PROCEEDINGS OF SCIENCE

Neutrino phenomenology, $(g-2)_{\mu,e}$ with U(1) gauge symmetries in inverse seesaw framework

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In the study, we have introduced two anomaly free gauge symmetries i.e. $U(1)_{B-L}$ and $U(1)_{L_e-L_\mu}$ in an inverse seesaw framework as extension of Standard Model. Inclusion of three right handed neutrinos N_{R_i} and three left handed fermions S_{L_i} explains neutrino phenomenology, neutrinoless double beta decay, electron and muon anomalous magnetic moment successfully. In addition to six new fermions, we have taken two scalar singlets χ_1 and χ_2 which break two extended gauge symmetries respectively. Two gauge bosons Z_1, Z_2 are used to explain $(g-2)_{e,\mu}$ where m_{Z_1} is in MeV range and m_{Z_2} is in GeV range. Idea for taking such type of gauge bosons mass ranges is verified by the upper limits of so many current experiments like Orsay, E141, E774, NA64, KLOE, Babar inv and future experiments like FASER, VEPP3, DUNE etc.

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1. Introduction and Model description

In our model framework, we have taken three right handed neutrinos (N_{R_i}) and three left handed fermions (S_{L_i}) in addition of SM particles. Two gauge anomaly free symmetries $U(1)_{B-L}\times U(1)_{L_e-L_\mu}$ have been introduced in presence of two scalar singlets χ_1 and χ_2. The quantum charges for these particles are taken(Table 1) in such a way that the model become gauge anomaly free. The

Particle	$SU(3)_C$	$SU(2)_L$	$U(1)_Y$	$U(1)_{B-L}$	$U(1)_{L_e-L_\mu}$
$\ell_{\alpha L}(\alpha=e,\mu,\tau)$	**1**	**2**	−1	−1	1, −1, 0
$\ell_{\alpha R}(\alpha=e,\mu,\tau)$	**1**	**1**	−2	−1	1, −1, 0
$N_{R_i}(i=1,2,3)$	**1**	**1**	0	−1	1, −1, 0
$S_{L_i}(i=1,2,3)$	**1**	**1**	0	0	1, −1, 0
H	**1**	**2**	1	0	0
χ_1	**1**	**1**	0	1	0
χ_2	**1**	**1**	0	0	1

Table 1: Particles and their corresponding charge assignment under $SU(3)_C\times SU(2)_L\times U(1)_Y\times U(1)_{B-L}\times U(1)_{L_e-L_\mu}$ model.

Lagrangian for leptonic sector can be written as:

$$\begin{aligned}\mathcal{L}_{lepton} \supset\ & \mathcal{L}_{SM}+\left[y_D^e\bar{\ell}_{eL}\tilde{H}N_{R_1}+y_D^\mu\bar{\ell}_{\mu L}\tilde{H}N_{R_2}+y_D^\tau\bar{\ell}_{\tau L}\tilde{H}N_{R_3}\right]\\ +\ & \left[y_N^1\bar{S}_{L_1}N_{R_1}\chi_1+y_N^2\bar{S}_{L_2}N_{R_2}\chi_1+y_N^3\bar{S}_{L_3}N_{R_3}\chi_1\right]\\ +\ & \left[\mathcal{M}_{12}\bar{S}^C_{L_1}S_{L_2}+y_{13}\bar{S}^C_{L_1}S_{L_3}\chi_2^*+y_{23}\bar{S}^C_{L_2}S_{L_3}\chi_2+\mathcal{M}_{33}\bar{S}^C_{L_3}S_{L_3}\right]+h.c.,\end{aligned} \tag{1}$$

where $\mathcal{L}_{SM}$ is the Lagrangian for leptonic sector coming from the Standard Model and $y_D^\alpha(\alpha=e,\mu,\tau)$ are the Yukawa couplings for Dirac interactions, y_N^i $(i=1,2,3)$ are the couplings for heavy fermions, $y_{j3}(j=1,2)$, are the couplings of Dirac mass and $\mathcal{M}_{12},\mathcal{M}_{33}$, the Majorana mass terms of extra neutral fermions S_{L_i}. Active neutrino mass matrix can be calculated by the expression of inverse seesaw mechanism:

$$m_\nu=\mathcal{M}_D^T(\mathcal{M}_N^{-1})^T\mathcal{M}_\mu\mathcal{M}_N^{-1}\mathcal{M}_D\ . \tag{2}$$

where $\mathcal{M}_\mathcal{D}$ is Dirac mass matrix, $\mathcal{M}_N$ is mixing matrix and $\mathcal{M}_\mu$ is Majorana mass of S_{L_i}.

2. Neutrino phenomenology and NDBD

We perform $\Delta\chi^2$ minimization method to get neutrino oscillation parameters where we have fixed all other free parameters, only two VEVs are varied. Best-fit values of free parameters with VEVs has shown in Table 2. Neutrino oscillation plots are shown in Figs.1 and 2, where the rightmost plot of Fig. 2 gives the points well below the upper bound of two experiments on $0\nu\nu\beta\beta$ decay, KamLAND-Zen and CUORE.

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Parameters	Best fit values	Parameters	Best fit values
y_D^e	2.18517×10^{-6}	y_{23}	7.31554×10^{-10}
y_D^μ	5.5844×10^{-6}	v_1	1.40329×10^{13} eV
y_D^τ	5.26279×10^{-6}	v_2	7.88154×10^{12} eV
y_N^1	9.40922×10^{-6}	$\mathcal{M}_{12}$	5590.056275 eV
y_N^2	4.7628×10^{-6}	$\mathcal{M}_{33}$	1714.181373 eV
y_N^3	8.21522×10^{-6}	ϕ	1.67648628 rad
y_{13}	1.02356×10^{-10}	$\chi^2_{\rm min}$	0.27014271

Table 2: Best-fit values of Yukawa couplings and vacuum expectation values.

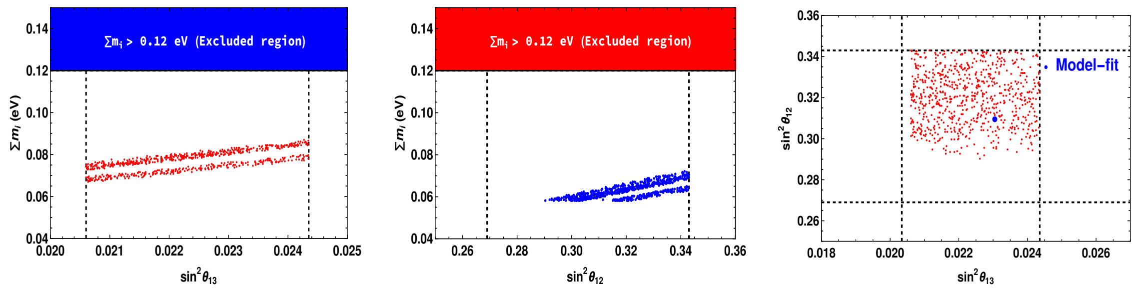

Figure 1: Left panel shows the variation of active neutrino mass $\sum m_i (i = 1, 2, 3)$ with oscillation parameter $\sin^2\theta_{13}$, middle one indicates the same with respect to $\sin^2\theta_{12}$, rightmost plot is the correlation of two mixing angles $\sin^2\theta_{13}$ and $\sin^2\theta_{12}$.

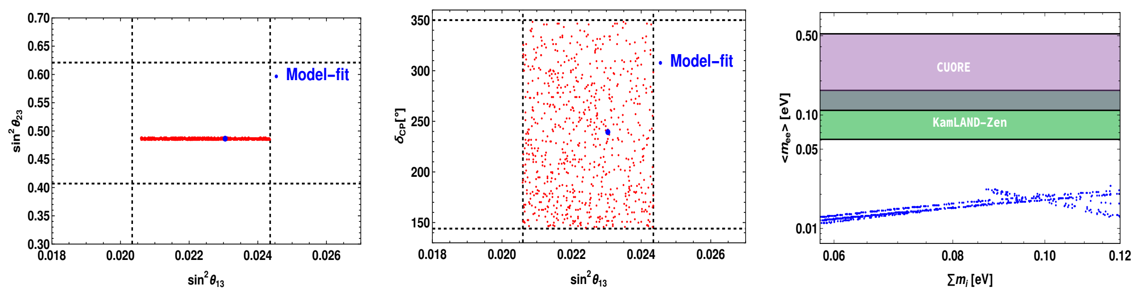

Figure 2: Left panel is the correlation of two mixing angles $\sin^2\theta_{13}$ and $\sin^2\theta_{23}$, middle plot shows the variation of CP violating phase δ_{CP} with $\sin^2\theta_{13}$, and rightmost panel is the plot of neutrinoless double beta decay effective mass parameter $\langle m_{ee}\rangle$ with $\sum m_i$.

3. Electron and muon anomalous magnetic moment

For electron, $(g-2)_e$ is still not accurately measured. Different experiments give the value of Δa_e with an issue with sign. Rubidium atom measurement gives us +ve value of $(g-2)_e$ with 1.6σ discrepancy over SM [1],

$$(\Delta a_e)_{\rm Rb} = (48 \pm 30) \times 10^{-14}, \tag{3}$$

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Our model parameters have shown a positive impact towards the result with Rubidium atom and the corresponding plots are shown in Fig. 3. Fermilab[2] has a very precise measurement of $(g-2)_\mu$ with 4.2σ discrepancy and the value of Δa_μ is:

$$\Delta a_\mu^{\text{FNAL}} = a_\mu^{exp} - a_\mu^{SM} = (25.1 \pm 59) \times 10^{-10}. \quad (4)$$

By taking a suitable combination of g_1, g_2, m_{Z_1} and m_{Z_2}, we have plotted Fig. 4 for Δa_μ.

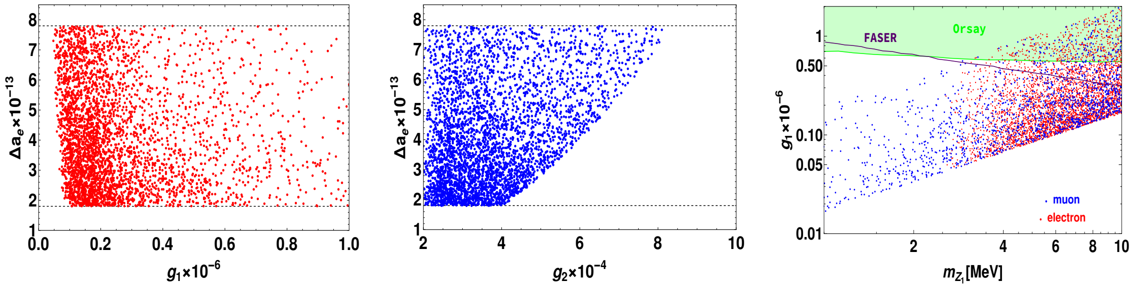

Figure 3: Left plot shows the variation of Δa_e with respect to gauge coupling g_1, middle one shows the same with respect to g_2, rightmost plot gives the variation of g_1 with m_{Z_1} and shows the common parameter space for electron and muon both.

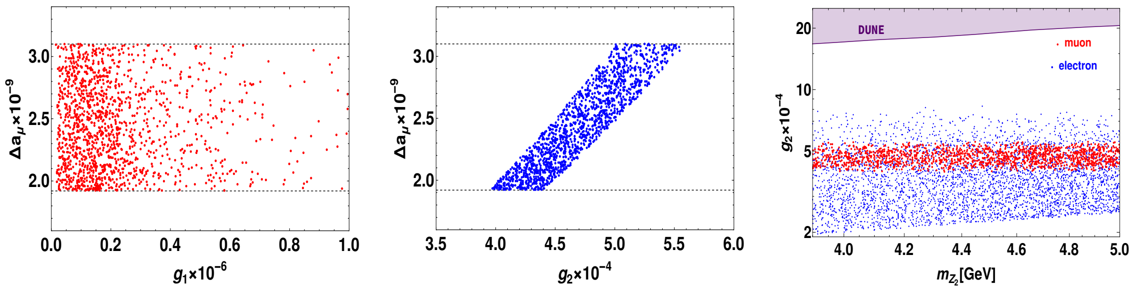

Figure 4: Left plot shows the variation of Δa_μ with respect to gauge coupling g_1, middle one shows the same with respect to g_2, rightmost plot gives the variation of g_2 with m_{Z_2} for electron as well as muon anomalous magnetic moments simultaneously in comparison of DUNE data.

4. Conclusion

Proposed model successfully described neutrino phenomenology, neutrinoless double beta decay, electron and muon anomalous magnetic moment with the presence of six extra fermions (N_{R_i}, S_{L_i}) in the framework of inverse seesaw mechanism.

References

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