Long-lived staus in a simplified model approach

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Based on Jörn Kersten, JH: Phys. Rev. **D86**, 055020 (2012), 1203.1581 [hep-ph]

Desy Theory Workshop 2012

Introduction

- Most SUSY searches concentrate on neutralino LSP
- Gravitino (or axino) LSP cosmologically well motivated or even favored
- Very weak LSP coupling $\rightarrow$ NLSP long-lived
- Lighter stau natural choice for the NLSP (or LOSP)
- NLSP determines signature at colliders:
  - Muon-like particle
  - For $\beta < 1 \rightarrow$ identification as a HSCP (ToF and $\mathrm{d}E/\mathrm{d}x$)

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Here we show:

- General HSCP search (+2 hard jets) suitable for model-independent bounds on sparticle masses
- Direct and strong production in simplified model approach

Simplified models

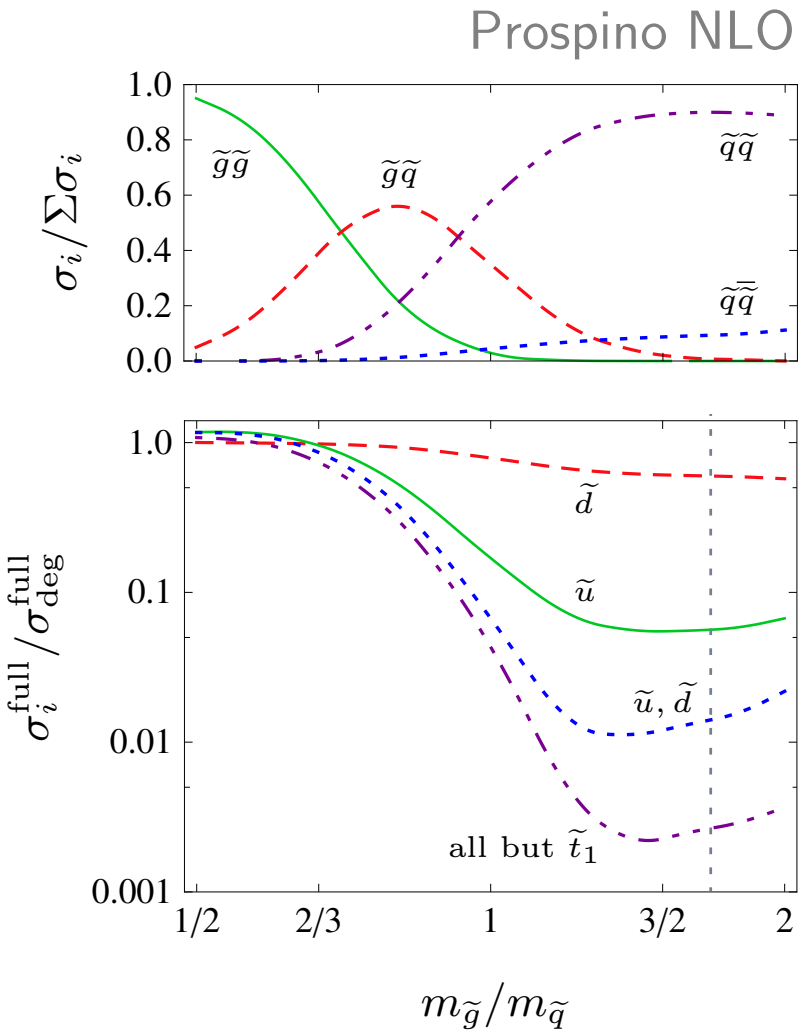
[Alwall et al. 0810.3921, LHC NPWG 1105.2838]

- Production and decay of gluinos and squarks: many parameters
- Reduction of parameters driven by low-scale phenomenology
- As few parameters as possible
- Divide problem into production and decay
- Introduce a discrete number of models serving as limiting cases

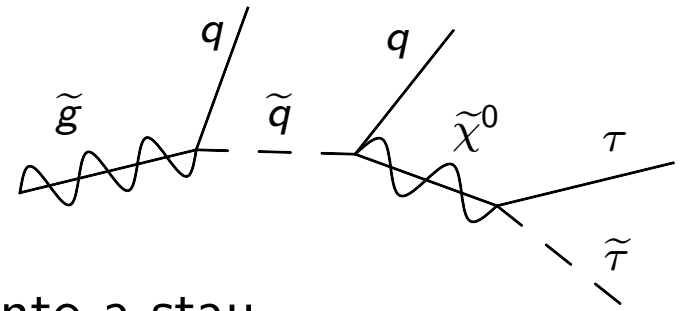
Simplified models – Production

- Consider
  $\widetilde{g}\widetilde{g}$, $\widetilde{g}\widetilde{q}$, $\widetilde{q}\widetilde{q}$, $\widetilde{q}\overline{\widetilde{q}}$
- Depend on $m_{\widetilde{g}}$, $m_{\widetilde{q}}$
- Show results for:
  - Common mass
    $\widetilde{q} = \widetilde{u}, \widetilde{d}, \widetilde{s}, \widetilde{c}, \widetilde{b}$
  - Only lighter stop
    $\widetilde{q} = \widetilde{t}_1$

$\rightarrow$ **2 parameters**



Simplified models – Decay



- Every gluino or squark decays into a stau
- Decay chain affects
  - Stau velocity, i.e. number of identified HSCPs
  - Number and type of SM radiation
- Identified HSCP strongest contribution to potential discovery/exclusion: focus on velocity

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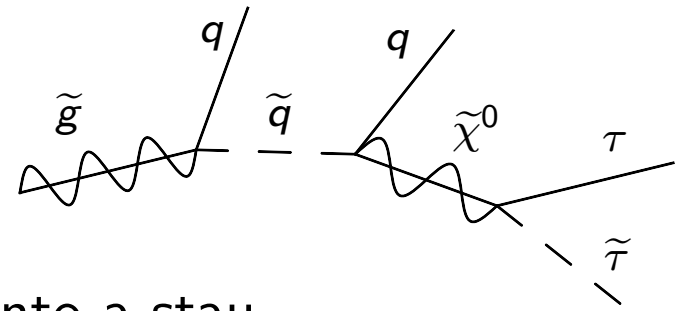

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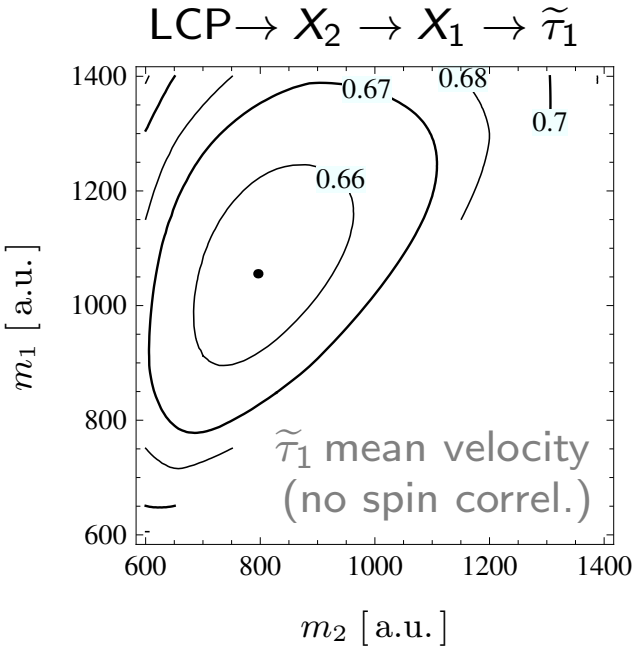
- Identified HSCP strongest contribution to potential discovery/exclusion: focus on velocity
- Velocity depends on total phase space $\sim m_{\mathrm{LCP}} - m_{\widetilde{\tau}_1}$
- Impact of intermediate sparticles $\rightarrow$ Limiting cases

Extrema in stau mean velocity $\overline{\beta}_{\widetilde{\tau}_1}$ (independent of β_{LCP})



