Lepton Flavour & Number Violation @ LHC

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IFIC-CSIC

- R-parity conservation
  - Sources flavour violation in supersymmetric models
  - Lepton flavour violating decays of supersymmetric particles; Implications for LHC observables
- R-parity violation

Experimental Information

Large mixing angles in neutrino sector

$$|\tan\theta_{atm}|^2 \simeq 1$$
$$|\tan\theta_{sol}|^2 \simeq 0.4$$
$$|U_{e3}|^2 \lesssim 0.05$$

Small flavour and CP violation violation in charged lepton sector

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

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

$BR(\tau \to l l l') \lesssim O(10^{-7})$ $(l, l' = e, \mu)$

$$|d_e| \lesssim 10^{-27}\ e\ cm,\ |d_\mu| \lesssim 1.5 \cdot 10^{-18}\ e\ cm,\ |d_\tau| \lesssim 1.5 \cdot 10^{-16}\ e\ cm$$

possible SUSY contributions to magnetic moments of leptons

$$|\Delta a_e| \leq 10^{-12},\ \ 0 \leq \Delta a_\mu \leq 43 \cdot 10^{-10},\ \ |\Delta a_\tau| \leq 0.058$$

Sources of Flavour Violation

Sleptons:

$$M_{\tilde{l}}^2 = \begin{pmatrix} M^2_{L,ij} + \frac{v_d^2 Y^{E*}_{ki} Y^E_{kj}}{2} + D_L \delta_{ij} & \frac{v_d A_{ij} - \mu v_u (Y^E_{ij})^*}{\sqrt{2}} \\ \frac{v_d A^*_{ij} - \mu v_u Y^E_{ij}}{\sqrt{2}} & M^2_{E,ij} + \frac{v_d^2 Y^E_{ik} Y^{E*}_{jk}}{2} + D_R \delta_{ij} \end{pmatrix}$$

Sneutrinos:

