LPCC MB&UE Working Group Meeting

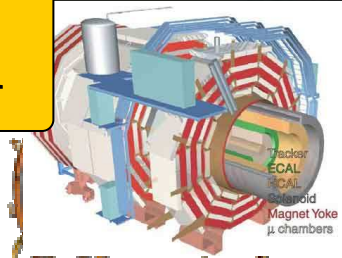
September 6 & 7, 2010

LHC Physics Centre at CERN

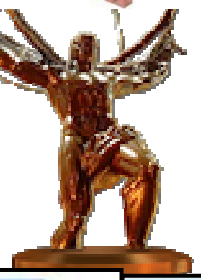
CMS UE Data and the New Tune Z1

Rick Field

University of Florida



CMS

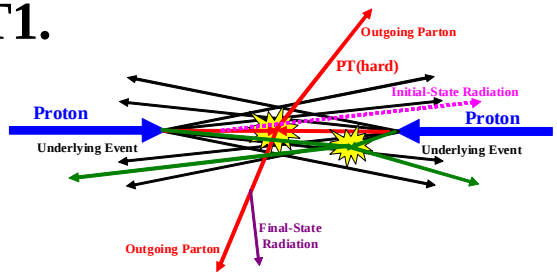


ATLAS

Outline of Talk

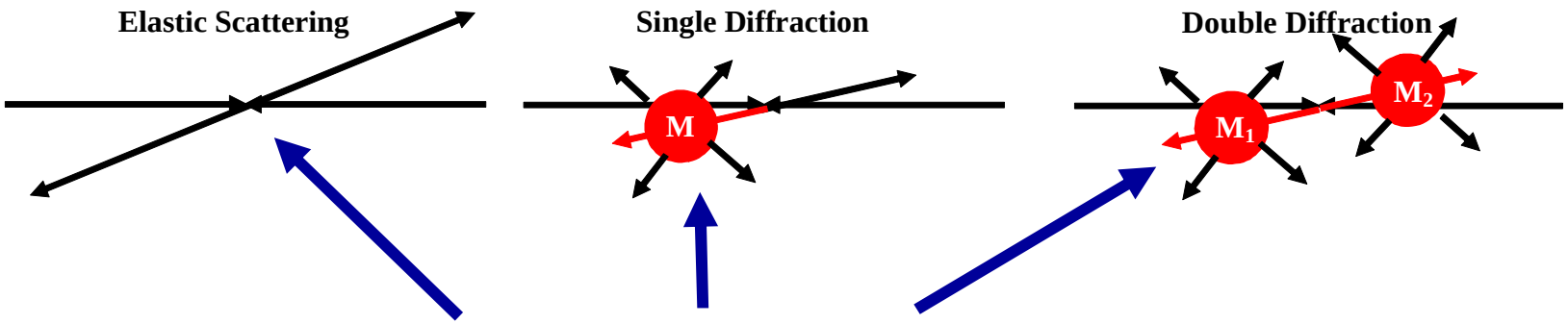
- **PYTHIA 6.2 Tune DW:** How well did we do at predicting the LHC UE data at 900 GeV and 7 TeV? A careful look.

- **PYTHIA 6.4 Tune Z1:** New CMS 6.4 tune (pT-ordered parton showers and new MPI) inspired by the ATLAS Tune AMBT1.



UE&MB@CMS

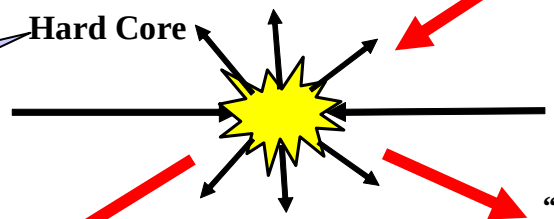
Proton-Proton Collisions

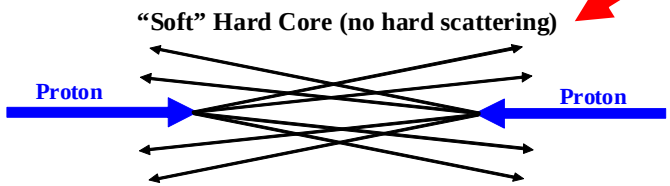


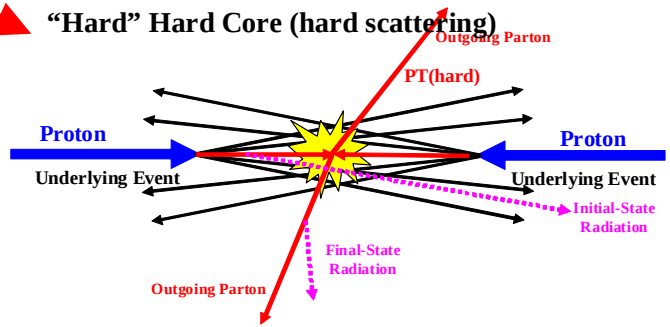
$$\sigma_{tot} = \sigma_{EL} + \sigma_{SD} + \sigma_{DD} + \sigma_{ND}$$

"Inelastic Non-Diffractive Component"

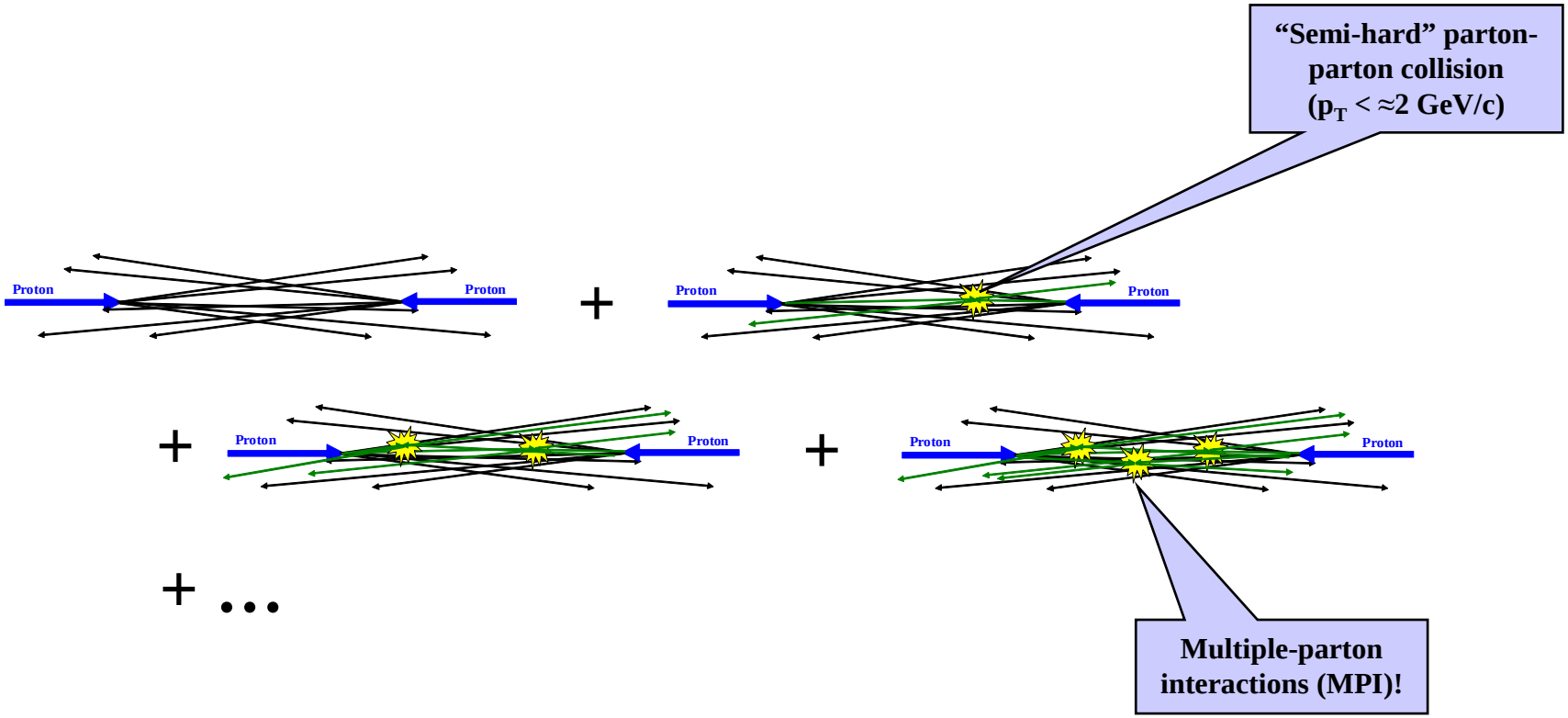
The "hard core" component contains both "hard" and "soft" collisions.



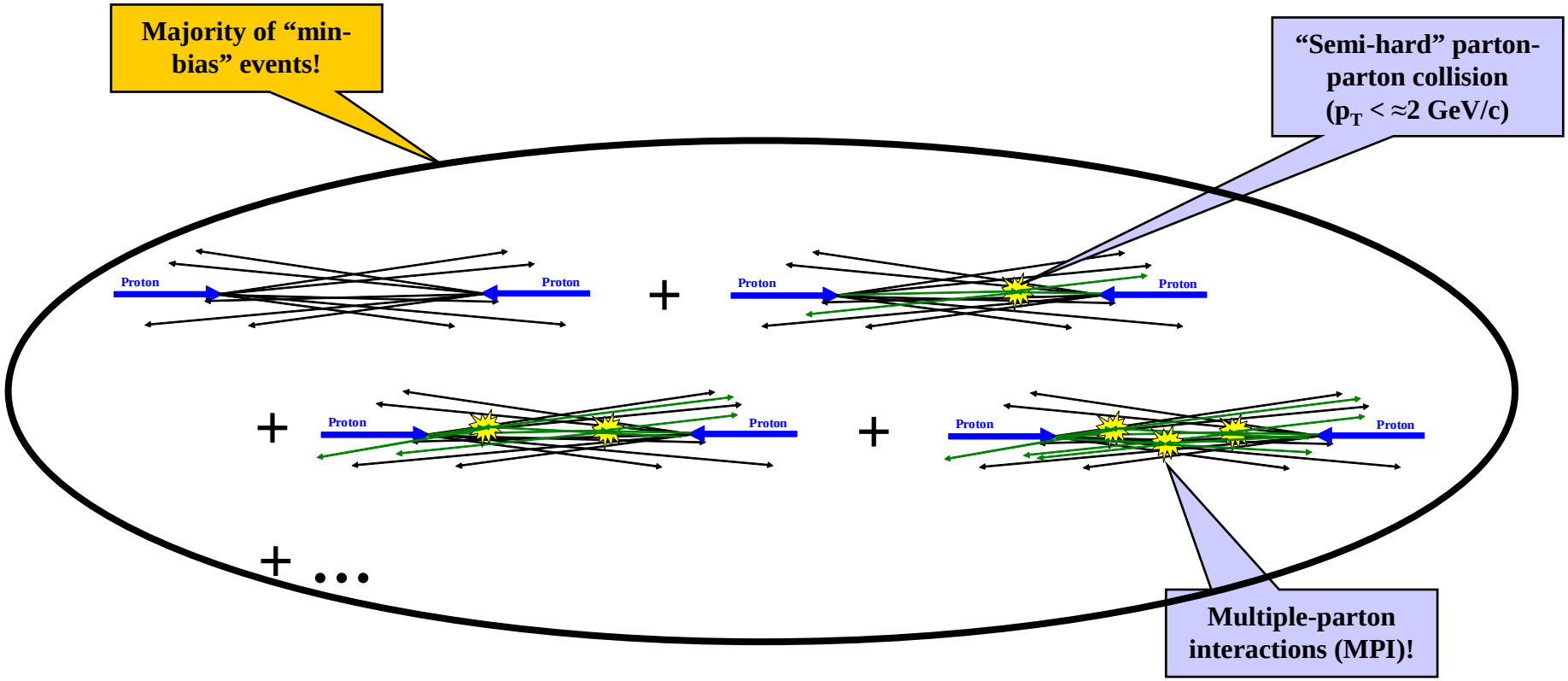




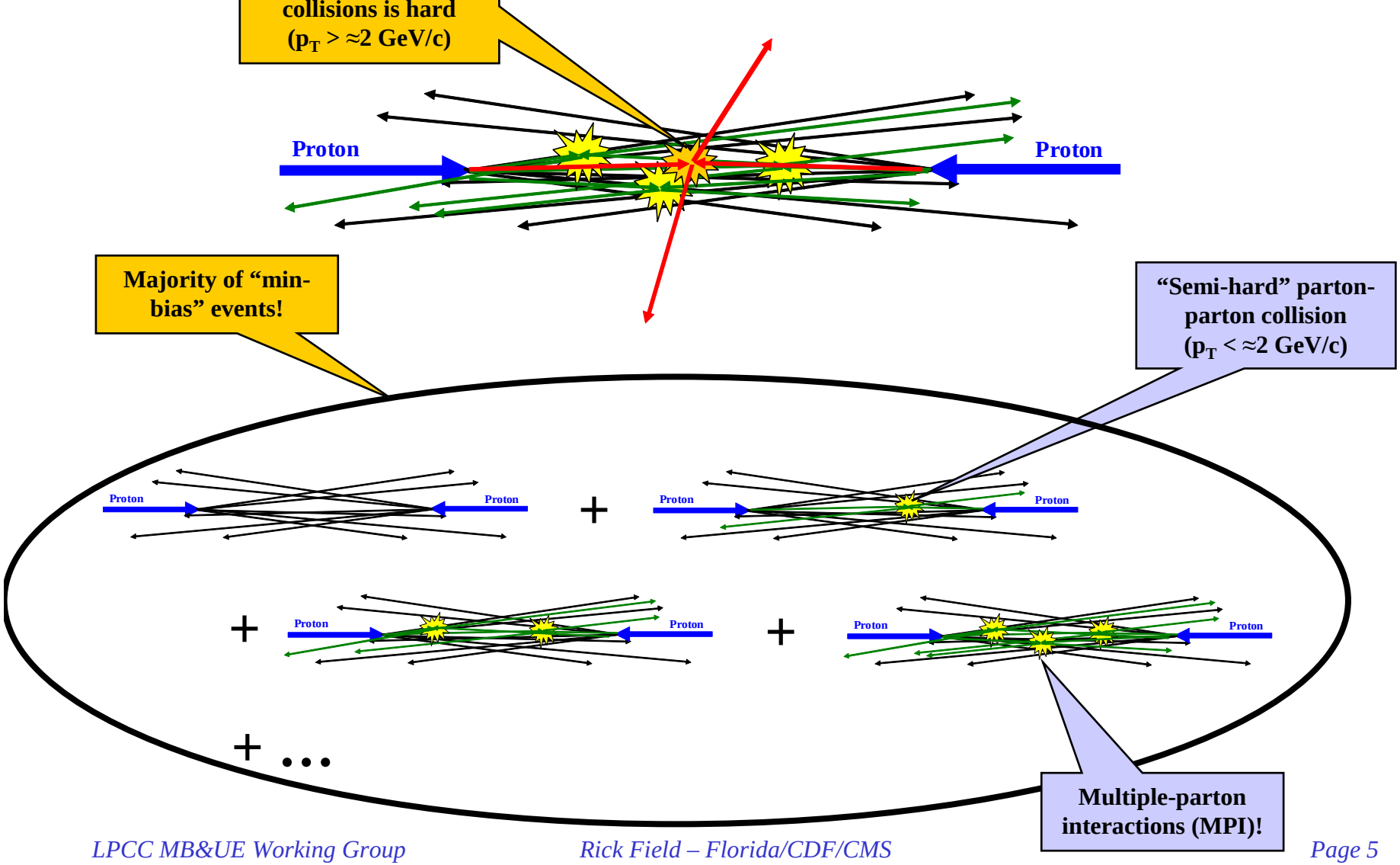
The Inelastic Non-Diffractive Cross-Section



The Inelastic Non-Diffractive Cross-Section

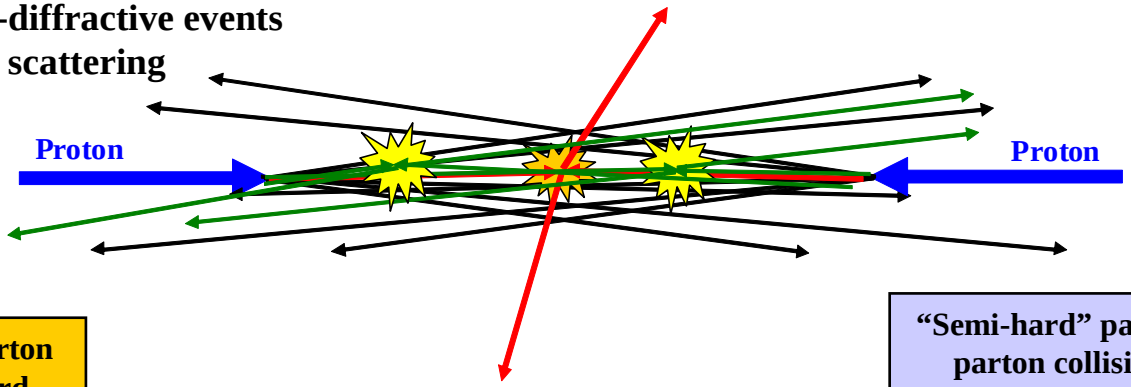


The Inelastic Non-Diffractive Cross-Section



The "Underlying Event"

Select inelastic non-diffractive events that contain a hard scattering

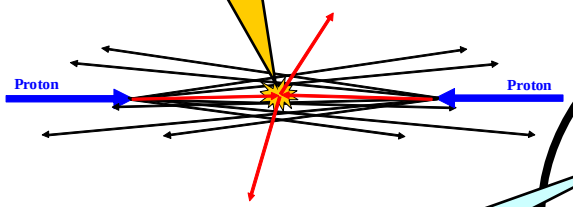


Hard parton-parton collisions is hard ($p_T > \approx 2$ GeV/c)

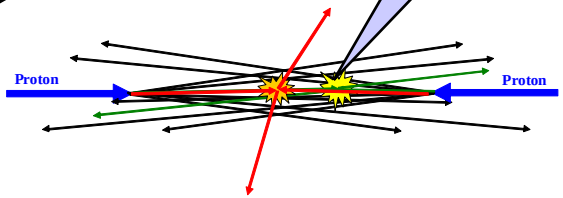
The "underlying-event" (UE)!

"Semi-hard" parton-parton collision ($p_T < \approx 2$ GeV/c)

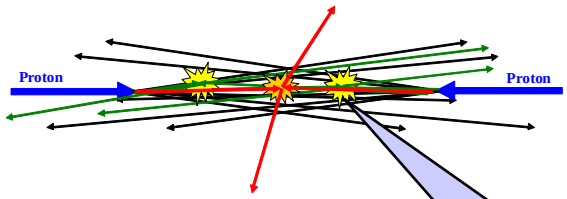
$$1/(p_T)^4 \rightarrow 1/(p_T^2+p_{T0}^2)^2$$



+



+



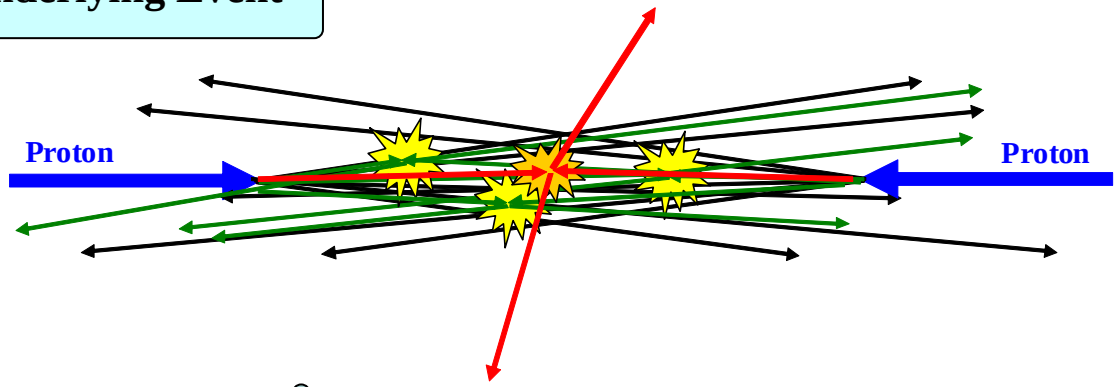
+ …

Given that you have one hard scattering it is more probable to have MPI! Hence, the UE has more activity than "min-bias".

Multiple-parton interactions (MPI)!

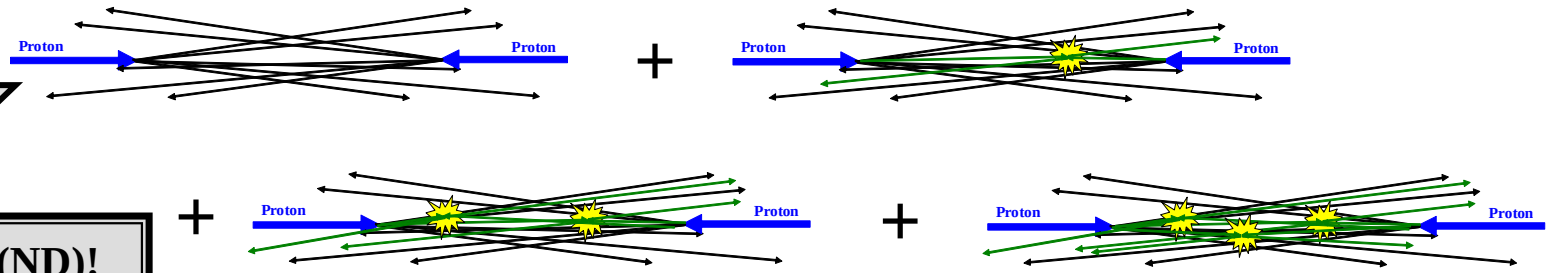
UE Tunes

"Underlying Event"



Fit the "underlying event" in a hard scattering process.

"Min-Bias" (ND)



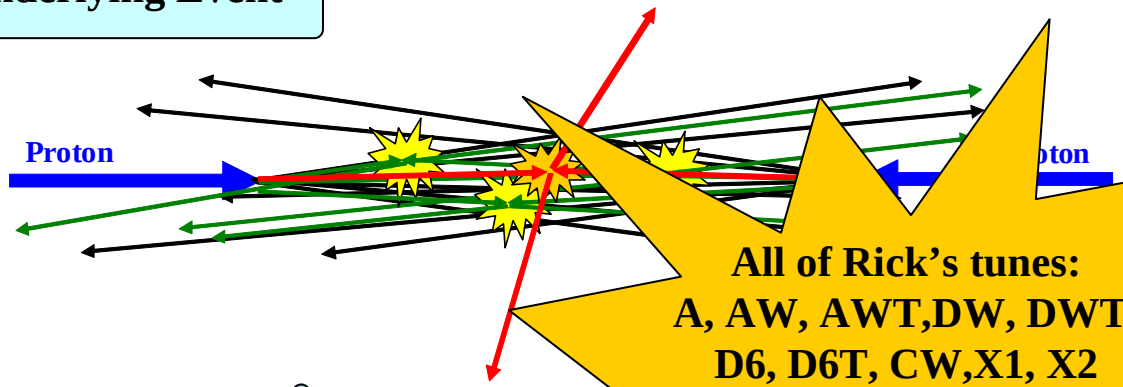
Predict MB (ND)!

+ …

UE Tunes

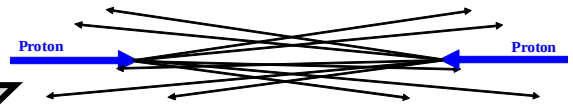
"Underlying Event"

Fit the "underlying event" in a hard scattering process.



All of Rick's tunes:
A, AW, AWT,DW, DWT,
D6, D6T, CW,X1, X2
and Tune Z1,
are UE tunes!

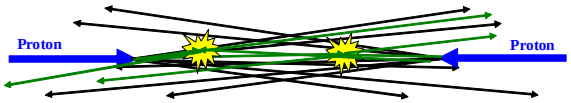
"Min-Bias" (ND)



+

Predict MB (ND)!

+



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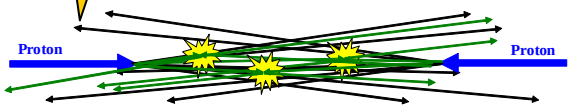
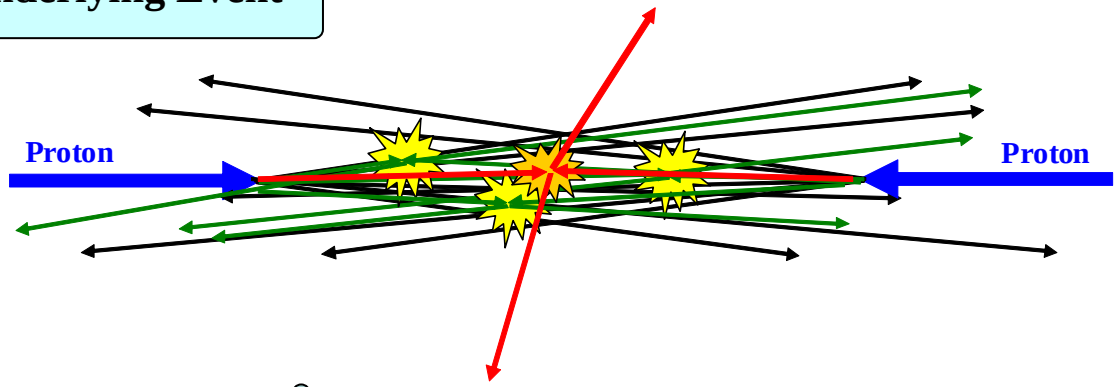


+ …

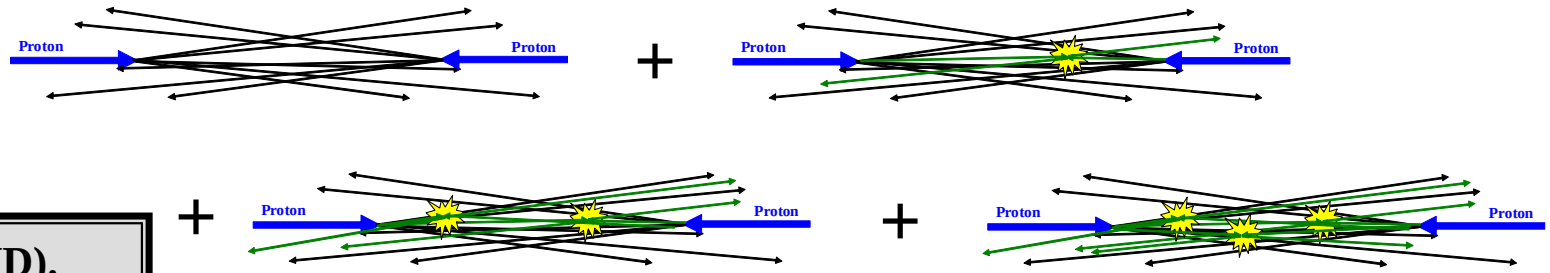
MB Tunes

"Underlying Event"



Predict the "underlying event" in a hard scattering process!

"Min-Bias" (ND)



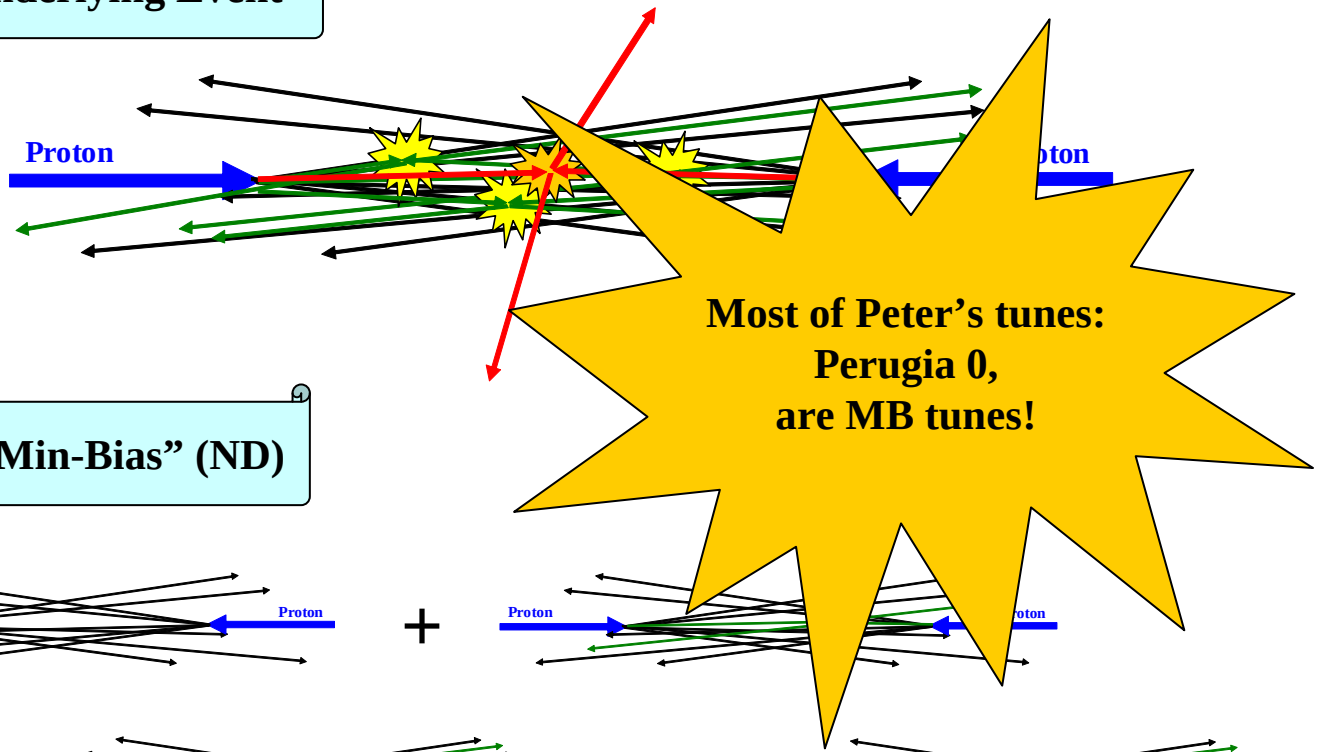
Fit MB (ND).

+ …

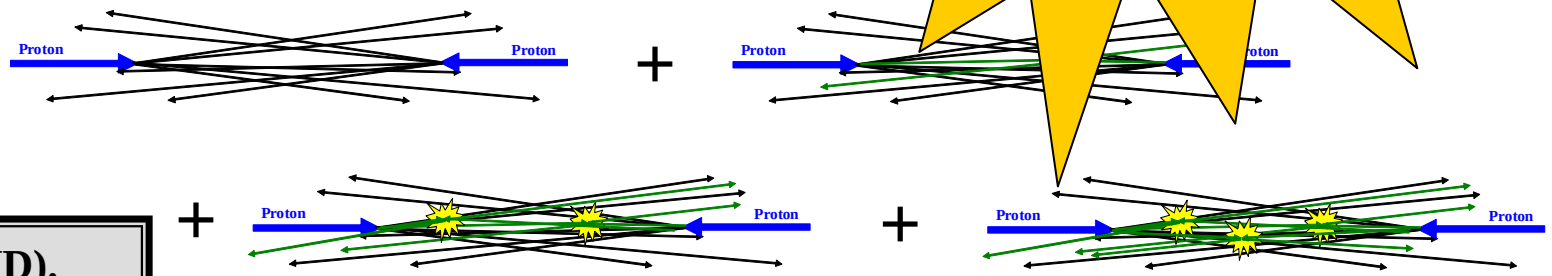
MB Tunes

"Underlying Event"

Predict the "underlying event" in a hard scattering process!



"Min-Bias" (ND)

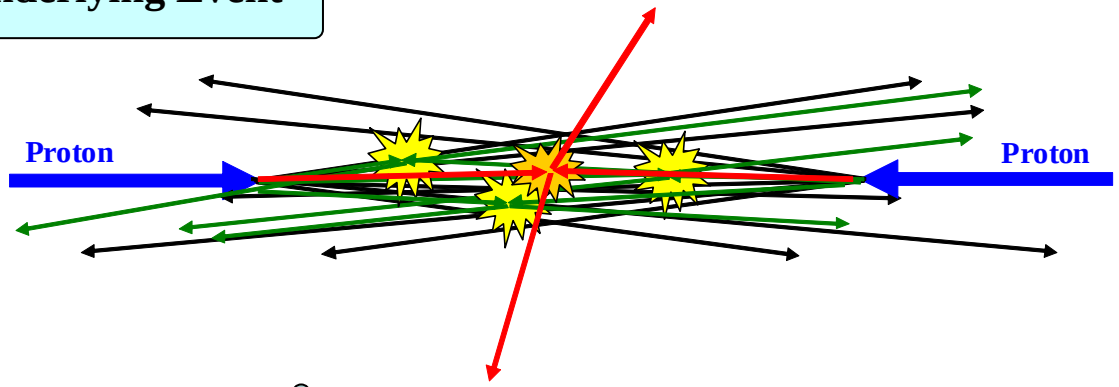


Fit MB (ND).

+ …

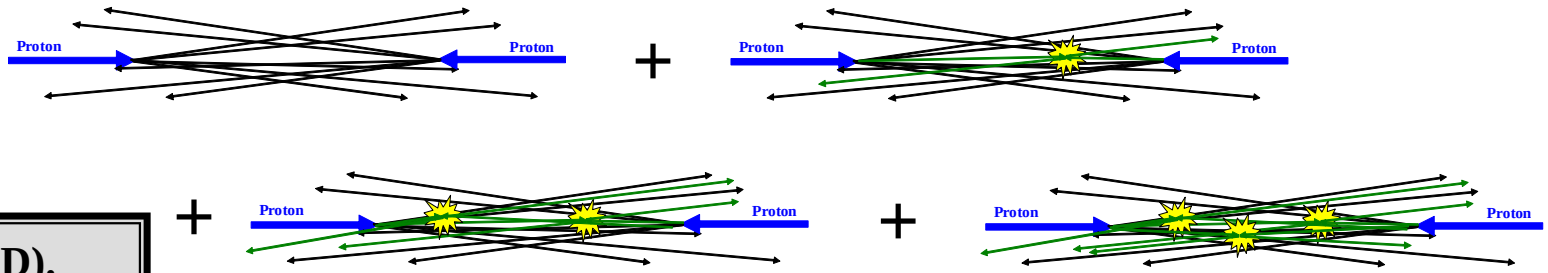
MB+UE Tunes

"Underlying Event"



Fit the "underlying event" in a hard scattering process!

"Min-Bias" (ND)



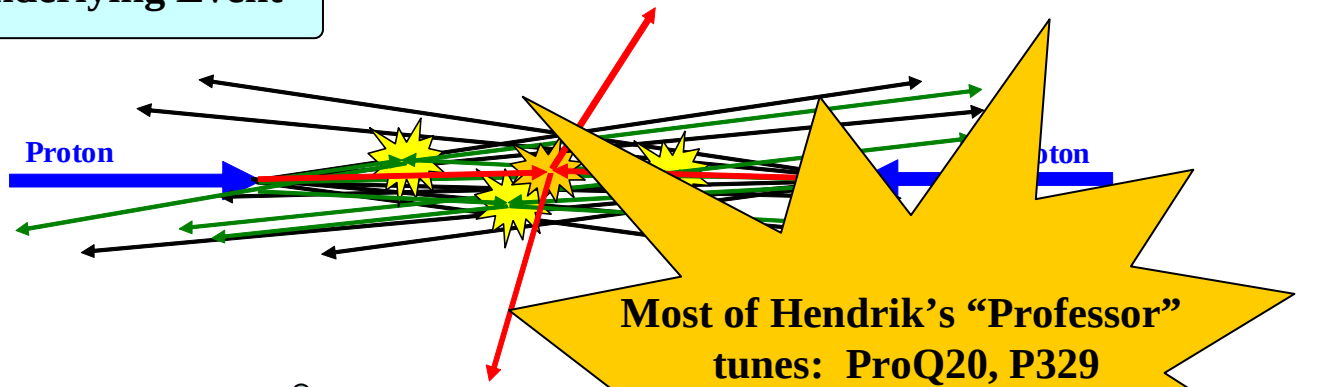
Fit MB (ND).

+ …

MB+UE Tunes

"Underlying Event"

Fit the "underlying event" in a hard scattering process!



Most of Hendrik's "Professor" tunes: ProQ20, P329 are MB+UE!

"Min-Bias" (ND)

Fit MB (ND).

+ 

+ …

The ATLAS AMBT1 Tune is an MB+UE tune, but because they include in the fit the ATLAS UE data with PTmax > 10 GeV/c (big errors) the LHC UE data does not have much pull (hence mostly an MB tune!).

CMS UE Analyses

Available on the CERN CDS information server — CMS PAS QCD-10-001

CMS Physics Analysis Summary

Contact: cms-pag-conveners-qcd@cern.ch — 2010/05/05

First Measurement of the Underlying Event Activity in Proton-Proton Collisions at 900 GeV at the LHC

The CMS Collaboration

- **Uncorrected data on the "transverse" region as defined by the leading track, PTmax, and the leading charged particle jet, PT(chgjet#1) at 900 GeV (p_T > 0.5 GeV/c, |η| < 2.0) compared with several QCD Monte-Carlo models after detector simulation.**

Available on the CERN CDS information server — CMS PAS QCD-10-010

CMS Physics Analysis Summary

Contact: cms-pag-conveners-qcd@cern.ch — 2010/07/21

Measurement of the Underlying Event Activity at the LHC with $\sqrt{s} = 7$ TeV and Comparison with $\sqrt{s} = 0.9$ TeV

The CMS Collaboration

- **Uncorrected data on the "transverse" region as defined by the leading charged particle jet, PT(chgjet#1) at 7 TeV and 900 GeV (p_T > 0.5 GeV/c, |η| < 2.0) compared with several QCD Monte-Carlo models after detector simulation.**

UE&MB@CMS

CMS UE Analyses

Traditional Approach

Available on the CERN CDS information server

CMS Physics Analysis Summary

Contact: cms-pag-conveners-qcd@cern.ch 2010/05/05

First Measurement of the Underlying Event Activity in Proton-Proton Collisions at 900 GeV at the LHC

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CMS Physics Analysis Summary

Contact: cms-pag-conveners-qcd@cern.ch 2010/07/21

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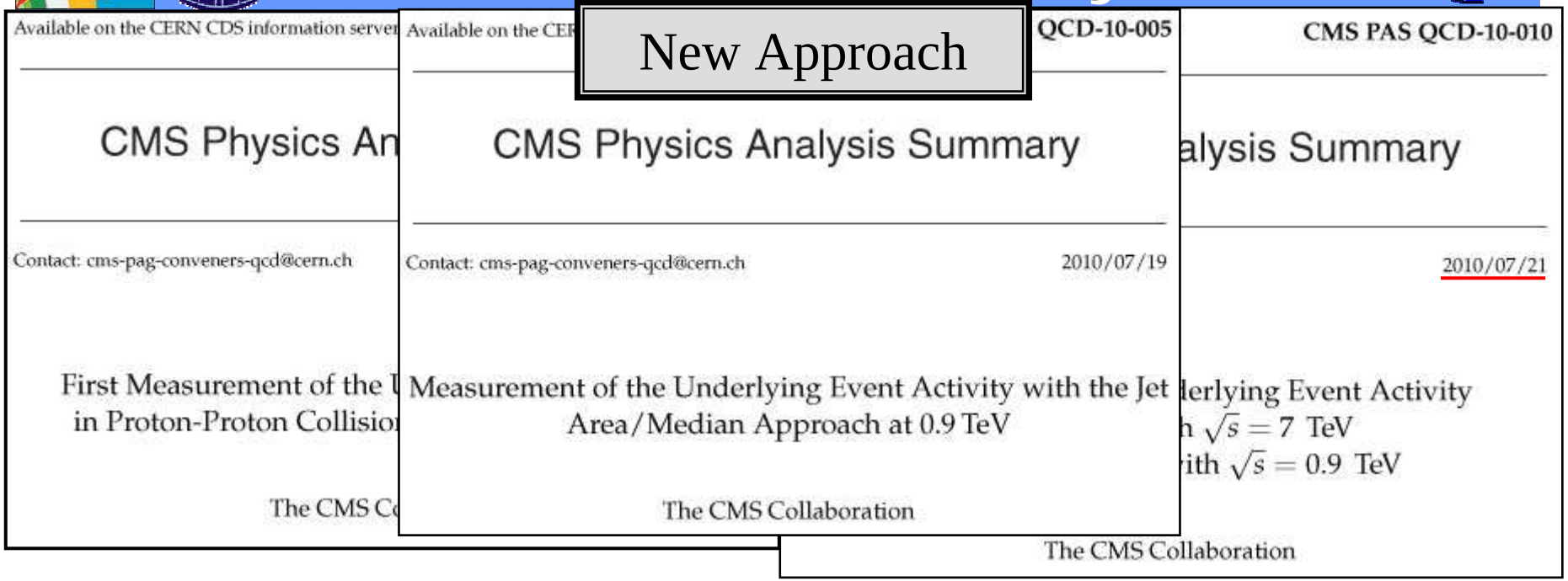
UE&MB@CMS

CMS UE Analyses


Available on the CERN CDS information server
CMS Physics An
Contact: cms-pag-conveners-qcd@cern.ch
First Measurement of the U
in Proton-Proton Collisio
The CMS Co

Available on the CER
QCD-10-005
CMS Physics Analysis Summary
Contact: cms-pag-conveners-qcd@cern.ch
2010/07/19
Measurement of the Underlying Event Activity with the Jet
Area/Median Approach at 0.9 TeV
The CMS Collaboration

CMS PAS QCD-10-010
alysis Summary
2010/07/21
derlying Event Activity
h $\sqrt{s} = 7$ TeV
ith $\sqrt{s} = 0.9$ TeV
The CMS Collaboration

New Approach

- **Uncorrected data on the "transverse" region as defined by the leading track, PTmax, and the leading charged particle jet, PT(chgjet#1) at 900 GeV ($p_T > 0.5$ GeV/c, $|\eta| < 2.0$) compared with several QCD Monte-Carlo models after detector simulation.**

- **Uncorrected data on the "transverse" region as defined by the leading charged particle jet, PT(chgjet#1) at 7 TeV and 900 GeV ($p_T > 0.5$ GeV/c, $|\eta| < 2.0$) compared with several QCD Monte-Carlo models after detector simulation.**

UE&MB@CMS

CMS UE Analyses

Available on the CERN CDS information server | Available on the CERN | QCD-10-005 | CMS PAS QCD-10-010

CMS Physics Analysis Summary

Contact: cms-pag-conveners-qcd@cern.ch | 2010/07/21

First Measurements of Charged Particle Event Activity in Proton-Proton Collisions at 7 TeV and 900 GeV

I assure you that we have not lost site of the ultimate goal of producing corrected data that the theorists can use to tune and improve the QCD Monte-Carlo models. Now that these papers have been released, we are working full speed on the corrected data!

- **Uncorrected charged particle distributions in the "transverse" region as defined by the leading charged PTmax, and the leading charged jet, PT(chgjet#1) at 900 GeV and 7 TeV (p_T > 0.5 GeV/c, |η| < 2.0) compared with several QCD Monte-Carlo models QCD Monte-Carlo models after detector simulation.**

UE&MB@CMS

ATLAS UE Analysis

ATLAS NOTE

ATLAS-CONF-2010-029

May 29, 2010

Track-based underlying event measurements in *pp* collisions at $\sqrt{s}$ = 900 GeV and 7 TeV with the ATLAS Detector at the LHC

The ATLAS collaboration

- **Corrected data on the "towards", "away", and "transverse" regions as defined by the leading track, PTmax, at 7 TeV and 900 GeV (p_T > 0.5 GeV/c, $|\eta|$ < 2.5) compared with several QCD Monte-Carlo models at the generator level.**

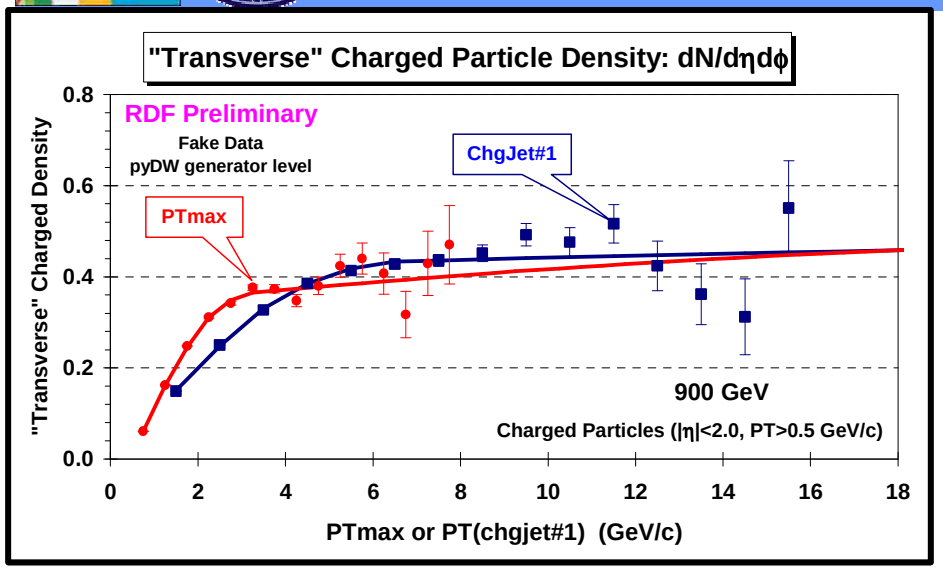
Traditional Approach

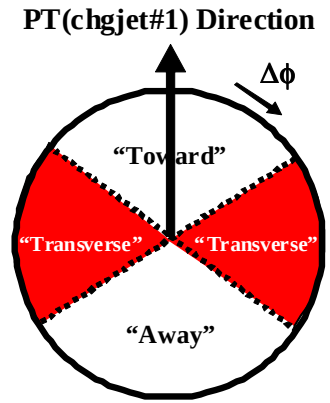
ATLAS UE Analysis

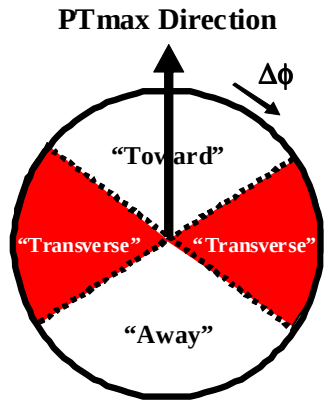
Please note that I have read the ATLAS and CMS data points off these papers with a ruler so that I can plot the data and make comparisons! Please refer to these papers (not my plots) for the true data points!

None of my plots are the original figures from the papers!

"Transverse" Charged Particle Density



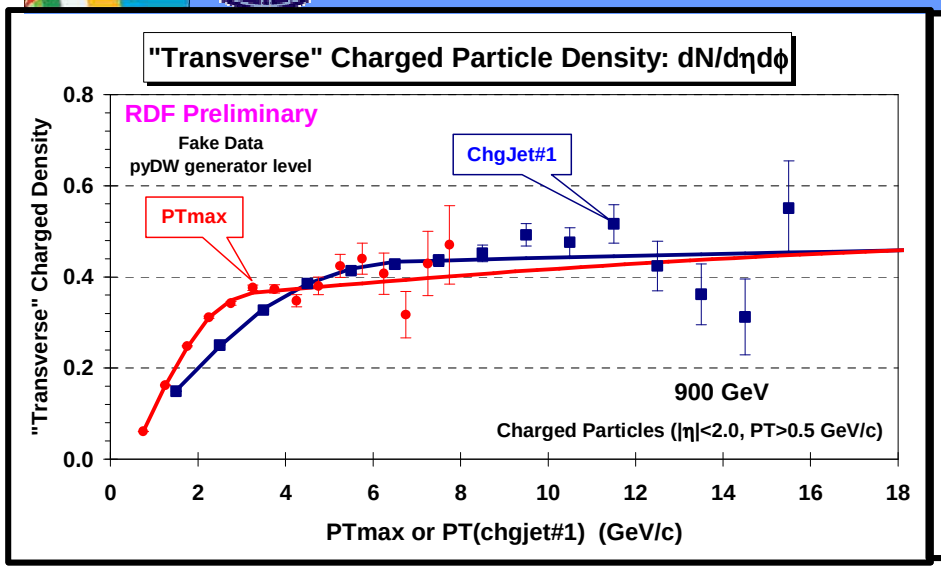


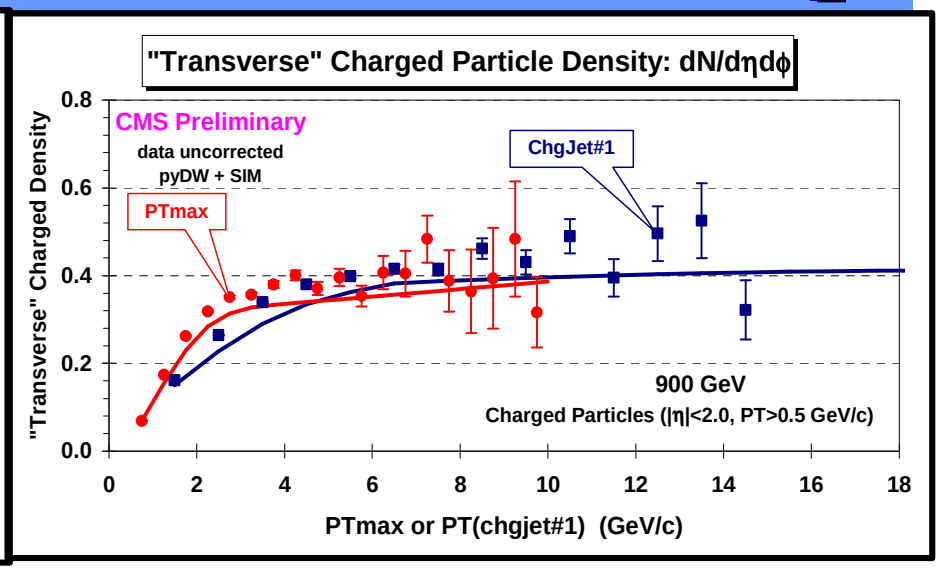


- **Fake data (from MC) at 900 GeV on the "transverse" charged particle density, dN/dηdϕ, as defined by the leading charged particle (PTmax) and the leading charged particle jet (chgjet#1) for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 2$. The fake data (from PYTHIA Tune DW) are generated at the particle level (*i.e.* generator level) assuming 0.5 M min-bias events at 900 GeV (361,595 events in the plot).**

Rick Field
MB&UE@CMS Workshop
CERN, November 6, 2009

"Transverse" Charged Particle Density





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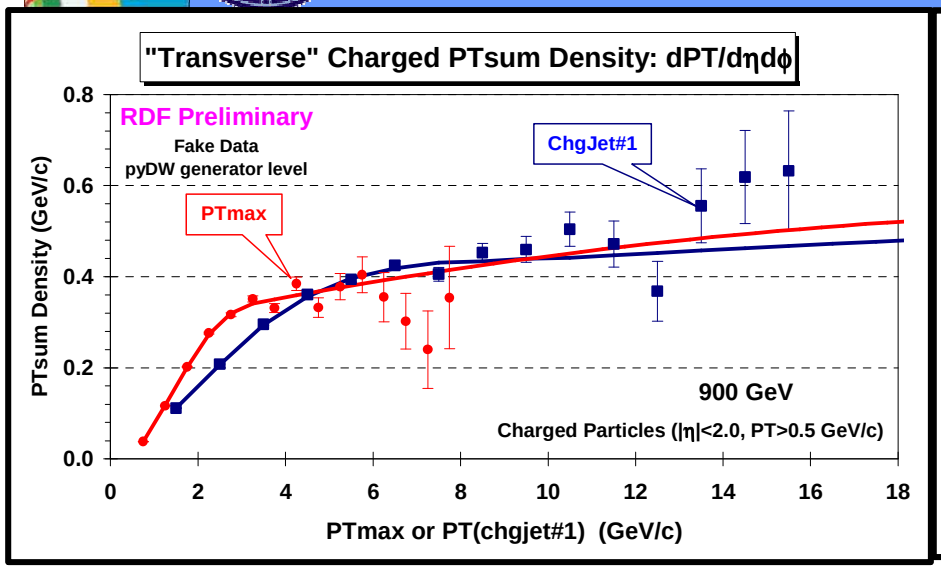
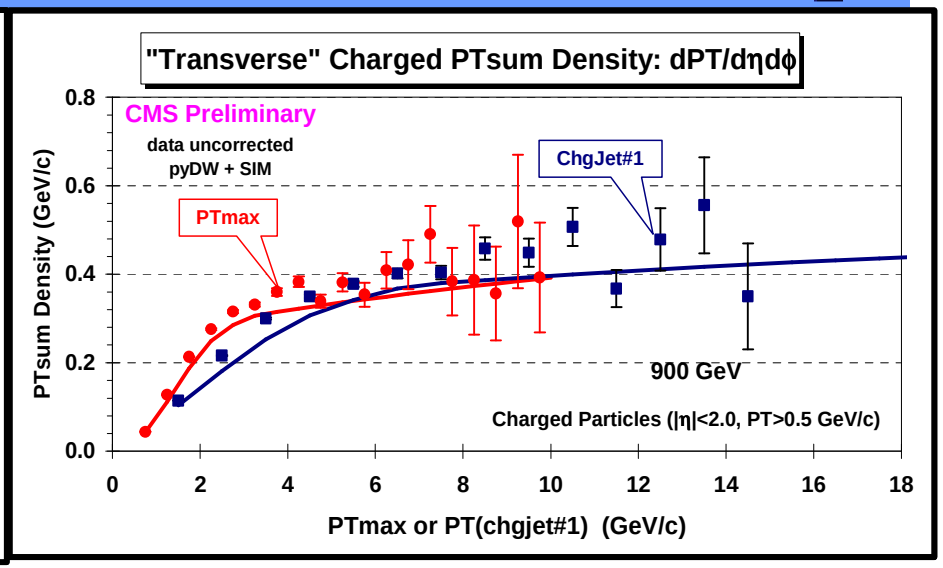
- **CMS preliminary data at 900 GeV on the "transverse" charged particle density, dN/dηdϕ, as defined by the leading charged particle (PTmax) and the leading charged particle jet (chgjet#1) for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 2$. The data are uncorrected and compared with PYTHIA Tune DW after detector simulation (216,215 events in the plot).**

"Transverse" Charged PTsum Density





- **Fake data (from MC) at 900 GeV on the "transverse" charged PTsum density, dPT/dηdϕ, as defined by the leading charged particle (PTmax) and the leading charged particle jet (chgjet#1) for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 2$. The fake data (from PYTHIA Tune DW) are generated at the particle level (*i.e.* generator level) assuming 0.5 M min-bias events at 900 GeV (361,595 events in the plot).**

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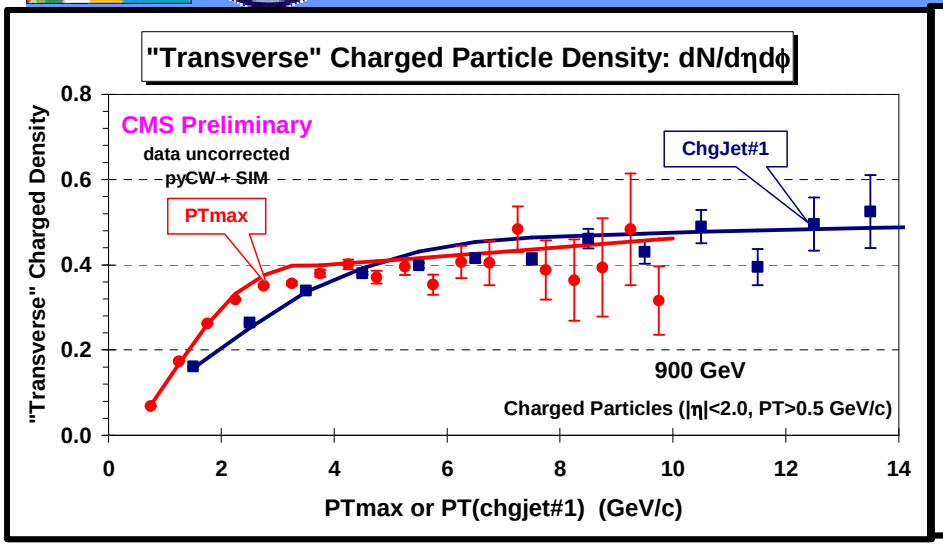
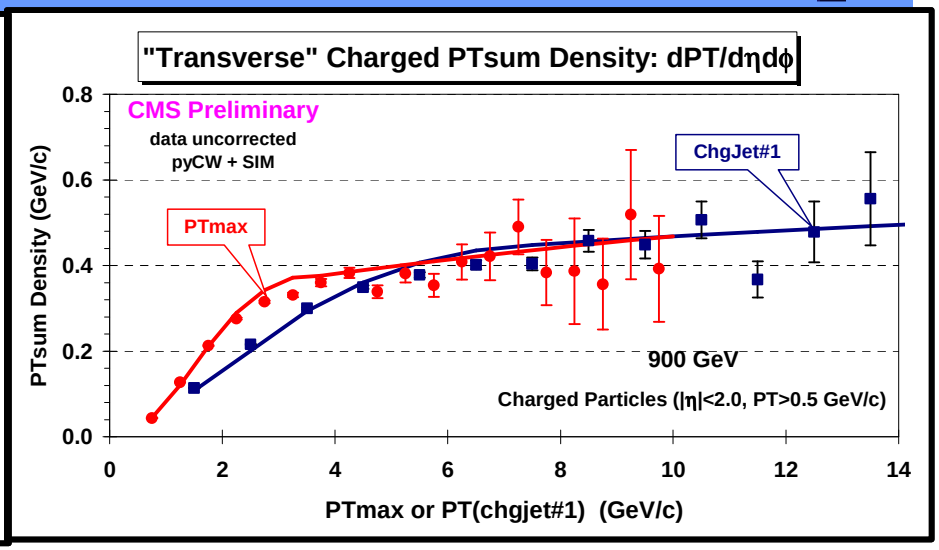
PYTHIA Tune CW



