Current constraints on SUSY parameters from LFV searches in τ decays

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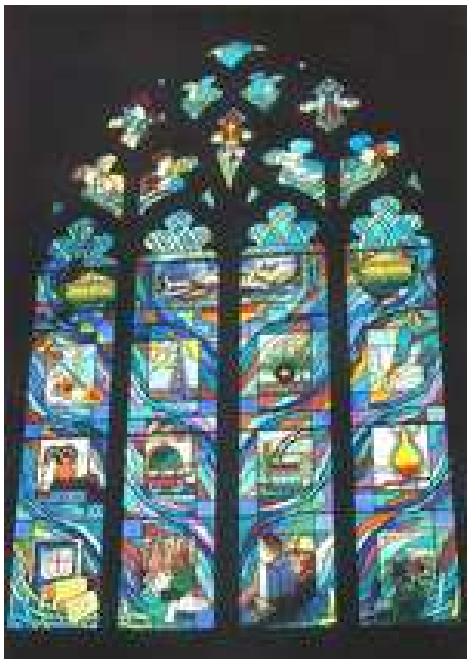
July 19, 2005



- Motivation
- Input to the comparison
- Results for mSUGRA with heavy right-handed neutrino
- Results for mSUGRA extended with off-diagonal elements
- Outlook

Motivation

- Many searches of supersymmetric contributions are being performed at current experiments. Among them are rare B decays, lepton flavor violation in τ decays, precision test of Standard Model
- Large work is being done by SUSY phenomenologists to prepare for LHC/ILC (E.g. SPA, SUSY Les Houches Accord). Low energy observables are being neglected.
- Lepton flavor violation is claimed to be significantly enhanced by SUSY. However, usual SUSY models to be compared to data (mSUGRA, GMSB, AMSB) are flavor blind. The alternatives are mSUGRA with heavy right-handed neutrinos and SU(5).
- Need to consider all data simultaneously - LFV, LEP searches, cold dark matter, neutrino mixing, etc.

Conclude on validity of SUSY with low energy observables

Theory ingredients

- Calculate SUSY spectrum at m_{GUT} and RGE to weak scale with SPheno
- Lepton flavor violation in tau, muon and Z decays follows Brignole and Rossi hep-ph/0404211, based on general unconstrained MSSM. Neglect cross-contribution of $\tau - \mu$, $\tau - e$ and $\mu - e$ mixing
- Cold dark matter density $\Omega_{CDM}h^2$ is estimated with Micromegas
- MSSM contribution to muon magnetic anomalous moment a_μ is as in hep-ph/0404211, taking into account LFV
- $\Delta\rho$ and $\mathcal{B}(b \to s\gamma)$ are taken from SPheno (not yet very precise calculation)
- comparison with data is done for grid of SUSY parameters

Experimental data

90% confidence limits:

$\mathcal{B}(\tau \to \mu\gamma)$	$< 6.8 \cdot 10^{-8}$	*BABAR*
$\mathcal{B}(\tau \to e\gamma)$	$< 1.1 \cdot 10^{-7}$	preliminary *BABAR* (talk by H.Hadavand)
$\mathcal{B}(\tau \to \ell\ell\ell)$	$< 0.7 - 2 \cdot 10^{-7}$	combined *BABAR* and Belle
$\mathcal{B}(\tau \to \ell\rho, \ell\eta, \ell\eta')$	$1 - 5 \cdot 10^{-7}$	*BABAR* or Belle
$\mathcal{B}(\mu \to e\gamma)$	$< 1.2 \cdot 10^{-11}$	PDG2004
$\mathcal{B}(\mu \to eee)$	$< 1.0 \cdot 10^{-12}$	PDG2004
$\Omega_{CDM} h^2$	< 0.129	WMAP
a_μ	$\in [0, 40 \cdot 10^{-9}]$	g-2 with a_μ^{hadr} from $e^+e^- \to \pi^+\pi^-$, not neglecting τ data
$\Delta\rho$	$\in [-0.0022, 0.0017]$	3σ, PDG2004
$\mathcal{B}(b \to s\gamma)$	$\in [2.2 \cdot 10^{-4}, 4.8 \cdot 10^{-4}]$	add 30% errors for NLO

mSugra with heavy right handed neutrinos (mSugraNuR)

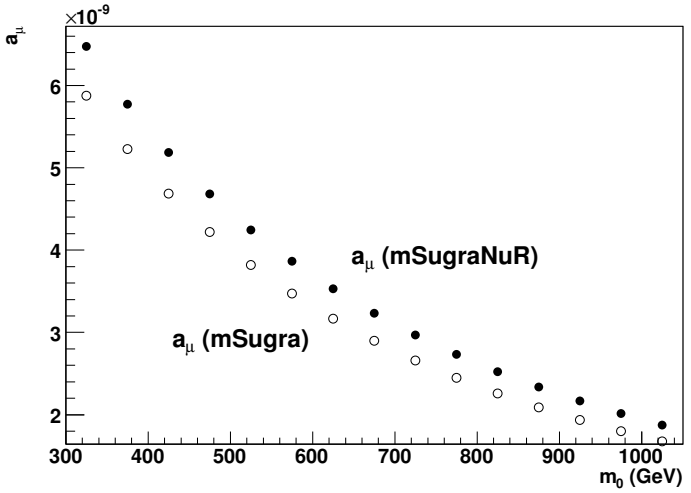
Relevant part of Lagrangian

$$\mathcal{L} = Y_\nu L \tilde{H}_2 N_R + Y_\ell L \tilde{H}_1 E - M^2_{\tilde{L}} \tilde{L}^* \tilde{L} - M^2_{\tilde{E}} \tilde{E}^* \tilde{E} - A_\ell \tilde{L} H_1 \tilde{E}^* - \mu \tilde{H}_1 \tilde{H}_2 - B\mu H_1 H_2 + h.c.$$

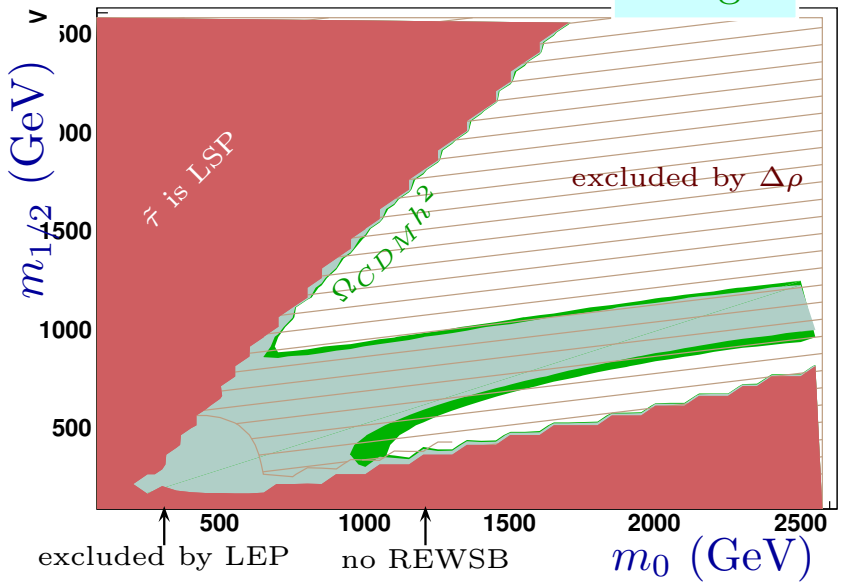
- gaugino mass parameter: $M_j(m_{GUT}) = m_{1/2}$
- scalar mass parameter: $M_i^2(m_{GUT}) = m_0^2$
- trilinear couplings: $A_i(m_{GUT}) = Y_i(m_{GUT}) \cdot A_0$
- $Y_\nu = V_R V_{MNS}$ where $V_{R_{ii}}(m_{\nu_R}) = \sqrt{2 m_{\nu_i} m_{\nu_R}}/v_2$ (as suggested by Hisano *et al.*), V_{MNS} is neutrino mixing matrix with normal hierarchy, taken from the best fit to data. $m_{\nu_R} = 5 \cdot 10^{14}$. $\Theta_{13} = 0$, $\delta = 0$
- Sign μ : positive μ is favored by g-2 data

mSugra and mSugraNuR

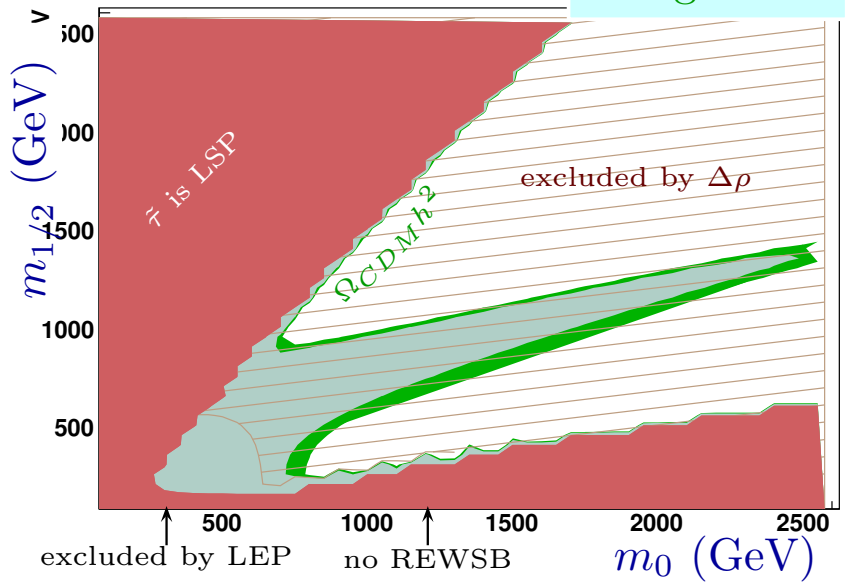
- a_μ is sensitive to off-diagonal $M^2_{\tilde{L}}$ and $M^2_{\tilde{E}}$
- $\Omega_{CDM}h^2$, $\Delta\rho$ slightly depend on N



mSugra

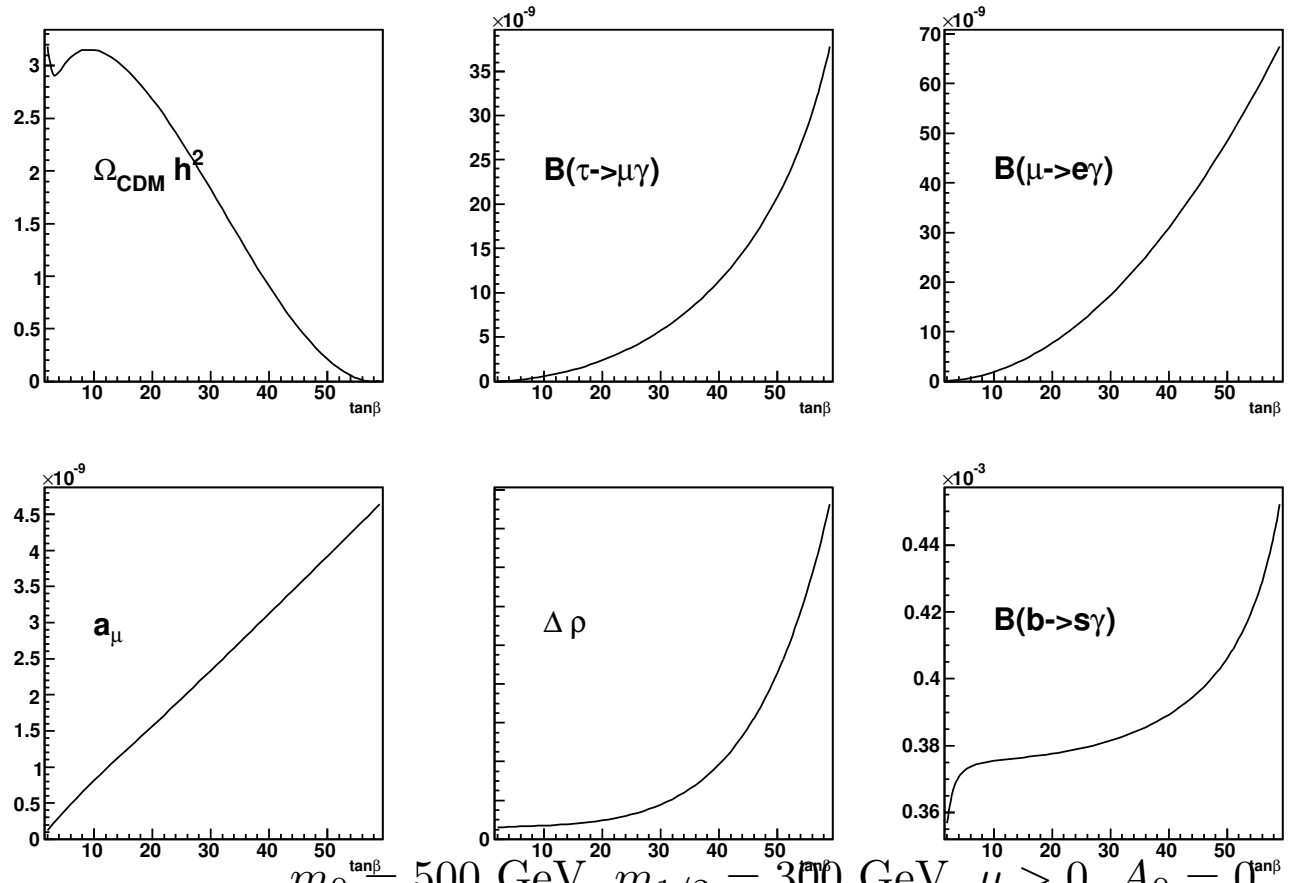


mSugraNuR



$\tan\beta = 55, A_0 = 0, \mu > 0$

mSugraNuR: Dependence on $\tan\beta$



$m_0 = 500$ GeV, $m_{1/2} = 300$ GeV, $\mu > 0$, $A_0 = 0$

the larger $\tan\beta$ the smaller $\Omega_{CDM}h^2$ and the larger LFV.

