Search for General Gauge Mediated SUSY Breaking with Photons

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On behalf of the CMS collaboration

Meeting of Department of Particle and Field
Providence, RI 8/8-8/15/2011
Introduction

- **General Gauge-Mediation Supersymmetry**
  - Neutralino is the next-to-lightest supersymmetric particle (bino, wino or higgsino)
  - Gravitino is the lightest particle.
  - Mass of strongly interacting SUSY partners can be light→large production production at LHC

Two photons + ME$_T$

Lepton+photon+ME$_T$
Event Selection

- Two photons + ME_T
  - 2 isolated photons with E_T > 30 GeV and |\eta| < 1.379
  - Require at least one jet (0.5-cone anti-k_T jet) with ET > 30 GeV and |\eta| < 2.6
  - Jets are separated from both photon candidates by \( \Delta R = 0.9 \)

- Lepton+photon+ME_T
  - Isolated electron or muon and isolated gamma, \( \Delta R > 0.4 \)
  - Include EB and EE electron with p_T > 20 GeV
  - \( \eta_{\text{muon}} < 2.1 \)
  - At least one good vertex and no jet requirement
Backgrounds

- **Two photons** + \( M_{E_T} \)
  - QCD with fake \( M_{E_T} \): multijet production, photon+jet, diphotons
  - Electroweak with real MET: \( W(\nu\gamma) \), \( W(e\gamma) \)+jet
  - Irreducible backgrounds: \( W\gamma\gamma \), \( Z\gamma\gamma \)

- **Lepton** + photon + \( M_{E_T} \)
  - \( W\gamma \) production
  - Instrument backgrounds with misidentified leptons and photons
    - Jet or electron misidentified as photons: \( W+\)jet, QCD multijet, \( Z \) and \( t\bar{t} \) production
  - QCD with fake \( M_{E_T} \)
Two photons+\text{ME}_T
QCD Backgrounds

- Model the $\mathbf{M}_{\mathcal{E}_T}$ using a data control sample containing 2 EM objects.
  - EM objects can be
    - Fake photons (identical to photons except fail showershape ($\sigma_{\text{IetaEta}}$ cut), may fail pixel match veto and good timing)
    - Electrons (identical to photons but have a matched pixel seed)
  - Reweight the model $\mathbf{M}_{\mathcal{E}_T}$ to take into account the kinematic differences between control and candidate samples. (the weight factors coming from comparing the $p_T$ spectrum of di-EM system in control and candidate samples)

- Normalize the model $\mathbf{M}_{\mathcal{E}_T}$ to $\mathbf{M}_{\mathcal{E}_T} < 20$ GeV in the candidate sample.
Electroweak Background with Real $\mathrm{MET}$

- $W+\gamma$ and $W+\text{jet}$ contribute to the background if electrons is misidentified as photons.
- Model $\mathrm{MET}$ from egamma control sample.
- Reweight the $\mathrm{MET}$ using the probability of electron misidentified as photons, $f_{e\rightarrow\gamma} = 1.4 \pm 0.4\%$
MET Distribution of Two Photons + ME_{T}

Good agreement between estimated background and observed data

Example GGM

Example GGM model:
\( m_{\tilde{g}} = 720 \text{ GeV}, m_{\tilde{q}} = 720 \text{ GeV}, m_{\chi_{1}^0} = 150 \text{ GeV} \)

<table>
<thead>
<tr>
<th>Type</th>
<th>Number of events</th>
<th>Stat error</th>
<th>Reweight error</th>
<th>Normalization error</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \gamma \gamma ) events</td>
<td>1</td>
<td>( 0.04 \pm 0.03 )</td>
<td>( \pm 0.02 )</td>
<td>( \pm 0.01 )</td>
</tr>
<tr>
<td>Electroweak background estimate (ff)</td>
<td>( 0.49 \pm 0.37 )</td>
<td>( \pm 0.36 )</td>
<td>( \pm 0.06 )</td>
<td>( \pm 0.07 )</td>
</tr>
<tr>
<td>QCD background estimate (ff)</td>
<td>( 1.67 \pm 0.64 )</td>
<td>( \pm 0.46 )</td>
<td>( \pm 0.38 )</td>
<td>( \pm 0.23 )</td>
</tr>
<tr>
<td>Total background (using ff)</td>
<td>( 0.53 \pm 0.37 )</td>
<td>( \pm 0.36 )</td>
<td>( \pm 0.06 )</td>
<td>( \pm 0.07 )</td>
</tr>
<tr>
<td>Total background (using ee)</td>
<td>( 1.71 \pm 0.64 )</td>
<td>( \pm 0.46 )</td>
<td>( \pm 0.38 )</td>
<td>( \pm 0.23 )</td>
</tr>
<tr>
<td>Combined total background</td>
<td>( 1.2 \pm 0.8 )</td>
<td>( \pm 0.02 )</td>
<td>( \pm 0.01 )</td>
<td></td>
</tr>
<tr>
<td>Expected from GGM sample point</td>
<td>( 8.0 \pm 1.7 )</td>
<td>( \pm 0.02 )</td>
<td>( \pm 0.01 )</td>
<td></td>
</tr>
</tbody>
</table>
Check Background Estimation

