Electroweak SUSY searches in Compressed SUSY Scenarios using the $3$-Lepton+$E_T^{\text{miss}}$ signature

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Outline

★ Motivation for Electroweak SUSY

★ Current 8 TeV Results

★ Nature of Compressed Spectra

★ Using the Initial State Radiation (ISR) as a Probe into Compressed Scenarios

★ Looking Into the Future

★ Summary & Outlook
Motivation for Electroweak SUSY

Why Electroweak SUSY?

- Current LHC limits push squark/gluino masses to > 1 TeV.
- If gauginos and higgsinos are light then weak production will dominate.
- May lead to signatures with multiple leptons and $E_T^{miss}$ - low SM background.

arXiv:1412.2784
SUSY 3-Lepton Signature

Three isolated, hard leptons.

Use sizeable lepton $p_T$ cuts and tight isolation requirements.
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For $W$-boson mass, using transverse mass calculation with lepton not from $Z$ boson decay

Reconstruct $Z$-boson mass using same flavour opposite sign lepton pair invariant mass

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Neutrinos and lightest neutralinos seen as $E_T^{\text{miss}}$ in final state. Target with sizeable $E_T^{\text{miss}}$ requirements.
Existing 8 TeV 3L Analyses

Twenty-five signal regions (SRs) to target four decay scenarios for chargino neutralino production. Regions are statistically combined for optimal sensitivity. Background estimated using MC and data-driven methods (Matrix Method).

Key Variables

<table>
<thead>
<tr>
<th>Signal region</th>
<th>SR0τa</th>
<th>SR0τb</th>
<th>SR1τ</th>
<th>SR2τa</th>
<th>SR2τb</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flavour/sign</td>
<td>ℓ⁺ℓ⁻ℓ⁺, ℓ⁺ℓ⁻ℓ⁺</td>
<td>ℓ⁺ℓ⁻ℓ⁺, ℓ⁺ℓ⁻ℓ⁺</td>
<td>ℓ⁺ℓ⁻ℓ⁺, ℓ⁺ℓ⁻ℓ⁺</td>
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<td>ℓ⁺ℓ⁻ℓ⁺, ℓ⁺ℓ⁻ℓ⁺</td>
</tr>
<tr>
<td>b-tagged jet</td>
<td>veto</td>
<td>veto</td>
<td>veto</td>
<td>veto</td>
<td>veto</td>
</tr>
<tr>
<td>( E_T^{miss} )</td>
<td>binned</td>
<td>&gt; 50</td>
<td>&gt; 50</td>
<td>&gt; 50</td>
<td>&gt; 60</td>
</tr>
<tr>
<td>Other</td>
<td>( m_{SFO} ) binned</td>
<td>( p_{T}^{\ell \ell \ell} &gt; 20 )</td>
<td>( p_{T}^{\ell \ell \ell} &gt; 30 )</td>
<td>( m_{T2}^{\max} &gt; 100 )</td>
<td>( \sum p_{T} &gt; 110 )</td>
</tr>
<tr>
<td>( m_T ) binned</td>
<td>( \Delta \phi_{\ell \ell \ell} \leq 1.0 )</td>
<td>( \sum p_{T} &gt; 70 )</td>
<td>( m_{\ell \ell} &lt; 120 )</td>
<td>( m_{\ell \ell} ) Z veto</td>
<td></td>
</tr>
</tbody>
</table>

Target model ℓ⁺WZ-mediated Wh-mediated Wh-mediated \( \tau_L \)-mediated Wh-mediated

31/03/15 Y. Shehu - U.of Sussex - IOP Meeting 2015
Existing 8 TeV 3L Yields and Limits

Observed and expected 95% CL exclusion contours for $\tilde{\chi}_1^\pm \tilde{\chi}_2^0$ production for:

- Via Slepton/WZ: large improvements wrt 7 TeV results (blue line)
- NO SUSY YET!!

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Is SUSY hiding in Compressed Spectra?

Compressed scenarios are where the mass gap between the $\tilde{\chi}_1^\pm$ and $\tilde{\chi}_2^0$ and the $\tilde{\chi}_1^0$ is of order 10 – 50 GeV.

- Leptons are soft.
- Experimentally challenging for triggering
- Experimentally challenging for particle reconstruction and identification.

Ewk Combined Summary Plot
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To improve the search sensitivity to **small mass gap** regions can utilize a **hard initial state radiation** (ISR). **Explored combined** lepton+jet+$E_T^{\text{miss}}$ to trigger on ISR.
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Using ISR allows soft lepton final states to be explored. Used Multilepton triggers with lower pt thresholds.
Discriminating Variables

For compressed signal points, final state leptons are soft. This can be used to discriminate against hard leptons from SM background. Direction of $E_T^{\text{miss}}$ is strongly correlated with (opposite to) the direction of the ISR Jet.

Same Flavour Opposite Sign (SFOS) pairs from compressed points exhibit low invariant mass cut off matching kinematic endpoint.

Signal Optimisation
3L Searches for SUSY at High Luminosity LHC

In addition to compressed spectra, sensitivity to electroweak SUSY 3L signatures explored under high luminosity LHC (HL-LHC) conditions.

Upgrade scenarios at $\sqrt{s} = 14$ TeV:
- $300 \text{ fb}^{-1}$ and $<\mu> \sim 60$ (LHC)
- $3000 \text{ fb}^{-1}$ and $<\mu> \sim 140$ (HL-LHC)

Reoptimisation of 3L analysis under these conditions

Higher energies and luminosities show very substantial improvement sensitivity to electroweak SUSY 3-lepton channel.

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Summary & Outlook

★ **3-Lepton** final states in *electroweak SUSY* processes are key to *potential* discovery of SUSY.

★ Significant region of parameter space explored, however not the compressed region.

★ Final states with *soft leptons* can be explored with an *ISR*.

★ Dedicated signal regions developed to take advantage of *boost* from the *ISR* jet.

★ SUSY 3-lepton searches extended to *High Luminosity LHC conditions*.

★ With *Run-2* data expect greater sensitivity with possibility of *discovery*!

**STAY TUNED**
Back-up
Existing 8 TeV 3L Background Estimation

Two main categories of background:

- **Reducible**: 1 or more fake light lepton/tau. Estimated with data-driven Matrix Method.

- **Irreducible**: Three leptons are all real and prompt in final state.
  - Dominant sources normalised to data in Control Regions.
  - Sub-dominant sources are simulated with MC.

\[
m_T \quad \text{in B-rich validation region (VR0_{\tau\text{noZa}})}
\]

\[
m_{T^2}\text{max} \quad \text{in B-rich validation region (VR2_{\tau a})}
\]

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