Lepton Flavour Violation in Neutrino Seesaw Scenarios

Anna Rossi
Padova University

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- Flavour Violation in the Standard Model (SM)
- The Seesaw Paradigm for the neutrino mass:
  Triplet versus Singlet realization
- Lepton Flavour Violation (LFV) in the T-Seesaw
- Triplet as Messenger of SUSY breaking: Very predictive picture relating

  ν masses

  LFV

  Superpartner and Higgs boson Spectrum

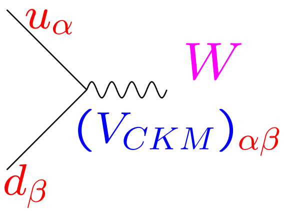
  Electroweak Symmetry Breaking (EWSB)

F.Joaquim, A. Rossi- PRL 97 (2006) 181801
NPB 765 (2007) 71

Flavour Violation (FV) in the Standard Model

At Tree-level only FV in charged current

Quark Sector



$V_{CKM} \neq 1$

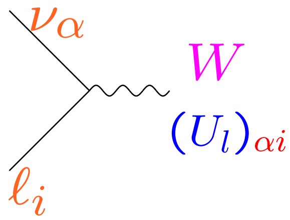
Many exp evidences:

$|\Delta S|, |\Delta B|, \ldots \neq 0$

e.g. $K \to \pi\pi,\ D \to K\ell\nu$

BUT total baryon number B is conserved

Lepton sector



$U_l \neq 1$

once $m_\nu \neq 0$

ONLY eqvidence of FV from Atmospheric, Solar, Accelerator and Reactor neutrinos

due to Vacuum oscillations and adiabatic resonance in matter

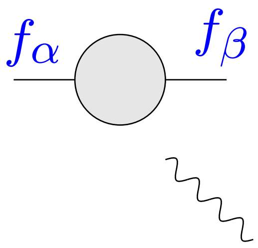
$$\nu_e \to \nu_\mu \quad , \quad \nu_\mu \to \nu_\tau$$

$$|\Delta L_e| = |\Delta L_\mu| \quad = \quad |\Delta L_\tau| = 1$$

$L = L_e + L_\mu + L_\tau$ conserved?

$\ldots \beta\beta 0\nu$??

FV in neutral currents only arises at one-loop



$\alpha \neq \beta$

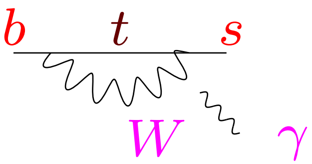
Quark Sector

many measured processes:

$|\Delta F| = 1, |\Delta F| = 2$

$|\Delta F| = 1$: *e.g.* $b \to s\gamma$

$$i\sqrt{\alpha}\ m_b \left[D_L \overline{s}\, \bar{\sigma}^{\mu\nu}\, \overline{b}^c + D_R s^c\, \sigma^{\mu\nu}\, b\right] F_{\mu\nu}$$



$$D_L \propto \frac{g^2}{16\pi^2} V_{tb}^\star\ V_{ts}\ \frac{m_t^2}{m_W^4}$$

SM prediction in agreement with exp. $BR \sim 3 \times 10^{-4}$

Strong constraint on New Physics

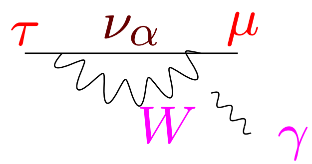
Lepton sector

no measured processes ... so far

WHY?

e.g. $\tau \to \mu\gamma$

$$i\sqrt{\alpha}\ m_\tau\, [D_L \overline{\mu}\, \bar{\sigma}^{\mu\nu}\, \overline{\tau}^c + D_R \mu^c\, \sigma^{\mu\nu}\, \tau]\, F_{\mu\nu}$$



$$D_L \propto \frac{g^2}{16\pi^2} \sum_\alpha U_{\mu\alpha}\ U_{\tau\alpha}^\star \frac{(m_\nu^2)_\alpha}{m_W^4}$$

SM prediction: $BR(\tau \to \mu\gamma) \approx 10^{-50}$

suppressed by tiny ν masses m_ν

Experimental bound

$$BR(\tau \to \mu\gamma) < 4.8 \times 10^{-8}$$

Potentially sensitive to New Physics

LFV Processes

BR	Present limits	Future sensitivity
$\mu^- \to e^- \gamma$	1.2×10^{-11}	10^{-14}
$\tau^- \to \mu^- \gamma$	4.8×10^{-8}	10^{-9}
$\tau^- \to e^- \gamma$	1.1×10^{-7}	10^{-9}
$\mu^- \to e^- e^+ e^-$	1.0×10^{-12}	10^{-14}
$\tau^- \to \mu^- \mu^+ \mu^-$	1.9×10^{-7}	10^{-9}
$\tau^- \to \mu^- e^+ e^-$	1.9×10^{-7}	10^{-9}
$\tau^- \to e^- e^+ e^-$	2.0×10^{-7}	10^{-9}
$\tau^- \to e^- \mu^+ \mu^-$	3.3×10^{-7}	10^{-9}
CR($\mu \to e$; Ti)	1.7×10^{-12}	10^{-18}

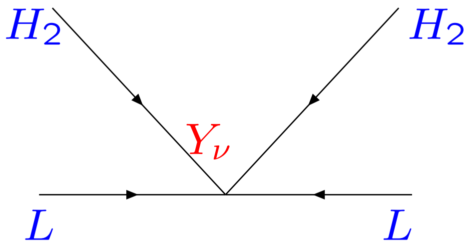
Detecting such LFV signals is a clear NEW Physics evidence

Lepton Flavour Violation in the (MS)SM comes from

$$m_\nu \neq 0, \qquad \theta^l_{ij} \neq 0, \qquad (i \neq j)$$

This is understood from $L = L_e + L_\mu + L_\tau$ violating $d = 5$ operator

S. Weinberg, 1979



$$\frac{1}{M_L} Y_\nu^{ij} (L_i H_2)(L_j H_2)$$

$M_L \gg M_Z$

$\langle H_2 \rangle = v_2$ $\qquad m_\nu^{ij} = \frac{v_2^2}{M_L} Y_\nu^{ij}$ $\qquad M_L$ scale suppression

$$m_\nu = U^* m_\nu^D U^\dagger$$

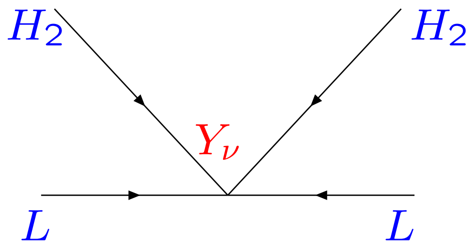
$m_\nu^D =$ diag(m_1, m_2, m_3) $\qquad U = V(\theta_{12}, \theta_{23}, \theta_{13}, \delta) \times$ diag$(1, e^{i\phi_1}, e^{i\phi_2})$

3 masses + 3 angles + 3 phases = 9 independent parameters

Provided by low energy experiments

How to get the neutrino $d = 5$ operator?

