

Single Electroweak Boson Production Measurements with ATLAS



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on behalf of the ATLAS Collaboration

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Cross Section Measurement

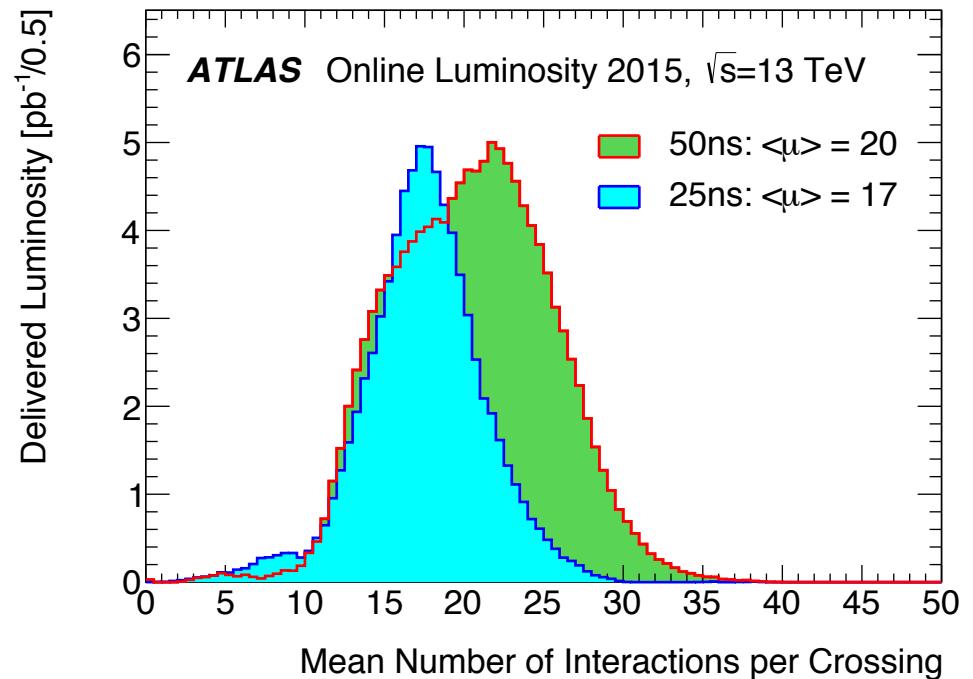
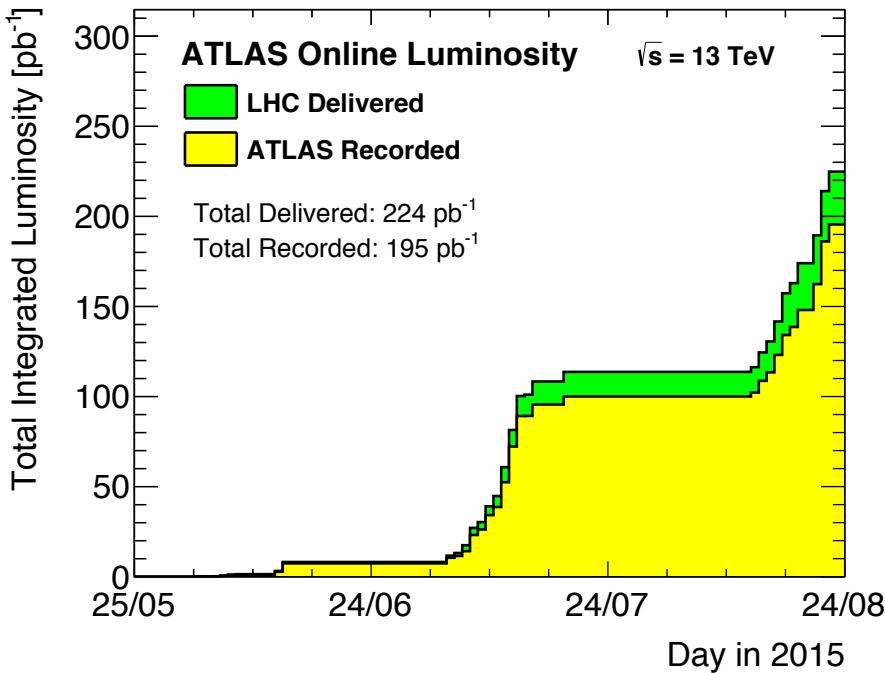
- Electroweak boson production: a benchmark for EW and QCD
 - Large production cross sections in pp collisions; easily identified decays
 - Precise predictions available at NNLO in QCD with NLO EW corrections
 - Measurements at 13 TeV are deep probes into the proton structure
 - Sensitive to parton distribution functions in new (lower-x, high-Q²) regime
- Experimental measurements of fiducial and total cross sections
 - Ratios of cross sections feature reduced experimental uncertainties

$$\sigma_W^{\text{fid}} \cdot BR(W \rightarrow \ell\nu) = \sigma_W^{\text{tot}} \cdot BR(W \rightarrow \ell\nu) \cdot A_W = \frac{N_W^{\text{sig}}}{C_W \cdot \mathcal{L}}$$

- Correction factors to derive cross sections from observed rates
 - C_W : experimental effects, such as reconstruction and trigger efficiencies
 - A_W : geometric and phase space acceptance effects
- Focus on new ATLAS measurements with 13 TeV dataset (85 pb⁻¹)



pp Collisions at 13 TeV in ATLAS



- ATLAS recorded 100 pb^{-1} of 13 TeV data with 50 ns bunch spacing
 - Average data-taking efficiency of 86% in June-July 2015
 - Highest-quality 85 pb^{-1} dataset, with average pileup $\langle\mu\rangle=19$
- Preliminary scan for luminosity calibration taken in June
 - Relative uncertainty on integrated luminosity is 9%

W/Z Baseline Event Selection

Emphasize common phase space across electron/muon channels

Vertex cut: require hard scatter vertex with ≥ 2 tracks

Electron trigger: 24 GeV isolated electron trigger OR 60 GeV electron trigger

Muon trigger: 20 GeV isolated muon trigger OR 50 GeV muon trigger

Good electron:

Electron passing likelihood definition

Isolation: track- and calo-based for 90% eff.

$p_T > 25$ GeV, $|\eta| < 2.47$ excluding (1.37-1.52)

No d_0 or z_0 cuts applied to electrons nor muons

Good muon:

Reconstructed using ‘medium’ quality criteria

Isolation: track- and calo-based (90% eff.)

$p_T > 25$ GeV, $|\eta| < 2.4$

W analysis selection:

Exactly 1 good electron or muon

- (veto events with 2nd lepton)

Missing $E_T > 25$ GeV (using calibrated objects)

W transverse mass > 50 GeV

Z analysis selection:

Exactly 2 good electron or muons

- Opposite charged leptons in pair

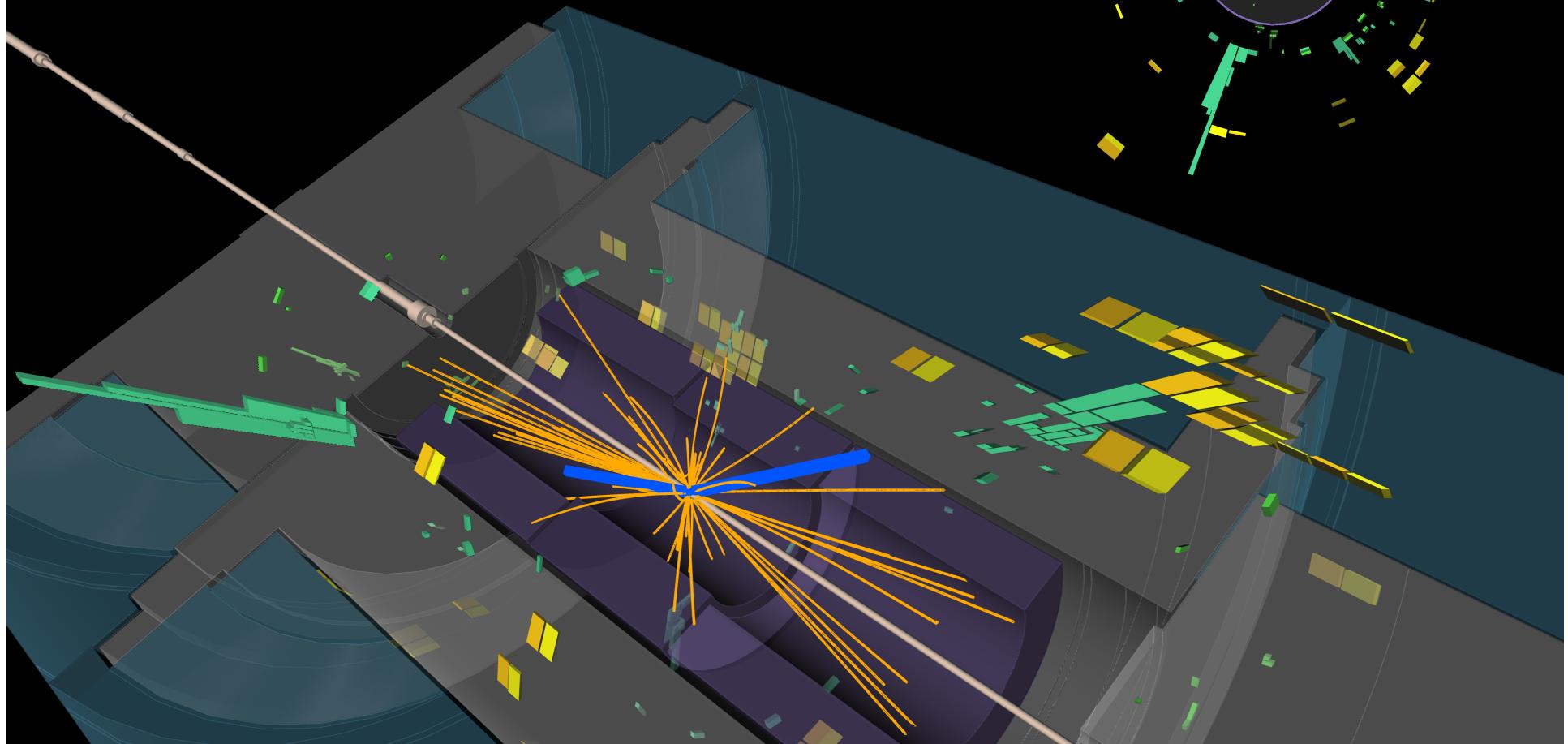
Z mass in range [66 – 116 GeV]

Candidate Z Event in Electron Channel



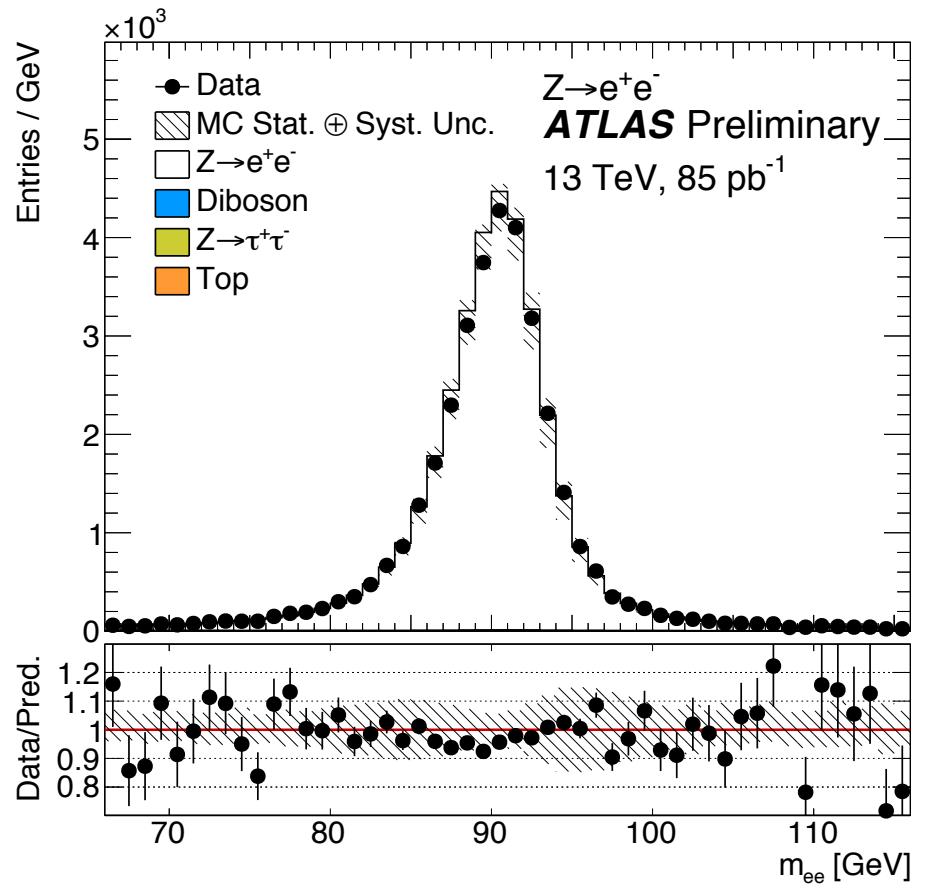
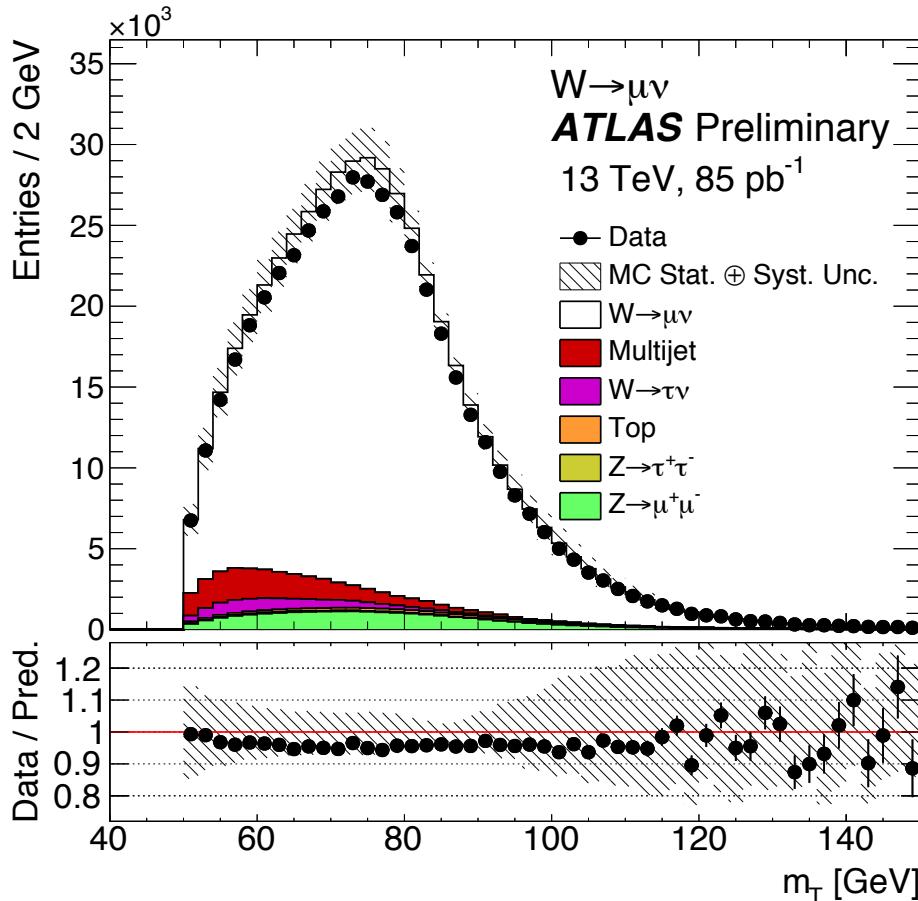
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Event: 173263110
2015-06-14 13:13:03 CEST

proton-proton collisions at 13 TeV



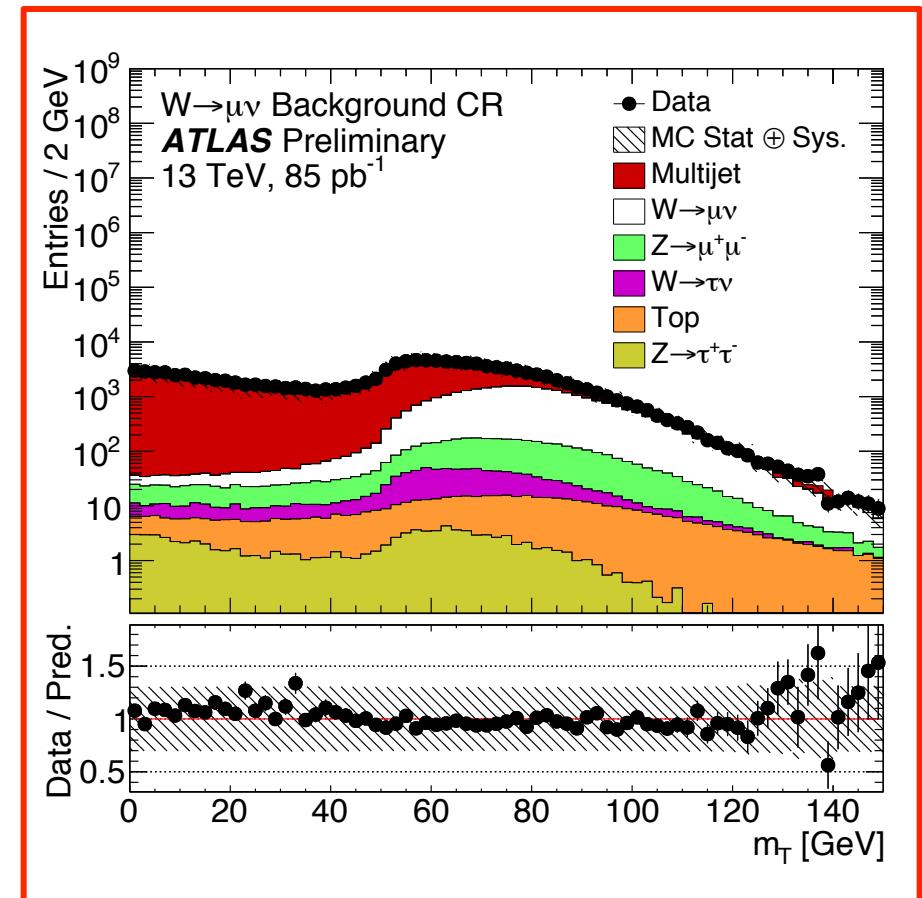
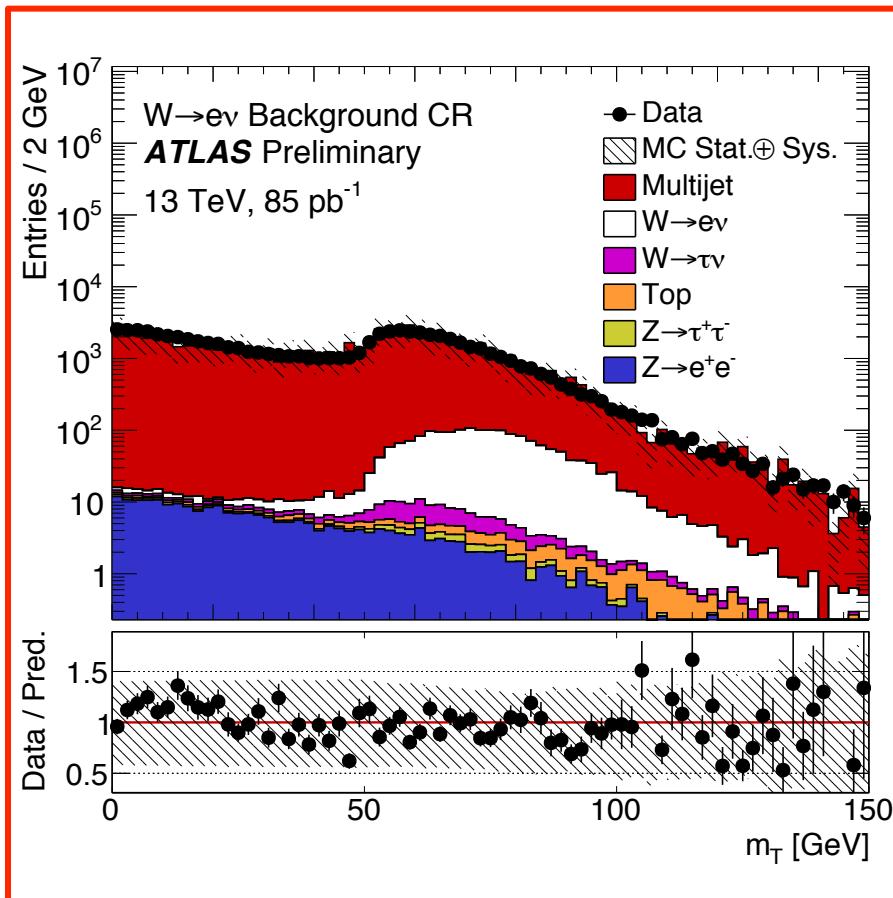
Kinematic Distributions After Selection

- W and Z event selections applied to 85 pb^{-1} 13 TeV dataset
- Signal distributions are Powheg + Pythia8 (AZNLO CTEQL1 tune)
- Systematic uncertainty bands do not include luminosity uncertainty



Estimate of Multijet Background

- Data-driven fits with multijet templates derived from data
 - Separate m_T fits for W^+ , W^- in electron and muon channels
 - Dominant uncertainty is the template shape used in the fit



Complete Background Estimates in 85 pb^{-1}

W event selection: MC predictions and data-driven estimates

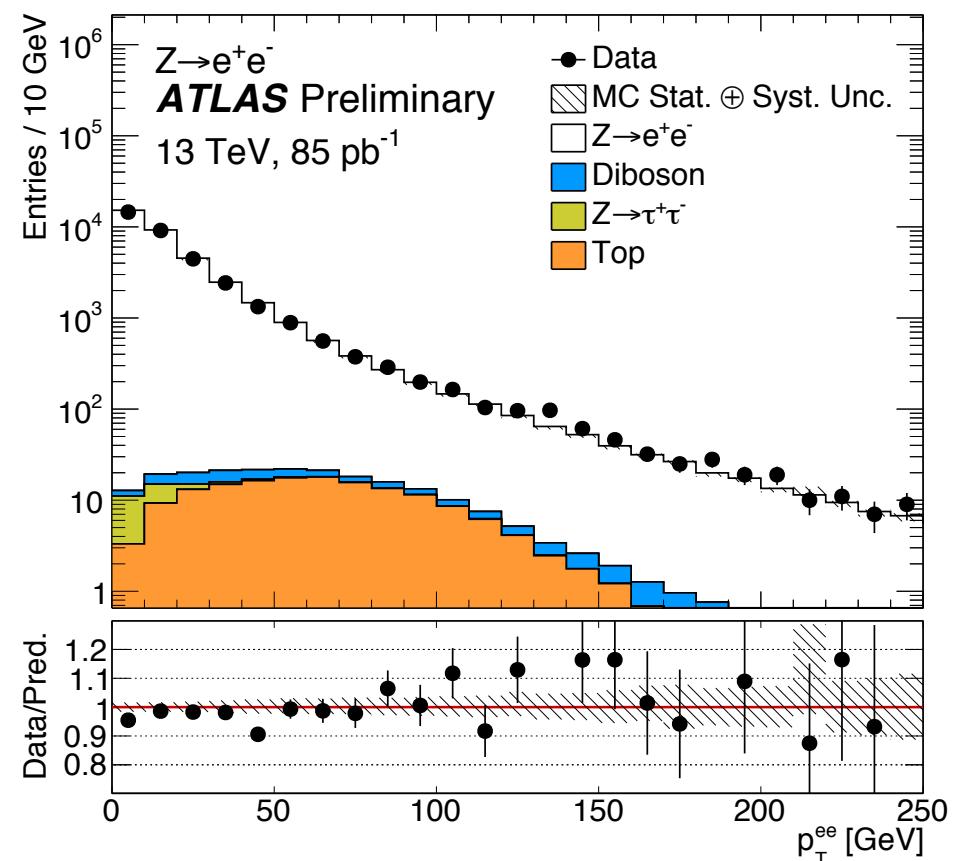
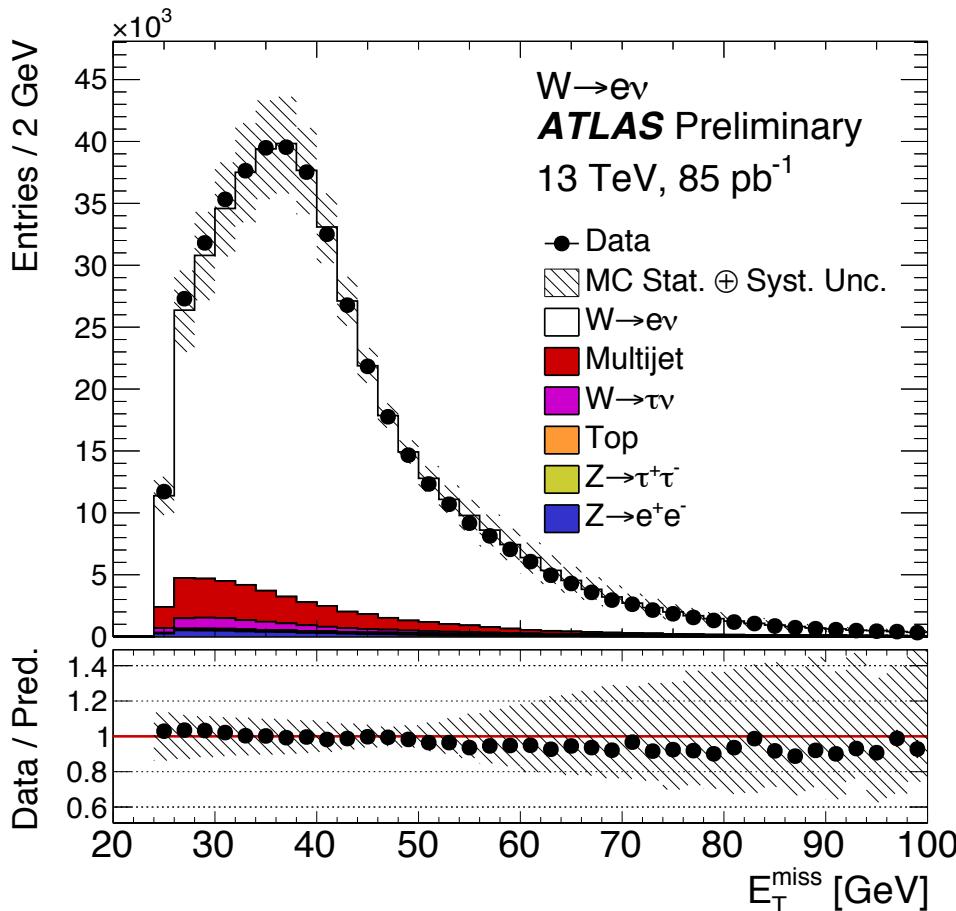
ℓ^\pm	Observed candidates	Background (EW+top)	Background (Multijet)	Background-subtracted events N_W^{sig}
e^+	256923	10100 ± 600	$15200 \pm 300 \pm 6700$	$231600 \pm 500 \pm 6700$
e^-	206140	8900 ± 500	$15600 \pm 300 \pm 6900$	$181600 \pm 500 \pm 6900$
μ^+	272841	20420 ± 920	$12200 \pm 200 \pm 3500$	$240300 \pm 500 \pm 3600$
μ^-	214249	18210 ± 830	$11500 \pm 100 \pm 3100$	$184500 \pm 500 \pm 3200$

Z event selection: MC predictions and data-driven estimates

ℓ^\pm	Observed candidates	Background (EW+top)	Background (Multijet)	Background-subtracted events N_Z^{sig}
e^\pm	34955	$229 \pm 1 \pm 24$	< 0.1%	$34730 \pm 190 \pm 20$
μ^\pm	44899	$296 \pm 2 \pm 31$	< 0.1%	$44600 \pm 210 \pm 30$

Kinematic Distributions of W, Z Events

- Observed distributions for W and Z bosons match simulation
- Signal distributions are Powheg + Pythia8 (AZNLO CTEQL1 tune)
 - Normalization of W, Z signals from FEWZ w/ CT10nnlo PDFs



Calculated Cross Sections

- A_W, C_W correction factors as introduced in formula

$$\sigma^{\text{fid}} \cdot BR = \sigma^{\text{tot}} \cdot BR \cdot A_W = \frac{N^{\text{sig}}}{C_W \cdot \mathcal{L}}$$

- Systematic uncertainties
 - Multijet backgrounds
 - Lepton reconstruction (esp. e)
 - Lepton trigger efficiency (esp. μ)
 - Missing energy calibration
 - Pileup effects
- 9% luminosity uncertainty
- Consistent cross section results for electrons & muons

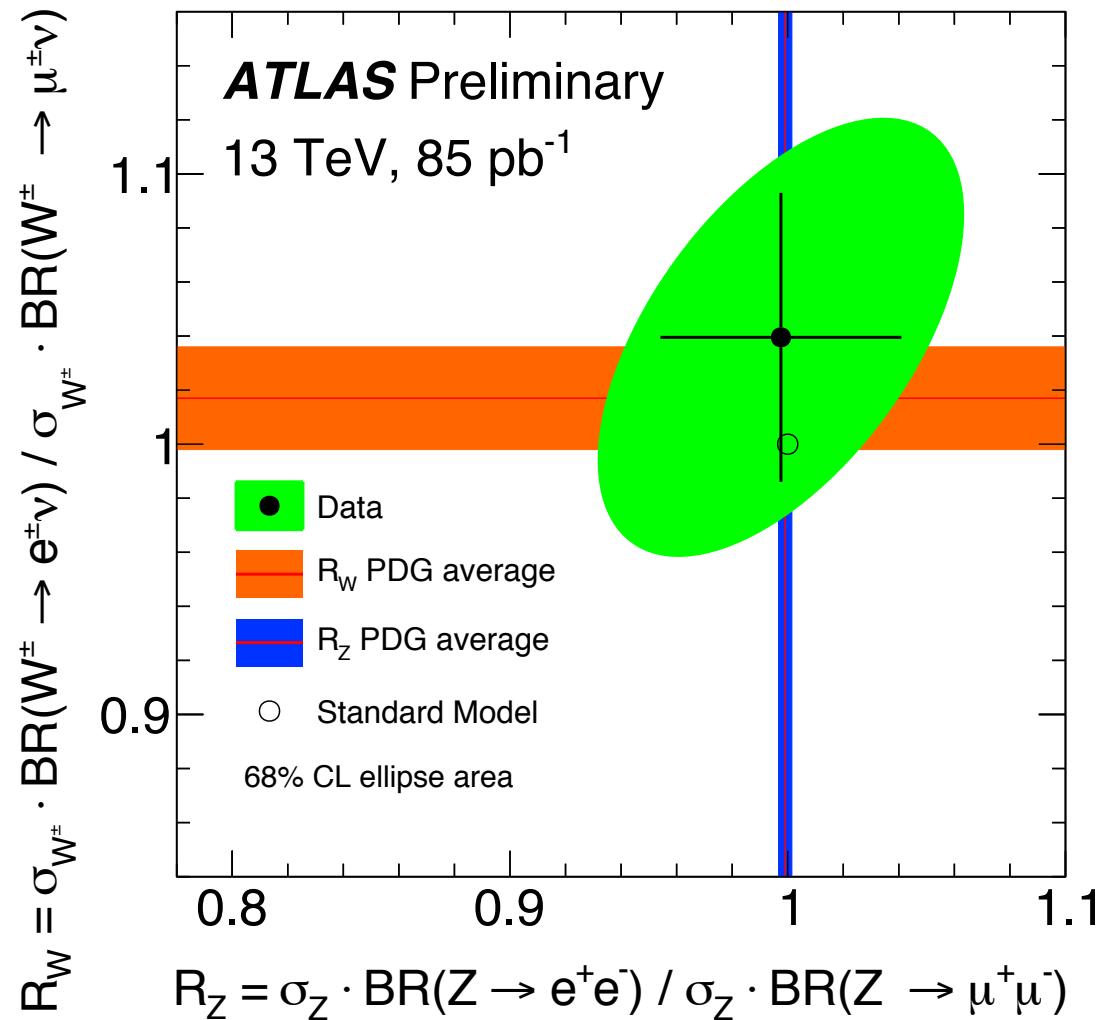
	W^+	W^-
Electron channel		
	value \pm stat \pm syst \pm lumi	value \pm stat \pm syst \pm lumi
Background-subtracted signal	$231600 \pm 500 \pm 6700 \pm 900$	$181600 \pm 500 \pm 6900 \pm 800$
Correction C_W	0.610 ± 0.028	0.623 ± 0.027
Fiducial cross section (pb)	$4490 \pm 10 \pm 240 \pm 420$	$3442 \pm 9 \pm 200 \pm 324$
Acceptance A_W	0.396 ± 0.010	0.399 ± 0.010
Total cross section (pb)	$11330 \pm 30^{+680}_{-670} \pm 1070$	$8630 \pm 20^{+540}_{-550} \pm 810$

	Muon channel	
	value \pm stat \pm syst \pm lumi	value \pm stat \pm syst \pm lumi
Background-subtracted signal	$240300 \pm 500 \pm 3600 \pm 1780$	$184500 \pm 500 \pm 3200 \pm 1587$
Correction C_W	$0.660^{+0.019}_{-0.020}$	0.656 ± 0.020
Fiducial cross section (pb)	$4304 \pm 9^{+140}_{-145} \pm 419$	$3325 \pm 8^{+113}_{-115} \pm 328$
Acceptance A_W	0.396 ± 0.010	0.399 ± 0.010
Total cross section (pb)	$10870 \pm 20^{+450}_{-460} \pm 1060$	$8330 \pm 20 \pm 360 \pm 820$

	Z	
	Electron channel	Muon channel
	value \pm stat \pm syst \pm lumi	value \pm stat \pm syst \pm lumi
Background-subtracted signal	$34730 \pm 190 \pm 20$	$44600 \pm 210 \pm 30$
Correction C_Z	0.552 ± 0.023	$0.708^{+0.012}_{-0.013}$
Fiducial cross section [pb]	$742 \pm 4 \pm 31 \pm 67$	$744 \pm 4 \pm 13 \pm 67$
Acceptance A_Z	0.399 ± 0.006	0.399 ± 0.006
Total cross section [pb]	$1861 \pm 10 \pm 82 \pm 167$	$1865 \pm 9 \pm 43 \pm 168$

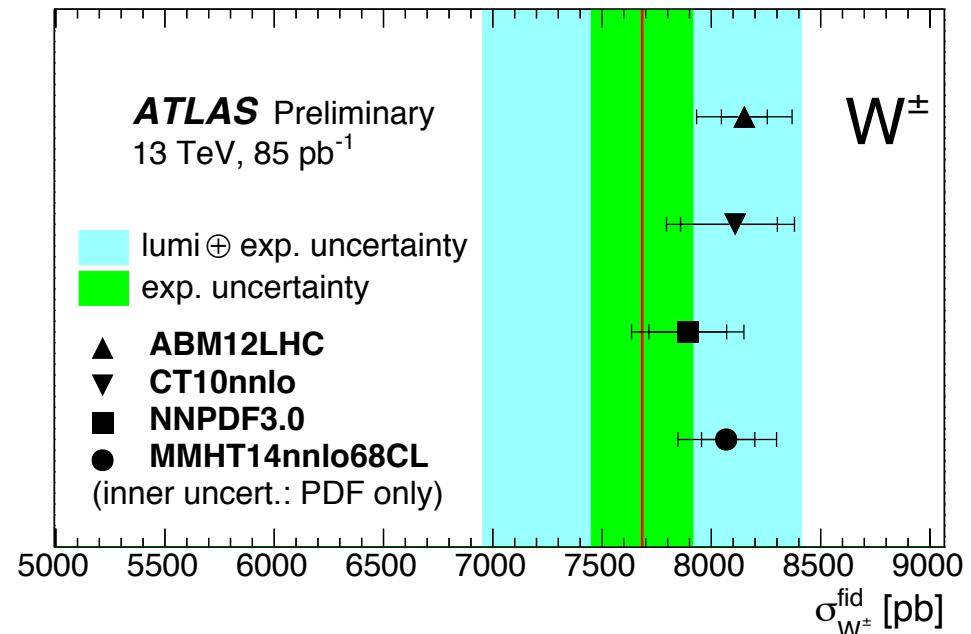
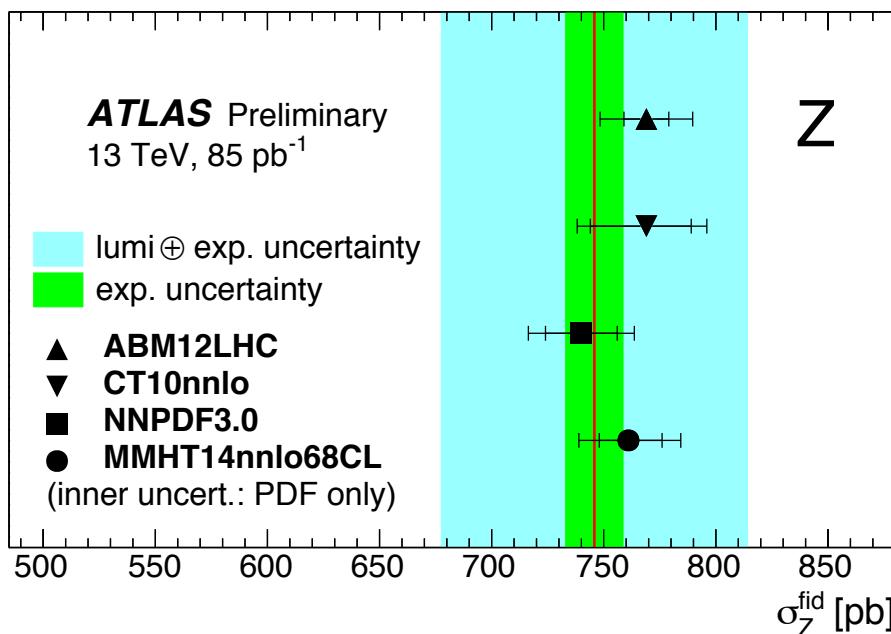
Lepton Universality in W, Z Production

- Ratios of fiducial cross sections in electron and muon channels
- Excellent agreement with PDG and SM values
- Indication of consistent understanding of detector and trigger performance
- Measurements can be combined for improved precision



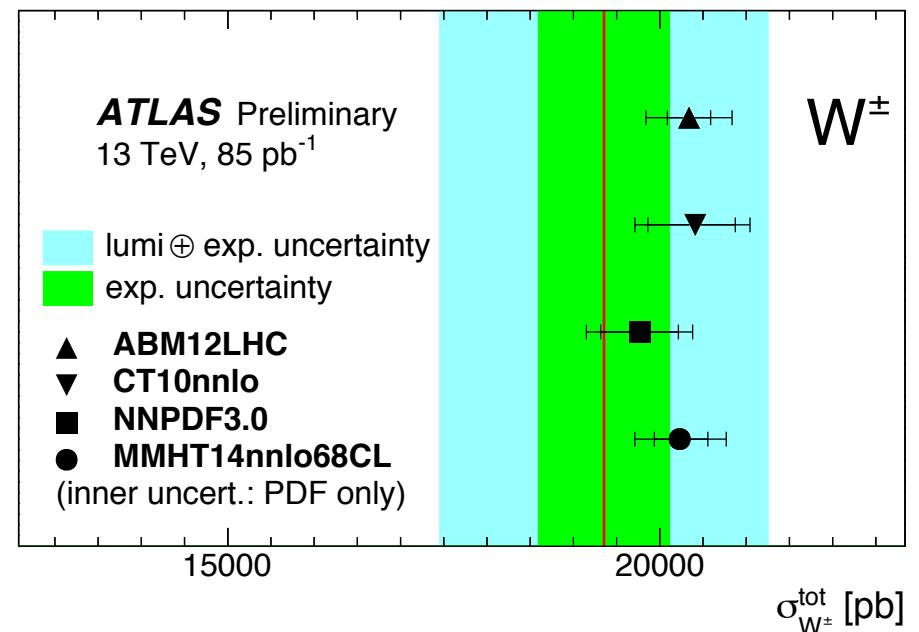
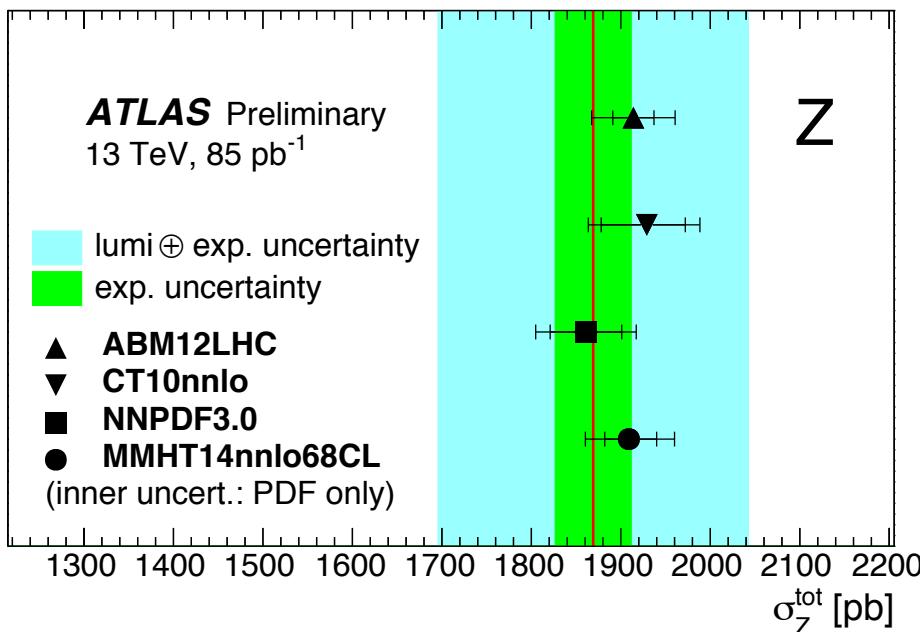
Fiducial Cross Section Measurements

- Combination using HERAverager: first e/μ , then W^+, W^-, W, Z
- Present purely experimental measurement in defined phase space
 - W phase space: lepton $p_T > 25$ GeV, $|\eta| < 2.5$, missing $E_T > 25$ GeV, $m_T > 50$ GeV
 - Z phase space: lepton $p_T > 25$ GeV, $|\eta| < 2.5$, $66 < m_{\parallel} < 116$ GeV
- Measurements dominated by luminosity uncertainty
 - Multijet background uncertainty included in green band (for W only)



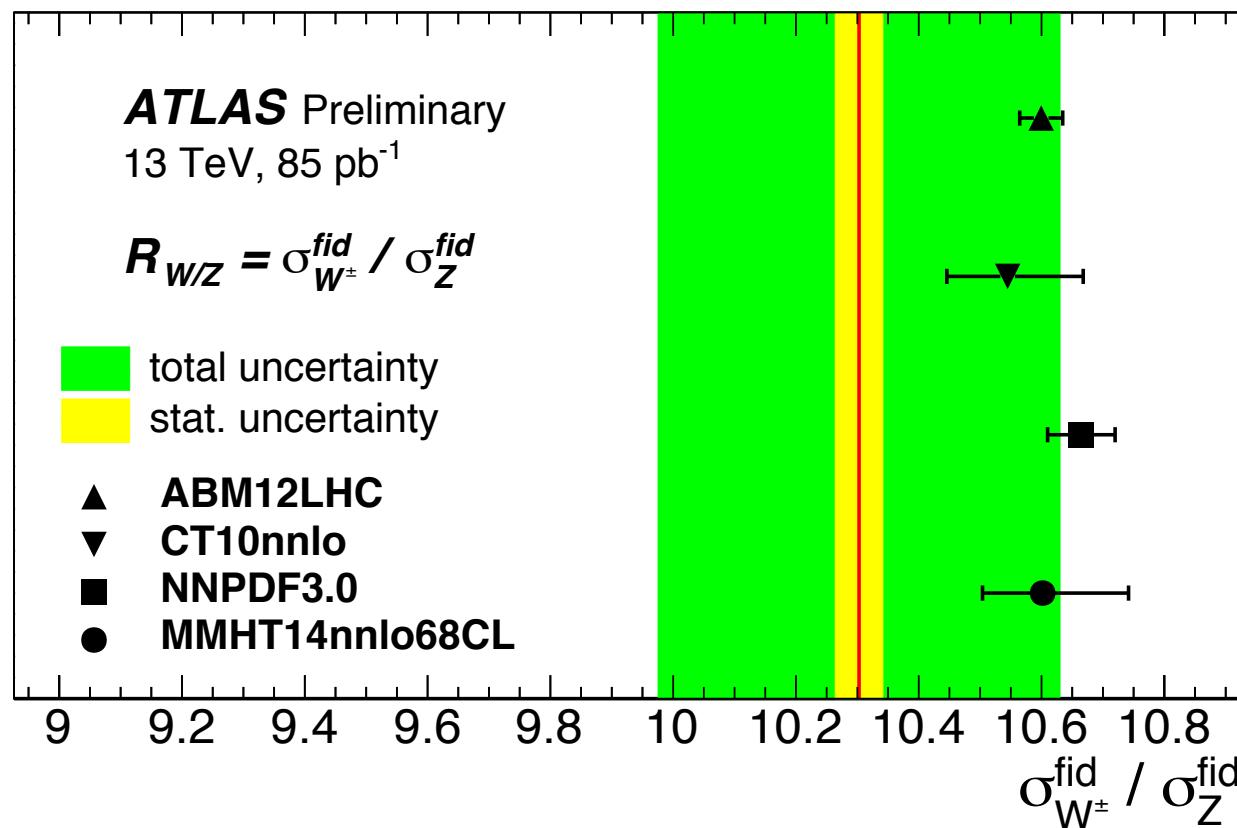
Total Inclusive W, Z Cross Sections

- Extrapolation to full phase space using the A_W and A_Z acceptance factors, calculated with FEWZ
- Experimental precision w/o luminosity already comparable to PDF uncertainties (represented by inner error bar in predictions)
 - Similar to precision of theoretical calculations, limited by PDF uncertainties
- Excellent agreement with calculations @ NLO (EWK) + NNLO (QCD)



W/Z Cross Section Ratio

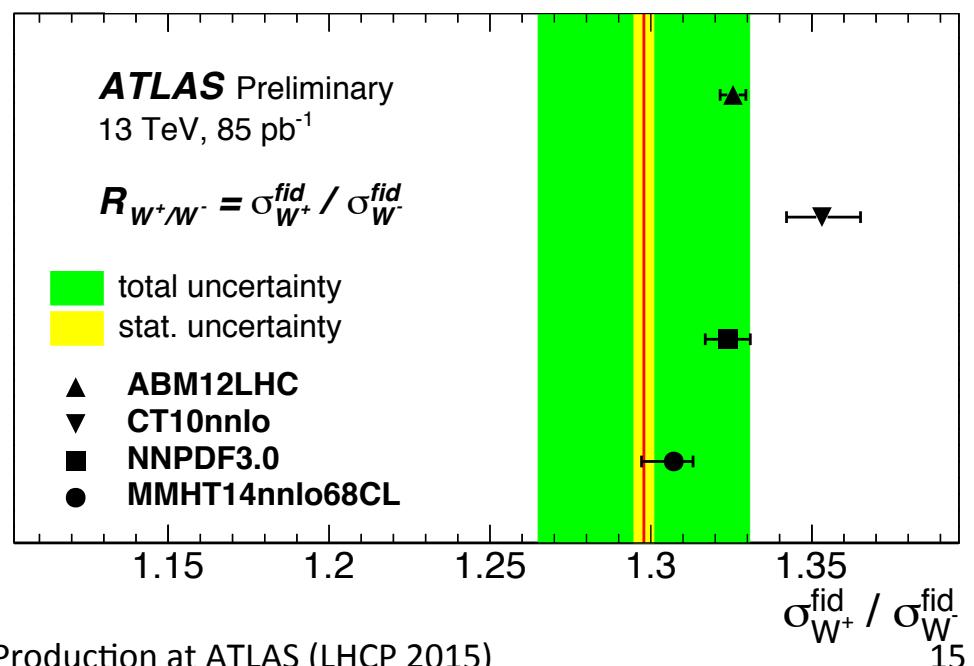
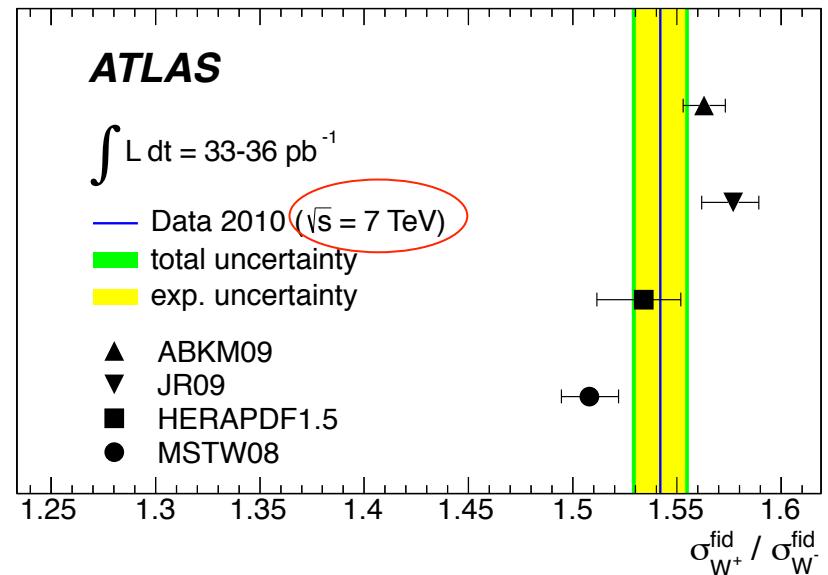
- Significant uncertainty cancellation in ratio measurement
 - Luminosity, parts of lepton identification and trigger efficiencies
- Predictions shown with PDF uncertainties only (no scale uncerts.)
 - Measurement constrains strange-quark distribution at low x



W^+/W^- Cross Section Ratio

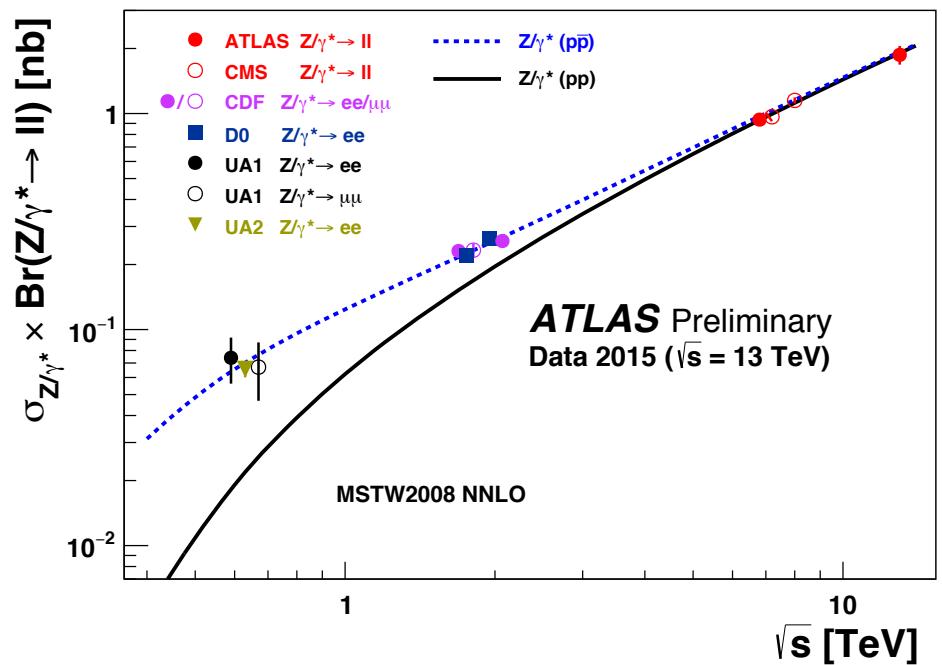
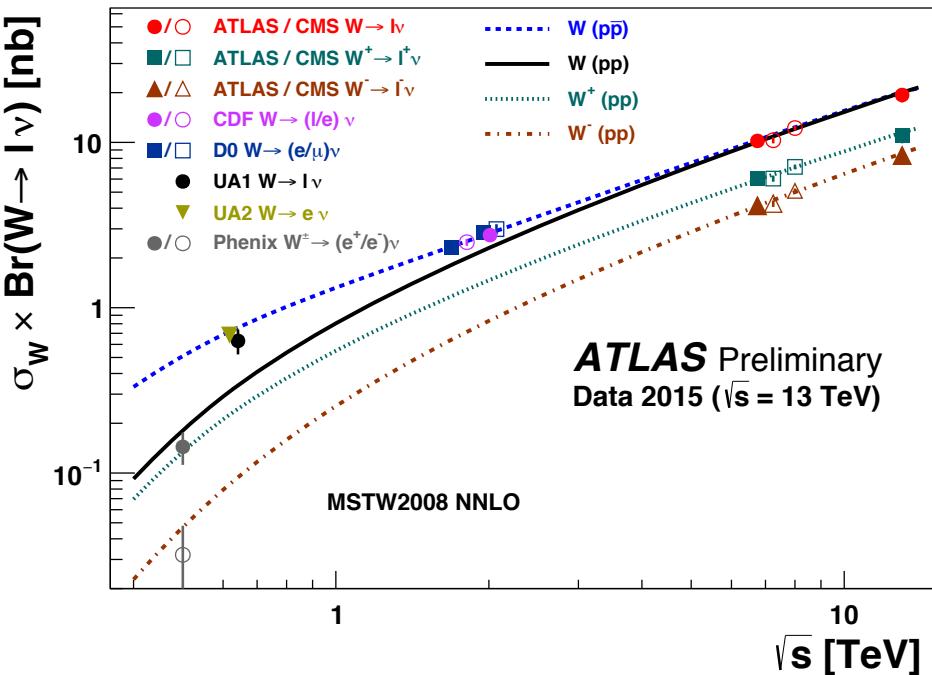
Asymmetry sensitive to u and d valence quark distributions at low-x

- Compared to 7 TeV result, asymmetry reduced at 13 TeV, due to smaller valence quark contribution at very low x
- Good agreement with PDF sets that include Run 1 data
- Start to constrain PDF fits once precision reaches 2%



Total Cross Section \sqrt{s} Dependence

- Two new measurements on electroweak boson cross section plots
- Total cross sections increase by a factor of 1.7 compared to 8 TeV



- Results consistent with inclusive NNLO calculations

Summary

- New ATLAS 13 TeV W and Z cross section measurements
 - Results from 85 pb^{-1} dataset validate ATLAS performance in early data-taking
 - Excellent agreement with Standard Model predictions
- Current measurements limited by luminosity uncertainty, but experimental uncertainties already small enough to constrain PDFs
- Ratios of cross sections show reduced systematic uncertainty and improved precision for comparison with predictions

Channel	value \pm stat \pm syst \pm lumi [pb]
W^-	$8380 \pm 20 \pm 350 \pm 750$
W^+	$10960 \pm 20 \pm 440 \pm 990$
W^\pm	$19350 \pm 20 \pm 760 \pm 1740$
Z	$1869 \pm 7 \pm 42 \pm 168$

Results and more details available in ATLAS-CONF-2015-039:
<https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/CONFNOTES/ATLAS-CONF-2015-039/>

