Long-lived staus – a promising scenario at colliders

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Introduction

SUSY (*R*-parity conserving) well motivated theory, lot of research
SUSY is able to provide DM, but leaves different possibilities
Electrically+color neutral:

- MSSM: neutralino LSP
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- Ext.: gravitino LSP
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  } LSP not be involved inside detector
  NLSP determines collider signature

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similar to neutralino LSP ↗ (neutral)

↖ totally different SUSY search (or charged)

⟶ Phenomenology of gravitino-stau scenario

Outline

- Cosmological implications of gravitino LSP
- Signal at colliders
- LHC reach for the scenario

Cosmological implications of gravitino LSP

- Gravitinos produced during reheating

  $\Omega_{3/2} \propto \frac{T_\mathrm{R}}{m_{3/2}} m_{\widetilde{g}}{}^2$ inelastic scattering $g, \widetilde{g}$
  annihilation inefficient, not thermal

- Other sparticles in thermal bath
  When stau annihilation becomes inefficient "freeze out"
  Left with long-lived staus

Ensure that not too many staus decay during BBN:

- Upper bound on stau lifetime $\tau_{\widetilde{\tau}} \propto \frac{m_{3/2}{}^2}{m_{\widetilde{\tau}}^5} \lesssim 5 \times 10^3\,\mathrm{sec}$
- Or decrease stau density (enhance stau annihilation, dilution)

Signal at colliders

- Stau NLSP long-lived → leave detector before decaying ($\tau_{\widetilde{\tau}} \gtrsim 10^{-7}$ sec)
- Charged tracks, high p_{T}, tracker+muon-chambers (muon-like)
- Muons always ultrarelativistic ↔ stau can travel slower than c

→ Main discrimination: velocity

- Measuring the velocity: ToF and $\mathrm{d}E/\mathrm{d}x$
- Cut on velocity $\beta < 0.8...0.9$ (finite β-resolution)
- Typically discovery/exclusion expected with very few events

LHC reach

- Model-independent analysis:
  Not restrict to any high-scale model (phenomenological MSSM)
- Assumption: Direct detection of the stau itself provides most significant contribution for identifying SUSY

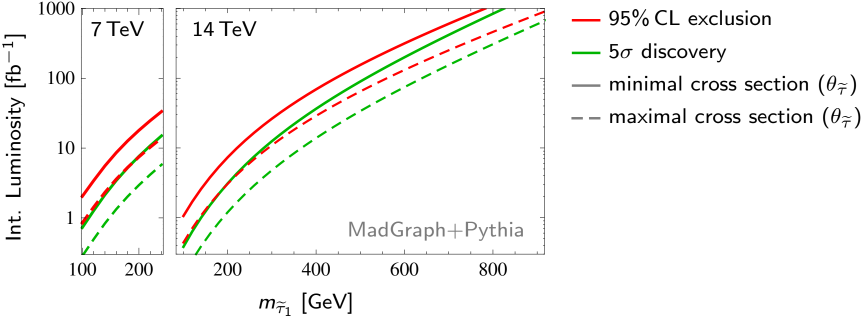
Production Channels

Amongst all possible production channels consider two "extreme cases":

- Direct Drell-Yan ($Z, \gamma \to \widetilde{\tau}\widetilde{\tau}$)
    - Theoretically interesting: Depends only on $m_{\widetilde{\tau}_1}$ and $\theta_{\widetilde{\tau}}$
    - Always present → Assured discovery potential and strict exclusion limits
    - Leading for "stretched spectra"
- Strong cascades ($\widetilde{g}, \widetilde{q} \to$ decay chain $\to \widetilde{\tau}\widetilde{\tau}$)
    - Potential to exceed direct Drell-Yan the most at LHC
    - Dominantly depends on $m_{\widetilde{g}}, m_{\widetilde{q}}$, but, in principle *many* MSSM parameters involved through intermediate SUSY particles
    - Large mass gap (Drell-Yan competes with Cascades): Fast staus (harder to detect)
    - Smaller mass gaps ("compact spectra"): Approximately independent of the number and kind of intermediate

Direct Drell-Yan: Luminosity at which one can

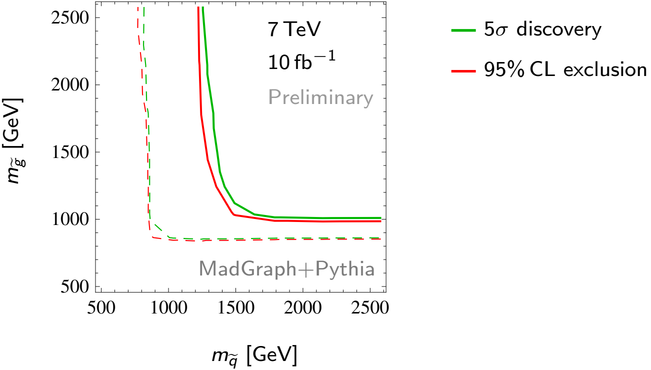
- expect discovery of a stau
- exclude all scenarios with a metastable stau



Jörn Kersten, JH, `arXiv:1106.0764`

LHC reach

Mass reach of the 7 TeV LHC with $10\,\text{fb}^{-1}$ for "compact spectra" (here $m_{\widetilde{\tau}_1} \gtrsim 400\,\text{GeV}$):



Jörn Kersten, JH, in preparation

Conclusion

- Gravitino LSP viable dark matter candidate
- Gravitino LSP can naturally provide long-lived sparticles with prominent signatures
- Direct production accessible and sets robust limits:
  $\sim 170\,\mathrm{GeV}$ @7 TeV, $10\,\mathrm{fb}^{-1}$ ($600\,\mathrm{GeV}$ @14 TeV, $300\,\mathrm{fb}^{-1}$)
- Limits in $m_{\widetilde{g}}$-$m_{\widetilde{q}}$-plane: @7 TeV, $10\,\mathrm{fb}^{-1}$
  Gluinos $\sim 1200\,\mathrm{GeV}$, squarks $\sim 1000\,\mathrm{GeV}$
- In Contrast to neutralino LSP "streched" and "compressed" spectra not hidden
- We hope to see some signals soon!

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Thank you for your attention!