ATLAS Results / Requests related to PDFs/xFitter

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Outline

1. Motivation
2. Ongoing analyses
3. Other measurements
4. Requests to xFitter
5. Summary

Motivations

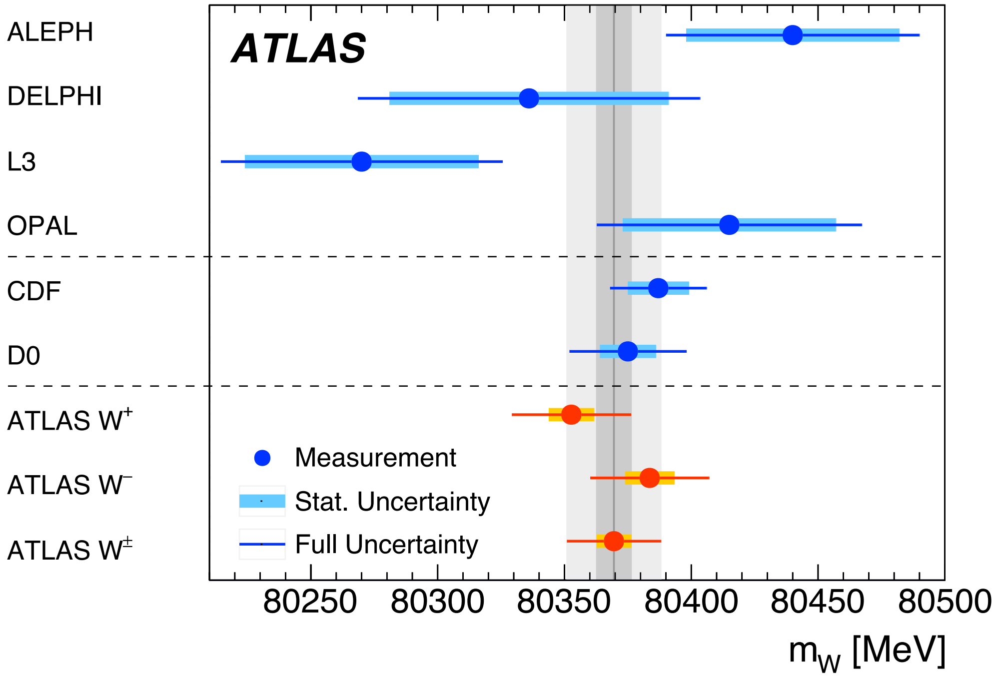
PDF uncertainties

- the dominant uncertainty for essentially all precision measurements at the LHC, e.g.
  - W boson mass
  - Weak mixing angle

- a limiting factor even for BSM searches

W Boson Mass and PDF Uncertainty

Eur. Phys. J. C 78 (2018) 110



The precision of ATLAS matches the best single experiment measurement

PDFs uncertainty is the dominant systematic uncertainty source

	Stat. Unc.	Muon Unc.	Elec. Unc.	Recoil Unc.	Bckg. Unc.	QCD Unc.	EW Unc.	PDF Unc.	Total Unc.
W^+	8.9	6.6	8.2	3.1	5.5	8.4	5.4	14.6	23.4
W^-	9.7	7.2	7.8	3.3	6.6	8.3	5.3	13.6	23.4
$W^\pm$	6.8	6.6	6.4	2.9	4.5	8.3	5.5	9.2	18.5

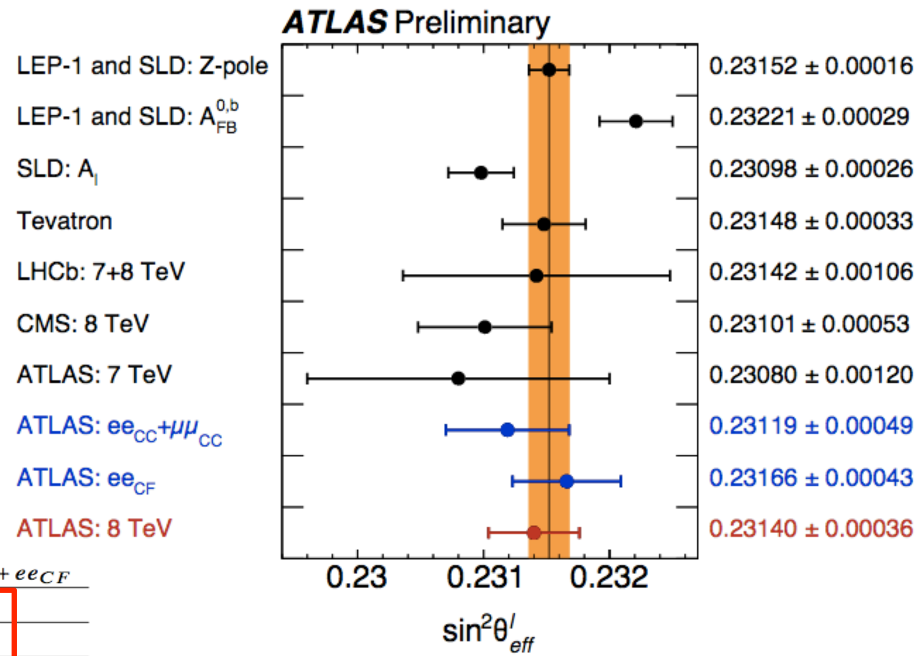
[MeV]

$CT10_{NNLO}$ vs. CT14 & MMHT14

Weak Mixing Angle and PDFs

ATLAS-CONF-2018-037

To be compared with
0.23150 ± 0.00006 (global EW fit)



Channel	ee_{CC}	$\mu\mu_{CC}$	ee_{CF}	$ee_{CC}+\mu\mu_{CC}$	$ee_{CC}+\mu\mu_{CC}+ee_{CF}$
Central value	0.23148	0.23123	0.23166	0.23119	0.23140
	Uncertainties				
Total	68	59	43	49	36
Stat.	48	40	29	31	21
Syst.	48	44	32	38	29
	Uncertainties in measurements				
PDF (meas.)	8	9	7	6	4
p_T^Z modelling	0	0	7	0	5
Lepton scale	4	4	4	4	3
Lepton resolution	6	1	2	2	1
Lepton efficiency	11	3	3	2	4
Electron charge misidentification	2	0	1	1	< 1
Muon sagitta bias	0	5	0	1	2
Background	1	2	1	1	2
MC. stat.	25	22	18	16	12
	Uncertainties in predictions				
PDF (predictions)	37	35	22	33	24
QCD scales	6	8	9	5	6
EW corrections	3	3	3	3	3

