CMS QCD MC Model Tuning Efforts?

Outline

- A few of the LHC PYTHIA Tunes: Rick’s CMS PYTHIA 6.4 tunes (Z1, Z2), Peter’s PYTHIA 6.4 Perugia 2011 tunes (S350, S356), and PYTHIA 8 Tune 4C (Corke & Sjöstrand).

- CMS Related PYTHIA Tunes (A. Knutsson, M. Zakaria): Pythia 6.4 (Tune Z2* and Tune Z2f), Pythia 8 (4C* and 4Cf).

- Baryon and Strange Particle Production at the LHC: Fragmentation tuning.
QCD@LHC 2011

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Rick Field
University of Florida

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- Baryon and Strange Particle Production at the LHC: Fragmentation tuning.

CMS Tune Z1 and Z2 are officially approved by CMS!

These tunes have not been officially approved by CMS!

I am not going to discuss all the nice tunes coming from the ATLAS tuning effort which is very impressive!

QCD@LHC, St. Andrews, Scotland
August 25, 2011

Rick Field – Florida/CDF/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 $P_Tmax$ UE data with $P_Tmax > 10$ GeV/c. Tune AMBT1 is primarily a min-bias tune, while Tune Z1 is a UE tune!
<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>
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<tr>
<td>PARP(89) – Reference energy, E0</td>
<td>1800.0</td>
<td>1800.0</td>
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<tr>
<td>PARP(90) – MPI Energy Extrapolation</td>
<td>0.275</td>
<td>0.25</td>
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<tr>
<td>PARP(77) – CR Suppression</td>
<td>1.016</td>
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<tr>
<td>PARP(78) – CR Strength</td>
<td>0.538</td>
<td>0.538</td>
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<tr>
<td>PARP(80) – Probability colored parton from BBR</td>
<td>0.1</td>
<td>0.1</td>
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<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>
</tr>
<tr>
<td>PARP(62) – ISR Cut-off</td>
<td>1.025</td>
<td>1.025</td>
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<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>
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<tr>
<td>MSTP(82) – Double gaussian matter distribution</td>
<td>4</td>
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<td>MSTP(91) – Gaussian primordial kT</td>
<td>1</td>
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<tr>
<td>MSTP(95) – strategy for color reconnection</td>
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</tr>
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</table>

Parameters not shown are the PYTHIA 6.4 defaults!
### PYTHIA 6.2 Tunes

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Tune AW</th>
<th>Tune DW</th>
<th>Tune D6</th>
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</thead>
<tbody>
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<td>CTEQ5L</td>
<td>CTEQ6L</td>
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<td>MSTP(82)</td>
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<tr>
<td>PARP(82)</td>
<td>2.0 GeV</td>
<td>1.9 GeV</td>
<td>1.8 GeV</td>
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<tr>
<td>PARP(83)</td>
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<td>0.5</td>
<td>0.5</td>
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<tr>
<td>PARP(84)</td>
<td>0.4</td>
<td>0.4</td>
<td>0.4</td>
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<tr>
<td>PARP(85)</td>
<td>0.9</td>
<td>1.0</td>
<td>1.0</td>
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<tr>
<td>PARP(86)</td>
<td>0.95</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>PARP(89)</td>
<td>1.8 TeV</td>
<td>1.8 TeV</td>
<td>1.8 TeV</td>
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<tr>
<td>PARP(90)</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
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<tr>
<td>PARP(62)</td>
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<td>1.25</td>
<td>1.25</td>
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<td>PARP(64)</td>
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<td>0.2</td>
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<td>PARP(67)</td>
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<tr>
<td>PARP(91)</td>
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<td>2.1</td>
<td>2.1</td>
</tr>
<tr>
<td>PARP(93)</td>
<td>15.0</td>
<td>15.0</td>
<td>15.0</td>
</tr>
</tbody>
</table>

**UE Parameters**

- **MSTP(81)**: 1
- **MSTP(82)**: 4
- **PARP(82)**: 2.0 GeV
- **PARP(83)**: 0.5
- **PARP(84)**: 0.4
- **PARP(85)**: 0.9
- **PARP(86)**: 0.95
- **PARP(89)**: 1.8 TeV
- **PARP(90)**: 0.25
- **PARP(62)**: 1.25
- **PARP(64)**: 0.2
- **PARP(67)**: 4.0
- **MSTR(91)**: 1
- **PARP(91)**: 2.1
- **PARP(93)**: 15.0

**ISR Parameter**

- **PARP(82)**: 2.0 GeV
- **PARP(83)**: 0.5
- **PARP(84)**: 0.4
- **PARP(85)**: 0.9
- **PARP(86)**: 0.95
- **PARP(89)**: 1.8 TeV
- **PARP(90)**: 0.25
- **PARP(62)**: 1.25
- **PARP(64)**: 0.2
- **PARP(67)**: 4.0
- **MSTR(91)**: 1
- **PARP(91)**: 2.1
- **PARP(93)**: 15.0

**Intrinsic KT**

- **PARP(82)**: 2.0 GeV
- **PARP(83)**: 0.5
- **PARP(84)**: 0.4
- **PARP(85)**: 0.9
- **PARP(86)**: 0.95
- **PARP(89)**: 1.8 TeV
- **PARP(90)**: 0.25
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- **PARP(64)**: 0.2
- **PARP(67)**: 4.0
- **MSTR(91)**: 1
- **PARP(91)**: 2.1
- **PARP(93)**: 15.0

**Uses CTEQ6L**

- **PARP(82)**: 2.0 GeV
- **PARP(83)**: 0.5
- **PARP(84)**: 0.4
- **PARP(85)**: 0.9
- **PARP(86)**: 0.95
- **PARP(89)**: 1.8 TeV
- **PARP(90)**: 0.25
- **PARP(62)**: 1.25
- **PARP(64)**: 0.2
- **PARP(67)**: 4.0
- **MSTR(91)**: 1
- **PARP(91)**: 2.1
- **PARP(93)**: 15.0

**Reduce PARP(82) by factor of 1.8/1.9 = 0.95**

**Everything else the same!**

---

**CMS: We wanted a CTEQ6L version of Tune Z1 in a hurry!**
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Tune Z1 (R. Field CMS)</th>
<th>Tune Z2 (R. Field CMS)</th>
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<td>CTEQ5L</td>
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<td>PARP(82) – MPI Cut-off</td>
<td>1.932</td>
<td>1.832</td>
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<td>1800.0</td>
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My guess!

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<td>6</td>
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PARP(90) same For Z1 and Z2!
## PYTHIA 8 Tunes

**R. Corke and T. Sjöstrand**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>CTEQ6L</th>
<th>MRST LO**</th>
<th>CTEQ6L</th>
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</thead>
<tbody>
<tr>
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<tr>
<td>SpaceShower:alphaSvalue</td>
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<td>0.137</td>
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<tr>
<td>SpaceShower:pT0Ref</td>
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<td>2.0</td>
<td>2.0</td>
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<tr>
<td>MultipleInteractions:alphaSvalue</td>
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<td>0.135</td>
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<td>MultipleInteractions:pT0Ref</td>
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<td>MultipleInteractions:ecmPow</td>
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<td><strong>0.19</strong></td>
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<td>MultipleInteractions:profile</td>
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<td>MultipleInteractions:expPow</td>
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<td>SigmaDiffractive:maxAX</td>
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<td>N/A</td>
<td>65</td>
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<td>SigmaDiffractive:maxXX</td>
<td>N/A</td>
<td>N/A</td>
<td>65</td>
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</table>

\[ p_{T0}(W) = p_{T0}(W/W_0)^\varepsilon \quad \varepsilon = PARP(90) \quad p_{T0} = PARP(82) \quad W = E_{cm} \]
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 corrected and compared with PYTHIA Tune Z1 at the generator level.

**Very nice agreement!**

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 (chgjet#1) for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 2.0$. The data are corrected and compared with PYTHIA Tune Z1 at the generator level.
CMS preliminary data at 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 $|\eta| < 2.0$ together with the ATLAS published data at 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 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| < 2.0. The data are corrected and compared with PYTHIA Tune Z2 at the generator level.

Not good! Bad energy dependence!

CMS corrected data!
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 corrected and compared with PYTHIA 8 Tune C4 at the generator level.

CMS corrected data!

Not good! PTsum too small!

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 (chgjet#1) for charged particles with $p_T > 0.5$ GeV/c and $|\eta| < 2.0$. The data are corrected and compared with PYTHIA 8 Tune C4 at the generator level.

CMS corrected data!
CMS data on the energy dependence (7 TeV divided by 900 GeV) of 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 $|\eta| < 2.0$ compared with PYTHIA Tune Z1, Z2, and PY8C4 at the generator level.

CMS corrected data!

Duh! The energy dependence depends on both PARP(90) and the structure function!
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Tune Z2 (R. Field CMS)</th>
<th>PY8 Tune C4 (Corke-Sjöstrand)</th>
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<tbody>
<tr>
<td>Parton Distribution Function</td>
<td>CTEQ6L</td>
<td>CTEQ6L</td>
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<tr>
<td>PARP(82) – MPI Cut-off</td>
<td>1.832</td>
<td>2.085</td>
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</tbody>
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PARP(90) much different!
CMS Tune Z2*  
(Professor tune, A. Knutsson & M. Zakaria)

<table>
<thead>
<tr>
<th>Tuning Range</th>
<th>Z2</th>
<th>Z2* (UE)</th>
<th>Z2f (Forward)</th>
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</thead>
<tbody>
<tr>
<td>PARP(82)</td>
<td>1.0-3.0</td>
<td>1.83</td>
<td>1.93</td>
</tr>
<tr>
<td>PARP(90)</td>
<td>0.0-0.4</td>
<td>0.28</td>
<td>0.23</td>
</tr>
</tbody>
</table>

\[ p_T^{min}(E_{CM}) = PARP(82) \cdot \frac{E_{CM}}{1.8 \cdot PARP(90)} \]

Big improvement at 900 GeV!

Compared to the old Z2:
- Z2* will increase the activity at 7 TeV (lower pt-cut)
- Z2* will decrease the activity at 0.9 TeV (higher pt-cut)
- Z2f will not do much at 0.9 TeV, but will increase the activity at 7 TeV.

"Transverse" Charged Particle Density
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Tune Z2 (R. Field CMS)</th>
<th>Tune Z2* (CMS)</th>
<th>PY8 Tune C4 (Corke-Sjöstrand)</th>
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<td>1800.0</td>
<td>1800.0</td>
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<td>PARP(90) – MPI Energy Extrapolation</td>
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<td>PARP(77) – CR Suppression</td>
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<td>PARP(78) – CR Strength</td>
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<td>PARP(80) – Probability colored parton from BBR</td>
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<td>PARP(83) – Matter fraction in core</td>
<td>0.356</td>
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<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>
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<td>PARP(93) – primordial kT-max</td>
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<td>10.0</td>
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<td>MSTP(81) – MPI, ISR, FSR, BBR model</td>
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<tr>
<td>MSTP(82) – Double gaussian matter distribution</td>
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<td>MSTP(91) – Gaussian primordial kT</td>
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<td>MSTP(95) – strategy for color reconnection</td>
<td>6</td>
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</tbody>
</table>

**CMS GEN Group:** Working on an improved Z2 tune (Tune Z2*) using the Professor (A. Knutsson & M. Zakaria).
Other CMS Tunes

CMS related tuning activities

A. Knutsson (DESY),
Mohammed Zakaria (Uni. Florida)

MB&UE meeting, CERN, 17th June 2011

Tunes to UE and forward energy flow data from CMS.

- Pythia 6 – the Z2* and Z2f tune
- Pythia 8 – the 4C* and 4Cf tune
- Status of CMS Rivet Routines

PYTHIA 6.4 “Forward Tune”!

Two PYTHIA tunes!
4th generation: tunes incorporating 7-TeV data

<table>
<thead>
<tr>
<th>Tune</th>
<th>Description</th>
<th>PYTUNE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Z1</td>
<td>Retune of AMBT1 by Field w CTEQ5L PDFs (2010)</td>
<td>CTEQ5L</td>
</tr>
<tr>
<td>Z2</td>
<td>Retune of Z1 by Skands w CTEQ5L PDFs (2010)</td>
<td>CTEQ5L</td>
</tr>
<tr>
<td>Z2-LEP</td>
<td>Retune of Z1 by Skands w CTEQ6L1 PDFs (2010)</td>
<td>CTEQ6L</td>
</tr>
<tr>
<td>Perugia 2011</td>
<td>Retune of Perugia 2010 incl 7-TeV data (Mar 2011)</td>
<td>CTEQ6L</td>
</tr>
<tr>
<td>P2011 radHi</td>
<td>Variation with alphaS(pT/2)</td>
<td>CTEQ5L</td>
</tr>
<tr>
<td>P2011 radLo</td>
<td>Variation with alphaS(2pT)</td>
<td>CTEQ5L</td>
</tr>
<tr>
<td>P2011 mpiHi</td>
<td>Variation with more semi-hard MPI</td>
<td>CTEQ5L</td>
</tr>
<tr>
<td>P2011 noCR</td>
<td>Variation without color reconnections</td>
<td>CTEQ5L</td>
</tr>
<tr>
<td>P2011 LO**</td>
<td>Perugia 2011 using MSTW LO** PDFs (Mar 2011)</td>
<td>CTEQ5L</td>
</tr>
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<td>P2011 C6</td>
<td>Perugia 2011 using CTEQ6L1 PDFs (Mar 2011)</td>
<td>CTEQ6L</td>
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<td>P2011 T16</td>
<td>Variation with PARP(90)=0.16 away from 7 TeV</td>
<td>CTEQ5L</td>
</tr>
<tr>
<td>P2011 T32</td>
<td>Variation with PARP(90)=0.32 away from 7 TeV</td>
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<td>P2011 TeV</td>
<td>Perugia 2011 optimized for Tevatron (Mar 2011)</td>
<td>CTEQ5L</td>
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<tr>
<td>360 S Global</td>
<td>Schulz-Skands Global fit (Mar 2011)</td>
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<td>361 S 7000</td>
<td>Schulz-Skands at 7000 GeV (Mar 2011)</td>
<td>CTEQ5L</td>
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<td>363 S 1800</td>
<td>Schulz-Skands at 1800 GeV (Mar 2011)</td>
<td>CTEQ5L</td>
</tr>
<tr>
<td>364 S 900</td>
<td>Schulz-Skands at 900 GeV (Mar 2011)</td>
<td>CTEQ5L</td>
</tr>
<tr>
<td>365 S 630</td>
<td>Schulz-Skands at 630 GeV (Mar 2011)</td>
<td>CTEQ5L</td>
</tr>
</tbody>
</table>

The Perugia tunes have “improved” LEP fragmentation tuning!
ATLAS published 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 pT > 0.5 GeV/c and |η| < 2.5. The data are corrected and compared with PYTHIA Tune Z1, Tune S350, and Tune S356 at the generator level.

Very similar to Tune Z1!

Tune S350 & S356 (Perugia 2011) fit the UE data at 900 GeV & 7 TeV very well!
## PY6.4 CTEQ5L Tunes

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Tune Z1 (R. Field CMS)</th>
<th>Tune S350 (P. Skands)</th>
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</thead>
<tbody>
<tr>
<td>Parton Distribution Function</td>
<td>CTEQ5L</td>
<td>CTEQ5L</td>
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<tr>
<td>PARP(82) – MPI Cut-off</td>
<td>1.932</td>
<td>2.93</td>
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<tr>
<td>PARP(89) – Reference energy, E0</td>
<td>1800.0</td>
<td>7000.0</td>
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<tr>
<td>PARP(90) – MPI Energy Extrapolation</td>
<td>0.275</td>
<td>0.265</td>
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<tr>
<td>PT0(at 900 GeV)</td>
<td>1.597</td>
<td>1.701</td>
</tr>
<tr>
<td>PT0(at 1.96 TeV)</td>
<td>1.978</td>
<td>2.091</td>
</tr>
<tr>
<td>PT0(at 7 TeV)</td>
<td>2.807</td>
<td>2.930</td>
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Tune S350 and Tune Z1 are very similar!
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Tune Z2 (CMS)</th>
<th>Tune Z2* (CMS)</th>
<th>Tune S356 (P. Skands)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parton Distribution Function</td>
<td>CTEQ6L</td>
<td>CTEQ6L</td>
<td>CTEQ6L</td>
</tr>
<tr>
<td>PARP(82) – MPI Cut-off</td>
<td>1.832</td>
<td>1.927</td>
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<tr>
<td>PARP(89) – Reference energy, E0</td>
<td>1800.0</td>
<td>1800.0</td>
<td>7000.0</td>
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<tr>
<td>PARP(90) – MPI Energy Extrapolation</td>
<td>0.275</td>
<td>0.225</td>
<td>0.220</td>
</tr>
<tr>
<td>PT0(at 900 GeV)</td>
<td>1.514</td>
<td>1.649</td>
<td>1.688</td>
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<tr>
<td>PT0(at 1.96 TeV)</td>
<td>1.875</td>
<td>1.964</td>
<td>2.003</td>
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<tr>
<td>PT0(at 7 TeV)</td>
<td>2.662</td>
<td>2.616</td>
<td>2.650</td>
</tr>
</tbody>
</table>

