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

| Photon25 (cph10d) | No Vtx Cut | NZvtx <=1 |
|---|---|---|
| Total Events | 9,671,427 | 9,671,427 |
| Good Events (QCDv5) | 8,289,860 | 8,289,860 |
| %Good | 85.71% | 85.71% |
| Vertex Cut | 8,289,860 | 5,284,078 |
| ZJetAnaModule | 8,289,860 | 5,284,078 |
| Z-Bosons (\|eta\|<6) | 15,127 | 10,634 |
| Tight-Tight | 4,306 | 2,995 |
| Back-to-Back | 5,987 | 4,195 |
| PTZ > 10 GeV | 6,356 | 4,426 |
| PTZ > 30 GeV | 1,261 | 853 |
| 20 < ET(jet1) < 30 GeV | 93,878 | 537 |
| 30 < ET(jet1) < 50 GeV | 182,498 | 320 |
| ET(jet1)> 50 | 59,000 | 143 |
| PhoJetAnaModule | 8,274,662 | 5,273,400 |
| Good Photon | 647,345 | 460,909 |
| pho1PT > 25 GeV | 467,314 | 339,267 |
| Back-to-Back | 374,050 | 271,701 |
| pho1PT > 30 GeV | 237,236 | 171,908 |
| pho1PT > 50 GeV | 27,055 | 19,622 |
| 25 < ET(jet1) < 30 GeV | 71,050 | 50,071 |
| 30 < ET(jet1) < 50 GeV | 94,290 | 65,020 |
| ET(jet1)> 50 | 17,378 | 11,569 |

$|\Delta\phi| > 150^o$

| py Tune A (jqcd0e) | No Vtx Cut |
|---|---|
| Total Events | 1,981,747 |
| PhoJetAnaModule | 1,981,747 |
| Good Photon | 290,064 |
| pho1PT > 25 GeV | 184,742 |
| Back-to-Back | 16,255 |
| pho1PT > 30 GeV | 97,271 |
| pho1PT > 50 GeV | 13,762 |
| 20 < ET(jet1) < 30 GeV | 5,745 |
| 30 < ET(jet1) < 50 GeV | 2,262 |
| ET(jet1)> 50 | 339 |

Thanks Ken and Anwar!

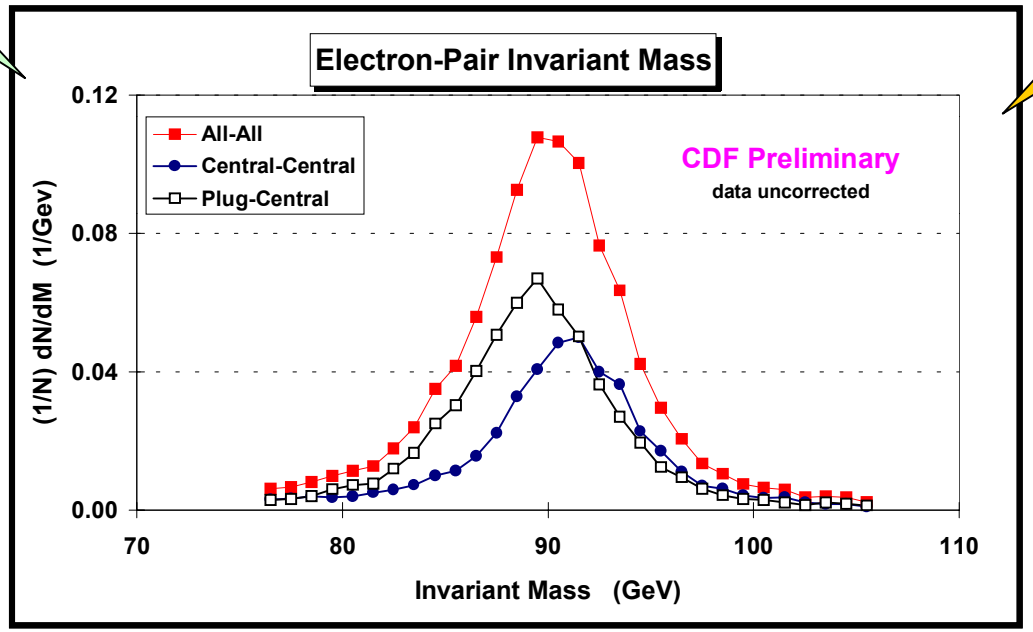
PY Tune A Direct Photon!

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

# CPH10d Containes Both Photons and Z-bosons!

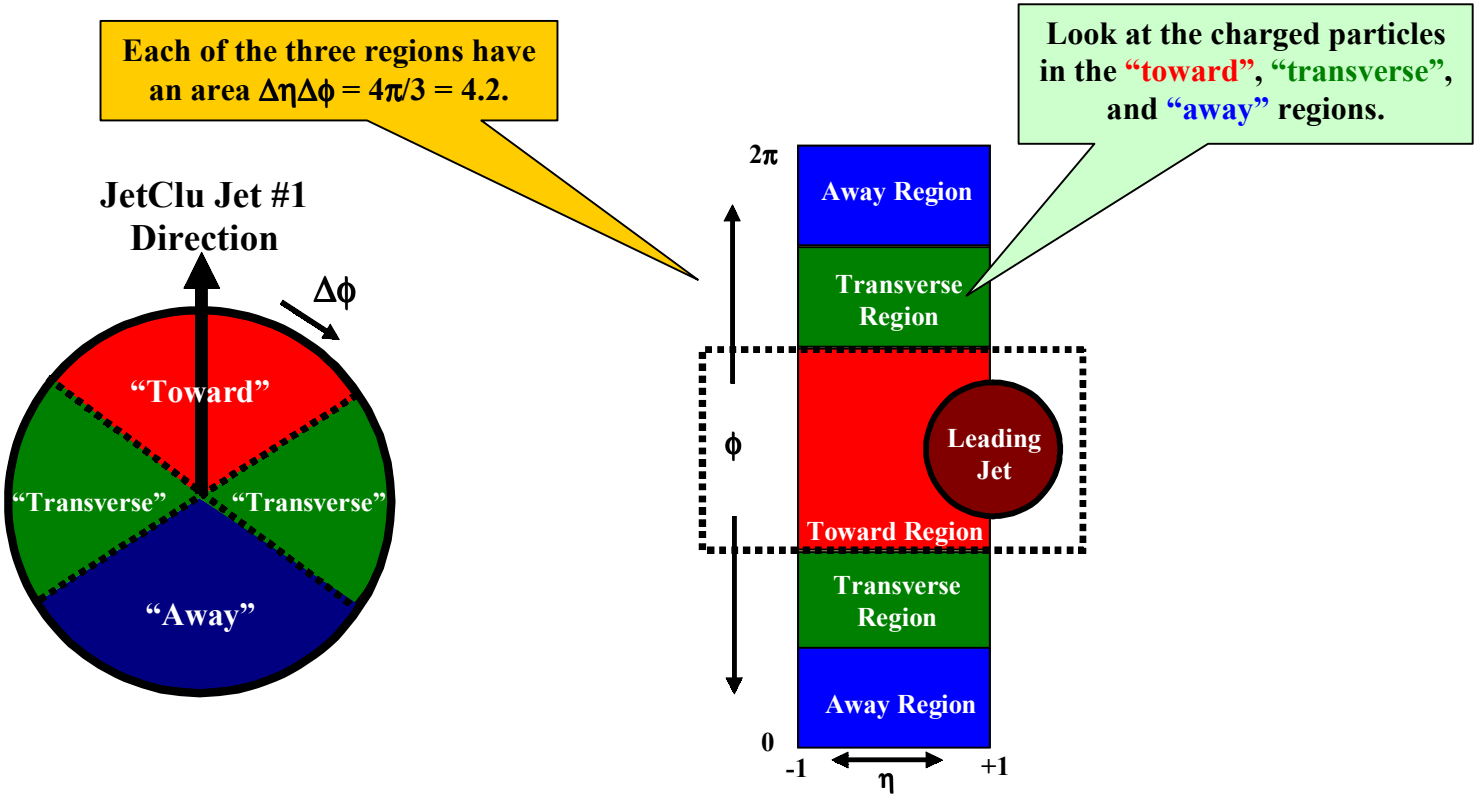
CDF Data!

Beatte taught me how to find Z-bosons!



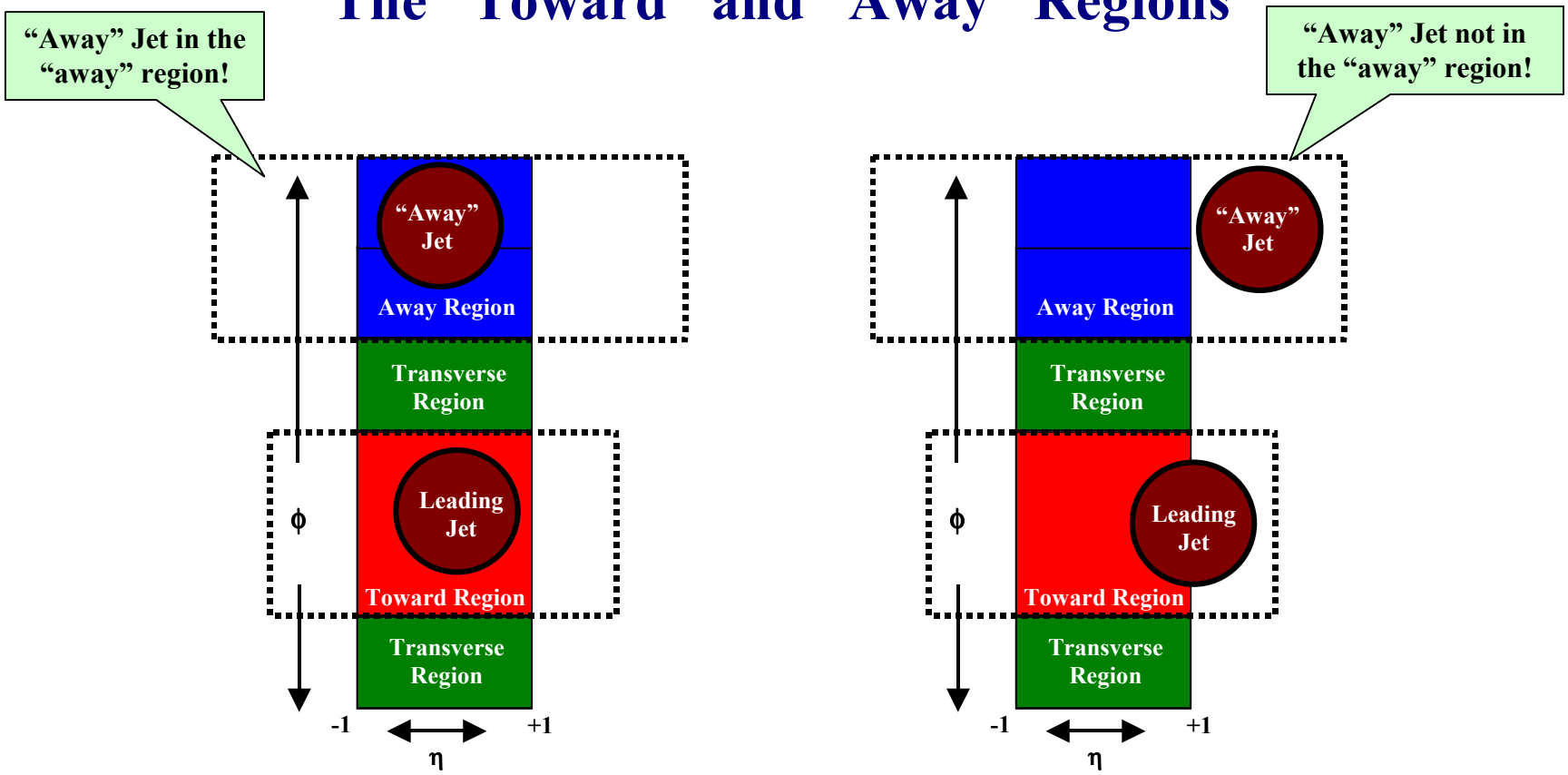

- **5.3.1 Z mass distribution not perfect! Plug electron calibration must not be exactly correct? I used only the correction factors provided in 5.3.1.**

# The "Toward", "Transverse", and "Away" Regions



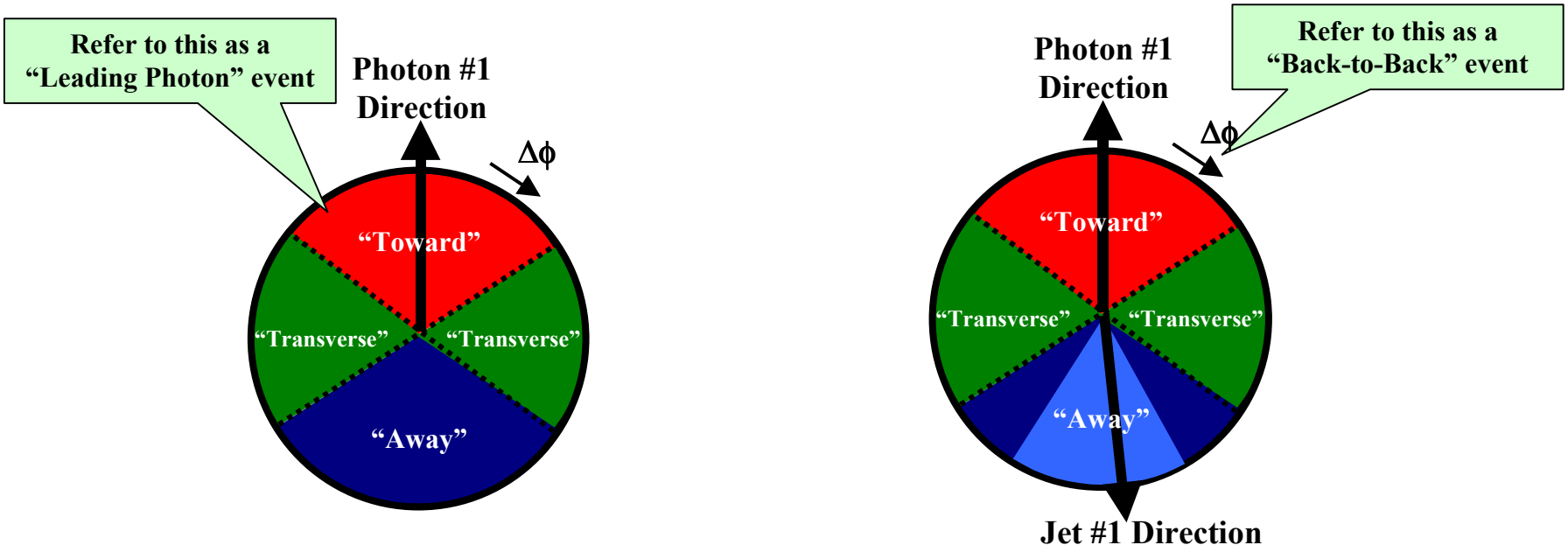

- **Look at the "toward", "transverse", and "away" regions as defined by the leading calorimeter jet (JetClu R = 0.7, $|\eta| < 2$).**
- **Study the charged particles in the region $p_T > 0.5$ GeV/c and $|\eta| < 1$.**

