Effects of the Neutrino B-term ($MB\tilde{\nu}_R\tilde{\nu}_R/2$) on Slepton Mixing and EDMs

Y. F. hep-ph/0310055

MSSM

$$W = \mu H_u H_d + Y_l^{ij} H_d l_{Ri}^c L_j,$$

where $L_j = (\nu_j,\ l_{Lj})$

Universal couplings as suggested by mSUGRA, at the GUT scale:

$$V_{soft} = m_0^2(H_u^\dagger H_u + H_d^\dagger H_d + \tilde{l}_{Ri}^\dagger \tilde{l}_{Ri} + \tilde{L}_i^\dagger \tilde{L}_i) +$$

$$bH_u H_d + A_l^{ij} H_d \tilde{l}_{Ri}^\dagger \tilde{L}_j$$

$$A_l^{ij} = a_0 Y_l^{ij}$$

$$\begin{cases} \text{SM} \\ \text{MSSM} \end{cases} \rightarrow \text{massless neutrino}$$

Neutrino anomalies: seesaw mechanism

N_1, N_2 and N_3 with $M_1, M_2, M_3 \gg m_{susy}$

$$W = Y_l^{ij} H_d l_{Ri}^c L_j + Y_\nu^{ij} H_u N_i L_j + \mu H_u H_d +$$

$$\frac{1}{2} M_{ij} N_i N_j,$$

$$Y_l^{ij} = diag(Y_e, Y_\mu, Y_\tau) \quad M^{ij} = diag(M_1, M_2, M_3).$$

At GUT scale

$$V_{soft} = m_0^2 \tilde{N}_i^\dagger \tilde{N}_i + (B M_{ij} \tilde{N}_i \tilde{N}_j / 2 + h.c.)$$

$$+ A_\nu^{ij} \tilde{N}_i H_u \tilde{L}_j,$$

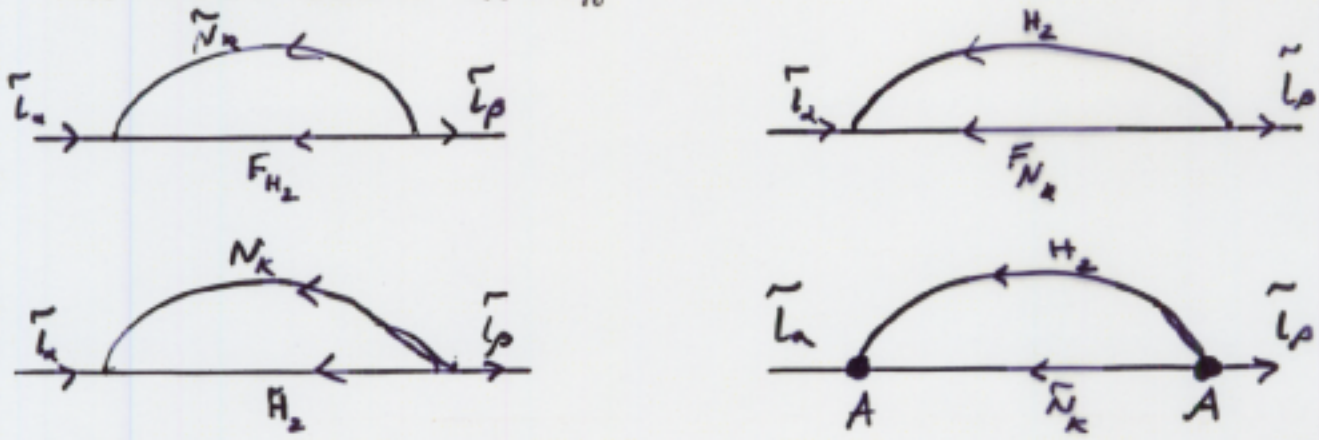
where $A_\nu^{ij} = a_0 Y_\nu^{ij}$

B-term is lepton number violating.
B-term $\rightarrow$ slepton anti-slepton oscillation at Linear colliders
Y. Grossman and H. E. Haber Phys. Rev. Lett. **78** (1997) 3438.

Right-handed neutrinos are electroweak singlet so B can be much larger than m_{EW}. In principle it can me as large as M_i.

B-term radiative correction to neutrino mass $\rightarrow B/m_{susy} < 10^3$ Y. Grossman and H. E. Haber Phys. Rev. Lett. **78** (1997) 3438.

At weak scale $\ll M_k$



$$m^2_{(1)\alpha\beta} = -\sum_k \frac{Y_\nu^{k\alpha}(Y_\nu^{k\beta})^*}{16\pi^2}$$

$$[6m_0^2(\log\frac{\Lambda_{GUT}}{M_k} - 1) + a_0^2(2\log\frac{\Lambda_{GUT}}{M_k} - 1)].$$

F. Borzumati and A. Masiero, *Phys. Rev. Lett.* **57** (1986) 961

$$\mathrm{Br}(l_\alpha \to l_\beta + \gamma) \sim \frac{\alpha^3}{G_F^2}\frac{|m^2_{\alpha\beta}|^2}{m^8_{susy}}\tan^2\beta.$$

$$\mathrm{Br}(\mu \to e\gamma) < 1.2\times10^{-11} \quad \mathrm{Br}(\tau \to \mu\gamma) < 1.1\times10^{-6}$$

$$\mathrm{Br}(\tau \to e\gamma) < 2.7 \times 10^{-6}$$

This means

$$|m^2_{e\mu}| < \frac{2\times 10^{-3}}{\tan\beta}(\frac{m_{susy}}{200\ \ \mathrm{GeV}})^2 m^2_{susy}$$

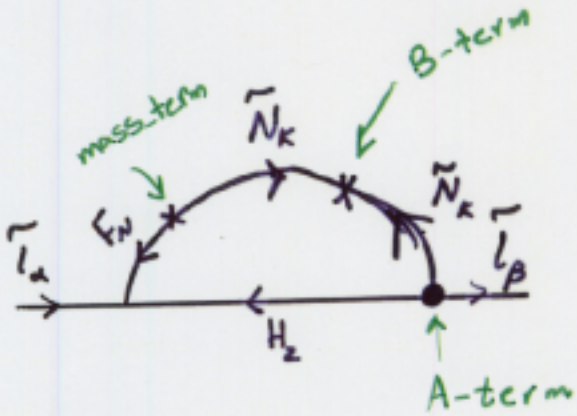
$$|m^2_{\tau\mu}| < \frac{0.7}{\tan\beta}(\frac{m_{susy}}{200\ \ \mathrm{GeV}})^2 m^2_{susy}$$

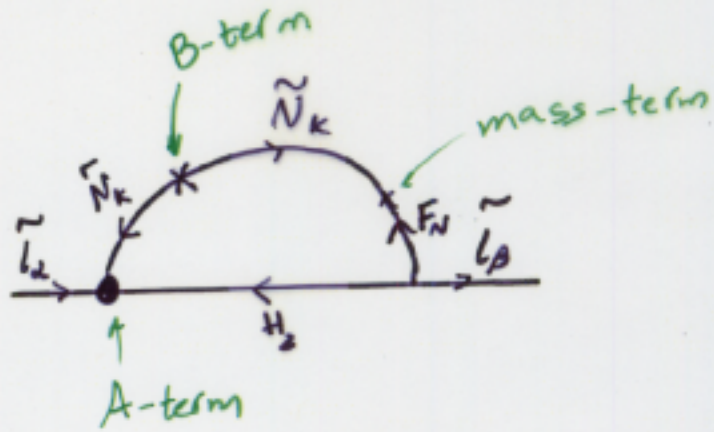
$$|m^2_{\tau e}| < \frac{1}{\tan\beta}(\frac{m_{susy}}{200\ \ \mathrm{GeV}})^2 m^2_{susy}$$

