DOGS THAT DO NOT BARK:

RIGHT-HANDED NEUTRINOS IN A SUPERSYMMETRIC WORLD

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Questions to ask...

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Does SUSY with ν_R enable ν-mass and mixing generation mechanisms?

Does the ν_R superfield help us in explaining something more than just neutrino masses?

Canonical SUSY signals at the LHC:

$$pp \longrightarrow \tilde{g}\tilde{g}(\tilde{q}\tilde{q^*})(\tilde{q}\tilde{q}) \longrightarrow (anti)quarks \;+\; \chi_1^0\chi_1^0$$

'jets + missing p_T'

$$pp \longrightarrow \tilde{g}\tilde{g} \longrightarrow \; \chi_1^{\pm}\chi_1^{\pm}... \longrightarrow (anti)quarks \;+\; l^{\pm}l^{\pm}\chi_1^0\chi_1^0$$

'like-sign dileptons (LSD) + jets + missing p_T'

Must χ_1^0 be the LSP?

If the RH neutrino superfield exists, then the $\tilde{\nu}_R$ is an LSP candidate

A right-sneutrino LSP...

More favoured than the $\tilde{\nu}_L$ in a setting where masses evolve from a high scale

Feeble interaction suppresses $\tilde{\nu}_R$ production side by side with low annihilation rate

Interaction with matter suppressed– direct dark matter search limits evaded

Bottomline: A $\tilde{\nu}_R$-type LSP in the mass range $O(100)$ GeV is consistent

Consequence in accelerator experiments: decay chains lead to different final states

New signals at the LHC (no L-violation)

The LSP (dominantly a $\tilde{\nu}_R$) couples to all other SUSY particles with a strength

$\sim y_\nu \sim m(Dirac)_\nu$

SUSY particle production

$\Rightarrow$ cascades into the next-to-lightest SUSY particle (NLSP)

$\Rightarrow$ Very slow decay of the NLSP to the LSP

New signals at the LHC

The LSP only is cosmologically stable, but the NLSP (maybe charged) appears stable in the collider detectors

The signal of the ‘stable’ NLSP can be *not* missing-p_T *but* charged tracks

The dog that does not bark makes its presence felt!

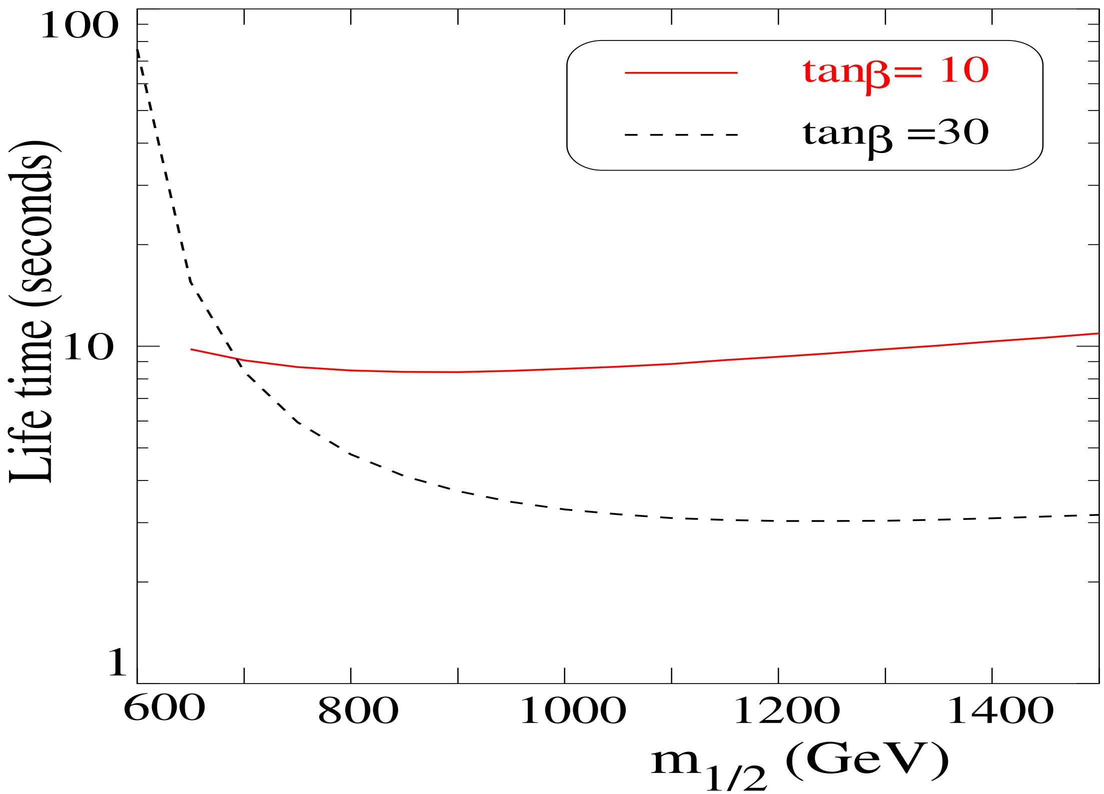
The NLSP can be...

$\tilde{\tau}_1$ (the lighter stau, dominated by $\tilde{\tau}_R$)

$\longrightarrow$ allowed over a large region

A charged track can be seen in the muon chamber– kinematically differentiable

S. K. Gupta + BM + S K Rai, PRD, 2007



Lifetime of stau NLSP against the universal gaugino mass parameter $m_{1/2}$.

$m_0 = 100$ *GeV*, $A = 100$ *GeV*, $sgn(\mu) = 1$.

A long-lived stau NLSP can occur in...

Supergravity theories with gravitino LSP

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MSSM with stau-neutralino near degeneracy
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Supergravity with $\tilde{\nu}_R$ LSP

T. Ashaka + K. Ishiwata + T. Moroi, 2006, S. K. Gupta + BM + S. K. Rai, 2007

Two types of signals

Jets + two muon-like stau tracks (equivalent of jets + $\not{p}_T$ in MSSM)

Jets + dimuons + two muon-like stau tracks (equivalent of jets + dimuons + $\not{p}_T$ in MSSM)

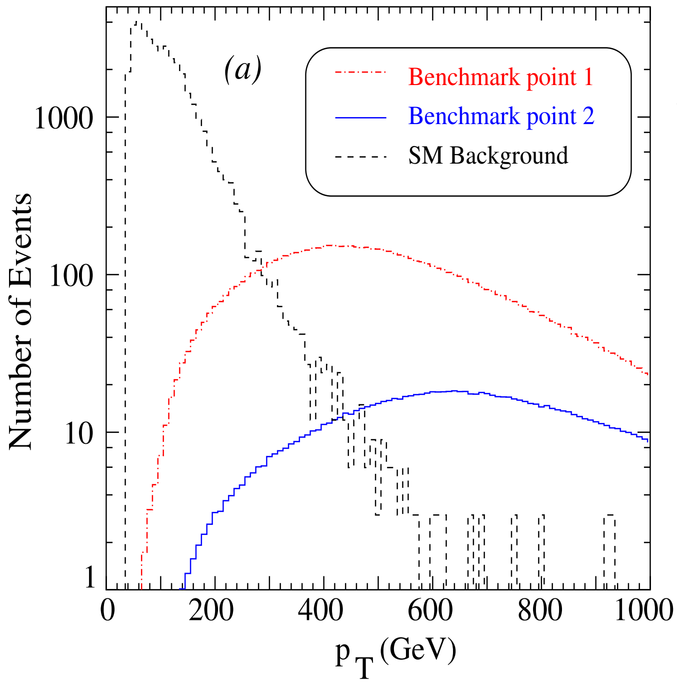
Differentiator: thickness of tracks, time delay, absorption in stoppers ....

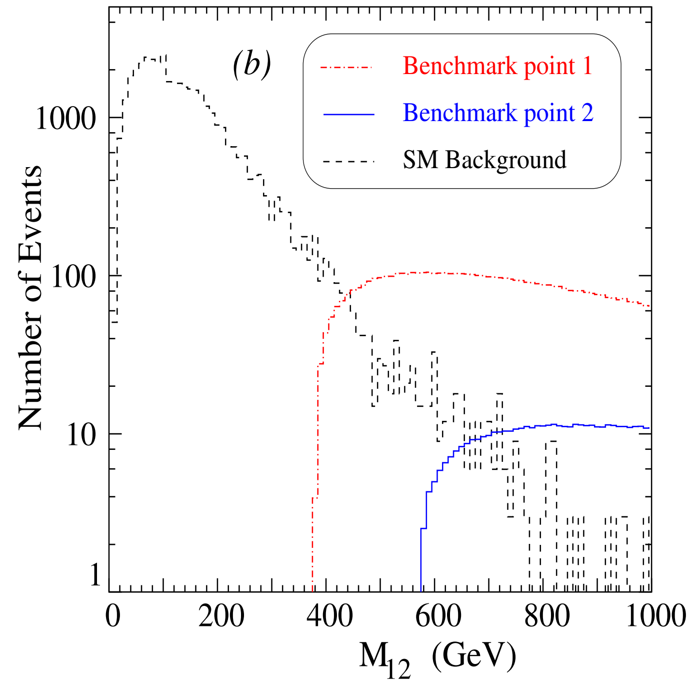
Observation: Kinematic separation of muonic and stable stau tracks is possible at the LHC

Benchmark points in a SUGRA setting...

Parameter	Benchmark point 1	Benchmark point 2
mSUGRA input	$m_0 = 100\ GeV,\ m_{1/2} = 600\ GeV$ $A = 100\ GeV,\ sgn(\mu) = +$ $\tan\beta = 30$	$m_0 = 110\ GeV,\ m_{1/2} = 700\ GeV$ $A = 100\ GeV,\ sgn(\mu) = +$ $\tan\beta = 10$
$\|\mu\|$	694	810
$m_{\tilde{e}_L}, m_{\tilde{\mu}_L}$	420	486
$m_{\tilde{e}_R}, m_{\tilde{\mu}_R}$	251	289
$m_{\tilde{\nu}_{eL}}, m_{\tilde{\nu}_{\mu L}}$	412	479
$m_{\tilde{\nu}_{\tau L}}$	403	478
$m_{\tilde{\nu}_{iR}}$	100	110
$m_{\tilde{\tau}_1}$	187	281
$m_{\tilde{\tau}_2}$	422	486
$m_{\chi_1^0}$	243	285
$m_{\chi_2^0}$	469	551
$m_{\chi_3^0}$	700	815
$m_{\chi_4^0}$	713	829
$m_{\chi_1^\pm}$	470	552
$m_{\chi_2^\pm}$	713	829
$m_{\tilde{g}}$	1366	1574
$m_{\tilde{u}_L}, m_{\tilde{c}_L}$	1237	1424
$m_{\tilde{u}_R}, m_{\tilde{c}_R}$	1193	1373
$m_{\tilde{d}_L}, m_{\tilde{s}_L}$	1239	1426
$m_{\tilde{d}_R}, m_{\tilde{s}_R}$	1189	1367
$m_{\tilde{t}_1}$	984	1137
$m_{\tilde{t}_2}$	1176	1365
$m_{\tilde{b}_1}$	1123	1330
$m_{\tilde{b}_2}$	1161	1358
m_{h^0}	118	118
m_{H^0}	712	941
m_{A^0}	707	935
$m_{H^\pm}$	717	944

Jets + two tracks: signal vs background





Kinematic distributions for the signal 2 stau$_1$ *+* (≥ 2) *hard jets: (a) the transverse momentum distributions for the harder stau*$_1$ *(b) the invariant mass distribution for the stau*$_1$ *pair. The dash-dot-dash (red) histograms are for benchmark point 1 and the solid (blue) histogram for benchmark point 2. The dashed histograms show the corresponding SM background.*

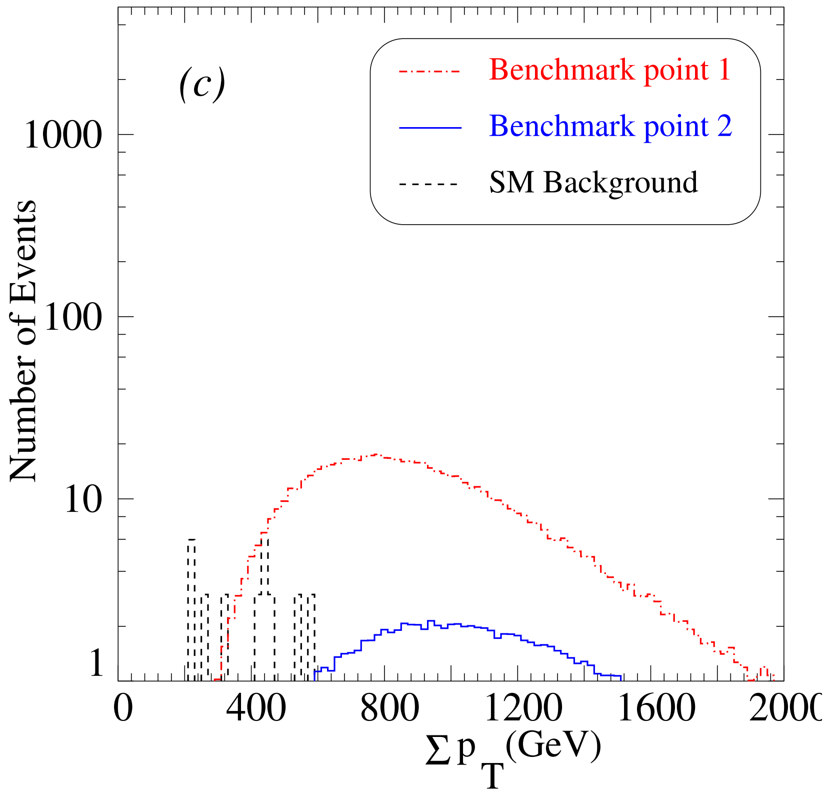
Jets + two tracks: signal vs background

Cuts	Background	Benchmark point 1(2)
Basic	39617	8337 (1278)
Basic $+ p_T > 350$ GeV	5	2587 (737)

The expected number of events for the signal and background with the cuts imposed. Integrated luminosity = $30\ fb^{-1}$.

Hardness cut on both tracks drastically reduces backgrounds

Jets + two μ's + two tracks:



Distributions in the scalar sum of p_T's of all tracks in the muon chamber.

Jets + two μ's + two tracks:

Final States	Background	Benchmark pt. 1(2)
$2\tilde{\tau}_1$ + 2μ	83	689 (103)
$2\tilde{\tau}_1$ + 2$\mu + (\geq 2)$ hard jets	29	686 (103)
$2\tilde{\tau}_1$ + 2$\mu + (\geq 2)$ hard jets	0	553 (89)
($\sum p_T > 600$ GeV)		

The expected number of events for the signal and background with the different cuts imposed on the selection of events. $\sum p_T$ corresponds to the scalar sum of the individual transverse momenta of the charged tracks in the muon chamber. Integrated luminosity = $30\ fb^{-1}$.

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- **They not only provide neutrino masses but also affect the mysteries of the TeV scale in very novel fashions.**

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- **They not only provide neutrino masses but also affect the mysteries of the TeV scale in very novel fashions.**
- *These dogs may not bark, but they can bite!*