Strongly-interacting Dark Matter

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NAWI Graz
Natural Sciences
FWF Österreichischer Wissenschaftsfonds

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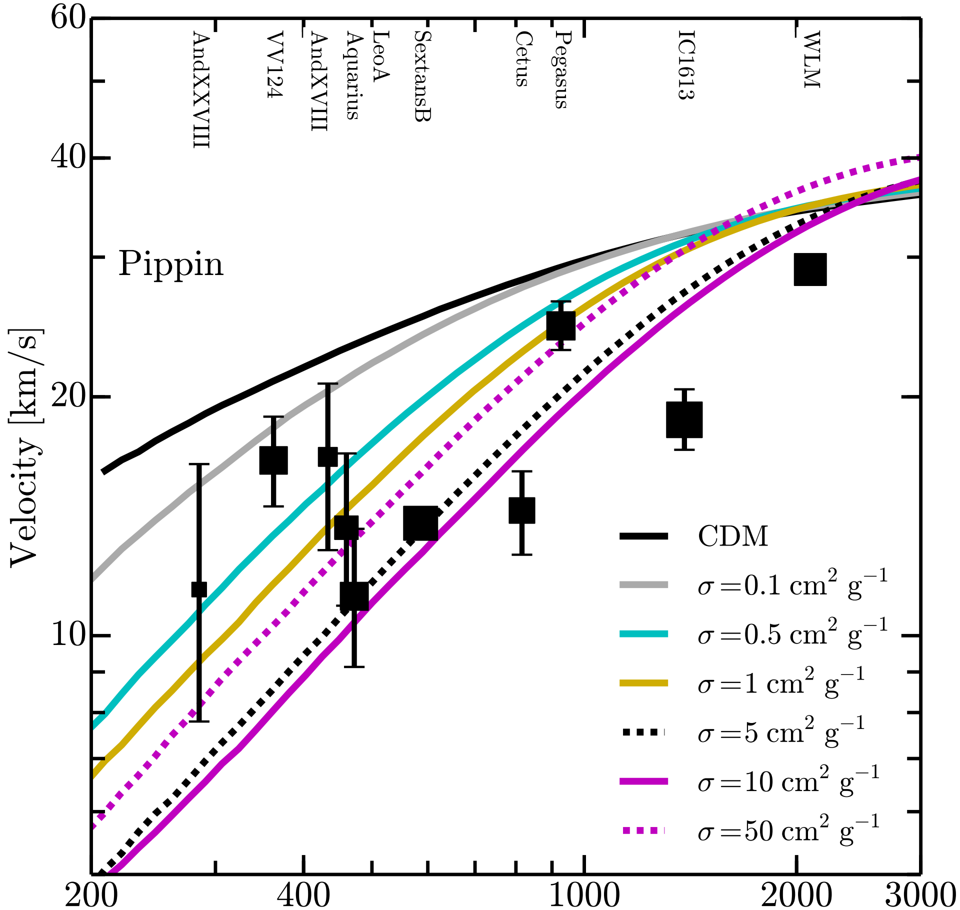
Massive field: 1000+ papers referring to this topic!

Why strongly-interacting dark matter?

- Astrophysics (slightly) prefers interactions



The allowed interactions can be quite large, similar to QCD!

However, results are subject to many systematic questions

Often significant modeling involved

[From Tulin et al.'17]

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Galaxy size
→ escape velocity differ
→ average speed differs for thermal distribution
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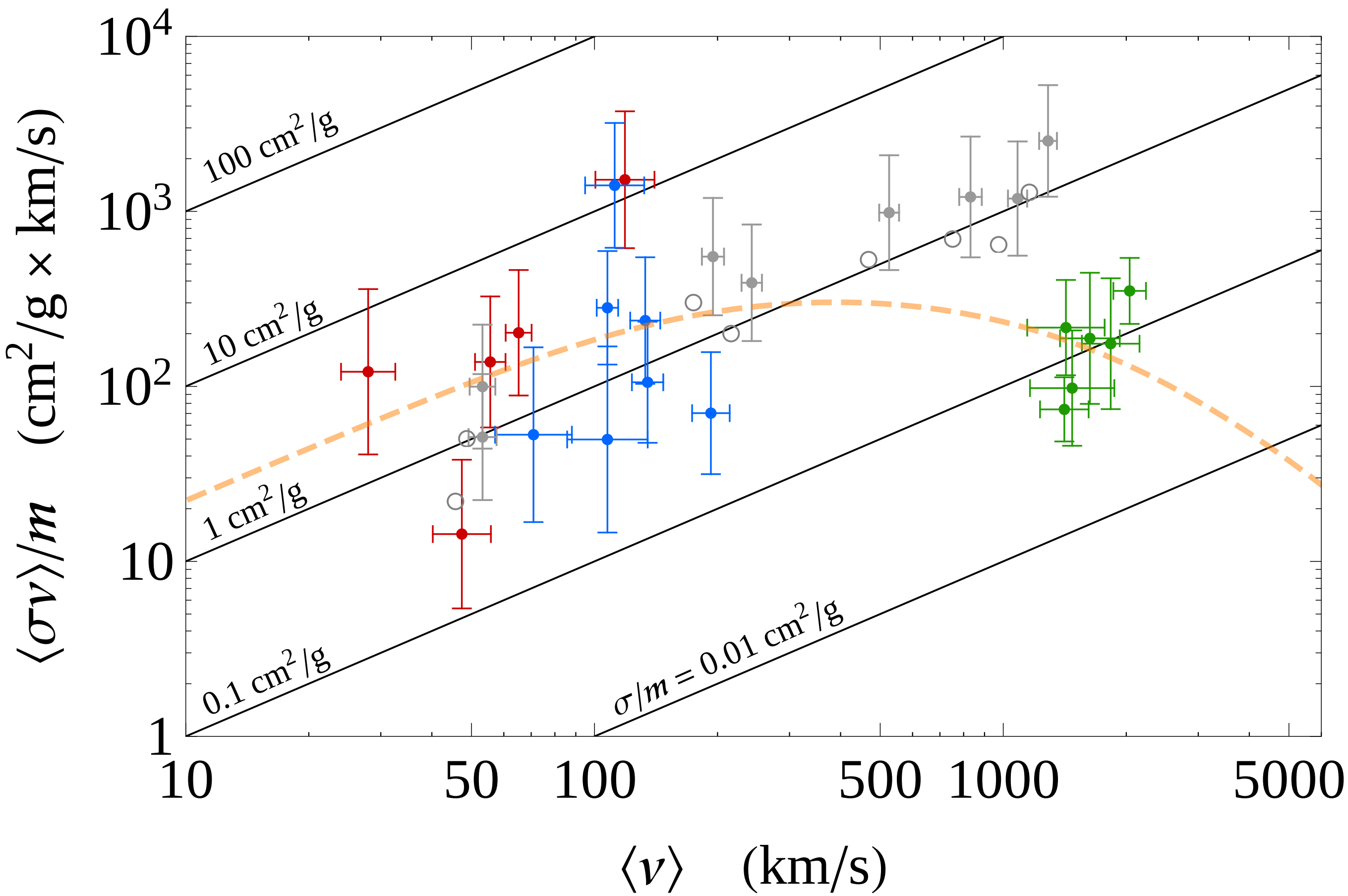

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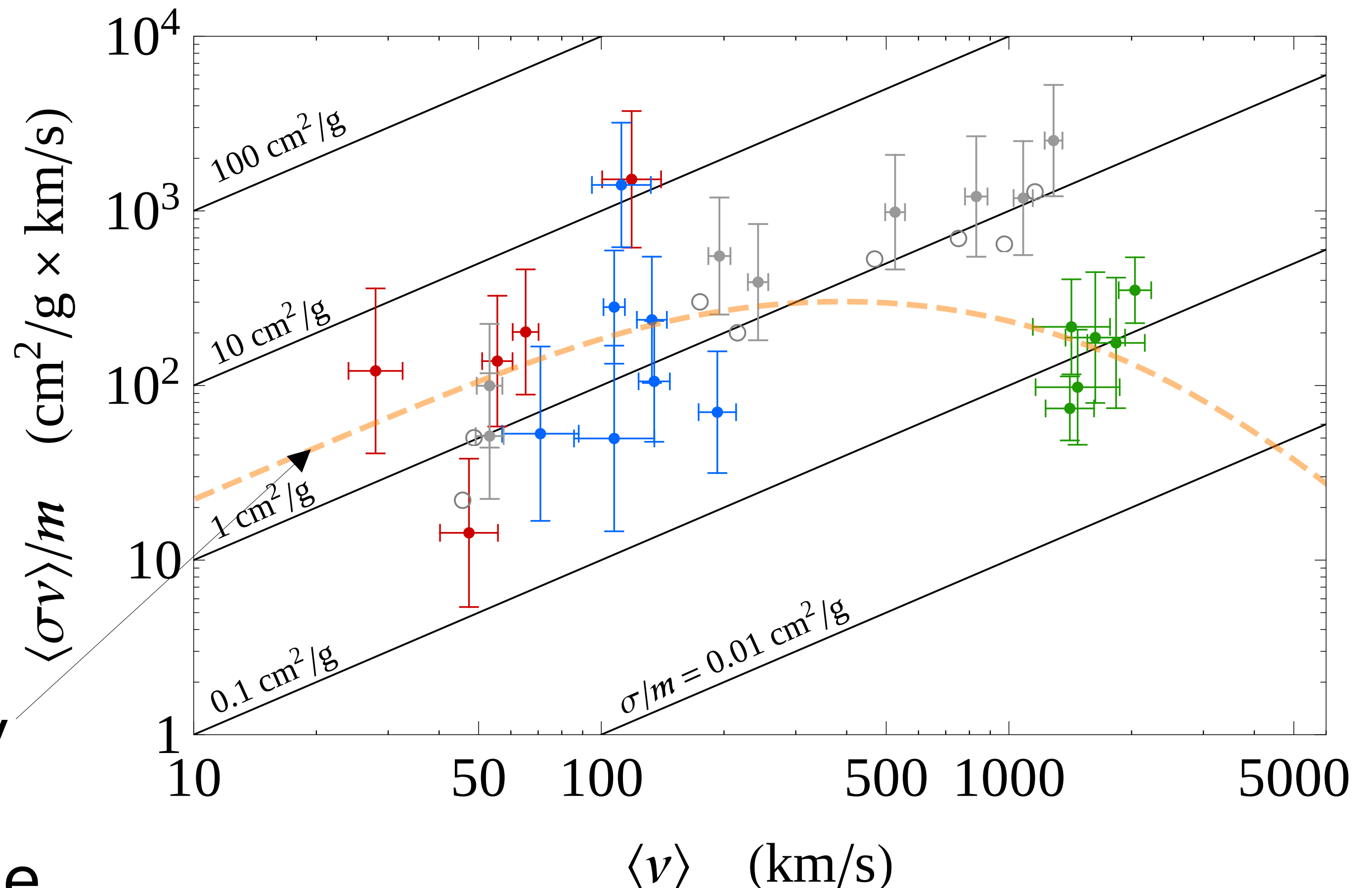

Best fit favors energy dependence in non-relativistic regime
→ non-trivial low-energy structures, e.g. resonances

[From Tulin et al.'17]

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      - Dark matter needs to be cold enough to be bound to galaxies

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  - Typical freeze-out process
    - Alternative: Late creation and freeze-in

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[Hochberg et al.'14
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Chu et al.'24]

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    - In QCD-like theories created by Wess-Zumino-Witten-type interactions
  - $2 \to 2$ processes
    - E.g. $YX \to XX$
      - With Y in a suitable mass range
    - In QCD-like theories supported by (suitably tuned) resonances

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    - WZW mechanism depends on gauge group and number of flavors [Hochberget al.’14, Pomper et al.’24]
    - Resonance properties depend on couplings/masses
      - Generically close-to-threshold quasi-stable states easier with heavy matter
      - Also phenomenologically preferred [Hochberg et al.’14]
      - Mass-splittings could be advantagous [Hochberg et al.’14]

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[See e.g. Kribs et al.'16 for other candidates]

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Similar, but less phenomenologically favored: SU(2)(=Sp(2))

[Hochberg et al.'14, Kulkarni et al.'22,Kogut et al.'00]

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- Well-studied theory on the lattice
  - Spectrum as function of heavy masses
    - Gaugeballs (only quenched) [Bennett et al.’20]
    - Flavored hadrons [Bennett et al.’19]
    - (Pseudo)scalar singlets [Bennett et al.’24]
    - Vector resonance [Bennett et al.’26]
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- Reusable for composite Higgs [Bennett et al.’17]

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- Example: Lattice cross sections

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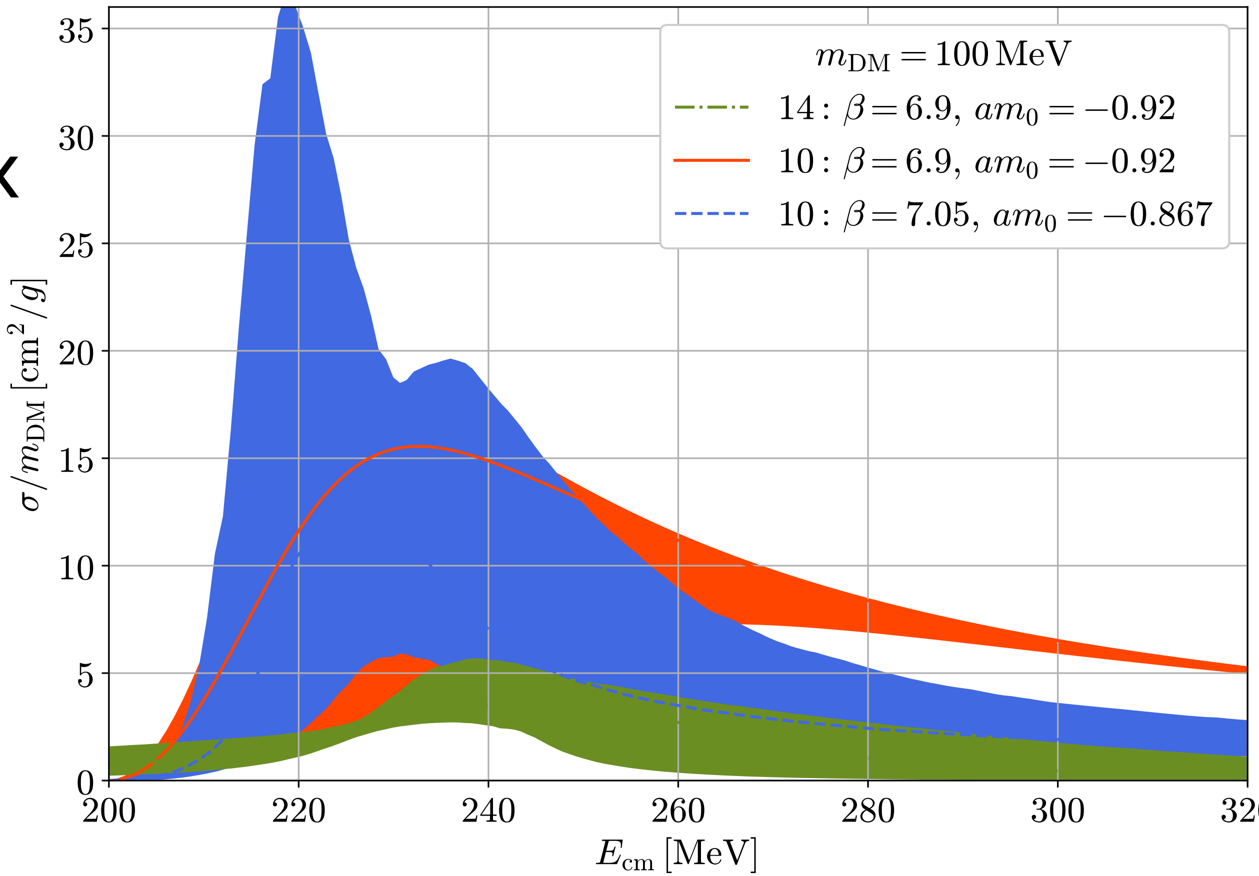

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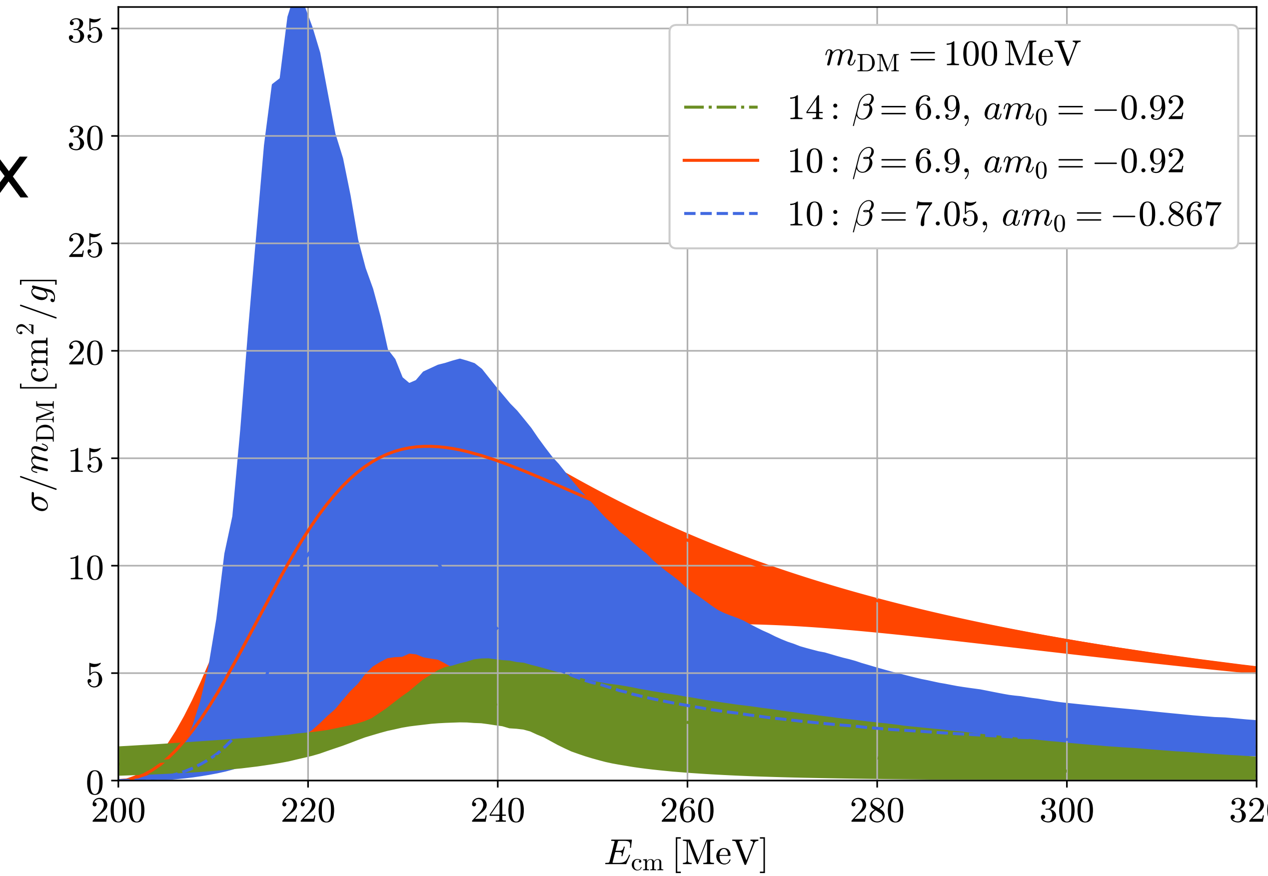

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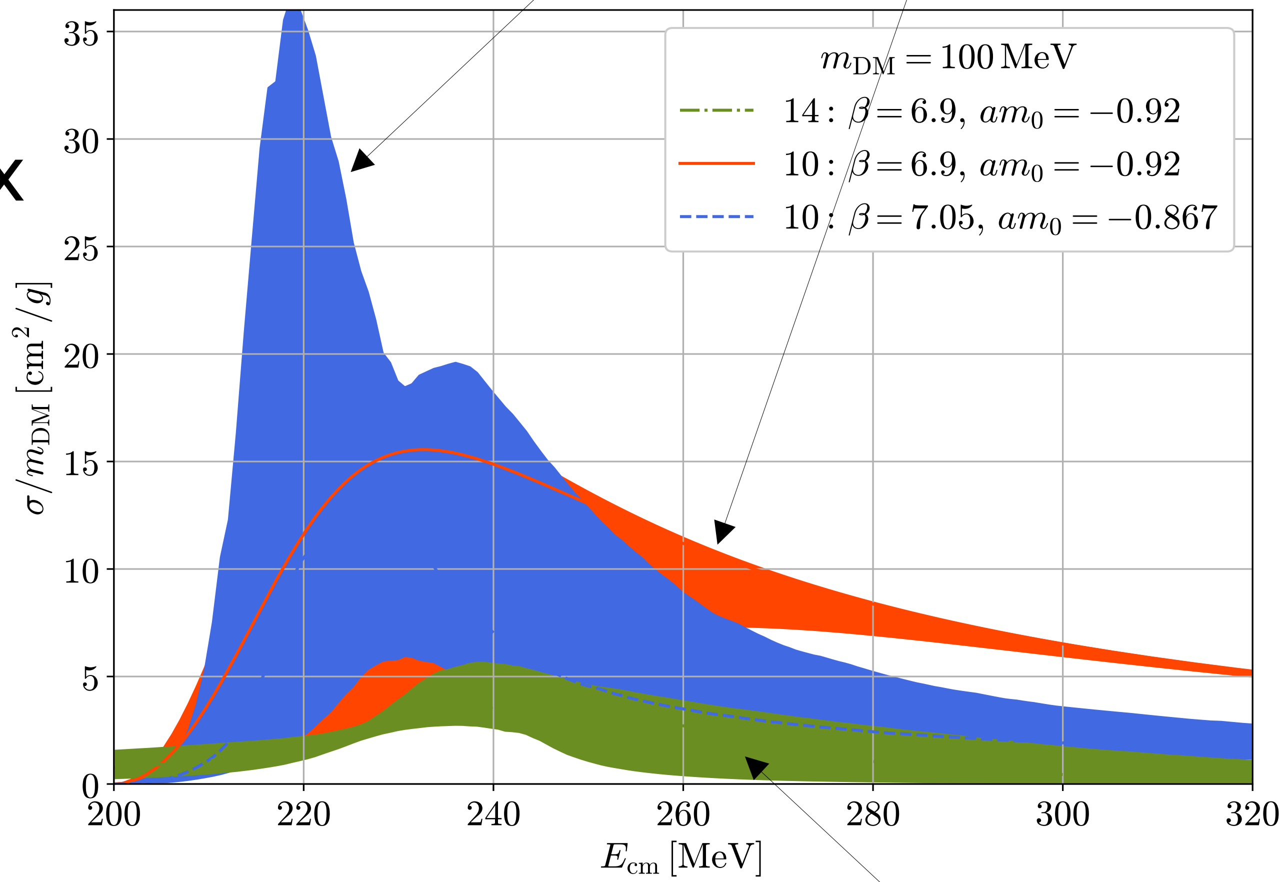

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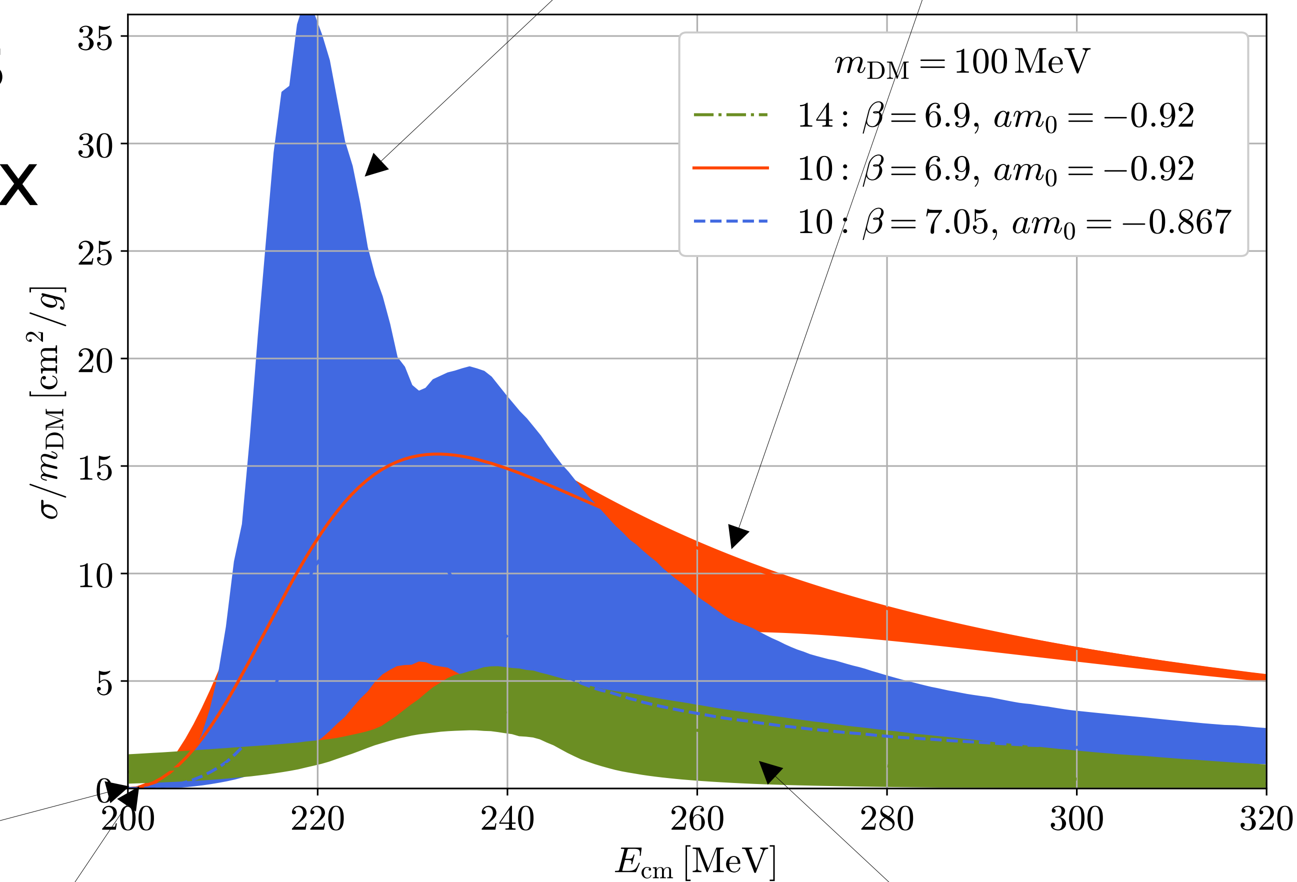

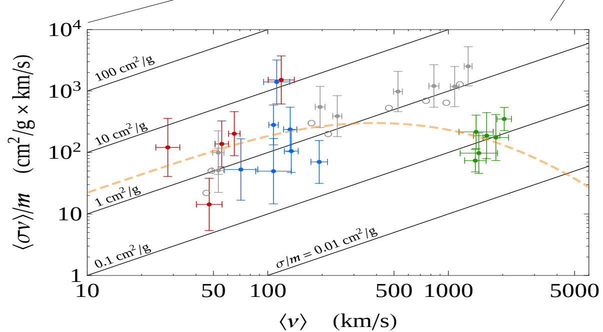

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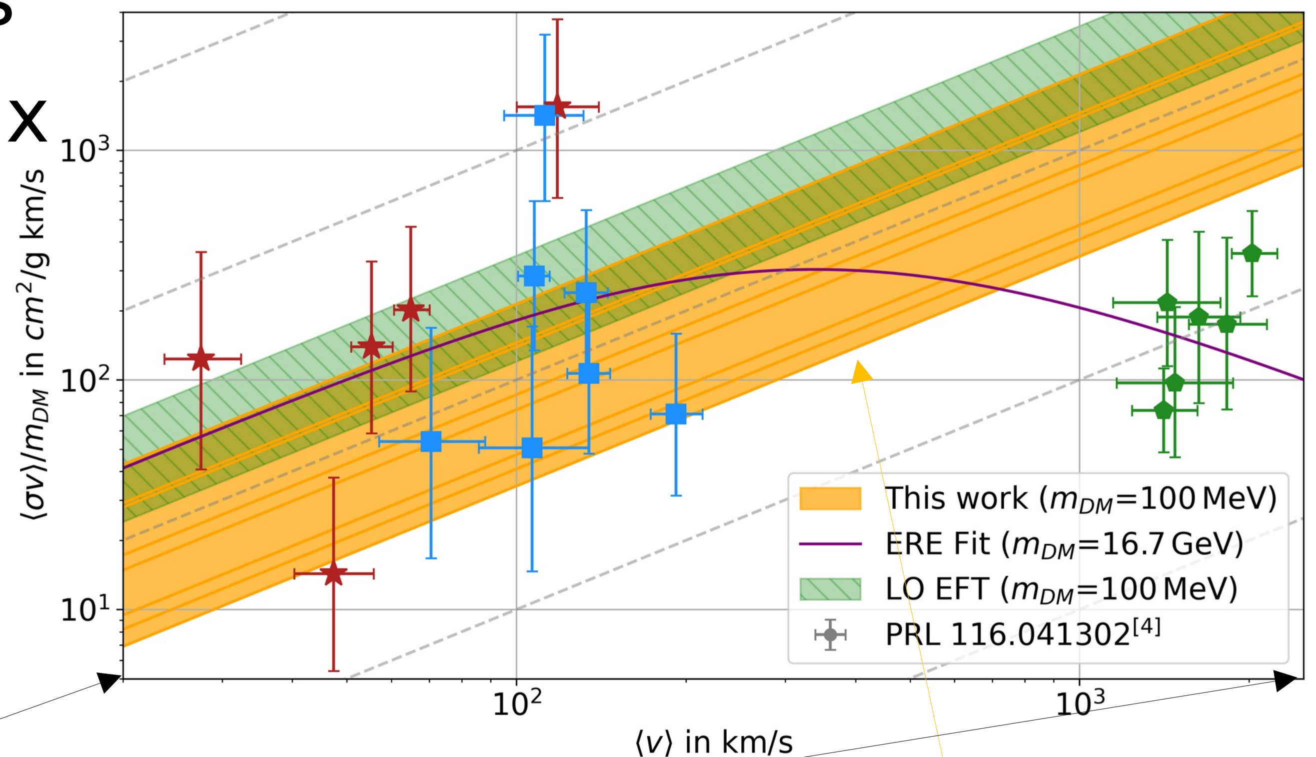

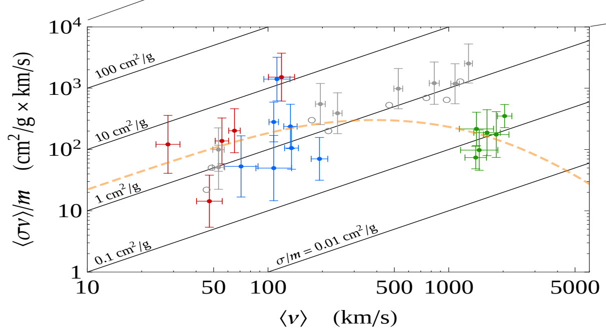

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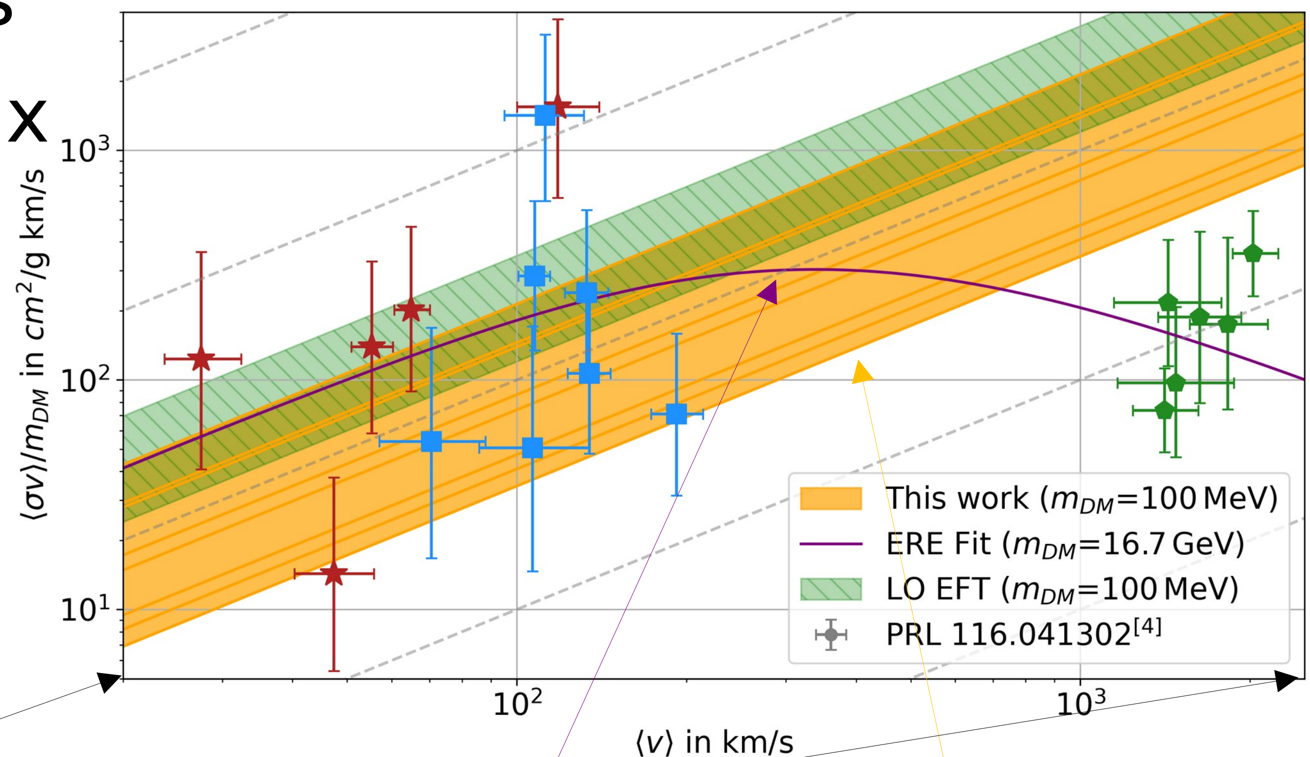

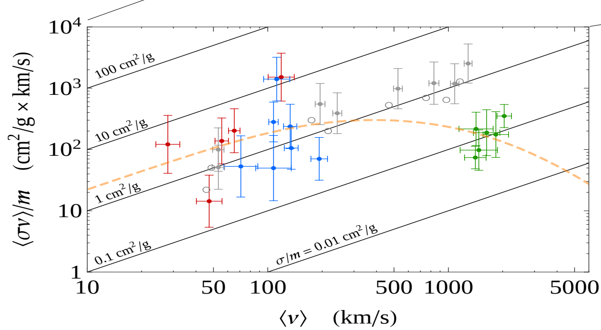

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Effective range fit
Very different than lattice!

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      - Significant NLO corrections: Parameter space!

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- Important quantitatively: E.g. Relic density

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            - Necessary, otherwise most stellar objects would be largely dark matter

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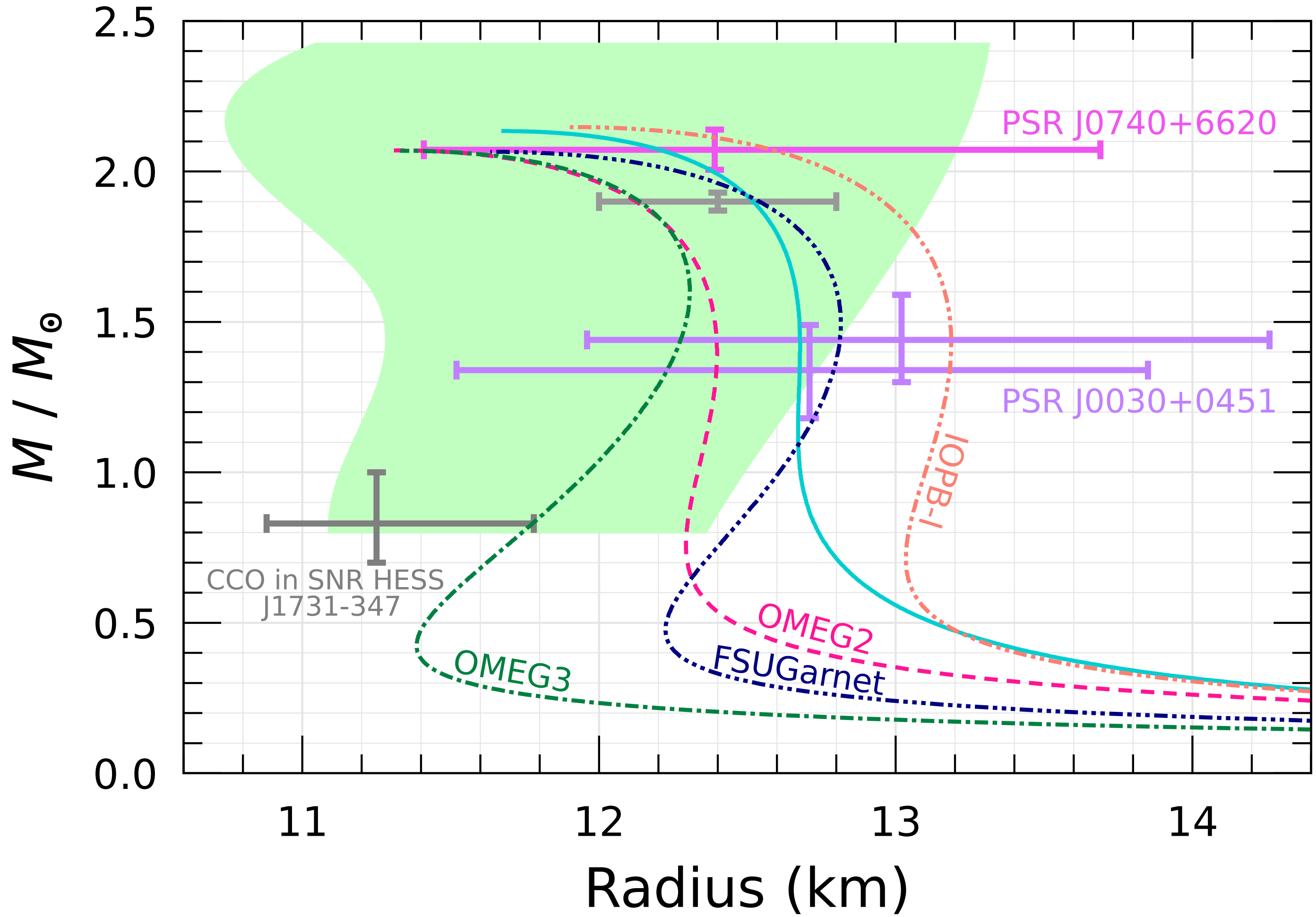
    - Impact on QCD EoS constraints?
  - No direct interactions: Two objects intersecting
    - Gravitationally bound
    - Interaction by gravity: Two-fluid system
    - Can be larger (core) or smaller (halo)

In (neutron) stars

[Sagun talk → Next up]



[Tsuyoshi et al.'23]

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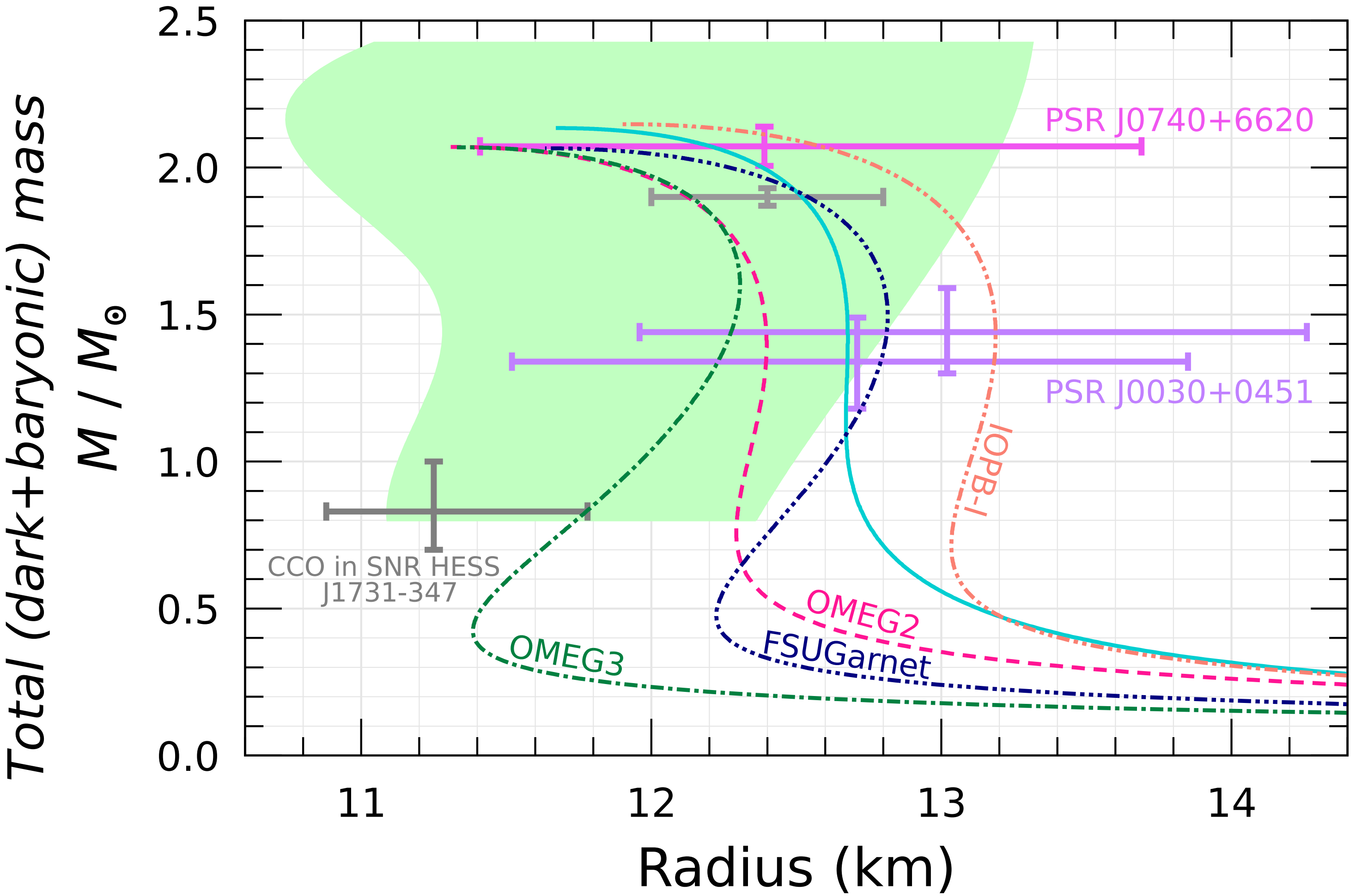

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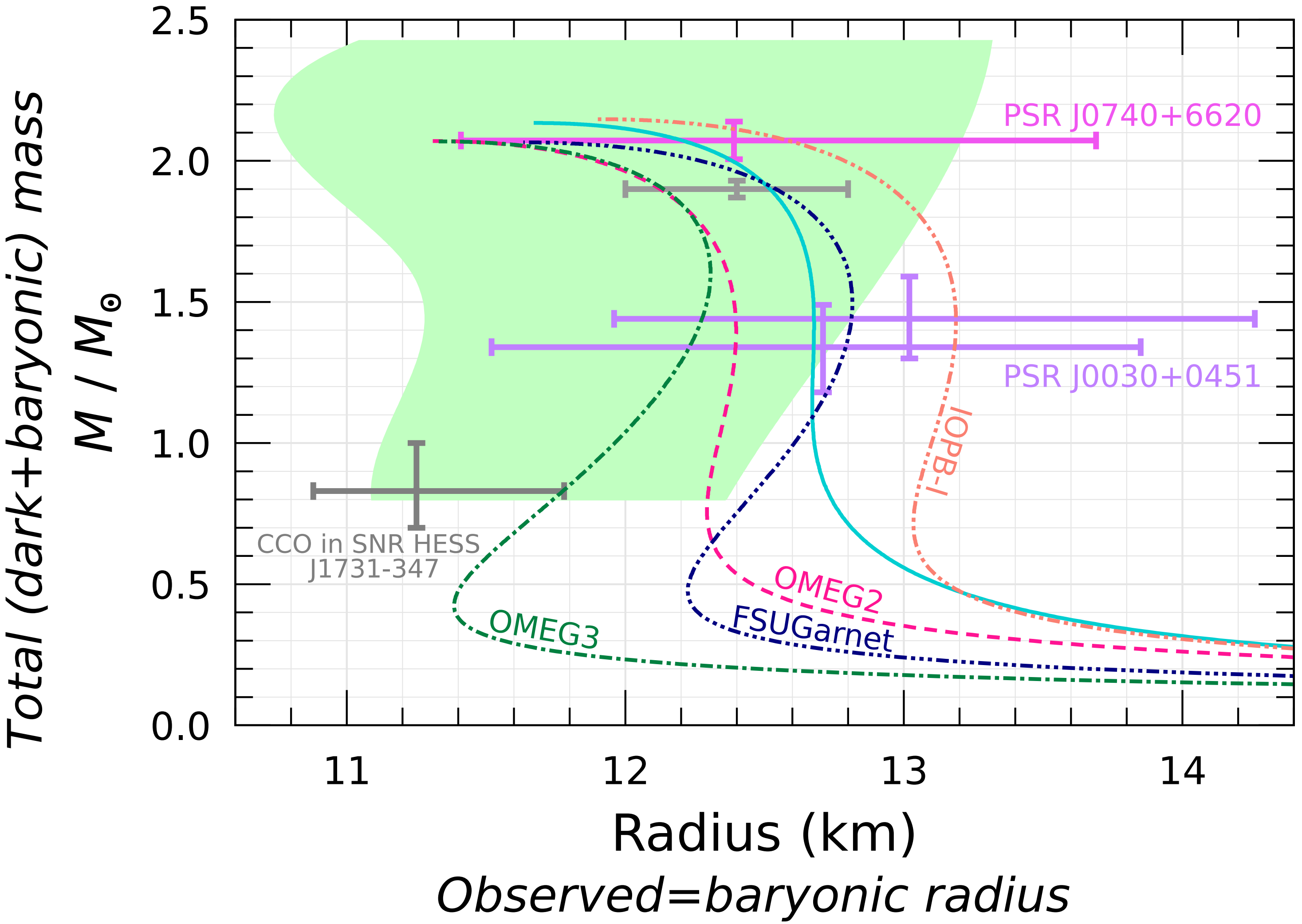

