The strong coupling constant and PDFs

Esteban Fullana Torregrosa\(^{(1)}\)

\(^{(1)}\) on behalf of the CMS and ATLAS collaborations
The strong coupling constant

\[ \alpha_s(Q) \]

**CMS Preliminary**
- CMS Incl. Jets: \( \alpha_s(M_Z) = 0.1185^{+0.0065}_{-0.0041} \)
- CMS R_{32}
- CMS tt cross section
- CMS 3-Jet mass
- CMS Incl. Jets

**Graphical Elements:**
- **D0 inclusive jets**
- **D0 angular correlation**
- **H1**
- **ZEUS**

**References:**
- CMS-PAS-SMP-12-028

**Instruments:**
- **HERA**
- **Tevatron**
- **LHC**

**Text:**
- Physics at the LHC and beyond, Quy-Nhon, August 2014
- Johannes Gutenberg-Universität Mainz

**Date:**
- Monday, August 11, 2014
Physics at the LHC and beyond, Quy-Nhon, August 2014

**CMS and ATLAS 7TeV Jet measurements**

**ATLAS Inclusive Jet 7 TeV**
Soon to be published

**ATLAS Dijet 7 TeV**
JHEP05(2014)059

**ATLAS 3 Jet 7 TeV**
ATLAS-CONF-2014-045

**CMS Inclusive Jet 7 TeV**

**CMS Dijet 7 TeV**

**CMS 3 Jet 7 TeV**
SMP-12-027-pas

---

**Physics at the LHC and beyond, Quy-Nhon, August 2014**

---

Johannes Gutenberg-Universität Mainz

---

Monday, August 11, 2014
CMS and ATLAS 7TeV Jet measurements

**ATLAS Inclusive Jet 7 TeV**

soon to be published

**ATLAS Preliminary**

- $|y| < 0.5 \times 10^0$
- $0.5 \leq |y| < 1.0 \times 10^{-3}$
- $1.0 \leq |y| < 1.5 \times 10^{-6}$
- $1.5 \leq |y| < 2.0 \times 10^{-9}$
- $2.0 \leq |y| < 2.5 \times 10^{-12}$
- $2.5 \leq |y| < 3.0 \times 10^{-15}$

$\int L \ dt = 4.5 \ \text{fb}^{-1}$, $\sqrt{s} = 7 \ \text{TeV}$

**CMS 3 Jet 7 TeV**

**ATLAS Dijet 7 TeV**

**ATLAS 3 Jet 7 TeV**

ATLAS-CONF-2014-045

**CMS 3 Jet 7 TeV**

SMP-12-027-pas

Physics at the LHC and beyond, Quy-Nhon, August 2014

Johannes Gutenberg-Universität Mainz
CMS and ATLAS 7TeV Jet measurements

ATLAS Inclusive Jet 7 TeV
soon to be published

ATLAS Dijet 7 TeV

ATLAS Preliminary

ATLAS 3 Jet 7 TeV

Outstanding work of both accelerator and detector operations

CMS 3 Jet 7 TeV
SMP-12-027-pas

ATLAS-CONF-2014-045

ATLAS Inclusive Jet 7 TeV

ATLAS 3 Jet 7 TeV

CMS 3 Jet 7 TeV

Johannes Gutenberg-Universität Mainz

Physics at the LHC and beyond, Quy-Nhon, August 2014
CMS and ATLAS 7 TeV Jet measurements

ATLAS Inclusive Jet 7 TeV
soon to be published

ATLAS Dijet 7 TeV

ATLAS Preliminary
- |y| < 0.5 (×10^0)
- 0.5 ≤ |y| < 1.0 (×10^-1)
- 1.0 ≤ |y| < 1.5 (×10^-2)
- 1.5 ≤ |y| < 2.0 (×10^-3)
- 2.0 ≤ |y| < 2.5 (×10^-4)
- 2.5 ≤ |y| < 3.0 (×10^-5)

NLOQCD (CT10) × non-pertem. corr.

Johannes Gutenberg-Universität Mainz

Physics at the LHC and beyond, Quy-Nhon, August 2014
CMS and ATLAS 7 TeV Jet measurements

ATLAS Inclusive Jet 7 TeV

soon to be published

ATLAS Preliminary

- $|y| < 0.5$ ($\times 10^6$)
- $0.5 \leq |y| < 1.0$ ($\times 10^5$)
- $1.0 \leq |y| < 1.5$ ($\times 10^4$)
- $1.5 \leq |y| < 2.0$ ($\times 10^3$)
- $2.0 \leq |y| < 2.5$ ($\times 10^2$)
- $2.5 \leq |y| < 3.0$ ($\times 10^1$)

CMS = 7 TeV

$\sqrt{s} = 7$ TeV

$L dt = 4.5$ fb^{-1}

Physics at the LHC and beyond, Quy-Nhon, August 2014

Johannes Gutenberg-Universität Mainz
Jet measurements and their uncertainty

Theory:
- QCD NLO : NLOJet++
  - Interfaced to APPLGRID
- Corrected by non-perturbative effects (UE and Hadronization)
- Electroweak corrections applied
  - (although not used for PDF fits)

Data:
- Event and jet quality selection
- Several triggers in the full eff. range
- Unfolded using IDS
- Cross-checks on: PU, detector effects, quality criteria, unfolding bias
- Uncertainty dominated by the jet energy scale (see the CMS measurement example)
Sensitivity of Jet measurements to PDFs

Inclusive Jet Cross section
Theoretical Uncertainty
(done by the ATLAS collaboration)

CMS 7 TeV Inclusive full 2011 dataset

Relative uncertainty [%]

Total Scale variation PDF

NLO pQCD (NLOJET++, CT10)
\( \sqrt{s} = 7 \text{ TeV} \)
anti-\( k_t \) jets, \( R=0.6 \)
\( \left| y \right| < 0.5 \)

jet measurements are sensitive to PDFs

PDF uncertainty dominates
**gluon quark PDF results**

*gluon pdf parametrization (HERA Fitter):*

\[ xg(x) = A_g x^{B_g}(1 - x)^{C_g} - A'_g x^{B'_g}(1 - x)^{C'_g} \]

---

**both ATLAS and CMS jets measurements prefer harder gluon PDF**
# Measurements used for PDF fits

<table>
<thead>
<tr>
<th>Observable:</th>
<th>Jets</th>
<th>$A_w(W \rightarrow \mu\nu)$</th>
<th>$W+c$</th>
<th>$W,Z$</th>
<th>High-Mass Drell Yan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitivity:</td>
<td>g and u quark PDF</td>
<td>$(u_v - d_v) / (u_v + d + 2u_{sea})$</td>
<td>s PDF</td>
<td>s PDF</td>
<td>quarks at high $Q^2$</td>
</tr>
<tr>
<td>ATLAS</td>
<td>7 TeV: inc. (<em>) , $m_{jj}$, $m_{3j}$ (</em>)</td>
<td>7 TeV</td>
<td>7 TeV (2010)</td>
<td>7 TeV</td>
<td></td>
</tr>
<tr>
<td>CMS</td>
<td>7 TeV: inc., $m_{jj}$, $m_{3j}$</td>
<td>7 TeV hep-ex/1312.6283</td>
<td>7 TeV JHEP 02 (2014) 013</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(*) Still preliminary
valence quark PDF results using $W$ asymmetry

hep-ex/1312.6283; (submitted to Phys. Rev. D)

The muon charged asymmetry in $W$-boson production imposes strong constraints on the valence-quark distributions
The strange-quark PDF has been determined by ATLAS indirectly with W/Z production and directly through W+c. CMS has done the same directly determination of sPDF the W+c channel.

\[ Q^2 = 1.9 \text{ GeV}^2 \]

\[ R_s = \frac{(s + s)}{(u + d)} \]

\[ x \cdot s = \frac{(s + s)}{(u + d)} \]

\[ \text{ATLAS \ JHEP05(2014)068} \]

\[ Q^2 = 1.90 \text{ GeV}^2 \]

\[ \text{HERAPDF1.5 + ATLAS Wc-jet/WD(*) data} \]

\[ \text{ATLAS-epWZ12} \]

\[ \text{ATLAS NLO free-s fit} \]

\[ \text{exp. unc.} \]

\[ \text{model unc.} \]

\[ \text{parametrization unc.} \]

\[ \text{only experimental uncertainty} \]
New inputs for PDFs

CMS inclusive jets @ 8 TeV
\(|y| < 0.5\)

CMS dijet @ 8 TeV

ATLAS 3jet @ 7 TeV

Once the new results get consolidated we will have a much better insight of the gluon PDF and \(\alpha_s\)

Physics at the LHC and beyond, Quy-Nhon, August 2014
in preparation for run 2

- Jet data is providing a deeper insight of the gluon PDF
  - the full 7 TeV analysis for CMS/ATLAS are or will be published soon, and the 8 TeV ones are coming
- JES uncertainty dominates jet physics measurements uncertainty
  - Better JES requires less PU
- Disentangle the role of EWC, NNLO and gluon pdf is a key in run 2
- Not mention in the talk but Photon analysis also show potential for PDF determination
  - A better insight of the theoretical calculations is needed
- Updates on measurements on W/Z measurements also have potential impact on PDFs
Wanderer, your footsteps are the road, and nothing more; wanderer, there is no road, the road is made by walking. By walking one makes the road, and upon glancing behind one sees the path that never will be trod again. Wanderer, there is no road--Only wakes upon the sea.

A. Machado, Campos de Castilla
BU
Outline

• ATLAS and CMS measurements relevant to PDFs and $\alpha_s$
  • Jets, W/Z, W+c
• Newest $\alpha_s$ determinations
• Newest PDF extraction
• Future prospects
Sensitivity of Jet measurements to $\alpha_s$

Both CMS and ATLAS jet measurements have been used to probe the running of $\alpha_s$ to the highest energy scales

no deviations from RGE is found

Physics at the LHC and beyond, Quy-Nhon, August 2014
Sensitivity of Jet measurements to $\alpha_s$ determination

World average (2014)
$\alpha_s(M_Z)= 0.1185 \pm 0.0006$ (0.5%)

CMS Most recent: inclusive jet (5%)
$\alpha_s(M_Z) = 0.1185 \pm 0.0019(\text{exp}) \pm 0.0028(\text{PDF})$
$\pm 0.0004(\text{NP}) \pm 0.0022$ (scale)

H1 most recent $\alpha_s$ extraction from inclusive and multijet cross-section. Best precision is reached from fit to normalized multijet cross sections:

$\alpha_s = 0.1165 \pm 0.0008(\text{exp}) \pm 0.0038(\text{PDF, theo})$

The current Zeus one is:

$\alpha_s(M_Z) = 0.1207 \pm 0.0014(\text{stat.})^{+0.0035}_{-0.0033}(\text{exp.})^{+0.0022}_{-0.0023}(\text{th.})$

The current Zeus one is:


Physics at the LHC and beyond, Quy-Nhon, August 2014

2 determinations using ATLAS data

4 determinations using CMS data

https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSMP