SEARCHES FOR SUPERSYMMETRY IN EVENTS CONTAINING A Z BOSON, JETS AND MISSING TRANSVERSE MOMENTUM

NExT Workshop
29 April 2015

Emma Kuwertz on behalf of the ATLAS Collaboration

University of Victoria
Overview

Presenting a search for SUSY in final states with a leptonically decaying Z boson, at least two jets and missing transverse energy (MET).

R-parity conservation

MET from escaping LSPs

Quarks from gluino and squark decays

jets in the final state

Presented here

Recent results from ATLAS: http://arxiv.org/abs/1503.03290 20.3 fb⁻¹, \( \sqrt{s} = 8 \) TeV

Recent results from CMS: http://arxiv.org/abs/1502.06031 19.4 fb⁻¹, \( \sqrt{s} = 8 \) TeV

\( \sigma_{\text{tot}}[^{\text{pb}}]: pp \to \text{SUSY} \)
\( \sqrt{s} = 8 \) TeV
SUSY signal scenarios

Analysis is optimised towards general gauge mediated SUSY models (GGM)
- Gravitino LSP
- *Prompt* higgsino NLSP

Max NLSP decay length ~ 2mm

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**GGM: higgsino-like $\tilde{\chi}_1^0$:**
- $\tan\beta = 1.5$, $M_1 = M_2 = 1$ TeV, $m(\tilde{q}) = 1.5$ TeV

**GGM: higgsino-like $\tilde{\chi}_1^0$:**
- $\tan\beta = 30$, $M_1 = M_2 = 1$ TeV, $m(\tilde{q}) = 1.5$ TeV

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ATLAS
Event selection

- At least 2 isolated leptons
- At least 2 jets
- 2 same-flavour opposite-sign (SFOS) leptons with $81 < m_{\ell\ell} < 101$ GeV

<table>
<thead>
<tr>
<th>On-Z Region</th>
<th>$E_T^{\text{miss}}$ [GeV]</th>
<th>$H_T$ [GeV]</th>
<th>$n_{\text{jets}}$</th>
<th>$m_{\ell\ell}$ [GeV]</th>
<th>SF/DF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Signal regions</td>
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<tr>
<td>SR-Z</td>
<td>&gt; 225</td>
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<td>SF</td>
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<tr>
<td>Seed region</td>
<td>-</td>
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<td>$m_{\ell\ell} \notin [81,101]$</td>
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<td>Validation regions</td>
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</tr>
<tr>
<td>VRZ</td>
<td>&lt; 150</td>
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<td>≥ 2</td>
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## Background estimation overview

<table>
<thead>
<tr>
<th>Background</th>
<th>Estimation method</th>
<th>Generator</th>
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</thead>
<tbody>
<tr>
<td><strong>Fake leptons:</strong></td>
<td></td>
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<tr>
<td>Multi-jets</td>
<td>Matrix method</td>
<td>-</td>
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<td>W $\to$ lnu</td>
<td>Matrix method</td>
<td>-</td>
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<td>Z $\to$ nose</td>
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<td>-</td>
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<tr>
<td>Single top</td>
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<tr>
<td><strong>DY/Z $\to$ ll</strong></td>
<td>Jet smearing</td>
<td>Sherpa</td>
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<tr>
<td>ttbar</td>
<td>Flavour-symmetry</td>
<td>Powheg+Pythia</td>
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<td></td>
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<td>Powheg+Jimmy</td>
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<td></td>
<td></td>
<td>Alpgen</td>
</tr>
<tr>
<td>Single top (Wt)</td>
<td>Flavour-symmetry</td>
<td>Powheg+Pythia</td>
</tr>
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<td>Flavour-symmetry</td>
<td>Powheg</td>
</tr>
<tr>
<td>WZ</td>
<td>MC</td>
<td>Powheg+Pythia8</td>
</tr>
<tr>
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<td>tt+W, tt+WW, tt+Z, t+Z</td>
<td>MC</td>
<td>MadGraph+Pythia</td>
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</table>

**Instrumental MET**

**Dominant backgrounds**

**Data driven backgrounds**

**MC backgrounds**
"Flavour-symmetric" backgrounds

Electron-muon channel $\rightarrow$ same-flavour channel

Estimation strategy

Flavour symmetric

$ee : \mu\mu : e\mu = 1 : 1 : 2$

$N_{ee}^{est.} = \frac{1}{2} N_{e\mu} k_{ee} \alpha$

$N_{\mu\mu}^{est.} = \frac{1}{2} N_{e\mu} k_{\mu\mu} \alpha$

Almost exclusively data-driven method

Estimate in SF channel

Data e-mu channel

Reconstruction efficiency scale factor

Trigger efficiency scale factor

29/04/2015

E. Kuwertz - Z+jets+MET
"Flavour-symmetric" backgrounds

Reconstruction efficiency scale factors

\[ k_{ee} = \sqrt{\frac{N_{ee}^{VRZ}}{N_{\mu\mu}^{VRZ}}}, \quad k_{\mu\mu} = \sqrt{\frac{N_{\mu\mu}^{VRZ}}{N_{ee}^{VRZ}}} \]

Use the number of events selected in Z dominated event samples in data

Trigger efficiency scale factors

\[ \alpha = \sqrt{\frac{\epsilon_{ee}^{\text{trig}}}{\epsilon_{\mu\mu}^{\text{trig}}}} \frac{\epsilon_{ee}}{\epsilon_{\mu\mu}} \]

Different channels use different triggers
→ need to account for this in efficiency correction

Efficiency calculations checked
Side band fit

**Diagram indicating the position in the parameter space, increasing to a maximum value close to the SR.** The second variation, denoted $\text{VRT}$, shows $\text{VRT}/\text{CRT}$ and these VRs is shown in Fig. 3. An overview of the nominal background predictions, using the flavour-symmetry estimate in the on-VRs is also included in Fig. 4.

### Normalise ttbar MC in Z side bands
- Alpgen+Pythia, Powheg+Pythia, Powheg +Jimmy

### Cross check this cross check using identical regions at lower MET

### Flavour-symmetry method also checked!

### Signal region | Flavour-symmetry | Sideband fit
---|---|---
SR-Z $ee$ | $2.8 \pm 1.4$ | $4.9 \pm 1.5$
SR-Z $\mu\mu$ | $3.3 \pm 1.6$ | $5.3 \pm 1.9$

Consistent results from cross-checks
Good agreement in validation regions
Jet smearing method

No real MET in $Z \rightarrow ll$ events

Define a **seed** region

well measured jets low MET

Smear jet $p_T$ and phi with jet response function

Bulk tuned to data using di-jet analysis

Non-Gaussian tails tuned to data using 3-jet analysis

“Pseudo-data”
Jet smearing – Z+jets background

Jet smearing tested on data in Z validation region

MC closure test applying jet smearing to Z+jets MC

Use high statistics Sherpa Z+jets MC to cross check data driven estimate

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<th>Signal region</th>
<th>Jet-smearing</th>
<th>Z+jets MC</th>
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<tr>
<td>SR-Z $ee$</td>
<td>0.05 ± 0.04</td>
<td>0.05 ± 0.03</td>
</tr>
<tr>
<td>SR-Z $\mu\mu$</td>
<td>0.02$^{+0.03}_{-0.02}$</td>
<td>0.09 ± 0.05</td>
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Results are consistent
Fake leptons

“Fake” lepton background:
- lepton from heavy flavour decay,
- electron from photon conversion,
- muon from meson decaying in flight,
- mis-identified hadron.

The matrix method

Analysis selects isolated leptons → remove isolation criteria

\[ N_{\text{fake}} = \frac{N_{\text{fail}} - (1/\epsilon_{\text{real}} - 1) N_{\text{pass}}}{(1/\epsilon_{\text{fake}} - 1/\epsilon_{\text{real}})} \]

Number of leptons failing isolation
Number of leptons passing isolation
Relative identification efficiency for fake leptons
Relative identification efficiency for real leptons
Results

<table>
<thead>
<tr>
<th>Channel</th>
<th>SR-Z ee</th>
<th>SR-Z $\mu\mu$</th>
<th>SR-Z same-flavour combined</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observed events</td>
<td>16</td>
<td>13</td>
<td>29</td>
</tr>
<tr>
<td>Expected background events</td>
<td>$4.2 \pm 1.6$</td>
<td>$6.4 \pm 2.2$</td>
<td>$10.6 \pm 3.2$</td>
</tr>
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1- Flavour-symmetric backgrounds
- $Z/\gamma^* + \text{jets (jet-smearing)}$: $2.8 \pm 1.4$ events
- Rare top: $0.05 \pm 0.04$ events

2- $WZ/ZZ$ diboson
- Fake leptons: $0.1_{-0.1}^{+0.7}$ events

An excess of events is observed in the signal regions

Excess more apparent in dielectron channel
Unblinded distributions

H\_T distributions

MET distributions
ATLAS vs CMS

CMS search:
- 2 x 3 SRs binned in MET
- No direct $H_T$ cut

100-200 GeV
200-300 GeV
300+ GeV

Optimised for similar signal models

CMS 1
CMS 2
CMS 3

MET [GeV]

CMS
ATLAS

$H_T$ [GeV]

Data
Prediction

Entries/10 GeV

ee + $\mu\mu$ events
$n_{jets} \geq 2$

ee + $\mu\mu$ events
$n_{jets} \geq 3$

$E_T^{miss}$ [GeV]

Z background
FS background
$(m(\tilde{q}), m(\tilde{\chi}_0^0))$
$(900, 150)$ GeV
$(1100, 800)$ GeV
Exclusion limits on GGM models

Limits set on GGM models are weaker than expected

Exclude up to $m(\text{gluino}) = 900$ GeV and $\mu = 1000$ GeV

Exclude up to $m(\text{gluino}) = 850$ GeV and $\mu = 900$ GeV
Conclusion and outlook

- ATLAS search for SUSY in final states with a Z boson, jets and MET presented.

- A 3 sigma deviation from the Standard Model expectation was observed.

- CMS reports good agreement with expectation in the same final state – but phase space cuts are different.

- Something to look out for in Run II.

ATLAS search for SUSY in final states with a Z boson, jets and MET presented. A 3 sigma deviation from the Standard Model expectation was observed. CMS reports good agreement with expectation in the same final state – but phase space cuts are different. Something to look out for in Run II.