Aspects of Strongly interacting Dark Sectors

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based on: H. Beauchesne, E. Bertuzzo, G^2dC and Z. Tabrizi, JHEP1808(2018)101, [1712.07160]
H. Beauchesne, E. Bertuzzo and G^2dC, JHEP 1904(2019)118, [1809.10152]
H. Beauchesne and G^2dC, JHEP 02 (2020) 196, [1910.10724]

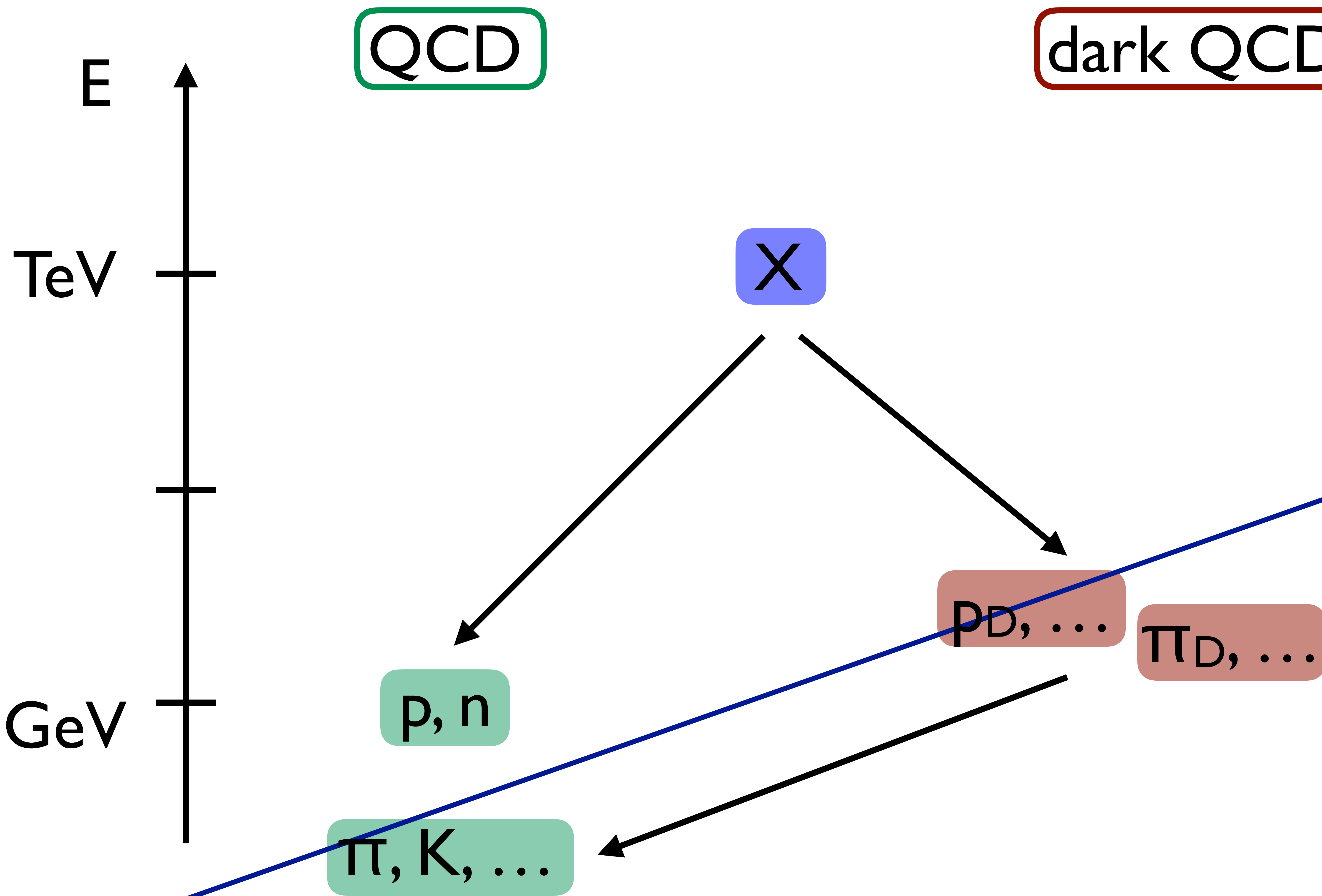
DM@LHC 2020

Outline

- Introduction and motivation
- Collider signatures
- Dark Matter
  1. Production mechanisms
  2. Benchmark models constraints
- Conclusions

Introduction

Introduction



extension to Sp(N) and O(N) groups in [Beauchesne and G²dC, '19]

1) SU(N) dark sector;
2) neutral dark quarks;
3) confinement scale Λ;
4) dark mesons can be unstable or long lived.

Motivated in Twin Higgs, Folded SUSY and Relaxion models + DM

Introduction

$$\lambda^S_{D^c_{ijk}} (X^S_{D^c_k})^\dagger \bar{n}_i P_R D^c_j + h.c.$$

$$\lambda^S_{D^c_{ijk}} = \lambda \delta_{i1} \delta_{jk}$$

two unstable dark pions

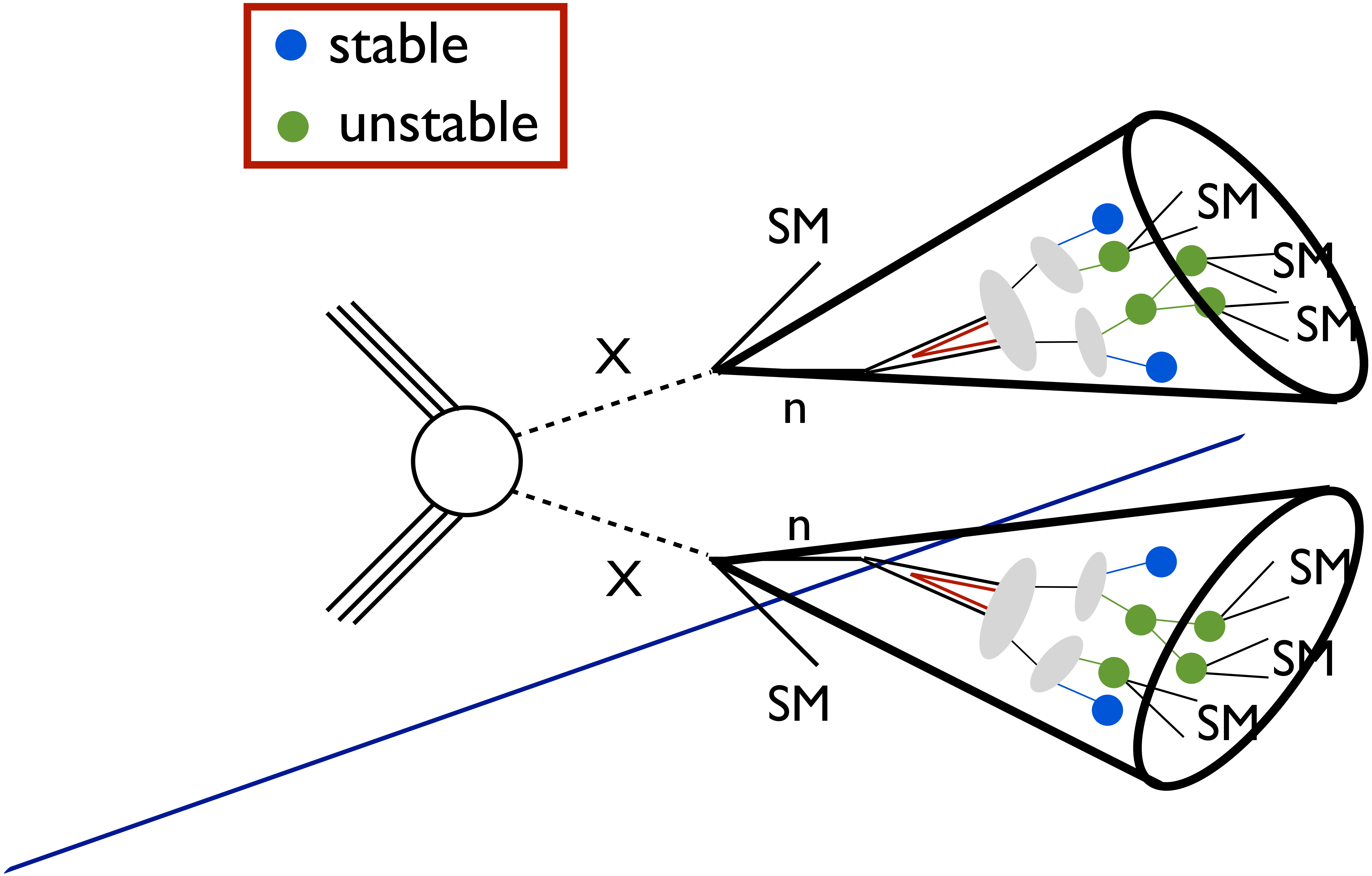
$$\Pi = \begin{pmatrix} \frac{1}{\sqrt{2}}\pi^u_1 + \frac{1}{\sqrt{6}}\pi^u_2 & \pi^s_1 & \pi^s_2 \\ \bar{\pi}^s_1 & -\frac{1}{\sqrt{2}}\pi^u_1 + \frac{1}{\sqrt{6}}\pi^u_2 & \pi^s_3 \\ \bar{\pi}^s_2 & \bar{\pi}^s_3 & -\sqrt{\frac{2}{3}}\pi^u_2 \end{pmatrix}$$