ν mass effective operator



Additional high-energy degrees of freedom decouple at M_L

(At tree-level) most-known realizations:

1. decoupling fermion singlets ('right-handed') N

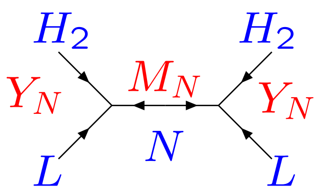
   P.Minkowski, 1977; M.Gell-Mann, P.Ramond, R.Slansky, 1979; T.Yanagida, 1979; S.Glashow, 1980; R.N.Mohapatra, G.Senjanovic, 1980

2. decoupling $SU(2)_W$ scalar triplets T

   R.Barbieri, D.Nanopoulos, 1980; M.Magg, C.Wetterich, 1980; G.Lazarides, Q,Shafi, C.Wetterich,1981; R.Mohapatra, G.Senjanovic, 1981

Seesaw with Singlets $N \sim (1,0)$

$$Y_N^{ij} H_2 L_i N_j + \frac{1}{2} M_N N_i N_j$$



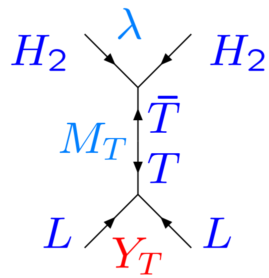
$$\rightarrow \frac{1}{M_L} Y_\nu = Y_N^T M_N^{-1} Y_N$$

$$m_\nu = v_2^2 \; Y_N^T M_N^{-1} Y_N$$

- $3N$ needed
- 2 LFV sources Y_N, M_N
  i.e. 12 reals + 6 phases

Seesaw with Triplets $T, \bar{T} \sim (3, \pm 1)$

$$Y_T^{ij} L_i T L_j + \lambda H_2 \bar{T} H_2 + M_T T \bar{T}$$



$$\rightarrow \frac{1}{M_L} Y_\nu = \frac{\lambda}{M_T} Y_T$$

$$m_\nu = \frac{v_2^2 \lambda}{M_T} Y_T$$

- 1 pair $(T, \bar{T})$ enough
- 1 LFV source Y_T (symmetric)
  i.e. 6 reals + 3 phases

Low energy data reconstruct Y_ν, *i.e.* 9 paramaters

Not enough to fix univocally Y_N, M_N

e.g. A.Casas, A.Ibarra, 2001

just match with Y_T : $Y_\nu \leftrightarrow Y_T$

High-energy Flavour Structure Known

A.R., 2002

Implications for low-energy LFV processes, such as

$$\ell_j \to \ell_i + \gamma, \;\ \ell_j \to \ell_i \ell_i \ell_i \; etc$$

... LFV in Y_ν (or m_ν) does not give sizeable effects (besides ν oscillations)

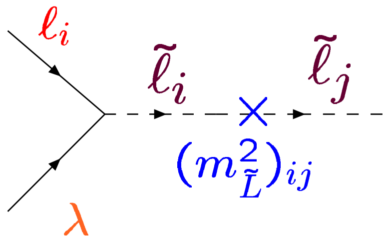
but consider that

- The one-loop decoupling of the heavy states (either N or T) could directly induce sizeable LFV under special conditions
  ... not addressed here

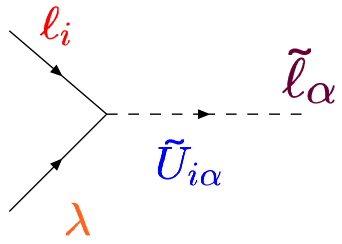
- SUPERSYMMETRY offers new LFV sources:
  sparticle masses $m^2_{\tilde{L}}$ and scalar couplings A_f PROVIDED the mass matrices $m^2_{\tilde{L}}$ of the sleptons are not aligned to the mass matrices of the leptons and the SUSY mass scale $\tilde{m}$ is not far from the Fermi scale

LFV : Window into New Physics – MSSM case

New LFV vertices: *e.g.* leptone (ℓ)-sleptone ($\tilde{\ell}$)-gaugino (λ)



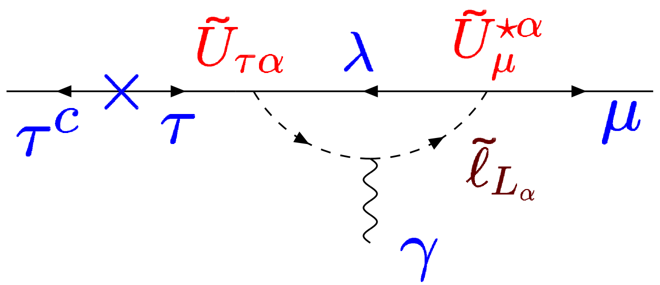
i.e.



$i = e, \mu, \tau \quad , \quad \alpha = 1, 2, 3$

LFV resides in $(m^2_{\tilde{L}})_{ij} = \tilde{U}_{i\alpha}\, m^2_{\tilde{L}\alpha} \tilde{U}^\dagger_{\alpha j}\ ,\ i \neq j$ $\qquad [M_\ell = \text{diag}(m_e, m_\mu, m_\tau)]$

Enhancement of $\tau \to \mu\gamma$ from SUSY contributions



$$\longrightarrow \quad D_L \sim \frac{g^2}{16\pi^2} \sum_\alpha \tilde{U}^*_{\mu\alpha}\ \tilde{U}_{\tau\alpha} \frac{m^2_{\tilde{L}\alpha}}{\tilde{m}^4}$$

$$D_L \neq 0 \longleftrightarrow (m^2_{\tilde{L}})_{\mu\tau} = \tilde{U}^*_{\mu\alpha}\ m^2_{\tilde{L}_\alpha} \tilde{U}_{\tau\alpha} \neq 0$$

No suppression unless $\tilde{m} \gg$ TeV

What about the soft SUSY-breaking (SSB) parameters $m^2_{\tilde{L}}$?

• Mass scale not far from the EW scale

• Flavour structure?: theoretically unknown (... more general and open issue) though phenomenologically constrained

Conservative approach inspired by Minimal SUGRA or (High Scale) Gauge Mediation:

- Universality/Flavour-Conservation at high (~~SUSY~~ - mediation) scale M_X
  $m^2_{\tilde{L}} = m^2_0 \mathbb{1}$

- At lower energy RENORMALIZATION-GROUP (RG) effects induced by LFV Yukawa couplings spoil universality/flavour-conservation

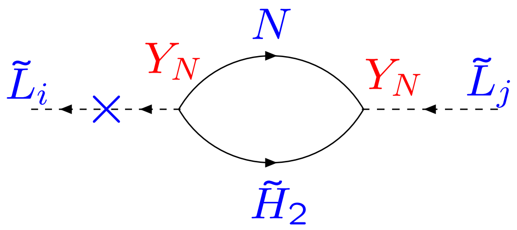
$$(m^2_{\tilde{L}})_{ij} \neq 0 \qquad\qquad i \neq j$$

L.Hall, V.Kostelecky, S.Raby,1986

F.Borzumati, A.Masiero,1986; A.R.2002

LFV in $\tilde{L}^\dagger m^2_{\tilde{L}} \tilde{L}$

N-Seesaw



$$(m^2_{\tilde{L}})_{ij} \sim \frac{m_0^2}{16\pi^2} (Y_N^\dagger Y_N)_{ij} \ln \frac{M_X}{M_N}$$