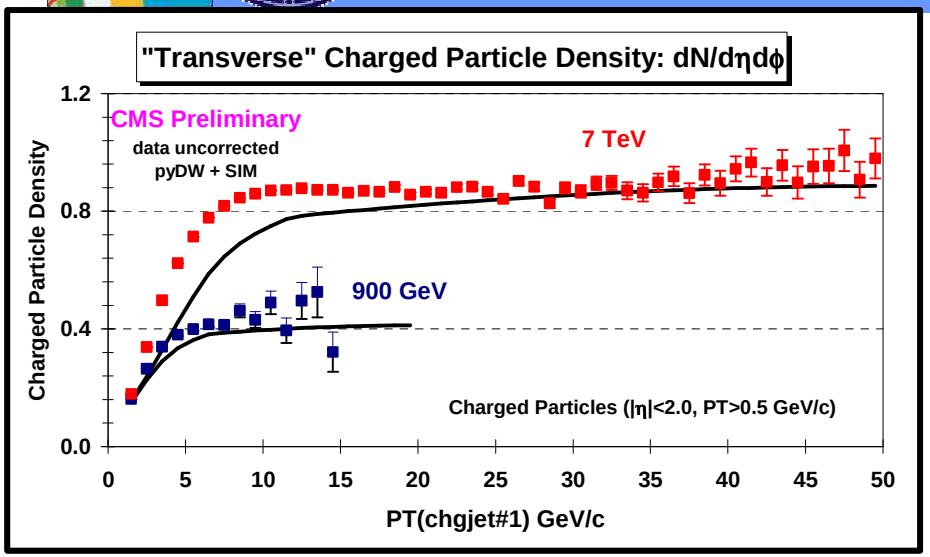


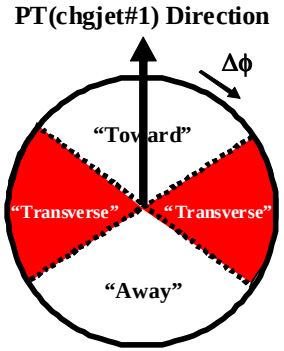
- **CMS preliminary data at 900 GeV on the "transverse" charged particle density, dN/dηdϕ, as defined by the leading charged particle (PTmax) and the leading charged particle jet (chgjet#1) for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 2$. The data are uncorrected and compared with PYTHIA Tune CW after detector simulation.**

- **CMS preliminary data at 900 GeV on the "transverse" charged PTsum density, dPT/dηdϕ, as defined by the leading charged particle (PTmax) and 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 CW after detector simulation.**

Tune DW → Tune CW
PARP(82) = 1.9 → 1.8
PARP(90) = 0.25 → 0.30
PARP(85) = 1.0 → 0.9
PARP(86) = 1.0 → 0.95

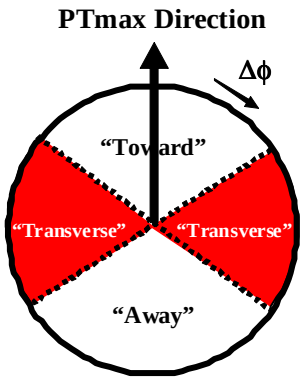
PYTHIA Tune DW

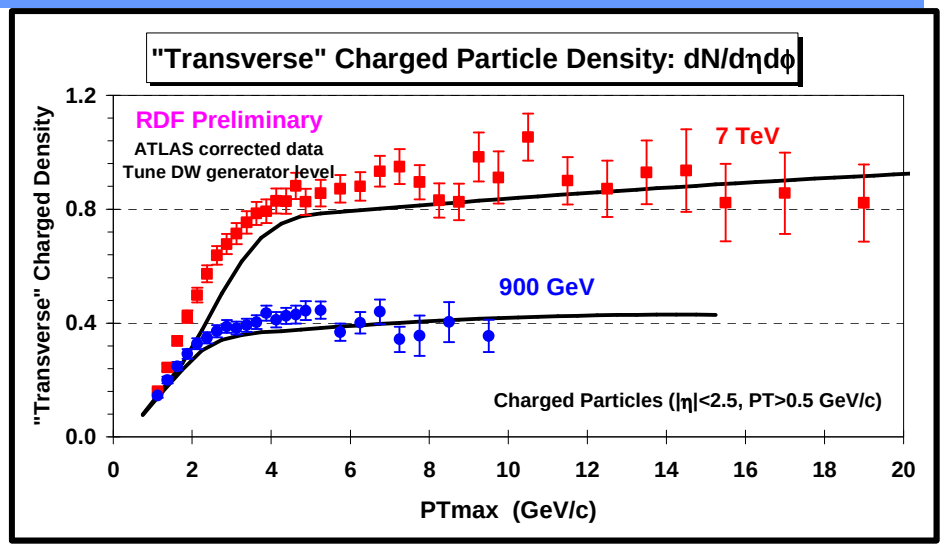




➡ **CMS preliminary data at 900 GeV and 7 TeV on the "transverse" charged particle density, dN/dηdϕ, as defined by the leading charged particle jet (chgjet#1) for charged particles with p_T > 0.5 GeV/c and |η| < 2. The data are uncorrected and compared with PYTHIA Tune DW after detector simulation.**

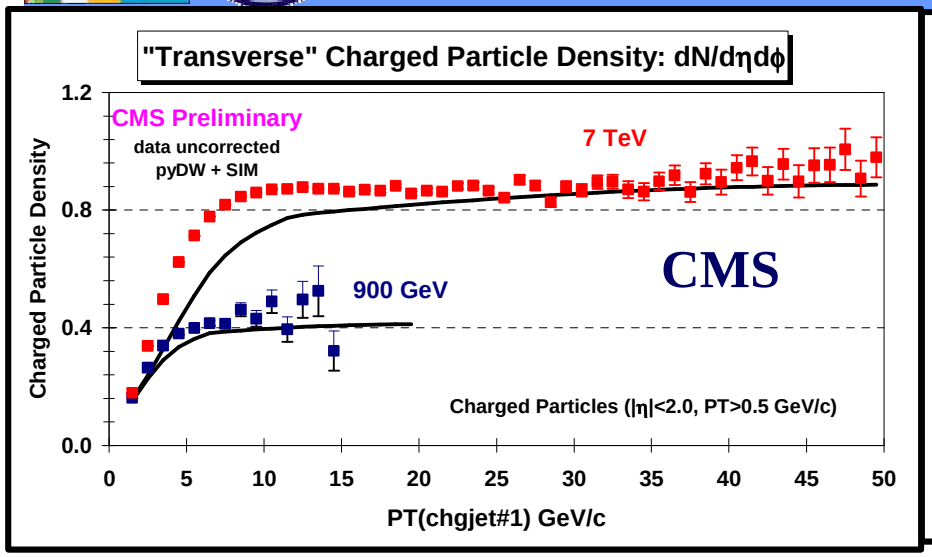
PYTHIA Tune DW

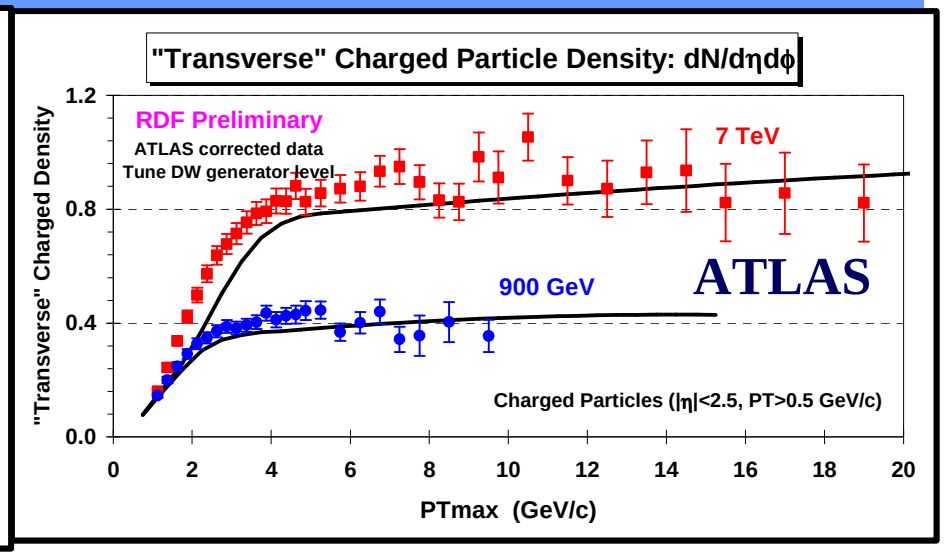




- **ATLAS preliminary data at 900 GeV and 7 TeV on the "transverse" charged particle density, dN/dηdϕ, as defined by the leading charged particle (PTmax) for charged particles with p_T > 0.5 GeV/c and |η| < 2.5. The data are corrected and compared with PYTHIA Tune DW at the generator level.**

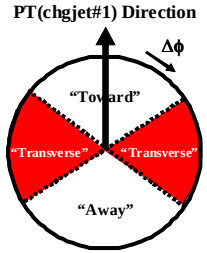
PYTHIA Tune DW

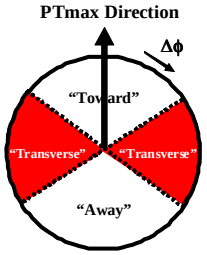




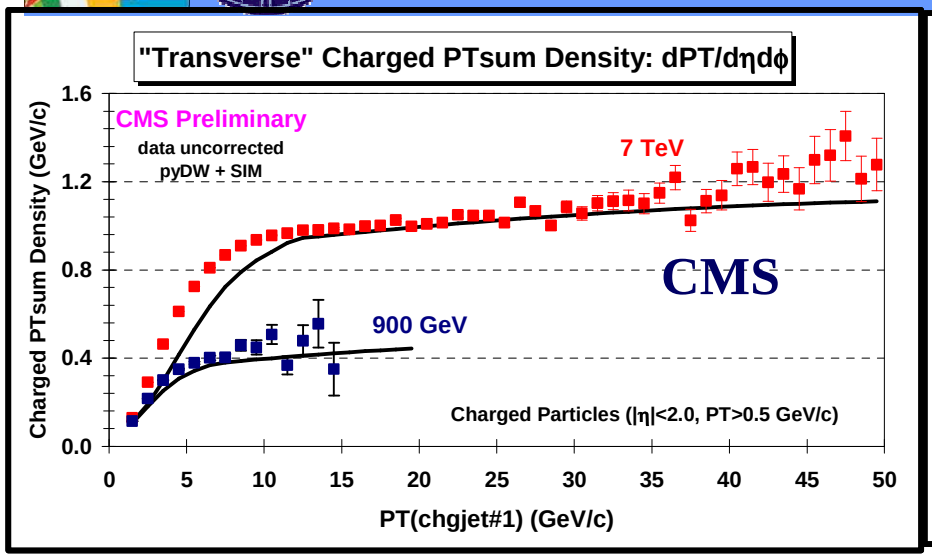
- **CMS preliminary data at 900 GeV and 7 TeV on the "transverse" charged particle density, dN/dηdϕ, as defined by the leading charged particle jet (chgjet#1) for charged particles with p_T > 0.5 GeV/c and |η| < 2. The data are uncorrected and compared with PYTHIA Tune DW after detector simulation.**

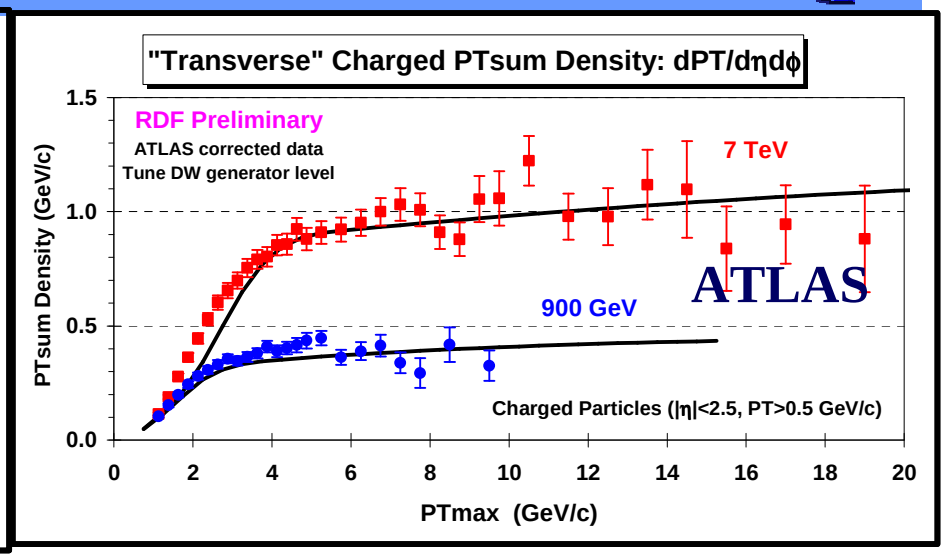
- **ATLAS preliminary data at 900 GeV and 7 TeV on the "transverse" charged particle density, dN/dηdϕ, as defined by the leading charged particle (PTmax) for charged particles with p_T > 0.5 GeV/c and |η| < 2.5. The data are corrected and compared with PYTHIA Tune DW at the generator level.**



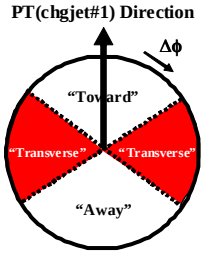


PYTHIA Tune DW

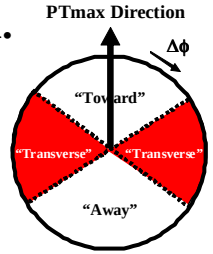




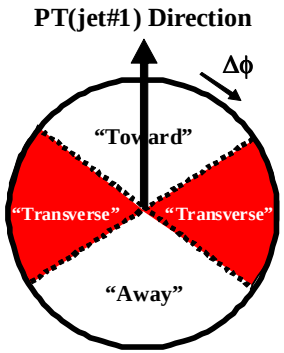
- **CMS preliminary data at 900 GeV and 7 TeV on the "transverse" charged PTsum density, dPT/dηdϕ, as defined by the leading charged particle jet (chgjet#1) for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 2$. The data are uncorrected and compared with PYTHIA Tune DW after detector simulation.**

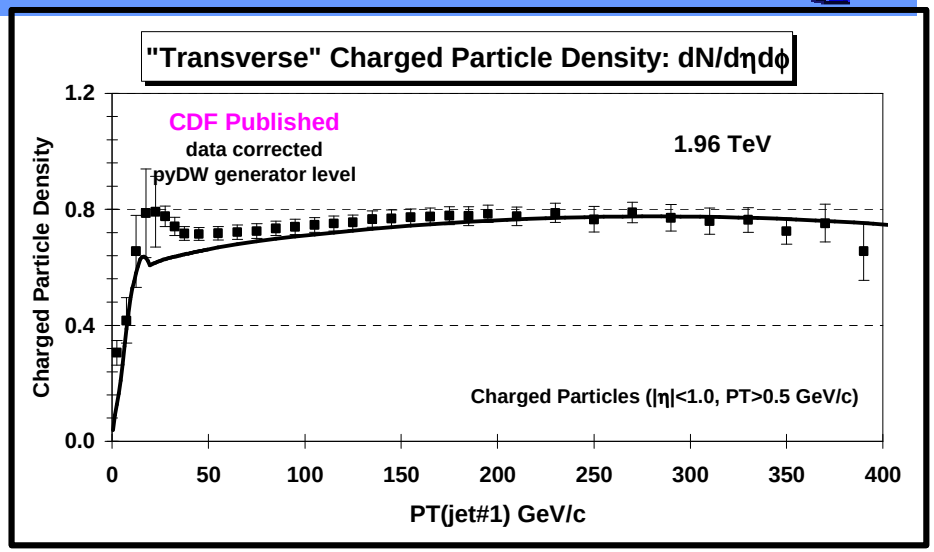


- **ATLAS preliminary data at 900 GeV and 7 TeV on the "transverse" charged PTsum density, dPT/dηdϕ, as defined by the leading charged particle (PTmax) for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 2.5$. The data are corrected and compared with PYTHIA Tune DW at the generator level.**



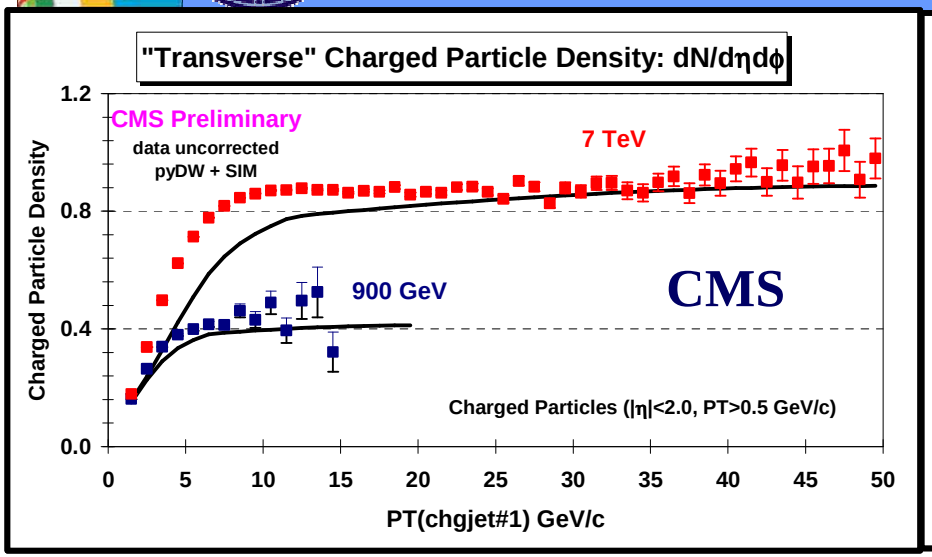
PYTHIA Tune DW

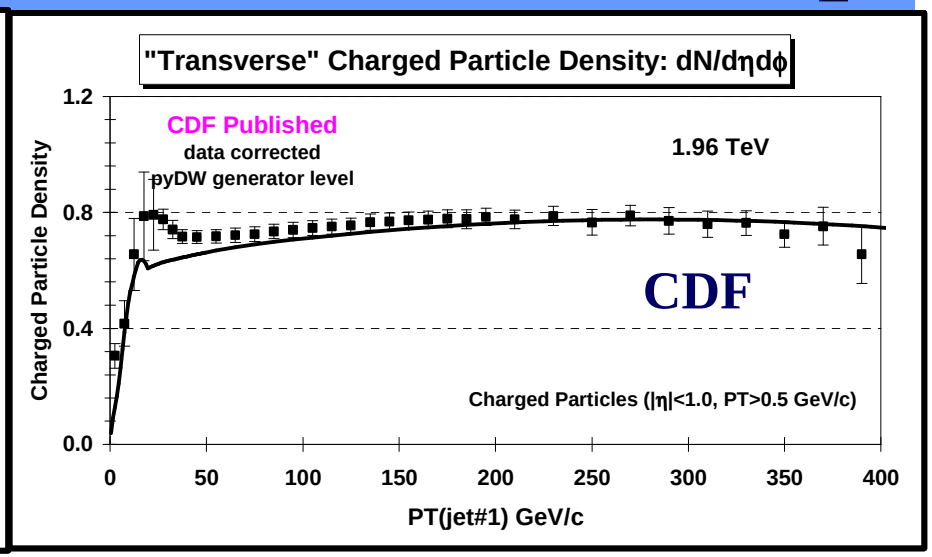




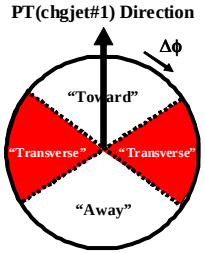
- **CDF published data at 1.96 TeV on the "transverse" charged particle density, dN/dηdϕ, as defined by the leading calorimeter jet (jet#1) for charged particles with p_T > 0.5 GeV/c and |η| < 1.0. The data are corrected and compared with PYTHIA Tune DW at the generator level.**

PYTHIA Tune DW

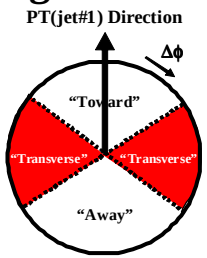




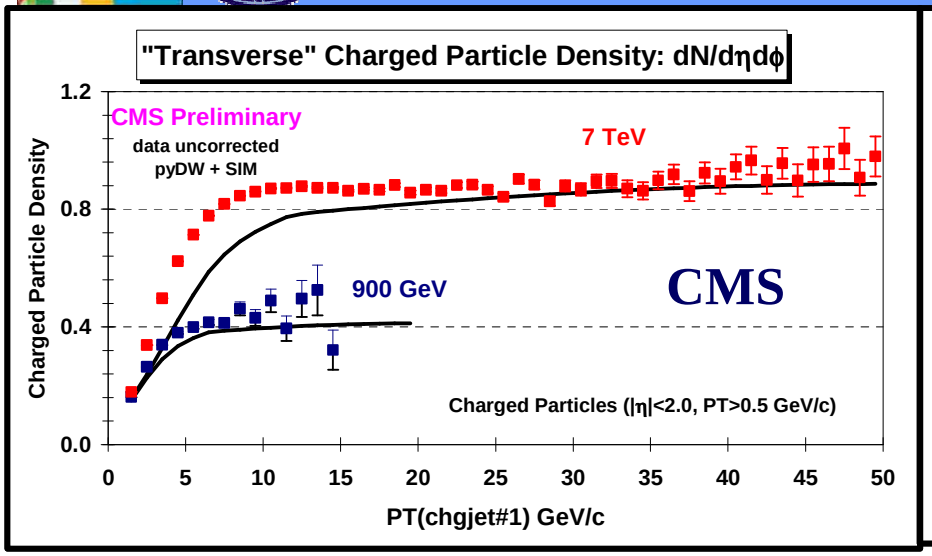
- **CMS preliminary data at 900 GeV and 7 TeV on the "transverse" charged particle density, dN/dηdϕ, as defined by the leading charged particle jet (chgjet#1) for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 2$. The data are uncorrected and compared with PYTHIA Tune DW after detector simulation.**

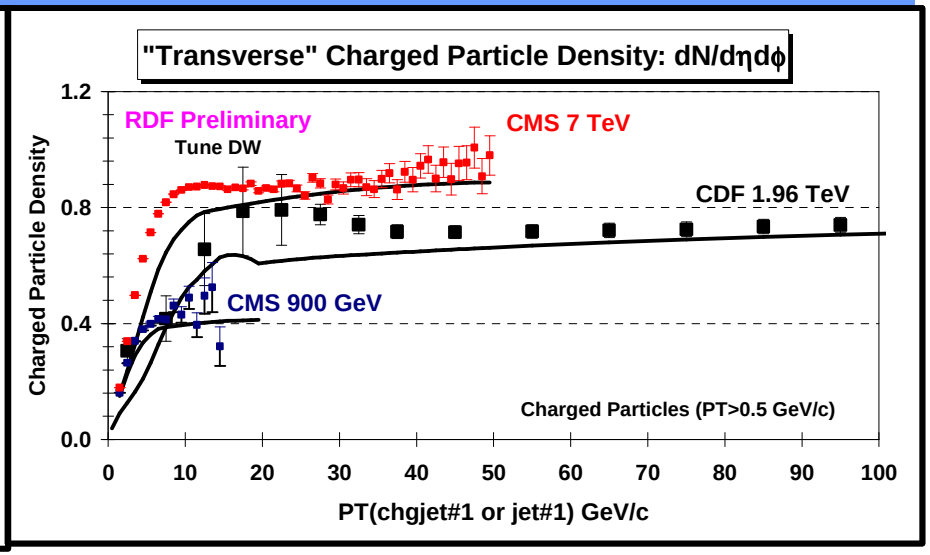


- **CDF published data at 1.96 TeV on the "transverse" charged particle density, dN/dηdϕ, as defined by the leading calorimeter jet (jet#1) for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 1.0$. The data are corrected and compared with PYTHIA Tune DW at the generator level.**



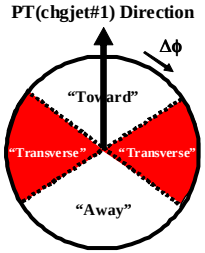
PYTHIA Tune DW

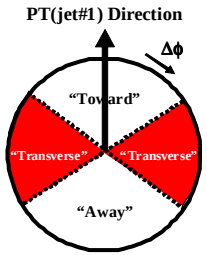




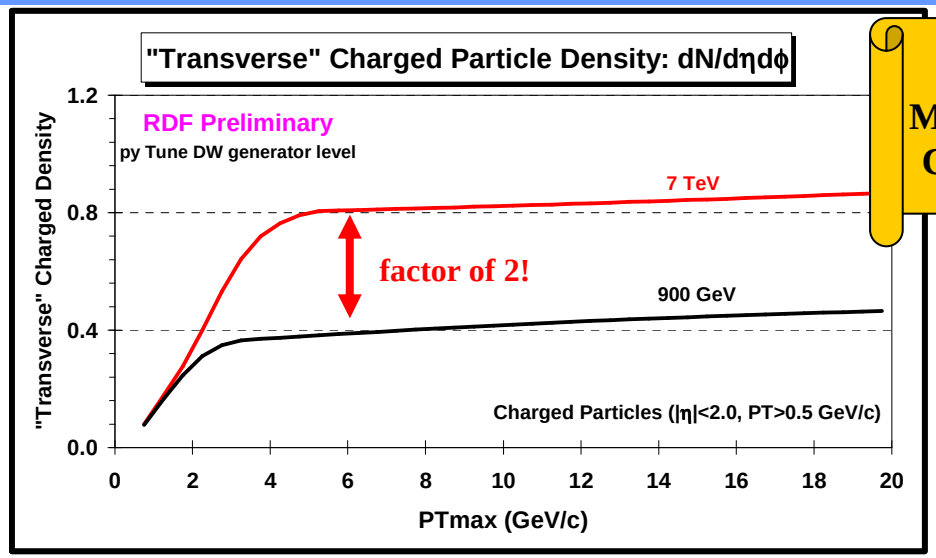
- **CMS preliminary data at 900 GeV and 7 TeV on the "transverse" charged particle density, dN/dηdϕ, as defined by the leading charged particle jet (chgjet#1) for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 2$. The data are uncorrected and compared with PYTHIA Tune DW after detector simulation.**

- **CDF published data at 1.96 TeV on the "transverse" charged particle density, dN/dηdϕ, as defined by the leading calorimeter jet (jet#1) for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 1.0$. The data are corrected and compared with PYTHIA Tune DW at the generator level.**



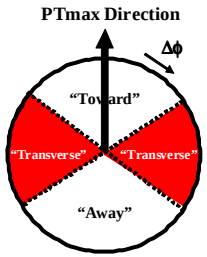


"Transverse" Charge Density



Rick Field
MB&UE@CMS Workshop
CERN, November 6, 2009

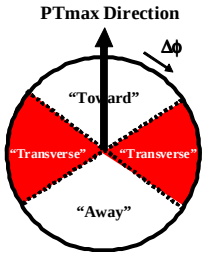
LHC 900 GeV



900 GeV → 7 TeV
(UE increase ~ factor of 2)

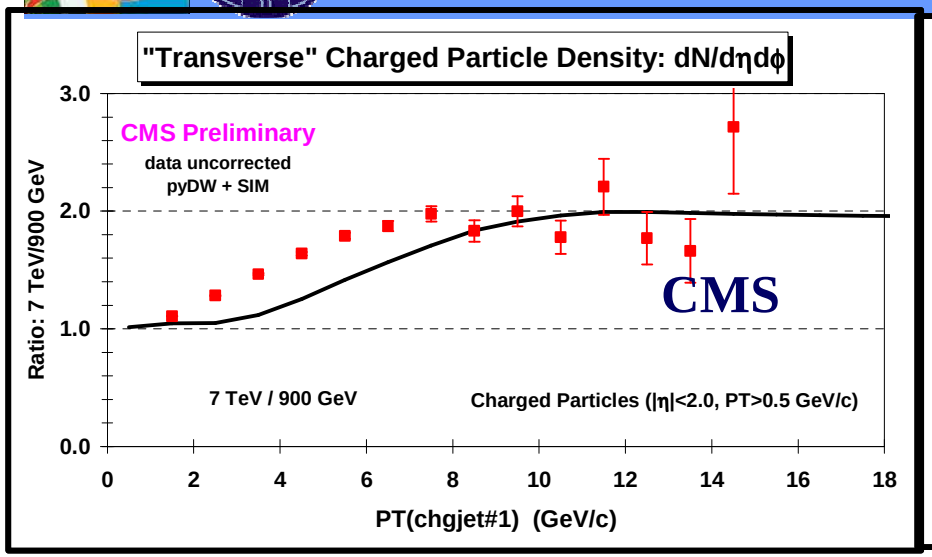
~0.4 → ~0.8

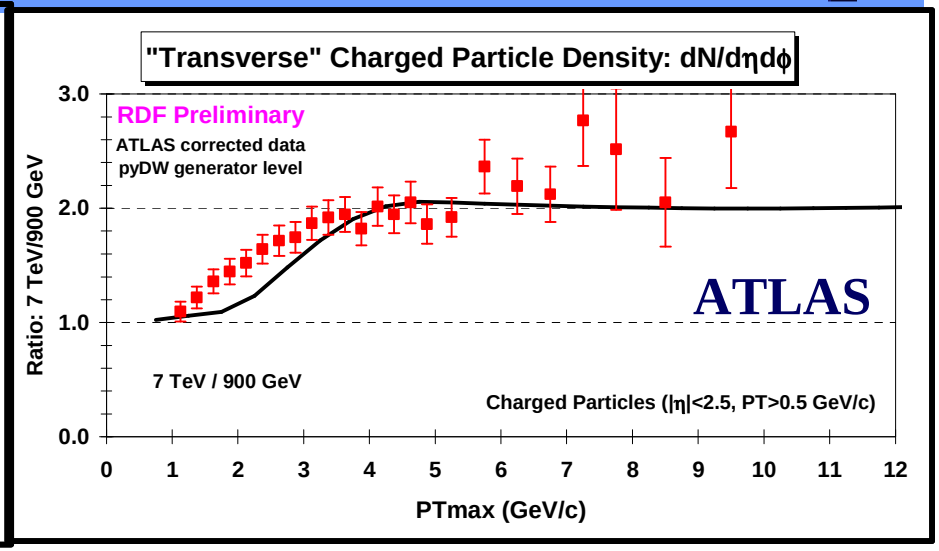
LHC 7 TeV



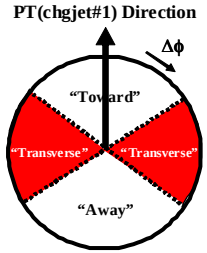
- **Shows the charged particle density in the "transverse" region for charged particles (p_T > 0.5 GeV/c, |η| < 2) at 900 GeV and 7 TeV as defined by PTmax from PYTHIA Tune DW and at the particle level (*i.e.* generator level).**

PYTHIA Tune DW

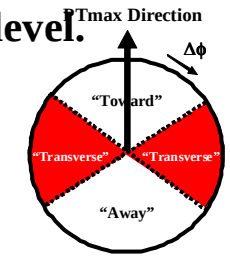




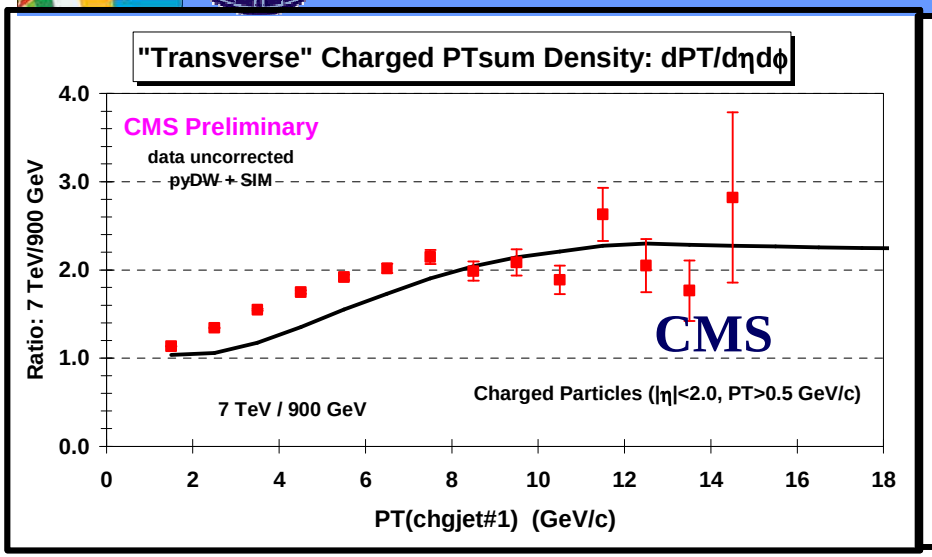
- **Ratio of CMS preliminary data at 900 GeV and 7 TeV on the "transverse" charged particle density, dN/dηdϕ, as defined by the leading charged particle jet (chgjet#1) for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 2$. The data are uncorrected and compared with PYTHIA Tune DW after detector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

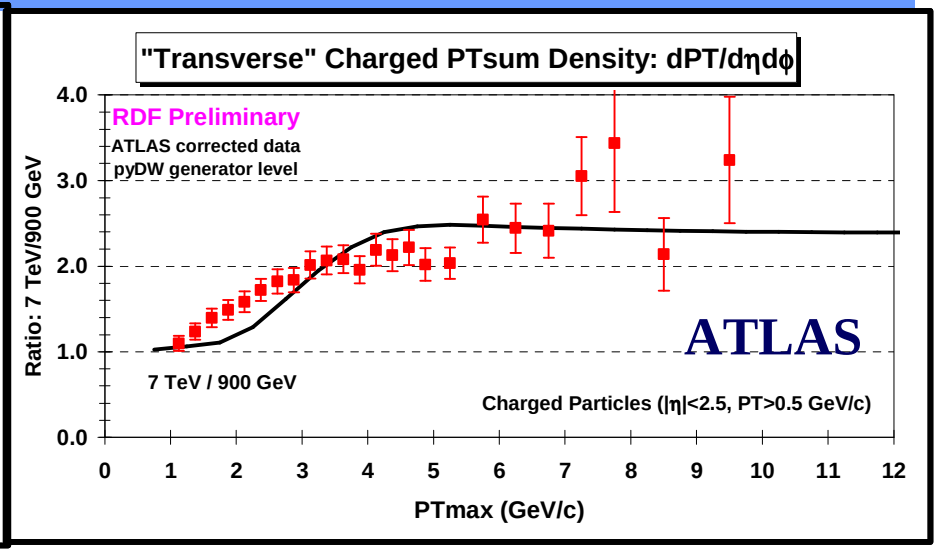


- **Ratio of the ATLAS preliminary data at 900 GeV and 7 TeV on the "transverse" charged particle density, dN/dηdϕ, as defined by the leading charged particle (PTmax) for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 2.5$. The data are corrected and compared with PYTHIA Tune DW at the generator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

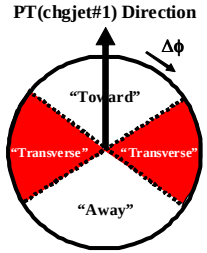


PYTHIA Tune DW

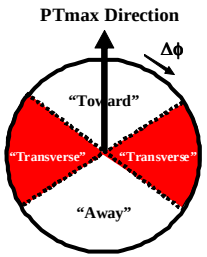




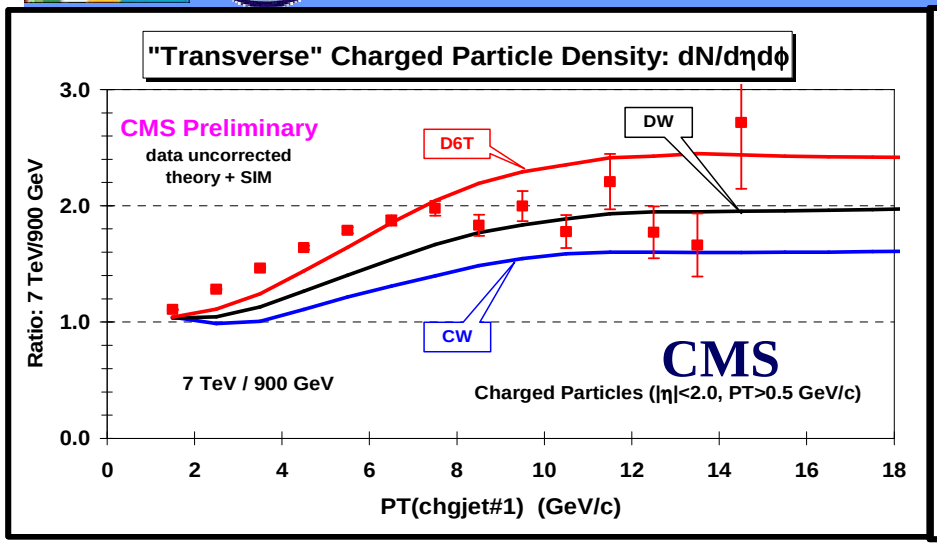
- **Ratio of the CMS preliminary data at 900 GeV and 7 TeV on the "transverse" charged PTsum density, dPT/dηdϕ, as defined by the leading charged particle jet (chgjet#1) for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 2$. The data are uncorrected and compared with PYTHIA Tune DW after detector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

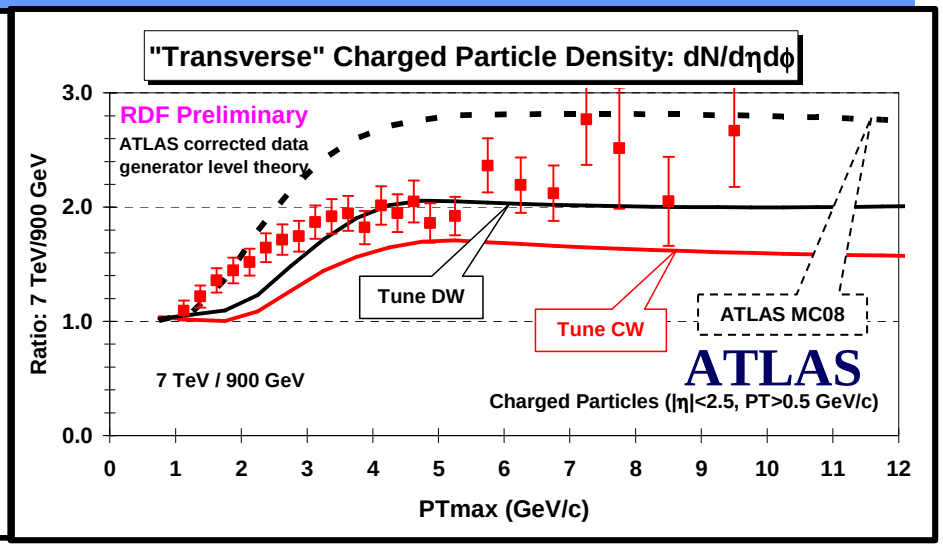


- **Ratio of the ATLAS preliminary data at 900 GeV and 7 TeV on the "transverse" charged PTsum density, dPT/dηdϕ, as defined by the leading charged particle (PTmax) for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 2.5$. The data are corrected and compared with PYTHIA Tune DW at the generator level.**

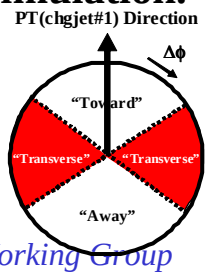


"Transverse" Energy Dependence

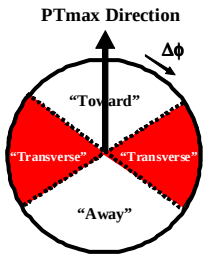




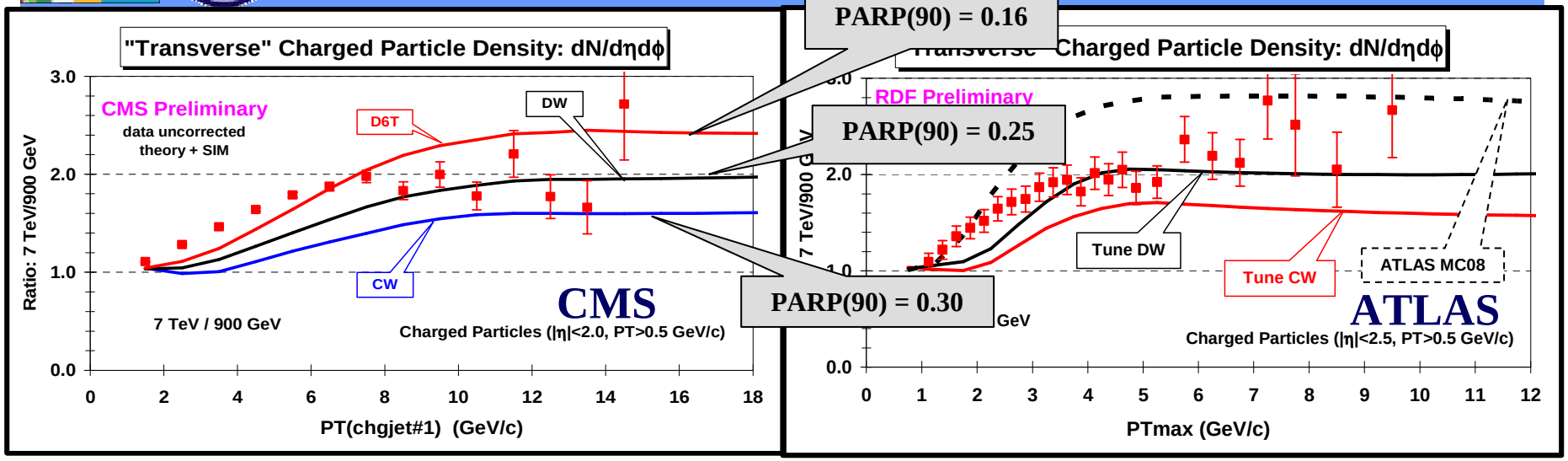
- **Ratio of the CMS preliminary data at 900 GeV and 7 TeV on the "transverse" charged particle density, dN/dηdϕ, as defined by the leading charged particle jet (chgjet#1) for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 2$. The data are uncorrected and compared with PYTHIA Tune DW, Tune CW, and Tune D6T after detector simulation.**



- **Ratio of the ATLAS preliminary data at 900 GeV and 7 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 $|\eta| < 2.5$. The data are corrected and compared with PYTHIA Tune DW, Tune CW, and ATLAS MC08 at the generator level.**



"Transverse" Energy Dependence

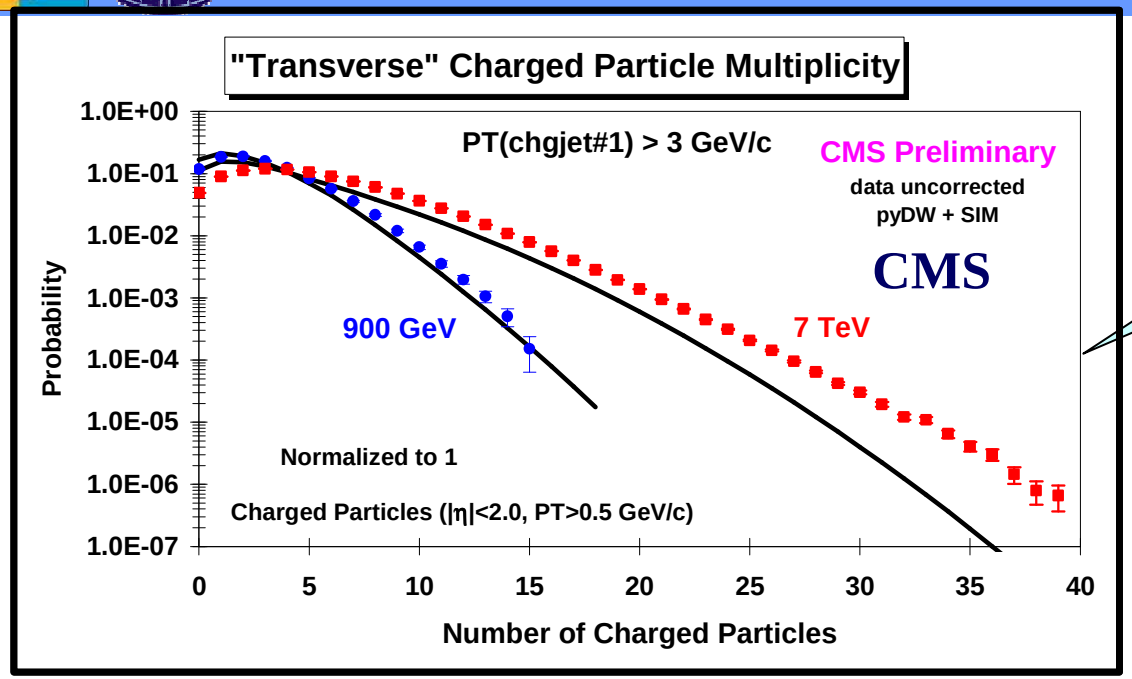


- **Ratio of the CMS preliminary data at 900 GeV and 7 TeV on the "transverse" charged particle density, dN/dηdϕ, as defined by the leading charged particle jet (chgjet#1) for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 2$. The data are uncorrected and compared with PYTHIA Tune DW, Tune CW, and Tune D6T after detector simulation.**

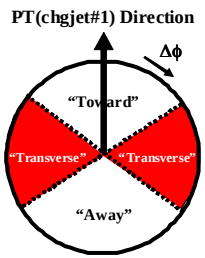
- **Ratio of the ATLAS preliminary data at 900 GeV and 7 TeV on the "transverse" charged particle density, dN/dηdϕ, as defined by the leading charged particle (PTmax) for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 2.5$. The data are corrected and compared with PYTHIA Tune DW, Tune CW, and ATLAS MC08 at the generator level.**

$$p_{T0}(W)=p_{T0}(W/W_0)^{\varepsilon} \quad \varepsilon = PARP(90) \quad p_{T0} = PARP(82) \quad W = E_{cm}$$

"Transverse" Multiplicity Distribution



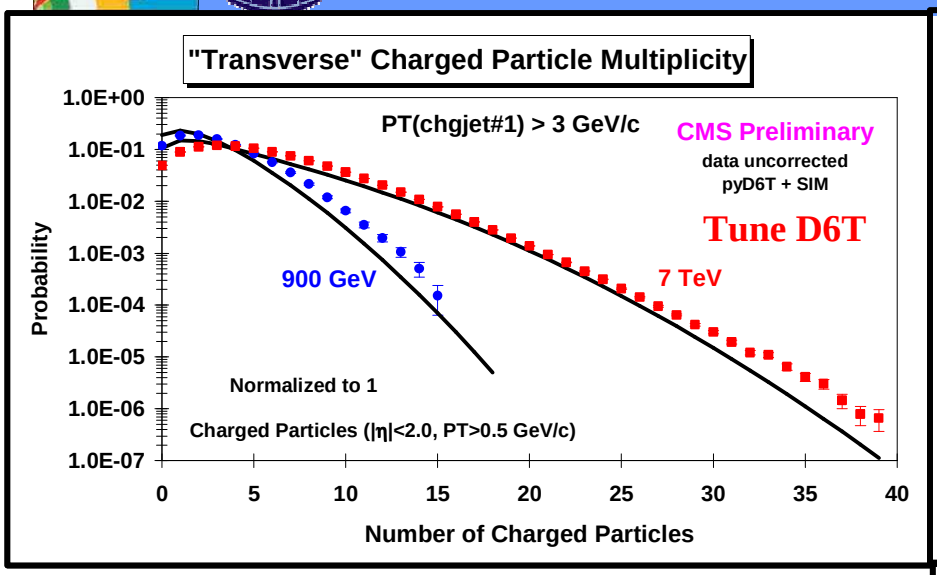
Same hard scale at two different center-of-mass energies!

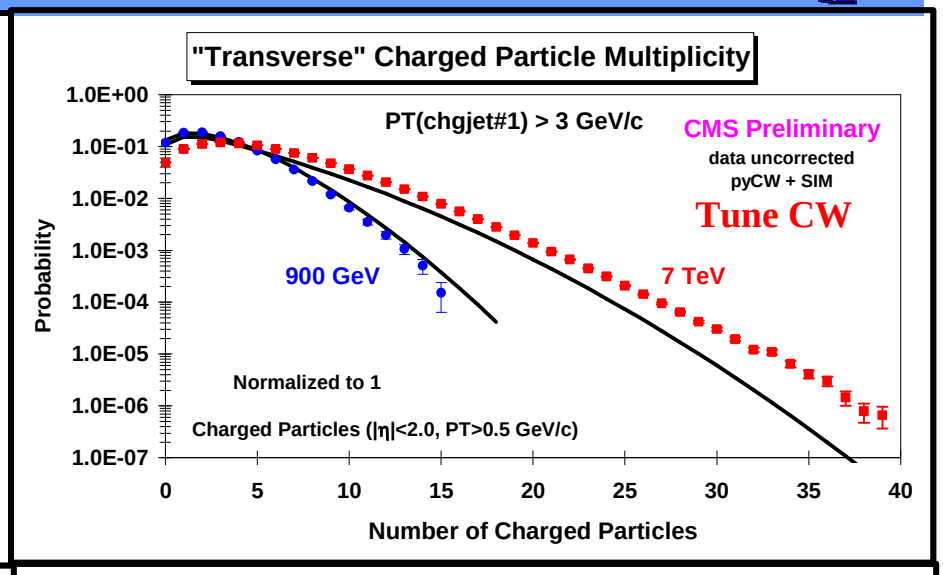


- **CMS uncorrected data at 900 GeV and 7 TeV on the charged particle multiplicity distribution in the "transverse" region for charged particles (p_T > 0.5 GeV/c, |η| < 2) as defined by the leading charged particle jet, chgjet#1, with PT(chgjet#1) > 3 GeV/c compared with PYTHIA Tune DW at the detector level (*i.e.* Theory + SIM).**

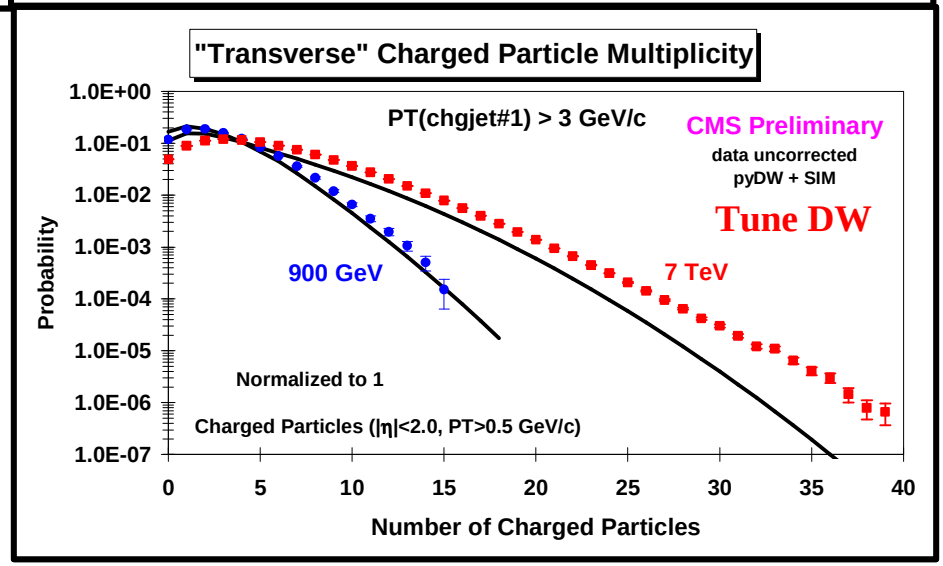
Shows the growth of the "underlying event" as the center-of-mass energy increases.

"Transverse" Multiplicity Distribution

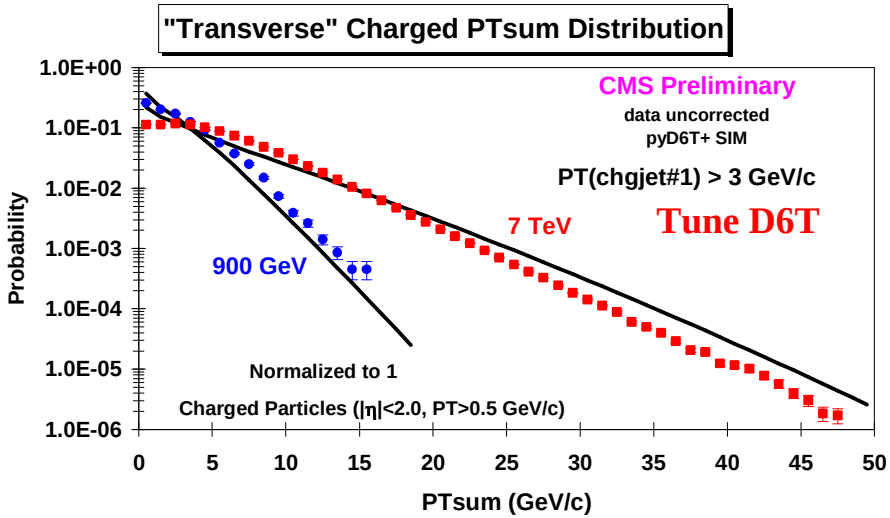


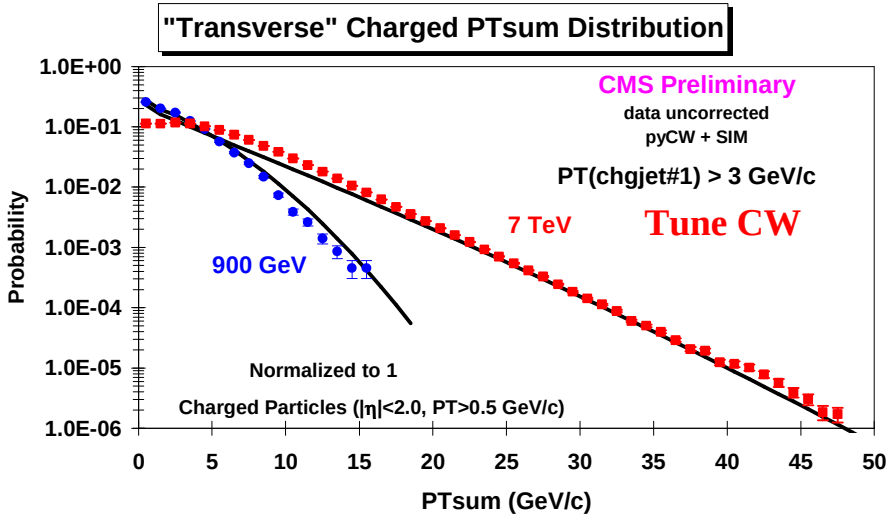


- **CMS uncorrected data at 900 GeV and 7 TeV on the charged particle multiplicity distribution in the "transverse" region for charged particles (p_T > 0.5 GeV/c, |η| < 2) as defined by the leading charged particle jet, chgjet#1, with PT(chgjet#1) > 3 GeV/c compared with PYTHIA Tune D6T, Tune DW, and Tune CW at the detector level (*i.e.* Theory + SIM).**

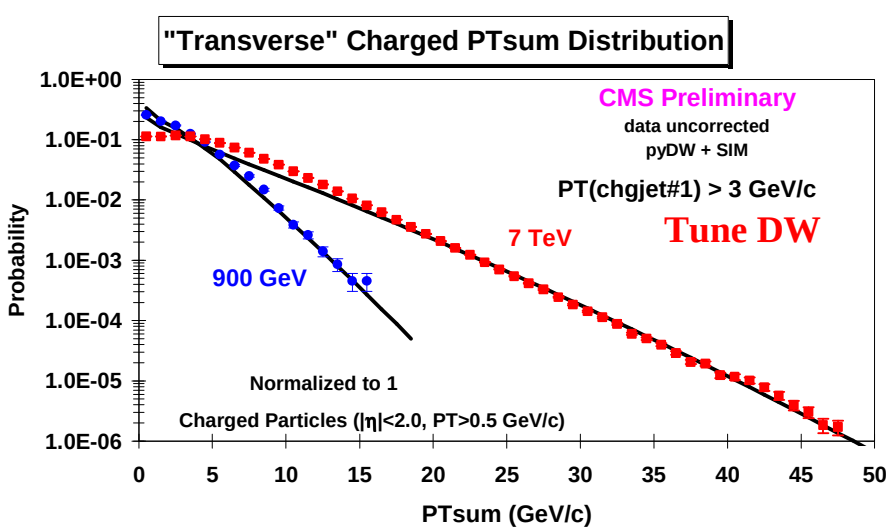


"Transverse" PTsum Distribution

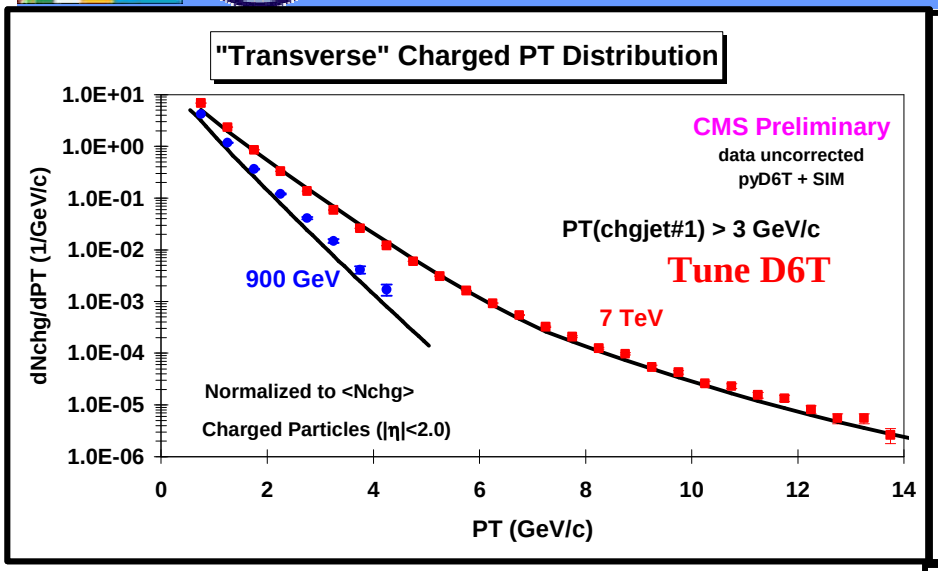


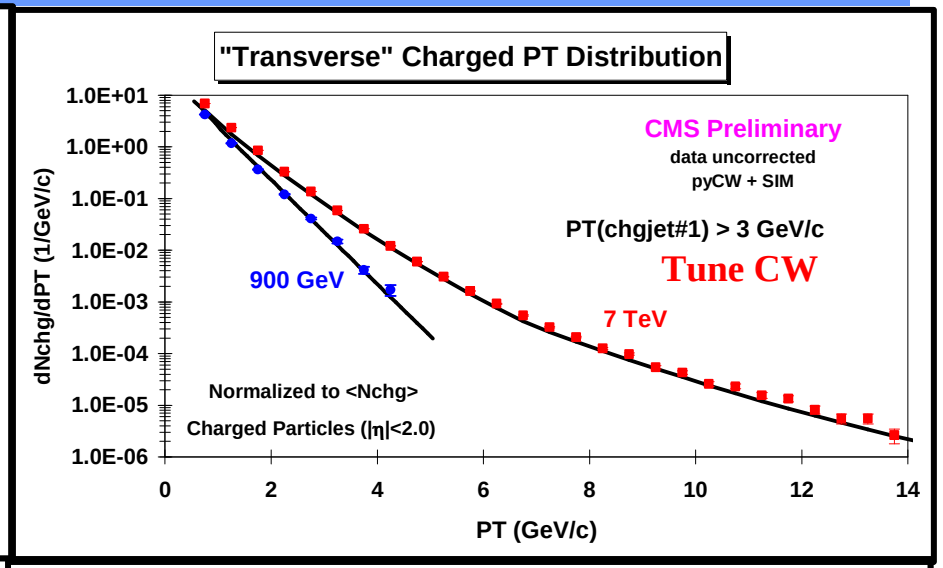


- **CMS uncorrected data at 900 GeV and 7 TeV on the charged scalar PTsum distribution in the "transverse" region for charged particles (p_T > 0.5 GeV/c, |η| < 2) as defined by the leading charged particle jet, chgjet#1, with PT(chgjet#1) > 3 GeV/c compared with PYTHIA Tune D6T, Tune DW, and Tune CW at the detector level (*i.e.* Theory + SIM).**

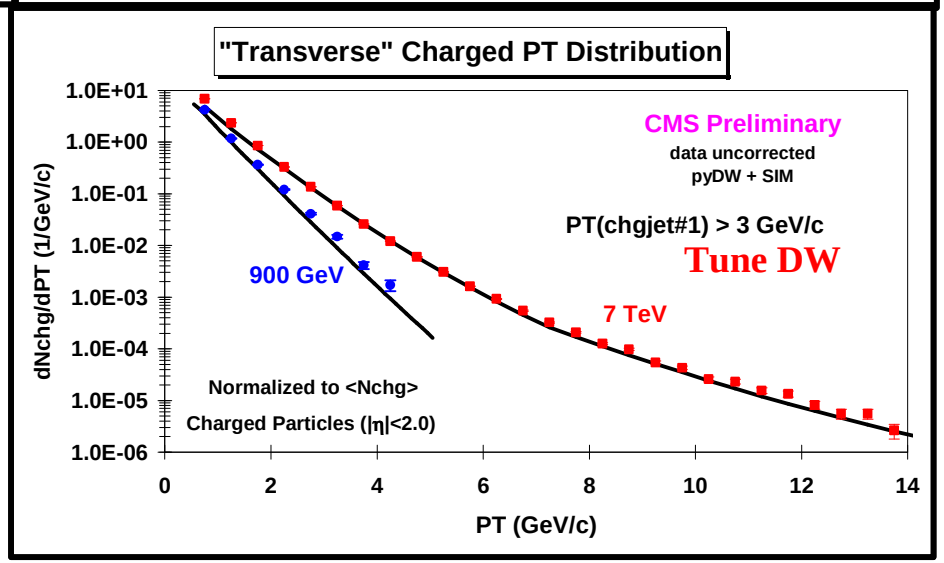


"Transverse" PT Distribution

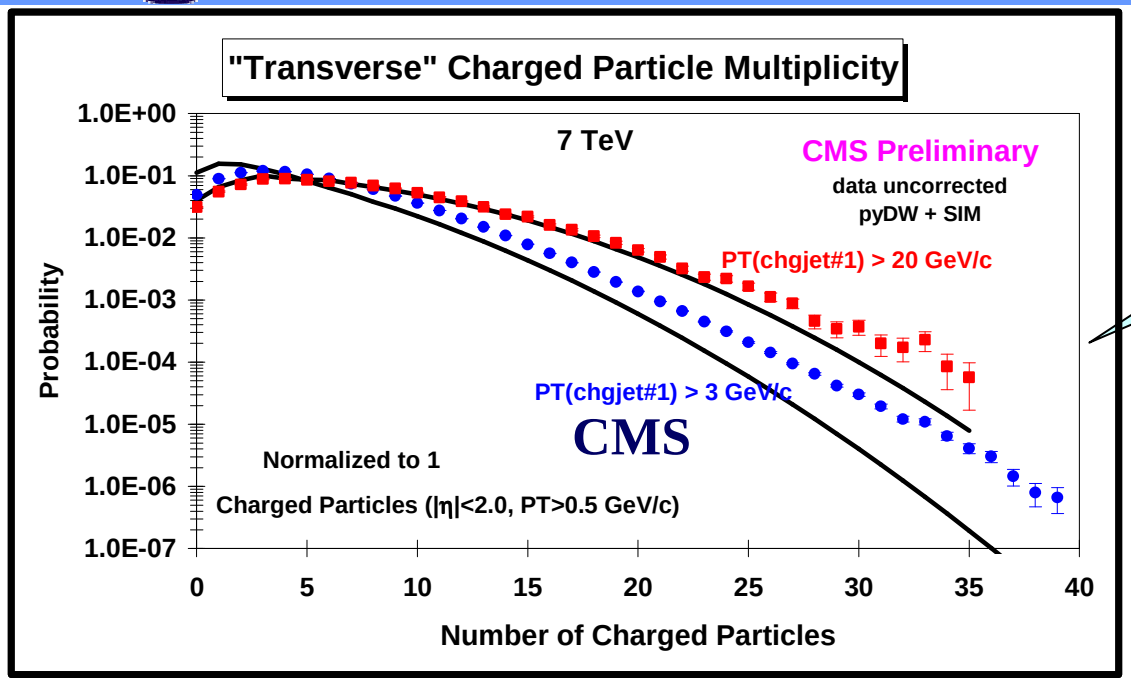




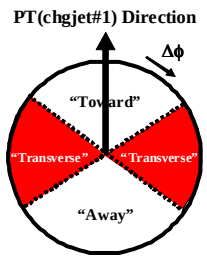
- **CMS uncorrected data at 900 GeV and 7 TeV on the charged particle PT distribution in the "transverse" region for charged particles (|η| < 2) as defined by the leading charged particle jet, chgjet#1, with PT(chgjet#1) > 3 GeV/c compared with PYTHIA Tune D6T, Tune DW, and Tune CW at the detector level (*i.e.* Theory + SIM).**



"Transverse" Multiplicity Distribution



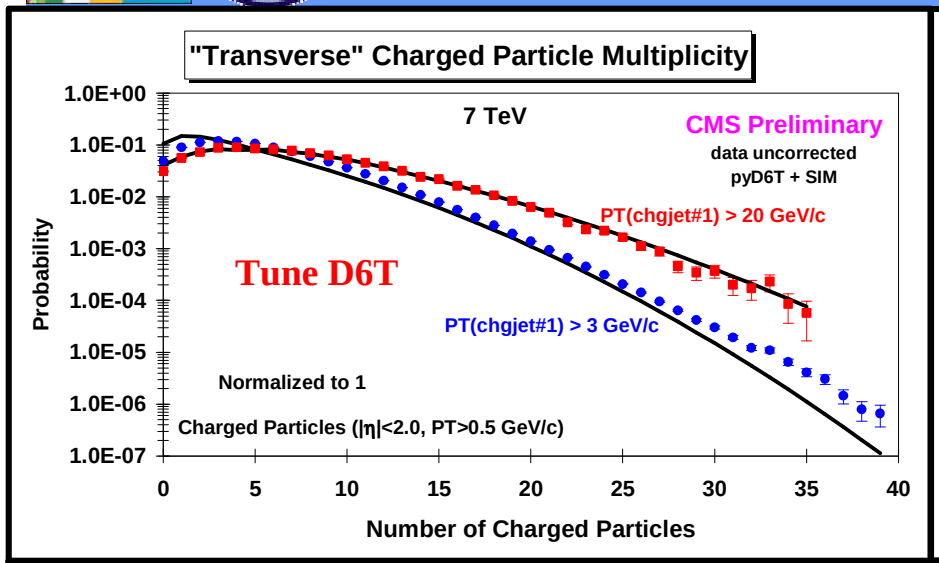
Same center-of-mass energy at two different hard scales!

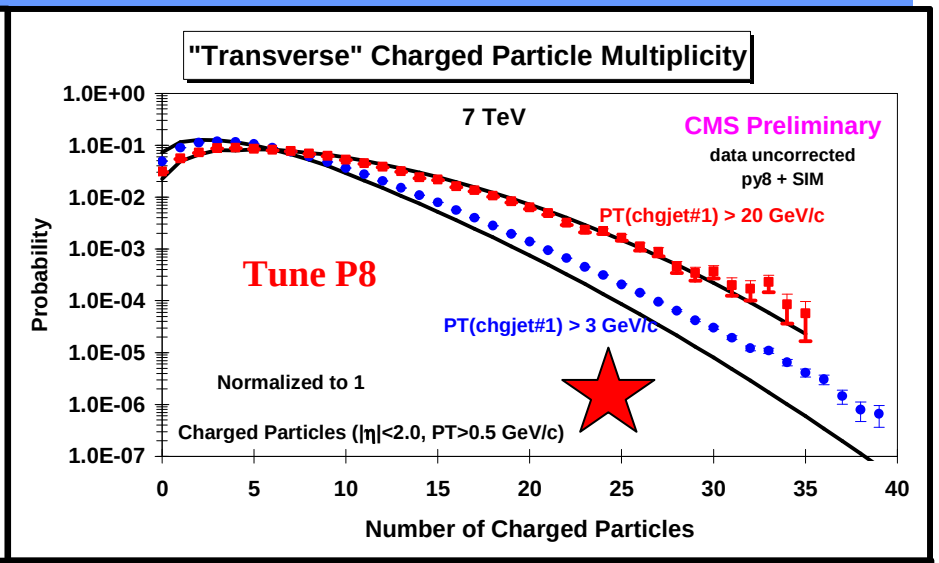


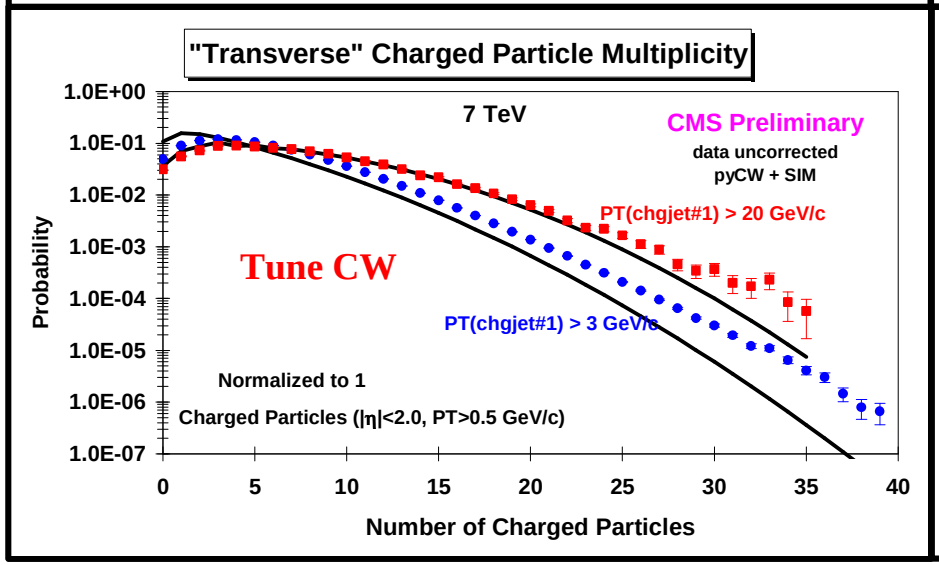
- **CMS uncorrected data at 7 TeV on the charged particle multiplicity distribution in the "transverse" region for charged particles (p_T > 0.5 GeV/c, |η| < 2) as defined by the leading charged particle jet, chgjet#1, with PT(chgjet#1) > 3 GeV/c and PT(chgjet#1) > 20 GeV/c compared with PYTHIA Tune DW at the detector level (*i.e.* Theory + SIM).**

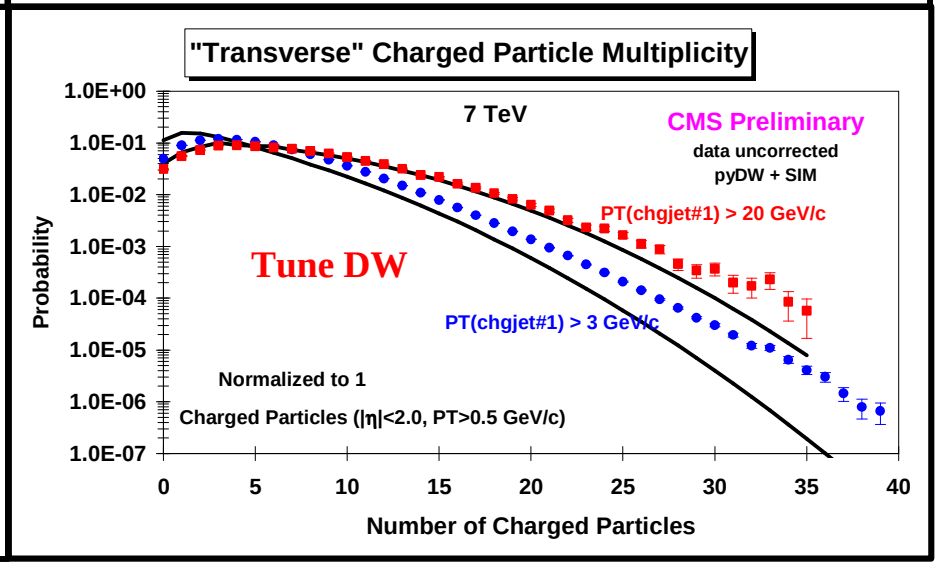
Shows the growth of the "underlying event" as the hard scale increases.

"Transverse" Multiplicity Distribution

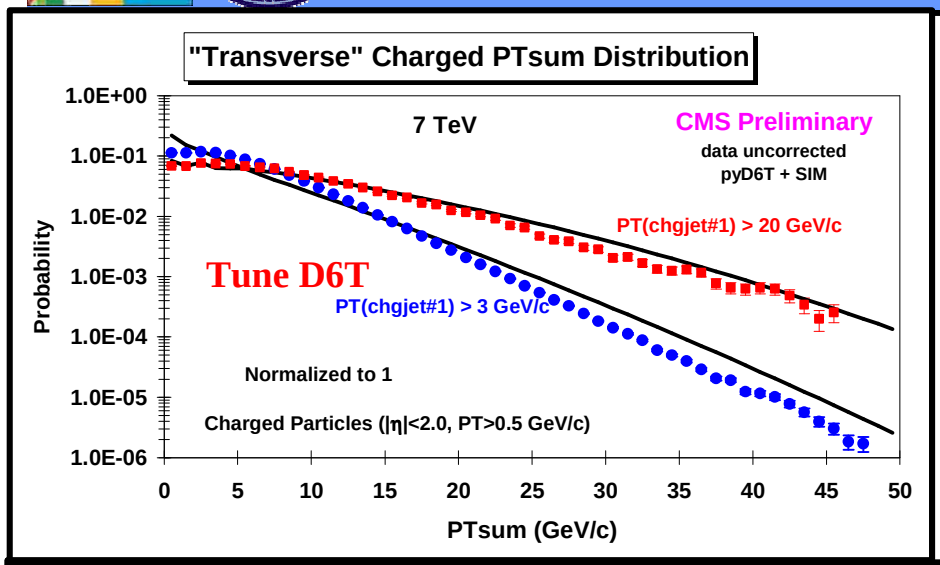


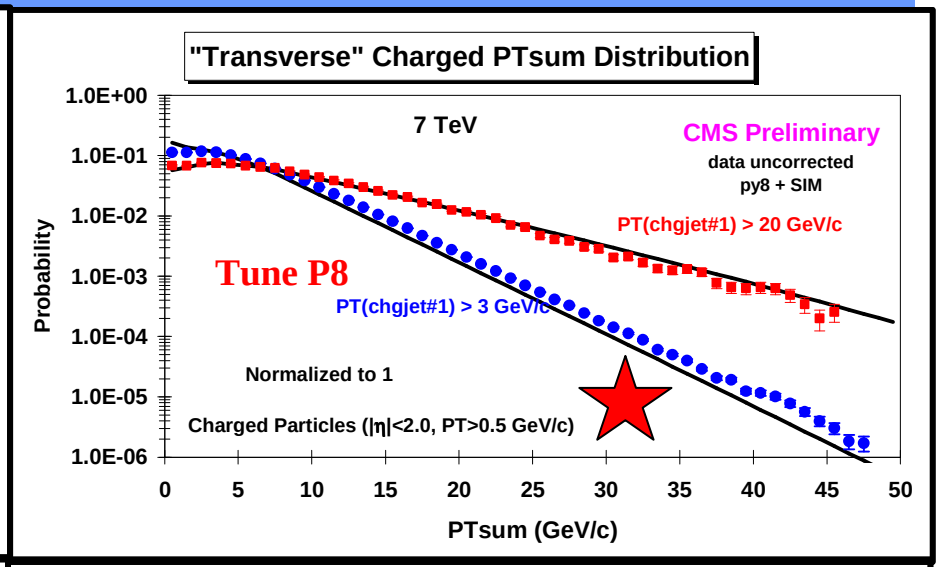


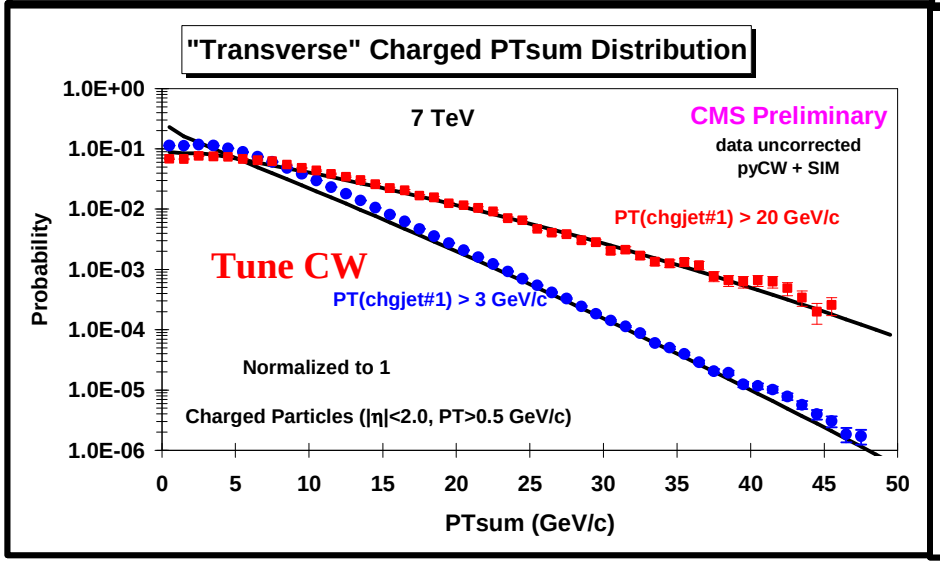


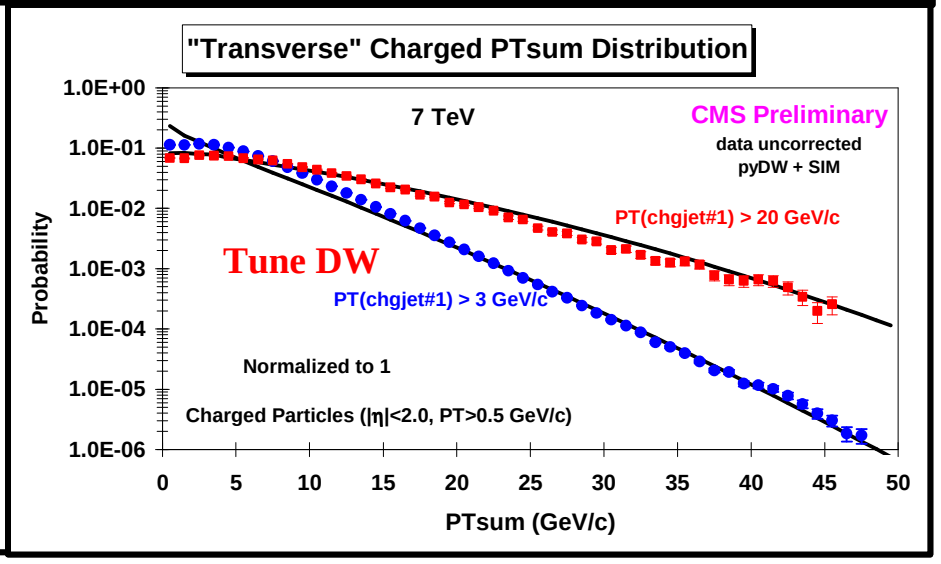


"Transverse" PTsum Distribution

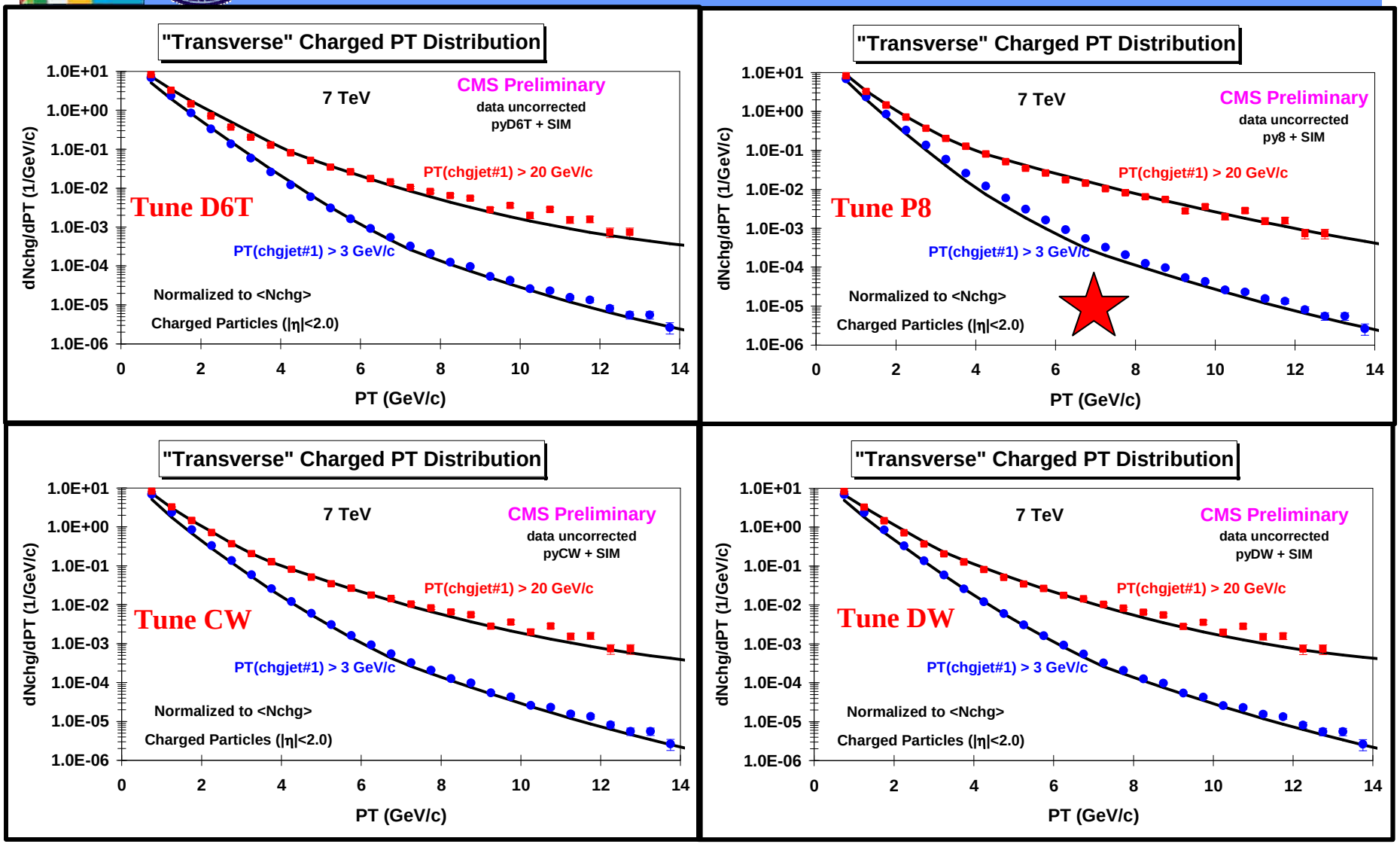






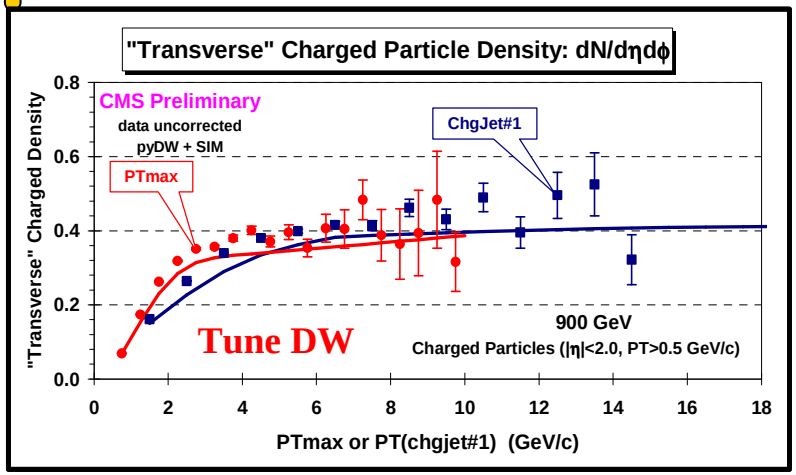


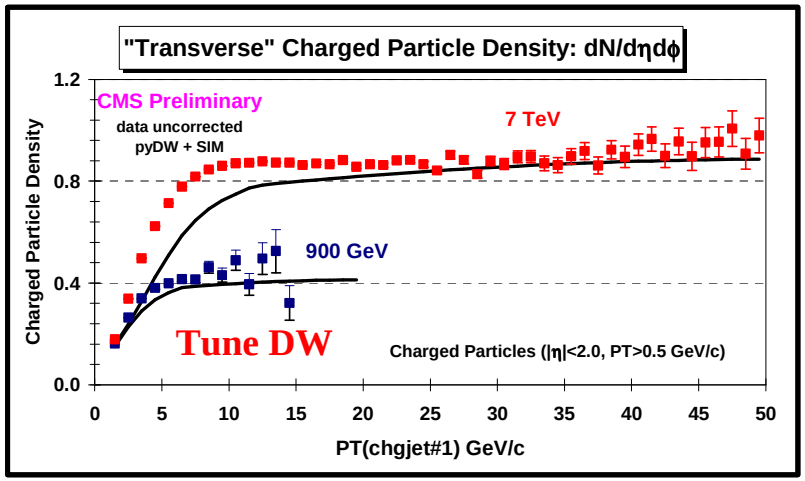
"Transverse" PT Distribution



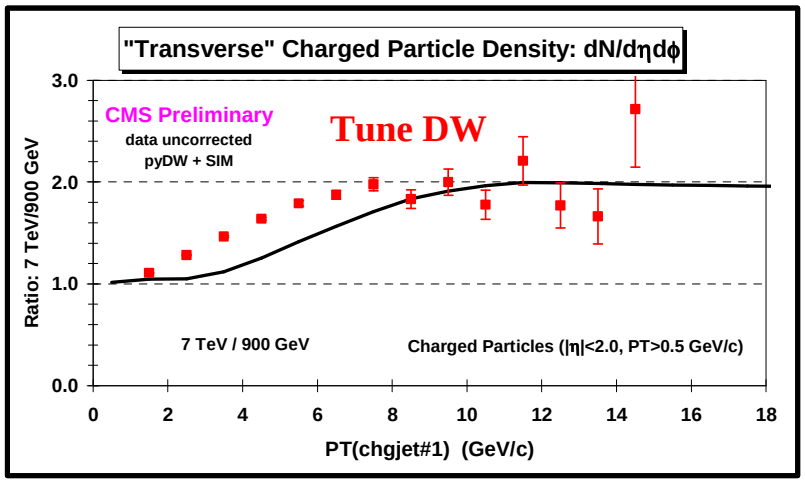
PYTHIA Tune DW

How well did we do at predicting the "underlying event" at 900 GeV and 7 TeV?