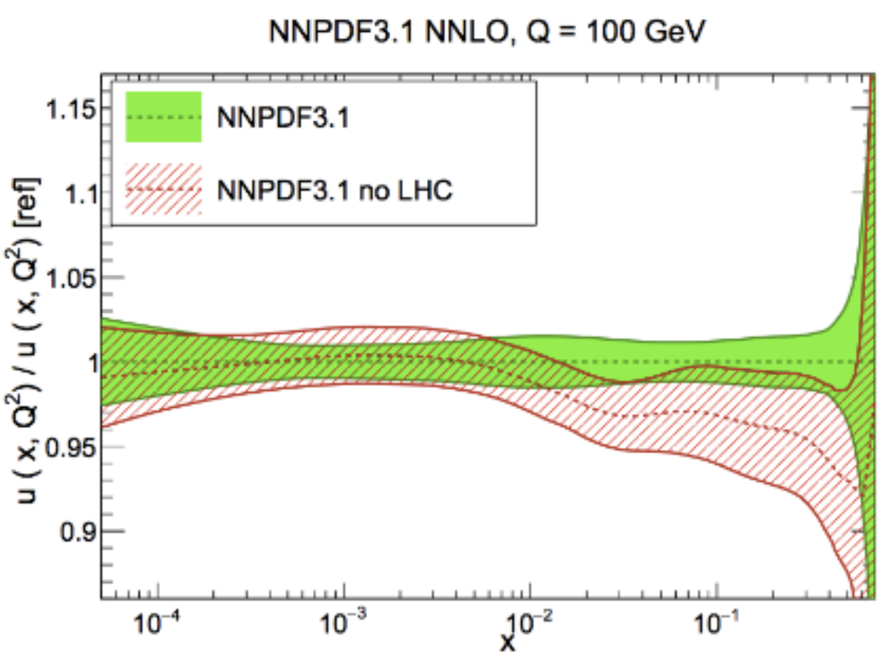
MMHT14

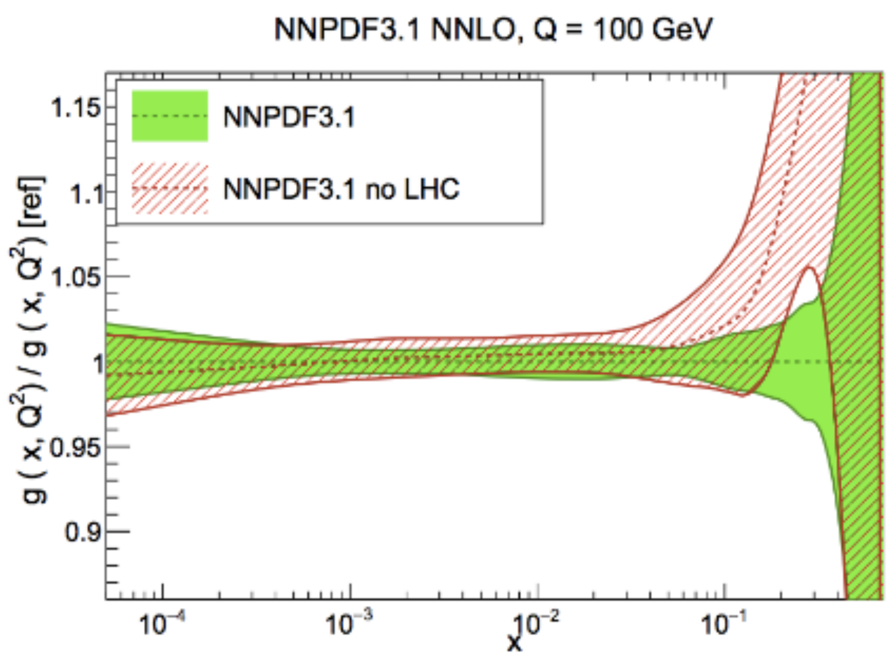
Comparable precision with other experiments

PDFs uncertainty is by far the dominant systematic uncertainty source

Impact of LHC Run-1 data on PDFs

1902.04070





- Around the Higgs boson mass, the uncertainty on the PDFs is reduced to a few %
- The uncertainty at large x is still large → need further improvement

ATLAS Results/Analyses using xFitter

- Previous publications:
  - QCD analysis W-lv Z-ll & strange sea density, 1203.4051 → **ATLAS-epWZ12**
  - High mass DY at 8 TeV, 1606.01736
  - W and Z inclusive cross section 2011, 1612.03016 → **ATLAS-epWZ16**
  - ttbar and Z xsection ratios, 1612.03636
  - XS ttbar lepton differential 8 TeV, 1709.09407

- Ongoing analyses [focus of the talk]:
  - Determination of the parton distributions functions of the proton from ATLAS measurements of differential W and Z/y* boson and ttbar cross sections, ATL-PHYS-PUB-2018-017 → **ATLASepWZtop18**
  - First ATLAS QCD analysis of W/(Z)+jets
  - Simultaneous fit of PDFs and weak mixing angle to Z3D 8 TeV

ATLASepWZtop18 Fit (1)

ATL-PHYS-PUB-2018-017

- Input data:
  - HERA ep
  - ATLAS W/Z inclusive 7 TeV
  - ATLAS ttbar lepton+jet (p_T^l, m_{ttbar}) + dilepton (y_{ttbar})
- Theoretical framework
  - xFitter
  - DIS ep NNLO, u_F=u_R=Q
  - Inclusive W/Z NNLO QCD + NLO EW (APPLGRID+K-factors), scale: m_{ll} (Z)/m_W(W)
  - ttbar NNLO lepton+jet (FastNLO grids), dilepton (APPLGRID+K-factors), scale: $m_{\mathrm{T}}/2 \quad \text{with} \quad m_{\mathrm{T}} = \sqrt{m_t^2 + p_{\mathrm{T}}^2}$ for p_T^l and $H_{\mathrm{T}}/4 \quad \text{with} \quad H_{\mathrm{T}} = \sqrt{m_t^2 + p_{\mathrm{T}}^{t2}} + \sqrt{m_t^2 + p_{\mathrm{T}}^{\bar{t}2}}$ for m_{ttbar}, y_{ttbar}
- PDF parameterisation

$$xq_i(x) = A_i x^{B_i}(1-x)^{C_i} P_i(x)$$

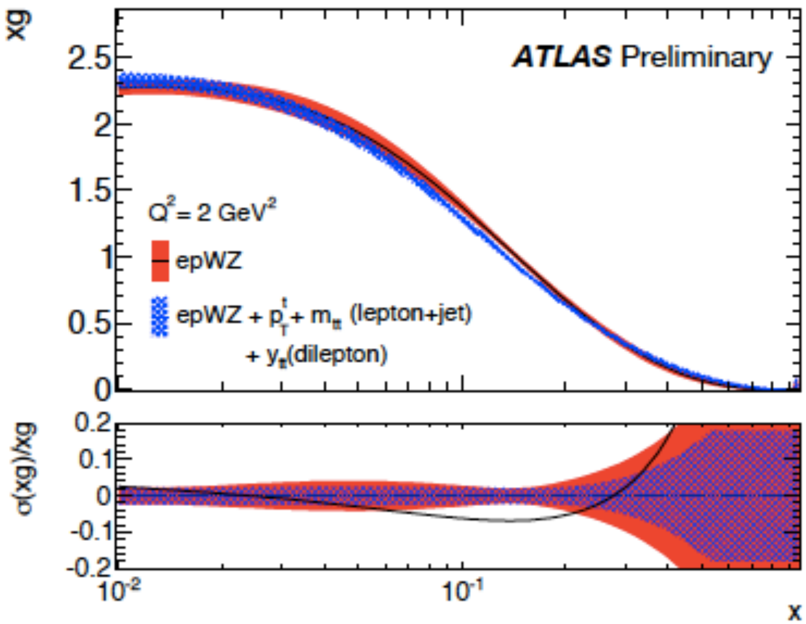
$$xg(x) = A_g x^{B_g}(1-x)^{C_g} P_g(x) - A'_g x^{B'_g}(1-x)^{C'_g}$$

$$\text{with} \quad P_i(x) = (1 + D_i x + E_i x^2) e^{F_i x}$$

ATLASepWZtop18 Fit (2)

		lepton+jets p_T^t, m_{tt} and dilepton y_{tt} spectra
total χ^2/NDF		1253.8 / 1061
Partial χ^2/NDP	HERA	1149 / 1016
Partial χ^2/NDP	ATLAS $W, Z/\gamma^*$	78.9 / 55
Partial χ^2/NDP	ATLAS lepton+jets p_T^t, m_{tt}	16.0 / 15
Partial χ^2/NDP	ATLAS dilepton y_{tt}	5.4 / 5