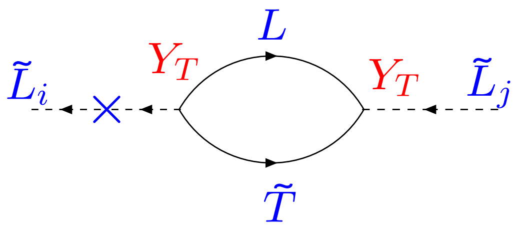
$Y_N^\dagger Y_N$: not directly linked to Y_ν *i.e.* m_ν

More (arbitrary) assumptions on Y_N and M_N needed to deal with $m^2_{\tilde{L}}$ flavour structure

J.Hisano et al.,1996;

J.A.Casas, A.Ibarra, 2001;

T-Seesaw



$$(m^2_{\tilde{L}})_{ij} \sim \frac{m_0^2}{16\pi^2} (Y_T^\dagger Y_T)_{ij} \ln \frac{M_X}{M_T}$$

direct link $Y_T \leftrightarrow Y_\nu$(or m_ν)

$$(m^2_{\tilde{L}})_{ij} \sim \frac{m_0^2}{16\pi^2} \left(\frac{M_T}{\lambda v_2^2}\right) (m_\nu^\dagger m_\nu)_{ij} \ln \frac{M_X}{M_T}$$

$$\sim \frac{m_0^2}{16\pi^2} \left(\frac{M_T}{\lambda v_2^2}\right) \left[V (m_\nu^D)^2 V^\dagger\right]_{ij} \ln \frac{M_X}{M_T}$$

A.R., 2002

In T-Seesaw $m^2_{\tilde{L}}$ inherits the low-energy neutrino flavour structure

T-Seesaw provides a realization of Minimal LFV

$$(m^2_{\tilde{L}})_{ij} \sim \frac{m_0^2}{16\pi^2}(\frac{M_T}{\lambda v_2^2}) \left[V (m_\nu^D)^2 V^\dagger\right]_{ij} \ln \frac{M_X}{M_T}$$

Relative LFV size predicted in a model-independent way

depends only on the neutrino masses $[m_\nu^D]$ and mixing angles $[V]$ measured at low-energy ... and not on high-energy parameters (as M_T or λ)

$$\frac{(m^2_{\tilde{L}})_{\tau\mu}}{(m^2_{\tilde{L}})_{\mu e}} \approx \frac{\left[V (m_\nu^D)^2 V^\dagger\right]_{\tau\mu}}{\left[V (m_\nu^D)^2 V^\dagger\right]_{\mu e}}, \qquad \frac{(m^2_{\tilde{L}})_{\tau e}}{(m^2_{\tilde{L}})_{\mu e}} \approx \frac{\left[V (m_\nu^D)^2 V^\dagger\right]_{\tau e}}{\left[V (m_\nu^D)^2 V^\dagger\right]_{\mu e}}$$

Plugging the neutrino exp data

$$\left|\frac{(m^2_{\tilde{L}})_{\tau\mu}}{(m^2_{\tilde{L}})_{\mu e}}\right| \approx 40, \quad \left|\frac{(m^2_{\tilde{L}})_{\tau e}}{(m^2_{\tilde{L}})_{\mu e}}\right| \approx 1 \quad , \quad [\sin\theta_{13} = 0]$$

$$\left|\frac{(m^2_{\tilde{L}})_{\tau\mu}}{(m^2_{\tilde{L}})_{\mu e}}\right| \approx 0.8\ (1.2), \quad \left|\frac{(m^2_{\tilde{L}})_{\tau e}}{(m^2_{\tilde{L}})_{\mu e}}\right| \approx 3.2\ (3.8) \quad , \quad [\sin\theta_{13} = 0.2]$$

for the Normal Hierarchy NH, Quasi Degenerate DG (Inverted Hierarchy IH) spectra

A.R., 2002

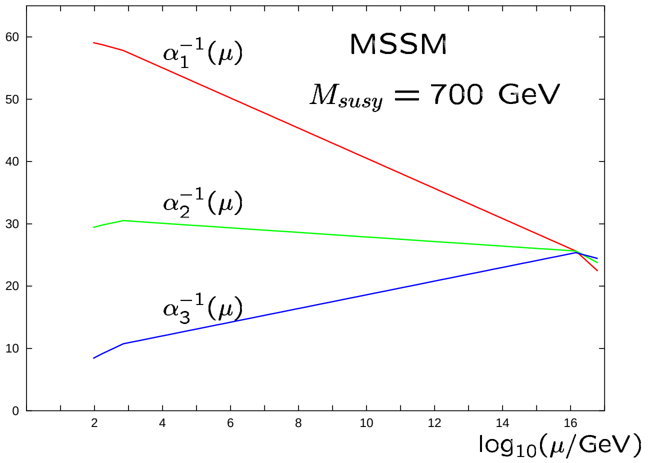
T-Seesaw: Strict predictions for the ratio of LFV Branching Ratios given the neutrino parameters ($\delta = 0$)

$$\frac{\mathrm{BR}(\tau \to \mu\gamma)}{\mathrm{BR}(\mu \to e\gamma)} \approx \left| \frac{(m^2_{\tilde{L}})_{\tau\mu}}{(m^2_{\tilde{L}})_{\mu e}} \right|^2 \frac{\mathrm{BR}(\tau \to \mu\nu_\tau\bar{\nu}_\mu)}{\mathrm{BR}(\mu \to e\nu_\mu\bar{\nu}_e)} \approx \begin{cases} 300 & [s_{13} = 0] \\ 2\,(3) & [s_{13} = 0.2] \end{cases}$$

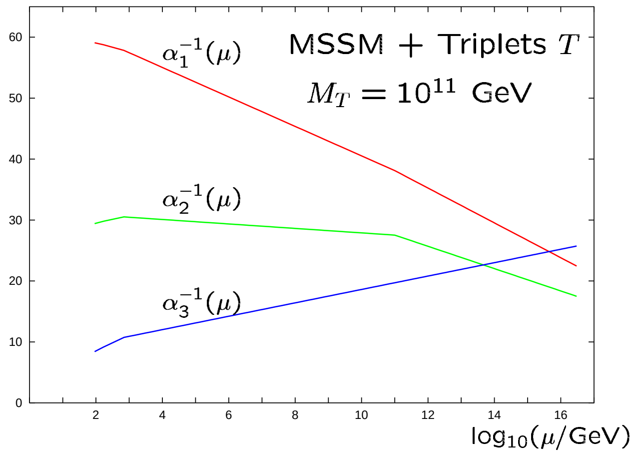
$$\frac{\mathrm{BR}(\tau \to e\gamma)}{\mathrm{BR}(\mu \to e\gamma)} \approx \left| \frac{(m^2_{\tilde{L}})_{\tau e}}{(m^2_{\tilde{L}})_{\mu e}} \right|^2 \frac{\mathrm{BR}(\tau \to e\nu_\tau\bar{\nu}_e)}{\mathrm{BR}(\mu \to e\nu_\mu\bar{\nu}_e)} \approx \begin{cases} 0.2 & [s_{13} = 0] \\ 0.1\ (0.3) & [s_{13} = 0.2] \end{cases} ,$$

