Large Lepton Flavor Violating Signals in Supersymmetric Particle Decays

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- experimental information
- sources of Lepton Flavour Violation in the MSSM
- Signals & Background
- Numerical Results

W. Porod and W. Majerotto
Phys. Rev. D 66 (2002) xxxx, hep-ph/0201284

related work:N. V. Krasnikov; N. Arkani-Hamed , H. C. Cheng, J. L. Feng, L. J. Hall; H. Baer, C. Balazs, S. Hesselbach, J. K. Mizukoshi, X. Tata; J. Hisano, M. M. Nojiri, Y. Shimizu, M. Tanaka; D. Nomura; M. Guchait, J. Kalinowski, P. Roy

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Experimental information

Neutrino Physics:

at least 1 large mixing angle, most likely 2:
atmospheric neutrinos, SNO
at least one small mixing angle: CHOOZ

Rare Lepton decays:

$\mathrm{BR}(\mu \to e\gamma) < O(10^{-11})$, $\mathrm{BR}(\mu \to eee) < O(10^{-12})$
$\mathrm{BR}(\tau \to l\gamma) < O(10^{-6})$, $\mathrm{BR}(\tau \to lll) < O(10^{-6})$
$\mathrm{BR}(\tau \to lll') < O(10^{-6})$ $(l, l' = e, \mu)$

Rare Z–boson decays:

$\mathrm{BR}(Z \to e^{\pm}\tau^{\mp}) < 1.7 \cdot 10^{-6}$
$\mathrm{BR}(Z \to e^{\pm}\tau^{\mp}) < 10^{-5}$
$\mathrm{BR}(Z \to \mu^{\pm}\tau^{\mp}) < 1.2 \cdot 10^{-5}$

Sources of LFV in the MSSM

- Superpotential
  $W = Y^l_{ij} \hat{L}_i \hat{H}_1 \hat{E}^c_j$
  Y^l_{ij} can be chosen diagonal

- Soft SUSY breaking terms
  $$V = \tilde{l}^\dagger_{Li} M^2_{\tilde{L},ij} \tilde{l}_{Lj} + \tilde{\nu}^\dagger_{Li} M^2_{\tilde{L},ij} \tilde{\nu}_{Lj} + \tilde{l}^\dagger_{Ri} M^2_{\tilde{E},ij} \tilde{l}_{Rj} + \left[A_{l,ij} \left(\tilde{l}_{Li} H^0_1 - \tilde{\nu}_{Li} H^-_1 \right) \tilde{l}^\dagger_{Rij} + \text{h.c.} \right]$$

$\Rightarrow$ Lepton flavour violating couplings:

- $\tilde{l}_i - l_j - \tilde{\chi}^0_k$
- $\tilde{\nu}_i - l_j - \tilde{\chi}^+_k$
- $\tilde{l}_i - \tilde{l}^\dagger_j - Z$, $\tilde{l}_i - \tilde{l}^\dagger_j - (h^0,\ H^0,\ A^0)$
- $\tilde{l}_i - \tilde{\nu}^\dagger_j - W$, $\tilde{l}_i - \tilde{\nu}^\dagger_j - H^+$
- $\tilde{\nu}_i - \nu_j - \tilde{\chi}^0_k$, $\tilde{l}_i - \nu_j - \tilde{\chi}^+_k$

Point under study

Snowmass Point SPS #1:

$M_0 = 100$ GeV, $M_{1/2} = 250$ GeV,

$A_0 = -100$ GeV, $\tan\beta = 10$

Spectrum (in GeV)

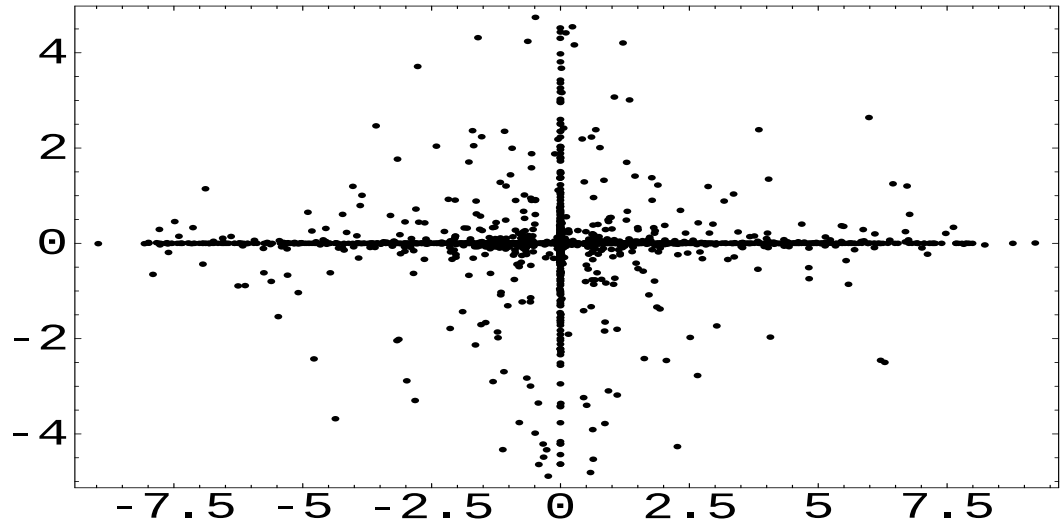
$m_{h^0} = 114$	$m_{A^0} = 395$	
$m_{\tilde{\chi}_1^+} = 193.6$	$m_{\tilde{\chi}_2^+} = 376.2$	$m_{\tilde{\chi}_1^0} = 103.1$
$m_{\tilde{\chi}_2^0} = 194.6$	$m_{\tilde{\chi}_3^0} = 355.1$	$m_{\tilde{\chi}_4^0} = 376.0$
$m_{\tilde{e}_R} = 146.9$	$m_{\tilde{e}_L} = 214.7$	$m_{\tilde{\nu}_e} = 199.4$
$m_{\tilde{\tau}_1} = 138.6$	$m_{\tilde{\tau}_2} = 217.7$	$m_{\tilde{\nu}_\tau} = 198.5$
$m_{\tilde{t}_1} = 407$	$m_{\tilde{b}_1} = 530$	$m_{\tilde{t}_2} = 600$

Add lepton flavour violating terms:

$A_{e,ij}$, $M_{L,ij}$, $M_{E,ij}$ $(i \neq j)$

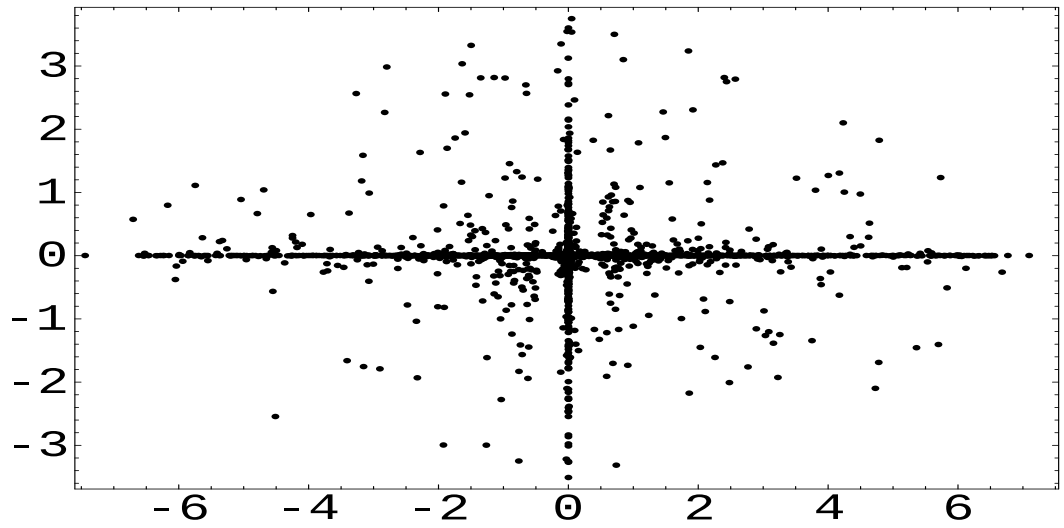
Parameter Ranges

$M^2_{L,13}$ [10^3 [GeV^2]



$M^2_{R,13}$ [10^3 GeV^2]

$M^2_{L,23}$ 10^3 [GeV^2]



$M^2_{R,23}$ [10^3 [GeV^2]

$M^2_{E,11} \simeq 19300$ GeV^2, $M^2_{E,33} \simeq 18700$ GeV^2

$M^2_{L,11} \simeq 40900$ GeV^2, $M^2_{L,33} \simeq 40600$ GeV^2

Possible Signals

- $e^+e^- \to e^\pm\tau^\mp 2\tilde{\chi}_1^0\, n\nu$; $e^+e^- \to \mu^\pm\tau^\mp 2\tilde{\chi}_1^0\, n\nu$
  $n = 0, 2, 4\ldots$
  Contributing processes:
  $e^+e^- \to \tilde{l}_i^+\tilde{l}_j^-$; $e^+e^- \to \tilde{\chi}_{2,3}^0\tilde{\chi}_1^0$

