$0\nu\beta\beta$ IN LEFT-RIGHT THEORIES WITH HIGGS DOUBLETS AND GAUGE COUPLING UNIFICATION

Published in Nucl. Phys. B951, 114875 (2020)

Chayan Majumdar (Presenter)[1], Sudhanwa Patra[2], Supriya Senapati[1], Urjit A. Yajnik[1]

[1]Dept. of Physics, IIT Bombay, Maharashtra, India, Pin-400076 [2]Dept. of Physics, IIT Bhilai, Chhattisgarh, India, Pin-492015

Template courtesy : https://www.overleaf.com/latex/examples/bound-states-in-the-continuum/bnghrghcdnfy

WHY LEFT-RIGHT THEORIES?

- Theoretical predictions of Standard Model match well with experimental findings so far.
- Though some discrepancies are there :
  - Explanation of small neutrino mass generation.
  - Parity violation in low-energy weak interactions.

$\Rightarrow$ Within Left-Right symmetric Models (LRSMs)[1], we have a unified explanation for both of them.

AIM

- Dirac mass generation for neutrinos at tree-level $\Rightarrow$ generation of Radiative Majorana mass at one-loop level.
- Gauge Coupling unification in doublet scalar LRSM.
- New physics signature in context of Neutrinoless-double beta decay ($0\nu\beta\beta$).
- Cosmological Connection of the framework.

MODEL DESCRIPTION

- **Gauge Group** : $SU(3)_C \otimes SU(2)_L \otimes SU(2)_R \otimes U(1)_{B-L}$.
- **Particle Content** [2]:

  Quarks : $q_L \equiv \begin{pmatrix} u_L \\ d_L \end{pmatrix} \sim (3,2,1,1/3)$ and $q_R \equiv \begin{pmatrix} u_R \\ d_R \end{pmatrix} \sim (3,1,2,1/3)$.

  Leptons : $\ell_L \equiv \begin{pmatrix} \nu_L \\ e_L \end{pmatrix} \sim (1,2,1,-1)$ and $\ell_R \equiv \begin{pmatrix} \nu_R \\ e_R \end{pmatrix} \sim (1,1,2,-1)$.

  Scalars : $\Phi \sim (1,2,2,0) \oplus H_L \sim (1,2,1,1) \oplus H_R \sim (1,1,2,1) \oplus \delta^+ \sim (1,1,1,2)$.

NEUTRINO MASS GENERATION

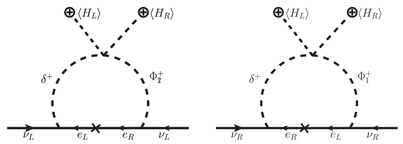

Figure 1: Radiative one-loop Majorana mass generation.

$$M_{L,R}^{1-\text{loop}} \simeq \frac{\lambda' \langle H_L \rangle \langle H_R \rangle}{16\pi^2} \frac{\lambda^{L,R} M_\ell Y_\ell^T}{M^2} \mathcal{I}$$

where $M = \max(M_{\delta^+}, M_\Phi)$, M_ℓ is the lepton mass and loop factor,

$$\mathcal{I} = \frac{\log\left[\frac{M_\ell^2}{M_{\delta^+}^2}\right] M_{\delta^+}^2}{M_{\delta^+}^2 - M_\ell^2} - \frac{\log\left[\frac{M_\ell^2}{M_\Phi^2}\right] M_\Phi^2}{M_\Phi^2 - M_\ell^2}.$$

- Complete neutral mass matrix,

$$M = \begin{pmatrix} M_L^{1-\text{loop}} & M_D \\ M_D^T & M_R^{1-\text{loop}} \end{pmatrix}$$

- In the mass hierarchy $M_R^{1-\text{loop}} \gg M_D \gg M_L^{1-\text{loop}}$ and $M_L^{1-\text{loop}} \to 0$, we have

$$m_\nu \sim -M_D (M_R^{1-\text{loop}})^{-1} M_D^T, \quad m_N \sim M_R^{1-\text{loop}}.$$

INTRODUCTION TO $0\nu\beta\beta$

- Half-life of an isotope :

$$\frac{1}{T_{1/2}^{0\nu}} = G_{01}[(\mathcal{M}_\nu \eta_\nu^L + \mathcal{M}_N \eta_N^L)^2 + (\mathcal{M}_N \eta_N^R + \mathcal{M}_\nu \eta_\nu^R)^2 + (\mathcal{M}_\lambda(\eta_\lambda^\nu + \eta_\lambda^N) + \mathcal{M}_\eta(\eta_\eta^\nu + \eta_\eta^N))^2].$$

- Contributions are coming from $W_L - W_L$ mediation, $W_R - W_R$ mediation and $W_L - W_R$ mixing (λ and η) diagrams.
- Majorana mass generation for neutrinos $\Rightarrow$ $0\nu\beta\beta$ decay signature.

GAUGE COUPLING UNIFICATION

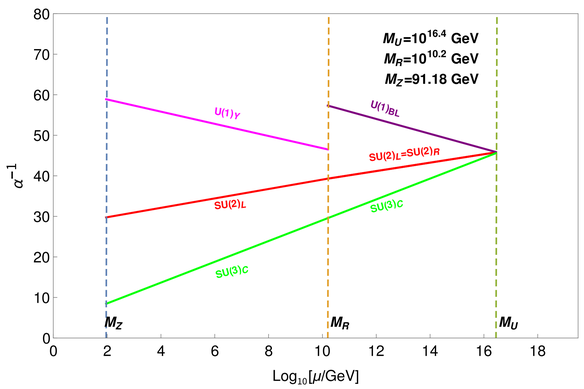

Figure 2: Gauge Coupling unification with usual particle content of doublet LRSM described in Model Description section, LR breaking scale at about 10^{10} GeV (Out of collider reach).

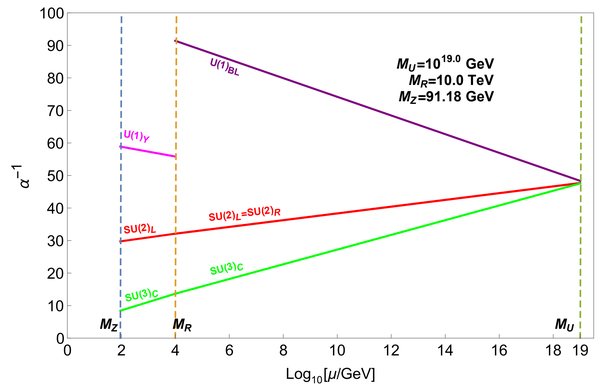

Figure 3: Gauge coupling unification with extended scalar sector, now LR symmetry breaks at 10 TeV (can be easily probed in present-day collider searches).

$0\nu\beta\beta$ SIGNATURE WITHIN THIS FRAMEWORK

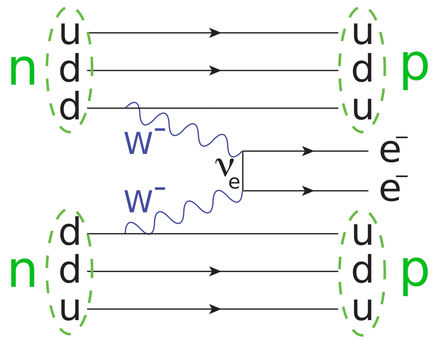

Figure 4: Standard $0\nu\beta\beta$ decay process.

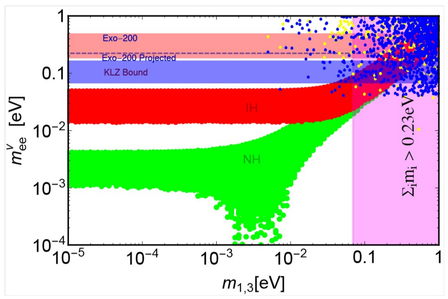

Figure 5: Plots for effective Majorana mass in context of $0\nu\beta\beta$ with various cosmological as well as collider constraints along this line.

- Yellow and Blue dots represent new physics contributions arising from λ and η diagrams which can easily saturate GERDA and KamLAND-Zen experimental bounds on $0\nu\beta\beta$.

COSMOLOGICAL CONNECTION

- Using values from gauge-coupling plots, we can have keV-MeV range massive right-handed neutrinos $\Rightarrow$ these can be visualised as warm DM candidate.
- keV range neutrinos cause overabundance of DM density in universe.
- To solve the problem heavier RH neutrino species (say $N_{2,3}$) play the role of diluters (by dint of processes like $N_{2,3} \to ljj$ or $l\pi$) [C. Majumdar *et. al.*(arxiv:1809.10577)].
- Remaining lighter species N_1 will act as warm DM candidates.

REFERENCES

[1] R. N. Mohapatra and J. C. Pati. "natural" left-right symmetry. *Phys. Rev. D*, 11:2558–2561, May 1975.

[2] Pavel Fileviez Perez, Clara Murgui, and Sebastian Ohmer. Simple left-right theory: Lepton number violation at the lhc. *Phys. Rev. D*, 94:051701, Sep 2016.