MPI@LHC 2014

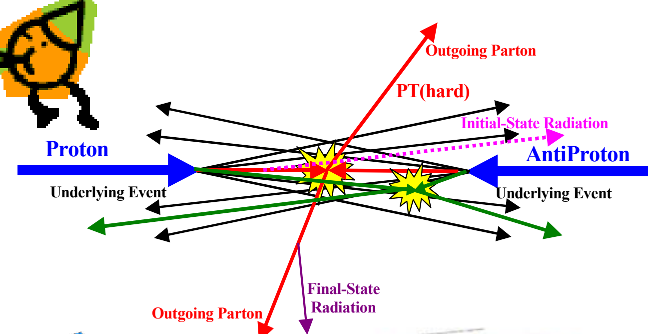
CMS UE and MB Tunes

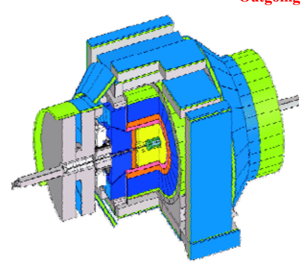
Rick Field
University of Florida

Quantum Chromo-Dynamics

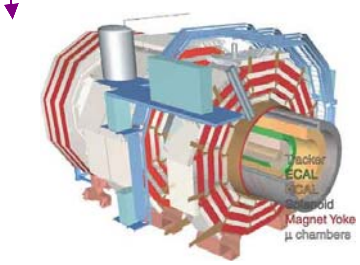
Outline of Talk

- **CMS UE Tunes:** Three PYTHA 8 tunes (CTEQ6L, HERALOPDF, NNPDF2.3LO) and one PYTHIA 6 tune (CTEQ6L) from the CMS "Physics Comparisons & Generator Tunes" subgroup.
- **UE Observables:** "transMAX","transMIN", "transAVE", "transDIF".
- **The Energy Dependence of the UE:** Detailed look at the energy dependence of the UE and the extrapolation to 13 TeV.
- **Predictions at 13 TeV:** Compare the CMS PYTHIA 8 tunes with the Skands Monash tune and the PYTHIA 6 Tune Z2* at 13 TeV.
- **MB Studies:** Look at dN/dη and the energy flow in the forward region.





CDF "Tevatron Energy Scan"
300 GeV, 900 GeV, 1.96 TeV



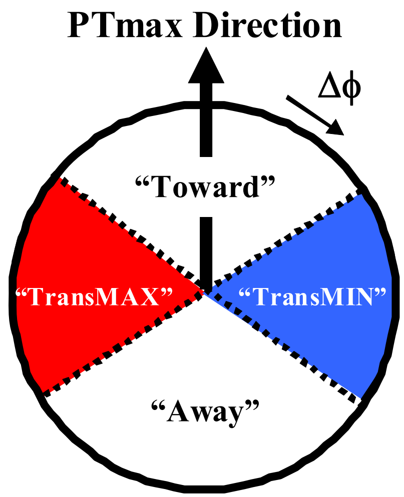
CMS at the LHC
900 GeV, 7 & 8 TeV

CMS UE Tunes

- **PYTHIA 6.4 Tune Z2*- CTEQ6L:** Start with Tune Z2 and tune to the CMS leading charged particle jet UE data at 900 GeV and 7 TeV. Improved version of Tune Z2.

- **PYTHIA 6.4 Tune CUETP6S1-CTEQ6L:** Start with Tune Z2*-lep and tune to the CDF PTmax "transMAX" and "transMIN" UE data at 300 GeV, 900 GeV, and 1.96 TeV and the CMS PTmax "transMAX" and "transMIN" UE data at 7 TeV. Improved version of Tune Z2*.

- **PYTHIA 8 Tune CUETP8S1-CTEQ6L:** Start with Tune 4C and tune to the CDF PTmax "transMAX" and "transMIN" UE data at 900 GeV, and 1.96 TeV and the CMS PTmax "transMAX" and "transMIN" UE data at 7 TeV. Exclude 300 GeV data. Improved version of Tune 4C.



- **PYTHIA 8 Tune CUETP8S1-HERALOPDF:** Start with Tune 4C and tune to the CDF PTmax "transMAX" and "transMIN" UE data at 900 GeV, and 1.96 TeV and the CMS PTmax "transMAX" and "transMIN" UE data at 7 TeV. Exclude 300 GeV data. Improved version of Tune 4C.

- **PYTHIA 8 Tune CUETP8M1-NNPDF2.3LO:** Start with the Skands Monash-NNPDF2.3LO tune and tune to the CDF PTmax "transMAX" and "transMIN" UE data at 900 GeV, and 1.96 TeV and the CMS PTmax "transMAX" and "transMIN" UE data at 7 TeV. Exclude 300 GeV data.

CMS Tune CUETP8S1-CTEQ6L

➡ **PYTHIA 8 Tunes:** Corke & Sjöstrand Tune 4C-CTEQ6L and CMS Tune CUETP8S1-CTEQ6L (CMS1).

	4C	CMS1
PDF	CTEQ6L	CTEQ6L
ecmRef	1800	1800
pT0Ref	2.085	**2.1006**
ecmPow	0.19	**0.21057**
expPow	2.0	**1.60889**
reconnectRange	1.5	**3.31257**
MultipartonInteractions:alphaSvalue	0.135	0.135
SigmaProcess:alphaSvalue	0.135	0.135
SpaceShower:alphaSvalue	0.137	0.137
TimeShower:alphaSvalue	0.1383	0.1383
TimeShower:pTmin	0.4	0.4
TimeShower:pTminChgQ	0.4	0.4
BeamRemnants:halfScaleForKT	1.0	1.0
BeamRemnants:primordialKThard	2.0	2.0
BeamRemnants:primordialKTsoft	0.50	0.50
Tune:ee	3	3

Start with Tune 4C and vary 4 parameters!

CMS Tune CUETP8S1-CTEQ6L
pT0Ref = 2.1006
ecmPow = 0.21057
ecmRef = 1800

Ecm (TeV)	pT0 (GeV/c)
0.3	1.440
0.9	1.815
1.96	2.139
7	2.796
13	3.185

$$pT0(E_{cm}) = pT0Ref \times (E_{cm}/ecmRef)^{ecmPow}$$

CMS Tune MonashStar

- **PYTHIA 8 Tunes:** Peter Skands Tune Monash-NNPDF2.3LO and CMS Tune CUETP8M1-NNPDF2.3LO (MonashStar).

	Monash	MonashStar
PDF	NNPDF2.3LO	NNPDF2.3LO
ecmRef	7000	7000
pT0Ref	2.280	**2.402374**
ecmPow	0.2150	**0.25208**
expPow	1.85	**1.6**
reconnectRange	1.80	1.80
MultipartonInteractions:alphaSvalue	0.13	0.13
SigmaProcess:alphaSvalue	0.13	0.13
SpaceShower:alphaSvalue	0.1365	0.1365
TimeShower:alphaSvalue	0.1365	0.1365
TimeShower:pTmin	0.5	0.5
TimeShower:pTminChgQ	0.5	0.5
BeamRemnants:halfScaleForKT	1.5	1.5
BeamRemnants:primordialKThard	1.8	1.8
BeamRemnants:primordialKTsoft	0.9	0.9
Tune:ee	7	7

New from CMS

Start with Monash and change 3 parameters!

CMS Tune MonashStar
pT0Ref = 2.402374
ecmPow = 0.25208
ecmRef = 7000

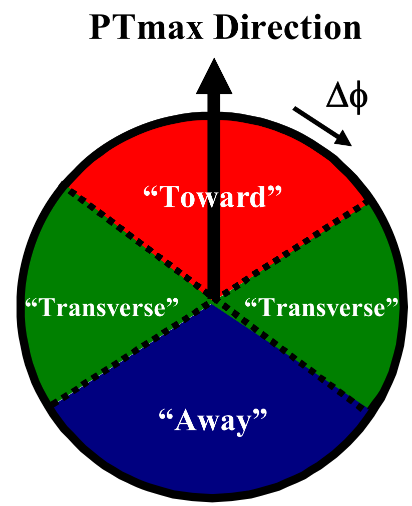
Ecm (TeV)	pT0 (GeV/c)
0.3	1.086
0.9	1.432
1.96	1.743
7	2.402
13	2.808

Skands-Monash
pT0Ref = 2.280
ecmPow = 0.2150
ecmRef = 7000

Ecm (TeV)	pT0 (GeV/c)
0.3	1.158
0.9	1.467
1.96	1.734
7	2.280
13	2.605

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, $|\eta| < \eta_{cut}$.

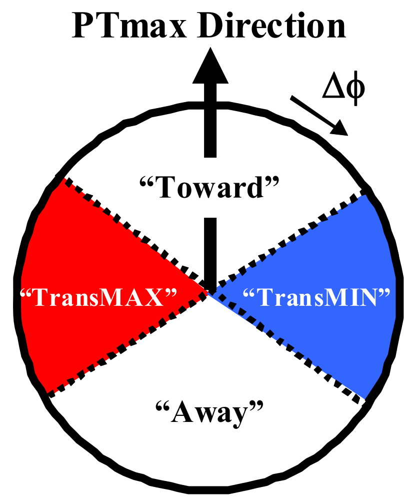
- **"Transverse" Charged Particle Average P_T:** Event-by-event $<p_T>$ = PTsum/Nchg for charged particles ($p_T > 0.5$ GeV/c, $|\eta| < \eta_{cut}$) in the "transverse" region as defined by the leading charged particle, PTmax, averaged over all events with at least one particle in the "transverse" region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

$\eta_{cut} = 0.8$

UE Observables

- **"transMAX" and "transMIN" Charged Particle Density:** Number of charged particles ($p_T > 0.5$ GeV/c, $|\eta| < 0.8$) in the the maximum (minimum) of the two "transverse" regions as defined by the leading charged particle, PTmax, divided by the area in η-ϕ space, $2\eta_{cut}\times 2\pi/6$, averaged over all events with at least one particle with $p_T > 0.5$ GeV/c, $|\eta| < \eta_{cut}$.
- **"transMAX" and "transMIN" Charged PTsum Density:** Scalar p_T sum of charged particles ($p_T > 0.5$ GeV/c, $|\eta| < 0.8$) in the the maximum (minimum) of the two "transverse" regions as defined by the leading charged particle, PTmax, divided by the area in η-ϕ space, $2\eta_{cut}\times 2\pi/6$, averaged over all events with at least one particle with $p_T > 0.5$ GeV/c, $|\eta| < \eta_{cut}$.



$\eta_{cut} = 0.8$

Overall "Transverse" = "transMAX" + "transMIN"

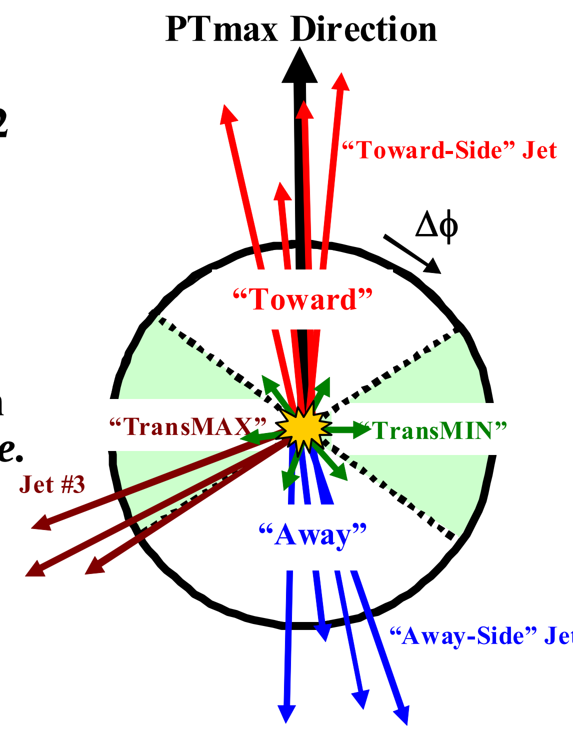
Note: The overall "transverse" density is equal to the average of the "transMAX" and "TransMIN" densities. The "TransDIF" Density is the "transMAX" Density minus the "transMIN" Density

"Transverse" Density = "transAVE" Density = ("transMAX" Density + "transMIN" Density)/2

"TransDIF" Density = "transMAX" Density - "transMIN" Density

“transMIN” & “transDIF”

- The “toward” region contains the leading “jet”, while the “away” region, on the average, contains the “away-side” “jet”. The “transverse” region is perpendicular to the plane of the hard 2-to-2 scattering and is very sensitive to the “underlying event”. For events with large initial or final-state radiation the “transMAX” region defined contains the third jet while both the “transMAX” and “transMIN” regions receive contributions from the MPI and beam-beam remnants. Thus, the “transMIN” region is very sensitive to the multiple parton interactions (MPI) and beam-beam remnants (BBR), while the “transMAX” minus the “transMIN” (*i.e.* “transDIF”) is very sensitive to initial-state radiation (ISR) and final-state radiation (FSR).



“TransMIN” density more sensitive to MPI & BBR.

“TransDIF” density more sensitive to ISR & FSR.

0 ≤ “TransDIF” ≤ 2×”TransAVE”

“TransDIF” = “TransAVE” if “TransMIX” = 3×”TransMIN”

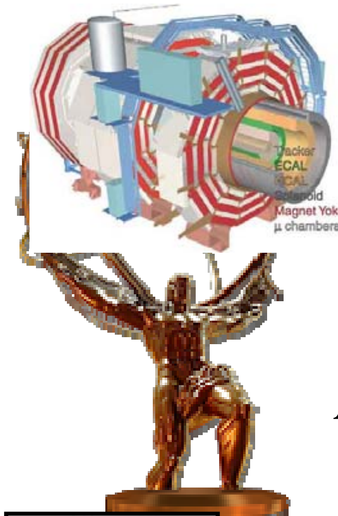
LPCC

MB&UE Working Group

LHC Physics Centre at CERN

MB & UE Common Plots

Quantum Chromo-Dynamics



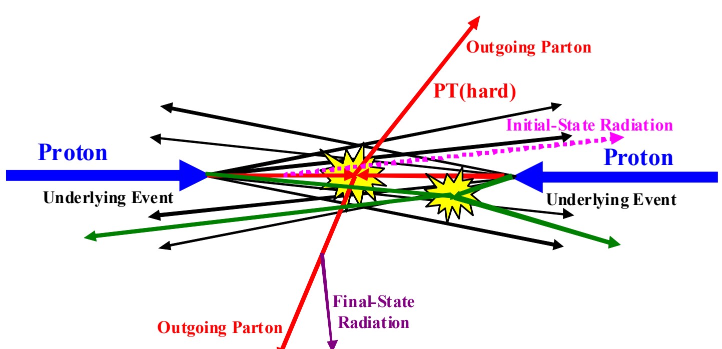
CMS

ATLAS

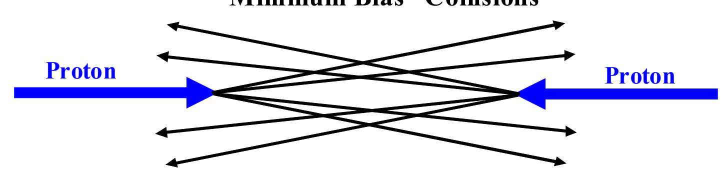
ALICE

LHCb

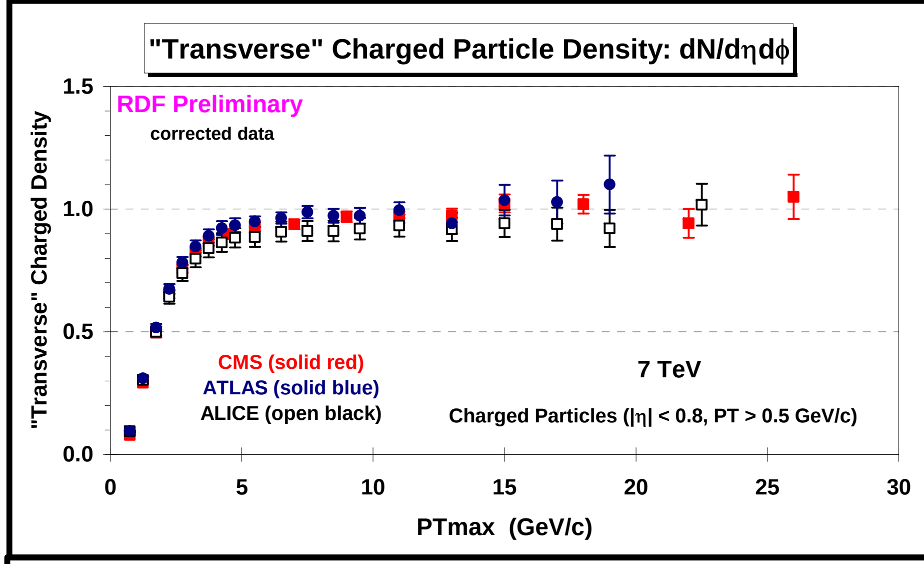
➡ **The LPCC MB&UE Working Group has suggested several MB&UE “Common Plots” the all the LHC groups can produce and compare with each other.**

