Charged LFV, RGEs and algebraic renormalization

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- LFV, charged LFV
- RGEs
- Algebraic renormalization

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Hrvatska zaklada za znanost

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Motivation for CLFV

- SM does not allow LFV and predicts massless neutrinos
- neutrino oscillations : $m_\nu \neq 0$, LFV exists: sign for a physics BSM

$$
\begin{aligned}
\sin^2\theta_{12} &= 0.307 \pm 0.013 \\
\sin^2\theta_{23} &= 0.51 \pm 0.04 \qquad \text{normal hieararchy} \\
\sin^2\theta_{23} &= 0.50 \pm 0.04 \qquad \text{inverted hieararchy} \\
\sin^2\theta_{13} &= (2.10 \pm 0.11) \times 10^{-2} \\
\Delta m^2_{12} &= (7.53 \pm 0.18) \times 10^{-5}\text{eV}^2 \qquad \text{normal hieararchy} \\
\Delta m^2_{23} &= (2.45 \pm 0.05) \times 10^{-3}\text{eV}^2 \qquad \text{inverted hieararchy}
\end{aligned}
$$

- scale of new physics not determined by neutrino oscillations
- CLFV, $d_e > 10^{-33}$ e cm, $(a_\mu^{th} - a_\mu^{exp})/a_\mu^{exp} > (a_\mu$ sensitivity): would be independent sign for a physics BSM

– information on a scale of new physics

Experiment

Observable	Upper Limit	Future sensitivity
$B(\mu \to e\gamma)$	2.4×10^{-12} [1]	$1-2 \times 10^{-13}$ [6], 10^{-14} [6]
$B(\mu \to eee)$	10^{-12} [2]	10^{-16} [8], 10^{-17} [7]
$R_{\mu e}^{\rm Ti}$	4.3×10^{-12} [3],	$3-7 \times 10^{-17}$ [10, 9], 10^{-18} [11, 7]
$R_{\mu e}^{\rm Au}$	7×10^{-13} [4]	$3-7 \times 10^{-17}$ [10, 9], 10^{-18} [11, 7]
$B(\tau \to e\gamma)$	3.3×10^{-8} [5]	$1-2 \times 10^{-9}$ [13, 12]
$B(\tau \to \mu\gamma)$	4.4×10^{-8} [5]	2×10^{-9} [13, 12]
$B(\tau \to eee)$	2.7×10^{-8} [5]	2×10^{-10} [13, 12]
$B(\tau \to e\mu\mu)$	2.7×10^{-8} [5]	10^{-10} [12]
$B(\tau \to \mu\mu\mu)$	2.1×10^{-8} [5]	2×10^{-10} [13, 12]
$B(\tau \to \mu ee)$	1.8×10^{-8} [5]	10^{-10} [12]
d_e	0.87×10^{-28} e cm [1]	$10^{-29} - 10^{-31}$ e cm [14]
a_μ^{exp}	Sensitivity ($\delta a_\mu / a_\mu$)	Future sensitivity
$(116592089) \times 10^{-11}$	0.54×10^{-6} [14]	0.14×10^{-6} [15, 16]

Table 1: Current upper limits and future sensitivities of CLFV observables, electron EDM and muon MDM.

[1] PDG, Chin. Phys. C 40 (2016) 100001

[2] U. Bellgart, (SINDRUM) NPB 299 (1988) 1

[3] C. Dohmen, (SINDRUM II) PLB 317 (1993) 631

[4] W. Bertl, EPJ C47 (2006) 337

[5] See A.I., arXiv:1212.5939, Ref. [11]

[6] B.A. Golden (MEG) PhD 2012, J. Adam (MEG) PhD 2012

[7] J.L. Hewett, arXiv:1205.2671

[8] N. Berger, (μ3e) JPCS 408, 122070 (2013)

[9] A. Kurup (COMET) NPPS 218, 38 (2011)

[10] R.J. Abrams (Mu2e) arXiv:1211.7019; E.C. Dukes NPPS 218 (2011) 44

[11] Y. Kuno (PRISM) NPPS 149 (2005) 376; R.J. Barow (PRISM) , NPPS 218 (2011) 44

[12] K. Hayasaka, JPCS 171 (2009) 012079

[13] M. Bona (SuperB), arXiv:0709.0451

[14] M. Jung, JHEP 1305 (2013) 168

[15] B.L. Roberts NPPS 218 (2011) 237

[16] G. Venanzoni, arXiv:1203.1501; J.Phys.Conf.Ser. 349 (2012) 012008

Used Models

Non-SUSY models CSS ISS

SS=see-saw, M=constrained, I=inverse

$$\mathcal{L}_{CSS} = \mathcal{L}_{SM} - (\overline{\nu_R} Y_\nu \tilde{H} l + \frac{1}{2}\overline{\nu_R^c} M \nu_R + h.c.)$$

$$\mathcal{L}_{ISS} = \mathcal{L}_{SM} - (\overline{\nu_R} Y_\nu \tilde{H} l + \overline{\nu_R} M_\nu x_L + \frac{1}{2}\overline{x_L^c} M x_L + h.c.)$$

SUSY models: superpotential

$$W_{CSS} = W_{MSSM} + Y_\nu^{ij} N_{iR}^c H_u \cdot L_{jL} + \frac{1}{2} M_M^{ij} N_{iR}^c N_{jR}^c$$

$$W_{ISS} = W_{MSSM} + Y_\nu^{ij} \overline{N_i^c} H_u \cdot L + (M_\nu)^{ij} \overline{N_i^c} X_{jL} + \frac{1}{2}\mu^{ij} \bar{X}_{iL}^c X_{jL}$$

LFV induced by neutrino terms

– Borzumati, Masiero PRL (1986) 961 : MSSM+$3\nu_R$ with SS-I has only LFV induced by soft SUSY breaking terms and $s_L \sim \sqrt{m_\nu / M_M}$

– models defined by W_{CSS} and W_{ISS} have additional neutrino induced LFV

LFV in low-scale seesaw models (ν_RMSSM)

- **Neutrino induced LFV mechanism: $\mathbf{m_N \gtrsim 1}$ TeV**

- **Neutrino mass matrix** (m_e diagonal basis; at scale m_N)

$$(M_\nu)_{CSS} = \begin{pmatrix} 0 & m_D^T \\ m_D & M_M \end{pmatrix}, \qquad \begin{aligned} M_\nu B^{\nu_L \dagger} &= 0, \quad m_{n_i} \approx m_{n_j}, \quad i,j > 3, \\ m_D &= \sqrt{2} M_W s_\beta g^{-1} Y_\nu^\dagger \end{aligned}$$

$$(M_\nu)_{ISS} = \begin{pmatrix} 0 & m_D^T & 0 \\ m_D & 0 & M_R \\ 0 & M_R^T & \mu_X \end{pmatrix}, \quad m_D = \sqrt{2} M_W s_\beta g^{-1} Y_\nu^\dagger$$

CSS : LFV induced by $B^{\nu_R} = v_u Y_\nu / (\sqrt{2} M_M)$,

· $\nu_\ell^{SM} = (Bn)_\ell = (B^{\nu_L} \nu_L)_\ell + (B^{\nu_R} \nu_R)_\ell$: B diagonalizes M_ν

· ν masses : sym. breaking ($m_{n_i} \neq m_{n_j}$, $M_\nu B^\nu \neq 0$) and radiatively induced

ISS : LFV induced by B^{ν_R}, B^{x_L}

· $\nu_\ell^{SM} = (Bn)_\ell = (B^{\nu_L} \nu_L)_\ell + (B^{\nu_R} \nu_R)_\ell + (B^{x_L} x_L)_\ell$: B diagonalizes M_ν

· ν masses : $m_\nu = m_D^T M_R^{T-1} \mu_X M_R^{-1} m_D$

- Sneutrino mass matrix (CSS MSSM)

$$M^2_{\tilde{\nu}} = \begin{pmatrix} H_1 & N & 0 & M \\ N^\dagger & H_2^T & M^T & M_B \\ 0 & M^* & H_1^T & N^* \\ M^\dagger & M_B^\dagger & N^T & H_2 \end{pmatrix}, \qquad M^2_{\tilde{\nu}} \xrightarrow{SUSY} \begin{pmatrix} M_\nu M_\nu^\dagger & 0_{6\times 6} \\ 0_{6\times 6} & M_\nu^\dagger M_\nu \end{pmatrix}$$

$$H_1 = m^2_{\tilde{L}} + (\frac{1}{2} M_Z^2 c_{2\beta} \mathbf{1}) + (m_D m_D^\dagger)$$

$$H_2 = m^2_{\tilde{\nu}} + (m_D^\dagger m_D) + (M_M^\dagger M_M)$$

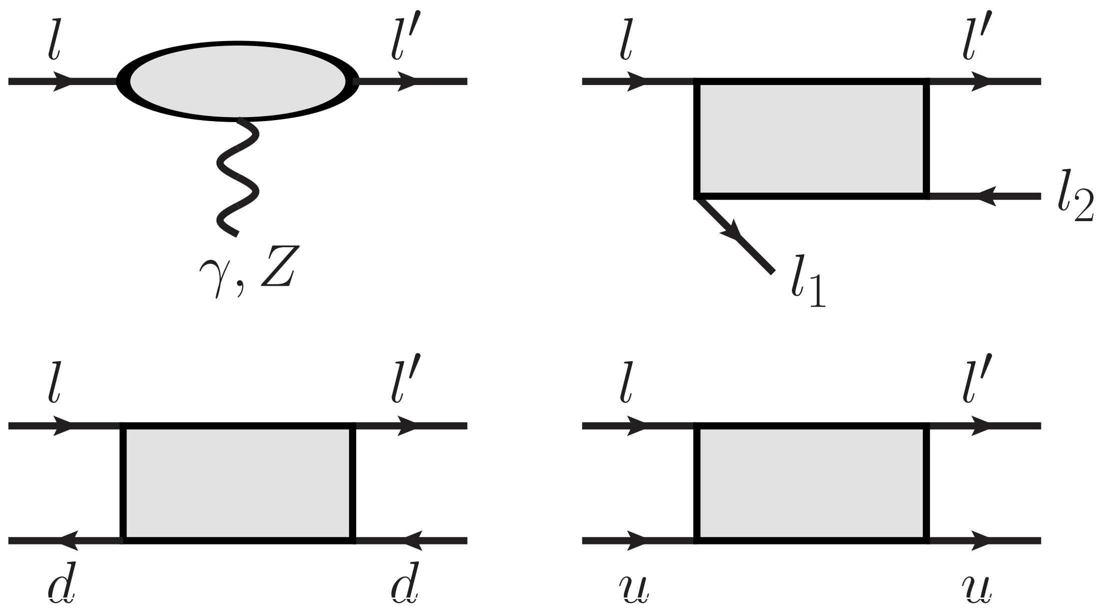
$$M = m_D (A_\nu - \mu\, ct_\beta)$$

$$N = m_D M_M^\dagger, \qquad M_B \equiv \frac{1}{2} B_{IJ} (M_\nu)_{IJ} \to 0; b_\nu$$

- N-$\tilde{N}$ sector nearly supersymmetric if $m_N > m_{SUSY}$ and $Y_\nu \leq 0.2$

Amplitudes

Amplitudes : diagrams



We took $\tan\beta < 20$. Neutral Higgs (h, H, A) contr. not taken into account

Amplitudes : structure

$$\mathcal{T}_{\mu}^{\gamma l' l} = \frac{e\,\alpha_w}{8\pi M_W^2}\,\bar{l}'[\underline{(F_\gamma^L)_{l'l}\,(q^2\gamma_\mu - \not{q}q_\mu)P_L} + (F_\gamma^R)_{l'l}\,(q^2\gamma_\mu - \not{q}q_\mu)P_R$$

$$+\underline{(G_\gamma^L)_{l'l}\,i\sigma_{\mu\nu}q^\nu P_L} + \underline{(G_\gamma^R)_{l'l}\,i\sigma_{\mu\nu}q^\nu P_R}]\,l,$$

$$\mathcal{T}_{\mu}^{Z l' l} = \frac{g_w\,\alpha_w}{8\pi\cos\theta_w}\,\bar{l}'[\underline{(F_Z^L)_{l'l}\,\gamma_\mu P_L} + (F_Z^R)_{l'l}\,\gamma_\mu P_R]\,l,$$

$$\mathcal{T}_{\gamma}^{l l' l_1 l_2} = \frac{\alpha_w^2 s_w^2}{2M_W^2}\{\delta_{l_1 l_2}\,\bar{l}'\,[\underline{(F_\gamma^L)_{l'l}\,\gamma_\mu P_L} + (F_\gamma^R)_{l'l}\,\gamma_\mu P_R$$

$$+\frac{(\not{p}-\not{p}')}{(p-p')^2}((\underline{(G_\gamma^L)_{l'l}\,\gamma_\mu P_L} + \underline{(G_\gamma^R)_{l'l}\,\gamma_\mu P_R})]\,l\;\;\bar{l}_1\gamma^\mu l_2^C \;-\; [\,l' \leftrightarrow l_1]\}\;,$$

$$\mathcal{T}_{Z}^{l l' l_1 l_2} = \frac{\alpha_w^2}{2M_W^2}[\delta_{l_1 l_2}\,\bar{l}'(\underline{(F_Z^L)_{l'l}\,\gamma_\mu P_L} + (F_Z^R)_{l'l}\,\gamma_\mu P_R)l$$

$$\times\;\bar{l}_1(g_L^l\,\gamma^\mu P_L + g_R^l\,\gamma^\mu P_R)l_2^C - (l' \leftrightarrow l_1)]\;,$$

$$\begin{aligned}\mathcal{T}^{ll'l_1l_2}_{\rm box} &= -\frac{\alpha_w^2}{4M_W^2}\big(\underline{B^{LL}_{\ell V}\,\bar{l}'\gamma_\mu P_L l\;\bar{l}_1\gamma^\mu P_L l_2^C} + B^{RR}_{\ell V}\,\bar{l}'\gamma_\mu P_R l\;\bar{l}_1\gamma^\mu P_R l_2^C \\
&\quad + B^{LR}_{\ell V}\,\bar{l}'\gamma_\mu P_L l\;\bar{l}_1\gamma^\mu P_R l_2^C + B^{RL}_{\ell V}\,\bar{l}'\gamma_\mu P_R l\;\bar{l}_1\gamma^\mu P_L l_2^C \\
&\quad + B^{LL}_{\ell S}\,\bar{l}' P_L l\;\bar{l}_1 P_L l_2^C + B^{RR}_{\ell S}\,\bar{l}' P_R l\;\bar{l}_1 P_R l_2^C \\
&\quad + B^{LR}_{\ell S}\,\bar{l}' P_L l\;\bar{l}_1 P_R l_2^C + B^{RL}_{\ell S}\,\bar{l}' P_R l\;\bar{l}_1 P_L l_2^C \\
&\quad + B^{LL}_{\ell T}\,\bar{l}'\sigma_{\mu\nu} P_L l\;\bar{l}_1\sigma^{\mu\nu} P_L l_2^C + B^{RR}_{\ell T}\,\bar{l}'\sigma_{\mu\nu} P_R l\;\bar{l}_1\sigma^{\mu\nu} P_R l_2^C\big) \\
&\equiv -\frac{\alpha_w^2}{4M_W^2}\sum_{X,Y=L,R}\;\sum_{A=V,S,T} B^{XY}_{\ell A}\,\bar{l}'\Gamma^X_A l\;\bar{l}_1\Gamma^Y_A l_2^C\,,\end{aligned}$$

$\mathcal{T}^{ll'dd}_{\rm box}$ and $\mathcal{T}^{ll'uu}_{\rm box}$ have the same structure as $\mathcal{T}^{ll'l_1l_2}_{\rm box}$

- form factors
- new form factors
- the underlined terms contribute to non-SUSY models

Form factors

Contributions

1. γ, Z, l-box, sl-box; h, H, A not included
2. Each form factor in principle has heavy neutrino (N), sneutrino ($\tilde{N}$) and soft SUSY breaking SB contributions, for instance

$$(F_\gamma^L)_{l'l} \quad = \quad F^N_{l'l\gamma} + F^{L,\tilde{N}}_{l'l\gamma} + F^{L,\mathrm{SB}}_{l'l\gamma}$$

A.I., A. Pilaftsis, PRD80 (2009) 091902 : N, $\tilde{N}$; γ, Z, l-box, sl-box; $\nu_R MSSM$ (CSS)

M. Hirsch, F. Staub, A. Vicente, Phys.Rev. D85 (2012) 113013, A. Abada, D. Das, A. Vicente, C. Weiland: N, $\tilde{N}$, SB; γ, Z, higgs, l-box, sl-box, but no N-box, MSISM (ISS)

A.I., A. Pilaftsis, L. Popov, PRD 87 (2013) 5, 053014: N, $\tilde{N}$, SB; γ, Z, l-box, sl-box but no higgs; $\nu_R MSSM$

M. E. Krauss, W. Porod, F. Staub, A. Abada, A. Vicente, C. Weiland, Phys.Rev. D90 (2014), 013008, MSISM: Z not dominant

A. Abada, Manuel E. Krauss, W. Porod, F. Staub, A. Vicente, C. Weiland JHEP 1411 (2014) 048: all contributions, detailed analysis

Dipole moments

Lagrangian and dipole moments

$$\mathcal{L} = \bar{l}[\gamma(i\partial^\mu + eA^\mu) - m_l - \frac{e}{2m_l}\sigma^{\mu\nu}(F_l + iG_l\gamma_5)\partial_\nu A_\mu]l$$

$$a_l = F_l \qquad d_l = eG_l/m_l$$

Amplitude and dipole moments

$$i\mathcal{T}^{\gamma ll} = \frac{ie\alpha_w}{8\pi M_W^2}[(G_\gamma^L)_{ll} i\sigma_{\mu\nu}q^\nu P_L + G_\gamma^R)_{ll} i\sigma_{\mu\nu}q^\nu P_R]$$

$$a_l = \frac{\alpha_w m_l}{8\pi M_W^2}[(G_\gamma^L)_{ll} + (G_\gamma^R)_{ll}] \qquad d_l = \frac{e\alpha_w}{8\pi M_W^2} i[(G_\gamma^L)_{ll} - (G_\gamma^R)_{ll}]$$

Possible sources of lepton EDM (CPV)

$$A_\nu = h_\nu A_0 e^{i\phi} \qquad -(A_\nu)^{ij}\tilde{\nu}_R^c(h_{uL}^+\tilde{e}_{jL} - h_{uL}^0\tilde{\nu}_{jL})$$

$$b_\nu = B_0 e^{i\theta} m_N \mathbf{1}_3 \qquad (b_\nu)_{ii}\tilde{\nu}_{Ri}\tilde{\nu}_{Ri}$$

$$\Delta_{\rm CP}^{LR} = \tilde{B}_{lkA}^L \tilde{B}_{lkA}^{R*} \qquad \Delta_{\rm CP}^{RL} = \tilde{B}_{lkA}^R B_{lkA}^{L*}$$

Scaling behaviour of MSSM contribution dipole moments

$$a_l^{MSSM} \quad \propto \quad \frac{m_l^2}{M_{SUSY}^2} \tan\beta \, \mathrm{sign}(\mu M_{1,2}) \qquad \text{(checked)}$$

$$d_l \quad \propto \quad \frac{e\, m_l}{M_{SUSY}^2} \tan\beta \sin(\phi_{CP}) \qquad \text{(expected,checked)}$$

$$d_l \quad \propto \quad \frac{e\, m_l\, f(m_0)}{M_N^x} \tan\beta, \quad 2/3 < x < 1 \qquad \text{(found)}$$

A. Pilaftsis, L. Popov, AI, PRD 89 (2014) no.1, 015001 : 1-loop CSS MSSM

A. Abada, T. Toma, JHEP 02 (2016) 174, JHEP 08 (2016) 079 : 2 loop ISS MSSM

mSUGRA Framework

Boundary conditions and RGEs:

1. SM parameters at M_Z scale (Fusaoka and Koide PRD57 (1998) 3986).
2. Neutrino Yukawa and heavy neutrino masses at heavy neutrino scale m_N, (Pilaftsis PRL95 (081602) 2005, PRD72 (2005) 113001, PRD83 (2011) 076007: U(1) fl. sym.; J. Kersten, A.Y. Smirnov, PRD76 (2007) 073005): A_4 fl. sym.)

$$m_{N_i} = m_N,$$

$$Y_\nu = \begin{pmatrix} 0 & 0 & 0 \\ ae^{-\frac{i\pi}{4}} & be^{-\frac{i\pi}{4}} & ce^{-\frac{i\pi}{4}} \\ ae^{\frac{i\pi}{4}} & be^{\frac{i\pi}{4}} & ce^{\frac{i\pi}{4}} \end{pmatrix} \qquad Y_\nu = \begin{pmatrix} a^* & b^* & c^* \\ a^* e^{-\frac{2\pi i}{3}} & b^* e^{-\frac{2\pi i}{3}} & c^* e^{-\frac{2\pi i}{3}} \\ a^* e^{\frac{2\pi i}{3}} & b^* e^{\frac{2\pi i}{3}} & c^* e^{\frac{2\pi i}{3}} \end{pmatrix}$$

3. mSUGRA conditions at gauge unification scale $g_1 = g_2 = g_3$,

$$m^2_{H_1,H_2} = m_0^2, \qquad m^2_{\tilde{u},\tilde{d},\tilde{e},\tilde{n}} = m_0^2\,\mathbf{1}$$
$$M_{1,2,3} = M_0, \qquad A_{u,d,e,n} = A_0\, Y_{u,d,e,n}\ .$$

4. MSSM+$3N$ RGE equations (P. Chankowski and S. Pokorski, IJMP A17 (2002) 575, S. Petcov et al. NPB676 (2004) 453).

Physical observables studied in considered models

$\mu^- \to e^-\gamma$	$\tau^- \to e^-\eta$	$\tau^- \to e^-\pi^0\pi^0$	$K^+ \to \pi^+e^\mp\mu^\pm$
$\mu^- \to e^-e^+e^-$	$\tau^- \to \mu^-\eta$	$\tau^- \to \mu^-\pi^0\pi^0$	$\bar{B}^0 \to e^\mp\mu^\pm$
$\tau^- \to e^-e^+e^-$	$\tau^- \to e^-\rho^0$	$\tau^- \to e^-\eta\eta$	$\bar{B}^0 \to e^\mp\tau^\pm$
$\tau^- \to \mu^-\mu^+\mu^-$	$\tau^- \to \mu^-\rho^0$	$\tau^- \to \mu^-\eta\eta$	$\bar{B}^0 \to \mu^\mp\tau^\pm$
$\tau^- \to e^-\mu^+\mu^-$	$\tau^- \to e^-\phi$	$\tau^- \to e^-\pi^0\eta$	$\bar{B}^0_s \to e^\mp\mu^\pm$
$\tau^- \to \mu^-e^+e^-$	$\tau^- \to \mu^-\phi$	$\tau^- \to \mu^-\pi^0\eta$	$\bar{B}^0_s \to e^\mp\tau^\pm$
$\tau^- \to e^+\mu^-\mu^-$	$\tau^- \to e^-K^0$	$\tau^- \to e^-K^0\bar{K}^0$	$\bar{B}^0_s \to \mu^\mp\tau^\pm$
$\tau^- \to \mu^+e^-e^-$	$\tau^- \to \mu^-K^0$	$\tau^- \to \mu^-K^0\bar{K}^0$	$\bar{B}^- \to \pi^-e^\mp\mu^\pm$
$\mu^-Ti \to e^-Ti$	$\tau^- \to e^-K^{*0}$	$\pi^0 \to e^-\mu^+$	$\bar{B}^- \to \pi^-e^\mp\tau^\pm$
$\mu^-Au \to e^-Au$	$\tau^- \to \mu^-K^{*0}$	$\eta \to e^-\mu^+$	$\bar{B}^- \to \pi^-\mu^\mp\tau^\pm$
$Z \to e^-\mu^+$	$\tau^- \to e^-\bar{K}^{*0}$	$K_L \to e^-\mu^+$	$\bar{B}^0 \to \bar{K}^0e^\mp\mu^\pm$
$Z \to e^-\tau^+$	$\tau^- \to \mu^-\bar{K}^{*0}$	$K_L \to \pi^0e^-\mu^+$	$\bar{B}^0 \to \bar{K}^0e^\mp\tau^\pm$
$Z \to \mu^-\tau^+$	$\tau^- \to e^-\pi^+\pi^-$	$\pi^0 \to e^-\mu^+$	$\bar{B}^0 \to \bar{K}^0\mu^\mp\tau^\pm$
	$\tau^- \to \mu^-\pi^+\pi^-$	$\eta \to e^-\mu^+$	$\bar{B}^0_s \to \eta e^\mp\mu^\pm$
$\tau^- \to e^-\pi^0$	$\tau^- \to e^-K^+K^-$	$K_L \to e^\mp\mu^\pm$	$\bar{B}^0_s \to \eta e^\mp\tau^\pm$
$\tau^- \to \mu^-\pi^0$	$\tau^- \to \mu^-K^+K^-$	$K_L \to \pi^0e^\mp\mu^\pm$	$\bar{B}^0_s \to \eta\mu^\mp\tau^\pm$

$\bar{B}_s^0 \to \eta' e^\mp \mu^\pm$
$\bar{B}_s^0 \to \eta' e^\mp \tau^\pm$
$\bar{B}_s^0 \to \eta' \mu^\mp \tau^\pm$
$B^- \to K^{*-} e^\mp \mu^\pm$
$B^- \to K^{*-} e^\mp \tau^\pm$
$B^- \to K^{*-} \mu^\mp \tau^\pm$
$\bar{B}^0 \to K^{*0} e^\mp \mu^\pm$
$\bar{B}^0 \to K^{*0} e^\mp \tau^\pm$
$\bar{B}^0 \to K^{*0} \mu^\mp \tau^\pm$
$\bar{B}_s^0 \to \phi e^\mp \mu^\pm$
$\bar{B}_s^0 \to \phi e^\mp \tau^\pm$
$\bar{B}_s^0 \to \phi \mu^\mp \tau^\pm$

Solved problems, Work in progress, Questions

1. 1 loop RGEs – solved – Marija Mađor Božinović
2. Algebraic renormalization (AR) – in progress – Jiangyang You
3. Implementation of AR techniques in evaluation of 2-loop RGEs and amplitudes – (many) questions – topic for a talk during next visit to Dresden

Thank you

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Hrvatska zaklada za znanost

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BACKUP SLIDES

LFV : Borzumati, Masiero PRL (1986) 961

$$\mathcal{M}^2_{\tilde{e}} = \begin{pmatrix} M^2_{\tilde{L}} + (m_e m_e^\dagger) + D_1 \mathbf{1} & m_e(A_e^* - \mu t_\beta \mathbf{1}) \\ (A_e^T - \mu^* t_\beta \mathbf{1}) m_e^\dagger & M^2_{\tilde{e}} + (m_e^\dagger m_e) + D_2 \mathbf{1} \end{pmatrix}$$

$$(\Delta M^2_{\tilde{L}})_{ij} \approx -\frac{1}{8\pi^2}(3m_0^2 + A_0^2) h_\nu^\dagger h_\nu \log\frac{M_X}{M_N},$$

$$(A_e)_{ij} \approx -\frac{3}{8\pi^2} A_0 h_e h_\nu^\dagger h_\nu \log\frac{M_X}{M_N},$$

Since recently : in SUSY LFV studies LFV induced by soft-SUSY breaking terms only

LFV in low-scale seesaw models (ν_RMSSM)

• **New supersymmetric LFV mechanism: $\mathbf{m_N \gtrsim 1}$ TeV**

- LFV parameters in N sector:

$$\Omega_{\ell\ell'} = \frac{v_u^2}{2m_N^2}(h_\nu^\dagger h_\nu)_{\ell\ell'} = B^*_{\ell N_i} B_{\ell' N_i}$$

- Neutrino mass matrix (m_e diagonal basis; at scale m_N)

$$M_\nu = \begin{pmatrix} 0 & m_D^T \\ m_D & M_M \end{pmatrix}, \qquad \begin{aligned} M_\nu B^{\nu\dagger} &= 0, \quad m_{n_i} \approx m_{n_j}, \quad i,j > 3, \\ m_D &= \sqrt{2} M_W s_\beta g^{-1} h_\nu^\dagger \end{aligned}$$

$$h_\nu = \begin{pmatrix} 0 & 0 & 0 \\ a e^{-\frac{i\pi}{4}} & b e^{-\frac{i\pi}{4}} & c e^{-\frac{i\pi}{4}} \\ a e^{\frac{i\pi}{4}} & b e^{\frac{i\pi}{4}} & c e^{\frac{i\pi}{4}} \end{pmatrix} \qquad h_\nu = \begin{pmatrix} a^* & b^* & c^* \\ a^* e^{-\frac{2\pi i}{3}} & b^* e^{-\frac{2\pi i}{3}} & c^* e^{-\frac{2\pi i}{3}} \\ a^* e^{\frac{2\pi i}{3}} & b^* e^{\frac{2\pi i}{3}} & c^* e^{\frac{2\pi i}{3}} \end{pmatrix}$$

· $\nu_\ell^{SM} = (Bn)_\ell = (B^\nu \nu)_\ell + (B^N N)_\ell$: B diagonalizes M_ν

· ν masses : sym. breaking; radiatively induced

Explanation of form factor structure in non-SUSY models

- The dominant terms of vertices appear in combinations that assure the $\gamma_\mu P_L$ structure in the $l \to l'\gamma$ and $l \to l'Z$ effective vertices.

- The box diagrams : Dirac (LNC currents) type diagrams have automatically $\gamma_\mu P_L \times \gamma^\mu P_L$ structure. Majorana (LNV currents) type diagrams have $\gamma_\mu P_L \times \gamma^\mu P_L$ structure only after Fiertz transformations, which replace the LNV currents by LNC currents.

In SUSY models the structure of amplitudes is more complex than in non-SUSY models. The vertices of the SUSY models and Fiertz transformations, necessary to receive the appropriate currents, lead to the most general structure of the amplitudes permitted by the Dirac algebra.

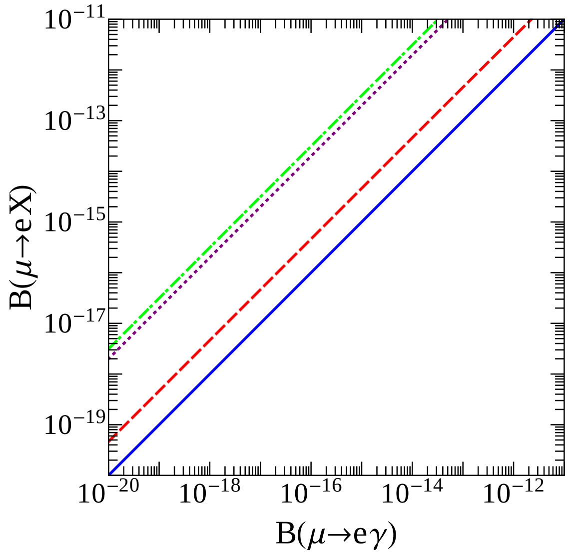
SUSY limit; cancelations

- $\tilde{m}^2_{\tilde{\chi}_{1,2}} \stackrel{SL}{\to} M_W^2, \quad t_\beta \stackrel{SL}{\to} 1, \quad \mu \stackrel{SL}{\to} 0$ (Barbieri, Giudice PLB309)
- $(G_\gamma^{\ell\ell'})^N + (G_\gamma^{\ell\ell'})^{\tilde{N}} \stackrel{SL}{=} 0$: Ferrara, Remiddi PLB53 (1974) 347

Numerical results for CLFV

Choice of parameters

1. $m_0 = 1000$ GeV, $A_0 = -3000$ GeV, $M_{1/2} = 1000$ GeV
   consistent with $m_h \approx 126$ GeV
   consistent with $m_{\tilde{g}},\ m_{\tilde{q}} > 1$ GeV
   in agreement with lightest neutralino as a dark matter candidate
2. $sign(\mu) > 0$
3. $\tan\beta = 10$ in most of calculations
4. Yukawa parameters:
   model 1: $a = b$, $c = 0$; $a = c$, $b = 0$; $b = c$, $a = 0$
   model 2: $a = b = c$
   Pertubativity condition $Trh_\nu^\dagger h_\nu < 4\pi$:
   model 1: $a < 0.34$
   model 2: $a < 0.23$
5. $m_N < 10$ TeV: consistency with resonant leptogenesis



