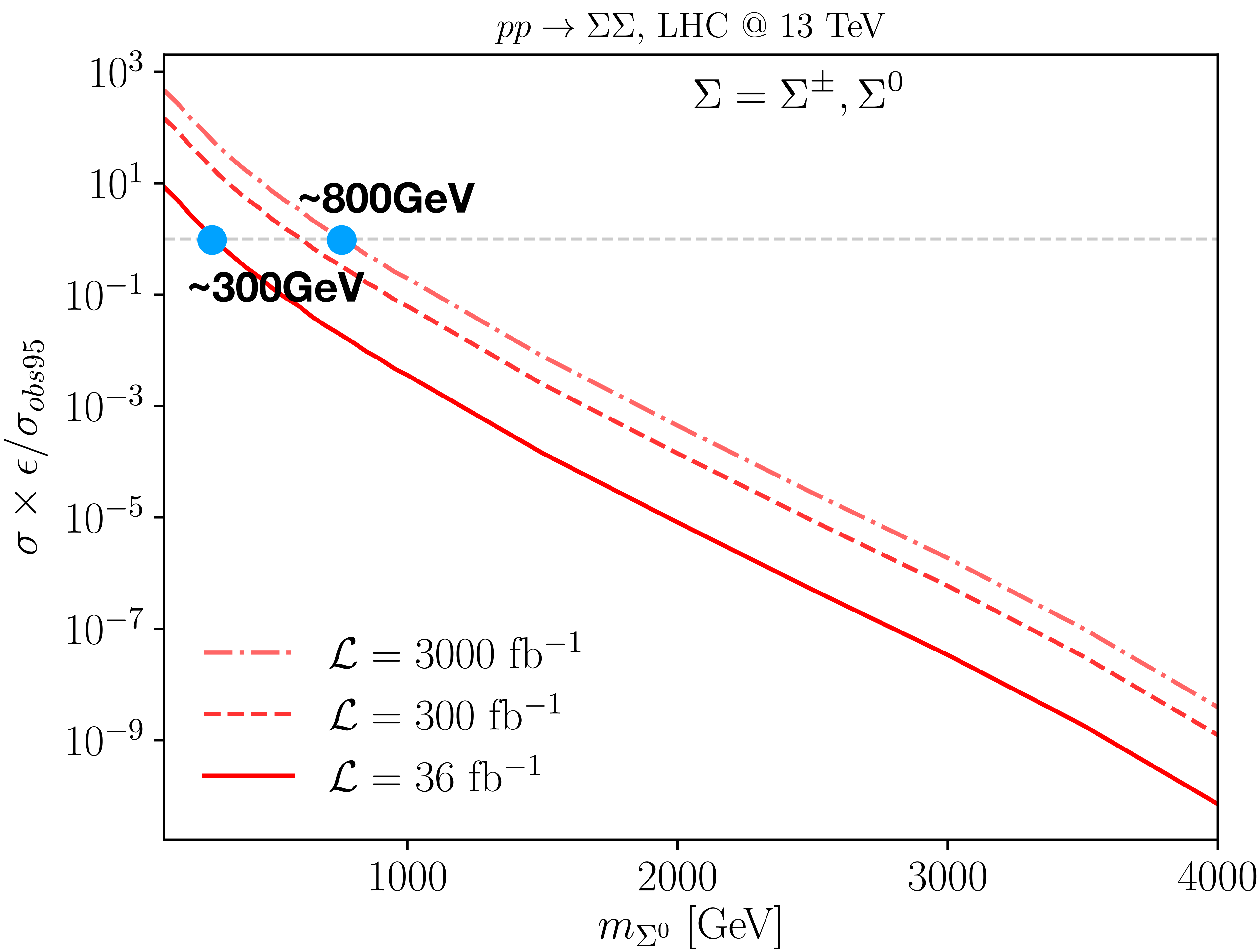
arXiv: 2003.07867

(HL-)LHC exclusion from cross section



What we find…Collider part

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FCC-pp discovery with different pileup control

Benchmark	σ [pb]	ϵ	S	B	$S/\sqrt{B}$
$m_{\Sigma^\pm} = 1.1$ TeV, $\overline{\mu} = 200$	5.8×10^{-2}	3.17×10^{-4}	553	673	21.3
$m_{\Sigma^\pm} = 1.1$ TeV, $\overline{\mu} = 500$	5.8×10^{-2}	3.17×10^{-4}	553	8214	6
$m_{\Sigma^\pm} = 3.1$ TeV, $\overline{\mu} = 200$	9.4×10^{-4}	4.69×10^{-4}	13.3	1.9	9.6
$m_{\Sigma^\pm} = 3.1$ TeV, $\overline{\mu} = 500$	9.4×10^{-4}	4.69×10^{-4}	13.3	27	2.6

