QCD Group Jet, Photon and Z Stntuples

Thanks Ken and Anwar!

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

py Tune A (jqcd0e)	No Vtx Cut
Total Events	1,981,747
PhoJetAnaModule	1,981,747
Good Photon	285,594
pho1PT > 25 GeV	184,742
Back-to-Back	160,784
pho1PT > 30 GeV	97,271
pho1PT > 50 GeV	13,762
25 < ET(jet1) < 30 GeV	21,870
30 < ET(jet1) < 50 GeV	24,999
ET(jet1)> 50	4,461

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

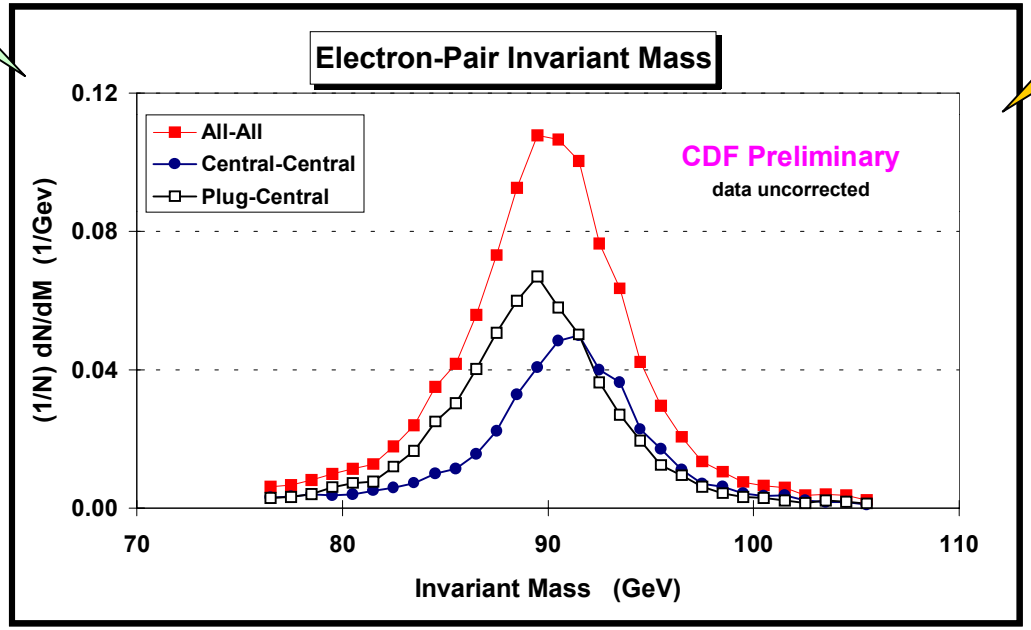
Need Z-boson Monte-Carlo!

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

CPH10d Containes Both Photons and Z-bosons!

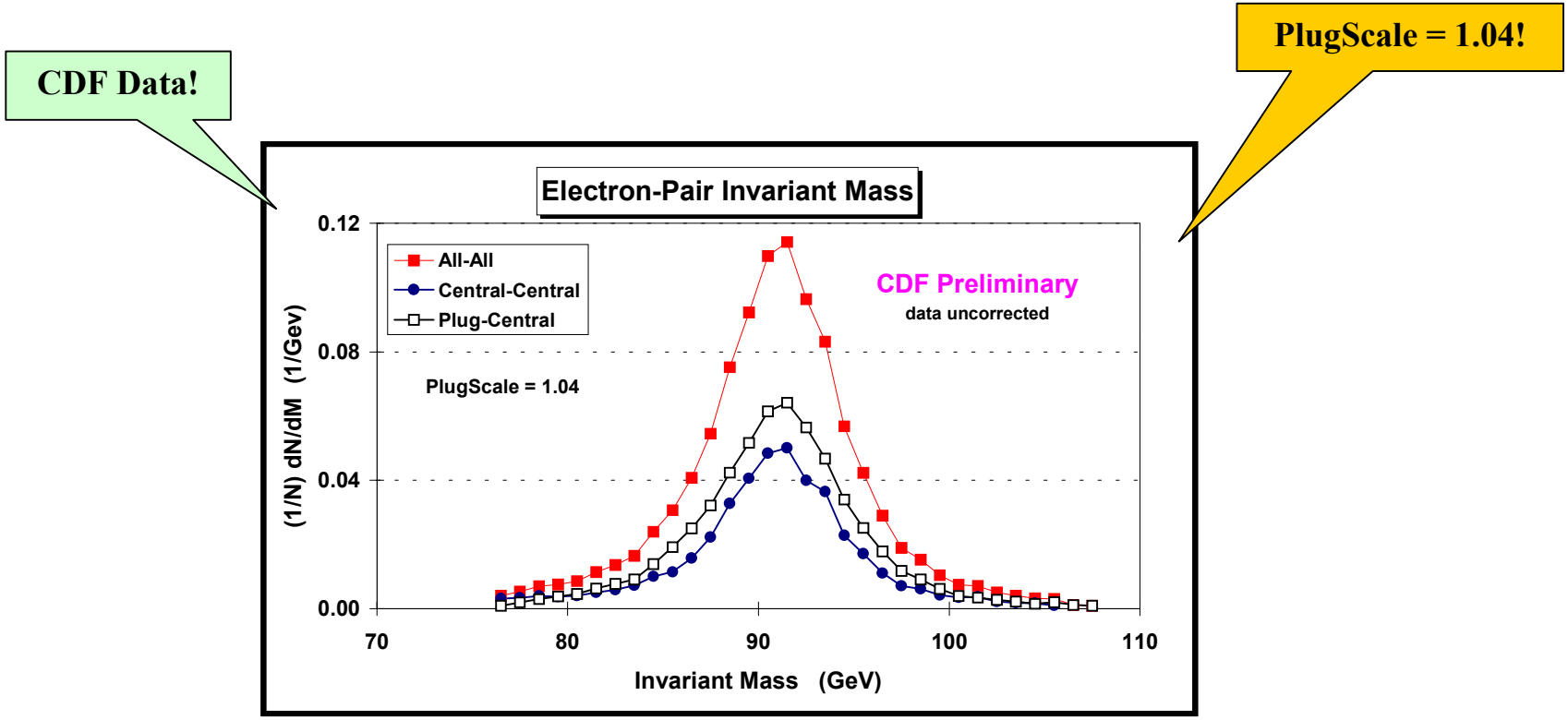
CDF Data!

Beatte taught me how to find Z-bosons!



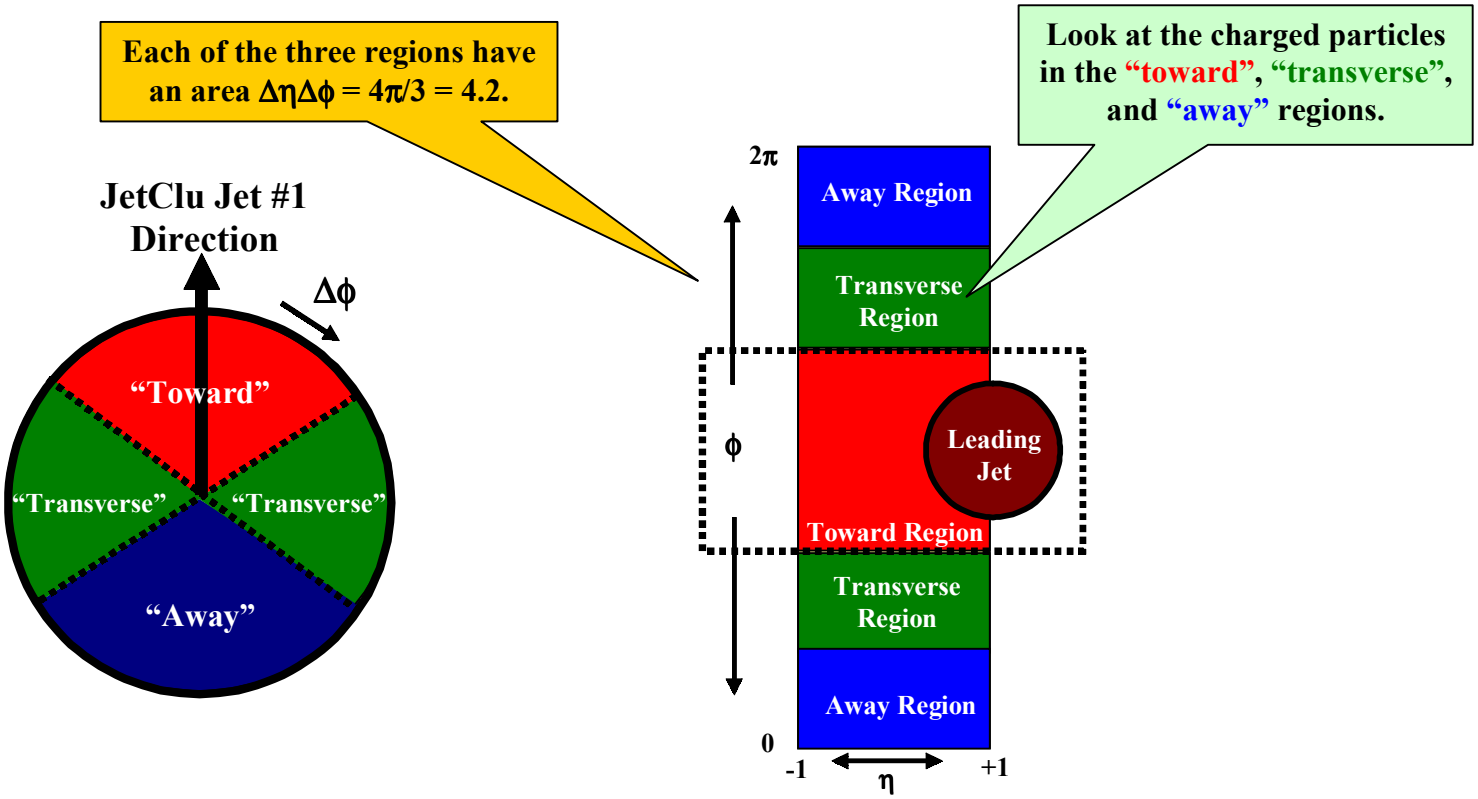
- **5.3.1 Z mass distribution not perfect! Plug electron calibration must not be exactly correct? I used only the correction factors provided in 5.3.1.**

CPH10d Containes Both Photons and Z-bosons!



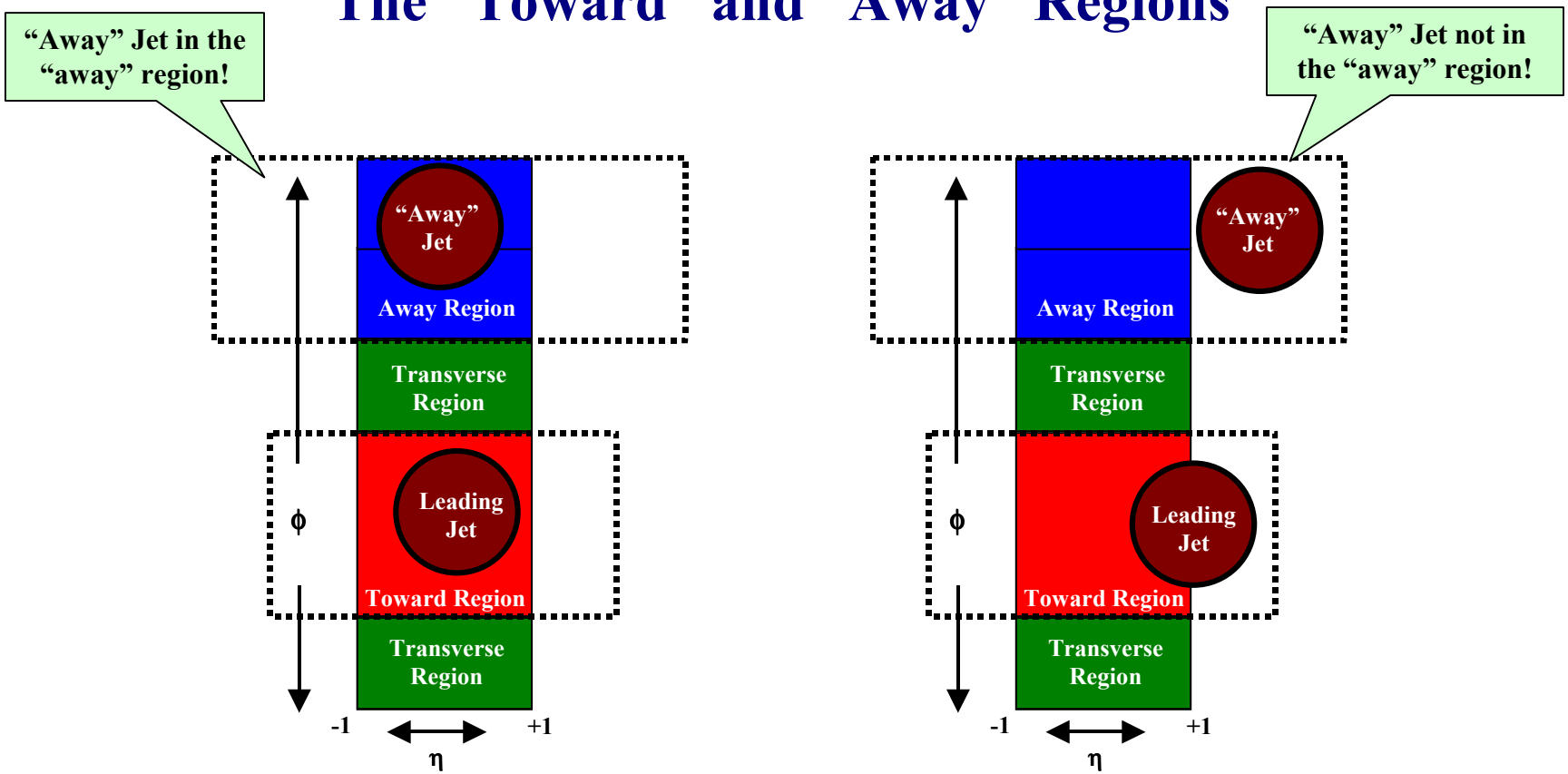
- **Re-scale plug electron energy by factor of 1.04. The central-central looks funny. I will work on it.**

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



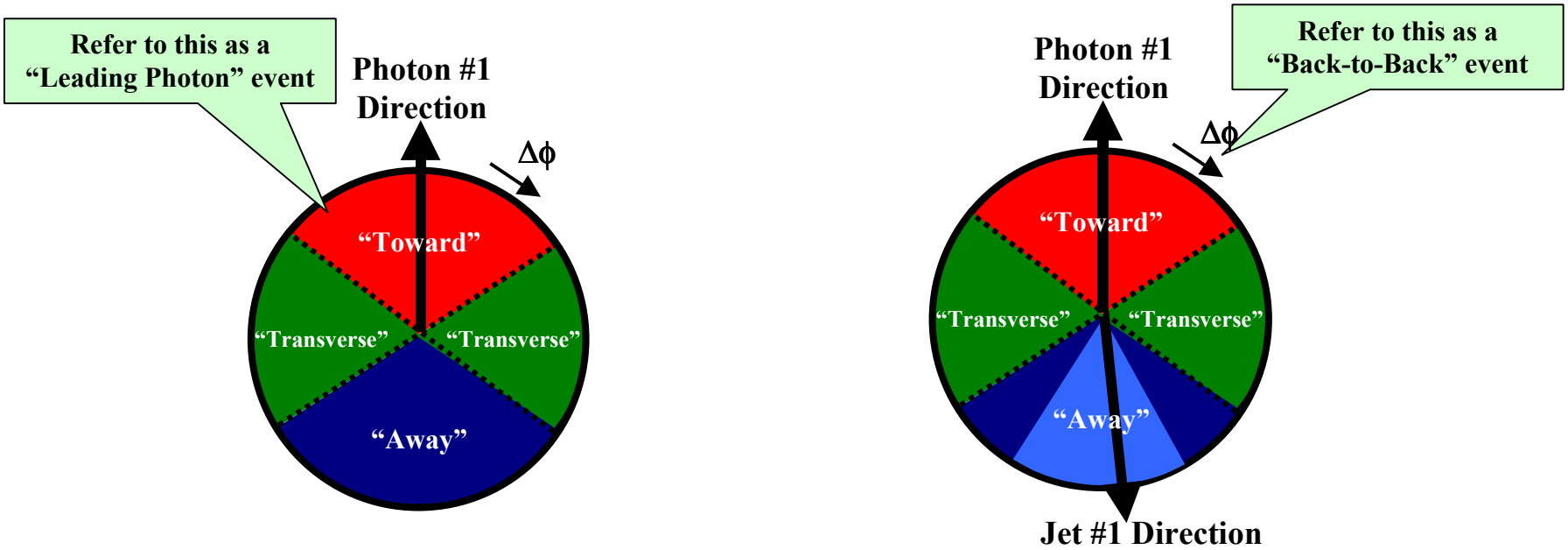
- Look at the "toward", "transverse", and "away" regions as defined by the leading calorimeter jet (JetClu R = 0.7, $|\eta| < 2$).
- Study the charged particles in the region $p_T > 0.5$ GeV/c and $|\eta| < 1$.

The "Toward" and "Away" Regions



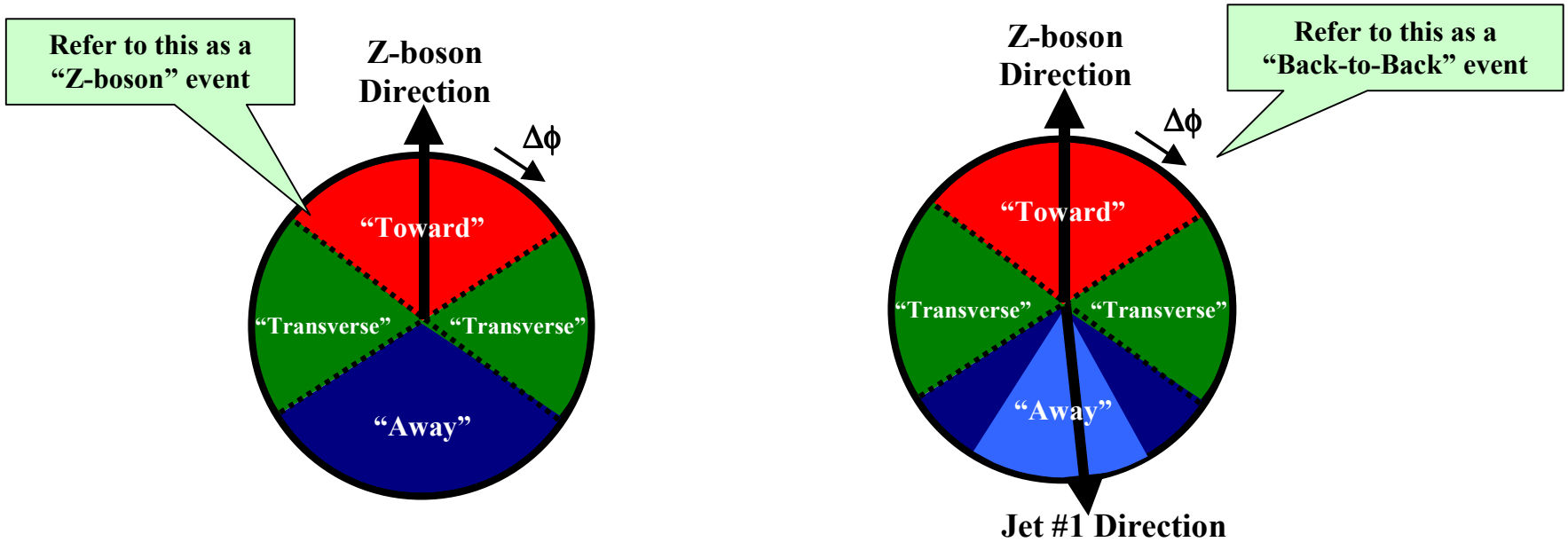
- **Note that the "toward" region does not always contain all of the leading jet and and the "away" regions do not always contain the "away" jet.**

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

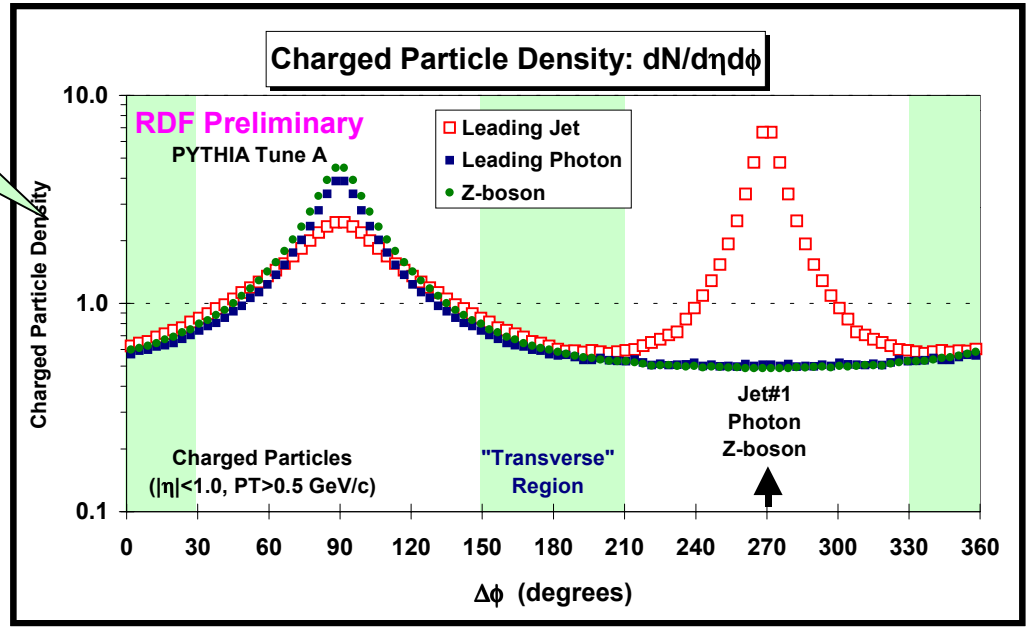
"Toward", Away", and "Transverse" Regions



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

Event Topologies: PYTHIA Tune A

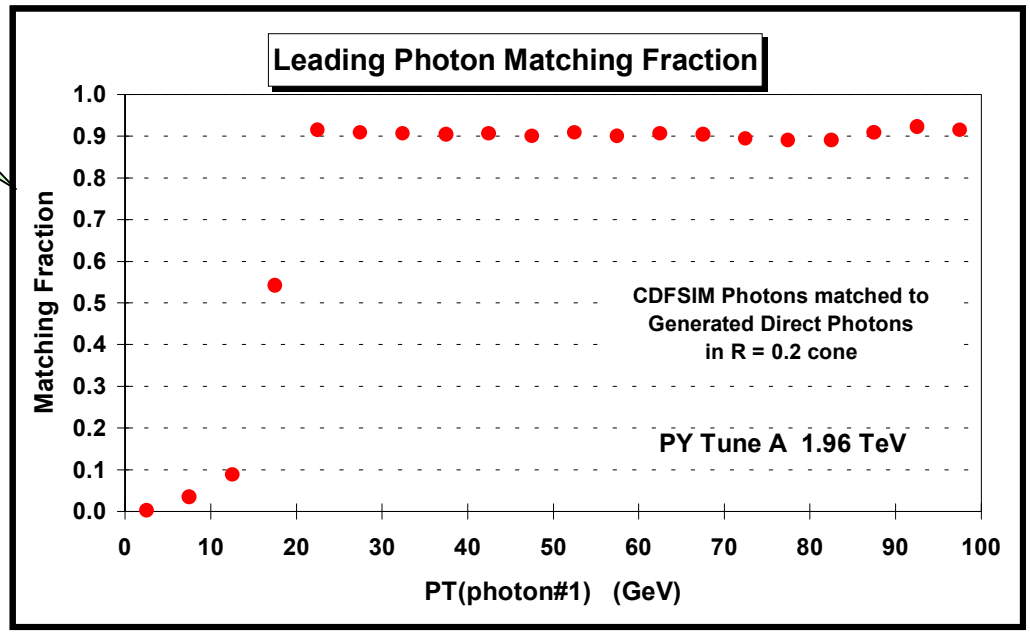
Generator Level MC Study!



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

Photon Purity: PYTHIA Tune A

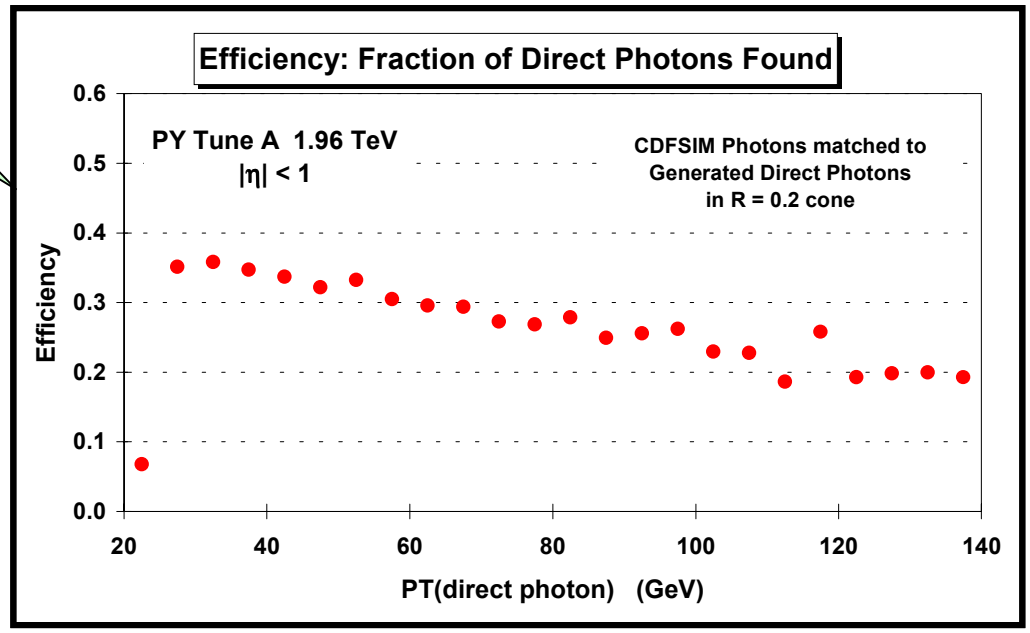
Generator Level Study!



- **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!**

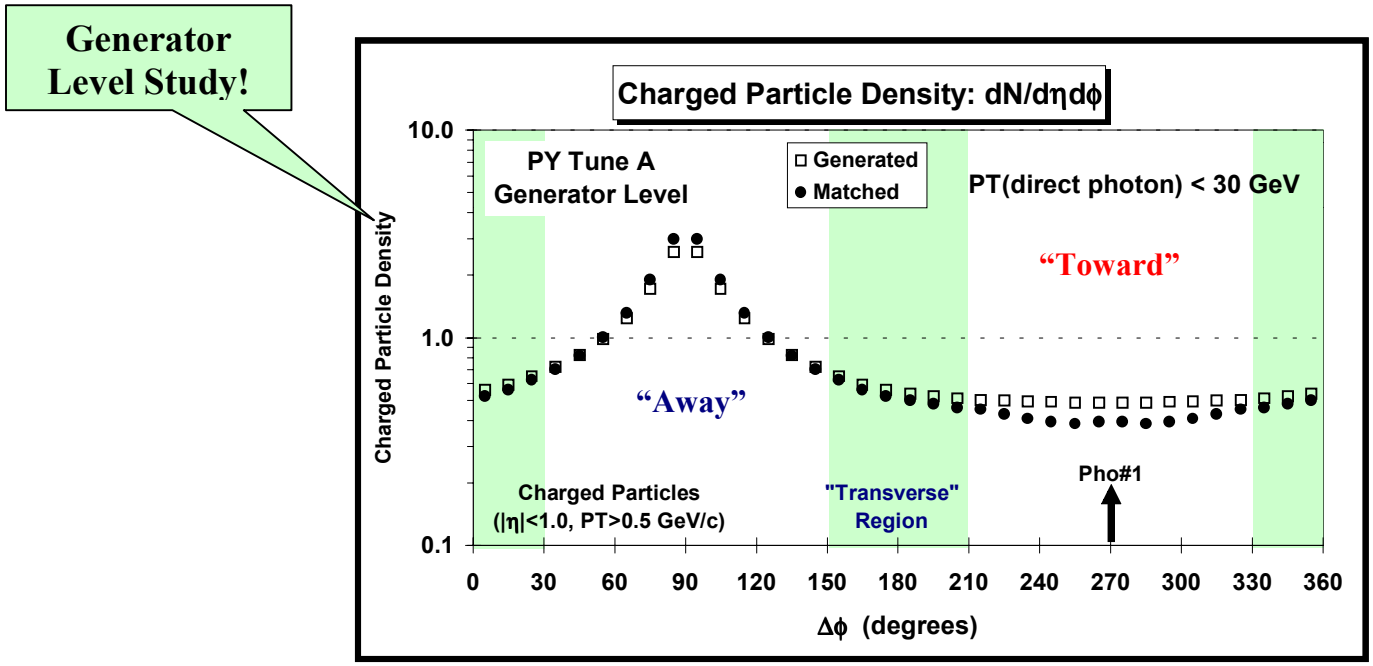
Photon Efficiency: PYTHIA Tune A

Generator Level Study!



- **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

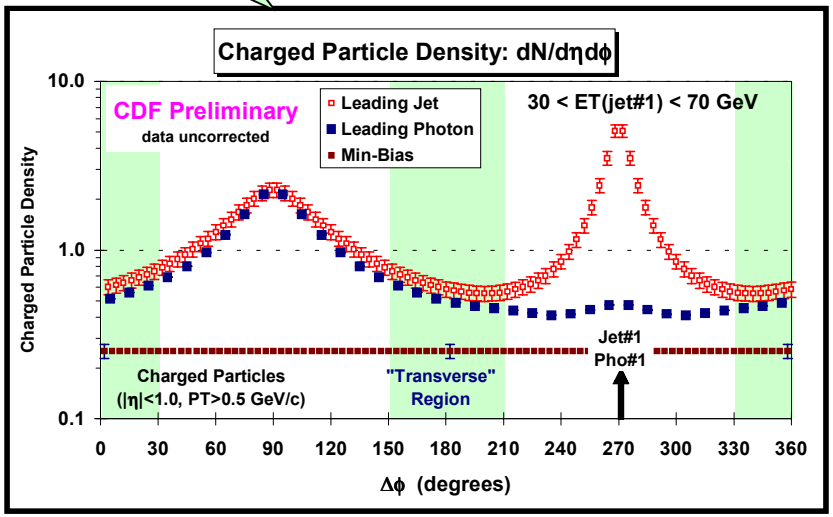


- **Shows the Δϕ dependence of the charged particle density, dN/dηdϕ, for charged particles in the range $p_T > 0.5$ GeV/c and $|\eta| < 1$ relative to the leading photon (rotated to 270°) for P_T(pho#1) > 30 GeV**

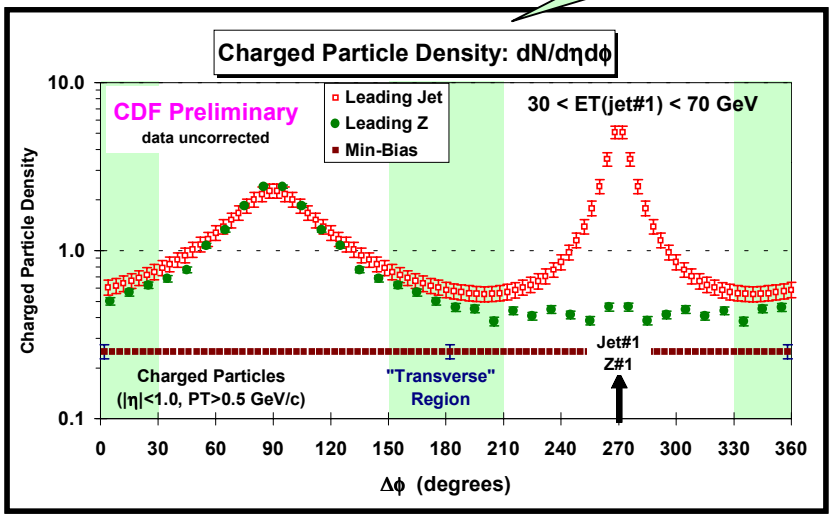
- **The photon isolation cuts produce a "photon selection bias". There are less charged particles in the "toward" region in the "matched" events!**

Charged Particle Density: "Jet", "Photon", and "Z"

Jet data vs photon data!