three stable dark pions

extension to other breaking patterns in [Beauchesne and G²dC, '19]

Signatures

Signatures



Signatures

Several combinations

[Schwaller+ '15]

Displaced vertices or emerging jets

[many exp. studies on D.V., 1810.10069 for Emerging jets]

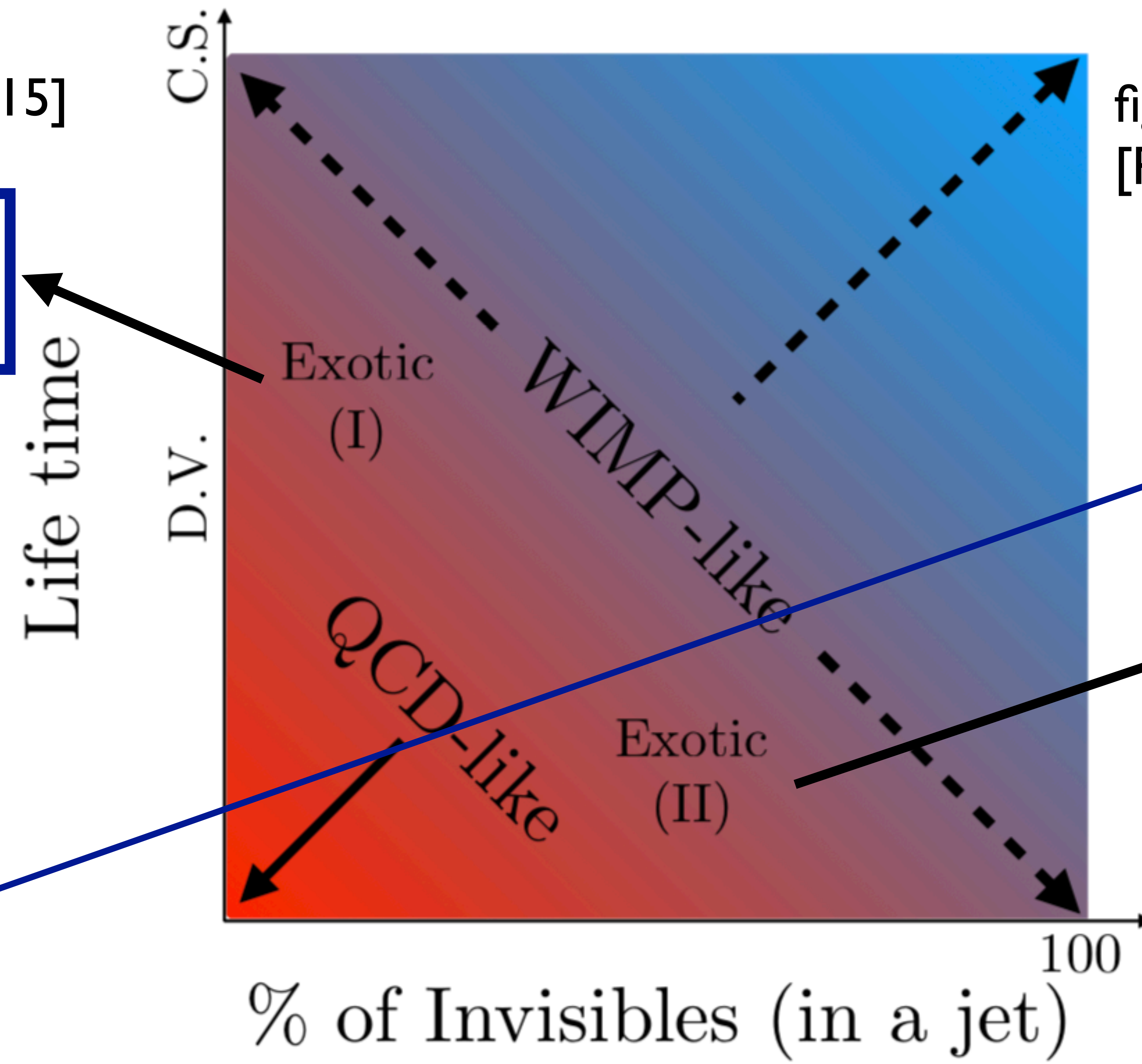


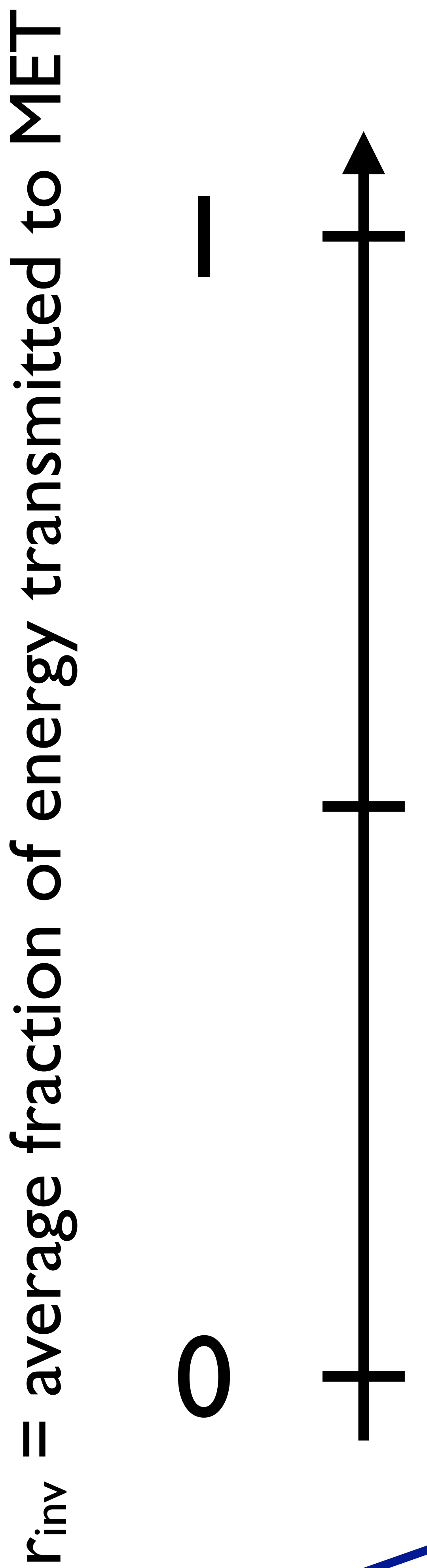
figure from [Park and Zhang, '17]

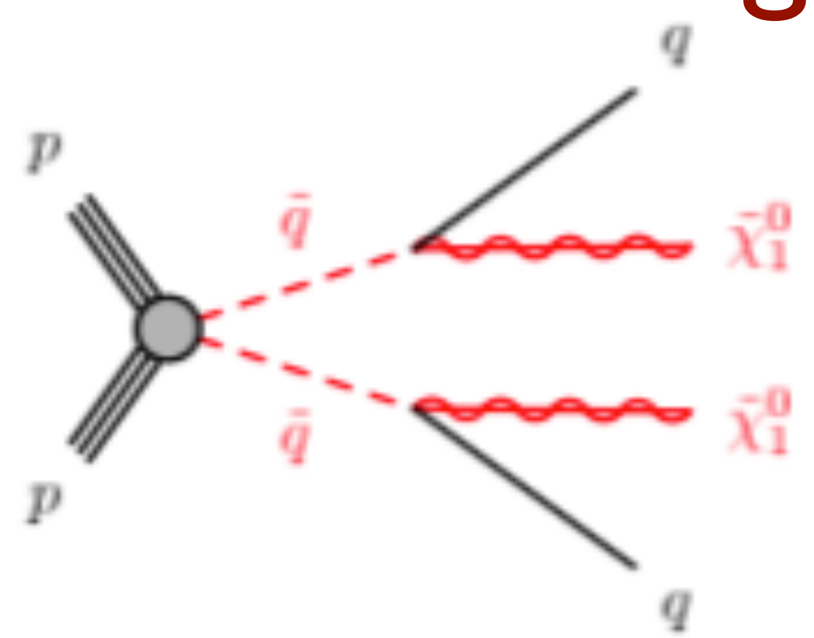
Semivisible jets

[Cohen+ '15 and '17, Beauchesne, G^{2}dC+'17, …, + CMS is working on that]

Constraints

Large r_{inv}: first two generations

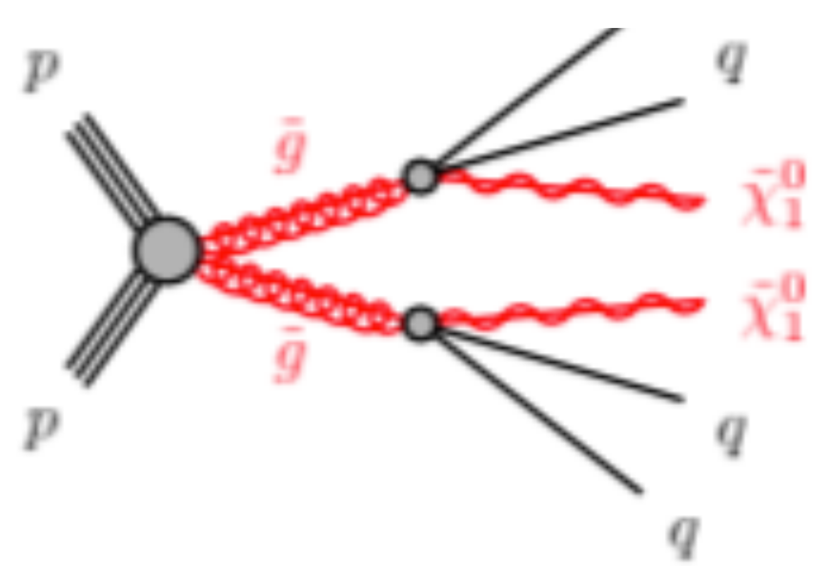




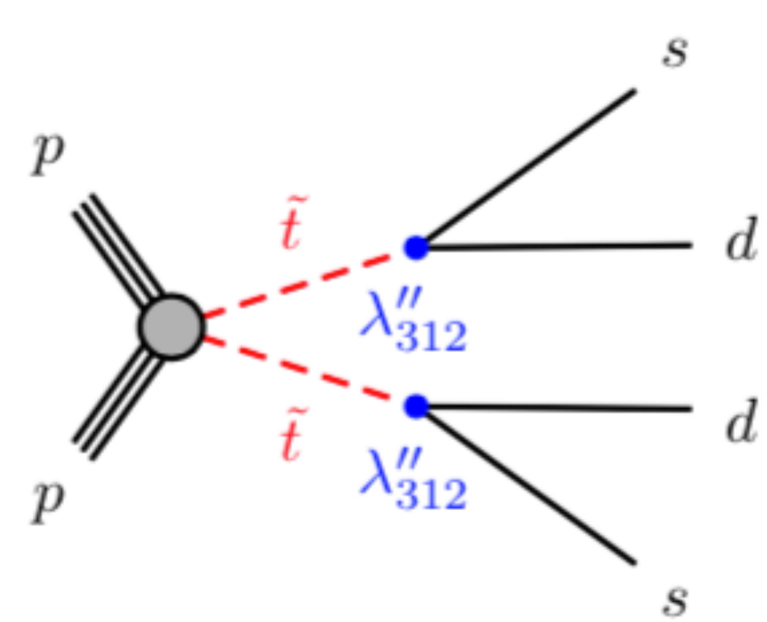
2 or 3 jets + MET,
cut on M_{eff}, cut on
MET $\lesssim$ 250 GeV

13 TeV, 36 fb^{-1}

[ATLAS-CONF-2017-022]



4 or 5 jets + MET,
cut on M_{eff}, cut on
MET $\lesssim$ 250 GeV

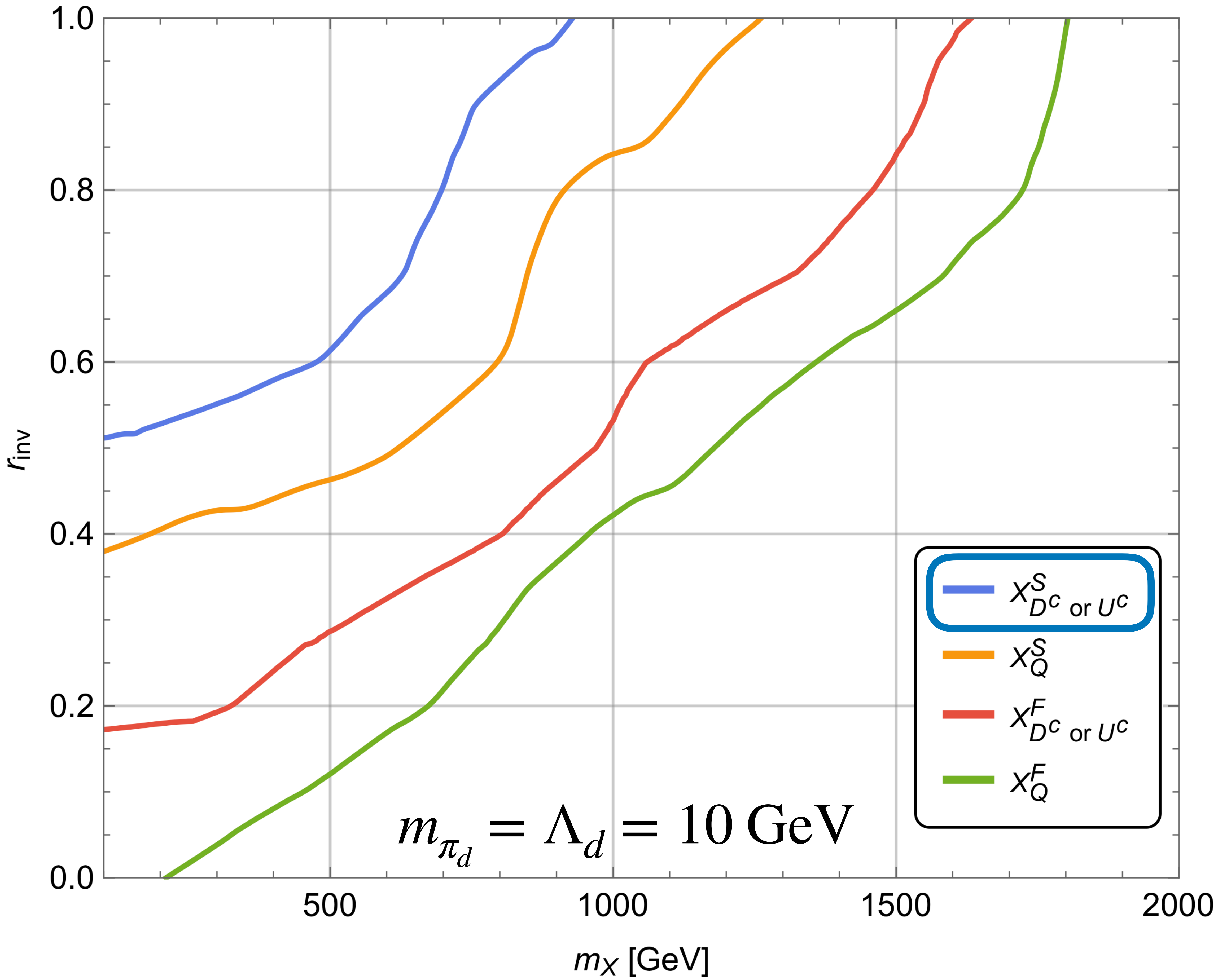


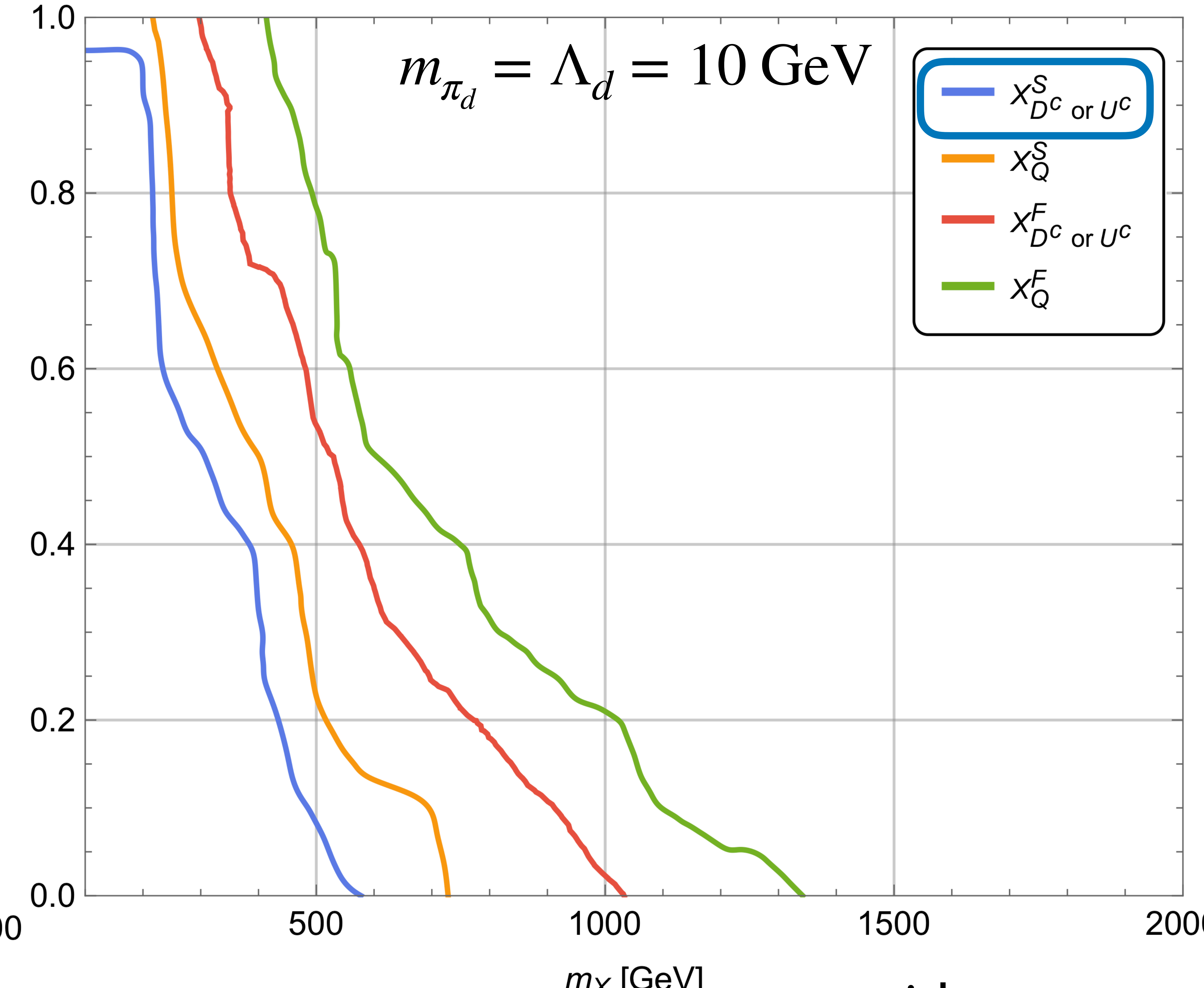
> 4 jets + reconstruct
the dijet pairs

13 TeV, 36 fb^{-1}

[ATLAS-CONF-2017-025]

Constraints



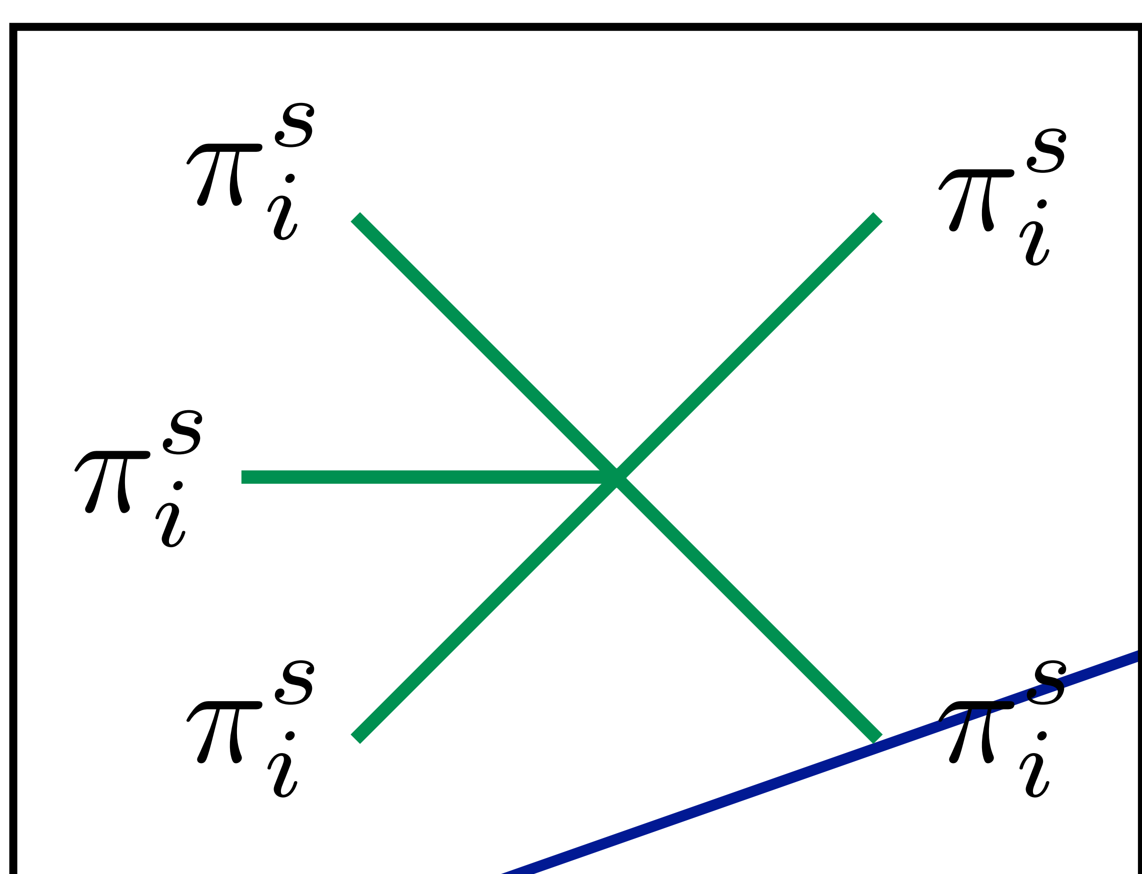


with caveats…

Dark mesons DM

The model

$$\mathcal{L} \supset \frac{2N_c}{15\pi^2 f_{\pi_D}^5}\epsilon^{\mu\nu\rho\sigma}\mathrm{Tr}[\Pi\partial_\mu\Pi\partial_\nu\Pi\partial_\rho\Pi\partial_\sigma\Pi]$$



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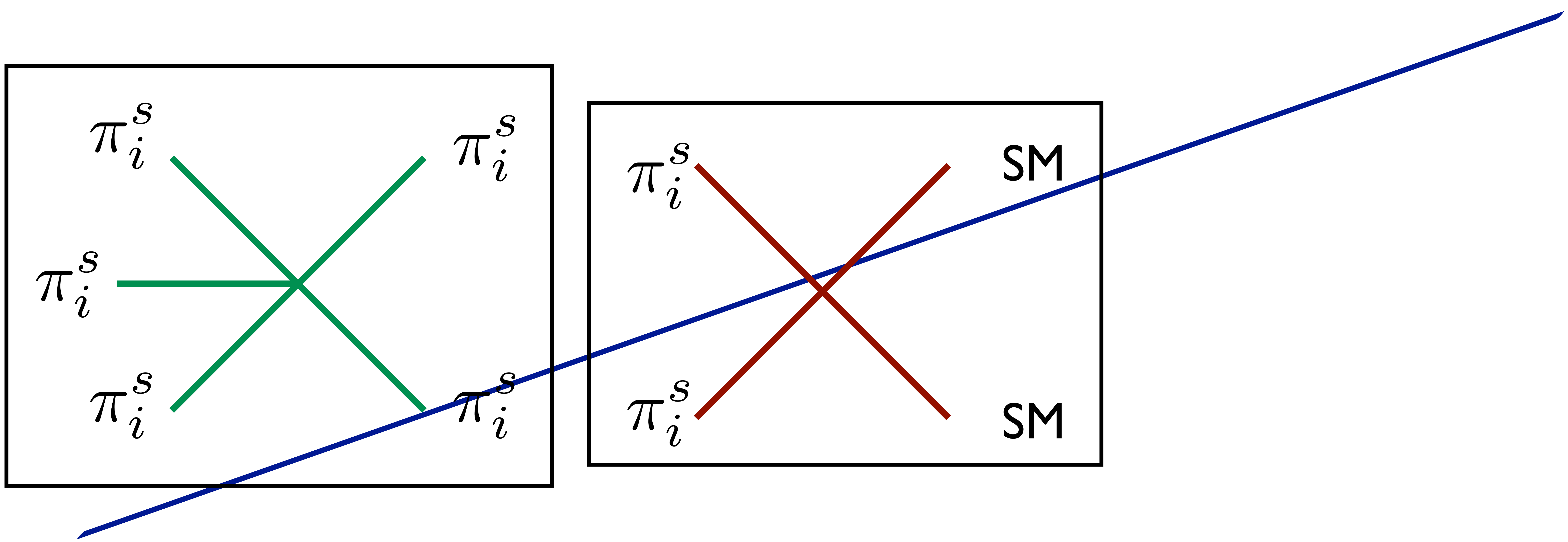
NB: qualitative Lagrangian, some terms have missing numerical factors, momentum dependence, etc. etc.



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$$+\, g_i\bar{\pi}_i^s\pi_i^s\bar{\pi}_j^u\pi_k^u$$

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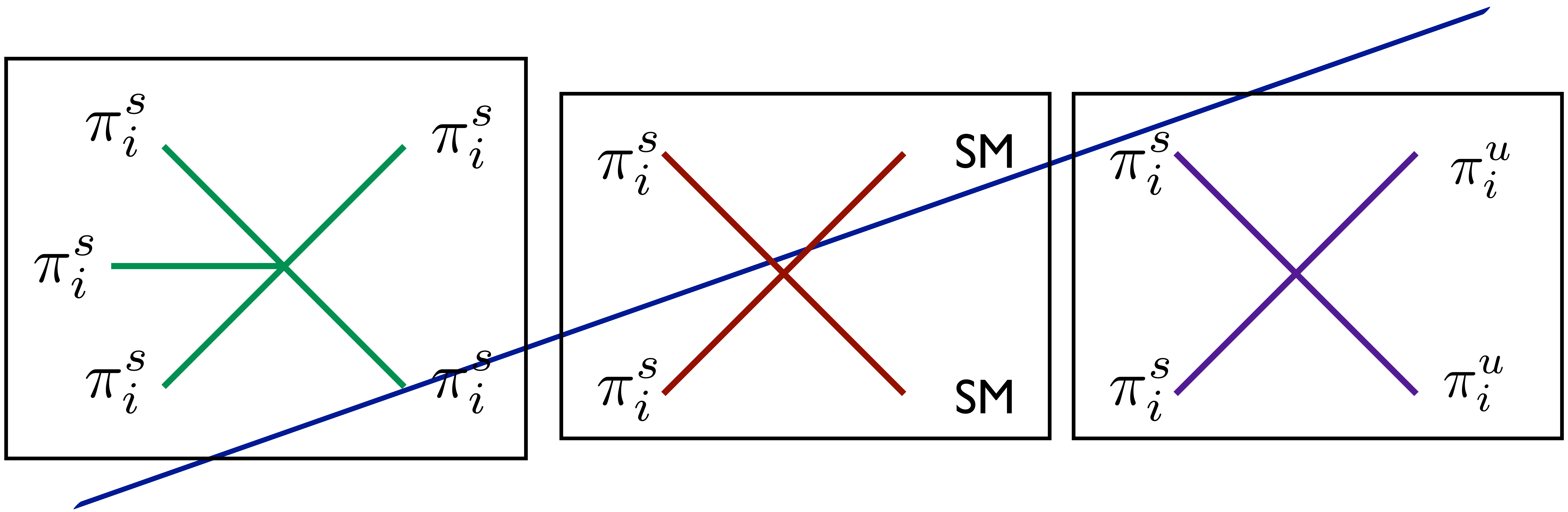

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$$+ g_i\bar{\pi}_i^s\pi_i^s\bar{\pi}_j^u\pi_k^u + \frac{f_{\pi_D}\lambda^2}{m_X^2}\partial_\mu\pi_i^u\bar{f}\gamma^\mu f + \ldots$$

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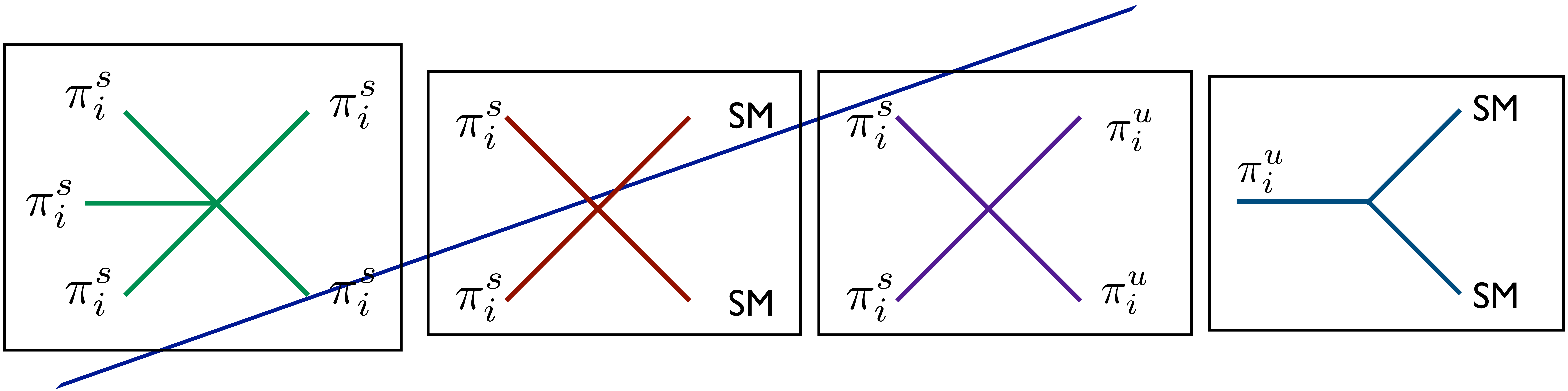
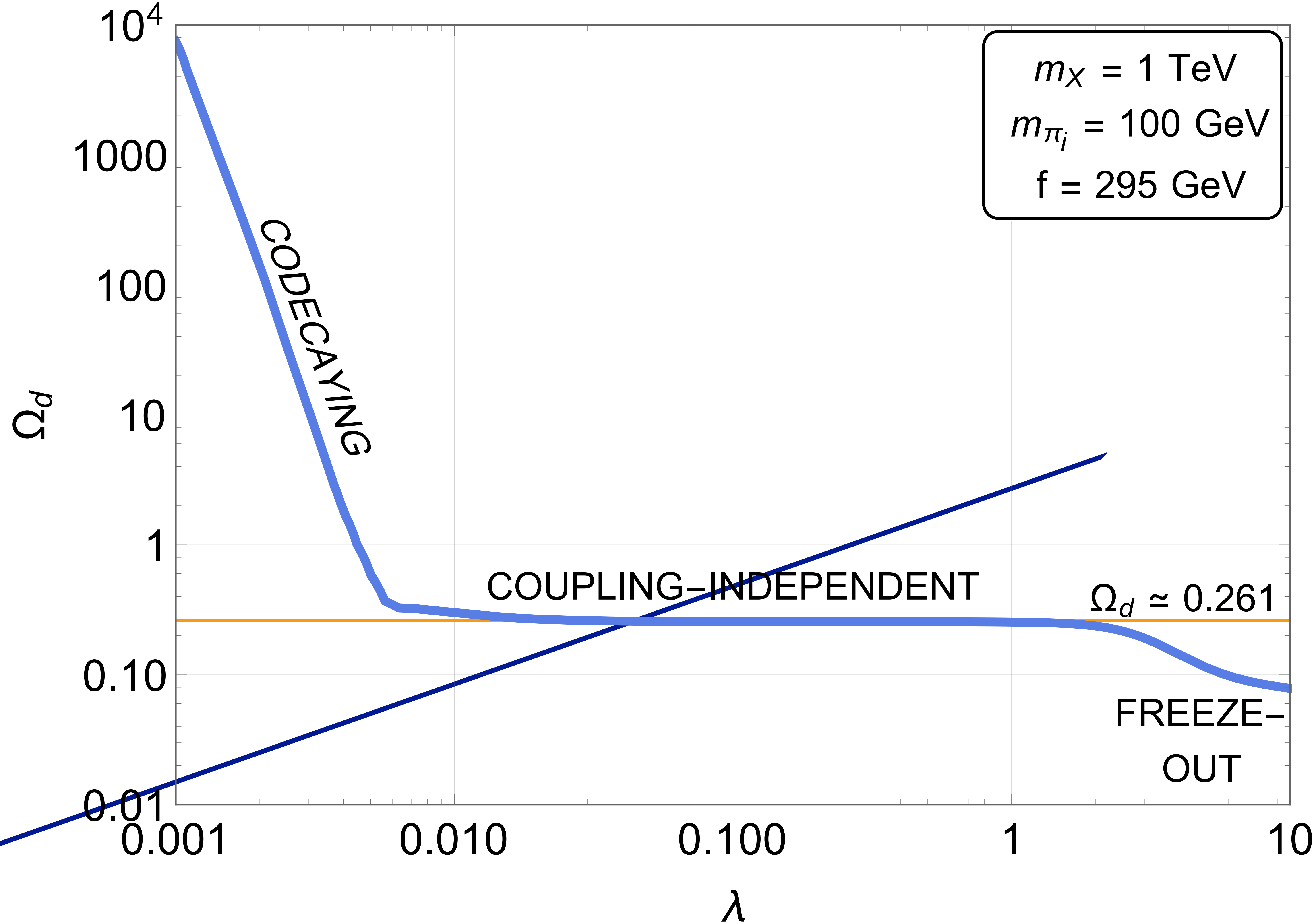


DM production mechanism



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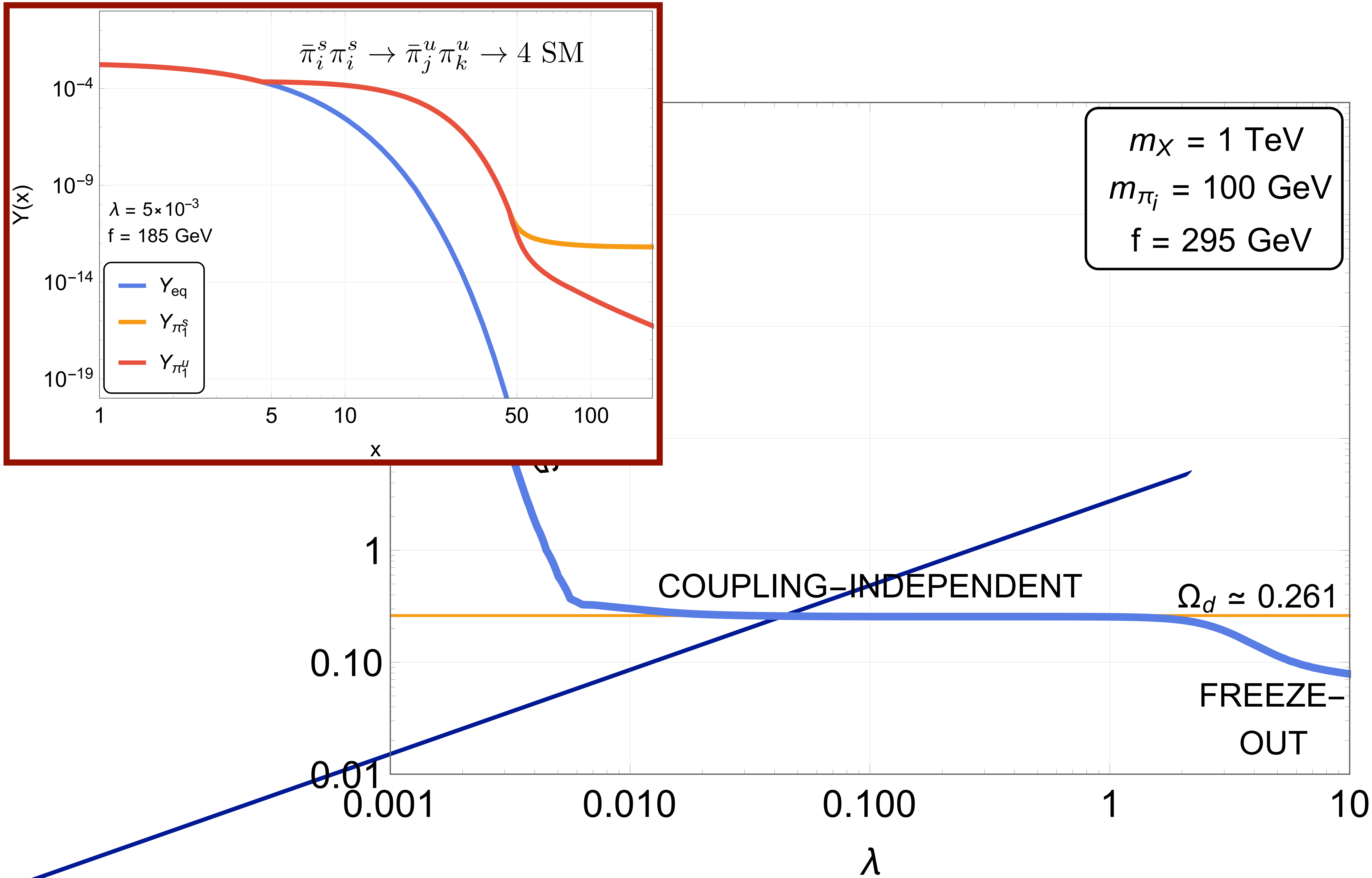

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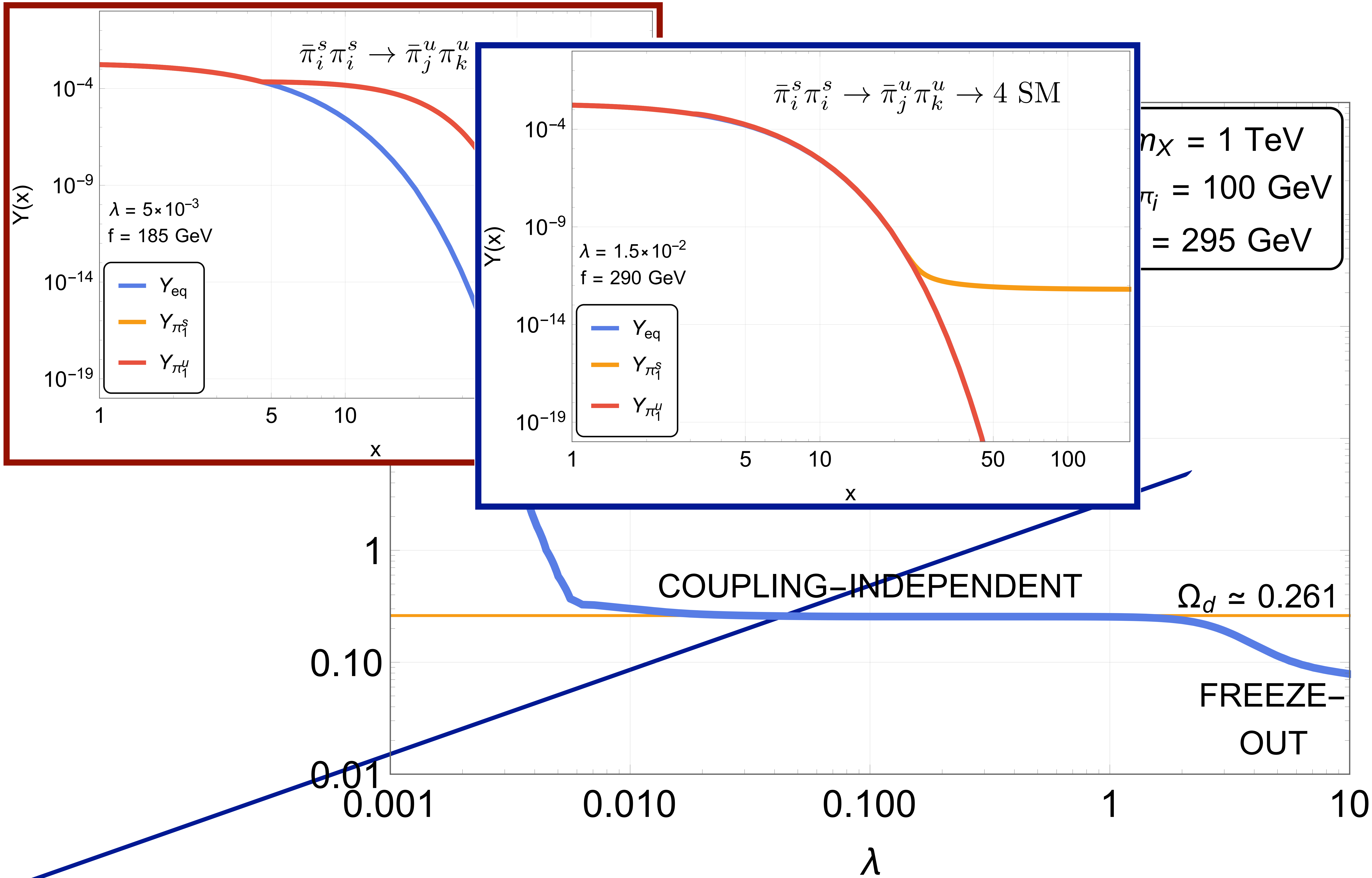


Overview of constraints

Direct Detection

Xenon1T bounds [Xenon Coll. '17]

Running effects [Crivellin et al. '14, D'Eramo et al. '15, '16]

Indirect Detection

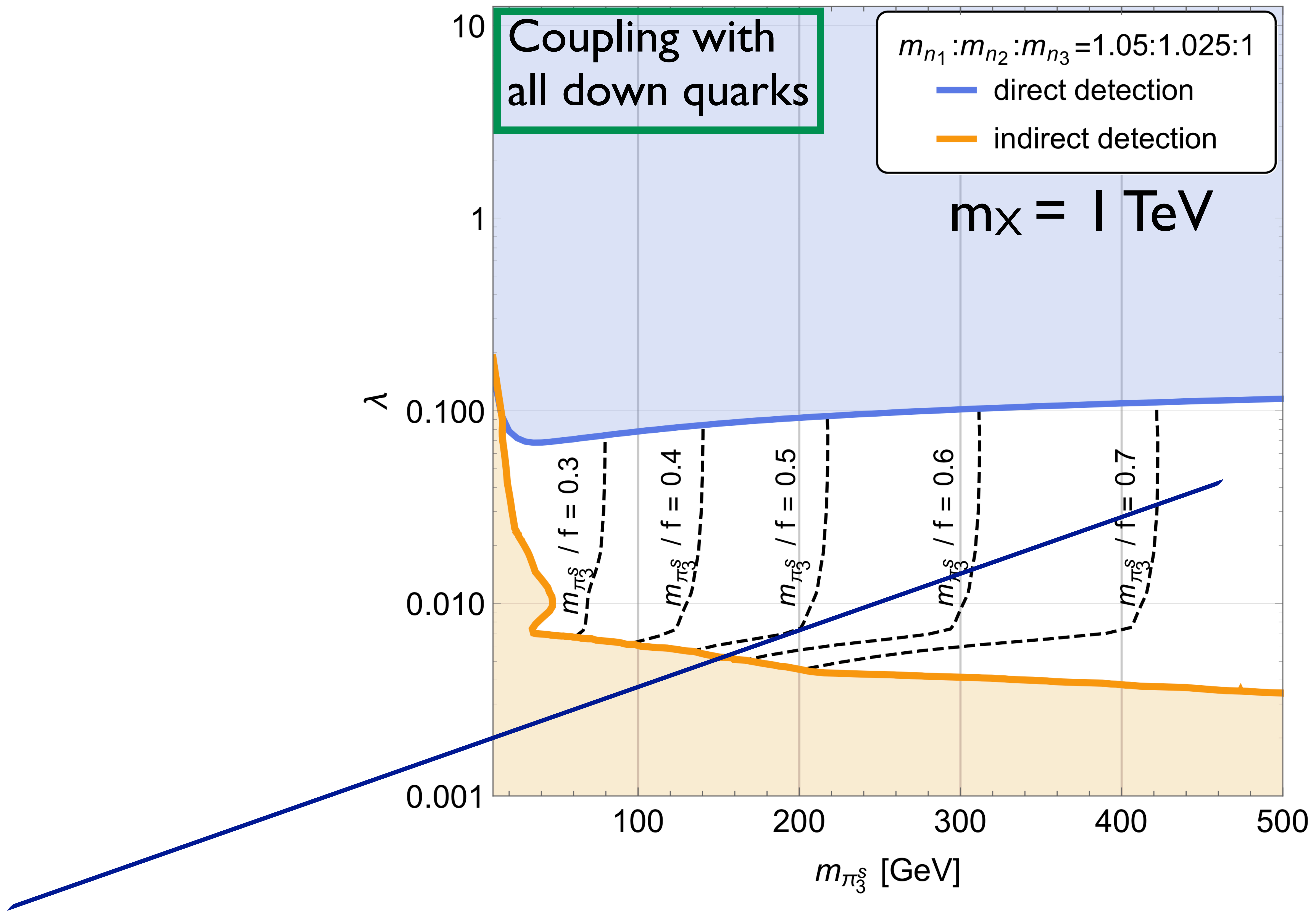
Cascade decays: [Elor et al. '15]

1) CMB from Planck [Planck Coll. '15]

