LFV and Leptogenesis in SUSY models

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Outline

- Introduction
- LFV in SUSY seesaw and leptogenesis
- Parameterization appropriate for LFV
- Flavour and Leptogenesis
- Conclusions

Motivations

- LF exactly conserved in the SM

$$
\begin{aligned}
BR(\tau^- \to \mu^-\mu^-\mu^+) &< 1.9 \times 10^{-7} \text{ (BaBar 05)} \\
BR(\tau^- \to e^-e^-e^+) &< 2.0 \times 10^{-7} \text{ (BaBar 05)} \\
BR(\mu^- \to e^-e^-e^+) &< 1.0 \times 10^{-12} \text{ (SINDRUM 88)} \\
BR(\tau \to \mu\gamma) &< 6.8 \times 10^{-8} \text{ (BaBar 05)} \\
BR(\tau \to e\gamma) &< 1.1 \times 10^{-7} \text{ (BaBar 05)} \\
BR(\mu \to e\gamma) &< 1.2 \times 10^{-11} \text{ (MEGA 99)}
\end{aligned}
$$

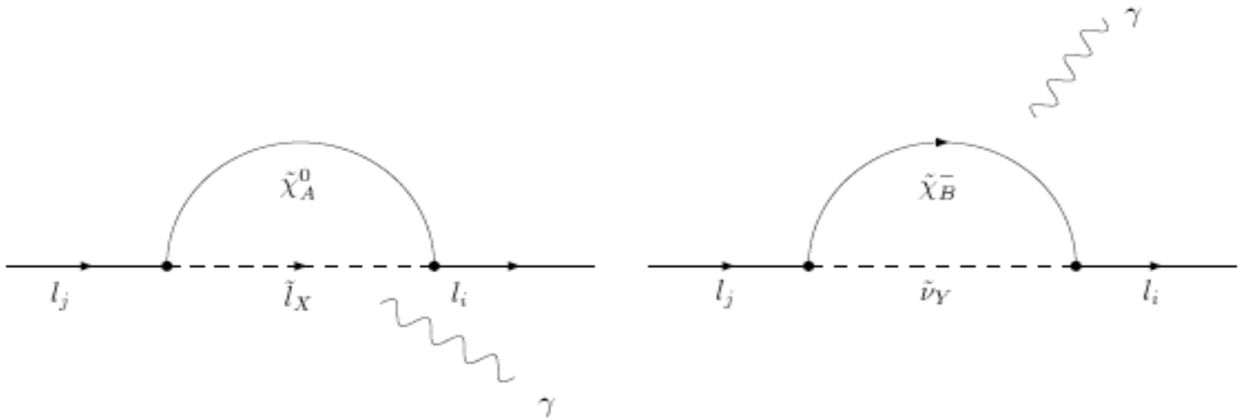
- However, LF is violated in the Nature! Light neutrinos are massive and mix!

- Light neutrino mixing alone implies negligible LFV rates of charged leptons

- To observe LFV decays of charged leptons, New Physics not far from the EW scale must exist.

- Natural candidate is SUSY

$$\begin{pmatrix} m_L^2 & m_{LR}^2 \\ (m_{LR}^2)^\dagger & m_R^2 \end{pmatrix} \qquad \begin{aligned} m_L^2 &= \overline{m}_L^2(\delta_{ij} + \delta_{ij}^{LL}) \\ m_R^2 &= \overline{m}_R^2(\delta_{ij} + \delta_{ij}^{RR}) \end{aligned}$$



- SUSY Flavour and CP problem
- Predictive scheme for LFV: MSSM+ N_R

- SUSY seesaw model

$$W = N_i^c (Y_\nu)_{ij} L_j H_2 - E_i^c (Y_e)_{ij} L_j H_1 + \frac{1}{2} N^c{}_i (M_N)_{ij} N_j^c$$

