Neutrino masses and leptogenesis in a $L_e - L_\mu - L_\tau$ model

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Description

- We present a simple extention of the Standard Model with three right-handed neutrinos in a SUSY framework, with an additional U(1) abelian flavor symmetry with a non standard leptonic charge for lepton doublet and arbitrary right-handed charges. We show how it is possible to provide the correct prediction for the mixing angles of the PMNS matrix and for the parameters with a moderate fine tuning.
- The baryon asymmetry of the Universe is generated via thermal leptogenesis through CP-violating decays of the heavy right-handed neutrinos. We present a detailed numerical solution of the relevant Boltzmann equations for the impact of the distribution of the asymmetry in the three lepton flavors.

Low Energy Model Building

Experimental values:

- $\theta_{13} = 8.64^{\circ}{}^{+0.12^\circ}_{-0.13^\circ}$
- $\theta_{12} = 33.45^{\circ}{}^{+0.75^\circ}_{-0.78^\circ} \equiv \theta_{sol}$
- $\theta_{23} = 49.3^{\circ}{}^{+0.9^\circ}_{-1.1^\circ} \equiv \theta_{atm}$
- $r = \frac{\Delta m^2_{sun}}{\Delta m^2_{atm}} \sim 0.03$

In order to provide the right values for the mixing angles, the parameter *r* and the charged lepton mass hierarchy, we introduce two heavy complex scalar fields Θ and ϕ, called *flavons*, charged under the additional U(1) flavor symmetry and inert under the Standard Model.

After the symmetry-breaking the relevant operators for the lepton masses can be written in the (simplified) form:

$$\mathcal{L} = \frac{x_{ij}}{\Lambda} l_i l_j \left(\frac{\langle\Theta\rangle}{M_F}\right)^{\alpha_{ij}} \left(\frac{\langle\Phi\rangle}{M_F}\right)^{\beta_{ij}} H_u H_u + a_{ij} l_i l_j^c \left(\frac{\langle\Theta\rangle}{M_F}\right)^{\gamma_{ij}} \left(\frac{\langle\Phi\rangle}{M_F}\right)^{\sigma_{ij}} H_d .$$

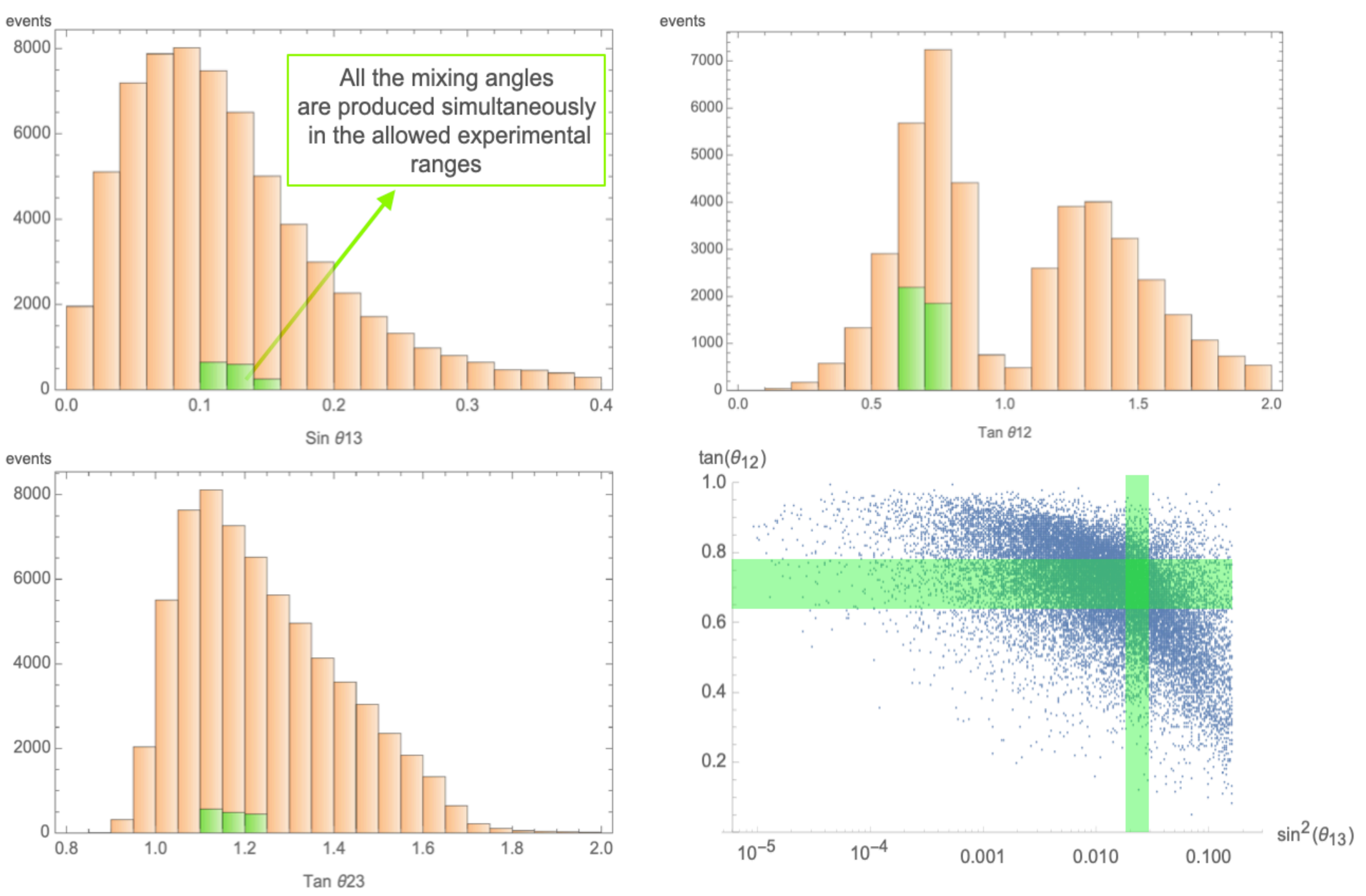
With λ=0.22 being the symmetry-breaking order parameter and the following charge assignment

	l_e	l_μ	l_τ	l_e^c	l_μ^c	l_τ^c	Θ	Φ
$U(1)_F$	+1	-1	-1	−13	7	3	+2	-2

we have:

$$m_\nu = m_0 \begin{pmatrix} x_1\lambda & 1 & x \\ 1 & x_2\lambda & x_3\lambda \\ x & x_3\lambda & x_4\lambda \end{pmatrix}, \qquad m_l = m_\tau \begin{pmatrix} \lambda^5 & \lambda^3 & \lambda \\ \lambda^6 & \lambda^2 e^{i\phi 22} & e^{i\phi 23} \\ \lambda^6 & \lambda^2 e^{i\phi 32} & 1 \end{pmatrix}.$$

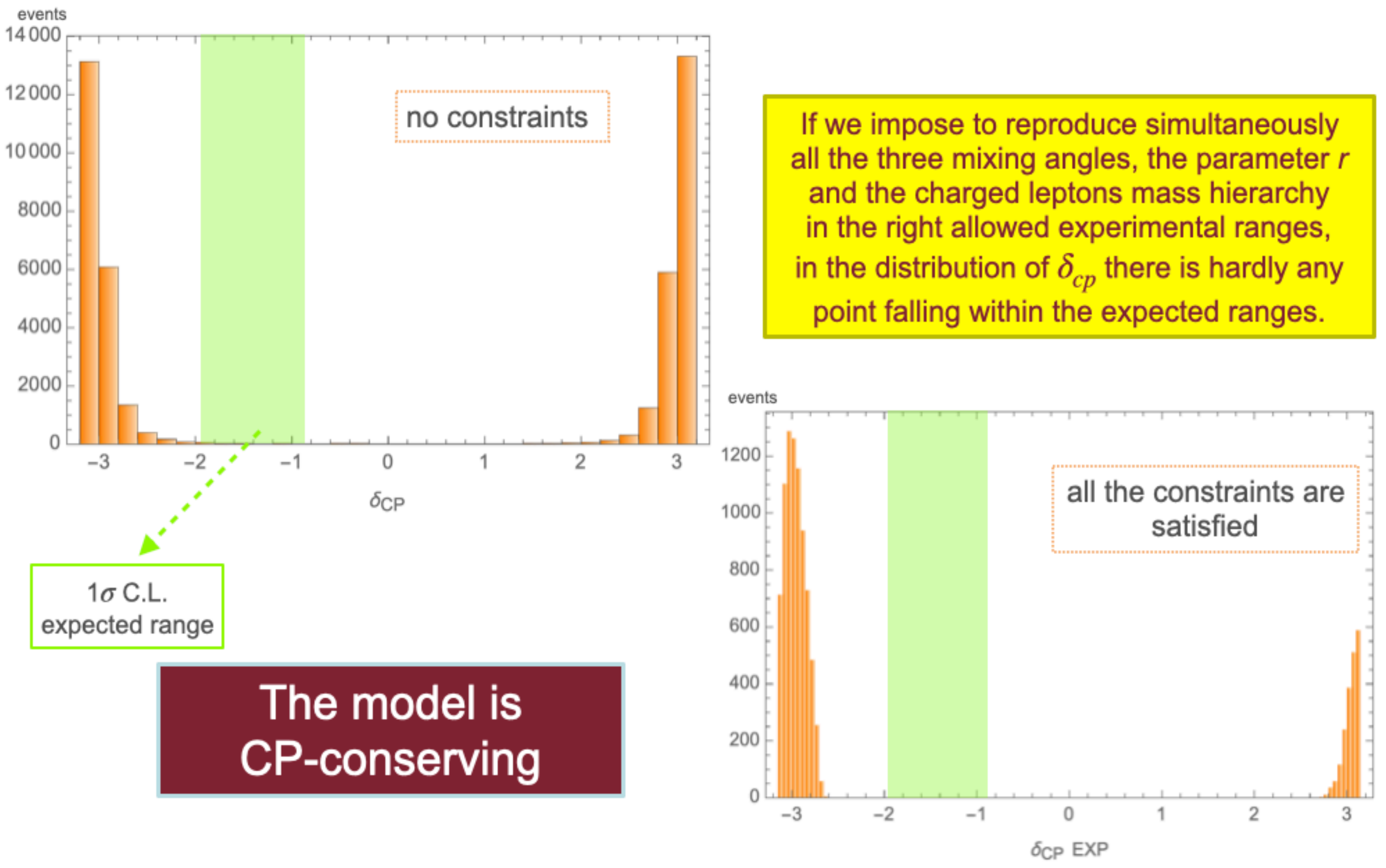
The charged lepton mass hierarchy is predicted in the allowed experimental range, as well as the parameter *r* (after a moderate fine tuning) and the three mixing angles.



CP-violation

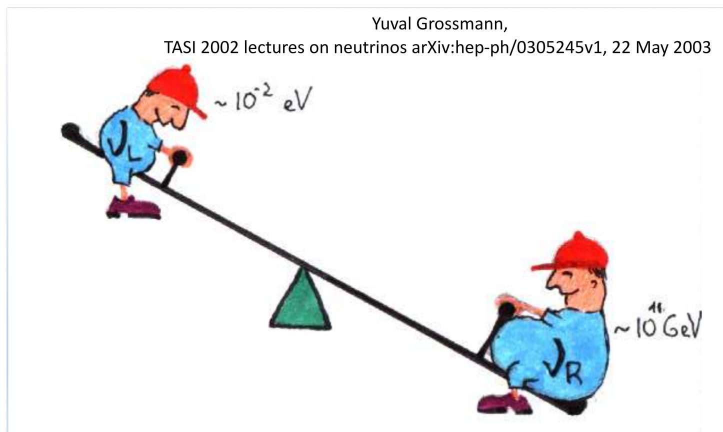
From the experiments we know that $\delta_{cp} = 282^{\circ}{}^{+26^\circ}_{-30^\circ}$ at 1σ of C.L.
Once we know the entries of the PMNS matrix we can evaluate it as

$$\delta_{cp} = -Arg\left(\frac{\frac{U^*_{ii}U_{ji}U_{ij}U^*_{jj}}{c_{12}c_{13}^2 s_{13} c_{23}} + c_{12}s_{13}c_{23}}{s_{12}s_{23}}\right), \quad \text{with} \begin{cases} c_{ij} = \cos\vartheta_{ij} \\ s_{ij} = \sin\vartheta_{ij} \end{cases}. \qquad \{i,j\} \in \{1,2,3\}, i \neq j$$



Type-I seesaw realization

We provided a simple type-I seesaw realization introducing three right-handed neutrinos, total singlet under the Standard Model and charged under the additional U(1) flavor symmetry, with charges $N_R \sim (-1,+1,0)$. We introduce other two *flavons* Δ and Υ with charges ±1/2.



In this way we obtain the following Dirac and Majorana mass matrix:

$$m_D = v\begin{pmatrix} \lambda e^{i\alpha} & a e^{i\beta} & b e^{i\gamma} \\ c e^{i\delta} & \lambda e^{i\rho} & \lambda e^{i\sigma} \\ \lambda^2 e^{i\zeta} & \lambda^2 e^{i\eta} & \lambda^2 e^{i\varphi} \end{pmatrix}, \qquad M_R = M_N \begin{pmatrix} \lambda & W & \lambda^2 \\ W & \lambda & \lambda^2 \\ \lambda^2 & \lambda^2 & Z \end{pmatrix}.$$

Through the type-I seesaw master formula $m_\nu = -m_D^T M_R^{-1} m_D$ we can reproduce the light neutrino mass matrix studied at low energies, for the price of a moderate fine tuning.

