Measurement of W and Z boson production at ATLAS

Aleksei Ezhilov

Petersburg Nuclear Physics Institute

on behalf of ATLAS Collaboration

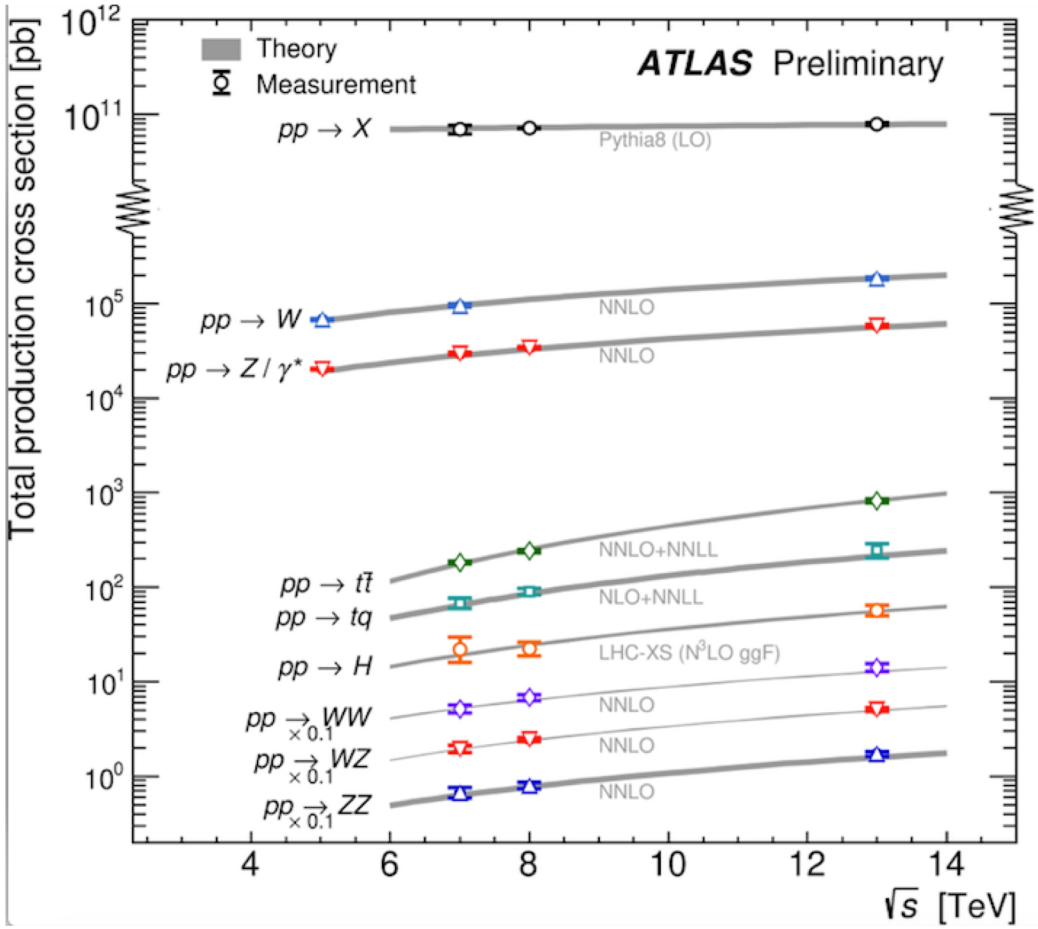
Introduction

W and Z boson production:

- benchmark for QCD and EW processes,
- rapidity distributions sensitive to PDF

(initial kinematics)

- test models of parton dynamics
- charge asymmetry for W^+ and W^-



This talk will cover:

- W and Z production in 5.02 TeV pp collisions

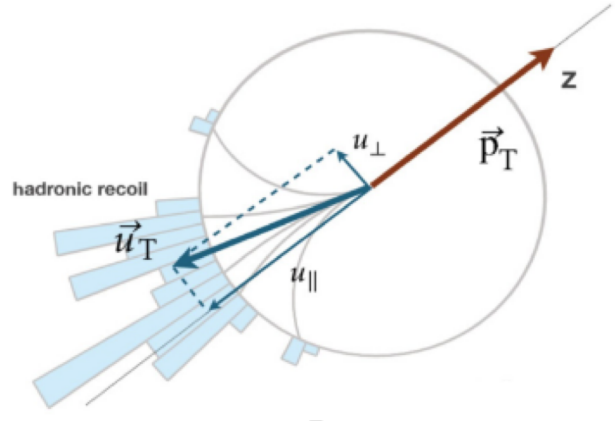
Eur. Phys. J. C 79 (2019) 128

- W cross section and W+/W- asymmetry at 8 TeV

arXiv:1904.05631 [hep-ex], submitted to EPJC

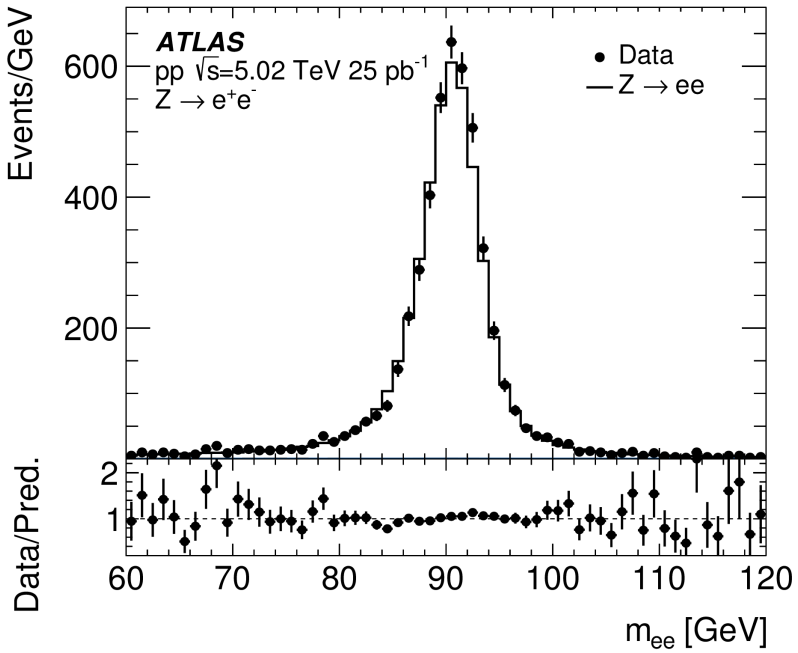
Measurement of W and Z boson production: selections

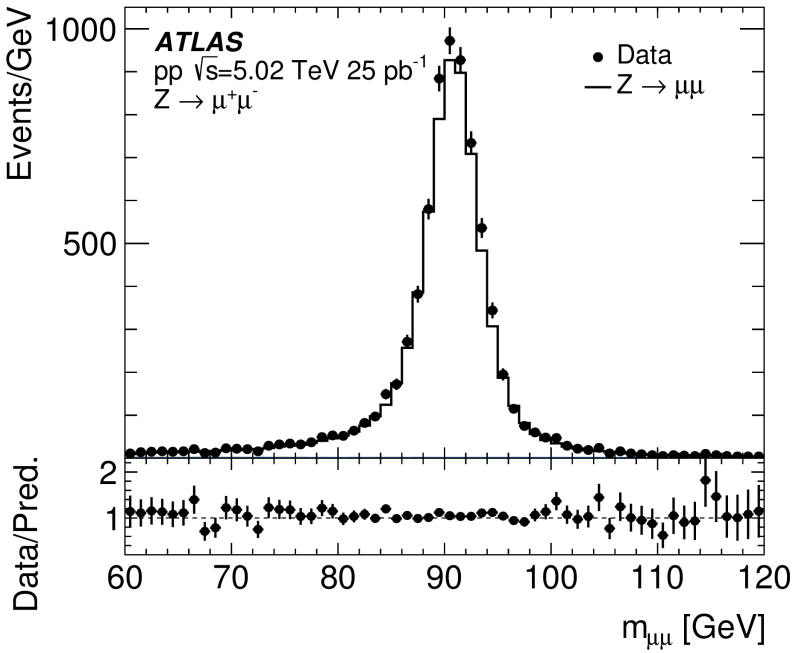
- Data collected in 2015 ($\sqrt{s}$=5.02TeV, 25.0 pb^{-1})
- Analysis channels: electron and muon
- W, Z-boson selections:
  - single lepton trigger
  - medium identification
  - isolation requirement
  - p_T>25(20) GeV
  - $|\eta_e|$<2.47 excluding 1.37<$|\eta_e|$<2.47, $|\eta_\mu|$<2.4
  - 66<m_{ll}<116 GeV for Z
  - $E_T^{miss} > 25\ GeV$, m_T>40 GeV for W



$$E_T^{miss} = -(\vec{u}_T + \overrightarrow{p_T^l})$$

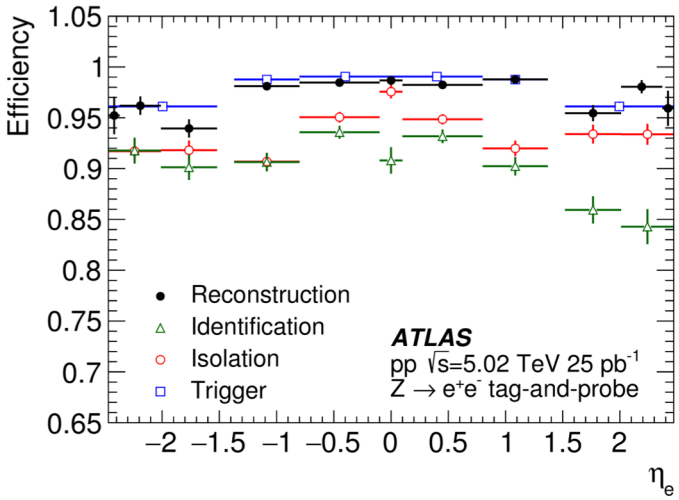
$$m_T = \sqrt{2p_T^l E_T^{miss}(1 - cos\Delta\phi_{l,E_T^{miss}})}$$

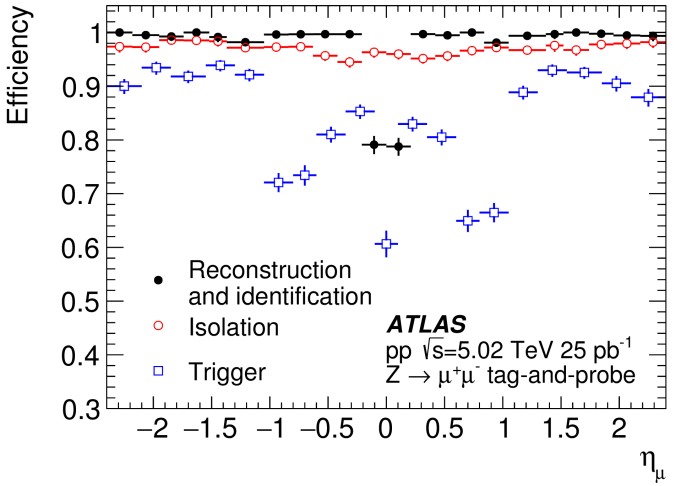




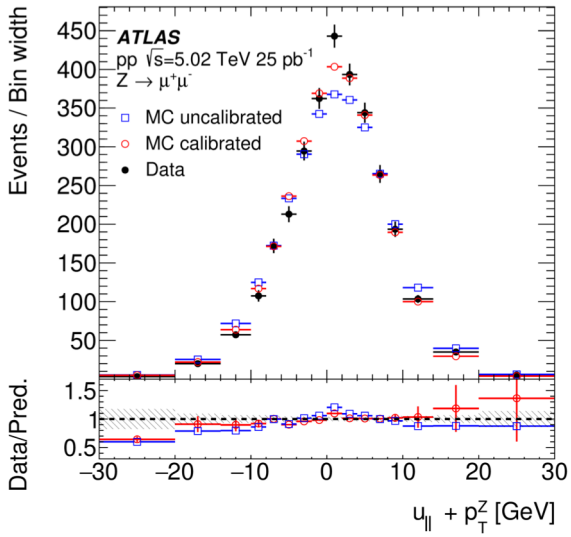
Measurement of W and Z boson production: calibrations

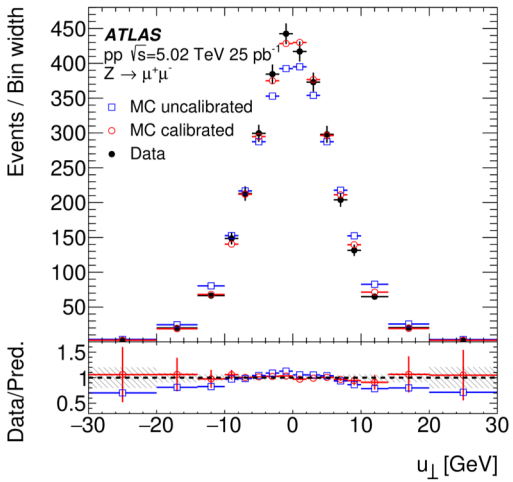
- Using Z-boson as reference
- Lepton calibration and efficiency correction (tag-and-probe method)





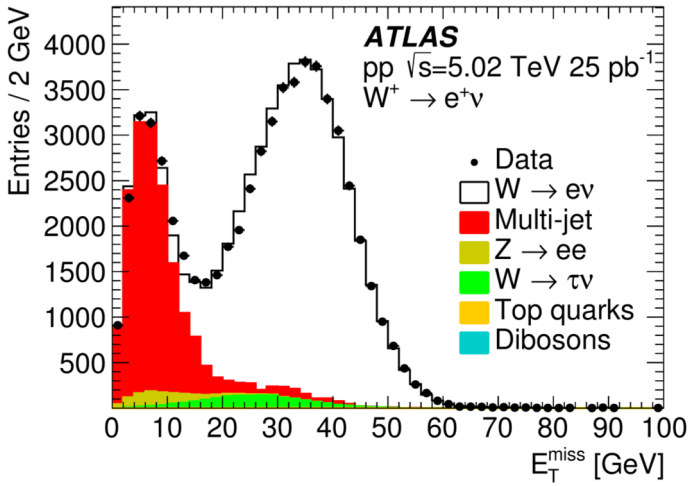
- Recoil calibration (in situ corrections to the momentum scale and resolution of u_T)

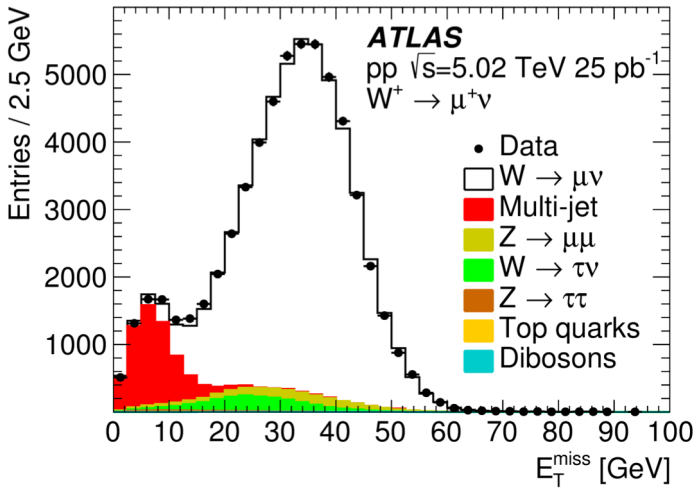


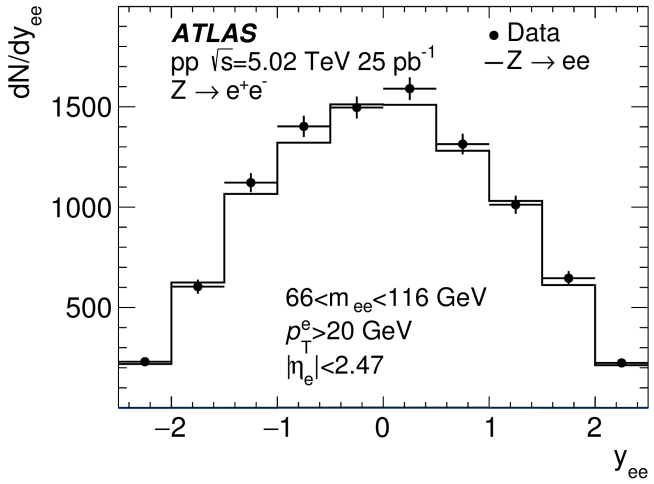


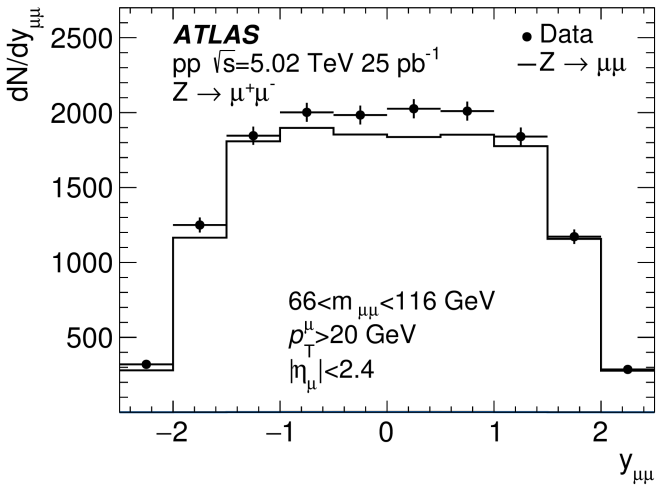
Measurement of W and Z boson production: background estimation

- MC signal: POWHEG+PYTHIA
- Backgrounds:
  - electroweak and top-quark from MC event samples
  - multi-jet - data-driven method