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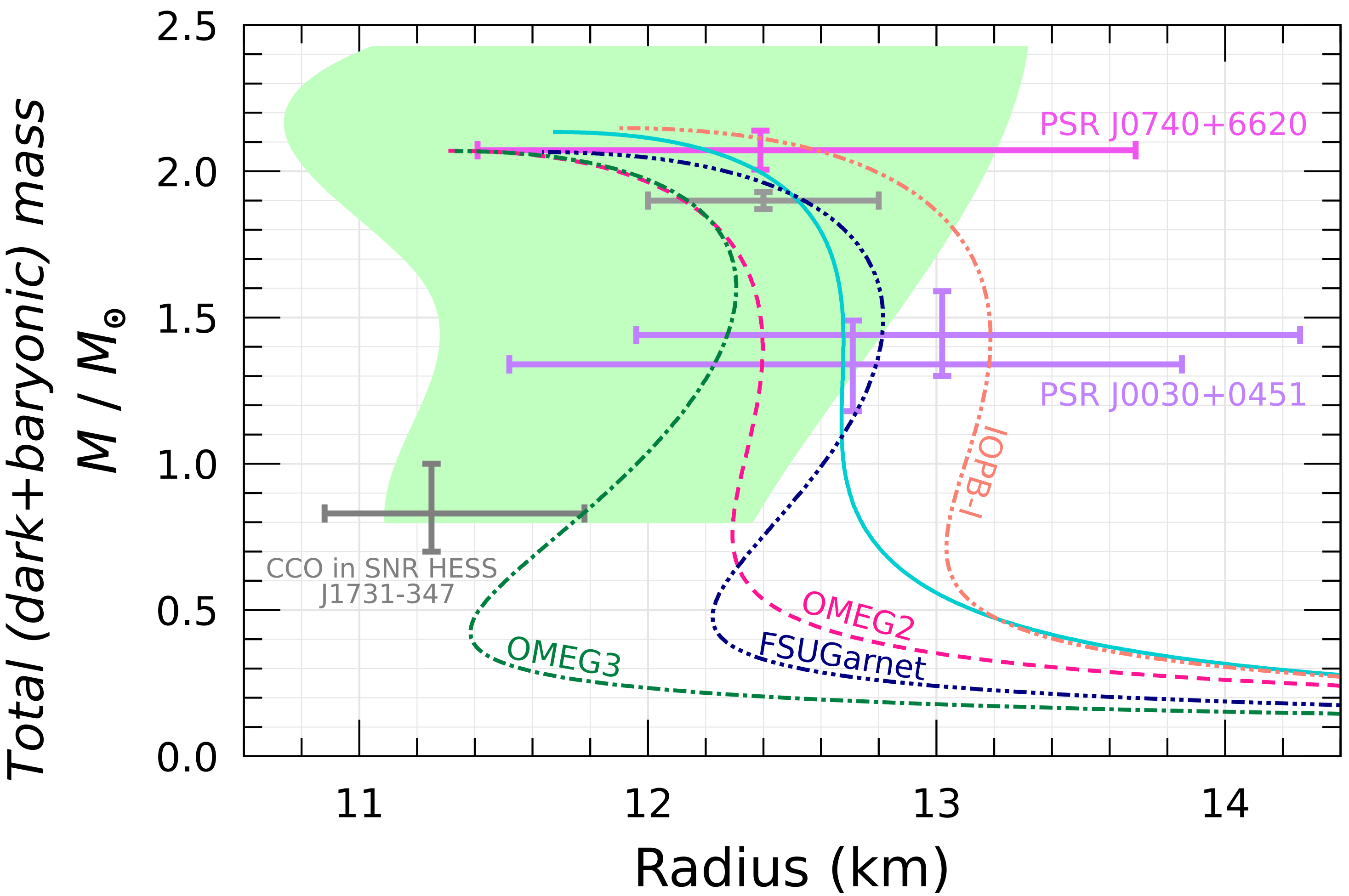

Observed=baryonic radius

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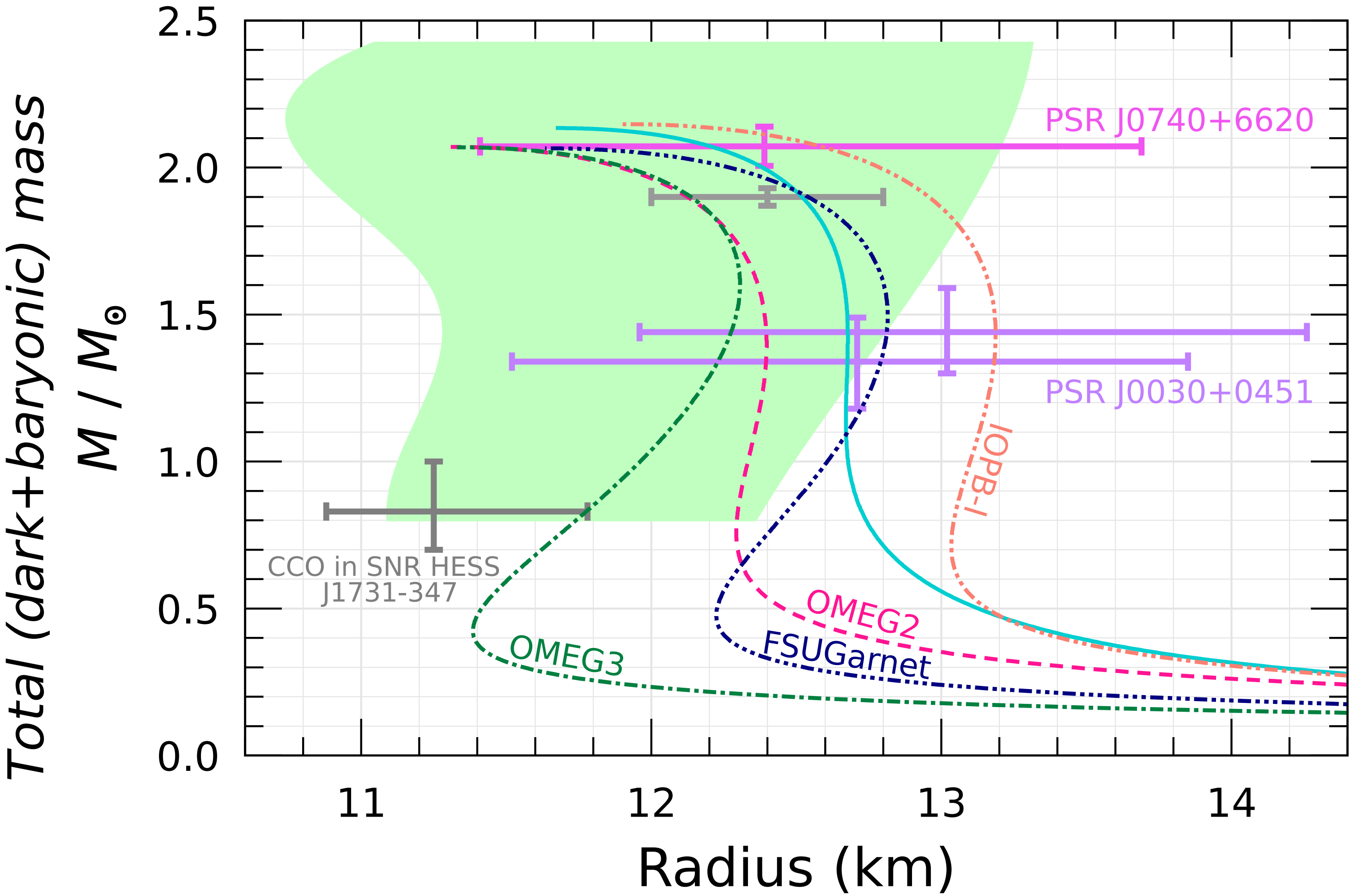

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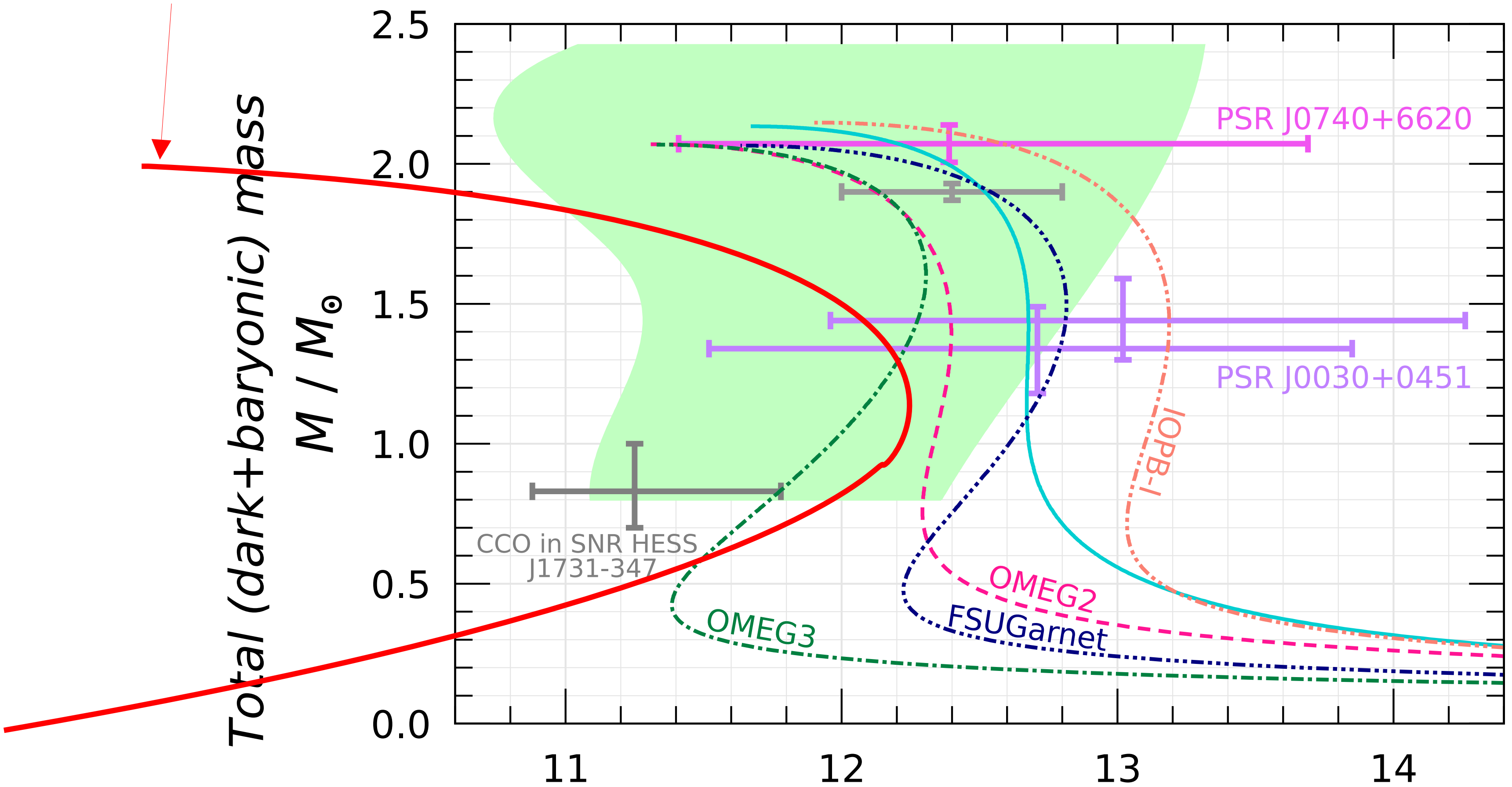

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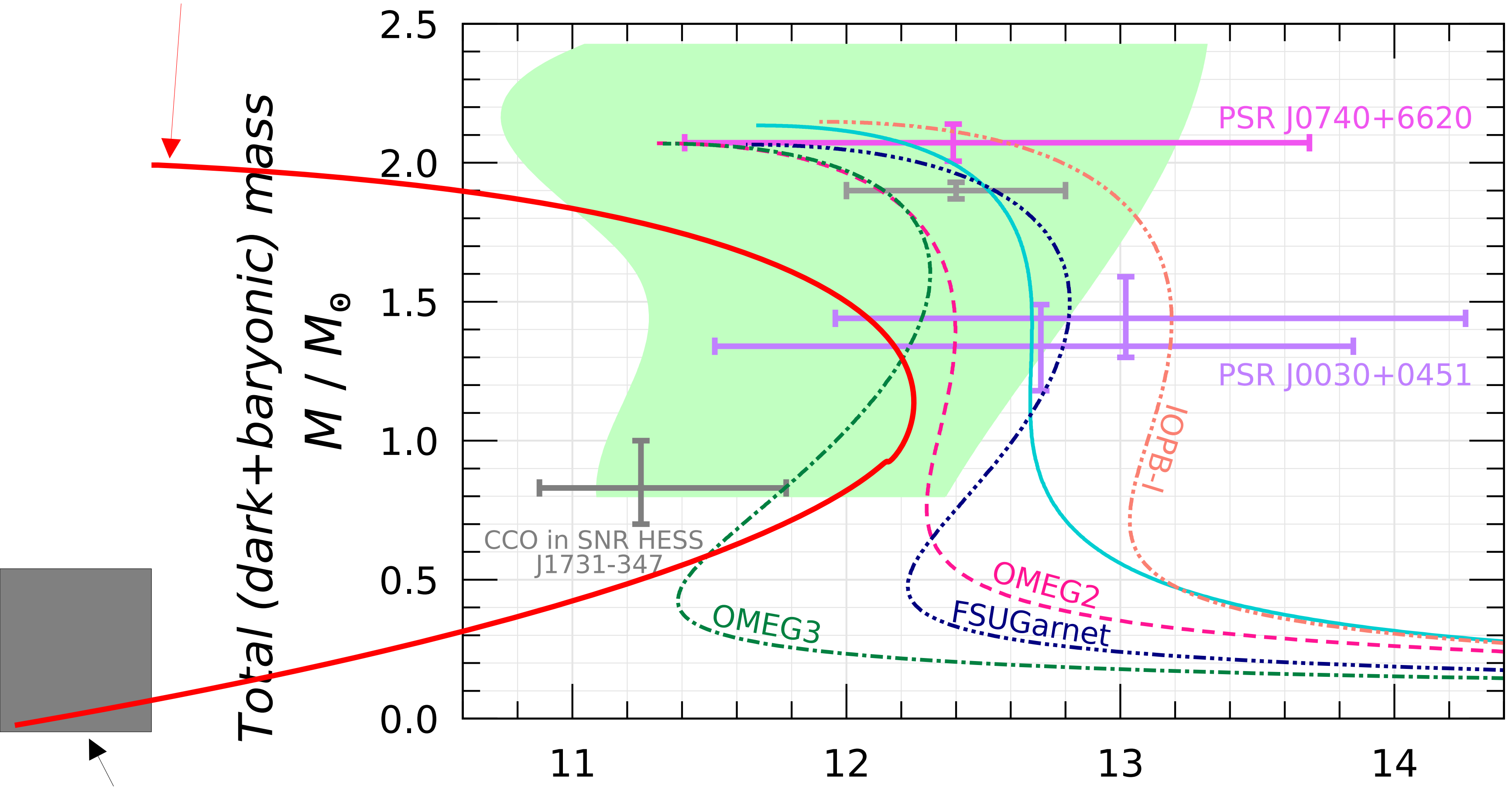

