Searches for third generation squarks with the ATLAS detector

Martin White
Outline

- Supersymmetric particle production was not an early LHC discovery

  - if all squarks are similar in mass, this raises limits on the squark masses
  - a priori, this is by no means a fair assumption however
  - SUSY with a light third generation is well motivated, but dedicated searches are required

- ATLAS has performed a variety of searches sensitive to third generation squark production

  - direct sbottom production (2 fb⁻¹)
  - gluino mediated stop/sbottom production (5 fb⁻¹)
  - Direct stop pair production
    In GMSB scenario (2fb⁻¹)

- Several searches covering:
  - different final states
  - different mass ranges
  - direct stop production (5 fb⁻¹)

- Main focus of the next 15 minutes
  - multijet search (5 fb⁻¹) (arxiv:1206.1760)
  - Same sign dilepton (2 fb⁻¹)(Phys. Rev. Lett. 108, 241802)
  - 0/1 lepton + 1/2 b (2 fb⁻¹) (Phys. Rev. D 85, 112006)
Direct stop production

- The stop cross section falls rapidly with increasing stop mass
  - dedicated searches must concentrate on reducing the large top background
  - stop pair production cross-section is smaller due to differing spin

- There is a rich variety of decay modes, though the final states are often similar

NEW ATLAS 5 fb\(^{-1}\) results (direct stop)

- Stop $\rightarrow$ b chargino (for m (stop) < 200 GeV)
  - very light stop search (2 leptons)
  - m(stop) $\sim$ m(top) (1 and 2 lepton(s))

- Stop $\rightarrow$ t neutralino (for m (stop) > 200 GeV)
  - both tops decay hadronically (0 lepton)
  - one top decays leptonically (1 lepton)
  - both tops decay leptonically (2 leptons)

- Let's review the latest ATLAS results in order of increasing stop mass...
Light stop analysis

- Search for stops with $m(\tilde{t}) \ll m(\tilde{t}_1) \gg m(\tilde{\chi}_1^{\pm})$

\[
m(t) > m(\tilde{t}_1) > m(\tilde{\chi}_1^{\pm})
\]
\[
\tilde{t}_1 \rightarrow b\tilde{\chi}_1^{\pm}
\]
\[
\tilde{\chi}_1^{\pm} \rightarrow W(\ast)\tilde{\chi}_1^0
\]

- Look for:
  - two low $p_T$ leptons, veto on leptons with high $p_T$
  - no $b$ jet requirement

- Background estimation:
  - semi-data-driven estimate using top and $Z/\gamma^*$ control regions

- Dominant systematics: jet energy scale, jet energy resolution, theory errors on top estimate

<table>
<thead>
<tr>
<th></th>
<th>$ee$</th>
<th>$e\mu$</th>
<th>$\mu\mu$</th>
<th>all</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Data</td>
<td>$61 \pm 6 \pm 6$</td>
<td>$189 \pm 8 \pm 21$</td>
<td>$190 \pm 19 \pm 31$</td>
<td>$440 \pm 21 \pm 43$</td>
</tr>
<tr>
<td>Data</td>
<td>48</td>
<td>188</td>
<td>195</td>
<td>431</td>
</tr>
<tr>
<td>$\sigma_{vis}$ (exp. limit) [fb]</td>
<td>4.9</td>
<td>11.1</td>
<td>16.2</td>
<td>22.0</td>
</tr>
<tr>
<td>$\sigma_{vis}$ (obs. limit) [fb]</td>
<td>3.3</td>
<td>10.9</td>
<td>16.9</td>
<td>21.0</td>
</tr>
</tbody>
</table>

$ATLAS$ Preliminary

$\text{LD} = 4.7 \text{ fb}^{-1}$, $\sqrt{s} = 7 \text{ TeV}$
m(stop) \sim m(top) search

- 1 and 2 lepton analysis looking for stop \rightarrow b \text{ chargino}, with m(stop) \sim m(top)

- Use b tagging, place upper cut on a new variable $\sqrt{s}_{\text{min}}^{(\text{sub})}$

