SUSY seesaw, thermal leptogenesis and lepton flavor violation

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SUSY seesaw

Neutrinos

Superpotential: $W \supset -\frac{1}{2}\upsilon_R^{cT} M \upsilon_R^C + \upsilon_R^{cT} Y_\upsilon L \cdot H_u$

$\Rightarrow$ Effective mass matrix: $m_\upsilon = m_D^T M^{-1} m_D = Y_\upsilon^T M^{-1} Y_\upsilon \left\langle H_u^0 \right\rangle^2$

for $M \gg m_D$

$\Rightarrow$ Masses and mixings: $U^T m_\upsilon U = \mathrm{diag}(m_1, m_2, m_3)$

Problem: Reconstruction of superpotential by observables not possible

Independent parameters: $9(U, m_i)$ vs. $18(Y_\upsilon, M_i)$

SUSY seesaw

The R matrix

Parametrization of Y_υ (Casas, Ibarra 2001):

$$Y_\upsilon = \mathrm{diag}(M_i) \cdot R \cdot \mathrm{diag}(m_i) \cdot U^\dagger, \quad R^T R = \mathbf{1}$$

$$R = \begin{pmatrix} c_2 c_3 & -c_1 s_3 - s_1 s_2 c_3 & s_1 s_3 - c_1 s_2 c_3 \\ c_2 s_3 & c_1 c_3 - s_1 s_2 s_3 & -s_1 c_3 - c_1 s_2 s_3 \\ s_2 & s_1 c_2 & c_1 c_2 \end{pmatrix}$$

$$\theta_j = x_j + i y_j, \quad j = 1,2,3$$

SUSY seesaw

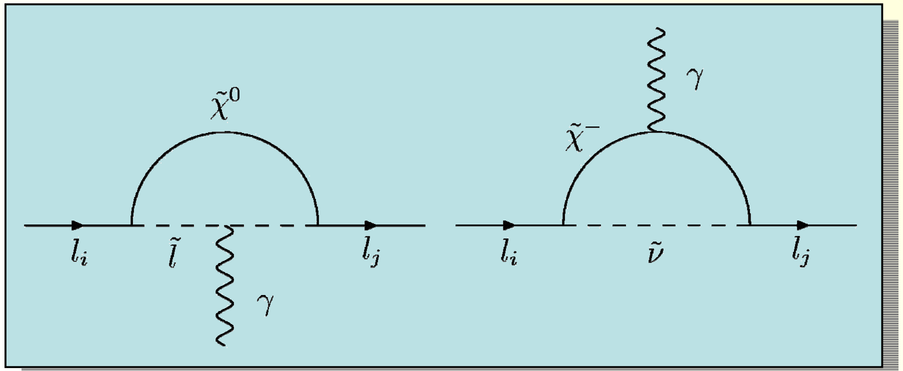
Sleptons

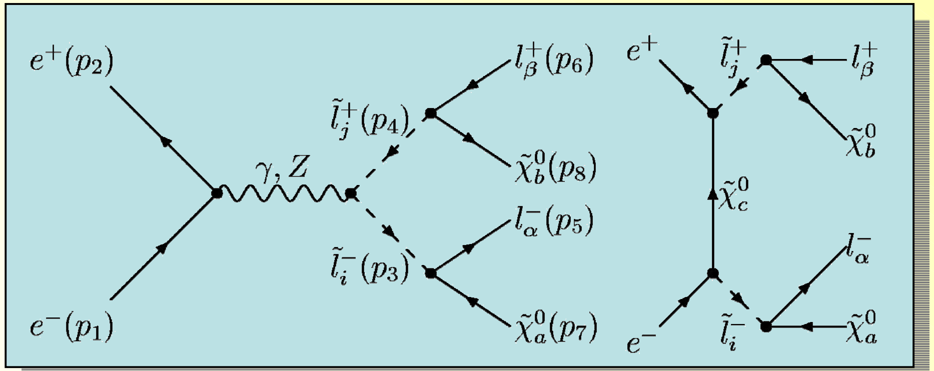
Radiative slepton mass corrections:

$$\left(\delta m_L^2\right)_{ij} = -\frac{1}{8\pi^2}\left(3m_0^2 + A_0^2\right)\left(Y_\nu L Y_\nu^\dagger\right)_{ij}, \quad L_{ij} = \ln\left(\frac{M_{GUT}}{M_i}\right)\delta_{ij}$$

