Search for diphoton events with large missing transverse energy at DO

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for DO collaboration
Outline

❖ Introduction
❖ Experimental Apparatus
❖ Event Selection
❖ Background Estimation
❖ Results
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Introduction

- Standard Model (SM) predicts low rate for high $p_T \gamma\gamma$ with large Missing Transverse Energy (MET)
- A sensitive channel to probe new physics beyond SM
- Two benchmark models are explored
  - Gauge Mediated Supersymmetry (SUSY) Breaking (GMSB)
    - SPS8 is used, effective SUSY breaking scale $\Lambda$
    - the next-to-lightest SUSY particle (NLSP) is the lightest neutralino, which decays to a photon and massless gravitino
  - Universal Extra Dimensions (UED)
    - a single UED compactified with radius $R_C$
    - the lightest Kaluza-Klein (KK) particle (LKP) is the KK photon, which decays to a photon and a graviton
  - both resulting in the final state $\gamma\gamma + \text{MET} + X$
Tevatron @ Fermilab

- Tevatron: $p\bar{p}$ collider with c.o.m. = 1.96 TeV
Thanks Accelerator Division (AD) for the large dataset!

\[ \mathcal{L}_{\text{int}} = 6.3 \text{ fb}^{-1} \]
DO Detector

- A general multi-purpose detector
- Central tracking system: determines Primary Vertex (PV)
- Calorimeter: detects photon objects and measures MET
- Central Preshower (CPS) detector helps both PV and $\gamma$
Event Selection

❖ Signal Monte Carlo (MC) samples are generated and simulated with GEANT for detector response

❖ Selection criteria:
  ‣ Events with at least two photon candidates satisfying:
    ✓ $E_T > 25 \text{GeV}$ in Central Calorimeter (CC)
    ✓ > 95% energy deposited in EM layers
    ✓ isolated in both calorimeter and tracking system without matched track
    ✓ shower shape consistent with an EM shower
    ✓ NN output to discriminate from jets
  ‣ MET $> 50 \text{ GeV}$
    ✓ correction from EM objects, jets, and $p_T$ of the muons
MET Measurement

- PV identification is crucial
  - $\Delta Z(\text{PV, CPS of EM}) < 10 \text{ cm}$ to reduce the misidentified PV
- $\Delta \phi$ requirements to reduce instrumental sources of MET
  - $\Delta \phi(\text{MET, leading jet}) < 2.5; \Delta \phi_{\text{min}}(\text{MET, } \gamma) > 0.2; \Delta \phi(\gamma, \gamma) > 0.1$

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**Figure**: The difference in $z$ position between the reconstructed and truth primary vertex ($\text{PVZ}_{\text{truth}}$) in SM $\gamma\gamma$ MC events. The PV is misidentified in $\sim 0$% of the events. The highest $E_T$ events in SM $\gamma\gamma$ MC are predominately those where the reconstructed and truth vertex disagree by $>0$ cm. Therefore, $\Delta Z(\text{CPS, PV})$ pointing is effective, although the precision is overestimated in MC. Once a $\Delta Z(\text{CPS, PV}) < 0.0$ cm requirement is made which is sufficiently tight to suppress potential induced $E_T$ events, the difference in efficiency must be taken into account. As stated above, the efficiency to pass a $\Delta Z(\text{CPS, PV}) < 0.0$ cm requirement is $9\%$ in data and $9\%$ in MC. In the following, all diEM subsample events are required to have at least one cluster with a CPS match. Using the single CPS match efficiencies quoted above this requirement is $9\%$ efficient for data and $9\%$ for MC. If the event has only one match, the CPS-PV $z$ position agreement must be within $0.0$ cm. If both clusters have matches, the CPS-CPS agreement must be within $0.0$ cm, and the average CPS $z$ position must agree to within $\pm 0.0$ cm with the PV. A scale factor of $0.89$ is applied to the signal and $W/Z+\gamma\gamma$ MC samples entering the final $E_T$ analysis. A $-0.8$ systematic uncertainty is assigned to this scale factor arising from the statistical error associated with the $Z\gamma$ sample size.
Background Estimation -- I

- Backgrounds with inherent MET
  - SM ($W \rightarrow e\nu$) with electron misidentified as $\gamma$
    - Electron faking photon rate is measured in real data
    - Estimated from $e\gamma$ data after removing possible contaminations
  - SM $\gamma\gamma$+MET events like $\gamma\gamma$ events produced with $W/Z$
    - Estimated using MC
SM events with instrumental MET

- two types:
  - SM $\gamma\gamma$ events
  - events with at least one jet misidentified as $\gamma$ so called misID jet events
  - estimated with data and normalized to control region data ($\text{MET} < 10 \text{ GeV}$)
Systematic Uncertainties

