Search for Supersymmetry in multileptonic final states

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Why looking into multi-lepton events?

The four-lepton final state, rare in the Standard Model, is an attractive channel for the search of supersymmetry. Charged decay-leptons may arise from the cascade decays of SUSY particles to the lightest supersymmetric particle (LSP), or from R-parity violating (RPV) decays of the LSP itself to Standard Model particles. A search for Supersymmetry in events with at least four charged leptons has been performed in 36 fb⁻¹ data at \( \sqrt{s} = 13 \text{ TeV} \) recorded by the ATLAS experiment. Final states with zero to two \( \tau \) leptons have been considered for this analysis. The results are interpreted in terms of RPV and GGM simplified models.

R-Parity violating (RPV) simplified models

Focus on all possible electroweak production modes \((\tilde{\chi}^{\pm}, \tilde{\chi}^{0}, \tilde{\nu})\)

LSP decays to leptons due to \( W_{L,L',E} \) or \( \tau \)-rich \((\lambda_{AB})\) or \( \tau \)-depleted \((\lambda_{CD})\) final-states studied

General Gauge Mediation (GGM)

Higgsino like \( \tilde{\chi}^{\pm}_{1,2} \) triplet produced in pp collisions

Each \( \tilde{\chi} \) decays to \( Z/h \) stable G-LSP

\( Z/h \)-boson cascade further to two same-flavour \((SFO)\) \( e/\mu \)-pairs

Object & event selection

Electrons

- \( p_T > 7 \text{ GeV} \), \( |\eta| < 2.47 \)
- \( p_T > 5 \text{ GeV} \), \( |\eta| < 2.7 \)
- \( p_T > 20 \text{ GeV} \), \( |\eta| < 2.47 \)

Impact parameter & modified isolation requirements

Signal Regions \((SROA,B,SRL,SR2)\) targeting for RPV models

are defined using the effective mass

\[ m_{\text{eff}} = |E_{\text{T}}| + \sum_{c=1}^{4} |p_T| + \sum_{c=1}^{4} |p_T| \]

and vetoing any \( \tau \) candidate.

The regions SRO/C/D are optimized for signature of the GGM model, which involves the presence of two \( Z \) bosons and a large amount of \( |E_{\text{T}}| \).

Observations

Sample

<table>
<thead>
<tr>
<th>SROA</th>
<th>SROB</th>
<th>SROC</th>
<th>SROD</th>
<th>SR1</th>
<th>SR2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observed</td>
<td>13</td>
<td>2</td>
<td>47</td>
<td>10</td>
<td>8</td>
</tr>
<tr>
<td>SM Total</td>
<td>10.2 ( \pm ) 2.1</td>
<td>1.3 ( \pm ) 0.24</td>
<td>37 ( \pm ) 9</td>
<td>4.1 ( \pm ) 0.7</td>
<td>4.9 ( \pm ) 1.6</td>
</tr>
<tr>
<td>( \Delta p_T/M_{\text{eff}} ) (fb)</td>
<td>0.32</td>
<td>0.14</td>
<td>0.87</td>
<td>0.36</td>
<td>0.28</td>
</tr>
<tr>
<td>( \Delta \phi ) (rad)</td>
<td>12</td>
<td>4.9</td>
<td>33</td>
<td>13</td>
<td>13</td>
</tr>
<tr>
<td>( \Delta \theta ) (rad)</td>
<td>9.3 ( \pm ) 3.2</td>
<td>3.9 ( \pm ) 1.1</td>
<td>23 ( \pm ) 1.2</td>
<td>6.1 ( \pm ) 1.1</td>
<td>6.5 ( \pm ) 1.1</td>
</tr>
<tr>
<td>( \Delta \phi ) (rad)</td>
<td>0.76</td>
<td>0.74</td>
<td>0.83</td>
<td>0.99</td>
<td>0.86</td>
</tr>
<tr>
<td>( \Delta p_T/M_{\text{eff}} ) (fb)</td>
<td>0.23</td>
<td>0.25</td>
<td>0.15</td>
<td>0.01</td>
<td>0.13</td>
</tr>
<tr>
<td>( Z )</td>
<td>0.75</td>
<td>0.69</td>
<td>1.0</td>
<td>2.3</td>
<td>1.2</td>
</tr>
</tbody>
</table>

The background-enriched validation regions show a good data-simulation agreement. No significant excess has been observed in any signal region except for SROD where a small excess of 2.3 \( \sigma \) is observed. The results have been used to derive the exclusion limit contours at 95\% C.L. for each model.