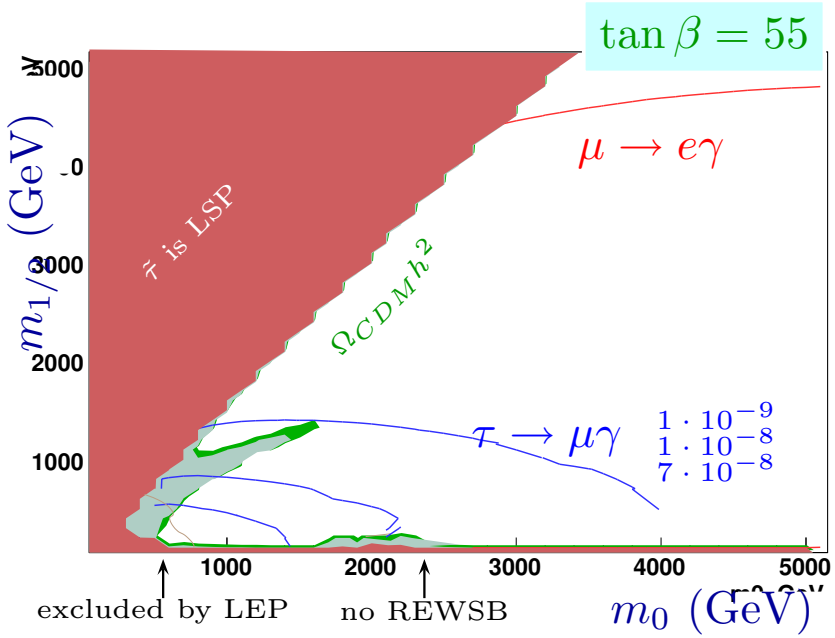
a_μ is small and does not favor g-2 + $e^+e^- \to \pi^+\pi^-$ data $(25.2 \pm 9.2)10^{-9}$, $b \to s\gamma$ deviation from SM is small

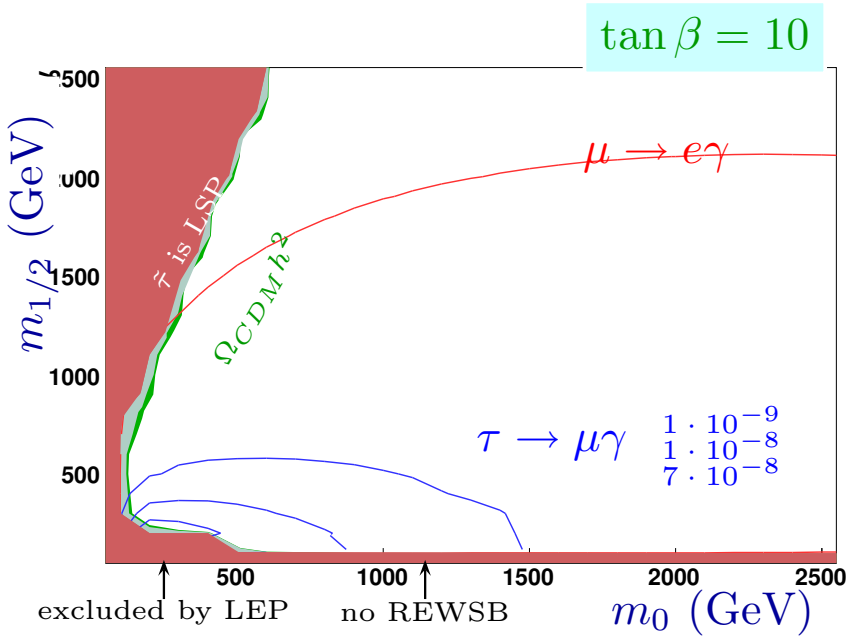
mSugraNuR: Exclusion plots for $\tan\beta = 55, 40, 10$

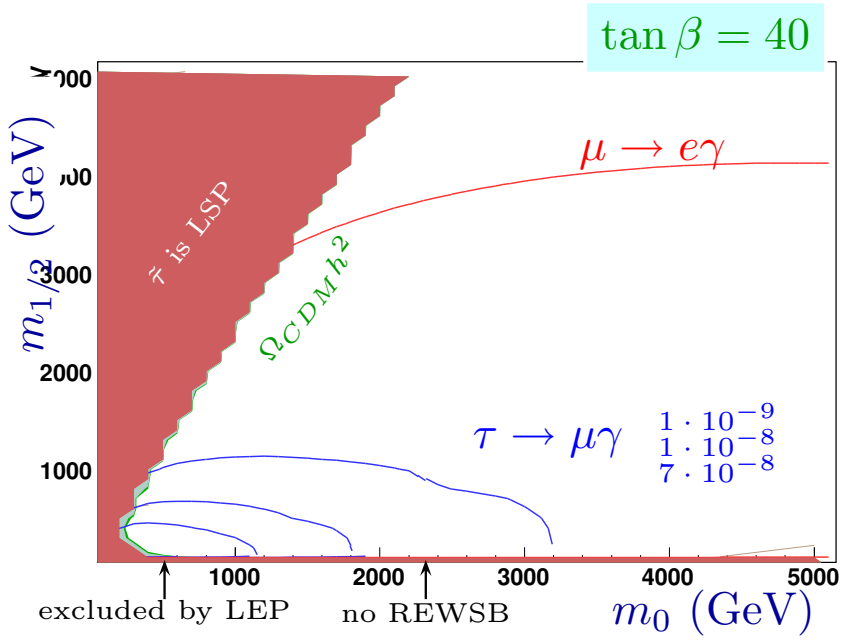
90% CL, $A_0 = 0$, $\mu > 0$

LFV excludes areas of *small* $m_{1/2}$ and *small* m_0.

