SUSY seesaw: neutrino masses and LFV

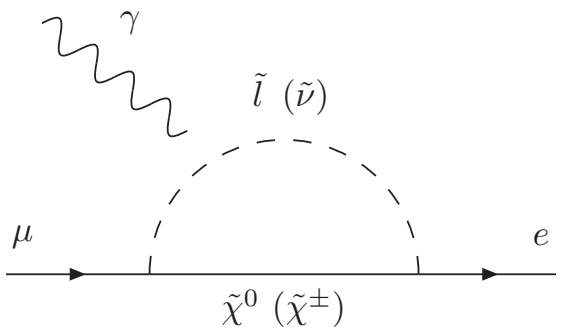
Large Y_ν, via **SUSY** loops $\Rightarrow$ sizable **slepton flavour mixing** $(l_i \not\leftrightarrow \tilde{l}_i, \tilde{\nu}_i)$

potentially **large LFV rates!**

LFV observables: sensitive probes to SUSY seesaw

If **no LFV** found $\Rightarrow$ **Restrictions** on SUSY seesaw parameters

If **LFV measured** $\Rightarrow$ **Important hints on SUSY seesaw parameters**



★ Explore these hints!

What are we feeding into the computation of all these observables?

- **BRs & CRs:** strongly sensitive to *what we don't know*

  dynamics of loop-process (scales, masses of mediators, ...)

  sources of **flavour violation** (Yukawas Y^ν, soft-breaking terms, ...)

- If **SUSY at low-energies**, eventual (partial) **reconstruction**

  of fundamental parameters ($\mathcal{L}_{\text{SUSY}}$) [post LHC, ILC, ...]

$\Rightarrow$ assume **"flavour-blind" SUSY breaking** (mSUGRA, NUHM, GMSB, etc)

- Without GUT, etc Y^ν *free parameters*

  at **low energies** comply with $\Delta m^2_{\text{atm}}, \Delta m^2_{\text{sol}}, \theta_{12}, \theta_{23}$ (and θ_{13} bound)

$\Rightarrow$ parametrise seesaw dynamics: $Y_\nu = (i/v_2)\sqrt{m_N^{\text{diag}}}\, R \sqrt{m_\nu^{\text{diag}}}\, U^\dagger_{\text{MNS}}$

$\Rightarrow$ if **BAU from leptogenesis:** **favour regimes** of m_{N_1} and $R(\theta_i)$

MEG & SUSY flavour problem??

BRs & CRs: $\underbrace{\{m_{N_i}, \theta_i, \Delta m^2_{\text{atm}}, \Delta m^2_{\text{sol}}, \theta_{12}, \theta_{23}, \theta_{13}\}}_{Y_\nu = (i/v_2)\sqrt{m_N^{\text{diag}}}\, R\, \sqrt{m_\nu^{\text{diag}}}\, U^\dagger_{\text{MNS}}} + \underbrace{\{\textbf{SUSY}\text{ masses and mixings}\}}_{\textbf{SUSY breaking scheme:}}$

flavour **blind / violating**

Higgs universality

- **No LFV $\mu \to e\gamma$ at MEG:**
  - **decoupled SUSY, cancellations, ...**
  - **non mSUGRA SUSY breaking ...**
  - θ_{13} is too **small?**
  - m_N not sufficiently **heavy?**

