Measurement of jet production with ATLAS and extraction of $\alpha_s$

Paul Laycock, on behalf of the ATLAS collaboration
The ATLAS Detector

- High precision silicon and micro-tube tracking
- Fine-granularity/longitudinally segmented calorimeter
- Air-core toroid muon spectrometer
Luminosity and Data Quality

- Data-taking successfully resumed in 2017
- Hoping to repeat the successes of 2016
Event Display

\[ m_{JJ} = 8.12 \text{ TeV} \]

Run: 305777
Event: 4144227629
2016-08-08 08:51:15 CEST
Inclusive Jet cross sections (8 TeV)

https://arxiv.org/pdf/1706.03192

- Differential measurements in $p_T$ and $y$
- Dominant uncertainty comes from jet energy calibration
Inclusive Jet cross sections (8 TeV)

- Large variations in NLO QCD predictions and Powheg
- Clear differences as a function of $p_T$ and $y$
Inclusive Jet cross sections (8 TeV)

- Large variations in NLO QCD predictions using different PDFs
- Generally reasonable agreement, but not possible to get a good $\chi^2$ for any PDF when combining all $y$ ranges
Inclusive Jet cross sections (8 TeV)

<table>
<thead>
<tr>
<th>$\chi^2$/ndf</th>
<th>$p_T^{\text{jet,max}}$</th>
<th>$R = 0.4$</th>
<th>$R = 0.6$</th>
<th>$p_T^{\text{jet}}$</th>
<th>$R = 0.4$</th>
<th>$R = 0.6$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$p_T &gt; 70$ GeV</td>
<td>CT14</td>
<td>349/171</td>
<td>398/171</td>
<td>340/171</td>
<td>392/171</td>
<td></td>
</tr>
<tr>
<td></td>
<td>HERAPDF2.0</td>
<td>415/171</td>
<td>424/171</td>
<td>405/171</td>
<td>418/171</td>
<td></td>
</tr>
<tr>
<td></td>
<td>NNPDF3.0</td>
<td>351/171</td>
<td>393/171</td>
<td>350/171</td>
<td>393/171</td>
<td></td>
</tr>
<tr>
<td></td>
<td>MMHT2014</td>
<td>356/171</td>
<td>400/171</td>
<td>354/171</td>
<td>399/171</td>
<td></td>
</tr>
<tr>
<td>$p_T &gt; 100$ GeV</td>
<td>CT14</td>
<td>321/159</td>
<td>360/159</td>
<td>313/159</td>
<td>356/159</td>
<td></td>
</tr>
<tr>
<td></td>
<td>HERAPDF2.0</td>
<td>385/159</td>
<td>374/159</td>
<td>377/159</td>
<td>370/159</td>
<td></td>
</tr>
<tr>
<td></td>
<td>NNPDF3.0</td>
<td>333/159</td>
<td>356/159</td>
<td>331/159</td>
<td>356/159</td>
<td></td>
</tr>
<tr>
<td></td>
<td>MMHT2014</td>
<td>335/159</td>
<td>364/159</td>
<td>333/159</td>
<td>362/159</td>
<td></td>
</tr>
<tr>
<td>$100 &lt; p_T &lt; 900$ GeV</td>
<td>CT14</td>
<td>272/134</td>
<td>306/134</td>
<td>262/134</td>
<td>301/134</td>
<td></td>
</tr>
<tr>
<td></td>
<td>HERAPDF2.0</td>
<td>350/134</td>
<td>331/134</td>
<td>340/134</td>
<td>326/134</td>
<td></td>
</tr>
<tr>
<td></td>
<td>NNPDF3.0</td>
<td>289/134</td>
<td>300/134</td>
<td>285/134</td>
<td>299/134</td>
<td></td>
</tr>
<tr>
<td></td>
<td>MMHT2014</td>
<td>292/134</td>
<td>311/134</td>
<td>284/134</td>
<td>308/134</td>
<td></td>
</tr>
<tr>
<td>$100 &lt; p_T &lt; 400$ GeV</td>
<td>CT14</td>
<td>128/72</td>
<td>149/72</td>
<td>118/72</td>
<td>145/72</td>
<td></td>
</tr>
<tr>
<td></td>
<td>HERAPDF2.0</td>
<td>148/72</td>
<td>175/72</td>
<td>141/72</td>
<td>170/72</td>
<td></td>
</tr>
<tr>
<td></td>
<td>NNPDF3.0</td>
<td>119/72</td>
<td>141/72</td>
<td>115/72</td>
<td>139/72</td>
<td></td>
</tr>
<tr>
<td></td>
<td>MMHT2014</td>
<td>132/72</td>
<td>143/72</td>
<td>122/72</td>
<td>140/72</td>
<td></td>
</tr>
</tbody>
</table>

- Not possible to get a good $\chi^2$ for any PDF when combining all $y$ ranges
- Various cuts on $p_T$ attempted
- Corresponding p-values are all $<< 10^{-3}$
Inclusive Jet cross sections (13 TeV)

• Large variations in NLO QCD predictions using different PDFs
• Generally reasonable agreement

Inclusive Jet cross sections (13 TeV)

- Large variations in NLO QCD predictions using different PDFs
- Generally reasonable agreement, except ABM12 at low $y$
Transverse energy-energy correlations

- Energy-energy correlations measured in pp
- Energy-weighted angular distributions of hadron pairs, in analogy with $e^+e^-$

$$\frac{1}{\sigma} \frac{d\Sigma}{d(cos \phi)} = \frac{1}{\sigma} \sum_{ij} \int \frac{d\sigma}{dx_{Ti}dx_{Tj}d(cos \phi)} x_{Ti}x_{Tj}d{x_{Ti}}d{x_{Tj}}$$

- $H_{T2} = \Sigma p_T$ (two highest $p_T$ jets)

- TEEC measured differentially in $H_{T2}$
- Good agreement with NLO and Pythia
Transverse energy-energy correlations

- Energy-energy correlations measured in pp
- Energy-weighted angular distributions of hadron pairs, in analogy with $e^+ e^-$

$$\frac{1}{\sigma} \frac{d\Sigma}{d(cos \phi)} = \frac{1}{\sigma} \sum_{ij} \int \frac{d\sigma}{dx_{Ti}, dx_{Tj}, d(cos \phi)} x_{Ti}, x_{Tj} dx_{Ti}, dx_{Tj}$$

- $H_{T2} = \Sigma p_T$ (two highest $p_T$ jets)

- TEEC measured differentially in $H_{T2}$
- Good agreement with NLO and Pythia
Asymmetry of TEEC (ATEEC)

- Energy-energy correlations measured in pp
- Energy-weighted angular distributions of hadron pairs, in analogy with $e^+e^-$

\[
\frac{1}{\sigma} \frac{d\Sigma^{\text{asym}}}{d(\cos \phi)} = \frac{1}{\sigma} \frac{d\Sigma}{d(\cos \phi)} \bigg|_\phi - \frac{1}{\sigma} \frac{d\Sigma}{d(\cos \phi)} \bigg|_{\pi-\phi}
\]

- ATEEC measured differentially in $H_{T2}$
- Good agreement with NLO and Pythia
Asymmetry of TEEC (ATEEC)

- Energy-energy correlations measured in pp
- Energy-weighted angular distributions of hadron pairs, in analogy with $e^+e^-$

\[
\frac{1}{\sigma} \frac{d\Sigma^{\text{asym}}}{d(\cos \phi)} = \frac{1}{\sigma} \frac{d\Sigma}{d(\cos \phi)} \bigg|_{\phi} - \frac{1}{\sigma} \frac{d\Sigma}{d(\cos \phi)} \bigg|_{\pi-\phi}
\]

- ATEEC measured differentially in $H_{T_2}$
- Good agreement with NLO and Pythia

ATLAS Preliminary  $\sqrt{s} = 8$ TeV; 20.2 fb$^{-1}$

- $N$-particle jets R = 0.4
- $\alpha_s^{\text{partia}}(m_Z) = 0.1203$
- 900 GeV < $H_{T_2}$ < 1000 GeV

Data / Theory
\( \alpha_s \) from TEEC

- Extract \( \alpha_s \) at different scales given by \( H_{T2} \)
- Minimise \( \chi^2 \) function:

\[
\chi^2(\alpha_s, \tilde{\lambda}) = \sum_i \frac{(x_i - F_i(\alpha_s, \tilde{\lambda}))^2}{\Delta x_i^2 + \Delta \tau_i^2} + \sum_k \lambda_k^2
\]

\[
\alpha_s(m_Z) = 0.1173 \pm 0.0010 \text{ (exp.)} \pm 0.0063 \pm 0.0020 \text{ (scale)} \pm 0.0017 \text{ (PDF)} \pm 0.0002 \text{ (NPC)}
\]

- Good agreement with existing measurements
- Dominant uncertainty is scale uncertainty
Summary

• Data-taking successfully resumed on ATLAS
• Inclusive jet cross sections at 8 and 13 TeV
  • Data show sensitivity to PDFs
  • Reasonable agreement with QCD predictions
  • Not possible to get a good $\chi^2$ for and PDF over all rapidity

• (A)TEEC measured at 8 TeV
  • Good agreement with NLO and Pythia
• Extraction of strong coupling constant
  • Good agreement with existing measurements
  • Dominant uncertainty is scale uncertainty

QCD is alive and well at the LHC