Minimal extension of seesaw mechanism in A4 symmetry and its phenomenological consequences

Mayengbam Kishan Singh
Supervisor : N. Nimai Singh

Department of Physics, Manipur Univesity

06/12/2021

Contents

Minimal Extended Seesaw (MES)

- The simplest extension of seesaw mechanism with three right-handed neutrinos $(\nu_{R1}, \nu_{R2}, \nu_{R3})$ and one singlet chiral field S.
- In the basis (ν_L, ν_R, S), the (7×7) neutrino mass matrix is

$$M_\nu^{7\times 7} = \begin{pmatrix} 0 & M_D & 0 \\ M_D^T & M_R & M_S^T \\ 0 & M_S & 0 \end{pmatrix}$$

- Applying seesaw with the conditions : $M_R >> M_S > M_D$ and $M_S > M_D$, the mass matrix is reduced to a (3×3) active neutrino mass matrix m_ν and sterile neutrino mass m_s as

$$m_\nu \simeq M_D M_R^{-1} M_S^T (M_S) M_R^{-1} M_S^T)^{-1} M_S (M_R^{-1})^T M_D^T - M_D M_R^{-1} M_D^T$$

$$m_s \simeq -M_S M_R^{-1} M_S^T$$

The model

The particle contents and their A_4 group charges are shown below:

Particles	l	e_r	μ_R	τ_R	H	ϕ	ψ	η	ζ	ζ'	χ
A_4	3	1	1"	1'	1	3	3	3	1	1"	1'
Z_4	1	-1	1	1	1	1	i	1	1	-1	1

Particles	ν_{R_1}	ν_{R_2}	ν_{R_3}	S
A_4	1	1"	1	1'
Z_4	1	-i	-1	1

Taking the vev alignments (NH Only) :

$$<\phi>=(v,0,0); <\psi>=(0,-v,v); <\eta>=(0,v,0);$$

$$<\chi>=<\zeta>=<\zeta'>=v$$

$$M_D = M_D + M'_D = \begin{pmatrix} a & -b & t \\ 0 & t & c \\ t & b & -c \end{pmatrix}; \quad M_R = v \begin{pmatrix} \lambda_1 & 0 & 0 \\ 0 & \lambda_2 & 0 \\ 0 & 0 & \lambda_3 \end{pmatrix}$$

$$M_S = (\rho u, 0, 0)$$

From this,we get the active neutrino mass matrix m_ν and sterile neutrino mass m_s as

$$m_\nu = \begin{pmatrix} -\frac{b^2}{e} - \frac{t^2}{f} & \frac{bt}{e} - \frac{ct}{f} & \frac{b^2}{e} + \frac{ct}{f} \\ \frac{bt}{e} - \frac{ct}{f} & -\frac{c^2}{f} - \frac{t^2}{e} & \frac{c^2}{f} - \frac{bt}{e} \\ \frac{b^2}{e} + \frac{ct}{f} & \frac{c^2}{f} - \frac{bt}{e} & -\frac{b^2}{e} - \frac{c^2}{f} \end{pmatrix}$$

$$m_s = -\frac{g^2}{d}$$

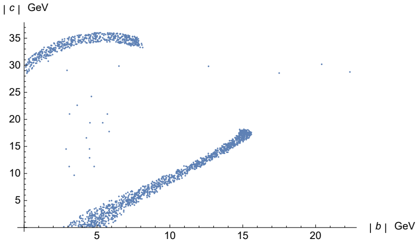
Numerical Analysis and results

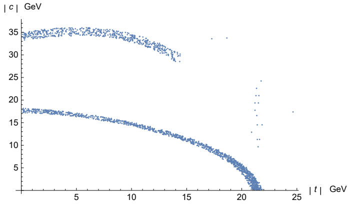
- For diagonalising the active neutrino mass matrix, we use the relation

$$m_\nu = U m_\nu^{diag} U^T$$

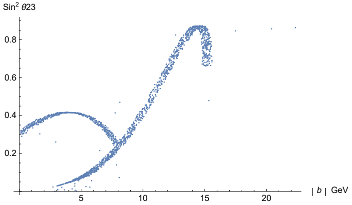
Assuming that U is the unitary U_{PMNS} matrix at the $\mathcal{O}(10^{-2})$ level.

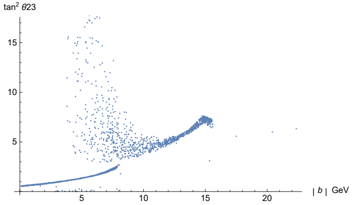
- Comparing the above relation with the results from latest neutrino oscillation, we draw the co-relation plot among the model parameters as shown below





Plots between model parameters and $sin^2\theta_{23}$ and $tan^2\theta_{23}$ is shown below





Discussion

- The co-relation plots shows a very narrow variation.
- This is a work in progress and a lot of other analysis are still to be done.
- We can also work out the phenomenological implications of this model explaining baryogenesis, dark matter problem, neutrinoless double beta decay, etc.
- For a start, this model is work out only for Normal Hierarchy of neutrino masses. But cases for Inverted Hierarchy will also be worked out.

References

1 J. Barry, W. Rodejohann, and H.Zhang, Light Sterile Neutrinos: Models and Phenomenology," JHEP 07 (2011) 091, arXiv:1105.3911 [hep-ph]

2 H. Zhang, Light Sterile Neutrino in the Minimal Extended Seesaw," Phys. Lett. B714 (2012) 262-266, arXiv:1110.6838 [hep-ph]

3 G. Altarelli and F. Feruglio, Tri-bimaximal neutrino mixing from discrete symmetry in extra dimensions," Nucl. Phys. B720 (2005) 64-88, arXiv:hep-ph/0504165 [hep-ph]

4 S. F. King, Neutrino mass models," Rept. Prog. Phys. 67 (2004) 107-158, arXiv:hep-ph/0310204 [hep-ph].

5 P. Das and M. K. Das, Phenomenology of keV sterile neutrino in minimal extended seesaw," Int. J. Mod. Phys. A 35 no. 22, (2020) 205-0125, arXiv:1908.08417 [hep-ph].