A new connection between WIMP dark matter and the hierarchy problem

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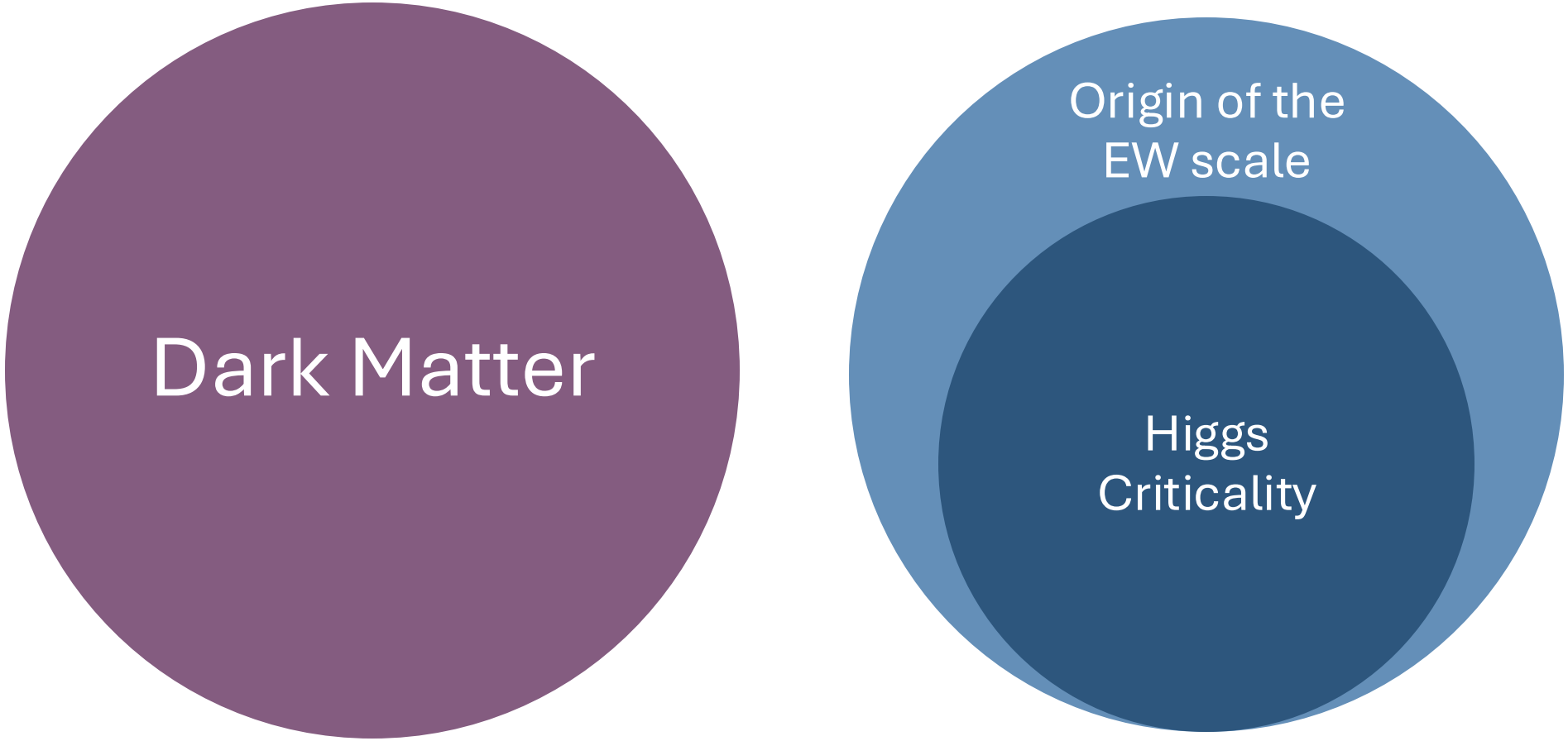
Work with Thomas Steingasser (MIT/IFT) and Tevong You (KCL)

arXiv:2512.xxxxx

When Two Mysteries Meet: The Hierarchy Problem and Dark Matter



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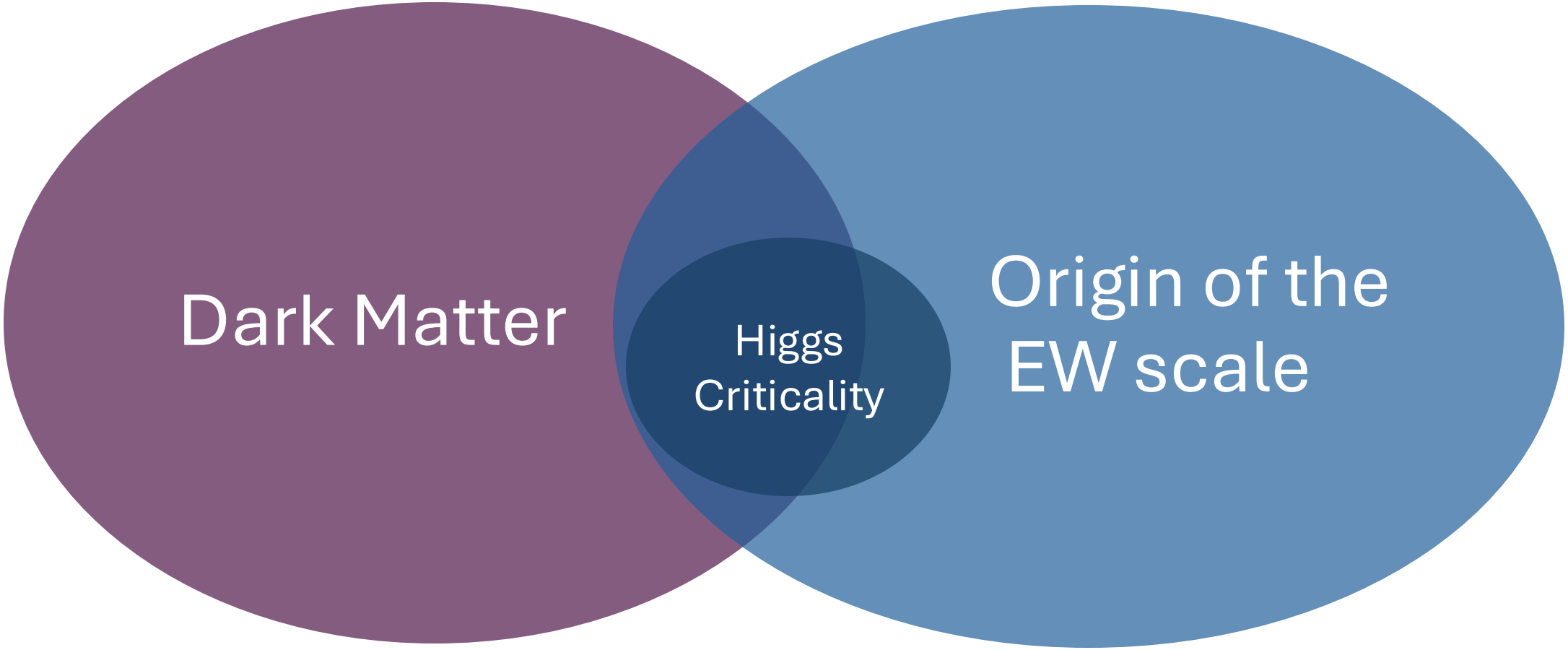
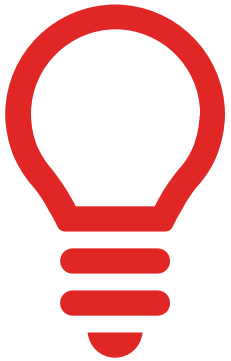


The Key Points



Idea of Higgs Criticality

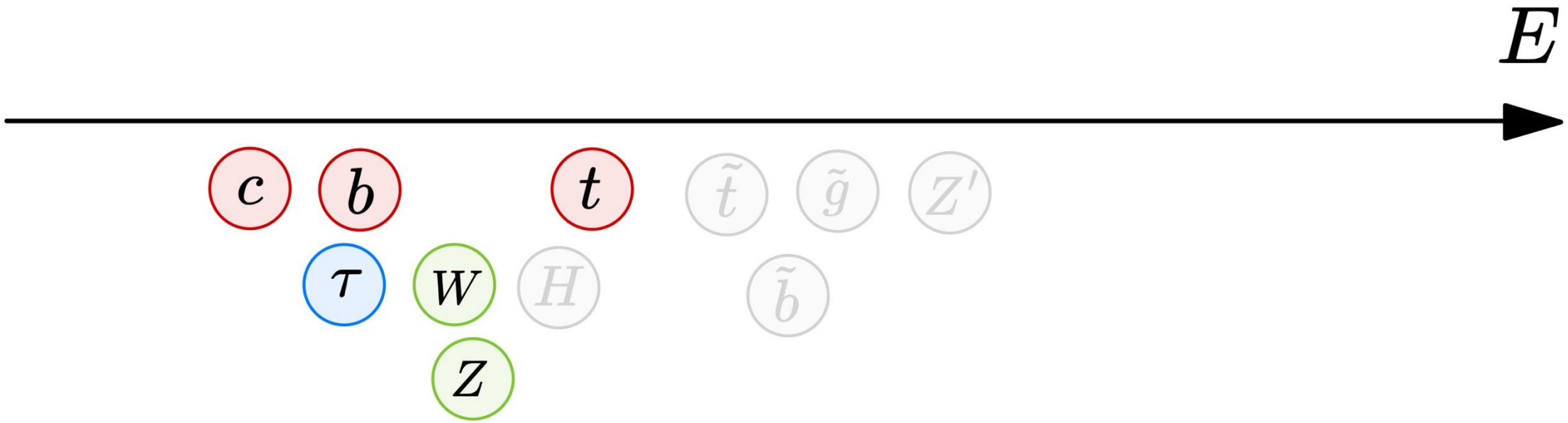
Implications of Higgs Criticality for Dark Matter searches

