SUSY Searches with ATLAS

16th Lomonosov Conference on Elementary Particle Physics – 27.08.2013

Matthias Hamer
Georg-August-Universität Göttingen

On behalf of the ATLAS Collaboration
Outline

1) Introduction & Overview
2) Inclusive Searches for Squarks and Gluinos
3) Searches for 3rd Generation Squarks
4) Searches for Electroweak SUSY Production
5) Searches for RPV and long-lived SUSY
6) Summary
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Introduction & Overview

★ the Standard Model is not the full story
→ CPV, Dark Matter, Higgs-Mass, GUT, . . .

★ SUSY is one concept which extends the SM towards a more complete theory of nature
→ symmetry that connects bosons and fermions

★ many possible manifestations of SUSY
→ excellent dark matter candidate
→ 'natural' Higgs mass
→ gauge unification

★ no evidence for SUSY so far
→ symmetry broken by unknown mechanism
→ modelled by effective Lagrangian at low scale
The MSSM

- Minimal Supersymmetric Extension to the Standard Model: MSSM
  - one SUSY operation
  - minimal particle content
  - each degree of freedom in the SM gets a superpartner with $|\Delta s| = \frac{1}{2}$
  - effective Lagrangian with 124 parameters
  - derived models with less parameters
  - useful multiplicative quantum number: R-parity

- R-parity conserved: stable LSP
  - if WIMP: DM candidate, MET signatures at LHC
  - other signatures possible

- R-parity violated: unstable LSP
  - decays and signature depend on RPV couplings, nature of NLSP, . . .
The ATLAS Detector

- acquired p-p collision data:
  - 2010: 45 pb\(^{-1}\) at \(\sqrt{s} = 7\) TeV
  - 2011: 5.25 fb\(^{-1}\) at \(\sqrt{s} = 7\) TeV
  - 2012: 21.7 fb\(^{-1}\) at \(\sqrt{s} = 8\) TeV
- most of that data analysed
SUSY searches with ATLAS

- **Prompt**
  - RPV
    - **RPC**
      - 1\textsuperscript{st}/2\textsuperscript{nd} gen. squarks and gluinos
        - high MET
          - 2-10 jets
          - 0-2 leptons
      - 3\textsuperscript{rd} gen. stop and sbottom
        - high MET
          - 0-6 jets / b-jets
          - 0-3 leptons
      - Direct EWK gauginos and sleptons
        - high MET
          - $\geq$ 2 leptons

- **Long-lived scenarios**
  - Displaced vertices
  - Disappearing tracks
  - Heavy charged leptons
  - Out-of-time decays

☆ limits in various models:
  - $\rightarrow$ CMSSM
  - $\rightarrow$ AMSB/GMSB
  - $\rightarrow$ pMSSM
  - $\rightarrow$ simplified models
  - $\rightarrow$ ...
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$\sigma_{\text{tot}}[\text{pb}]: pp \rightarrow \text{SUSY}$

$\sqrt{S} = 8$ TeV

prospino2

$m_{\text{average}} [\text{GeV}]$
Inclusive Searches for Squarks and Gluinos

★ targets scenarios with
→ direct squark/gluino production (jets)
→ R-parity conservation (MET signature)
→ full hadronic decays preferred (lepton veto)

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Channel</th>
<th>A (2-jets)</th>
<th>B (3-jets)</th>
<th>C (4-jets)</th>
<th>D (5-jets)</th>
<th>E (6-jets)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$E_T^{\text{miss}}$ [GeV] &gt;</td>
<td>160</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$p_T(j_1)$ [GeV] &gt;</td>
<td>130</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$p_T(j_2)$ [GeV] &gt;</td>
<td></td>
<td>60</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$p_T(j_3)$ [GeV] &gt;</td>
<td></td>
<td></td>
<td>60</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$p_T(j_4)$ [GeV] &gt;</td>
<td></td>
<td></td>
<td></td>
<td>60</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$p_T(j_5)$ [GeV] &gt;</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>60</td>
<td></td>
</tr>
</tbody>
</table>

$\Delta\phi(j, E_T^{\text{miss}})_{\text{min}} > 0.4 \ (i = [1, 2, 3] \text{ if } p_T(j) > 40 \text{ GeV}))$ $0.4 \ (i = [1, 2, 3], 0.2 \ (p_T > 40 \text{ GeV} \text{ jets})$

$E_T^{\text{miss}} / m_{\text{eff}}(N_j) > 0.2$ $^a 0.3$ $0.4$ $0.25$ $0.25$ $0.2$ $0.15$ $0.2$ $0.25$

$m_{\text{eff}}(\text{incl.})$ [GeV] > $1000$ $1600$ $1800$ $2200$ $1200$ $2200$ $1600$ $1000$ $1200$ $1500$

(a) For SR A-medium the cut on $E_T^{\text{miss}} / m_{\text{eff}}(N_j)$ is replaced by a requirement $E_T^{\text{miss}} / \sqrt{H_T} > 15 \text{ GeV}^{1/2}$.

