Search for Anomalous Production of Photon+Jets

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On behalf of the CDF collaboration

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Outline

• Introduction
• Event Selection
• Backgrounds
• Results

CDF Detector
• What are we looking for? photon+jets...

• Why this signature?

• This is a model-independent signature-based search.

• We are doing a semi-blind analysis and look at only 1/10 of the total available integrated luminosity.
Datasets

- CDF Run II data collected through 2002-2007
  - Total integrated luminosity for the entire sample = 2.0 fb$^{-1}$
  - We use events with event number divisible by 10.
  - Effective integrated luminosity for these results = 200 pb$^{-1}$
- Pythia tune A inclusive photon Monte Carlo with photon $p_T > 22$ GeV.
- Pythia tune A inclusive electroweak Monte Carlo samples.

<table>
<thead>
<tr>
<th>$Z \rightarrow ee$ ($M_{ee} &gt; 20$ GeV)</th>
<th>$W \rightarrow e\nu$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$Z \rightarrow \mu\mu$ ($M_{\mu\mu} &gt; 20$ GeV)</td>
<td>$W \rightarrow \mu\nu$</td>
</tr>
<tr>
<td>$Z \rightarrow \tau\tau$ ($M_{\tau\tau} &gt; 20$ GeV)</td>
<td>$W \rightarrow \tau\nu$</td>
</tr>
</tbody>
</table>
• Require a reconstructed primary vertex
• Require a trigger photon passing tight photon ID cuts ($E_T > 30 \text{ GeV, central}$)
• Photon must be in-time $\rightarrow$ Cosmic veto
• Reject beam halo
• No track $\rightarrow$ lepton veto
• One or more jets, $E_T > 15 \text{ GeV and } |\eta| < 3.0$
Backgrounds

- Non-collision
- PMT (Photomultiplier tube) spikes
- Beam halo
- Cosmic rays
- Standard model processes where lepton fakes photon
  - W, Z
- QCD Multi-jets (where a jet fakes a photon)
- Standard model prompt photons
Background Rejection

PMT Spike: Can reject 100% using PMT asymmetry.

Cosmic: Use calorimeter EM timing, require photon to be \(-4.8\) ns and \(+4.8\) ns.

\[
PMT\ \text{Asymmetry} = \frac{|E_{PMT1}^P - E_{PMT2}^P|}{E_{PMT1}^P + E_{PMT2}^P}
\]
Background Rejection II

Beam halo: Use topological cuts (see backup slides). We have a rejection power of ~95%
Reject leptons by finding track or track segments.
Background Templates

- Two major backgrounds
  - SM Photon
    - Use photon MC
  - QCD Multi-jet
    - We invert one of the photon selection cuts to select a region with large fake photon fraction.
- Normalize the sum of these two background to the data minus other backgrounds.
Summary of Backgrounds

- We have ~400k signal events (1/10)
- All background predictions are for the entire dataset. We scale it down by a factor of 10 to make the plots.

<table>
<thead>
<tr>
<th>Main Backgrounds</th>
<th>&gt;= 1 Jets</th>
<th>&gt;= 2 Jets</th>
</tr>
</thead>
<tbody>
<tr>
<td>SM Photon</td>
<td>2.6M</td>
<td>650k</td>
</tr>
<tr>
<td>QCD Multi-jet</td>
<td>1M</td>
<td>280k</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Other Backgrounds</th>
<th>&gt;= 1 Jets</th>
<th>&gt;= 2 Jets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electron</td>
<td>459</td>
<td>111</td>
</tr>
<tr>
<td>Cosmic</td>
<td>110±9</td>
<td>7±2</td>
</tr>
<tr>
<td>Beam halo</td>
<td>9</td>
<td>&lt;1</td>
</tr>
<tr>
<td>PMT Spikes</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
Results

Photon \( E_T \geq 1 \) Jet

Photon \( E_T \geq 2 \) Jets
Results II

CDF Run II Preliminary 2.0 fb⁻¹

Photon + Leading Jet
Invariant Mass

CDF Run II Preliminary 2.0 fb⁻¹

Photon + 2 Leading Jets
Invariant Mass
Jet Multiplicity for Photon + ≥1 Jet
Summary and Outlook

• We have studied photon+jet events in CDF data.

• Looked at 1/10 of the data sample and found a very good agreement between data and the background predictions.

• Plan to improve background rejections and estimates.

• Look only at events with significant MET.

• Open the box and scan the full dataset.

• Will look for resonance (bump).

Thank you.
Backup Slides
Systematics

- We have used two different approaches.
  - 32% photon sideband and 68% photon Monte Carlo
  - 100% photon sideband
• When we use the 32% photon sideband and 68% photon Monte Carlo mixture, vary the mixture.

• When we use 100% photon sideband,
  • Vary cuts common(HadEm/Iso/TrkPt/TrkIso) to both loose and tight photon ID cuts
  • Tighten up one cut at a time and run the sideband sample through this modified set of cuts.
  • Normalize to sideband and divide by the sideband.
  • Repeat for all 4 and take the maximum variation out of the 4 in each bin as the systematic for that bin.
Systematics III

- Jet Energy Scale
- Photon EM energy (~1%)
- For EWK: Use the uncertainty in luminosity (~6%) to vary the normalization.
- For Cosmics: Use a smaller time window and compare the predictions.
- For Beam Halo: Assign a 50% error.
# Tight Photon ID cuts

<table>
<thead>
<tr>
<th>Variable</th>
<th>Cut value</th>
</tr>
</thead>
<tbody>
<tr>
<td>detector</td>
<td>central</td>
</tr>
<tr>
<td>$E_T^{corr}$</td>
<td>$&gt; 30$ GeV</td>
</tr>
<tr>
<td>CES X and Z fiducial</td>
<td>$</td>
</tr>
<tr>
<td></td>
<td>$9$ cm $\leq</td>
</tr>
<tr>
<td>Had/Em</td>
<td>$\leq 0.125 \parallel \leq 0.055 + 0.00045 \times E_T^{corr}$</td>
</tr>
<tr>
<td>$E_T^{iso(corr)}$ in cone 0.4</td>
<td>$\leq 0.1 \times E_T^{corr}$ if $E_T^{corr} &lt; 20$ GeV</td>
</tr>
<tr>
<td></td>
<td>$\leq 2.0 + 0.02 \times (E_T^{corr} - 20)$ if $E_T^{corr} &gt; 20$ GeV</td>
</tr>
<tr>
<td>average CES $\chi^2$ (Strips+Wires)/2</td>
<td>$\leq 20$</td>
</tr>
<tr>
<td>N tracks in cluster (N3D)</td>
<td>$\leq 1$</td>
</tr>
<tr>
<td>Track $p_T$</td>
<td>$&lt; 1 + 0.005 \times E_T^{corr}$</td>
</tr>
<tr>
<td>Track Iso(0.4)</td>
<td>$&lt; 2.0 + 0.005 \times E_T^{corr}$</td>
</tr>
<tr>
<td>2nd CES cluster $E \times \sin(\theta)$ (both wire and strip E individually)</td>
<td>$\leq 0.14 \times E_T^{corr}$ if $E_T^{corr} &lt; 18$ GeV</td>
</tr>
<tr>
<td></td>
<td>$\leq 2.4 + 0.01 \times E_T^{corr}$ if $E_T^{corr} \geq 18$ GeV</td>
</tr>
</tbody>
</table>
## Loose Photon ID cuts

