Flavour physics in an SO(10) grand unified model

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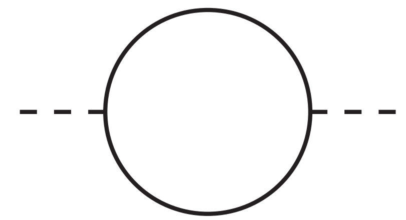
Outline

- SUSY & SUSY GUTs
- CMM model & RG analysis
- Phenomenology
  - particle spectrum & Higgs mass
  - $b \rightarrow s\gamma$, $\tau \rightarrow \mu\gamma$, B_s mixing & interplay
- Conclusions

SUSY & the role of flavour

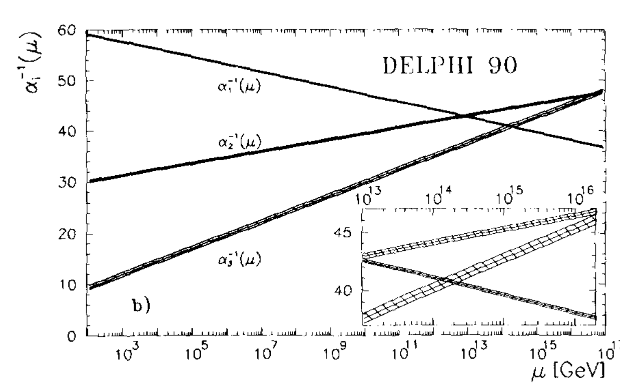
- SUSY motivated

  naturalness problem

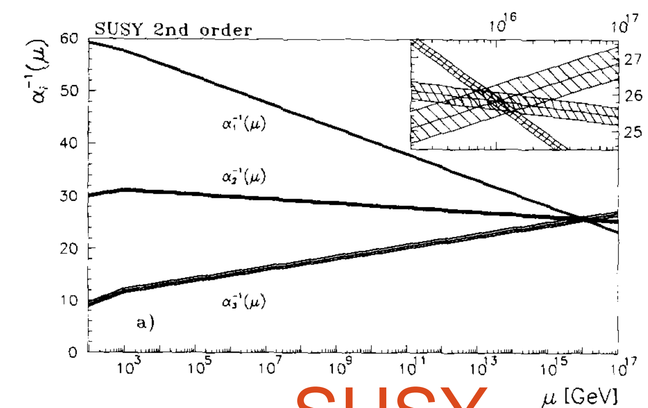


$$\propto y_t^2 \Lambda_{\rm UV}^2$$

  gauge coupling unification



SM



SUSY

[Amaldi et al 1991]

  dark matter, strings, ...

- many ‘soft’ parameters in absence of a theory of SUSY breaking

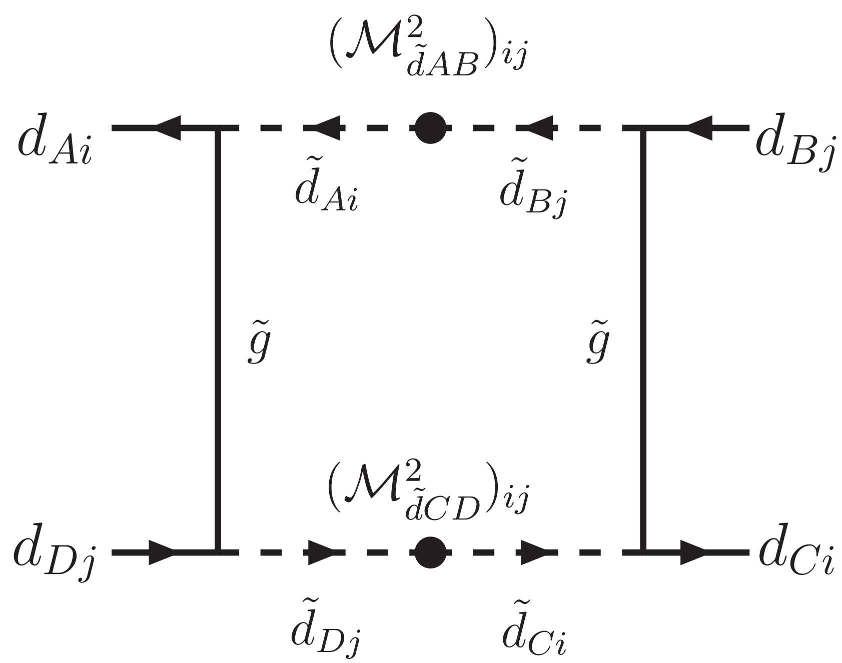
$$\left(\delta_{ij}^{u,d,e,\nu}\right)_{AB} \equiv \frac{\left(\mathcal{M}^2_{\tilde{u},\tilde{d},\tilde{e},\tilde{\nu}}\right)_{ij}^{AB}}{m_{\tilde{f}}^2}$$

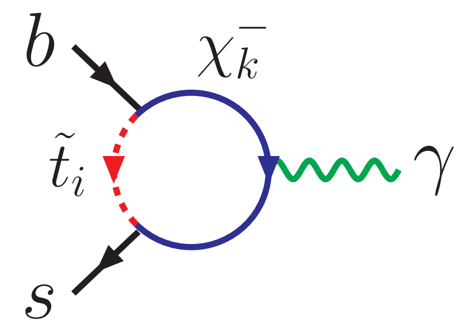
33 flavour-violating parameters

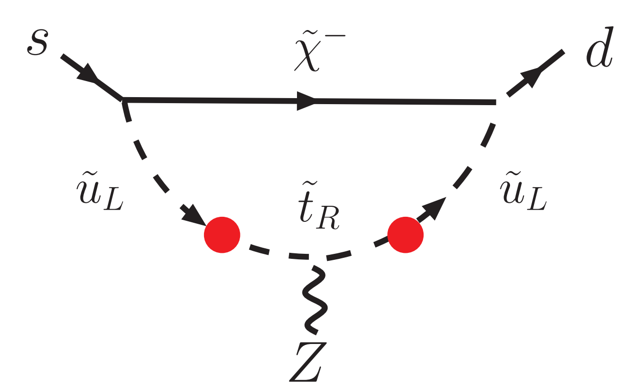
45 CPV (some flavour-conserving)

- flavour probes the SUSY breaking

SUSY flavour - observables



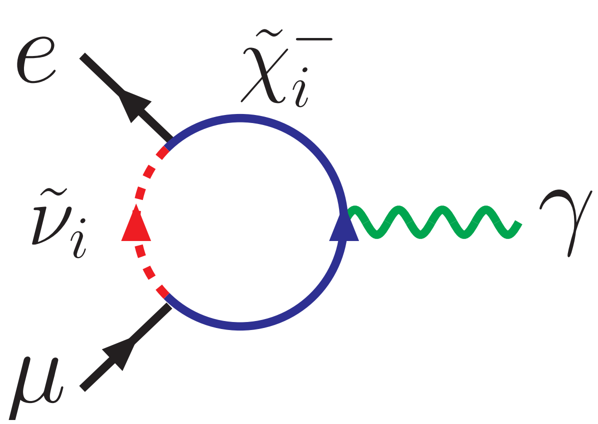




K-$\overline{\text{K}}$, B_d-$\overline{B}_d$, B_s-$\overline{B}_s$ mixing

ΔF=1 decays

$B \rightarrow X_s\ \gamma$
$B \rightarrow X_s\ \mu^+\mu^-$
$B \rightarrow K^*\gamma$, $B \rightarrow K^*\mu^+\mu^-$, $B \rightarrow K\pi$
$B_{s,d} \rightarrow \mu^+\mu^-$
$K \rightarrow \pi\nu\nu$
$B \rightarrow K\nu\nu$
...



lepton flavour violation

$\mu \rightarrow e\gamma$, $\tau \rightarrow e\gamma$ $\tau \rightarrow \mu\gamma$
$\tau \rightarrow \mu\mu\mu$, ...
$\mu \rightarrow e$ conversion
...

