Long lived charged slepton NLSP

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DER FORSCHUNG | DER LEHRE | DER BILDUNG

Based on Jörn Kersten, JH, arXiv:1106.0764, 1203.1581

Implications of LHC results for TeV-scale physics

March 29th, 2012

Long-Lived charged sleptons

Supersymmetry provides three major LSP candidates

- neutralino
- gravitino
- axino

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neutralino, gravitino, axino → fine-tuned: degeneracy [hep-ph/0512197]

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- neutralino
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→ fine-tuned: degeneracy [hep-ph/0512197] (neutralino, gravitino, axino)

naturally: very weakly coupled (gravitino, axino)

each allow for long-lived NLSP!

Long-lived: Decay length $\gg$ Detector size
→ NLSP determines signatures at colliders

Assumption: lightest charged slepton = stau

Models

	χ^0	$\widetilde{G}$	$\widetilde{a}$
CMSSM/ NUHM/NUGM	✓	✓	✓
GMSB	–	✓	(✓)
$\widetilde{\text{G}}$MSB	✓	✓	✓
AMSB/ Mirage	✓	–	✓
⋮			

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Aim for a model-independent search!
$\Rightarrow$ Choose simplified model approach

↖ 'bottom-up approach'

Simplified models

Cover SUSY parameter space (at least approximately) by a few low-scale parameters that dominantly determine the signature

[Alwall et al. 0810.3921, LHC NPWG 1105.2838]

Assuptions: $\widetilde{q}$ mass degenerate, only NLSP long-lived, consider strong production and direct NLSP production

$\rightarrow$ Most dominant dependence on $m_{\widetilde{g}}, m_{\widetilde{q}}, m_{\widetilde{\tau}_1}$

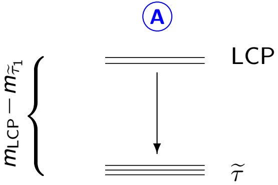
Classification of spectra $\rightarrow$ Elementary mass spectra

[Horn 0905.4497, Konar et al. 1008.24831]

Dependence on mass pattern of intermediate sparticles captured by extreme cases

Limiting cases

(Most powerful discriminating variable: Velocity of staus)



one dominat decay

$\rightarrow$ staus fast

$\rightarrow$ hard jets/ leptons/MET

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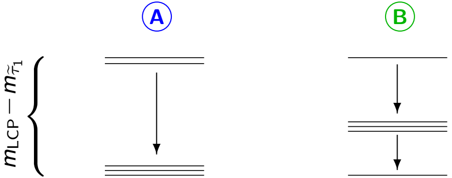

A

one dominat decay

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→ hard jets/ leptons/MET

B

rel. mass gaps equally spaced

$m_I = \sqrt{m_{\tilde{\tau}_1} m_{\mathrm{LCP}}}$

→ moderate $\beta_{\tilde{\tau}}$

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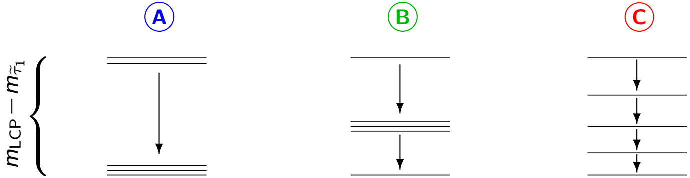

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$m_I = \sqrt{m_{\tilde{\tau}_1} m_{\mathrm{LCP}}}$

→ moderate $\beta_{\tilde{\tau}}$

C

rel. mass gaps equally spaced

→ slow staus

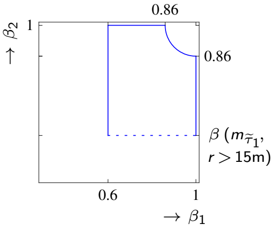
→ moderate SM particle rad.

Selection criteria

Selection 1:

2 iso. $\widetilde{\tau}$, $p_{\mathrm{T}} > 80$ GeV,

$\Delta p_{\mathrm{T}} > 50$ GeV

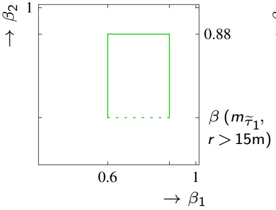


$+$ 2 jets $p_{\mathrm{T}} > 200$ GeV

Selection 2:

2 isolated $\widetilde{\tau}$,

$p_{\mathrm{T}} > 160$ GeV

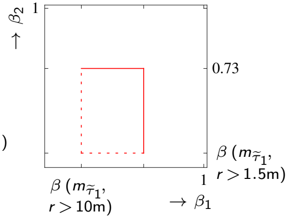


no jets required

Selection 3:

2 isolated $\widetilde{\tau}$,

$p_{\mathrm{T}} > 300$ GeV



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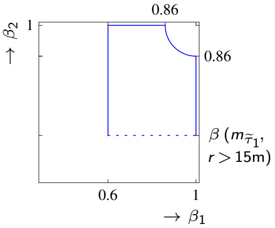

