Gravitino LSP and long-lived staus at the LHC

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Based on Jörn Kersten, JH, `arXiv:1106.0764 [hep-ph]`, and work in progress

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Motivation

- R-parity conserving SUSY with a gravitino LSP well motivated
- Gravitino perfectly good DM candidate
- Gravitino LSP naturally provides rather long-lived NLSP
- Charged long-lived NLSP interesting signature at colliders

In the following

- Consider stau NLSP (but results also valid for other $\widetilde{\ell}$)
- Not restrict to any high-scale model (phenomenological MSSM)
- Examine properties of this scenario at the LHC

Channels

Amongst all possible production channels consider two “extreme cases”:

- Direct Drell-Yan ($Z, \gamma \rightarrow \widetilde{\tau}\widetilde{\tau}$)
  - Theoretically interesting: Depends only on $m_{\widetilde{\tau}_1}$ and $\theta_{\widetilde{\tau}}$
  - Always present $\rightarrow$ Assured discovery potential and strict exclusion limits
  - Leading for “stretched spectra”
- Strong cascades ($\widetilde{g}, \widetilde{q} \rightarrow$ decay chain $\rightarrow \widetilde{\tau}\widetilde{\tau}$)
  - Potential to exceed direct Drell-Yan the most at LHC
  - But, in principle *many* MSSM parameters involved through intermediate SUSY particles
  - Systematic analysis dependence on intermediate sparticles
  - Appropriate $m_{\widetilde{g}}$-$m_{\widetilde{q}}$-plane plot

Signature

- Assumption: Direct detection of the stau itself provides most significant contribution for identifying SUSY
- Background for stable charged sleptons are muons

Preselection: $\left.\begin{array}{l} p_{\mathrm{T}} > 50\,\mathrm{GeV} \\ \eta < 2.5 \\ \Delta R_{\mathrm{jet},\tilde{\tau}} > 0.5 \end{array}\right\} \rightarrow$ Background: Drell-Yan and $t\bar{t}$

- main discrimination: velocity
  - CMS: both ToF and $\mathrm{d}E/\mathrm{d}x$ included CMS PAS EXO-11-022
  - Velocity cut $\beta_{\mathrm{ToF},\,\mathrm{d}E/\mathrm{d}x} < 0.8$ provides very effective background rejection CMS PAS EXO-08-003

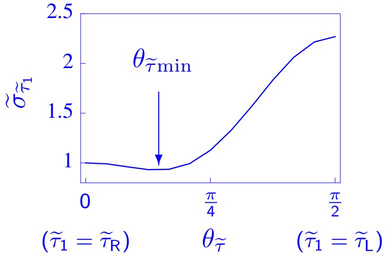
Direct Drell-Yan production

Stau mixing angle

- Mixing angle $\theta_{\tilde\tau}$: $\begin{pmatrix}\tilde\tau_1\\ \tilde\tau_2\end{pmatrix} = \begin{pmatrix}\cos\theta_{\tilde\tau} & \sin\theta_{\tilde\tau}\\ -\sin\theta_{\tilde\tau} & \cos\theta_{\tilde\tau}\end{pmatrix}\begin{pmatrix}\tilde\tau_R\\ \tilde\tau_L\end{pmatrix}$
- In the considered mass range "universal" $\theta_{\tilde\tau}$-dependence:

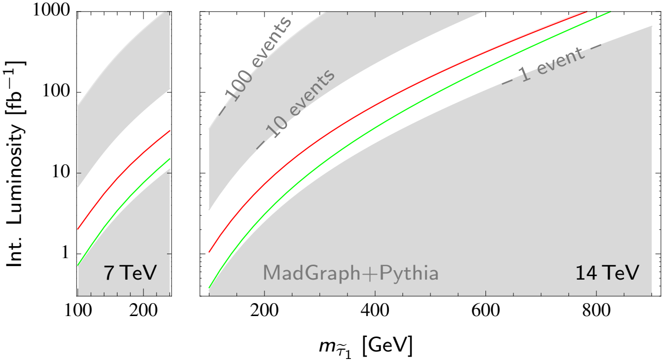
$$\sigma_{\tilde\tau_1}(m_{\tilde\tau_1}, \theta_{\tilde\tau}, \text{kinematics}) \simeq \sigma_{\tilde\tau_1}(m_{\tilde\tau_1}, \text{kinematics}) \times \widetilde{\sigma}_{\tilde\tau_1}(\theta_{\tilde\tau})$$

