



Determination of proton parton distribution functions using ATLAS data

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On behalf of ATLAS collaboration

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Motivation

Proton parton density functions describe kinematic properties and structure of the proton

This talk is based on:
ATL-PHYS-PUB-2018-017 (ttbar)
ATL-PHYS-PUB-2019-016 (W+jets)

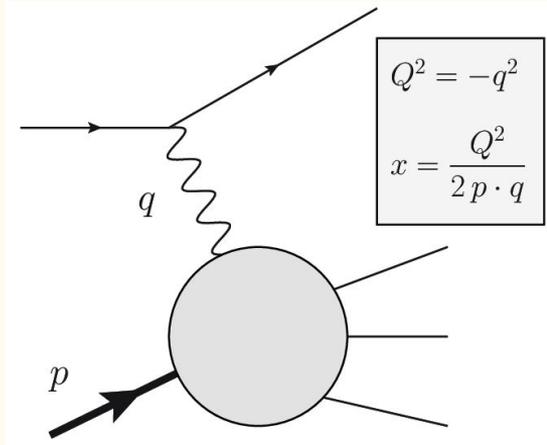
Essential for **all** differential cross sections measurements

FACTORISATION Theorem

$$d\sigma_x = \sum_{i,j} \int dx_1 \int dx_2 f_i(x_1, \mu_F^2) f_j(x_2, \mu_F^2) \times \widehat{\sigma}_{i,j \rightarrow X}(x_1, x_2, \mu_R^2)$$

Precise measurement of PDFs are required to identify clues for BSM theories and is also needed for SM

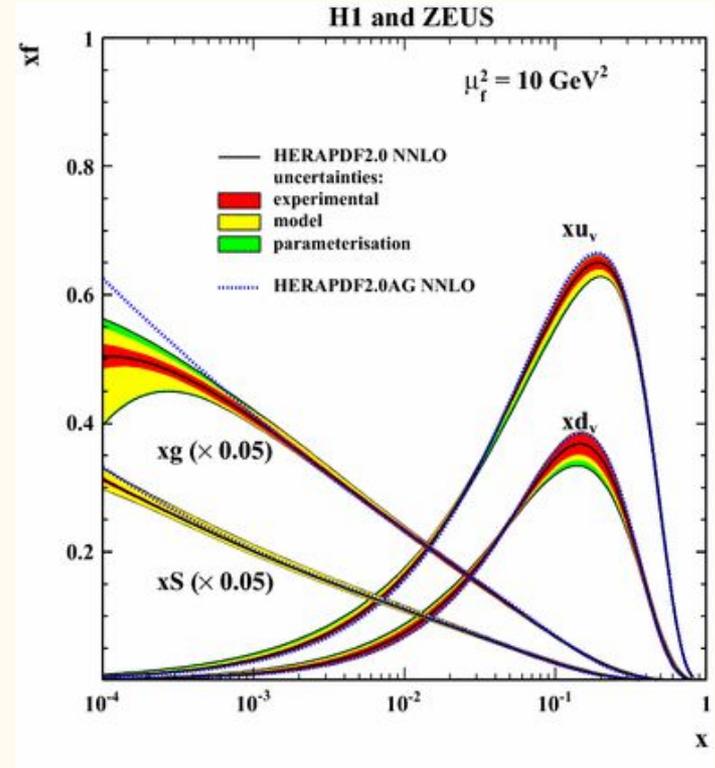
HERA datasets



Virtuality of exchanged boson

Bjorken scaling parameter

HERA dataset work as baseline for all present PDF measurements, extracted from both charged and neutral current



QCD fits

PDFs extracted from data fitted with following function for quarks:

$$xf(x) = Ax^B(1-x)^C(1+Dx+Ex^2)e^{Fx}$$

and for gluons:

$$xf(x) = Ax^B(1-x)^C(1+Dx+Ex^2)e^{Fx} - A'x^{B'}(1-x)^{C'}$$

16 parameters are used in total for central fit

Present QCD analysis uses xFitter with APLLgrid or APLLGRID

Using additional parameters in the fit was also studied to estimate the systematic and model uncertainties of the fit

NNLO QCD analysis on W +jet data

NNLO QCD analysis contains contribution from following datasets:

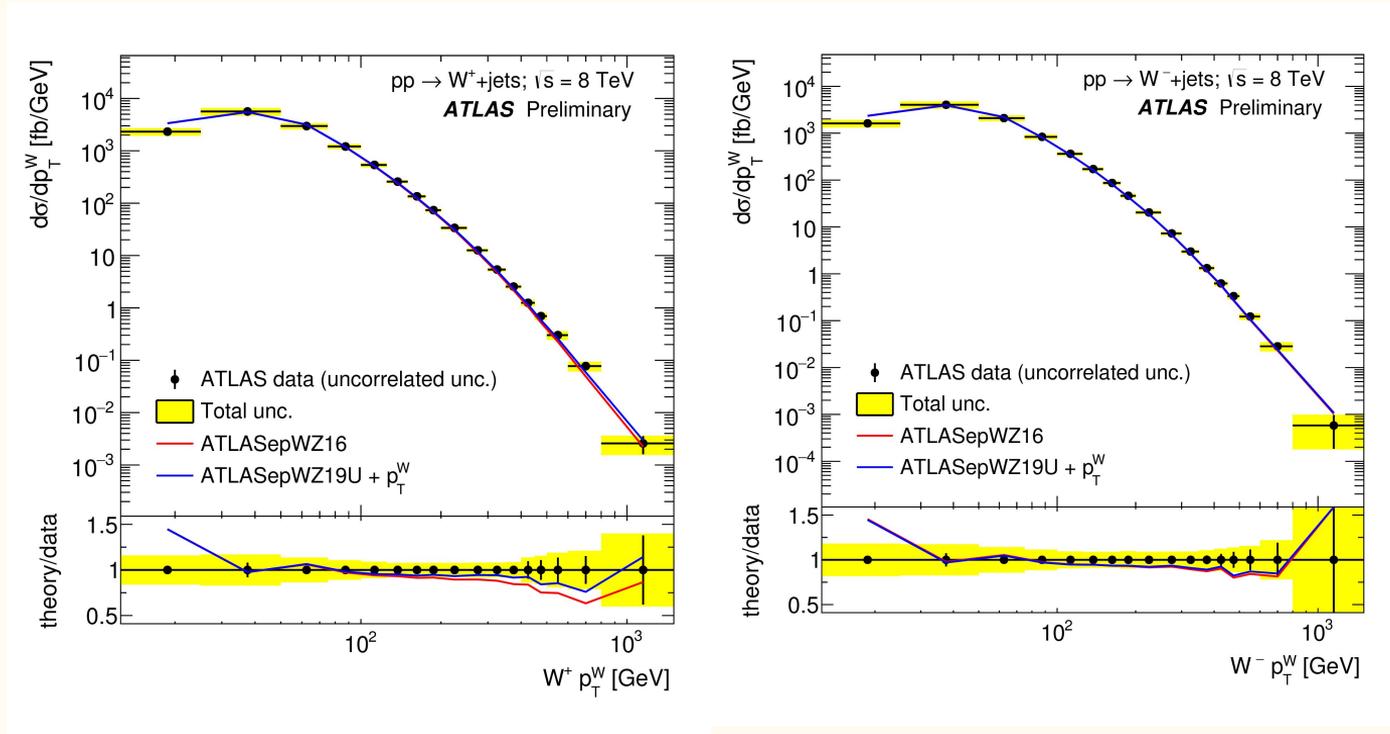
HERA I; HERA II; ATLAS W,Z (full paper [here](#)); **ATLAS W+Jet differential cross sections at 8 TeV** (public note [here](#))

W +jet is more sensitive in higher x and Q^2 than inclusive data

Resulting in **ATLASepWZWjet19** dataset, which is complementary with previous ATLAS measurements

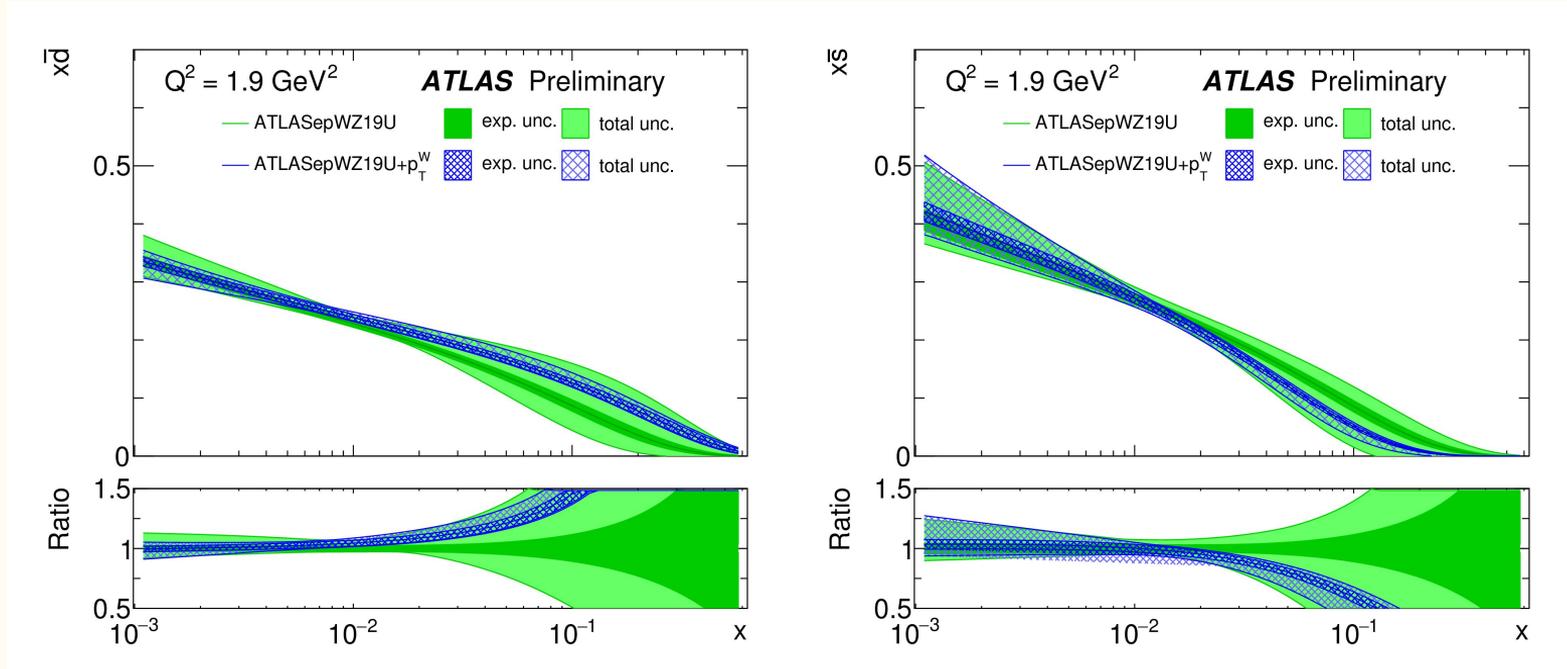
More information in ATL-PHYS-PUB-2019-016

