My 1st Look at Ken’s 5.3.1 Photon (and Z) Stntuples

<table>
<thead>
<tr>
<th>Photon25 (cph10d)</th>
<th>No Vtx Cut</th>
<th>NZvtx &lt;=1</th>
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<tbody>
<tr>
<td><strong>Total Events</strong></td>
<td>9,671,427</td>
<td>9,671,427</td>
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<tr>
<td>Good Events (QCDv5)</td>
<td>8,289,860</td>
<td>8,289,860</td>
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<tr>
<td>%Good</td>
<td>85.71%</td>
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<td>Vertex Cut</td>
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<tr>
<td>ZJetAnaModule</td>
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<td>**Z-Bosons (**eta</td>
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<table>
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<th>py Tune A (jqcd0e)</th>
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</thead>
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<tr>
<td><strong>Total Events</strong></td>
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<tr>
<td>PhoJetAnaModule</td>
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<td>30 &lt; ET(jet1) &lt; 50 GeV</td>
<td>2,262</td>
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<td>ET(jet1)&gt; 50</td>
<td>339</td>
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</table>

- Study “Z-bosons”, “Photons”, and “Jets” and compare with each other and with PYTHIA Tune A. I need Z Monte-Carlo (PYTHIA Tune A)!

Thanks Ken and Anwar!

PY Tune A Direct Photon!

| \(|\Delta \phi| > 150^\circ\) |
|----------------|---|
|                  |   |

CDF Jet Corrections Meeting | Page 1 of 41
**CPH10d Contains Both Photons and Z-bosons!**

- **5.3.1 Z mass distribution not perfect!** Plug electron calibration must not be exactly correct? I used only the correction factors provided in 5.3.1.

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Beatte taught me how to find Z-bosons!

CDF Data!
The “Toward”, “Transverse”, and “Away” Regions

Each of the three regions have an area $\Delta \eta \Delta \phi = 4\pi/3 = 4.2$.

• Look at the “toward”, “transverse”, and “away” regions as defined by the leading calorimeter jet (JetClu R = 0.7, $|\eta| < 2$).

• Study the charged particles in the region $p_T > 0.5$ GeV/c and $|\eta| < 1$. 
The “Toward” and “Away” Regions

- Note that the “toward” region does not always contain all of the leading jet and
  and the “away” regions do not always contain the “away” jet.
**“Toward”, Away”, and “Transverse” Regions**

- Look at the “toward”, “away”, and “transverse” regions as defined by the leading photon (central photons only |\(\eta| < 1\)).

- **“Back-to-Back”** events are selected to have at least one jet with Jet#1 nearly “back-to-back” with the leading photon (\(\Delta \phi_{1\gamma} > 150^\circ\)).
“Toward”, Away”, and “Transverse” Regions

- Look at the “toward”, “away”, and “transverse” regions as defined by the Z-boson (all Z’s $|\eta| < 6$).

- “Back-to-Back” events are selected to have at least one jet with Jet#1 nearly “back-to-back” with the Z-boson ($\Delta \phi_{1Z} > 150^\circ$).
Direct Photon Production: PYTHIA Tune A

• Match the generated direct photon (before CDFSIM) with the leading photon (after CDFSIM) using R = 0.2 cone.

• For pho1PT > 25 GeV about 90% of the observed leading photons have a direct photon within R = 0.2 cone!
Photon Selection Bias: PYTHIA Tune A

- Shows the $\Delta\phi$ dependence of the charged particle density, $dN/d\eta d\phi$, for charged particles in the range $p_T > 0.5$ GeV/c and $|\eta| < 1$ relative to the leading photon (rotated to $270^\circ$) for $P_{T}(\text{pho#1}) > 30$ GeV.

- The photon isolation cuts produce a “photon selection bias”. There are less charged particles in the “toward” region in the “matched” events!
Photon Selection Bias: PYTHIA Tune A

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Photon Selection Bias: PYTHIA Tune A

- Generator level study showing the “true” average charged particle density ($p_T > 0.5$ GeV/c, $|\eta| < 1$) with the “matched” densities.

- The photon isolation cuts produce a “photon selection bias”. There are less charged particles in the “toward” region in the “matched” events!
Photon Energy Resolution: PYTHIA Tune A

- The observed “matched” photons (after CDFSIM) have less $p_T$ than the “true” generated direct photons.

