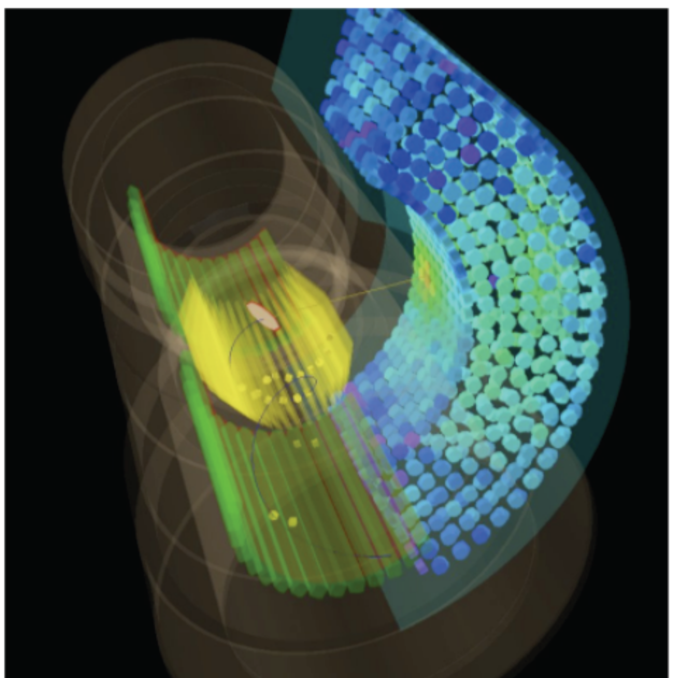
Planck 2010

CERN, Geneva, Switzerland, May 31-June 4, 2010

Lepton-flavor-violating signals from SUSY leptogenesis



With D.Marfatia and A.Mustafayev, to appear

Steve Blanchet

UNIVERSITY OF MARYLAND

Testing Leptogenesis?

- ★ Leptogenesis is an attractive explanation to the matter-antimatter asymmetry of the Universe.

- ★ However, the vanilla framework with hierarchical RH neutrinos needs a very high scale, $M_{N_1} \gtrsim 10^9$ GeV , clearly out of reach of collider experiments.

  ➡ How can one know that leptogenesis happened in the early Universe?

- ★ One possibility is to have a TeV scale seesaw mechanism, e.g. motivated by the presence of a TeV Z', so that the RH neutrinos, which have to be quasi-degenerate for leptogenesis, $M_{N_1} \simeq M_{N_2}$, are accessible at the LHC, and can have definite ~~CP~~ signatures. [SB, Chacko, Granor, Mohapatra, 2009]

- ★ Another possibility is when the seesaw parameters, through the RG evolution, indirectly affect low-energy phenomenology, for instance leading to observable lepton-flavor-violation.

THIS TALK

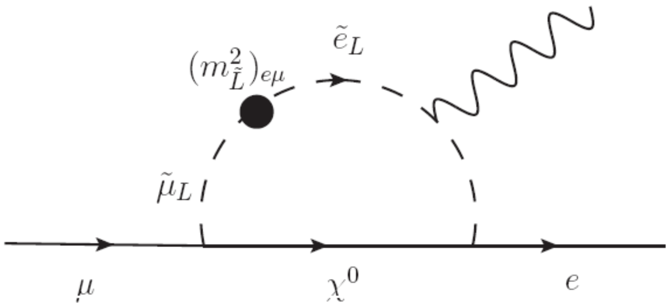
Idea

- Consider the SUSY-seesaw framework:

$$\hat{f} = \hat{f}_{\mathrm{MSSM}} + (\mathbf{f}_\nu)_{\alpha j}\epsilon_{ab}\hat{L}^a_\alpha \hat{H}^b_u \hat{N}^c_i + \frac{1}{2}(\mathbf{M}_N)_{ij}\hat{N}^c_i\hat{N}^c_j$$

