Clean leptonic signatures with a sneutrino NLSP at the LHC

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Outline

1. Introduction
   - GDM
   - NUMH Model
   - NUMH Parameter Space

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Gravitino Dark Matter

- The gravitino is one candidate for dark matter in supergravity models
- The gravitino is a very weakly interacting particle, with coupling $\sim 1/M_{Pl}$
  - Practically undetectable. (Except for its gravitational effects.)
  - The next to lightest supersymmetric particle (NLSP) could be long lived.
- There are several possibilities for the NLSP: $\tilde{\chi}$, $\tilde{\tau}$,$\tilde{t}$, $\tilde{\nu}$, . . .
- This talk: $\tilde{\nu}_L$, assuming R–parity conservation.

The Non-universal Higgs Masses (NUMH) Model

- As in the CMSSM we have universal gaugino mass, $m_{1/2}$, sfermion mass m_0, and trilinear coupling A_0, at the GUT scale.
- However, the Higgs masses $m_{1,2}$ are not equal to m_0
- We can trade $m_{1,2}$ with μ and m_A as our free parameters through the electroweak symmetry breaking condition.
- Thus the NUMH parameters are: $m_{1/2}$, m_0, A_0, $\tan\beta$, μ, and m_A.
- Note: The gravitino mass, $m_{3/2}$, is another free parameter.

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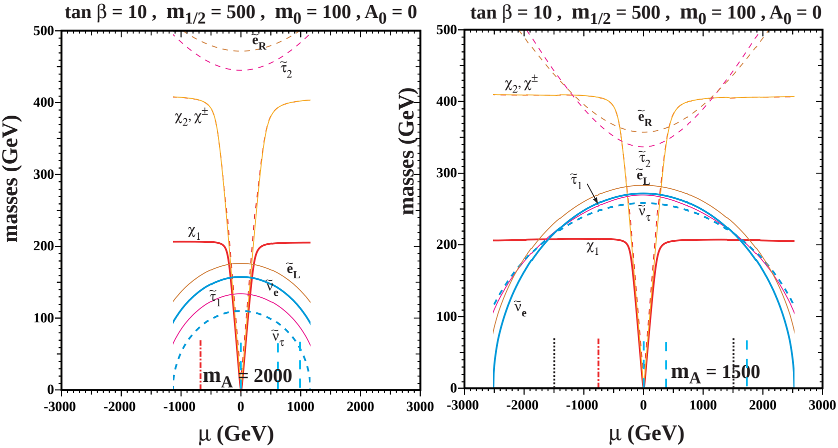
NUMH Spectrum [1]



[1] J. Ellis, K. A. Olive, and Y. Santoso,arXiv:0807.3736

Tau Sneutrino NLSP Scenario

	Mass [GeV]
$m_{\tilde{\nu}_e}$	140.64
$m_{\tilde{\nu}_\tau}$	90.54
$m_{\tilde{e}_L}$	161.42
$m_{\tilde{\tau}_1}$	115.31
$m_{\tilde{\chi}_1^0}$	206.46
$m_{\tilde{\chi}_1^\pm}$	395.95
$m_{\tilde{\chi}_2^0}$	396.10

	Mass [GeV]
m_h	115.9
m_H	2000
m_A	2000
$m_H^\pm$	2002

Tau Sneutrino NLSP Scenario

	Mass [GeV]
$m_{\tilde{\chi}_3^0}$	-617.39
$m_{\tilde{\chi}_4^0}$	632.96
$m_{\tilde{\chi}_2^\pm}$	633.47
$m_{\tilde{e}_R}$	482.67
$m_{\tilde{\tau}_2}$	459.61
$m_{\tilde{t}_1}$	723.55
$m_{\tilde{t}_2}$	994.69

	Mass [GeV]
$m_{\tilde{b}_1}$	956.40
$m_{\tilde{b}_2}$	1000.91
$m_{\tilde{u}_R}$	925.64
$m_{\tilde{u}_L}$	1033.42
$m_{\tilde{d}_R}$	1012.69
$m_{\tilde{d}_L}$	1036.45
$m_{\tilde{g}}$	1176.18

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Production Cross Sections

	$\tilde{\ell}_L^+\tilde{\ell}_L^-$	$\tilde{\nu}_\ell\tilde{\nu}_\ell^*$	$\tilde{\ell}_L^+\tilde{\nu}_\ell$	$\tilde{\ell}_L^-\tilde{\nu}_\ell^*$	$\tilde{\tau}_1^+\tilde{\tau}_1^-$	$\tilde{\tau}_1^+\tilde{\nu}_\tau$	$\tilde{\tau}_1^-\tilde{\nu}_\tau^*$	$\tilde{\nu}_\tau\tilde{\nu}_\tau^*$
Tevatron	3.6	6.0	6.0	6.0	17	38	38	44
LHC	53	88	158	88	177	610	367	454

