First look at 13 TeV data for the Exotic dilepton search using the ATLAS Detector.
Theoretical Motivation

Many theories Beyond the Standard Model (BSM) predict new phenomena which give rise to dilepton final states, such as narrow resonances or broad non-resonant deviations from the SM in the dilepton invariant mass spectrum.

\[ Z' \]

- Additional Spin-1 Gauge Boson.
- SSM: Simple extension to the SM invoking an additional heavy boson, with same couplings as Z.
- Also motivated by Grand Unified Theories (GUT), such as \( E_6 \). Depends on \( \theta \) mixing of additional U(1) states.

\[
E_6 \rightarrow SO(10) \times U(1)_\psi \rightarrow SU(5) \times U(1)_\chi \times U(1)_\psi
\]

GUT Decomposition SM Forces New Physics

\[
Z'(\theta) = Z'_{\chi} \cos \theta + Z'_{\psi} \sin \theta
\]

- Six commonly motivated values for \( \theta \) lead to different models with specific \( Z' \) states named:
  \( Z'_{\psi}, Z'_{N}, Z'_{\eta}, Z'_{I}, Z'_{S}, Z'_{\chi} \)

Contact Interactions (CI)

- \( q-\ell \) compositeness, depending on energy scale, \( \Lambda \).
- Broad excess over the SM invariant mass spectrum.

\[
\frac{d\sigma}{dm_{\ell\ell}} = \frac{d\sigma_{DY}}{dm_{\ell\ell}} - \eta \frac{F_I}{\Lambda^2} + \frac{F_C}{\Lambda^4}
\]

- Interaction describes a color and isospin singlet with couplings to L/R- handed fermion states.
- \( \eta_{XY} \) describes whether the interference is constructive (-), or destructive (+), and the couplings i.e. \( \eta_{LL} = 1, \eta_{RR} = \eta_{LR} = 0 \)
Table VII. Even though the width of the theoretical cross-sections on $Z'$ SSM (1.5 TeV) gets stronger with decreasing width. At large than in the dimuon channel. The observed (expected) ratio (line) 95% CL upper limits on cross-section times branching fraction ($\sigma \times B$) for the $Z'$ SSM (1.5 TeV) and combined dilepton channel limits are shown for ADD signal in the GRW, Hewett and HLZ formalisms.

Expected and observed lower limits on $\Lambda$ [TeV]

<table>
<thead>
<tr>
<th>Channel</th>
<th>Prior</th>
<th>Left-Left</th>
<th>Left-Right</th>
<th>Right-Right</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exp: $ll$</td>
<td>$1/\Lambda^2$</td>
<td>21.4</td>
<td>14.7</td>
<td>24.8</td>
</tr>
<tr>
<td>Obs: $ll$</td>
<td>$1/\Lambda^2$</td>
<td>21.6</td>
<td>17.2</td>
<td>26.3</td>
</tr>
<tr>
<td>Exp: $ll$</td>
<td>$1/\Lambda^4$</td>
<td>19.1</td>
<td>13.8</td>
<td>23.1</td>
</tr>
<tr>
<td>Obs: $ll$</td>
<td>$1/\Lambda^4$</td>
<td>19.6</td>
<td>15.4</td>
<td>23.8</td>
</tr>
</tbody>
</table>

\[ \int L \, dt = 20.3 \, fb^{-1} \]
\[ \int L \, dt = 20.5 \, fb^{-1} \]

Data 2012
- Z'/$\gamma$
- Top quark
- Dijet & W+Jets
- Diboson
- Z' SSM (1.5 TeV)
- Z' SSM (2.5 TeV)

Resonant
\[ \text{arXiv:1405.4123} \]

Non-Res
\[ \text{arXiv:1407.2410} \]

Width of the resonance template with negligible parton-luminosity effects. Limits on the theoretical cross-sections on $Z'/\gamma$ are also displayed. The 95% CL limits on $\sigma \times B$ for the $Z'$ SSM (2.5 TeV) and combined dilepton channel limits are shown for ADD signal in the GRW, Hewett and HLZ formalisms.
Run-2

With the increase from 8 TeV to 13 TeV in center-of-mass energy, provided by the LHC in Run-2, it is a very exciting time and opportunity to discover new physics!

qq Parton Luminosity Increases by a factor of ~20 at a mass of 3 TeV!

Even more for qq/gg initiated processes (Graviton).

MSTW2008NLO

arXiv:0901.0002

http://www.hep.ph.ic.ac.uk/~wstirlin/plots/plots.html
Signal & Background Processes

The backgrounds to a dilepton search come from: Drell-Yan, Tops, Diboson, and Multi-Jet & W+Jets processes.

<table>
<thead>
<tr>
<th>Process</th>
<th>Generator</th>
<th>Order</th>
<th>Parton Shower</th>
<th>PDF</th>
</tr>
</thead>
<tbody>
<tr>
<td>$q\bar{q} \rightarrow Z/\gamma^{*} \rightarrow \ell^{+}\ell^{-}$</td>
<td>POWHEG [28]</td>
<td>NLO</td>
<td>PYTHIA 8.165 [30]</td>
<td>CT10 [29]</td>
</tr>
<tr>
<td>$t\bar{t} \rightarrow \ell X$, $Wt \rightarrow X$</td>
<td>POWHEG [28]</td>
<td>NLO</td>
<td>PYTHIA 6.400 [35]</td>
<td>CT10 [29]</td>
</tr>
<tr>
<td>$WW, WZ, ZZ \rightarrow \ell X/\ell\nu/\ell\ell$</td>
<td>SHERPA 2.1.1 [33]</td>
<td>NLO</td>
<td>SHERPA 2.1.1 [33]</td>
<td>CT10 [29]</td>
</tr>
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<td>$q\bar{q} \rightarrow Z/\gamma^{*} \rightarrow \ell^{+}\ell^{-}$</td>
<td>PYTHIA 8.165 [30]</td>
<td>LO</td>
<td>PYTHIA 8.165 [30]</td>
<td>NNPDF23LO [34]</td>
</tr>
<tr>
<td>$q\bar{q} \rightarrow Z^{'} \rightarrow \ell^{+}\ell^{-}$</td>
<td>PYTHIA 8.165 [30]</td>
<td>LO</td>
<td>PYTHIA 8.165 [30]</td>
<td>NNPDF23LO [34]</td>
</tr>
<tr>
<td>CI: $q\bar{q} \rightarrow \ell^{+}\ell^{-}$</td>
<td>PYTHIA 8.165 [30]</td>
<td>LO</td>
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</table>

Most of these are estimated using Monte Carlo, and corrected to NNLO where possible.

The Multi-Jet & W+Jets background, which is relevant in the electron channel, is estimated using a Data-Driven Method.

This contribution is expected to be small, and there are not enough statistics to produce an estimate in the plots shown today.
Event Selection

<table>
<thead>
<tr>
<th>Electron Channel</th>
<th>Muon Channel</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Event-Level Criteria</strong></td>
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<tr>
<td>Require low pT threshold, non-prescaled triggers.</td>
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<td>Perform event cleaning to remove “noisy” events.</td>
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<td>Require at least two electrons or muons in the event.</td>
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<th><strong>Lepton-Level Criteria.</strong></th>
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</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$</td>
</tr>
<tr>
<td>Remove electrons with bad calo clusters</td>
<td>High-$p_T$ req. based on ID and MS hits</td>
</tr>
<tr>
<td>$E_T &gt; 30$ GeV</td>
<td>$d_0$ impact parameter requirement</td>
</tr>
<tr>
<td>$d_0$ impact parameter requirement</td>
<td>$z_0$ impact parameter requirement</td>
</tr>
<tr>
<td>e-identification = Likelihood “Medium”</td>
<td>Muon must be well isolated</td>
</tr>
<tr>
<td>Electron must be well Isolated</td>
<td>Opposite charge sign</td>
</tr>
</tbody>
</table>

**Select Highest $E_T/p_T$ Pair**

| Dielectron Invariant Mass > 80 GeV | Dimuon Invariant Mass > 80 GeV |
Dielectron invariant mass ($m_{ee}$) distribution after the dilepton search event selection, showing the stacked sum of all expected Monte Carlo backgrounds. The Data-Driven Multi-Jet & W+Jets background is not included, but is expected to be small. Events are selected which have two electrons with $E_T$ greater than 30 GeV, $|\eta| < 2.47$ (also excluding the crack region), and are well isolated. The bin width is constant in $\log(m_{\ell\ell})$, and the Monte Carlo expectation is normalised to data in the invariant mass region 80–120 GeV. The previous search results at 8 TeV can be found at: arXiv:1405.4123.
Highest dielectron invariant mass event. The highest momentum electron has an $E_T$ of 189 GeV and an $\eta$ of 1.08. The subleading electron has an $E_T$ of 177 GeV and an $\eta$ of -1.58. The invariant mass of the pair is 739 GeV.
Dimuon invariant mass ($m_{\mu\mu}$) distribution after the dilepton search event selection, showing the stacked sum of all expected backgrounds. Events are selected which have two muons with $p_T$ greater than 30 GeV, $|\eta| < 2.5$, and are well isolated. The bin width is constant in $\log(m_{\ell\ell})$, and the Monte Carlo expectation is normalised to data in the invariant mass region 80–120 GeV. The previous search results at 8 TeV can be found at: arXiv:1405.4123.
Highest dimuon invariant mass event. The highest momentum muon has a $p_T$ of 305 GeV and an $\eta$ of -1.03. The subleading muon has a $p_T$ of 300 GeV and an $\eta$ of 0.82. The invariant mass of the pair is 881 GeV.
Conclusion and Plans

- We have presented a first look at 13 TeV data using 78 /pb of integrated luminosity, when applying the dilepton search event selection for Run-2.

- Data/MC agreement looks good with the current dataset, and we estimate that ~2-3 /fb are needed to exceed our Run-I sensitivity.

- Focus on being ready for a discovery, we’re not starting in limit setting mode!

50 ns Data.
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A New Discovery Could Be Just Around The Beam Pipe..... ....And We’re Ready!
Backup

Theoretician's Cat

Experimentalist's Cat

Link to Public Result: