Flavour in the Era of LHC

WG3 report

Martti Raidal

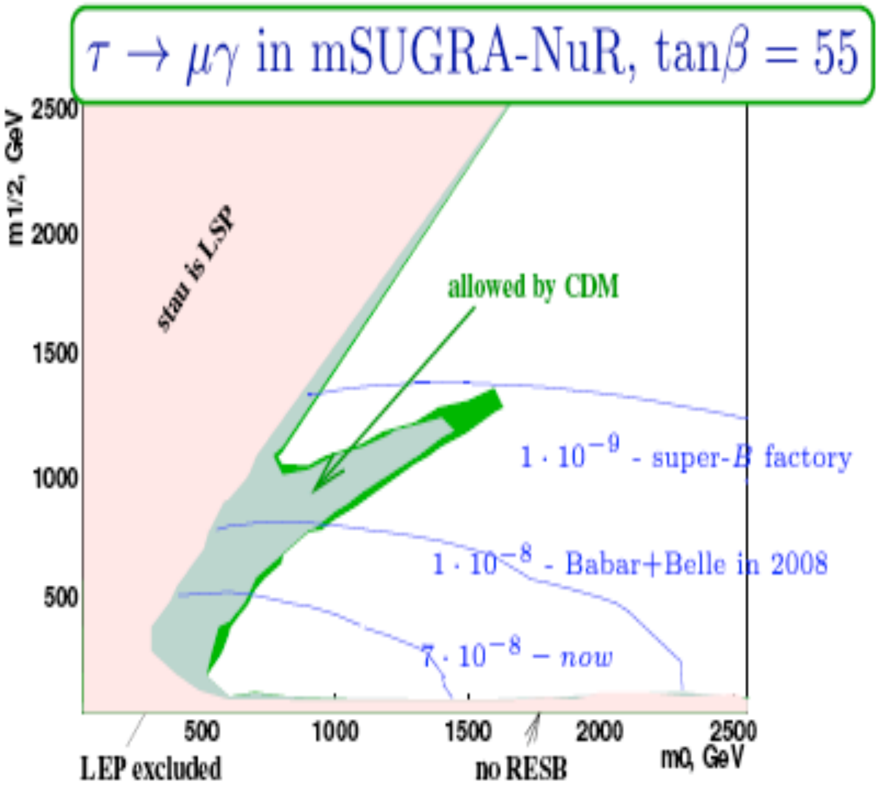
Tallinn

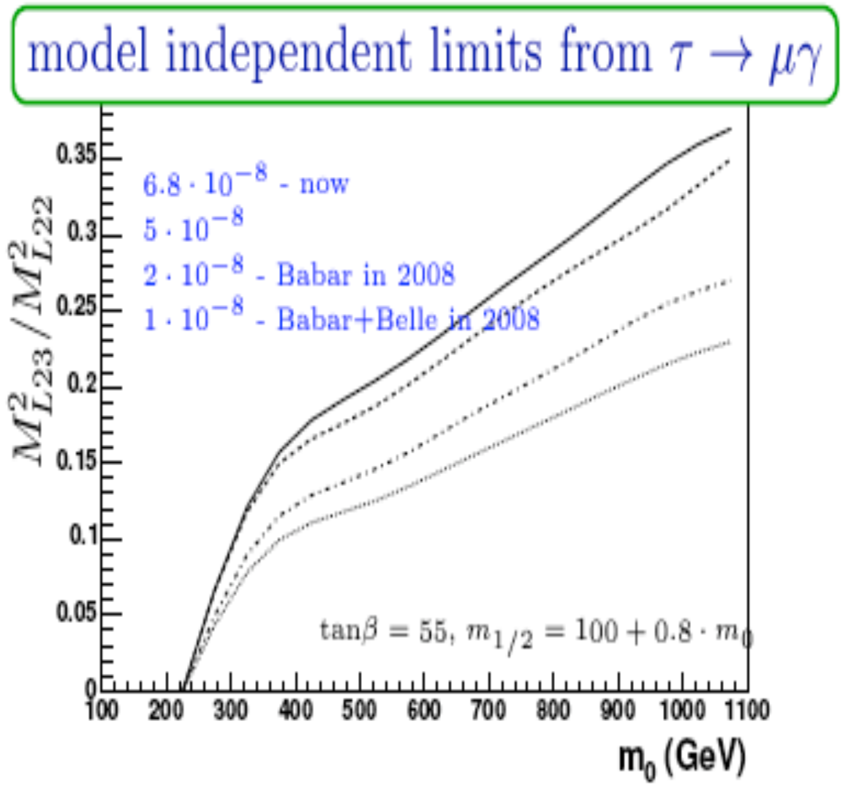
Outline

- Review of presentations
  - 4 experimental talks
  - 13 theoretical talks
- Summary of discussions

Tau LFV at BABAR

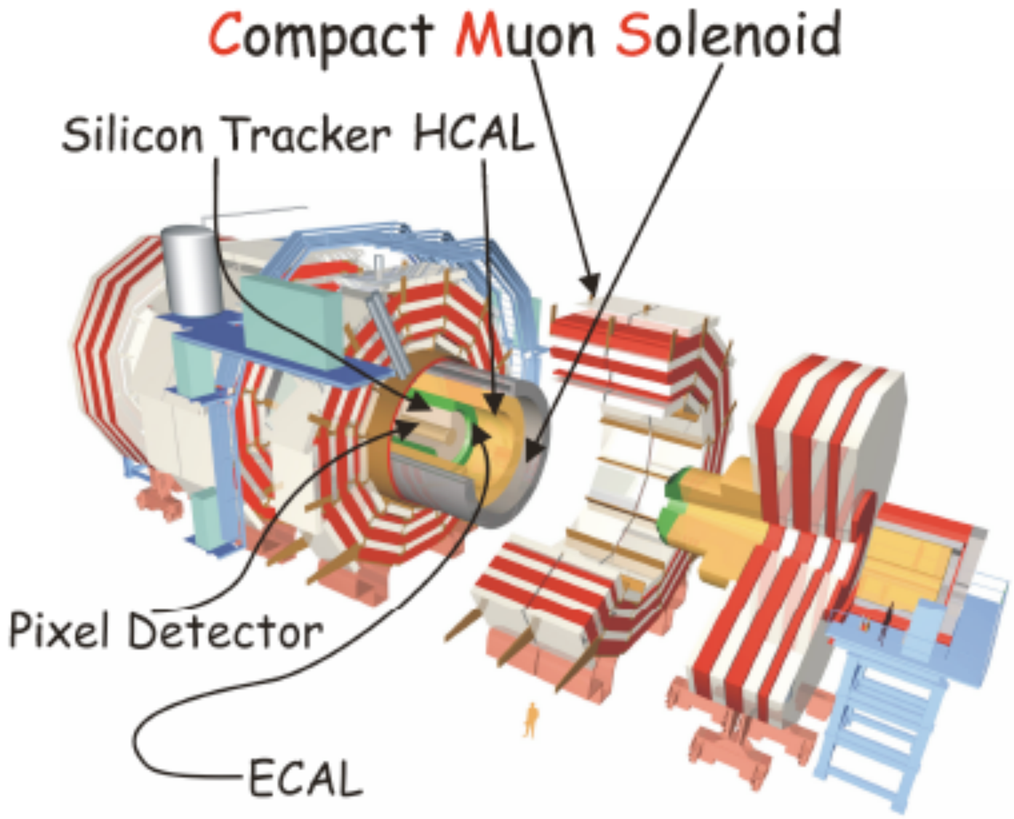
Olga Igonkina





LFV tau decays at CMS

Manuel Giffels



Older results:

CMS NOTE 2002/37
hep-ex/0210033

Expected limit:(W-Source)

- $BR(\tau \to \mu\mu\mu) = 7.0 \cdot 10^{-8}$ $(10\,fb^{-1})$
- $BR(\tau \to \mu\mu\mu) = 3.8 \cdot 10^{-8}$ $(30\,fb^{-1})$

Expected limit:(Z-Source)

- $BR(\tau \to \mu\mu\mu) = 3.4 \cdot 10^{-7}$ $(30\,fb^{-1})$

Prospects for update:

- Now a detailed detector(trigger) simulation is available
- Rare decays to be studied with higher MC statistics

Feasibility study of mu-tau conversion experiment

Alberto Lusiani

Use fixed target $\mu N \to \tau X$ conversion experiment to probe tau-related LFV?

$\mathrm{BR}(\tau \to \mu X) < 10^{-8}$ ➔ $\sigma_{\mu\to\tau} < 3.5$ ab

$1000\ \mu \to \tau$ events/year for $\sigma_{\mu\to\tau} = 1$ ab

$3{\cdot}10^{14}$ muons/s

experiment appears unfeasible because of the muon flux

- distribute muon flux over larger surface ➔ proportional increase in cost
- consider less ambitious flux of $3{\cdot}10^{11}$ muons/s/m^2

Tau EDM

Eugenio Pauloni

A super B-factory is also a superb τ factory!

Luminosity

$$\mathcal{L} \sim 10^{36}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$$

$$\sigma\left(e^+e^- \to \tau^+\tau^- \;@\; \Upsilon(4S)\right) \sim 1\,\mathrm{nb}$$

$$f_{\mathrm{prod.}} \sim 1\,\mathrm{KHz} \Rightarrow \frac{10\ \mathrm{billions}\ \tau^+\tau^-}{\mathrm{Snowmass\,Year}}$$

- measure the mean value of the *CP* odd observables:

$$O_1 = \hat{\mathbf{p}}_+ \cdot (\mathbf{q}_+ \times \mathbf{q}_-) \propto \Re(d_\tau) \quad O_2 = \hat{\mathbf{p}}_+ \cdot (\mathbf{q}_+ + \mathbf{q}_-) \propto \Im(d_\tau)$$

PDG 2004 e, μ

$$d_e = (0.07 \pm 0.07) \times 10^{-26} e\,\mathrm{cm}$$

$$d_m u = (3.7 \quad \pm 3.4) \times 10^{-19} e\,\mathrm{cm}$$

PDG 2004 τ

$$\Re(d_\tau) = (-0.22 \,\mathrm{to}\, 0.45) \times 10^{-16}\,\mathrm{cm}$$

$$\Im(d_\tau) = (-0.25 \,\mathrm{to}\, 0.01) \times 10^{-16}\,\mathrm{cm}$$

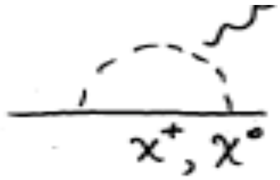
- With a sample in excess of $10^{10}\tau$ pairs it seems possible to enter in the very high precision realm $d_\tau \sim 10^{-20} e\,\mathrm{cm}$

EDM correlations in SUSY

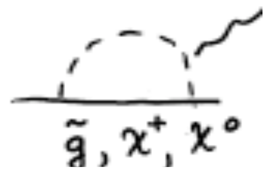
Oleg Lebedev

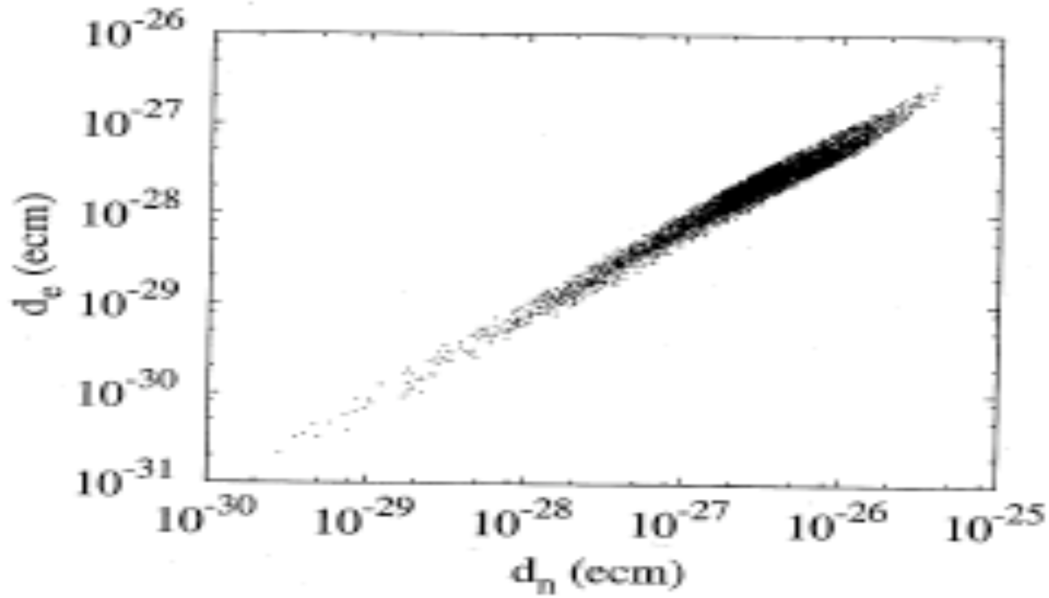
$$d_e \simeq \left(\frac{300 \text{ GeV}}{M_{SUSY}} \right)^2 \sin \varphi_{CP} \times 10^{-25} \text{ e}\cdot\text{cm}$$