SUSY flavour puzzle

$$\left(\delta_{ij}^{u,d,e,\nu}\right)_{AB} \equiv \frac{\left(\mathcal{M}^2_{\tilde{u},\tilde{d},\tilde{e},\tilde{\nu}}\right)^{AB}_{ij}}{m^2_{\tilde{f}}}$$

where are their effects?

Quantity	upper bound
$\sqrt{\lvert \mathrm{Re}(\delta^{\tilde{d}}_{ds})^2_{LL}\rvert}$	4.0×10^{-2}
$\sqrt{\lvert \mathrm{Re}(\delta^{\tilde{d}}_{ds})^2_{RR}\rvert}$	4.0×10^{-2}
$\sqrt{\lvert \mathrm{Re}(\delta^{\tilde{d}}_{ds})^2_{LR}\rvert}$	4.4×10^{-3}
$\sqrt{\lvert \mathrm{Re}(\delta^{\tilde{d}}_{ds})_{LL}(\delta^{\tilde{d}}_{ds})_{RR}\rvert}$	2.8×10^{-3}
$\sqrt{\lvert \mathrm{Im}(\delta^{\tilde{d}}_{ds})^2_{LL}\rvert}$	3.2×10^{-3}
$\sqrt{\lvert \mathrm{Im}(\delta^{\tilde{d}}_{ds})^2_{RR}\rvert}$	3.2×10^{-3}
$\sqrt{\lvert \mathrm{Im}(\delta^{\tilde{d}}_{ds})^2_{LR}\rvert}$	3.5×10^{-4}
$\sqrt{\lvert \mathrm{Im}(\delta^{\tilde{d}}_{ds})_{LL}(\delta^{\tilde{d}}_{ds})_{RR}\rvert}$	2.2×10^{-4}

Quantity	upper bound
$\sqrt{\lvert \mathrm{Re}(\delta^{\tilde{d}}_{db})^2_{LL}\rvert}$	9.8×10^{-2}
$\sqrt{\lvert \mathrm{Re}(\delta^{\tilde{d}}_{db})^2_{RR}\rvert}$	9.8×10^{-2}
$\sqrt{\lvert \mathrm{Re}(\delta^{\tilde{d}}_{db})^2_{LR}\rvert}$	3.3×10^{-2}
$\sqrt{\lvert \mathrm{Re}(\delta^{\tilde{d}}_{db})_{LL}(\delta^{\tilde{d}}_{db})_{RR}\rvert}$	1.8×10^{-2}
$\sqrt{\lvert \mathrm{Re}(\delta^{\tilde{d}}_{sb})^2_{LL}\rvert}$	4.8×10^{-1}
$\sqrt{\lvert \mathrm{Re}(\delta^{\tilde{d}}_{sb})^2_{RR}\rvert}$	4.8×10^{-1}
$\sqrt{\lvert \mathrm{Re}(\delta^{\tilde{d}}_{sb})^2_{LR}\rvert}$	1.62×10^{-2}
$\sqrt{\lvert \mathrm{Re}(\delta^{\tilde{d}}_{sb})_{LL}(\delta^{\tilde{d}}_{sb})_{RR}\rvert}$	8.9×10^{-2}

Quantity	upper bound
$\sqrt{\lvert \mathrm{Re}(\delta^{\tilde{u}}_{uc})^2_{LL}\rvert}$	3.9×10^{-2}
$\sqrt{\lvert \mathrm{Re}(\delta^{\tilde{u}}_{ud})^2_{RR}\rvert}$	3.9×10^{-2}
$\sqrt{\lvert \mathrm{Re}(\delta^{\tilde{u}}_{uc})^2_{LR}\rvert}$	1.20×10^{-2}
$\sqrt{\lvert \mathrm{Re}(\delta^{\tilde{u}}_{uc})_{LL}(\delta^{u}_{uc})_{RR}\rvert}$	6.6×10^{-3}

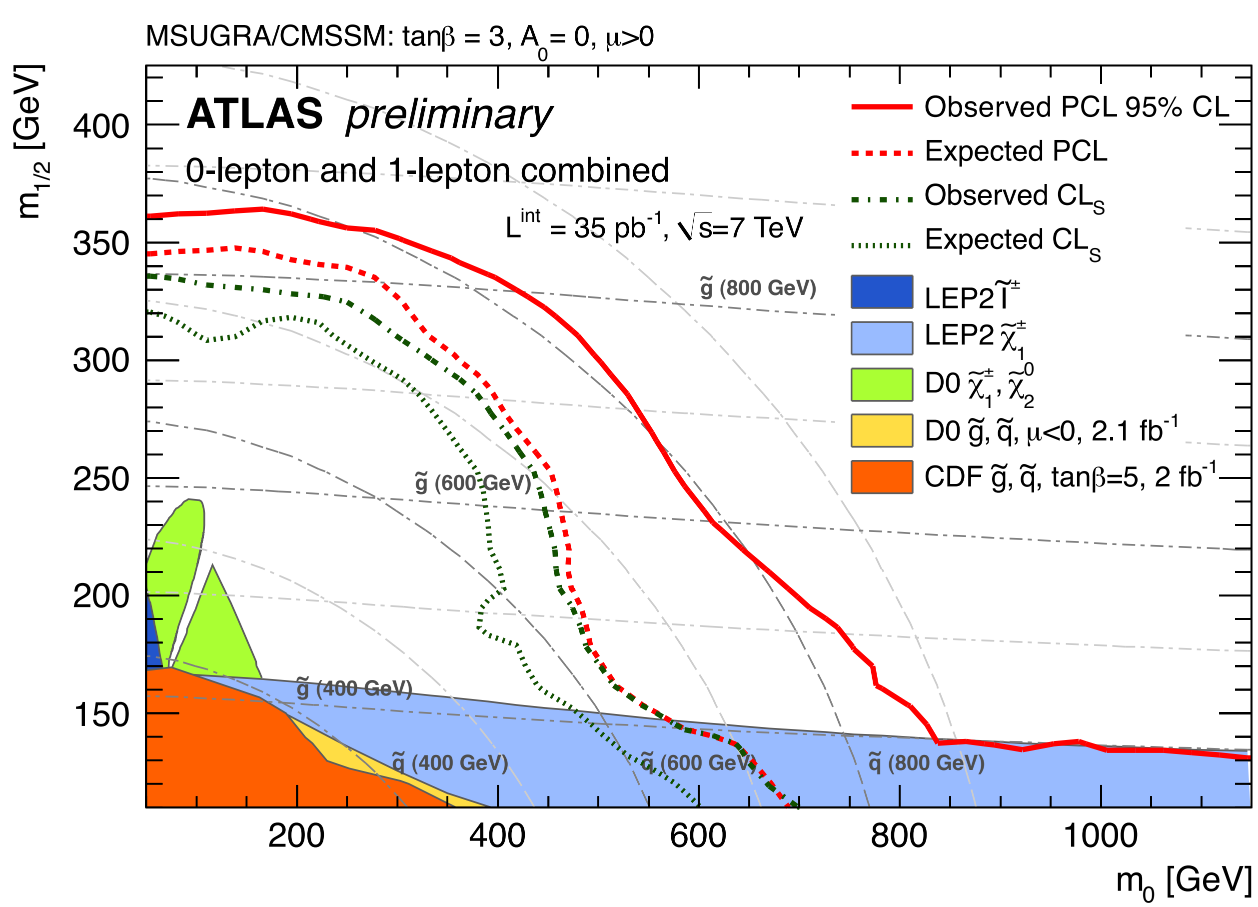
[Gabbiani et al 96; Misiak et al 97]
these numbers from [SJ, 0808.2044]

- elusiveness of deviations from SM in flavour physics seems to make MSSM look unnatural

- pragmatic point of view: flavour physics highly sensitive to MSSM parameters - probes the SUSY breaking mechanism in particular

CMSSM / mSUGRA

- standard approach: "CMSSM" ("mSUGRA")
  - universal scalar mass, gaugino mass, A-terms (A_{ij}=a Y_{ij}) at the GUT scale, sign(μ)
  - 3 parameters & 1 sign, RG evolution down to TeV scale
- flavour puzzle absent [CMSSM still needs to be justified]
- Straightforward interpretation of experimental constraints



ATLAS-CONF-2011-064

Grand unification

$\begin{pmatrix} u_L \\ d_L \end{pmatrix}$	$\begin{matrix} u_R \\ d_R \end{matrix}$	$\begin{pmatrix} c_L \\ s_L \end{pmatrix}$	$\begin{matrix} c_R \\ s_R \end{matrix}$	$\begin{pmatrix} t_L \\ b_L \end{pmatrix}$	$\begin{matrix} t_R \\ b_R \end{matrix}$	$\begin{matrix} Q = +2/3 \\ Q = -1/3 \end{matrix}$
$\begin{pmatrix} \nu_{eL} \\ e_L \end{pmatrix}$	$\begin{matrix} - \\ e_R \end{matrix}$	$\begin{pmatrix} \nu_{\mu L} \\ \mu_L \end{pmatrix}$	$\begin{matrix} - \\ \mu_R \end{matrix}$	$\begin{pmatrix} \nu_{\tau L} \\ \tau_L \end{pmatrix}$	$\begin{matrix} - \\ \tau_R \end{matrix}$	$\begin{matrix} Q = 0 \\ Q = -1 \end{matrix}$

- SM in highly reducible representations of the gauge group
  SM gen = $(3,2)_{1/6} + (\overline{3},1)_{-2/3} + (\overline{3},1)_{1/3} + (1,2)_{-1/2} + (1,1)_{1}$

- however,
  SM gen = $[10 + \overline{5}]_{SU(5)}$
  SM gen + ν_R^c = $16_{SO(10)}$

- if either group is gauged, no gauge invariant distinction of baryons and leptons - baryon & lepton number violation

  what about flavour?

Flavour of SUSY GUTs

- small, hierarchical mixing in the quark sector

$$K = \begin{pmatrix} 1-\frac{1}{2}\lambda^2 & \lambda & A\lambda^3(\rho - i\eta) \\ -\lambda & 1-\frac{1}{2}\lambda^2 & A\lambda^2 \\ A\lambda^3(1-\rho-i\eta) & -A\lambda^2 & 1 \end{pmatrix}$$

- large mixings in the lepton sector

$$U = \begin{pmatrix} c\, e^{i\alpha_1/2} & s\, e^{i\alpha_2/2} & s_{13}\, e^{-i\delta} \\ -s\, e^{i\alpha_1/2} & c\, e^{i\alpha_2/2}/\sqrt{2} & 1/\sqrt{2} \\ s\, e^{i\alpha_1/2} & -c\, e^{i\alpha_2/2}/\sqrt{2} & 1/\sqrt{2} \end{pmatrix} \qquad s = \mathcal{O}(1)$$

SUSY radiative corrections can “transfer” leptonic mixing angles to the hadronic sector

Barbieri&Hall 1994, Barbieri,Hall,Strumia 1995

CMM Model

[Chang, Masiero, Murayama 03]

- SO(10) gauge theory with superpotential

$$W_Y = \frac{1}{2} 16_i \, \mathsf{Y}_1^{ij} \, 16_j \, 10_H \; + \; 16_i \, \mathsf{Y}_2^{ij} \, 16_j \, \frac{45_H \, 10'_H}{2 \, M_{\rm Pl}} \; + \; 16_i \, \mathsf{Y}_N^{ij} \, 16_j \, \frac{\overline{16}_H \overline{16}_H}{2 \, M_{\rm Pl}}$$

SO(10) spinor $\quad 16_i = (Q, u^c, d^c, L, e^c, \nu^c)_i \, , \qquad i = 1, 2, 3$

M_U, $M_\nu^{\rm Dirac}$ $\qquad$ M_D, M_L $\qquad$ $M_{\nu R}$

- assumptions:
  - Y_1 and Y_N simultaneously diagonalisable
  - breaking via SU(5)

$$\mathrm{SO(10)} \xrightarrow{\langle 16_H \rangle, \langle \overline{16}_H \rangle, \langle 45_H \rangle} \mathrm{SU(5)} \xrightarrow{\langle 45_H \rangle} \mathrm{G_{SM}} \equiv \mathrm{SU(3)}_C \times \mathrm{SU(2)}_L \times \mathrm{U(1)}_Y$$

$$\xrightarrow{\langle 10_H \rangle, \langle 10'_H \rangle} \mathrm{SU(3)}_C \times \mathrm{U(1)}_{\rm em}$$

  - MSSM Higgs doublets in different copies of 10 of SO(10)

$$\begin{aligned} \mathbf{10}_H &= (*, \mathbf{5}_H) = (*, (\mathbf{3}_H, H_u)) \\ \mathbf{10}'_H &= (\overline{\mathbf{5}}_H, *) = ((\overline{\mathbf{3}}_H, H_d), *) \end{aligned}$$

Nonrenormalizable Y_2 term gives naturally small tan(β)

Flavour structure

$$W_Y = \frac{1}{2} 16_i \, \mathsf{Y}_1^{ij} \, 16_j \, 10_H \; + \; 16_i \, \mathsf{Y}_2^{ij} \, 16_j \, \frac{45_H \, 10'_H}{2 \, M_{\mathrm{Pl}}} \; + \; 16_i \, \mathsf{Y}_N^{ij} \, 16_j \, \frac{\overline{16}_H \overline{16}_H}{2 \, M_{\mathrm{Pl}}}$$

$$\mathsf{Y}_1 = L_1 \, \mathsf{D}_1 \, L_1^\top \, ,$$
$$\mathsf{Y}_2 = L_2 \, \mathsf{D}_2 \, R_2^\dagger \, ,$$
$$\mathsf{Y}_N = R_N \, \mathsf{D}_N \, P_N \, R_N^\top$$

$L_1^\dagger R_N = \mathbb{1}$ (Y_1 and Y_N simultaneously diagonalisable)

$$V_q = L_1^\top L_2^*$$ CKM quark mixing matrix

$$U_D = P_N^* R_2^\dagger L_1^*$$ PMNS lepton mixing matrix

- Now fix a U-basis where Y_1 and Y_N. Then

$$\mathsf{Y}_2 = V_q^* \, \mathsf{D}_2 \, U_D \longrightarrow M_D, M_L$$

contains all flavour violation
In the *SM*, U_D is unphysical in hadronic physics.