<table>
<thead>
<tr>
<th>Variable</th>
<th>Cut value</th>
</tr>
</thead>
<tbody>
<tr>
<td>detector</td>
<td>central</td>
</tr>
<tr>
<td>$E_T^{corr}$</td>
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<td>$</td>
</tr>
<tr>
<td></td>
<td>$9$ cm $\leq</td>
</tr>
<tr>
<td>Had/Em</td>
<td>$\leq 0.125$</td>
</tr>
<tr>
<td>$E_T^{Iso,(corr)}$ in cone 0.4</td>
<td>$\leq 0.15 \times E_T^{corr}$ if $E_T^{corr} &lt; 20$ GeV</td>
</tr>
<tr>
<td></td>
<td>$\leq 3.0$ if $E_T^{corr} &gt; 20$ GeV</td>
</tr>
<tr>
<td>Track $p_T$</td>
<td>$&lt; 0.25 \times E_T^{corr}$</td>
</tr>
<tr>
<td>Track Iso(0.4)</td>
<td>$&lt; 5.0$</td>
</tr>
</tbody>
</table>

Table 1: Loose Photon ID cuts.
Beam Halo Rejection

<table>
<thead>
<tr>
<th>Halo Type</th>
<th>Selection Cut</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>seedWedge &gt; 8</td>
</tr>
<tr>
<td>1</td>
<td>seedWedge &gt; 4 &amp; Nhad &gt; 1</td>
</tr>
<tr>
<td>2</td>
<td>seedWedge &gt; 4 &amp; Nhad &gt; 2</td>
</tr>
<tr>
<td>3</td>
<td>seedWedge &gt; 7 &amp; Nhad &gt; 2</td>
</tr>
<tr>
<td>4</td>
<td>seedWedge &gt; 8 &amp; Nhad &gt; 2</td>
</tr>
<tr>
<td>5</td>
<td>seedWedge &gt; 8 &amp; Nhad &gt; 3</td>
</tr>
</tbody>
</table>

seedWedge = number of EM towers (Et>0.1 GeV) in same wedge as photon
Nhad = number of plug HAD towers (Et>0.1 GeV) in same wedge as photon
# Photon-like Electron ID cuts

<table>
<thead>
<tr>
<th>Variable</th>
<th>Cut value</th>
</tr>
</thead>
<tbody>
<tr>
<td>detector</td>
<td>central</td>
</tr>
<tr>
<td>conversion</td>
<td>no</td>
</tr>
<tr>
<td>corrected $E_T$</td>
<td>$&gt; 30$ GeV</td>
</tr>
<tr>
<td>CES fiduciality</td>
<td>$</td>
</tr>
<tr>
<td>average CES $\chi^2$</td>
<td>$\leq 20$</td>
</tr>
<tr>
<td>Had/Em</td>
<td>$\leq 0.055 + 0.00045 \times E$</td>
</tr>
<tr>
<td>$E_{T}^{iso(corr)}$ in cone 0.4</td>
<td>$\leq 0.1 \times E_T$ if $E_T &lt; 20$ GeV \n$\leq 2.0 + 0.02 \times (E_T - 20)$ if $E_T \geq 20$ GeV</td>
</tr>
<tr>
<td>N3D tracks in cluster</td>
<td>$= 1, 2$</td>
</tr>
<tr>
<td>$E/p$ of 1st track</td>
<td>$0.8 \leq E/p \leq 1.2$ if $p_T &lt; 50$ GeV \nno cut if $p_T \geq 50$ GeV</td>
</tr>
<tr>
<td>2nd track $p_T$ if N3D = 2</td>
<td>$\leq 1.0 + 0.005 \times E_T$</td>
</tr>
<tr>
<td>TrkIso(0.4) - $p_T$ 1sttrk</td>
<td>$\leq 2.0 + 0.005 \times E_T$</td>
</tr>
<tr>
<td>$E_T$ of 2nd CES cluster (wire and strip)</td>
<td>$\leq 0.14 \times E_T$ if $E_T &lt; 18$ GeV \n$\leq 2.4 + 0.01 \times E_T$ if $E_T \geq 18$ GeV</td>
</tr>
<tr>
<td>$</td>
<td>\Delta z</td>
</tr>
</tbody>
</table>