Correlating LSP Decay Properties with Neutrino Mixing Angles

Werner Porod

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based on work with M. Díaz, M. Hirsch, J.C. Romão, J. Valle

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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 violation in charged lepton sector

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

$BR(\mu^- \to e^- e^+ e^-) \lesssim 10^{-12}$

$BR(\tau \to e\gamma) \lesssim 2.7 \cdot 10^{-6}$

$BR(\tau \to \mu\gamma) \lesssim 1.1 \cdot 10^{-6}$

$BR(\tau \to l l l') \lesssim O(10^{-6})$ $(l, l' = e, \mu)$

Bilinearly broken R-parity

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

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$(\tau \to e\gamma, \mu\gamma) < 10^{-18}$.

Leads to predictions for collider physics

Neutralino Mass Matrix

basis $\psi^{0T} = (-i\lambda', -i\lambda^3, \widetilde{H}_d^1, \widetilde{H}_u^2, \nu_e, \nu_\mu, \nu_\tau)$ we get:

$$M_N = \begin{bmatrix} \mathcal{M}_{\chi^0} & m^T \\ m & 0 \end{bmatrix}$$

with

$$\mathcal{M}_{\chi^0} = \begin{bmatrix} M_1 & 0 & -\frac{1}{2}g'v_d & \frac{1}{2}g'v_u \\ 0 & M_2 & \frac{1}{2}gv_d & -\frac{1}{2}gv_u \\ -\frac{1}{2}g'v_d & \frac{1}{2}gv_d & 0 & -\mu \\ \frac{1}{2}g'v_u & -\frac{1}{2}gv_u & -\mu & 0 \end{bmatrix}, \quad m = \begin{bmatrix} -\frac{1}{2}g'v_1 & \frac{1}{2}gv_1 & 0 & \epsilon_1 \\ -\frac{1}{2}g'v_2 & \frac{1}{2}gv_2 & 0 & \epsilon_2 \\ -\frac{1}{2}g'v_3 & \frac{1}{2}gv_3 & 0 & \epsilon_3 \end{bmatrix}$$

Approximate diagonalization as in usual seesaw mechanism gives

$$m_{\nu,eff} = \frac{M_1 g^2 + M_2 g'^2}{4\, det(\mathcal{M}_{\chi^0})} \begin{pmatrix} \Lambda_1^2 & \Lambda_1\Lambda_2 & \Lambda_1\Lambda_3 \\ \Lambda_1\Lambda_2 & \Lambda_2^2 & \Lambda_2\Lambda_3 \\ \Lambda_1\Lambda_3 & \Lambda_2\Lambda_3 & \Lambda_3^2 \end{pmatrix}$$

where

$$\Lambda_i = \mu v_i + v_d \epsilon_i$$

Parameters controlling ν-Physics

If $m_{\nu,Loop} \ll m_{\nu,Tree}$

Δm^2_{atm}	$M_2/det(\mathcal{M}_{\chi^0})\ |\vec{\Lambda}|^2$
$\tan^2\theta_{atm}$	$|\Lambda_2/\Lambda_3|^2$
CHOOZ	$|\Lambda_1|/\sqrt{\Lambda_2^2+\Lambda_3^2}$
$\tan^2\theta_{sol}$	$|\epsilon_1/\epsilon_2|^2$
m^2_{sol}/m^2_{atm}	$|\vec{\epsilon}|^2/|\vec{\Lambda}|$