$d_e \sim$



$d_n \sim$





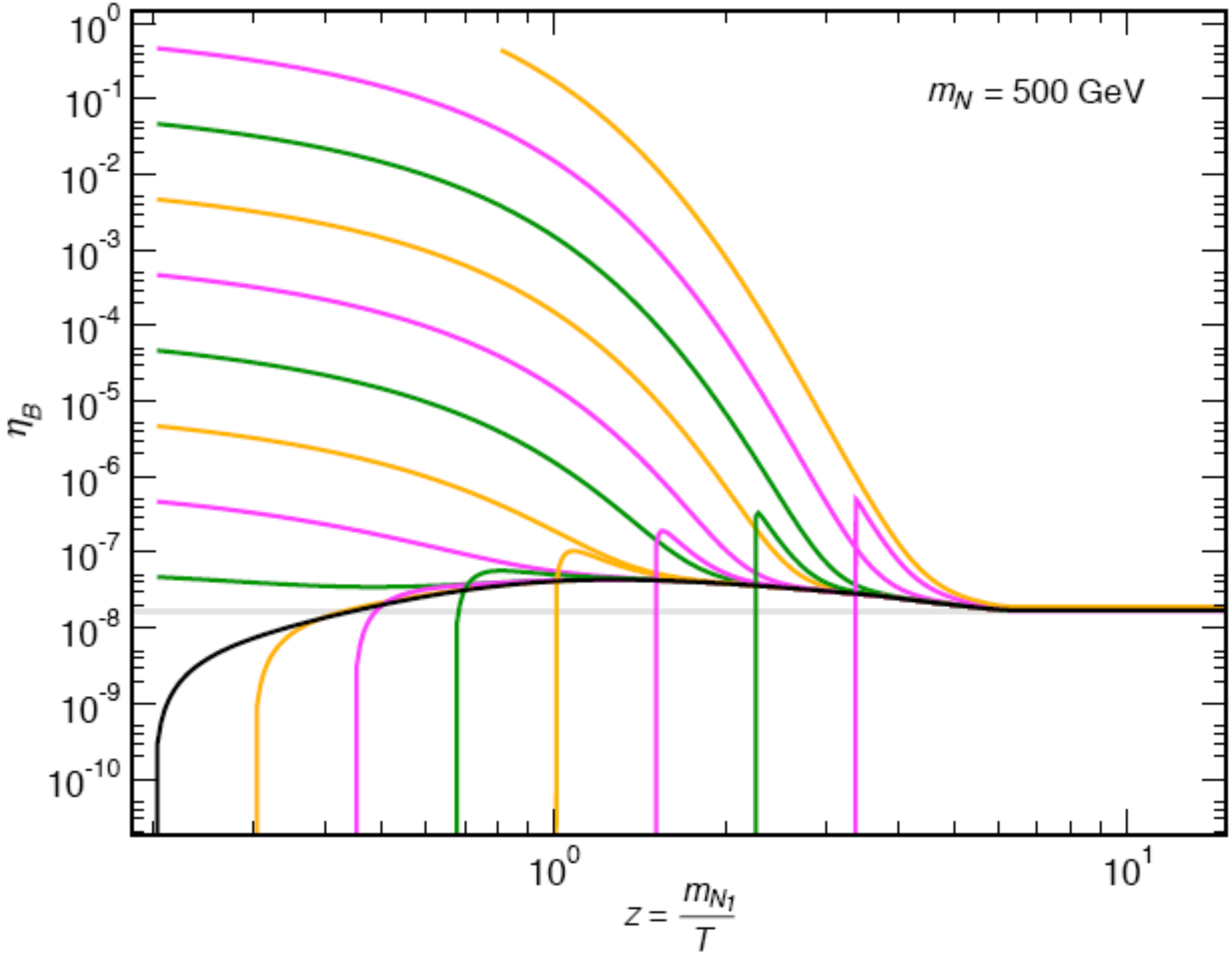
Flavoured resonant leptogenesis

Apostolos Pilaftsis

$$-\mathcal{L}_Y^{\rm lepton} \;=\; \frac{m_N}{2}\,(\bar{\nu}_{iR})^C \nu_{iR} \;+\; h^l_{ii}\,\bar{L}_i \Phi l_{iR} \;+\; h^{\nu_R}_{ij}\,\bar{L}_i \widetilde{\Phi} \nu_{jR} \;+\; {\rm H.c.}$$

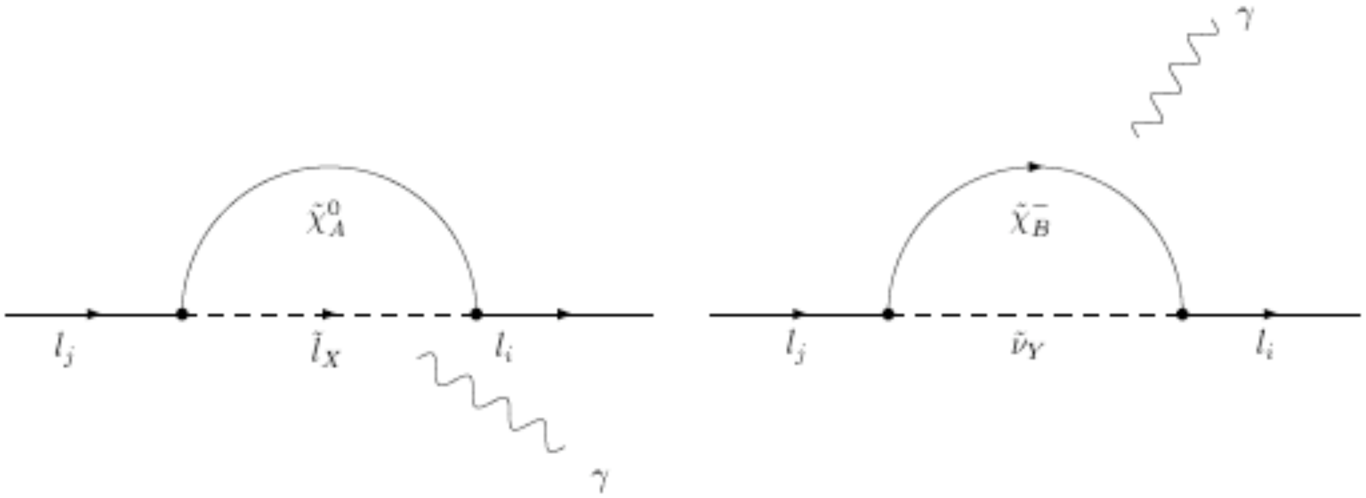
$$h^{\nu_R} \;=\; \begin{pmatrix} 0 & a\,e^{-i\pi/4} & a\,e^{i\pi/4} \\ 0 & b\,e^{-i\pi/4} & b\,e^{i\pi/4} \\ 0 & c\,e^{-i\pi/4} & c\,e^{i\pi/4} \end{pmatrix}$$

- Models with signatures at the observable level: $B(\mu \to e\gamma) \sim 10^{-13}$, $B(\mu \to eee) \sim 10^{-14}$, $B(\mu \to e) \sim 10^{-13}$, LNV/LFV at the ILC.
- Observation of an electron EDM $d_e \gtrsim 10^{-32}\ e \cdot {\rm cm}$ will rule out non-SUSY leptogenesis.



m_N = 500 GeV
η_B
$z = \frac{m_{N_1}}{T}$
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{-9}
10^{-10}
10^0
10^1

