R-Parity Violating mSUGRA at the LHC

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Outline

1. Introduction
   - R-Parity violation
   - Minimal Supergravity (mSUGRA)

2. Phenomenology of R-Parity violating mSUGRA at the LHC
   - General hadron collider signatures
   - Benchmark scenarios

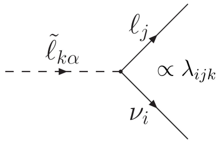
3. Summary and Outlook

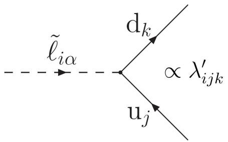
MSSM with R-Parity violation (RPV)

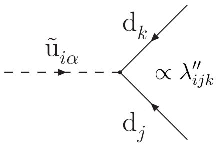
General Superpotential of the Minimal Supersymmetric extension of the SM (MSSM):

$$W_{R_p} = (\mathbf{Y}_E)_{ij} L_i H_d \bar{E}_j + (\mathbf{Y}_D)_{ij} Q_i H_d \bar{D}_j + (\mathbf{Y}_U)_{ij} Q_i H_u \bar{U}_j + \mu H_d H_u \,,$$

$$W_{\not{R}_p} = \underbrace{\frac{1}{2}\lambda_{ijk} L_i L_j \bar{E}_k + \lambda'_{ijk} L_i Q_j \bar{D}_k}_{\Delta L \neq 0} + \underbrace{\frac{1}{2}\lambda''_{ijk} \bar{U}_i \bar{D}_j \bar{D}_k}_{\Delta B \neq 0} + \underbrace{\kappa_i L_i H_u}_{\Delta L \neq 0} \,.$$







The lepton/baryon number violating terms lead to proton decay.
It is sufficient to suppress $\Delta L \neq 0$ or $\Delta B \neq 0$ terms to keep proton stable.

Minimal Supergravity (mSUGRA)

number of new parameters

- $\mathcal{O}(100)$ if R_p is conserved.
- $\mathcal{O}(200)$ if R_p is violated.

Assume simple boundary conditions at the scale $M_{GUT} = \mathcal{O}(10^{16})$ GeV.

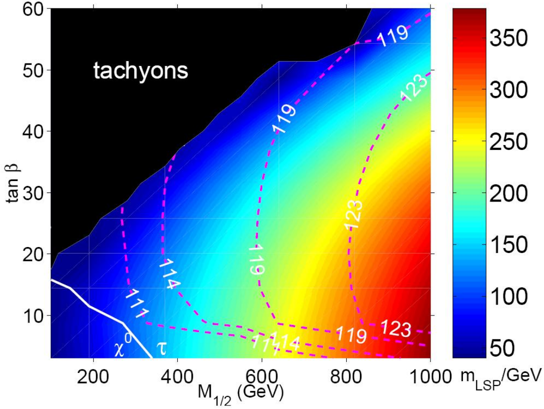
mSUGRA parameter space

- M_0 : Universal soft breaking scalar mass.
- $M_{1/2}$: Universal gaugino soft breaking mass.
- A_0 : Universal trilinear scalar interaction.
- $\tan\beta$: Ratio of vevs of the two Higgs doublets H_u, H_d.
- sgn μ : Solution of EW symmetry breaking scalar potential.

Parameters at the scale $M_{EW} = \mathcal{O}(10^2)$ GeV are obtained by RGEs.
Programs: `Softsusy`, `SPheno`, `Suspect`, `Isajet` etc.

Consider: $M_0 = A_0 = 0$, $\mathrm{sgn}\mu = +1$.

[Allanach, Dedes, Dreiner, Phys.Rev.D69:115002,2004]



- If R_p conserved: Scenario is excluded.
- If R_p violated: Most of the $\tilde{\tau}$-LSP region is allowed.

Add one parameter at M_{GUT}: $\mathbf{\Lambda} \in \{\lambda_{ijk}, \lambda'_{ijk}, \lambda''_{ijk}\}$.

$\Rightarrow$ **R-Parity violating mSUGRA**

What is the phenomenology of a $\tilde{\tau}$ LSP
at hadron colliders?

Typical mass ordering for $\tilde{\tau}$ LSP scenarios.

$$m_{\tilde{g}} > m_{\tilde{q}_2} > m_{\tilde{q}_1} > m_{\tilde{\chi}_2^+} > m_{\tilde{\chi}_1^+} \approx m_{\tilde{\ell}_2} > m_{\tilde{\chi}_1^0} \approx m_{\tilde{\mu}_1} \approx m_{\tilde{e}_1} > m_{\tilde{\tau}_1}$$

If $\mathbf{\Lambda} \leq \mathcal{O}(10^{-2})$

- Sparticles are produced in pairs via gauge interactions, e.g. $\tilde{g}\tilde{g}$, $\tilde{q}\tilde{q}$.
- Sparticle undergo 2-body decays to the $\tilde{\tau}_1$ via gauge interactions.

$$\begin{aligned}\tilde{g} &\rightarrow \tilde{t}\bar{t} \\ &\hookrightarrow \tilde{\chi}_1^+ b \\ &\qquad \hookrightarrow \tilde{\nu}_\mu \mu^+ \\ &\qquad\qquad \hookrightarrow \tilde{\chi}_1^0 \nu_\mu \\ &\qquad\qquad\qquad \hookrightarrow \tilde{\tau}_1^- \tau^+\end{aligned}$$

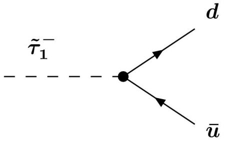
If $\mathbf{\Lambda} \geq \mathcal{O}(10^{-1})$

- Single sparticle production may dominate.
- RPV 2-body decays may alter the decay chains.

