Lepton Flavor Violation and SUSY Dirac Leptogenesis [a]

by

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at

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[a]based on PRD73, 063512 (Brooks Thomas, MT) and ongoing work with B. Thomas

Outline

- Introduction
- Neutrinogenesis: Dirac Leptogenesis + Neutrino pheno.
- Lepton Flavor Violation in the scenario
- Conclusions

Introduction

- (Majorana) Leptogenesis: economic way to address:
  - the observed baryon asymmetry in the universe
  - the neutrino phenomenology (large mixing angles and tiny non-zero masses)
- Dirac Leptogenesis (or neutrinogeness): less economical, but can also address succesfully both these puzzles.

If every every particle in our theory is charged, Dirac leptogenesis becomes an interesting alternative mechanism.

In *PRD73, 063512 (B.Thomas, M.T.)*, we tried to put together constraints from baryogenesis and neutrino physics.

Here we want continue exploring this scenario and try to add constraints from Lepton Flavor Violation (LFV) processes.

Dirac Leptogenesis*

We add new fields and a new $U(1)_N$ to the MSSM:

Field	L	$U(1)_N$	$SU(2)$	$U(1)_Y$
N_R	-1	+1	**1**	0
Φ	+1	-1	**2**	$-\frac{1}{2}$
$\overline{\Phi}$	-1	+1	**2**	$\frac{1}{2}$
χ	0	-1	**1**	0

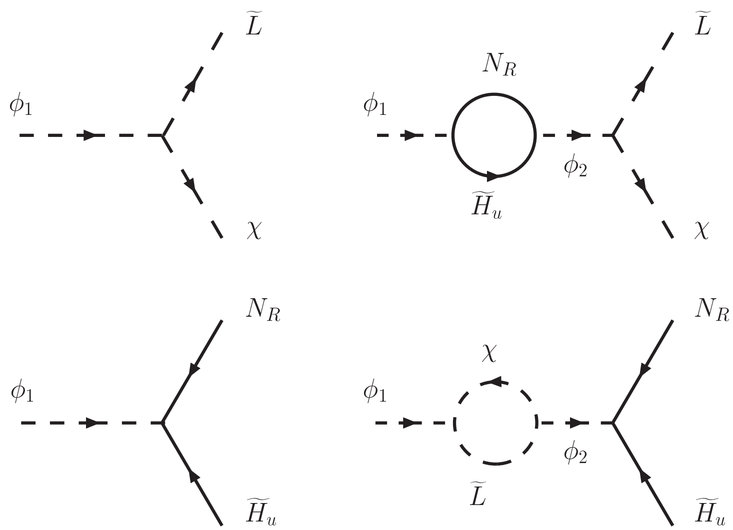
New terms in superpotential:

$$\mathcal{W} \ni \lambda \; N_R H_u \Phi + h \; L\overline{\Phi}\chi + M_\Phi \Phi\overline{\Phi}$$

*non-SUSY version→ Dick-Lindner-Ratz-Wright [PRL84,4039(2000)]
SUSY version→ Murayama-Pierce [PRL89,271601(2002)]

Baryogenesis

- Out-of-equilibrium decays of Φ fields
- CP Violation



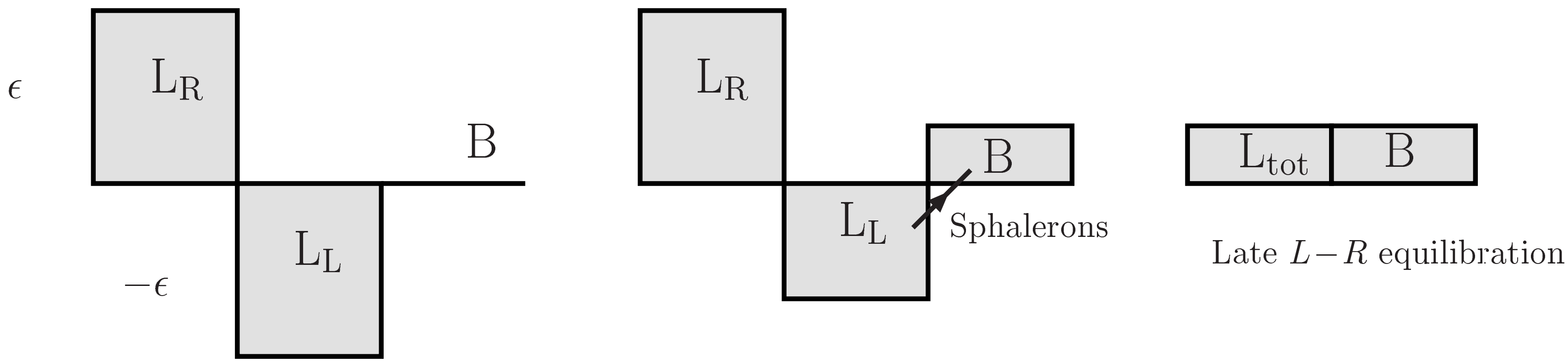
$$\frac{\Gamma(\phi_1 \to \widetilde{L}\chi) - \Gamma(\phi_1^c \to \widetilde{L}^c \chi^c)}{\Gamma_{\phi_1}} = \epsilon$$