Part I: Higgs Criticality

Going beyond naturalness: A dynamical mechanism setting the weak scale

The Hierarchy Problem

't Hooft '79; Craig '22; McCullough '24 and many more



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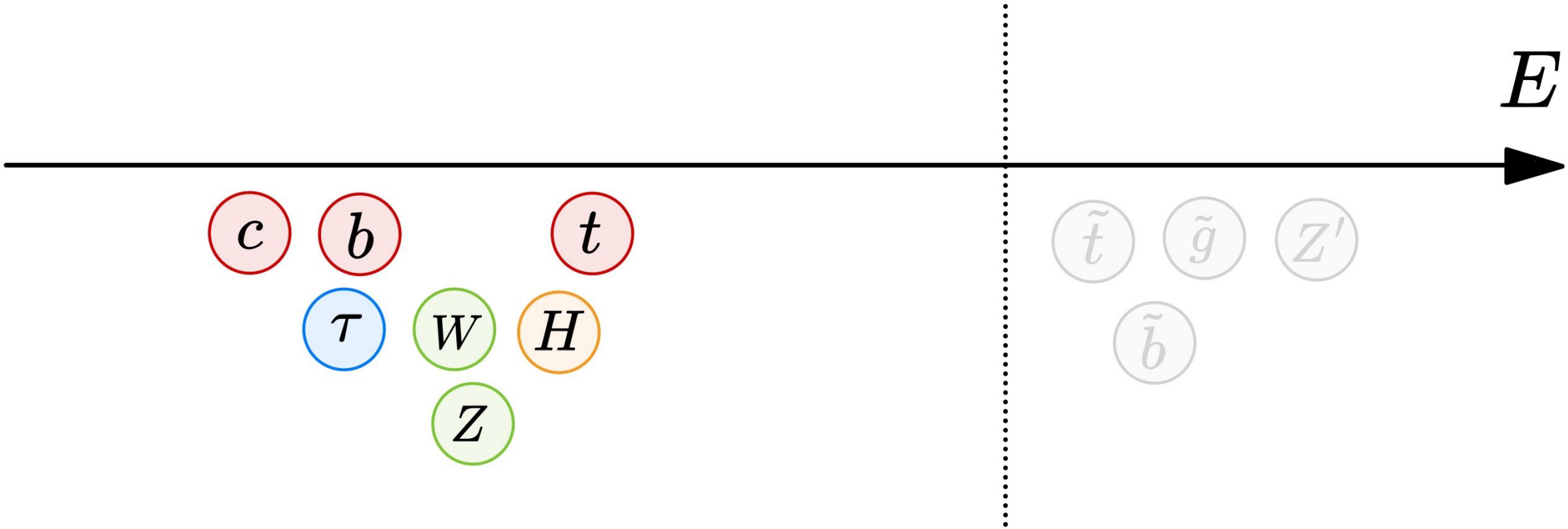
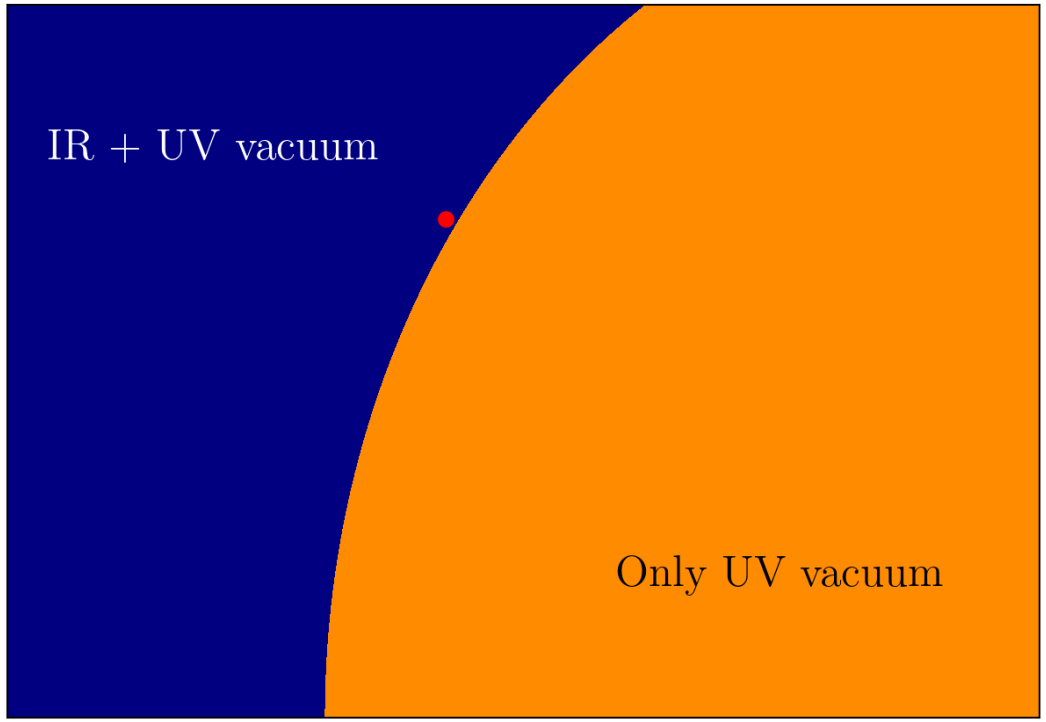