- $e^+e^- \to e^\pm\tau^\mp 2\tilde{\chi}_1^0\, n\nu$ k jets, $n, k = 0, 2, 4\ldots$
  Contributing processes:
  $e^+e^- \to \tilde{l}_i^+\tilde{l}_j^-$; $e^+e^- \to \tilde{\nu}_i\tilde{\nu}_j^*$; $e^+e^- \to \tilde{q}_i\tilde{q}_j^*$;
  $e^+e^- \to \tilde{\chi}_{2,3}^0\tilde{\chi}_{1,2}^0$

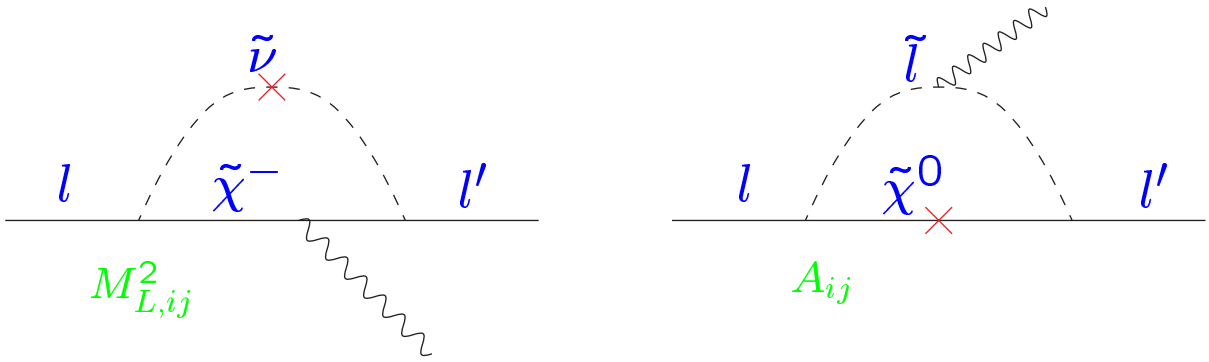
signal	(electron,positron polarization)		
$\sqrt{s} = 500$ GeV	(0,0)	(-0.8,0.6)	(0.8,-0.6)
$e^\pm\mu^\mp\not{E}_T$	149	208	231
$e^\pm\tau^\mp\not{E}_T$	178	220	248
$\mu^\pm\tau^\mp\not{E}_T$	61	127	115
$e^\pm\mu^\mp 2j\not{E}_T$	0.13	0.01	0.38
$e^\pm\tau^\mp 2j\not{E}_T$	0.51	0.04	1.46
$\mu^\pm\tau^\mp 2j\not{E}_T$	0.5	0.04	1.43
$e^\pm\mu^\mp 4j\not{E}_T$	0.02	0	0.05
$e^\pm\tau^\mp 4j\not{E}_T$	0.07	0	0.21
$\mu^\pm\tau^\mp 4j\not{E}_T$	0.07	0	0.20

SM + SUSY Background

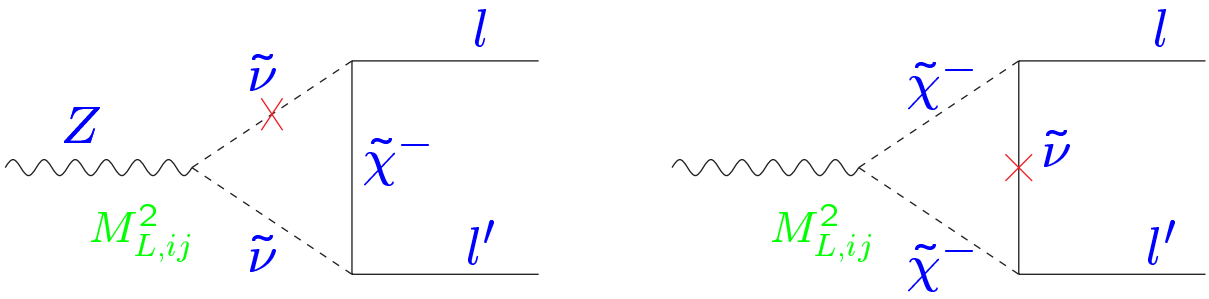
- $\tau^+\tau^-$ production
- W^+W^- + n jets production, including off–shell W
  $e^+e^- \to W^+W^- \to e^+\mu^- \not{E}_T$
- H^+H^- + n jets production, including off–shell H
- $\tilde{\chi}_i^+\tilde{\chi}_j^-$ production
  $e^+e^- \to \tilde{\chi}_1^+\tilde{\chi}_1^- \to e^+\mu^-\tilde{\nu}_i\tilde{\nu}_j^* \to e^+\mu^- \not{E}_T$
- W^+, H^+, $\tilde{\chi}_i^+$ in SUSY cascade decays
  $\tilde{\nu}_e \to e^-\tilde{\chi}_1^+ \to e\mu^+\nu_\mu\tilde{\chi}_1^0$

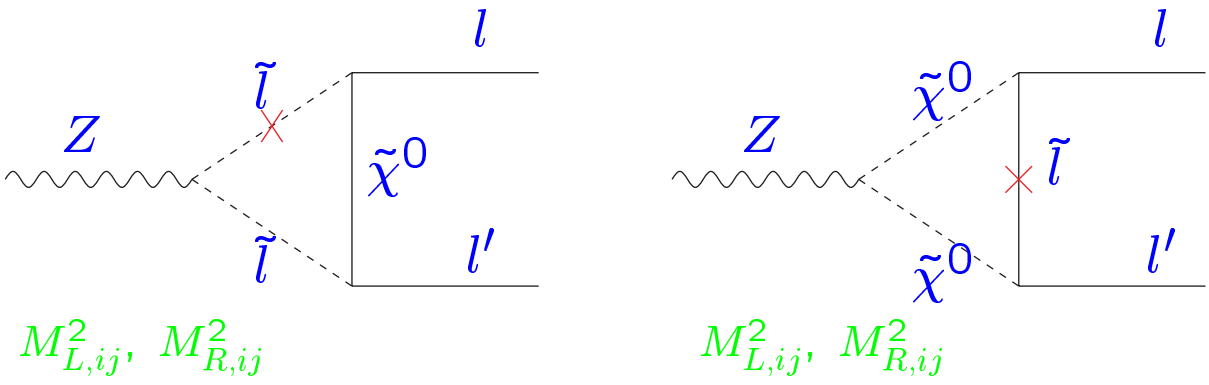
Lepton Flavour Violating Decays

$l \to l' \gamma$

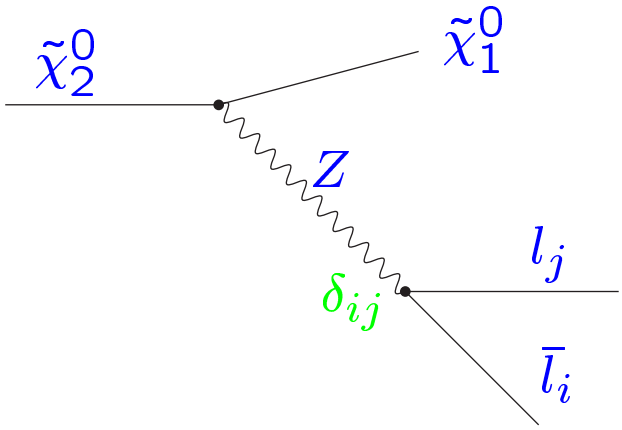


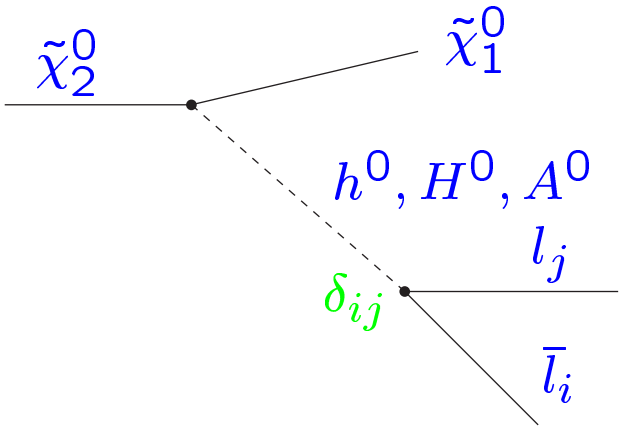
$Z \to l\, l'$

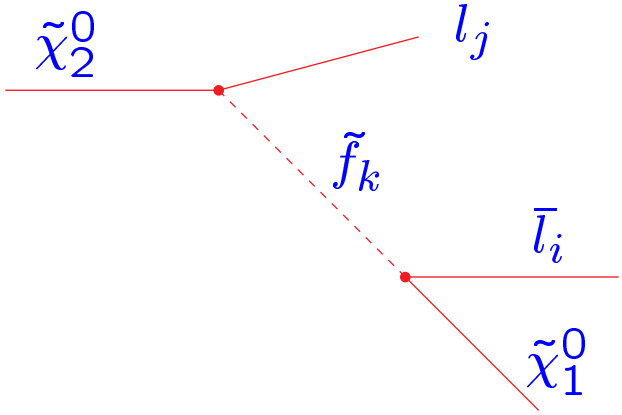


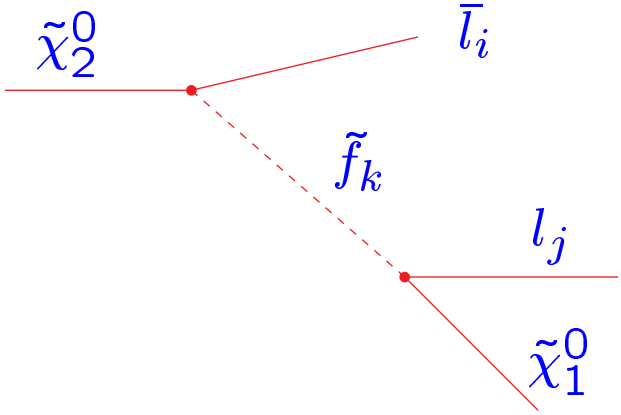


Neutralino Decays



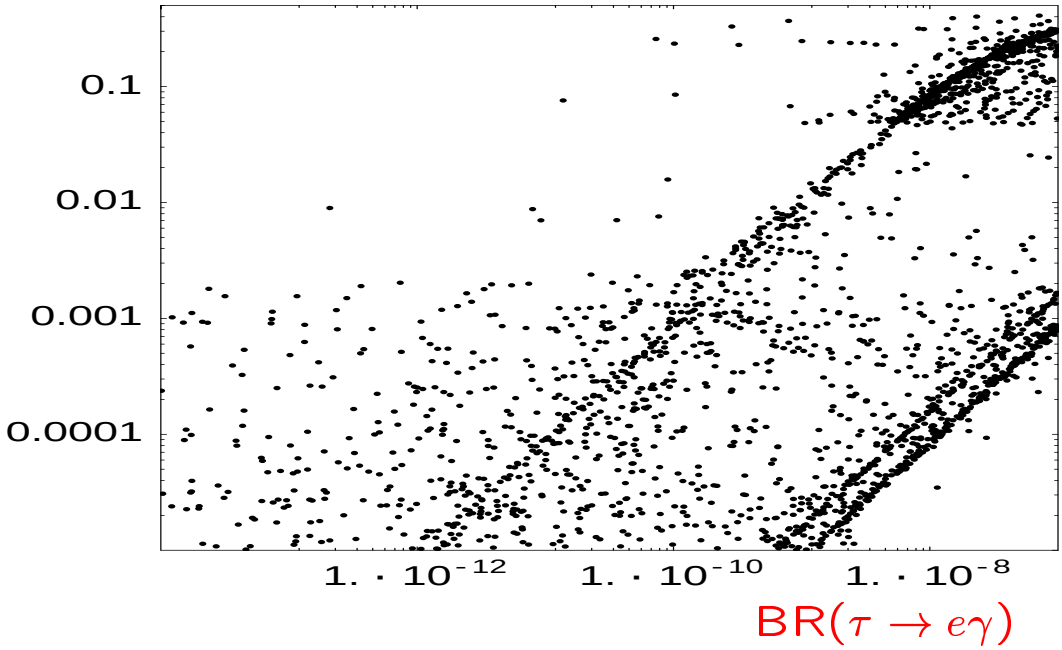




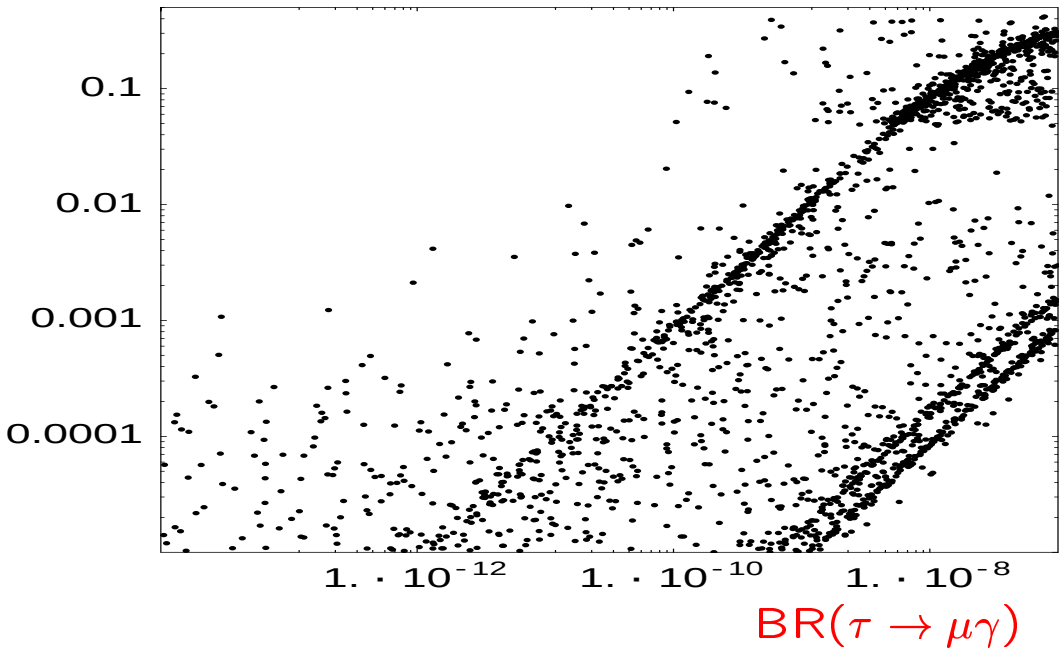


$\tilde{\chi}_2^0$ Decays

$\mathrm{BR}(\tilde{\chi}_2^0 \to \tilde{\chi}_1^0 e^{\pm} \tau^{\mp})$