- $\theta_{\tilde\tau\text{min}} \neq 0$
- In the following conservative: $\theta_{\tilde\tau\text{min}}$



Mass dependence: Luminosity at which one can

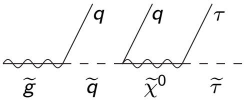
- expect 5σ-discovery of a stau
- exclude (95% CL) all scenarios with a metastable stau



Production via Strong Cascades

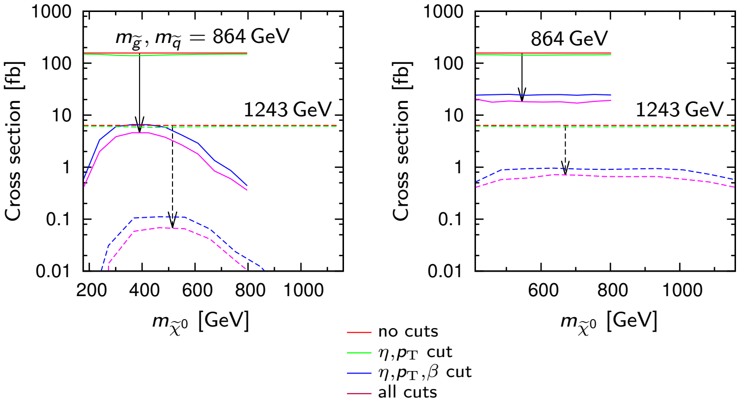
Production via Cascades

- Concentrate on 7 TeV LHC
- We took $\widetilde{g}\widetilde{g}, \widetilde{g}\widetilde{q}, \widetilde{q}\widetilde{q}$ into account (summed over u, d and L,R)
- First, focus on minimal decay chain:



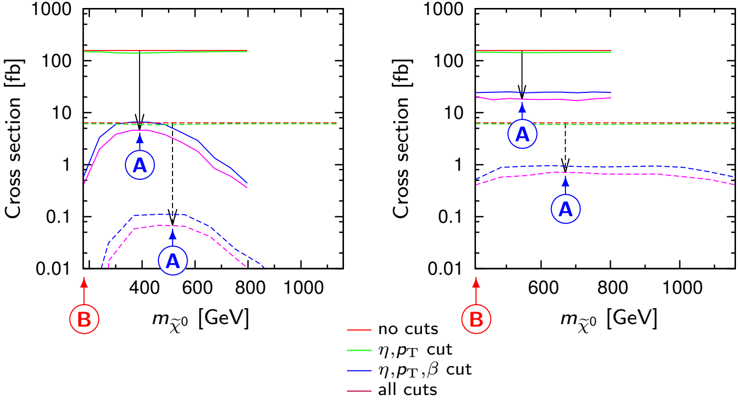
Minimal decay chain (varying $m_{\tilde{\chi}^0}$)

$m_{\tilde{\tau}_1} = 167$ GeV: $m_{\tilde{\tau}_1} = 400$ GeV:



Minimal decay chain (varying $m_{\tilde{\chi}^0}$)

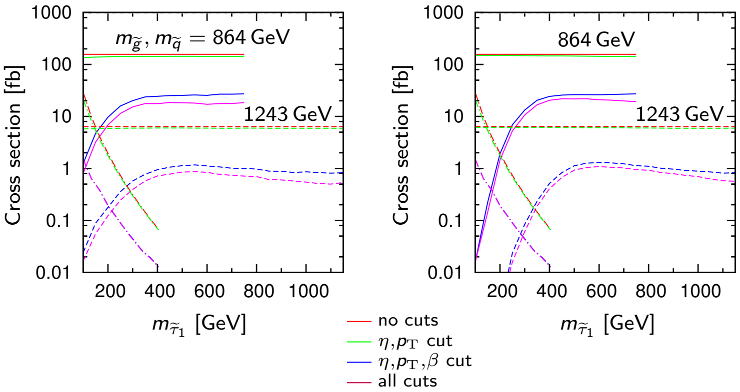
$m_{\tilde{\tau}_1} = 167$ GeV: $\quad$ $m_{\tilde{\tau}_1} = 400$ GeV:



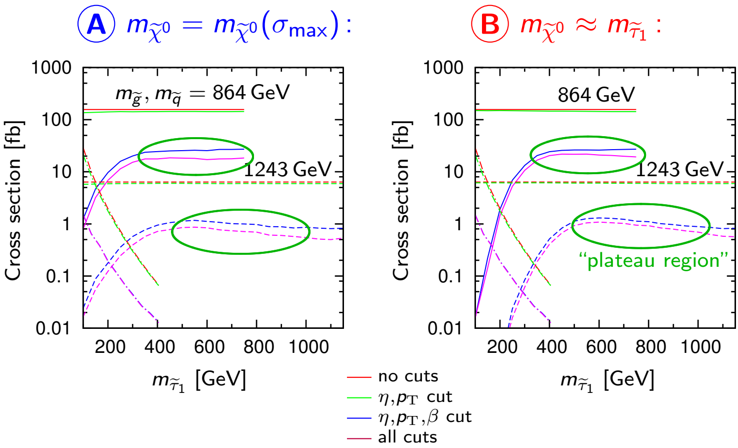
Minimal decay chain (varying $m_{\tilde{\tau}_1}$)

A $m_{\tilde{\chi}^0} = m_{\tilde{\chi}^0}(\sigma_{\max})$:

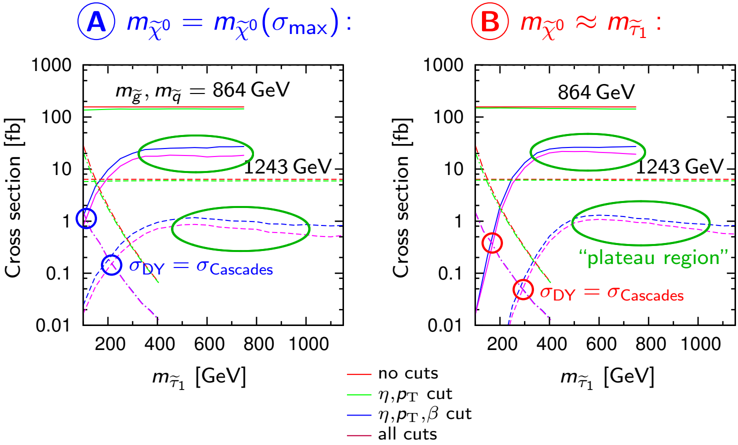
B $m_{\tilde{\chi}^0} \approx m_{\tilde{\tau}_1}$:



Minimal decay chain (varying $m_{\widetilde{\tau}_1}$)

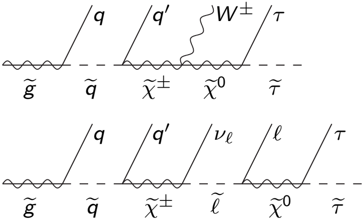


Minimal decay chain (varying $m_{\widetilde{\tau}_1}$)



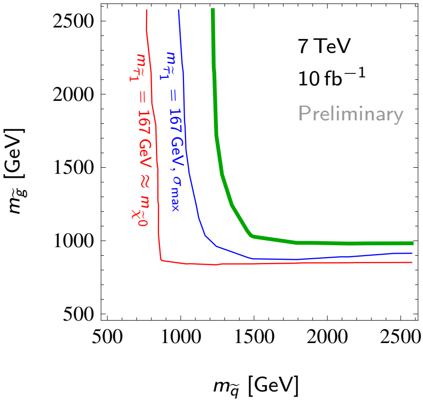
Longer decay chains

- E.g.

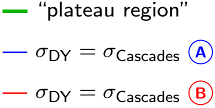


- More parameters involved
- Minima rise, distributions become flattend
- Impact of β-cut does not become less than "plateau region"

Expected exclusion (discovery) in the $m_{\tilde{g}}$-$m_{\tilde{q}}$-plane



Minimal Decay chain:



Mass reach of the 7 TeV LHC with $10\,\text{fb}^{-1}$ requiring 3 events passing all cuts.

Conclusion

- Gravitino LSP can naturally provide long-lived sparticles with prominent signatures
- Direct production sets robust limits:
  $\sim 170\,\text{GeV}$ @7 TeV, $10\,\text{fb}^{-1}$ (600 GeV @14 TeV, $300\,\text{fb}^{-1}$)
- Cascades:
  - Dependence on intermediate sparticles
  - Limits in $m_{\tilde{g}}$-$m_{\tilde{q}}$-plane:
    Gluinos 800...1200 GeV, squarks 800...1000 GeV
    @7 TeV, $10\,\text{fb}^{-1}$
- Outlook:
  - Potential benefit from loosening the β-cut
  - K-factors only conservatively estimated
  - Including SM radiation signature might be interesting

Thank you for your attention!