$\Rightarrow$ LFV decays and collider processes:

$$Br(l_i \to l_j \gamma) \approx \frac{\alpha^3 \tan^2\beta}{\tilde{m}^8}\frac{m_{l_i}^5}{\Gamma_i}\left|\left(\delta m_L^2\right)_{ij}\right|^2$$





Leptogenesis

Observed baryon asymmetry: $\eta_B = (6.3 \pm 0.3) \cdot 10^{-10}$ (WMAP)

CP asymmetry in decays of the lightest r.-h. neutrino:

$$\varepsilon_1 \approx -\frac{3}{8\pi} \frac{1}{\left(Y_\upsilon Y_\upsilon^\dagger\right)_{11}} \sum_{j\neq 1} \mathrm{Im}\left[\left(Y_\upsilon Y_\upsilon^\dagger\right)_{ij}^2\right] \frac{M_1}{M_j}$$

for $M_1 \lesssim M_2, M_3$

$\Rightarrow$ Fixing M_1:

$$M_1 \approx \frac{32\pi}{9} \eta_B \frac{\left\langle H_u^0 \right\rangle^2}{c_{sph} f_{dil}} \frac{\kappa_f(\tilde{m}_1)\tilde{m}_1}{\sum_j m_j^2 \,\mathrm{Im}\left[R_{1j}^2\right]}, \quad \tilde{m}_1 = \sum_j m_j \left|R_{1j}\right|^2$$

lower bound: $M_1 \geq 5 \cdot 10^9\,\mathrm{GeV}$

Setup

Seesaw ⇔ neutrino masses and mixing
+ SUSY ⇔ LFV processes
+ Thermal Leptogenesis ⇔ baryon asymmetry
+ mSUGRA (SPS1a) ⇔ gravitino bound

- Hierarchical light and heavy neutrinos:

$$m_1 \ll m_2 \ll m_3, \quad M_1 \ll M_2 \ll M_3$$

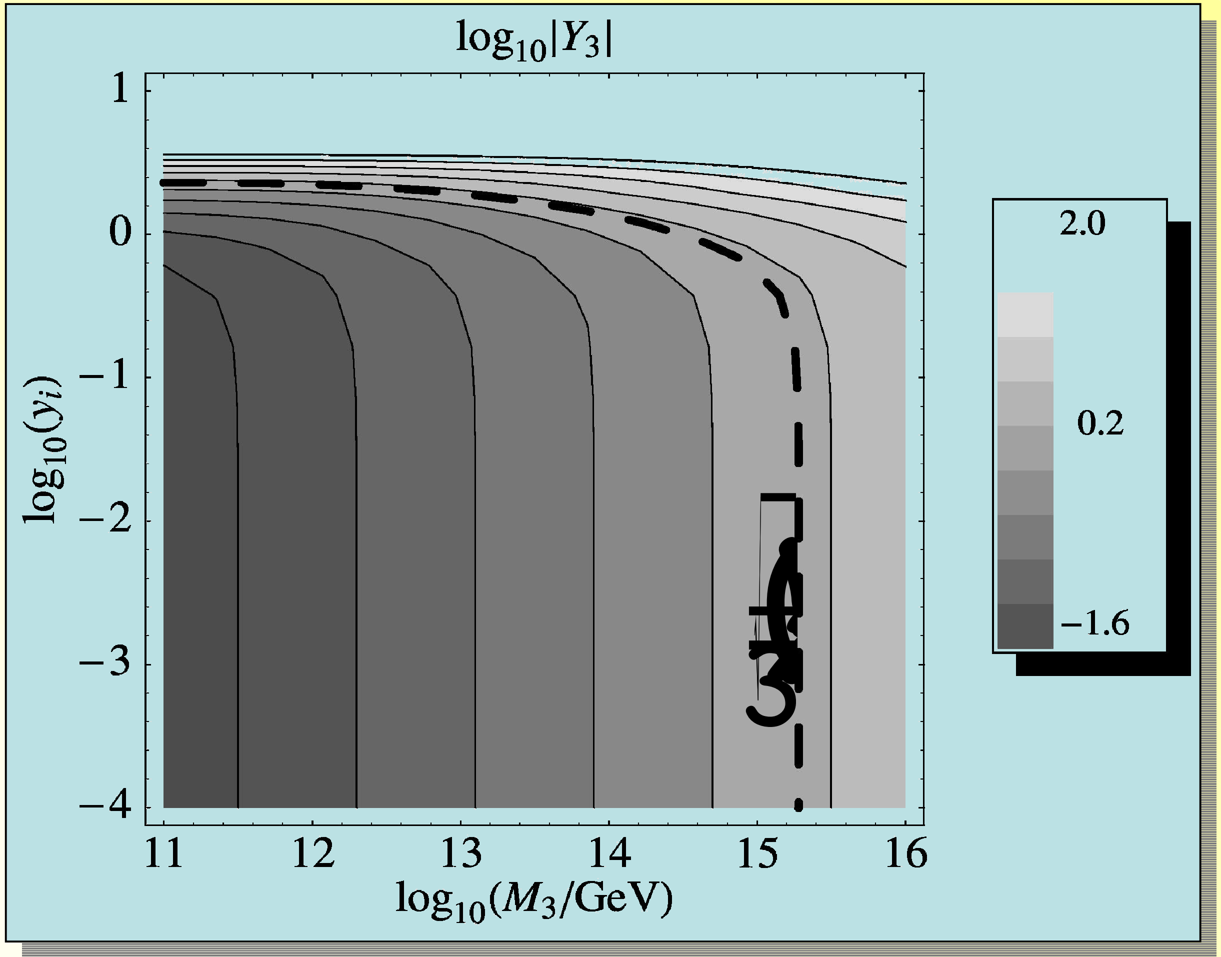
- Future neutrino oscillation uncertainties

Perturbativity

Consistency Requirement:

$|Y_3|^2/(4\pi) \leq 0.3$

$\Rightarrow y_i \leq O(1)$



$M_1 = 10^{10}\,\mathrm{GeV},\ M_2 = 10^{11}\,\mathrm{GeV}$

$x_i = 0,\ y_i = y$, best fit υ_L

Constraining x_2 and x_3

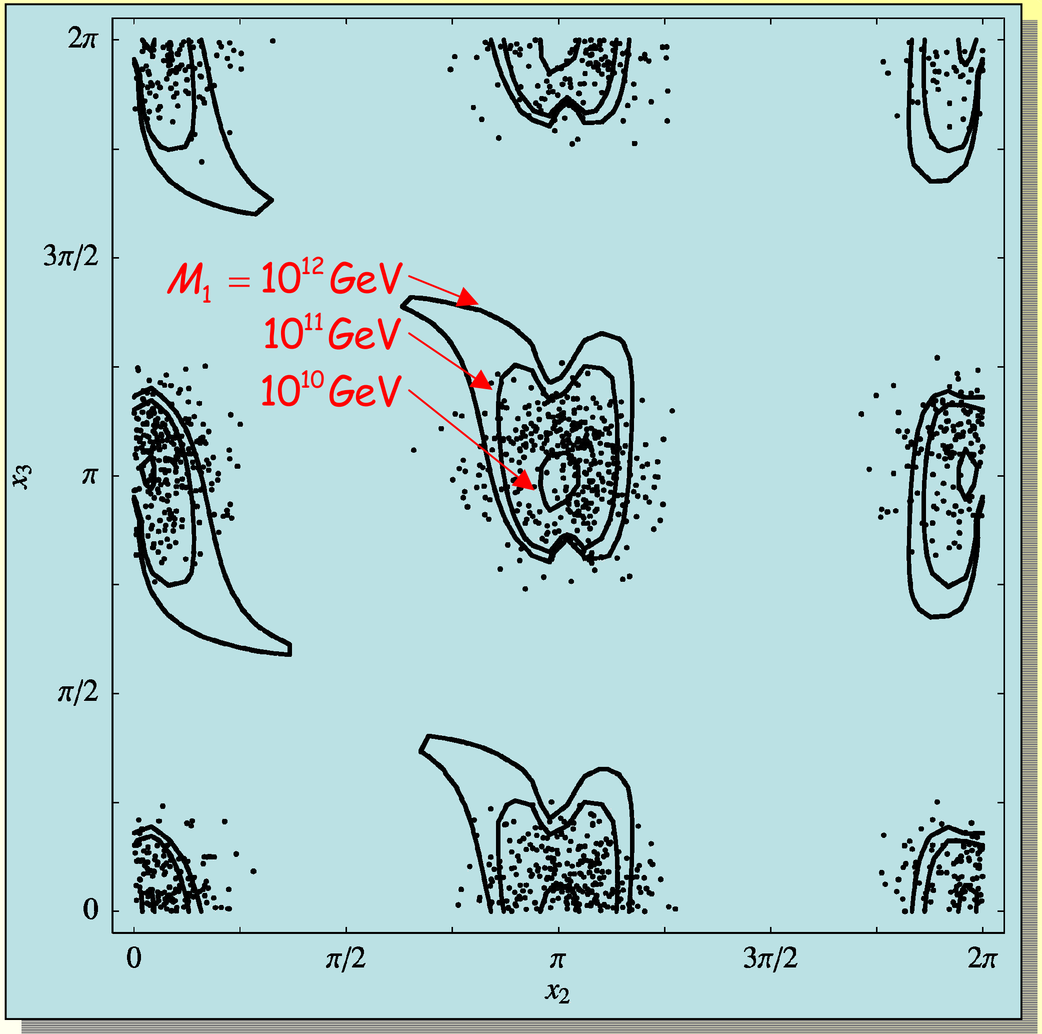
Overabundance of gravitinos for

$T_R > 10^{10}\text{GeV}$ ($m_{3/2} \approx 1\text{TeV}$)

$\Rightarrow M_1 < 10T_R$