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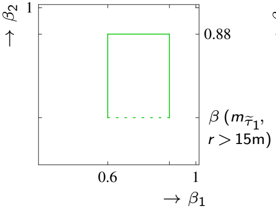

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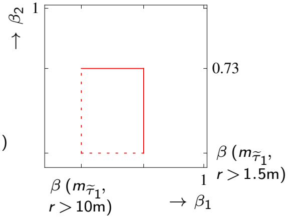
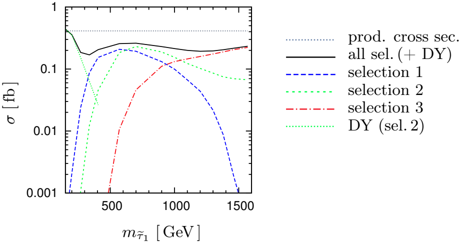


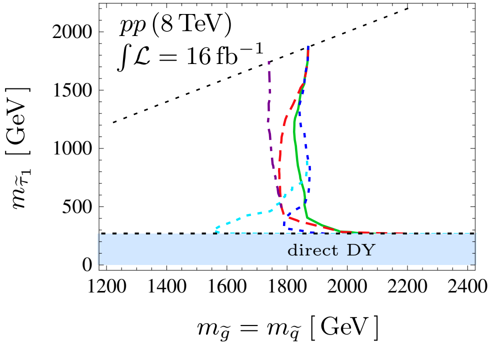
$\beta\,(m_{\tilde{\tau}_1}, r > 10\text{m}) \lesssim 0.6 \Rightarrow$ trigger: buffer tracker data!

Selection criteria

- Background rejection saturated
- Very high efficiencies throughout the whole parameter space
- Cut on additional leptons can partially raise the efficiency of worst case scenarios
- Additional leptons or MET can raise trigger efficiencies for very slow staus



Limits in the $m_{\widetilde{\tau}_1}$-$m_{\widetilde{g}}$-plane



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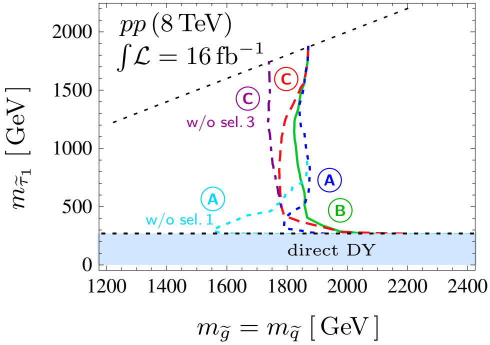
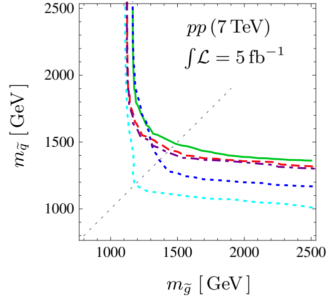
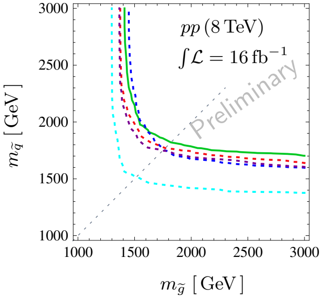


Limits in the $m_{\tilde{g}}$-$m_{\tilde{q}}$-plane

Explore spectra along minima (concerning $m_{\tilde{\tau}_1}$ variation)





Stopped staus and stau decays

Stau lifetimes of $\tau_{\widetilde{\tau}} \lesssim 5 \times 10^3$ sec cosmologically motivated

[Pospelov hep-ph/0605215]

From reconstructed 2-body decays ($\widetilde{\tau} \to \tau +$ LSP): m_{LSP}
$\to$ probe the SUSY breaking scale

$$\langle F \rangle \sim m_{\widetilde{G}} M_{\text{Pl}} \quad \text{(gravitino)}$$

or (by measuring $\tau_{\widetilde{\tau}}$) the Peccei-Quinn scale

[Brandenburg et al. hep-ph/0501287]

$$f_a^2 \sim \tau_{\widetilde{\tau}}\, m_{\widetilde{\tau}_1}\, m_{\widetilde{B}}^2 \quad \text{(axino)}$$

In 3-body decay: measure spin of the LSP $\to$ probe supergravity!

[Buchmüller et al. hep-ph/0402179]

Conclusion

- Gravitino or axino LSP scenarios are well motivated, scenarios naturally provide long-lived NLSPs
- Prospects for discovery and exclusion in a model-independent way
- Robust bounds on $m_{\widetilde{g}}, m_{\widetilde{q}}, m_{\widetilde{\tau}_1}$
- Discovery of long-lived charged sleptons has far-reaching implications on LHC updates and future colliders
  $\rightarrow$ Unique key to probe SUSY breaking scale and test supergravity

Thank you for your attention!