Flavour structure (2)

- work in the (U) basis

$$Y_2 = V_q^* D_2 U_D$$

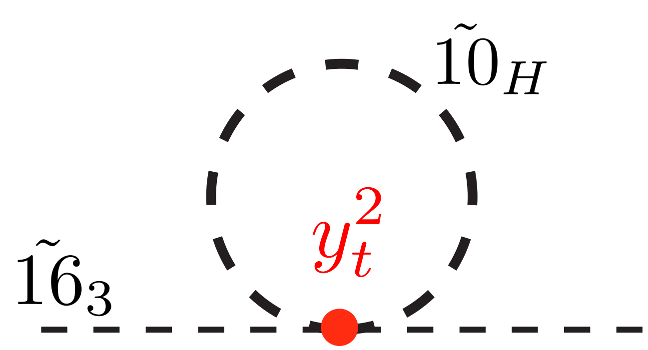
$M_D = v_d Y_2$

rotating to mass eigenstates eliminates U_D

$M_L = v_d Y_2^T$

rotating to mass eigenstates eliminates V_q

so no physical effect in the SM, or unbroken SUSY theory



However, the large top Yukawa coupling in Y_1 fixes the U-basis as the *universal* mass eigenbasis for the sfermions

“msugra GUTs”

Assume that SUSY breaking is flavour blind and universal (like msugra) at or near the Planck scale

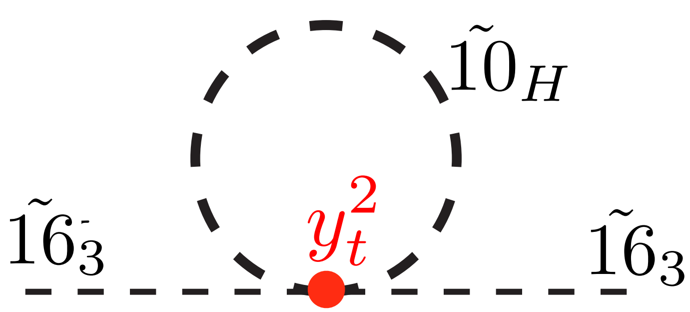
$$
\begin{aligned}
\mathscr{L}_{\rm soft} = & -\widetilde{16}_i^* \, \mathsf{m}^{2\,ij}_{\widetilde{16}} \, \widetilde{16}_j - m^2_{10_H} \, 10^*_H 10_H - m^2_{10'_H} \, 10^*_{H'} 10_{H'} \\
& - m^2_{\overline{16}_H} \, \overline{16}^*_H \overline{16}_H - m^2_{16_H} 16^*_H 16_H - m^2_{45_H} \, 45^*_H 45_H \\
& - \left(\frac{1}{2} \widetilde{16}_i \, \mathsf{A}_1^{ij} \, \widetilde{16}_j \, 10_H + \widetilde{16}_i \, \mathsf{A}_2^{ij} \, \widetilde{16}_j \, \frac{45_H \, 10_{H'}}{2\, M_{\rm Pl}} + \widetilde{16}_i \, \mathsf{A}_N^{ij} \, \widetilde{16}_j \frac{\overline{16}_H \overline{16}_H}{2\, M_{\rm Pl}} + \text{h.c.} \right)
\end{aligned}
$$

$$
\mathsf{m}^2_{\widetilde{16}_i} = m_0^2 \; \mathbb{1} \, , \qquad m^2_{10_H} = m^2_{10'_H} = m^2_{16_H} = m^2_{\overline{16}_H} = m^2_{45_H} = m_0^2
$$

$$
\mathsf{A}_1 = a_0 \, \mathsf{Y}_1 \, , \qquad \mathsf{A}_2 = a_0 \, \mathsf{Y}_2 \, , \qquad \mathsf{A}_N = a_0 \, \mathsf{Y}_N \, ,
$$

radiative corrections lead to a *nonuniversal* sfermion mass matrix at the GUT scale, *diagonal in the U-basis*

[Hall, Kostelecky, Raby 86; Barbieri, Hall, Strumia 95]



$$
m^2_{\tilde{16}_3} = m_0^2 - \Delta
$$

$$
m^2_{\tilde{16}_1} \approx m^2_{\tilde{16}_2} = m_0^2 + \delta
$$

Observables

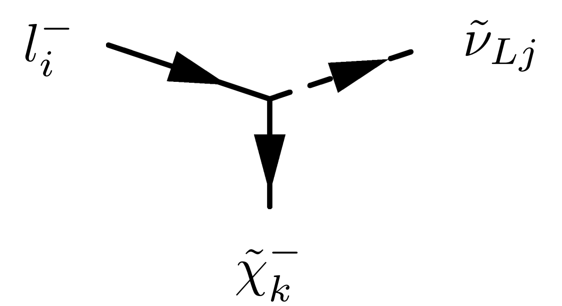
- There is now a mismatch of the sfermion and fermion mass bases for the right-handed down-type particles and the left-handed leptons

$$\mathsf{m}^2_D = U_D \mathsf{m}^2_{\tilde{d}} U_D^\dagger = \begin{pmatrix} m^2_{\tilde{d}} & 0 & 0 \\ 0 & m^2_{\tilde{d}} - \frac{1}{2}\Delta_{\tilde{d}} & -\frac{1}{2}\Delta_{\tilde{d}} \mathrm{e}^{i\xi} \\ 0 & -\frac{1}{2}\Delta_{\tilde{d}} \mathrm{e}^{-i\xi} & m^2_{\tilde{d}} - \frac{1}{2}\Delta_{\tilde{d}} \end{pmatrix}$$

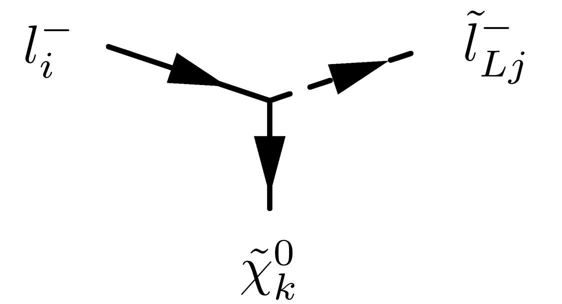
complex phase

- Diagonalizing the matrix introduces flavour violation into neutral current vertices

