Measurement of the W and Z Boson Production Cross-sections at $\sqrt{s} = 13$ TeV with the ATLAS Detector

Rhys Owen[1,2]
University of Birmingham[1], Rutherford Appleton Laboratory[2]
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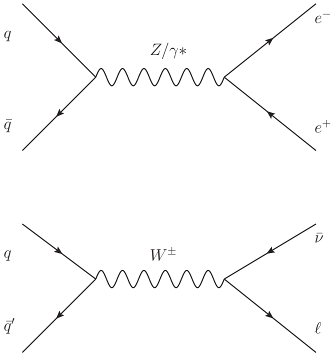
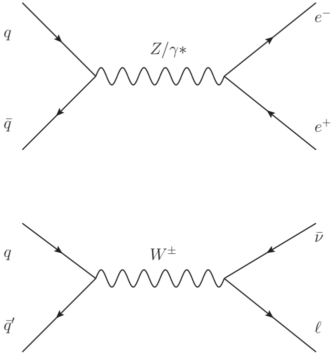
Science & Technology Facilities Council
Rutherford Appleton Laboratory

SM Introduction



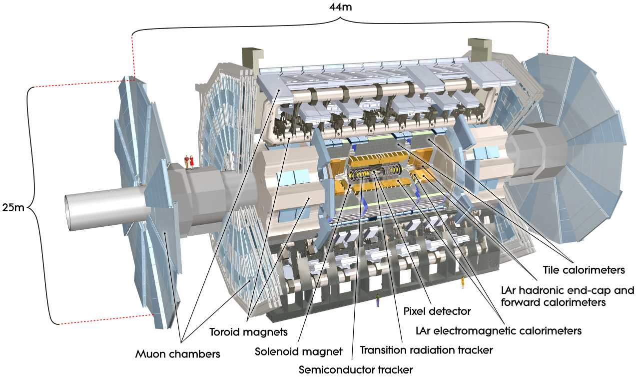
- Measuring the W and Z boson cross-sections at a new centre of mass energy provides a test of our understanding of both QCD and EW processes.
- Theoretical predictions are available at NNLO for QCD and NLO for the EW processes.
- The cross-section are dependent on the parton distributions of the colliding protons so can be used to provide a constraint on these PDFs

Analysis Introduction



- This analysis performed measurements of the leptonic cross-sections using 85 pb^{-1} of data from early 2015
- Providing the first results for these measurements at the centre-of-mass energy of 13 TeV
- The full results are found in ATLAS-CONF-2015-039 [1]

ATLAS Introduction



- The ATLAS experiment is a general purpose detector based at the Large Hadron Collider.
- The LHC recently resumed operations for Run 2 with an unprecedented centre-of-mass energy of 13 TeV.

Theoretical Predictions

PDF	$\sigma^{\mathrm{tot}}_{W+}$ [pb]	$\sigma^{\mathrm{tot}}_{W-}$ [pb]	$\sigma^{\mathrm{tot}}_{W\pm}$ [pb]	$\sigma^{\mathrm{tot}}_{Z}$ [pb]
CT10NNLO	11770^{+270}_{-310}	8640^{+210}_{-240}	20400^{+500}_{-500}	1930^{+40}_{-50}
NNPDF3.0	11360 ± 260	8410 ± 200	19800 ± 500	1860 ± 40
MMHT14NNLO	11610^{+200}_{-170}	8620^{+140}_{-130}	20230^{+330}_{-290}	1909^{+31}_{-27}
ABM12LHC	11760 ± 150	8580 ± 100	20340 ± 250	1914 ± 23

ATLAS-CONF-2015-039 [1]

- Theoretical predictions of the W and Z cross-sections are computed using different pdf sets and including full NNLO QCD calculations and up to NLO electro weak corrections.
- These are calculated using FEWZ3.1 [2, 3, 4, 5]
- The following PDFs are used CT10NNLO, NNPDF3.0 [6], MMHT14NNLO68CL [7], and ABM12LHC [8].
- Also shown here are the PDF variation uncertainties which are the dominant uncertainties in the calculation.

Cross-section Methodology

$$\sigma^{tot}_{W,Z} \times BR(W, Z \to l\nu, ll) = \frac{N - B}{A \cdot C \cdot E \cdot \mathcal{L}} \quad (1)$$

- A counting experiment is performed using the above equation:
  - where N is the number of candidate events
  - B is the number of background events
  - A, C and E are acceptance factors:
    - E: accounts for the difference between MC and data efficiencies
    - C: account for the difference between experimental and fiducial volume
    - A: accounts for the difference between the fiducial volume and the total cross-section phase space
  - $\mathcal{L}$ is the luminosity

Event Selection

- Leptons are selected for this analysis using the following criteria
- Electrons:
  - $p_{\mathrm{T}} > 25$ GeV
  - $|\eta| < 2.47$ excluding regions with bad acceptance
  - Medium likelihood based identification requirement
  - Track and calorimeter based isolation.
- Muons:
  - $p_{\mathrm{T}} > 25$ GeV
  - $|\eta| < 2.4$
  - Cut based identification requirements.
  - Track and calorimeter based isolation.
- After the lepton selection the specific selections for the W and Z