All the systematic uncertainties as shown in the table

<table>
<thead>
<tr>
<th>Component</th>
<th>Systematic</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instrumental $\not{E}_T (\gamma\gamma + \text{jet misID})$</td>
<td>$\gamma\gamma \not{E}_T$ distribution - $ee$ data vs. $\gamma\gamma$ MC jet misID $\not{E}_T$ distribution purity uncertainty</td>
<td>Shape</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Shape</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Shape</td>
</tr>
<tr>
<td>$e\ell$ misID</td>
<td>uncertainty in residual from instrumental $\not{E}_T$ normalization uncertainty (25%) from $e\rightarrow \gamma$ fake rate</td>
<td>Shape</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Flat</td>
</tr>
<tr>
<td>$W/Z + \gamma$</td>
<td>luminosity (6.1%)</td>
<td>Flat</td>
</tr>
<tr>
<td></td>
<td>CPS-PV scale factor (3%)</td>
<td>Flat</td>
</tr>
<tr>
<td></td>
<td>PhotonID (3% per photon)</td>
<td>Flat</td>
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<tr>
<td></td>
<td>Trigger (2%)</td>
<td>Flat</td>
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<td></td>
<td></td>
<td>Flat</td>
</tr>
<tr>
<td>GMSB and UED Signal</td>
<td>luminosity (6.1%)</td>
<td>Flat</td>
</tr>
<tr>
<td></td>
<td>CPS-PV scale factor (3%)</td>
<td>Flat</td>
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<td>Trigger (2%)</td>
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</tr>
<tr>
<td></td>
<td>PDFs (5% GMSB, 20% UED)</td>
<td>Flat</td>
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</tbody>
</table>
Results

- No evidence for BSM is observed
- GMSB: $\Lambda < 124$ TeV ($m_{\chi_0^1} < 175$ GeV) excluded at 95% C.L.
- UED: $R_c^{-1} < 477$ GeV excluded at 95% C.L.

![Graphs showing cross sections and limits for GMSB and UED models.]

<table>
<thead>
<tr>
<th>$E_T$ Interval, GeV</th>
<th>Observed Events</th>
<th>Instr. $E_T$</th>
<th>Genuine $E_T$</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>35 – 50</td>
<td>18</td>
<td>9.6 ± 1.9</td>
<td>2.3 ± 0.5</td>
<td>11.9 ± 2.0</td>
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<tr>
<td>50 – 75</td>
<td>3</td>
<td>3.5 ± 0.8</td>
<td>1.5 ± 0.3</td>
<td>5.0 ± 0.9</td>
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<tr>
<td>&gt; 75</td>
<td>1</td>
<td>1.1 ± 0.4</td>
<td>0.8 ± 0.1</td>
<td>1.9 ± 0.4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Expected Signal Events</th>
<th>GMSB $\Lambda = 100$ TeV</th>
<th>GMSB $\Lambda = 120$ TeV</th>
<th>UED $R_c^{-1} = 420$ GeV</th>
<th>UED $R_c^{-1} = 460$ GeV</th>
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<tbody>
<tr>
<td></td>
<td>1.8 ± 0.1</td>
<td>0.3 ± 0.1</td>
<td>1.4 ± 0.1</td>
<td>0.3 ± 0.1</td>
</tr>
<tr>
<td></td>
<td>4.1 ± 0.3</td>
<td>0.8 ± 0.1</td>
<td>2.9 ± 0.2</td>
<td>0.6 ± 0.1</td>
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<tr>
<td></td>
<td>14.3 ± 1.1</td>
<td>4.4 ± 0.4</td>
<td>24.7 ± 2.0</td>
<td>6.4 ± 0.5</td>
</tr>
</tbody>
</table>
Conclusions

❖ No evidence for BSM is observed in $\gamma\gamma + \text{MET} + X$ samples

❖ Results are interpreted with two benchmark models

› SPS8 GMSB:
  ✓ $\Lambda < 124$ TeV excluded at 95% C.L.
  ✓ $m_{\chi_0^1} < 175$ GeV excluded at 95% C.L.

› UED:
  ✓ $R_c^{-1} < 477$ GeV excluded at 95% C.L.

❖ Published on PRL 105, 221802 (2010) also available @arxiv: 1008.2133
Thank you!
Backup Slides
The GMSB model parameters:

- **SPS8**:
  - $M_{\text{mes}} = 2\Lambda$, $N_{\text{mes}} = 1$, $\tan\beta = 15$, $\text{sgn}(\mu) > 0$, and $\Lambda$ is free
CPS confirmed PV

- Use CPS associated with the photon to confirm the PV identification

Figure 8: The left plot shows the $\gamma\gamma$ distribution in SM MC events with a correctly identified PV before and after the EM-CPS pointing confirmation, while the right plot shows the distribution in events with an incorrectly identified PV. The pointing confirmation substantially suppresses the later class of events.

Figure 9: The CPS match efficiency is shown on the left as a function of $\eta$ in $Z\gamma$ data and MC. The difference in z-position between the reconstructed PV and that predicted by EM-CPS pointing is shown on the right. The arrows indicate the interval of agreement required for the pointing confirmation.