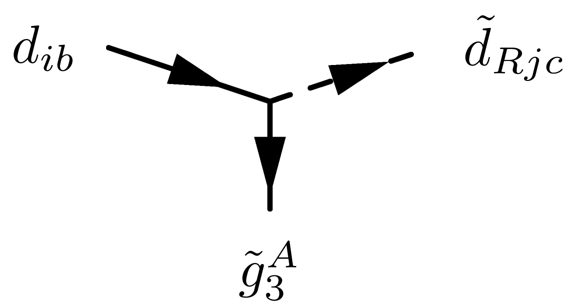
Soft flavour violation



$$-i\left(\frac{e}{\sin\theta_W} Z_+^{1i} P_L + y_{l_i^-} Z_-^{2i*} P_R\right) U_{ij}$$



$$i\left(\left[\frac{e}{\sqrt{2}\cos\theta_W} Z_N^{1k} + \frac{e}{\sqrt{2}\sin\theta_W} Z_N^{2k}\right] P_L + y_{l_i^-} Z_N^{3k*} P_R\right) U_{ij}$$



$$i\sqrt{2} g_3 T_{cb}^A P_R U_{ij}$$

may be complex

large effects in b ➔s transitions, CP violation
correlations of hadronic & leptonic observables

2 ➔1 and 3 ➔1 transitions less clearly correlated

but see Trine et al 2009, Girrbach et al 2010

Earlier work

- Ours is not the first flavour analysis of SUSY GUTs, earlier related work includes:

  Barbieri et al 1995
  SO(10) model with small leptonic mixing

  Moroi JHEP 0003 (2000) 019, PLB 493 (2000) 366
  SUSY SU(5) model with right-handed neutrinos, radiative effects due to atmospheric mixing angle

  Harnik et al 2003
  analysis of effective model with large sbottom-sstrange mixing, inspired by the CMM model

  Ciuchini et al 2004,2007
  SUSY breaking parameterised in mass insertion approximation, SU(5) GUT relations imposed at M_{GUT}

  Analysis strategy here resembles Barbieri et al 1995

PHENOMENOLOGICAL PART

RG evolution

- 2-loop RGE for gauge couplings and y_t, analytic formulas for soft terms, matched at SUSY, SU(5) and SO(10) thresholds
- relate Planck-scale inputs to set of low-energy inputs:

at M_Z $\quad m^2_{\tilde{u}_1}(M_Z)\,, \qquad m^2_{\tilde{d}_1}(M_Z)\,, \qquad a^d_1(M_Z) \equiv \left[a^d(M_Z)\right]_{11}$

$\downarrow$ evolve to M_{GUT}

$$m^2_{\tilde{\Psi}_1}(t_{\mathrm{GUT}}) = m^2_{\tilde{u}_1}(t_{\mathrm{GUT}})\,, \qquad m^2_{\tilde{\Phi}_1}(t_{\mathrm{GUT}}) = m^2_{\tilde{d}_1}(t_{\mathrm{GUT}})$$

$\downarrow$ evolve to M_{10}

$$m^2_{\widetilde{16}_1}(t_{\mathrm{SO(10)}}) = \frac{1}{4}\left[3m^2_{\tilde{\Psi}_1}(t_{\mathrm{SO(10)}}) + m^2_{\tilde{\Phi}_1}(t_{\mathrm{SO(10)}})\right]$$

$\downarrow$ evolve to M_{Pl}

$$m_0^2 = m^2_{\widetilde{16}_1}(t_{\mathrm{Pl}})$$

similarly for a_1^d

evolve all soft terms down to M_Z, calculate spectrum & observables

Example

$M_{\tilde q} = 1500$ GeV, $m_{\tilde g_3} = 500$ GeV, $a_1^d(M_Z)/M_{\tilde q} = 1.5$, $\arg(\mu) = 0$ and $\tan\beta = 6$

upward evolution

$a_0 = 1273$ GeV, $\quad m_0 = 1430$ GeV, $\quad m_{\tilde g} = 184$ GeV

SO(10) & SU(5) RGE

$$\hat{\hat{\mathsf{A}}}_u(M_{\rm GUT}) = \begin{pmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 46 \end{pmatrix} \text{ GeV}, \quad \hat{\hat{\mathsf{A}}}_d(M_{\rm GUT}) = \begin{pmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0.3 & -3.5 \end{pmatrix} \text{ GeV}$$

non-universal at M_{GUT}!

$$\hat{\hat{\mathsf{A}}}_\nu(M_{\rm GUT}) = \begin{pmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ -0.0013 & 0.0023 & 43.4 \end{pmatrix} \text{ GeV},$$

$m_{\tilde\Phi}(M_{\rm GUT}) = \mathrm{diag}\,(1426, 1426, 1074)$ GeV,

$m_{\tilde\Psi}(M_{\rm GUT}) = \mathrm{diag}\,(1444, 1444, 1077)$ GeV,

$m_{\tilde N}(M_{\rm GUT}) = \mathrm{diag}\,(1459, 1459, 1078)$ GeV,

$m_{H_u}(M_{\rm GUT}) = 1126$ GeV, $\quad m_{H_d}(M_{\rm GUT}) = 1446$ GeV,

$m_{\tilde g}(M_{\rm GUT}) = 211$ GeV.

MSSM RGE

$m_{\tilde g_1} = 83$ GeV, $\quad m_{\tilde g_2} = 165$ GeV,

$m_{\tilde\chi_i^0} = (640,\ 632,\ 159,\ \underline{81})$ GeV

LSP

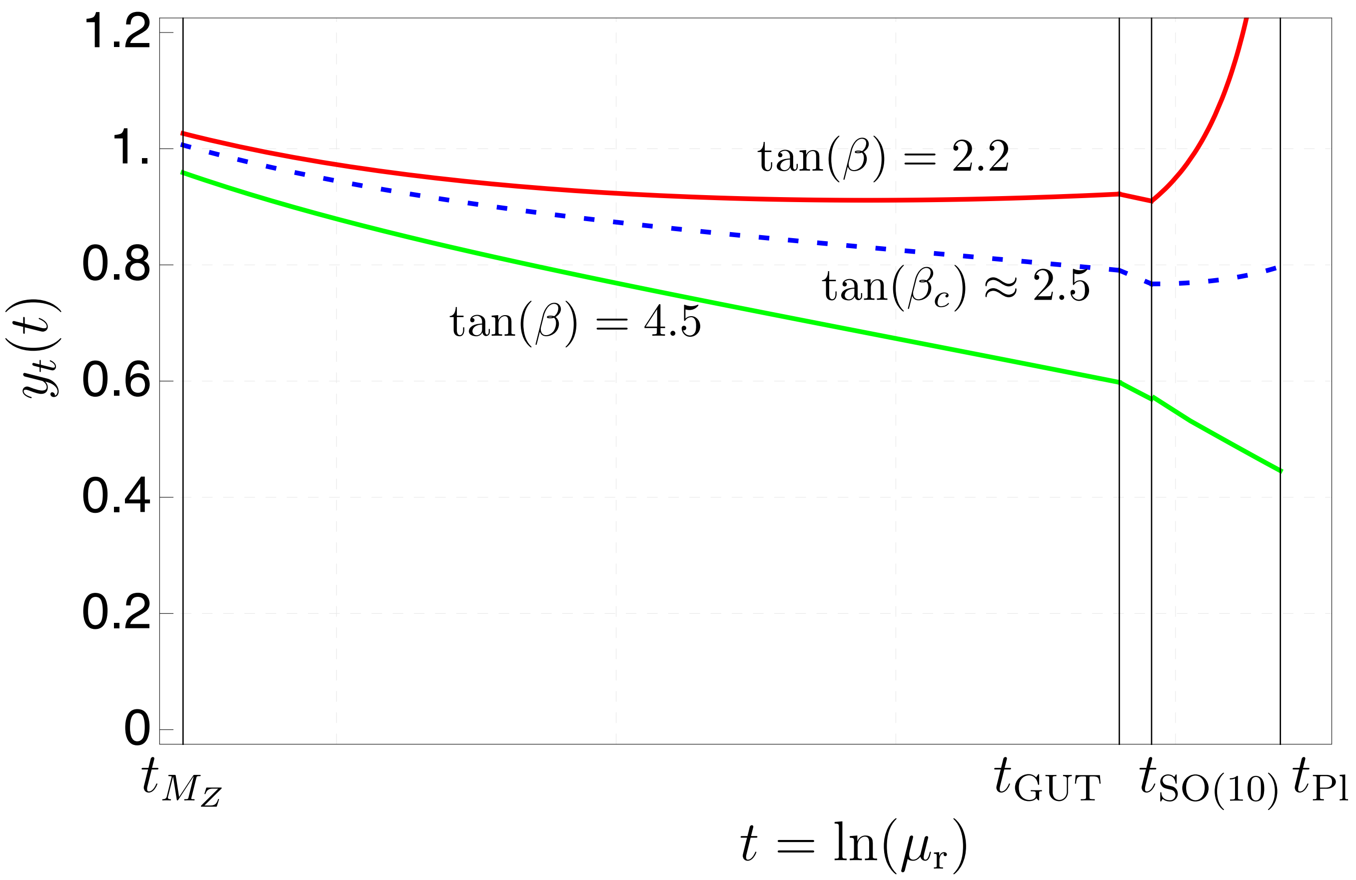
$m_{\tilde\chi_i^\pm} = (640,\ 159)$ GeV

