Scotogenic mechanism from a 3221 symmetry

[2507.XXXXX] (soon™)

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in collaboration with Avelino Vicente (IFIC, CSIC-UV)

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The scotogenic model

From ancient greek

Σκότος : Darkness
Γένος : Kin, generation

- Take the SM and **add a Z_2 symmetry**

$$SU(3)_C \times SU(2)_L \times U(1)_Y \times Z_2$$

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$$\eta \sim (\,\mathbf{2}, 1/2, -\,) \quad N^\sigma \sim (\,\mathbf{1}, 0, -\,)$$

- The η_0 VEV is zero, so that **$\boldsymbol{Z_2}$ is exact**

$$\langle \eta_0 \rangle = 0 \rightarrow Z_2 \text{ does not break}$$

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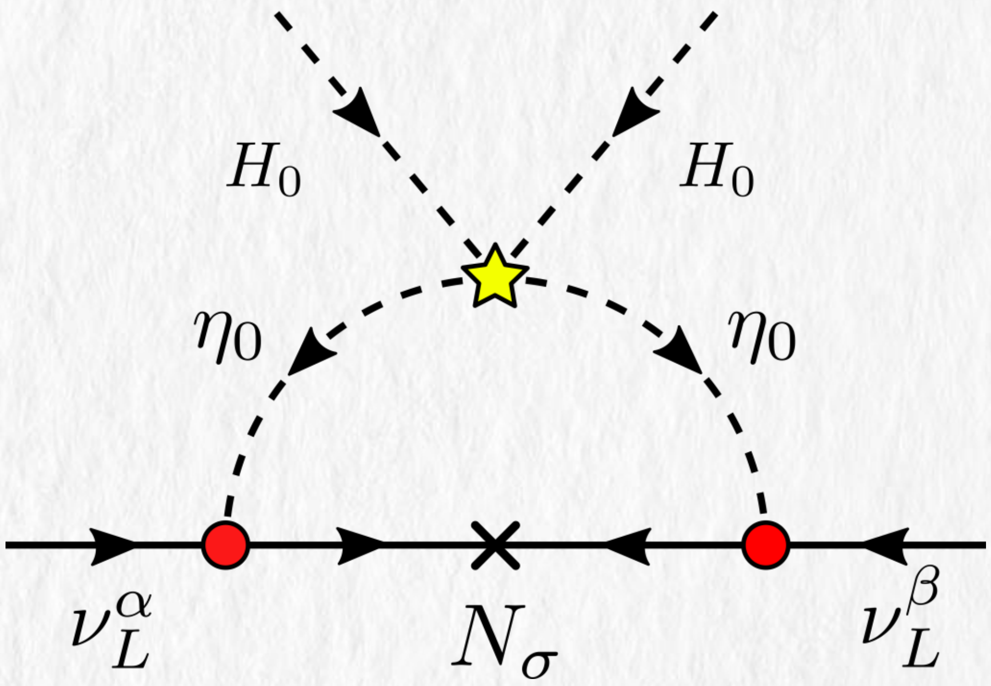

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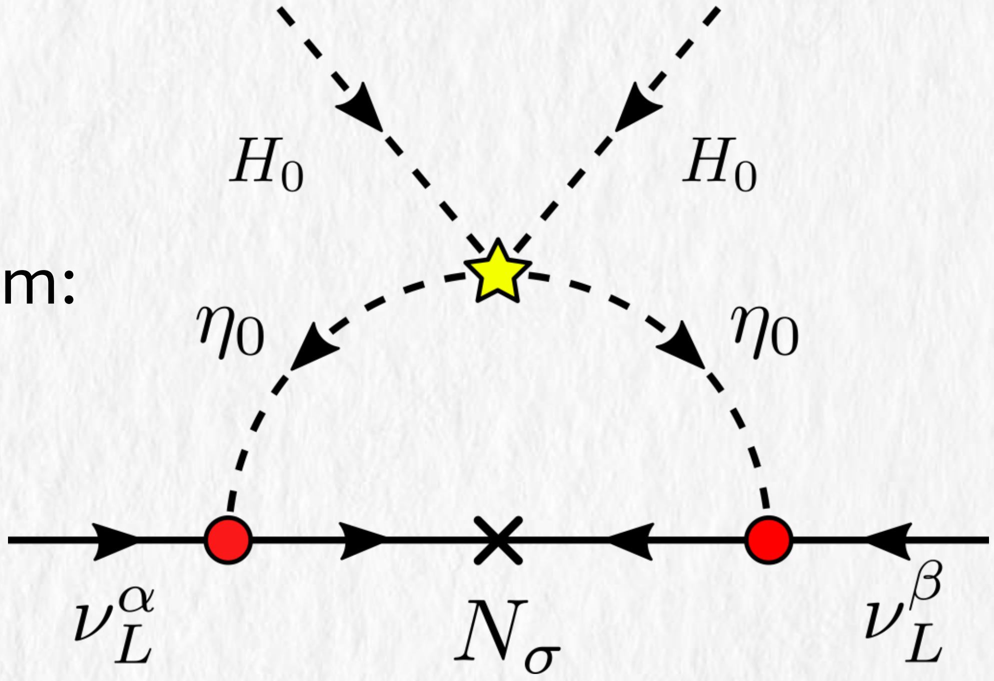
Radiative Majorana neutrino masses at 1-loop LO

Neutrino masses!

- The neutrino mass loop is generated from:



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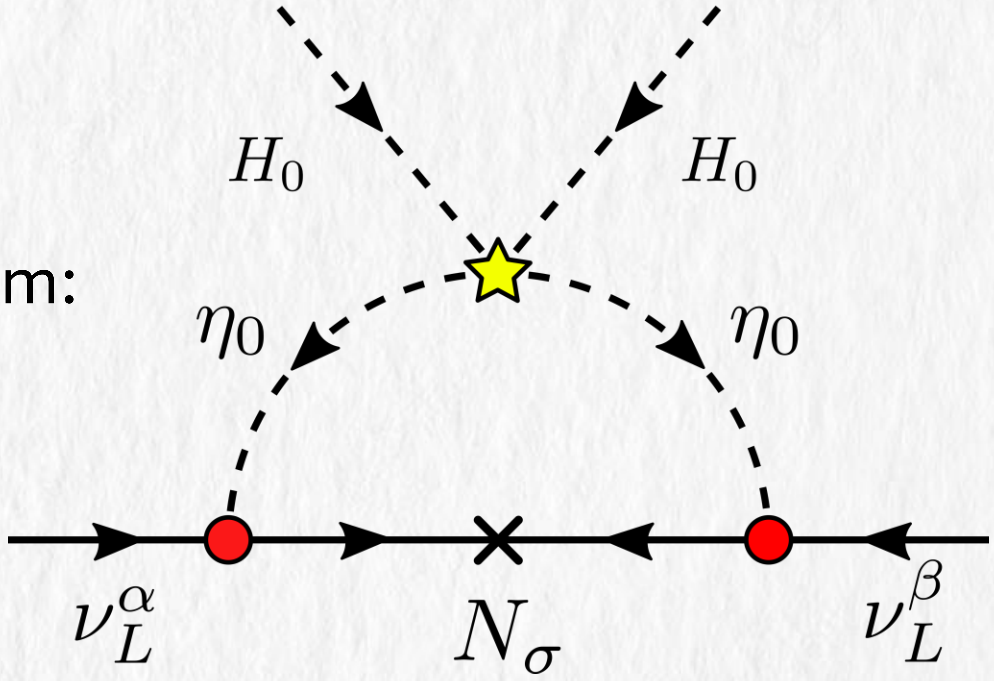

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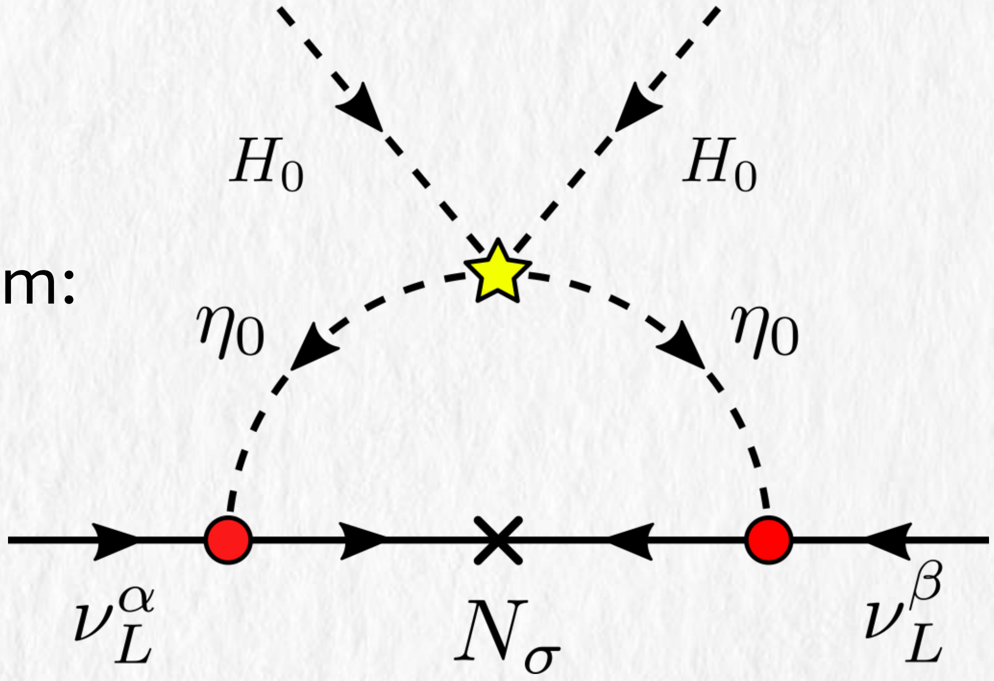

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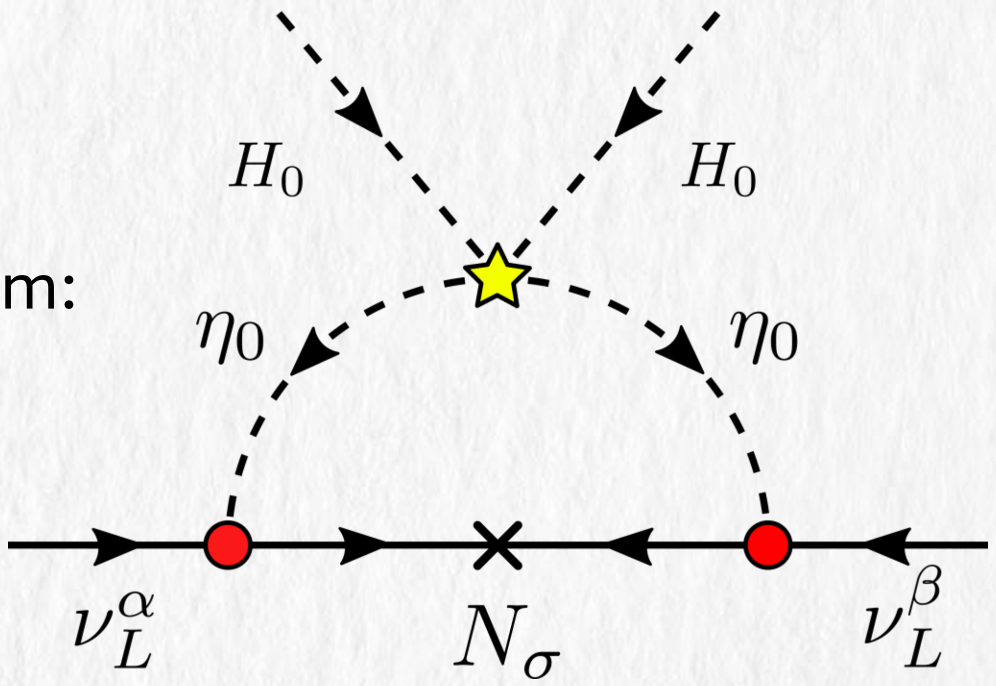