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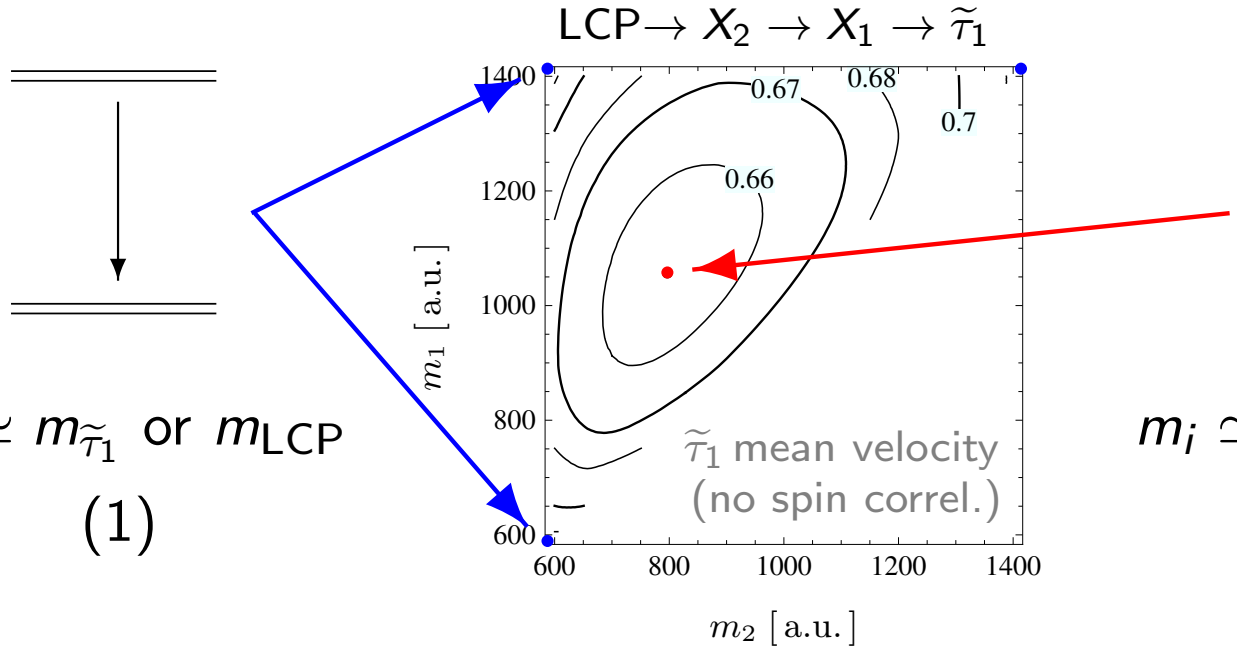


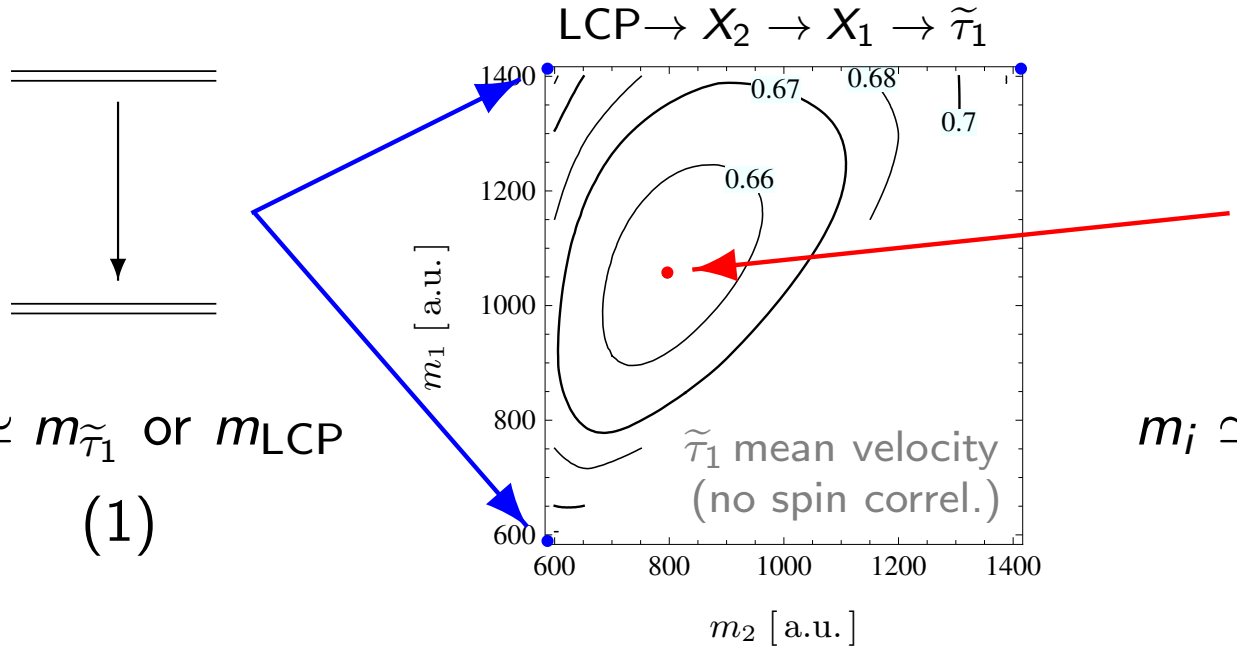
$m_i \simeq m_{\widetilde{\tau}_1}$ or m_{LCP}

(1)

$m_i \simeq (m_{\mathrm{LCP}})^{\frac{n-i}{n}} m_{\widetilde{\tau}_1}^{\frac{i}{n}}$

(2)

Extrema in stau mean velocity $\overline{\beta}_{\widetilde{\tau}_1}$ (independent of β_{LCP})



Model $\mathcal{A}$: The 'direct decay' (1).