Notice: Major uncertainty from θ_{13}

$SU(2)_W$ Triplet States below M_G alter (simple) Gauge Coupling Unification



... with Triplets

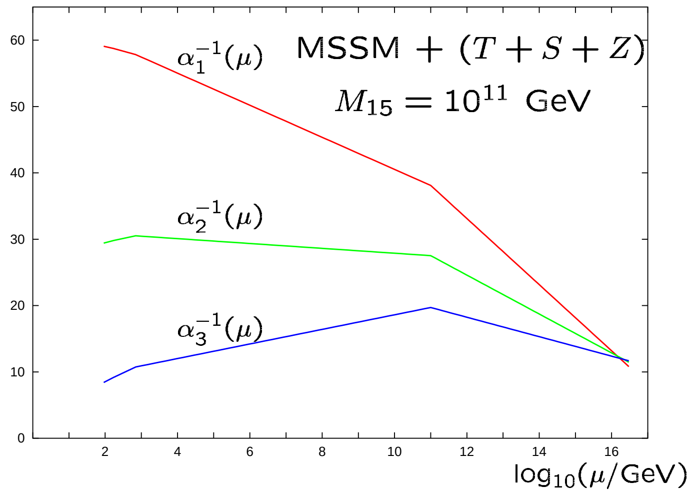


Recovered by adding extra states to complete a GUT supermultiplet : $T + \ldots$

Minimal extension: SUSY SU(5) with T fitting into 15: 15 = S + T + Z

$SU(3)_C \times SU(2)_W \times U(1)_Y$ decomposition

$$S \sim (6, 1, -\frac{2}{3}), \quad T \sim (1, 3, 1), \quad Z \sim (3, 2, \frac{1}{6})$$



... And which implications for Flavour Violation ?

Supersymmetric SU(5) + 15 = T + S + Z

Relevant Yukawa term $Y_{15}\ \bar{5}\ 15\ \bar{5} = Y_T LTL + Y_S d^c S d^c + Y_Z d^c Z L$

$[\bar{5} = d^c + \ell]$

- what happens in MSUGRA with universality at M_G?

FV driven by Y_{15} induced in both the quark and lepton sectors

$$(m^2_{\tilde{d}})_{ij} \approx \frac{m_0^2}{16\pi^2}\left(Y_T^\dagger Y_T\right)_{ij} \ln\frac{M_X}{M_T} \sim \frac{m_0^2}{16\pi^2}\left(\frac{M_T}{\lambda v_2^2}\right)\left[V(m_\nu^D)^2 V^\dagger\right]_{ij} \ln\frac{M_X}{M_T}$$

Direct connection between Quark and Lepton FV (from GUT symmetry) given by low-energy neutrino parameters

$$(m^2_{\tilde{d}})_{ij} \sim (m^2_{\tilde{L}})_{ij}$$

$$\frac{(m^2_{\tilde{L}})_{\tau\mu}}{(m^2_{\tilde{L}})_{\mu e}} \sim \frac{(m^2_{\tilde{d}})_{bs}}{(m^2_{\tilde{d}})_{sd}} \sim \frac{\left[V(m_\nu^D)^2 V^\dagger\right]_{\tau\mu}}{\left[V(m_\nu^D)^2 V^\dagger\right]_{\mu e}} \quad , \quad \frac{(m^2_{\tilde{L}})_{\tau e}}{(m^2_{\tilde{L}})_{\mu e}} \sim \frac{(m^2_{\tilde{d}})_{bd}}{(m^2_{\tilde{d}})_{sd}} \sim \frac{\left[V(m_\nu^D)^2 V^\dagger\right]_{\tau e}}{\left[V(m_\nu^D)^2 V^\dagger\right]_{\mu e}}$$

A.R, 2002

A Different way to generate LFV $(m^2_{\tilde{L}})_{ij}$

BEFORE: in 2 (unrelated) Steps

1) Flavour universal overall SSB mass m_0 generated at some high scale (unrelated to the dynamics of the triplets T)

2) LFV $(m^2_{\tilde{L}})_{ij}$ structure generated by RG quantum effects due to the triplet Yukawa Y_T

NOW: Ambitious, more economical and hence predictive program

1 single Step:

Both the overall SSB mass and the LFV $(m^2_{\tilde{L}})_{ij}$ structure are generated at the scale M_T by exchanging the triplets T at quantum level

F.Joaquim, A.R., 2006

Novel SUSY + GUT Triplet Seesaw

F. Joaquim and A.R, 2006

Basic observation: $15 \supset T$ exchange can generate all soft ~~SUSY~~ masses provided 15 interact with X breaking SUSY

$$W = \xi X 15\ \overline{15} + Y_{15}\ \bar{5}\ 15\ \bar{5} + \lambda 5_H\ \overline{15}\ 5_H + Y_5\ 10\ \bar{5}\ \bar{5}_H + Y_{10}\ 10\ 10\ 5_H + M_5 \bar{5}_H\ 5_H$$

$B - L$ is conserved

$10 = (u^c, d^c, Q); 5_H = (t, H_2)$

$\bar{5}_H = (\bar{t}, H_1)$

X singlet with B-L charge and VEV: $\langle X \rangle = \langle S_X \rangle + \theta^2 \langle F_X \rangle$

$\langle S_X \rangle \neq 0$ breaks B-L: $\xi \langle S_X \rangle = M_{15} \longrightarrow W \supset M_{15}\ 15\ \overline{15}$

$\langle F_X \rangle \neq 0$ breaks SUSY and B-L: $\xi \langle F_X \rangle = B_{15} M_{15} \longrightarrow \mathcal{L}_{SSB} = B_{15} M_{15}\ 15\ \overline{15}$

this is the only Soft ~~SUSY~~ term at M_G

SU(5) BROKEN at M_G : $\quad \to W_{SU(5)} = W_{MSSM} + W_T + W_{S,Z}$

$$W_{MSSM} = Y_d\ d^c H_1 Q + Y_e e^c H_1 L + Y_u u^c Q H_2 + \mu H_1 H_2$$

$$W_T = Y_T\, LTL + \lambda H_2 \bar{T} H_2 + M_T T\bar{T}$$

$$W_{S,Z} = Y_S\ d^c S d^c + Y_Z\, d^c Z L + M_Z Z\bar{Z} + M_S S\bar{S}$$

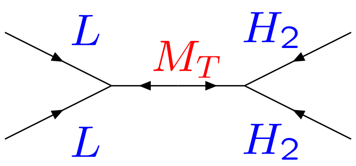
$\to$ New LFV and Quark FV ints

$$\mathcal{L}_{SSB} = -B_T M_T (T\bar{T} + S\bar{S} + Z\bar{Z}) + \text{h.c.}$$

$B_T M_T \equiv B_{15} M_{15}$

Down to the energy scale $M_T < M_G$

- Only $T, \bar{T}$ are Messengers of $\not L$ at tree level:



ν Masses

Colored $S, \bar{S}, Z, \bar{Z}$ are not Messengers of $\not B$

- All $T, \bar{T}$ and $S, \bar{S}, Z, \bar{Z}$ are Messengers of ~~SUSY~~ at quantum level

All SSB mass parameters are generated as FINITE CONTRIBUTIONS at M_T

at one loop: Gaugino masses, Trilinear couplings A_f, bilinear Higgs parameter B_H

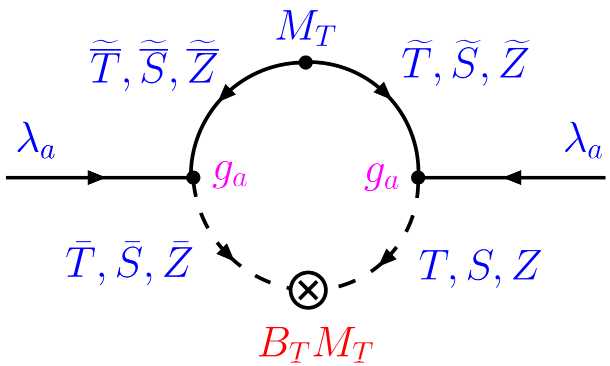
at two loops: all Scalar masses $m^2_{\tilde{f}}$ and $m^2_{H_1}, m^2_{H_2}$

All SSB mass parameters $\quad \tilde{M} \sim \frac{B_T}{16\pi^2}$: $\quad \tilde{M} \sim \mathcal{O}(100\text{ GeV}) \leftrightarrow B_T \sim \mathcal{O}(10\text{ TeV})$

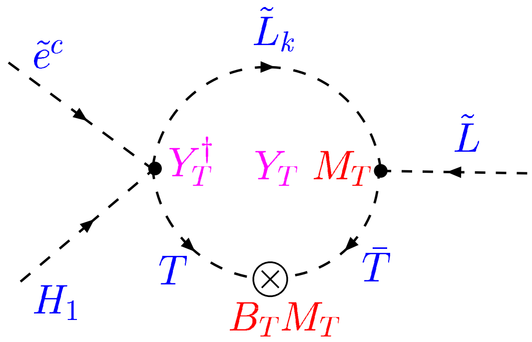
one mass scale fixes all the SSB masses

SSB terms: Boundary conditions at M_T

examples: at one loop



$M_a \propto \frac{B_T}{16\pi^2} g_a^2$



$A_e \propto \frac{B_T}{16\pi^2} Y_T^\dagger Y_T$

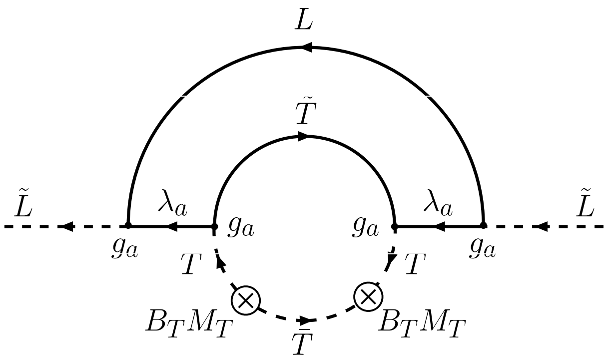
$$A_e = \frac{3B_T}{16\pi^2} Y_e (Y_T^\dagger Y_T + Y_Z^\dagger Y_Z)$$

$$A_d = \frac{2B_T}{16\pi^2} (Y_Z Y_Z^\dagger + 2 Y_S Y_S^\dagger) Y_d, \qquad A_u = \frac{3B_T}{16\pi^2} Y_u |\lambda|^2$$

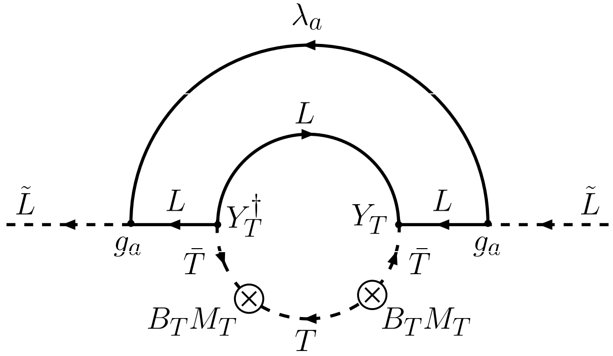
$$M_a = \frac{7B_T}{16\pi^2} g_a^2\,, \qquad B_H = \frac{3B_T}{16\pi^2} |\lambda|^2$$

Y_T, Y_S, Y_Z induce Flavor Violation in A_e, A_d

examples at two - loop for $m^2_{\tilde{L}}$



$\propto \left(\frac{B_T}{16\pi^2}\right)^2 g_a^4$



$\propto \left(\frac{B_T}{16\pi^2}\right)^2 g_a^2\, Y_T^\dagger Y_T$

$$m^2_{\tilde{L}} = \frac{|B_T|^2}{(16\pi^2)^2}\left[\frac{21}{10}g_1^4 + \frac{21}{2}g_2^4 - (\frac{27}{5}g_1^2 + 21 g_2^2) Y_T^\dagger Y_T - (\frac{21}{15}g_1^2 + 9 g_2^2 + 16 g_3^2) Y_Z^\dagger Y_Z + \mathcal{O}(Y^4)\right]$$

$$m^2_{\tilde{d}^c} = \frac{|B_T|^2}{(16\pi^2)^2}\left[\frac{14}{15}g_1^4 + \frac{56}{3}g_3^4 - (\frac{16}{5}g_1^2 + 48 g_3^2) Y_S^\dagger Y_S - (\frac{14}{15}g_1^2 + 6 g_2^2 + \frac{32}{3} g_3^2) Y_Z Y_Z^\dagger + \mathcal{O}(Y^4)\right]$$

$$m^2_{\tilde{Q}} = \frac{|B_T|^2}{(16\pi^2)^2}\left[\frac{7}{30}g_1^4 + \frac{21}{2}g_2^4 + \frac{56}{3}g_3^4 + \mathcal{O}(Y^4)\right], \quad m^2_{\tilde{u}^c} = \frac{|B_T|^2}{(16\pi^2)^2}\left[\frac{56}{15}g_1^4 + \frac{56}{3}g_3^4 + \mathcal{O}(Y^4)\right]$$

$$m^2_{\tilde{e}^c} = \frac{|B_T|^2}{(16\pi^2)^2}\left[\frac{42}{5}g_1^4 + \mathcal{O}(Y^4)\right], \quad m^2_{H_1} = \frac{|B_T|^2}{(16\pi^2)^2}\left[\frac{21}{10}g_1^4 + \frac{21}{2}g_2^4 + \mathcal{O}(Y^4)\right]$$

$$m^2_{H_2} = \frac{|B_T|^2}{(16\pi^2)^2}\left[\frac{21}{10}g_1^4 + \frac{21}{2}g_2^4 - (\frac{27}{5}g_1^2 + 21 g_2^2)\lambda^2 + 9\lambda^2 Y_t^2 + \mathcal{O}(Y^4)\right]$$

