LFV SUSY searches with Rp conservation

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Dubna, CALC 2009

OUTLINE

- **Basic physics**
- **Input / bounds from FV processes**
  (emphasis on rare charged lepton decays/conversions)
- **Effects of Quantum Corrections**
- **Constraining non-universality from symmetries**
- **Cosmological data**
- **LFV collider signatures**

Recent Reviews:

- *Flavour Physics of Leptons & Dipole Moments, M. Raidal et al., hep-ph/0801.1826*

- *Collider aspects of flavour physics at high Q, F. del Aguila et al.,hep-ph/0801.1800*

- *RGEs: See i.e. Hisano & Nomura, hep-ph/9810479.*

MSSM content & parameters

- SM particles & superpartners
- 2 Higgs fields with coupling μ, ratio of v.e.v.s = $\tan\beta$
- SUSY-breaking parameters:

  Scalar masses m_0 Gaugino masses $m_{1/2}$

  Trilinear soft terms A_λ Bilinear soft terms B_μ
- Assume universality? constrained MSSM = CMSSM

  Single m_0, single $m_{1/2}$, single A_λ, B_μ
- CMSSM different from mSUGRA

  where we have additional relations, as functions of $m_{3/2}$

Strong bounds from flavour violating processes
motivate Universality in soft scalar masses

$$BR(\mu \to e\gamma) \lesssim 1.2 \cdot 10^{-11} \qquad BR(\mu^- \to e^- e^+ e^-) \lesssim 10^{-12}$$

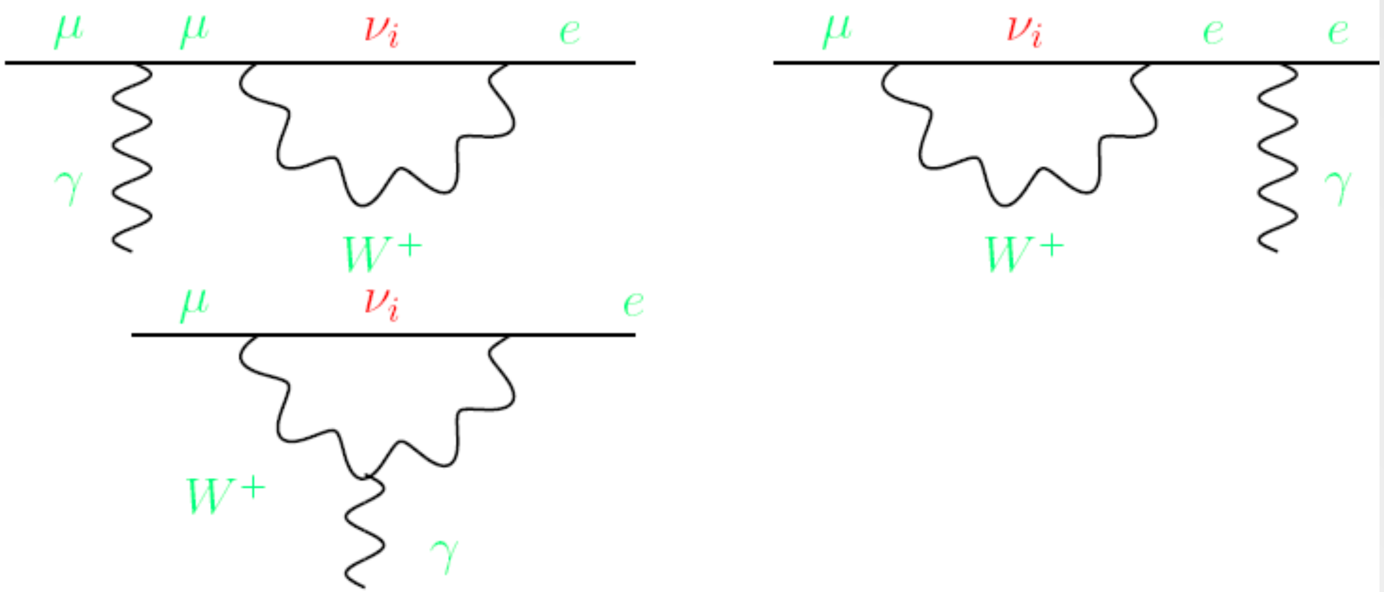
$$BR(\tau \to e\gamma) \lesssim 1.1 \cdot 10^{-7} \qquad BR(\tau \to \mu\gamma) \lesssim 6.8 \cdot 10^{-8}$$

$$BR(\tau \to ll') \lesssim O(10^{-8}) \; (l, l' = e, \mu)$$

Very good expected future BR sensitivities:

$\mu \to e\gamma$	10^{-14}
$\mu^- Ti \to e^- Ti$	10^{-18}

1. $\mu \to e\gamma$ in the SM with $m_{\nu_i} \neq 0$



$\nu_i = \nu_\mu \cos\theta + \nu_e \sin\theta$, $\Gamma = \frac{1}{16} \frac{G_F^2 \; m_\mu^5 \; \alpha}{128 \; \pi^4} \left(\frac{m_2^2 - m_1^2}{m_W^2} \right) \sin^2\theta \cos^2\theta$

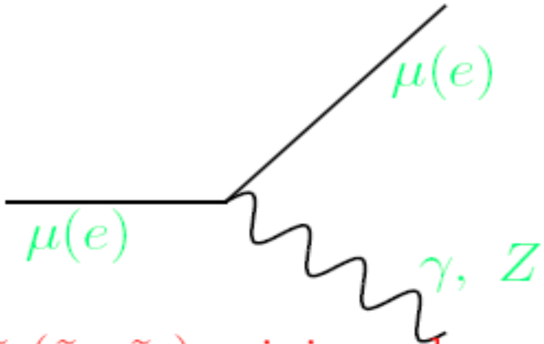
$BR \leq 10^{-50}$, for Δm_{12}^2 from neutrino data too small!

LFV in minimal SUSY

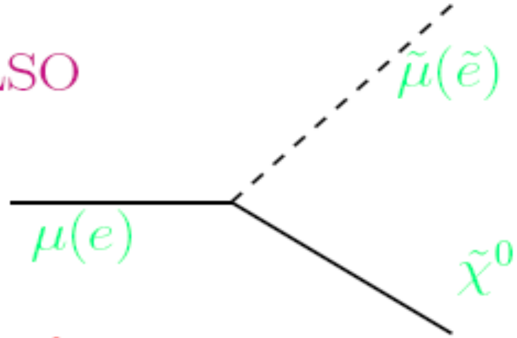
MSSM: For each SM vertex, also the one with

2 particles → superparticles

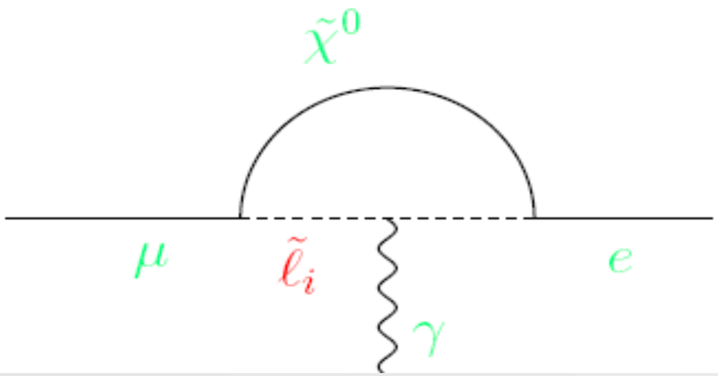
FOR

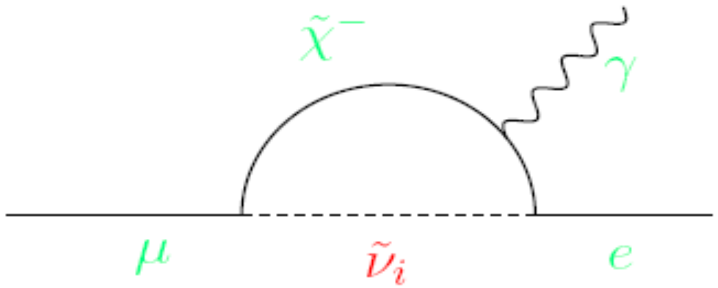


ALSO

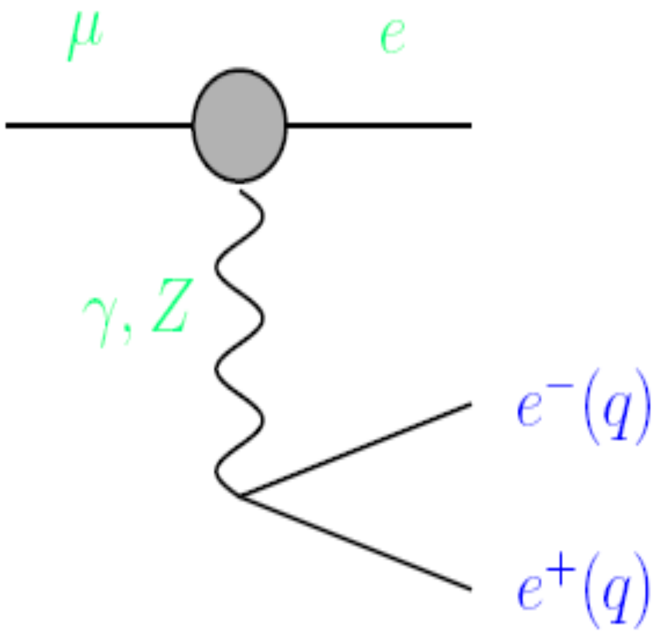


If $\tilde{\mu}$-$\tilde{e}$ ($\tilde{\nu}_\mu$-$\tilde{\nu}_e$) mixing, large rates for:





2. $\mu \to 3e$ et μ-e conversion on nuclei



+ ...(suppressed box-diagr.)