- In this model, the neutrino Yukawa couplings generate off-diagonal elements in the slepton squared mass matrices which lead to large LFV [Borzumati, Masiero, 1986] :

$$m^2_{\tilde{L}} = \begin{pmatrix} m_0^2 & (m^2_{\tilde{L}})_{e\mu} \\ (m^2_{\tilde{L}})_{\mu e} & m_0^2 \end{pmatrix}$$



$$(\boldsymbol{m}^2_L)_{i\neq j} \simeq -\frac{1}{8\pi^2}(3m_0^2 + A_0^2)\sum_k (\mathbf{f}^T_\nu)_{ik}(\mathbf{f}^*_\nu)_{kj}\log\frac{M_{GUT}}{M_{N_k}}$$

$$\mathrm{Br}(\mu\to e\gamma) \simeq \frac{\alpha^3}{G_F^2 m_s^8}|(m^2_{\tilde{L}})_{e\mu}|^2\tan^2\beta$$

- On the other hand, the CP asymmetry of leptogenesis goes like

$$\tilde{\varepsilon}_{i\alpha} = \frac{1}{8\pi(\mathbf{f}^\dagger_\nu \mathbf{f}_\nu)_{ii}}\sum_{j\neq i}\left\{\mathrm{Im}\left[\mathbf{f}^\star_{\nu,\alpha i}\mathbf{f}_{\nu,\alpha j}(\mathbf{f}^\dagger_\nu\mathbf{f}_\nu)_{ij}\right]g(x_j/x_i)\right)$$

⇒ LFV rates must have some correlation with leptogenesis!

Setup

- For illustration, we consider an mSUGRA framework with flavor-blind universal boundary conditions, and consider exclusively points where neutralino dark matter has the correct relic density.

- At the GUT scale, we assume hierarchical neutrino Yukawa couplings, as given in SO(10), given by the following relation:

$$\left(\mathbf{f}_\nu^{\text{diag}}\right)_{ij} = R_i \left(\mathbf{f}_u^{\text{diag}}\right)_{ij} \qquad R_i \lesssim \mathcal{O}(5)$$

  Since we stick to a strict type-I seesaw framework (or subdominant Type-II), this leads to a normal hierarchy for the light neutrinos.

- The running of the MSSM parameters includes the effects of $\mathbf{f}_\nu$ and a multistep RH neutrino decoupling at different scales.

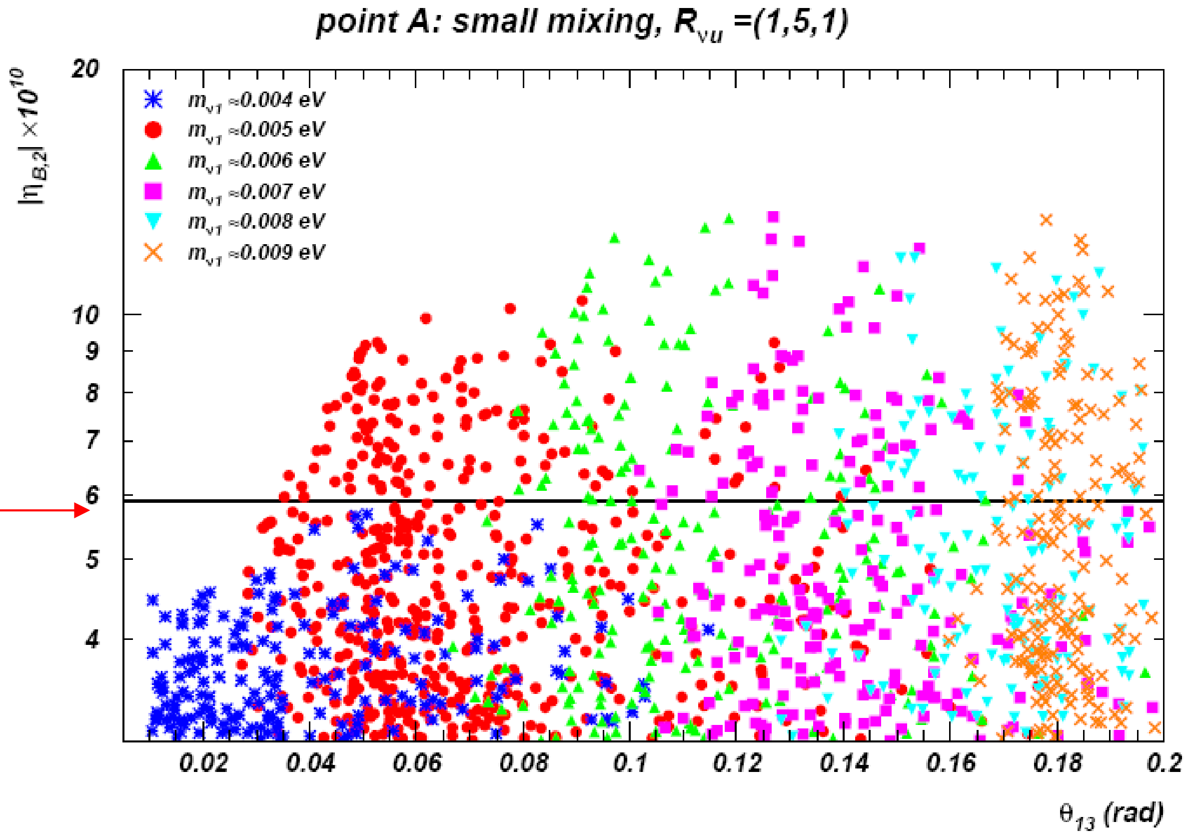
- As for leptogenesis, the main contribution to the lepton asymmetry will be given by N_2, because N_1, being around 10^5 GeV, has a tiny CP asymmetry.

$$\eta_B = \eta_{B,2} \simeq 0.01 \sum_\alpha \tilde{\varepsilon}_{2\alpha} \kappa(K_{2\alpha}) \exp\left(-\frac{3\pi}{8} K_{1\alpha}\right)$$

Results: thermal case

★ Varying over the unknown parameters in the MNS matrix (Majorana phases, Dirac phase, θ_{13} , and the lightest neutrino mass), we obtain:

WMAP



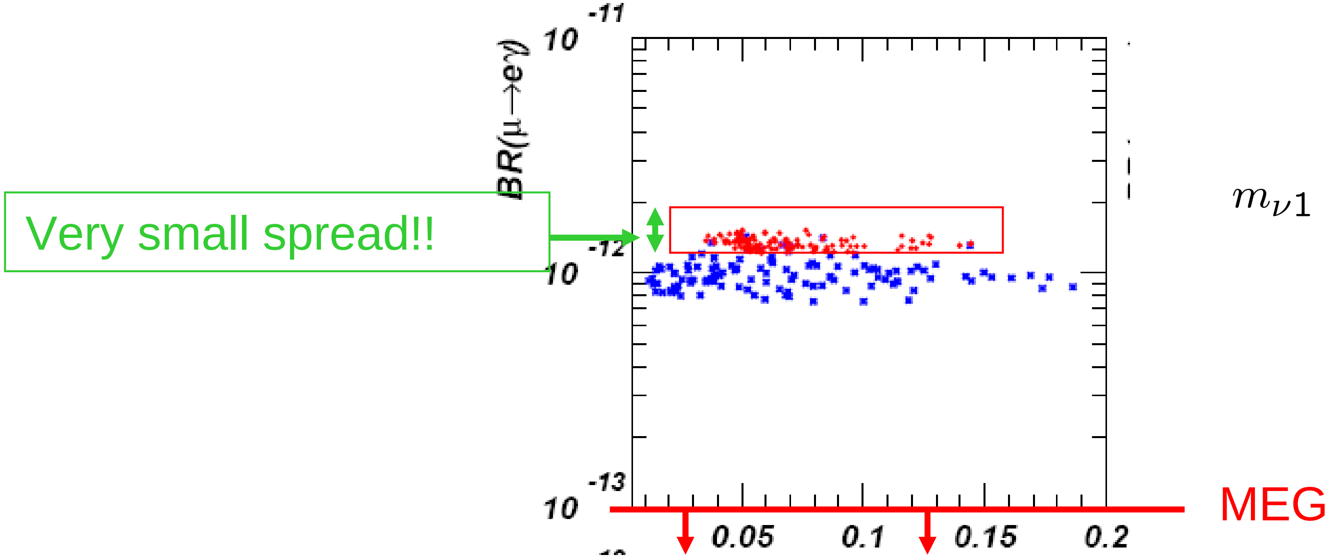
Results: LFV rates

- We find a lower bound on both m_{ν_1} and θ_{13} which can be probed in future experiments!

$$m_{\nu 1} > 0.004 \text{ eV}\,, \quad \theta_{13} > 0.04\,.$$

- What about LFV rates? For the bulk region

$$m_0 = 80 \text{ GeV},\ m_{1/2} = 170 \text{ GeV},\ A_0 = -250 \text{ GeV and } \tan\beta = 10$$