20.3 fb$^{-1}$ of p-p collisions at $\sqrt{s} = 8 \text{ TeV}$ analysed

transfer factors (DD, MC) to estimate SM background in the SR

ATLAS-CONF-2013-047
Inclusive Searches for Squarks and Gluinos

★ good agreement between SM prediction and data

MSUGRA/CMSSM: tanβ = 30, A₀ = -2m₀, μ > 0

ATLAS Preliminary

∫ L dt = 20.3 fb⁻¹, σ = 8 TeV

0-lepton combined

Observed limit (∓ σ_theory)

Expected limit (∓ σ_{exp})

Stau LSP

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Inclusive Searches for Squarks and Gluinos

- scenarios with higher jet multiplicity
- gluino decays via stops
- squark decays involving charginos and the heavier neutralinos

<table>
<thead>
<tr>
<th>Identifier</th>
<th>Multi-jet + flavour stream</th>
<th>Multi-jet + $M_T^2$ stream</th>
</tr>
</thead>
<tbody>
<tr>
<td>$8j50$</td>
<td>$9j50$</td>
<td>$10j50$</td>
</tr>
<tr>
<td>$7j80$</td>
<td>$8j80$</td>
<td>$9j50$</td>
</tr>
<tr>
<td>$&gt; 10j50$</td>
<td>$&lt; 2.0$</td>
<td>$&lt; 2.0$</td>
</tr>
<tr>
<td>$&gt; 2.0$</td>
<td>$&gt; 50$ GeV</td>
<td>$&gt; 80$ GeV</td>
</tr>
<tr>
<td>$&gt; 80$ GeV</td>
<td>$&gt; 50$ GeV</td>
<td></td>
</tr>
<tr>
<td>Jet count</td>
<td>$= 8$</td>
<td>$= 9$</td>
</tr>
<tr>
<td>$= 7$</td>
<td>$= 10$</td>
<td>$= 8$</td>
</tr>
<tr>
<td>$&gt; 8$</td>
<td>$&gt; 9$</td>
<td>$&gt; 10$</td>
</tr>
<tr>
<td>$&gt; 10$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$b$-jets</td>
<td>$0$</td>
<td>$1$</td>
</tr>
<tr>
<td>$(p_T &gt; 40$ GeV,$\eta &lt; 2.5$)</td>
<td>$1$</td>
<td>$2$</td>
</tr>
<tr>
<td>$0$</td>
<td>$1$</td>
<td>$2$</td>
</tr>
<tr>
<td>$1$</td>
<td>$2$</td>
<td></td>
</tr>
<tr>
<td>$&gt; 10$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$M_T^2$ [GeV]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$&gt; 4$ GeV$^{1/2}$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$E_T^{miss}/\sqrt{H_T}$</td>
<td></td>
<td>$&gt; 4$ GeV$^{1/2}$</td>
</tr>
</tbody>
</table>

20.3 fb$^{-1}$ of p-p collisions at $\sqrt{s} = 8$ TeV analysed

background estimation: DD and MC

BG model validated in CR

SUSY Searches with ATLAS – Lomonosov Conference 2013, Matthias Hamer - Georg-August-Universität Göttingen
Inclusive Searches for Squarks and Gluinos

★ good agreement between SM expectation and data

**gluino – stop (off-shell)**

**gluino – squark via gauginos**

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\[ \sigma_{\text{tot}}[\text{pb}]: pp \rightarrow \text{SUSY} \]
\[ \sqrt{S} = 8 \text{ TeV} \]

prospino2
Search for 3rd Generation Squarks

- targets scenarios with
  - direct production of stops and sbottoms
  - heavy gluinos and 1st/2nd generation squarks
  - various decays of stop/sbottom/W

- here: stop search for an exclusive decay
  \[ \bar{t} \rightarrow c \tilde{\chi}_1^0 \]

Primary vertex
- \( E_T^{\text{miss}} > 120 \text{ GeV} \)
- Jet quality requirements
  - At least one jet with \( p_T > 120 \text{ GeV} \) and \( |\eta| < 2.8 \)
- Lepton vetoes: no isolated electrons (muons) with \( p_T > 20 \text{ GeV} \) (\( p_T > 10 \text{ GeV} \))

Monojet-like selection M1

- At most three jets with \( p_T > 30 \text{ GeV} \) and \( |\eta| < 2.8 \)
- \( \Delta\phi(\text{jet}, p_T^{\text{miss}}) > 0.4 \)

Charm-tagged selection C1

- At least three jets with \( p_T > 30 \text{ GeV} \) and \( |\eta| < 2.5 \)
- \( b \)-veto for second and third jet
- \textit{medium} \( c \)-tag for fourth jet
- \( \Delta\phi(\text{jet}, p_T^{\text{miss}}) > 0.4 \)

<table>
<thead>
<tr>
<th>Minimum leading jet $p_T$ (GeV)</th>
<th>280</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum $E_T^{\text{miss}}$ (GeV)</td>
<td>220</td>
</tr>
</tbody>
</table>

ATLAS CONF-2013-068

20.3 fb⁻¹ of p-p collisions at \( \sqrt{s} = 8 \text{ TeV} \) analysed
Search for 3rd Generation Squarks

★ good agreement between SM prediction and data

ATLAS Preliminary \( \int L dt = 20.3 \text{ fb}^{-1}, \sqrt{s} = 8 \text{ TeV} \)

**Signal Region**

<table>
<thead>
<tr>
<th>Signal Region</th>
<th>M1</th>
<th>C1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observed events (20.3 fb^{-1})</td>
<td>30793</td>
<td>25</td>
</tr>
<tr>
<td>SM prediction</td>
<td>29800 ± 900</td>
<td>29 ± 7</td>
</tr>
</tbody>
</table>

**ATLAS Preliminary** \( \int L dt = 20.3 \text{ fb}^{-1}, \sqrt{s} = 8 \text{ TeV} \)

Charm-tagged + Monojet-like selection
Search for 3rd Generation Squarks

**ATLAS** Preliminary

- **Observed limits**
- **Observed limits (-1σ_{theo})**
- **Expected limits**

### Status: EPS 2013

- $L_{int} = 20 - 21 \text{ fb}^{-1} \quad s = 8 \text{ TeV}$
- $L_{int} = 4.7 \text{ fb}^{-1} \quad s = 7 \text{ TeV}$

#### $\tilde{t}_1 \rightarrow b \tilde{\chi}_1^\pm, \tilde{\chi}_1^\pm \rightarrow W^{(*)} \tilde{\chi}_1^0$

- $0L$, $\tilde{t}_1 \rightarrow t \tilde{\chi}_1^0$
- $1L$, $\tilde{t}_1 \rightarrow t \tilde{\chi}_1^0$
- $2L$, $\tilde{t}_1 \rightarrow t \tilde{\chi}_1^0$
- $2L$, $\tilde{t}_1 \rightarrow Wb \tilde{\chi}_1^0$

- $0L$, $m_{\tilde{t}_1} = m_{\tilde{\chi}_1^0} + 5 \text{ GeV}$
- $1L$, $m_{\tilde{t}_1} = m_{\tilde{\chi}_1^0}$
- $1L$, $m_{\tilde{t}_1} = 150 \text{ GeV}$
- $2L$, $m_{\tilde{t}_1} = 150 \text{ GeV}$
- $2L$, $m_{\tilde{t}_1} = m_{\tilde{\chi}_1^0} - 10 \text{ GeV}$
- $1L$, $m_{\tilde{t}_1} = 2 \times m_{\tilde{\chi}_1^0}$

### CDF 2.6 fb$^{-1}$ [1203.4171]

### SUSY Searches with ATLAS – Lomonosov Conference 2013, Matthias Hamer - Georg-August-Universität Göttingen

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$\sqrt{S} = 8 \text{ TeV}$

prospino2

$m_{\text{average}} [\text{GeV}]$
Search for Electroweak SUSY production

- targets scenarios with
  - direct production of EW gauginos and sleptons
  - heavy coloured superpartners
  - different production and decay mechanisms
  - typically leptons in the final state

