Neutrino Mass in Loop Mechanism Without R-Parity

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Based on
MG, F. Šimkovic, W. A. Kamiński *Phys. Rev. D 70 (2004) 0955005*
MG, F. Šimkovic, W. A. Kamiński, A. Faessler (in preparation)

*** Kraków Epiphany Conference on Neutrinos and Dark Matter 5-8.I.2006 ***

Minimal Supersymmetric Standard Model (MSSM) defined by superpotential

$$\begin{aligned} W_{\rm MSSM} &= \epsilon_{ab}[(\mathbf{Y}_E)_{ij}\hat{L}_i^a\hat{H}_d^b\hat{E}_j^c + (\mathbf{Y}_D)_{ij}\hat{Q}_i^{ax}\hat{H}_d^b\hat{D}_{jx}^c \\ &+ (\mathbf{Y}_U)_{ij}\hat{Q}_i^{ax}\hat{H}_u^b\hat{U}_{jx}^c + \mu\hat{H}_d^a\hat{H}_u^b] \end{aligned}$$

R-parity conservation implies conservation of $B-L$ number

$$R = (-1)^{3B+L+2S} = (-1)^{3(B-L)+2S}$$

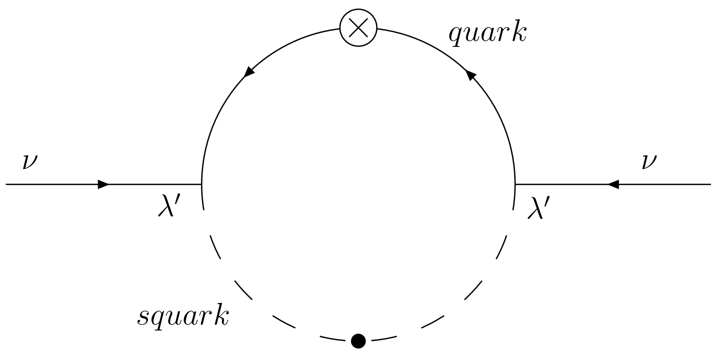
RpV allows for $0\nu 2\beta$ decay and other lepton number violating processes (usually $\lambda'' = 0$)

$$W_{\not R} = \epsilon_{ab}[\lambda_{ijk}\hat{L}_i^a\hat{L}_j^b\hat{E}_k^c + \lambda'_{ijk}\hat{L}_i^a\hat{Q}_j^b\hat{D}_k^c] + \lambda''_{ijk}\hat{U}_i^c\hat{D}_j^c\hat{D}_k^c + \epsilon_{ab}\mu_j\hat{L}_j^a\hat{H}_u^b$$

Full superpotential of RpV MSSM

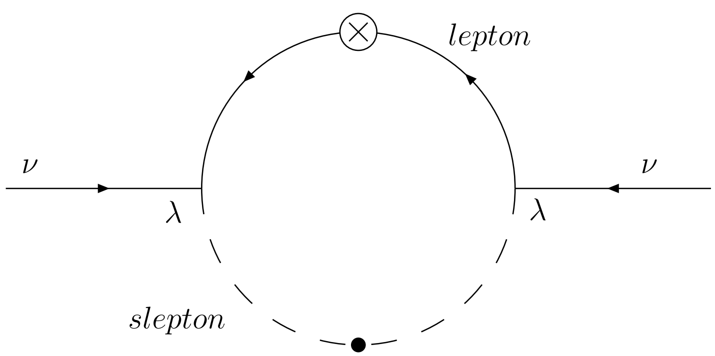
$$W = W_{\rm MSSM} + W_{\not R}$$

Supersymmetry introduces LOTS of new possible interactions...



...like the squark–quark

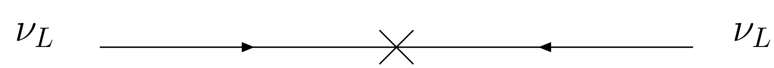
$$\mathcal{L} \supset \lambda'_{ijk} L_i Q_j \bar{D}_k$$



and slepton–lepton

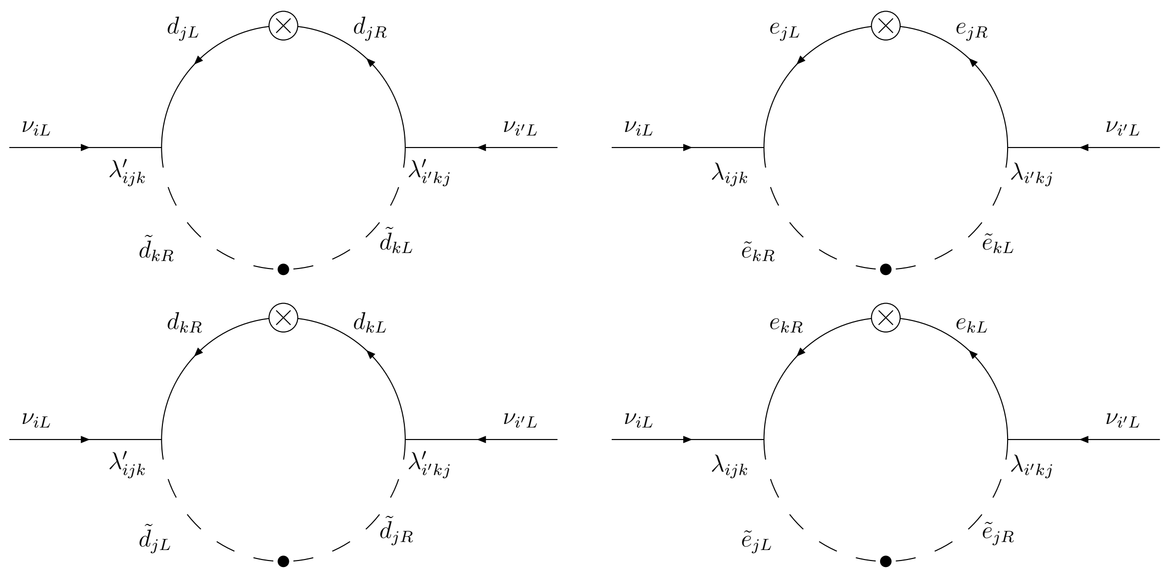
$$\mathcal{L} \supset \lambda_{ijk} L_i L_j \bar{E}_k$$

self-energy loops which give rise to Majorana neutrino masses



Old things (Haug *et al.*, Abada & Losada, Bhattacharyya *et al.*):

- tree level + 1-loop contribution



- estimates on sparticles' masses (eg. everything set to 100 GeV)

- approximate squark masses, no quark mixing included

Improved procedure is characterized by:

- GUT constraints + full RGE evolution of MSSM spectrum
- squark mixing treated exactly
- we want to treat quark mixing exactly (?)
- comparison with the latest phenomenological neutrino mass matrices derived from oscillation data and $0\nu2\beta$ experiments

The goal is to constrain MSSM coupling constants λ and λ'
and to find Majorana neutrino transition magnetic moment

Neutrino mass matrix: lepton–slepton contribution

$$\mathcal{M}^{\ell}_{ii'} = \sum_{jk} \lambda_{ijk} \lambda_{i'kj} \left(v^{\ell}_{jk} + v^{\ell}_{kj} \right)$$

$$v^{\ell}_{jk} = \frac{1}{16\pi^2} m_{e^j} \frac{1}{2} \sin 2\phi^k \left(\frac{\ln y_2^{jk}}{1 - y_2^{jk}} - \frac{\ln y_1^{jk}}{1 - y_1^{jk}} \right)$$

$y_1^{jk} \equiv m^2_{e^j} / m^2_{\tilde{l}_1^k}$ $\qquad$ $y_2^{jk} \equiv m^2_{e^j} / m^2_{\tilde{l}_2^k}$

ϕ – sleptons mixing angle

Neutrino mass matrix: quark–squark contribution

$$\mathcal{M}^q_{ii'} = \sum_{jkl} \Bigg[\lambda'_{ijk}\lambda'_{i'kl} \left(\sum_m V_{jm} V_{lm} v^q_{mk} \right) + \lambda'_{ijk}\lambda'_{i'lj} \left(\sum_m V_{km} V_{lm} v^q_{mj} \right) \Bigg]$$

$$v^q_{jk} = \frac{3}{16\pi^2} m_{q^j} \frac{1}{2} \sin 2\theta^k \left(\frac{\ln x_2^{jk}}{1 - x_2^{jk}} - \frac{\ln x_1^{jk}}{1 - x_1^{jk}} \right)$$

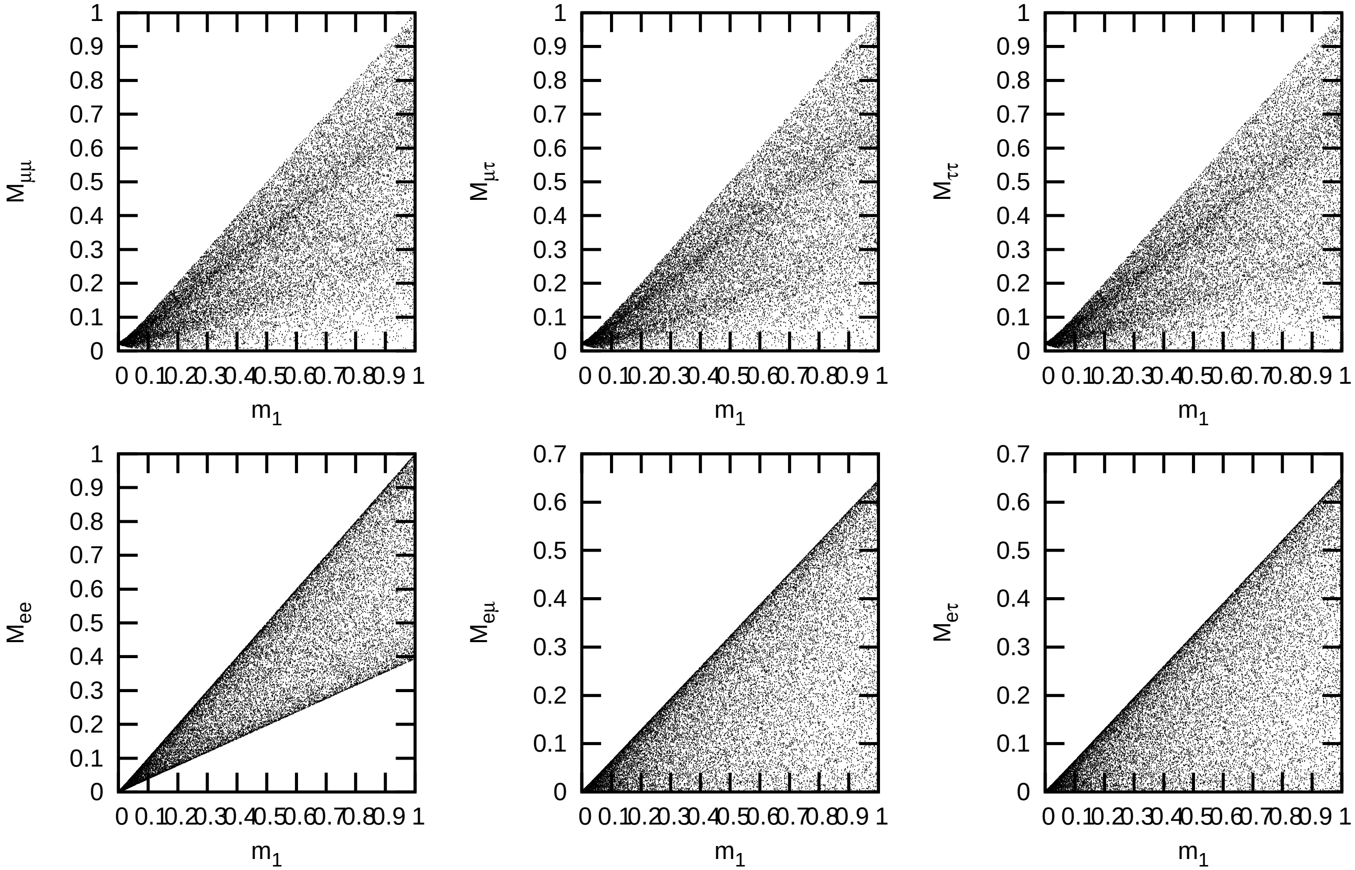
$x_1^{jk} \equiv m^2_{q^j}/m^2_{\tilde{q}^k_1}$ $\qquad$ $x_2^{jk} \equiv m^2_{q^j}/m^2_{\tilde{q}^k_2}$

θ – squarks mixing angle

How CP-phases affect the mass matrix elements?

Best fit values: $\sin(\theta_{12}) = 0.55$, $\sin(\theta_{23}) = 0.71$, $\sin(\theta_{13}) = 0$