ATL-PHYS-PUB-2018-017

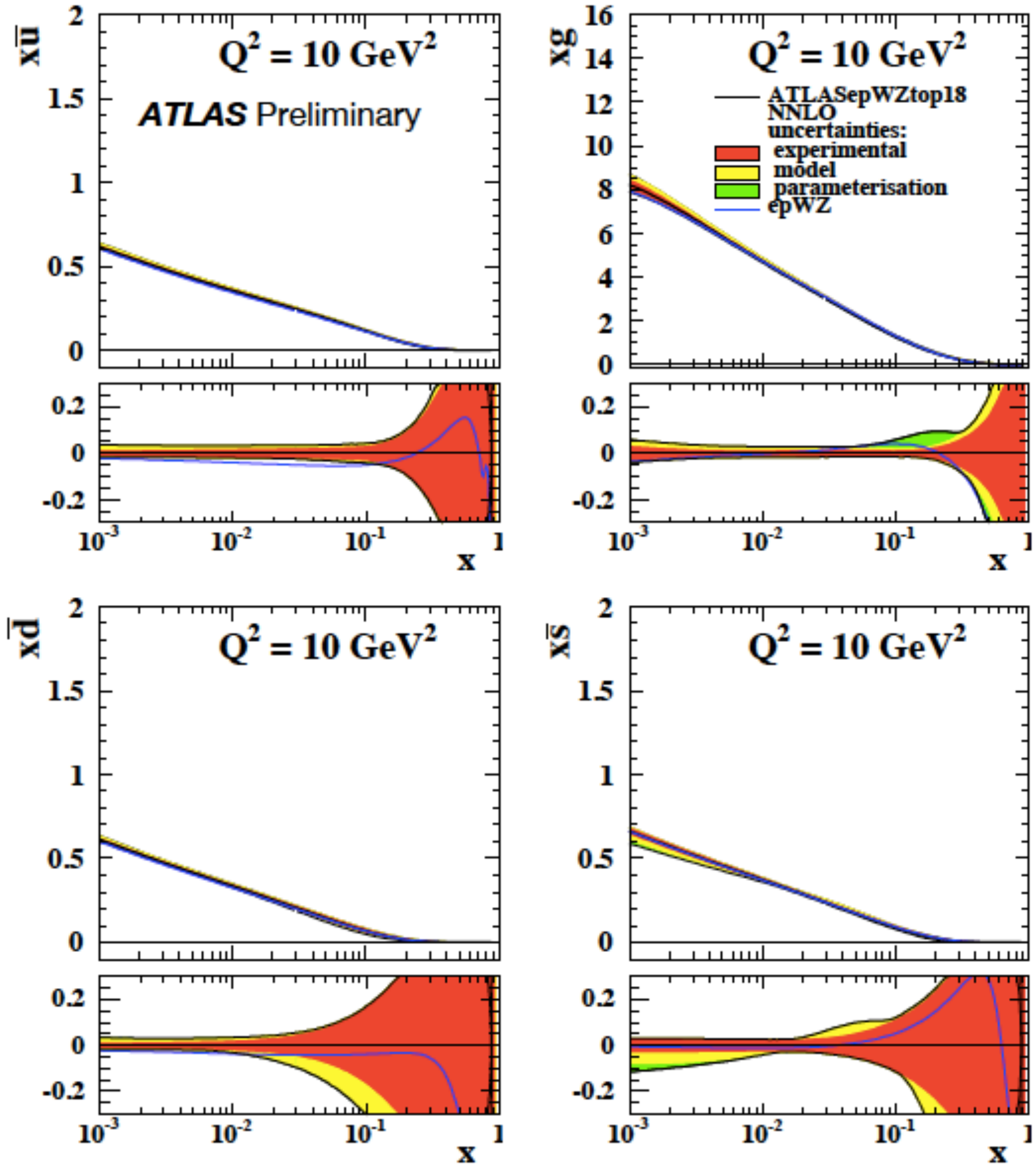


Good partial chi2 values for top data sets

Harder gluon density at high x

Improved experimental uncertainty in particular at high x

ATLASepWZtop18 Fit (3)



ATL-PHYS-PUB-2018-017

Other sea quarks compatible with epWZ PDF set

Somewhat softer strange quark at high x

Though all difference remain essentially within the new uncertainty bands

W+jets Cross Sections at 8 TeV (1)

Based on data at 8 TeV, 20.2 fb-1

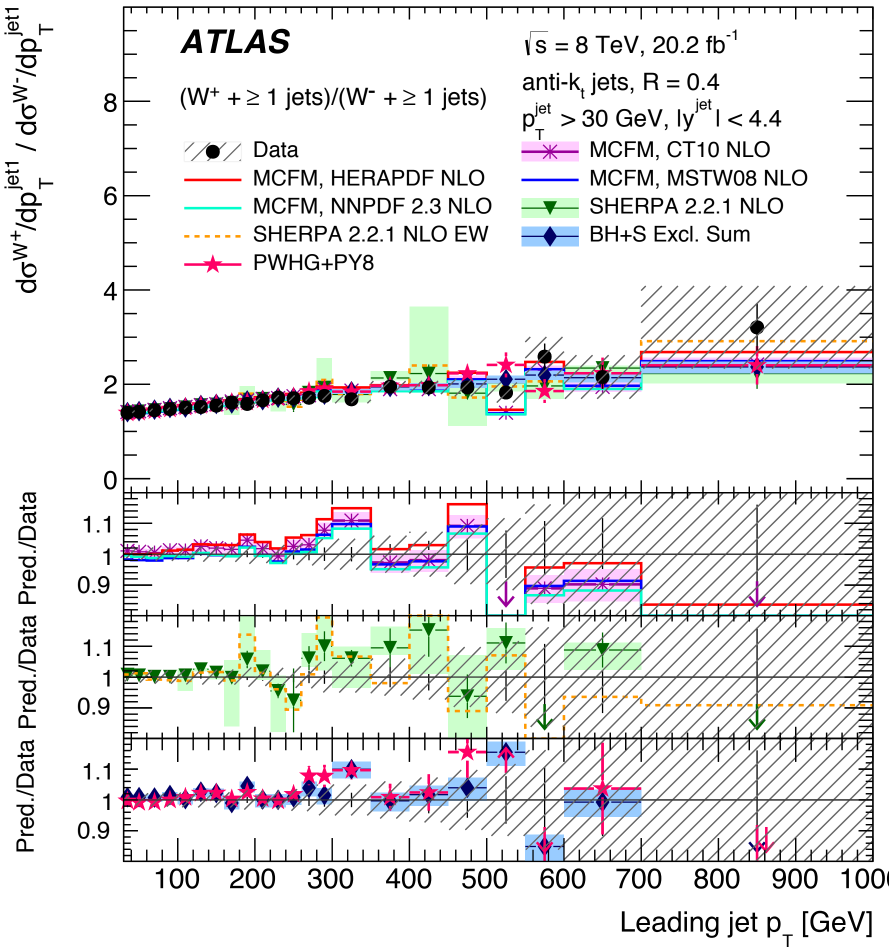
1711.03296

$W^{+/-}$+jets cross sections measured as functions of leading jet P_T, W p_T, H_T, and rapidity in the e+ν channel for events with at least one or two jets

