Long-Lived Superparticles with Hadronic Decays at the LHC

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Talk based on work with B. Tweedie, arxiv:1503.05923
THINKING OUTSIDE THE BEAMPIPE
THINKING OUTSIDE THE BEAMPIPE

See many interesting discussions on various channels in talks yesterday by P.R. PAIS, W. Wulsin, J. Evans and more in this conference.
Space of All Models
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explicitly searched for by ATLAS/CMS
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OVERVIEW OF OUR STUDY

Applied to all models
- CMS displaced dijets (tracker)
- ATLAS low-EM jets (HCAL)
- ATLAS muon spectrometer vertices*
- CMS charged stable particles

Applied to models with leptonic decays
- CMS displaced dileptons
- CMS displaced electron & muon
- ATLAS displaced muon + tracks

* 7 TeV, 2 fb⁻¹
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\[ \tilde{t} \rightarrow \bar{d}_i \bar{d}_j \text{ via baryonic RPV including } \tilde{t} \rightarrow \bar{b} \bar{b} \]

\[ \tilde{g} \rightarrow u_i d_j d_k \text{ via baryonic RPV} \]

\[ \tilde{H} \rightarrow u_i d_j d_k \text{ (+soft) via baryonic RPV} \]

\[ \tilde{q} \rightarrow q \tilde{G} \text{ in GMSB} \]

\[ \tilde{g} \rightarrow g \tilde{G} \text{ in GMSB} \]

\[ \tilde{t} \rightarrow t(\ast) \tilde{G} \text{ in GMSB} \]

\[ \tilde{H} \rightarrow h/Z \tilde{G} \text{ (+soft) in GMSB} \]

\[ \tilde{g} \rightarrow q\bar{q}\tilde{B} \text{ in mini-split SUSY} \]

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** All via direct pair-production
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Our selection of signals covers a large range of displace decay topologies, including 1j+MET, 2j+MET, 3j+MET, 2j, 3j, as well as heavy flavors, making it easy for theorists to estimate exclusions for their own models in concern.
A EXAMPLE OF DISPLACED DIJET

standard 2j

2j + MET

showered 1j + MET

3j
A TYPICAL EFFICIENCY MAP

Location of Decays in ATLAS

Meade, Reece, Shih (2010)
A TYPICAL EFFICIENCY MAP

Depend on lifetime, how is the particle being produced (How Lorentz factor distributes), the decay distributes shape differently at different layers of the detector.
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Efficiency map for RPV stop decays into light jet pairs in the CMS displaced dijet analysis.
• Lines at increase of 100 GeV
• Low mass suffers more for cuts on jet energy
• High mass approaches constant efficiency shape
• Low efficiency at low lifetime (cut to remove SM)
• (Shift in peak due to Lorentz Factor)
EXAMPLE 1: GMSB STOP

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GMSB Stop → Top (*) + Gravitino

- Displaced searches (dijet, \(\mu + \text{tracks}, e + \mu\), HCAL, \(\mu\) spectrometer) covers mid-lifetime Heavy charges
- Stable particle searches (pink; CHAMP) covers long lifetime
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FULL lifetime coverage up to 500 GeV!
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Diagram showing full lifetime coverage up to 500 GeV!

Dijet search has very good sensitivity reach, lepton plus tracks searches also sensitive to leptonic top- and b-decays. HCAL and muon spectrometer searches sensitive to higher lifetimes but so far suffers large efficiency cost. Optimization may provide additional information, e.g., heavy neutral displaced particles.
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MINI-SPLIT GLUINO $\rightarrow 2J +$ LSP

mass

$\sim 1000$ TeV

$\sim 1$ TeV

$\sim 0.1$ TeV

squarks and sleptons
(scalar partners)

$\tilde{g}$ $\tilde{q}^*$

EM-neutral LSP

gauuginos, Higgsinos
(fermionic partners)

SM

Arvanitaki, Craig, Dimopoulos, Villadoro (2012)
MINI-SPLIT GLUINO $\rightarrow$ 2J + LSP

\[ c\tau \propto m_{\text{squark}}^4 / m_{\text{gluino}}^5 \]
MINI-SPLIT GLUINO $\rightarrow$ 2J + LSP

$\tilde{g} \rightarrow q q \tilde{B}$, $m(\tilde{B}) = 0$ (mini-split)

$c\tau \propto m_{\text{squark}}^4 / m_{\text{gluino}}^5$

$\tau$
MINI-SPLIT GLUINO $\rightarrow$ 2J + LSP

\[ c\tau \propto \frac{m_{\text{squark}}}{m_{\tilde{g}_{\text{gluino}}}} \]

- The dijet in the final boosts the efficiencies for displaced dijet searches.
- The prompt jets+MET searches also covers a range of lifetime in the low mass, as fractions of long-lived particles decay promptly (boundary in dashed lines indicates possible extrapolation.)
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FULL lifetime coverage up to >1 TeV!
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This figure shows one extreme case with large mass splitting between the LSP and NLSP. How about a bit compressed?
MINI-SPLIT GLUINO $\rightarrow$ 2J + LSP
MINI-SPLIT GLUINO → 2J + LSP

In case of compressed spectra (right panel)
MINI-SPLIT GLUINO ➞ 2J + LSP

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Most searches rely on visible SM particles greatly reduced due to energy cuts (necessary to cut away SM backgrounds from non-prompt decay and cosmic rays, etc)
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• Major classes of well-motivated SUSY models exhibit displaced decays
  • R
    broad range of possible particle spectra and decay topologies
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- Understanding the full LHC potential requires careful recastings for many models
  - Map ranges/overlaps in coverage
  - Identify gaps/ambiguities/opportunities
  - We have made some first steps in this direction
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  RPV, Mini-split, GMSB
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Thank you!