$BR \leq 10^{-53}$

for Δm^2_{12} from neutrino data

Quite some space for deviations from universality
in consistency with all bounds

✧ Universality violations possible at a high scale?
If yes, we need to predict their magnitude
(possibly through flavour symmetries)

✧ Even if we have universality at a high scale,
it may be broken at low energies
due to <u>quantum corrections</u>

<u>Let us now look at all these in more detail:</u>

Generic SLEPTON mass matrices

In the unrotated basis $\tilde{\ell}_i = (\tilde{e}_L, \tilde{\mu}_L, \tilde{\tau}_L, \tilde{e}^*_R, \tilde{\mu}^*_R, \tilde{\tau}^*_R)$, the slepton mass matrix reads as:

$$\mathcal{L}_M = -\frac{1}{2}\tilde{\ell}^\dagger M^2_{\tilde{\ell}}\tilde{\ell}, \quad M^2_{\tilde{\ell}} = \begin{pmatrix} M^2_{LL} & M^2_{LR} \\ M^2_{RL} & M^2_{RR} \end{pmatrix},$$

where

$$\begin{aligned}
M^2_{LL} &= \frac{1}{2}m^\dagger_\ell m_\ell + M^2_L - \frac{1}{2}(2m^2_W - m^2_Z)\cos 2\beta \; I \\
M^2_{RR} &= \frac{1}{2}m^\dagger_\ell m_\ell + M^2_R - (m^2_Z - m^2_W)\cos 2\beta \; I \\
M^2_{LR} &= (A^e - \mu \tan\beta)\; m_\ell \\
M^2_{RL} &= (M^2_{LR})^\dagger
\end{aligned}$$

$$A^e_{ij} = A_0 \cdot \delta_{ij}, \quad M^2_L = M^2_R \; = \; m^2_0 \; I$$

$$\delta^{ij}_{XX} = (M^2_{XX})^{ij}/(M^2_{XX})^{ii} \qquad (X = L, R)$$

Universal soft terms at GUT(mSUGRA models)

In a basis such that m_l is diagonal:

$$M^2_{\tilde{\ell}} = \left(\begin{array}{ccc|ccc} m^2_{\tilde{e}_L} & 0 & 0 & \bar{A}_{\tilde{e}} \cdot m_e & 0 & 0 \\ 0 & m^2_{\tilde{\mu}_L} & 0 & 0 & \bar{A}_{\tilde{\mu}} \cdot m_\mu & 0 \\ 0 & 0 & m^2_{\tilde{\tau}_L} & 0 & 0 & \bar{A}_{\tilde{\tau}} \cdot m_\tau \\ \hline \bar{A}_{\tilde{e}} \cdot m_e & 0 & 0 & m^2_{\tilde{e}_R} & 0 & 0 \\ 0 & \bar{A}_{\tilde{\mu}} \cdot m_\mu & 0 & 0 & m^2_{\tilde{\mu}_R} & 0 \\ 0 & 0 & \bar{A}_{\tilde{\tau}} \cdot m_\tau & 0 & 0 & m^2_{\tilde{\tau}_R} \end{array}\right)$$

The 1st and 2nd generation sleptons are almost degenerate:

$$m_{\tilde{\tau}_L} < m_{\tilde{e}_L} = m_{\tilde{\mu}_L} \quad ; \quad m_{\tilde{\tau}_R} < m_{\tilde{e}_R} = m_{\tilde{\mu}_R}$$

$$m_{\tilde{\tau}_R} < m_{\tilde{\tau}_L}$$

Simplest Scheme: 2-3 Lepton Flavour Violation

(motivated by large Atmospheric Neutrino Mixing)

If large 2-3 mixing, in a basis such that m_l is diagonal:

$$M_{\tilde{\ell}}^2 = \left(\begin{array}{ccc|ccc} m_{\tilde{e}_L}^2 & 0 & 0 & \bar{A}_{\tilde{e}} \cdot m_e & 0 & 0 \\ 0 & m_{\tilde{\mu}_L}^2 & M_{LL}^2 & 0 & \bar{A}_{\tilde{\mu}} \cdot m_\mu & 0 \\ 0 & M_{LL}^2 & m_{\tilde{\tau}_L}^2 & 0 & 0 & \bar{A}_{\tilde{\tau}} \cdot m_\tau \\ \hline \bar{A}_{\tilde{e}} \cdot m_e & 0 & 0 & m_{\tilde{e}_R}^2 & 0 & 0 \\ 0 & \bar{A}_{\tilde{\mu}} \cdot m_\mu & 0 & 0 & m_{\tilde{\mu}_R}^2 & M_{RR}^2 \\ 0 & 0 & \bar{A}_{\tilde{\tau}} \cdot m_\tau & 0 & M_{RR}^2 & m_{\tilde{\tau}_R}^2 \end{array}\right)$$

Flavor mixing entries are defined as

$$\delta_{XX}^{ij} = (M_{XX}^2)^{ij} / (M_{XX}^2)^{ii} \quad (X = L, R).$$

LFV through RGE effects

Including See-Saw neutrinos

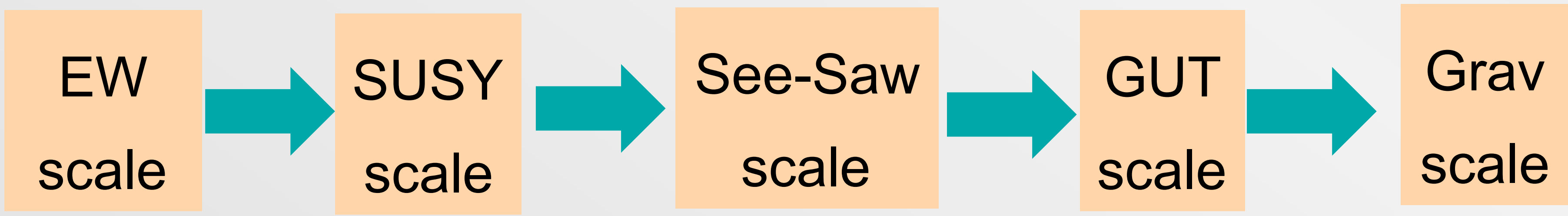
Leptonic Sector of Superpotential *(up to See-Saw scale)*:

$$W = N_i^c(\lambda_\nu)_{ij} L_j H_2 - E_i^c(\lambda_e)_{ij} L_j H_1 + \frac{1}{2} {N^c}_i \mathcal{M}_{ij} N_j^c + \mu H_2 H_1$$

Superpotential of Effective Low Energy Theory:

$$W_{eff} \;=\; L_i H_2 \left(\lambda_\nu^T \left(\mathcal{M}^D\right)^{-1} \lambda_\nu\right)_{ij} L_j H_2 - E_i^c(\lambda_e)_{ij} L_j H_1$$

RGE evolution: *Various Steps*



Even if:

$$M_{\rm GUT} : m_{\tilde{\ell},\tilde{\nu}} \propto \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix}, \quad \text{REGs} \longrightarrow \begin{pmatrix} 1 & \star & \star \\ \star & 1 & \star \\ \star & \star & 1 \end{pmatrix}$$

- RGEs for the charged-lepton mass matrix

$$t\frac{d}{dt}(m^2_{\tilde{\ell}})^j_i = \frac{1}{16\pi^2}\left\{(m^2_{\tilde{\ell}}\lambda^\dagger_\ell\lambda_\ell)^j_i + (m^2_{\tilde{\ell}}\lambda^\dagger_\nu\lambda_\nu)^j_i + \ldots\right\}$$

The corrections in the basis where $(\lambda^\dagger_\ell\lambda_\ell)^j_i$ is diagonal, are:

$$\delta m_{\tilde{\ell}} \propto \frac{1}{16\pi} \ln\frac{M_{\rm GUT}}{M_N}\lambda^\dagger_\nu\lambda_\nu m^2_{\rm SUSY}$$

(And similar corrections for $\delta m_{\tilde{\nu}}$)

For big μ-e lepton mixing, big rates for $\mu \to e\gamma$

Provided the neutrino Yukawas are sufficiently large (larger M_N in See-Saw)

Corrections from Massive Neutrinos to Yukawa Couplings
(from M_{GUT} to M_N)

$$
\begin{aligned}
16\pi^2\mu\frac{d}{d\mu}f_{e_{ij}} &= \left\{-\frac{9}{5}g_1^2 - 3g_2^2 + 3\mathrm{Tr}(f_d f_d^\dagger) + \mathrm{Tr}(f_e f_e^\dagger)\right\} f_{e_{ij}} \\
&\quad +3(f_e f_e^\dagger f_e)_{ij} + (f_e f_\nu^\dagger f_\nu)_{ij}, \\
16\pi^2\mu\frac{d}{d\mu}f_{\nu_{ij}} &= \left\{-\frac{3}{5}g_1^2 - 3g_2^2 + 3\mathrm{Tr}(f_u f_u^\dagger) + \mathrm{Tr}(f_\nu f_\nu^\dagger)\right\} f_{\nu_{ij}} \\
&\quad +3(f_\nu f_\nu^\dagger f_\nu)_{ij} + (f_\nu f_e^\dagger f_e)_{ij}.
\end{aligned}
$$

(very simple at 1-loop, small tanβ)

$$16\pi^2\frac{d}{dt}\lambda_\tau = \left(\lambda_N^2 - G_E\right)\lambda_\tau$$

$$16\pi^2\frac{d}{dt}\lambda_N = \left(4\lambda_N^2 + 3\lambda_t^2 - G_N\right)\lambda_N$$

Slepton contributions from runs if Mgrav ~MGUT

RGEs from Mgrav ~ $M_{GUT} \rightarrow M_N$:

$$
\begin{aligned}
(m_{\tilde{L}}^2)_{ij} &\simeq -\frac{1}{8\pi^2}(3m_0^2 + a_0^2)V_{Dki}^* V_{Dkj} f_{\nu_k}^2 \log\frac{M_{\rm grav}}{M_{\nu_k}}, \\
(m_{\tilde{e}}^2)_{ij} &\simeq 0, \\
A_e^{ij} &\simeq -\frac{3}{8\pi^2} a_0 f_{e_i} V_{Dki}^* V_{Dkj} f_{\nu_k}^2 \log\frac{M_{\rm grav}}{M_{\nu_k}},
\end{aligned}
$$

Contribute only to LL slepton mixing

Slepton contributions from runs if Mgrav > MGUT

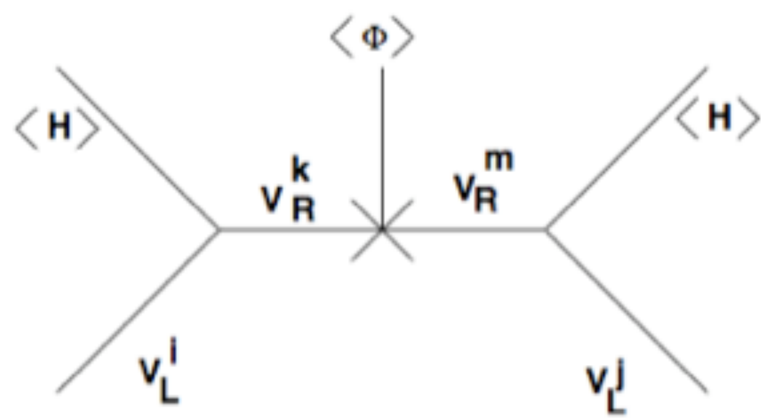
Renormalisation effects from $M_{GUT} \to M_G$ *(=* M_P*?)*

$$(m_L^2)_{ij} \simeq -\frac{2}{(4\pi)^2} U_{ik} f_{\nu_k}^2 U_{jk}^{\star} (3m_0^2 + A_0^2) \log \frac{M_G}{M_{N_k}},$$

$$(m_{\overline{E}}^2)_{ij} \simeq -\frac{6}{(4\pi)^2} \mathrm{e}^{-i\varphi_{d_i}} V_{ki}^{\star} f_{u_k}^2 V_{kj} \mathrm{e}^{i\varphi_{d_j}} (3m_0^2 + A_0^2) \log \frac{M_G}{M_{GUT}},$$

Contribute also to RR slepton mixing

Keep also in mind renormalisation of effective neutrino operator



$$16\pi^2 \frac{d}{dt} \sin^2 2\theta_{23} = -2\sin^2 2\theta_{23}(1-\sin^2 2\theta_{23})(Y_\tau^2)\frac{m_{eff}^{33}+m_{eff}^{22}}{m_{eff}^{33}-m_{eff}^{22}}$$

$$\frac{m_{eff}^{ij}}{m_{eff,0}^{ij}} = exp\left\{\frac{1}{8\pi^2}\int_{t_0}^{t}\left(-c_i g_i^2 + 3\lambda_t^2 + \frac{1}{2}(\lambda_i^2+\lambda_j^2)\right)\right\}$$

$$= I_g \cdot I_t \cdot \sqrt{I_{\lambda_i}} \cdot \sqrt{I_{\lambda_j}}$$

$$I_{\lambda_i} = exp[\frac{1}{8\pi^2}\int_{t_0}^{t}\lambda_i^2 dt]$$

$\mathbf{SU(5)}$ - small $\tan\beta$

(large top, <u>small</u> bottom and tau Yuka

Observables	Numerical Values
m_{ν_1}/m_{ν_3}	0.16(0.09)
m_{ν_2}/m_{ν_3}	0.20(0.37)
M_1/M_3	0.06(0.16)
M_2/M_3	0.12(0.42)
θ_{23}	0.91(1.13)
θ_{12}	0.56(0.10)
θ_{13}	0.21(0.07)
δ	0.43(-0.45)
J_{CP}	0.0088(0.00066)
ϵ_1	0.00046(0.0039)
ϵ_2	0.0007(0.00014)
ϵ_3	0.0003(0.000001)
$BR(\mu \to e\gamma)$	$8.5 \times 10^{-12}(6.1 \times 10^{-14})$
$BR(\tau \to e\gamma)$	$5.95 \times 10^{-13}(1.74 \times 10^{-14})$
$BR(\tau \to \mu\gamma)$	$5.1 \times 10^{-12}(2.6 \times 10^{-12})$

[Ellis, Gomez, SL]

LFV through non-Universality at high energies

SU(5) unification

$$5^* : \quad \begin{pmatrix} d_1^c \\ d_2^c \\ d_3^c \\ e^- \\ -\nu_e \end{pmatrix}_L , \quad \begin{pmatrix} s_1^c \\ s_2^c \\ s_3^c \\ \mu^- \\ -\nu_\mu \end{pmatrix}_L , \quad \begin{pmatrix} b_1^c \\ b_2^c \\ b_3^c \\ \tau^- \\ -\nu_\tau \end{pmatrix}_L$$

SU(5) to SU(3) X SU(2) X U(1) decomposition:

5 : (3*, 1, 1/3) + (1, 2*, -1/2)*

SU(5) unification

$$10: \left(\begin{array}{ccc|cc} 0 & u_3^c & -u_2^c & -u^1 & -d^1 \\ -u_3^c & 0 & u_1^c & -u^2 & -d^2 \\ u_2^c & -u_1^c & 0 & -u^3 & -d^3 \\ \hline u^1 & u^2 & u^3 & 0 & -e^+ \\ d^1 & d^2 & d^3 & e^+ & 0 \end{array}\right)_L , \quad \begin{pmatrix} & c^i & \\ \mu^+ & & c_i^c \\ & s^i & \end{pmatrix}_L , \quad \begin{pmatrix} & t^i & \\ \tau^+ & & t_i^c \\ & b^i & \end{pmatrix}_L$$

SU(5) to SU(3) X SU(2) X U(1) decomposition:

10 : (3, 1, -2/3) + (3, 2, 1/6) + (1, 1, 1)*

$SU(5)$

(i) Assume the family symmetry is combined with $SU(5)$

(ii) Use the GUT structure ONLY to constrain $U(1)$ charges

Under this group we have the following relations:

$$Q_{(q,u^c,e^c)_i} = Q_i^{10}$$
$$Q_{(l,d^c)_i} = Q_i^{\bar{5}}$$
$$Q_{(\nu_R)_i} = Q_i^{\nu_R}$$

- M_{up} symmetric
- $M_{\ell^\pm} = M_{down}^T$
- L lepton mixing $\approx$ R down-quark one

Can we obtain acceptable patterns of masses/mixings? i.e.

$$\frac{M_u}{m_t} = \begin{pmatrix} \bar{\epsilon}^6 & \bar{\epsilon}^5 & \bar{\epsilon}^3 \\ \bar{\epsilon}^5 & \bar{\epsilon}^4 & \bar{\epsilon}^2 \\ \bar{\epsilon}^3 & \bar{\epsilon}^2 & 1 \end{pmatrix}, \frac{M_{down}}{m_b} = \begin{pmatrix} \bar{\epsilon}^4 & \bar{\epsilon}^3 & \bar{\epsilon}^3 \\ \bar{\epsilon}^3 & \bar{\epsilon}^2 & \bar{\epsilon}^2 \\ \bar{\epsilon} & 1 & 1 \end{pmatrix}$$

$$\frac{M_\ell}{m_\tau} = \begin{pmatrix} \bar{\epsilon}^4 & \bar{\epsilon}^3 & \bar{\epsilon} \\ \bar{\epsilon}^3 & \bar{\epsilon}^2 & 1 \\ \bar{\epsilon}^3 & \bar{\epsilon}^2 & 1 \end{pmatrix}, m_{eff} \propto \begin{pmatrix} \bar{\epsilon}^2 & \bar{\epsilon} & \bar{\epsilon} \\ \bar{\epsilon} & 1 & 1 \\ \bar{\epsilon} & 1 & 1 \end{pmatrix}$$

Flavour symmetries determine soft SUSY terms

$$\mathcal{L}_{m^2} = m_0^2(\phi_1^*\phi_1+\phi_2^*\phi_2+\phi_3^*\phi_3+\left(\frac{\langle\theta\rangle}{M_{\rm fl}}\right)^{q_2-q_1}\phi_1^*\phi_2+\left(\frac{\langle\theta\rangle}{M_{\rm fl}}\right)^{q_3-q_1}\phi_1^*\phi_3+\left(\frac{\langle\theta\rangle}{M_{\rm fl}}\right)^{q_3-q_2}\phi_2^*\phi_3+\text{h.c.}).$$

L-R symmetric

$$\begin{pmatrix} 1 & \tilde\epsilon^{|a+2b|} & \tilde\epsilon^{|a+b|} \\ \tilde\epsilon^{|a+2b|} & 1 & \tilde\epsilon^{|b|} \\ \tilde\epsilon^{|a+b|} & \tilde\epsilon^{|b|} & 1 \end{pmatrix}$$

SU(5)

$$\mathbf{E}_L \sim \begin{pmatrix} 1 & \lambda^2 & \lambda^2 \\ \lambda^2 & 1 & 1 \\ \lambda^2 & 1 & 1 \end{pmatrix} \qquad \mathbf{E}_R \sim \begin{pmatrix} 1 & \lambda & \lambda^3 \\ \lambda & 1 & \lambda^2 \\ \lambda^3 & \lambda^2 & 1 \end{pmatrix}$$

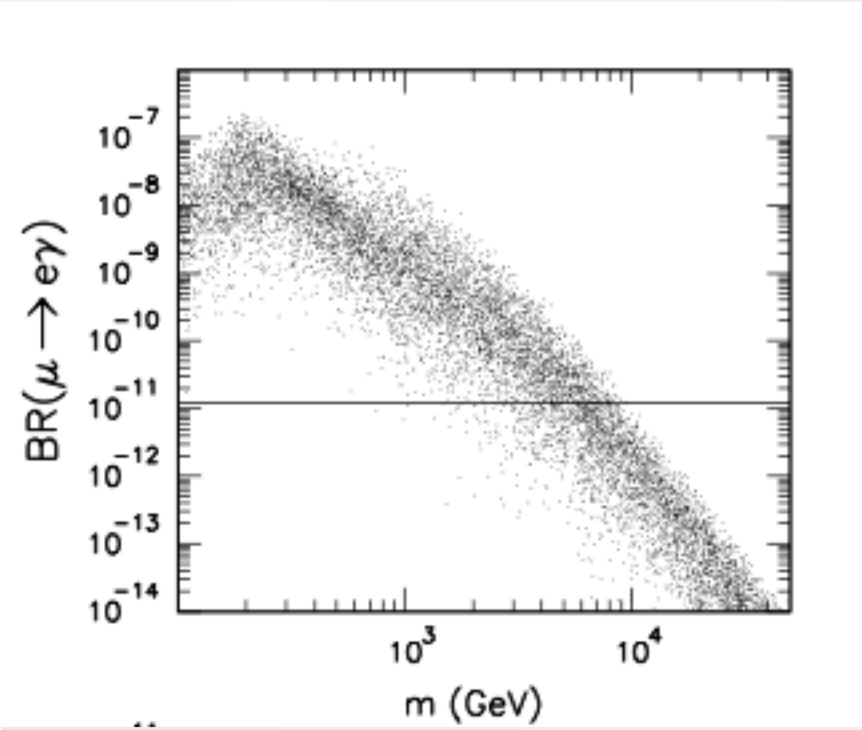
$$Q_{(q,u^c,e^c)_i} = Q_i^{10}$$
$$Q_{(l,d^c)_i} = Q_i^{\bar 5}$$
$$Q_{(\nu_R)_i} = Q_i^{\nu_R}$$

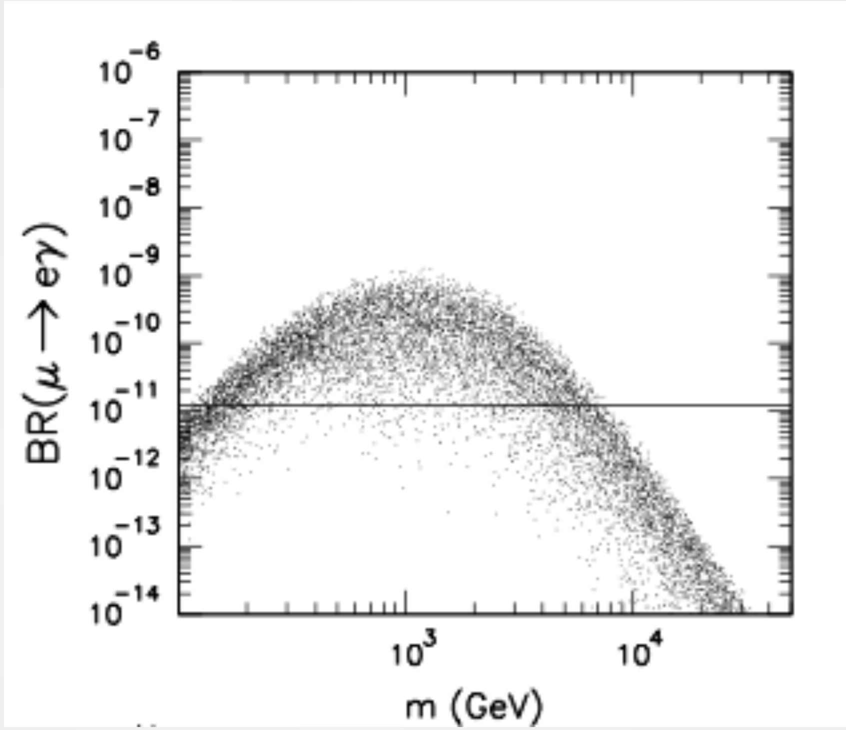
$$\frac{M_\ell}{m_\tau} = \begin{pmatrix} \bar\epsilon^4 & \bar\epsilon^3 & \bar\epsilon \\ \bar\epsilon^3 & \bar\epsilon^2 & 1 \\ \bar\epsilon^3 & \bar\epsilon^2 & 1 \end{pmatrix}$$

L: (1,0,0)

R: (3,2,0)

[Chankowski,Kowalska,Lavignac,Pokorski]





$M_{1/2}$=400,   m ~ m0

$M_{1/2}$=1000

Very large sparticle masses required

Viable models with non-Abelian flavour symmetries

i.e. SU(3) family symmetry [Antusch,King,Malinsky]

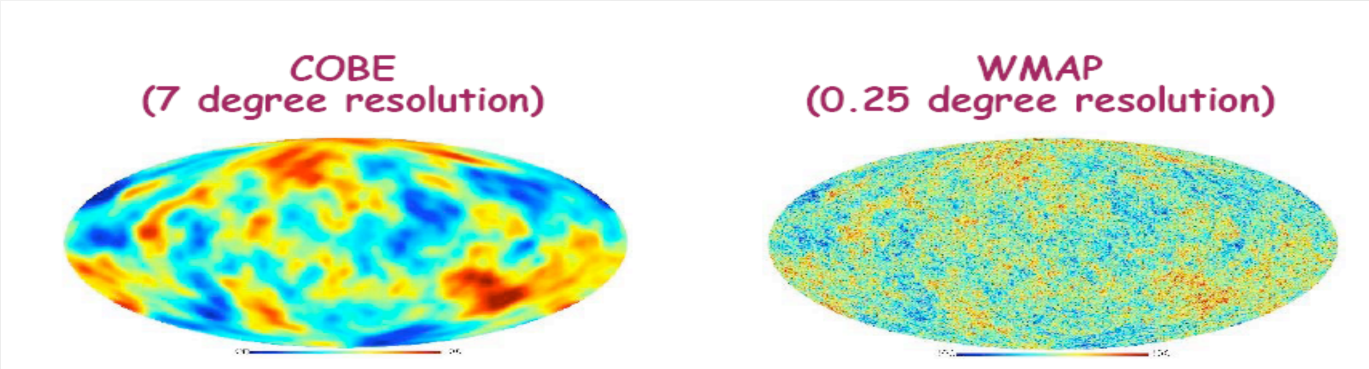
$$\hat{m}^2_{\nu^c} \approx m_0^2 \left[b_0^{\nu^c} \mathbb{1} + \begin{pmatrix} \varepsilon^2 \bar{\varepsilon}^2 \, b_1^{\nu^c} & \varepsilon^2 \bar{\varepsilon}^2 \, b_1^{\nu^c} e^{i\phi_1} & \varepsilon^2 \bar{\varepsilon}^2 \, b_1^{\nu^c} e^{i\phi_2} \\ . & \varepsilon^2 b_2^{\nu^c} & \varepsilon^2 b_2^{\nu^c} e^{i\phi_3} \\ . & . & \varepsilon_3^2 b_3^{\nu^c} \end{pmatrix} + \ldots \right]$$

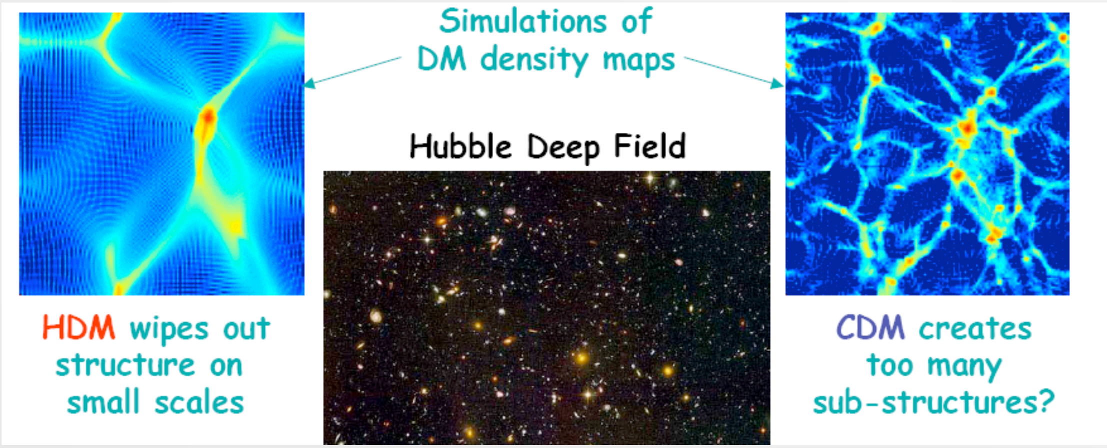
$$\hat{m}^2_{e^c} \approx m_0^2 \left[b_0^{e^c} \mathbb{1} + \begin{pmatrix} \bar{\varepsilon}^4 b_1^{e^c} & \bar{\varepsilon}^4 b_1^{e^c} e^{i\phi_1} & \bar{\varepsilon}^4 b_1^{e^c} e^{i\phi_2} \\ . & \varepsilon^2 b_2^{e^c} & \varepsilon^2 b_2^{e^c} e^{i\phi_3} \\ . & . & \bar{\varepsilon}_3^2 b_3^{e^c} \end{pmatrix} + \ldots \right].$$

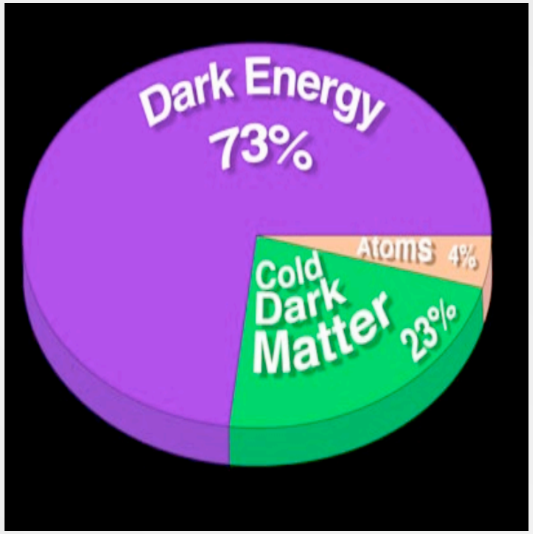
Viable predictions for smaller SUSY masses

Including Dark Matter Considerations in SUSY with massive neutrinos

COSMOLOGICAL OBSERVATIONS







Dark Matter– What can it be?

Has to be Weakly Interacting

(if strong or EM would couple to matter and be detectable)

- Baryonic? (i.e. Neutron Stars, Black Holes)
- Neutrinos? *(simpest schemes excluded by WMAP)*
- Axions?

- **Lightest SUSY particle (LSP)?**

- Neutralino?
- S-neutrino *(excluded by LEP direct searches)*
- Gravitino? *(would be really hard to detect)*

The parametric space favoured by Cosmology

also constrains the allowed channels in Colliders

(for instance SUSY cascade chains)

WMAP on CMSSM *(stable neutralino LSP)*

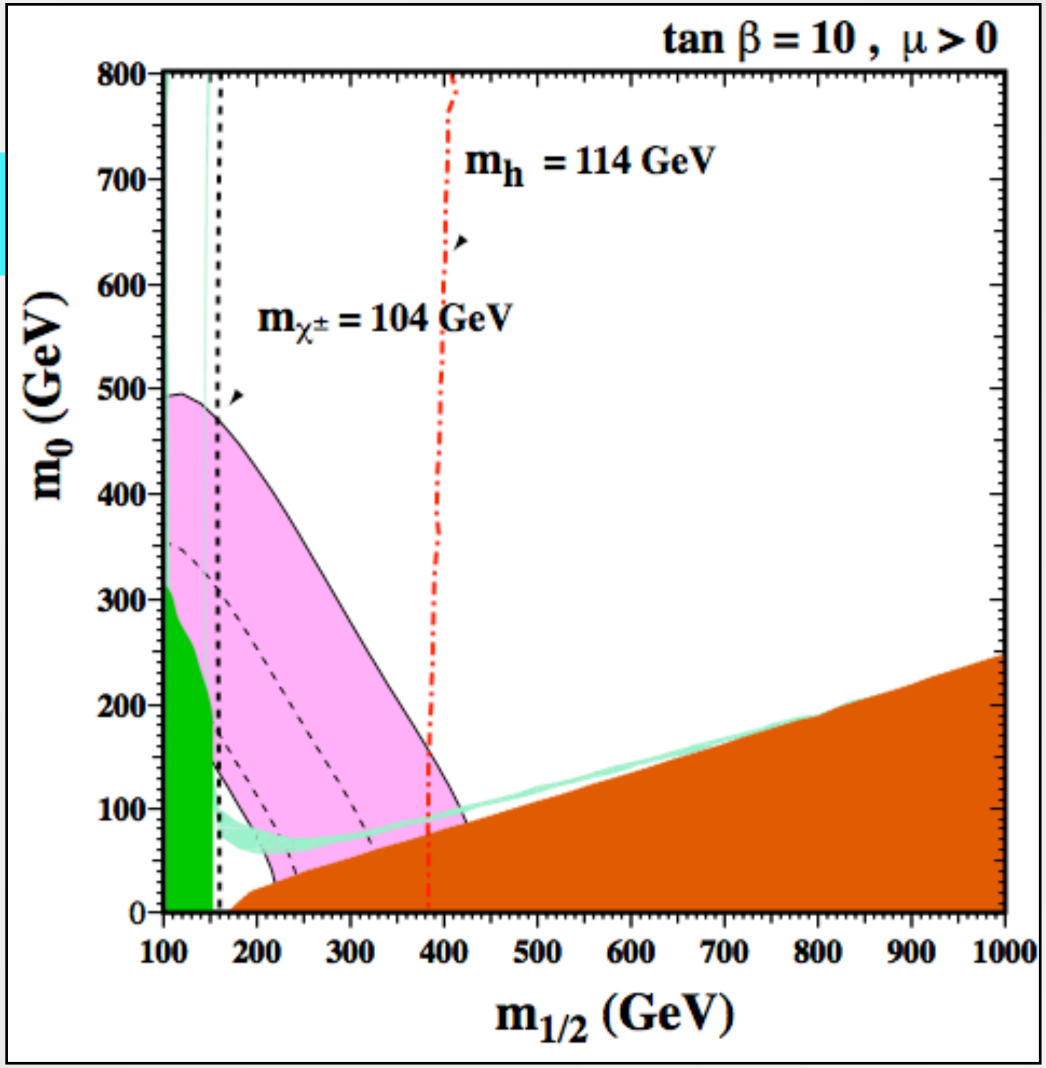
[Ellis, Olive, Santoso, Spanos]

WMAP bound on relic density

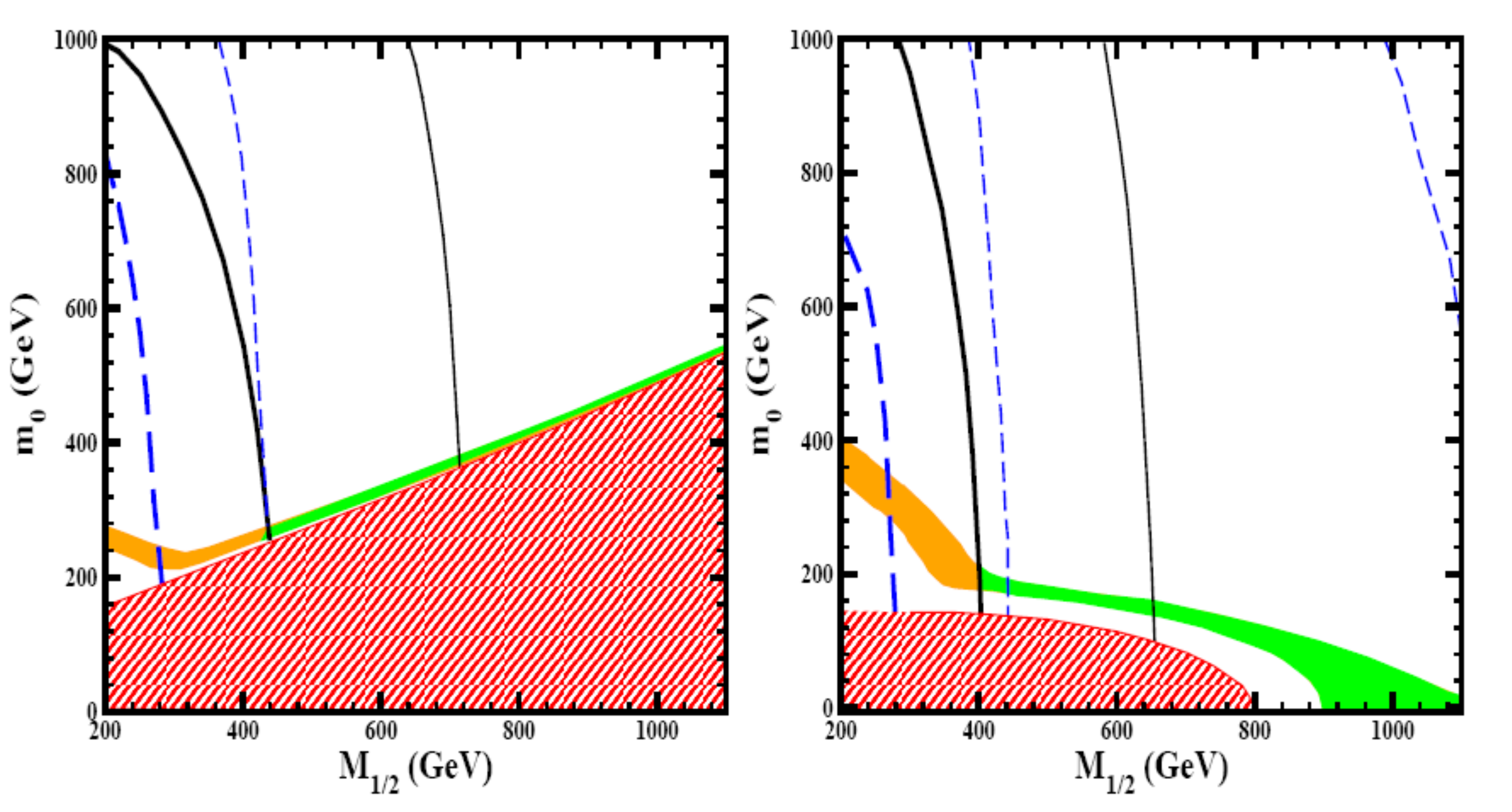
Excluded since stau LSP

Excluded by b → s gamma

Favoured by g – 2 (?)



If massive neutrinos with large Yukawa couplings and/or additional GUT corrections, picture significantly modified!

