Generalizing

Minimal Dark Matter

Millicharge or Decay

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DM stability → Symmetries → *ad hoc* / accidental

Minimal Dark Matter

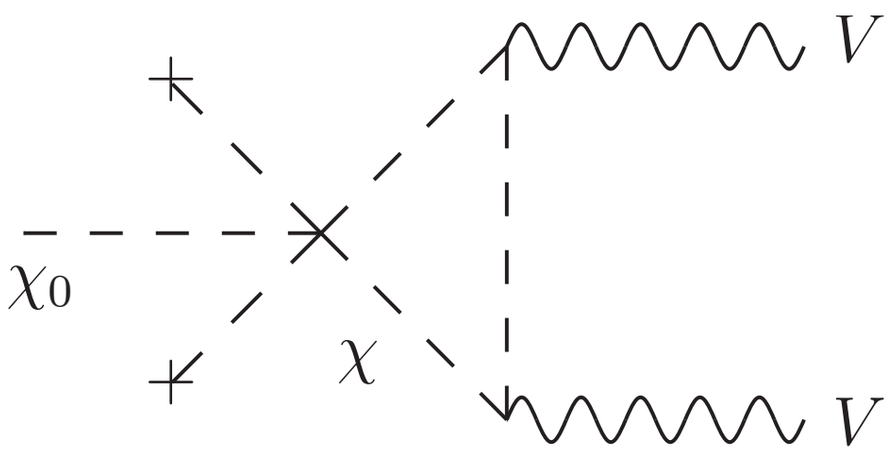
- Only SM gauge symmetries
- New DM multiplet under the SM gauge group
- Accidentally stable DM (up to dim. 5 in EFT)
- DM mass fixed by relic density

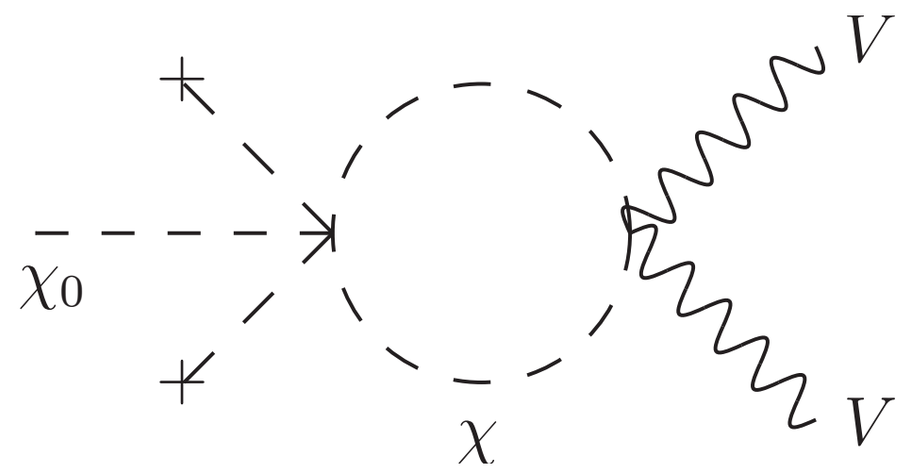
Quantum numbers			DM can	DD	Stable?
$SU(2)_L$	$U(1)_Y$	Spin	decay into	bound?	
2	1/2	S	EL	$\times$	$\times$
2	1/2	F	EH	$\times$	$\times$
3	0	S	HH^*	$\surd$	$\times$
3	0	F	LH	$\surd$	$\times$
3	1	S	HH, LL	$\times$	$\times$
3	1	F	LH	$\times$	$\times$
4	1/2	S	HHH^*	$\times$	$\times$
4	1/2	F	(LHH^*)	$\times$	$\times$
4	3/2	S	HHH	$\times$	$\times$
4	3/2	F	(LHH)	$\times$	$\times$
5	0	S	(HHH^*H^*)	$\surd$	$\times$
5	0	F	$-$	$\surd$	$\surd$
5	1	S	$(HH^*H^*H^*)$	$\times$	$\times$
5	1	F	$-$	$\times$	$\surd$
5	2	S	$(H^*H^*H^*H^*)$	$\times$	$\times$
5	2	F	$-$	$\times$	$\surd$
6	1/2, 3/2, 5/2	S	$-$	$\times$	$\surd$
7	0	S	$-$	$\surd$	$\surd$
8	1/2, 3/2 ...	S	$-$	$\times$	$\surd$

arXiv:0903.3381

Real scalar eptaplet

$$\frac{1}{\Lambda}\chi^3 H^2$$

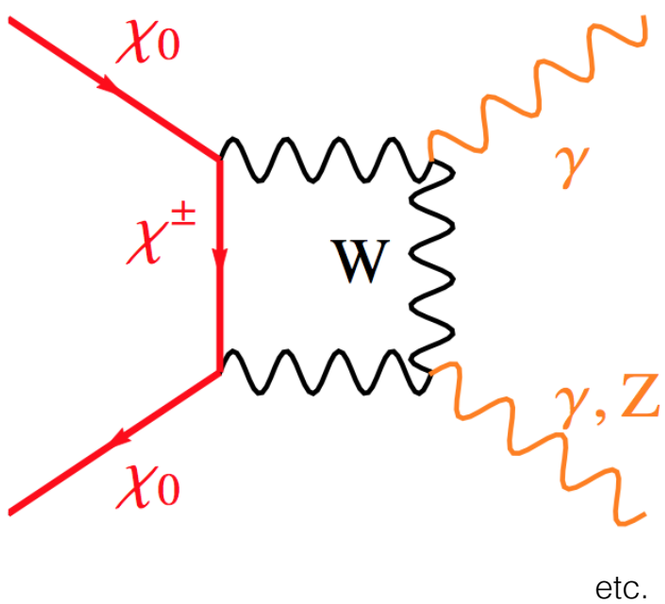


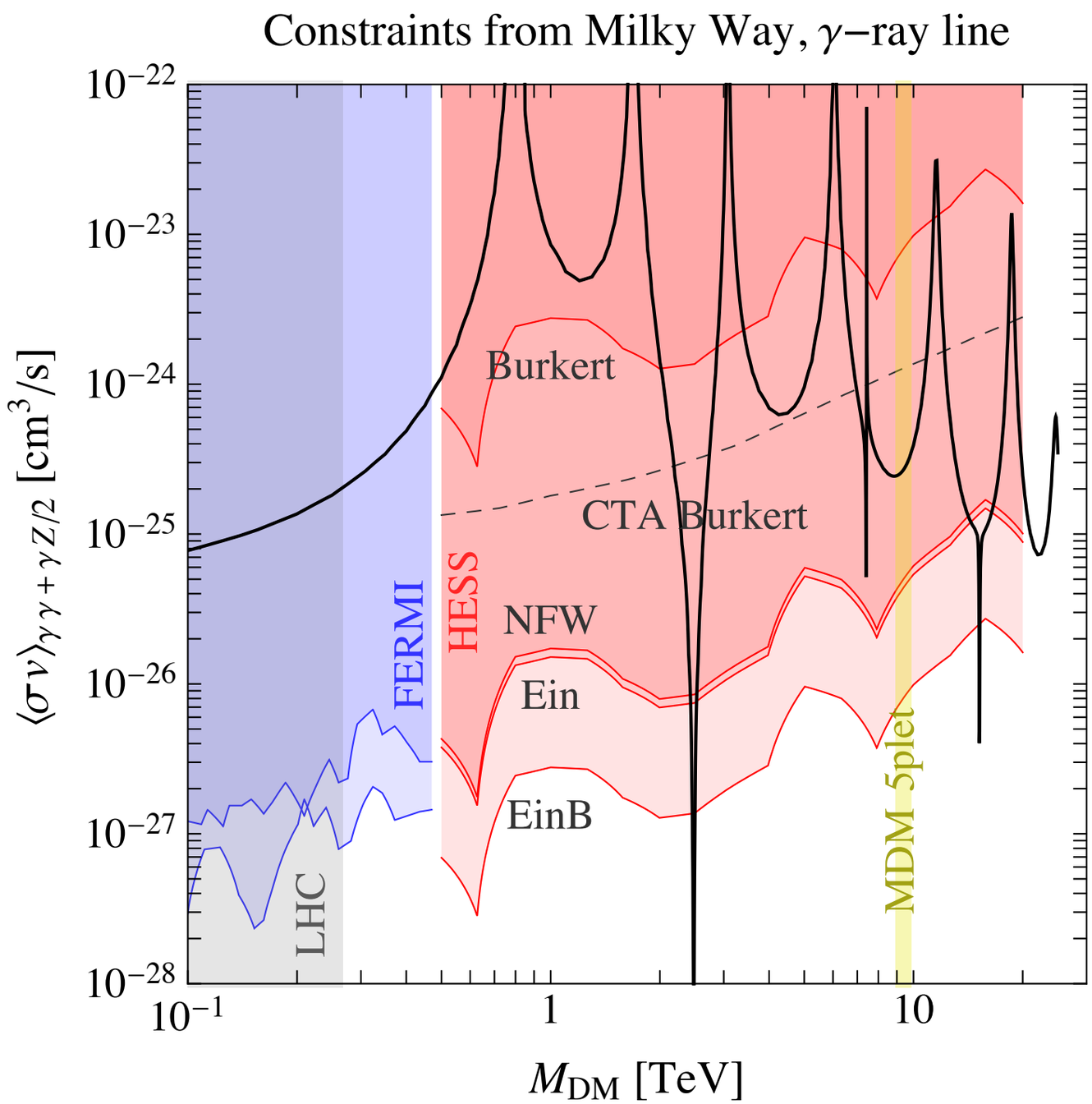


This affects **any** scalar SU(2)$_L$ multiplet
with odd dimension and $Y = 0$

(for the same reason, fermion MDM decays at most through the dimension-7 $\chi^3 LH$ operator)

Majorana quintuplet





arXiv:1507.05519

Minimal Dark Matter: assumptions

1. Thermal relic, all of DM (fixes DM mass)
2. Small Higgs-portal interactions for scalars
3. Cutoff at the Planck scale
4. Electrically neutral DM (forces $Y = 0$)

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Giving up 1.

- Needs not being enforced
- Modern analyses consider the DM mass as a free parameter

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Giving up 2.

- These couplings can change mass splittings and hierarchy and thus the phenomenology of the model
- They actually run very fast and induce low-energy Landau poles
- In any case, scalar MDM with $Y = 0$ decays too quickly

Minimal Dark Matter: assumptions

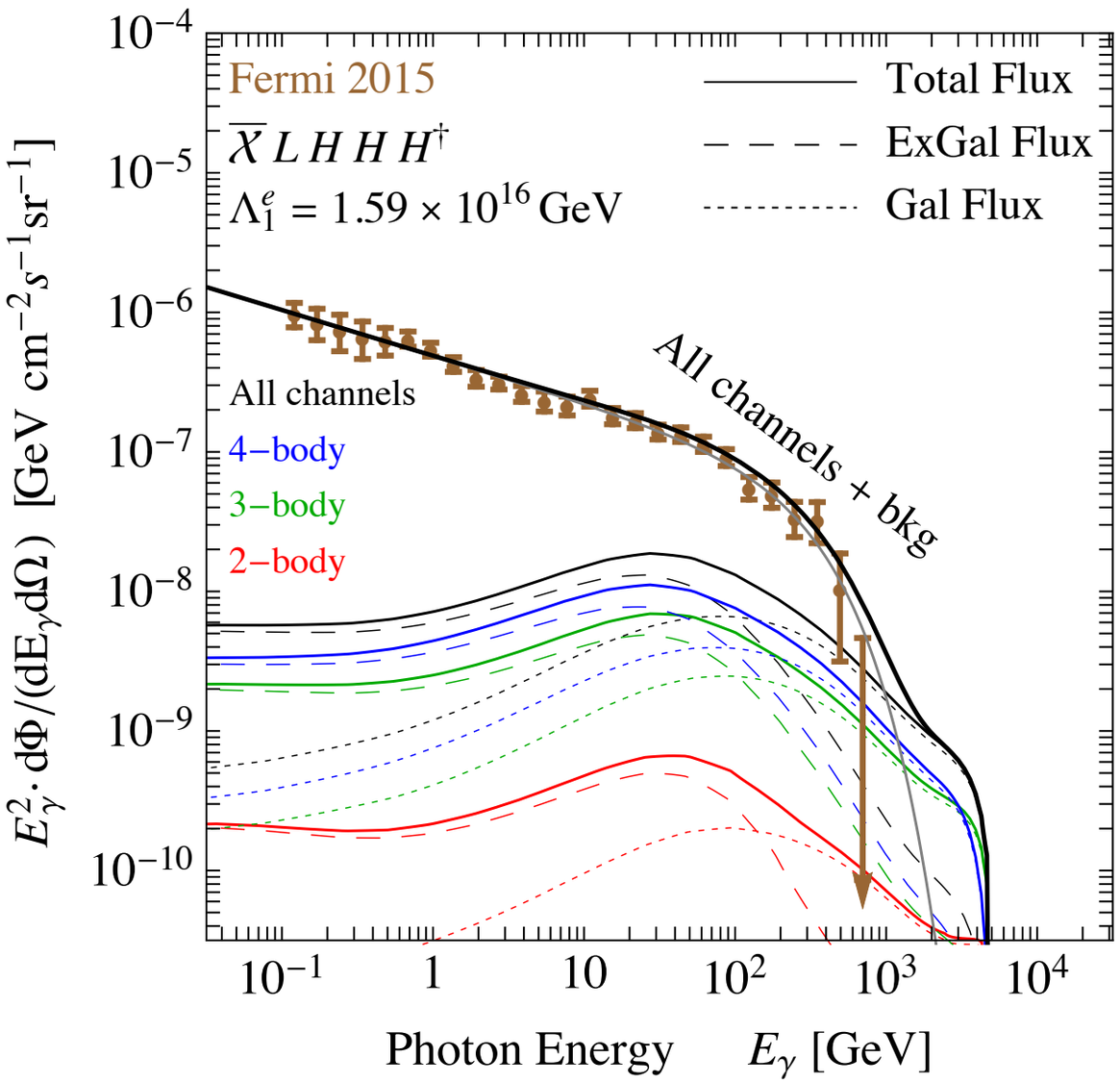
1. Thermal relic, all of DM (fixes DM mass)
2. Small Higgs-portal interactions for scalars
3. Cutoff at the Planck scale
4. Electrically neutral DM (forces $Y = 0$)

Giving up 3. and 4.

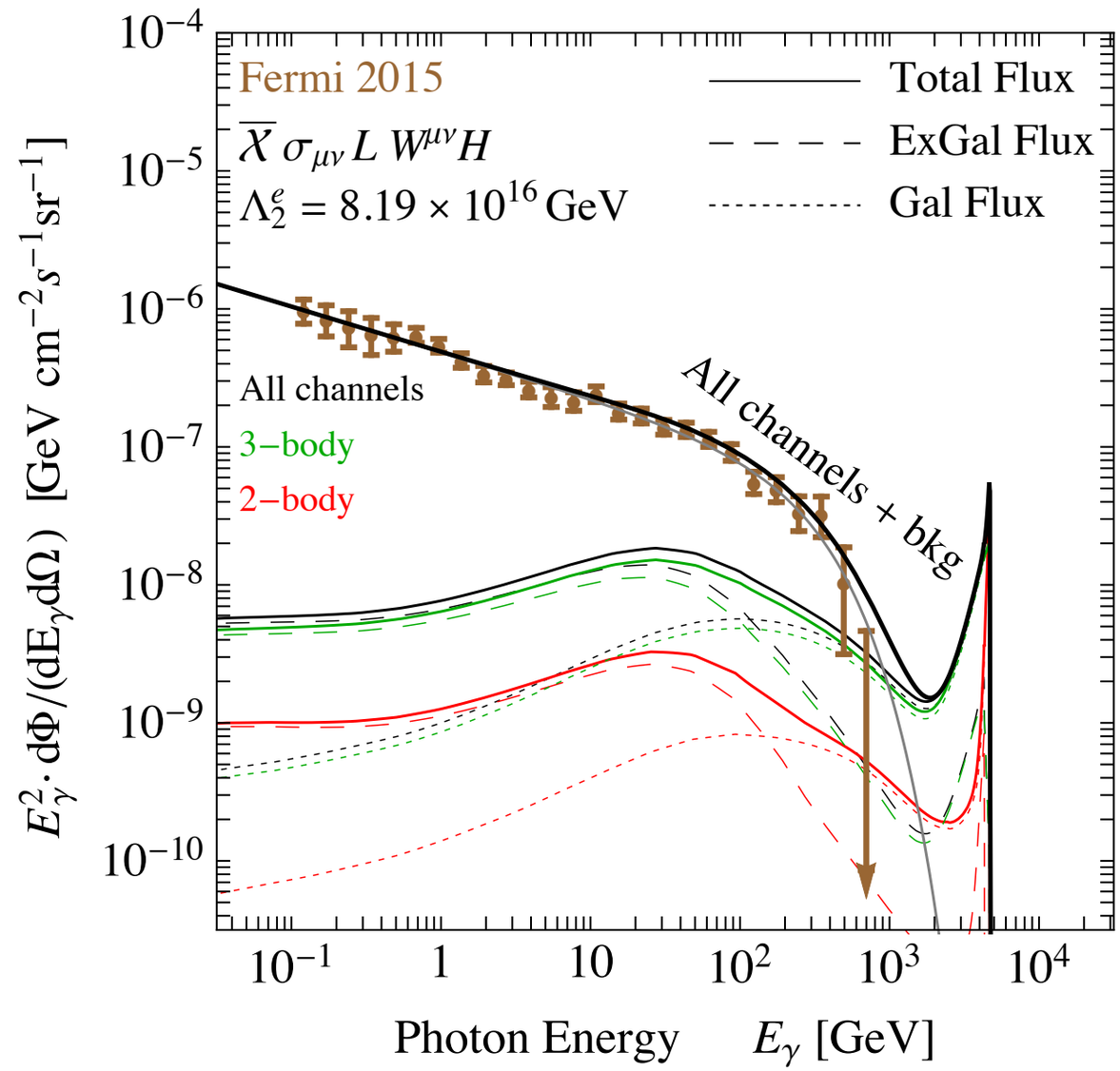
The remainder of this talk

Decaying Majorana quintuplet

$$\frac{1}{(\Lambda_1^e)^2}\overline{\mathcal{X}}LHHH^\dagger$$

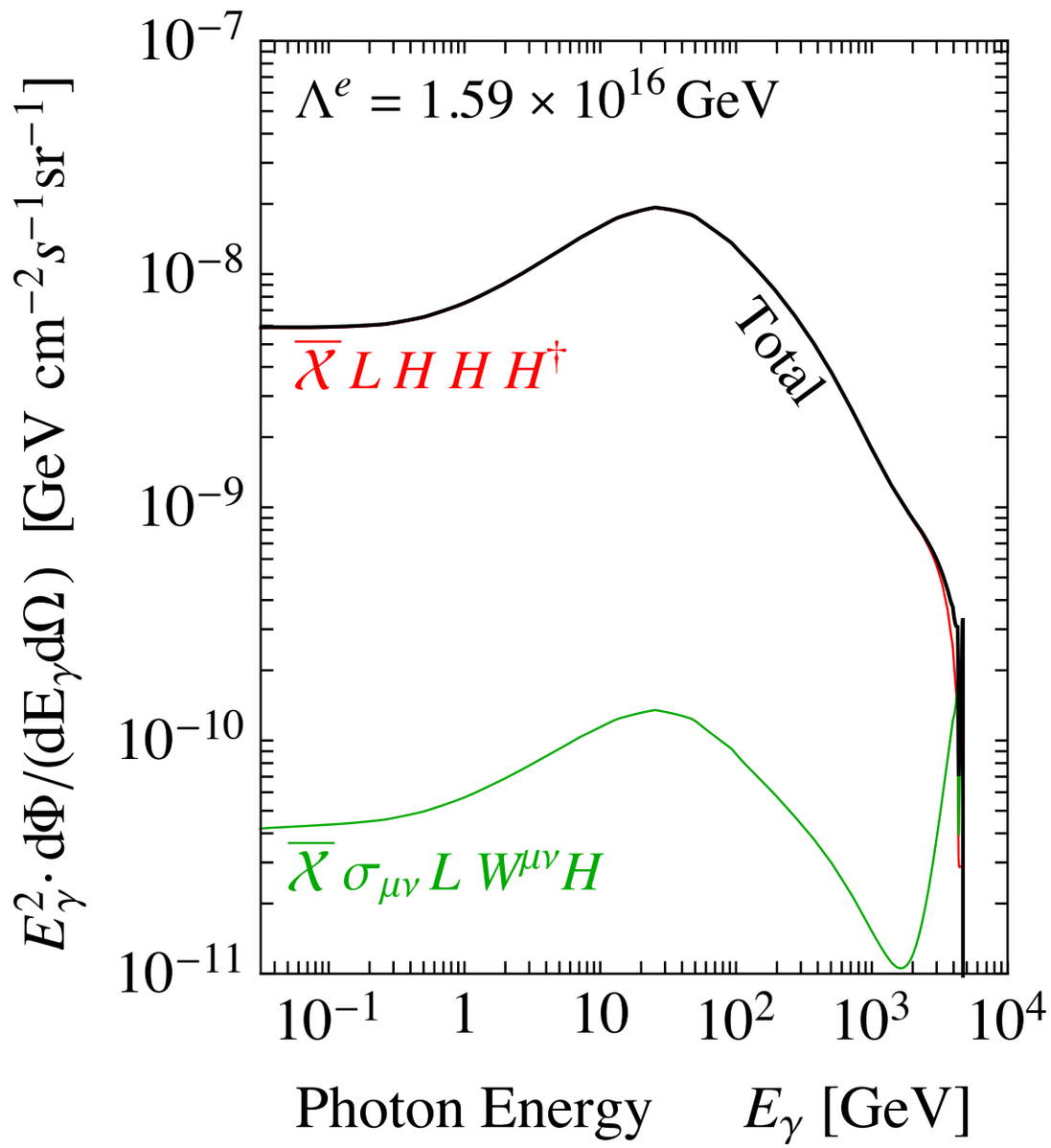


$$\frac{1}{(\Lambda_2^e)^2}\overline{\mathcal{X}}\sigma_{\mu\nu}LW^{\mu\nu}H$$



Decaying Majorana quintuplet

$$\frac{1}{(\Lambda^e)^2}\left(\overline{\mathcal{X}}LHHH^\dagger + \frac{\alpha_2}{4\pi}\overline{\mathcal{X}}\sigma_{\mu\nu}LW^{\mu\nu}H\right)$$



Millicharged MDM

Automatically stable DM

No need to worry about higher order operators

Nor about Landau poles and cutoffs

In principle larger multiplets are possible

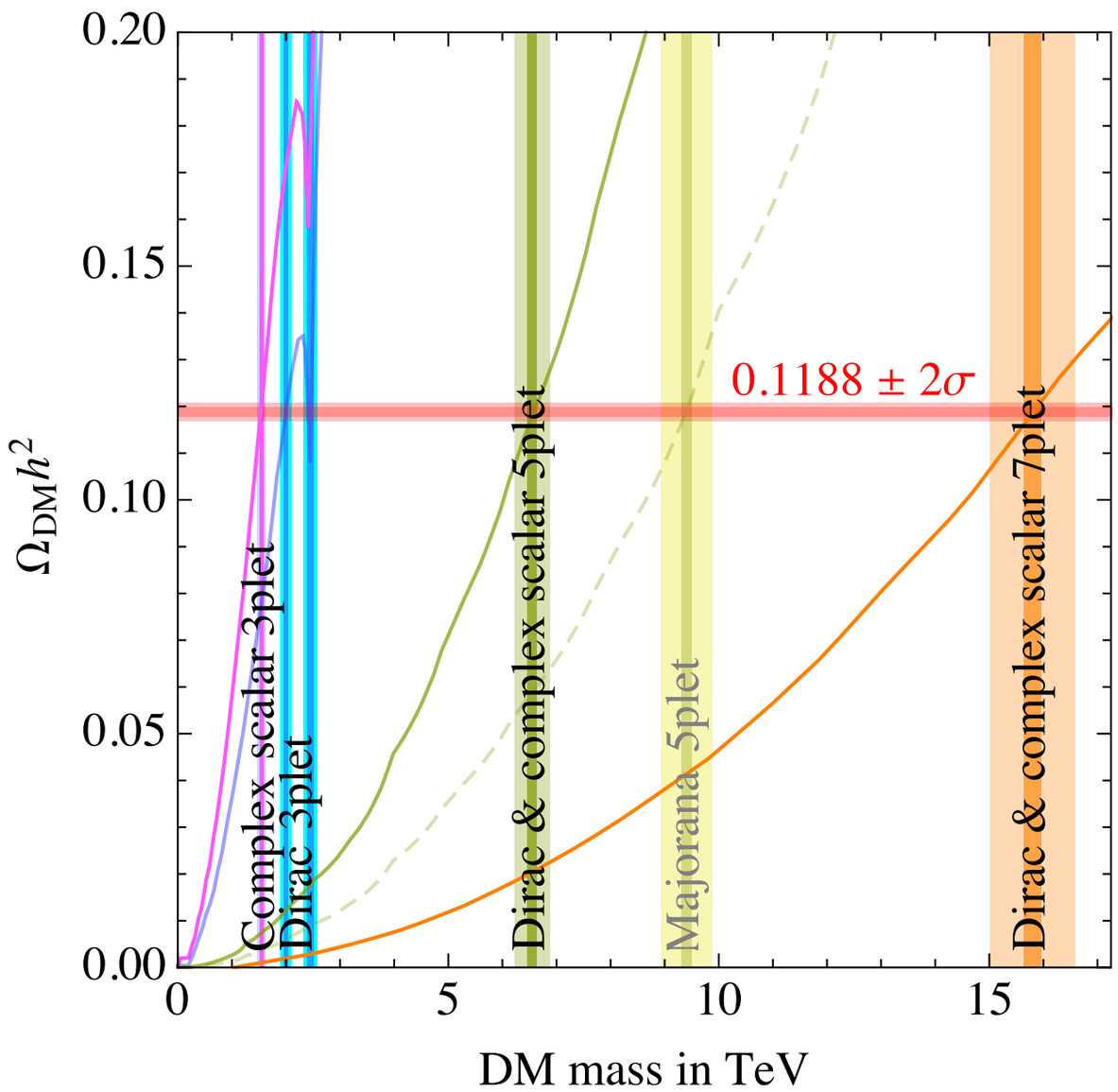
The millicharge ϵ must be small: only weak interactions matter

