Recent ATLAS PDF-related results and xFitter users' wishlist

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xFitter External Meeting – DESY, Hamburg

26/02/2020

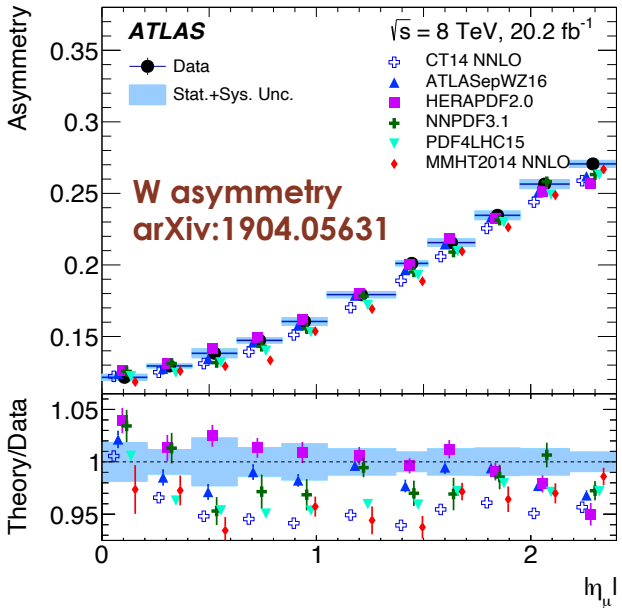
Overview of useful PDF-related analyses

- W and Z at 7 TeV 4.6 fb^{-1} precision measurement - arXiv:1612.03016
  - Provides the ATLASepWZ16 PDFs - **available in LHAPDF**
- Top data at 8 TeV - arXiv:1511.04716 and arXiv:1607.07281
  - Fit including W,Z and top data → ATLAS epWZtop18 - **available in LHAPDF**
  - ATLS-PHYS-PUB-2018-017
- W charge asymmetry at 8 TeV 20.2 fb^{-1} - arXiv:1904.05631
- Triple differential Z cross section (Z3D) at 8 TeV - arXiv:1710.05167
- Direct-photon production at 8 and 13 TeV - arXiv:1901.10075
  - NNLO predictions are available, but not NNLO grids yet
- Jets 7, 8, 13 TeV inclusive - arXiv:1304.4739, arXiv:1706.03192 and arXiv:1711.02692
  - High χ^2 for NLO fits when correlations between rapidity bins are used
  - Decorrelation models explored and recommendations allow χ^2 /ndp ~ 260/149 for 8 TeV – Chris Young's talk at DIS19
  - NLO APPLgrids are available – waiting for NNLO jet grids
- Photon + heavy flavour - arXiv:1710.09560
  - New data analysis on 8 TeV data is now published
  - Photon + charm is not very discrimination for intrinsic charm
  - γ + b favours 5F not 4F schemes

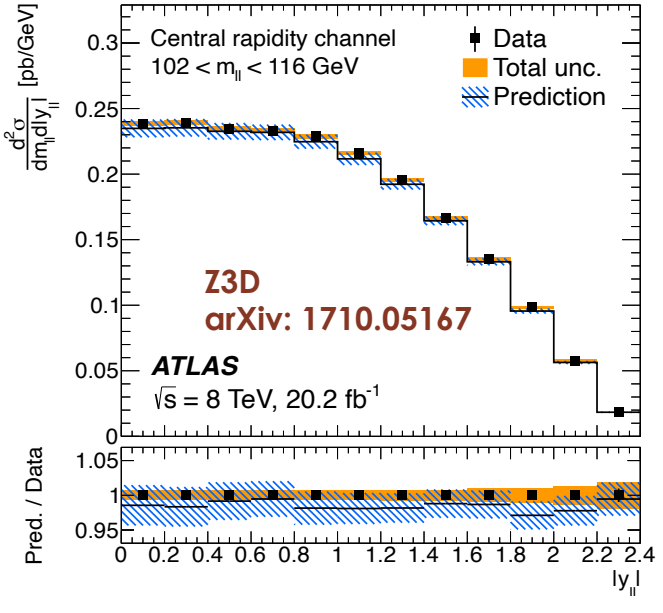
Overview of useful PDF-related analyses

- W+jets 8 TeV data - arXiv:1711.03296
  - Fit available and sent to DIS19 - **epWZWjets19**
  - ATL-PHYS-PUB-2019-016
  - NNLO cross section is available for this in NNLOJET (arxiv:1712.07543) → grids will become available at some point
- Z+jets and possibly Z(p_T) at 8 TeV - arXiv:1907.06728
  - Include them in a fit with the W+jets data - **epWZVjets20 out soon**
  - NNLO predictions are available in NNLOJET (arxiv:1507.02850) – much better agreement than at NLO
- W/Z + heavy flavour
  - New data analysis coming through the system: W+c and W+D* at 13 TeV
  - Unclear how to properly include fragmentation in a theoretically consistent manner
- Z+jets and Z(p_T) at 13 TeV - arXiv:1702.05725 and arXiv:1912.02844
  - Pythia8 predictions with parameters tuned to 7 TeV data describe the 13 TeV data very well at low p_T
  - Fixed-order NNLOJET predictions with and without NLO EW effects describe data very well in the high-p_T regime
- Top data at 13 TeV - arXiv:1908.07305 and arXiv:1910.08819
  - Lepton+jets and dilepton already available
  - Fully hadronic final state data should be available really soon