$$M_{\tilde{\nu}}^2 = M^2_{L,ij} + D_\nu \delta_{ij}$$

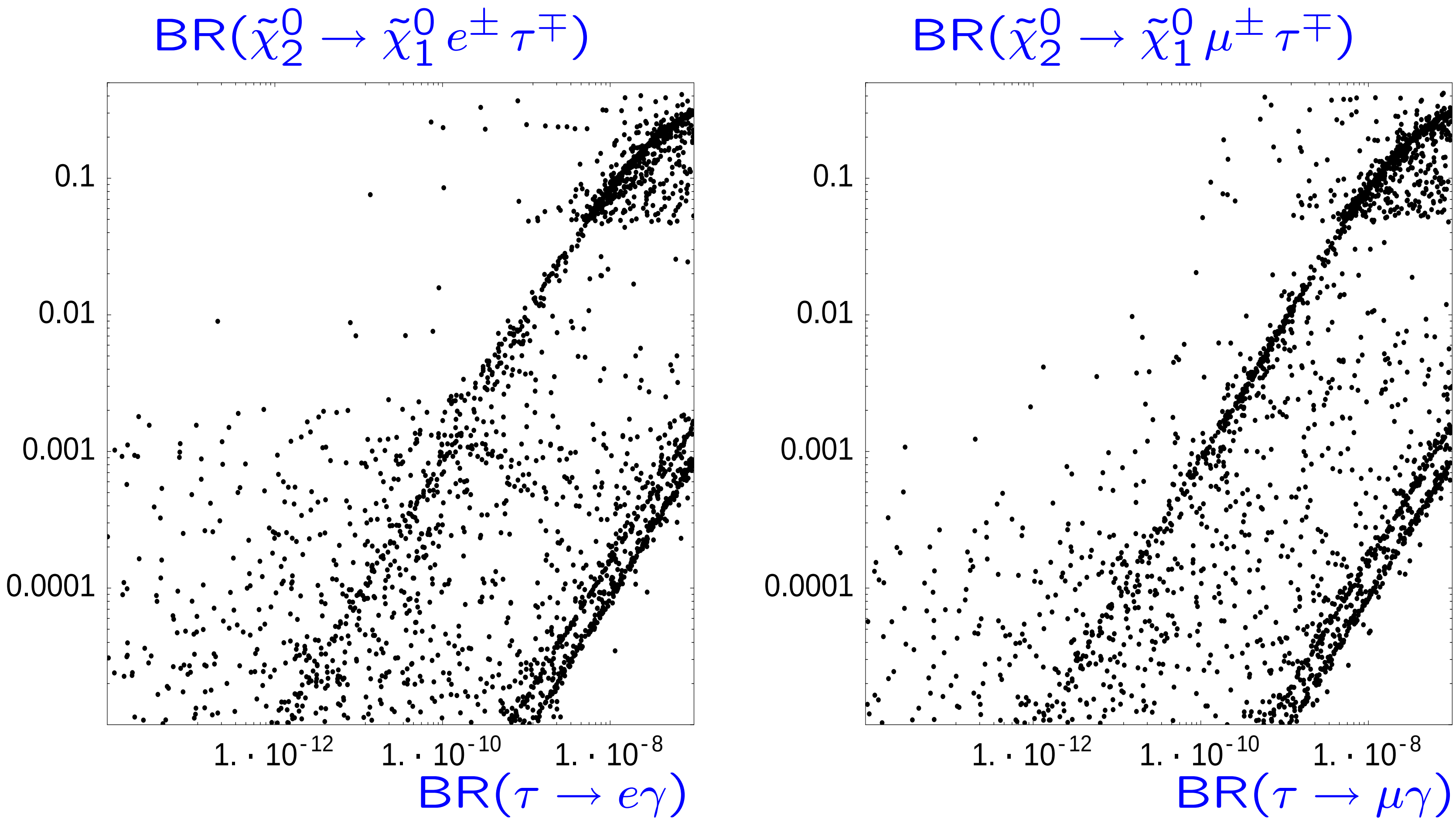
where

$$D_L = \frac{\left(g'^2 - g^2\right)(v_d^2 - v_u^2)}{8}, \qquad D_R = \frac{g'^2 (v_d^2 - v_u^2)}{4}$$

$$D_\nu = \frac{\left(g^2 + g'^2\right)(v_d^2 - v_u^2)}{8}$$

Without loss of generality: $Y^E_{ij} = Y^E_i \delta_{ij}$, Y^E_i real

$$\tilde{\chi}^0_2 \to \tilde{l}_i l_j \to l_k l_j \tilde{\chi}^0_1$$



Variations around SPS1a

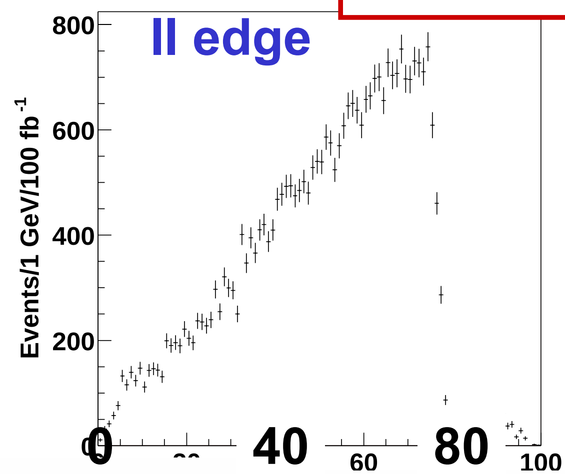
Left squark cascade decay

SPS1a (bulk region)
m_0= 100 GeV,
$m_{1/2}$= 250 GeV,
A_0= -100 GeV,
tan(β)=10 , μ>0