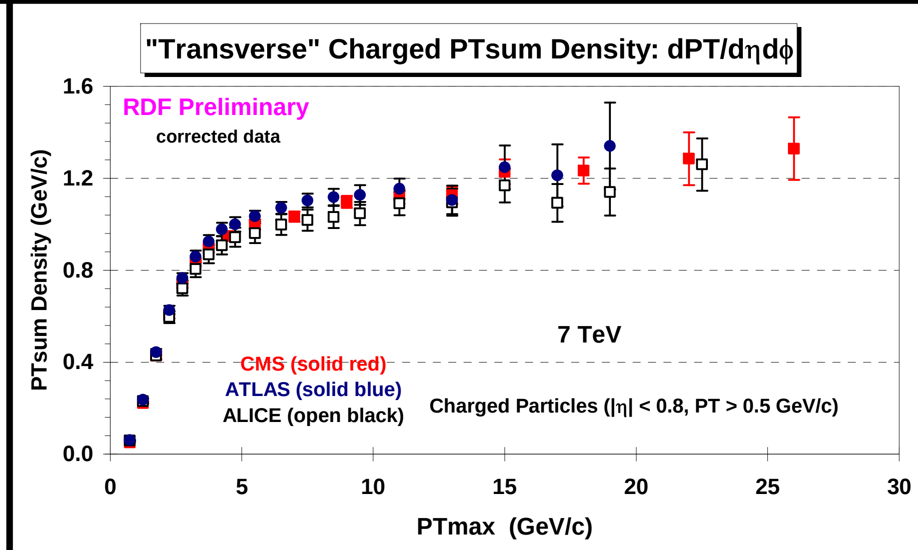


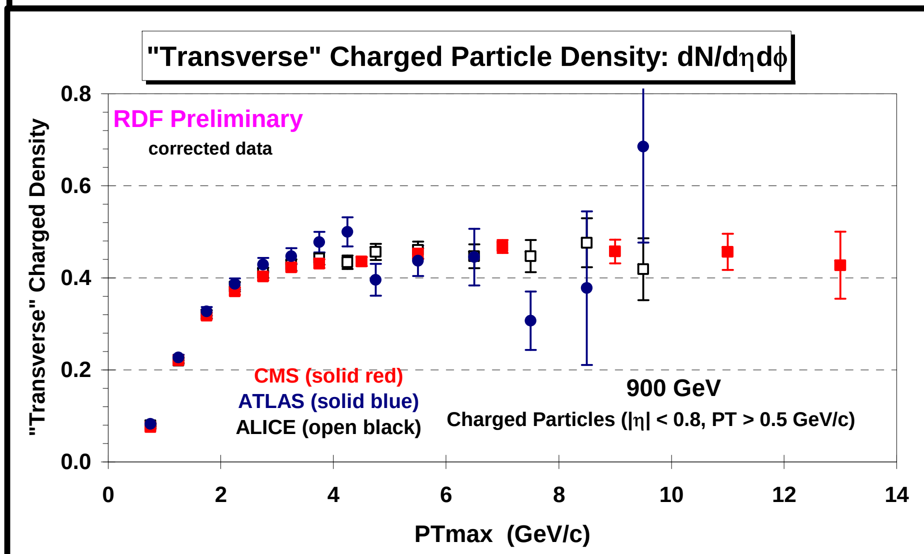
“Minimum Bias” Collisions

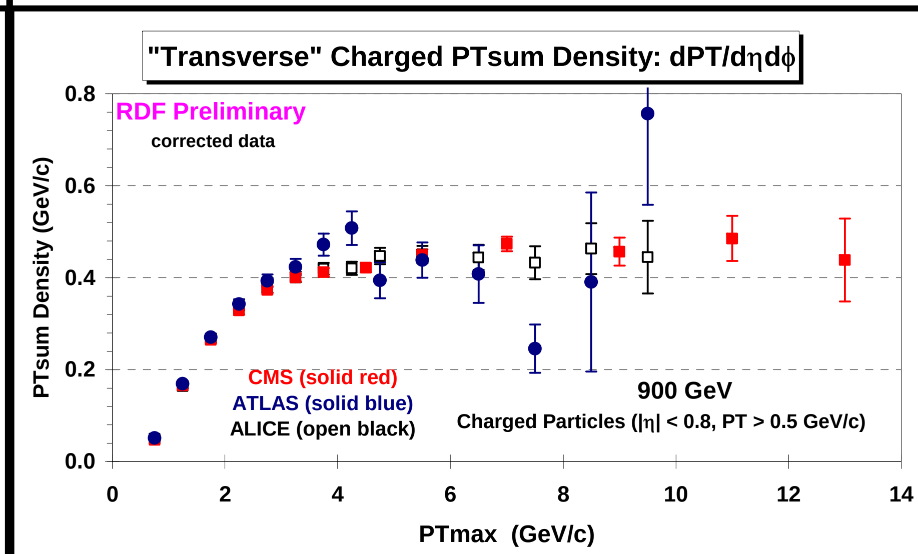


UE Common Plots

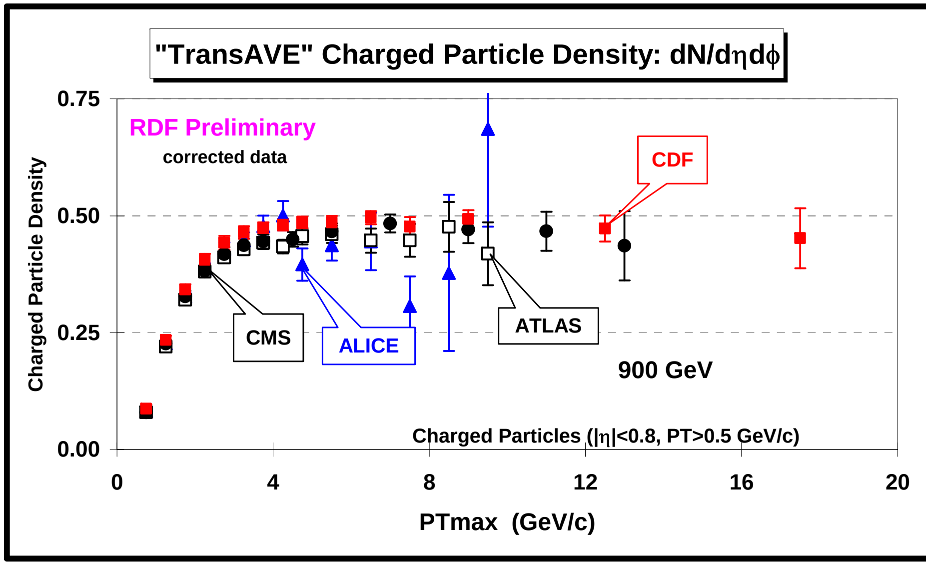


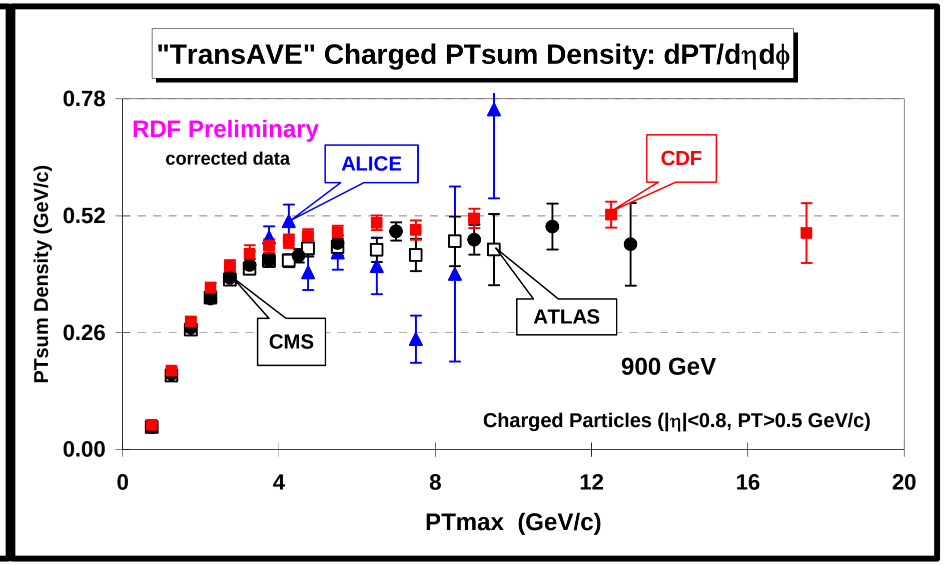






CDF versus LHC

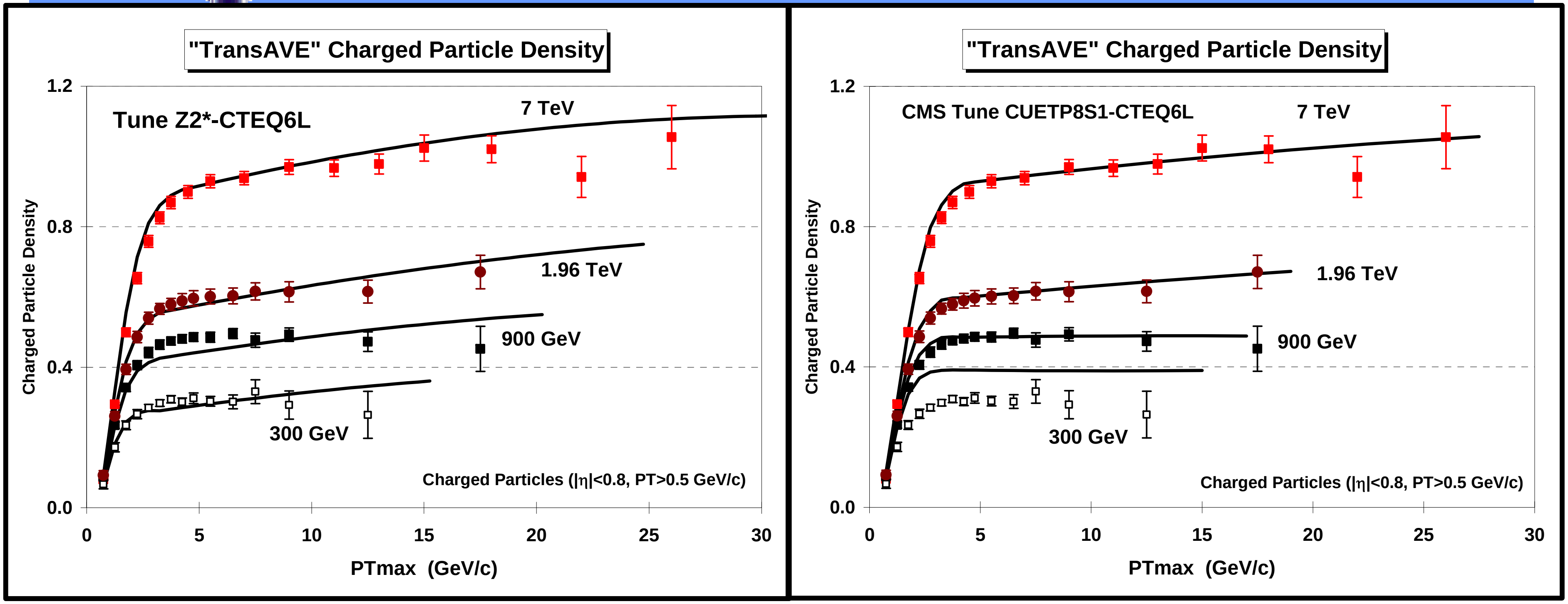




- **CDF and LHC data at 900 GeV/c on the charged particle density in the "transverse" region as defined by the leading charged particle (PTmax) for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 0.8$. The data are corrected to the particle level with errors that include both the statistical error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

- **CDF and LHC data at 900 GeV/c on the charged PTsum 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.**

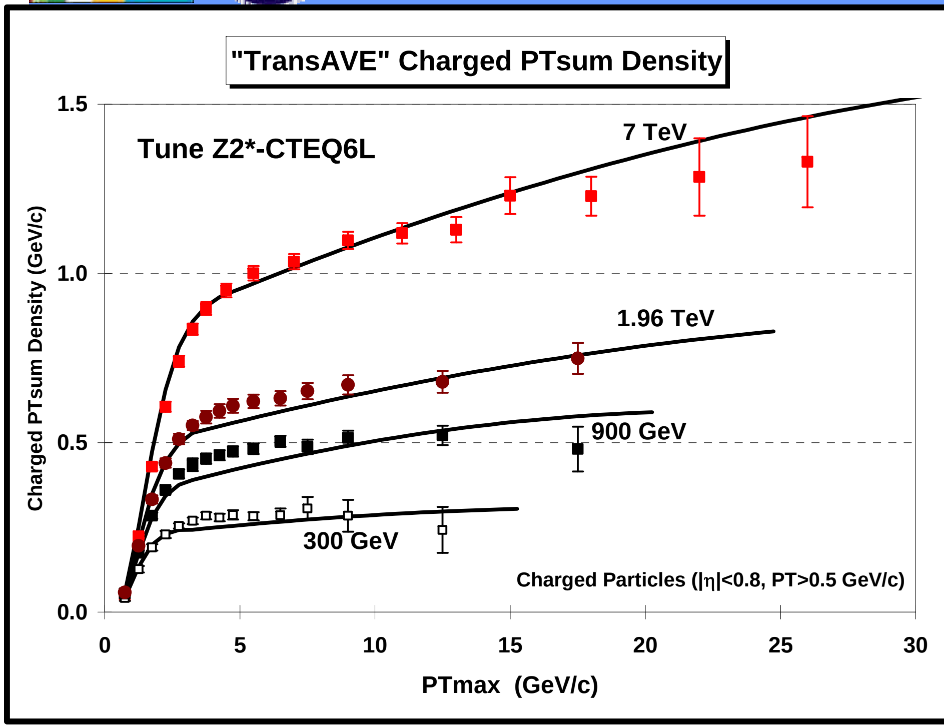
CUETP8S1-CTEQ6L

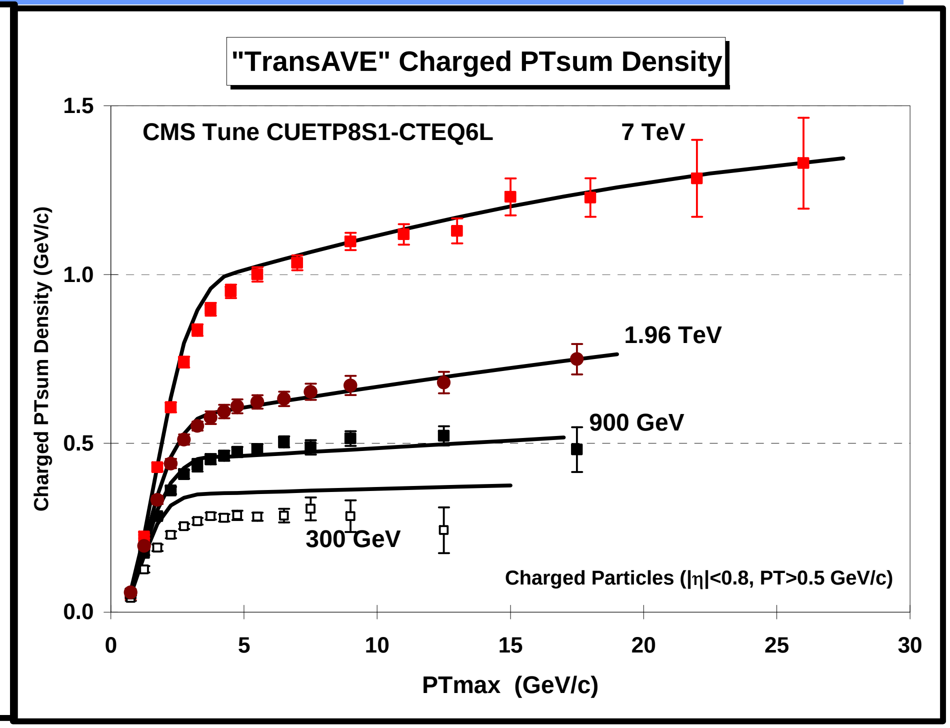


- **CMS data at 7 TeV and CDF data at 1.96 TeV, 900 GeV, and 300 GeV** on the charged particle density in the **"transAVE"** region as defined by the leading charged particle (PTmax) for charged particles with p_T > 0.5 GeV/c and |η| < 0.8. The data are compared with PYTHIA 6.4 Tune Z2*.

- **CMS data at 7 TeV and CDF data at 1.96 TeV, 900 GeV, and 300 GeV** on the charged particle density in the **"transAVE"** region as defined by the leading charged particle (PTmax) for charged particles with p_T > 0.5 GeV/c and |η| < 0.8. The data are compared with PYTHIA 8 Tune CUETP8S1-CTEQ6L (**excludes 300 GeV in fit**).

CUETP8S1-CTEQ6L

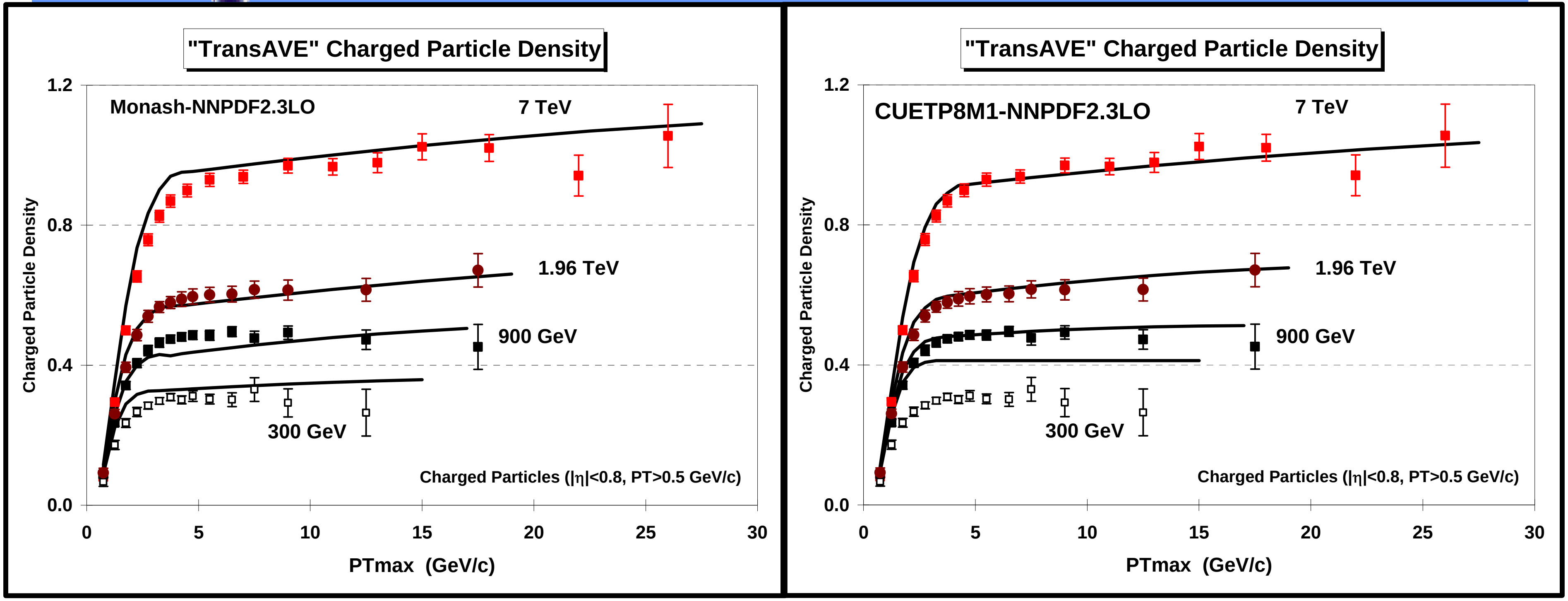




- **CMS data at 7 TeV and CDF data at 1.96 TeV, 900 GeV, and 300 GeV on the charged PTsum density in the "transAVE" region as defined by the leading charged particle (PTmax) for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 0.8$. The data are compared with PYTHIA 6.4 Tune Z2*.**

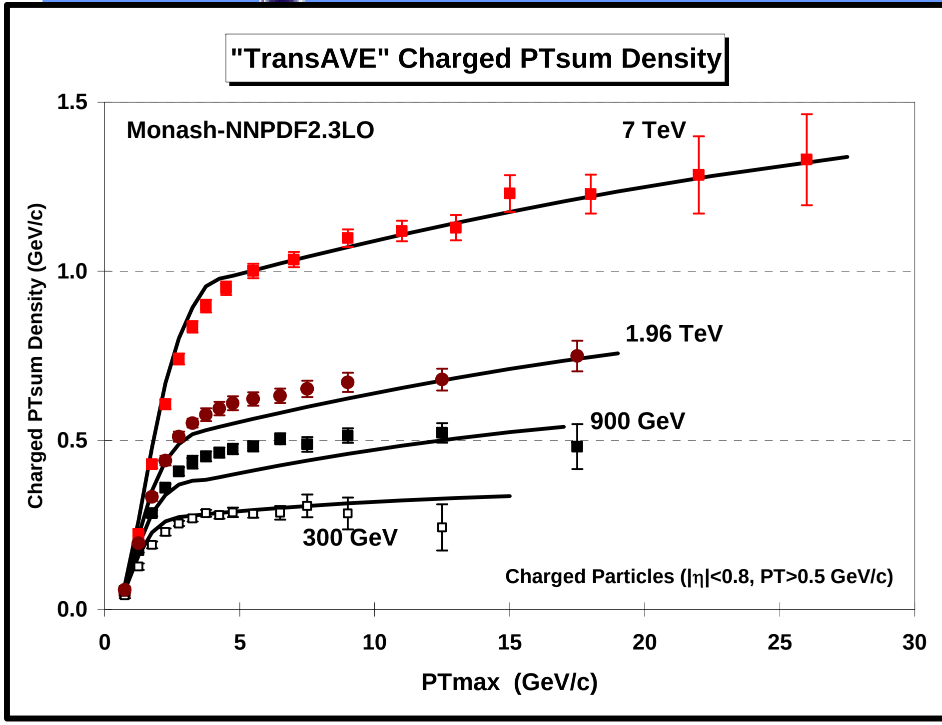
- **CMS data at 7 TeV and CDF data at 1.96 TeV, 900 GeV, and 300 GeV on the charged PTsum density in the "transAVE" region as defined by the leading charged particle (PTmax) for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 0.8$. The data are compared with PYTHIA 8 Tune CUETP8S1-CTEQ6L (excludes 300 GeV in fit).**

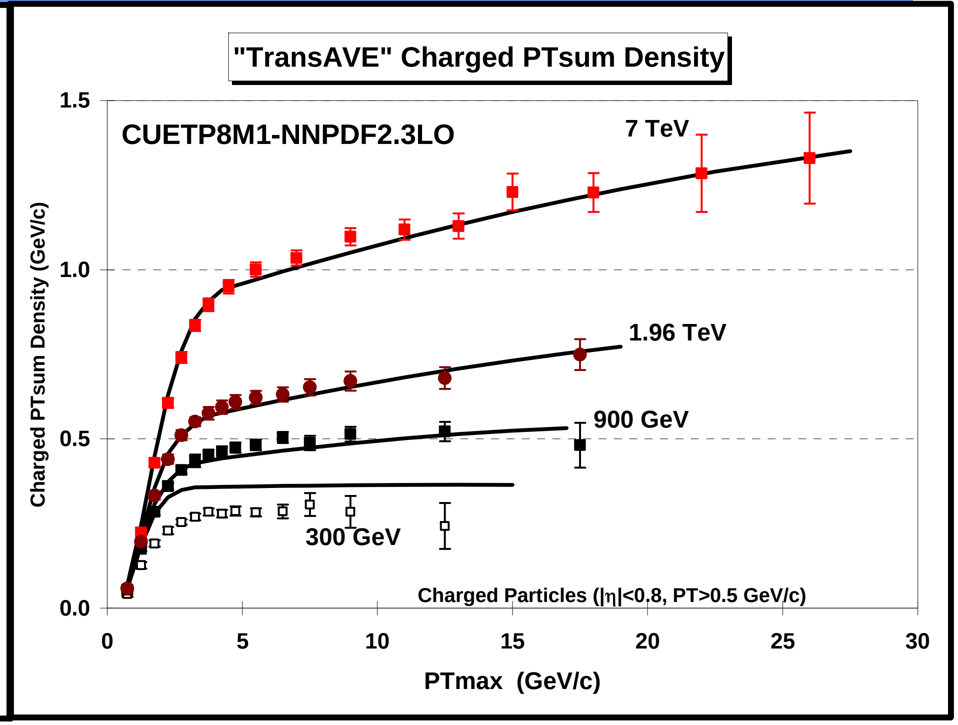
CUETP8M1-NNPDF2.3LO



- **CMS data at 7 TeV and CDF data at 1.96 TeV, 900 GeV, and 300 GeV on the charged particle density in the "transAVE" 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 compared with the PYTHIA 8 Tune Monash-NNPDF2.3LO.**
- **CMS data at 7 TeV and CDF data at 1.96 TeV, 900 GeV, and 300 GeV on the charged particle density in the "transAVE" 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 compared with the PYTHIA 8 Tune CUETP8M1-NNPDF2.3LO (excludes 300 GeV in fit).**

Energy Dependence

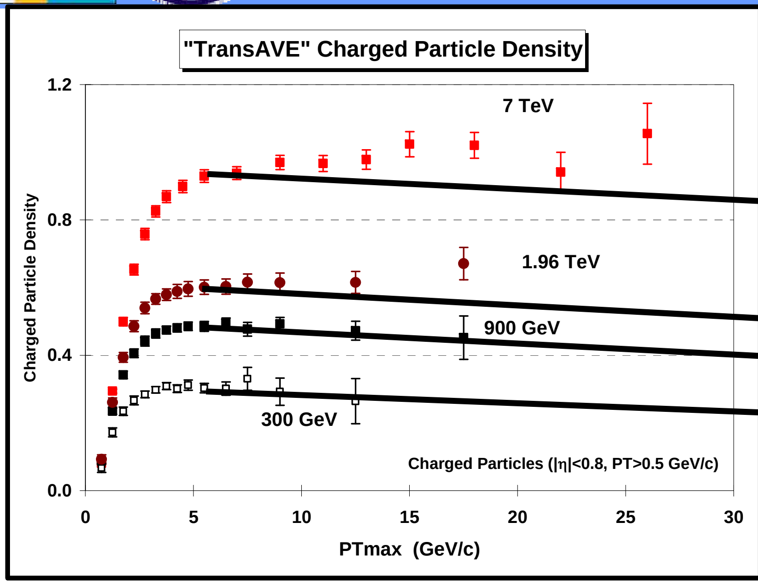


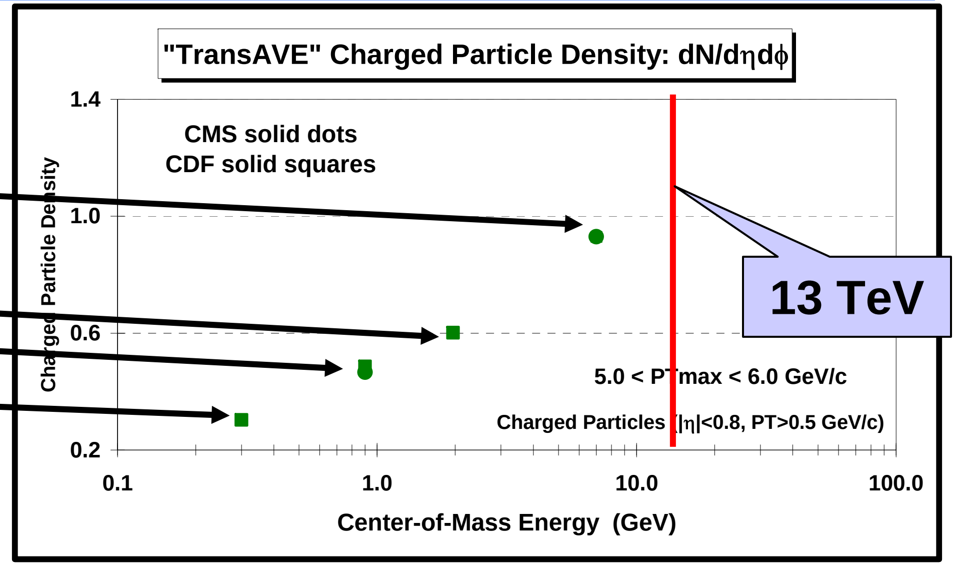


- **CMS data at 7 TeV and CDF data at 1.96 TeV, 900 GeV, and 300 GeV on the charged PTsum density in the "transAVE" region as defined by the leading charged particle (PTmax) for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 0.8$. The data are compared with the PYTHIA 8 Tune Monash-NNPDF2.3LO.**

- **CMS data at 7 TeV and CDF data at 1.96 TeV, 900 GeV, and 300 GeV on the charged PTsum density in the "transAVE" 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 compared with the PYTHIA 8 Tune CUETP8M1-NNPDF2.3LO (excludes 300 GeV in fit).**

Energy Dependence

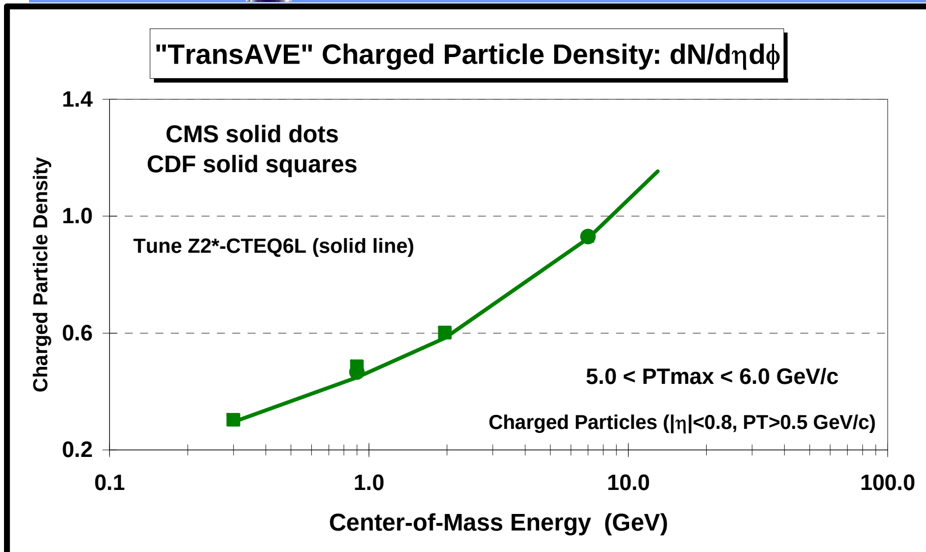


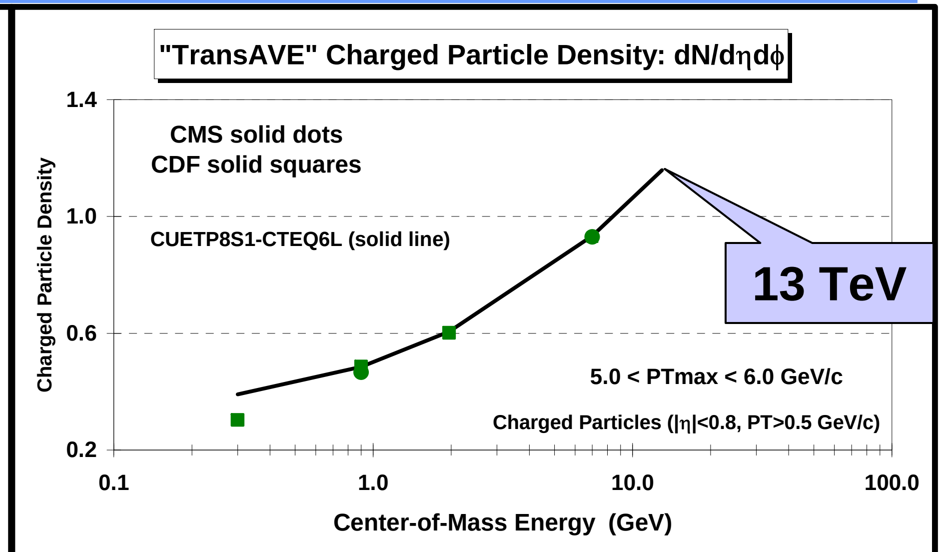


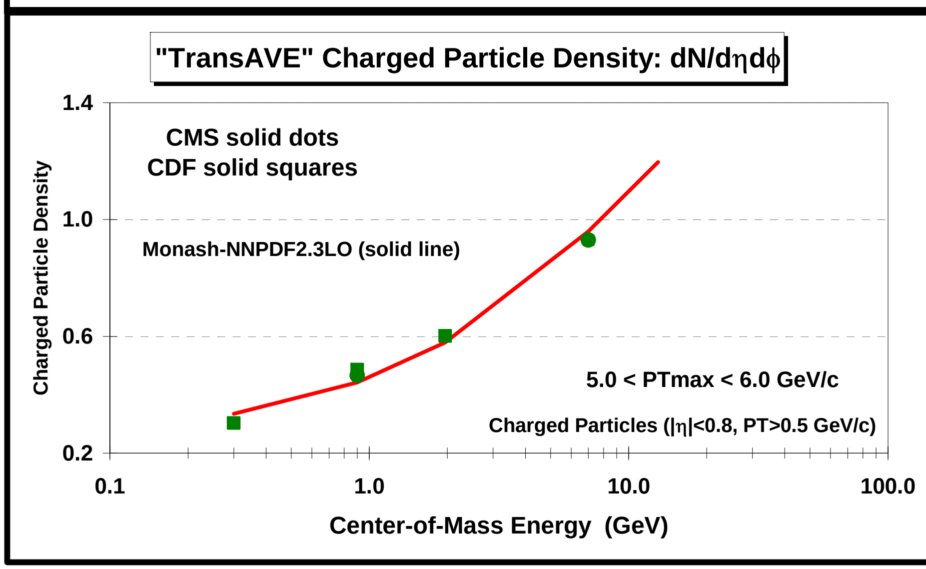
- **CMS data at 7 TeV and CDF data at 1.96 TeV, 900 GeV, and 300 GeV on the charged particle density in the "transAVE" region as defined by the leading charged particle (PTmax) for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 0.8$.**

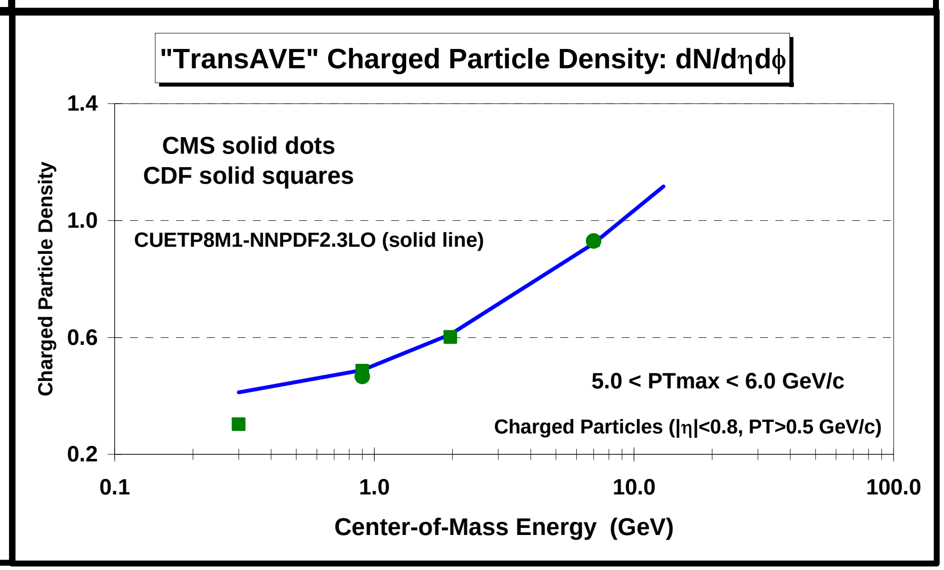
- **CMS and CDF data on the charged particle density in the "transAVE" region as defined by the leading charged particle (PTmax) for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 0.8$ with 5 < PTmax < 6 GeV/c. The data are plotted versus the center-of-mass energy (*log scale*).**

Energy Dependence

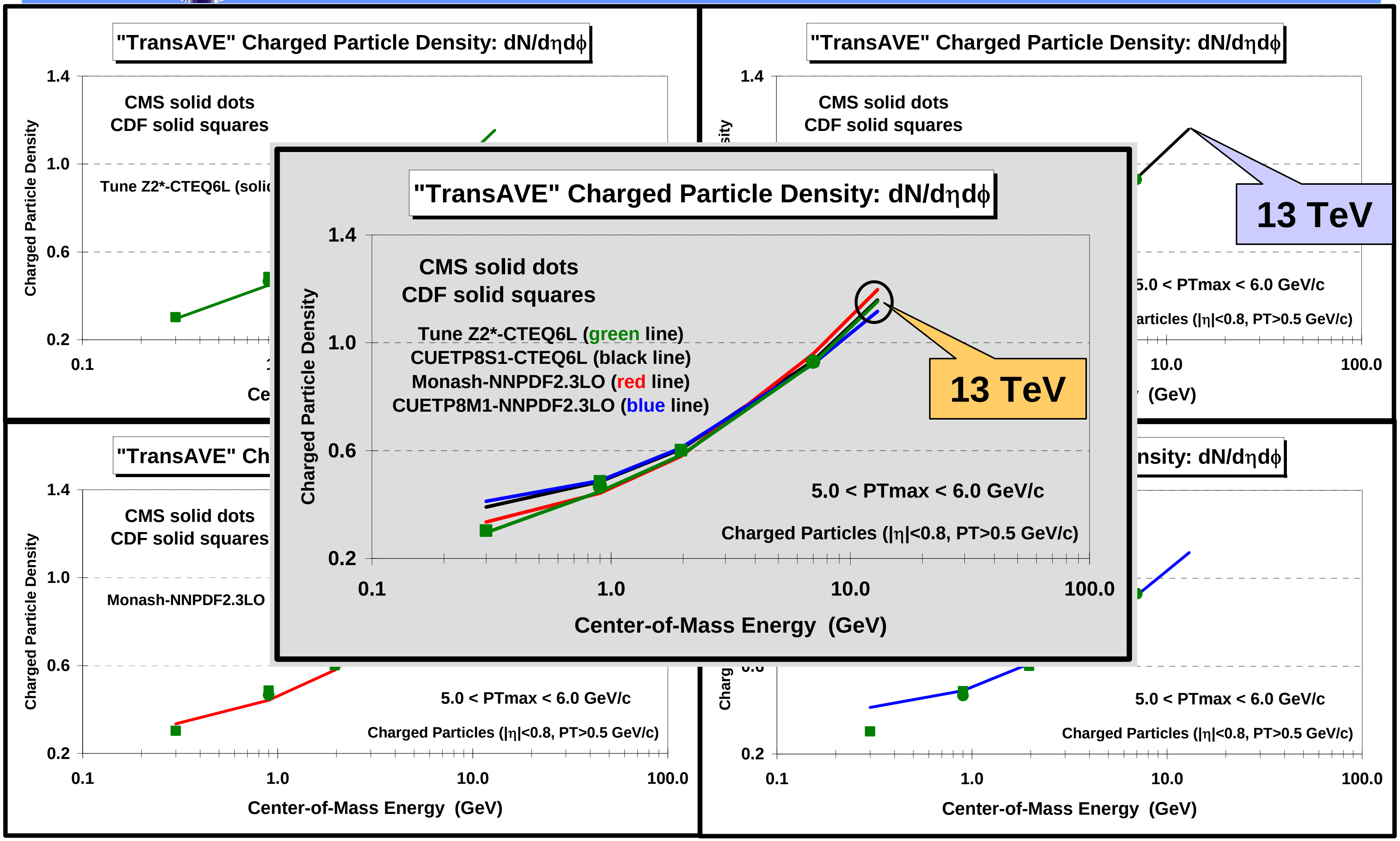




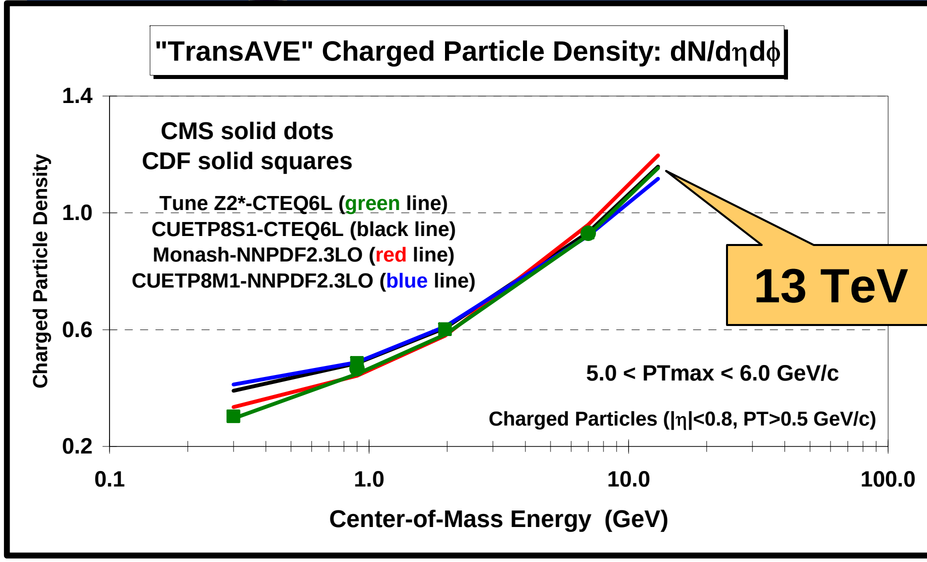


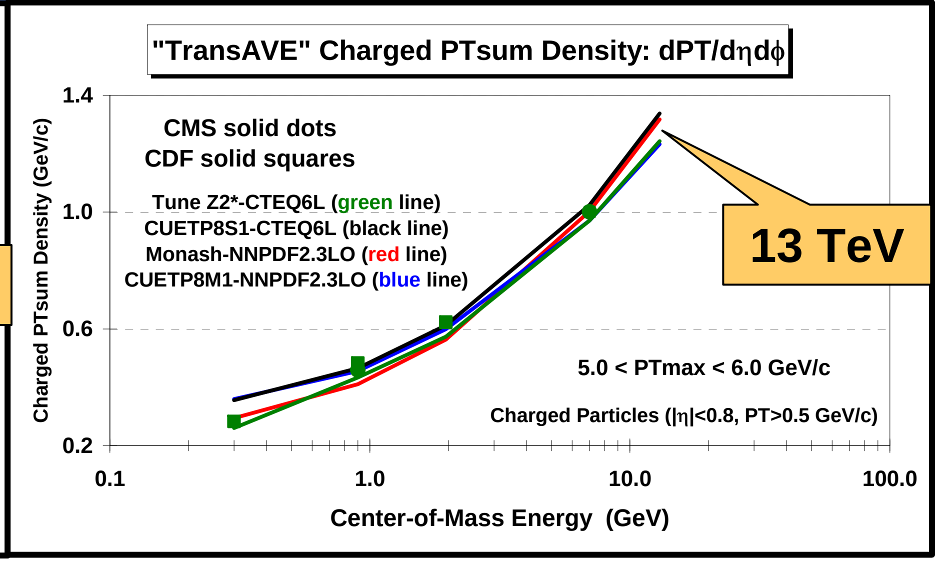


Energy Dependence



Energy Dependence

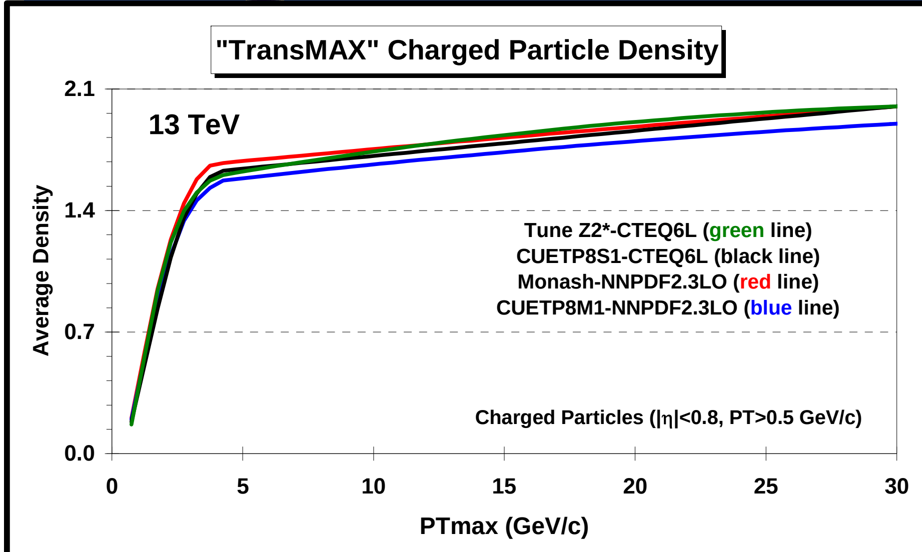


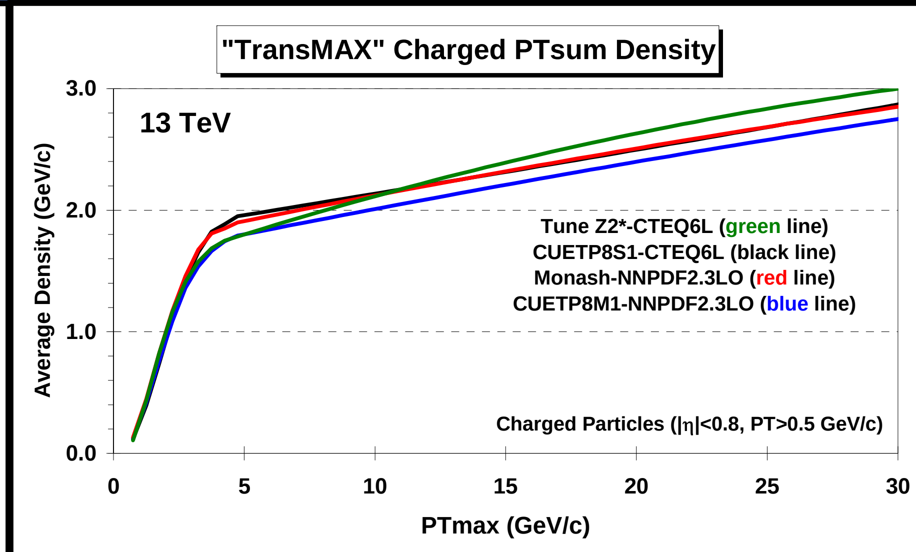


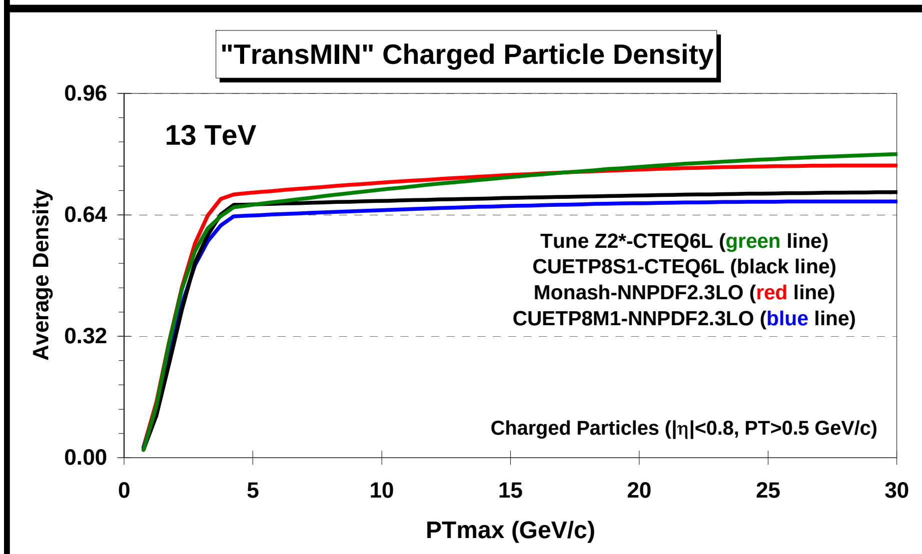
- **CMS and CDF data on the charged particle density in the "transAVE" region as defined by the leading charged particle (PTmax) for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 0.8$ with 5 < PTmax < 6 GeV/c. The data are plotted versus the center-of-mass energy (*log scale*). The data are compared with PYTHIA 6 Tune Z2* and PYTHIA 8 Tune CUETP8S1, Tune Monash, and Tune CUETP8M1.**

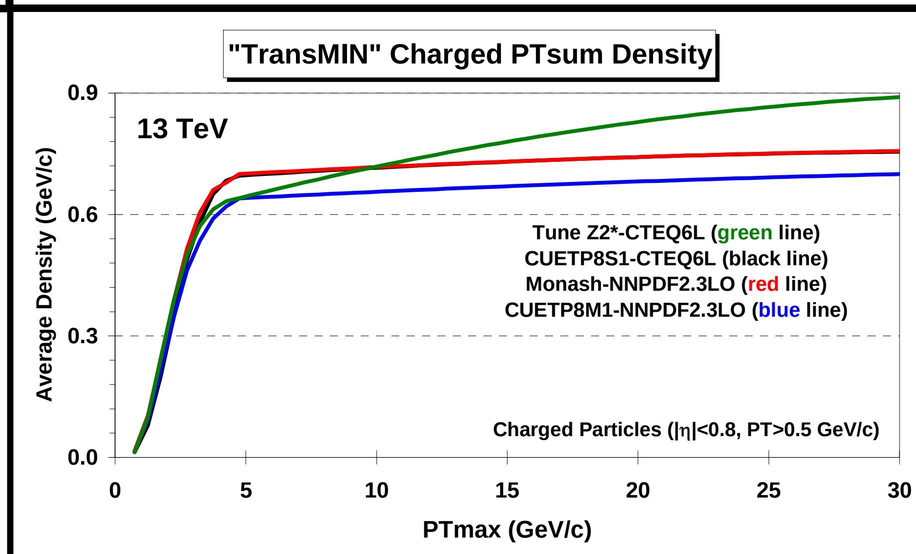
- **CMS and CDF data on the charged PTsum density in the "transAVE" region as defined by the leading charged particle (PTmax) for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 0.8$ with 5 < PTmax < 6 GeV/c. The data are plotted versus the center-of-mass energy (*log scale*). The data are compared with PYTHIA 6 Tune Z2* and PYTHIA 8 Tune CUETP8S1, Tune Monash, and Tune CUETP8M1.**

Predictions at 13 TeV

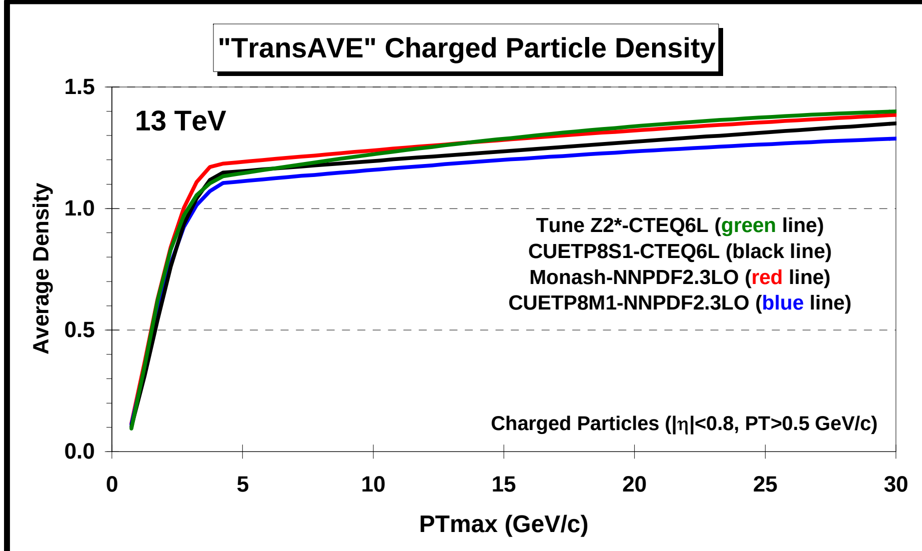


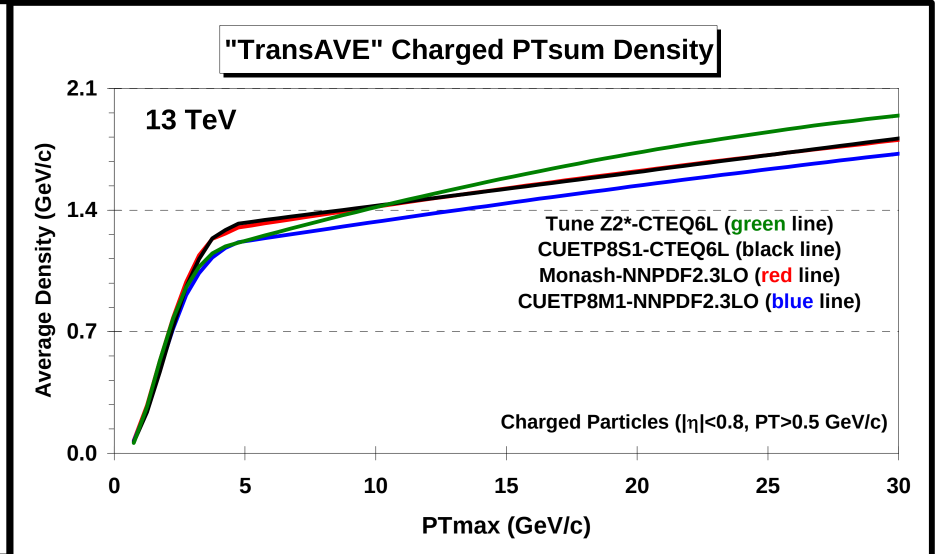


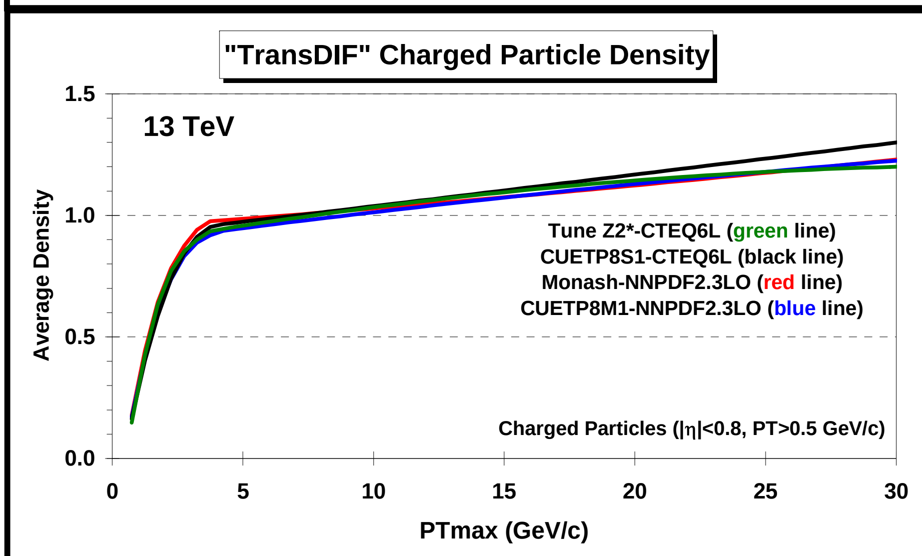


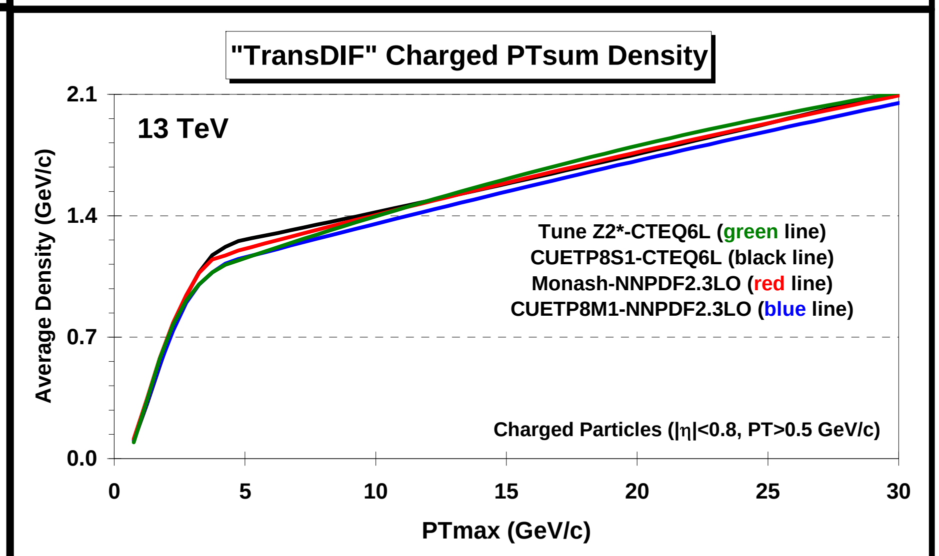


Predictions at 13 TeV

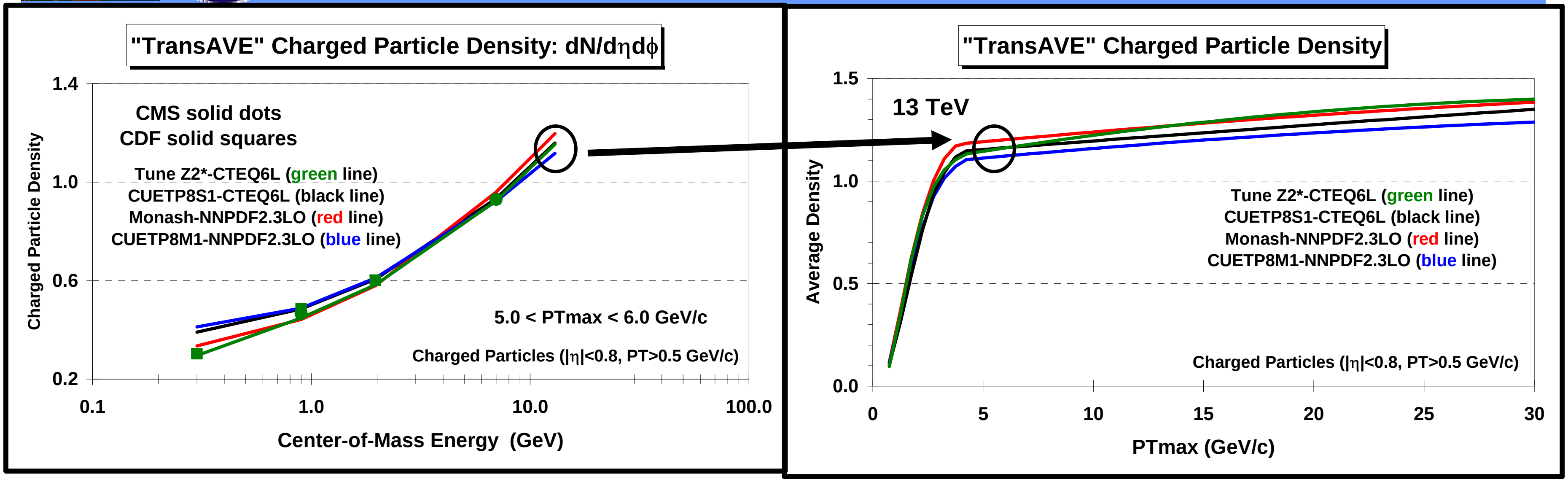






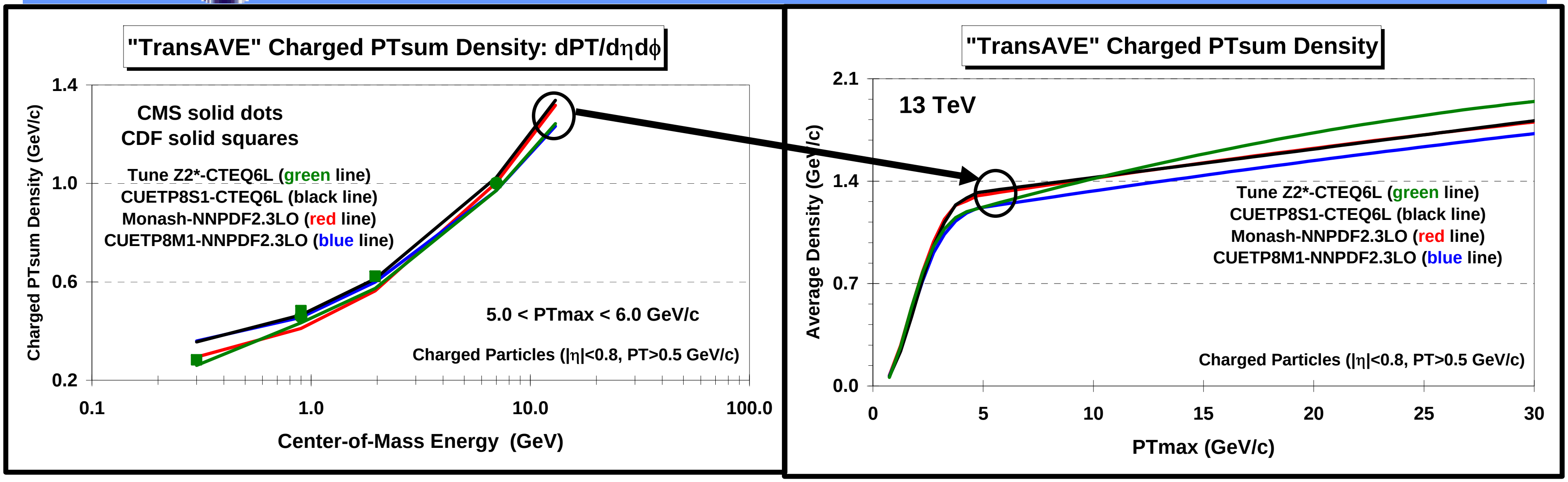


Predictions at 13 TeV



- **CMS and CDF data** on the charged particle density in the **"transAVE"** region as defined by the leading charged particle (PTmax) for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 0.8$ with 5 < PTmax < 6 GeV/c. The data are plotted versus the center-of-mass energy (*log scale*). The data are compared with PYTHIA 6 **Tune Z2*** and PYTHIA 8 Tune CUETP8S1, Tune **Monash**, and Tune **CUETP8M1**.
- **CMS data at 7 TeV and CDF data at 1.96 TeV, 900 GeV, and 300 GeV** on the charged particle density in the **"transAVE"** 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 compared with PYTHIA 6 **Tune Z2*** and PYTHIA 8 Tune CUETP8S1, Tune **Monash**, and Tune **CUETP8M1**.

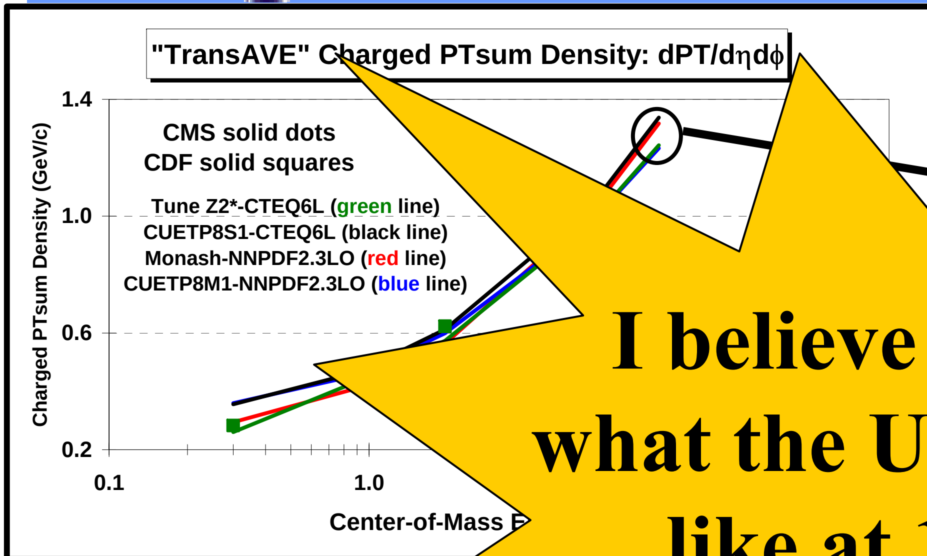
Predictions at 13 TeV

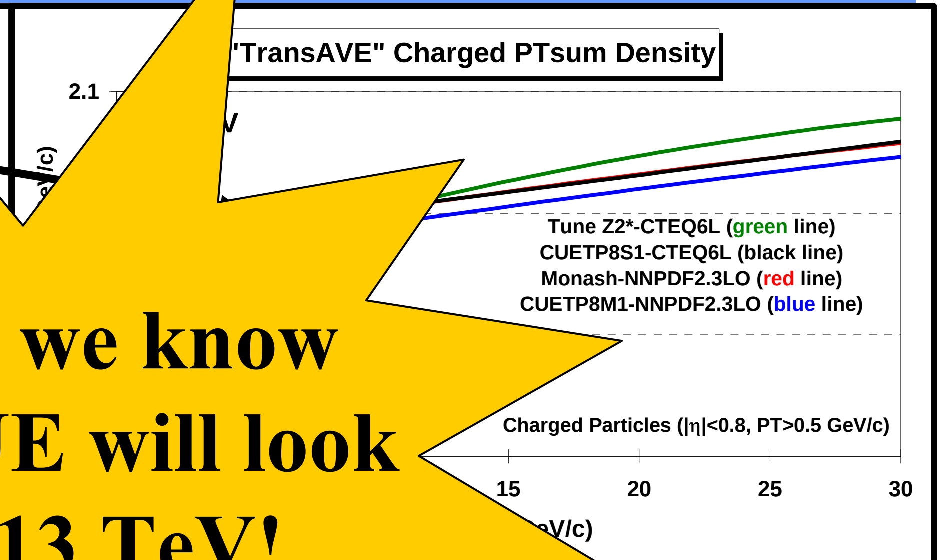


- **CMS and CDF data** on the charged PTsum density in the **"transAVE"** region as defined by the leading charged particle (PTmax) for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 0.8$ with 5 < PTmax < 6 GeV/c. The data are plotted versus the center-of-mass energy (*log scale*). The data are compared with PYTHIA 6 **Tune Z2*** and PYTHIA 8 Tune CUETP8S1, Tune **Monash**, and Tune **CUETP8M1**.

- **CMS data at 7 TeV and CDF data at 1.96 TeV, 900 GeV, and 300 GeV** on the charged PTsum density in the **"transAVE"** 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 compared with PYTHIA 6 **Tune Z2*** and PYTHIA 8 Tune CUETP8S1, Tune **Monash**, and Tune **CUETP8M1**.

Predictions at 13 TeV



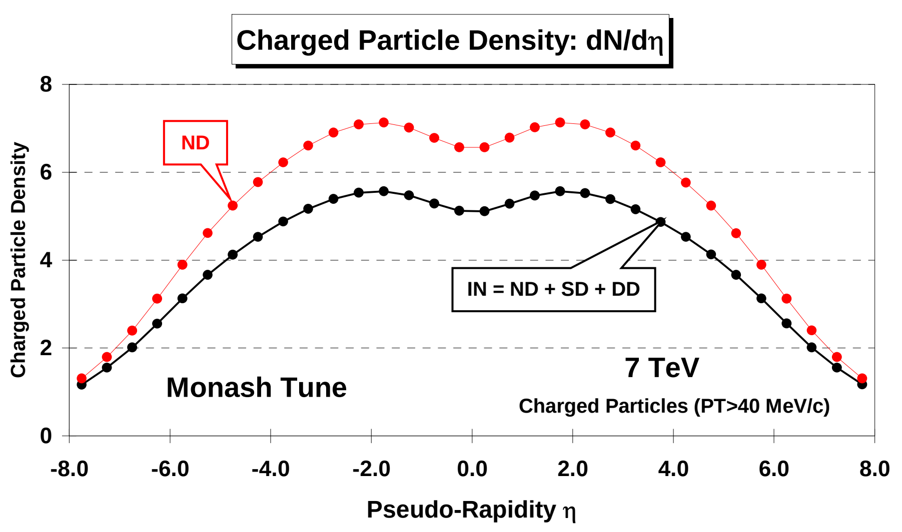


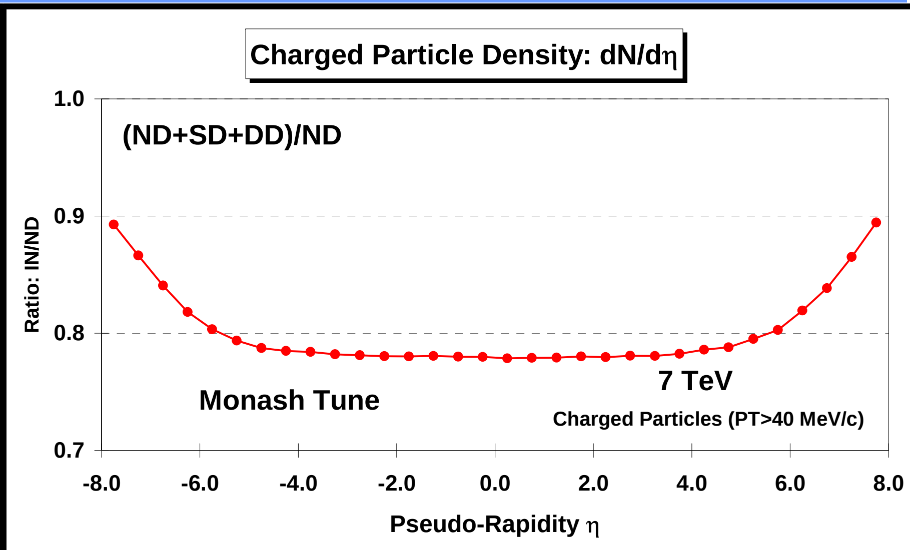
I believe we know what the UE will look like at 13 TeV!

- CMS and CDF dat... density in the "transAVE" regi... by the leading charged particl... charged particles with $p_T > 0.$... /c ... < 0.8 with 5 < PTmax < 6 Ge.../c. The d... are plotted versus the center-of-mass e... (*log scale*). The data are compared with PYTHIA 6 Tune Z2* and PYTHIA 8 Tu...e CUETP8S1, Tune Monash, and Tune CUETP8M1.

...TeV and CDF data at 1.96 ...nd 300 GeV on the charged ...n de... the "transAVE" region as ...d by th... ling charged particle ...ax) for cha...ed particles with $p_T > 0.5$ G...c and $|\eta| < 0.8$. The data are compared wit... PYTHIA 6 Tune Z2* and PYTHIA 8 Tune CUETP8S1, Tune Monash, and Tune CUETP8M1.

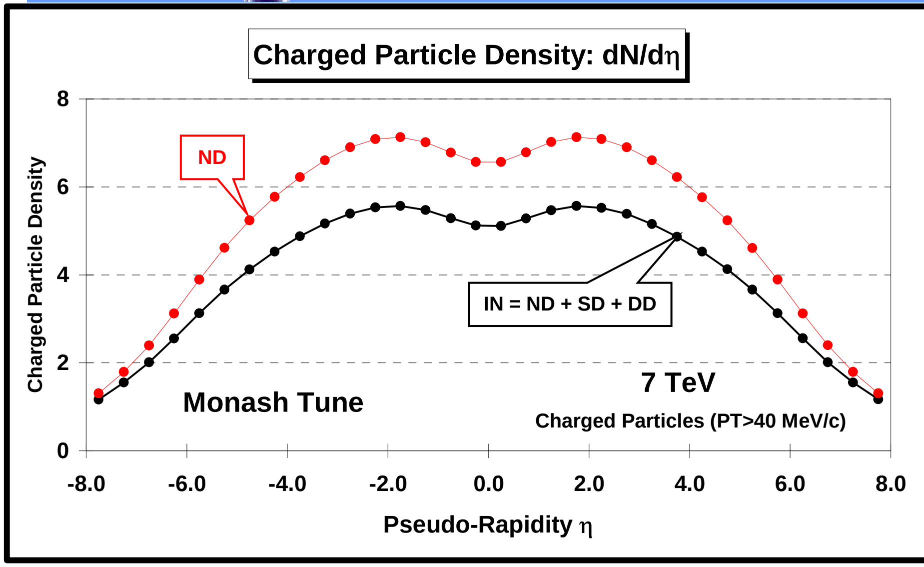
Charged Particle Density

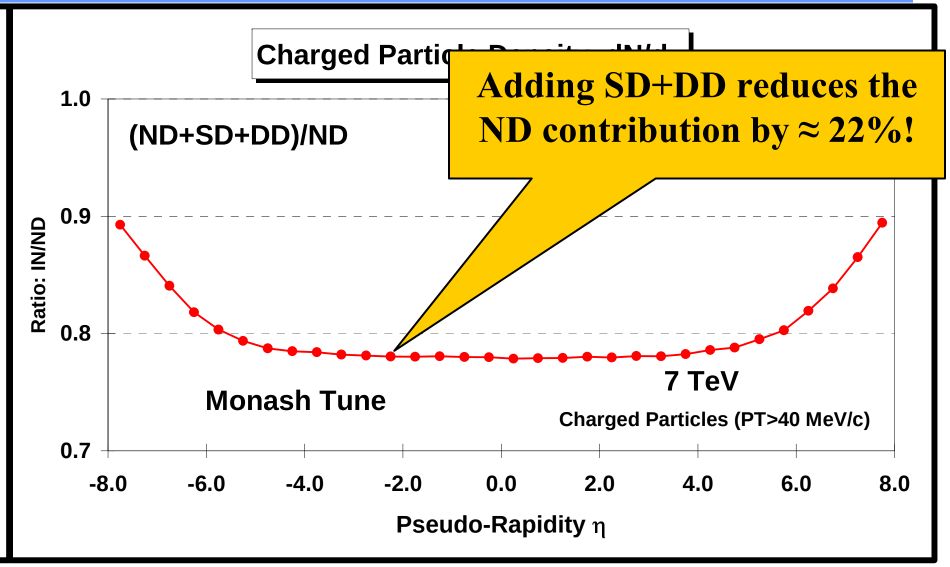




- **The charged particle density, dN/dη, for charged particles with p_T > 40 MeV/c at 7 TeV predicted by the Monash tune for the non-diffractive component (ND) and the inelastic component (IN = ND+SD+DD).**
- **The ratio on the inelastic component (IN = ND+SD+DD) and the non-diffractive component (ND) for the charged particle density, dN/dη, for charged particles with p_T > 40 MeV/c as predicted by the Monash tune at 7 TeV.**

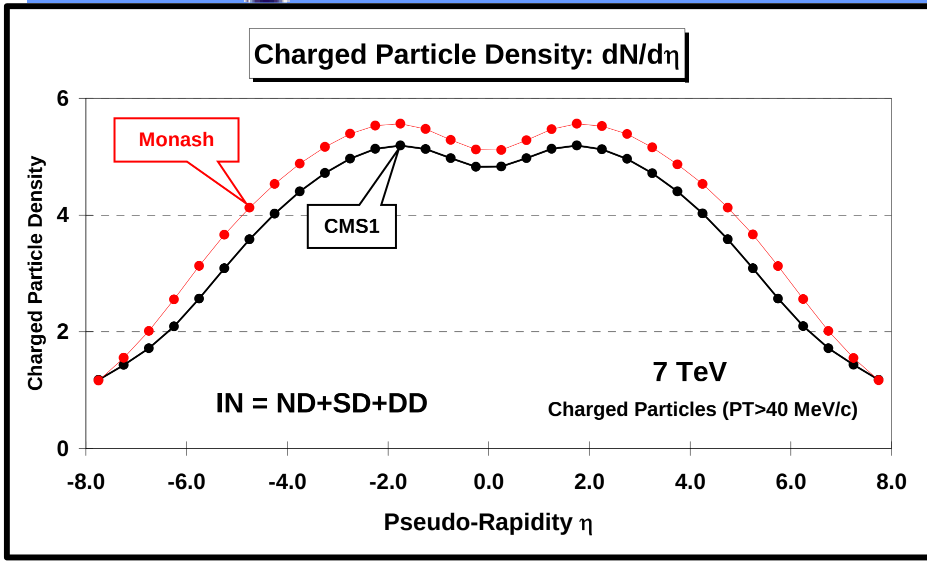
Charged Particle Density

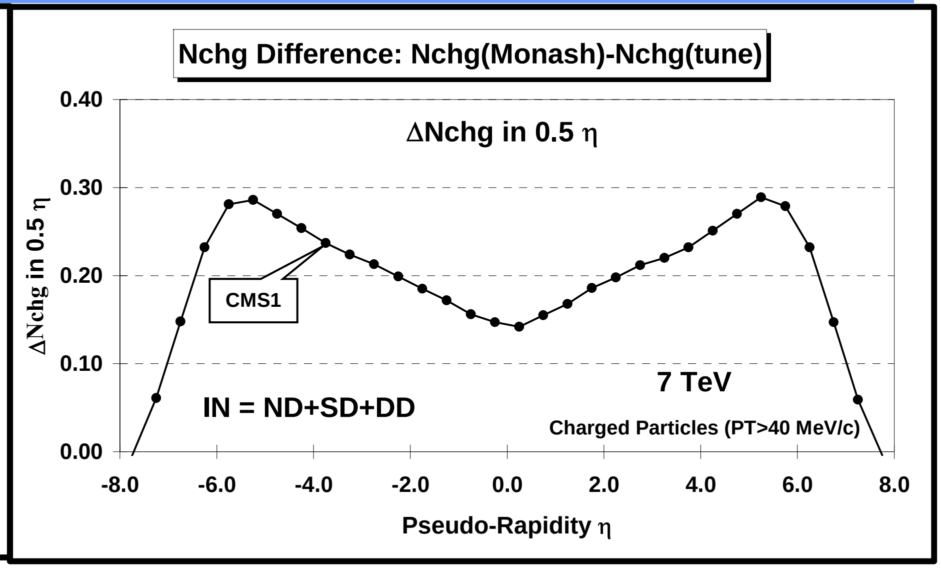




- The charged particle density, dN/dη, for charged particles with p_T > 40 MeV/c at 7 TeV predicted by the Monash tune for the non-diffractive component (ND) and the inelastic component (IN = ND+SD+DD).
- The ratio on the inelastic component (IN = ND+SD+DD) and the non-diffractive component (ND) for the charged particle density, dN/dη, for charged particles with p_T > 40 MeV/c as predicted by the Monash tune at 7 TeV.

Charged Particle Density

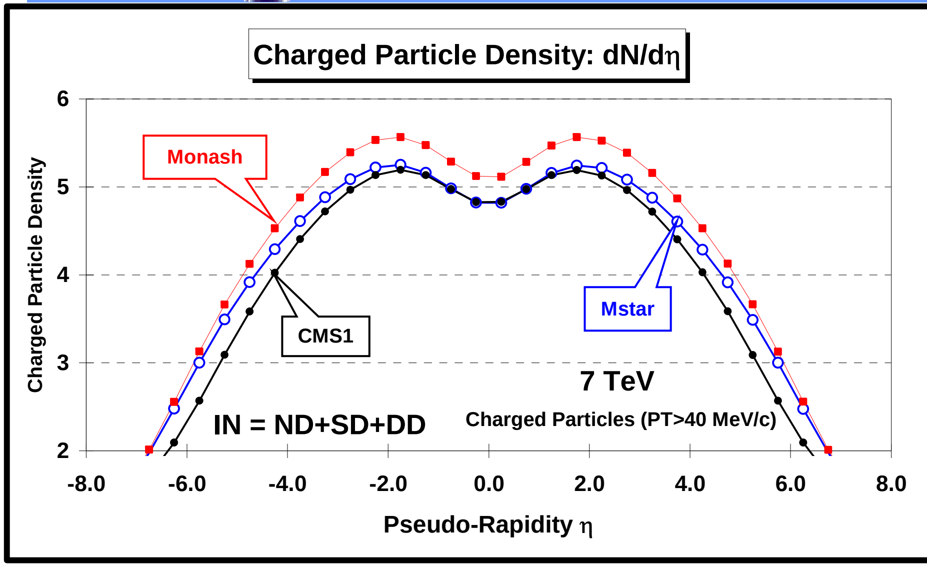


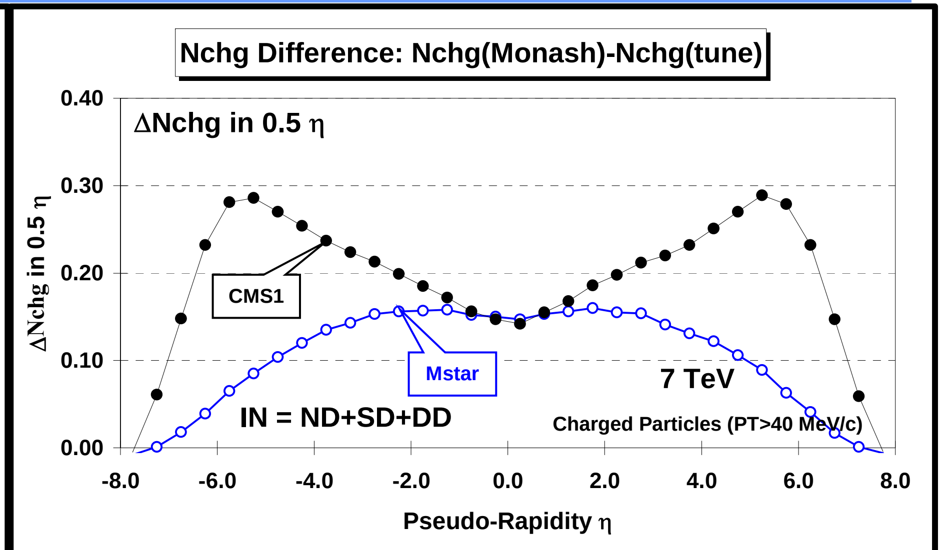


- **The charged particle density, dN/dη, for charged particles with p_T > 40 MeV/c at 7 TeV predicted by the Monash tune and the CMS tune CMS tune CUETP8S1-CTEQ6L for the inelastic component (IN = ND+SD+DD).**

- **The charged particle difference, ΔN_{chg}, for charged particles with p_T > 40 MeV/c at 7 TeV between the Monash tune and the CMS tune CMS tune CUETP8S1-CTEQ6L for the inelastic component (IN = ND+SD+DD), where $\Delta N_{chg} = N_{chg}$(Monash)-N_{chg}(CMS1) and corresponds to the number of charged particles in 0.5 η.**

Charged Particle Density

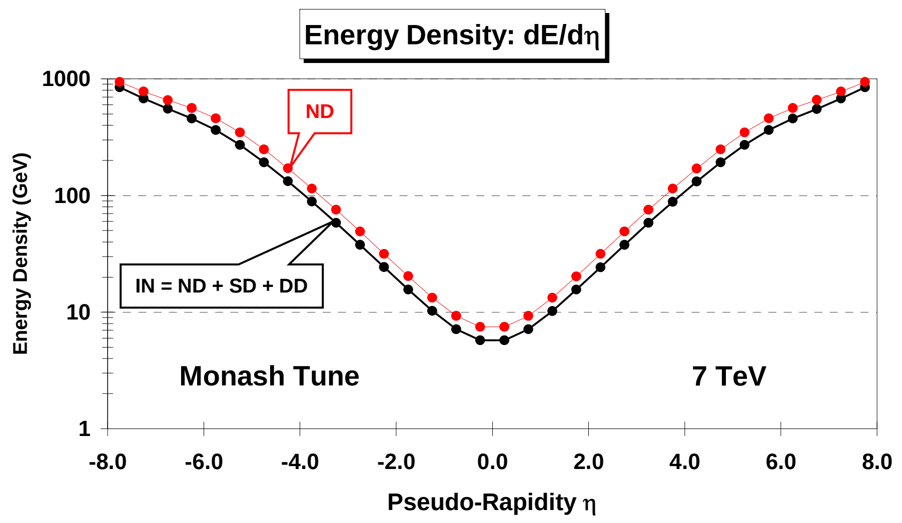


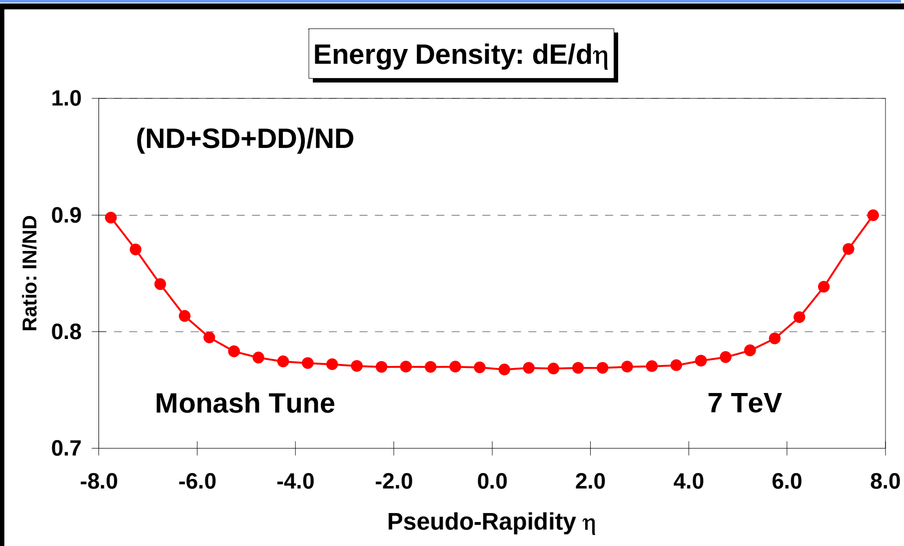


- **The charged particle density, dN/dη, for charged particles with $p_T > 40$ MeV/c at 7 TeV predicted by the Monash-NNPDF2.3LO tune, the tune CUETP8S1-CTEQ6L (CMS1), and tune CUEP8M1-NNPDF2.3LO (Mstar) for the inelastic component (IN = ND+SD+DD).**

- **Shows the charged particle difference, ΔN_{chg}, for charged particles with $p_T > 40$ MeV/c at 7 TeV between the Monash-NNPDF2.3LO tune and tune CUETP8S1-CTEQ6L (CMS1), and tune CUEP8M1-NNPDF2.3LO (Mstar) for the inelastic component (IN = ND+SD+DD), where $\Delta N_{chg} = N_{chg}$(Monash)-N_{chg}(tune) and corresponds to the number of charged particles in 0.5 η.**

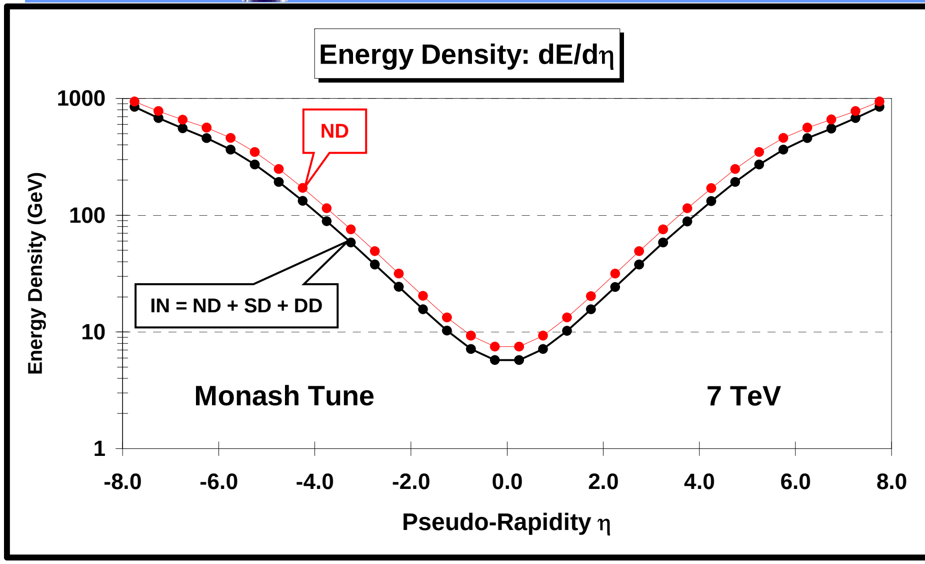
Energy Flow: dE/dη

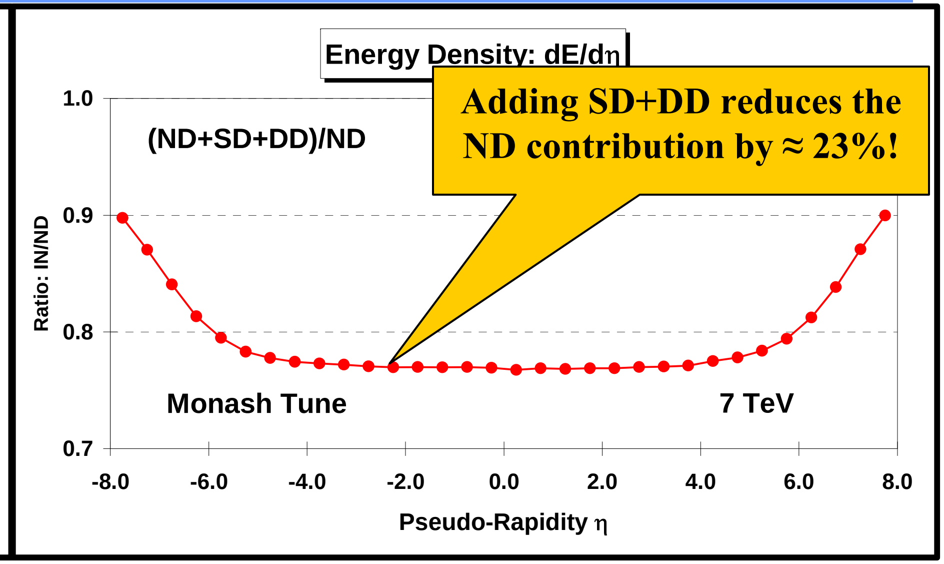




- **The energy density, dE/dη, at 7 TeV predicted by the Monash tune for the non-diffractive component (ND) and the inelastic component (IN = ND+SD+DD).**
- **The ratio on the inelastic component (IN = ND+SD+DD) and the non-diffractive component (ND) energy density, dE/dη, predicted by the Monash tune at 7 TeV.**

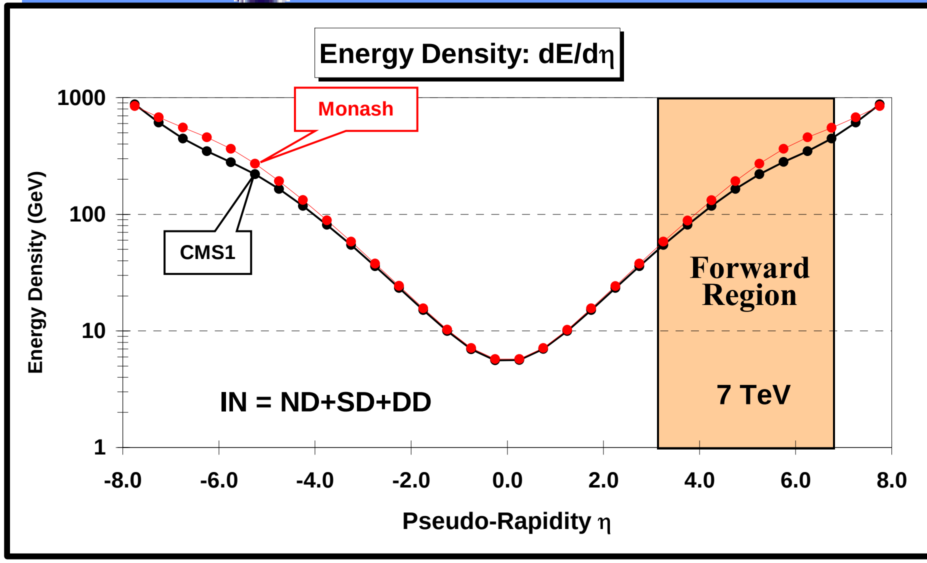
Energy Flow: dE/dη

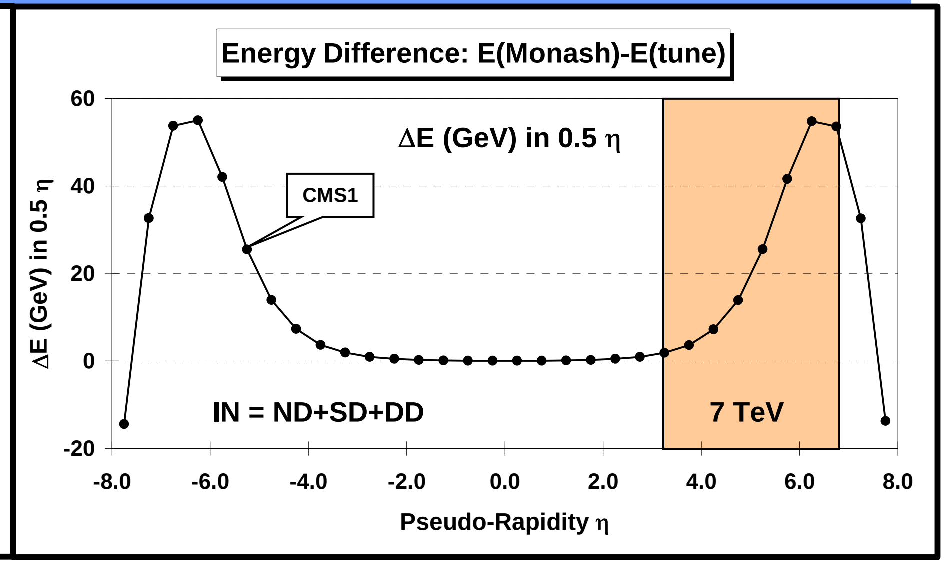




- **The energy density, dE/dη, at 7 TeV predicted by the Monash tune for the non-diffractive component (ND) and the inelastic component (IN = ND+SD+DD).**
- **The ratio on the inelastic component (IN = ND+SD+DD) and the non-diffractive component (ND) energy density, dE/dη, predicted by the Monash tune at 7 TeV.**

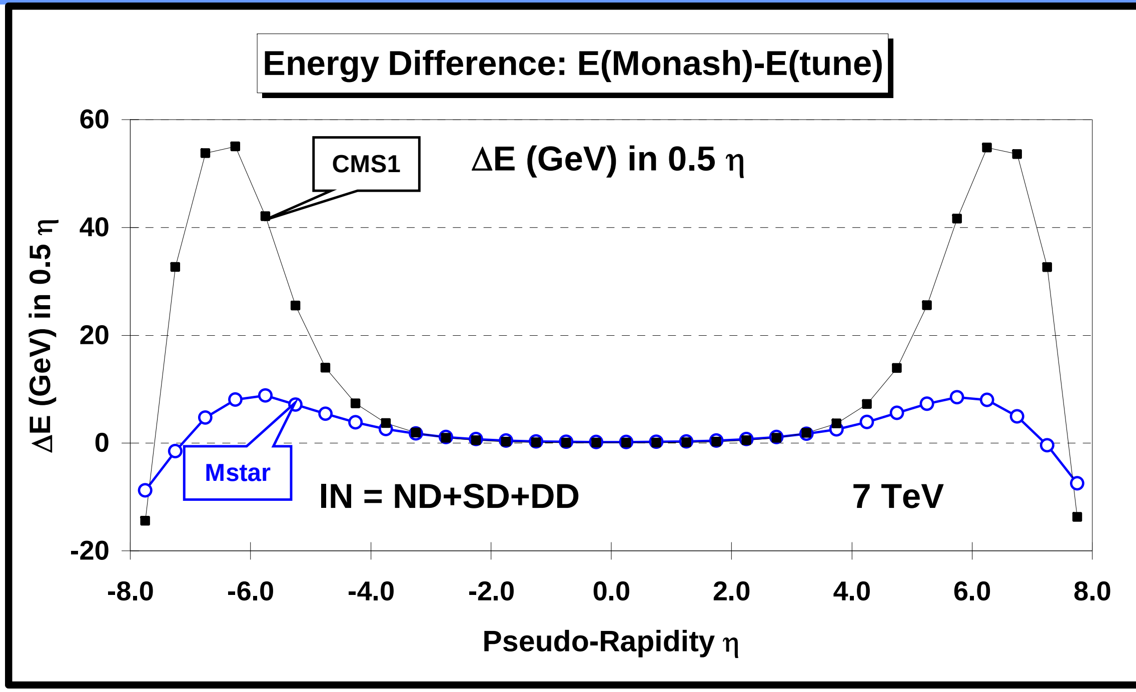
Energy Flow: dE/dη





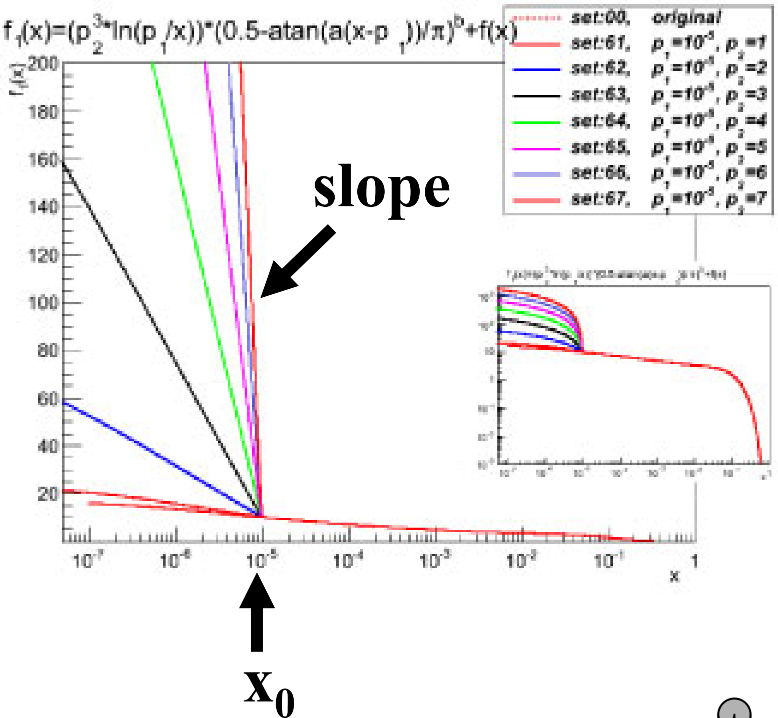
- **The energy density, dE/dη, at 7 TeV predicted by the Monash-NNPDF2.3LO tune and the tune CUETP8S1-CTEQ6L (CMS1) for the inelastic component (IN = ND+SD+DD).**
- **The energy difference, ΔE, at 7 TeV between the Monash-NNPDF2.3LO and tune CUETP8S1-CTEQ6L (CMS1) for the inelastic component (IN = ND+SD+DD), where ΔE = E(Monash)-E(CMS1) and corresponds to the amount of energy in GeV in 0.5 η.**

Energy Flow: dE/dη

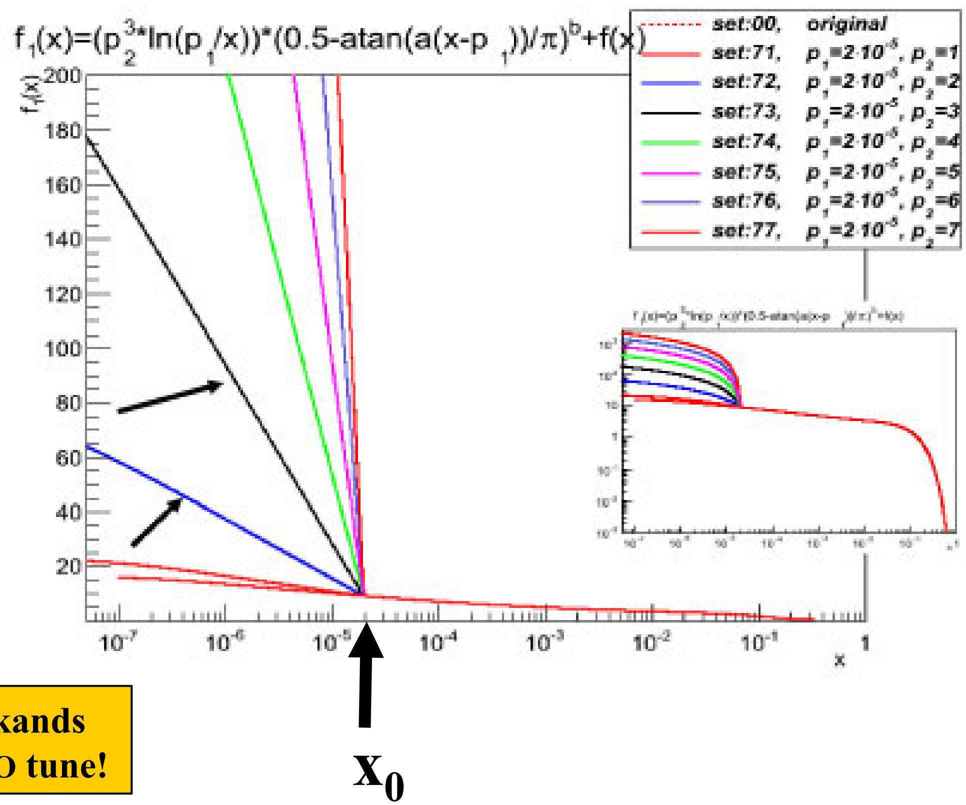


- **Shows the energy density difference, ΔE, at 7 TeV between the Monash-NNPDF2.3LO tune, and tune CUETP8S1-CTEQ6L (CMS1), and tune CUEP8M1-NNPDF2.3LO (Mstar) for the inelastic component (IN = ND+SD+DD), where ΔE = E(Monash)-E(tune) and corresponds to the amount of energy in GeV in 0.5 η.**

Tuning the PDF!



➡ Start with the HERALOPDF functions, f(x). Modify the gluon distribution at small x by adding a function $f_1(x,p_1,p_2)$ with 2 parameters ($p_1 = x_0$, p_2 = slope).

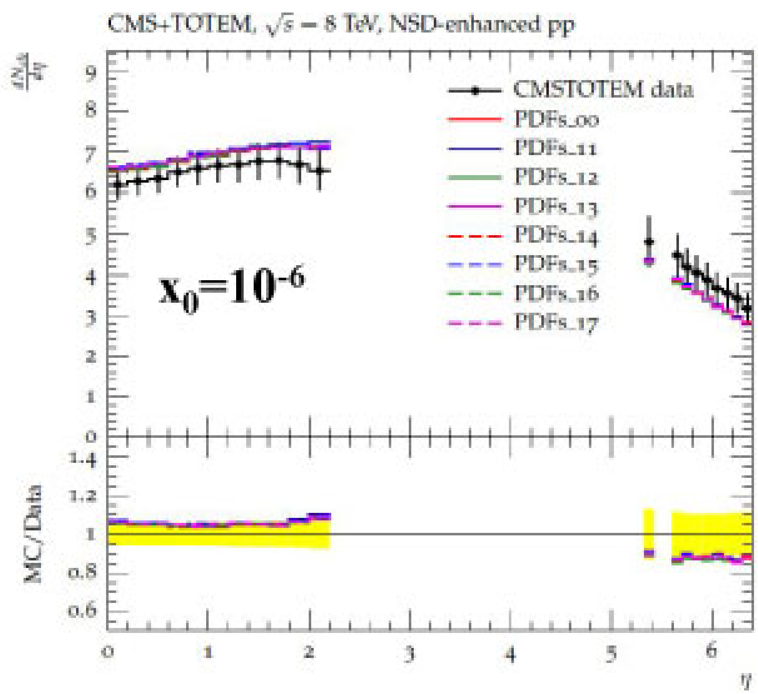


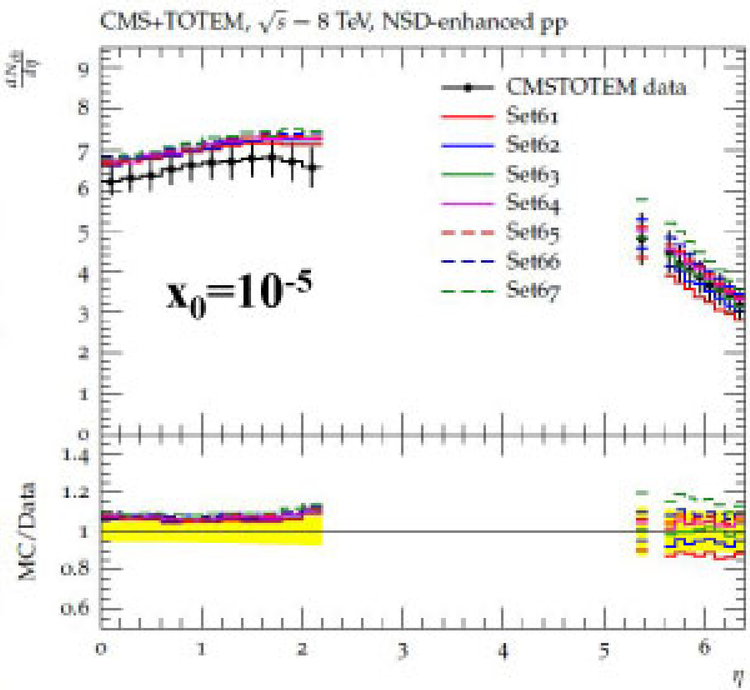
New Approach

Tune the PDF

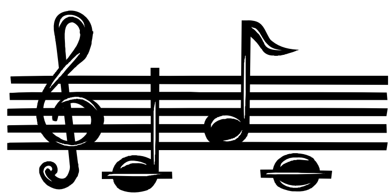
Started with the Skands Monash-NNPDF2.3LO tune!

TOTEM Forward dN/dη

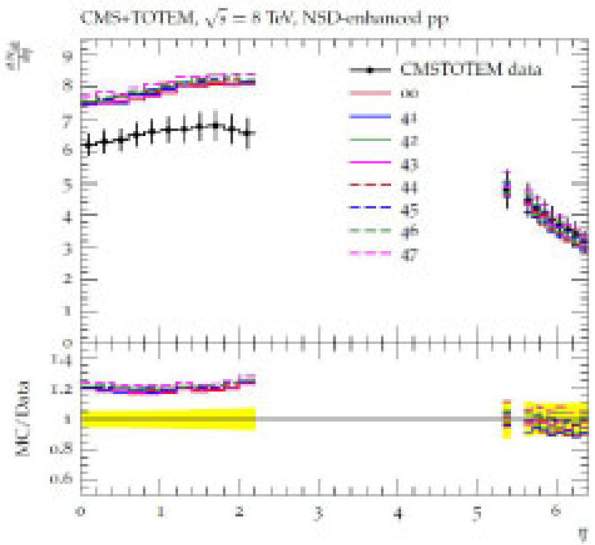




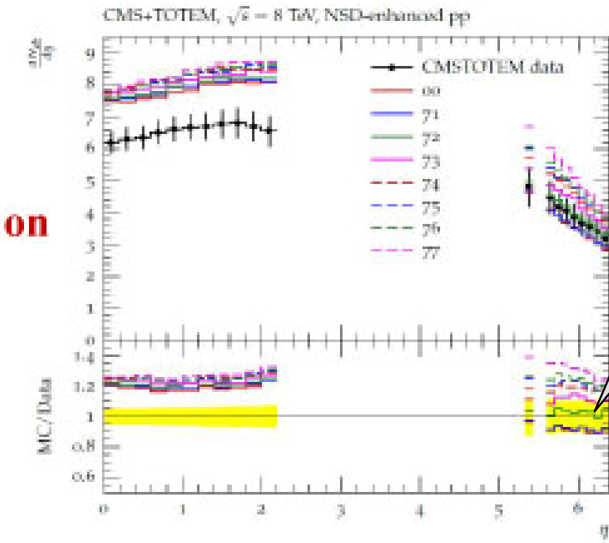
- **Use the CMS Tune CUETP8S1-HERALOPDF and vary the low x gluon distribution to try to improve the fit to the forward region (TOTEM data). Need to increase the gluon distribution at x <≈ 10^{-5}!**



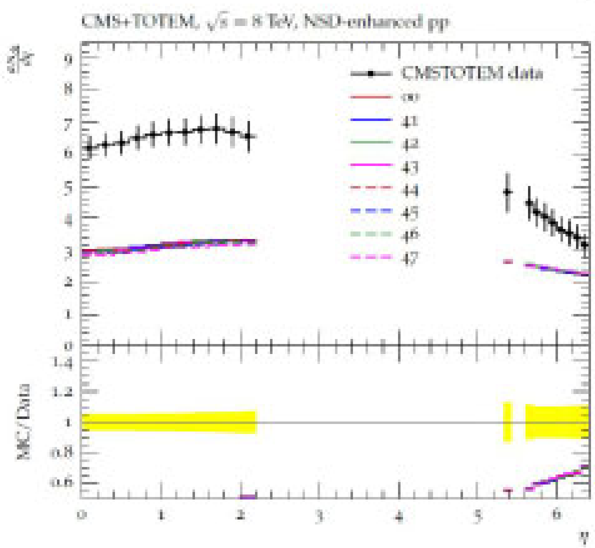
TOTEM Forward dN/dη



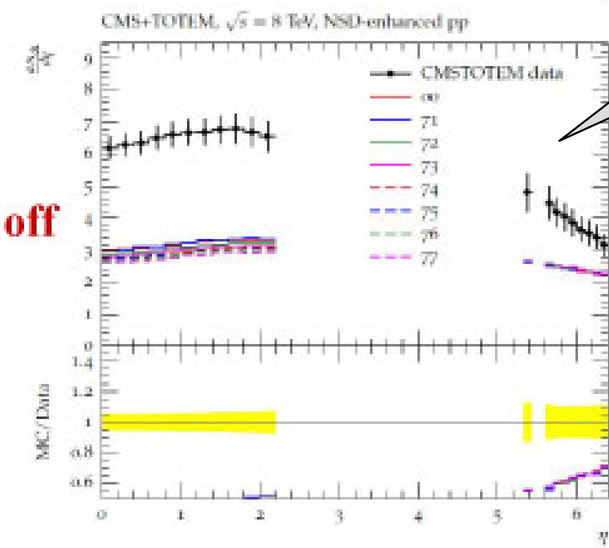
MPI= on



Can improve agreement with TOTEM!

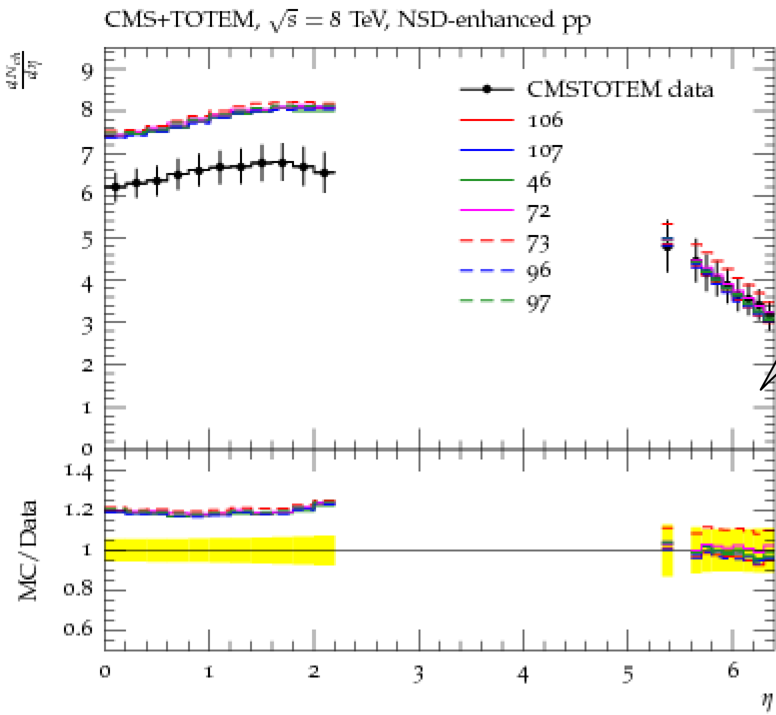


MPI= off



MPI contributes a lot to both central and forward dN/dη!

TOTEM Forward dN/dη



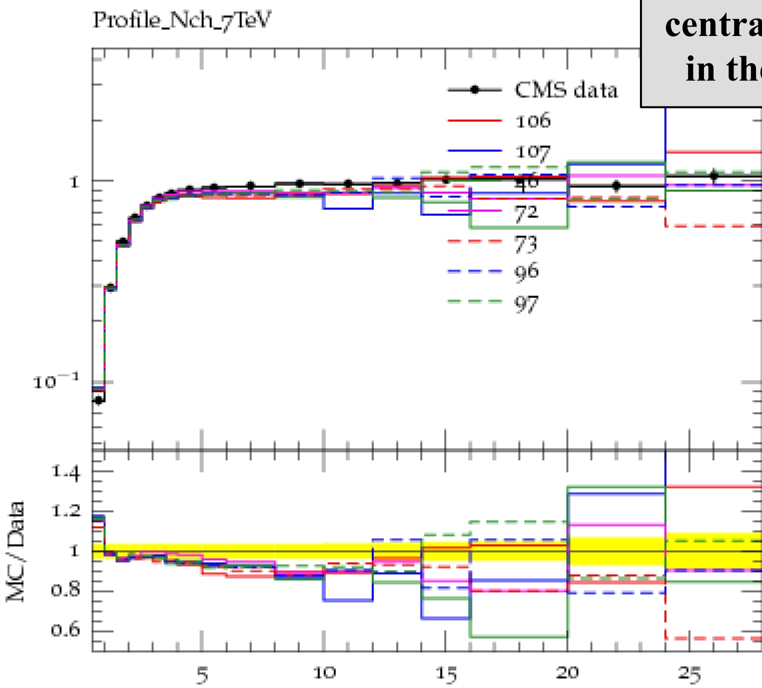
Can improve agreement with TOTEM! Does not affect the central region.

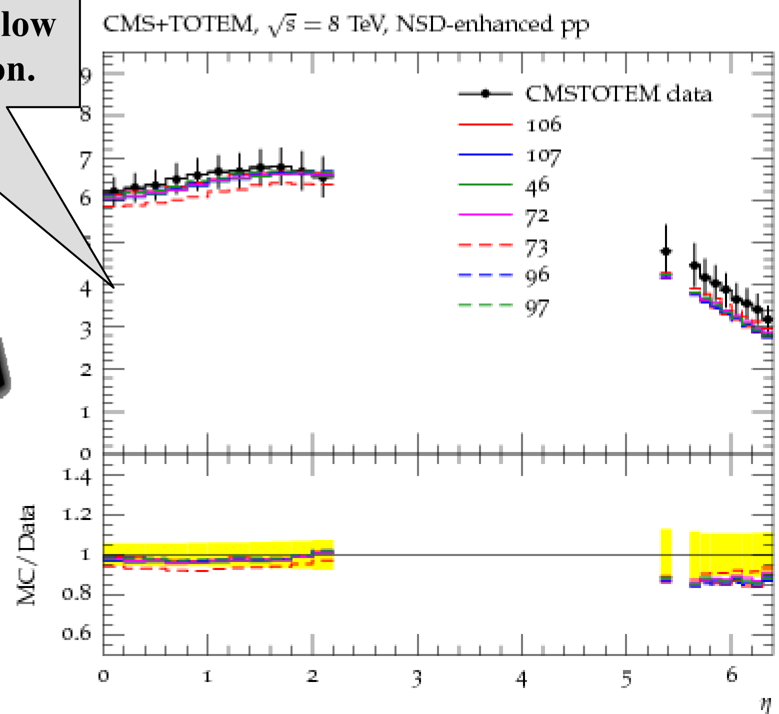
➡ **Use the CMS Tune CUETP8S1-HERALOPDF and vary the low x gluon distribution to try to improve the fit to the forward region (TOTEM data).**

However, changing the gluon distribution at low x destroys the fit to the UE data!
If you change the PDF, you must change the UE tune accordingly!

Re-Tune the UE Parameters

Oops! Now agrees in the central region and is low in the forward region.

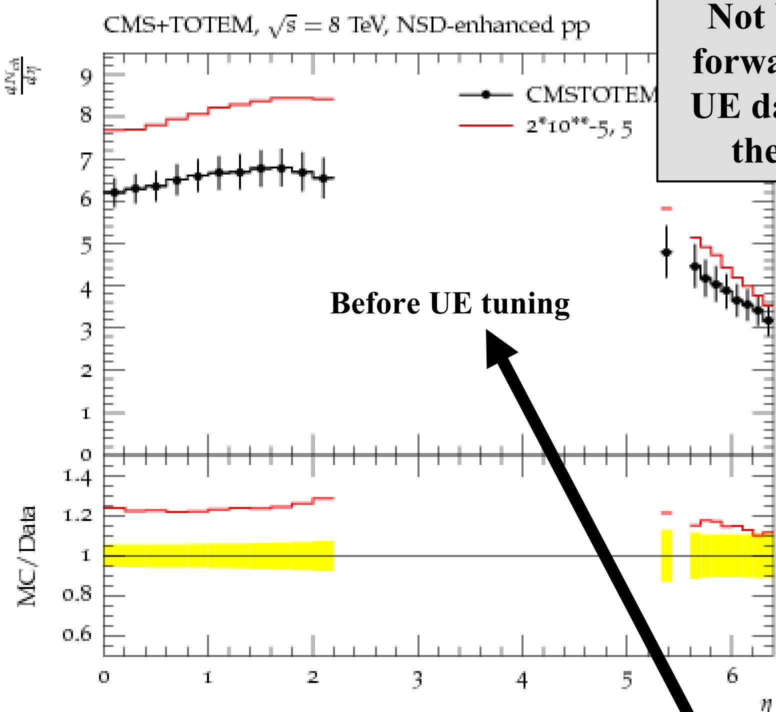




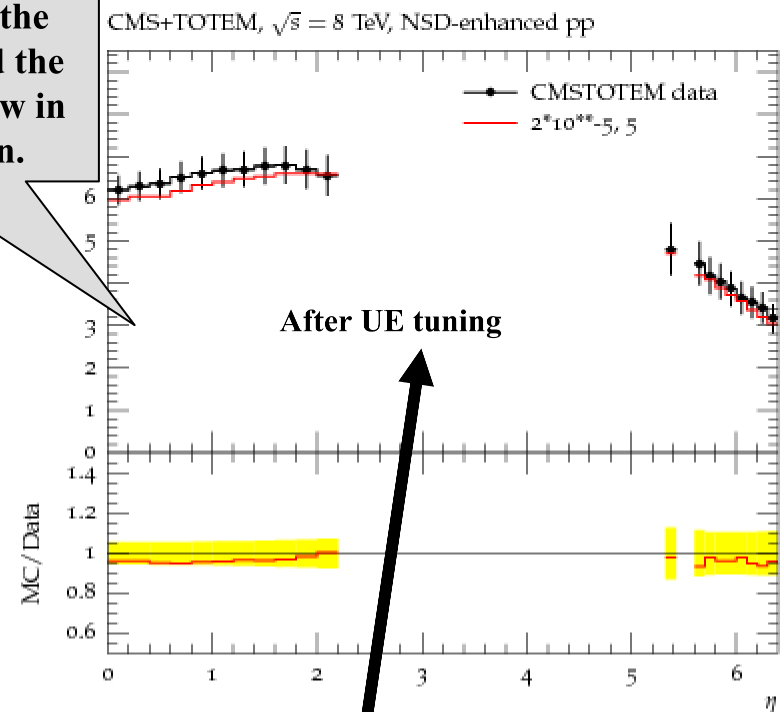
- Starting with the tunes that fit to the forward region (TOTEM data) re-tune the UE parameters of CMS Tune CUETP8S1-HERALOPDF to fit the UE data.

- Need to start with a slightly different low x gluon distribution or do a simultaneous fit that varies both the low x gluon distribution and the UE parameters in an attempt to fit the central and forward dN/dη and the UE data.

Try Again

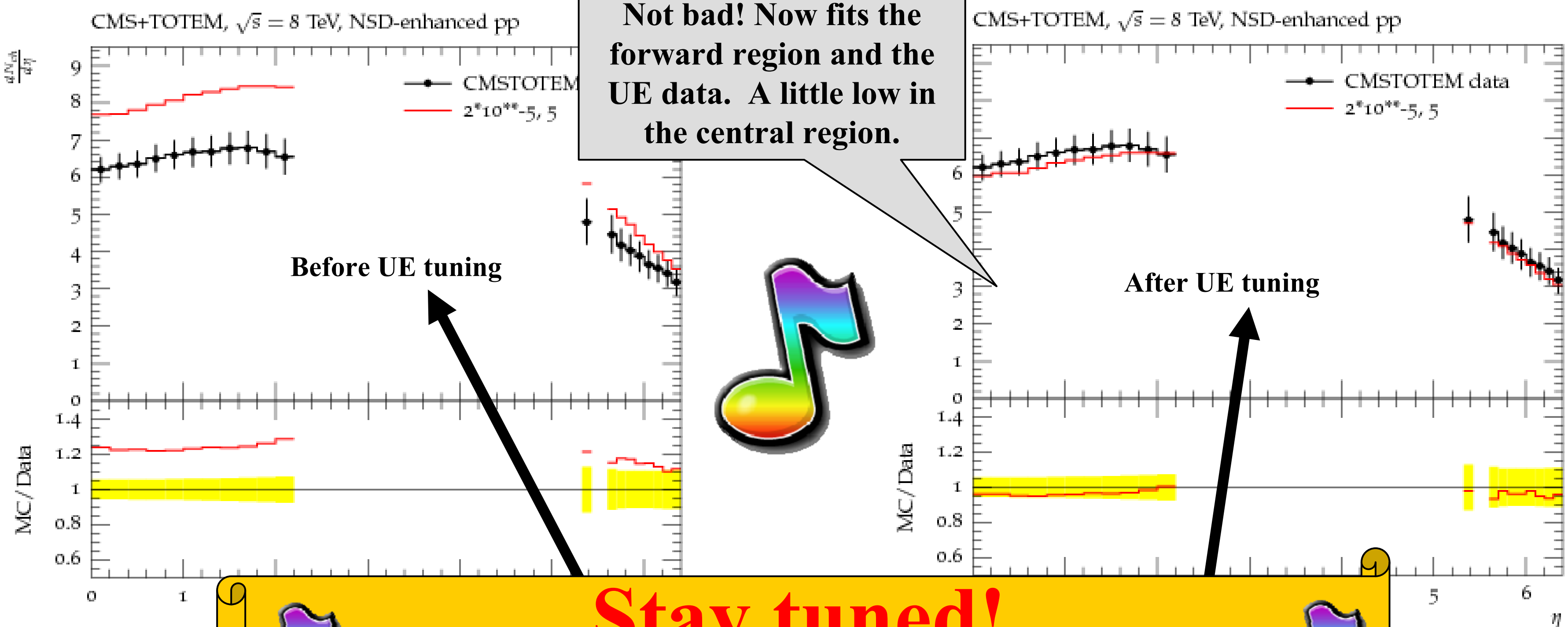


Not bad! Now fits the forward region and the UE data. A little low in the central region.



- **Starting with a different low x gluon distribution re-tune the UE parameters of CMS Tune CUETP8S1-HERALOPDF to fit the UE data.**
- **Perhaps we should do a simultaneous fit that varies both the low x gluon distribution and the UE parameters in an attempt to fit the central and forward dN/dη and the UE data.**

Try Again



Not bad! Now fits the forward region and the UE data. A little low in the central region.

Stay tuned!
More CMS tunes coming!

- **Starting w... S Tune CUETP8S...**
- **Perhaps we should do a simultaneous fit that varies both the low x gluon distribution and the UE parameters in an attempt to fit the central and forward dN/dη and the UE data.**