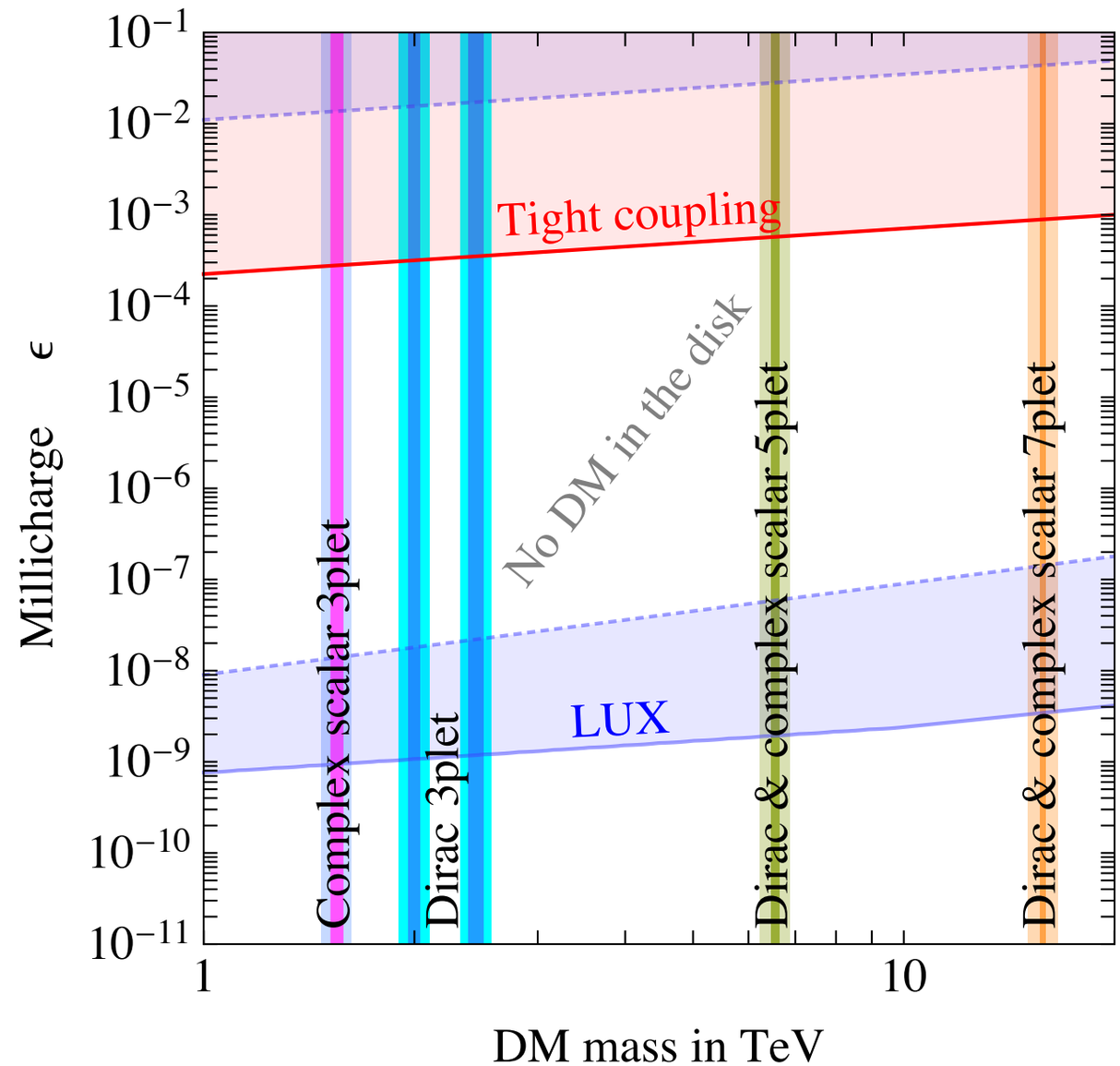
However, any $\epsilon \neq 0$ implies a **doubling of degrees of freedom**

This changes the relic density and therefore the DM mass

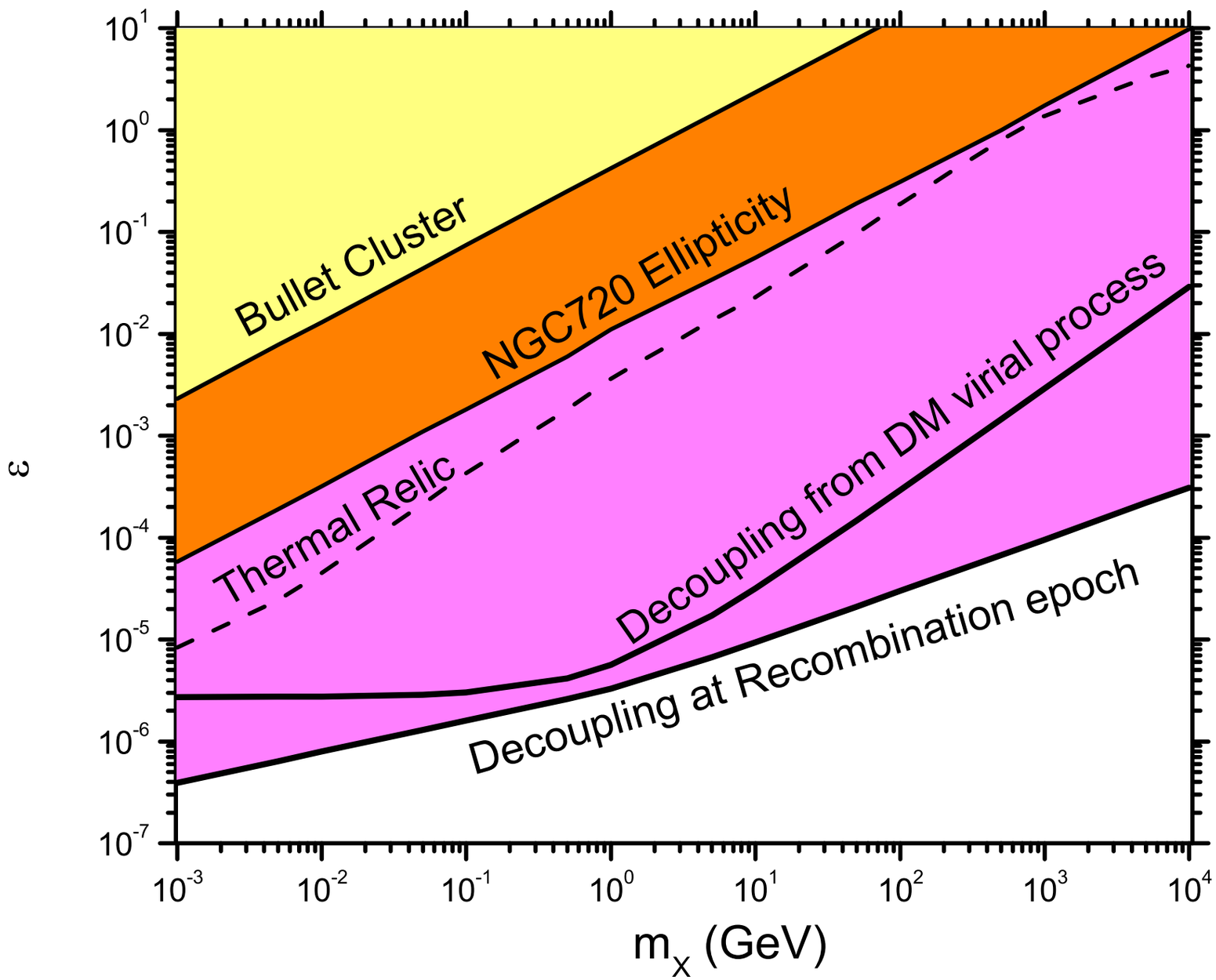
Also changes the bounds from indirect detection