Jet data vs Z-boson data!

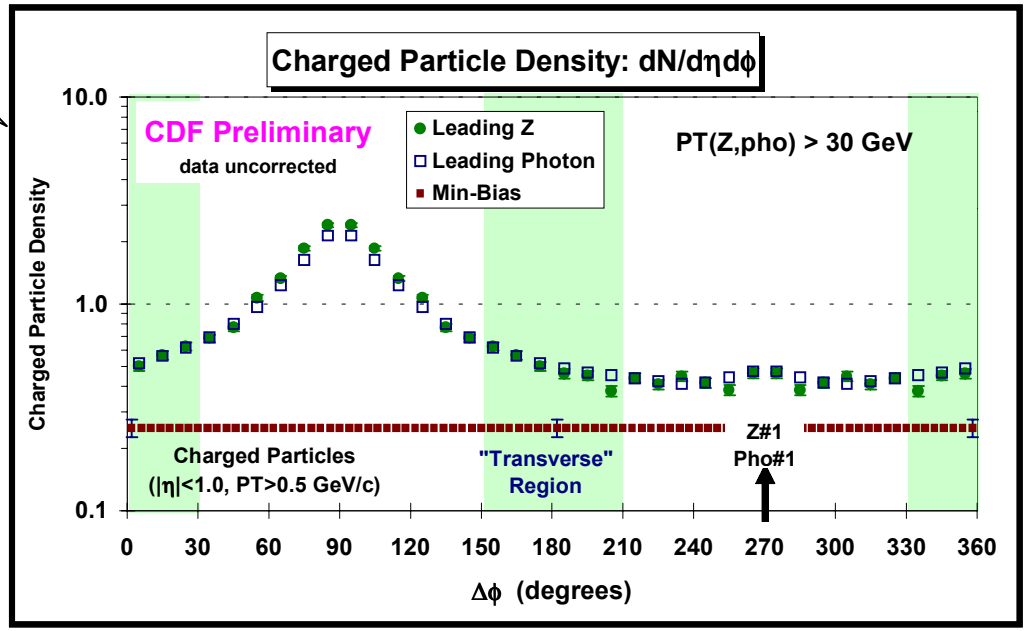


- (*left*) Compares the $\Delta\phi$ dependence of the particle density, $dN/d\eta d\phi$, for charged particles in the range $p_T > 0.5$ GeV/c and $|\eta| < 1$ for "leading photon" events (P_T(pho#1) > 30 GeV) with "leadig jet" events (30 < E_T(jet#1) < 70 GeV).

- (*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).

Charged Particle Density: Photon vs Z-boson

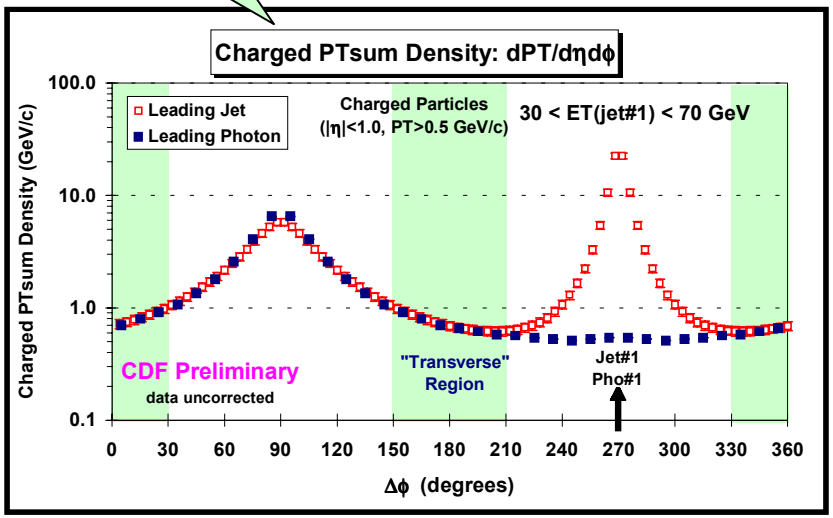
Z data vs photon data!



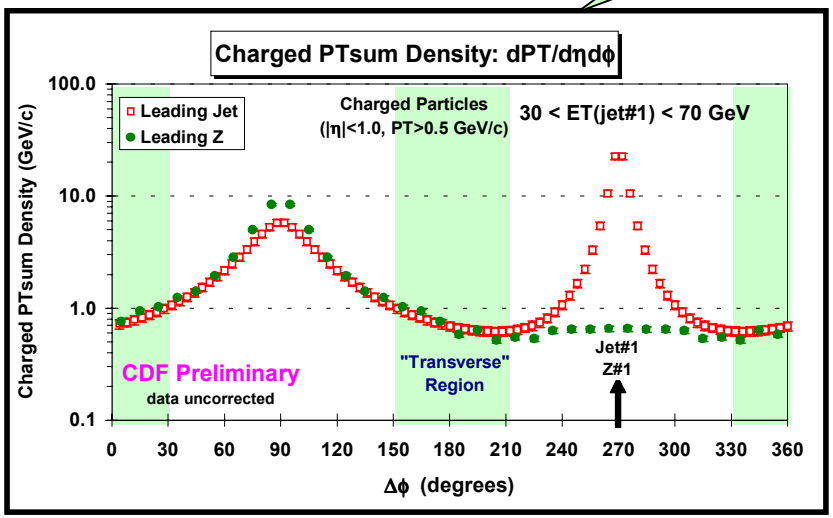
- Comparess the $\Delta\phi$ dependence of the charged particle density, $dN/d\eta d\phi$, for charged particles in the range $p_T > 0.5$ GeV/c and $|\eta| < 1$ for "leading photon" events (P_T(pho#1) > 30 GeV) with Z-boson events (P_T(Z) > 30 GeV/c).
- There is also a "bump" in the direction of the Z-boson?

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

Jet data vs photon data!



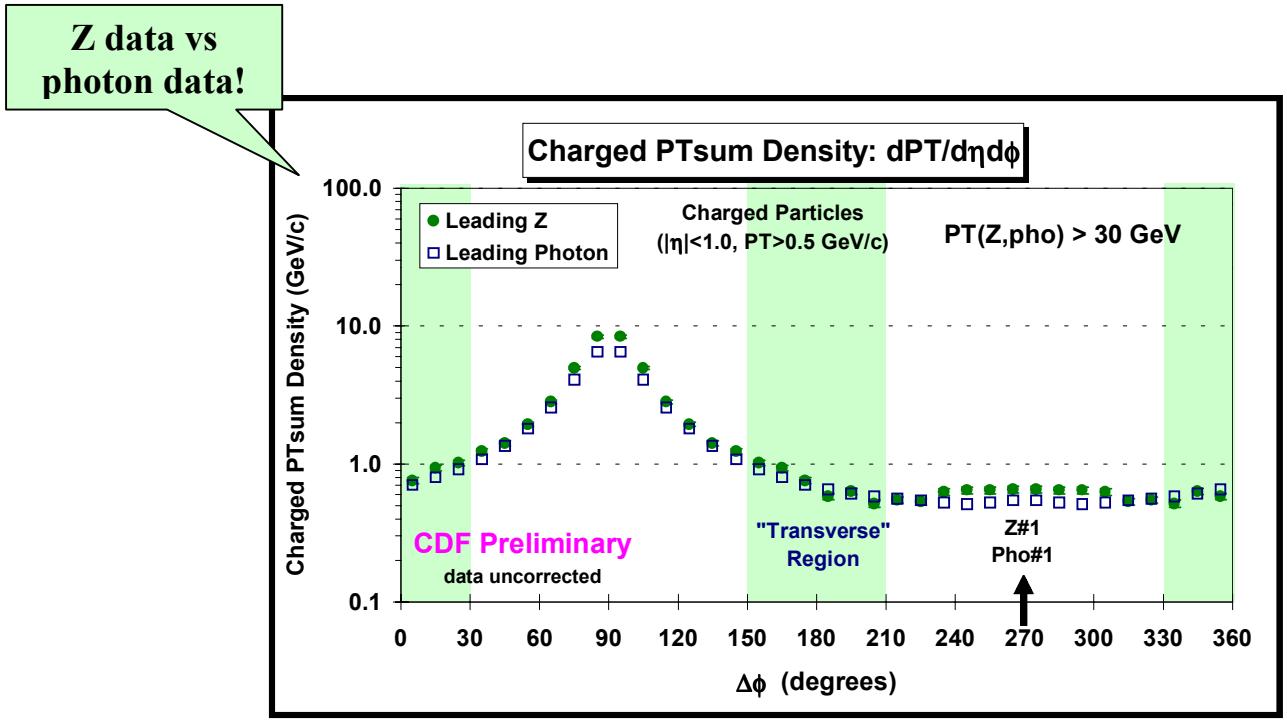
Jet data vs Z-boson data!



- (*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 "leadig jet" events ($30 < E_T$(jet#1) < 70 GeV).

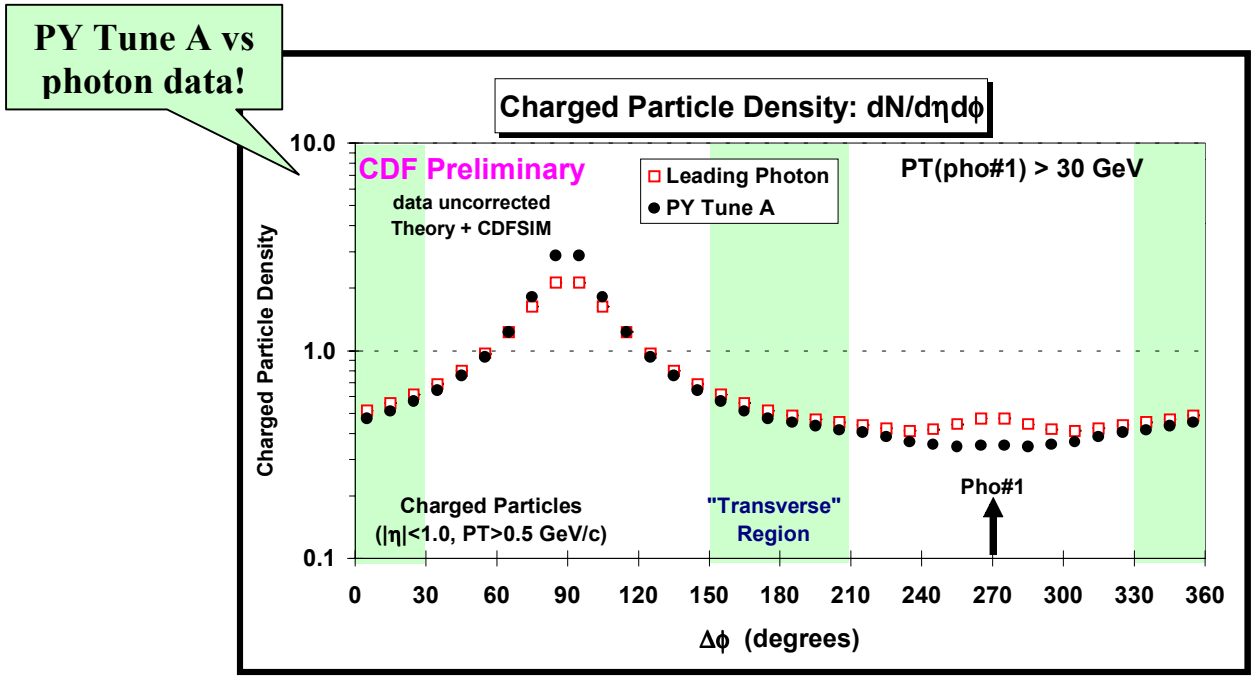
- (*right*) Compares the $\Delta\phi$ dependence of the *scalar* PTsum density, $dN/d\eta d\phi$, for charged particles in the range $p_T > 0.5$ GeV/c and $|\eta| < 1$ for "Z-boson" events (P_T(Z) > 30 GeV) with "leadig jet" events ($30 < E_T$(jet#1) < 70 GeV).

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?

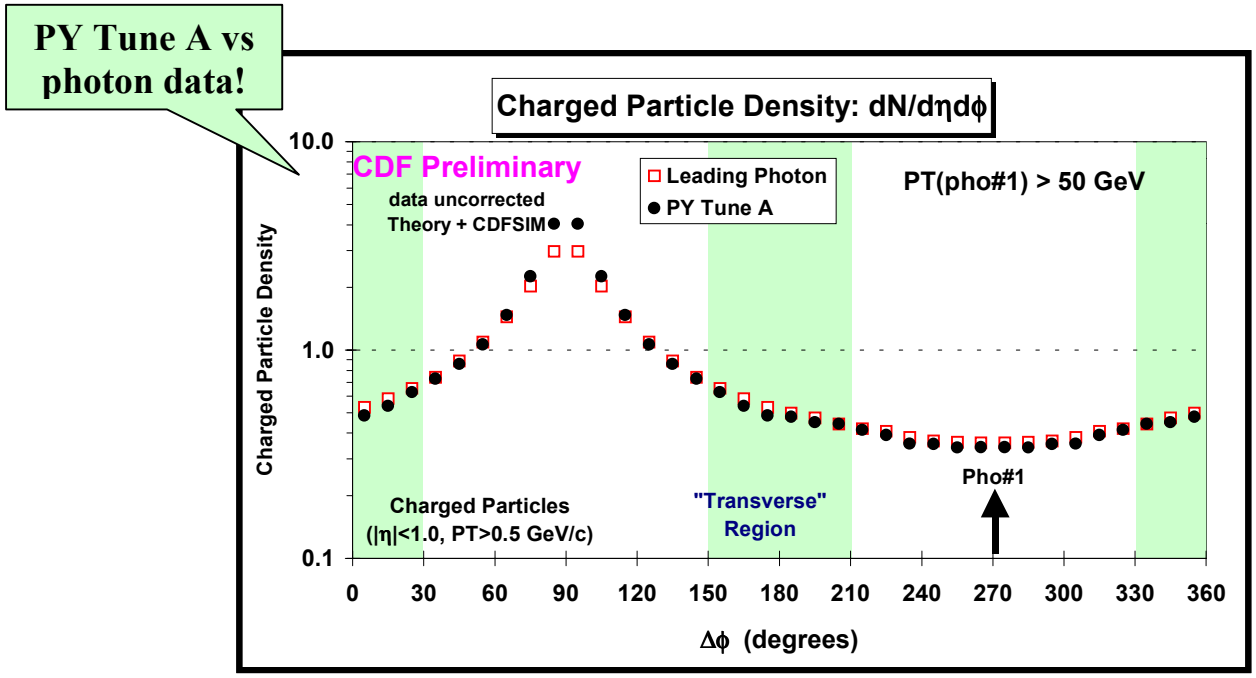
Photon Charged Particle Density: PY Tune A vs Data



- **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!**

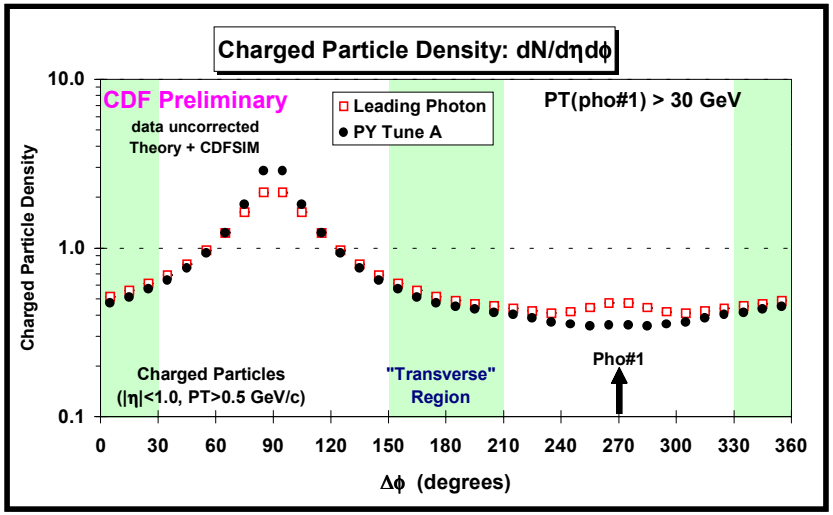
Photon Charged Particle Density: PY Tune A vs Data

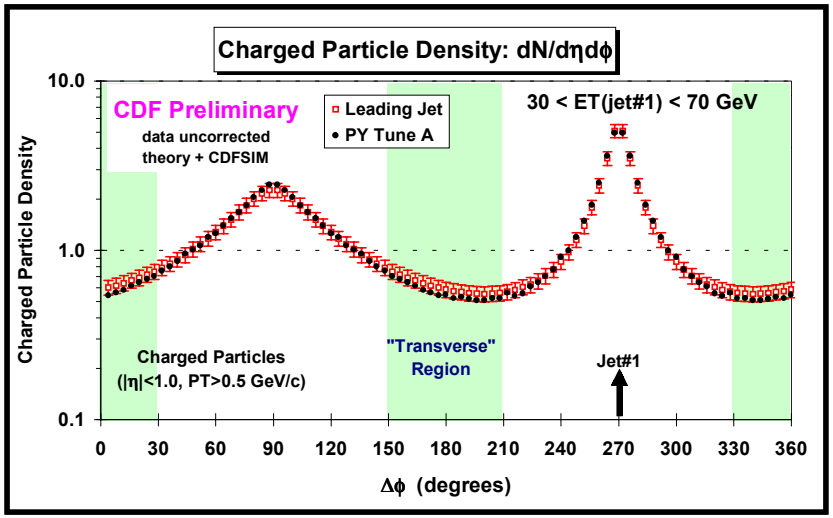


- Shows the $\Delta\phi$ dependence of the particle density, $dN/d\eta d\phi$, for charged particles ($p_T > 0.5$ GeV/c, $|\eta| < 1$) for "leading photon" events (P_T(pho#1) > 50 GeV) compared with PYTHIA Tune A (after CDFSIM).

- The bump in the data in the "toward" region has gone away!

Charged Particle Density: PY Tune A vs Data

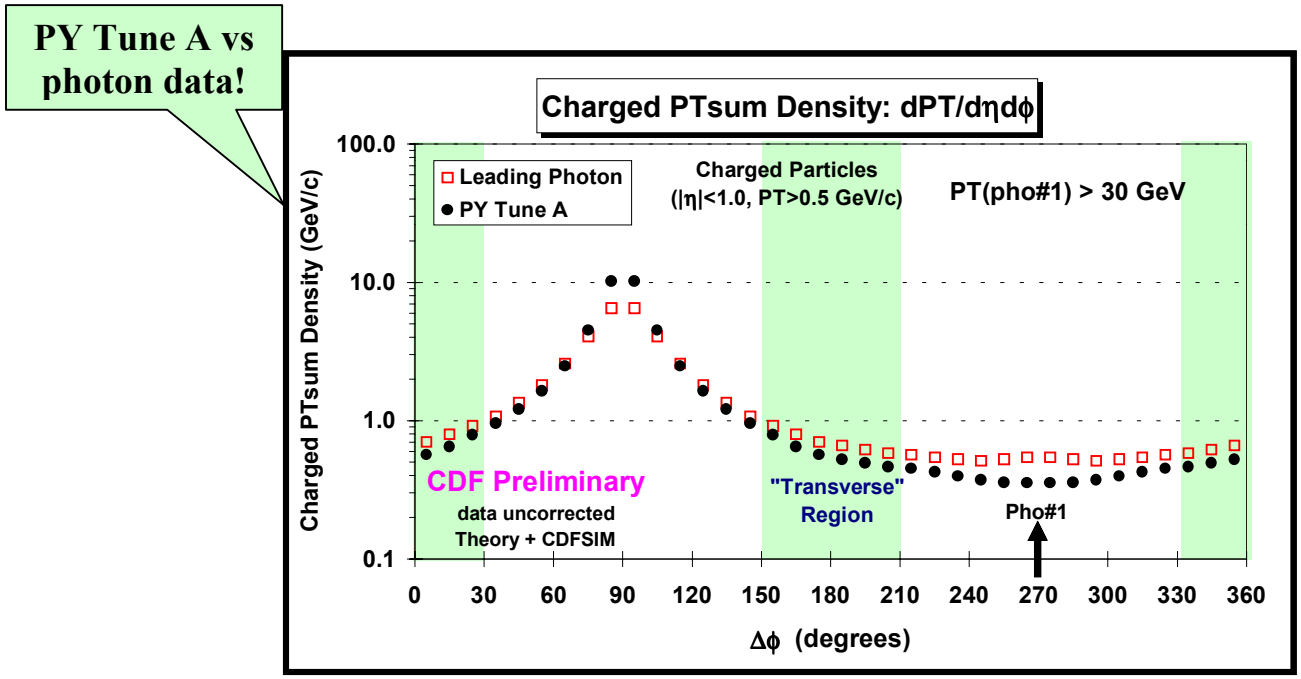




- (*left*) Shows the $\Delta\phi$ dependence of the charged particle density, $dN/d\eta d\phi$, for charged particles ($p_T > 0.5$ GeV/c, $|\eta| < 1$) for "leading photon" events (P_T(pho#1) > 30 GeV) compared with PYTHIA Tune A (after CDFSIM).

- (*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(jet#1) < 70 GeV) compared with PYTHIA Tune A (after CDFSIM).

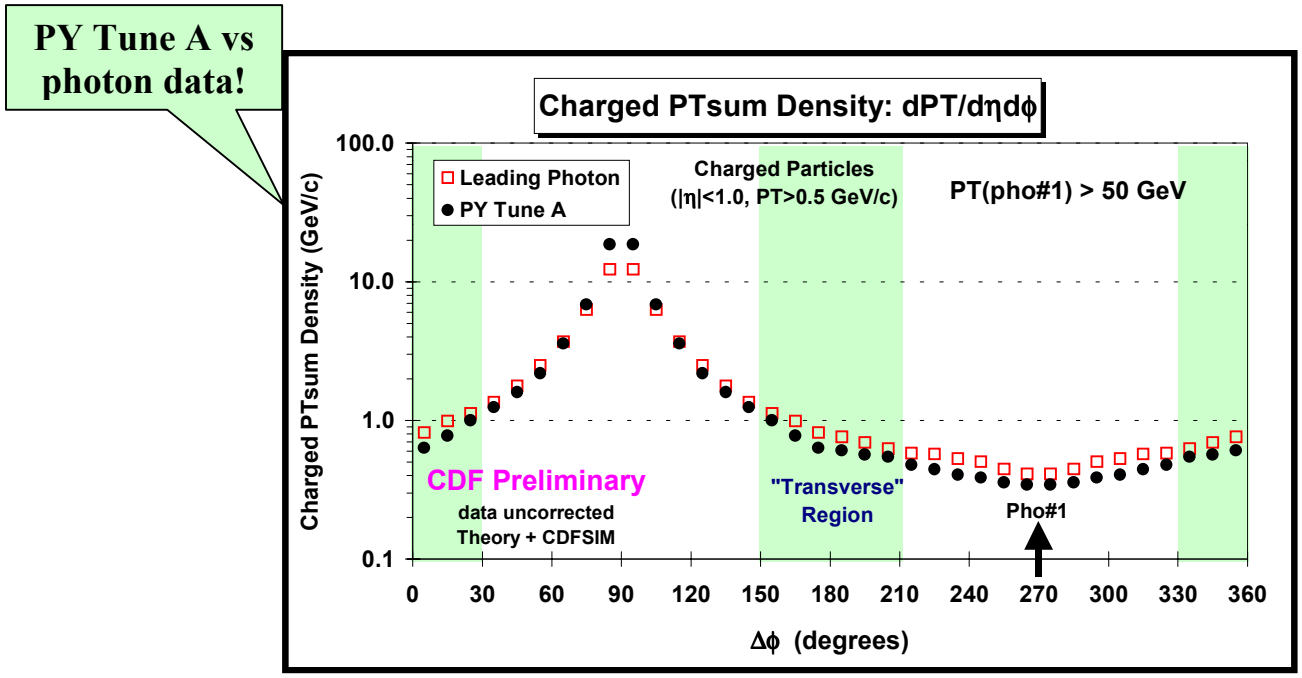
Photon PTsum Particle Density: PY Tune A vs Data



- **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??**

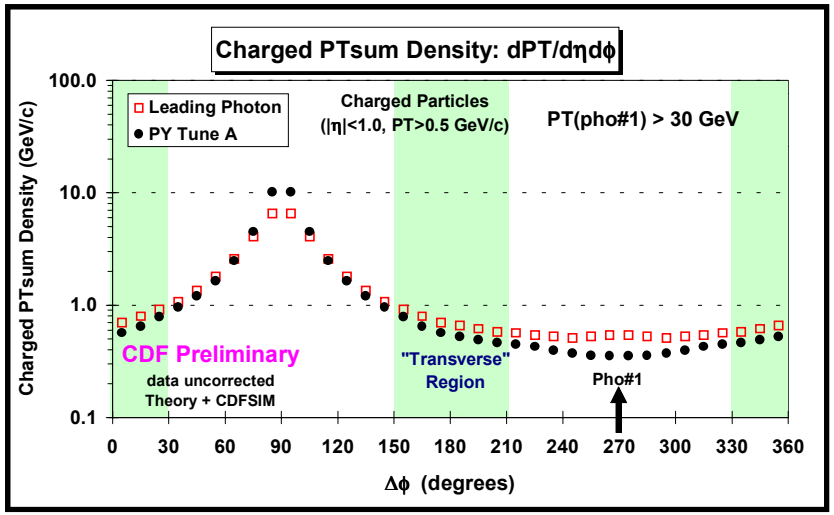
Photon PTsum Particle Density: PY Tune A vs Data

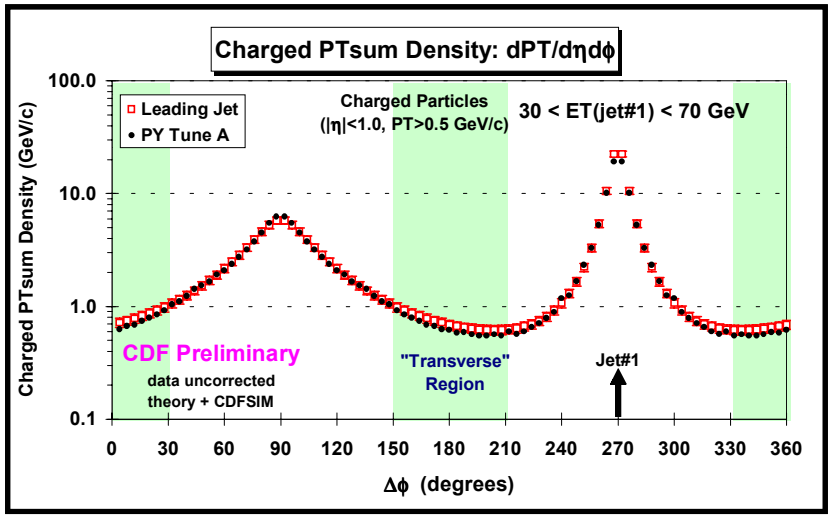


- **Shows the Δϕ dependence of the *scalar* PTsum density, dPT/dηdϕ, for charged particles (p_T > 0.5 GeV/c, |η| < 1) for "leading photon" events (P_T(pho#1) > 50 GeV) compared with PYTHIA Tune A (after CDFSIM).**

- **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

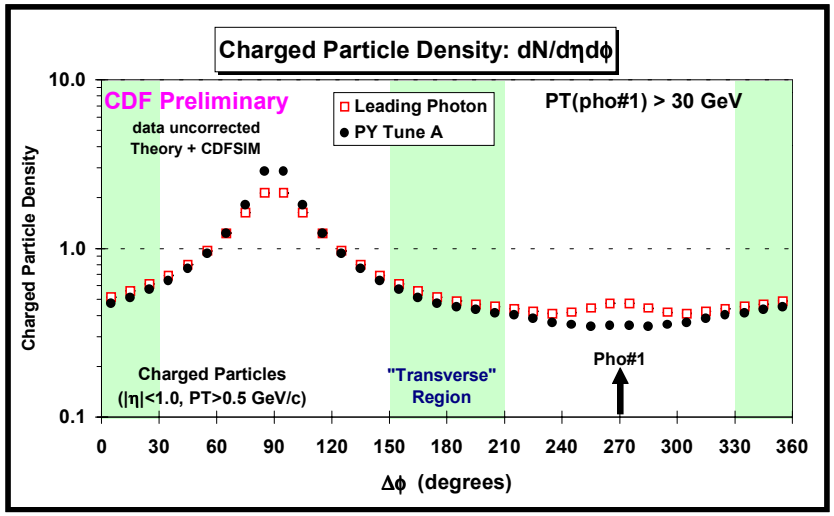


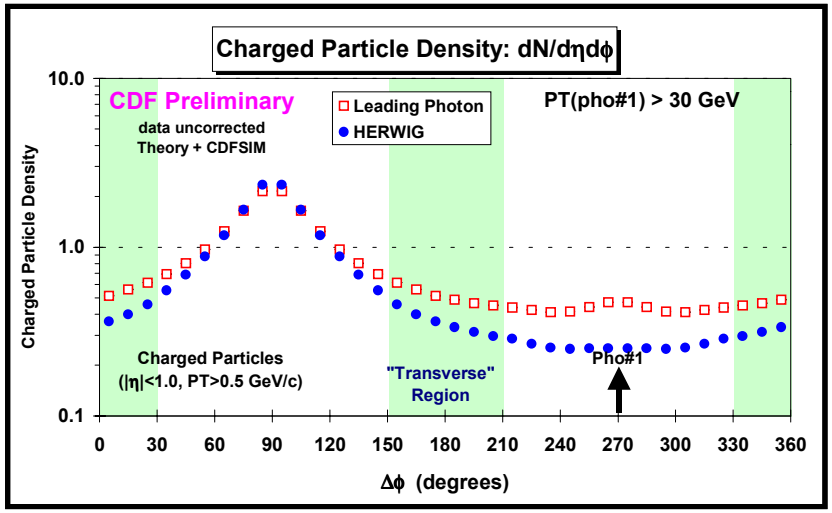


- **(*left*) Shows the Δϕ dependence of the charged PTsum density, dPT/dηdϕ, for charged particles (p_T > 0.5 GeV/c, |η| < 1) for "leading photon" events (P_T(pho#1) > 30 GeV) compared with PYTHIA Tune A (after CDFSIM).**

- **(*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 Charged Particle Density: PY Tune A vs HERWIG

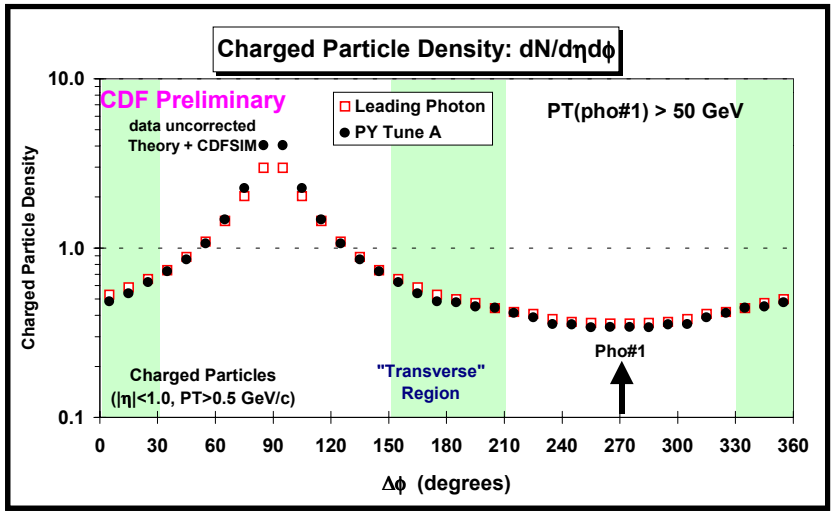


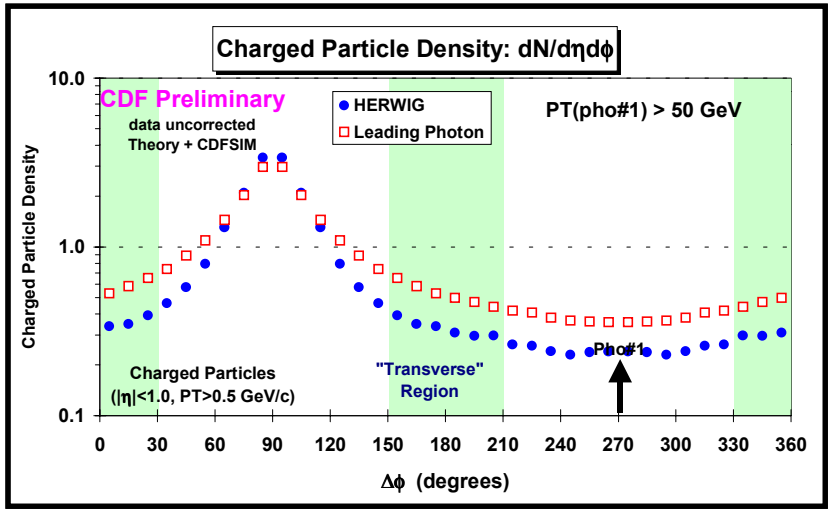


- **(*left*) Shows the Δϕ dependence of the charged particle density, dN/dηdϕ, for charged particles (p_T > 0.5 GeV/c, |η| < 1) for "leading photon" events (P_T(pho#1) > 30 GeV) compared with PYTHIA Tune A (after CDFSIM).**

- **(*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 photon" events (P_T(pho#1) > 30 GeV) compared with HERWIG (after CDFSIM).**

Photon Charged Particle Density: PY Tune A vs HERWIG

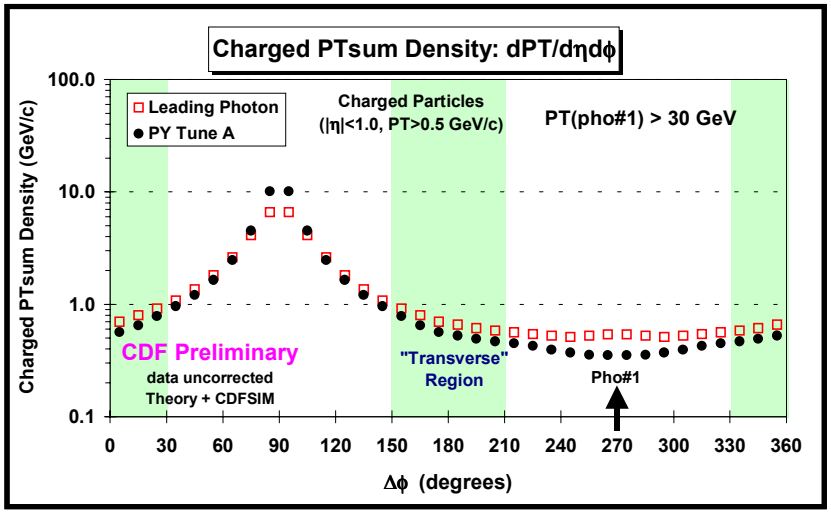


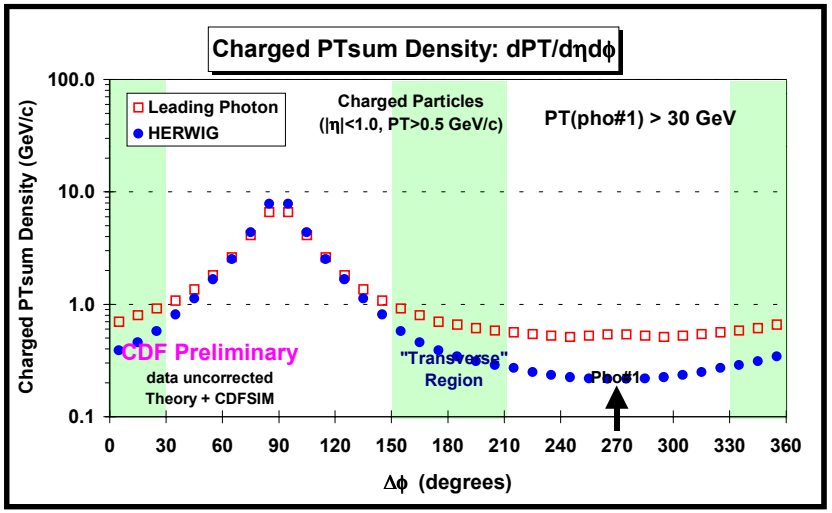


- **(*left*) Shows the Δϕ dependence of the charged particle density, dN/dηdϕ, for charged particles (p_T > 0.5 GeV/c, |η| < 1) for "leading photon" events (P_T(pho#1) > 50 GeV) compared with PYTHIA Tune A (after CDFSIM).**

- **(*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 photon" events (P_T(pho#1) > 50 GeV) compared with HERWIG (after CDFSIM).**

Photon PTsum Particle Density: PY Tune A vs HERWIG

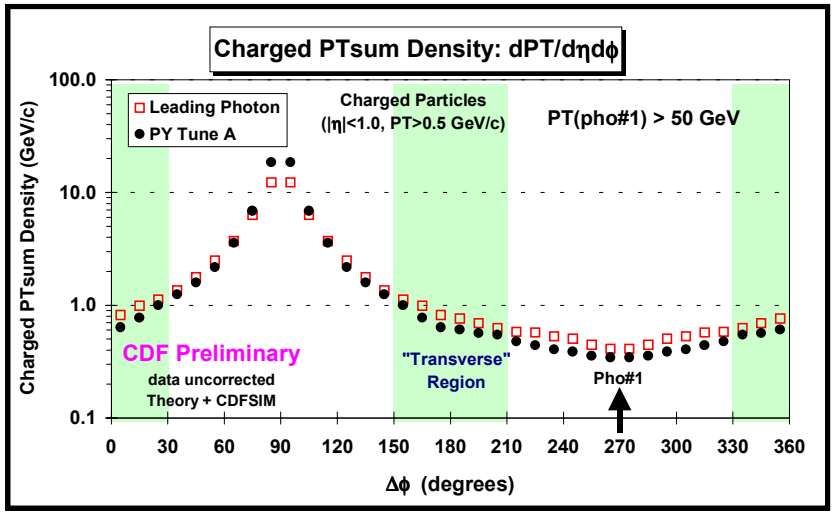


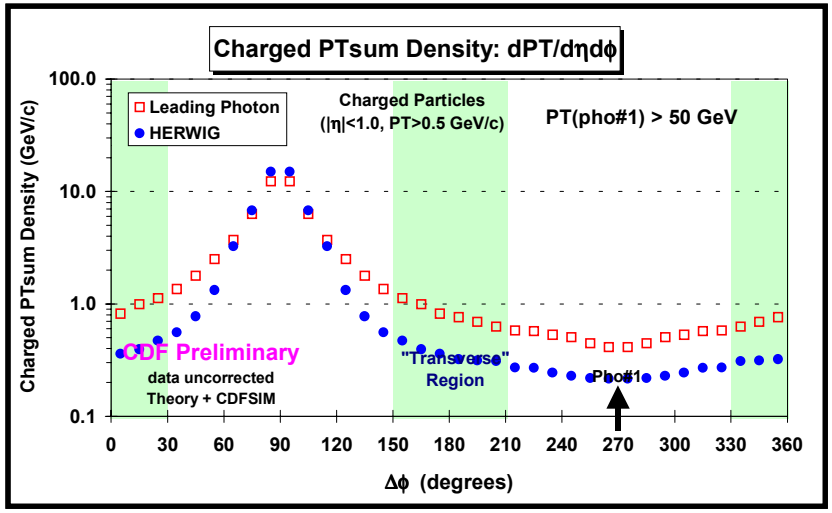


- **(*left*) Shows the Δϕ dependence of the charged PTsum density, dPT/dηdϕ, for charged particles (p_T > 0.5 GeV/c, |η| < 1) for "leading photon" events (P_T(pho#1) > 30 GeV) compared with PYTHIA Tune A (after CDFSIM).**

- **(*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 photon" events (P_T(pho#1) > 30 GeV) compared with HERWIG (after CDFSIM).**

Photon PTsum Particle Density: PY Tune A vs HERWIG

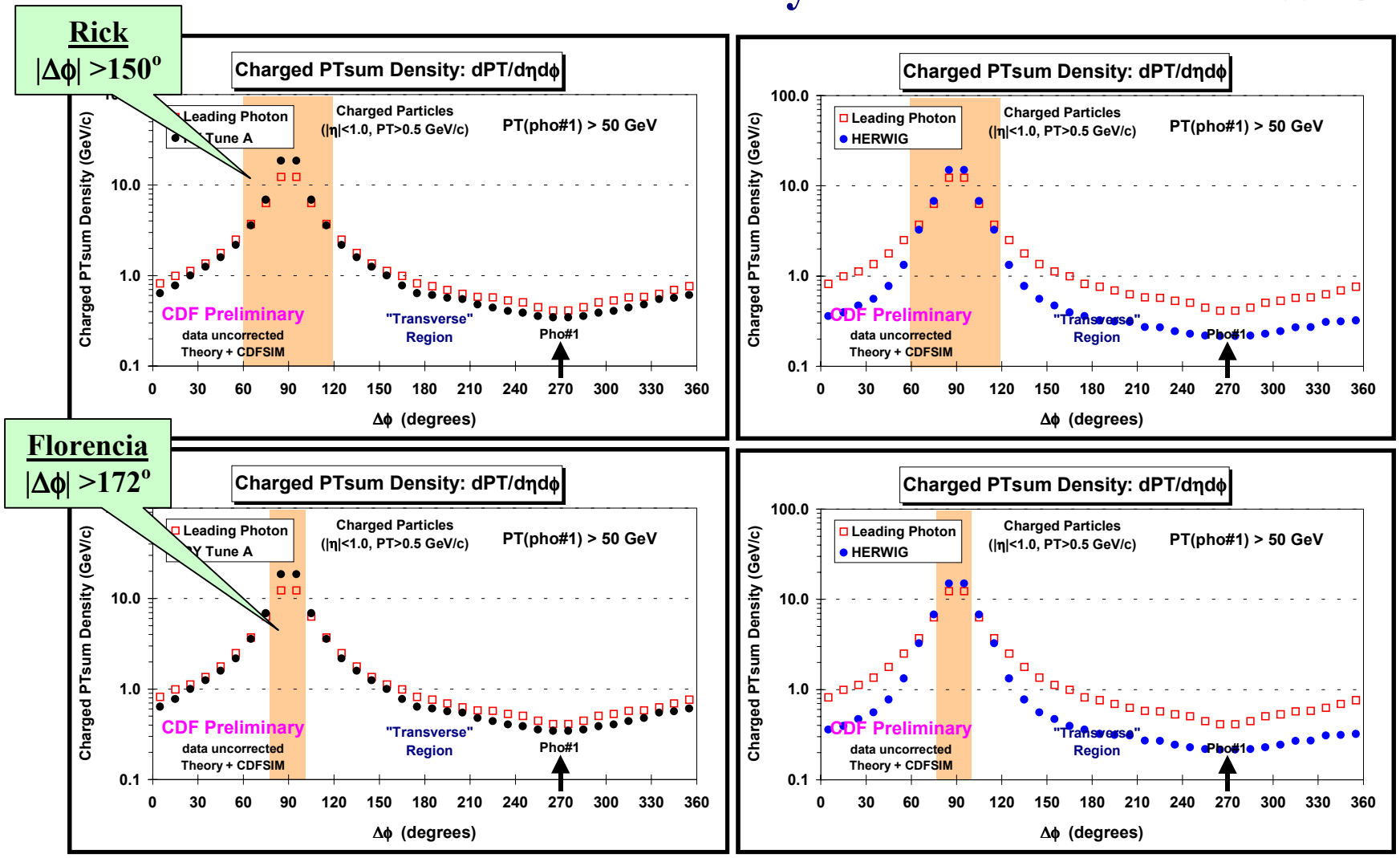




- **(*left*) Shows the Δϕ dependence of the charged PTsum density, dPT/dηdϕ, for charged particles (p_T > 0.5 GeV/c, |η| < 1) for "leading photon" events (P_T(pho#1) > 50 GeV) compared with PYTHIA Tune A (after CDFSIM).**

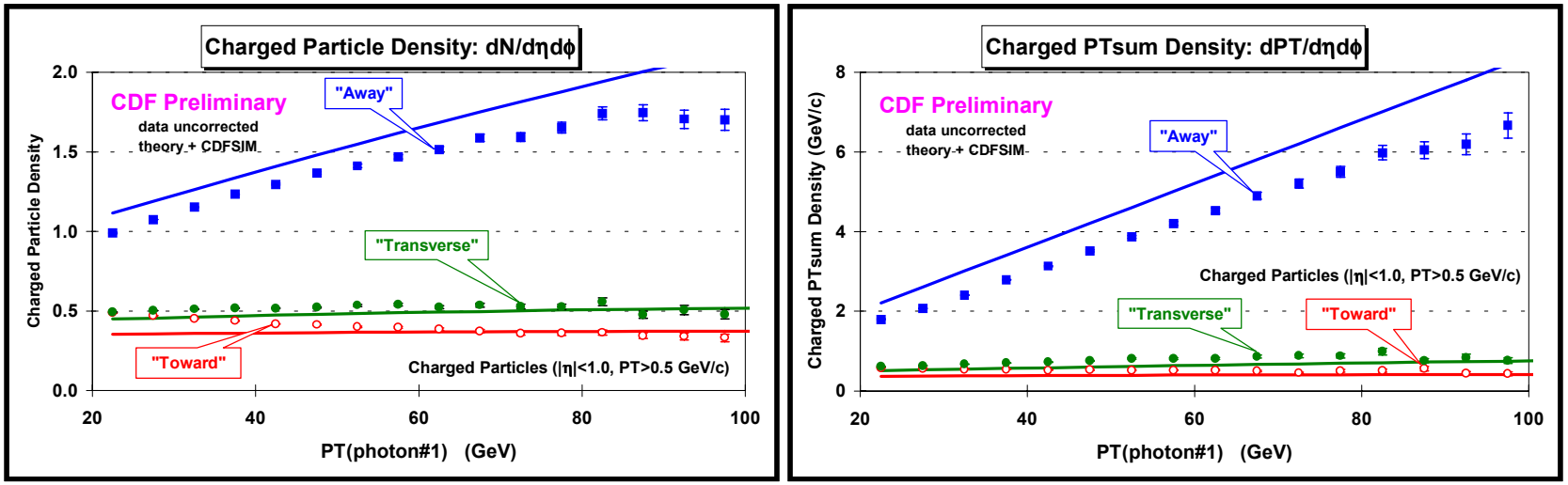
- **(*right*) Shows the Δϕ dependence of the charged PTsum density, dPT/dηdϕ, for charged particles (p_T > 0.5 GeV/c, |η| < 1) for "leading photon" events (P_T(pho#1) > 50 GeV) compared with HERWIG (after CDFSIM).**

Photon PTsum Particle Density: PY Tune A vs HERWIG



- **Note: I have define "back-to-back" to be $|\Delta\phi| > 150^0$. Florencia uses $|\Delta\phi| > 172^0$.**

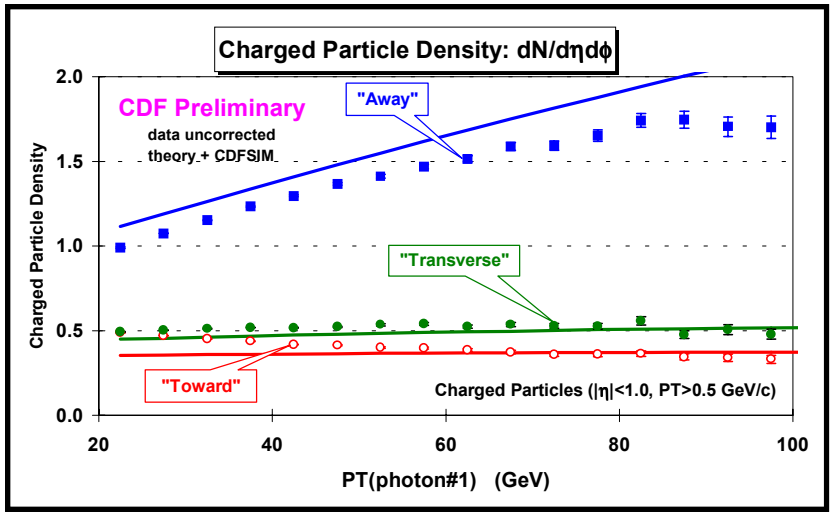
Photon Particle Densities: PY Tune A vs Data

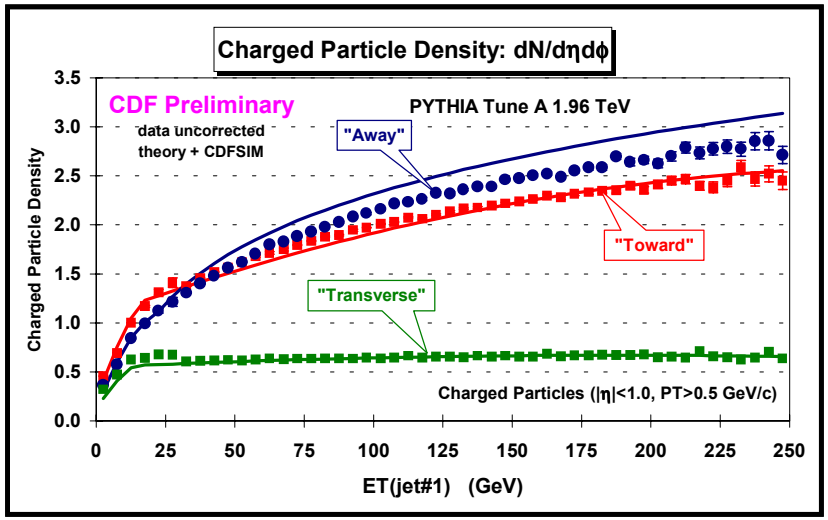


- **Shows the average charged particle density, dN/dηdϕ, and PTsum density, dPT/dηdϕ, for charged particles (p_T > 0.5 GeV/c, |η| < 1) in the "toward", "away", and "transverse" regions versus P_T(pho#1) for "leading photon" events compared with PYTHIA Tune A (after CDFSIM).**

- **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

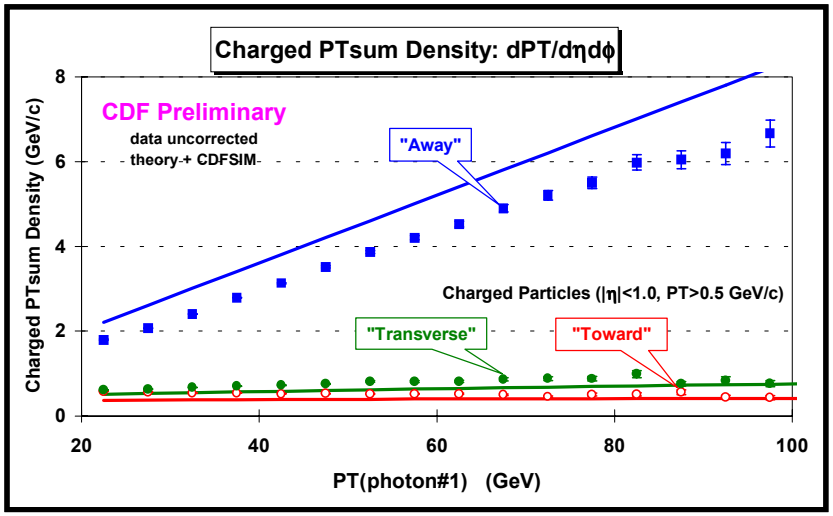


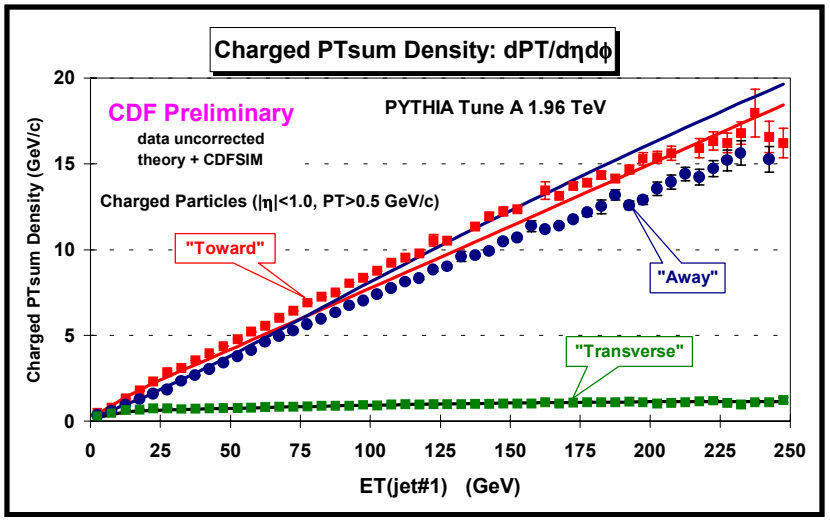


- **(*left*) Shows the average density, dN/dηdϕ, charged particles (p_T > 0.5 GeV/c, |η| < 1) in the "toward", "away", and "transverse" regions versus P_T(pho#1) for "leading photon" events compared with PYTHIA Tune A (after CDFSIM).**

- **(*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



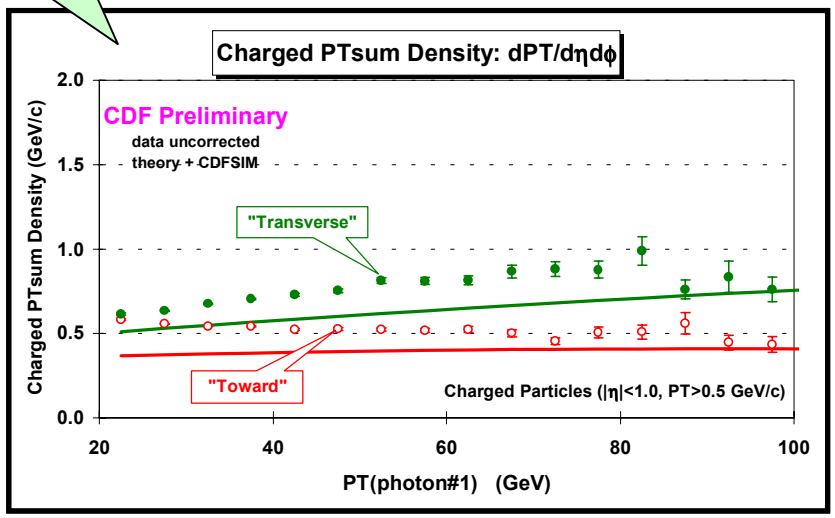


- **(*left*) Shows the average PTsum density, dPT/dηdϕ, charged particles (p_T > 0.5 GeV/c, |η| < 1) in the "toward", "away", and "transverse" regions versus P_T(pho#1) for "leading photon" events compared with PYTHIA Tune A (after CDFSIM).**

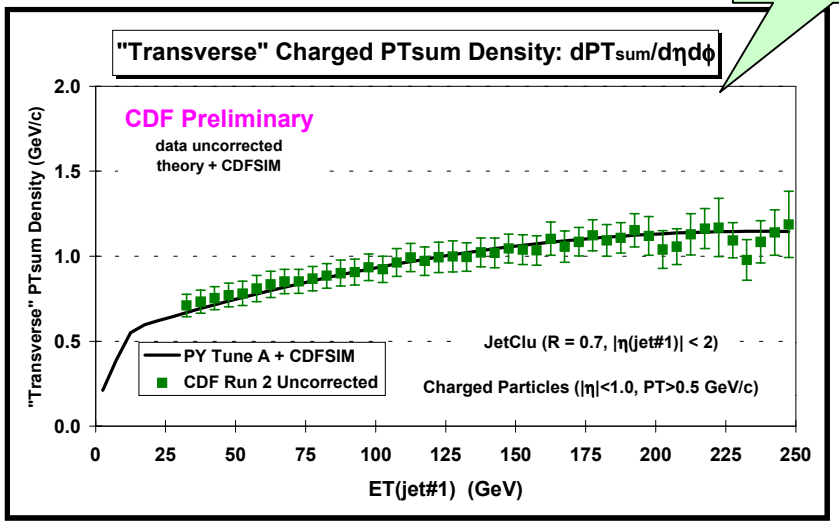
- **(*right*) Shows the average PTsum density, dPT/dηdϕ, charged particles (p_T > 0.5 GeV/c, |η| < 1) in the "toward", "away", and "transverse" regions versus E_T(jet#1) for "leading jet" events compared with PYTHIA Tune A (after CDFSIM).**

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

All NZvtx!



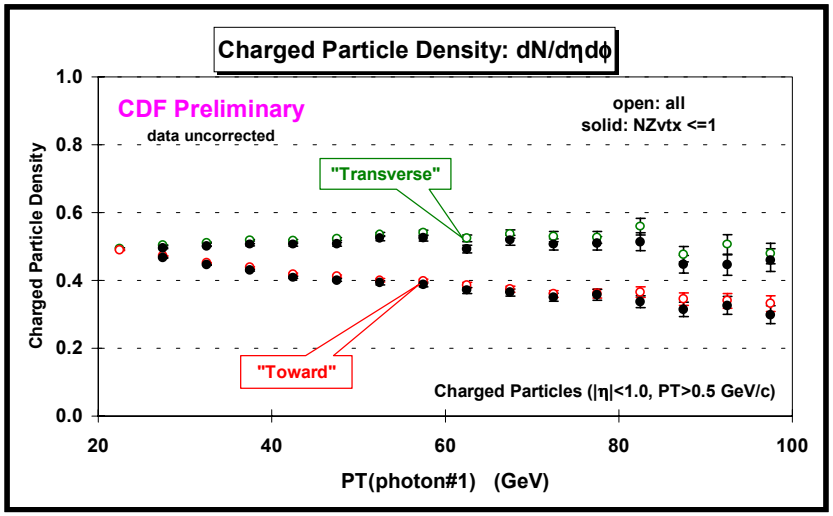
NZvtx <= 1

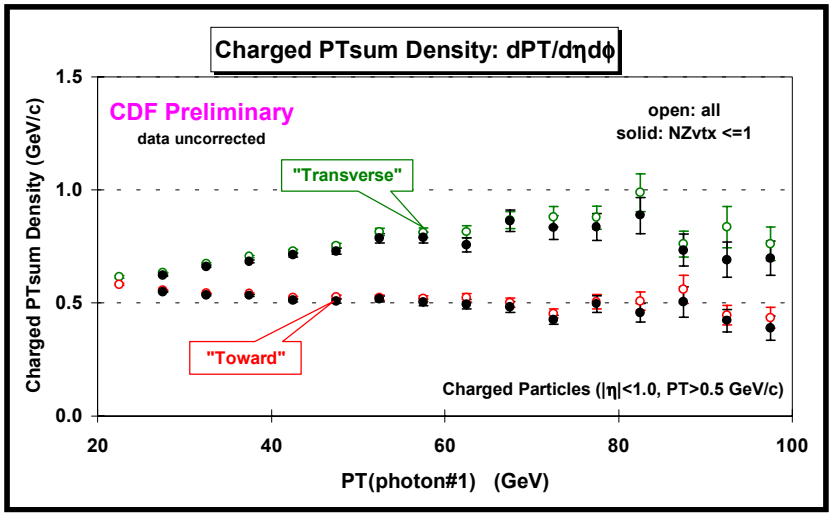


- **(*left*) Shows the average PTsum density, dPT/dηdϕ, for charged particles (p_T > 0.5 GeV/c, |η| < 1) in the "toward", and "transverse" regions versus P_T(pho#1) for "leading photon" events compared with PYTHIA Tune A (after CDFSIM).**

- **(*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

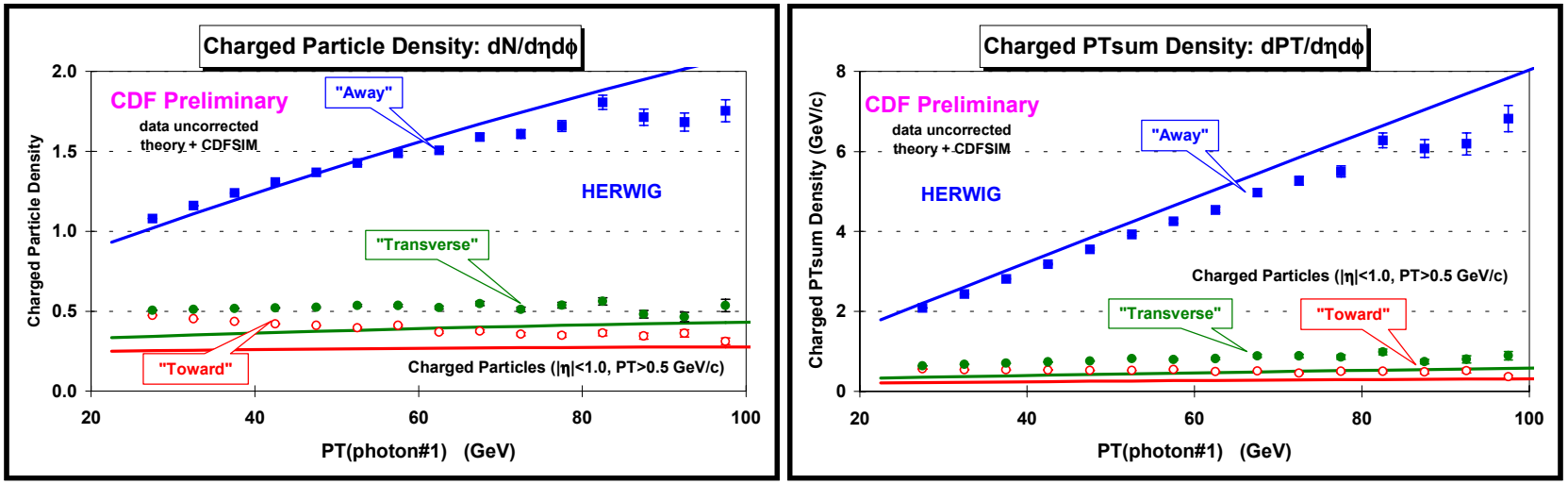




- **Shows the average charged particle density, dN/dηdϕ, and PTsum density, dPT/dηdϕ, for charged particles (p_T > 0.5 GeV/c, |η| < 1) in the "toward", and "transverse" regions versus P_T(pho#1) for all "leading photon" events compared with "leading photon" events with <= 1 z-vertex (class 12 or higher).**

- **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 Particle Densities: HERWIG vs Data

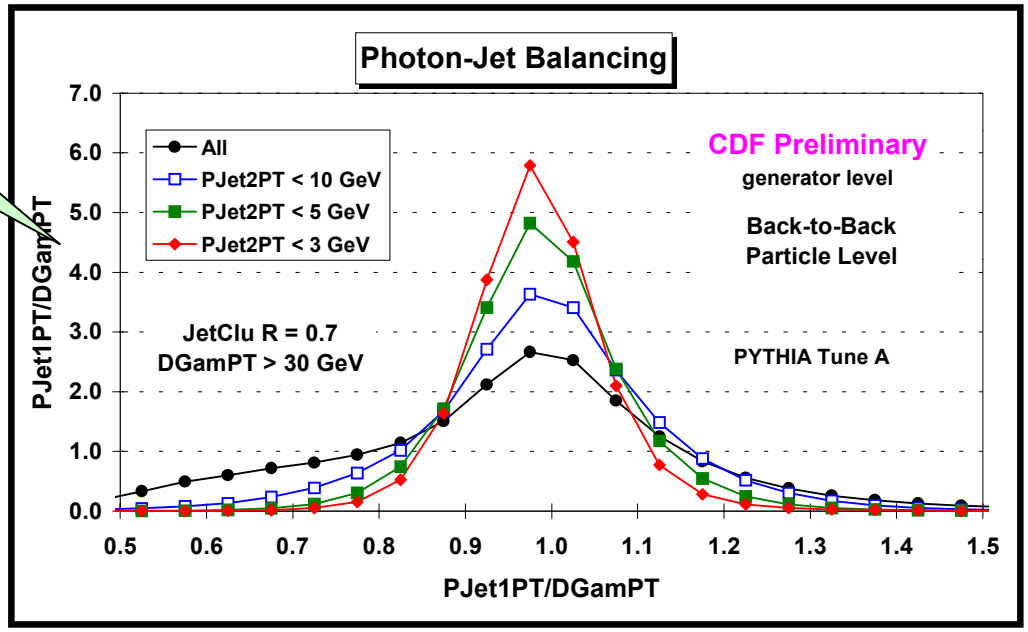


- **Shows the average charged particle density, dN/dηdϕ, and PTsum density, dPT/dηdϕ, for charged particles (p_T > 0.5 GeV/c, |η| < 1) in the "toward", "away", and "transverse" regions versus P_T(pho#1) for "leading photon" events compared with PYTHIA Tune A (after CDFSIM).**

