DARK MATTER IN E_6 UNIFICATION

Jakob Schwichtenberg

based on JHEP 02 (2018) 16

September 25, 2018

Institut für Theoretische Teilchenphysik, Karlsruhe Institute of Technology

Can (a larger gauge) symmetry tell us anything about dark matter?

WHICH GROUP?

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- Only 5 exceptional groups!
- non-self-conjugate fermion representation
  $\rightarrow$ no mirror fermions
  $\Rightarrow E_6$
- Automatic absence of anomalies, fermions in the fundamental representations, ...

E_6

PARTICLE CONTENT

- **Fermions** in the fundamental 27-dimensional representation

$$27 = 16 \oplus 10 \oplus 1 = 16 \oplus (D, N_E, E, E^c, N_E^c, D^c) \oplus 1 \tag{1}$$

  (3 generations)
- **Gauge Bosons** in the adjoint 78-dimensional representation
- Only **Scalars** that couple to fermions $(27 \otimes 27)_s = 27 \oplus 351'$

FERMION MASSES

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- Yukawas for SM and exotic fermions have common origin $\rightarrow$ Fit, such that SM masses are correctly reproduced
- **Exotic fermions superheavy**
- **Lightest exotic generation**: $M > 10^9$ GeV

STABILITY

- E_6 (rank 6) $\rightarrow$ SO(10) (rank 5)
  $\Rightarrow$ possibly **discrete remnant symmetry**;
  (L. M. Krauss and F. Wilczek; Phys. Rev. Lett. 62 (Mar, 1989) 1221–1223)
- In our breaking chain: $E_6 \rightarrow \ldots \rightarrow SM \otimes \mathbb{Z}_2$
- Under SO(10) $\otimes \mathbb{Z}_2$: $27 = 1^+ \oplus 10^+ \oplus 16^-$

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- Under SO(10) $\otimes \mathbb{Z}_2$: $27 = 1^+ \oplus 10^+ \oplus 16^-$
- $\Rightarrow$ **Lightest exotic fermion is stable**

EXOTIC FERMIONS AS DM CANDIDATES

SO(10) singlet s

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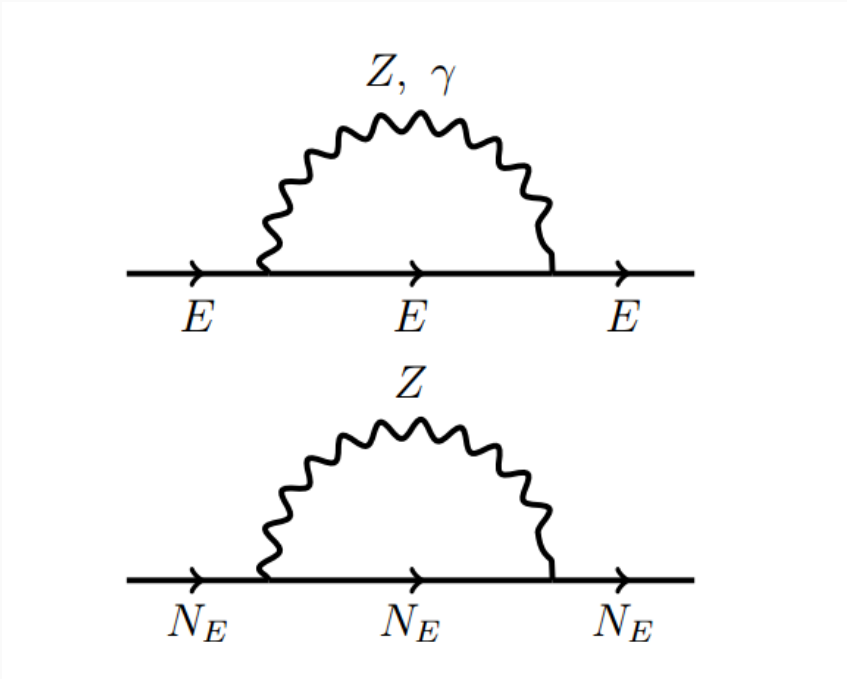
Color-charged D

- Bound on strongly interacting DM $\gtrsim 10^{15}$ GeV (direct detection experiments + IceCube) (Albuquerque et. al 0301188)
- $\lightning$ 10^{15} GeV $> Y_1 M_{E_6}$ for $M_{E_6} < M_{PL}$

Lepton doublet (N_E, E)

- Degenerate mass before breaking of $SU(2)_Y \times U(1)_Y$
- 

- $\Rightarrow m_{N_E} < m_E$
- N_E carries Hypercharge $\rightarrow$ phenomenologically interesting, although superheavy?

A SPECIFIC SCENARIO FOR N

BREAKING CHAIN

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$$E_6 \to ? \to SU(3)_C \otimes SU(2)_L \otimes U(1)_Y \otimes \mathbb{Z}_2$$

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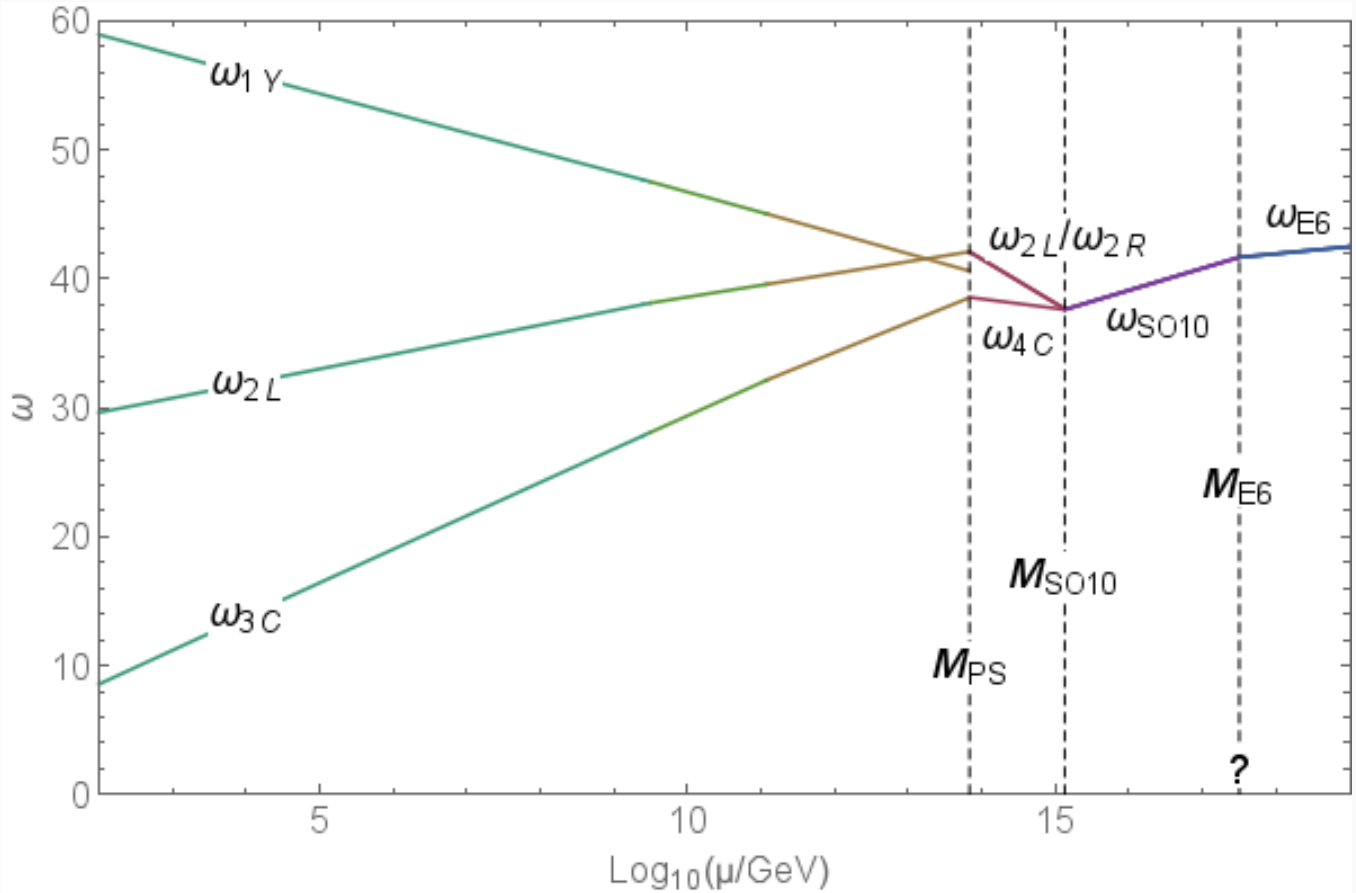
$$\begin{aligned} E_6 \to SO(10) \otimes \mathbb{Z}_4 &\to SU(2)_L \otimes SU(2)_R \otimes SU(4)_C \otimes D \otimes \mathbb{Z}_4 \\ &\to SU(3)_C \otimes SU(2)_L \otimes U(1)_Y \otimes \mathbb{Z}_2 \end{aligned}$$