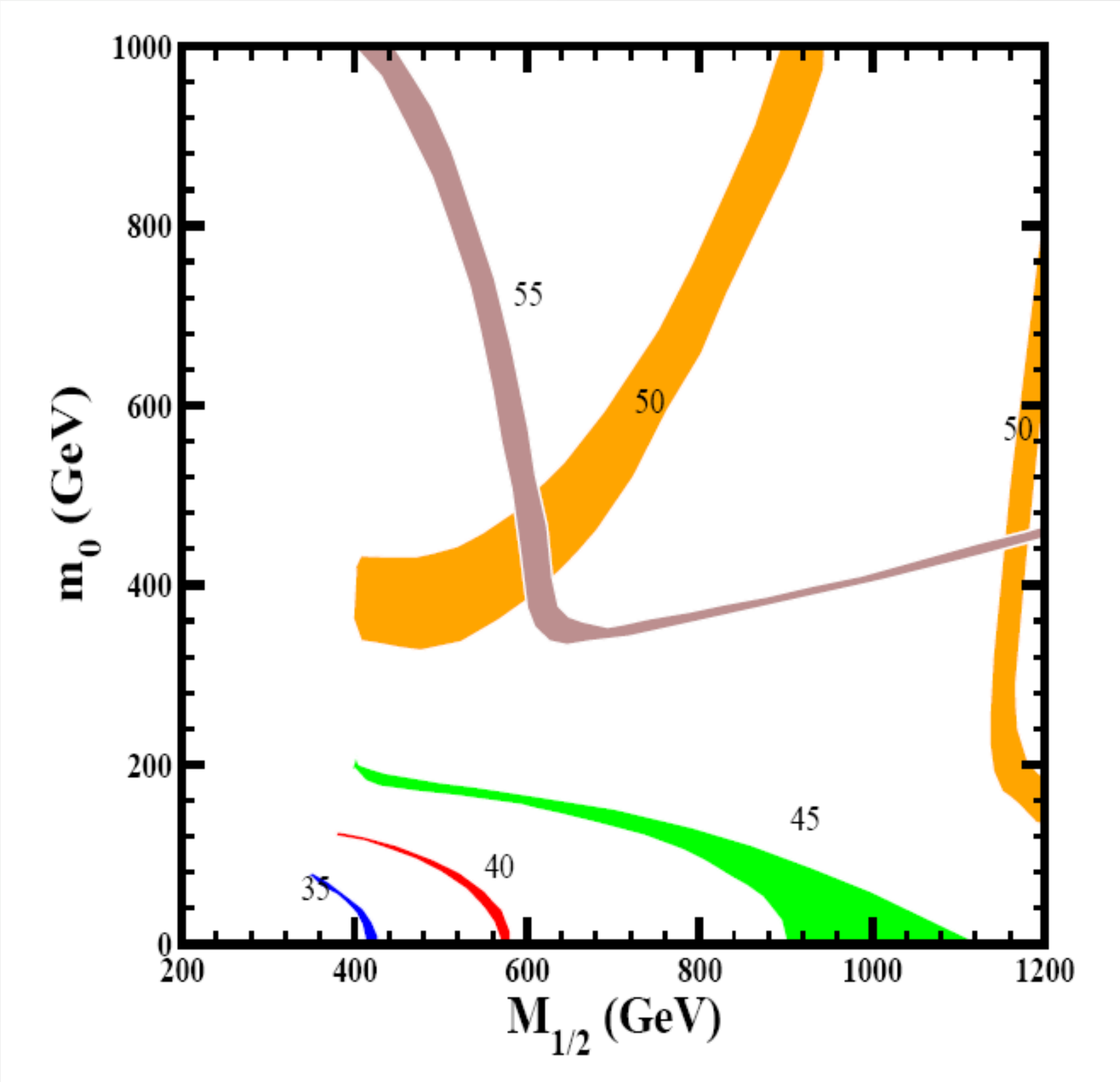


Effect of quantum corrections to Yukawas & (s-)particle masses

[Gomez, SL, Naranjo,Rodriguez-Quintero]

Allowed region (linked to sparticle spectra)

very sensitive to tanβ



LFV in Colliders

Bounds from Rare processes very strong

Can the LHC or the ILC see LFV?

In which channels?

For which area of the SUSY parameter space?

IT TURNS OUT THAT:

✧In general, the LHC and the ILC good for probes for a heavy sparticle spectrum

✧Also for areas where cancellations take place in the loop diagrams for rare decays

[Gomez, Leontaris,SL,Vergados]

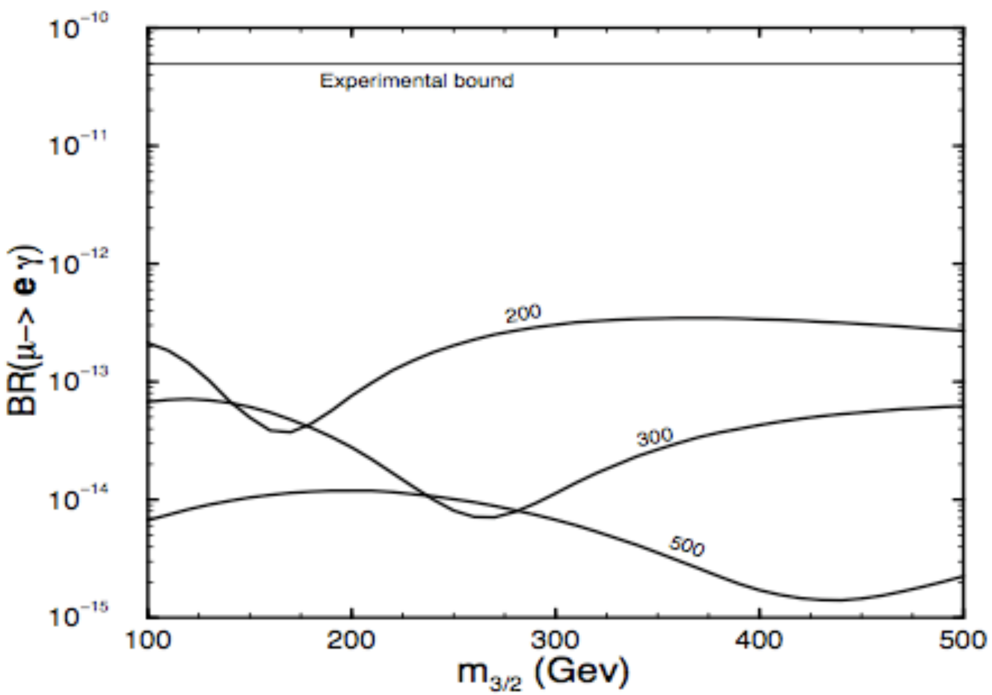
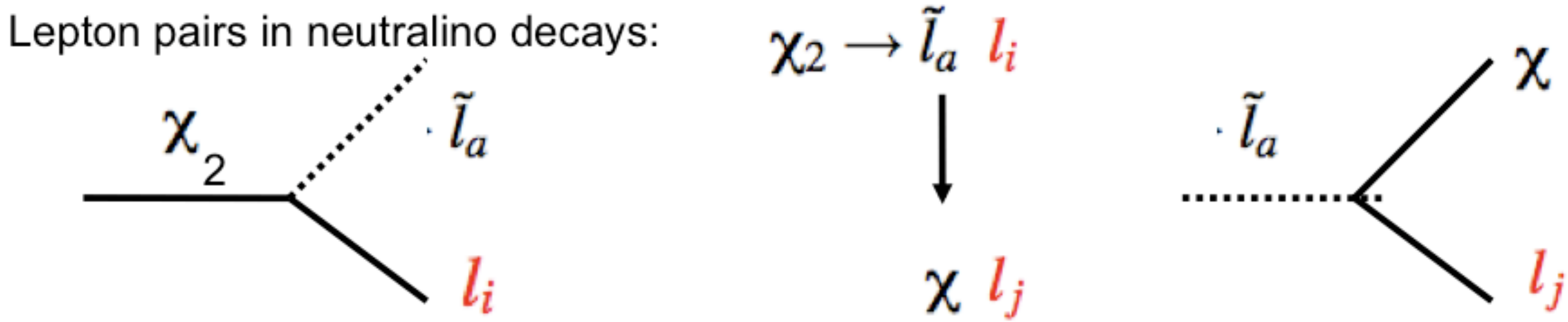


Figure 3: $BR(\mu \to e\gamma)$ for a range of values of $m_{1/2}$ (labeled above). Universal soft masses at the GUT scale are considered ($\Delta = 0$). The curves are obtained using $\tan\beta = 7$ and $A_0 = -1.5m_{3/2}$ as input parameters.

Example of FC versus LFV

[Hisano,Kitano,Nojiri]



LFV: Decays involving leptons of different flavour

How large LFV?

Depends on sfermion mixing (back to MODEL BUILDING)

LFV in μ-e channel

[Andreev,Bityukov,Krasnikov,Toropin]

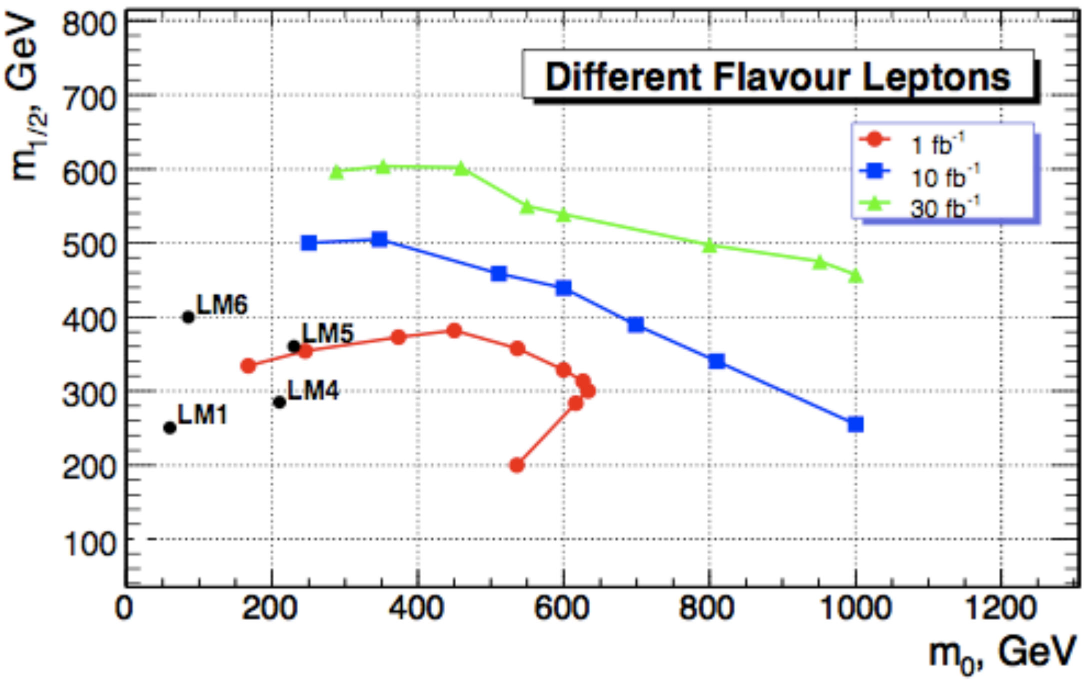
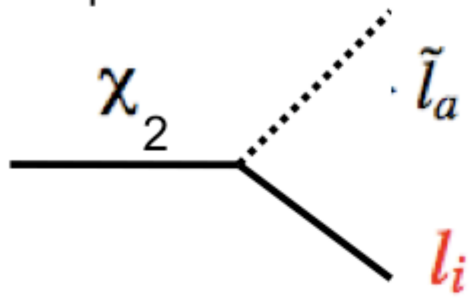


Fig. 3.10: Discovery plot ($\tan\beta = 10$, $sign(\mu) = +$, $A = 0$) for the luminosities $\mathcal{L} = 1,\ 10,\ 30\ fb^{-1}$ for the $e^{\pm}\mu^{\mp} + \not{E}_T$ signature.