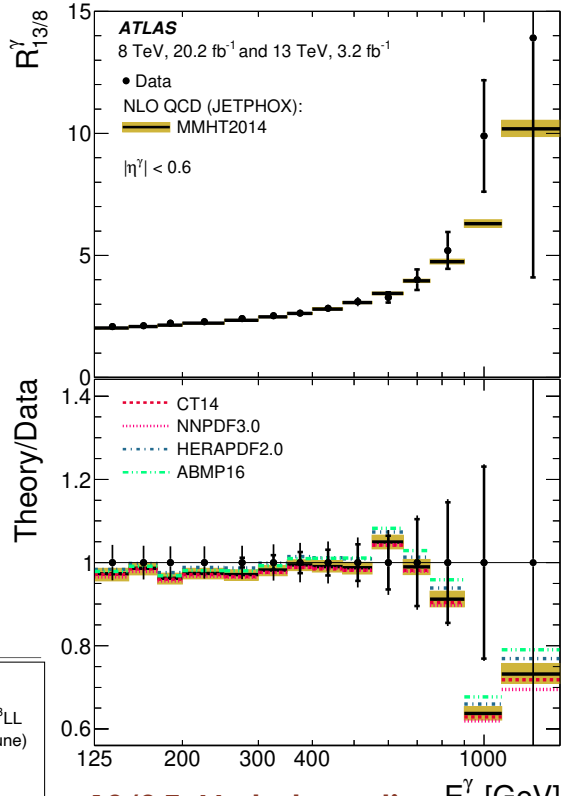
Overview of useful PDF-related analyses



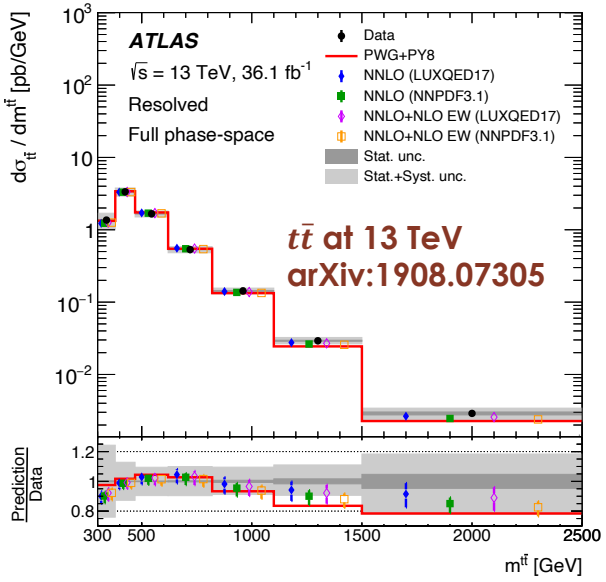
W asymmetry
arXiv:1904.05631



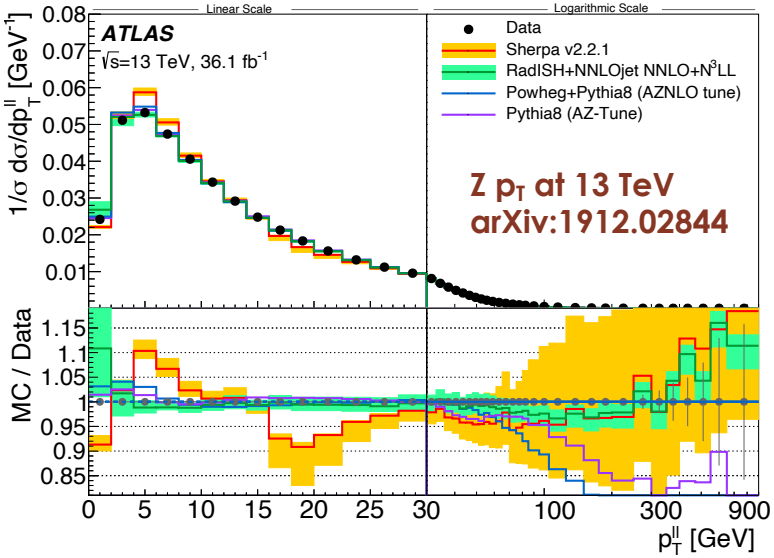
Z3D
arXiv: 1710.05167



13/8 TeV photon ratio
arxiv:1901.10075



$t\bar{t}$ at 13 TeV
arXiv:1908.07305



Z p_T at 13 TeV
arXiv:1912.02844

ATLAS PDF fits

- DIS HERA data are the backbone of ATLAS PDF fits – we add ATLAS measurements on top of them
- LHC cross sections from fastNLO and APPLgrid
  - NNLO QCD accuracy achieved via k_F, or NNLO grids from fastNLO
- PDF parametrisation:

$$
\begin{aligned}
xd_v(x) &= A_{u_v} x^{B_{u_v}} (1-x)^{C_{u_v}} (1+D_{d_v} x + E_{d_v} x^2) \exp F_{d_v} x \\
xu_v(x) &= A_{d_v} x^{B_{d_v}} (1-x)^{C_{d_v}} (1+D_{u_v} x + E_{u_v} x^2) \exp F_{d_v} x \\
x\bar{d}(x) &= A_{\bar{d}} x^{B_{\bar{d}}} (1-x)^{C_{\bar{d}}} (1+D_{\bar{d}} x + E_{\bar{d}} x^2) \\
x\bar{u}(x) &= A_{\bar{u}} x^{B_{\bar{u}}} (1-x)^{C_{\bar{u}}} (1+D_{\bar{u}} x + E_{\bar{u}} x^2) \\
x\bar{s}(x) &= A_{\bar{s}} x^{B_{\bar{s}}} (1-x)^{C_{\bar{s}}} (1+D_{\bar{s}} x + E_{\bar{s}} x^2) \\
xg(x) &= A_g x^{B_g} (1-x)^{C_g} (1+D_g x + E_g x^2) + A'_g x^{B'_g} (1-x)^{C'_g}
\end{aligned}
$$

In **grey** variations for assessing parametrisation uncertainties

- Additional constraints for the central fit from sum rules
- $A_{\bar{u}} = A_{\bar{d}}$, $B_{\bar{s}} = B_{\bar{u}} = B_{\bar{d}}$, with $A_{\bar{s}}$ and $C_{\bar{s}}$ free, C'_g = 25.0 and $s(x) = \bar{s}(x)$
- Central fits with 16 parameters with α_S = 0.118 and Q_0^2 = 1.9 GeV^2

W+jets data at 8 TeV

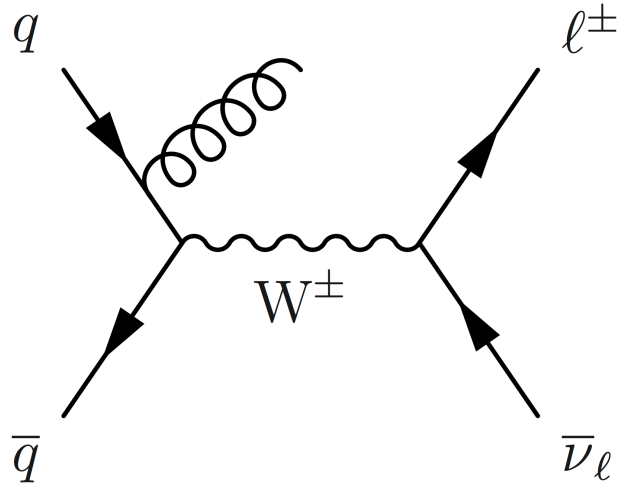
- QCD fit to W+jets at 8 TeV data added on top of DIS data from HERA and the W,Z data at 7 TeV

- Some differences and improvements wrt the ATLAS epWZ16 fit to accommodate or exploit the new data:
  - More parameter variations and extended central parametrisation, consistent with ATLAS epWZtop18 fit
  - The new fit uses the W,Z data at 7 TeV before the combination (electron and muon decay channel **uncombined**) in order to correlate common sources of systematic uncertainties to those of the W+jets data
  - Variation of the minimum Q^2 selection of 10 GeV^2 (rather than 7.5 Gev^2) to exclude the low-Q^2, low-x HERA data which may be more adversely affected by large-logs, higher twist effects etc.

- NNLO corrections included as k-factors

- ATL-PHYS-PUB-2019-016

- Ongoing effort to include Z+jets data at 8 TeV in the same QCD fit - **epWZVjets20 fit out soon**



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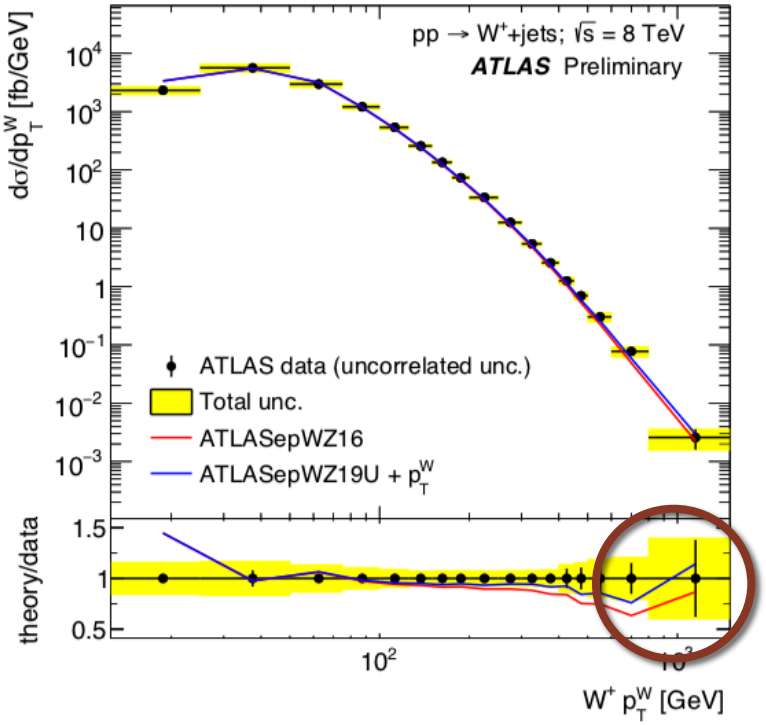
Fit quality

Fit	ATLASepWZ19U	ATLASepWZ19U + p_T^W	ATLASepWZ19U + $p_T^{leading}$
Total χ^2/NDF	1310 / 1106	1354 / 1140	1365 / 1152
HERA partial χ^2/NDF	1123 / 1016	1132 / 1016	1141 / 1016
HERA correlated χ^2	48	49	50
HERA log penalty χ^2	-18.38	-22.4	-24.72
ATLAS W, Z partial χ^2/NDF	117 / 106	116 / 106	109 / 106
ATLAS W + jets partial χ^2/NDF	-	18 / 34	43 / 46
ATLAS correlated χ^2	40	62	47

- Fits including the W+jets data showing no tension with the HERA data or inclusive W,Z data
- Slightly better χ^2 when including the p_T^W spectrum
- New PDF fit released: **ATLAS epWZ-Wjets19**
- Clear improvements in the description of the data in the large-p_T region with the new fits



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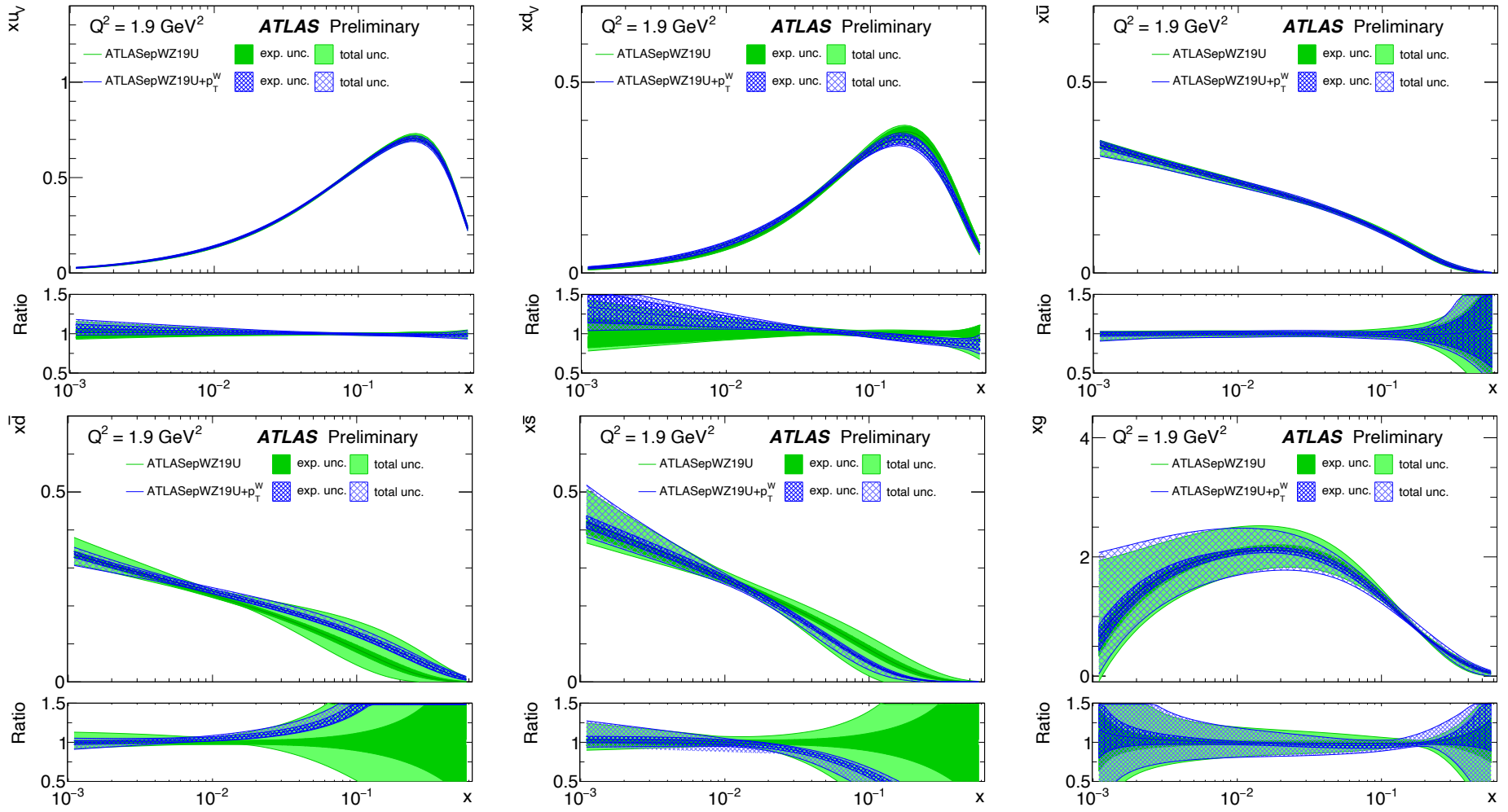
New fits results



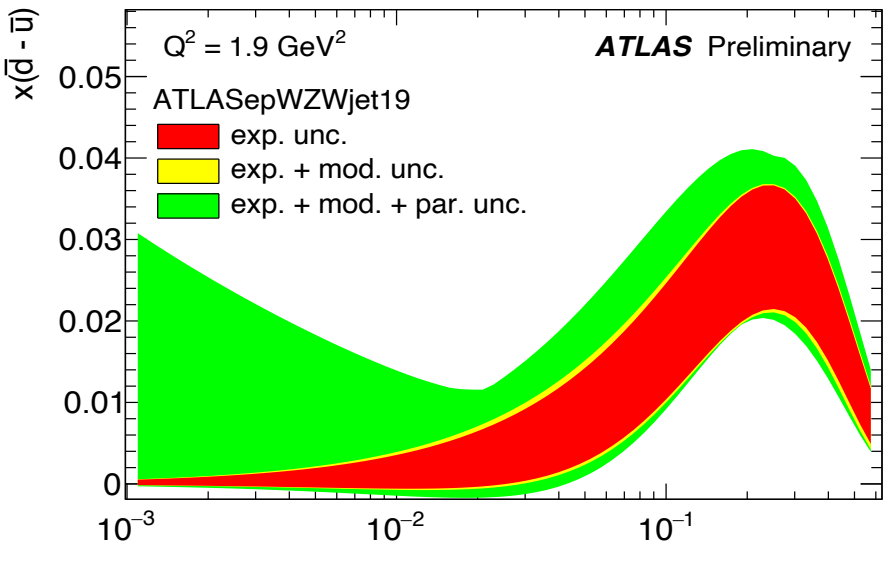
Compared to ATLAS epWZ16 fit:

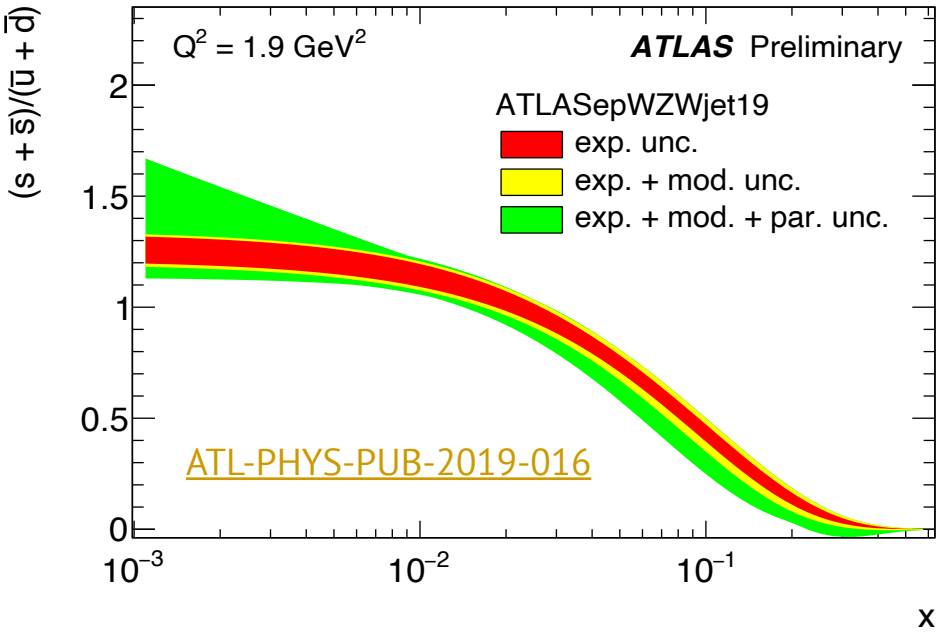
- Softer d_v at medium-x
- Harder $\bar{d}$
- Softer strange PDF at high-x

