Searches with long-lived or unusual signatures at LHC

2013-05-16

Sigve Haug
On behalf of the
ATLAS and CMS collaborations
**Long-lived and unusual signatures**

- **Experimental motivation:** Keep an eye open for the unexpected ...
- **Theoretical motivations:** RPV, Split, GMSB ... SUSY, hidden valleys ...

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**MetaStable**

- lepton jets
- displaced vertex
- non-pointing photons

**Stable**

- odd dE/dx
- disappearing track or kink
- stopped
- delayed decay
- stable massive particle
- slow
- leaving the detector

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**O(10)mm**

**O(100)mm**

**> O(1000)mm**

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**Decay Length**

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**Walk through recent results from right to left**
Heavy Stable Charged Particles (HSCP) or / and Stable Massive Particles (SMP)

q < |e| or q > |e|

See also D0 : 1211.2466 14 Nov 2012
Common considerations catching HSCP/SMP

- Long-lived, $O(10 \ \text{ns})$, i.e. traverses the detector

- Anomalously slow
  - $\beta_{SM} = \frac{v}{c} = \frac{p}{E} \sim 1$
  - $\beta_{SMP} < 1 \ \Delta \beta < 0.1$
  - TOF with calo or muon system

- Anomalous $dE/dx$
  - Fractional or multiple charge can be seen in several sub-detectors

- Use muon and MET triggers and a combination of $\beta$ and $dE/dx$
Searches for Long-lived Charged Particles in pp Collisions at $\sqrt{s} = 7$ and 8 TeV

- High pT muon & MET triggers
- SRs with pT, dE/dx and ToF (from MS)
- Bkg from data (ABCD)
- No excess

<table>
<thead>
<tr>
<th>Selection criteria</th>
<th>$p_T$ (GeV/c)</th>
<th>$I_{93}^{(t)}$</th>
<th>$1/\beta$</th>
<th>Mass (GeV/c^2)</th>
<th>$\sqrt{s} = 7$ TeV</th>
<th>$\sqrt{s} = 8$ TeV</th>
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</thead>
<tbody>
<tr>
<td>tracker-only</td>
<td>&gt; 70</td>
<td>&gt; 0.4</td>
<td>-</td>
<td>&gt; 0</td>
<td>7.1 ± 1.5 8</td>
<td>32.5 ± 6.5 41</td>
</tr>
<tr>
<td></td>
<td>&gt; 100</td>
<td></td>
<td></td>
<td>6.0 ± 1.3</td>
<td>7</td>
<td>26.0 ± 5.2  29</td>
</tr>
<tr>
<td></td>
<td>&gt; 200</td>
<td></td>
<td></td>
<td>0.65 ± 0.14</td>
<td>0.55 ± 0.11 1</td>
<td>3.1 ± 0.6  3</td>
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<tr>
<td></td>
<td>&gt; 300</td>
<td></td>
<td></td>
<td>0.11 ± 0.02</td>
<td></td>
<td>0.030 ± 0.006 0</td>
</tr>
<tr>
<td></td>
<td>&gt; 400</td>
<td></td>
<td></td>
<td>0.003 ± 0.006 0</td>
<td>0.15 ± 0.03 0</td>
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<tr>
<td>tracker+TOF</td>
<td>&gt; 70</td>
<td>&gt; 0.125</td>
<td>&gt; 1.225</td>
<td>&gt; 0</td>
<td>8.5 ± 1.7 7</td>
<td>43.5 ± 8.7 42</td>
</tr>
<tr>
<td></td>
<td>&gt; 100</td>
<td></td>
<td></td>
<td>1.0 ± 0.2</td>
<td>5.6 ± 1.1  7</td>
<td></td>
</tr>
<tr>
<td></td>
<td>&gt; 200</td>
<td></td>
<td></td>
<td>0.11 ± 0.02</td>
<td>0.56 ± 0.11 0</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>&gt; 300</td>
<td></td>
<td></td>
<td>0.020 ± 0.004 0</td>
<td>0.909 ± 0.02 0</td>
<td></td>
</tr>
</tbody>
</table>

- muon-only
- $|Q| > 1e$ $> 230$ $> 1.40$ $-$ $-$ $5.6 ± 2.9$ 3
- $|Q| < 1e$ $125$ $>$ 0.275 $-$ $-$ $0.12 ± 0.07$ 0

5 fb^{-1} @ 7 TeV
18.8 fb^{-1} @ 8 TeV

- stau limit (GMSB)
- R-Hadron limits on stop and gluino (direct production, split SUSY)
- Odd charge limits
• High pT muon and MET triggers (ToF from calo)
• Signal regions in mass plane
  • MS only (R-Hadrons)
  • ID only (“short” lived, charge flip)
  • ID+MS (sleptons, R-Hadrons)
• Bkg mass distr from data samples
• No excess

Slepton limit (GMSB) 300 GeV, 5<\tan\beta<20
R-Hadron limits (direct gluino&squark prod.)
  • Gluino 986 GeV (gluino fraction 0.1)
  • Stop 683 GeV
  • sbottom 612 GeV
• $|q| = \text{from 2e to 6e}$
• Single muon trigger

• Using $dE/dx$ significance $S$ wrt muon in MDT and TRT for two signal regions (2e and >2e)

• Bkg from data (ABCD)

• Background: $0.41 \pm 0.08 \pm 0.02$ and $1.37 \pm 0.46 \pm 0.07$

• 0 observed

• Exclusions in simplified Drell-Yan model in mass ranges from 50 to about 450 GeV
Stopped R-Hadrons with out-of-time decays
• Long-lived, beyond the time between bunches (25 - ~100 ns), i.e. decay associated with later bunch

• Paired, unpaired and empty crossings. Use latter to have minimal background.

• Backgrounds are cosmics, noise, beam halo interactions

• Use a low threshold veto trigger on beam, empty or/and unpaired crossings together with some calorimeter activity
Search for Decays of Stopped, Long-Lived Particles from 7 TeV $pp$ Collisions with the ATLAS Detector

- Calo trigger $> 10$ GeV, $>125$ ns after last paired crossing
- 4 signal regions
- Bkg from cosmic and halo data samples

<table>
<thead>
<tr>
<th>Selection criterion</th>
<th>Expected cosmic ray muons</th>
<th>Expected beam-halo</th>
<th>Observed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Jet: Muon Veto</td>
<td>$4 \pm 1$</td>
<td>$4 \pm 1.8$</td>
<td>9</td>
</tr>
<tr>
<td>Single Jet: $&gt; 100$ GeV</td>
<td>$0.3 \pm 0.3$</td>
<td>$0.5 \pm 0.2$</td>
<td>0</td>
</tr>
<tr>
<td>Multi-Jet: Muon Veto</td>
<td>$1 \pm 0.6$</td>
<td>$0.8 \pm 0.8$</td>
<td>3</td>
</tr>
<tr>
<td>Multi-Jet: $&gt; 100$ GeV</td>
<td>$0.6 \pm 0.4$</td>
<td>$0.2 \pm 0.2$</td>
<td>1</td>
</tr>
</tbody>
</table>

- Mass limit on gluino 341 GeV for lifetimes $10^{-5} - 10^3$ s

**ATLAS**

- Search Sample
- Background Sample
- Beam Halo Sample

**ATLAS**

- $N_{\text{jets}} = 1$
- $\sqrt{s} = 7$ TeV
- $L \, dt = 31 \, \text{pb}^{-1}$

- Expected Limit $\pm 2 \sigma$
- Expected Limit $\pm 1 \sigma$
- Prosperi SUSY
- Observed SUSY
- Expected Limit

**ATLAS**

- $N_{\text{jets}} = 1$
- $\sqrt{s} = 7$ TeV
- $L \, dt = 31 \, \text{pb}^{-1}$

- 50% CL (pp $\rightarrow g \rightarrow g$ pb)

- $M_0$ (GeV) vs Jet Energy [GeV]
Search for stopped long-lived particles produced in pp collisions at $\sqrt{s} = 7$ TeV

- BPTX + jet trigger, ± 2BX veto, max trigger live time 246h
- Bkg from cosmics and noise samples, tag and probe for halo

<table>
<thead>
<tr>
<th>Cosmic rays</th>
<th>Beam-halo</th>
<th>Noise</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.71 ± 0.62</td>
<td>1.50 ± 0.70</td>
<td>1.4 ± 2.2</td>
<td>8.6 ± 2.4</td>
</tr>
</tbody>
</table>


- 12 observed
- Mass limits on gluino and stop at 640 and 340 GeV for life times $10^{-5} - 10^3$ s

Sigve Haug, AEC University of Bern
Displaced Vertices
Disappearing Tracks
Non-Pointing Photons
Search in leptonic channels for heavy resonances decaying to long-lived neutral particles

- Benchmark signal: $H \rightarrow 2X \rightarrow 4\ell$
- Opposite charge $ee$ and $\mu\mu$ pairs with displaced vertex. Cut on impact parameter significance

**4-5 fb$^{-1}$ @ 7 TeV**

Cosmics to estimate efficiency

** CMS $\sqrt{s} = 7$ TeV $L = 5.1$ fb$^{-1}$**

- $ee$: $\text{exp}=1.4+1.8-1.2$, $\text{obs}=4$
- $\mu\mu$: $\text{exp}=0.02+0.09-0.02$, $\text{obs}=0$
- Several limits on $X$ production, dependent on decay length and Higgs mass
• Benchmark signal

\[ \tilde{\chi}^0, \tilde{\mu}^-, \tilde{\tau}_{2j} \]

\[ \mu \]

\[ q_i \]

\[ q_j \]

\[ \bar{q}_j \]

\[ \bar{\chi}_0 \]

\[ \bar{\chi}_1 \]

RPV

<table>
<thead>
<tr>
<th>Sample</th>
<th>( m_{\tilde{q}} ) [GeV]</th>
<th>( \sigma ) [fb]</th>
<th>( m_{\tilde{\chi}_0^0} ) [GeV]</th>
<th>( \langle \gamma/\beta \rangle_{\tilde{\chi}_1^0} )</th>
<th>( c\tau_{MC} ) [mm]</th>
<th>( \chi_{211}^\prime \times 10^{-5} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>MH</td>
<td>700</td>
<td>66.4</td>
<td>494</td>
<td>1.0</td>
<td>78</td>
<td>0.3</td>
</tr>
<tr>
<td>ML</td>
<td>700</td>
<td>66.4</td>
<td>108</td>
<td>3.1</td>
<td>101</td>
<td>1.5</td>
</tr>
<tr>
<td>HH</td>
<td>1500</td>
<td>0.2</td>
<td>494</td>
<td>1.9</td>
<td>82</td>
<td>1.5</td>
</tr>
</tbody>
</table>

• Selection: Muon pT > 50GeV, \( d_T(PV,DV) > 4 \text{ mm} \)
  displaced vertex mass and tracks

• Bkg from rndm vtx and gas interactions

• Exp < 0.01. Obs=0

• Cross section x BR limits for various RPV signals

• $O(10)\text{mm} < c\tau < O(100)\text{mm}$

• Benchmark signal: $pp \to \tilde{\chi}_1^\pm \tilde{\chi}_1^0$,

• Selection: High $p_T$ jet, MET, disapp. track using the Transition Radiation Tracker

• Background-only (hadron and electron tracks) fit to observed $p_T$ with $p_0=0.54$.

• Limits in AMSB are $m_{\chi^\pm}=103\ (83)\ \text{GeV}$ for the typical small mass splitting $160\ (170)\ \text{MeV}$.
Search for non-pointing photons in the diphoton and $E_{T}^{miss}$ final state in $\sqrt{s} = 7$ TeV proton–proton collisions using the ATLAS detector

- Long-lived neutral particles to photons (>50 GeV) + MET (>75 GeV)
- Using ATLAS em calo pointing capability

ATLAS

Data 2011
$\sqrt{s} = 7$ TeV, $\int L dt = 4.8$ fb$^{-1}$

- Fit to the $Z_{DCA}$ data distribution of a loose photon using signal, prompt e/gamma and jet templates
- No excess
- Limits in GMSB, $m_{N0} \sim 230$ GeV for $c\tau \sim 1$ m
• Long-lived particle to photons + MET (see diagram from previous slide)

• Selection features:
  3 jets with $p_T > 35$ GeV
  $p_T(\text{photon}) > 100$ GeV

• Fit to 2D MET and ECAL time distribution

• No excess

• Limits in GMSB
  $m_{N_0} \succsim 220$ GeV
  for $c\tau \lesssim 1$ m

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Lepton Jets

Lepton jets

MetaStable

- displaced vertex
- non-pointing photons

Stable

- disappearing track or kink
- odd dE/dx
- stable massive particle
- slow
- leaving the detector

O(10)mm  O(100)mm  > O(1000)mm

Decay Length
Search for $WH$ production with a light Higgs boson decaying to prompt electron-jets in proton–proton collisions at $\sqrt{s} = 7$ TeV with the ATLAS detector

- 2-3 step cascade decay via Hidden Valley particles. Boosted dark photons making collimated lepton jets (2 step in diagram)

- Signal: lep + MET (W) + e-Jet

- Exploring ECAL properties of e-Jets, e.g. fraction of E associated with tracks $f_{CH}$

<table>
<thead>
<tr>
<th>Signal</th>
<th>three-step model</th>
<th>two-step model</th>
</tr>
</thead>
<tbody>
<tr>
<td>$m_H$ (GeV)</td>
<td>$m_{\gamma_1} = 100$ MeV</td>
<td>$m_{\gamma_1} = 200$ MeV</td>
</tr>
<tr>
<td>100</td>
<td>14.3 ± 1.7 ± 0.8</td>
<td>12.4 ± 1.6 ± 0.7</td>
</tr>
<tr>
<td>125</td>
<td>11.3 ± 1.0 ± 0.6</td>
<td>10.7 ± 1.1 ± 0.6</td>
</tr>
<tr>
<td>140</td>
<td>9.6 ± 0.8 ± 0.5</td>
<td>9.0 ± 0.8 ± 0.4</td>
</tr>
</tbody>
</table>

- Bkg estimates with Matrix, ABCD and MC (xcheck)

- No excess (left)
- Limits produced

A search for prompt lepton-jets in $pp$ collisions at $\sqrt{s} = 7$ TeV with the ATLAS detector

- Benchmark motivation: dark photon
- Trigger on muons and electrons
- Use ECAL and TRT (example in figure)

- Single lepton jet (LJ) $\geq 4$ muons
- Pair of LJs with each $\geq 2$ muons
- Pair of LJs with each $\geq 2$ electrons

- Bkg from ABCD Likelihood (with xchecks)

<table>
<thead>
<tr>
<th></th>
<th>Electron LJ</th>
<th>1 Muon LJ</th>
<th>2 Muon LJ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data</td>
<td>15</td>
<td>7</td>
<td>3</td>
</tr>
<tr>
<td>All background</td>
<td>15.2±2.7</td>
<td>3.0 ± 1.0</td>
<td>0.5 ± 0.3</td>
</tr>
</tbody>
</table>

4.7 fb$^{-1}$ @ 7 TeV

- No significant excess.

- Limits on Hidden-Valley model visible cross sections from $0.017$ to $1.2$ pb$^{-1}$ (table)
R-Parity Violating Signals

(if not covered by 3rd gen. and multilepton SUSY search talks)

LFVs Decay and 3-jet Resonances
**Search for a heavy narrow resonance decaying to $e\mu$, $e\tau$, or $\mu\tau$ with the ATLAS detector in $\sqrt{s} = 7$ TeV $pp$ collisions at the LHC**

- Lepton Flavor Violating Decays (OSDF)
  
  \[ d\bar{d} \rightarrow \tilde{\nu}_\tau \rightarrow \ell \ell' \]

- Single lepton trigger
- Signal region $m_{ll} > 200$ GeV
- Bkg from MC and data, controlled with $m_{ll} < 200$ GeV
- No excess

- Distributions and exclusion shown for $e\mu$ channel only
- Limits produced for various RPV couplings

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Search for three-jet resonances in pp collisions at $\sqrt{s} = 7$ TeV

- Benchmark: gluino pair production with
  \[ (\tilde{g} \rightarrow q\tilde{q} \rightarrow qqq \text{ with } m_{\tilde{q}} \gg m_{\tilde{g}}) \]

- Uses triplet mass

Results SM consistent
Limits on gluinos in benchmark model up to 460 GeV


5.0 fb$^{-1}$ @ 7 TeV
• Heavy Long-Lived Particles (LLPs) in several SM extensions with some special signatures

  • Odd dE/dx, $\beta < 1$, displaced vertex, disappearing tracks, out-of-time decays, non-pointing photons

• ATLAS and CMS do have a LLP strategy and several published searches over the last months. No excesses so far, consequently many new limits

• Also new results on prompt lepton-jets, LFV resonance decays and 3 jet resonances. Same conclusion.

• Mostly 7 TeV. More 8 TeV coming ...

See the summary plots in the additional material for the full landscape !
ADDITIONAL MATERIAL
### ATLAS SUSY Searches - 95% CL Lower Limits

**Status:** LHCP 2013

<table>
<thead>
<tr>
<th>Model</th>
<th>e, μ, τ, γ</th>
<th>Jets</th>
<th>E_{T}</th>
<th>( L_{tt} ) (fb^{-1})</th>
<th>Mass limit</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>MSUGRA/CMSSM</td>
<td>0</td>
<td>2-6 jets</td>
<td>Yes</td>
<td>20.3</td>
<td>( m_{\tilde{g}}=m_{\tilde{q}} )</td>
<td>ATLAS-CONF-2013-047</td>
</tr>
<tr>
<td>MSUGRA/CMSSM</td>
<td>0</td>
<td>7-10 jets</td>
<td>Yes</td>
<td>20.3</td>
<td>( m_{\tilde{g}}=m_{\tilde{q}} )</td>
<td>ATLAS-CONF-2013-054</td>
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<tr>
<td>GMSB (NLO)</td>
<td>0</td>
<td>2-6 jets</td>
<td>Yes</td>
<td>20.3</td>
<td>( m_{\tilde{g}}=m_{\tilde{q}} )</td>
<td>ATLAS-CONF-2013-047</td>
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<tr>
<td>Other</td>
<td>~</td>
<td>~</td>
<td>~</td>
<td>~</td>
<td>~</td>
<td></td>
</tr>
<tr>
<td>GMSB (NLO)</td>
<td>0</td>
<td>2-6 jets</td>
<td>Yes</td>
<td>20.3</td>
<td>( m_{\tilde{g}}=m_{\tilde{q}} )</td>
<td>ATLAS-CONF-2013-047</td>
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<tr>
<td>GGM (wino NLSP)</td>
<td>0</td>
<td>3 jets</td>
<td>Yes</td>
<td>20.3</td>
<td>( m_{\tilde{g}}=m_{\tilde{q}} )</td>
<td>ATLAS-CONF-2013-007</td>
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<tr>
<td>GGM (higgsino-bino NLSP)</td>
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<td>3 jets</td>
<td>Yes</td>
<td>20.3</td>
<td>( m_{\tilde{g}}=m_{\tilde{q}} )</td>
<td>ATLAS-CONF-2013-026</td>
</tr>
<tr>
<td>Gravitino LSP</td>
<td>0</td>
<td>0-3 jets</td>
<td>Yes</td>
<td>20.3</td>
<td>( m_{\tilde{g}}=m_{\tilde{q}} )</td>
<td>ATLAS-CONF-2013-144</td>
</tr>
<tr>
<td>Gravitino LSP</td>
<td>0</td>
<td>mono-jet</td>
<td>Yes</td>
<td>10.5</td>
<td>( m_{\tilde{g}}=m_{\tilde{q}} )</td>
<td>ATLAS-CONF-2013-152</td>
</tr>
</tbody>
</table>

**Inclusive searches**

- \( b \rightarrow b\tilde{b}_{1} \)
- \( b \rightarrow b\tilde{b}_{2} \)
- \( \tau \rightarrow \tau\tilde{\tau}_{1} \)
- \( \gamma \rightarrow \gamma\tilde{\gamma}_{1} \)
- \( Z \rightarrow Z\tilde{Z}_{1} \)

**3rd gen., squarks direct production**

- \( b_{1}, b_{2}, b_{3} \rightarrow b\tilde{b}_{1}, b\tilde{b}_{2}, b\tilde{b}_{3} \)
- \( t_{1}, t_{2}, t_{3} \rightarrow t\tilde{t}_{1}, t\tilde{t}_{2}, t\tilde{t}_{3} \)
- \( \tilde{t}_{1}, \tilde{t}_{2}, \tilde{t}_{3} \rightarrow \tilde{t}\tilde{t}_{1}, \tilde{t}\tilde{t}_{2}, \tilde{t}\tilde{t}_{3} \)

**EW direct**

- \( \nu_{i}, e_{i}, \mu_{i}, \tau_{i} \rightarrow \ell_{i} \)
- \( \tilde{e}_{i}, \tilde{\mu}_{i}, \tilde{\tau}_{i} \rightarrow \tilde{\nu}_{i} \)
- \( \tilde{Z}_{1,2,3} \rightarrow W^{+}W^{-}Z_{1,2,3} \)

**Direct**

- \( \tilde{c}, \tilde{d}, \tilde{u} \rightarrow c\tilde{c}_{1}, d\tilde{d}_{1}, u\tilde{u}_{1} \)
- \( \tilde{c}, \tilde{d}, \tilde{u} \rightarrow c\tilde{c}_{2}, d\tilde{d}_{2}, u\tilde{u}_{2} \)
- \( \tilde{c}, \tilde{d}, \tilde{u} \rightarrow c\tilde{c}_{3}, d\tilde{d}_{3}, u\tilde{u}_{3} \)

**Low-mass particles**

- \( \tilde{g} \rightarrow q\tilde{q} \)
- \( \tilde{\chi}_{1} \rightarrow \ell_{i}\nu_{i} \)
- \( \tilde{\chi}_{2} \rightarrow b\tilde{b}_{1} \)

**Gauge bosons**

- \( Z \rightarrow Z\tilde{Z}_{1} \)
- \( H \rightarrow H\tilde{H}_{1} \)
- \( \omega \rightarrow \omega\tilde{\omega}_{1} \)

**Other**

- WIMP interaction (DS, Dirac \( \chi \))
- 4 jets, mono-jet

<table>
<thead>
<tr>
<th>Mass scale [TeV]</th>
<th>( \sqrt{s} = 7 \text{ TeV} )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>full data</td>
</tr>
<tr>
<td></td>
<td>partial data</td>
</tr>
<tr>
<td></td>
<td>full data</td>
</tr>
</tbody>
</table>

*Only a selection of the available mass limits on new states or phenomena is shown. All limits quoted are observed minus 1σ theoretical signal cross section uncertainty.*
ATLAS Exotics Searches* - 95% CL Lower Limits (Status: HCP 2012)

**Extra dimensions**
- Large ED (ADD): monojet + E_Tmiss
- Large ED (ADD): monophoton + E_Tmiss
- Large ED (ADD): dielepton + E_Tmiss
- UED: dielepton + E_Tmiss
- S/Z* ED: dielepton, m_{T/Z*}
- RS1: dielepton + E_Tmiss
- RS1: ZZ resonance, m_{Z/Z'}
- RSs: WW resonance, m_{WW}
- RS g_{K*} (BR=0.926): 7 + jet, m_{K*}

**ADD BH (M_{H+}/M_{H-}=3)**:
- SS dimuon, N_{μμ}\text{part.}
- ADD BH (M_{H+}/M_{H-}=3):
  - leptons + jets, Lp
  - Quantum black hole: dijet, F(m_{QBH})

**qqq contact interaction**: \Lambda(m_{qqq})

**Cl**
- uutl Cl: SS dielepton + jets + E_Tmiss
- Z' (SSM): m_{e,e'μ,μ'}
- Z' (SSM): m_{t,t'\tau,τ'}
- W (SSM): m_{W'}
- W' (→ tt, g → W'L': m_{W'})

**V**
- Scalar LQ pair (β=1):
  - kin. vars. in e,e',μ,μ',τ,τ'
- Scalar LQ pair (β=1):
  - kin. vars. in μ,μ',τ,τ'
- Scalar LQ pair (β=1):
  - kin. vars. in e,μ,τ,τ'

**New quarks**
- 4th generation: f^t \rightarrow WbWb
- 4th generation: b^b \rightarrow WbWb
- New quark b': b'^{+} → Zb+X, m_{b'}
- Top partner: T \rightarrow t + A_{τ,T}
- Vector-like quark CC, m_{CC}
- Vector-like quark NC, m_{NC}

**Excit. ferm.**
- Excited quarks: Z', jet resonance, m_{Z'}
- Excited leptons: W', jet resonance, m_{W'}

**Techni-hadrons (LSTC)**:
- dielepton, m_{e,e'μ,μ',τ,τ'}
- Techni-hadrons (LSTC): WZ resonance (WWW), m_{W}\_W\_W

**Major. neutr. (LRSM, no mixing)**:
- 2:lep + jets
- W_R (LRSM, no mixing): 2:lep + jets
- H^{±} (DY prod., BR(H^{±} \rightarrow l'\ell)=1): SS ee (μμ), m_{H^{±}}
- Color octet scalar: dijet resonance, m_{ΣOCT}

**Other**

\[ \int dt = (1.0 - 13.0) \text{ fb}^{-1} \]
\[ f_s = 7.8 \text{ TeV} \]

At cut: 7.8 TeV
L (construction int.)

*Only a selection of the available mass limits on new states or phenomena shown*
The ATLAS Detector

- Weight: 7000 tons
- Dimensions: 46 x 22 x 22 m³
- Magnetic Field: 2.6 T (solenoid) and 4.1 T (toroid)
The CMS Detector

Total Weight: 14,500 t.
Overall diameter: 14.60 m
Overall length: 21.60 m
Magnetic field: 4 Tesla
List of publications used

CMS : Searches for long-lived charged particles in pp collisions at sqrt(s)=7 and 8 TeV arXiv:1305.0491v1 [hep-ex] 2 May 2013


ATLAS, Search for long-lived, heavy particles in final states with a muon and multi-track displaced vertex in proton-proton collisions at \( \sqrt{s} = 7 \text{ TeV} \) with the ATLAS detector, arXiv:1210.7451v2 [hep-ex] 22 Mar 2013
ATLAS, Search for direct chargino production in anomaly-mediated supersymmetry breaking models based on a disappearing-track signature in pp collisions at \( \sqrt{s} = 7 \text{ TeV} \) with the ATLAS detector, arXiv:1210.2852v2 [hep-ex] 22 Mar 2013
ATLAS, Search for non-pointing photons in the diphoton and Emiss final state, ATLAS-CONF-2013-016 07 March 2013
CMS, Search for long-lived particles decaying to photons and missing energy in proton-proton collisions at \( \sqrt{s} = 7 \text{ TeV} \), arXiv:1212.1838v1 [hep-ex] 8 Dec 2012

ATLAS, Search for W H production with a light Higgs boson decaying to prompt electron-jets in proton–proton collisions at \( \sqrt{s} = 7 \text{ TeV} \) with the ATLAS detector, arXiv:1302.4403v1 [hep-ex] 18 Feb 2013

ATLAS, Search for a heavy narrow resonance decaying to e\( \mu \), e\( \tau \), or \( \mu \tau \) with the ATLAS detector in s = 7 TeV pp collisions at the LHC, arXiv:1212.1272v2 [hep-ex] 7 Dec 2012

CMS, Search for three-jet resonances in pp collisions at \( \sqrt{s} = 7 \text{ TeV} \), arXiv:1208.2931v2 [hep-ex] 12 Mar 2013
ATLAS, Search for pair production of massive particles decaying into three quarks with the ATLAS detector in \( \sqrt{s} = 7 \text{ TeV} \) pp collisions at the LHC, arXiv:1210.4813v2 [hep-ex] 8 Nov 2012
CMS, Search for RPV supersymmetry with three or more leptons and b-tags, CMS PAS SUS-12-027
ATLAS, ATLAS-CONF-2013-007, 10 Mar 2013