$B(\mu \to e\gamma)$ $B(\mu \to eee)$ $R^{Ti}_{\mu e}$ $R^{Au}_{\mu e}$

$m_0 = M_{1/2} = 1$ TeV, $A_0 = -3$ TeV

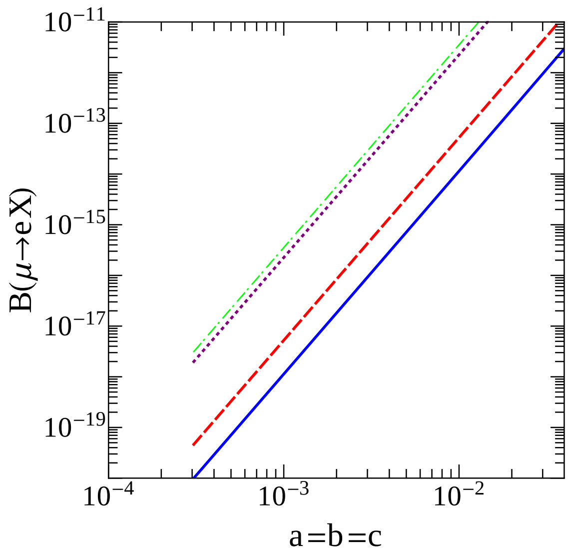
$m_N = 1$ TeV, $\tan\beta = 10$

model 2: $a = b = c$

pertubativity condition $Tr h^\dagger_\nu h_\nu < 4\pi$

quadratic Yukawa dependence

$R^{Au}_{\mu e},\ R^{Ti}_{\mu e}, B(\mu \to eee) > B(\mu \to e\gamma)$



$B(\mu \to e\gamma)$ $B(\mu \to eee)$ $R^{Ti}_{\mu e}$ $R^{Au}_{\mu e}$

$m_0 = M_{1/2} = 1$ TeV, $A_0 = -3$ TeV

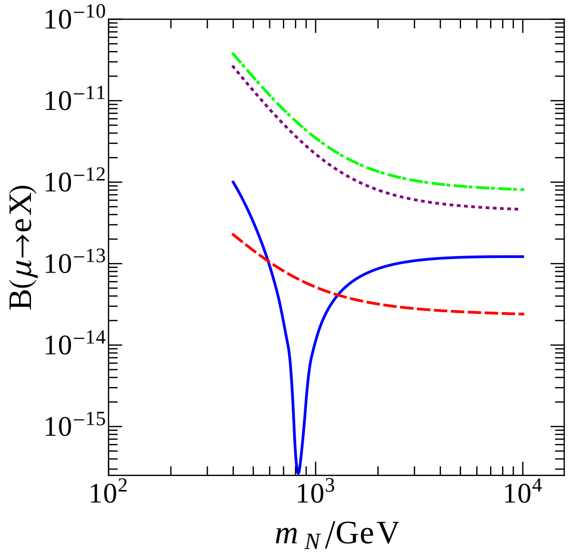
$m_N = 1$ TeV, $\tan\beta = 10$

model 2: $a = b = c$

pertubativity condition $Tr h^\dagger_\nu h_\nu < 4\pi$

quadratic Yukawa dependence

$R^{Au}_{\mu e},\ R^{Ti}_{\mu e}, B(\mu \to eee) > B(\mu \to e\gamma)$



$B(\mu \to e\gamma)$ $B(\mu \to eee)$ $R_{\mu e}^{Ti}$ $R_{\mu e}^{Au}$

$m_0 = M_{1/2} = 1$ TeV, $A_0 = -3$ TeV

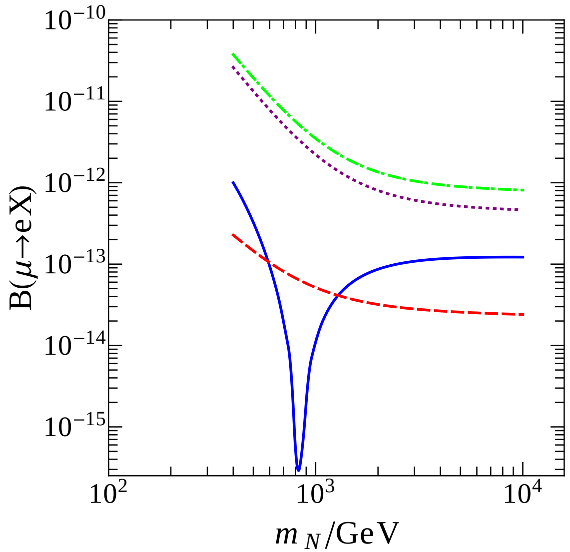
a: $B(\mu \to eee) = 10^{-12}$ for $m_N = 400$ GeV

$\tan\beta = 10$

model 2: $a = b = c$

$B(\mu \to e\gamma)$: cancelation of N, $\tilde{N}$ and SB contributions

$R_{\mu e}^{Au}, \; R_{\mu e}^{Ti} > B(\mu \to e\gamma)$



$B(\mu \to e\gamma)$ $B(\mu \to eee)$ $R_{\mu e}^{Ti}$ $R_{\mu e}^{Au}$

$m_0 = M_{1/2} = 1$ TeV, $A_0 = -3$ TeV

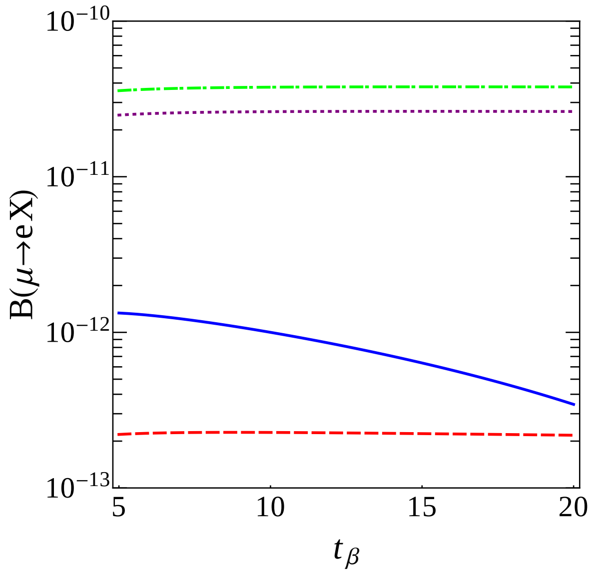
a: $B(\mu \to eee) = 10^{-12}$ for $m_N = 400$ GeV

$\tan\beta = 10$

model 1: $a = b$, $c = 0$

$B(\mu \to e\gamma)$: cancelation of N, $\tilde{N}$ and SB contributions

$R_{\mu e}^{Au}, \; R_{\mu e}^{Ti} > B(\mu \to e\gamma)$



$B(\mu \to e\gamma)$ $B(\mu \to eee)$ $R_{\mu e}^{Ti}$ $R_{\mu e}^{Au}$

$m_0 = M_{1/2} = 1$ TeV, $A_0 = -3$ TeV

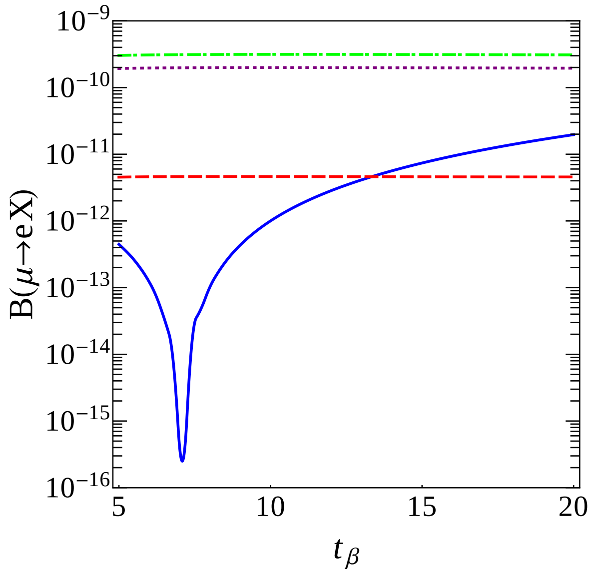
$m_N = 400$ GeV

a: $B(\mu \to eee) = 10^{-12}$ for $\tan\beta = 10$

model 2: $a = b = c$

weak dependence on $\tan\beta$

$R_{\mu e}^{Au}, \ R_{\mu e}^{Ti} > B(\mu \to e\gamma)$



$B(\mu \to e\gamma)$ $B(\mu \to eee)$ $R_{\mu e}^{Ti}$ $R_{\mu e}^{Au}$

$m_0 = M_{1/2} = 1$ TeV, $A_0 = -3$ TeV

$m_N = 1$ TeV

a: $B(\mu \to eee) = 10^{-12}$ for $m_N = 1$ TeV

model 2: $a = b = c$

$B(\mu \to e\gamma)$: cancelation of N, $\tilde{N}$ and SB contributions

$R_{\mu e}^{Au}, \ R_{\mu e}^{Ti} > B(\mu \to e\gamma)$

$$R_1 \equiv \frac{B(l \to l' l_1 l_1^c)}{B(l \to l'\gamma)} \to \frac{\alpha}{3\pi}(\ln \frac{m_l^2}{m_{l'}^2} - 3)$$

$$R_2 \equiv \frac{B(l \to l' l' l'^c)}{B(l \to l'\gamma)} \to \frac{\alpha}{3\pi}(\ln \frac{m_l^2}{m_{l'}^2} - \frac{11}{4})$$

$$R_3 \equiv \frac{R^J_{\mu e}}{B(\mu \to e\gamma)}$$

$$\to 16\alpha^4 \frac{\Gamma_\mu}{\Gamma_{\rm capture}} Z Z^4_{eff} |F(-\mu^2)|^2$$

$(G^L_\gamma)_{l'l}$, $(G^R_\gamma)_{l'l}$ only:

$R_1(\tau \to e\mu\mu) = 1/90$,

$R_1(\tau \to e\mu\mu) = 1/419$

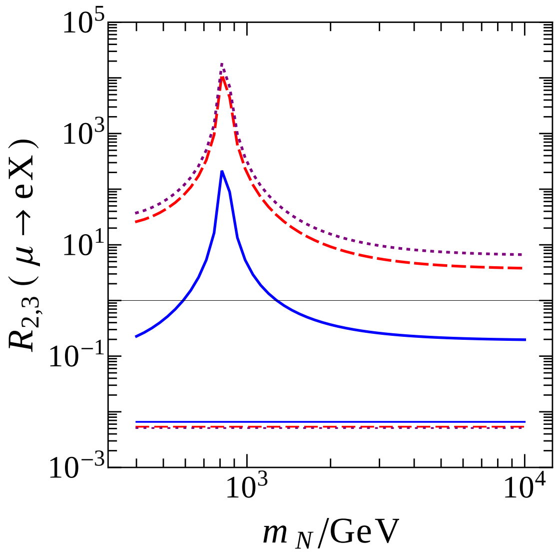
$R_2(\mu \to eee) = 1/159$,

$R_2(\tau \to eee) = 1/91$,

$R_2(\tau \to \mu\mu\mu) = 1/460$

$R_3^{Ti} = 1/198$,

$R_3^{Au} = 1/188$



$R_2(\mu \to eee)$, R_3^{Ti}, R_3^{Au}

$m_0 = M_{1/2} = 1$ TeV, $A_0 = -3$ TeV

$m_N = 400$ GeV, $\tan\beta = 10$

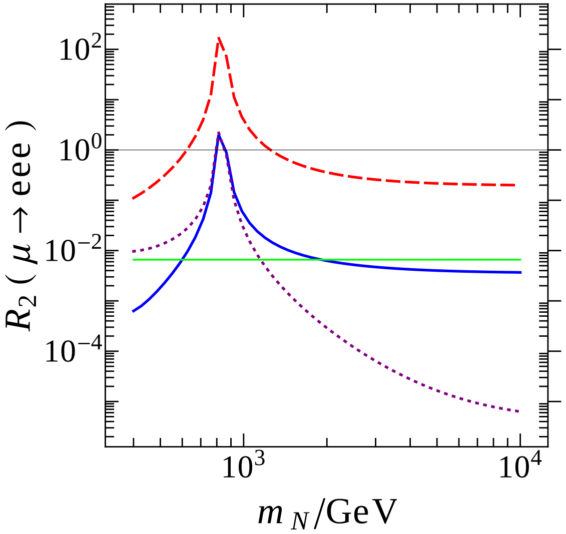
model 1 : $a = b$, $c = 0$

$R_2(\mu \to eee)$: full: $0.2 - 10^2$, $(G^{L,R}_\gamma)_{l'l}$ only: $1/159$

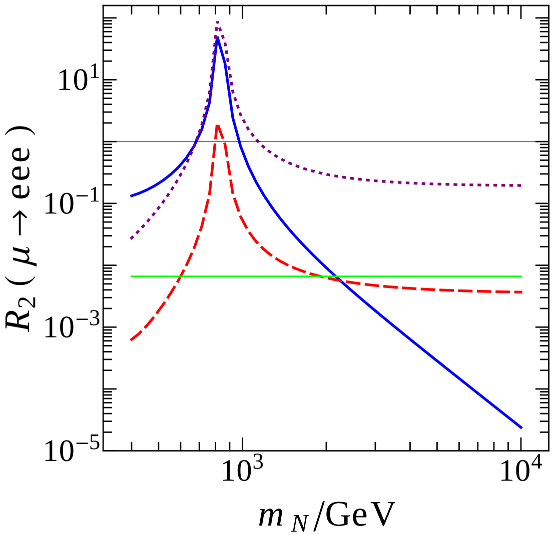
R_3^{Ti}: full: $3 - 10^4$, $(G^{L,R}_\gamma)_{l'l}$ only: $1/198$

R_3^{Au}: full: $6 - 2 \times 10^2$, $(G^{L,R}_\gamma)_{l'l}$ only: $1/188$

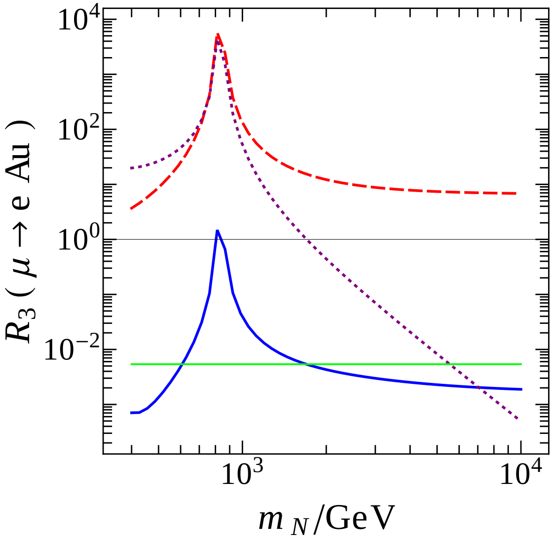
- source of strong enhancement?



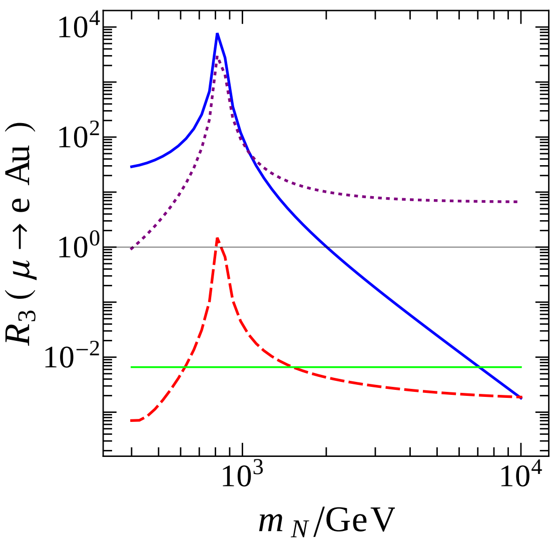
$R_2(\mu \to eee)$: form factor contributions
G_γ and F_γ, F_Z, box, $G_\gamma^{L,R}$ only
$\tan\beta = 10$
a : $B(\mu \to e\gamma) = 10^{12}$ for $m_N = 400$ GeV
- dominance of the F_Z contribution



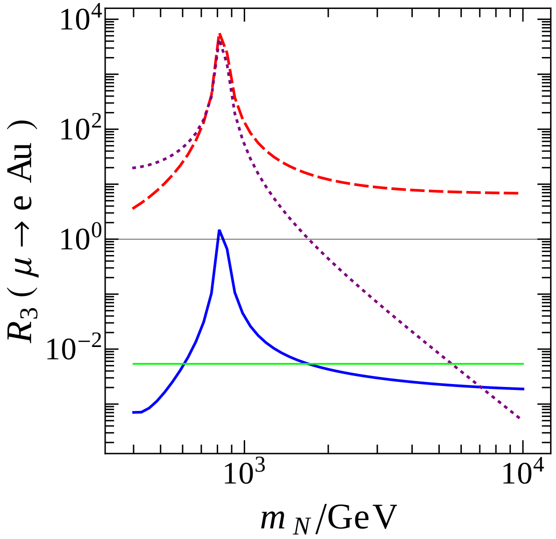
$R_2(\mu \to eee)$: N, $\tilde{N}$, SB, $G_\gamma^{L,R}$ only
$\tan\beta = 10$
a : $B(\mu \to e\gamma) = 10^{12}$ for $m_N = 400$ GeV
- dominance of N for $m_N < 1$ TeV,
- dominance of SB for $m_N > 1$ TeV



R_3^{Au} : form factor contributions
G_γ and F_γ, F_Z, box, $G_\gamma^{L,R}$ only
$\tan\beta = 10$
a : $B(\mu \to e\gamma) = 10^{12}$ for $m_N = 400$ GeV
- dominance of F_Z cont. for $m_N > 1$ TeV
- dominance of box cont. for $m_N < 1$ TeV



R_3^{Au}: N, $\tilde{N}$, SB, $G_\gamma^{L,R}$ only
$\tan\beta = 10$
a : $B(\mu \to e\gamma) = 10^{12}$ for $m_N = 400$ GeV
- dominance of N cont. for $m_N < 1$ TeV,
- dominance of SB cont. for $m_N > 1$ TeV



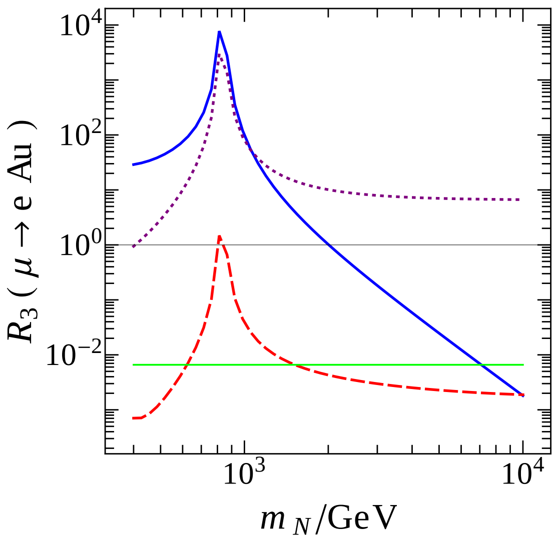
R_3^{Au} : form factor contributions

G_γ and F_γ, F_Z, box, $G_\gamma^{L,R}$ only

$\tan\beta = 10$

a : $B(\mu \to e\gamma) = 10^{12}$ for $m_N = 400$ GeV

- dominance of F_Z cont. for $m_N > 1$ TeV
- dominance of box cont. for $m_N < 1$ TeV



R_3^{Au}: N, $\tilde{N}$, SB, $G_\gamma^{L,R}$ only

$\tan\beta = 10$

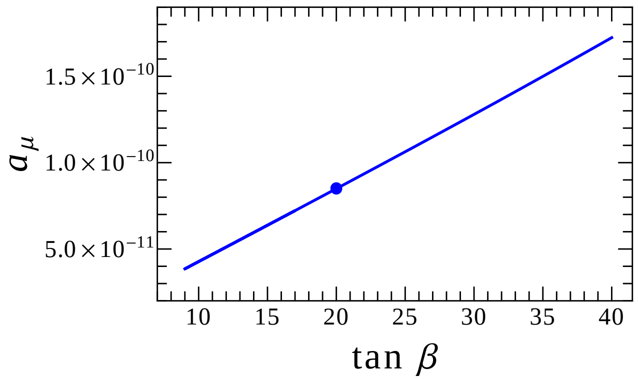
a : $B(\mu \to e\gamma) = 10^{12}$ for $m_N = 400$ GeV

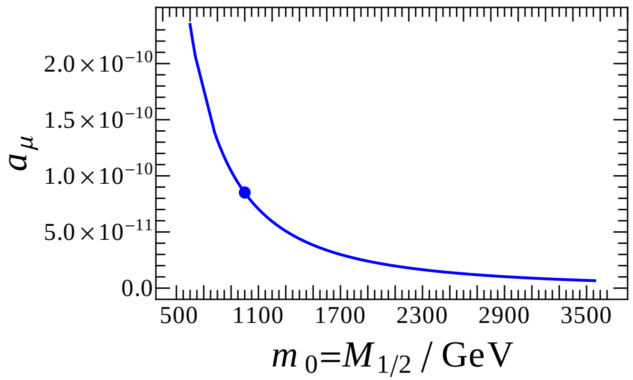
- dominance of N cont. for $m_N < 1$ TeV,
- dominance of SB cont. for $m_N > 1$ TeV

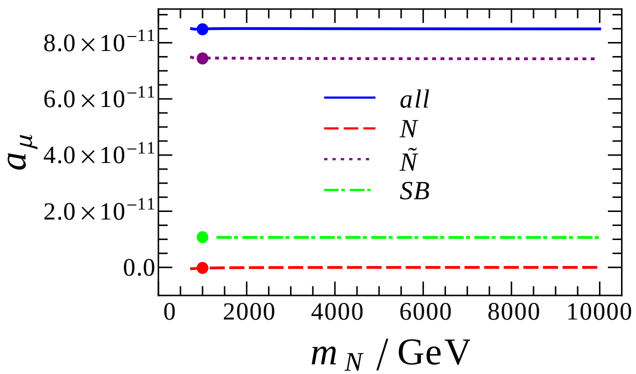
Numerical results for lepton dipole moments

