



# MPI@TAU 2012



## Energy Dependence of the UE



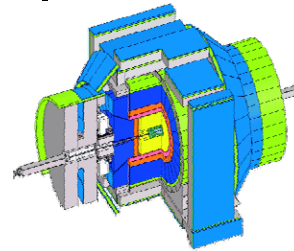
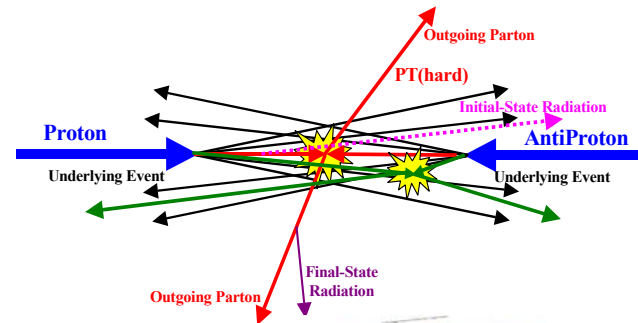
**Rick Field**  
University of Florida

**Q**uantum  
**C**hromo-  
**D**ynamics

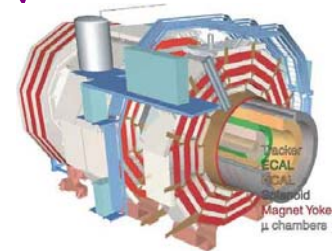
Tel Aviv University October 14-18, 2012

### Outline of Talk

- ➔ CDF PYTHIA 6.2 Tevatron Tune DW.
- ➔ CMS PYTHIA 6.4 LHC Tune Z1.
- ➔ LPCC MB&UE working group “common plots”.
- ➔ New UE data at 300 GeV, 900 GeV, and 1.96 TeV from the Tevatron Energy-Scan.
- ➔ New comparisons with PYTHIA 6.4 Tune Z1.
- ➔ New MB data at 300 GeV, 900 GeV, and 1.96 TeV from the Tevatron Energy-Scan.



**CDF Run 2**  
300 GeV, 900 GeV, 1.96 TeV



**CMS at the LHC**  
900 GeV, 7 & 8 TeV

# Traditional Approach



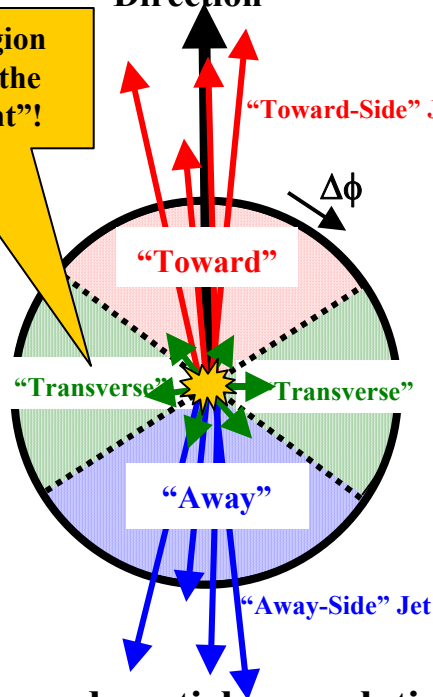
## CDF Run 1 Analysis Charged Particle $\Delta\phi$ Correlations

Charged Jet #1  
Direction

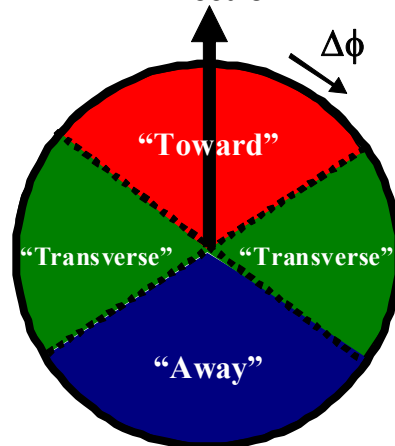
$$P_T > P_{T\min} \quad |\eta| < \eta_{\text{cut}}$$

Leading Calorimeter Jet or  
Leading Charged Particle Jet or  
Leading Charged Particle or  
Z-Boson

“Transverse” region  
very sensitive to the  
“underlying event”!



Leading Object  
Direction



- ➔ Look at charged particle correlations in the azimuthal angle  $\Delta\phi$  relative to a leading object (*i.e.* CaloJet#1, ChgJet#1,  $P_{T\max}$ , Z-boson). For CDF  $P_{T\min} = 0.5 \text{ GeV}/c$   $\eta_{\text{cut}} = 1$ .
- ➔ Define  $|\Delta\phi| < 60^\circ$  as “Toward”,  $60^\circ < |\Delta\phi| < 120^\circ$  as “Transverse”, and  $|\Delta\phi| > 120^\circ$  as “Away”.
- ➔ All three regions have the same area in  $\eta$ - $\phi$  space,  $\Delta\eta \times \Delta\phi = 2\eta_{\text{cut}} \times 120^\circ = 2\eta_{\text{cut}} \times 2\pi/3$ . Construct densities by dividing by the area in  $\eta$ - $\phi$  space.



# Traditional Approach

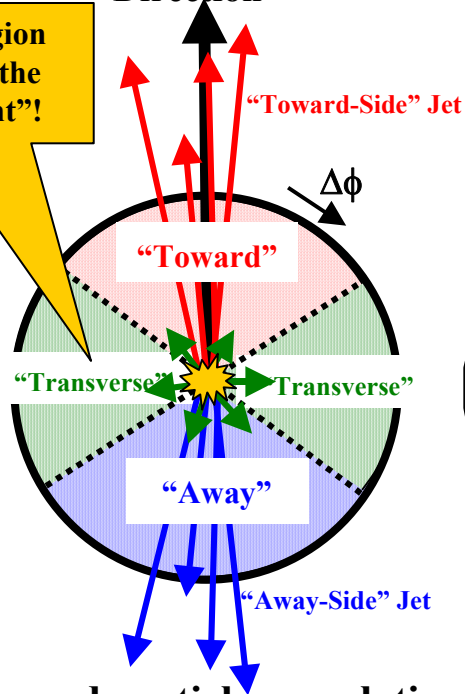


## CDF Run 1 Analysis Charged Particle $\Delta\phi$ Correlations

Charged Jet #1

Direction

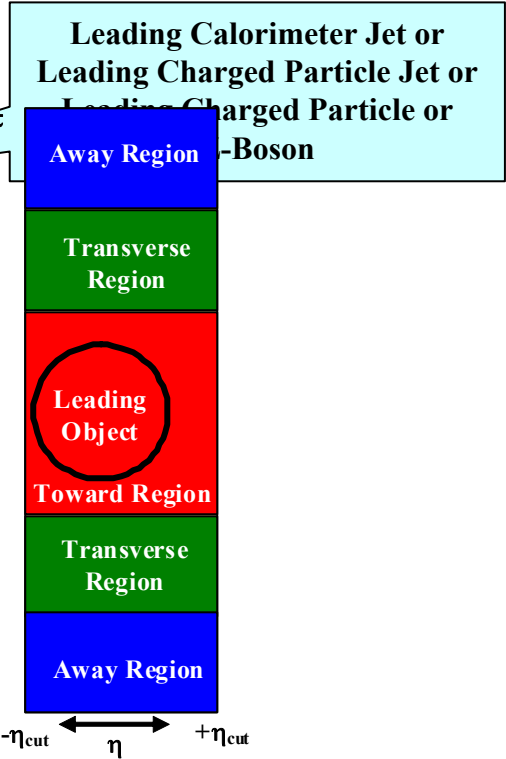
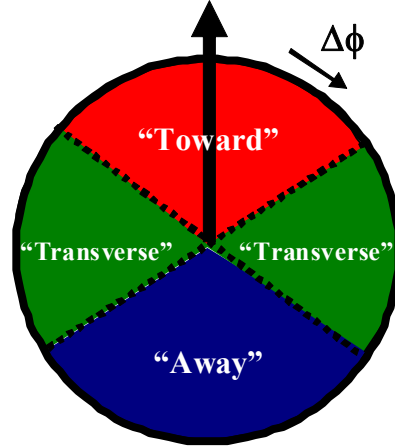
“Transverse” region very sensitive to the “underlying event”!



## Charged Particle $\Delta\phi$ Correlations

$$P_T > P_{T\min} \quad |\eta| < \eta_{\text{cut}}$$

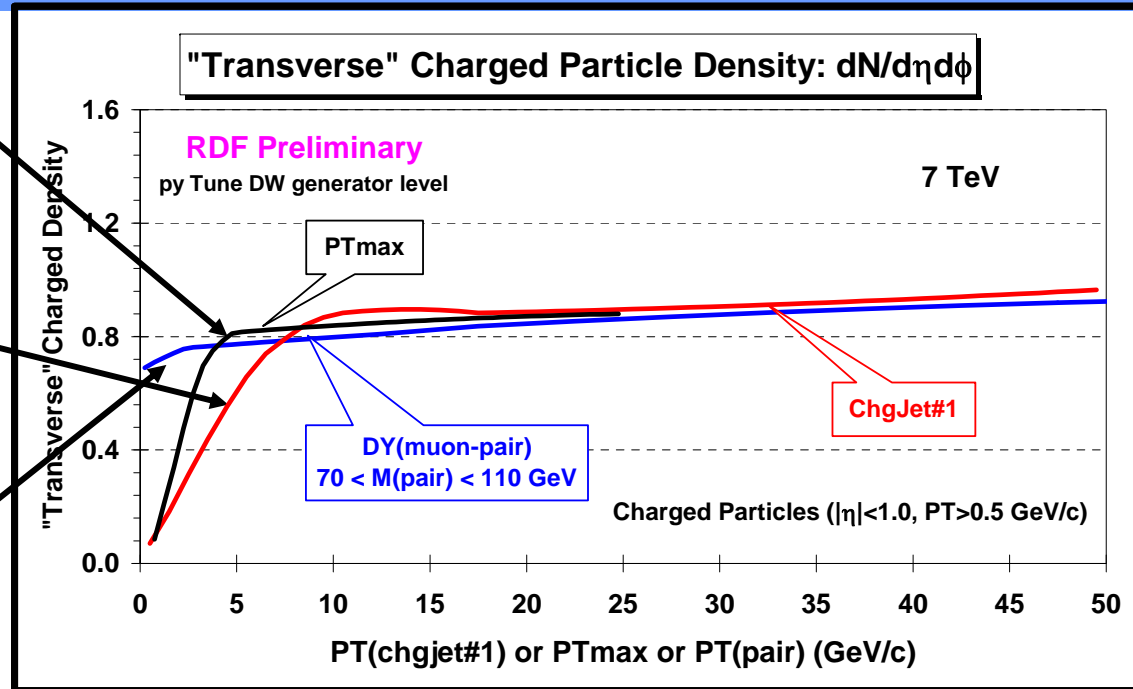
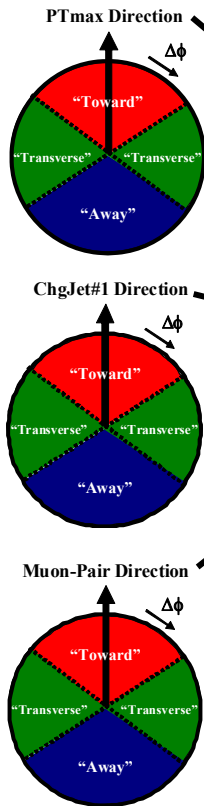
Leading Object Direction



- ➔ Look at charged particle correlations in the azimuthal angle  $\Delta\phi$  relative to a leading object (*i.e.* CaloJet#1, ChgJet#1,  $P_{T\max}$ , Z-boson). For CDF  $P_{T\min} = 0.5 \text{ GeV}/c$   $\eta_{\text{cut}} = 1$ .
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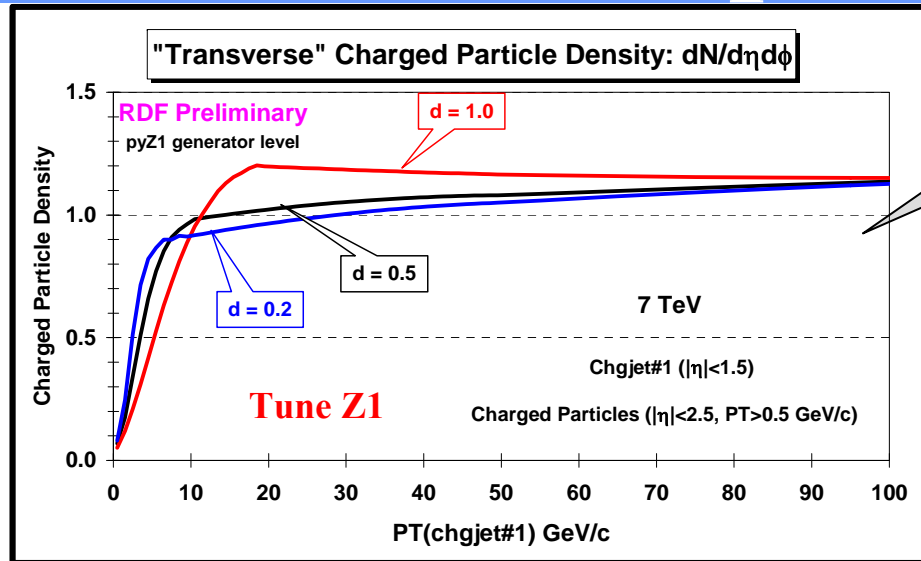
# “Transverse” Charged Density



- ➔ Shows the charged particle density in the “**transverse**” region for charged particles ( $p_T > 0.5 \text{ GeV}/c, |\eta| < 1$ ) at 7 TeV as defined by PTmax, PT(chgjet#1), and PT(muon-pair) from PYTHIA **Tune DW** at the particle level (*i.e.* generator level). Charged particle jets are constructed using the **Anti-KT algorithm** with  $d = 0.5$ .



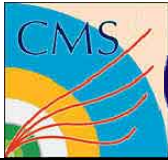
# Jet Radius Dependence



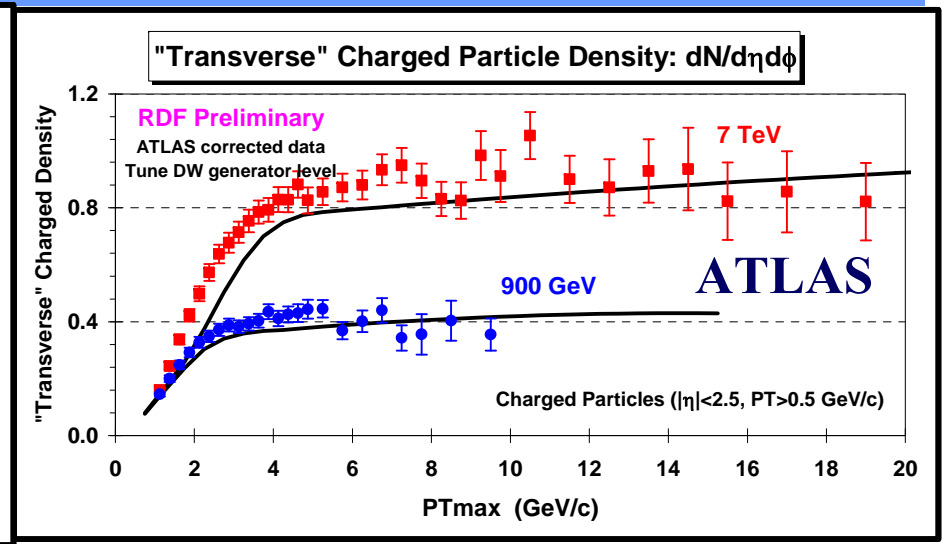
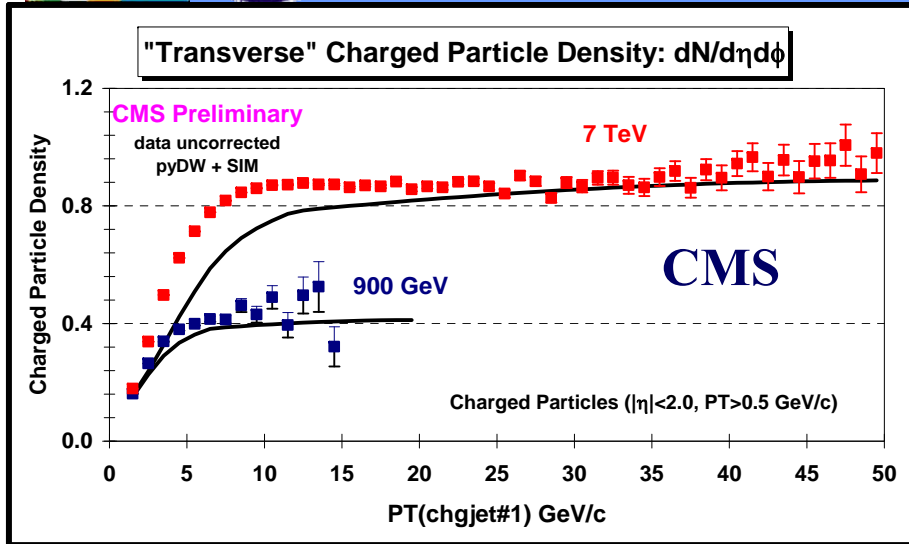
The UE activity is higher for large jet radius!

- ➔ The charged particle density in the “transverse” region as defined by the leading charged particle jet from PYTHIA **Tune Z1**. The charged particles are in the region  $p_T > 0.5$  GeV/c and  $|\eta| < 2.5$ . Charged particle jets are constructed using the Anti-KT algorithm with  $d = 0.2, 0.5, \text{ and } 1.0$  from charged particles in the region  $p_T > 0.5$  GeV/c and  $|\eta| < 2.5$ , however, the leading charged particle jet is required to have  $|\eta(\text{chgjet}\#1)| < 1.5$ .

It seems that large jet radius “biases” the UE to be more active!

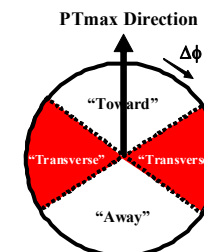
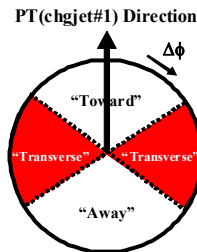


# PYTHIA Tune DW

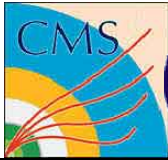


➔ **CMS preliminary data at 900 GeV and 7 TeV** ➔ on the “transverse” charged particle density,  $dN/d\eta d\phi$ , as defined by the leading charged particle jet (chgjet#1) for charged particles with  $p_T > 0.5$  GeV/c and  $|\eta| < 2$ . The data are uncorrected and compared with PYTHIA **Tune DW** after detector simulation.

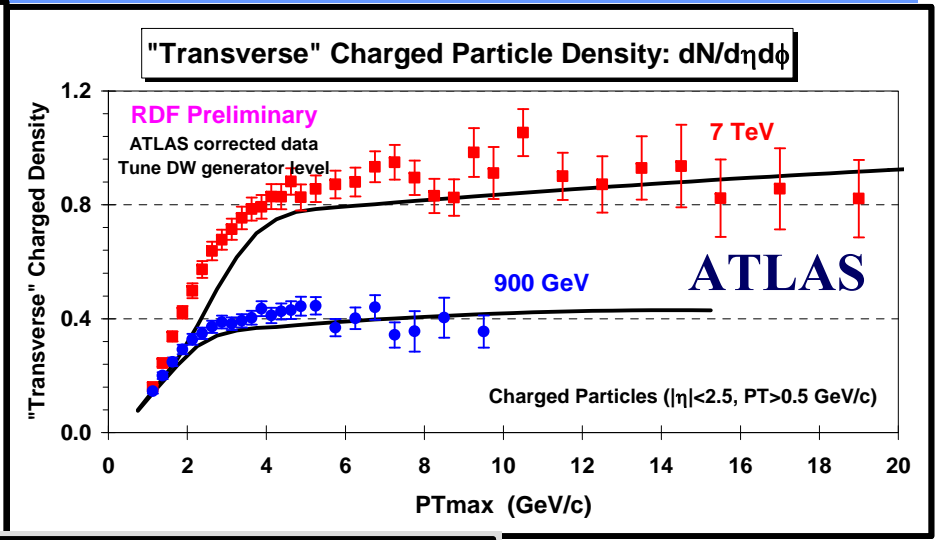
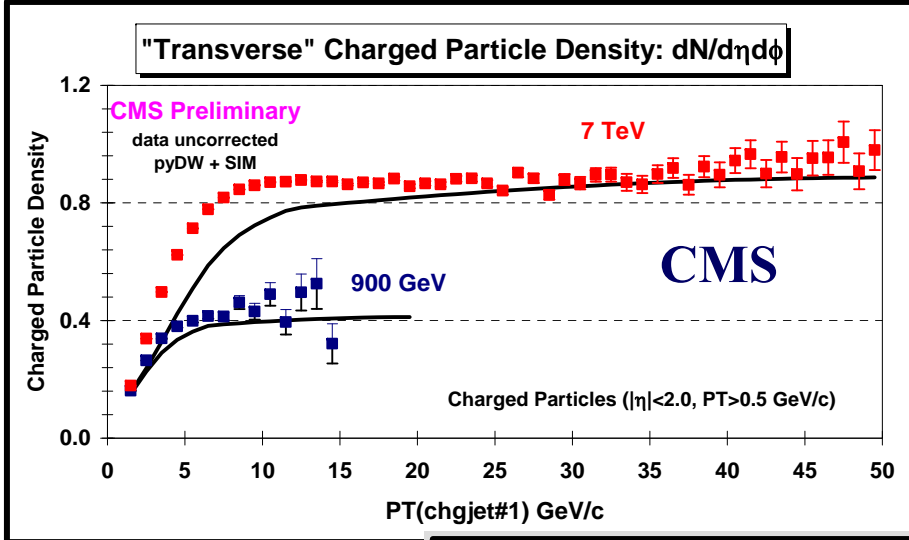
➔ **ATLAS preliminary data at 900 GeV and 7 TeV** ➔ on the “transverse” charged particle density,  $dN/d\eta d\phi$ , as defined by the leading charged particle (PTmax) for charged particles with  $p_T > 0.5$  GeV/c and  $|\eta| < 2.5$ . The data are corrected and compared with PYTHIA **Tune DW** at the generator level.



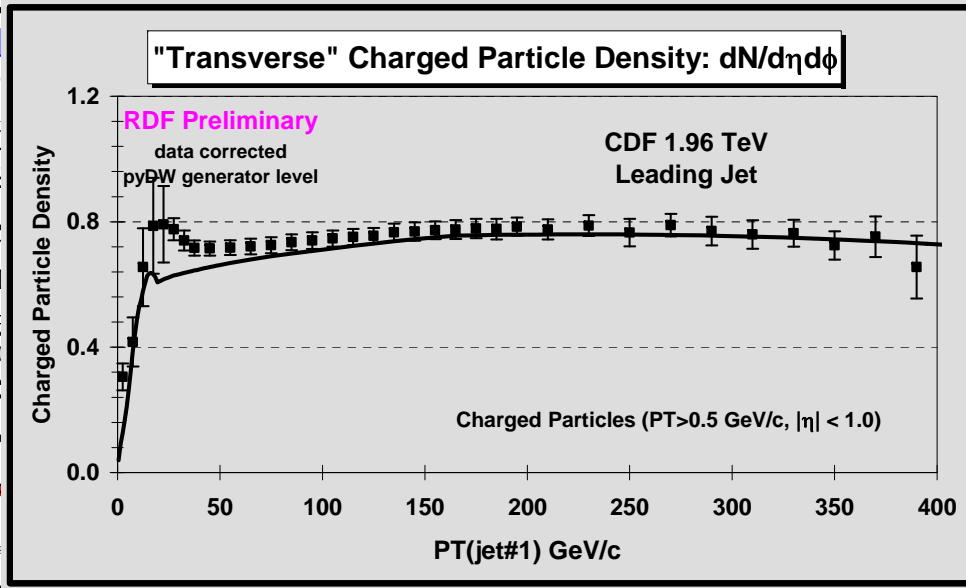
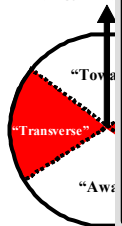




# PYTHIA Tune DW



→ CMS preliminary data on the “transverse”  $dN/d\eta d\phi$ , as defined by the leading particle jet (chgjet#1) with  $p_T > 0.5$  GeV/c. The data are uncorrected and compared with PYTHIA Tune DW after detector simulation.

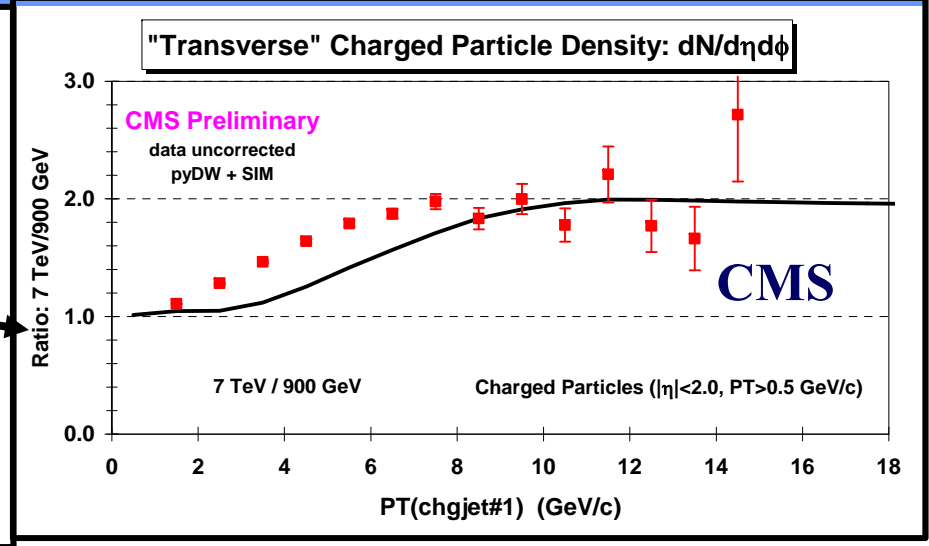
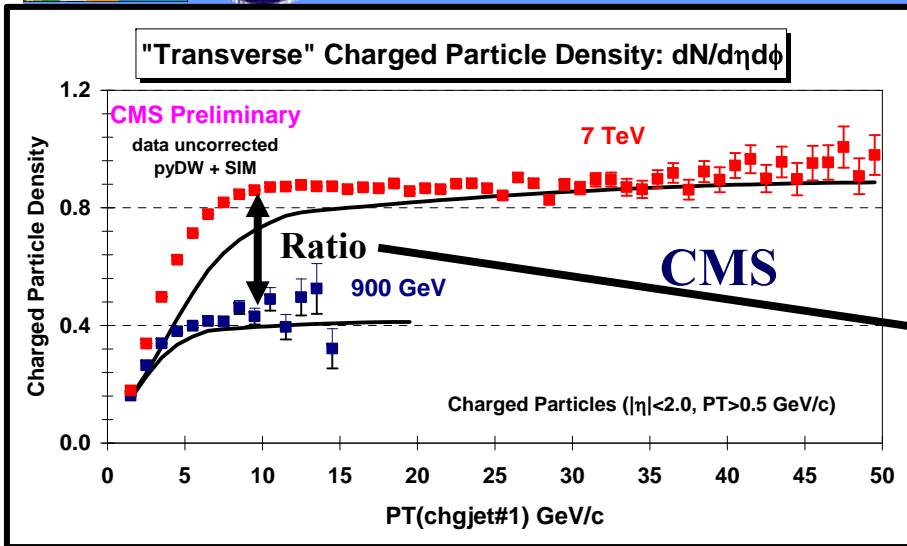


data at 900 GeV and 7 TeV. The data are defined by the leading particle jet (chgjet#1) for charged particles with  $|\eta| < 2.5$ . The data are compared with PYTHIA Tune DW after detector simulation.



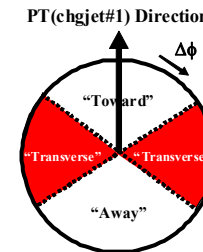
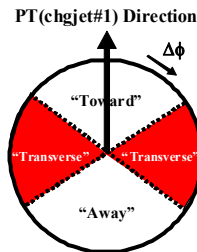


# PYTHIA Tune DW



→ CMS preliminary data at 900 GeV and 7 TeV on the “transverse” charged particle density,  $dN/d\eta d\phi$ , as defined by the leading charged particle jet (chgjet#1) for charged particles with  $p_T > 0.5$  GeV/c and  $|\eta| < 2$ . The data are uncorrected and compared with PYTHIA Tune DW after detector simulation.

→ Ratio of CMS preliminary data at 900 GeV and 7 TeV on the “transverse” charged particle density,  $dN/d\eta d\phi$ , as defined by the leading charged particle jet (chgjet#1) for charged particles with  $p_T > 0.5$  GeV/c and  $|\eta| < 2$ . The data are uncorrected and compared with PYTHIA Tune DW after detector simulation.



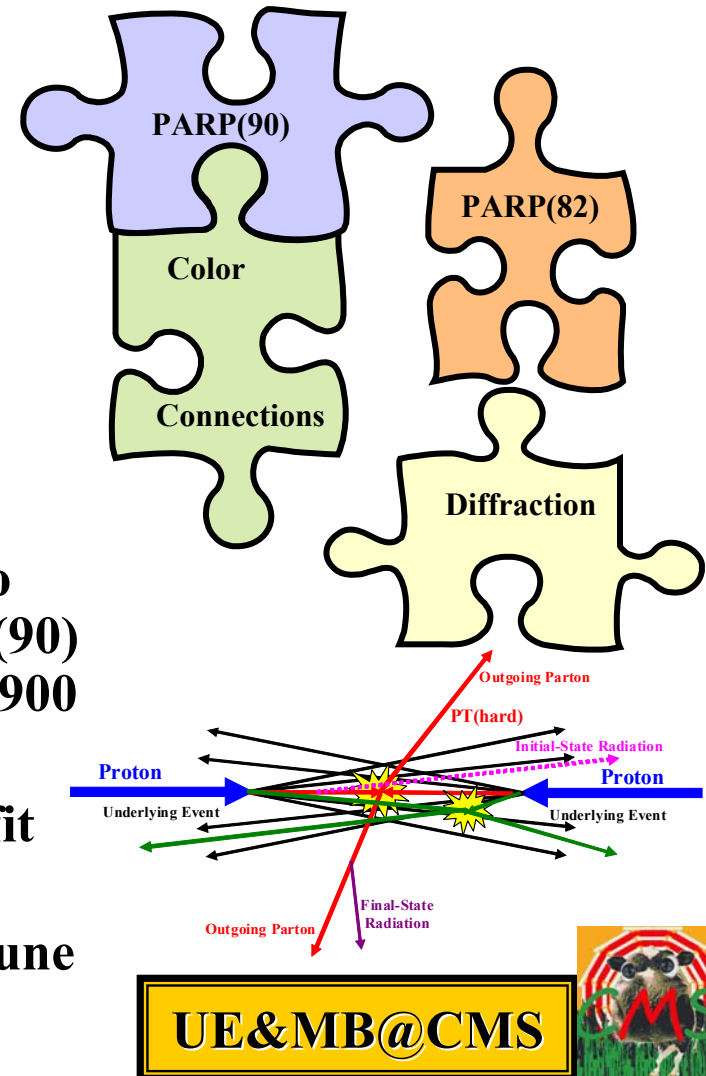




# PYTHIA Tune Z1



- ➔ All my previous tunes (A, DW, DWT, D6, D6T, CW, X1, and X2) were PYTHIA 6.4 tunes using the old  $Q^2$ -ordered parton showers and the old MPI model (really 6.2 tunes)!
- ➔ I believe that it is time to move to PYTHIA 6.4 ( $p_T$ -ordered parton showers and new MPI model)!
- ➔ **Tune Z1:** I started with the parameters of ATLAS Tune AMBT1, but I changed  $LO^*$  to CTEQ5L and I varied PARP(82) and PARP(90) to get a very good fit of the CMS UE data at 900 GeV and 7 TeV.
- ➔ The ATLAS Tune AMBT1 was designed to fit the inelastic data for  $N_{chg} \geq 6$  and to fit the  $PT_{max}$  UE data with  $PT_{max} > 10$  GeV/c. Tune AMBT1 is primarily a min-bias tune, while Tune Z1 is a UE tune!





# PYTHIA Tune Z1

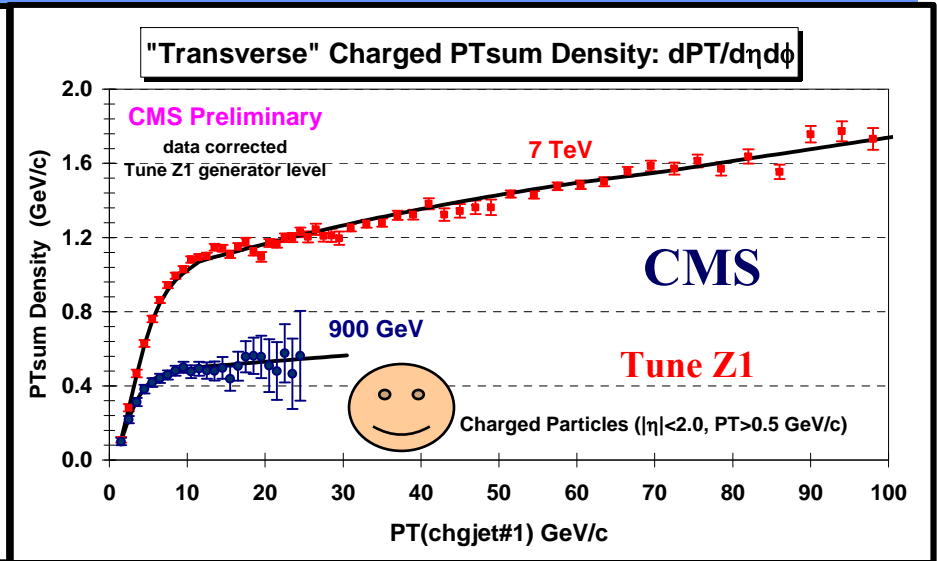
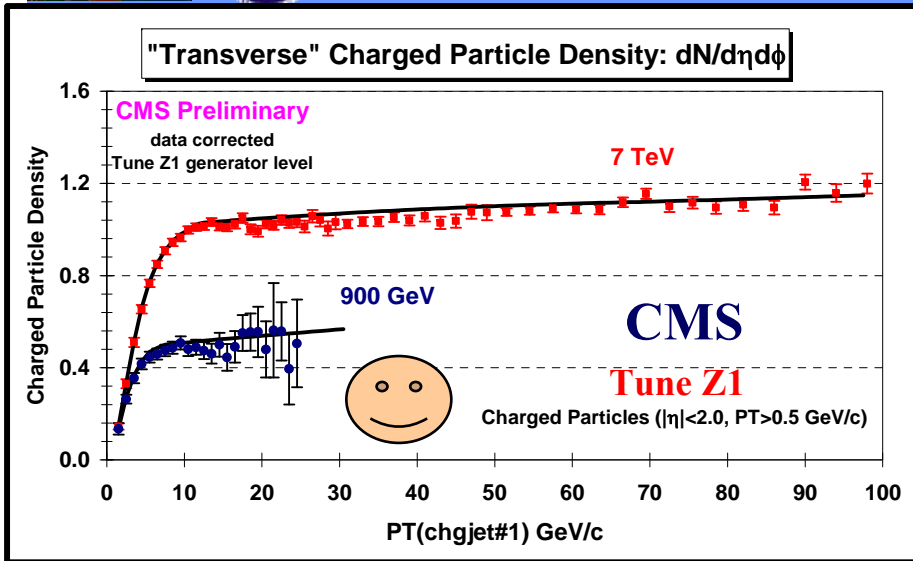


Parameters not shown are the PYTHIA 6.4 defaults!

Parameter	Tune Z1 (R. Field CMS)	Tune AMBT1 (ATLAS)
<b>Parton Distribution Function</b>	<b>CTEQ5L</b>	<b>LO*</b>
<b>PARP(82) – MPI Cut-off</b>	<b>1.932</b>	<b>2.292</b>
<b>PARP(89) – Reference energy, E0</b>	<b>1800.0</b>	<b>1800.0</b>
<b>PARP(90) – MPI Energy Extrapolation</b>	<b>0.275</b>	<b>0.25</b>
<b>PARP(77) – CR Suppression</b>	<b>1.016</b>	<b>1.016</b>
<b>PARP(78) – CR Strength</b>	<b>0.538</b>	<b>0.538</b>
<b>PARP(80) – Probability colored parton from BBR</b>	<b>0.1</b>	<b>0.1</b>
<b>PARP(83) – Matter fraction in core</b>	<b>0.356</b>	<b>0.356</b>
<b>PARP(84) – Core of matter overlap</b>	<b>0.651</b>	<b>0.651</b>
<b>PARP(62) – ISR Cut-off</b>	<b>1.025</b>	<b>1.025</b>
<b>PARP(93) – primordial kT-max</b>	<b>10.0</b>	<b>10.0</b>
<b>MSTP(81) – MPI, ISR, FSR, BBR model</b>	<b>21</b>	<b>21</b>
<b>MSTP(82) – Double gaussian matter distribution</b>	<b>4</b>	<b>4</b>
<b>MSTP(91) – Gaussian primordial kT</b>	<b>1</b>	<b>1</b>
<b>MSTP(95) – strategy for color reconnection</b>	<b>6</b>	<b>6</b>

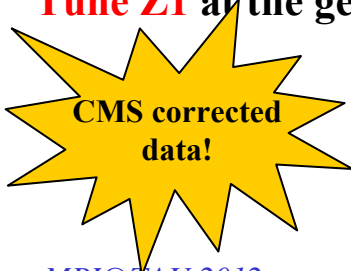


# CMS UE Data

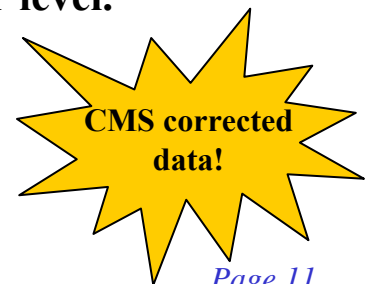


➔ CMS published data at 900 GeV and 7 TeV on the “transverse” charged particle density,  $dN/d\eta d\phi$ , as defined by the leading charged particle jet (chgjet#1) for charged particles with  $p_T > 0.5 \text{ GeV}/c$  and  $|\eta| < 2.0$ . The data are corrected and compared with **PYTHIA Tune Z1** at the generator level.

➔ CMS published data at 900 GeV and 7 TeV on the “transverse” charged PTsum density,  $dPT/d\eta d\phi$ , as defined by the leading charged particle jet (chgjet#1) for charged particles with  $p_T > 0.5 \text{ GeV}/c$  and  $|\eta| < 2.0$ . The data are corrected and compared with **PYTHIA Tune Z1** at the generator level.

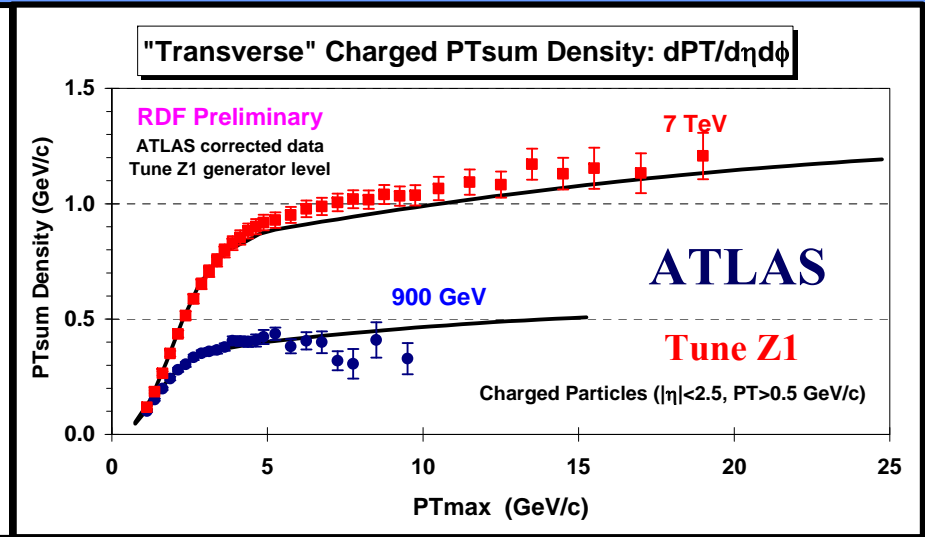
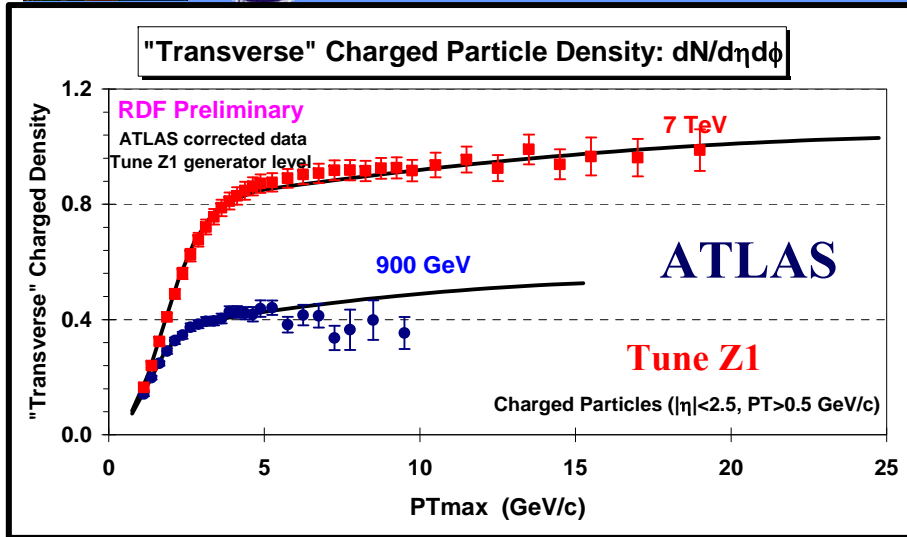


Very nice agreement!





# ATLAS UE Data



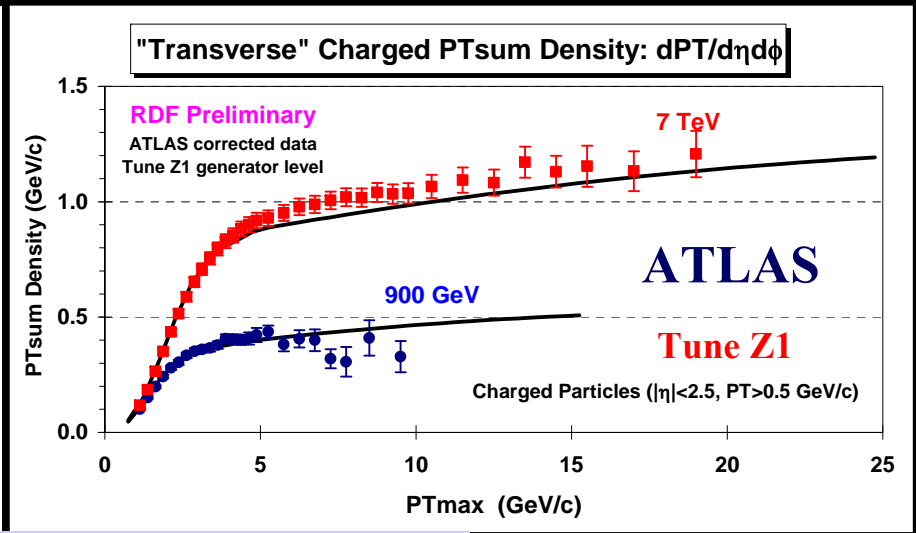
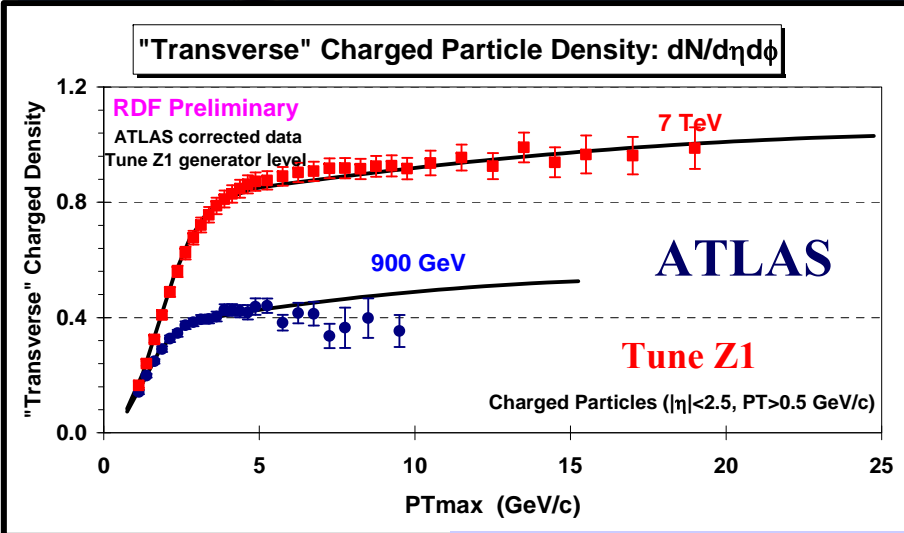
➔ **ATLAS published data at 900 GeV and 7 TeV** on the “transverse” charged particle density,  $dN/d\eta d\phi$ , as defined by the leading charged particle ( $PT_{max}$ ) for charged particles with  $p_T > 0.5$  GeV/c and  $|\eta| < 2.5$ . The data are corrected and compared with **PYTHIA Tune Z1** at the generator level.

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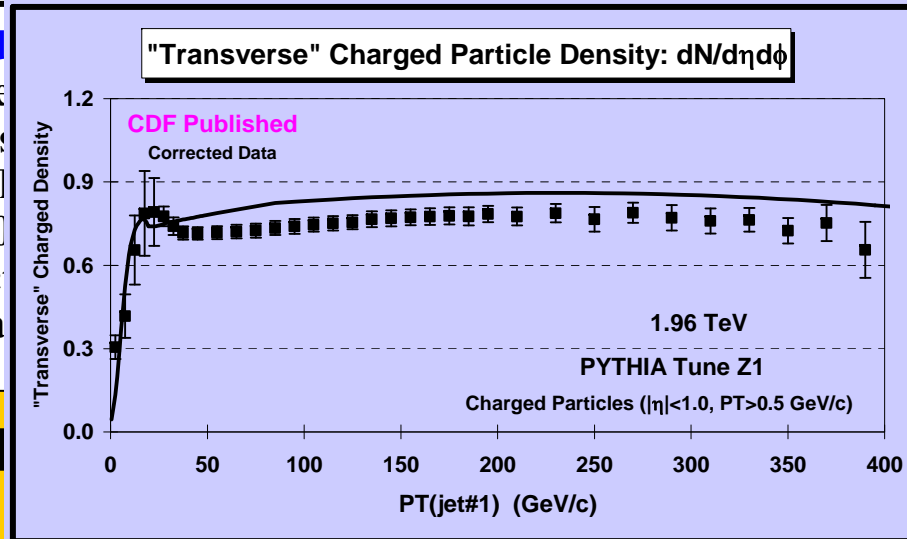
**ATLAS publication – arXiv:1012.0791**  
*December 3, 2010*



# ATLAS UE Data



➔ **ATLAS published data at 900 GeV and 7 TeV** on the "transverse" charged density,  $dN/d\eta d\phi$ , and "transverse" charged PTsum density,  $dPT/d\eta d\phi$ , as a function of the leading charged particle ( $PT_{max}$ ) for charged particles with  $p_T > 0.5$  GeV/c and  $|\eta| < 2.5$ . The data are corrected for detector effects and compared with the **PYTHIA Tune Z1** generator level.



**ATLAS published data at 900 GeV and 7 TeV** on the "transverse" charged PTsum density,  $dPT/d\eta d\phi$ , as a function of the leading charged particle ( $PT_{max}$ ) for charged particles with  $p_T > 0.5$  GeV/c and  $|\eta| < 2.5$ . The data are corrected for detector effects and compared with the generator level.

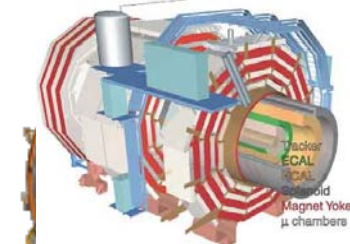
# LPCC

# MB&UE Working Group

LHC Physics Centre at CERN

## MB & UE Common Plots

Quantum  
Chromo-  
Dynamics

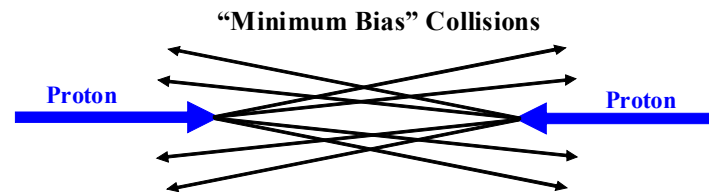
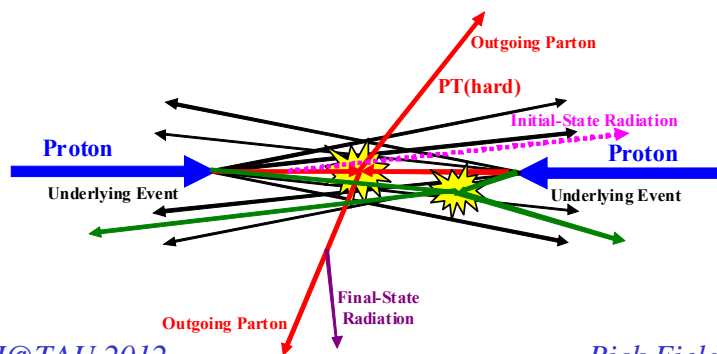


CMS



ATLAS

➔ The LPCC MB&UE Working Group has suggested several MB&UE “Common Plots” the all the LHC groups can produce and compare with each other.







# CMS Common Plots



Observable	900 GeV	7 TeV
<b>MB1: <math>dN_{\text{chg}}/d\eta N_{\text{chg}} \geq 1</math> <math> \eta  &lt; 0.8</math> <math>p_T &gt; 0.5</math> GeV/c &amp; 1.0 GeV/c</b>	<b>Done</b> <b>QCD-10-024</b>	<b>Done</b> <b>QCD-10-024</b>
<b>MB2: <math>dN_{\text{chg}}/dp_T N_{\text{chg}} \geq 1</math> <math> \eta  &lt; 0.8</math></b>	<b>Stalled</b>	<b>Stalled</b>
<b>MB3: Multiplicity Distribution <math> \eta  &lt; 0.8</math> <math>p_T &gt; 0.5</math> GeV/c &amp; 1.0 GeV/c</b>	<b>Stalled</b>	<b>Stalled</b>
<b>MB4: <math>\langle p_T \rangle</math> versus Nchg <math> \eta  &lt; 0.8</math> <math>p_T &gt; 0.5</math> GeV/c &amp; 1.0 GeV/c</b>	<b>In progress</b> <b>(Antwerp)</b>	<b>In progress</b> <b>(Antwerp)</b>
<b>UE1: Transverse Nchg &amp; PTsum as defined by the leading charged particle, PTmax <math> \eta  &lt; 0.8</math> <math>p_T &gt; 0.5</math> GeV/c &amp; 1.0 GeV/c</b>	<b>Done</b> <b>FSQ-12-020</b>	<b>Done</b> <b>FSQ-12-020</b>

**Direct charged particles (including leptons) corrected to the particle level with no corrections for SD or DD.**



# CMS Common Plots



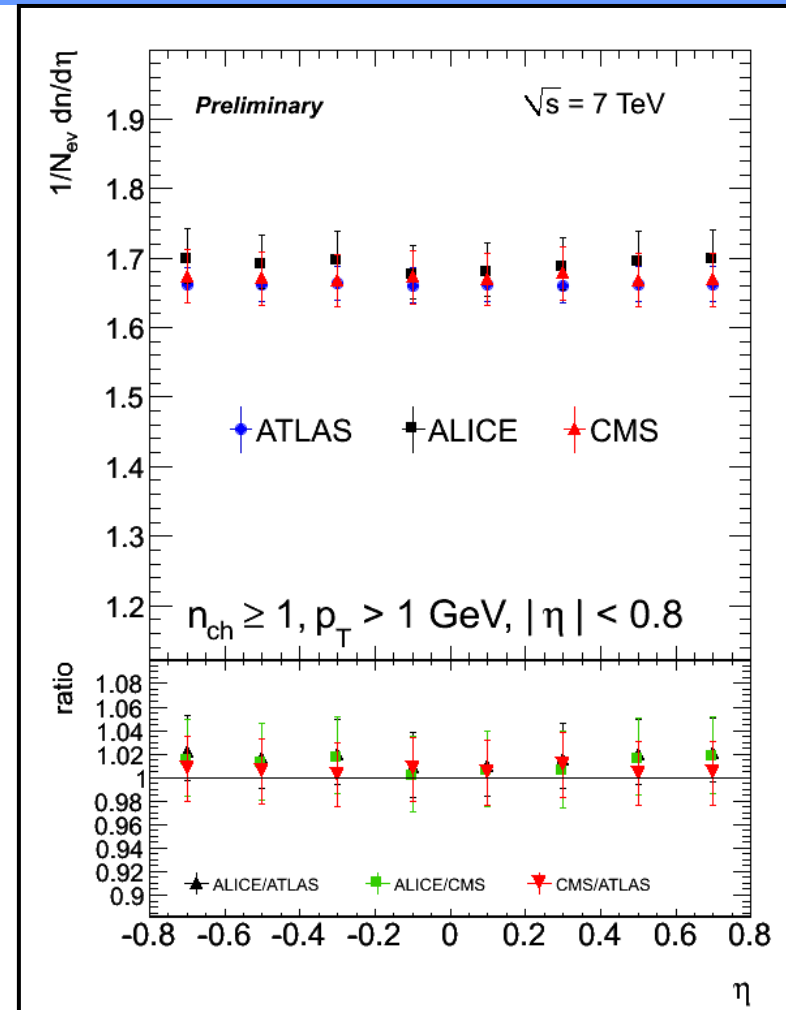
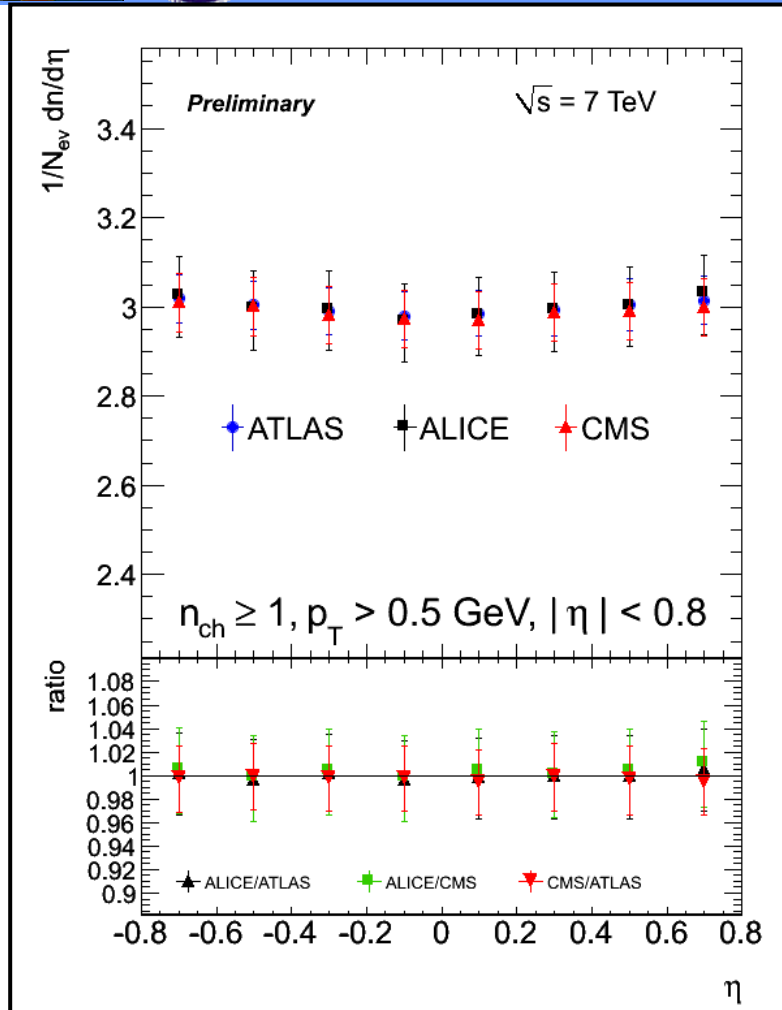
Observable	900 GeV	7 TeV
MB1: $dN_{\text{chg}}/d\eta$ $N_{\text{chg}} \geq 1$ $ \eta  < 0.8$ $p_T > 0.5 \text{ GeV/c} \& 1.0 \text{ GeV/c}$	Done QC	Done QC 10-024
MB2: $dN_{\text{chg}}/dp_T$		Stalled
MB3: $\langle p_T \rangle$ $ \eta  < 0.8$ $p_T > 0.5 \text{ GeV/c}$		Stalled
MB4: $\langle p_T \rangle$ vertex $ \eta  < 0.8$ $p_T > 0.5 \text{ GeV/c}$		Stalled
UE1: $N_{\text{chg}}$ transverse defined by the leading particle, $PT_{\text{max}}$ $ \eta  < 0.8$ $p_T > 0.5 \text{ GeV/c} \& 1.0 \text{ GeV/c}$	Done FSC	Done FSC 12-020

Note that all the “common plots” require at least one charged particle with  $p_T > 0.5 \text{ GeV/c}$  and  $|\eta| < 0.8!$   
**This done so that the plots are less sensitive to SD and DD.**

Direct charged particles (including leptons) corrected to the particle level with no corrections for SD or DD.



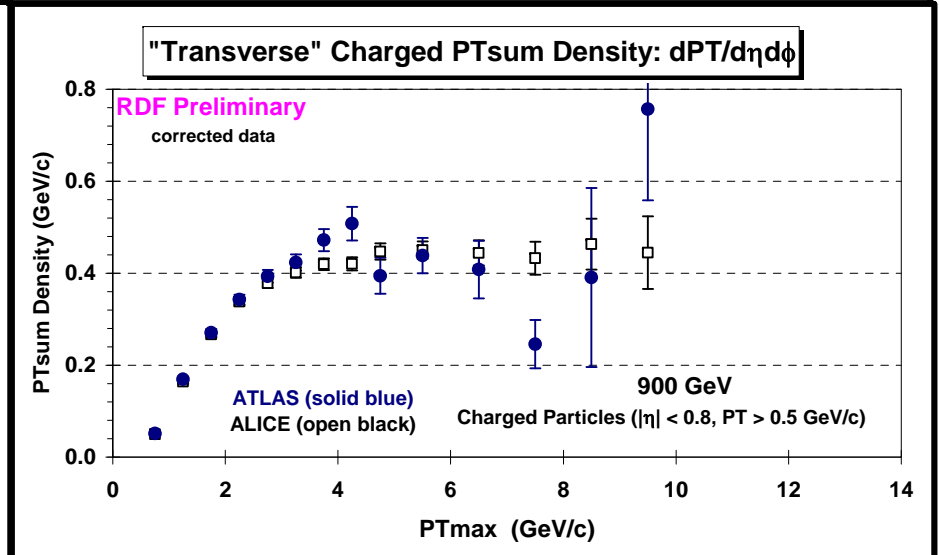
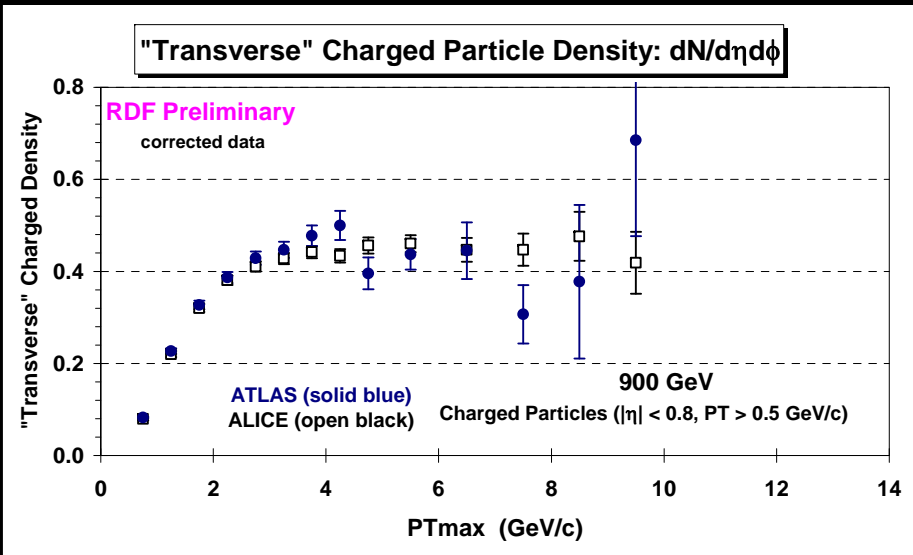
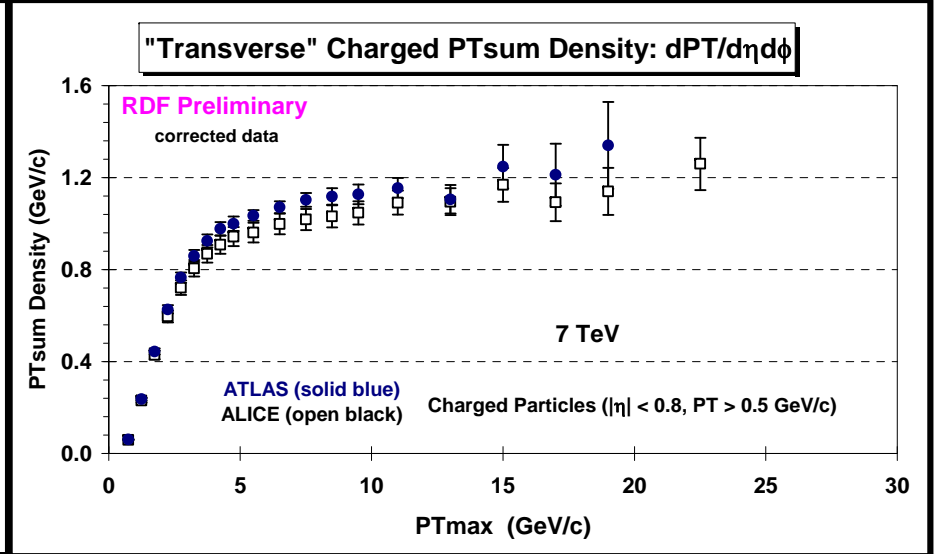
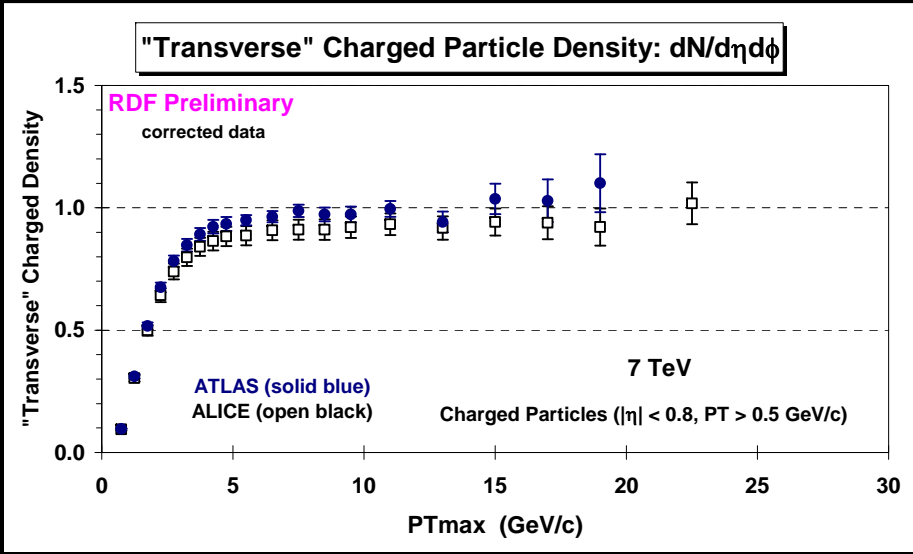
# MB Common Plots 7 TeV

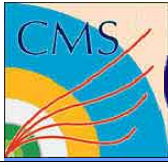


**Direct charged particles (including leptons) corrected to the particle level with no corrections for SD or DD.**

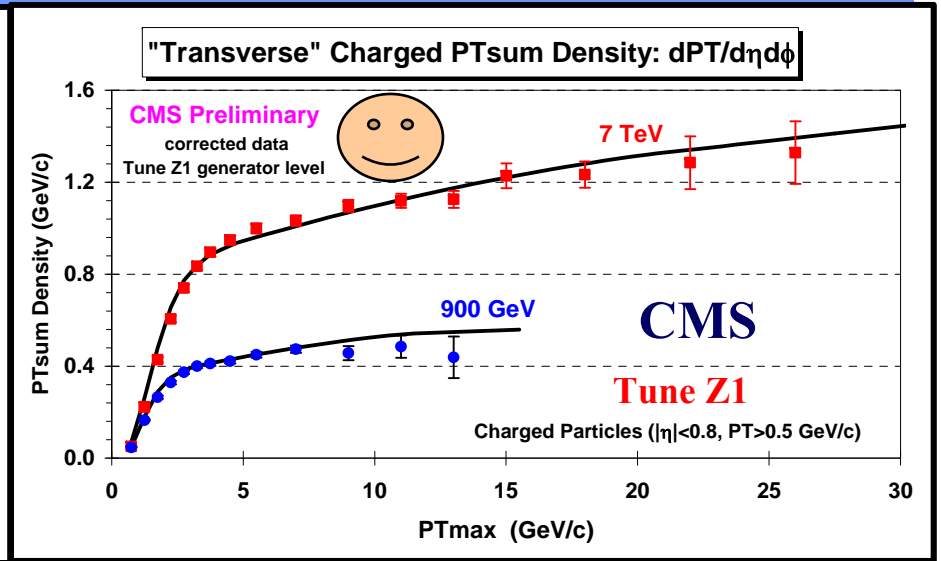
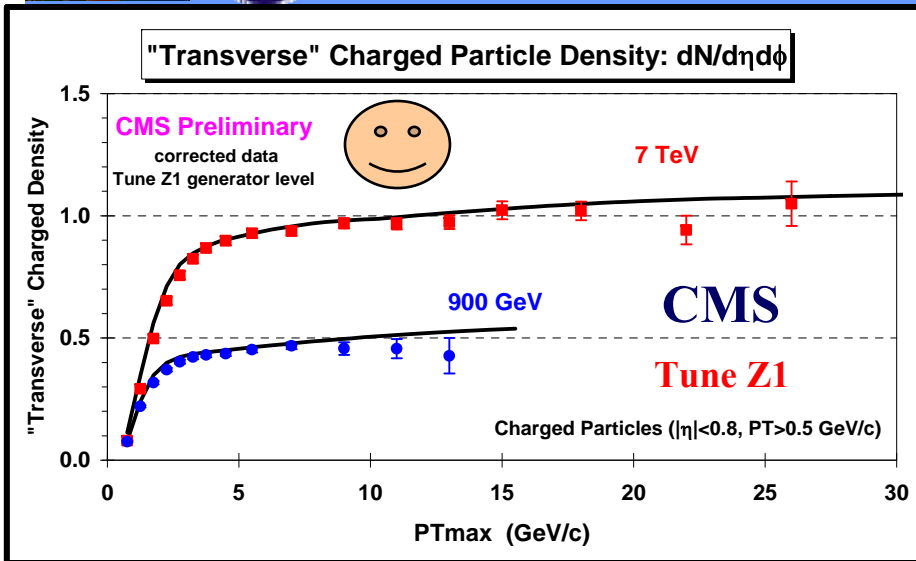


# UE Common Plots



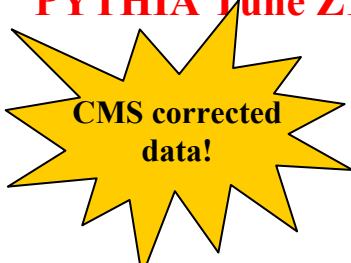


# New CMS UE Data

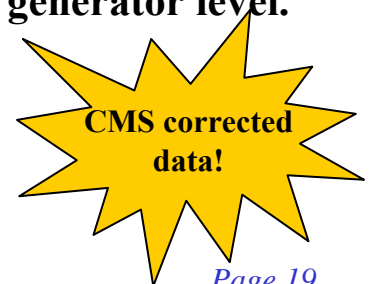


→ CMS preliminary data at 900 GeV and 7 TeV on the “transverse” charged particle density,  $dN/d\eta d\phi$ , as defined by the leading charged particle (PTmax) for charged particles with  $p_T > 0.5 \text{ GeV}/c$  and  $|\eta| < 0.8$ . The data are corrected and compared with **PYTHIA Tune Z1** at the generator level.

→ CMS preliminary data at 900 GeV and 7 TeV on the “transverse” charged PTsum density,  $dPT/d\eta d\phi$ , as defined by the leading charged particle (PTmax) for charged particles with  $p_T > 0.5 \text{ GeV}/c$  and  $|\eta| < 0.8$ . The data are corrected and compared with **PYTHIA Tune Z1** at the generator level.



Very nice agreement!

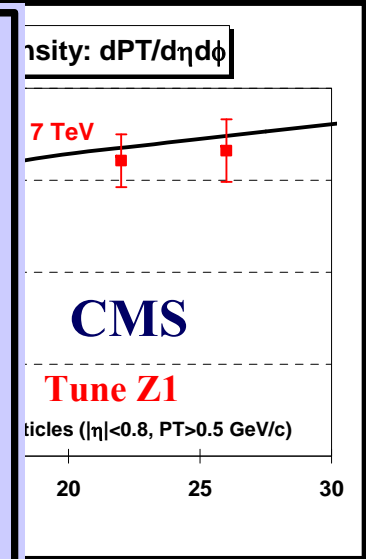
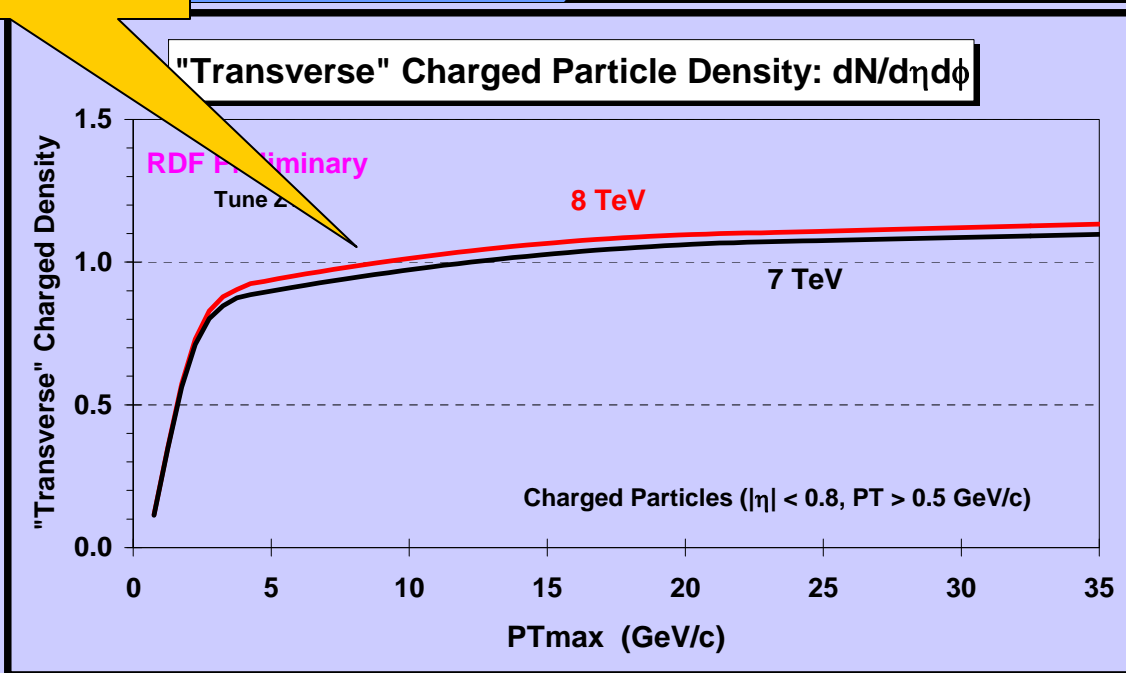
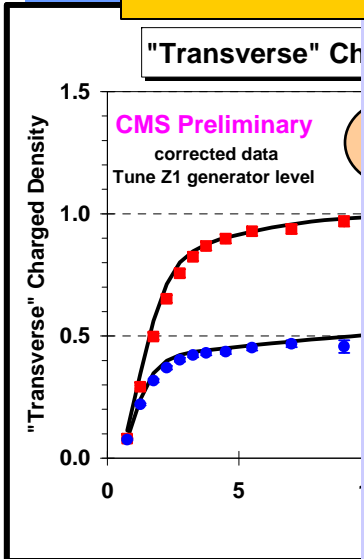




# New CMS UE Data



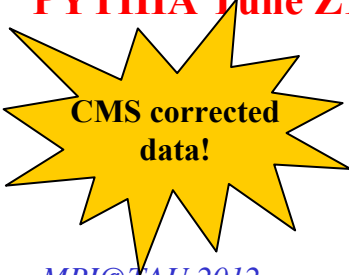
Less than 4% change!



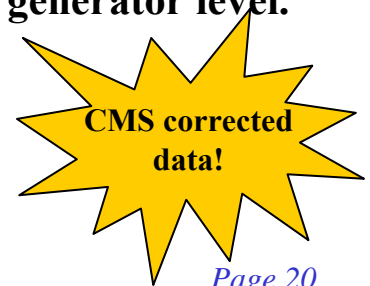
→ CMS preliminary data at 8 TeV on the "transverse" charged particle density,  $dN/d\eta d\phi$ , as defined by the leading charged particle (PTmax) for charged particles with  $p_T > 0.5 \text{ GeV/c}$  and  $|\eta| < 0.8$ . The data are corrected and compared with **PYTHIA Tune Z1** at the generator level.

→ CMS preliminary data at 8 TeV on the "transverse" charged particle density,  $dN/d\eta d\phi$ , as defined by the leading charged particle (PTmax) for charged particles with  $p_T > 0.5 \text{ GeV/c}$  and  $|\eta| < 0.8$ . The data are corrected and compared with **PYTHIA Tune Z1** at the generator level.

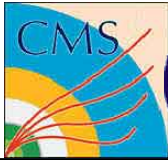
→ CMS preliminary data at 8 TeV on the "transverse" charged particle density,  $dN/d\eta d\phi$ , as defined by the leading charged particle (PTmax) for charged particles with  $p_T > 0.5 \text{ GeV/c}$  and  $|\eta| < 0.8$ . The data are corrected and compared with **PYTHIA Tune Z1** at the generator level.



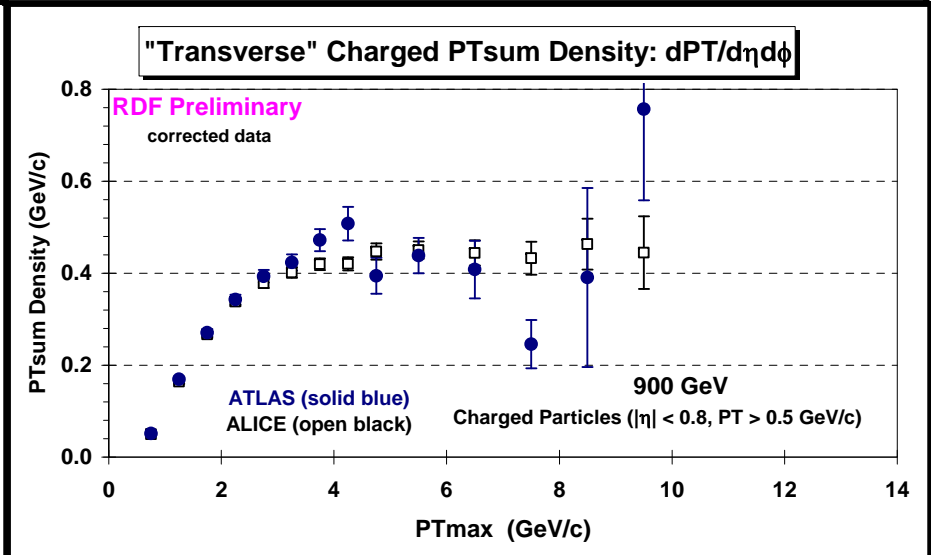
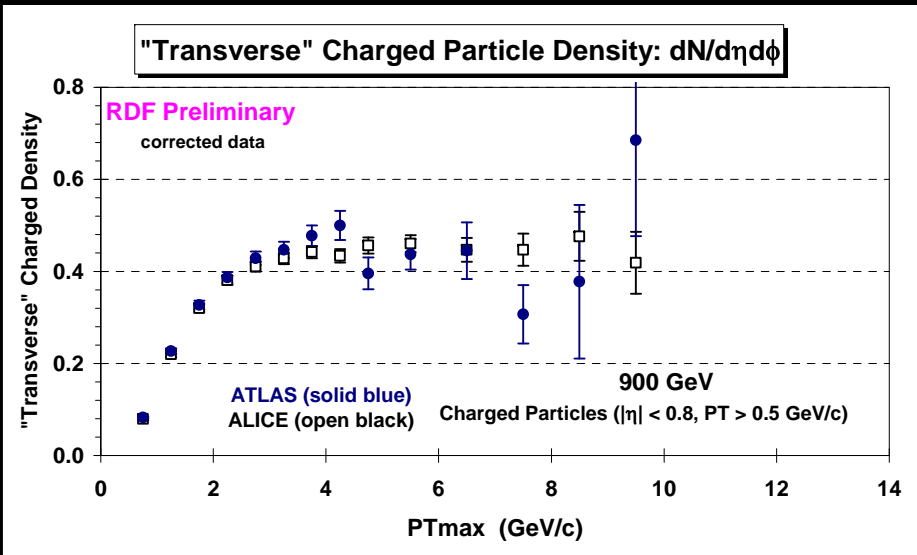
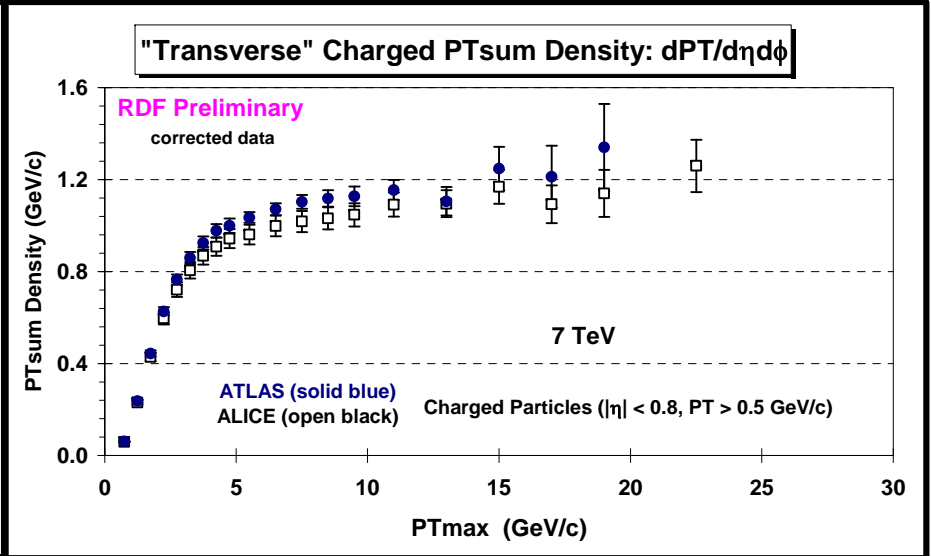
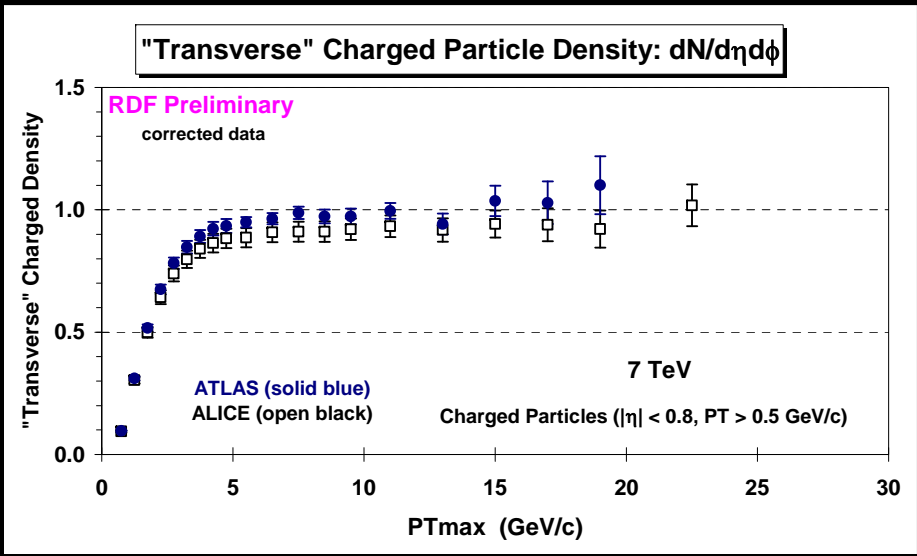
Very nice agreement!

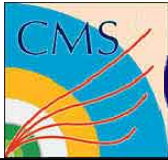




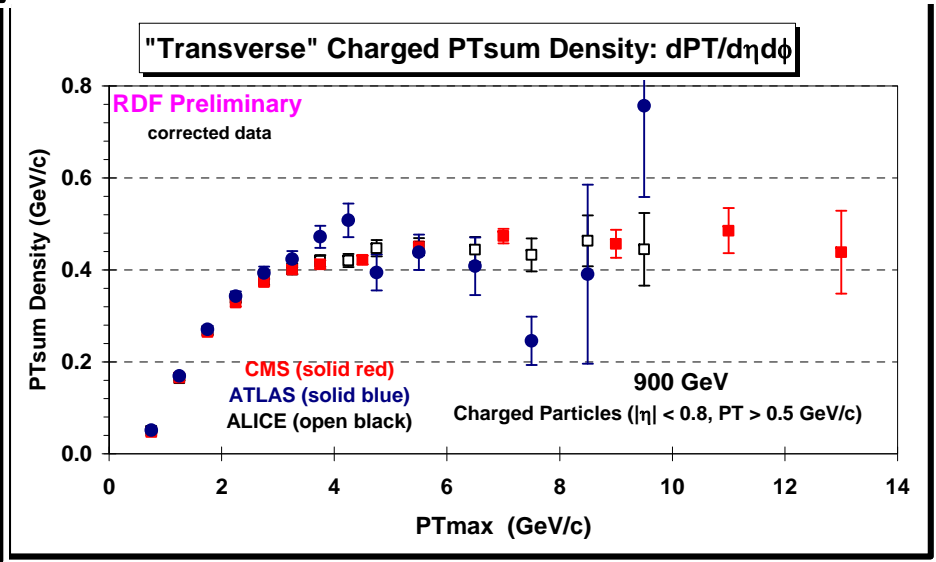
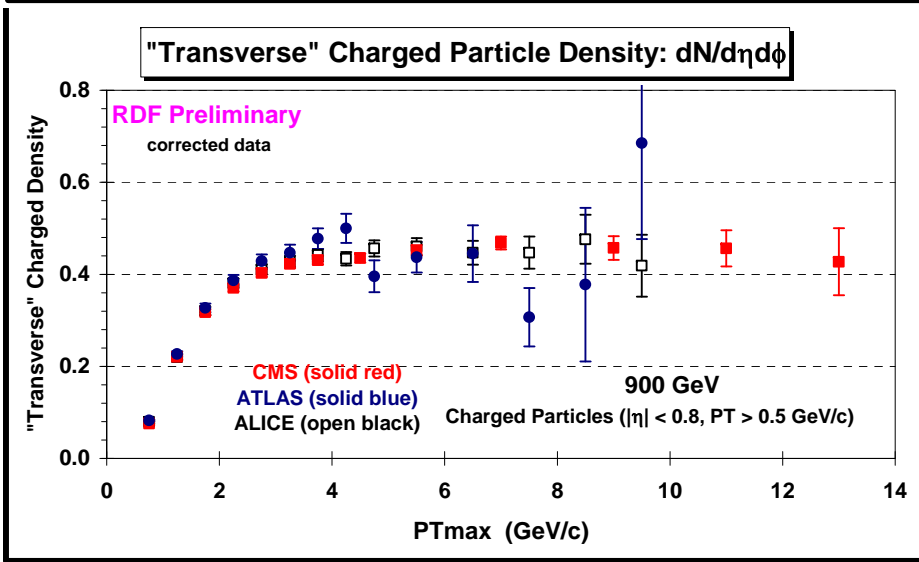
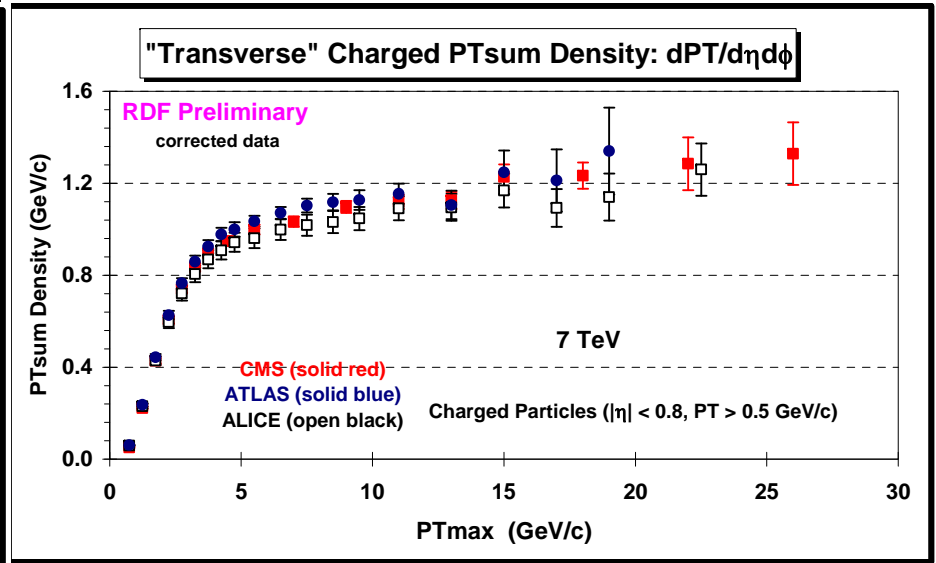
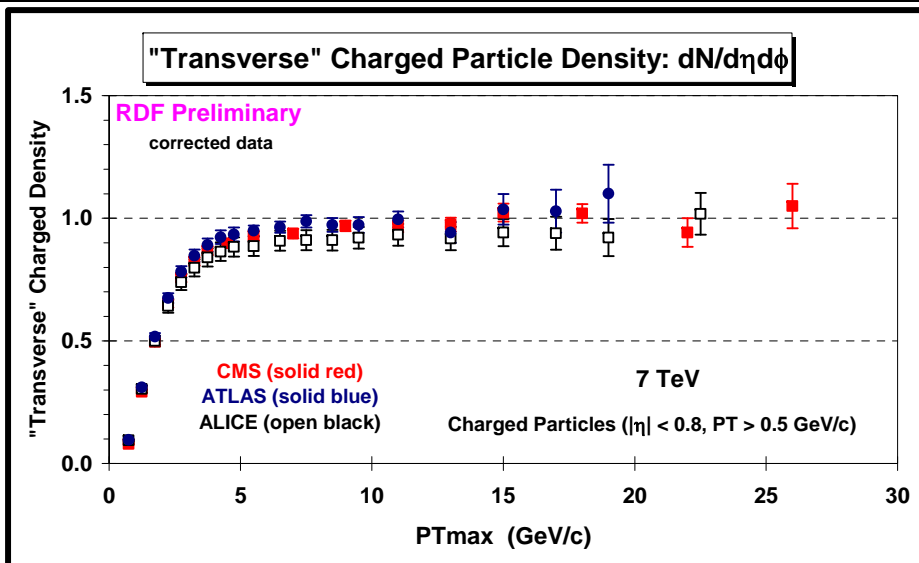


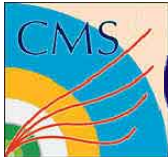
# UE Common Plots



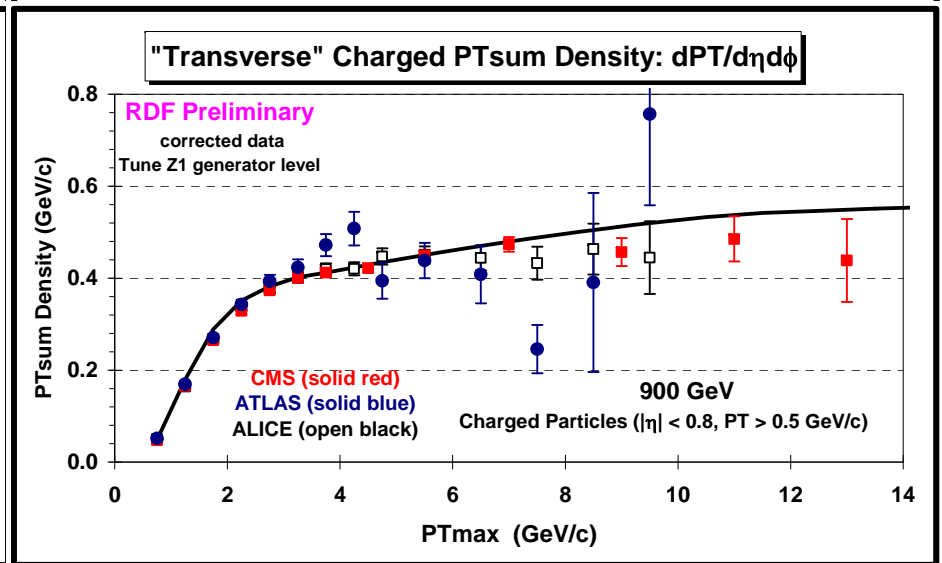
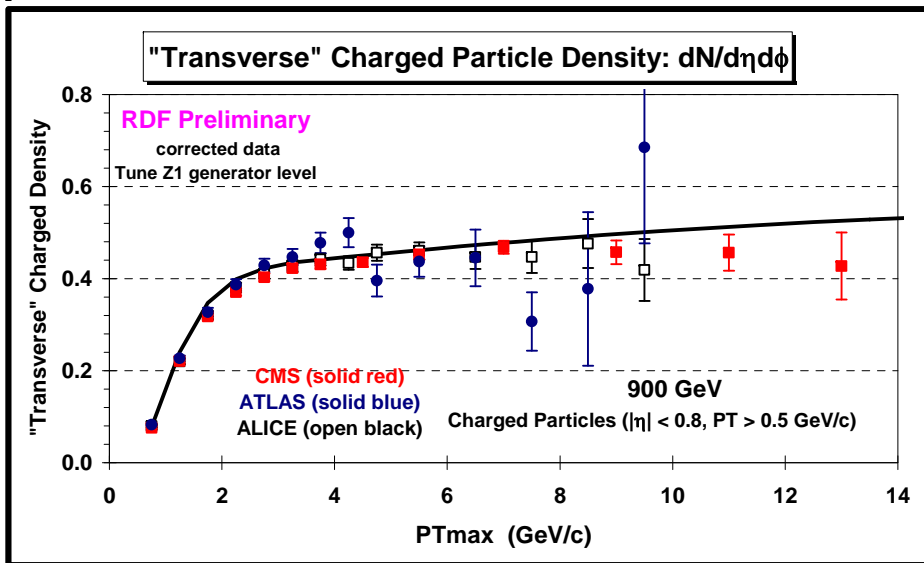
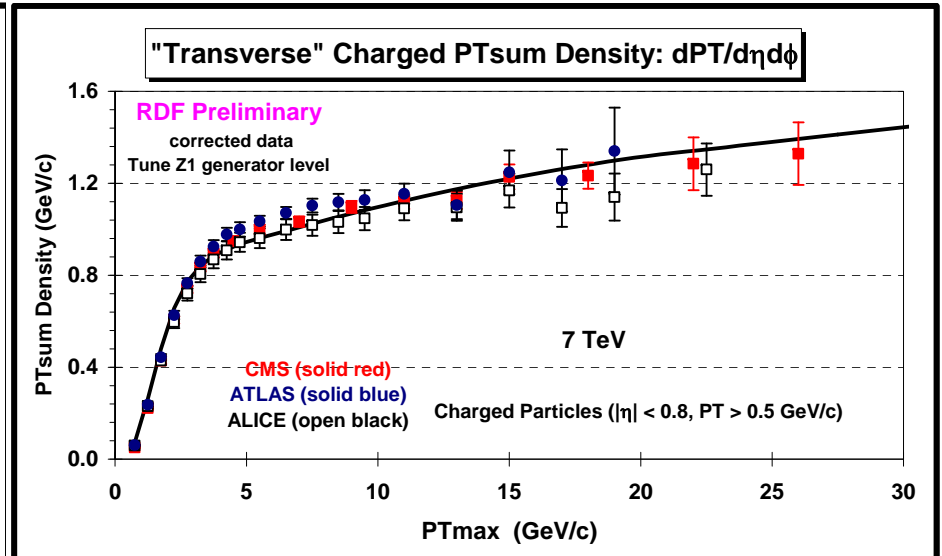
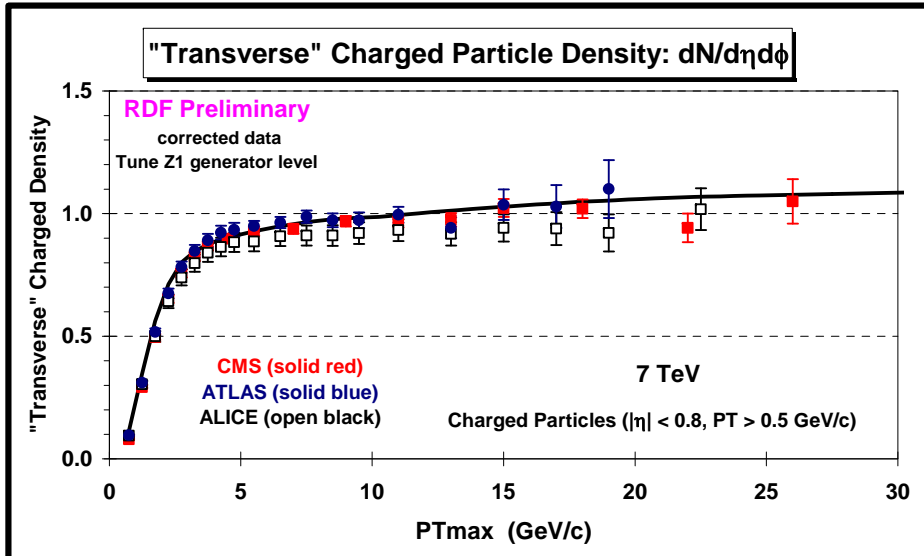


# UE Common Plots



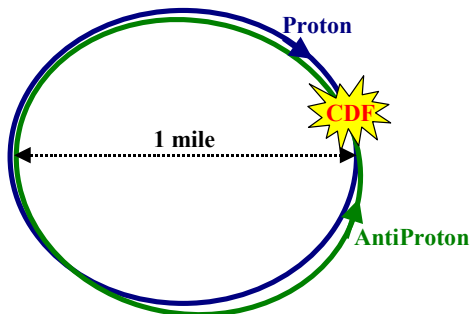
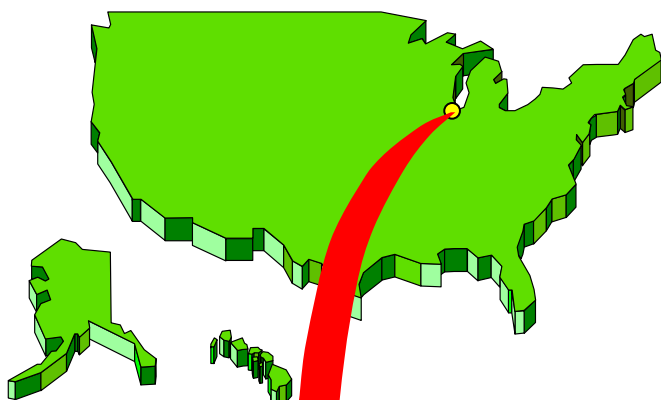


# UE Common Plots





# Tevatron Energy Scan



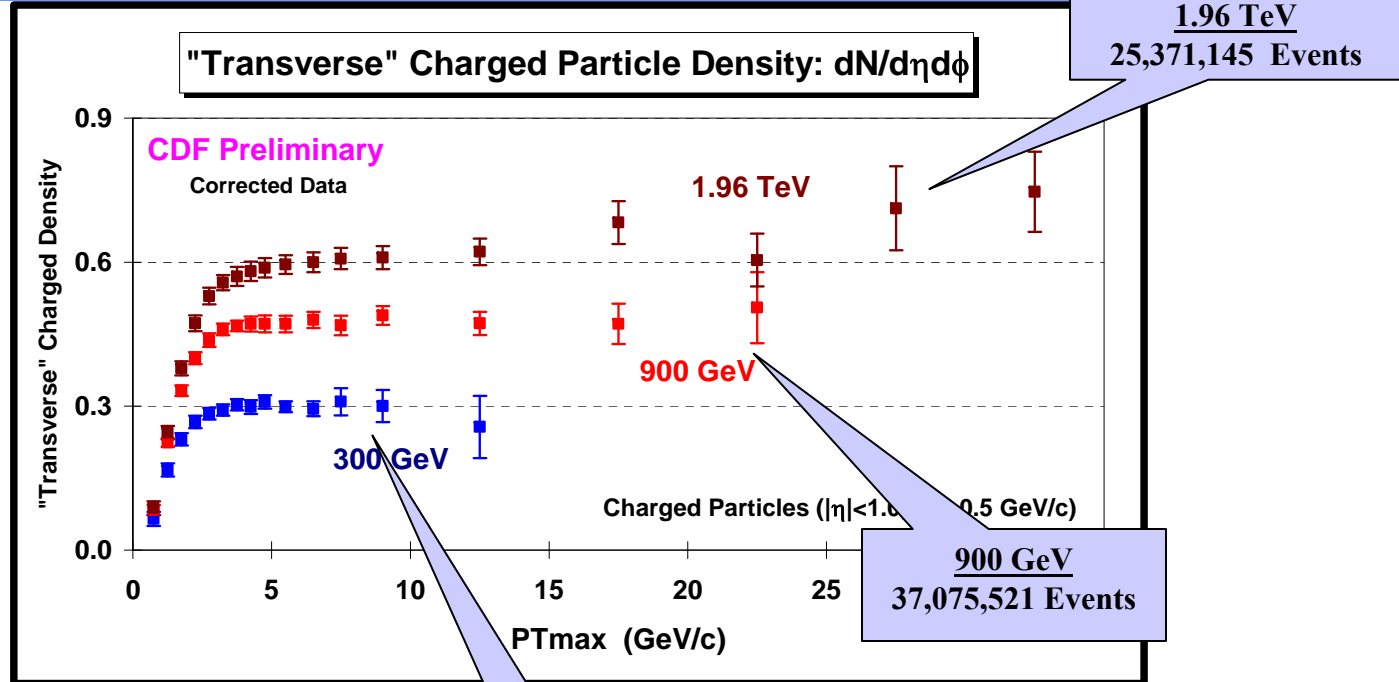
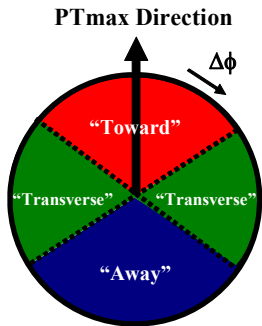
➔ Just before the shutdown of the Tevatron CDF has collected more than 10M “min-bias” events at several center-of-mass energies!

**300 GeV 12.1M MB Events**

**900 GeV 54.3M MB Events**



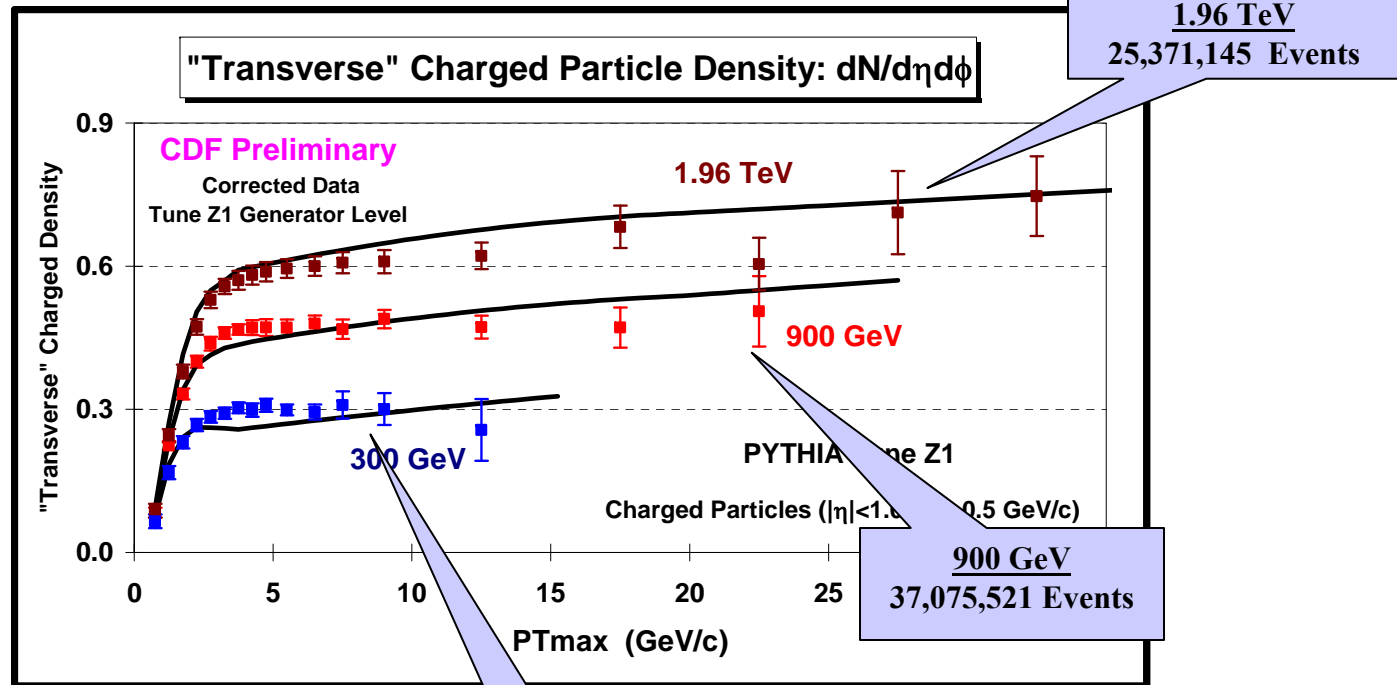
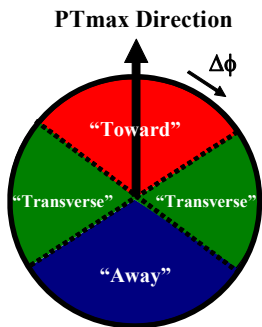
# New CDF UE Data



➔ **New Corrected CDF data at 300 GeV, 900 GeV, and 1.96 TeV on the “transverse” charged particle density,  $dN/d\eta d\phi$ , as defined by the leading charged particle (PTmax) for charged particles with  $p_T > 0.5$  GeV/c and  $|\eta| < 1.0$ .**



# New CDF UE Data

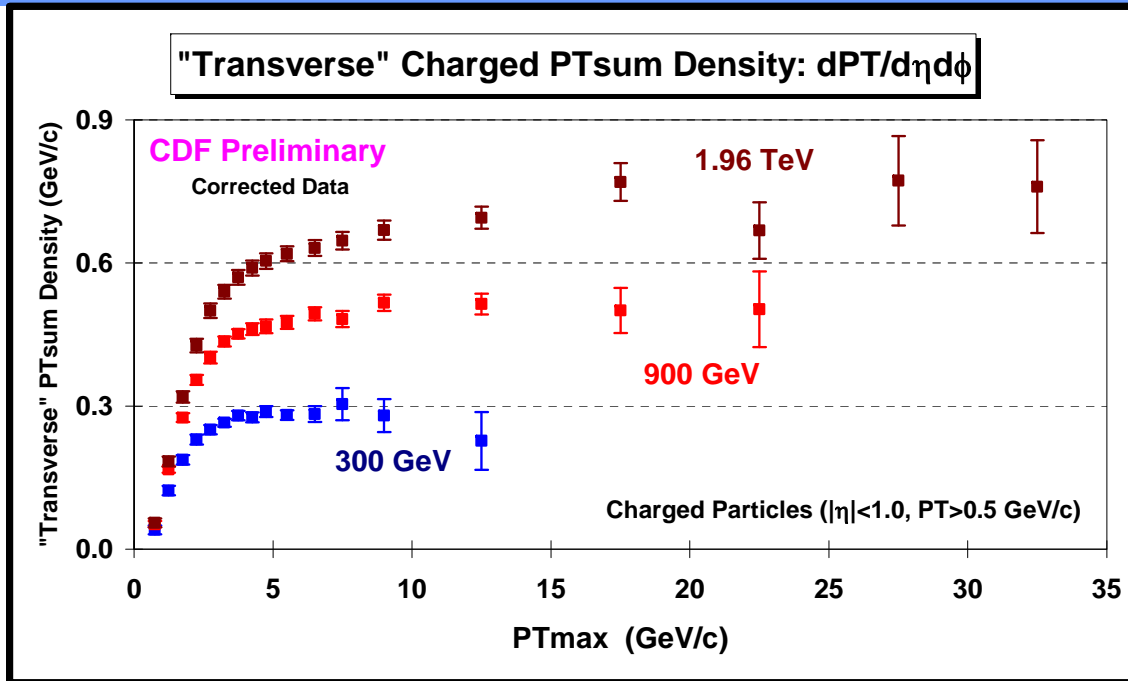
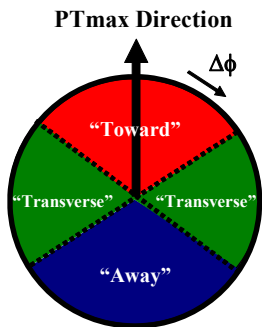


➔ **New Corrected CDF data at 300 GeV, 900 GeV, and 1.96 TeV on the "transverse" charged particle density,  $dN/d\eta d\phi$ , as defined by the leading charged particle ( $PT_{max}$ ) for charged particles with  $p_T > 0.5$  GeV/c and  $|\eta| < 1.0$ .**





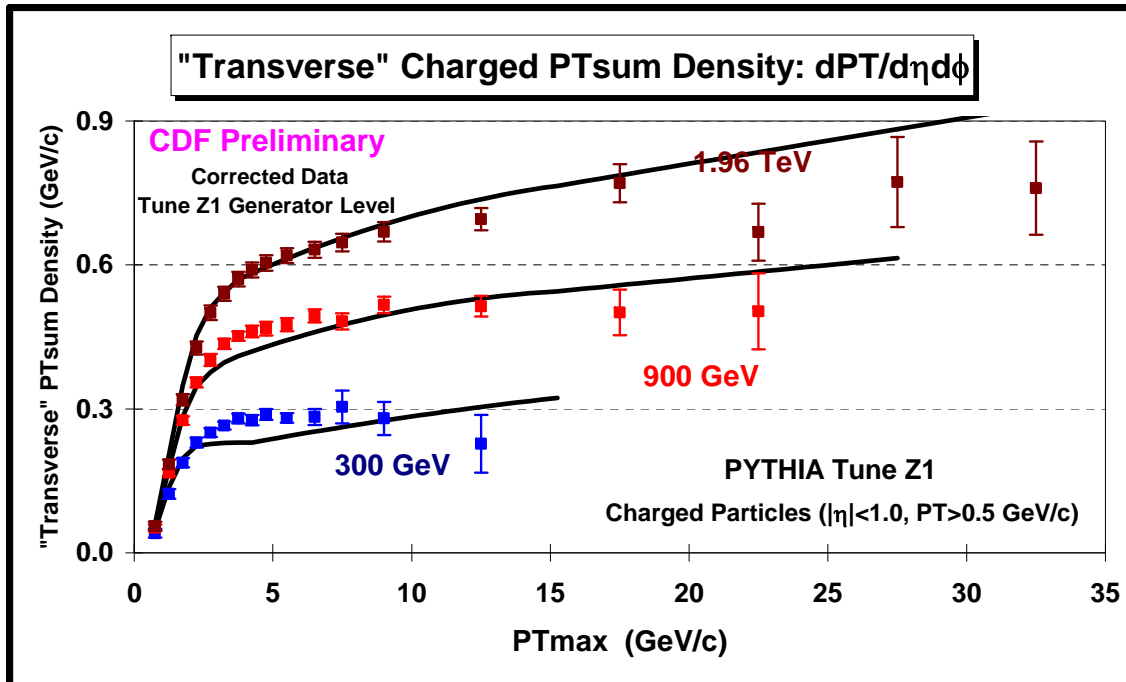
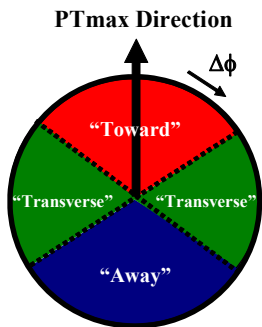
# New CDF UE Data



- ➔ **New Corrected CDF data at 300 GeV, 900 GeV, and 1.96 TeV on the “transverse” charged PTsum density,  $dPT/d\eta d\phi$ , as defined by the leading charged particle ( $PT_{max}$ ) for charged particles with  $p_T > 0.5$  GeV/c and  $|\eta| < 1.0$ .**



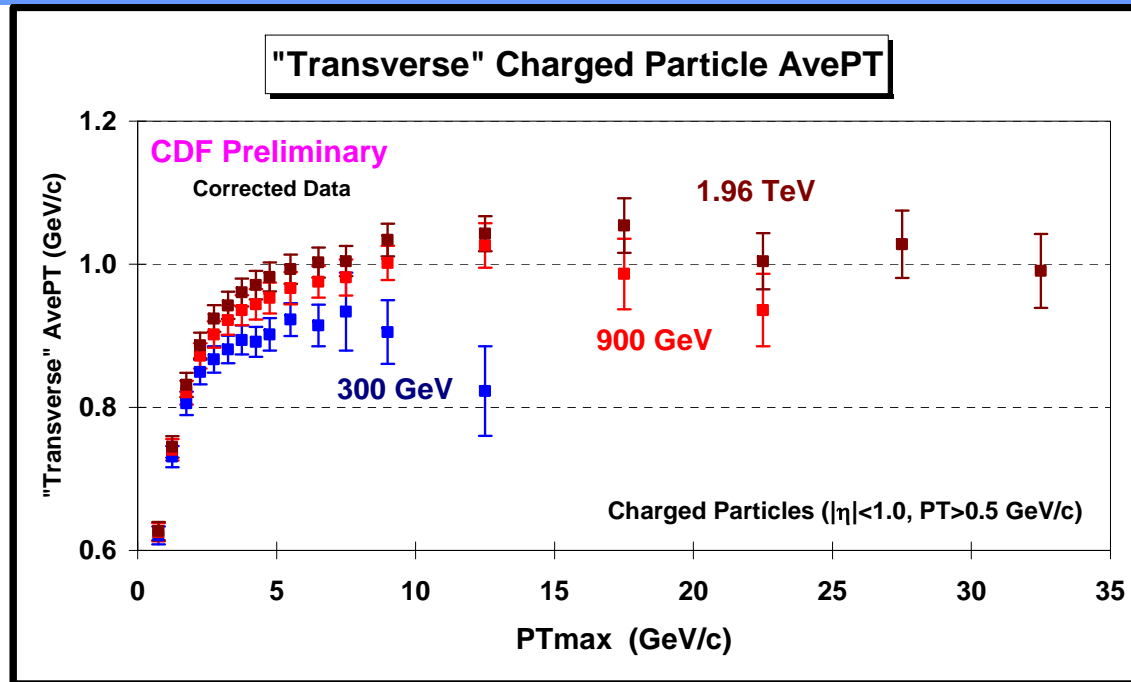
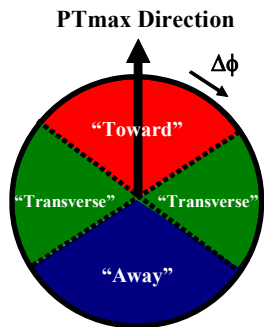
# New CDF UE Data



- ➔ **New Corrected CDF data at 300 GeV, 900 GeV, and 1.96 TeV** on the “transverse” charged PTsum density,  $dPT/d\eta d\phi$ , as defined by the leading charged particle (PTmax) for charged particles with  $p_T > 0.5 \text{ GeV/c}$  and  $|\eta| < 1.0$ .



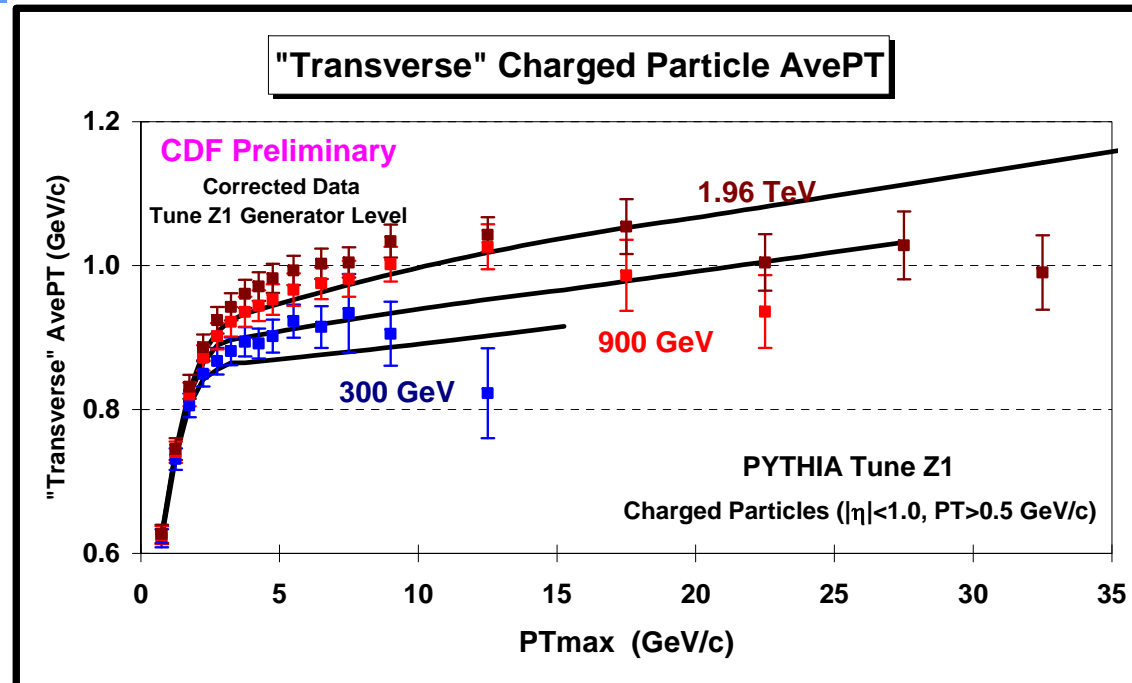
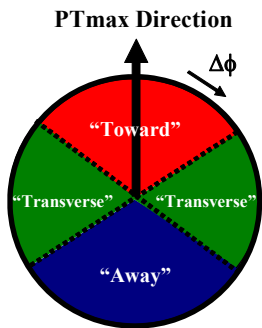
# New CDF UE Data



- ➔ **New Corrected CDF data at 300 GeV, 900 GeV, and 1.96 TeV on the “transverse” charged particle average  $p_T$ , as defined by the leading charged particle (PTmax) for charged particles with  $p_T > 0.5$  GeV/c and  $|\eta| < 1.0$ .**



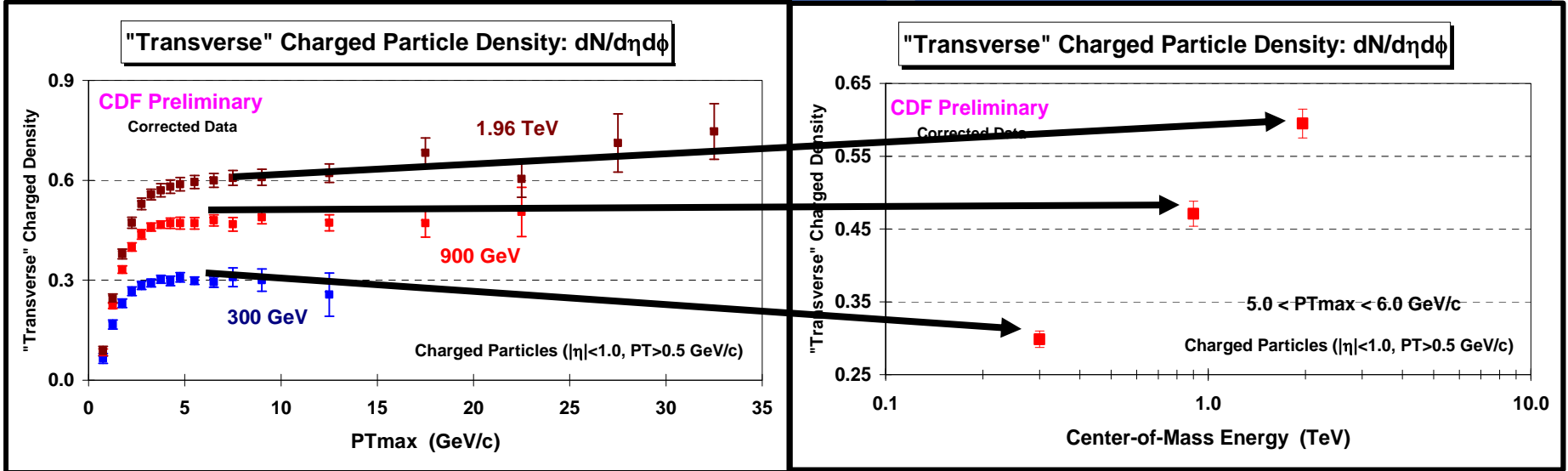
# New CDF UE Data



- ➔ **New Corrected CDF data at 300 GeV, 900 GeV, and 1.96 TeV** on the “transverse” charged particle average  $p_T$ , as defined by the leading charged particle (PTmax) for charged particles with  $p_T > 0.5$  GeV/c and  $|\eta| < 1.0$ .



# Energy Dependence

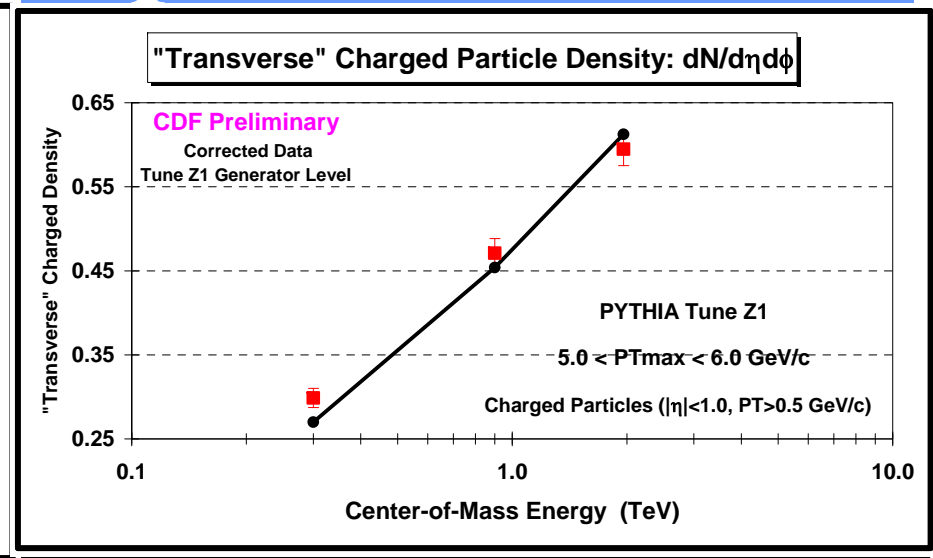
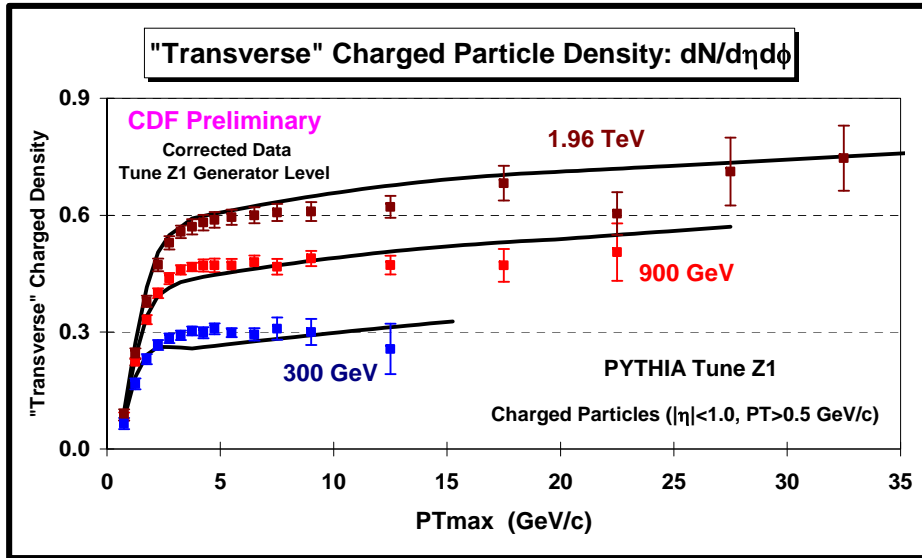


➔ **New Corrected CDF data at 300 GeV, 900 GeV, and 1.96 TeV on the “transverse” charged particle density,  $dN/d\eta d\phi$ , as defined by the leading charged particle ( $PT_{max}$ ) for charged particles with  $p_T > 0.5$  GeV/c and  $|\eta| < 1.0$ .**

➔ **New Corrected CDF data at 300 GeV, 900 GeV, and 1.96 TeV on the “transverse” charged particle density,  $dN/d\eta d\phi$ , as defined by the leading charged particle ( $PT_{max}$ ) for charged particles with  $p_T > 0.5$  GeV/c and  $|\eta| < 1.0$  for  $5.0 < PT_{max} < 6.0$  GeV/c.**



# Energy Dependence



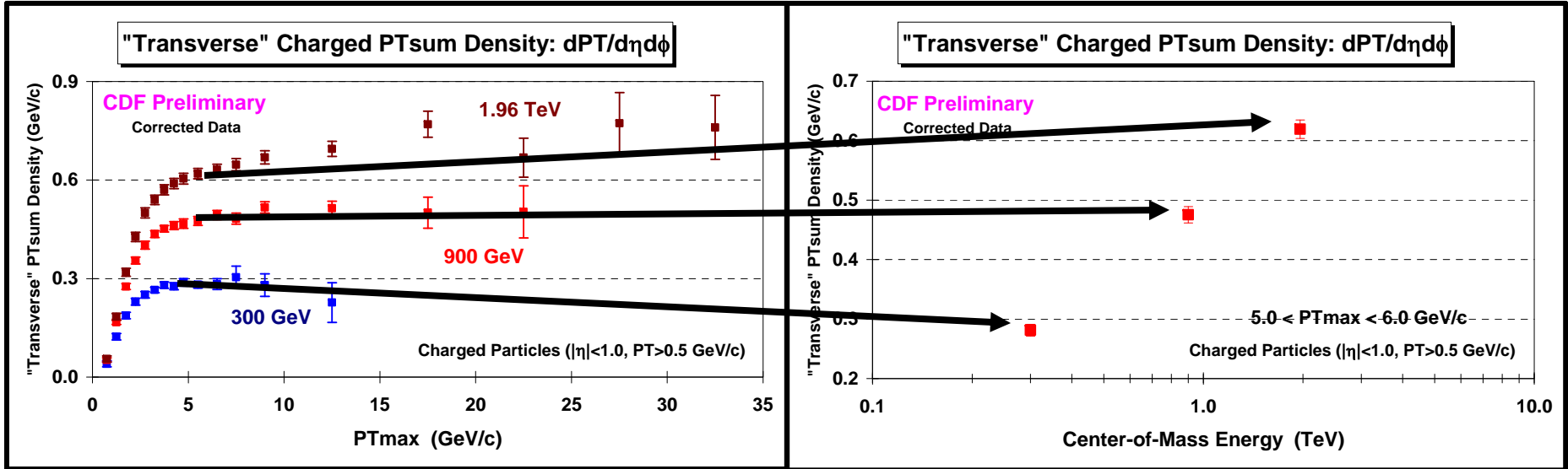
➔ **New Corrected CDF data at 300 GeV, 900 GeV, and 1.96 TeV on the “transverse” charged particle density,  $dN/d\eta d\phi$ , as defined by the leading charged particle ( $PT_{max}$ ) for charged particles with  $p_T > 0.5$  GeV/c and  $|\eta| < 1.0$ .**

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# Energy Dependence

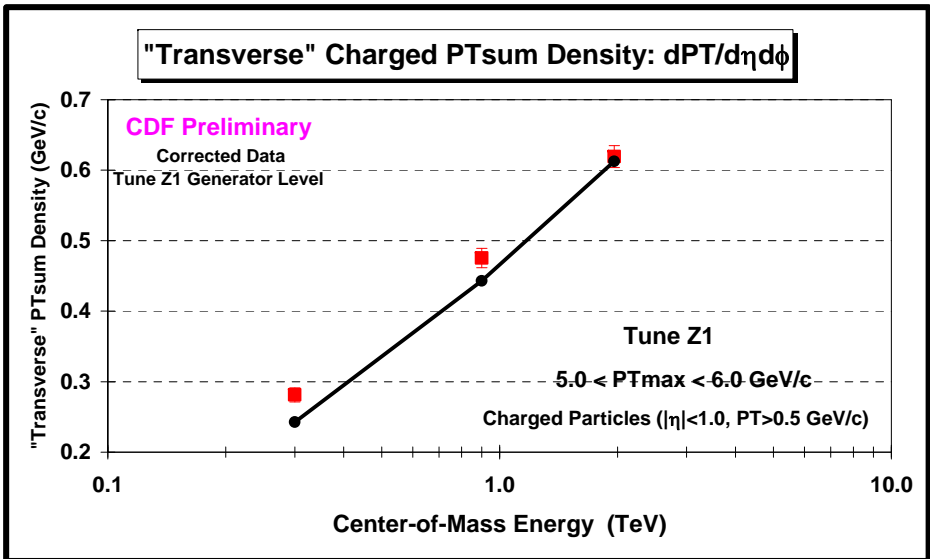
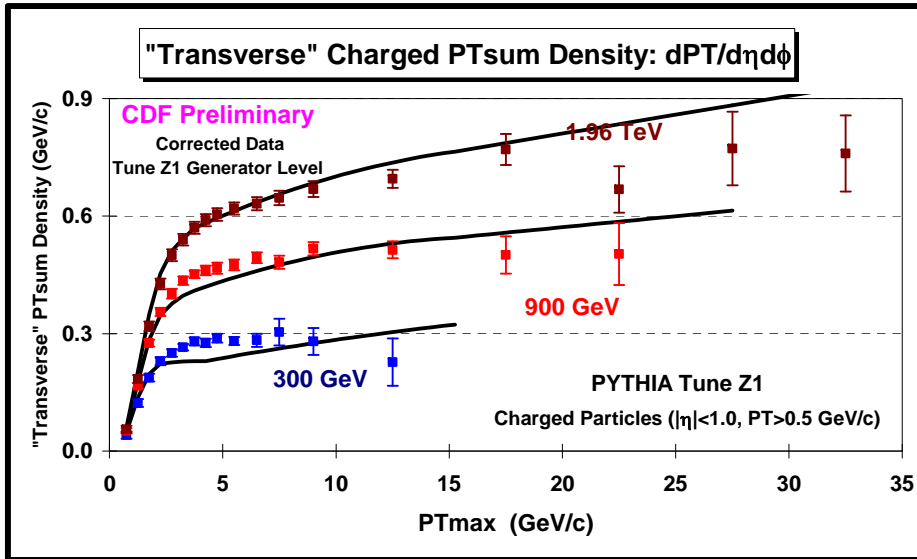


➔ **New Corrected CDF data at 300 GeV, 900 GeV, and 1.96 TeV on the “transverse” charged PTsum density,  $dPT/d\eta d\phi$ , as defined by the leading charged particle (PTmax) for charged particles with  $p_T > 0.5 \text{ GeV/c}$  and  $|\eta| < 1.0$ .**

➔ **New Corrected CDF data at 300 GeV, 900 GeV, and 1.96 TeV on the “transverse” charged PTsum density,  $dPT/d\eta d\phi$ , as defined by the leading charged particle (PTmax) for charged particles with  $p_T > 0.5 \text{ GeV/c}$  and  $|\eta| < 1.0$  for  $5.0 < PTmax < 6.0 \text{ GeV/c}$ .**



# Energy Dependence

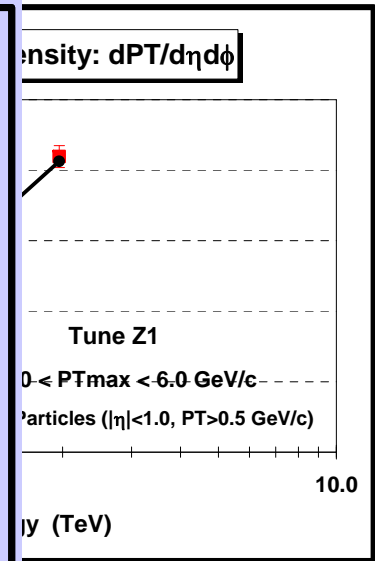
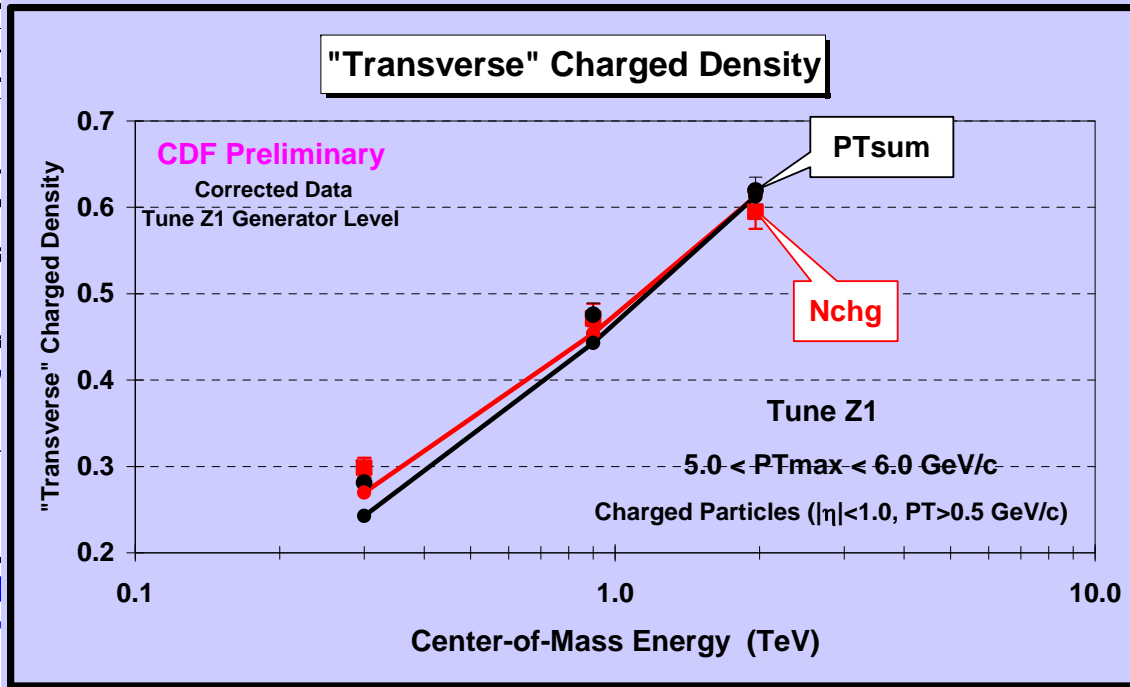
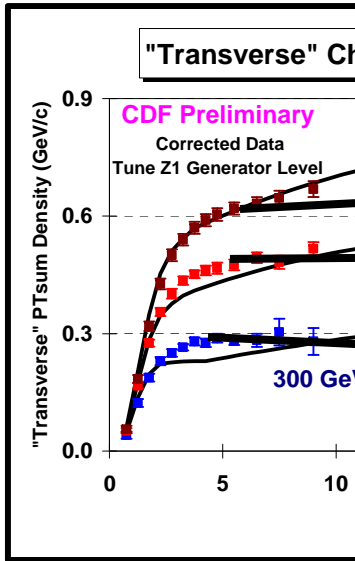


➔ **New Corrected CDF data at 300 GeV, 900 GeV, and 1.96 TeV on the “transverse” charged PTsum density,  $dPT/d\eta d\phi$ , as defined by the leading charged particle (PTmax) for charged particles with  $p_T > 0.5$  GeV/c and  $|\eta| < 1.0$ .**

➔ **New Corrected CDF data at 300 GeV, 900 GeV, and 1.96 TeV on the “transverse” charged PTsum density,  $dPT/d\eta d\phi$ , as defined by the leading charged particle (PTmax) for charged particles with  $p_T > 0.5$  GeV/c and  $|\eta| < 1.0$  for  $5.0 < PTmax < 6.0$  GeV/c.**



# Energy Dependence



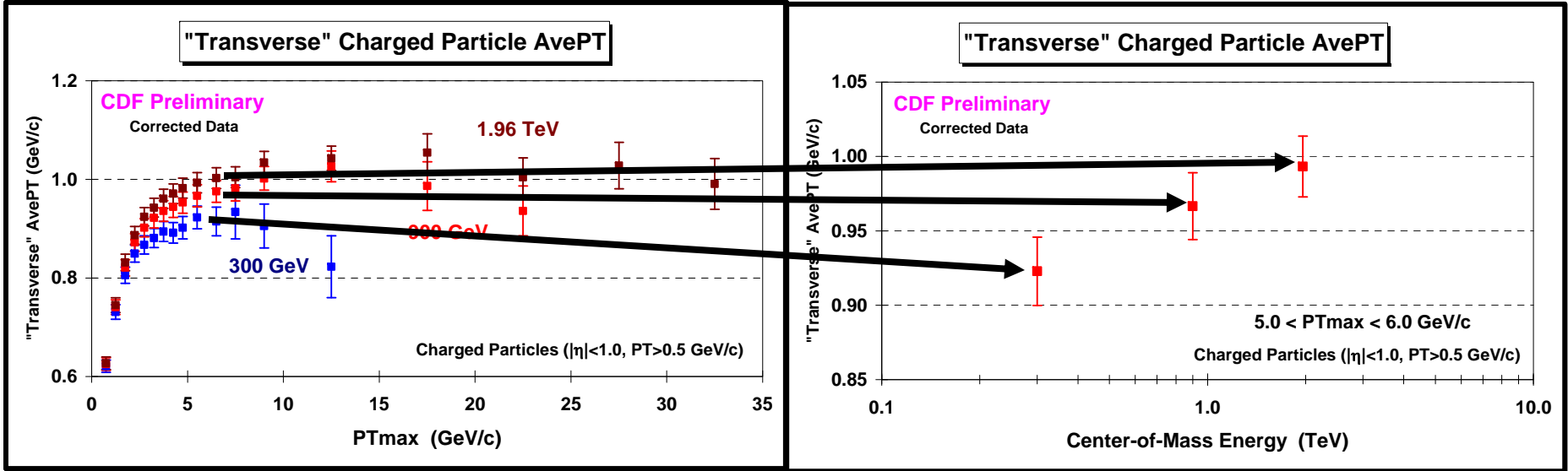
→ **New Corrected (300 GeV, and 1.96 TeV) "Transverse" charged PTsum** defined by the leading charged particle (PTmax) for charged particles with  $p_T > 0.5$  GeV/c and  $|\eta| < 1.0$ .

defined by the leading charged particle (PTmax) for charged particles with  $p_T > 0.5$  GeV/c and  $|\eta| < 1.0$  for  $5.0 < PT_{max} < 6.0$  GeV/c.

**300 GeV, 900 GeV, and 1.96 TeV "Transverse" charged density:  $dPT/d\eta d\phi$**



# Energy Dependence

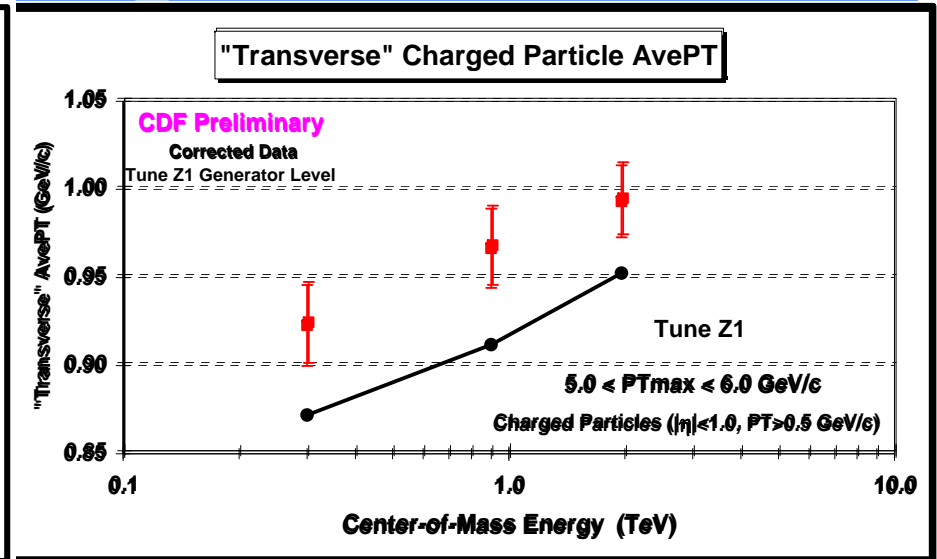
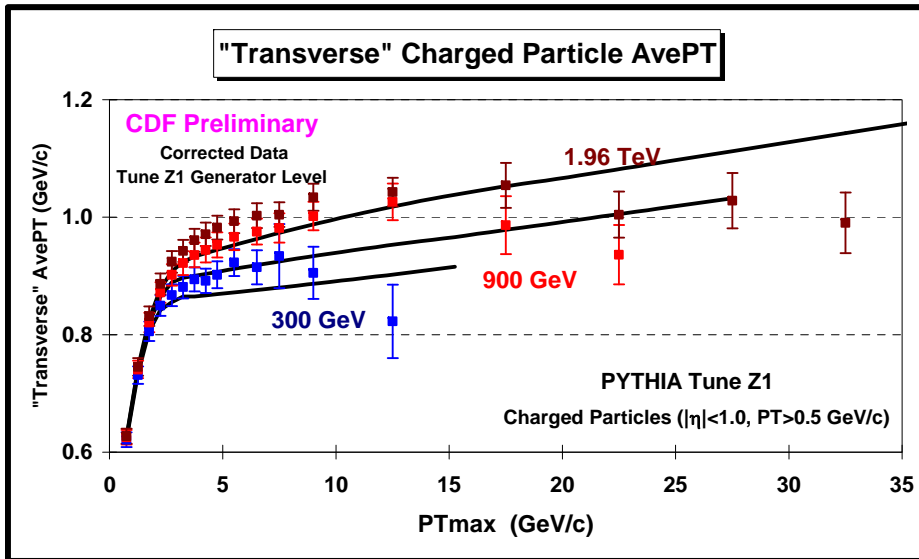


➔ **New Corrected CDF data at 300 GeV, 900 GeV, and 1.96 TeV on the “transverse” charged particle average  $p_T$  as defined by the leading charged particle (PTmax) for charged particles with  $p_T > 0.5 \text{ GeV}/c$  and  $|\eta| < 1.0$ .**

➔ **New Corrected CDF data at 300 GeV, 900 GeV, and 1.96 TeV on the “transverse” charged particle average  $p_T$  as defined by the leading charged particle (PTmax) for charged particles with  $p_T > 0.5 \text{ GeV}/c$  and  $|\eta| < 1.0$  for  $5.0 < PTmax < 6.0 \text{ GeV}/c$ .**



# Energy Dependence

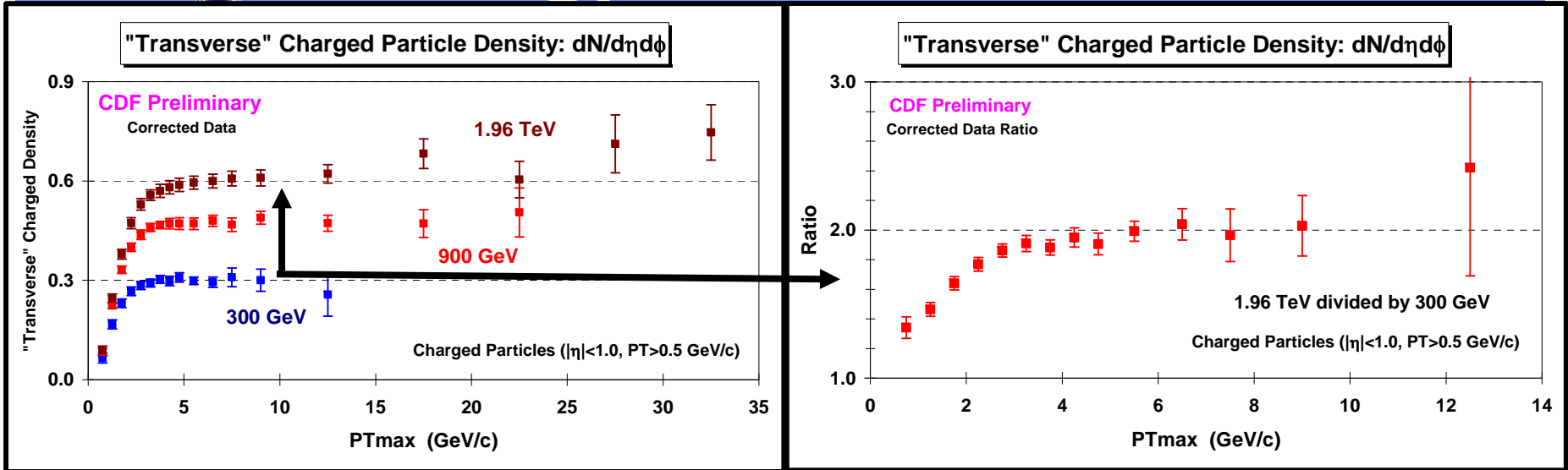


➔ **New Corrected CDF data at 300 GeV, 900 GeV, and 1.96 TeV on the “transverse” charged particle average  $p_T$  as defined by the leading charged particle ( $PT_{max}$ ) for charged particles with  $p_T > 0.5$  GeV/c and  $|\eta| < 1.0$ .**

➔ **New Corrected CDF data at 300 GeV, 900 GeV, and 1.96 TeV on the “transverse” charged particle average  $p_T$  as defined by the leading charged particle ( $PT_{max}$ ) for charged particles with  $p_T > 0.5$  GeV/c and  $|\eta| < 1.0$  for  $5.0 < PT_{max} < 6.0$  GeV/c.**



# Energy Ratio: 1960/300

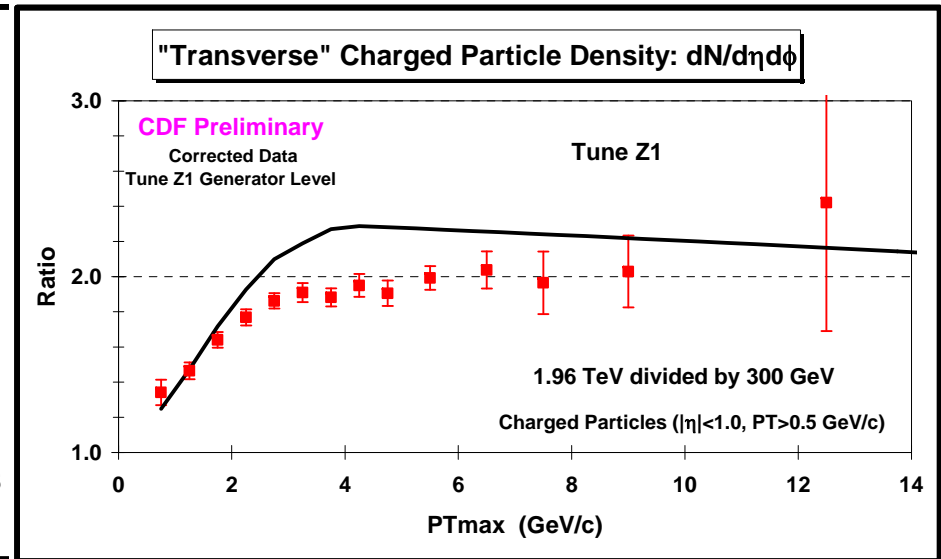
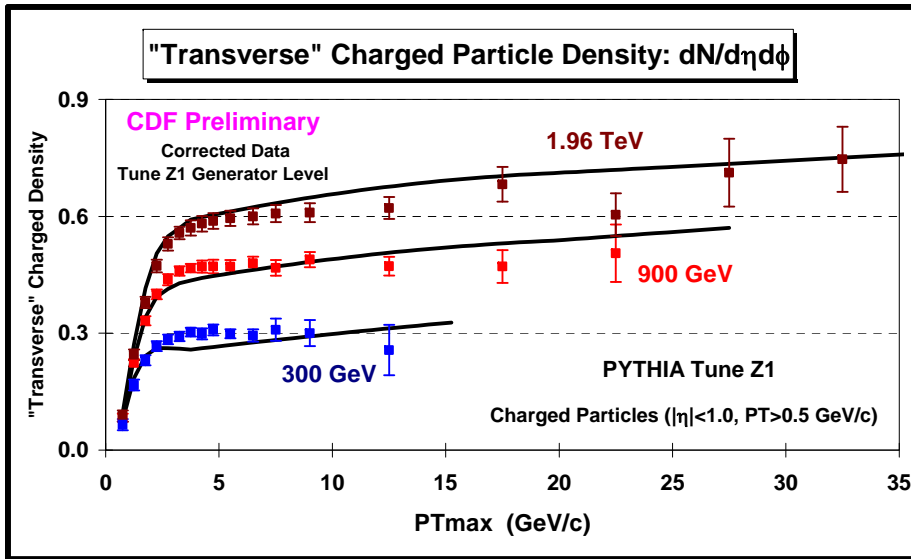


➔ **New Corrected CDF data at 300 GeV, 900 GeV, and 1.96 TeV** on the “transverse” charged particle density,  $dN/d\eta d\phi$ , as defined by the leading charged particle ( $PT_{max}$ ) for charged particles with  $p_T > 0.5$  GeV/c and  $|\eta| < 1.0$ .

➔ **Ratio of the CDF data at 300 GeV and 1.96 TeV** on the “transverse” charged particle density,  $dN/d\eta d\phi$ , as defined by the leading charged particle ( $PT_{max}$ ) for charged particles with  $p_T > 0.5$  GeV/c and  $|\eta| < 1.0$ . Shows 1.96 TeV divided by 300 GeV.



# Energy Ratio: 1960/300



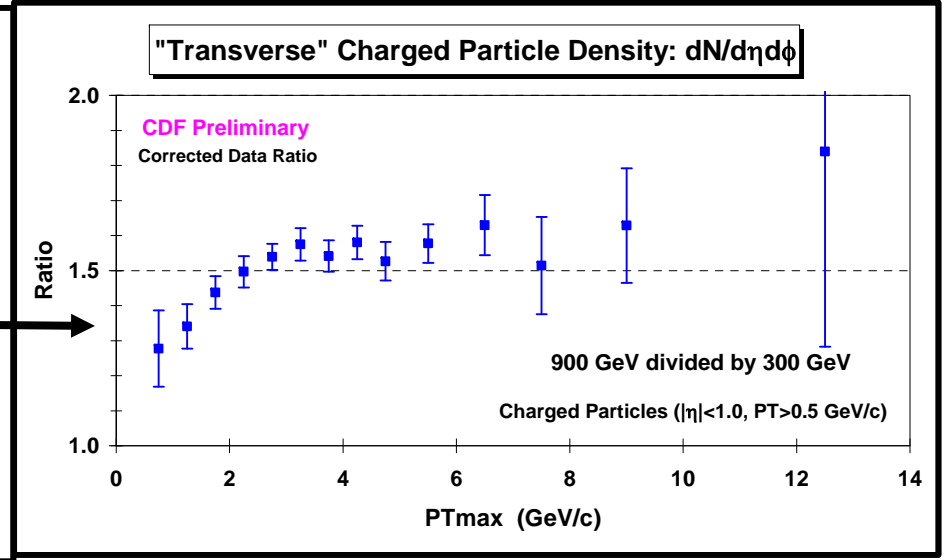
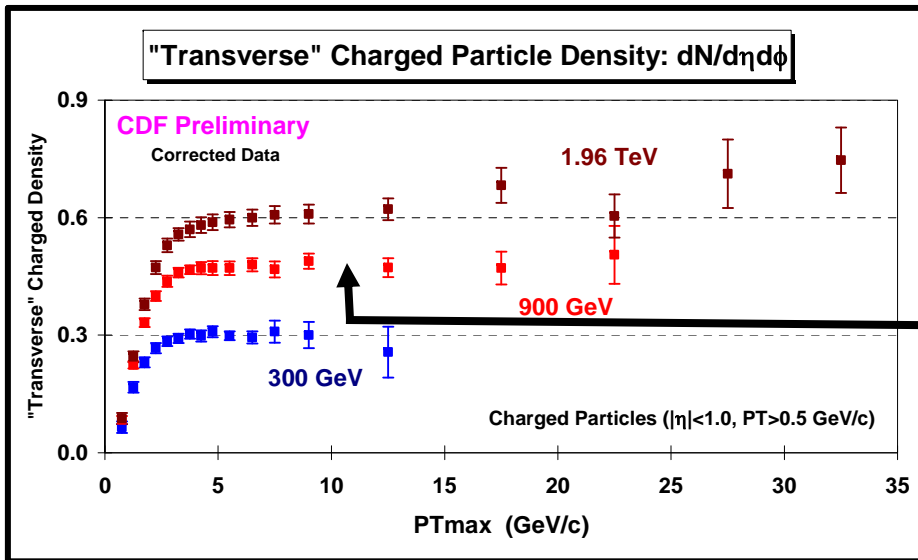
➔ **New Corrected CDF data at 300 GeV, 900 GeV, and 1.96 TeV on the “transverse” charged particle density,  $dN/d\eta d\phi$ , as defined by the leading charged particle (PTmax) for charged particles with  $p_T > 0.5 \text{ GeV}/c$  and  $|\eta| < 1.0$ .**

➔ **Ratio of the CDF data at 300 GeV and 1.96 TeV on the “transverse” charged particle density,  $dN/d\eta d\phi$ , as defined by the leading charged particle (PTmax) for charged particles with  $p_T > 0.5 \text{ GeV}/c$  and  $|\eta| < 1.0$ . Shows 1.96 TeV divided by 300 GeV.**





# Energy Ratio: 900/300

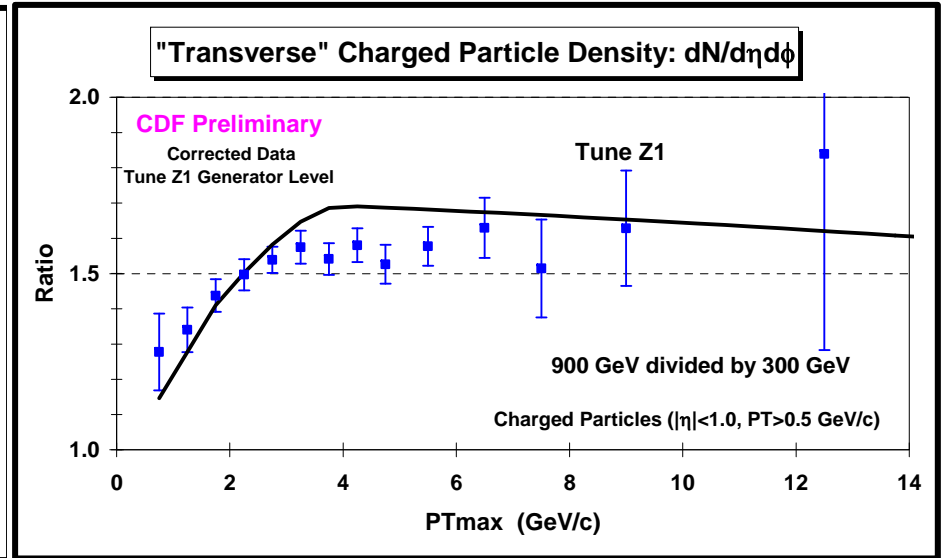
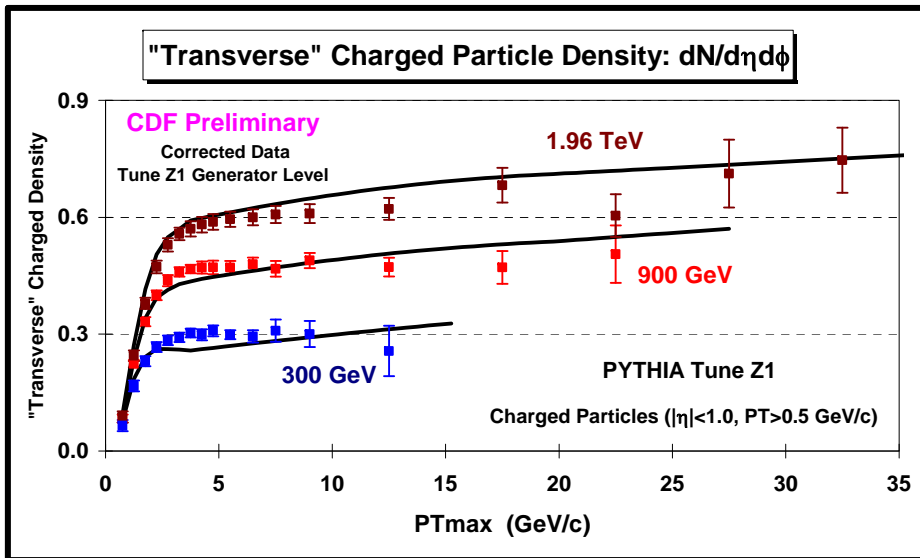


➔ **New Corrected CDF data at 300 GeV, 900 GeV, and 1.96 TeV** on the “transverse” charged particle density,  $dN/d\eta d\phi$ , as defined by the leading charged particle (PTmax) for charged particles with  $p_T > 0.5$  GeV/c and  $|\eta| < 1.0$ .

➔ **Ratio of the CDF data at 300 GeV and 900 GeV** on the “transverse” charged particle density,  $dN/d\eta d\phi$ , as defined by the leading charged particle (PTmax) for charged particles with  $p_T > 0.5$  GeV/c and  $|\eta| < 1.0$ . Shows 900 GeV divided by 300 GeV.



# Energy Ratio: 900/300

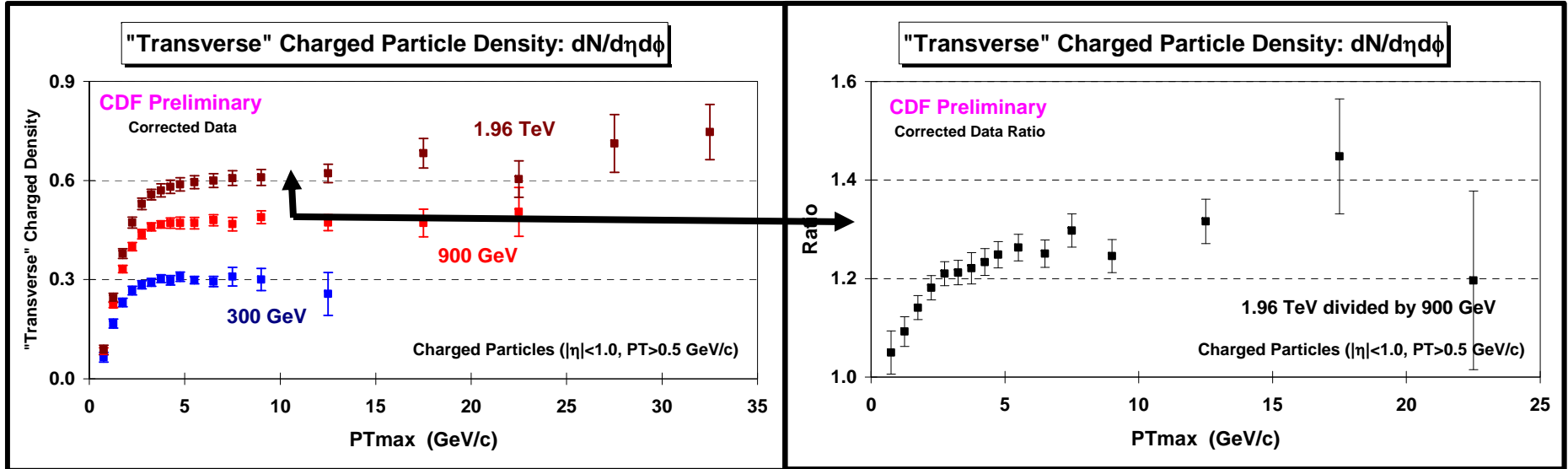


➔ **New Corrected CDF data at 300 GeV, 900 GeV, and 1.96 TeV** on the “transverse” charged particle density,  $dN/d\eta d\phi$ , as defined by the leading charged particle (PTmax) for charged particles with  $p_T > 0.5 \text{ GeV}/c$  and  $|\eta| < 1.0$ .

➔ **Ratio of the CDF data at 300 GeV and 900 GeV** on the “transverse” charged particle density,  $dN/d\eta d\phi$ , as defined by the leading charged particle (PTmax) for charged particles with  $p_T > 0.5 \text{ GeV}/c$  and  $|\eta| < 1.0$ . Shows 900 GeV divided by 300 GeV.



# Energy Ratio: 1960/900

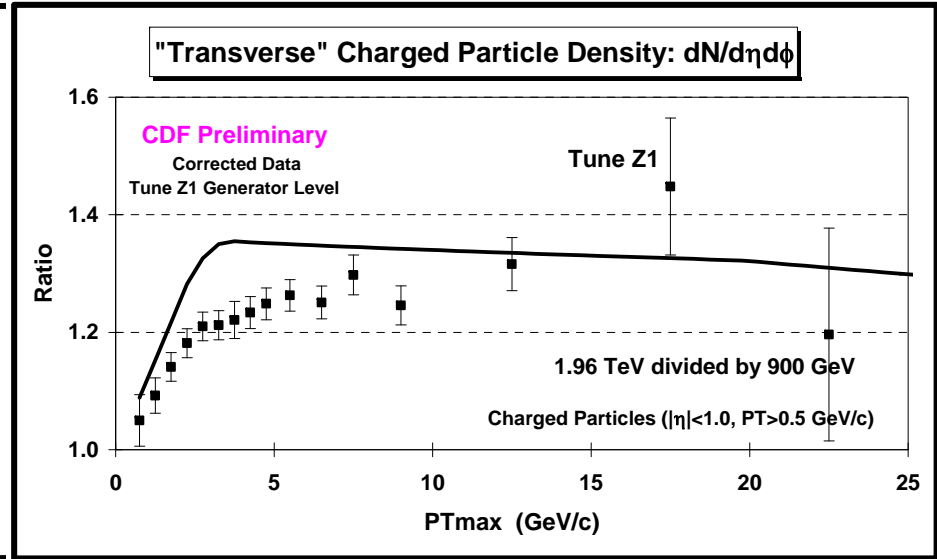
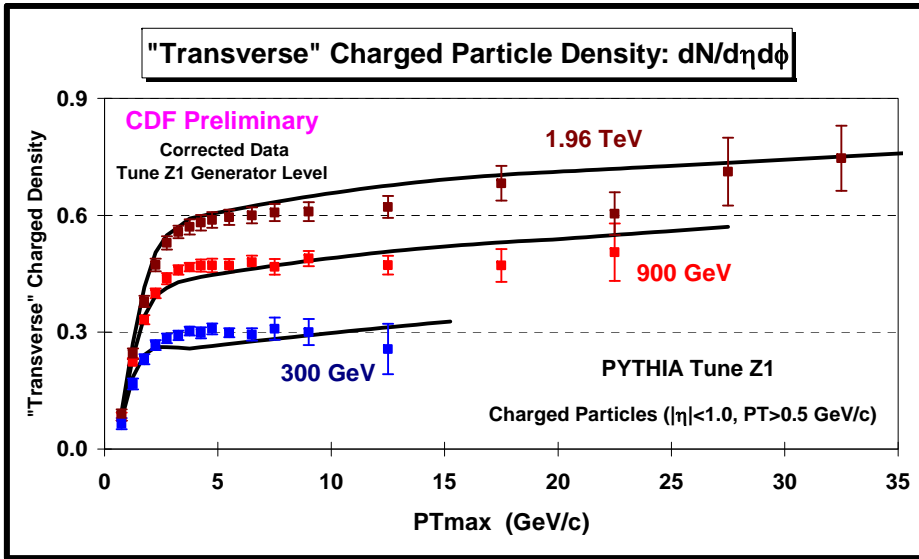


➔ **New Corrected CDF data at 300 GeV, 900 GeV, and 1.96 TeV** on the “transverse” charged particle density,  $dN/d\eta d\phi$ , as defined by the leading charged particle (PTmax) for charged particles with  $p_T > 0.5 \text{ GeV}/c$  and  $|\eta| < 1.0$ .

➔ **Ratio of the CDF data at 900 GeV and 1.96 TeV** on the “transverse” charged particle density,  $dN/d\eta d\phi$ , as defined by the leading charged particle (PTmax) for charged particles with  $p_T > 0.5 \text{ GeV}/c$  and  $|\eta| < 1.0$ . Shows 1.96 TeV divided by 900 GeV.



# Energy Ratio: 1960/900

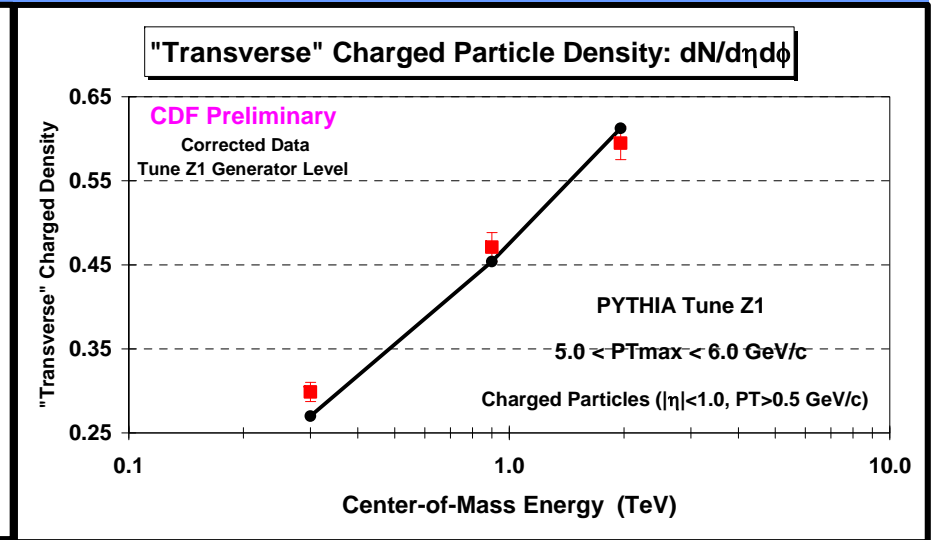
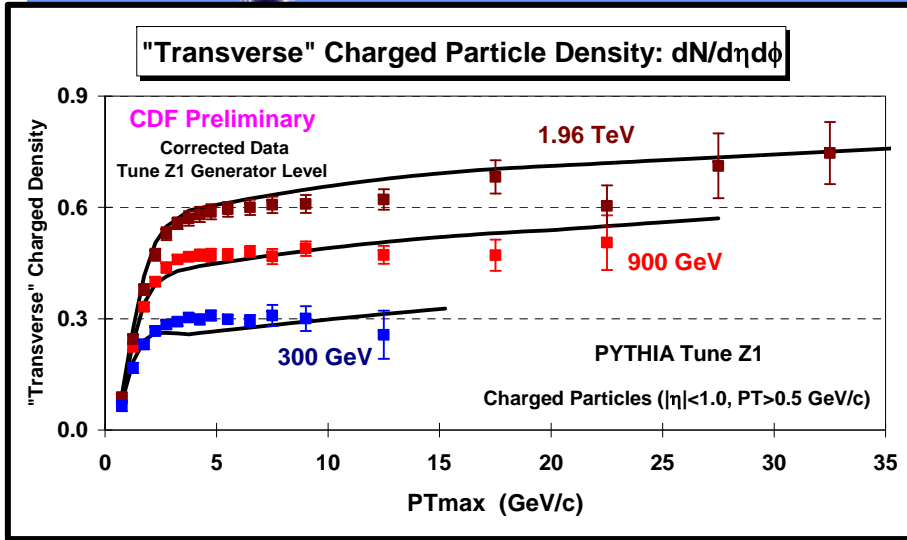


➔ **New Corrected CDF data at 300 GeV, 900 GeV, and 1.96 TeV** on the “transverse” charged particle density,  $dN/d\eta d\phi$ , as defined by the leading charged particle (PTmax) for charged particles with  $p_T > 0.5$  GeV/c and  $|\eta| < 1.0$ .

➔ **Ratio of the CDF data at 900 GeV and 1.96 TeV** on the “transverse” charged particle density,  $dN/d\eta d\phi$ , as defined by the leading charged particle (PTmax) for charged particles with  $p_T > 0.5$  GeV/c and  $|\eta| < 1.0$ . Shows 1.96 TeV divided by 900 GeV.

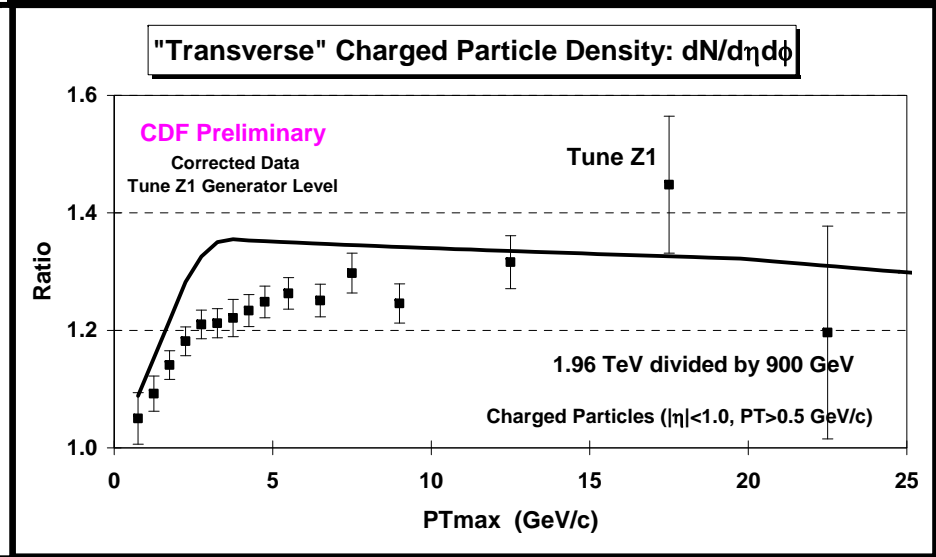
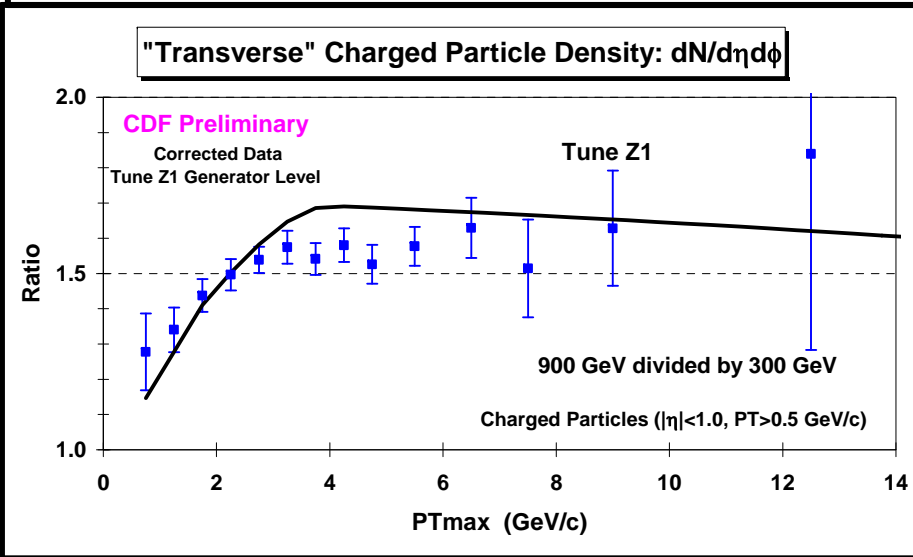
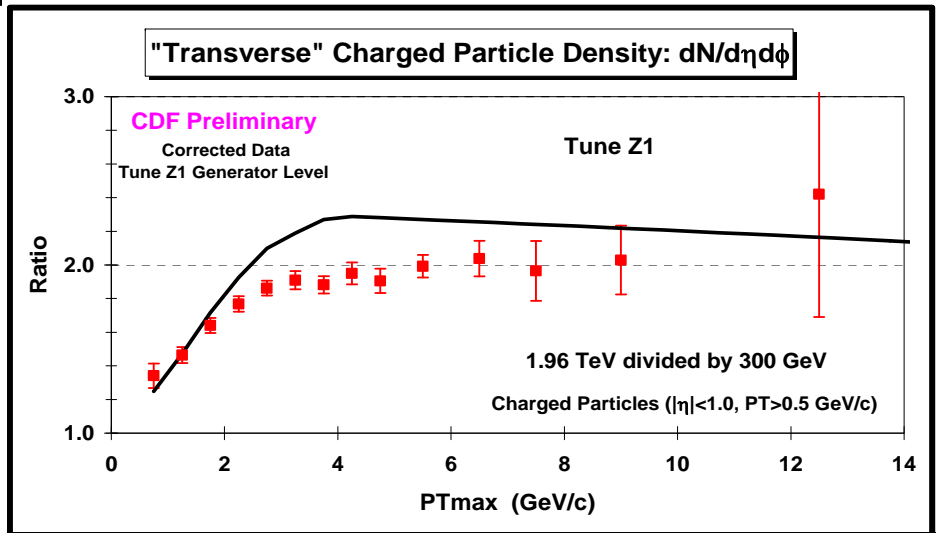
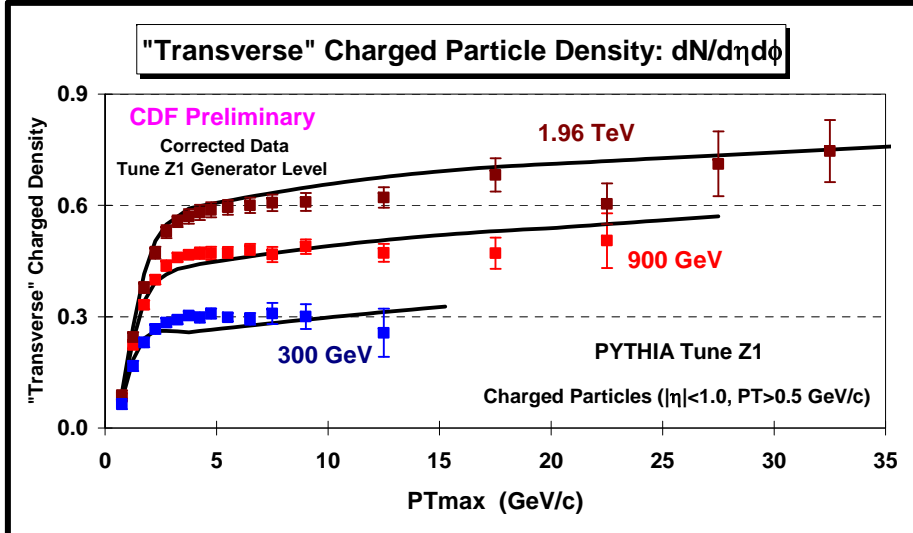


# PYTHIA 6.4 Tune Z1





# PYTHIA 6.4 Tune Z1



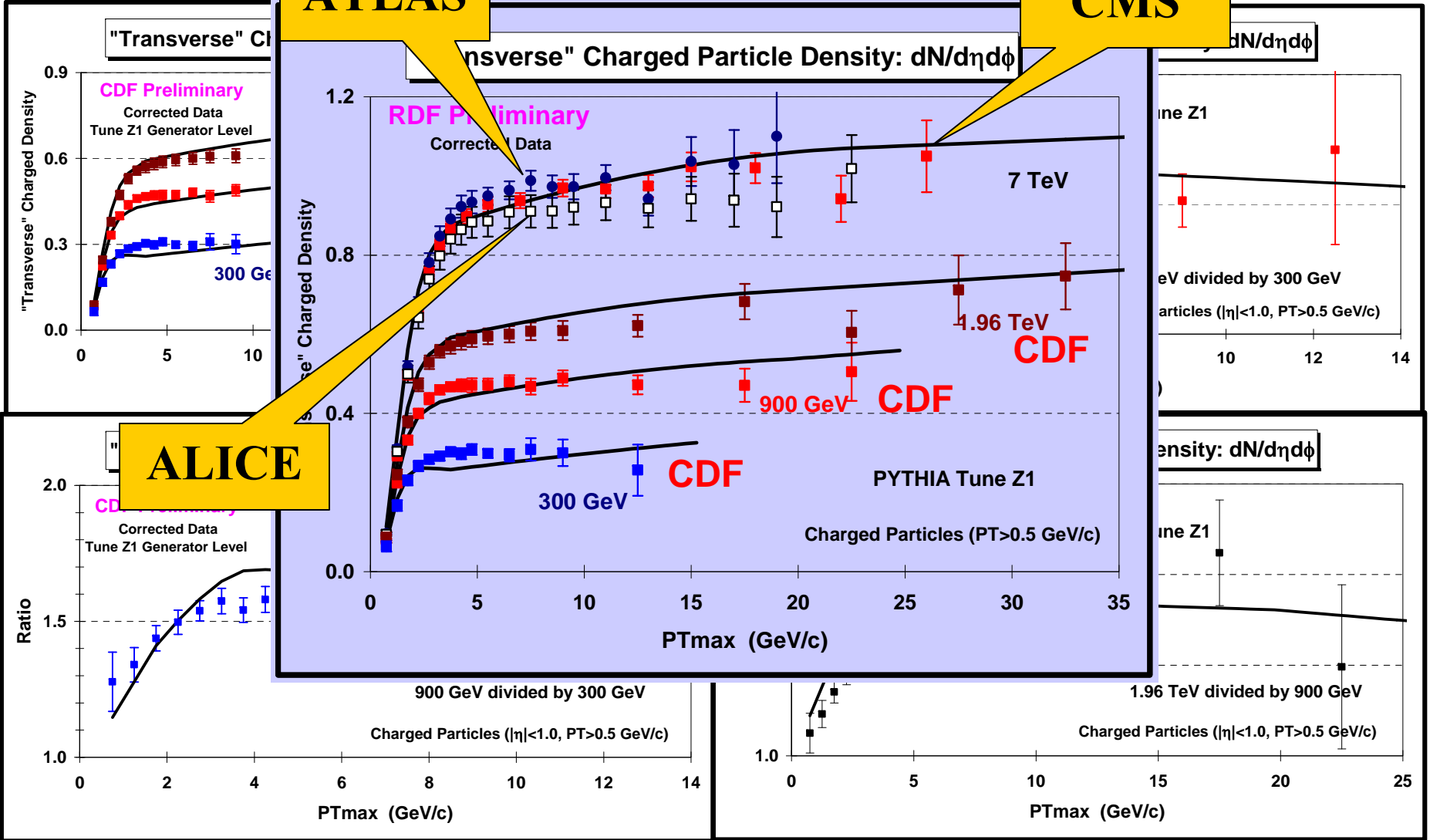


# PYTHIA 6.4 Tune Z1



ATLAS

CMS

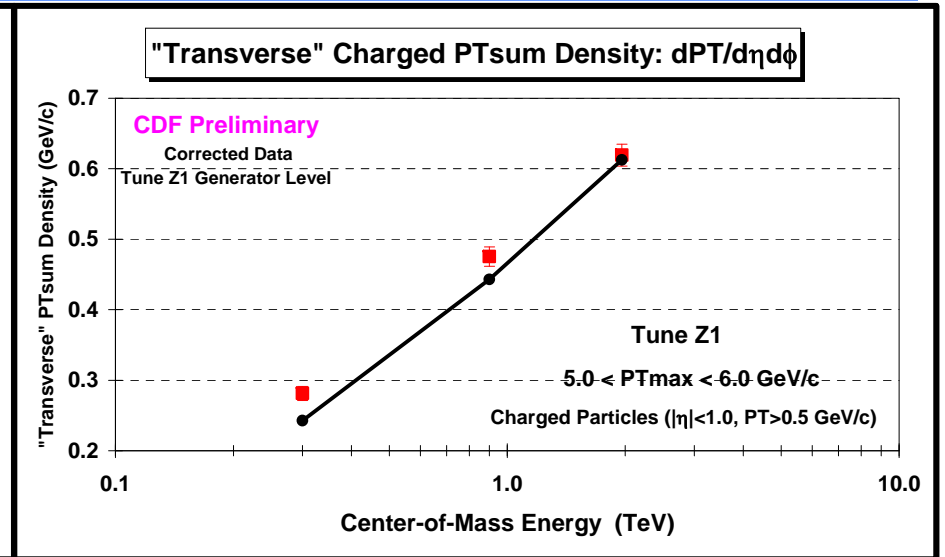
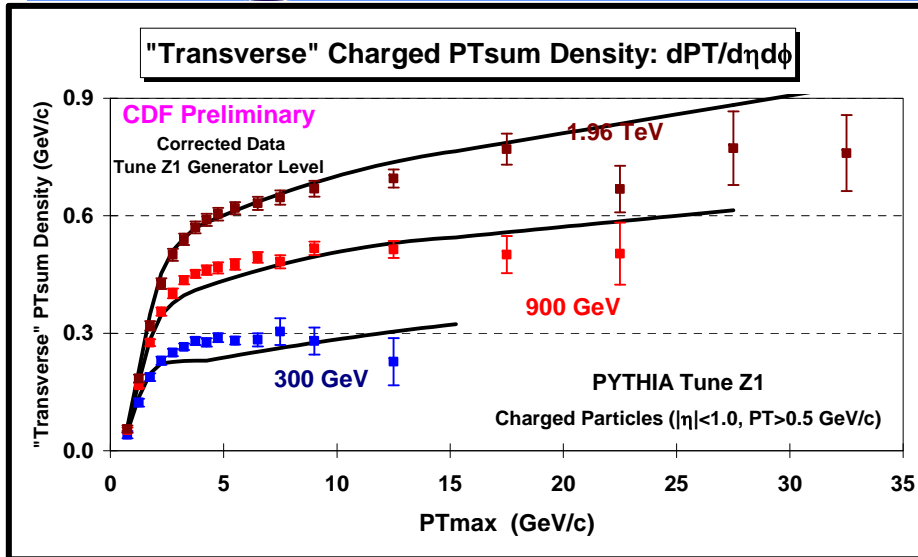


ALICE



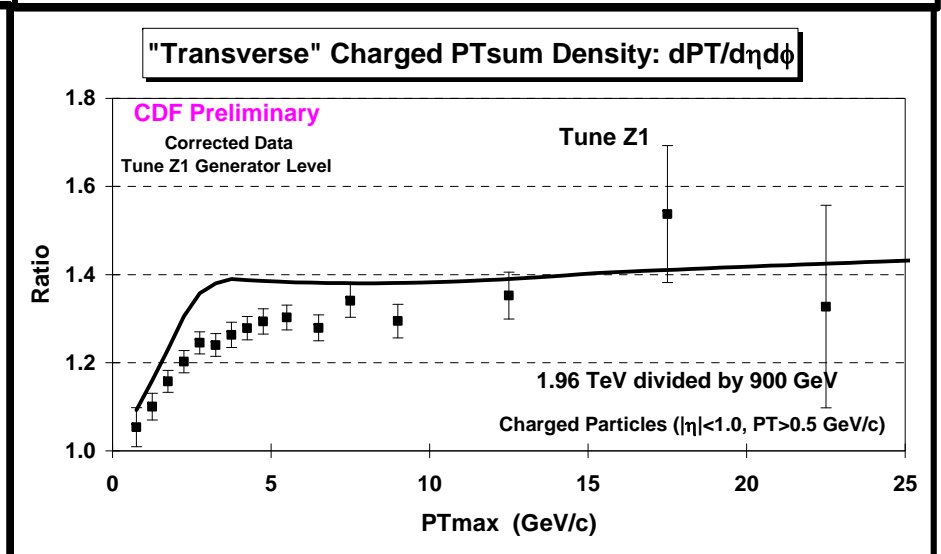
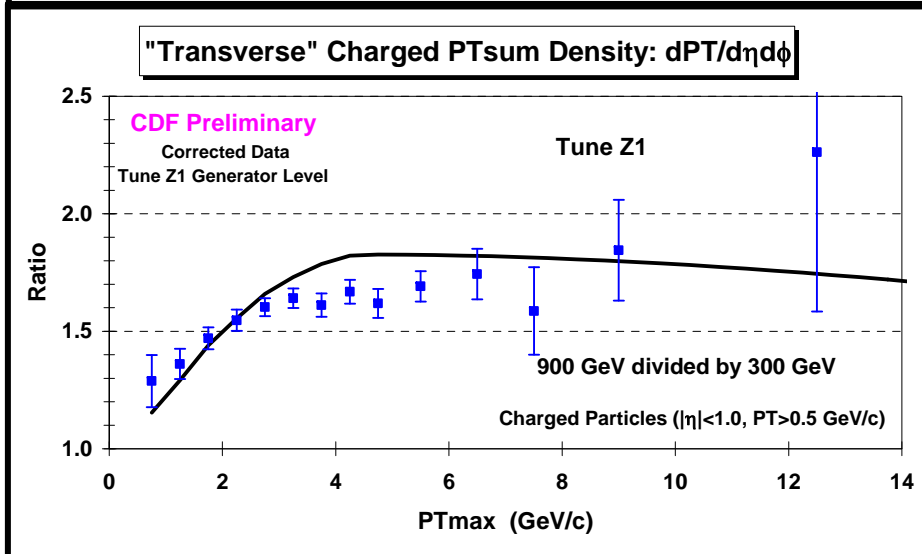
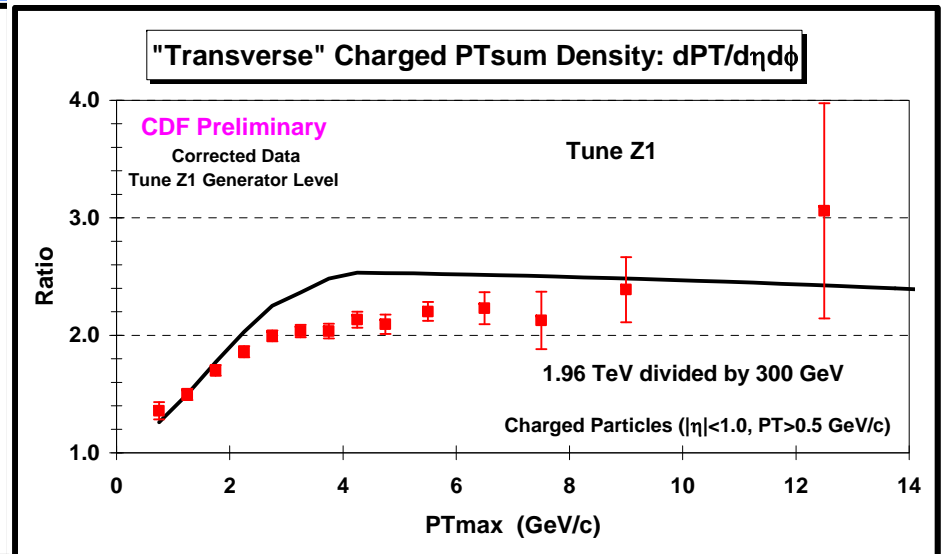
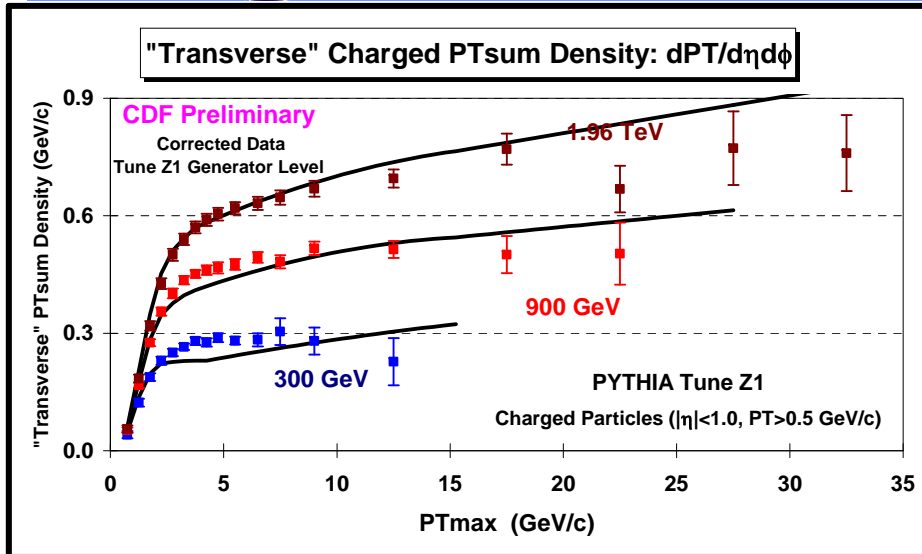


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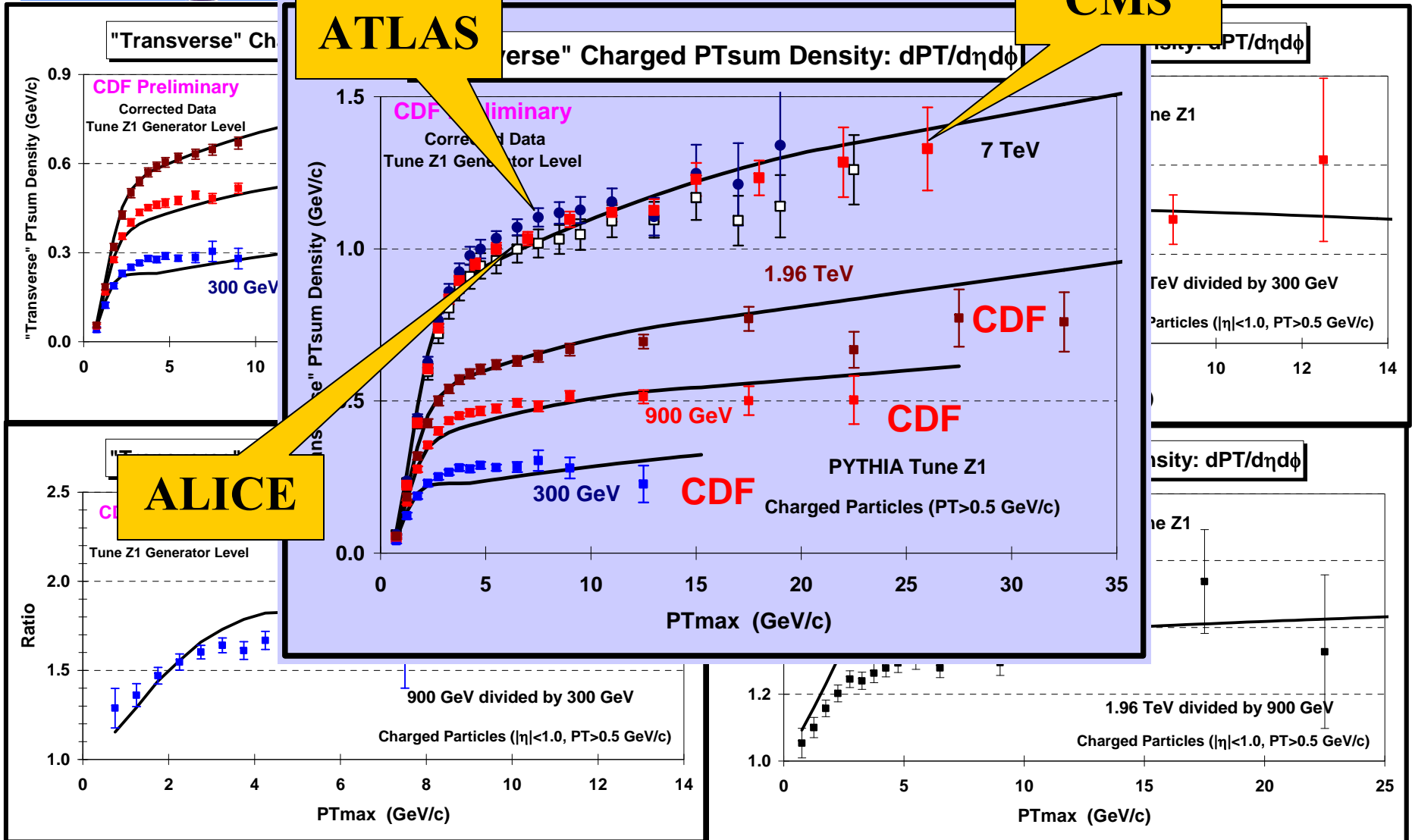


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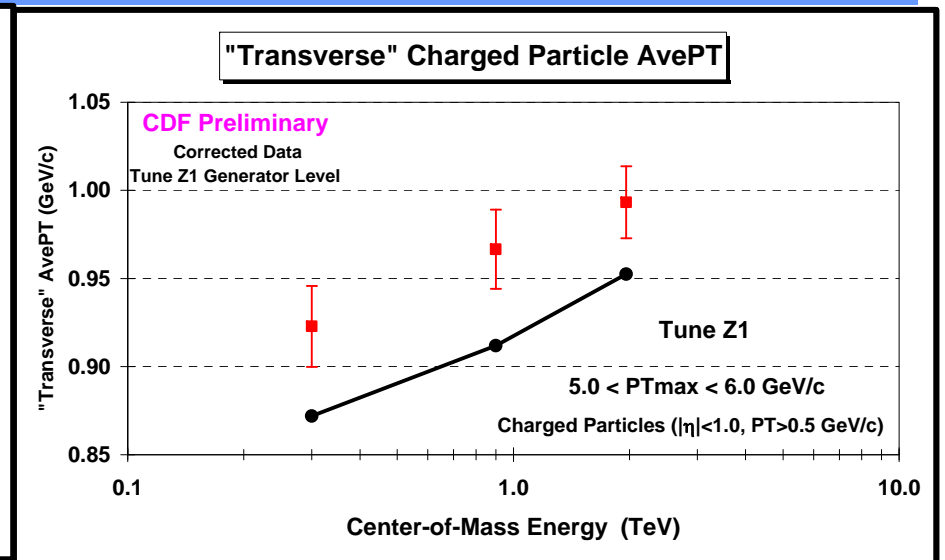
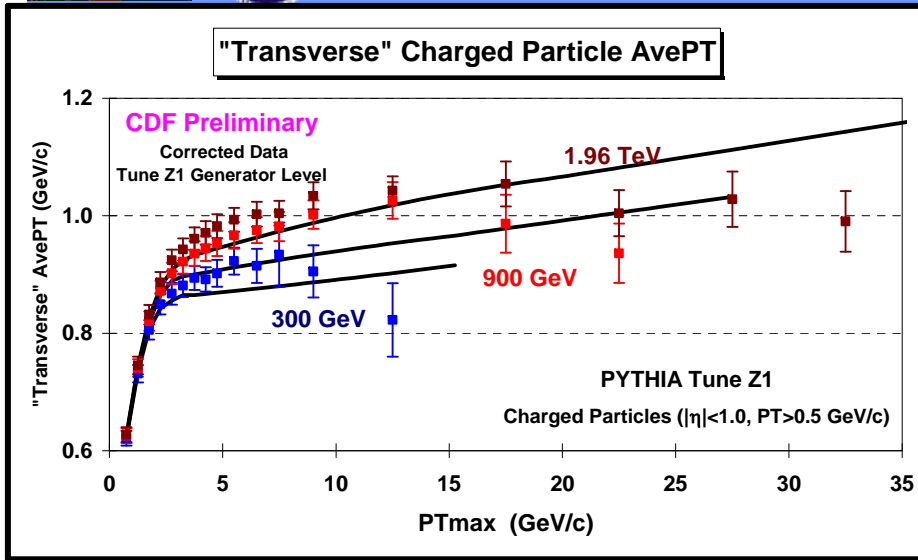


# PYTHIA 6.4 Tune Z1



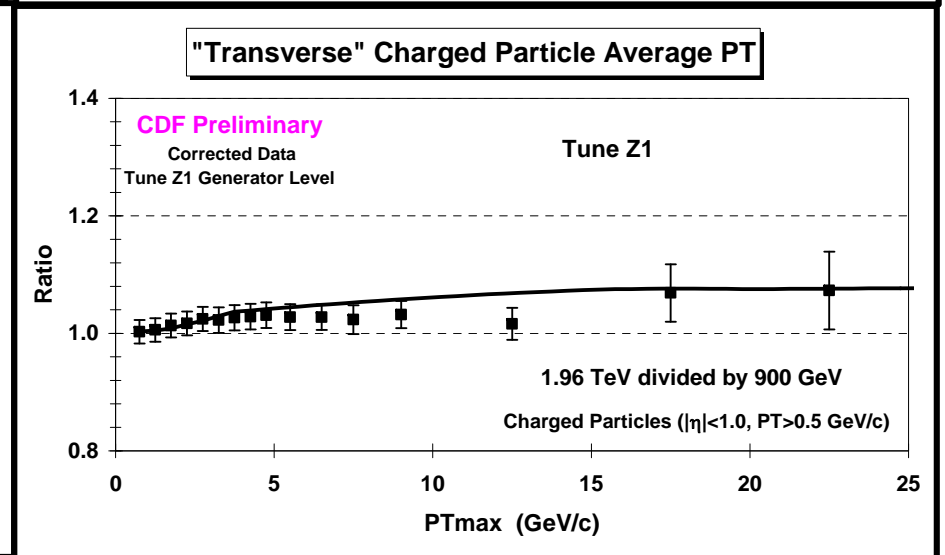
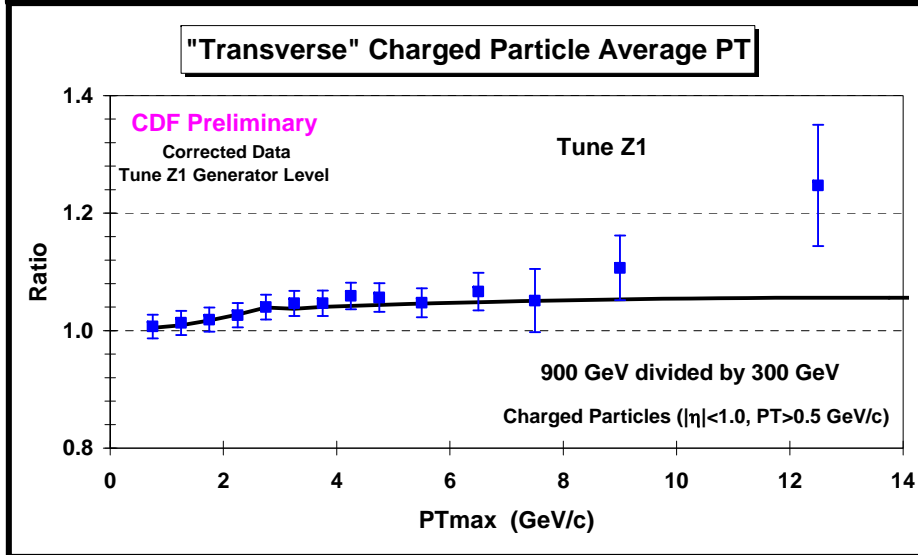
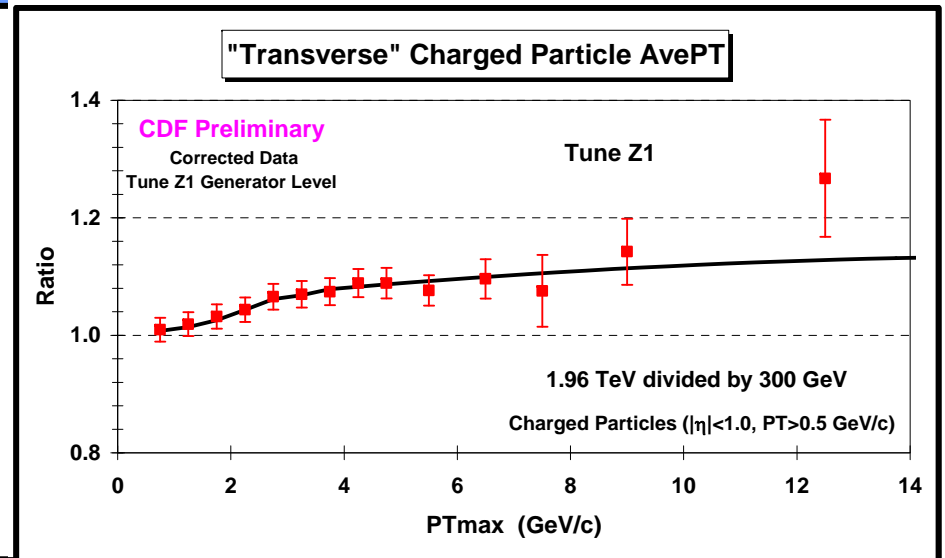
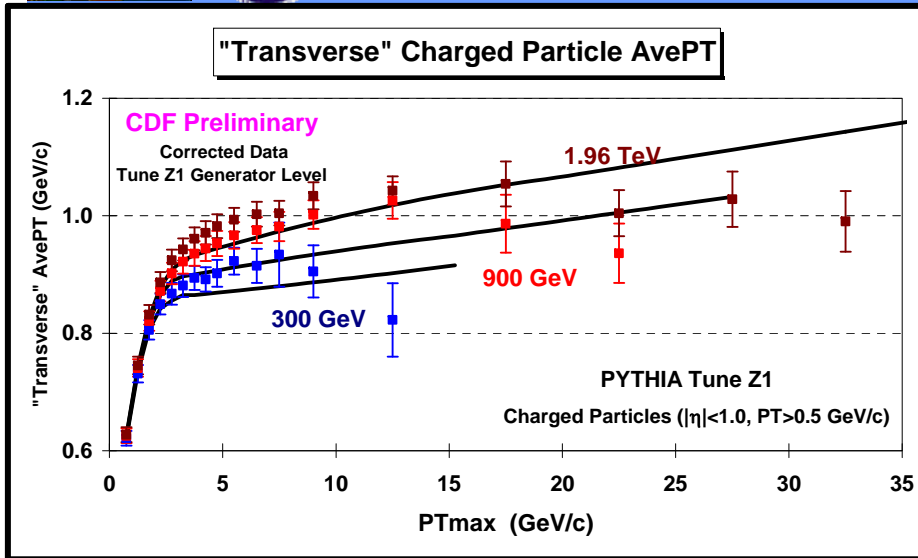


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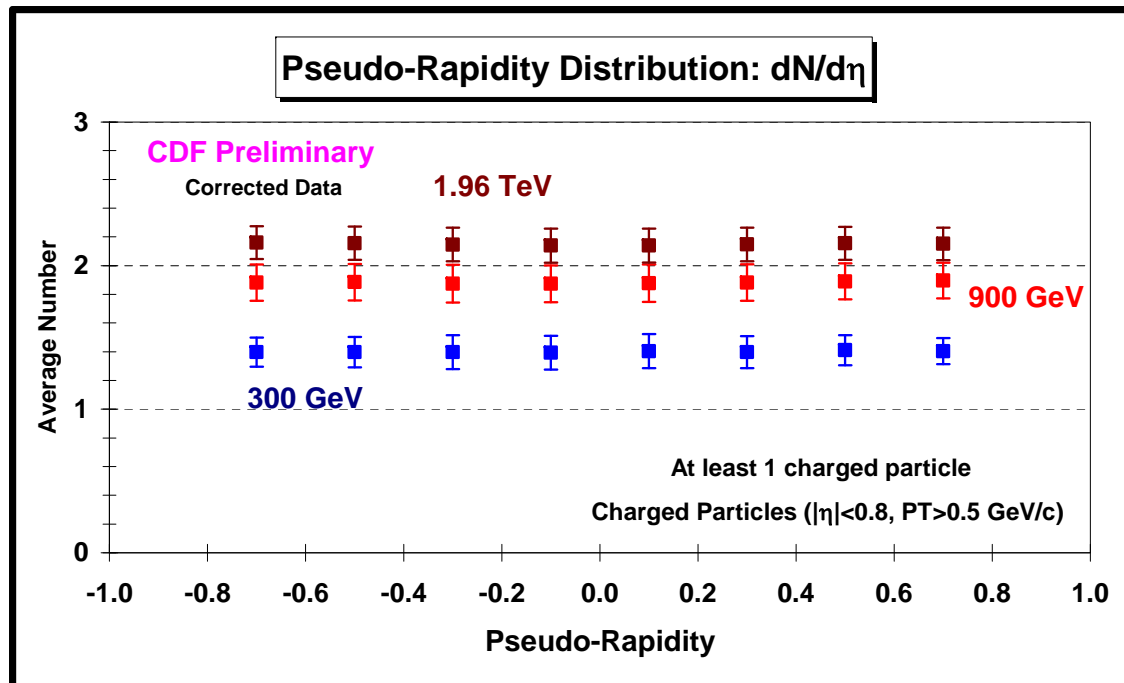


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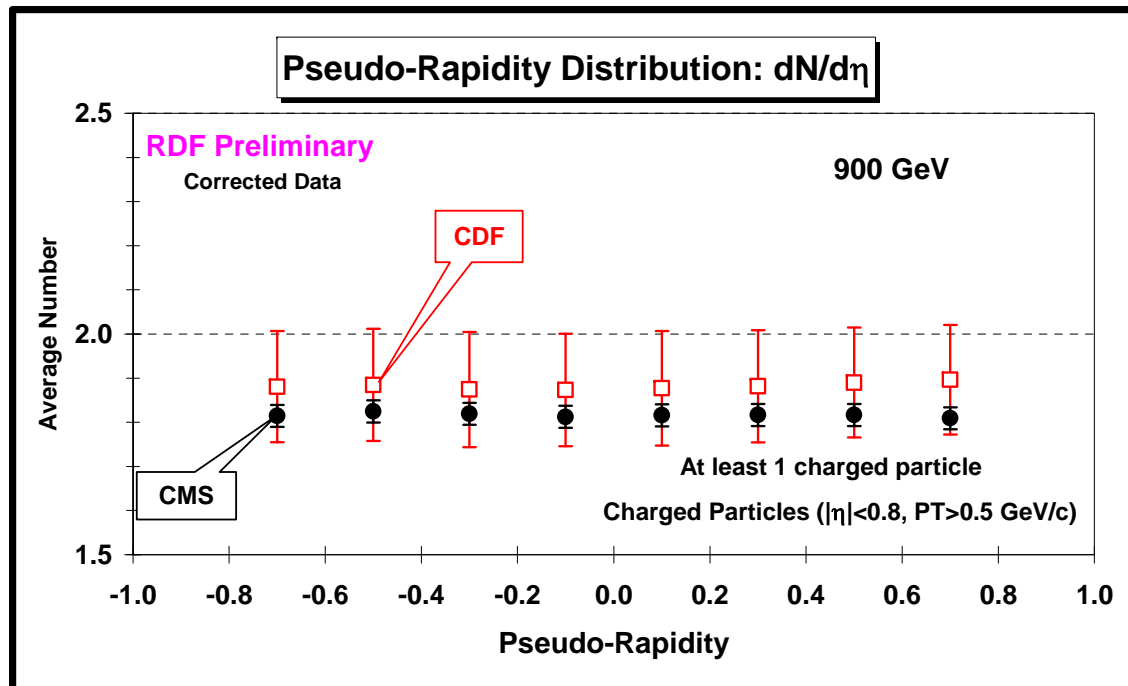
# New CDF MB Data



- ➔ **New Corrected CDF data at 300 GeV, 900 GeV, and 1.96 TeV** on on pseudo-rapidity distribution of charged particles,  $dN/d\eta$ , with  $p_T > 0.5$  GeV/c. Events are required to have at least one charged particle with  $|\eta| < 0.8$  and  $p_T > 0.5$  GeV/c. The data are corrected to the particle level with errors that include both the statistical error and the systematic uncertainty.



# New CDF MB Data

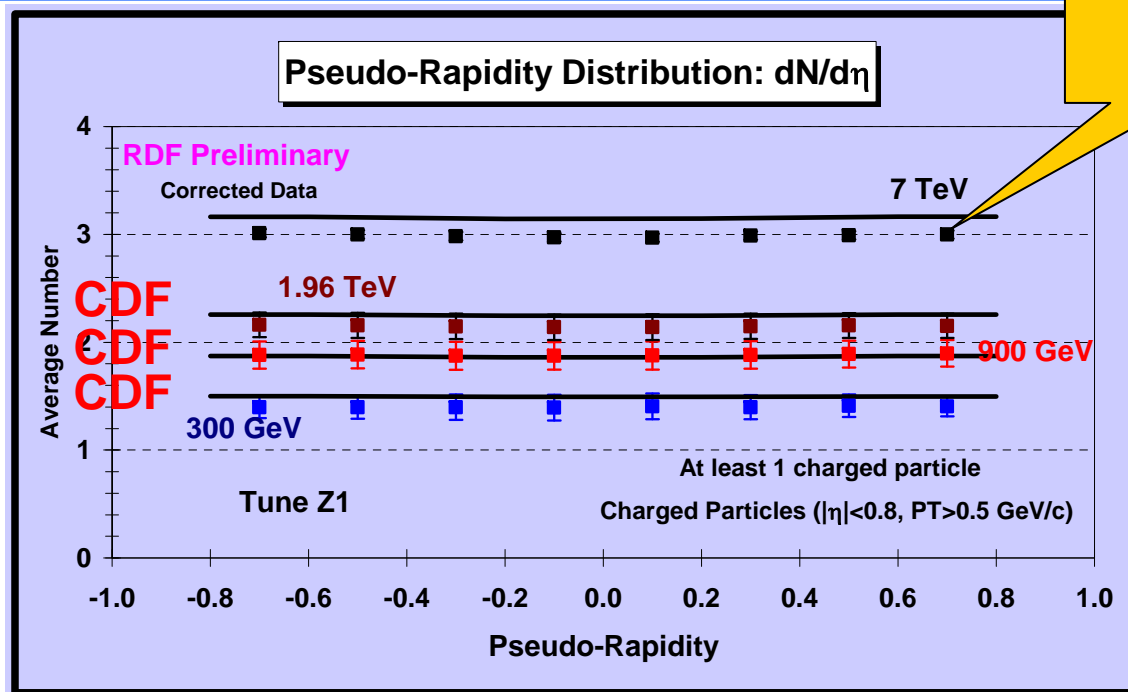


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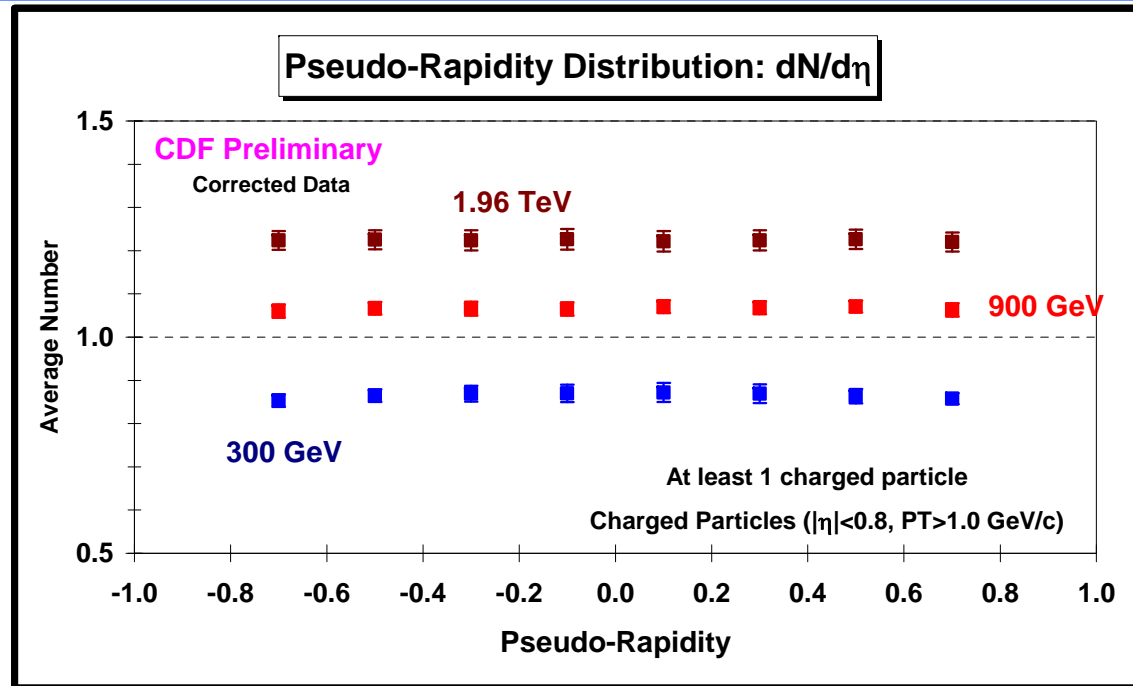




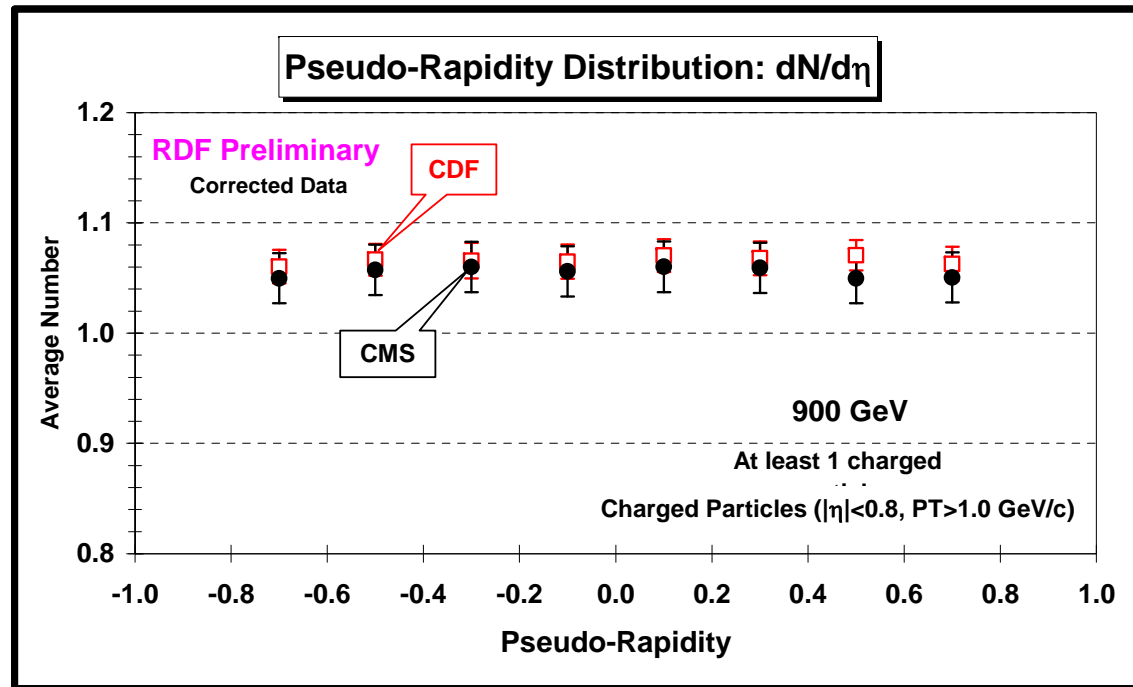
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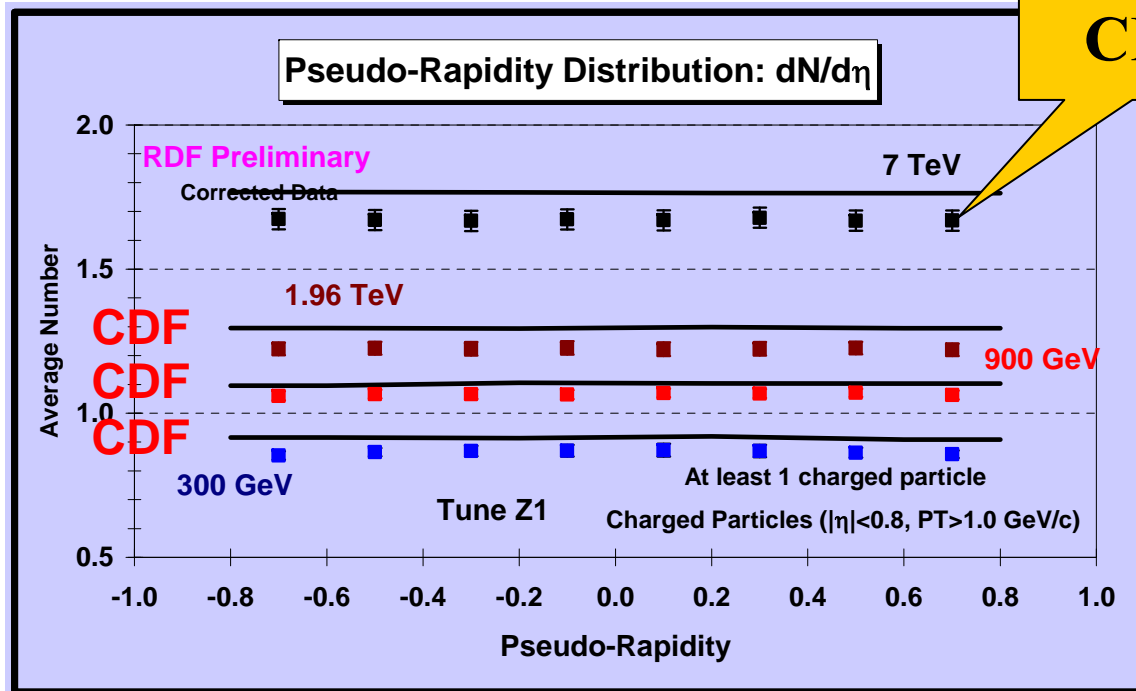
- ➔ **New Corrected CDF data at 300 GeV, 900 GeV, and 1.96 TeV** on on pseudo-rapidity distribution of charged particles,  $dN/d\eta$ , with  $p_T > 1.0$  GeV/c. Events are required to have at least one charged particle with  $|\eta| < 0.8$  and  $p_T > 1.0$  GeV/c. The data are corrected to the particle level with errors that include both the statistical error and the systematic uncertainty.



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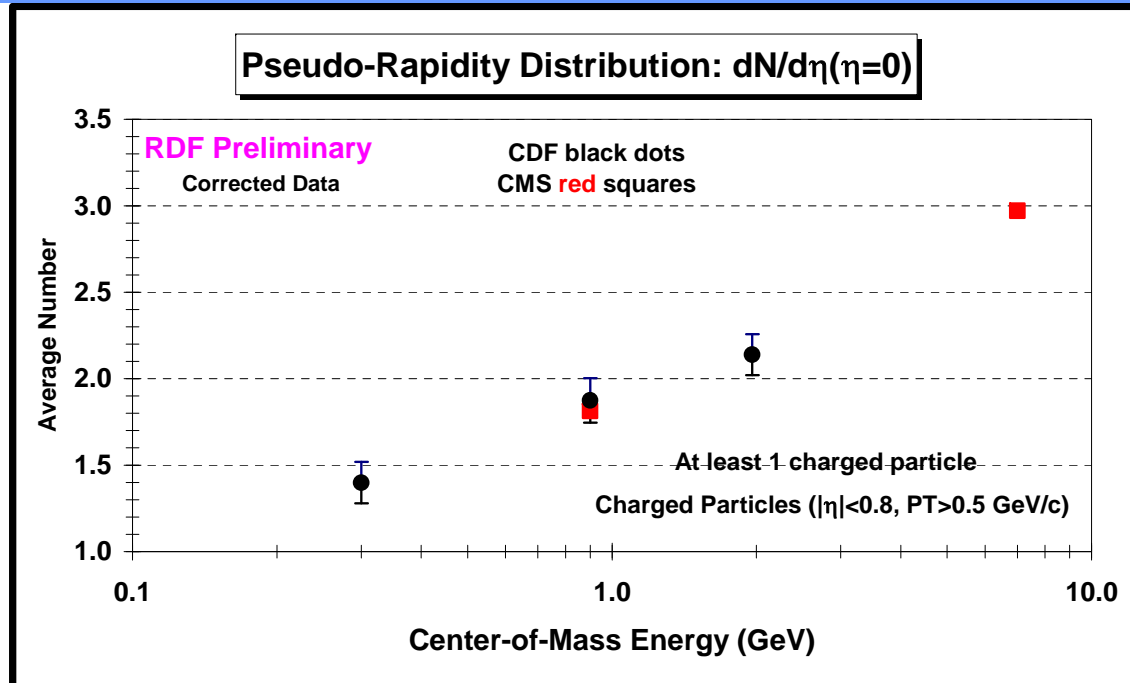
# New CDF MB Data



- ➔ **New Corrected CDF data at 300 GeV, 900 GeV, and 1.96 TeV** on on pseudo-rapidity distribution of charged particles,  $dN/d\eta$ , with  $p_T > 1.0 \text{ GeV}/c$ . Events are required to have at least one charged particle with  $|\eta| < 0.8$  and  $p_T > 1.0 \text{ GeV}/c$ . The data are corrected to the particle level with errors that include both the statistical error and the systematic uncertainty.



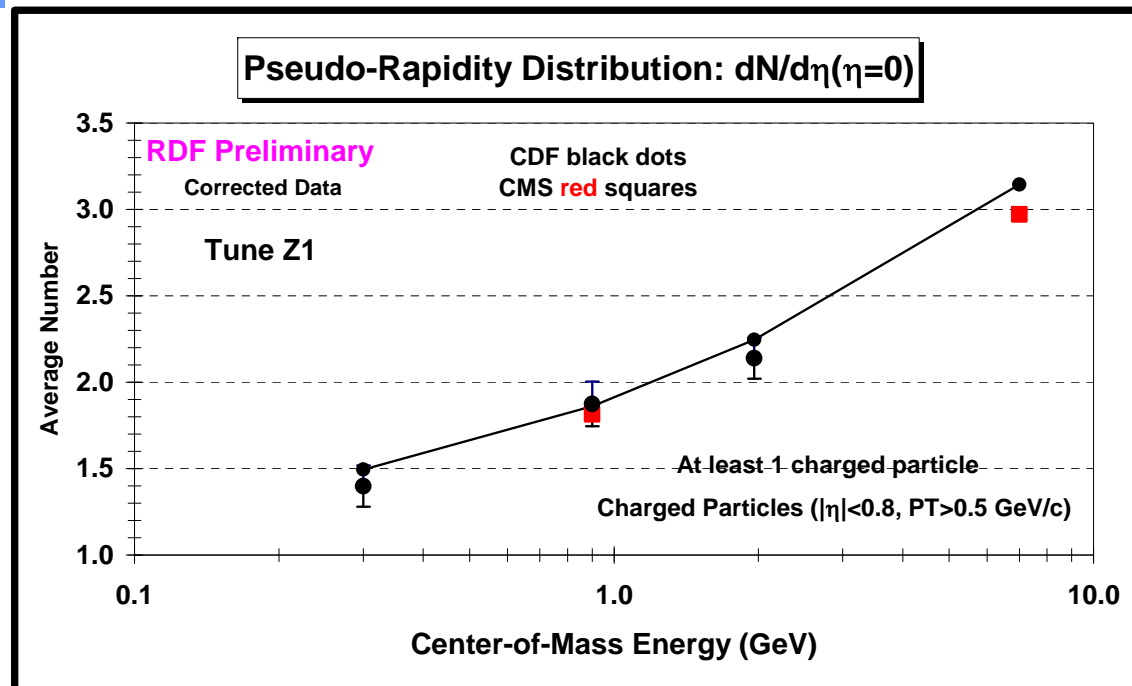
# Energy Dependence $dN/d\eta$



- ➔ **CMS** data at 7 TeV and 900 GeV and **CDF** data at 1.96 TeV, 900 GeV, and 300 GeV on  $dN/d\eta$  at  $\eta = 0$  with  $p_T > 0.5$  GeV/c as a function of the center-of-mass energy. Events are required to have at least one charged particle with  $|\eta| < 0.8$  and  $p_T > 0.5$  GeV/c. The data are corrected to the particle level with errors that include both the statistical error and the systematic uncertainty.



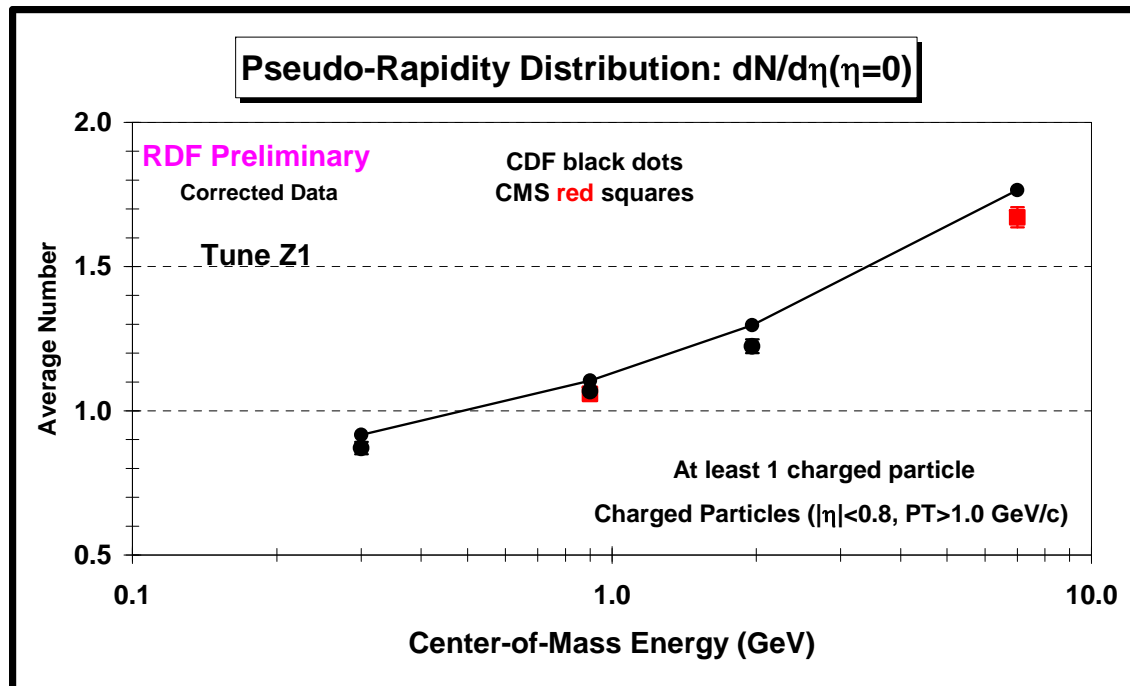
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# Energy Dependence $dN/d\eta$

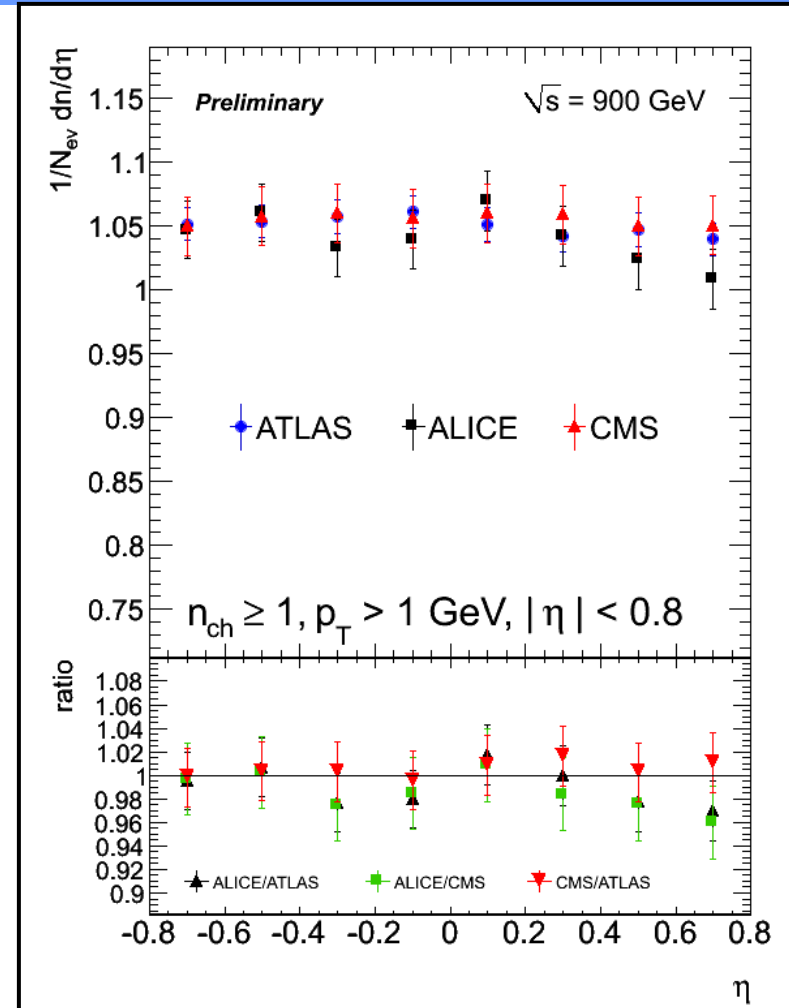
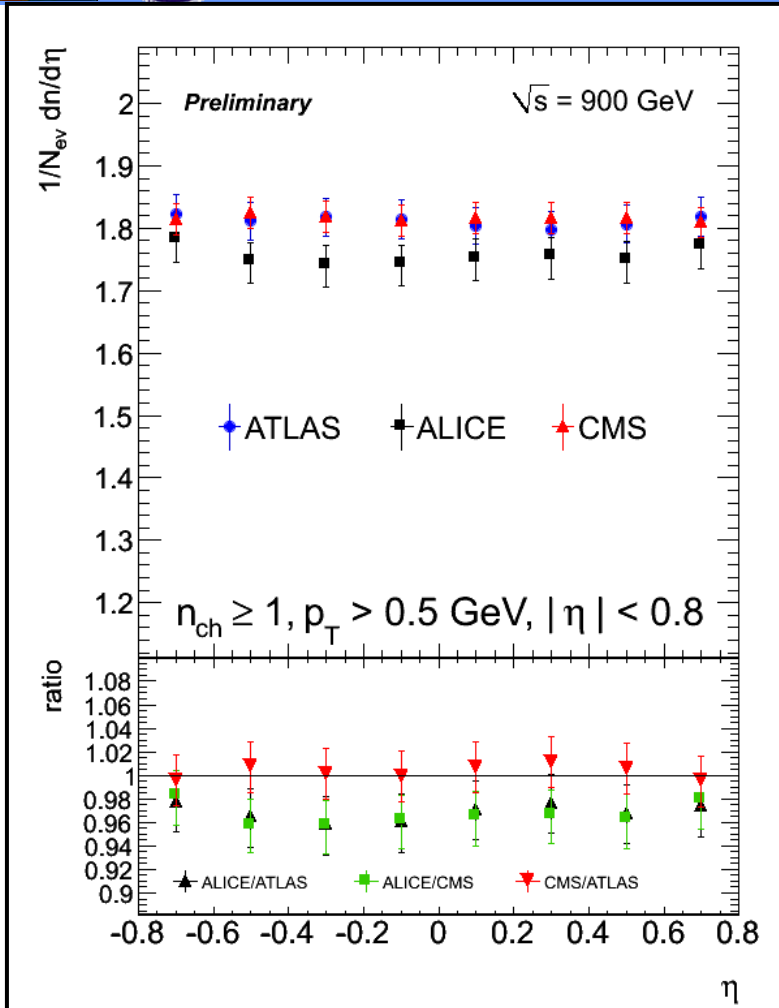


- ➔ **CMS** data at 7 TeV and 900 GeV and **CDF** data at 1.96 TeV, 900 GeV, and 300 GeV on  $dN/d\eta$  at  $\eta = 0$  with  $p_T > 1.0$  GeV/c as a function of the center-of-mass energy. Events are required to have at least one charged particle with  $|\eta| < 0.8$  and  $p_T > 1.0$  GeV/c. The data are corrected to the particle level with errors that include both the statistical error and the systematic uncertainty.





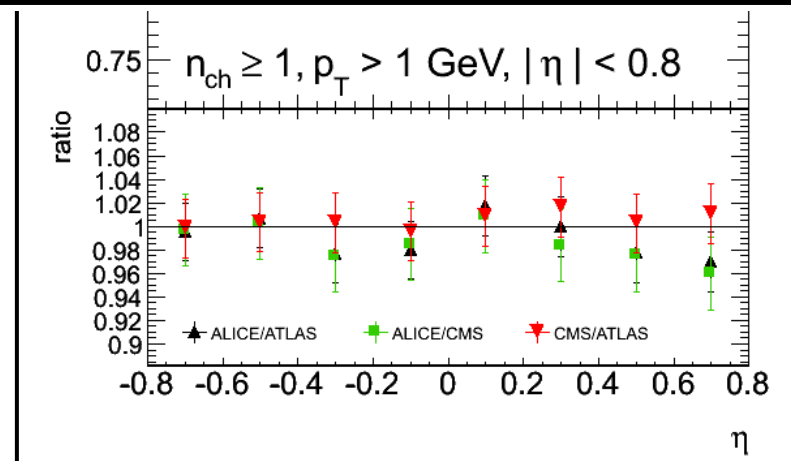
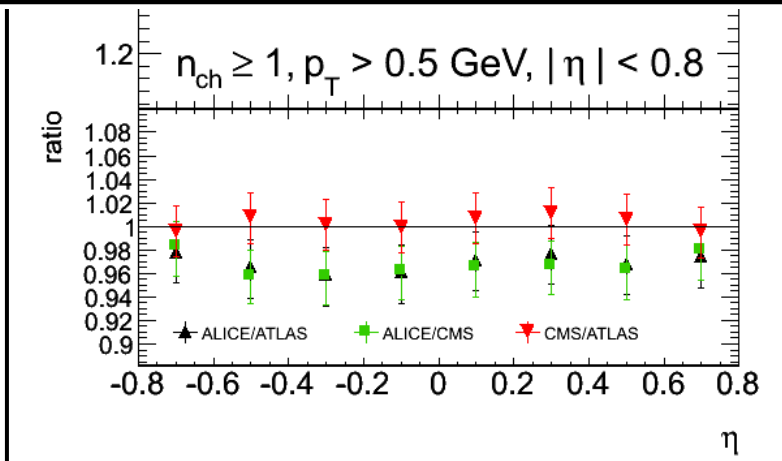
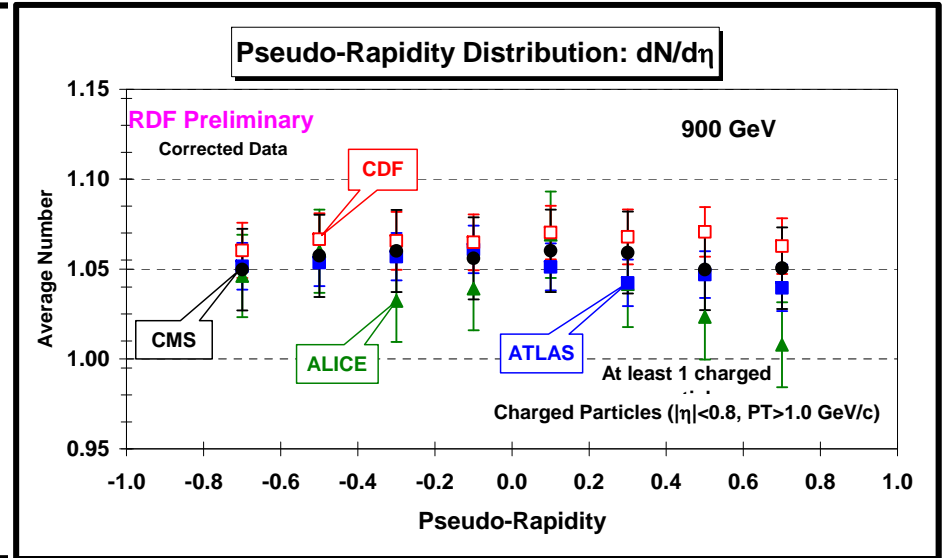
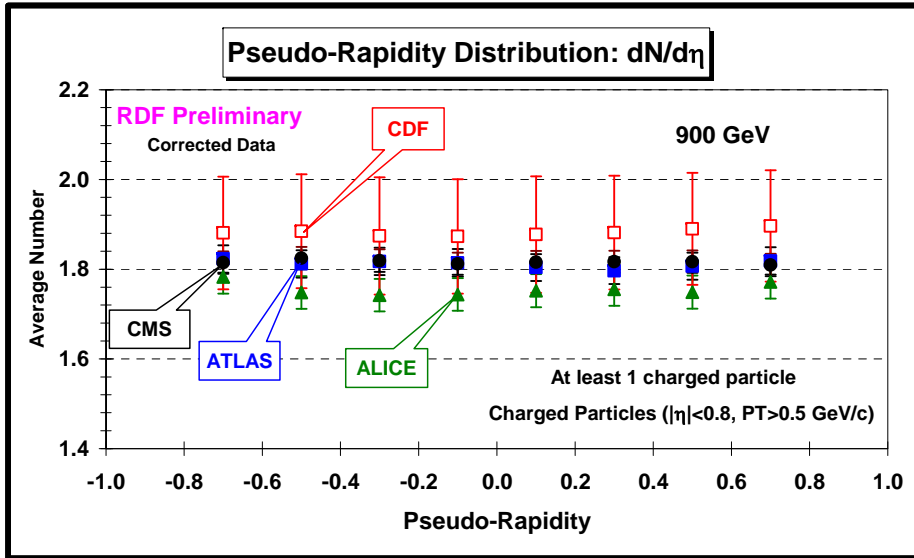
# MB Common Plots 900 GeV



**Direct charged particles (including leptons) corrected to the particle level with no corrections for SD or DD.**



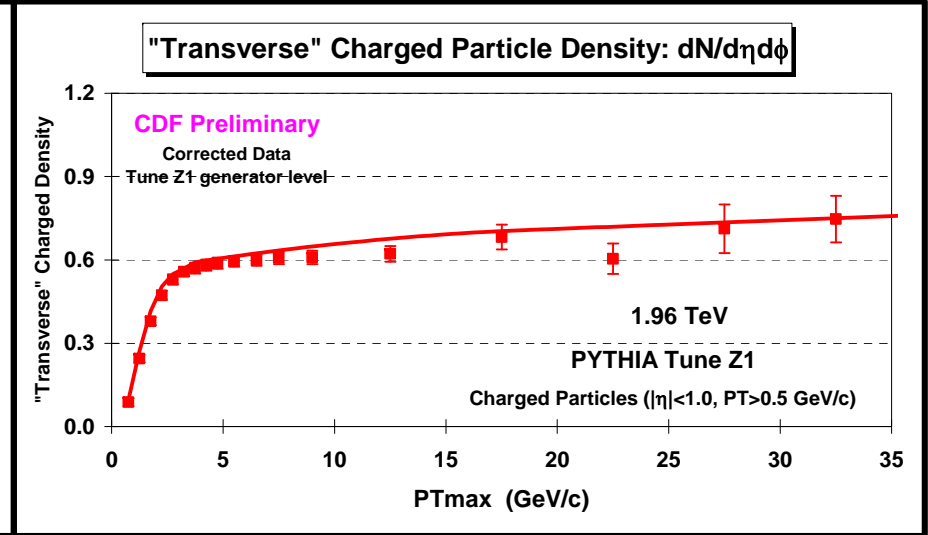
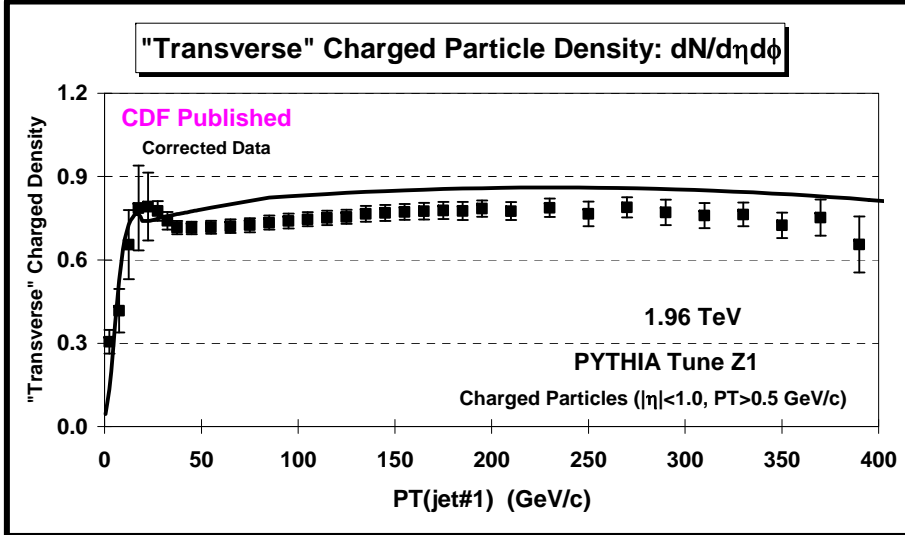
# MB Common Plots 900 GeV



**Direct charged particles (including leptons) corrected to the particle level with no corrections for SD or DD.**

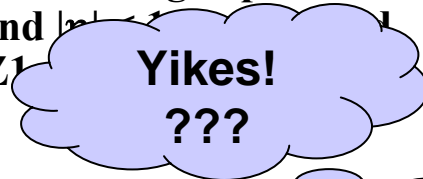


# PTmax versus Leading Jet



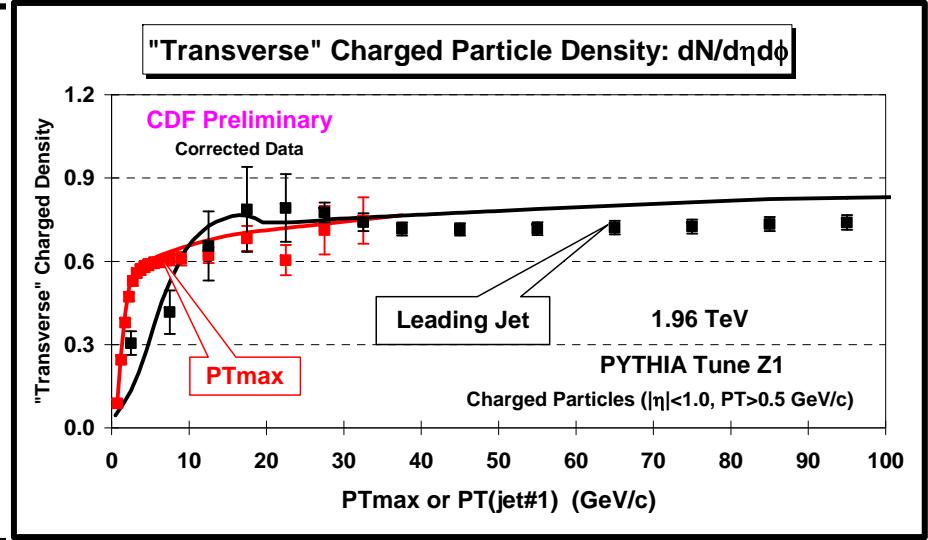
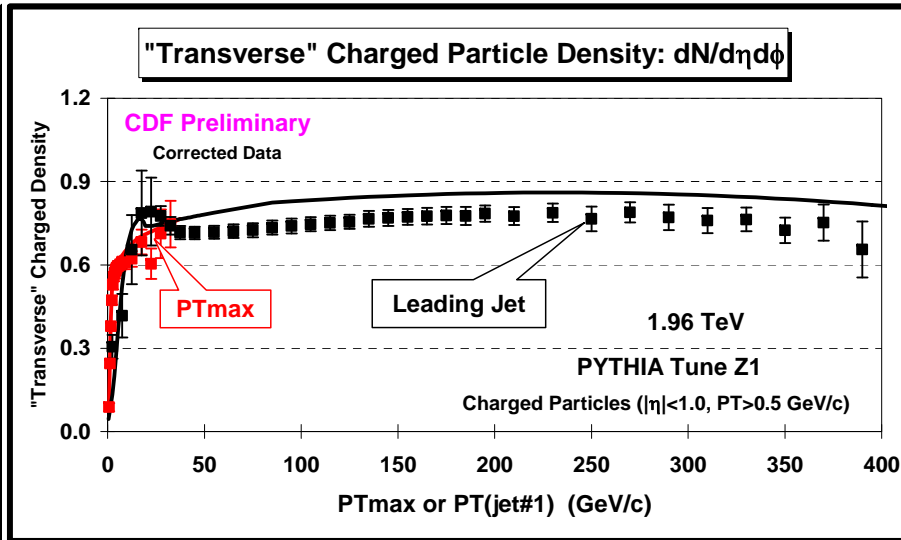
➔ **Published CDF Run 2 data at 1.96 TeV** on the “transverse” charged particle density,  $dN/d\eta d\phi$ , as defined by the leading calorimeter jet (jet#1) for charged particles with  $p_T > 0.5$  GeV/c and  $|\eta| < 1.0$  compared with PYTHIA Tune Z1.

➔ **New CDF data 1.96 TeV** on the “transverse” charged particle density,  $dN/d\eta d\phi$ , as defined by the leading charged particle ( $PTmax$ ) for charged particles with  $p_T > 0.5$  GeV/c and  $|\eta| < 1.0$  compared with PYTHIA Tune Z1.





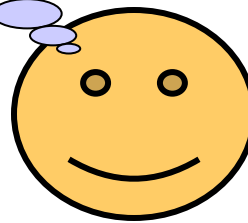
# PTmax versus Leading Jet



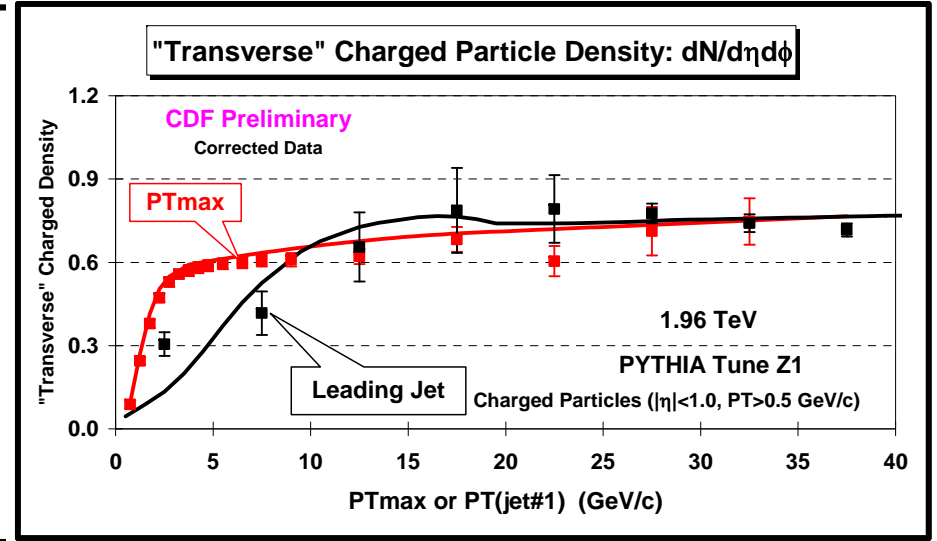
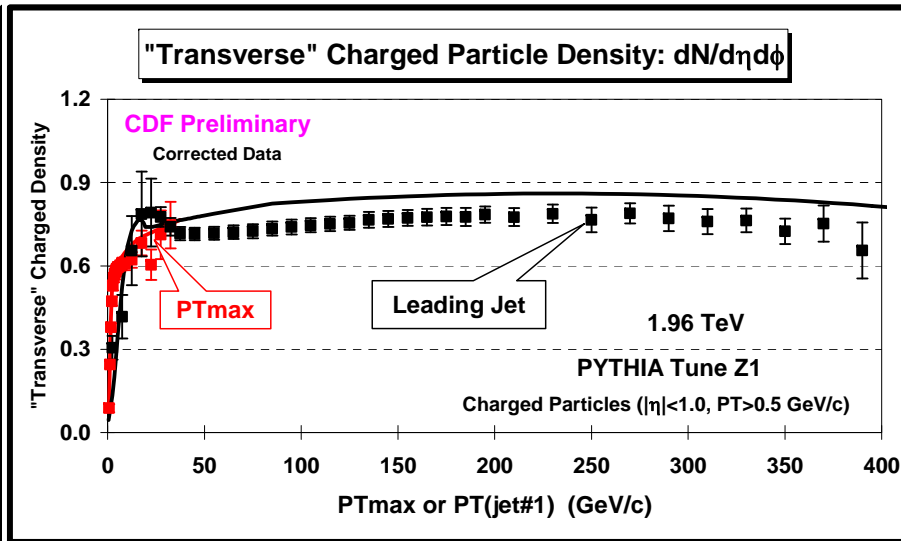
➔ **Published CDF Run 2 data at 1.96 TeV** on the “transverse” charged particle density,  $dN/d\eta d\phi$ , as defined by the leading calorimeter jet (jet#1) for charged particles with  $p_T > 0.5$  GeV/c and  $|\eta| < 1.0$  compared with PYTHIA Tune Z1.

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Yikes!  
???



# PTmax versus Leading Jet

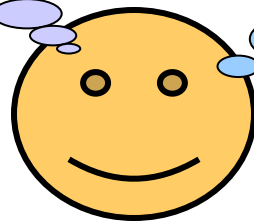


➔ **Published CDF Run 2 data at 1.96 TeV** on the “transverse” charged particle density,  $dN/d\eta d\phi$ , as defined by the leading calorimeter jet (jet#1) for charged particles with  $p_T > 0.5$  GeV/c and  $|\eta| < 1.0$  with PYTHIA Tune Z1

Yikes!  
???

➔ **New CDF data 1.96 TeV** on the “transverse” charged particle density,  $dN/d\eta d\phi$ , as defined by the leading calorimeter jet (jet#1) for charged particles with  $p_T > 0.5$  GeV/c and  $|\eta| < 1.0$  with PYTHIA Tune Z1

Okay  
No inconsistency  
But need to understand!





# More Coming Soon!



- ➔ **CDF - Many More UE Observables:** Nchg density, PTsum density, average  $p_T$ , “toward”, “away”, “transverse”, “transMAX”, “transMIN”, distributions, etc..
- ➔ **CDF - Two  $\eta$  Ranges:** Must do ( $p_T > 0.5 \text{ GeV}/c$ ,  $|\eta| < 0.8$ ) as well as ( $p_T > 0.5 \text{ GeV}$ ,  $|\eta| < 1$ ).
- ➔ **CDF - Min-Bias:** Many MB observables: Multiplicity,  $dN/d\eta$ ,  $p_T$  distribution,  $\langle p_T \rangle$  versus Nchg, etc.

Soon we will have MB & UE data at 300 GeV, 900 GeV, 1.96 TeV, 7 TeV, and 8 TeV!  
We can study the energy dependence more precisely than ever before!