9 par. $\boxed{\mathcal{M}_\nu = Y_\nu^T (M_N)^{-1} Y_\nu v^2 \sin^2\beta}$ 18 par.

$$U^T \mathcal{M}_\nu U = \mathcal{M}_\nu^D$$

$$U_{\rm MNS} = \begin{pmatrix} c_{13}c_{12} & c_{13}s_{12} & s_{13}e^{-i\delta} \\ -c_{23}s_{12} - s_{13}s_{23}c_{12}e^{i\delta} & c_{23}c_{12} - s_{13}s_{23}s_{12}e^{i\delta} & c_{13}s_{23} \\ s_{23}s_{12} - s_{13}c_{23}c_{12}e^{i\delta} & -s_{23}c_{12} - s_{13}c_{23}s_{12}e^{i\delta} & c_{13}c_{23} \end{pmatrix}$$

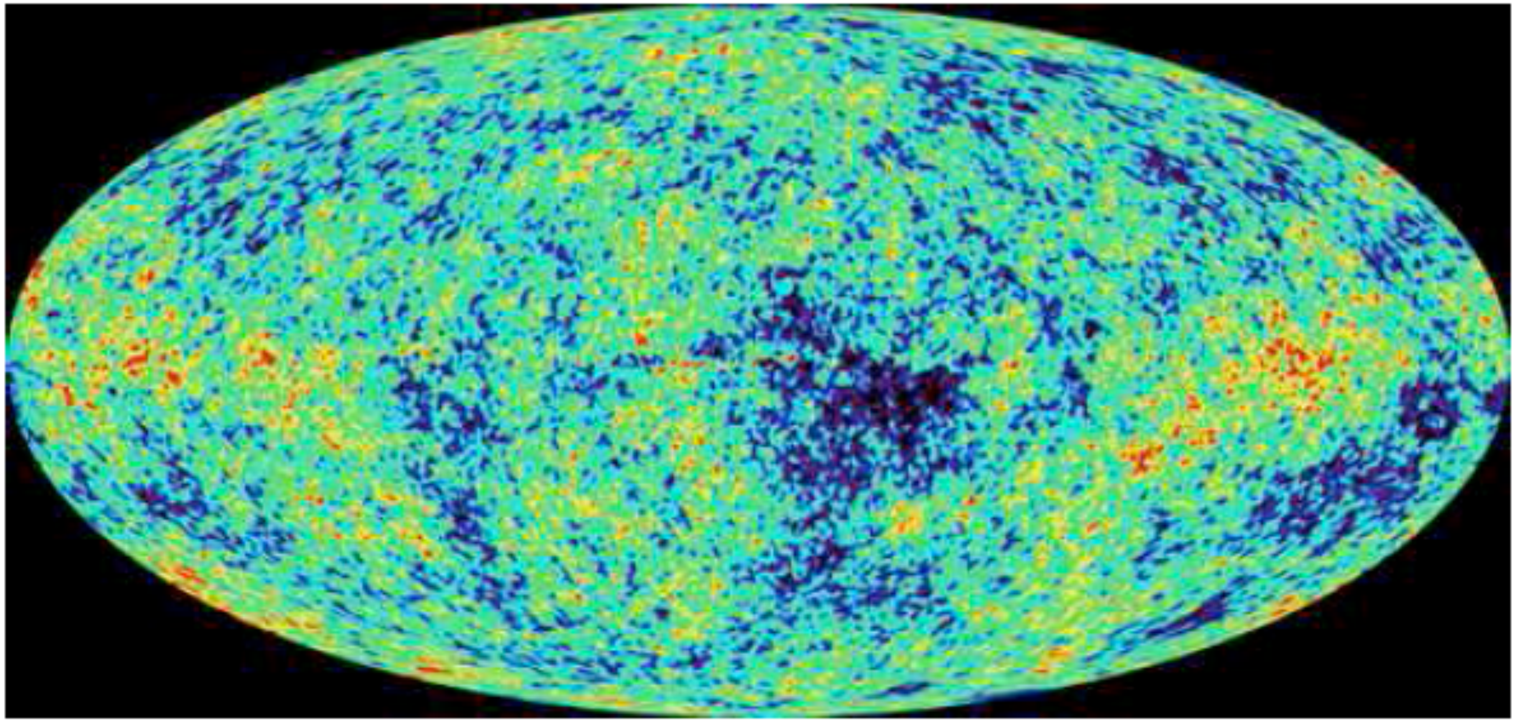
$RR^T=1$ $$Y_\nu(M_R) = \frac{1}{v_u}\sqrt{D_N(M_R)}\; R\; \sqrt{D_\nu(M_R)}\; U^\dagger(M_R)$$

- Renormalization of Y_ν induces off-diagonal soft terms below 1 TeV

$$
\begin{aligned}
\delta_{ij}^{LL} &\propto -\frac{1}{8\pi^2}(3m_0^2 + A_0^2)(Y_\nu^\dagger L Y_\nu)_{ij} \\
\delta_{ij}^{RR} &\propto 0_{ij} \\
\delta_{ij}^{LR} &\propto -\frac{3}{16\pi^2} A_0 v \cos\beta Y_e \cdot (Y_\nu^\dagger L Y_\nu)_{ij}
\end{aligned}
$$

- Implies observable BR of LFV decays of charged leptons

- Density perturbations observed by WMAP



$$\frac{n_B}{n_\gamma} = 6.1^{+0.3}_{-0.2} \times 10^{-10}$$

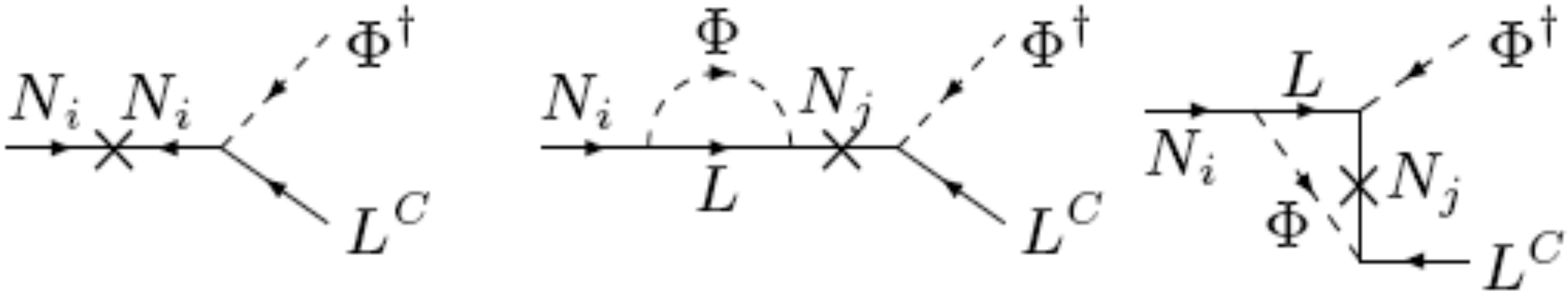
Baryogenesis via Leptogenesis

Sakharov:

- B violation
- C and CP violation
- Out-of-equilibrium conditions

Yanagida:

- B-L violation
- Sphalerons

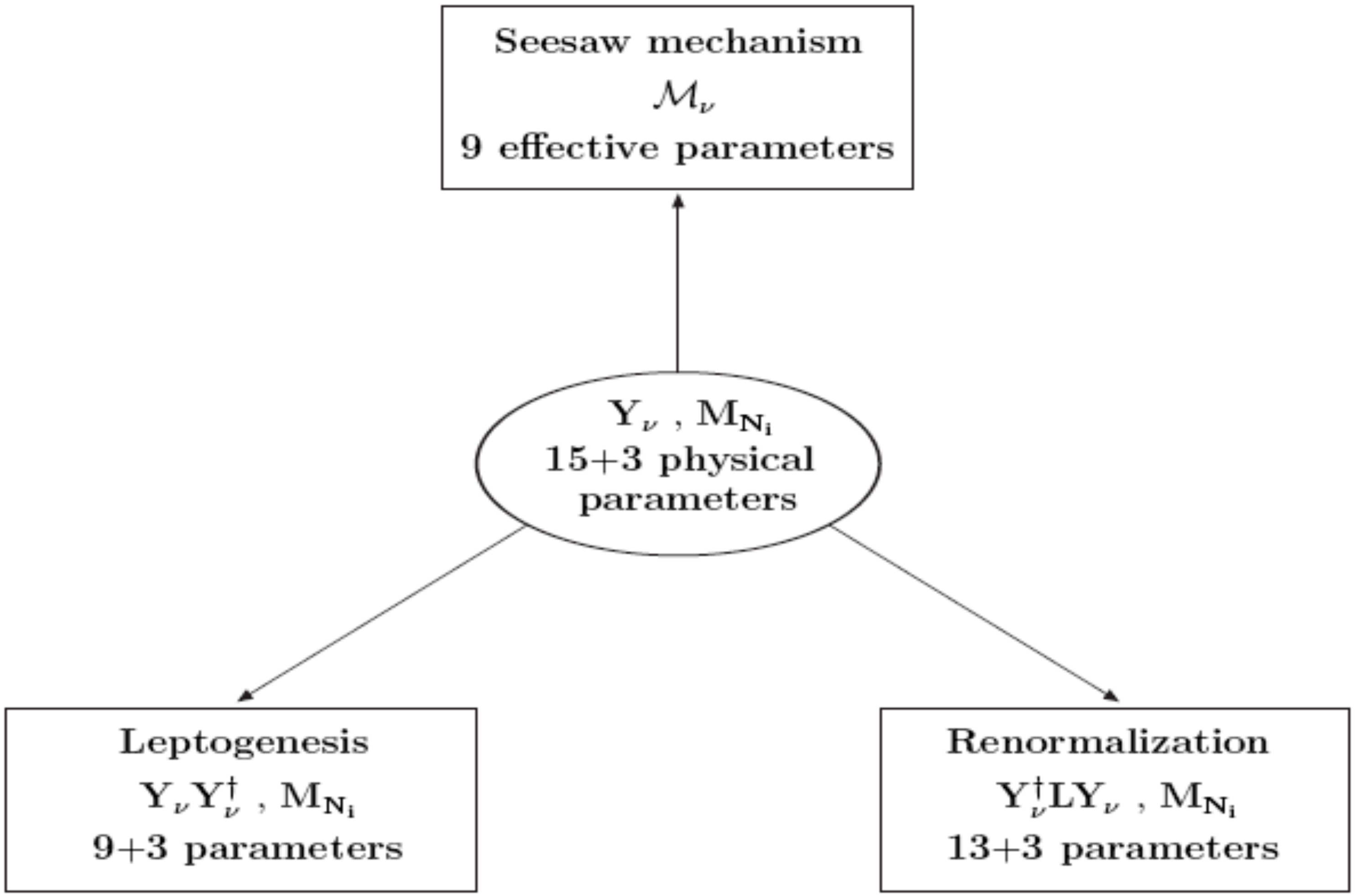


$$\epsilon_1 \simeq \frac{1}{8\pi (Y_\nu Y_\nu^\dagger)_{11}} \sum_{i=2,3} \mathrm{Im}\left[\left\{(Y_\nu Y_\nu^\dagger)_{1i}\right\}^2\right] f(x_i) \qquad x_l \equiv (M_{N_l}/M_{N_1})^2.$$

washout effects calculable

- Seesaw and thermal leptogenesis are consistent
- For hierarchical M_N , $M_{N1} > 10^9$ GeV
- For degenerate M_N f(x) exhibits a resonance behaviour

Roadmap of SUSY Seesaw phenomenology



Phenomenological analyses of LFV

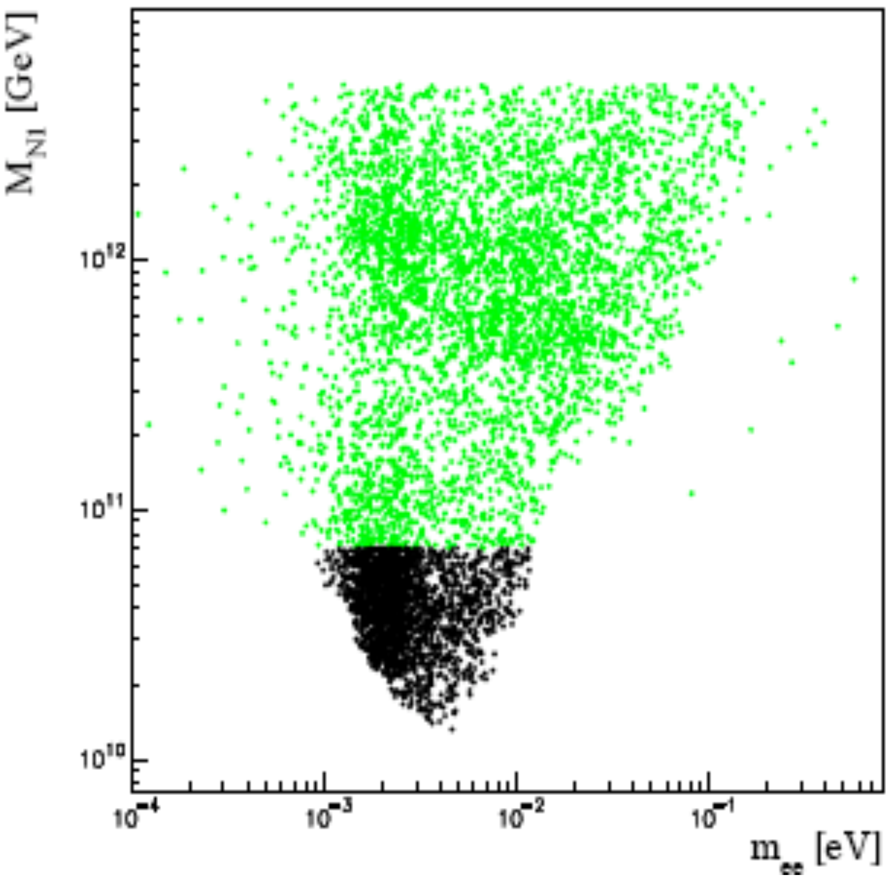
- Fix the measured neutrino parameters
- Generate all the rest, including the parameter matrix *R* randomly
- Assume values of the universal soft terms
- Typical result: bound on $\mu \to e\gamma$ implies small LFV tau lepton decays