- searching in final states with 2, 3 and ≥4 leptons

### 2 Leptons

<table>
<thead>
<tr>
<th>SR-$m_{T2,90}$</th>
<th>$e^+e^-$</th>
<th>$e^+\mu^-$</th>
<th>$\mu^+\mu^-$</th>
<th>all</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observed</td>
<td>15</td>
<td>19</td>
<td>19</td>
<td>53</td>
</tr>
<tr>
<td>Background total</td>
<td>16.6 ± 2.3</td>
<td>20.7 ± 3.2</td>
<td>22.4 ± 3.3</td>
<td>59.7 ± 7.3</td>
</tr>
<tr>
<td>$WW$</td>
<td>9.3 ± 1.6</td>
<td>14.1 ± 2.2</td>
<td>12.6 ± 2.0</td>
<td>36.1 ± 5.1</td>
</tr>
<tr>
<td>$ZV$ ($V = W$ or $Z$)</td>
<td>6.3 ± 1.5</td>
<td>0.8 ± 0.3</td>
<td>7.3 ± 1.7</td>
<td>14.4 ± 3.2</td>
</tr>
<tr>
<td>Top</td>
<td>0.9^{+1.1}_{-0.9}</td>
<td>5.6 ± 2.1</td>
<td>2.5 ± 1.8</td>
<td>8.9 ± 3.9</td>
</tr>
<tr>
<td>Higgs</td>
<td>0.11 ± 0.04</td>
<td>0.19 ± 0.05</td>
<td>0.08 ± 0.04</td>
<td>0.38 ± 0.08</td>
</tr>
<tr>
<td>Fake</td>
<td>0.00^{+0.18}_{-0.00}</td>
<td>0.00^{+0.14}_{-0.00}</td>
<td>0.00^{+0.15}_{-0.00}</td>
<td>0.00^{+0.28}_{-0.00}</td>
</tr>
</tbody>
</table>

**Signal expectation**

- $(m_{\tilde{t}}, m_{\tilde{\chi}^0_1}) = (191, 90)$ GeV
  - $21.6$  $0$  $21.6$  $43.2$
- $(m_{\tilde{t}}, m_{\tilde{\chi}^0_1}) = (251, 10)$ GeV
  - $12.2$  $0$  $12.5$  $24.7$
- $(m_{\tilde{t}}, m_{\tilde{\chi}^0_1}) = (350, 0)$ GeV
  - $11.7$  $16.6$  $10.5$  $38.8$
- $(m_{\tilde{t}}, m_{\tilde{\chi}^0_1}) = (425, 75)$ GeV
  - $4.3$  $6.7$  $4.4$  $15.4$

20.3 – 20.7 fb$^{-1}$ of p-p collisions at $\sqrt{s} = 8$ TeV analysed.

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**Background estimation:** DD and MC

**ATLAS-CONF-2013-035**

**ATLAS-CONF-2013-049**
Search for Electroweak SUSY production

- good agreement between SM prediction and data
- limits in simplified models with well defined mass hierarchy, gaugino mixing and branching fractions

SUSY Searches with ATLAS – Lomonosov Conference 2013, Matthias Hamer - Georg-August-Universität Göttingen
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**Searches for RPV and long-lived SUSY**

★ **RPV scenarios**
- LSP is unstable
- may decay into multilepton final states
- direct LSP production typically negligible
- consider NLSP production only
- chargino and gluino NLSP considered here

\[ \lambda_{ijk} L_i L_j \tilde{E}_k + \lambda'_{ijk} L_i Q_j D_k + \lambda''_{ijk} \tilde{U}_i \tilde{D}_j \tilde{D}_k + \kappa_i L_i H_2 \]

<table>
<thead>
<tr>
<th>SR</th>
<th>(N(\ell = e, \mu))</th>
<th>(N(\tau))</th>
<th>Z Candidate</th>
<th>(E_T^{\text{miss}} \text{[GeV]})</th>
<th>(m_{\text{eff}} \text{[GeV]})</th>
</tr>
</thead>
<tbody>
<tr>
<td>SR0noZb</td>
<td>(\geq 4)</td>
<td>(\geq 0)</td>
<td>extended veto</td>
<td>(&gt; 75)</td>
<td>or</td>
</tr>
<tr>
<td>SR1noZ</td>
<td>(= 3)</td>
<td>(\geq 1)</td>
<td>extended veto</td>
<td>(&gt; 100)</td>
<td>or</td>
</tr>
</tbody>
</table>

**background estimation DD and MC**

20.7 fb\(^{-1}\) of p-p collisions at \(\sqrt{s} = 8\) TeV analysed
Searches for RPV and long-lived SUSY

★ good agreement between SM expectation and data
→ limits set in various models
Searches for RPV and long-lived SUSY

