Anomalous Production of Photon+Jets (+MET)

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Outline

- Intro
- Triggers and Datasets
- Event, Photon, Jet and Signal Selection
- Backgrounds
- Results
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) \(\text{Lum} = 2.0 \text{ fb}^{-1}\) (exclude 1\(^{st}\) 400pb\(^{-1}\))

- **Photon MC**
  - QCD group, PYTHIA-TuneA, \(\text{Pt} > 22 \text{ GeV}\), jqcdfh

- **W/Z MC**
  - EWK group, PYTHIA, \(\text{Z} \rightarrow \text{e}+\text{e}, \text{W} \rightarrow \text{\mu}+\text{\mu}, \text{W} \rightarrow \tau+\tau, \text{W} \rightarrow \text{e}+\text{\nu}, \text{W} \rightarrow \text{\mu}+\text{\nu}\) and \(\text{W} \rightarrow \tau+\nu\), 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_pho)
- >=1 Class 12 vertices *
- z < 60 cm *
- Photon + >=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 (DetEta<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->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>Expected for &gt;=1 Jets</th>
<th>Expected for &gt;=2 Jets</th>
</tr>
</thead>
<tbody>
<tr>
<td>PMT Spikes</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Cosmic</td>
<td>110</td>
<td>7</td>
</tr>
<tr>
<td>Beam halo</td>
<td>9</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Electron</td>
<td>459</td>
<td>111</td>
</tr>
<tr>
<td>QCD</td>
<td>1M</td>
<td>280K</td>
</tr>
<tr>
<td>SM PHOTON</td>
<td>2.6M</td>
<td>650K</td>
</tr>
</tbody>
</table>
PMT spikes

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

SAMPLE PLOTS

Halos from no vertex events.
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

Increase rejection power

Increase efficiency
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 through 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)

![Sample Plot]

Times of all reconstructed photons

Entries: 1664099
Mean: 2.072
RMS: 4.275
χ²/ndf: 572.7 / 25
Prob: 0
Constant: 7.292e+04 ± 114
Mean: 1.893 ± 0.002
Sigma: 1.73 ± 0.00

We have run dependent EM timing correction thanx to Max.
Cosmic Estimates

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

Expect 110 events (≥1 Jet)
Expect 7 events (≥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.
- $Z \rightarrow ee$, $Z \rightarrow \mu\mu$, $Z \rightarrow \tau\tau$, $W \rightarrow e\nu$, $W \rightarrow \mu\nu$, $W \rightarrow \tau\nu$
EWK Template

General event selections +

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

General event selections +

1. Use sideband photons (photons pass loose photon cuts but fails tight photon cuts)
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 sample from MC

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)
Normalization by luminosity overshoots the data
RESULTS ...

- WE LOOK AT ONLY 1/10 OF THE DATA!
- ALL BACKGROUNDS ARE ESTIMATED FOR THE FULL DATASET.
- ALL BACKGROUNDS ARE SCALED DOWN BY 10 TO MATCH DATA.
- AND THE RED LINE ...
RESULTS
RESULTS
RESULTS
Next...

- Work on systematics.
- Plan to bless with 1/10 results for APS.
- 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>$&gt; 30$ 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</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 $E \times sin(\theta)$</td>
<td>$\leq 0.14 \times E_T^{corr}$ if $E_T^{corr} &lt; 18$ GeV</td>
</tr>
<tr>
<td>(both wire and strip E individually)</td>
<td>$\leq 2.4 + 0.01 \times E_T^{corr}$ if $E_T^{corr} \geq 18$ GeV</td>
</tr>
</tbody>
</table>
## 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>$&gt; 30 \text{ GeV}$</td>
</tr>
<tr>
<td>CES fiduciality</td>
<td>$</td>
</tr>
<tr>
<td></td>
<td>$9 \text{ cm} \leq</td>
</tr>
<tr>
<td>average CES $\chi^2$</td>
<td>$\leq 20$</td>
</tr>
<tr>
<td>$\frac{\text{Had/Em}}{\text{Em}}$</td>
<td>$\leq 0.055 + 0.00045 \times E$</td>
</tr>
<tr>
<td>$E_T^{iso,\text{corr}}$ in cone 0.4</td>
<td>$\leq 0.1 \times E_T$ if $E_T &lt; 20 \text{ GeV}$</td>
</tr>
<tr>
<td></td>
<td>$\leq 2.0 + 0.02 \times (E_T - 20)$ if $E_T \geq 20 \text{ GeV}$</td>
</tr>
<tr>
<td>N3D tracks in cluster</td>
<td>$= 1, 2$</td>
</tr>
<tr>
<td>$E/p$ of 1$^{\text{st}}$ track</td>
<td>$0.8 \leq E/p \leq 1.2$ if $p_T &lt; 50 \text{ GeV}$</td>
</tr>
<tr>
<td></td>
<td>no cut if $p_T \geq 50 \text{ GeV}$</td>
</tr>
<tr>
<td>2$^{\text{nd}}$ 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$^{\text{st}}$trk</td>
<td>$\leq 2.0 + 0.005 \times E_T$</td>
</tr>
<tr>
<td>$E_T$ of 2$^{\text{nd}}$ CES cluster (wire and strip)</td>
<td>$\leq 0.14 \times E_T$ if $E_T &lt; 18 \text{ GeV}$</td>
</tr>
<tr>
<td></td>
<td>$\leq 2.4 + 0.01 \times E_T$ if $E_T \geq 18 \text{ GeV}$</td>
</tr>
<tr>
<td>$</td>
<td>\Delta z</td>
</tr>
</tbody>
</table>

*Photon-like electron ID cuts*
**Loose Photon ID cuts**

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>detector</td>
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<td>$E_T^{corr}$</td>
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<tr>
<td>CES X and Z fiducial</td>
<td>$</td>
</tr>
<tr>
<td>Had/Em</td>
<td>$\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 $\leq 3.0$ 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.