Outline of Talk

- **UE Studies**: Past, present, and future.
- **CMS UE Tunes**: Two PYTHIA 6 tunes, three PYTHIA 8 tunes, and one HERWIG++ tune from the CMS “Physics Comparisons & Generator Tunes” subgroup.
- **The Energy Dependence of the UE**: Detailed look at the energy dependence of the UE and the extrapolation to 13 TeV.
- **Predictions at 13 TeV**: Compare the CMS PYTHIA 8 tunes with the Skands Monash tune and the PYTHIA 6 Tune Z2* at 13 TeV.
- **MB & UE Data 13 TeV**: Look at the early MB data from CMS and ATLAS and the early UE data from ATLAS.
The Inelastic Non-Diffractive Cross-Section

Occasionally one of the parton-parton collisions is hard ($p_T > \approx 2 \text{ GeV/c}$)

Majority of “min-bias” events!

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

Multiple-parton interactions (MPI)!

Proton + Proton + Proton + Proton + ...
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)!

Multiple-parton interactions (MPI)!

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

$p_{T0}(E_{cm}) = p_{T0\text{Ref}} \times (E_{cm}/E_{cm\text{Ref}})^{ecm\text{Pow}}$

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

Look at charged particle correlations in the azimuthal angle $\Delta \phi$ relative to a leading object (i.e. CaloJet#1, ChgJet#1, PTmax, Z-boson). For CDF $PT_{min} = 0.5$ GeV/c $\eta_{cut} = 1.0$ or 0.8.

Define $|\Delta \phi| < 60^\circ$ as “Toward”, $60^\circ < |\Delta \phi| < 120^\circ$ as “Transverse”, and $|\Delta \phi| > 120^\circ$ as “Away”.

All three regions have the same area in $\eta$-$\phi$ space, $\Delta \eta \times \Delta \phi = 2\eta_{cut} \times 120^\circ = 2\eta_{cut} \times 2\pi/3$. Construct densities by dividing by the area in $\eta$-$\phi$ space.
Early Studies of the UE

Charged Jet Evolution and the Underlying Event in Proton-Antiproton Collisions at 1.8 TeV

- Use the CDF “min-bias” data in conjunction with the CDF JET20 data to study the growth and development of “charged particle jets”.
- Study a variety of “local” leading charged jet observables and compare with the QCD “hard” scattering Monte-Carlo models of Herwig, Isajet, and Pythia.
- Study a number of “global” observables, where to fit the observable the QCD Monte-Carlo models have to describe correctly the entire event structure. In particular, examine carefully the “underlying event” in hard-scattering processes.
- Compare the “underlying event” in dijet versus Z-boson production.

DPF 2000: My first presentation on the “underlying event”!

Studying the “Underlying Event” at CDF

- The underlying event in a hard scattering process is a complicated and not very well understood object. It is an interesting region since it probes the interface between perturbative and non-perturbative physics.
- There are three CDF analyses which collectively study the underlying event and compare with the QCD Monte-Carlo models (2 Run I and 1 Run II).
- It is important to model this region well since it is an unavoidable background to all collider observables. Also, we need a good model of “min-bias” collisions.

First CDF UE Studies
Rick Field Wine & Cheese Talk
October 4, 2002
My First Talk on the UE

DiJet: Charged Multiplicity versus PT(chgjet#1)

The Underlying Event: Summary & Conclusions

- The underlying event is very similar in dijet and the Z-boson production as predicted by the QCD Monte-Carlo models. The “toward” region in Z-boson production is a direct measure of the underlying event.
- The number of charged particles per unit rapidity (height of the “plateau”) is at least twice that observed in “soft” collisions at the same corresponding energy.
- None of the QCD Monte-Carlo models correctly describe the underlying event. Herwig and Pythia 6.125 do not have enough activity in the underlying event. Pythia 6.115 has about the right amount of activity in the underlying event, but as a result produces too much overall multiplicity. Isajet has a lot of activity in the underlying event, but with the wrong dependence on $p_T$ of the beam-beam remnant component of the underlying event.

Need to “tune” the QCD MC models!