where

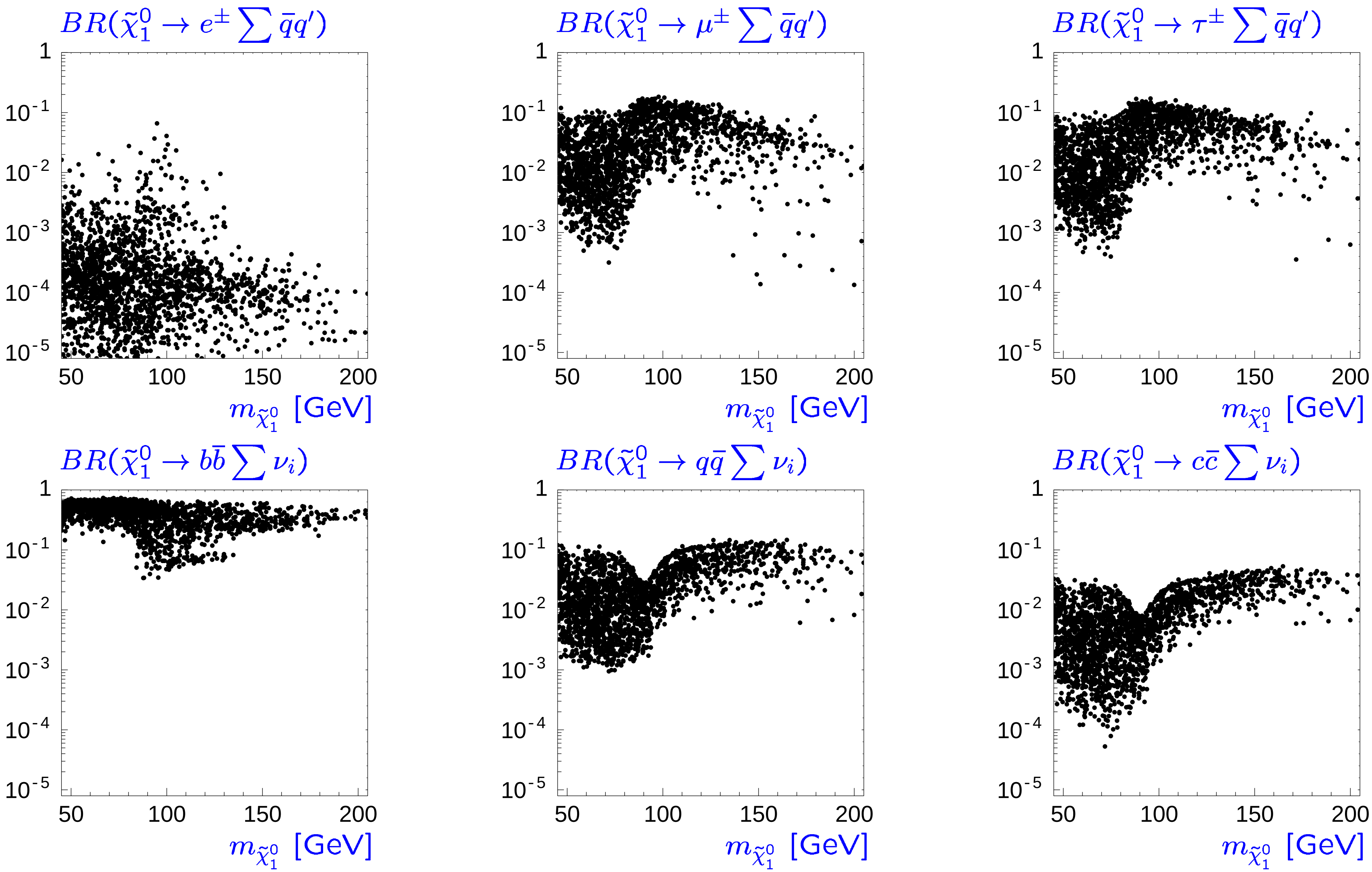
$$\Lambda_i = \mu v_i + v_d \epsilon_i$$

Approximate Couplings

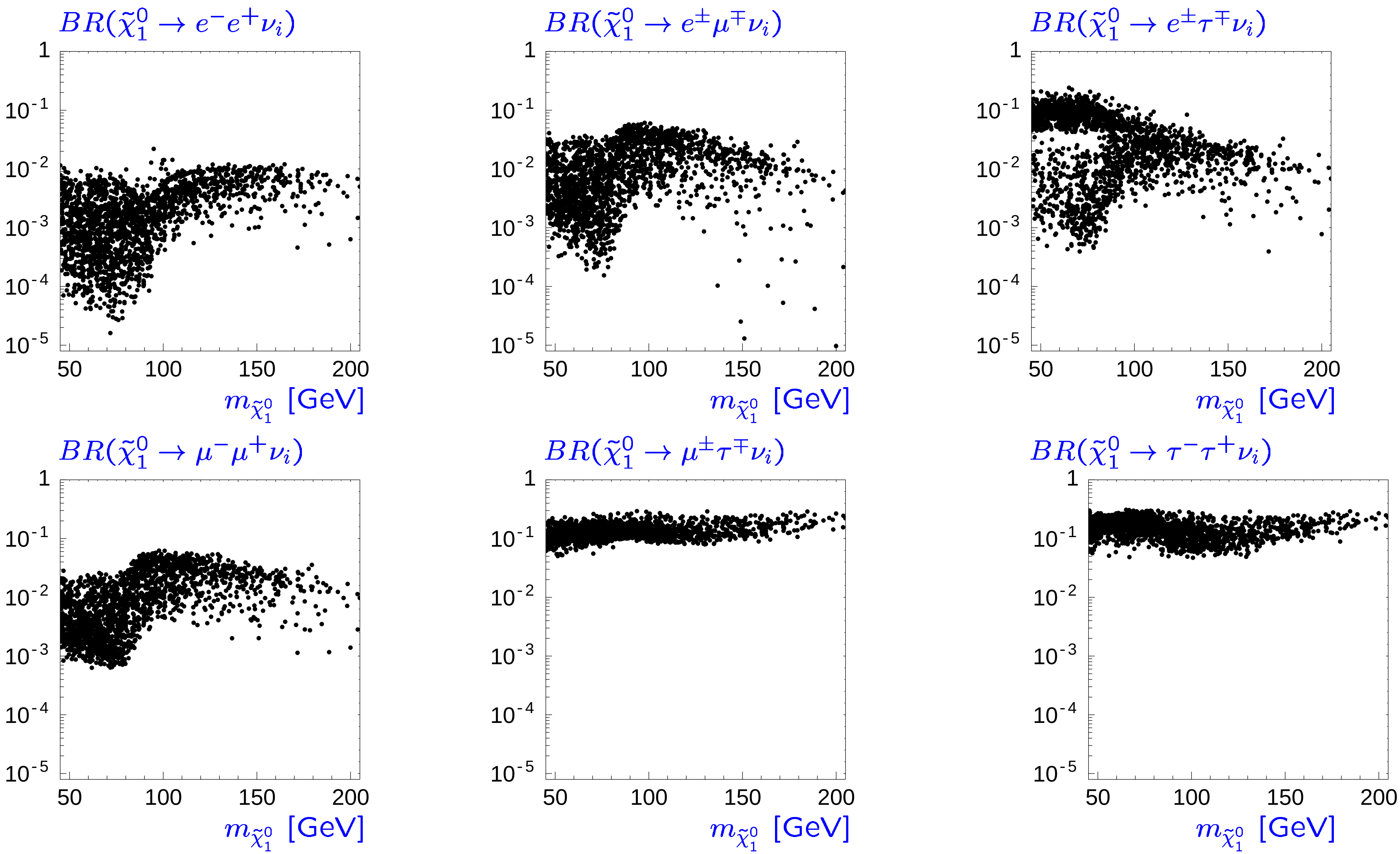
$\tilde{\chi}^0_1$-$W^\pm$-l_i couplings:

$$
\begin{aligned}
O_{Ri} &= \frac{g h^E_{ii} v_d}{2\text{Det}_+}\left[\frac{g v_d N_{12} + M_2 N_{14}}{\mu}\epsilon_i\right.\\
&+ \left. g\,\frac{\left(2\mu^2 + g^2 v_d v_u\right) N_{12} + (\mu + M_2)\, g v_u N_{14}}{2\mu\text{Det}_+}\Lambda_i\right]\\
O_{Li} &= \frac{g\Lambda_i}{\sqrt{2}}\left[-\frac{g' M_2 \mu}{2\text{Det}_0}N_{11} + g\left(\frac{1}{\text{Det}_+} + \frac{M_1\mu}{2\text{Det}_0}\right)N_{12}\right.\\
&\qquad -\frac{v_u}{2}\left(\frac{g^2 M_1 + g'^2 M_2}{2\text{Det}_0} + \frac{g^2}{\mu\text{Det}_+}\right)N_{13}\\
&\qquad \left. + \frac{v_d(g^2 M_1 + g'^2 M_2)}{4\text{Det}_0}N_{14}\right]\\
|O_{Ri}| &\ll |O_{Li}|\\
\left|\frac{O_{L2}}{O_{L3}}\right|^2 &= \left|\frac{\Lambda_2}{\Lambda_3}\right|^2 \simeq \tan^2\theta_{atm}
\end{aligned}
$$

