Multi-parton interactions and underlying events from Tevatron to LHC

Outline

1) Multiple Parton Interactions (MPI) Models
2) Review of the older Min Bias (MB) & Underlying Event (UE) Phenomenology
3) MB&UE Feasibility Studies for the LHC
4) New ideas, generator level studies
   - Double Parton Scattering
   - The mini-jet structure of the MB
   - Central-Forward correlations
   - Multiple Parton Interactions & Diffraction
**pQCD Models**

ISR, FSR, SPECTATORS… Not enough to account for the observed multiplicities & $P_T$ spectra

Inspired by observations of double high $P_T$ scatterings

**Main Parameter: $P_T$ cut-off $P_{T0}$**

\[
\sigma(P_T) \rightarrow \sigma(P_T) \cdot \frac{(P_T)^4}{((P_{T0})^2 + (P_T)^2)^2}
\]

- **Cross Section Regularization for $P_T \rightarrow 0$**
- $P_{T0}$ can be interpreted as inverse of effective colour screening length
- **Controls the number of interactions hence the Multiplicity:**

\[
\langle N_{\text{int}} \rangle = \frac{\sigma_{\text{parton-parton}}}{\sigma_{\text{proton-proton}}}
\]

Tuning for the LHC: Emphasis on the Energy-dependence of the parameters.

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The Pythia solution:


Multiple Parton Interactions (MPI) (now available in other general purpose MCs: Herwig/Jimmy, Sherpa, etc.)
Quarkonia also prefers dampening

\[ \sigma(\widehat{P}_T) \rightarrow \sigma(\widehat{P}_T) \cdot \frac{(\widehat{P}_T)^4}{((\widehat{P}_{T0})^2 + (\widehat{P}_T)^2)^2} \]

\[ \text{CDF data} \]

\[ |y| < 0.6 \]

\[ \text{disagreement at low } P_T \]

\[ P_{T0} = 2.85 \text{ GeV} \rightarrow \text{nice agreement} \]

Regularization natural: gluon exchange in the t channel \( d\sigma / dP_T^2 \sim 1 / dP_T^4 \)

\( P_{T0} \) very much along the lines of the one adopted in MPI MB & UE Tunes
“post Hera” PDFs have increased color screening at low $x$?

\[ x g(x, Q^2) \rightarrow x^{-\epsilon} \text{ for } x \rightarrow 0 \]

- $P_T(s)$ cut-off fitted with exponential function using the average charged multiplicity in the central region from SPS & Tevatron [CERN 2000-004, pgg 293-300]

MB: Charged Multiplicty vs MPI models

- Introduce IP correlations in Multiple Parton Interactions


\[ <P_T> \text{ vs Multiplicity: see [hep/ph 0703081]} \]
Data at 1.96 TeV on the average $p_T$ of charged particles versus the number of charged particles ($p_T > 0.4$ GeV/c, $|\eta| < 1$) for “min-bias” collisions at CDF Run 2. The data are corrected to the particle level and are compared with PYTHIA Tune A at the particle level (i.e. generator level).
Model expectations for charged particles at $|\eta| = 0$ vs. $\sqrt{s}$:
- Pythia: $\sim \ln^2(s)$
- Phojet: $\sim \ln(s)$

Non-single diffractive (NSD)

Assumes trigger efficiencies:
- SD 60%, DD 70%, ND 99%

CMS:
Tracklets, i.e. Only pixel triplets down to 75 MeV!

Reference for trigger performances:
CMS Physics Analysis Summary QCD-07-002

Tunes & Trigger performances -> backup slides

Pythia tune DWT

Simulated tracks

8% syst.
MB: Hadron spectra at the LHC

**ATLAS**

**Track**

**Reco**

**Summary of systematic uncertainties**

<table>
<thead>
<tr>
<th>Source</th>
<th>Uncertainty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Track selection cuts</td>
<td>2%</td>
</tr>
<tr>
<td>Mis-estimate of secondaries</td>
<td>1.5%</td>
</tr>
<tr>
<td>Vertex reconstruction</td>
<td>0.1%</td>
</tr>
<tr>
<td>Mis-alignment</td>
<td>6%</td>
</tr>
<tr>
<td>Beam-gas &amp; pile-up</td>
<td>1%</td>
</tr>
<tr>
<td>Particle composition</td>
<td>2%</td>
</tr>
<tr>
<td>Diffractive cross-sections</td>
<td>0.1%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>6.9%</strong></td>
</tr>
</tbody>
</table>

**Good reconstruction quality**

**CMS:**

**Tracklets:**

Only pixel triplets down to 75 MeV!

**Systematic:**

Trigger, feed-down, geom. acceptance, alg. efficiency

Diff. yields of identified $\pi^+$, $K^\pm$, $p/\bar{p}$ together with Tsallis-function fits (inverse slope $T = 0.2$ GeV/c, high $p_T$ exponent $n = 7.2$)

**Tunes & Trigger performances -> backup slides**

Paolo Bartalini (NTU)
The Calo jet (or Charged jet) provides a scale and defines a direction in the $\phi$ plane. The transverse region is expected to be particularly sensitive to the UE. Several Jet topologies can be tested to increase the sensitiveness to the MPI component of the UE.

Main observables built from charged tracks:
+ $dN/d\eta d\phi$, charged density
+ $d(\text{PT}_{\text{sum}})/d\eta d\phi$, energy density

LHC experiments have a much wider $\Delta\eta$ region with respect to the Tevatron ones.

**DY events**

observables are the same

The PT of the boson is used to define a direction.
Data at 1.96 TeV on the charged scalar PTsum density, dPT/dηdφ, with p_T > 0.5 GeV/c and |η| < 1 for “Z-Boson” and “Leading Jet” events as a function of the leading jet p_T or p_T(Z) for the “toward”, “away”, and “transverse” regions. The data are corrected to the particle level (with errors that include both the statistical error and the systematic uncertainty) and are compared with PYTHIA Tune AW and Tune A, respectively, at the particle level (i.e. generator level).

Further details in next talk (from D. Kar)
ATLAS: UE in the transverse region

Up to 1 TeV in few pb⁻¹

\[ N_{\text{jets}} > 1, \]
\[ |\eta_{\text{jet}}| < 2.5, \]
\[ E_{T}\text{jet} > 10 \text{ GeV}, \]
\[ |\eta_{\text{track}}| < 2.5, \]
\[ p_{T}\text{track} > 1.0 \text{ GeV/c} \]

Good RECO/MC agreement

Tune of the energy dependent MPI parameters (run at 900 GeV coming!)

LHC / Tevatron ~ 1.5 - 3

Pythia 14 TeV
Pythia 10 TeV
CDF

Jimmy 14 TeV
Jimmy 10 TeV
CDF

Tunes -> backup slides
CMS: UE in the transverse region (I)

Select charged tracks in $|\eta| < 2$ with $p_T > 0.9$ GeV/c (no pile-up included)

$\Ldt = 100 \text{ pb}^{-1}$

Herwig

"Soft UE"

CMS Preliminary CMS Preliminary

CMS Physics Analysis Summary QCD-07-003

→ discriminate DW against DWT

P.P. Skands, New MPI, colour-flow

All these Pythia tunes describe MB & UE at Tevatron. Further information in backup slides.

→
UE in jets: Ratios in the transverse region

- **Ratios between uncorrected UE-observables:**
  - UE-density($p_T$(track) > 0.9 GeV/c) / UE-density($p_T$(track) > 1.5 GeV/c)

- **No additional track reconstruction corrections needed!**
  - track reconstruction performance uniform in $p_T$ for $p_T > 0.9$ GeV/c

→ discriminate DW/DWT against $S_0$
Tracks: PT > 0.9 |

CMS: Activity vs distance to charged jet

UE Observables VS $\Delta \phi$ Leading Charged Jet
Uncorrected distributions from 10pb$^{-1}$

Tracks: PT > 0.9 |

CMS Physics Analysis Summary QCD-07-003

DESY, September 16 2008

Paolo Bartalini (NTU)
THE ULTIMATE GOAL WOULD BE TO ACHIEVE A UNIFORM DESCRIPTION FOR HIGH $P_T$ AND LOW $P_T$ MPI

HOW?