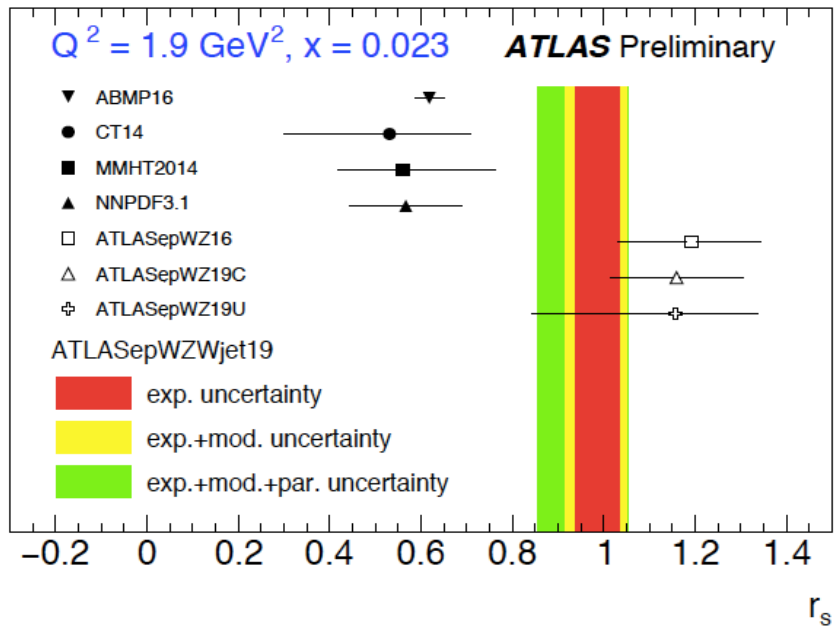
- u-quark and gluon distributions essentially unchanged

Main outcome of the fit

- Including the W + jet data reduces the strange density at higher-x… But still consistent with **enhanced strange at low-x!**
- New fit with the W + jet data results in the new $x(\bar{d}-\bar{u})$ **to be positive**
- Much more consistent with the fits from the global fitters (previous ATLASepWZ16 fit showed a negative $x(\bar{d}-\bar{u})$)





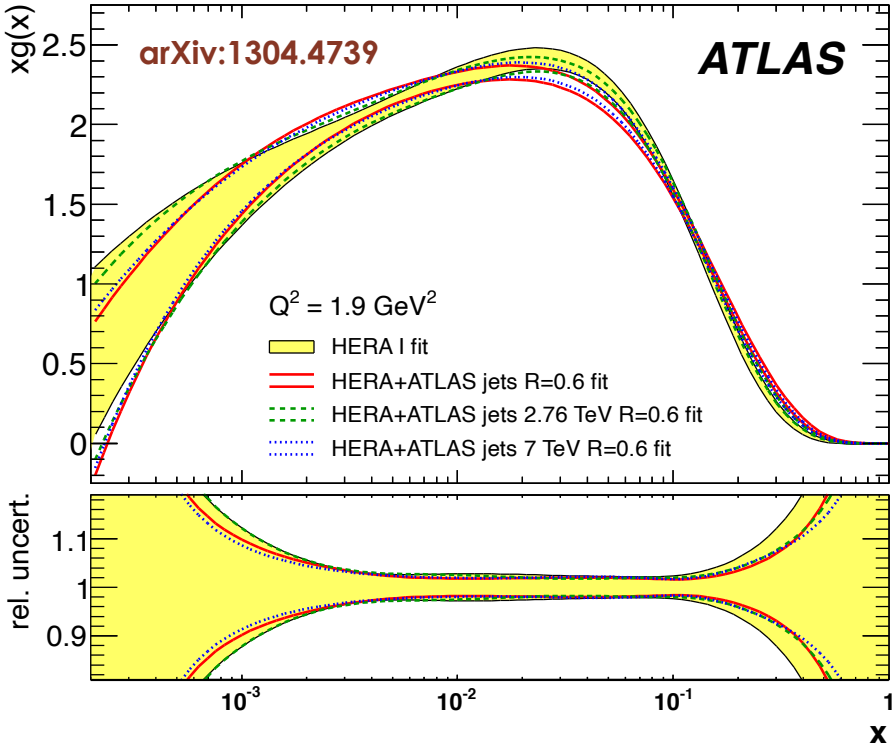


ATLAS 'global' fit

- Fit to complement the current V+jets and recent top fits
- 'Global' in the sense of multiple ATLAS data sets – **NO** data from multiple LHC experiments
- Attempt to simultaneously fit as many useful ATLAS data sets as possible
  - HERA data for constraining low-x and Q^2 region
  - LHC data provide stronger constraints at higher x and Q^2
- Time scale: aiming for the end of 2020 or shortly after
- So far, on top of the **epWZtop18** fit (ATLS-PHYS-PUB-2018-017) we added:
  - W+jets at 8 TeV - arXiv:1711.03296
  - Z+jets at 8 TeV - arXiv:1907.06728
  - Z3D asymmetry and cross section - arxiv:1710.05167
  - W asymmetry at 8 TeV - arXiv:1904.05631
  - W,Z data at 2.76, 5.02 TeV - arXiv:1907.03567, arXiv:1810.08424
  - 13/8 TeV photon ratios - arxiv:1901.10075
  - Top data at 13 TeV (lepton+jets decay channel) - arXiv:1908.07305
  - HERA inclusive and dijets data

Including jet data in the global fit

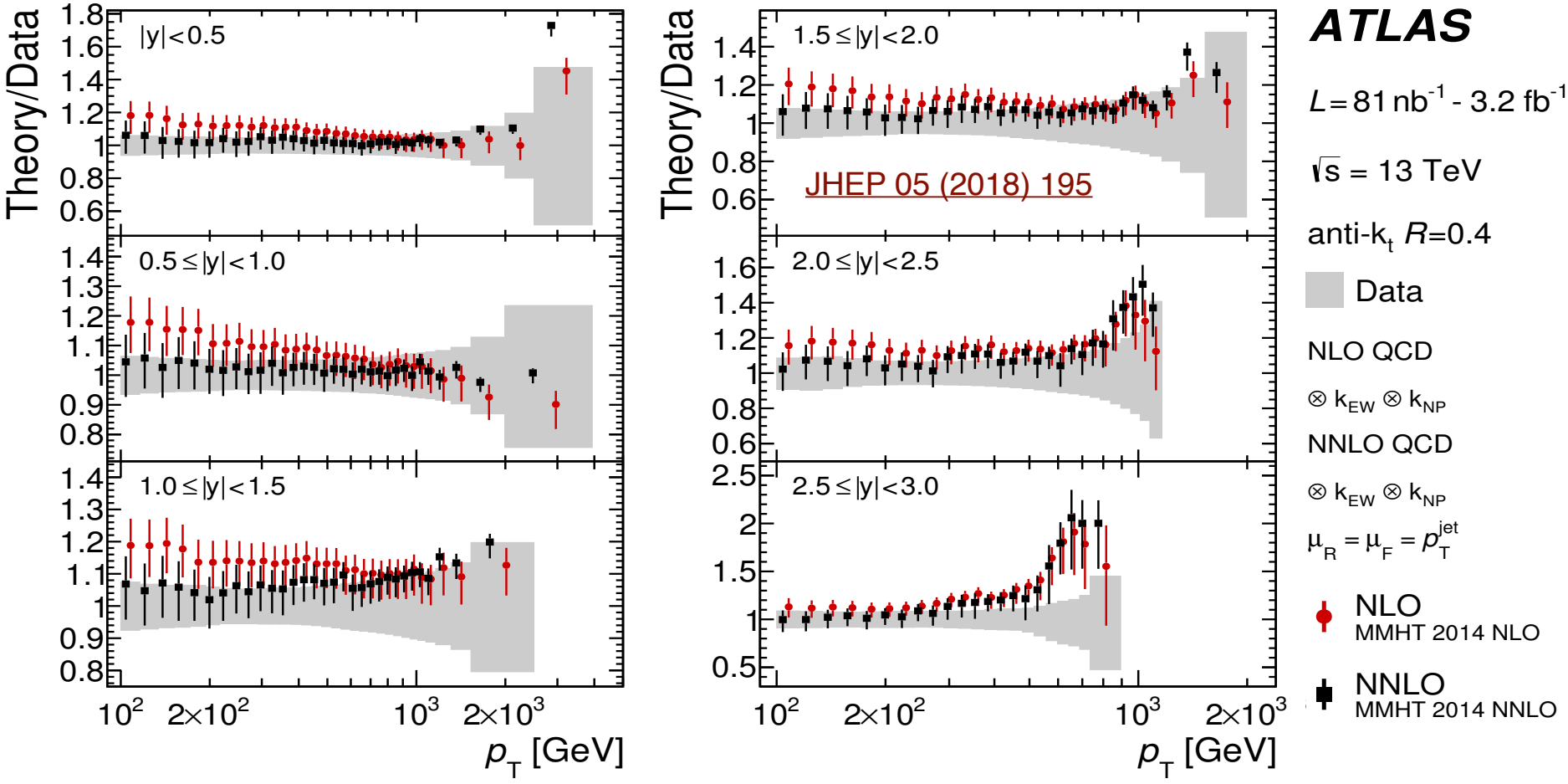
- We would like to include jet data in the ATLAS global fit
- Previous attempts in 2017 appeared extremely promising, but were stymied by systematics
- Each η region could be fitted separately, but χ^2 poor when including all the regions due to correlated η inter-calibration



Dataset	N_{bins}	χ^2 separate	χ^2_{corr} separate	χ^2 all η bins together	χ^2_{corr} all η bins together
Incjet y 00 05 R=0.4	31	26.08	4.9487	82.14	
Incjet y 05 10 R=0.4	29	18.76	4.6316	93.92	
Incjet y 10 15 R=0.4	26	13.59	4.2986	123.14	
Incjet y 15 20 R=0.4	23	10.67	3.9753	55.62	
Incjet y 20 25 R=0.4	19	10.61	3.6875	53.65	
Incjet y 25 30 R=0.4	12	4.07	1.3920	14.51	40.20

- Lots of progresses on both systematics and jet cross section since then
- Now inclusive and dijet cross section at LHC available at NNLO

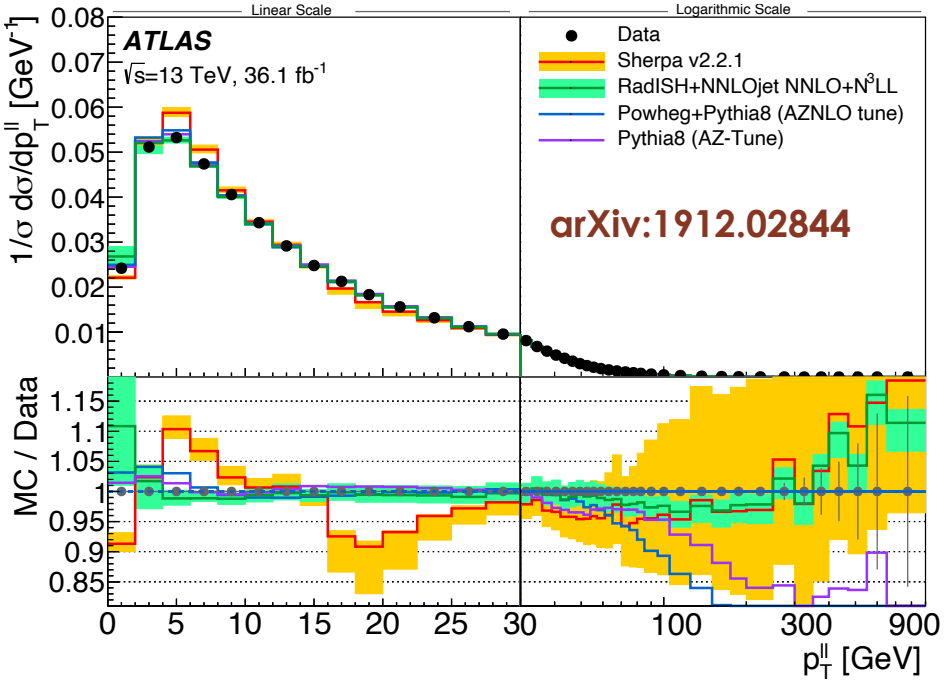
JHEP 05 (2018) 195 Jet data at 13 TeV

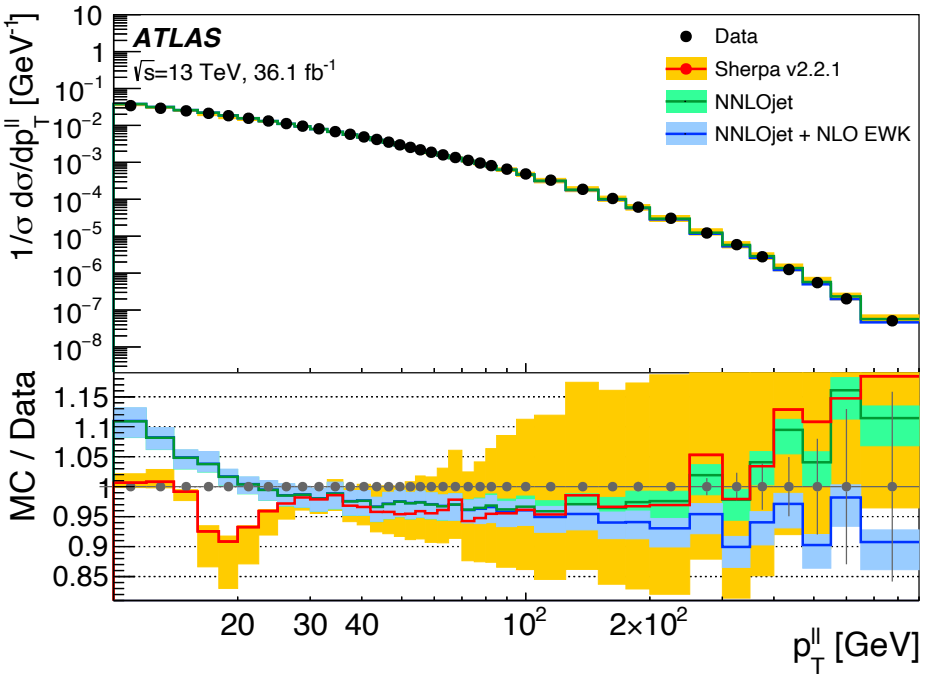


- NNLO predictions agree with data much better than NLO
- Hopefully even if NNLO grids are not available, we can use NNLO k_F in the fits

Z p_T and ϕ^* at 13 TeV

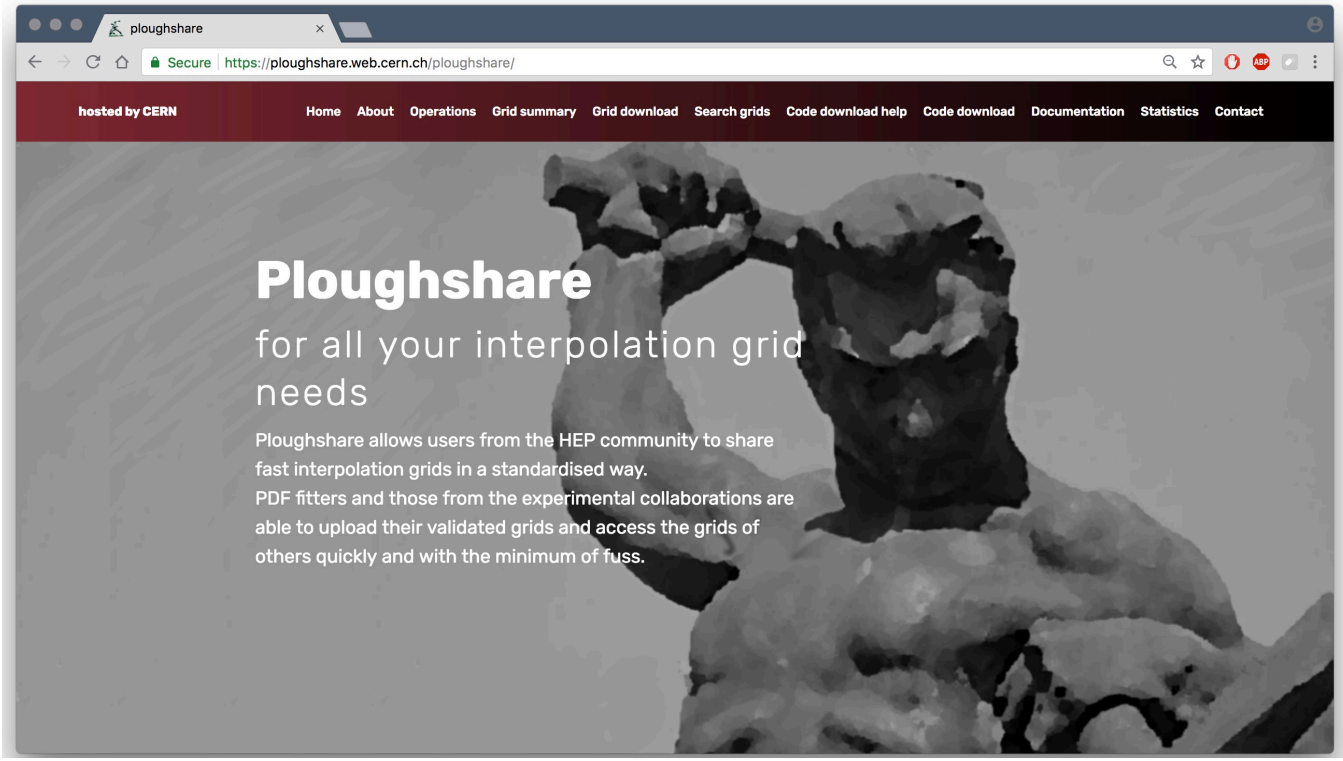
- Pythia8 predictions with parameters tuned to 7 TeV data describe the 13 TeV data very well at low p_T
- Fixed-order NNLO predictions from NNLOJET with and without NLO EWK corrections describe data in the high-p_T regime within uncertainties
- NNLO+N^{3}LL RadISH prediction agrees well with data within 1-3% uncertainties over the full p_T spectrum → **log(m_{ll}/p_T)-resummation IS crucial**





