Searches for third generation squarks with the ATLAS detector

Steve Muanza CPPM, CNRS-IN2P3 & AMU

On Behalf of the ATLAS Collaboration

April 30, 2014
## Introduction

SUSY predicts a partner with $\Delta S = 1/2$ for all SM particles

<table>
<thead>
<tr>
<th>Spin</th>
<th>Interaction Eigenstates</th>
<th>Mass Eigenstates</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>$\begin{pmatrix} e^* \bar{\nu}_e \ \tilde{e}_R \end{pmatrix}_L$</td>
<td>$\begin{pmatrix} u^* \bar{\nu}_u \ \tilde{u}_R \end{pmatrix}_L$</td>
</tr>
<tr>
<td></td>
<td>$\begin{pmatrix} \mu^* \bar{\nu}_\mu \ \tilde{\mu}_R \end{pmatrix}_L$</td>
<td>$\begin{pmatrix} \tau^* \bar{\nu}_\tau \ \tilde{\tau}_R \end{pmatrix}_L$</td>
</tr>
<tr>
<td></td>
<td>$\begin{pmatrix} \tilde{e}^* \tau \end{pmatrix}_L$</td>
<td>$\begin{pmatrix} \tilde{\mu}^* \tau \end{pmatrix}_L$</td>
</tr>
<tr>
<td></td>
<td>$\tilde{\tau}^* \tau$</td>
<td>$\tilde{\tau}^* \tau$</td>
</tr>
</tbody>
</table>

Sleptons

| 1/2  | $\begin{pmatrix} \tilde{e}_R \\ \tilde{\nu}_e \\ e_R^* \bar{\nu}_e \end{pmatrix}_L$ | $\begin{pmatrix} \tilde{\mu}_R \\ \tilde{\nu}_\mu \\ \mu_R^* \bar{\nu}_\mu \end{pmatrix}_L$ |
|      | $\begin{pmatrix} \tilde{\tau}_R \\ \tilde{\nu}_\tau \\ \tau_R^* \bar{\nu}_\tau \end{pmatrix}_L$ | $\begin{pmatrix} \tilde{\tau}_R \\ \tilde{\nu}_\tau \\ \tau_R^* \bar{\nu}_\tau \end{pmatrix}_L$ |

Leptons

| 0    | $\begin{pmatrix} \tilde{u}_R \tilde{d}_R \\ \tilde{d}_R \end{pmatrix}_L$ | $\begin{pmatrix} \tilde{c}_R \tilde{s}_R \\ \tilde{s}_R \end{pmatrix}_L$ |
|      | $\begin{pmatrix} \tilde{c}_R \tilde{s}_R \\ \tilde{s}_R \end{pmatrix}_L$ | $\begin{pmatrix} \tilde{t}_R \tilde{b}_R \\ \tilde{b}_R \end{pmatrix}_L$ |

Squarks

| 1/2  | $\begin{pmatrix} u_R \tilde{d}_R \\ \tilde{d}_R \end{pmatrix}_L$ | $\begin{pmatrix} c \tilde{s}_R \\ \tilde{s}_R \end{pmatrix}_L$ |
|      | $\begin{pmatrix} c \tilde{s}_R \\ \tilde{s}_R \end{pmatrix}_L$ | $\begin{pmatrix} t \tilde{b}_R \\ \tilde{b}_R \end{pmatrix}_L$ |

Quarks

| 0    | $\Phi_u = \begin{pmatrix} \phi_u^0 \\ \phi_u^0 \end{pmatrix}$ | $h^0 = A^0$ |
|      | $\Phi_d = \begin{pmatrix} \phi_d^0 \\ \phi_d^0 \end{pmatrix}$ | $H^0 = H^\pm$ |

Higgs Doublet Fields

| 1/2  | $\Phi_u = \begin{pmatrix} \phi_u^0 \\ \phi_u^0 \end{pmatrix}$ | $\tilde{\chi}_{1,2,3,4}^0$ |
|      | $\Phi_d = \begin{pmatrix} \phi_d^0 \\ \phi_d^0 \end{pmatrix}$ | $\tilde{\chi}_{1,2}^\pm$ |

Higgsinos

| 1    | $\begin{pmatrix} B^0 \tilde{W}^+_{1,2} \tilde{g} \end{pmatrix}$ | $\begin{pmatrix} \tilde{\chi}_{1,2}^\pm \tilde{g} \end{pmatrix}$ |

Bino, Wino, Gluinos

| 3/2  | $\begin{pmatrix} Z^0 \tilde{W}^\pm \tilde{g} \end{pmatrix}$ | $\begin{pmatrix} \tilde{\chi}_{1,2}^\pm \tilde{g} \end{pmatrix}$ |