W^+/W^- cross section ratios have improved precision up to a factor 9

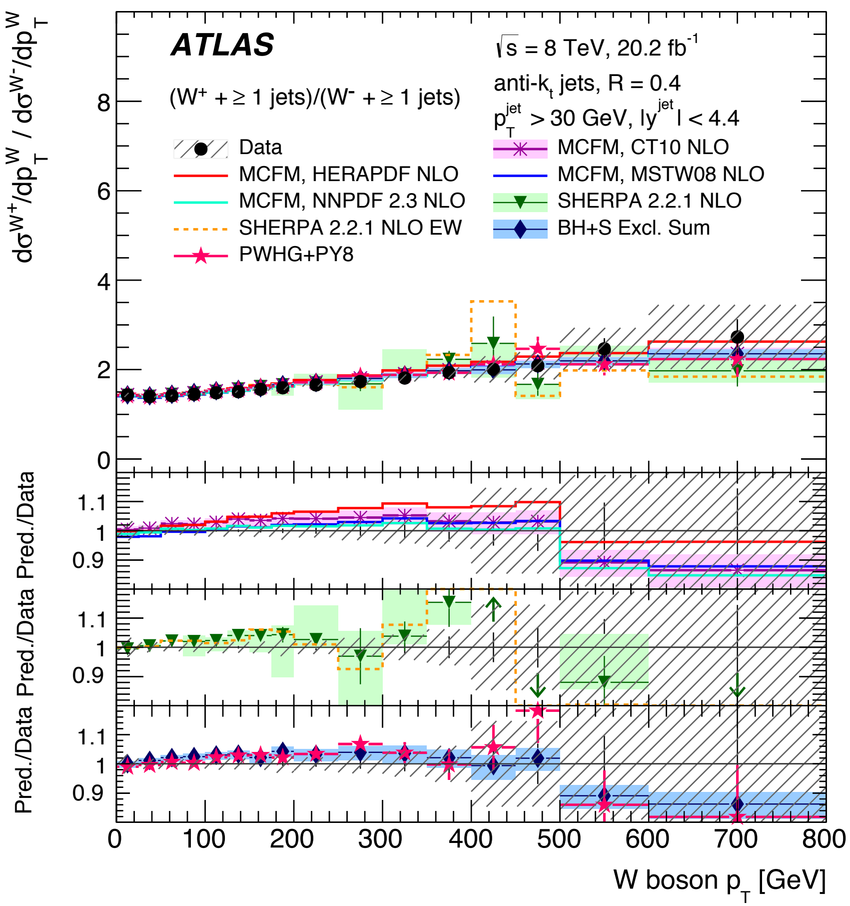
The measurements are compared with predictions from different PDF sets and event generators

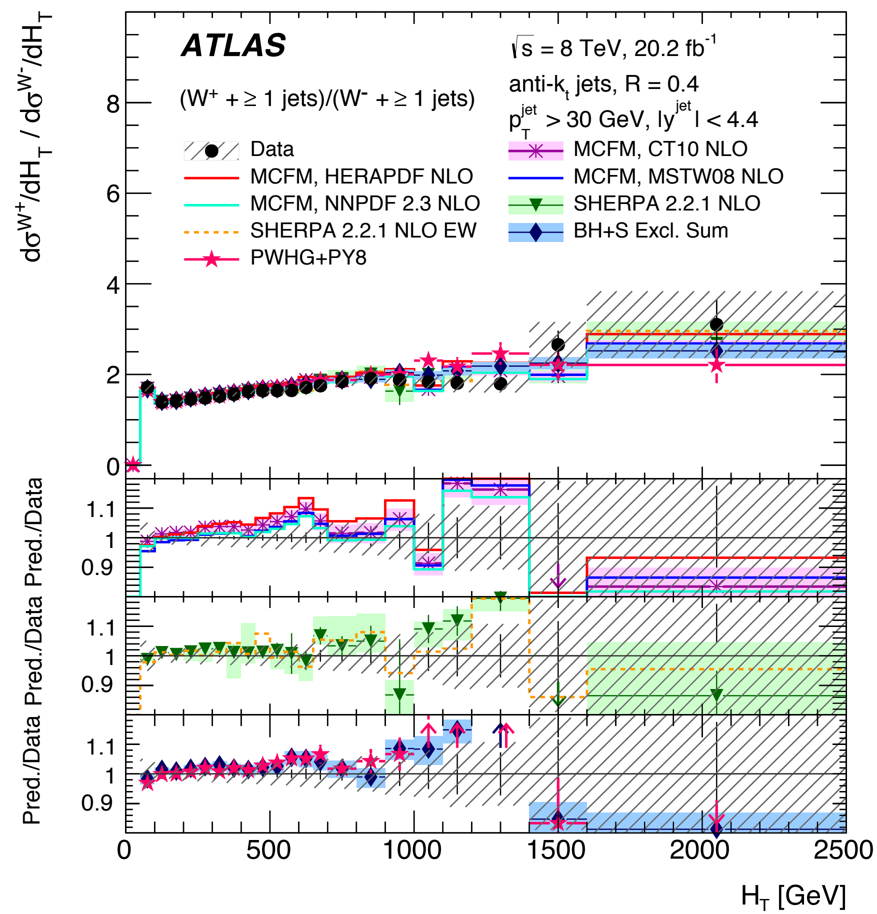
➔ Valuable measurements for constraining u/d-quark & g densities



W+jets Cross Sections at 8 TeV (2)

1711.03296





These data together with others are being used to produce a PDF set ATLASepWZVjet19

Mains results on high-x strange sea and dbar-ubar distributions

3D Cross-Section of DY Events at 8 TeV (1)

Also based on data at 8 TeV, 20.2 fb^{-1} 1710.05167

3d cross sections measured in the m_{ll} range 46-200 GeV, $|y_{ll}|<2.4$ for ee & $\mu\mu$

66-150 GeV, $|y_{ee}|<3.6$ for ee

The precision of combined ee and $\mu\mu$ cross sections better than 0.5%

The 3d cross section are sensitive to both PDFs and weak mixing angle

$$\frac{\mathrm{d}^3\sigma}{\mathrm{d}m_{\ell\ell}\mathrm{d}y_{\ell\ell}\mathrm{d}\cos\theta^*} = \frac{\pi\alpha^2}{3m_{\ell\ell}s}\sum_q P_q\left[f_q(x_1,Q^2)f_{\bar{q}}(x_2,Q^2) + (q \leftrightarrow \bar{q})\right]$$

This terms takes over at m_{ll}~m_Z

$$P_q = e_\ell^2 e_q^2(1+\cos^2\theta^*)$$

γ exchange

$$+e_\ell e_q\frac{2m_{\ell\ell}^2(m_{\ell\ell}^2-m_Z^2)}{\sin^2\theta_W\cos^2\theta_W\left[(m_{\ell\ell}^2-m_Z^2)^2+\Gamma_Z^2m_Z^2\right]}\left[v_\ell v_q(1+\cos^2\theta^*)+2a_\ell a_q\cos\theta^*\right]$$

