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Constrained Neutrino Masses and Flavour Observables from a Dual Seesaw Framework

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MOTIVATION & AIM

- ✓ Neutrino oscillation confirms tiny non-zero masses and non-trivial mixing, pointing clearly to physics beyond the Standard Model (SM).
- ✓ Precision measurements of θ_{13} and CP violation rule out simple flavour-symmetric structures, motivating refined and realistic mass textures.
- ✓ A dual seesaw (Type-I + Type-II) framework provides a natural mechanism to generate small Majorana neutrino masses with structured correlations.
- ✓ We construct a constrained and predictive neutrino mass texture by reducing independent parameters while maintaining consistency with oscillation data.
- ✓ The framework reproduces realistic neutrino masses and mixing, and tests its efficacy through measurable observables such as effective Majorana mass ($m_{\beta\beta}$) and branching ratio (BR) of the dominant charged lepton flavour violating (cLFV) decay $\mu \to e + \gamma$.

THE MODEL

- We extend the SM with additional scalar fields and enforce A_4 and cyclic symmetries.
- The transformation properties of the field content under $A_4 \times Z_3 \times Z_{10} \times SU(2)_L \times U(1)_Y$ are shown below

Field	D_{l_L}	l_R	ν_{l_R}	H	Φ	η	κ	Δ	ξ	ζ
A_4	3	$(1, 1'', 1')$	$(1, 1'', 1')$	3	3	$1''$	$1'$	3	1	1
Z_3	1	(ω, ω, ω)	$(1, 1, 1)$	ω^2	1	1	1	1	1	1
Z_{10}	0	0	$(0, 4, 6)$	0	0	2	8	0	6	4
$SU(2)_L$	2	1	1	2	2	1	1	3	1	1
$U(1)_Y$	-1	-2	0	1	-1	0	0	-2	0	0

- The Yukawa Lagrangian $(-L_Y)$ of the model is formulated in the T basis and is presented below

$$y_e(\bar{D}_{l_L} H)\, e_R + y_\mu(\bar{D}_{l_L} H)\, \mu_R + y_\tau(\bar{D}_{l_L} H)\tau_R + y_1 (\bar{D}_{l_L}\Phi)\, \nu_{e_R} + \frac{y_2}{\Lambda}(\bar{D}_{l_L}\Phi)\nu_{\mu_R}\xi + \frac{y_3}{\Lambda}(\bar{D}_{l_L}\Phi)\,\nu_{\tau_R}\,\zeta + \frac{1}{2}M_1(\bar{\nu^c_{e_R}}\,\nu_{e_R}) + \frac{1}{2}M_2\left[(\bar{\nu^c_{\mu_R}}\nu_{\tau_R}) + (\bar{\nu^c_{\tau_R}}\nu_{\mu_R})\right] + \frac{1}{2}y_{R_1}(\bar{\nu^c_{\mu_R}}\nu_{\mu_R})\eta + \frac{1}{2}y_{R_2}(\bar{\nu^c_{\tau_R}}\nu_{\tau_R})\,\kappa + \frac{1}{2}y_\Delta(\bar{D}_{l_L} D^c_{l_L})\,\tilde{\Delta} + h.c.$$

- The vacuum alignment associated with the scalar fields is chosen as $< H > = v_h(1,0,0)$, $< \Phi > = u\,(0,1,1)$, $< \Delta > = v_\Delta(0,1,-1)$, $< \eta > = v_\eta$, $< \kappa > = v_\kappa$, $< \xi > = v_\xi$, $< \zeta > = v_\zeta$. The Type-I +Type-II seesaw neutrino mass matrix (M_ν) is obtained as shown below

$$\begin{pmatrix} a+b & a & b \\ a & c & d \\ b & d & t \end{pmatrix}$$

$$a = \frac{u^2\widetilde{y_3}\,(M_3\,\widetilde{y_3} - M_2\widetilde{y_2})}{M_2^2 - M_3M_4} + \frac{v_\Delta y_\Delta}{3}$$

$$b = \frac{u^2\widetilde{y_2}\,(M_4\,\widetilde{y_2} - M_2\widetilde{y_3})}{M_2^2 - M_3M_4} - \frac{v_\Delta y_\Delta}{3}$$

$$c = u^2\left(\frac{M_3\,\widetilde{y_3}^2}{M_2^2 - M_3M_4} - \frac{y_1^2}{M_1}\right) + \frac{2\,v_\Delta y_\Delta}{3}$$

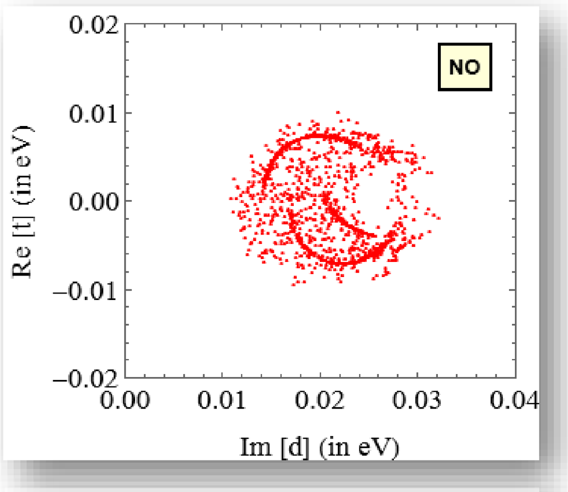
$$d = u^2\left(\frac{-M_2\,\widetilde{y_2}\widetilde{y_3}}{M_2^2 - M_3M_4} - \frac{y_1^2}{M_1}\right)$$

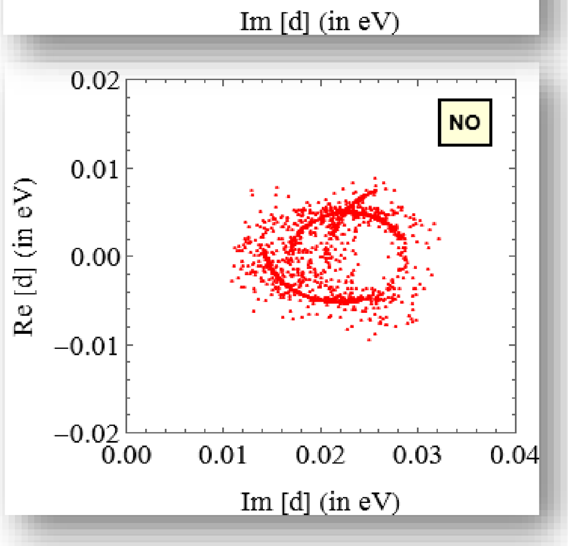
$$t = u^2\left(\frac{M_4\,\widetilde{y_2}^2}{M_2^2 - M_3M_4} - \frac{y_1^2}{M_1}\right) - \frac{2\,v_\Delta y_\Delta}{3}$$

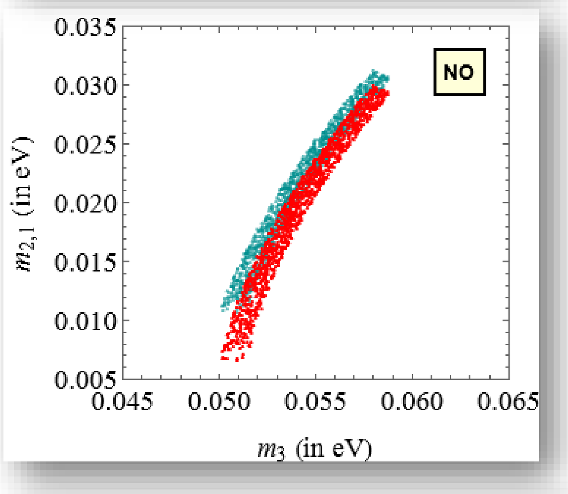
Where, $M_3 = y_{R_1} v_\eta$, $M_4 = y_{R_2} v_\kappa$,