LFV in the τ –μ channel

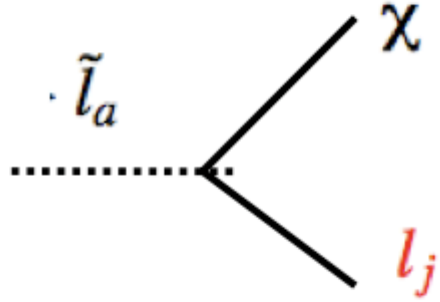
Lepton pairs in neutralino decays:



$$\chi_2 \to \tilde{l}_a \; l_i$$

$$\downarrow$$

$$\chi \; l_j$$



LFV:

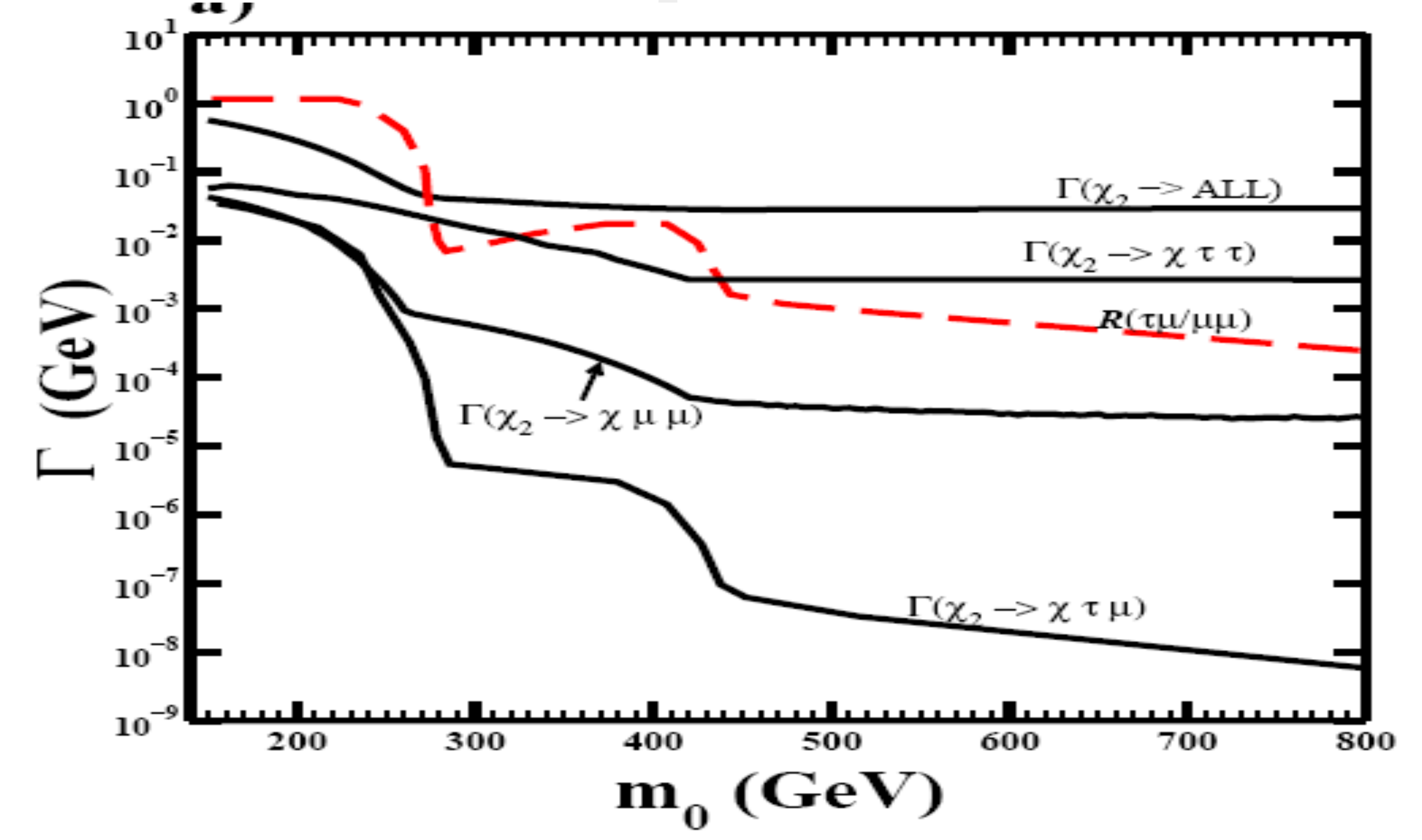
$$\chi_2 \to \chi + \tau^{\pm}\mu^{\mp}$$

[Hinchliffe,Paige]

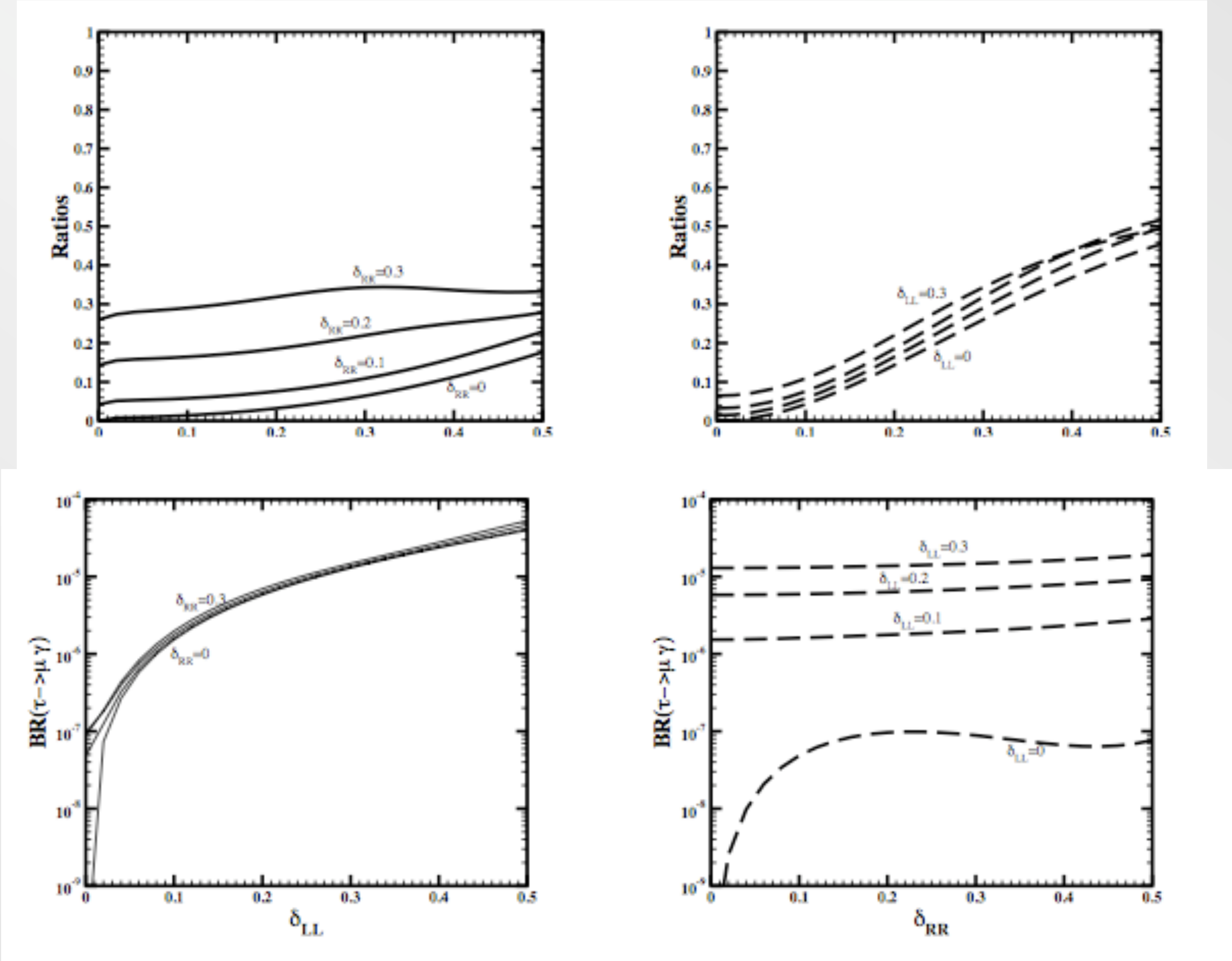
LFV at the LHC

$$\tilde{\chi}_2^0 \to \tilde{\ell}_i^+ \ell_j^- \to \tilde{\chi}_1^0 \ell_i^+ \ell_j^-$$

