Searching for low-mass Long Lived Particles from strongly interacting dark sectors

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Based on arXiv:20xx.xxxxx

Outline

- Our dark matter model set-up, with a Z’ portal to the SM
- Key signature: dark showers with an Long Lived Particle (LLP) decaying visibly
- Existing ATLAS search for displaced vertices and missing energy
- Possible new searches with relaxed cuts

Strongly interacting dark sector: $SU(3)_d$

Dark QCD charges: $N_d = 3$ **Dark flavours:** $N_f = 2$

Confinement Λ_d

Dark Matter: $\pi^0, \pi^\pm$ **Dark Mesons:** $\rho^0, \rho^\pm$

(These are exotic mesons, not SM particles…)

Portal to SM: $U(1)'$

$$\mathcal{L} \supset e_d Z'_\mu \bar{q}_d \gamma^\mu q_d + g_q Z'_\mu \bar{q}_{\mathrm{SM}} \gamma^\mu q_{\mathrm{SM}}$$

→ Dark quark production at LHC from SM quarks (similar to Drell-Yan)

Z' mixes with exotic ρ^0

→ Induces couplings of ρ^0 to SM quarks

$$\mathcal{L}_{\mathrm{EFT}} \supset \frac{2\, e_{\mathrm{d}}\, g_q}{g} \frac{m_\rho^2}{m_{Z'}^2} \rho^{0\mu} \sum_{q_{\mathrm{SM}}} \overline{q}_{\mathrm{SM}} \gamma_\mu q_{\mathrm{SM}}$$

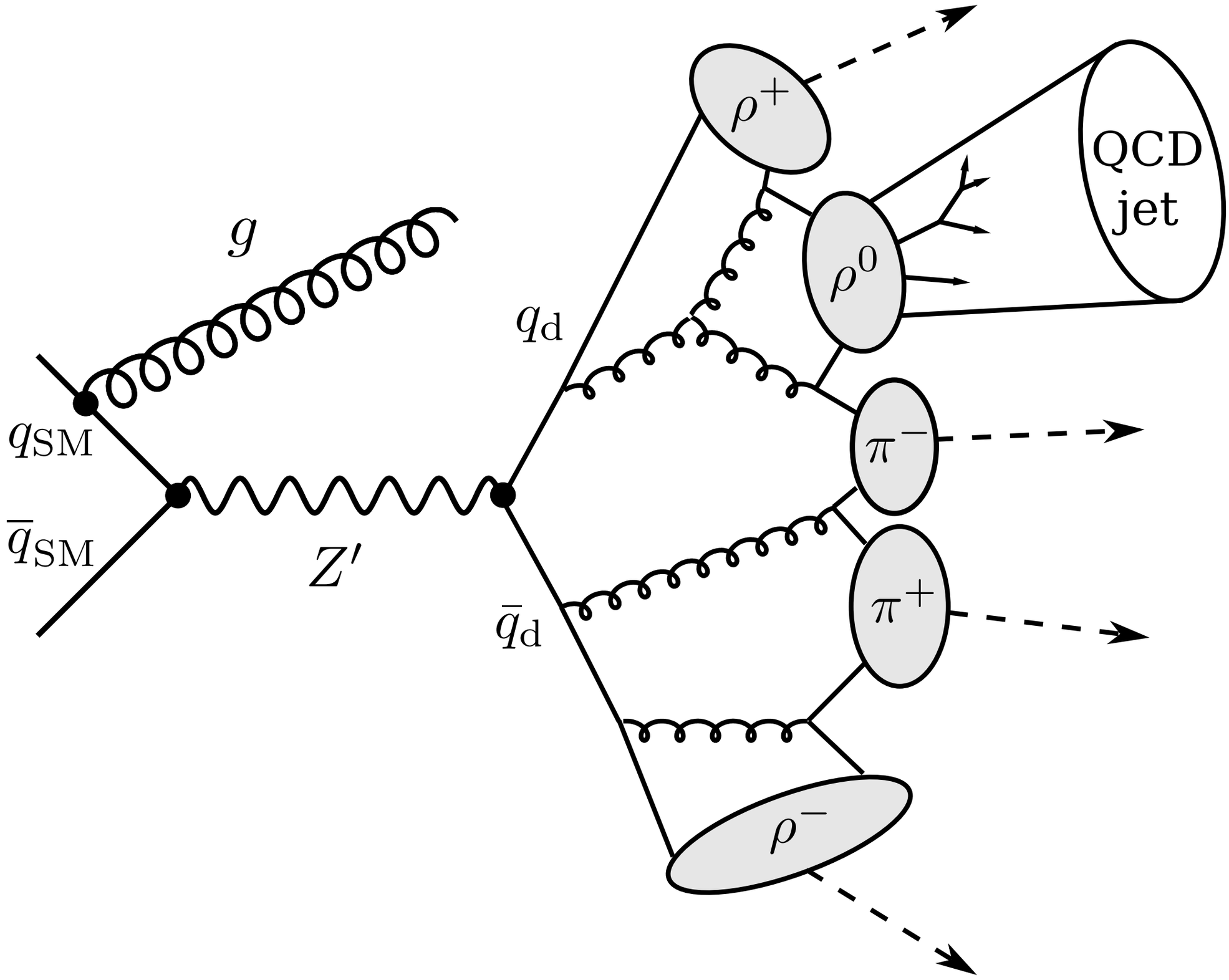
ρ^0 long-lived

Decay is purely to SM quarks $\rho^0 \to q_{\rm SM} q_{\rm SM}$

$$\Gamma\left(\rho^0 \to q_{\rm SM}\bar{q}_{\rm SM}\right) = \frac{1}{\pi}\frac{g_q^2 e_{\rm d}^2}{g^2}\, m_\rho \left(\frac{m_\rho}{m_{Z'}}\right)^4 \left(1 - 4\frac{m_{q_{\rm SM}}^2}{m_\rho^2}\right)^{1/2} \left(1 + 2\frac{m_{q_{\rm SM}}^2}{m_\rho^2}\right)$$

$$c\tau_\rho \approx 3.2\ \text{mm} \times \left(\frac{g_q}{0.01}\right)^{-2} \left(\frac{e_d}{0.4}\right)^{-2} \left(\frac{m_\rho}{5\ \text{GeV}}\right)^{-5} \left(\frac{m_{Z'}}{1\ \text{TeV}}\right)^4$$

For more model details see arXiv:1907.04346


g
q_{SM}
$\overline{q}_{\mathrm{SM}}$
Z'
q_{d}
$\overline{q}_{\mathrm{d}}$
ρ^+
ρ^0
π^-
π^+
ρ^-
QCD
jet

ATLAS DV+MET search, L = 32.8 fb^{-1}

Tracks:

- The track originates from a stable and charged particle
- The track has $p_T > 1$ GeV
- The particle has a transverse impact parameter $d_0 > 2$ mm.