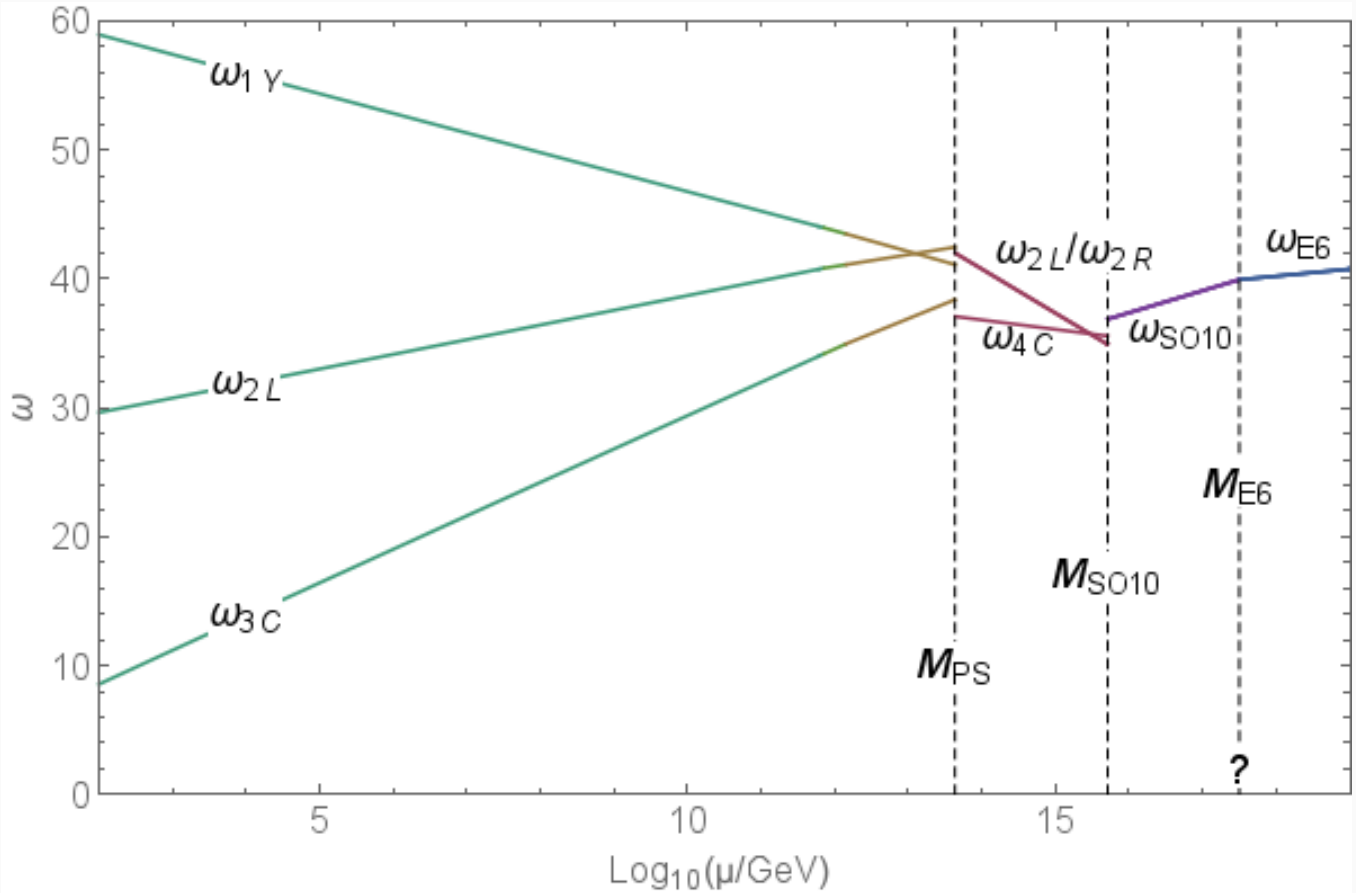
RGE RUNNING



Proton Lifetime: $\tau_P \approx \frac{M_{SO10}^4 \omega_{SO10}^2}{m_p^5} = 1.3 \cdot 10^{33}$ yrs $< 1.6 \cdot 10^{34}$ yrs