In what follows: **mSUGRA-like Seesaw**

LFV: sensitivity to θ_{13}

- **Sensitivity** of **LFV** to θ_{13}

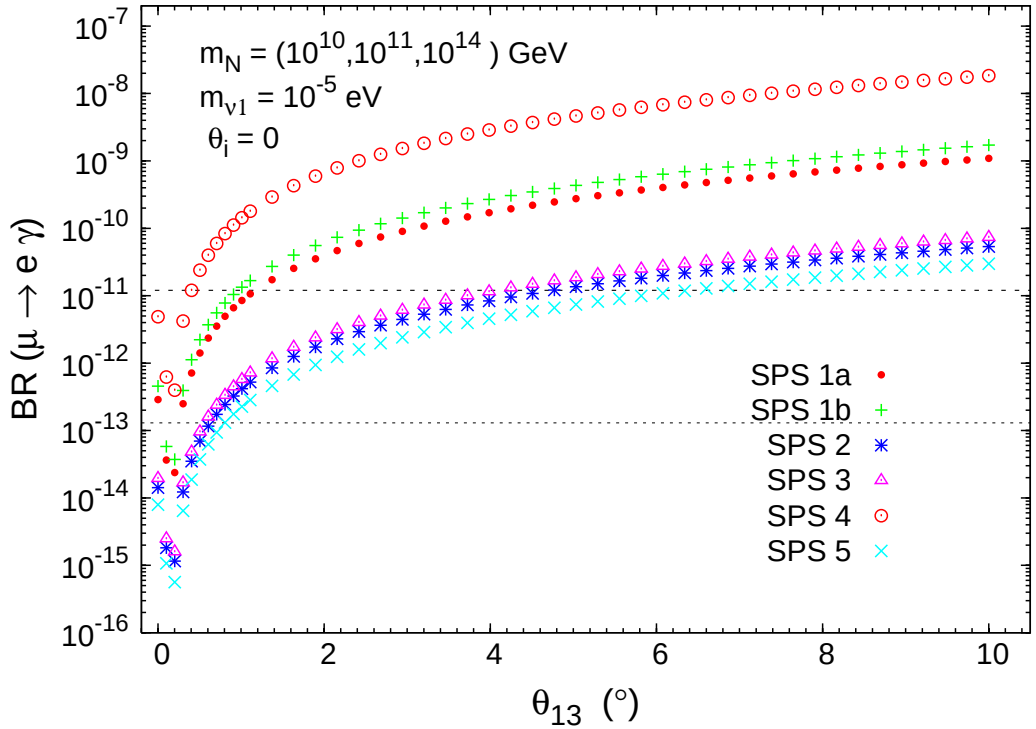
  $\boldsymbol{\theta_{13}}$ yet to be determined: $\theta_{13} \lesssim 10^\circ$!

- **BR($\mu \to e\gamma$)**: very sensitive to θ_{13}

  [cMSSM benchmark points (with $R = 1$)]

  $$\mathbf{BR}(\mu \to e\gamma) \propto m_{N_3} m_{\nu_3} c_{13}^2 \boldsymbol{s_{13}^2}$$

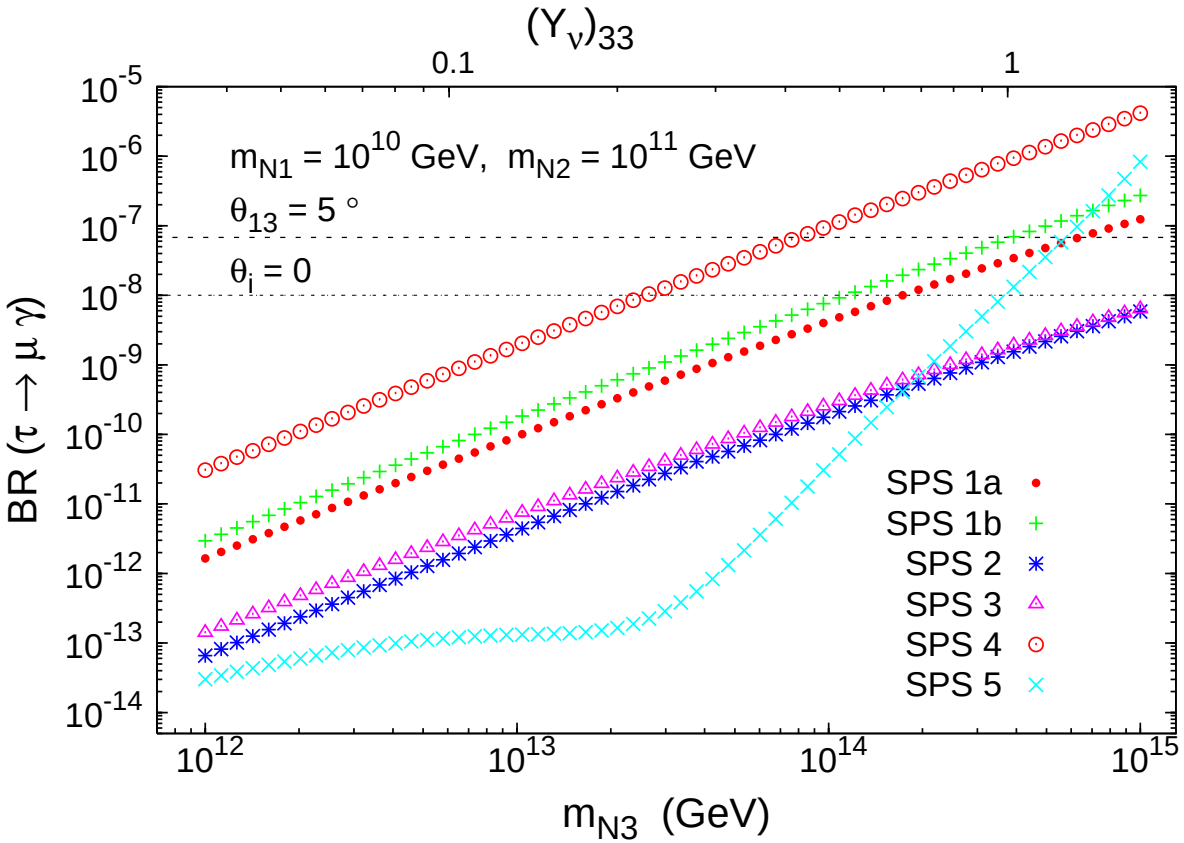
  SUSY estimates: $\theta_{13} \Rightarrow \mathcal{O}(10^5)$ factor



