FLAVOURED LEPTOGENESIS AND TYPE-II SEESAW MECHANISM WITH TWO HIGGS TRIPLET SCALARS

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Abstract

Type-II seesaw mechanism has been widely studied already as the link between neutrino mass generation beyond Standard Model (SM) and leptogenesis. The SM is minimally extended by two triplet Higgs scalars, with one triplet having complex vacuum expectation value. The triplet vevs are bounded by the ρ-parameter constraint. The neutrino mass gets generated by type-II seesaw mechanism with two massive triplet Higgs, without any right-handed neutrino. On the other hand, purely flavoured leptogenesis is achieved when the triplet Higgs scalar of mass $M_T \sim 10^9$ GeV, undergoes out-of-equilibrium bi-lepton decay through lepton loop. The lepton asymmetries get converted into baryon asymmetry via nonperturbative sphaleron process. Here, baryon asymmetry of the order $\sim 10^{-10}$ is achieved. The dependence of the baryon asymmetry on the branching ratios of triplet scalar deays is also studied here. The effectiveness of two-zero texture B_2 in neutrino mass matrix is mentioned.

1. Model description

- Two Triplet Higgs scalars $T_1(\delta_1^{++}, \delta_1^{+}, \delta_1^{0})$ and $T_2(\delta_2^{++}, \delta_2^{+}, \delta_2^{0})$ with hypercharge $\mathcal{Y} = 2$ [1],

$$T_1 = \begin{pmatrix} \frac{\delta_1^+}{\sqrt{2}} & \delta_1^{++} \\ \delta_1^0 & -\frac{\delta_1^+}{\sqrt{2}} \end{pmatrix}, \quad T_2 = \begin{pmatrix} \frac{\delta_2^+}{\sqrt{2}} & \delta_2^{++} \\ \delta_2^0 & -\frac{\delta_2^+}{\sqrt{2}} \end{pmatrix}$$

- Triplet scalar vevs:

$$< \delta_1^0 >= \omega_1 = |\omega_1| e^{i\alpha}, \quad < \delta_2^0 >= \omega_2$$

- ρ-parameter constrain on triplet vevs:

$$\rho = \frac{v^2 + 2\omega_1^2 + 2\omega_2^2}{v^2 + 4\omega_1^2 + 4\omega_2^2}$$

where v is the SM Higgs doublet vev, and $\omega_1, \omega_2 \ll v$, $\omega_1 \sim [10^{-8} - 10^{-6}]$GeV

- Triplet scalars' masses: $M_{T_1} \gg M_{T_2}$, $M_{T_2} \sim 10^9$ GeV

2. Neutrino mass generation

- The Lagrangian beyond SM,

$$\mathcal{L} = Tr[(D_\mu T_k)^\dagger (D^\mu T_k)] - \frac{Y_{ij} L_i^T C_i \sigma T_k L_j}{\sqrt{2}},$$

with $k = 1, 2$ and $i, j = e, \mu, \tau$.

- Lepton number breaking trilinear term $\mu_k \phi^\dagger T_k i\sigma_2 \phi^*$ in the potential $V(\phi, T_1, T_2)$, $\mu_1 = |\mu_1| e^{i\beta}$

- Neutrino mass generation through the contributions of two Higgs triplets by type-II seesaw mechanism:

$$M_\nu = M_\nu^{(1)} + M_\nu^{(2)} = Y_1 \omega_1 cos\alpha + Y_2 \omega_2 \quad (1)$$

3. Two-zero texture-B_2

- Two-zero texture B_2:

$$B_2 = \begin{pmatrix} \times & 0 & \times \\ 0 & \times & \times \\ \times & \times & 0 \end{pmatrix}$$

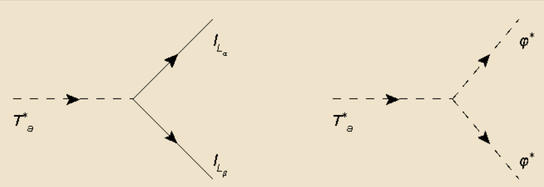
- The chosen neutrino mass matrix:

$$M_\nu = \begin{bmatrix} 0.04135 & 0 & 0.03411 \\ 0 & 0.05465 & 0.05085 \\ 0.03411 & 0.05085 & 0 \end{bmatrix}.$$

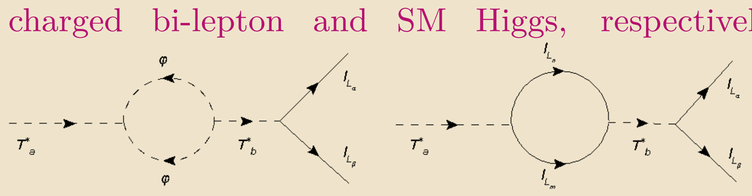
$$\Sigma = m_1 + m_2 + m_3 \approx 0.1459eV < 0.16eV$$

- Inverse Hierarchy (IH) of neutrino mass is disfavoured [2].