(Super-Kamiokande 1610.03597)

RGE RUNNING WITH THRESHOLD CORRECTION



Proton Lifetime: $\tau_P \approx \frac{M_{SO10}^4 \omega_{SO10}^2}{m_p^5} = 3.1 \cdot 10^{35}$ yrs $> 1.6 \cdot 10^{34}$ yrs

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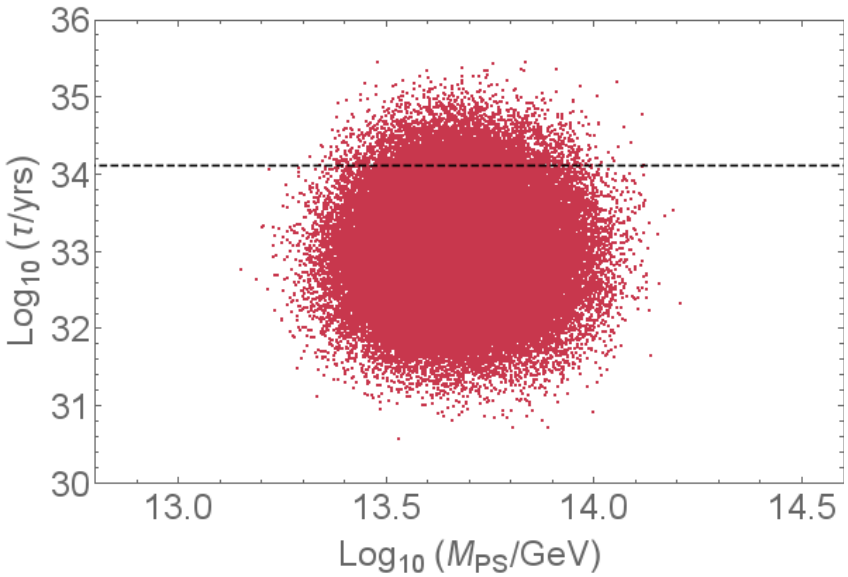
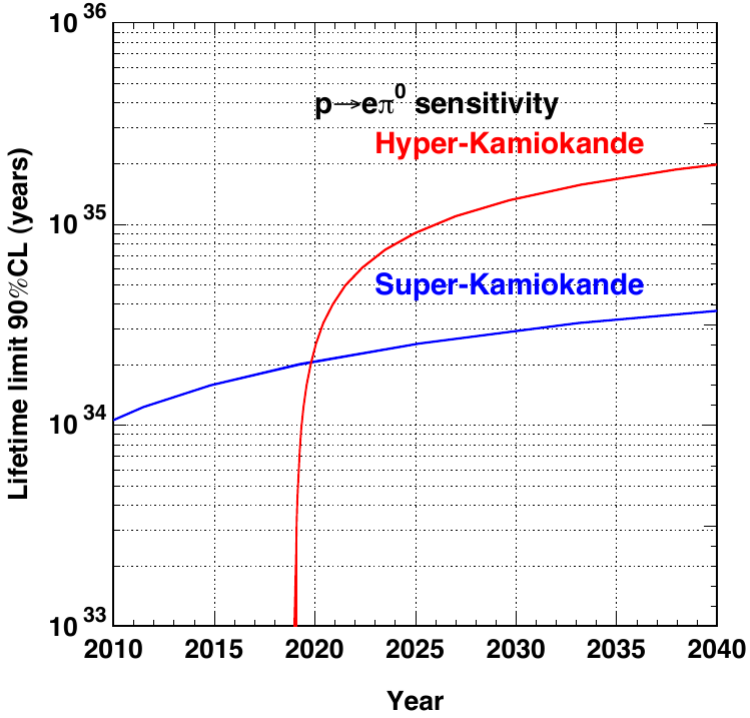
THRESHOLD CORRECTIONS



(a) $R \in \{\frac{1}{10}, 2\}$

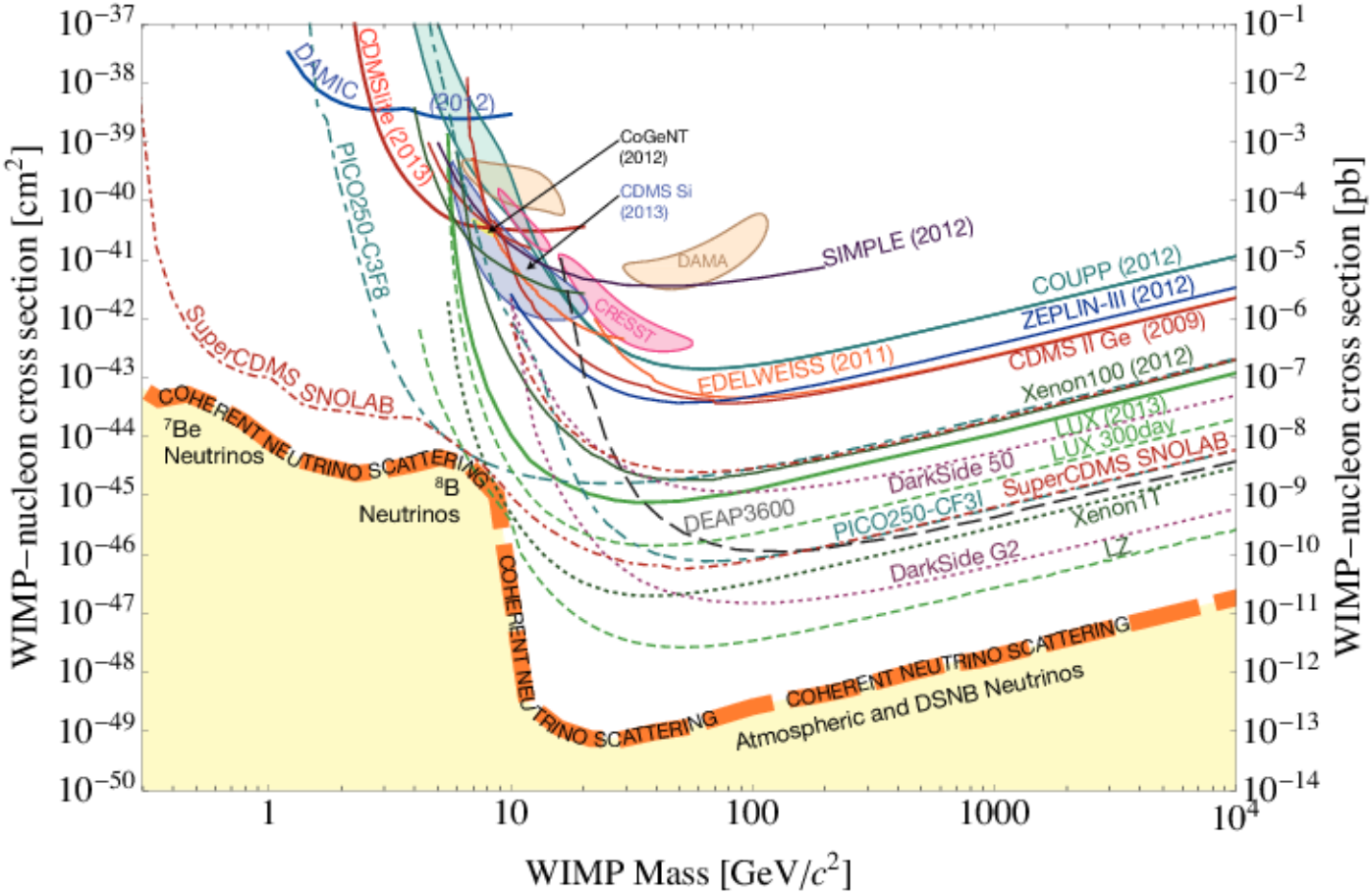


(b) From Letter of Intent: The Hyper-Kamiokande Experiment

Figure: Proton lifetime for randomized Scalar masses $M_S = RM_V$.

DETECTION

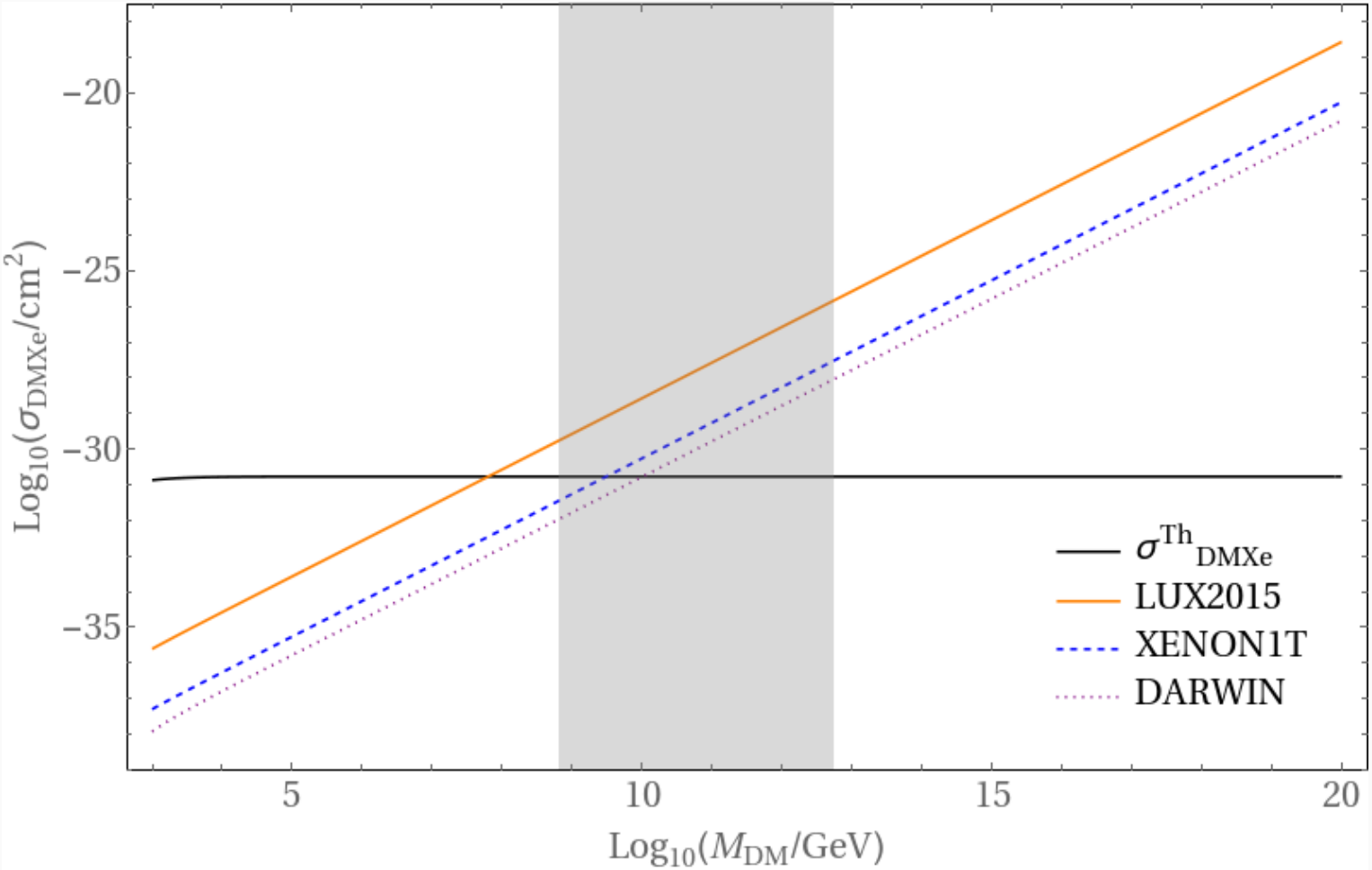
DIRECT DETECTION OF DARK MATTER



(J. Cooley 1410.4960)

DIRECT DETECTION OF SUPER HEAVY DARK MATTER

$$Y(N_E) \neq 0 \rightarrow \sigma_{DMN} = \frac{G_F^2 \mu_N^2}{2\pi} \cdot \frac{1}{4}(N - 4\sin(\theta_W)Z)^2$$



CONCLUSION

SUMMARY

- **Inherent DM candidates** in the fundamental fermionic 27 of E_6
- $E_6 \to SO(10) \to PS \to SM$
- **Proton lifetime** slightly above present bound through threshold corrections
- **Lightest exotic fermion** is **electrically neutral, but hypercharged and superheavy N_E**
- **Stable** through remnant $\mathbb{Z}_2$
- Possibly **direct detection signal** in the near future