★ AMSB scenarios
→ lightest chargino and neutralino nearly mass degenerate
→ chargino has significant lifetime
→ look for disappearing tracks

<table>
<thead>
<tr>
<th>Selection requirement</th>
<th>Observed events</th>
<th>Expected signal events (efficiency [%])</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quality requirements and trigger</td>
<td>20479553</td>
<td>1873 (8.8)</td>
</tr>
<tr>
<td>Jet cleaning</td>
<td>18627508</td>
<td>1867 (8.8)</td>
</tr>
<tr>
<td>Lepton veto</td>
<td>12485944</td>
<td>1827 (8.6)</td>
</tr>
<tr>
<td>Leading jet $p_T &gt; 90$ GeV</td>
<td>10308840</td>
<td>1571 (7.4)</td>
</tr>
<tr>
<td>$E_T^{miss} &gt; 90$ GeV</td>
<td>6113773</td>
<td>1484 (7.0)</td>
</tr>
<tr>
<td>$\Delta\phi_{min} &gt; 1.5$</td>
<td>5604087</td>
<td>1444 (6.8)</td>
</tr>
<tr>
<td>High-$p_T$ isolated track selection</td>
<td>34379</td>
<td>21.9 (0.10)</td>
</tr>
<tr>
<td>Disappearing-track selection</td>
<td>3256</td>
<td>18.4 (0.087)</td>
</tr>
</tbody>
</table>

20.3 fb⁻¹ of p-p collisions at $\sqrt{s} = 8$ TeV analysed

ATLAS-CONF-2013-069
Searches for RPV and long-lived SUSY

★ good agreement between the background expectation and data
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### SUSY Searches with ATLAS – Lomonosov Conference 2013, Matthias Hamer - Georg-August-Universität Göttingen

<table>
<thead>
<tr>
<th>Model</th>
<th>e, μ, τ, γ Jets</th>
<th>$E_{\text{T}}^{\text{miss}}$</th>
<th>$\sqrt{s}$ [TeV]</th>
<th>Mass limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>MSUGRA/CMSSM</td>
<td>2-6 jets</td>
<td>Yes</td>
<td>20.3</td>
<td>1.2 TeV</td>
</tr>
<tr>
<td>MSUGRA/CMSSM</td>
<td>3-6 jets</td>
<td>Yes</td>
<td>20.3</td>
<td>1.1 TeV</td>
</tr>
<tr>
<td>MSUGRA/CMSSM</td>
<td>7-10 jets</td>
<td>Yes</td>
<td>20.3</td>
<td>1.3 TeV</td>
</tr>
<tr>
<td>$\tilde{g} \rightarrow q\tilde{q}^0$</td>
<td>2-6 jets</td>
<td>Yes</td>
<td>20.3</td>
<td>1.18 TeV</td>
</tr>
<tr>
<td>$\tilde{g} \rightarrow q\tilde{q}^0$</td>
<td>3 jets</td>
<td>Yes</td>
<td>20.7</td>
<td>1.4 TeV</td>
</tr>
<tr>
<td>GMSB (f NLSP)</td>
<td>2-4 jets</td>
<td>Yes</td>
<td>4.7</td>
<td>1.24 TeV</td>
</tr>
<tr>
<td>GMSB (f NLSP)</td>
<td>7 jets</td>
<td>Yes</td>
<td>20.7</td>
<td>1.24 TeV</td>
</tr>
<tr>
<td>GGM (bino NLSP)</td>
<td>3 jets</td>
<td>Yes</td>
<td>20.3</td>
<td>1.45 TeV</td>
</tr>
<tr>
<td>GGM (wino NLSP)</td>
<td>0</td>
<td>Yes</td>
<td>4.8</td>
<td>619 GeV</td>
</tr>
<tr>
<td>GGM (higgsino-bino NLSP)</td>
<td>1</td>
<td>Yes</td>
<td>4.8</td>
<td>900 GeV</td>
</tr>
<tr>
<td>$\tilde{g}$</td>
<td>0-3 jets</td>
<td>Yes</td>
<td>5.8</td>
<td>690 GeV</td>
</tr>
<tr>
<td>Gravitino LSP</td>
<td>0</td>
<td>mono-jet</td>
<td>Yes</td>
<td>10.5</td>
</tr>
</tbody>
</table>

### 3'gen. squarks, sparticles direct production

<table>
<thead>
<tr>
<th>Model</th>
<th>$b_1, b_1 \rightarrow b_1, b_1$</th>
<th>$E_{\text{T}}^{\text{miss}}$</th>
<th>$\sqrt{s}$ [TeV]</th>
<th>Mass limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>$b_1, b_1 \rightarrow b_1, b_1$</td>
<td>2-6 jets</td>
<td>Yes</td>
<td>20.3</td>
<td>1.2 TeV</td>
</tr>
<tr>
<td>$b_1, b_1 \rightarrow b_1, b_1$</td>
<td>3 jets</td>
<td>Yes</td>
<td>20.7</td>
<td>1.1 TeV</td>
</tr>
<tr>
<td>$b_1, b_1 \rightarrow b_1, b_1$</td>
<td>7 jets</td>
<td>Yes</td>
<td>20.3</td>
<td>1.3 TeV</td>
</tr>
<tr>
<td>$t_1, t_1 \rightarrow Wb_1, b_1$</td>
<td>1-2 jets</td>
<td>Yes</td>
<td>4.7</td>
<td>220 GeV</td>
</tr>
<tr>
<td>$t_1, t_1 \rightarrow Wb_1, b_1$</td>
<td>3 jets</td>
<td>Yes</td>
<td>20.3</td>
<td>225-525 GeV</td>
</tr>
<tr>
<td>$t_1, t_1 \rightarrow Wb_1, b_1$</td>
<td>7 jets</td>
<td>Yes</td>
<td>20.3</td>
<td>150-580 GeV</td>
</tr>
<tr>
<td>$t_1, t_1 \rightarrow Wb_1, b_1$</td>
<td>1 jets</td>
<td>Yes</td>
<td>4.7</td>
<td>200-610 GeV</td>
</tr>
<tr>
<td>$t_1, t_1 \rightarrow Wb_1, b_1$</td>
<td>3 jets</td>
<td>Yes</td>
<td>20.3</td>
<td>320-660 GeV</td>
</tr>
<tr>
<td>$t_1, t_1 \rightarrow Wb_1, b_1$</td>
<td>1 jets</td>
<td>Yes</td>
<td>4.7</td>
<td>200 GeV</td>
</tr>
</tbody>
</table>

### EW direct

<table>
<thead>
<tr>
<th>Model</th>
<th>$\ell_1, \ell_1 \rightarrow \tilde{e} \tilde{\nu}$</th>
<th>$E_{\text{T}}^{\text{miss}}$</th>
<th>$\sqrt{s}$ [TeV]</th>
<th>Mass limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\ell_1, \ell_1 \rightarrow \tilde{e} \tilde{\nu}$</td>
<td>2-6 jets</td>
<td>Yes</td>
<td>20.3</td>
<td>100-630 GeV</td>
</tr>
<tr>
<td>$\ell_1, \ell_1 \rightarrow \tilde{e} \tilde{\nu}$</td>
<td>4 jets</td>
<td>Yes</td>
<td>20.3</td>
<td>430 GeV</td>
</tr>
<tr>
<td>$\ell_1, \ell_1 \rightarrow \tilde{e} \tilde{\nu}$</td>
<td>6 jets</td>
<td>Yes</td>
<td>20.3</td>
<td>167 GeV</td>
</tr>
</tbody>
</table>

### Long-lived particles

<table>
<thead>
<tr>
<th>Model</th>
<th>$\chi_1 \rightarrow \tilde{e}_L \tilde{\nu}$</th>
<th>$E_{\text{T}}^{\text{miss}}$</th>
<th>$\sqrt{s}$ [TeV]</th>
<th>Mass limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\chi_1 \rightarrow \tilde{e}_L \tilde{\nu}$</td>
<td>2-6 jets</td>
<td>Yes</td>
<td>20.3</td>
<td>85-315 GeV</td>
</tr>
<tr>
<td>$\chi_1 \rightarrow \tilde{e}_L \tilde{\nu}$</td>
<td>4 jets</td>
<td>Yes</td>
<td>20.3</td>
<td>125-450 GeV</td>
</tr>
<tr>
<td>$\chi_1 \rightarrow \tilde{e}_L \tilde{\nu}$</td>
<td>6 jets</td>
<td>Yes</td>
<td>20.3</td>
<td>180-330 GeV</td>
</tr>
</tbody>
</table>