- This is presumably due to energy resolution and a steeply falling $p_T$ spectrum!
Charged Particle Density: “Jet”, “Photon”, and “Z”

Jet data vs photon data!

Jet data vs Z-boson data!

- (left) Compares the $\Delta \phi$ dependence of the particle density, $dN/d\eta d\phi$, for charged particles in the range $p_T > 0.5$ GeV/c and $|\eta| < 1$ for “leading photon” events ($P_T(\text{pho#1}) > 30$ GeV) with “leading jet” events ($30 < E_T(\text{jet#1}) < 70$ GeV).

- (right) Compares the $\Delta \phi$ dependence of the particle density, $dN/d\eta d\phi$, for charged particles in the range $p_T > 0.5$ GeV/c and $|\eta| < 1$ for “Z-boson” events ($P_T(Z) > 30$ GeV) with “leading jet” events ($30 < E_T(\text{jet#1}) < 70$ GeV).
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• (left) Compares the \( \Delta \phi \) dependence of the particle density, \( dN/d\eta d\phi \), for charged particles in the range \( p_T > 0.5 \text{ GeV/c} \) and \( |\eta| < 1 \) for “leading photon” events \( (P_T(\text{pho#1}) > 30 \text{ GeV}) \) with “leading jet” events \( (30 < E_T(\text{jet#1}) < 70 \text{ GeV}) \).

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Charged Particle Density: Photon vs Z-boson

- Comparress the $\Delta\phi$ dependence of the charged particle density, $dN/d\eta d\phi$, for charged particles in the range $p_T > 0.5$ GeV/c and $|\eta| < 1$ for “leading photon” events ($P_T(\text{pho#1}) > 30$ GeV) with Z-boson events ($P_T(Z) > 30$ GeV/c).

- There is also a “bump” in the direction of the Z-boson?
Charged Particle Density: Photon vs Z-boson

- Comparess the $\Delta\phi$ dependence of the charged particle density, $dN/d\eta d\phi$, for charged particles in the range $p_T > 0.5$ GeV/c and $|\eta| < 1$ for “leading photon” events ($P_T(\text{pho#1}) > 30$ GeV) with Z-boson events ($P_T(Z) > 30$ GeV/c).

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Charged PTsum Density: “Jet”, “Photon”, and “Z”

Jet data vs photon data!

Jet data vs Z-boson data!

• *(left)* Compares the $\Delta \phi$ dependence of the *scalar* PTsum density, $dN/d\eta d\phi$, for charged particles in the range $p_T > 0.5$ GeV/c and $|\eta| < 1$ for “leading photon” events ($P_T(pho#1) > 30$ GeV) with “leading jet” events ($30 < E_T(jet#1) < 70$ GeV).

• *(right)* Compares the $\Delta \phi$ dependence of the *scalar* PTsum density, $dN/d\eta d\phi$, for charged particles in the range $p_T > 0.5$ GeV/c and $|\eta| < 1$ for “Z-boson” events ($P_T(Z) > 30$ GeV) with “leading jet” events ($30 < E_T(jet#1) < 70$ GeV).
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Charged PTsum Density: Photon+Jet vs Z+Jet

• Shows the $\Delta \phi$ dependence of the *scalar* PTsum density, $dP_T/d\eta d\phi$, for charged particles in the range $p_T > 0.5$ GeV/c and $|\eta| < 1$ for “leading photon” events ($P_T(\text{pho}\#1) > 30$ GeV) and Z-boson events ($P_T(Z) > 30$ GeV/c).

• There is also a “bump” in the direction of the Z-boson?
Charged PTsum Density: Photon+Jet vs Z+Jet

- Shows the $\Delta\phi$ dependence of the *scalar* PTsum density, $d\text{PT}/d\eta d\phi$, for charged particles in the range $p_T > 0.5$ GeV/c and $|\eta| < 1$ for “leading photon” events ($P_T(\text{pho#1}) > 30$ GeV) and Z-boson events ($P_T(Z) > 30$ GeV/c).

- There is also a “bump” in the direction of the Z-boson?
Photon Charged Particle Density: PY Tune A vs Data

- Shows the $\Delta \phi$ dependence of the particle density, $dN/d\eta d\phi$, for charged particles ($p_T > 0.5$ GeV/c, $|\eta| < 1$) for “leading photon” events ($P_T(\text{pho#1}) > 30$ GeV) compared with PYTHIA Tune A (after CDFSIM).

- The direct photon Monte-Carlo cannot reproduce the “bump” in the direction of the leading photon! The “bump” must be background!
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• **(left)** Shows the $\Delta \phi$ dependence of the charged particle density, $dN/d\eta d\phi$, for charged particles ($p_T > 0.5$ GeV/c, $|\eta| < 1$) for “leading photon” events ($P_T(\text{pho}\#1) > 30$ GeV) compared with PYTHIA Tune A (after CDFSIM).

• **(right)** Shows the $\Delta \phi$ dependence of the charged particle density, $dN/d\eta d\phi$, for charged particles ($p_T > 0.5$ GeV/c, $|\eta| < 1$) for “leading jet” events ($30 < E_T(\text{jet}\#1) < 70$ GeV) compared with PYTHIA Tune A (after CDFSIM).
Charged Particle Density: PY Tune A vs Data

- (left) Shows the Δφ dependence of the charged particle density, dN/dηdφ, for charged particles (p_T > 0.5 GeV/c, |η| < 1) for “leading photon” events (P_T(pho#1) > 30 GeV) compared with PYTHIA Tune A (after CDFSIM).

- (right) Shows the Δφ dependence of the charged particle density, dN/dηdφ, for charged particles (p_T > 0.5 GeV/c, |η| < 1) for “leading jet” events (30 < E_T(jet#1) < 70 GeV) compared with PYTHIA Tune A (after CDFSIM).
Photon PTsum Particle Density: PY Tune A vs Data

- Shows the $\Delta\phi$ dependence of the *scalar* PTsum density, $dPT/d\eta d\phi$, for charged particles ($p_T > 0.5$ GeV/c, $|\eta| < 1$) for “leading photon” events ($P_T(\text{pho}\#1) > 30$ GeV) compared with PYTHIA Tune A (after CDFSIM).

- This is not very good agreement! I do not yet understand why the agreement in the “toward” and “transverse” regions is not better??
Photon PTsum Particle Density: PY Tune A vs Data

- Shows the $\Delta \phi$ dependence of the scalar PTsum density, $dPT/d\eta d\phi$, for charged particles ($p_T > 0.5$ GeV/c, $|\eta| < 1$) for “leading photon” events ($P_T(\text{pho#1}) > 30$ GeV) compared with PYTHIA Tune A (after CDFSIM).

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PTsum Particle Density: PY Tune A vs Data

• (left) Shows the $\Delta \phi$ dependence of the charged PTsum density, $dP_T/d\eta d\phi$, for charged particles ($p_T > 0.5$ GeV/c, $|\eta| < 1$) for “leading photon” events ($P_T(\text{pho#1}) > 30$ GeV) compared with PYTHIA Tune A (after CDFSIM).

• (right) Shows the $\Delta \phi$ dependence of the charged PTsum density, $dP_T/d\eta d\phi$, for charged particles ($p_T > 0.5$ GeV/c, $|\eta| < 1$) for “leading jet” events ($30 < E_T(\text{jet#1}) < 70$ GeV) compared with PYTHIA Tune A (after CDFSIM).
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- **(right)** Shows the $\Delta \phi$ dependence of the charged PTsum density, $dP_T/d\eta d\phi$, for charged particles ($p_T > 0.5$ GeV/c, $|\eta| < 1$) for “leading jet” events ($30 < E_T(jet#1) < 70$ GeV) compared with PYTHIA Tune A (after CDFSIM).
Photons Particle Densities: PY Tune A vs Data

- Shows the average charged particle density, $dN/d\eta d\phi$, and PTsum density, $dPT/d\eta d\phi$, for charged particles ($p_T > 0.5$ GeV/c, $|\eta| < 1$) in the “toward”, “away”, and “transverse” regions versus $P_T$(pho#1) for “leading photon” events compared with PYTHIA Tune A (after CDFSIM).

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Charged Particle Densities: PY Tune A vs Data

- (left) Shows the average density, $dN/d\eta d\phi$, charged particles ($p_T > 0.5$ GeV/c, $|\eta| < 1$) in the “toward”, “away”, and “transverse” regions versus $P_T(\text{pho#1})$ for “leading photon” events compared with PYTHIA Tune A (after CDFSIM).

- (right) Shows the average density, $dN/d\eta d\phi$, charged particles ($p_T > 0.5$ GeV/c, $|\eta| < 1$) in the “toward”, “away”, and “transverse” regions versus $E_T(\text{jet#1})$ for “leading jet” events compared with PYTHIA Tune A (after CDFSIM).
Charged PTsum Densities: PY Tune A vs Data

- **(left)** Shows the average PTsum density, $dPT/d\eta d\phi$, charged particles ($p_T > 0.5$ GeV/c, $|\eta| < 1$) in the “toward”, “away”, and “transverse” regions versus $P_T(\text{pho}\#1)$ for “leading photon” events compared with PYTHIA Tune A (after CDFSIM).

- **(right)** Shows the average PTsum density, $dPT/d\eta d\phi$, charged particles ($p_T > 0.5$ GeV/c, $|\eta| < 1$) in the “toward”, “away”, and “transverse” regions versus $E_T(\text{jet}\#1)$ for “leading jet” events compared with PYTHIA Tune A (after CDFSIM).
“Transverse” PTsum Particle Density: PY Tune A vs Data

- (left) Shows the average PTsum density, dPT/d\(\eta d\phi\), for charged particles (p_T > 0.5 GeV/c, |\(\eta\)| < 1) in the “toward”, and “transverse” regions versus P_T(\(\text{pho#1}\)) for “leading photon” events compared with PYTHIA Tune A (after CDFSIM).

- (right) Shows the average PTsum density, dPT/d\(\eta d\phi\), for charged particles (p_T > 0.5 GeV/c, |\(\eta\)| < 1) in the “toward”, and “transverse” regions versus E_T(\(\text{jet#1}\)) for “leading jet” events compared with PYTHIA Tune A (after CDFSIM).
“Pile-Up” and the Charged Particle Densities

- Shows the average charged particle density, $dN/d\eta d\phi$, and PTsum density, $dPT/d\eta d\phi$, for charged particles ($p_T > 0.5$ GeV/c, $|\eta| < 1$) in the “toward”, and “transverse” regions versus $PT(\text{pho#1})$ for all “leading photon” events compared with “leading photon” events with $\leq 1$ z-vertex (class 12 or higher).

- Because I am making “tight” track cuts on the primary vertex “pile-up” effects are negligible for the charged particles! But “pile-up” may affect the jet energies!
Photon-Jet Balancing

- Shows the average ratio of $E_T(jet#1)/P_T(\text{pho#1})$ versus $P_T(\text{pho#1})$ for “back-to-back” events with $E_T(jet#2) < 10 \text{ GeV}$, $5 \text{ GeV}$, and $3 \text{ GeV}$ for JetClu R = 0.7 with no “jet corrections” and no vertex cuts.

- For “jet energy corrections” need the ratio of $P_T(\text{pho#1})/ E_T(jet#1)$ versus $E_T(jet#1)$ (i.e. bins of $E_T(jet#1)$ instead of bins of $P_T(\text{pho#1})$.

- Why am I using $E_T(jet#1)$ and not $P_T(jet#1)$?
Photon-Jet Balancing

- Shows the average ratio of $E_T(jet\#1)/P_T(pho\#1)$ versus $P_T(pho\#1)$ for “back-to-back” events with $E_T(jet\#2) < 10$ GeV, 5 GeV, and 3 GeV for JetClu $R = 0.7$ with no “jet corrections” and no vertex cuts.

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Photon-Jet Balancing

- **(left)** Shows the average ratio of $E_T$(jet#1)/$P_T$(pho#1) versus $P_T$(pho#1) for “back-to-back” events with $E_T$(jet#2) < 10 GeV, 5 GeV, and 3 GeV for JetClu R = 0.7 with no “jet corrections” and no vertex cuts.

- **(right)** Shows the average ratio of $P_T$(pho#1)/$E_T$(jet#1) versus $E_T$(jet#1) for “back-to-back” events with $E_T$(jet#2) < 10 GeV, 5 GeV, and 3 GeV for JetClu R = 0.7 with $P_T$(pho#1) > 25 GeV and no “jet corrections” and no vertex cuts.

- Why am I using $E_T$(jet#1) and not $P_T$(jet#1)?
Z-Jet Balancing

- (left) Shows the average ratio of $E_T(\text{jet#1})/P_T(Z)$ versus $P_T(Z)$ for “back-to-back” events with $E_T(\text{jet#2}) < 10 \text{ GeV}$, $5 \text{ GeV}$, and $3 \text{ GeV}$ for JetClu $R = 0.7$ with no “jet corrections” and no vertex cuts.

- (right) Shows the average ratio of $P_T(Z)/E_T(\text{jet#1})$ versus $E_T(\text{jet#1})$ for “back-to-back” events with $E_T(\text{jet#2}) < 10 \text{ GeV}$, $5 \text{ GeV}$, and $3 \text{ GeV}$ for JetClu $R = 0.7$ with no “jet corrections” and no vertex cuts.

- Why am I using $E_T(\text{jet#1})$ and not $P_T(\text{jet#1})$?
Photon-Jet Balancing versus Z-Jet Balancing

- (left) Compares the average ratio of $E_T^{\text{jet#1}}/P_T(Z)$ versus $P_T(Z)$ for “back-to-back” Z events with $E_T^{\text{jet#2}} < 5$ GeV for JetClu $R = 0.7$ with the average ratio of $E_T^{\text{jet#1}}/P_T(\text{pho#1})$ versus $P_T(\text{pho#1})$ for “back-to-back” photon events with $E_T^{\text{jet#2}} < 5$ GeV for JetClu $R = 0.7$ with no “jet corrections” and no vertex cuts.

- (right) Compares the average ratio of $P_T(Z)/ E_T^{\text{jet#1}}$ with $P_T(\text{pho#1})/E_T(\text{jet#1})$ versus $E_T^{\text{jet#1}}$ for “back-to-back” Z and photon events with $E_T^{\text{jet#2}} < 5$ GeV for JetClu $R = 0.7$ with no “jet corrections” and no vertex cuts.

Why are Z and Photon different??
“Pile-Up” Effects in Photon-Jet Balancing

- **(left)** Compares the average ratio of $E_T(\text{jet#1})/P_T(\text{pho#1})$ versus $P_T(\text{pho#1})$ for all “back-to-back” photon events with $E_T(\text{jet#2}) < 5$ GeV for JetClu R = 0.7 with events selected to have no “pile-up” (*i.e.*, number of z-vertices $\leq 1$).

- **(right)** Compares the average ratio of $P_T(\text{pho#1})/E_T(\text{jet#1})$ versus $E_T(\text{jet#1})$ for all “back-to-back” photon events with $E_T(\text{jet#2}) < 5$ GeV for JetClu R = 0.7 with events selected to have no “pile-up” (*i.e.*, number of z-vertices $\leq 1$).
Jet#1 PseudoRapidity: Photon vs Z-boson

- Shows the “away-side” jet#1 pseudorapidity distribution for “back-to-back” photon events with P_T(pho#1) > 30 GeV and “back-to-back” Z-boson events with P_T(Z) > 30 GeV with E_T(jet#2) < 5 GeV for JetClu R = 0.7 with no “jet corrections” and no vertex cuts.

- Differences between photon and Z jet balancing not due to η!
Leading Photon $P_T$ Distribution: PY Tune A vs Data

- Shows the leading photon $P_T$ distribution compared with PYTHIA Tune A (after CDFSIM).

- Unlike the inclusive “jet” cross section the data does not rise above the theory at high $P_T$!
*** The Plan ***

- I need to understand why Z-jet and Photon-jet balancing is different in the data!

- I need to understand why PYTHIA Tune A fits the “leading jet” events better than the “leading photon” events! The “photons” are not pure. I need to simulate the “background”.

- I will look at Ken’s HERWIG photon events.

- I need 5.3.1 Z-jet and jet-jet PYTHIA Tune A and HERWIG Monte-Carlo events! We need more Monte-Carlo and more Stntuples!

- I will look at R = 0.4 conesize and Mid-Point Algorithm.

- I will look at photon-jet balancing at the MC generator level.

- I will compare PYTHIA Tune A and HERWIG photon-jet balancing with the data.