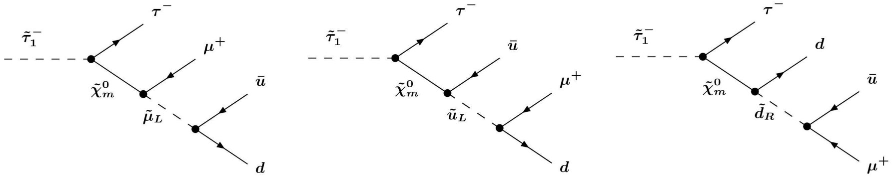
RPV decays of the $\tilde{\tau}$ LSP (simplified picture)

- The dominant operator is: $L_3 L_j \bar{E}_k, L_i L_3 \bar{E}_k$, $L_i L_j \bar{E}_3$ or $L_3 Q_j \bar{D}_k$.
  $\Rightarrow$ 2-body decays.
- The dominant operator is: $L_{i\neq 3} L_{j\neq 3} \bar{E}_{k\neq 3}$, $L_{i\neq 3} Q_j \bar{D}_k$ or $\bar{U}_i \bar{U}_j \bar{D}_k$.
  $\Rightarrow$ 4-body decays.

For example $\lambda'_{311} \neq 0$:



For example $\lambda'_{211} \neq 0$:



Promising signatures

- Detached vertex from long-lived $\tilde{\tau}_1$.
  (if $\mathbf{\Lambda} \leq 10^{-6}$ for 2-body decay
  if $\mathbf{\Lambda} \leq 10^{-2} - 10^{-4}$ for 4-body decay)
- Multi-lepton final states.
  (for $\lambda_{ijk} \neq 0$)
- Multi-tau final states.
  ($\tilde{\chi}_1^0 \to \tilde{\tau}_1^+ \tau^-$, $\tilde{\tau}_1^- \to \tau^- + X$)
- Like-sign dileptons.
  (majorana nature of $\tilde{\chi}_i^0$)

Benchmark points

Next step: Perform simulations of signatures.

$\Rightarrow$ Consider benchmark scenarios with typical spectra and novel collider signatures. [Allanach et. al., Phys.Rev.D75:035002,2007]

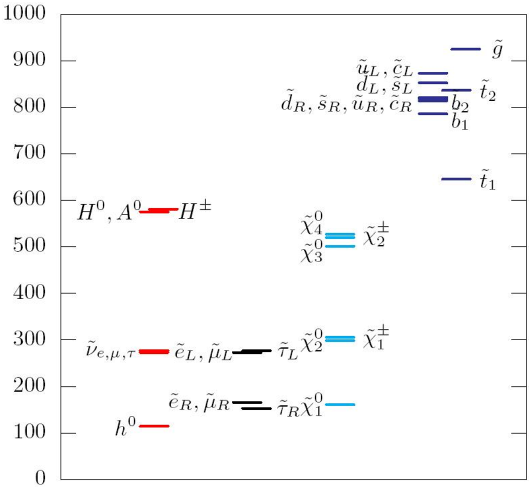
- All spectra are calculated with a R_p violating version of `Softsusy`. [Allanach, Bernhardt, September 2007]
- The simulations are done with `Isajet` and `Herwig`, including all R_p violating $\tilde{\tau}_1$ decays.

Now: Pair-production of sparticles at the LHC.

Benchmark scenario BC1

BC1

- $M_0 = A_0 = 0$
- $\lambda_{121}(M_{GUT}) = 0.032$
- $\tan\beta = 13$
- $M_{1/2} = 400$ GeV
- $\text{sgn}(\mu) = +1.$



Branching ratios in benchmark scenario BC1

	mass [GeV]	channel	BR	channel	BR
$\tilde{\tau}_1$	148	$\mu^+\bar{\nu}_e e^-\tau^-$	32 %	$e^+\bar{\nu}_\mu e^-\tau^-$	32 %
		$\mu^-\nu_e e^+\tau^-$	18 %	$e^-\nu_\mu e^+\tau^-$	18 %
$\tilde{e}_R$	161	$e^-\nu_\mu$	50 %	$\mu^-\nu_e$	50 %
$\tilde{\mu}_R$	161	$\tilde{\tau}^+\mu^-\tau^-$	51 %	$\tilde{\tau}^-\mu^-\tau^+$	49 %
$\tilde{\chi}_1^0$	162	$\tilde{\tau}_1^+\tau^-$	50 %	$\tilde{\tau}_1^-\tau^+$	50%
$\tilde{\nu}_\tau$	265	$\tilde{\chi}_1^0\nu_\tau$	67 %	$W^+\tilde{\tau}_1$	33 %
$\tilde{\nu}_e(\tilde{\nu}_\mu)$	266	$\tilde{\chi}_1^0\nu_e(\nu_\mu)$	92 %	$\mu^+(e^+)e^-$	7.5 %
$\tilde{e}_L^-(\tilde{\mu}_L^-)$	280	$\tilde{\chi}_1^0 e^-(\mu^-)$	92 %	$e^-\bar{\nu}_\mu(\bar{\nu}_e)$	8.1 %
$\tilde{\tau}_2$	283	$\tilde{\chi}_1^0\tau^-$	63 %	$Z^0\tilde{\tau}_1^-$	18 %
		$h^0\tilde{\tau}_1^-$	19 %		