Semi-leptonic final states

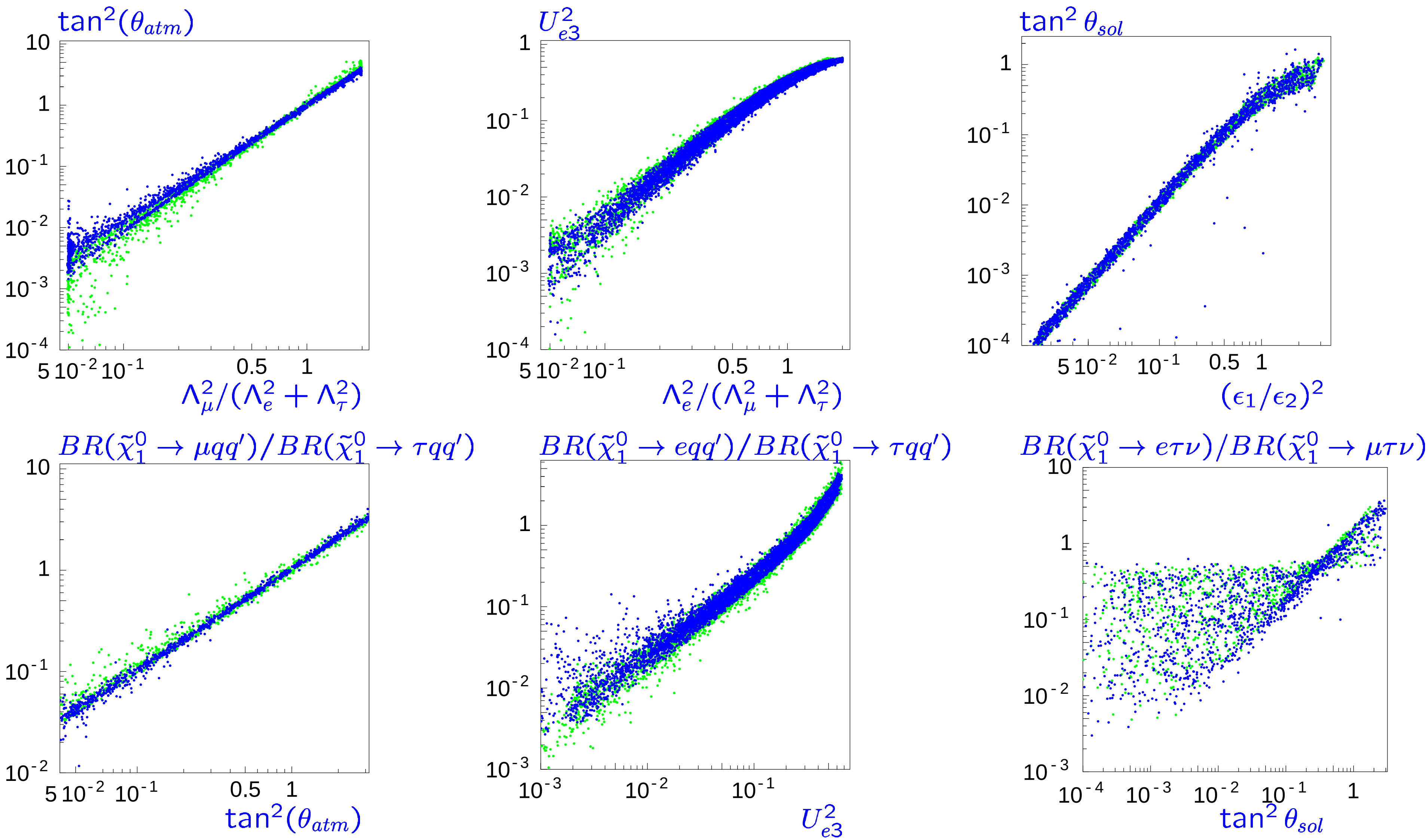


Leptonic final states



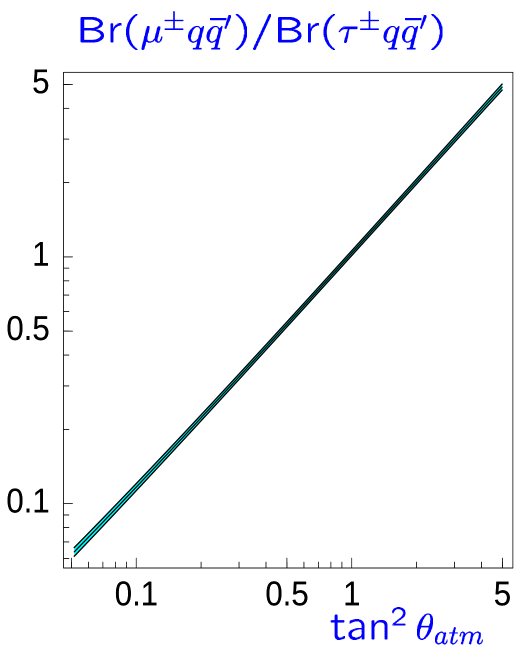