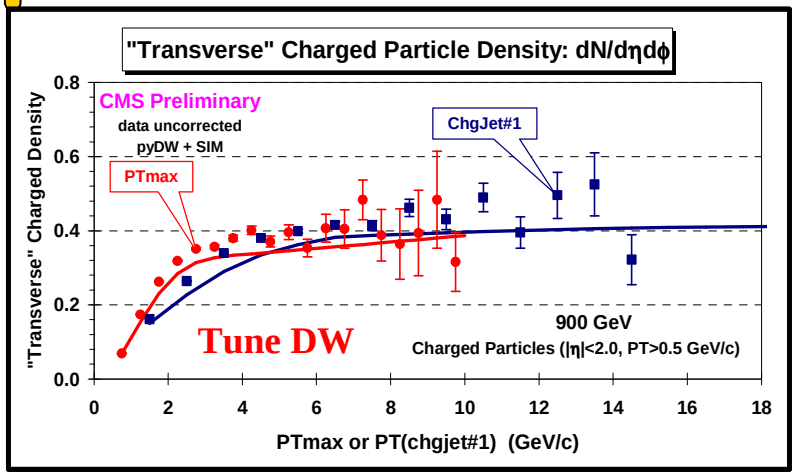


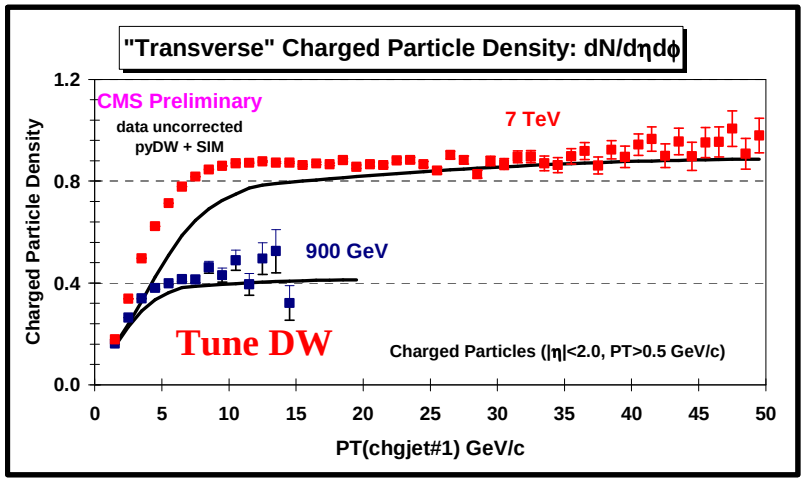
➡ **I am surprised that the Tunes did not do a better job of predicting the behavior of the "underlying event" at 900 GeV and 7 TeV!**



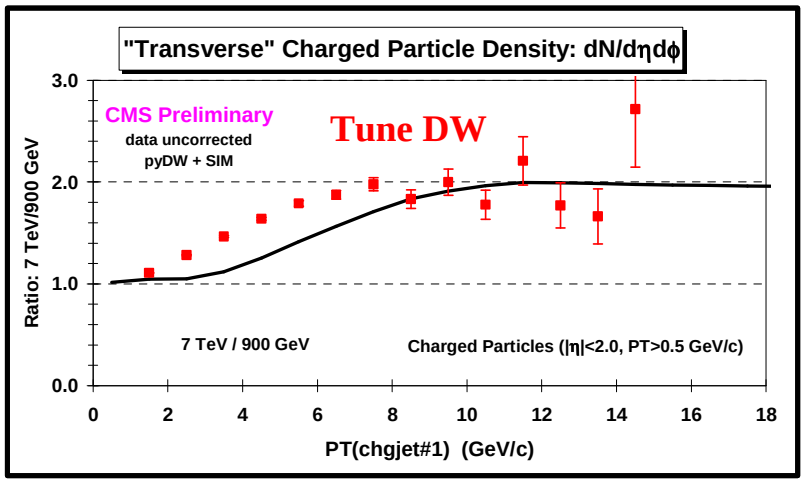
PYTHIA Tune DW

How well did we do at predicting the "underlying event" at 900 GeV and 7 TeV?



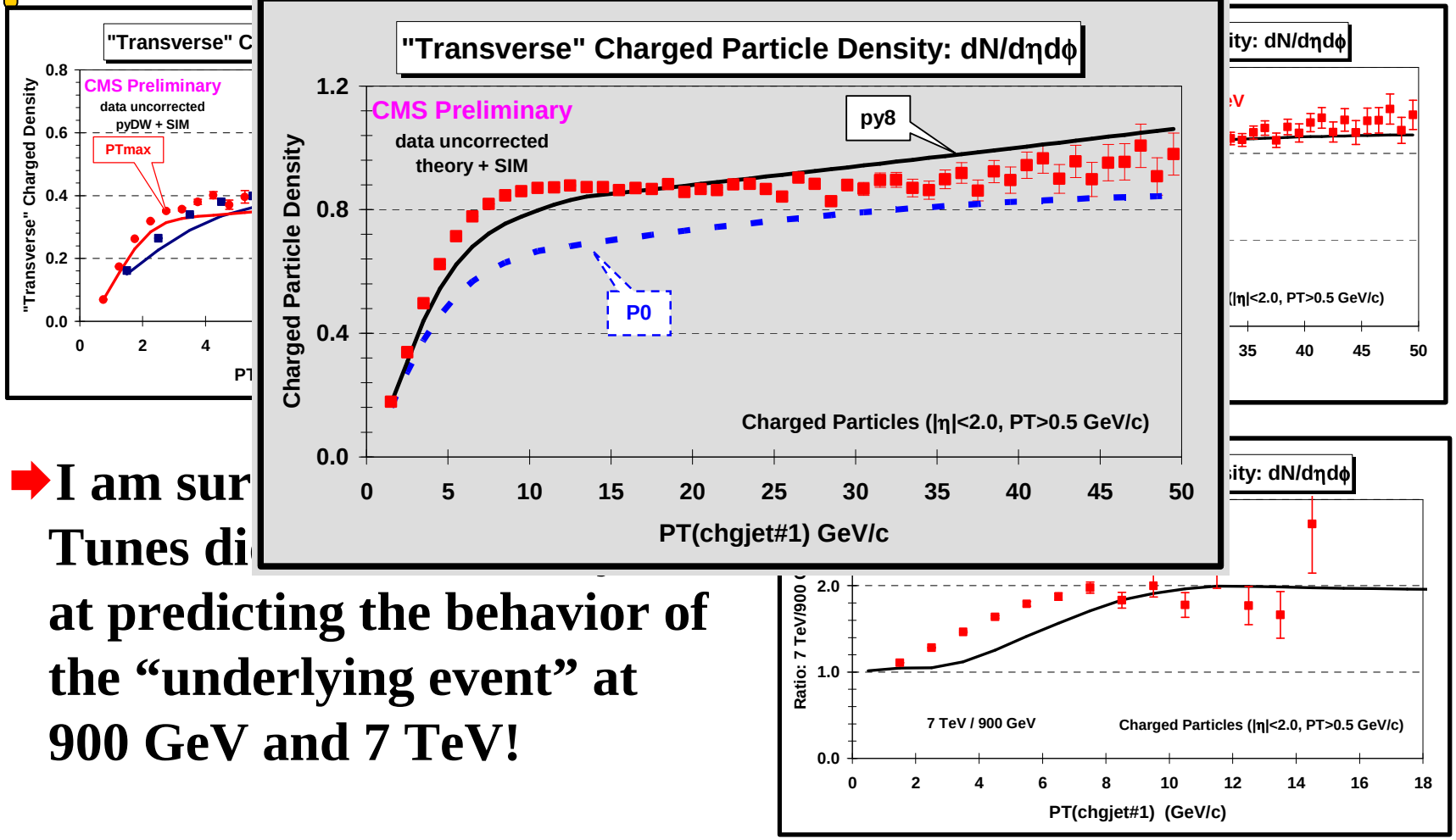


➡ **I am surprised that the Tunes did as well as they did at predicting the behavior of the "underlying event" at 900 GeV and 7 TeV!**



PYTHIA Tune DW

How well did we do at predicting the "underlying event" at 900 GeV and 7 TeV?



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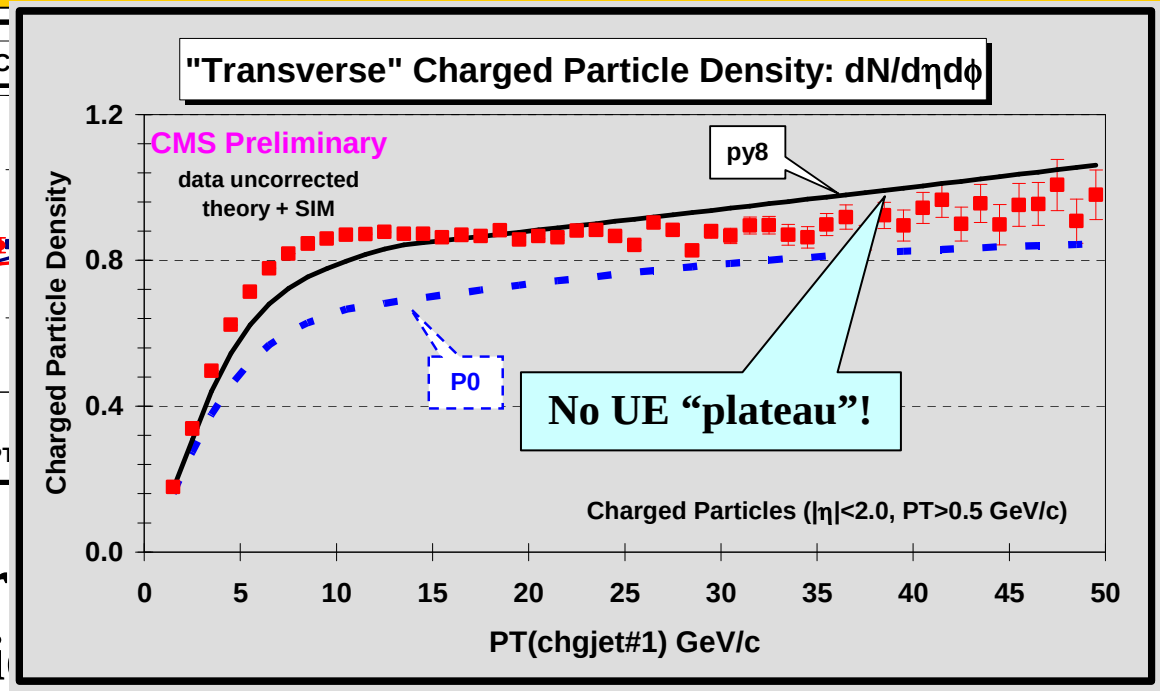
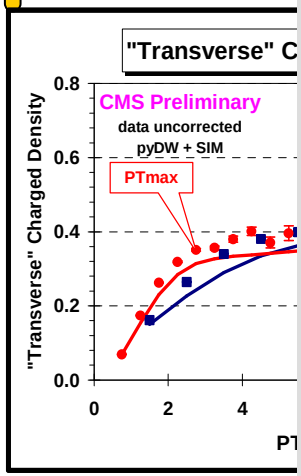
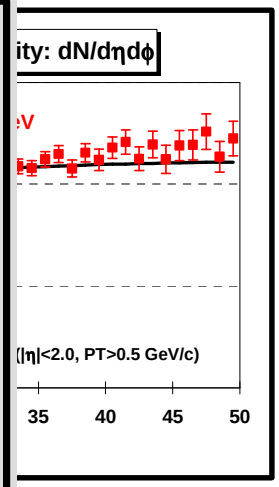
Tunes di
at predicting the behavior of the "underlying event" at 900 GeV and 7 TeV!

PYTHIA Tune DW

How well did we do at predicting the "underlying event" at 900 GeV and 7 TeV?







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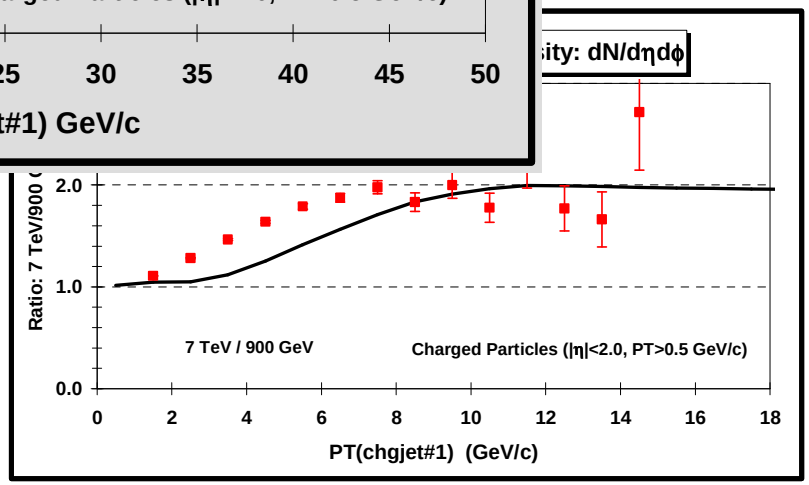

ATLAS Tune AMBT1

Charged particle multiplicities in p p interactions at $\sqrt{s}$ = 0.9 and 7 TeV in a diffractive limited phase-space and a new Pythia tune.

Judith Katzy (DESY)
On behalf of the ATLAS Collaboration

Judith Katzy LPCC MB&UE working group meeting, *May 31, 2010*.

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UCL

Minimum bias and Underlying Event studies with Monte Carlo tune for pp events with the ATLAS detector

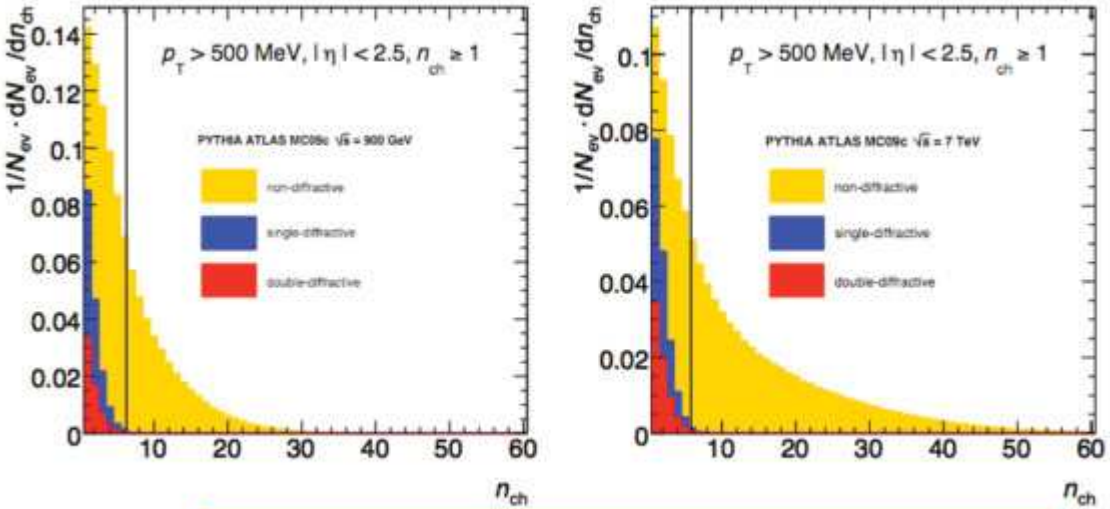
Emily Nurse
(for the ATLAS collaboration)
ICHEP, Paris
24th July 2010

Emily Nurse ICHEP, *July 24, 2010*.

ATLAS-CONF-2010-031

ATLAS Tune AMBT1

Example: pythia6 predictions



Build diffractive suppressed sample with $n_{ch} \geq 6$

Resulting number of events:

	$n_{ch} \geq 1$	$n_{ch} \geq 6$
7TeV:	369673	231665
900 GeV:	326201	157896

Subset of the "min-bias" data!

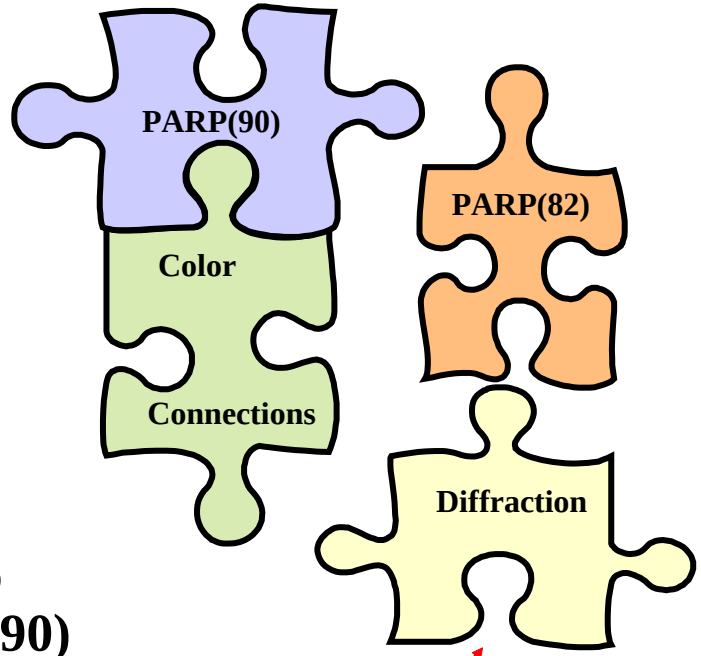
Parameters used for tuning

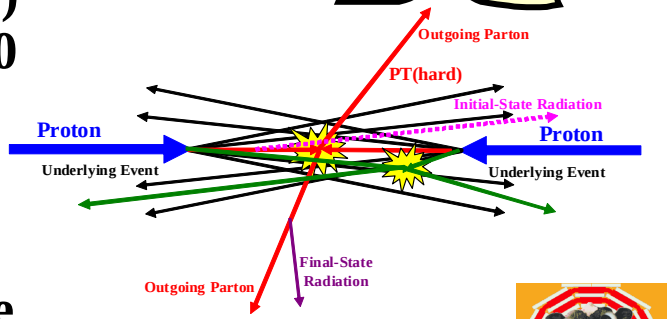
Parameter	related model	MC09c value	scanning range	AMBT1 value
PARP(62)	ISR cut-off	1.0	fixed	1.025
PARP(93)	primordial kt	5.0	fixed	10.0
PARP(77)	CR suppression	0.0	0.25 – – – 1.15	1.016
PARP(78)	CR strength	0.224	0.2 – – – 0.6	0.538
PARP(83)	MPI (matter fraction in core)	0.8	fixed	0.356
PARP(84)	MPI (core of matter overlap)	0.7	0.0 – – – 1.0	0.651
PARP(82)	MPI (p_T^{min})	2.31	2.1 – – – 2.5	2.292
PARP(90)	MPI (energy extrapolation)	0.2487	0.18 – – – 0.28	0.250

➡ **Attempt to fit a subset of the "min-bias" data (Nchg ≥ 6) where the contamination due to diffraction is expected to be small!**

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 Nchg ≥ 6 and to fit the PTmax UE data with PTmax > 10 GeV/c. Tune AMBT1 is primarily a min-bias tune, while Tune Z1 is a UE tune!





UE&MB@CMS

PYTHIA Tune Z1

Parameters not shown are the PYTHIA 6.4 defaults!

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

PYTHIA Tune Z1

Tune Z2 with CTEQ6L is coming soon!

Parameters not shown are the PYTHIA 6.4 defaults!

Parameter	Tune Z1 (R. Field CMS)	Tune AMBT1 (ATLAS)
Parton Distribution Function	CTEQ5L	LO*
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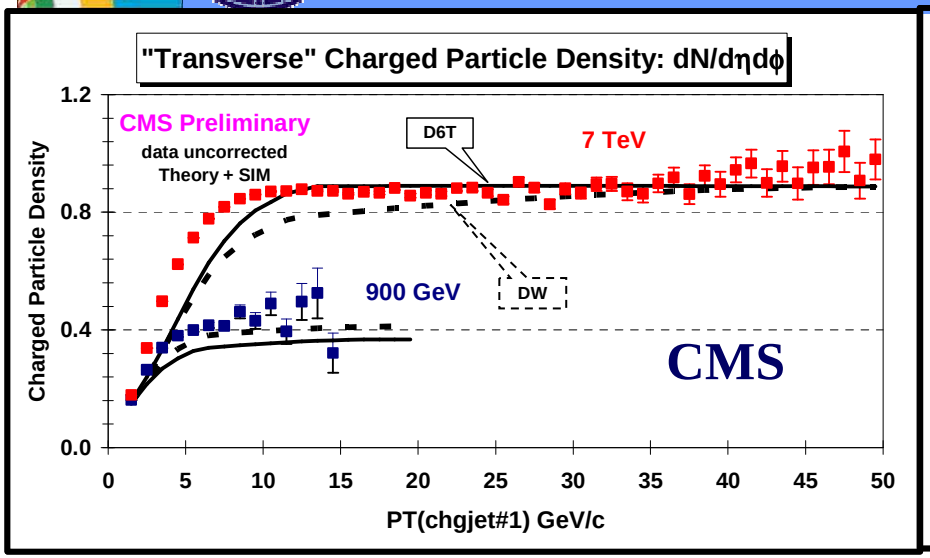
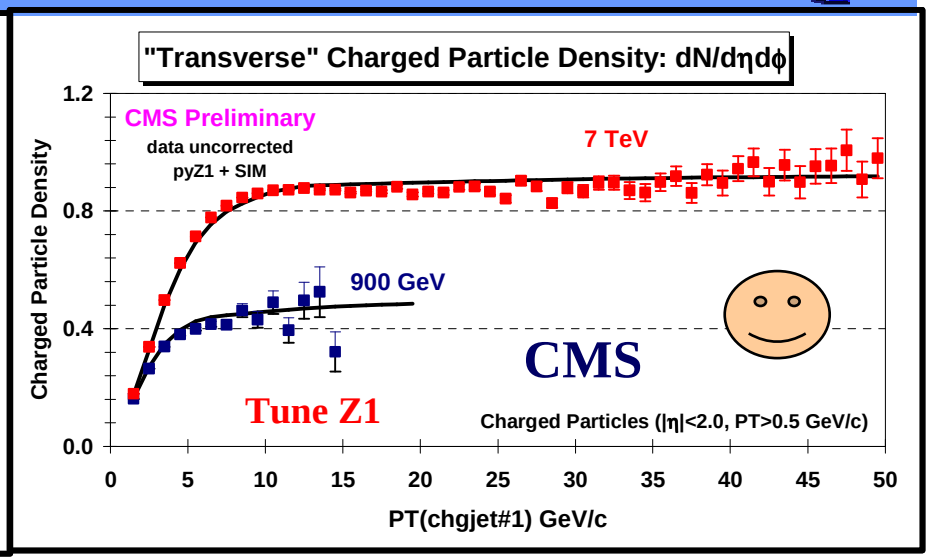
PYTHIA Tune Z1





- **CMS preliminary data at 900 GeV and 7 TeV on the "transverse" charged particle density, dN/dηdϕ, as defined by the leading charged particle jet (chgjet#1) for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 2.0$. The data are uncorrected and compared with PYTHIA Tune DW and D6T after detector simulation (SIM).**

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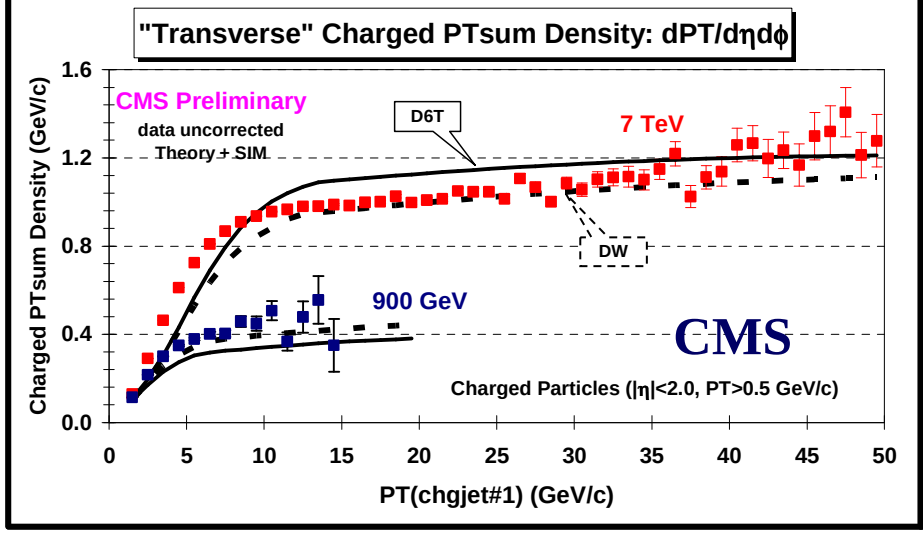
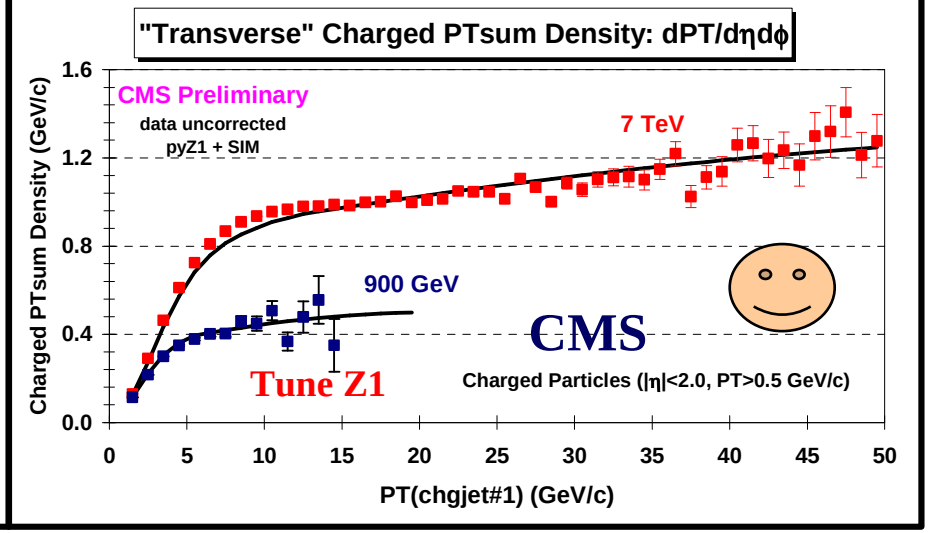
Color reconnection suppression.
Color reconnection strength.

Tune Z1 (CTEQ5L)
PARP(82) = 1.932
PARP(90) = 0.275
PARP(77) = 1.016
PARP(78) = 0.538

Tune Z1 is a PYTHIA 6.4 using p_T-ordered parton showers and the new MPI model!

PYTHIA Tune Z1





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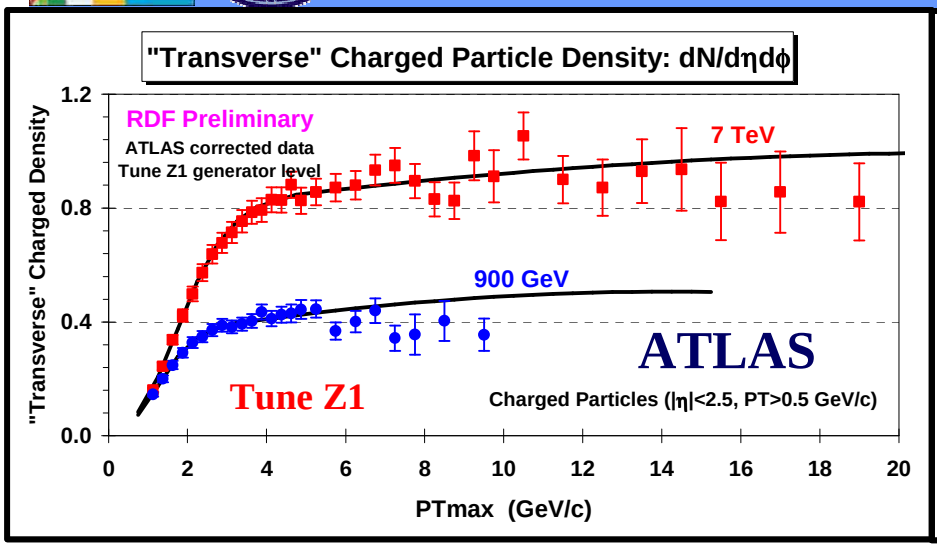

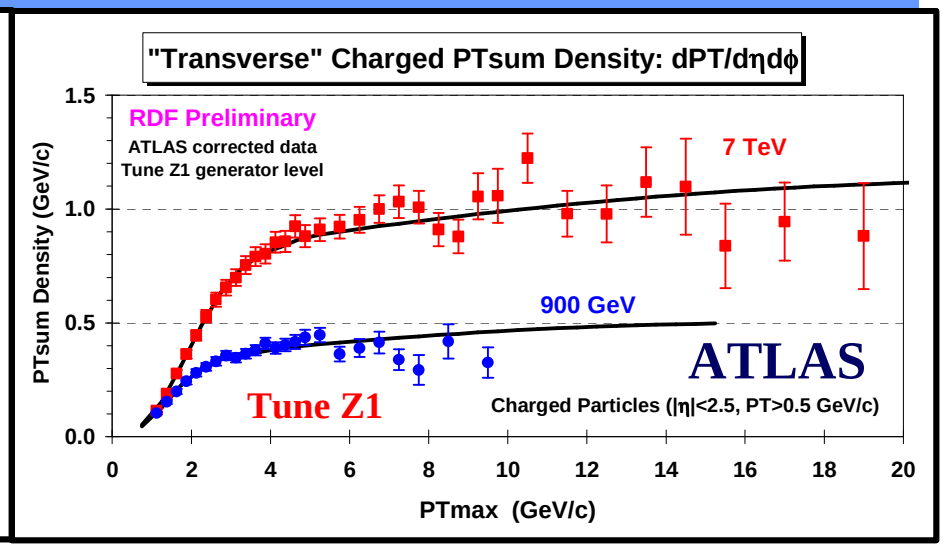

- **ATLAS preliminary data at 900 GeV and 7 TeV on the "transverse" charged particle density, dN/dηdϕ, as defined by the leading charged particle (PTmax) for charged particles with p_T > 0.5 GeV/c and |η| < 2.5. The data are corrected and compared with PYTHIA Tune Z1 at the generator level.**

- **ATLAS preliminary data at 900 GeV and 7 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 |η| < 2.5. The data are corrected and compared with PYTHIA Tune Z1 at the generrator level.**

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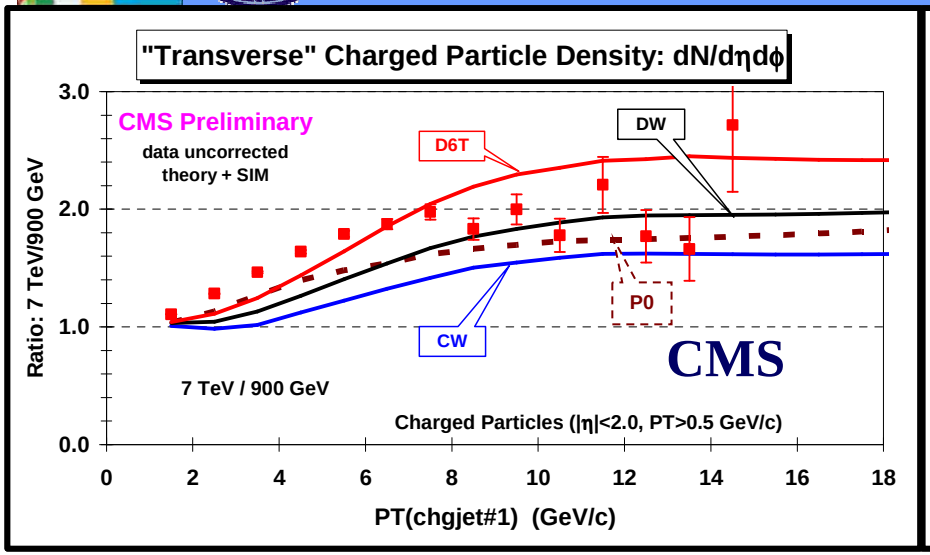
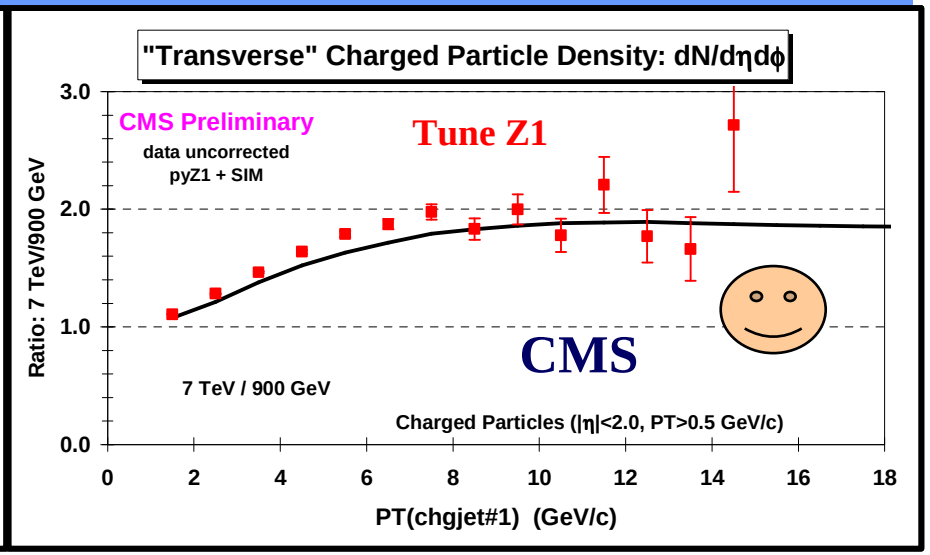
PYTHIA Tune Z1

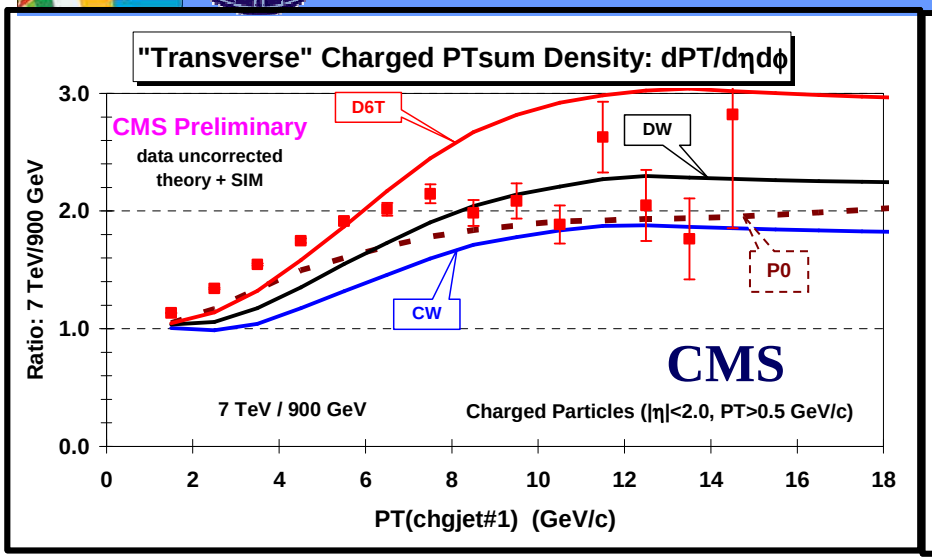


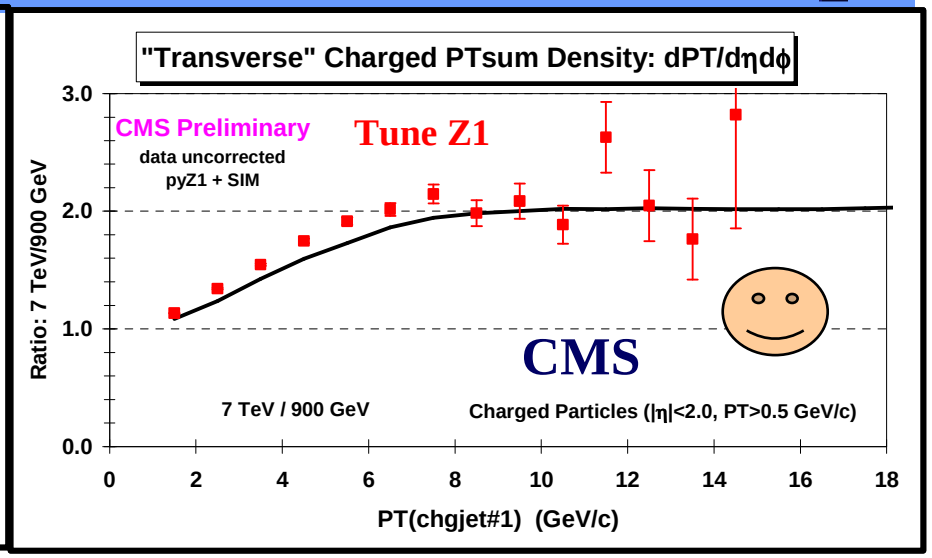


- **Ratio of CMS preliminary data at 900 GeV and 7 TeV (7 TeV divided by 900 GeV) on the "transverse" charged particle density as defined by the leading charged particle jet (chgjet#1) for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 2.0$. The data are uncorrected and compared with PYTHIA Tune DW, D6T, CW, and P0 after detector simulation (SIM).**

- **Ratio of CMS preliminary data at 900 GeV and 7 TeV (7 TeV divided by 900 GeV) on the "transverse" charged particle density as defined by the leading charged particle jet (chgjet#1) for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 2.0$. The data are uncorrected and compared with PYTHIA Tune Z1 after detector simulation (SIM).**

PYTHIA Tune Z1





- **Ratio of CMS preliminary data at 900 GeV and 7 TeV (7 TeV divided by 900 GeV) on the "transverse" charged PTsum density as defined by the leading charged particle jet (chgjet#1) for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 2.0$. The data are uncorrected and compared with PYTHIA Tune DW, D6T, CW, and P0 after detector simulation (SIM).**

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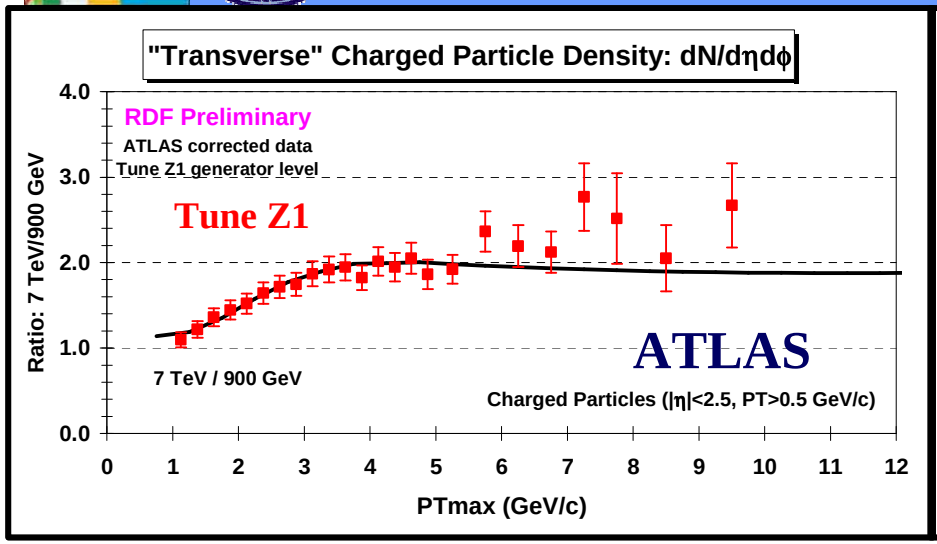
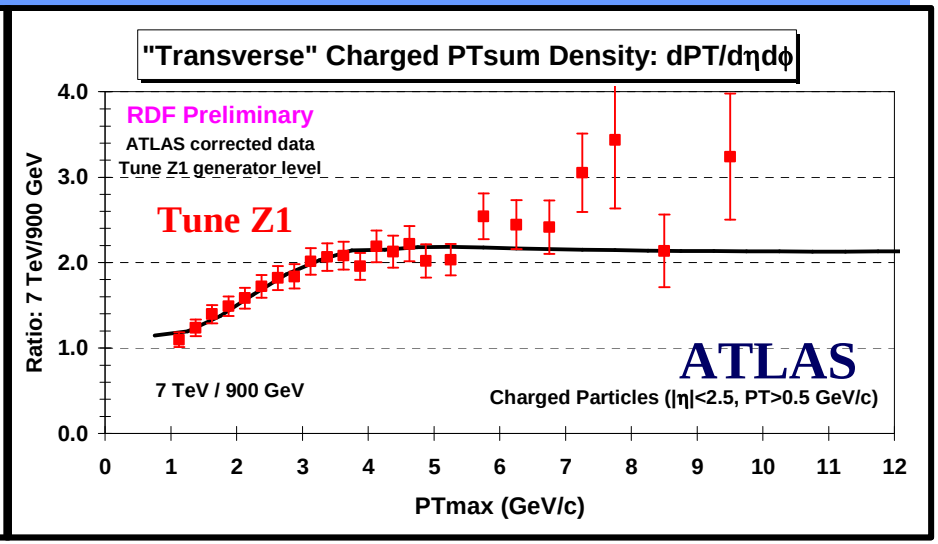
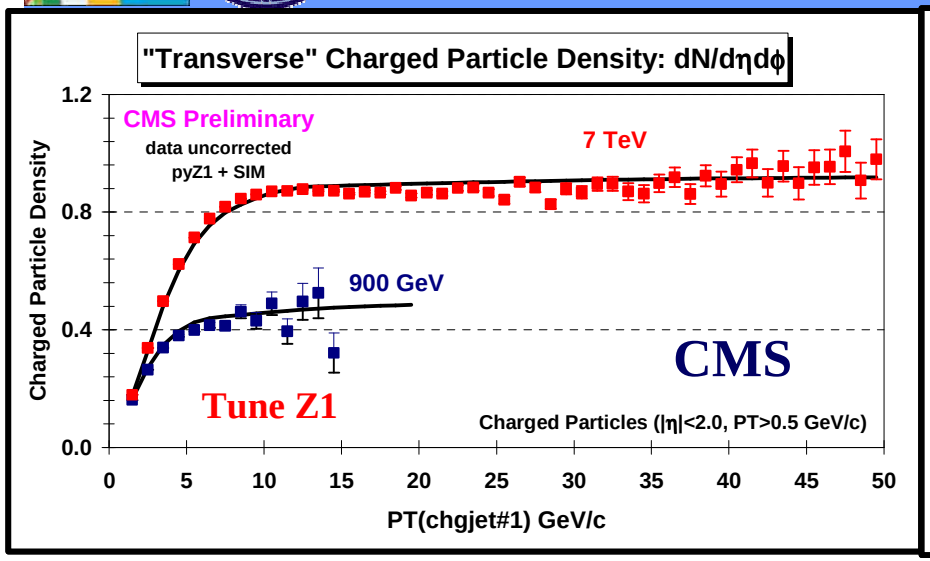


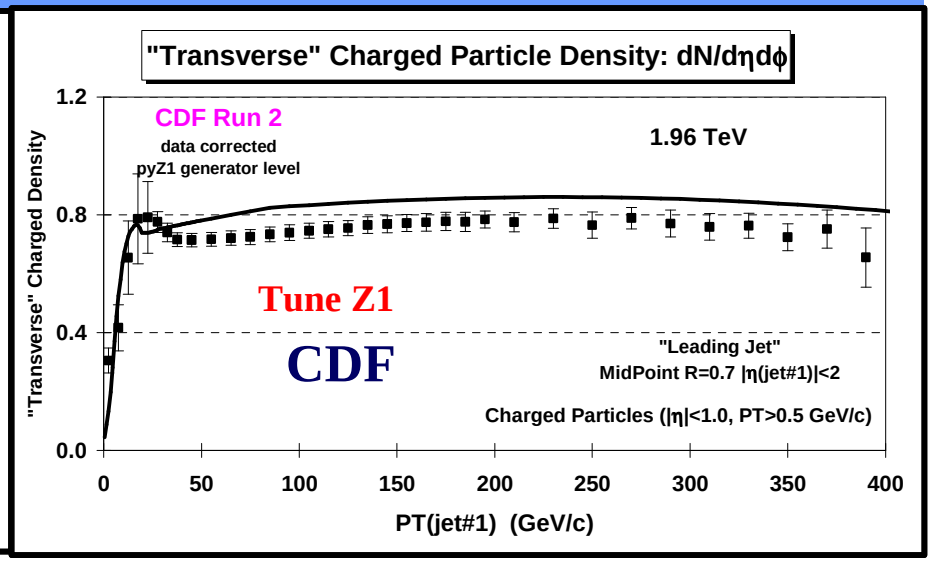


- **Ratio of the ATLAS preliminary data on the charged particle density in the "transverse" region for charged particles (p_T > 0.5 GeV/c, |η| < 2.5) at 900 GeV and 7 TeV as defined by PTmax compared with PYTHIA Tune Z1 at the generator level.**

- **Ratio of the ATLAS preliminary data on the charged PTsum density in the "transverse" region for charged particles (p_T > 0.5 GeV/c, |η| < 2.5) at 900 GeV and 7 TeV as defined by PTmax compared with PYTHIA Tune Z1 at the generator level.**

PYTHIA Tune Z1

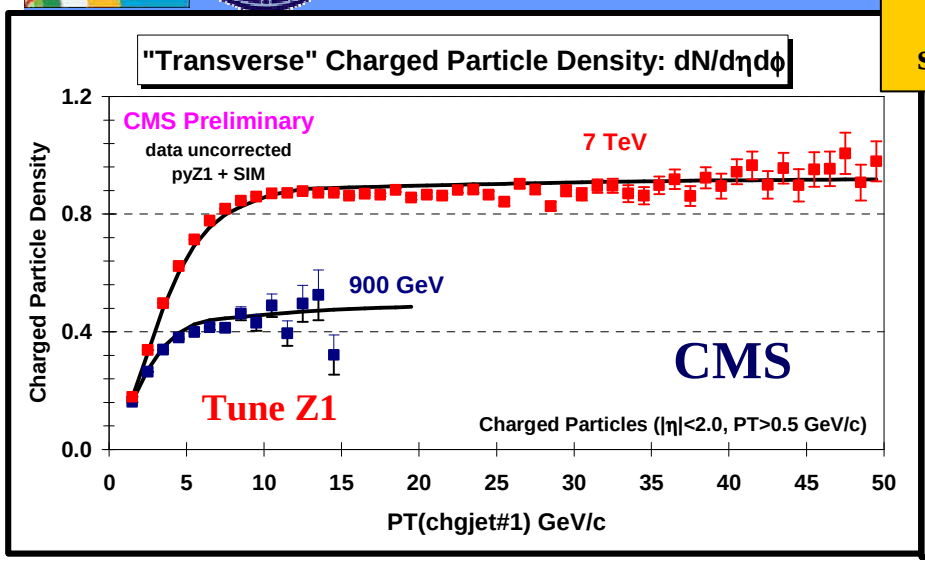


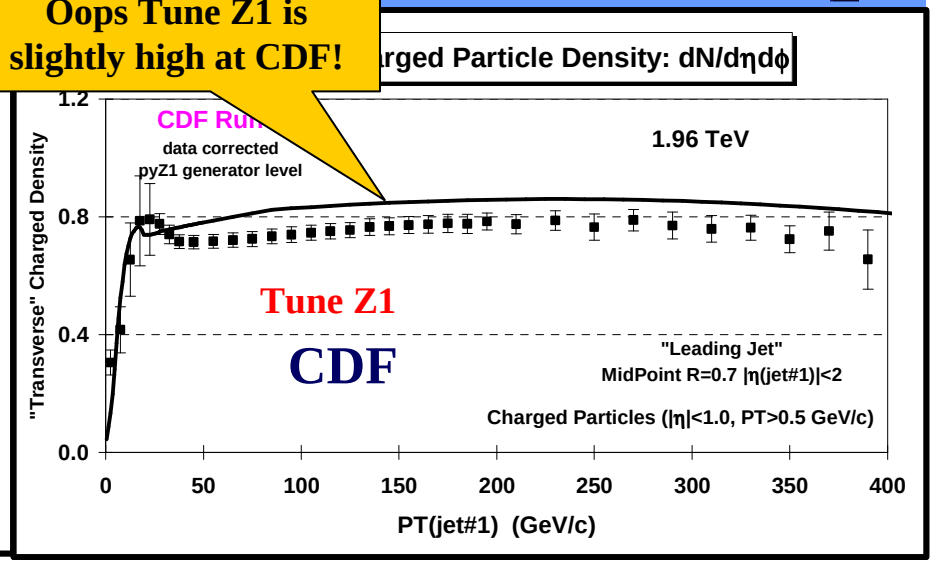


- **CMS preliminary data at 900 GeV and 7 TeV on the "transverse" charged particle density, dN/dηdϕ, as defined by the leading charged particle jet (chgjet#1) for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 2$. The data are uncorrected and compared with PYTHIA Tune Z1 after detector simulation.**

- **CDF published data at 1.96 TeV on the "transverse" charged particle density, dN/dηdϕ, as defined by the leading calorimeter jet (jet#1) for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 1.0$. The data are corrected and compared with PYTHIA Tune Z1 at the generator level.**

PYTHIA Tune Z1





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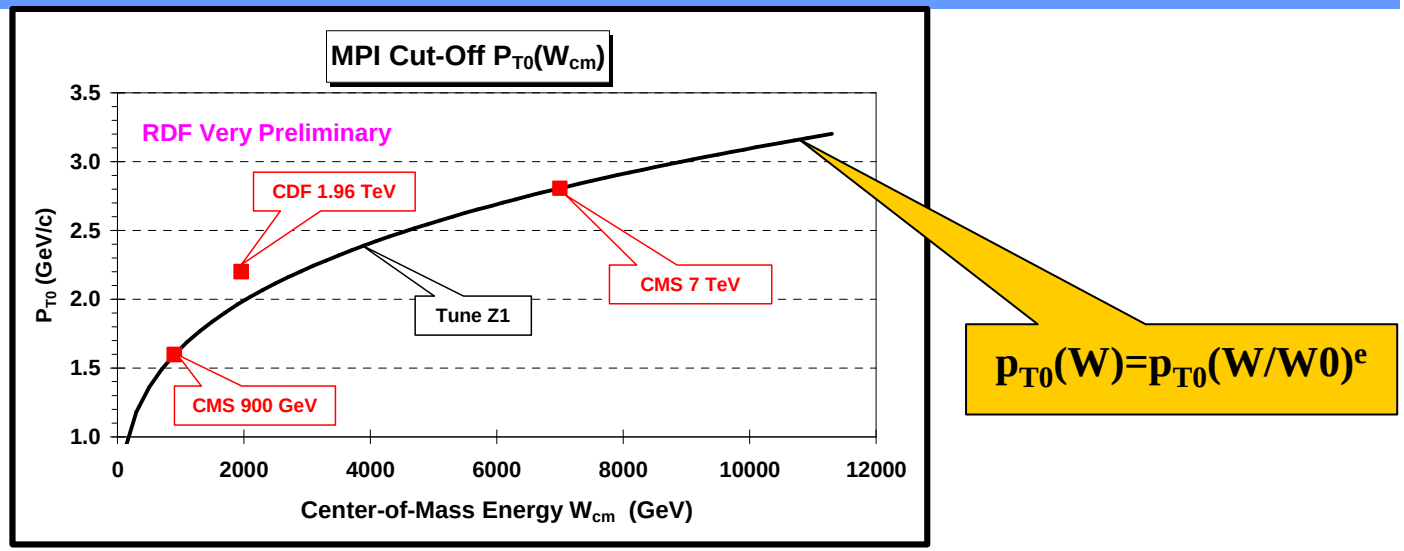
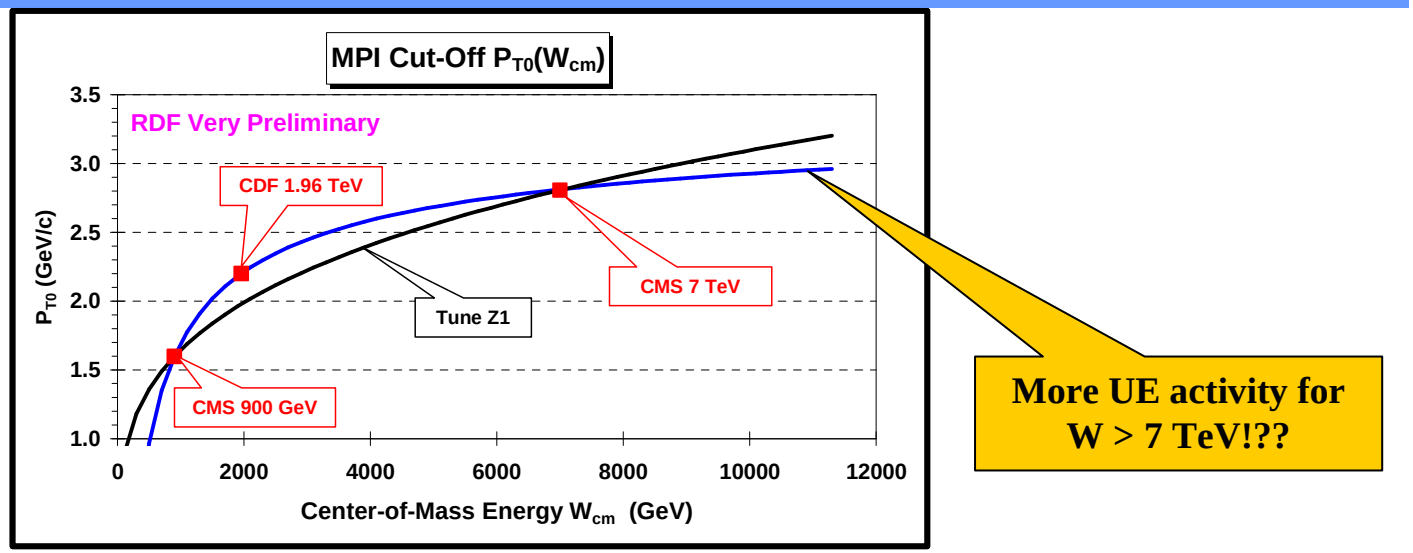
PYTHIA Tune Z1



➡ **MPI Cut-Off versus the Center-of Mass Energy W_{cm}: PYTHIA Tune Z1 was determined by fitting p_{T0} independently at 900 GeV and 7 TeV and calculating ε = PARP(90). The best fit to p_{T0} at CDF is slightly higher than the Tune Z1 curve. This is very preliminary! Perhaps with a global fit to all three energies (*i.e.* "Professor" tune) one can get a simultaneous fit to all three??**

$$p_{T0}(W)=p_{T0}(W/W_0)^{\varepsilon} \quad \varepsilon = PARP(90) \quad p_{T0} = PARP(82) \quad W = E_{cm}$$

PYTHIA Tune Z1



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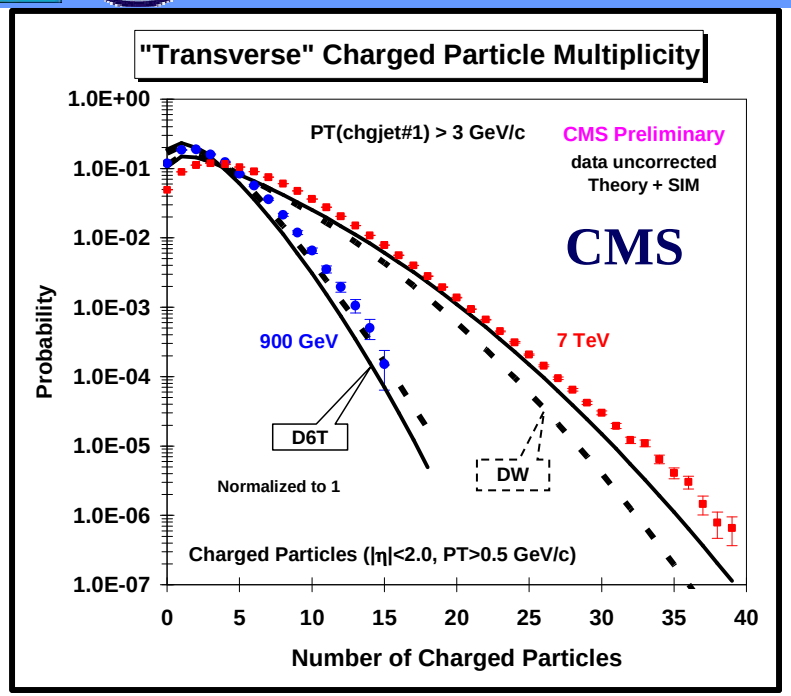
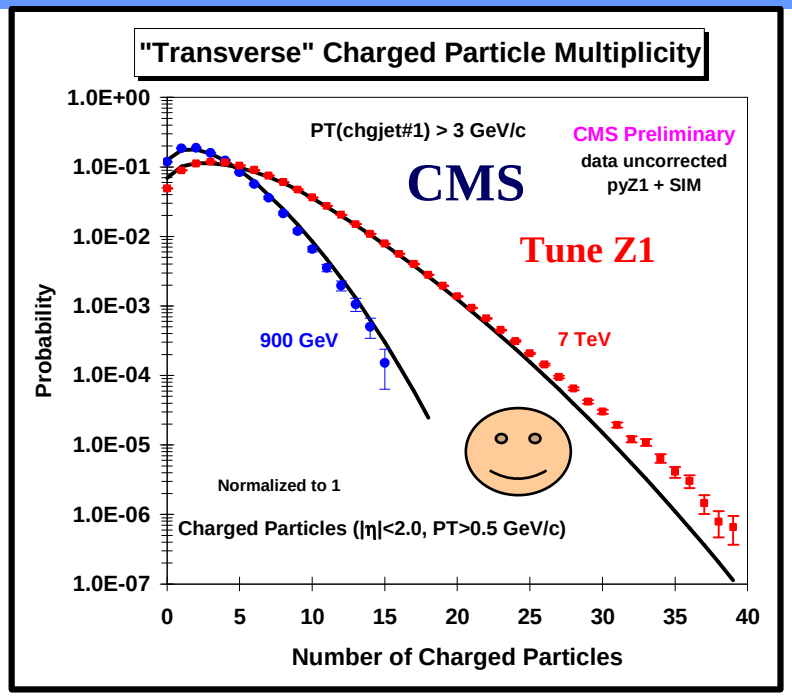
"Transverse" Multiplicity Distribution





- **CMS uncorrected data at 900 GeV and 7 TeV on the charged particle multiplicity distribution in the "transverse" region for charged particles (p_T > 0.5 GeV/c, |η| < 2) as defined by the leading charged particle jet with PT(chgjet#1) > 3 GeV/c compared with PYTHIA Tune DW and Tune D6T at the detector level (*i.e.* Theory + SIM).**

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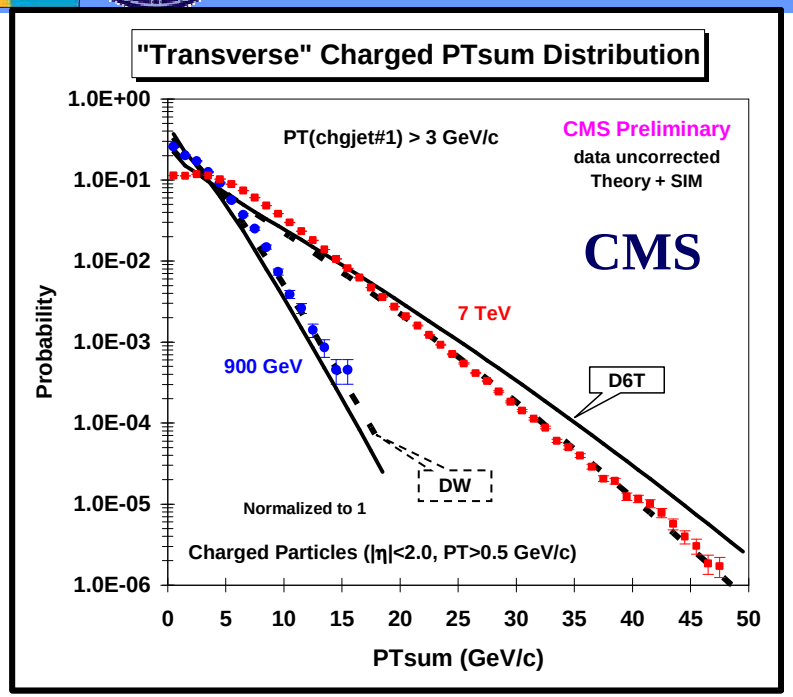
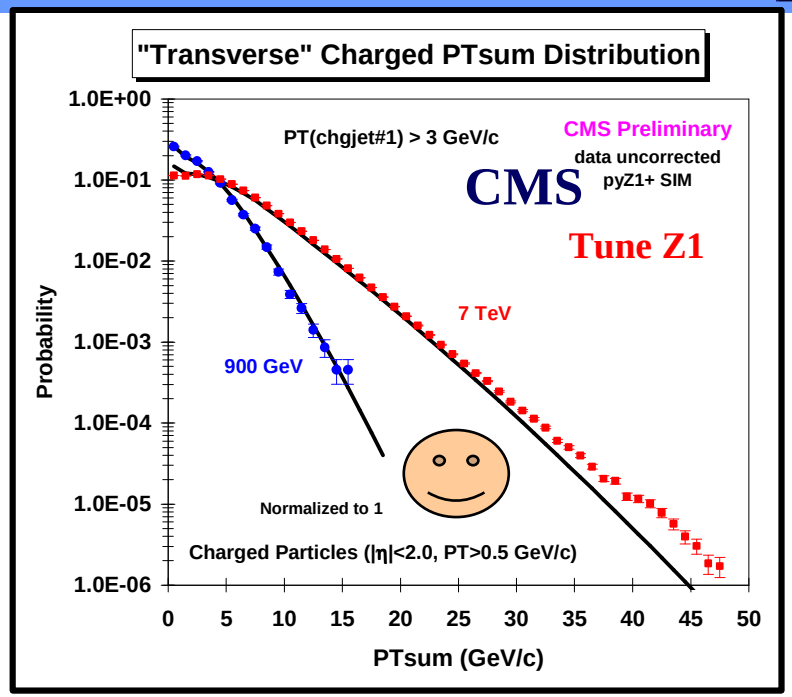
"Transverse" PTsum Distribution





- **CMS uncorrected data at 900 GeV and 7 TeV on the charged scalar PTsum distribution in the "transverse" region for charged particles (p_T > 0.5 GeV/c, |η| < 2) as defined by the leading charged particle jet with PT(chgjet#1) > 3 GeV/c compared with PYTHIA Tune DW, and Tune D6T at the detector level (*i.e.* Theory + SIM).**

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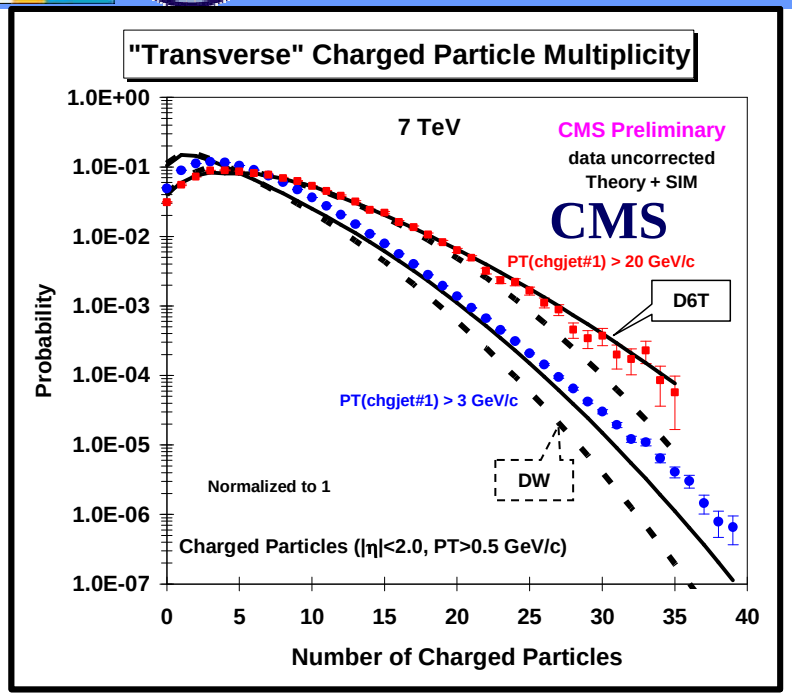
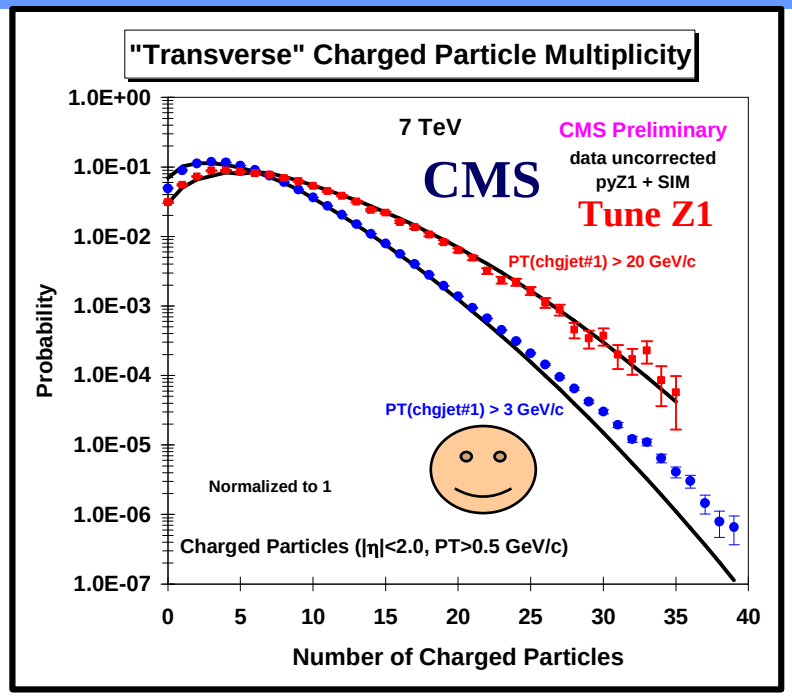
"Transverse" Multiplicity Distribution





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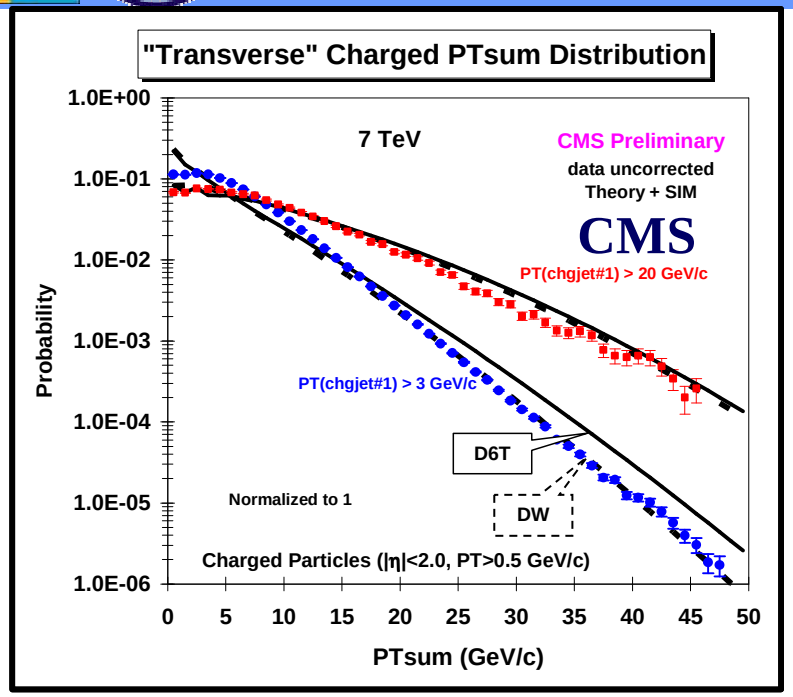

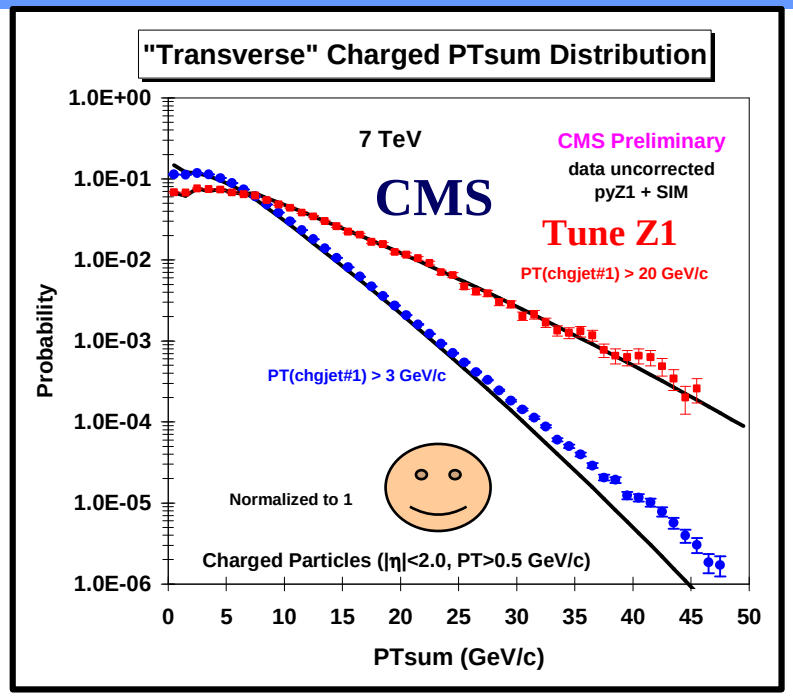

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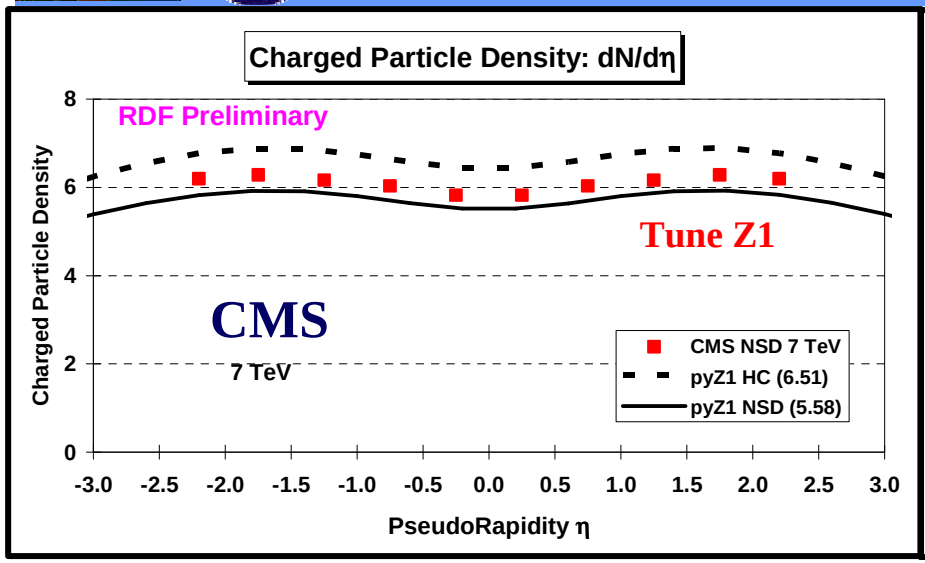
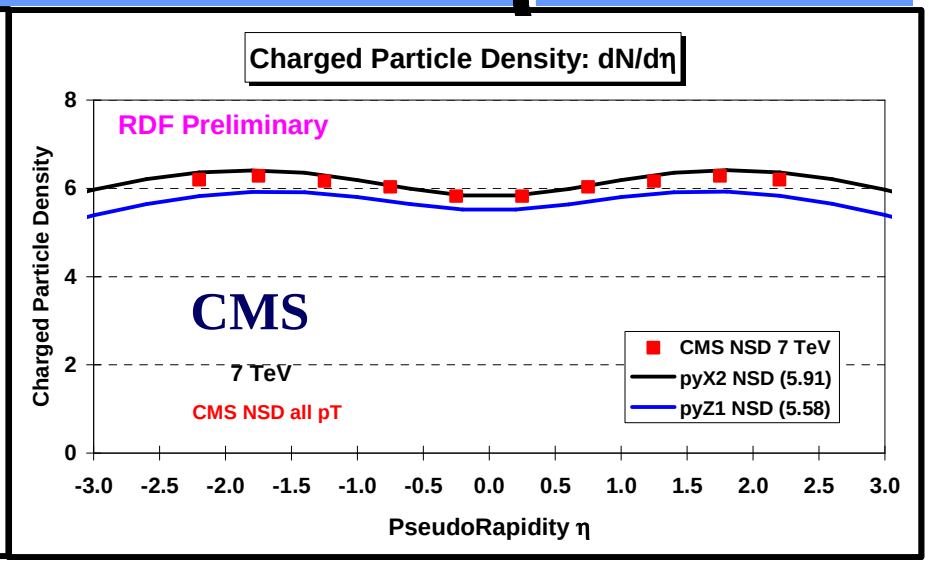
CMS dN/dη

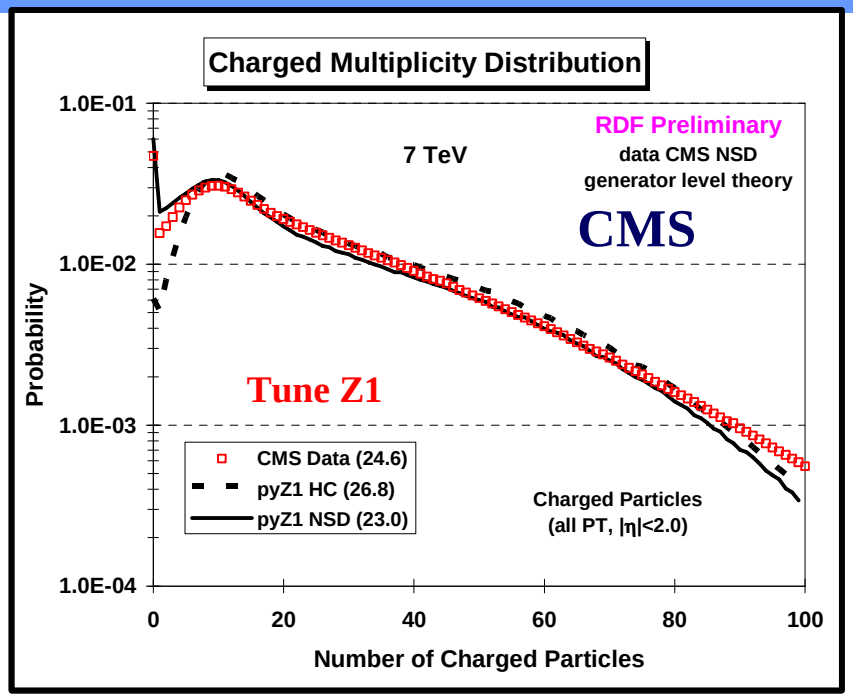




- **Generator level dN/dη (all pT). Shows the NSD = HC + DD and the HC = ND contributions for Tune Z1. Also shows the CMS NSD data.**
- **Generator level dN/dη (all pT). Shows the NSD = HC + DD prediction for Tune Z1 and Tune X2. Also shows the CMS NSD data.**

Okay not perfect, but remember we do not know if the DD is correct!

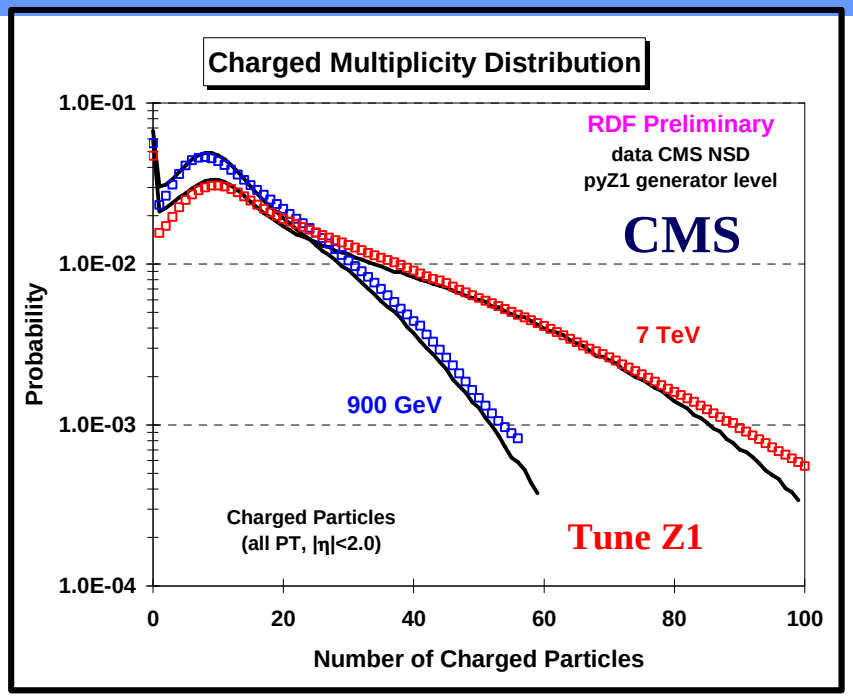
NSD Multiplicity Distribution



➡ **Generator level charged multiplicity distribution (all pT, |η| < 2) at 7 TeV. Shows the NSD = HC + DD and the HC = ND contributions for Tune Z1. Also shows the CMS NSD data.**

Okay not perfect!
But better than most tunes!

NSD Multiplicity Distribution



- **Generator level charged multiplicity distribution (all pT, |η| < 2) at 900 GeV and 7 TeV. Shows the NSD = HC + DD prediction for Tune Z1. Also shows the CMS NSD data.**

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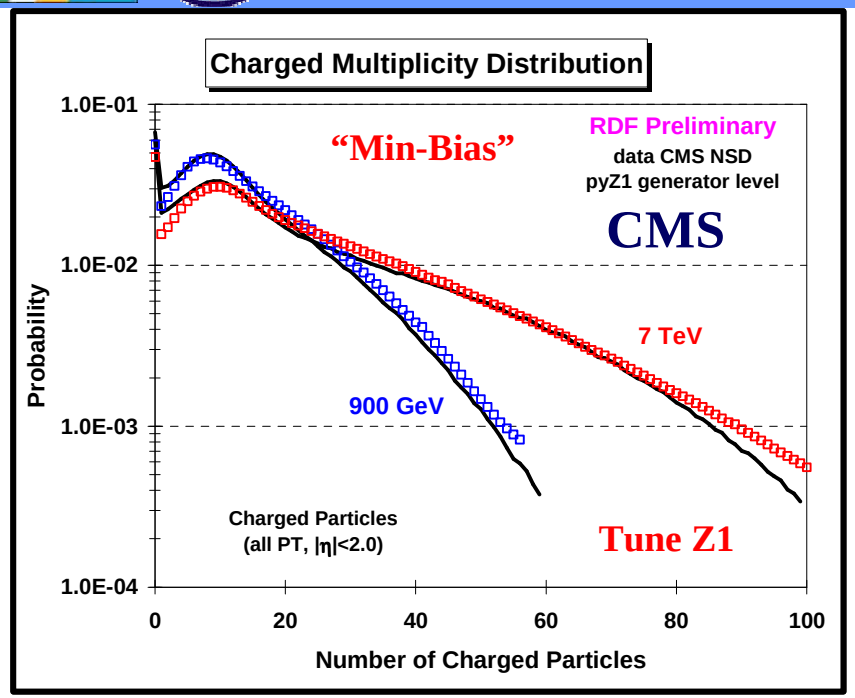
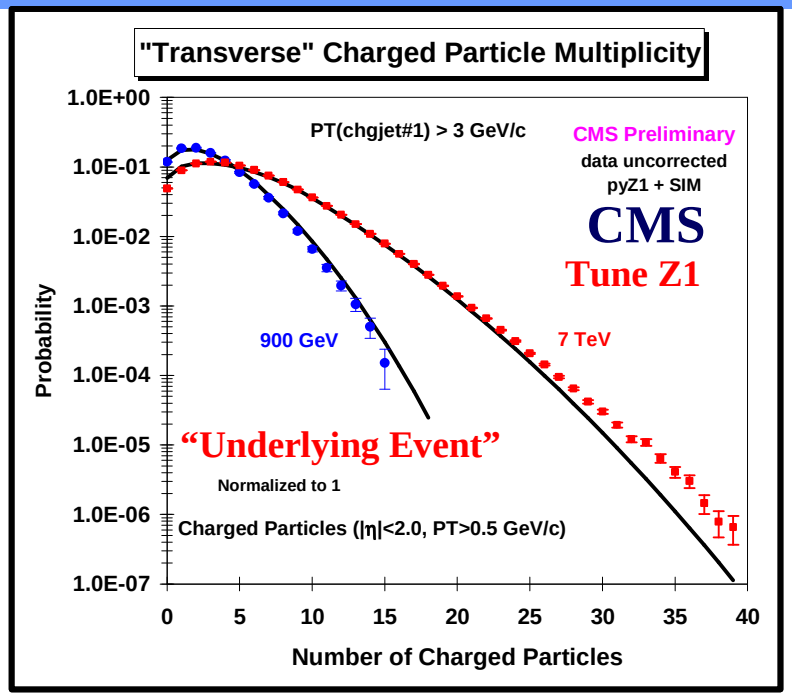
NSD Multiplicity Distribution

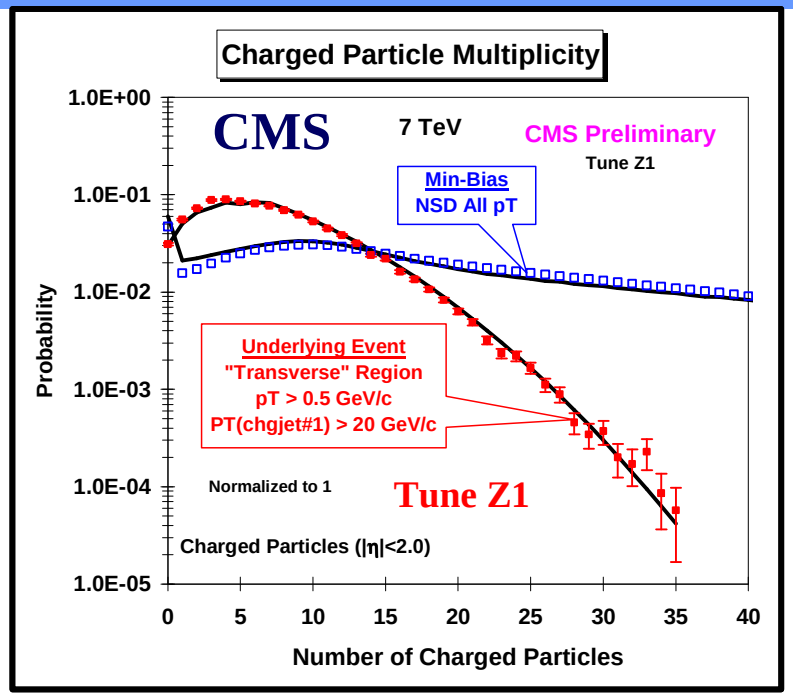




- **Generator level charged multiplicity distribution (all pT, |η| < 2) at 900 GeV and 7 TeV. Shows the NSD = HC + DD prediction for Tune Z1. Also shows the CMS NSD data.**

- **CMS uncorrected data at 900 GeV and 7 TeV on the charged particle multiplicity distribution in the "transverse" region for charged particles (p_T > 0.5 GeV/c, |η| < 2) as defined by the leading charged particle jet with PT(chgjet#1) > 3 GeV/c compared with PYTHIA Tune Z1 at the detector level (*i.e.* Theory + SIM).**

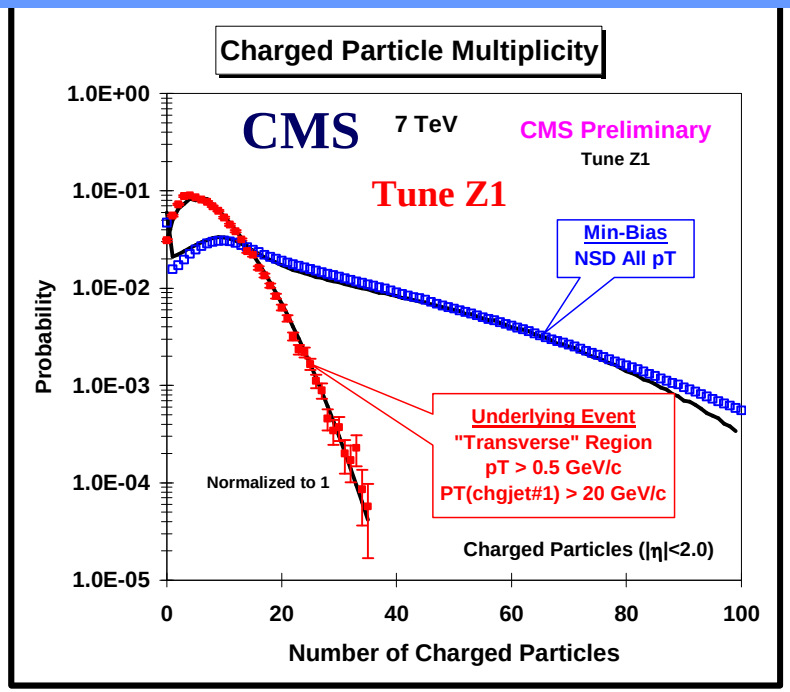
PYTHIA Tune Z1



- **CMS uncorrected data at 7 TeV on the charged particle multiplicity distribution in the "transverse" region for charged particles (p_T > 0.5 GeV/c, |η| < 2) as defined by the leading charged particle jet with PT(chgjet#1) > 20 GeV/c compared with PYTHIA Tune Z1 at the detector level (*i.e.* Theory + SIM). Also shows the CMS corrected NSD multiplicity distribution (all pT, |η| < 2) compared with Tune Z1 at the generator.**

Amazing what we are asking the Monte-Carlo models to fit!

PYTHIA Tune Z1



- **CMS uncorrected data at 7 TeV on the charged particle multiplicity distribution in the "transverse" region for charged particles (p_T > 0.5 GeV/c, |η| < 2) as defined by the leading charged particle jet with PT(chgjet#1) > 20 GeV/c compared with PYTHIA Tune Z1 at the detector level (*i.e.* Theory + SIM). Also shows the CMS corrected NSD multiplicity distribution (all pT, |η| < 2) compared with Tune Z1 at the generator.**

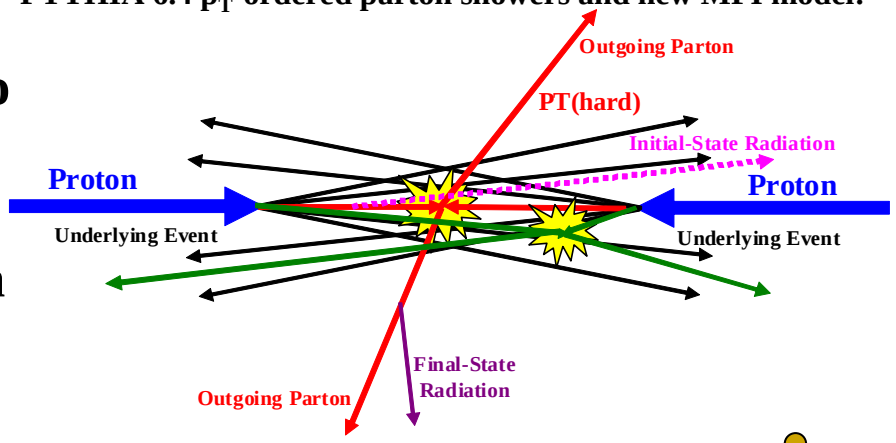
Amazing what we are asking the Monte-Carlo models to fit!

Summary & Conclusions

- I am surprised that the Tunes did as well as they did at predicting the behavior of the "underlying event" at 900 GeV and 7 TeV! Remember this is "soft" QCD!
- Tune Z1 does nice fob of fitting the CMS and ATLAS UE data at 900 GeV and 7 TeV! But Tune Z1 is a little high at CDF (1.96 TeV)! Not bad on MB!
- I am surprised that PYTHIA 8 does so well (right out of the box, Tune 1)! Good on MB! Slight problem with the UE "plateau" which is fixed in version 8.142.
- Next Step: More PYTHIA 6.4 and PYTHIA 8 tunes. Time to look more closely at Sherpa and HERWIG++!

I still dream of a "universal" tune that fits the UE at all energies! Need to simultaneously tune LHC plus CDF ("professor" tune)!

PYTHIA 6.4 p_T-ordered parton showers and new MPI model!



And CMS must correct the data so it can be used outside CMS!