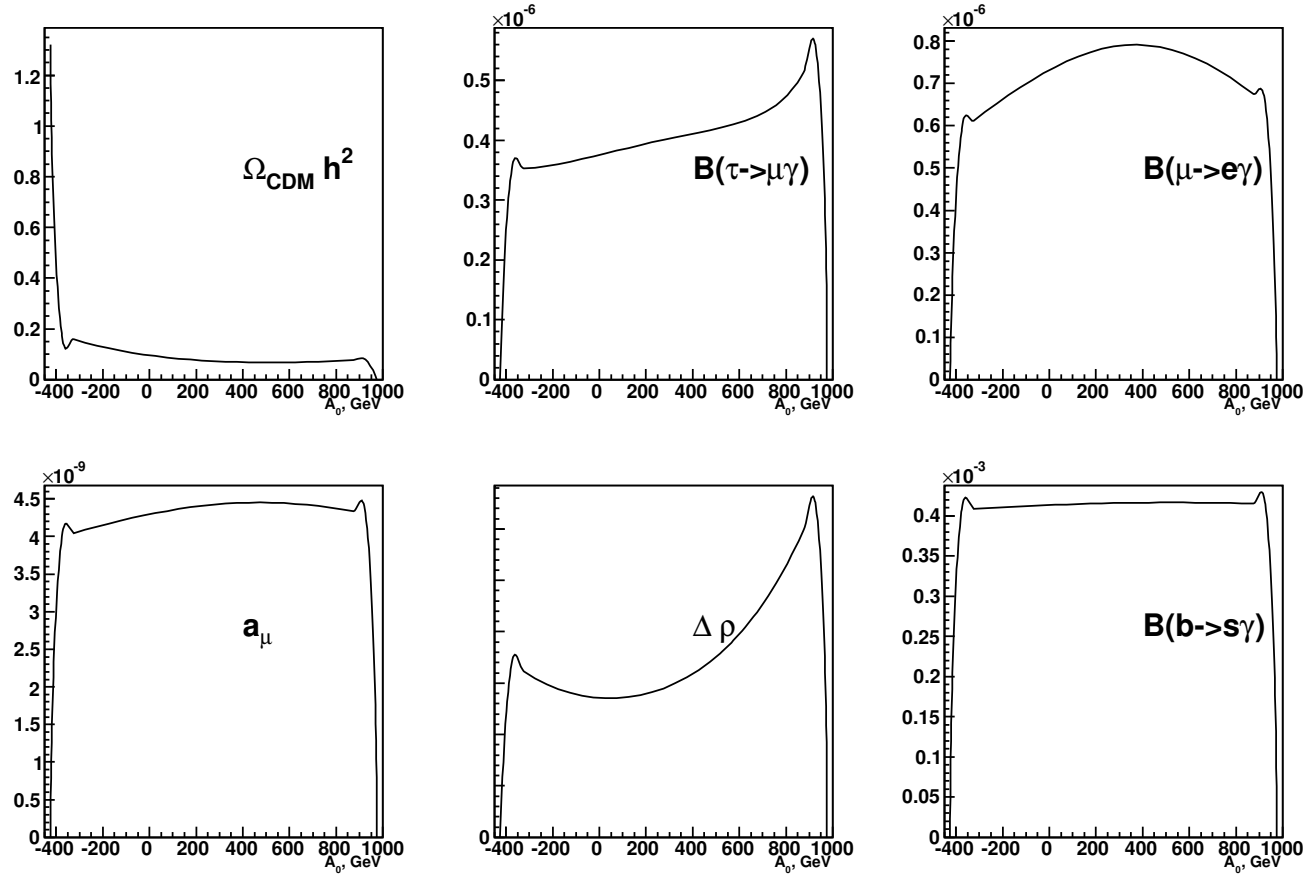
LFV together with $\Omega_{CDM}h^2$ and $\Delta\rho$ excludes practically complete range







mSugraNuR: Dependence on trilinear constant A_0



$m_0 = 500$ GeV, $m_{1/2} = 300$ GeV, $\mu > 0$, $\tan\beta = 55$

for $A_0 < -400$ GeV and $A_0 > 1000$ GeV $M^2_{\tilde{L}}(2,3), M^2_{\tilde{L}}(1,2) > M^2_{\tilde{L}}(i,i)$

mSugraNuR: Correlation between different LFV processes

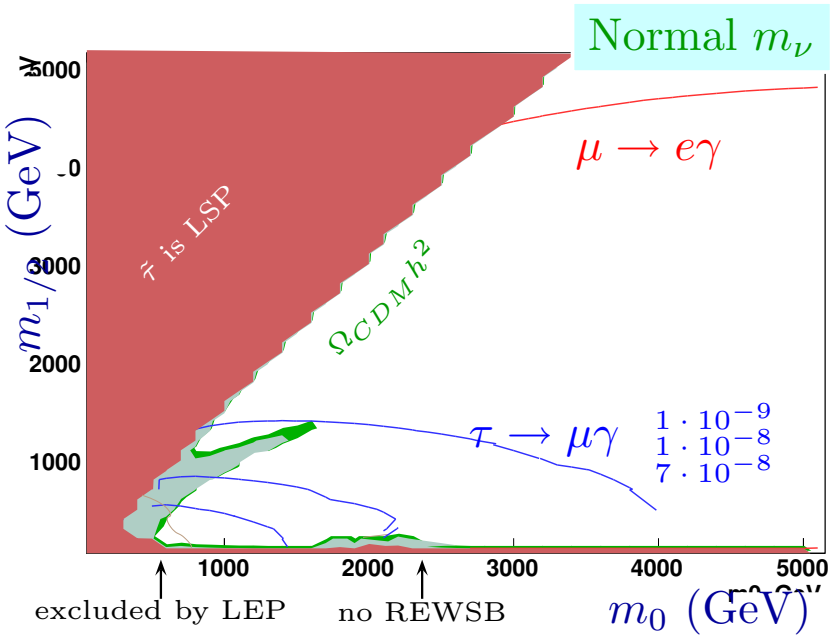
- Given best fit neutrino data and *normal* m_ν hierarchy
  $\mathcal{B}(\tau \to \mu\gamma) \sim \mathcal{B}(\mu \to e\gamma) >> \mathcal{B}(\tau \to e\gamma)$ for most range of parameters. Therefore current upper limits of $\mathcal{B}(\mu \to e\gamma)$ provides stringiest constraints.
  In case of *inverted* m_ν hierarchy $\mathcal{B}(\tau \to \mu\gamma)$ can be order of magnitude larger or smaller than $\mathcal{B}(\mu \to e\gamma)$, while $\mathcal{B}(\tau \to e\gamma)$ is significantly larger than both. →