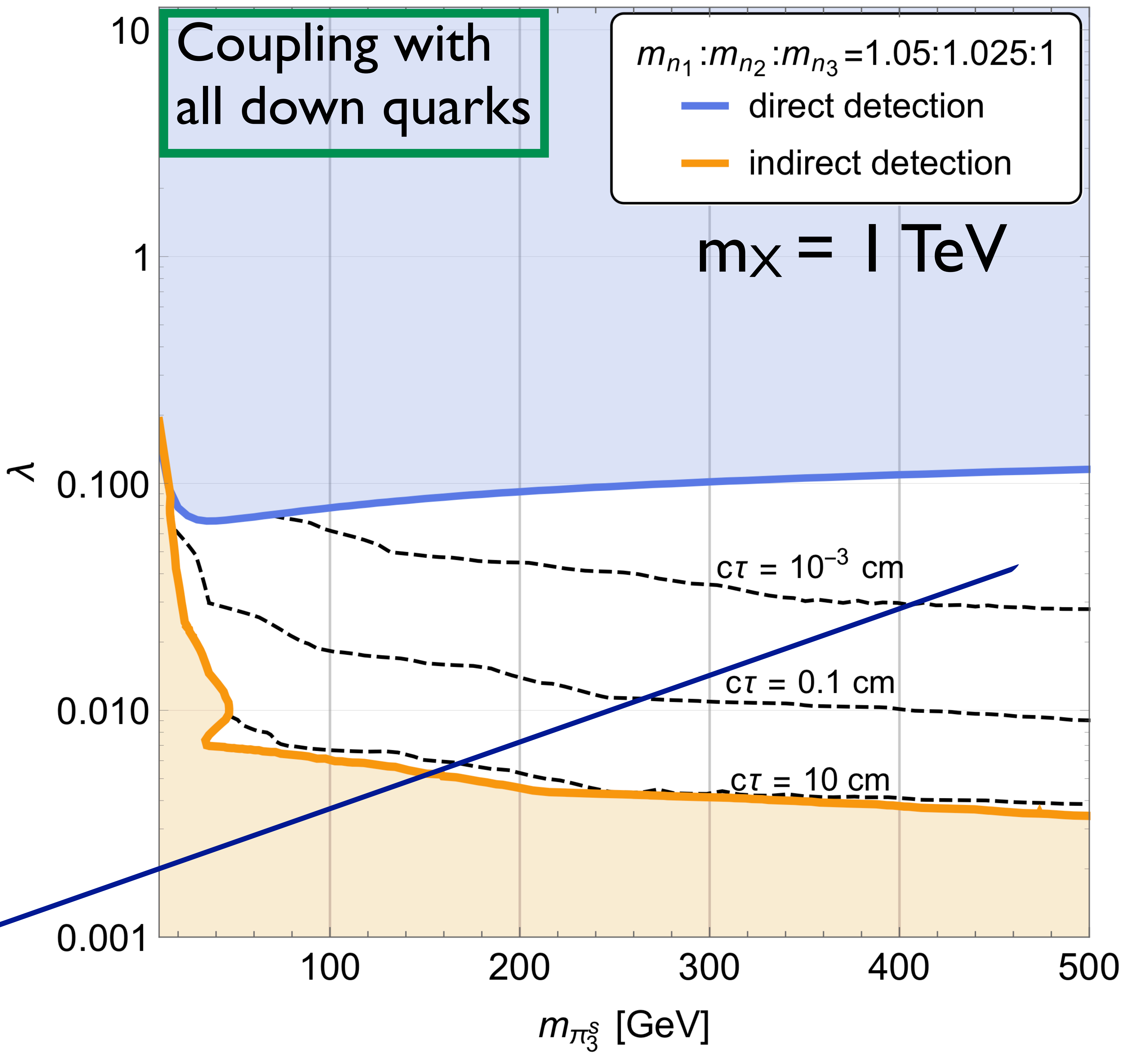
2) dwarf galaxies from Fermi-LAT [Fermi Coll. '15]

3) Positrons from AMS [AMS Coll. '14]

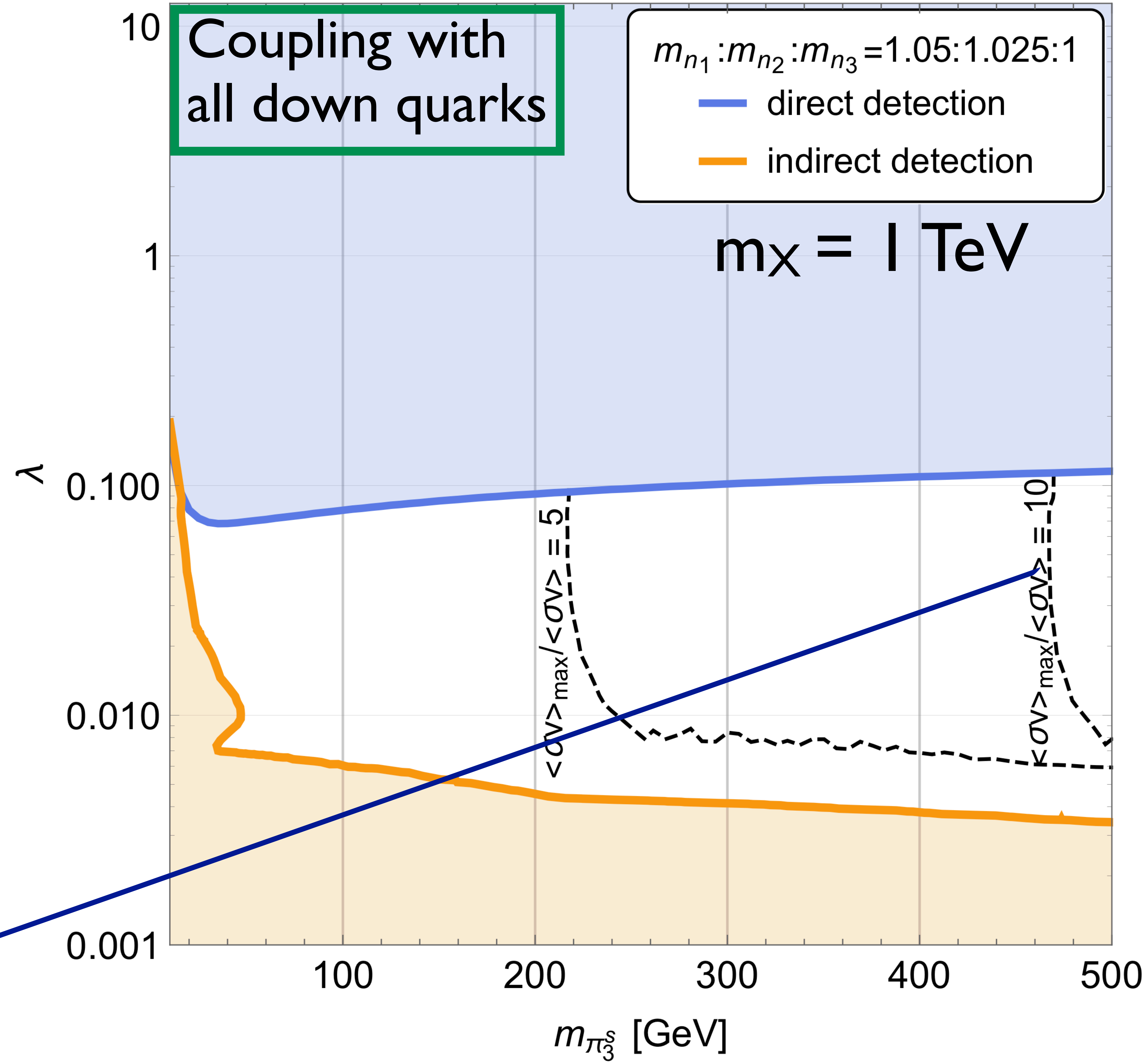
Benchmark model



Benchmark model



Benchmark model



Conclusions

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- Hidden confining dark sectors arise in many new physics models (Twin Higgs, Folded SUSY, Relaxion, DM) and lead to interesting collider signatures, such as emerging/semivisible jets.

- Stable Dark Mesons of confining sectors can be suitable DM candidates. Their parameter space can be mapped to possible exotic signatures at colliders and future indirect detection experiments.