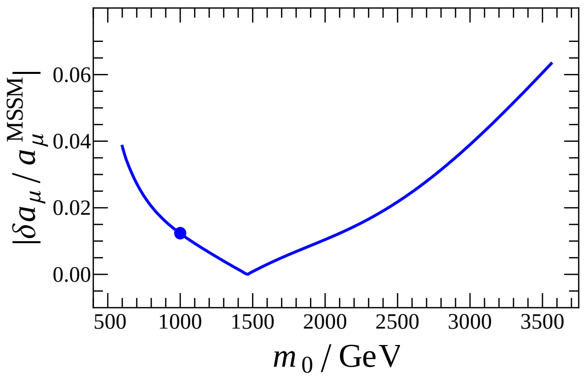
Choice of baseline parameters

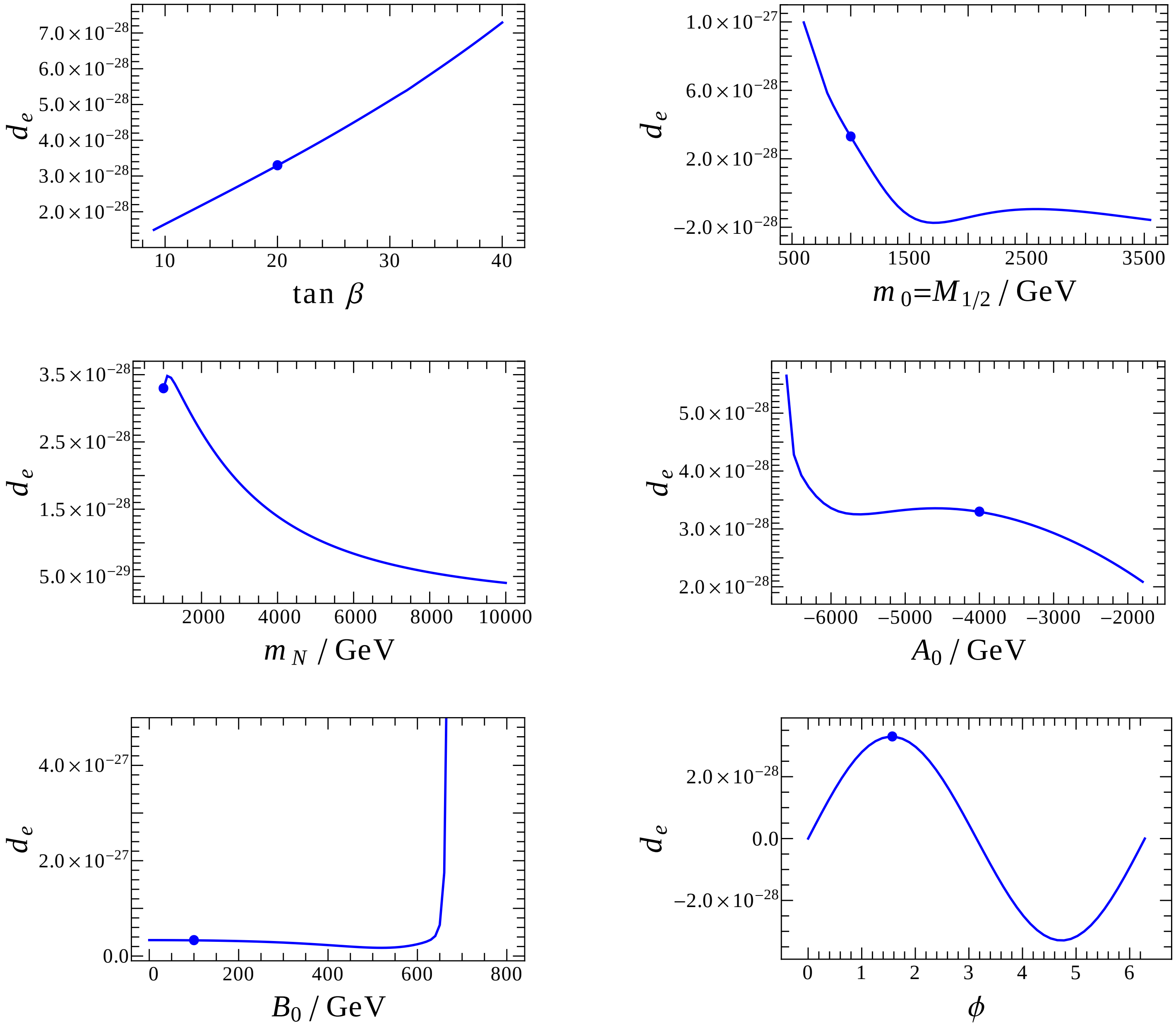
$$m_0 = 1\ \text{TeV}\ , \qquad M_{1/2} = 1\ \text{TeV}\ , \qquad A_0 = -4\ \text{TeV}\ , \qquad \tan\beta = 20\ ,$$
$$m_N = 1\ \text{TeV}\ , \qquad B_0 = 0.1\ \text{TeV}\ , \qquad a = b = c = 0.05\ ,$$

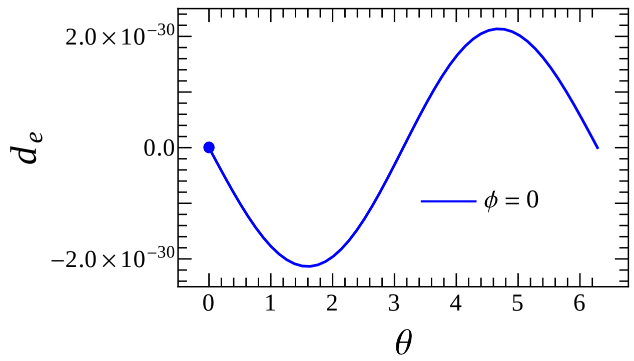


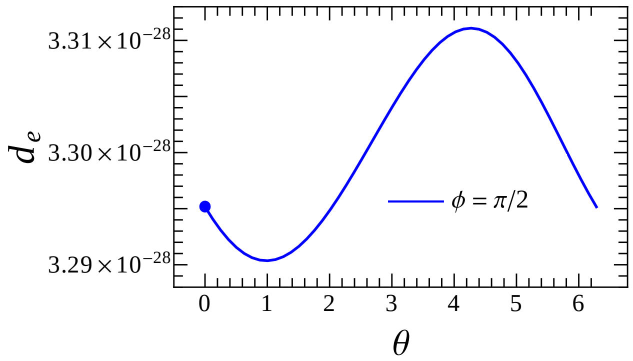







d_e
7.0×10^{-28}
6.0×10^{-28}
5.0×10^{-28}
4.0×10^{-28}
3.0×10^{-28}
2.0×10^{-28}
10
20
30
40
$\tan\beta$
1.0×10^{-27}
6.0×10^{-28}
2.0×10^{-28}
-2.0×10^{-28}
500
1500
2500
3500
$m_0=M_{1/2}$ / GeV
3.5×10^{-28}
2.5×10^{-28}
1.5×10^{-28}
5.0×10^{-29}
2000
4000
6000
8000
10000
m_N / GeV
5.0×10^{-28}
4.0×10^{-28}
3.0×10^{-28}
2.0×10^{-28}
−6000
−5000
−4000
−3000
−2000
A_0 / GeV
4.0×10^{-27}
2.0×10^{-27}
0.0
0
200
400
600
800
B_0 / GeV
2.0×10^{-28}
0.0
-2.0×10^{-28}
0
1
2
3
4
5
6
ϕ


2.0 × 10^−30
0.0
−2.0 × 10^−30
d_e
0
1
2
3
4
5
6
θ
ϕ = 0


3.31 × 10^−28
3.30 × 10^−28
3.29 × 10^−28
d_e
0
1
2
3
4
5
6
θ
ϕ = π/2

Summary

- We have carefully studied the N, $\tilde{N}$ and soft SB contributions to LFV. For the first time complete set of box diagrams is included. Complete set of chiral amplitudes is included ($B^{LR}_{\ell S}$, $B^{RL}_{\ell S}$) - this decomposition is valid for any model.

- We have shown that in $\mu \to eee$ N Z-boson-mediated graphs dominate for $m_N < 1$ TeV and soft SB Z-boson-mediated graphs dominate for $m_N > 1$ TeV. In $\mu \to e$ conversion in nuclei N box graphs dominate for $m_N < 1$ TeV and soft SB Z-boson-mediated graphs dominate for $m_N > 1$ TeV. It is interesting that the low-scale seesaw model setup strongly influences soft SB part of the amplitude.

- Due to partial cancelation of N and $\tilde{N}$ contributions in magnetic dipole amplitudes the $l \to l'\gamma$ amplitudes are suppressed relative to other CLFV amplitudes.

- Due to pertubativity condition on Yukawa couplings, the CLFV amplitudes are dominated by quadratic Yukawa contributions, while quartic contributions are small.

- The dependence of LFV amplitudes on $\tan\beta$ for $5 \leq \tan\beta \leq 20$ is weak, except for $l \to l'\gamma$ processes. $(B_s \to \mu\mu)$

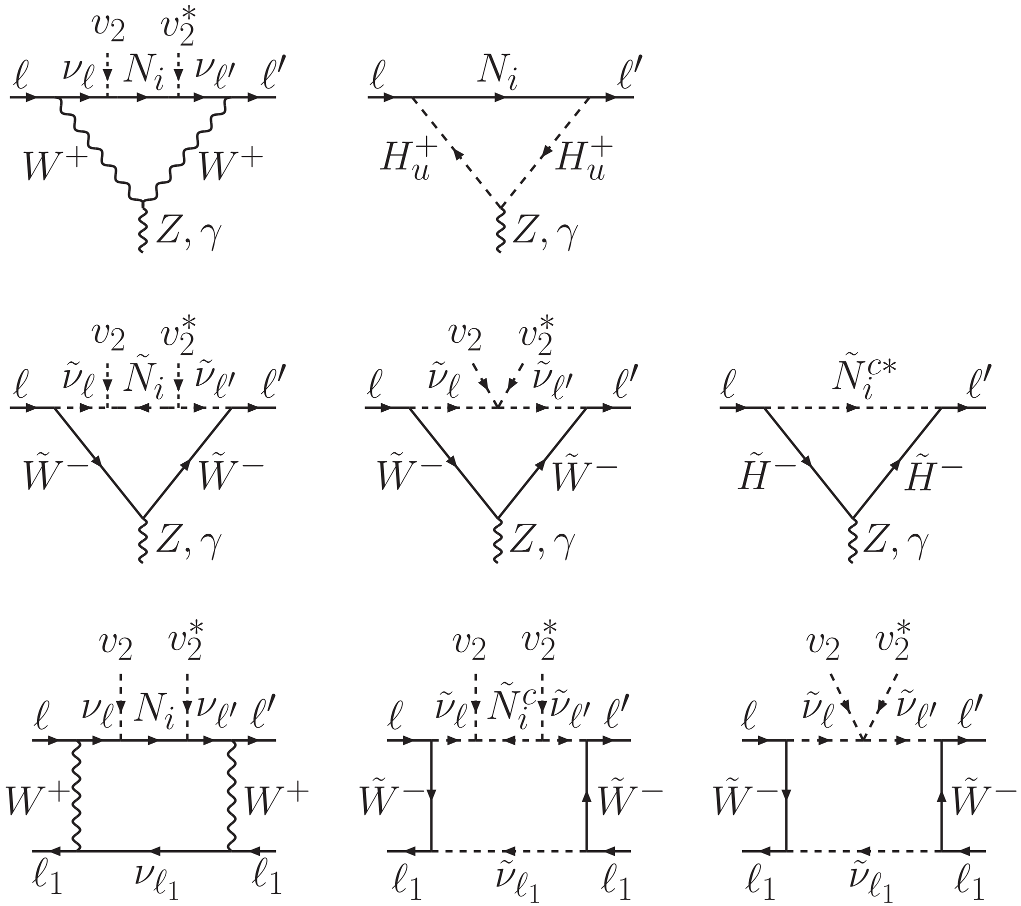
- Relative to the MSSM with ordinary seesaw mechanism, $l \to l' l_1 l_2$ and $\mu \to e$ conversion branching ratios are enhanced $2 - 3$ orders of magnitude in the region of parametric space where are no accidental cancelations of amplitudes. Opposed to the high-scale seesaw MSSM models, in the low-scale seesaw MSSM models $l \to l' l_1 l_2$ and $\mu \to e$ may give stronger constraint to the model parameters than $l \to l'\gamma$ processes.

- We made an analysis of the lepton dipole moments, with particular regard to muon magnetic dipole moment a_μ and electron electric dipole moment d_e. Up to our knowledge such analysis has been done for the first time in a model with a low scale seesaw mechanism. We showed that a_μ satisfies scaling behaviour as in MSSM, and the heavy neutrino and sneutrino contributions do not numerically change the MSSM prediction for a_μ. For d_e we found a scaling behaviour which almost agrees with the naive scaling prediction. That is new result. Further, at one loop level, only the additional phases of the soft SUSY breaking bilinear and trilinear couplings induce d_e, while the potential source of CPV from $\nu_R MSSM$ vertices which are not complex conjugate to each other give numerically zero contribution to d_e. That is in accord with the result obtained for the one loop result for d_e in models with high scale seesaw mechanism.

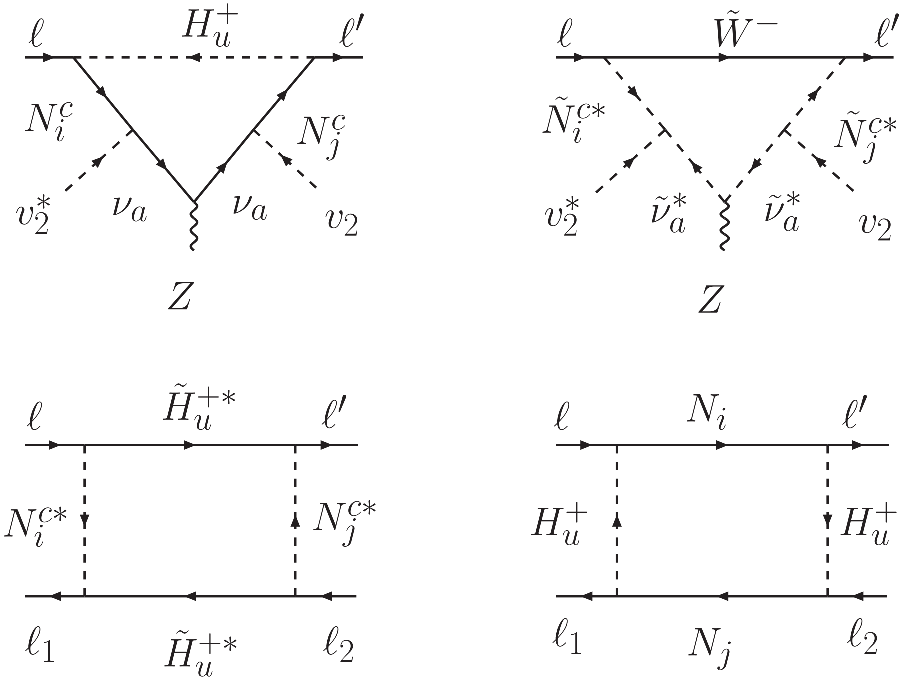
Amplitudes : Dominant contributions

- dominant terms in lowest order in g_W and v_u (Y_ν)

Two Yukawas



— **Four Yukawas**



Form factors

$$(F_\gamma^{\ell\ell'})^N = \frac{\Omega_{\ell\ell'}}{6s_\beta^2} \ln \underbrace{\frac{m_N^2}{M_W^2}}_{=\lambda_N},$$

$$(F_\gamma^{\ell\ell'})^{\tilde{N}} = \frac{\Omega_{\ell\ell'}}{3s_\beta^2} \sum_{k=1}^{2} \mathcal{V}_{k1}^2 \ln \frac{m_N^2}{\tilde{m}_{\tilde{\chi}_k^2}},$$

$$(G_\gamma^{\ell\ell'})^N = -\Omega_{\ell\ell'}\left(\frac{1}{6s_\beta^2} + \frac{5}{6}\right)$$

$$(G_\gamma^{\ell\ell'})^{\tilde{N}} = \Omega_{\ell\ell'}\left(\frac{1}{6s_\beta^2} + g_\gamma\right)$$

$$g_\gamma = -\sum_{k=1}^{2} \left[\mathcal{V}_{k1}^2 \frac{2M_W^2}{m_{\tilde{\chi}_i}^2} g_{\gamma,1}\left(\frac{m_{\tilde{\nu}}^2}{m_{\tilde{\chi}_i}^2}\right) + \mathcal{V}_{k1}\mathcal{U}_{k1} \frac{\sqrt{2}}{c_\beta} \frac{M_W^2}{m_{\tilde{\chi}_i}^2} g_{\gamma,2}\left(\frac{m_{\tilde{\nu}}^2}{m_{\tilde{\chi}_i}^2}\right) \right]$$

$$(F_Z^{\ell\ell'})^N = -\frac{3\Omega_{\ell\ell'}}{2}\ln\frac{m_N^2}{M_W^2} - \frac{\Omega_{\ell\ell'}^2}{2s_\beta^2}\frac{m_N^2}{M_W^2},$$

$$(F_Z^{\ell\ell'})^{\tilde{N}} = \frac{\Omega_{\ell\ell'}}{2}\ln\frac{m_N^2}{\tilde{m}_1^2}\Big(-\frac{1}{2}+2s_W^2+\frac{1}{s_\beta^2}f_Z\Big)$$

$$f_Z = \sum_{k,l=1}^{2}\frac{m_{\tilde{\chi}_k}m_{\tilde{\chi}_l}}{M_W^2}\Big(\mathcal{V}_{k2}\mathcal{U}_{k1}\mathcal{U}_{l1}\mathcal{V}_{l2}+\frac{1}{2}\mathcal{V}_{k2}\mathcal{U}_{k2}\mathcal{U}_{l2}\mathcal{V}_{l2}-s_W^2\delta_{kl}\mathcal{V}_{k2}\mathcal{V}_{l2}\Big)$$

$$(F_{box}^{\ell\ell'\ell_1\ell_2})^N = -(\Omega_{\ell\ell'}\delta_{\ell_2\ell_1}+\Omega_{\ell\ell_1}\delta_{\ell_2\ell'})+\frac{1}{4s_\beta^4}(\Omega_{\ell\ell'}\Omega_{\ell_2\ell_1}+\Omega_{\ell\ell_1}\Omega_{\ell_2\ell'})\frac{m_N^2}{M_W^2}$$

$$(F_{box}^{\ell\ell'\ell_1\ell_2})^{\tilde{N}} = (\Omega_{\ell\ell'}\delta_{\ell_2\ell_1}+\Omega_{\ell\ell_1}\delta_{\ell_2\ell'})\ f_{box}^{\ell}+\frac{1}{4s_\beta^4}(\Omega_{\ell\ell'}\Omega_{\ell_2\ell_1}+\Omega_{\ell\ell_1}\Omega_{\ell_2\ell'})\frac{m_N^2}{M_W^2}$$

$$f_{box}^{\ell} = \sum_{k,l=1}^{2}\mathcal{V}_{k1}^2\mathcal{V}_{l1}^2 f_{box,1}^{\ell}(\lambda_{\tilde{\chi}_k},\lambda_{\tilde{\chi}_l},\lambda_{\tilde{\nu}},\lambda_N)+\mathcal{V}_{k2}\mathcal{V}_{k1}\mathcal{V}_{l2}\mathcal{V}_{l1}f_{box,2}^{\ell}()$$

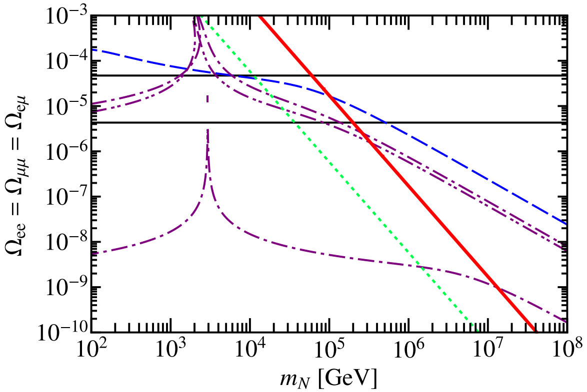
$$
\begin{aligned}
(F_{box}^{\ell\ell' uu})^{N} &= -4(F_{box}^{\ell\ell' dd})^{N} = 4\Omega_{e\mu} \\
(F_{box}^{\ell\ell' uu})^{\tilde{N}} &= \sum_{k,l=1}^{2} \mathcal{V}_{k1}^{2}\mathcal{V}_{l1}^{2} f_{box}^{u}(\lambda_{\tilde{\chi}_k}, \lambda_{\tilde{\chi}_l}, \lambda_{\tilde{d}}, \lambda_N) \\
(F_{box}^{\ell\ell' dd})^{\tilde{N}} &= \sum_{k,l=1}^{2} \mathcal{V}_{k1}^{2}\mathcal{V}_{l1}^{2} f_{box}^{d}(\lambda_{\tilde{\chi}_k}, \lambda_{\tilde{\chi}_l}, \lambda_{\tilde{u}}, \lambda_N)
\end{aligned}
$$

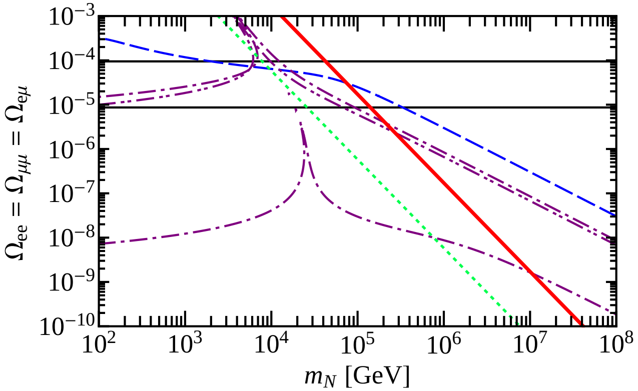
SUSY limit; cancelations, enhancements:

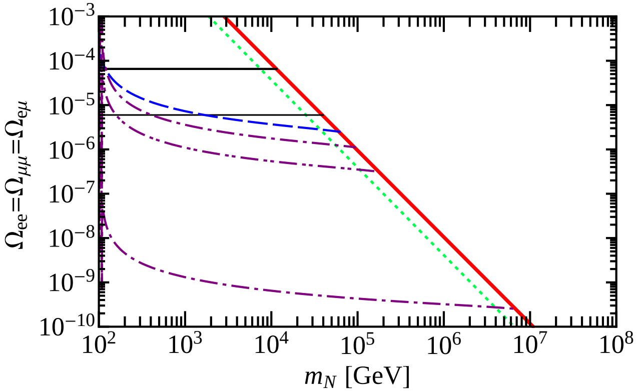
- $\tilde{m}^2_{\tilde{\chi}_{1,2}} \stackrel{SL}{\to} M_W^2, \quad t_\beta \stackrel{SL}{\to} 1, \quad \mu \stackrel{SL}{\to} 0$ (Barbieri, Giudice PLB309)
- $(G_\gamma^{\ell\ell'})^N + (G_\gamma^{\ell\ell'})^{\tilde{N}} \stackrel{SL}{=} 0$: Ferrara, Remiddi PLB53 (1974) 347
- box form factors : positive interference
- Y_ν^4 terms : become important when $Y_\nu/g_W \sim 1$ $\quad (\Omega_{\ell\ell'}\frac{m_N^2}{M_W^2} = 2(Y^\dagger Y)_{\ell\ell'}/g_W^2)$

  (A. Pilaftsis, A.I, NPB437 (1995) 491)

Numerical estimates







$\tan\beta = 3$

$m_0 = 100$ GeV, $M_0 = 250$ GeV

$A_0 = 100$ GeV

$\Omega_{\mu e} = \Omega_{ee} = \Omega_{\mu\mu}$, other $\Omega_{\ell\ell'} = 0$

Upper bounds

$B(\mu^- \to e^-\gamma)$	1.2×10^{-11}	[1]
	1×10^{-13}	[2]
$B(\mu^- \to e^-e^-e^+)$	1×10^{-12}	[1]
$R_{\mu e}^{Ti}$	4.3×10^{-12}	[3]
	1×10^{-18}	[4]
$R_{\mu e}^{Au}$	7×10^{-13}	[5]

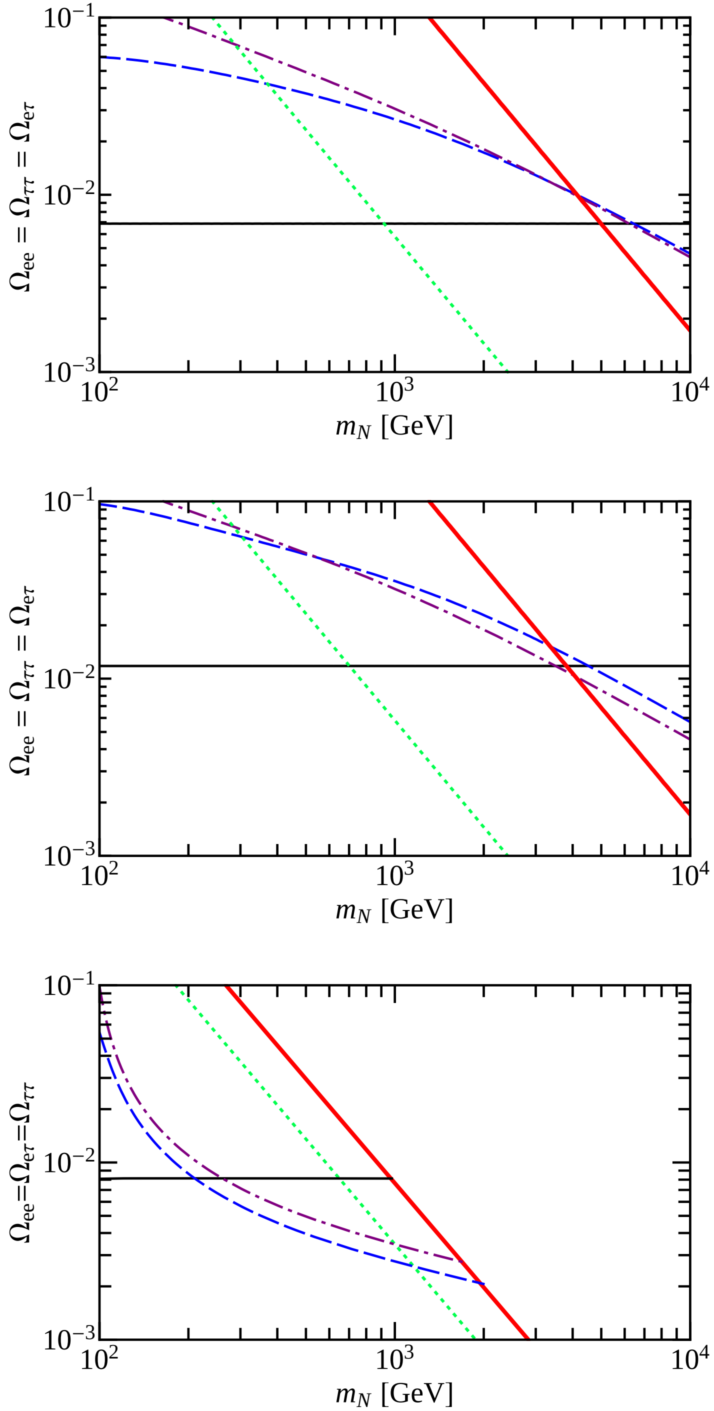
[1] Amsler, PLB 667 (2008) 1

[2] Ritt, NPBPS 162 (2006) 279

[3] Dohmen, PLB 317 (1993) 631

[4] Kuno, NPBPS 149 (2005) 376

[5] Bertl, EPJC 47 (2006) 337



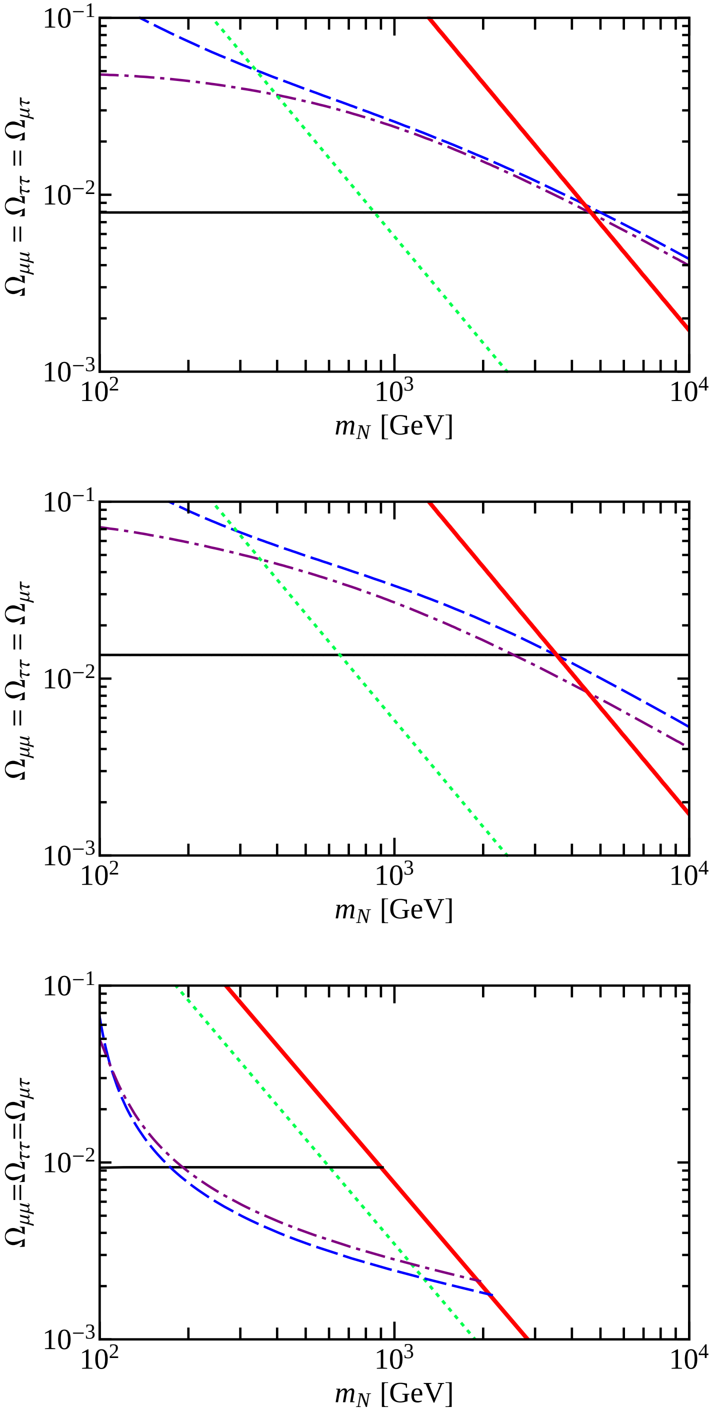
$\Omega_{\tau e} = \Omega_{ee} = \Omega_{\tau\tau}$, other $\Omega_{\ell\ell'} = 0$

Upper bounds

$B(\tau^- \to e^-\gamma)$	3.3×10^{-8}	[1]
$B(\tau^- \to e^-e^-e^+)$	2.7×10^{-8}	[2]
$B(\tau^- \to e^-\mu^-\mu^+)$	2.7×10^{-8}	[2]

[1] Aubert, PRL 104 (2010) 021802

[2] Hayasaka, PRL 687 (2010) 139



$\Omega_{\tau\mu} = \Omega_{\mu\mu} = \Omega_{\tau\tau}$, other $\Omega_{\ell\ell'} = 0$

Upper bounds

$B(\tau^- \to \mu^-\gamma)$	4.4×10^{-8}	[1]
$B(\tau^- \to \mu^-\mu^-\mu^+)$	2.1×10^{-8}	[2]
$B(\tau^- \to \mu^- e^- e^+)$	1.8×10^{-8}	[2]

[1] Aubert, PRL 104 (2010) 021802

[2] Hayasaka, PRL 687 (2010) 139

Summary

- We have shown that in the low-scaled supersymmetric seesaw models sneutrinos might give large effects indenpenent of SUSY breaking mechanism.
- Due to SUSY the $\ell \to \ell'\gamma$ are suppressed.
- That makes $\mu \to e$ conversion especially interesting candidate for finding LFV. $\mu \to 3e$ and $\tau \to 3e$ give complementary information on LFV.
- Inclusion of the mSUGRA boundary conditions strongly influences te final results of the model. Particularly it leads to lo larger theoretical prediction for LFV observables $R_{\mu e}$, $\mu \to 3e$ and $\tau \to 3$ leptons by up to factor of 25. The branching fractions for $\ell \to \ell'\gamma$ variation show smaller variation – they are slightly larger than those obtained in in MSSM+3N without mSUGRA boundary condition, but larger than results obtained in non-supersymmetric version of the model.