Hidden Valley phenomenology: from cosmology to colliders

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based on: H. Beauchesne, E. Bertuzzo, G²dC and Z. Tabrizi, JHEP1808(2018)101, [1712.07160]
H. Beauchesne, E. Bertuzzo and G²dC, JHEP 1904(2019)118, [1809.10152]
H. Beauchesne and G²dC, [19xx.xxxxx]

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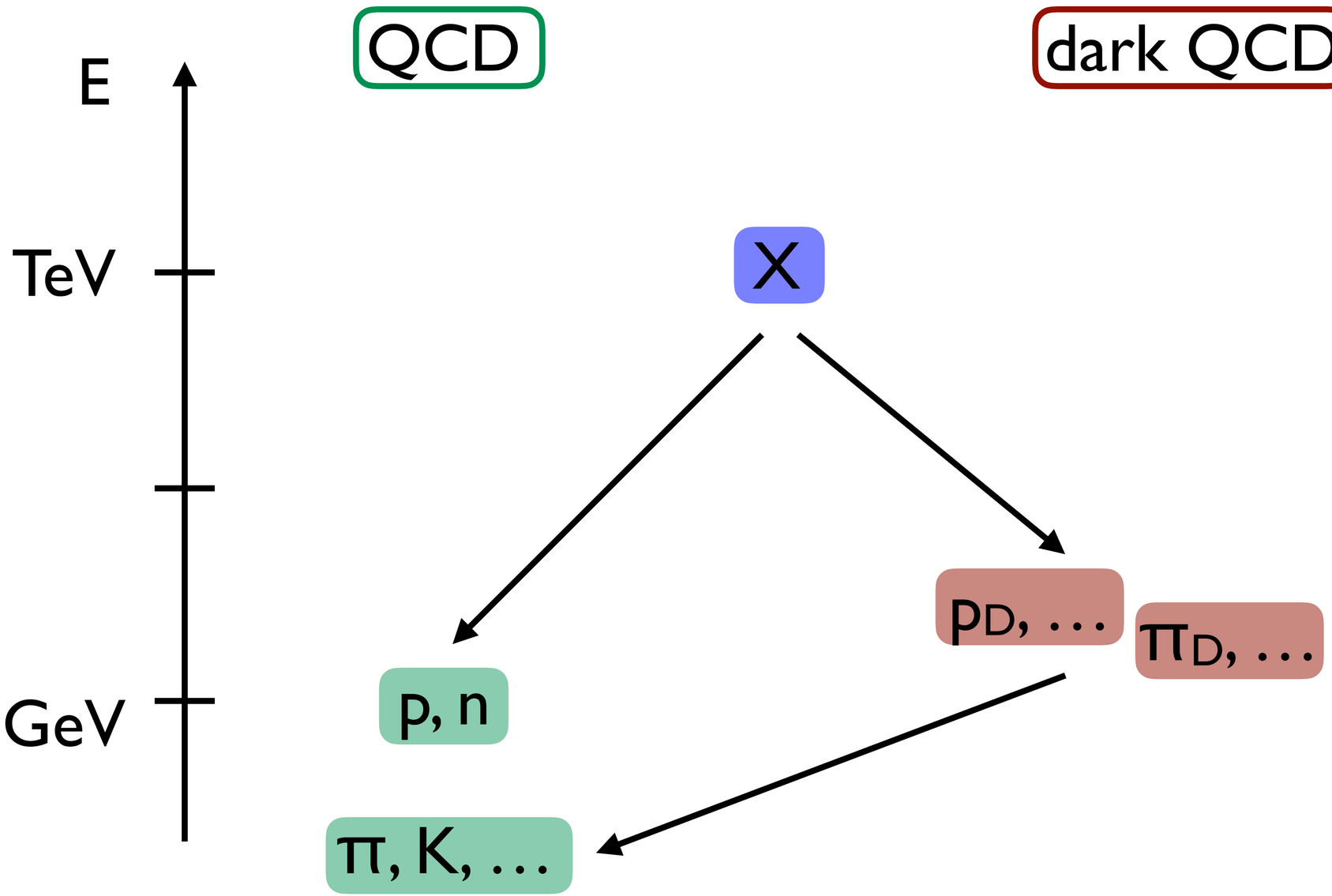
Outline

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

Introduction

Introduction



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

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

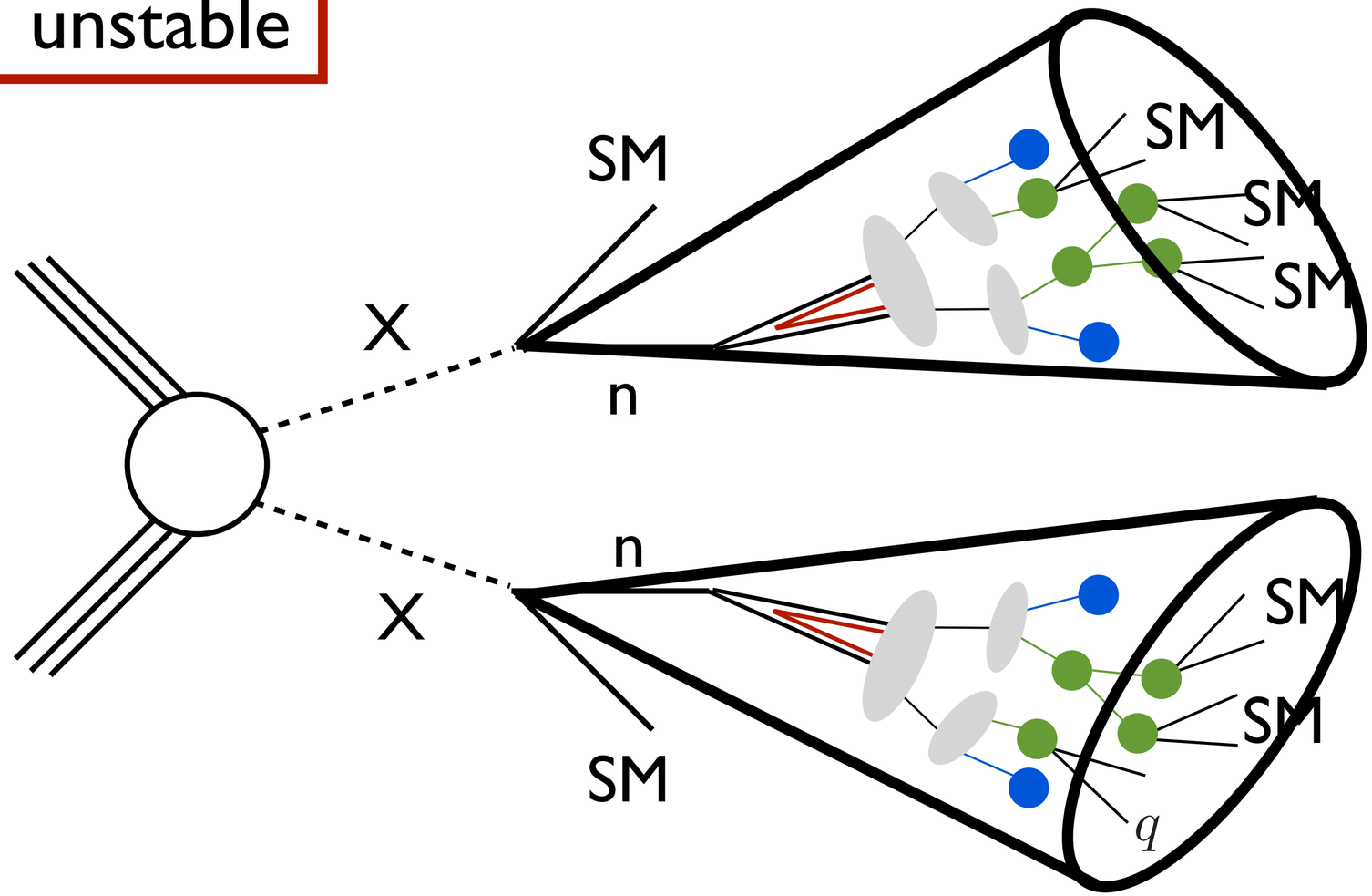
$$\Pi = \begin{pmatrix} \frac{1}{\sqrt{2}}\pi^u_1 + \frac{1}{\sqrt{6}}\pi^u_2 & \pi^s_1 & \pi^s_2 \\ \bar{\pi}^s_1 & -\frac{1}{\sqrt{2}}\pi^u_1 + \frac{1}{\sqrt{6}}\pi^u_2 & \pi^s_3 \\ \bar{\pi}^s_2 & \bar{\pi}^s_3 & -\sqrt{\frac{2}{3}}\pi^u_2 \end{pmatrix}$$