Dark planets

[e.g. Schaffner-Bielich et al. 22+]

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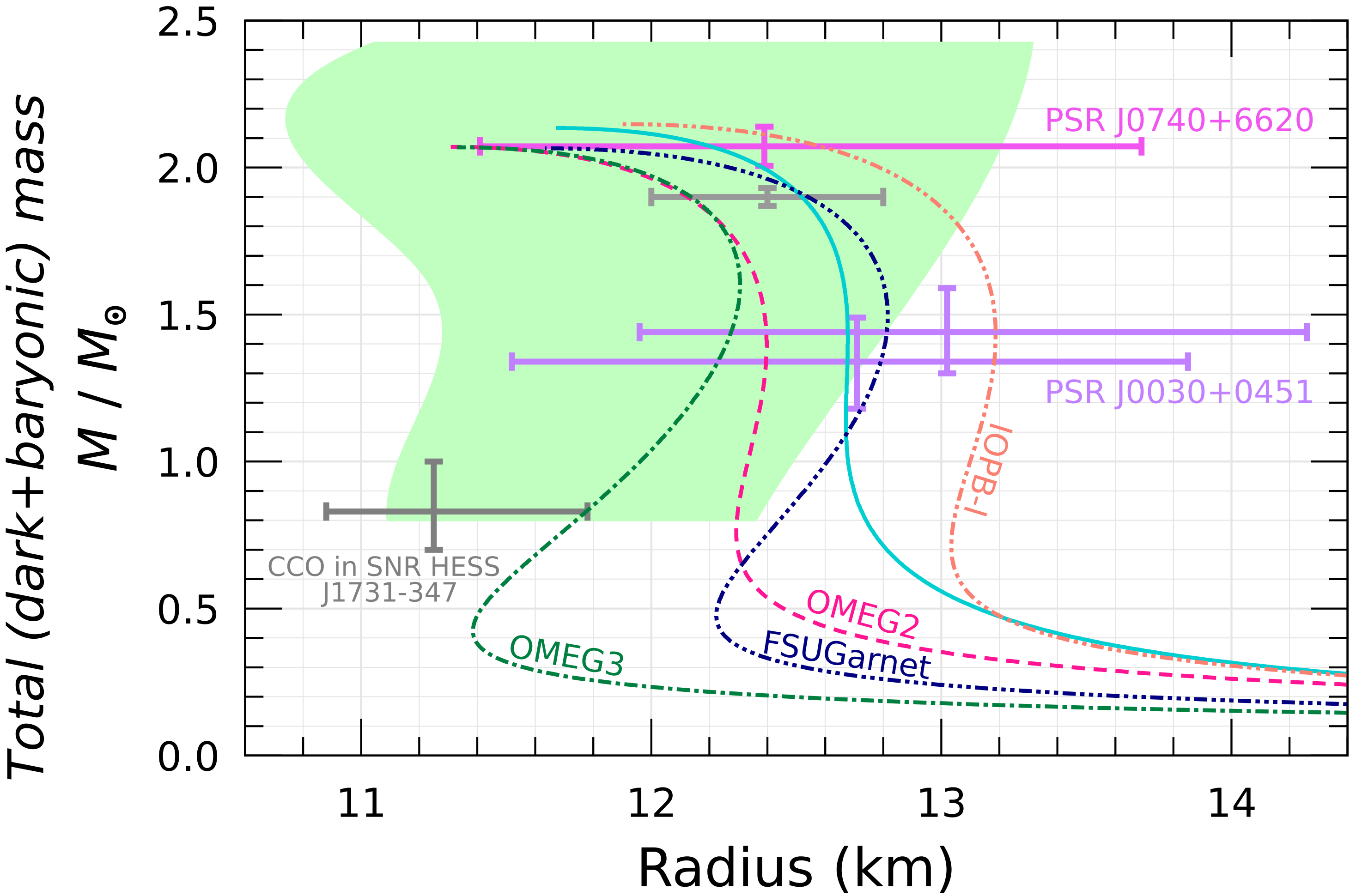

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Dark halos can intersect in collisions first: Possible GW signal

[Tsuyoshi et al.'23]

In (neutron) stars

[Sagun talk → Next up]

Only QCD-like dark scales yield consistent, slight admixtures
→ Newton constant and Neutron mass absolute reference

[Y. Dengler et al.'25]

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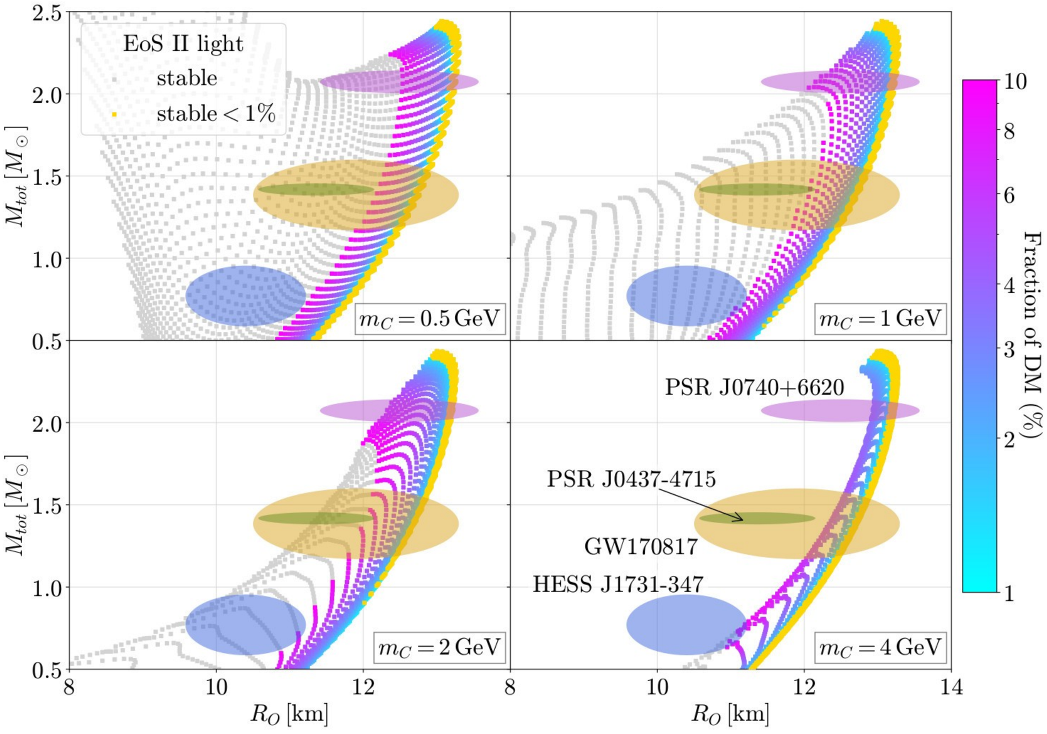

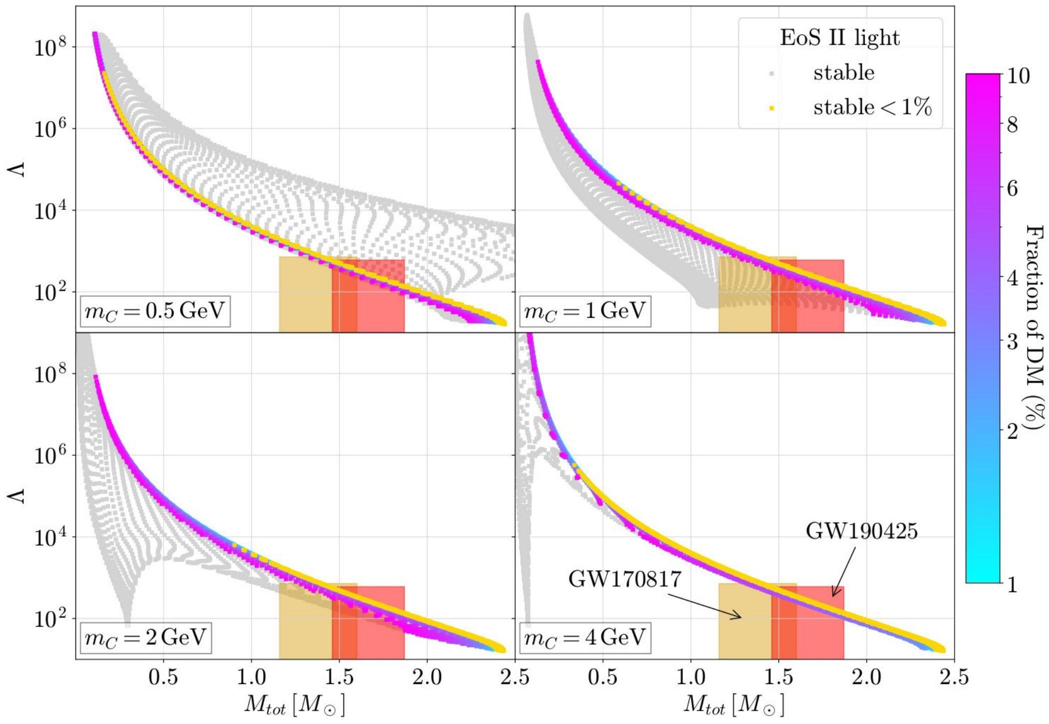

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Example: G_2-QCD as dark matter with fermionic baryons
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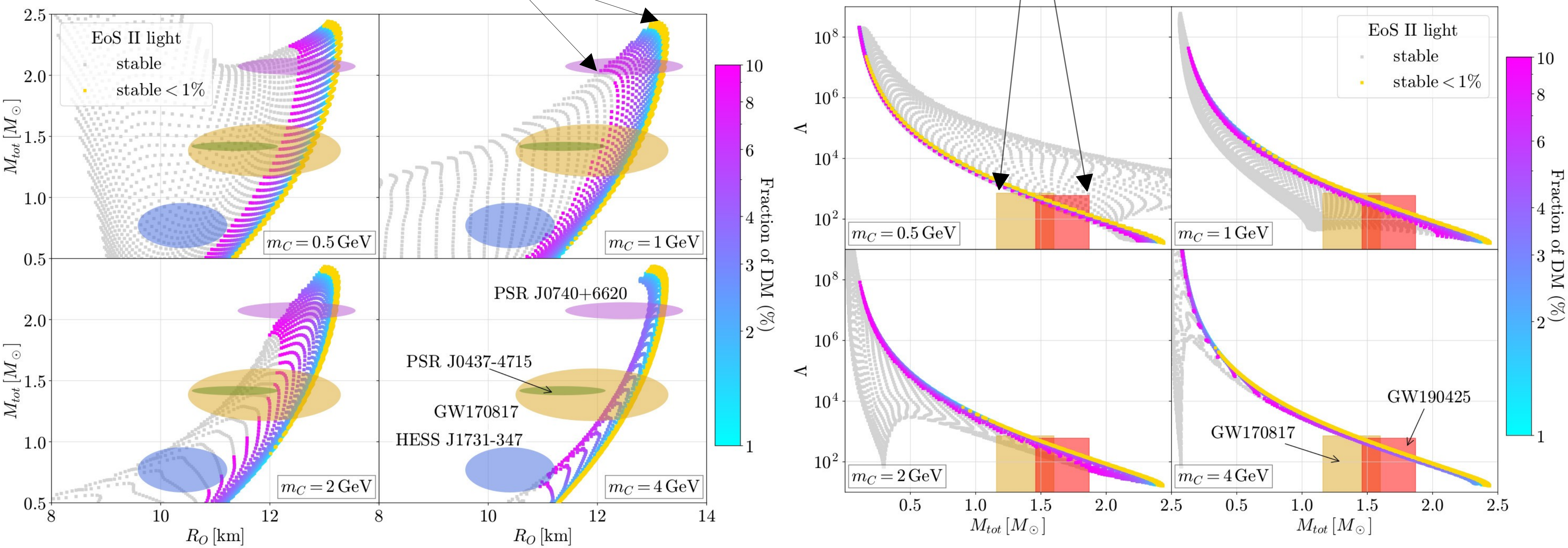
Significant amount of dark matter comaptible



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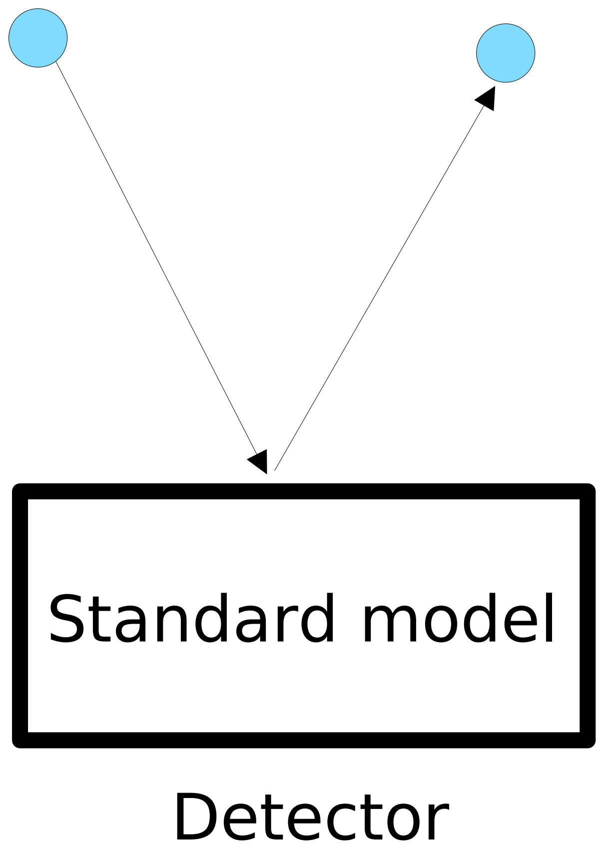

[R. Laha et al.'24, A. Hietanen et al.'14]

Signatures in direct detection

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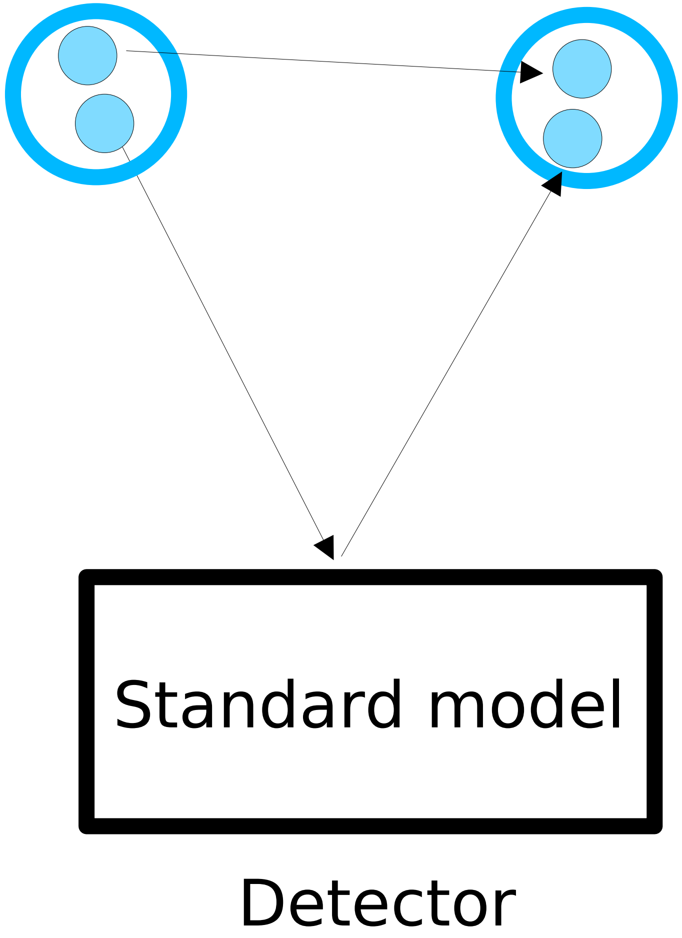