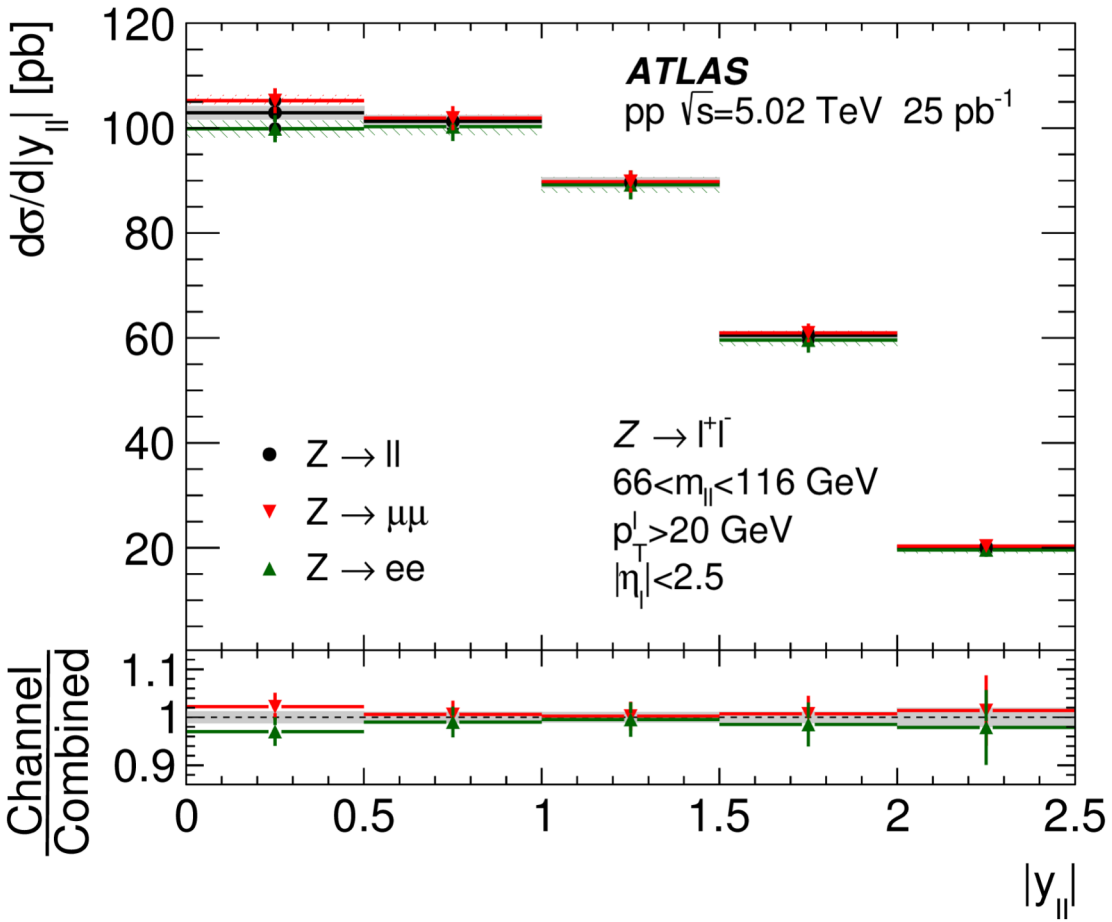






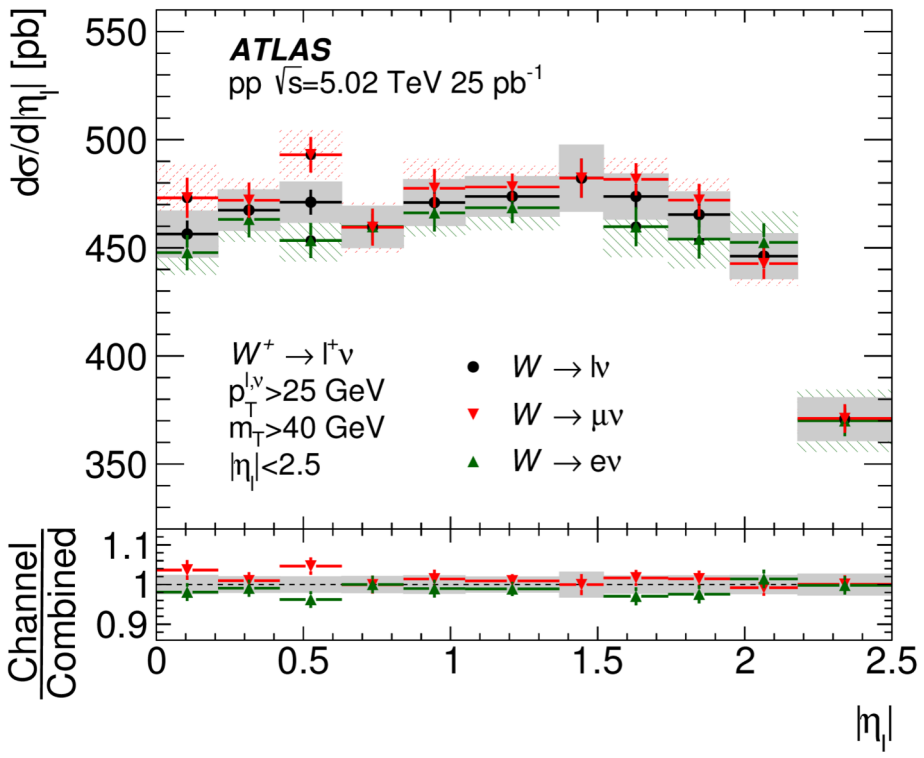


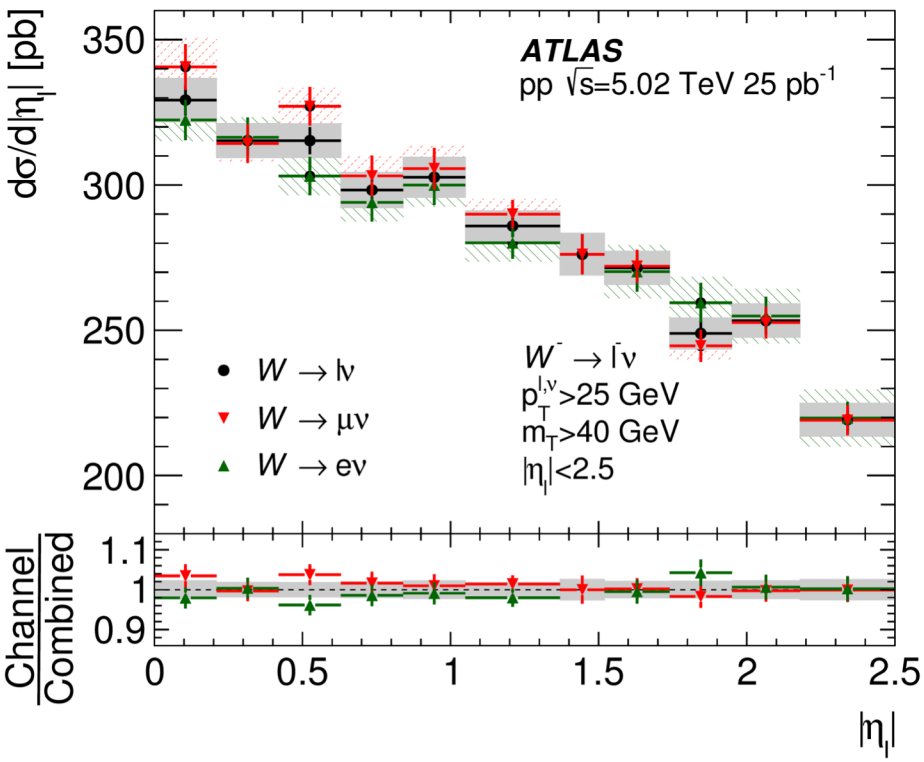
Measurement of W and Z boson production: fiducial cross section



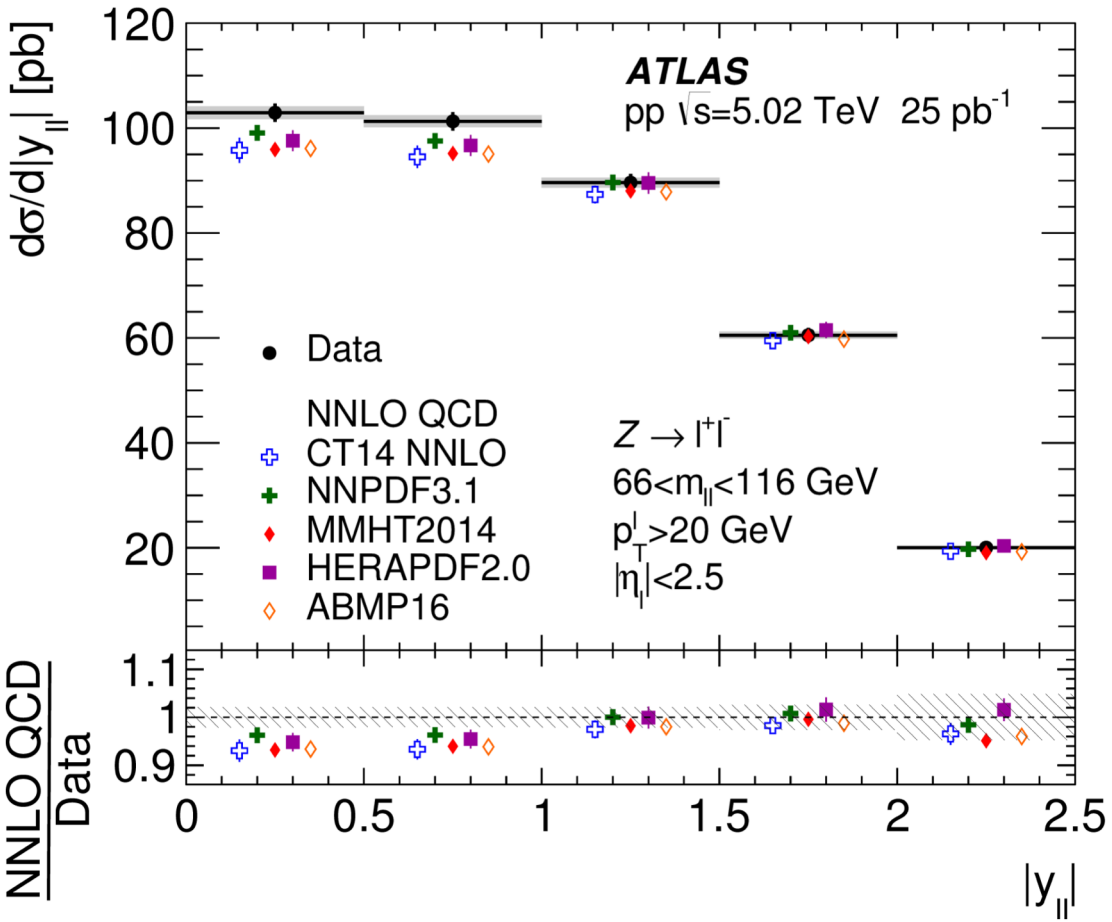
- Combination of measurements using Best Linear Unbiased Estimate (BLUE)
- χ^2 / $N_{d.f.}$=3.0/5
- Systematic uncertainties:
  - Lepton calibration and efficiency ~1.3%
  - Background evaluation ~0.2%
  - Luminosity ~1.9%

Measurement of W and Z boson production: fiducial cross section

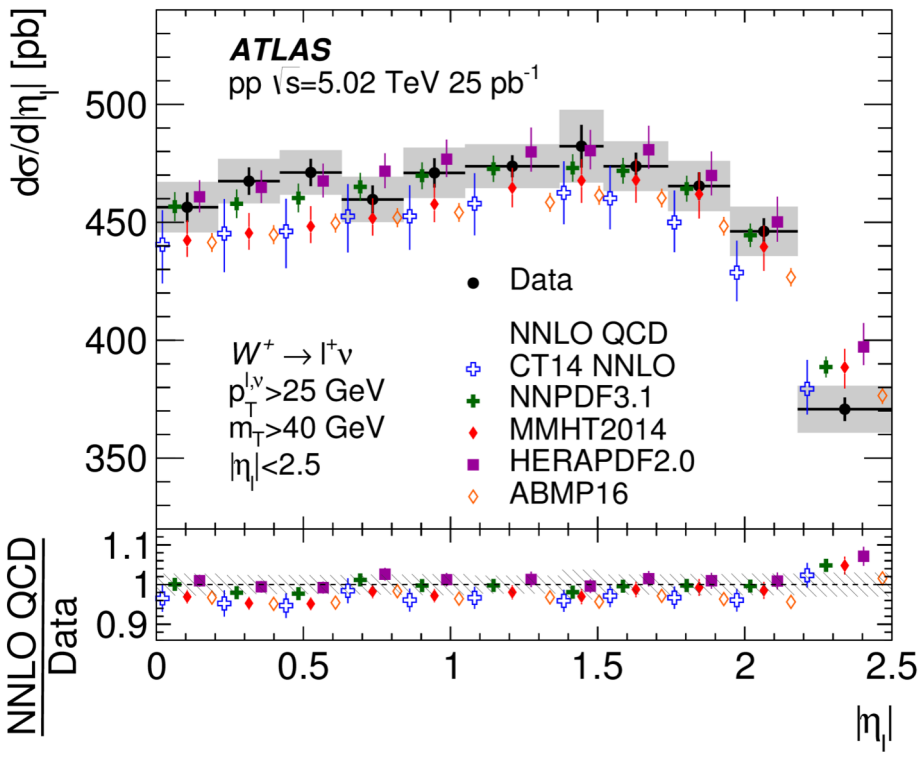


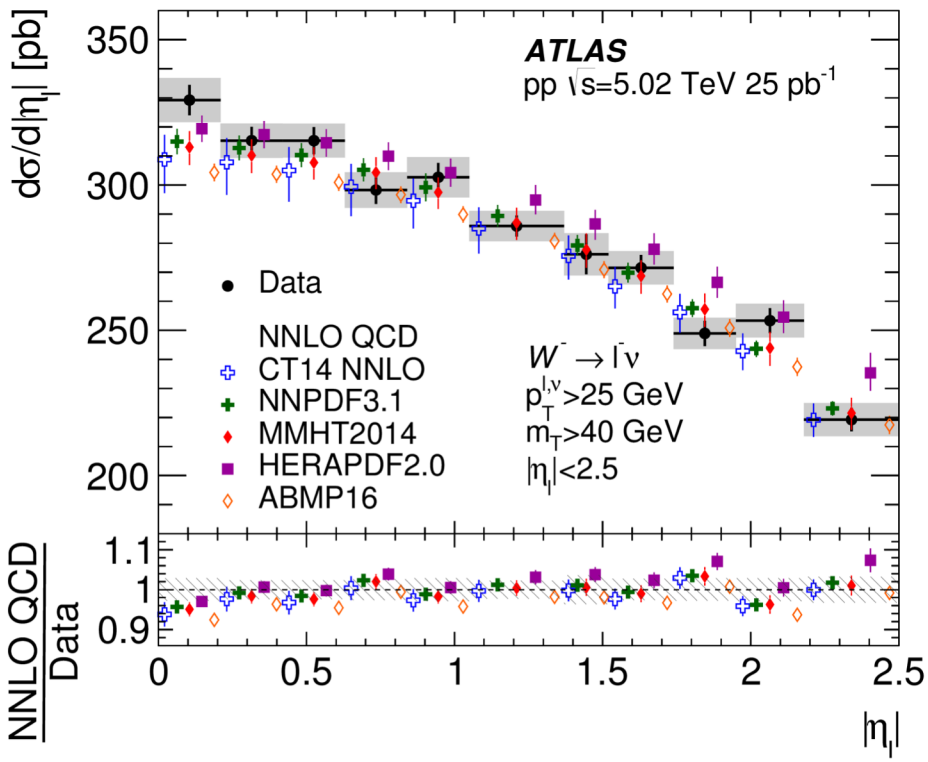


- Combination of measurements using Best Linear Unbiased Estimate (BLUE)
- χ^2 / $N_{d.f.}$=37.5/25
- Systematic uncertainties:
  - Lepton calibration and efficiency ~0.8% - 1.4 %
  - Background evaluation ~0.8%
  - Hadronic recoil correction ~0.5%
  - Luminosity ~1.9%



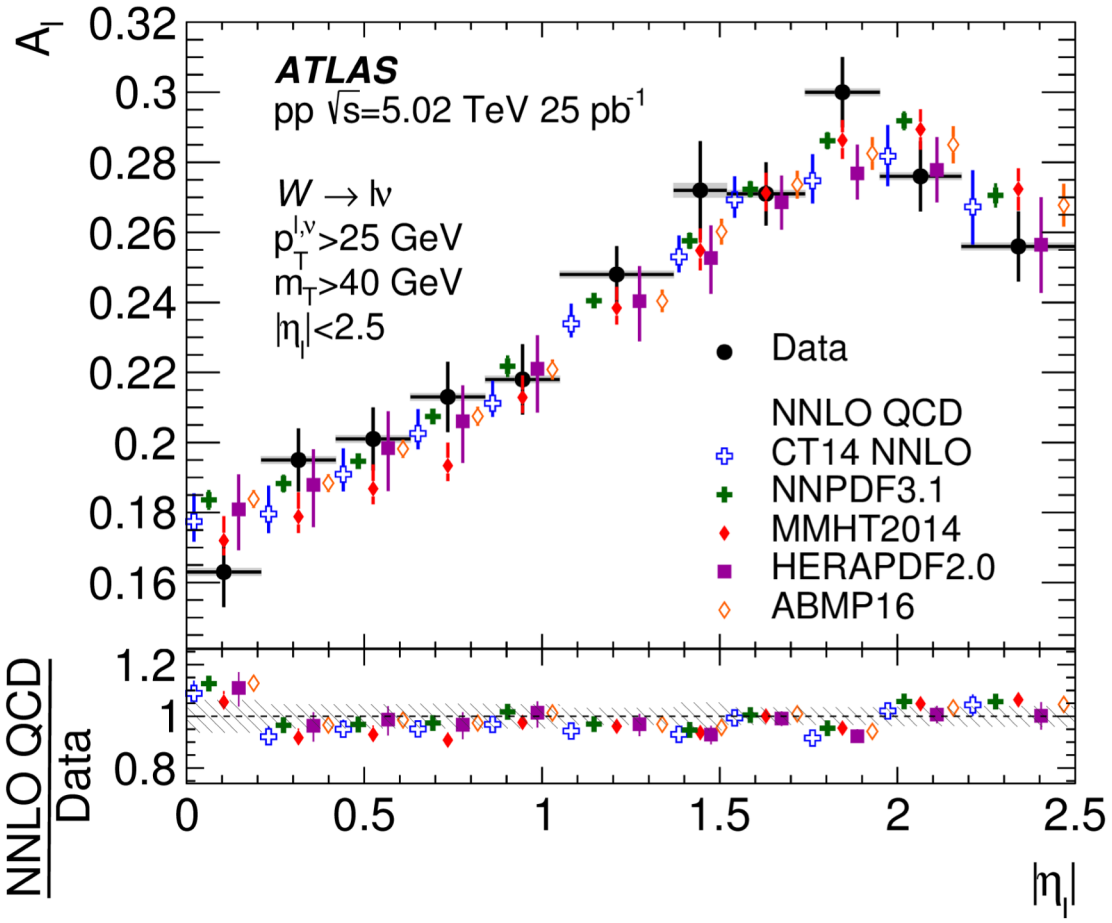
- Predictions – modified version of DYNNLO 1.5
- NNLO at QCD and LO in EW theory
- Predicted values in the central region of rapidity is lower than measured





- Predictions – modified version of DYNNLO 1.5
- NNLO at QCD and LO in EW theory
- Predicted values in the central region of rapidity is lower than measured for W^-
- Predicted values in all regions of rapidity is lower than measured for W^+

Measurement of W and Z boson production: charge asymmetry



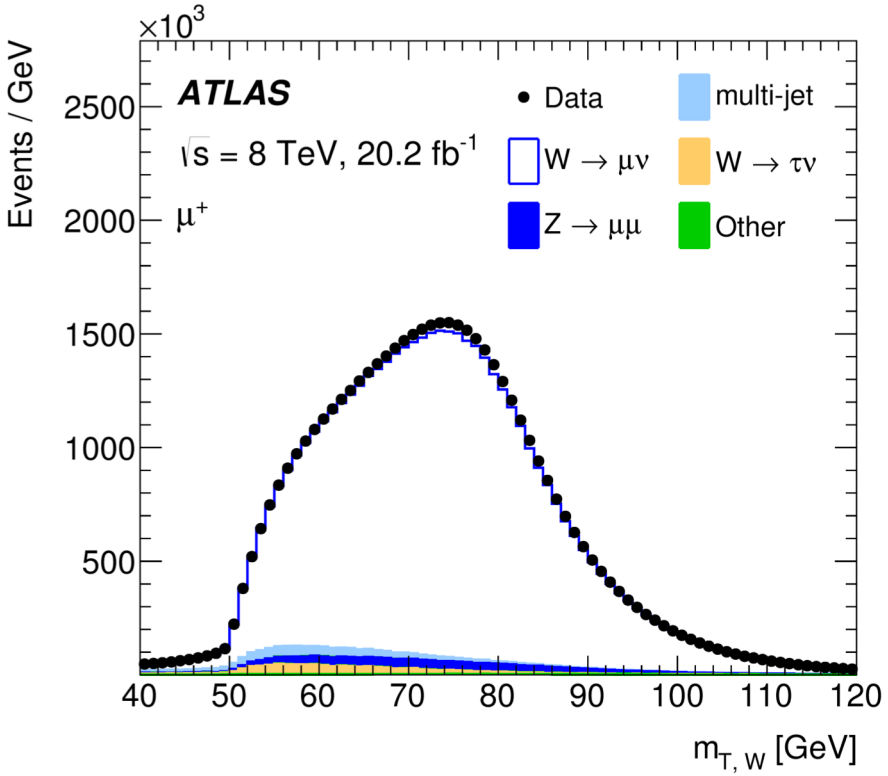
Lepton charge asymmetry:

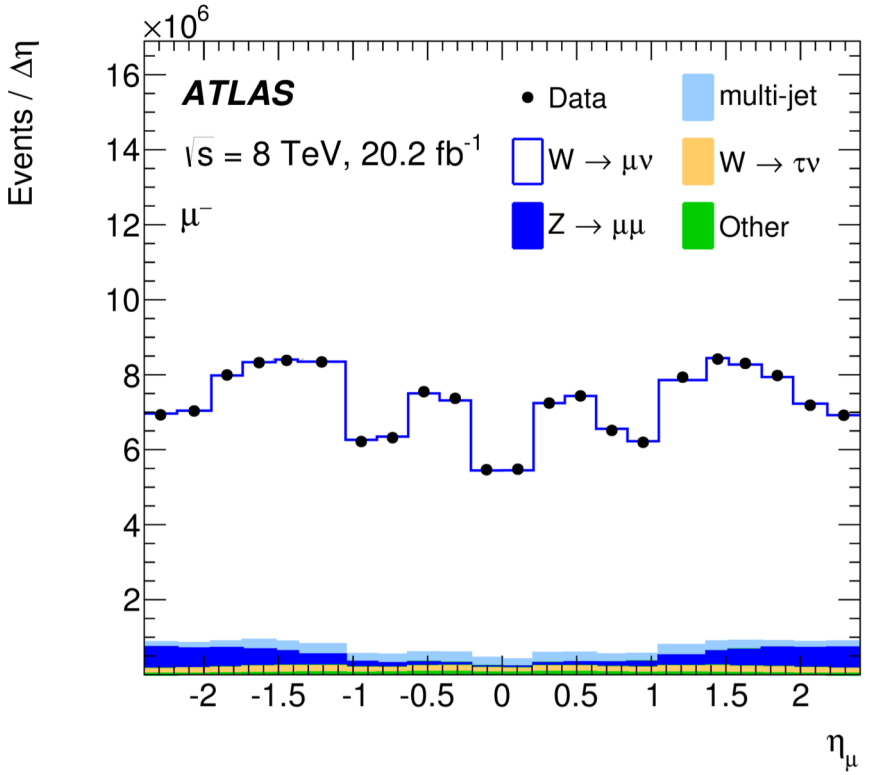
$$A_l(|\eta_l|) = \frac{\frac{d\sigma_{W^+}}{d|\eta_l|} - \frac{d\sigma_{W^-}}{d|\eta_l|}}{\frac{d\sigma_{W^+}}{d|\eta_l|} + \frac{d\sigma_{W^-}}{d|\eta_l|}}$$

- Predictions – modified version of DYNNLO 1.5
- NNLO at QCD and LO in EW theory
- Most of rapidity range prediction tend to underestimate the measured asymmetry by few percent

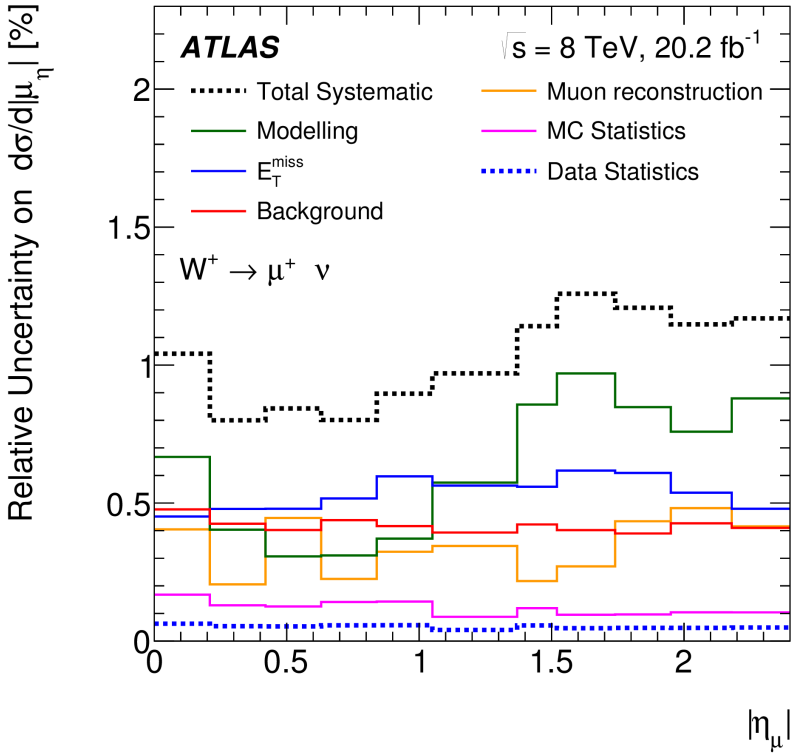
Measurement of charge asymmetry of W boson production: selections

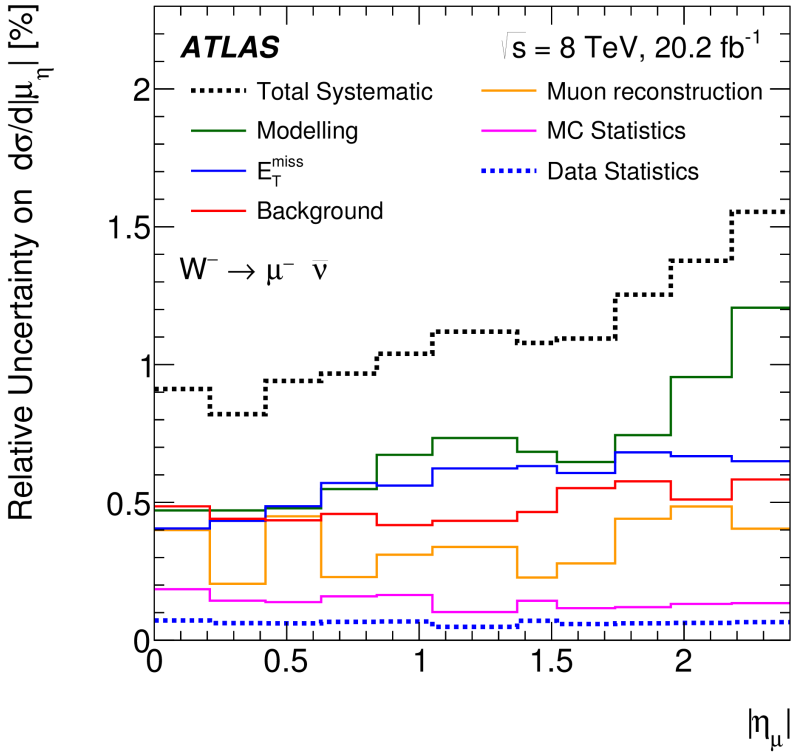
- Data collected in *pp* collisions at $\sqrt{s}$=8 TeV (20.2 pb^{-1})
- Analysis channel: muon
- W-boson selections:
  - single lepton trigger
  - isolation requirement
  - p_T>25 GeV
  - $|\eta_\mu|$<2.4
  - $E_T^{miss} > 25\ GeV$, m_T>40 GeV





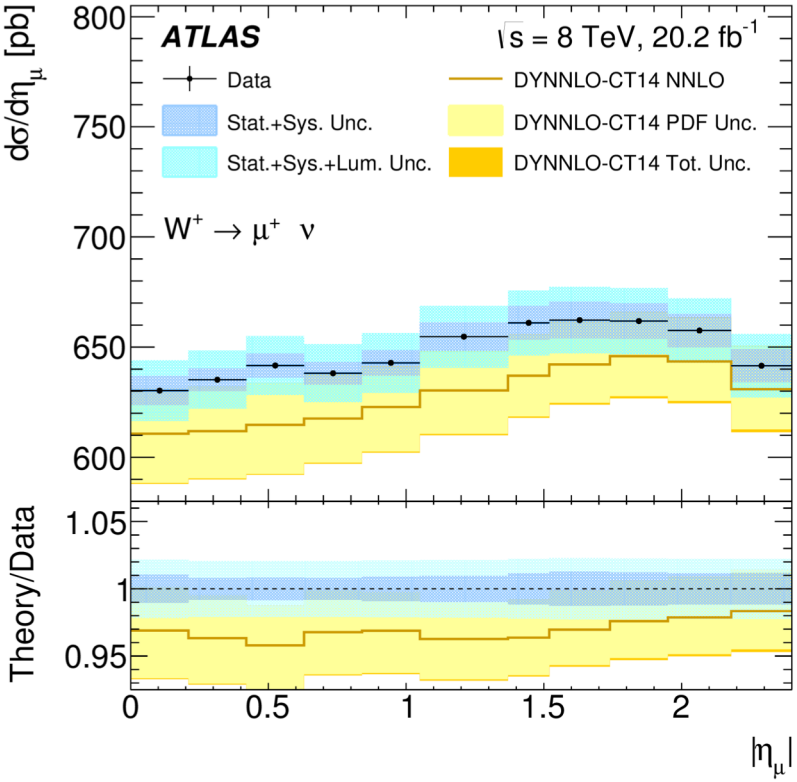
Measurement of charge asymmetry of W boson production: uncertainties

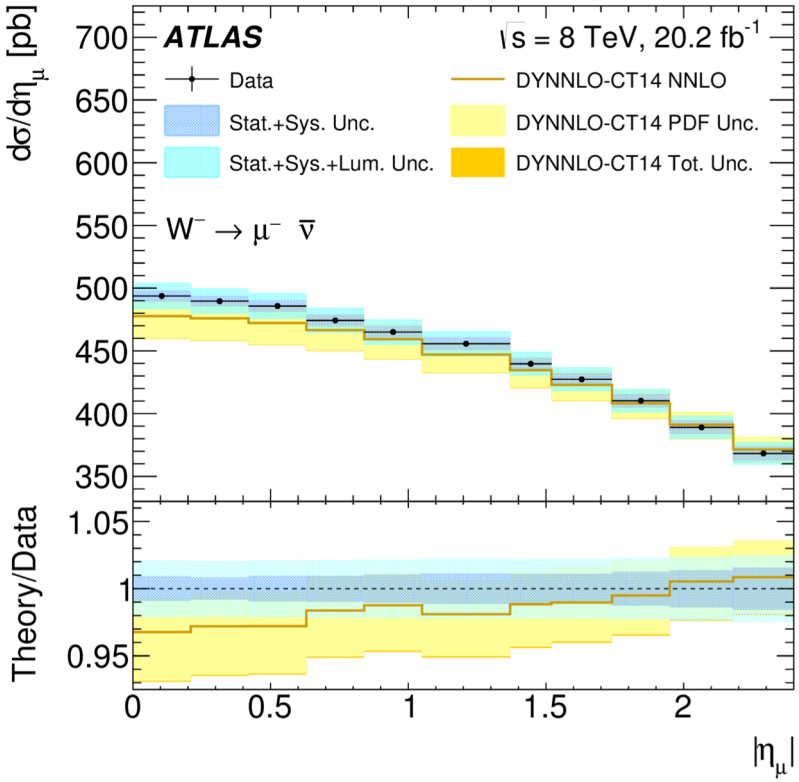




- Main sources: modelling uncertainty (different level truth muon definition and different generators), muon reconstruction, background estimation and missing energy mis-modelling
- Measurements in positive and negative muon are important check of the correction procedure
- Some of sources are treated as correlated between W^+ and W^- to reduce the impact on A_l

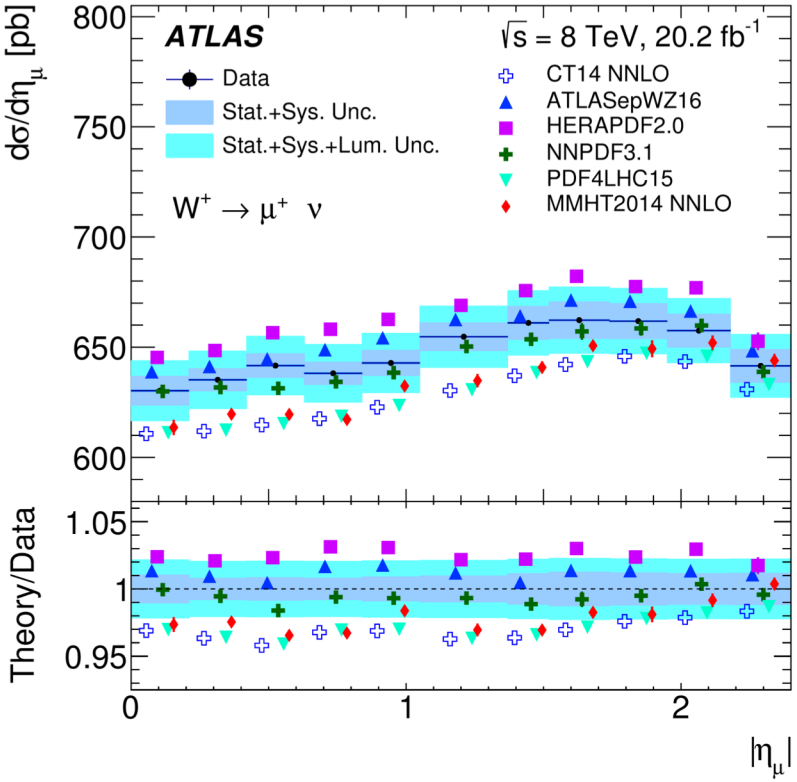
Measurement of charge asymmetry of W boson production: theoretical predictions

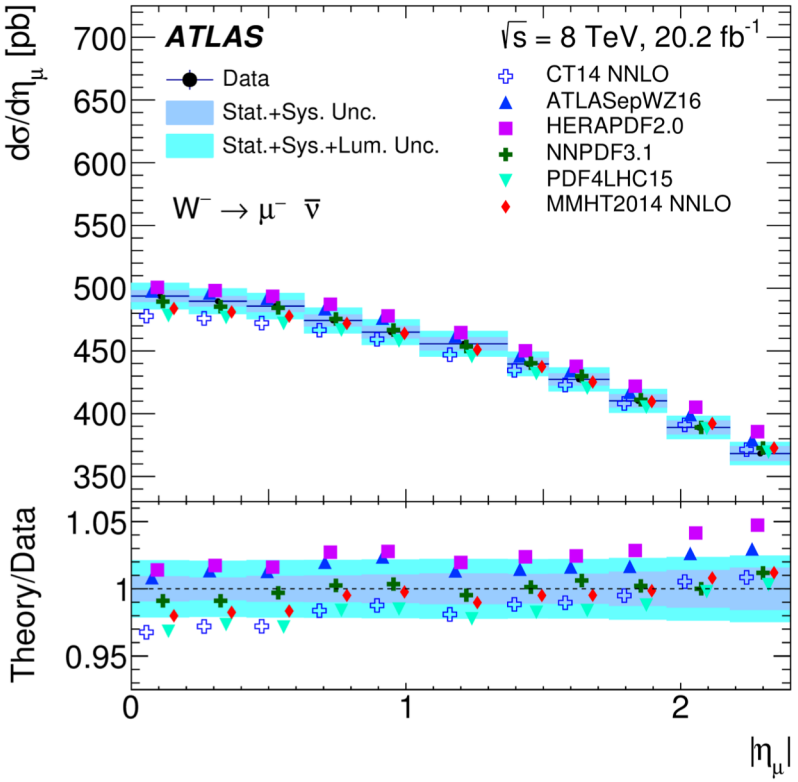




- Theoretical predictions – DYNNLO with CT14 PDF set
- NNLO at QCD and LO in EW theory
- Data and theory agree well within the uncertainties (PDF uncertainty component dominate for the theory predictions)
- Data precision is higher then the PDF uncertainty – useful for constraining and evaluating performance of different PDF sets

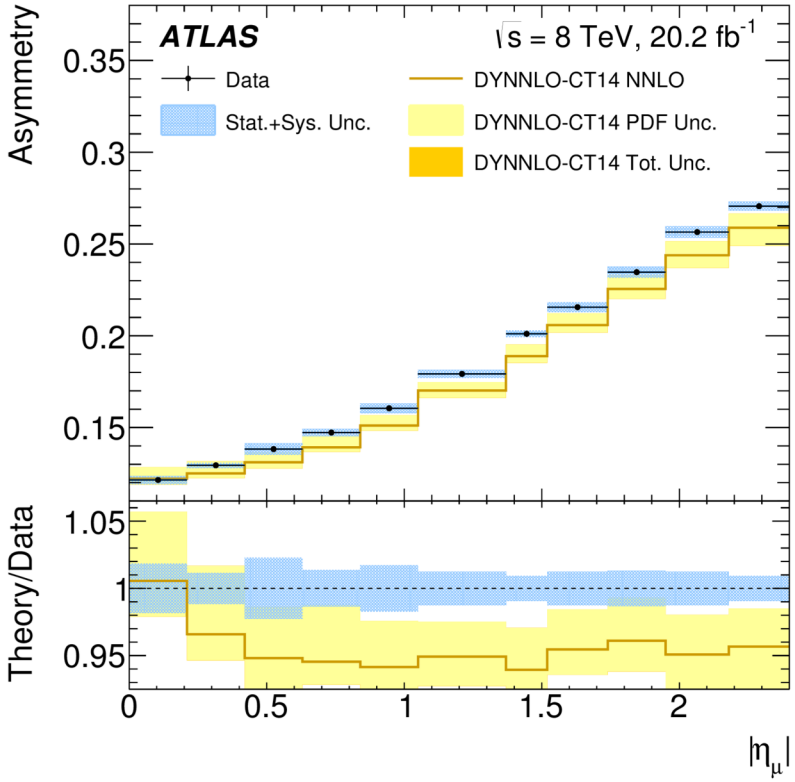
Measurement of charge asymmetry of W boson production: theoretical predictions

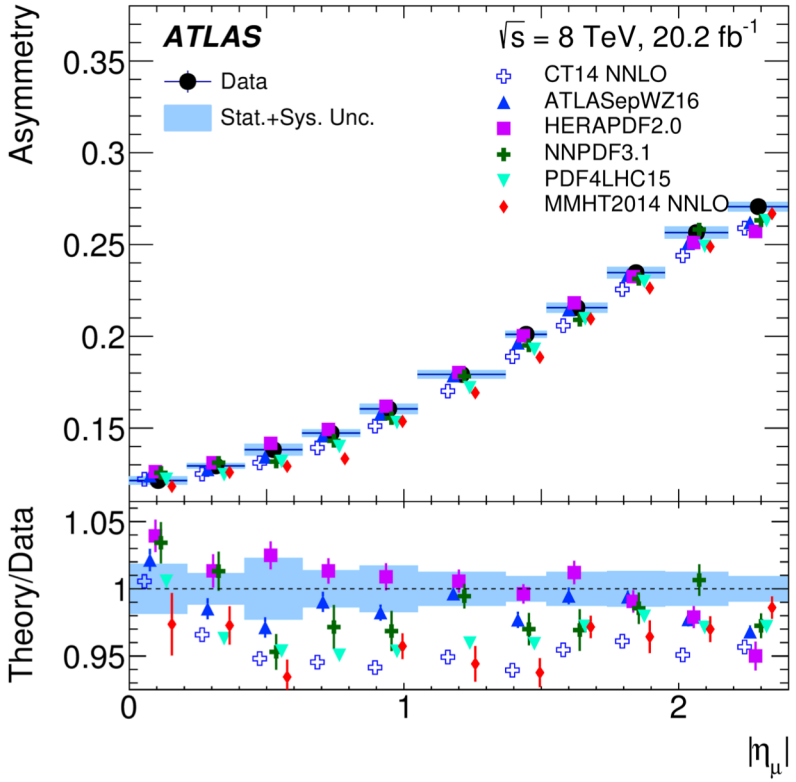




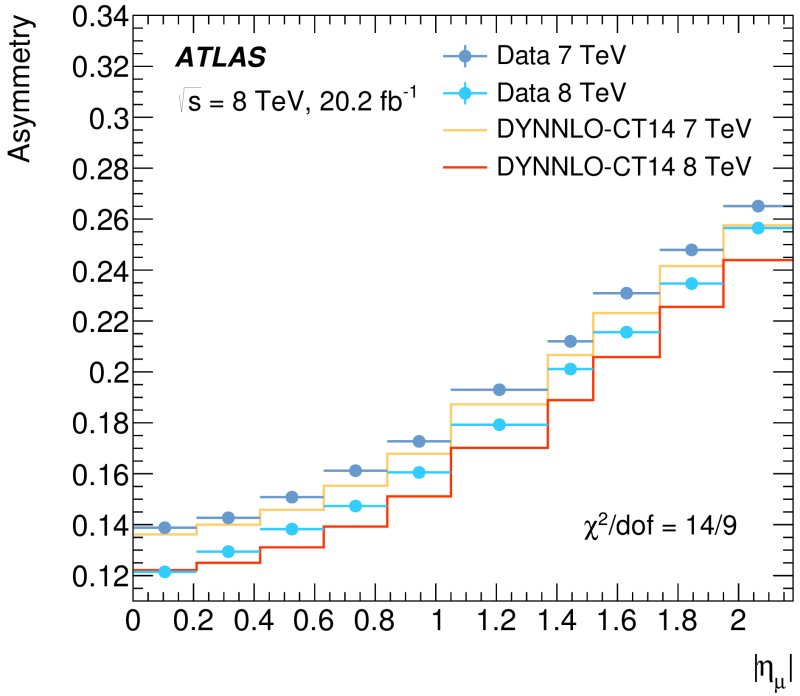
- Theoretical predictions – DYNNLO with different PDF sets
- NNLO at QCD and LO in EW theory
- Data and theory agree well within the uncertainties

Measurement of charge asymmetry of W boson production: charge asymmetry





- Theoretical predictions – DYNNLO with different PDF sets
- NNLO at QCD and LO in EW theory
- The comparison with ATLASepWZ16 and NNPDF3.1 include information from ATLAS W charge asymmetry data at 7 TeV measurements (uncorrelated measurements) and are closest to data



- Theoretical predictions – DYNNLO with CT14nnlo PDF set
- Same behavior for 7 (Eur. Phys. J. C 77 (2017) 367) and 8 TeV data:
- Compatibility test of the two measurements is performed taking into account all uncertainties and their bin-to-bin correlations (assuming the two data curves are fully uncorrelated): χ^2 / $N_{d.f.}$=14/9

Conclusions

- Main results of measurements W and Z boson production at 5.02 TeV:
  - The first measurements of W and Z production cross section at 5.02 TeV
  - The results presented compliment the previous result at $\sqrt{s}$=7,8,13 TeV
  - The combined cross sections are measured with a precision of 1.2-1.7%
  - Integrated and differential cross sections compared with NNLO QCD predictions using different PDF sets showing 1-2 $\boldsymbol{\sigma}$ deviation from the obtained predictions

- Main results of measurements of W cross-section and charge asymmetry at 8 TeV:
  - Cross-sections are measured with the precision of 0.8-1.5%
  - A_l uncertainty 0.002-0.003 (absolute units)
  - The measurement precision is better than the prediction uncertainties
  - The measured data is sensitive to discriminate the PDF sets and serve to improve the knowledge of proton structure

Thanks for attention

BACKUP

W and Z boson production: background contribution

Background	$W^+ \to e^+\nu$ ($W^+ \to \mu^+\nu$) [%]	$W^- \to e^-\nu$ ($W^- \to \mu^-\nu$) [%]	$Z \to e^+e^-$ ($Z \to \mu^+\mu^-$) [%]
$Z \to \ell^+\ell^-$, $\ell = e, \mu$	0.1 (2.8)	0.2 (3.8)	–
$W^\pm \to \ell^\pm\nu$, $\ell = e, \mu$	–	–	<0.01 (<0.01)
$W^\pm \to \tau^\pm\nu$	1.8 (1.8)	1.8 (1.8)	<0.01 (<0.01)
$Z \to \tau^+\tau^-$	0.1 (0.1)	0.1 (0.1)	0.07 (0.07)
Multi-jet	0.9 (0.1)	1.4 (0.2)	<0.01 (<0.01)
Top quark	0.1–0.2 (0.1–0.2)	0.1–0.2 (0.1–0.2)	0.06 (0.08)
Diboson	0.1 (0.1)	0.1 (0.1)	0.14 (0.08)

W and Z boson production: background contribution