- Check to see if QCD background estimation method works?
- Reweight the di-electron $M_{E_T}$ spectrum by matching di-electron $p_T$ spectrum to that of di-EM spectrum.
- Excess is observed, which is consistent with $W\gamma$ and $W$+jet MC
Limits on GGM Model

Upper 95%CL cross section limits for 150 GeV neutralino mass

95% CL exclusions limits

CMS
36 pb⁻¹
\(\sqrt{s} = 7 \text{ TeV}\)
Lepton+photon+$\text{ME}_T$
Backgrounds (I)

- $W\rightarrow e\nu\gamma$, $W\rightarrow \mu\nu\gamma$
  - Estimated in MC simulation using MadGraph+Pythia
  - K-factor to correct for NLO effect.
    - NLO cross section obtained from WGRAD NLO Wgamma generator with CTEQ6.6 NLO PDF
    - K-factor in the range of 1.5-1.6 depending on photon $E_T$

- Instrument backgrounds:
  - Jet-$\gamma$ backgrounds:
    - Control sample: lepton+fakeable photon (from jet)
    - Weight the MET of control sample by jet-$\gamma$ fake rate
  - Electron-$\gamma$ backgrounds
    - Control sample: lepton+fakeable photon (from electron)
    - Weight the $M_{E_T}$ of control sample by electron-$\gamma$ fake rate
Background (II)

- **Qcd background:**
  - Di-electron samples as the control sample
  - Reweight events from control sample to produce candidate event lepton+gamma kinematics:
    - Reproduce the lepton+γ transverse energy distribution
    - Lepton $p_T$ is also reweighted to reproduce the transverse mass of lepton+ME$_T$
  - Normalized the model ME$_T$ at ME$_T < 30$ GeV in the control sample
**MET Distribution of Candidate Sample**

**Table:**

<table>
<thead>
<tr>
<th>Process</th>
<th>No $E_T^{miss}$ selection</th>
<th>$E_T^{miss} &gt; 40$ GeV</th>
<th>$E_T^{miss} &gt; 100$ GeV</th>
</tr>
</thead>
<tbody>
<tr>
<td>$W\gamma$</td>
<td>44.5 ± 9.2</td>
<td>16.1 ± 3.4</td>
<td>1.68 ± 0.42</td>
</tr>
<tr>
<td>jet $\rightarrow$ $\gamma$</td>
<td>20.3 ± 4.5</td>
<td>3.1 ± 0.9</td>
<td>0.02 ± 0.02</td>
</tr>
<tr>
<td>$e \rightarrow$ $\gamma$</td>
<td>70.5 ± 19.1</td>
<td>0.3 ± 0.1</td>
<td>0.04 ± 0.03</td>
</tr>
<tr>
<td>QCD</td>
<td>134 ± 28</td>
<td>0.4 ± 0.2</td>
<td>0.00 ± 0.00</td>
</tr>
<tr>
<td>Total background</td>
<td>269 ± 18</td>
<td>19.9 ± 3.7</td>
<td>1.74 ± 0.43</td>
</tr>
<tr>
<td>data</td>
<td>264</td>
<td>16</td>
<td>1</td>
</tr>
<tr>
<td>SUSY GMC prediction</td>
<td>3.94 ± 0.79</td>
<td>3.76 ± 0.75</td>
<td>2.79 ± 0.56</td>
</tr>
</tbody>
</table>
Lepton pT distributions
Limits

95% CL upper cross section limits

95% CL exclusion limits on squark/gluino mass and wino mass
Conclusions

- Searches for gauge-mediation SUSY scenario are performed in the two photons+$\text{MET}$ and lepton+photon+$\text{MET}$ channels.
- No excess of events has been found in these channel and the most stringent exclusion limits to date are set for squark and gluino (two photons+$\text{MET}$), squark, gluino and wino masses (lepton+photon+$\text{MET}$).