Anomalous Production of Photon
+Jets (+MET)

CDF Note # 9267

Samantha Hewamanage, Jay Dittmann, Nils Krumnack
Baylor University

Ray Culbertson, Sasha Pronko
Fermilab
Outline

• Intro
• Triggers and Datasets
• Event, Photon, Jet and Signal Selection
• Backgrounds
• Systematics
• Results
Intro

SUSY GMSB processes for Photon+Jet production (source 8378)

SM- Tree level diagrams for Photon+Jet production
Triggers and Datasets

• Triggers
  • PHOTON_25ISO, 50 and 70

• Datasets
  • cph10d, 0h,0i,0j (p0-p13) Lum = 2.0 fb⁻¹ (exclude 1ˢᵗ 400pb⁻¹)

• Photon MC
  • QCD group, PYTHIA-TuneA, Pt > 22 GeV, jqcdfh

• W/Z MC
  • EWK group, PYTHIA, Z→e+e, W→m+m, W→t+t, W→e+n, W→m+n and W→t+n, periods 0-13
General Event Selection

- Require at least one of the three triggers
  - PHOTON_25ISO, 50 and 70
- Must be in good run list (v19_phco)
- $\geq 1$ Class 12 vertices *
- $z < 60$ cm *
- Photon + $\geq 1$ Jet

* Omitted in the Beam Halo Template
Jet Selection

- Cone size =0.4, JetClu
- Remove EM object/s that is used
- Corrected up to level 6 (UE), particle jet
- Require one or more jets with Et >15 GeV
- Can be in Central or plug (EvtEta<3.0)
Selecting the Photon + Jets Signal

1. A photon passing tight photon ID cuts
2. Photon must be in-time (> -4.8ns & <4.8ns)
3. Reject photons with phoenix track
4. Reject if beam halo
5. 1 or more Jets
Backgrounds

- Non-collision
  - PMT spikes
  - Beam halo
  - Cosmics
- SM processes where $e \rightarrow \gamma$
  - largely from Ws.
  - smaller contributions from Zs, di-boson, tau ...
- QCD (jet faking photon)
- SM Photon+Jets (MC based)
## Summary of Backgrounds

<table>
<thead>
<tr>
<th></th>
<th>Photon + ≥1 Jet</th>
<th>Photon + ≥2 Jets</th>
</tr>
</thead>
<tbody>
<tr>
<td>SM Photon</td>
<td>2.6M</td>
<td>650k</td>
</tr>
<tr>
<td>QCD</td>
<td>1M</td>
<td>280k</td>
</tr>
<tr>
<td>EWK</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>

For Blessing
PMT spikes

• Can reject 100% using PMT asymmetry.
Beam Halo Identification

CDF Run II Preliminary

Halos from no vertex events.

For Blessing
**Beam Halo Rejection**

- Use topological cuts (cdfnote:8409)

<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
Beam Halo Mis-ID Rates

- Use electrons to measure mis-id rates
  - Use photon-like electron ID (cdf 8220) cuts and $e^+ > = 1$ Jet events.

<table>
<thead>
<tr>
<th>Halo Type</th>
<th>Mis-ID rates</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>68%</td>
</tr>
<tr>
<td>1</td>
<td>55%</td>
</tr>
<tr>
<td>2</td>
<td>16%</td>
</tr>
<tr>
<td>3</td>
<td>6.5%</td>
</tr>
<tr>
<td>4</td>
<td>4.1%</td>
</tr>
<tr>
<td>5</td>
<td>1.2%</td>
</tr>
</tbody>
</table>
Beam Halo Rejection Power

1. Pick events with no vertex
2. No requirement on number of jets
3. Use Photon phi wedge distribution
4. Count events in wedges 0,23
5. Subtract off the flat component (average of wedges 1-22)
6. Repeat steps 4 and 5 for events identified as beam halo

Rejection Power = 94.8%
Beam Halo Estimates

1. Repeat step 4 and 5 in previous slide for events identified (rejected) as halo from the signal

2. Use the rejection power to estimate the halos left

   Expect 9 events (>=1 Jet)
   Expect <1 event (>=2 Jets)
Beam Halo Template

General event selections ( - vtx requirement)

1. Pick events with no vertex
2. Then pick events in phi wedges 0 and 23
3. Require a tight photon
4. Must be in-time (> - 4.8ns & < 4.8ns)
5. Pass beam halo ID cuts
6. Normalize to number of events expected
Cosmic Rejection

• Use EM timing
  • require photon to be in-time ( >-4.8ns & <4.8ns)

Corrected EM Timing for all reconstructed photons. Thanx to Max.
Cosmic Estimates

\[
\text{Cosmics left in the sample} = \frac{\text{Number of Events in window (30ns - 90ns)}}{90 - 30} \times (4.8 \times 2)
\]

Expect 110 events (\(\geq 1\) Jet)
Expect 7 events (\(\geq 2\) Jets)
Cosmic Template

General event selections +

- A Tight photon
- EM Time between >30ns and < 90ns
- 1 or more Jets
- Normalize to number of events expected
• Use Phoenix tracking to reject electrons.

• Use EWK MC to predict the shapes and normalization.
  • $Z \rightarrow ee$, $Z \rightarrow mumu$, $Z \rightarrow tautau$, $W \rightarrow enu$, $W \rightarrow munu$, $W \rightarrow taunu$
EWK Templates

General event selections +

1. An electron/muon/tau passing photon ID cuts
2. 1 or more Jets
3. Normalize each background by luminosity.
QCD Template

General event selections +

1. Use sideband photons
2. Must be in-time (> -4.8ns & < 4.8ns)
3. Not a phoenix track
4. Not beam halo
5. 1 or more Jets

Fake photon fraction >30GeV = 0.319 +/- 0.001 (stat) +/- 0.068 (syst)
(From CER/CPR method Thanx to Eiko)

Normalization = (Total Signal Events/ Total sideband events) x 0.319
Pure Photon Template

General event selections +

1. Find a tight detector photon
2. Not a phoenix track
3. Not beam halo
4. Must match to stable HEPG photon (DelR<0.1)
5. 1 or more Jets

Normalized to Data - other Backgrounds (~70% of data)
Systematics

- Different methods for different plots - *hard*
  - 100% photon sideband
  - 30% photon sideband + 70% photon MC
- Cosmic and Beam Halo - *simple*
Systematics

• When 100% photon sideband is used
  • Notice the there are 4 cuts common among both tight and loose photon ID cuts
    • HadEm/Iso/TrkPt and TrkIso (see backup slides)

• Tighten up one loose cut to match with tight cuts
• Run the sideband sample through modified loose ID cuts
• Normalized the events passed to the sideband
• Divide by the sideband.
• Repeat for all 4 and take the maximum variation in each bin as the systematic error for that bin.
Systematics

- When the sideband and Photon MC mixture is used, vary the mixture
- JES and Photon EM shift is included
- For EWK
  - Use uncertainty in Lum to vary the normalization...
- For Cosmosics
  - Use statistical error
- For Beam Halo
  - Assign a 50% error
RESULTS

For Blessing

CDF Run II Preliminary 2.0 fb⁻¹

For Blessing

04-10-08

Sam@Exotic - Blessing
RESULTS

For Blessing

04-10-08
RESULTS

For Blessing
Next...

- Open the box.
- Incorporate MET model and look at events with significant MET.
- Find new physics.
Thank you.
## 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>$&gt; 30 \text{ GeV}$</td>
</tr>
<tr>
<td>CES X and Z fiducial</td>
<td>$</td>
</tr>
<tr>
<td></td>
<td>$9 \text{ cm} \leq</td>
</tr>
<tr>
<td>Had/Em</td>
<td>$\leq 0.125</td>
</tr>
<tr>
<td>$E_T^{Iso(corr)}$ in cone 0.4</td>
<td>$\leq 0.1 \times E_T^{corr}$ if $E_T^{corr} &lt; 20 \text{ GeV}$</td>
</tr>
<tr>
<td></td>
<td>$\leq 2.0 + 0.02 \times (E_T^{corr} - 20)$ if $E_T^{corr} &gt; 20 \text{ GeV}$</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 $E \times \sin(\theta)$</td>
<td>$\leq 0.14 \times E_T^{corr}$ if $E_T^{corr} &lt; 18 \text{ GeV}$</td>
</tr>
<tr>
<td>(both wire and strip E individually)</td>
<td>$\leq 2.4 + 0.01 \times E_T^{corr}$ if $E_T^{corr} \geq 18 \text{ GeV}$</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>
<td>$&gt; 30 \text{ GeV}$</td>
</tr>
<tr>
<td>CES X and Z fiducial</td>
<td>$</td>
</tr>
<tr>
<td></td>
<td>$9 \text{ cm} \leq</td>
</tr>
<tr>
<td>Had/Em</td>
<td>$\leq 0.125$</td>
</tr>
<tr>
<td>$E_T^{Iso(corr)}$ in cone 0.4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$\leq 0.15 \times E_T^{corr}$ if $E_T^{corr} &lt; 20 \text{ GeV}$</td>
</tr>
<tr>
<td></td>
<td>$\leq 3.0$ if $E_T^{corr} &gt; 20 \text{ GeV}$</td>
</tr>
<tr>
<td>Track $p_T$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$&lt; 0.25 \times E_T^{corr}$</td>
</tr>
<tr>
<td>Track Iso(0.4)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$&lt; 5.0$</td>
</tr>
</tbody>
</table>

Table 1: Loose Photon ID cuts.
# 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>$E_T^{iso,corr}$ in cone $0.4$</td>
<td>$\leq 0.1 \times E_T$ if $E_T &lt; 20$ GeV, $\leq 2.0 + 0.02 \times (E_T - 20)$ 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 1$^{st}$ track</td>
<td>$0.8 \leq E/p \leq 1.2$ if $p_T &lt; 50$ GeV, no cut if $p_T \geq 50$ GeV</td>
</tr>
<tr>
<td>2$^{nd}$ track $p_T$ if N3D = 2</td>
<td>$\leq 1.0 + 0.005 \times E_T$</td>
</tr>
<tr>
<td>TrkIso(0.4) - $p_T$ $1^{st}$trk</td>
<td>$\leq 2.0 + 0.005 \times E_T$</td>
</tr>
<tr>
<td>$E_T$ of 2$^{nd}$ CES cluster (wire and strip)</td>
<td>$\leq 0.14 \times E_T$ if $E_T &lt; 18$ GeV, $\leq 2.4 + 0.01 \times E_T$ if $E_T \geq 18$ GeV</td>
</tr>
<tr>
<td>$</td>
<td>\Delta z</td>
</tr>
</tbody>
</table>