Summing over all neutrinos.

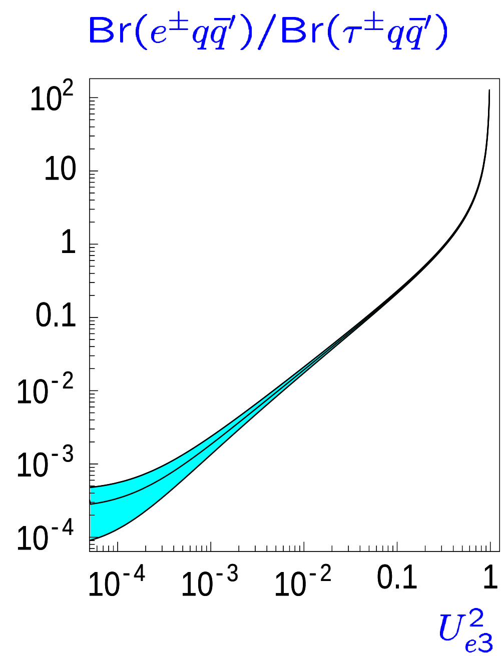
Correlations

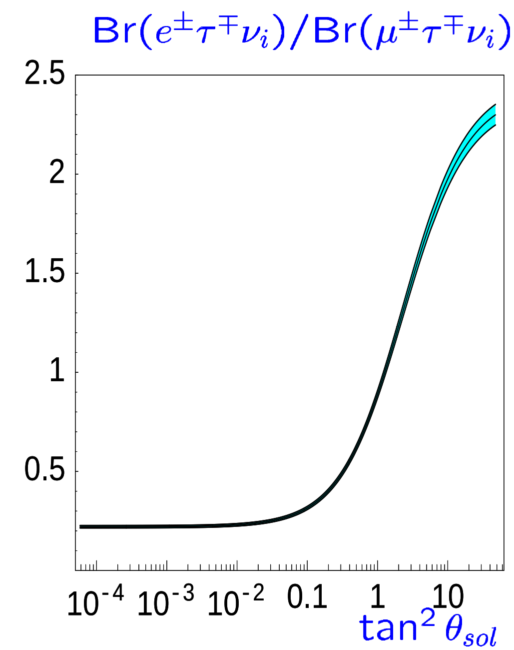


Summing over all neutrinos.

