UE Lessons Learned & What’s Next

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Outline of Talk

→ LHC UE Data: ALICE-ATLAS-CMS UE data. Comparisons with each other and with PYTHIA Tune Z1.

→ LHC MB Data: Attempts to describe both MB and the UE with the same tune.

→ Coming Soon: Corrected UE from CMS!
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 PT$_{max}$ UE data with PT$_{max} > 10$ 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>
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<tr>
<td>PARP(84) – Core of matter overlap</td>
<td>0.651</td>
<td>0.651</td>
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<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!
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 PTmin = 0.5 GeV/c $\eta_{\text{cut}} = 1$.

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, $\Delta \eta \times \Delta \phi = 2\eta_{\text{cut}} \times 120^\circ = 2\eta_{\text{cut}} \times 2\pi/3$. Construct densities by dividing by the area in $\eta$-$\phi$ space.
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| < 2.0. The data are uncorrected and compared with PYTHIA Tune DW and D6T after detector simulation (SIM).

Tune Z1 (CTEQ5L)
PARP(82) = 1.932
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Color reconnection suppression. Color reconnection strength.

Tune Z1 is a PYTHIA 6.4 using p_{T}-ordered parton showers and the new MPI model!
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I read the points off with a ruler!

ATLAS publication – arXiv:1012.0791
December 3, 2010
ALICE 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 ($P_{T\text{max}}$) for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 0.8$. The data are corrected and compared with PYTHIA Tune Z1 at the generator level.

ALICE preliminary data at 900 GeV and 7 TeV on the “transverse” charged $P_T$ sum density, $dP_T/d\eta d\phi$, as defined by the leading charged particle ($P_{T\text{max}}$) for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 0.8$. The data are corrected and compared with PYTHIA Tune Z1 at the generator level.

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Difficult to produce enough events with large “transverse” multiplicity at low hard scale!
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).

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

“Minimum Bias” Collisions

Okay not perfect! But not that bad!
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**Difficult to produce enough events with large multiplicity!**

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Amazing what we are asking the Monte-Carlo models to fit!
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Also new CMS UE results using the “jet area” approach will be coming soon at 7 TeV with comparisons to 900 GeV!
The “underlying event” at 7 TeV and 900 GeV is almost what we expected! The new tunes, AMBT1, Tune Z1, and PYTHIA8 do a fairly good job of describing the LHC UE data. Need to also fit the Tevatron UE data!

For the UE there was more “soft” particles than expected and more “soft” high multiplicity events than expected. The high multiplicity events need to be studied in much more detail!

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