Model $\mathcal{B}$: (2) for the 1-step decay LCP $\to \widetilde{\chi}^0 \to \widetilde{\tau}_1$.

Model $\mathcal{C}$: (2) for the 3-step decay LCP $\to \widetilde{\chi}_2^0 \to \widetilde{\ell} \to \widetilde{\chi}_1^0 \to \widetilde{\tau}_1$.

Selection criteria and background

Selection 1: 2 staus (loose β-cut) + 2 hard jets $p_{\mathrm{T}} > 200\,\mathrm{GeV}$.

Selection 2: 2 staus only, $\beta < 0.88$ and $p_{\mathrm{T}} > 150\,\mathrm{GeV}$

Selection 3: 2 staus only, $\beta < 0.73$ and $p_{\mathrm{T}} > 300\,\mathrm{GeV}$, buffering of tracker data

Background:

- DY($\mu\mu$), $t\bar{t}$
- Strong reduction through velocity cut

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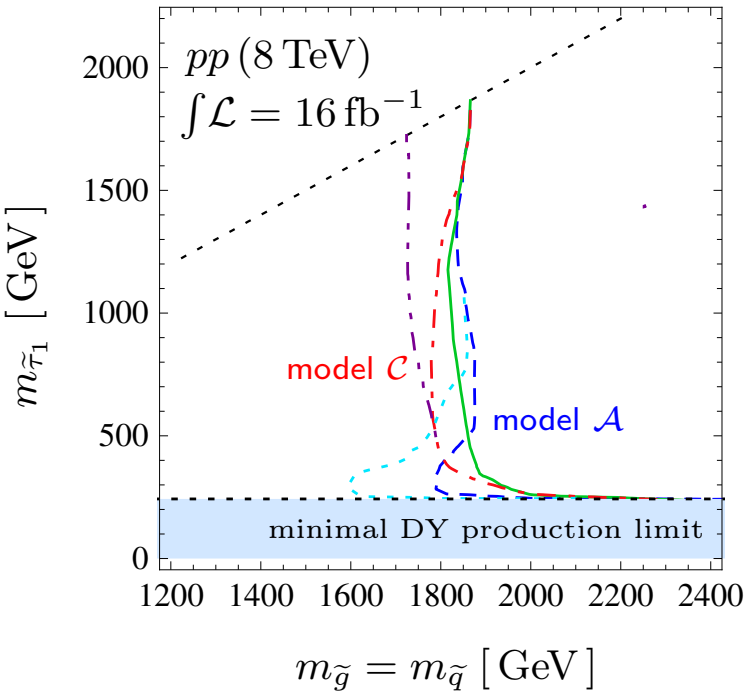
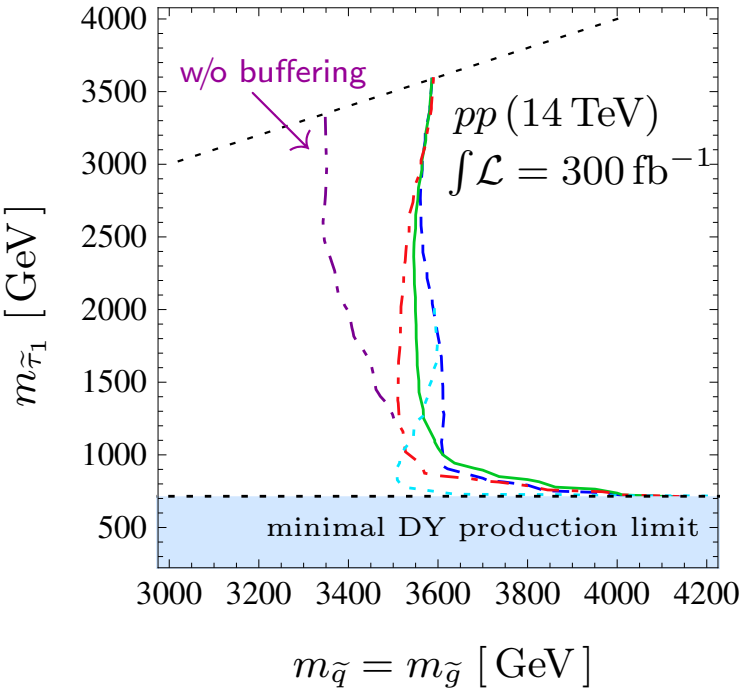
Computation:

- Production: Prospino, MadEvent (channelwise weighting)
- Decay: SDECAY, Pythia; Detector: Delphes

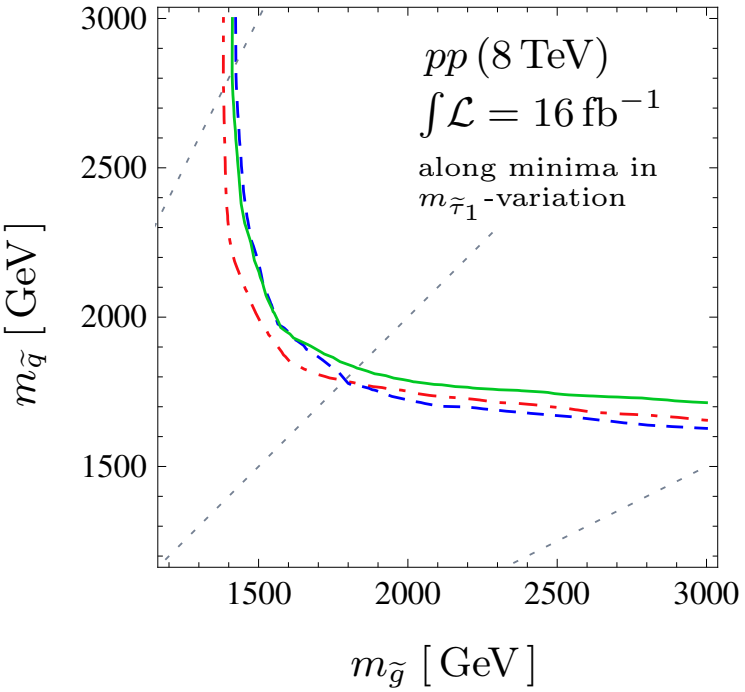
Projected exclusion (discovery) limits

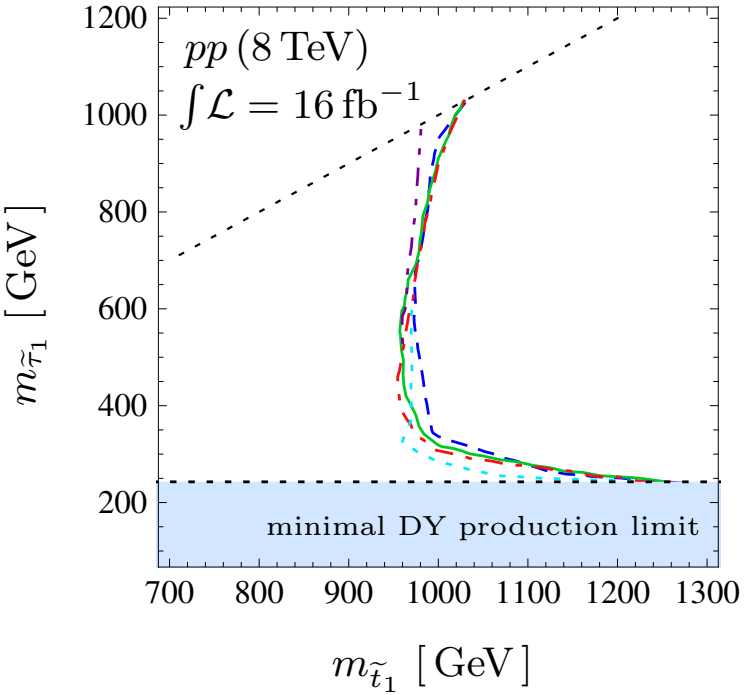




- Models $\mathcal{A}$-$\mathcal{C}$ lie within narrow band
- Direct DY 'saves' model-independent approach
- Trigger: buffering important for long-term run

