

Flavour Violating Decays

of Supersymmetric Particles

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- Flavour violating decays of supersymmetric particles, MSSM
- Current implementation of flavour violation (including CP phases) in SPheno
- Future plans

Flavour violating SUSY decays

Off-diagonal entries in the soft SUSY breaking terms imply flavour violating decays such as:

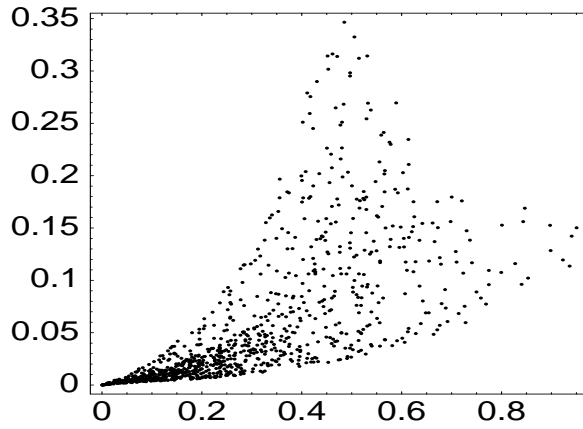
$$\begin{aligned}\tilde{t}_i &\rightarrow c\tilde{\chi}_k^0, s\tilde{\chi}_j^+ \\ \tilde{c}_i &\rightarrow t\tilde{\chi}_k^0, b\tilde{\chi}_j^+ \\ \tilde{g} &\rightarrow c\tilde{t}_i, t\tilde{c}_i \\ \tilde{\chi}_k^0 &\rightarrow e\tilde{\mu}_i, \mu\tilde{\tau}_i\end{aligned}$$

Despite stringent constraints from 'low' energy physics (rare decays of leptons and mesons, electric and magnetic moments of leptons): decays of SUSY particle with sizable flavour violating branching ratios are possible

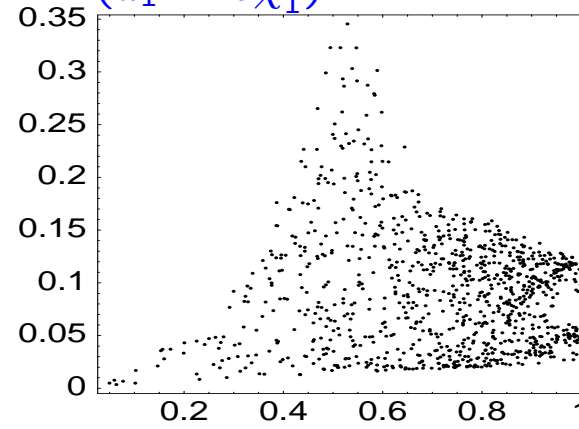
Branching of \tilde{d}_1

define: $R_s = (R_{12}^{\tilde{d}})^2 + (R_{15}^{\tilde{d}})^2$, $R_b = (R_{13}^{\tilde{d}})^2 + (R_{16}^{\tilde{d}})^2$

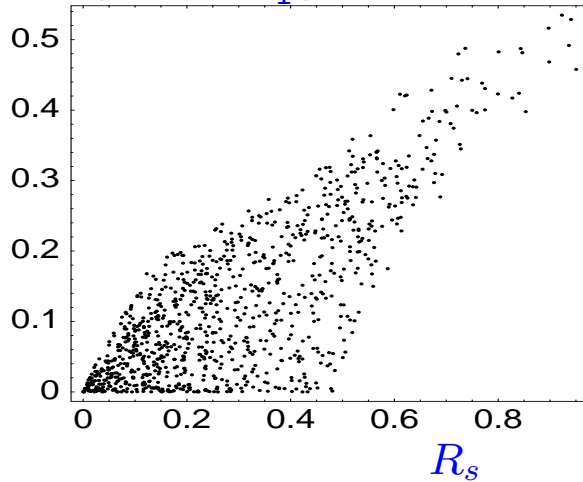
$BR(\tilde{d}_1 \rightarrow s\tilde{\chi}_1^0)$