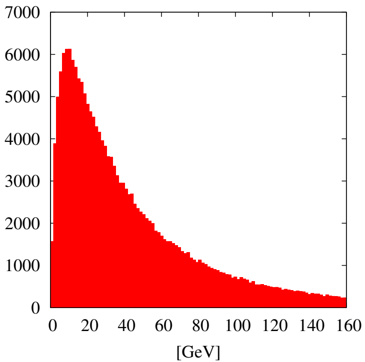
Signal rates of benchmark scenario BC1

σ(total sparticle pair production) $= 4.8 \cdot 10^3$fb

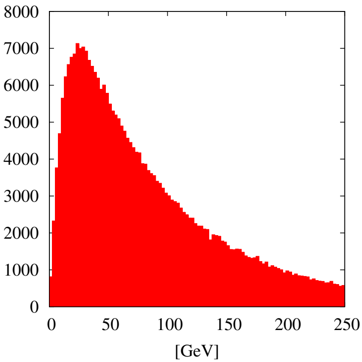
e^+ or μ^+	e^- or μ^-	τ^+	τ^-	$\not{p}_T$	event fraction
2	2	2	2	yes	35 %
3	2	2	2	yes	12 %
2	3	2	2	yes	8.3 %
3	3	2	2	yes	7.3 %
2	2	2	1	yes	4.7 %
2	2	3	2	yes	4.3 %
2	2	3	3	yes	1.4 %
4	3	2	2	yes	1.1 %

- Multi-lepton final states ($\approx$ 8 leptons).
- Multi-tau final states ($\approx$ 4 taus).
- 2-4 jets
- Missing p_T due to neutrinos from $\tilde{\tau}_1$ decay.

p_T distributions in benchmark scenario BC1



p_T distribution of the τ from $\tilde{\tau}_1$ decays.



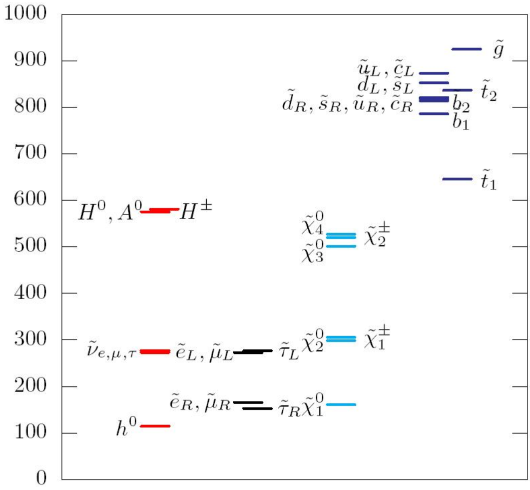
p_T distribution of the neutrinos.

- Taus with $p_T > 30$ GeV might usefull to identify the scenario.
- Missing p_T is less than in the R_p conserving MSSM.

Benchmark scenario BC2

BC2

- $M_0 = A_0 = 0$
- $\lambda'_{311}(M_{GUT}) = 3.5 \cdot 10^{-7}$
- $\tan\beta = 13$
- $M_{1/2} = 400$ GeV
- $\mathrm{sgn}(\mu) = +1.$



Branching ratios in benchmark scenario BC2

	mass [GeV]	channel	BR	channel	BR
$\tilde{\tau}_1$	148	$\bar{u}d$	100 %		
$\tilde{e}_R(\tilde{\mu}_R)$	161	$\tilde{\tau}_1^+ e^-(\mu^-)\tau^-$	51 %	$\tilde{\tau}_1^- e^-(\mu^-)\tau^+$	49 %
$\tilde{\chi}_1^0$	162	$\tilde{\tau}_1^+ \tau^-$	50 %	$\tilde{\tau}_1^- \tau^+$	50 %
$\tilde{\nu}_\tau$	265	$\tilde{\chi}_1^0 \nu_\tau$	67 %	$W^+ \tilde{\tau}_1$	33 %
$\tilde{\nu}_e(\tilde{\nu}_\mu)$	266	$\tilde{\chi}_1^0 \nu_e(\nu_\mu)$	100 %		
$\tilde{e}_L^-(\tilde{\mu}_L^-)$	280	$\tilde{\chi}_1^0 e^-(\mu^-)$	100 %		
$\tilde{\tau}_2$	283	$\tilde{\chi}_1^0 \tau^-$	63 %	$Z^0 \tilde{\tau}_1^-$	18 %
		$h^0 \tilde{\tau}_1^-$	15 %		

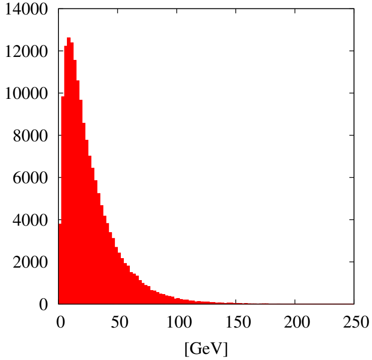
Signal rates of benchmark scenario BC2

$$\sigma(\text{sparticle pair production}) = 4.8 \cdot 10^3 \text{fb}$$

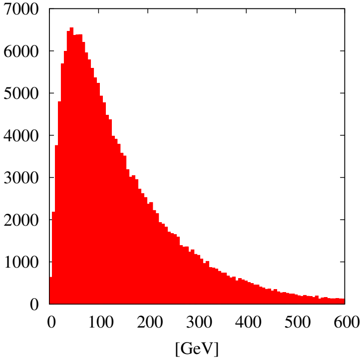
e^+ or μ^+	e^- or μ^-	τ^+	τ^-	$\not{p}_T$	event fraction
0	0	1	1	no	14 %
0	0	2	0	no	7.1 %
0	0	0	2	no	6.8 %
1	0	1	1	yes	6.5 %
0	0	1	1	yes	4.5 %
1	0	0	2	yes	3.3 %
1	0	2	0	yes	3.2 %
1	1	1	1	yes	2.4 %

- Like-sign τ events.
- 6-8 jets
- Not necessarily missing p_T signature.
- Detached vertex, i.e. $c \cdot \tau_{\tilde{\tau}_1} = 0.3$ mm.

p_T distributions in benchmark scenario BC2



p_T distribution of the τ from $\tilde{\chi}_1^0$ decays.



p_T distribution of the d-jets from $\tilde{\tau}_1$ decays.