Projected exclusion (discovery) limits II





- Conservative limits on squark and gluino masses
  $16\,\mathrm{fb}^{-1}$@8 TeV: $m_{\tilde{g}} \gtrsim 1.4\,\mathrm{TeV}$, $m_{\tilde{q}} \gtrsim 1.6\,\mathrm{TeV}$, $m_{\tilde{t}_1} \gtrsim 950\,\mathrm{GeV}$
- Experiments might turn out to perform even better

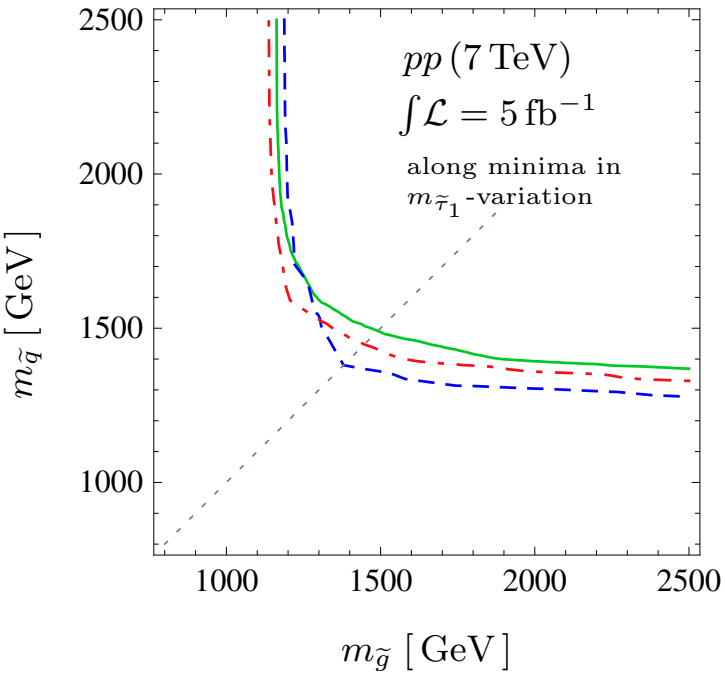
Conclusion

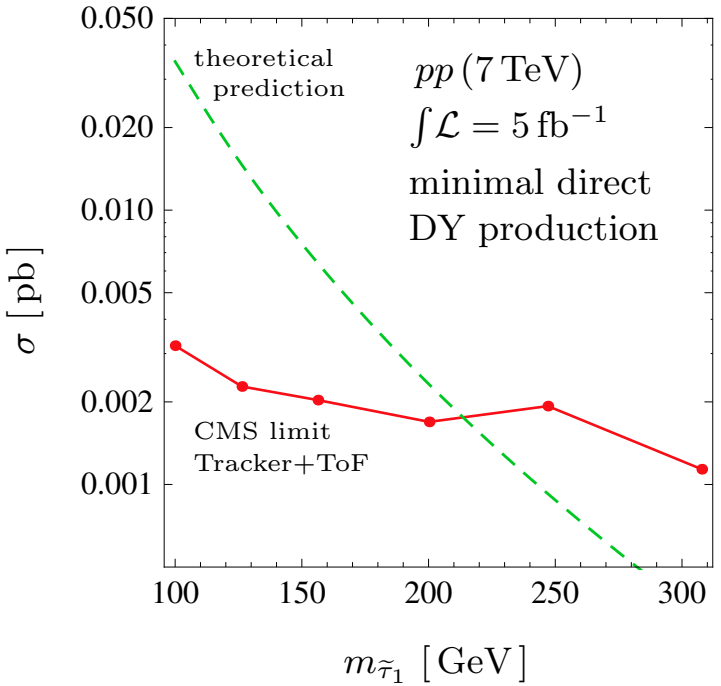
- Long-lived stau scenario cosmologically well motivated
- Prominent HSCP signature $\rightarrow$ very few events required: LHC potential for exclusion & discovery similar
- Model-independent approach suitable
- Robust (conservative) bounds on $m_{\tilde{g}}$, $m_{\tilde{q}}$, $m_{\tilde{t}}$ and $m_{\tilde{\tau}_1}$
- From 2011 null-searches: $m_{\tilde{\tau}_1} > 216\,\text{GeV}$, $m_{\tilde{g}} \gtrsim 1.1\,\text{TeV}$, $m_{\tilde{q}} \gtrsim 1.4\,\text{TeV}$

Thank you for your attention!

Backup slides I

Exclusion for the 7TeV LHC run:





Backup slides II

Expected number of stopped stau events: