Monte-Carlo Workshop

New MB & UE Data and Tunes

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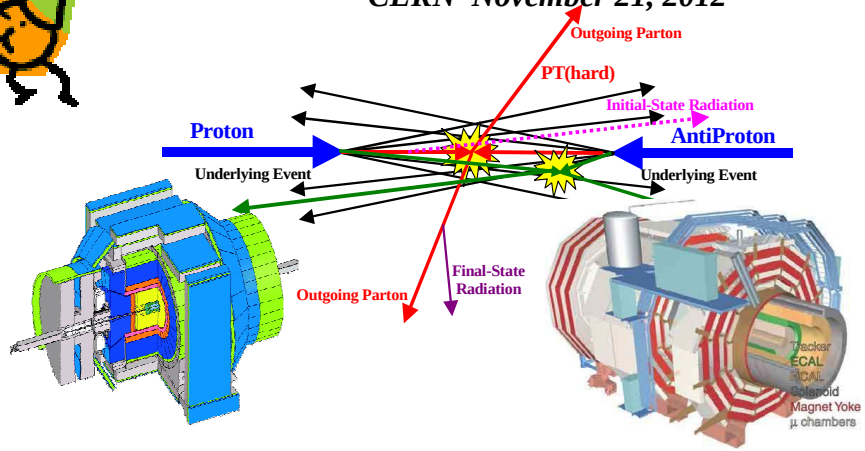
Quantum Chromo-Dynamics

CERN November 21, 2012

Outline of Talk

- **LPCC MB&UE working group "common plots".**
- **New CMS UE "common plots".**
- **New CDF MB & UE "common plots" from the Tevatron Energy Scan.**
- **CDF-CMS comparisons!**
- **Comparisons with PYTHIA 6.4 Tune Z1.**
- **More data coming!**
- **More Monte-Carlo tunes coming!**



CDF Run 2

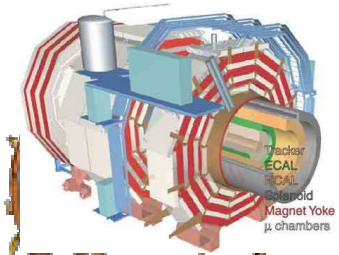
300 GeV, 900 GeV, 1.96 TeV

CMS at the LHC

900 GeV & 7 TeV

MB & UE Common Plots

Quantum Chromo-Dynamics



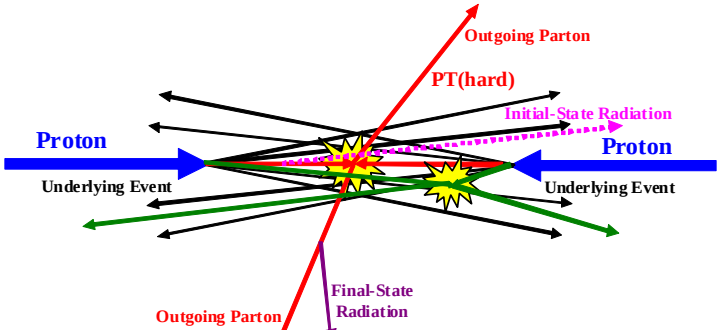
CMS

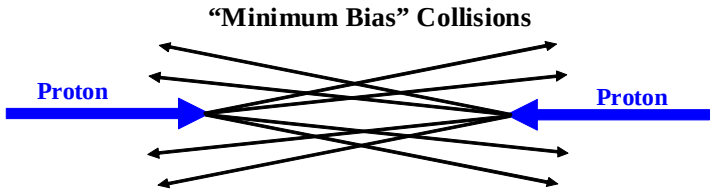
ATLAS

➡ **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.**

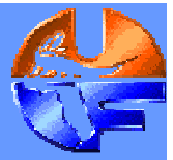
ALICE

LHCb





CMS Common Plots



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

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

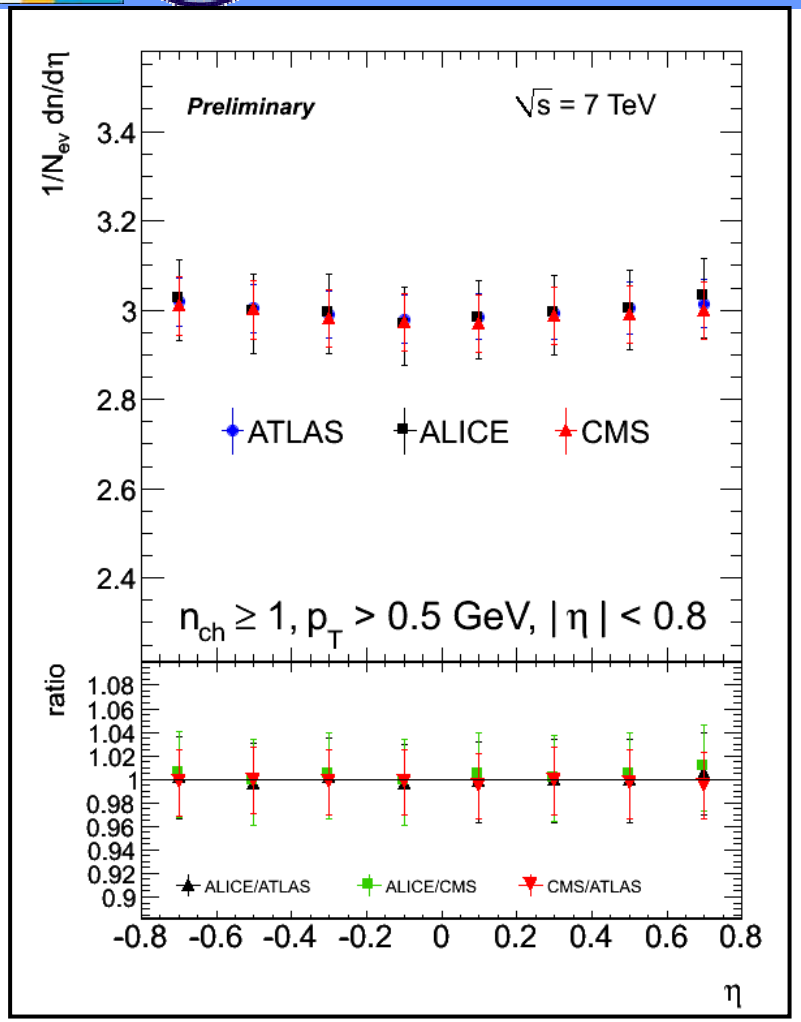
CMS Common Plots

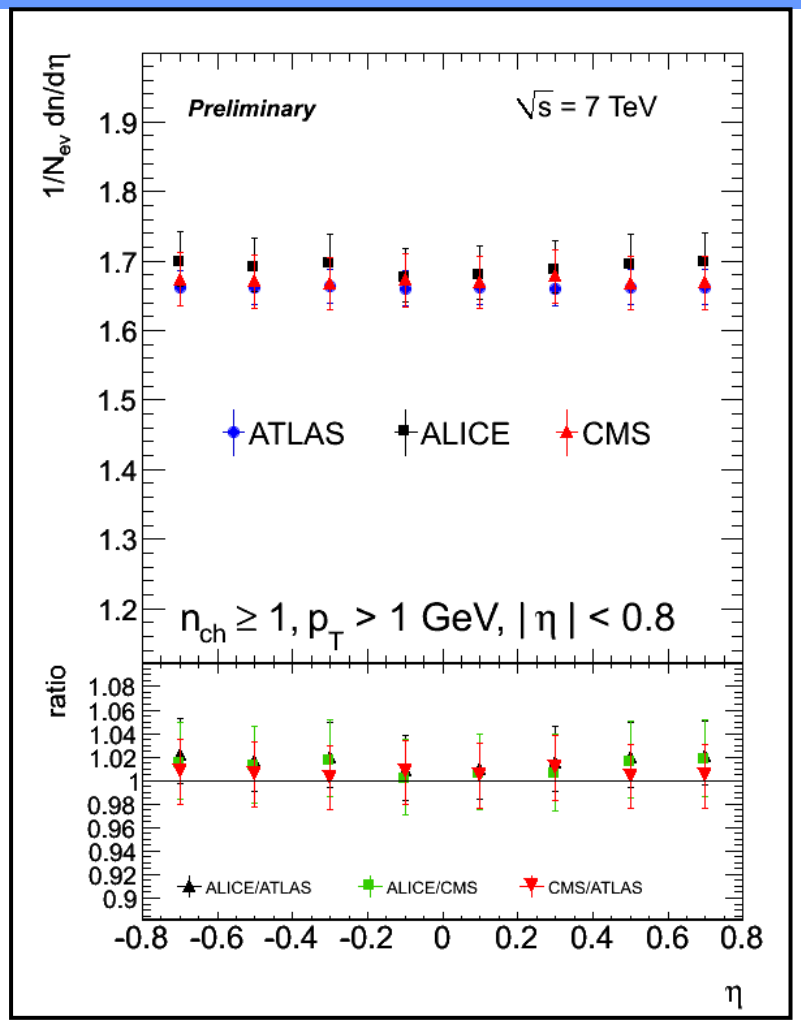
Observable	900 GeV	7 TeV
MB1: d… $N_{chg} \geq 1$	Do…	Done
$\|\eta\| < 0.8$ p_T > …/c & 1.0 G…	QC…	…0-024
MB2: dN_{chg}/dp_T …		Stalled
MB…		
$\|\eta\| < 0.8$ …		
MB4: $\langle p_T \rangle$ ver…		…cs
$\|\eta\| < 0.8$ p_T > …		
UE1: …ransverse Nchg defined by the leading particle, PTmax		…one
$\|\eta\| < 0.8$ p_T > 0.5 GeV/c & 1.0 G…	FSQ…	F… 12-020

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

Direct charged partic… (including leptons) corrected to the particle level with …o corrections for SD or DD.

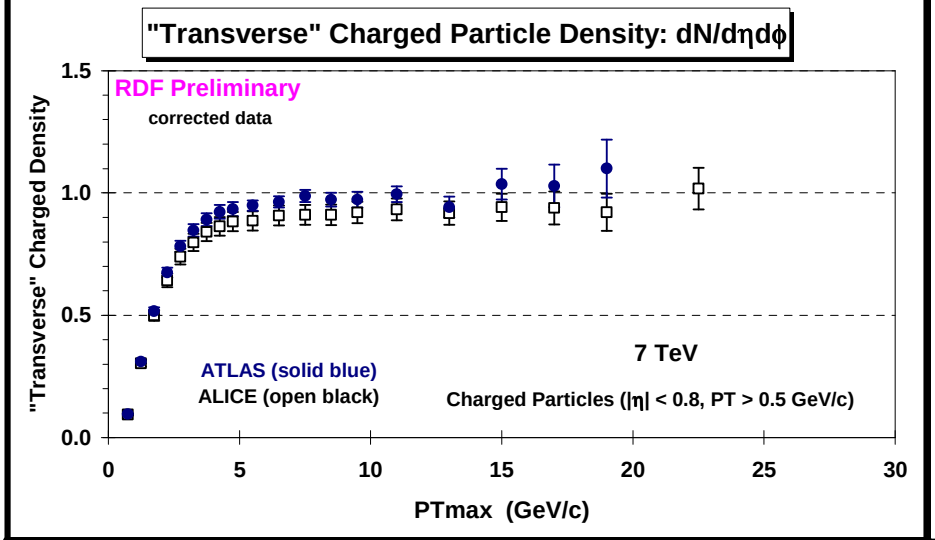
MB Common Plots 7 TeV

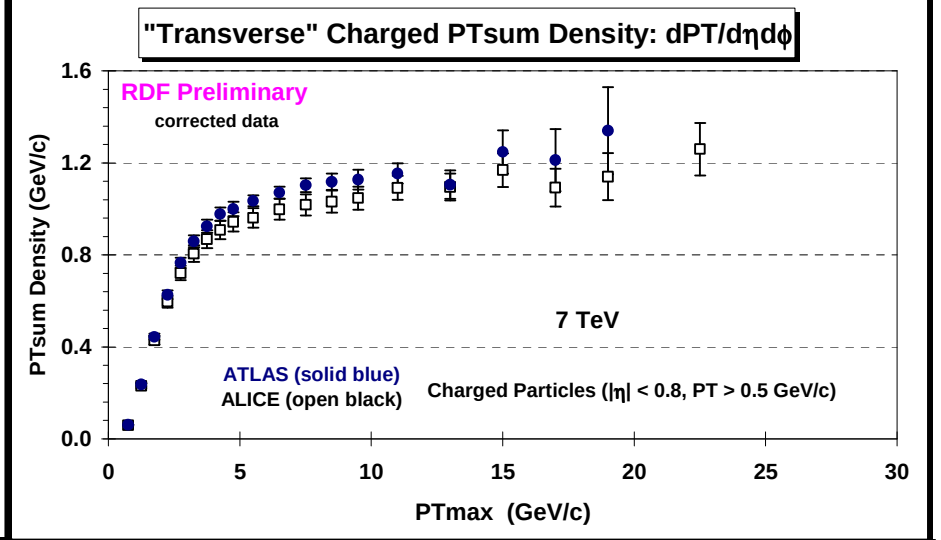


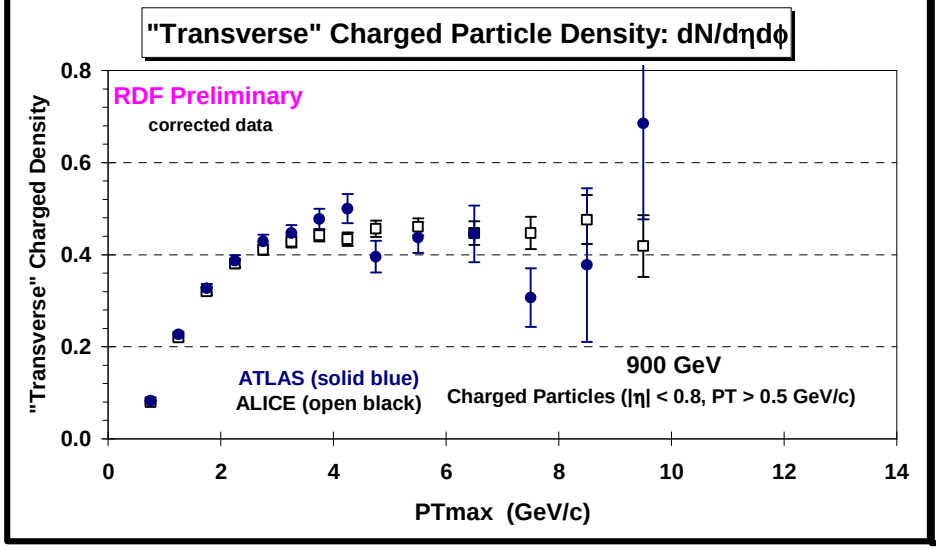


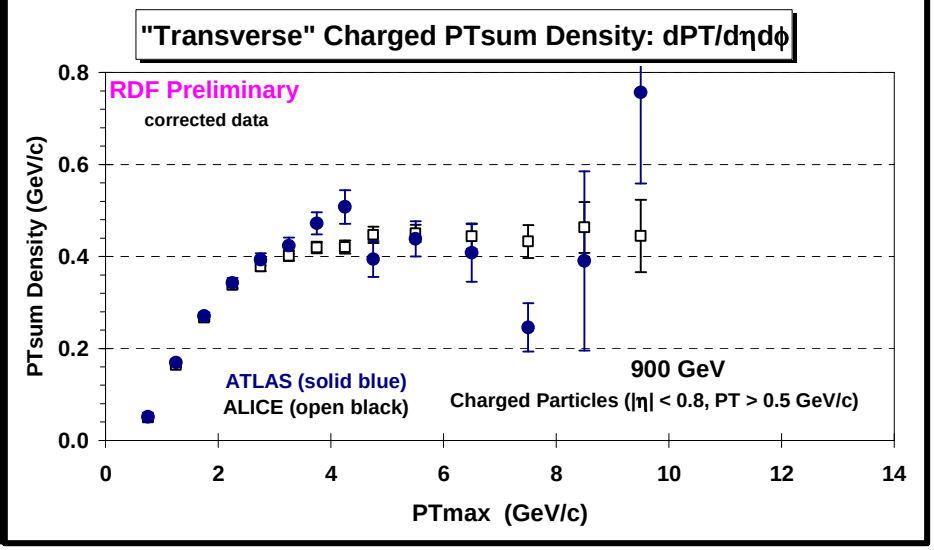
Direct charged particles (including leptons) corrected to the particle level with no corrections for SD or DD.

UE Common Plots

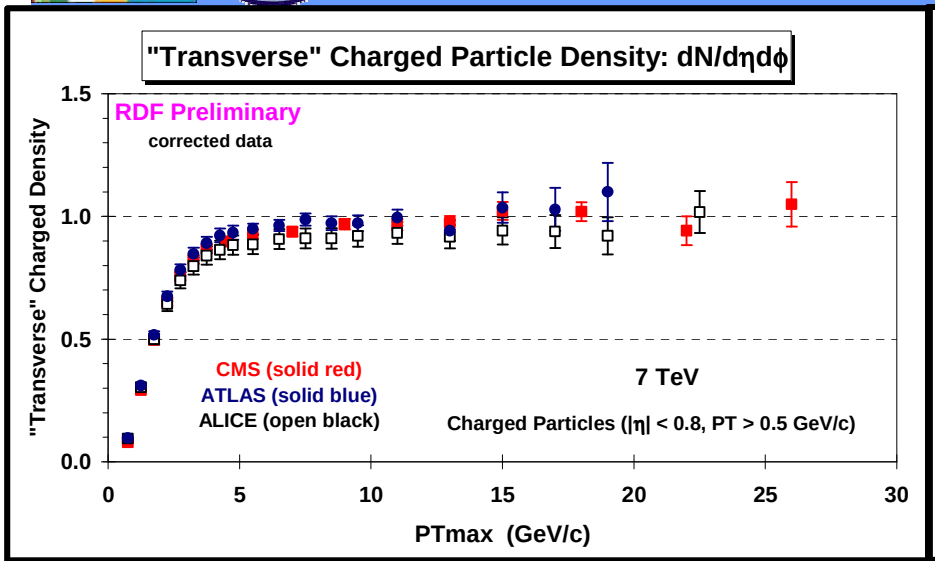


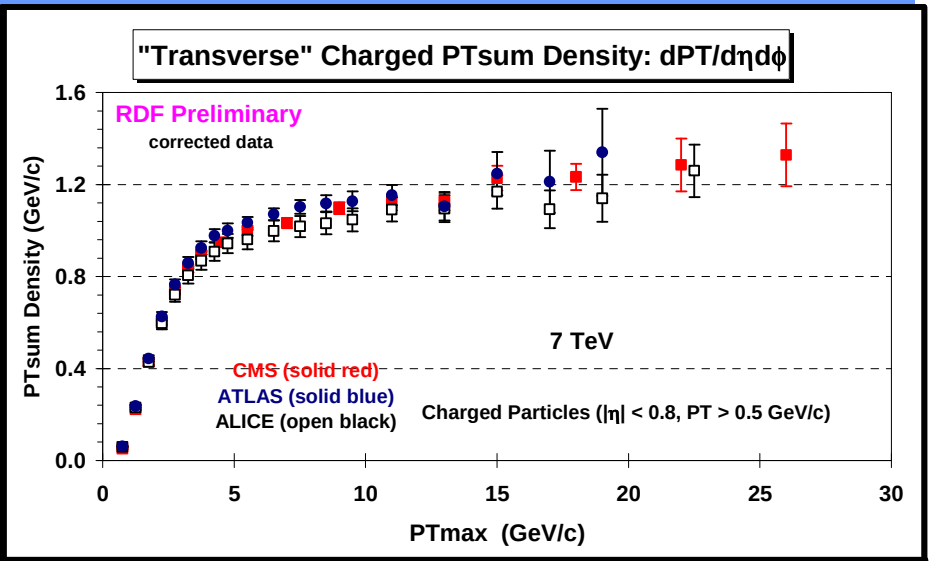


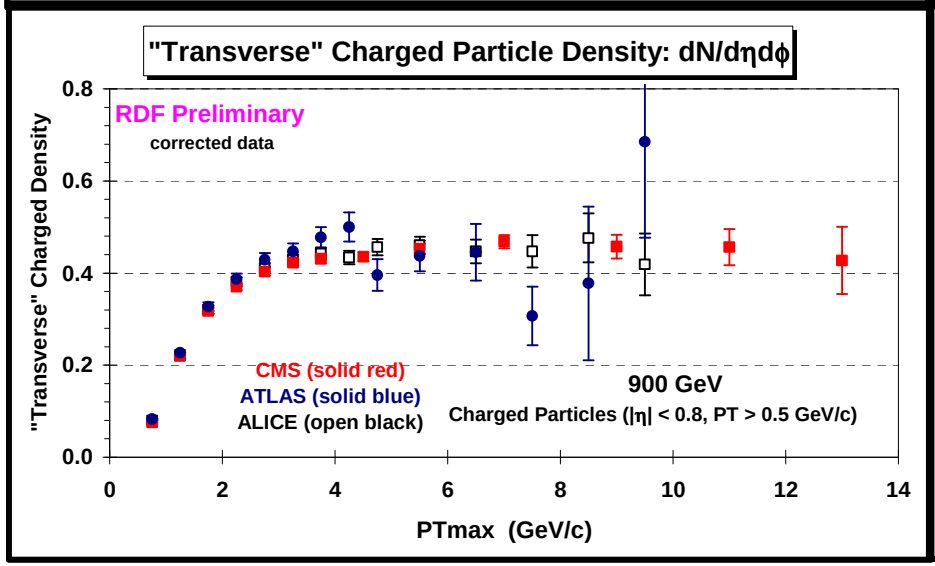


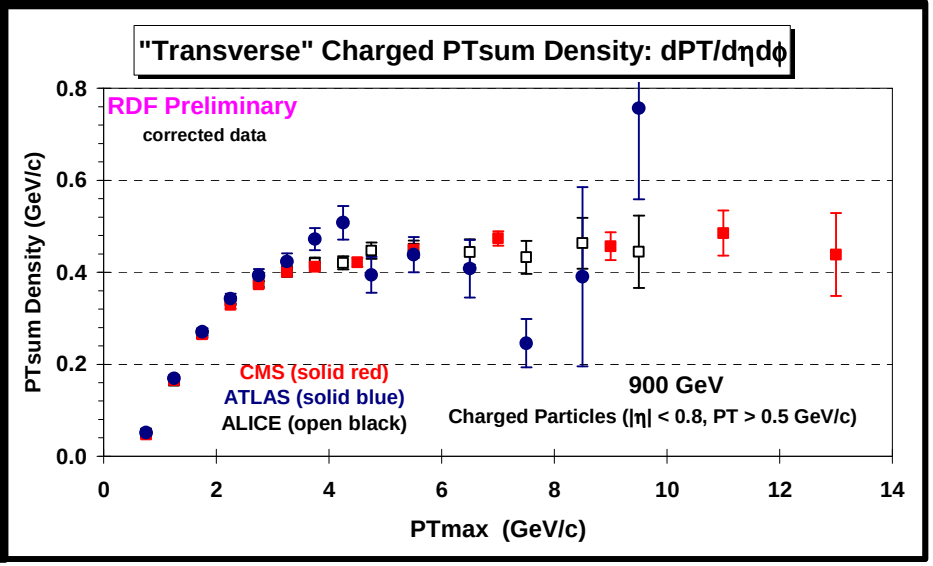


UE Common Plots

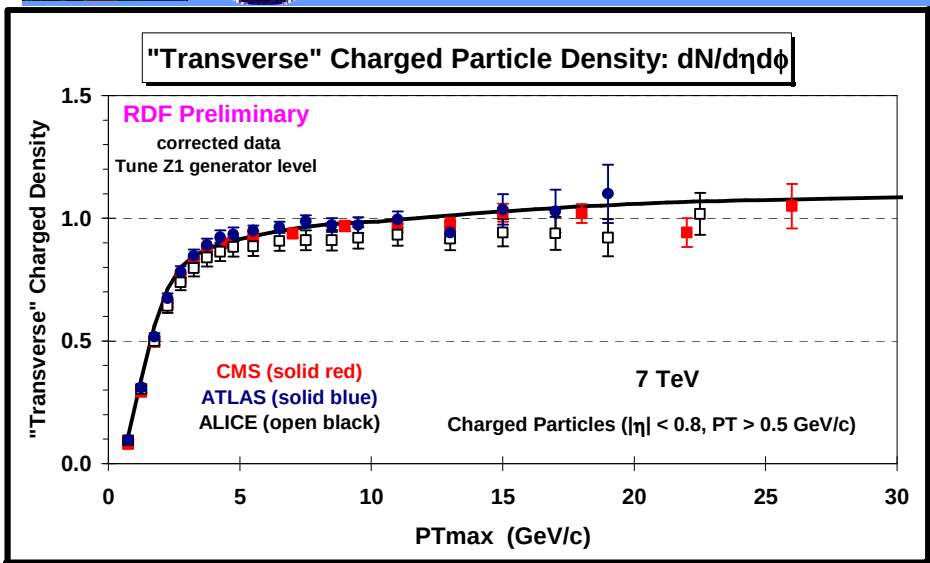


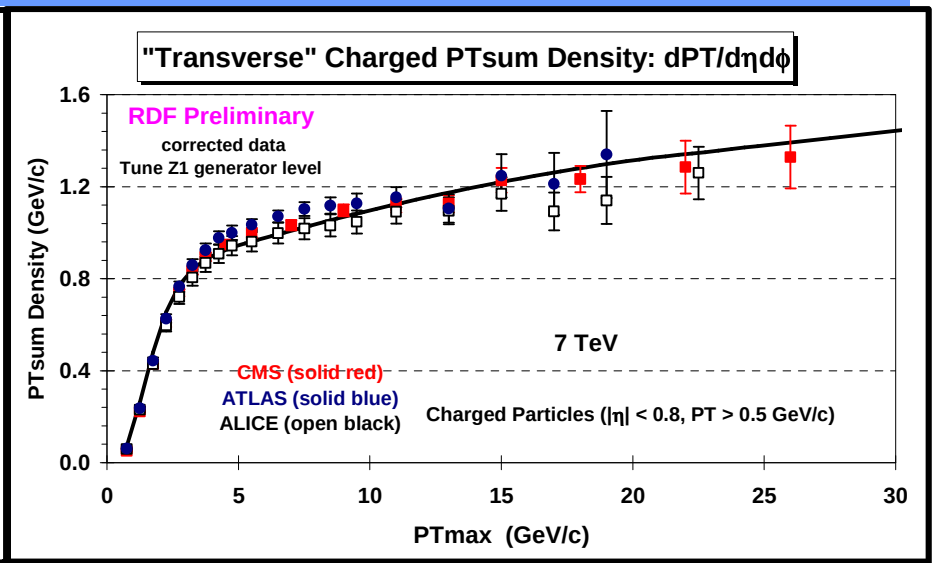


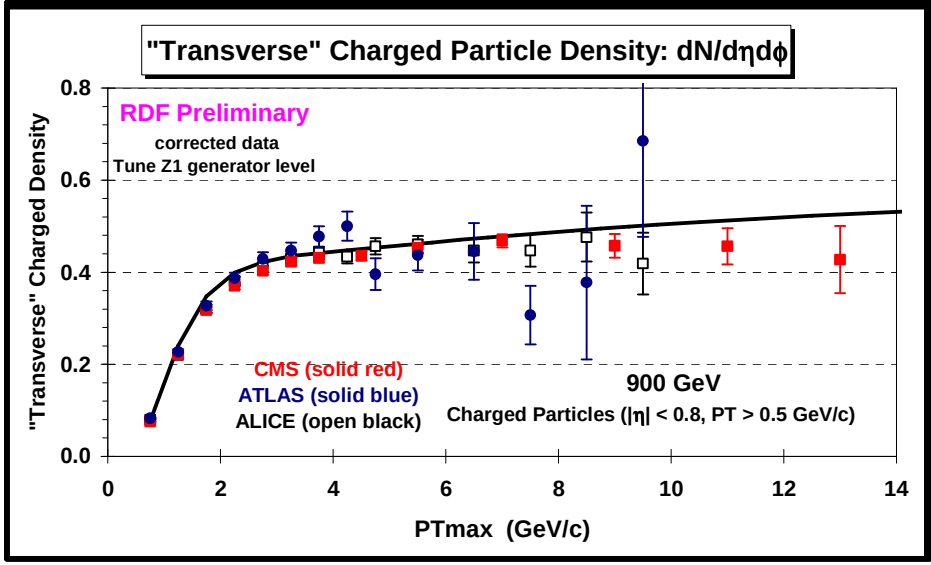


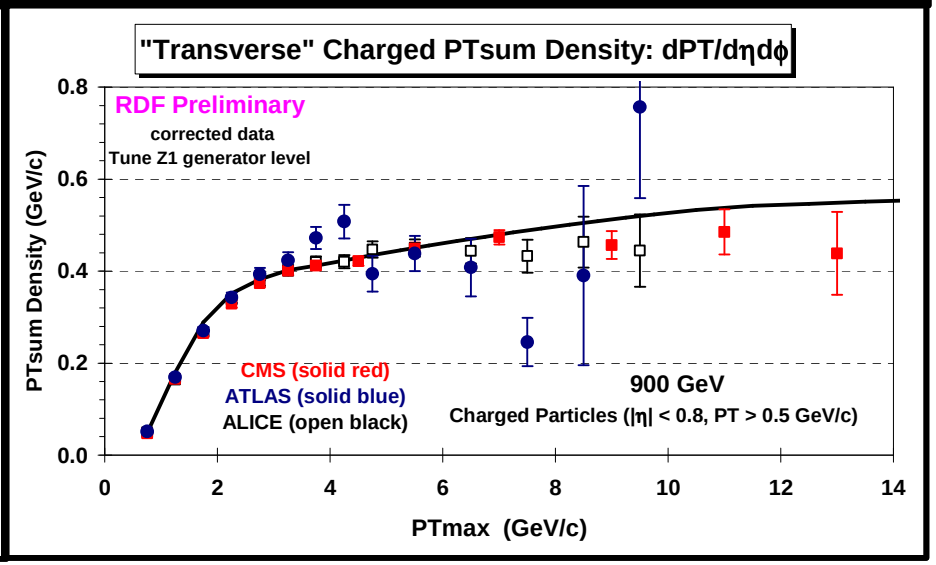


UE Common Plots

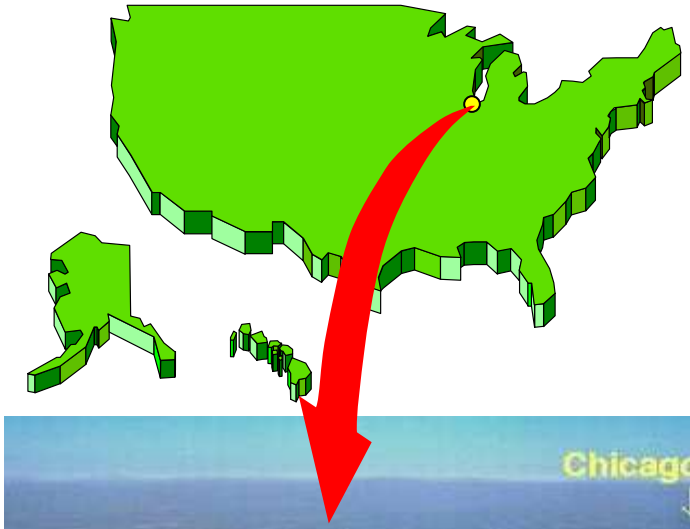


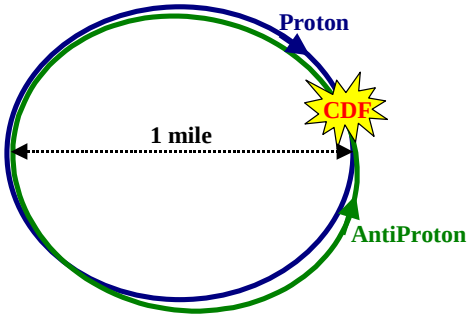






Tevatron Energy Scan





➡ **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

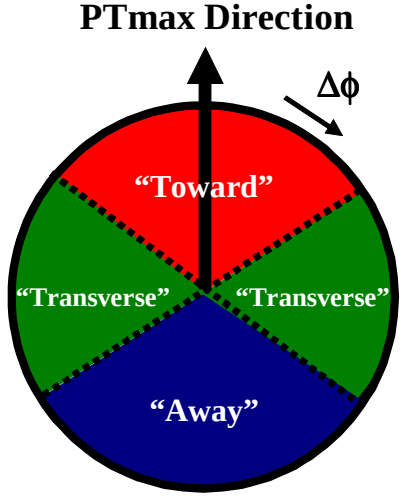
CDF Common Plots

Observable	300 GeV	900 GeV	1.96 TeV
MB1: $dN_{chg}/d\eta$ $N_{chg} \geq 1$ $\|\eta\| < 0.8$ $p_T > 0.5$ Gev/c & 1.0 GeV/c	Done	Done	Done
MB2: dN_{chg}/dp_T $N_{chg} \geq 1$ $\|\eta\| < 0.8$	In progress	In progress	In progress
MB3: Multiplicity Distribution $\|\eta\| < 0.8$ $p_T > 0.5$ GeV/c & 1.0 GeV/c	In progress	In progress	In progress
MB4: $\langle p_T \rangle$ versus Nchg $\|\eta\| < 0.8$ $p_T > 0.5$ GeV/c & 1.0 GeV/c	In progress	In progress	In progress
UE1: Transverse Nchg & PTsum as defined by the leading charged particle, PTmax $\|\eta\| < 0.8$ $p_T > 0.5$ GeV/c & 1.0 GeV/c	$p_T > 0.5$ GeV/c Done	$p_T > 0.5$ GeV/c Done	$p_T > 0.5$ GeV/c Done

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

UE Observables

➡ **"Transverse" Charged Particle Density: Number of charged particles ($p_T > 0.5$ GeV/c, $|\eta| < \eta_{cut}$) in the "transverse" region as defined by the leading charged particle, PTmax, divided by the area in η-ϕ space, $2\eta_{cut} \times 2\pi/3$, averaged over all events with at least one particle with $p_T > 0.5$ GeV/c, $|\eta| < \eta_{cut}$.**



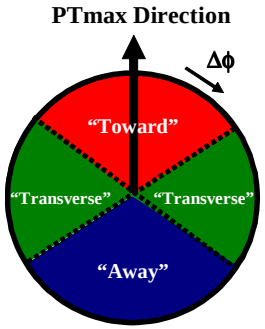
➡ **"Transverse" Charged PTsum Density: Scalar p_T sum of the charged particles ($p_T > 0.5$ GeV/c, $|\eta| < \eta_{cut}$) in the "transverse" region as defined by the leading charged particle, PTmax, divided by the area in η-ϕ space, $2\eta_{cut} \times 2\pi/3$, averaged over all events with at least one particle with $p_T > 0.5$ GeV/c, $|\eta| < \eta_{cut}$.**

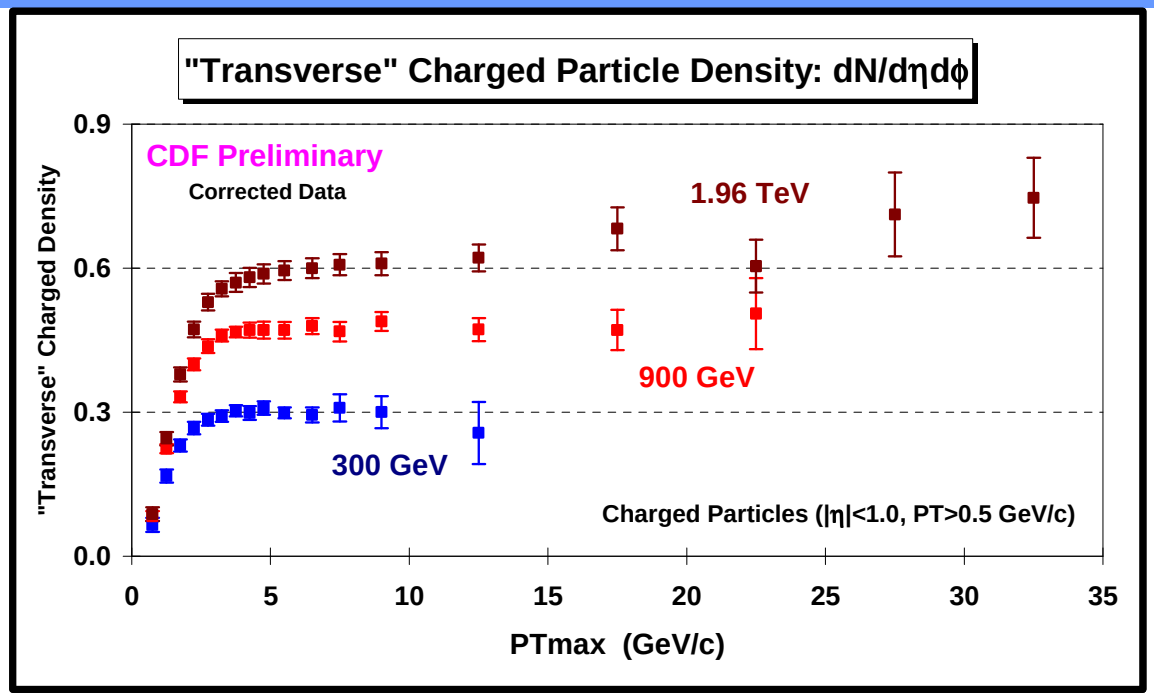
➡ **"Transverse" Charged Particle Average P_T: Event-by-event $\langle p_T \rangle$ = PTsum/Nchg for charged particles ($p_T > 0.5$ GeV/c, $|\eta| < \eta_{cut}$) in the "transverse" region as defined by the leading charged particle, PTmax, averaged over all events with at least one particle in the "transverse" region with $p_T > 0.5$ GeV/c, $|\eta| < \eta_{cut}$.**

➡ **Zero "Transverse" Charged Particles: If there are no charged particles in the "transverse" region then Nchg and PTsum are zero and one includes these zeros in the average over all events with at least one particle with $p_T > 0.5$ GeV/c, $|\eta| < \eta_{cut}$. However, if there are no charged particles in the "transverse" region then the event is not used in constructing the "transverse" average p_T.**

$\eta_{cut} = 1.0$ and $\eta_{cut} = 0.8$

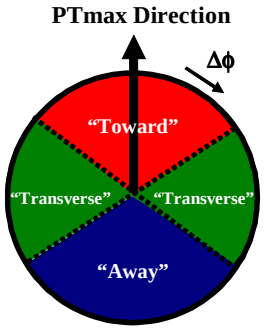
New CDF UE Data

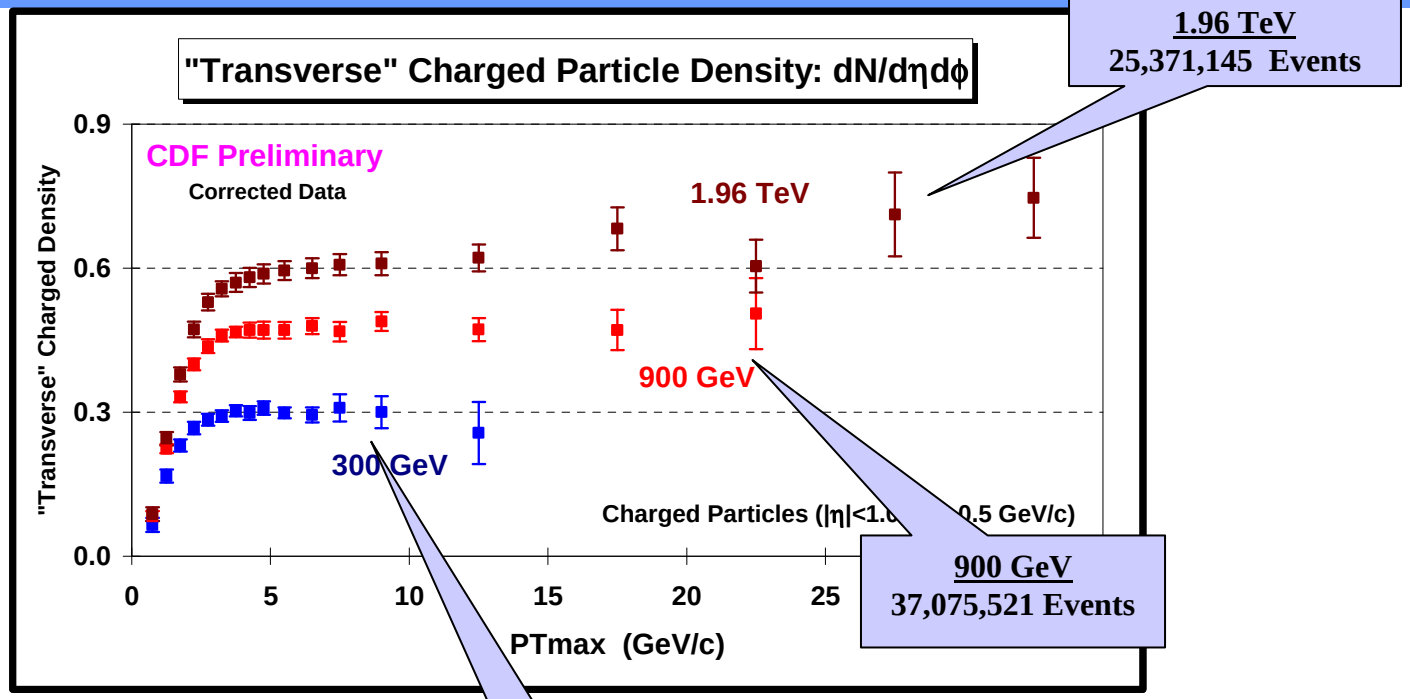




➡ **Corrected CDF data at 300 GeV, 900 GeV, and 1.96 TeV on the "transverse" charged particle density, dN/dηdϕ, as defined by the leading charged particle (PTmax) for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 1.0$.**

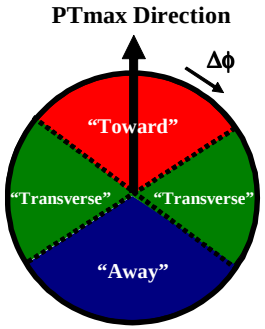
New CDF UE Data

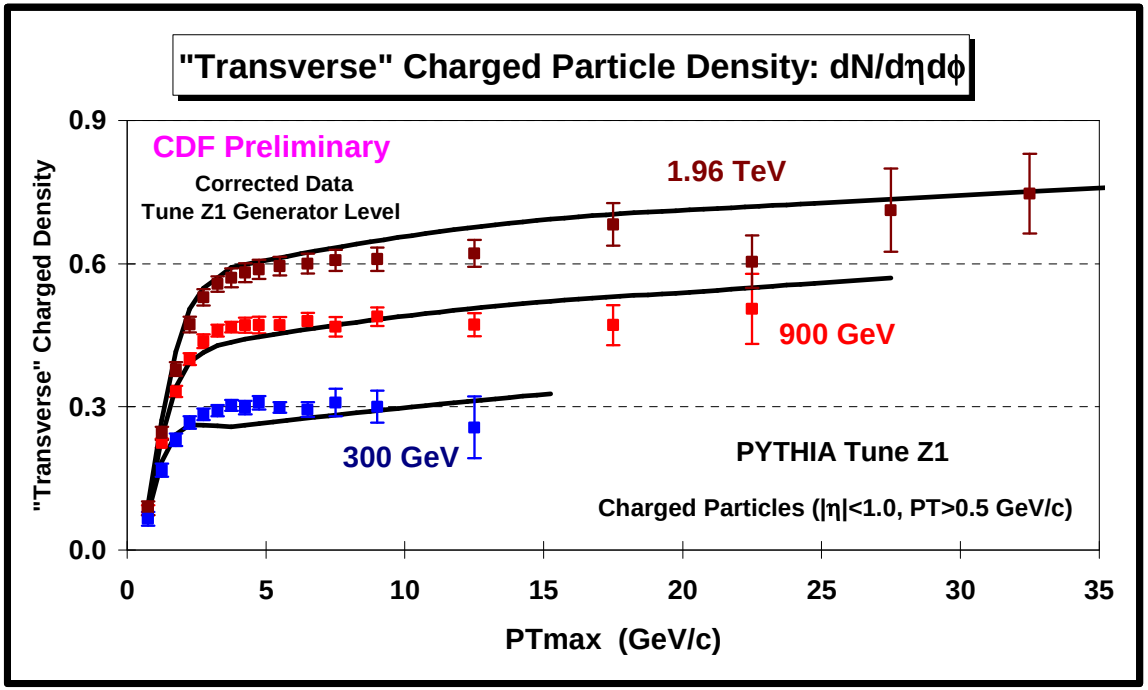




➡ **New Corrected CDF data at 300 GeV, 900 GeV, and 1.96 TeV on the "transverse" charged particle density, dN/dηdφ, as defined by the leading charged particle (PTmax) for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 1.0$.**

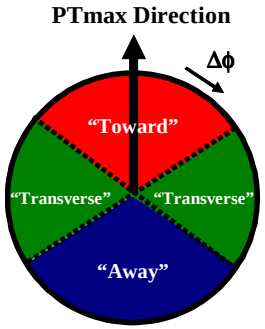
New CDF UE Data

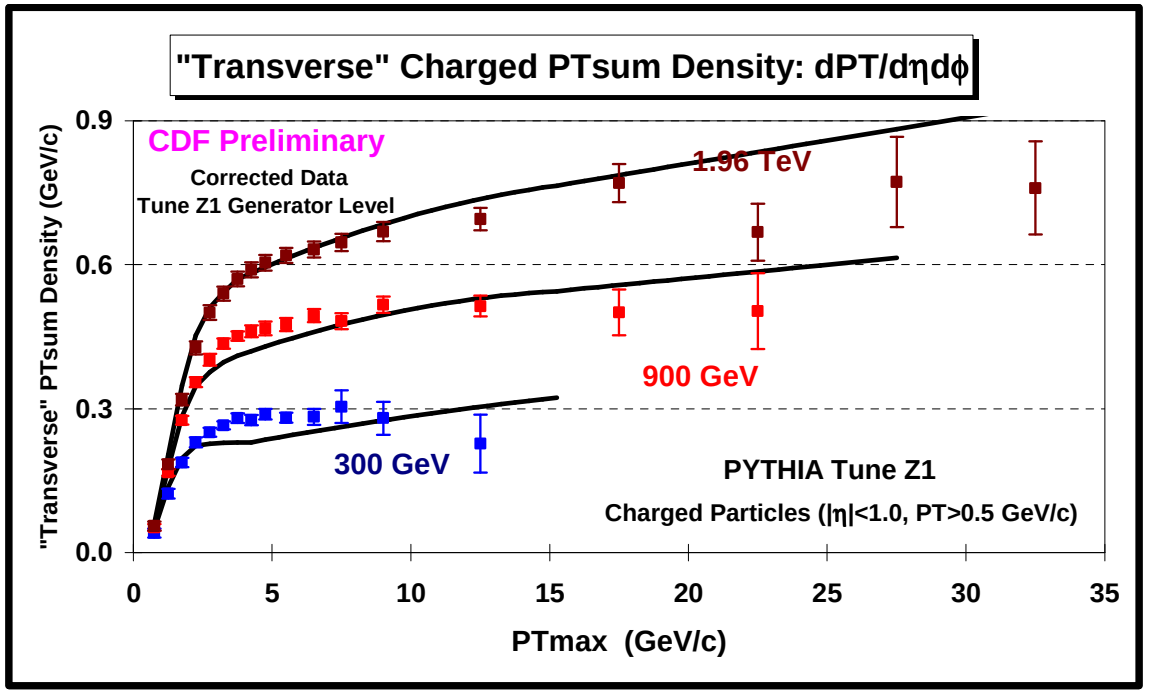




➡ **Corrected CDF data at 300 GeV, 900 GeV, and 1.96 TeV on the "transverse" charged particle density, dN/dηdϕ, as defined by the leading charged particle (PTmax) for charged particles with p_T > 0.5 GeV/c and |η| < 1.0 compared with PYTHIA 6.4 Tune Z1.**

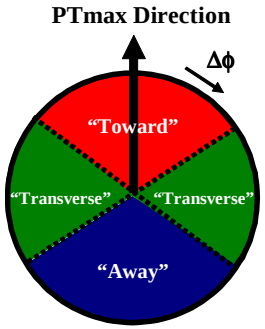
New CDF UE Data

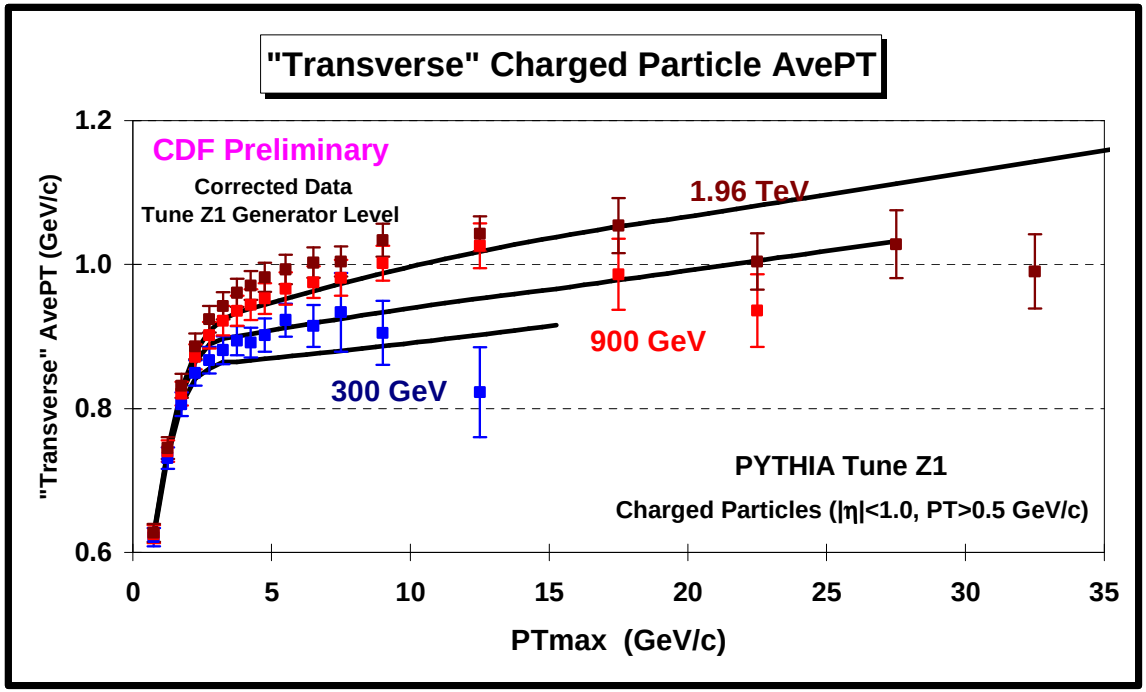




➡ **Corrected CDF data at 300 GeV, 900 GeV, and 1.96 TeV on the "transverse" charged PTsum density, dPT/dηdφ, as defined by the leading charged particle (PTmax) for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 1.0$ compared with PYTHIA 6.4 Tune Z1.**

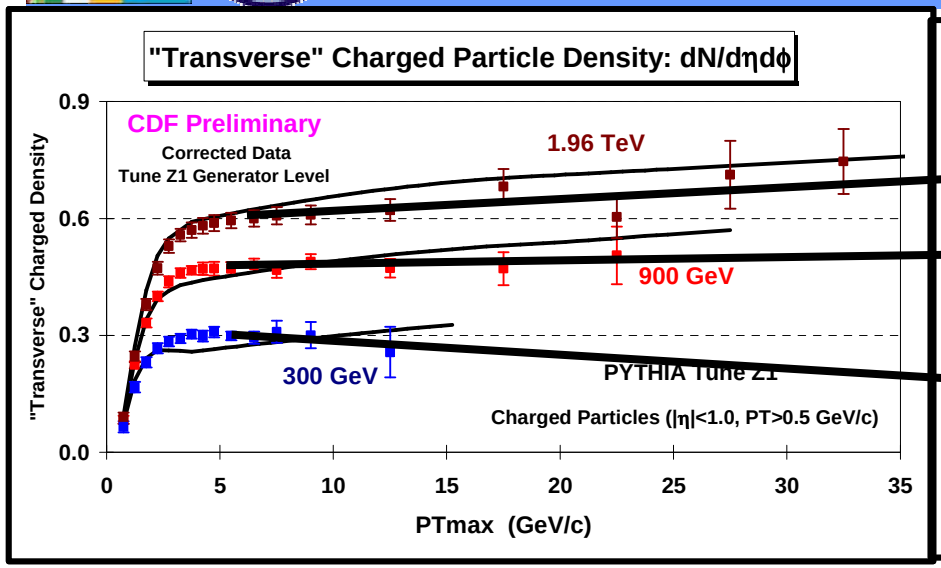
New CDF UE Data

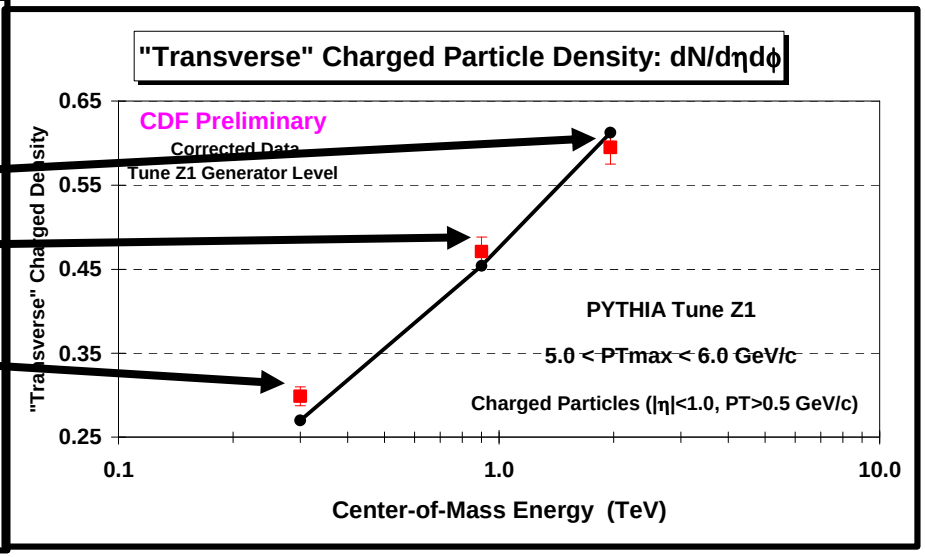




➡ **New Corrected CDF data at 300 GeV, 900 GeV, and 1.96 TeV on the "transverse" charged particle average p_T, as defined by the leading charged particle (PTmax) for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 1.0$.**

Energy Dependence

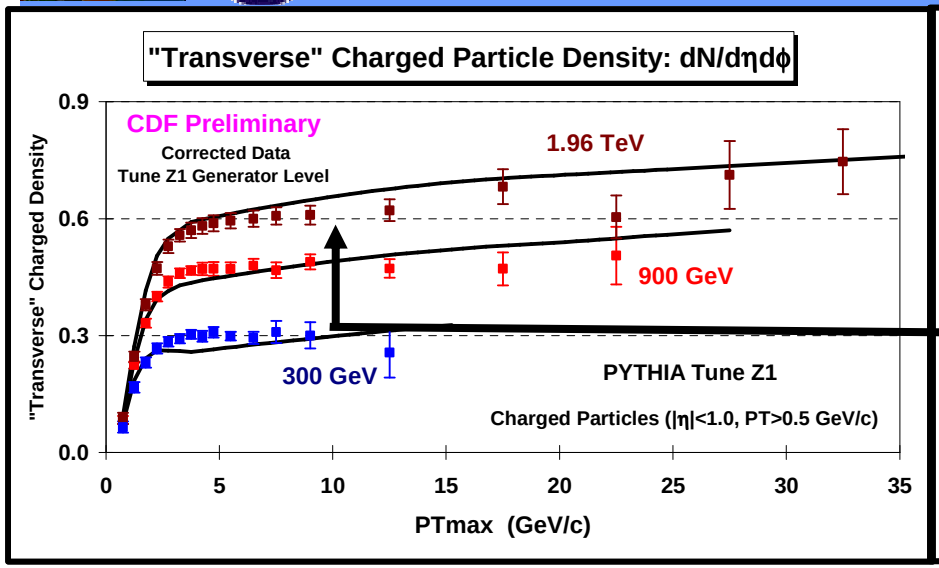


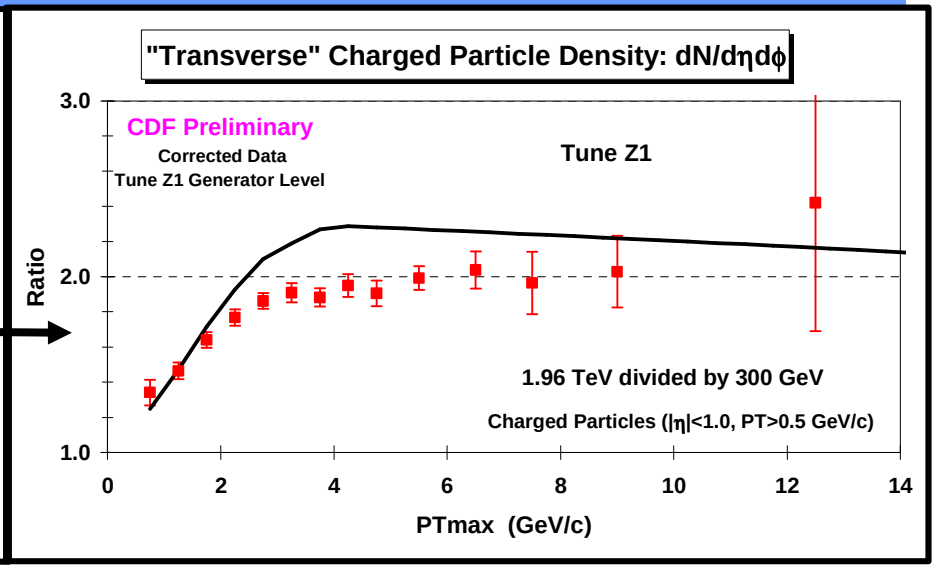


➡ **New Corrected CDF data at 300 GeV, 900 GeV, and 1.96 TeV on the "transverse" charged particle density, dN/dηdϕ, as defined by the leading charged particle (PTmax) for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 1.0$.**

➡ **New Corrected CDF data at 300 GeV, 900 GeV, and 1.96 TeV on the "transverse" charged particle density, dN/dηdϕ, 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 Ratio: 1960/300

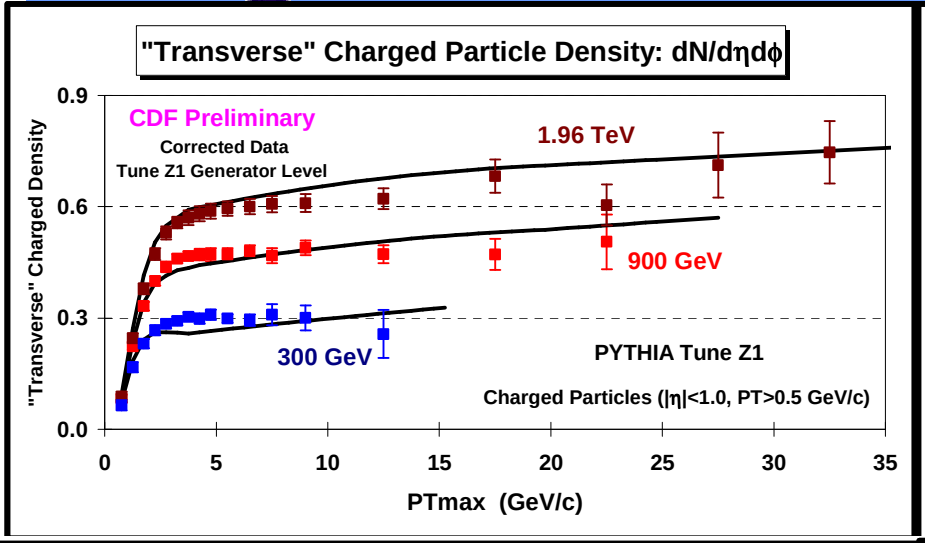


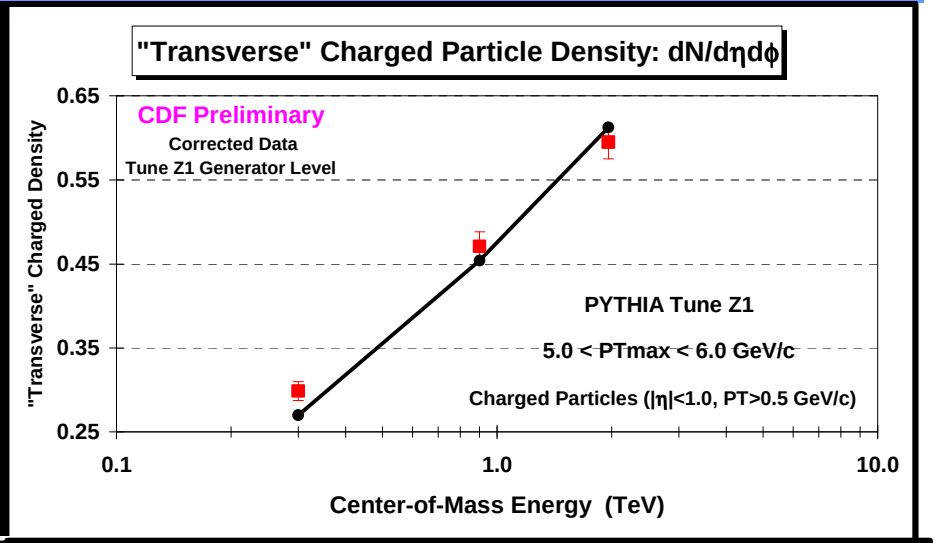


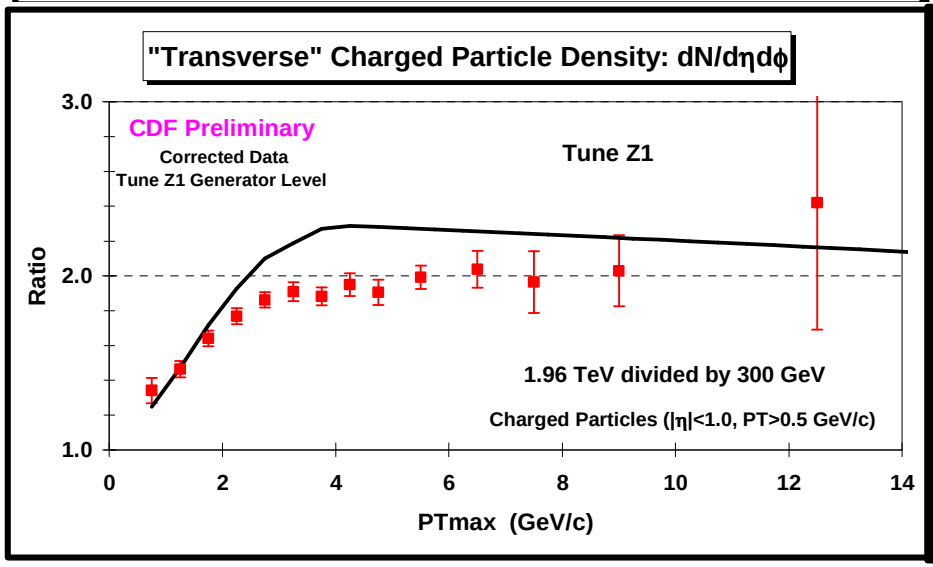
➡ **New Corrected CDF data at 300 GeV, 900 GeV, and 1.96 TeV on the "transverse" charged particle density, dN/dηdϕ, as defined by the leading charged particle (PTmax) for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 1.0$.**

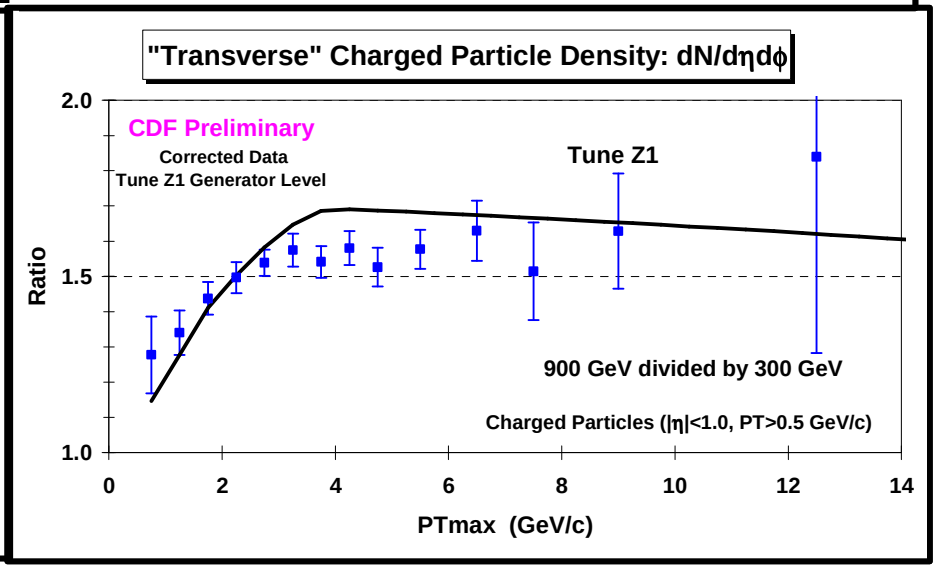
➡ **Ratio of the CDF data at 300 GeV and 1.96 TeV on the "transverse" charged particle density, dN/dηdϕ, as defined by the leading charged particle (PTmax) for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 1.0$. Shows 1.96 TeV divided by 300 GeV.**

PYTHIA 6.4 Tune Z1

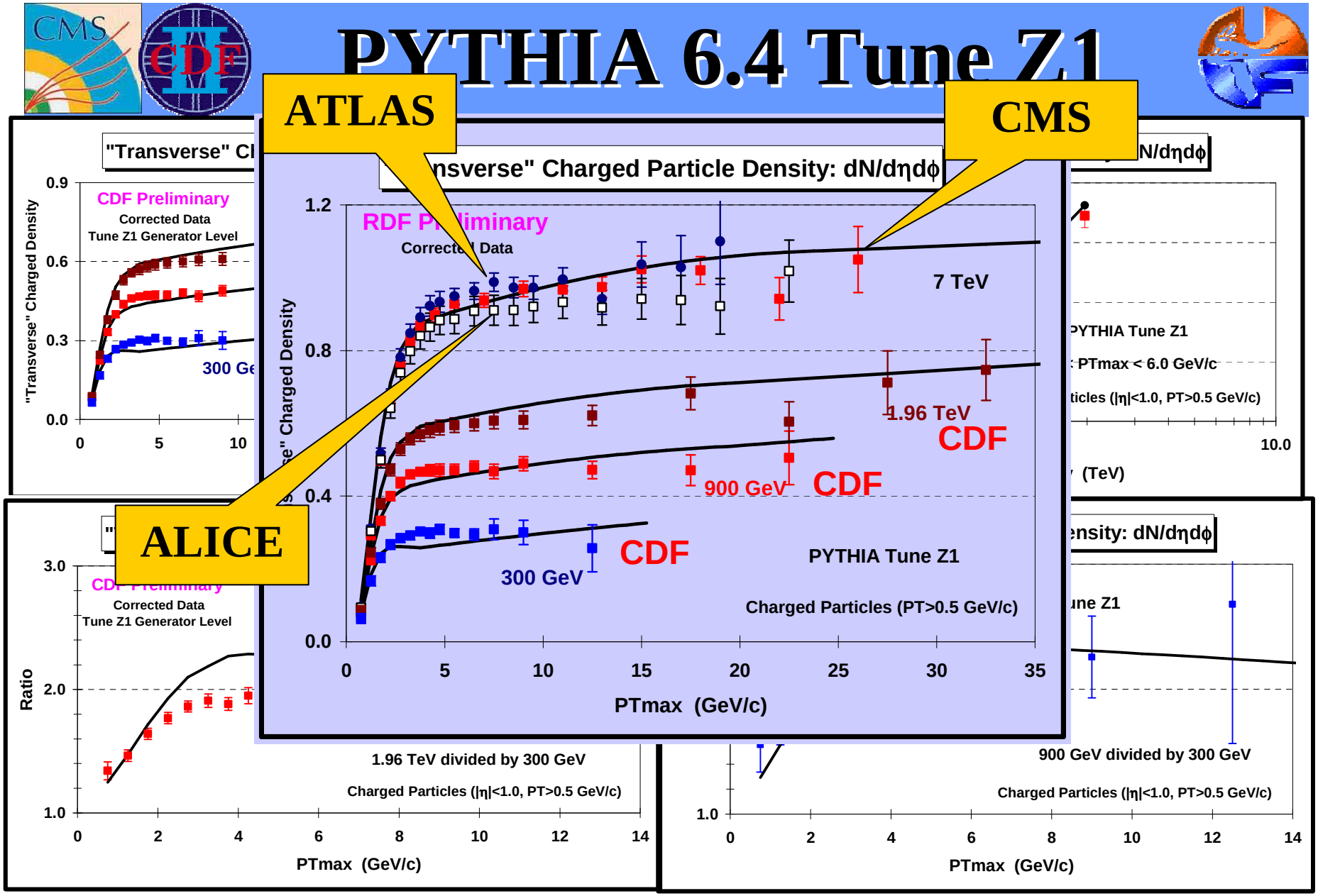




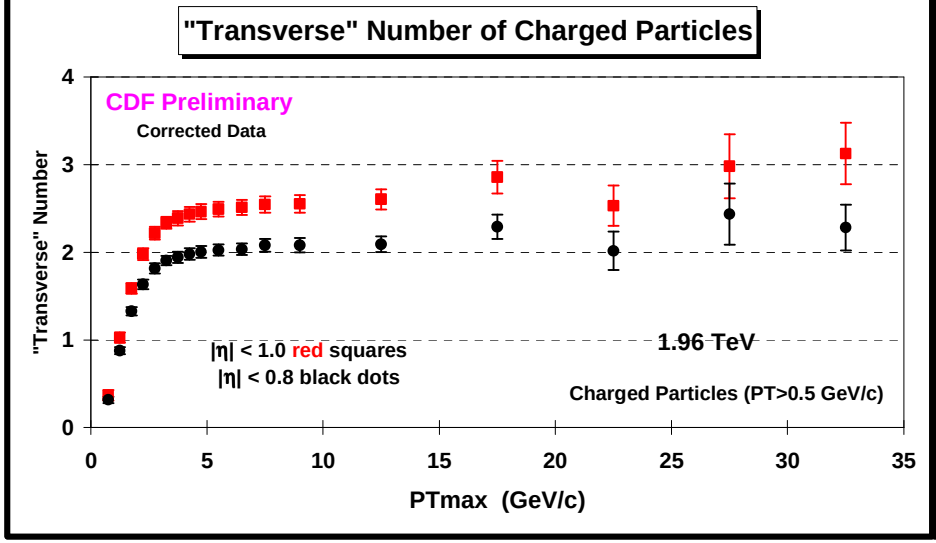


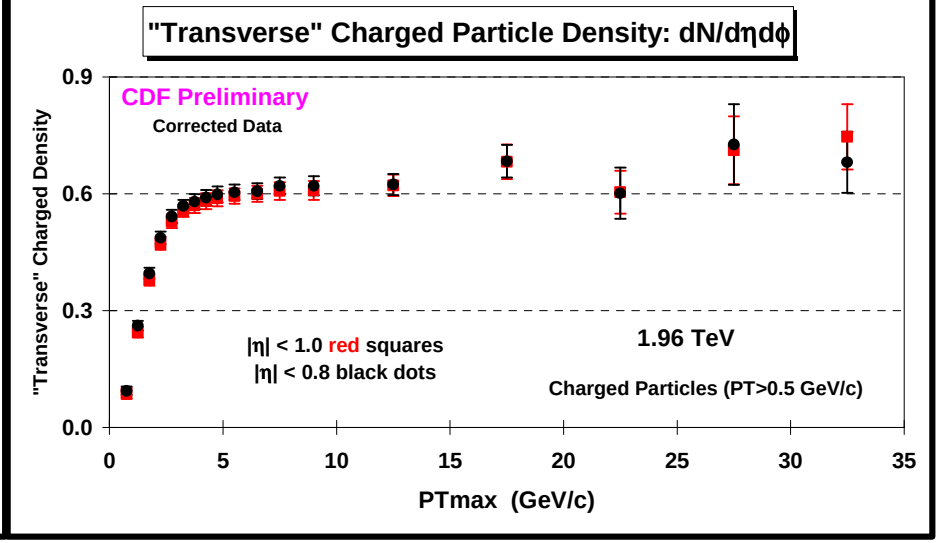


PYTHIA 6.4 Tune Z1



|η| < 0.8 versus |η| < 1.0

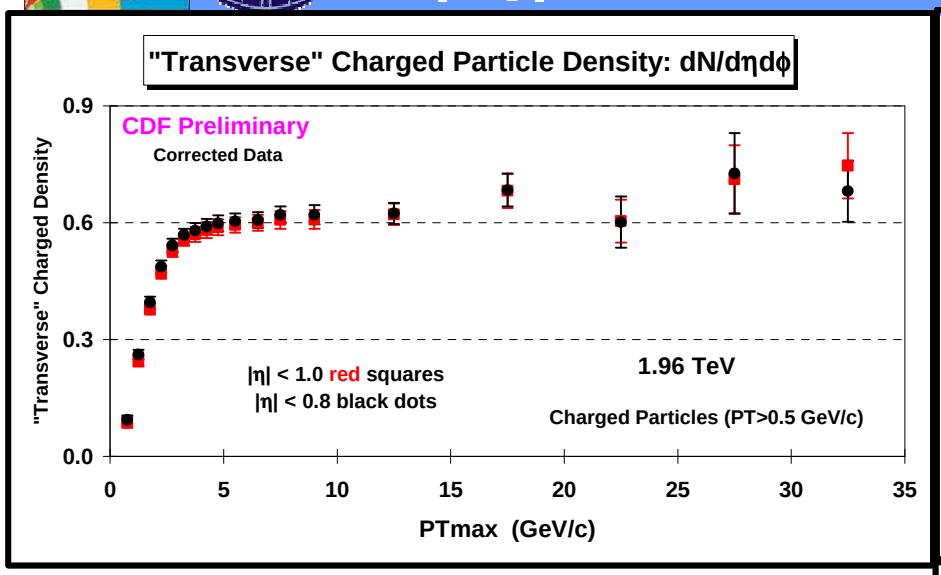


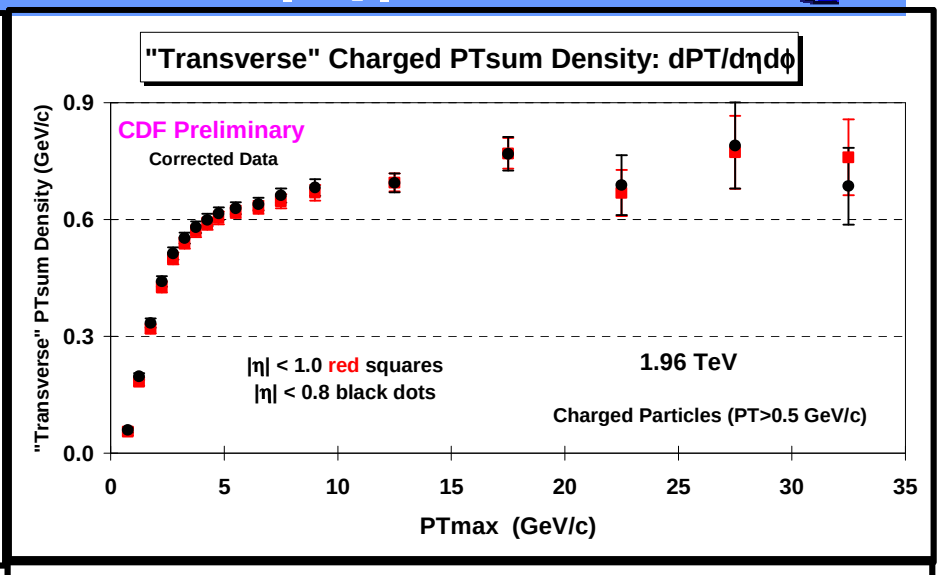


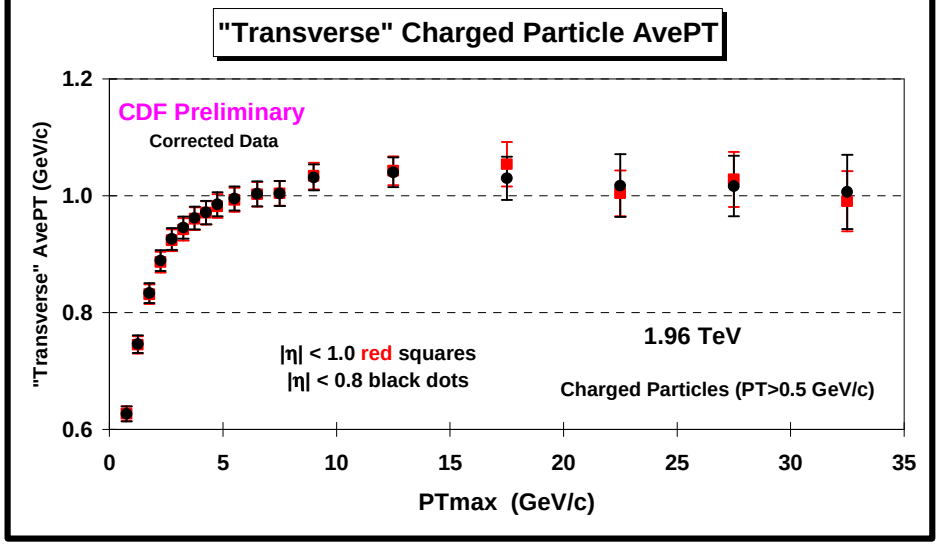
➡ **Corrected CDF data at 1.96 TeV on the average number of charged particle in the "transverse" region as defined by the leading charged particle (PTmax) for charged particles with $p_T > 0.5$ GeV/c and |η| < 0.8 and |η| < 1.0. The data are corrected to the particle level with errors that include both the statistical error and the systematic uncertainty.**

➡ **Corrected CDF data at 1.96 TeV on the average charged particle density, dN/dηdϕ, in the "transverse" region as defined by the leading charged particle (PTmax) for charged particles with $p_T > 0.5$ GeV/c and |η| < 0.8 and |η| < 1.0. The data are corrected to the particle level with errors that include both the statistical error and the systematic uncertainty.**

|η| < 0.8 versus |η| < 1.0

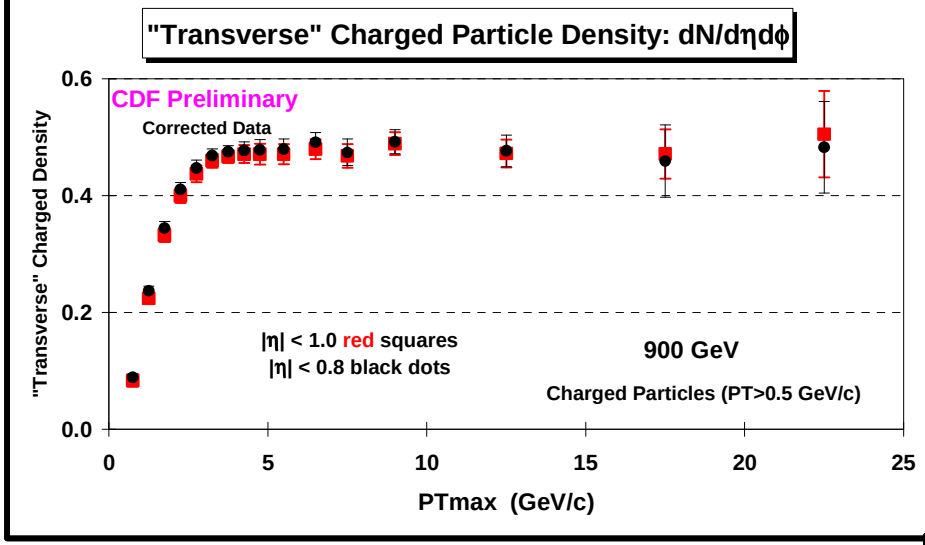


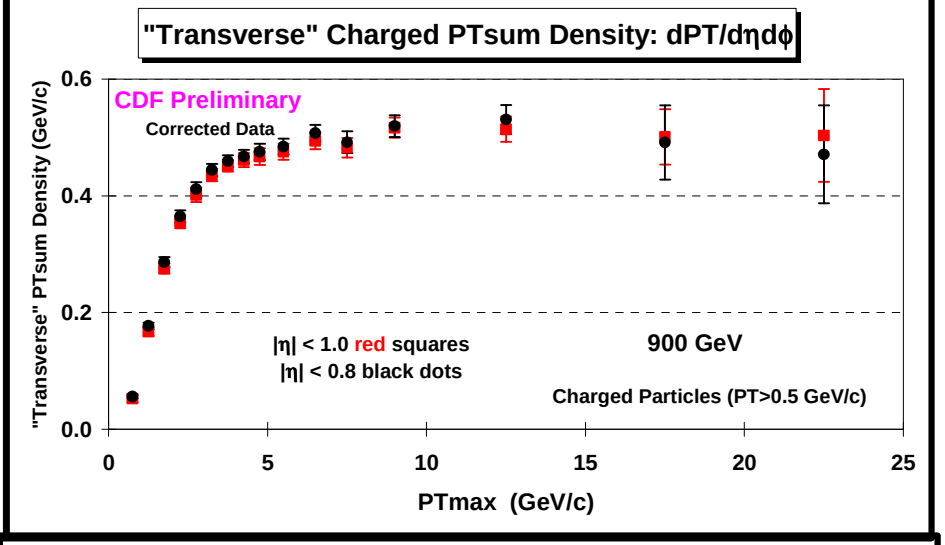




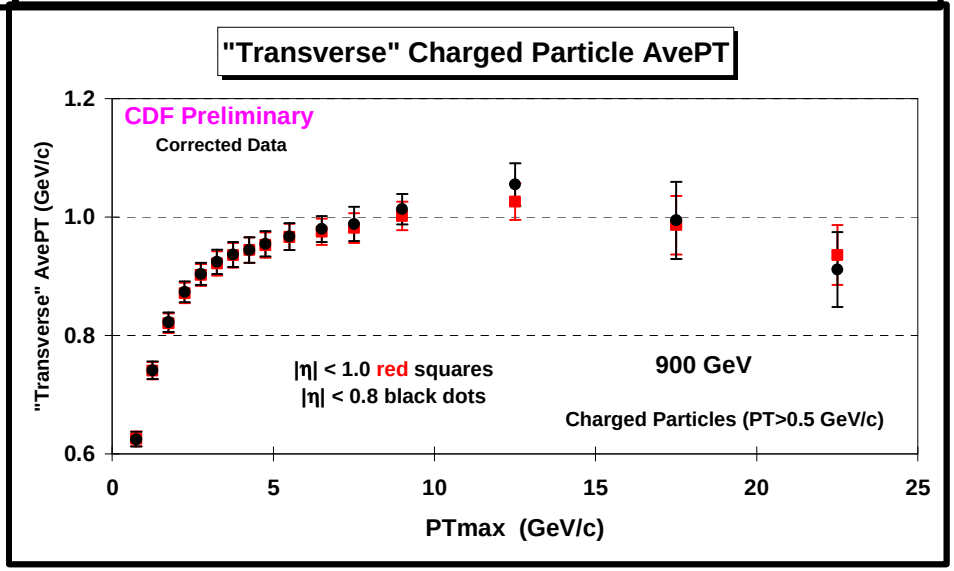
➡ **Corrected CDF data at 1.96 TeV on the charged particle density, the charged PTsum density, and the average p_T in the "transverse" region as defined by the leading charged particle (PTmax) for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 0.8$ and $|\eta| < 1.0$. The data are corrected to the particle level with errors that include both the statistical error and the systematic uncertainty.**

|η| < 0.8 versus |η| < 1.0

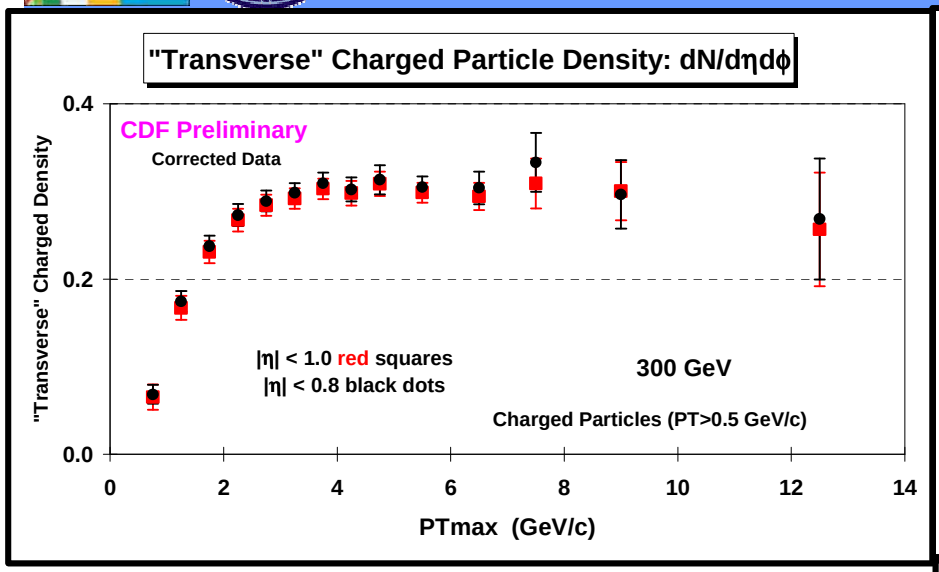


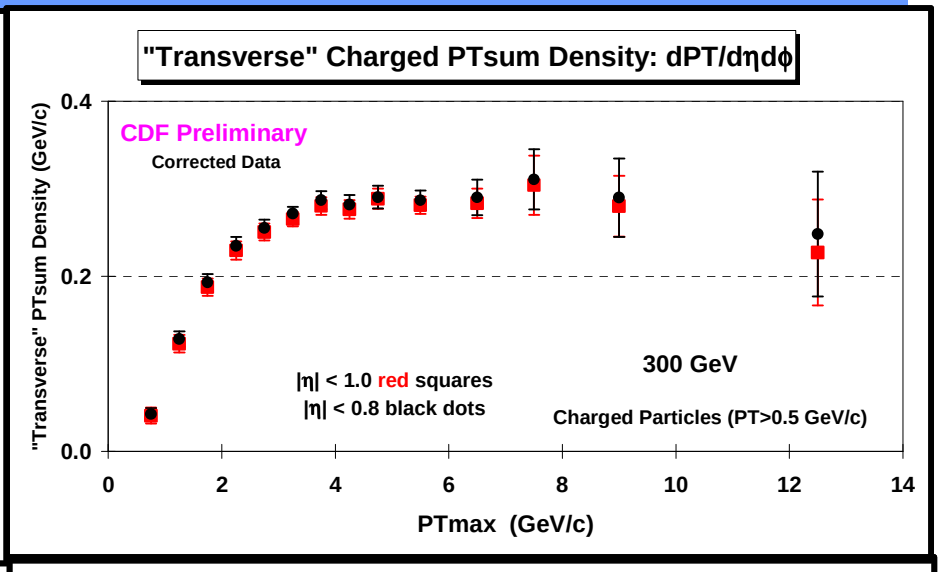


➡ **Corrected CDF data at 900 GeV on the charged particle density, the charged PTsum density, and the average p_T in the "transverse" region as defined by the leading charged particle (PTmax) for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 0.8$ and $|\eta| < 1.0$. The data are corrected to the particle level with errors that include both the statistical error and the systematic uncertainty.**

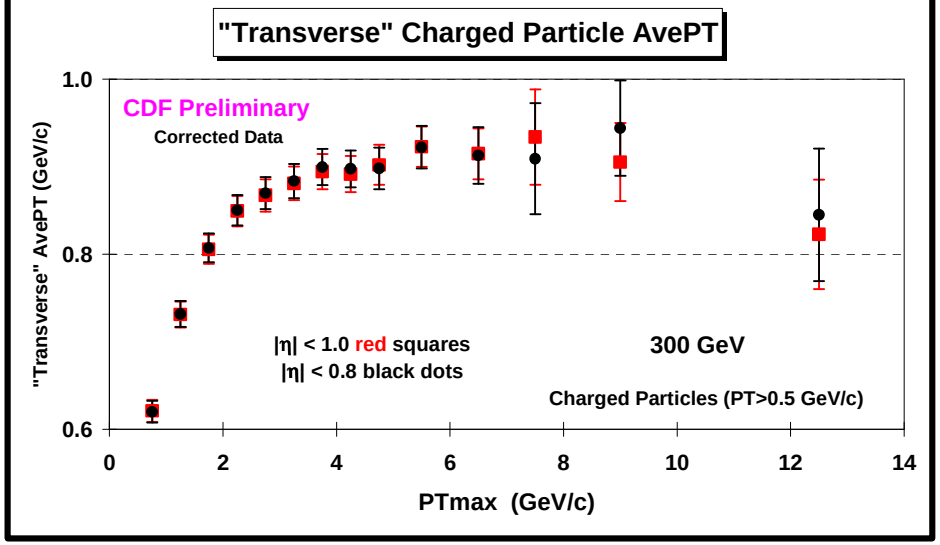


|η| < 0.8 versus |η| < 1.0

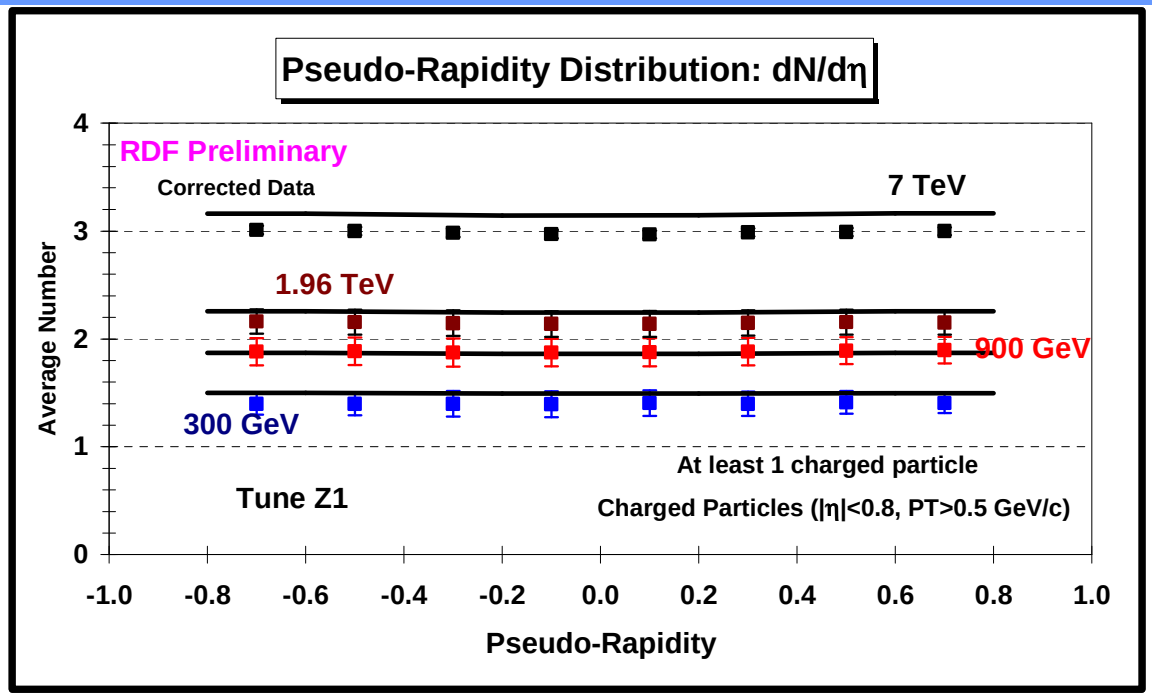




➡ **Corrected CDF data at 300 GeV on the charged particle density, the charged PTsum density, and the average p_T in the "transverse" region as defined by the leading charged particle (PTmax) for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 0.8$ and $|\eta| < 1.0$. The data are corrected to the particle level with errors that include both the statistical error and the systematic uncertainty.**

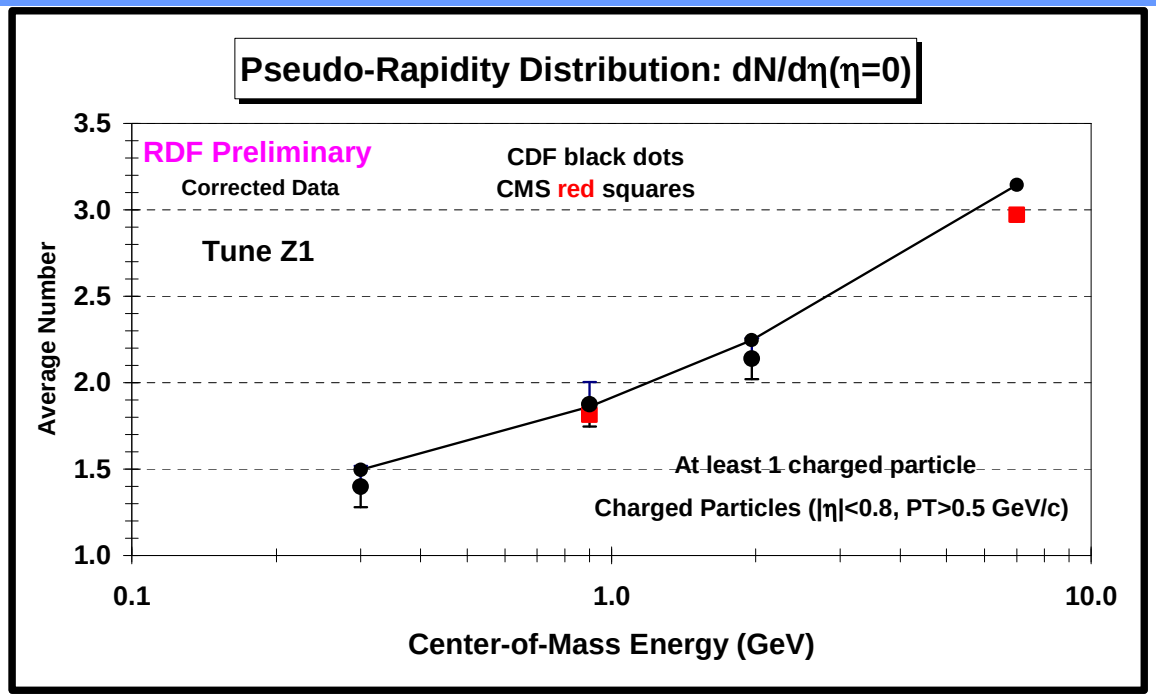


New CDF MB Data



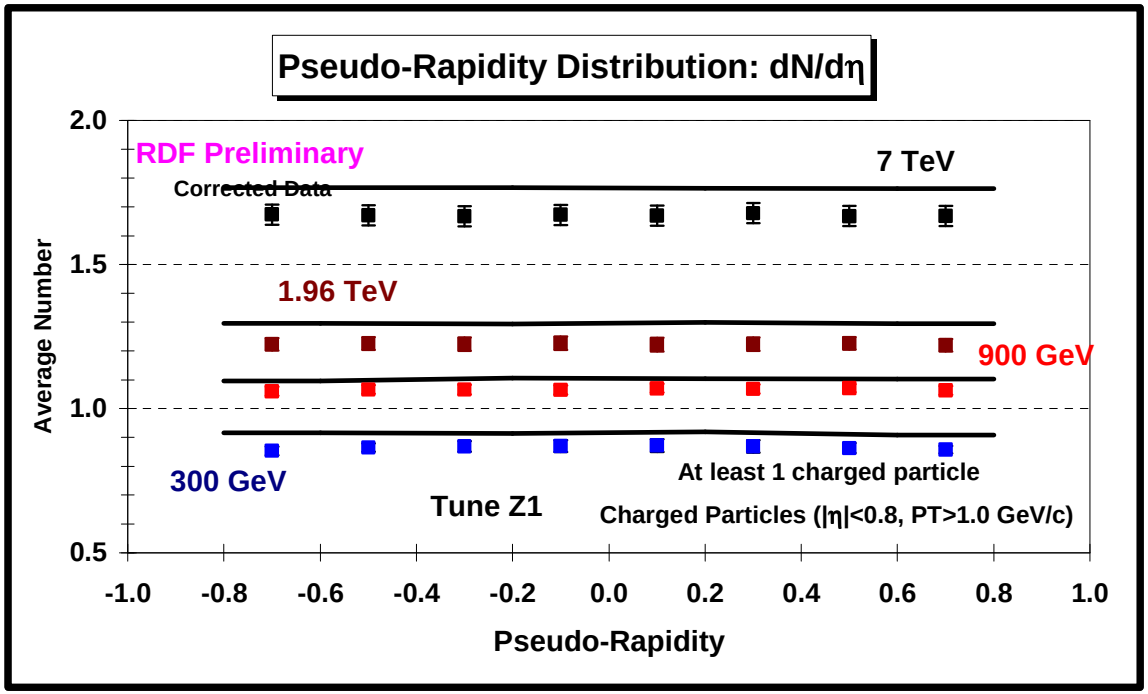
➡ **CDF data at 300 GeV, 900 GeV, and 1.96 TeV and CMS data at 7 TeV on on pseudo-rapidity distribution of charged particles, dN/dη, with $p_T > 0.5$ GeV/c. Events are required to have at least one charged particle with $|\eta| < 0.8$ and $p_T > 0.5$ GeV/c. The data are corrected to the particle level with errors that include both the statistical error and the systematic uncertainty and are compared with PYTHIA 6.4 Tune Z1.**

Energy Dependence dN/dη



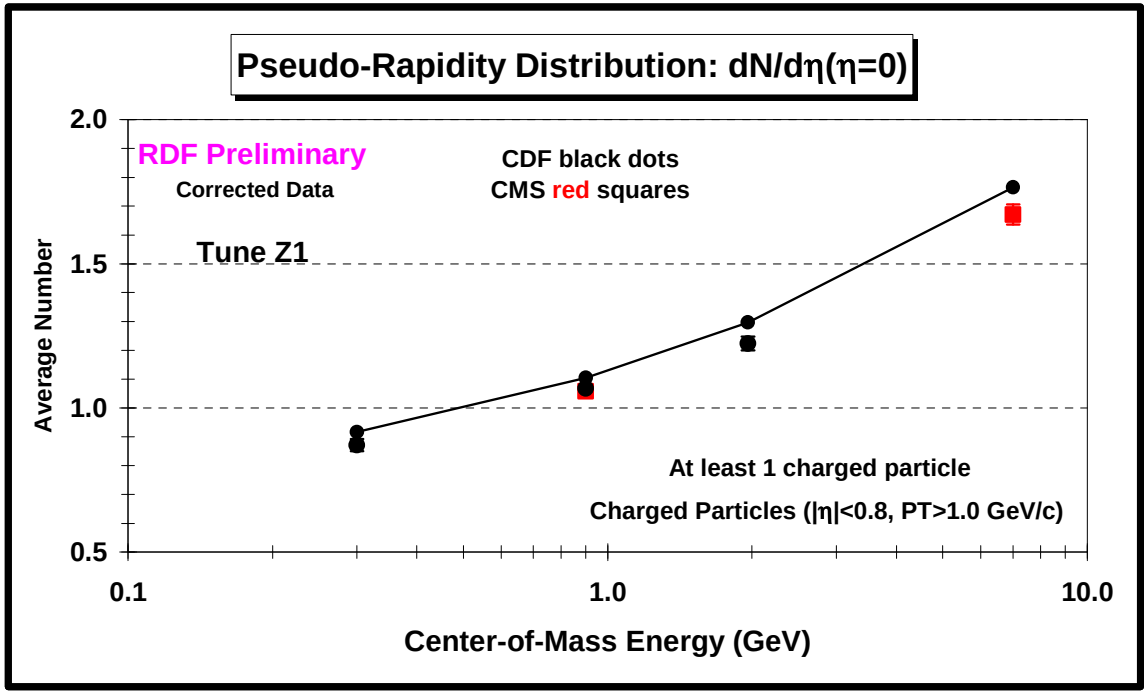
➡ **CMS data at 7 TeV and 900 GeV and CDF data at 1.96 TeV, 900 GeV, and 300 GeV on dN/dη at η = 0 with p_T > 0.5 GeV/c as a function of the center-of-mass energy. Events are required to have at least one charged particle with |η| < 0.8 and p_T > 0.5 GeV/c. The data are corrected to the particle level with errors that include both the statistical error and the systematic uncertainty and are compared with PYTHIA 6.4 Tune Z1.**

New CDF MB Data



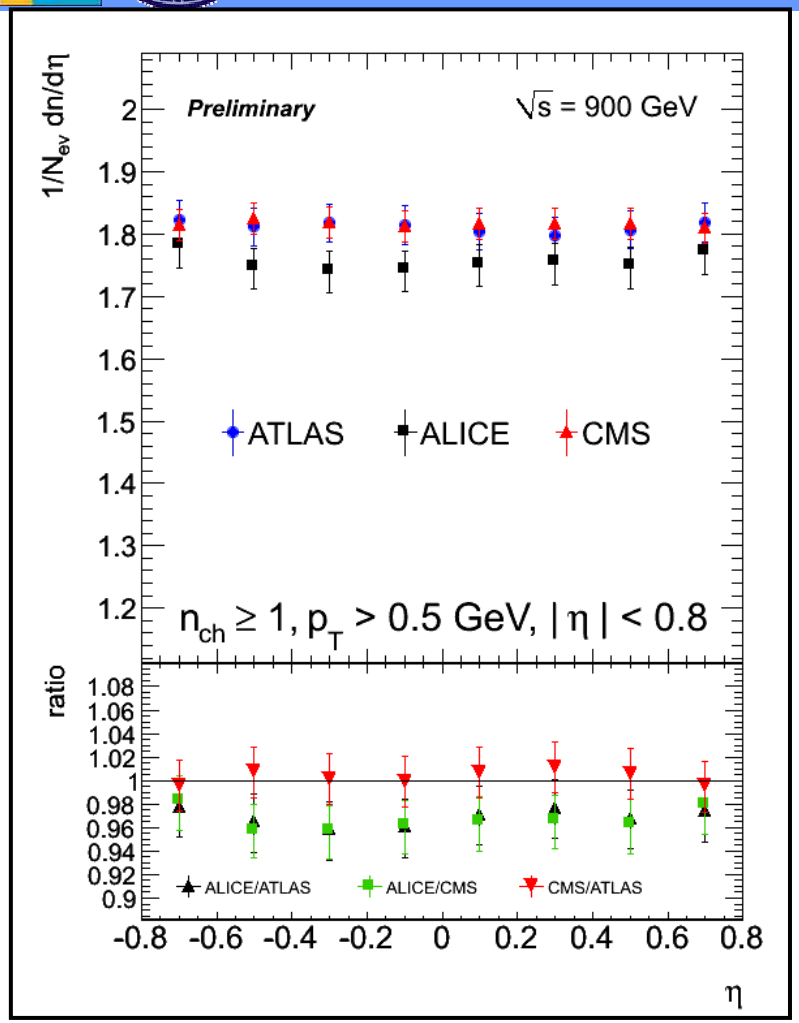
➡ **New Corrected CDF data at 300 GeV, 900 GeV, and 1.96 TeV on on pseudo-rapidity distribution of charged particles, dN/dη, with p_T > 1.0 GeV/c. Events are required to have at least one charged particle with |η| < 0.8 and p_T > 1.0 GeV/c. The data are corrected to the particle level with errors that include both the statistical error and the systematic uncertainty and are compared with PYTHIA 6.4 Tune Z1.**

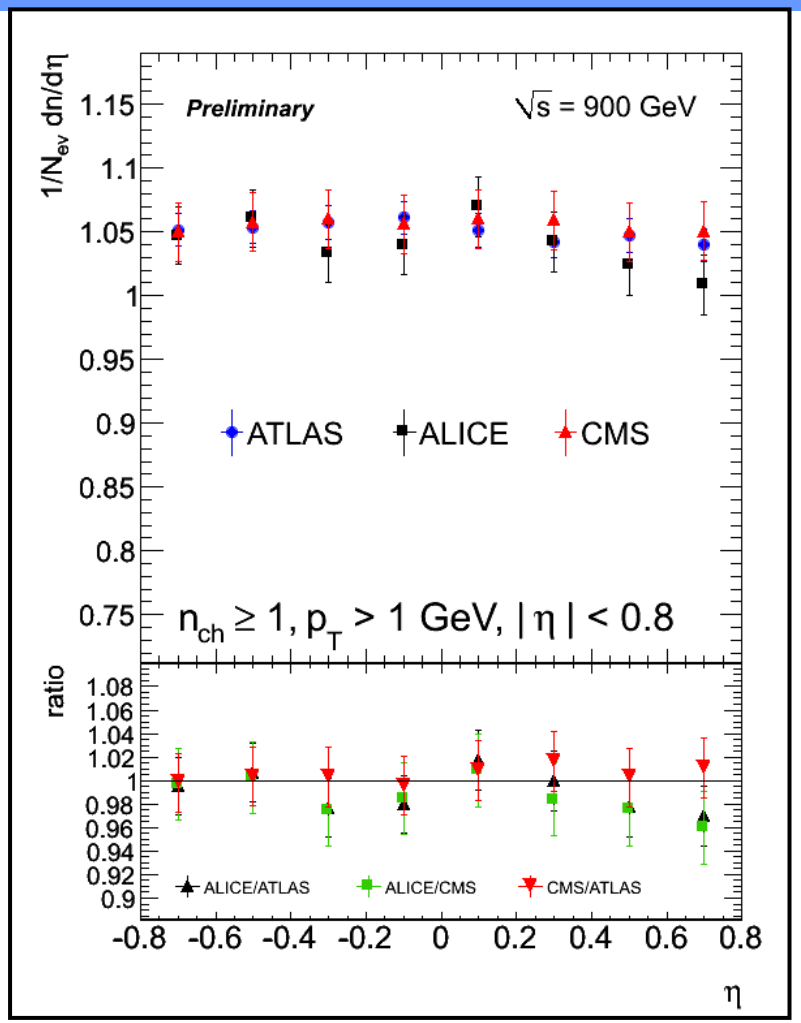
Energy Dependence dN/dη



➡ **CMS data at 7 TeV and 900 GeV and CDF data at 1.96 TeV, 900 GeV, and 300 GeV on dN/dη at η = 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 |η| < 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 and are compared with PYTHIA 6.4 Tune Z1.**

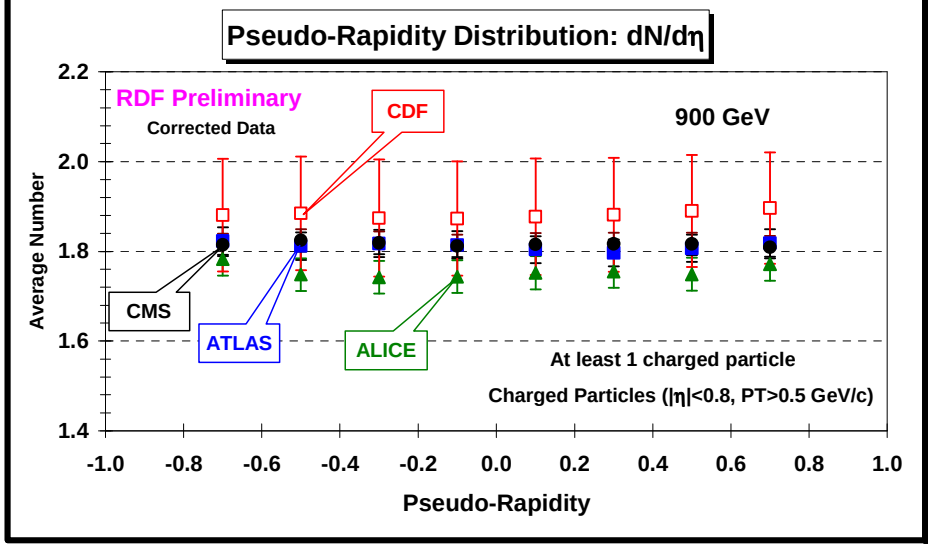
MB Common Plots 900 GeV

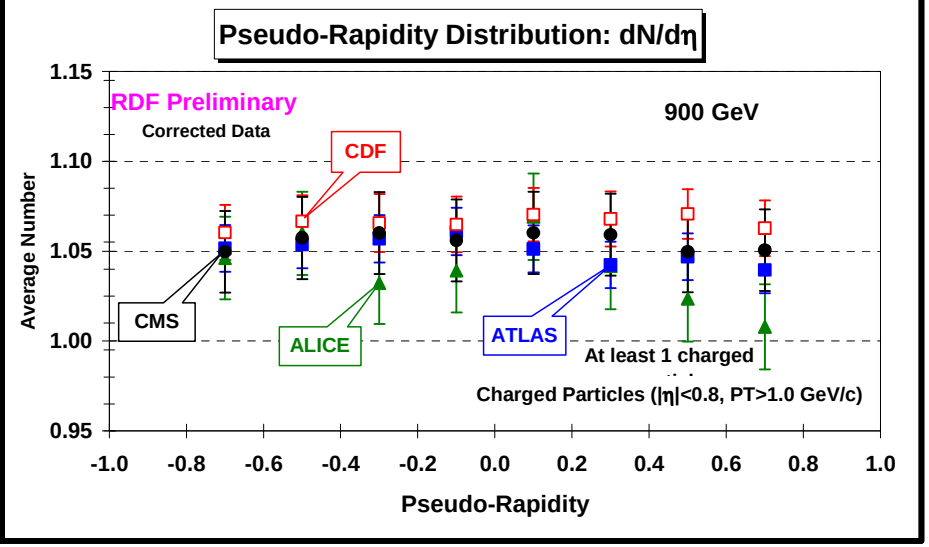




Direct charged particles (including leptons) corrected to the particle level with no corrections for SD or DD.

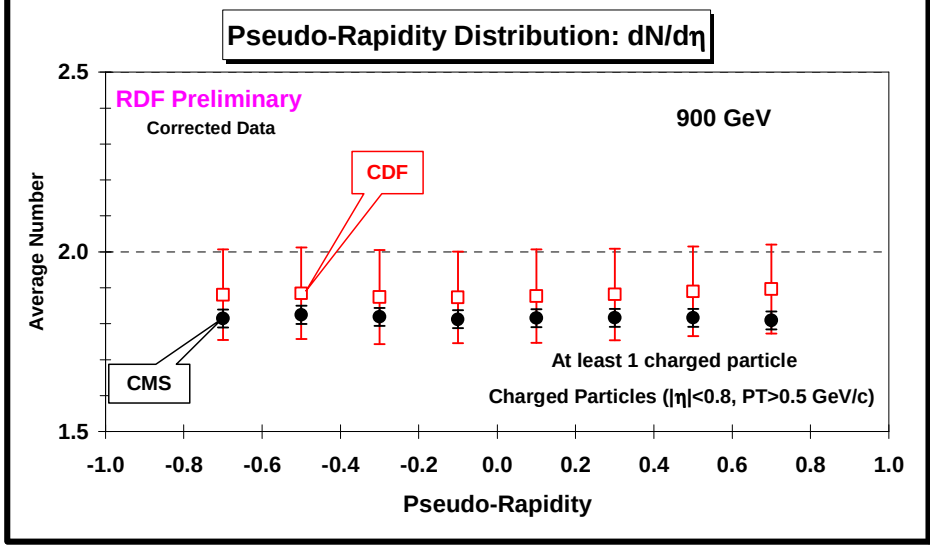
MB Common Plots 900 GeV

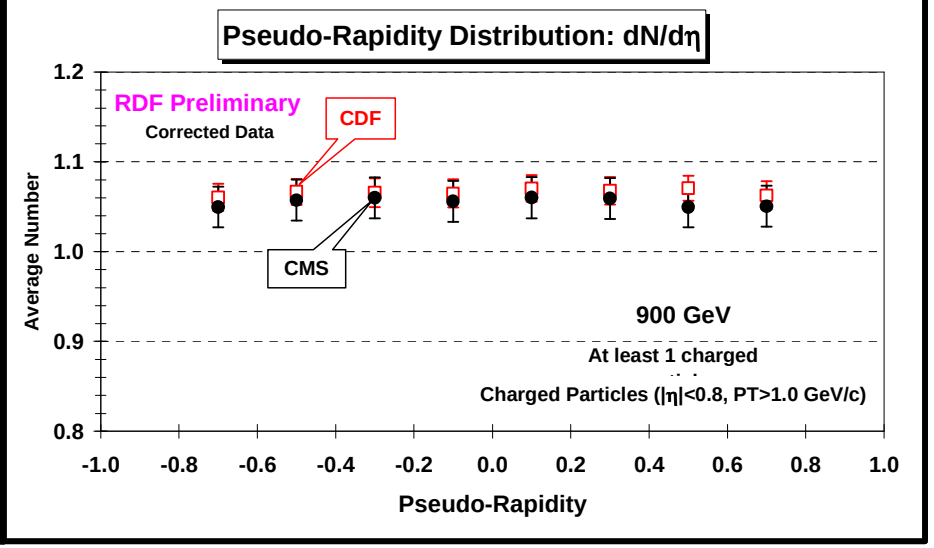




➡ **CDF, CMS, ATLAS, and ALICE data at 900 GeV on on pseudo-rapidity distribution of charged particles, dN/dη, with $p_T > 0.5$ GeV/c and with $p_T > 1.0$ GeV/c. Events are required to have at least one charged particle with $|\eta| < 0.8$ and $p_T > 0.5$ GeV/c or $p_T > 1.0$ GeV/c, respectively. The data are corrected to the particle level with errors that include both the statistical error and the systematic uncertainty.**

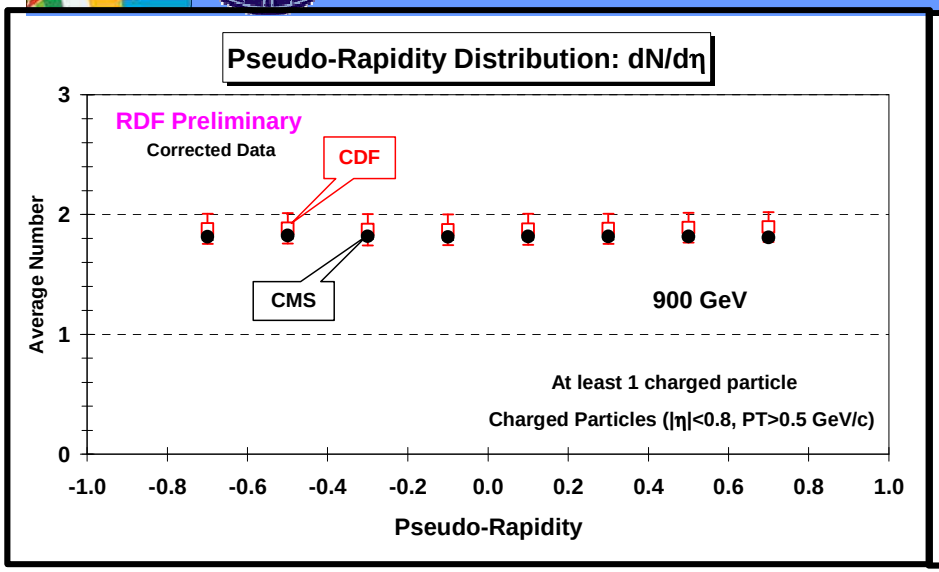
CDF versus CMS

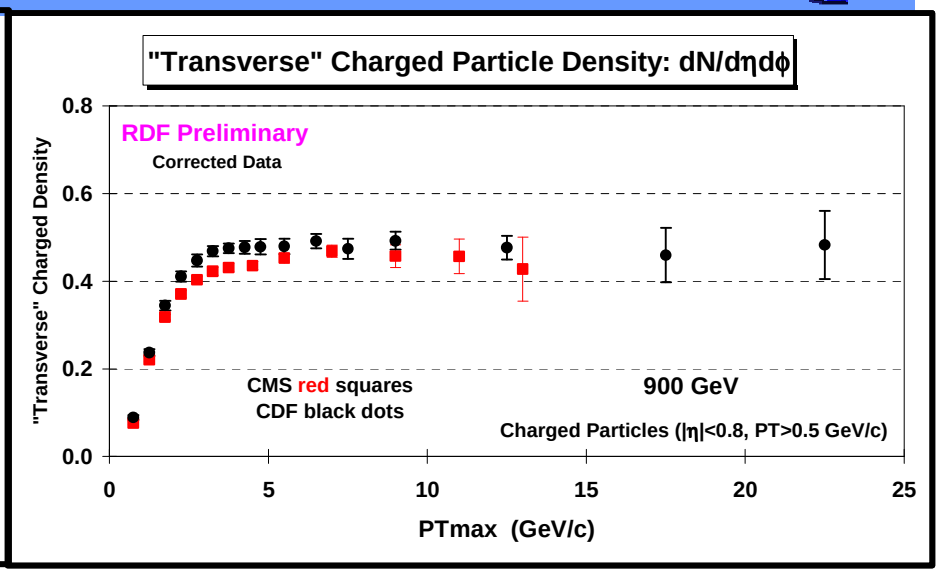




➡ **CDF and CMS data at 900 GeV on on pseudo-rapidity distribution of charged particles, dN/dη, with $p_T > 0.5$ GeV/c and with $p_T > 1.0$ GeV/c. Events are required to have at least one charged particle with $|\eta| < 0.8$ and $p_T > 0.5$ GeV/c or $p_T > 1.0$ GeV/c, respectively. The data are corrected to the particle level with errors that include both the statistical error and the systematic uncertainty.**

CDF versus CMS

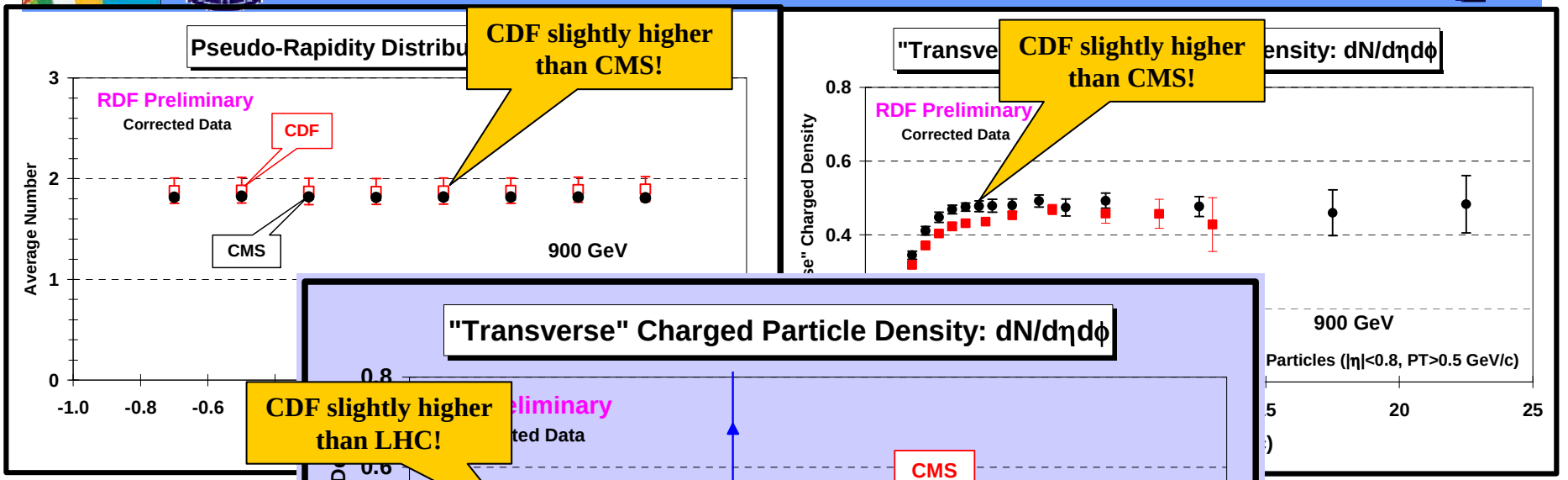


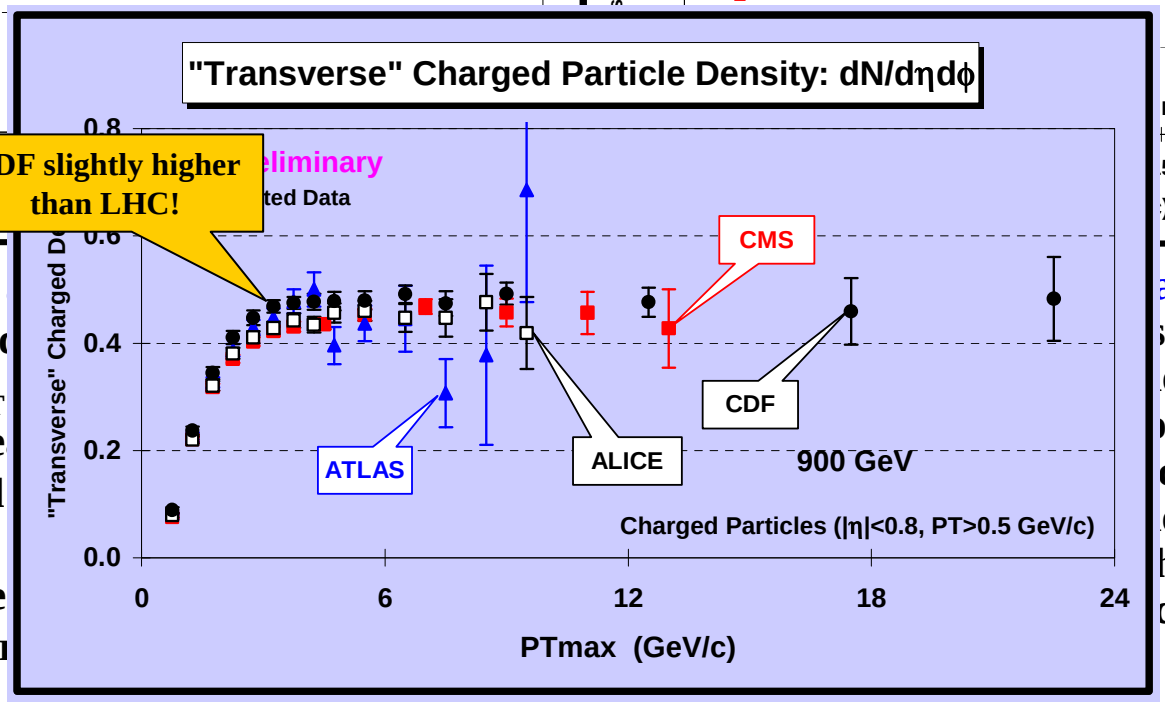


➡ **CDF and CMS data at 900 GeV on the pseudo-rapidity distribution, dN/dη, for charged with $p_T > 0.5$ GeV/c and $|\eta| < 0.8$ for events with at least one charged particle with $p_T > 0.5$ GeV/c and $|\eta| < 0.8$. The data are corrected to the particle level with errors that include both the statistical error and the systematic uncertainty.**

➡ **CDF and CMS data at 900 GeV/c on the charged particle density in the "transverse" region as defined by the leading charged particle (PTmax) for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 0.8$. The data are corrected to the particle level with errors that include both the statistical error and the systematic uncertainty.**

CDF versus CMS

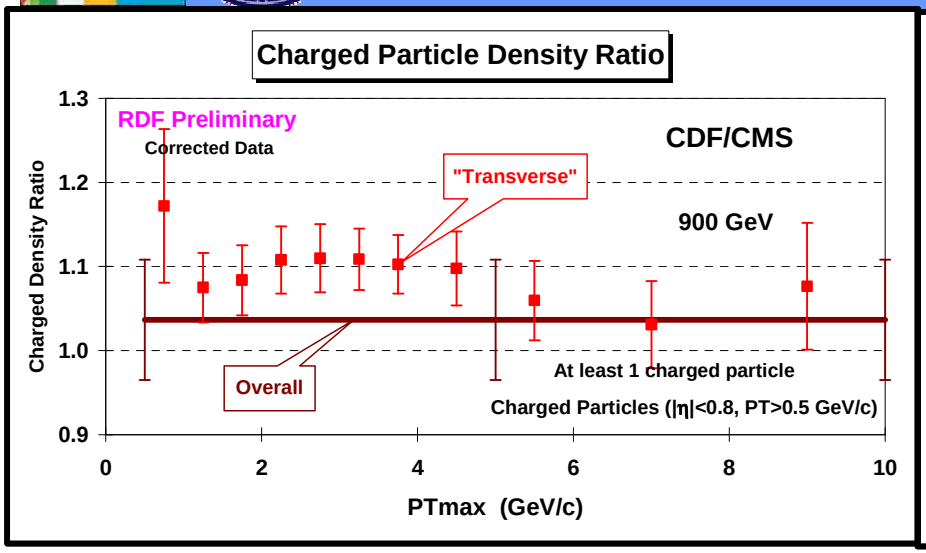


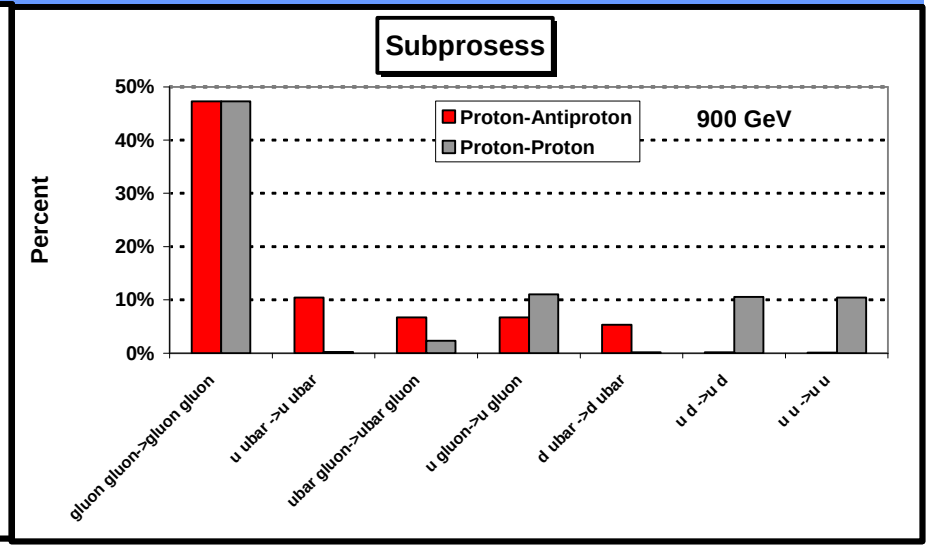


➡ **Corrected CDF**
the pseudo-rapi
charged with p_T
events with at le
> 0.5 GeV/c and
corrected to the
include both the
systematic uncer

ata at 900 GeV/c
ity in the
ed by the leading
r charged
c and $|\eta| < 0.8$.
e particle level
h the statistical
certainty.

CDF versus CMS

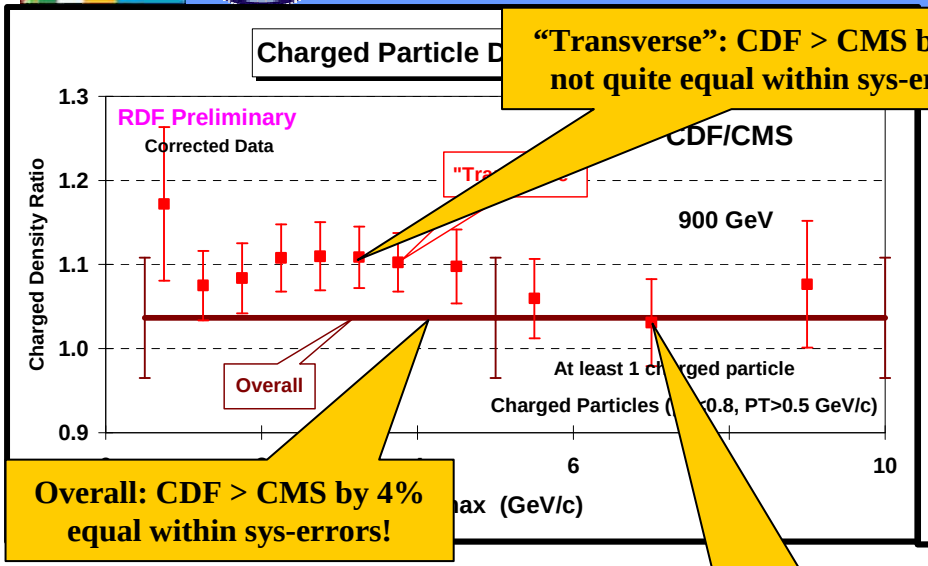




- **CDF data divided by the CMS data at 900 GeV** for the charged particle density in the "transverse" region as defined by the leading charged particle (PTmax) for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 0.8$ and for the overall density of charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 0.8$ for events with at least one charged particle with $p_T > 0.5$ GeV/c and $|\eta| < 0.8$ (*straight line*).

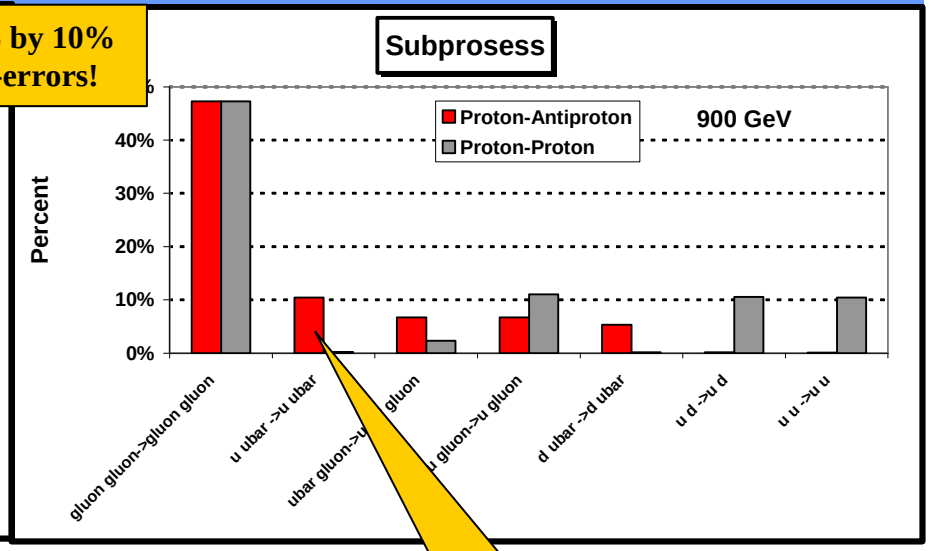
- **QCD 2-2 sub-processes** contributing to proton-proton and proton-antiproton collisions at 900 GeV from PYTHIA Tune Z1.

CDF versus CMS



"Transverse": CDF > CMS by 10% not quite equal within sys-errors!

Overall: CDF > CMS by 4% equal within sys-errors!



"Transverse" Plateau: CDF > CMS by 4% equal within sys-errors!

Different sub-processes in proton-antiproton and proton-proton collisions!

➡ **CDF data divided by the CMS data a GeV for the charged particle density in the "transverse" region as defined by the charged particle (PTmax) for charged with $p_T > 0.5$ GeV/c and $|\eta| < 0.8$ overall density of charged particl 0.5 GeV/c and $|\eta| < 0.8$ for events with at least one charged particle with $p_T > 0.5$ GeV/c and $|\eta| < 0.8$ (*straight line*).**

➡ **QCD 2-2 sub-process ntributing to proton-proton and proton-ant on collisions at 900 GeV from PYTHIA Tu**

More Coming Soon!

➡ **CDF - Many More UE Observables:** Nchg density, PTsum density, average p_T, "toward", "away", "transverse", "transMAX", "transMIN", distributions, etc..

➡ **CDF - Two η Ranges:** Will do ($p_T > 0.5$ GeV/c, $|\eta| < 0.8$) as well as ($p_T > 0.5$ GeV, $|\eta| < 1$).

➡ **CDF - Min-Bias:** Many MB observables: Multiplicity, $dN/d\eta$, p_T distribution, $\langle p_T \rangle$ versus Nchg, etc.

We now 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!

More Data Coming!

- **CDF - Many More UE Observables** **density, PTsum density, av p_T, "to" "a" trans" e", "transMAX"**
- **CDF - T** **as well as**
- **CDF - Min-I** **dN/dη, p**

What we are learning should allow for a deeper understanding of MPI which will result in more precise predictions at the future LHC energy of 13 TeV!

We **dat** **300 GeV, 9** **GeV** **Te** **eV, an** **TeV! We can study** **energy** **ependence more preci** **y than ev** **before!**

More Tunes Coming!

➡**New PYTHIA 6.2 Tune:** **Rick is working an improved version of Tune DW and Tune D6 using the CDF and CMS data.**

➡**New PYTHIA 6.4 Tune:** **Rick is working an improved version of Tune Z1 and Tune Z2 using the CDF and CMS data.**

➡**New SHERPA UE Tune:** **Mohammed (Rick's grad student) is working on an improved SHERPA tune using the CDF and CMS data.**

➡**New PYTHIA 8 UE Tune:** **Mohammed (Rick's grad student) is working on an improved PYTHIA 8 tune using the CDF and CMS data.**