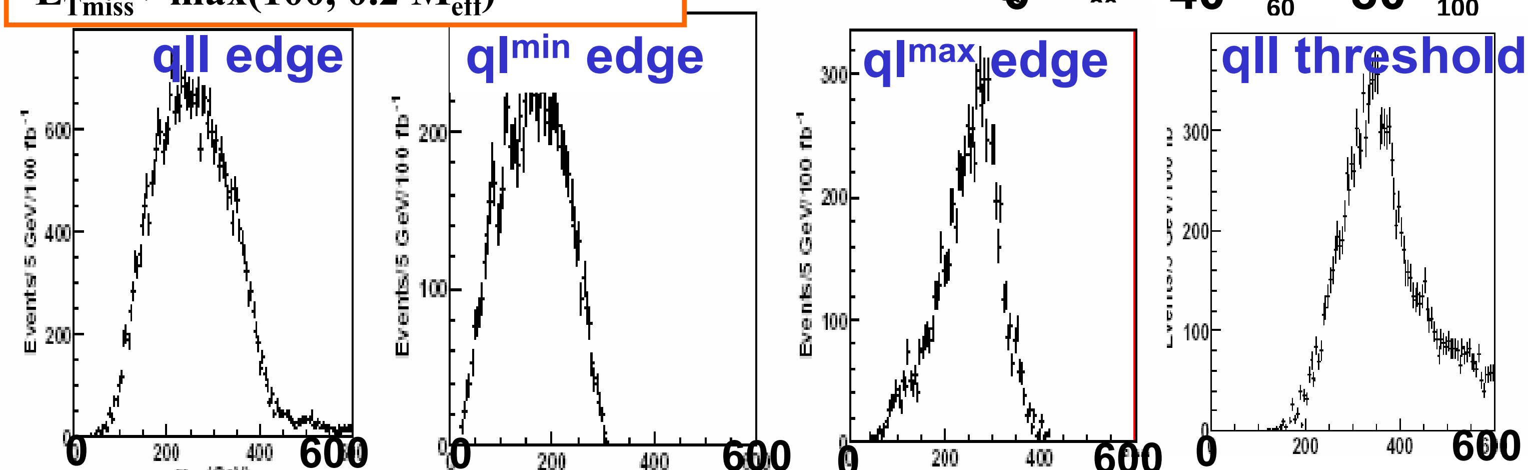
fast sim.

L=**100 fb^{-1}**

$$\tilde{q}_L \to \tilde{\chi}_2^0\, q \to \tilde{l}_R\, l\, q \to llq\, \tilde{\chi}_1^0$$



2 SFOS lep., p_T>20, 10 GeV
≥ 4 jets, p_T>150,100,50,50 GeV
M_{eff} > 600 GeV
E_{Tmiss} >max(100, 0.2 M_{eff})



Gjelsten, Lytken, Miller, Osland, Polesello, ATL-PHYS-2004-007

$L=100\ fb^{-1}$

Fit results

Edge	Nominal Value	Fit Value	Syst. Error Energy Scale	Statistical Error
$m(ll)^{\text{edge}}$	77.077	77.024	0.08	0.05
$m(qll)^{\text{edge}}$	431.1	431.3	4.3	2.4
$m(ql)^{\text{edge}}_{\text{min}}$	302.1	300.8	3.0	1.5
$m(ql)^{\text{edge}}_{\text{max}}$	380.3	379.4	3.8	1.8
$m(qll)^{\text{thres}}$	203.0	204.6	2.0	2.8

Mass reconstruction

5 endpoints measurements, 4 unknown masses

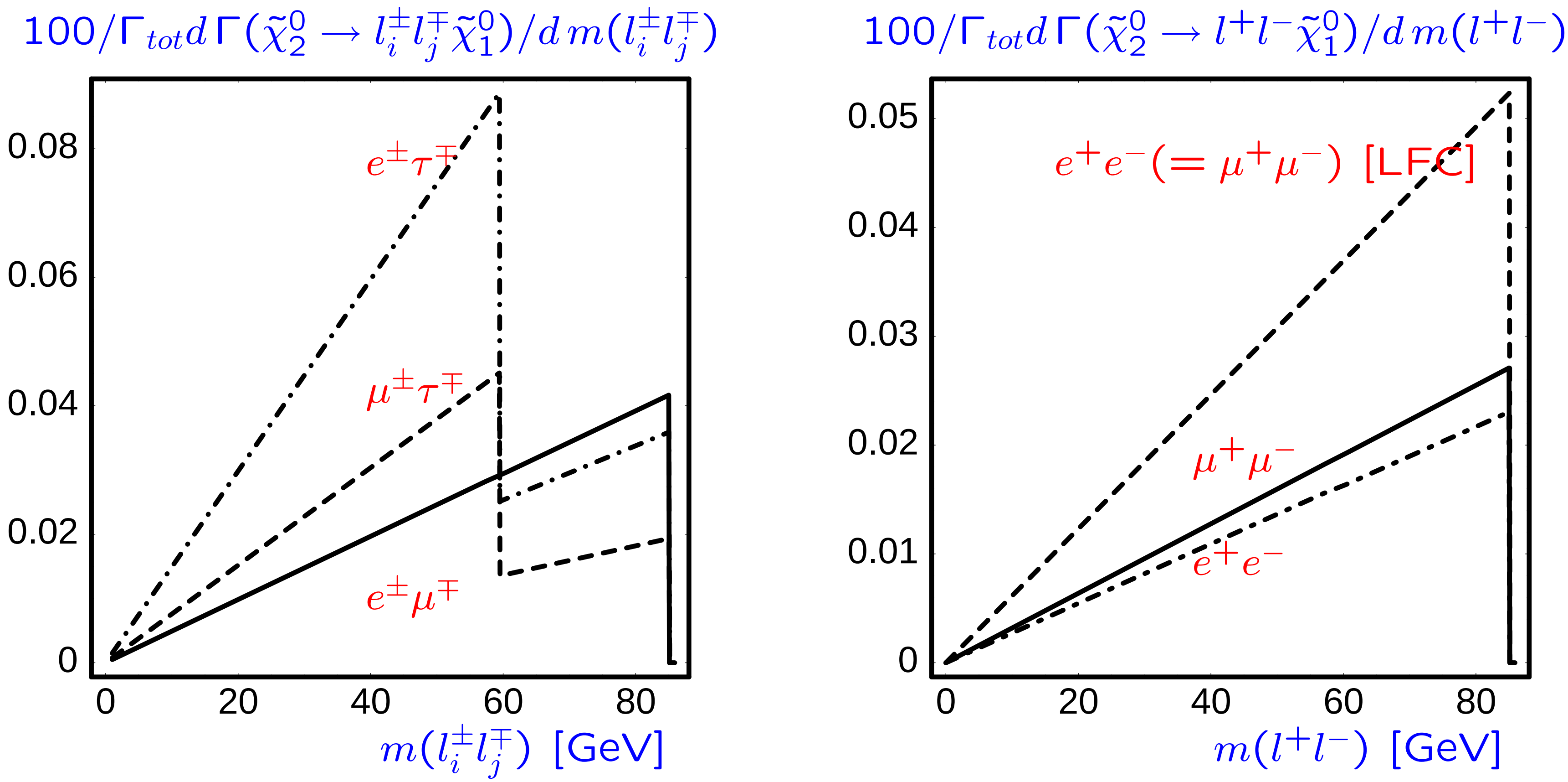
$$\chi^2 = \sum \chi_j^2 = \sum \left[\frac{E_j^{\text{theory}}(\vec{m}) - E_j^{\text{exp}}}{\sigma_j^{\text{exp}}} \right]^2$$

$$E_j^i = E_j^{\text{nom}} + a_j^i \sigma_j^{\text{fit}} + b^i \sigma_j^{Escale}$$

$m(\chi_1^0) =$ 96 GeV
$m(l_R) =$ 143 GeV
$m(\chi_2^0) =$ 177 GeV
$m(q_L) =$ 540 GeV

$\Delta m(\chi_1^0) = 4.8$ GeV, $\Delta m(\chi_2^0) = 4.7$ GeV,
$\Delta m(l_R) = 4.8$ GeV, $\Delta m(q_L) = 8.7$ GeV

Gjelsten, Lytken, Miller, Osland, Polesello, ATL-PHYS-2004-007



A.Bartl et al., hep-ph/0510074

Bilinearly broken R-parity

Is defined as MSSM + $\epsilon_i \widehat{L}_i \widehat{H}_u$ + $B_i \epsilon_i \tilde{L}_i H_u$

$B_i \epsilon_i$ induces sneutrinos vevs v_i

$(\lambda'_{ijk} \simeq (\epsilon_i/\mu) h^D_{jk},\ \lambda_{ijk} \simeq (\epsilon_{[i}/\mu) h^E_{j]k} + v'_i\ )$

Induced mixings: (leptons, charginos), (neutrinos, neutralinos), (Higgs bosons, sleptons)

Solves neutrino problems:

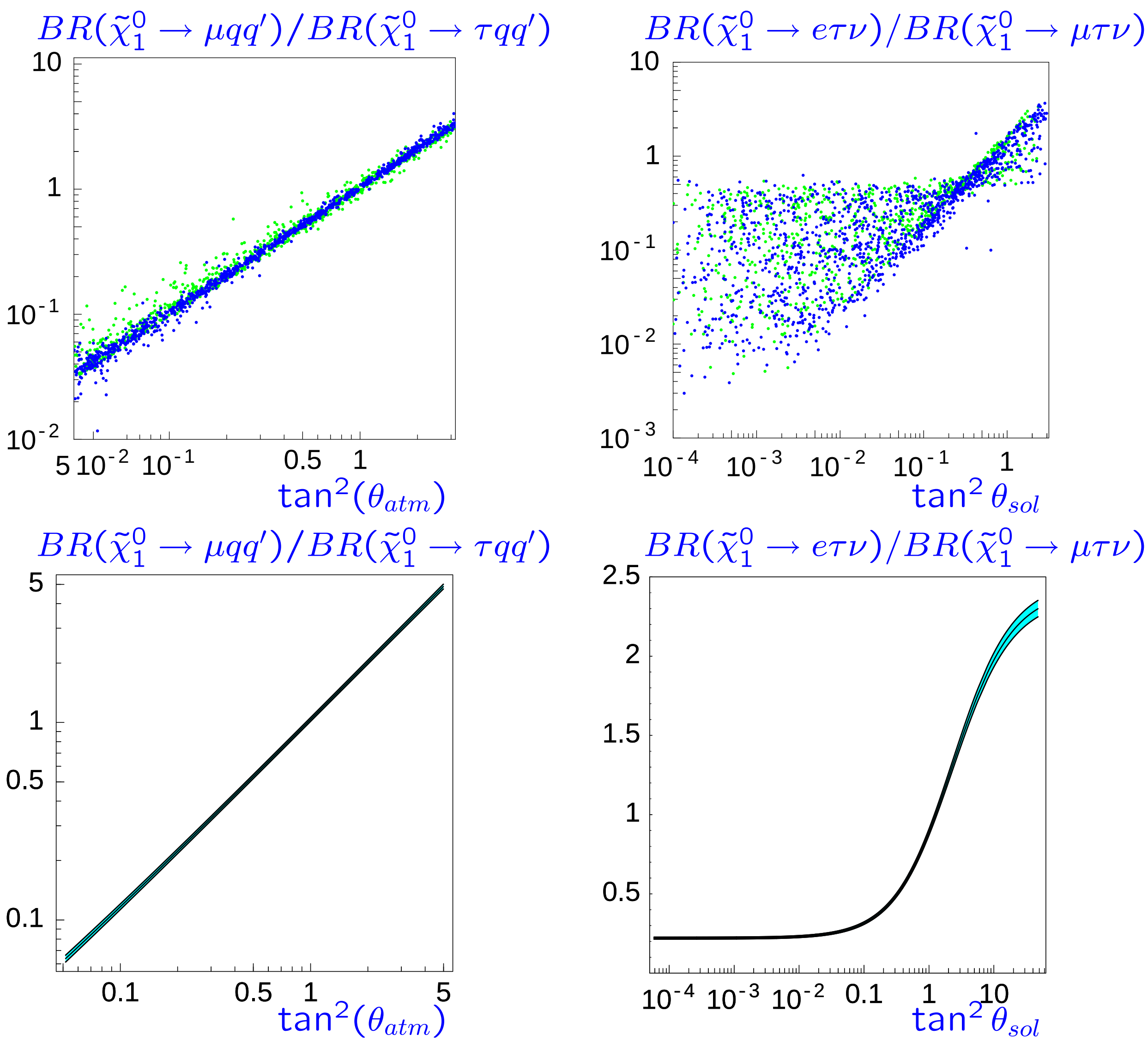
Atmospheric at tree level, solar at loop level

Negligible flavour violating decays of leptons:

BR($\mu \to e\gamma$) $< 10^{-17}$, BR($\tau \to e\gamma, \mu\gamma$) $< 10^{-16}$.

Leads to predictions for collider physics

Correlations



Assumptions:

- spectrum, mixing angles within 10 percent
- statistical error: 10^5 χ^0_1

Parameters:

$M_2 = 120$ GeV, $\mu = 500$ GeV
$\tan\beta = 5$, $m_0 = 500$ GeV
$A = -500$ GeV

Summing over all neutrinos.

W.Porod et al., hep-ph/0011248

Conclusions

- Lepton flavour violating SUSY decays can have large branching ratios despite tight constraints from rare decay

- Lepton flavour violating SUSY decays affect flavour conserving observables

- R-parity violation: additional leptons/ jets
  it is possible to measure neutrino mixing angles at LHC