Precision Measurements







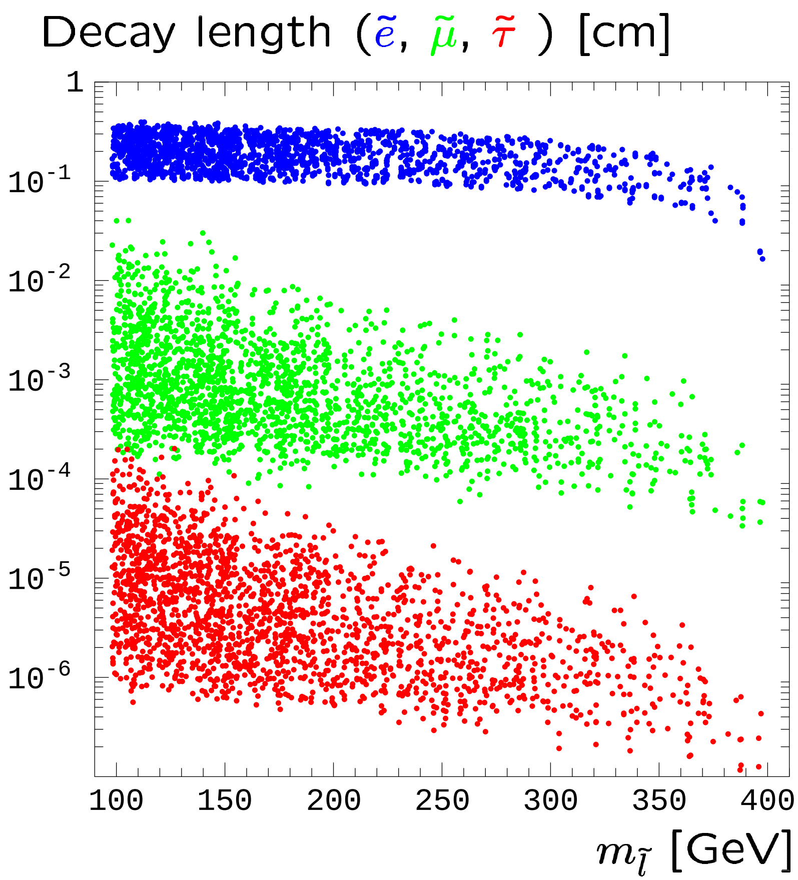
Assumptions:

- spectrum and mixing angles are known within a few percent or better
- Purely statistical error assuming 10^5 measured χ_1^0.

Parameters:

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

Charged Scalar LSP

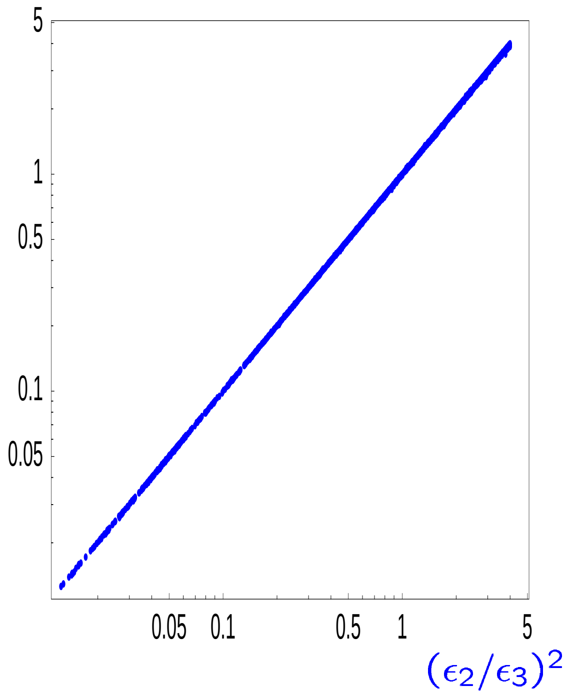


$\Rightarrow$ $\tilde{e}$, $\tilde{\mu}$, $\tilde{\tau}$ can be seperated in this model.

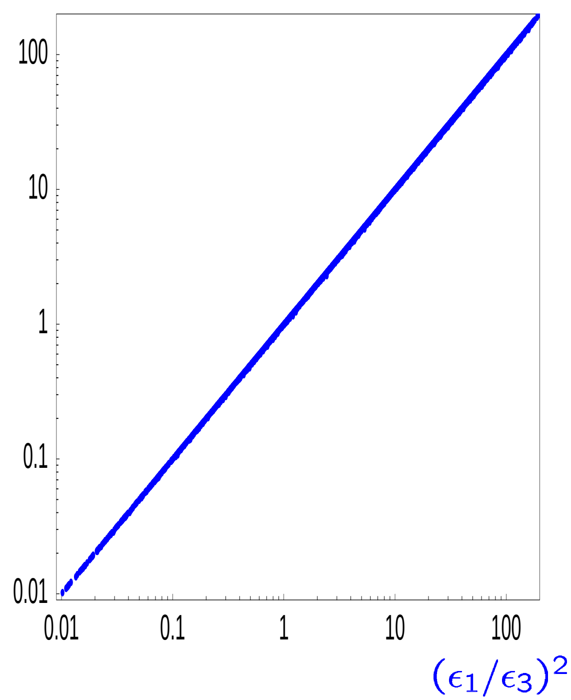
Moreover

$$\frac{\Gamma(\tilde{\tau})}{\Gamma(\tilde{\mu})} \simeq \left(\frac{Y_\tau}{Y_\mu}\right)^2$$

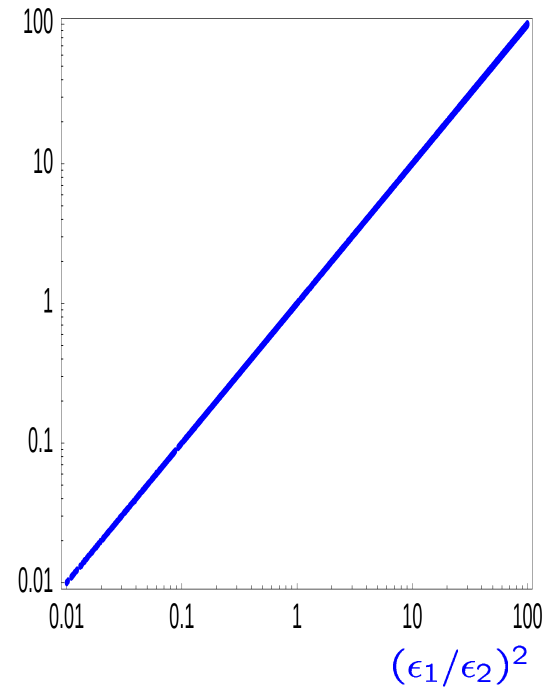
$\text{Br}(\tilde{e}_1 \to \mu\nu_i)/\ \text{Br}(\tilde{e}_1 \to \tau\nu_i)$



$\text{Br}(\tilde{\mu}_1 \to e\nu_i)/\ \text{Br}(\tilde{\mu}_1 \to \tau\nu_i)$



$\text{Br}(\tilde{\tau}_1 \to e\nu_i)/\ \text{Br}(\tilde{\tau}_1 \to \mu\nu_i)$



Cross check possible: $(\epsilon_1/\epsilon_3)^2/(\epsilon_1/\epsilon_2)^2 \equiv (\epsilon_2/\epsilon_3)^2$

$\Rightarrow$ Measure 2 ratios, 3rd is fixed.

Comments & Summary

- Solution to ν problems imply:
  $BR(\tilde{\chi}_1^0 \to \sum_{i,j,k} \nu_i \nu_j \nu_k) < 10\%$; $BR(\tilde{\chi}_1^0 \to \nu_k \gamma) < 10^{-5}\%$
  $BR(\tilde{\nu}_i \to \sum_{j,k} \nu_j \nu_k) < 1\%$
- It can be shown, that all SUSY particles show these correlations if they are LSP
- Potential problem: the Gravitino, because it lives too long (e.g. GMSB); Solution: the NLSP decays R-parity violating with O(10%), study correlations of NLSP