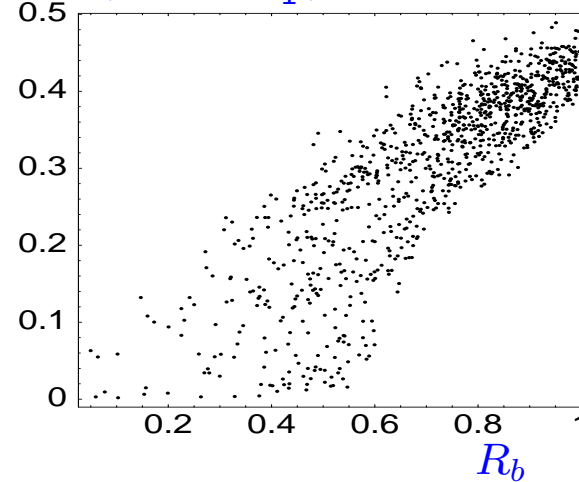
$BR(\tilde{d}_1 \rightarrow b\tilde{\chi}_1^0)$



$BR(\tilde{d}_1 \rightarrow c\tilde{\chi}_1^-)$



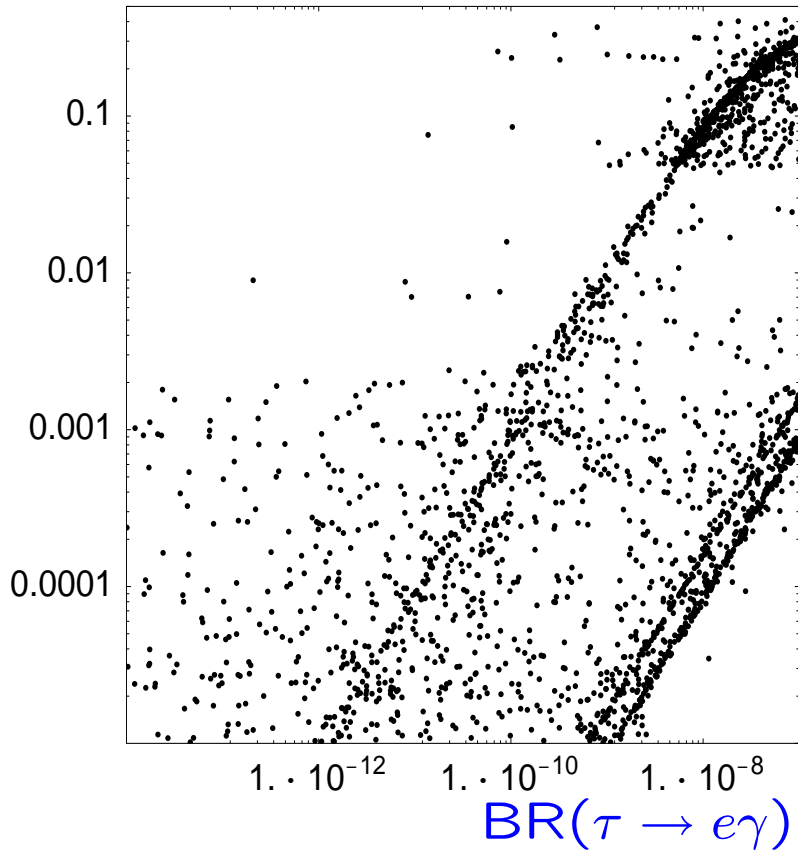
$BR(\tilde{d}_1 \rightarrow t\tilde{\chi}_1^-)$