$$m_{\nu}^{\alpha\beta}\propto\frac{\lambda_5\,v^2\,Y^2}{16\pi^2 M}$$

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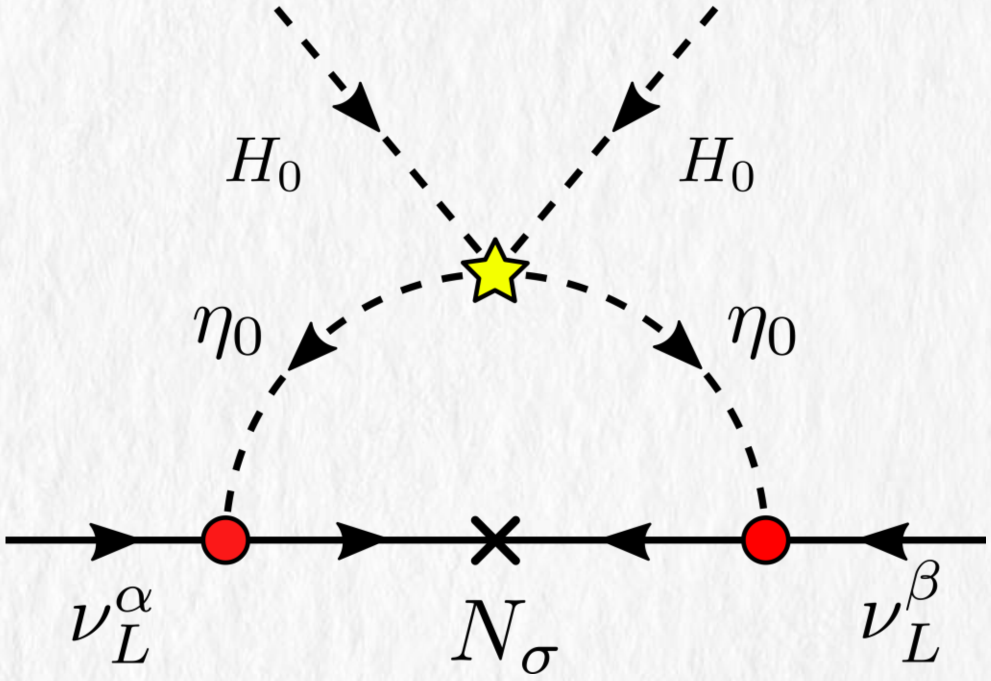
- We can get **neutrino masses ~ eV** with **loop masses M ~ 1 TeV** if:

$$\lambda_5\, Y^2 \sim 10^{-8}$$



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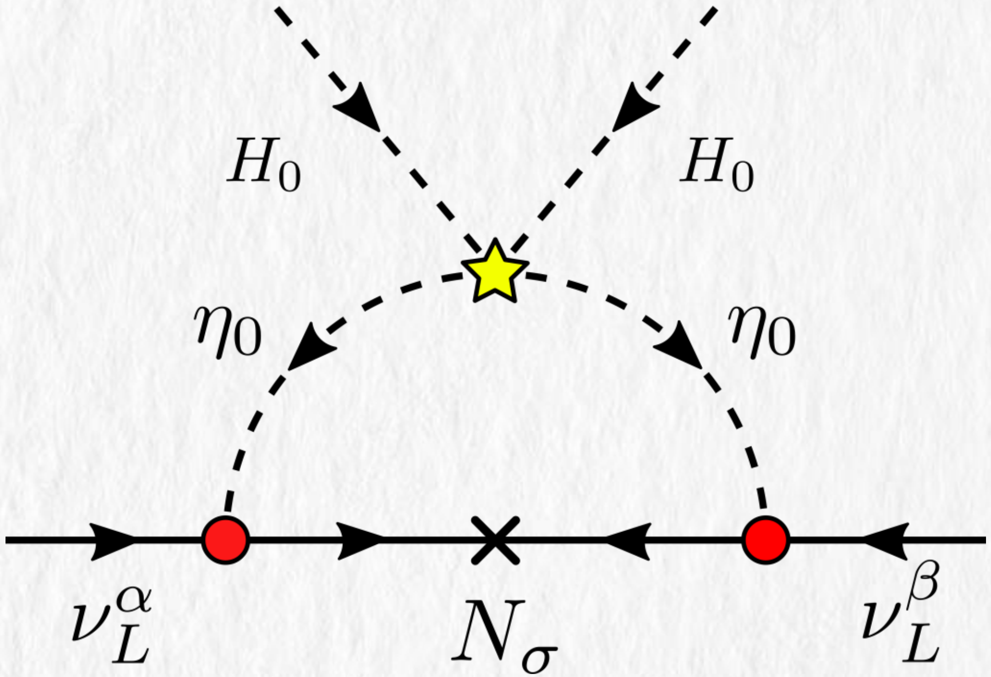

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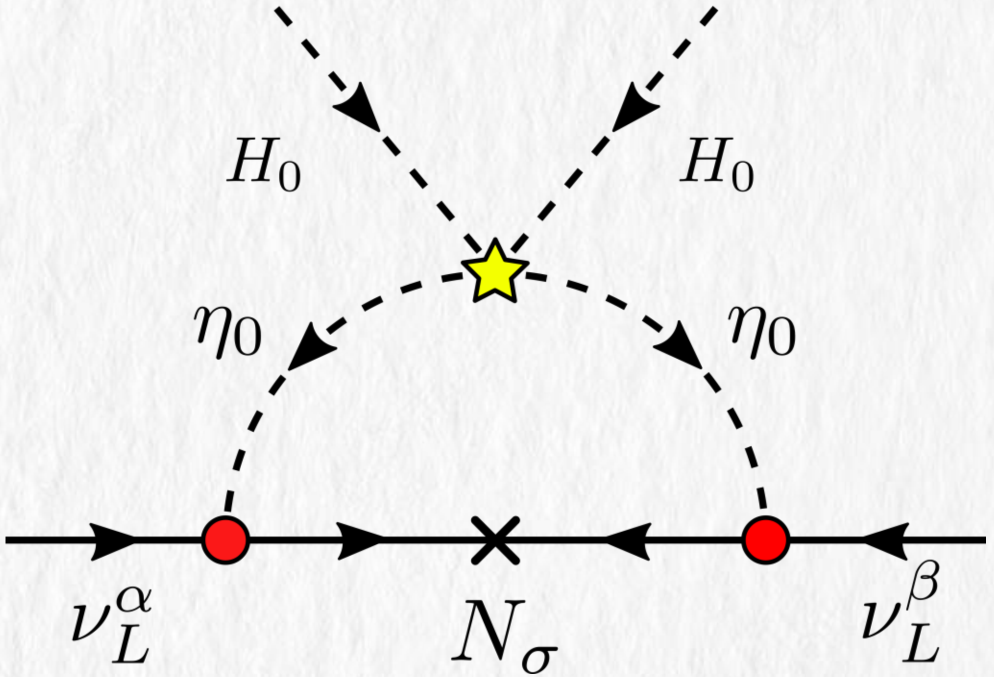
☆ **But why's λ_5 small?**



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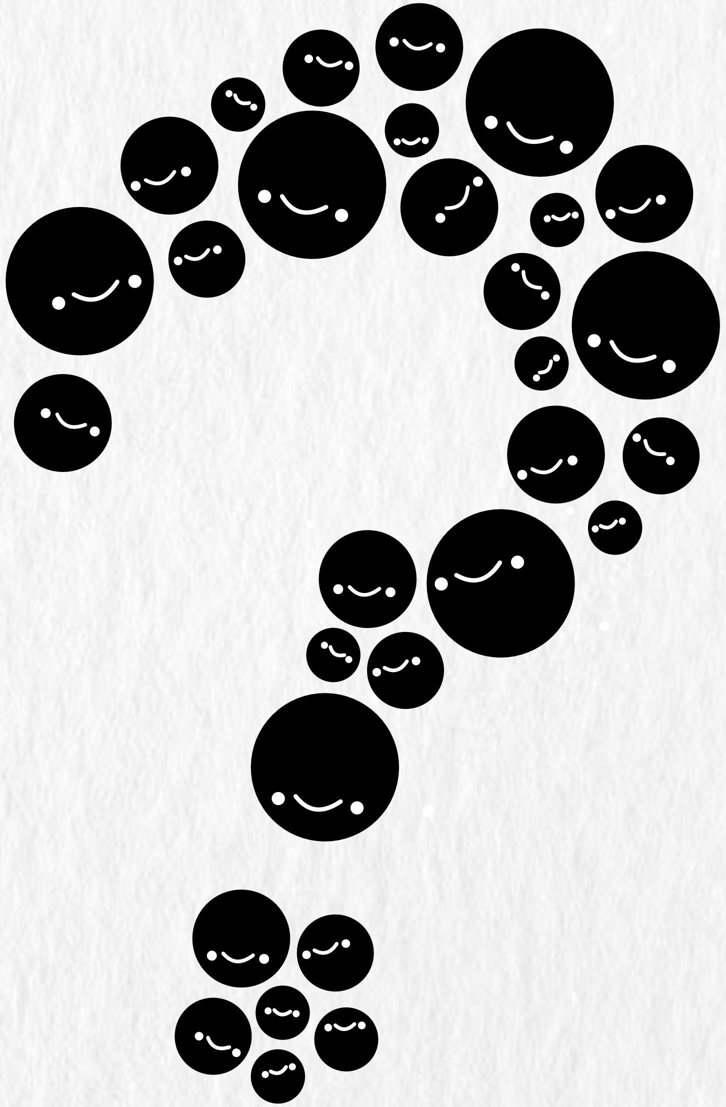
- We want to build a SM extension that includes the **Scotogenic at low energies**…



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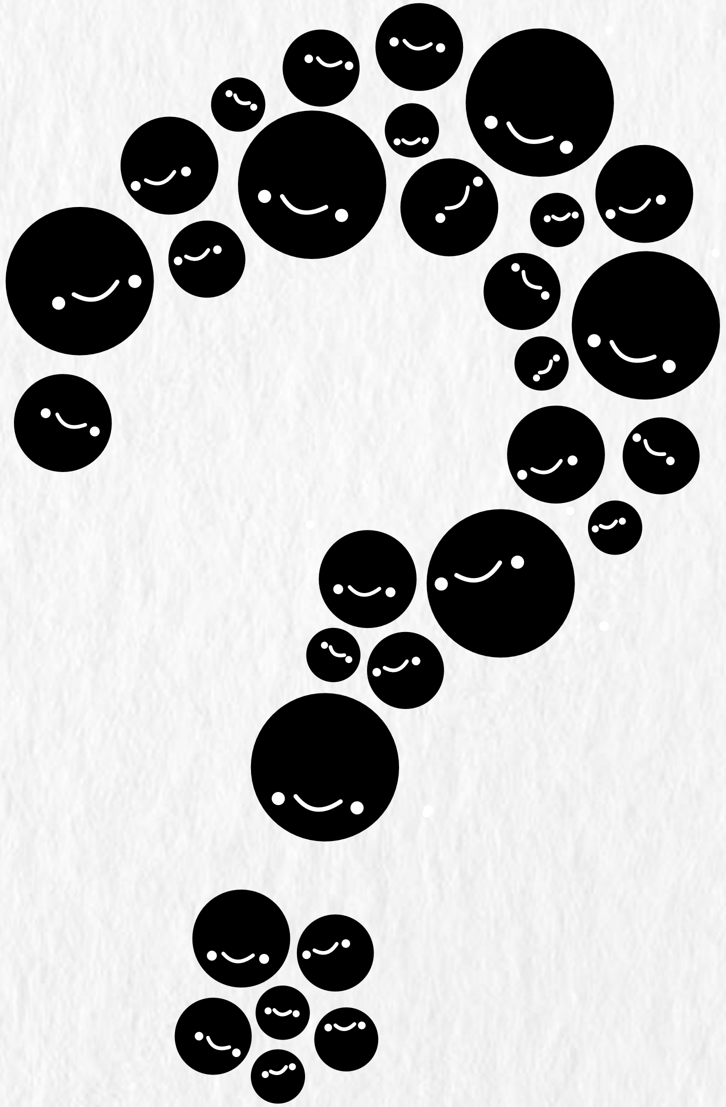