My first look at the “underlying event plateau”!
"Underlying Event" Publications

<table>
<thead>
<tr>
<th>Year</th>
<th>CDF</th>
<th>Other</th>
<th>Many LHC UE Studies</th>
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</table>


- Many LHC UE Studies
- HERWIG++ UE Tune, M. Seymour and A. Siódmok!
- Monash Tune, Peter Skands!
- Perugia Tunes, Peter Skands!
The goal is to produce data (corrected to the particle level) that can be used by the theorists to tune and improve the QCD Monte-Carlo models that are used to simulate hadron-hadron collisions.

http://arxiv.org/abs/1508.05340
“Transverse” Charged Particle Density: Number of charged particles \((p_T > 0.5 \text{ GeV}/c, |\eta| < \eta_{\text{cut}})\) in the “transverse” region as defined by the leading charged particle, \(P\text{Tmax}\), divided by the area in \(\eta\)-\(\phi\) space, \(2\eta_{\text{cut}} \times 2\pi/3\), averaged over all events with at least one particle with \(p_T > 0.5 \text{ GeV}/c, |\eta| < \eta_{\text{cut}}\).

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

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

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

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

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

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

\[
\text{“Transverse” Density} = \text{“transAVE” Density} = \frac{\text{“transMAX” Density} + \text{“transMIN” Density}}{2}
\]

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

“TransMIN” density more sensitive to MPI & BBR.

“TransDIF” density more sensitive to ISR & FSR.

0 \leq \text{“TransDIF”} \leq 2 \times \text{“TransAVE”}

\text{“TransDIF”} = \text{“TransAVE”} \text{ if “TransMIX”} = 3 \times \text{“TransMIN”}
Corrected CMS data at 7 TeV and CDF data at 1.96 TeV, 900 GeV, and 300 GeV on the charged particle density in the “transMAX”, “transMIN”, and “transDIF” regions as defined by the leading charged particle (PTmax) for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 0.8$. The data are corrected to the particle level with errors that include both the statistical error and the systematic uncertainty.
Corrected CDF data at 1.96 TeV, 900 GeV, and 300 GeV on the charged PTsum density in the “transMAX”, “transMIN”, and “transDIF” regions as defined by the leading charged particle (PTmax) for charged particles with \( p_T > 0.5 \) GeV/c and \( |\eta| < 0.8 \). The data are corrected to the particle level with errors that include both the statistical error and the systematic uncertainty.
Corrected CMS data at 7 TeV and CDF data at 1.96 TeV, 900 GeV, and 300 GeV on the charged particle density in the “transMAX” region as defined by the leading charged particle (PTmax) for charged particles with p_T > 0.5 GeV/c and |\eta| < 0.8. The data are corrected to the particle level with errors that include both the statistical error and the systematic uncertainty.

Corrected CMS and CDF data on the charged particle density in the “transMAX” region as defined by the leading charged particle (PTmax) for charged particles with p_T > 0.5 GeV/c and |\eta| < 0.8 with 5 < PTmax < 6 GeV/c. The data are plotted versus the center-of-mass energy (log scale).
Corrected CMS data at 7 TeV and CDF data at 1.96 TeV, 900 GeV, and 300 GeV on the charged particle density in the “transMIN” region as defined by the leading charged particle (PTmax) for charged particles with p_T > 0.5 GeV/c and |η| < 0.8. The data are corrected to the particle level with errors that include both the statistical error and the systematic uncertainty.

Corrected CMS and CDF data on the charged particle density in the “transMIN” region as defined by the leading charged particle (PTmax) for charged particles with p_T > 0.5 GeV/c and |η| < 0.8 with 5 < PTmax < 6 GeV/c. The data are plotted versus the center-of-mass energy (log scale).
Corrected CMS data at 7 TeV and CDF data at 1.96 TeV, 900 GeV, and 300 GeV on the charged particle density in the “transMAX” and “transMIN” regions as defined by the leading charged particle (PTmax) for charged particles with p_T > 0.5 GeV/c and |η| < 0.8 with 5 < PTmax < 6 GeV/c. The data are plotted versus the center-of-mass energy (log scale).

Ratio of CMS data at 7 TeV and CDF data at 1.96 TeV, 900 GeV, and 300 GeV to the value at 300 GeV for the charged particle density in the “transMAX” and “transMIN” regions as defined by the leading charged particle (PTmax) for charged particles with p_T > 0.5 GeV/c and |η| < 0.8 with 5 < PTmax < 6 GeV/c. The data are plotted versus the center-of-mass energy (log scale).
Corrected CMS data at 7 TeV and CDF data at 1.96 TeV, 900 GeV, and 300 GeV on the charged particle density in the “transAVE” and “transDIF” regions as defined by the leading charged particle (PTmax) for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 0.8$ with $5 < PTmax < 6$ GeV/c. The data are plotted versus the center-of-mass energy (log scale).

Ratio of CMS data at 7 TeV and CDF data at 1.96 TeV, 900 GeV, and 300 GeV to the value at 300 GeV for the charged particle density in the “transAVE” and “transDIF” regions as defined by the leading charged particle (PTmax) for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 0.8$ with $5 < PTmax < 6$ GeV/c. The data are plotted versus the center-of-mass energy (log scale).
Ratio of CMS data at 7 TeV and CDF data at 1.96 TeV, 900 GeV, and 300 GeV to the value at 300 GeV for the charged particle density in the “transMIN”, and “transDIF” regions as defined by the leading charged particle (PTmax) for charged particles with p_T > 0.5 GeV/c and |η| < 0.8 with 5 < PTmax < 6 GeV/c. The data are plotted versus the center-of-mass energy (log scale).

Ratio of CMS data at 7 TeV and CDF data at 1.96 TeV, 900 GeV, and 300 GeV to the value at 300 GeV for the charged PTsum density in the “transMIN”, and “transDIF” regions as defined by the leading charged particle (PTmax) for charged particles with p_T > 0.5 GeV/c and |η| < 0.8 with 5 < PTmax < 6 GeV/c. The data are plotted versus the center-of-mass energy (log scale).
The “transMIN” (MPI-BBR component) increases much faster with center-of-mass energy than the “transDIF” (ISR-FSR component)!

Ratio of CMS data at 7 TeV and CDF data at 1.96 TeV, 900 GeV, and 300 GeV to the value at 300 GeV for the charged particle density in the “transMIN” and “transDIF” regions as defined by the leading charged particle (PTmax) for charged particles with pT > 0.5 GeV/c and |η| < 0.8 with 5 < PTmax < 6 GeV/c. The data are plotted versus the center-of-mass energy (log scale).
CMS at the LHC
900 GeV, 2.96 TeV, 7 TeV, 8 TeV, 13 TeV

Sorry to be so slow!!

Proton
Underlying Event
Outgoing Parton
PT(hard)
Initial State Radiation

AntiProton
Underlying Event
Outgoing Parton
Final State Radiation

http://arxiv.org/abs/soon!

CMS underlying event and double parton scattering tunes

To be submitted to JHEP

DRAFT
CMS Paper
The content of this note is intended for CMS internal use and distribution only

The CMS Collaboration

Abstract

Three new PYTHIA-8 underlying event (UE) tunes are constructed, one using the CTEQ6L1 parton distribution function (PDF), one using HERAPDF 1.5 leading order (LO), and one using the NNPDF2.3LO PDF; two new PYTHIA-6 UE tunes, one for the CTEQ6L PDF and one for the HERAPDF 1.5 LO, and one new HERWIG++ UE tune for the CTEQ6L PDF are also available. Simultaneous fits to CDF UE data at 300 GeV, 900 GeV, and 1.96 TeV, together with CMS UE data at 7 TeV, check the UE models and constrain their parameters, providing thereby more precise predictions for proton-proton collisions at 13 TeV. In addition, several new double-parton scattering (DPS) tunes are investigated when the values of the UE parameters from fits to observables are consistent with the values determined from fitting DPS-sensitive observables. Also examined is how well the new UE tunes predict “minimum bias” (MB) events, jet and Drell-Yan (q̅q →Z/γ*→lepton-antilepton+jets) observables, as well as the MB and UE observables at 13 TeV.
Fit the “underlying event” in a hard scattering process.

