New Results for Light Gravitinos at Hadron Colliders – Tevatron Limits and LHC Perspectives

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Outline

SUSY breaking, goldstinos and gravitinos

SUSY Goldstone theorem When SUSY is spontaneously broken, there is a massless fermion, the *goldstino*, that couples every SM particle with its superpartner:

$$\mathcal{L}_{\text{goldstino}} = -\frac{1}{F}\ \tilde{G}\ \partial_\mu J^\mu$$

$\sqrt{F}$ is the SUSY-Breaking energy scale.

Super-Higgs mechanism In supergravity, the gravitino eats the goldstino when SUSY is broken, and the gravitino gets a mass:

$$m_{\tilde{G}} = \frac{F}{\sqrt{3}M} \quad \text{with} \quad M = m_{\text{Pl}}/\sqrt{8\pi} = 2.44\ 10^{18}\ \text{GeV}$$

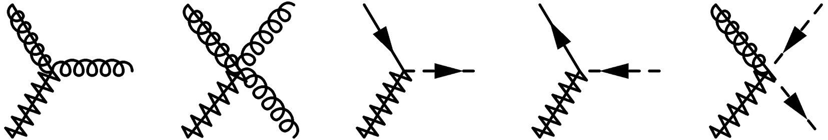
TeV-Scale SUSY Breaking

- TeV scale SUSY breaking
  - Worth to be studied: a "natural" hypothesis.
  - $\sqrt{F} = 1$ TeV corresponds to $m_{\tilde{G}} = 2 \times 10^{-4}$ eV.
  - Gravitino is the LSP.
- Standard cosmology
  - Light gravitino as a warm dark matter candidate.
  - If $m_{\tilde{G}} > 1$ keV, gravitinos overclose the universe.
  - $m_{\tilde{G}} > 12$ eV is unconsistent with WMAP data.
- Collider limits: Several model-dependant studies give constraints: $m_{\tilde{G}} > 10^{-5}$ eV.
- There is room for:

$$\begin{aligned} 10^{-5}\ \text{eV} < & \quad m_{\tilde{G}} \quad < 10\ \text{eV} \\ 200\ \text{GeV} < & \quad \sqrt{F} \quad < 200\ \text{TeV} \end{aligned}$$

Effective couplings of goldstino with SUSY-QCD particles

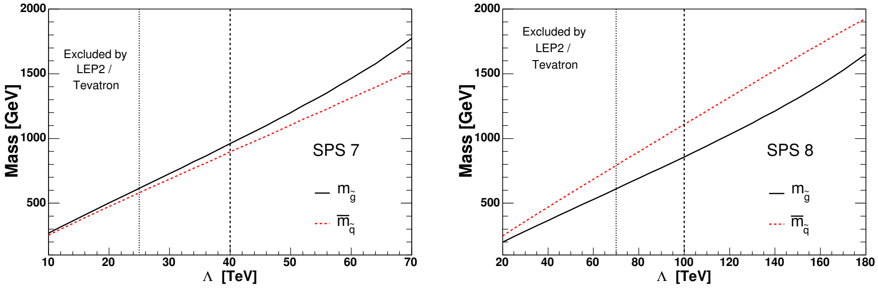
It has been shown that both global and local SUSY breaking scenarios lead to the same results for single gravitinos processes. We checked and used the following effective non-derivative couplings for gravitino with SUSY-QCD particles:



$\approx \frac{m_{\tilde{g}}}{M \; m_{\tilde{G}}}$ $\approx \frac{m_{\tilde{g}}}{M \; m_{\tilde{G}}} g_s$ $\approx \frac{m_{\tilde{q}}^2}{M \; m_{\tilde{G}}}$ $\approx \frac{m_{\tilde{q}}^2}{M \; m_{\tilde{G}}}$ $\approx \frac{m_{\tilde{g}}}{M \; m_{\tilde{G}}} g_s$

Model lines SPS7 and SPS8

GMSB scenarios lead to gravitino LSP.
For our study we used model lines SPS 7 and SPS 8 as standard GMSB slopes.



SPS 7: squarks lighter than gluino, SPS 8: gluino lighter than squarks.

Direct production of gravitinos at hadron colliders

monojet + $\not{E}_T$ signals:

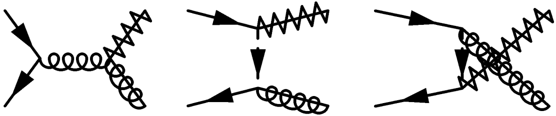
$$\begin{aligned} pp \text{ or } p\bar{p} &\rightarrow \tilde{G}\ \tilde{g} &\rightarrow \tilde{G}\ \tilde{G} g \\ pp \text{ or } p\bar{p} &\rightarrow \tilde{G}\ \tilde{q} &\rightarrow \tilde{G}\ \tilde{G} q \end{aligned}$$

Using Narrow Width Approximation (NWA) for intermediary particles, we have to:

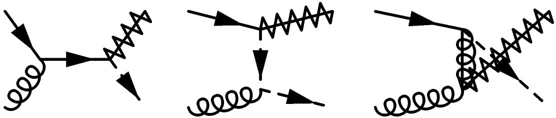
- Calculate the amplitudes for partonic subprocesses.
- Compute the convolution of partonic X-sections with PDFs.
- Calculate branching ratios for the sparticles decays.

Born Diagrams for partonic production of gravitinos

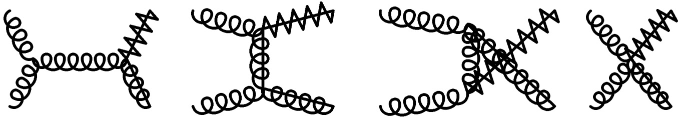
$q\bar{q} \longrightarrow \tilde{G}\tilde{g}$



$qg \longrightarrow \tilde{G}\tilde{q}$



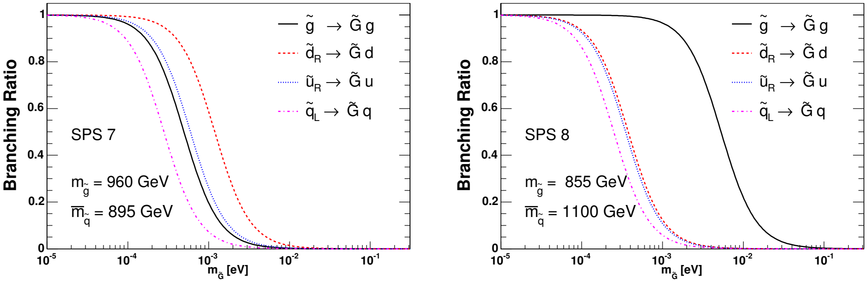
$gg \longrightarrow \tilde{G}\tilde{g}$



Branching ratios 1/2

We computed Branching Ratios: $BR_{\tilde{X}} = \frac{\Gamma_{\tilde{G}}}{\Gamma_{\tilde{G}}+\Gamma_{MSSM}}$, with:

$$\Gamma_{\tilde{X}\to X\tilde{G}} = \frac{m_{\tilde{X}}^5}{48\pi M^2 m_{\tilde{G}}^2}$$



For very light gravitinos, superparticles mainly decay into jet + $\tilde{G}$.

Branching ratios 2/2

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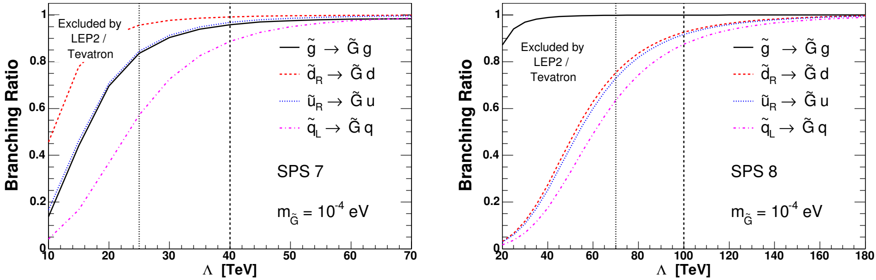
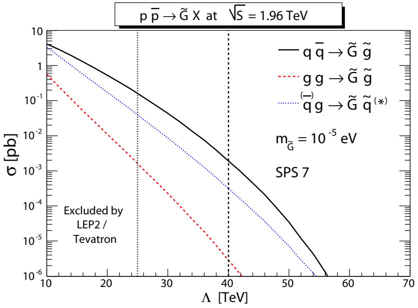
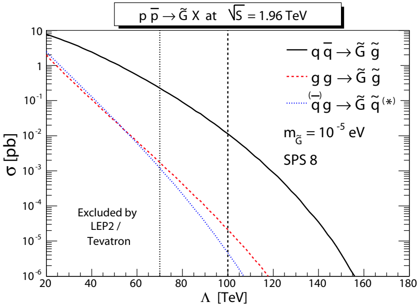


For heavy superparticles, superparticles mainly decay into jet + $\tilde{G}$.