$$\frac{\Gamma(\phi_1 \to \widetilde{H}_u^c N_R^c) - \Gamma(\phi_1^c \to \widetilde{H}_u N_R)}{\Gamma_{\phi_1}} = -\epsilon$$

With

$$\epsilon = \frac{1}{4\pi}\frac{\delta}{1-\delta}\frac{\mathrm{Im}(\lambda_{1\alpha}^* \lambda_{2\alpha} h_{1\beta}^* h_{2\beta})}{(|\lambda_{1\gamma}|^2 + |h_{1\gamma}|^2)} \quad \text{where} \quad \delta = M_{\Phi_1}/M_{\Phi_2}$$

- Baryogenesis



$L_L \ni \widetilde{L},\, \widetilde{e}_R,\, L,\, e_R,\, \widetilde{N}_R$ all in equilibrium due to:

- gauge interactions
- yukawa interactions
- large trilinear $\widetilde{N_R}\widetilde{L}H$

L_L and N_R are NOT in equilibrium (tiny neutrino yukawas)

AND sphalerons only act on L_L ($SU(2)$ doublets)

Improved Boltzman equations

We originally neglected thermalization effects of SM gauge bosons on the Heavy fields Φ.

This is a higher order term in the equations but is now implemented in our code.

The $drift - and - decay$ limit for the heavy fields is somewhat reduced, but it is as small effect.

Dirac Neutrinos from Hierarchical Dirac Leptogenesis

Integrating-out the heavy Φ and $\overline{\Phi}$ we get

$$\mathcal{W}_{eff} \ni \frac{\lambda h}{M_{\Phi_1}} \chi L H_u N$$

After χ acquires a vev $\langle\chi\rangle$, the effective Dirac neutrino Yukawas are

$$y_\nu \sim \lambda h \frac{\langle\chi\rangle}{M_{\Phi_1}}$$

If $\langle\chi\rangle \sim$ TeV-ish $\;\rightarrow\;$ small Dirac neutrino yukawa

Hierarchical Dirac Leptogenesis

We can reduce the number of new parameters from

$$\mathcal{W} \ni \lambda \; N_R H_u \Phi + h \; L\overline{\Phi}\chi + M_\Phi \Phi\overline{\Phi} + y_e H_d L e_R$$

and also address neutrino spectrum and mixing angles:

In the basis where the Charged Lepton Yukawa matrix and (M_Φ) are diagonal, we ASSUME that the matrices λ and h are antisymmetric $\rightarrow$ Generically one obtains a neutrino mass matrix corresponding to normal hierarchy scenario:

$$(m_\nu^2) \propto \begin{pmatrix} \delta^2 & \delta & \delta \\ . & 1 & 1 \\ . & . & 1 \end{pmatrix} + \mathcal{O}(\epsilon)$$

For $\delta \equiv M_{\Phi_1}/M_{\Phi_2} = 10^{-1}$ $\longrightarrow$ correct neutrino pheno. for

$$\lambda = f \begin{pmatrix} 0 & 1 & 0.8\text{-}1.2 \\ -1 & 0 & 1.5\text{-}4.5 \\ -(0.8\text{-}1.2) & -(1.5\text{-}4.5) & 0 \end{pmatrix}$$

$$h = f \begin{pmatrix} 0 & 0.8\text{-}1.2 & 0.8\text{-}1.2 \\ -(0.8\text{-}1.2) & 0 & 1.4\text{-}2.8 \\ -(0.8\text{-}1.2) & -(1.4\text{-}2.8) & 0 \end{pmatrix}$$

- CP parameter is $\longrightarrow$ $\epsilon \propto f^4 \dfrac{\delta}{1-\delta} \sin\phi_{cp}$
- Heaviest Neutrino $\rightarrow m_\nu = .05$ eV $\propto \frac{f^2 \langle\chi\rangle}{M_{\Phi_1}} v$

Lepton Flavor Violation

The new contributions to slepton masses from the new terms of the superpotential will come from new F-term contributions giving

$$M^2_{LL} = \langle\chi\rangle^2 \; hh^+$$

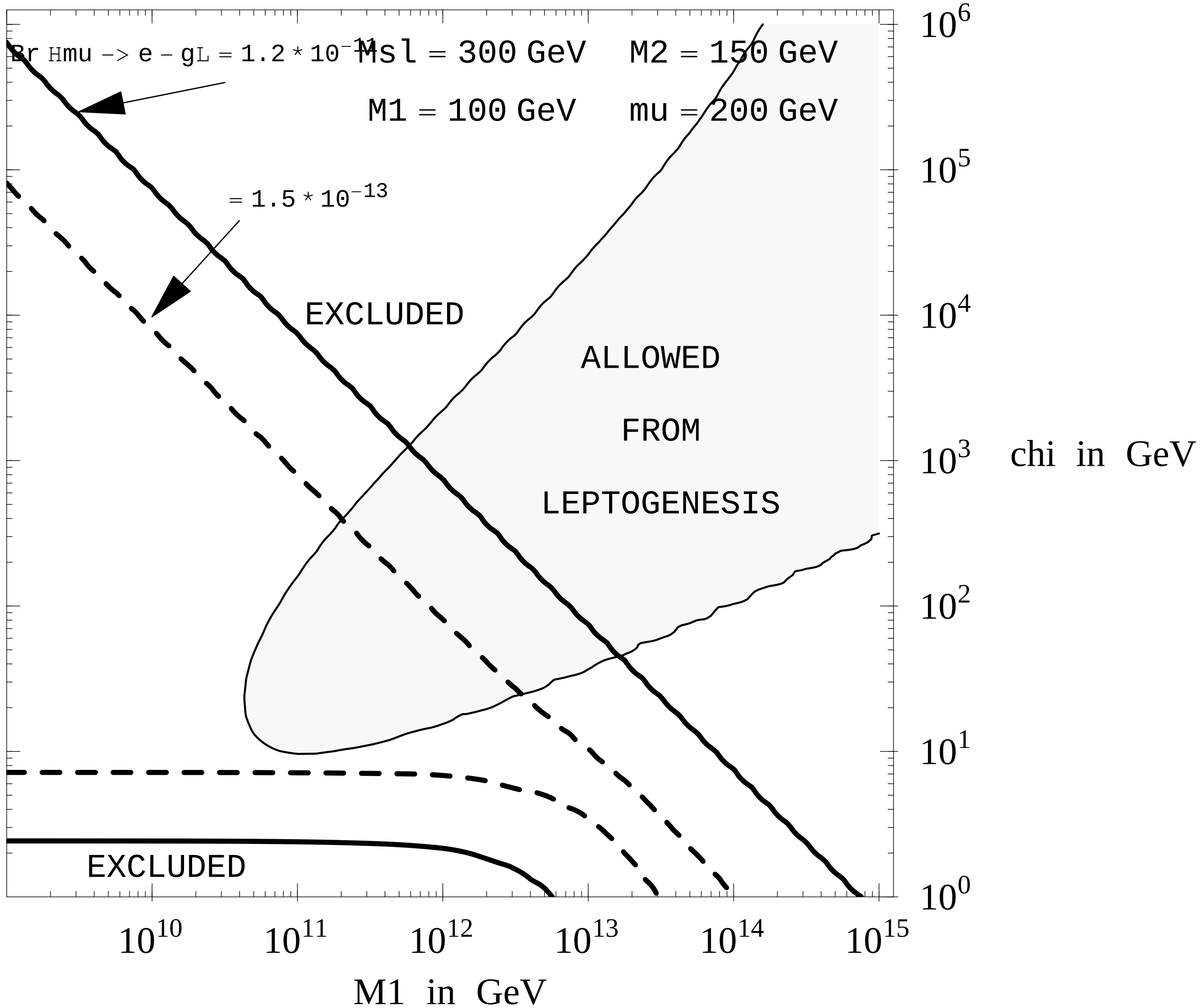
$$M^2_{N_R N_R} = v^2 \sin^2\beta \; \lambda^+\lambda$$

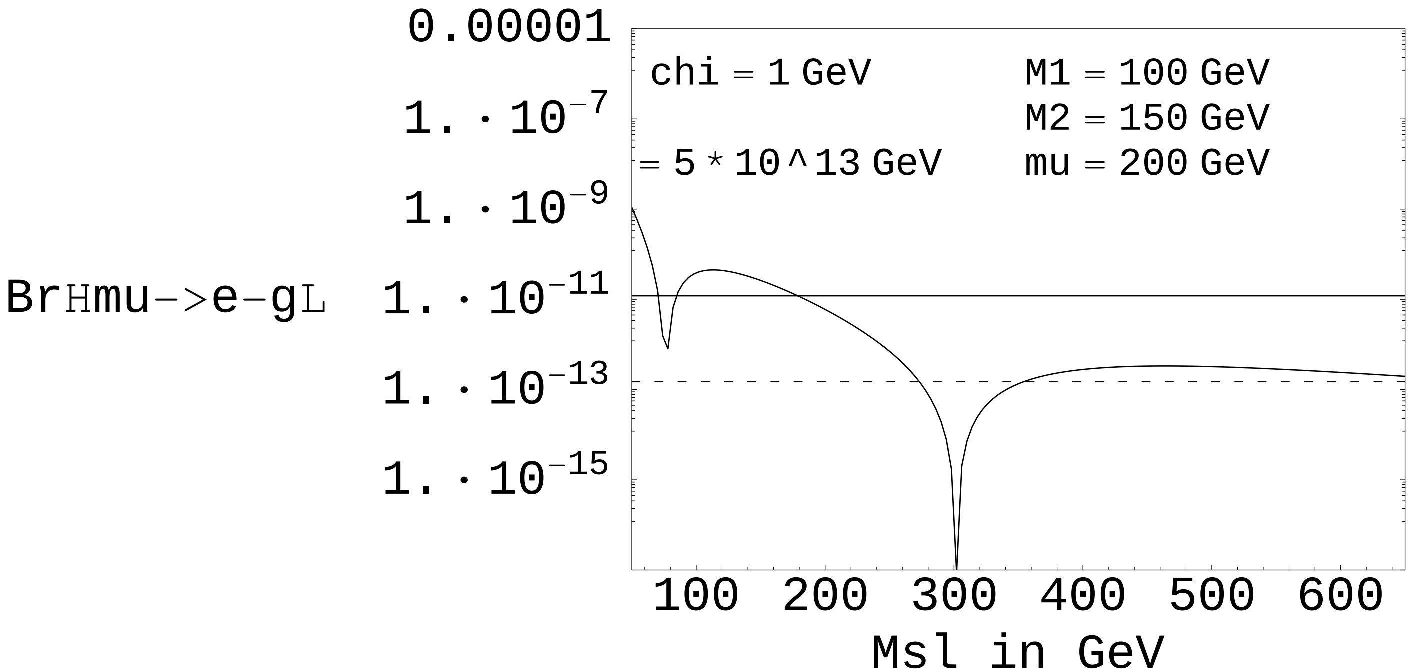
It is also possible to obtain a contribution to sneutrino masses from SUSY breaking if χ acquires a SUSY breaking F-term. Giving

$$M^2_{N_R L} = v \sin\beta \; F_\chi \; \frac{h^+\lambda}{M_\Phi}$$

The off-diagonal entries will scale as

- $\delta M^2_{LL} \;\propto\; f^2 \langle \chi \rangle^2 \;\propto M_{\Phi_1} \langle \chi \rangle$
- $\delta M^2_{RR} \;\propto\; f^2 \propto \frac{M_{\Phi_1}}{\langle \chi \rangle}$
- $\delta M^2_{LR} \;\propto\; \frac{f^2}{M_{\Phi_1}} \propto \frac{1}{\langle \chi \rangle}$


Br Hmu -> e - gL = 1.2 * 10^-11
= 1.5 * 10^-13
Msl = 300 GeV
M2 = 150 GeV
M1 = 100 GeV
mu = 200 GeV
EXCLUDED
ALLOWED
FROM
LEPTOGENESIS
EXCLUDED
10^6
10^5
10^4
10^3
10^2
10^1
10^0
chi in GeV
10^10
10^11
10^12
10^13
10^14
10^15
M1 in GeV



chi = 1 GeV
= 5 * 10 ^ 13 GeV
M1 = 100 GeV
M2 = 150 GeV
mu = 200 GeV
0.00001
1. · 10^-7
1. · 10^-9
1. · 10^-11
1. · 10^-13
1. · 10^-15
BrHmu->e-gL
100
200
300
400
500
600
Msl in GeV

Conclusions

- Dirac Leptogenesis is an interesting alternative to Majorana Leptogenesis-SeeSaw mechanism
- Neutrinos are DIRAC (no neutrinoless double beta decay)
- We explored a simple scenario in which we could link successful Leptogenesis to neutrino data.
- We tried also to further constrain the setup with LFV
- It will be interesting to try to constrain it further by considering the possibility of Sneutrino dark Matter, and the possibility of invisible higgs decays into sneutrinos.