Tune S356 and Tune Z2* are very similar!
Baryon & Strange Particle Production at the LHC


Step 1: Look at the overall particle yields (all pT).

\[
\begin{align*}
\frac{K^+}{\text{Strange Meson}} & = \frac{u \bar{s}}{\text{Non-strange Meson}}, \\
\frac{K^-}{\text{Strange Meson}} & = \frac{\bar{u} s}{\text{Non-strange Meson}}, \\
\frac{K_{\text{short}}}{\text{Strange Meson}} & = \frac{d \bar{s} + \bar{d} s}{\text{Non-strange Meson}}, \\
\frac{p}{\text{Non-strange Baryon}} & = \frac{uud}{\text{Non-strange Meson}}, \\
\frac{\Lambda}{\text{Single-strange Baryon}} & = \frac{ud s}{\text{Strange Meson}}, \\
\frac{\Xi^-}{\text{Double-strange Baryon}} & = \frac{d ss}{\text{Strange Meson}}.
\end{align*}
\]

Step 2: Look at the ratios of the overall particle yields (all pT).

\[
\begin{align*}
\frac{(K^+ + K^-)}{(\pi^+ + \pi^-)} & = \frac{\text{Strange Meson}}{\text{Non-strange Meson}}, \\
\frac{K_{\text{short}}}{(\pi^+ + \pi^-)} & = \frac{\text{Strange Meson}}{\text{Non-strange Meson}}, \\
\frac{(p + \bar{p})}{(\pi^+ + \pi^-)} & = \frac{\text{Non-strange Baryon}}{\text{Non-strange Meson}}, \\
\frac{(\Lambda + \bar{\Lambda})}{2K_{\text{short}}} & = \frac{\text{Single-strange Baryon}}{\text{Strange Meson}}, \\
\frac{(\Xi^- + \bar{\Xi})}{2K_{\text{short}}} & = \frac{\text{Double-strange Baryon}}{\text{Strange Meson}}.
\end{align*}
\]

Step 3: Look at the pT dependence of the particle yields and ratios.

QCD@LHC, St. Andrews, Scotland
August 25, 2011
Rick Field – Florida/CDF/CMS
Page 22
CMS NSD data on the $K_{\text{short}}$ rapidity distribution at 7 TeV and 900 GeV compared with PYTHIA Tune Z1. The plot shows the average number of $K_{\text{short}}$ per NSD collision per unit $Y$, $(1/N_{\text{NSD}}) \, dN/dY$.

CMS NSD data on the $K_{\text{short}}$ rapidity distribution at 900 GeV and the ALICE point at $Y = 0$ (INEL) compared with PYTHIA Tune Z1. The ALICE point is the average number of $K_{\text{short}}$ per INEL collision per unit $Y$ at $Y = 0$, $(1/N_{\text{INEL}}) \, dN/dY$.

"Minimum Bias" Collisions

No overall shortage of Kaons in PYTHIA Tune Z1!
CMS NSD data on the K\textsubscript{short} rapidity distribution at 7 TeV and 900 GeV compared with PYTHIA Tune Z1. The plot shows the average number of K\textsubscript{short} per NSD collision per unit Y, \((1/N_{\text{NSD}}) \, dN/dY\).

ALICE point at Y = 0 (INEL) compared with PYTHIA Tune Z1. The ALICE point is the average number of K\textsubscript{short} per INEL collision per unit Y at Y = 0, \((1/N_{\text{INEL}}) \, dN/dY\).

“Minimum Bias” Collisions

No overall shortage of Kaons in PYTHIA Tune Z1!
ALICE INEL data on the charged kaon rapidity distribution at 900 GeV compared with PYTHIA Tune Z1. The plot shows the average number of charged kaons per INEL collision per unit Y at Y = 0, \( \frac{1}{N_{\text{INEL}}} \) dN/dY.

ALICE INEL data on the charged kaon to charged pion rapidity ratio at 900 GeV compared with PYTHIA Tune Z1.

\[
\frac{(K^+ + K^-)}{(\pi^+ + \pi^-)} = \frac{\text{Strange Meson}}{\text{Non-strange Meson}}
\]

No overall shortage of Kaons in PYTHIA Tune Z1!
**Kaon Production**

ALICE INEL data on the charged kaon rapidity distribution at 900 GeV compared with PYTHIA Tune Z1. The plot shows the average number of charged kaons per INEL collision per unit Y at Y = 0, \((1/N_{\text{INEL}}) \, dN/dY\).

ALICE INEL data on the charged kaon to charged pion rapidity ratio at 900 GeV compared with PYTHIA Tune Z1.

\[
\frac{(K^+ + K^-)}{(\pi^+ + \pi^-)} = \frac{\text{Strange Meson}}{\text{Non-strange Meson}}
\]

"Minimum Bias" Collisions

No overall shortage of Kaons in PYTHIA Tune Z1!
ALICE INEL data on the charged kaon rapidity distribution at 900 GeV compared with PYTHIA Tune Z1. The plot shows the average number of charged kaons per INEL collision per unit Y at Y = 0, \((1/N_{\text{INEL}}) \, dN/dY\).