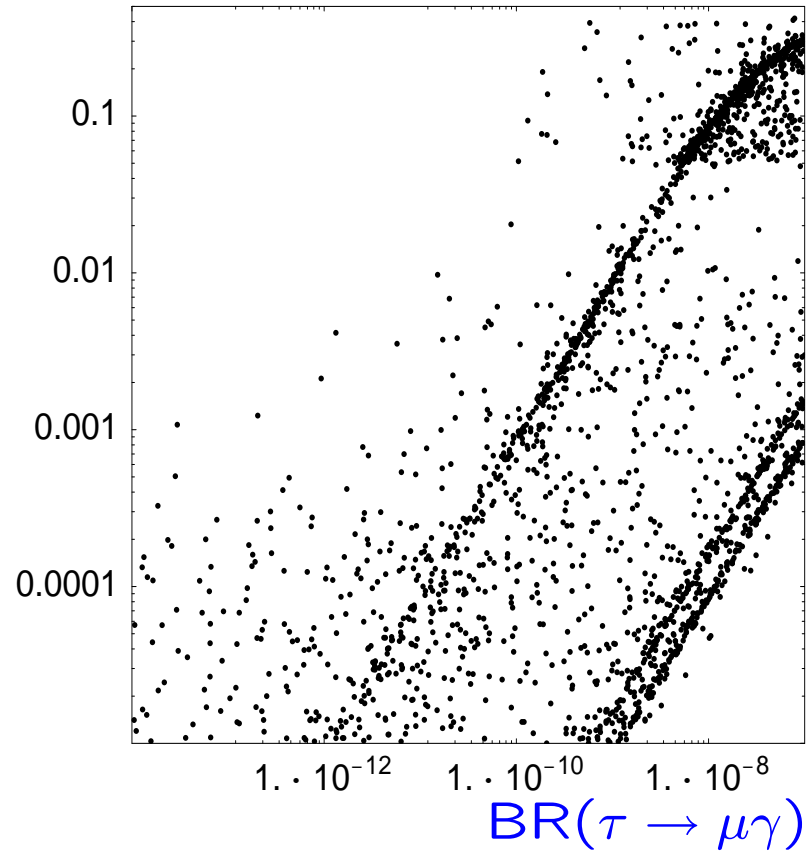
Variations around SPS1a, only mixing between 2nd and 3rd generation

$$\tilde{\chi}_2^0 \rightarrow \tilde{l}_i l_j \rightarrow l_k l_j \tilde{\chi}_1^0$$

$$\text{BR}(\tilde{\chi}_2^0 \rightarrow \tilde{\chi}_1^0 e^\pm \tau^\mp)$$



$$\text{BR}(\tilde{\chi}_2^0 \rightarrow \tilde{\chi}_1^0 \mu^\pm \tau^\mp)$$



Variations around SPS1a

Implications for LHC

Decay chains like $\tilde{g} \rightarrow \tilde{b}_1 \bar{b} \rightarrow \tilde{\chi}_2^0 b \bar{b} \rightarrow \tilde{e}_R^- e^+ b \bar{b} \rightarrow \tilde{\chi}_1^0 e^+ e^- b \bar{b}$
 are used to get masses of SUSY particles

Edge variables Magnitude changes only slightly: $\pm(1-2)$ %

However, new combinations: $m_{ll}^{max} \rightarrow m_{e\mu}^{max} m_{e\tau}^{max} m_{\mu\tau}^{max}$
 similarly for m_{llq}^{max} and m_{llq}^{min}

Note: $\text{BR}(\tilde{\chi}_2^0 \rightarrow \tilde{\chi}_1^0 e^\pm \tau^\mp)$, $\text{BR}(\tilde{\chi}_2^0 \rightarrow \tilde{\chi}_1^0 \mu^\pm \tau^\mp) \simeq \text{BR}(\tilde{\chi}_2^0 \rightarrow \tilde{\chi}_1^0 e^\pm e^\mp)$
 or even larger