- Main backgrounds are top, W (1 lepton) and Z (2 lepton)

\[
\text{ATLAS Preliminary}
\]

\begin{align*}
\text{Observed limit (} & 1 \sigma_{\text{SUSY}}) \\
\text{Expected limit (} & 1 \sigma_{\text{theory}}) \\
\text{All limits at 95\% CL_{\nu}}
\end{align*}

\begin{align*}
L \text{ dt} = 4.7 \text{ fb}^{-1}, t\bar{s} = 7 \text{ TeV} \\
\text{Leptons + b-jets combined}
\end{align*}

\begin{align*}
\tilde{t}_1 \rightarrow b + \tilde{\chi}_1^+ \text{ production, } & \\
\tilde{t}_1 \rightarrow b + \tilde{\tau}_1 \text{ forbidden}
\end{align*}

\begin{tabular}{|c|c|c|c|}
\hline
\text{Process} & 1LSR & 2LSR1 & 2LSR2 \\
\hline
\text{Top} & 24 \pm 3 \pm 5 & 89 \pm 6 \pm 10 & 36 \pm 2 \pm 5 \\
\text{W+jets} & 6 \pm 1 \pm 2 & n/a & n/a \\
\text{Z+jets} & 0.5 \pm 0.3 \pm 0.3 & 11 \pm 4 \pm 3 & 3 \pm 1 \pm 1 \\
\text{Fakes} & 7 \pm 1 \pm 2 & 12 \pm 5 \pm 11 & 6 \pm 4 \pm 4 \\
\text{Others} & 0.3 \pm 0.1 \pm 0.1 & 2.7 \pm 0.9 \pm 0.7 & 0.9 \pm 0.2 \pm 0.5 \\
\hline
\text{Total SM} & 38 \pm 3 \pm 7 & 115 \pm 8 \pm 15 & 46 \pm 4 \pm 7 \\
\text{Data} & 50 & 123 & 47 \\
\text{m}_{\tilde{t}_1} = 170 \text{ GeV, } m_{\tilde{\chi}_1^0} = 70 \text{ GeV} & 30 \pm 4 \pm 10 & 70 \pm 7 \pm 9 & 44 \pm 5 \pm 7 \\
\text{m}_{\tilde{t}_1} = 180 \text{ GeV, } m_{\tilde{\chi}_1^0} = 20 \text{ GeV} & 18 \pm 3 \pm 5 & 53 \pm 5 \pm 5 & 37 \pm 4 \pm 6 \\
\sigma_{\text{vis}} \text{ (exp.) [fb]} & 4.2 & 9.7 & 5.3 \\
\sigma_{\text{vis}} \text{ (obs.) [fb]} & 6.6 & 11 & 5.4 \\
\hline
\end{tabular}

\text{ATLAS-CONF-2012-070}
2 lepton search

- Search for stops decaying to top quark, both tops decay leptonically
  - look for either same flavour (SF) or opposite flavour (OF) leptons

- Dilepton final state, $m_{T2}$ used to suppress background

<table>
<thead>
<tr>
<th></th>
<th>SF</th>
<th>DF</th>
</tr>
</thead>
<tbody>
<tr>
<td>$Z/\gamma^*+\text{jets}$</td>
<td>1.2 ± 0.5</td>
<td>-</td>
</tr>
<tr>
<td>($Z/\gamma^*+\text{jets}$ scale factor)</td>
<td>(1.27)</td>
<td>-</td>
</tr>
<tr>
<td>$t\bar{t}$</td>
<td>0.23 ± 0.23</td>
<td>0.4 ± 0.3</td>
</tr>
<tr>
<td>($t\bar{t}$ scale factor)</td>
<td>(1.21)</td>
<td>(1.10)</td>
</tr>
<tr>
<td>$t\bar{t}W + t\bar{t}Z$</td>
<td>0.11 ± 0.07</td>
<td>0.19 ± 0.12</td>
</tr>
<tr>
<td>WW</td>
<td>0.01 ± 0.02</td>
<td>0.19 ± 0.18</td>
</tr>
<tr>
<td>WZ + ZZ</td>
<td>0.05 ± 0.05</td>
<td>0.03 ± 0.03</td>
</tr>
<tr>
<td>Wt</td>
<td>0.00 ± 0.00</td>
<td>0.10 ± 0.18</td>
</tr>
<tr>
<td>Fake leptons</td>
<td>0.00 ± 0.00</td>
<td>0.00 ± 0.00</td>
</tr>
<tr>
<td>Total SM</td>
<td>1.6 ± 0.6</td>
<td>0.9 ± 0.6</td>
</tr>
<tr>
<td>Signal, $m(t_1) = 300$ GeV, $m(\tilde{\chi}_1^0) = 50$ GeV</td>
<td>2.15</td>
<td>3.73</td>
</tr>
<tr>
<td>Signal, $m(T) = 450$ GeV, $m(A_0) = 100$ GeV</td>
<td>3.10</td>
<td>5.78</td>
</tr>
<tr>
<td>Observed</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>95% CL limit on $\sigma_{\text{obs}}^{t_1\tilde{\chi}}$</td>
<td>0.86</td>
<td>1.08</td>
</tr>
<tr>
<td>95% CL limit on $\sigma_{\text{vis}}^{t_1\tilde{\chi}}$</td>
<td>0.89</td>
<td>0.79</td>
</tr>
</tbody>
</table>

$\tilde{t}_1$ production, $\tilde{t}_1 \rightarrow \tilde{\chi}_1^0 t$

- $2$ leptons DF+SF

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Martin White

University of Melbourne
1 lepton search

- Search for stops decaying to top quark, one top decays leptonically

<table>
<thead>
<tr>
<th>Requirement</th>
<th>SR A</th>
<th>SR B</th>
<th>SR C</th>
<th>SR D</th>
<th>SR E</th>
</tr>
</thead>
<tbody>
<tr>
<td>$E_T^{\text{miss}}$ [GeV] $&gt;$</td>
<td>150</td>
<td>150</td>
<td>150</td>
<td>225</td>
<td>275</td>
</tr>
<tr>
<td>$E_T^{\text{miss}}/\sqrt{H_T}$ [GeV$^{1/2}$] $&gt;$</td>
<td>7</td>
<td>9</td>
<td>11</td>
<td>11</td>
<td>11</td>
</tr>
<tr>
<td>$m_T$ [GeV] $&gt;$</td>
<td>120</td>
<td>120</td>
<td>120</td>
<td>130</td>
<td>140</td>
</tr>
</tbody>
</table>

- Main backgrounds estimated using dedicated control regions
  - single leptonic ttbar, dileptonic ttbar and $W$+jets
  - simultaneous fit performed to all three control regions, plus one signal region at a time

- Main uncertainties are top theory uncertainties, JES, JER and $b$-tagging uncertainties
Exclude a wide range of stop masses

<table>
<thead>
<tr>
<th>Regions</th>
<th>SR A</th>
<th>SR B</th>
<th>SR C</th>
<th>SR D</th>
<th>SR E</th>
<th>2-lep TR</th>
<th>1-lep TR</th>
<th>1-lep WR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total background</td>
<td>42 ± 6</td>
<td>31 ± 4</td>
<td>13 ± 2</td>
<td>6.4 ± 1.4</td>
<td>1.8 ± 0.7</td>
<td>118 ± 10</td>
<td>421 ± 20</td>
<td>228 ± 15</td>
</tr>
<tr>
<td>Signal benchmark 1 (2)</td>
<td>25.6 (8.8)</td>
<td>23.0 (8.1)</td>
<td>17.5 (6.9)</td>
<td>13.5 (6.2)</td>
<td>7.1 (4.5)</td>
<td>1.7 (0.6)</td>
<td>2.3 (0.6)</td>
<td>0.4 (0.1)</td>
</tr>
<tr>
<td>Observed events</td>
<td>38</td>
<td>25</td>
<td>15</td>
<td>8</td>
<td>5</td>
<td>118</td>
<td>421</td>
<td>228</td>
</tr>
<tr>
<td>$p_0$-values</td>
<td>0.5</td>
<td>0.5</td>
<td>0.32</td>
<td>0.24</td>
<td>0.015</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Obs. (exp.) $N_{\text{beyond-SM}}$</td>
<td>15.1 (17.2)</td>
<td>10.1 (13.8)</td>
<td>10.8 (9.2)</td>
<td>8.4 (7.0)</td>
<td>8.2 (4.6)</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
0 lepton search

- Search for stops decaying to top quark, both tops decay hadronically
  - expect 6 high $p_T$ jets
  - kinematic reconstruction of both tops is possible (no missing momentum)

<table>
<thead>
<tr>
<th>Selection Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 tight $b$-tagged jet OR 2 loose $b$-tagged jets</td>
</tr>
<tr>
<td>$E_{T,\text{miss,track}} &gt; 30$ GeV and $</td>
</tr>
<tr>
<td>$\min</td>
</tr>
<tr>
<td>$80$ GeV $&lt; m_{jjj}, m_{jjj} &lt; 270$ GeV</td>
</tr>
<tr>
<td>Veto events with a $\tau$ candidate based on $m_T(\tau \text{ candidate}, E_{T,\text{miss}})$</td>
</tr>
<tr>
<td>Events with 1 tight $b$-tagged jet: $\min m_T(\text{jet}^{0-3}, E_{T,\text{miss}}) &gt; 175$ GeV</td>
</tr>
<tr>
<td>Events with 2 loose $b$-tagged jets: $m_T(b_{\min[\Delta\phi(b, E_{T,\text{miss}})]}, E_{T,\text{miss}}) &gt; 175$ GeV</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Signal Region I</th>
<th>Signal Region II</th>
</tr>
</thead>
<tbody>
<tr>
<td>$E_{T,\text{miss}} &gt; 150$ GeV</td>
<td>$E_{T,\text{miss}} &gt; 260$ GeV</td>
</tr>
</tbody>
</table>

- Top background estimated using CR
- SM theory, jet energy scale and jet energy resolution are dominant uncertainties
0 lepton search: Results

**ATLAS Preliminary**

- $t\bar{t}$
- Single Top
- $V (V) + \text{jets}$
- $t\bar{t} + V$
- Bkg Syst Error
- SM Exp. + $(m_{\tilde{t}}, m_{\tilde{\chi}_1^0}) = (400,1)$ GeV
- Data 2011

\[
\int L dt = 4.7 \, \text{fb}^{-1}, \sqrt{s} = 7 \text{ TeV}
\]

---

<table>
<thead>
<tr>
<th>$E_T^{\text{miss}}$</th>
<th>SRA</th>
<th>SRB</th>
</tr>
</thead>
<tbody>
<tr>
<td>$&gt; 150 \text{ GeV}$</td>
<td>$9.2 \pm 2.7$</td>
<td>$2.32 \pm 0.61$</td>
</tr>
<tr>
<td>$&gt; 260 \text{ GeV}$</td>
<td>$0.8 \pm 0.2$</td>
<td>$0.39 \pm 0.12$</td>
</tr>
</tbody>
</table>

**SUSY $(m_{\tilde{t}}, m_{\tilde{\chi}_1^0}) = (400,1)$ GeV**
- $t\bar{t}$
- $t\bar{t} + W/Z$
- Single top
- $Z + \text{jets}$
- $W + \text{jets}$
- Multi-jets
- Total SM
- Data (observed)

- $14.8 \pm 4.0$
- $8.9 \pm 3.1$
- $16$
- $4$

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**ATLAS Preliminary**

- $\tilde{t}\tilde{t}$ production, $\tilde{t} \rightarrow t + \tilde{\chi}_1^0$
- $\int L dt = 4.7 \, \text{fb}^{-1}, \sqrt{s} = 7 \text{ TeV}$
- All limits at 95% CL$_{\text{susy}}$

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**ATLAS-CONF-2012-074**
All exclusion limits on one plot

\( \tilde{t}\tilde{t} \) production:  
\[ \tilde{t}_1 \to b+\tilde{\chi}_1^\pm, \tilde{\chi}_1^\pm \to W^{(*)}+\tilde{\chi}_1^0 \quad (BR=1, m_{\tilde{t}_1} < 200 \text{ GeV}) \]
\[ \tilde{t}_1 \to t+\tilde{\chi}_1^0 \quad (BR=1, m_{\tilde{t}_1} > 200 \text{ GeV}) \]

\[ \int L \, dt = 4.7 \text{ fb}^{-1} \quad \sqrt{s}=7 \text{ TeV} \]

All limits at 95\% CL_{s}

**ATLAS** Preliminary

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**Observed limits (nominal)**

**Expected limits (nominal)**

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**Observed limits (-1\sigma_{SUSY}^{\text{theory}})**

---

**Expected limits (nominal)**

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**2-lepton (m_{\tilde{t}_1} = 106 \text{ GeV})**

**1/2-leptons + b-jets (m_{\tilde{t}_1} = 106 \text{ GeV})**

**1/2-leptons + b-jets (m_{\tilde{t}_1} = 2 \times m_{\tilde{\chi}_1^0})**

**0-lepton**

**1-lepton**

**2-lepton**

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**Status:** ICHEP 2012

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**Martin White**

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**University of Melbourne**
Gluino mediated stop/sbottom production

- Search for gluino mediated stop/sbottom production in the 0 lepton channel with 5 fb\(^{-1}\) of ATLAS data

<table>
<thead>
<tr>
<th>SR</th>
<th>(N_J)</th>
<th>(E_T^{\text{miss}})</th>
<th>(m_{\text{eff}})</th>
<th>(b)-tag OP</th>
</tr>
</thead>
<tbody>
<tr>
<td>SR4-L</td>
<td>(\geq 4j)</td>
<td>&gt;160 GeV</td>
<td>&gt;500 GeV</td>
<td>60%</td>
</tr>
<tr>
<td>SR4-M</td>
<td>(\geq 4j)</td>
<td>&gt;160 GeV</td>
<td>&gt;700 GeV</td>
<td>60%</td>
</tr>
<tr>
<td>SR4-T</td>
<td>(\geq 4j)</td>
<td>&gt;160 GeV</td>
<td>&gt;900 GeV</td>
<td>70%</td>
</tr>
<tr>
<td>SR6-L</td>
<td>(\geq 6j)</td>
<td>&gt;160 GeV</td>
<td>&gt;700 GeV</td>
<td>70%</td>
</tr>
<tr>
<td>SR6-T</td>
<td>(\geq 6j)</td>
<td>&gt;200 GeV</td>
<td>&gt;900 GeV</td>
<td>75%</td>
</tr>
</tbody>
</table>

- Multi-b jet final states enhance the sensitivity

- Various signal regions are optimised for a variety of pMSSM scenarios:
  - models with both stop (or sbottom) production and gluino production
  - models with the gluino lighter than all squarks, with gluino pair production only

ATLAS-CONF-2012-058
• No evidence for BSM physics!

• 95% confidence limits are set using the $C_{LS}$ prescription

<table>
<thead>
<tr>
<th>SR</th>
<th>$tt^\pm +jets$ (MC)</th>
<th>others</th>
<th>SM</th>
<th>data</th>
</tr>
</thead>
<tbody>
<tr>
<td>SR4-L</td>
<td>$33.3 \pm 7.9$</td>
<td>$11.1 \pm 4.9$</td>
<td>$44.4 \pm 10.0$</td>
<td>$45$</td>
</tr>
<tr>
<td></td>
<td>($32.6 \pm 15.4$)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SR4-M</td>
<td>$16.4 \pm 4.1$</td>
<td>$6.6 \pm 2.9$</td>
<td>$23.0 \pm 5.4$</td>
<td>$14$</td>
</tr>
<tr>
<td></td>
<td>($16.1 \pm 8.4$)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SR4-T</td>
<td>$9.7 \pm 2.1$</td>
<td>$3.8 \pm 1.6$</td>
<td>$13.3 \pm 2.6$</td>
<td>$10$</td>
</tr>
<tr>
<td></td>
<td>($11.4 \pm 5.4$)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SR6-L</td>
<td>$10.3 \pm 3.3$</td>
<td>$2.4 \pm 1.4$</td>
<td>$12.7 \pm 3.6$</td>
<td>$12$</td>
</tr>
<tr>
<td></td>
<td>($10.0 \pm 6.2$)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SR6-T</td>
<td>$8.3 \pm 2.4$</td>
<td>$1.6 \pm 1.1$</td>
<td>$9.9 \pm 2.6$</td>
<td>$8$</td>
</tr>
<tr>
<td></td>
<td>($7.9 \pm 5.3$)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
A variety of analyses targeting third generation squark production have been presented

- most use 5 fb^{-1} of ATLAS data

No analysis has shown evidence for BSM physics

- further work to probe the remaining corners of phase space is ongoing

Analyses are now turning their attention to the 2012 8 TeV data

- much more to come!
Backup
Light stop analysis cuts

- Search for stops with \(m(\tilde{t}) \ll m(t) \ll m(\tilde{\chi}_1^\pm)\)

\[
m(t) > m(\tilde{t}_1) > m(\tilde{\chi}_1^\pm)
\]

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

\[
\tilde{\chi}_1^\pm \rightarrow W^{(*)}\tilde{\chi}_1^0
\]

- Assume top decays to a \(b\) and chargino with BR 100%
- Chargino decays leptonically through off-shell \(W\)
- Expect: Soft \(b\) jets (not tagged), soft leptons, low missing \(E_T\)

- Background estimation:
  - semi-data-driven estimate using top and \(Z/\gamma^*\) control regions
  - multijet contribution taken from data using a template fitting method

- Dominant systematics: jet energy scale, jet energy resolution, theory errors on top estimate

<table>
<thead>
<tr>
<th>Requirement</th>
<th>(ee) channel</th>
<th>(e\mu) channel</th>
<th>(\mu\mu) channel</th>
</tr>
</thead>
<tbody>
<tr>
<td>lepton (p_T)</td>
<td>(&gt; 17) GeV</td>
<td>(&gt; 17) GeV (12) GeV for (e(\mu))</td>
<td>(&gt; 12) GeV</td>
</tr>
<tr>
<td>highest lepton (p_T)</td>
<td>(&lt; 30) GeV</td>
<td>(&lt; 30) GeV</td>
<td>(&lt; 30) GeV</td>
</tr>
<tr>
<td>(m_\parallel)</td>
<td>(&gt; 20) GeV and Z veto</td>
<td>(&gt; 20) GeV</td>
<td>(&gt; 20) GeV and Z veto</td>
</tr>
<tr>
<td>(\geq 1) jet, (p_T &gt; 25) GeV</td>
<td>(\geq 1) jet, (p_T &gt; 25) GeV</td>
<td>(\geq 1) jet, (p_T &gt; 25) GeV</td>
<td></td>
</tr>
<tr>
<td>(\geq 1) jet, (p_T &gt; 25) GeV</td>
<td>(&gt; 20) GeV</td>
<td>(&gt; 20) GeV</td>
<td></td>
</tr>
<tr>
<td>(\geq 1) jet, (p_T &gt; 25) GeV</td>
<td>(&gt; 20) GeV</td>
<td>(&gt; 20) GeV</td>
<td></td>
</tr>
<tr>
<td>(\geq 1) jet, (p_T &gt; 25) GeV</td>
<td>(&gt; 7.5) GeV(^{1/2})</td>
<td>(&gt; 7.5) GeV(^{1/2})</td>
<td></td>
</tr>
<tr>
<td>(E_T^{miss})</td>
<td>(&gt; 7.5) GeV(^{1/2})</td>
<td>(&gt; 7.5) GeV(^{1/2})</td>
<td>(&gt; 7.5) GeV(^{1/2})</td>
</tr>
<tr>
<td>(E_T^{miss, sig})</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Light stop search: results and interpretation

- Observation is consistent with SM background
- 95% confidence limit is set in the stop-neutralino mass plane, assuming a fixed chargino mass (106 GeV), using the CL$_s$ prescription
- The results extend the previous limit set by CDF
- Particularly interesting for MSSM electroweak baryogenesis scenarios...

<table>
<thead>
<tr>
<th></th>
<th>$ee$</th>
<th>$e\mu$</th>
<th>$\mu\mu$</th>
<th>all</th>
</tr>
</thead>
<tbody>
<tr>
<td>$t\bar{t}$</td>
<td>$44 \pm 4 \pm 6$</td>
<td>$139 \pm 7 \pm 23$</td>
<td>$111 \pm 8 \pm 10$</td>
<td>$293 \pm 12 \pm 34$</td>
</tr>
<tr>
<td>$Z/\gamma^*+jets$</td>
<td>$5 \pm 1 \pm 2$</td>
<td>$23 \pm 2 \pm 8$</td>
<td>$48 \pm 16 \pm 27$</td>
<td>$76 \pm 16 \pm 27$</td>
</tr>
<tr>
<td>Single top</td>
<td>$3 \pm 0.5 \pm 1$</td>
<td>$12 \pm 1 \pm 2$</td>
<td>$12 \pm 1 \pm 2$</td>
<td>$28 \pm 2 \pm 5$</td>
</tr>
<tr>
<td>$W+Jets$</td>
<td>$4 \pm 3 \pm 4$</td>
<td>$3 \pm 1 \pm 2$</td>
<td>$15 \pm 9 \pm 3$</td>
<td>$23 \pm 9 \pm 8$</td>
</tr>
<tr>
<td>Diboson</td>
<td>$4 \pm 0.4 \pm 0.5$</td>
<td>$9 \pm 0.7 \pm 2$</td>
<td>$10 \pm 0.7 \pm 1$</td>
<td>$22 \pm 1 \pm 3$</td>
</tr>
<tr>
<td>QCD multijet</td>
<td>$2.9^{+3.2}_{-2.9} \pm 2.2$</td>
<td>$2.0 \pm 1.4 \pm 0.3$</td>
<td>$3.0 \pm 2.8 \pm 0.3$</td>
<td>$8.0 \pm 3.7 \pm 2.3$</td>
</tr>
</tbody>
</table>

| Total          | $62 \pm 6 \pm 6$    | $188 \pm 8 \pm 21$ | $199 \pm 21 \pm 31$ | $450 \pm 23 \pm 44$ |
| Data           | $48$               | $188$           | $195$          | $431$          |
| $\sigma_{\text{vis}}$ (exp.) [fb] | $4.9$           | $11.3$          | $16.9$         | $22.8$         |
| $\sigma_{\text{vis}}$ (obs.) [fb] | $3.4$           | $11.3$          | $16.3$         | $19.8$         |
| $p_0$          | $0.89$             | $0.52$          | $0.55$         | $0.64$         |
| $m(t,\tilde{\chi}_1^0) = (112,55) \text{ GeV}$ | $44.1 \pm 4.8$ | $137 \pm 8$ | $140 \pm 8$ | $322 \pm 13$ |
| $m(t,\tilde{\chi}_1^0) = (160,55) \text{ GeV}$ | $8.8 \pm 1.5$ | $31.4 \pm 2.7$ | $36.5 \pm 2.9$ | $76.6 \pm 4.3$ |
m(stop) \sim m(top) \text{ search}

- 1 and 2 lepton analysis looking for stop \rightarrow b \text{ chargino}, with m(stop) \sim m(top)

- Use b tagging, and a new variable $\sqrt{s}_{\text{min}}^{(\text{sub})}$

- Two variables are used to reduce the top background

$m_{\text{had}}^t$: Invariant mass of hadronic top decay products
Generally smaller for stop events

$\sqrt{s}_{\text{min}}^{(\text{sub})}$: Minimum mass compatible with “subsystem” of top/stop decay products (see backup)
arXiv:1006.0653
Observation is consistent with SM background in all channels.