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

PYTHIA Tune A: Particle Level Photon-Jet Balancing

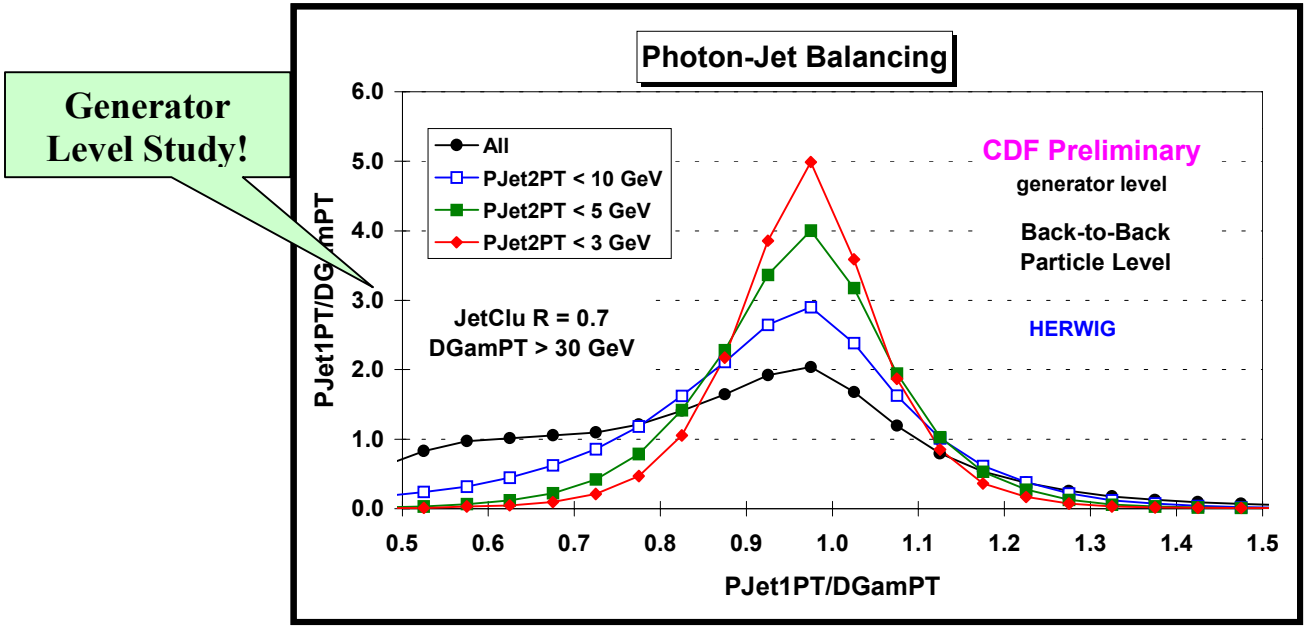
Generator Level Study!



- **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 intrensic uncertainty due to not knowing which particles in the event actually belong to the "jet".**

HERWIG: Particle Level Photon-Jet Balancing

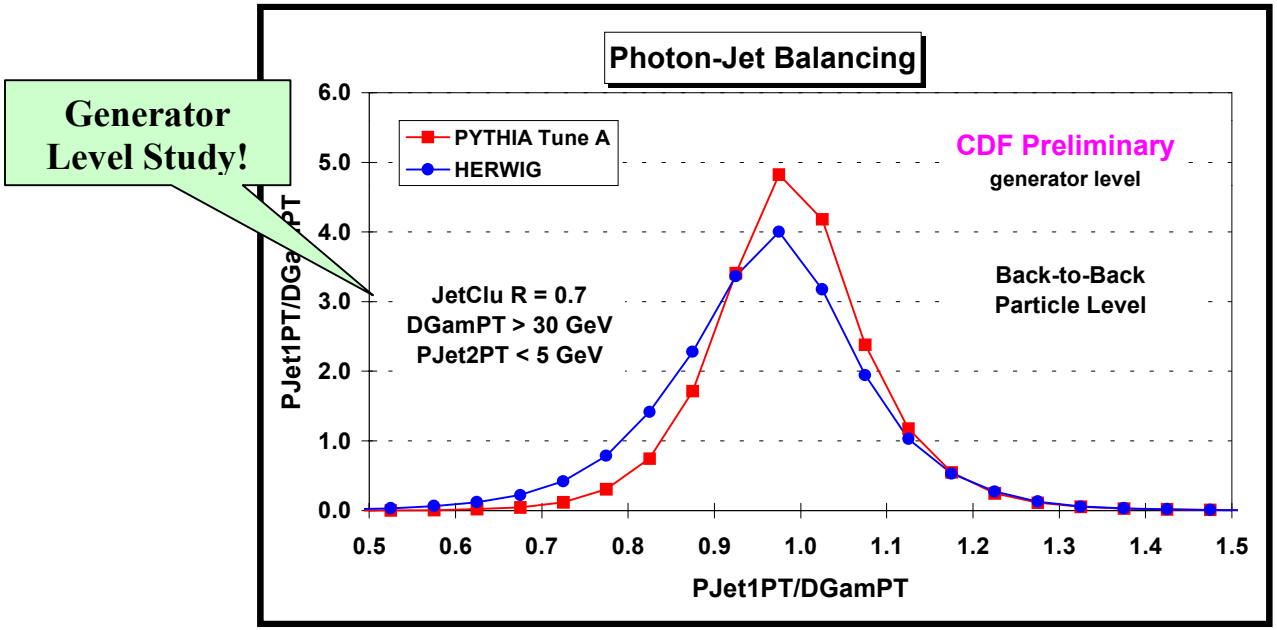


- **Shows the average ratio of P_T(particle jet#1)/P_T(direct photon) for "back-to-back" direct photon events with P_T(direct photon) > 30 GeV/c for JetClu R = 0.7 at the particle level for HERWIG.**

- **The spread in these curves represents an intrensic 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

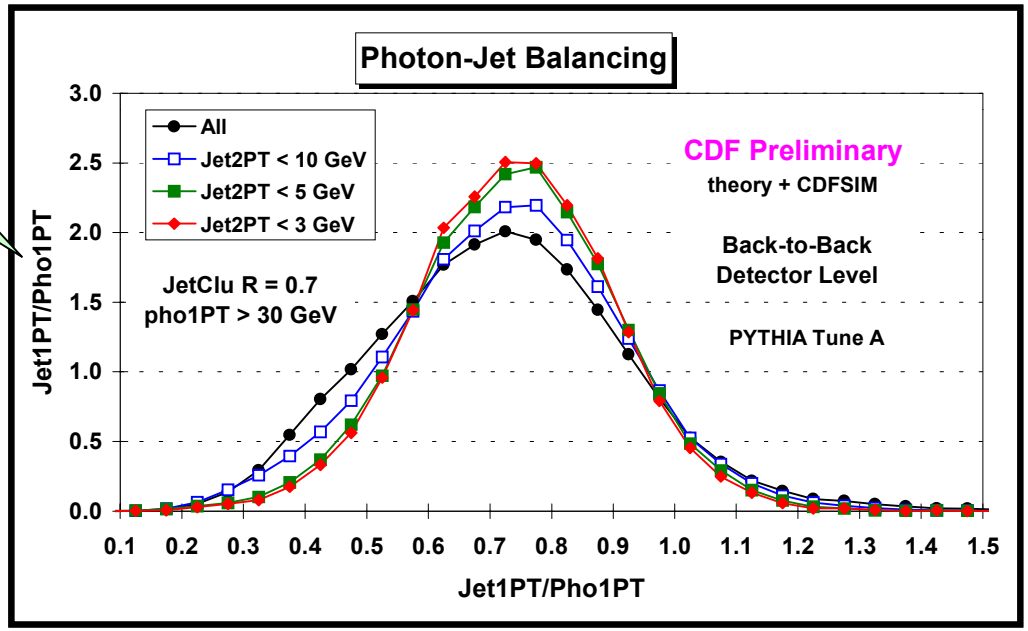


- **Shows the average ratio of P_T(particle jet#1)/P_T(direct photon) for "back-to-back" direct photon events with P_T(direct photon) > 30 GeV/c and Pjet2PT < 5 GeV/c for JetClu R = 0.7 at the particle level for PYTHIA Tune A and HERWIG.**

- **Note that PYTHIA Tune A and HERWIG differ at the generator level!**

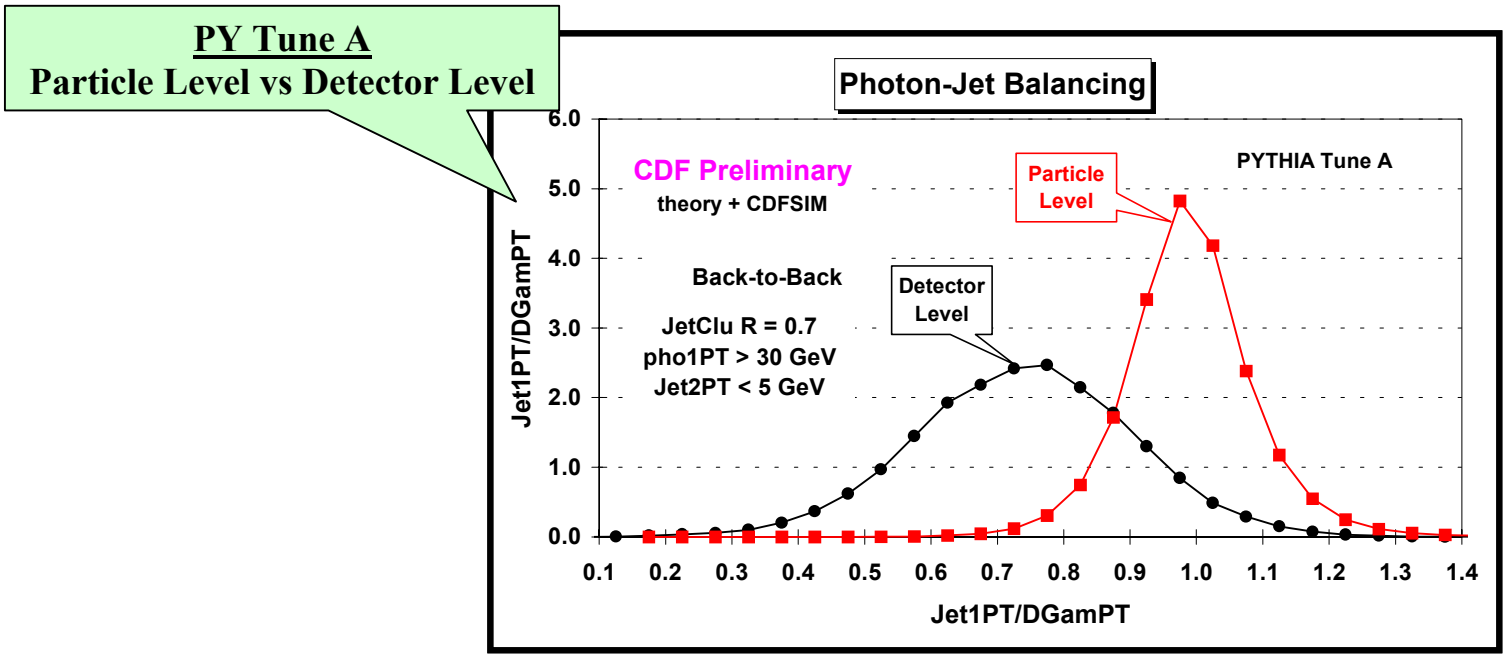
PYTHIA Tune A: Detector Level Photon-Jet Balancing

MC Detector Level Study!



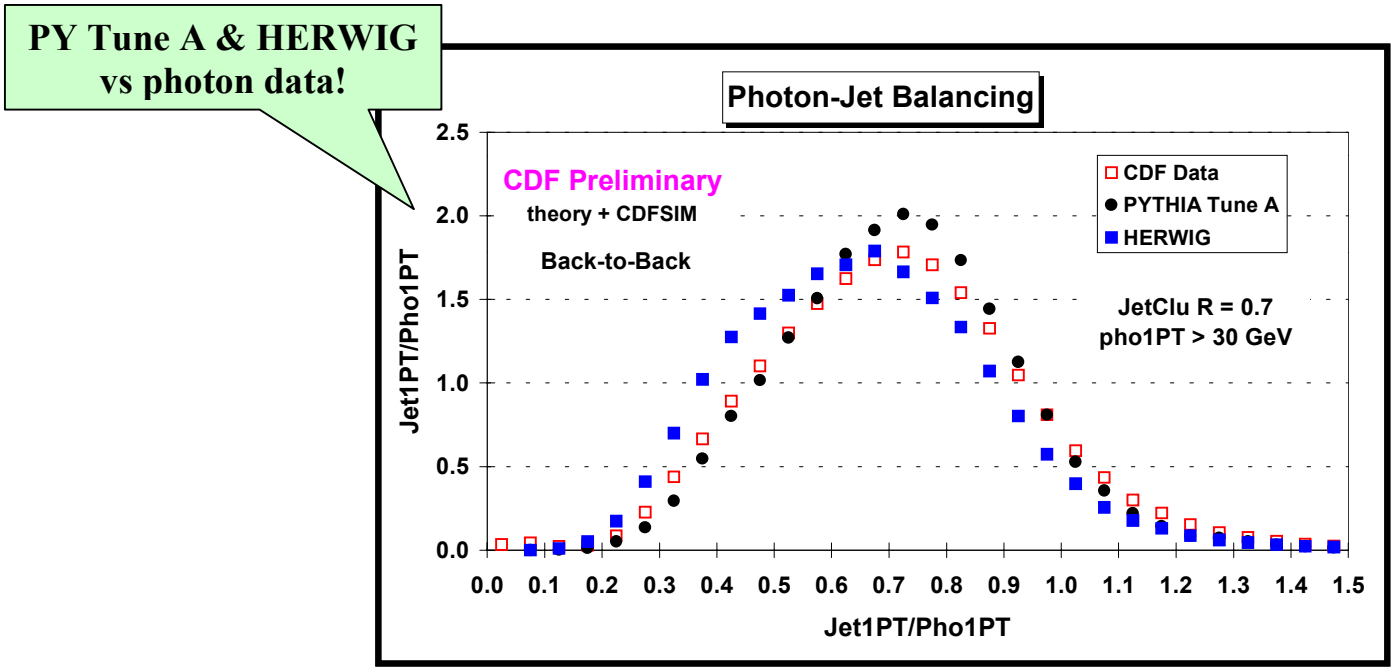
- **Shows the average ratio of P_T(jet#1)/P_T(pho#1) for "back-to-back" leading photon events with P_T(pho#1) > 30 GeV/c for JetClu R = 0.7 at the detector level for PYTHIA Tune A (*i.e.* after CDFSIM).**

Photon-Jet Balancing: Particle Level vs Detector Level



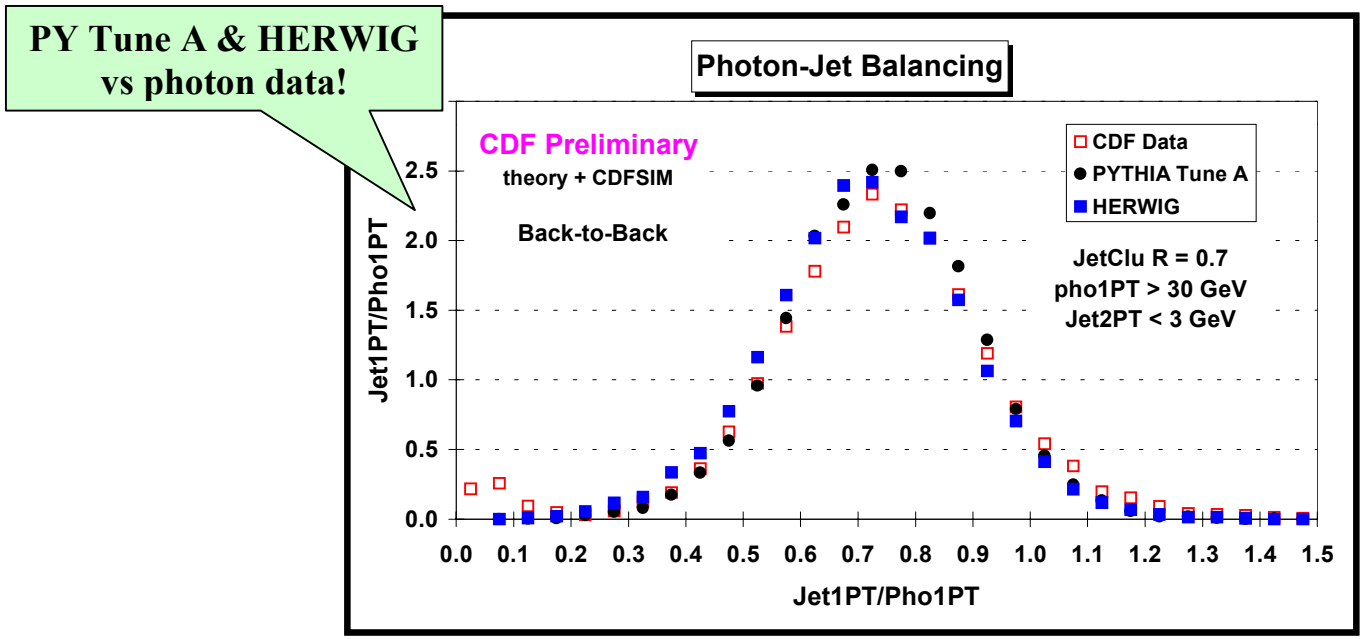
- **Shows the average ratio of P_T(jet#1)/P_T(pho#1) for "back-to-back" leading photon events with P_T(pho#1) > 30 GeV/c and Jet2PT < 5 GeV for JetClu R = 0.7 for PYTHIA Tune A at the particle level and at the detector level (*i.e.* after CDFSIM).**

Photon-Jet Balancing: Data versus Monte-Carlo



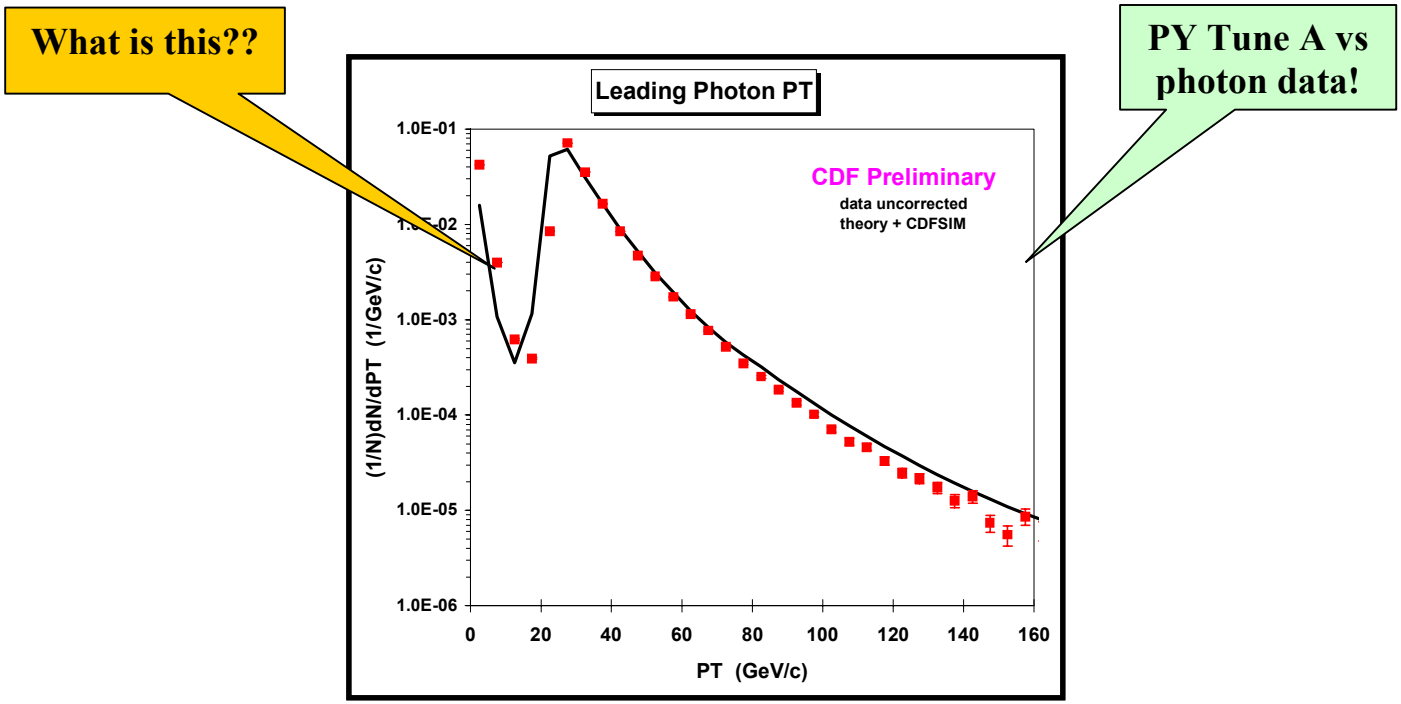
- **Data on the average ratio of P_T(jet#1)/P_T(pho#1) for "back-to-back" leading photon events with P_T(pho#1) > 30 GeV/c for JetClu R = 0.7 compared with PYTHIA Tune A and HERWIG after CDFSIM.**

Photon-Jet Balancing: Data versus Monte-Carlo



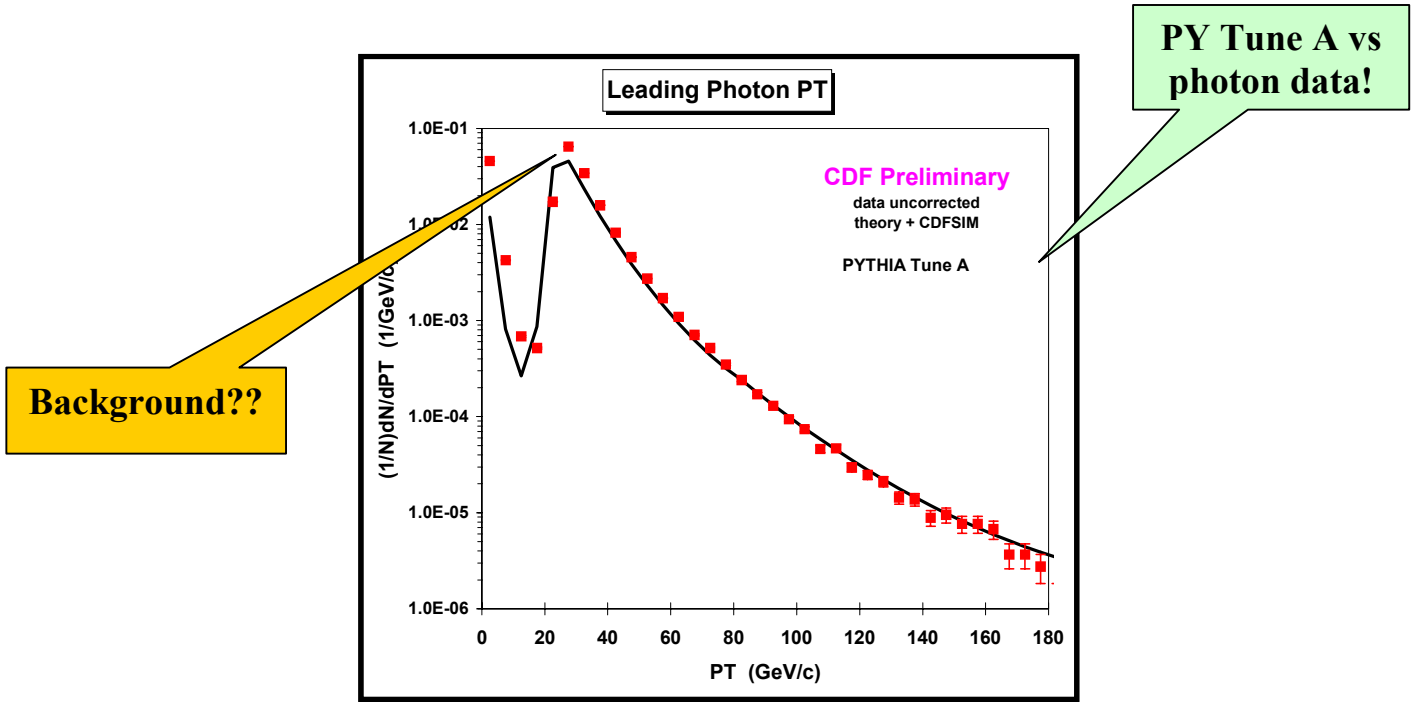
- **Data on the average ratio of P_T(jet#1)/P_T(pho#1) for "back-to-back" leading photon events with P_T(pho#1) > 30 GeV/c and Jet2PT < 3 GeV for JetClu R = 0.7 compared with PYTHIA Tune A and HERWIG after CDFSIM.**

Leading Photon P_T Distribution: PY Tune A vs Data



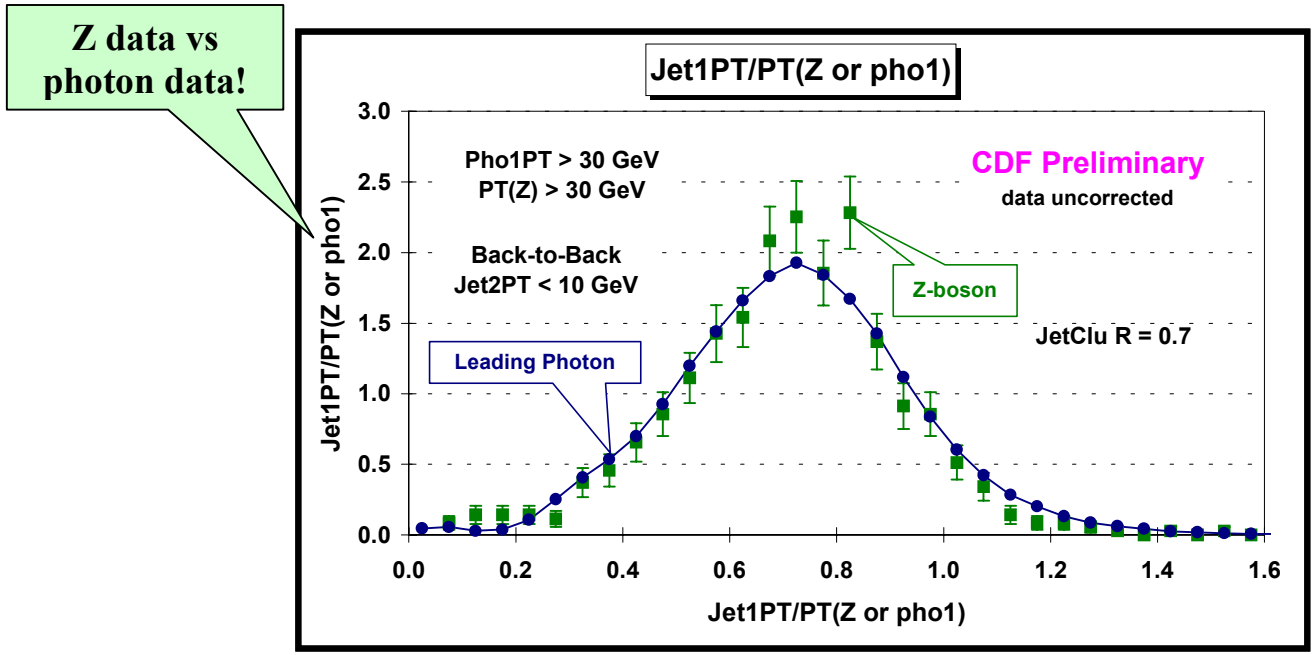
- **Data on the leading photon P_T distribution compared with PYTHIA Tune A (after CDFSIM). Both data and theory normalized to one.**
- **Unlike the inclusive "jet" cross section the data does not rise above the theory at high P_T!**

Leading Photon P_T Distribution: PY Tune A vs Data



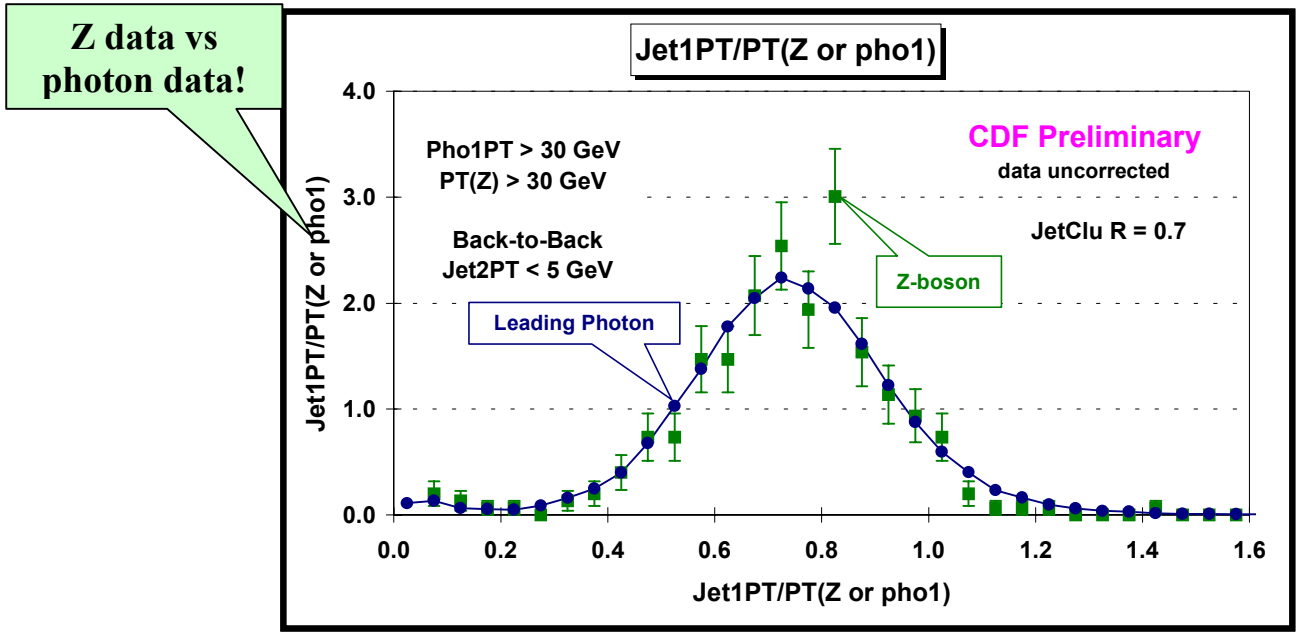
- **Data on the leading photon P_T distribution compared with PYTHIA Tune A (after CDFSIM). Normalized to agree at high P_T.**
- **Unlike the inclusive "jet" cross section the data does not rise above the theory at high P_T!**

Jet Balancing: Photon versus Z-boson



- **Data on the average ratio of P_T(jet#1)/P_T(pho#1) for "back-to-back" leading photon events with P_T(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 (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(pho#1) for "back-to-back" leading photon events with P_T(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 consistant 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!**