LFV in SUSY Seesaw

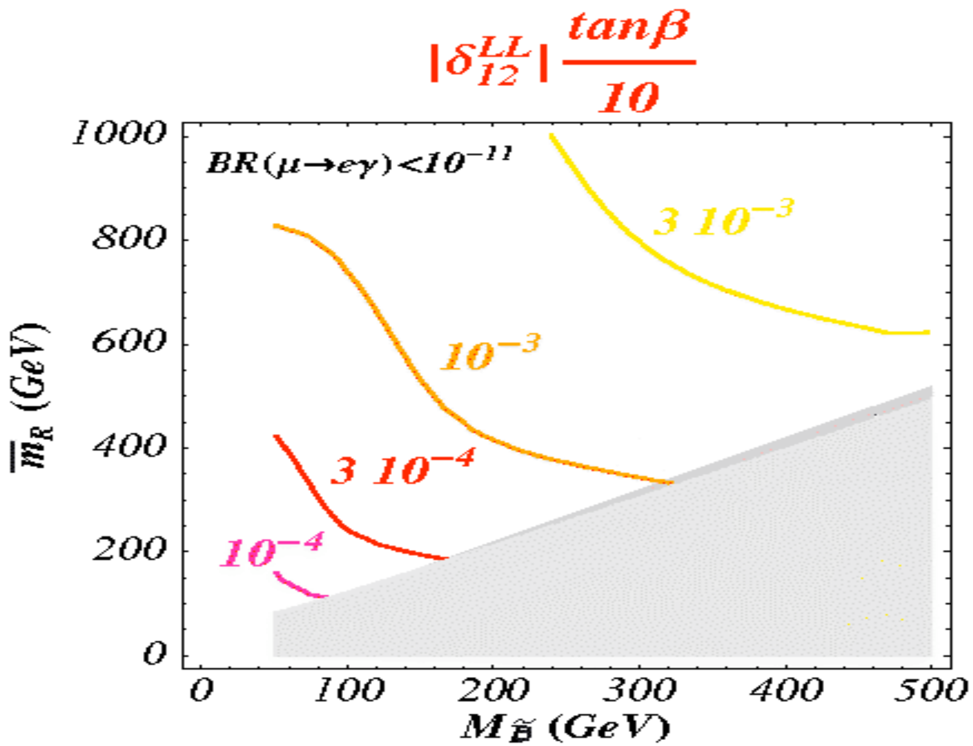


$$(\Delta m_{\tilde{L}}^2)_{ji} \approx -\frac{\ln(M_{\rm GUT}/M_R)}{16\pi^2}\left(6m_0^2 + 2A_0^2\right)\left(Y_\nu^\dagger Y_\nu\right)_{ji}\tan^2\beta$$

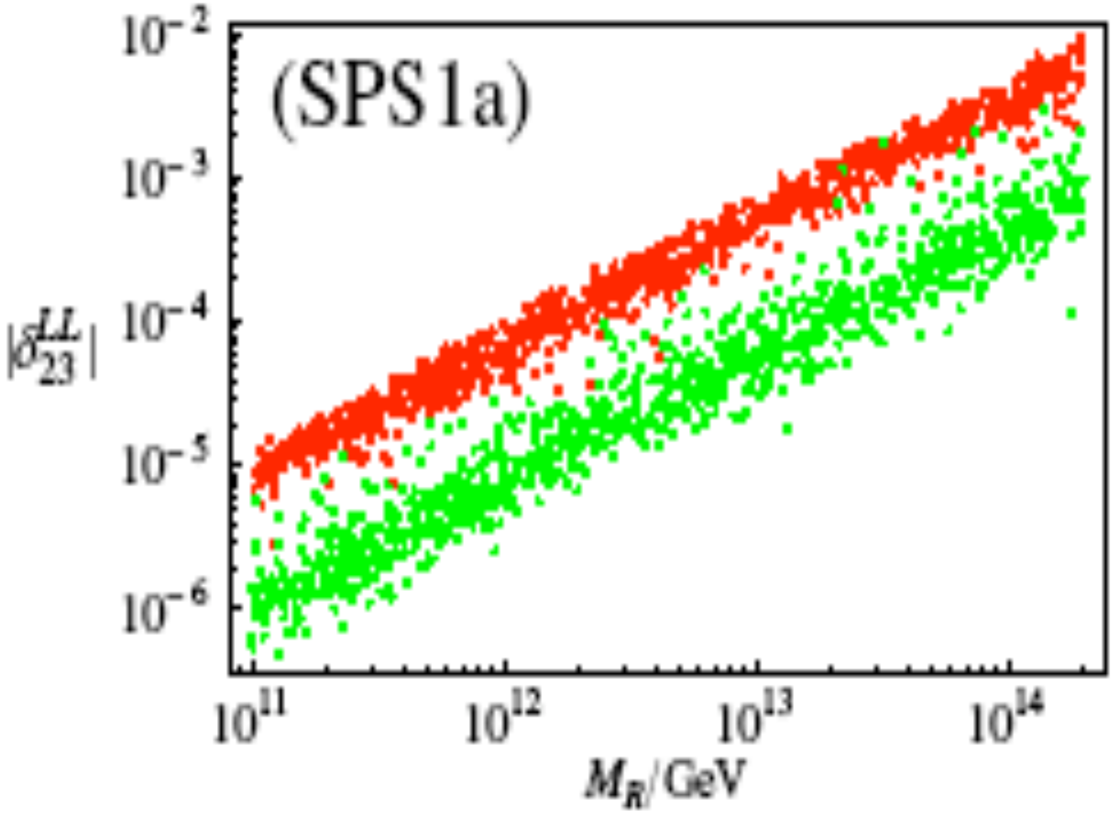
$$Y_\nu(M_R) = \frac{1}{v_u}\sqrt{D_N(M_R)}\ R\ \sqrt{D_\nu(M_R)}\ U^\dagger(M_R)$$

Slepton FV

Isabella Masina, Simon Albino



SUSY seesaw + $U(1)_F$ model can be tested



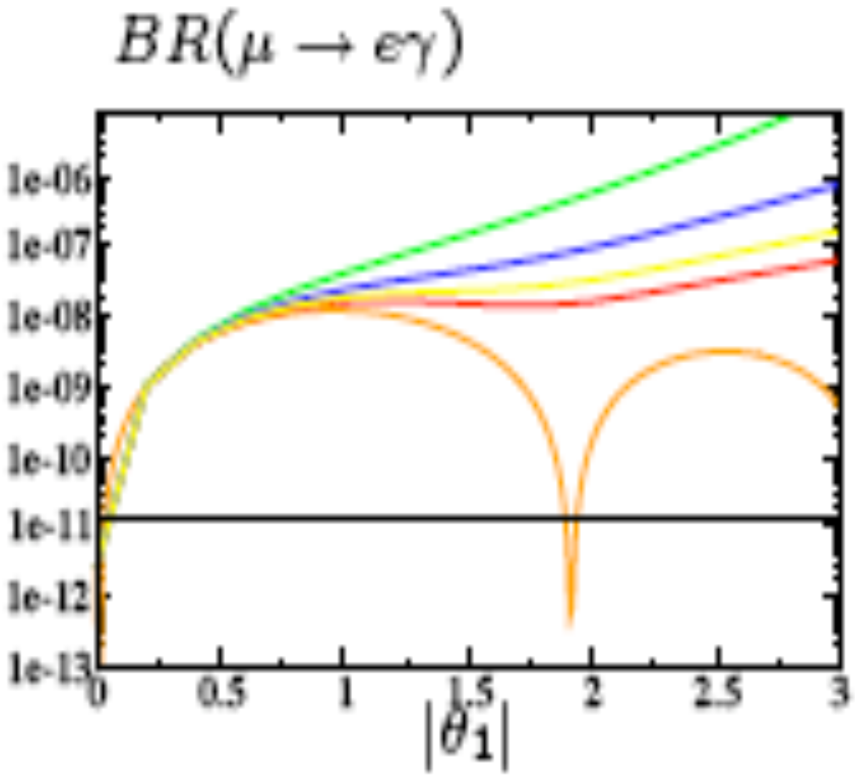
Presently: $\mathrm{BR}(\mu \to e\gamma) < 10^{-11} \implies |\delta_{12}^{LL}| < 10^{-4.3}$