$< 10^{11}\,\text{GeV}$

$\Rightarrow x_{2,3} \approx 0, \pi, 2\pi$



Contours: $y_i = 0.1$, best fit υ_L

Lepton flavor violation

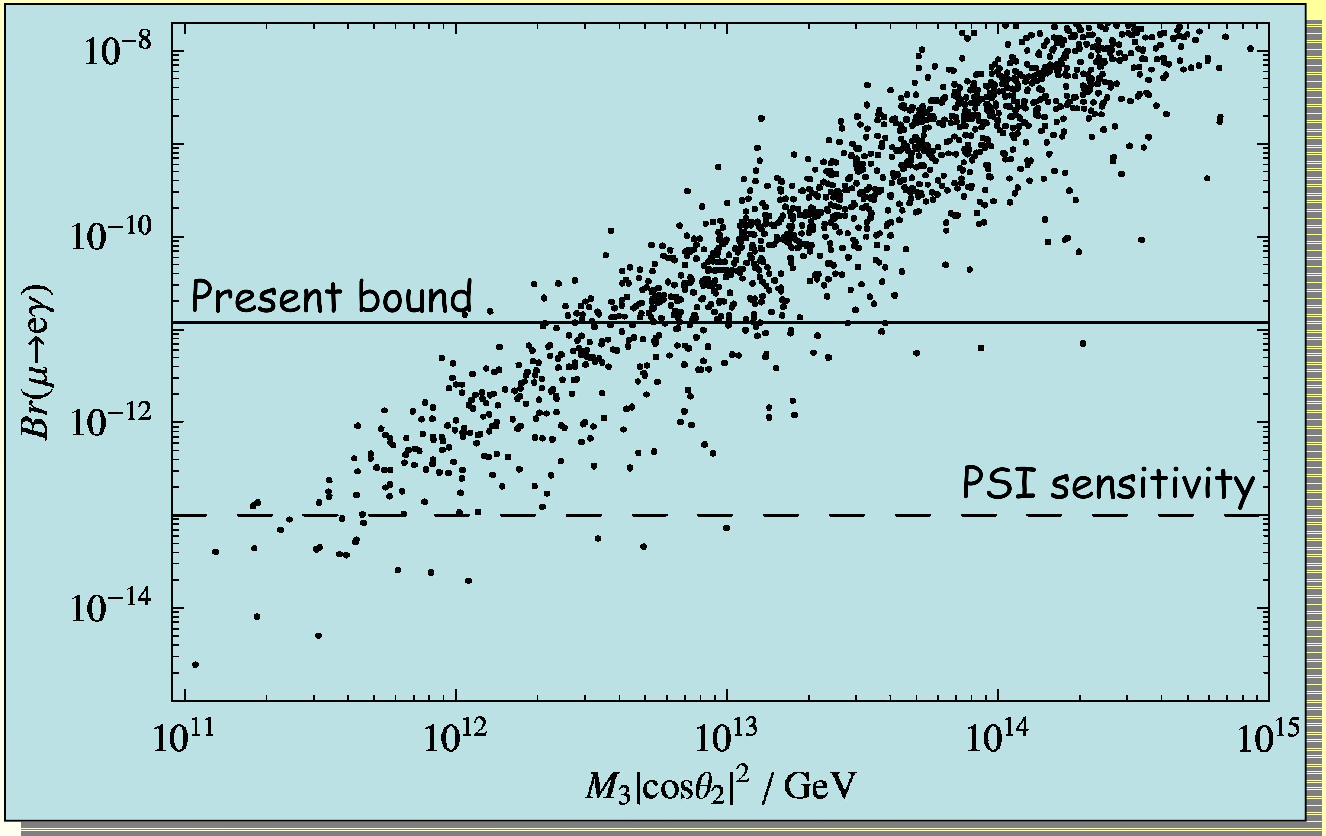
$$Br(l_i \to l_j \gamma)$$

$$\propto \left| \left(Y_\upsilon L Y_\upsilon^\dagger \right)_{ij} \right|^2$$

$$\propto M_3^2 \left| \cos(x_2 + i y_2) \right|^4$$

$\Rightarrow M_3 \lesssim 10^{13-14}\,GeV$

(present bound)