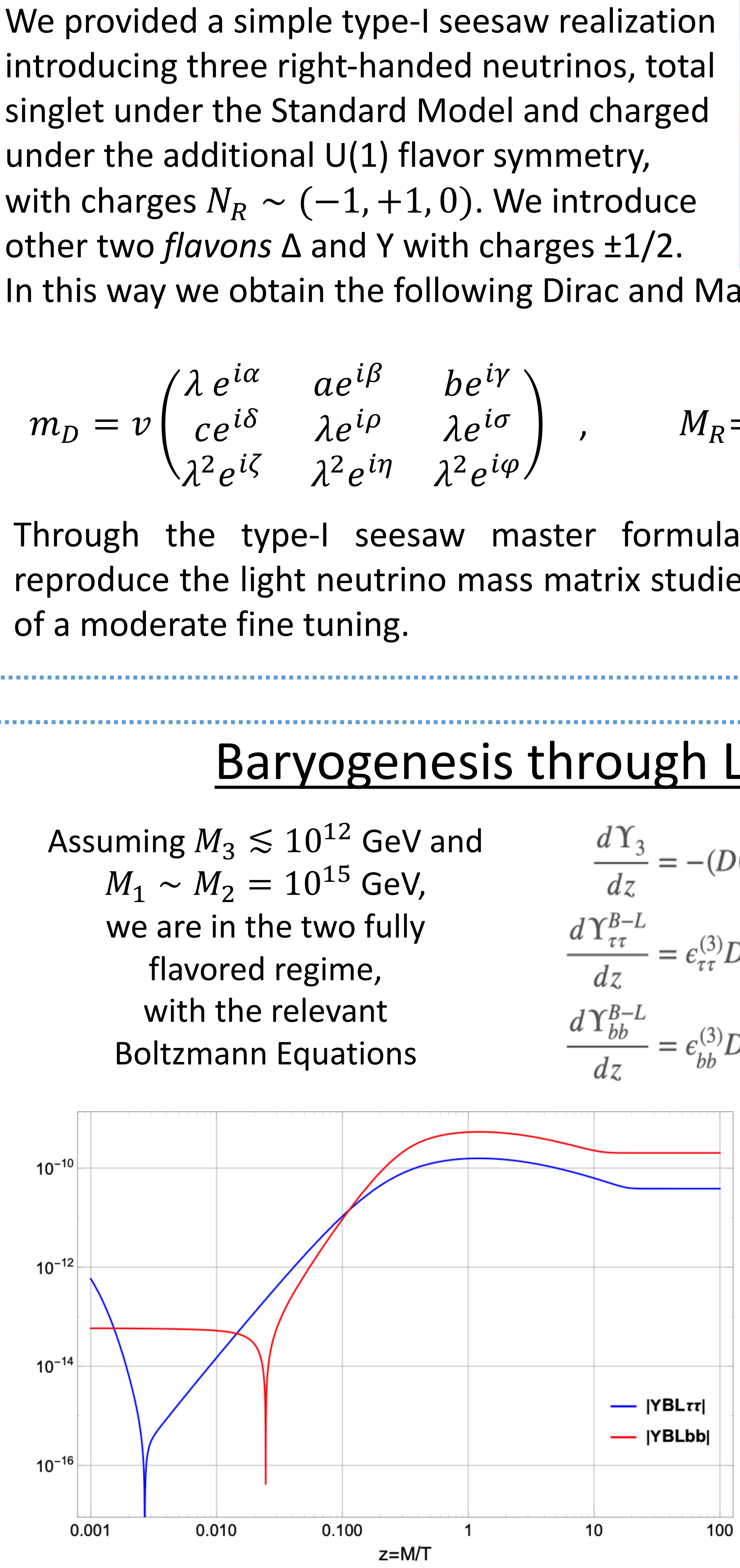
Baryogenesis through Leptogenesis

Assuming $M_3 \lesssim 10^{12}$ GeV and $M_1 \sim M_2 = 10^{15}$ GeV, we are in the two fully flavored regime, with the relevant Boltzmann Equations

$$\frac{dY_3}{dz} = -(D(z) - S(z))(Y_3 - Y_3^{eq})$$

$$\frac{dY_{\tau\tau}^{B-L}}{dz} = \epsilon_{\tau\tau}^{(3)} D(z)(Y_3 - Y_3^{eq}) - p_{3\tau}^{(0)}(W(z) + \Delta W) Y_{\tau\tau}^{B-L}$$

$$\frac{dY_{bb}^{B-L}}{dz} = \epsilon_{bb}^{(3)} D(z)(Y_3 - Y_3^{eq}) - p_{3b}^{(0)}(W(z) + \Delta W) Y_{bb}^{B-L}$$



Results

$Y_{\Delta B} = 8.52 \times 10^{-11}$
$\Omega_B h^2 = 2.19 \times 10^{-2}$
$\eta_B = 6.01 \times 10^{-10}$