- $3j + \gamma$
- Standard MB & UE measurements (along the lines of the CDF experience)
- Counting pairs of same sign $W$
- Counting pairs of mini-charged jets in MB interactions

[D.Treleani et al.]

In the simplest model, DPS produces a final state that mimics a combination of two independent scatterings.

\[ \sigma_{DP} = m \frac{\sigma_A \sigma_B}{2\sigma_{eff}}. \]

\( m=2 \) for distinguishable scatterings
\( m=1 \) for indistinguishable scatterings

\( \sigma_{eff} \) is the probability of hard scattering \( B \) taking place given \( A \), and this will be larger or smaller depending on the parton spatial density. \( \sigma_{eff} \) contains the information on the spatial distribution of partons.

Double high \( p_T \) interactions observed by AFS, UA2, CDF

\( 3\text{jet+}\gamma: \)

[CDF Collab, Phys. Rev. Lett. 79, 584 (1997)]

Treleani corrects to \( \sigma_{eff} \sim 10\text{mb} \)

Model comparison @ LHC

Pythia 8.1
- physics ~ Pythia 6.4 Tune S0
- Herwig++ 2.2
- MPI along the lines of Jimmy

More statistics underway to clear potential disagreement
Default PDFs used: CTEQ5L (Pythia) and MRST98 (Herwig)

florian.bechtel@desy.de
HERA-LHC Workshop, CERN, May 2008
LHC: Quoting MPIs with paired charged MiniJets

$\Delta \phi$ distribution for the two most energetic charged Mini-Jets of the events

<table>
<thead>
<tr>
<th>$p_T^{\text{jet}}&gt;2$ GeV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pythia 6.409, Tune DWT</td>
</tr>
<tr>
<td>Charged Particles</td>
</tr>
<tr>
<td>$</td>
</tr>
<tr>
<td>$R=0.5$, Seed 1 GeV</td>
</tr>
</tbody>
</table>

Pairing Algorithm:
- MiniJets ordered in decreasing $p_T$
- Start from the first
- Paired = jet with closest $p_T$ that satisfies the condition $|\Delta \phi^0|<|\Delta \phi|

Tracks:
- $p_T>0.5$
- $|\eta|<2$
- Jet $p_T>6$

Tracks:
- $p_T>0.5$
- $|\eta|<2$
- Jet $p_T>10$

Tracks:
- $p_T>0.5$
- $|\eta|<2$
- Jet $p_T>20$

The Number of pairs deeply depends on jet $p_T$ and acceptance

DESY, September 16 2008

Paolo Bartalini (NTU)
LHC: Quoting MPIs with paired MiniJets

The idea of the measurement (D. Treleani) is to study the Rates for a given number N of Mini-Jet Pairs above a given $P_T$ threshold -> Infrared Safe Quantity

$$\langle N \rangle \sigma_H = \sigma_S \text{ and } \frac{1}{2} \langle N(N-1) \rangle \sigma_H = \sigma_D \quad \langle N(N-1) \rangle = \langle N \rangle^2 \frac{\sigma_H}{\sigma_{eff}}$$

Where $\sigma_{\text{inel}} = \sigma_{\text{soft}} + \sigma_H$


$\sigma_{\text{eff}}(P_T)$ contains the information on the spatial distribution of partons

**Enhancement in the probability of additional interactions**

$\sigma_{\text{eff}} \sim$ independent from acceptance & efficiency (also from theory)
**UE & Long Range Correlations**

**Long range Correlations:**

- Charged particles in central region
- Trigger particle
- No correlations
- Large range correlations

**Charged particle multiplicities (E_{part} > 1 GeV) in Pythia:**

\[ E_{CASTOR} = \sum E_{part}, \quad 5.2 < \eta_{part} < 6.6 \]

- **Without MI:** no correlations
- **With MI:** large trigger E in Castor
- \( \rightarrow \) high particle multiplicities in central region
- **Triggering on CASTOR calorimeter** enhances differences between various UE tunes

[Z.Rurikova, HERA/LHC, May08]
Conclusions

- **LHC ready to go with the standard reference MB and UE measurements relying on soft track reconstruction**
  - New ideas, synergies with the Tevatron measurements in ongoing w/s

- **Tevatron keeps providing progress/refinements**
  - Rich set of particle level observables (directly comparable with the predictions of the QCD models)
  - New measurements (UE in Drell-Yan, MB Correlations)
  - Recent progress also from HERA (see backup slides)

- **Progress of the MPI models**
  - “New” MPI model in Pythia (comparisons with data needed)
  - MPI now in most of the new reference MCs: Pythia 8, Herwig++, Sherpa.
  - New ideas: dynamical structure of the hadrons, connection to diffraction

- **LHC: TH progress & generator level studies prepare the ground for a uniform description of high \( P_T \) and low \( P_T \) MPIs**
  - Same sign \( W, 3\text{jet}+\gamma \), mini-jets, long distance correlations, connection to diffraction (i.e. hard factorization breaking, survival of rapidity gaps)
Credits:

Filippo Ambroglini,
Manuel Bähr,
Florian Bechtel,
Jon Butterworth,
Livio Fanò,
Rick Field,
David Hofman,
Lluis Martí,
Arthur Moraes,
Klaus Rabbertz,
Zuzana Rurikova,
Ferenc Siklér,
Torbjörn Sjöstrand,
Daniele Treleani,

etc...
Backup
## Pythia Tunes

<table>
<thead>
<tr>
<th>Parameter</th>
<th>A</th>
<th>ATLAS</th>
<th>DW</th>
<th>DWT</th>
<th>S0</th>
</tr>
</thead>
<tbody>
<tr>
<td>UE model MSTP(81)</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>21</td>
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<tr>
<td>UE infrared regularisation scale PARP(82)</td>
<td>2.0</td>
<td>1.8</td>
<td>1.9</td>
<td>1.9409</td>
<td>1.85</td>
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<td>UE scaling power with $\sqrt{s}$ PARP(90)</td>
<td>0.25</td>
<td>0.16</td>
<td>0.25</td>
<td>0.16</td>
<td>0.16</td>
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<tr>
<td>UE hadron transverse mass distribution MSTP(82)</td>
<td>4</td>
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<td>4</td>
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<td>5</td>
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<td>UE parameter 1 PARP(83)</td>
<td>0.5</td>
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<td>0.5</td>
<td>0.5</td>
<td>1.6</td>
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<tr>
<td>UE parameter 2 PARP(84)</td>
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<td>0.4</td>
<td>0.4</td>
<td>n/a</td>
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<tr>
<td>UE total gg fraction PARP(86)</td>
<td>0.95</td>
<td>0.66</td>
<td>1.0</td>
<td>1.0</td>
<td>n/a</td>
</tr>
<tr>
<td>ISR infrared cutoff PARP(62)</td>
<td>1.0</td>
<td>1.0</td>
<td>1.25</td>
<td>1.25</td>
<td>( = PARP(82) )</td>
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<tr>
<td>ISR renormalisation scale prefactor PARP(64)</td>
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<td>1.0</td>
<td>0.2</td>
<td>0.2</td>
<td>1.0</td>
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<tr>
<td>ISR $Q^2_{\text{max}}$ factor PARP(67)</td>
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<td>1.0</td>
<td>2.5</td>
<td>2.5</td>
<td>n/a</td>
</tr>
<tr>
<td>ISR infrared regularisation scheme MSTP(70)</td>
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<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>2</td>
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<tr>
<td>ISR FSR off ISR scheme MSTP(72)</td>
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<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>0</td>
</tr>
<tr>
<td>FSR model MSTJ(41)</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>(pT – ordered)</td>
</tr>
<tr>
<td>FSR $\Delta QCD$ PARP(81)</td>
<td>0.29</td>
<td>0.29</td>
<td>0.29</td>
<td>0.29</td>
<td>0.14</td>
</tr>
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<td>BR colour scheme MSTP(89)</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>1</td>
</tr>
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<td>BR composite x enhancement factor PARP(79)</td>
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<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>2</td>
</tr>
<tr>
<td>BR primordial $k_T$ width $&lt;k_T&gt;$ PARP(91)</td>
<td>1.0</td>
<td>1.0</td>
<td>2.1</td>
<td>2.1</td>
<td>n/a</td>
</tr>
<tr>
<td>BR primordial $k_T$ UV cutoff PARP(93)</td>
<td>5.0</td>
<td>5.0</td>
<td>15.0</td>
<td>15.0</td>
<td>5.0</td>
</tr>
<tr>
<td>CR model MSTP(95)</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>6</td>
</tr>
<tr>
<td>CR strength $\xi_R$ PARP(78)</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>0.2</td>
</tr>
<tr>
<td>CR gg fraction (old model) PARP(85)</td>
<td>0.9</td>
<td>0.33</td>
<td>1.0</td>
<td>1.0</td>
<td>n/a</td>
</tr>
</tbody>
</table>

Table 3.1: **Pythia** parameters, divided into main categories: UE (underlying event), ISR (initial state radiation), FSR (final state radiation), BR (beam remnants), and CR (colour reconnections). The UE reference energy for all models is PARP(89)=1800GeV, and all dimensionful parameters are given in units of GeV.
New UE Model in Herwig++ [M.Bähr]

- Fully working model included from Herwig++ 2.1 onwards. It allows for the simulation of multiple partonic interactions (MPI) to describe the underlying event (UE). Same functionality and physics than JIMMY.
- Overview available in *Herwig++ Physics and Manual* [arXiv:0803.0883]
- A more detailed description including tuning results: [arXiv:0803.3633, MB, S. Gieseke and M. H. Seymour]

Description of Tevatron UE truly satisfactory

Similar predictions with respect to the Pythia tunes at the LHC (constant cut-offs)

Soft interactions (minimum-bias) will be available in the next release.
Low-pT QCD - Minimum Bias - Trigger

dN/d\eta_{\eta=0}: large uncertainty on LHC extrapolation

The study of MB events depends on:
+ Constraining QCD models at 14 TeV
+ Calibrating detectors and main physics tools

MB is defined by the trigger - usually Not Single Diffractive

\[ \sigma_{\text{tot}} = \sigma_{\text{Elastic}} + \sigma_{\text{SD}} + \sigma_{\text{DD}} + \sigma_{\text{HardCore}} \]
\[ (14 \text{ TeV}) \]
\[ \sim 20 \text{ mb} \quad \sim 15 \text{ mb} \quad \sim 10 \text{ mb} \quad \sim 55 \text{ mb} = \sim 100 \text{ mb} \]

Issues:
Keep as much inelastic
Reject beam/halo, beam/gas, empty or pile-up events (low or high luminosity)

ATLAS - MBTS

Accidental rate from noise must be suppressed to \( \sim \)Hz, limited by trigger output-rate of 100Hz

CMS - based on forward H-CAL towers

All events
+ OR -
+ AND -

[Livio Fano', ICHEP08]
CMS: Tracklets: Only pixel triplets down to 75 MeV!

Systematic: Trigger, feed-down, geom. acceptance, alg. efficiency

Diff. yields of identified $\pi^\pm$, $K^\pm$, $p/p$ together with Tsallis-function fits (inverse slope $T = 0.2$ GeV/c, high $p_T$ exponent $n = 7.2$)

Summary of systematic uncertainties:
- Track selection cuts: 2%
- Mis-estimate of secondaries: 1.5%
- Vertex reconstruction: 0.1%
- Mis-alignment: 6%
- Beam-gas & pile-up: 1%
- Particle composition: 2%
- Diffractive cross-sections: 0.1%
- Total: 6.9%

Good reconstruction quality

Charged hadrons

Charged pions
CMS Tracking performances

MB and Jet events
1 pb\(^{-1}\)

Efficiency and fake performances at the LHC start-up are recovered using APE (error to the hits taking into account alignment precision)

Ideal aligned detector
Misaligned + APE
Misaligned

The CMS tracking is optimized for \(P_T>900\) MeV

Seeding and tracking from 500 MeV is also possible with sufficient high efficiency (\(>70\%\)) and fakes under control (\(<2\%\))

Tracking from 500 MeV is used to enhance discriminative power of the UE observables in the transverse region
Charged jet instead of calorimetric:

+ access to low PT region
+ intrinsically free from pile up
+ better control of systematic effects at startup

**Figure 1**: Charged Jet performances. *Left*: $\Delta R = \sqrt{\Delta \phi + \Delta \eta}$ between the charged and the calorimetric leading jets. *Right*: charged jet response function ($P_T^{charged}/P_T^{calorimetric}$).
Jimmy Tune:
Charged Multiplicity OK, Softer PT spectrum

PyTHIA6.416 (CTEQ6II) parameters tuned to the UE:

- Results are comparable to those obtained with previous tunings.

- $<p_T>/N_{\text{chg}}$ has improved (requiring shorter strings and more connections to the hard scatter system).
Disentangle double-parton-scattering from bremsstrahlung

• No correlation (DPS) versus strong correlation  
Make use of different correlations between jet pairs

**AFS solution:**
• Study $\Delta \varphi$ between $\mathbf{p}_T(jet_1) - \mathbf{p}_T(jet_2)$ and $\mathbf{p}_T(jet_3) - \mathbf{p}_T(jet_4)$

**CDF solution:**
• Study $\Delta \varphi$ between $\mathbf{p}_T(jet_1) + \mathbf{p}_T(jet_2)$ and $\mathbf{p}_T(jet_3) + \mathbf{p}_T(jet_4)$  
(CDF nomenclature: $\Delta S$)
Generator-level analysis
• Combine $\gamma$ (MC truth) with 3 jets (Midpoint-Cone, $R=0.7$) where $\Delta R_{ij} > 0.8$
• assign jets following UA2/CDF method (minimize imbalance)

$pp \rightarrow \gamma j + X$

**Pythia 6.413 $p_T > 20$ GeV/c**
- DWT (CMS default)
- $S0$ (→ colour reconnection)

**Pythia 8.1 $p_T > 20$ GeV/c**
- default (physics ~ Pythia 6.4 S0)
- multiple parton-parton interactions switched off
  + simulate two hard jets
  (in addition to $\gamma j$)

**Herwig 6.510 $p_T > 20$ GeV/c**
- soft underlying event
- Jimmy 4.2
LHC: Prediction for the 3rd jet PT in 3jet + $\gamma$ events

MPI vs radiation: generator level results

Comparison between the reference selection cuts: LHC vs Tevatron

- **Photon:**
  - $|\eta| < 1.1$ (CMS: $|\eta| < 2.5$)
  - $E_T > 16$ GeV (CMS HLT thresholds: $E_T > 10, ..., 40$ GeV)

- **Jets:**
  - $|\eta| < 4.2$ (CMS: $|\eta| < 5$)
  - $E_T > 5$ GeV (CMS: $E_T > 30$ GeV)
  - exactly at least three jets
  - two-lowest $E_T$-jets: $E_T < 7$ GeV

(F.Bechtel)
Need double-parton component to describe the data

→ Pythia and Herwig predictions for $p\bar{p} \rightarrow \gamma j + X$ agree
→ Next: Simulate $p\bar{p} \rightarrow jj + X$ to compare with CDF rates

Pythia 8.1
- physics ~ Pythia 6.4
Tune S0
Herwig++ 2.2
- MPI along the lines of Jimmy

Distributions normalized to luminosity
LHC: Quoting MPIs with paired MiniJets

\[ N = \text{Number of jet pairs for different } \eta, P_T^{\text{track}}, P_T^{\text{jet}} \]

- \( P_T^{\text{jet}} > 2 \text{ GeV} \)
  - Tracks: \( P_T > 0.5 \), \( |\eta| < 2 \)
  - Tracks: \( P_T > 0.9 \), \( |\eta| < 2 \)

- \( P_T^{\text{jet}} > 6 \text{ GeV} \)
  - Tracks: \( P_T > 0.5 \), \( |\eta| < 2 \)

- \( P_T^{\text{jet}} > 10 \text{ GeV} \)
  - Tracks: \( P_T > 0.5 \), \( |\eta| < 2 \)

- \( P_T^{\text{jet}} > 20 \text{ GeV} \)
  - Tracks: \( P_T > 0.5 \), \( |\eta| < 2 \)

\( N \) deeply depends on PT-jet and acceptance

DESY, September 16 2008

Paolo Bartalini (NTU)
Study of multi-parton interactions using dijet photoproduction

- Study of multi-parton interactions in photoproduction by measuring the charged-particle multiplicity in dijet events $p_T^{jet} > 5$ GeV and $-1.5 < \eta^{jet}_{lab} < 1.5$
- Kinematic region: $Q^2 < 0.01$ GeV$^2$, $0.3 < y < 0.65$
- Jets are reconstructed using the $k_T$-cluster algorithm in the LAB frame: leading jet at $\phi = 180^\circ$
- Measurement of $\langle N_{charged} \rangle$ in four regions: “Toward”, “Away”, “High-activity” and “Low-activity”

Comparison to PYTHIA with/without MI in two regions in $x^\gamma_{obs}$:

- resolved-photon $x^\gamma_{obs} < 0.7$
- direct-photon $x^\gamma_{obs} > 0.7$

J Terrón (Madrid) Philadelphia, ICHEP 2008

See also [L. Marti, HERA/LHC - May08]
Study of multi-parton interactions using dijet photoproduction

- **Direct-photon:** reasonably well described by PYTHIA with parton showers and no MI
- **Resolved-photon:** excess observed in the data with respect to PYTHIA without MI
  → inclusion of multi-parton interactions describes the data well

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J Terrón (Madrid)  
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See also [L. Marti, HERA/LHC - May08]
**UE in Hard Diffractive Topologies**

Single diffraction (SD) | Double Pomeron exchange (DPE)

\[
p \rightarrow x \rightarrow p_1, p_2
\]

**Scale given by** \(X\) \(\rightarrow\) **Study** \(UE(M_X)\)

**MPI** in diffractive events are strongly suppressed

The **Beam Remnant** component is also strongly suppressed  
(at least in the hemispheres with surviving protons)

\(\rightarrow\) **Comparing with corresponding not diffractive topologies may allow to better disentangle the different UE components**  
\(\rightarrow\) **Optimize LRG definition**
Interplays Between Multiple Interactions and Hard Diffraction at the LHC

- **Handle on soft multiple parton-parton interactions in hard diffractive events**
  - Breaking of factorization in hard diffraction
    - Survival probability of protons and LRGs $\sim e^{-<N_{int}>}$

Where $<N_{int}> = \frac{\sigma_{parton-parton}}{\sigma_{inel proton-proton}}$

<table>
<thead>
<tr>
<th>[R.Field]</th>
<th>$\sigma_{parton-parton}$ at 1.96 TeV</th>
<th>$\sigma_{parton-parton}$ at 14 TeV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tune A</td>
<td>309.7 mb</td>
<td>484.0 mb</td>
</tr>
<tr>
<td>Tune DW</td>
<td>351.7 mb</td>
<td>549.2 mb</td>
</tr>
<tr>
<td>Tune DWT</td>
<td>351.7 mb</td>
<td>829.1 mb</td>
</tr>
</tbody>
</table>

~ 80 mb

Our goal would be to give a more “concrete” meaning to the $\sigma_{parton-parton}$ ($P_T$) numbers for example through the mini-jet pair counting method

- **On the other hand there’s a well consolidated experimental methodology to measure hard diffraction from data**
  - Extrapolate the dPDFs measured at HERA and Tevatron and compare the resulting cross section predictions for the LHC with the cross sections measured at the LHC
  - Measure $F_2^D$, via e.g. dijet production, in SD and DPE and compare