Y_T, Y_S, Y_Z induce Flavor Violation in $m^2_{\tilde{L}}, m^2_{\tilde{d}^c}$: At variance with pure Gauge Mediation Models where SSB $m^2_{\tilde{f}}$ are Flavor Blind

VERY PREDICTIVE FRAMEWORK

3 Free parameters: B_T, M_T, λ

Bottom-up approach to fix:

$Y_T = U m_\nu^D U^\dagger \frac{M_T}{\lambda v_2^2}$ (as well as Y_S, Y_Z) from neutrino parameters

μ and $\tan\beta$ from the radiative EWSB conditions

$\longrightarrow$ Lepton Flavour Violation fixed in the SSB parameters

Y_T, Y_S, Y_Z drive both LFV and QFV

$$(m^2_{\tilde{L}})_{ij} \propto Y_T^\dagger Y_T + Y_Z^\dagger Y_Z, \qquad (m^2_{\tilde{d}^c})_{ij} \propto Y_S Y_S^\dagger + Y_Z Y_Z^\dagger$$

Correlation between LFV and QFV can be predicted

$$\frac{(m^2_{\tilde{d}^c})_{bs}}{(m^2_{\tilde{d}^c})_{sd}} \sim \frac{(m^2_{\tilde{L}})_{\tau\mu}}{(m^2_{\tilde{L}})_{\mu e}} \approx \frac{\left[V (m_\nu^D)^2 V^\dagger\right]_{\tau\mu}}{\left[V (m_\nu^D)^2 V^\dagger\right]_{\mu e}} \quad , \quad \frac{(m^2_{\tilde{d}^c})_{bd}}{(m^2_{\tilde{d}^c})_{sd}} \sim \frac{(m^2_{\tilde{L}})_{\tau e}}{(m^2_{\tilde{L}})_{\mu e}} \approx \frac{\left[U (m_\nu^D)^2 U^\dagger\right]_{\tau e}}{\left[U (m_\nu^D)^2 U^\dagger\right]_{\mu e}}$$

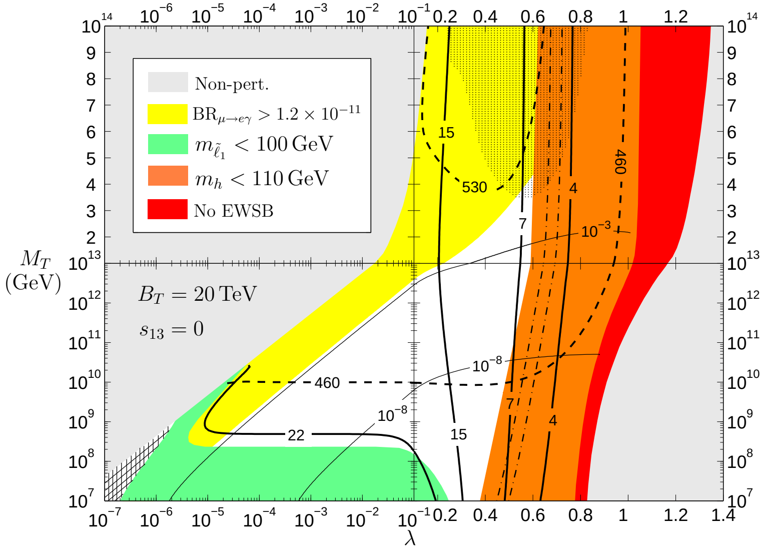
Phenomenological Viability

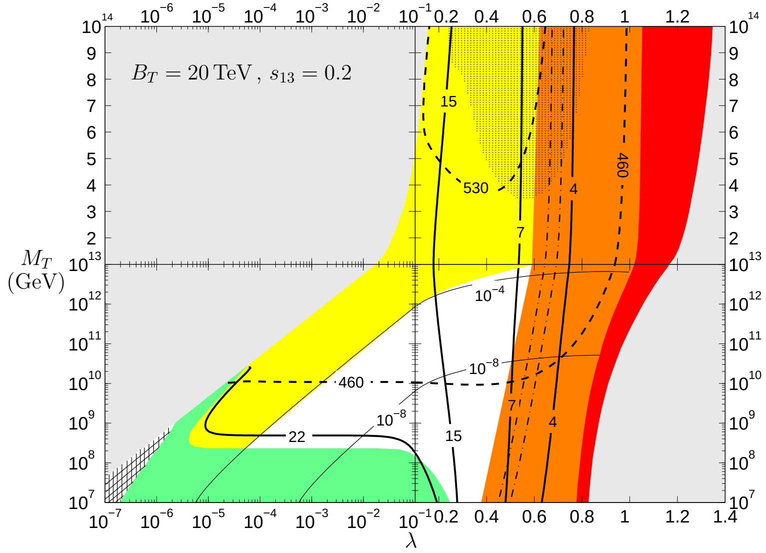
in the next

(B_T, M_T, λ) - Parameter Space Exploration

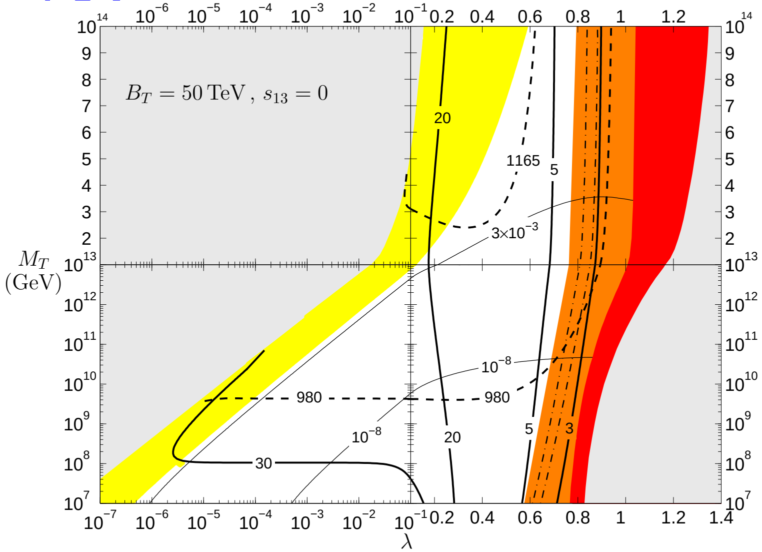
$B_T = 20$ TeV

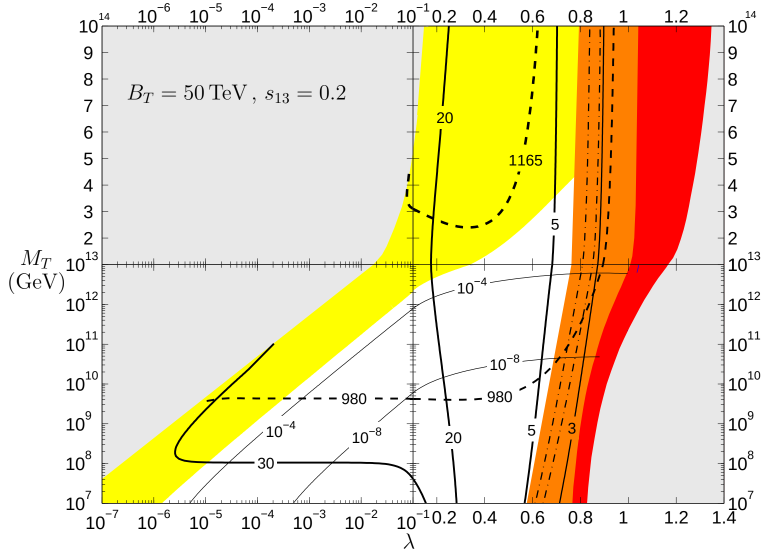
F.Joaquim and A.R., PRL + NPB 2006





$B_T = 50$ TeV





The model is compatible with experiments for $M_T \geq 10^7 - 10^8$ GeV and $B_T \geq 20$ TeV