95% confidence limits are placed on a variety of mass hypotheses using the $\text{CL}_s$ prescription.
Florida Variable

- Minimum mass compatible with subsystem
  - [link](http://arxiv.org/abs/1006.0653v1)
- Subsystem defined from assuming $t\bar{t}$ decay products
  - $M = 0$ due to neutrinos
  - $\sqrt{s_{\text{min}}}^{(\text{sub})}$ expected to peak at $\sim m(t\bar{t}) = 2m(t)$

$$
\sqrt{s_{\text{min}}}^{(\text{sub})} (M) = \left\{ \left( \sqrt{M^2_{(\text{sub})}} + p^2_{T(\text{sub})} + \sqrt{M^2 + P_T^2} \right)^2 - \left( P_T T(\text{sub}) + P_T \right)^2 \right\}^{\frac{1}{2}}
$$
Two final states are considered

1 lepton selection

- One signal electron (muon), $p_T > 25$ (20) GeV
- $\geq 4$ jets with $p_T > 20$ GeV, two light, two b tagged
- $E_T^{miss} > 40$ GeV
- $m_T(l, E_T^{miss}) > 30$ GeV
- $m_{t\ had} < \mu - 0.5\sigma$ (from Gaussian fit to top mass)
- $\sqrt{s_{\ min}}^{(sub)} < 250$ GeV

2 lepton selection

- 2 signal leptons:
  - $ee$: $p_T > 25, 20$ GeV
  - $\mu\mu$: $p_T > 20, 10$ GeV
  - $e\mu$: $p_T(e) > 25$ or $p_T(\mu) > 20$ GeV
- $\geq 2$ jets with $p_T > 20$ GeV ($\geq 1$ b tag in leading two)
- $E_T^{miss} > 40$ GeV
- $30$ GeV $< m_{ll} <$ 81 GeV
- Two signal regions with different $\sqrt{s_{\ min}}^{(sub)}$ cuts:
  - SR1: $\sqrt{s_{\ min}}^{(sub)} < 225$ GeV
  - SR2: $\sqrt{s_{\ min}}^{(sub)} < 235$ GeV, $m_{lljj} < 140$ GeV

Main backgrounds: top, W + jets

Main backgrounds: top, Z + jets

Main backgrounds are estimated from dedicated control regions in both cases
**Top background:** the lepton-neutrino transverse mass obeys

\[ M_T(l, \nu) = \sqrt{2 p_T(l) p_T(\nu) [1 - \cos(\phi_l - \phi_\nu)]} < m(W) \]

obviously, it is true on both sides:

\[ \max\left[ m_T(l_1, \nu_1), m_T(l_2, \nu_2) \right] < m(W) \]

We do not have the direction of the two neutrinos, but we can try out all possibilities and take the minimum:

\[ M_{T2}^2(l_1, l_2, p_T^{\text{Miss}}) = \min \left\{ \max\left[ m_T^2(l_1, \nu_1), m_T^2(l_2, \nu_2) \right] \right\} \]

Minimum is over all possible decompositions \( \vec{p}_T^{\text{Miss}} = \vec{p}_T(\nu_1) + \vec{p}_T(\nu_2) \)

it's \( M_{T2} < m(W) \) for top pairs, and also for \( Wt \) and \( WW \)
**ATLAS detector**

- **Inner tracker:** 2 T magnetic field providing precision tracking of charged particles

- **Calorimeter systems:** Liquid argon or scintillating tiles provide energy measurements

- **Muon spectrometer:** Surrounded by air-core superconducting magnets providing a magnetic field strength varying from 1 to 8 T. The muon spectrometer provides trigger and high precision tracking capabilities.