What we find...Combination

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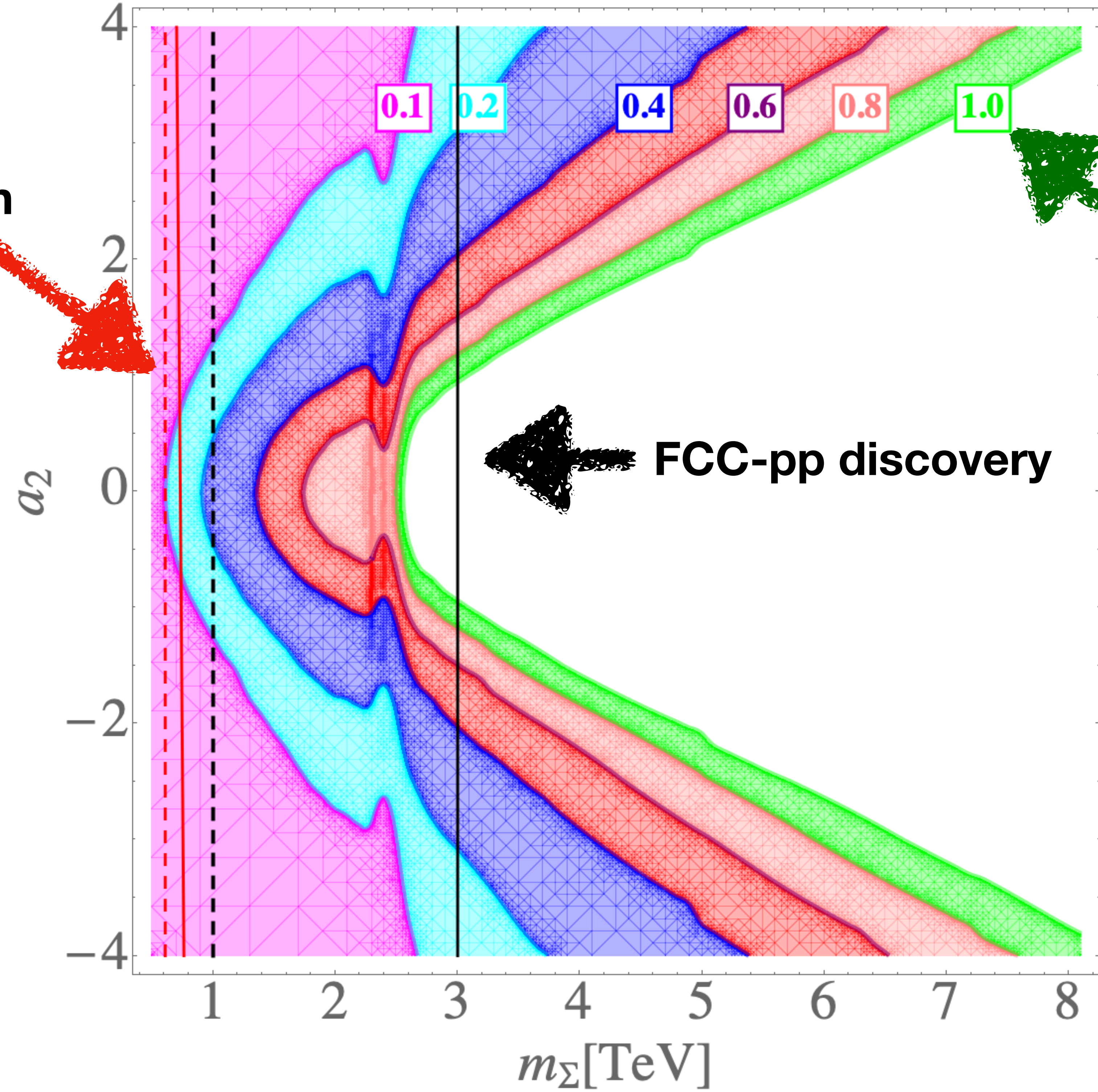
Colliders+relic abundance



$$\mathcal{R} = \frac{\Omega_\Sigma}{\Omega_{\rm DM}}$$

What we find…Combination

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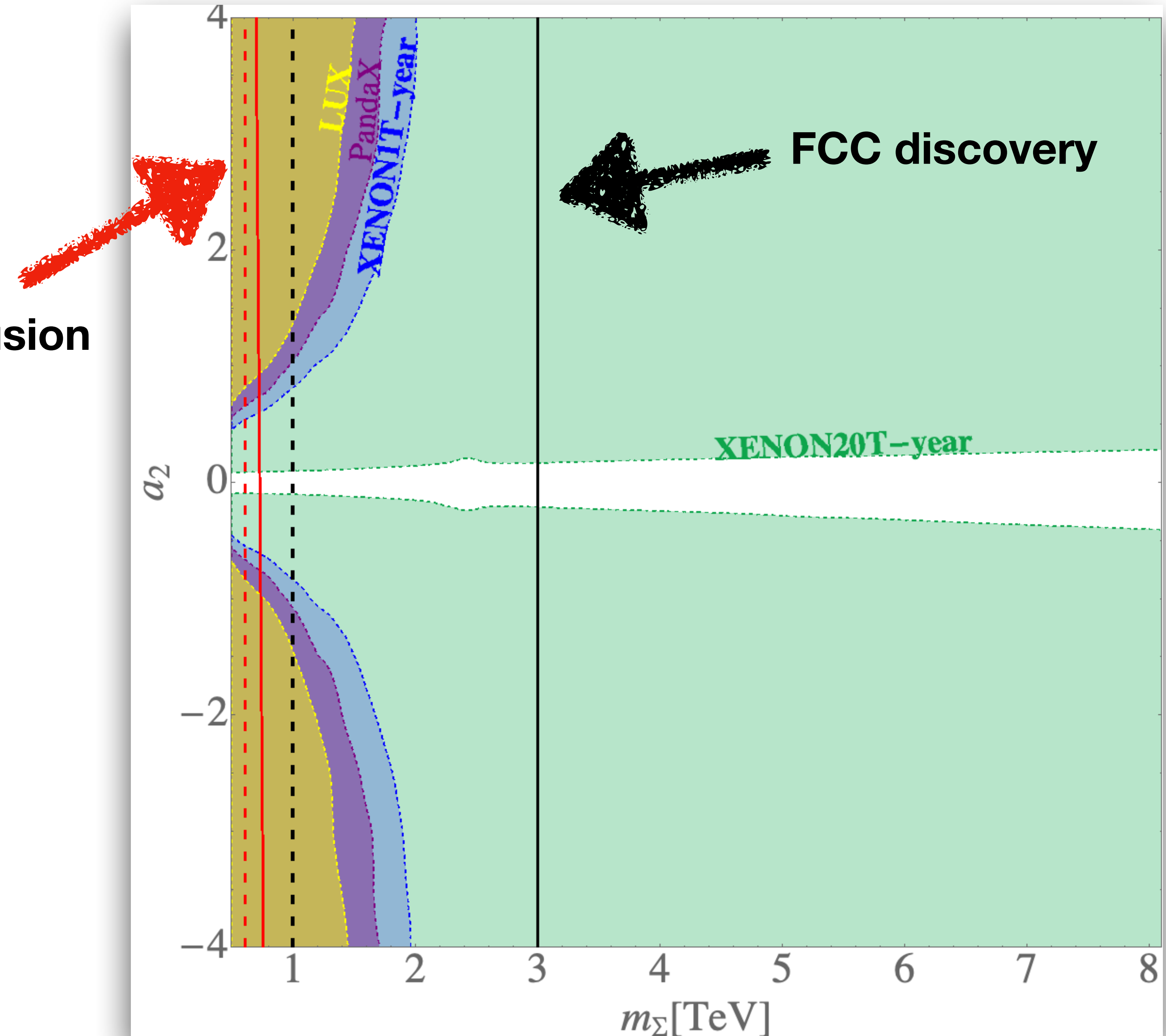
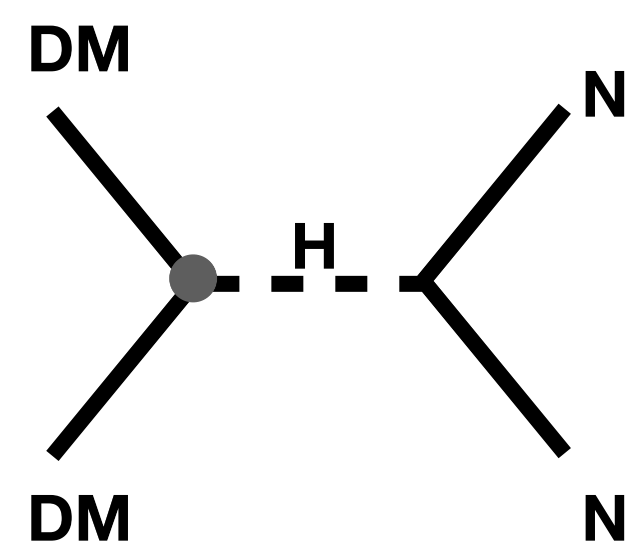
LHC exclusion



$$\sigma_{\rm SI}^{\rm scaled} \equiv \frac{\sigma_{\rm SI}\Omega h^2}{(\Omega h^2)_{\rm Planck}}$$



Summary

1. We study the real triplet (1,3,0) model with the neutral triplet component being our dark matter candidate.

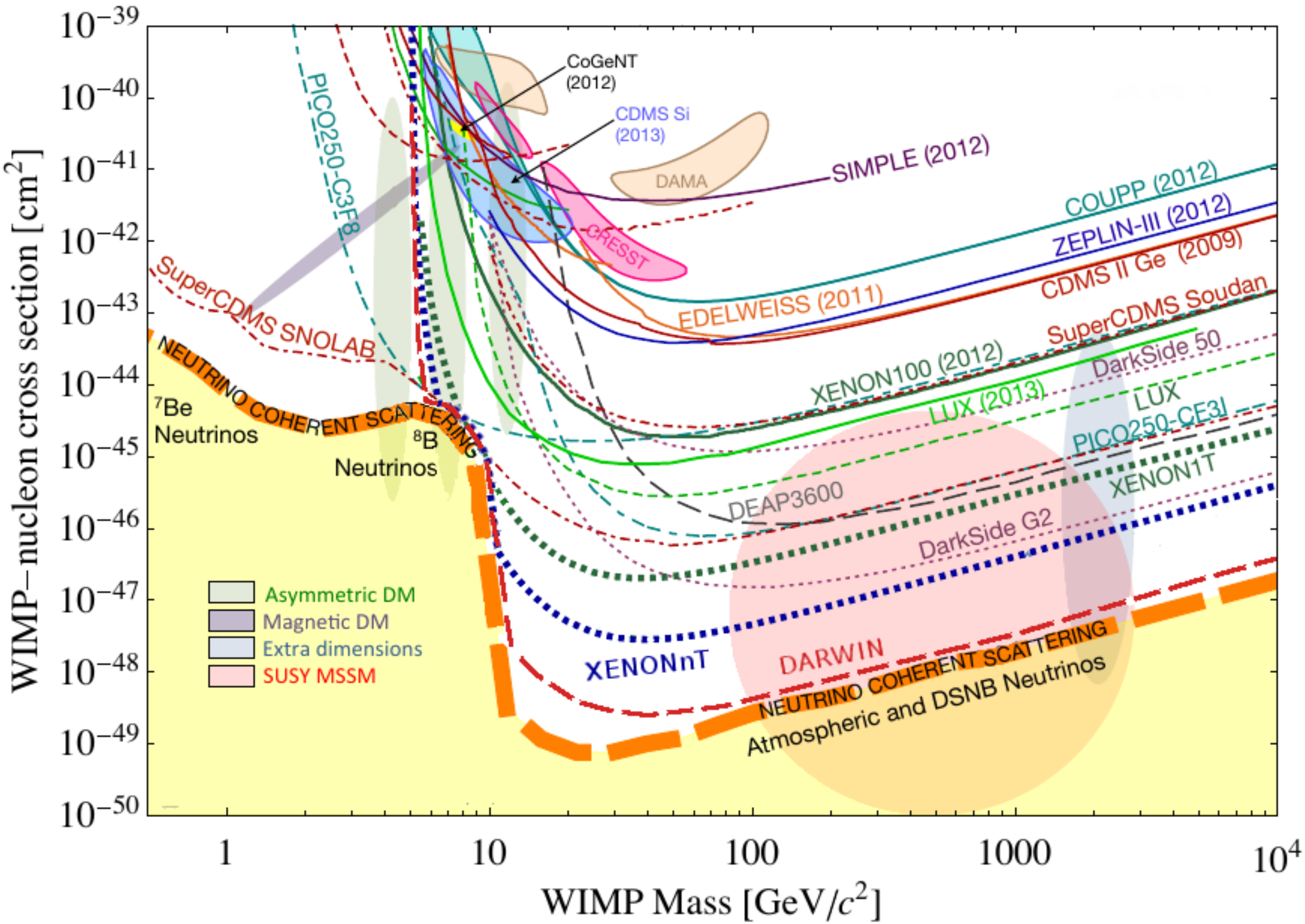
2. Current LHC and HL-LHC (would) exclude the triplet lighter than ~300GeV and ~800GeV. FCC-pp could discover 3 TeV triplet depending on pileup control.

3. XENON1T rules out 1~2TeV triplet (depending on a2), XENON20T would cover almost the entire parameter space.

4. Collider and dark matter direct detection are complementary.

Backup

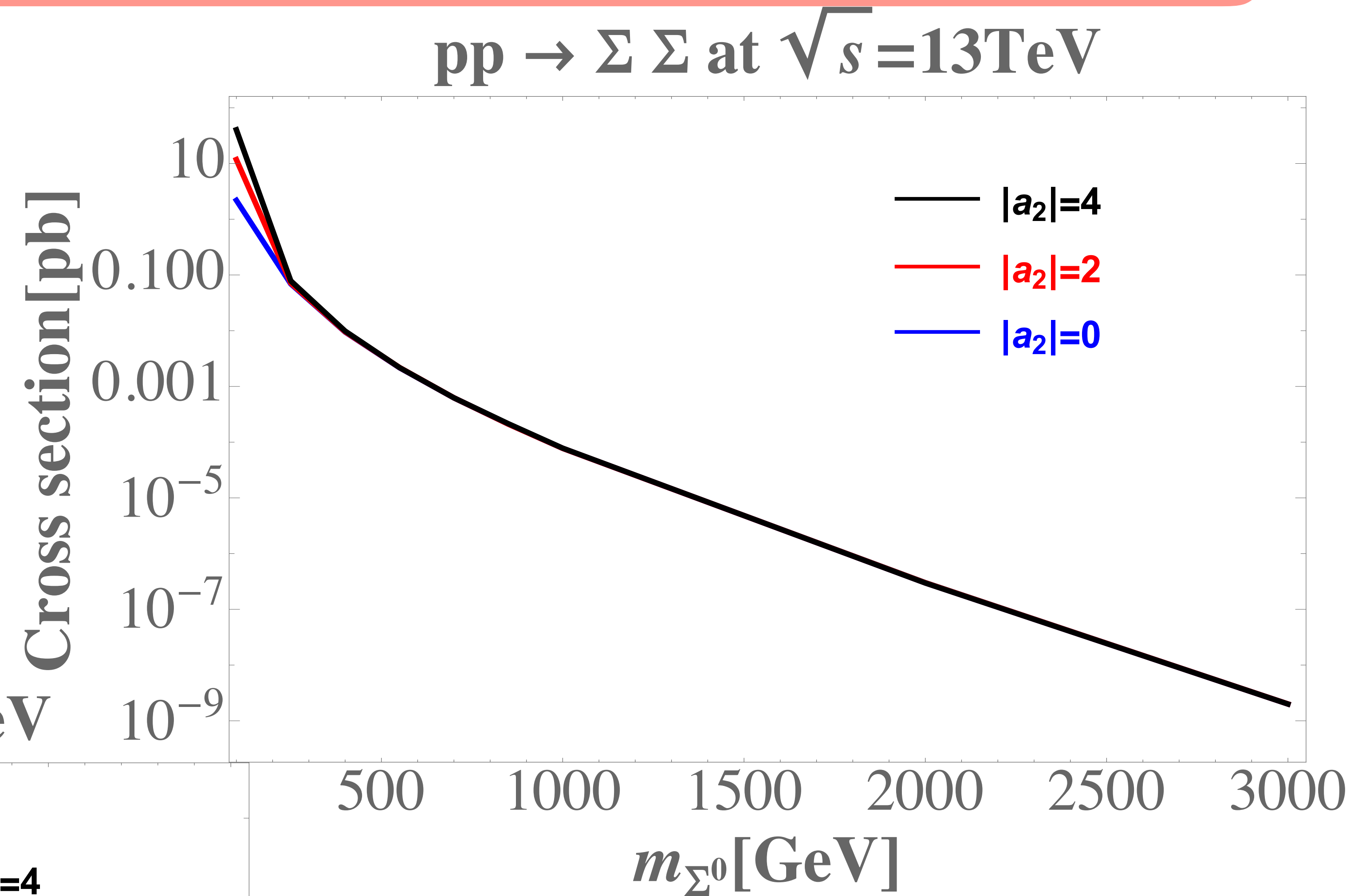
Spin-independent DM-nucleon cross section

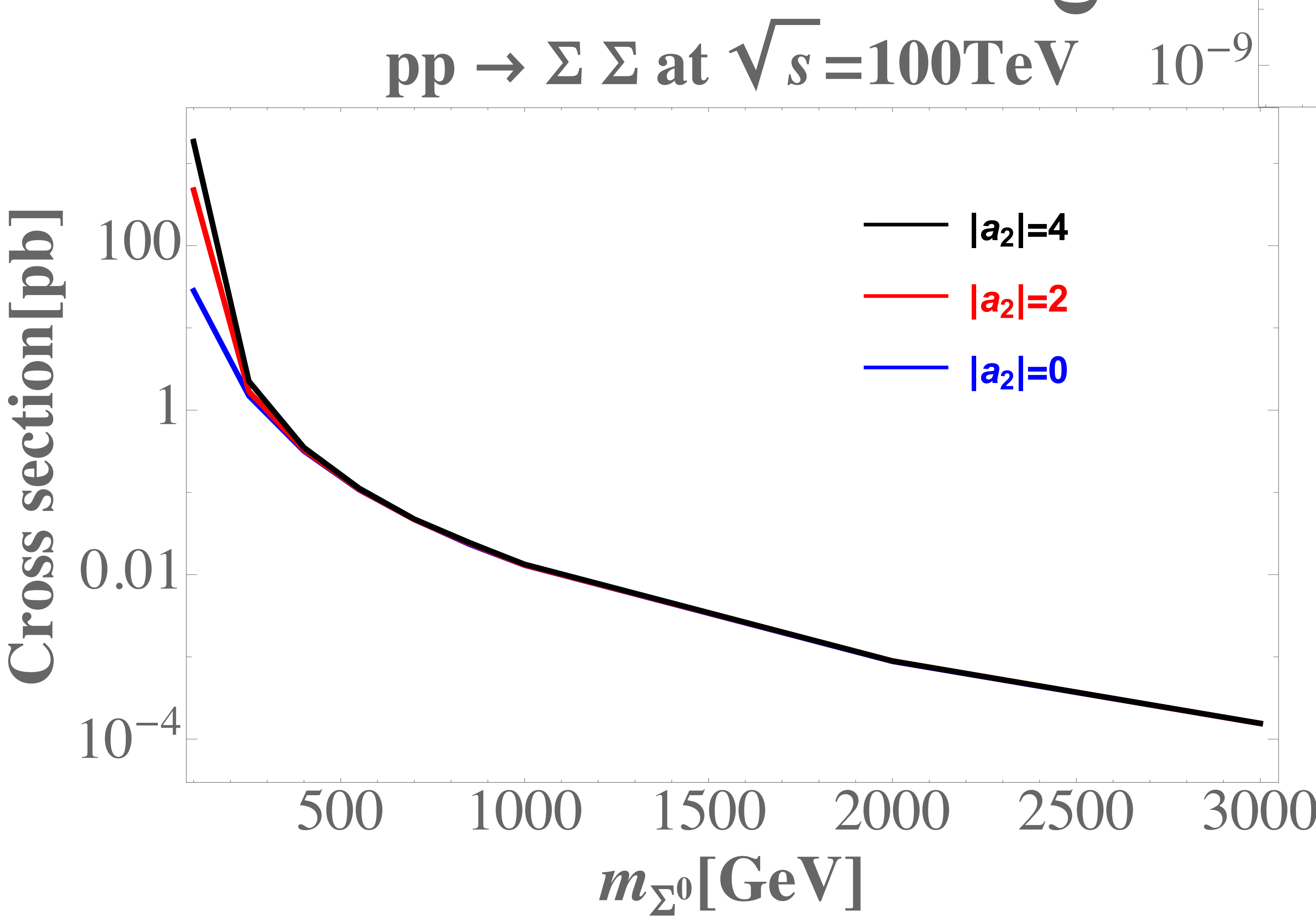


Klasen et al, arXiv: 1507.03800

Production cross section: a2 dependence

13 TeV





100 TeV

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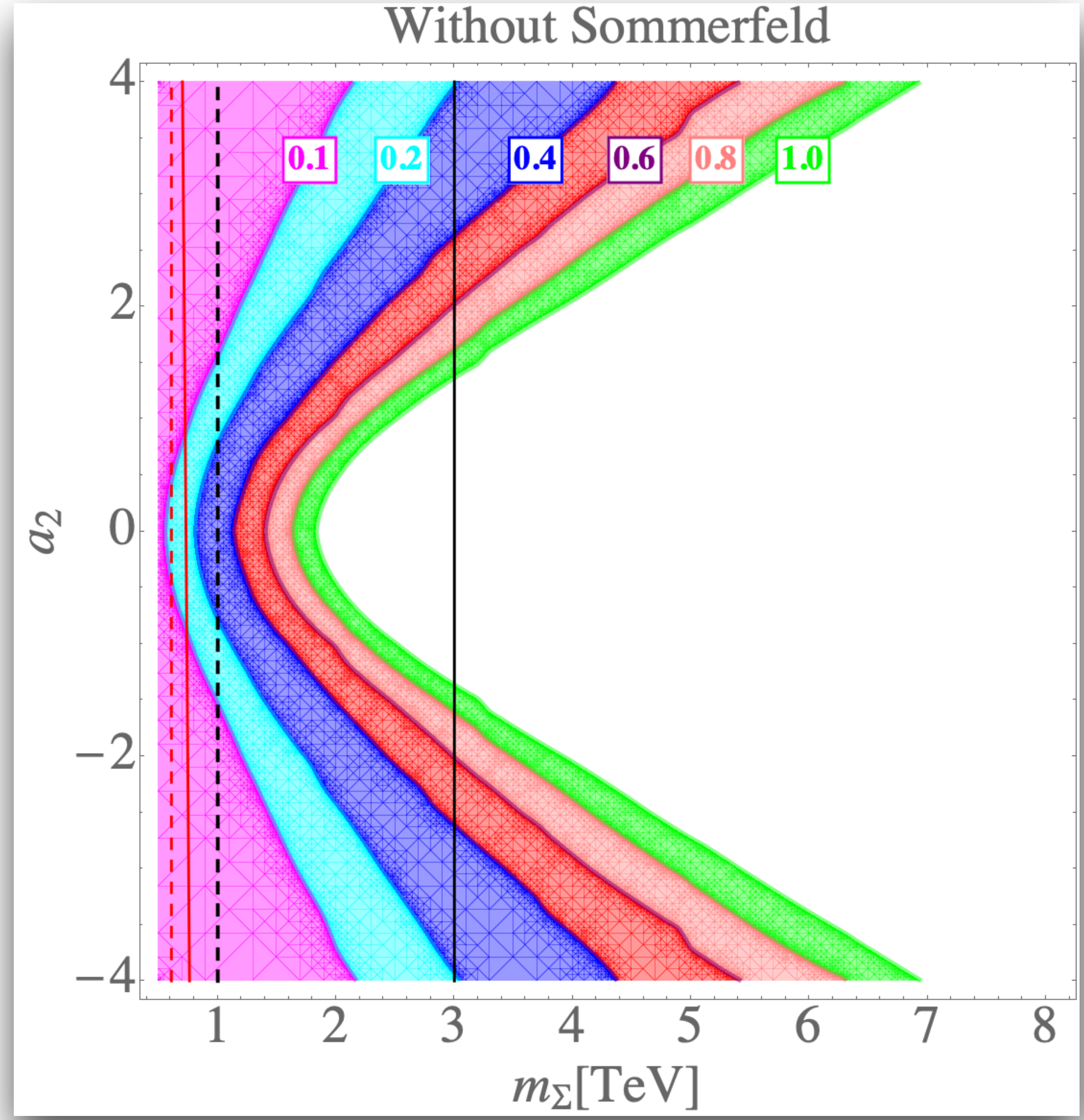
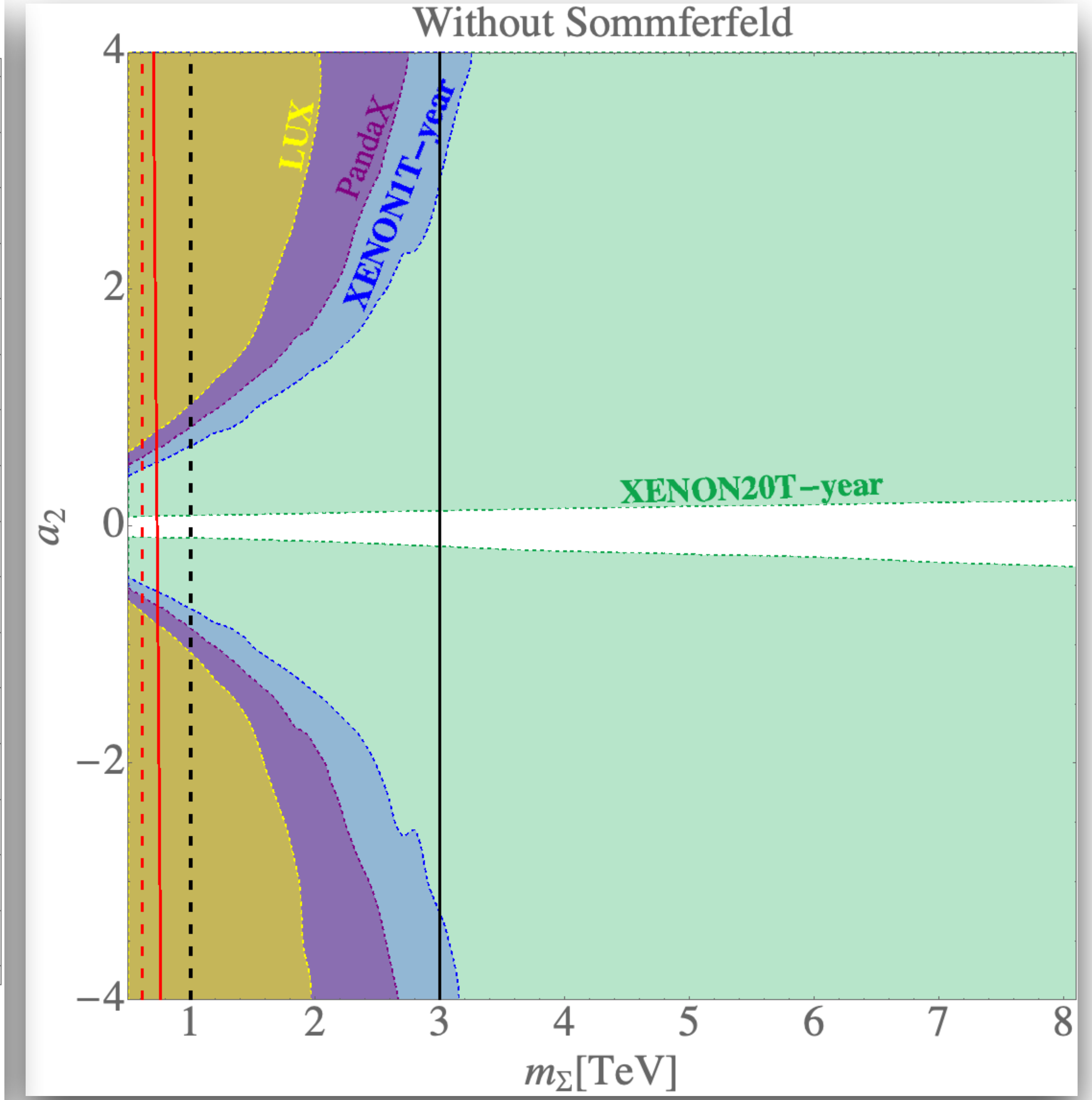
Constraints w/o including the Sommerfeld





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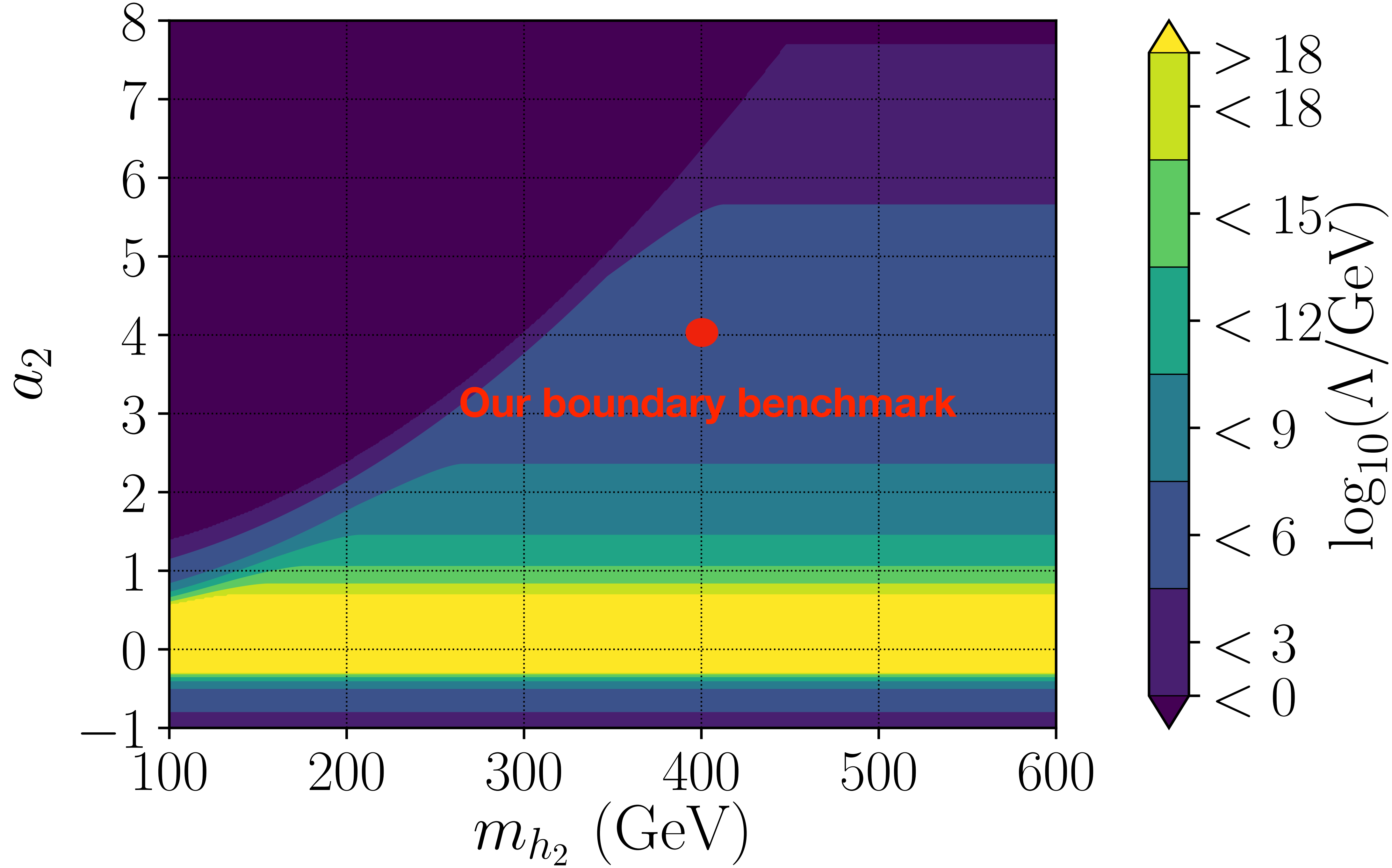
Constraints from perturbativity and perturbative unitarity



Bell et al, arXiv: 2001.05335