### RPV

<table>
<thead>
<tr>
<th>Model</th>
<th>$\tilde{g} \rightarrow \tilde{t} \tilde{t}$</th>
<th>$E_{\text{T}}^{\text{miss}}$</th>
<th>$\sqrt{s}$ [TeV]</th>
<th>Mass limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\tilde{g} \rightarrow \tilde{t} \tilde{t}$</td>
<td>2-6 jets</td>
<td>Yes</td>
<td>20.3</td>
<td>315 GeV</td>
</tr>
<tr>
<td>$\tilde{g} \rightarrow \tilde{t} \tilde{t}$</td>
<td>3 jets</td>
<td>Yes</td>
<td>20.3</td>
<td>270 GeV</td>
</tr>
</tbody>
</table>

### Other

<table>
<thead>
<tr>
<th>Model</th>
<th>$\tilde{g} \rightarrow \tilde{t} \tilde{t}$</th>
<th>$E_{\text{T}}^{\text{miss}}$</th>
<th>$\sqrt{s}$ [TeV]</th>
<th>Mass limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\tilde{g} \rightarrow \tilde{t} \tilde{t}$</td>
<td>2-6 jets</td>
<td>Yes</td>
<td>20.3</td>
<td>270 GeV</td>
</tr>
</tbody>
</table>

### Mass scale [TeV]

- $\sqrt{s} = 7$ TeV full data
- $\sqrt{s} = 8$ TeV partial data
- $\sqrt{s} = 8$ TeV full data

*Only a selection of the available mass limits on new states or phenomena is shown. All limits quoted are observed minus 1$\sigma$ theoretical signal cross section uncertainty.*
Summary

★ p-p collision data taken during three years of LHC operation has been/is being analysed

★ no evidence for the existence of superpartners has been found

★ superpartners with masses of \( O(1) \) TeV ruled out in many models

★ standard scenarios have been strongly constrained by the results → difficult to sustain these scenarios ('naturalness')

★ wide variety of simplified models derived from more complicated models are being studied

★ more results to come
Thank you!
Extra Material
Inclusive Searches for Squarks and Gluinos

★ good agreement between SM prediction and data

SUSY Searches with ATLAS – Lomonosov Conference 2013, Matthias Hamer - Georg-August-Universität Göttingen
Inclusive Searches for Squarks and Gluinos

observe no excess in signal regions → constrain models

simplified model: gluino NLSP

simplified model: squark NLSP

ATLAS-CONF-2013-047
**Search for 3rd Generation Squarks**

★ targets scenarios with
  → direct production of stops and sbottoms
  → heavy gluinos and 1\(^{st}\)/2\(^{nd}\) generation squarks
  → various decays of stop/sbottom/W

★ here: stop search for 2 exclusive decays

1) \( t \rightarrow b \chi_1^+ \)

   SR: 2 OS leptons (pT < 60 GeV)
   2 b-jets
   \( m_{T2} < 90 \text{ GeV} \)
   \( m_{b-Jet} > 160 \text{ GeV} \)

2) \( \bar{t} \rightarrow t \chi_1^0 \)

   SR: 2 OS leptons
   \( \geq 2 \) jets (leading jet: pT > 50 GeV)
   \( m_{eff} > 300 \text{ GeV} \)

   BDT to define 11 SR

\( m_{T2}(p_T^1, p_T^2, q_T) = \min_{q_T^1 + q_T^2 = q_T} \left\{ \max\left[ m_T(p_T^1, q_T^1), m_T(p_T^2, q_T^2) \right] \right\} \)

<table>
<thead>
<tr>
<th>Training Sample ((m(t\bar{t}), m(\tilde{\chi}_1^0))) [GeV]</th>
</tr>
</thead>
<tbody>
<tr>
<td>SR(^{DF})_1</td>
</tr>
<tr>
<td>SR(^{DF})_2</td>
</tr>
<tr>
<td>SR(^{DF})_3</td>
</tr>
<tr>
<td>SR(^{DF})_4</td>
</tr>
<tr>
<td>SR(^{DF})_5</td>
</tr>
<tr>
<td>SR(^{DF})_6</td>
</tr>
<tr>
<td>SR(^{DF})_7</td>
</tr>
<tr>
<td>SR(^{SF})_1</td>
</tr>
<tr>
<td>SR(^{SF})_2</td>
</tr>
<tr>
<td>SR(^{SF})_3</td>
</tr>
<tr>
<td>SR(^{SF})_4</td>
</tr>
</tbody>
</table>

20.3 fb\(^{-1}\) of p-p collisions at \(\sqrt{s} = 8\) TeV analysed

**ATLAS-CONF-2013-065**
Search for 3rd Generation Squarks

★ good agreement between SM prediction and data
Search for 3rd Generation Squarks