three stable dark pions

Signatures

Signatures

- stable
- unstable



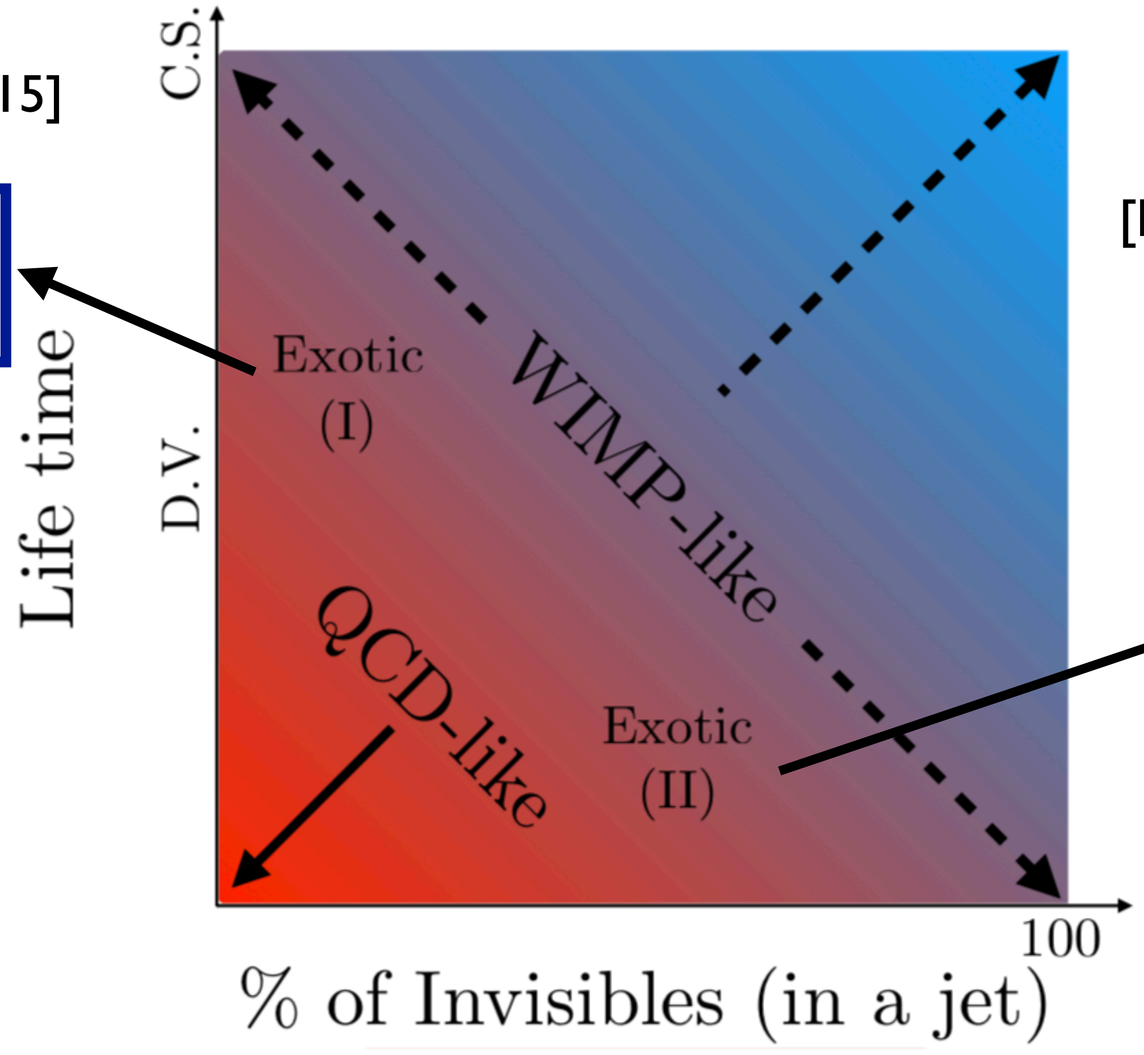
Signatures

Several combinations

[Schwaller+ '15]

Displaced vertices or emerging jets

[many exp. studies on D.V., CMS-PAS-EXO-18-001 for Emerging jets]



[Park and Zhang, '17]

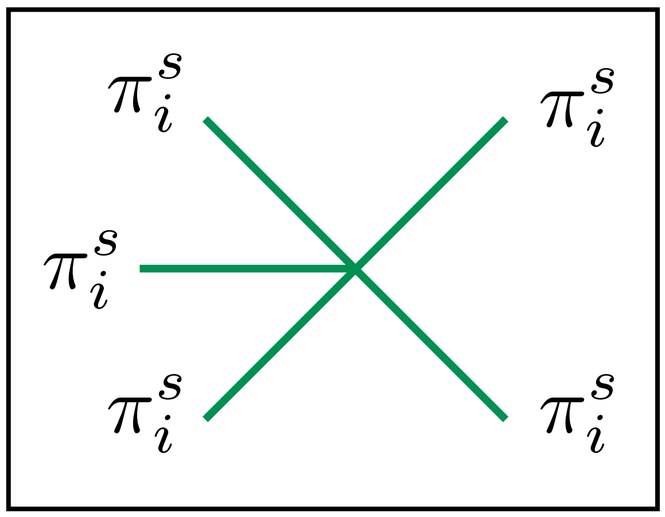
Semivisible jets

[Cohen+ '15 and '17, Beauchesne, G²dC+'17, …, + CMS is working on that]

Dark mesons DM

The model

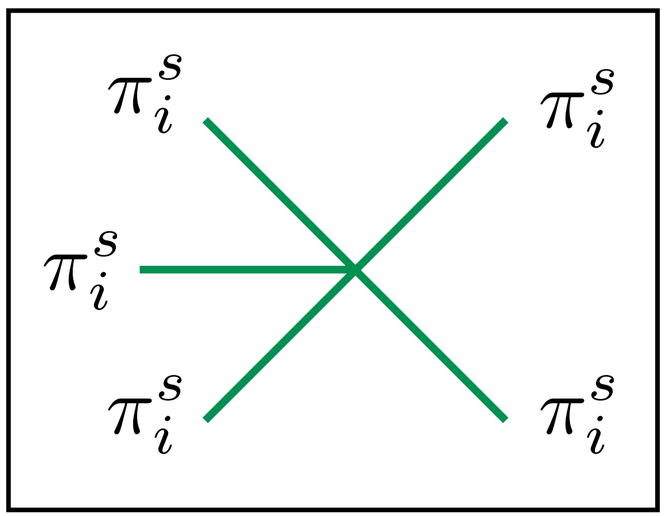
$$\mathcal{L} \supset \frac{2N_c}{15\pi^2 f_{\pi_D}^5}\epsilon^{\mu\nu\rho\sigma}\mathrm{Tr}[\Pi\partial_\mu\Pi\partial_\nu\Pi\partial_\rho\Pi\partial_\sigma\Pi]$$

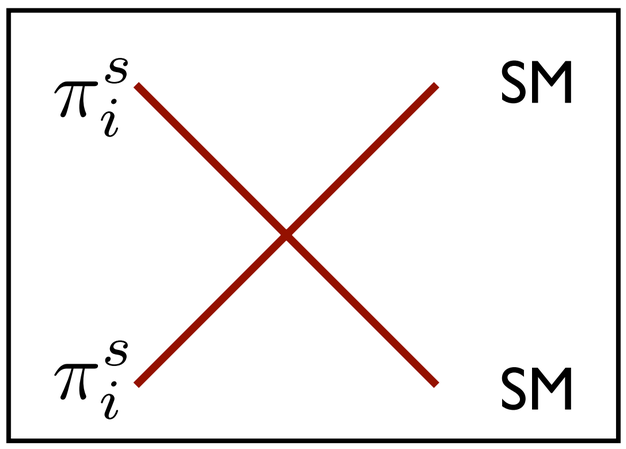


The model

$$\mathcal{L} \supset \frac{2N_c}{15\pi^2 f_{\pi_D}^5}\epsilon^{\mu\nu\rho\sigma}\mathrm{Tr}[\Pi\partial_\mu\Pi\partial_\nu\Pi\partial_\rho\Pi\partial_\sigma\Pi] + i\frac{\lambda^2}{m_X^2}(\pi_i^s\partial_\mu\bar{\pi}_i^s - \bar{\pi}_i^s\partial_\mu\pi_i^s)\bar{f}\gamma^\mu f$$

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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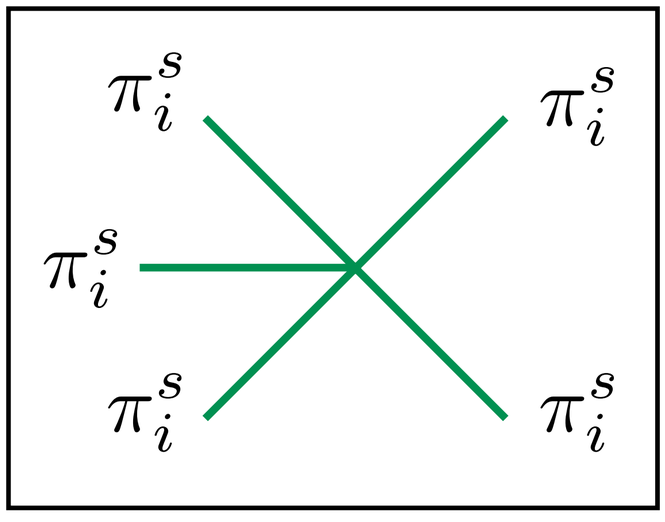

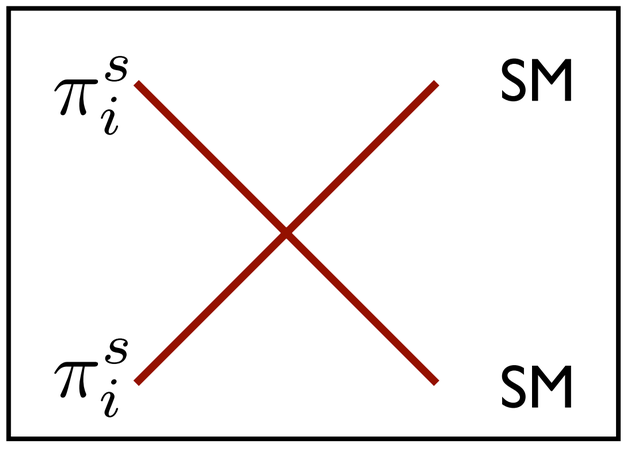

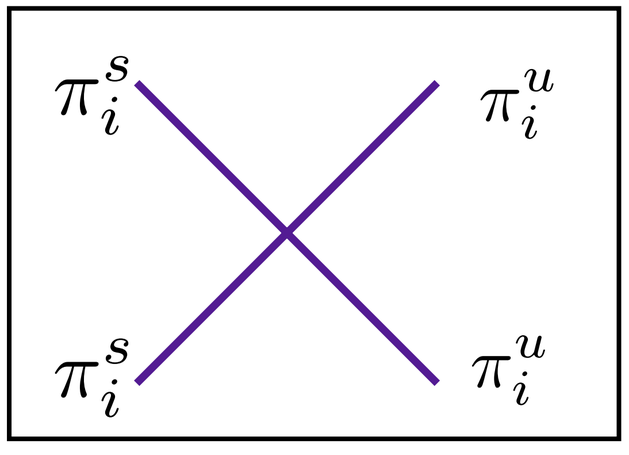

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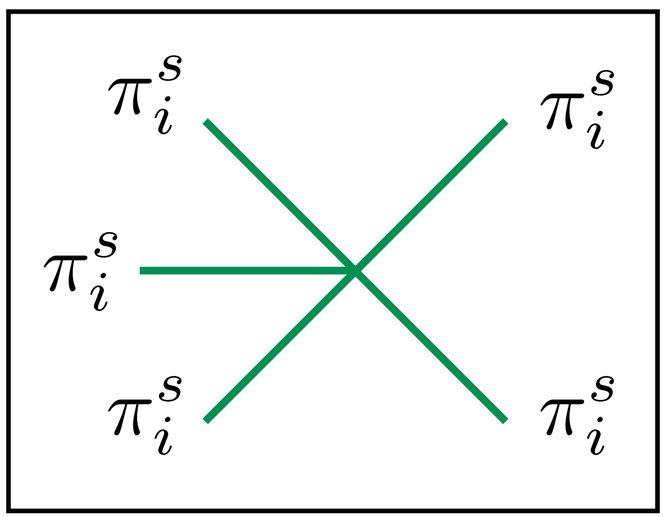
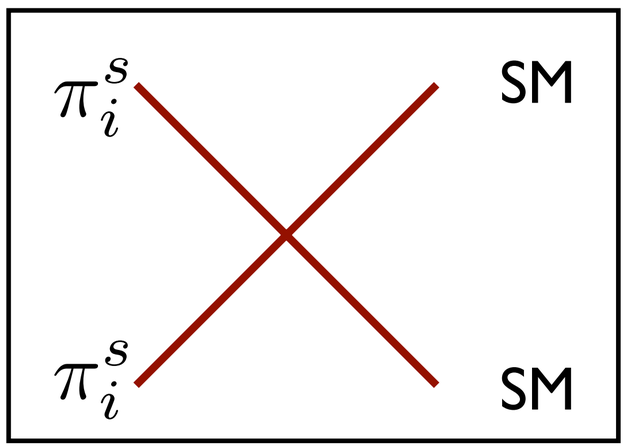
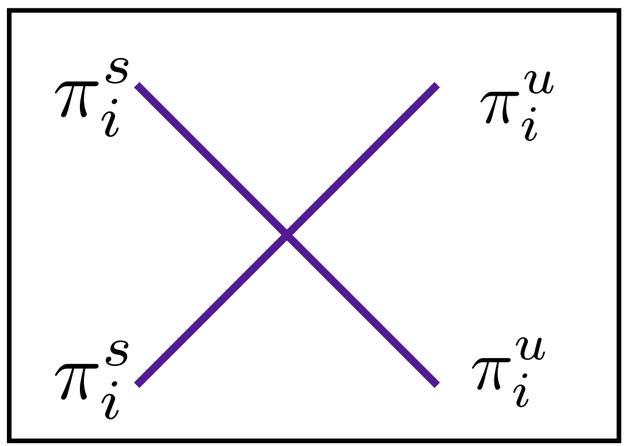
$$\mathcal{L} \supset \frac{2N_c}{15\pi^2 f_{\pi_D}^5}\epsilon^{\mu\nu\rho\sigma}\mathrm{Tr}[\Pi\partial_\mu\Pi\partial_\nu\Pi\partial_\rho\Pi\partial_\sigma\Pi] + i\frac{\lambda^2}{m_X^2}(\pi_i^s\partial_\mu\bar{\pi}_i^s - \bar{\pi}_i^s\partial_\mu\pi_i^s)\bar{f}\gamma^\mu f$$

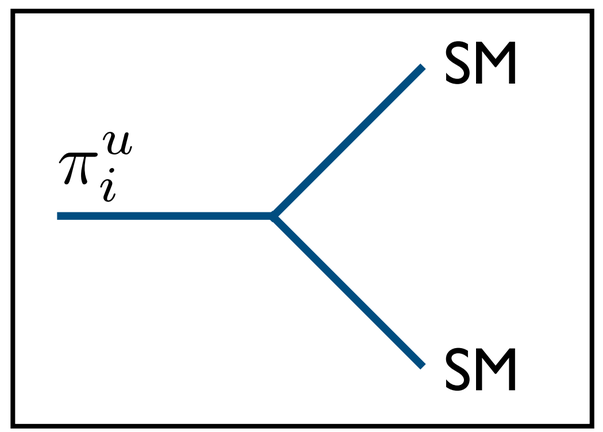
$$+ g_i\bar{\pi}_i^s\pi_i^s\bar{\pi}_j^u\pi_k^u + \frac{f_{\pi_D}\lambda^2}{m_X^2}\partial_\mu\pi_i^u\bar{f}\gamma^\mu f + \dots$$

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

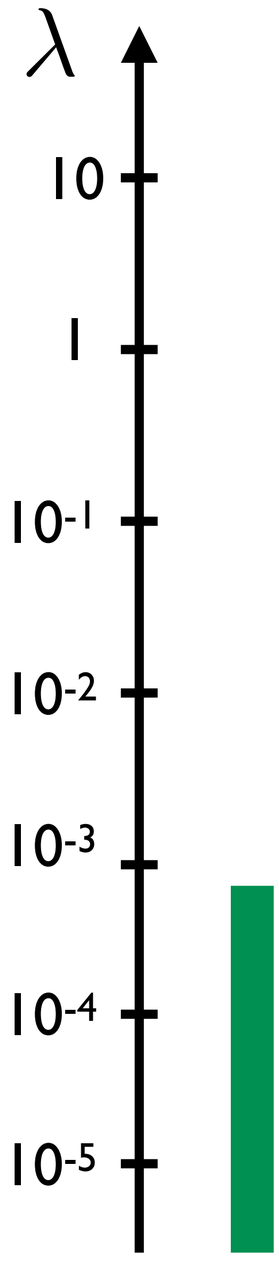








DM production mechanism



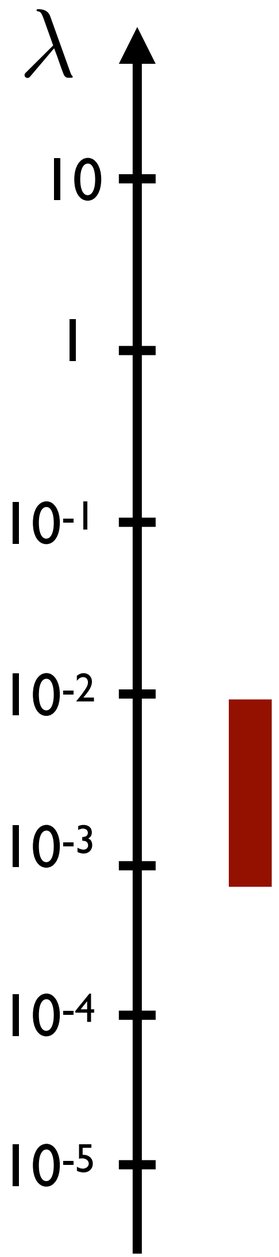
For $\lambda \to 0$:

[Hochberg et al.'14,…]

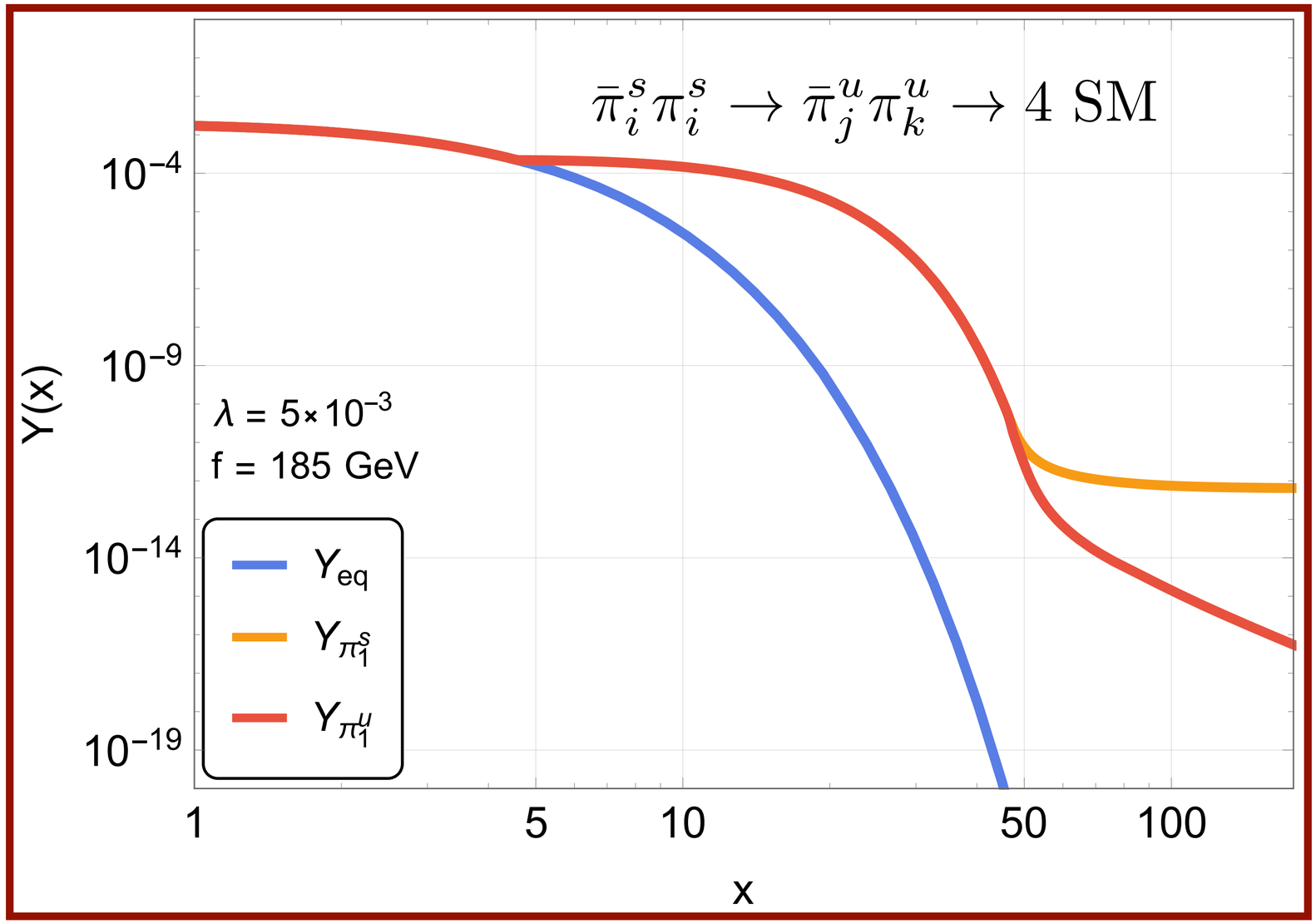
- Strongly Interacting Massive Particle
- ELastic DEcoupling Relic

[Kuflik et al.'15,…]

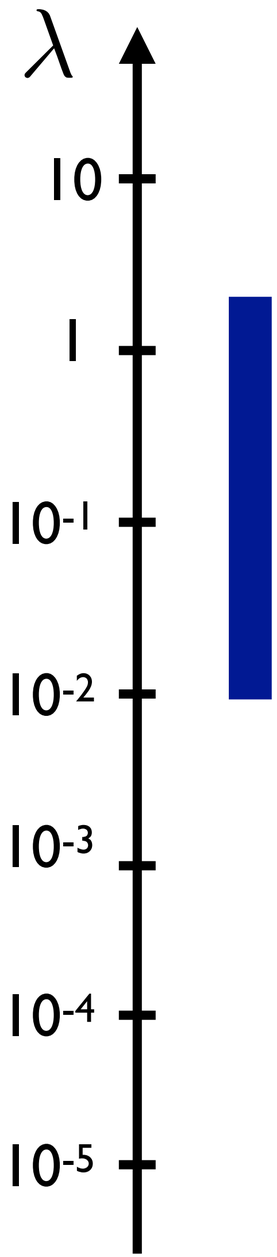
DM production mechanism



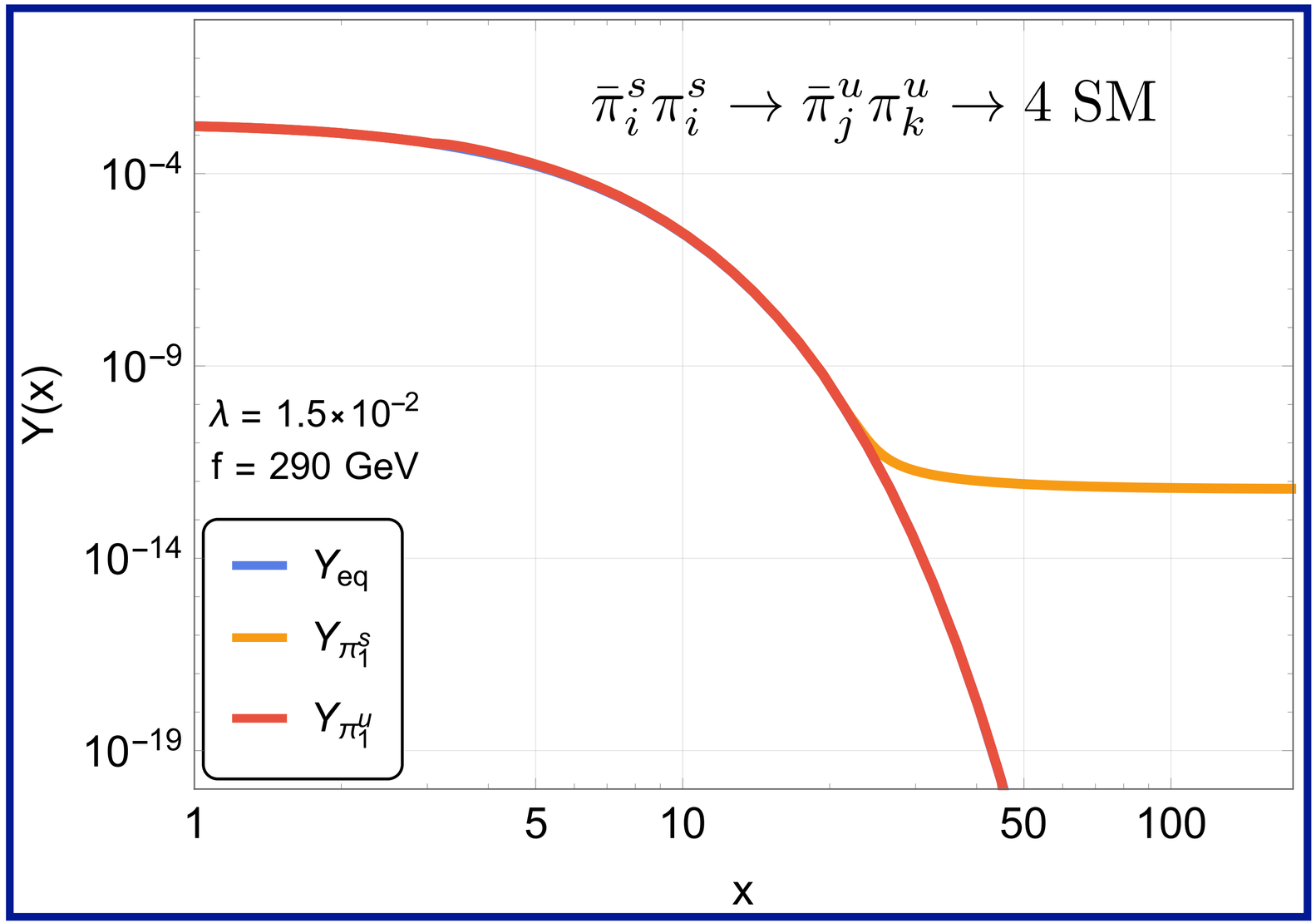
Codecaying regime



DM production mechanism



Coupling independent regime



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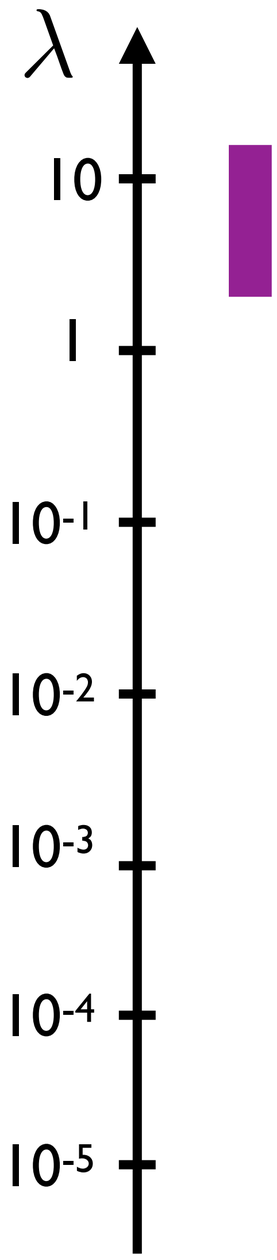
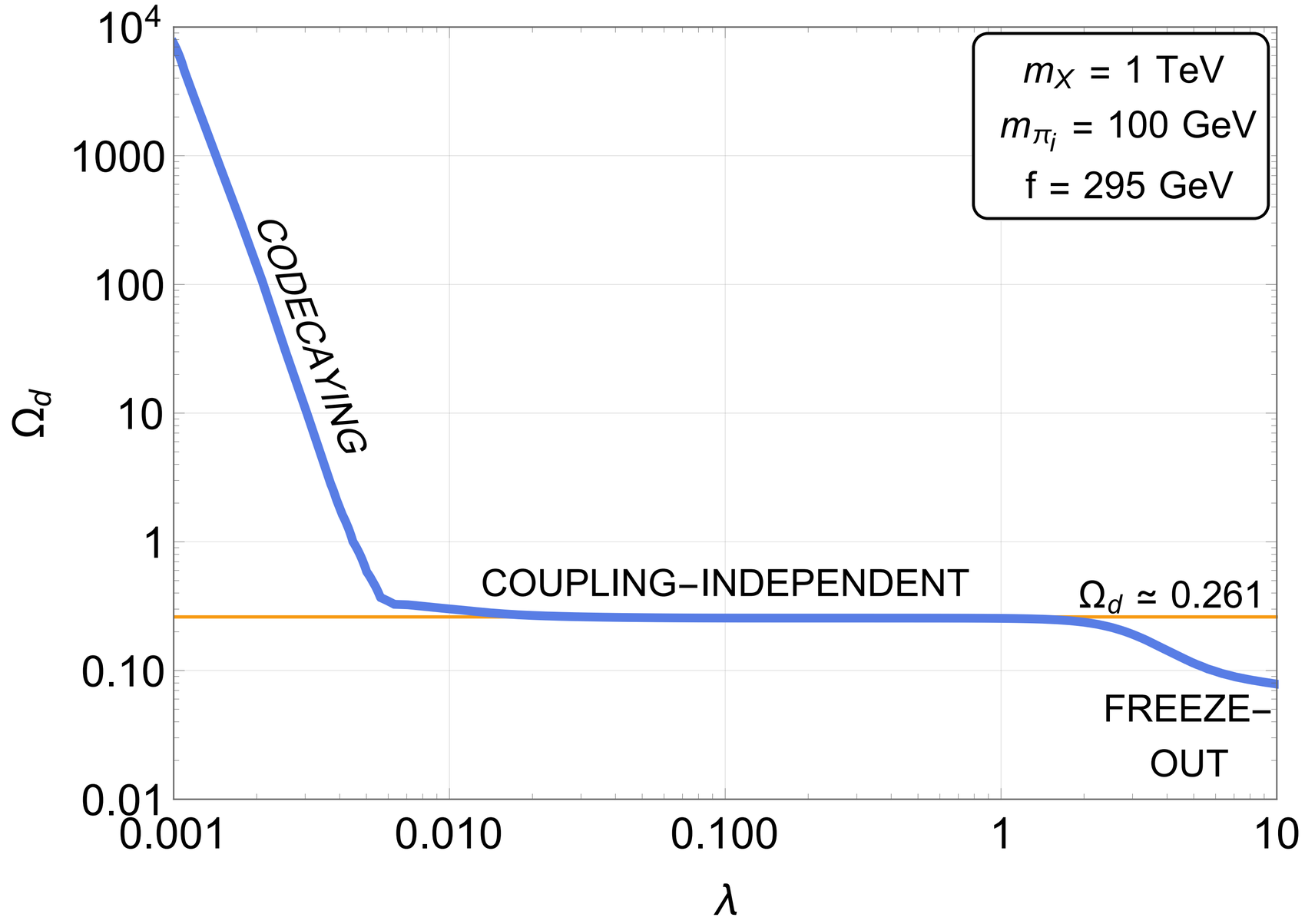


Thermal freeze-out

$$\bar{\pi}_i^s \pi_i^s \to \mathrm{SM}\,\mathrm{SM}$$

DM production mechanism



Overview of constraints

Direct Detection

Xenon1T bounds [Xenon Coll.'17]

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

Indirect Detection

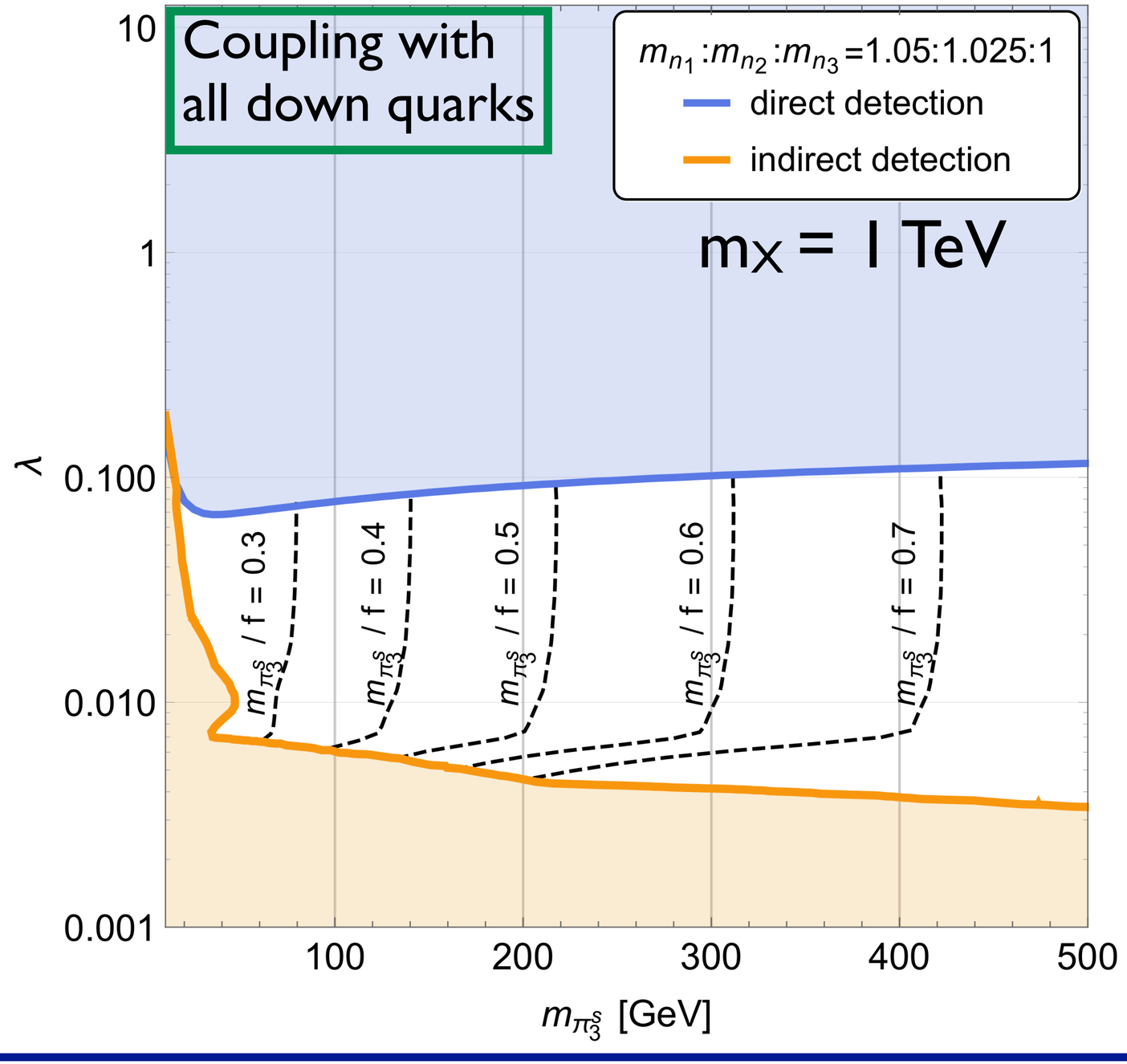
Cascade decays: [Elor et al.'15]

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



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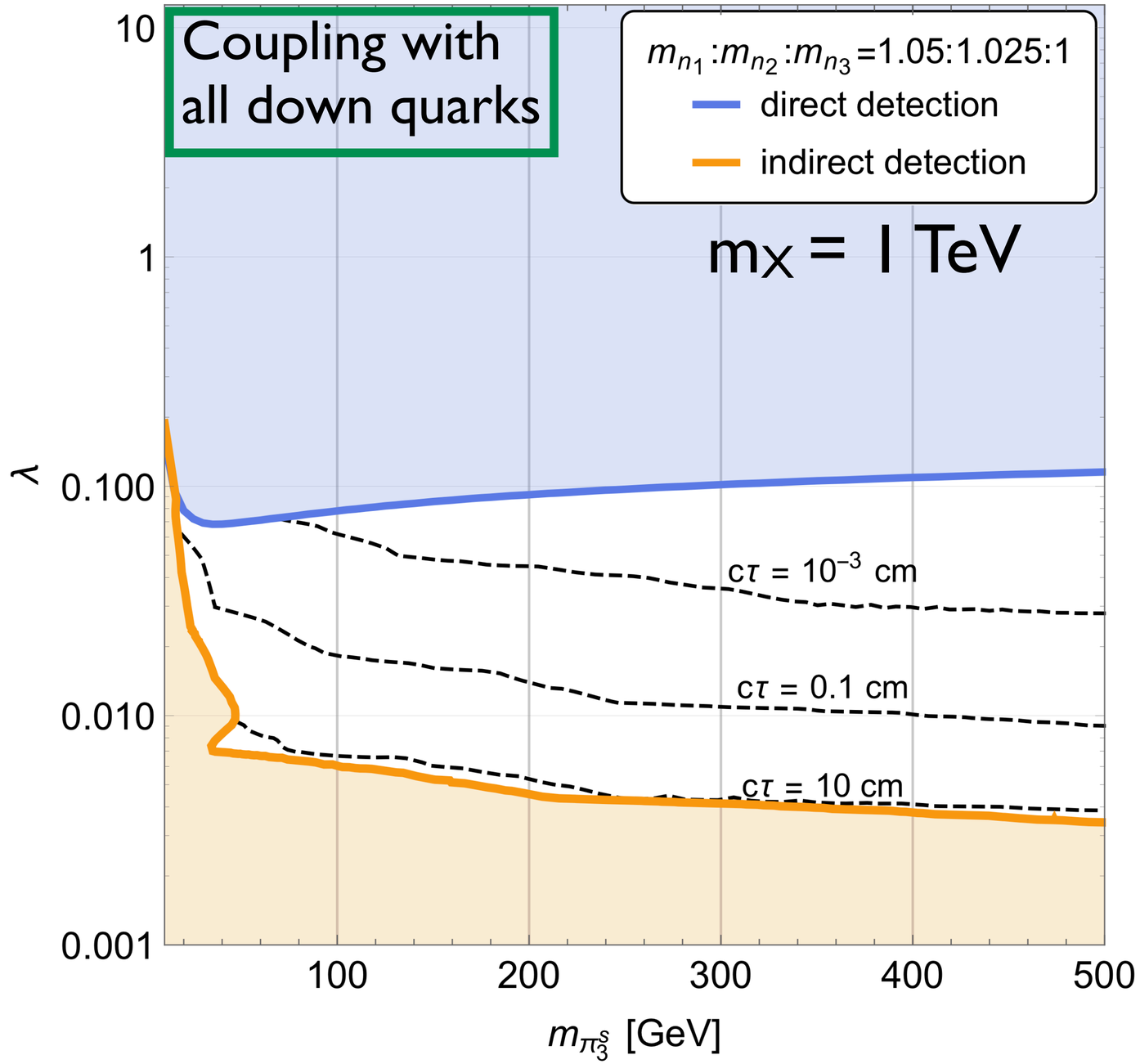

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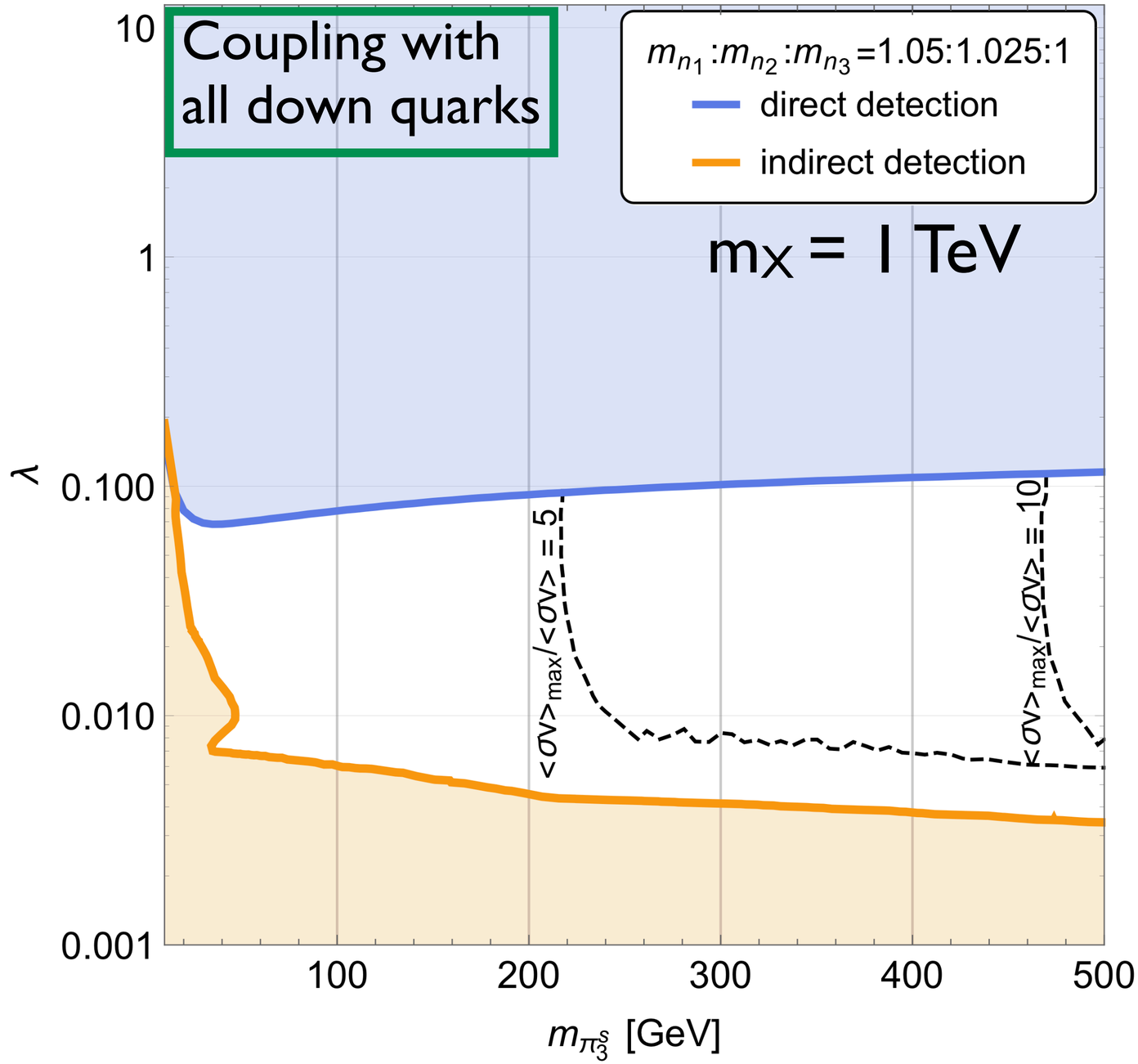

Conclusions

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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.