- Tau identfication is difficult but possible.
- Reconstruction of the $\tilde{\tau}_1$ mass is possible via the two jets.

Summary and Outlook

Summary

- R_p violating mSUGRA models provide $\tilde{\chi}_1^0$, $\tilde{\tau}_1$ as the LSP.
- Promising collider signatures are:
  detached vertices, multi-lepton and like-sign lepton final states.
- Leptons, taus and their p_T distributions can be used to identify a specific (benchmark) scenario.

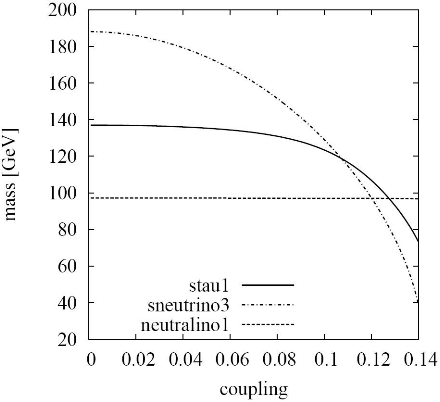
Outlook

- Detailed anlaysis including background and detector simulations.
  [K.Desch, S. Fleischmann]
- Single sparticle production in $\tilde{\tau}_1$ LSP scenarios,
  e.g. single slepton production via λ'_{ijk}.
  [H.Dreiner, SG, M.Trenkel]
- 2-body vs. 4-body decay.

backup slides

What is the LSP?

A non-vanishing coupling $\lambda'_{331}(M_{GUT})$ may change the nature of the LSP.
Looking at SPS1a: [Allanach et. al., Phys.Rev.D75:035002,2007]



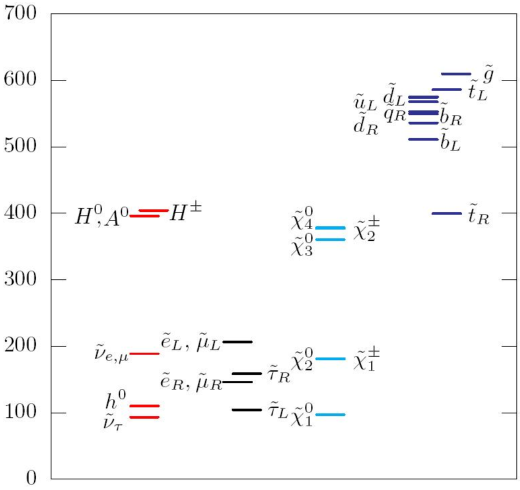
LSP candidates:

$$\text{LSP} \in \{\tilde{\chi}_1^0, \tilde{\tau}_1, \tilde{\nu_\tau}\}.$$

Benchmark scenario BC3

BC3

- $M_0 = 100$ GeV
- $A_0 = -100$ GeV
- $\lambda'_{331}(M_{GUT}) = 0.122$
- $\tan\beta = 10$
- $M_{1/2} = 250$ GeV
- $\text{sgn}(\mu) = +1.$



Branching ratios in benchmark scenario BC3

	mass [GeV]	channel	BR	channel	BR
$\tilde{\nu}_\tau$	93	$\bar{b}d$	100 %		
$\tilde{\chi}_1^0$	97	$\bar{\tilde{\nu}}_\tau \nu_\tau$	50 %	$\tilde{\nu}_\tau \bar{\nu}_\tau$	50%
$\tilde{\tau}_1^-$	105	$\nu_\tau b\bar{d}\tau^-$	37 %	$\bar{\nu}_\tau \bar{b} d\tau^-$	37 %
		$\tilde{\chi}_1^0 \tau^-$	26 %		
$\tilde{e}_R^-(\tilde{\mu}_R^-)$	146	$\tilde{\chi}_1^0 e^-(\mu^-)$	100 %		
$\tilde{\tau}_2^-$	159	$\tilde{\chi}_1^0 \tau^-$	100 %		
$\tilde{\chi}_2^0$	181	$\bar{\tilde{\nu}}_\tau \nu_\tau$	27 %	$\tilde{\nu}_\tau \bar{\nu}_\tau$	27 %
		$\tilde{\tau}_1^+ \tau^-$	22 %	$\tilde{\tau}_1^- \tau^+$	22 %
$\tilde{\chi}_1^-$	181	$\tilde{\nu}_\tau \tau^-$	63 %	$\tilde{\tau}_1^- \nu_\tau$	35 %
$\tilde{\nu}_e(\tilde{\nu}_\mu)$	189	$\tilde{\chi}_1^0 \nu_e(\nu_\mu)$	85 %	$\tilde{\chi}_1^+ e^-(\mu^-)$	11 %
$\tilde{e}_L^-(\tilde{\mu}_L^-)$	206	$\tilde{\chi}_1^0 e^-(\mu^-)$	48 %	$\tilde{\chi}_1^- \bar{\nu}_e(\bar{\nu}_\mu)$	33 %
		$\tilde{\chi}_2^0 e^-(\mu^-)$	19 %		

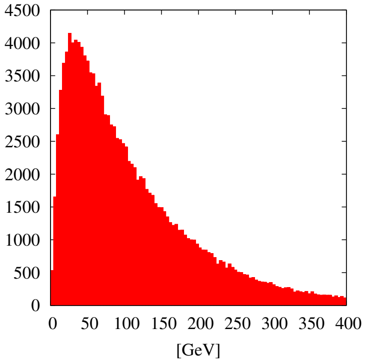
Signal rates of benchmark scenario BC3

$$\sigma(\text{sparticle pair production}) = 4.7 \cdot 10^4 \text{fb}$$

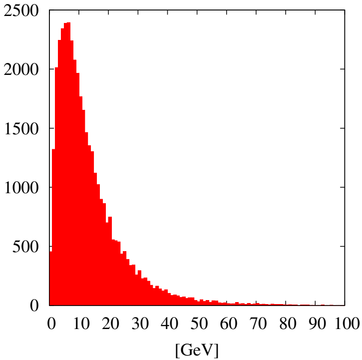
e^+ or μ^+	e^- or μ^-	τ^+	τ^-	$\not{p}_T$	event fraction
0	0	0	0	yes	27 %
0	0	1	0	yes	19 %
0	0	0	1	yes	16 %
0	0	1	1	yes	14 %
0	0	1	1	no	4.4 %
0	0	2	1	yes	4.0 %
0	0	1	2	yes	3.0 %
1	0	0	1	yes	1.9 %