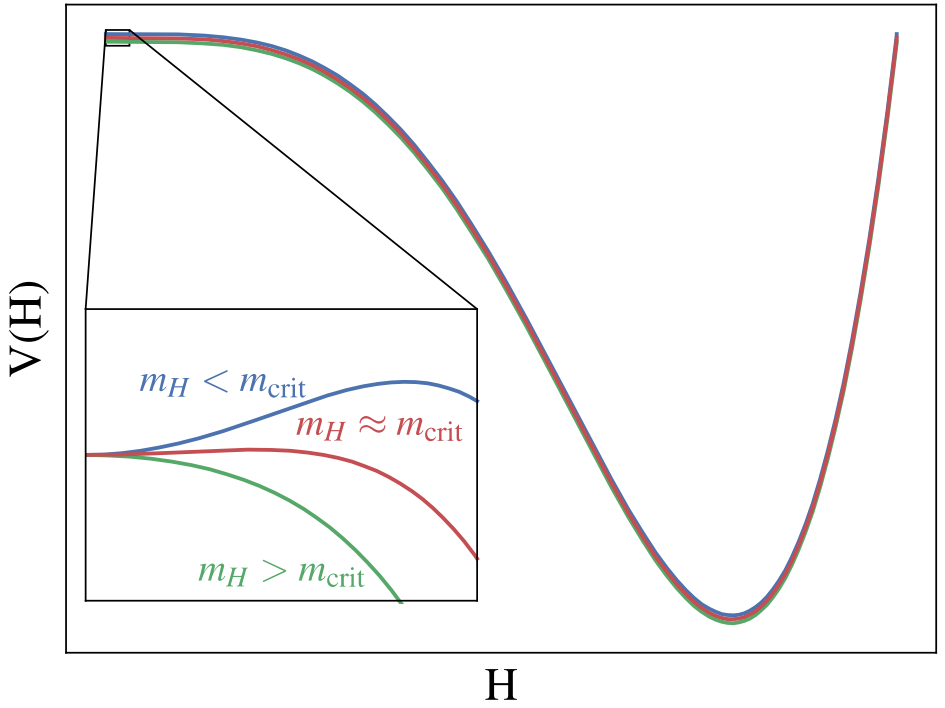
Higgs Criticality

Khoury, Parrikar '19; McCullough, Giudice, You '21; Benevedes, Ismail, Steingasser '25; Steingasser '24