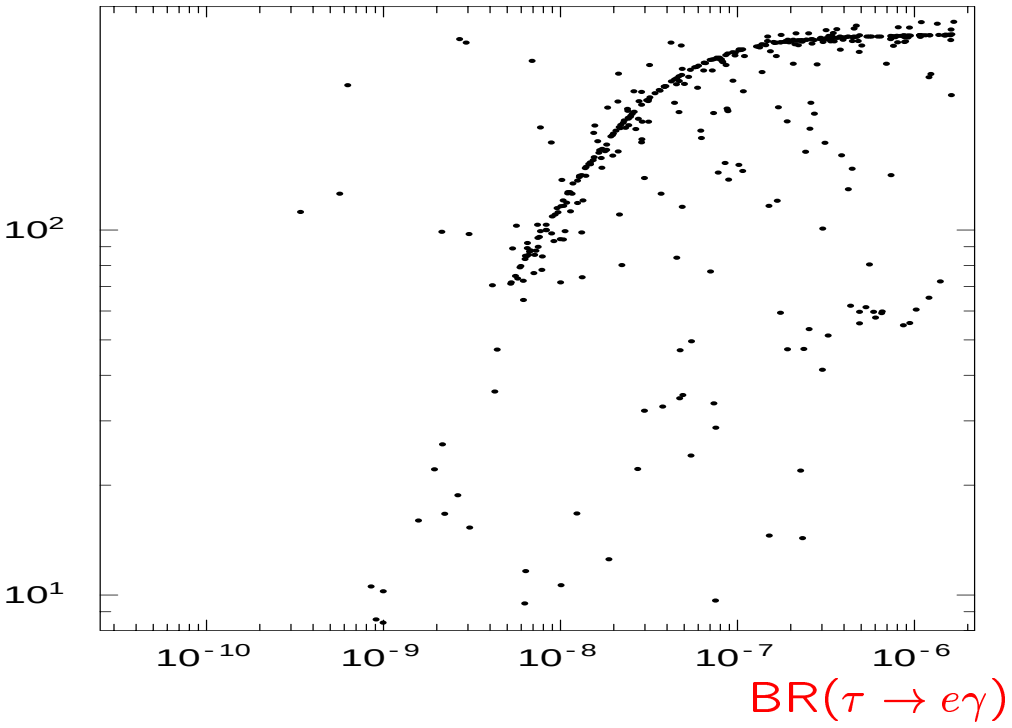


$\mathrm{BR}(\tilde{\chi}_2^0 \to \tilde{\chi}_1^0 \mu^{\pm} \tau^{\mp})$

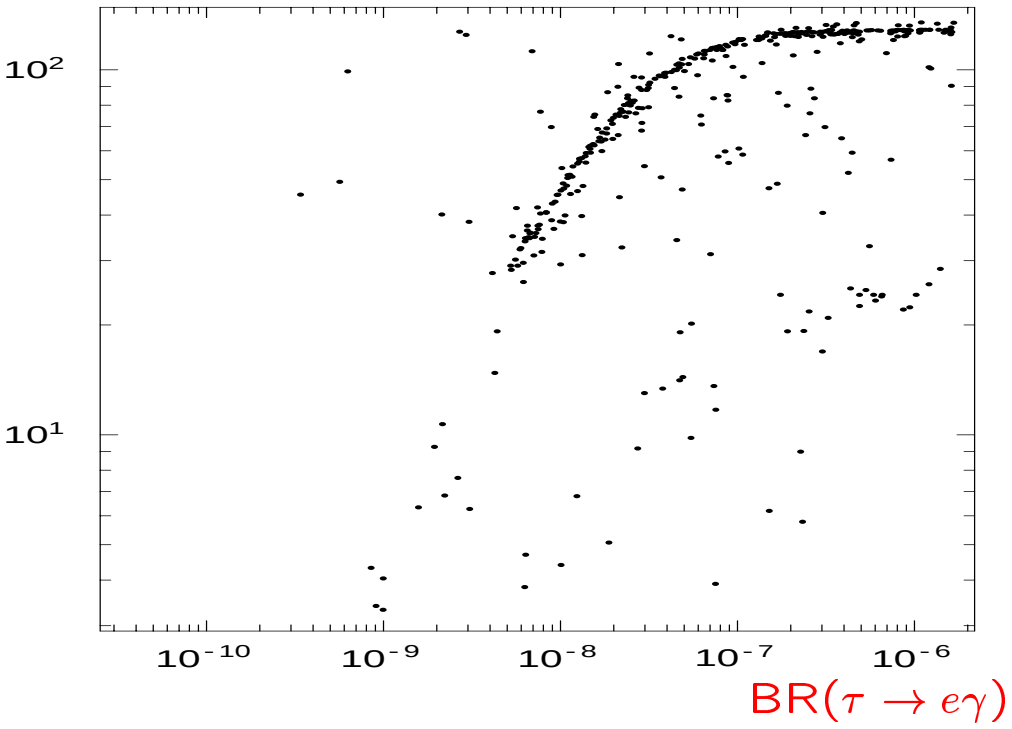


The signal $e^+e^- \to e^\pm\tau^\mp \not{E}_T$