Allow primary hard-scattering to go to $p_T = 0$ with same cut-off!

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

“Min-Bias” (add single & double diffraction)

Predict MB (ND)!

Predict MB (IN)!

QCD@LHC 2015
London, September 1, 2015
Most of the time MPI are much “softer” than the primary “hard” scattering, however, occasionally two “hard” 2-to-2 parton scatterings can occur within the same hadron-hadron. This is referred to as double parton scattering (DPS).

\[
\frac{1}{p_T^4} \rightarrow \frac{1}{(p_T^2 + p_T^0)^2}
\]
PYTHIA 6.4 Tune CUETP6S1-CTEQ6L: Start with Tune Z2*-lep and tune to the CDF PTmax “transMAX” and “transMIN” UE data at 300 GeV, 900 GeV, and 1.96 TeV and the CMS PTmax “transMAX” and “transMIN” UE data at 7 TeV.

PYTHIA 6.4 Tune CUETP6S1-HERAPDF1.5LO: Start with Tune Z2*-lep and tune to the CDF PTmax “transMAX” and “transMIN” UE data at 300 GeV, 900 GeV, and 1.96 TeV and the CMS PTmax “transMAX” and “transMIN” UE data at 7 TeV.

PYTHIA 8 Tune CUETP8S1-CTEQ6L: Start with Corke & Sjöstrand Tune 4C and tune to the CDF PTmax “transMAX” and “transMIN” UE data at 900 GeV, and 1.96 TeV and the CMS PTmax “transMAX” and “transMIN” UE data at 7 TeV. Exclude 300 GeV data.

PYTHIA 8 Tune CUETP8S1-HERAPDF1.5LO: Start with Corke & Sjöstrand Tune 4C and tune to the CDF PTmax “transMAX” and “transMIN” UE data at 900 GeV, and 1.96 TeV and the CMS PTmax “transMAX” and “transMIN” UE data at 7 TeV. Exclude 300 GeV data.

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

HERWIG++ Tune CUETHS1-CTEQ6L: Start with the Seymour & Siódmok UE-EE-5C tune and tune to the CDF PTmax “transMAX” and “transMIN” UE data at 900 GeV, and 1.96 TeV and the CMS PTmax “transMAX” and “transMIN” UE data at 7 TeV.
See talk on Saturday morning by Frank Siegert entitled, “Overview of MC Tuning to LHC Data”.
CMS data at 7 TeV and CDF data at 1.96 TeV, 900 GeV, and 300 GeV on the charged particle density in the “transAVE” region as defined by the leading charged particle (PTmax) for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 0.8$. The data are compared with PYTHIA 6.4 Tune Z2*.

CMS data at 7 TeV and CDF data at 1.96 TeV, 900 GeV, and 300 GeV on the charged particle density in the “transAVE” region as defined by the leading charged particle (PTmax) for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 0.8$. The data are compared with PYTHIA 8 Tune CUETP8S1-CTEQ6L (excludes 300 GeV in fit).
CMS data at 7 TeV and CDF data at 1.96 TeV, 900 GeV, and 300 GeV on the charged particle density in the “transAVE” region as defined by the leading charged particle (PTmax) for charged particles with p_T > 0.5 GeV/c and |η| < 0.8. The data are compared with the PYTHIA 8 Tune Monash-NNPDF2.3LO.

CMS data at 7 TeV and CDF data at 1.96 TeV, 900 GeV, and 300 GeV on the charged particle density in the “transAVE” region as defined by the leading charged particle (PTmax) for charged particles with p_T > 0.5 GeV/c and |η| < 0.8. The data are compared with the PYTHIA 8 Tune CUETP8M1-NNPDF2.3LO (excludes 300 GeV in fit).
Energy Dependence

"TransAVE" Charged Particle Density: $dN/d\eta d\phi$

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<th>Center-of-Mass Energy (GeV)</th>
<th>Charged Particle Density</th>
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Charged Particles ($|\eta|<0.8$, $PT>0.5$ $\text{GeV/c}$)

- CMS solid dots
- CDF solid squares

Tune Z2*-CTEQ6L (solid line)