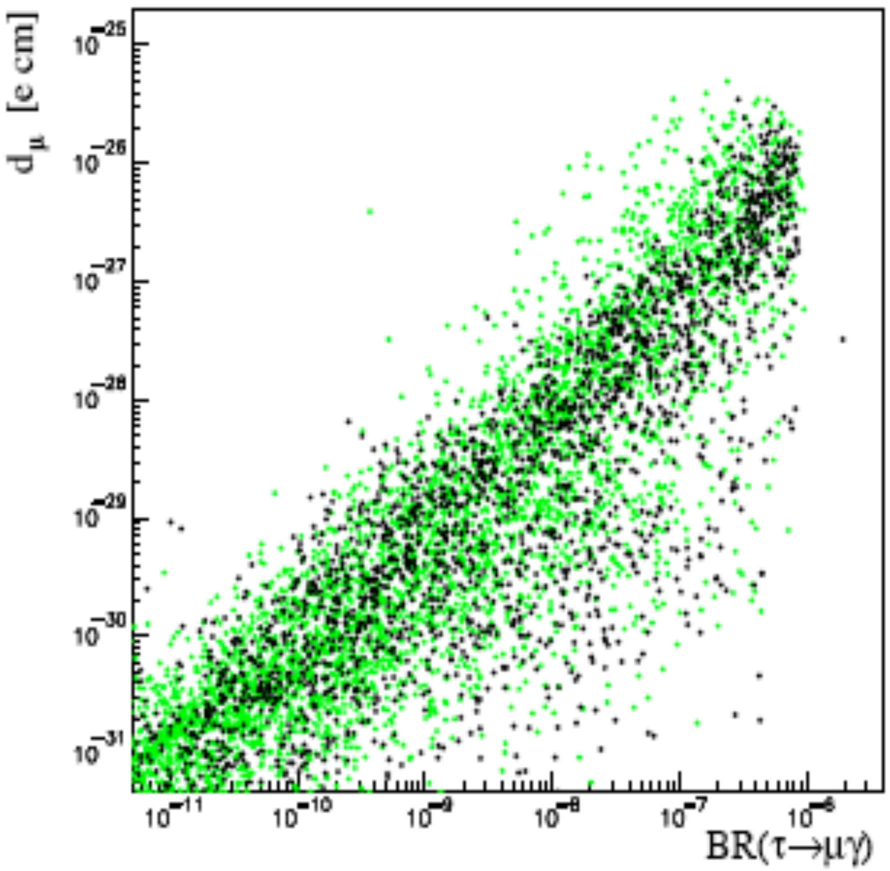
Parametrization of seesaw suitable for studies of LFV

- Assume Hermitian parameter matrix *H*
- Identify *H* with $(Y_\nu^\dagger L Y_\nu)$
- Solve $(\mathcal{M}_\nu\,,\, H) \longrightarrow (\mathcal{M}_\nu\,,\overline{M_N},\, R') \longrightarrow (Y_\nu\,,\, M_{N_i})$
- Choose required *H*

$$H_1 = \begin{pmatrix} a & 0 & 0 \\ 0 & b & d \\ 0 & d^\dagger & c \end{pmatrix}$$

Observation of LFV in τ decays possible





Flavoured Leptogenesis

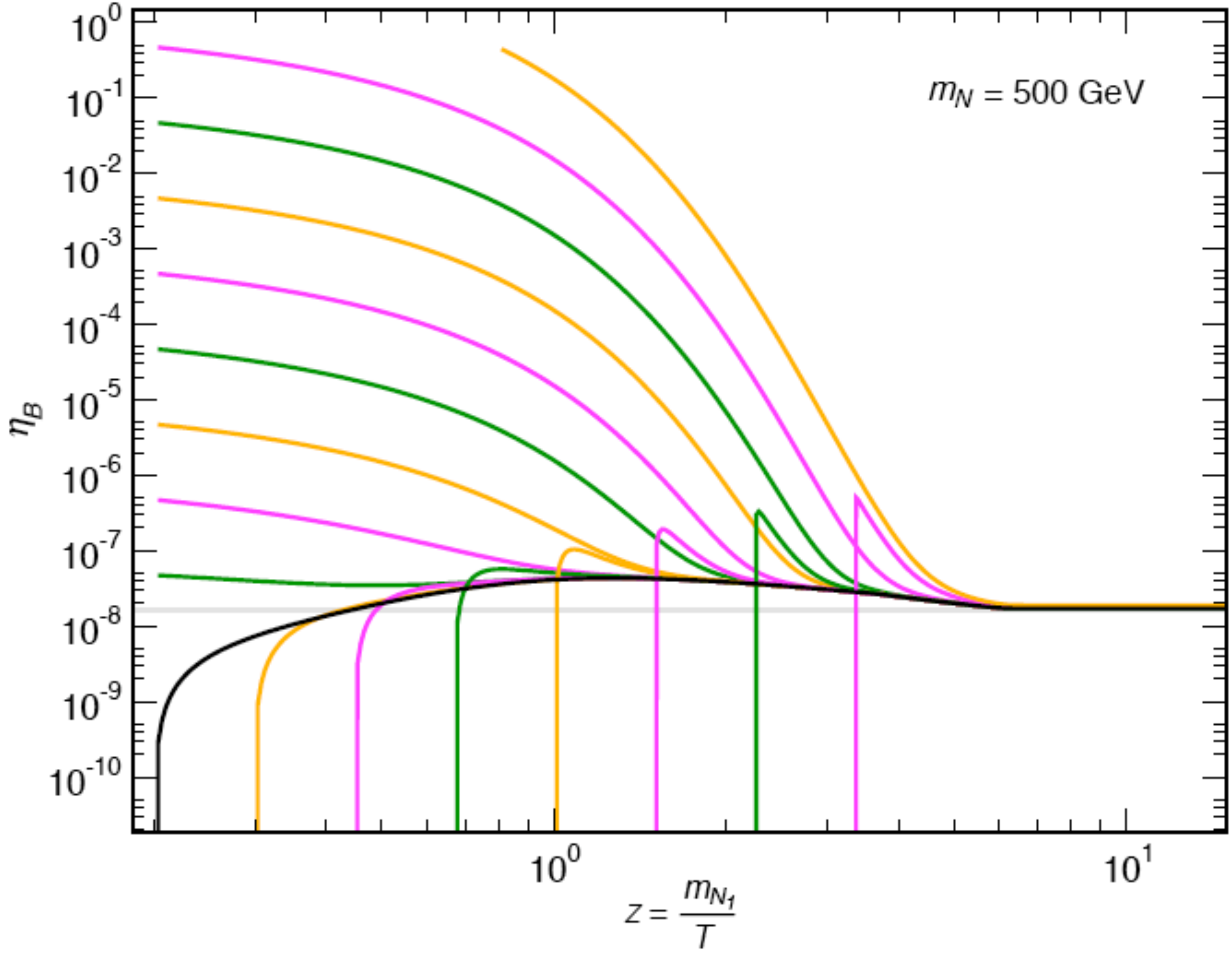
- An idea: create out-of-equilibrium condition for one flavour only $1/3B-L_{\tau}$
- Requires flavour symmetries

$$\mathrm{SO}(3)_{\nu_R} \otimes \mathrm{U}(1)_{L_i + l_{iR}} \Longrightarrow \mathrm{U}(1)_l$$

$$Y_\nu = \begin{pmatrix} \varepsilon_e & a\, e^{-i\pi/4} & a\, e^{i\pi/4} \\ \varepsilon_\mu & b\, e^{-i\pi/4} & b\, e^{i\pi/4} \\ \varepsilon_\tau & c\, e^{-i\pi/4} & c\, e^{i\pi/4} \end{pmatrix}$$

M_N degenerate

$$|\varepsilon_l| \sim 10^{-7},\ |c| \sim 10^{-6},\ |a| \sim |b| \sim 10^{-2}$$


m_N = 500 GeV
η_B
$Z = \frac{m_{N_1}}{T}$
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{-9}
10^{-10}
10^0
10^1

Predictions of tau leptogenesis

- Inversely hierarchical light neutrino mass spectrum
- Observable BR($\mu \rightarrow e\gamma$), suppressed BR($\tau \rightarrow \mu\gamma$)
- N_i can be very light, observable at collider experiments

Predictions of e-Leptogenesis

- Normally ordered light neutrino mass spectrum
- Large BR($\tau \rightarrow \mu\gamma$), suppressed BR($\mu \rightarrow e\, \gamma$)

Conclusions

- Searches for LFV decays of charged leptons give info SUSY and seesaw
- Exist parameterizations and models in which τ LFV is large, μ LFV suppressed
- Leptogenesis constraint in general enhances LFV rates (large Yukawas)
- Possibility of flavoured leptogenesis