4.Triplet scalar decay modes:



Tree level decay diagram: Triplet decaying into charged bi-lepton and SM Higgs, respectively



One-loop decay diagram: Triplet decaying into charged bi-lepton through Higgs loop and lepton loop, respectively

5. Fully flavoured leptogenesis

- Temperature scale: $T \lesssim 10^9$ GeV "Fully flavoured leptogenesis"[3]

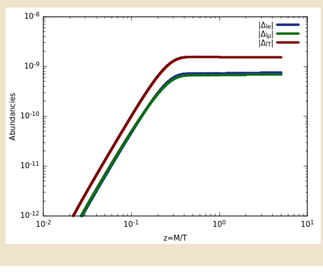
- Fully flavoured CP asymmetry parameter:

$$\epsilon^{\alpha\beta} = \frac{M_{T_2} (B_l B_\phi)^{\frac{1}{2}}}{4\pi v^2} \frac{cIm[(M_\nu^{(2)})_{\alpha\beta} (M_\nu^{(1)*})_{\alpha\beta}]}{[Tr(M_\nu^{(2)\dagger} M_\nu^{(2)})]^{\frac{1}{2}}}$$

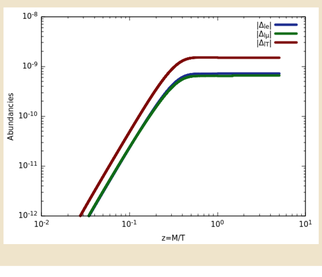
- Purely Flavoured Leptogenesis (PFL) conditions: $B_l \gg B_\phi$,

$$\sum_{\alpha,\beta} \epsilon_{\alpha\beta} = 0$$

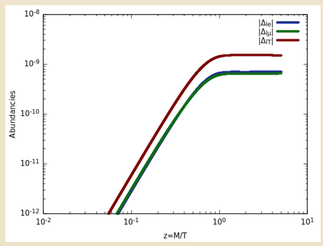
6a. $B_l = 0.99999$



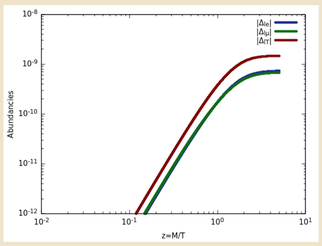
6b. $B_l = 0.9999$



6c. $B_l = 0.99$



6d. $B_l = 0.50$



7. Conclusion

- After solving the set of Boltzmann equations we obtain the lepton asymmetry plots for four different set of branching ratios. The baryon asymmetry is calculated through the expression

$$\eta_B = 3c_{sph} \sum_{\alpha,\beta} A^{-1}_{\alpha\beta} \Delta_{l_\beta}, \quad [c_{sph} = \frac{28}{79}, \quad A = \begin{pmatrix} -\frac{151}{179} & \frac{20}{179} & \frac{20}{179} \\ \frac{25}{358} & -\frac{344}{537} & \frac{14}{537} \\ \frac{25}{358} & \frac{14}{537} & -\frac{344}{537} \end{pmatrix}]$$

B_l	ϵ_{ee}	$\epsilon_{e\tau}$	$\epsilon_{\mu\mu}$	$\epsilon_{\mu\tau}$	η_B
0.99999	7.0×10^{-10}	-2.6×10^{-9}	-8.6×10^{-9}	6.55×10^{-9}	-5.24×10^{-10}
0.9999	7.0×10^{-10}	-2.6×10^{-9}	-8.4×10^{-9}	6.45×10^{-9}	-5.30×10^{-10}
0.99	7.0×10^{-10}	2.55×10^{-9}	8.4×10^{-9}	-6.4×10^{-9}	5.85×10^{-10}
0.50	-7.0×10^{-10}	2.55×10^{-9}	8.4×10^{-9}	-6.4×10^{-9}	5.34×10^{-10}

Result table: PFL with two-zero texture B_2: $M_T = 10^9$GeV

References

[1] Avinanda Chaudhuri and Biswarup Mukhopadhyaya. CP -violating phase in a two Higgs triplet scenario: Some phenomenological implications. *Phys. Rev. D*, 93(9):093003, 2016.

[2] Madan Singh. Testing texture two-zero neutrino mass matrices under current experimental scenario. *EPL*, 129(1):1, 2020.

[3] R. Gonzalez Felipe, F.R. Joaquim, and H. Serodio. Flavoured CP asymmetries for type II seesaw leptogenesis. *Int. J. Mod. Phys. A*, 28:1350165, 2013.