σ [fb]



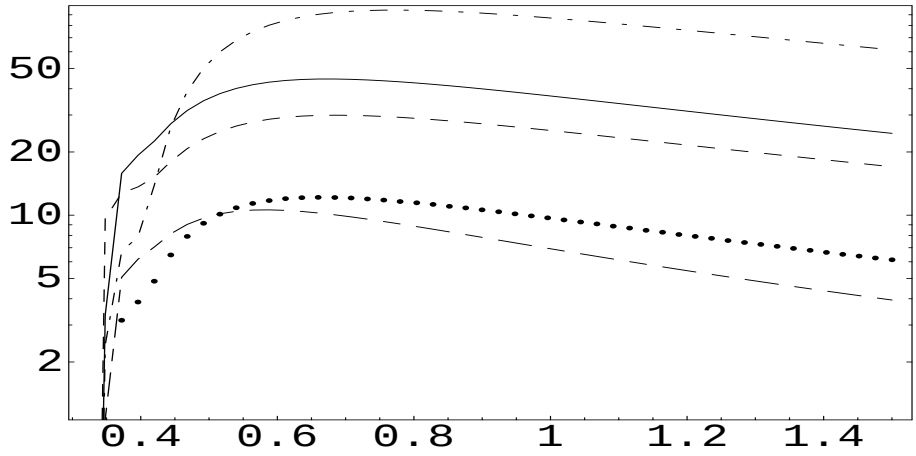
$signal/\sqrt{background}$ for $\mathcal{L} = 100$ fb^{-}1



$\sqrt{s} = 500$ GeV

The signal $e^+e^- \to l_i^\pm l_j^\mp \not{E}_T$

$\sigma(e^\pm\mu^\mp \not{E}_T)$ [fb]



