Measurement of W and Z boson production at ATLAS

Artur Trofymov on behalf of the ATLAS Collaboration

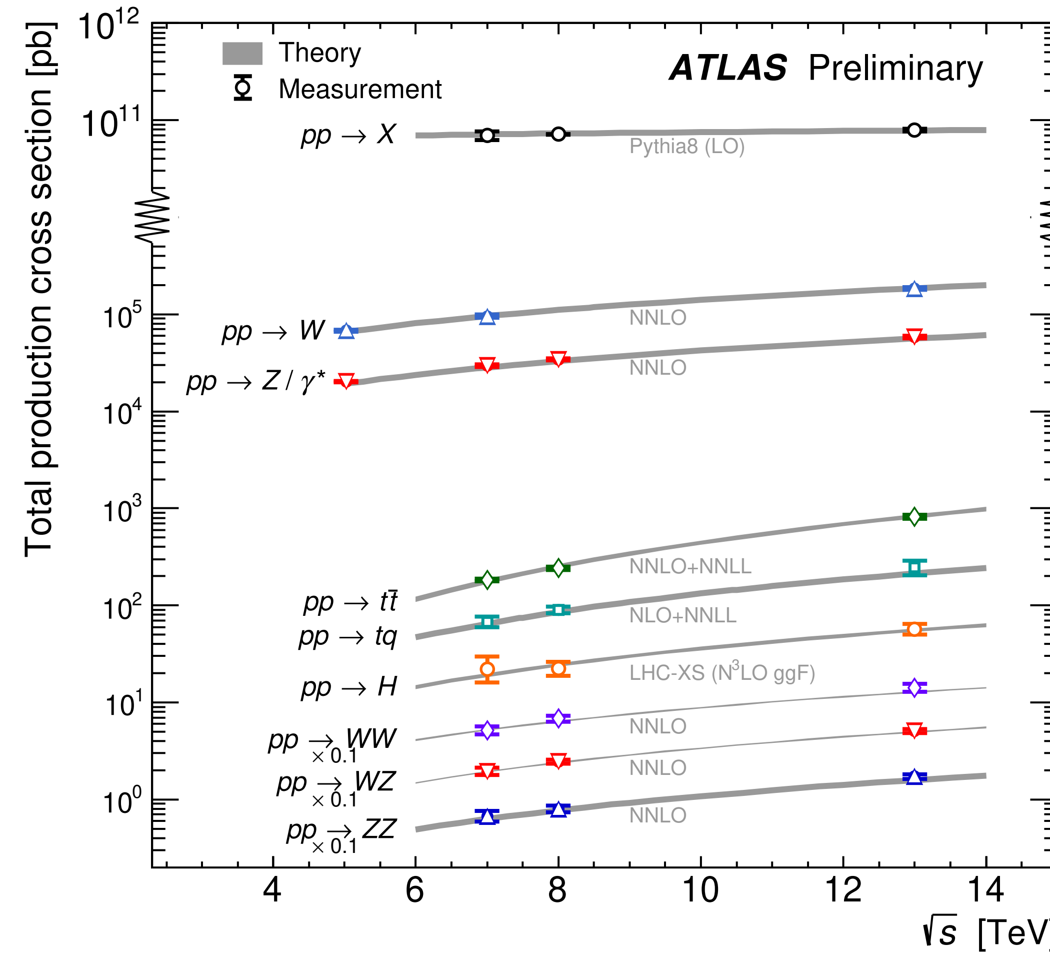
DIS 2019, Torino, 10.04.2019

XXVII International Workshop on Deep Inelastic Scattering and Related Subjects

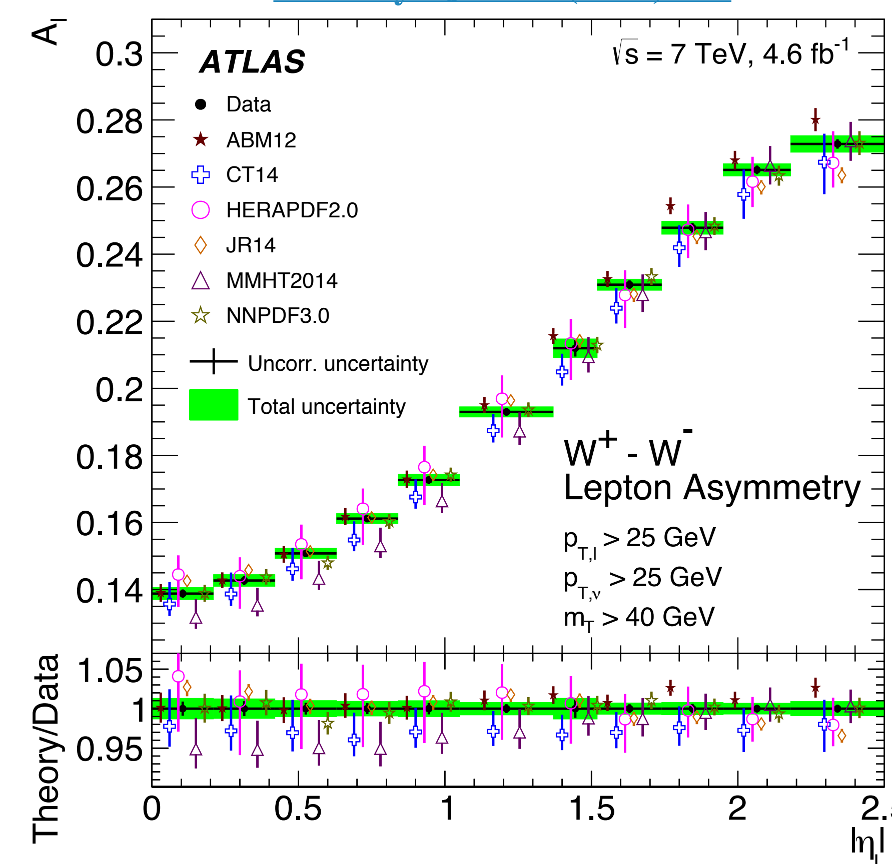
Introduction

- **Single weak-boson production at LHC:**
  - Precision test of **pQCD**
  - Measurements in **rapidity bins** $\Longrightarrow$ information for **parton flavour parametrisation** as a function of $\boldsymbol{x}$
  - Production **charge asymmetry** between W^+ and W^-

- **In this talk:**
  - W and Z boson production at 5.02 TeV
  - W cross-section and charge asymmetry at 8TeV

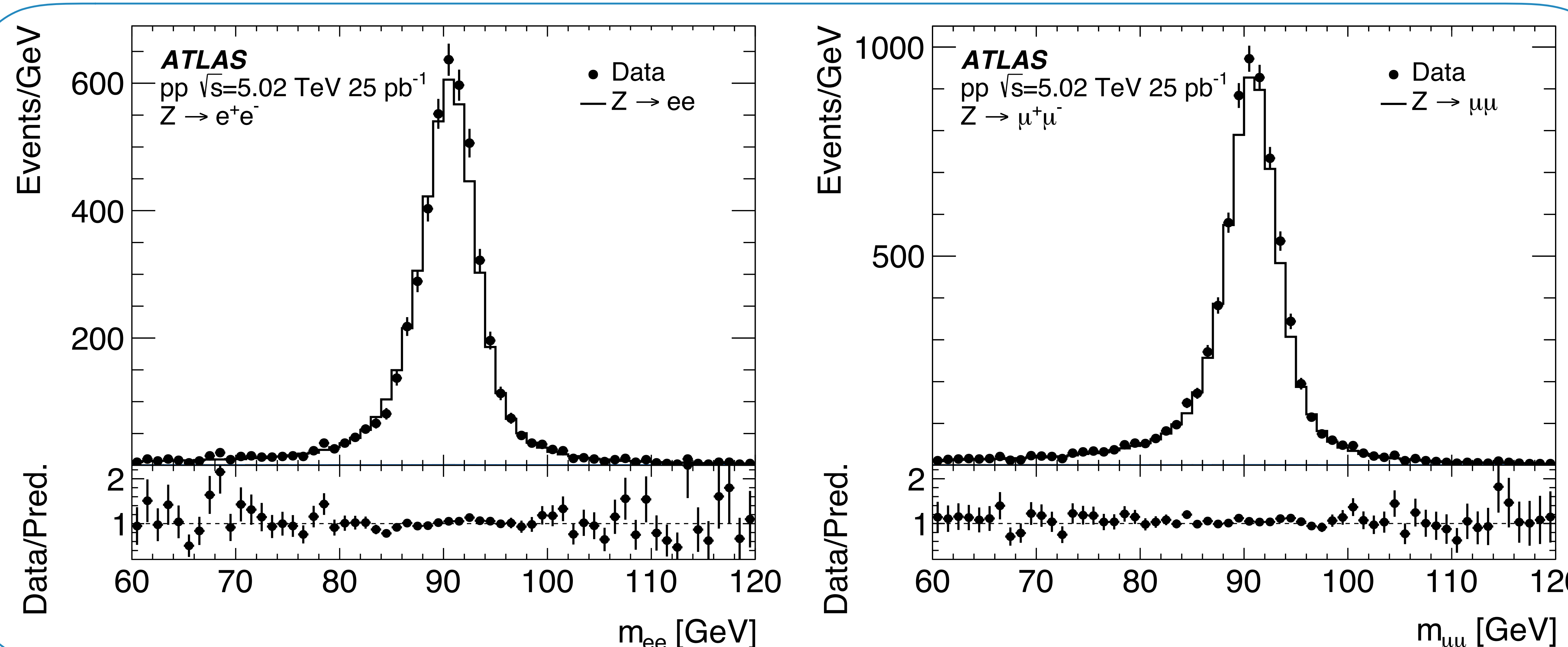


Eur. Phys. J. C 77 (2017) 367



W and Z boson production at 5.02 TeV

- **First** W,Z measurements at **5.02 TeV in ATLAS** with ***pp* collisions**, $\int \mathcal{L}\, dt = 25\ \mathrm{pb}^{-1}$
- Serves as **references for Pb+Pb** interactions at the LHC
- W, Z event **selection**:
  - Single-lepton trigger
  - Isolated leptons
  - $p_T^{e(\mu)} > 25$ GeV
  - $66 < m_{\ell\ell} < 116$ GeV **Z**
  - $|\eta_e| < 1.37$ or $1.52 < |\eta_e| < 2.47$, $|\eta_\mu| < 2.4$
  - $E_T^{\mathrm{miss}} > 25$ GeV
  - $m_T > 40$ GeV **W**

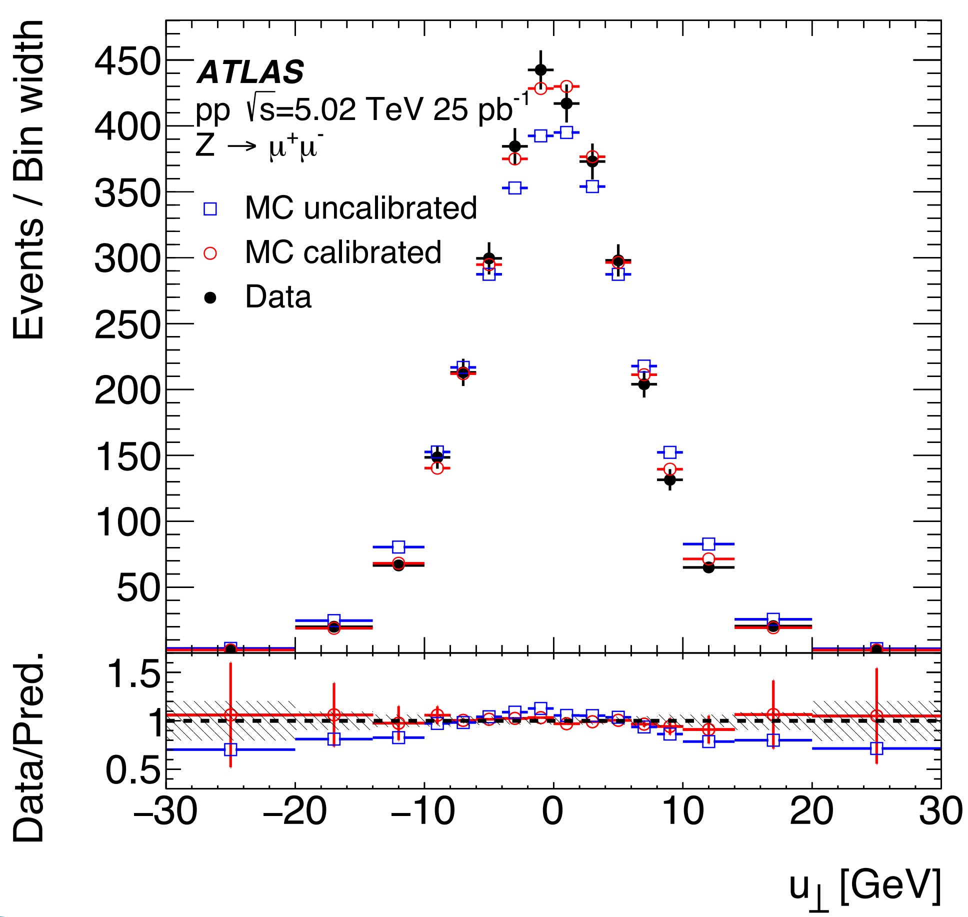


Eur. Phys. J. C 79 (2019) 128

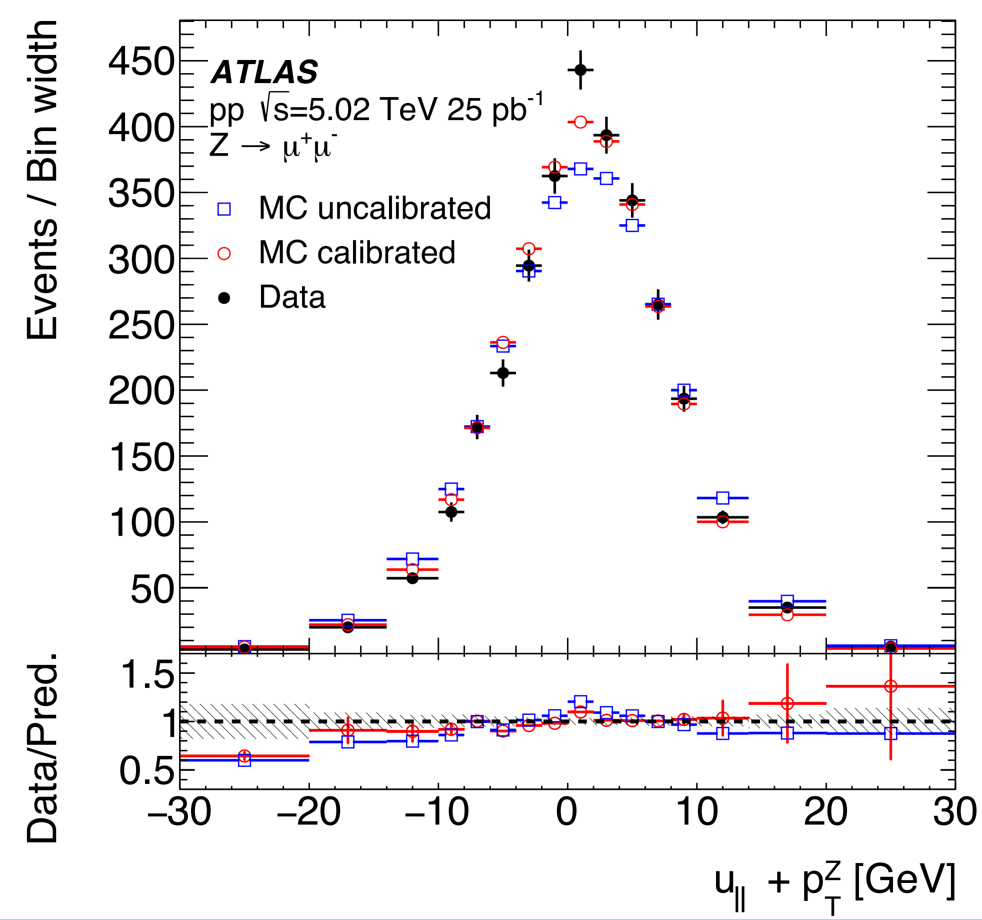
W and Z boson production at 5.02 TeV

- Use of Z-boson:
  - **Lepton calibration** and **efficiency** correction (tag-and-probe method)
  - **Recoil calibration** (*in situ* corrections to resolution/scale of u_T)
- Use of hadronic recoil ($\vec{u}_T$) for missing transverse energy definition
  - $\vec{E}_T^{\text{miss}} = -\left(\vec{u}_T + \vec{p}_T^{\,\ell}\right)$

Recoil resolution



Momentum scale of recoil



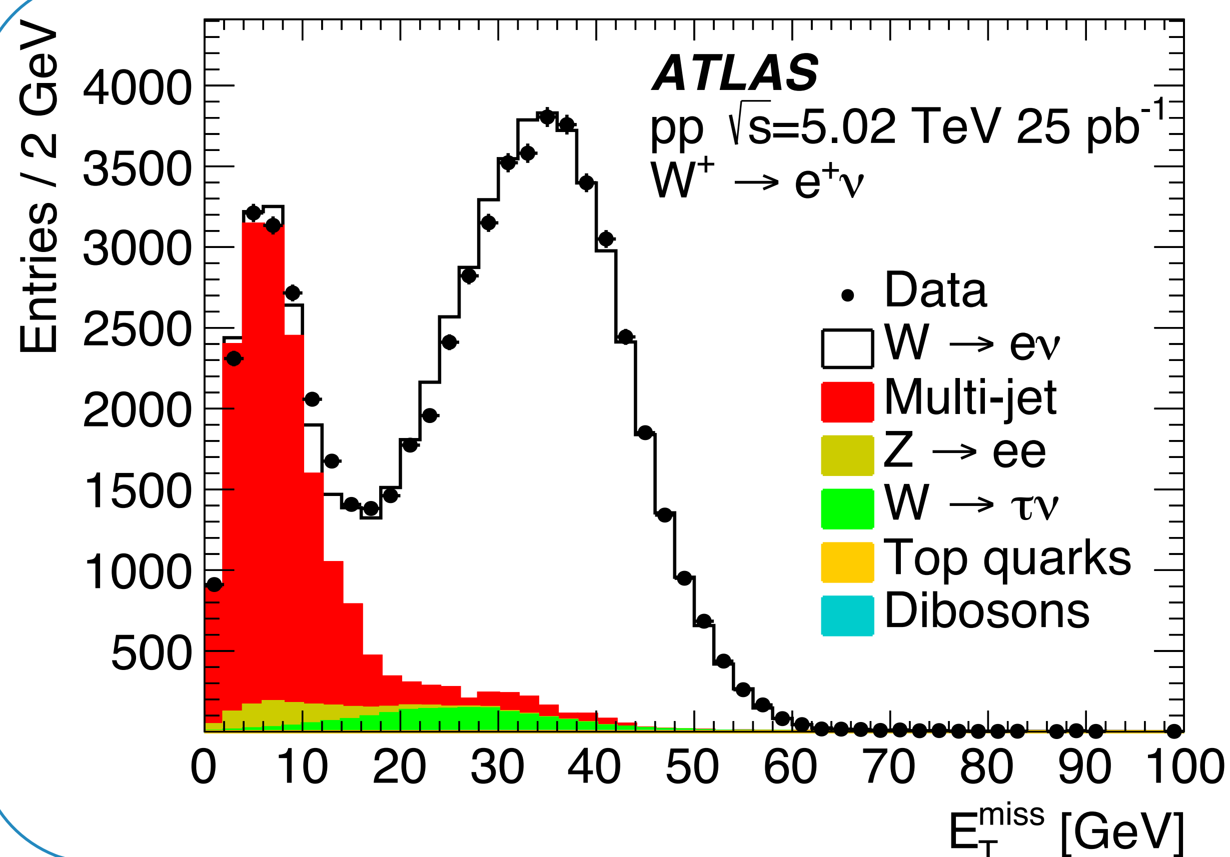
Eur. Phys. J. C 79 (2019) 128

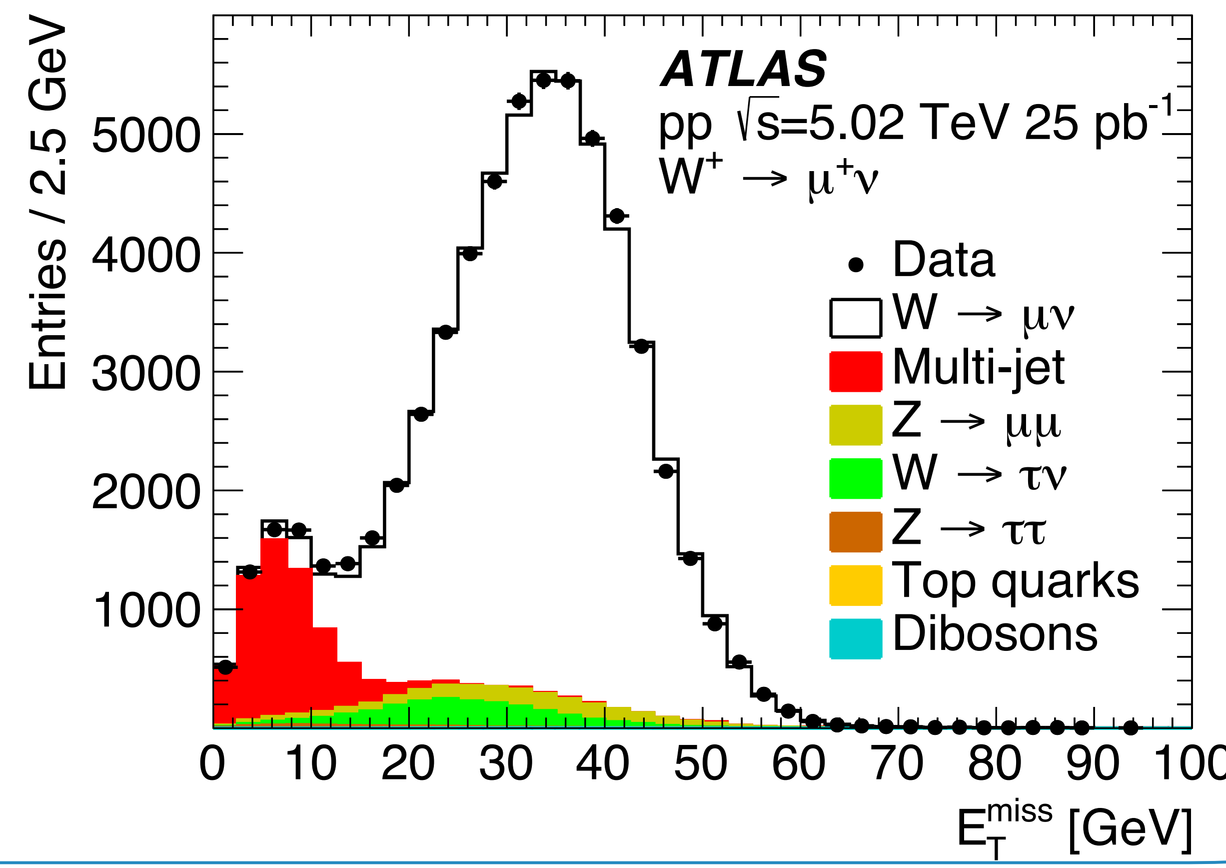
W and Z boson production at 5.02 TeV

- **Selected events**:
  - ~38k $W^+ \to e^+\nu$ and ~44k $W^+ \to \mu^+\nu$
  - ~24k $W^- \to e^-\nu$ and ~28k $W^- \to \mu^-\nu$
  - ~4.8k $Z \to ee$ and ~7.4k $Z \to \mu\mu$
- **Background contributions:**

In $W \to \ell\nu$ events
- Electroweak ~ 2 - 6%, top-quark ~ 0.2%
- Multi-jet 0.1 - 1.4% $\Longrightarrow$ data-driven method

In $Z \to \ell\ell$ events
- Electroweak + top-quark + multi-jet ~0.3%

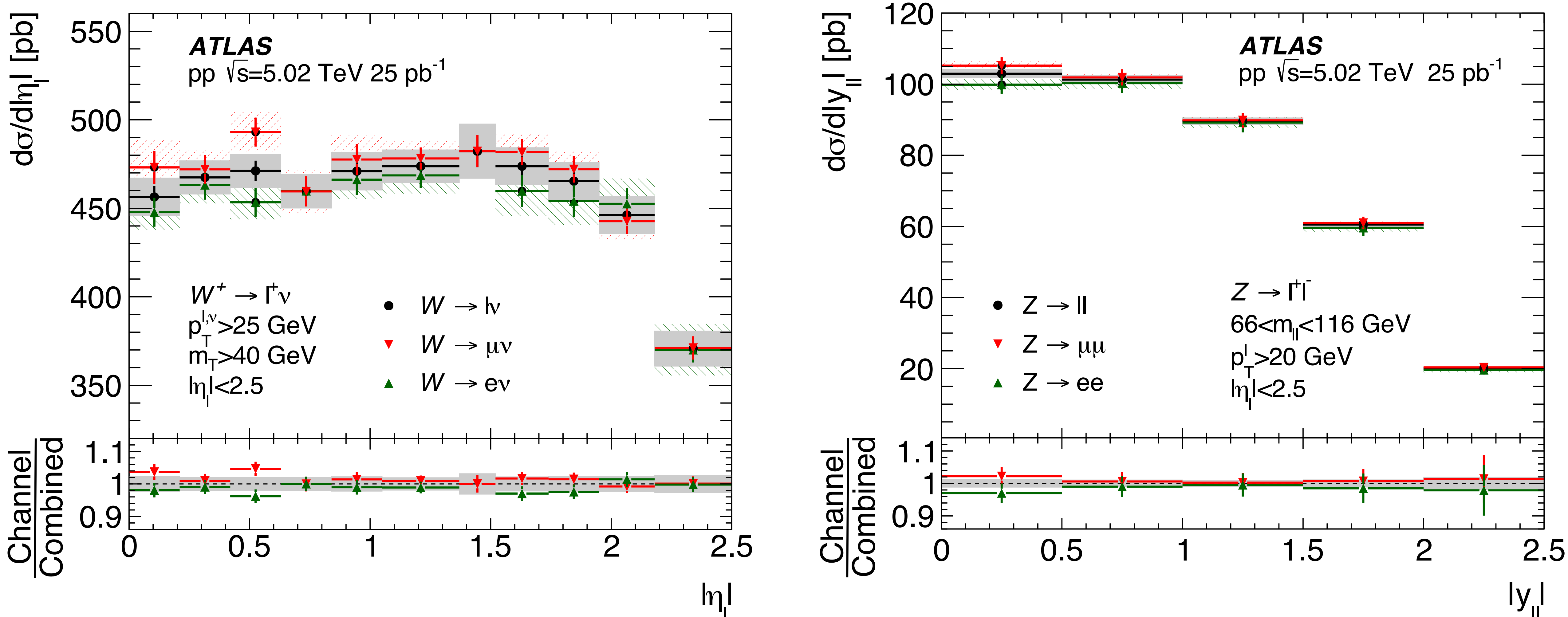




Eur. Phys. J. C 79 (2019) 128

W and Z boson production at 5.02 TeV

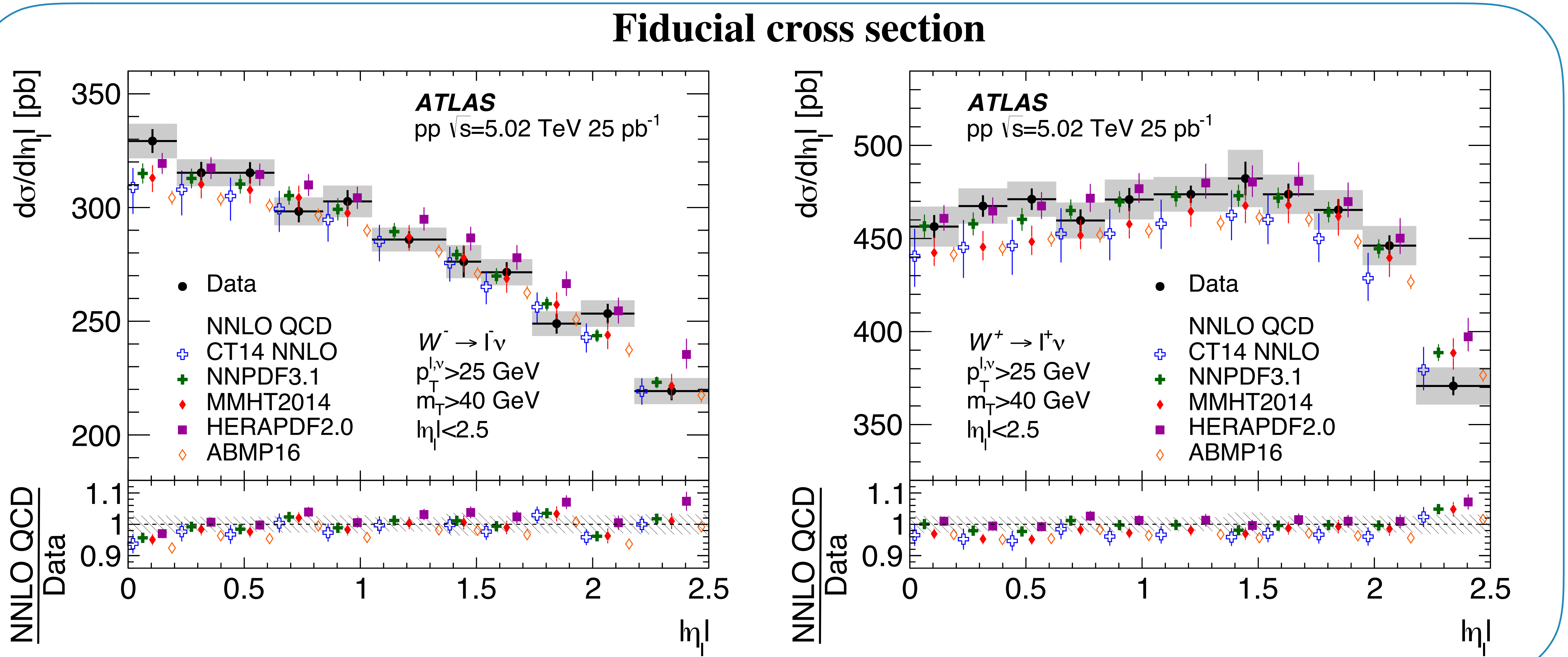
Fiducial cross section



- Measurements combination yields a good $\chi^2/N_{d.f} = 37.5/25$
- Dominant systematic uncertainties (integrated cross section):
  - Lepton calibration and efficiency ~0.8 - 1.4%
  - Recoil correction ~0.5%
  - Background evaluation ~0.8% (W) and ~0.2% (Z)
  - Luminosity: 1.9%

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

W and Z boson production at 5.02 TeV

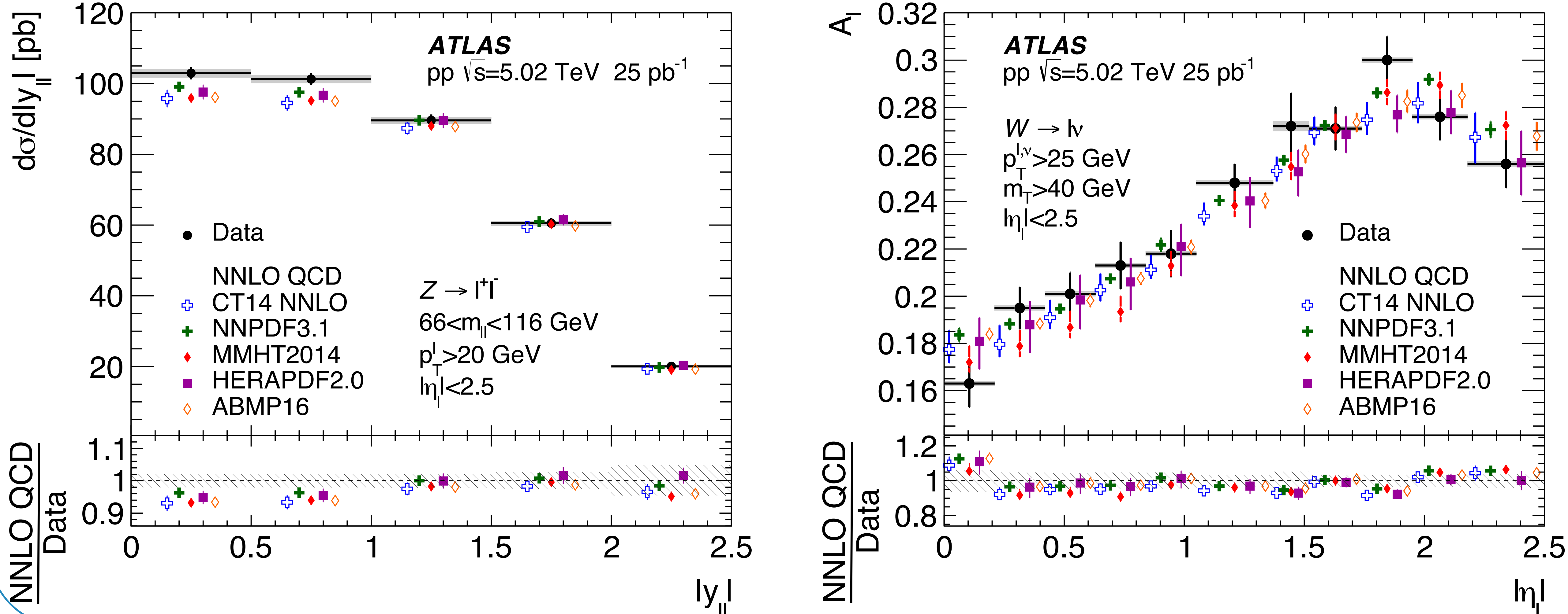


- Predictions are at $O(\alpha_s^2)$ in QCD (NNLO) and LO in EW
- Predicted cross sections are **systematically lower** than measured
  - At low η region for W^-
  - In most of η range for W^+

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

W and Z boson production at 5.02 TeV

Fiducial cross section

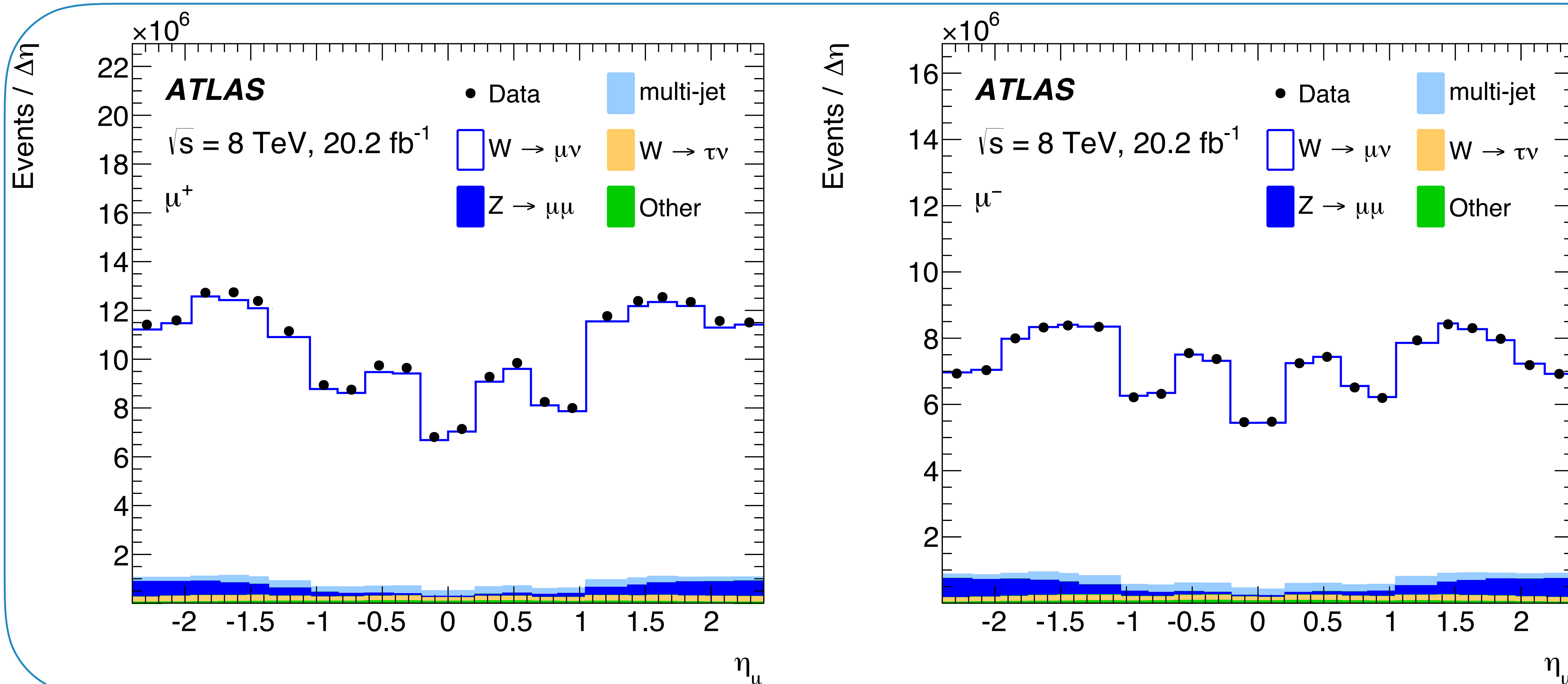


- Lepton charge asymmetry: $A_\ell(|\eta_\ell|) = \dfrac{d\sigma_{W^+}/d|\eta_\ell| - d\sigma_{W^-}/d|\eta_\ell|}{d\sigma_{W^+}/d|\eta_\ell| + d\sigma_{W^-}/d|\eta_\ell|}$
- Precision of measurements does **not** allow to **discriminate among PDFs**
- In most of $|\eta_\ell|$ range predictions tend to **underestimate the measured asymmetry** by a few percent

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

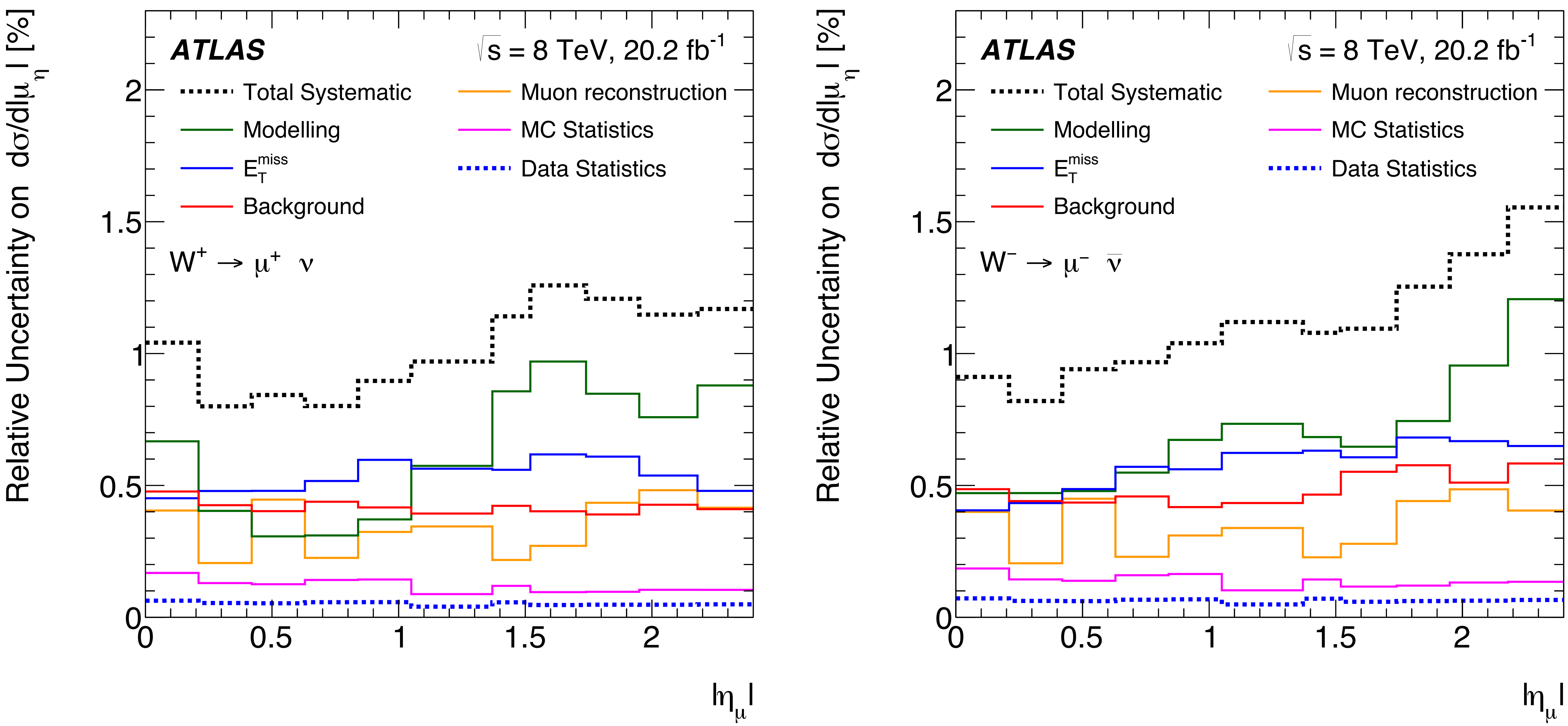
W cross-section and charge asymmetry at 8TeV

- Use data collected in pp collisions at $\sqrt{s} = 8$ TeV, luminosity: $\int \mathcal{L}\, dt = 20.2\ \mathrm{fb}^{-1}$
- Integrated and differential cross-sections for $W^+ \to \mu^+\nu$ and $W^- \to \mu^-\bar{\nu}$
- Dominant background contributions $\mu^+(\mu^-)$:
  - Multijet ~ 2% (3%)
  - $Z \to \mu^+\mu^-$ ~ 3% (4%)
  - $W \to \tau\nu$ ~ 2% (2%)



To be submitted to Eur. Phys. J. C

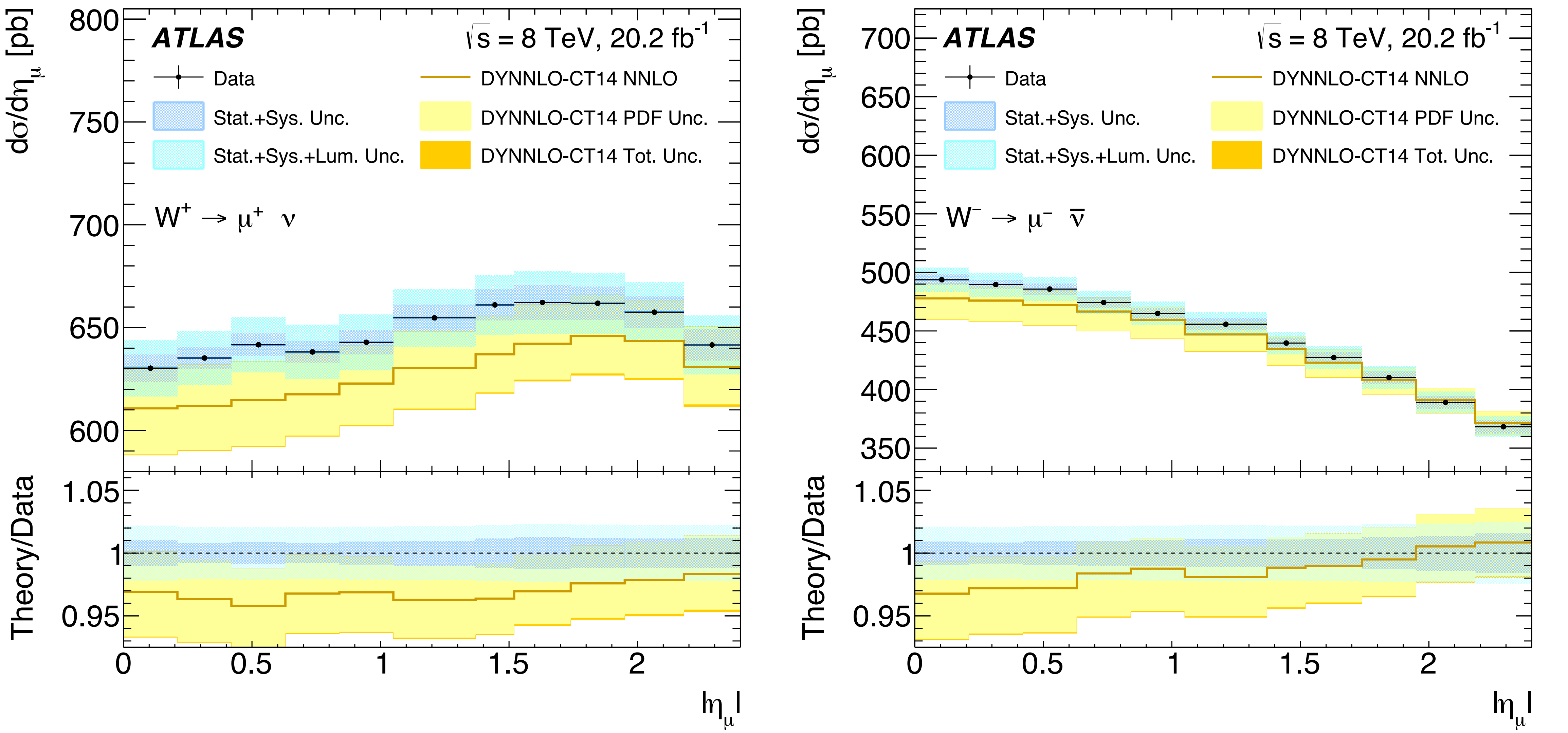
W cross-section and charge asymmetry at 8TeV



- Dominant sources: E_T^{miss} miss-modelling, modelling uncertainty → comparing several generators (Powheg+Pythia8 and Sherpa1.4.1), muon efficiency
- Measurement in μ^+ and μ^- channels provide a check of corrections procedure
- Most sources are treated as correlated between μ^+ and μ^- (reduce impact on A_l)

To be submitted to Eur. Phys. J. C

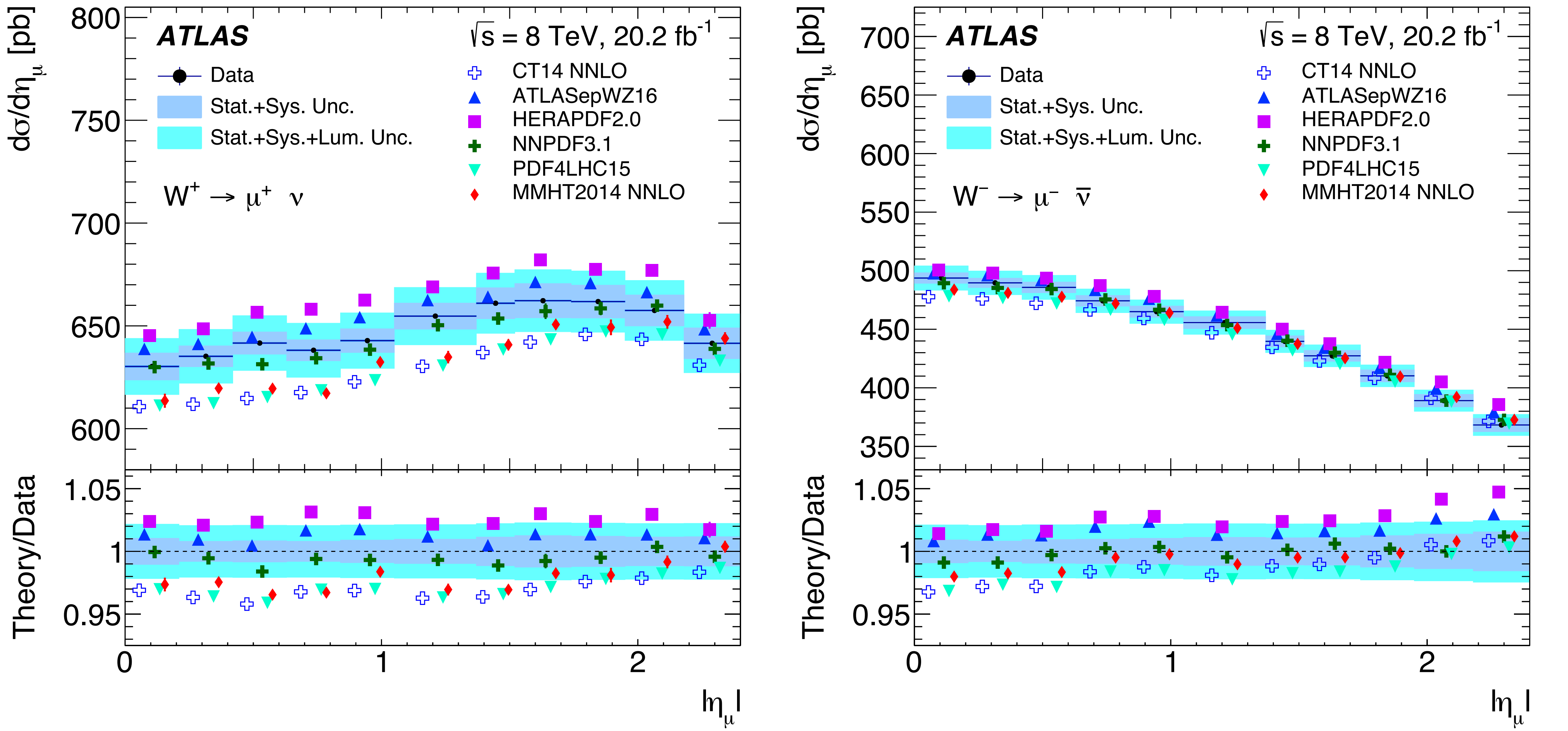
W cross-section and charge asymmetry at 8TeV



- Theory predictions: NNLO QCD with LO EW using DYNNLO with CT14nnlo PDF set
- **Data and theory agree** within the total systematic and PDF uncertainties
- **PDF dominates** over scale uncertainty in theory prediction
- **Data precision** is **higher than the PDF uncertainty** $\Longrightarrow$ constraining potential

To be submitted to Eur. Phys. J. C

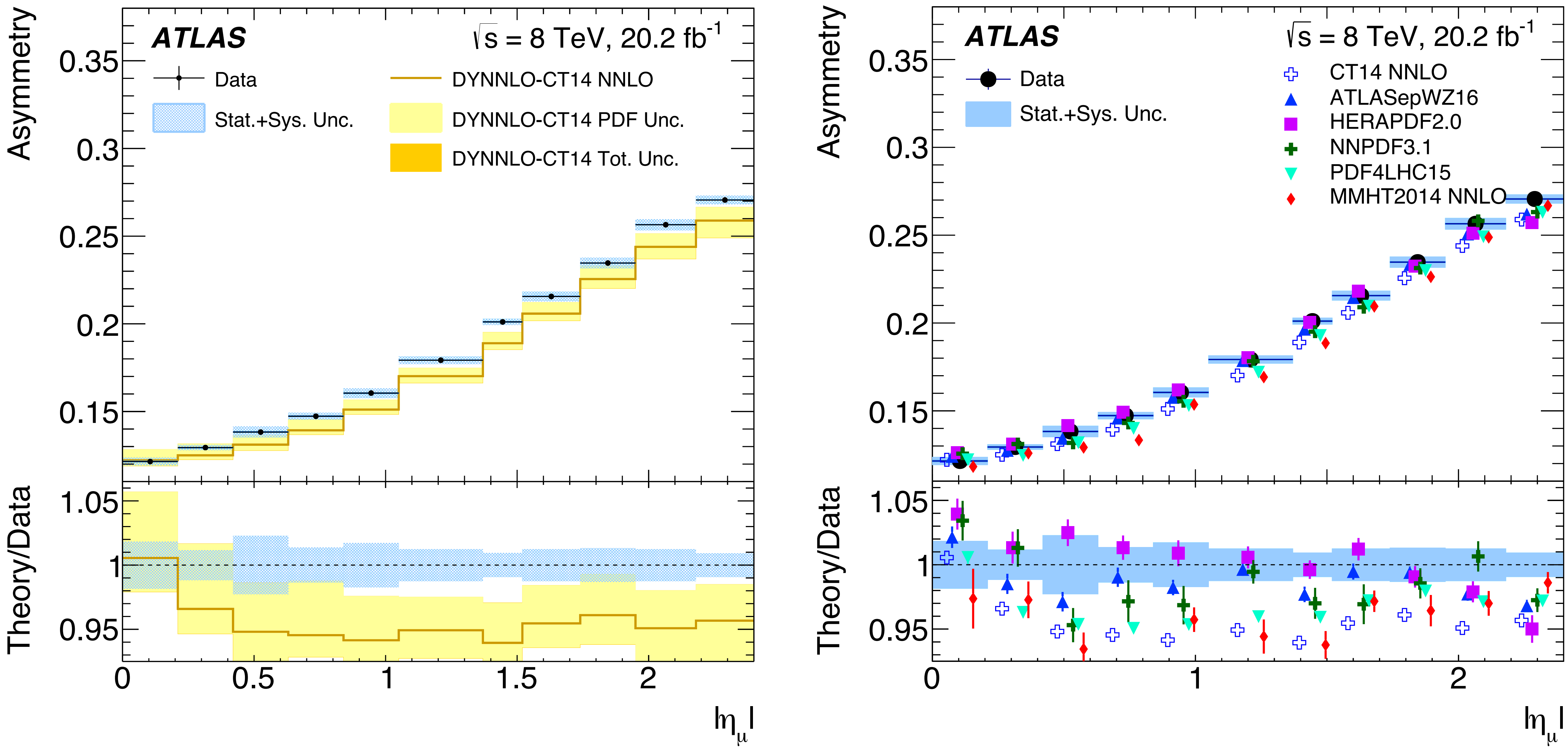
W cross-section and charge asymmetry at 8TeV



- Shape of W differential cross section is well described with predictions
- ATLAS data **discriminate among PDFs**
- Predictions with **NNPDF3.1 are closest to the measured data**

To be submitted to Eur. Phys. J. C

W cross-section and charge asymmetry at 8TeV



- Predictions with **CT14nnlo are systematically lower** then the measured A_l
  - Similar trend as for **7 TeV** measurement [Eur. Phys. J. C 77 (2017) 367]
- ATLASepWZ2016 is generally closer to data than the alternatives
  - Given PDF set includes ATLAS W charge asymmetry data at 7 TeV, which is uncorrelated to the given measurement

[To be submitted to Eur. Phys. J. C]

Summary

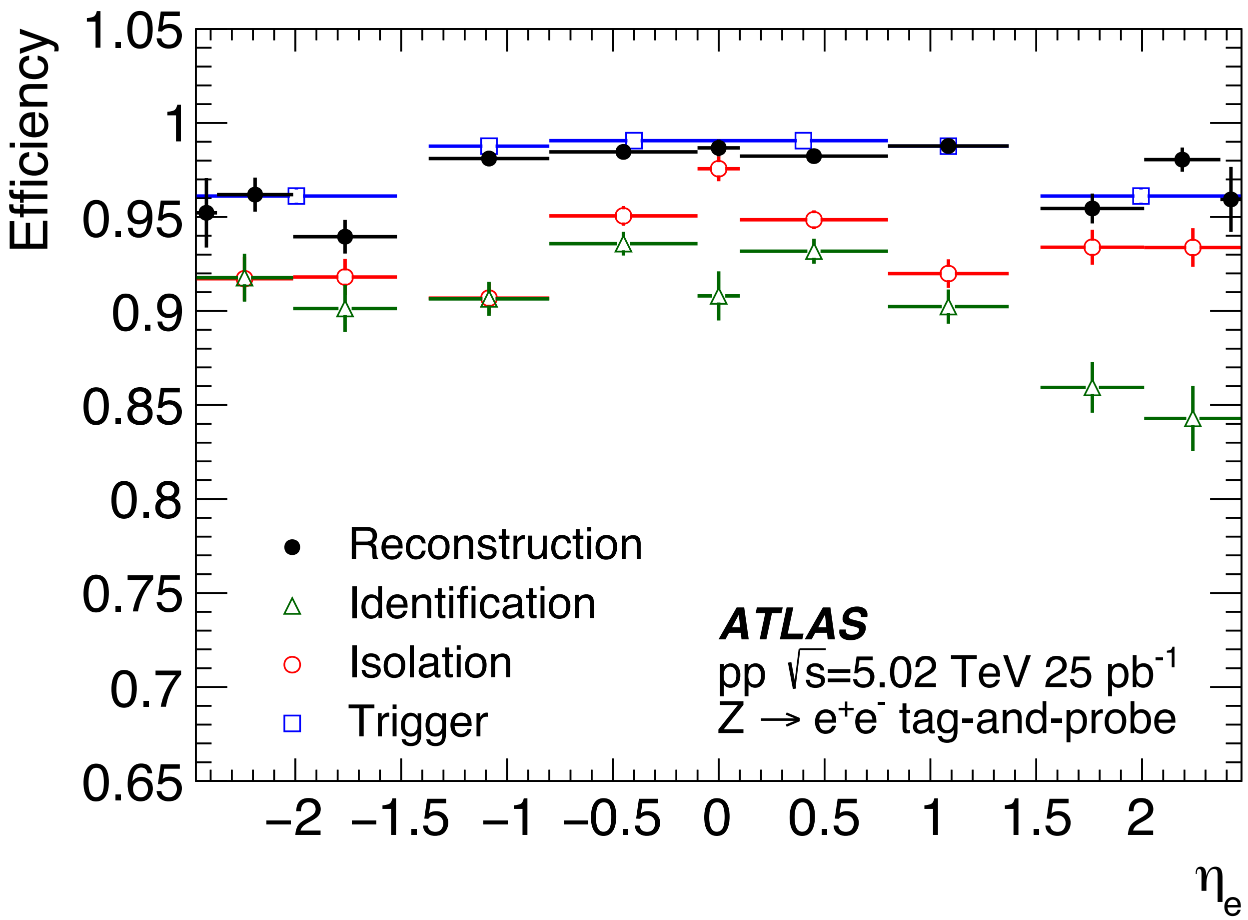
- W and Z boson production at 5.02 TeV
  - First W,Z measurements at 5.02 TeV in ATLAS are performed
  - Fiducial W^+, W^- and Z cross sections are measured with a precision of 1.2–1.7%
  - Measured differential cross sections show 1–2σ deviations from the predictions based on different PDF sets.

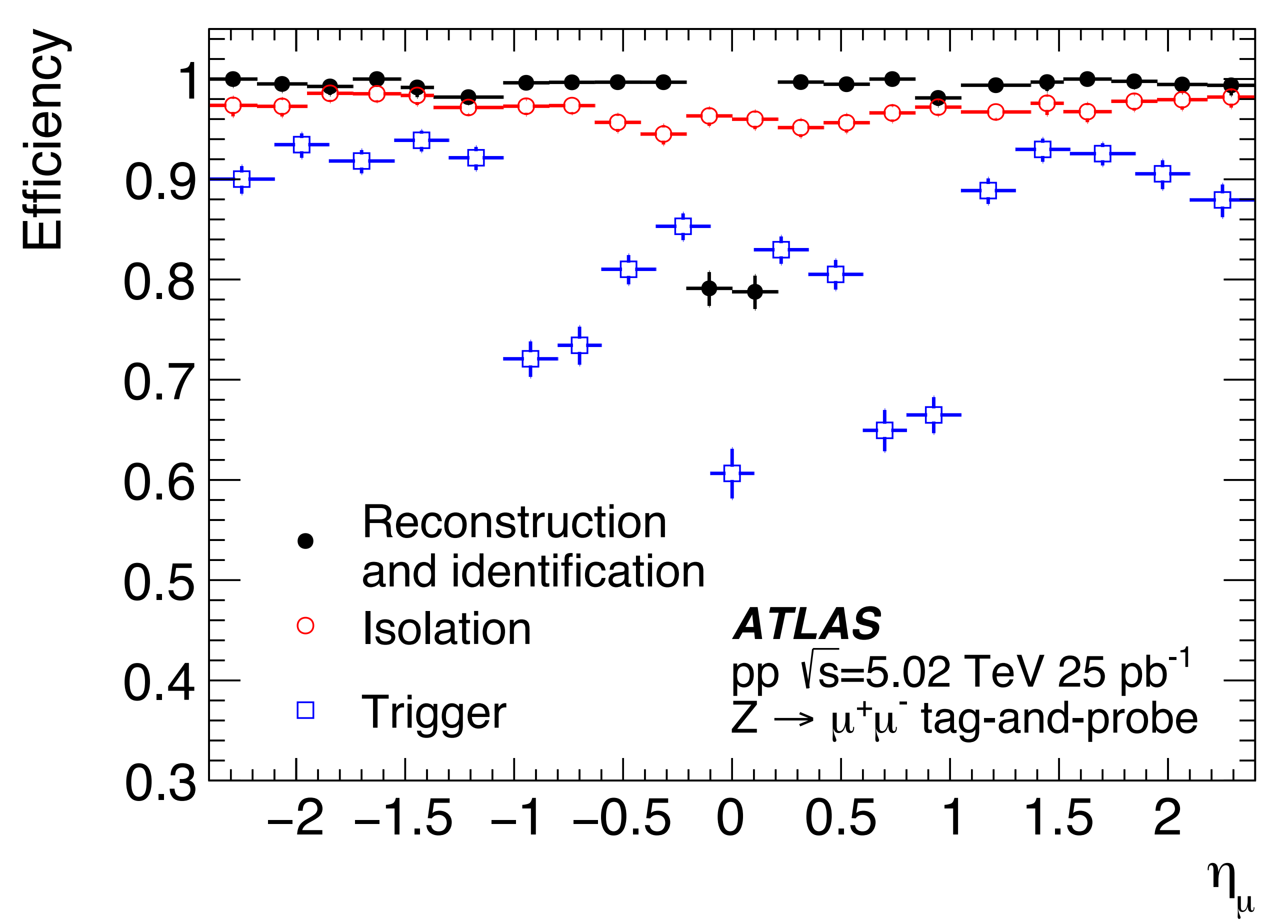
- W cross-section and charge asymmetry at 8TeV
  - Cross-sections are measured with the precision of 0.8–1.5% in bins of η
  - Precision of measured charge asymmetry is higher than the predictions
  - The measured data demonstrate sensitivity to the performance of PDF selection

Backup slides

W and Z boson production at 5.02 TeV

- Lepton efficiencies

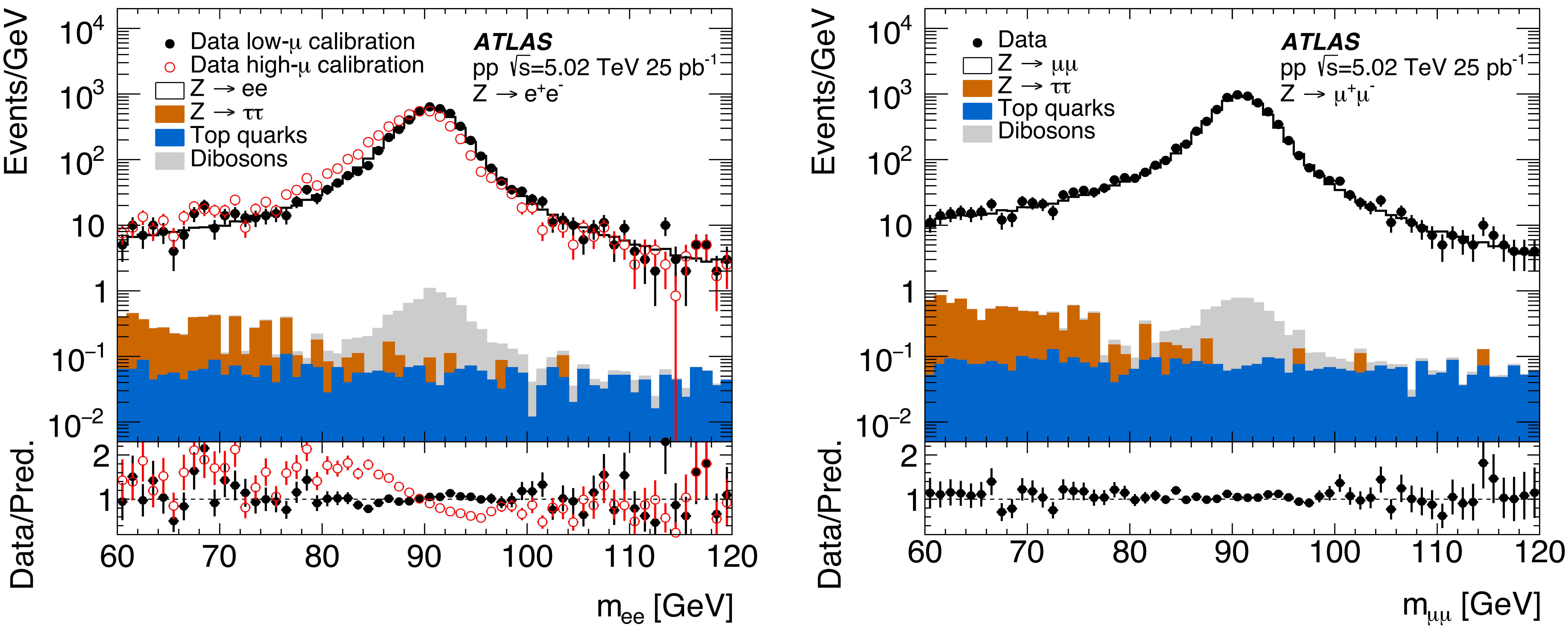




ATLAS EXPERIMENT

W and Z boson production at 5.02 TeV

- Di-lepton invariant mass (log-scale)



W and Z boson production at 5.02 TeV

- Recoil corrections

$$u_{\parallel}^{W,\text{corr}} = \langle u_{\parallel}^{Z} + p_{\text{T}}^{Z} \rangle^{\text{data}} - \langle u_{\parallel}^{Z} + p_{\text{T}}^{Z} \rangle^{\text{MC}} + \langle u_{\parallel}^{Z,\text{data}} \rangle + \left(u_{\parallel}^{W,\text{MC}} - \langle u_{\parallel}^{Z,\text{data}} \rangle \right) \cdot \frac{\sigma_{u_\perp}^{\text{data}}}{\sigma_{u_\perp}^{\text{MC}}};$$

$$u_{\perp}^{W,\text{corr}} = u_{\perp}^{W,\text{MC}} \cdot \frac{\sigma_{u_\perp}^{\text{data}}}{\sigma_{u_\perp}^{\text{MC}}}.$$

- Background:

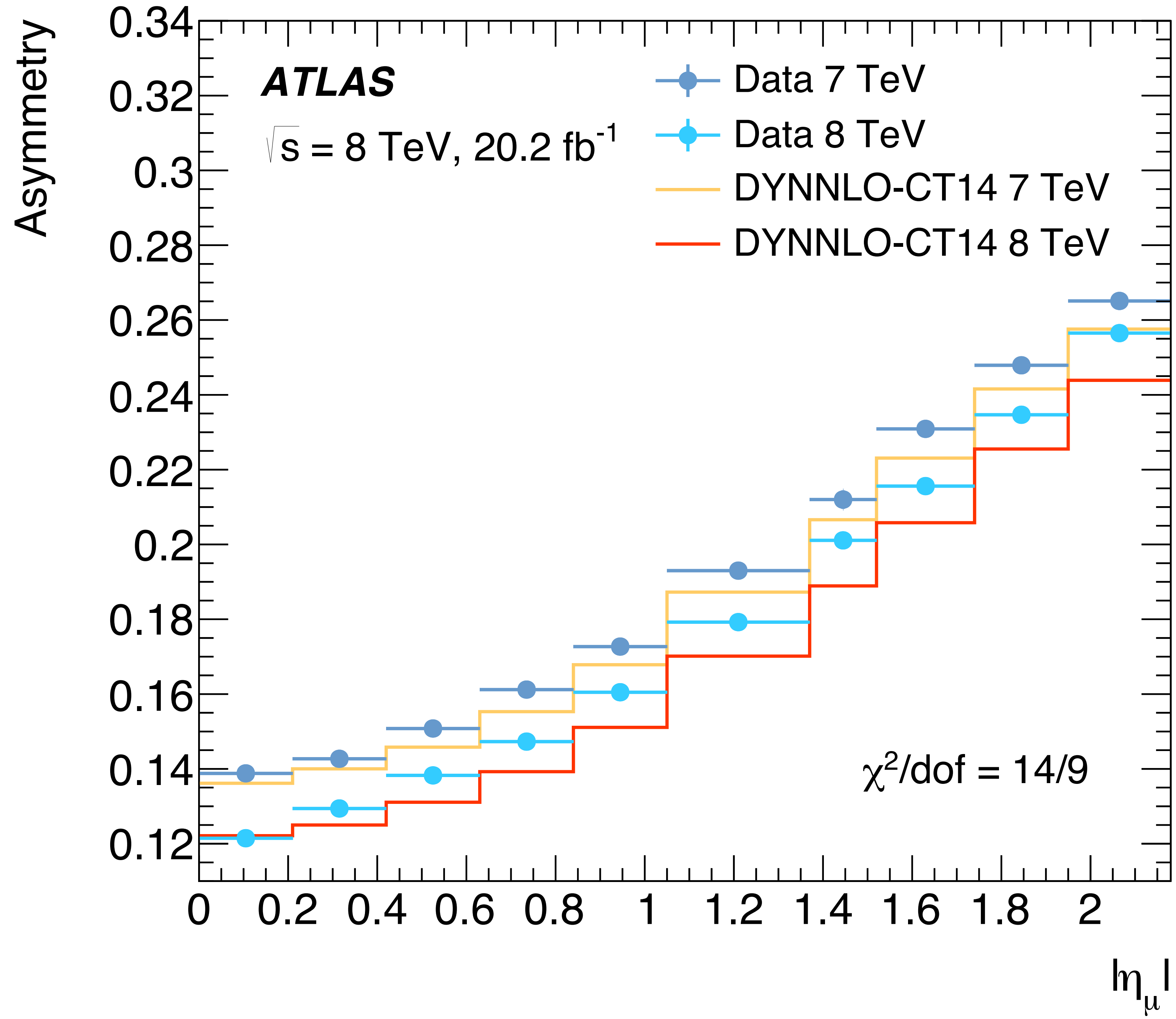
Background	$W^+ \to e^+\nu$ ($W^+ \to \mu^+\nu$) [%]	$W^- \to e^-\nu$ ($W^- \to \mu^-\nu$) [%]	$Z \to e^+e^-$($Z \to \mu^+\mu^-$) [%]
$Z \to \ell^+\ell^-, \ell = e, \mu$	0.1 (2.8)	0.2 (3.8)	–
$W^\pm \to \ell^\pm\nu, \ell = e, \mu$	–	–	<0.01 (<0.01)
$W^\pm \to \tau^\pm\nu$	1.8 (1.8)	1.8 (1.8)	<0.01 (<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)

- Ratios:

$R^{\text{fid}}_{W^+/W^-}$	1.617 ± 0.012 (stat) ± 0.003 (syst)
$R^{\text{fid}}_{W/Z}$	9.81 ± 0.13 (stat) ± 0.01 (syst)
$R^{\text{fid}}_{W^+/Z}$	6.06 ± 0.08 (stat) ± 0.01 (syst)
$R^{\text{fid}}_{W^-/Z}$	3.75 ± 0.05 (stat) ± 0.01 (syst)

W cross-section and charge asymmetry at 8TeV

- Charge asymmetry (comparison to 7TeV results)



W cross-section and charge asymmetry at 8TeV

- Cross sections (comparison of electron and muon channels)