$\widetilde{y_2} = \frac{y_2\, v_\xi}{\Lambda}$, $\widetilde{y_3} = \frac{y_3\, v_\zeta}{\Lambda}$

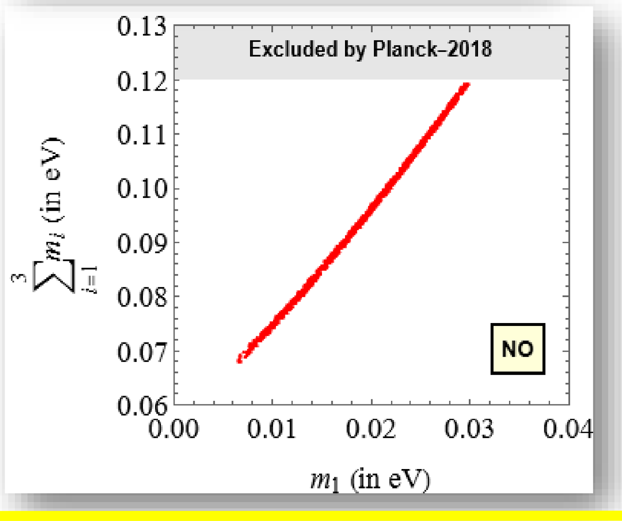
NUMERICAL ANALYSIS & RESULTS

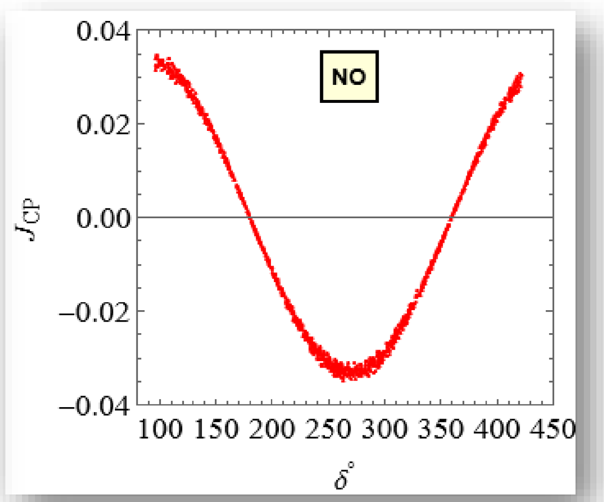


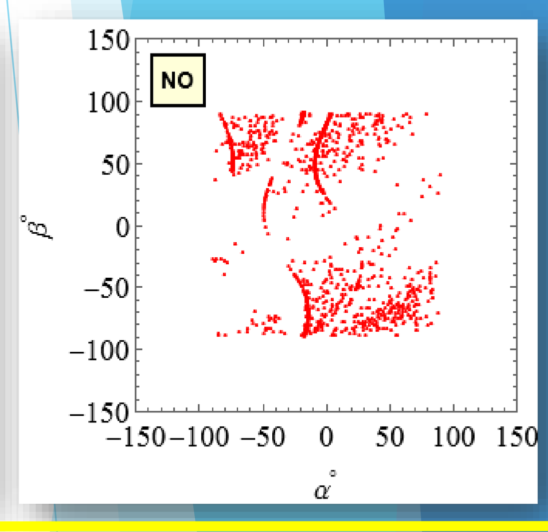




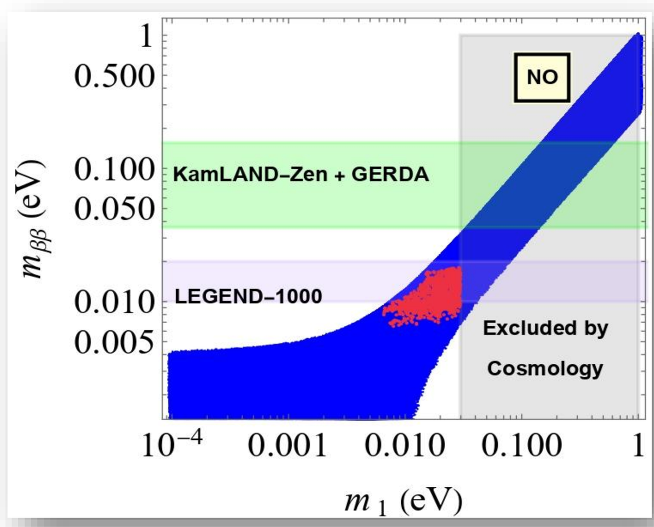
- ❖ $M\nu \to M_\nu^{diag} = \widetilde{U}^T M_\nu \widetilde{U} = diag\,(\widetilde{m_1}, \widetilde{m_2}, 1)$
- ❖ Where, $\widetilde{m_1} = m_1 e^{-2i\alpha}$ and $\widetilde{m_2} = m_2 e^{-2i\beta}$
- ❖ As a result, $a, b, c, d, t \to Re[d], Im[d], Re[t]$
- ❖ Hence, $Re[d], Im[d], Re[t]$ spans the entire texture and the predictions associated with it.
- ❖ We determine the most compatible parameter space for $Re[d]$, $Im[d]$, $Re[t]$ such that Δm^2_{21} and Δm^2_{31} lie within 3σ[1] oscillation bounds and $\sum m_i < 0.12\, eV$[2].
- ❖ We find that the model is viable only for Normal Ordering (NO)
- ❖ We predict the three neutrino mass eigenvalues (m_1, m_2, m_3), two Majorana phases (α, β) and Jarlskog invariant (J_{CP})