5.0 < $PT_{\text{max}}$ < 6.0 $\text{GeV/c}$

13 TeV

CMS solid dots
CDF solid squares
CUETP8S1-CTEQ6L (solid line)

Monash-NNPDF2.3LO (solid line)

CUETP8M1-NNPDF2.3LO (solid line)

5.0 < $PT_{\text{max}}$ < 6.0 $\text{GeV/c}$

Charged Particles ($|\eta|<0.8$, $PT>0.5$ $\text{GeV/c}$)
Energy Dependence

"TransAVE" Charged Particle Density: $dN/d\eta d\phi$

Charged Particle Density

Charged Particles ($|\eta|<0.8$, $P_T>0.5$ GeV/c)

5.0 < $P_T_{\text{max}}$ < 6.0 GeV/c

CMS solid dots
CDF solid squares

Tune Z2*-CTEQ6L (solid line)
CUETP8S1-CTEQ6L (solid line)
CUETP8M1-NNPDF2.3LO (solid line)
CMSTune Z2*-CTEQ6L (green line)
CUETP8S1-CTEQ6L (black line)
Monash-NNPDF2.3LO (red line)
CUETP8M1-NNPDF2.3LO (blue line)

Center-of-Mass Energy (GeV)

13 TeV
Predictions at 13 TeV

"TransMAX" Charged Particle Density

13 TeV

Average Density

Charged Particles (|η|<0.8, PT>0.5 GeV/c)

PTmax (GeV/c)

Tune Z2*-CTEQ6L (green line)
CUETP8S1-CTEQ6L (black line)
Monash-NNPDF2.3LO (red line)
CUETP8M1-NNPDF2.3LO (blue line)

"TransMIN" Charged Particle Density

13 TeV

Average Density

Charged Particles (|η|<0.8, PT>0.5 GeV/c)

PTmax (GeV/c)

Tune Z2*-CTEQ6L (green line)
CUETP8S1-CTEQ6L (black line)
Monash-NNPDF2.3LO (red line)
CUETP8M1-NNPDF2.3LO (blue line)

"TransMAX" Charged PTsum Density

13 TeV

Average Density (GeV/c)

Charged Particles (|η|<0.8, PT>0.5 GeV/c)

PTmax (GeV/c)

Tune Z2*-CTEQ6L (green line)
CUETP8S1-CTEQ6L (black line)
Monash-NNPDF2.3LO (red line)
CUETP8M1-NNPDF2.3LO (blue line)

"TransMIN" Charged PTsum Density

13 TeV

Average Density (GeV/c)

Charged Particles (|η|<0.8, PT>0.5 GeV/c)

PTmax (GeV/c)

Tune Z2*-CTEQ6L (green line)
CUETP8S1-CTEQ6L (black line)
Monash-NNPDF2.3LO (red line)
CUETP8M1-NNPDF2.3LO (blue line)
Predictions at 13 TeV

"TransAVE" Charged Particle Density

13 TeV

PTmax (GeV/c)

Average Density

Charged Particles (|\(\eta|<0.8, \text{PT}>0.5\) GeV/c)

Tune Z2*-CTEQ6L (green line)
CUETP8S1-CTEQ6L (black line)
Monash-NNPDF2.3LO (red line)
CUETP8M1-NNPDF2.3LO (blue line)

"TransDIF" Charged Particle Density

13 TeV

PTmax (GeV/c)

Average Density

Charged Particles (|\(\eta|<0.8, \text{PT}>0.5\) GeV/c)

Tune Z2*-CTEQ6L (green line)
CUETP8S1-CTEQ6L (black line)
Monash-NNPDF2.3LO (red line)
CUETP8M1-NNPDF2.3LO (blue line)

"TransAVE" Charged PTsum Density

13 TeV

PTmax (GeV/c)

Average Density (GeV/c)

Charged Particles (|\(\eta|<0.8, \text{PT}>0.5\) GeV/c)

Tune Z2*-CTEQ6L (green line)
CUETP8S1-CTEQ6L (black line)
Monash-NNPDF2.3LO (red line)
CUETP8M1-NNPDF2.3LO (blue line)

"TransDIF" Charged PTsum Density

13 TeV

PTmax (GeV/c)

Average Density (GeV/c)

Charged Particles (|\(\eta|<0.8, \text{PT}>0.5\) GeV/c)

Tune Z2*-CTEQ6L (green line)
CUETP8S1-CTEQ6L (black line)
Monash-NNPDF2.3LO (red line)
CUETP8M1-NNPDF2.3LO (blue line)
CMS and CDF data on the charged particle density in the “transAVE” region as defined by the leading charged particle (PTmax) for charged particles with p_T > 0.5 GeV/c and |\eta| < 0.8 with 5 < PTmax < 6 GeV/c. The data are plotted versus the center-of-mass energy (log scale). The data are compared with PYTHIA 6 Tune Z2* and PYTHIA 8 Tune CUETP8S1, Tune Monash, and Tune CUETP8M1.

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

CMS data at 7 TeV and CDF data at 1.96 TeV, 900 GeV, and 300 GeV on the charged PTsum density in the “transAVE” region as defined by the leading charged particle (PTmax) for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 0.8$. The data are compared with PYTHIA 6 Tune Z2* and PYTHIA 8 Tune CUETP8S1, Tune Monash, and Tune CUETP8M1.
MB at 13 TeV: $dN/d\eta$

CMS UE Tune CUETP8S1-HERAPDF1.5LO.
The UE tune do a fairly good job predicting the MB data.

Do not need separate MB tunes!
 ATLAS data at 13 TeV on the charged particle density (keft) and charged PTsum density in the “transAVE” region as defined by the leading charged particle for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 2.5$. The data are uncorrected and compared with the MC models after detector simulation.
ATLAS data at 13 TeV on the charged particle density (left) and charged PTsum density in the “transAVE” region as defined by the leading charged particle for charged particles with \( p_T > 0.5 \) GeV/c and \( |\eta| < 2.5 \). The data are uncorrected and compared with the MC models after detector simulation.

- ATLAS data at 13 TeV
- EPOS does a poor job on the UE!
- Monash doing well except the turn on region!
- Very strange behavior by HERWIG++ in the turn on region!
More 13 TeV Predictions

"TransAVE" Charged Particle Density

13 TeV (generator level)

Average Density

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

13 TeV (generator level)

Average Density

Charged Particles (|\eta|<2.0, PT>0.5 GeV/c)
Very strange behavior by CUETHS1 in the turn on region!
"TransAVE" Charged Particle Density: $dN/d\eta d\phi$

My dream!

Mapping out the Energy Dependence of the UE

(300 GeV, 900 GeV, 1.96 TeV, 7 TeV, 13 TeV)
"TransAVE" Charged Particle Density: $dN/d\eta d\phi$

**RDF Preliminary Corrected Data**

**Mapping out the Energy Dependence of the UE**

(300 GeV, 900 GeV, 1.96 TeV, 7 TeV, 13 TeV)

Fake data generated by Rick using the Monash tune with the statistics we currently have at CMS!
“Tevatron” to the LHC

13 TeV UE data coming soon from both ATLAS and CMS!

Mapping out the Energy Dependence of the UE
(300 GeV, 900 GeV, 1.96 TeV, 7 TeV, 13 TeV)

My dream!

"TransAVE" Charged Particle Density: $dN/d\eta d\phi$

Charged Particle Density

CDF

CMS

RDF Preliminary Corrected Data

Coming soon!

Charged Particles (|\eta|<0.8, PT>0.5 GeV/c)
Measure the “Underlying Event” at 13 TeV at CMS

Measure the UE observables as defined by the leading charged particle jet, chgjet#1, for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 2.0$.

Measure the UE observables as defined by the leading charged particle, PTmax, for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 2.0$ and $|\eta| < 0.8$.
Measure the "Underlying Event" at 13 TeV at CMS

Measure the UE observables as defined by the leading charged particle, PTmax, for charged particles with \( p_T > 0.5 \) GeV/c and \( |\eta| < 2.0 \) and \( |\eta| < 0.8 \).

Sorry to be slow! We hope to have the CMS "Common Plots" finished for the LPCC UE&MB meeting on November 19 and 20!