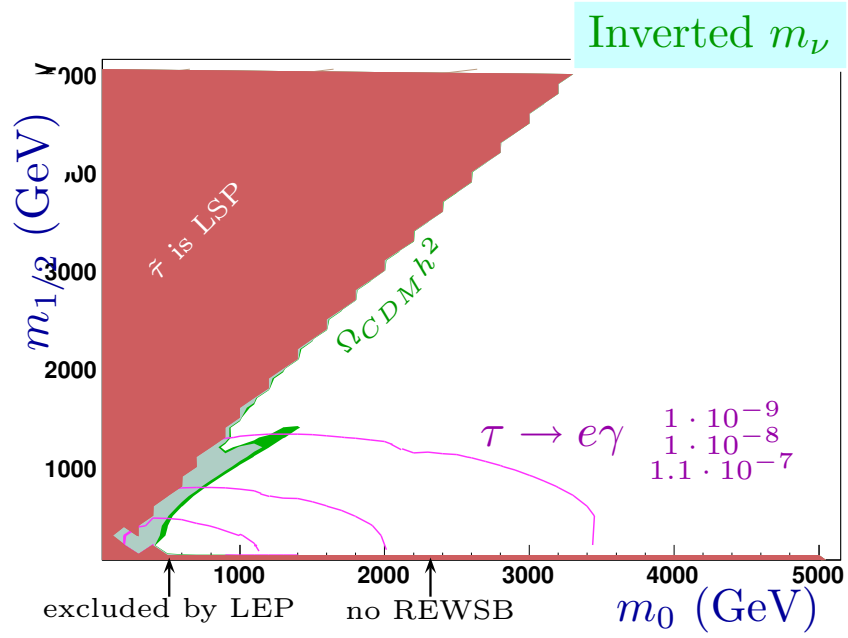
- $\mathcal{B}(\tau \to \mu\gamma)$ can be much larger or much smaller than $\mathcal{B}(\tau \to e\gamma)$

- For the set of parameters scanned
  $\mathcal{B}(\tau \to \mu\gamma) >> \mathcal{B}(\tau \to \mu X, X \neq \gamma)$ and
  $\mathcal{B}(\tau \to e\gamma) >> \mathcal{B}(\tau \to eX, X \neq \gamma)$

- $\mathcal{B}(Z \to \ell\tau) \sim 10^{-12}$ not yet reachable by experiment

mSugraNuR: Neutrino hierarchy

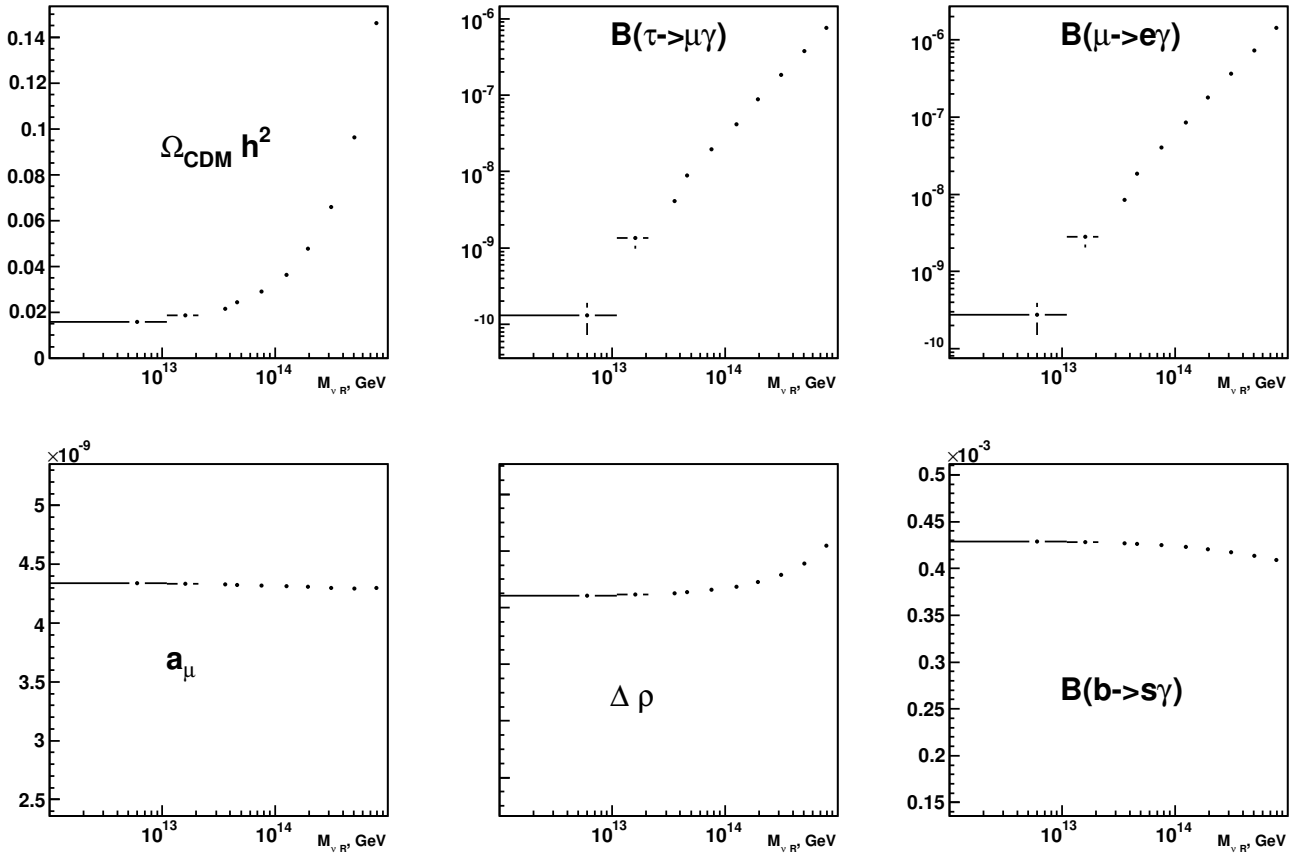




scale of m_0, $m_{1/2}$ is different from previous plot

variation of neutrino mixing parameters (V_{MNS}, m_ν) within experimental uncertainties results in $\sim 30\%$ variation of LFV

mSugraNuR: Dependence on M_{ν_R}

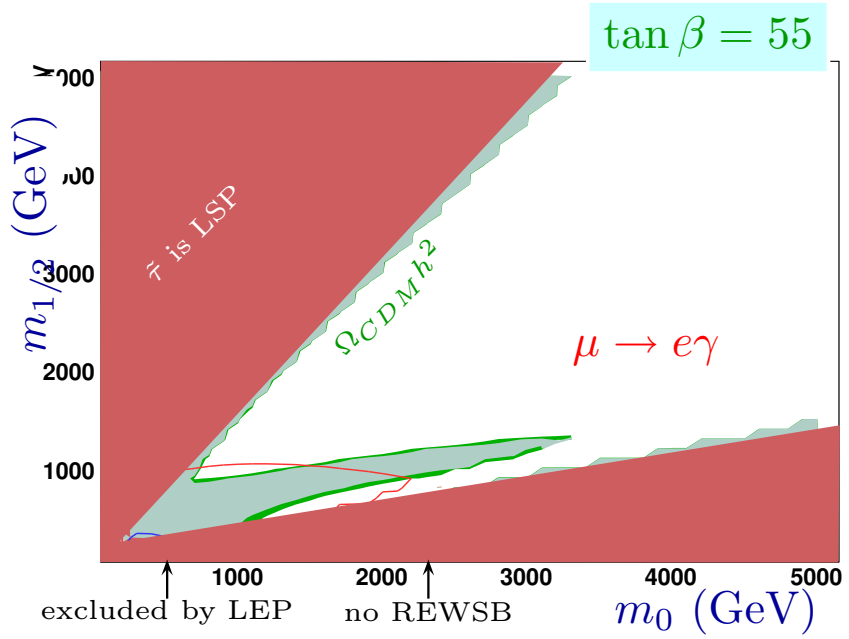


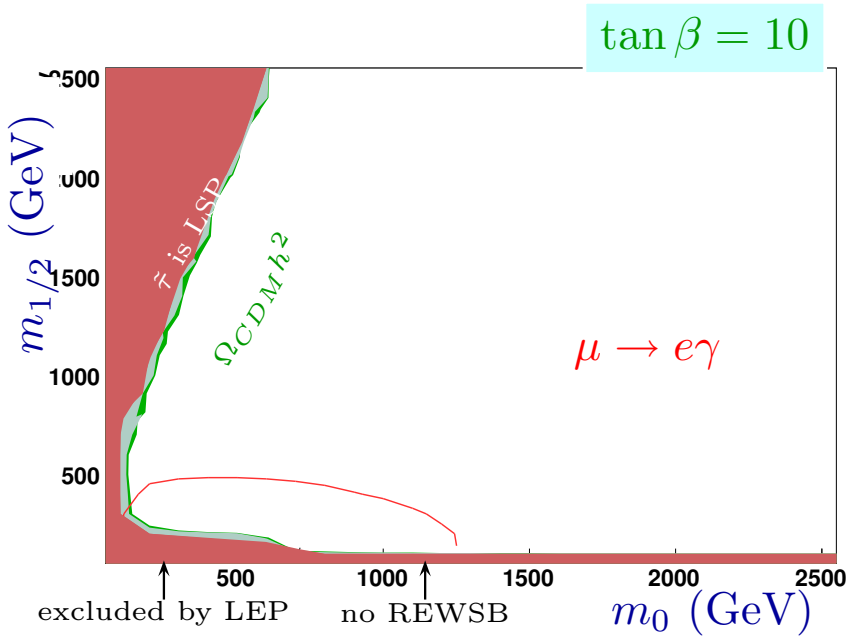
$m_0 = 500$ GeV, $m_{1/2} = 300$ GeV, $\mu > 0$, $A_0 = 0$, $\tan\beta = 55$

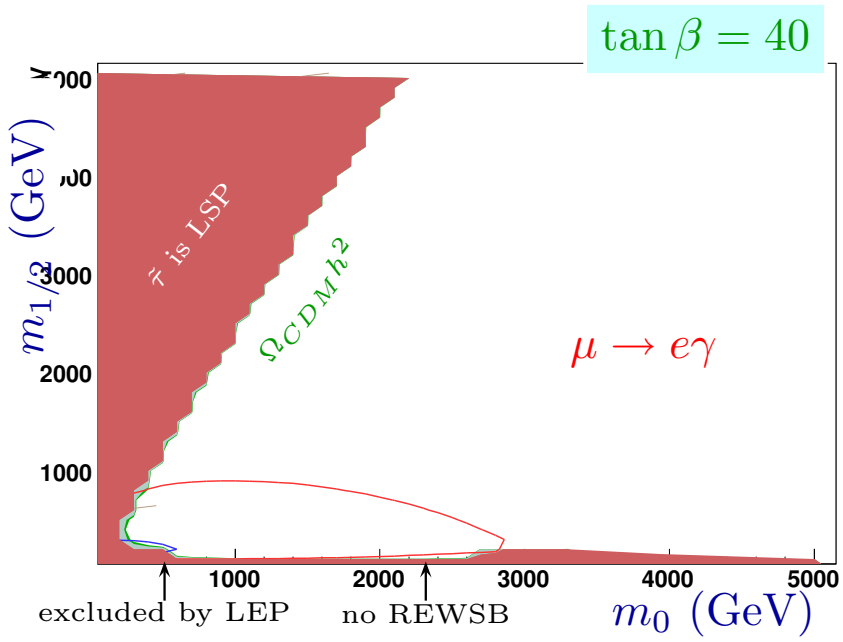
mSugraNuR: Exclusion plots for $m_{\nu_R} = 10^{13}$

90% CL, $m_{\nu_R} = 1 \cdot 10^{13}$, $A_0 = 0$

the constraints are weaker for smaller m_{ν_R}, but still quite exclusive







mSugraNuR summary

- LFV rates can be significant in mSugra with heavy right handed neutrinos
- LFV excludes area of small m_0 and small $m_{1/2}$. Together with $\Omega_{CDM}h^2$ and $\Delta\rho$ it excludes very large range of parameters.
- LFV is very sensitive to m_{ν_R}, m_ν and to neutrino mixing angles.
- $\mathcal{B}(\mu \to e\gamma$ provides strongest LFV limits in case of normal neutrino hierarchy, while $\mathcal{B}(\tau \to e\gamma)$ is critical for inverted neutrino hierarchy.