$M_{\tilde l_i} = (1427,\ 1427,\ \mathbf{1074},\ 1462,\ 1462,\ \mathbf{1095})$ GeV

$M_{\tilde u_i} = (1519,\ 1519,\ \mathbf{934},\ 1501,\ 1501,\ \mathbf{485})$ GeV

$M_{\tilde d_i} = (1519,\ 1519,\ \mathbf{908},\ 1498,\ 1498,\ \mathbf{1164})$ GeV.

Perturbativity of y_t



- y_t has quasi-fixed point $y_t^2/g^2=55/56 \sim 1$ in SO(10)
- above this ratio, fast running and typically blowup below M_{Pl}
- below, perturbative treatment of SO(10) radiative corrections possible

Mass splittings

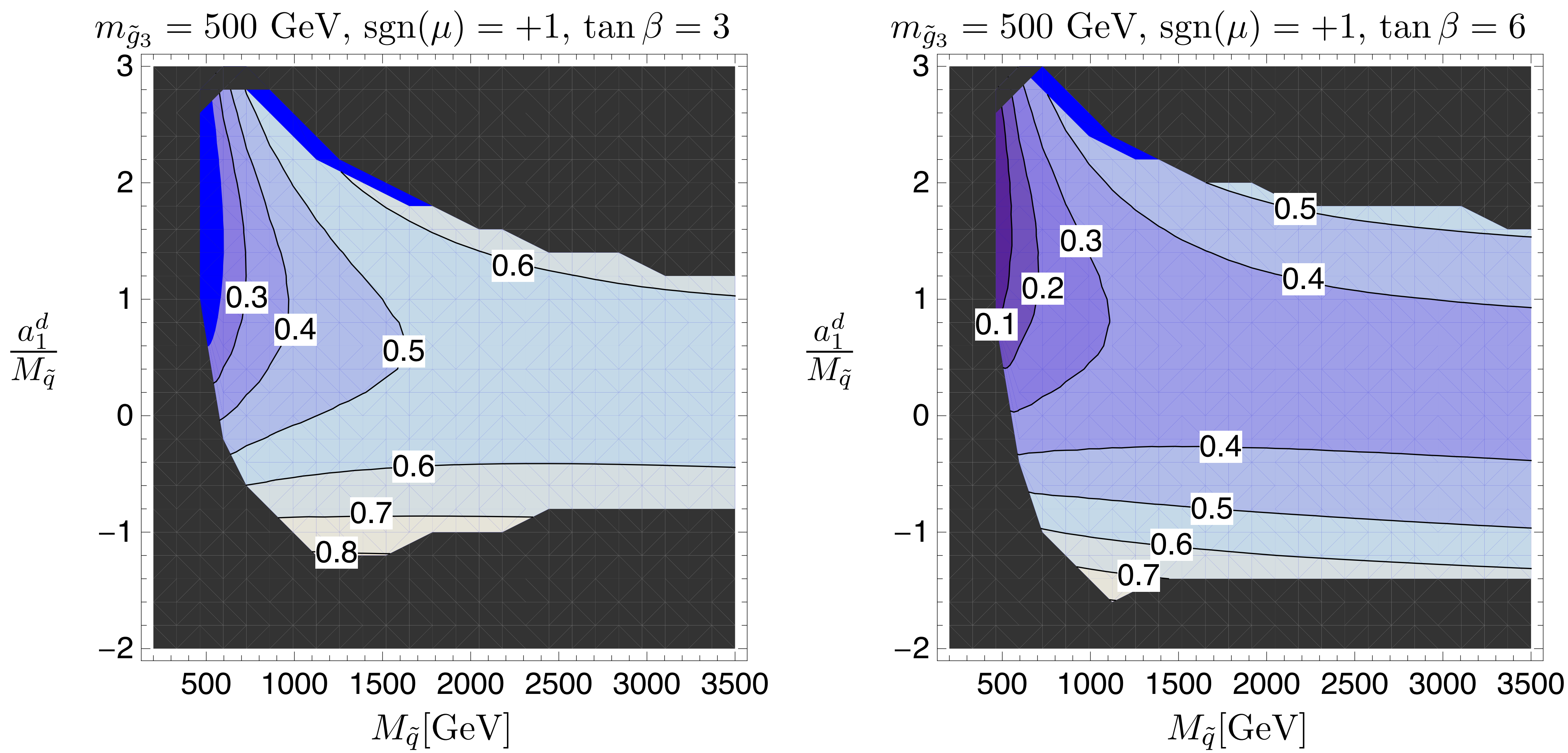


Figure 3: Relative mass splitting $\Delta_{\tilde{d}}^{\mathrm{rel}} = 1 - m_{\tilde{d}_3}^2 / m_{\tilde{d}_2}^2$ among the bilinear soft terms for the right-handed squarks of the second and third generations with $\tan\beta = 3$ (left) and 6 (right) in the $M_{\tilde{q}}(M_Z) - a_1^d(M_Z)/M_{\tilde{q}}(M_Z)$ plane for $m_{\tilde{g}_3} = 500$ GeV and sgn$(\mu) = +1$.