Neutralinos, Charginos, Gluinos

| 2    | $\begin{pmatrix} \tilde{G}_{3/2} \end{pmatrix}$ | $\begin{pmatrix} G_{\mu\nu} \end{pmatrix}$ |

Gravitino, Graviton
Natural SUSY

- It requires sparticles with dominant contributions to $M_h$ radiative corrections to be relatively light

<table>
<thead>
<tr>
<th>$	ilde{g}$</th>
<th>$\tilde{W}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\tilde{b}_L$</td>
<td>$\tilde{b}_R$</td>
</tr>
<tr>
<td>$\tilde{t}_L$</td>
<td>$\tilde{t}_R$</td>
</tr>
<tr>
<td>$\tilde{H}$</td>
<td>decoupled SUSY</td>
</tr>
<tr>
<td>natural SUSY</td>
<td></td>
</tr>
</tbody>
</table>

- In this context one expects
  - not too heavy gluinos
  - stop/sbottom as lightest squark

Present talk reports on recent ATLAS analyses (or updates)

- Dataset: $\int \mathcal{L} dt = (20.3 \pm 0.6) fb^{-1}$ of p+p collisions at $\sqrt{s} = 8$ TeV in 2012
- All limits at the 95% C.L.
Gluino Mediated Production

- Start with the highest cross section process
- Hypothesis: gluino lighter than $1^{st}/2^{nd}$ generation squarks
- Large b-jet multiplicity and large $E_T \Rightarrow$ low SM background
Direct Production

- Also look for direct production in case gluinos are out of reach
- Lower cross sections, still higher than those of EWK gauginos
- Lower b-jet multiplicity
Analysis

"Search for supersymmetry at $\sqrt{s} = 8$ TeV in final states with jets and two same-sign leptons or three leptons with the ATLAS detector"

- Ref: arXiv:1404.2500 [hep-ex], subm. to JHEP
- See ATLAS talk by T. Gillam

Inclusive Search Topology

- $\ell^\pm \ell^\pm + [1 - 3]b - jets + \not{E}_T$, ($\ell^\pm = e^\pm/\mu^\pm$)
- $\ell^\pm \ell^\pm + [0]b - jets + \not{E}_T$
- $3\ell^\pm + [1 - 3]b - jets + \not{E}_T$
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2. Motivation
3. Search Strategy
4. Multilepton Search
5. Search with 2 b-jets and No Leptons
6. Search with All Hadronic $t\bar{t} + E_T$
7. Search with c-jets+$E_T$
8. Search with 3b-jets+$E_T$
9. Direct Stop Pair Production (1)
10. Direct Stop Pair Production (2)
11. Conclusion
12. Summary

Limits & Interpretations

$M_T = \sqrt{2p_T(\ell^\pm )E_T[1 - \cos\Delta\phi(\ell^\pm , E_T)]}$

Distr. in $e^\pm \mu^\pm + [0]b - jet + E_T$
inclusive topology
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Limits & Interpretations: Simplified Models
Limits & Interpretations: Complete Models

$M_{\text{eff}} = E_T + \sum_{\text{leptons}} p_T + \sum_{\text{jets}} p_T$

Distr. in $e^\pm e^\pm + [1-3]b$-jet + $E_T$

inclusive topology

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Searches for third generation squarks with the ATLAS detector
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Limits & Interpretations

- $M_T = \sqrt{2p_T (\ell^\pm) E_T [1 - \cos \Delta \phi (\ell^\pm, E_T)]}$
- Distr. in $e^\pm \mu^\pm + [0] b - jet + E_T$
  inclusive topology

- $M_{\text{eff}} = E_T + \sum_{\text{leptons}} p_T + \sum_{\text{jets}} p_T$
- Distr. in $e^\pm e^\pm + [1 - 3] b - jet + E_T$
  inclusive topology
**Limits & Interpretations**

- $M_T = \sqrt{2p_T(\ell^\pm)E_T[1 - \cos\Delta\phi(\ell^\pm, E_T)]}$
- Distr. in $e^\pm\mu^\pm + [0]b - jet + E_T$ inclusive topology
- $M_{\text{eff}} = E_T + \sum_{\text{leptons}} p_T + \sum_{\text{jets}} p_T$
- Distr. in $e^\pm e^\pm + [1 - 3]b - jet + E_T$ inclusive topology

![Graph showing data and SM comparison](attachment:graph.png)
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**Background**

- **MC estimate of physics background:**
  - $ttW$, $ttZ$, $WW$, $WZ$

- **Data-driven estimate of instrumental background:**
  - hadron faking isolated $\ell^\pm$
  - non-isolated $\ell^\pm$ from heavy flavor hadron decay faking isolated $\ell^\pm$
  - $e^\pm$ from $\gamma - \text{conversion}$
  - $e^\pm$ with mis-measured charge

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**Limits Derivation**

- Signal exclusion fit simultaneously all SRs (maximizes sensitivity to SUSY scenario)
- No excess observed in data wrt SM expectations in any analyses
- Limits are calculated using the CL$_S$ prescription
Gluino Mediated Production

\[ M_{\tilde{g}} << M_{\tilde{t}_1} \]
Gluino Mediated Production

- \( M_{\tilde{g}} > M_{\tilde{t}_1} \)
- \( (M_{\tilde{\chi}_1^\pm}, M_{\tilde{\chi}_1^0}) = (118, 60) \text{ GeV} \)

Limits & Interpretations: Simplified Models
Limits & Interpretations: Complete Models

Gluino Mediated Production

\[ \tilde{g} \rightarrow \tilde{t}_{\perp} \tilde{\chi}_{\perp} \]

\[ m_{\tilde{t}_{\perp}} > m_{\tilde{\chi}_{\perp}} \]

\[ m_{\tilde{g}} > M_{\tilde{t}_1} \)

(\( M_{\tilde{\chi}_1^\pm}, M_{\tilde{\chi}_1^0} \) = (118, 60) \text{ GeV})

- 2 same-charge leptons/3 leptons + jets
- Expected limit (\( \pm 1 \sigma_{\text{exp}} \))
- Observed limit (\( \pm 1 \sigma_{\text{obs}} \))

All limits at 95% CL

\[ L \, dt = 20.3 \text{ fb}^{-1}, \sqrt{s} = 8 \text{ TeV} \]

- 0 lepton, 7-10 jets, \( \sqrt{s} = 8 \text{ TeV}, 20.3 \text{ fb}^{-1} \)
- 0 lepton, \( \geq 3 \) bjets, \( \sqrt{s} = 7 \text{ TeV}, 4.7 \text{ fb}^{-1} \)
Gluino Mediated Production

\[ M_{\tilde{g}} \ll M_{\tilde{t}_1} \]

\[ M_{\tilde{g}} > M_{\tilde{t}_1} \]
\[ \left( M_{\tilde{\chi}^\pm_1}, M_{\tilde{\chi}^0_1} \right) = (118, 60) \text{ GeV} \]
Gluino Mediated Production

- \( m_{\tilde{g}} << M_{\tilde{t}_1} \)

- \( \tilde{g} \rightarrow t + c + \tilde{\chi}^0_1 \)
  \( M_{\tilde{t}_1} - M_{\tilde{\chi}^0_1} = 20 \text{ GeV} \)
Gluino Mediated Production

- $M_{\tilde{g}} << M_{\tilde{t}_1}$

- $M_{\tilde{g}} > M_{\tilde{t}_1}$
  $\left( M_{\tilde{\chi}^\pm_1}, M_{\tilde{\chi}^0_1} \right) = (118, 60) \text{ GeV}$

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**Gluino Mediated Production**

- $M_{\tilde{g}} << M_{\tilde{t}_1}$

- $M_{\tilde{g}} > M_{\tilde{t}_1}$
  $(M_{\tilde{\chi}^\pm_1}, M_{\tilde{\chi}^0_1}) = (118, 60)$ GeV

- $\tilde{g}\tilde{g} \to \tilde{t}_1 + \tilde{t}$
  $	ilde{t}_1 \to b + s (R_P)$

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**Limits & Interpretations: Simplified Models**

**Limits & Interpretations: Complete Models**

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**ATLAS**

2 same-charge leptons/3 leptons + jets

$L dt = 20.3$ fb$^{-1}$, $\sqrt{s}$=8 TeV

Observed limit $(\pm 1\, \sigma_{\text{theor}})$

Expected limit $(\pm 1\, \sigma_{\text{exp}})$

All limits at 95% CL
Gluino Mediated Production

- \( M_{\tilde{g}} << M_{\tilde{t}_1} \)

- \( M_{\tilde{g}} > M_{\tilde{t}_1} \)
  \( (M_{\tilde{\chi}^\pm_1}, M_{\tilde{\chi}^0_1}) = (118, 60) \) GeV

- \( \tilde{g} \rightarrow t + c + \tilde{\chi}^0_1 \)
  \( M_{\tilde{t}_1} - M_{\tilde{\chi}^0_1} = 20 \) GeV

- \( \tilde{g} \rightarrow \tilde{t}_1 + \tilde{t} \)
  \( \tilde{t}_1 \rightarrow b + s \ (R_P) \)
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Limits & Interpretations: Simplified Models
Limits & Interpretations: Complete Models

