Phenomenological and Cosmological Implications of a Scotogenic three-Loop Neutrino Mass Model

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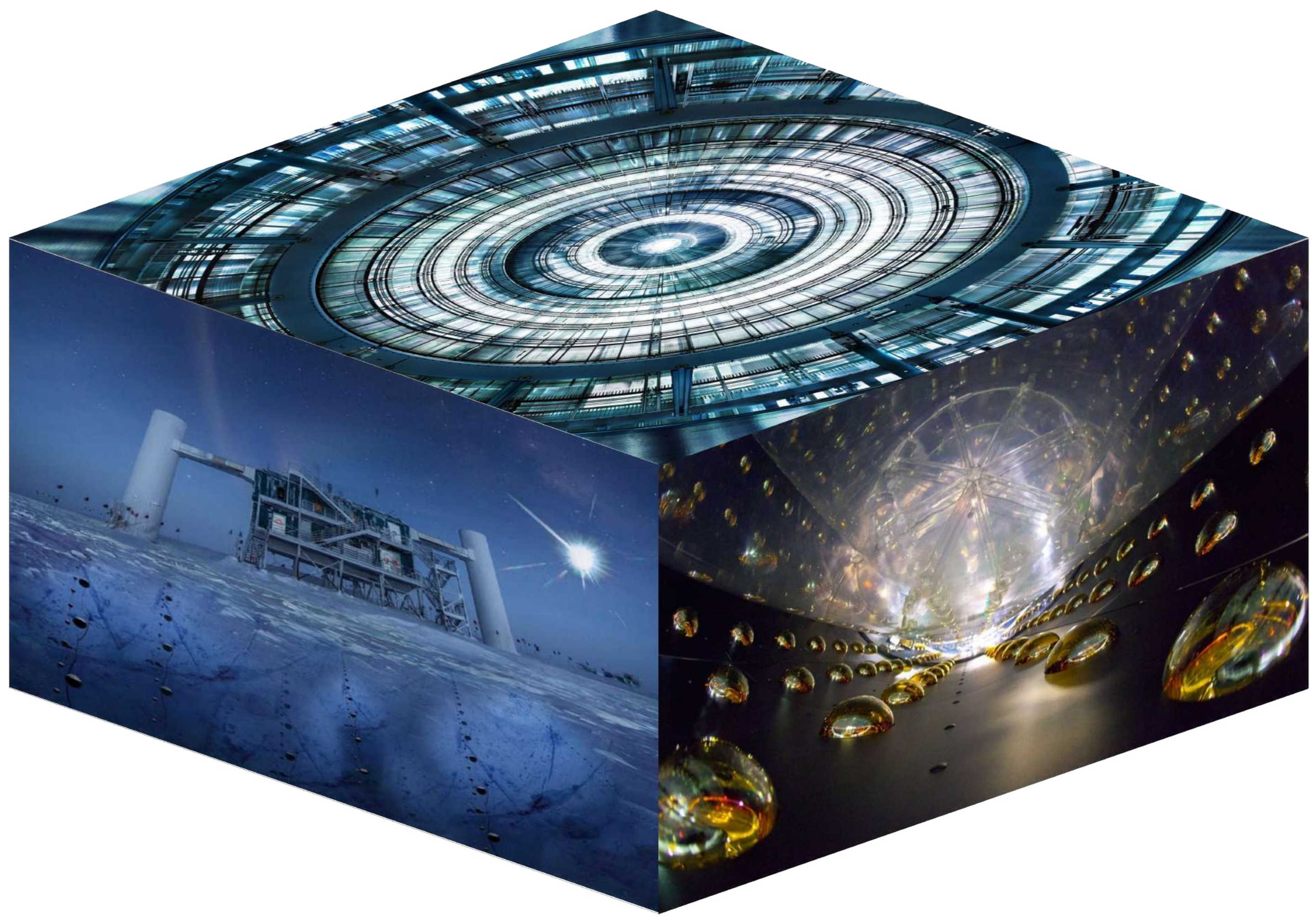
Introduction

The tiny light active neutrino masses and the current amount of dark matter (DM) relic density observed in the Universe, remain as two big open questions the Standard Model (SM) cannot answer. Several extensions of the SM have been constructed in order to address these questions. In this work [1] we consider neutrino masses generated radiatively.
In most radiative seesaw models, the light neutrino masses are generated at a one-loop level, thus implying that in order to successfully reproduce neutrino data as observed, one has to rely either on very small neutrino Yukawa couplings (of the order of the electron Yukawa coupling) or on an unnaturally small mass splitting between the CP-even and CP-odd components of the neutral scalar mediators. Three-loop neutrino mass models have been proposed in the literature to provide a more natural explanation for the smallness of the light active neutrino masses than those relying on one- or two-loop seesaw realizations. We propose here a scotogenic like model, where light-active neutrino masses arise from a three-loop-level radiative seesaw mechanism.

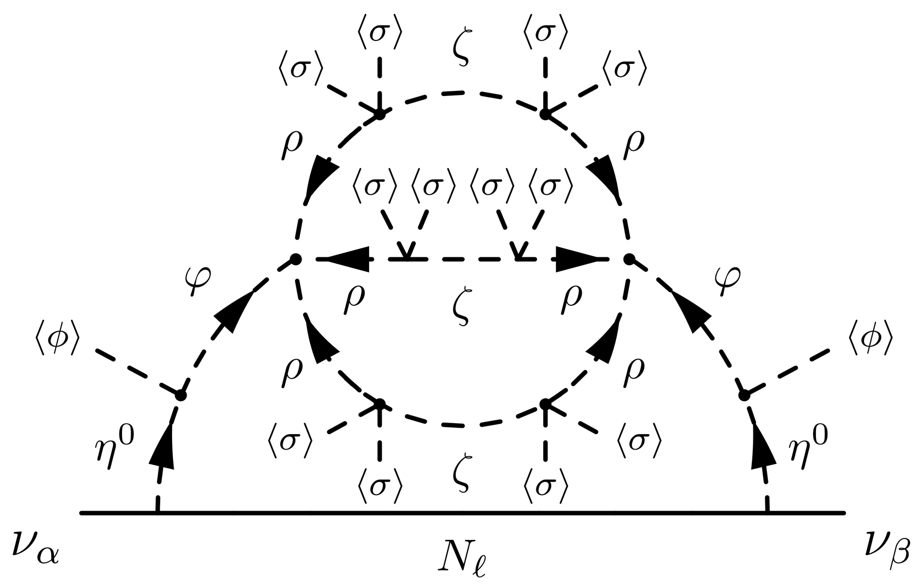


Symmetries and Particle Content

- We extend the symmetries of the SM with a spontaneously broken global symmetry $U(1)'$ and a preserved $\mathbb{Z}_2$ symmetry $\longrightarrow$ fermionic and scalar DM candidates.

Field	q_{iL}	u_{iR}	d_{iR}	ℓ_{iL}	ℓ_{iR}	N_{R_k}	ϕ	η	φ	ρ	ζ	σ
$SU(3)_C$	3	3	3	1	1	1	1	1	1	1	1	1
$SU(2)_L$	2	1	1	2	1	1	2	2	1	1	1	1
$U(1)_Y$	$\frac{1}{6}$	$\frac{2}{3}$	$-\frac{1}{3}$	$-\frac{1}{2}$	-1	0	$\frac{1}{2}$	$\frac{1}{2}$	0	0	0	0
$U(1)'$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	-3	-3	0	0	3	3	-1	0	$\frac{1}{2}$
$\mathbb{Z}_2$	1	1	1	1	1	-1	1	-1	-1	-1	-1	1

- Neutrino mass generation: scotogenic diagram at 3-loop level

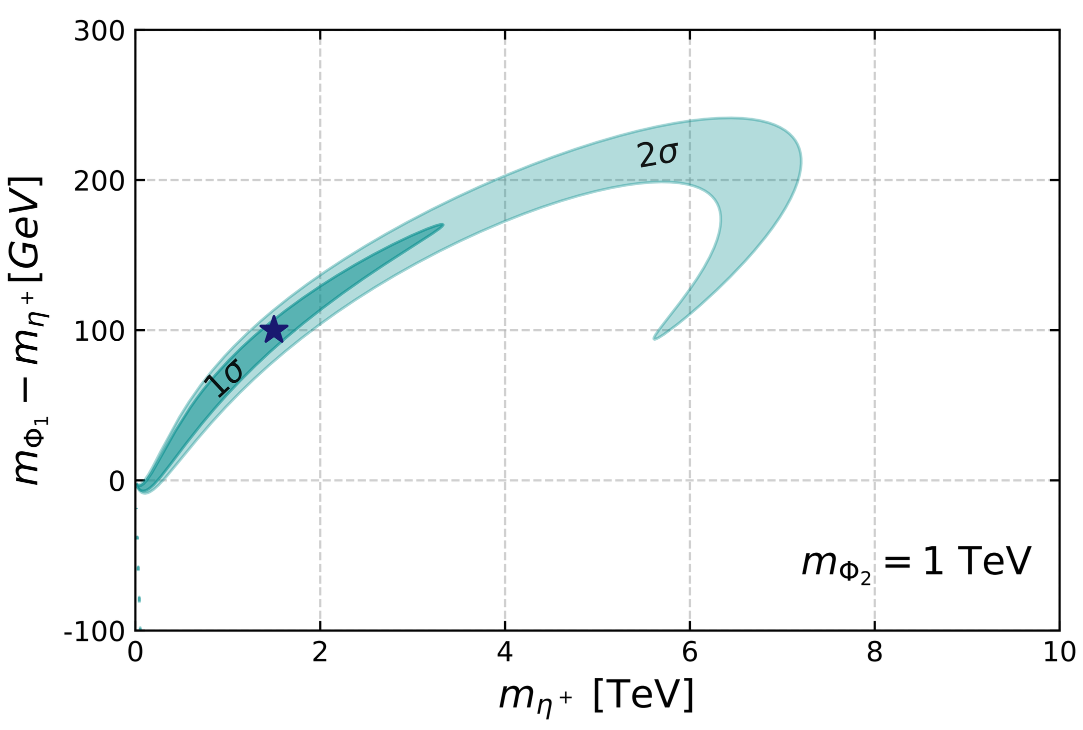


- No parameter in the model has to be artificially suppressed to obtain the correct neutrino mass scale.
- Yukawa couplings can be of order $O(1)$ with the new particles in the TeV range.

Oblique parameters and W boson mass

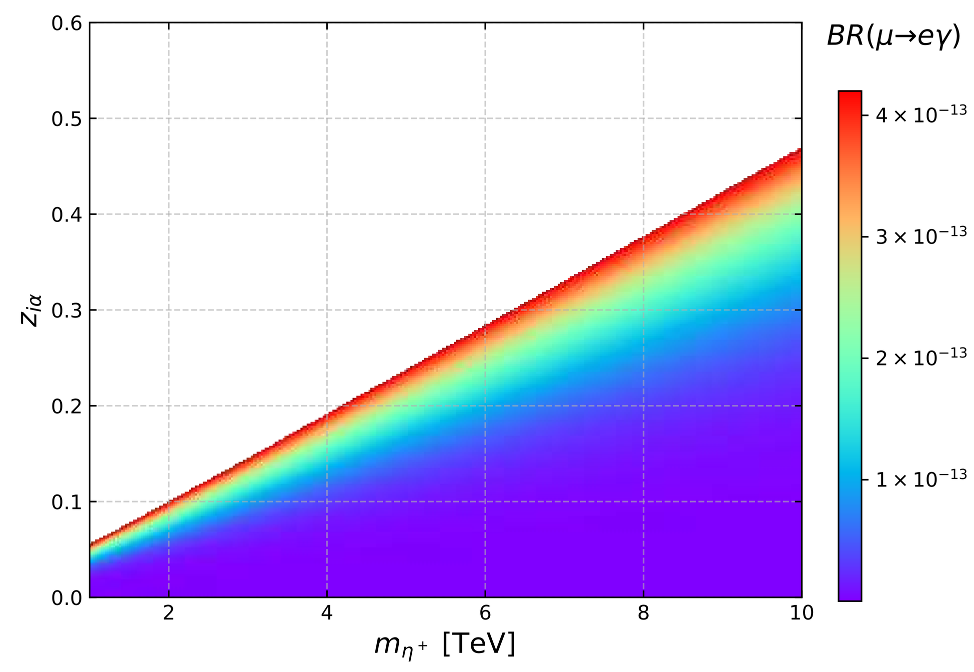
- The extra scalars from the inert scalar doublet affect the oblique parameters S ,T and U.
- The measurement of the W gauge boson mass by the CDF collaboration [2], can be interpreted as an indication of non-trivial S, T, U:

$$\mathrm{M}_W^2 = (M_W^2)_{\mathrm{SM}} + \frac{\alpha_{\mathrm{EM}}(M_Z)\cos^2\theta_W M_Z^2}{\cos^2\theta_W - \sin^2\theta_W}\left[-\frac{S}{2} + \cos^2\theta_W\, T + \frac{\cos^2\theta_W - \sin^2\theta_W}{4\sin^2\theta_W} U\right]$$

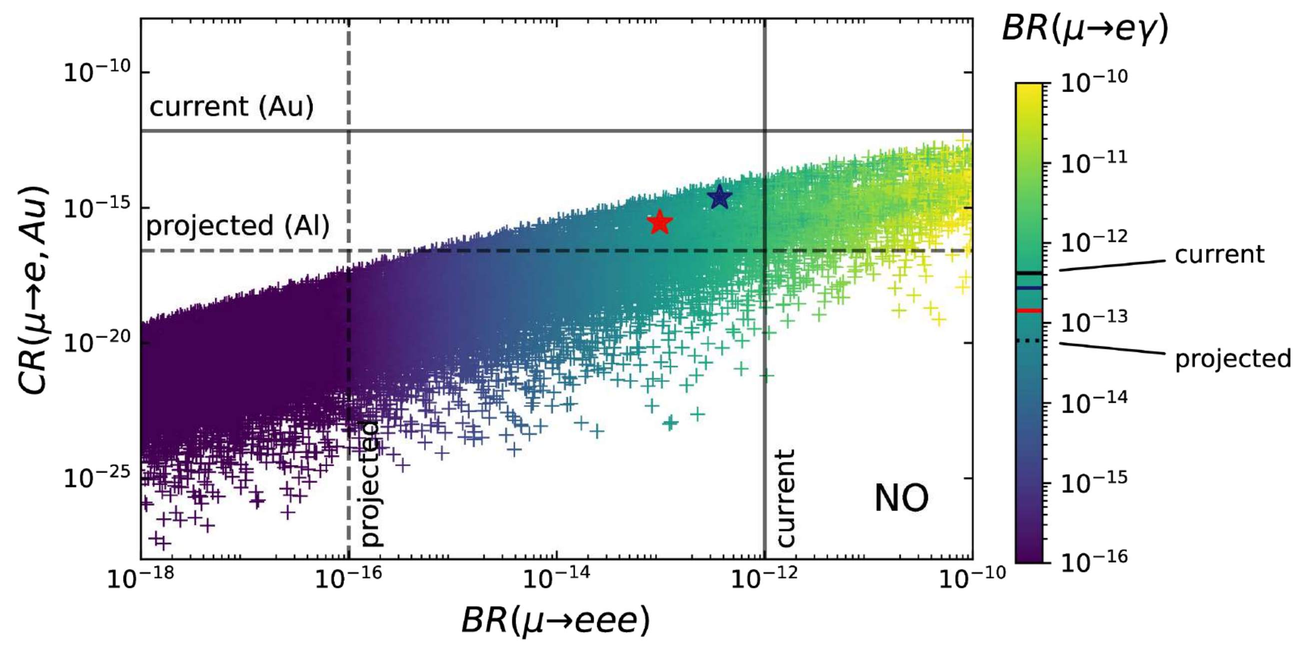


Charged Lepton Flavor Violation

- Charged lepton flavor violating (cLFV) processes, such as $\mu \to e\gamma$, $\mu \to eee$ and $\mu - e$ conversion in nuclei, arise from the exchange of RH Majorana neutrinos N_{R_i} and the charged scalar $\eta^{\pm}$ from the inert doublet.
- Yukawa couplings of order $O(0.1)$ are allowed for masses in the TeV scale:



- The sizeable Yukawa couplings (made possible due to the 3-loop suppression in the neutrino mass generation) imply good prospects for a signal in near future cLFV experiments:



Conclusion and Perspective

- We constructed a model which implements a 3-loop radiative seesaw mechanism that **successfully produces the tiny neutrino masses**.
- A fermionic or scalar **DM candidate can be easily accommodated**.
- The three-loop suppression allows the new particles to have masses in the TeV scale **without fine-tuning** the Yukawa (or any other) parameters.
- The model is **capable of successfully explaining the *W* mass anomaly**, while satisfying all the current constraints.
- The large Yukawa couplings lead to **sizable rates for cLFV**, rendering the **model testable in the next generation of cLFV experiments**.

References

[1] A. Abada, N. Bernal, A. E. Cárcamo Hernández, S. Kovalenko, T. B. de Melo and T. Toma, *Phenomenological and cosmological implications of a scotogenic three-loop neutrino mass model*, *JHEP* **03** (2023) 035 [2212.06852].

[2] CDF collaboration, T. Aaltonen et al., *High-precision measurement of the W boson mass with the CDF II detector*, *Science* **376** (2022) 170.

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