	$\tilde{\chi}_1^0\tilde{\chi}_1^0$	$\tilde{\chi}_1^0\tilde{\chi}_1^-$	$\tilde{\chi}_1^0\tilde{\chi}_1^+$	$\tilde{\chi}_2^0\tilde{\chi}_1^-$	$\tilde{\chi}_2^0\tilde{\chi}_1^+$	$\tilde{\chi}_2^0\tilde{\chi}_2^0$	$\tilde{\chi}_1^-\tilde{\chi}_1^+$
Tevatron	0.03	0.002	0.002	0.09	0.09	0.003	0.18
LHC	1.1	0.19	0.42	17	36	1.6	29

	$\tilde{q}\tilde{q}^*$	$\tilde{q}\tilde{q}$	$\tilde{t}_1\tilde{t}_1^*$	$\tilde{g}\tilde{q}$	$\tilde{g}\tilde{g}$	$\tilde{\chi}_1^0\tilde{q}$	$\tilde{\chi}_2^0\tilde{q}$	$\tilde{\chi}_1^+\tilde{q}$	$\tilde{\chi}_1^-\tilde{q}$
LHC	255	460	69	636	91	17	26	35	16

Table: Cross sections in fb for (a) slepton pair, (b) chargino and neutralino pair, and (c) squarks and gluino production at the Tevatron and LHC. The calculation was done with Prospino 2.1. Note that squarks and gluino are too heavy to be produced at the Tevatron. Here $\tilde{q}$ represents the total of the light squarks $\tilde{u}+\tilde{d}+\tilde{s}+\tilde{c}$, whilst $\tilde{\ell}$ is for $\tilde{e}$, $\tilde{\mu}$ (each).

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3 leptons $+\not{E}_T$

The SUSY signal can come from

- $\tilde{\ell}\tilde{\nu}_\ell^*$ ($\tilde{\ell}^*\tilde{\nu}_\ell$) associated production, followed by $\tilde{\ell} \to \tilde{\nu}_\tau + \nu_\ell + \tau$ and $\tilde{\nu}_\ell \to \tilde{\nu}_\tau + \ell + \tau$ decays.
- $\tilde{\chi}_1^\pm \tilde{\chi}_2^0$ associated production, with the chargino decays as $\tilde{\chi}^- \to \tau + \tilde{\nu}_\tau^*$ and the neutralino decays as (a) $\tilde{\chi}^0 \to \tilde{\ell} + \ell$ followed by $\tilde{\ell} \to \tilde{\nu}_\tau + \nu_\ell + \tau$, (b) $\tilde{\chi}^0 \to \tilde{\tau} + \tau$ follwed by $\tilde{\tau} \to \tilde{\nu}_\tau + \nu_{\ell'} + \ell'$, or (c) $\tilde{\chi}^0 \to \tilde{\nu}_\ell + \nu_\ell$ followed by $\tilde{\nu}_\ell \to \tilde{\nu}_\tau + \tau + \ell$.

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$\tau^{\pm}\tau^{\pm}\ell^{\mp} + \not{E}_T$

Signals and backgrounds

- Signal: $pp \to \tilde{\ell}_L^{+}\tilde{\nu}_\ell \to (\tilde{\nu}_\tau\tau^{+}\bar{\nu}_\ell)(\tilde{\nu}_\tau\tau^{+}\ell^{-})$
- Background: $pp \to \chi_1^{+}\chi_2^{0} \to (\tau^{+}\tilde{\nu}_\tau)(\tilde{\nu}_\tau\tau^{+}\ell^{-}\bar{\nu}_\ell)$
- Background: $pp \to W^{+}W^{+}W^{-} \to \tau^{+}\nu_\tau\tau^{+}\nu_\tau\ell^{-}\bar{\nu}_\ell$

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Selection Criteria

1. Leptons are required to have

$$p_T^\ell > 10 \text{ GeV} , \qquad |\eta_\ell| < 2.5 .$$

2. Taus are required to have

$$p_T^\tau > 10 \text{ GeV} , \qquad |\eta_\tau| < 2.5 .$$

3. Leptons and taus are required to be isolated with

$$R_{\ell,\tau} > 0.3 \qquad R_{\tau,\tau} > 0.3 .$$

4. We, also, apply a jet veto: no jets of $p_T^j > 10$ GeV with $|\eta_j| < 4.5$, $R_{j,\tau} > 0.3$, and $R_{j,\ell} > 0.3$.

Preliminary Results [2]

	$\tilde{\ell}^+\tilde{\nu}_\ell$	$\chi_1^+\chi_2^0$	$W^+W^+W^-$
$\sigma_{\rm tot}^{\rm gen}$ [fb]	2.84	0.407	0.219
cut 1	0.735	0.828	0.753
cut 2	0.669	0.851	0.654
cut 3	1.00	0.996	1.00
cut 4	0.678	0.339	0.610
$\sigma_{\rm eff}$ [fb]	0.950	9.717×10^{-2}	6.589×10^{-2}

Table: Generation characteristics for $pp \to \ell^-\tau^+\tau^+ + \not{E}_T$ with $\ell = e, \mu$.