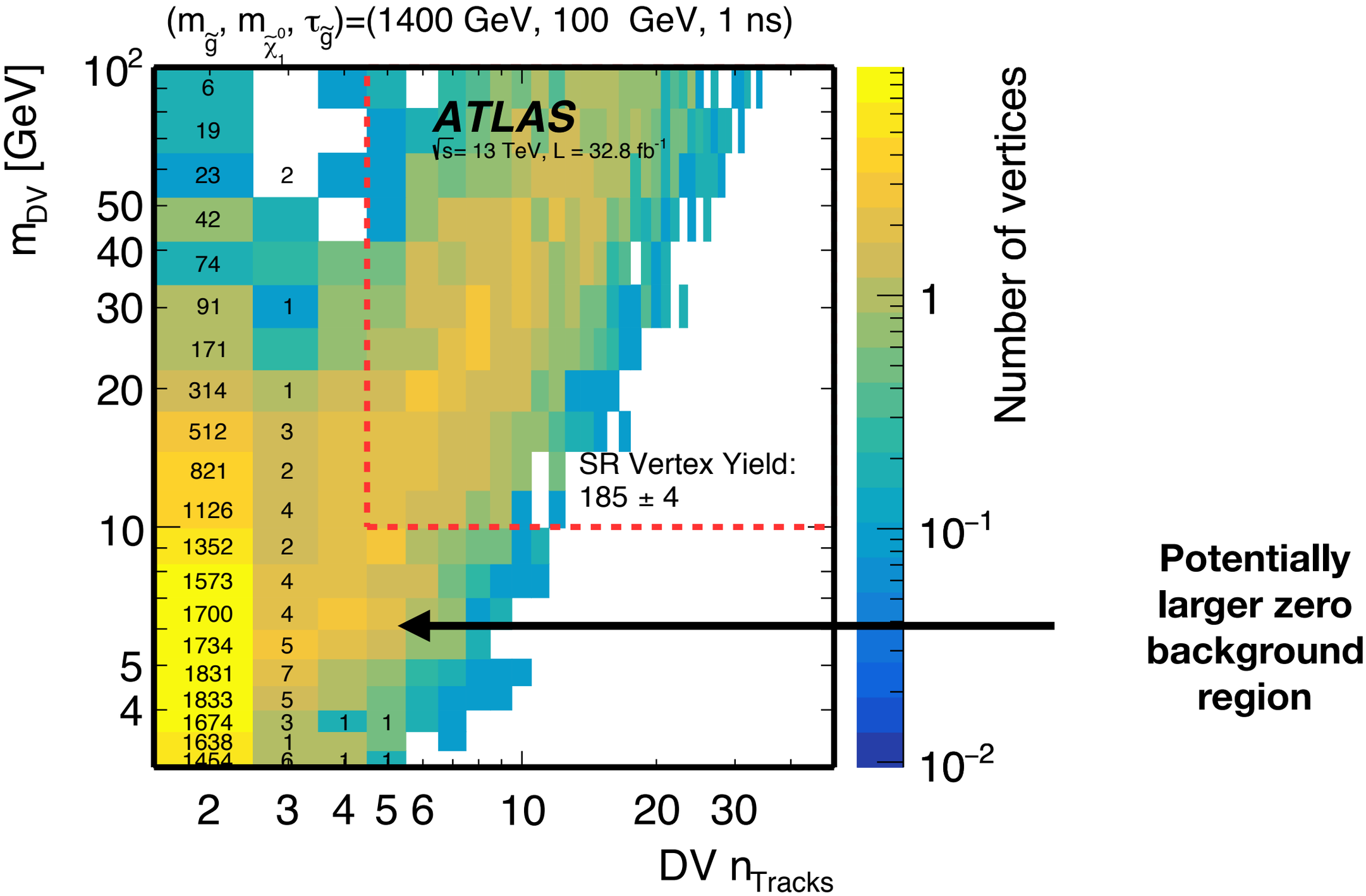
Displaced Vertices (DVs):

- The DV position must satisfy 4 mm $< R <$ 300 mm and $|z| < 300$.
- The number of tracks associated to a particular DV $n_{\text{tracks}} \geq 5$.
- The DV mass $m_{\text{DV}} > 10$ GeV.

Events:

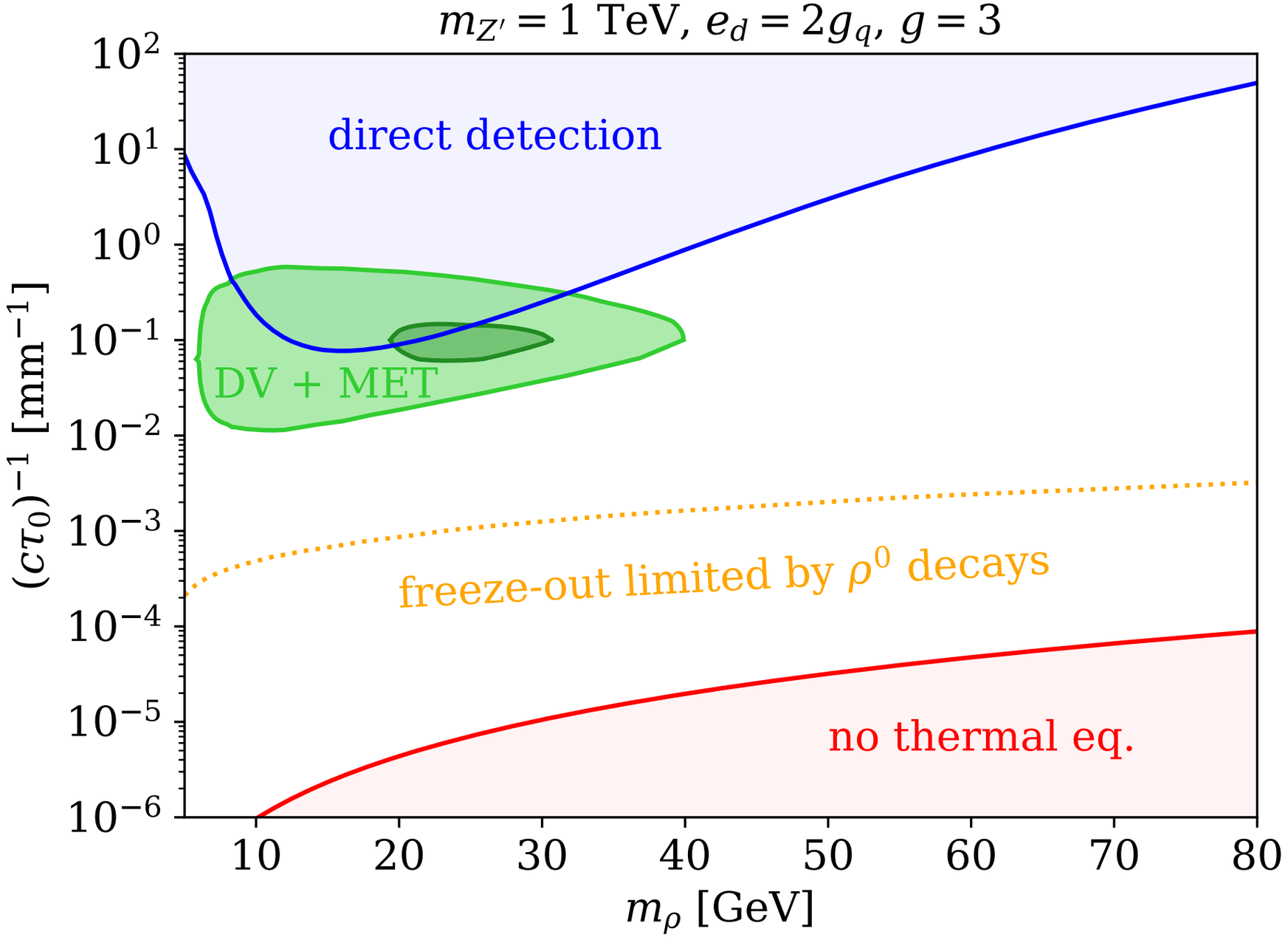
- Missing energy $E_T^{\text{miss}} > 200$ GeV.
- 75% of the events should have at least one jet with $p_T > 70$ GeV or at least two jets with $p_T > 25$ GeV.

arXiv:1710.04901



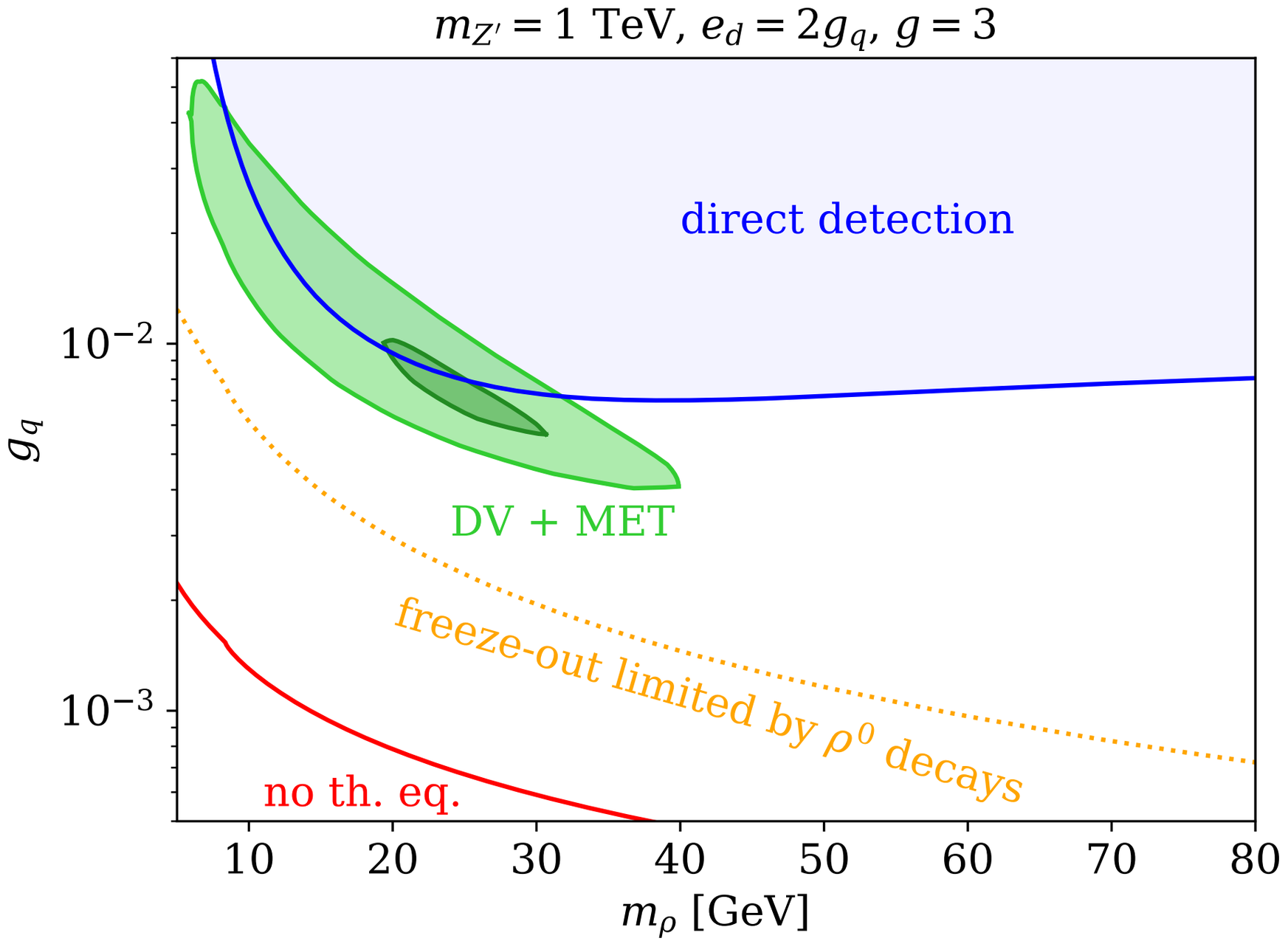
Potentially larger zero background region

arXiv:1710.04901



Existing analysis: $m_{\mathrm{DV}} > 10$ GeV, $n_{\mathrm{tracks}} \geq 5$

Relaxed analysis: $m_{\mathrm{DV}} > 5$ GeV, $n_{\mathrm{tracks}} \geq 4$



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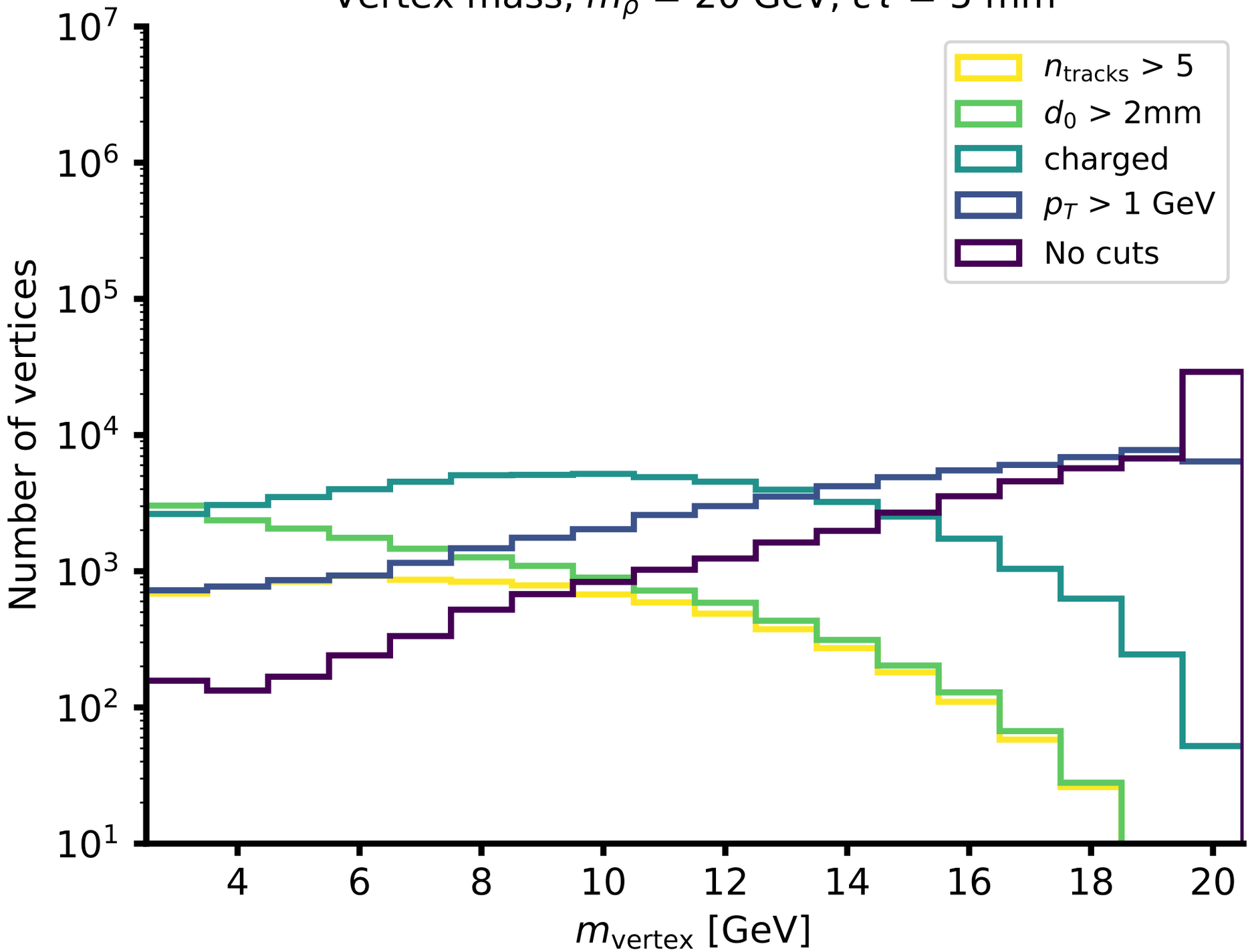
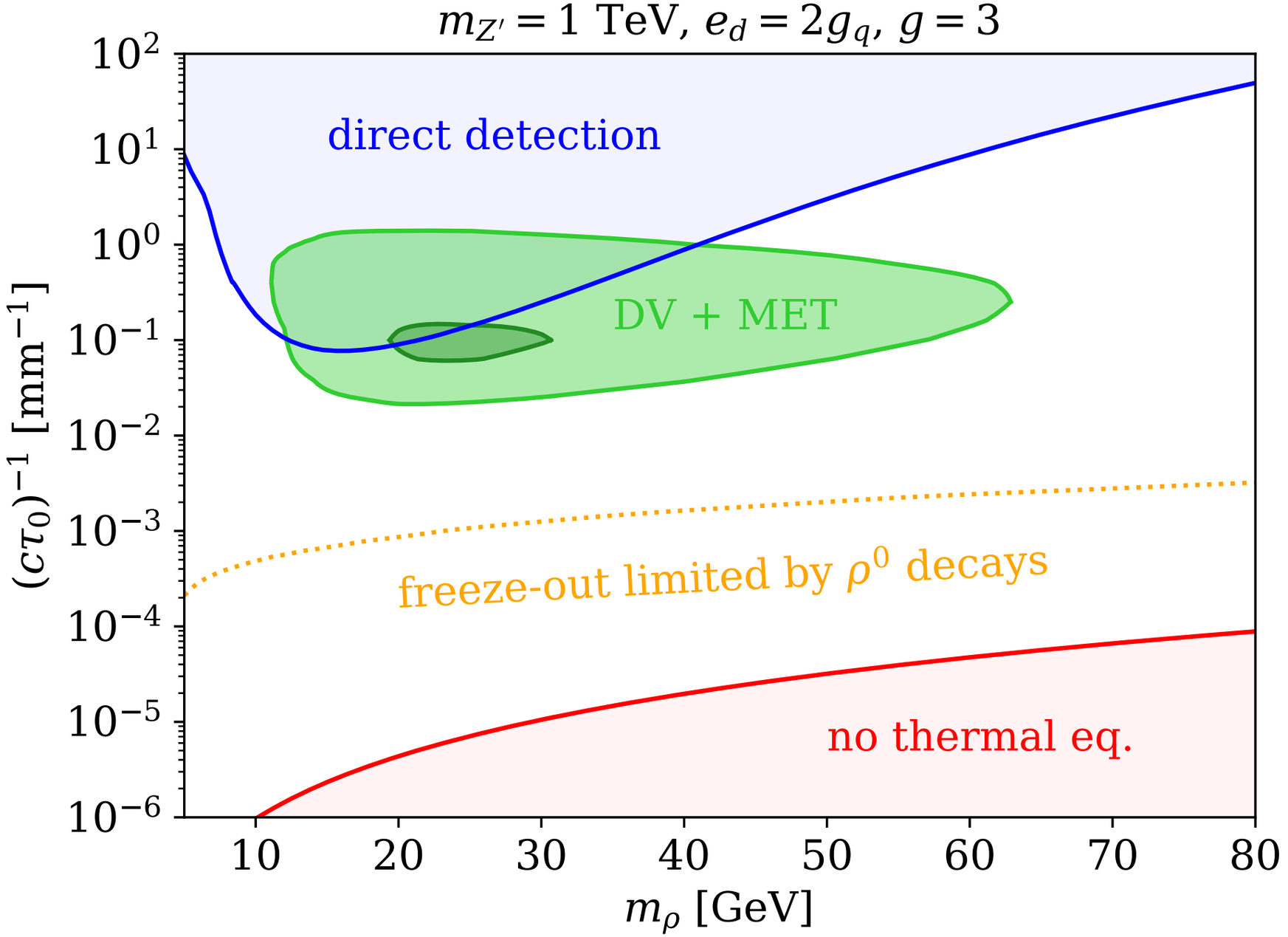
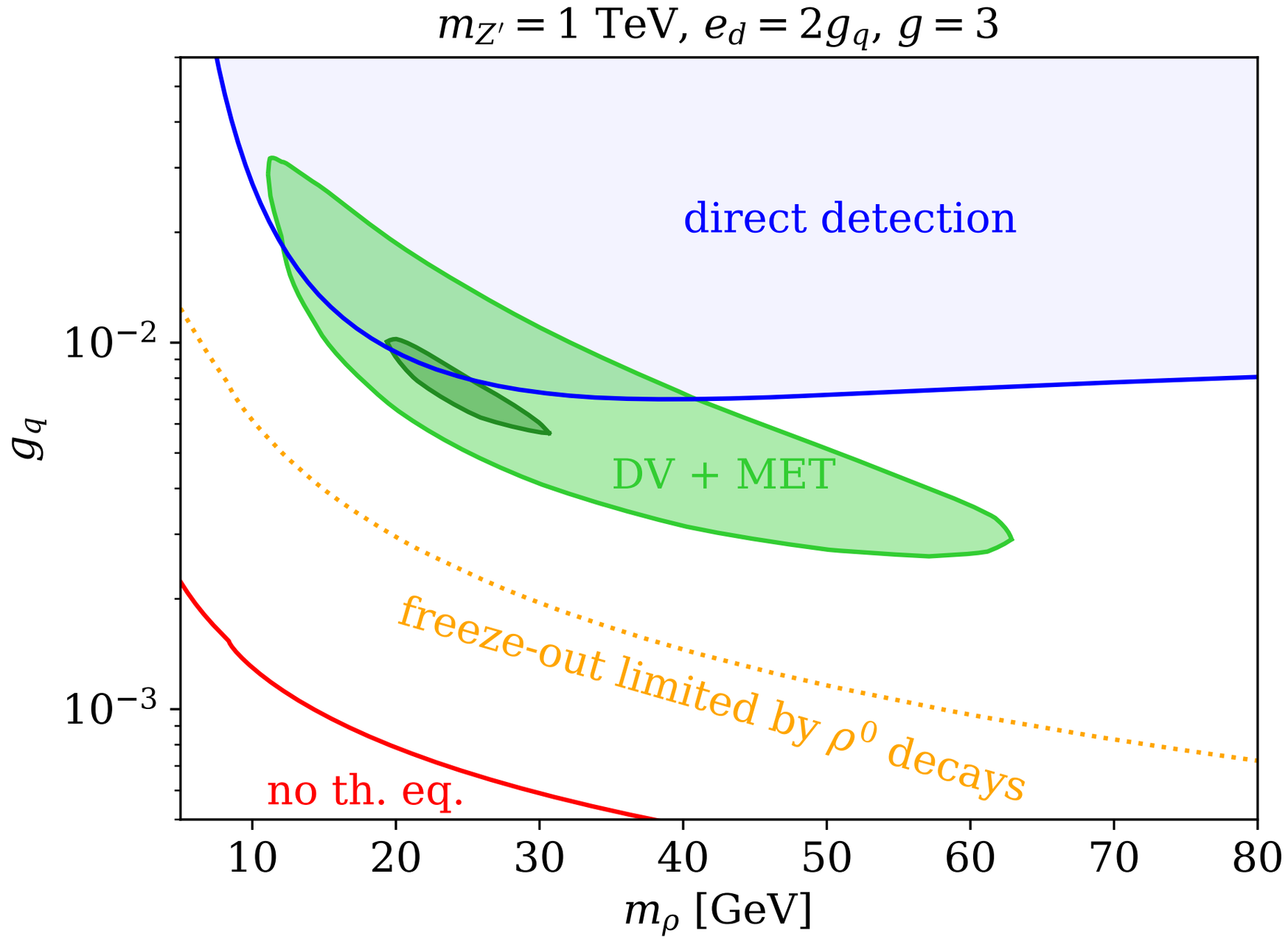


→ Track requirements reduce the observed vertex mass



Existing analysis: all tracks d_0 > 2mm

Relaxed analysis: 2 (or more) tracks d_0 > 2mm



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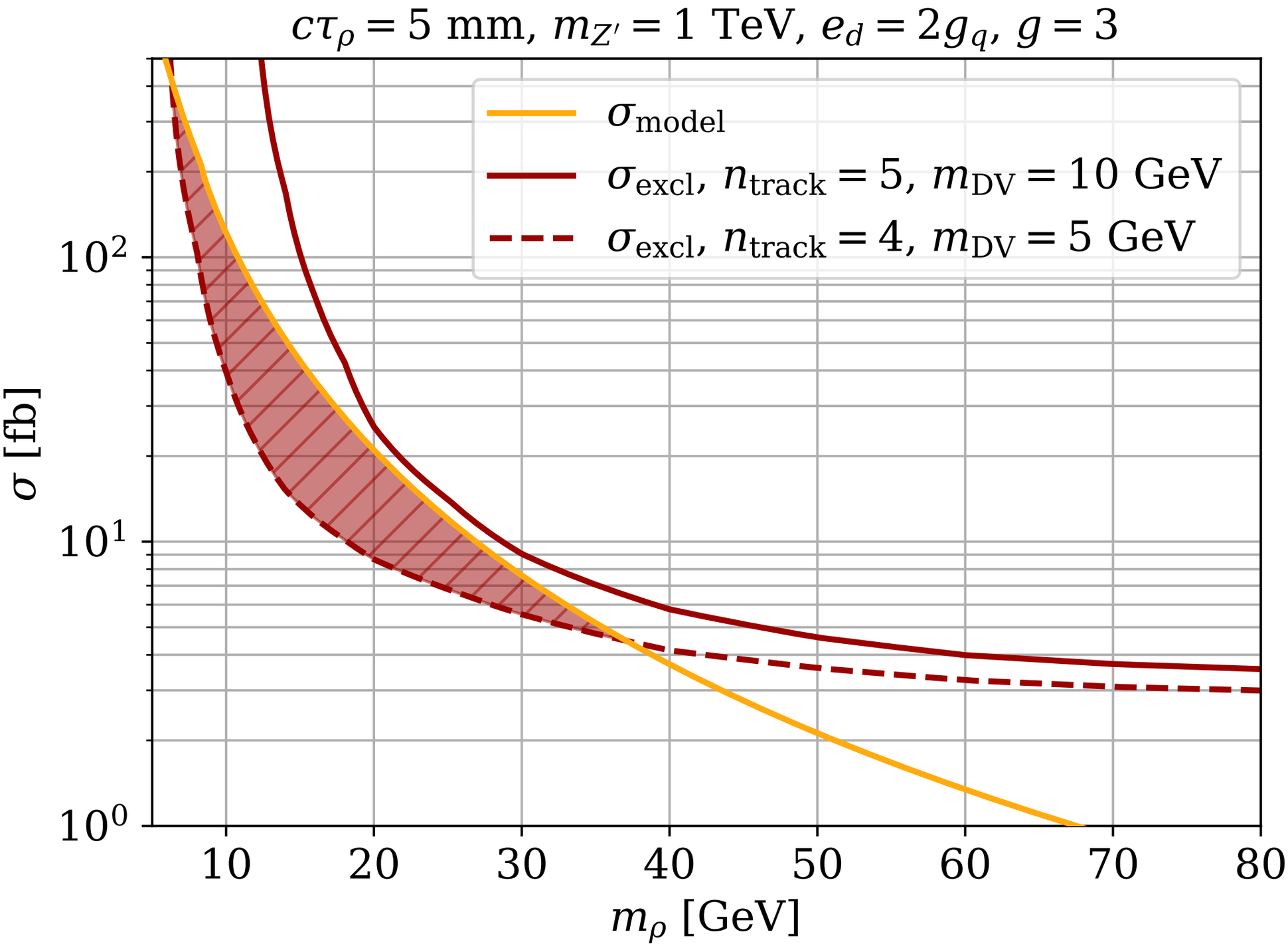
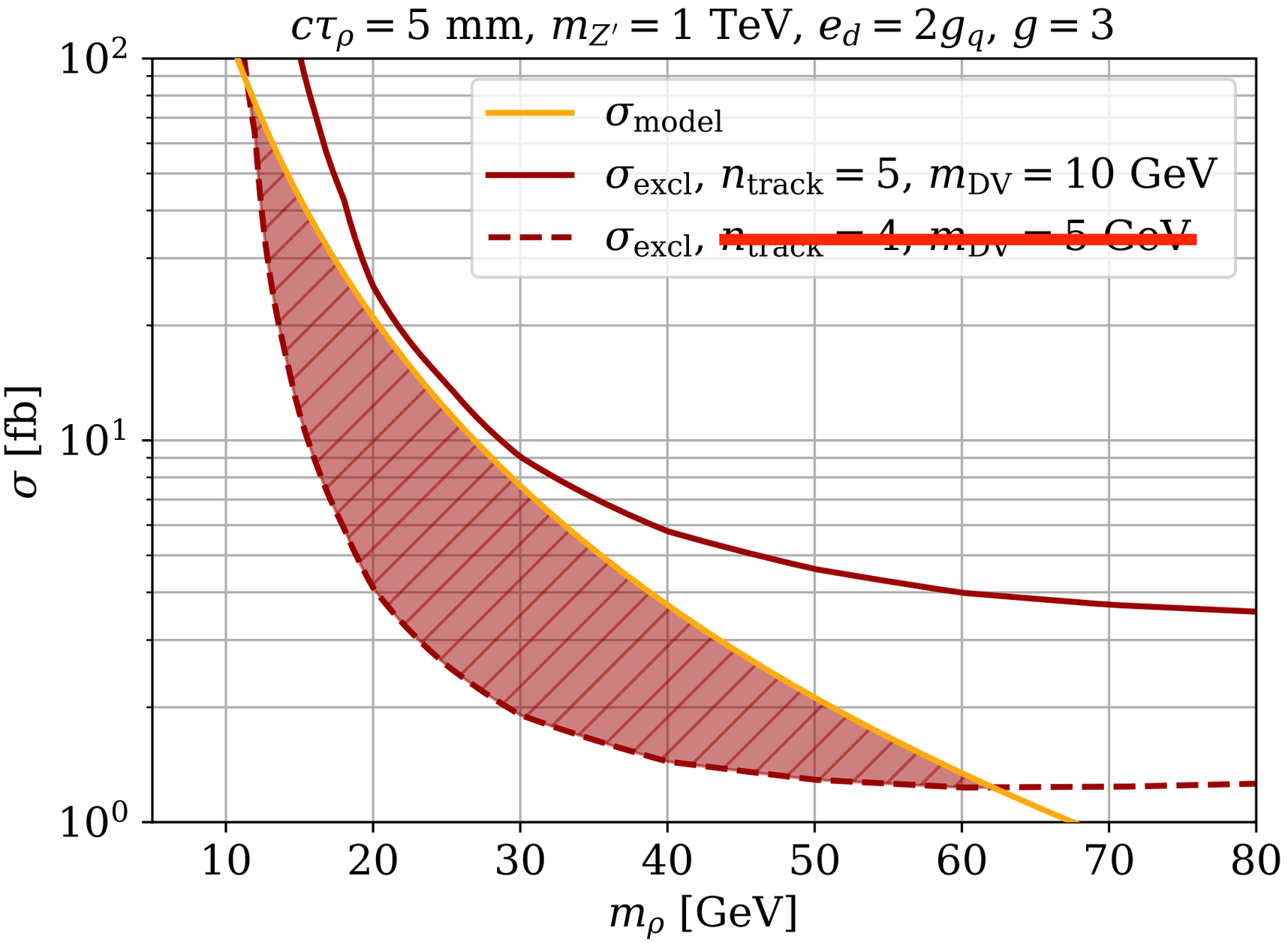
Relaxed analysis: 2 (or more) tracks d_0 > 2mm

Conclusions

- Dark showers are an interesting source of LLPs
- Existing searches tend to target higher masses
- New effort required to explore 10 GeV and lower masses
- Relaxed searches are possible targets, but also non-zero background regions, multiple vertices in one event…

BACKUP


$c\tau_\rho = 5$ mm, $m_{Z'} = 1$ TeV, $e_d = 2g_q$, $g = 3$
σ_{model}
σ_{excl}, $n_{\text{track}} = 5$, $m_{\text{DV}} = 10$ GeV
σ_{excl}, $n_{\text{track}} = 4$, $m_{\text{DV}} = 5$ GeV
σ [fb]
10^2
10^1
10^0
10
20
30
40
50
60
70
80
m_ρ [GeV]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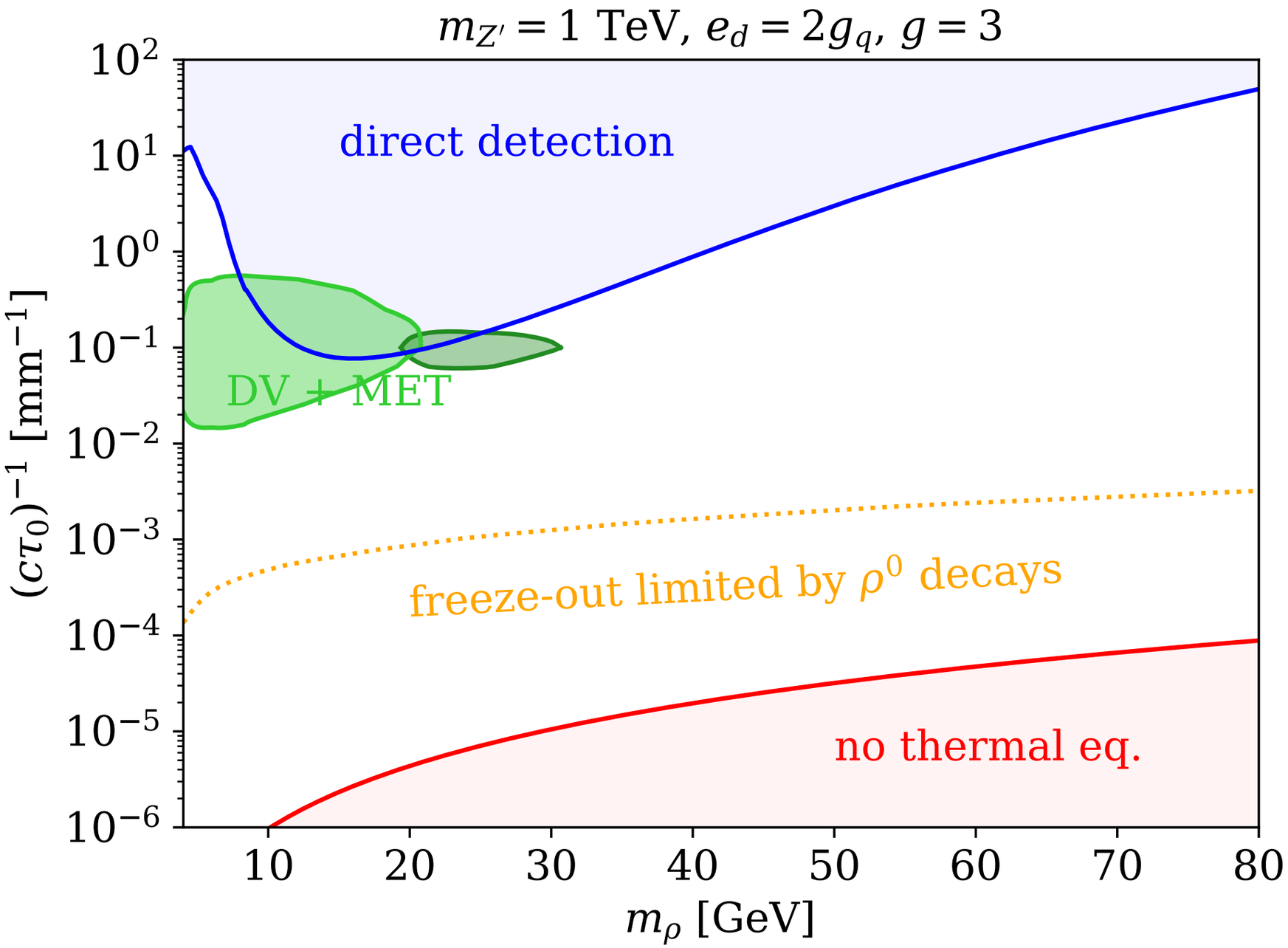
σ_{model}
σ_{excl}, $n_{\text{track}} = 5$, $m_{\text{DV}} = 10$ GeV
σ_{excl}, $n_{\text{track}} = 4$, $m_{\text{DV}} = 5$ GeV
σ [fb]
10^2
10^1
10^0
10
20
30
40
50
60
70
80
m_ρ [GeV]