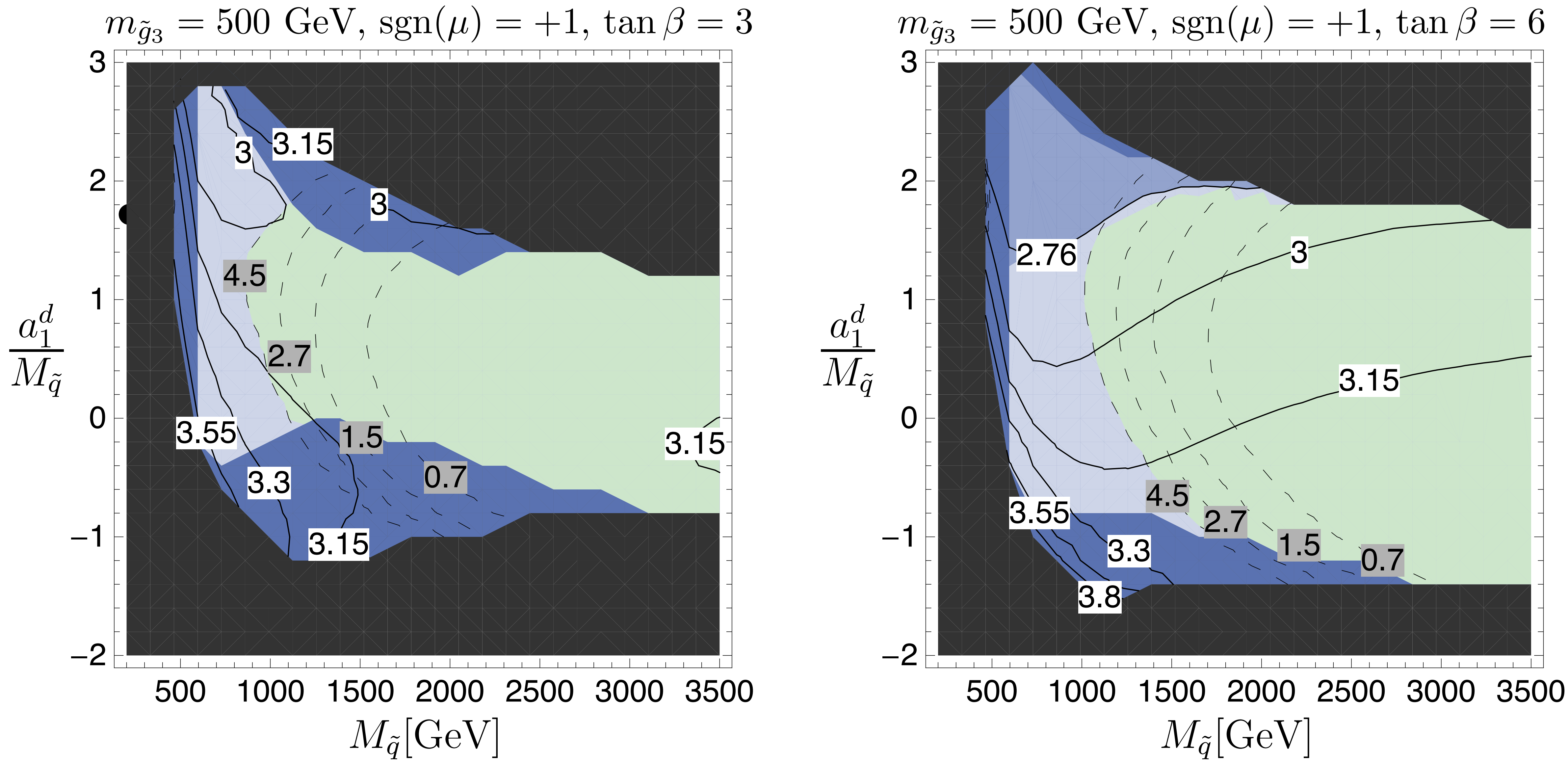


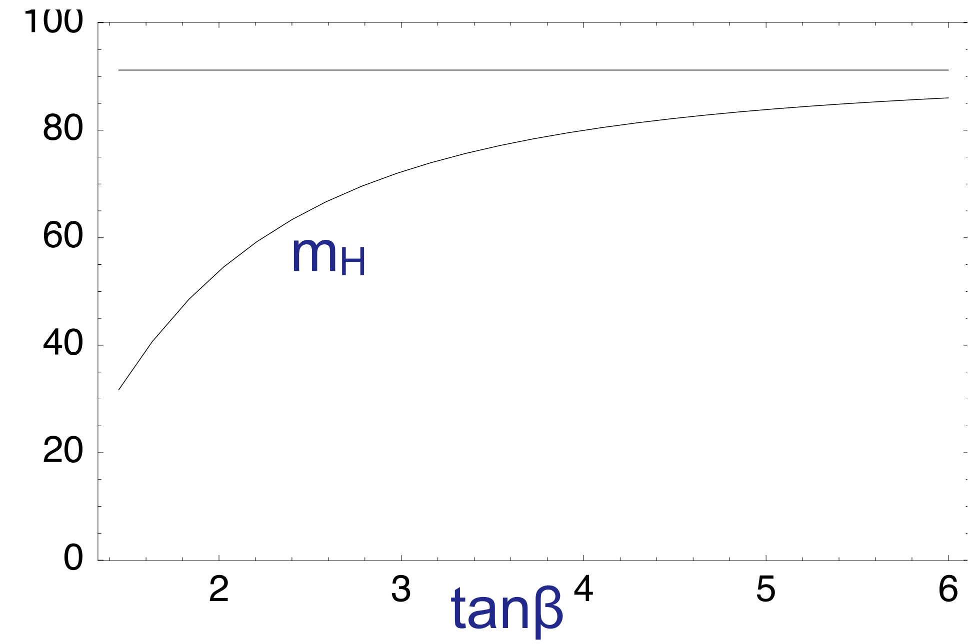
Figure 4: Correlation of FCNC processes as a function of $M_{\tilde{q}}(M_Z)$ and $a_1^d(M_Z)/M_{\tilde{q}}(M_Z)$ for $m_{\tilde{g}_3}(M_Z) = 500$ GeV and $\operatorname{sgn}\mu = +1$ with $\tan\beta = 3$ (left) and $\tan\beta = 6$ (right). $\mathcal{B}(b \to s\gamma)[10^{-4}]$ solid lines with white labels; $\mathcal{B}(\tau \to \mu\gamma)[10^{-8}]$ dashed lines with gray labels. Black region: $m_{\tilde{f}}^2 < 0$ or unstable $|0\rangle$; dark blue region: excluded due to $B_s - \overline{B}_s$; medium blue region: consistent with $B_s - \overline{B}_s$ but excluded due to $b \to s\gamma$; light blue region: consistent with $B_s - \overline{B}_s$ and $b \to s\gamma$ but inconsistent with $\tau \to \mu\gamma$; green region: compatible with all three FCNC constraints.

Higgs mass constraint

- like in mSUGRA, the weak scale gives one relation between μ and the soft SUSY breaking parameters

- like always in the MSSM, the Higgs 'likes' to be light tree level

  (very) small values of tanβ disfavoured



- one & two loops

$$+\frac{3}{2}\frac{G_F\sqrt{2}\,\overline{m}_t^4}{\pi^2}\left\{-\ln\left(\frac{\overline{m}_t^2}{M_S^2}\right)+\frac{|X_t|^2}{M_S^2}\left(1-\frac{|X_t|^2}{12M_S^2}\right)\right\}$$

$$-3\frac{G_F\sqrt{2}\alpha_s\overline{m}_t^4}{\pi^3}\left\{\ln^2\left(\frac{\overline{m}_t^2}{M_S^2}\right)+\left[\frac{2}{3}-2\frac{|X_t|^2}{M_S^2}\left(1-\frac{|X_t|^2}{12M_S^2}\right)\right]\ln\left(\frac{\overline{m}_t^2}{M_S^2}\right)\right\}$$

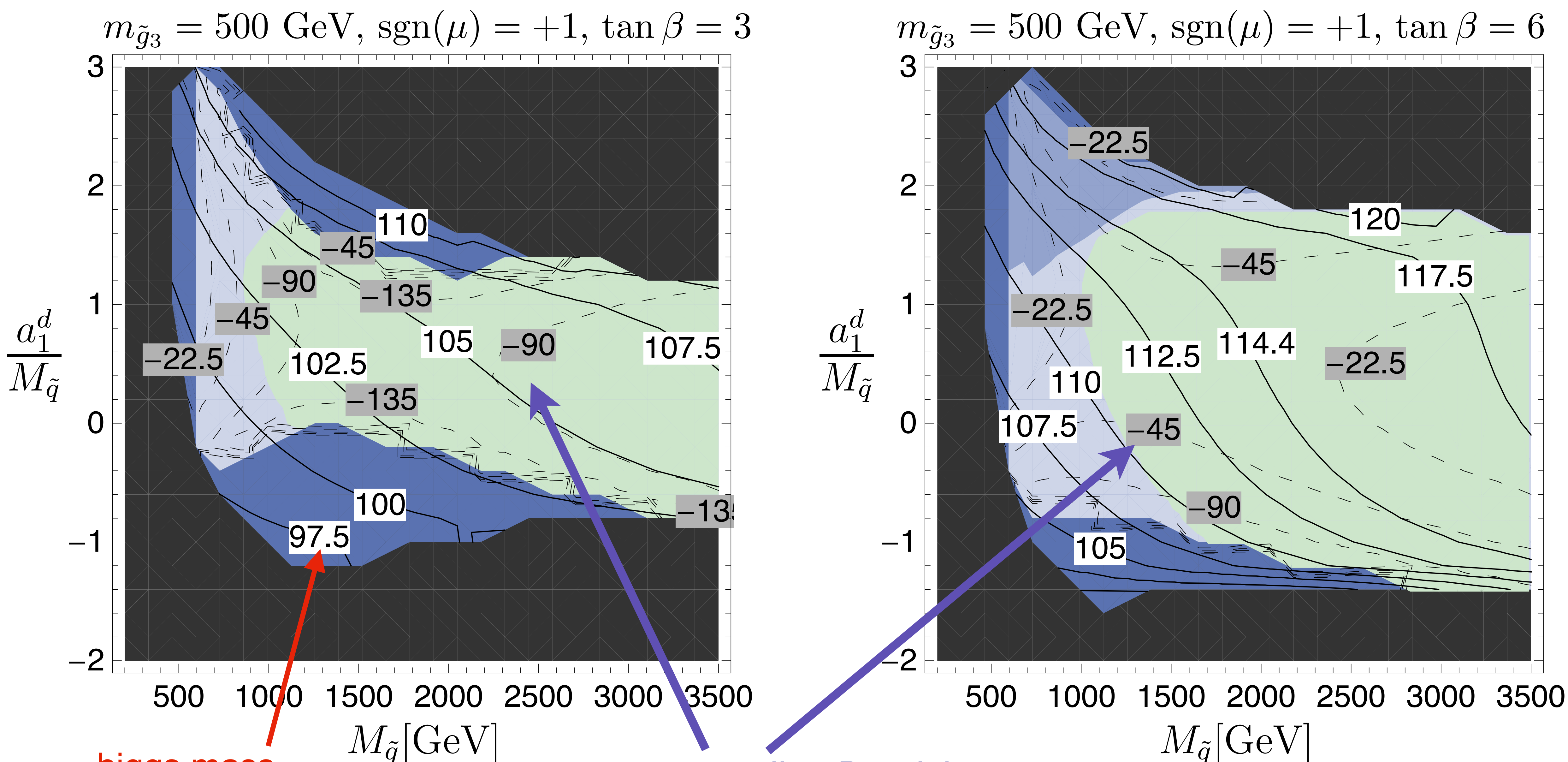
$$X_t=-\frac{A_t}{y_t}-\frac{\mu^*}{\tan\beta}$$

$$M_S^2=\sqrt{m_{\tilde{q}3}^2 m_{\tilde{u}3}^2}$$

- larger tanβ reduces y_t and size of flavour effects

- could be relaxed by allowing the Higgs multiplets to have different Planck-scale masses from the sfermions (similarly to the 'non-universal Higgs model' (NUHM))

Higgs mass & CPV in B_s mixing



higgs mass

excludes whole green region at tanβ = 3

max possible B_s mixing phase (degrees)

higgs mass bound can be satisfied for tanβ = 6 (or greater)

Interplay

More information on the golden matrix can be found in arXiv:1008.1541, arXiv:0909.1333, and arXiv:0810.1312.

- Combine measurements to elucidate structure of new physics.

	Observable/mode	H^+ high $\tan\beta$	MFV	non-MFV	NP Z penguins	Right-handed currents	LTH	SUSY AC	SUSY RVV2	SUSY AKM	SUSY δLL	SUSY FBMSSM	SUSY GUT CMM
✓	$\tau \to \mu\gamma$							★★★	★★★	★	★★★	★★★	***
✓	$\tau \to \ell\ell\ell$						★★★						?
✓	$B \to \tau\nu, \mu\nu$	★★★(CKM)											-
✓	$B \to K^{(*)+}\nu\bar{\nu}$			★	★★★			★	★	★	★	★	?
✓	S in $B \to K^0_S\pi^0\gamma$					★★★							
✓	S in other penguin modes			★★★(CKM)		★★★		★★★	★★	★	★★★	★★★	?
✓	$A_{CP}(B \to X_s\gamma)$			★★★		★★		★	★	★	★★★	★★★	?
✓	$BR(B \to X_s\gamma)$		★★★	★		★							**
✓	$BR(B \to X_s\ell\ell)$			★	★	★							?
✓	$B \to K^{(*)}\ell\ell$ (FB Asym)							★	★	★	★★★	★★★	?
	$B_s \to \mu\mu$							★★★	★★★	★★★	★★★	★★★	*
	β_s from $B_s \to J/\psi\phi$							★★★	★★★	★★★	★	★	***
✓	a_{sl}						★★★						***
✓	Charm mixing							★★★	★	★	★	★	
✓	CPV in Charm	★★									★★★		

✓= SuperB can measure these modes

this model

[Adrian Bevan, this conference]

Conclusions

- SUSY GUTs are theoretical well motivated, viable, and predictive BSM scenarios
- A generic feature are correlations between hadronic and leptonic flavour violation, although details depend on the GUT model
  There is also strong interplay between the mass spectrum (including Higgs mass) and the flavour violation, similar to the CMSSM
- The model analysed here makes predictions for hadronic and leptonic observables relevant to SuperB in terms of a few BSM parameters, and can hopefully serve as a benchmark scenario for SuperB