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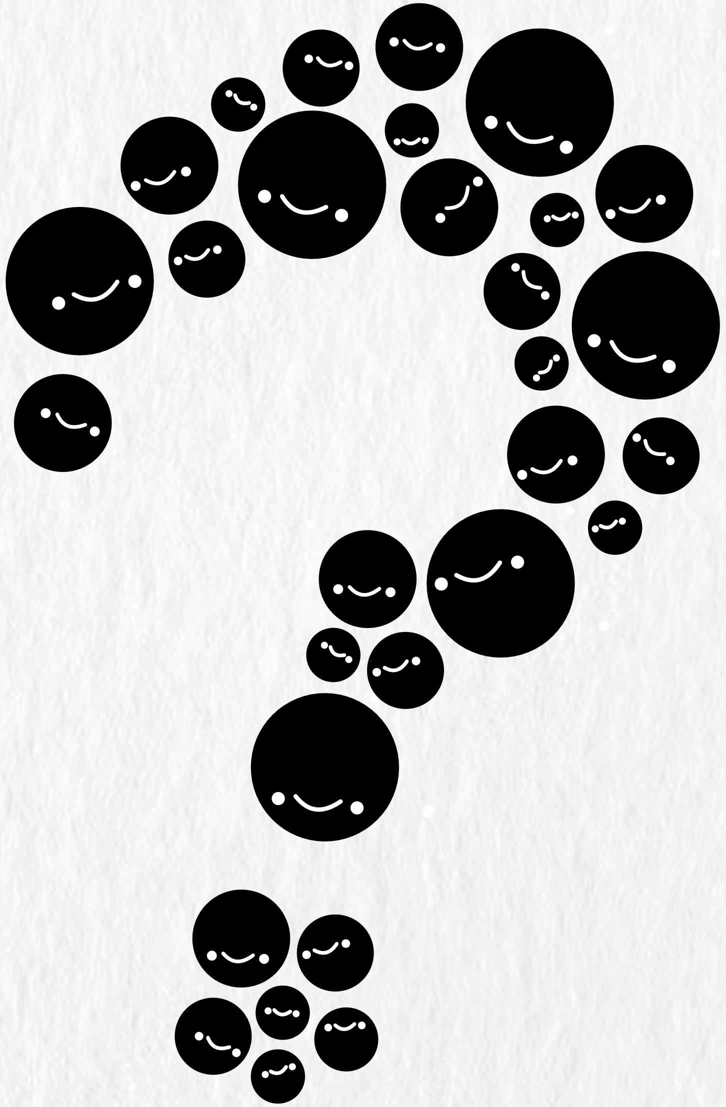
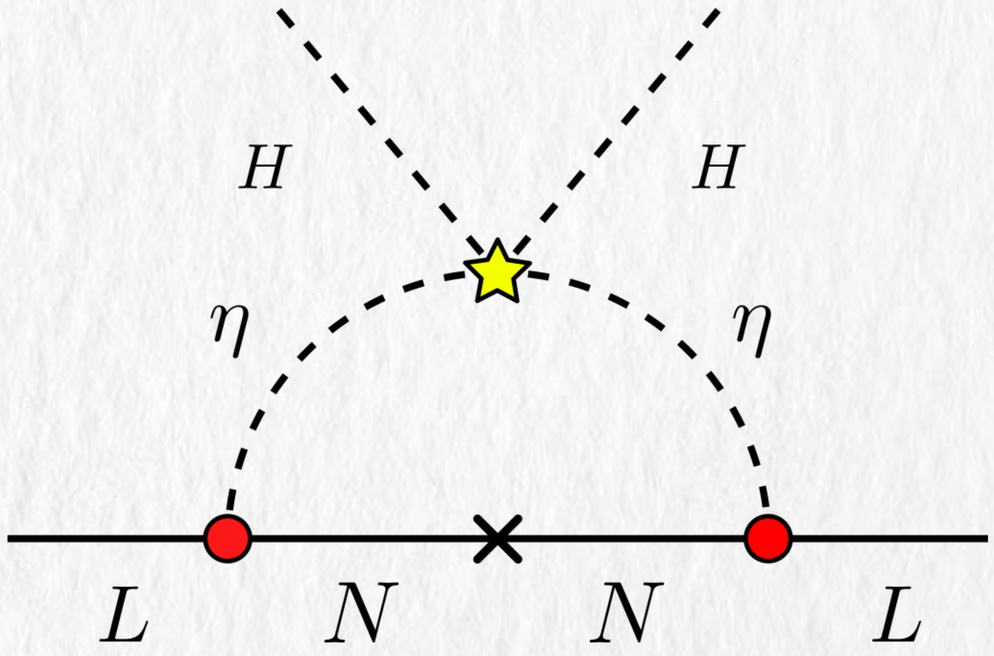
- We will also **generate Z_2 as an accidental symmetry**



How to model build

$$SU(3)_C \times SU(2)_1 \times SU(2)_2 \times U(1)_Y$$



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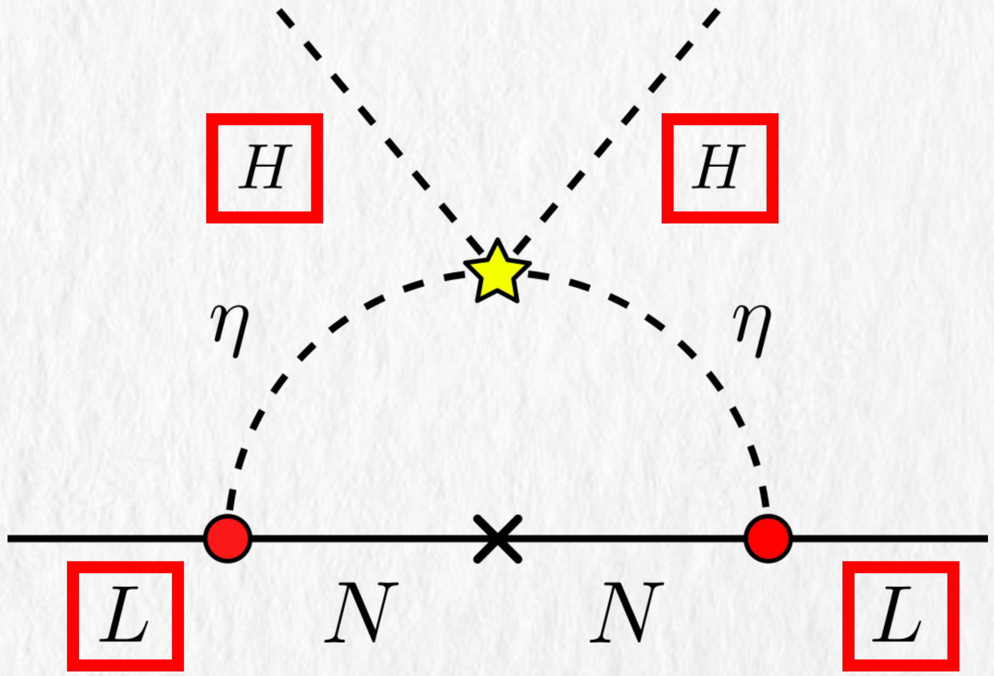

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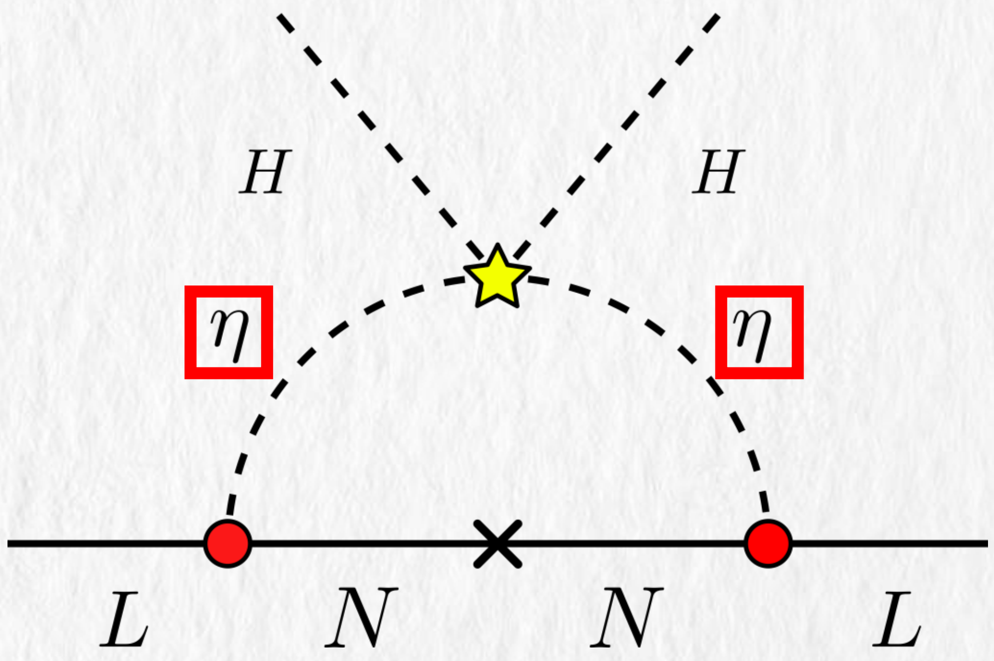

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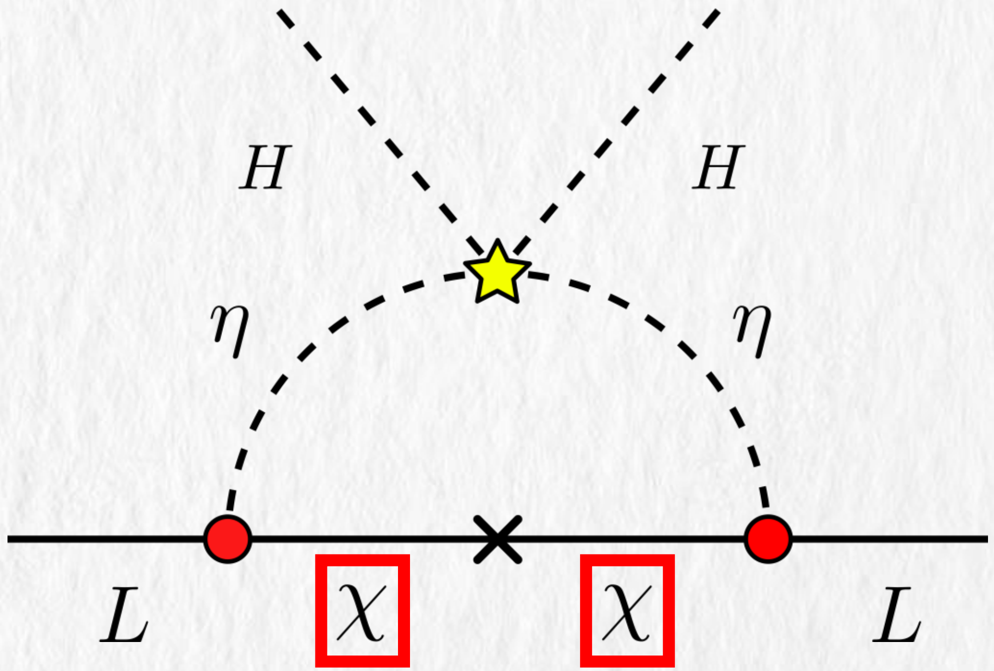

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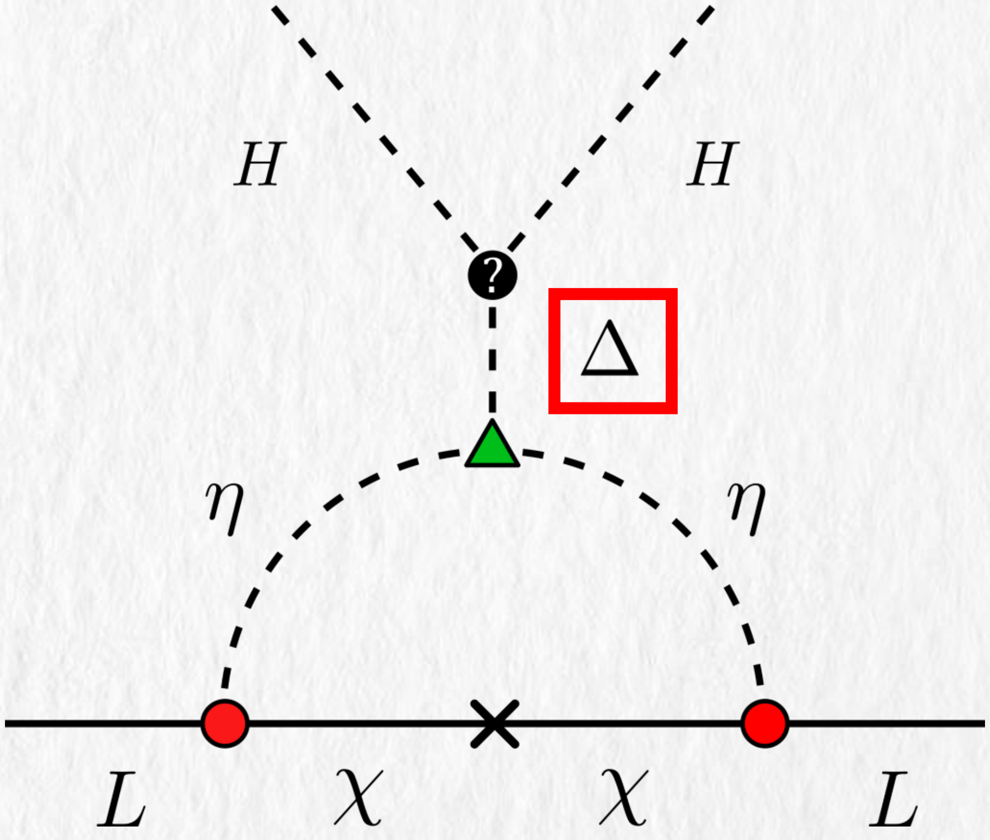

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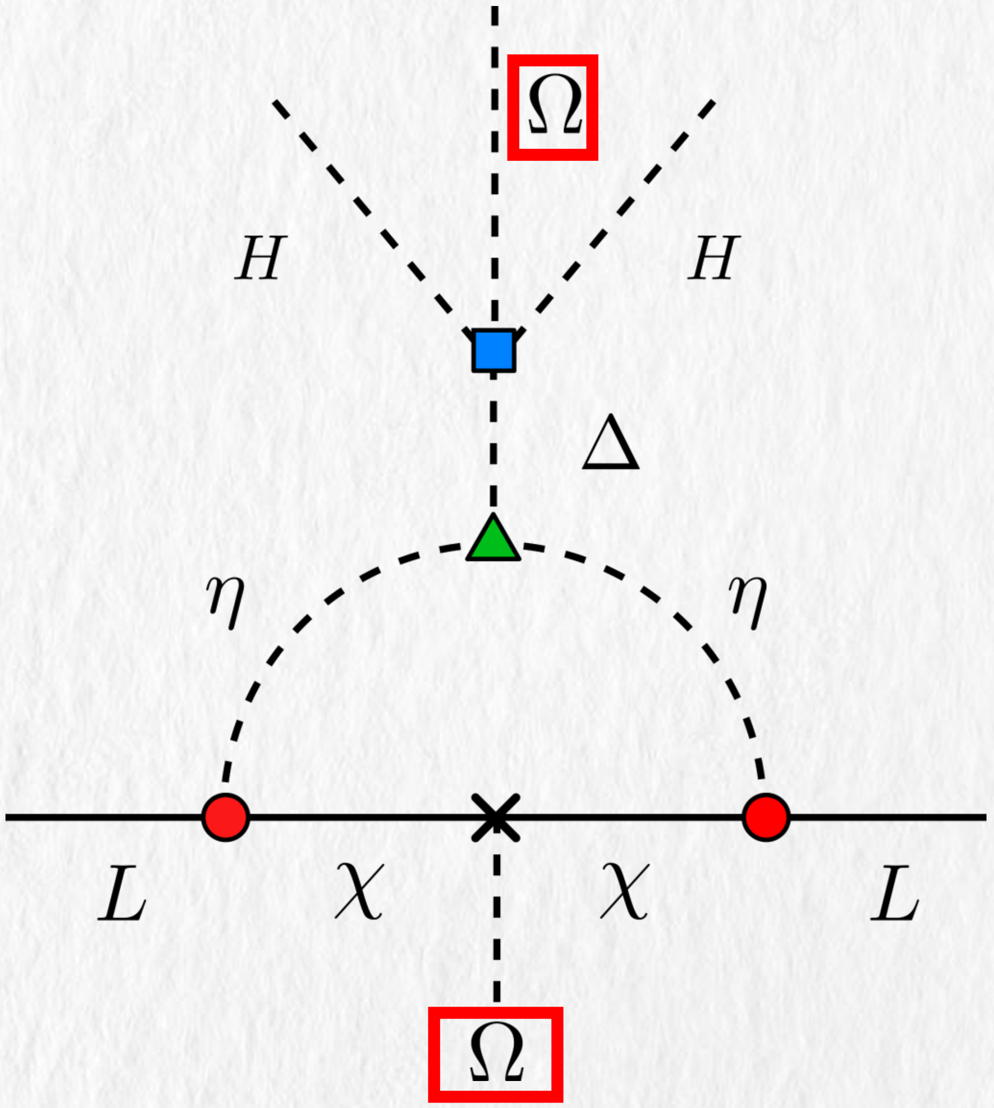
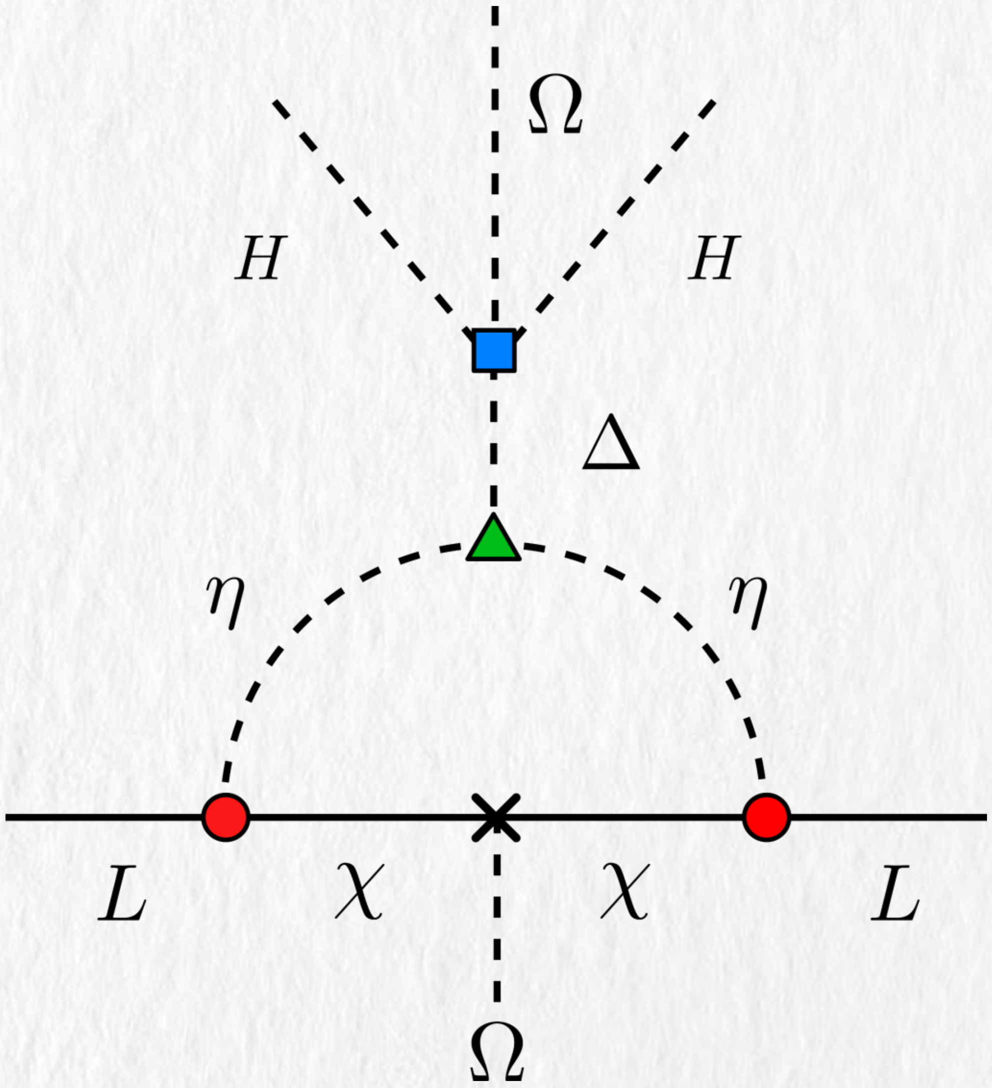


Going down the ladder

- How do we **return to the scotogenic's diagram?**



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$$\langle \Omega \rangle \propto \begin{pmatrix} v_\Omega & 0 & 0 \\ 0 & v_\xi & 0 \\ 0 & 0 & v_\Omega \end{pmatrix} \qquad \langle \Delta \rangle \propto \begin{pmatrix} 0 \\ 0 \\ v_\Delta \end{pmatrix}$$

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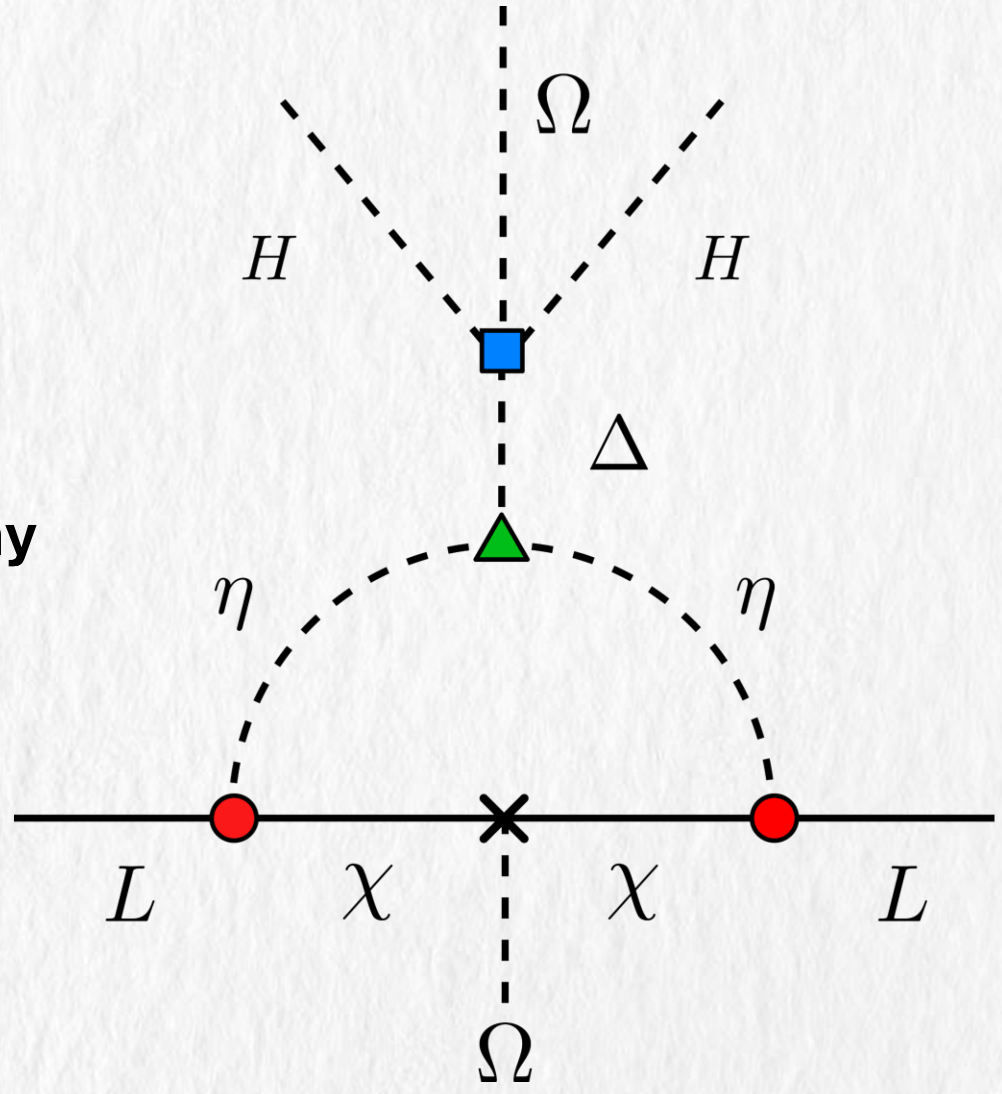

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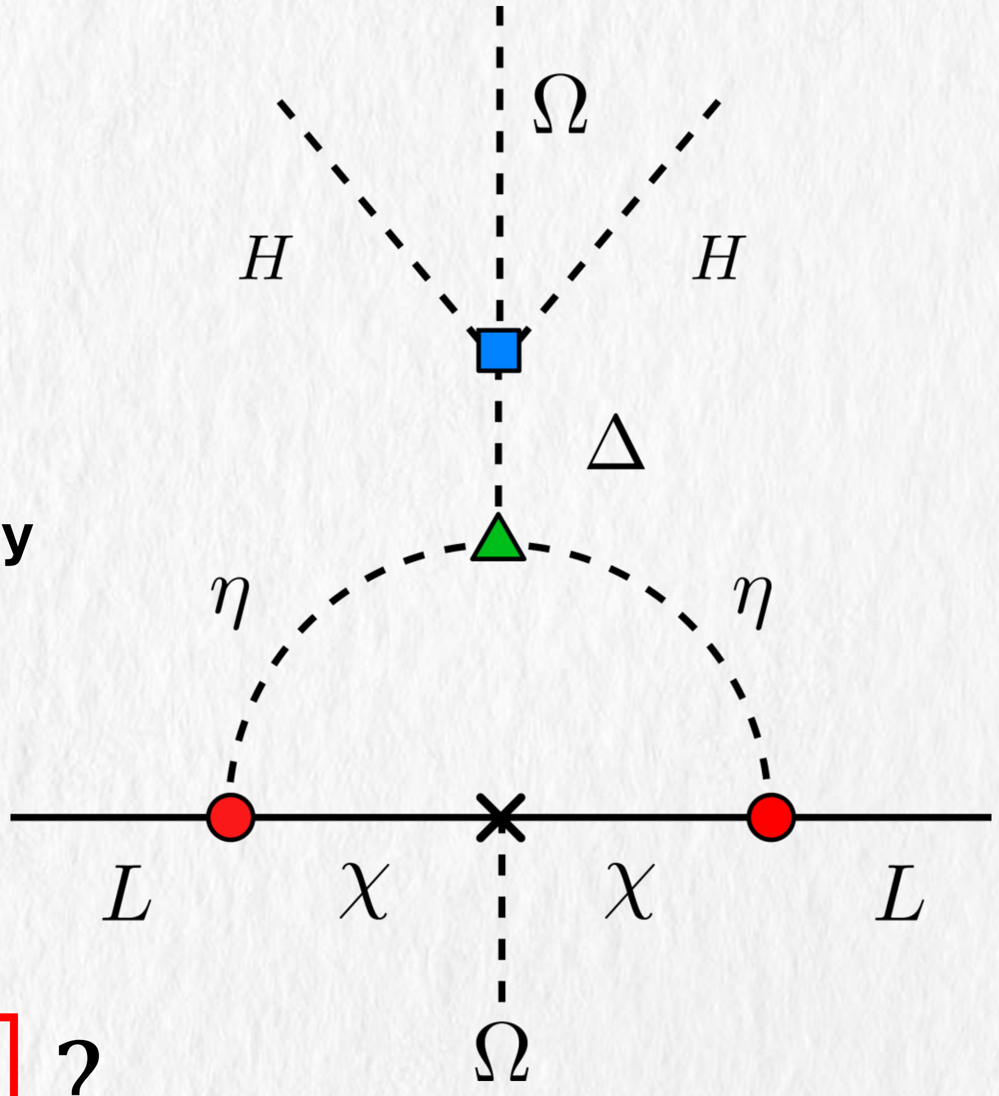
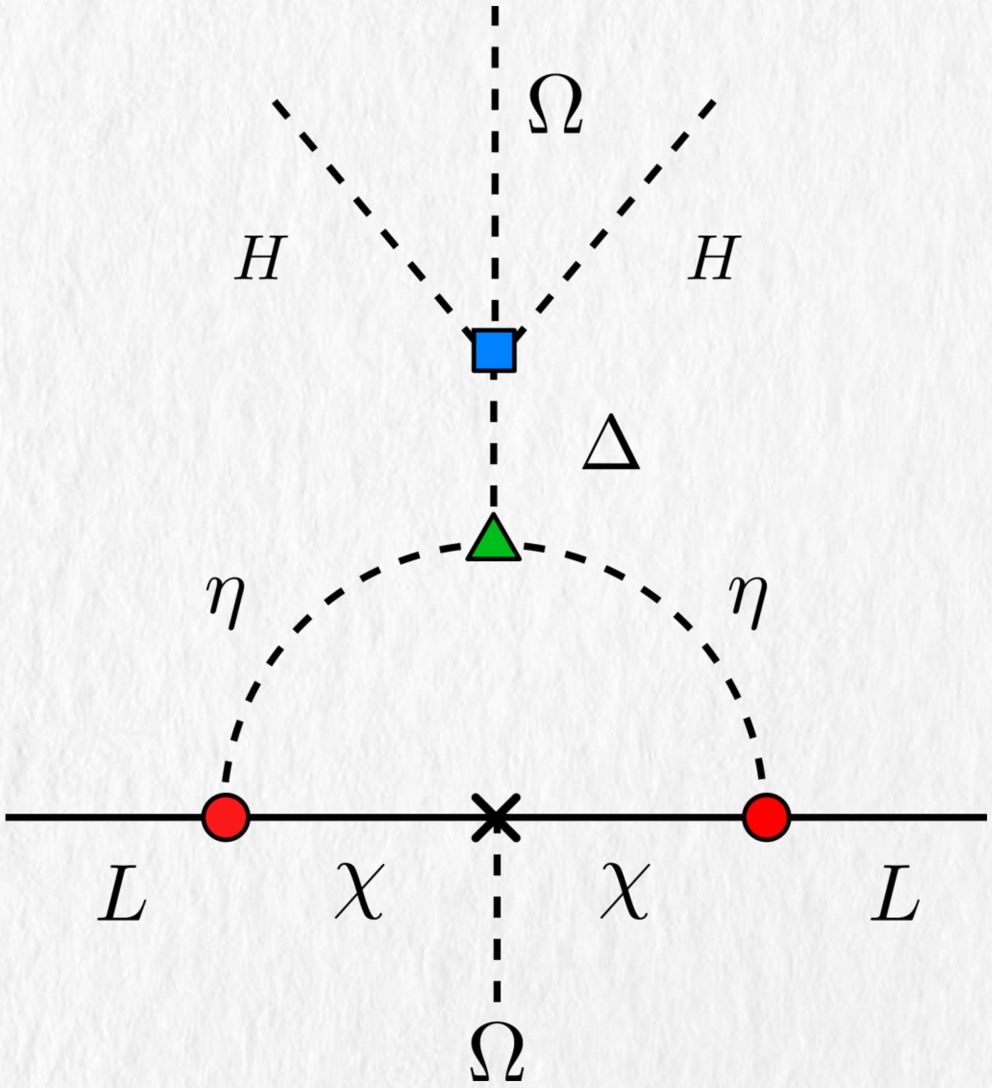


Why is v_Δ the smallest?

- The **smallness of λ_5** comes from it being **an effective operator after Δ is integrated out.**



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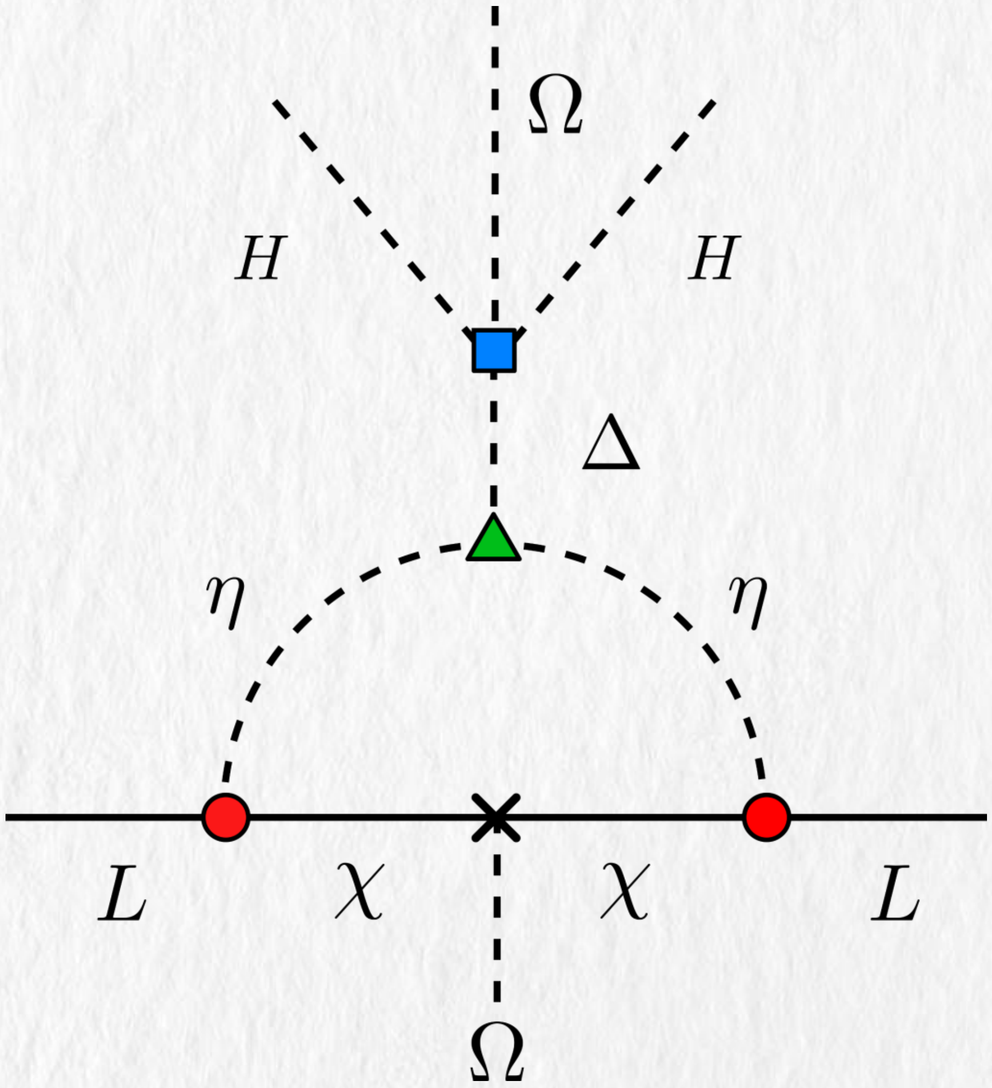

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Effective theory!

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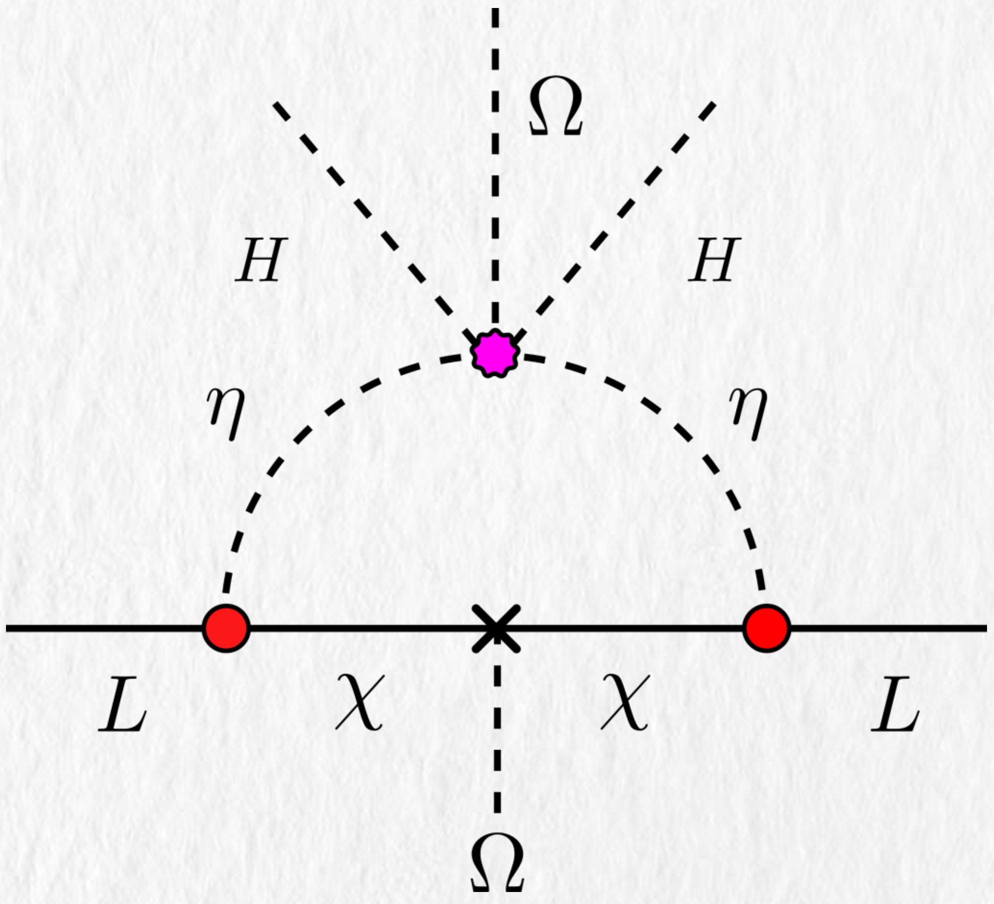
- From the tadpole equations, **this forces small v_Δ**

$$\boxed{v_\Delta \propto \frac{v_H^2 v_\Omega}{m_\Delta^2}}$$



Symmetry breaking

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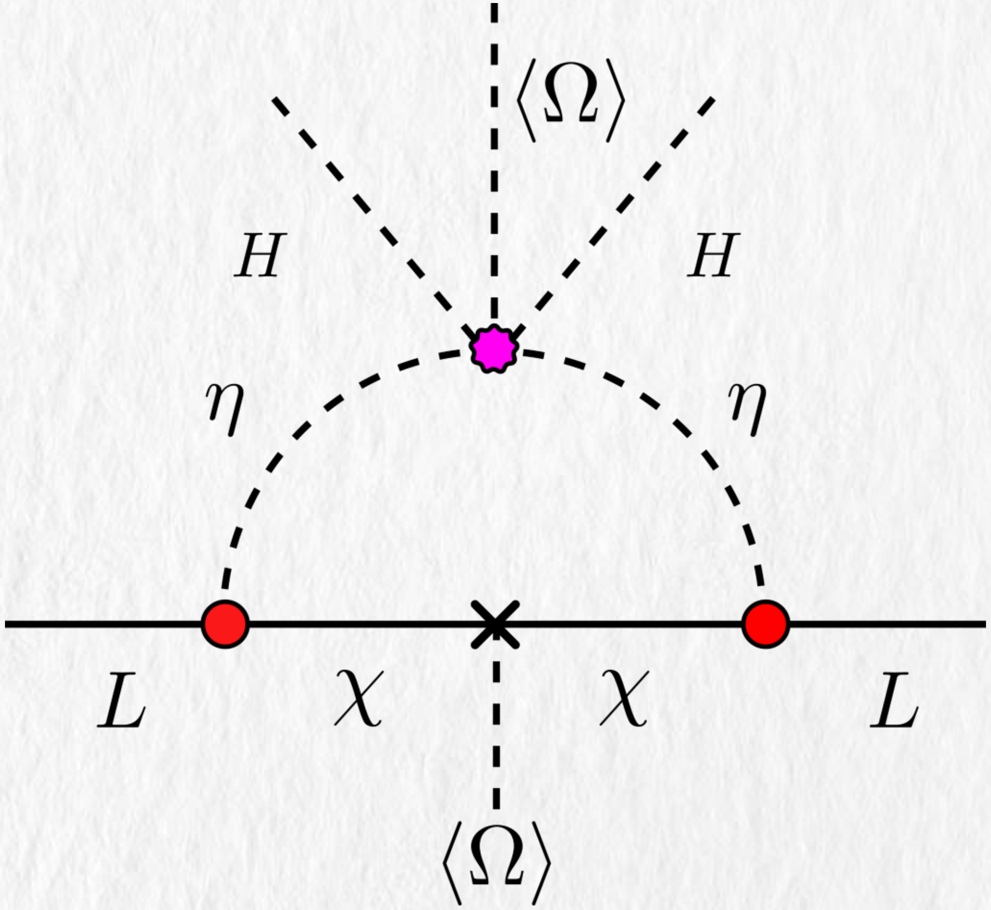

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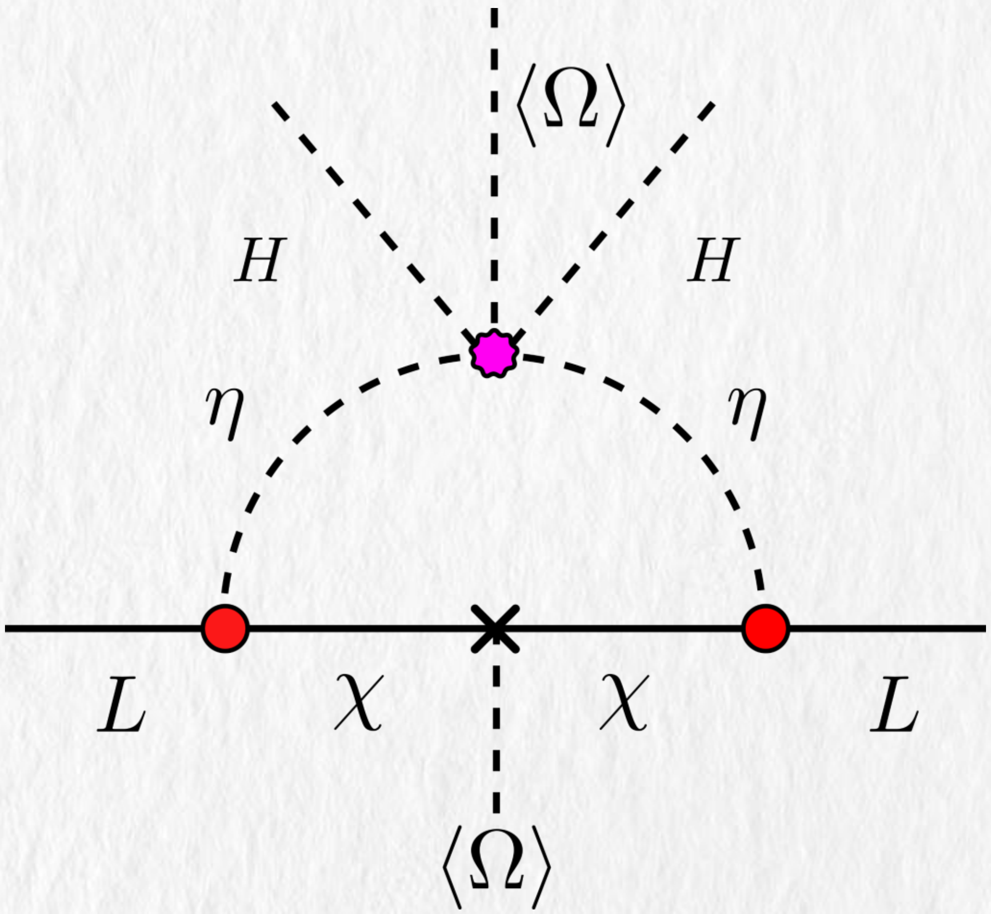

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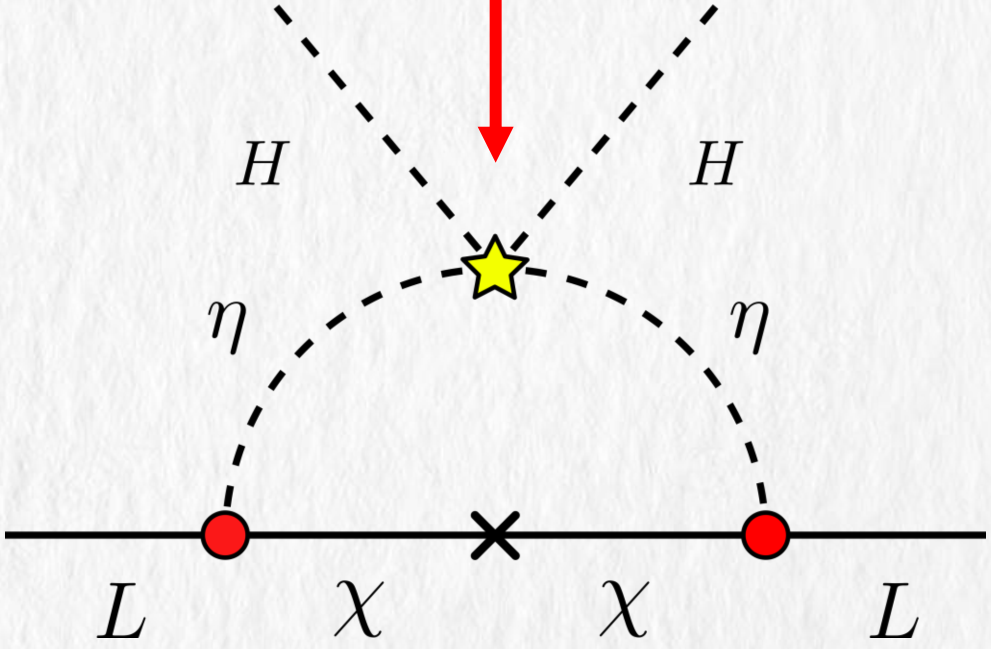

Symmetry breaking

$$\lambda_5 = \frac{v_\Omega\, \mu_2\, \lambda_{H\Delta\Omega}}{\boxed{4m_\Delta^2}}$$ **Small!**

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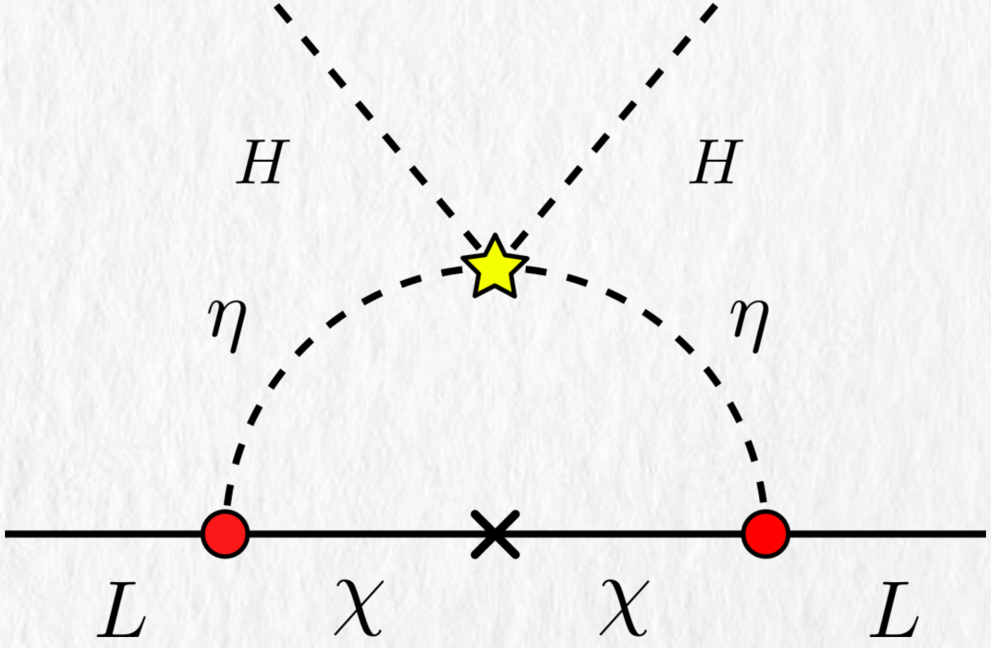

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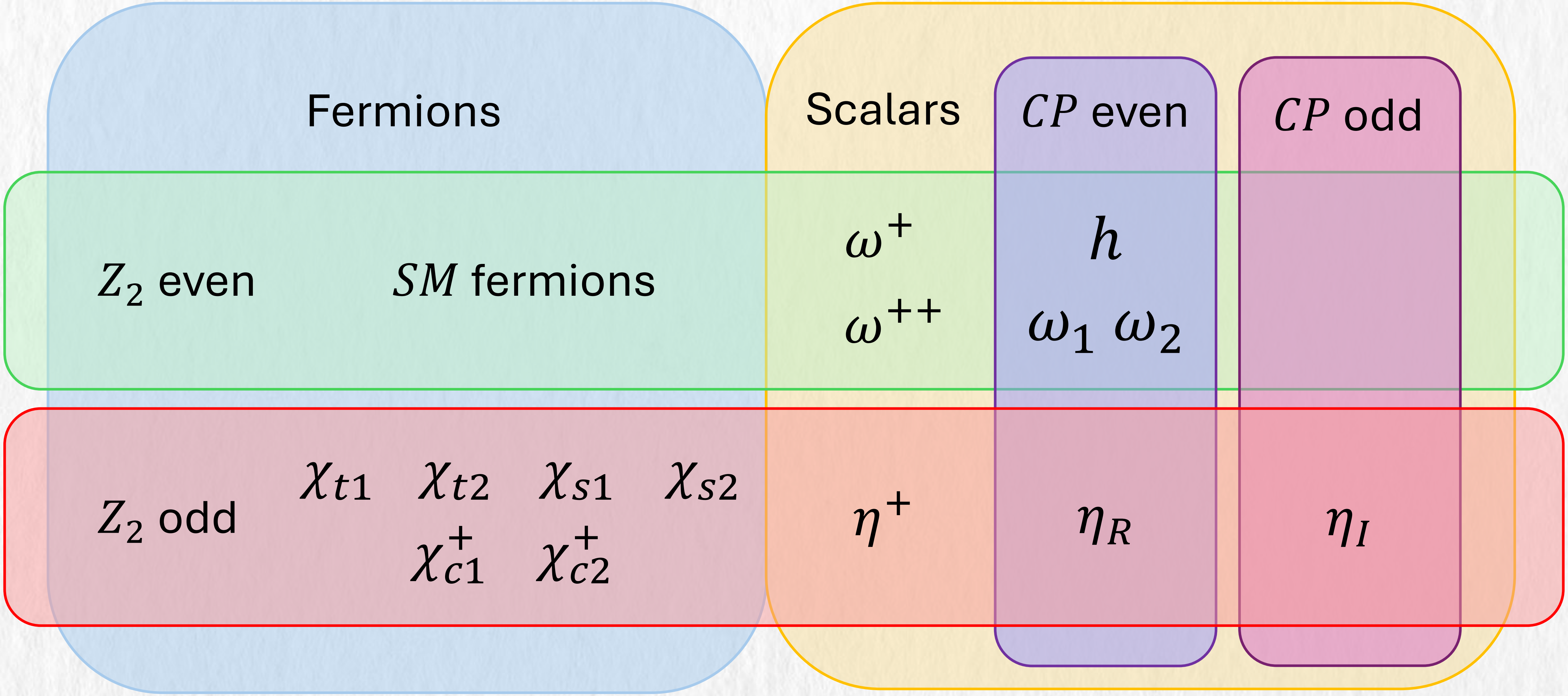
*Artist's rendition



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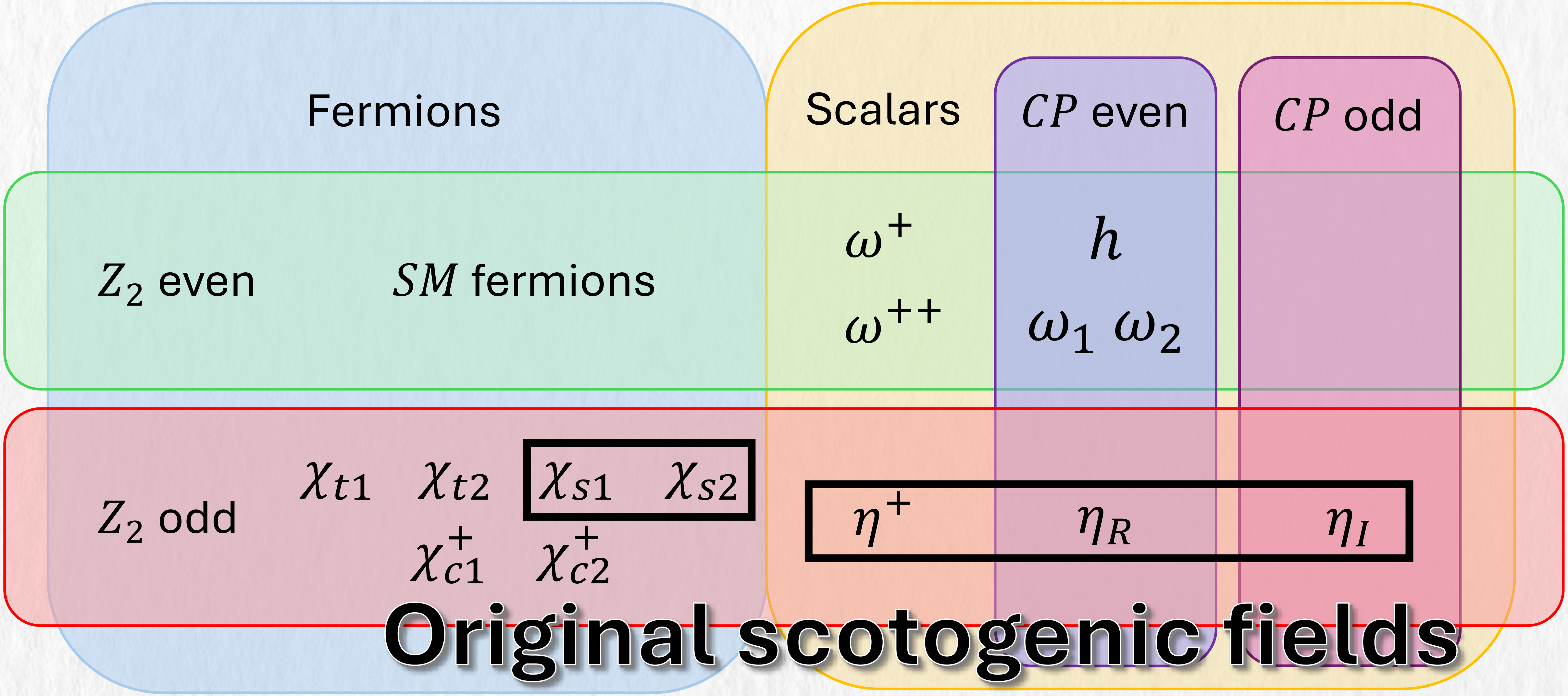

Original scotogenic fields

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Original scotogenic fields

Fermions

Scalar…

…odd

Z_2 even — SM fermions

Z_2 odd — χ_{t1} χ_{t2} $\boxed{\chi_{s1} \quad \chi_{s2}}$ χ^+_{c1} χ^+_{c2}

And four gauge bosons

$W, Z \sim SM$ bosons

$W', Z' \sim BSM$ bosons

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Sir, this is the pheno session

- It is indeed!

Session

Particle Phenomenology

21 Jul 2025, 16:00

Durham

Scotogenic mechanism from an extended $SU(2)_1 \times SU(2)_2 \times U(1)_Y$ electroweak symmetry

17:20 - 17:40

Presenter Javier Perez-Soler

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$$\rho = 1.00031 \pm 0.00019$$

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These limits also suppress gauge boson mixing

$$\theta_c, \theta_n \leq 10^{-3}$$

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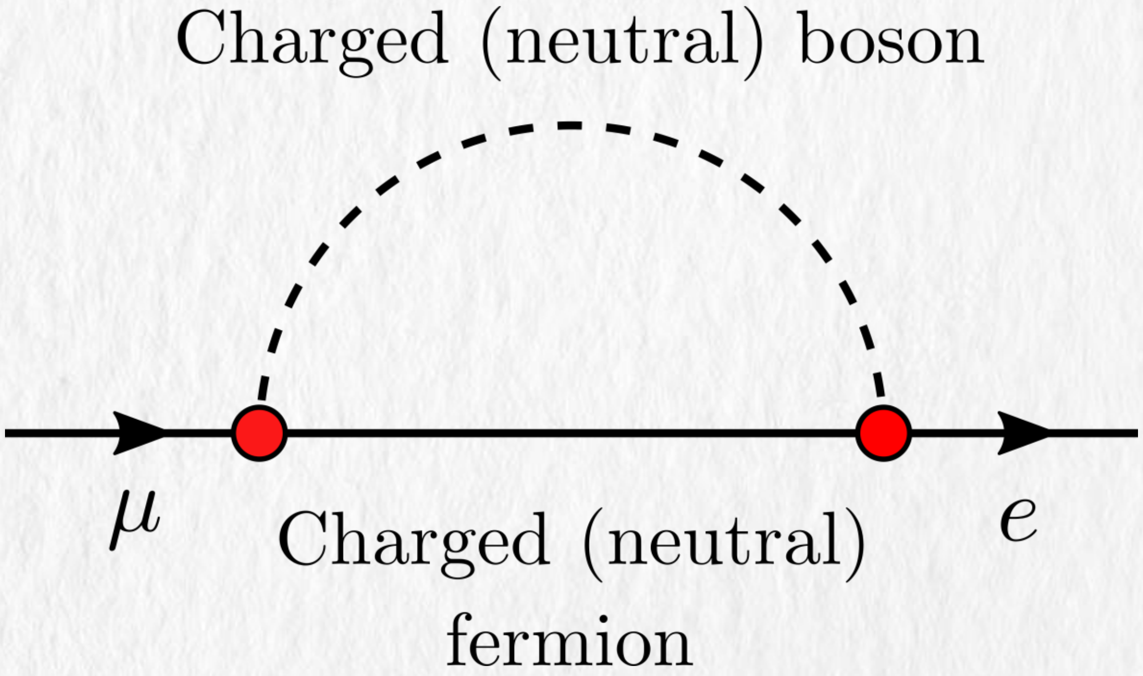
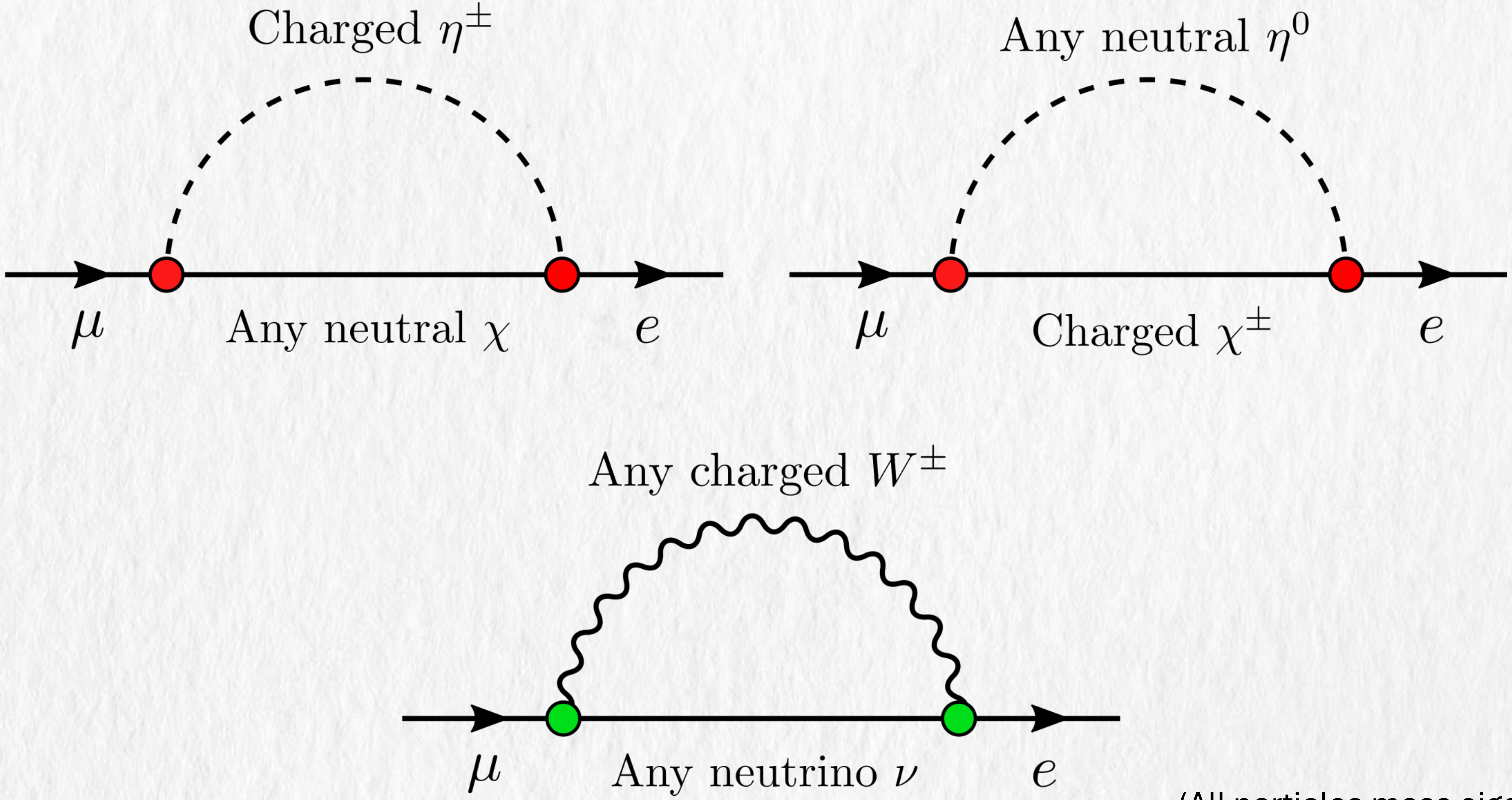
- We have Majorana neutrino masses… LFV decays?
- $\mu \to e + \gamma$ is a classic choice
- $\mathrm{BR}(\mu \to e + \gamma) < 1.5 \cdot 10^{-13}$

(90% CL, MEG II 2021-2022)



(All particles mass eigenstates)



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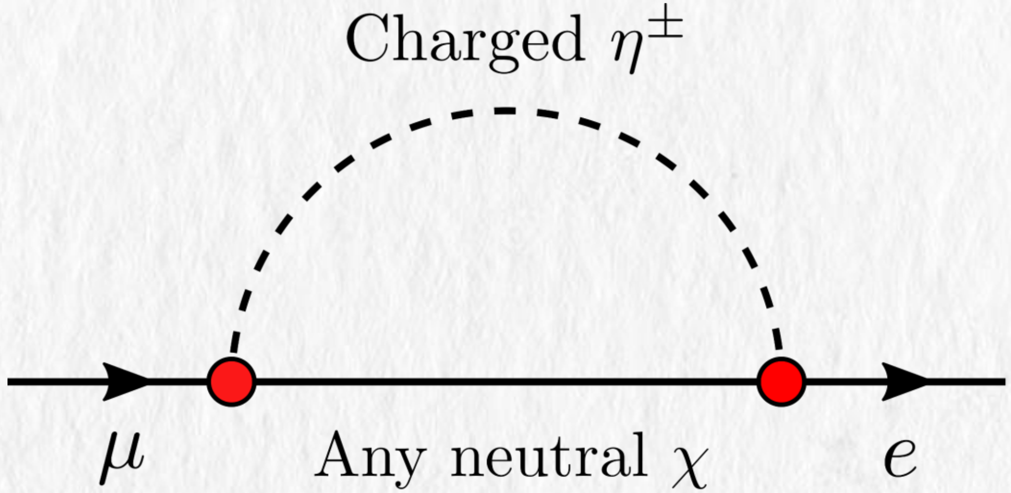
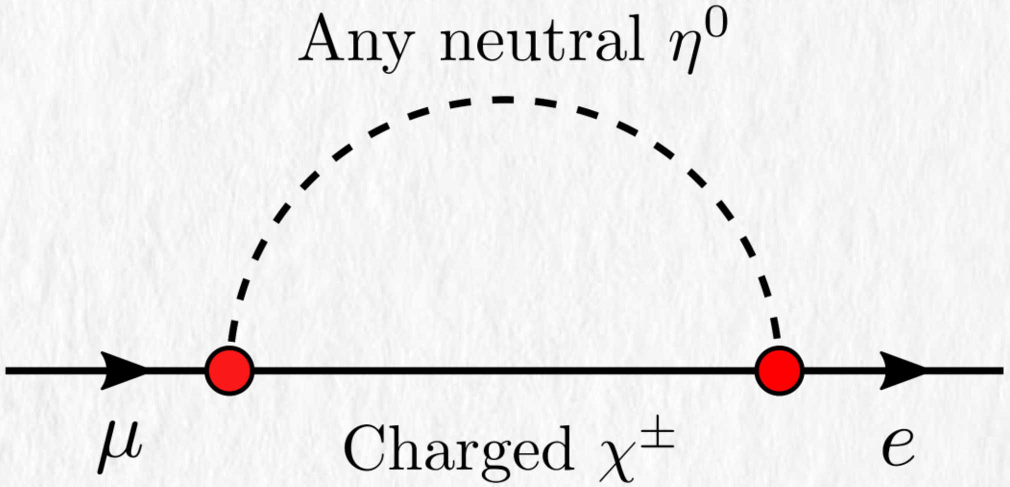
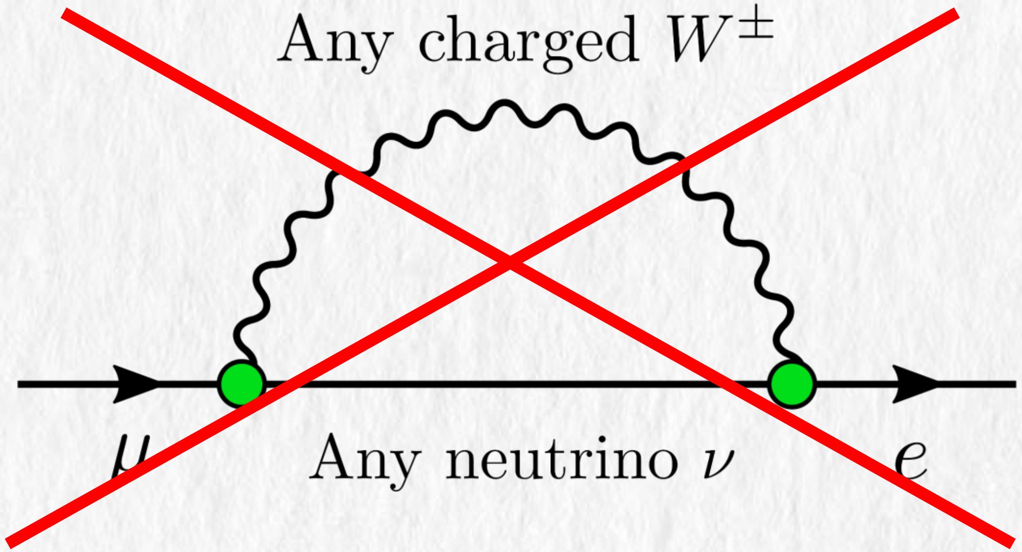


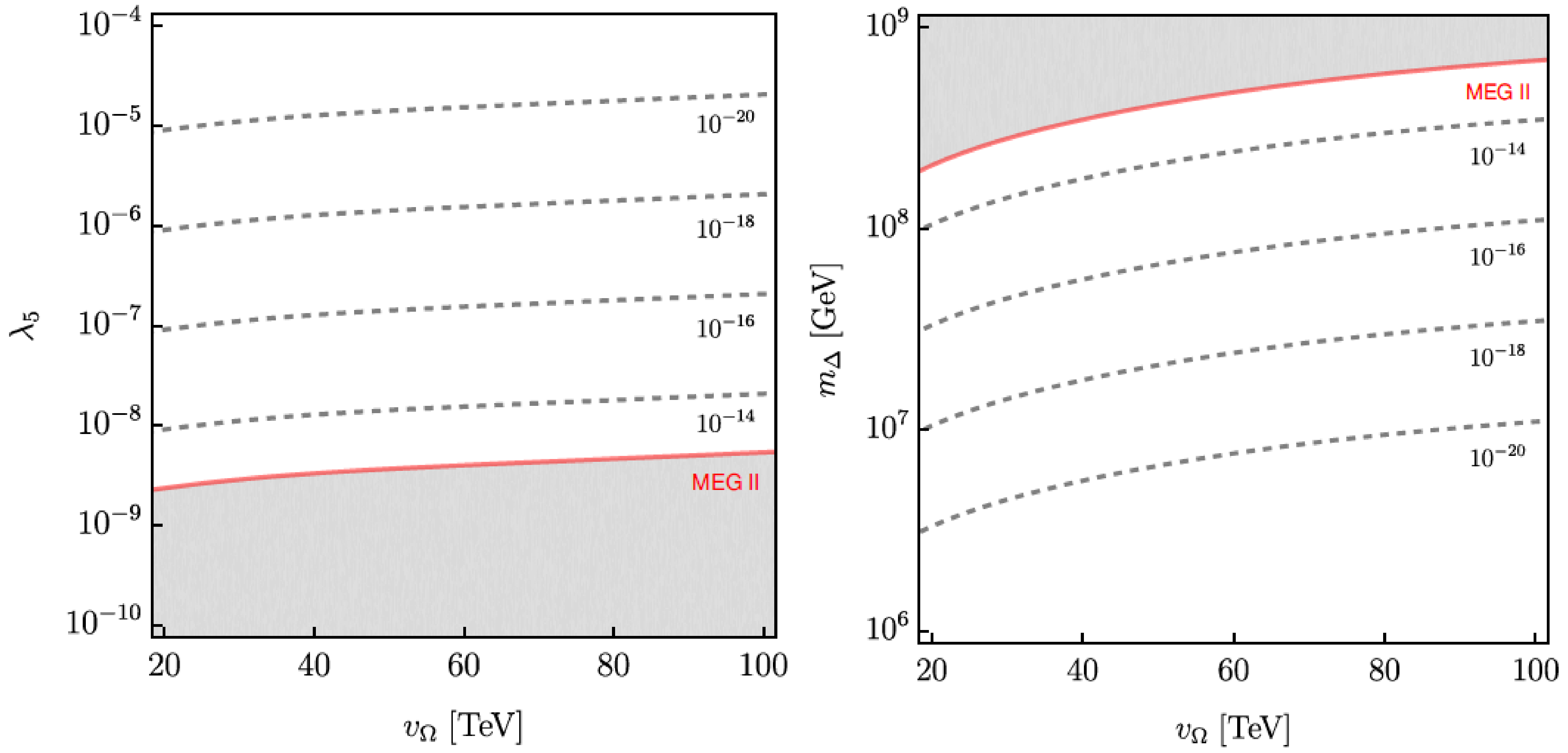


Mega suppressed

$$\sim \left(\frac{m_\nu}{m_W}\right)^4$$



(All particles mass eigenstates)



λ_5
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{-9}
10^{-10}
10^{-20}
10^{-18}
10^{-16}
10^{-14}
MEG II
20
40
60
80
100
v_Ω [TeV]
m_Δ [GeV]
10^{9}
10^{8}
10^{7}
10^{6}
MEG II
10^{-14}
10^{-16}
10^{-18}
10^{-20}
20
40
60
80
100
v_Ω [TeV]

Final point: Dark matter

- We have a bunch of stable DM candidates thanks to Z_2

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- For scalars, it's the scotogenic guys η_R and η_I

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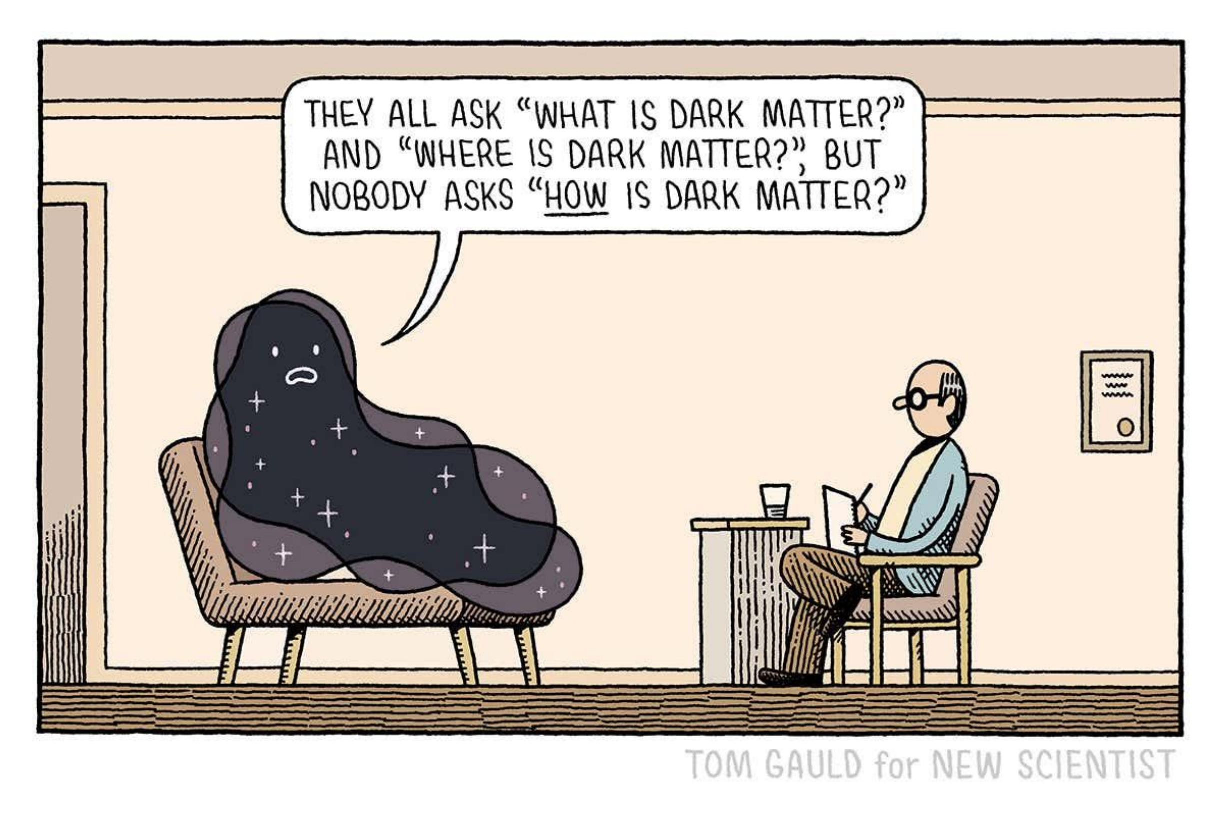
Final point: Dark matter

- We have a bunch of stable DM candidates thanks to Z_2
- For scalars, it's the scotogenic guys η_R and η_I
- For fermions, we have two, χ_{t1} and χ_{s1} ; coming from the neutral components of

$$\chi \to \mathbf{3} \oplus \mathbf{1}$$



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Thanks!

r/Physics
Posted by u/[redacted] • 1h

What to do if i have theories?

Question

I contacted a college and they ignored me

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The other picture displayed on the door to my office