\Rightarrow pairing of different lepton flavours necessary

Particularity of SPS1a

$$\tilde{\chi}_1^+ \rightarrow \tilde{\tau}^+ \nu_\tau \rightarrow \tau^+ \nu \tilde{\chi}_1^0$$

\Rightarrow extremely difficult to detect if not impossible

with LFV: $\tilde{\chi}_1^+ \rightarrow \tilde{\tau}_1^+ \nu_\tau \rightarrow e^+ \nu_\tau \tilde{\chi}_1^0$ or $\tilde{\chi}_1^+ \rightarrow \tilde{\tau}_1^+ \nu_\tau \rightarrow \mu^+ \nu_\tau \tilde{\chi}_1^0$
 with $\text{BR}(\tilde{\chi}_1^+ \rightarrow l^+ \nu \tilde{\chi}_1^0)$ up to 15%.

SPheno, public version

- complete 2-loop SUSY RGEs
- complete 1-loop SUSY masses + 2-loop Higgs masses
- all 2-body decays of SUSY and Higgs particles at tree-level
- all 3-body decay modes of $\tilde{\chi}_k^0$, $\tilde{\chi}_j^\pm$, \tilde{g} , \tilde{t}_1
- decays into gravitino in case of GMSB models
- production of SUSY particles in e^+e^- annihilation

However, no generation mixing in the public version yet

SPheno, development version

Generation mixing and all complex phases are included in:

- complete 2-loop SUSY RGEs (including ν_R), several tests passed
- complete 1-loop SUSY masses, several tests passed
- all 2-body decays of SUSY and Higgs particles at tree-level, several tests passed
- all 3-body decay modes of $\tilde{\chi}_k^0$, $\tilde{\chi}_j^\pm$, \tilde{g} , \tilde{t}_1 , several tests passed
- production of SUSY particles in e^+e^- annihilation, several tests passed

- Higgs masses complete 1-loop formulas, in case of real parameters: 2-loop part implemented assuming that there is no generation mixing.

However: no mixing yet of h^0, H^0, A^0

- Low energy observables, several tests passed

1. electric and magnetic moments of leptons: $a_i, d_i, [i = e, \mu, \tau]$

2. rare lepton decays: $\mu \rightarrow e\gamma, \tau \rightarrow e\gamma, \tau \rightarrow \mu\gamma$

3. $b \rightarrow q\gamma, A_{CP}(b \rightarrow q\gamma) [q = d, s]$

4. $B_q^0 \rightarrow \mu^+ \mu^- [q = d, s]$

- Low energy observables, partly implemented

1. $\Delta M_{B_q^0}, (q = d, s): W^+, H^+, \tilde{\chi}^+$ implemented, $\tilde{g}, \tilde{\chi}^0$ missing

Input/Models

at M_Z : α , G_F , m_Z , α_s , m_f (f . . . all SM fermion masses), CKM

Two possibilities: CKM stems either solely from left u -quarks or solely from left d -quarks

SUSY parameters

- mSUGRA, GMSB, AMSB, string inspired models: usual parameters but taking the effect of CKM into account in RGE running and mass calculation
 - at M_{GUT} : specification of all SUSY parameters is possible
- all MSSM parameters at a user given scale $Q \leq 1$ TeV

Future plans

- Implementation of the mixing between h^0 , H^0 and A^0
- link to FeynHiggs to get Higgs masses at 2-loop level for complex but generation diagonal parameters
- release of new version with complex but generation diagonal parameters end of June/beginning of July

- finish the implementation of $\Delta M_{B_q^0}$
- $b \rightarrow q\nu\nu$, $b \rightarrow ql^+l^-$, [$q = s, d$], $s \rightarrow d\nu\nu$, $s \rightarrow dl^+l^-$
- release of version including generation mixing: beginning 2006
- version with R-parity violating couplings/decays but no RGE running during 2nd half of 2005
- In parallel: proposals for SUSY Les Houches Accord including complex phases and generation mixing