No overall shortage of Kaons in PYTHIA Tune Z1!
LEP: $K_{\text{short}}$ Spectrum

mcplots.cern.ch

June 2011 - A. Karneyeu, D. Konstantinov, M. Mangano, L. Mijovic, W. Pokorski, S. Prestel, A. Pytel, P. Skands

(BOINC users, see Test4Theory@Home page)

QCD@LHC, St. Andrews, Scotland

August 25, 2011

Rick Field – Florida/CDF/CMS

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CMS NSD data on the Lambda+AntiLambda rapidity distribution at 7 TeV and 900 GeV compared with PYTHIA Tune Z1. The plot shows the average number of particles per NSD collision per unit Y, \((1/N_{NSD}) \, dN/dY\).

CMS NSD data on the Lambda+AntiLambda to 2Kshort rapidity ratio at 7 TeV compared with PYTHIA Tune Z1.

\[
\frac{(\Lambda + \bar{\Lambda})}{2K_{short}} = \text{Single-strange Baryon to Strange Meson Ratio}
\]

“Minimum Bias” Collisions

Oops! Not enough Lambda’s in PYTHIA Tune Z1!
CMS NSD data on the Lambda+AntiLambda rapidity distribution at 7 TeV and 900 GeV compared with PYTHIA Tune Z1. The plot shows the average number of particles per NSD collision per unit Y, $(1/N_{NSD}) \frac{dN}{dY}$.

CMS NSD data on the Lambda+AntiLambda to 2Kshort rapidity ratio at 7 TeV compared with PYTHIA Tune Z1.

$$\frac{(\Lambda + \bar{\Lambda})}{2K_{\text{short}}} = \text{Single-strange Baryon}$$

$$\text{Strange Meson}$$

"Minimum Bias" Collisions

Oops! Not enough Lambda’s in PYTHIA Tune Z1!
LEP: $\Lambda$ Spectrum

mcplots.cern.ch

June 2011 - A. Karneyeu, D. Konstantinov, M. Mangano, L. Mijovic, W. Pokorski, S. Prestel, A. Pytel, P. Skands

(BOINC users, see Test4Theory@Home page)
CMS NSD data on the Cascade⁻ + AntiCascade⁻ rapidity distribution at 7 TeV and 900 GeV compared with PYTHIA Tune Z1. The plot shows the average number of particles per NSD collision per unit Y, \((1/N_{NSD}) \, dN/dY\).

**“Minimum Bias” Collisions**

Yikes! Way too few Cascade’s in PYTHIA Tune Z1!

CMS data on the Cascade⁻ + AntiCascade⁻ to 2K_short rapidity ratio at 7 TeV compared with PYTHIA Tune Z1.

\[
\frac{(\Xi^- + \Xi^-)}{2K_{short}} = \text{Double-strange Baryon Strange Meson}
\]
CMS NSD data on the Cascade$^-$ +AntiCascade$^-$ rapidity distribution at 7 TeV and 900 GeV compared with PYTHIA Tune Z1. The plot shows the average number of particles per NSD collision per unit Y, $(1/N_{NSD}) dN/dY$.

CMS data on the Cascade$^-$+AntiCascade$^-$ to 2Kshort rapidity ratio at 7 TeV compared with PYTHIA Tune Z1.

\[
\frac{(S^- + S^-)}{2K_{short}} = \text{Double-strange Baryon Strange Meson}
\]

“Minimum Bias” Collisions

Yikes! Way too few Cascade’s in PYTHIA Tune Z1!
LEP: $\Xi$ Spectrum

mcplots.cern.ch

June 2011 - A. Karneyeu, D. Konstantinov, M. Mangano, L. Mijovic, W. Pokorski, S. Prestel, A. Pytel, P. Skands

(BOINC users, see Test4Theory@Home page)
Can we increase the overall rate of strange baryons by varying a few fragmentation parameters? For now ignore $e^+e^-$!

- **PARJ(1)**: $(D = 0.10)$ is $P(qq)/P(q)$, the suppression of diquark-antidiquark pair production in the colour field, compared with quark–antiquark production. **Notation:** $\text{PARJ}(1) = qq/q$.

- **PARJ(2)**: $(D = 0.30)$ is $P(s)/P(u)$, the suppression of $s$ quark pair production in the field compared with $u$ or $d$ pair production. **Notation:** $\text{PARJ}(2) = s/u$.

- **PARJ(3)**: $(D = 0.4)$ is $(P(us)/P(ud))/(P(s)/P(u))$, the extra suppression of strange diquark production compared with the normal suppression of strange quarks. **Notation:** $\text{PARJ}(3) = us/u$.

This work is in progress!
Can we increase the overall rate of strange baryons by varying a few fragmentation parameters? For now ignore e+e-!

**Warning!** This may cause problems fitting the LEP data. If so we must understand why! We do not want one tune for e+e- and another one for hadron-hadron collisions!

- **PARJ(1)**: (D = 0.10) is $P(qq)/P(q)$, the suppression of diquark-antidiquark pair production compared with quark–antiquark production in the colour field. Notation: $PARJ(1) = qq/q$

- **PARJ(2)**: (D = 0.30) is $P(s)/P(u)$, the suppression of s quark pair production in the field compared with u or d pair production. Notation: $PARJ(2) = s/u$

- **PARJ(3)**: (D = 0.4) is $(P(us)/P(ud))/(P(s)/P(u))$, the extra suppression of strange diquark production compared with normal quark–antiquark strangeness quark production. Notation: $PARJ(3) = us/u$

This work is in progress!
**PYTHIA Tune Z1C**: Same as Tune Z1 except $qq/q$ is increased $0.1 \rightarrow 0.12$ and $us/s$ is increased from $0.4 \rightarrow 0.8$. 

- **CMS Data**: 
  - Rapidity Distribution Ratio: $(\Lambda\bar{\Lambda}+\Lambda\bar{\Lambda})/(2K_{short})$
  - $dN/dY$ Particle Ratio
  - $qq/q: 0.1 \rightarrow 0.2$
  - $us/s: 0.4 \rightarrow 1.0$
  - $s/u: 0.3 \rightarrow 0.5$
  - Z1 default

- **ALICE Data**: 
  - Rapidity Distribution Ratio: $K^+/K^-$
  - $dN/dY$ Particle Ratio
  - $qq/q: 0.1 \rightarrow 0.2$
  - $us/s: 0.4 \rightarrow 1.0$
  - Z1 default

- **PYTHIA Tune Z1**: 
  - Rapidity Distribution Ratio: $(\Lambda\bar{\Lambda}+\Lambda\bar{\Lambda})/(2K_{short})$
  - $dN/dY$ Particle Ratio
  - $qq/q: 0.1 \rightarrow 0.2$
  - $us/s: 0.4 \rightarrow 1.0$
  - $s/u: 0.3 \rightarrow 0.5$
  - Z1 default

- **INEL (all pT) 900 GeV**: 
  - Rapidity Distribution Ratio: $K^+K^-/(\pi^+\pi^-)$
  - $dN/dY$ Particle Ratio
  - $qq/q: 0.1 \rightarrow 0.2$
  - $us/s: 0.4 \rightarrow 1.0$
  - $s/u: 0.3 \rightarrow 0.5$
  - Z1 default
CMS NSD data on the K_{short} rapidity distribution at 7 TeV and 900 GeV compared with PYTHIA Tune Z1. The plot shows the average number of K_{short} per NSD collision per unit Y, (1/N_{NSD}) dN/dY.

CMS dNSD data on the K_{short} rapidity distribution at 7 TeV and 900 GeV compared with PYTHIA Tune Z1C. The plot shows the average number of K_{short} per NSD collision per unit Y, (1/N_{NSD}) dN/dY.

“Minimum Bias” Collisions

For Kaon production Tune Z1 and Z1C are almost identical!
CMS NSD data on the $K_{short}$ rapidity distribution at 7 TeV and 900 GeV compared with PYTHIA Tune Z1. The plot shows the average number of $K_{short}$ per NSD collision per unit $Y$, $(1/N_{NSD}) \, dN/dY$.

CMS dNSD data on the $K_{short}$ rapidity distribution at 7 TeV and 900 GeV compared with PYTHIA Tune Z1C. The plot shows the average number of $K_{short}$ per NSD collision per unit $Y$, $(1/N_{NSD}) \, dN/dY$.

"Minimum Bias" Collisions

For Kaon production Tune Z1 and Z1C are almost identical!
Lambda Production

CMS NSD data on the Lambda+AntiLambda rapidity distribution at 7 TeV and 900 GeV compared with PYTHIA Tune Z1. The plot shows the average number of particles per NSD collision per unit Y, \((1/N_{\text{NSD}}) dN/dY\).

Not bad! Many more Lambda’s in PYTHIA Tune Z1C!
CMS NSD data on the Lambda+AntiLambda rapidity distribution at 7 TeV and 900 GeV compared with PYTHIA Tune Z1. The plot shows the average number of particles per NSD collision per unit Y, \((1/\text{N}_{\text{NSD}}) \, dN/dY\).

Not bad! Many more Lambda’s in PYTHIA Tune Z1C!
CMS NSD data on the Cascade- +AntiCascade- rapidity distribution at 7 TeV and 900 GeV compared with PYTHIA Tune Z1. The plot shows the average number of particles per NSD collision per unit Y, (1/N_{NSD}) dN/dY.

Wow! PYTHIA Tune Z1C looks very nice here!
CMS NSD data on the Cascade-+AntiCascade- rapidity distribution at 7 TeV and 900 GeV compared with PYTHIA Tune Z1. The plot shows the average number of particles per NSD collision per unit Y, $(1/N_{NSD}) \, dN/dY$.

“Minimum Bias” Collisions

Wow! PYTHIA Tune Z1C looks very nice here!
CMS NSD data on the Cascade-+AntiCascade- rapidity distribution at 7 TeV and 900 GeV compared with PYTHIA Tune Z1. The plot shows the average number of particles per NSD collision per unit $Y$, $(1/N_{NSD}) \, dN/dY$.

CMS NSD data on the Cascade-+AntiCascade-rapidity distribution at 7 TeV and 900 GeV compared with PYTHIA Tune Z1. The plot shows the average number of particles per NSD collision per unit $Y$, $(1/N_{NSD}) \, dN/dY$.

“Minimum Bias” Collisions

Wow! PYTHIA Tune Z1C looks very nice here!
CMS NSD data on the $K_{short}$ transverse momentum distribution at 7 TeV compared with PYTHIA Tune Z1 & Z1C. The plot shows the average number of particles per NSD collision per unit $p_T$, $(1/N_{NSD}) \, dN/dp_T$ for $|Y| < 2$.

CMS NSD data on the Lambda+AntiLambda transverse momentum distribution at 7 TeV compared with PYTHIA Tune Z1 & Z1C. The plot shows the average number of particles per NSD collision per unit $p_T$, $(1/N_{NSD}) \, dN/dp_T$ for $|Y| < 2$.

PYTHIA Tune Z1 & Z1C are a bit off on the $p_T$ dependence!
CMS NSD data on the Cascade+AntiCascade transverse momentum distribution at 7 TeV compared with PYTHIA Tune Z1 & Z1C. The plot shows the average number of particles per NSD collision per unit $p_T$ (1/N_{NSD}) $dN/dp_T$ for $|Y| < 2$. PYTHIA Tune Z1 & Z1C are a bit off on the $p_T$ dependence!

CMS NSD data on the Cascade+AntiCascade transverse momentum distribution at 7 TeV (normalized to 1) compared with PYTHIA Tune Z1 & Z1C.

“Minimum Bias” Collisions...
CMS NSD data on the Lambda+AntiLambda to $2K_{\text{short}}$ ratio versus $p_T$ at 7 TeV ($|Y| < 2$) compared with PYTHIA Tune Z1 & Z1C.

ALICE INEL data on the Lambda+AntiLambda to $2K_{\text{short}}$ ratio versus $p_T$ at 900 GeV ($|Y| < 0.75$) compared with PYTHIA Tune Z1 & Z1C.

$\frac{(\Lambda + \bar{\Lambda})}{2K_{\text{short}}} = \text{Single-strange Baryon} / \text{Strange Meson}$

"Minimum Bias" Collisions

Tune Z1C is not too bad but a bit off on the $p_T$ dependence!
CMS NSD data on the Cascade$^-$
+AntiCascade$^-$ to 2K$_{short}$ ratio versus p$_T$ at 7 TeV ($|Y| < 2$) compared with PYTHIA Tune Z1 & Z1C

$\frac{(\Xi^- + \Xi^-)}{2K_{short}} = \text{Double-strange Baryon}$
$\frac{\text{Strange Meson}}{\text{Single-strange Baryon}}$

CMS NSD data on the Cascade$^-$+AntiCascade$^-$
to Lambda+AntiLambda ratio versus p$_T$ at 7 TeV ($|Y| < 2$) compared with PYTHIA Tune Z1 & Z1C

$\frac{(\Xi^- + \Xi^-)}{(\Lambda + \Lambda)}$

“Minimum Bias” Collisions

Tune Z1C is not too bad but a bit off on the p$_T$ dependence!
ALICE INEL data on the charged kaon to charged pions ratio versus $p_T$ at 900 GeV ($|Y| < 0.75$) compared with PYTHIA Tune Z1 & Z1C. Z1C is not too bad but a way off on the $p_T$ dependence!
Particle Ratios versus PT

**PT Particle Ratio:** \((P + P\bar{p})/\text{Pions}\)

- **ALICE Data**
- **PYTHIA Tune Z1 & Z1C**

**Rapidity Distribution Ratio:** \((P + P\bar{p})/(\pi^+ + \pi^-)\)

- **ALICE Data**
- **PYTHIA Tune Z1 & Z1C**

**Tails of the \(p_T\) distribution:**
Way off due to the wrong \(p_T\) dependence!

**ALICE INEL data** on the Proton+AntiProton to charged pion ratio versus \(p_T\) at 900 GeV (\(|Y| < 0.75\)) compared with PYTHIA Tune Z1 & Z1C.

**Tune Z1C** is not too bad but way off on the \(p_T\) dependence!
Particle Ratios versus PT

Rapidity Distribution Ratio: \((P+P\bar{p})/\text{Pions}\)

\[ \text{ALICE Data} \]

PYTHIA Tune Z1 & Z1C

\[ \text{INEL (|Y| < 0.75)} \]

900 GeV

\[ \text{dN/dY Particle Ratio} \]

ALICE INEL data on the Proton+AntiProton to charged pions ratio versus 
\(p_T\) at 900 GeV (|Y| < 0.75) compared with PYTHIA Tune Z1 & Z1C.

Tune Z1C is not too bad but way off on the \(p_T\) dependence!
Before making any conclusion about $e^+e^-$ versus pp collisions one must check the predictions of Herwig++ and Sherpa!

Strange particle production in pp at 200 GeV (STAR_2006_S6860818)

Hendrik Hoeth
http://users.hepforge.org/~hoeth/STAR_2006_S6860818/
Before making any conclusion about $e^+e^-$ versus pp collisions one must check the predictions of Herwig++ and Sherpa!

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http://users.hepforge.org/~hoeth/STAR_2006_S6860818/
Shows the density of charged particles in the “transverse” region as a function of PTmax for charged particles (All p_T, |η| < 2) at 7 TeV from PYTHIA Tune Z1.

CMS NSD data on the charged particle rapidity distribution at 7 TeV compared with PYTHIA Tune Z1. The plot shows the average number of charged particles per NSD collision per unit η–ϕ, (1/N_{NSD}) dN/dηdϕ.
Shows the density of charged particles in the “transverse” region as a function of PTmax for charged particles (All p_T, |η| < 2) at 7 TeV from PYTHIA Tune Z1.

Shows the density of particles in the “transverse” region as a function of PTmax for charged particles (All p_T, |η| < 2) at 7 TeV from PYTHIA Tune Z1.

Log Scale!
Shows the density of $K_{\text{short}}$ particles in the "transverse" region as a function of PTmax for charged particles (All $p_T$, $|\eta| < 2$) at 7 TeV from PYTHIA Tune Z1. The plot shows the average number of particles per ND collision per unit $\eta-\phi$, $(1/N_{\text{ND}}) dN/d\eta d\phi$.

Shows the $K_{\text{short}}$ pseudo-rapidity distribution (all $p_T$) at 7 TeV from PYTHIA Tune Z1. The plot shows the average number of particles per ND collision per unit $\eta-\phi$, $(1/N_{\text{ND}}) dN/d\eta d\phi$. 

"Minimal Bias" Collisions

Proton

Initial State Radiation

PT(hard)

Outgoing Parton

Underlying Event

Proton

Final State Radiation

Outgoing Parton

Proton

Underlying Event

"Minimum Bias" Collisions

Proton

Initial State Radiation

PT(hard)

Outgoing Parton

Underlying Event

Proton

Final State Radiation

Outgoing Parton

Proton

Underlying Event
"Transverse" Particle Density: $dN/d\eta d\phi$

- **Factor of ~2!**

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

Shows the density of P+antiP particles in the "transverse" region as a function of $p_T\text{max}$ for charged particles (All $p_T$, $|\eta| < 2$) at 7 TeV from PYTHIA Tune Z1.

Shows the P+antiP pseudo-rapidity distribution (all $p_T$) at 7 TeV from PYTHIA Tune Z1. The plot shows the average number of particles per ND collision per unit $\eta-\phi$, $(1/N_{ND}) \, dN/d\eta d\phi$. 

QCD@LHC, St. Andrews, Scotland
August 25, 2011
Shows the density of Proton Proton "Minimum Bias" Collisions versus PTmax for charged particles (All $p_T$, $|\eta| < 2$) at 7 TeV from PYTHIA Tune Z1. The plot shows the average number of particles per ND collision per unit $\eta-\phi$, $(1/N_{ND}) \, dN/d\eta d\phi$.

"Minimum Bias" Collisions

Proton

Underlying Event

Final-State Radiation

Outgoing Parton

PT(hard)

Initial-State Radiation

Proton

Proton
 Shows the density of $\Lambda$+anti-$\Lambda$ particles in the “transverse” region as a function of PTmax for charged particles (All pT, $|\eta| < 2$) at 7 TeV from PYTHIA Tune Z1.

 Shows the $\Lambda$+anti-$\Lambda$ pseudo-rapidity distribution (all pT) at 7 TeV from PYTHIA Tune Z1. The plot shows the average number of particles per ND collision per unit $\eta$–$\phi$, $(1/N_{ND}) \, dN/d\eta d\phi$. 
Shows the density of charged particles in the "transverse" region as a function of \( p_T \) for charged particles (\(|\eta| < 2\)) at 7 TeV from PYTHIA Tune Z1. The plot shows the average number of particles per ND collision per unit \( \eta - \phi \).
"Transverse" Particle Density: \( \frac{dN}{d\eta d\phi} \)

- **Tune Z1**
  - Shows the density of \( \Lambda + \text{anti}\Lambda \) particles in the "transverse" region as a function of \( \text{PT}_{\text{max}} \) for charged particles (All \( p_T \), \( |\eta| < 2 \)) at 7 TeV from PYTHIA Tune Z1.

Charged Particle Density: \( \frac{dN}{d\eta d\phi} \)

- **Tune Z1**
  - Shows the \( \Lambda + \text{anti}\Lambda \) pseudo-rapidity distribution (all \( p_T \)) at 7 TeV from PYTHIA Tune Z1. The plot shows the average number of particles per ND collision per unit \( \eta - \phi \), \( \frac{1}{N_{\text{ND}}} \frac{dN}{d\eta d\phi} \).

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**QCD@LHC, St. Andrews, Scotland**

**Rick Field – Florida/CDF/CMS**

**August 25, 2011**

Page 63
Coming soon! Measurements from CMS, ATLAS, and ALICE on the strange particles and baryons in the “underlying event”.

Shows the density of \( \Lambda \Lambda \) particles as a function of \( P_T \) for charged particles (all \( |\eta| < 2 \)) at 7 TeV from PYTHIA Tune Z1. The plot shows the average number of particles per ND collision per unit \( \eta - \phi \) (1/N_{ND}) dN/d\eta d\phi.

"Minimum Bias" Collisions

Proton

Underlying Event

Outgoing Parton

Final-State Radiation

Initial-State Radiation

Proton

Underlying Event

Proton

Initial-State Radiation

Outgoing Parton

Final-State Radiation

Underlying Event
Not too hard to get the overall yields of baryons and strange particles roughly right at 900 GeV and 7 TeV. Tune Z1C does a fairly good job with the overall particle yields at 900 GeV and 7 TeV.

PT Distributions: PYTHIA does not describe correctly the $p_T$ distributions of heavy particles (MC softer than the data). None of the fragmentation parameters I have looked at changes the $p_T$ distributions. Hence, if one looks at particle ratios at large $p_T$ you can see big discrepancies between data and MC (out in the tails of the distributions)!

ATLAS Tuning Effort: Fragmentation flavor tuning at the one of the four stages.

Herwig++ & Sherpa: Before making any conclusions about fragmentation one must check the predictions of Herwig++ and Sherpa carefully!
Not too hard to get the overall yields of baryons and strange particles roughly right at 900 GeV and 7 TeV. Tune Z1C does a fairly good job with the overall particle yields at these energies.

PT Distributions: PYTHIA does not describe correctly the $p_T$ distributions of heavy particles (MC softer than the data). None of the fragmentation parameters I have looked at changes the $p_T$ distributions. Hence, if one looks at particle ratios at large $p_T$ you can see big discrepancies between data and MC!

Warning! The Tune Z1C fragmentation parameters may cause problems fitting the LEP data. If so we must understand why! We do not want one tune for $e^+e^-$ and another one for hadron-hadron collisions!

ATLAS Tuning Effort: Fragmentation flavor tuning at the one of the four stages.

Herwig++ & Sherpa: Before making any conclusions about fragmentation one must check the predictions of Herwig++ and Sherpa carefully!