- Most difficult scenario to trigger, although light spectrum.
- 4.7 million sparticle events at the LHC with $\int \mathcal{L} = 100\,\text{fb}^{-1}$.
- b-tagging should be possible.

p_T distributions in benchmark scenario BC3



p_T distribution of the b-jets from $\tilde{\nu}_\tau$ decays.



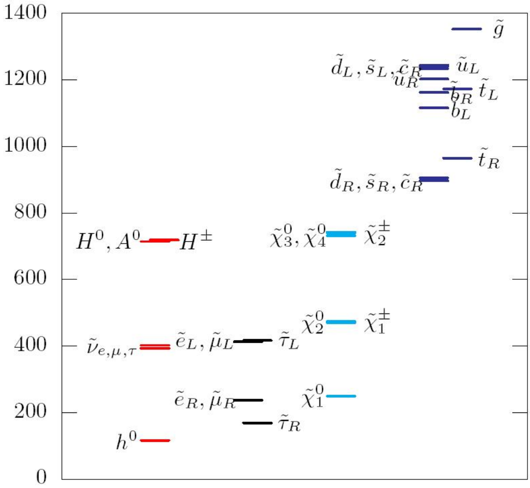
p_T distribution of the τ from $\tilde{\tau}_1$ decays.

- b-tagging should be possible.
- Most of the taus from $\tilde{\tau}_1$ decays are invisble ($p_T \leq 30$ GeV).

Benchmark scenario BC4

BC4

- no-scale mSUGRA
- $\lambda''_{212}(M_{GUT}) = 0.5$
- $\tan\beta = 30$
- $M_{1/2} = 600$ GeV
- $\text{sgn}(\mu) = +1.$



Branching ratios in benchmark scenario BC4

	mass [GeV]	channel	BR	channel	BR
$\tilde{\tau}_1$	169	$cds\tau^-$	79 %	$\bar{c}\bar{d}\bar{s}\tau^-$	21 %
$\tilde{e}_R(\tilde{\mu}_R)$	236	$\tilde{\tau}_1^+ e^-(\mu^-)\tau^-$	58 %	$\tilde{\tau}_1^- e^-(\mu^-)\tau^+$	42 %
$\tilde{\chi}_1^0$	249	$\tilde{\tau}_1^+\tau^-$	47 %	$\tilde{\tau}_1^-\tau^+$	47 %
$\tilde{\nu}_\tau$	393	$W^+\tilde{\tau}_1$	89 %	$\tilde{\chi}_1^0\nu_\tau$	12 %
$\tilde{\nu}_e(\tilde{\nu}_\mu)$	402	$\tilde{\chi}_1^0\nu_e(\nu_\mu)$	100 %		
$\tilde{e}_L^-(\tilde{\mu}_L^-)$	413	$\tilde{\chi}_1^0 e^-(\mu^-)$	100 %		
$\tilde{\tau}_2$	417	$Z^0\tilde{\tau}_1^-$	48 %	$h^0\tilde{\tau}_1^-$	38 %
		$\tilde{\chi}_1^0\tau^-$	15 %		
$\tilde{d}_R(\tilde{s}_R)$	897	$\bar{c}\bar{s}(\bar{d})$	99 %	$\tilde{\chi}_1^0 d(s)$	1.2 %
$\tilde{c}_R$	906	$\bar{s}\bar{d}$	95 %	$\tilde{\chi}_1^0 c$	4.7 %

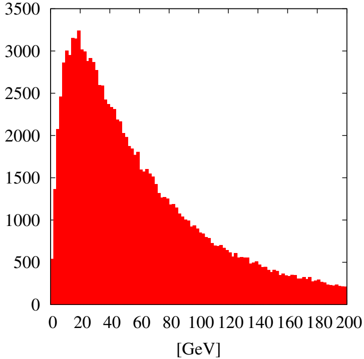
Signal rates of benchmark scenario BC4

$$\sigma(\text{sparticle pair production}) = 7.1 \cdot 10^2 \text{fb}$$

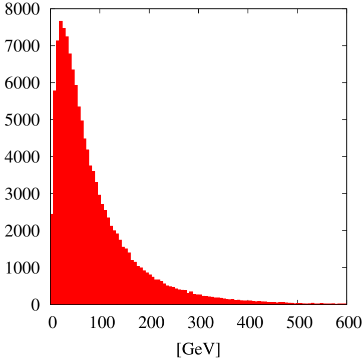
e^+ or μ^+	e^- or μ^-	τ^+	τ^-	$\not{p}_T$	event fraction
0	0	1	1	no	23 %
0	0	0	0	no	18 %
0	0	2	2	no	8.0 %
1	0	2	2	yes	5.6 %
0	0	2	1	yes	4.1 %
1	1	2	2	no	3.7 %
1	0	1	1	yes	3.6 %
0	1	2	2	yes	3.2 %

- Many jets in final state (6-8 jets).
- Very little missing p_T.
- Heavy spectrum.
- First two generations of $\tilde{q}_R$ undergo RPV decays.

p_T distributions in benchmark scenario BC4



p_T distribution of the τ from $\tilde{\tau}_1$ decay.