ATLAS grids for PDF fits

- ATLAS grids are now being distributed via the ploughshare website: http://ploughshare.web.cern.ch
- All the ATLAS and non-ATLAS available grids can be found here: https://ploughshare.web.cern.ch/ploughshare/download.php
- NNLO top grids from Czakon et al. available in APPLgrid format



ATLAS xFitter users' desiderata

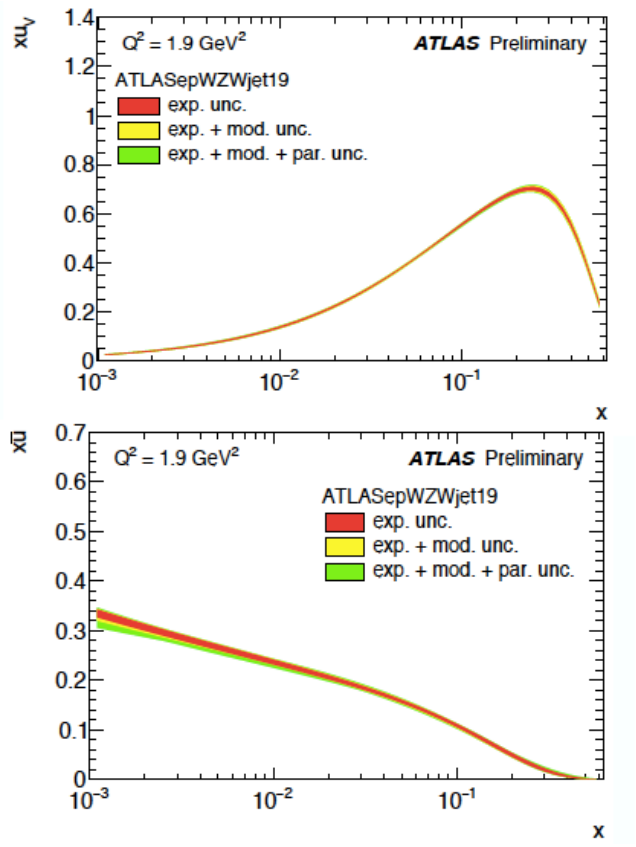
- Fix the issue with partial χ^2 to be 0 when statistical correlation matrices in use
- A tool to convert HEPData tables to xFitter data files format needed
- TOP++ interfaced to xFitter as an alternative to Hathor
- Perform QCD + EW fits
- When fitting data sensitive to $\sin^2\vartheta_W$, a recipe to access uncertainty due to this input parameter
- Any plan to interface xFitter to Plugshare?
- Strategy for sharing/generating common grids
- ln(1/x)-resummation for low-mass DY (once theory is ready) and small-q_T resummation for low p_T (e.g. interface to DYTurbo)

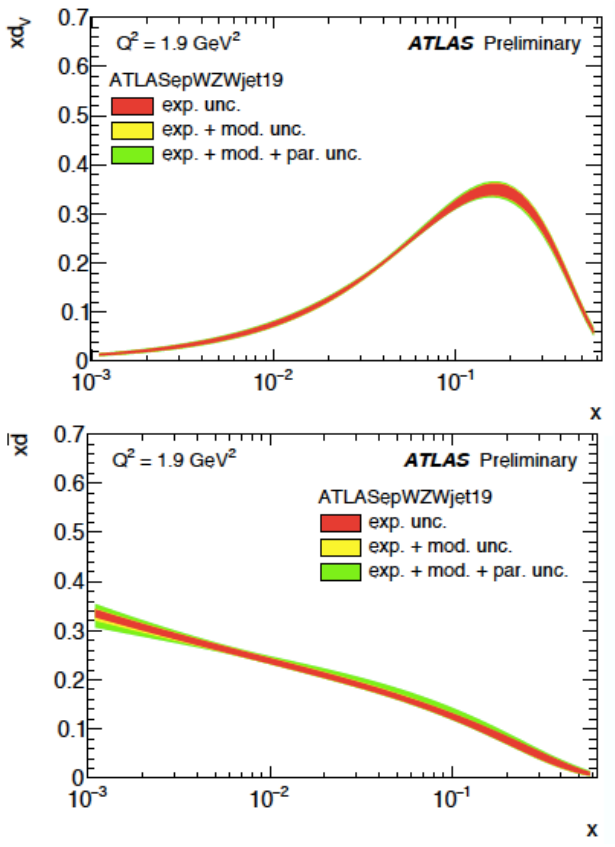
Conclusions

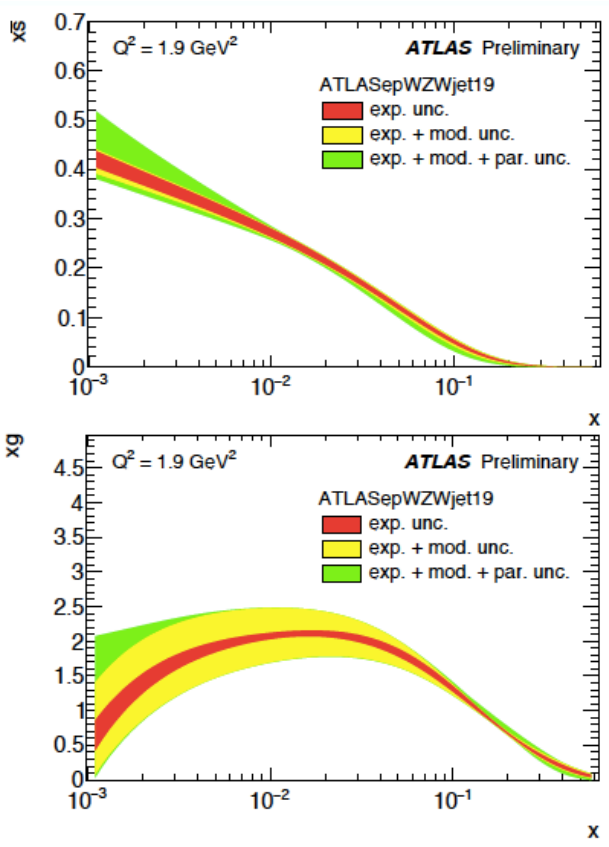
- New ATLAS measurements at $\sqrt{s}$ = 13 TeV coming out soon → ready to exploit possible potential to constraint PDFs
- A fit to DIS HERA data, ATLAS W/Z at 7 TeV and V+jets at 8 TeV should be presented at DIS2020
- Ongoing effort of a much more 'global' ATLAS PDF fit – longer timescale e.g. aiming for the end of 2020 or shortly after
- xFitter and the Oxford PDF fitting code are the main framework for PDF analyses
- ATLAS grids distributed via the plougshare website

Backup Slides

Fit including the W+jets data





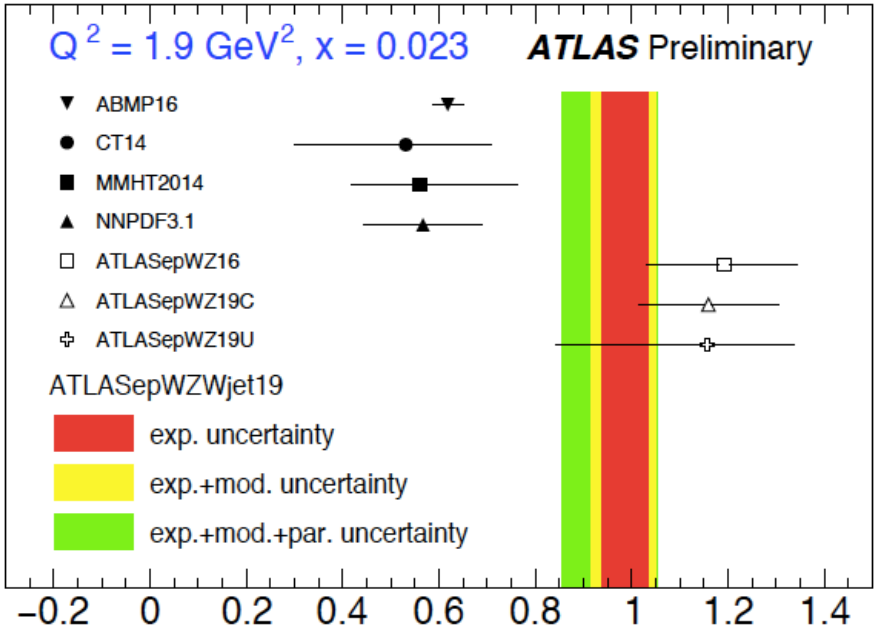


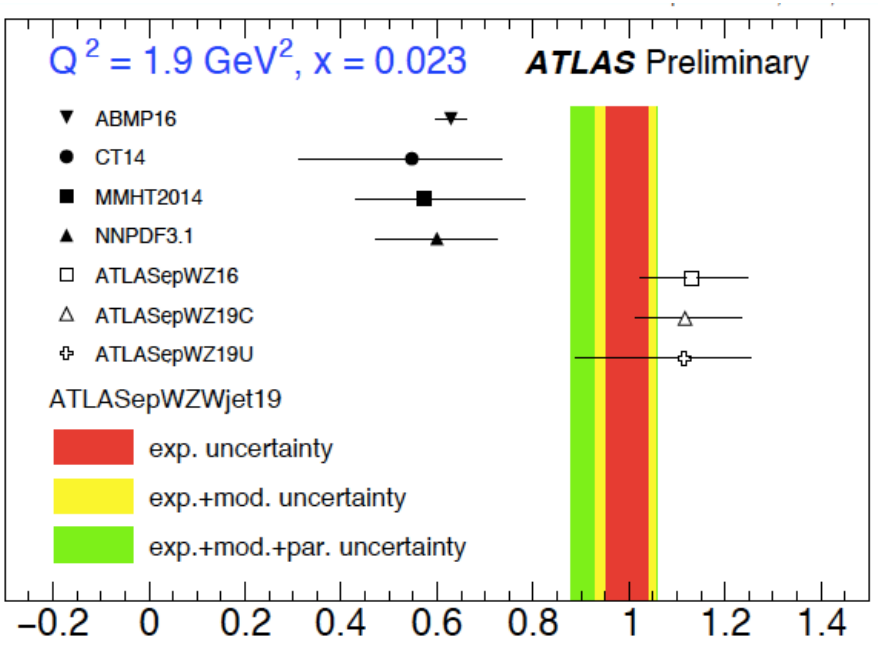
Compared to previous ATLAS epWZ16 fit:

- Softer d_v
- Harder $\bar{d}$
- u-quark distributions unchanged
- Softer strange PDF at low-x

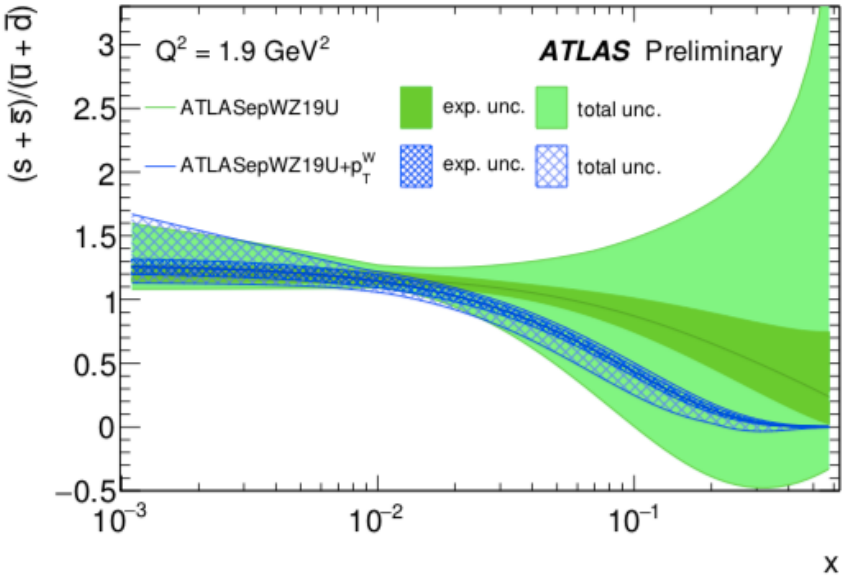
ATL-PHYS-PUB-2019-016

How strange is the proton?





$$r_s = \frac{1}{2}(s+\bar{s})/\bar{d} \qquad R_s = \frac{s(x)+\bar{s}(x)}{\bar{u}(x)+\bar{d}(x)}$$



- Consistent with earlier ATLAS fits
- Slightly higher than PDF from the global fitters