γZ interf

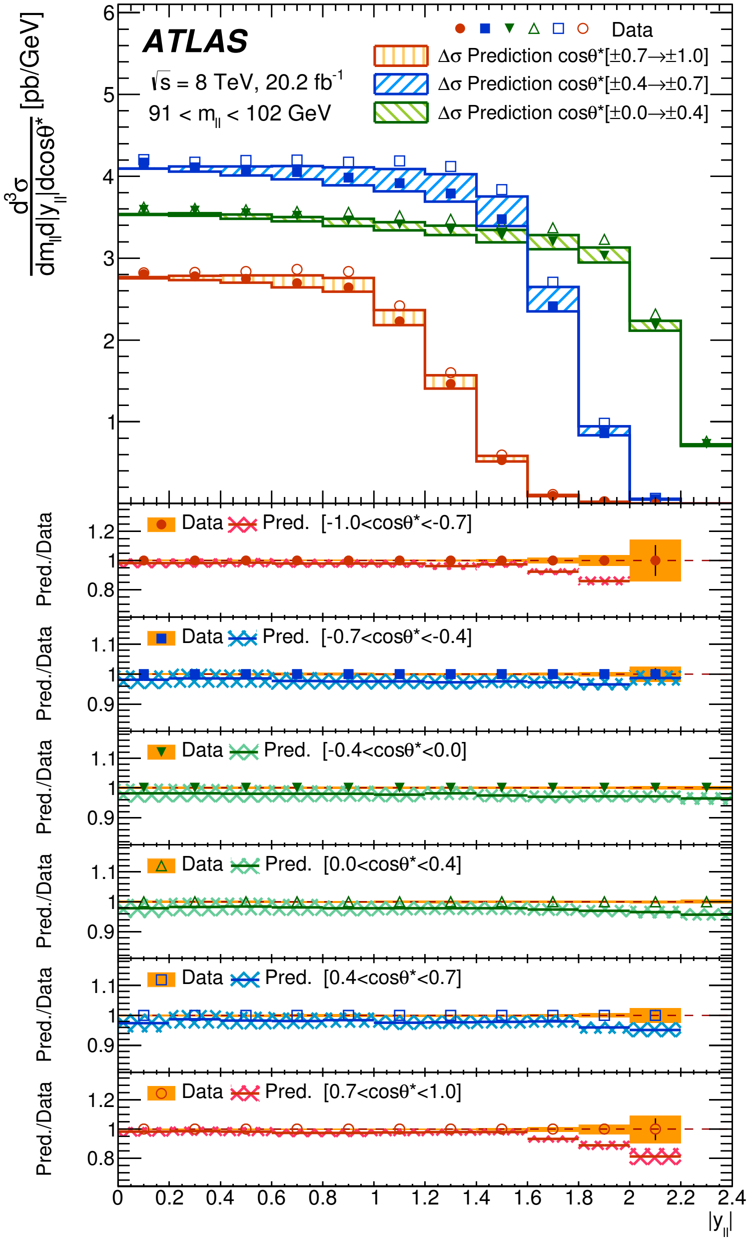
$$+\frac{m_{\ell\ell}^4}{\sin^4\theta_W\cos^4\theta_W\left[(m_{\ell\ell}^2-m_Z^2)^2+\Gamma_Z^2m_Z^2\right]}\left[(a_\ell^2+v_\ell^2)(a_q^2+v_q^2)(1+\cos^2\theta^*)+8a_\ell v_\ell a_q v_q\cos\theta^*\right]$$

Z exchange

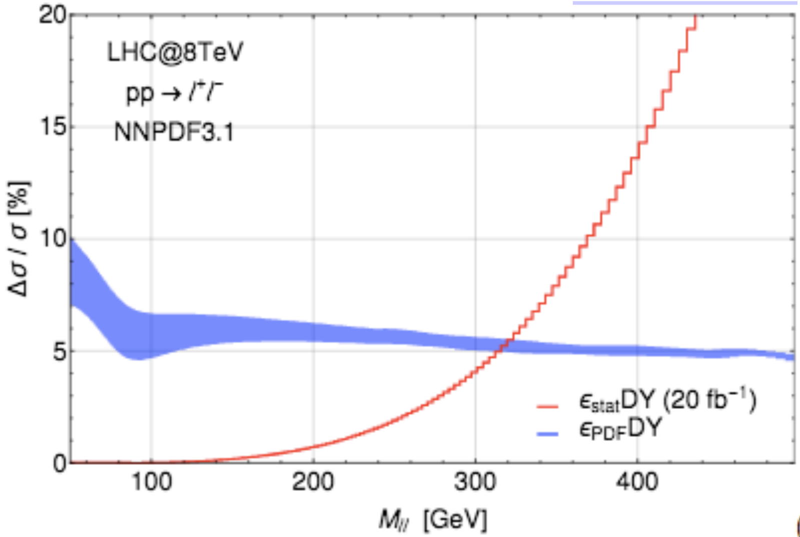
Dominant term inducing forward-backward asymmetry, A_{FB}

$$a_{\ell,q} = \frac{1}{2}I_{\ell,q}^3 \qquad v_{\ell,q} = I_{\ell,q}^3 - 2e_{\ell,q}\sin^2\theta_W$$

3D Cross-Section of DY Events at 8 TeV (2)



1712.06318



Z3D cross sections and A_{FB} are being used in a fit to determine simultaneously the PDFs and weak mixing angle

Other Measurements

- Data used by others e.g. for TMDs (1902.08474):
  - Z transverse momentum at 7 TeV, 1406.3660
  - Z pt and Zphistar with 2012 data, 1512.02192
- Data sensitive to α_s and gluon at high x:
  - Inclusive jets at 7 TeV in 2011, 1410.8857 [already used in global PDF fits]
  - Inclusive jets at 8 TeV, 1706.03192
  - Inclusive jets and dijets 2015 data, 1711.02692
- Data sensitive to quark flavour decomposition:
  - W and Z cross sections at 13 TeV, 1603.09222
  - 2015 pp 5.02 TeV W and Z, 1810.08424
  - W± and Z cross sections at 2.76 TeV, ongoing
  - Z inclusive jets pTy 8 TeV, ongoing
  - W cross section (and A_l) at 8TeV, ongoing
- Data sensitive to heavy flavours and gluon:
  - Photon + heavy flavour at 8 TeV, 1710.09560
  - Photon cross-section ratios at 8/13, 1901.10075