Millicharged MDM



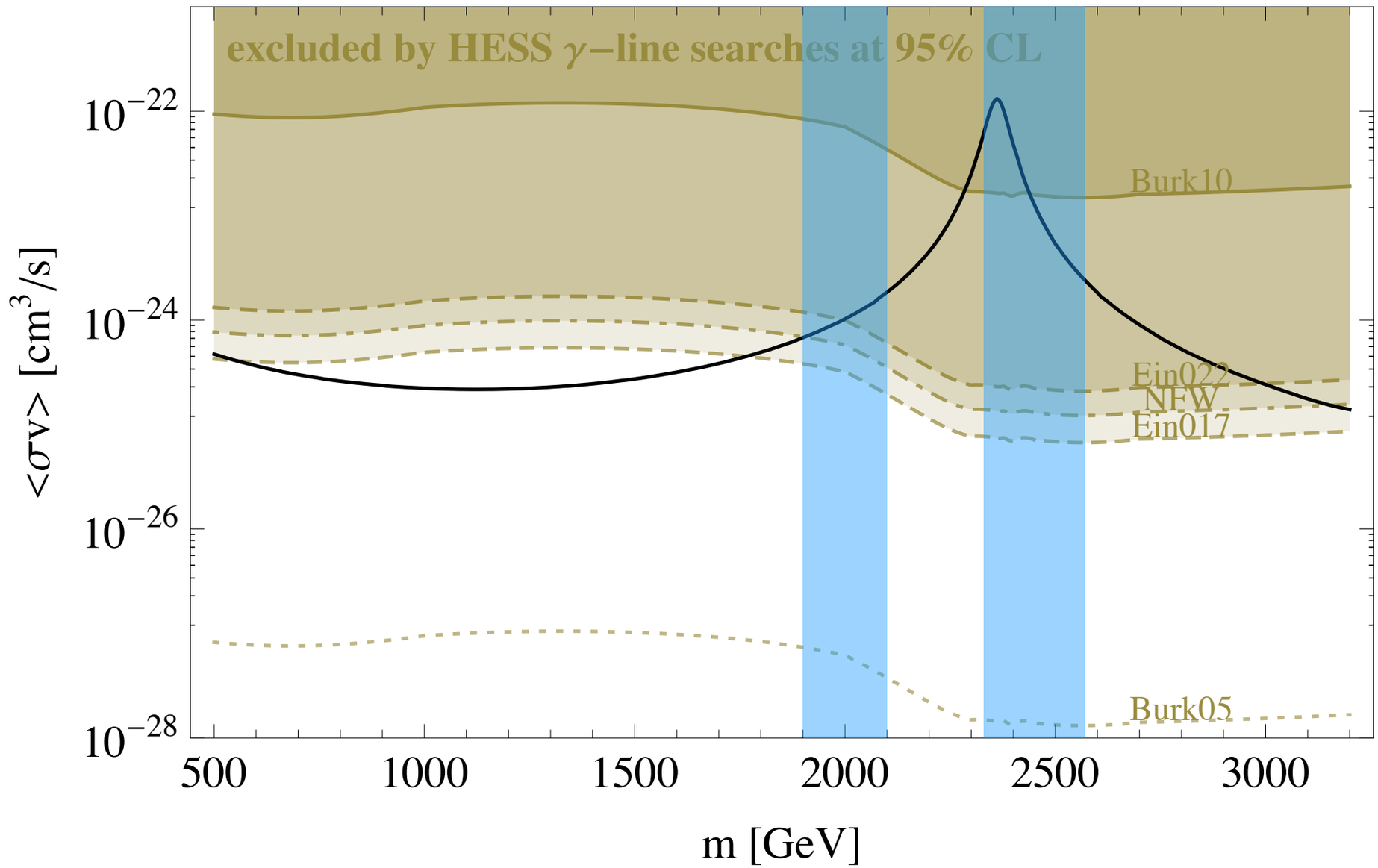


Millicharged MDM: Dirac singlet



arXiv:1011.2907

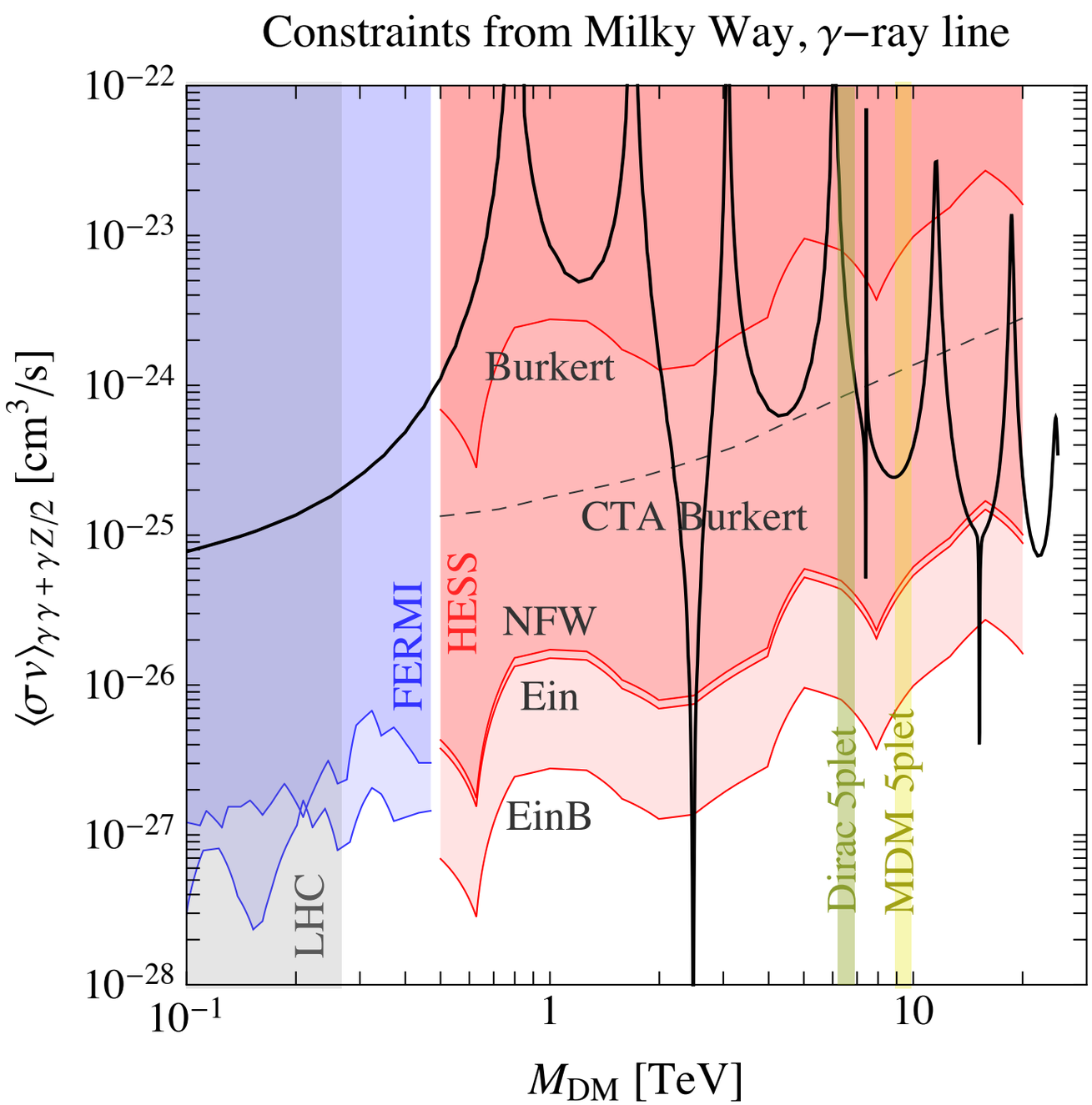
Millicharged MDM: Dirac triplet



All bounds to be multiplied by 2

arXiv:1401.6212

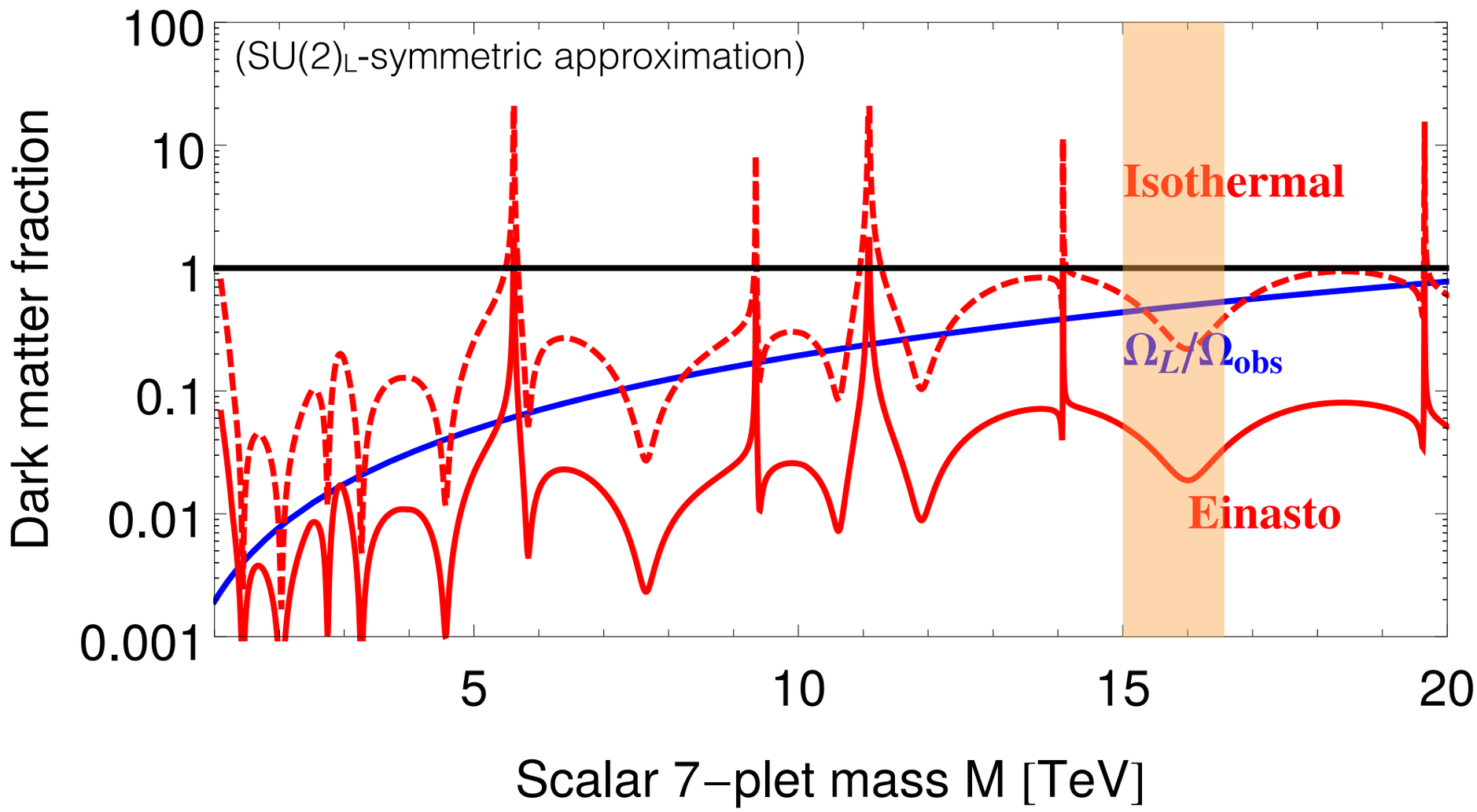
Millicharged MDM: Dirac quintuplet



All bounds to be multiplied by 2