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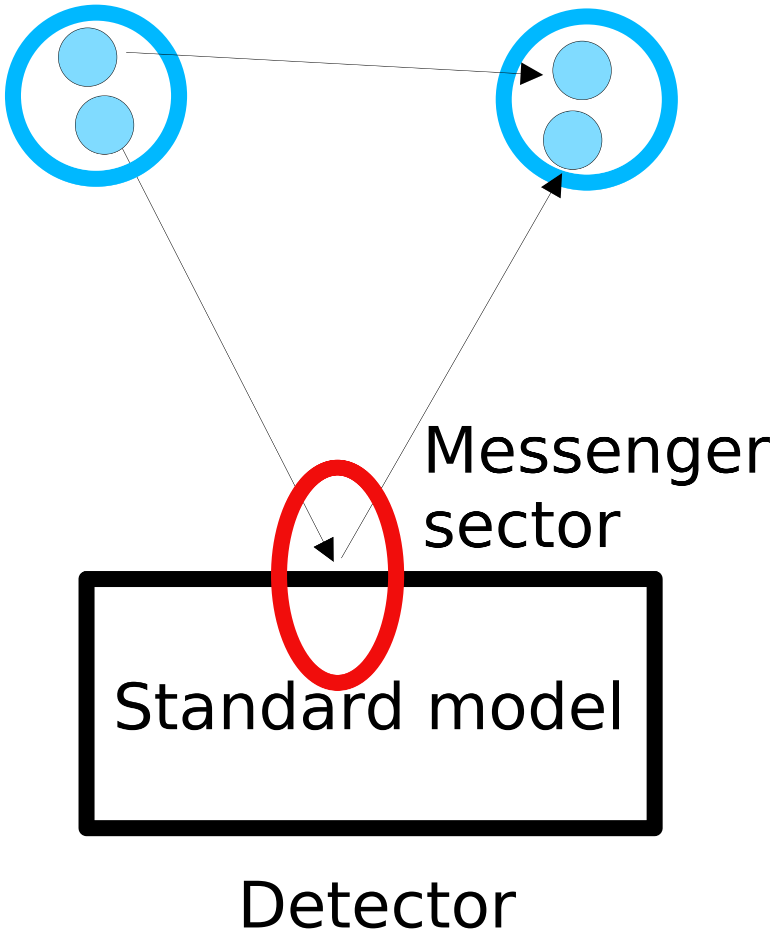
- Requires assumption on messenger sector
  - Effect of form factors at fixed messenger



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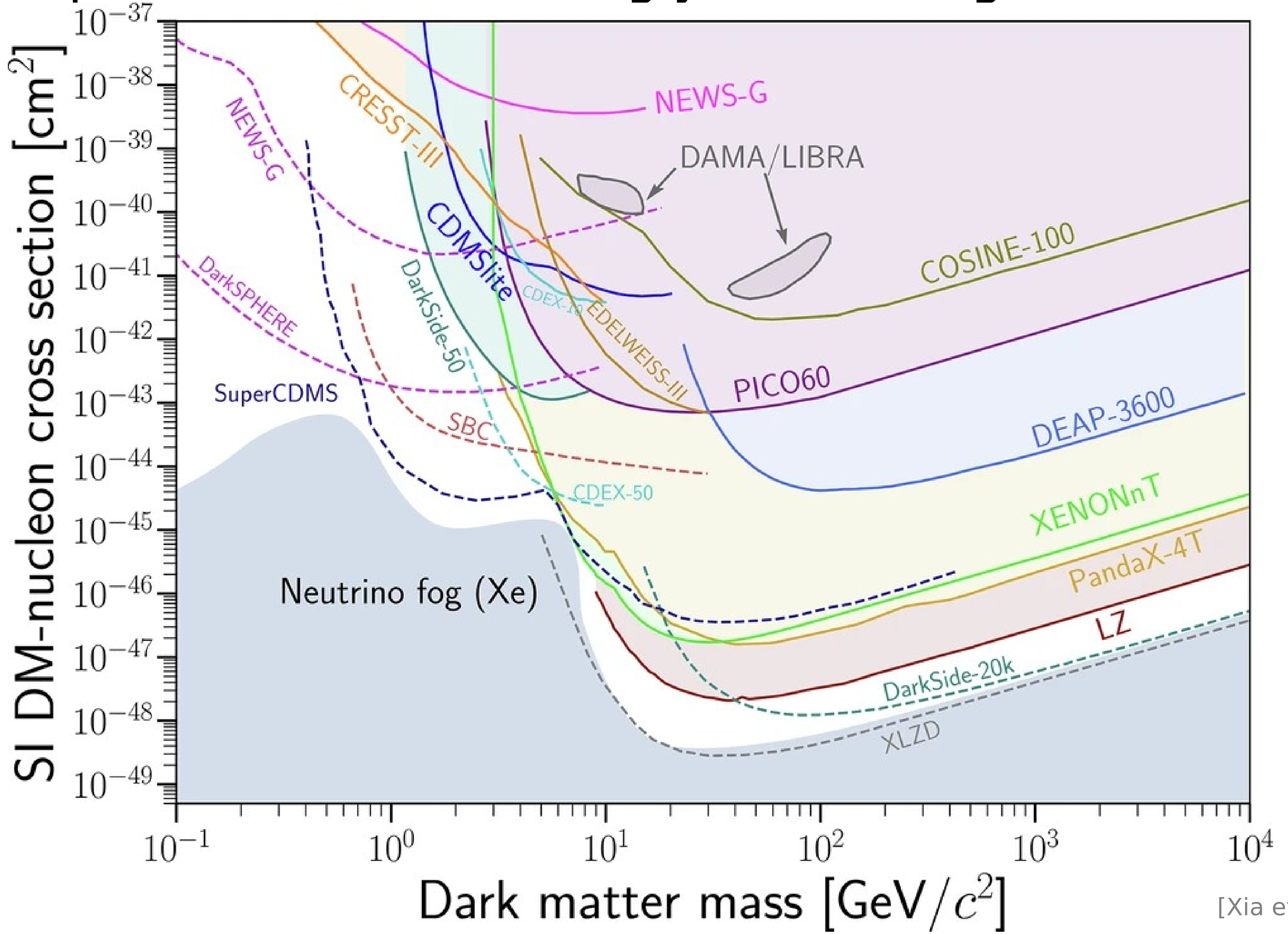

[Xia et al.'26]

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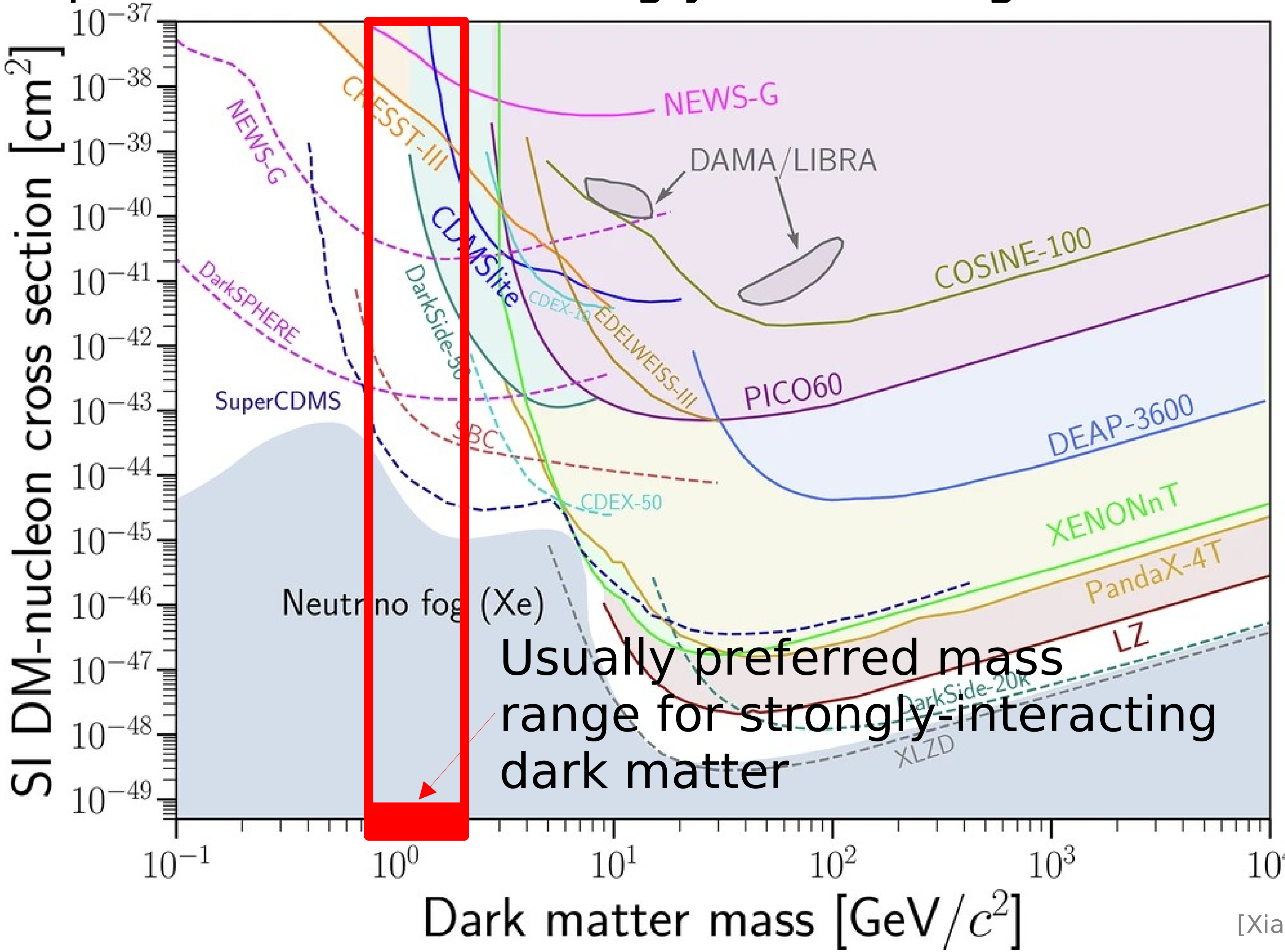

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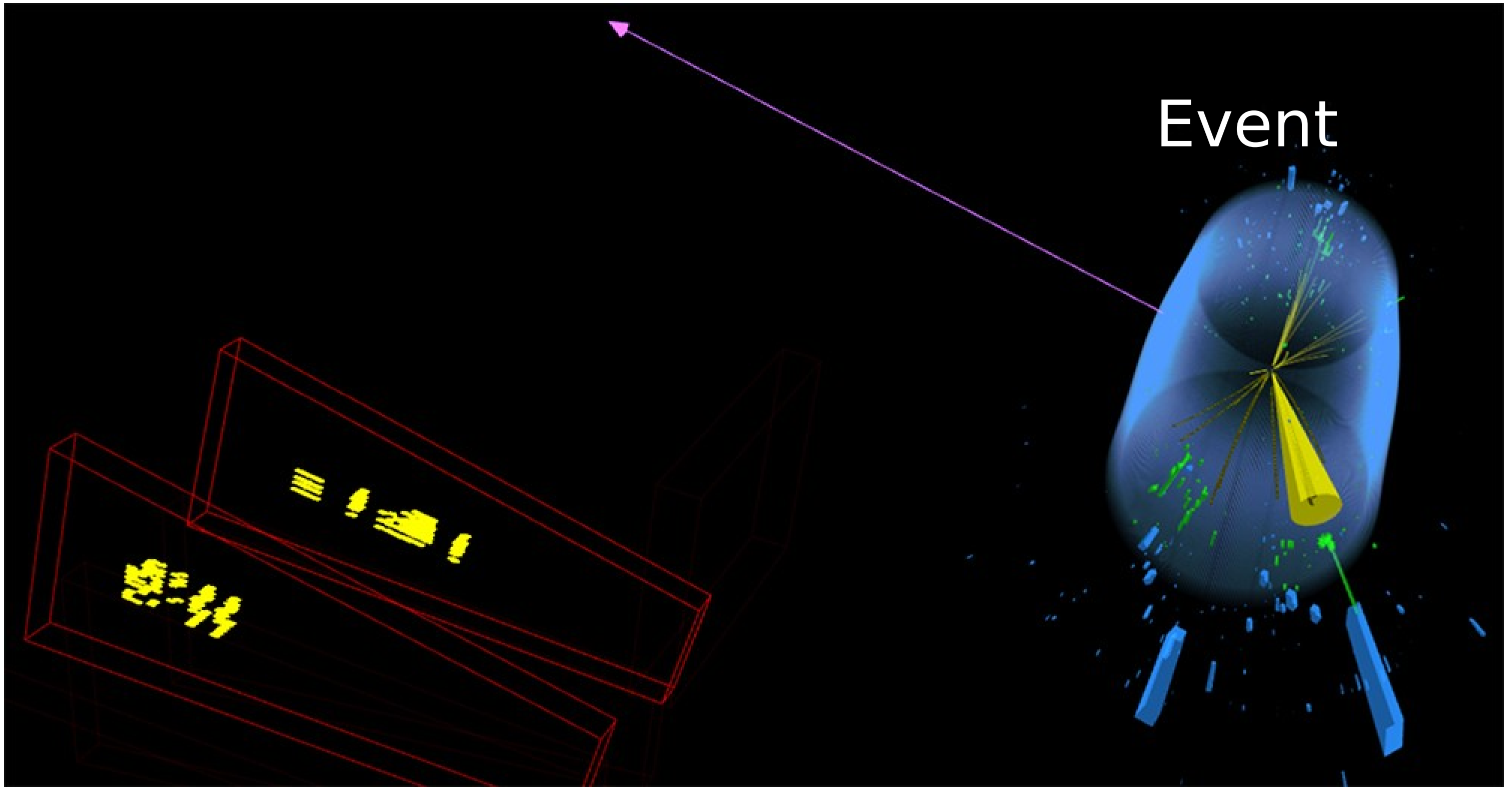

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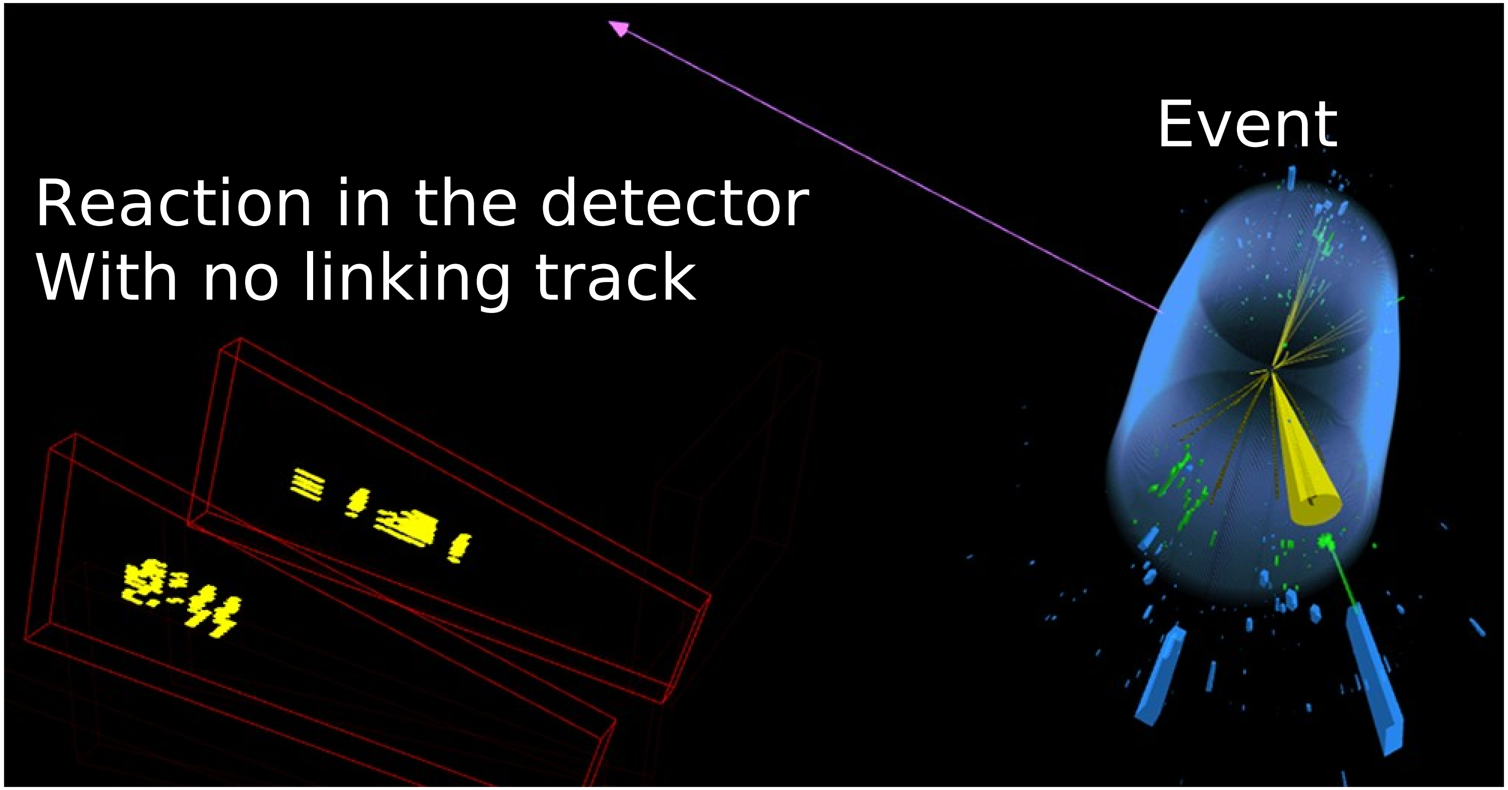

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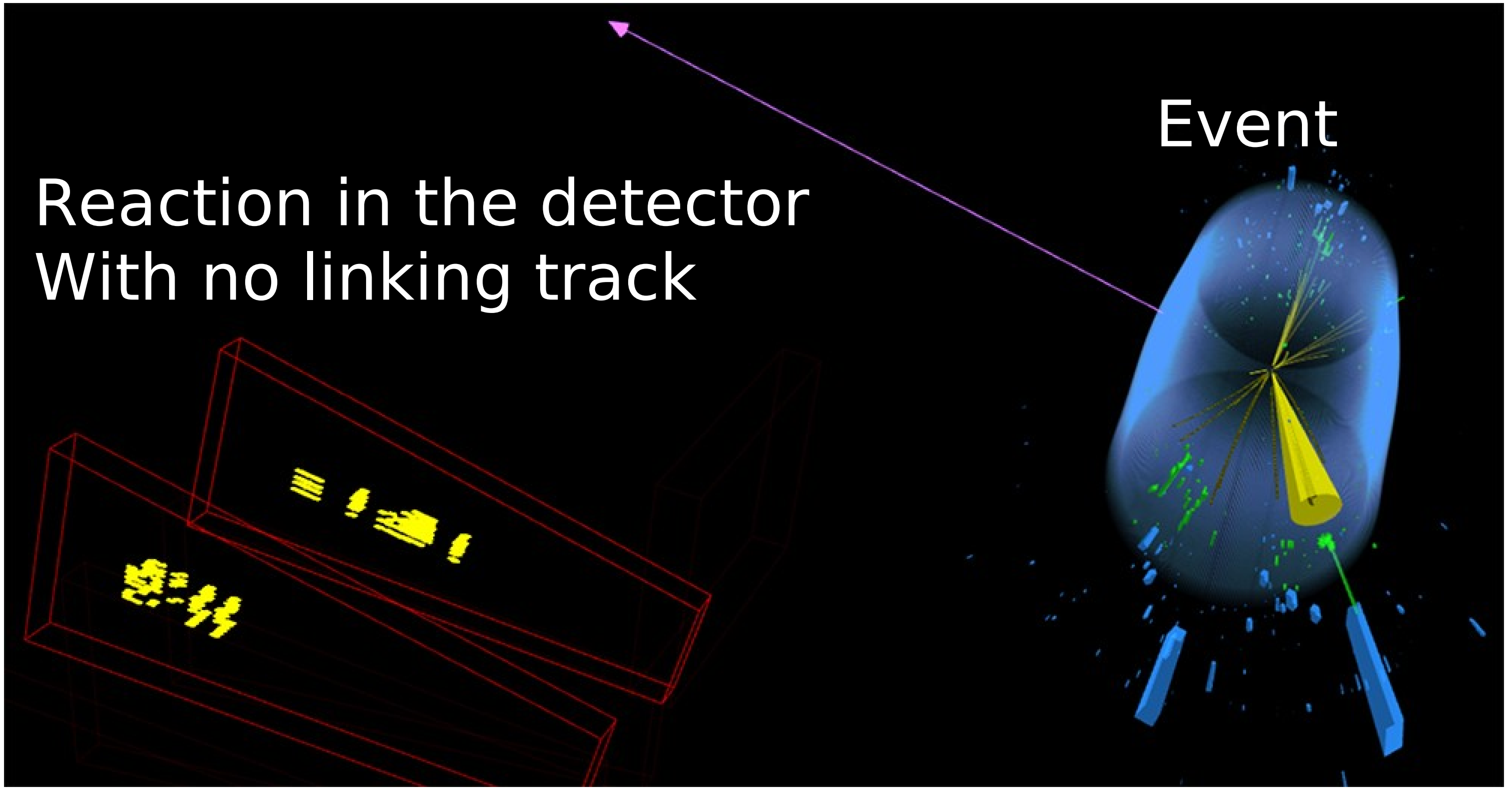

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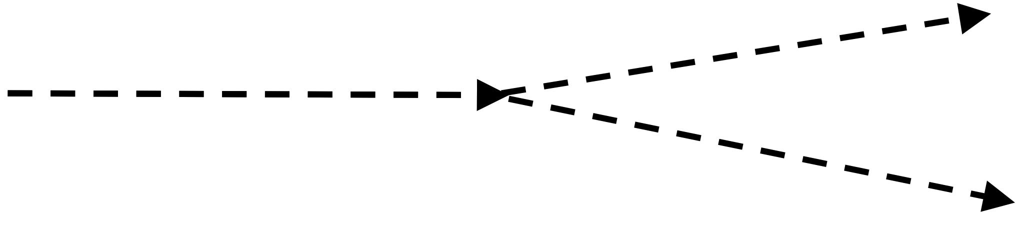

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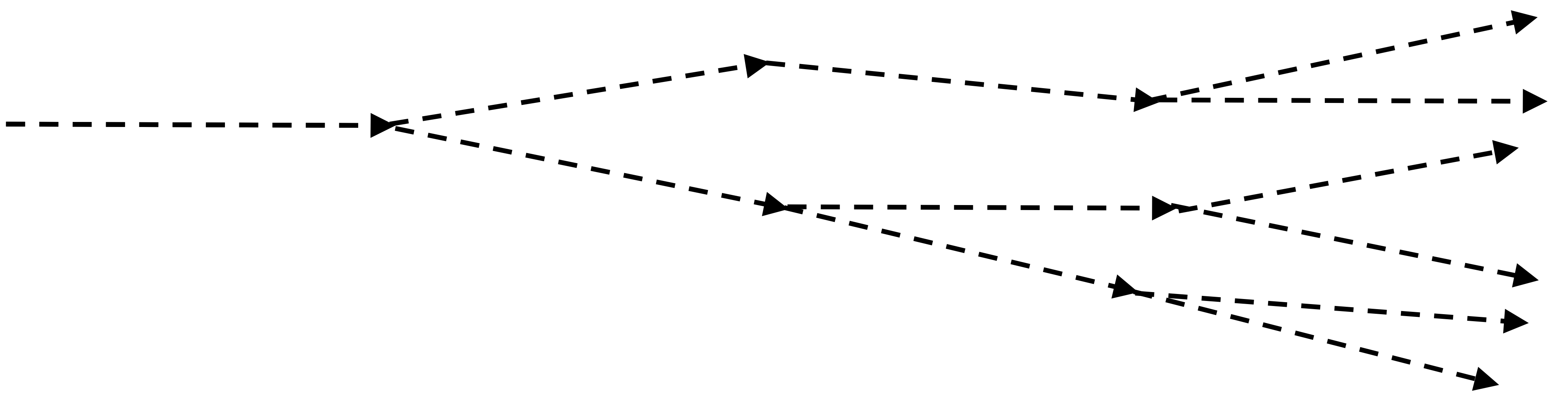

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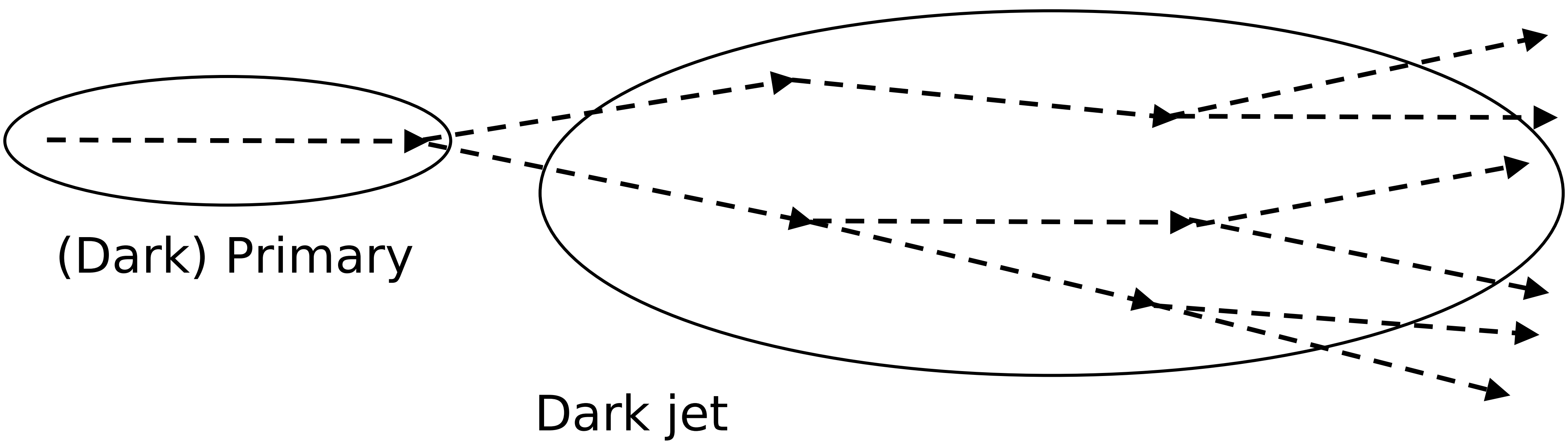

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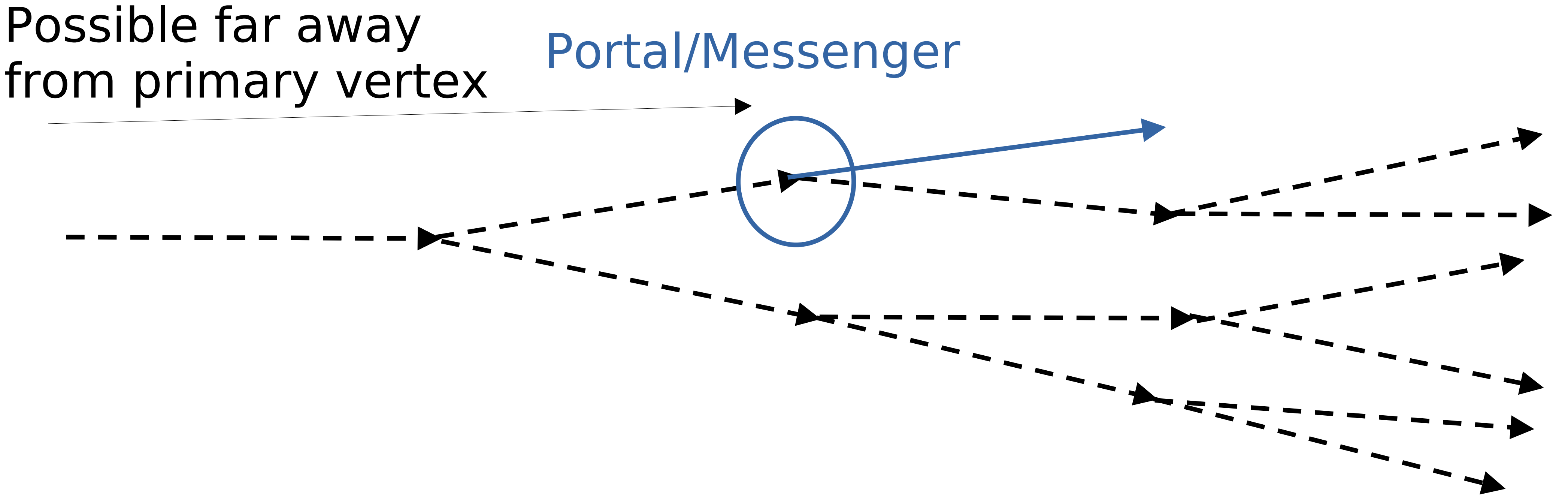