TESTING THE ALLOWED PARAMETER BY PREDICTIONS ON

MSSM Sparticle and Higgs boson Spectrum

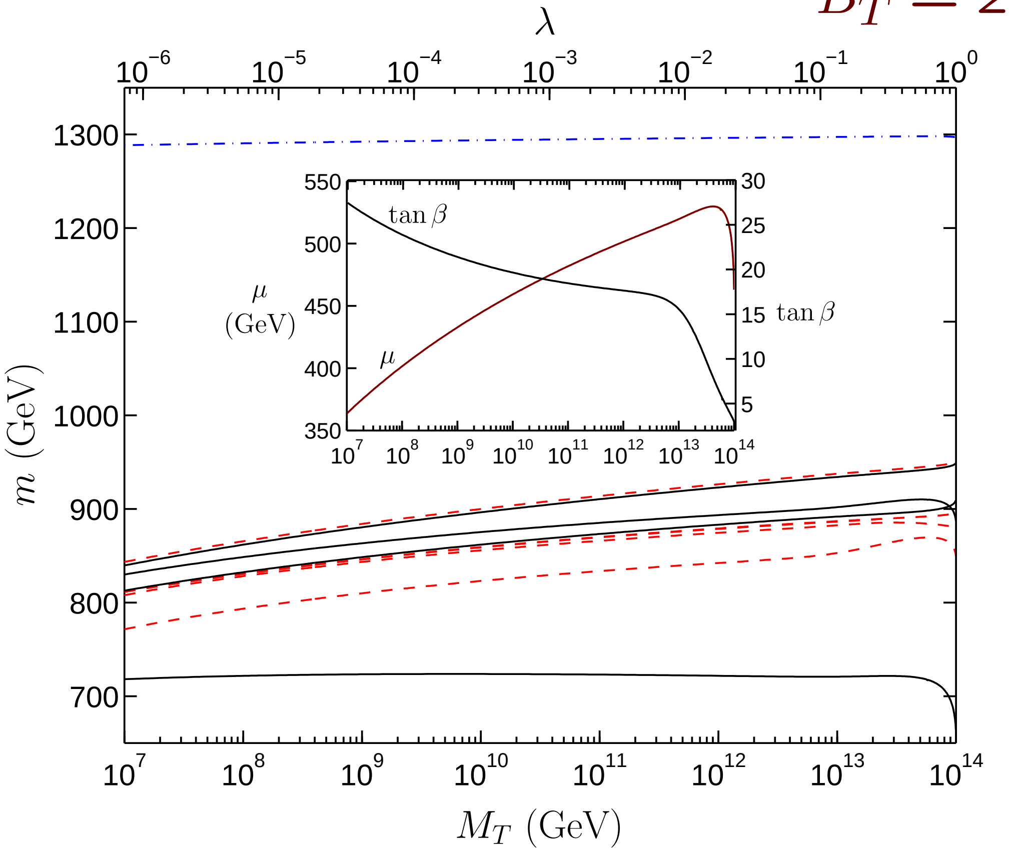
LFV decays

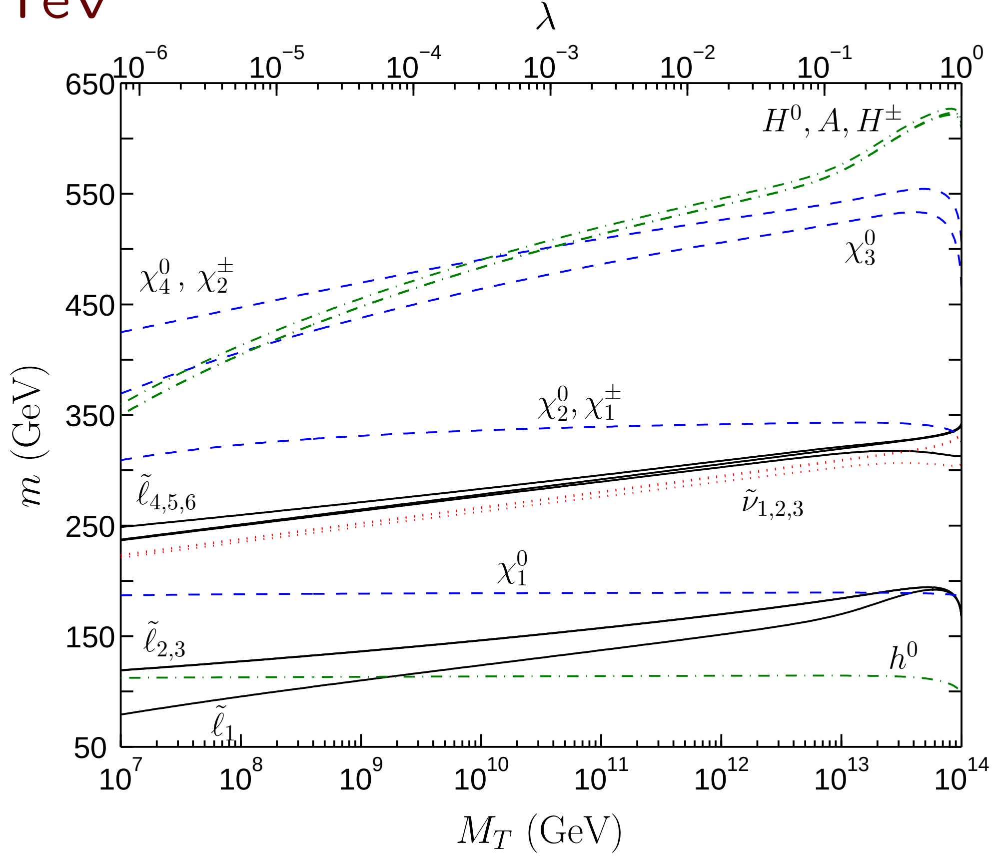
in the next

Spectrum:
Gluino $\tilde{g}$, squark $\tilde{u}$, squarks $\tilde{d}$

Spectrum: Sleptons, neutralinos and Higgs bosons

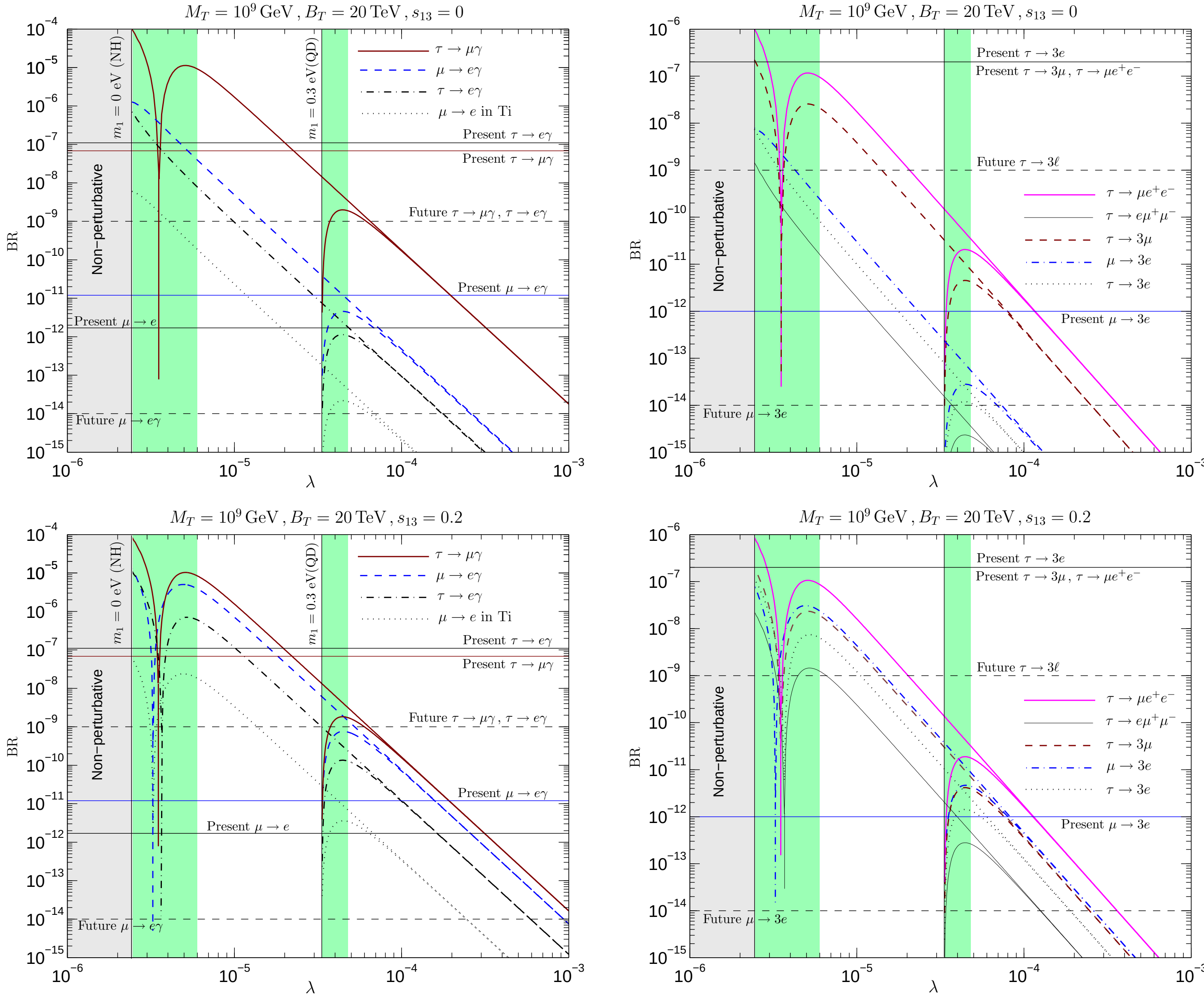
$B_T = 20$ TeV





- The sparticle masses are within the discovery reach of LHC
- Gluino is the heaviest sparticle, $M_{\tilde{g}} \sim 1.3$ TeV
- The slepton $\tilde{\ell}_1$ is the lightest $\longrightarrow$ gravitino is LSP
- 1 light SM-like Higgs $(h)+$ 3 heavy Higgs $(H, A, H^\pm)$

Predictions for LFV Processes $(B_T = 20$ TeV, $M_T = 10^9$ GeV – NH)



BR$(\tau \to \mu\gamma)$/BR$(\mu \to e\gamma) \sim 300$ for $s_{13} = 0$ or BR$(\tau \to \mu\gamma)$/BR$(\mu \to e\gamma) \sim 2$ for $s_{13} = 0.2$
etc. indep. of λ

LFV Correlation pattern taking $\mathrm{BR}(\mu \to e\gamma) = 1.2 \times 10^{-11}$

Expectation	$s_{13} = 0$	$s_{13} = 0.2$
$\mathrm{BR}(\tau^- \to \mu^-\gamma)$	3×10^{-9}	$2\,(3) \times 10^{-11}$
$\mathrm{BR}(\tau^- \to e^-\gamma)$	2×10^{-12}	$1\,(3) \times 10^{-12}$
$\mathrm{BR}(\mu^- \to e^-e^+e^-)$	6×10^{-14}	6×10^{-14}
$\mathrm{BR}(\tau^- \to \mu^-\mu^+\mu^-)$	7×10^{-12}	$4\,(6) \times 10^{-14}$