[2] Events were generated using SHERPA-MC version 1.1.3

Preliminary Results

	$\tilde{\ell}^- \tilde{\nu}_\ell^*$	$\chi_1^- \chi_2^0$	$W^- W^- W^+$
$\sigma_{\rm tot}^{\rm gen}$ [fb]	1.53	8.36×10^{-2}	0.1
cut 1	0.758	0.907	0.869
cut 2	0.689	0.829	0.620
cut 3	1.00	0.999	0.999
cut 4	0.713	0.401	0.649
$\sigma_{\rm eff}$ [fb]	0.57	2.523×10^{-2}	3.501×10^{-2}

Table: Generation characteristics for $pp \to \ell^+\tau^-\tau^- + \not{E}_T$ with $\ell = e, \mu$.

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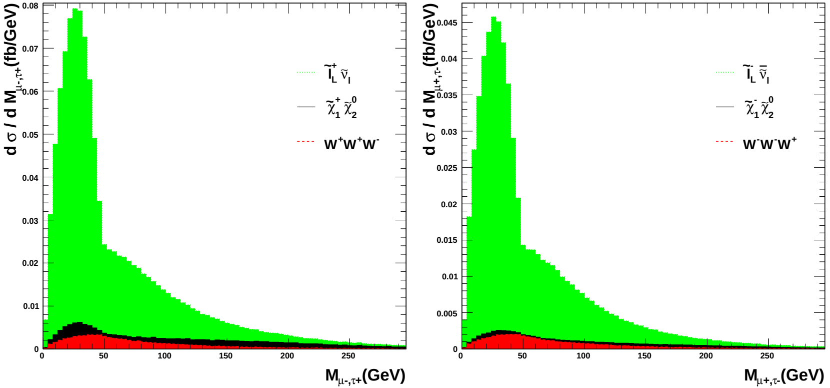
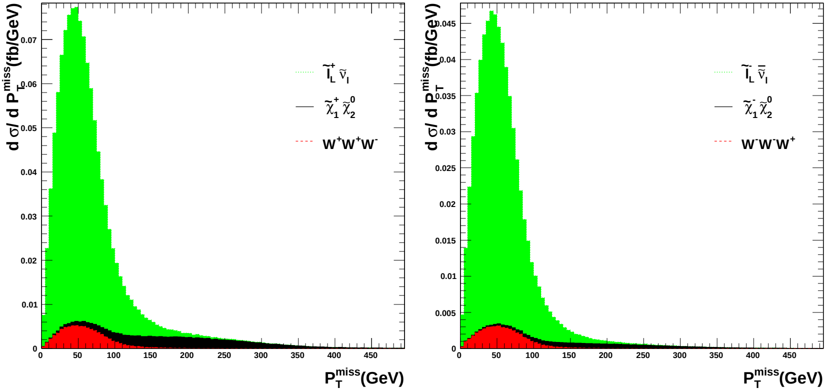
Histograms


d σ / d M$_{\mu-,\tau+}$(fb/GeV)
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0
50
100
150
200
250
M$_{\mu-,\tau+}$(GeV)
$\tilde{l}^+_L \tilde{\nu}_l$
$\tilde{\chi}^+_1 \tilde{\chi}^0_2$
$W^+W^+W^-$
d σ / d M$_{\mu+,\tau-}$(fb/GeV)
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
0
50
100
150
200
250
M$_{\mu+,\tau-}$(GeV)
$\tilde{l}^-_L \bar{\tilde{\nu}}_l$
$\tilde{\chi}^-_1 \tilde{\chi}^0_2$
$W^-W^-W^+$

Histograms


$d\sigma/ d P_T^{miss}$(fb/GeV)
$\tilde{l}_L^+ \tilde{\nu}_l$
$\tilde{\chi}_1^+ \tilde{\chi}_2^0$
$W^+W^+W^-$
P_T^{miss}(GeV)
$d\sigma/ d P_T^{miss}$(fb/GeV)
$\tilde{l}_L^- \bar{\tilde{\nu}}_l$
$\tilde{\chi}_1^- \tilde{\chi}_2^0$
$W^-W^-W^+$
P_T^{miss}(GeV)

Conclusions

- There are several possible NLSP in GDM scenarios.
- The NLSP can be long–lived and thus decay outside the detector.
- An excess of $\tau^{\pm}\tau^{\pm}\ell^{\mp} + \not{E}_T$ events may indicate a sneutrino NLSP
- We need to be prepared for the non-standard collider signatures at the LHC.