$x_i \in [0, 2\pi]$, $y_i \in [10^{-3}, 10^0]$

$M_1(\eta_B)$, $M_3 \in [10, 10^4] M_1$, $M_2 \in [M_1, 0.1 M_3]$

Constraining x_1

Strong variation of $\frac{Br(\mu \to e\gamma)}{Br(\tau \to \mu\gamma)}$ with x_1.

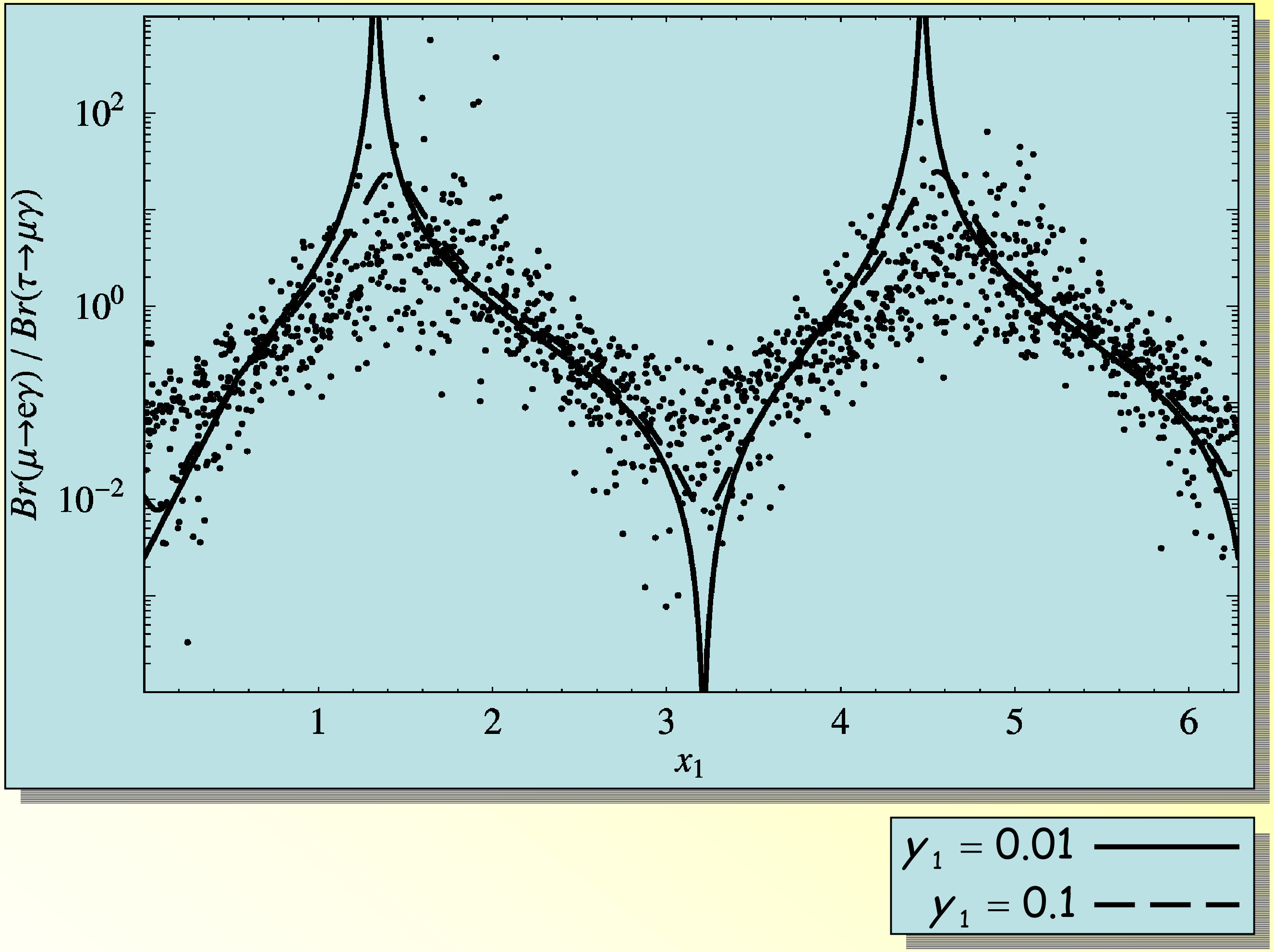
LHC:

$Br(\tau \to \mu\gamma) \approx 10^{-8}$

$\Downarrow$

Sensitivity:

$\frac{Br(\mu \to e\gamma)}{Br(\tau \to \mu\gamma)} \leq O(10^{-3})$

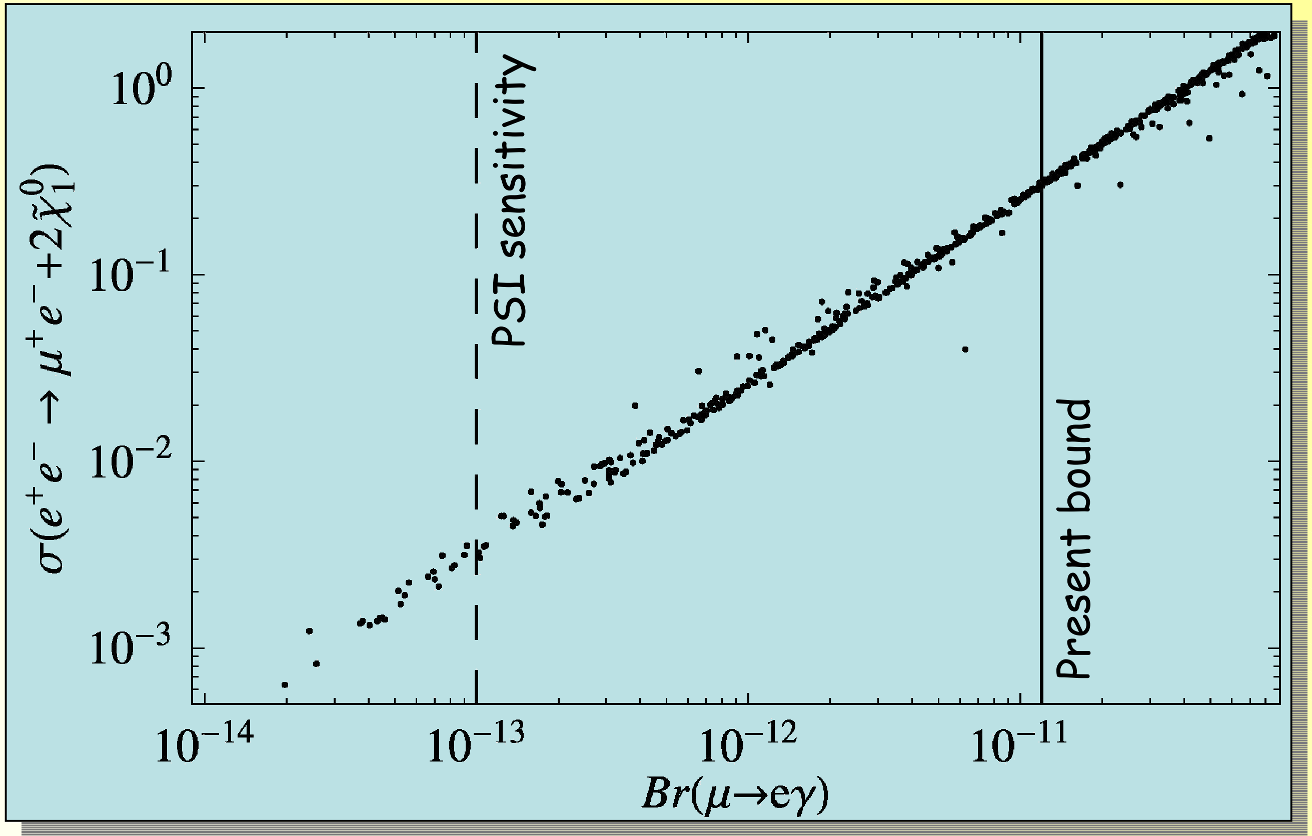


LFV at a e^+e^- collider

Strong correlation between rare decays and slepton pair production.

⇓

$\sigma(e^+e^- \to \mu^+e^- + 2\tilde{\chi}_1^0)$
< 0.3 fb



$\sqrt{s} = 500GeV$