W + jet results - comparison with data



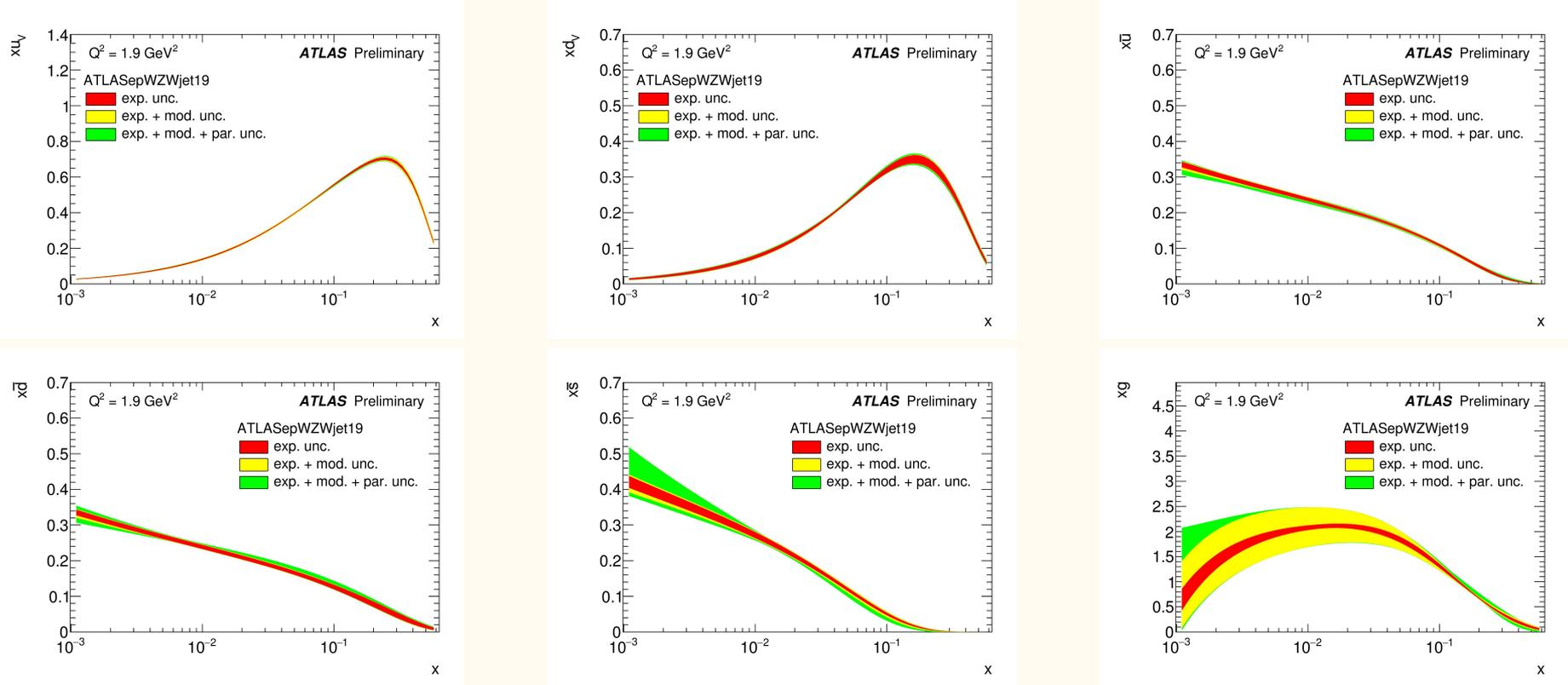
There is larger improvement after addition of W+jet dataset for W^+ than for W^- in area with higher p_{T^W} , which corresponds to higher x

W + jet results - impact on PDFs



Significant change in PDFs is visible for sea down and strange quarks essentially at large x , other PDFs changed only slightly

