Anomalous Production of Photon+Jets (+MET)

CDF Note # 9267

Preblessing

Sam Hewamanage, Jay Dittmann, Nils Krumnack
Baylor University

Ray Culbertson, Sasha Pronko
Fermilab
Outline

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

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 1\(^{st}\) 400pb\(^{-1}\))

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

• W/Z MC
  • EWK group, PYTHIA, Z\(\rightarrow\)e+e, Z\(\rightarrow\)\(\mu\)+\(\mu\), Z\(\rightarrow\)\(\tau\) + \(\tau\), W\(\rightarrow\)e+\(\nu\), W\(\rightarrow\)\(\mu\)+\(\nu\) and W\(\rightarrow\)\(\tau\) +\(\nu\), periods 0-2
Reasons to drop first 400 pb$^{-1}$!

- Already have 2.5 fb$^{-1}$, and will have >3 fb$^{-1}$ by the time we finish. Including this yield \( \sim 10\% \)
- Comic background becomes significant in the high MET
  - No EM timing information to reject cosmics
  - Cosmic expectation is higher than the rest of the dataset.
  - Require different method for systematics
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
Jet Selection

- Cone size = 0.4, JetClu
- Remove only the photon from jet list
- 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)
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
  - Cosmos
- 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>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>5362</td>
<td>1321</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>
PMT spikes

• Can reject 100% using PMT asymmetry.

CDF Run II Preliminary

Events

$10^3$

$10^2$

$10$

$1$

PMT Asymmetry

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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 ( \parallel ) Nhad &gt; 1</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>
1. No requirement on number of jets
2. Use Photon $\phi$ wedge distribution
3. Count events in wedges 0,23
4. Subtract off the flat component (average of wedges 1-22)
5. Repeat steps 2 - 4 for events identified as beam halo

Rejection Power = 94.8%
1. Repeat step 2 - 4 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 +

1. Require a tight photon
2. Must be in-time (> - 4.8ns & < 4.8ns)
3. Pass beam halo ID cuts
4. Occupy photon phi-wedge 0 or 23
5. Normalize to number of events expected
Cosmic Rejection and Estimates

- Reject comic photons by requiring EM time (>-4.8ns & <4.8ns)
- Estimate the remainder as follows:

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

- Expect 110 events (>=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
EWK Rejection & Prediction

- Use Phoenix tracking to reject electrons.

- Use EWK MC to predict the shapes and normalization.
  - $Z \rightarrow e^+e^-$, $Z \rightarrow \mu^+\mu^-$, $Z \rightarrow \tau^+\tau^-$, $W \rightarrow e^+\nu$, $W \rightarrow \mu^+\nu$ and $W \rightarrow \tau^+\nu$
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. 1 or more Jets

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

- JES
- Fake photon fraction
- Uncertainty in the Cosmic and Beam Halo estimates
- Statistical
- Luminosity 6%
- EM uncertainty of 1%
Systematics

• When 100% photon sideband is used
  • Notice the there are 4 cuts common to 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 within the systematic uncertainty of the fake photon fraction.

- For Cosmics
  - Use statistical error

- For Beam Halo
  - Assign a 50% error
A Note ...

- This is from full dataset (2.0 fb\(^{-1}\))
- Fake photon fraction is used to determine the normalization of the QCD template and the true photons template after subtracting other backgrounds. There is no other correlation between the two templates.
- Fixed loose photon cuts and trigger object identification.
- Apologies for not including your some of your suggestions in the plots. Will have it next time.
RESULTS

CDF Run II Preliminary 2.0 fb⁻¹

Events/10 GeV

- γ + >=1 Jet
- γ MC (0.681 of signal)
- QCD (γ sideband, 0.319 of signal)
- EWK MC
- γ (MC) + >=1 Jet
- γ (MC) + >=1 Jet
- Systematics

γ + >=1 Jet

Bin size = 10

0 50 100 150 200 250 300

0 0.2 0.4 0.6 0.8 1

0 0.2 0.4 0.6 0.8

0 50 100 150 200 250 300
RESULTS

CDF Run II Preliminary 2.0 fb⁻¹

γ + >=1 Jet
γ MC (0.681 of signal)
QCD (γ sideband, 0.319 of signal)
EWK MC
γ^cosmic + >=1 Jet
γ^nab + >=1 Jet
Systematics

γ+>=1 Jet

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RESULTS

CDF Run II Preliminary 2.0 fb^{-1}

- $\gamma + >=1$ Jet
- QCD (100% $\gamma$ sideband)
- EWK MC
- $\gamma_{\text{cosmic}} + >=1$ Jet
- $\gamma_{\text{helo}} + >=1$ Jet
- Systematics

Jet Multiplicity ($E_{T}>15$GeV)

Bin size = 1

NJet15

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RESULTS

CDF Run II Preliminary 2.0 fb⁻¹

- γ + >=2 Jet
- γ MC (0.681 of signal)
- CCD (γ sideband, 0.319 of signal)
- EWK MC
- γ⁺⁻⁻⁺ (≥2 Jet)
- γ + >=2 Jet
- Systematics

γ + >=2 Jets

Events/10 GeV

E_T' (GeV)
RESULTS

CDF Run II Preliminary 2.0 fb⁻¹

γ + >=1 Jet
γ MC (0.681 of signal)
QCD (γ sideband, 0.319 of signal)
EWK MC
γ^{cosmic} + >=1 Jet
γ^{hilo} + >=1 Jet
Systematics
Plan for the ICHEP

• Make suggested cosmetic changes to plots.
• Fix Ht plot by applying photon fake rate event by event basis.
• Answer your Qs.
• Update note with Chris’s suggestions.

Thank you.
BACKUP SLIDES
## 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>$E_T^{Iso\text{(corr)}}$ 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>$2^{nd}$ 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>$&gt; 30$ 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$</td>
</tr>
<tr>
<td>$E_T^{Iso\text{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.
### 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></td>
<td>$9$ cm $\leq</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>$E_{T}^{iso\text{(corr)}}$ in cone 0.4</td>
<td>$\leq 0.1 \times E_T$ if $E_T &lt; 20$ GeV</td>
</tr>
<tr>
<td></td>
<td>$\leq 2.0 + 0.02 \times (E_T - 20)$ 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</td>
</tr>
<tr>
<td></td>
<td>no 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) - $p_T$ 1st trk</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</td>
</tr>
<tr>
<td></td>
<td>$\leq 2.4 + 0.01 \times E_T$ if $E_T \geq 18$ GeV</td>
</tr>
<tr>
<td>$</td>
<td>\Delta z</td>
</tr>
</tbody>
</table>