Searches for direct pair production of third generation squarks with the ATLAS detector

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on behalf of the ATLAS collaboration
Supersymmetry (SUSY) is a very predictive set of models that describe the SM and beyond SM physics.

FCNC supression favors heavy 1st and 2nd generation squarks (lower bounds from LHC > 1 TeV)

We have a « recent » observation ($m_H = 125.5$ GeV)

Naturalness arguments favor the 3rd generation squarks to be « light » (< 1 TeV)

Strong physics case to search for 3rd generation squarks

Here will be presented final results for direct top/bottom squark pair production searches at the LHC with the full ATLAS 2012 8 TeV dataset (20.3 fb$^{-1}$)
Direct top squark pair production
All-hadronic final state searches

**Model**

\( \tilde{t}_1 \) can decay to \( t \tilde{\chi}_1^0 \) or \( b \tilde{\chi}_1^+ \)

\[ m(\tilde{\chi}_1^+) = 2m(\tilde{\chi}_1^0) \]

6 jets (2 being bjets) expected at leading order

**Selections**

in common 2\(^+\) bjets, 0 leptons, missing transverse energy

- 6 jets (modes A, B)
- 4-5 «fatter» (\( \Delta R = 0.8, 1.2 \)) jets (boosted W in A)
- 5 jets (lost jet in B due to small \( \Delta m(\tilde{\chi}_1^+, \tilde{\chi}_1^0) \))

Important discriminant variable:

\[ m_{T}^{b,\text{min}}(A \text{ and } B) \]

\[ m_{T}^{b,\text{min}} = \sqrt{2 p_{T}^{b} E_{T}^{\text{miss}} \left[ 1 - \cos \Delta \phi (p_{T}^{b}, p_{T}^{\text{miss}}) \right]} > 175 \text{ GeV} \]
All-hadronic final state searches

Background control and Results

\textbf{ttbar, Z+jets, W+jets :}
Yield correction estimated with background enriched data samples (Control Regions)

CLs approach used for fits

\begin{figure}
\centering
\includegraphics[width=\textwidth]{figure.png}
\end{figure}

\textbf{Limits}

All limits at 95 \% CL

\begin{figure}
\centering
\includegraphics[width=\textwidth]{figure.png}
\end{figure}
Models

stop decays which involve 1 lepton in the final state are generic enough to target several different processes

Overview

Selection: 1 lepton, 2 b-jets, 2 jets, missing transverse energy (MET)
Strategy: Dedicated analysis strategies to target various scenarios → 15 signal regions
Hypothesis testing: done with « cut and count » and « shape-fit » techniques
1 lepton, jets and Missing Transverse momentum searches

**SM adjustments and validation**

Transverse mass ($m_T$) used to separate data samples enriched in background or signal.

Correction factors for background estimates checked with dedicated validation regions.

**Limits**

Prefered region from LHC W+W** excess (arXiv:1406.0848[hep-ph])

Summary of comparisons in validation regions
Compressed spectra searches

**Model**

Compressed spectra
\( \Delta M(\tilde{t}_1, \chi_1) < m(W) + m(b) \)

Rich physics decay chains:
- Loop diagram stop to charm
  \( \tilde{t}_1 \rightarrow b f f' \chi_1 \)

Expect soft jets and soft lepton
Use initial state radiation jets to improve signal purity

**Limits**

**ATLAS**

- c-tagged + monojet-like selection
- \( \tilde{t}_1 \) production, \( \text{BR}(\tilde{t}_1 \rightarrow c \chi_1^0) = 1 \)

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

- Observed limit (\( \pm 1 \sigma_{\text{SUSY}} \))
- Expected limit (\( \pm 1 \sigma_{\text{exp}} \))
- LEP (\( \theta = 0^\circ \))
- CDF (2.6 \( \text{fb}^{-1} \))

All limits at 95% CL

**ATLAS**

- monojet-like selection: M1, M2, M3
- \( \tilde{t}_1 \) production, \( \text{BR}(\tilde{t}_1 \rightarrow b f f' \chi_1^0) = 1 \)

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

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

All limits at 95% CL

See talk from Robert SCHOEFBECK
See dedicated poster from Roger Caminal
Overview

If \( \Delta m(\tilde{t}_1, \tilde{\chi}_1^0) \) close to \( m(\text{top}) \), stop signature is very similar to SM ttbar production.

If \( \tilde{t}_2 \) is not too heavy, its decay to \( \tilde{t}_1 \) via \( Z/h \) can be observed

Selection: 3 leptons (1Z), 5+(jets)(1bjet), MET

Limits

1st direct limits of \( \tilde{t}_2 \) at the LHC

\[ m(\tilde{t}_2) < 600 \text{ GeV} \]
for \( m(\tilde{\chi}_1) < 200 \text{ GeV} \)

Same analysis used to interpret \( \tilde{t}_1 \rightarrow \) gravitino model
Direct bottom squark pair production
3 b-jet searches

Looking for scenarios where the \( \tilde{b} \) only decays via \( \tilde{\chi}^0 \)

Simplified model
\( m(\tilde{\chi}^0) = 60 \text{ GeV} \)

Selection:
4+ jets (3+ bjets), MET

Jets, 2-3 leptons search

In scenarios with a light stop_L, sbottom_L may be light from SM weak-isosping symmetry.

2 simplified models studied
\( m(\tilde{\chi}^0) = 60 \text{ GeV} \)
\( m(\tilde{\chi}^+_1) = 2 \times m(\tilde{\chi}^0) \)

\( m(\tilde{b}) < 440 \text{ GeV} \) excluded.
No excess from SM is found so far.
For $\tilde{t}_1 \to t \tilde{\chi}_1^0$, $m(\tilde{t}_1) < 680$ GeV (for $m(\tilde{\chi}_1^0) \sim 0$ GeV) is excluded.

<table>
<thead>
<tr>
<th>Status: ICHEP 2014</th>
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</thead>
<tbody>
<tr>
<td>$L_{\text{int}} = 20$ fb$^{-1}$ $\sqrt{s}=8$ TeV</td>
</tr>
<tr>
<td>$L_{\text{int}} = 4.7$ fb$^{-1}$ $\sqrt{s}=7$ TeV</td>
</tr>
<tr>
<td>0L [1406.1122]</td>
</tr>
<tr>
<td>1L [1407.0583]</td>
</tr>
<tr>
<td>2L [1403.4853]</td>
</tr>
<tr>
<td>1L [1407.0583], 2L [1403.4853]</td>
</tr>
<tr>
<td>0L [1407.0608]</td>
</tr>
<tr>
<td>0L [1407.0608], 1L [1407.0583]</td>
</tr>
</tbody>
</table>

![Graph](image)
No excess from SM is found so far. For $\tilde{t}_1 \to t \tilde{\chi}_1^0$, $m(\tilde{t}_1) < 680$ GeV (for $m(\tilde{\chi}_1^0) \sim 0$ GeV) is excluded.

Re-interpretation of $t\bar{t}$ pair production in terms of $\tilde{t}_1$ pair production with 1 GeV $\tilde{\chi}_1^0$.
No excess from SM is found so far.

For $\tilde{t}_1 \rightarrow t \tilde{\chi}_1^0$, $m(\tilde{t}_1) < 680$ GeV (for $m(\tilde{\chi}_1^0) \sim 0$ GeV) is excluded.
Looking forward for Run II with increased center of mass energy and increased luminosity.
Backup
**All-hadronic final state searches**

**Common selection**

<table>
<thead>
<tr>
<th>Trigger</th>
<th>$E_T^{\text{miss}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$N_{\text{lep}}$</td>
<td>0</td>
</tr>
<tr>
<td>$b$-tagged jets</td>
<td>$\geq 2$</td>
</tr>
<tr>
<td>$E_T^{\text{miss}}$</td>
<td>$&gt; 150$ GeV</td>
</tr>
<tr>
<td>$</td>
<td>\Delta\phi (\text{jet, } p_T^{\text{miss}})</td>
</tr>
<tr>
<td>$</td>
<td>\Delta\phi (p_T^{\text{miss}}, p_T^{\text{miss,track}})</td>
</tr>
<tr>
<td>$m_{b,\text{min}}$</td>
<td>$&gt; 175$ GeV</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SRA1</th>
<th>SRA2</th>
<th>SRA3</th>
<th>SRA4</th>
</tr>
</thead>
<tbody>
<tr>
<td>anti-$k_t$, $R = 0.4$ jets</td>
<td>$\geq 6$, $p_T &gt; 80, 80, 35, 35, 35, 35$ GeV</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$m_{b, jj}^0$</td>
<td>$&lt; 225$ GeV</td>
<td>[50,250] GeV</td>
<td></td>
</tr>
<tr>
<td>$m_{b, jj}^1$</td>
<td>$&lt; 250$ GeV</td>
<td>[50,400] GeV</td>
<td></td>
</tr>
<tr>
<td>$\min[m_T (\text{jet}^i, p_T^{\text{miss}})]$</td>
<td>–</td>
<td>$&gt; 50$ GeV</td>
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</tr>
<tr>
<td>$\tau$ veto</td>
<td>yes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$E_T^{\text{miss}}$</td>
<td>$&gt; 150$ GeV</td>
<td>$&gt; 250$ GeV</td>
<td>$&gt; 300$ GeV</td>
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### All-hadronic final state searches

<table>
<thead>
<tr>
<th></th>
<th>SRB1</th>
<th>SRB2</th>
</tr>
</thead>
<tbody>
<tr>
<td>anti-$k_t$ $R = 0.4$ jets</td>
<td>4 or 5, $p_T &gt; 80, 80, 35, 35, (35)$ GeV</td>
<td>5, $p_T &gt; 100, 100, 35, 35, 35$ GeV</td>
</tr>
<tr>
<td>$\Delta m_b$</td>
<td>$&lt; 0.5$</td>
<td>$&gt; 0.5$</td>
</tr>
<tr>
<td>$p_{T,\text{jet},R=1.2}$</td>
<td>-</td>
<td>$&gt; 350$ GeV</td>
</tr>
<tr>
<td>$m_{\text{jet},R=1.2}$</td>
<td>$&gt; 80$ GeV</td>
<td>[140, 500] GeV</td>
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<tr>
<td>$m_{\text{jet},R=1.2}$</td>
<td>[60, 200] GeV</td>
<td>-</td>
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<tr>
<td>$m_{\text{jet},R=0.8}$</td>
<td>$&gt; 50$ GeV</td>
<td>[70, 300] GeV</td>
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<tr>
<td>$m_T^{\text{min}}$</td>
<td>$&gt; 175$ GeV</td>
<td>$&gt; 125$ GeV</td>
</tr>
<tr>
<td>$m_T (\text{jet}^3, p_T^{\text{miss}})$</td>
<td>$&gt; 280$ GeV for 4-jet case</td>
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</tr>
<tr>
<td>$E_T^{\text{miss}} / \sqrt{H_T}$</td>
<td>-</td>
<td>$&gt; 17 \sqrt{\text{GeV}}$</td>
</tr>
<tr>
<td>$E_T^{\text{miss}}$</td>
<td>$&gt; 325$ GeV</td>
<td>$&gt; 400$ GeV</td>
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### SRC1

<table>
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<tr>
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<th>SRC1</th>
<th>SRC2</th>
<th>SRC3</th>
</tr>
</thead>
<tbody>
<tr>
<td>anti-$k_t$ $R = 0.4$ jets</td>
<td>5, $p_T &gt; 80, 80, 35, 35, 35$ GeV</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$</td>
<td>\Delta\phi (b, b)</td>
<td>$</td>
<td></td>
</tr>
<tr>
<td>$m_{T,\text{min}}^b$</td>
<td>$&gt; 185$ GeV</td>
<td>$&gt; 200$ GeV</td>
<td>$&gt; 200$ GeV</td>
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<td>$m_{T,\text{max}}^b$</td>
<td>$&gt; 205$ GeV</td>
<td>$&gt; 290$ GeV</td>
<td>$&gt; 325$ GeV</td>
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<td>$\tau$ veto</td>
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<td></td>
</tr>
<tr>
<td>$E_T^{\text{miss}}$</td>
<td>$&gt; 160$ GeV</td>
<td>$&gt; 160$ GeV</td>
<td>$&gt; 215$ GeV</td>
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All-hadronic final state searches

<table>
<thead>
<tr>
<th></th>
<th>VRA1</th>
<th>VRA2</th>
<th>VRB</th>
<th>VRC1</th>
<th>VRC2</th>
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<tbody>
<tr>
<td><strong>Observed events</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total SM</td>
<td>$189 \pm 26$</td>
<td>$50 \pm 6$</td>
<td>$70 \pm 19$</td>
<td>$110 \pm 12$</td>
<td>$21.1 \pm 2.9$</td>
</tr>
<tr>
<td>$t\bar{t}$</td>
<td>$170 \pm 27$</td>
<td>$34 \pm 7$</td>
<td>$60 \pm 19$</td>
<td>$93 \pm 12$</td>
<td>$17.3 \pm 2.8$</td>
</tr>
<tr>
<td>Z + jets</td>
<td>$4.0 \pm 1.1$</td>
<td>$1.5 \pm 0.4$</td>
<td>$1.5 \pm 0.5$</td>
<td>$6.9 \pm 1.5$</td>
<td>$0.24 \pm 0.20$</td>
</tr>
<tr>
<td>W + jets</td>
<td>$2.8 \pm 1.2$</td>
<td>$4.8 \pm 2.2$</td>
<td>$2.1 \pm 1.4$</td>
<td>$3.9 \pm 1.8$</td>
<td>$1.1 \pm 0.5$</td>
</tr>
<tr>
<td>Others</td>
<td>$11.8 \pm 3.1$</td>
<td>$9.1 \pm 2.2$</td>
<td>$7.2 \pm 2.5$</td>
<td>$6.7 \pm 2.0$</td>
<td>$2.4 \pm 0.7$</td>
</tr>
<tr>
<td><strong>Fitted background events</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Figure 9.** Exclusion contours at 95\% CL in the scenario where the top squarks are allowed to decay via $\tilde{t}\rightarrow b\tilde{c}^{\pm}$. The $\tilde{c}^{\pm}$ mass is fixed to twice the $\tilde{c}^{0}$ mass, and the grey filled areas correspond to the LEP limit of $103.5$ GeV on the lightest chargino mass \[66\text{–}97\text{–}100\text{].} (a) Expected and observed limits for $B_{\tilde{t} \rightarrow \tilde{c}^{0}} = 50\%$. The blue dashed line indicates the expected limit, and the yellow band indicates the $\pm 1\sigma$ uncertainties, which include all uncertainties except the theoretical uncertainties in the signal. The red solid line indicates the observed limit, and the red dotted lines indicate the sensitivity to $\pm 1\sigma$ variations of the signal theoretical uncertainties. (b) The observed and expected exclusion contours are shown for $B_{\tilde{t} \rightarrow \tilde{c}^{0}}$ values from 0\% (inner contours) to 100\% (outer contours). For each branching fraction, the observed (solid line) and expected (dashed line) limits are displayed.
1 lepton, jets and Missing Transverse momentum searches

**ATLAS**

- **\( \tilde{t}\tilde{t} \) production, \( \tilde{t} \rightarrow t \tilde{\chi}^0_1 / b \tilde{\chi}^{\pm}_1, \tilde{\chi}^+_1 \rightarrow W^+ \chi_1^0 \), \( m_{\tilde{t}} = 2 m_{\chi_1^0} \)**

- **Integral** \( \int L \, dt = 20 \text{ fb}^{-1}, \sqrt{s} = 8 \text{ TeV} \)

- **1-lepton + jets + \( E_T^{\text{miss}} \)**

**Observed limits** and **Expected limits**

- **All limits at 95% CL**
1 lepton, jets and Missing Transverse momentum searches

\[ 1\text{-lepton} + \text{jets} + E_{T}^{\text{miss}} \]

**pMSSM models:**
- \( m(\tilde{t}_1, \tilde{\chi}_1^0) \approx (400,50) \text{ GeV} \)
- \( m(\tilde{t}_1, \tilde{\chi}_1^0) \approx (550,50) \text{ GeV} \)
- \( m(\tilde{t}_1, \tilde{\chi}_1^0) \approx (550,150) \text{ GeV} \)

**Simplified models:**
- \( m(\tilde{t}_1, \tilde{\chi}_1^0) = (400,50) \text{ GeV} \)
- \( m(\tilde{t}_1, \tilde{\chi}_1^0) = (550,50) \text{ GeV} \)

\[ x = \text{BR}(\tilde{t}_1 \rightarrow t\chi_1^0) \]

**ATLAS**
- \( \int L \, dt = 20 \text{ fb}^{-1} \)
- \( \sqrt{s} = 8 \text{ TeV} \)
ttbar + Z(h) + E_{miss} T searches
Gravitinos

Naturalness requires higgsino to be light

If gravitino is LSP, then the decay of higgsino to gravitino (via h,Z) gives similar signature. The stop2 analysis is re-interpreted in this scenario

Results combined with 2L Signal regions.
**Overview**

In scenarios with a light stop $L$, sbottom$_L$ may be light from SM weak-isosping symmetry.

Selection:
SS(3L), $3^+ + b$, $m_{\text{eff}}, \text{MET}$

Main bkgs estimation
Prompt leptons: $t\bar{t} + V, VV$ (from MC validated in special regions)
Fake-leptons: Matrix method

**Results and Limits**

2 simplified models studied
$m(\chi_{10}) = 60 \, \text{GeV}$
$m(\chi_{1+}) = 2 \times m(\chi_{10})$

Simultaneous fit to Signal regions (profile likelihood)

$m(\text{sbottom}) > 440 \, \text{GeV}$ at 95% CL
Model

sbottom decays only to $b ~ \chi_1^0$

Expect 2 b-jets and significant missing transverse momentum

Use initial state radiation jets to improve signal purity

Limits

**FIG. 11:** Exclusion plane at 95% CL as a function of sbottom and neutralino masses for the decay channel $\tilde{b}_1 \rightarrow b + \tilde{\chi}_1^0$ (BR=100%). The observed (red line) and expected (blue line) upper limits from this analysis are compared to previous results from CDF \[28\], D0 \[29\], and ATLAS \[22\]. For the latter, the area below the dashed-dotted line is excluded. The dotted lines around the observed limit indicate the range of observed limits corresponding to $\pm 1\sigma$ variations on the NLO SUSY cross-section predictions. The shaded area around the expected limit indicates the expected $\pm 1\sigma$ ranges of limits in the absence of a signal.

For $m_{\tilde{b}_1} - m_{\tilde{\chi}_1} - m_b < 2$ GeV indicates the region in the phase space for which the sbottom can become long-lived.
Compressed spectra searches

Model

Compressed spectra
\(\Delta M(\tilde{t}_1, \chi_1) < m(W) + m(b)\)

Rich physics decay chains:
Loop diagram stop to charm
\(\tilde{t}_1 \rightarrow b f f' \tilde{\chi}_1\)

Expect soft jets and soft lepton
Use initial state radiation jets to improve signal purity

Selections

- 4\(^+\) loose c-tagged jets with 1 tighter c-tagged jet (A)
- 3\(^-\) jets (B)
- 1\(^+\) energetic jet (A, B)

Discriminating variables:
MET, 0 leptons, \(\Delta\phi(\text{jet,MET})\)

charm-quark tagging inputs:
Impact parameter of displaced tracks
Topological information of 2\(^{nd}\) 3rd vertices within jet
Jets and same-sign leptons or 3 leptons searches

<table>
<thead>
<tr>
<th>SR</th>
<th>Leptons</th>
<th>$N_b$--jets</th>
<th>Other variables</th>
<th>Additional requirement on $m_{\text{eff}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>SR1b</td>
<td>SS</td>
<td>$\geq 1$</td>
<td>$N_{\text{jets}} \geq 3$, $E_{T}^{\text{miss}} &gt; 150$ GeV, $m_T &gt; 100$ GeV, SR3b veto</td>
<td>$m_{\text{eff}} &gt; 700$ GeV</td>
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<tr>
<td>SR3Llow</td>
<td>3L</td>
<td>-</td>
<td>$N_{\text{jets}} \geq 4$, $50 &lt; E_{T}^{\text{miss}} &lt; 150$ GeV, $Z$ boson veto, SR3b veto</td>
<td>$m_{\text{eff}} &gt; 400$ GeV</td>
</tr>
<tr>
<td>SR3Lhigh</td>
<td>3L</td>
<td>-</td>
<td>$N_{\text{jets}} \geq 4$, $E_{T}^{\text{miss}} &gt; 150$ GeV, SR3b veto</td>
<td>$m_{\text{eff}} &gt; 400$ GeV</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Background</th>
<th>Method</th>
<th>SR1b</th>
<th>SR3Llow</th>
<th>SR3Lhigh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Charge-flip</td>
<td>Nominal</td>
<td>$0.5 \pm 0.1$</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Tag and probe</td>
<td>$0.5 \pm 0.2$</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Fake</td>
<td>Nominal</td>
<td>$0.8^{+1.2}_{-0.8}$</td>
<td>$1.6 \pm 1.6$</td>
<td>$&lt; 0.1$</td>
</tr>
<tr>
<td></td>
<td>Monte Carlo based</td>
<td>$0.6^{+1.4}_{-0.6}$</td>
<td>$1.0^{+0.8}_{-0.7}$</td>
<td>$&lt; 0.1$</td>
</tr>
<tr>
<td>Total 3 $b$-jets</td>
<td>Nominal</td>
<td>-</td>
<td>-</td>
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<tr>
<td></td>
<td>$b$-jets matrix method</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
3 b-jet searches

Baseline 0-lepton selection: lepton veto, $p_T^{j_1} > 90$ GeV, $E_T^{\text{miss}} > 150$ GeV, 
≥ 4 jets with $p_T > 30$ GeV, $\Delta\phi_{\text{min}}^{4j} > 0.5$, $E_T^{\text{miss}}/m_{\text{eff}}^{4j} > 0.2$, ≥ 3 b-jets with $p_T > 30$ GeV

<table>
<thead>
<tr>
<th>N jets ($p_T$ [GeV])</th>
<th>$E_T^{\text{miss}}$ [GeV]</th>
<th>$m_{\text{eff}}$ [GeV]</th>
<th>$E_T^{\text{miss}}/\sqrt{H_T^{4j}}$ [\sqrt{\text{GeV}}]</th>
</tr>
</thead>
<tbody>
<tr>
<td>SR-0\ell-4j-A</td>
<td>≥ 4 (50)</td>
<td>&gt; 250</td>
<td>$m_{\text{eff}}^{4j}$ &gt; 1300</td>
</tr>
<tr>
<td>SR-0\ell-4j-B</td>
<td>≥ 4 (50)</td>
<td>&gt; 350</td>
<td>$m_{\text{eff}}^{4j}$ &gt; 1100</td>
</tr>
<tr>
<td>SR-0\ell-4j-C*</td>
<td>≥ 4 (30)</td>
<td>&gt; 400</td>
<td>$m_{\text{eff}}^{4j}$ &gt; 1000</td>
</tr>
</tbody>
</table>
3 b-jet searches

![Graph A](image1)

**ATLAS**

- Data 2012
- SM total
- Reducible bkg (MM)
- t\(\bar{t}\)b\(\bar{b}\)E (MC)
- t\(\bar{t}\)Z/h (MC)

**SR-0l-4j-A**

- 

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

**Graph B**

- Data 2012
- SM total
- Reducible bkg (MM)
- t\(\bar{t}\)b\(\bar{b}\)E (MC)
- t\(\bar{t}\)Z/h (MC)

**SR-0l-4j-B**

- 

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

**Graph C**

- Data 2012
- SM total
- Reducible bkg (MM)
- t\(\bar{t}\)b\(\bar{b}\)E (MC)
- t\(\bar{t}\)Z/h (MC)

**SR-0l-4j-C**

- 

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