Measurement of 3-jet differential cross section

\[ \frac{d\sigma}{dM_{3\text{jet}}} \text{ in } pp \bar{p} \text{ collisions} \]

at \( \sqrt{s} = 1.96 \text{ TeV} \)

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Motivation

- 3-jet events are directly sensitive to the pQCD matrix elements of $\mathcal{O}(\alpha^3_s)$
- Similar sensitivity to the PDFs as in 1-, 2-jet cross section measurements
- Precision phenomenology
  - Can be used for simultaneous determination of $\alpha_s$ and PDFs
- Search for physics beyond the SM
Detector & Event

- Liquid Ar/U Calorimeter
  - Jet triggering
  - Three R=0.7 cone jets
  - Jet midpoint cone algorithm
- Silicon & Scintillating fiber tracking
  - Vertexion
  - JES corrections
- Muon system
  - Trigger efficiency studies
- 3-Level trigger system
0.7 fb\textsuperscript{-1} of data between 2004-2005

- Inclusive jet triggers with different $p_T$ thresholds
- In each $M_{3\text{jet}}$ bin chosen trigger fully efficient

- Particle-level jets from MC with MSTW2008LO PDFs to correct data for detector resolution
- Fast simulation parameterized from GEANT full detector simulation
  - Jet reconstruction efficiencies
  - Vertex misidentification
  - Resolution effects in jet $p_T$, angles
Events are triggered by the highest $p_T$ jet

Primary vertex within 50 cm of the center
- Vertex is required to have 3 tracks pointing to it

3 reconstructed $p_T$ ordered jets, $p_T^1 > 150$ GeV
- 3 inclusive rapidity measurements:
  - $|y| < 0.8$, $|y| < 1.6$, $|y| < 2.4$, $p_T^3 > 40$ GeV

2 high $p_T$ measurements:
- $p_T^3 > 70$ GeV, $p_T^3 > 100$ GeV, $|y| < 2.4$
Jet $p_T$ are corrected for:
- Calorimeter response
- Energy flow through the jet cone
- Additional interactions and pile-up

Absolute energy calibration from data:
- $Z \rightarrow ee$ events
- $p_T$ imbalance in $\gamma +$ jet events in $|y| < 0.4$
- Di-jet events for higher $|y|$, $p_T$

Total correction 50-20% for jet $p_T$ 50-400 GeV

Corrections due to different fractional contributions of gluon and quark jets (2-4%)

$M_{3\text{jet}}$ is calculated using the corrected jet $p_T$
Resolution Effects

- Trigger efficiency for each bin 99%
- Vertex acceptance 91.4-92.9%
- JetID (shower shape, etc.) requirement efficiency 97.5%
- Jet misID < 0.1%
- Detector resolution for jet $p_T$ 15-10% for 40-400 GeV jets
- Generated events reweighted to match $M_{3\text{jet}}, |y|, p_T$
- $M_{3\text{jet}}$ binning chosen as twice the resolution
## Systematics

65 independent sources of systematic uncertainty

<table>
<thead>
<tr>
<th>Source</th>
<th>Value</th>
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<th>Value</th>
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<tbody>
<tr>
<td>Jet energy calibration</td>
<td>±10-30%</td>
<td>Reweighting of gen. events</td>
<td>±2.5%</td>
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<tr>
<td>Luminosity</td>
<td>±6.1%</td>
<td>Trigger efficiency</td>
<td>±2%</td>
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<td>Jet $p_T$ resolution</td>
<td>±1-5%</td>
<td>Jet $\theta$ resolution</td>
<td>±1%</td>
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<tr>
<td>Systematic shifts in $</td>
<td>y</td>
<td>$</td>
<td>±3%</td>
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Differential Cross Section

\[ \frac{d\sigma_{3\text{jet}}}{dM_{3\text{jet}}} (\text{pb/TeV}) \]

- DØ
- pQCD from FASTNLO based of NLOJET++
- MSTW08NLO PDFs
- \( \alpha_s(M_Z) = 0.1202 \)
- Non-perturbative corrections from PYTHIA DW

Different PYTHIA tunes (A, BW, Z1, Perugia, Perugia hard tunes) affect the total corrections by less than 5%
Different PDFs with uncertainties

Data below theory by 4-15% but within $\mu_{r,f}$ variations

Scale variations affect prediction by +5-10% to -15-20%

CT10 ($\alpha_s(M_z) = 0.118$)

Published at 90% C.L., rescaled by 1/1.645 to 68% C.L.

30% higher at $M_{3\text{jet}} = 1.2$ TeV
More PDFs

- NNPDF ($\alpha_s(M_Z)=0.119$) agrees with MSTW08NLO within 4%
- HERAPDFv1.0 ($\alpha_s(M_Z)=0.1176$) is 15-20% below CT10
- ABKM09NLO ($\alpha_s(M_Z)=0.1179$) predict smallest cross section at high $\mathcal{M}_{3\text{jet}}$
X² test

- At world average ($\alpha_s(M_Z)=0.1184$) for all PDFs, lowest $X^2$ is at $\mu_r=\mu_f=\mu_0$
- Best agreement MSTW08NLO $\alpha_s(M_Z)=0.121$ with $X^2=59.5$
- NNPDFv2.1 at $\alpha_s(M_Z)=0.123$ close
- ABKM09NLO $\alpha_s(M_Z)=0.1179$ only 1 value
- HERAPDFv1.0, CT10 large $X^2$
- PDF sensitivity of 3-jet cross section data

- Experimental uncertainties with correlations
- Underlying event and hadronization uncertainties
  - $\frac{1}{2}$ the size of individual correction, independent
- PDF uncertainties, statistical uncertainties ignored
Conclusions

- First measurement of inclusive 3-jet differential cross section as a function of $M_{3\text{jet}}$ in the
- 5 scenarios, 3 rapidity regions, 3 requirements on $p_T$ of the 3rd jet
- Compared to pQCD in NLO in $\alpha_s$ and various PDF parametrizations
  - Computed $X^2$ for different scale choices and different $\alpha_s(M_Z)$ values
  - Best description of the data from MSTW2008NLO and NNPDFv2.1 PDF sets
    - Describe both the normalization and shape
  - ABKM09NLO reasonable description of the data, slightly different shape
  - HERAPDFv1.0 and CT10 predict different $M_{3\text{jet}}$ shape, poorer agreement with the data