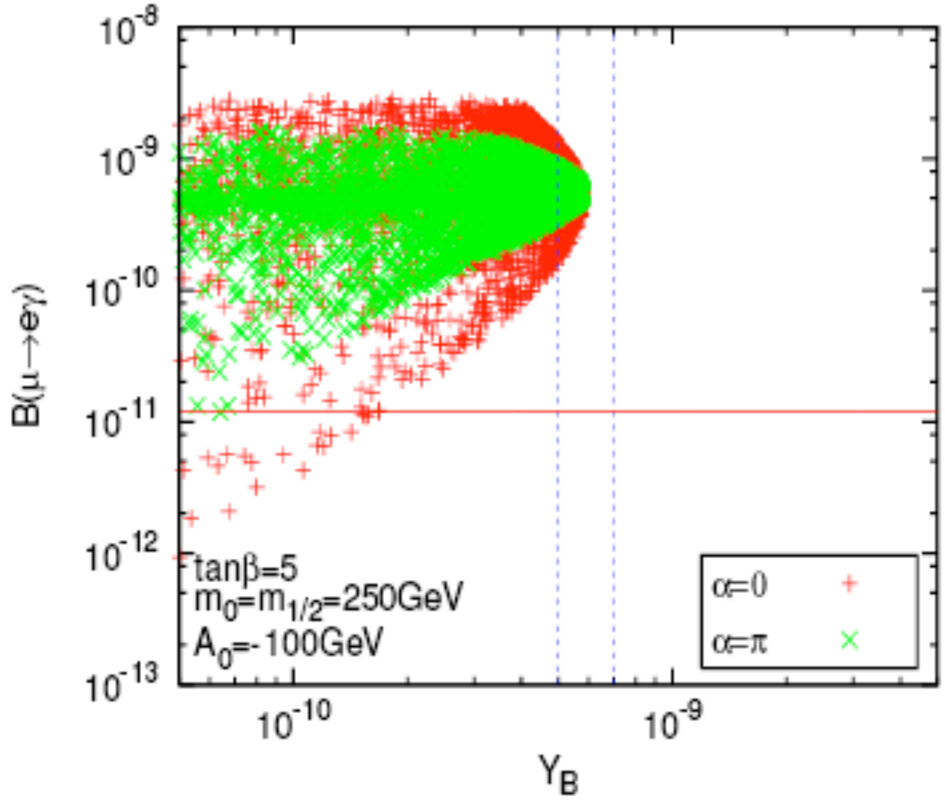
$\implies |\delta_{23}^{LL}| < 10^{-3} \implies \mathrm{BR}(\tau \to \mu\gamma) < 10^{-9}$

* Stronger than direct exp. $\tau \to \mu$ bound 6.8×10^{-8}

LFV BR

Maria Herrero, Yasutaka Takanishi





LFV, leptogenesis an all that

Serguey Petcov

$BR(\mu \to e + \gamma) < 1.2 \times 10^{-11}$ implies:

terms $\sim M_3$ in $|(\mathbf{Y}_\nu^\dagger L \mathbf{Y}_\nu)_{21}|$ – **suppressed**.

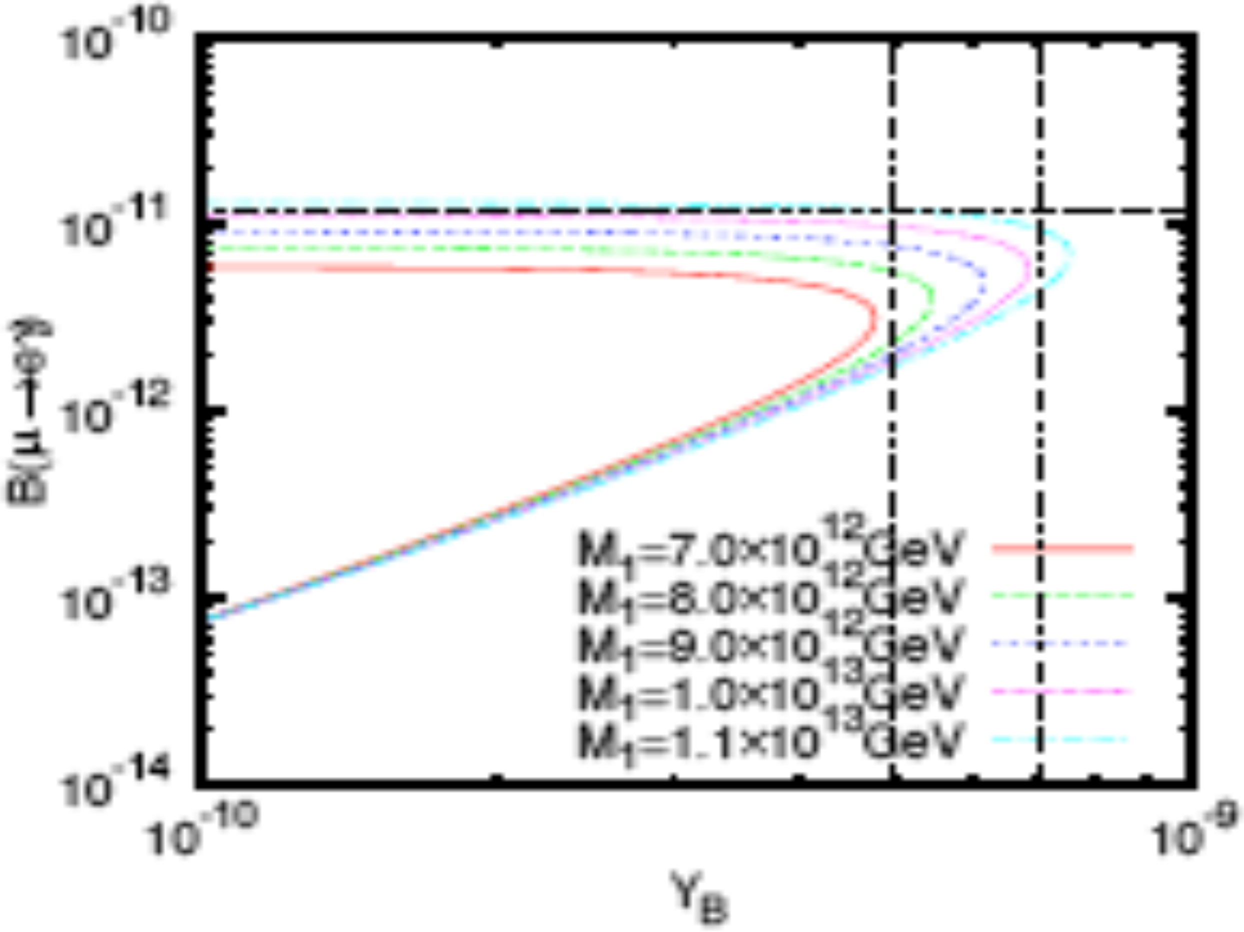
- $M_{SUSY} \sim (600 - 2000)$ GeV, ($m_{1/2} \gg m_0$, e.g, $m_0 = 300$ GeV, $m_{1/2} = 1400$ GeV, $a_0 m_0 = 0$)
- $M_{SUSY} \sim (100 - 600)$ GeV, but $\mathbf{Y}_{\nu 21} = 0$, or $\mathbf{Y}_{\nu 22} = 0$

