CMS UE Data and the New Tune Z1

**Richard Field**
University of Florida

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.
Proton-Proton Collisions

Elastic Scattering

Single Diffraction

Double Diffraction

\[ \sigma_{\text{tot}} = \sigma_{\text{EL}} + \sigma_{\text{SD}} + \sigma_{\text{DD}} + \sigma_{\text{ND}} \]

“Inelastic Non-Diffractive Component”

The “hard core” component contains both “hard” and “soft” collisions.

“Soft” Hard Core (no hard scattering)

“Hard” Hard Core (hard scattering)

Proton

Proton

Proton

Proton

Underlying Event

Underlying Event

Initial-State Radiation

Initial-State Radiation

Final-State Radiation

Final-State Radiation

PT(hard)

PT(hard)
The Inelastic Non-Diffractive Cross-Section

"Semi-hard" parton-parton collision (p_T < ≈ 2 GeV/c)

Multiple-parton interactions (MPI)!
The Inelastic Non-Diffractive Cross-Section

Majority of “min-bias” events!

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

Multiple-parton interactions (MPI)!
Occasionally one of the parton-parton collisions is hard ($p_T \approx 2$ GeV/c)

Majority of “min-bias” events!

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

Multiple-parton interactions (MPI)!
The “Underlying Event”

Select inelastic non-diffractive events that contain a hard scattering

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

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

The “underlying-event” (UE)!

“Semi-hard” parton-parton collision ($p_T < \approx 2 \text{ GeV/c}$)

Multiple-parton interactions (MPI)!

$1/(p_T)^4 \rightarrow 1/(p_T^2 + p_T^2)$

$1/(p_T)^4 \rightarrow 1/(p_T^2 + p_T^2)^2$
Fit the “underlying event” in a hard scattering process.

"Underlying Event"

"Min-Bias" (ND)

Predict MB (ND)!

+ …
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)

UE Tunes

“Underlying Event”

Predict MB (ND)!
MB Tunes

"Underlying Event"

"Min-Bias" (ND)

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

Fit MB (ND).

+ ...
MB Tunes

“Underlying Event”

Predict the “underlying event” in a hard scattering process!

“Min-Bias” (ND)

Most of Peter’s tunes: Perugia 0, are MB tunes!

Fit MB (ND).

+ …
"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!

“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 $\text{PTmax} > 10 \text{ GeV/c}$ (big errors) the LHC UE data does not have much pull (hence mostly an MB tune!).

Most of Hendrik’s “Professor” tunes: ProQ20, P329 are MB+UE!

LPCC MB&UE Working Group
CERN September 7, 2010

Rick Field – Florida/CDF/CMS
Page 12
CMS UE Analyses

CMS Physics Analysis Summary

Contact: cms-pag-conveners-qcd@cern.ch

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.

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.
Traditional Approach

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, \( p_T \text{max} \), and the leading charged particle jet, \( p_T(\text{chgjet#1}) \) at 900 GeV (\( p_T > 0.5 \) GeV/c, \( |\eta| < 2.0 \)) compared with several QCD Monte-Carlo models after detector simulation.

CMS PAS QCD-10-010

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, \( p_T(\text{chgjet#1}) \) 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.

LPCC MB&UE Working Group
CERN September 7, 2010
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.

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.
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!
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
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!

Traditional Approach

None of my plots are the original figures from the papers!
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 |η| < 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).
Fake data (from MC) at 900 GeV on the "transverse" charged particle density, $dN/d\eta d\phi$, 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).

CMS preliminary data at 900 GeV on the "transverse" charged particle density, $dN/d\eta d\phi$, 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).
Fake data (from MC) at 900 GeV on the “transverse” charged PTsum density, $d\text{PT}/d\eta d\phi$, 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).