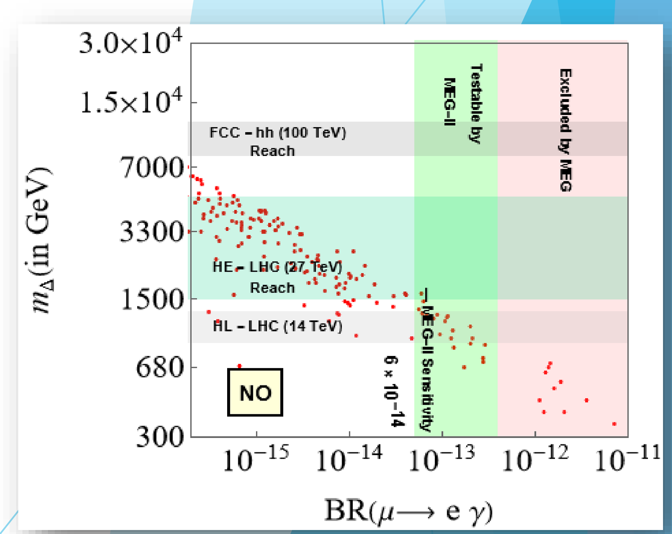






- ❖ The model predicts the effective Majorana mass: $m_{\beta\beta} = \sum_{i=1}^{3} |U_{ei}^2 m_i|$.
- ❖ We analyse CLFV via the decay $\mu \to e + \gamma$ and compute BR($\mu \to e\gamma$).
- ❖ The branching ratio arising from Type-I seesaw is strongly suppressed and phenomenologically negligible.
- ❖ The scalar triplet of Type-II seesaw gives the dominant contribution to BR($\mu \to e\gamma$)[3], making $\mu \to e + \gamma$ an important experimental test of the model and its parameter space.





SUMMARY

We present a flavour symmetric dual seesaw framework, which constrains the neutrino mass matrix to three effective parameters while reproducing current oscillation data. The model favours NO, predicts non-zero leptonic CP violation, and remains consistent with experimental data. It provides experimentally testable predictions in $m_{\beta\beta}$ and BR($\mu \to e\gamma$).

SUGGESTED READS & CONTACT INFORMATION

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