A. $\mathbf{Y}_{\nu 21} = 0$:

$$\tan\omega = e^{-i\alpha/2} \ \tan\theta_{12}.$$

B. $\mathbf{Y}_{\nu 22} \cong 0$, neglecting s_{13}:

$$\tan\omega = -e^{-i\alpha/2} \ \cot\theta_{12}.$$



10^-10
10^-11
10^-12
10^-13
10^-14
B(μ→eγ)
M1=7.0×10^12GeV
M1=8.0×10^12GeV
M1=9.0×10^12GeV
M1=1.0×10^13GeV
M1=1.1×10^13GeV
10^-10
10^-9
YB

$(Y_\nu)_{21} = 0$

Reconstructing seesaw from low energy data

Alejandro Ibarra

$\{Y_\nu, \mathcal{M}\}$ depend on 18 parameters — 12 real, 6 phases

$\{\mathcal{M}_\nu\}$ depends on 9 parameters — 6 real, 3 phases

$$\mathbf{Y}_\nu^\dagger \mathbf{Y}_\nu = V_L^\dagger \mathrm{diag}(Y_1^2, Y_2^2, Y_3^2) V_L$$

⋆ Is it possible to reconstruct the see-saw parameters with the information from $\mathcal{M}$ and $Y_\nu^\dagger Y_\nu$? **YES!!**

neutrino mass matrix, $\mathcal{M}_\nu$			radiative effects, $P \equiv \mathbf{Y}_\nu^\dagger \mathbf{Y}_\nu$		
~~m_1~~	~~m_1~~	☺	~~P_{11}~~	mass splittings ~~largest~~	☺
m_2	Δm^2_{atm}	√	~~P_{22}~~	~~smallest~~	☹
m_3	Δm^2_{sol}	√	~~P_{33}~~	~~absolute scale~~	☹
θ_{12}	√		$\|P_{12}\|$	$\mu \to e\gamma$	☺
θ_{13}	☺		$\|P_{13}\|$	rare decays $\tau \to e\gamma$	☺
θ_{23}	√		$\|P_{23}\|$	$\tau \to \mu\gamma$	☺
δ		☺	argP_{12}	e-EDM, one of them	☺
ϕ	$\nu 0\beta\beta$ phase	☹	~~argP_{13}~~	~~μ-EDM~~ ~~the other two~~	☹
~~ϕ'~~	~~orthogonal combination~~	☹☹	~~argP_{23}~~	~~τ-EDM~~	

★ In the 2RHN model, there are correlations among the elements of $Y_\nu^\dagger Y_\nu$ $\longrightarrow$ they could give rise to correlations among slepton parameters.

LFV in non-minimal SUGRA

Steve King

1. Non-minimal SUGRA

--due to different families coupling to the moduli differently

$$m_L^2 = m_{3/2}^2 \begin{bmatrix} a & & \\ & a & \\ & & b_L \end{bmatrix}$$

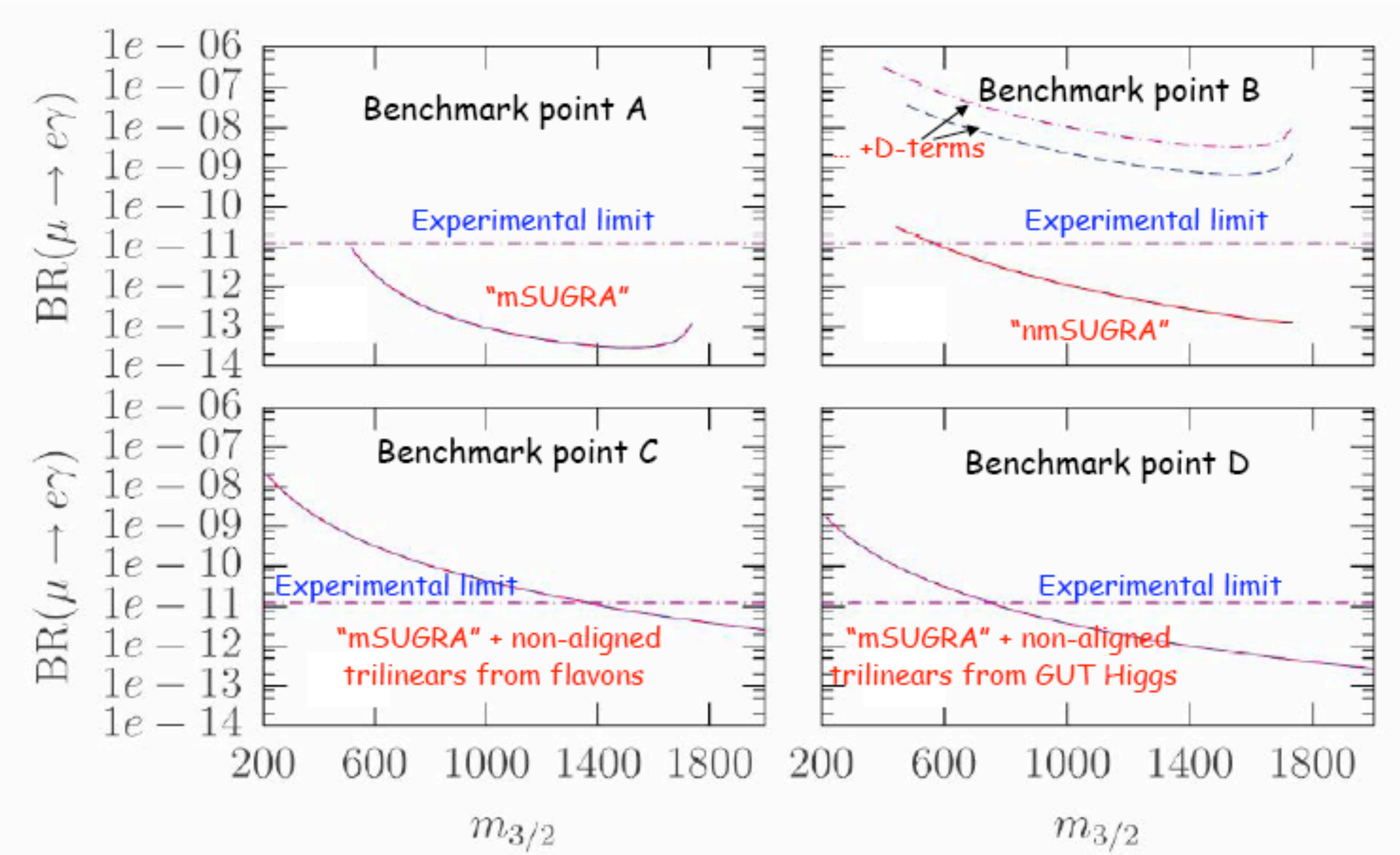
$$a = 1 - \frac{3}{2}(X_S^2 + X_{T_3}^2)$$
$$b_L = 1 - 3X_{T_3}^2$$

2. D-terms

3. Misaligned soft trilinears

$\mu \to e\gamma$ in non-minimal SUGRA

Hayes, Peddie, SFK 05

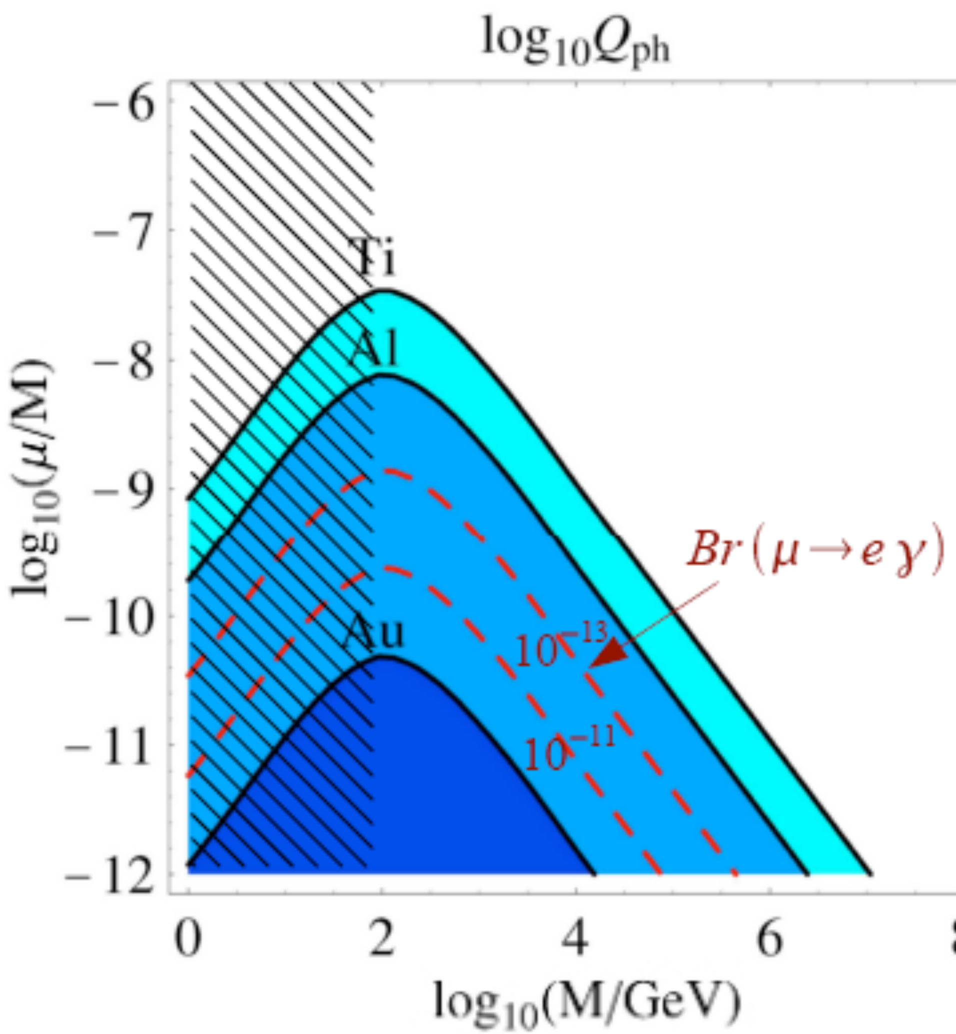


LFV in inverse seesaw

Frank Deppisch

$$W \ni \hat{\nu}^{cT} Y_\nu \hat{L} \cdot \hat{H}_u + \hat{\nu}^{cT} M \hat{S} + \frac{1}{2} \hat{S}^T \mu \hat{S}$$

$$m_\nu = 0.1\mathrm{eV} \left(\frac{m_D}{100\,GeV} \right)^2 \left(\frac{\mu}{1\,keV} \right) \left(\frac{M}{10^4\,GeV} \right)^{-2}$$


$\log_{10} Q_{ph}$
Ti
Al
Au
$Br(\mu \to e\gamma)$
10^{-13}
10^{-11}
$\log_{10}(\mu/M)$
$\log_{10}(M/GeV)$
-6
-7
-8
-9
-10
-11
-12
0
2
4
6
8

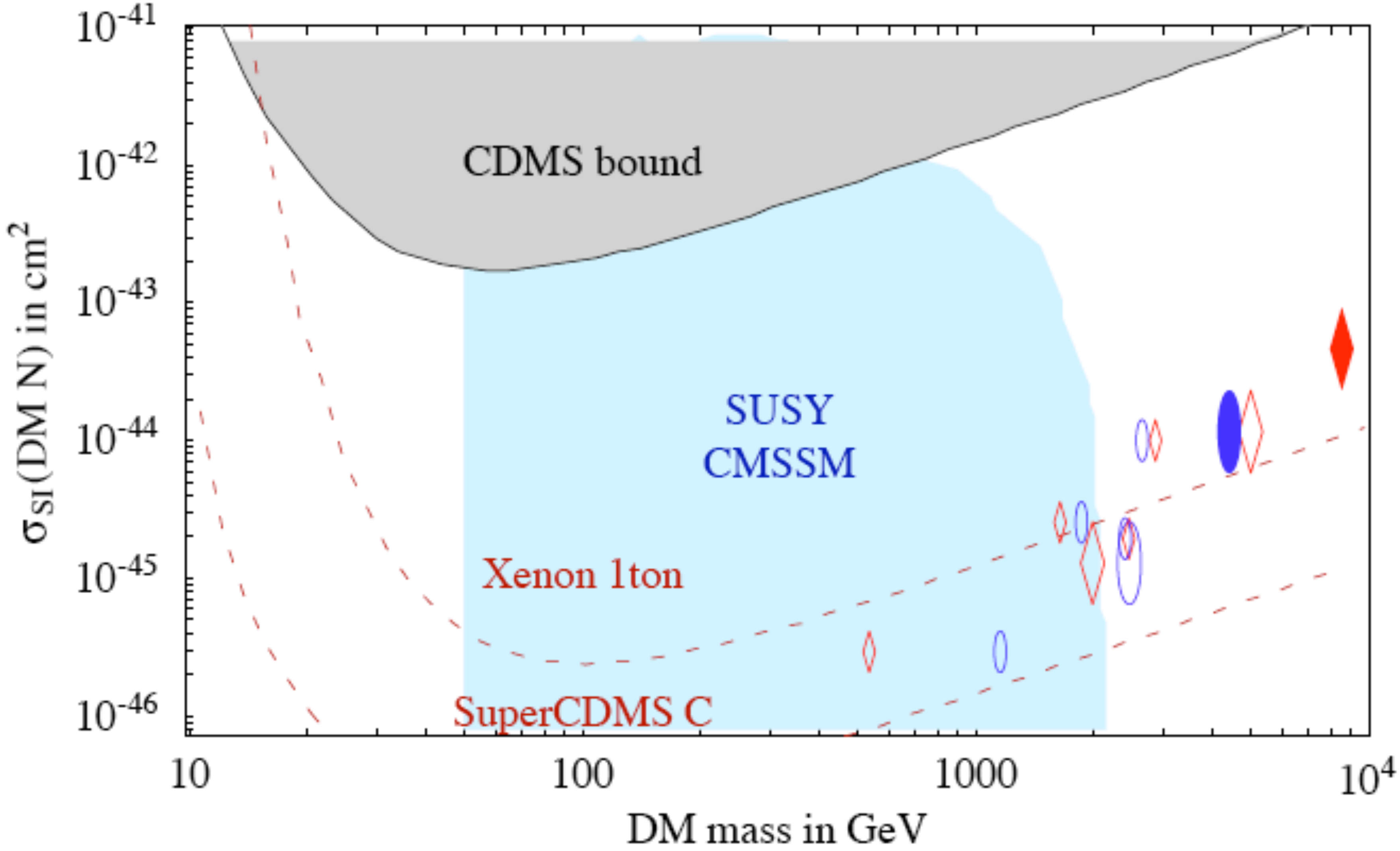
Minimal DM

Alessandro Strumia

Quantum numbers $SU(2)_L$	$U(1)_Y$	Spin	DM can decay into	DM mass in TeV	$m_{DM^\pm} - m_{DM}$ in MeV	Events at LHC $\int \mathcal{L}\, dt = 100/\text{fb}$	σ_{SI} in $10^{-45}\,\text{cm}^2$	Rating
2	1/2	0	EL	0.54 ± 0.01	350	$320 \div 510$	0.3	××
2	1/2	1/2	EH	1.2 ± 0.03	341	$150 \div 300$	0.3	××
3	0	0	HH^*	2.0 ± 0.05	166	$0.2 \div 1.0$	1.3	√×
3	0	1/2	LH	2.5 ± 0.06	166	$0.7 \div 3.5$	1.3	√×
3	1	0	HH, LL	1.6 ± 0.04	540	$3.0 \div 10$	2.5	××
3	1	1/2	LH	1.9 ± 0.05	526	$25 \div 80$	2.5	××
4	1/2	0	HHH^*	2.4 ± 0.06	353	$0.1 \div 0.6$	1.9	××
4	1/2	1/2	(LHH^*)	2.4 ± 0.06	347	$4.8 \div 23$	1.9	××
4	3/2	0	HHH	2.9 ± 0.07	729	$0.01 \div 0.09$	10	××
4	3/2	1/2	(LHH)	2.6 ± 0.07	712	$1.5 \div 8.5$	10	××
5	0	0	(HHH^*H^*)	5.0 ± 0.1	166	$\ll 1$	12	√×
5	0	1/2	–	4.4 ± 0.1	166	$\ll 1$	12	√√
7	0	0	–	8.5 ± 0.2	166	$\ll 1$	46	√√

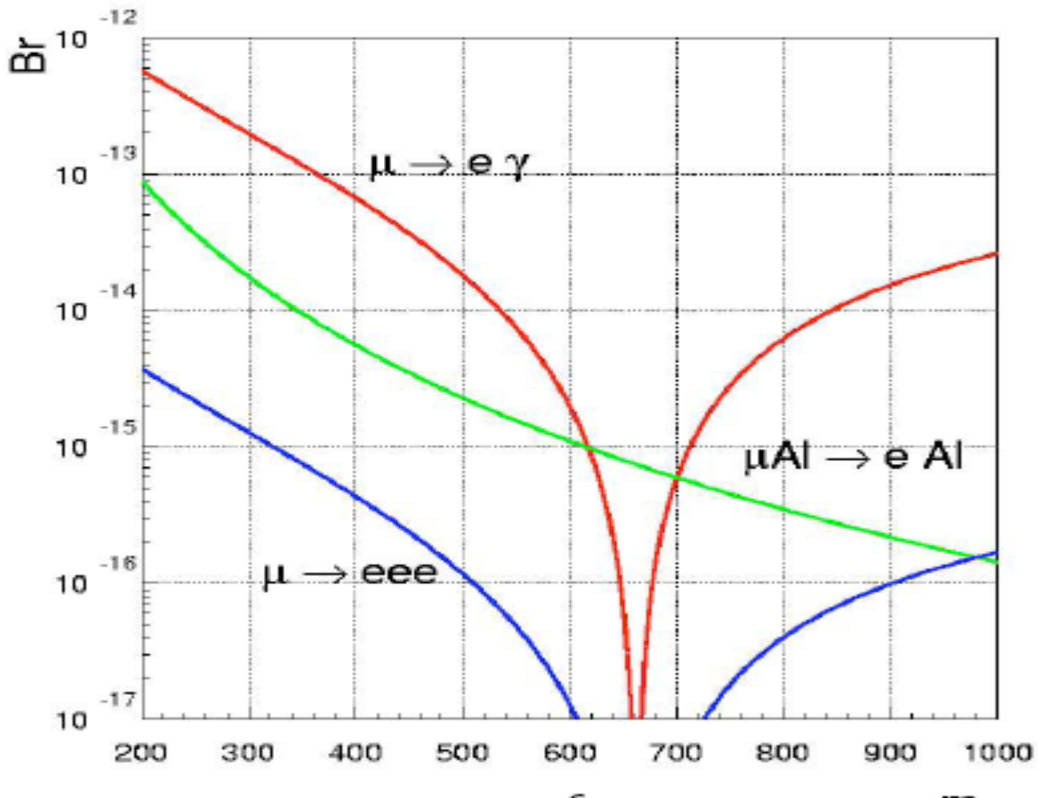
Rating = { allowed without tricks , stable without tricks }

Predictions for $\sigma_{\rm SI}(\text{DM } N)$



Higgs mediated LFV

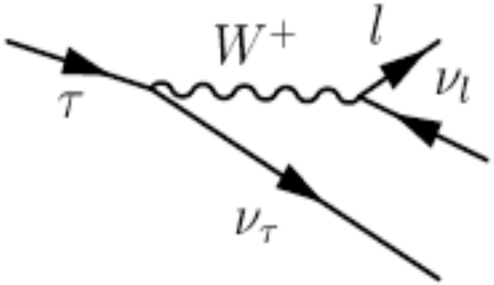
Paride Paradisi

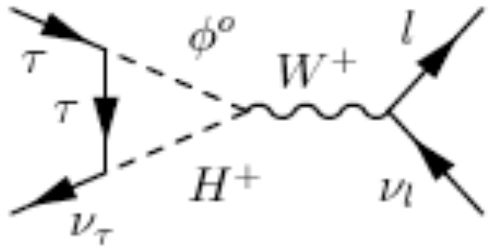


$\Delta_{21} = 10^{-6} \quad t_\beta = 50$

Leptonic tau decays in 2HDM

Maria Krawczyk





- New lower limit on mass of $M_{H^\pm}$ as a function of $\tan\beta$, which differs significantly from what was considered as standard constraint (based on the tree-level $H^\pm$ exchange only)

Minimal Realistic SO(10) GUT

Borut Bajc

ALL TOGETHER

$$10_H + 126_H + \overline{126}_H + 210_H$$

$$W_{YUKAWA} = 16_F \left(Y_{10}\, 10_H + Y_{126}\, \overline{126}_H \right) 16_F$$

TOTAL NUMBER OF MODEL PARAMETERS =

26 ⇝ (AS IN MSSM!)

Summary of discussion