	$\mu \to e\gamma$	$\tau \to e\gamma$	$\tau \to \mu\gamma$	$\mu \to 3e$	$\tau \to 3e$	$\tau \to 3\mu$	$\mu - e$, Ti
θ_{13}	✔	✔	✘	✔	✔	✘	✔

- **SUSY & Seesaw scenarios:** $\theta_{13} \gtrsim 2^o$ within **MEG reach**

Large Yukawa couplings: m_{N_3}



★ m_{N_3} drives Y_ν:

hierarchical N_i, $m_D \propto \sqrt{m_N^{\text{diag}}}$

strongly **affects** BR($\tau \to \mu\,\gamma$)

and all other BRs!

★ Without predictive framework

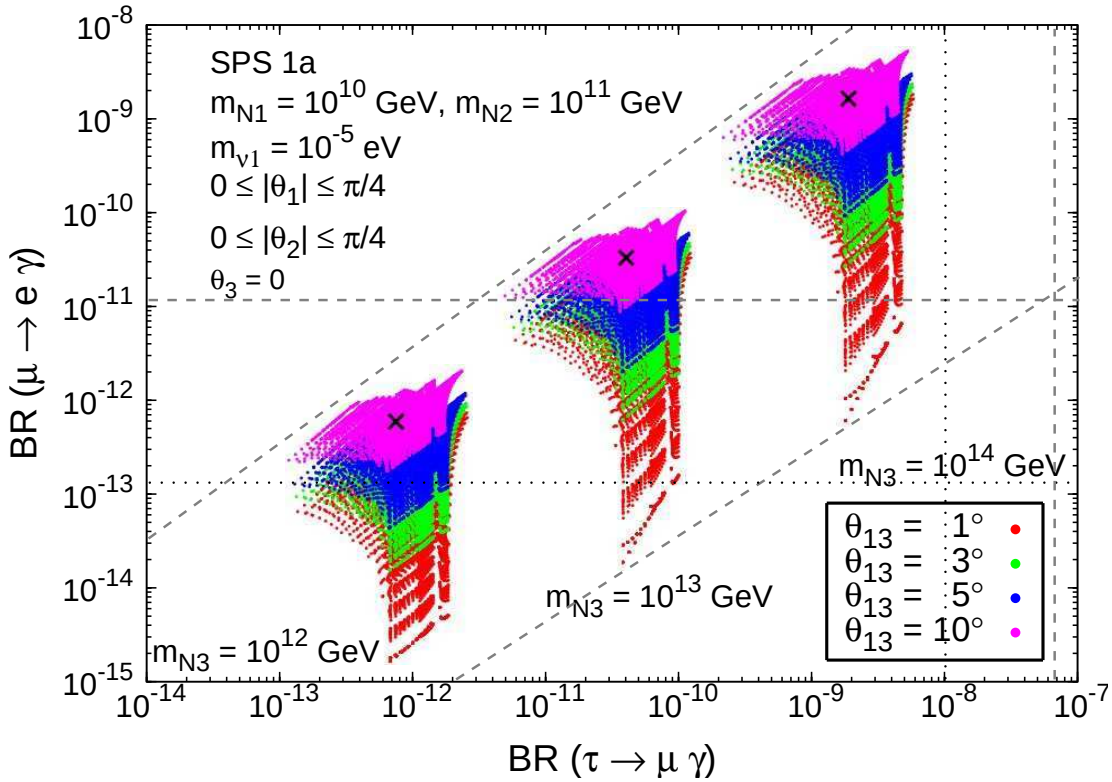
$$m_{N_3} \sim [a\,10^{10},\, b\,10^{15}] \text{ GeV}$$

(indirect lower bound - Leptogenesis)

★ SUSY seesaw scenario $\Rightarrow$ **indirect bounds** via BRs: $\begin{cases} m_{N_3} \lesssim 10^{14} \text{ GeV (SPS 4)} \\ m_{N_3} \lesssim 5 \times 10^{14} \text{ GeV (1a,1b)} \end{cases}$

Useful hints on m_{N_3} from potential BR and θ_{13} measurement!!

Impact of θ_{13} on LFV observables: hints on m_{N_3}



- ⋆ All points: viable BAU

  constraints on θ_i, $m_{N_1} > m_{N_1}^{\text{BAU}}$
- ⋆ Conclude on impact of

  allowed/excluded m_{N_3}
- ⋆ $\text{BR}(\mu \to e\,\gamma)|_{\text{MEG}} + \theta_{13} = 1°$

  $\Rightarrow$ $m_{N_3} < 3 \times 10^{12}$ **GeV**
- ⋆ $\text{BR}(\tau \to \mu\,\gamma)|_{\text{SuperB}} + \forall\,\theta_{13}$

  $\Rightarrow$ $m_{N_3} < 10^{13}$ **GeV**

Discovery of SUSY (LHC, Tevatron)

Measurement of θ_{13}

Observation of LFV τ, μ decays

$\Rightarrow$ **Window to higher scales!**

Insight into Seesaw parameters

A few open questions:

- **Disentangle sources** of **SUSY** (lepton) **flavour violation:**

  Minimal: $Y^\nu[U_{\text{MNS}}]$

  BAU via leptogenesis allowing: $Y^\nu[U_{\text{MNS}}, R(\theta_i)]$

  Soft-SUSY breaking: $m^2_{\tilde{L}ij}, m^2_{\tilde{R}ij} \neq 0$

  R-parity Violation?

- **Sensitivity of LFV** BR's to θ_{13} :

  Disentangle from θ_i effects [e.g. study of $\mu \to e\gamma$ vs $\tau \to \mu\gamma$ (joint MEG-SuperB)]

- μe **transitions:** BR vs CR

  CR **future sensitivity** $\mathcal{O}(10^{-16,-18})$

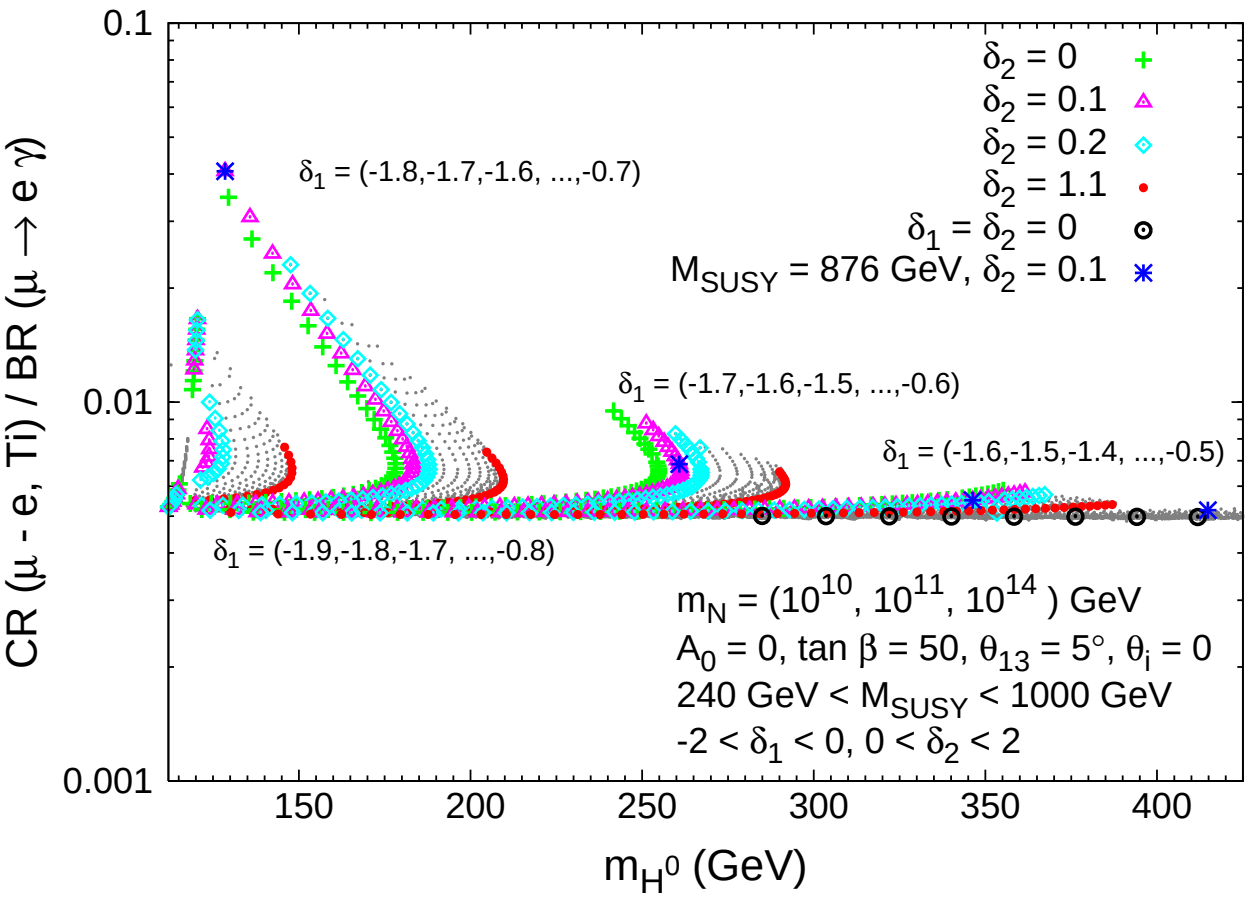
  Challenging for regimes of **suppressed** $\mu \to e\gamma$: very small θ_{13}

- LFV reflects M_{R_3} **regime:**

  Leptogenesis: hints on M_{R_1} $\Rightarrow$ Close the right-handed neutrino mass window?

CR vs BR: Hints on Soft-SUSY breaking

Address **several scenarios** of **non-universal Higgs masses** **(NUHM)**



★ **Universality**

$$M_{H_i}^2 = M_0^2 \quad \text{[CMSSM]}$$

dominant γ penguins

$\mathrm{CR}(\mu - e,\ \mathrm{Ti}) \approx 0.005\ \mathrm{BR}(\mu \to e\gamma)$

★ **Non-Universality**

$$M_{H_i}^2 = M_0^2(1+\delta_i)$$

light M_{H^0}, large $\tan\beta$

enhancement of H-penguins

$\mathrm{CR}(\mu - e,\ \mathrm{Ti}) \lesssim \mathbf{0.04}\ \mathrm{BR}(\mu \to e\gamma)$

Knowledge of SUSY scale & $\tan\beta$

Measurement of CR & BR

Comparison with th predictions

$\Rightarrow$ **Window into Higgs sector?**

Clues on SUSY breaking