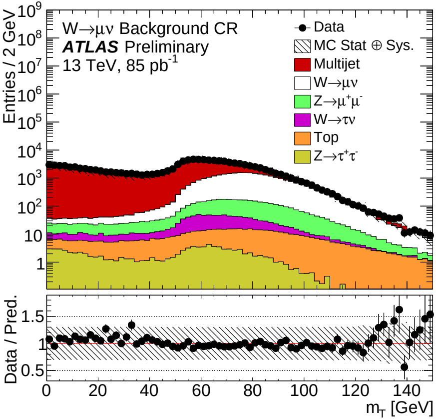
- For W:
  - Exactly 1 selected lepton
  - $E_{\mathrm{T}}^{\mathrm{miss}} > 25$ GeV
  - $m_{\mathrm{T}} > 50$ GeV
  - using the transverse mass of the lepton and missing energy (m_T)

- For Z:
  - Exactly 2 selected leptons
    - ★ Same flavour
    - ★ Opposite charge
  - 66 GeV $< m_{\ell\ell} <$ 116 GeV

Background Determination

- In order to extract the cross-section it is essential to estimate the number of background events which fall into the signal selection.
- The number of background events found in the signal region is determined in a number of different ways.
- The background contributions from electroweak processes are taken from Monte Carlo simulation.
- For the W cross-section in particular a large proportion of the background comes from multijet events which are not well modelled in Monte Carlo.
- Data driven methods were used to derive the number of multijet background events.

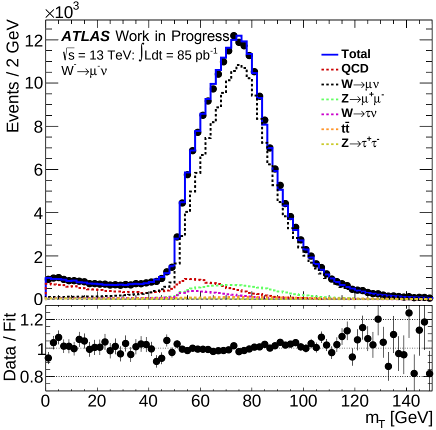
Details of the *W* Multijet Background Fit



ATLAS-CONF-2015-039 [1]

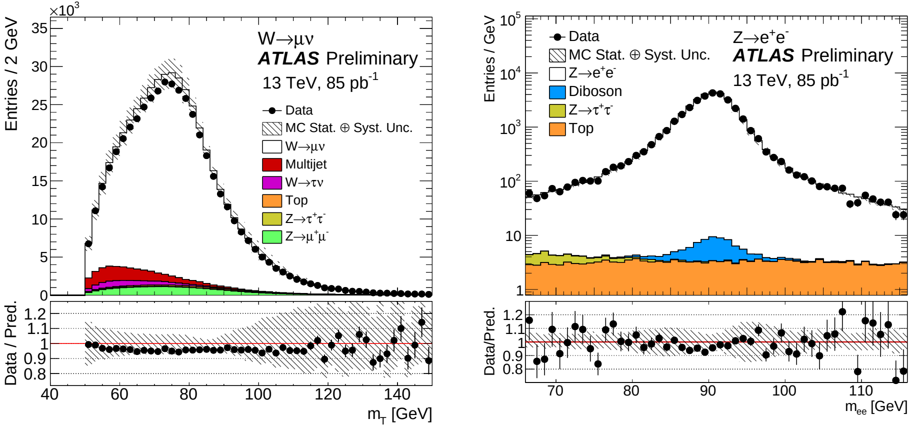
- One such method was a template fit to the m_T distribution.
- This method was used for both the $W \to e\nu$ and $W \to \mu\nu$ channels.
- In order to determine the number of multijet background events a multijet control region is defined with an inverted isolation requirement.
- From this, signal and other background components are removed for create a multijet template.

Details of the *W* Multijet Background Fit



- The resulting multijet template is used in a maximum likelihood fit over the full transverse mass distribution.
- Here the signal requirement on the m_{T} has been removed.
- The transverse mass was chosen as it has the greatest discrimination between signal and background especially at low values of m_{T}

Example Kinematic Distributions



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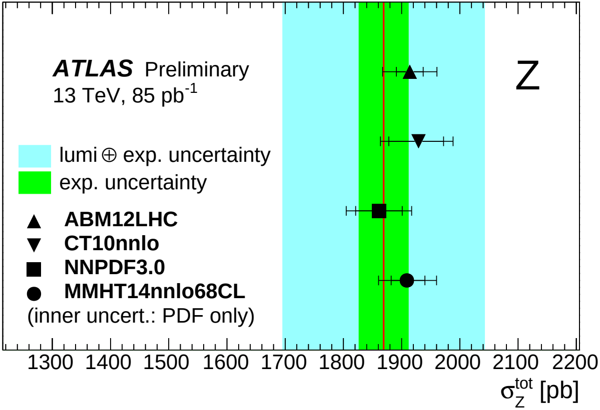
- These plots show the good agreement between the predictions and data for both the W and Z bosons.

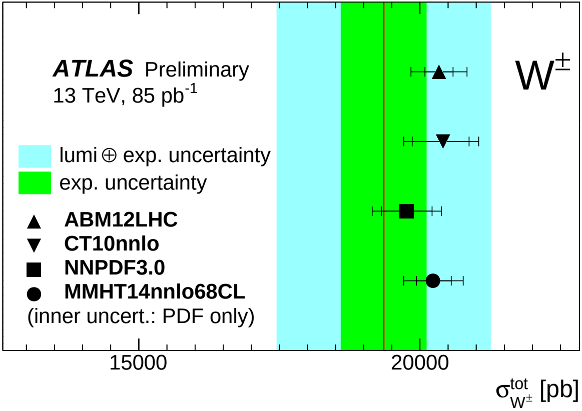
Cross-section Results



ATLAS-CONF-2015-039 [1]

- The large uncertainty is largely caused by the luminosity uncertainty in this early data.

Cross-section Results



ATLAS-CONF-2015-039 [1]

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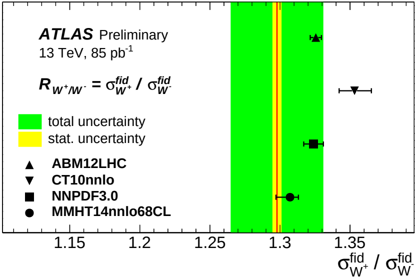
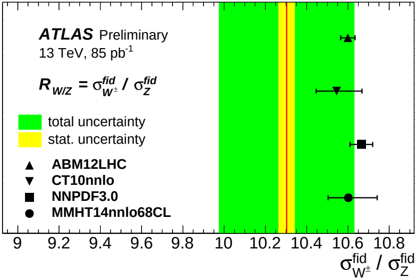
Ratio Results





- Taking ratios of the cross-sections allows for many of the experimental uncertainties to be cancelled out, therefore it is a useful tool for constraining the pdf's.
- Here the ratios are taken directly from the fiducial cross-sections.

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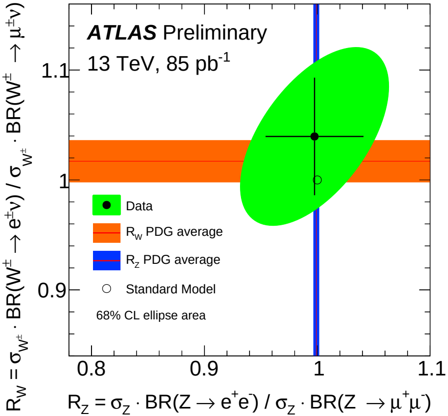
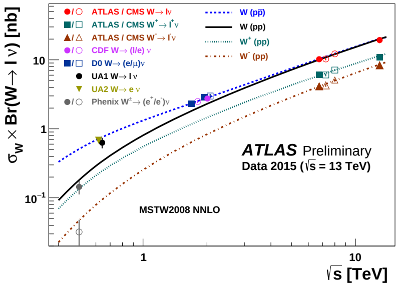
Lepton Universality Results

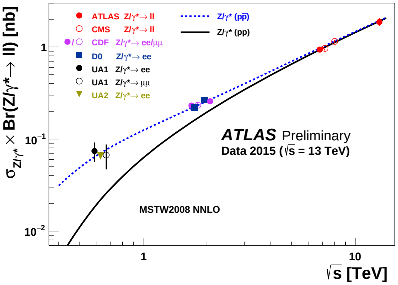


ATLAS-CONF-2015-039 [1]

- A further ratio that can be taken is that of the cross-section to lepton flavour.
- This shows the compatibility of the results for both the electron and muon channels.
- This can then be compared with the PDG world average and the standard model expectation of (1, 1)

Summary





- Results of the W and Z boson cross-section measurements at $\sqrt{s} = 13$ TeV with the ATLAS detector are presented.
- These measurements are in agreement with the standard model but start to provide input on the nature of the particle density functions at this centre-of-mass energy.

ATLAS-CONF-2015-039 [1]

Backup

[1] *Measurement of W and Z Boson Production Cross Sections in pp Collisions at root s = 13 TeV in the ATLAS Detector*. Tech. rep. ATLAS-CONF-2015-039. Geneva: CERN, Aug. 2015. URL: https://cds.cern.ch/record/2045487.

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[3] Ryan Gavin et al. "FEWZ 2.0: A code for hadronic Z production at next-to-next-to-leading order". In: *Comput. Phys. Commun.* 182 (2011), p. 2388. DOI: 10.1016/j.cpc.2011.06.008. arXiv: 1011.3540 [hep-ph].

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