$$\tilde{\chi}_2^0 \to \chi_1^0 Z(h) \to \tilde{\chi}_1^0 \ell_i^+ \ell_i^-$$

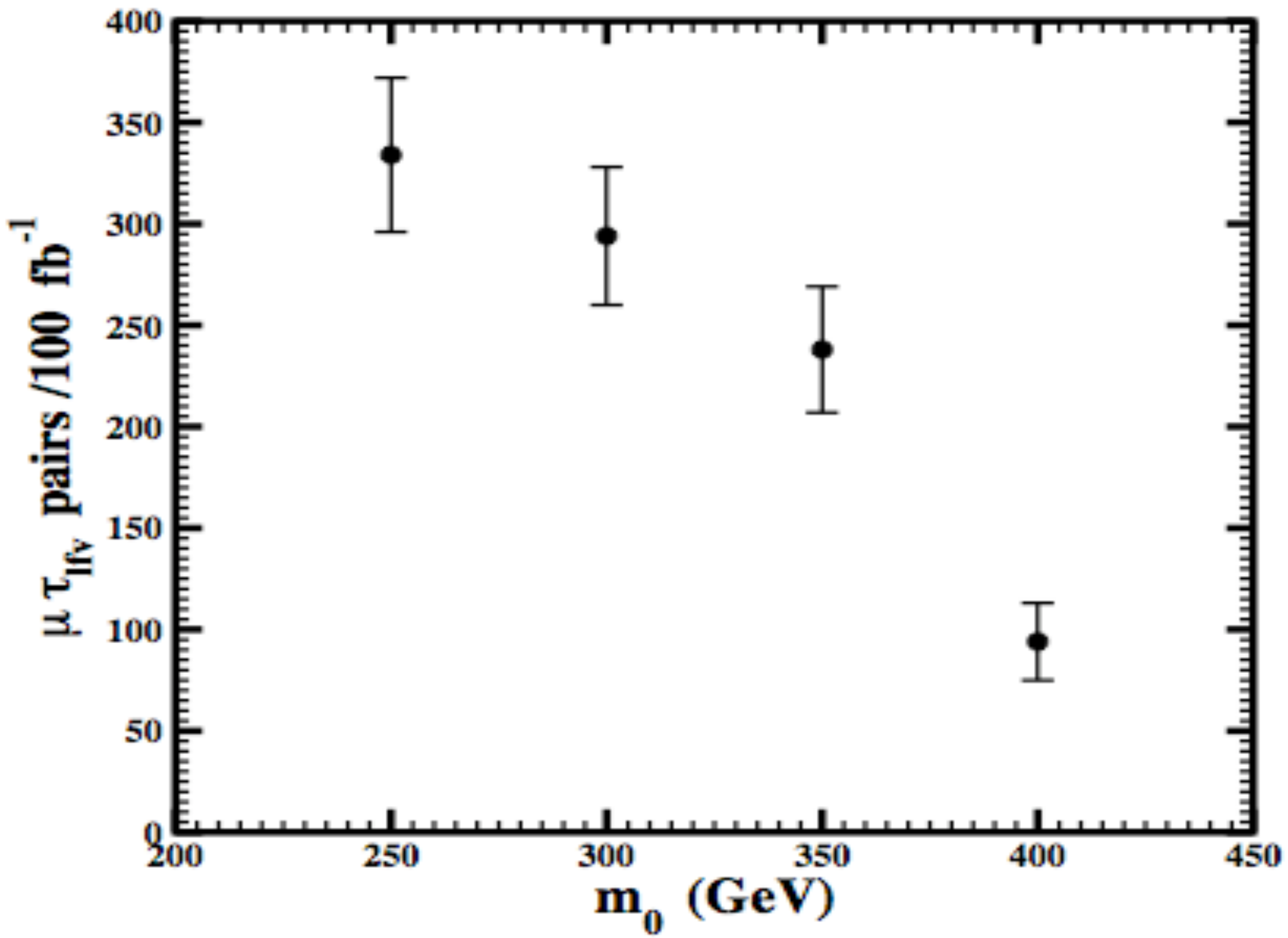


[Ellis,Carvahlo,Gomez,SL,Romao]



[Carquin,Ellis,Gomez,SL,Rodriguez-Quintero]

Results for Varying m_0 at Fixed $M_{1/2}$



LFV at a LC

$$
\begin{aligned}
e^+e^- &\rightarrow \tilde{\ell}_i^- \tilde{\ell}_j^+ \rightarrow \tau^\pm \mu^\mp \tilde{\chi}_1^0 \tilde{\chi}_1^0 \\
e^+e^- &\rightarrow \tilde{\nu}_i \tilde{\nu}_j^c \rightarrow \tau^\pm \mu^\mp \tilde{\chi}_1^+ \tilde{\chi}_1^- \\
e^+e^- &\rightarrow \tilde{\chi}_2^\pm \tilde{\chi}_1^\mp \rightarrow \tau^\pm \mu^\mp \tilde{\chi}_1^+ \tilde{\chi}_1^- \\
e^+e^- &\rightarrow \tilde{\chi}_2^0 \tilde{\chi}_1^0 \rightarrow \tau^\pm \mu^\mp \tilde{\chi}_1^0 \tilde{\chi}_1^0
\end{aligned}
$$

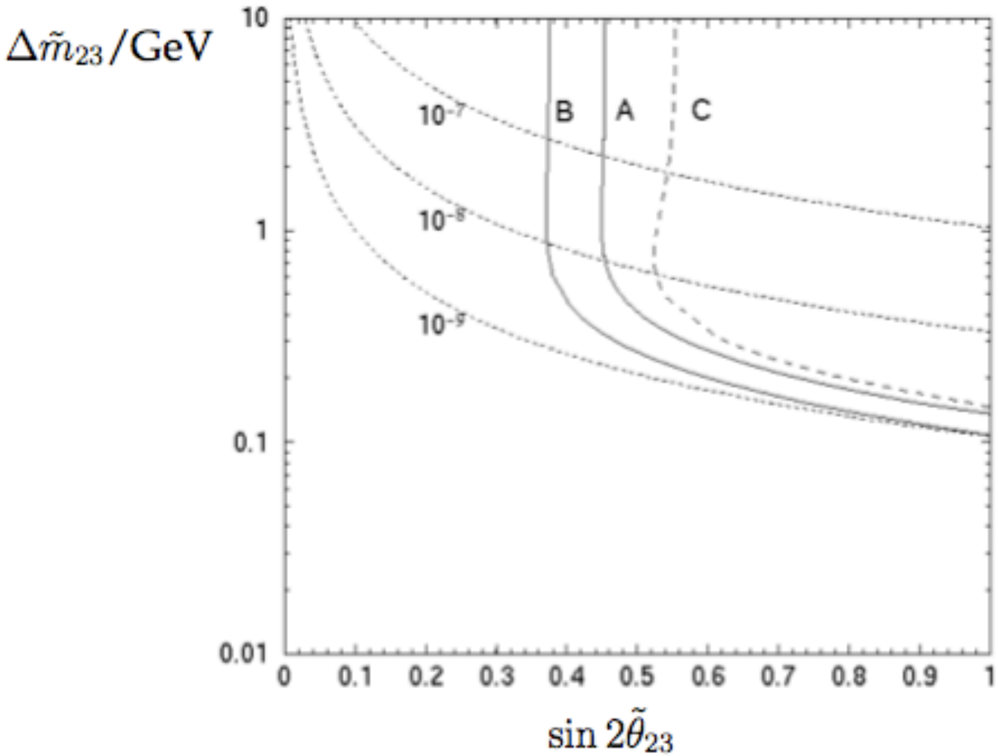


Figure 1: Various 3σ significance contours in the $\Delta\tilde{m}_{23} - \sin 2\tilde{\theta}_{23}$ plane, for the SUSY point mentioned in the text. The contours A and B show the integrated signals (8–9) at $\sqrt{s}$ =500 GeV and for 500 fb^{-1} and 1000 fb^{-1}, respectively. The contour C shows the $\tilde{\nu}\tilde{\nu}^c$ contribution separately for 500 fb^{-1} [6]. The dotted lines indicate contours for $Br(\tau \rightarrow \mu\gamma)$=$10^{-7}$, 10^{-8} and 10^{-9} [11].

[Deppish,Kalinowski,Pas,Redelbach,Ruckl]

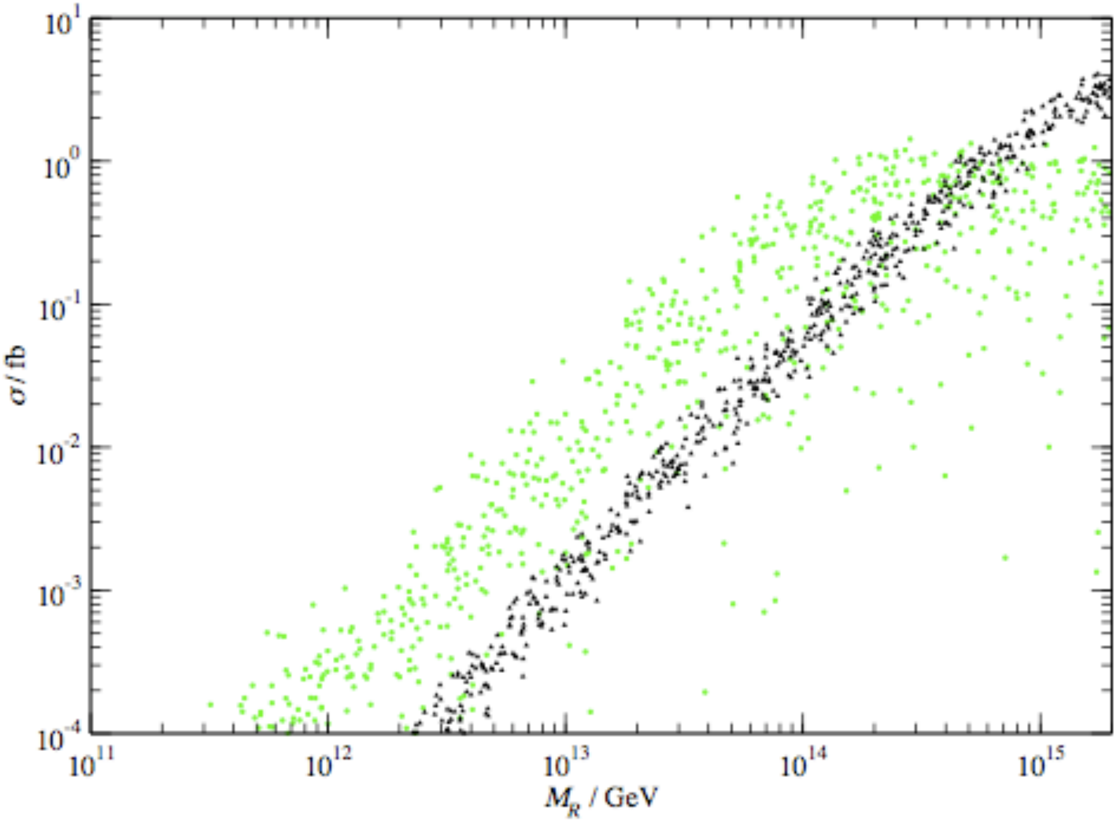


Figure 2: Cross-sections at $\sqrt{s} = 500$ GeV for $e^+e^- \to \mu^+e^- + 2\tilde{\chi}_1^0$ (circles) and $e^+e^- \to \tau^+\mu^- + 2\tilde{\chi}_1^0$ (triangles) in scenario B.

Scenario	$m_{1/2}$/GeV	m_0/GeV	$\tan\beta$	$\tilde{m}_6$/GeV	$\tilde{\Gamma}_6$/GeV	$m_{\tilde{\chi}_1^0}$/GeV
B	250	100	10	208	0.32	98

CONCLUSIONS

- ✓ Neutrino data point towards SM extensions with LFV

- ✓ LFV strongly bounded by various experimental processes, but there is significant space for LFV physics searche

- ✓ Predictions differ sufficiently enough to give input for Model Building Aspects and sources of LFV

Non-universalities versus RGE effects

Minimal versus non-Minimal GUT schemes

R-conserving versus R-violating SUSY

A very exciting ERA to come!