$\mathrm{BR}(\tau^- \to \mu^-e^+e^-)$	3×10^{-11}	$2\,(3) \times 10^{-13}$
$\mathrm{BR}(\tau^- \to e^-e^+e^-)$	2×10^{-14}	$1\,(3) \times 10^{-14}$
$\mathrm{BR}(\tau^- \to e^-\mu^+\mu^-)$	3×10^{-15}	$2\,(4) \times 10^{-15}$
$CR(\mu \to e;\ \mathrm{Ti})$	6×10^{-14}	6×10^{-14}

Upcoming experimental sensitivity allows to measure

- $s_{13} \ll 0.2$: $\mathrm{BR}(\mu \to e\gamma)$, $\mathrm{BR}(\mu \to eee)$, $CR(\mu \to e;\ \mathrm{Ti})$, $\mathrm{BR}(\tau \to \mu\gamma)$

- $s_{13} \lesssim 0.2$: $\mathrm{BR}(\mu \to e\gamma)$, $\mathrm{BR}(\mu \to eee)$, $CR(\mu \to e;\ \mathrm{Ti})$

CONCLUSIONS

LFV already seen with $\nu_i \to \nu_j$, but detection of alternative LFV signals is crucial to confirm NP

The (SUSY) triplet seesaw scenario looks promising:

- Neutrino masses can arise from the exchange of heavy triplets $T, \bar{T}$

  Specific feature: Simple flavour structure ... Hence:

- Potential predictive scenario for LFV: *e.g.* $\frac{BR(\tau\to\mu\gamma)}{BR(\mu\to e\gamma)}$ fixed by neutrino parameters only

- New predictive SUSY+GUT version with T playing also the role of ~~SUSY~~ messengers:

  the whole sparticle spectrum is fixed by the effective ~~SUSY~~ scale $B_T \gtrsim 20$ TeV

  strong correlation among neutrino parameters, LFV/QFV, the sparticle and Higgs spectrum and electroweak symmetry breaking