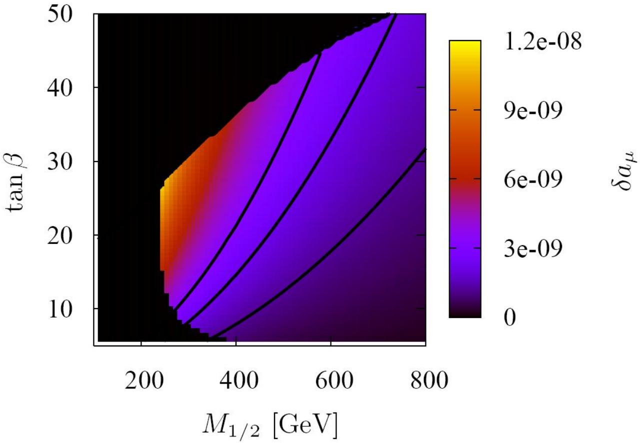


p_T distribution of the d-jets from $\tilde{\tau}_1$ decay.

- Triggering to taus should be possible.

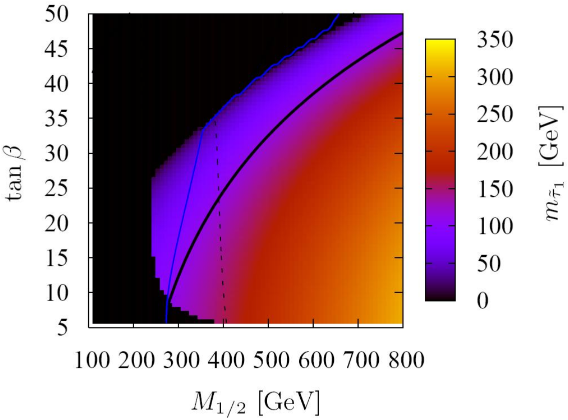
Bounds from $(g-2)_\mu$ in no scale mSUGRA ($M_0 = A_0 = 0$)

$$\delta a_\mu = a_\mu^{exp} - a_\mu^{SM} = (22.2 \pm 10.2) \cdot 10^{-10}$$



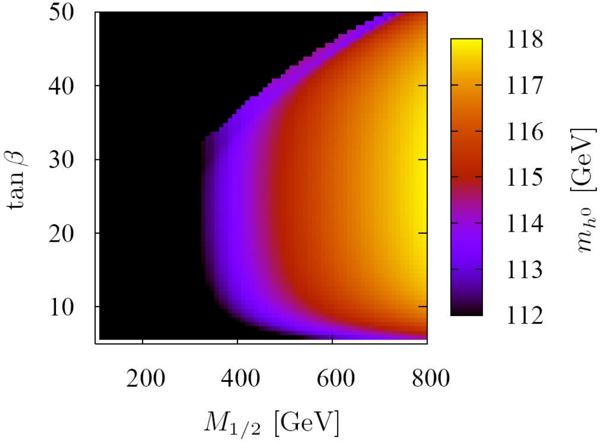
The black contours show the region that is consistent with the central value of $\delta a_\mu = (g-2)_\mu/2 \pm 1\sigma$.

Mass ordering in no scale mSUGRA ($M_0 = A_0 = 0$)



- black contour: $m_{h^0} = m_{\tilde{\tau}_1}$
- dashed contour: $m_{\tilde{\chi}_1^0} = m_{\tilde{e}_1} \approx m_{\tilde{\mu}_1}$
- blue contour: $m_{\tilde{\chi}_1^0} = m_{\tilde{\tau}_2}$

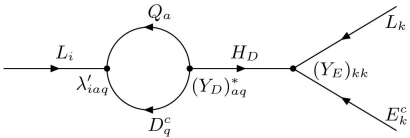
Higgs mass in no scale mSUGRA ($M_0 = A_0 = 0$)



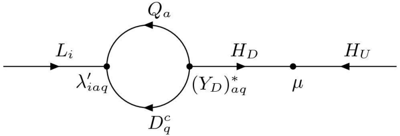
Mass of h_0 in no scale mSUGRA parameter space.

Dynamical generation of RPV couplings

Dynamical generation of λ_{ikk}



Dynamical generation of κ_i



$$
\begin{aligned}
16\pi^2 \frac{d}{dt}\lambda_{ikk} &= (Y_E)_{kk}[3\lambda'_{iaq}(Y_D)^*_{aq} + \lambda_{ill}(Y_E)^*_{ll}] \\
16\pi^2 \frac{d}{dt}\lambda'_{ijk} &= \lambda'_{ijl}2(Y_D^\dagger Y_D)_{kl} + \lambda'_{ilk}[(Y_D Y_D^\dagger)_{lj} + (Y_U Y_U^\dagger)_{lj}] \\
&\quad +3\lambda'_{iaq}(Y_D)^*_{aq}(Y_D)_{jk} + \lambda_{iaa}(Y_E)^*_{aa}(Y_D)_{jk} \\
16\pi^2 \frac{d}{dt}\kappa_i &= \mu[3\lambda'_{iaq}(Y_D)^*_{aq} + \lambda_{ill}(Y_E)^*_{ll}].
\end{aligned}
$$

Breaking of one lepton number does not break the two other lepton numbers.

Dynamical generation of RPV couplings

At M_{GUT}

BC1	BC3	BC4
$\lambda_{121} = 0.032$	$\lambda'_{331} = 0.122$	$\lambda''_{212} = 0.5$

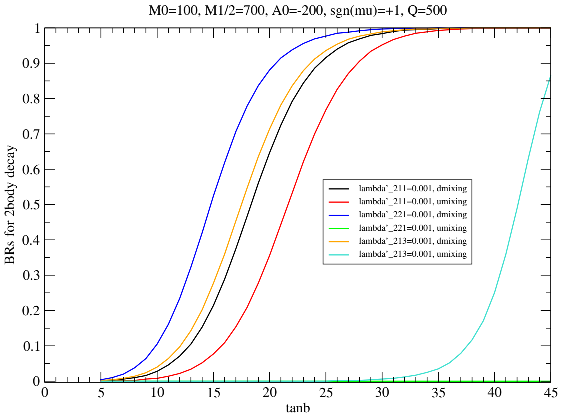
At M_{EW}

BC1	BC3	BC4
$\lambda_{121} = 0.047$ $\lambda'_{233} = 4.2 \cdot 10^{-8}$ $\lambda_{233} = 3.1 \cdot 10^{-8}$ $\lambda'_{232} = 1.7 \cdot 10^{-9}$ $\lambda'_{212} = 2.3 \cdot 10^{-10}$	$\lambda'_{331} = 0.32$ $\lambda'_{321} = -2.1 \cdot 10^{-5}$ $\lambda'_{333} = -8.6 \cdot 10^{-6}$ $\lambda'_{311} = -1.9 \cdot 10^{-6}$ $\lambda_{232} = 2.1 \cdot 10^{-7}$	$\lambda''_{212} = 0.93$ $\lambda''_{213} = -1.0 \cdot 10^{-3}$ $\lambda''_{223} = 9.0 \cdot 10^{-5}$ $\lambda''_{312} = -3.8 \cdot 10^{-7}$ $\lambda''_{313} = 4.2 \cdot 10^{-10}$

RGEs may generate R_p violating operators, which directly couple to the $\tilde{\tau}$!

2-body versus 4-body decay.

Consider: $M_{1/2} = 700$ GeV, $M_0 = 100$ GeV, $A_0 = -200$ GeV, $\text{sgn}(\mu) = +1$ and $\lambda'_{ijk} \neq 0$ at M_{GUT}. $\Rightarrow \lambda_{i33} \neq 0$ at M_{EW}.



Bounds on RPV couplings

From experiment, e.g. measuring Fermi constant in muon decay, we obtain:

Weakest 2σ direct bounds at M_{EW}

λ_{ijk}	λ'_{1jk}	λ'_{2jk}	λ'_{3jk}	λ''_{ijk}
0.07	0.28	0.56	0.52	pert.

Most of the bounds scale with $(\tilde{m}/100\ \text{GeV})$.

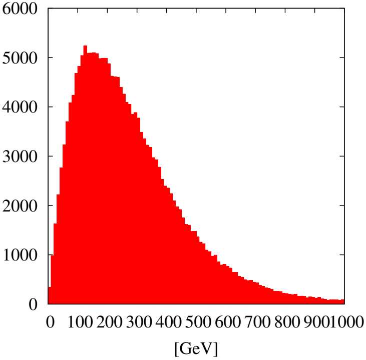
From the RGE generated κ_i and the lack of tachyons we obtain:

Weakest bounds at M_{GUT} for SPS1a

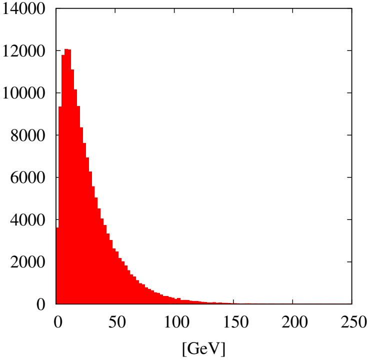
	λ_{ijk}	λ'_{1jk}	λ'_{2jk}	λ'_{3jk}
d-mixing	0.046	$9.1 \cdot 10^{-4\ \nu}$	$9.1 \cdot 10^{-4\ \nu}$	$9.0 \cdot 10^{-4\ \nu}$
u-mixing	0.046	0.15^t	0.15^t	0.15^t

ν: neutrino mass constraint. t: absence of tachyons.

More p_T distributions in benchmark scenario BC1

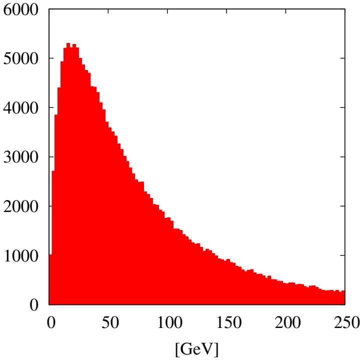


p_T distribution of the $\tilde{\tau}_1$.

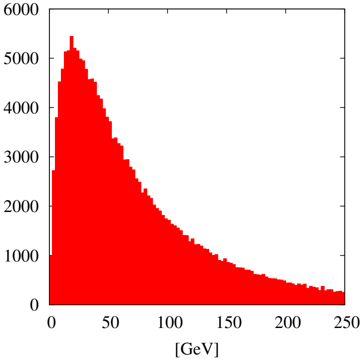


p_T distribution of τ coming from $\tilde{\chi}^0_m$ decays.

More p_T distributions in benchmark scenario BC1

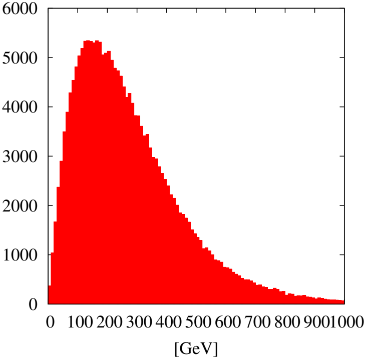


p_T distribution of the ℓ^+ coming from $\tilde{\tau}_1$ decays.

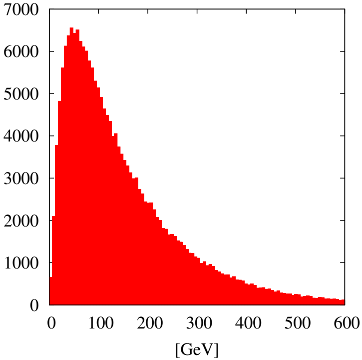


p_T distribution of the ℓ^- coming from $\tilde{\tau}_1$ decays.

More p_T distributions in benchmark scenario BC2

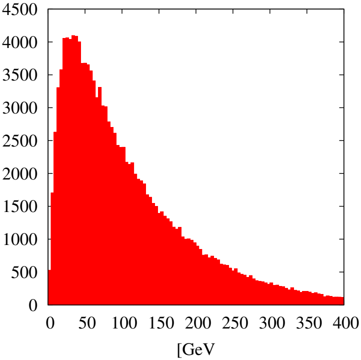


p_T distribution of the $\tilde{\tau}_1$.

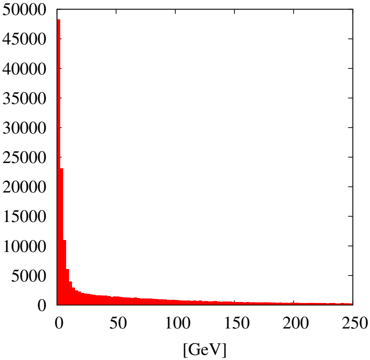


p_T distribution of the u-jets from $\tilde{\tau}_1$ decays.

More p_T distributions in benchmark scenario BC3

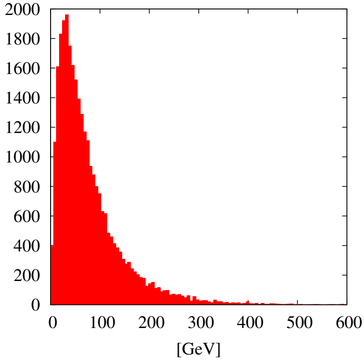


p_T distribution of the d-jets from $\tilde{\nu}_\tau$ decays.

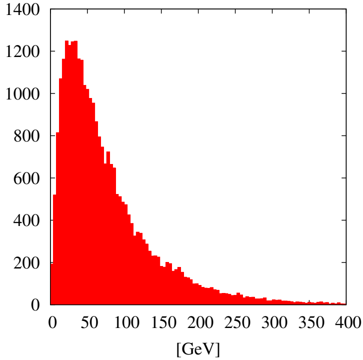


p_T distribution of the neutrinos.

More p_T distributions in benchmark scenario BC3

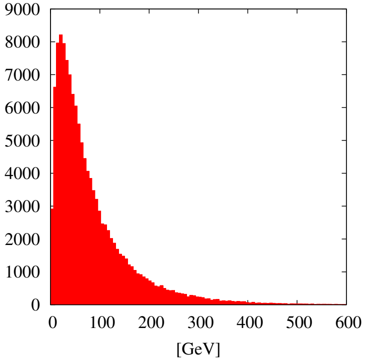


p_T distribution of the d-jets from $\tilde{\tau}_1$ decays.

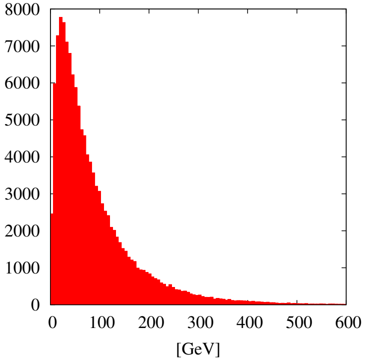


p_T distribution of the s-jets from $\tilde{\tau}_1$ decays.

More p_T distributions in benchmark scenario BC4

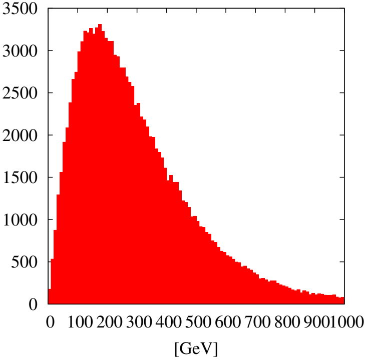


p_T distribution of the c-jets from $\tilde{\tau}_1$ decay.

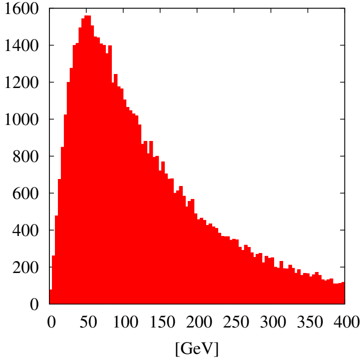


p_T distribution of the s-jets from $\tilde{\tau}_1$ decay.

More p_T distributions in benchmark scenario BC4

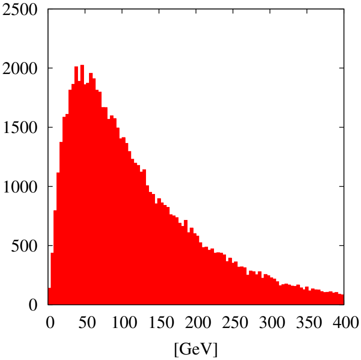


p_T distribution of the $\tilde{\tau}_1$.

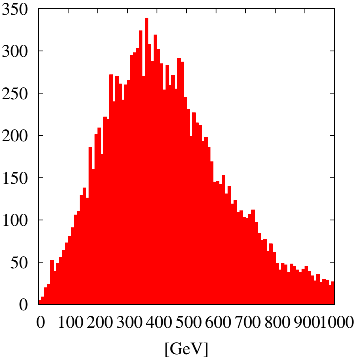


p_T distribution of the neutrinos.

More p_T distributions in benchmark scenario BC4



p_T distribution of τ from $\tilde{\chi}^0_m$ decays.



p_T distribution of the d-jets from $\tilde{c}_R$ decay.