mSugra with off-diagonal elements

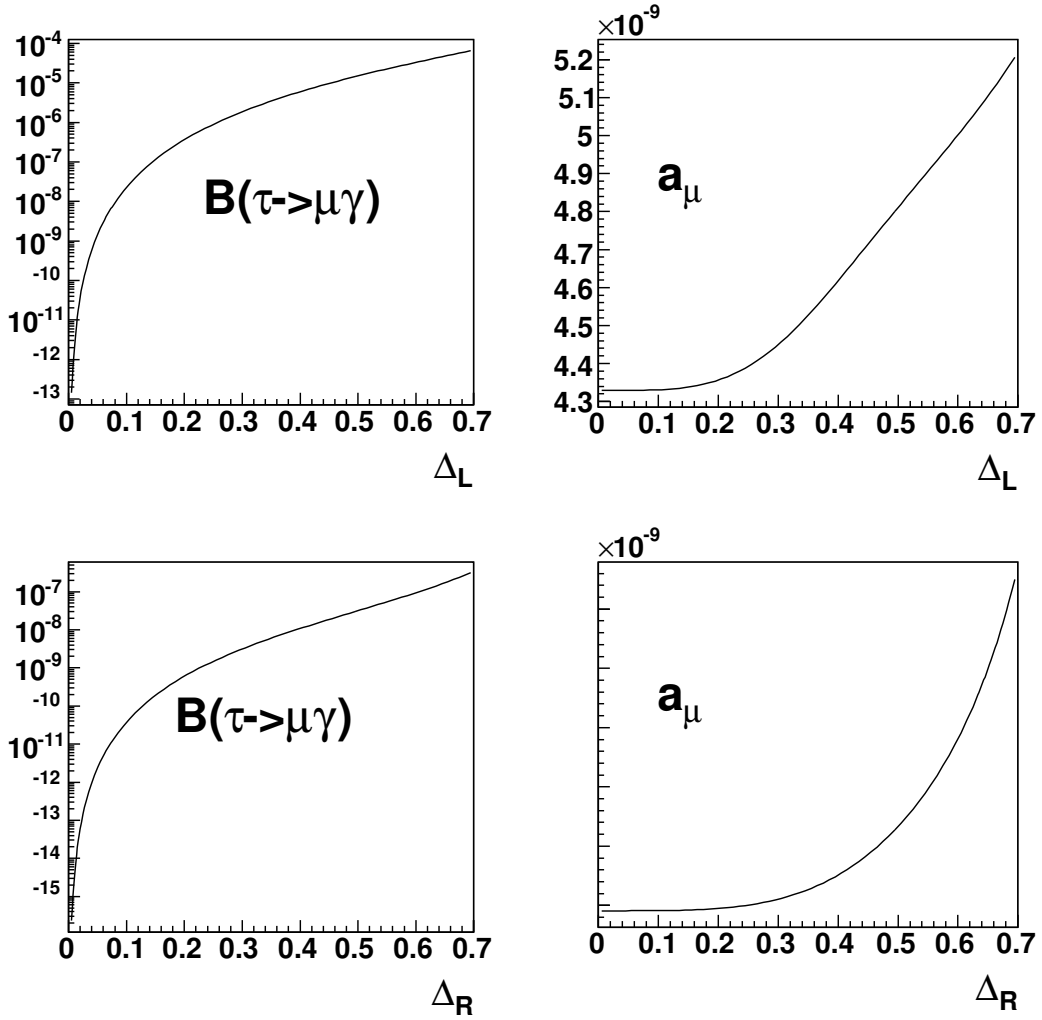
Relevant part of Lagrangian:

$$\mathcal{L} = Y_\ell L \tilde{H}_1 E - M^2_{\tilde{L}} \tilde{L}^* \tilde{L} - M^2_{\tilde{E}} \tilde{E}^* \tilde{E} - A_\ell \tilde{L} H_1 \tilde{E}^* - \mu \tilde{H}_1 \tilde{H}_2 - B\mu H_1 H_2 + h.c.$$

- gaugino mass parameter: $M_j(m_{GUT}) = m_{1/2}$
- scalar mass parameter: $M_i^2(m_{GUT}) = m_0^2$
- trilinear couplings: $A_i(m_{GUT}) = Y_i(m_{GUT}) \cdot A_0$
- Extend flavor blind mSugra with off-diagonal elements
  $M^2_{\tilde{L}}(2,3)(m_{GUT}) = \Delta^2_L m_0^2$,
  $M^2_{\tilde{E}}(2,3)(m_{GUT}) = \Delta^2_R m_0^2$
  (mixing angle is maximal) .
- Sign μ : positive μ is favored by g-2 data

Use MSSM RGE (no right-handed neutrinos) to estimate parameters at weak scale. The plots shown are for $\tau \to \mu X$ only, but the conclusions are applicable to $\mu \to eX$ and $\tau \to eX$ as well.

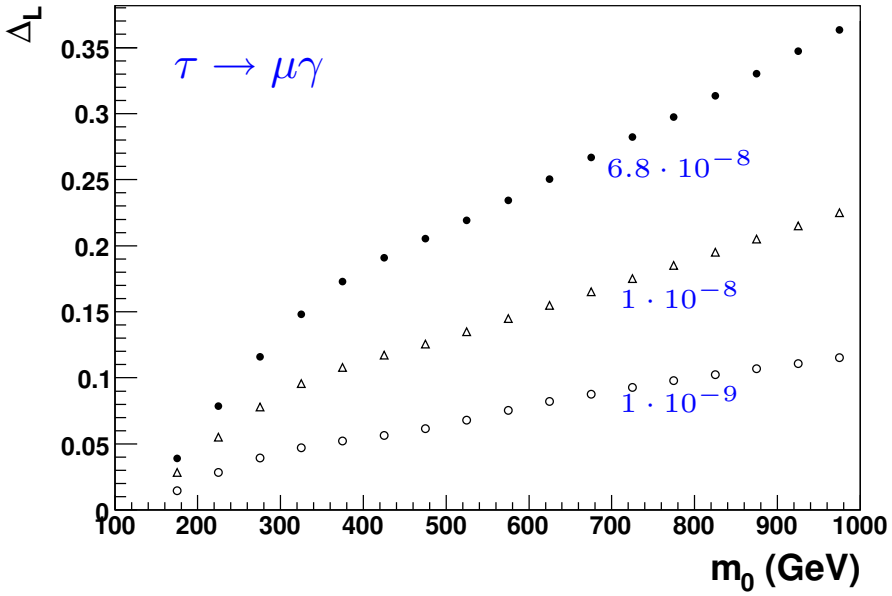
mSugraNuR: Dependence on Δ_L, Δ_R

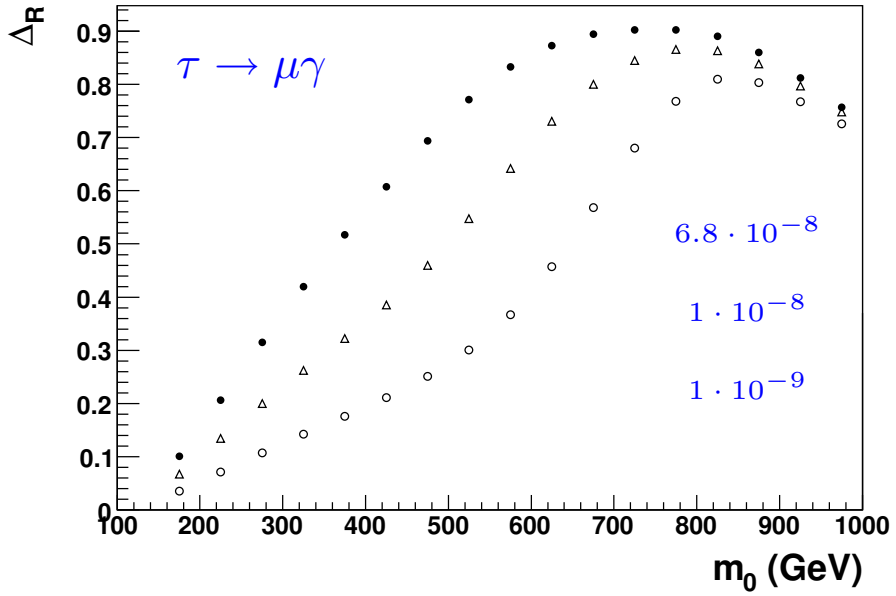


$m_0 = 500$ GeV, $m_{1/2} = 300$ GeV, $\mu > 0$, $A_0 = 0$

Constraints on Δ_L and Δ_R from $\mathcal{B}(\tau \to \mu\gamma)$

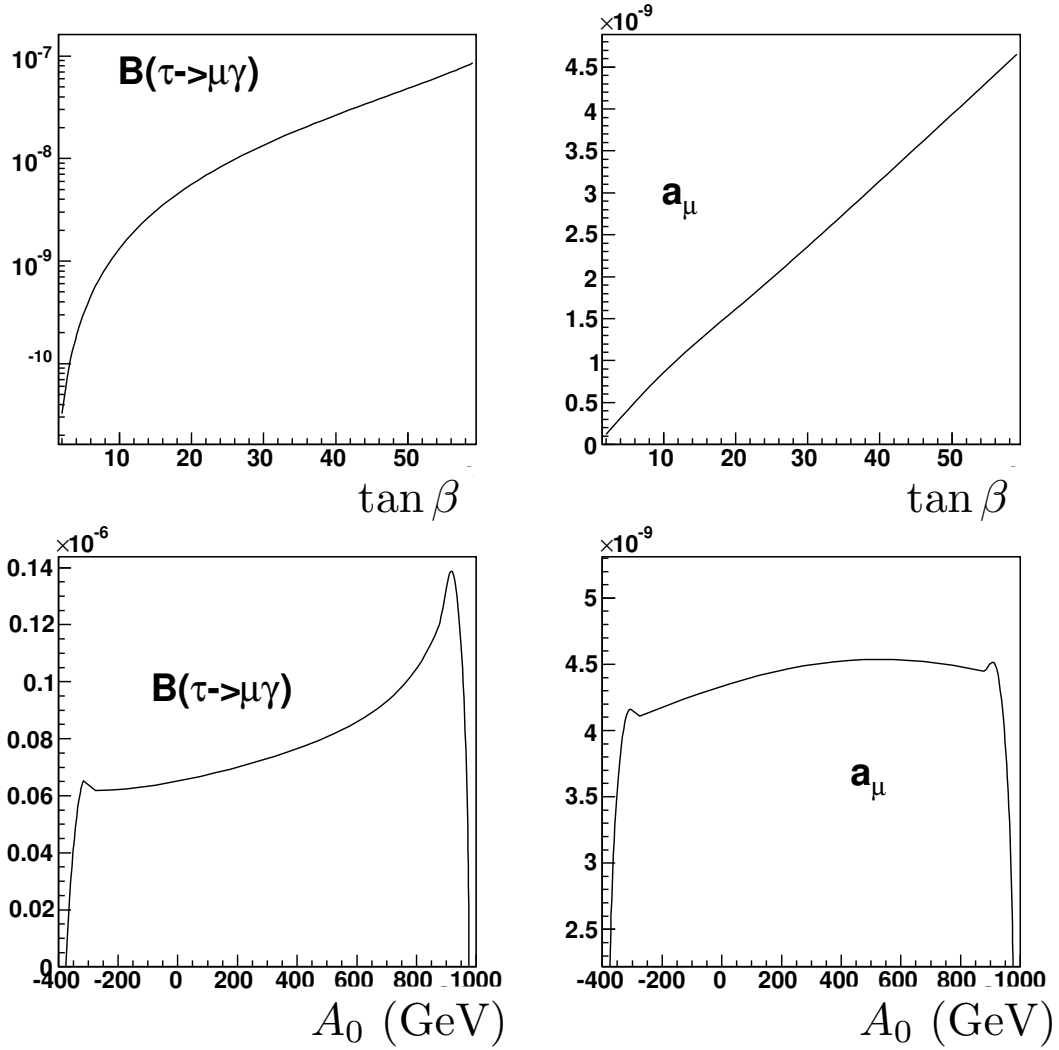
$m_{1/2} = 100 + 0.8 \cdot m_0$ (within favorable $\Omega_{CDM}h^2$ region)
$\tan\beta = 55$, $\mu > 0$, $A_0 = 0$





Strong constrains on Δ_L, less strong on Δ_R

mSugraNuR: Dependence on $\tan\beta$ and on A_0



$m_0 = 500$ GeV, $m_{1/2} = 300$ GeV, $\mu > 0$, $A_0 = 0$

similar to mSugraNuR, but different amplitude

Conclusions and Outlook

- It is important to consider LFV process/low energy observables to validate SUSY

- mSugraNuR:
  - a_μ and $\Omega_{CDM}h^2$ are sensitive to presence of heavy right-handed neutrinos
  - a_μ is small ($\sim 4 \cdot 10^{-9}$)
  - large $\tan\beta$ results in small $\Omega_{CDM}h^2$ and large LFV
  - given normal m_ν hierarchy $\mathcal{B}(\mu \to e\gamma)$ excludes large range of SUSY parameters. For inverted m_ν hierarchy $\mathcal{B}(\tau \to e\gamma)$ is very strict.
  - LFV strongly depends on m_{ν_R} and less strongly on V_{MNS}

- mSugra with off-diagonal elements:
  - both $\mathcal{B}(\tau \to \mu\gamma)$ and a_μ are very sensitive to off-diagonal $\Delta_L(2,3)$ and $\Delta_R(2,3)$
  - $\mathcal{B}(\ell_i \to \ell_j\gamma)$ strongly constrains Δ_L and less Δ_R. E.g. current constraint on $\mathcal{B}(\tau \to \mu\gamma)$ suggests that $\Delta_L < 0.4$ for full range of other parameters.
  - $\mathcal{B}(\tau \to \mu X, X \neq \gamma)$ is less restrictive than $\mathcal{B}(\tau \to \mu\gamma)$

- Analysis is in progress -
  interested to test well motivated high scale SUSY models,
  aiming to constrain SUSY parameters in *model independent* way