arXiv:1507.05519

Millicharged MDM: Complex scalar eptaplet



All bounds to be multiplied by 2

arXiv:1512.03332

Conclusions

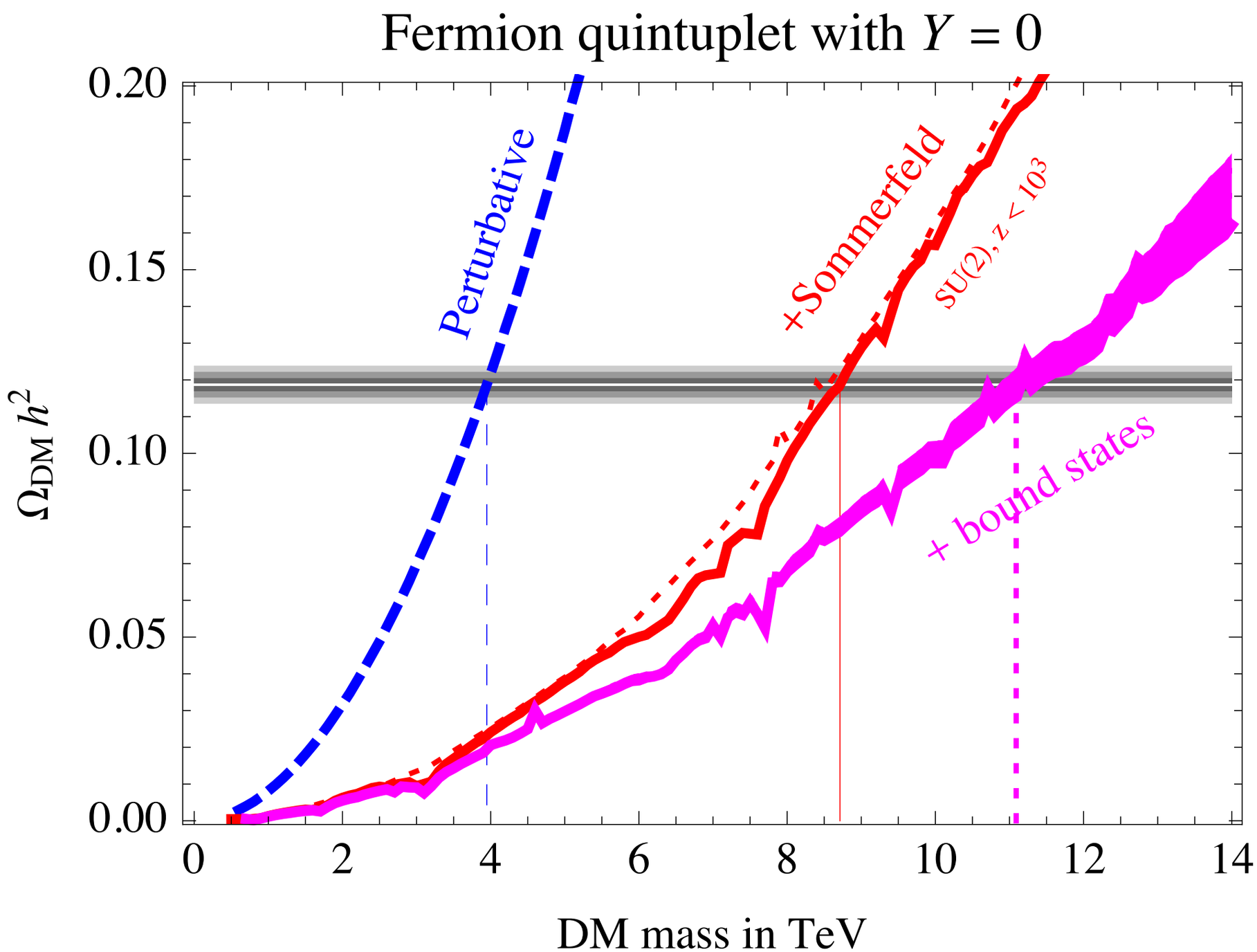
MDM dead or close to discovery

MDM decays can give a handle on new physics scale

New host of millicharged MDM candidates to be probed

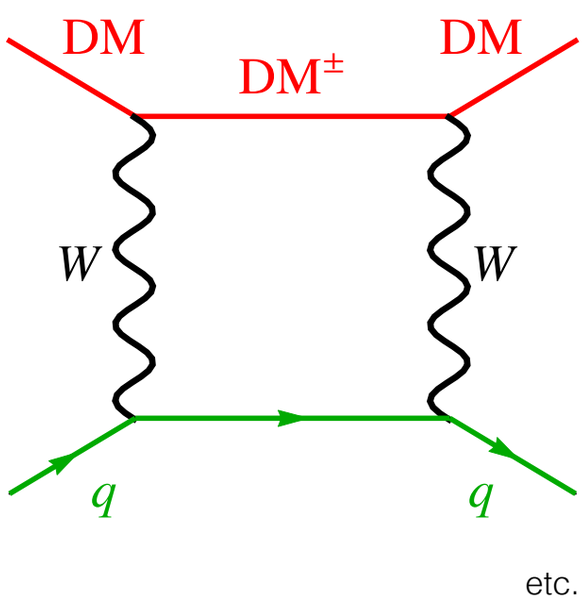
Backup slides

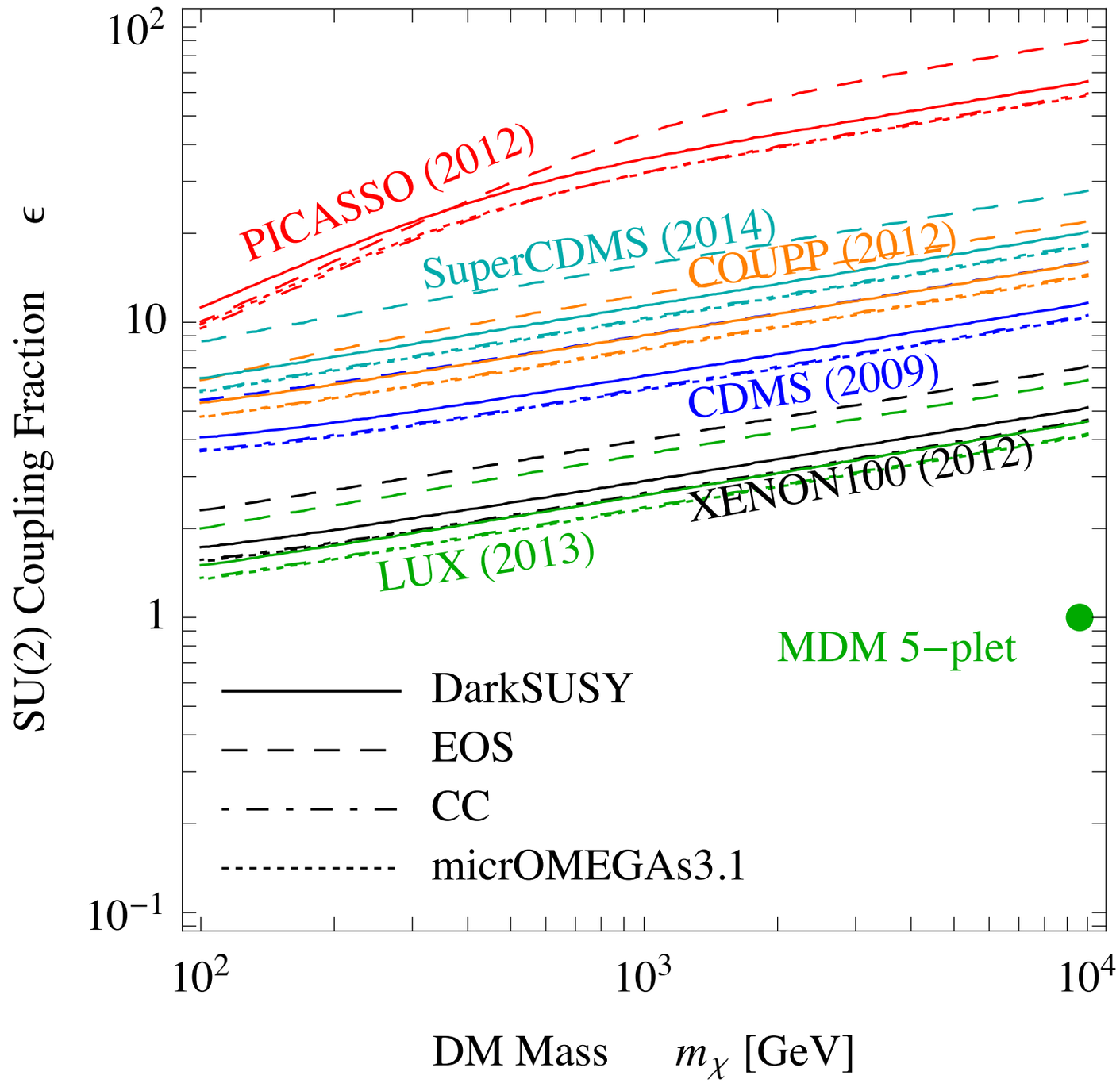
Majorana quintuplet



arXiv:1702.01141

Majorana quintuplet

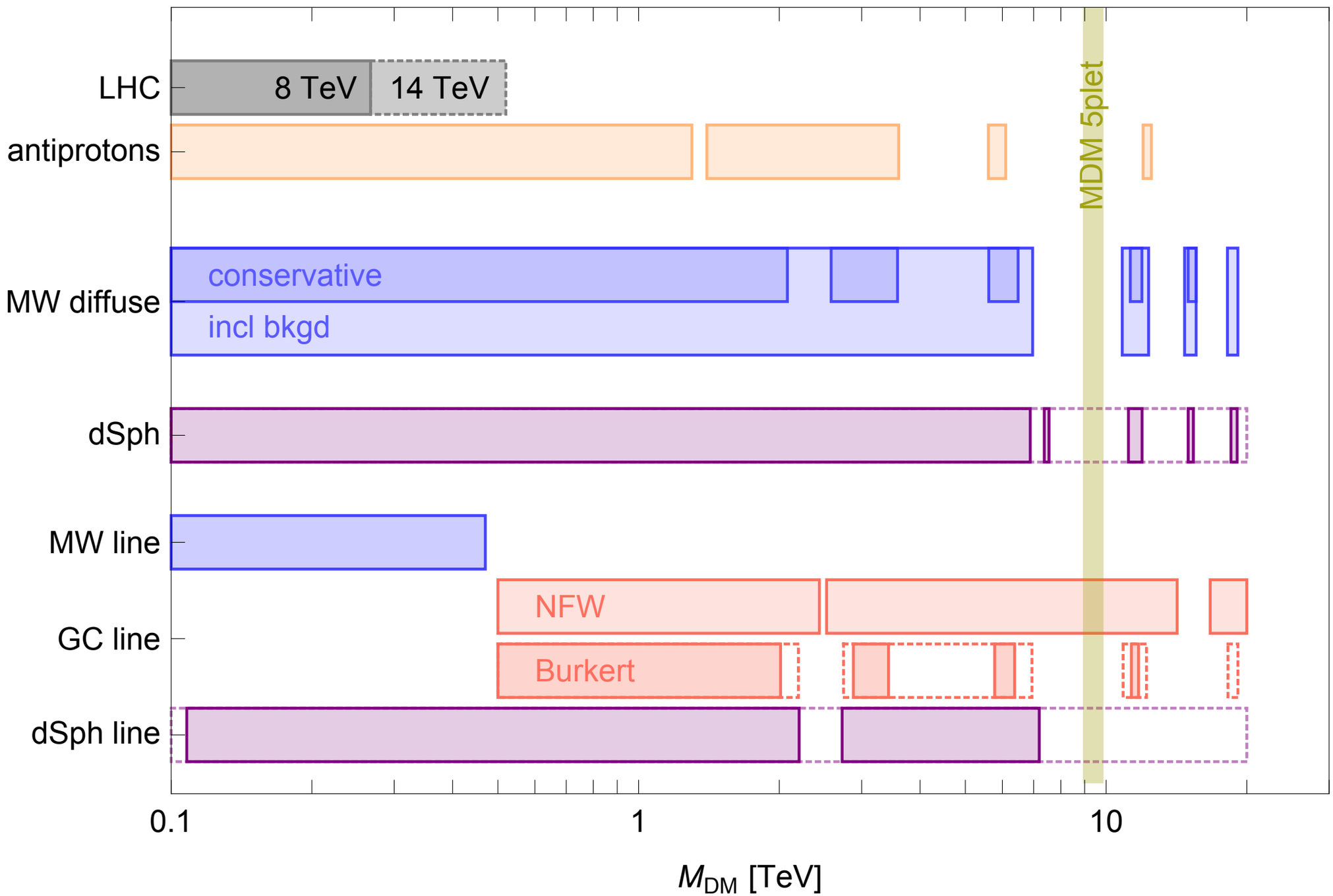




arXiv:1307.5955

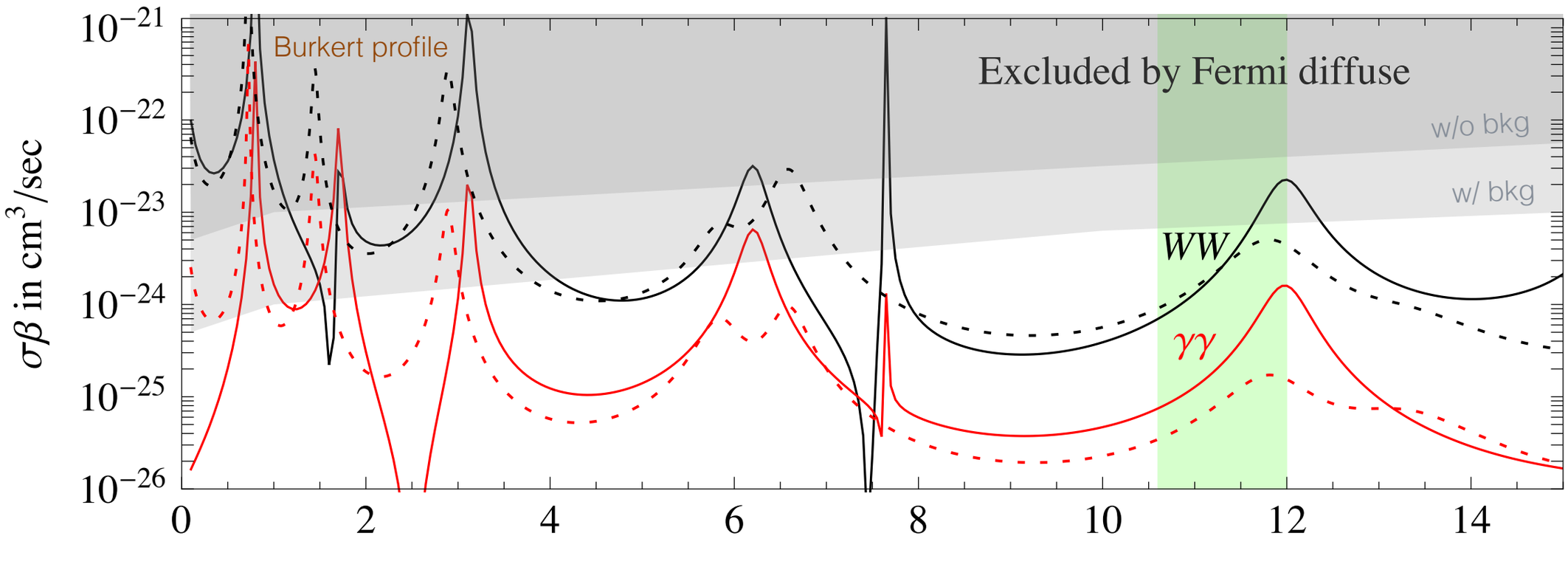
Majorana quintuplet

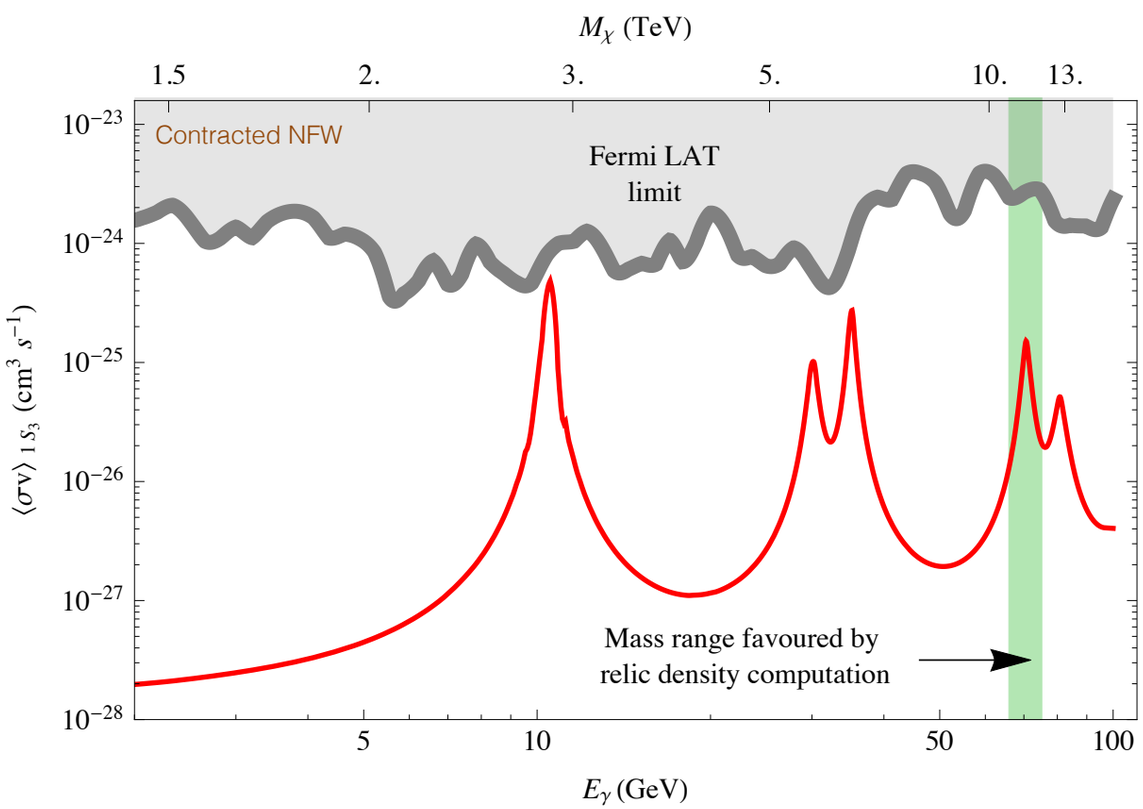
Summary of constraints (solid edge) and reaches (dashed edge)

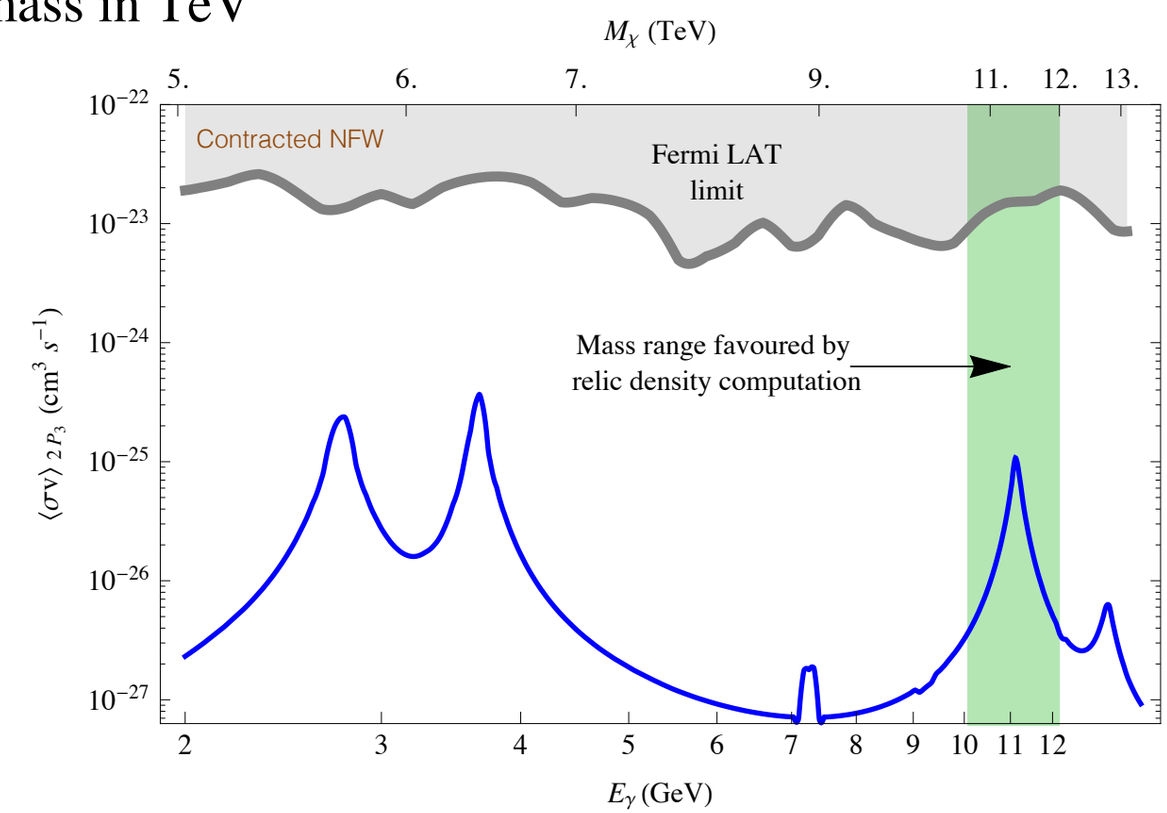


arXiv:1507.05519

Majorana quintuplet







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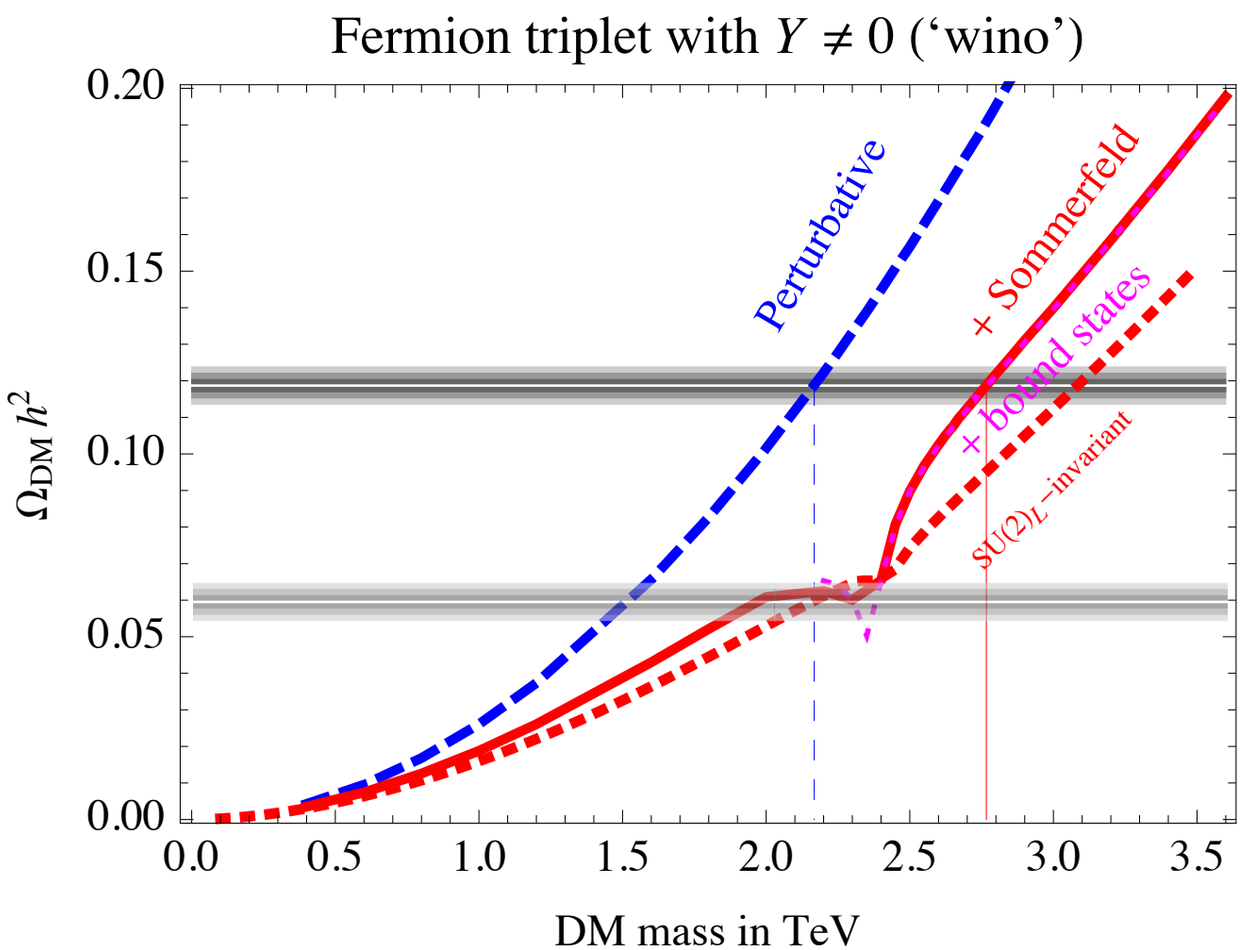
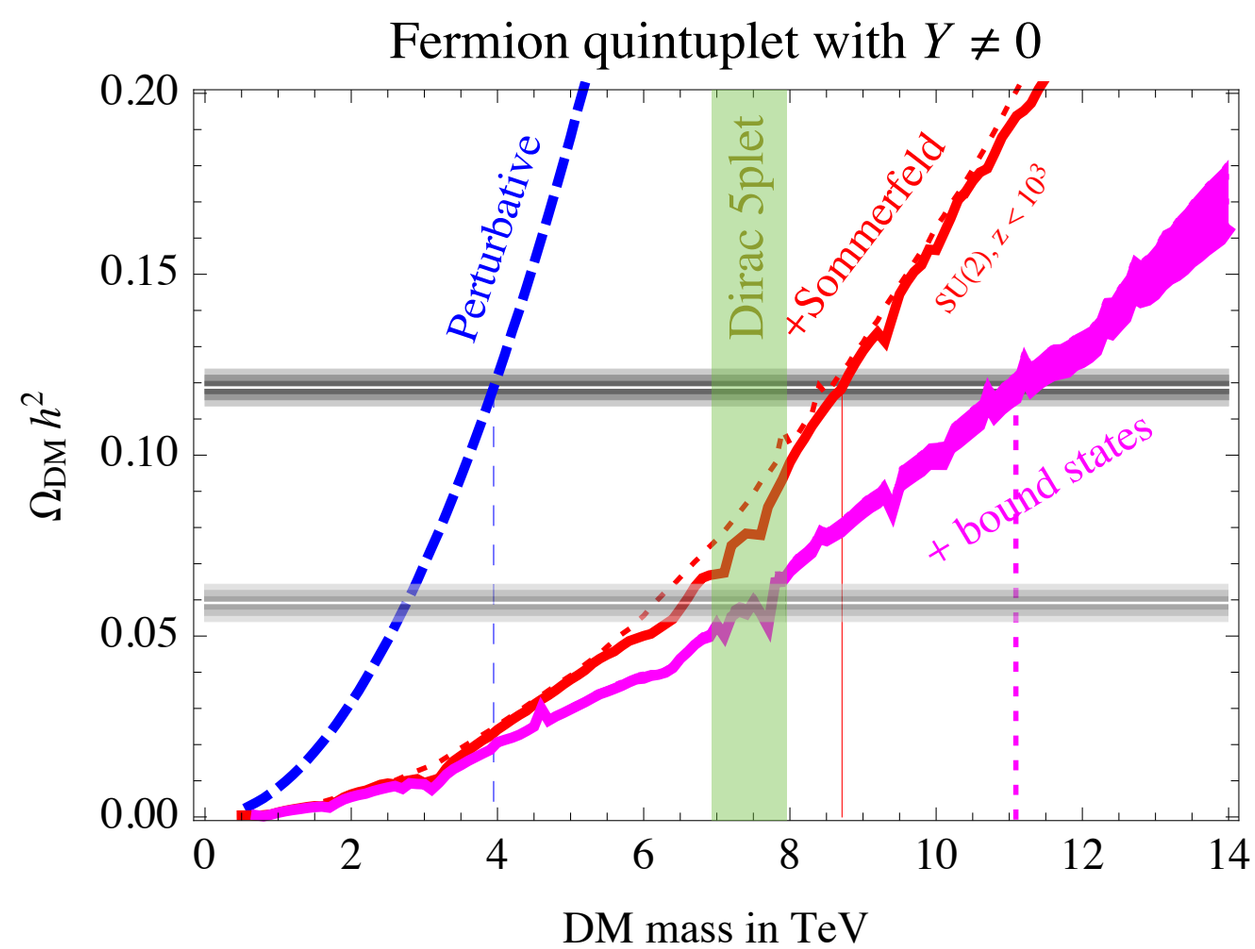
Millicharged MDM





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