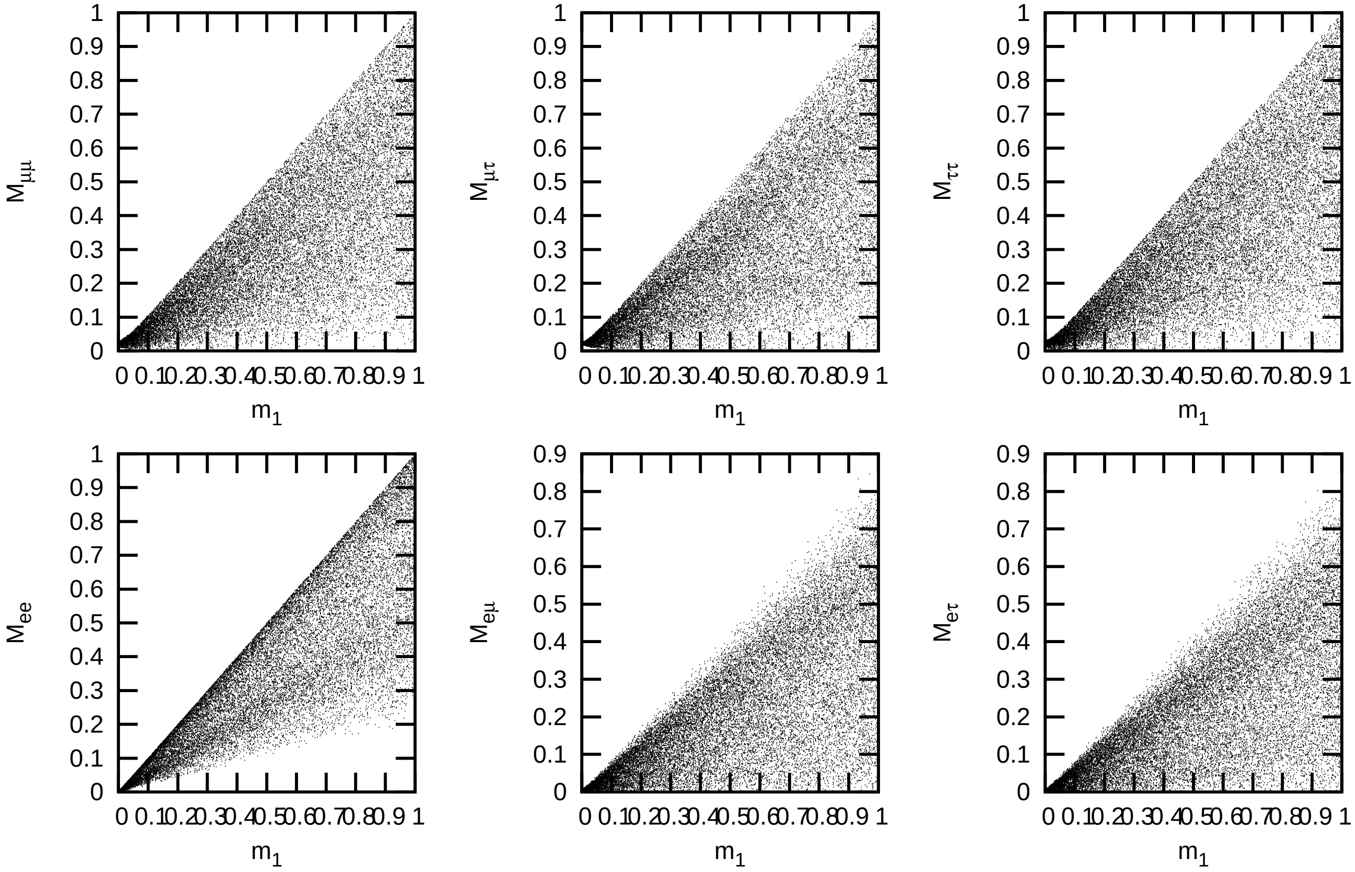
[Maltoni *et al.*, New J. Phys. 6 (2004) 122]



3σ values:

$\sin(\theta_{12}) = 0.48 - 0.62$, $\sin(\theta_{23}) = 0.58 - 0.82$, $\sin(\theta_{13}) = 0 - 0.22$

[Maltoni *et al.*, New J. Phys 6 (2004) 122]



Magnetic moment without CKM mixing

The GUT and SUSY input parameters:

$$A_0 = 100\text{GeV},\ m_0 = m_{1/2} = 150\ \text{GeV},\ \tan(\beta) = 19,\ \mu > 0$$

	$\mathbf{0\nu 2\beta}$	**Inverted Hierarchy**	**Normal Hierarchy**
$\mu^q_{e\mu}$	2.0×10^{-17}	9.0×10^{-19}	1.5×10^{-19}
$\mu^q_{e\tau}$	1.7×10^{-17}	7.4×10^{-19}	1.6×10^{-19}
$\mu^q_{\mu\tau}$	1.7×10^{-17}	7.2×10^{-19}	6.8×10^{-19}
$\mu^\ell_{e\mu}$	8.3×10^{-17}	3.8×10^{-18}	6.3×10^{-19}
$\mu^\ell_{e\tau}$	7.0×10^{-17}	3.1×10^{-18}	6.8×10^{-19}
$\mu^\ell_{\mu\tau}$	7.3×10^{-17}	3.1×10^{-18}	2.9×10^{-18}

Conclusions and (still) open problems

- The problem of quark mixing is rather non-trivial
- One cannot neglect CP phases present in $\mathcal{M}$
- GUT parameters dependence needed

Not the end of the story: bi-linear LH term & combinations of bi– and trilinear vertices! [J. Vergados, private communication]