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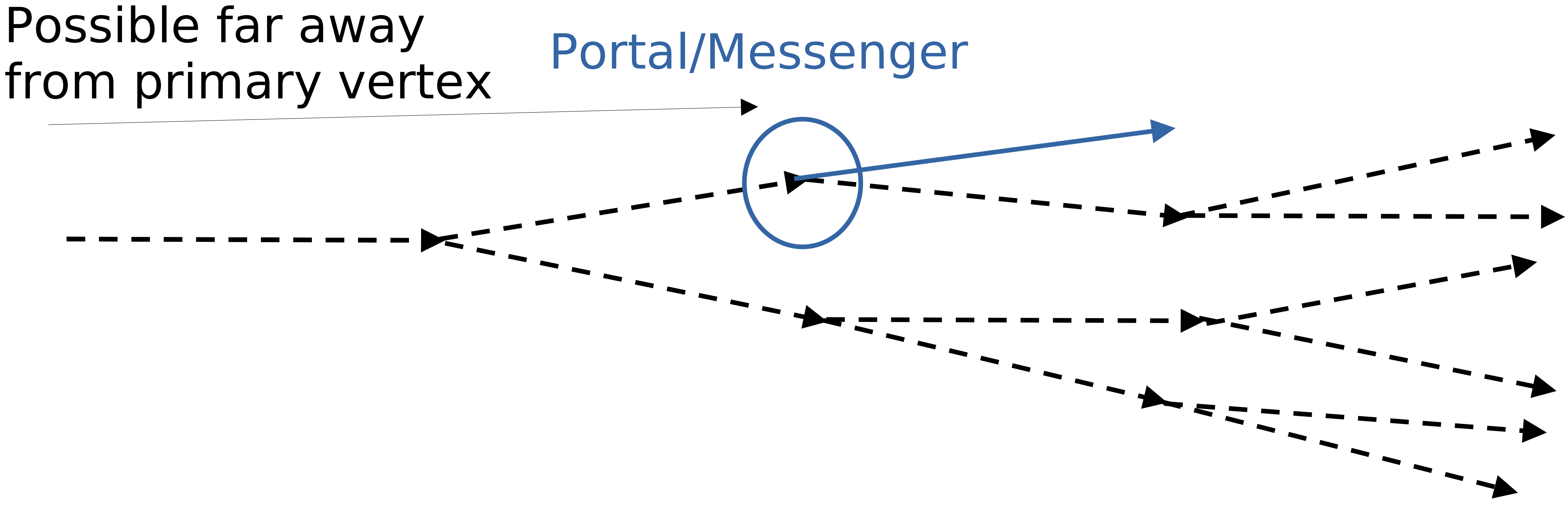

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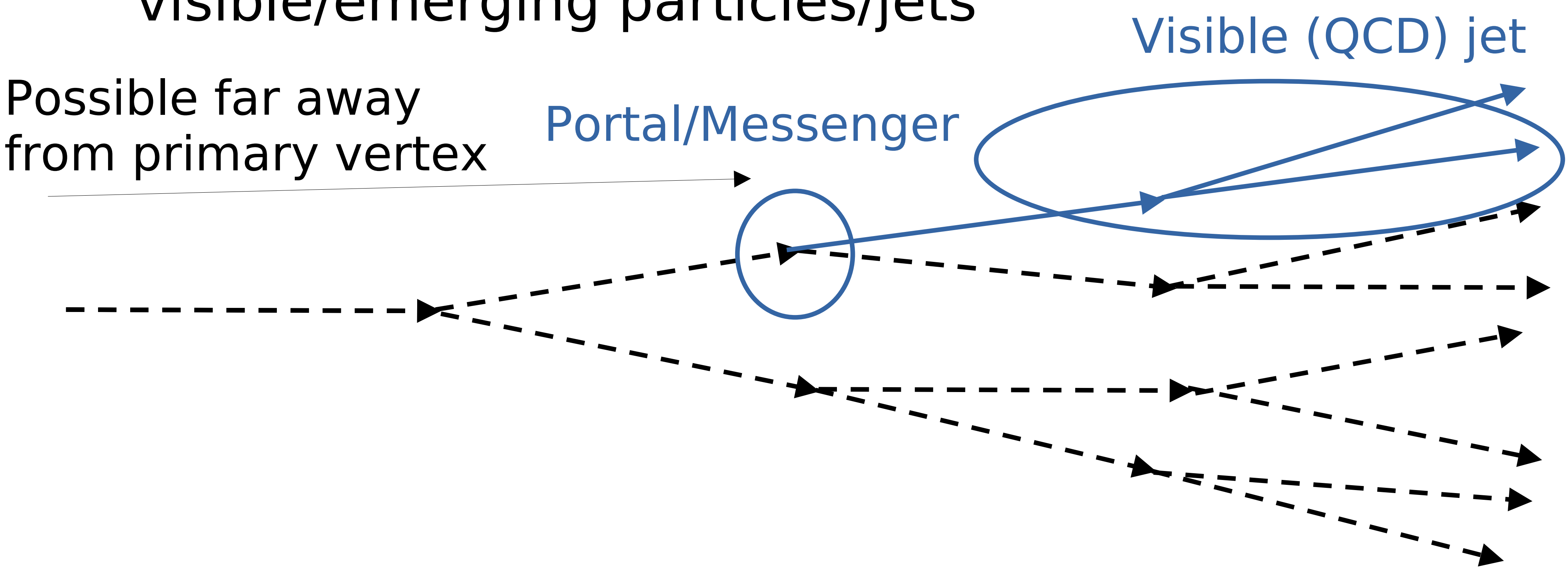

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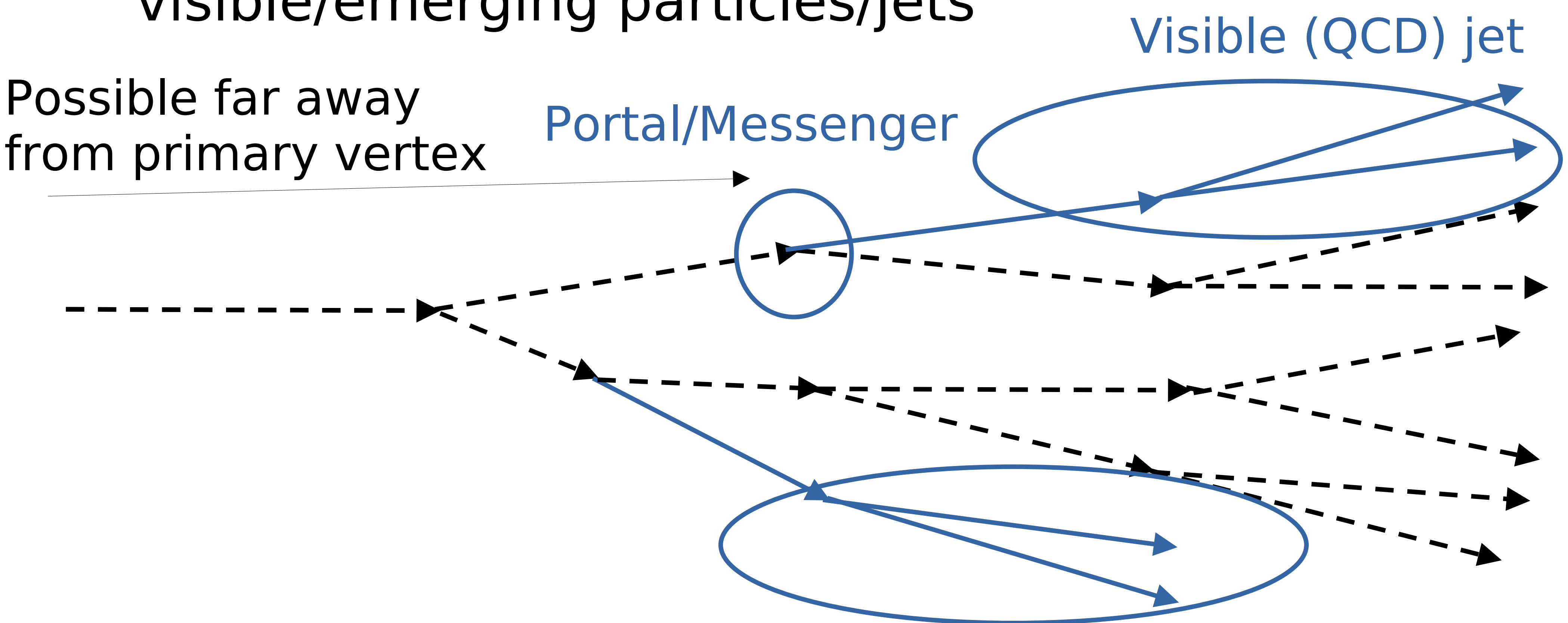

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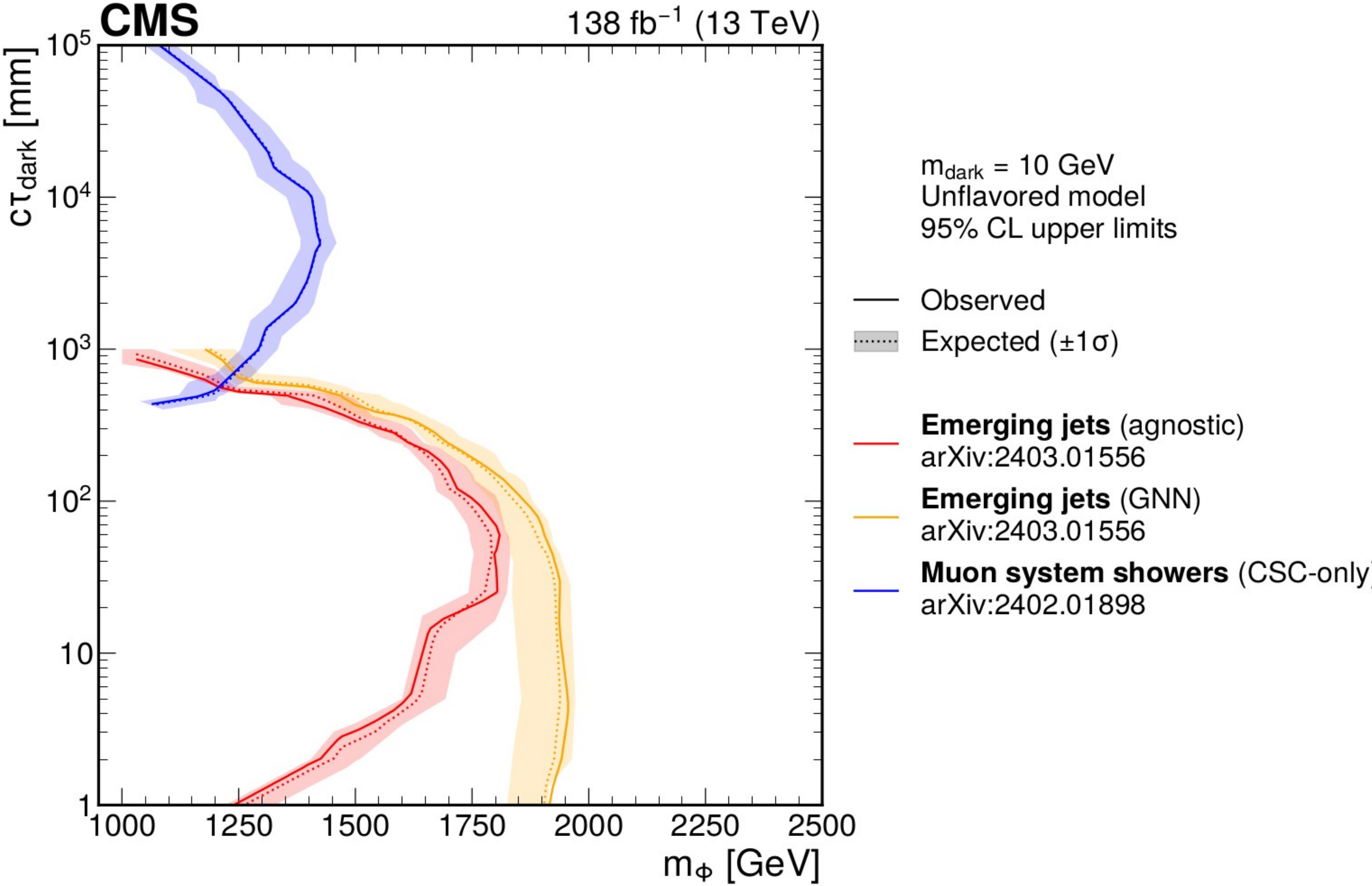

[CMS Phys. Rep.'25]

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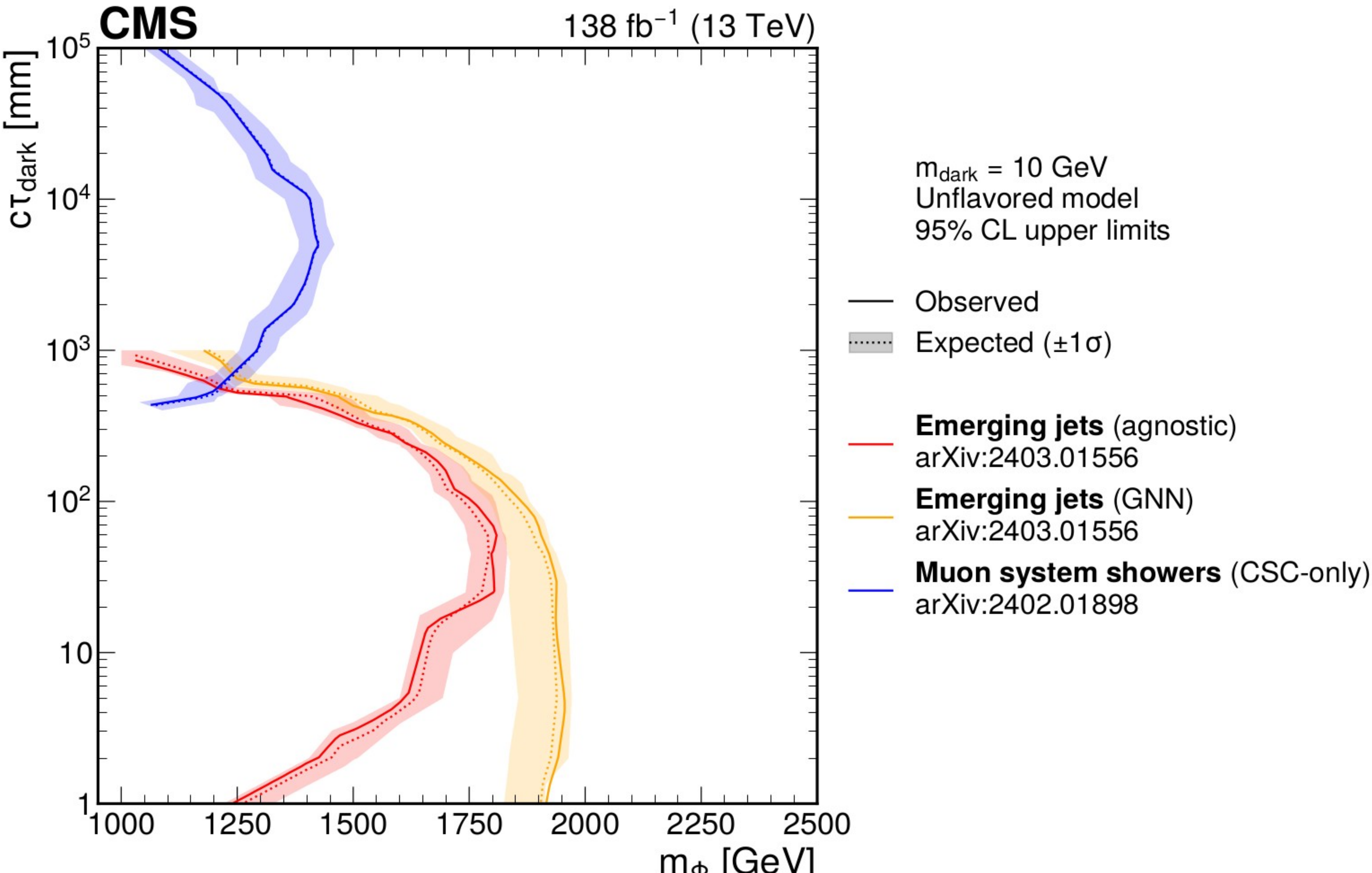

Assumption: Life-time of mediator

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[CMS Phys. Rep.'25]

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