Measurements of inclusive W and Z cross sections at 13 TeV with the ATLAS detector

Hayk Pirumov on behalf of the ATLAS Collaboration

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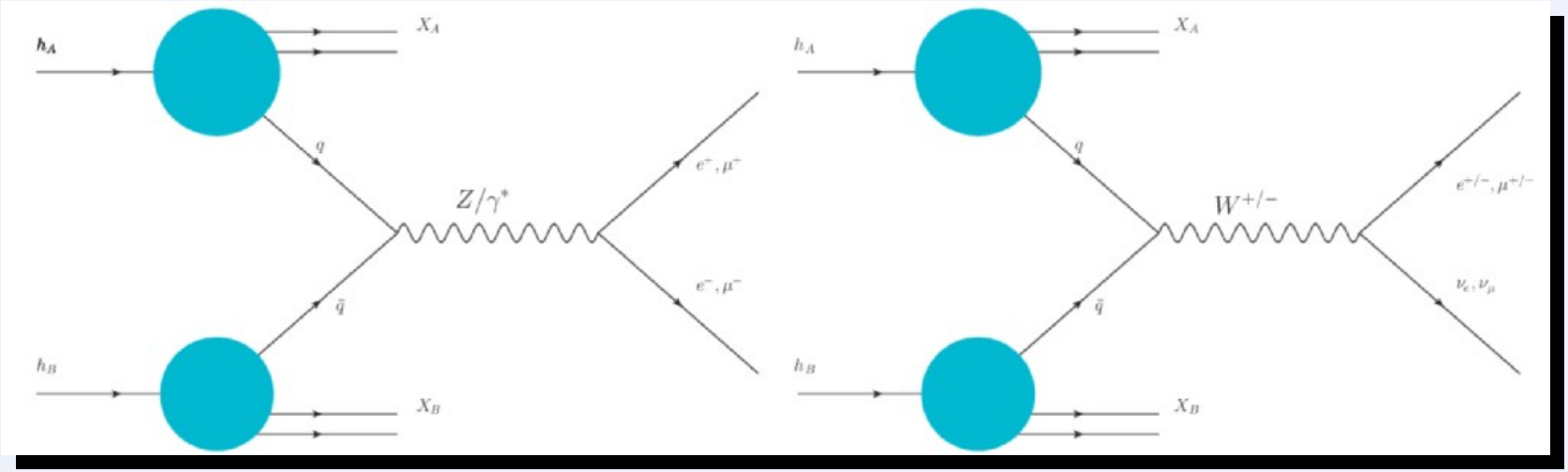
Introduction

- Measurements of electroweak vector-boson production provide a **benchmark for** the understanding of **QCD and EW** processes
- Large cross section and easily identifiable leptonic final states provide a clean experimental signature → **high precision**
- Test models of parton dynamics at the LHC's new higher operating centre of mass energy of 13 TeV
- Cross section ratios benefit from cancellation of some experimental uncertainties → tool for **PDF constrains**



W and Z at 13 TeV in ATLAS

arXiv:1603.09222

New ATLAS measurements of W and Z cross sections at 13 TeV:

- Based on 81 pb^{-1} of data taken in June - July 2015
- arXiv:1603.09222 *(submitted to Phys. Lett. B)*

Event selection *(main points)*:

- Lepton and trigger selection synchronized between W and Z

  ➔ reduced exp. uncertainty for cross section ratios

- Lepton kinematics: $p_T > 25$ GeV,
  $|\eta| < 2.47$, excluding (1.37,1.52) for electron
  $|\eta| < 2.4$ for muon
- Leptons isolated both in calorimeter and tracking
- W boson: $E_T^{miss} > 25$ GeV,
  $m_T > 50$ GeV
- Z boson: $66 < m_{ll} < 116$ GeV

Background contributions

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EW and top-quark background:

- estimated from MC samples
- dominant contributions to $W^{\pm}$ measurements:
  - $Z \to \mu\mu$ *(~5%)*, $W \to \tau\nu$ *(~2%)*, $Z \to ee$ and *ttbar (~1%)*
- in Z measurements:
  - total EW background *~0.2%*, *ttbar* contribution *~0.5%*

Multijet background:

- for Z analysis is estimated from simulation to be < *0.1%*
- sizable for $W^{\pm}$ → estimated in data-driven approach

Multijet background estimation

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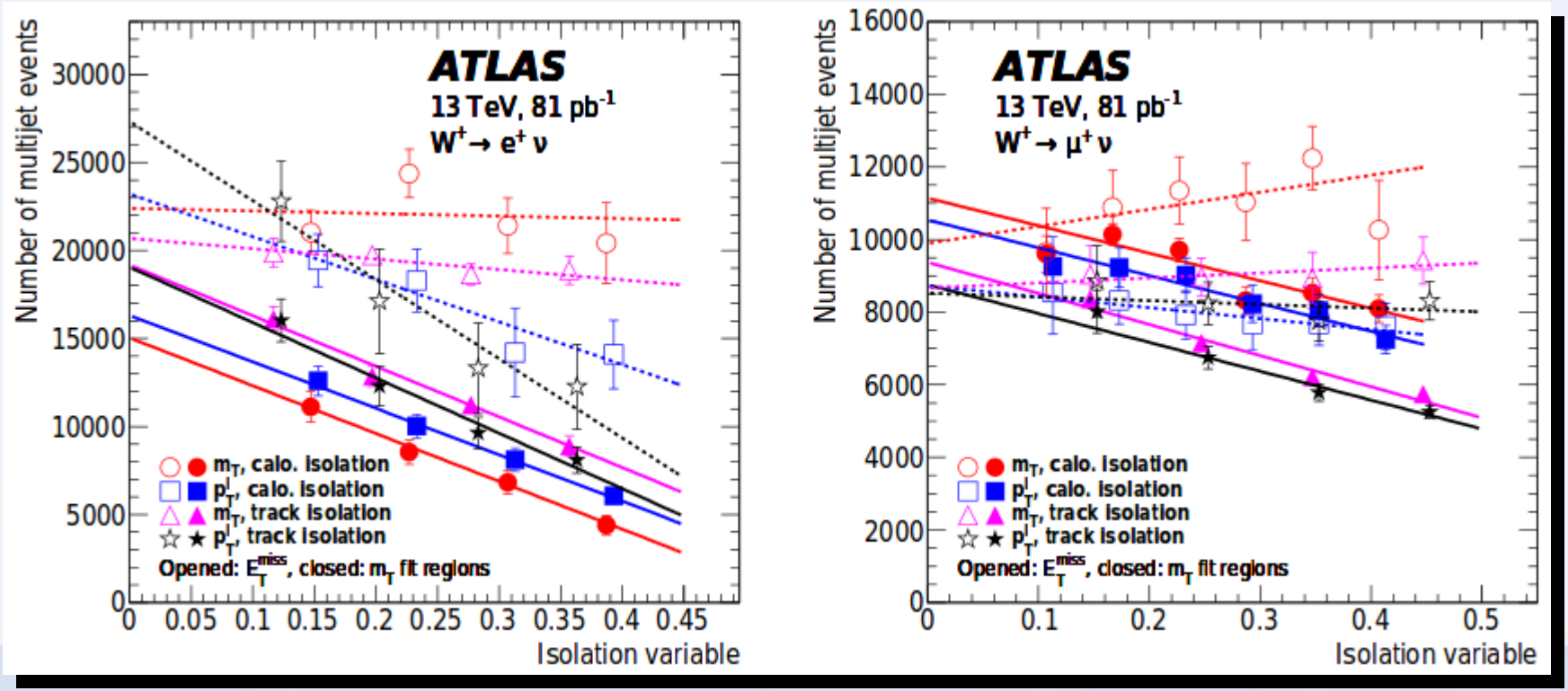
- Multijet templates are created by inverting the track and calo isolation requirements and slicing them → statistically independent templates
- For each template kinematic distribution *(i.e. p_T^l and m_T)* two fit regions *(E_T^{miss} relaxed and m_T relaxed)* are used to extract the normalization
- Results are extrapolated to the "isolated" signal region *(dashed and continuous lines corresponding to E_T^{miss} relaxed and m_T relaxed regions)*



