QCD Group Jet, Photon and Z Stntuples

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<th>Photon25 (cph10d)</th>
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<tbody>
<tr>
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<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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<tr>
<td>Vertex Cut</td>
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<td>**Z-Bosons (</td>
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<tr>
<td>Tight-Tight</td>
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<td>Back-to-Back</td>
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<table>
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<tr>
<td>ET(jet1)&gt; 50</td>
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</table>

- Study “Z-bosons”, “Photons”, and “Jets” and compare with each other and with PYTHIA Tune A and HERWIG.

Thanks Ken and Anwar!

Need Z-boson Monte-Carlo!

| Δφ | 150° |

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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.
• Re-scale plug electron energy by factor of 1.04. The central-central looks funny. I will work on it.
The “Toward”, “Transverse”, and “Away” Regions

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

- Study the charged particles in the region $p_T > 0.5$ GeV/c and |η| < 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 ($\Delta\phi_{1Z} > 150^\circ$).
Event Topologies: PYTHIA Tune A

- Shows the $\Delta\phi$ dependence of the density, $dN_{\text{chg}}/d\eta d\phi$, for charged particles in the range $p_T > 0.5$ GeV/c and $|\eta| < 1$ for “Leading Jet” events with $E_T(\text{jet#1}) > 30$ GeV and for “Leading Photon” events with $P_T(\text{pho1}) > 30$ GeV and for “Z-boson” events with $P_T(Z) > 30$ GeV from PYTHIA Tune A.
Photon Purity: 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 Efficiency: PYTHIA Tune A

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

- Shows the fraction of generated direct photons that are found (after CDFSIM).

- Note that the efficiency depends on PT!
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°) 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!
Charged Particle Density: “Jet”, “Photon”, and “Z”

• (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 “leadig 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 “leadig jet” events ($30 < E_T(\text{jet#1}) < 70$ GeV).
**Charged Particle Density: Photon vs Z-boson**

- Compare 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 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).
**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!
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 ($P_T(\text{pho#1}) > 50$ GeV) compared with PYTHIA Tune A (after CDFSIM).

- The bump in the data in the “toward” region has gone away!
Charged Particle Density: PY Tune A vs Data

- **(left)** Shows the ∆φ 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 ∆φ 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, $dP_T/d\eta d\phi$, 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).

- This is not very good agreement! I do not yet understand why the agreement in the “toward” and “transverse” regions is not better??
Phonon 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 ($P_T(\text{pho#1}) > 50$ GeV) compared with PYTHIA Tune A (after CDFSIM).

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

- **(left)** Shows the $\Delta \phi$ dependence of the charged 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).

- **(right)** Shows the $\Delta \phi$ dependence of the charged PTsum density, $dPT/d\eta d\phi$, 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).
**Photon Charged Particle Density: PY Tune A vs HERWIG**

- *(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 photon” events ($P_T(\text{pho#1}) > 30$ GeV) compared with HERWIG (after CDFSIM).
Photon Charged Particle Density: PY Tune A vs HERWIG

- **(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 ($P_T(\text{pho#1}) > 50$ 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 photon” events ($P_T(\text{pho#1}) > 50$ GeV) compared with HERWIG (after CDFSIM).
Photon PTsum Particle Density: PY Tune A vs HERWIG

- **(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 photon” events ($P_T(\text{pho#1}) > 30$ GeV) compared with HERWIG (after CDFSIM).
Photon PTsum Particle Density: PY Tune A vs HERWIG

- *(left)* Shows the $\Delta \phi$ dependence of the charged PTsum density, $dPT/d\eta d\phi$, for charged particles ($p_T > 0.5$ GeV/c, $|\eta| < 1$) for “leading photon” events ($P_T(\text{pho#1}) > 50$ GeV) compared with PYTHIA Tune A (after CDFSIM).

- *(right)* Shows the $\Delta \phi$ dependence of the charged PTsum density, $dPT/d\eta d\phi$, for charged particles ($p_T > 0.5$ GeV/c, $|\eta| < 1$) for “leading photon” events ($P_T(\text{pho#1}) > 50$ GeV) compared with HERWIG (after CDFSIM).
Photon PTsum Particle Density: PY Tune A vs HERWIG

- Note: I have define “back-to-back” to be $|\Delta \phi| > 150^0$. Florencia uses $|\Delta \phi| > 172^0$. 
Photon 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).

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

- *(left)* Shows the average density, \(\frac{dN}{d\eta d\phi}\), charged particles (\(p_T > 0.5 \text{ GeV/c}, |\eta| < 1\)) 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, \(\frac{dN}{d\eta d\phi}\), charged particles (\(p_T > 0.5 \text{ GeV/c}, |\eta| < 1\)) 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 $P_T(pho#1)$ for all “leading photon” events compared with “leading photon” events with <= 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 Particle Densities: HERWIG 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).

- This is not very good agreement! I do not yet understand why the agreement in the “toward” and “transverse” regions is not better??
PYTHIA Tune A: Particle Level Photon-Jet Balancing

- Shows the average ratio of $P_T$(particle jet#1)/$P_T$(direct photon) for “back-to-back” direct photon events with $P_T$(direct photon) > 30 GeV/c for JetClu R = 0.7 at the particle level for PYTHIA Tune A.

- The spread in these curves represents an intrinsic uncertainty due to not knowing which particles in the event actually belong to the “jet”.
HERWIG: Particle Level Photon-Jet Balancing

- Shows the average ratio of $P_T(\text{particle jet#1})/P_T(\text{direct photon})$ for “back-to-back” direct photon events with $P_T(\text{direct photon}) > 30 \text{ GeV}/c$ for JetClu R = 0.7 at the particle level for HERWIG.

- The spread in these curves represents an intrinsic uncertainty due to not knowing which particles in the event actually belong to the “jet”.

- Note that PYTHIA Tune A and HERWIG differ at the generator level!
PY Tune A vs HERWIG: Particle Level Photon-Jet Balancing

- Shows the average ratio of $P_T$(particle jet#1)/$P_T$(direct photon) for “back-to-back” direct photon events with $P_T$(direct photon) > 30 GeV/c and Pjet2PT < 5 GeV/c for JetClu R = 0.7 at the particle level for PYTHIA Tune A and HERWIG.

- Note that PYTHIA Tune A and HERWIG differ at the generator level!
PYTHIA Tune A: Detector Level Photon-Jet Balancing

• Shows the average ratio of $P_T(jet#1)/P_T(pho#1)$ for “back-to-back” leading photon events with $P_T(pho#1) > 30$ GeV/c for JetClu $R = 0.7$ at the detector level for PYTHIA Tune A (i.e. after CDFSIM).
Photon-Jet Balancing: Particle Level vs Detector Level

- Shows the average ratio of $P_T(jet#1)/P_T(pho#1)$ for “back-to-back” leading photon events with $P_T(pho#1) > 30$ GeV/c and $Jet2PT < 5$ GeV for $JetClu R = 0.7$ for PYTHIA Tune A at the particle level and at the detector level (i.e. after CDFSIM).
• Data on the average ratio of $P_T(jet#1)/P_T(pho#1)$ for “back-to-back” leading photon events with $P_T(pho#1) > 30$ GeV/c for JetClu R = 0.7 compared with PYTHIA Tune A and HERWIG after CDFSIM.
• Data on the average ratio of $P_T(\text{jet#1})/P_T(\text{pho#1})$ for “back-to-back” leading photon events with $P_T(\text{pho#1}) > 30 \text{ GeV/c}$ and Jet2PT < 3 GeV for JetClu R = 0.7 compared with PYTHIA Tune A and HERWIG after CDFSIM.
Leading Photon $P_T$ Distribution: PY Tune A vs Data

- Data on the leading photon $P_T$ distribution compared with PYTHIA Tune A (after CDFSIM). Both data and theory normalized to one.

- Unlike the inclusive “jet” cross section the data does not rise above the theory at high $P_T$!
Leading Photon $P_T$ Distribution: PY Tune A vs Data

- Data on the leading photon $P_T$ distribution compared with PYTHIA Tune A (after CDFSIM). Normalized to agree at high $P_T$.

- Unlike the inclusive “jet” cross section the data does not rise above the theory at high $P_T$!
Jet Balancing: Photon versus Z-boson

- Data on the average ratio of $P_T\text{(jet#1)}/P_T\text{(pho#1)}$ for “back-to-back” leading photon events with $P_T\text{(pho#1)} > 30$ GeV/c and the ratio of $P_T\text{(jet#1)}/P_T\text{(Z)}$ for “back-to-back” Z-boson events with $P_T\text{(Z)} > 30$ GeV/c (Jet2PT < 10 GeV) for JetClu R = 0.7 at 1.96 TeV.
Jet Balancing: Photon versus Z-boson

- Data on the average ratio of $P_T(jet#1)/P_T(\text{pho#1})$ for “back-to-back” leading photon events with $P_T(\text{pho#1}) > 30$ GeV/c and the ratio of $P_T(jet#1)/P_T(Z)$ for “back-to-back” Z-boson events with $P_T(Z) > 30$ GeV/c and (Jet2PT < 5 GeV) for JetClu R = 0.7 at 1.96 TeV.
*** Summary & Plans ***

- Z-jet and Photon-jet balancing seem consistent in the data. Although I need to do a little more checking.

- HERWIG does not describe the “underlying event” in leading photon events. PYTHIA Tune A does much better is not perfect. This explains the differences seen between PYTHIA Tune A and HERWIG.

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

- 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 the Mid-Point Algorithm.

- I plan to get some plots blessed on the “underlying event” in Z-jet and Photon-Jet events and comparisons with PYTHIA Tune A and HERWIG to show at ISMD2004 at the end of July!