(P_-, P_+)

$(-0.8, 0.6)$

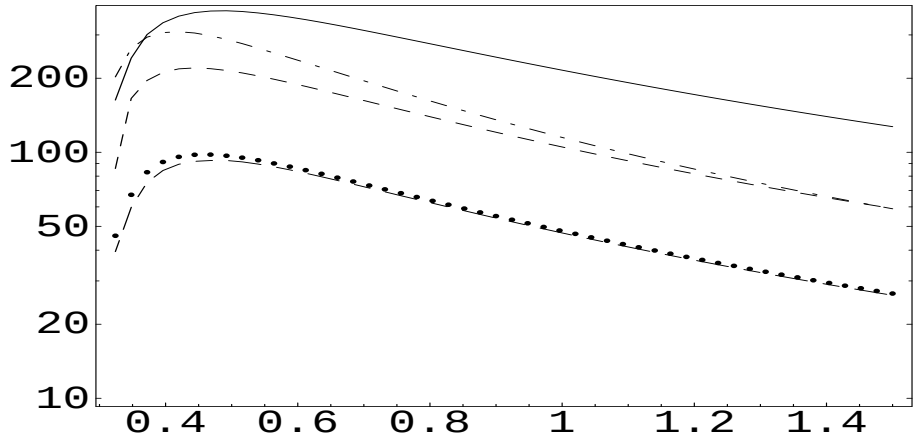
$(0, 0)$

$(-0.8, -0.6)$

$(0.8, 0.6)$

$(0.8, -0.6)$

$\sigma(e^\pm\tau^\mp \not{E}_T)$ [fb]



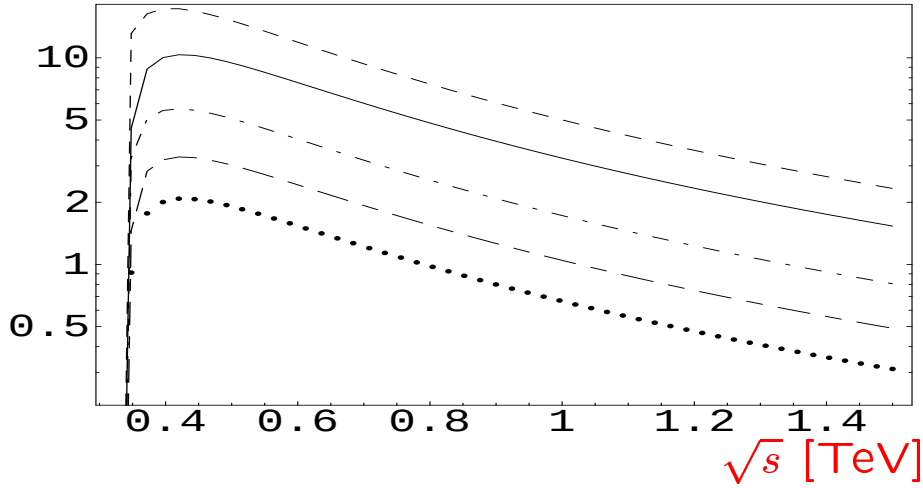
$M^2_{E,13} = 3440$ GeV^2

$M^2_{L,12} = -2.4$ GeV^2

$v_d A_{l,31} = 1.8$ GeV^2

$\sqrt{s} = 500$ GeV

$\sigma(\mu^\pm\tau^\mp \not{E}_T)$ [fb]



$\sqrt{s}$ [TeV]

Large signals and small $l \to l' \gamma$

$$\Gamma(l_i \to l_k \gamma) \propto \left| \sum_n R^*_{in} R_{nk} \frac{m_n^2 - \overline{m}^2}{\overline{m}^2} \right|^2$$

$$\overline{m}^2 = \frac{1}{r} \sum_{n=1}^{r} m_n^2$$

$$\Gamma(\tilde{\chi}_2^0 \to l_i^+ l_j^- \tilde{\chi}_1^0) \propto \left| \sum_n R^*_{in} R_{nk} \frac{1}{m_n^2} \right|^2$$

Summary

We have performed a study of lepton number violating decays of SUSY particles.

- Several non-diagonal parameters can be relatively large at the same time
- Large lepton number violating signal at future colliders
- Require most likely high luminosity e^+e^- colliders to measure the branching ratios precisely. They are important to get information on the SUSY flavour structure.