Gluino Mediated Production

- $M_{\tilde{g}} < M_{\tilde{t}_1}$

- $M_{\tilde{g}} > M_{\tilde{t}_1}$
  $(M_{\tilde{\chi}_1^\pm}, M_{\tilde{\chi}_1^0}) = (118, 60) \text{ GeV}$

- $\tilde{g} \rightarrow t + c + \tilde{\chi}_1^0$
  $M_{\tilde{t}_1} - M_{\tilde{\chi}_1^0} = 20 \text{ GeV}$
Direct Sbottom Pair Production

\[ \tilde{b}_1 \rightarrow t + \tilde{\chi}_1^\pm \]

\[ M_{\tilde{\chi}_1^0} = 60 \text{ GeV} \]
Direct Sbottom Pair Production

\[ \tilde{b}_1 \rightarrow t + \tilde{\chi}_1^\pm \]

\[ M_{\tilde{\chi}_1^\pm} = 2M_{\tilde{\chi}_1^0} \]
Direct Sbottom Pair Production

\[ \tilde{b}_1 \rightarrow t + \tilde{\chi}_1^\pm \]
\[ M_{\tilde{\chi}_1^0} = 60 \text{ GeV} \]

\[ \tilde{b}_1 \rightarrow t + \tilde{\chi}_1^\pm \]
\[ M_{\tilde{\chi}_1^\pm} = 2M_{\tilde{\chi}_1^0} \]
Direct Sbottom Pair Production

\[ \tilde{b}_1 \rightarrow t + \tilde{\chi}^\pm_1 \]

\[ M_{\tilde{\chi}^0_1} = 60 \text{ GeV} \]
Minimal Supergravity

- $\tan \beta = 30$, $A_0 = -2m_0$
- $\mu > 0$
Minimal Supergravity

- $\tan\beta = 30$, $A_0 = -2m_0$
- $\mu > 0 (b\bar{R}P)$

**ATLAS**

$\tan(\beta)=30$, $A_0=-2m_0$, $\mu > 0$

MSUGRA/CMSSM: $\tan(\beta)=30$, $A_0=-2m_0$, $\mu > 0$

- $L dt = 20.3$ fb$^{-1}$, $\sqrt{s}=8$ TeV
- 2 same-charge leptons/3 leptons + jets
- Observed limit ($\pm 1 \sigma_{\text{exp}}$)
- Expected limit ($\pm 1 \sigma_{\text{exp}}$)
- All limits at 95% CL
Minimal Supergravity

- $\tan \beta = 30$, $A_0 = -2m_0$
  - $\mu > 0$

- $\tan \beta = 30$, $A_0 = -2m_0$
  - $\mu > 0$ ($bR_P$)
**Minimal Supergravity**

- $\tan\beta = 30, \ A_0 = -2m_0, \ \mu > 0$

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**Limits & Interpretations: Simplified Models**

**Limits & Interpretations: Complete Models**

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**Searches for third generation squarks with the ATLAS detector**
Gauge Mediated SUSY Breaking

- $M_{mess} = 250$ TeV, $N_5 = 3$
- $\mu > 0$, $C_{grav} = 1$
Gauge Mediated SUSY Breaking

Limits & Interpretations: Simplified Models

Limits & Interpretations: Complete Models

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Searches for third generation squarks with the ATLAS detector
Universal Extra Dimensions

Non SUSY Model
Universal Extra Dimensions

2 same-charge leptons/3 leptons + jets

Observed limit

Expected limit (±1σExp)

All limits at 95% CL

ATLAS

$\int L \cdot dt = 20.3 \text{ fb}^{-1}, \sqrt{s} = 8 \text{ TeV}$
"Search for direct third-generation squark pair production in final states with missing transverse momentum and two b-jets in $\sqrt{s} = 8$ TeV pp collisions with the ATLAS detector"


Inclusive Search Topology

$2b - jets + 0\ell^{\pm} + \not E_T$
The document outlines various search strategies for third generation squarks, including:

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The diagram illustrates a process involving partons $p$ and $b$ leading to particles $\tilde{b}$, $\tilde{t}$, and $\tilde{\chi}^0$, with $b$ decay products shown.
• $\tilde{\chi}_1^\pm \rightarrow SoftTrack(s) + E_T$

$M_{\tilde{\chi}_1^\pm} - M_{\tilde{\chi}_1^0} = 5 \text{ GeV}$
Limits & Interpretations: Simplified Models

\[ \tilde{\chi}_1^{\pm} \rightarrow \text{SoftTrack}(s) + E_T \]
\[ M_{\tilde{\chi}_1^{\pm}} - M_{\tilde{\chi}_1^0} = 5 \text{ GeV} \]
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Limits & Interpretations: Simplified Models

- $\tilde{\chi}_1^\pm \to Soft Tracks + E_T$
- $M_{\tilde{\chi}_1^\pm} - M_{\tilde{\chi}_1^0} = 20 \text{ GeV}$

Stop pair production, $\tilde{t} \to b \tilde{\chi}_1^\pm$, $m(\tilde{\chi}_1^\pm) - m(\tilde{\chi}_1^0) = 5 \text{ GeV}$

All limits at 95% CL
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**Limits & Interpretations: Simplified Models**

- $\tilde{\chi}_1^\pm \rightarrow \text{SoftTrack}(s) + E_T$
  
  $M_{\tilde{\chi}_1^\pm} - M_{\tilde{\chi}_1^0} = 5$ GeV

- $\tilde{\chi}_1^\pm \rightarrow \text{SoftTracks} + E_T$
  
  $M_{\tilde{\chi}_1^\pm} - M_{\tilde{\chi}_1^0} = 20$ GeV

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Searches for third generation squarks with the ATLAS detector
Limits & Interpretations: Simplified Models

- \tilde{\chi}_1^{\pm} \rightarrow SoftTrack(s) + \not{E}_T
  \quad M_{\tilde{\chi}_1^{\pm}} - M_{\tilde{\chi}_1^0} = 5 \text{ GeV}

- \tilde{\chi}_1^{\pm} \rightarrow SoftTracks + \not{E}_T
  \quad M_{\tilde{\chi}_1^{\pm}} - M_{\tilde{\chi}_1^0} = 20 \text{ GeV}
Analysis

"Search for direct production of the top squark in the all-hadronic $t\bar{t} + \not{E}_T$ final state in 21 fb$^{-1}$ of pp collisions at $\sqrt{s} = 8$ TeV with the ATLAS detector"

Ref: ATLAS-CONF-2013-024

Inclusive Search Topology

$t\bar{t} \to jets + 0\ell^{\pm} + \not{E}_T$

Event Selection

- Trigger: $\not{E}_T > 80$ GeV
- Offline:
  - Main Variables: $M_T$ and $\not{E}_T$
  - Tau Veto
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Limits & Interpretations: Simplified Models
Searches for third generation squarks with the ATLAS detector

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Analysis

"Search for strong production of supersymmetric particles in final states with missing transverse momentum and at least three b-jets using 20.1 fb$^{-1}$ of pp collisions at $\sqrt{s} = 8$ TeV with the ATLAS Detector"

Ref: ATLAS-CONF-2013-068

Inclusive Search Topology

- $2c - jets + E_T$

Event Selection

- Trigger: $E_T > 80$ GeV
- Offline:
  - Very Low $\Delta M$: tag an ISR-jet → mono-jet selection
  - Low $\Delta M$: tag a c-jet
c-tagging

- **Trigger**: $E_T > 80$ GeV
- **Offline**:
  - MVA: Tracks I.P. and properties of 2ndary vertices
  - Performance: $\epsilon_c = 20\%$, $R_b \approx 5$, $R_{LF} \approx 140$

**Limits & Interpretations: Simplified Models**

Search for third generation squarks with the ATLAS detector
c-tagging

- **Trigger:** $E_T > 80$ GeV
- **Offline:**
  - MVA: Tracks I.P. and properties of 2ndary vertices
  - Performance: $\epsilon_c = 20\%$, $R_b \approx 5$, $R_{LF} \approx 140$

**Limits & Interpretations: Simplified Models**

- $t\bar{t}$ production, $t\rightarrow c + \chi^0_1$
- Expected limit (±1σ)
- Observed limit (±1σ)

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Searches for third generation squarks with the ATLAS detector
Analysis

"Search for strong production of supersymmetric particles in final states with missing transverse momentum and at least three b-jets using 20.1 fb$^{-1}$ of pp collisions at $\sqrt{s} = 8$ TeV with the ATLAS Detector"

- Ref: ATLAS-CONF-2013-061

Inclusive Search Topology

- $[0−1]\ell^{±} + jets + 3b − jets + E_T$

Event Selection

- Main Variables: $M_{\text{eff}}$ and $E_T/\sqrt{H_T}$
Direct Sbottom Pair Production

\[ BR(\tilde{b}_1 \rightarrow b + \tilde{\chi}_2^0) = 1 \]
\[ BR(\tilde{\chi}_2^0 \rightarrow h + \tilde{\chi}_1^0) = 1 \]
Direct Sbottom Pair Production

0 and 1 lepton + 3 b-jets channels

\( m(\tilde{b}^0) = 60 \text{ GeV} \)

\( \tilde{b}^0 \to b + \tilde{\chi}^0_1 \)

\( \tilde{b}^0 \to b + \tilde{\chi}^0_2 \) forbidden

All limits at 95% CL

**ATLAS Preliminary**

- Expected limit ±1\( \sigma_{\text{exp}} \)
- Observed limit ±1\( \sigma_{\text{SUSY}} \)

\( L = 20.1 \text{ fb}^{-1}, \sqrt{s} = 8 \text{ TeV} \)
Gluino Mediated Sbottom Pair Production

\[ BR(\tilde{g} \rightarrow \tilde{b}_1 + \tilde{b}) = 1 \]
\[ \text{on-shell } \tilde{b}_1 \]
\[ BR(\tilde{b}_1 \rightarrow b + \tilde{\chi}^0_1) = 1 \]
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**Gluino Mediated Sbottom Pair Production**

$BR(\tilde{g} \rightarrow b + \tilde{b} + \tilde{\chi}_1^0) = 1$

off-shell $\tilde{b}_1$

![Graph showing Gluino Mediated Sbottom Pair Production](image)

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**Limits & Interpretations: Simplified Models**

- **Limits & Interpretations: Complete Models**

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### Gluino Mediated Sbottom Pair Production

- $BR(\tilde{g} \to \tilde{b}_1 + \bar{b}) = 1$
  - on-shell $\tilde{b}_1$
  - $BR(\tilde{b}_1 \to b + \tilde{\chi}_1^0) = 1$

- $BR(\tilde{g} \to b + \bar{b} + \tilde{\chi}_1^0) = 1$
  - off-shell $\tilde{b}_1$

---

*Searches for third generation squarks with the ATLAS detector*
**1. Introduction**

2. **Motivation**

3. **Search Strategy**

4. **Multilepton Search**

5. **Search with 2 b-jets and No Leptons**

6. **Search with All Hadronic $t\bar{t} + E_T$**

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8. **Search with 3b-jets + $E_T$**

9. **Direct Stop Pair Production (1)**

10. **Direct Stop Pair Production (2)**

**11. Conclusion**

**12. Summary**

---

**Gluino Mediated Sbottom Pair Production**

- $BR(\tilde{g} \rightarrow \tilde{b}_1 + \tilde{b}) = 1$
  
  on-shell $\tilde{b}_1$

- $BR(\tilde{b}_1 \rightarrow b + \tilde{\chi}_1^0) = 1$
  
  off-shell $\tilde{b}_1$

---

**ATLAS Preliminary**

0 lepton + 3 b-jets channel

$\tilde{g} \rightarrow b\bar{b} + \tilde{\chi}_1^0$, $m(\tilde{g}) > m(\tilde{b}_1)$

$L^{\text{int}} = 20.1$ fb$^{-1}$, $\sqrt{s} = 8$ TeV

---

Steve Muanza CPPM, CNRS-IN2P3 & AMU

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**Gluino Mediated Stop Pair Production**

\[
BR(\tilde{g} \rightarrow t + \tilde{\chi}^0_1) = 1,

BR(\tilde{t}_1 \rightarrow b + \tilde{\chi}^\pm_1) = 1

BR(\tilde{\chi}^\pm_1 \rightarrow W^\pm + \tilde{\chi}^0_1) = 1

(M_{\tilde{\chi}^\pm_1}, M_{\tilde{\chi}^0_1}) = (120, 60) \text{ GeV}
\]
**Gluino Mediated Stop Pair Production**

- \( BR(\tilde{t}_1 \rightarrow t + \tilde{\chi}_1^0) = 1 \)
- \( M_{\tilde{\chi}_1^0} = 60 \text{ GeV} \)

![Graph showing exclusion limits](image)
**Gluino Mediated Stop Pair Production**

- $BR(\tilde{g} \rightarrow t + \tilde{\chi}_1^0) = 1$
- $BR(\tilde{t}_1 \rightarrow b + \tilde{\chi}_1^\pm) = 1$
- $BR(\tilde{\chi}_1^\pm \rightarrow W^\pm + \tilde{\chi}_1^0) = 1$
- $(M_{\tilde{\chi}_1^\pm}, M_{\tilde{\chi}_1^0}) = (120, 60)$ GeV

- $BR(\tilde{t}_1 \rightarrow t + \tilde{\chi}_1^0) = 1$
- $M_{\tilde{\chi}_1^0} = 60$ GeV
Gluino Mediated Stop Pair Production

- \( BR(\tilde{g} \to t + \tilde{\chi}_1^0) = 1 \),
- \( BR(\tilde{t}_1 \to b + \tilde{\chi}_1^\pm) = 1 \)
- \( BR(\tilde{\chi}_1^\pm \to W^\pm + \tilde{\chi}_1^0) = 1 \)
- \( (M_{\tilde{\chi}_1^\pm}, M_{\tilde{\chi}_1^0}) = (120, 60) \text{ GeV} \)

- \( BR(\tilde{t}_1 \to t + \tilde{\chi}_1^0) = 1 \)
- \( M_{\tilde{\chi}_1^0} = 60 \text{ GeV} \)
Gluino Mediated Stop Pair Production (cont’d)

- \( BR(\tilde{g} \rightarrow t + \bar{t} + \tilde{\chi}^0_1) = 1 \)
- off-shell \( \tilde{t}_1 \)
Gluino Mediated Stop Pair Production (cont’d)

- \( BR(\tilde{g} \rightarrow b + \tilde{t} + \tilde{\chi}_1^\pm) = 1 \)
- \( M_{\tilde{\chi}_1^\pm} - M_{\tilde{\chi}_1^0} = 2 \text{ GeV} \)
Gluino Mediated Stop Pair Production (cont’d)

- $BR(\tilde{g} \rightarrow t + \tilde{t} + \tilde{\chi}_1^0) = 1$
  off-shell $\tilde{t}_1$

- $BR(\tilde{g} \rightarrow b + \tilde{t} + \tilde{\chi}_1^{\pm}) = 1$
  $M_{\tilde{\chi}_1^{\pm}} - M_{\tilde{\chi}_1^0} = 2$ GeV

$$M_{\tilde{\chi}_1^{\pm}} - M_{\tilde{\chi}_1^0} = 2 \text{ GeV}$$
Gluino Mediated Stop Pair Production (cont’d)

- $BR(\tilde{g} \rightarrow t + \tilde{t} + \tilde{\chi}_1^0) = 1$
  - off-shell $\tilde{t}_1$

- $m_{\tilde{g}} = 400, 600, 800, 1000, 1200, 1400$ [GeV]
- $m_{\tilde{t}_1}$

- $d + b + \chi_1^0$, forbidden

---

**Figure**: ATLAS Preliminary

- Expected limit $\pm \sigma_{exp}$
- Observed limit $\pm \sigma_{SUSY}$
- $0\ell + 3$ b-jets, $4.7$ fb$^{-1}$, $7$ TeV
- All limits at $95\%$ CL

- $m(\tilde{\chi}_1^0) - m(\tilde{\chi}_1^0) = 2$ GeV
- $\tilde{\chi}_1^0 \rightarrow f + \tilde{\chi}_1^0$
Minimal Supergravity

ATLAS Preliminary

- Expected limit ±1σ_{exp}
- Observed limit ±1σ_{SUSY Theory}

All limits at 95% CL

0 and 1 lepton + 3 b-jets channels

mSUGRA/CMSSM: tan(β)=30, A_0=−2m_0, μ>0

L^{int} = 20.1 fb⁻¹, \(\sqrt{s}=8\) TeV

m_{12} [GeV] vs m_0 [GeV]

Stau LSP

Limits & Interpretations: Simplified Models
Limits & Interpretations: Complete Models

Steve Muanza CPPM, CNRS-IN2P3 & AMU
Searches for third generation squarks with the ATLAS detector
Analysis

"Search for the direct pair production of top squarks decaying to a b quark, a tau lepton, and weakly interacting particles, in $\sqrt{s} = 8$ TeV pp collisions using 20 fb$^{-1}$ of ATLAS data"

Ref: ATLAS-CONF-2014-014

Inclusive Search Topology

$\ell^{\pm}\ell^{\mp} + \not{E}_T$

Event Selection

Main variable: $M_{T2}$

$M_{T2}(p_T^{vis_1}, p_T^{vis_2}, p_T) = \min_{p_T^{invis_1} + p_T^{invis_2} = p_T} \max[M_T(p_T^{vis_1}, p_T^{invis_1}), M_T(p_T^{vis_2}, p_T^{invis_2})]$
Analysis

"Search for the direct pair production of top squarks decaying to a b quark, a tau lepton, and weakly interacting particles, in $\sqrt{s} = 8$ TeV pp collisions using 20 fb$^{-1}$ of ATLAS data"

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Inclusive Search Topology

$\ell^\pm\ell^\mp + \not{E_T}$

Event Selection

$M_{T2}(p_T^{vis_1}, p_T^{vis_2}, p_T') = \min_{p_T^{invis_1} + p_T^{invis_2} = p_T'} \max [M_T(p_T^{vis_1}, p_T^{invis_1}), M_T(p_T^{vis_2}, p_T^{invis_2})]$  

Re-interpretation of the "3 b-jets" analysis
New selection for small $\tilde{t}_1$ and $\tilde{\nu}_1^\pm$ masses
Analysis

"Search for the direct pair production of top squarks decaying to a b quark, a tau lepton, and weakly interacting particles, in $\sqrt{s} = 8$ TeV pp collisions using 20 fb$^{-1}$ of ATLAS data"

- Ref: ATLAS-CONF-2014-014

Inclusive Search Topology

$\ell^\pm \ell^\mp + \mathcal{E}_T$

Event Selection

- Main variable: $M_{T2}$
- Re-interpretation of the "3 b-jets" analysis
- New selection for small $\tilde{t}_1$ and $\tilde{\tau}_1^\pm$ masses
Event Selection (cont’d)

ATLAS Preliminary

Data/MC

Events / bin

$\int L \, dt \sim 20.3 \, fb^{-1}$, $\sqrt{s} = 8$ TeV

CRTb: different flavour

SM Background
Z+jets
$t\bar{t}$
Single top
Reducible
others

$m_{\tilde{t}_1, \tilde{t}_2} = (337, 305) \, GeV$
$m_{\tilde{t}_1, \tilde{t}_2} = (153, 117) \, GeV$

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Gauge Mediated SUSY Breaking

- $BR(\tilde{t}_1 \rightarrow b + \nu + \tilde{\tau}_1^{\pm}) = 1$
- $BR(\tilde{\tau}_1^{\pm} \rightarrow \tau^{\pm} + \tilde{G}_{3/2}) = 1$
Gauge Mediated SUSY Breaking

\[ BR(\tilde{t}_1 \rightarrow b + \nu + \tilde{\tau}^\pm) = 1 \]
\[ BR(\tilde{\tau}_1^\pm \rightarrow \tau^\pm + \tilde{G}_{3/2}) = 1 \]
Analysis

"Search for direct top squark pair production in events with a Z boson, b-jets and missing transverse momentum in $\sqrt{s} = 8$ TeV pp collisions with the ATLAS detector"

- Ref: arXiv:1403.5222 [hep-ex], subm. to EJPC
- Motivation: In case direct $\tilde{t}_1 \tilde{t}_1$ searches have limited sensitivities due to compressed scenarios, consider production of $\tilde{t}_2 \tilde{t}_2$

Inclusive Search Topology

- $Z(\rightarrow \ell^\pm \ell'^\mp) + 2b - jets + \not\! E_T$
Gauge Mediated SUSY Breaking

- $BR(\tilde{t}_2 \rightarrow Z + \tilde{t}_1) = 1$
Gauge Mediated SUSY Breaking

- $BR(\tilde{t}_2 \rightarrow Z + \tilde{t}_1) = 1$

---

**Figure:**

- $BR(\tilde{t}_2 \rightarrow Z + \tilde{t}_1) = 1$

---

**Diagram:**

- $BR(\tilde{t}_2 \rightarrow Z + \tilde{t}_1) = 1$

---

**Graph:**

- $BR(\tilde{t}_2 \rightarrow Z + \tilde{t}_1) = 1$
Natural Gauge Mediated SUSY Breaking

- $\tilde{\chi}^0_1 \rightarrow Z + \tilde{G}_{3/2}$
- or $\tilde{\chi}^0_1 \rightarrow h + \tilde{G}_{3/2}$
Natural Gauge Mediated SUSY Breaking

\[ \tilde{\chi}_1^0 \rightarrow Z + \tilde{G}_{3/2} \]

or \[ \tilde{\chi}_1^0 \rightarrow h + \tilde{G}_{3/2} \]
Conclusion

- Several searches for 3\textsuperscript{rd} generation squarks presented
- No excess observed in data wrt SM expectations
Conclusion

- No excess observed in data wrt SM expectations
- Improved or new exclusion limits
Conclusion

- Several searches for 3rd generation squarks presented
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- Several interpretations of these results in different SUSY scenarios
Conclusion

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- Several interpretations of these results in different SUSY scenarios
- Summary plot
Conclusion

- Several searches for 3rd generation squarks presented
- No excess observed in data wrt SM expectations
- Improved or new exclusion limits

Summary plot
Conclusion (cont’d)

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**ATLAS Preliminary**

- **Observed limits**
- **Expected limits**

**All limits at 95% CL**

**CDF 2.6 fb⁻¹ [1203.4171]***

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ATLAS SUSY Limits

ATLAS SUSY Searches* + 95% CL Lower Limits
Status: Moriond 2014

<table>
<thead>
<tr>
<th>Model</th>
<th>e, µ, τ, γ, Jets $E_T^{vis}$</th>
<th>$L [fb^{-1}]$</th>
<th>Mass limit</th>
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<tbody>
<tr>
<td></td>
<td></td>
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<td>$m_{\tilde{g}}$ (GeV)</td>
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<td></td>
<td></td>
<td>$m_{\tilde{b}}$ (GeV)</td>
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<td>$m_{\tilde{\chi}}$ (GeV)</td>
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[Legend and further details of the table can be added here, but the focus is on the Introduction and Motivation sections.]

Searches for third generation squarks with the ATLAS detector

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