CMS preliminary data at 900 GeV on the “transverse” charged PTsum density, $d\text{PT}/d\eta d\phi$, 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).
 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 |η| < 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 |η| < 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
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, $dN/d\eta d\phi$, as defined by the leading charged particle (PTmax) for charged particles with $p_T > 0.5 \text{ GeV/c}$ and $|\eta| < 2.5$. The data are corrected and compared with PYTHIA Tune DW at the generator level.
CMS preliminary data at 900 GeV and 7 TeV on the “transverse” charged particle density, \( dN/d\eta d\phi \), as defined by the leading charged particle jet (chgjet#1) for charged particles with \( p_T > 0.5 \text{ GeV/c} \) and \( |\eta| < 2 \). The data are uncorrected and compared with PYTHIA Tune DW after detector simulation.

ATLAS preliminary data at 900 GeV and 7 TeV on the “transverse” charged particle density, \( dN/d\eta d\phi \), as defined by the leading charged particle (PTmax) for charged particles with \( p_T > 0.5 \text{ GeV/c} \) and \( |\eta| < 2.5 \). The data are corrected and compared with PYTHIA Tune DW at the generator level.
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 |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 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 DW at the generator level.
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.
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.
CMS preliminary data at 900 GeV and 7 TeV on the “transverse” charged particle density, $dN/d\eta d\phi$, as defined by the leading charged particle jet (chgjet#1) for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 2$. The data are uncorrected and compared with PYTHIA Tune DW after detector simulation.

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

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

LHC 900 GeV $\rightarrow$ 7 TeV (UE increase ~ factor of 2) $\sim 0.4 \rightarrow \sim 0.8$

RDF Preliminary
by Tune DW generator level

LHC 900 GeV $\rightarrow$ 7 TeV
(CERN, November 6, 2009)
Ratio of CMS preliminary data at 900 GeV and 7 TeV on the “transverse” charged particle density, $dN/d\eta d\phi$, as defined by the leading charged particle jet (chgjet#1) for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 2$. The data are uncorrected and compared with PYTHIA Tune DW after detector simulation.

Ratio of the ATLAS preliminary data at 900 GeV and 7 TeV on the “transverse” charged particle density, $dN/d\eta d\phi$, as defined by the leading charged particle (PTmax) for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 2.5$. The data are corrected and compared with PYTHIA Tune DW at the generator level.
The CMS preliminary data at 900 GeV and 7 TeV on the “transverse” charged PTsum density, \( dPT/d\eta d\phi \), as defined by the leading charged particle jet (\text{chgjet}\#1) for charged particles with \( p_T > 0.5 \text{ GeV/c} \) and \( |\eta| < 2 \). The data are uncorrected and compared with PYTHIA Tune DW after detector simulation.

The ATLAS preliminary data at 900 GeV and 7 TeV on the “transverse” charged PTsum density, \( dPT/d\eta d\phi \), as defined by the leading charged particle (\text{PTmax}) for charged particles with \( p_T > 0.5 \text{ GeV/c} \) 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 |η| < 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 |η| < 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, \( \frac{dN}{d\eta d\phi} \), as defined by the leading charged particle jet (chgjet#1) for charged particles with \( p_T > 0.5 \text{ GeV/c} \) and \( |\eta| < 2 \). 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, \( \frac{dN}{d\eta d\phi} \), as defined by the leading charged particle (PTmax) for charged particles with \( p_T > 0.5 \text{ GeV/c} \) and \( |\eta| < 2.5 \). The data are corrected and compared with PYTHIA Tune DW, Tune CW, and ATLAS MC08 at the generator level.**

\[
p_{T0}(W) = p_{T0}(W/W_0)^\epsilon \quad \epsilon = \text{PARP}(90) \quad p_{T0} = \text{PARP}(82) \quad W = E_{cm}
\]
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, $|\eta| < 2$) 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.
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, $|\eta| < 2$) 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).
CMS uncorrected data at 900 GeV and 7 TeV on the charged scalar PTsum distribution in the "transverse" region for charged particles \( (p_T > 0.5 \text{ GeV/c}, |\eta| < 2) \) as defined by the leading charged particle jet, chgjet#1, with \( PT(chgjet#1) > 3 \text{ GeV/c} \) compared with PYTHIA Tune D6T, Tune DW, and Tune CW at the detector level (i.e. Theory + SIM).
CMS uncorrected data at 900 GeV and 7 TeV on the charged particle PT distribution in the “transverse” region for charged particles ($|\eta| < 2$) as defined by the leading charged particle jet, chgjet#1, with $\text{PT(chgjet#1)} > 3 \text{ GeV/c}$ compared with PYTHIA Tune D6T, Tune DW, and Tune CW at the detector level (i.e. Theory + SIM).
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, $|\eta| < 2$) 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.