Phase diagram

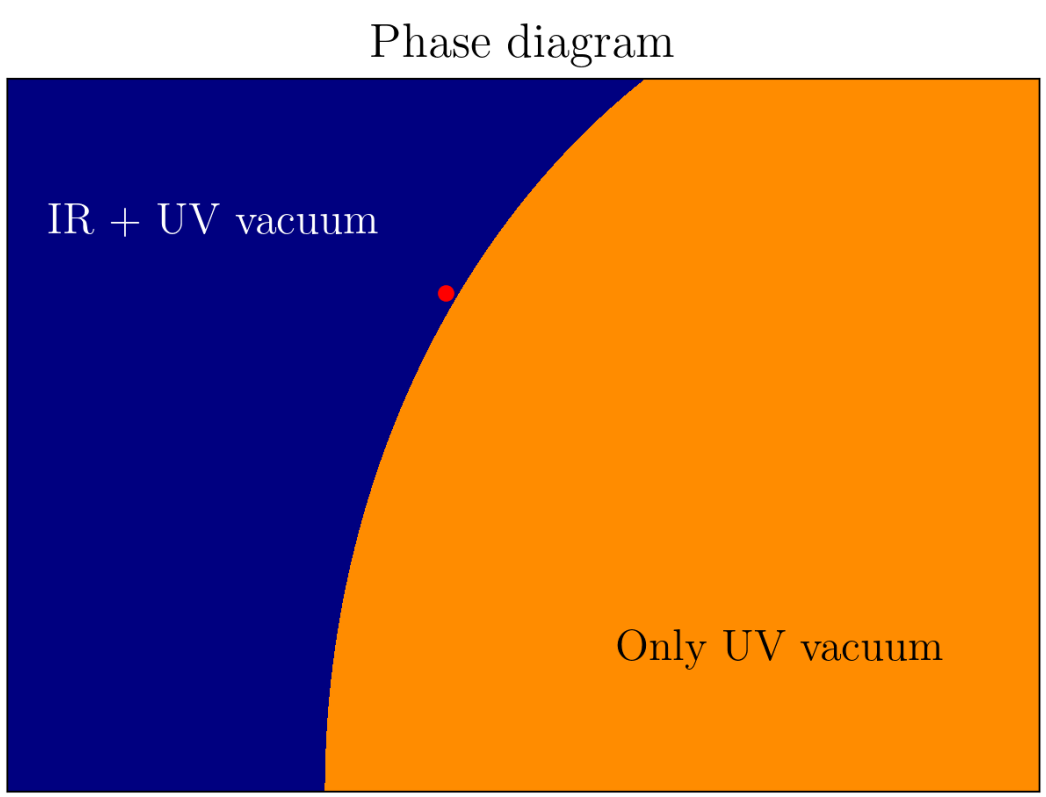


$$V(H) = -m_H^2 H^2 + \lambda H^4$$



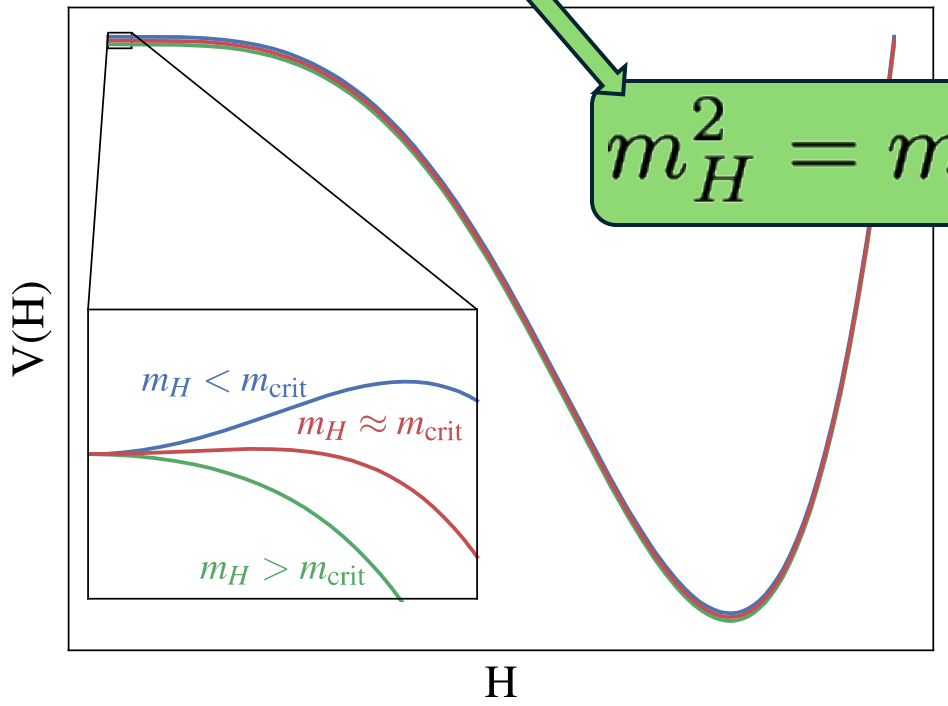
Higgs Criticality

Khoury, Parrikar '19; McCullough, Giudice, You '21; Benevedes, Ismail, Steingasser '25; Steingasser '24

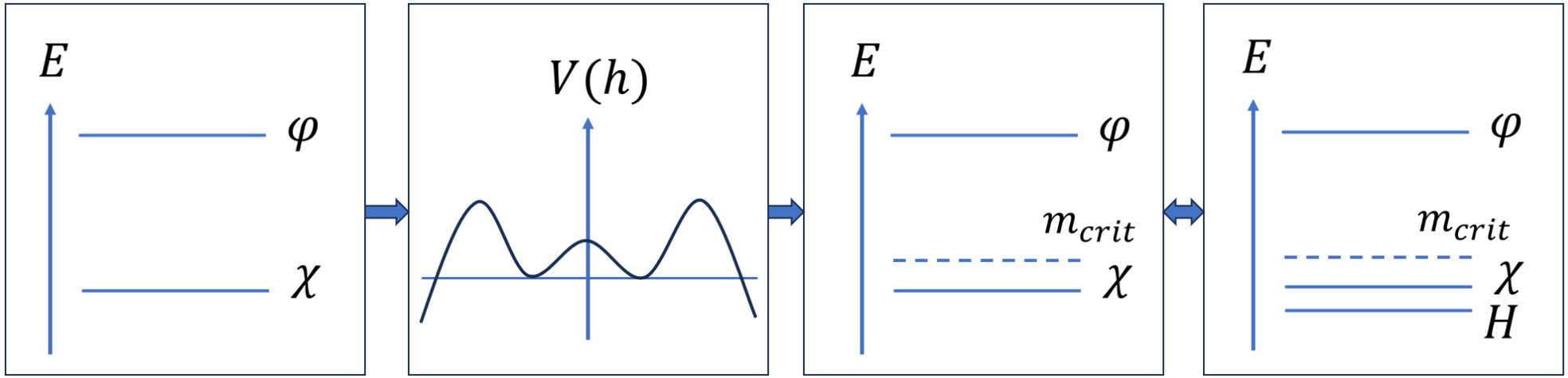


$$V(H) = -m_H^2 H^2 + \lambda H^4$$

$$m_H^2 = m_0^2 + g\phi$$



Predictions of Higgs Criticality



Split spectrum expected from naturalness: Light fermions and heavy scalars

Split spectrum can destabilise the Higgs potential

This implies an upper bound on the Higgs mass for the EW vacuum to exist

A cosmological mechanism could place the Higgs mass close to this critical boundary

Part II: Implications for Dark Matter

When the lamppost is the right place to look

The Singlet-Doublet Model

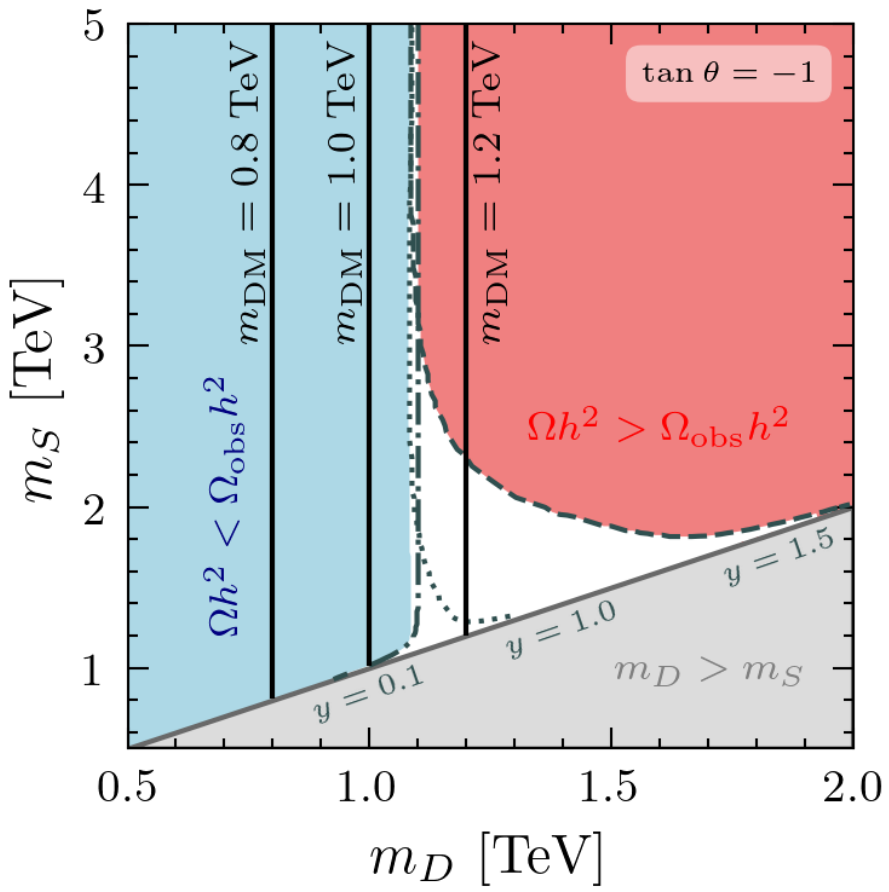
- SM extension with weak isospin doublet and singlet

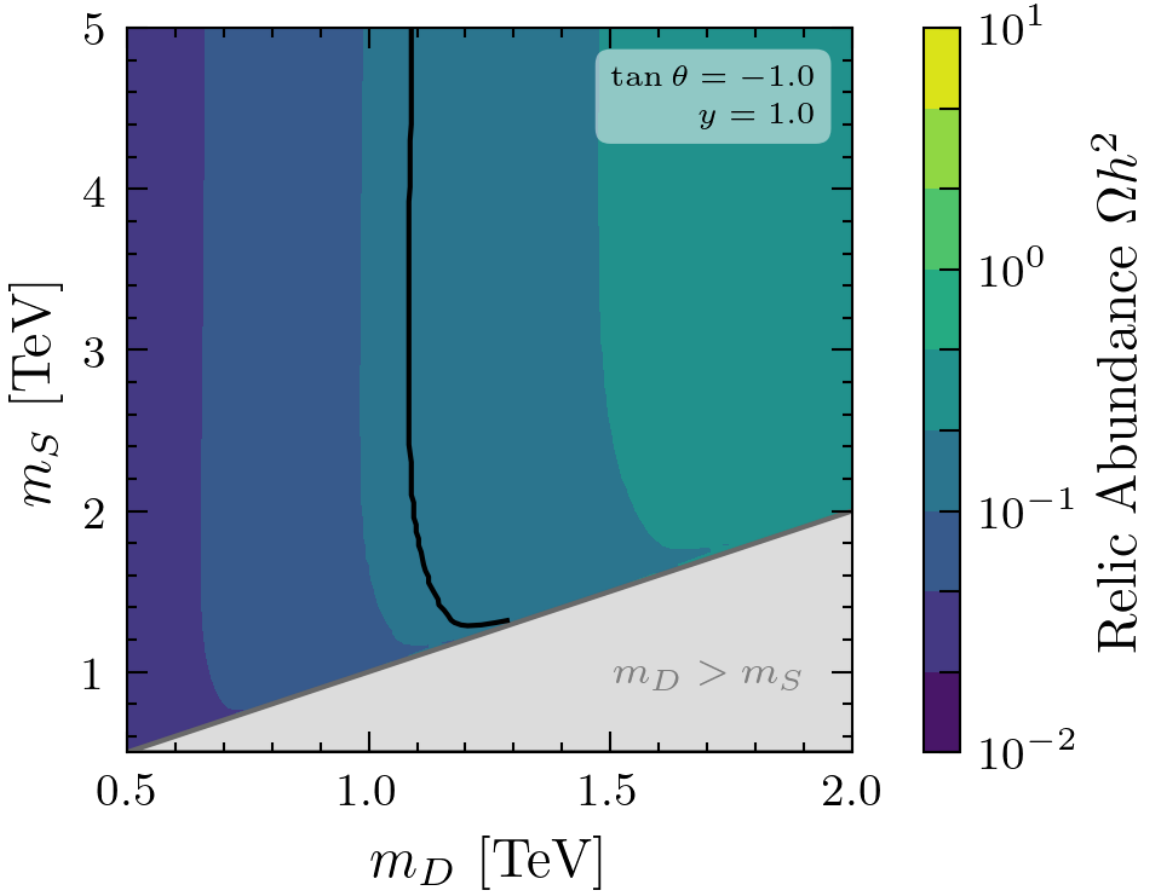
$$\mathcal{L}_{\mathrm{SD}} = i\bar{\psi}\partial\!\!\!/\psi + i\bar{\chi}_u \not{D}\chi_u + i\bar{\chi}_d \not{D}\chi_d$$
$$- \frac{1}{2} m_S \psi^c \psi - m_D \chi_d \cdot \chi_u - y_1 \chi_u H^\dagger \psi - y_2 \chi_d \cdot H\psi + \mathrm{h.c.}$$