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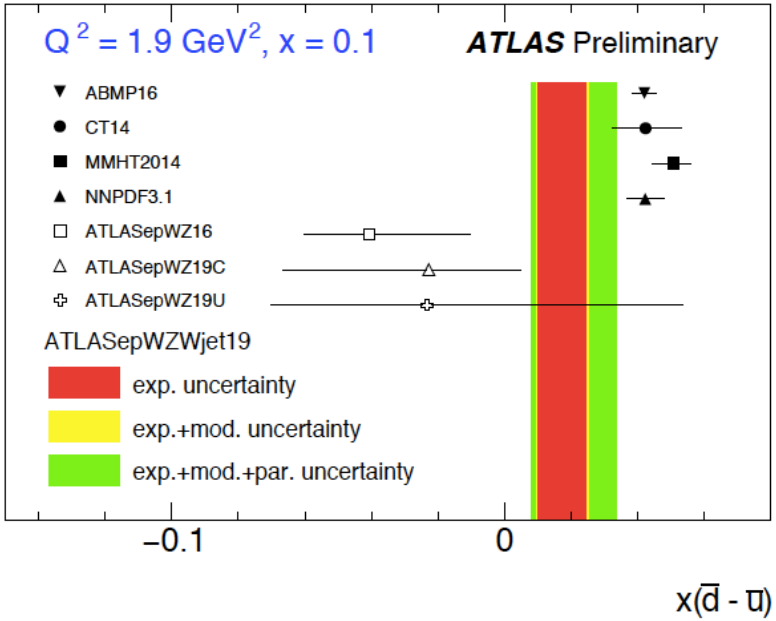
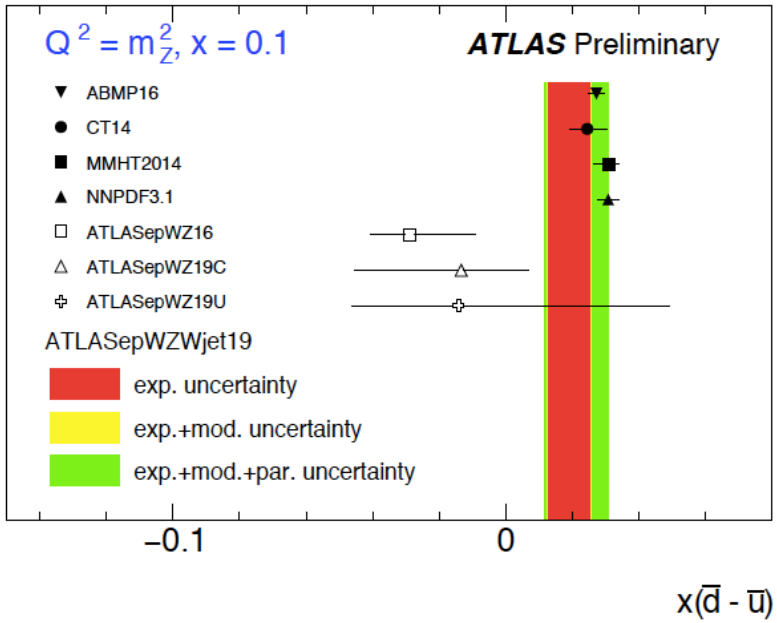
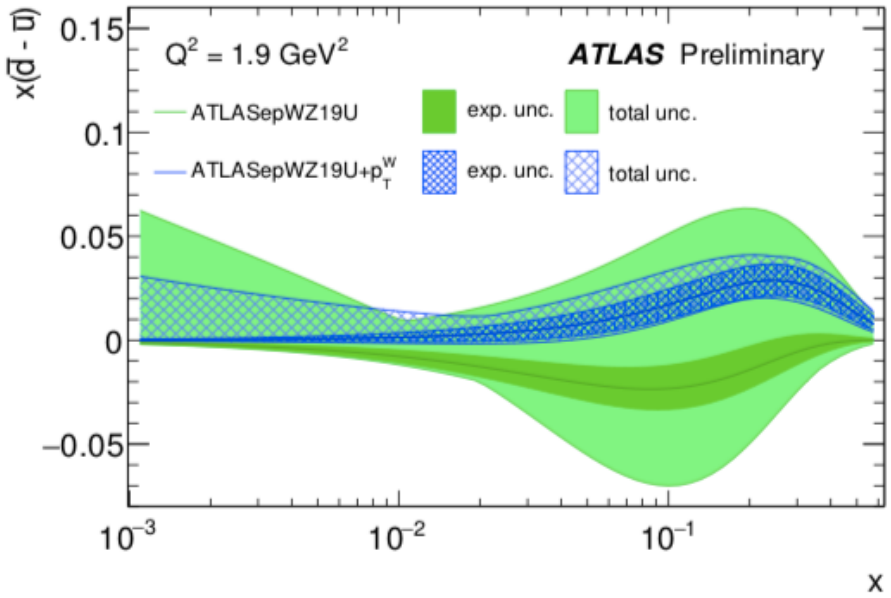
Light-quark asymmetry





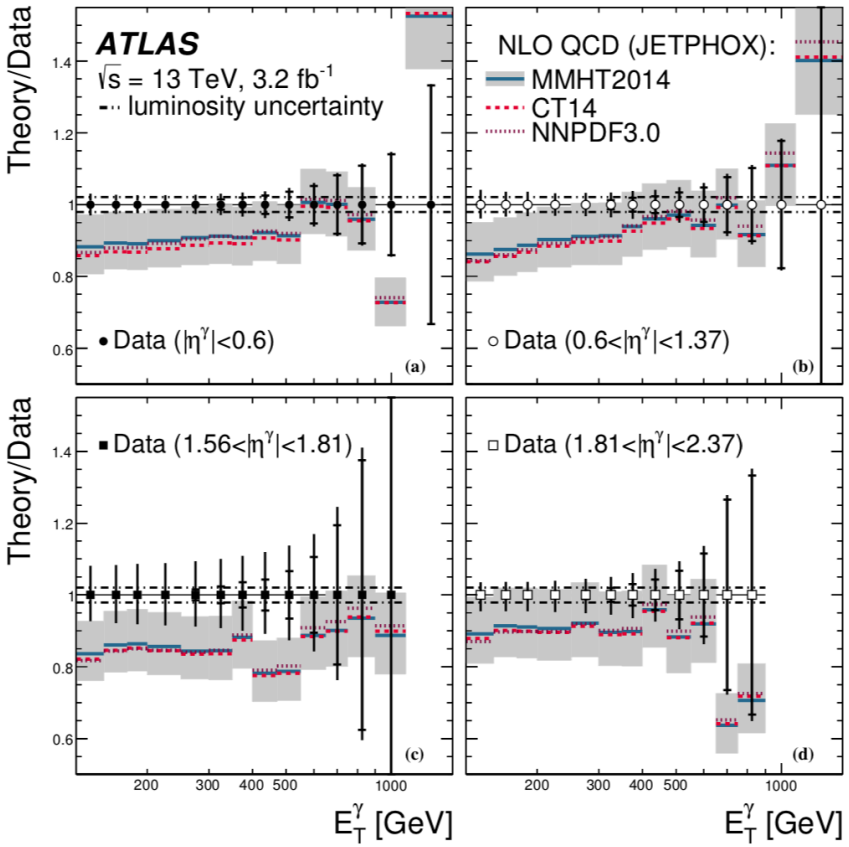
ATL-PHYS-PUB-2019-016

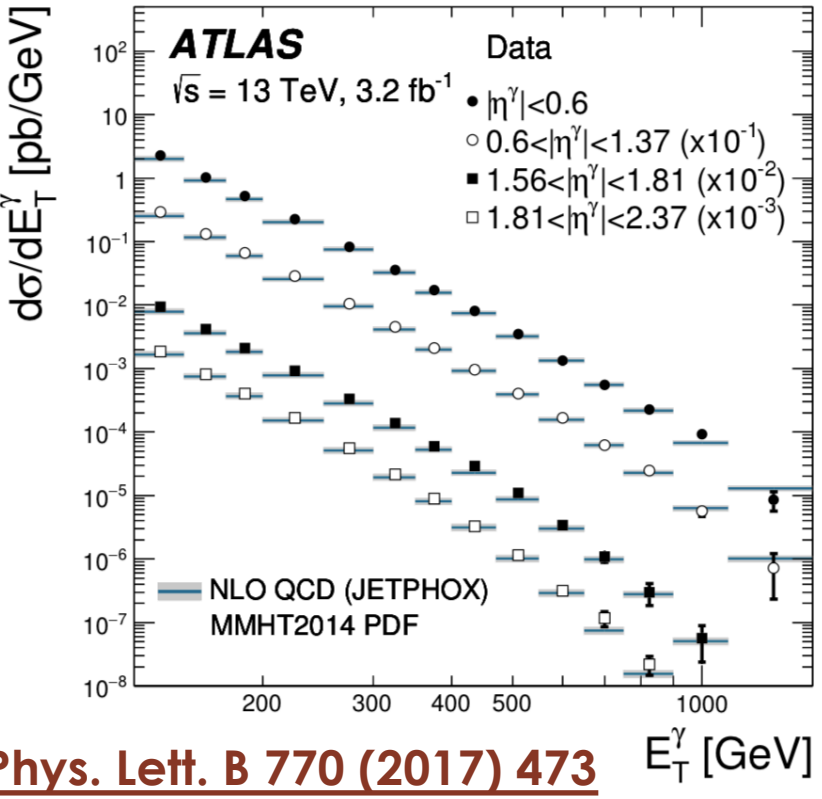
- Comparison with global fitters shown here
- New fit more in line with global fitters predictions



Isolated photons data at 13 TeV

- Dominant production: $gq \rightarrow q\gamma$
- Constraint on gluon at medium x e.g. x ≃ 0.1
- Range: 125 GeV < E_T ≲ 2 TeV
- Dominant systematic uncertainties:
  - Energy scale
  - Background correlations





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- JetPhox: low in normalisation (~20% lower than data)
- Result independent from the PDF set in use
- NLO predictions: large scale uncertainties