★ limits are set in simplified models

combination with an analysis requiring $m_{T2} > 90$ GeV
Search for Electroweak SUSY production

★ targets scenarios with
   → direct production of EW gauginos and sleptons
   → heavy coloured superpartners
   → different production and decay mechanisms
   → typically leptons in the final state

★ here: search for production of neutralino pairs

SR: ≥ 4 leptons

MET > 50 GeV

veto Z → 2,3,4 l candidates

20.7 fb\(^{-1}\) of p-p collisions at \(\sqrt{s} = 8\) TeV analysed

<table>
<thead>
<tr>
<th>Sample</th>
<th>VR0noZ</th>
<th>VR0Z</th>
</tr>
</thead>
<tbody>
<tr>
<td>ZZ</td>
<td>7.2 ± 3.6</td>
<td>167 ± 38</td>
</tr>
<tr>
<td>ZWW</td>
<td>0.031 ± 0.031</td>
<td>0.35 ± 0.35</td>
</tr>
<tr>
<td>t\bar{t}Z</td>
<td>0.17 ± 0.05</td>
<td>1.5 ± 0.7</td>
</tr>
<tr>
<td>Higgs</td>
<td>0.17 ± 0.05</td>
<td>4.5 ± 0.9</td>
</tr>
<tr>
<td>Irreducible Bkg.</td>
<td>7.4 ± 3.6</td>
<td>173 ± 39</td>
</tr>
<tr>
<td>Reducible Bkg.</td>
<td>0.3^{+0.7}_{-0.3}</td>
<td>2.0^{+2.6}_{-2.0}</td>
</tr>
<tr>
<td>Total Bkg.</td>
<td>7.7 ± 3.4</td>
<td>175 ± 37</td>
</tr>
<tr>
<td>Data</td>
<td>3</td>
<td>201</td>
</tr>
</tbody>
</table>

background estimation: DD and MC
validated using control regions

ATLAS-CONF-2013-036
Search for Electroweak SUSY production

★ good agreement between SM prediction and data

<table>
<thead>
<tr>
<th>Sample</th>
<th>SR0noZa</th>
</tr>
</thead>
<tbody>
<tr>
<td>ZZ</td>
<td>0.6 ± 0.5</td>
</tr>
<tr>
<td>ZWW</td>
<td>0.12 ± 0.12</td>
</tr>
<tr>
<td>t\bar{t}Z</td>
<td>0.73 ± 0.34</td>
</tr>
<tr>
<td>Higgs</td>
<td>0.26 ± 0.07</td>
</tr>
<tr>
<td>Irreducible Bkg.</td>
<td>1.7 ± 0.8</td>
</tr>
<tr>
<td>Reducible Bkg.</td>
<td>0.0^{+0.16}_{-0}</td>
</tr>
<tr>
<td>Total Bkg.</td>
<td>1.7 ± 0.8</td>
</tr>
</tbody>
</table>

\[ \int L \, dt = 20.7 \text{fb}^{-1}, \, \sqrt{s} = 8\text{TeV} \]
Search for Electroweak SUSY production

★ limits are set in simplified models

All limits at 95% CL

ATLAS Preliminary

$\int L dt = 20.7 \text{ fb}^{-1}, \sqrt{s}=8 \text{ TeV}$

$m_{\tilde{\chi}_2^0} - m_{\tilde{\chi}_1^0} = 5 \text{ GeV}$

$m_{\tilde{\chi}_2^0} - m_{\tilde{\chi}_1^0} = 80 \text{ GeV}$

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

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

ATLAS-CONF-2013-036
Search for Electroweak SUSY production

★ final states with two and three leptons

**ATLAS Preliminary**

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

- Observed limit (±1 \(\sigma_{\text{SUSY}}\))
- Expected limit (±1 \(\sigma_{\text{exp}}\))
- LEP \(\tilde{\mu}_{\text{R}}\) excluded

All limits at 95% CL

**ATLAS Preliminary**

\[
\int L \, dt = 20.7 \, fb^{-1}, \, \sqrt{s} = 8 \, TeV
\]

- Observed limit (±1 \(\sigma_{\text{SUSY}}\))
- Expected limit (±1 \(\sigma_{\text{exp}}\))
- ATLAS 13.0 \(fb^{-1}\), \(\sqrt{s} = 8 \, TeV\)

All limits at 95% CL

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**ATLAS-CONF-2013-049**

**ATLAS-CONF-2013-035**