Kinematic distributions

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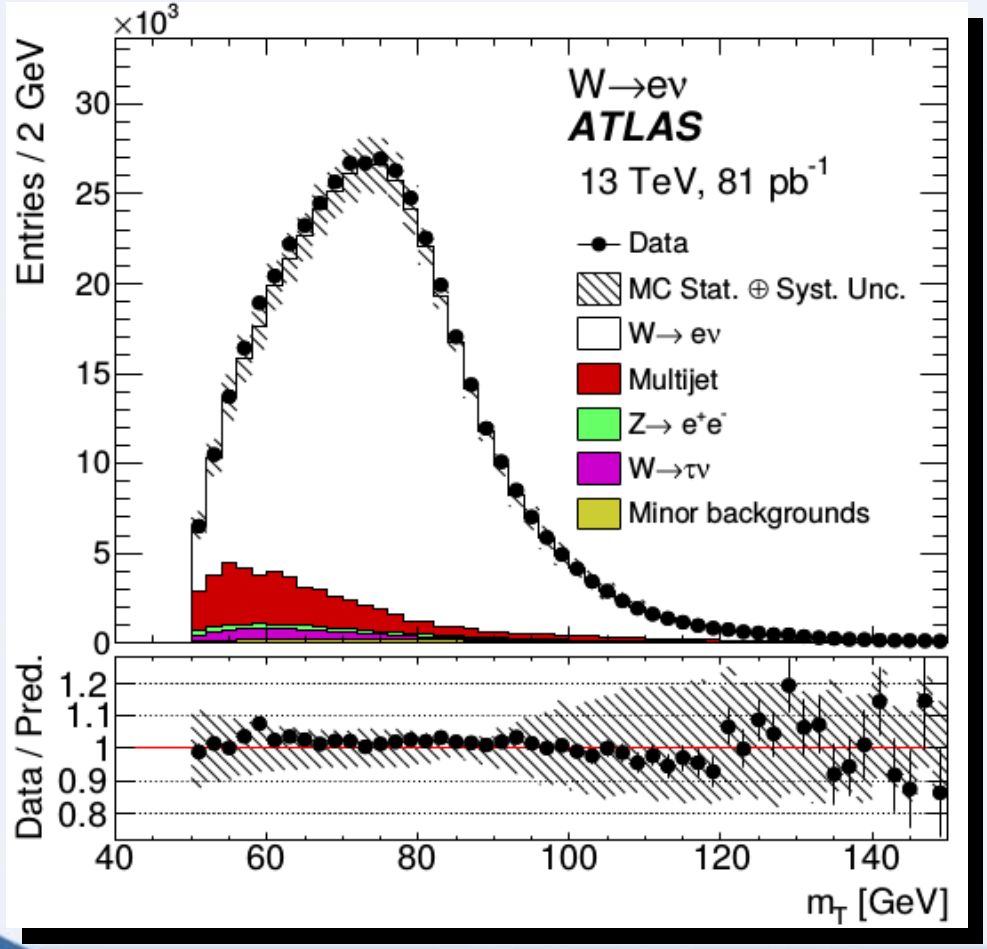
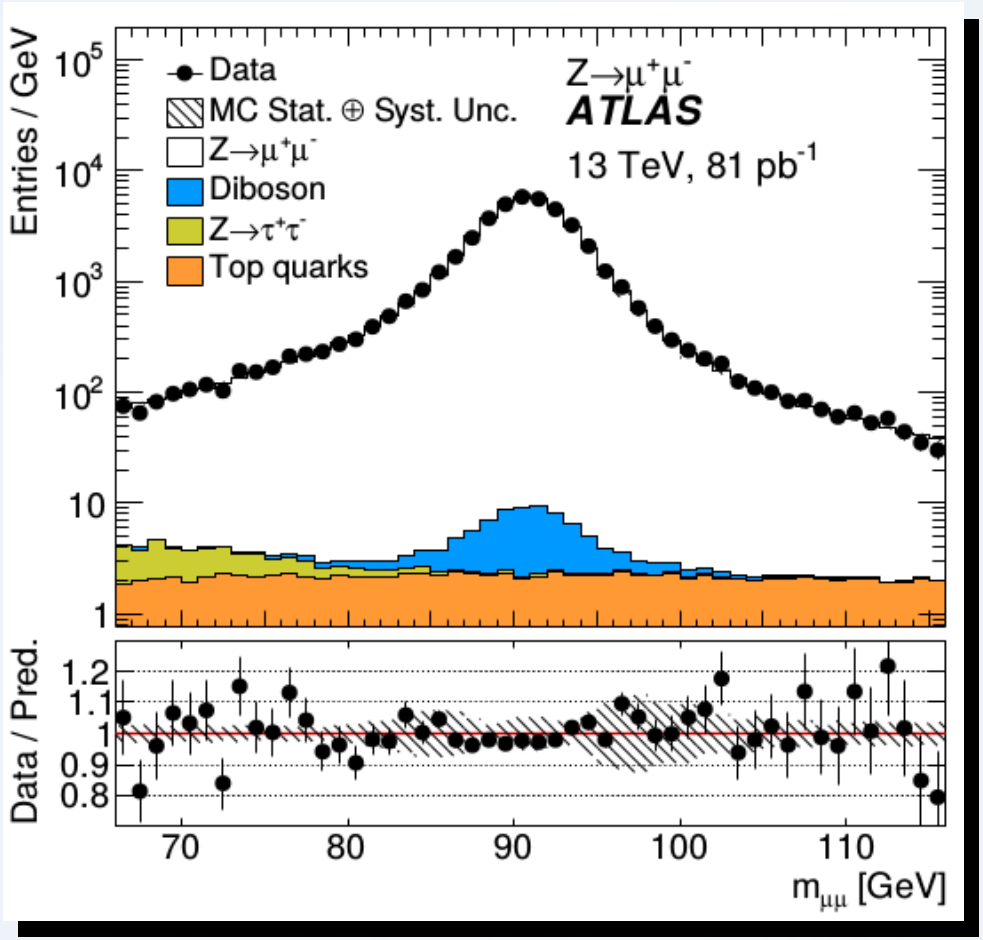
- Selected W and Z events as a function of (transverse) invariant mass
- MC signal distributions from Powheg+Pythia8
- **NOTE**: systematic uncertainty **do not** include lumi error *(~5%)*





Cross section calculation

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Fiducial and total cross sections calculation:

$$\sigma^{fid}_{W,Z} \times BR(W,Z \to l\nu, ll) = \sigma^{tot}_{W,Z} \times BR(W,Z \to l\nu, ll) \cdot A_{W,Z} = \frac{N - B}{C_{W,Z} \cdot \mathcal{L}_{W,Z}}$$

- N – number of candidate events after selection is applied
- B – estimated number of background events
- A – geometric and phase space acceptance
- C – correction factor for the experimental selection and resolution effects
- L – integrated luminosity

Systematic uncertainties

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The experimental systematic uncertainties in the measurements of the cross sections enter via the evaluation of the correction factor C and luminosity

$\delta C/C$ [%]	$Z \to e^+e^-$	$W^+ \to e^+\nu$	$W^- \to e^-\bar{\nu}$	$Z \to \mu^+\mu^-$	$W^+ \to \mu^+\nu$	$W^- \to \mu^-\bar{\nu}$
Lepton trigger	0.1	0.3	0.3	0.2	0.6	0.6
Lepton reconstruction, identification	0.9	0.5	0.6	0.9	0.4	0.4
Lepton isolation	0.3	0.1	0.1	0.5	0.3	0.3
Lepton scale and resolution	0.2	0.4	0.4	0.1	0.1	0.1
Charge identification	0.1	0.1	0.1	–	–	–
JES and JER	–	1.7	1.7	–	1.6	1.7
E_T^{miss}	–	0.1	0.1	–	0.1	0.1
Pile-up modelling	< 0.1	0.4	0.3	< 0.1	0.2	0.2
PDF	0.1	0.1	0.1	< 0.1	0.1	0.1
Total	1.0	1.9	1.9	1.1	1.8	1.8

- Dominant uncertainty sources:
  - Multijet background evaluation up to *3.4%* ($W \to e\nu$) and *1.4%* ($W \to \mu\nu$)
  - Jet-Energy Scale and Resolution ~*1.7%*
  - Lepton reconstruction and identification *0.4 – 0.9%* depending on the channel
- Luminosity uncertainty about *5%*

Total and fiducial cross sections

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	W^+	W^-	Z
	Electron channel (value ± stat ± syst ± lumi)		
Signal events	228060 ± 510 ± 4920 ± 480	177890 ± 450 ± 6110 ± 430	34865 ± 187 ± 10 ± 7
Correction C	0.602 ± 0.012	0.614 ± 0.012	$0.552^{+0.006}_{-0.005}$
σ^{fid}[nb]	4.66 ± 0.01 ± 0.13 ± 0.24	3.57 ± 0.01 ± 0.14 ± 0.19	0.777 ± 0.004 ± 0.008 ± 0.039
Acceptance A	0.383 ± 0.007	0.398 ± 0.007	0.393 ± 0.007
σ^{tot}[nb]	12.18 ± 0.03 ± 0.41 ± 0.63	8.96 ± 0.02 ± 0.38 ± 0.47	1.98 ± 0.01 ± 0.04 ± 0.10
	Muon channel (value ± stat ± syst ± lumi)		
Signal events	237721.3 ± 516 ± 2209.6±970	183182.5 ± 457 ± 2520.1±870	44706 ± 212 ± 13 ± 10
Correction C	0.653 ± 0.012	0.650 ± 0.012	0.711±0.008
σ^{fid}[nb]	4.48 ± 0.01 ± 0.09 ± 0.24	3.47 ± 0.01 ± 0.08 ± 0.19	0.774 ± 0.004 ± 0.008 ± 0.039
Acceptance A	0.383 ± 0.007	0.398 ± 0.007	0.393 ± 0.007
σ^{tot}[nb]	11.70 ± 0.02 ± 0.32 ± 0.63	8.71 ± 0.02 ± 0.25 ± 0.48	1.97 ± 0.01 ± 0.04 ± 0.10

- Total and fiducial cross sections for W^+, W^- and Z in electron and muon channels together with correction factors C and A

Lepton universality

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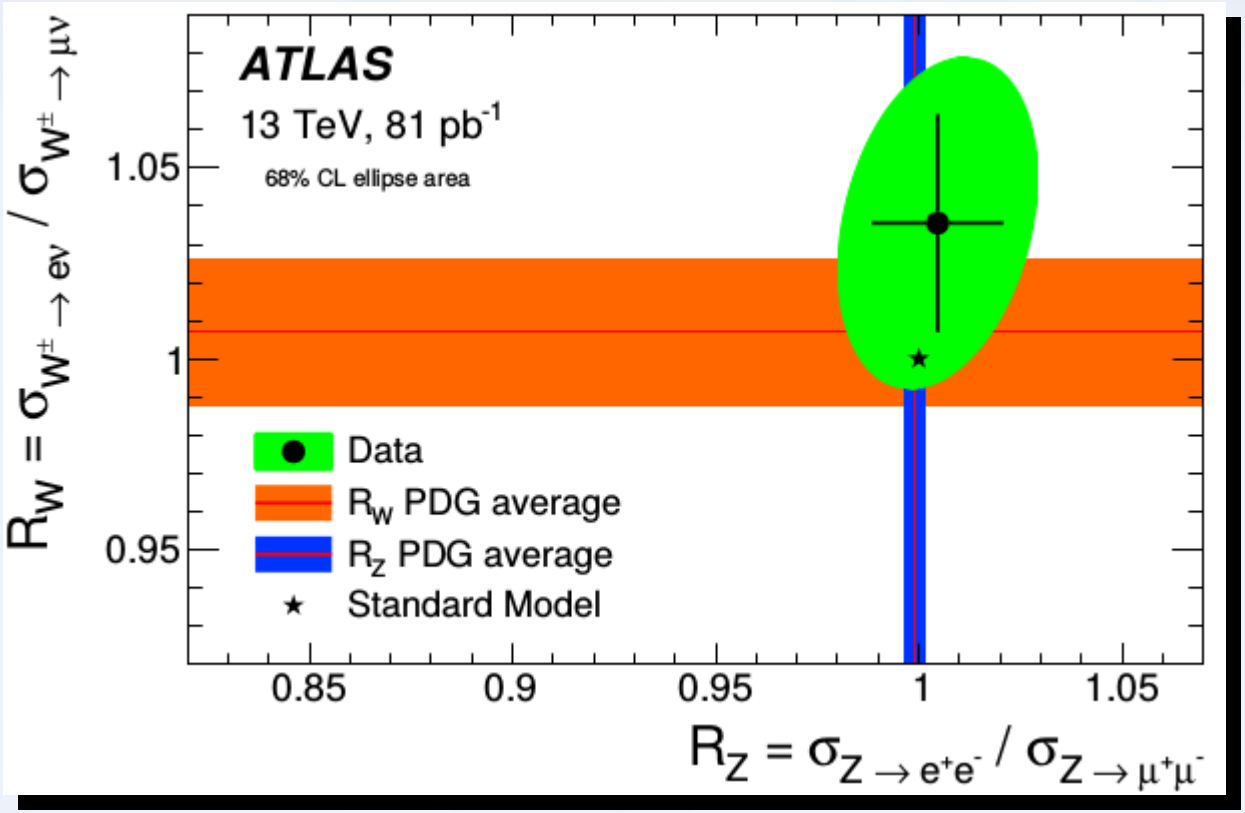
- Ratios of $W^{\pm}$ and Z fiducial cross sections in electron and muon channels:



- Good agreement with SM expectations and previous experimental measurements
- Combination of W^{+}, W^{-} and Z fiducial cross sections is performed to improve the precision

Measured vs predicted cross sections

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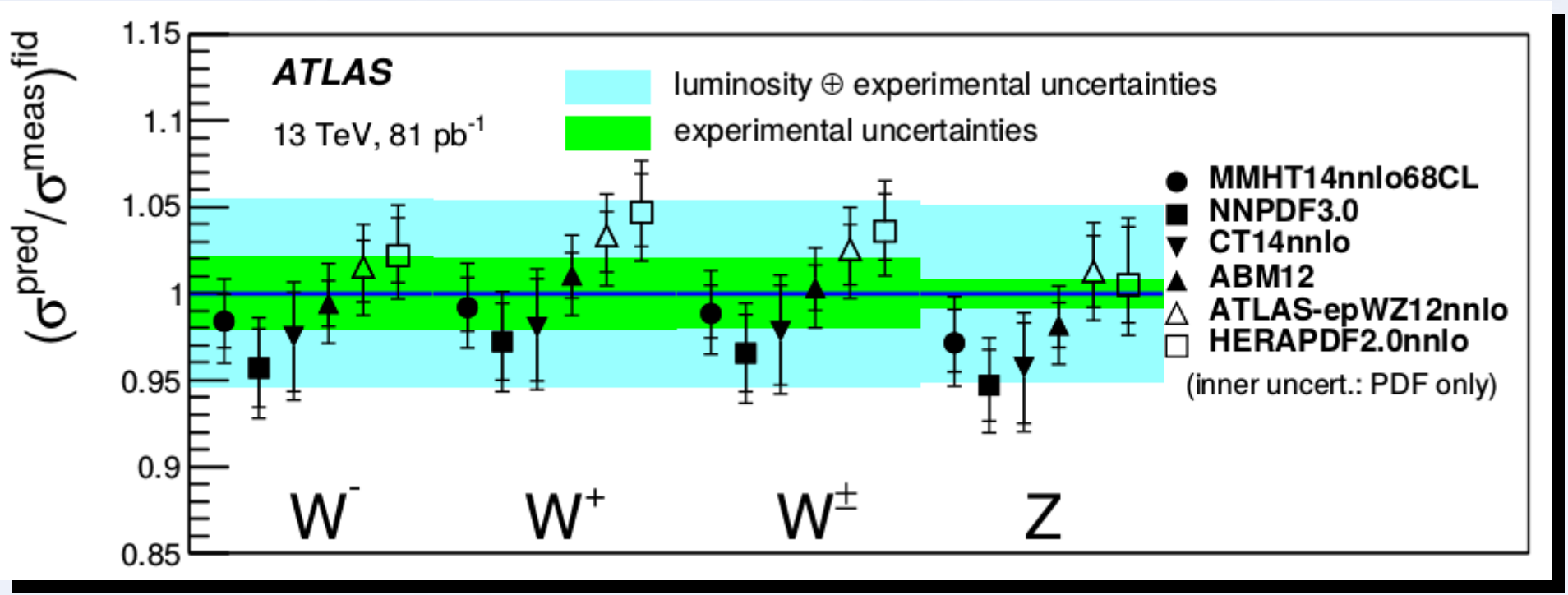
- Ratio of the predicted to measured fiducial cross section for the combined electron and muon channels using various PDFs



- The measurements agree well with NNLO predictions including NLO EW corrections
- Experimental precision excluding lumi uncertainty is comparable to the PDF uncertainties

Cross section ratios

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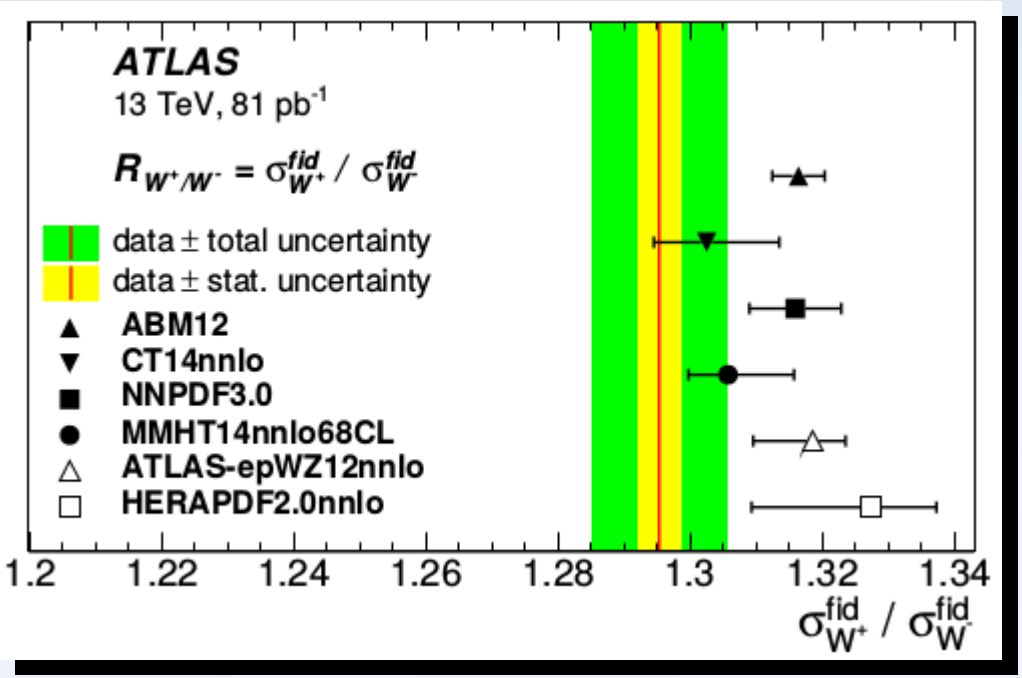

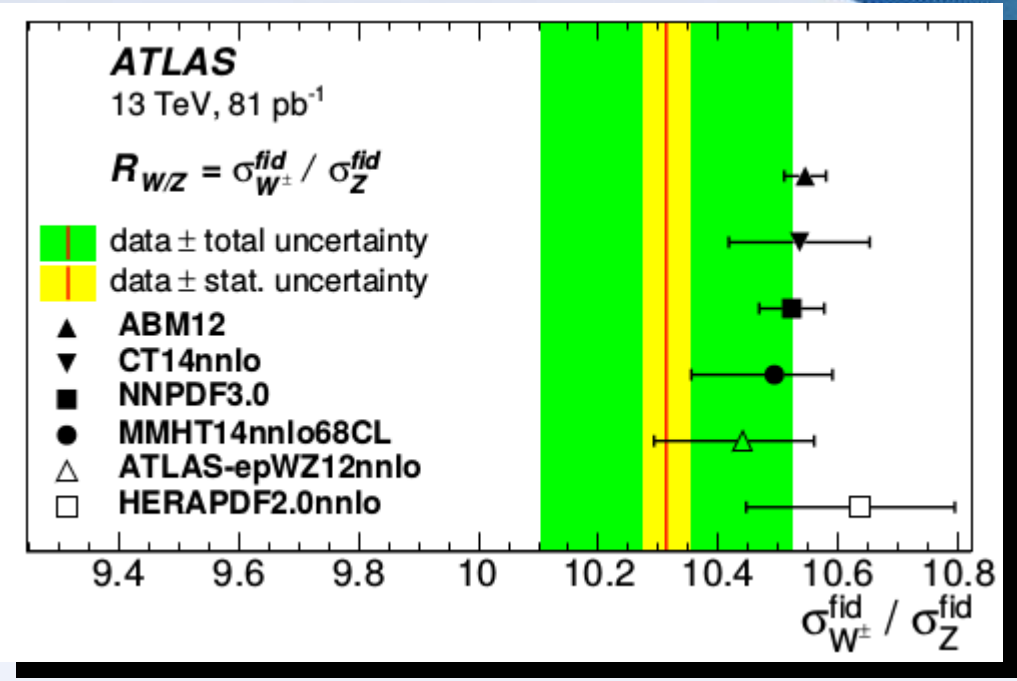

- Cancellation of lumi uncertainty
- Partial cancellation of lepton identification and trigger systematics
- W^+ / W^- sensitive to $u_v - d_v$ valence quark distribution at low x
- $W^\pm / Z$ constrains strange quark distribution

Total cross section √s dependence

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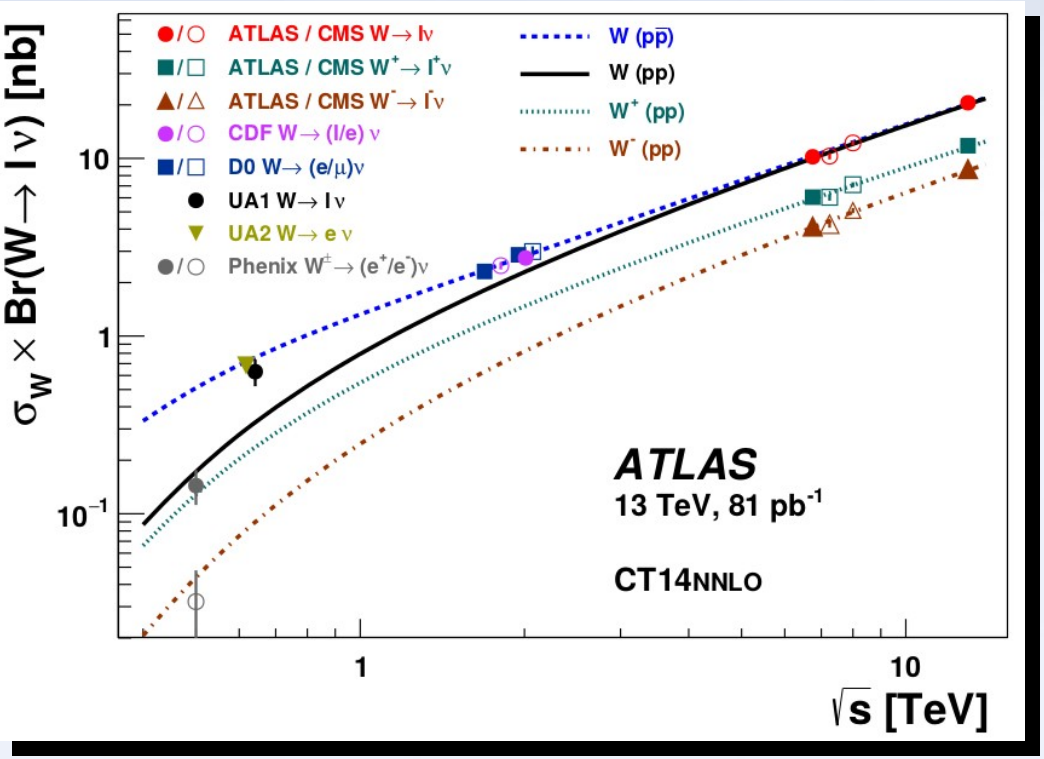

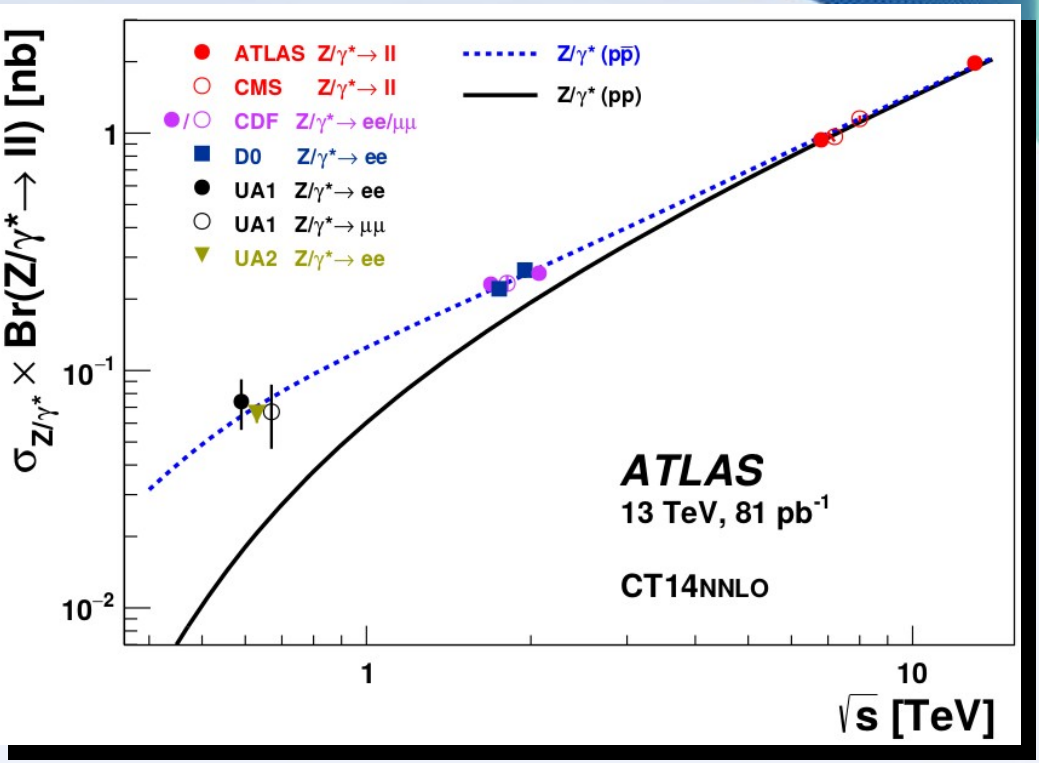

- Measured W and Z cross sections as a function of √s
- Results consistent with NNLO QCD calculations
- Size of $W^{\pm}$ and Z production cross sections at 13 TeV are enhanced by almost a factor of two compared to 7 and 8 TeV at Run-1

Summary

- **The very first measurement of W and Z cross sections at 13 TeV !**
- Measured fiducial and total cross sections are in a good agreement with Standard Model predictions at NNLO
- Results have small systematic uncertainties (not more than *1%* for Z and under *3%* for W), apart from global *5%* luminosity uncertainty
- The measurements of cross-section ratios benefit from the cancellation of some experimental uncertainties, and are powerful tools to constrain PDFs
- Publication available at ***arXiv:1603.09222*** (submitted to Phys. Lett. B)
- More details can be found at: *https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PAPERS/STDM-2015-03/*