# The "Toward" and "Away" Regions



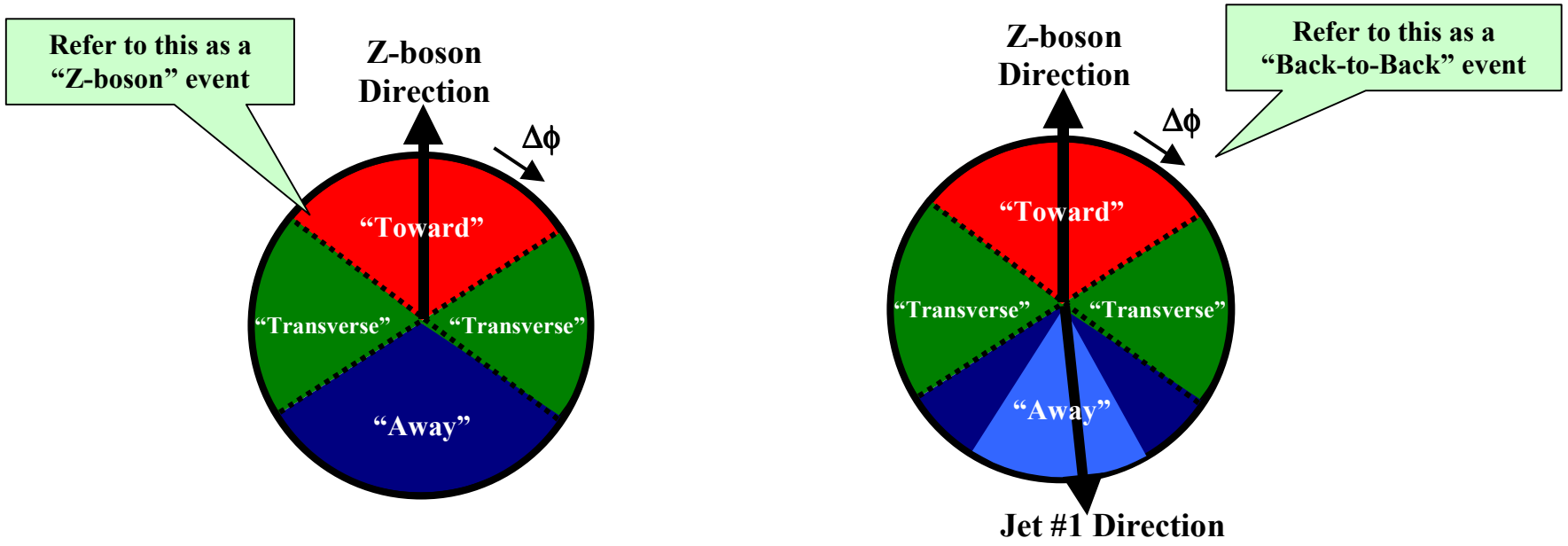

- **Note that the "toward" region does not always contain all of the leading jet and and the "away" regions do not always contain the "away" jet.**

# "Toward", Away", and "Transverse" Regions



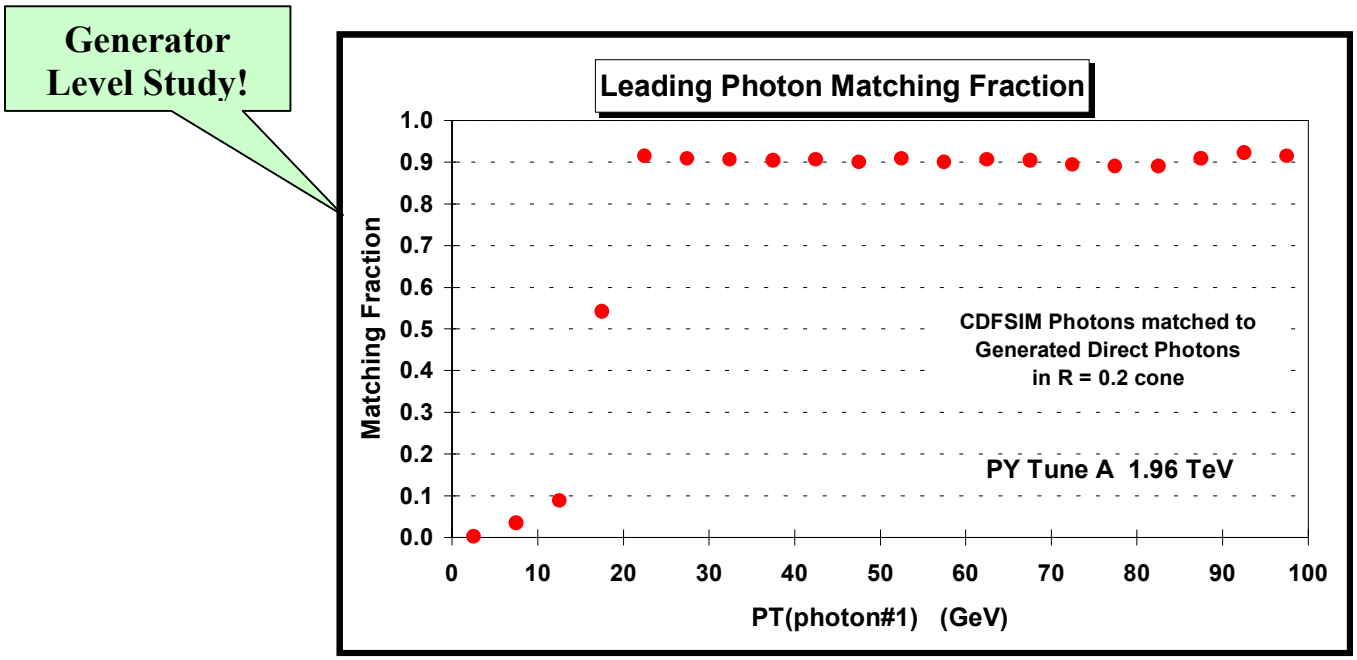

- **Look at the "toward", "away", and "transverse" regions as defined by the leading photon (central photons only $|\eta| < 1$).**
- **"Back-to-Back" events are selected to have at least one jet with Jet#1 nearly "back-to-back" with the leading photon ($\Delta\phi_{1\gamma} > 150^{o}$).**

# "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 ($\Delta\phi_{1Z} > 150^{o}$).**

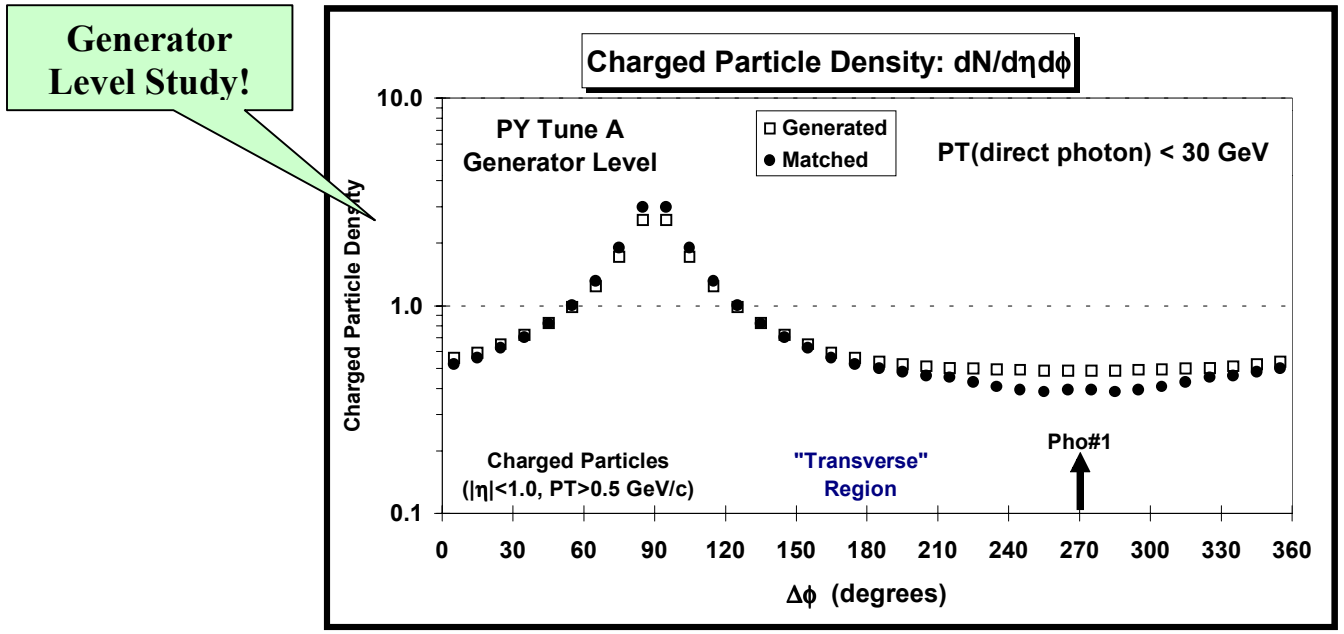
# Direct Photon Production: PYTHIA Tune A




- **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!**

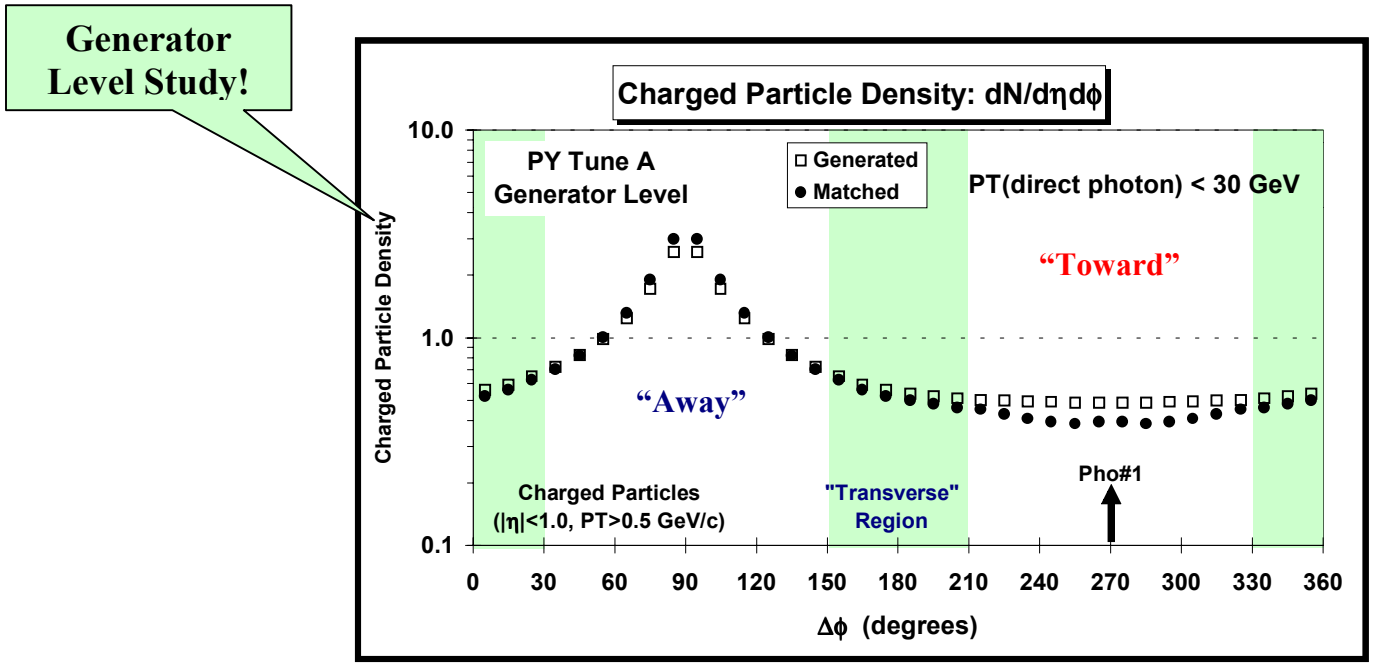
# Photon Selection Bias: PYTHIA Tune A




- **Shows the Δϕ dependence of the charged particle density, dN/dηdϕ, for charged particles in the range $p_T > 0.5$ GeV/c and $|\eta| < 1$ relative to the leading photon (rotated to 270°) for $P_T$(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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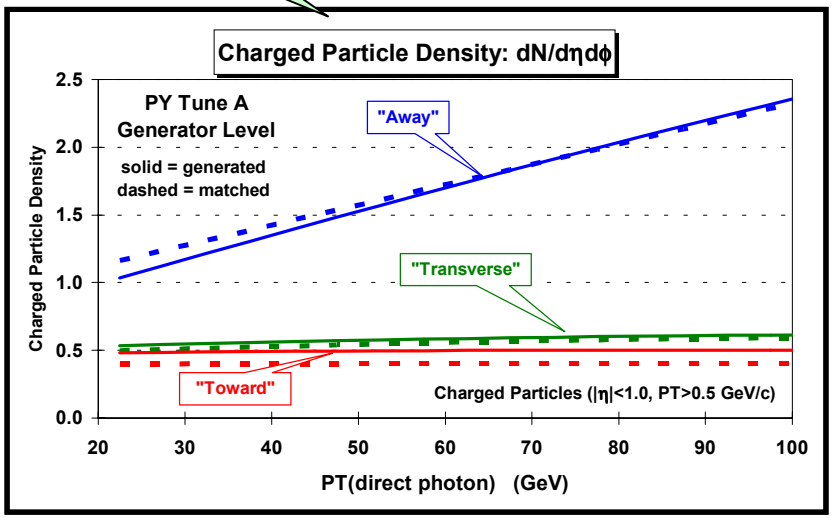
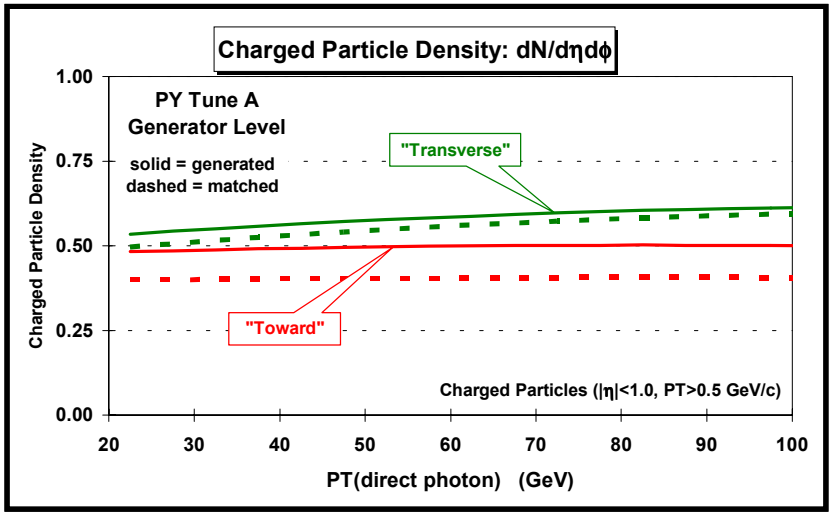
# Photon Selection Bias: PYTHIA Tune A

Generator Level Study!

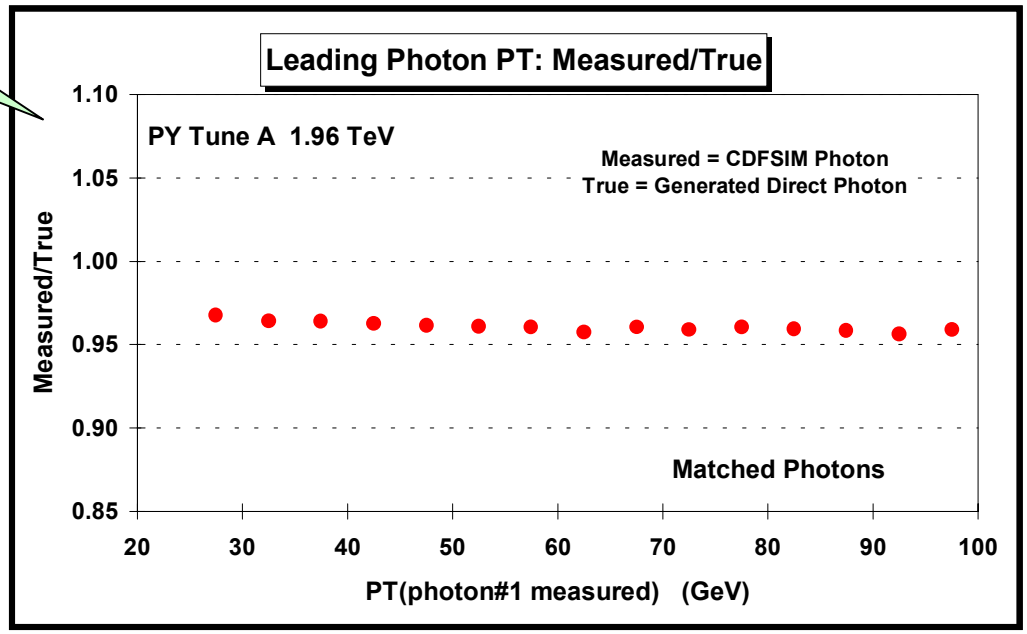



- **Generator level study showing the "true" average charged particle density ($p_T$ > 0.5 GeV/c, |η| < 1) with the "matched" densities.**
- **The photon isolation cuts produce a "photon selection bias". There are less charged particles in the "toward" region in the "matched" events!**

# Photon Energy Resolution: PYTHIA Tune A

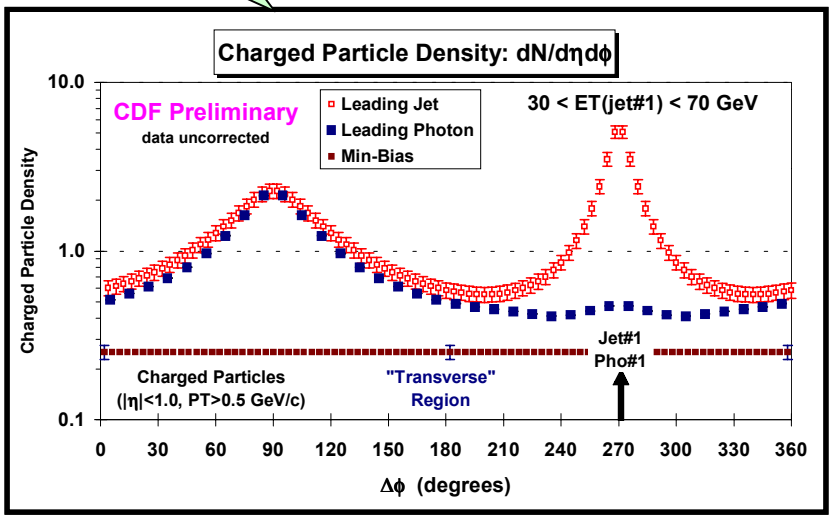
Before and After CDFSIM!



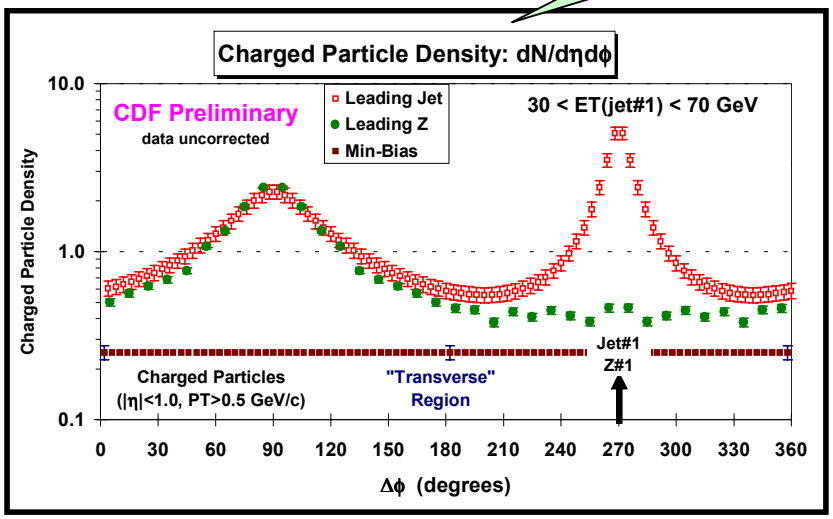

- The observed "matched" photons (after CDFSIM) have less $p_T$ than the "true" generated direct photons.
- This is presumably due to energy resolution and a steeply falling $p_T$ spectrum!

# 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 ($P_T$(pho#1) > 30 GeV) with "leadig jet" events (30 < $E_T$(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 < $E_T$(jet#1) < 70 GeV).

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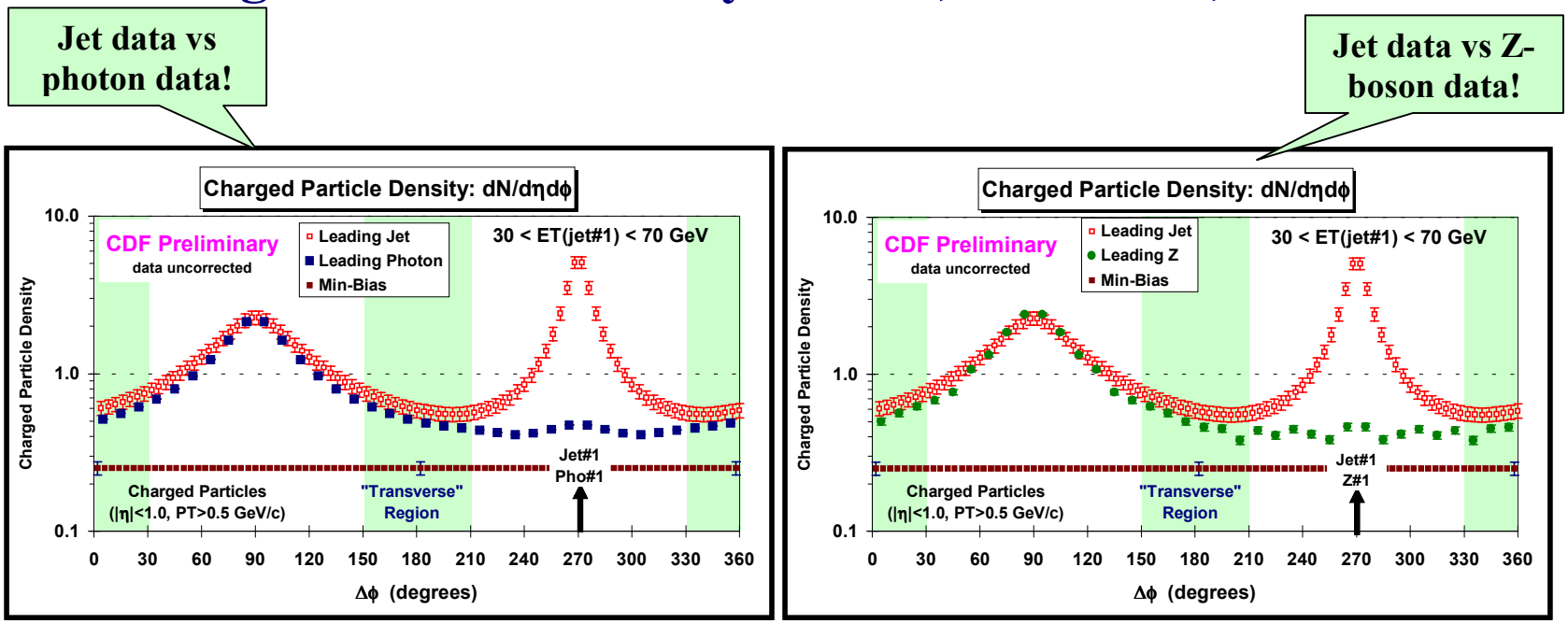
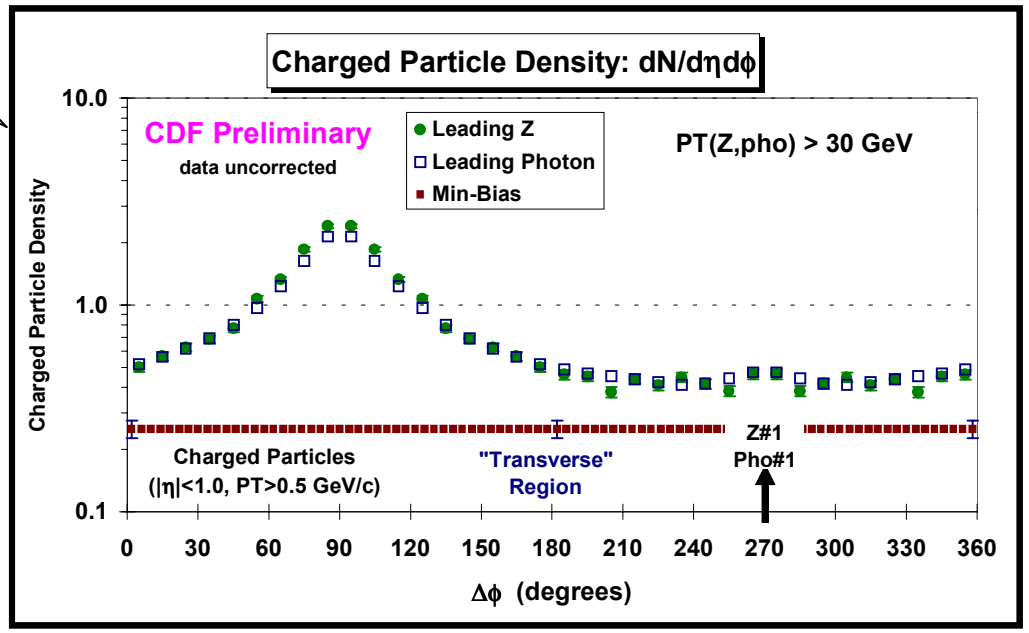



- (*left*) Compares the Δϕ dependence of the particle density, dN/dηdϕ, for charged particles in the range $p_T > 0.5$ GeV/c and $|\eta| < 1$ for "leading photon" events ($P_T$(pho#1) > 30 GeV) with "leadig jet" events (30 < $E_T$(jet#1) < 70 GeV).

- (*right*) Compares the Δϕ dependence of the particle density, dN/dηdϕ, 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 < $E_T$(jet#1) < 70 GeV).

# Charged Particle Density: Photon vs Z-boson

Z data vs photon data!




- 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 ($P_T$(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

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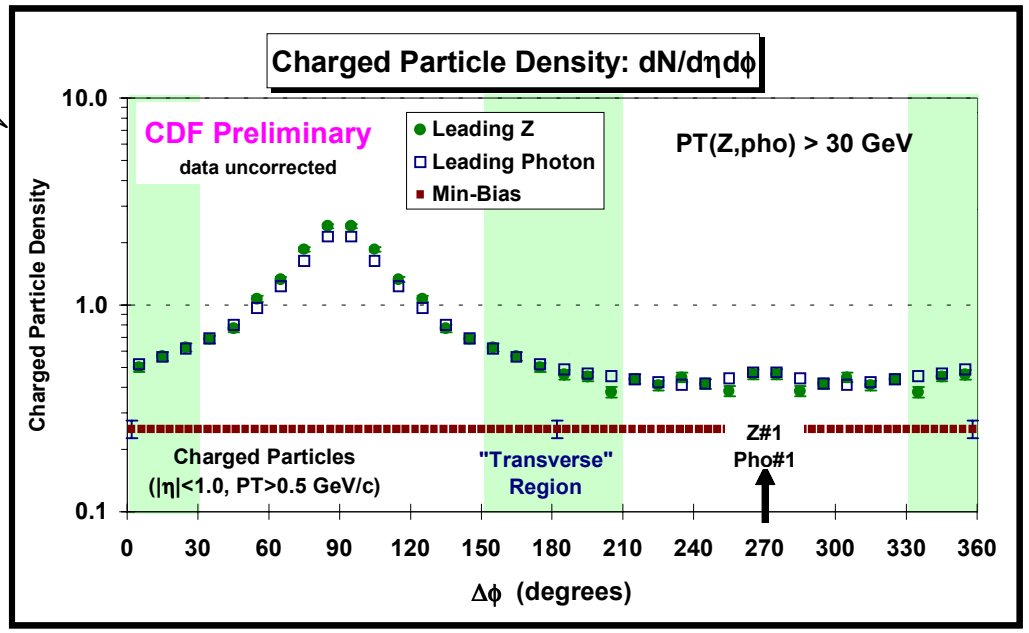


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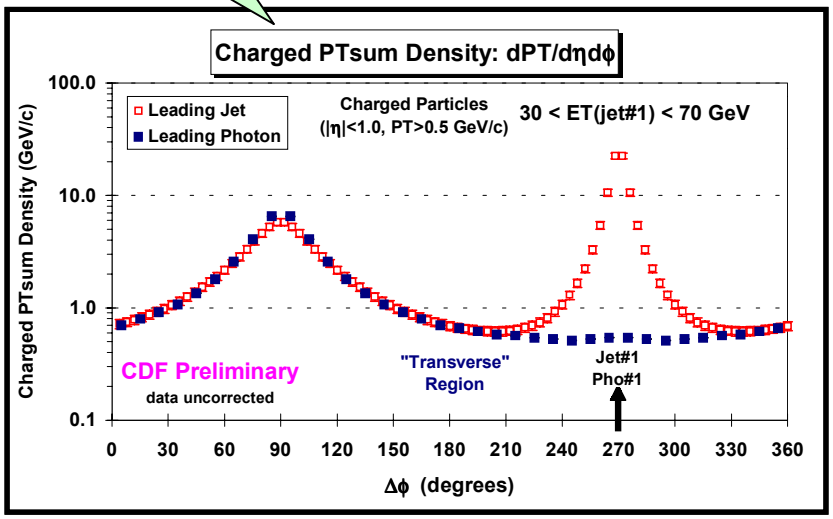
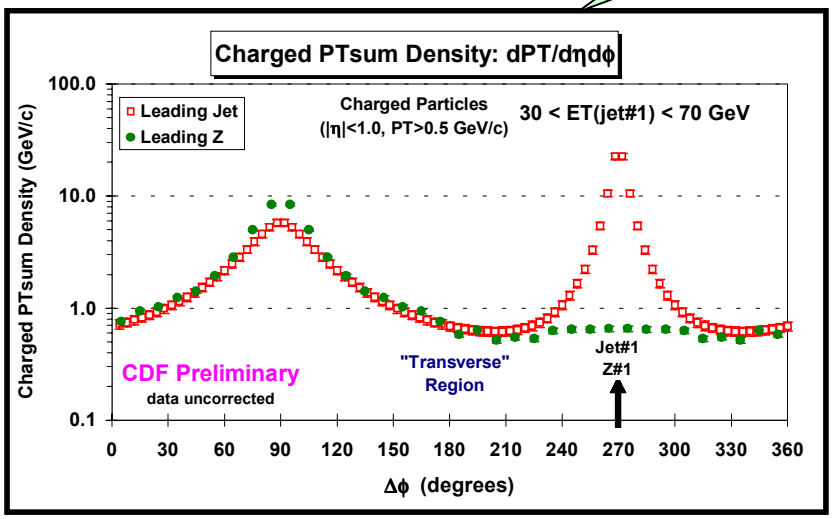
# Charged PTsum Density: "Jet", "Photon", and "Z"

Jet data vs photon data!




Jet data vs Z-boson data!




- (*left*) Compares the Δφ dependence of the *scalar* PTsum density, dN/dηdφ, 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 "leadig jet" events (30 < $E_T$(jet#1) < 70 GeV).

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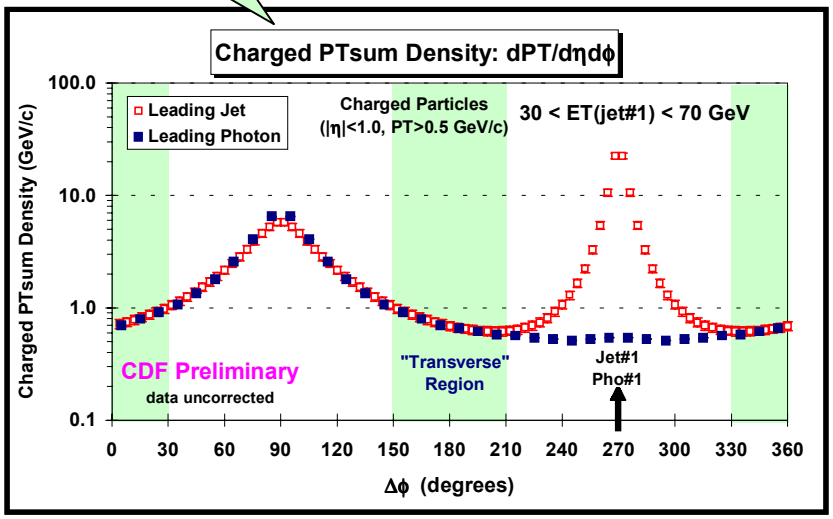
# Charged PTsum Density: "Jet", "Photon", and "Z"

Jet data vs photon data!

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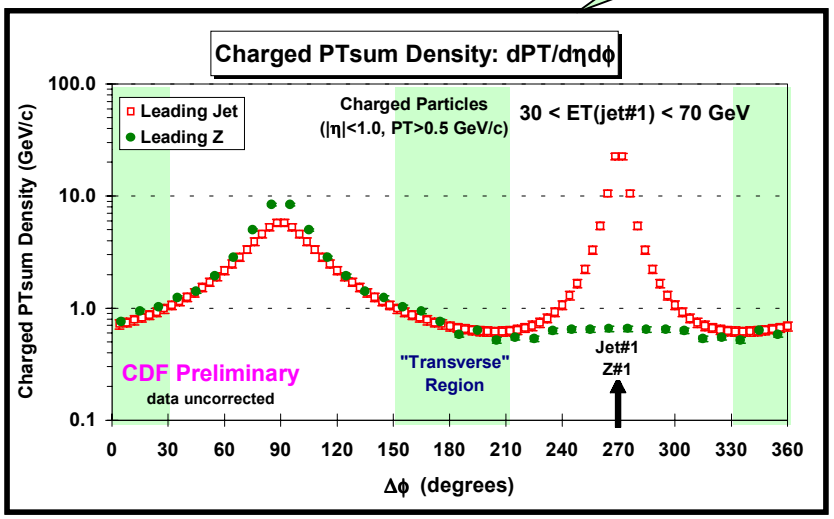


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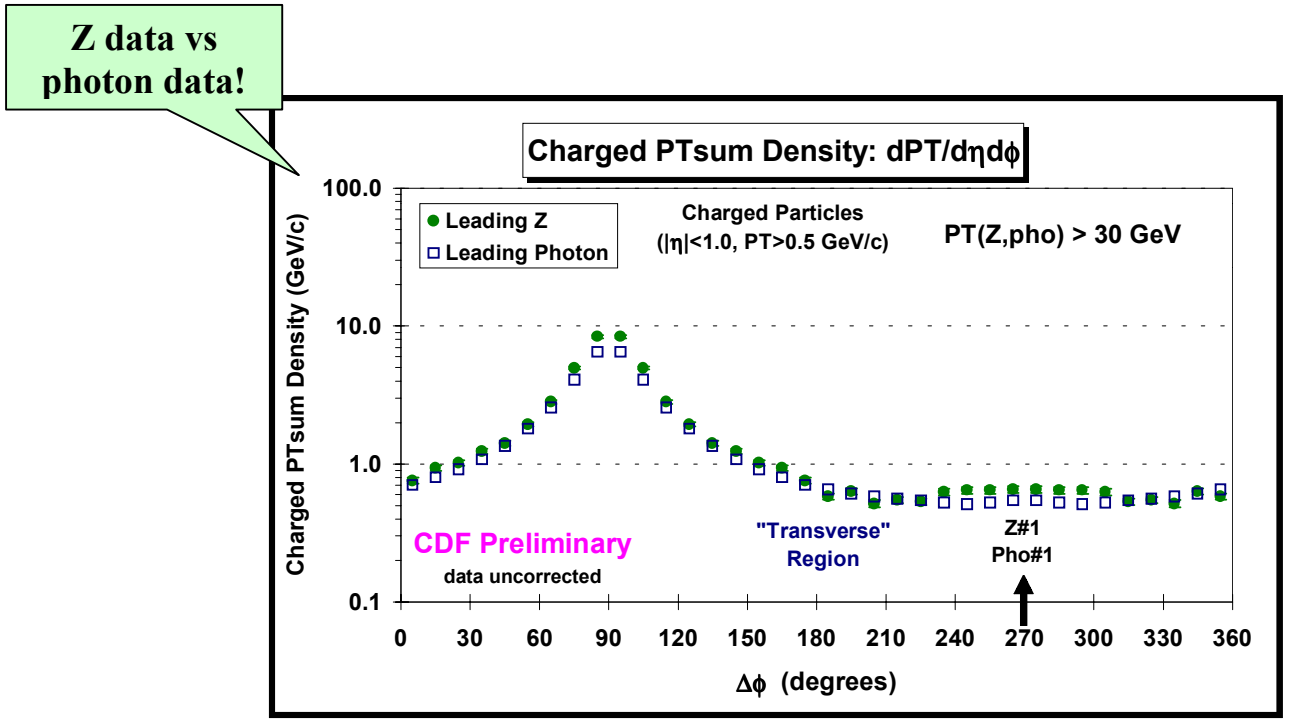
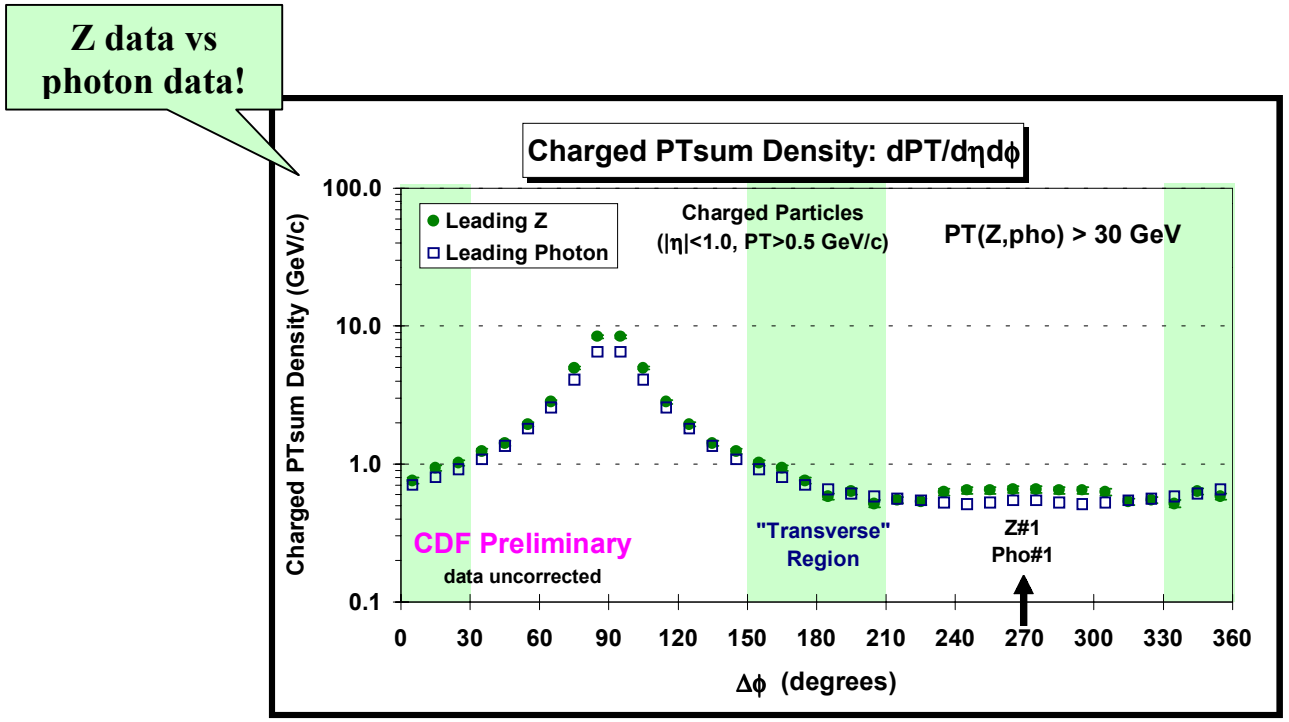
# Charged PTsum Density: Photon+Jet vs Z+Jet




- **Shows the Δϕ dependence of the *scalar* PTsum density, dPT/dηdϕ, 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) 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

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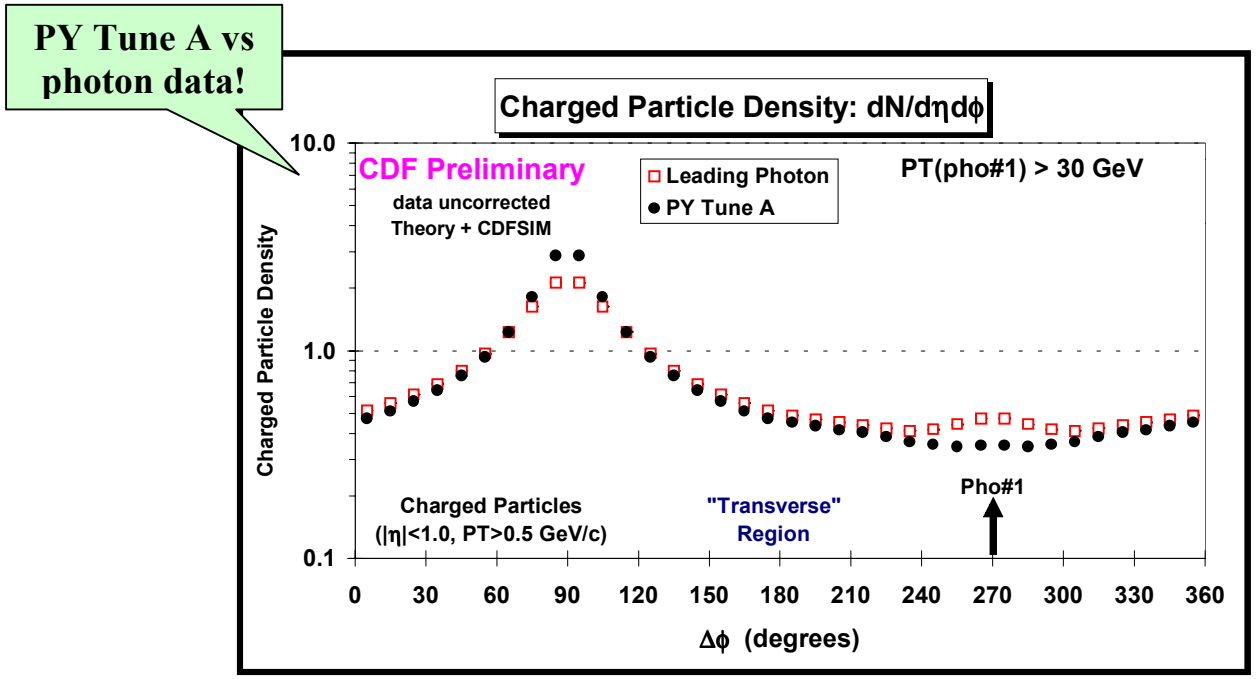
# Photon Charged Particle Density: PY Tune A vs Data




- **Shows the Δϕ dependence of the 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).**

- **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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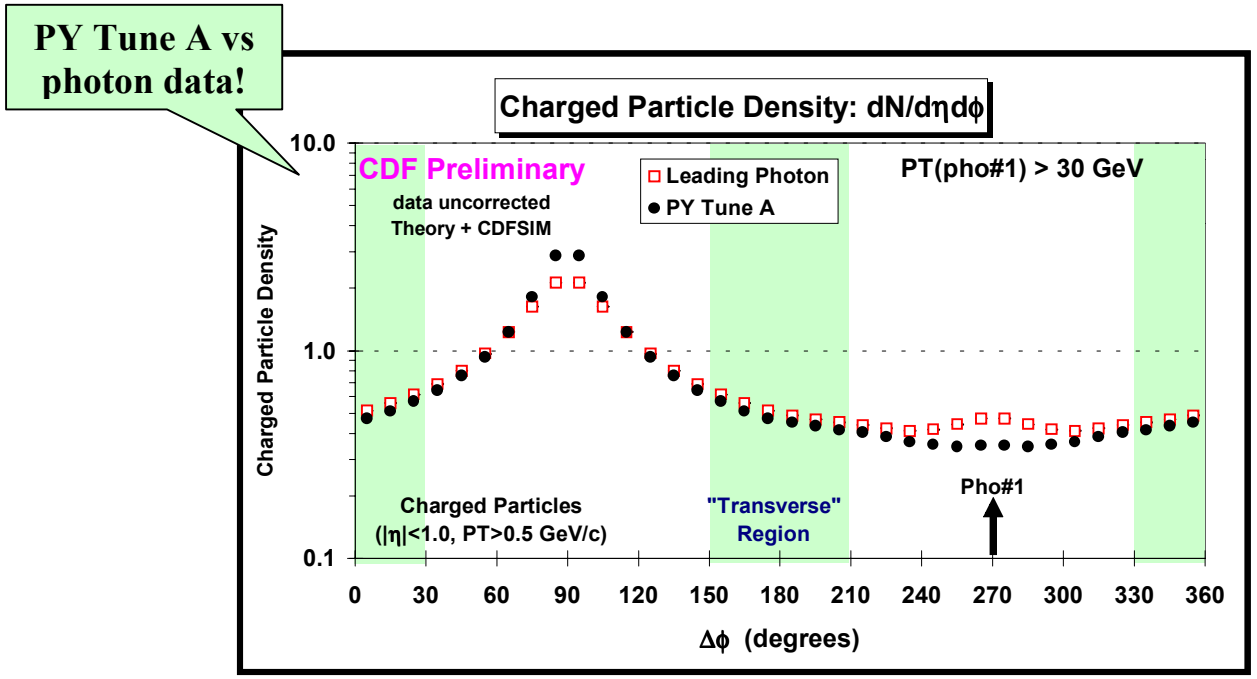


- **Shows the Δϕ dependence of the particle density, dN/dηdϕ, for charged particles ($p_T$ > 0.5 GeV/c, |η| < 1) for "leading photon" events ($P_T$(pho#1) > 30 GeV) compared with PYTHIA Tune A (after CDFSIM).**

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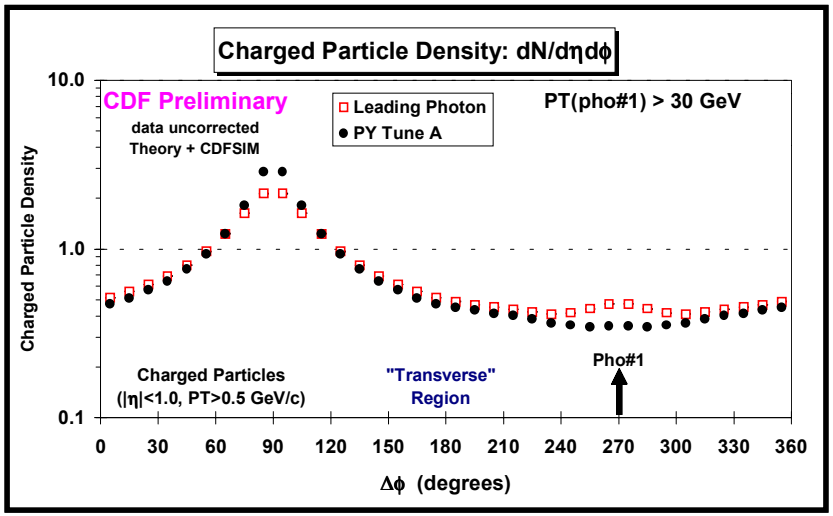
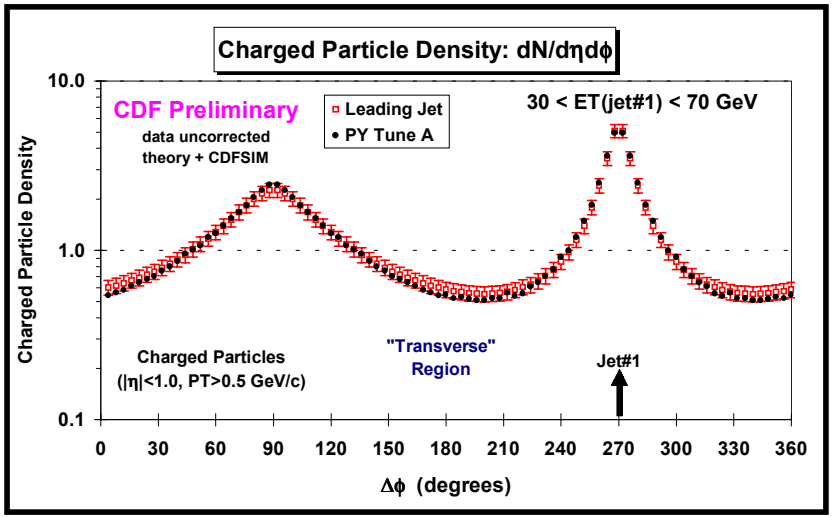
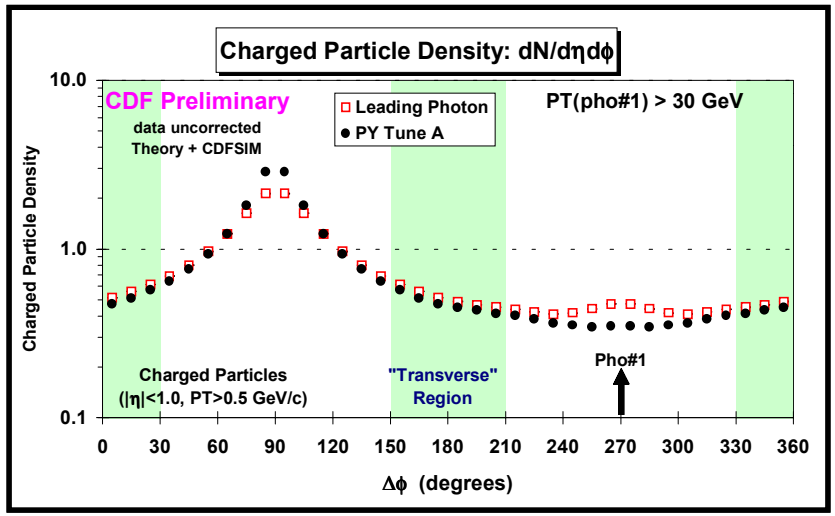


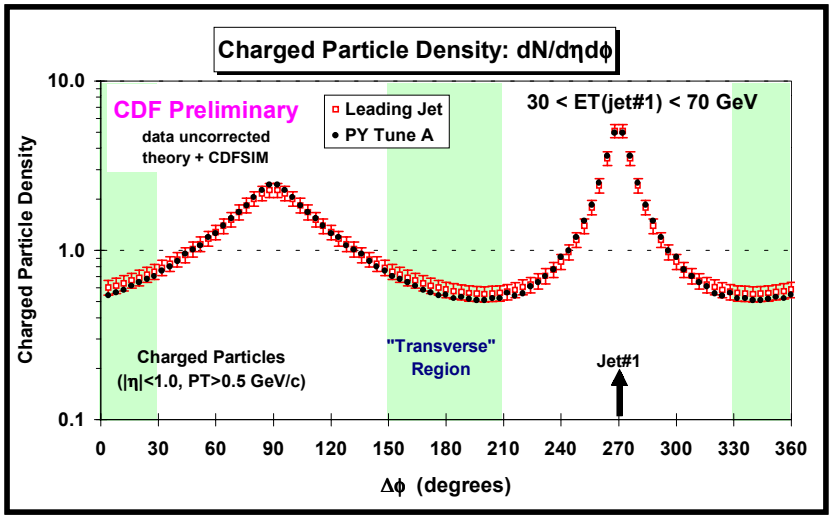




- (*left*) Shows the Δϕ dependence of the charged particle density, dN/dηdϕ, for charged particles ($p_T$ > 0.5 GeV/c, |η| < 1) for "leading photon" events ($P_T$(pho#1) > 30 GeV) compared with PYTHIA Tune A (after CDFSIM).

- (*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).

# Charged Particle Density: PY Tune A vs Data

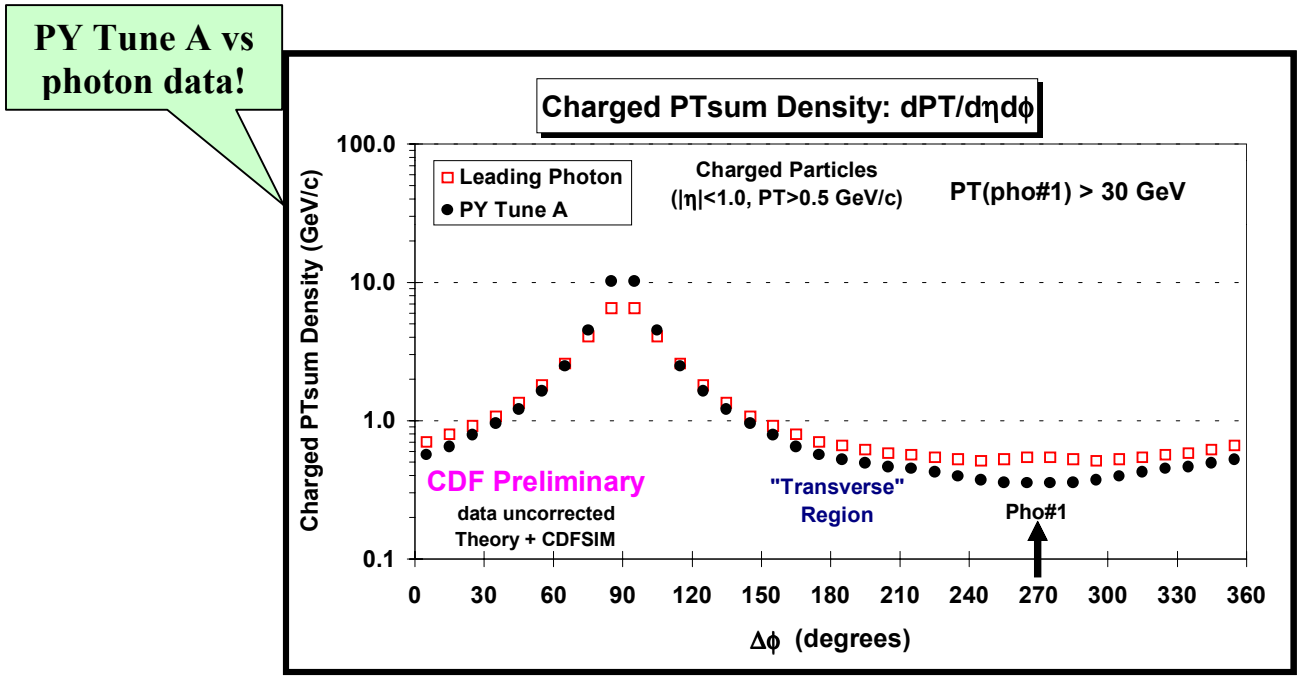



- **(*left*) Shows the Δϕ dependence of the charged particle density, dN/dηdϕ, for charged particles ($p_T$ > 0.5 GeV/c, |η| < 1) for "leading photon" events ($P_T$(pho#1) > 30 GeV) compared with PYTHIA Tune A (after CDFSIM).**

- **(*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).**

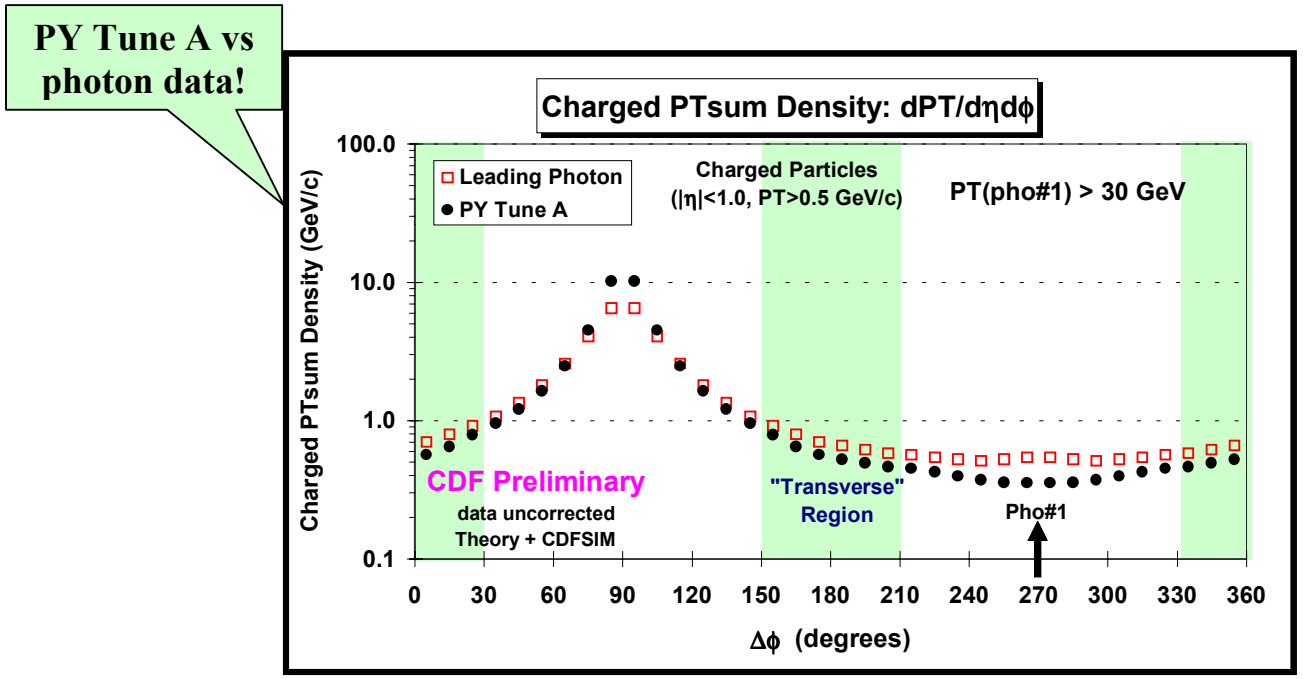
# Photon PTsum Particle Density: PY Tune A vs Data




- **Shows the Δϕ dependence of the *scalar* PTsum density, dPT/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).**

- **This is not very good agreement! I do not yet understand why the agreement in the "toward" and "transverse" regions is not better??**

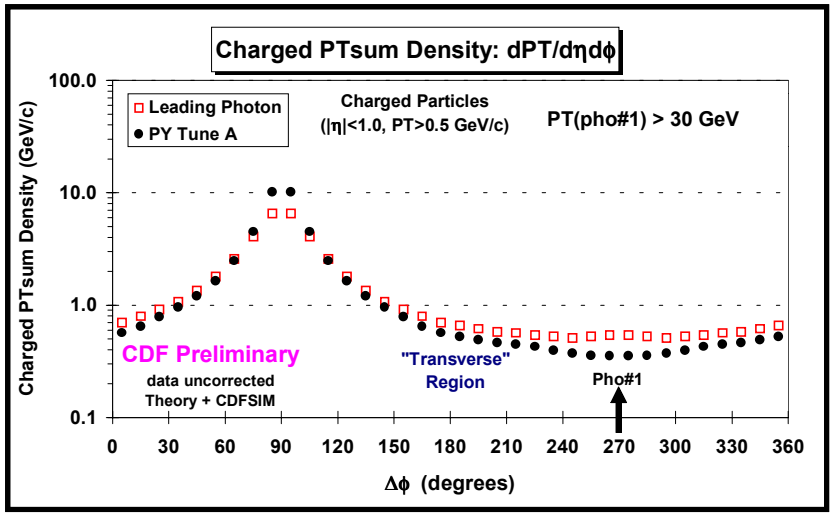
# Photon PTsum Particle Density: PY Tune A vs Data

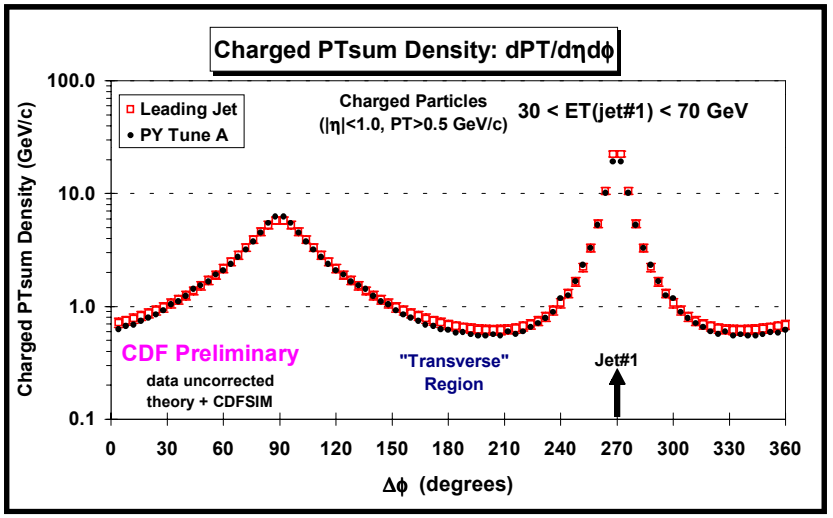



- **Shows the Δϕ dependence of the *scalar* PTsum density, dPT/dηdϕ, for charged particles ($p_T$ > 0.5 GeV/c, |η| < 1) for "leading photon" events ($P_T$(pho#1) > 30 GeV) compared with PYTHIA Tune A (after CDFSIM).**

- **This is 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

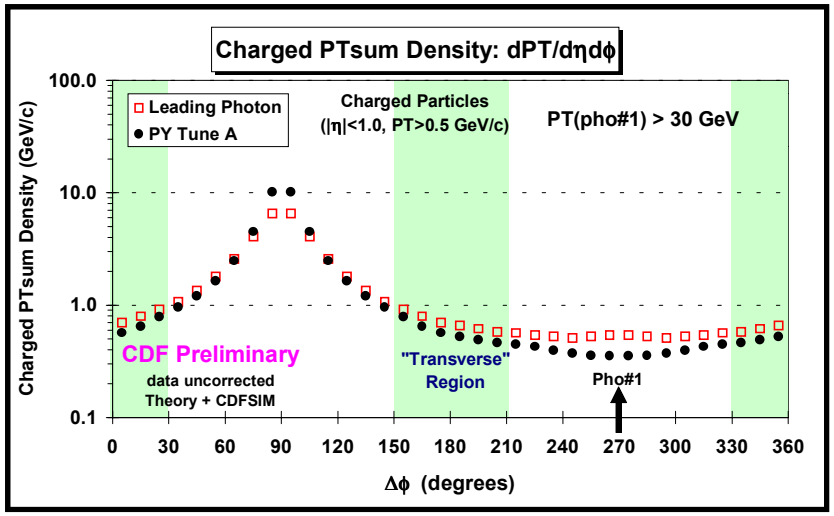


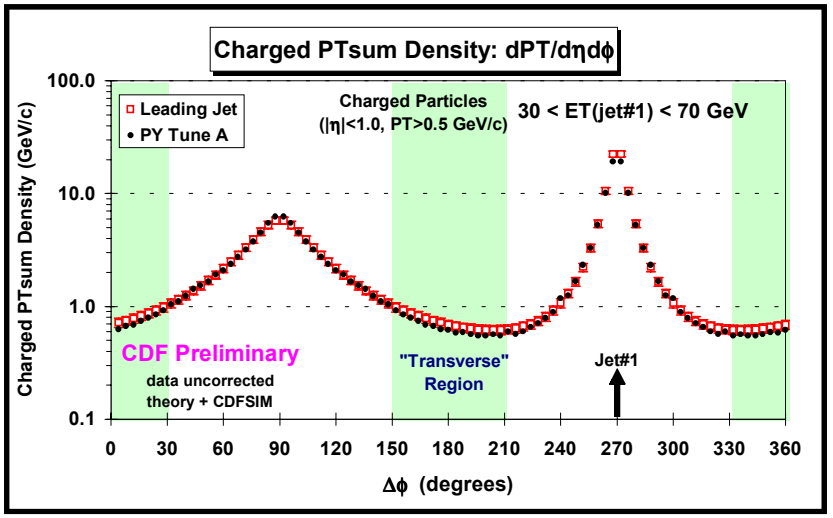




- **(*left*) Shows the Δϕ dependence of the charged PTsum density, dPT/dηdϕ, for charged particles ($p_T$ > 0.5 GeV/c, |η| < 1) for "leading photon" events ($P_T$(pho#1) > 30 GeV) compared with PYTHIA Tune A (after CDFSIM).**

- **(*right*) Shows the Δϕ dependence of the charged PTsum density, dPT/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).**

# PTsum Particle Density: PY Tune A vs Data

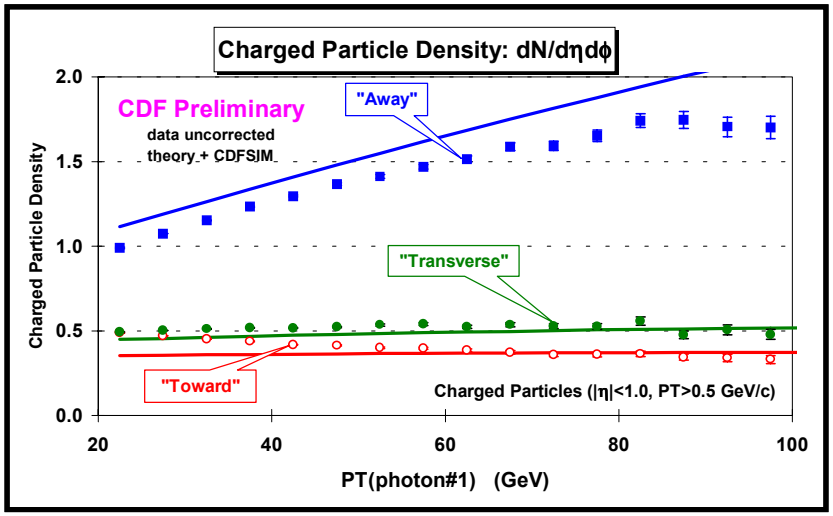


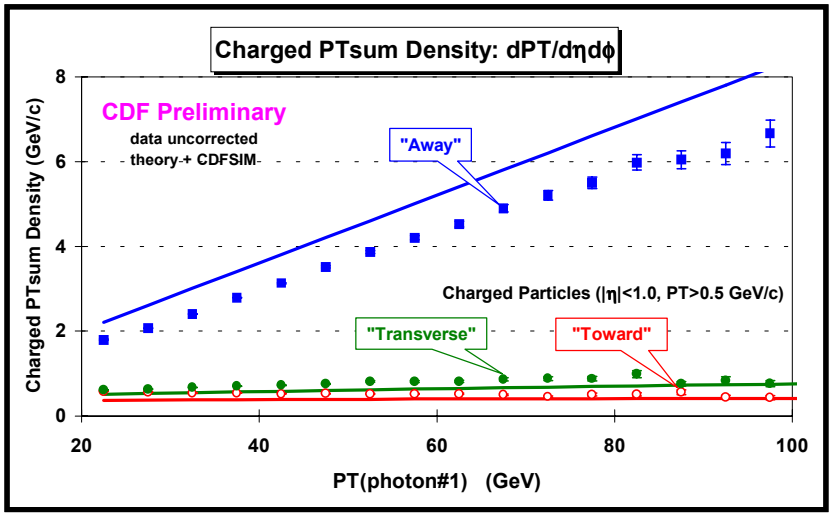




- **(*left*) Shows the Δϕ dependence of the charged PTsum density, dPT/dηdϕ, for charged particles ($p_T$ > 0.5 GeV/c, |η| < 1) for "leading photon" events ($P_T$(pho#1) > 30 GeV) compared with PYTHIA Tune A (after CDFSIM).**

- **(*right*) Shows the Δϕ dependence of the charged PTsum density, dPT/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 Particle Densities: PY Tune A vs Data

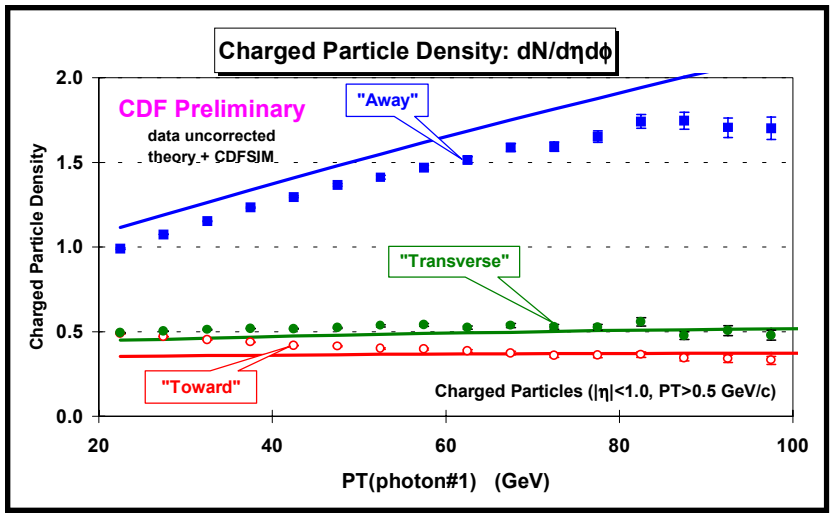


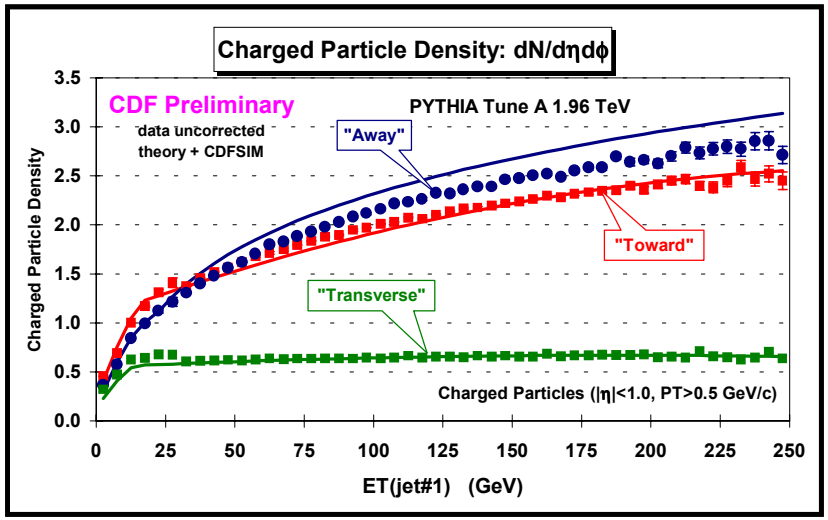




- **Shows the average charged particle density, dN/dηdϕ, and PTsum density, dPT/dηdϕ, for charged particles ($p_T$ > 0.5 GeV/c, |η| < 1) in the "toward", "away", and "transverse" regions versus $P_T$(pho#1) for "leading photon" events compared with PYTHIA Tune A (after CDFSIM).**

- **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

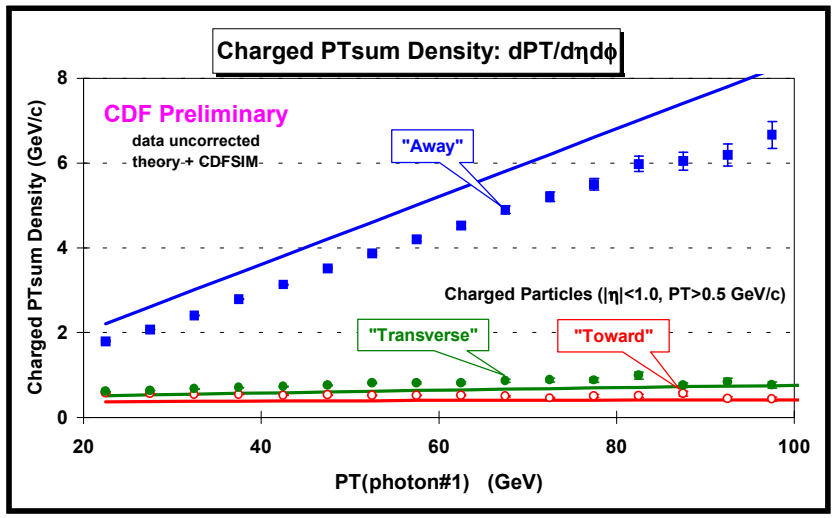


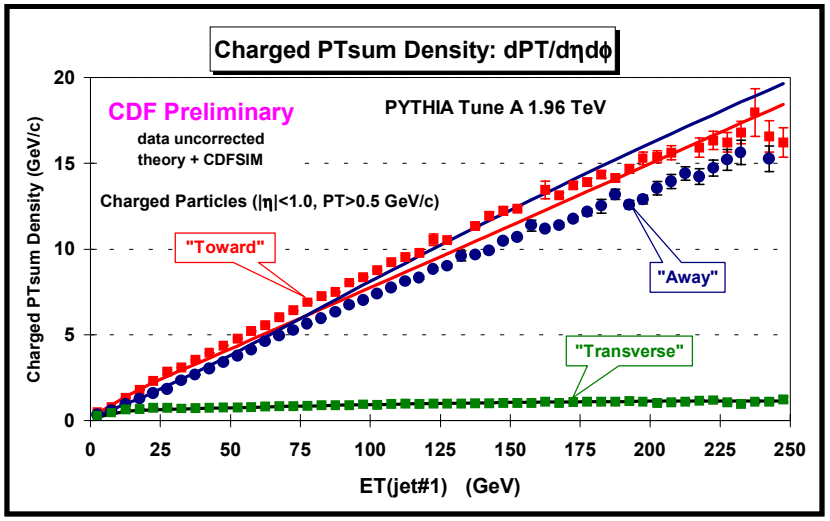




- **(*left*) Shows the average density, dN/dηdϕ, charged particles ($p_T$ > 0.5 GeV/c, |η| < 1) in the "toward", "away", and "transverse" regions versus $P_T$(pho#1) for "leading photon" events compared with PYTHIA Tune A (after CDFSIM).**

- **(*right*) Shows the average density, dN/dηdϕ, charged particles ($p_T$ > 0.5 GeV/c, |η| < 1) in the "toward", "away", and "transverse" regions versus $E_T$(jet#1) for "leading jet" events compared with PYTHIA Tune A (after CDFSIM).**

# Charged PTsum Densities: PY Tune A vs Data



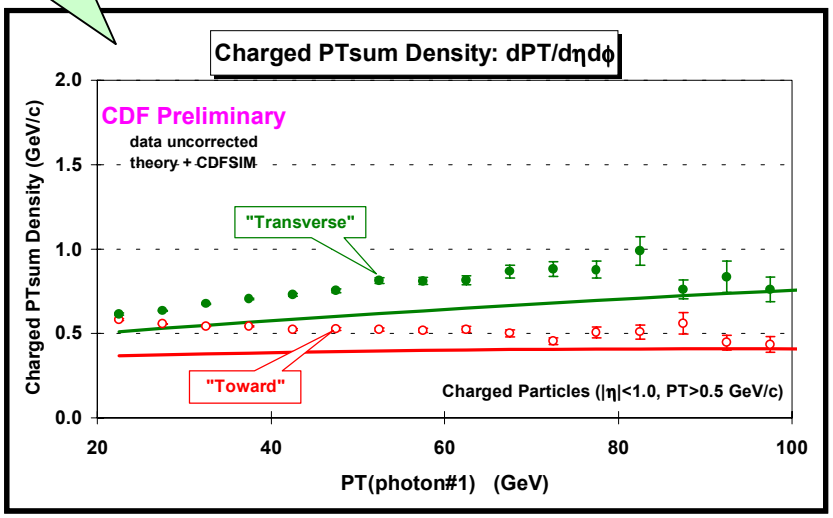




- (*left*) Shows the average PTsum density, dPT/dηdϕ, charged particles ($p_T > 0.5$ GeV/c, $|\eta| < 1$) in the "toward", "away", and "transverse" regions versus $P_T$(pho#1) for "leading photon" events compared with PYTHIA Tune A (after CDFSIM).

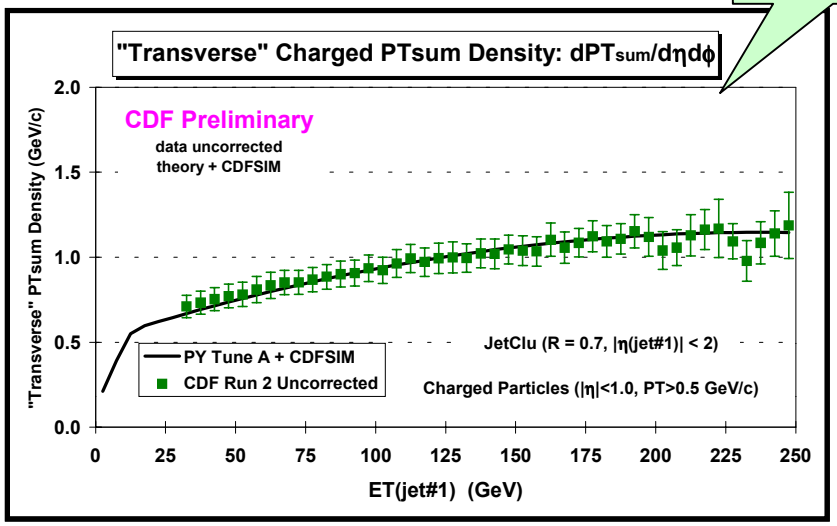
- (*right*) Shows the average PTsum density, dPT/dηdϕ, charged particles ($p_T > 0.5$ GeV/c, $|\eta| < 1$) in the "toward", "away", and "transverse" regions versus $E_T$(jet#1) for "leading jet" events compared with PYTHIA Tune A (after CDFSIM).

# "Transverse" PTsum Particle Density: PY Tune A vs Data

All NZvtx!



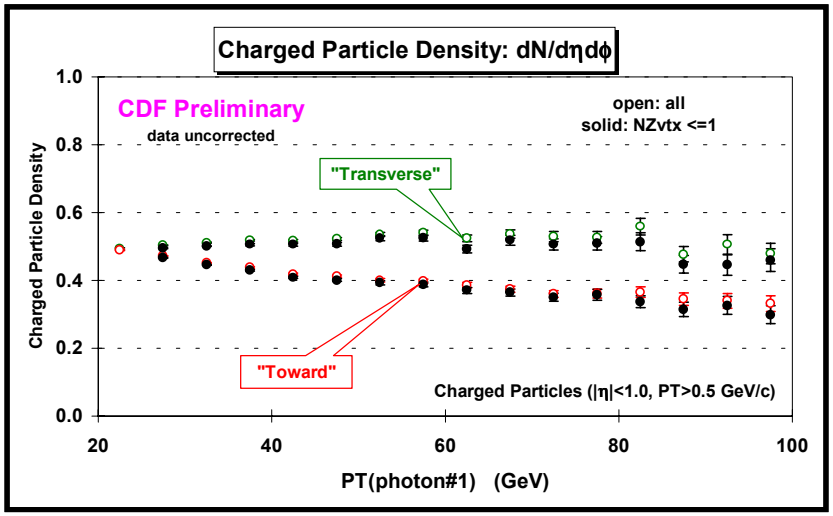

NZvtx <= 1

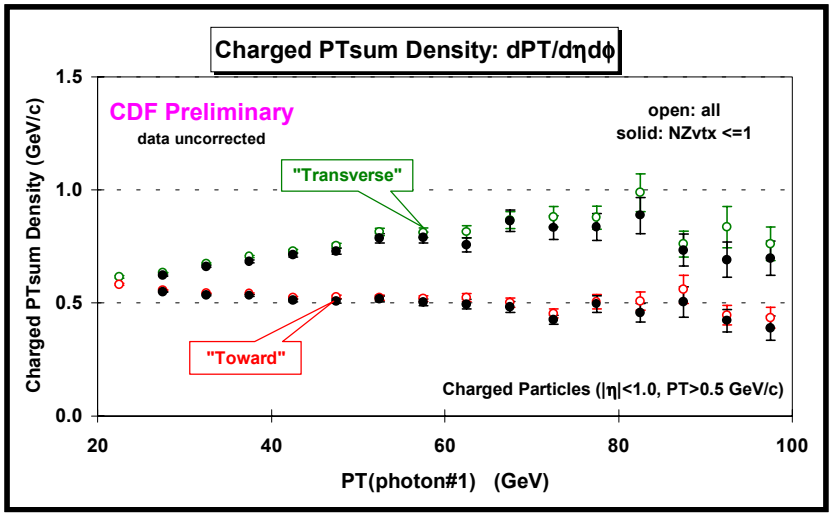



- ***(left)*** **Shows the average PTsum density, dPT/dηdϕ, for charged particles ($p_T$ > 0.5 GeV/c, |η| < 1) in the "toward", and "transverse" regions versus $P_T$(pho#1) for "leading photon" events compared with PYTHIA Tune A (after CDFSIM).**

- ***(right)*** **Shows the average PTsum density, dPT/dηdϕ, for charged particles ($p_T$ > 0.5 GeV/c, |η| < 1) in the "toward", and "transverse" regions versus $E_T$(jet#1) for "leading jet" events compared with PYTHIA Tune A (after CDFSIM).**

# "Pile-Up" and the Charged Particle Densities

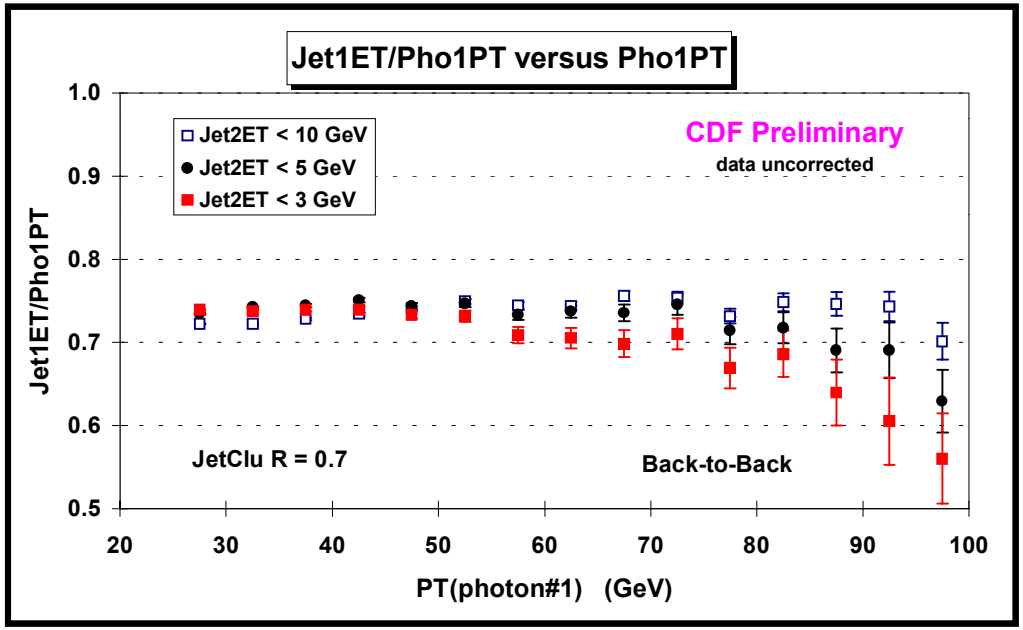



- **Shows the average charged particle density, dN/dηdϕ, and PTsum density, dPT/dηdϕ, for charged particles ($p_T$ > 0.5 GeV/c, |η| < 1) in the "toward", and "transverse" regions versus $P_T$(pho#1) for all "leading photon" events compared with "leading photon" events with <= 1 z-vertex (class 12 or higher).**

- **Because I am making "tight" track cuts on the primary vertex "pile-up" efects are negligable for the charged particles! But "pile-up" may affect the jet energies!**

# Photon-Jet Balancing

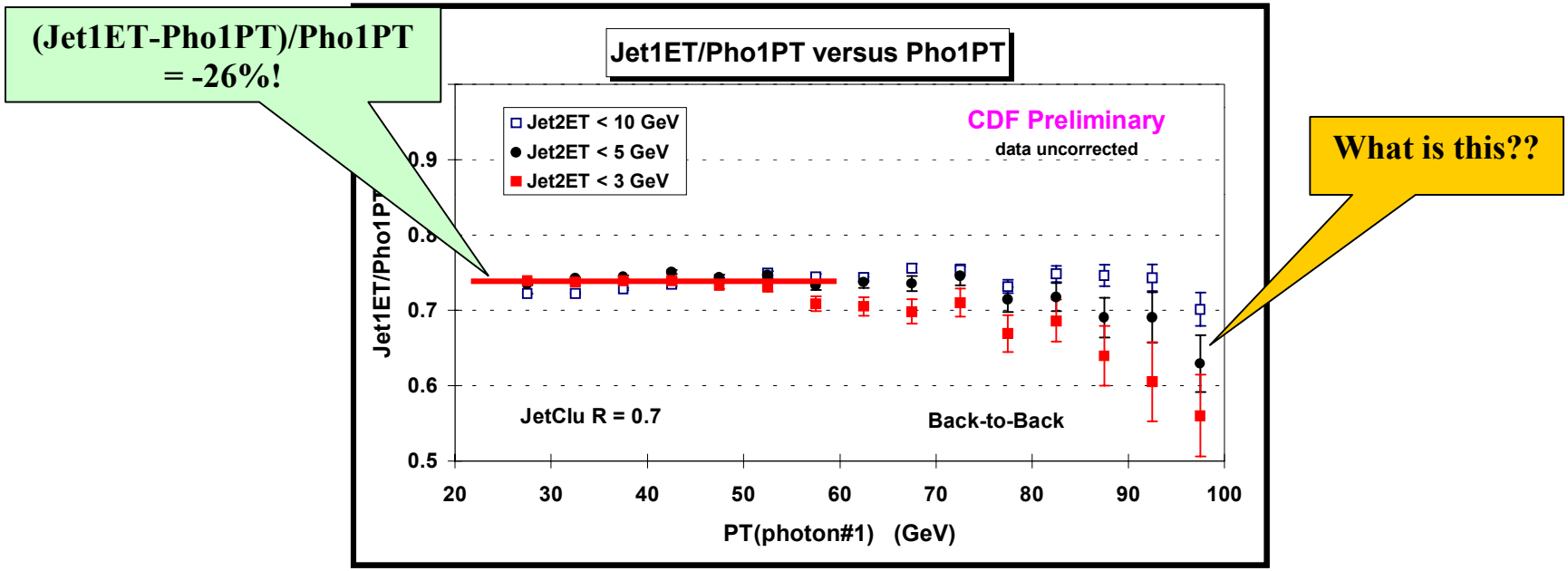



- **Shows the average ratio of $E_T$(jet#1)/$P_T$(pho#1) versus $P_T$(pho#1) for "back-to-back" events with $E_T$(jet#2) < 10 GeV, 5 GeV, and 3 GeV for JetClu R = 0.7 with no "jet corrections" and no vertex cuts.**

- **For "jet energy corrections" need the ratio of $P_T$(pho#1)/ $E_T$(jet#1) versus $E_T$(jet#1) (*i.e.* bins of $E_T$(jet#1) instead of bins of $P_T$(pho#1).**

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

# Photon-Jet Balancing



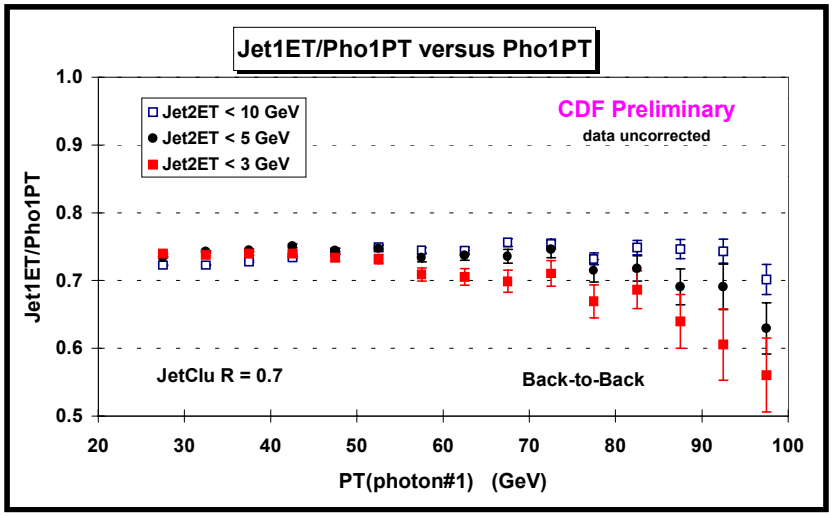

- **Shows the average ratio of $E_T$(jet#1)/$P_T$(pho#1) versus $P_T$(pho#1) for "back-to-back" events with $E_T$(jet#2) < 10 GeV, 5 GeV, and 3 GeV for JetClu R = 0.7 with no "jet corrections" and no vertex cuts.**

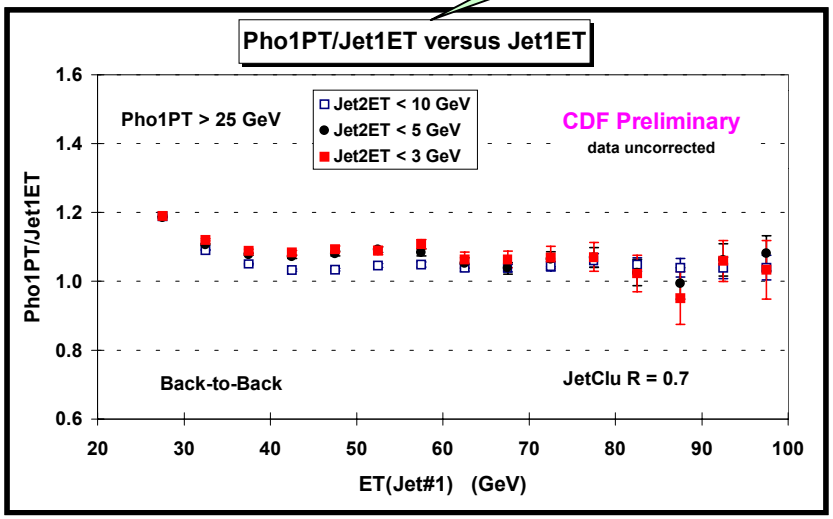
- **For "jet energy corrections" need the ratio of $P_T$(pho#1)/ $E_T$(jet#1) versus $E_T$(jet#1) (*i.e.* bins of $E_T$(jet#1) instead of bins of $P_T$(pho#1).**

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

# Photon-Jet Balancing

Correction Factor!



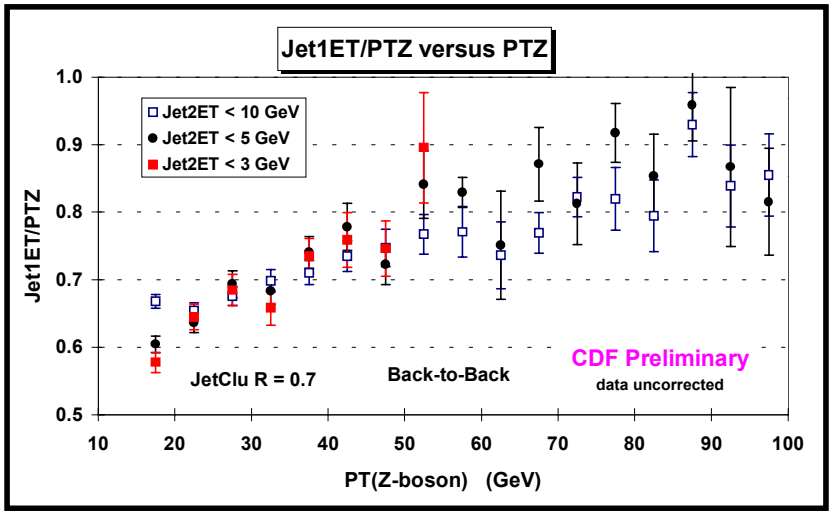



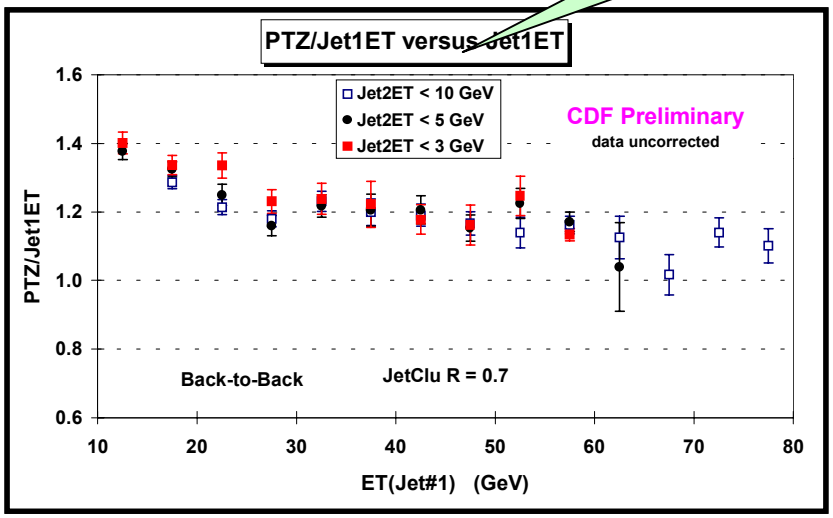

- (*left*) Shows the average ratio of $E_T$(jet#1)/$P_T$(pho#1) versus $P_T$(pho#1) for "back-to-back" events with $E_T$(jet#2) < 10 GeV, 5 GeV, and 3 GeV for JetClu R = 0.7 with no "jet corrections" and no vertex cuts.

- (*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



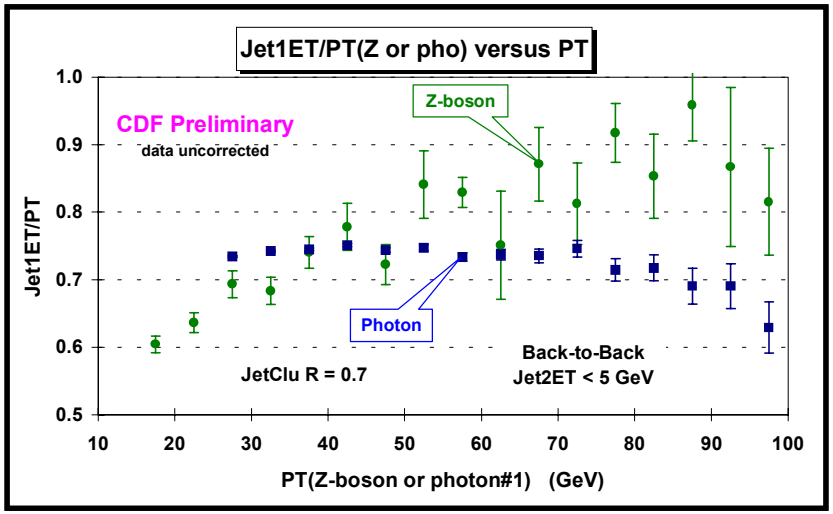

- (*left*) Shows the average ratio of $E_T$(jet#1)/$P_T$(Z) versus $P_T$(Z) for "back-to-back" events with $E_T$(jet#2) < 10 GeV, 5 GeV, and 3 GeV for JetClu R = 0.7 with no "jet corrections" and no vertex cuts.

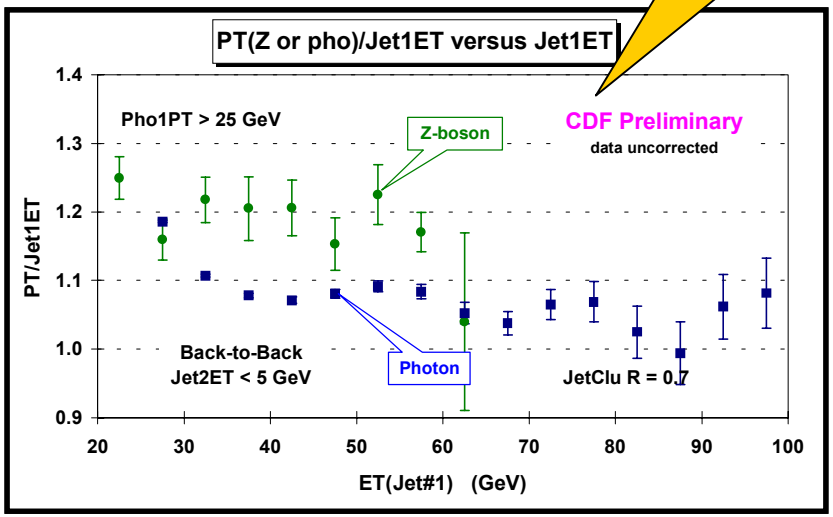
- (*right*) Shows the average ratio of $P_T$(Z)/ $E_T$(jet#1) versus $E_T$(jet#1) for "back-to-back" events with $E_T$(jet#2) < 10 GeV, 5 GeV, and 3 GeV for JetClu R = 0.7 with no "jet corrections" and no vertex cuts.

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

# Photon-Jet Balancing versus Z-Jet Balancing

Why are Z and Photon different??



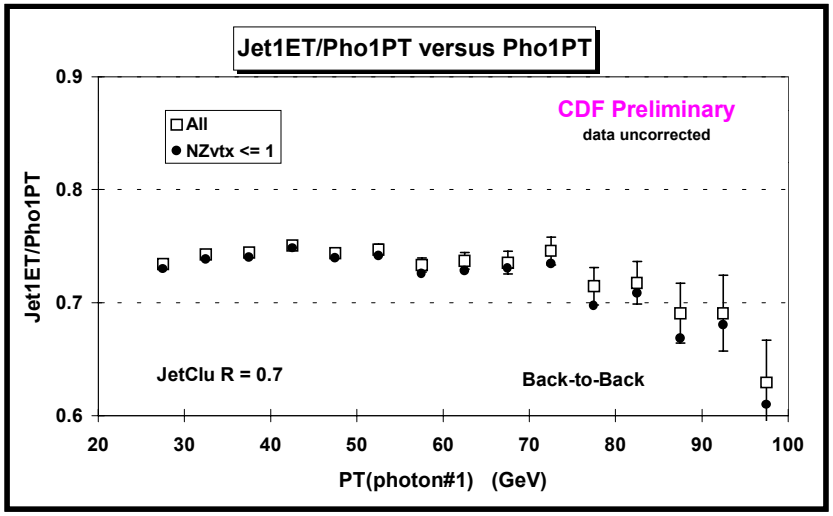



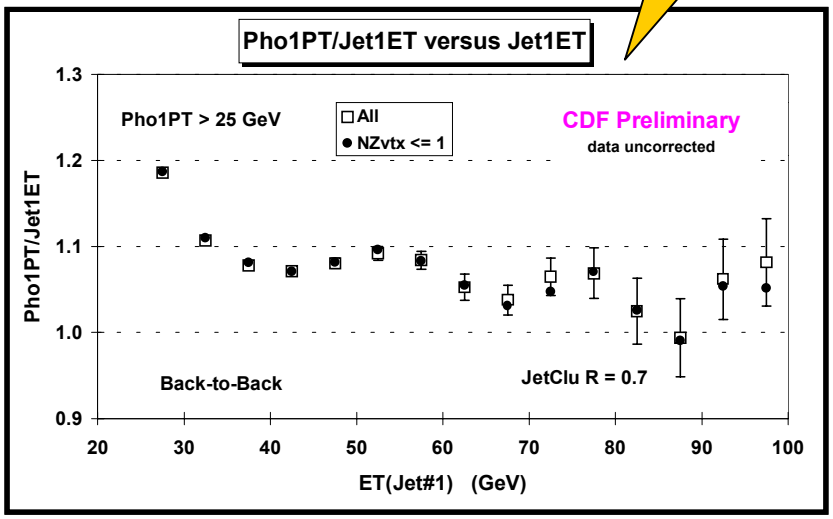

- (*left*) Compares the average ratio of $E_T$(jet#1)/$P_T$(Z) versus $P_T$(Z) for "back-to-back" Z events with $E_T$(jet#2) < 5 GeV for JetClu R = 0.7 with the average ratio of $E_T$(jet#1)/$P_T$(pho#1) versus $P_T$(pho#1) for "back-to-back" photon events with $E_T$(jet#2) < 5 GeV for JetClu R = 0.7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

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

# "Pile-Up" Effects in Photon-Jet Balancing

Not much affect on the mean values!

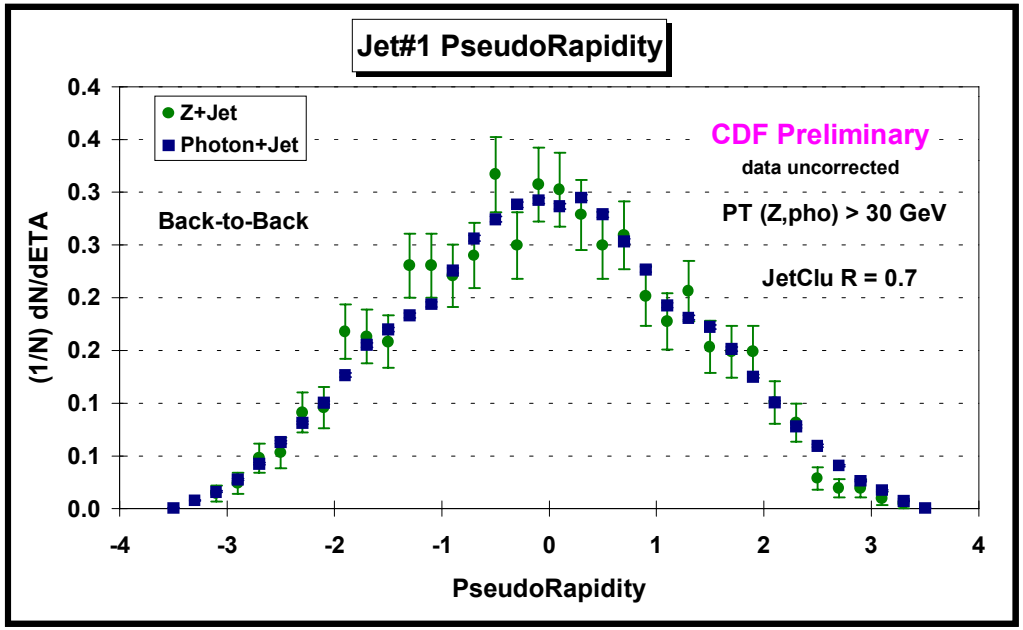



- (*left*) Compares the average ratio of $E_T$(jet#1)/$P_T$(pho#1) versus $P_T$(pho#1) for all "back-to-back" photon events with $E_T$(jet#2) < 5 GeV for JetClu R = 0.7 with events selected to have no "pile-up" (*i.e.* number of z-vertices <= 1).

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

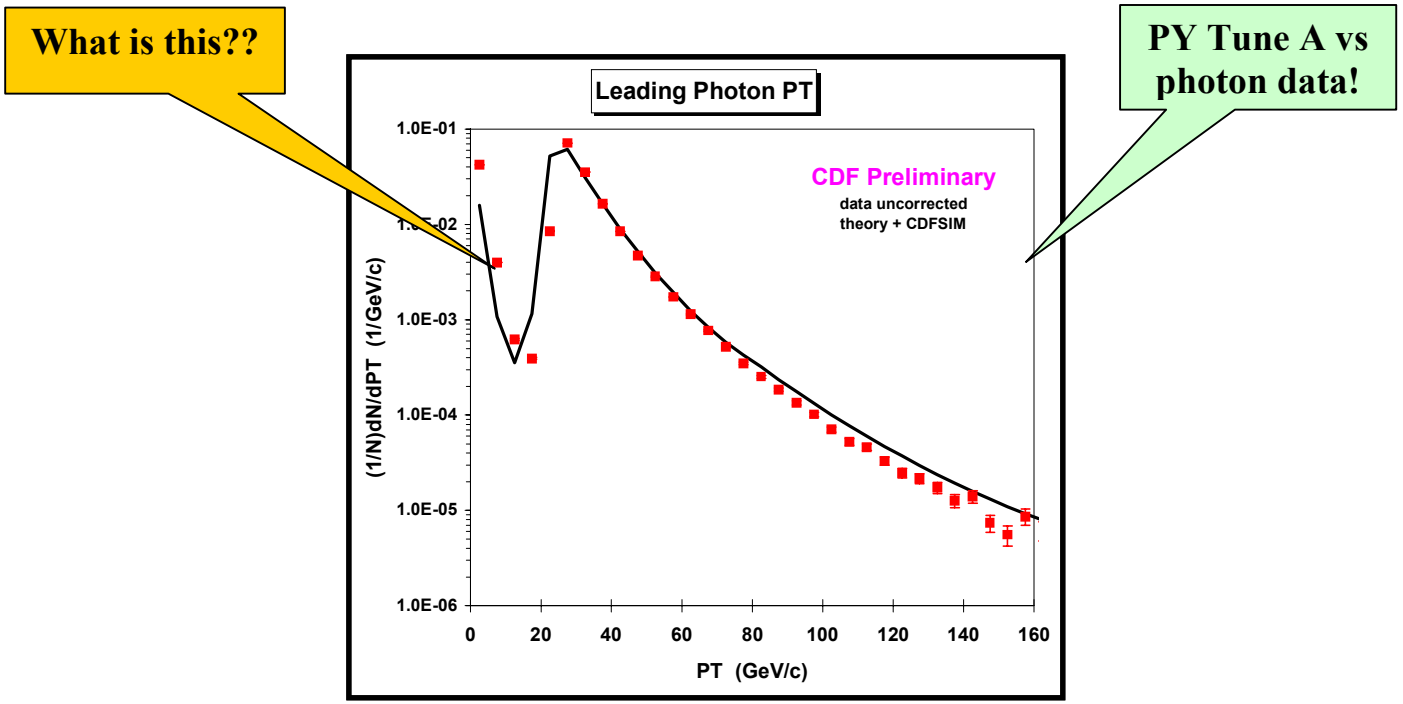
# Jet#1 PseudoRapidity: Photon vs Z-boson




- **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.**