W + jets results - summary



ATLASepWZWjet19 dataset (HERA I+HERA II+ATLAS W,Z+ATLAS W+Jet)

NNLO QCD analysis on $t\bar{t}$ data

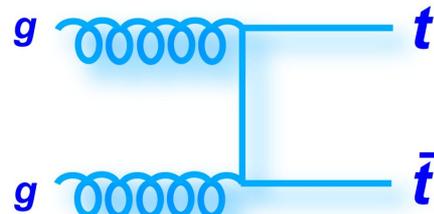
NNLO QCD analysis uses following datasets:

HERA I; HERA II; ATLAS W,Z; ATLAS $t\bar{t}$ differential cross sections in lepton+jet and dilepton decay channel at 8 TeV (public note [here](#))

Top quark pair production is sensitive to gluon parton distribution function

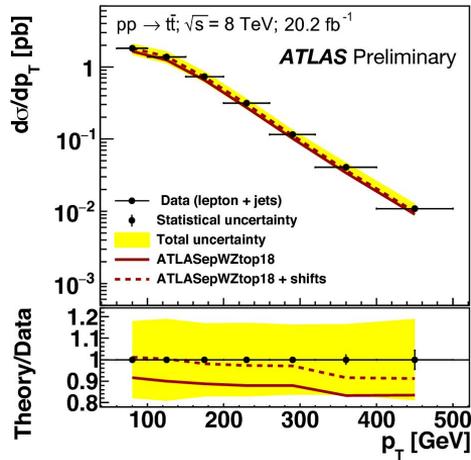
The main difference is in simultaneous analysis on several spectra at once with considering statistical and systematic correlations

More information in ATL-PHYS-PUB-2018-017

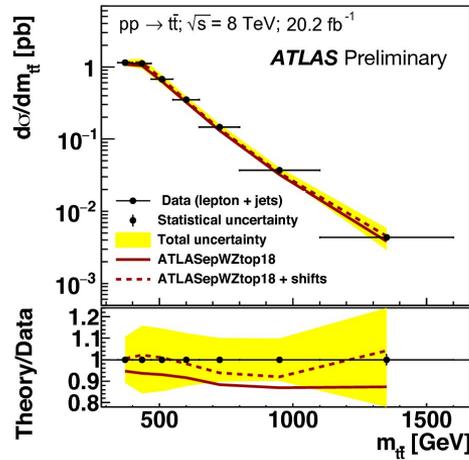


ATLAS $t\bar{t}$ samples - studied spectra

$l+jets$ channel

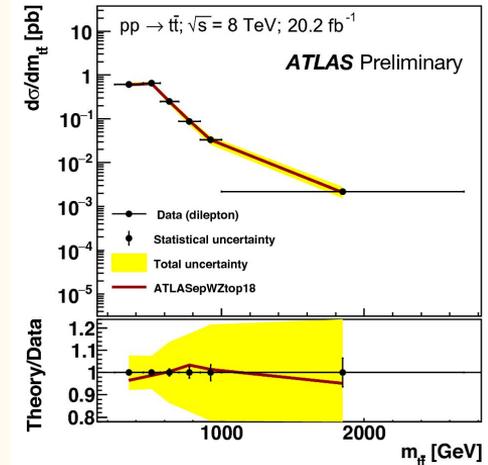


top quark p_T



top quark pair mass

dilepton channel

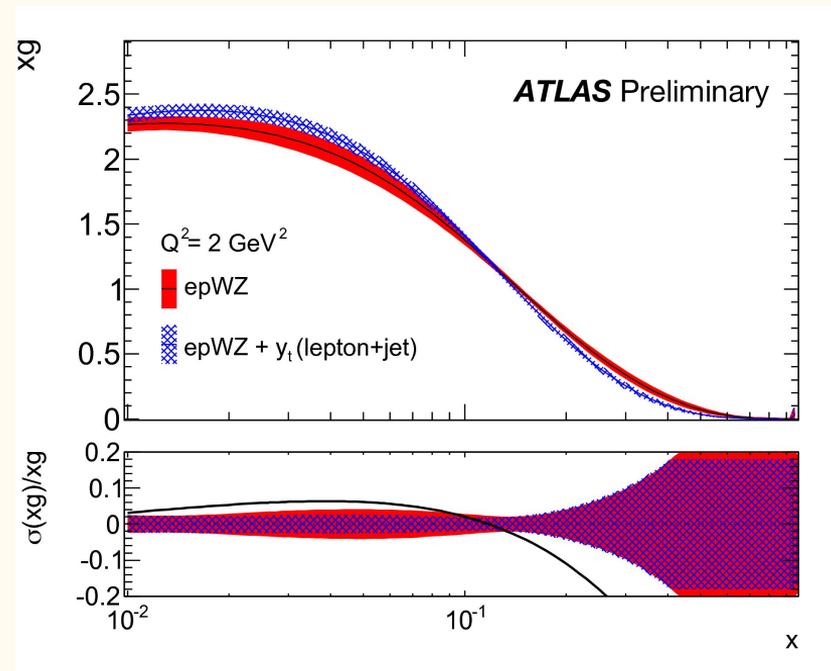
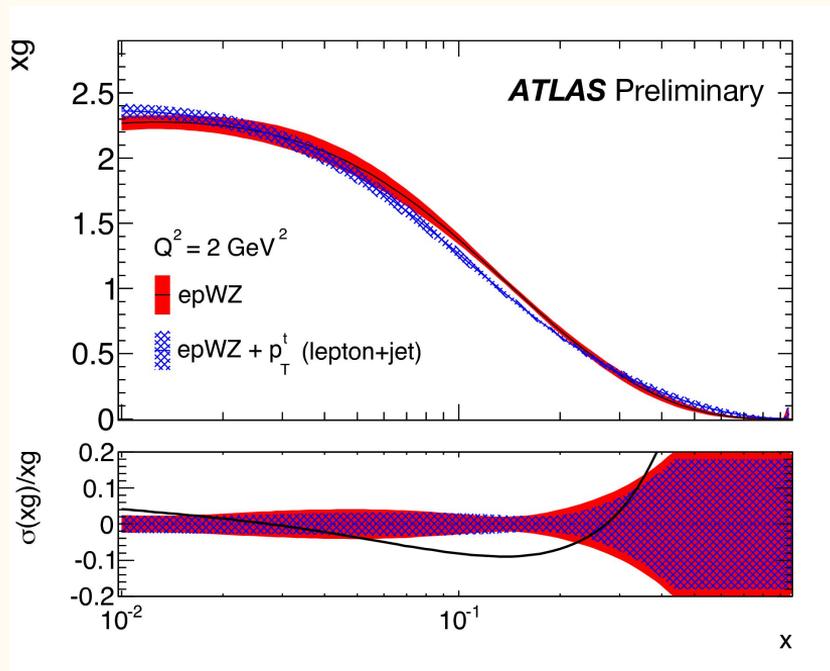


top quark pair mass

Studied $l+jets$ spectra: top quark p_T , top quark y , top quark pair y , top quark pair mass

Studied dilepton spectra: top quark pair y , top quark pair mass

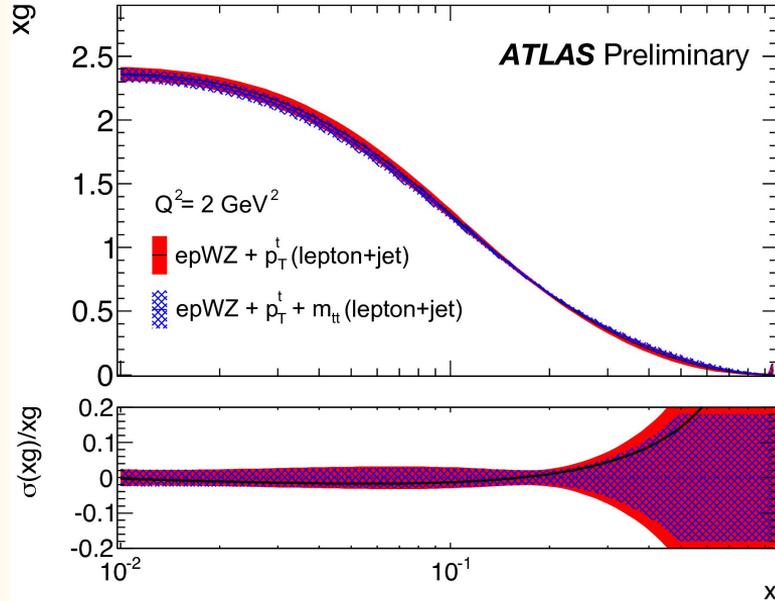
ATLAS $t\bar{t}$ samples - individual fits



The p_{T_t} and $m_{t\bar{t}}$ spectra prefer harder gluons in opposite to y_t $y_{t\bar{t}}$ which prefer softer gluons

The fits are good except for y_t and $y_{t\bar{t}}$ in l+jets decay channel (flexible parameterisation does not help)

ATLAS $t\bar{t}$ samples - simultaneous fits



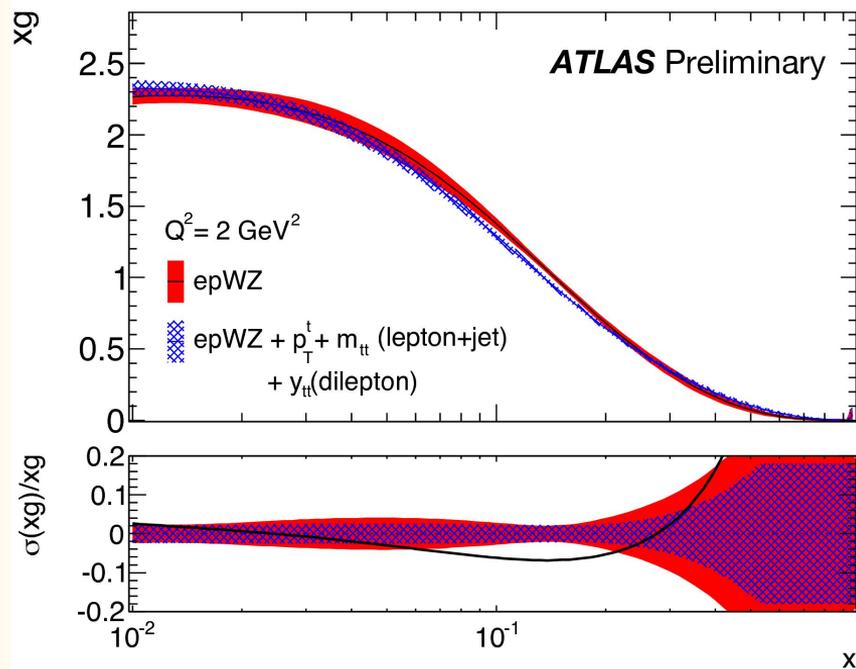
The simultaneous fit for p_T and $m_{t\bar{t}}$ with nominal correlated systematic uncertainties, finished with poor χ^2 , even though fits were good for each individual spectrum

Good fits can be achieved by using relaxed correlation model for some of the Monte Carlo systematics

		lepton+jets spectra			
		p_T^t and y_t with statistical correlations	p_T^t and y_t without statistical correlations	p_T^t and $m_{t\bar{t}}$ with statistical correlations	p_T^t and $m_{t\bar{t}}$ without statistical correlations
Total χ^2 /NDF		1264 / 1068	1260 / 1068	1290 / 1070	1287 / 1070
Partial χ^2 /NDP	HERA	1148 / 1016	1147 / 1016	1162 / 1016	1162 / 1016
Partial χ^2 /NDP	ATLAS $W, Z/\gamma^*$	82.7 / 55	83.5 / 55	83.2 / 55	83.1 / 55
Partial χ^2 /NDP	ATLAS $t\bar{t}$	33 / 13	30 / 13	45 / 15	42 / 15

ATLAS $t\bar{t}$ samples - final fit

The combination of $m_{t\bar{t}} + p_T(\text{lepton} + \text{jets}) + y_{t\bar{t}}(\text{dilepton})$ was chosen for final fit

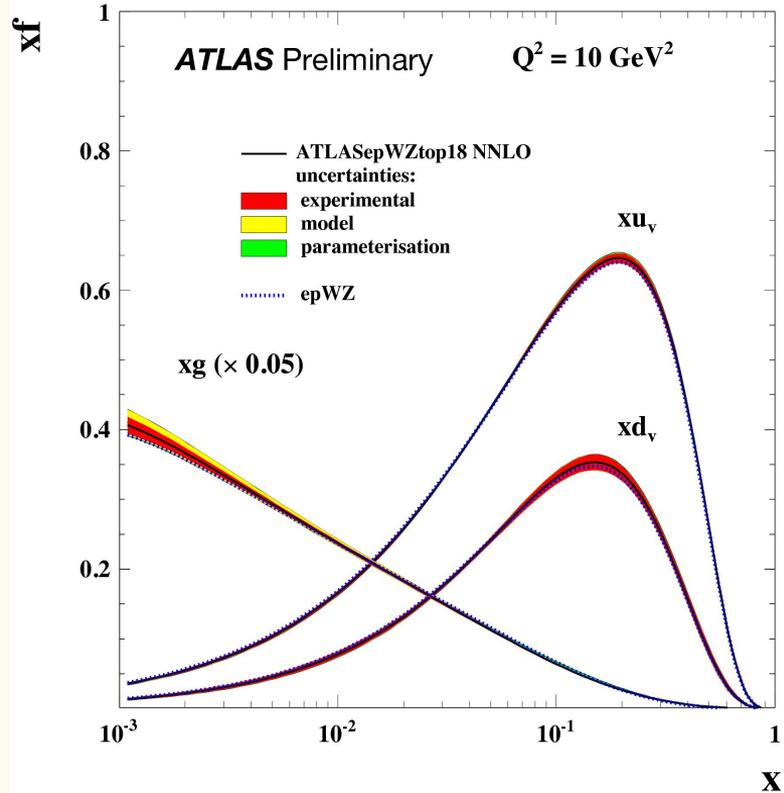
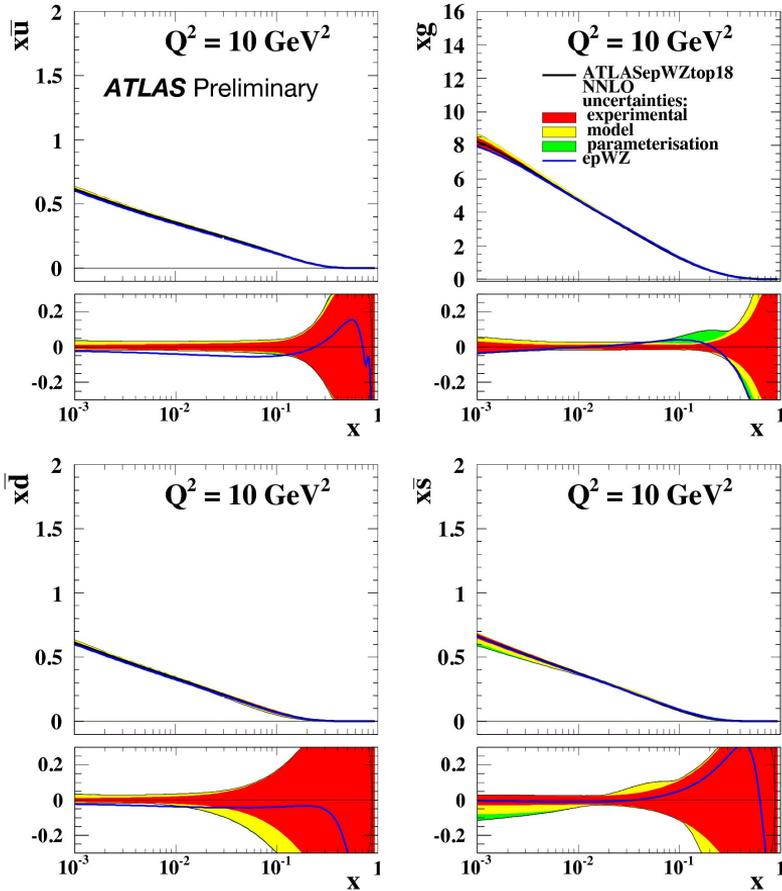


Final fit is obtained by using modified correlation model.

The resulting influence is in harder gluons and significant constraint in higher x region

		lepton+jets $p_T^t, m_{t\bar{t}}$ and dilepton $y_{t\bar{t}}$ 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 $p_T^t, m_{t\bar{t}}$	16.0 / 15
Partial χ^2/NDP	ATLAS dilepton $y_{t\bar{t}}$	5.4 / 5

Combined results



ATLASepWZtop18 pdf

Summary

Two analyses were presented from which resulted two sets of PDFs

ATLASepWZWjet19 PDFs

Results consistent with previous ATLAS analyses, supports unsuppressed strange at low x (0.05),

ATLASepWZtop18 PDFs

Tighter constraint on gluon at larger x , multiple spectra from lepton + jets and dilepton decay channels, full statistical correlation in lepton + jets decay channel

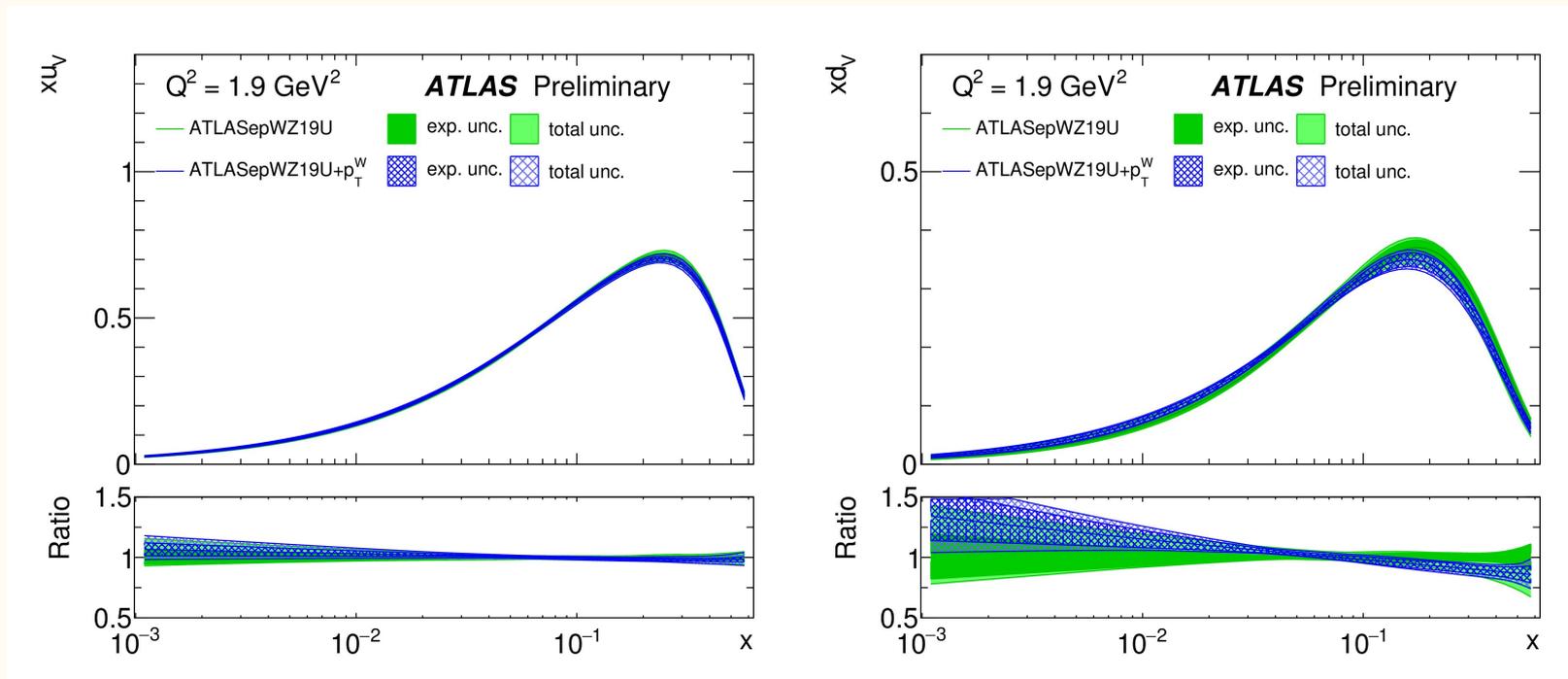
Top fit is available for LHAPDF and the grids from W +jets cross sections are available at ploughshare.web.cern.ch

ATLAS measurement sensitivity to PDF has large potential and there is still lot to explore in this areas.

Thanks for your attention!

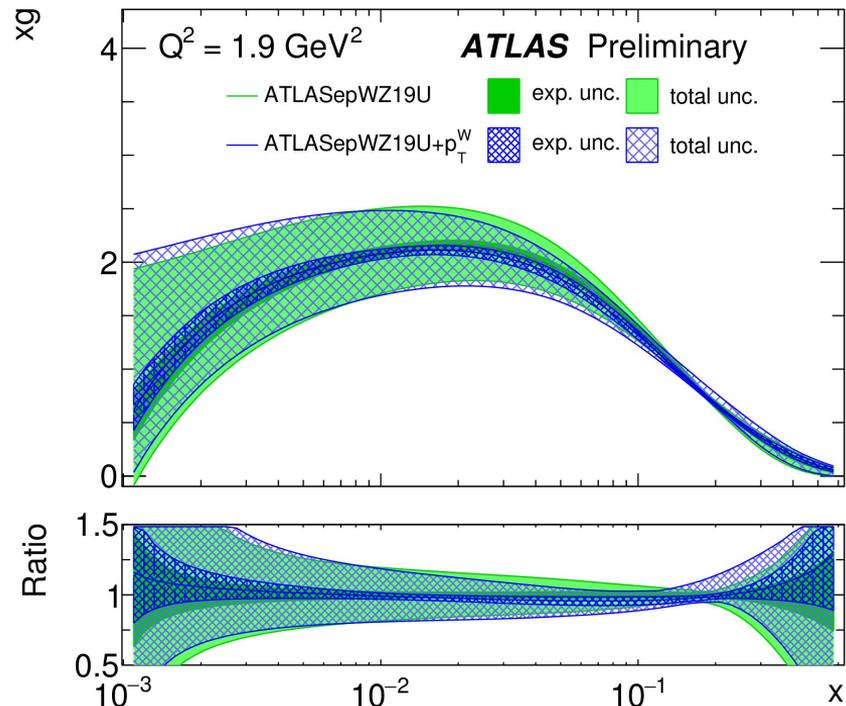
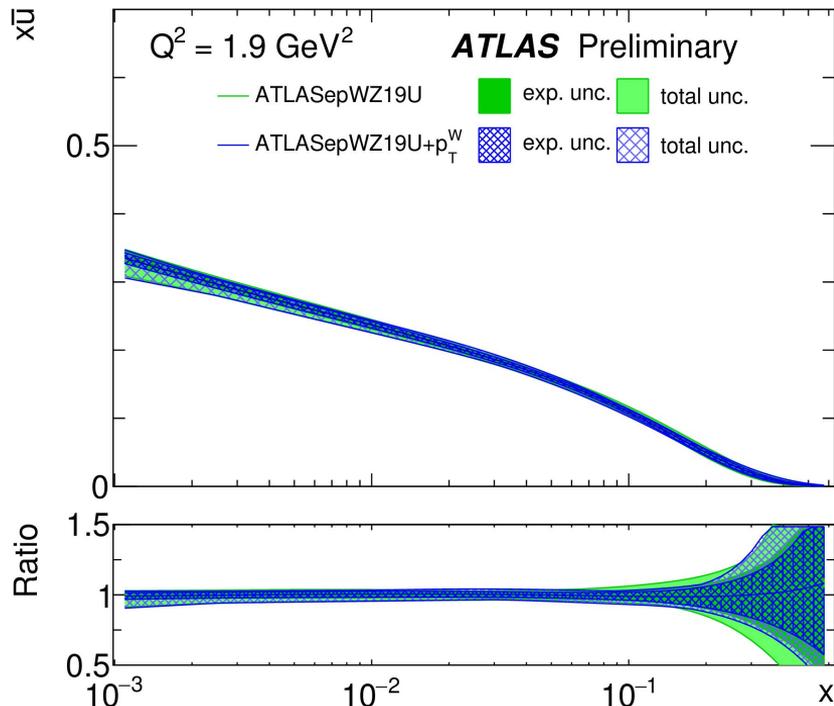
Backup slides - $W + \text{jet}$ results - impact on PDFs

Valence up and down quark PDFs



Backup slides - $W + \text{jet}$ results - impact on PDFs

Sea u quark and gluon PDFs



Backup slides - ATLAS $t\bar{t}$ samples - studied rapidity spectra

l +jets channel

dilepton channel

