Overview of PDF-sensitive measurements from Run I in ATLAS

Sue Cheatham (Technion)
on behalf of ATLAS

CENTRO DE CIENCIAS DE BENASQUE PEDRO PASCUAL

Parton Distributions for the LHC
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TECHNION Israel Institute of Technology

ATLAS SM Measurements

Traditional processes for PDF fits include jets, Drell-Yan and inclusive W,Z production.

Content of this talk:

Focus on ATLAS measurements

- inclusive jet cross section [arXiv:1410.8857]
- Dijet cross sections [arXiv:1312.3524]
- Three-jet production cross sections [arXiv:1411.1855]
- Inclusive prompt photon cross section [arXiv:1311.1440]
- W+charm [arxiv:1402.6263]
- Ratio of cross sections for W + jets and Z + jets [arXiv:1408.6510]
- Low mass Drell-Yan [arXiv:1404.1212] + High mass Drell-Yan [arXiv:1305.4192]
- Measurement of top-quark pair differential cross sections [arXiv:1407.0371]
- Z transverse momentum distribution [arXiv:1406.3660]
- Z boson in association with b-jets [arXiv:1407.3643]
- Simultaneous measurements of tt,WW,and Z->$\tau\tau$ cross sections [arXiv:1407.0573]

ATLAS

ATLAS talks this week:

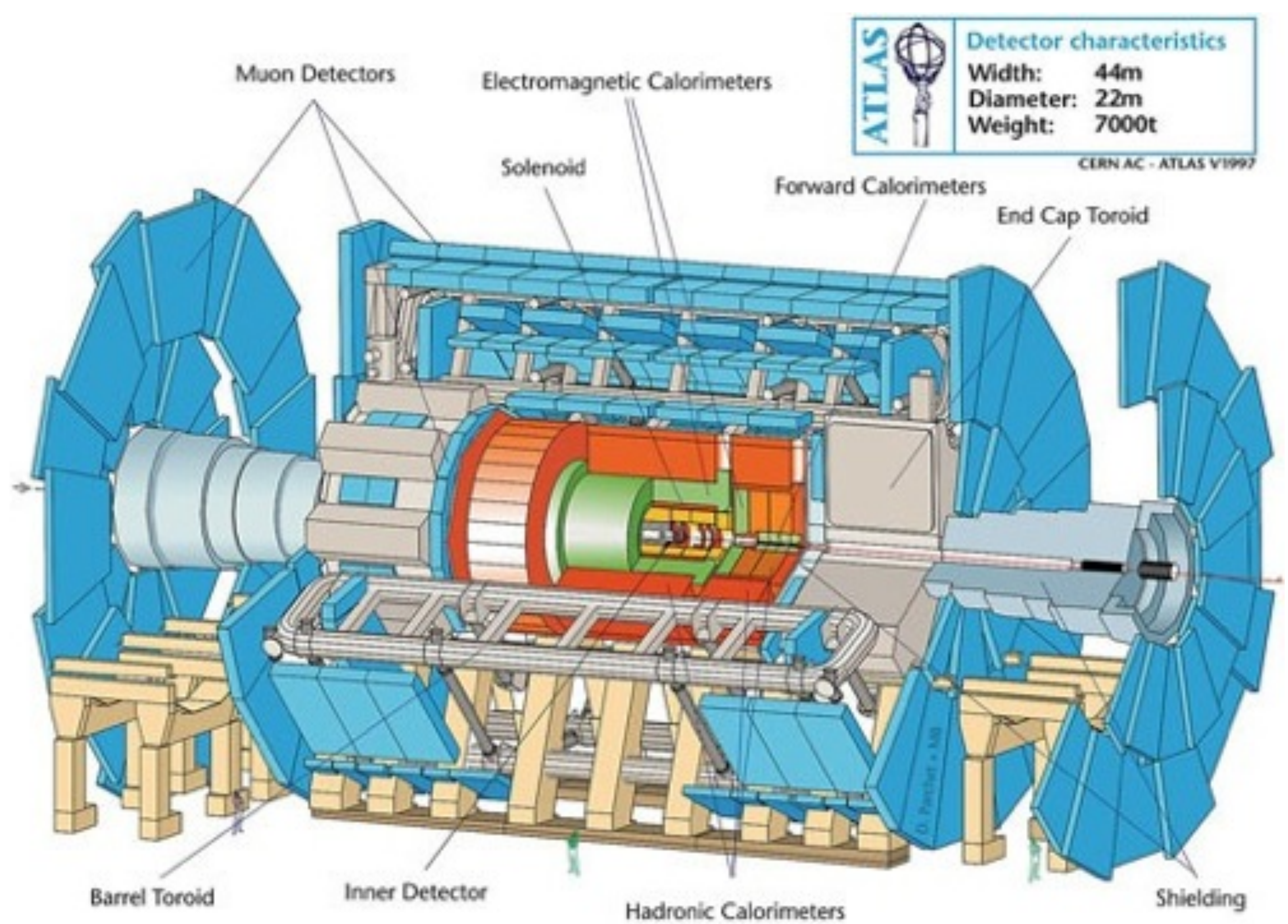
‘PDF uncertainties in precision electroweak measurements, including the W mass, in ATLAS’
Amanda Cooper-Sarkar

‘Plans for PDF measurements at Run II and role of PDFs in MC tuning in ATLAS’
Voica Radescu

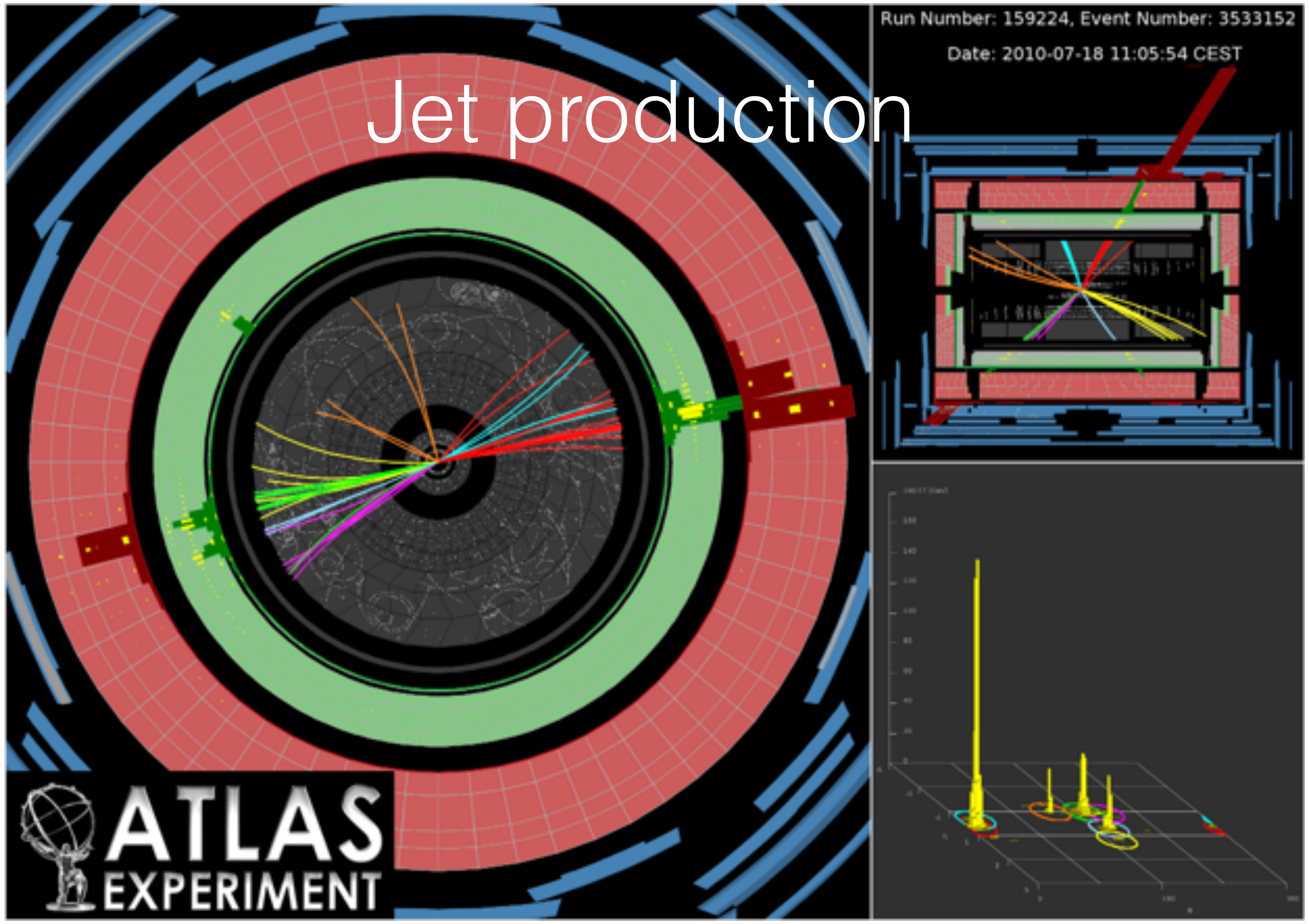
~29 fb^{-1} of data delivered during Run 1

	Nominal	2011	2012
Energy centre-of-mass[TeV]	**14**	**7**	**8**
Peak luminosity [$cm^{-2}s^{-1}$]	**$1x10^{34}$**	**$3.7x10^{33}$**	**$7.7x10^{33}$**
Max. average interactions per b.c.	**23**	**24**	**37**
ATLAS luminosity uncertainty	**-**	**1.8%**	**2.8%**

Magnetic field	2 T solenoid + toroid: 0.5 T (barrel), 1 T (endcap)
Tracker	Silicon pixels and strips + transition radiation tracker $\sigma/p_T \approx 5 \cdot 10^{-4} p_T + 0.01$
EM calorimeter	Liquid argon + Pb absorbers $\sigma/E \approx 10\%/\sqrt{E} + 0.007$
Hadronic calorimeter	Fe + scintillator / Cu+LAr (10λ) $\sigma/E \approx 50\%/\sqrt{E} + 0.03$ GeV
Muon	$\sigma/p_T \approx 2\%$ @ 50GeV to 10% @ 1TeV (Inner Tracker + muon system)
Trigger	L1 + HLT (L2+EF)



Jet production



Systematic uncertainties in jet measurements are dominated by the Jet Energy Scale (JES).

Jets in ATLAS are reconstructed from energy deposits forming topological clusters of calorimeter cells using the anti-kt algorithm with distance parameters R=0.4 or R=0.6.

Jets are first calibrated using MC: energy offset due to pileup activity in calorimetry + redefine PV_{jet}
Then data/MC in-situ correction: account for remaining differences in calorimeter response.

Typically JES uncertainty ~1-4% for central rapidities increasing to 4-5% in the forward regions.

Measurement of the inclusive jet cross section in pp collisions at $\sqrt{s}$=7 TeV using 4.5 fb^{-1}

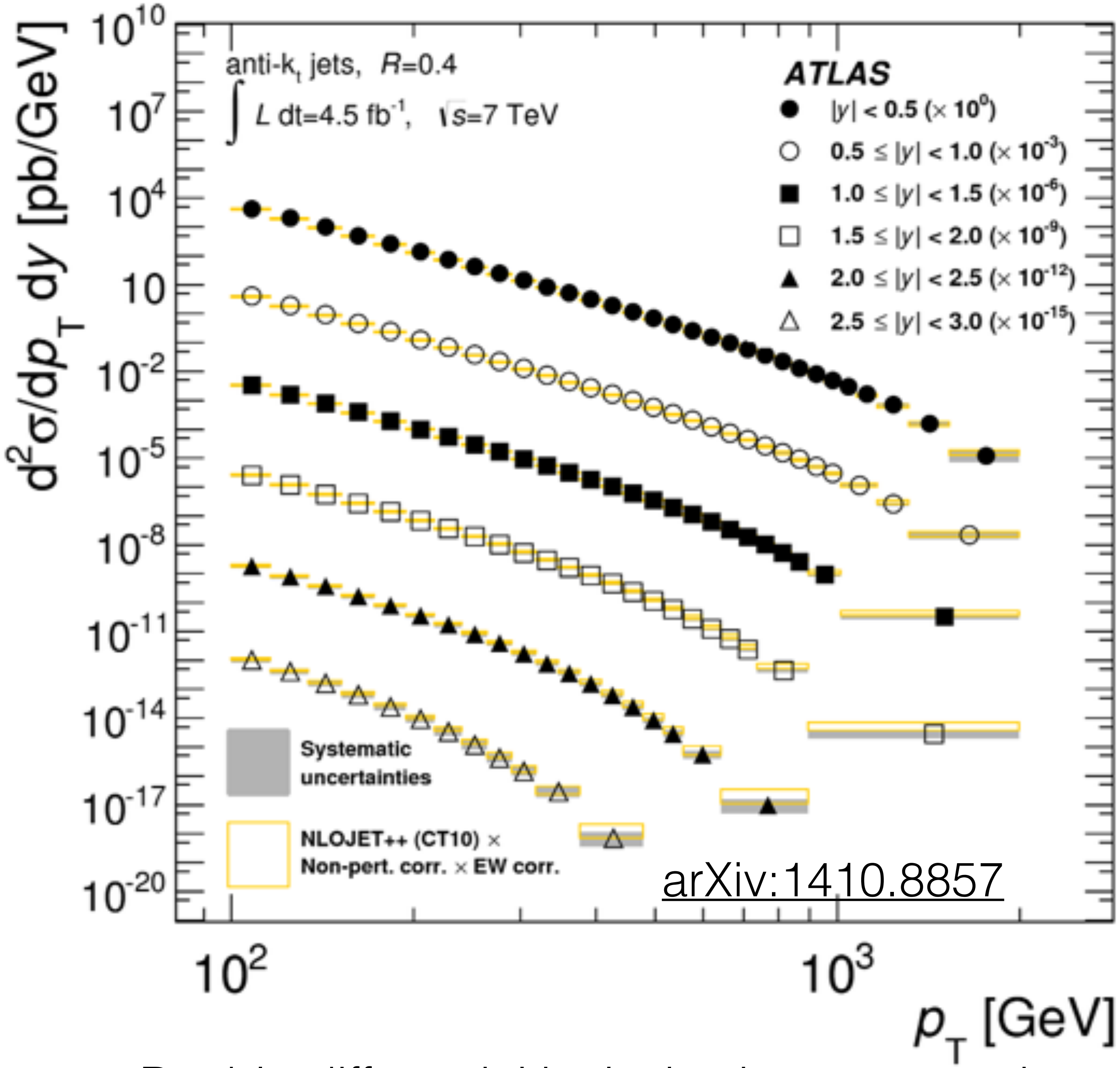
Data span large kinematic range:
100 GeV<p_T^{Jet}<2 TeV & $|y^{jet}|$<3.

Data are compared to NLO pQCD predictions calculated using NLOJET++ with the CT10 NLO PDF set, to which non-perturbative and electroweak corrections are applied.

Non-perturbative correction calculated using Pythia/Herwig with various tunes.

The 1.8% uncertainty from the luminosity measurement is not shown.

Good agreement between data and theory over 8 orders of magnitude in the 6 rapidity bins.



Double-differential inclusive jet cross sections as a function of the jet p_T in bins of rapidity.

Inclusive jet cross section : Comparison to theory

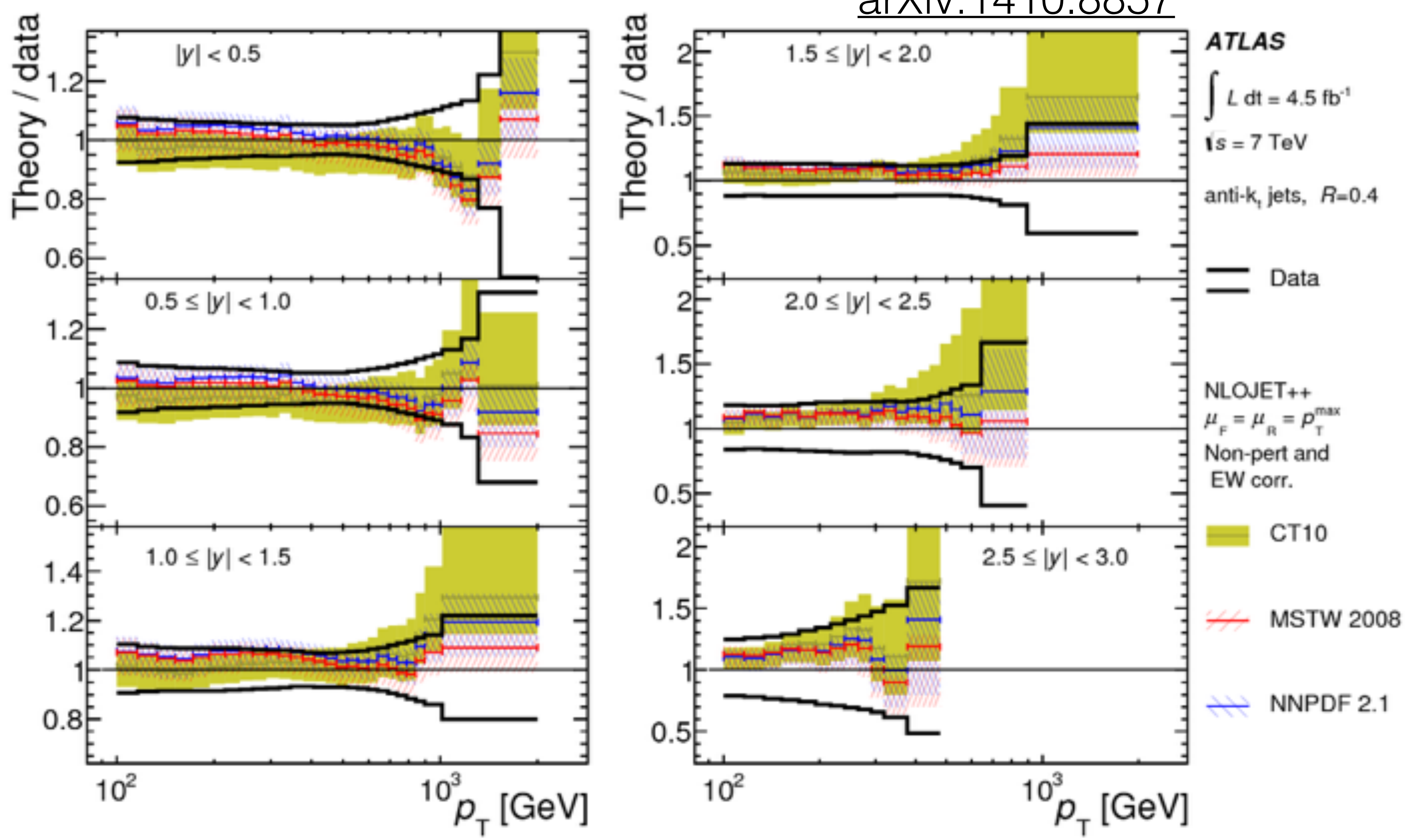
arXiv:1410.8857

Predictions are calculated using NLOJET++ with different NLO PDF sets; CT10, MSTW2008 and NNPDF 2.1

The predictions are generally consistent with the measured jet cross sections.

Confirmation that perturbative QCD can describe jet production up to jet p_T 2TeV.

Data sensitive to PDFs. PDF fit information public: statistical & systematic uncertainties, together with their correlations.



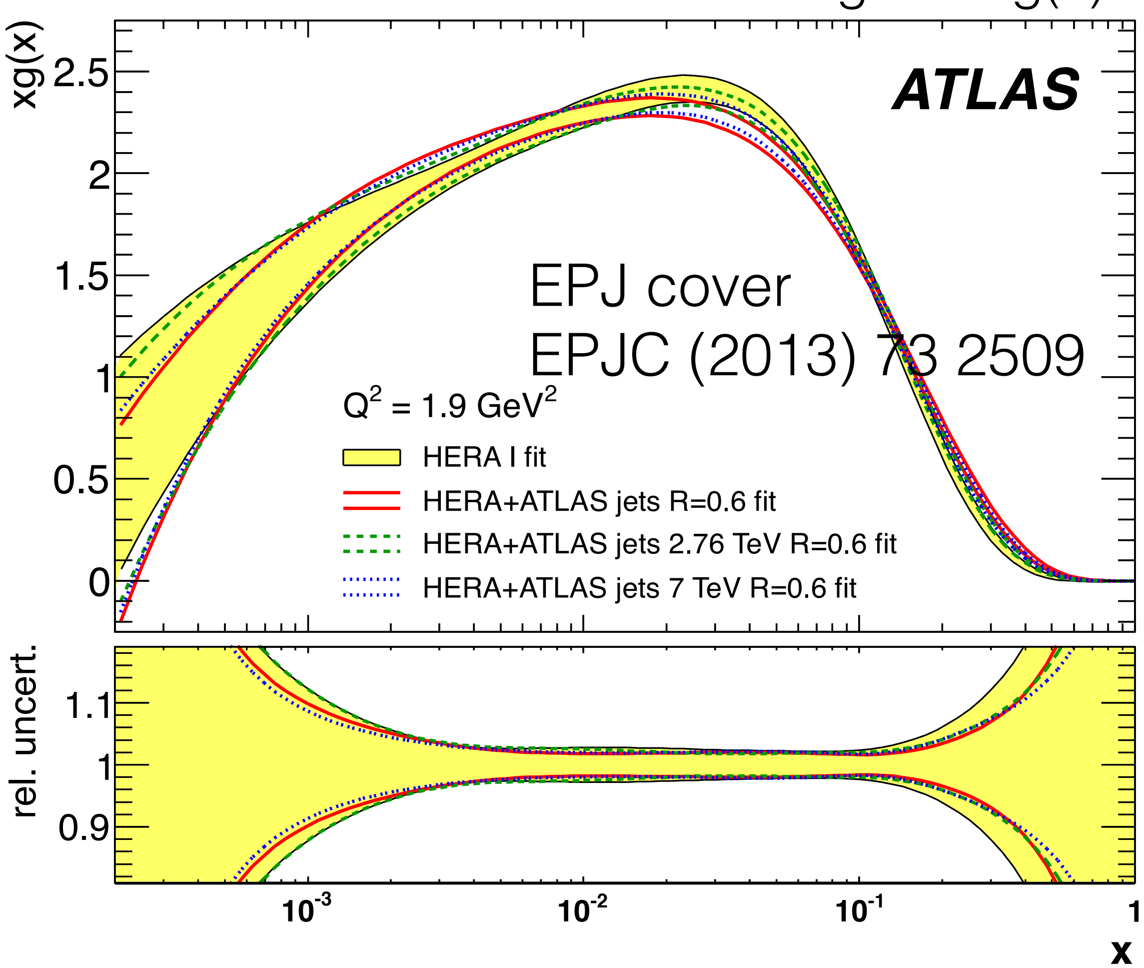
Ratio of NLO pQCD predictions to the measured double-differential inclusive jet cross section, as a function of the jet p_T in bins of the jet rapidity.

Accepted by JHEP

Inclusive Jet cross section ratios
($\sqrt{s}$ = 2.76 to $\sqrt{s}$ =7TeV)

The major experimental systematic, the Jet Energy Scale, largely cancels out.
The two different beam energies probe different x and Q^2 values for the same p_T and y ranges so that the sensitivity to PDFs does not cancel in the ratio.

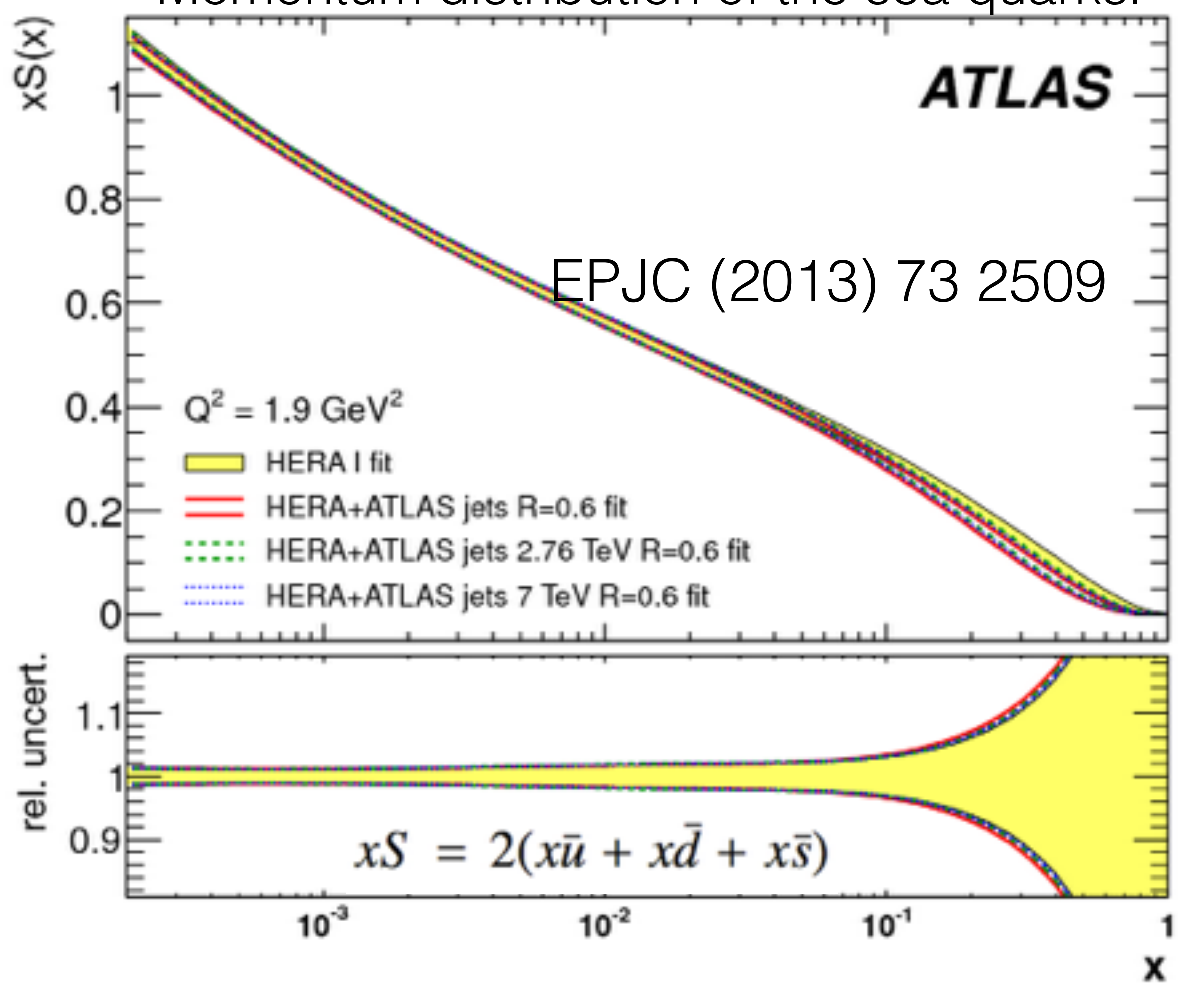
Momentum distribution of the gluon xg(x)



The uncertainty is reduced by including the ATLAS jet data in the fit.

epATLJet13 : New PDF set derived, by including ATLAS jet data in the HERA1.5 dataset.

Momentum distribution of the sea quarks.



Softer sea-quark distribution in the high Bjorken-x region are obtained with respect to the fit of HERA data only.

Measurement of dijet cross sections in pp collisions at 7 TeV

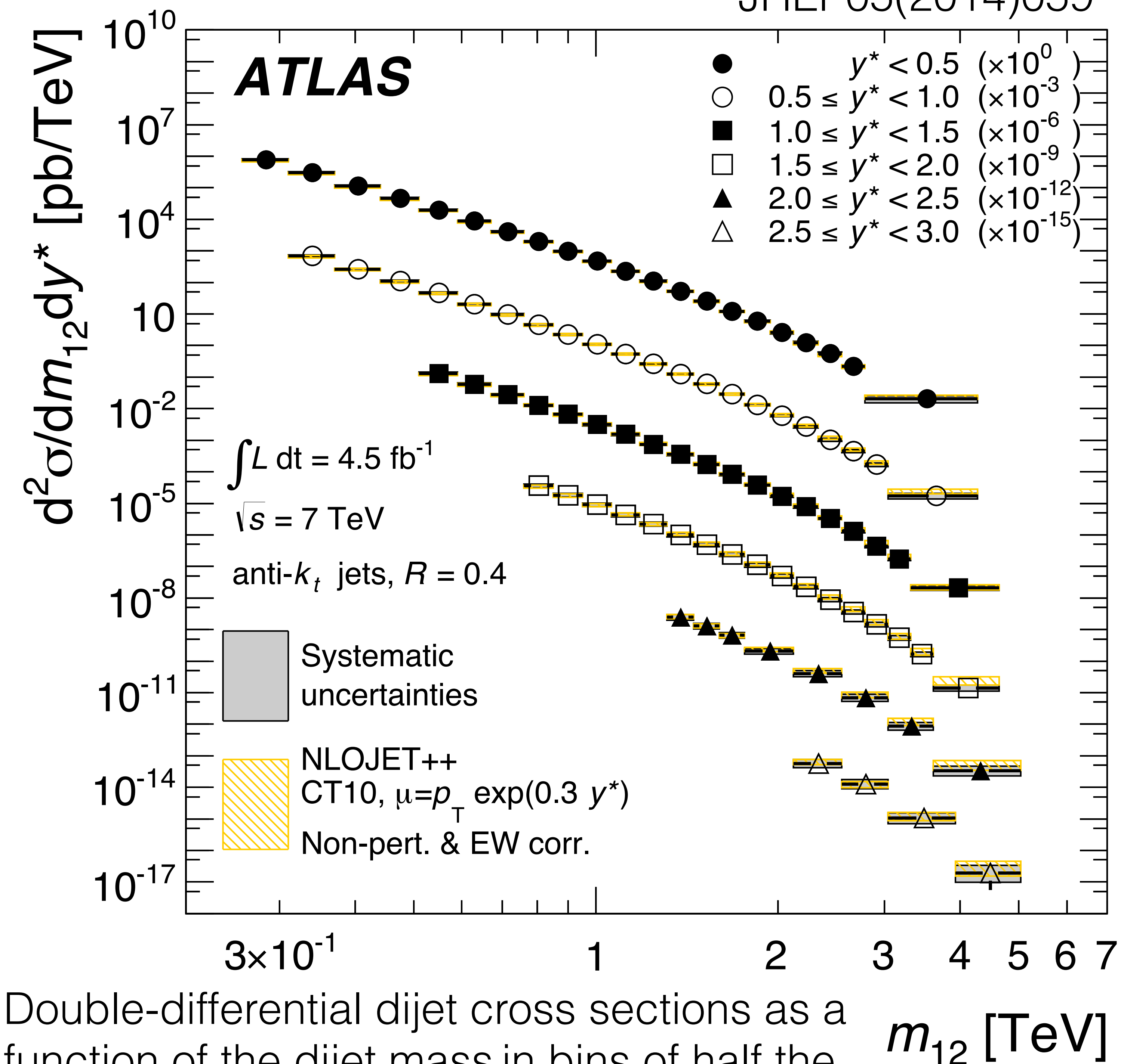
JHEP05(2014)059

Jet kinematics:
$p_T^{J1} > 100$ GeV & $p_T^{J2} > 50$ GeV
$|y^{jet}| < 3$ and $y^* < 3$ ($y^* = |y_1 - y_2| / 2$)

Data are compared to NLO pQCD predictions calculated using NLOJET++ with various PDF sets, to which non-perturbative corrections and electroweak corrections are applied.

Non-perturbative correction calculated using Pythia/Herwig with various tunes.

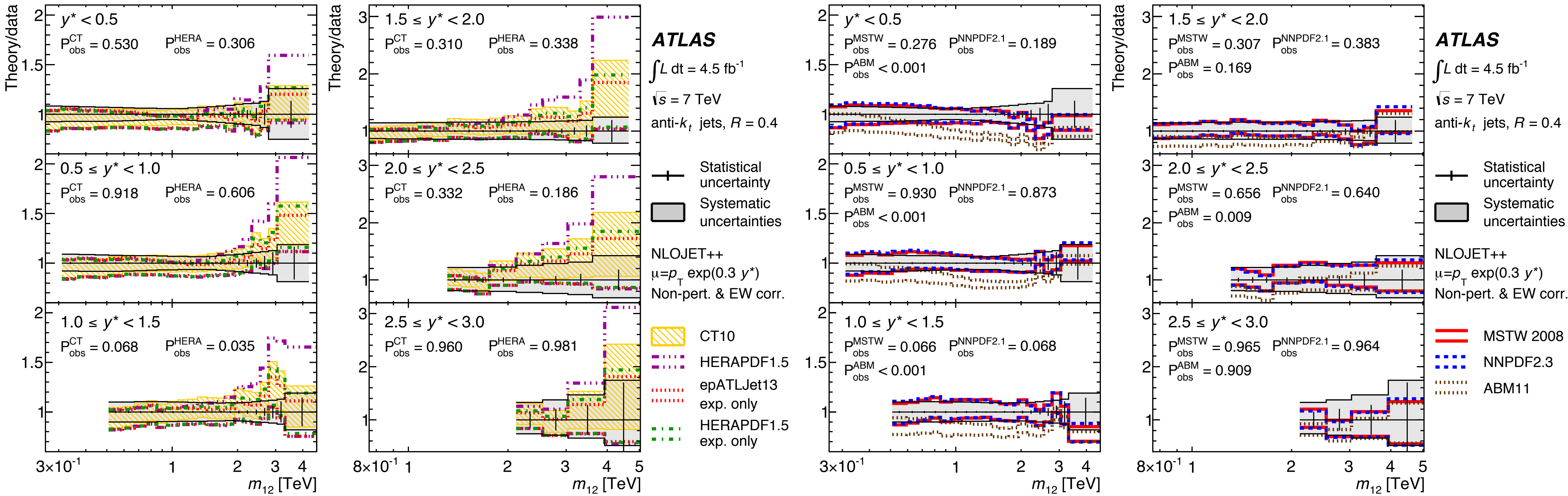
Good agreement with data for CT10 over 7 orders of magnitude.



Double-differential dijet cross sections as a function of the dijet mass in bins of half the rapidity separation, y*, of the 2 leading jets.

Dijet cross sections : Comparison to theory

JHEP05(2014)059



Ratio of NLO pQCD predictions to measurements as a function of dijet mass in different ranges of y*

Data is sensitive to PDF sets.

Data well described by CT10, NNPDF2.1 and MSTW 2008 PDF sets.
Small tensions with HERAPDF1.5.
ABM11 disfavoured since underestimates measured cross section.

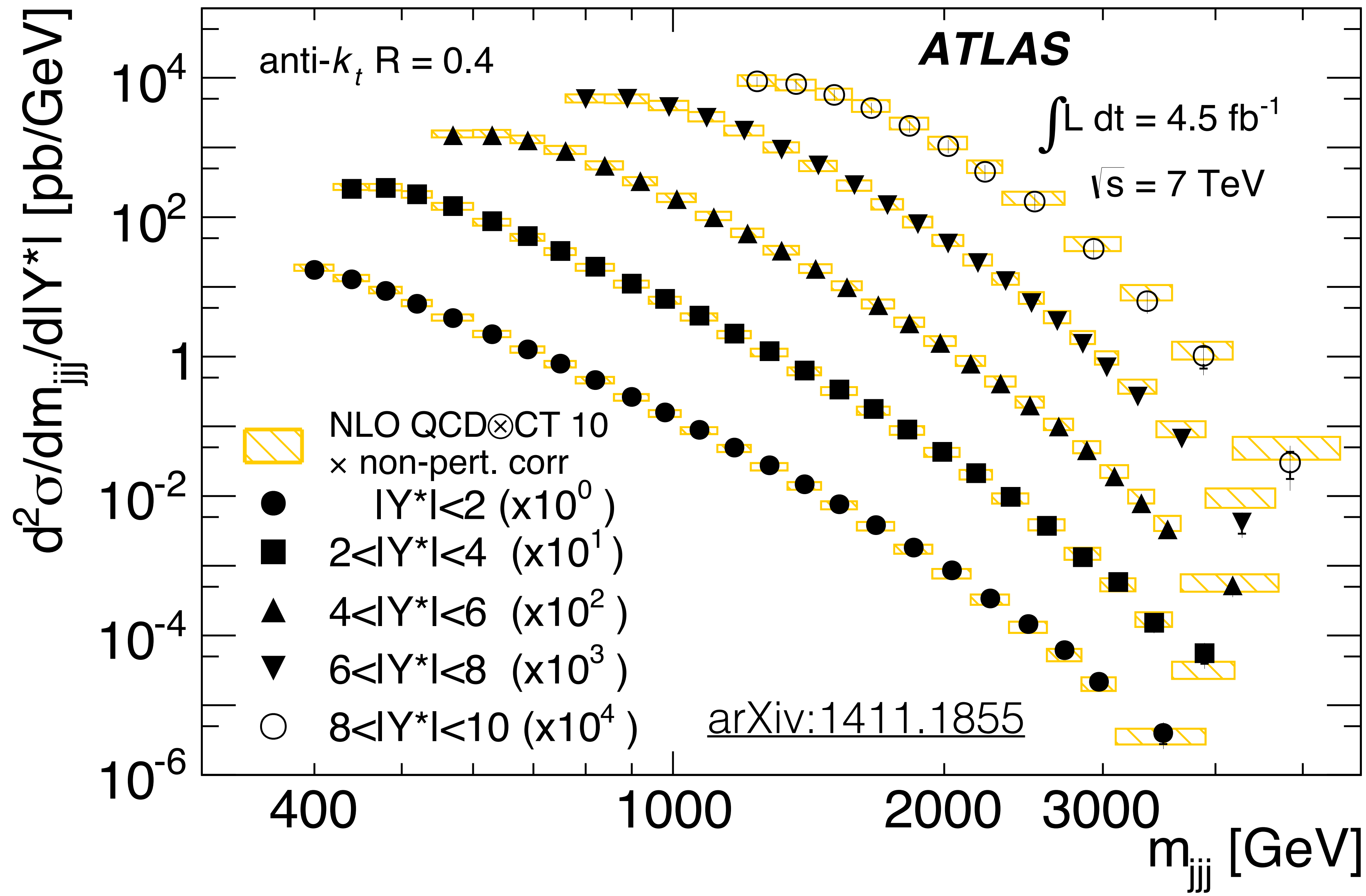
Measurement of three-jet production cross sections

Jet kinematics:
m_{jjj} <5 TeV, |Y*|<10
p_T^1 >150 GeV, p_T^2>100 GeV, p_T^3 >50 GeV

Y*=|y1-y2| + |y1-y3| + |y2- y3|

A massive three-jet system can be built either from high-p_T jets or from jets with large rapidity separation.
Binning in |Y*| allows separation.

3-jet study probes a different region of phase space in (x,Q^2) cf 1 and 2 jet.
Provide constraints on gluon PDF and α_s



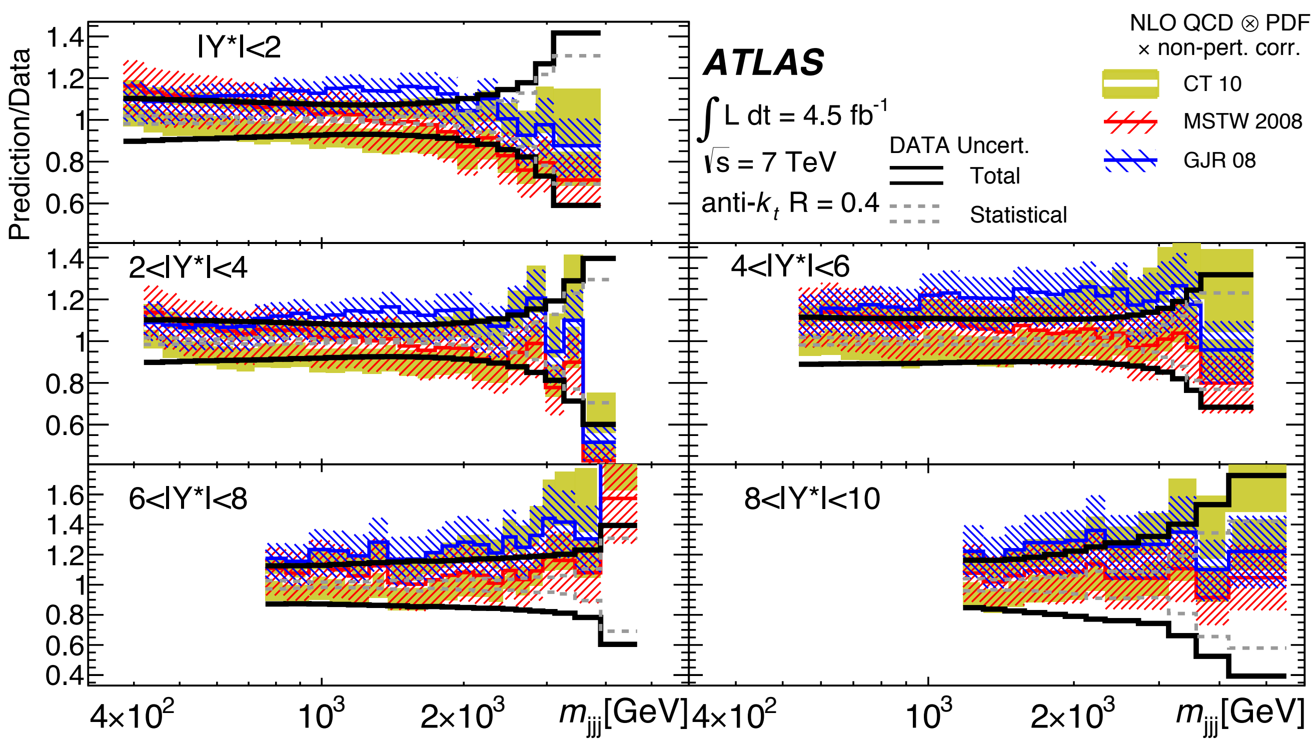
Double-differential 3-jet cross sections as a function of the 3-jet mass in bins of Y*, the sum of absolute rapidity separations between the 3 leading jets.

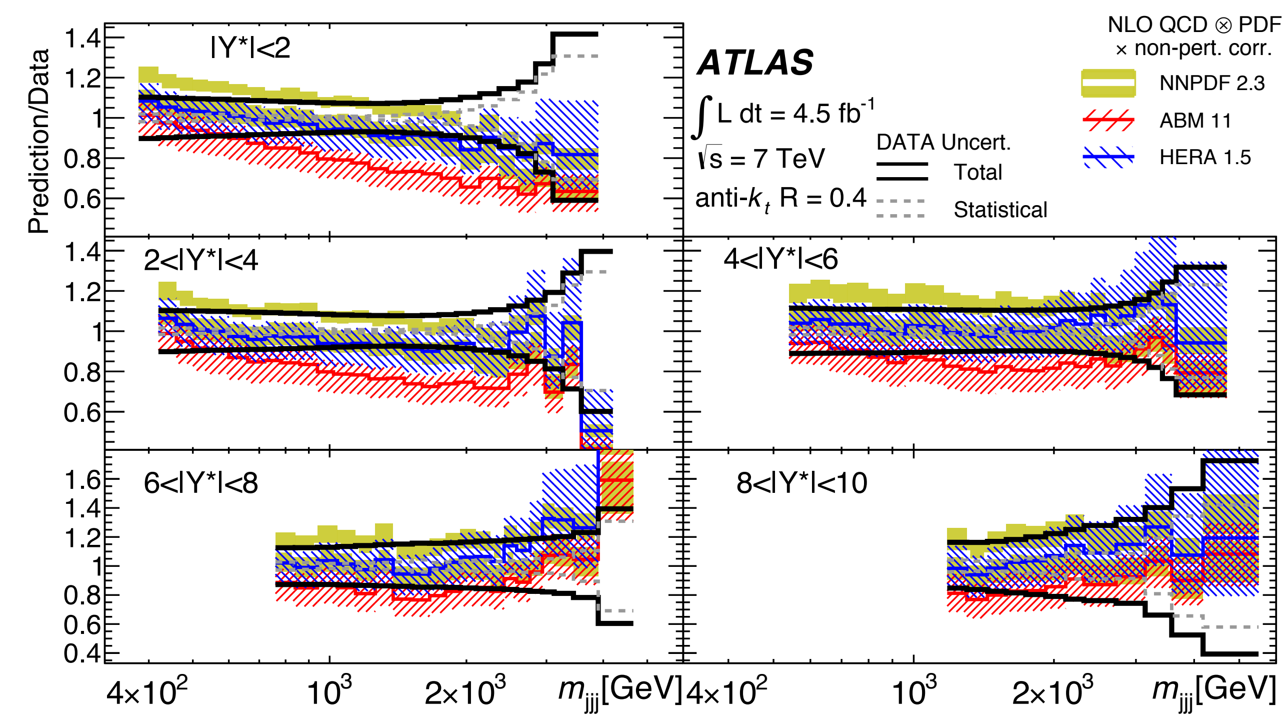
No EW corrections available.

Probes the gluon density function

Three-jet cross sections : Comparison to theory

arXiv:1411.1855





The ratio of NLO QCD predictions, obtained by using NLOJET++ with different PDF sets, to data.

Generally good agreement between the data and the theoretical predictions based on most of the global PDF sets

Agreement over the full kinematic range, covering almost seven orders of magnitude.

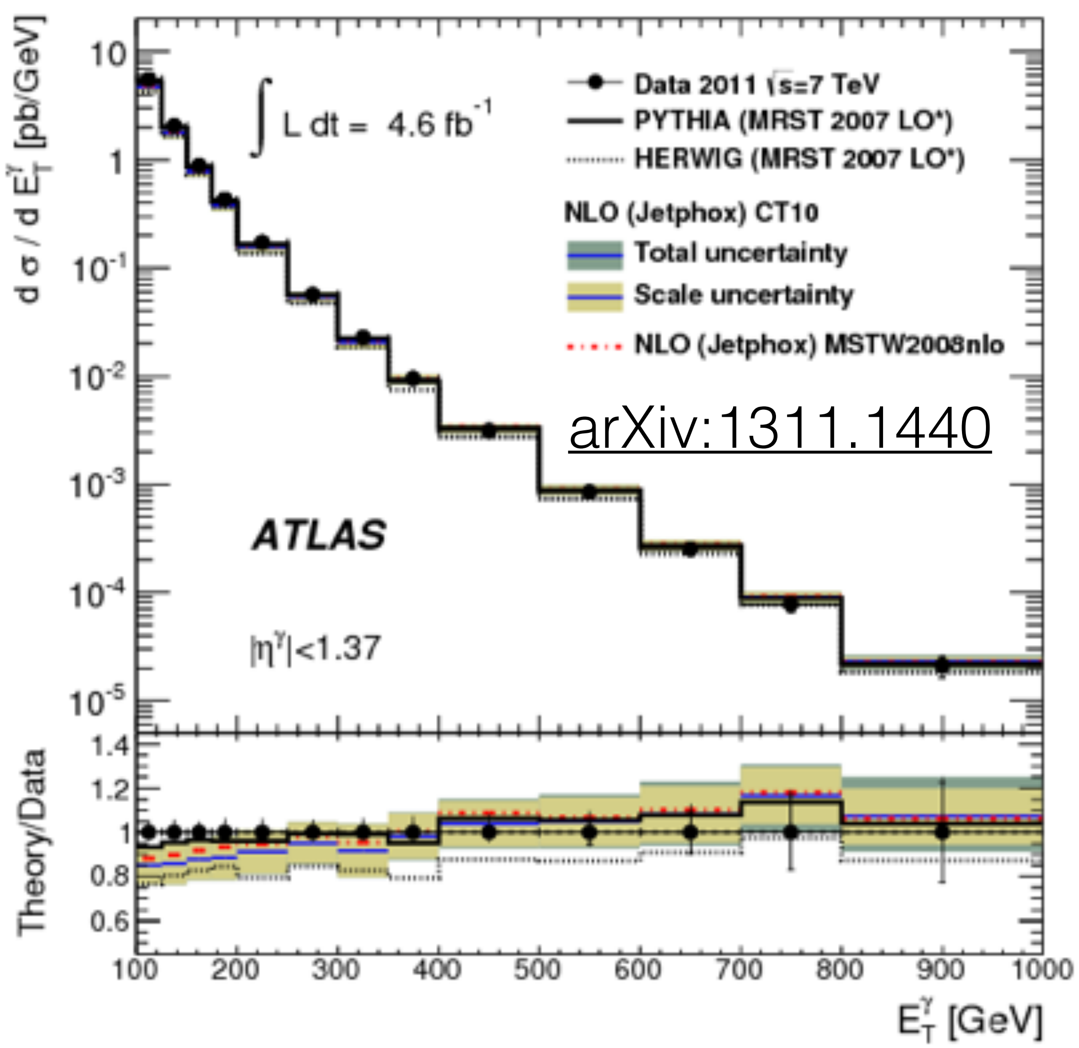
Tensions between data and ABM11.

Prompt photon production

Cleaner experimental environment compared to jet cross section measurements.
Photon data could improve the determination of the gluon density at high-x.

Kinematics: 100 GeV < E_T^γ < 1 TeV

Validated the use of MCFM for fast NLO calculation against JETPHOX.



arXiv:1311.1440

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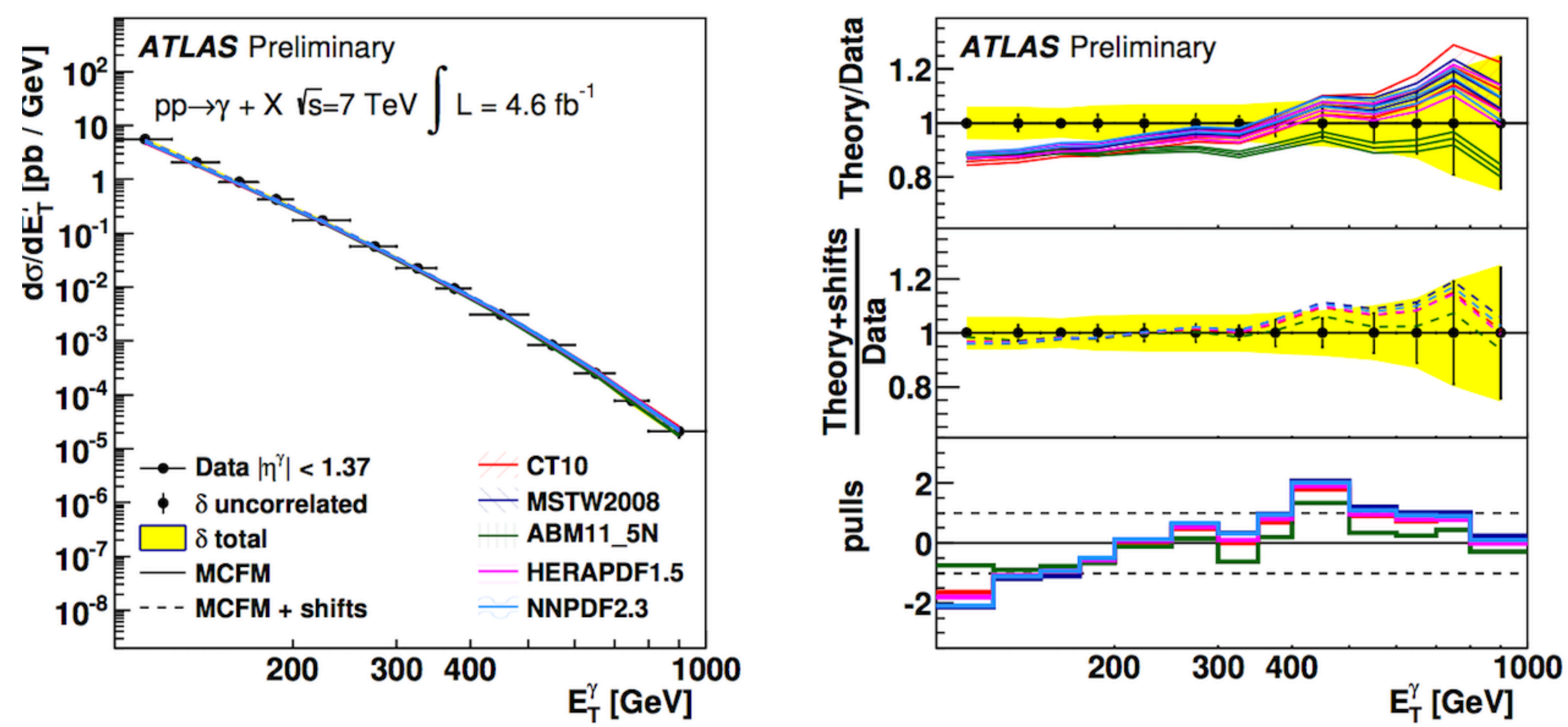
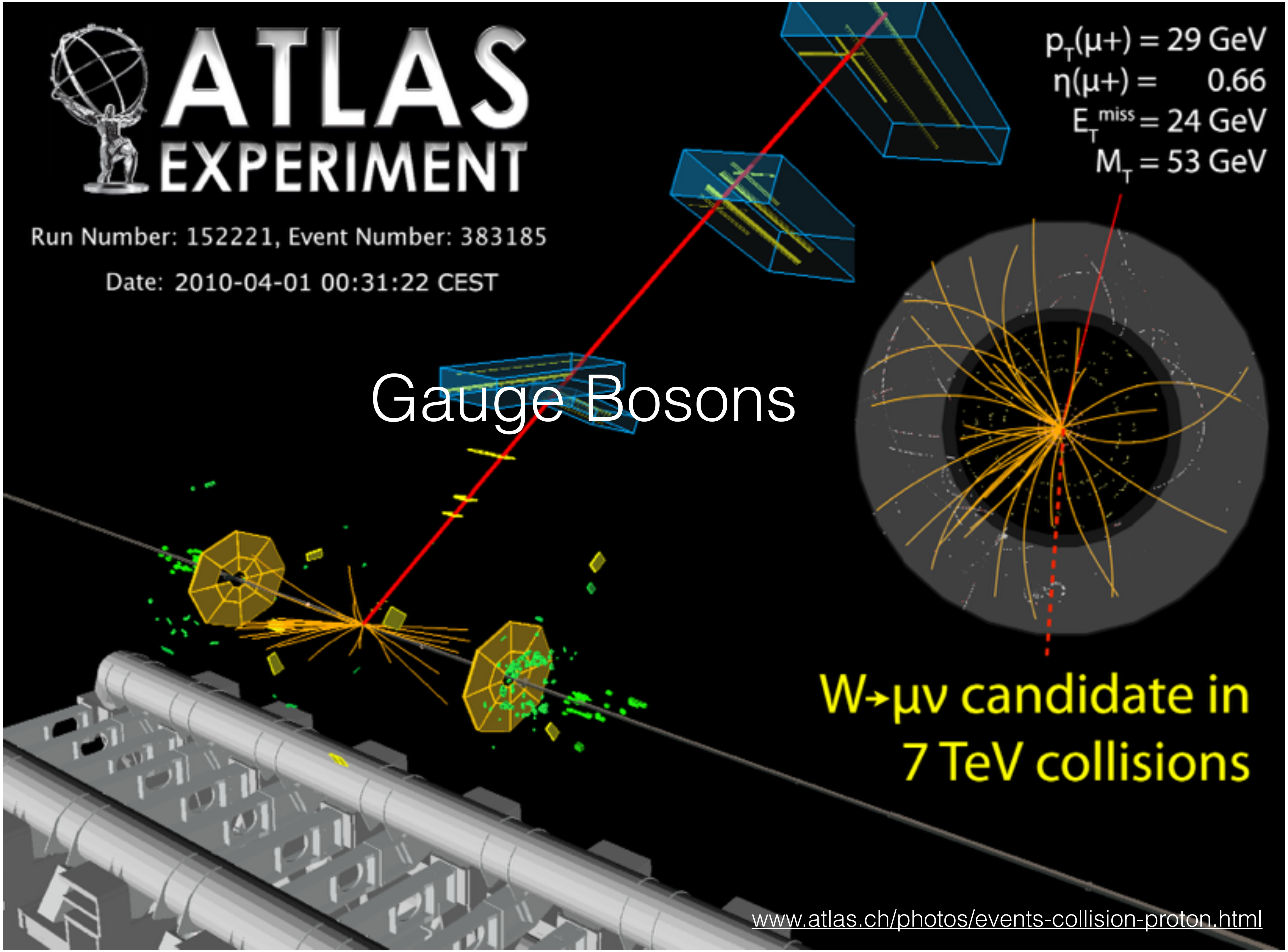


Measured and expected inclusive prompt photon cross section as a function of photon E_T in the barrel region.

Measured cross sections as a function of E_T^γ compared to MCFM NLO predictions with different PDF sets.

Gauge Bosons

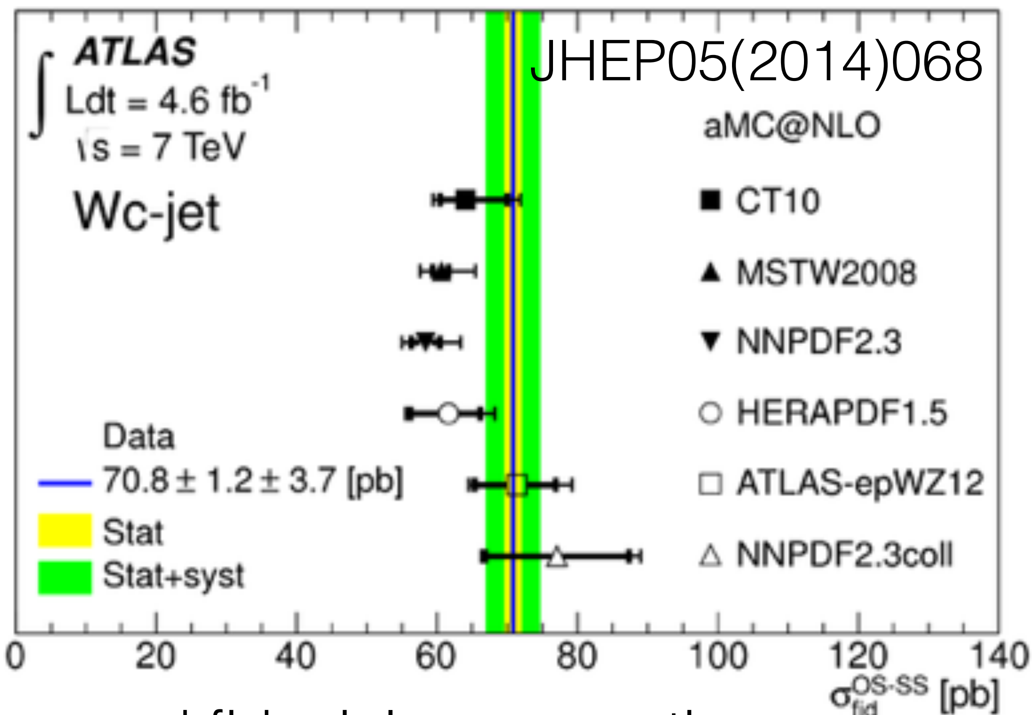


www.atlas.ch/photos/events-collision-proton.html

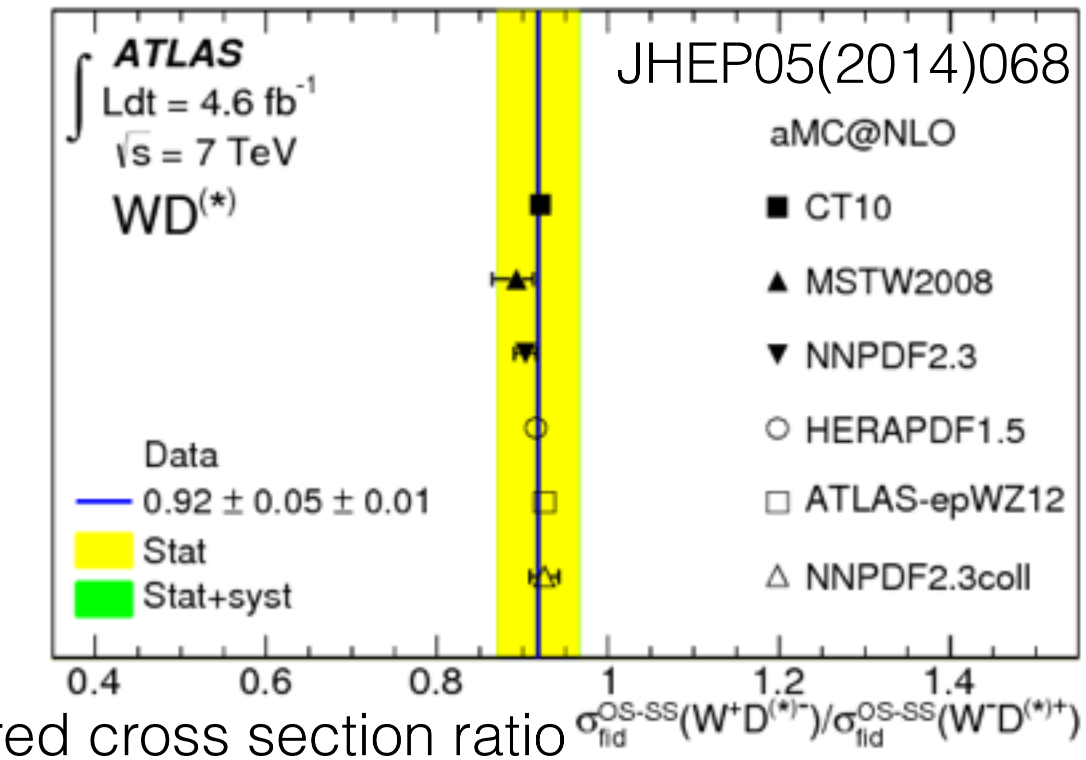
Clean experimental signatures + advanced theoretical predictions.
Probe quarks and photon density functions.

W+charm

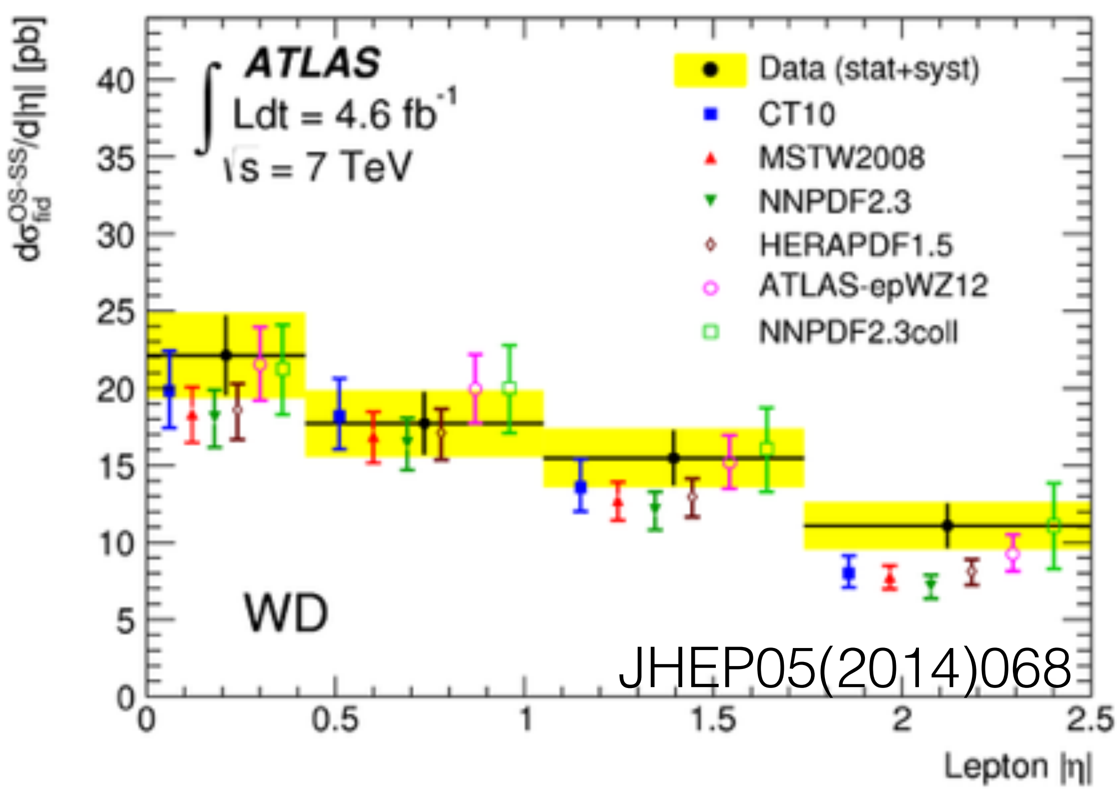
arxiv:1402.6263



Measured fiducial cross sections



Measured cross section ratio



Measured fiducial cross section differential in lepton |η|

Theory predictions based on aMC@NLO+Herwig++

W^++charm / W^-+charm sensitive to the $s\bar{s}$ asymmetry

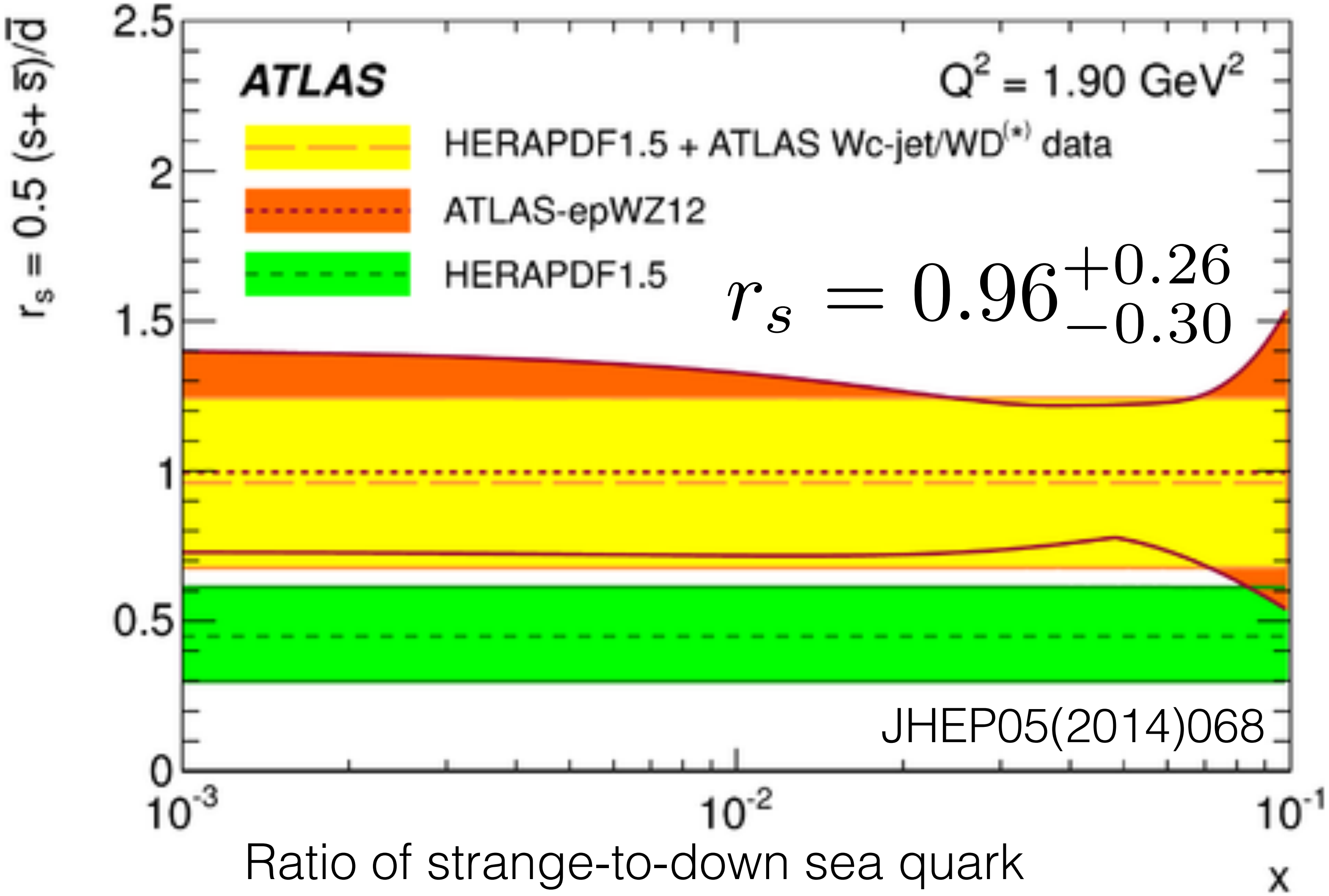
PDF variation mostly affects the total cross section.

Data are consistent with a wide range of PDFs, but show a preference for ATLAS-epWZ12 and NNPDF2.3coll with an SU(3)-symmetric light-quark sea.

Directly sensitive to the strange PDF

W+charm

$$r_s(x) = 0.5\frac{s(x)+\bar{s}(x)}{\bar{d}(x)}$$



$$r_s = 0.96^{+0.26}_{-0.30}$$

Ratio of strange-to-down sea quark distributions as a function of x

Adding the ATLAS W+charm data on top of the HERA1.5 data.

Results consistent with ATLAS-epWZ12

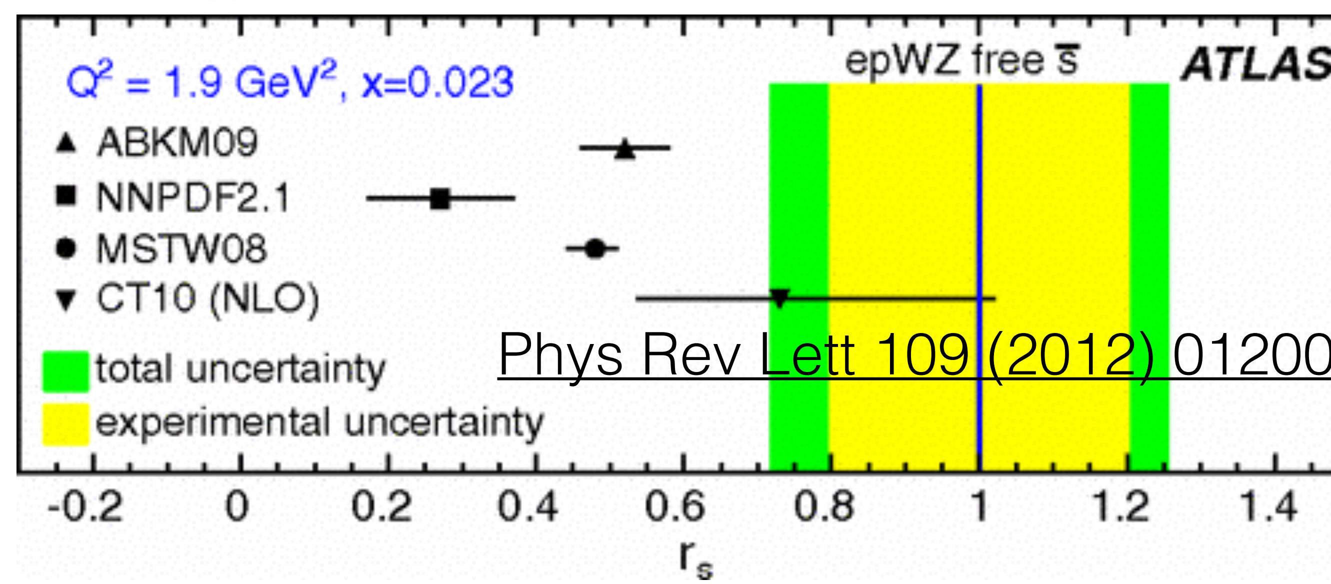
Supports unsuppressed strange.

Disagreement with CMS: could just be due to different treatment of hadronisation corrections ?

PhysRevD.85.072004

Compatible with r_s determination from ATLAS W, Z inclusive measurement

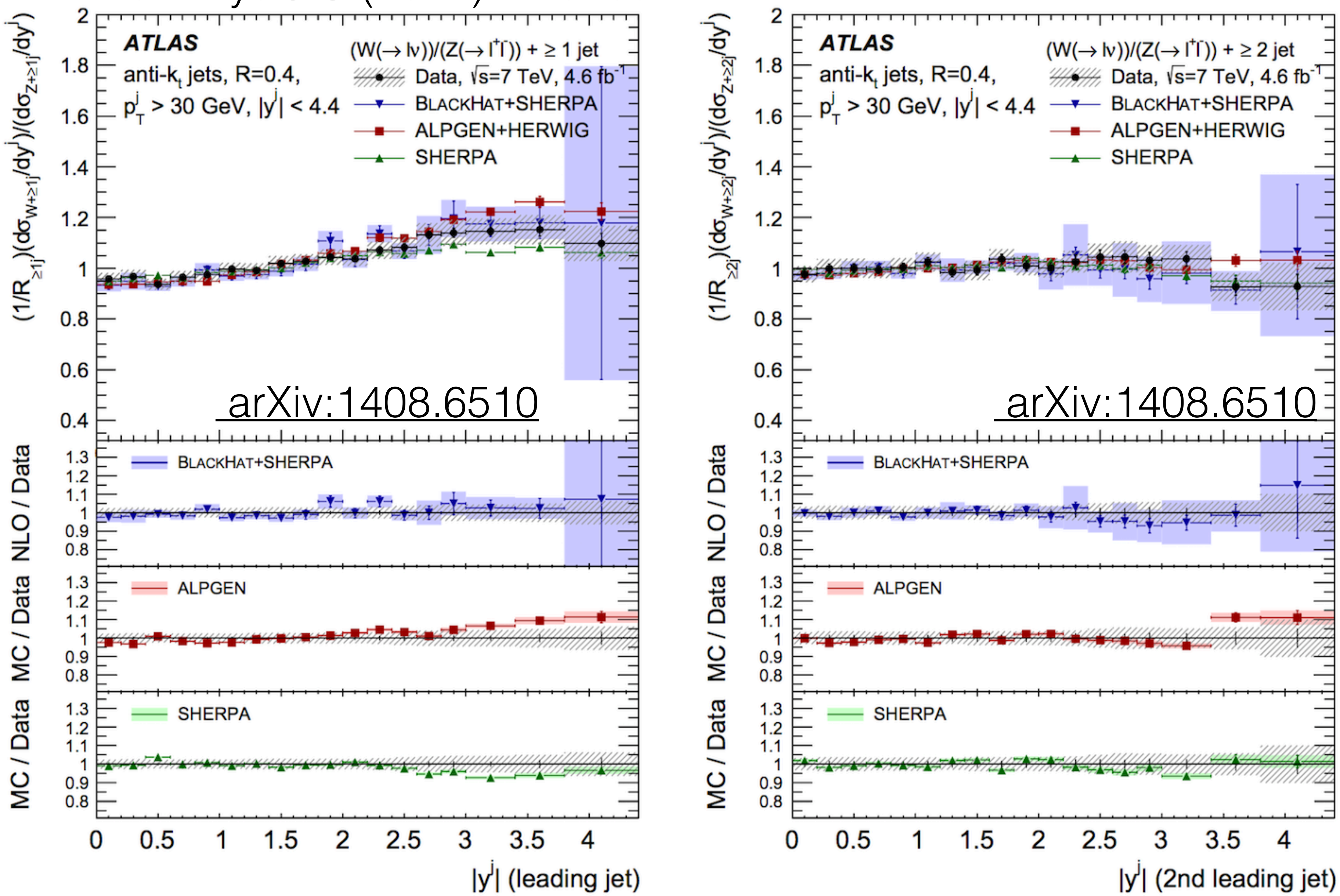
$$r_s = 1.00^{+0.25}_{-0.28}$$



Phys Rev Lett 109 (2012) 012001

The ratio of the production cross sections for W and Z bosons in association with jets

Eur Phys J C (2014) 74:3168



The ratio of W + jets and Z + jets production cross sections versus the leading (2nd leading)-jet rapidity.

First look at fitting ATLAS 2011 V+Jets.

Large cancellations of experimental systematic uncertainties and non-perturbative QCD effects.

Complementary to individual W+jets and Z+jets measurements.

Some small impact on sea quarks.

BlackHat+SHERPA NLO consistent with results from tuned generators ALPGEN and SHERPA.

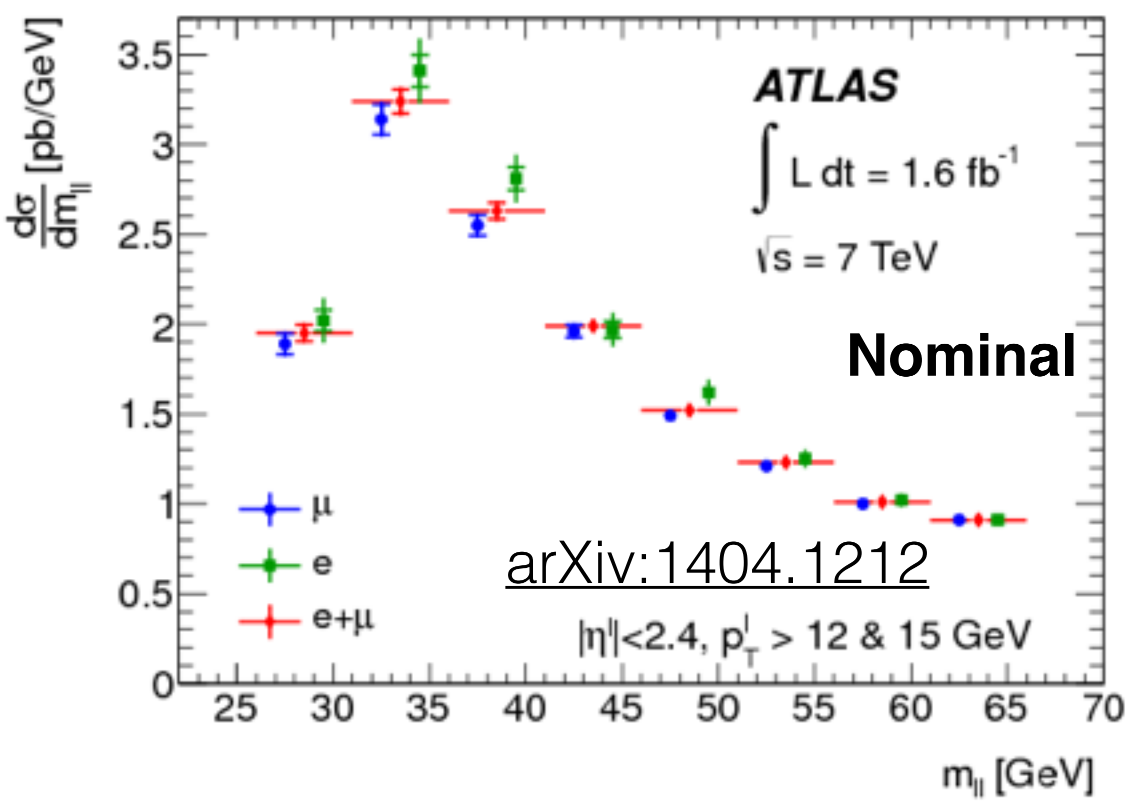
Low mass Drell-Yan

kinematics:
Nominal analysis (ℓ = e,μ):
p_T^ℓ>15 &12 GeV
26 GeV < $m_{\ell\ell}$ < 66 GeV

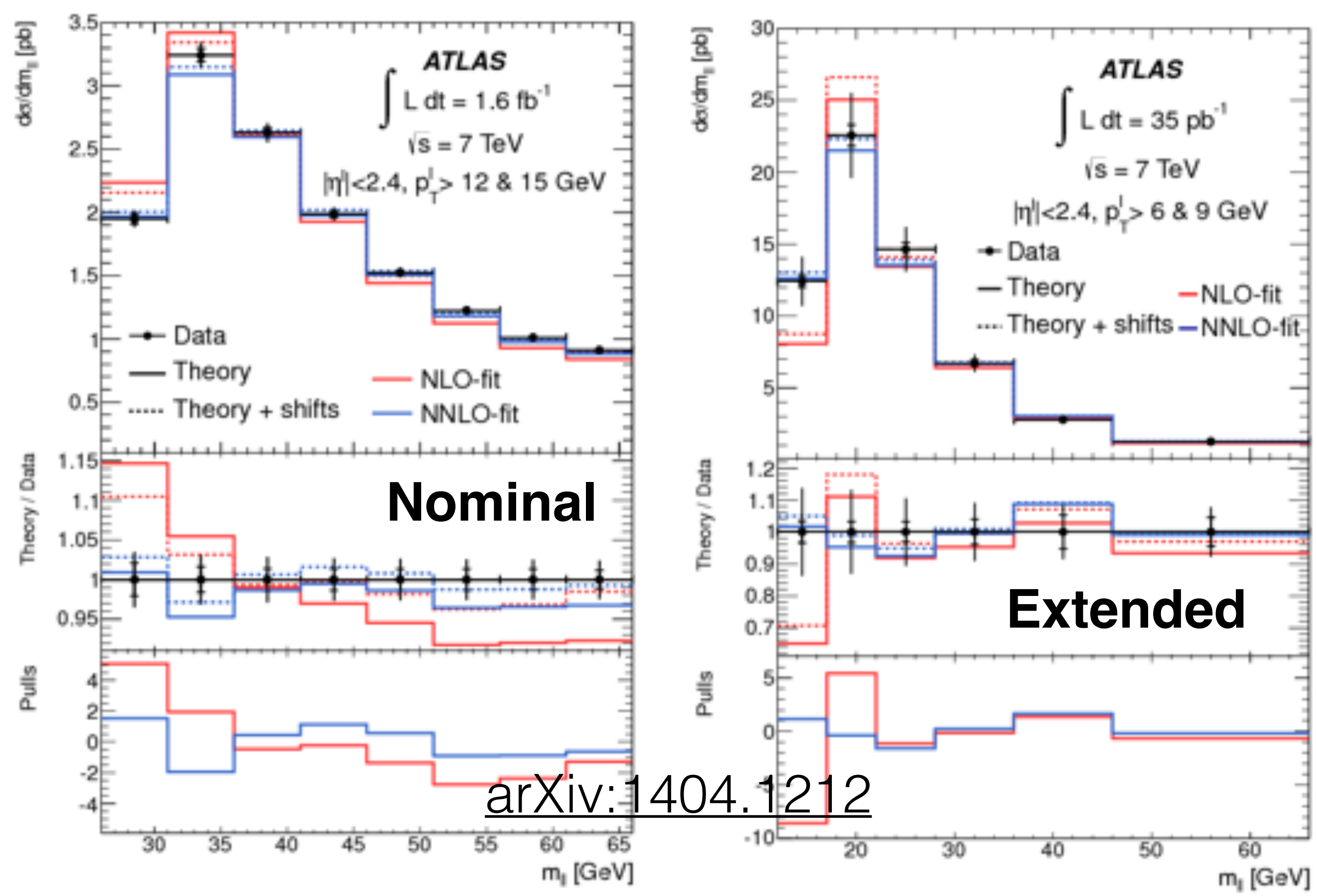
Extended analysis (ℓ = μ):
p_T^ℓ>6 & 9 GeV
12 GeV < $m_{\ell\ell}$ < 66 GeV

Complementary to measurements near the Z mass peak.

Prediction combining NNLO QCD + NLO EW provides significantly better fit to data than NLO.



The fiducial Born-level individual and combined e,μ channel cross section measurements as a function of $m_{\ell\ell}$.



The measured differential cross section as a function of $m_{\ell\ell}$ compared to NLO and NNLO fits.

High mass Drell-Yan

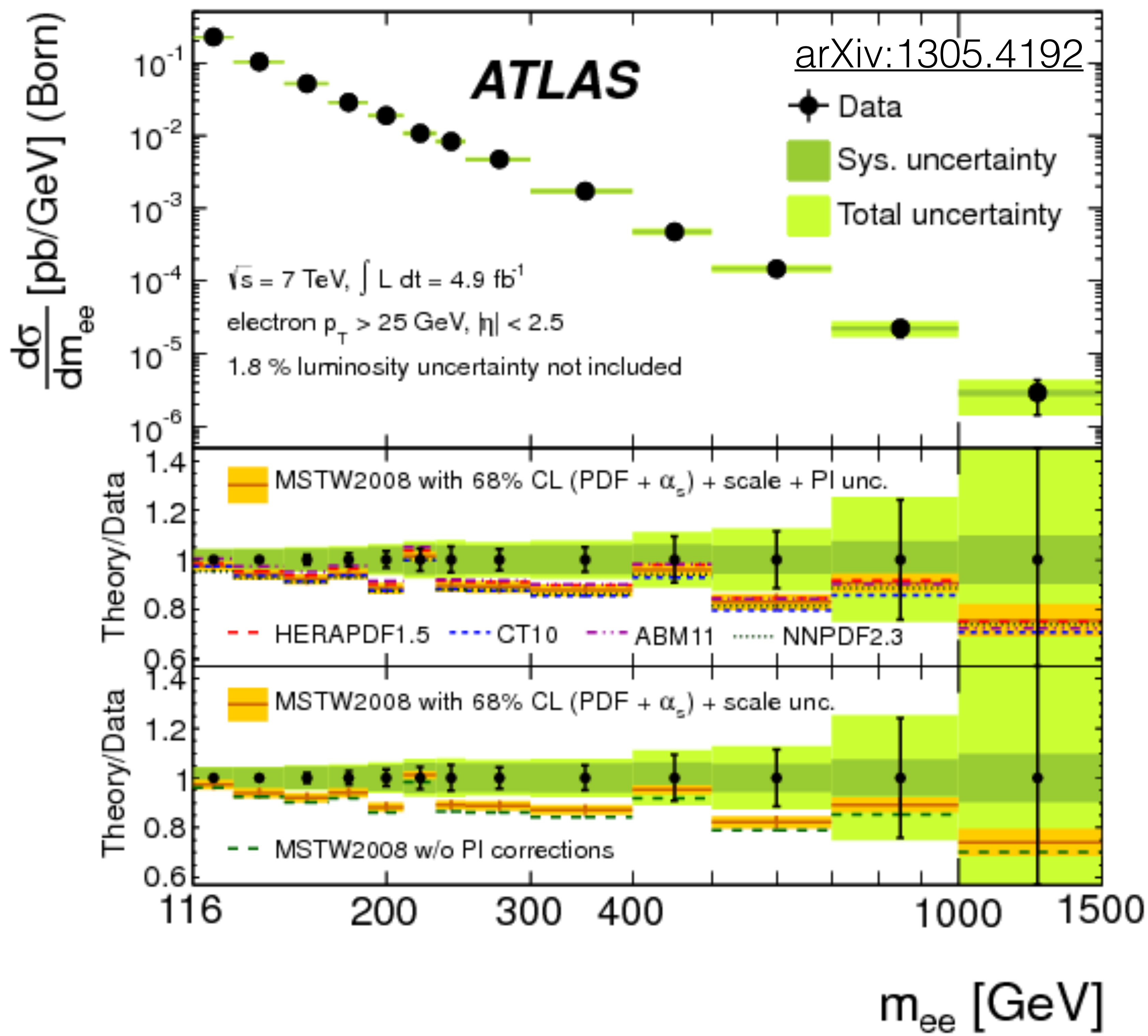
Phys Lett B725 (2013) 223

NNLO predictions with NLO EW corrections.

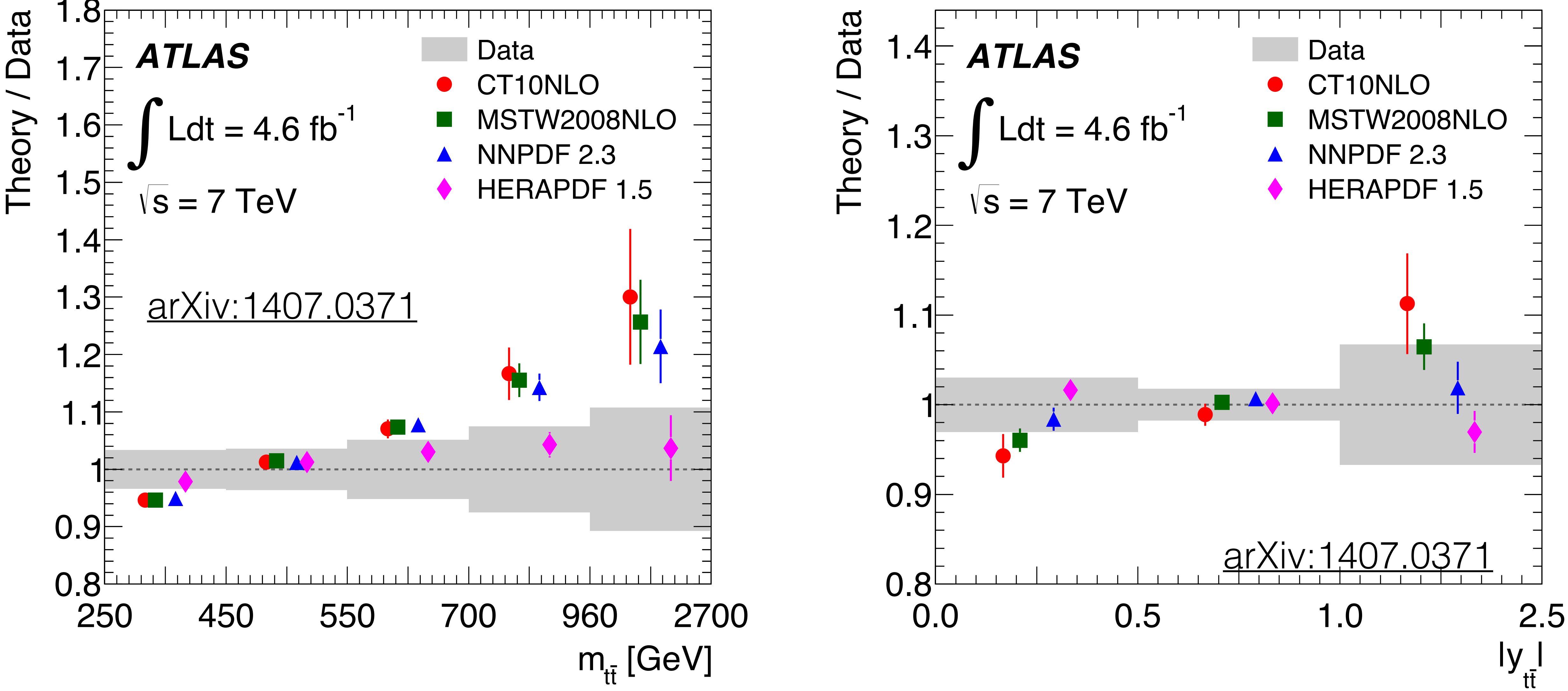
Reasonable description by all current proton PDFs.

Measurement statistically limited for m_{ee}>400 GeV.

Data used for the first fit to the photon PDF (NNPDF Collaboration, arXiv:1308.0598)



Top quark production



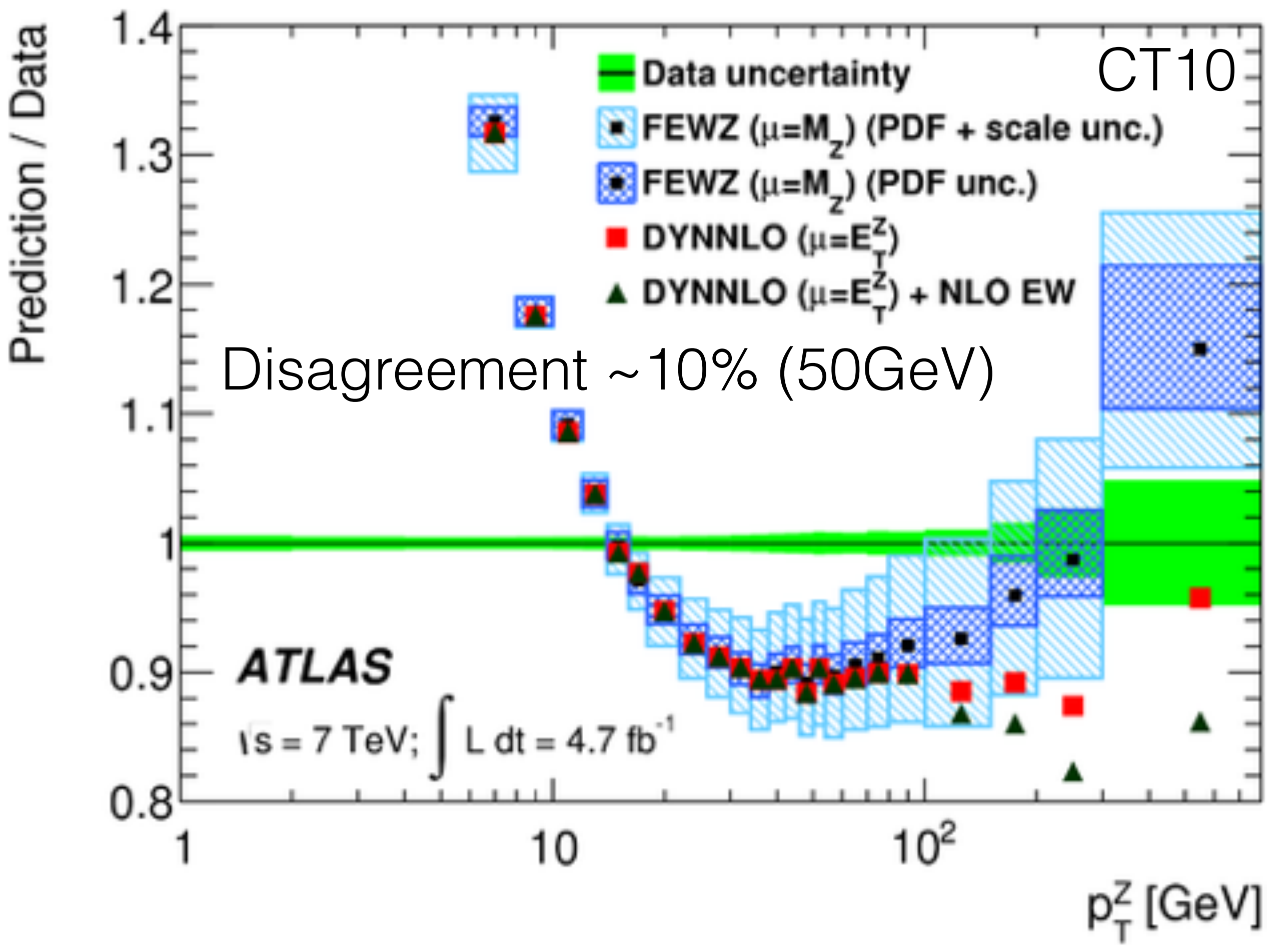
Ratios of the NLO QCD predictions to the measured normalised differential cross sections for different PDF sets for mass and rapidity of tt system.

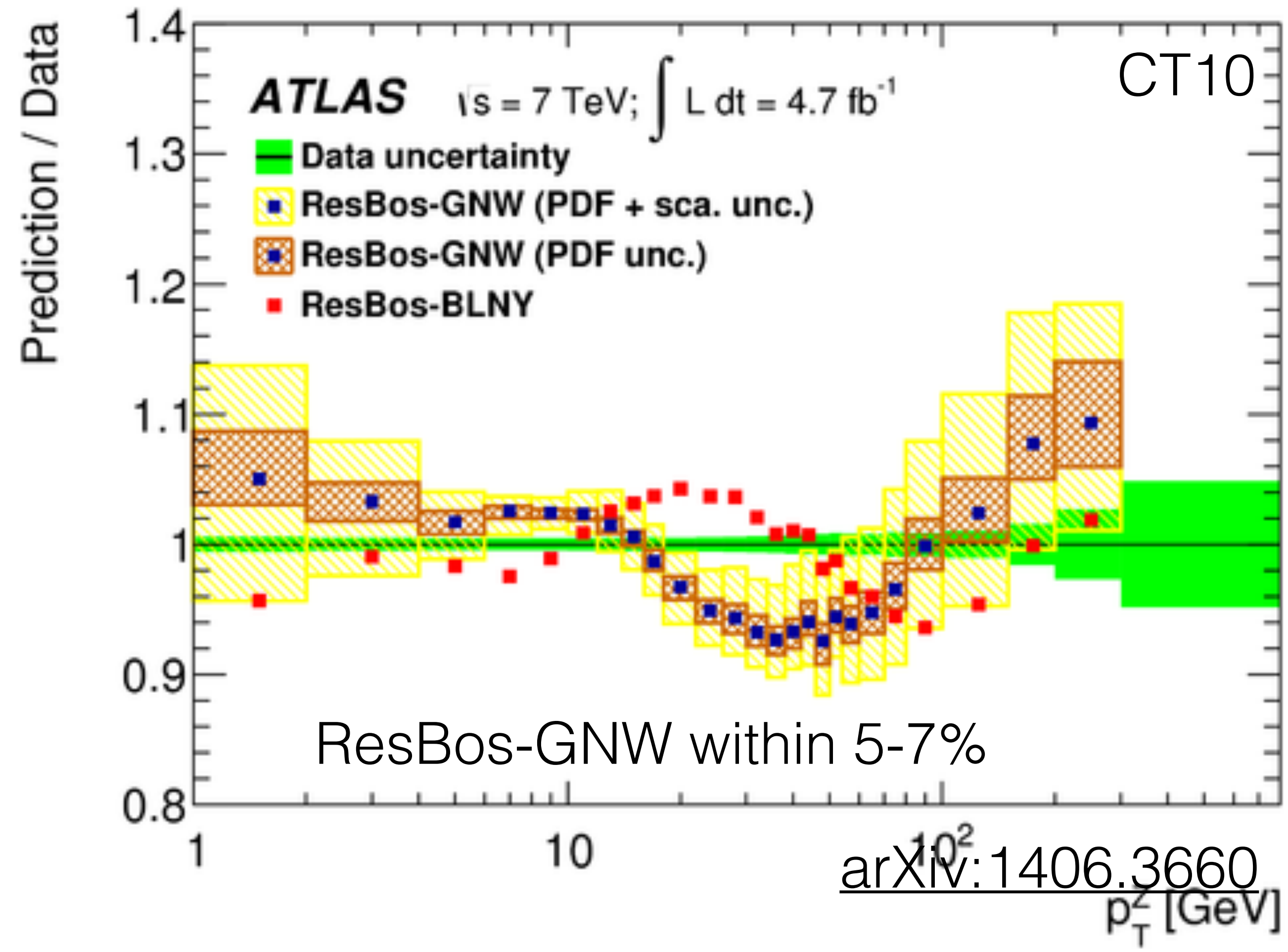
Normalised cross sections reduce dependance on higher order QCD corrections.
NLO predictions derived with MCFM. NLO EW corrections are not included in the NLO predictions.

HERAPDF 1.5 describes data well. Tensions between data and other PDF sets.
Maybe just lack NNLO QCD prediction and EW corrections?

Z transverse momentum

Ratios between various p_T^Z distribution predictions and the combined measurement.





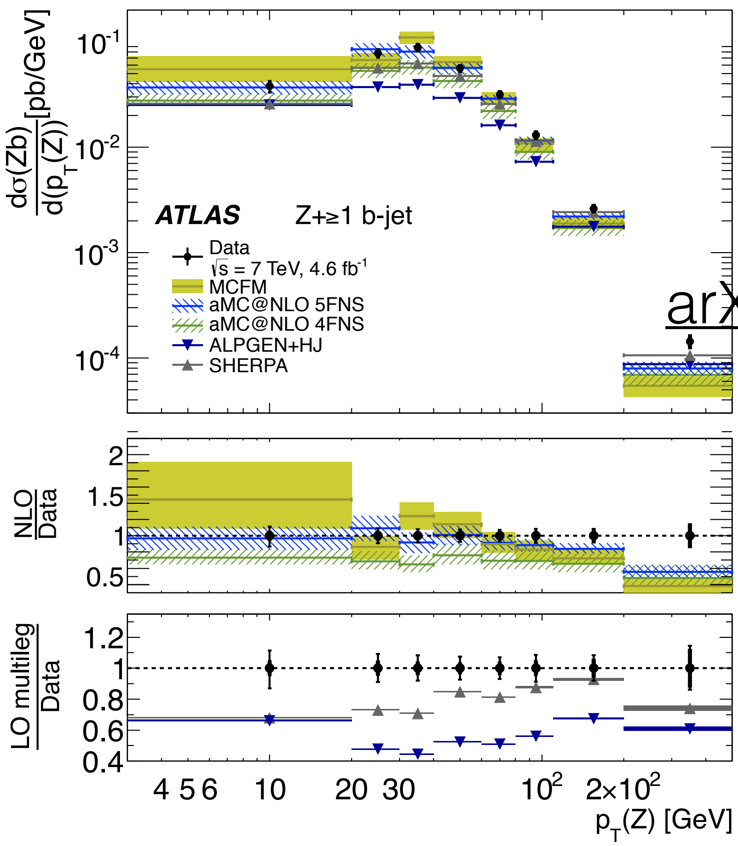
The measurement is sensitive to PDF at low and high p_T^Z

At high p_T^Z (qg scattering dominates) higher order QCD and EW corrections are needed.
At low p_T^Z (governed by ISR) need to account for interplay between PDF and soft QCD parameters.

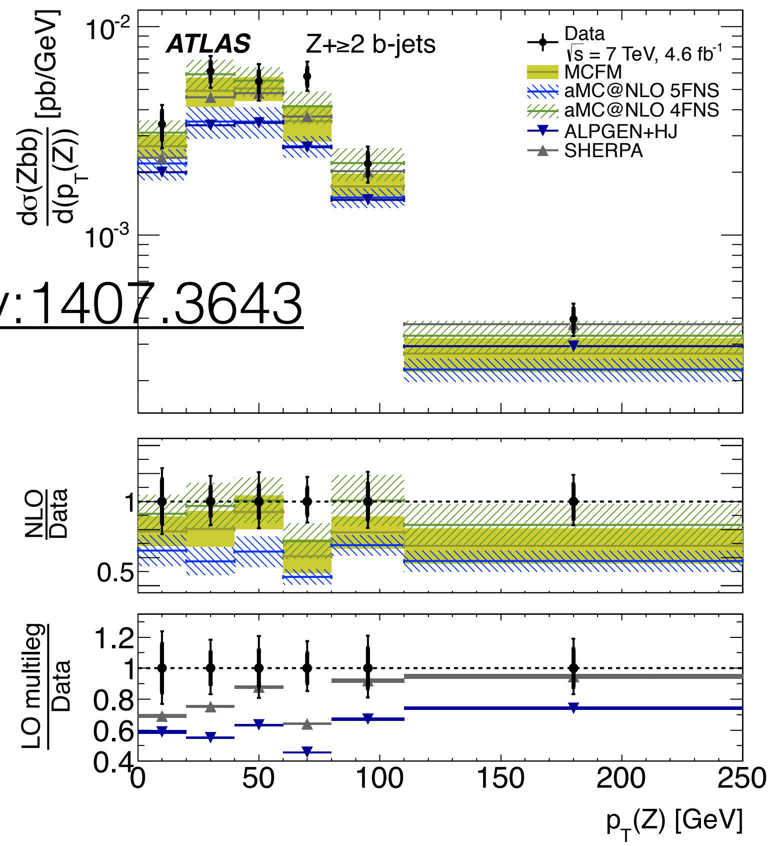
Large factorisation and renormalisation scale variations. Large resummation scales variations. Large dependence on non-pQCD parametrisation.

Measurements used to tune the Pythia8 and Powheg+Pythia8 generators.

Z boson in association with b-jets



arXiv:1407.3643



The cross section σ(Zb) and σ(Zbb) as a function of $p_T(Z)$.

NLO predictions from MCFM and aMC@NLO both using the MSTW2008 PDF set.

LO multi-legged predictions for Alpgen+Herwig+Jimmy and Sherpa.

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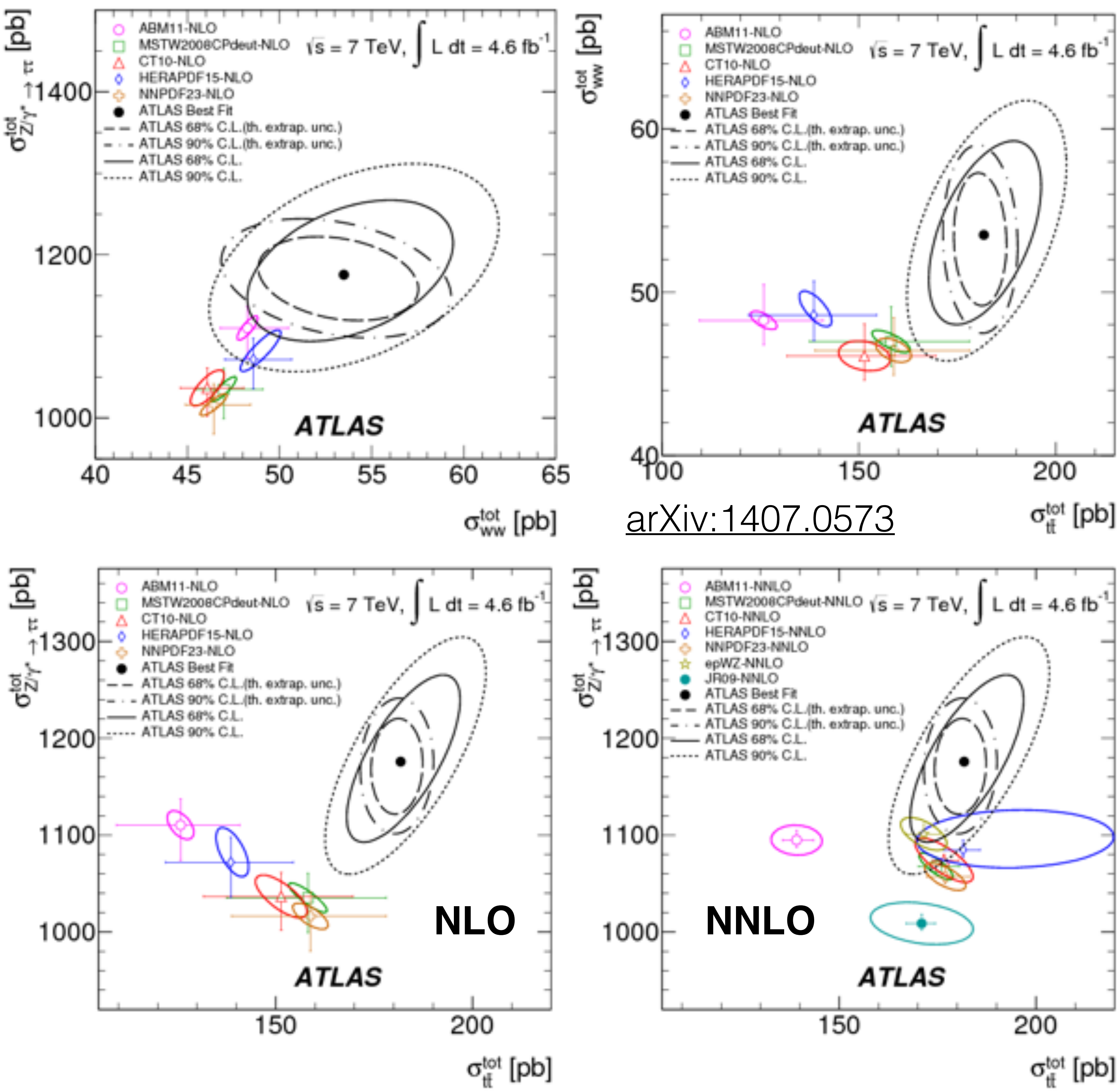
NLO predictions from MCFM and aMC@NLO generally provide the best overall description of the data.

Z+≥1b-jet better described by 5 Flavour Number Scheme (5FNS) prediction.
Z+≥2b-jet better described by 4 Flavour Number Scheme (4FNS) prediction.

Descriptions of the shapes of the differential cross sections are generally good within uncertainties for both LO and NLO predictions.

Even at NLO, scale uncertainties dominate and currently limit any sensitivity to different PDF sets.

Simultaneous measurements of the $t\bar{t}$,WW,and Z->$\tau\tau$ production cross sections : AIDA



arXiv:1407.0573

Contours of the likelihood function as a function of two full production cross sections of interest.

Global test of SM through study of a common final state (e^+e^- or $\mu^+\mu^-$).

2D parameter space (E_T^{miss}, N_{jets}) processes naturally separated.

Fiducial results are corrected to the total phase-space.

@NLO PDFs underestimate data. @NNLO most (but not all) PDFs generally describe data well.

Scale uncertainty @NLO is the dominant source.

PDF uncertainty @NNLO is the dominant source.

Summary

ATLAS has a wealth of SM precision measurements from the successful LHC Run 1. Many are sensitive to PDFs allowing PDF discrimination and improved PDFs.

New precise measurements of Jets, Vector Bosons and Top processes provide PDF constraints complementary to DIS and fixed target data.

First PDF fits have been performed in ATLAS by using jet, W/Z and W+charm data

- Improving knowledge on the gluon density function at high-x and strange quark PDF.
- Inclusive photon data and tt cross section exhibit good potential to further constrain the gluon density.

W+charm studies give motivation for a global fit. Only then the optimal value for strangeness can be determined.

The future

New jets fit: incorporating all of ATLAS 2011 inclusive single jet, diet and trijet measurements, with full statistical and systematic correlations.

Combined fit: including multiple ATLAS measurements (on top of HERA), with full statistical and systematic correlations.

- act as a consistency check between different datasets.
- act as a consistency check between data and various theoretical predictions.
- demonstrate impact of ATLAS data.
- provide improved PDFs that give best description of ATLAS data.