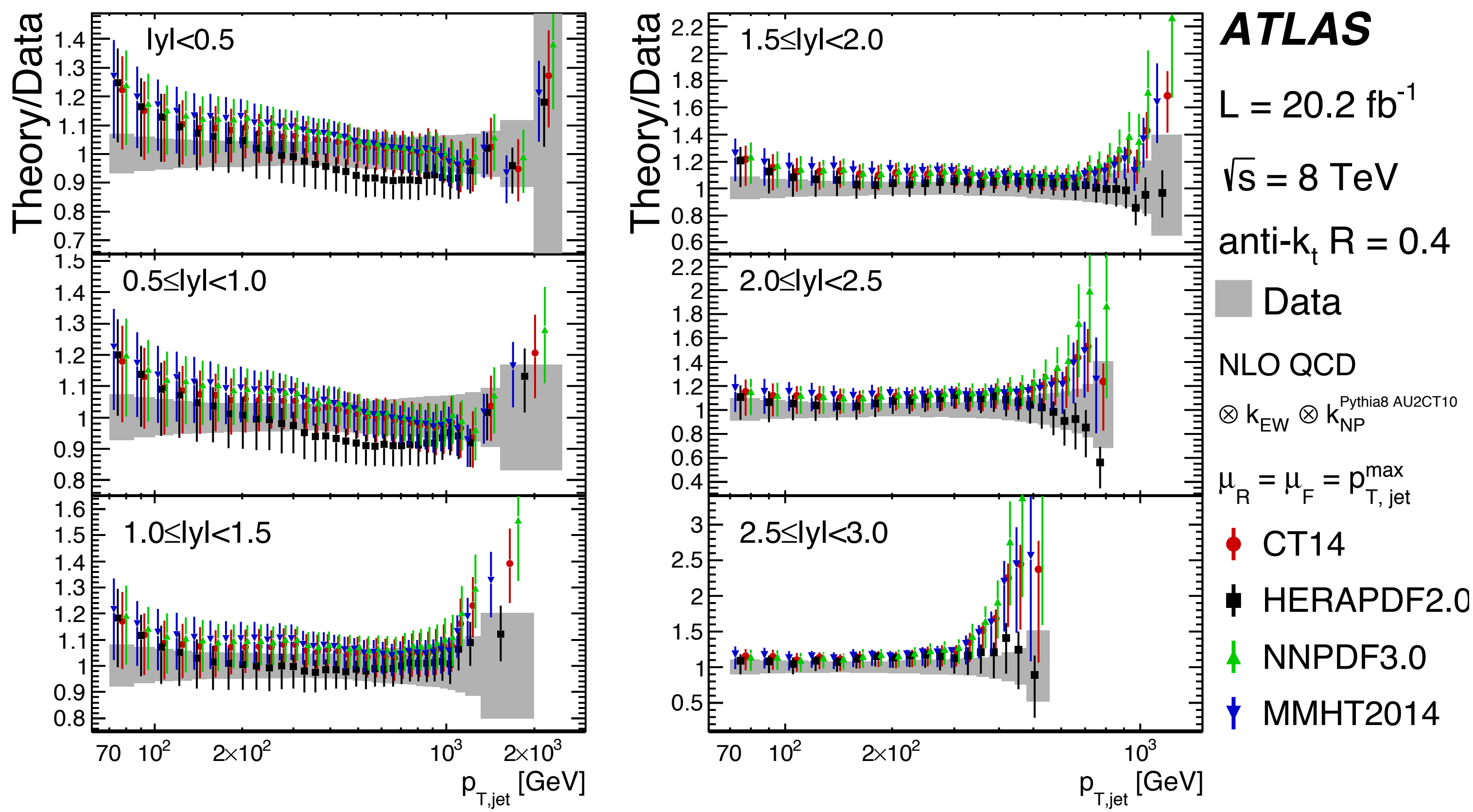
Inclusive jets at 8 TeV

Based on data at 8 TeV, 20.2 fb^{-1} 1706.03192

Measurement of double differential cross section with anti-kt R=0.4 or 0.6 in 6 rapidity bins between 0 and 3 for jet p_T between 70 GeV and 2.5 TeV

Theory/data ratio is shown here, the data itself varies over 9 order of magnitude

The data are sensitive to qg scattering @ p_T < 1 TeV qq scattering at higher p_T



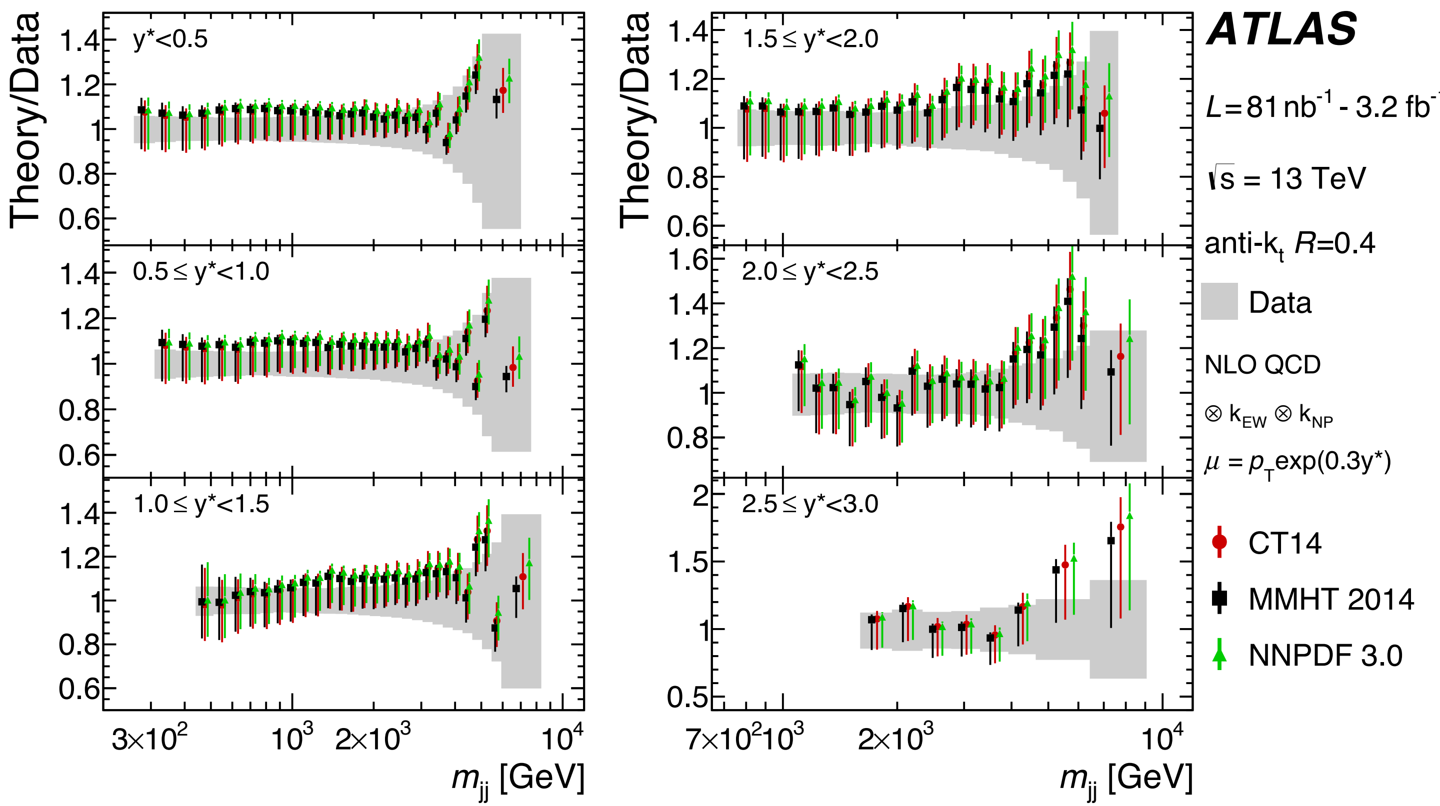
Inclusive jets and dijets 2015 data

1711.02692

Based on data at 8 TeV,
effective luminosity value varies from 81 nb^{-1} (prescaled low p_T jet) to 3.2 fb^{-1}

Measurement of inclusive and dijet differential cross section with anti-kt R=0.4 in 6 rapidity bins between 0 and 3 for inclusive jet p_T between 100 GeV and 3.5 TeV and dijet mass between 300 GeV and 9 TeV

Dijet theory/ data ratio is shown here as an example (scale error dominates the theory uncertainty)



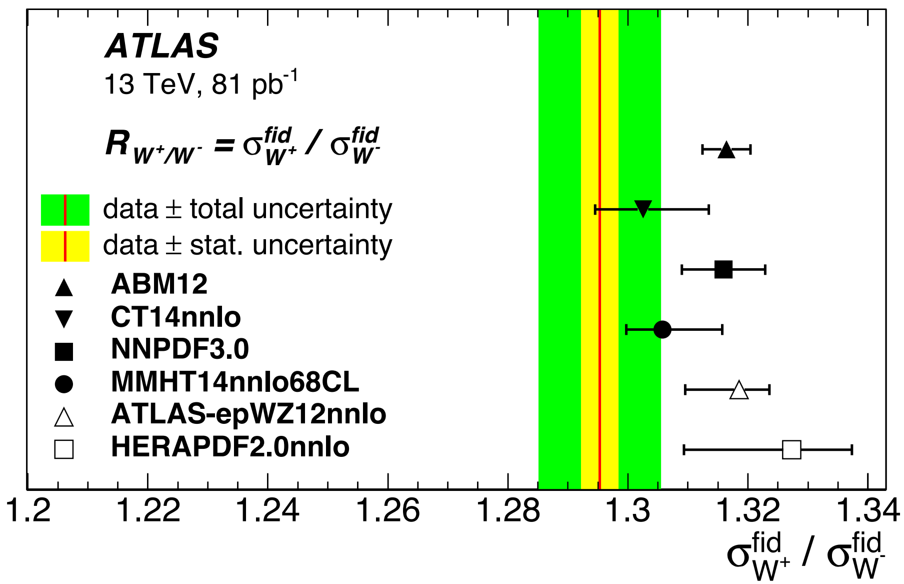
W and Z cross sections at 13 TeV

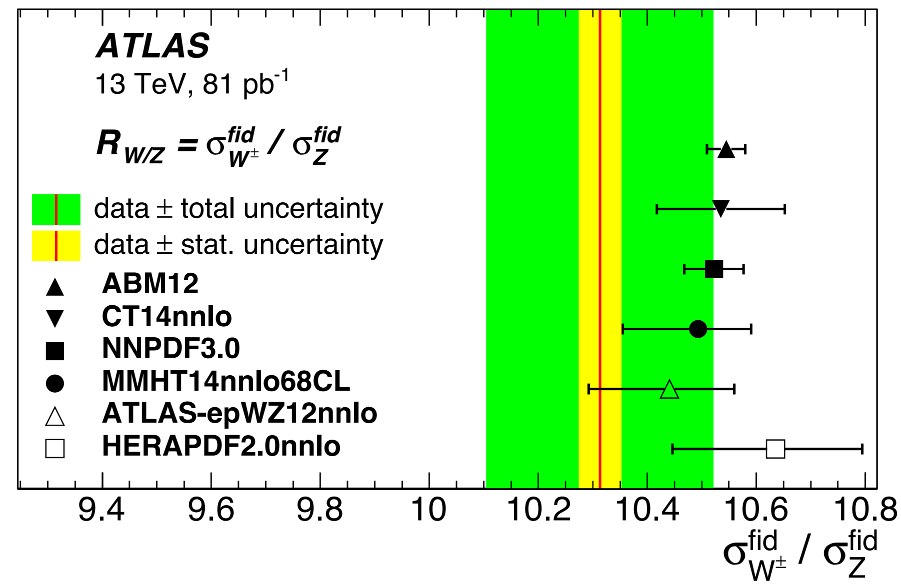
1603.09222

Small data set at 13 TeV, 81 pb^{-1}

Measurements of fiducial W, Z cross sections and their ratios. W^+/W^- cross section ratio has a precision of 0.8%

The measurements are compared with predictions of NNLO QCD + NLO EW



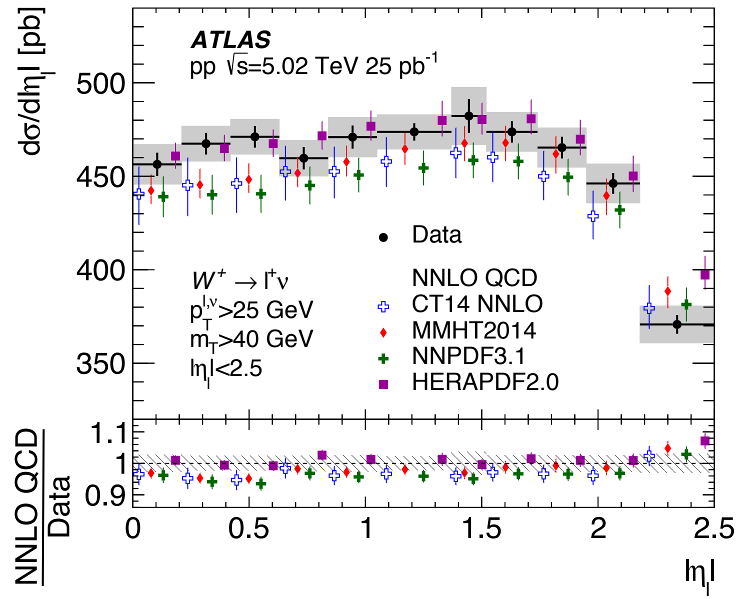


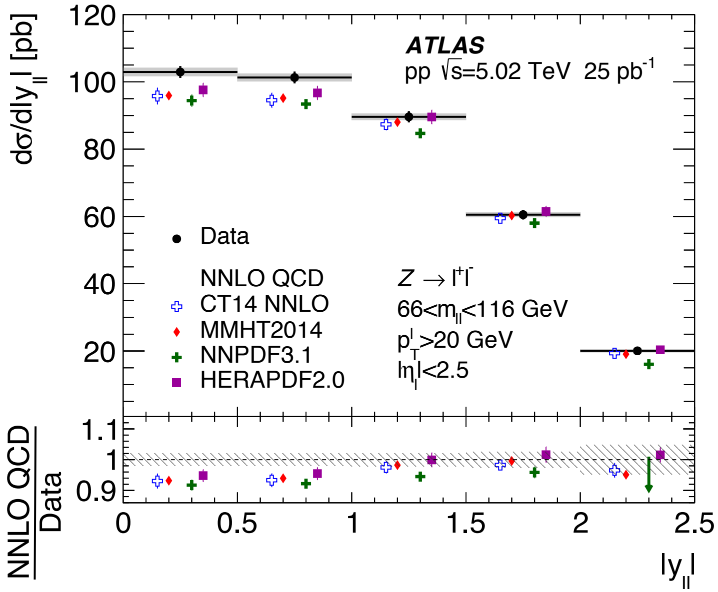
2015 pp 5.02 TeV W and Z

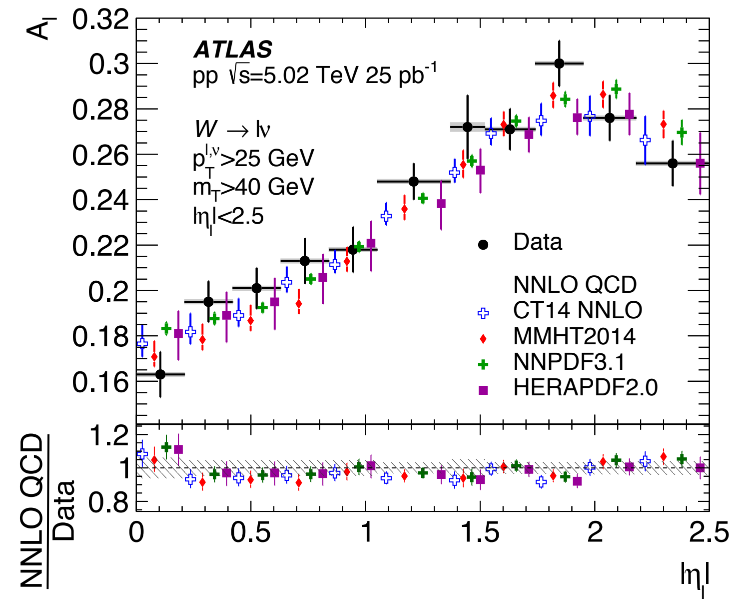
1810.08424

Small data set at 5.02 TeV, 25 pb^{-1}

Measurements of differential W, Z cross section vs rapidity as well as W charge asymmetry







Photon + Heavy Flavor at 8 TeV

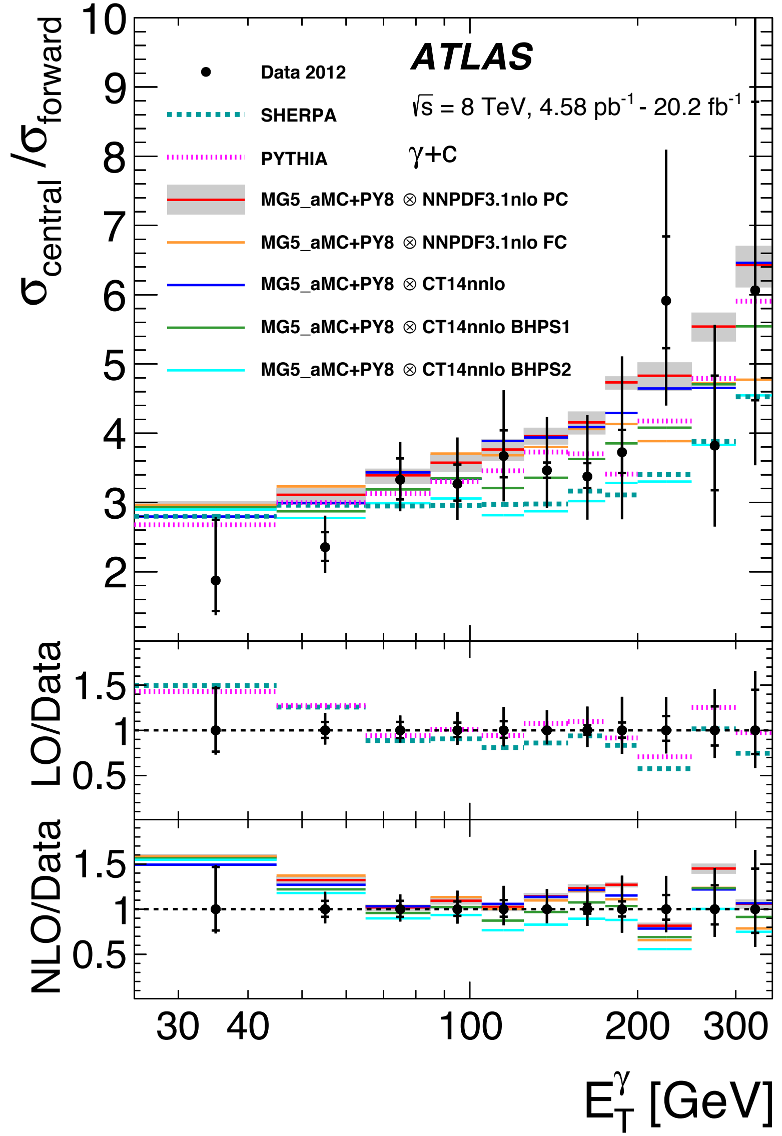
1710.09560

Based on data at 8 TeV with 4.58 pb^{-1} at E_T^γ trigger threshold of 20 GeV up to 20.2 fb^{-1} at 120 GeV

Central: E_T^γ: 25-400 GeV, $|\eta_\gamma|<1.37$
Forward: E_T^γ: 25-300GeV, $|\eta_\gamma|$: 1.56-2.37

Measurements of differential cross sections γ + b/c vs. E_T^γ in two eta regions as well as the ratio of central over forward cross section.

PC: perturbative charm
FC: fitted charm
BHPS: intrinsic charm model (1, 2 refer to different fractions)



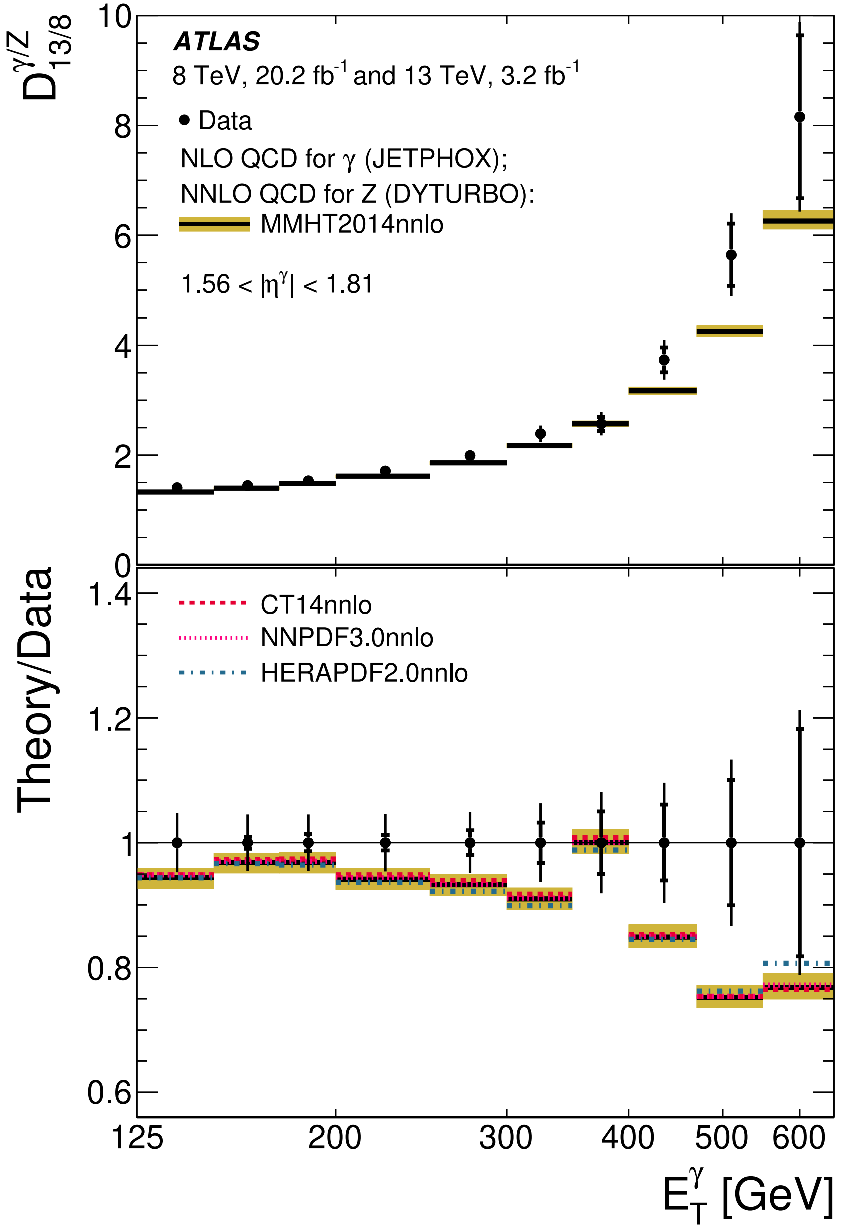
Photon Cross-Section Ratios at 8/13

1901.10075

Based on data samples:
8 TeV, 20.2 fb^{-1}
13 TeV, 3.2 fb^{-1}

Measurements of cross section ratios of inclusive isolated photon production of 13 TeV over 8 TeV as well as double ratios over fiducial cross section ratios of Z boson production in 4 photon pseudorapidity ranges for photon E_T of 125 - 1500 GeV

The dominant production process qg->qγ is sensitive to the gluon density



Requests to xFitter

- Is there a tool to convert a data set from HEPData to the format needed by xFitter [Juan Tafoya]?
- To have TOP++ interfaced to xFitter as an alternative to Hathor [Artur Trofymov started, was it done?]
- Any plan to interface with Ploughshare [Mark Sutton]?
- Is it possible to generate/share grid files?
- Extension to perform combined PDFs (QCD) + EW fits

Summary

- Early LHC Run-1 data already helped to constrain the PDFs
- A few fits are being performed mainly to improve the uncertainty of the gluon density and assess the behaviour of the strange quark
- More data are available to further constrain the PDFs as well as other (EW) parameters
- Important to have higher order QCD (and EW) calculations and (jet) production grid files ready in parallel