relaxed d0



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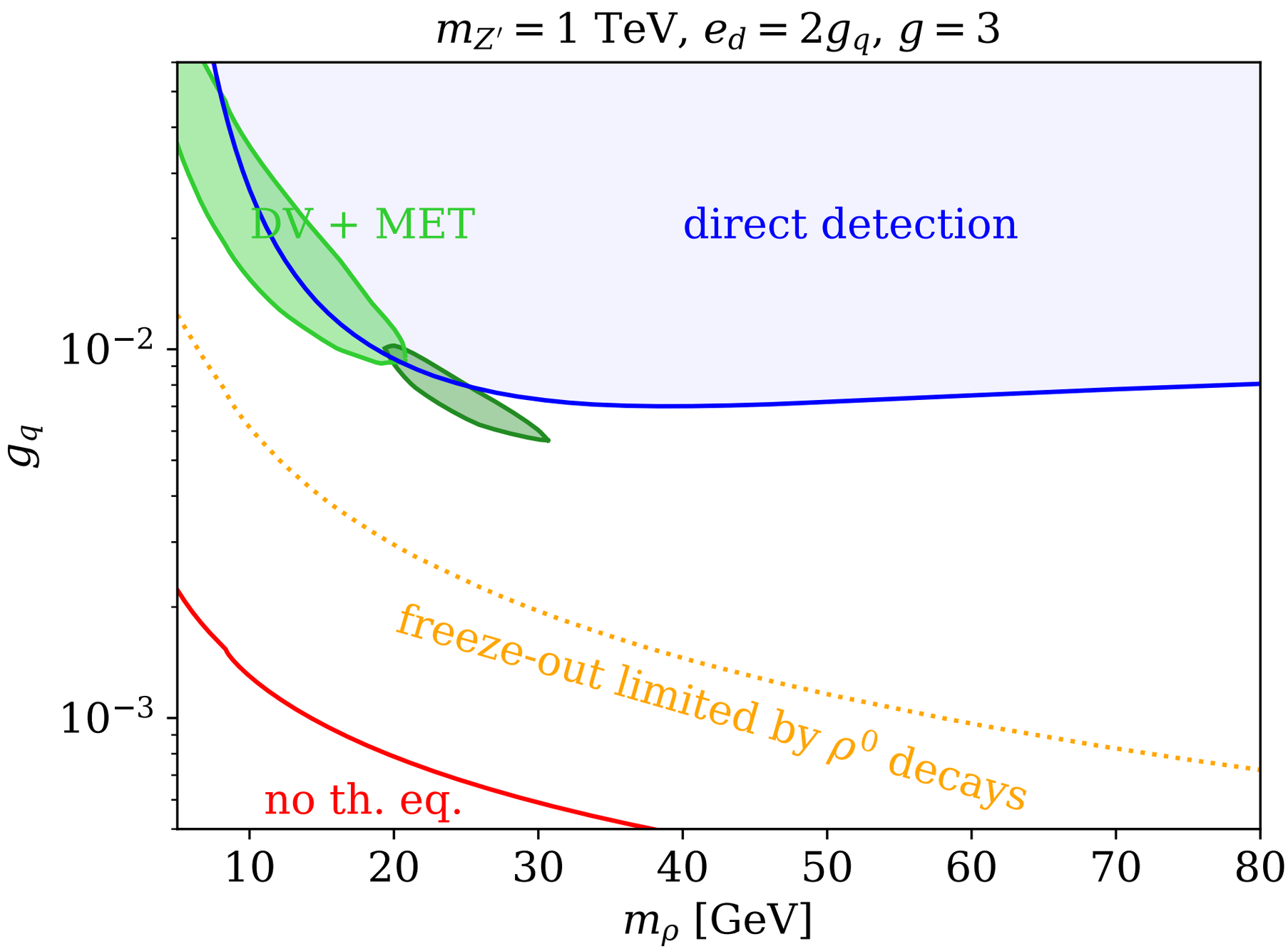
Background ~ 4 events



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