In future

$$|m^2_{e\mu}| < \frac{6\times 10^{-5}}{\tan\beta}(\frac{m_{susy}}{200\ \ \mathrm{GeV}})^2 m^2_{susy},$$

$$|m^2_{\tau\mu}| < \frac{0.02}{\tan\beta}(\frac{m_{susy}}{200\ \ \mathrm{GeV}})^2 m^2_{susy}.$$





$$m^2_{(2)\alpha\beta} = -2\sum_k \frac{Y_\nu^{k\alpha}(Y_\nu^{k\beta})^* \mathrm{Re}[a_0 B^*]}{(4\pi)^2}$$

For $a_0 \sim m_0$ while $B \sim 10^3 m_0$ this effect will be dominant.

Sources of CP-violation within MSSM with Universal Couplings

$$\mu \qquad a_0$$

EDM of elementary particles $\leftrightarrow$ CP-violation

$d_e < 1.5 \times 10^{-27}$ e cm $\qquad d_\mu < 7 \times 10^{-19}$ e cm

$d_\tau < 5 \times 10^{-16}$ e cm $\qquad d_n < 6 \times 10^{-26}$ e cm

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For $m_{susy} \sim 200$ GeV, $d_e < 1.5 \times 10^{-27}$ e cm [hep-ph/0211283]

$$\mathrm{Im}\frac{a_0}{m_{susy}} \lesssim 0.1 \qquad \sin\phi_\mu \frac{\tan\beta}{10} \lesssim 10^{-3}$$

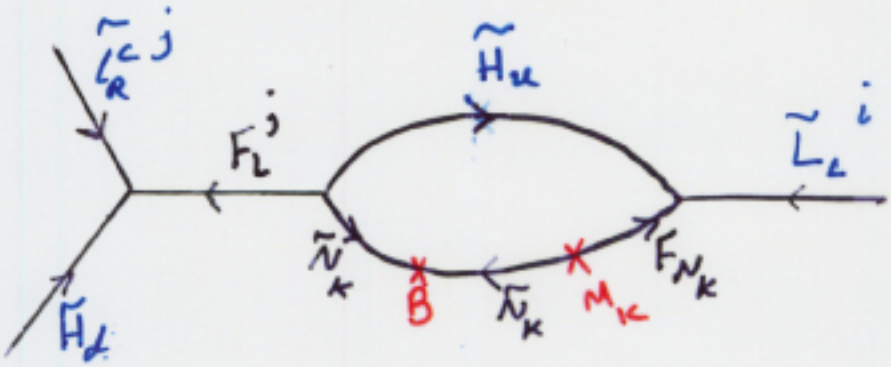
Adding three right-handed neutrinos

New sources of CP-violation

$$B \quad Y_\nu$$

Effect of Y_ν on EDM Three-loop effect

Y. F. and M. Peskin to appear



$$-iA_l^{ji} = -ia_0 Y_l^{ji}\delta_{ij} - \frac{i}{(4\pi)^2} Y_l^{jj} (Y_\nu^{kj})^* Y_\nu^{ki} B$$

No d_n

$$d_\tau/(m_\tau \sum_k |Y_\nu^{k\tau}|^2) = d_\mu/(m_\mu \sum_k |Y_\nu^{k\mu}|^2) =$$

$$d_e/(m_e \sum_k |Y_\nu^{ke}|^2)$$

$d_e \sim 10^{-27}$ e cm $\rightarrow$ $d_\mu \sim 10^{-25}$ e cm which can be tested in the proposed experiments

J. Aysto *et. al.*, hep-ph/0109217

Summary

Effects of the B-term both on $m^2_{\alpha\beta}$ and the EDMs of charged leptons can be dominant.

$d_n \ll d_e \sim \frac{m_e}{m_\mu} d_\mu$ will be a hint for complex neutrino B-term.

(Remember that $\mathrm{Im}\, c_0$ and $\sin \varphi_\mu$ create both d_n and d_e.)