$$\chi_d = \begin{pmatrix} \chi_d^0 \\ \chi_d^- \end{pmatrix}, \quad \chi_u = \begin{pmatrix} \chi_u^+ \\ \chi_u^0 \end{pmatrix}$$

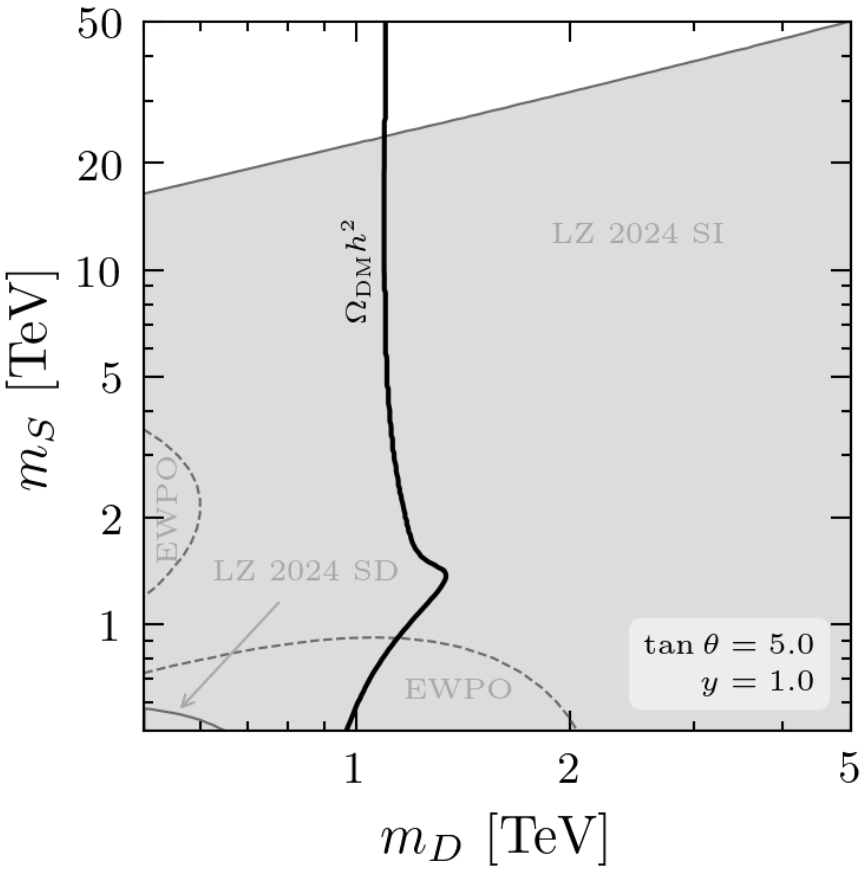
- Majorana DM candidate with weak scale mass

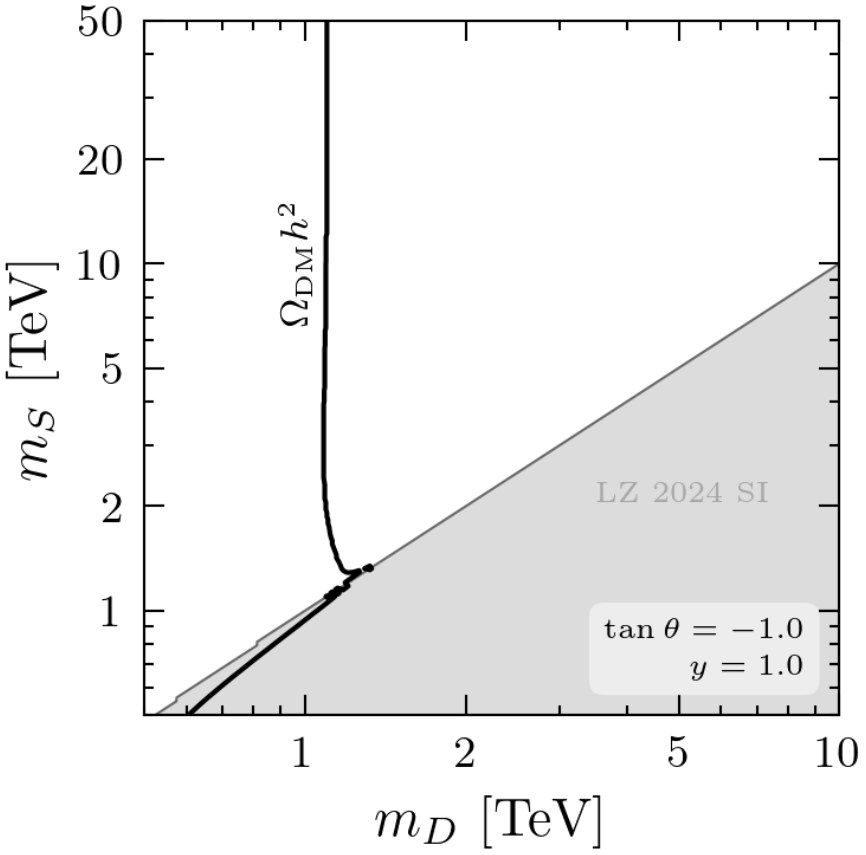
Implications for Dark Matter



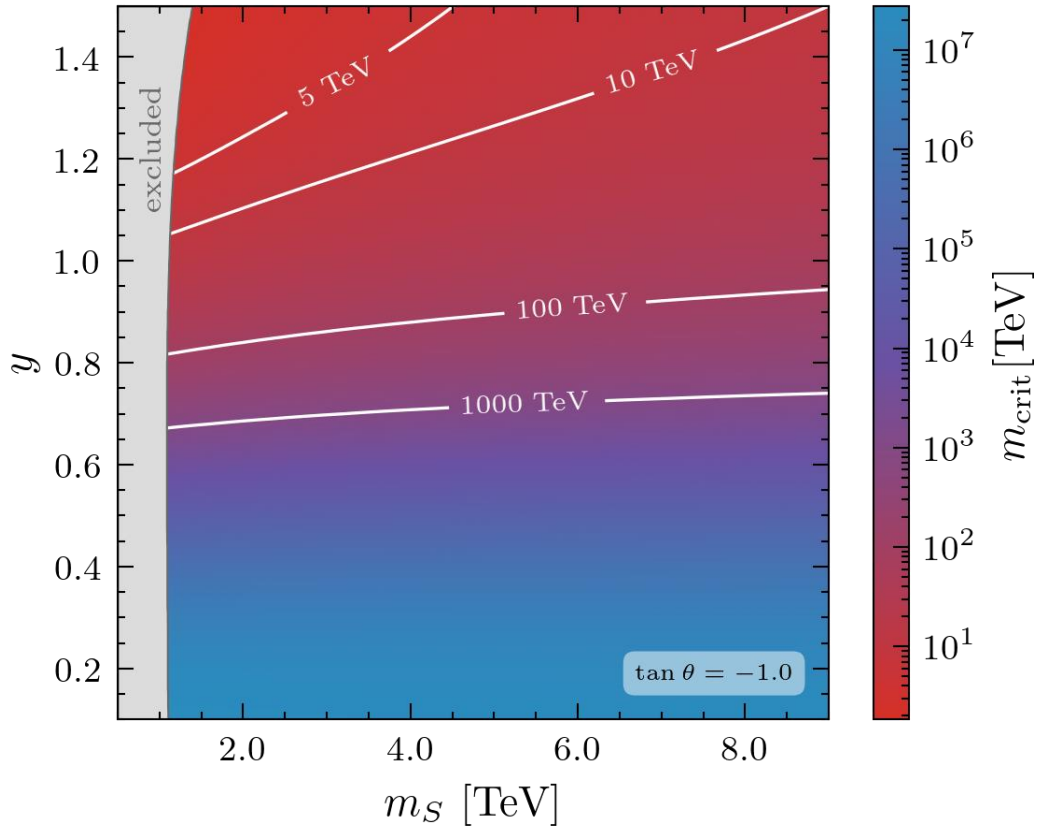


Implications for Dark Matter





The difference to natural solutions



- It is the WIMP that *dynamically* sets the mass scale for the Higgs!
- *WIMP miracle* could be more than just a coincidence of scales

Conclusion

- **Naturalness reframed:** A split spectrum remains a motivated organising principle in light of null LHC results
- **Key mechanism:** Light VL fermions + heavy bosons naturally yield a low metastability scale of the Higgs potential
- **WIMP miracle:** independently points toward the weak scale and the existence of VL fermions as WIMPs
- **Resulting picture:** The weak scale emerges dynamically form the interplay of VL WIMP DM and Higgs Criticality
- **Simplified model outcome:** singlet-doublet model prefers TeV-scale masses and sizeable Yukawa coupling; heavy new states must appear at 10-10^4 TeV to restore stability
- **Experimental prospects:** TeV-scale modifications of the Higgs potential are unavoidable; future collider and DM searches can probe essentially all viable parameter space