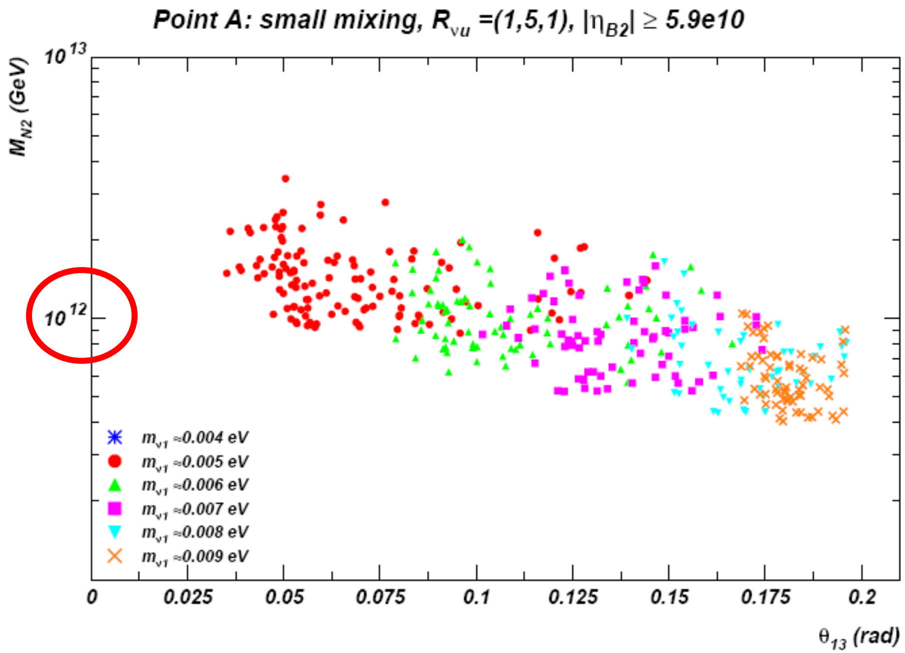


$m_{\nu 1} = 0.005$ eV

Accessible at MEG!! Changing m_{ν_1} does not change the rates! Points in the stop-coannihilation region give similar rates.

Results: reheat temperature

★ What about the gravitino problem, i.e. the overproduction of gravitinos when $T_{\rm RH} \gtrsim 10^9$ GeV ?



➡ Since $T_{\rm RH} \sim M_{N_2}$, it is even more serious than usual!!

➡ A consistent cosmology requires either giving up on thermal leptogenesis, or on neutralino dark matter!

Non-thermal leptogenesis

- Insisting on having neutralino dark matter, we can look at scenarios where the reheat temperature required is lower, for instance non-thermal leptogenesis.

- We followed the work by Giudice, Mether, Riotto and Riva in 2008, where leptogenesis from SUSY flat directions in the preheating phase was considered.

  More precisely, they use instant preheating [Felder, Kofman, Linde, 98] which is a very efficient non-perturbative way of producing very heavy particles

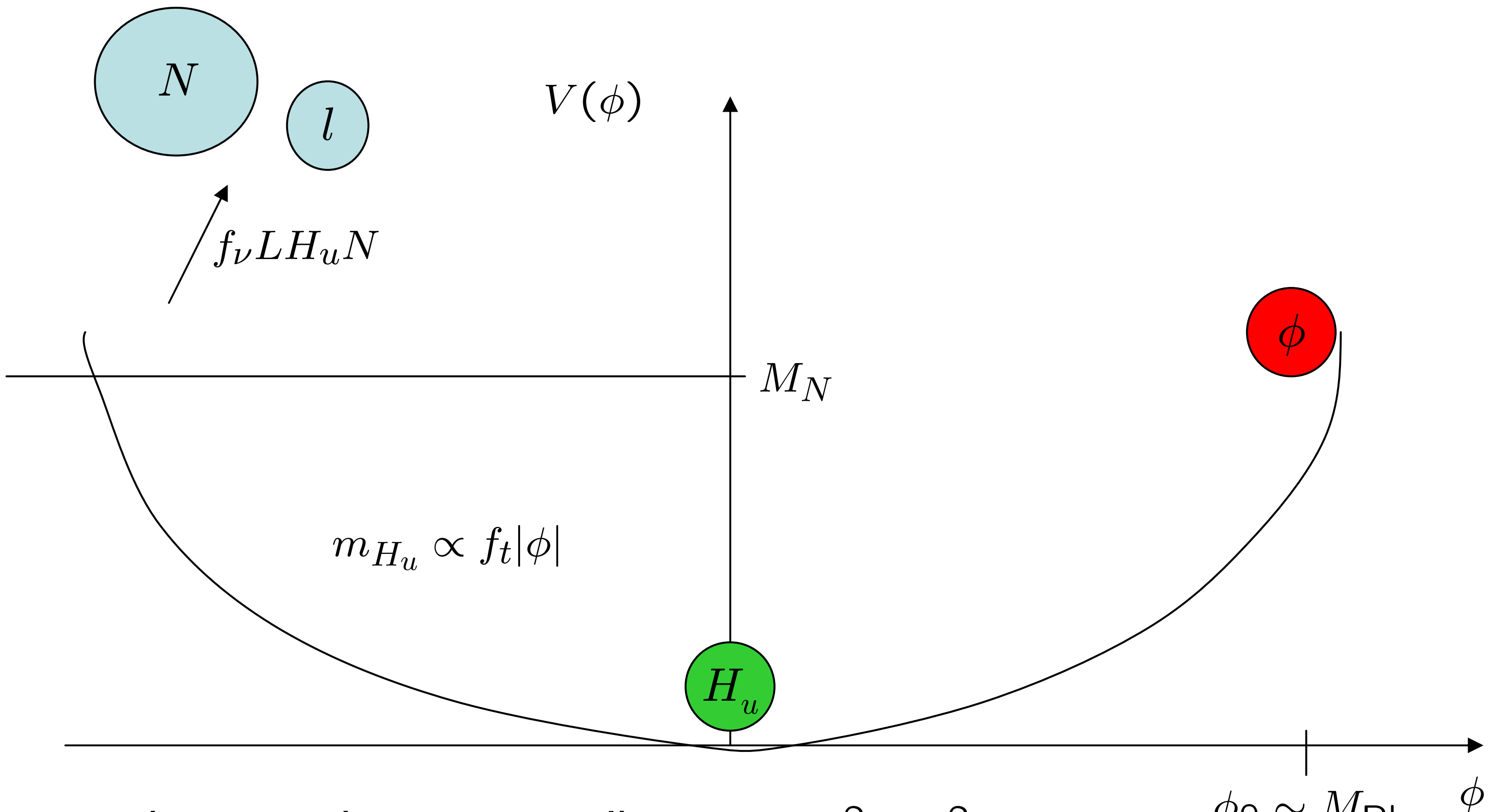
$$\eta_B \simeq 7 \times 10^{-5}\,\tilde{\varepsilon}\left(\frac{T_{\rm RH}}{10^8\ \rm GeV}\right)\left(\frac{|\phi_0|}{M_{\rm Pl}}\right)^{3/2}\left(\frac{100\ \rm GeV}{\tilde{m}}\right)^{1/2}$$

- Within this framework, we found that leptogenesis was more easily achievable than in the non-thermal case, and at a reheat temperature as low as 10^7 GeV. Interestingly, LFV rates are still predicted to be withing range of MEG for points in the bulk region or stop coannihilation.

Summary

- We studied the correlation between successul thermal (and non-thermal) leptogenesis and LFV rates in an mSUGRA-seesaw framework where the lightest neutralino is the dark matter particle.
- We find that thermal leptogenesis is possible in a restricted region of the parameter space, with observable LFV rates in the bulk or stop coannihilation regions.
- However, due to the very large reheat temperatures necessary, the gravitino problem is very severe, and actually untenable unless either thermal leptogenesis or neutralino dark matter are abandoned.
- Another possibility is to make non-thermal leptogenesis at a lower reheat temperature. With the mechanism of instant preheating from SUSY flat directions, we find that 10^7 GeV is possible, keeping LFV signatures comparable to the thermal case.

Instant preheating



Higgs-condensate coupling $f_t|\phi|^2|H_u|^2$

Higgs production when adiabaticity is violated $\dot{m}_{H_u}/m_{H_u}^2 \gtrsim 1$, which happens around $\phi = 0$