Same center-of-mass energy at two different hard scales!
"Transverse" Charged Particle Multiplicity

1.0E-07 1.0E-06 1.0E-05 1.0E-04 1.0E-03 1.0E-02 1.0E-01 1.0E+00
0 5 10 15 20 25 30 35 40
Number of Charged Particles

Probability

CMS Preliminary data uncorrected
pyD6T + SIM

Normalized to 1 Charged Particles (|\eta|<2.0, PT>0.5 GeV/c)

PT(chgjet#1) > 20 GeV/c
PT(chgjet#1) > 3 GeV/c

Tune D6T

CMS Preliminary data uncorrected
py8 + SIM

Normalized to 1 Charged Particles (|\eta|<2.0, PT>0.5 GeV/c)

PT(chgjet#1) > 20 GeV/c
PT(chgjet#1) > 3 GeV/c

Tune P8

CMS Preliminary data uncorrected
pyCW + SIM

Normalized to 1 Charged Particles (|\eta|<2.0, PT>0.5 GeV/c)

PT(chgjet#1) > 20 GeV/c
PT(chgjet#1) > 3 GeV/c

Tune CW

CMS Preliminary data uncorrected
pyDW + SIM

Normalized to 1 Charged Particles (|\eta|<2.0, PT>0.5 GeV/c)

PT(chgjet#1) > 20 GeV/c
PT(chgjet#1) > 3 GeV/c

Tune DW
"Transverse" Charged PTsum Distribution

7 TeV

CMS Preliminary

data uncorrected
pyD6T + SIM

PT(chgjet#1) > 20 GeV/c

Normalized to 1

Charged Particles (|η|<2.0, PT>0.5 GeV/c)

Tune D6T

Probability

PTsum (GeV/c)

1.0E-06 1.0E-05 1.0E-04 1.0E-03 1.0E-02 1.0E-01 1.0E+00

0 5 10 15 20 25 30 35 40 45 50

Charged Particles (|η|<2.0, PT>0.5 GeV/c)

CMS Preliminary

data uncorrected
pyP8 + SIM

PT(chgjet#1) > 20 GeV/c

Normalized to 1

Tune P8

Probability

PTsum (GeV/c)

1.0E-06 1.0E-05 1.0E-04 1.0E-03 1.0E-02 1.0E-01 1.0E+00

0 5 10 15 20 25 30 35 40 45 50

Charged Particles (|η|<2.0, PT>0.5 GeV/c)

CMS Preliminary

data uncorrected
pyCW + SIM

PT(chgjet#1) > 20 GeV/c

Normalized to 1

Tune CW

Probability

PTsum (GeV/c)

1.0E-06 1.0E-05 1.0E-04 1.0E-03 1.0E-02 1.0E-01 1.0E+00

0 5 10 15 20 25 30 35 40 45 50

Charged Particles (|η|<2.0, PT>0.5 GeV/c)

CMS Preliminary

data uncorrected
pyDW + SIM

PT(chgjet#1) > 20 GeV/c

Normalized to 1

Tune DW

Probability

PTsum (GeV/c)

1.0E-06 1.0E-05 1.0E-04 1.0E-03 1.0E-02 1.0E-01 1.0E+00

0 5 10 15 20 25 30 35 40 45 50

Charged Particles (|η|<2.0, PT>0.5 GeV/c)
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!
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!
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!
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!
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

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

Resulting number of events:

- $n_{ch} \geq 6$
  - 7 TeV: 369673
  - 900 GeV: 326201

Attempt to fit a subset of the “min-bias” data ($N_{chg} \geq 6$) where the contamination due to diffraction is expected to be small!

Parameters used for tuning

<table>
<thead>
<tr>
<th>Parameter</th>
<th>related model</th>
<th>MC09c value</th>
<th>scanning range</th>
<th>AMBT1 value</th>
</tr>
</thead>
<tbody>
<tr>
<td>PARP(62)</td>
<td>ISR cut-off</td>
<td>1.0</td>
<td>fixed</td>
<td>1.025</td>
</tr>
<tr>
<td>PARP(93)</td>
<td>primordial kt</td>
<td>5.0</td>
<td>fixed</td>
<td>10.0</td>
</tr>
<tr>
<td>PARP(77)</td>
<td>CR suppression</td>
<td>0.0</td>
<td>0.25 -- -- 1.15</td>
<td>1.016</td>
</tr>
<tr>
<td>PARP(78)</td>
<td>CR strength</td>
<td>0.224</td>
<td>0.2 -- -- 0.6</td>
<td>0.538</td>
</tr>
<tr>
<td>PARP(83)</td>
<td>MPI (matter fraction in core)</td>
<td>0.8</td>
<td>fixed</td>
<td>0.356</td>
</tr>
<tr>
<td>PARP(84)</td>
<td>MPI (core of matter overlap)</td>
<td>0.7</td>
<td>0.0 -- -- 1.0</td>
<td>0.651</td>
</tr>
<tr>
<td>PARP(82)</td>
<td>MPI ($p_T^{min}$)</td>
<td>2.31</td>
<td>2.1 -- -- 2.5</td>
<td>2.292</td>
</tr>
<tr>
<td>PARP(90)</td>
<td>MPI (energy extrapolation)</td>
<td>0.2487</td>
<td>0.18 -- -- 0.28</td>
<td>0.250</td>
</tr>
</tbody>
</table>
⇒ All my previous tunes (A, DW, DWT, D6, D6T, CW, X1, and X2) were PYTHIA 6.4 tunes using the old $Q^2$-ordered parton showers and the old MPI model (really 6.2 tunes)!

⇒ I believe that it is time to move to PYTHIA 6.4 ($p_T$-ordered parton showers and new MPI model)!

⇒ **Tune Z1**: I started with the parameters of ATLAS Tune AMBT1, but I changed LO* to CTEQ5L and I varied PARP(82) and PARP(90) to get a very good fit of the CMS UE data at 900 GeV and 7 TeV.

⇒ The ATLAS Tune AMBT1 was designed to fit the inelastic data for $N_{ch} \geq 6$ and to fit the $P_T^{\text{max}}$ UE data with $P_T^{\text{max}} > 10$ GeV/c. Tune AMBT1 is primarily a min-bias tune, while Tune Z1 is a UE tune!
### PYTHIA Tune Z1

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

Parameters not shown are the PYTHIA 6.4 defaults!
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Tune Z1 (R. Field CMS)</th>
<th>Tune AMBT1 (ATLAS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parton Distribution Function</td>
<td>CTEQ5L</td>
<td>LO*</td>
</tr>
<tr>
<td>PARP(82) – MPI Cut-off</td>
<td>1.932</td>
<td>2.292</td>
</tr>
<tr>
<td>PARP(89) – Reference energy, E0</td>
<td>1800.0</td>
<td>1800.0</td>
</tr>
<tr>
<td>PARP(90) – MPI Energy Extrapolation</td>
<td>0.275</td>
<td>0.25</td>
</tr>
<tr>
<td>PARP(77) – CR Suppression</td>
<td>1.016</td>
<td>1.016</td>
</tr>
<tr>
<td>PARP(78) – CR Strength</td>
<td>0.538</td>
<td>0.538</td>
</tr>
<tr>
<td>PARP(80) – Probability colored parton from BBR</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>PARP(83) – Matter fraction in core</td>
<td>0.356</td>
<td>0.356</td>
</tr>
<tr>
<td>PARP(84) – Core of matter overlap</td>
<td>0.651</td>
<td>0.651</td>
</tr>
<tr>
<td>PARP(62) – ISR Cut-off</td>
<td>1.025</td>
<td>1.025</td>
</tr>
<tr>
<td>PARP(93) – primordial kT-max</td>
<td>10.0</td>
<td>10.0</td>
</tr>
<tr>
<td>MSTP(81) – MPI, ISR, FSR, BBR model</td>
<td>21</td>
<td>21</td>
</tr>
<tr>
<td>MSTP(82) – Double gaussian matter distribution</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>MSTP(91) – Gaussian primordial kT</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>MSTP(95) – strategy for color reconnection</td>
<td>6</td>
<td>6</td>
</tr>
</tbody>
</table>

Parameters not shown are the PYTHIA 6.4 defaults!

Tune Z2 with CTEQ6L is coming soon!
CMS preliminary data at 900 GeV and 7 TeV on the “transverse” charged particle density, \(dN/d\eta d\phi\), as defined by the leading charged particle jet (chgjet\#1) for charged particles with \(p_T > 0.5\) GeV/c and \(|\eta| < 2.0\). The data are uncorrected and compared with PYTHIA Tune DW and D6T after detector simulation (SIM).

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!
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 |η| < 2.0. The data are uncorrected and compared with PYTHIA Tune DW and D6T after detector simulation (SIM).

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 |η| < 2.0. The data are uncorrected and compared with PYTHIA Tune Z1 after detector simulation (SIM).

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

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

**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!
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 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).
Ratio of the ATLAS preliminary data on the charged particle density in the “transverse” region for charged particles ($p_T > 0.5$ GeV/c, $|\eta| < 2.5$) at 900 GeV and 7 TeV as defined by $\text{PTmax}$ compared with PYTHIA Tune Z1 at the generator level.
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 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 |η| < 1.0. The data are corrected and compared with PYTHIA Tune Z1 at the generator level.
CMS preliminary data at 900 GeV and 7 TeV on the “transverse” charged 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 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 |η| < 1.0. The data are corrected and compared with PYTHIA Tune Z1 at the generator level.
**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 $\varepsilon = \text{PARP}(90)$. 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??

\[ p_{T0}(W) = p_{T0}(W/W_0)^\varepsilon \quad \varepsilon = \text{PARP}(90) \quad p_{T0} = \text{PARP}(82) \quad W = E_{cm} \]
**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 $\varepsilon = \text{PARP}(90)$. 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??

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

**More UE activity for $W > 7$ TeV??**
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, $|\eta| < 2$) 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).
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, $|\eta| < 2$) 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).
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, $|\eta| < 2$) as defined by the leading charged particle jet with $PT(chgjet#1) > 3$ GeV/c and $PT(chgjet#1) > 20$ GeV/c compared with PYTHIA Tune DW and Tune D6T at the detector level (i.e. Theory + SIM).

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, $|\eta| < 2$) as defined by the leading charged particle jet with $PT(chgjet#1) > 3$ GeV/c and $PT(chgjet#1) > 20$ GeV/c compared with PYTHIA Tune Z1 at the detector level (i.e. Theory + SIM).
CMS uncorrected data at 7 TeV on the charged PTsum distribution in the “transverse” region for charged particles ($p_T > 0.5$ GeV/c, $|\eta| < 2$) as defined by the leading charged particle jet with $PT(chgjet#1) > 3$ GeV/c and $PT(chgjet#1) > 20$ GeV/c compared with PYTHIA Tune DW and Tune D6T at the detector level (i.e. Theory + SIM).

CMS Preliminary data uncorrected Theory + SIM

CMS Preliminary data uncorrected pyZ1 + SIM

Normalized to 1

Charged Particles ($|\eta|<2.0$, $PT>0.5$ GeV/c)

Normalized to 1

Charged Particles ($|\eta|<2.0$, $PT>0.5$ GeV/c)
Generator level $dN/d\eta$ (all pT). Shows the NSD = HC + DD and the HC = ND contributions for Tune Z1. Also shows the CMS NSD data.

Generator level $dN/d\eta$ (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!
Generator level charged multiplicity distribution (all pT, |\(\eta|<2\)) 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!
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.

Okay not perfect! But better than most tunes!
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).
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!
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, $|\eta| < 2$) as defined by the leading charged particle jet with $P_T(chgjet#1) > 20$ GeV/c compared with PYTHIA Tune Z1 at the detector level (i.e. Theory + SIM). Also shows the CMS corrected NSD multiplicity distribution (all $p_T$, $|\eta| < 2$) compared with Tune Z1 at the generator.

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

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