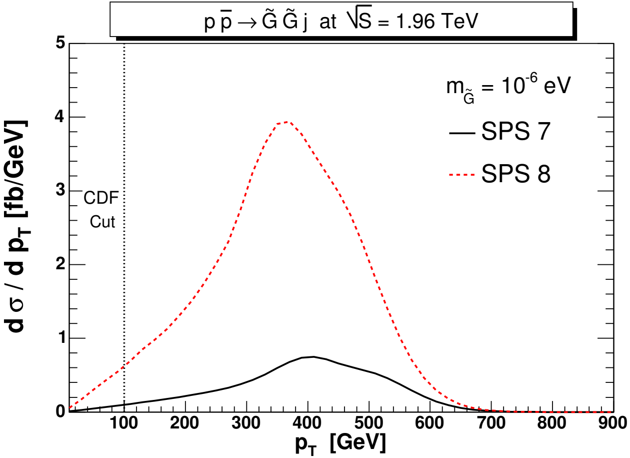
Gravitino production @ Tevatron

- $q\bar{q} \rightarrow \tilde{G}\ \tilde{g}$ is the dominant subprocess at Tevatron.
- SPS 8 gives stronger X-section because of the mass hierarchy $m_{\tilde{g}} < m_{\tilde{q}}$.





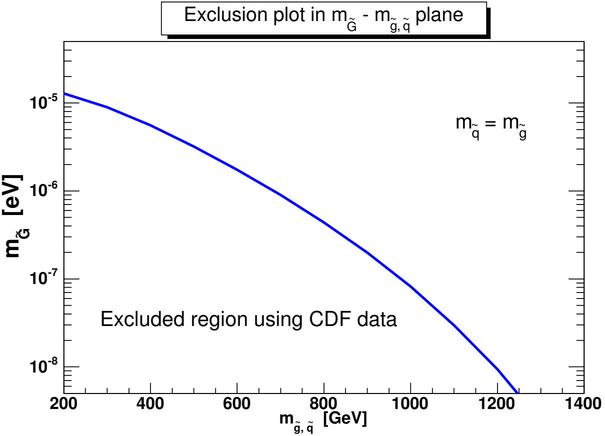
p_t spectrum of the monojet @ Tevatron



The signal is not affected by large cuts in p_T.

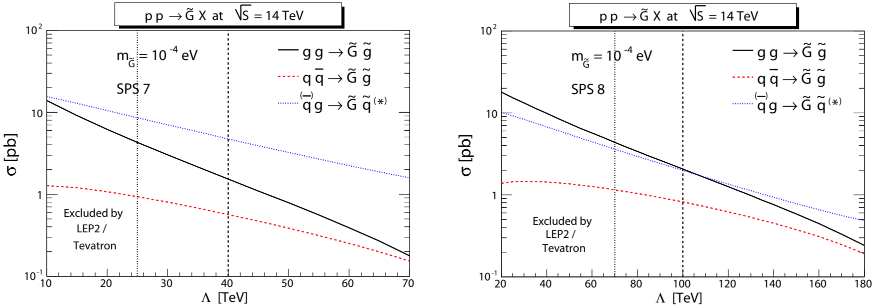
Exclusion plot from CDF

We used the CDF limit $\sigma_{\text{monojet}+\not E_T} < 3.1$ pb from 87 pb^{-1} RUN-I data.

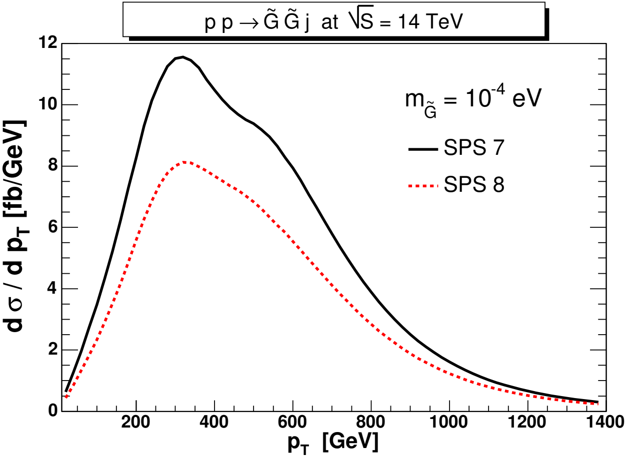


Gravitino production @ LHC

- The X-section for gravitino production is large everywhere in the parameters space !
- $q\bar{q} \longrightarrow \tilde{G}\ \tilde{g}$ is no longer the dominant subprocess.



p_t spectrum of the monojet @ LHC



Striking monojet signal, but the background $pp \to Z\ j \to \nu\ \nu j$ has to be taken into account.

Conclusion and Perspectives

- Previous analytical X-sections calculated with derivative Lagrangian are confirmed by our calculations using non-derivative Lagrangian.
- We provide a limit on the gravitino mass using on-shell production of superparticles. This limit is complementary to the one obtained by the CDF coll. in the infinite sparticle mass limit.
- We are ready to use RUN-II data to improve this limit.
- SUSY scenarios with light gravitinos will lead to striking monojet signal at the LHC.