

A measurement of the inclusive W^\pm and Z/γ^* cross sections in the e and μ decay channels in pp collisions at $\sqrt{s} = 7 \text{ TeV}$ with the ATLAS detector

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on behalf of the ATLAS Collaboration

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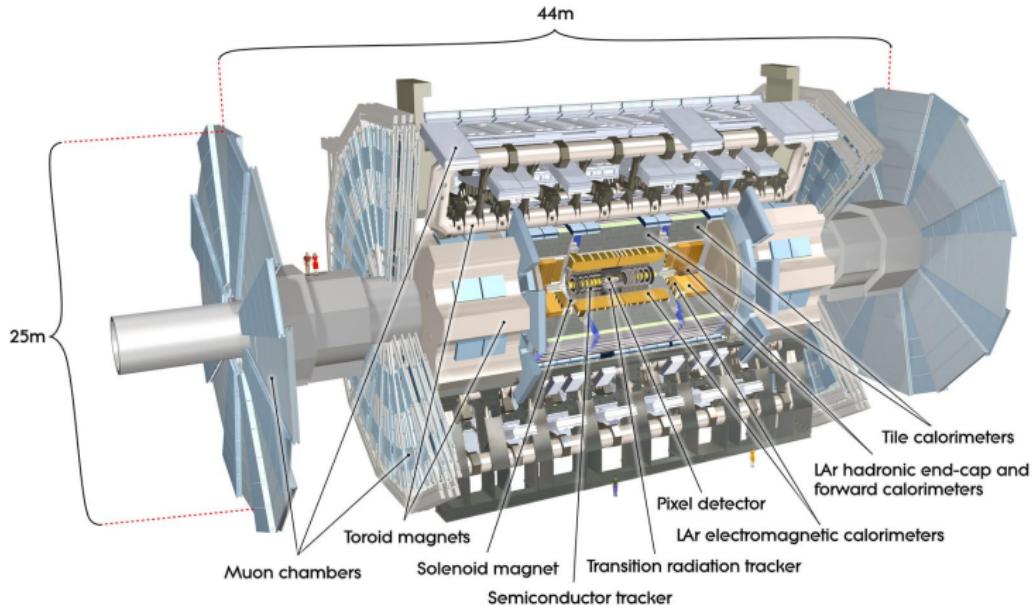
- Introduction
- Inclusive W and Z production in electron and muon channels
- Total and Fiducial¹ cross sections
- Cross-section ratios
- Rapidity Differential measurements
- W Charge Asymmetry
- Summary & Outlook

Results are based on the 2010 dataset – $\mathcal{L} \sim 35 \text{ pb}^{-1}$ ($\delta\mathcal{L} = 3.4\%$)

¹The “fiducial” cross section is defined within detector acceptance

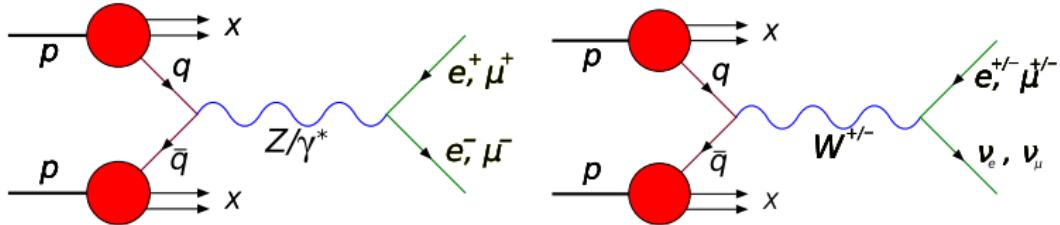
The ATLAS Detector

- EM calorimeter and tracking up to $|\eta| < 2.5 \Rightarrow$ electrons
- Muon spectrometer up to $|\eta| < 2.7$, trigger coverage to $|\eta| < 2.4 \Rightarrow$ muons
- Calorimetric coverage up to $|\eta| < 4.9 \Rightarrow$ jets, E_T^{miss} , forward electrons



W and Z production at LHC

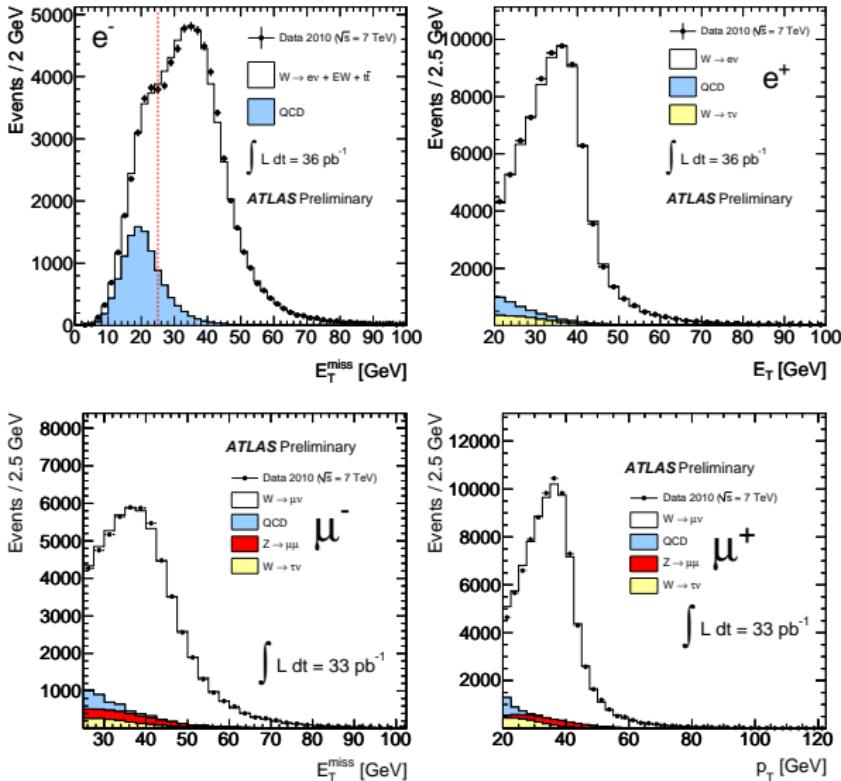
- Drell-Yan production of W and Z bosons calculable to high orders in pQCD
- An interesting testing ground of PDFs and their evolution to high Q^2 scale



- Inclusive W and Z production with $Q^2 \sim M_{W/Z}^2$ and $10^{-3} < \bar{x} < 10^{-1}$
- Need most accurate theory predictions to match experimental precision, e.g. σ_{tot} calculated with FEWZ using MSTW08 (NNLO):
$$\sigma(W^+ \rightarrow \ell^+ \nu) = 6.16 \text{ nb}, \quad \sigma(W^- \rightarrow \ell^- \bar{\nu}) = 4.30 \text{ nb}, \quad \sigma(Z \rightarrow \ell\ell) = 0.96 \text{ nb}$$
- Error estimate from PDF at 90 % CL, α_s and scale uncertainties is $\sim 5\%$; only considering PDF at 68 % CL gives $\sim 2\%$

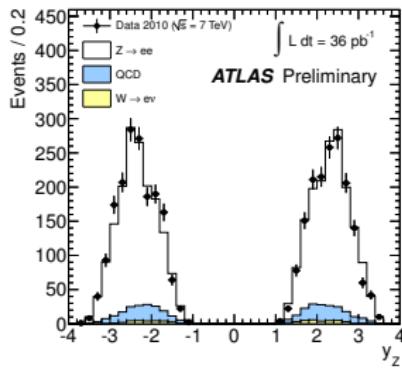
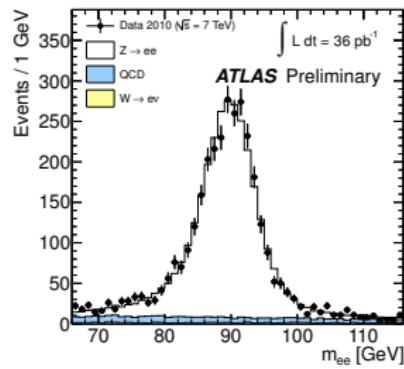
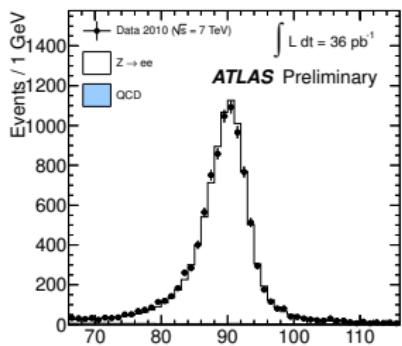
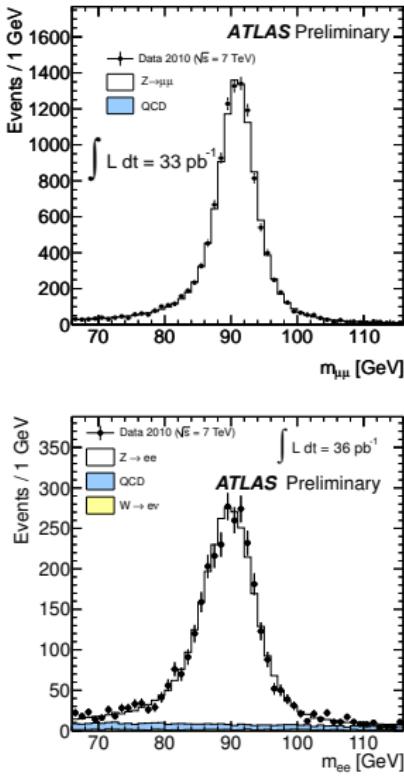
$W \rightarrow \ell\nu$ selection

- Single lepton triggers with high efficiency
- $p_{T,\ell} > 20 \text{ GeV}$
 $|\eta_e| < 2.47, |\eta_\mu| < 2.4$
(elec. excl. calo crack)
isolated leptons
 $E_T^{\text{miss}} > 25 \text{ GeV}$
 $m_T > 40 \text{ GeV}$
- QCD from data fitting E_T^{miss} (e) and studying control regions in $iso - E_T^{\text{miss}}$ plane (μ)
- 131 – 140 K candidates with 7–9% background



$Z \rightarrow ll$ selection

- Single lepton triggers with high efficiency
- $p_{T,l} > 20\text{ GeV}$
 $|\eta_e| < 2.47, |\eta_\mu| < 2.4$
(elec. excl. calo crack)
isolated leptons
opposite charge
 $66 < m_{ll} < 116\text{ GeV}$
- QCD from data fitting m_{ll} lineshape and studying control regions in (iso, m_{ll})
- $\sim 10 - 12\text{ }K$ candidates with 1–2% background



Electron and muon systematics uncertainties

- $\delta\sigma_{W \rightarrow e\nu}$ of 1.8 – 2.1 %, dominated by electron reconstruction, identification and E_T^{miss}
- $\delta\sigma_{Z \rightarrow ee}$ of 2.7 %, dominated by el. reconstruction and identification
- $\delta\sigma_{W \rightarrow \mu\nu}$ of 1.6 – 1.7 %, dominated by muon efficiencies, QCD background and E_T^{miss}
- $\delta\sigma_{Z \rightarrow \mu\mu}$ of 0.9 %, dominated by muon efficiencies

Electron channels (%)	W^\pm	W^+	W^-	Z	Muon channels (%)	W^\pm	W^+	W^-	Z
Trigger	0.4	0.4	0.4	<0.1	Trigger	0.5	0.5	0.5	0.1
Reconstruction	0.8	0.8	0.8	1.6	Reconstruction	0.4	0.3	0.3	0.6
Identification	0.9	0.8	1.1	1.8	Isolation	0.2	0.1	0.2	0.3
Isolation	0.3	0.3	0.3	—	p_T Resolution	0.04	0.03	0.05	0.02
Energy scale and resolution	0.5	0.5	0.5	0.2	p_T Scale	0.4	0.6	0.6	0.2
Defective LAr channels	0.4	0.4	0.4	0.8	E_T^{miss}	0.5	0.4	0.6	-
Charge misidentification	<0.1	0.1	0.1	0.6	Pile-up	0.3	0.3	0.3	0.3
E_T^{miss}	0.8	0.7	1.0	—	Vertex position	0.1	0.1	0.1	0.1
Pile-up	0.3	0.3	0.3	0.3	QCD Background	0.6	0.5	0.8	0.3
Vertex position	0.1	0.1	0.1	0.1	EWK+ $t\bar{t}$ Background	0.4	0.3	0.4	0.02
QCD Background	0.4	0.4	0.4	0.7	$C_{W/Z}$ Theor. uncertainty	0.8	0.8	0.7	0.3
EWK+ $t\bar{t}$ Background	0.2	0.2	0.2	<0.1	Total Exp. uncertainty	1.6	1.7	1.7	0.9
$C_{W/Z}$ Theor. uncertainty	0.6	0.6	0.6	0.3	$A_{W/Z}$ Theor. uncertainty	1.4	1.6	2.0	2.0
Total Exp. uncertainty	1.8	1.8	2.0	2.7	Total excluding Luminosity	2.1	2.3	2.6	2.2
$A_{W/Z}$ Theor. uncertainty	1.4	1.6	1.9	1.9					
Total excluding Luminosity	2.3	2.4	2.8	3.3					

$W \rightarrow \ell\nu$ and $Z \rightarrow \ell\ell$ integrated cross sections

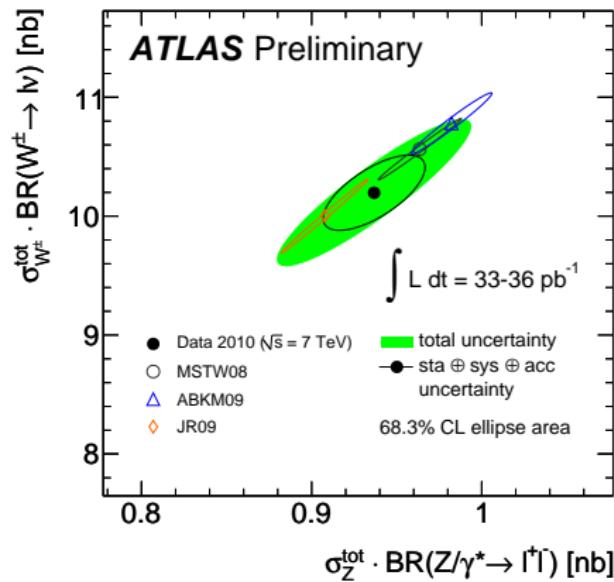
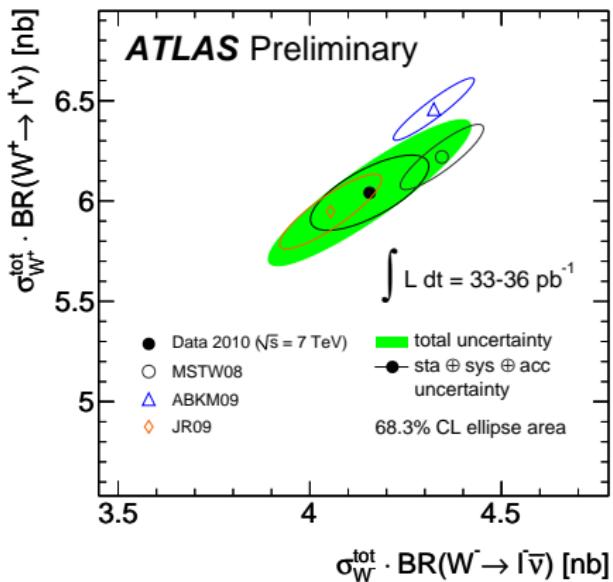
- **Fiducial cross section** corrected for efficiency factor ($C_{W/Z}$), adjusted to data/MC differences

$$\sigma_{fid} = \frac{N - B}{C_{W/Z} \cdot L_{int}}, \quad \sigma_{tot} = \frac{\sigma_{fid}}{A_{W/Z}}$$
- **Total cross section** corrected for acceptance ($A_{W/Z} \sim 0.45 - 0.50$) based on MC@NLO and CTEQ 6.6 NLO PDF set
- Theoretical uncert. on $A_{W/Z}$ from error-set, PDF sets, MC@NLO-PowHEG and PYTHIA-HERWIG comparisons ($\delta A_{W/Z} \sim 1.5\%$, $\delta A_Z \sim 2.0\%$)

$\sigma_W^{fid} \cdot BR(W \rightarrow \ell\nu)$	$5.123 \pm 0.011(\text{sta}) \pm 0.064(\text{sys}) \pm 0.174(\text{lum}) \pm 0.005(\text{acc})$ [nb]
$\sigma_{W^+}^{fid} \cdot BR(W \rightarrow \ell\nu)$	$3.108 \pm 0.008(\text{sta}) \pm 0.038(\text{sys}) \pm 0.106(\text{lum}) \pm 0.004(\text{acc})$ [nb]
$\sigma_{W^-}^{fid} \cdot BR(W \rightarrow \ell\nu)$	$2.016 \pm 0.007(\text{sta}) \pm 0.028(\text{sys}) \pm 0.069(\text{lum}) \pm 0.002(\text{acc})$ [nb]
$\sigma_{Z/\gamma^*}^{fid} \cdot BR(Z/\gamma^* \rightarrow ll)$	$0.479 \pm 0.003(\text{sta}) \pm 0.005(\text{sys}) \pm 0.016(\text{lum}) \pm 0.001(\text{acc})$ [nb]
$\sigma_W^{tot} \cdot BR(W \rightarrow \ell\nu)$	$10.197 \pm 0.021(\text{sta}) \pm 0.127(\text{sys}) \pm 0.347(\text{lum}) \pm 0.165(\text{acc})$ [nb]
$\sigma_{W^+}^{tot} \cdot BR(W \rightarrow \ell\nu)$	$6.041 \pm 0.016(\text{sta}) \pm 0.077(\text{sys}) \pm 0.205(\text{lum}) \pm 0.096(\text{acc})$ [nb]
$\sigma_{W^-}^{tot} \cdot BR(W \rightarrow \ell\nu)$	$4.156 \pm 0.014(\text{sta}) \pm 0.058(\text{sys}) \pm 0.141(\text{lum}) \pm 0.083(\text{acc})$ [nb]
$\sigma_{Z/\gamma^*}^{tot} \cdot BR(Z/\gamma^* \rightarrow ll)$	$0.937 \pm 0.006(\text{sta}) \pm 0.009(\text{sys}) \pm 0.032(\text{lum}) \pm 0.016(\text{acc})$ [nb]

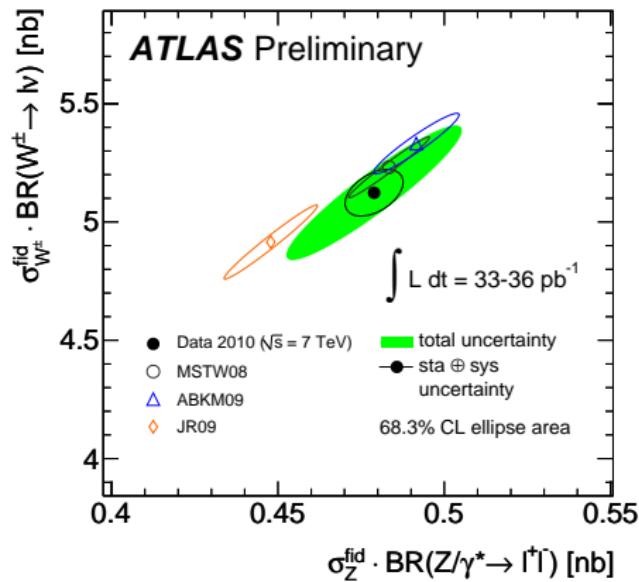
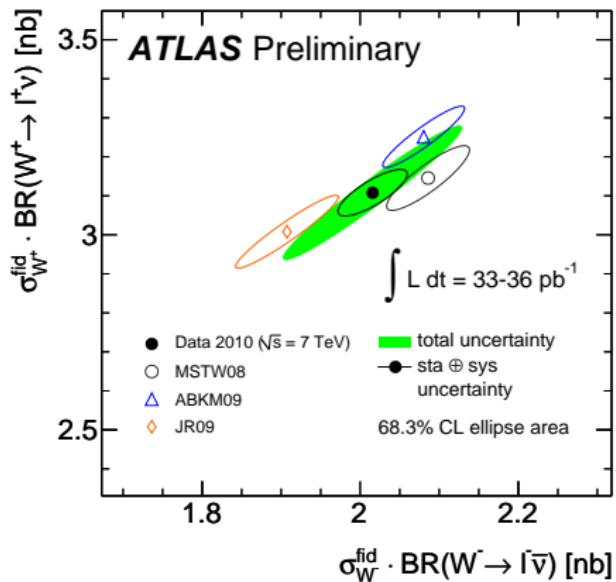
Theory comparisons - total cross sections

- Overall remarkable agreement with NNLO PDF predictions
- A few differences between different PDFs (w/ only 68 % CL PDF errors)
- Comparing total cross sections, the acceptance uncertainty accounts for effect of different PDFs on the unmeasured phase space ...



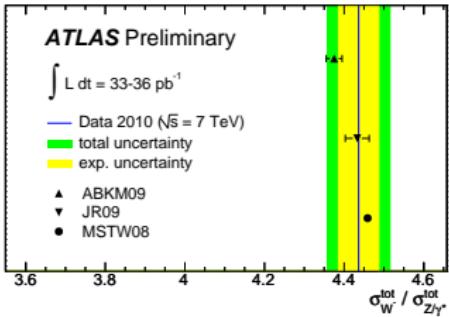
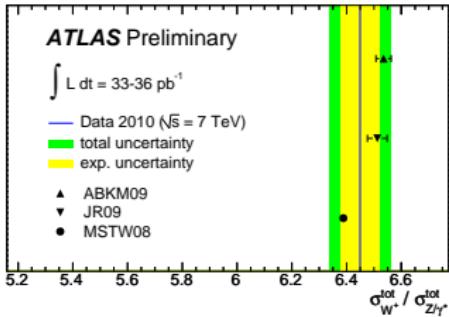
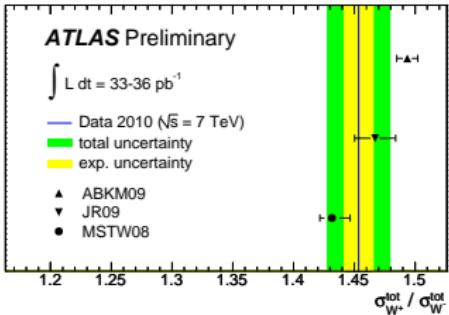
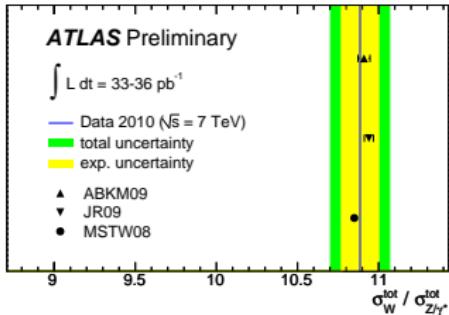
Theory comparisons - fiducial cross sections

- ... comparing in the fiducial region disentangles theor. and exp. effects
- This enables more interesting comparisons among different PDF sets
- First dedicated calculation of NNLO predictions based on FEWZ and DYNNNLO with experimental cuts



Theory comparisons - total cross section ratios

- W^\pm/Z , W^+/W^- ratios profit from exp. and theor. systematics cancellation
- W^\pm/Z ratio measured with total uncert. of 1.5%, W^+/W^- with 1.7%



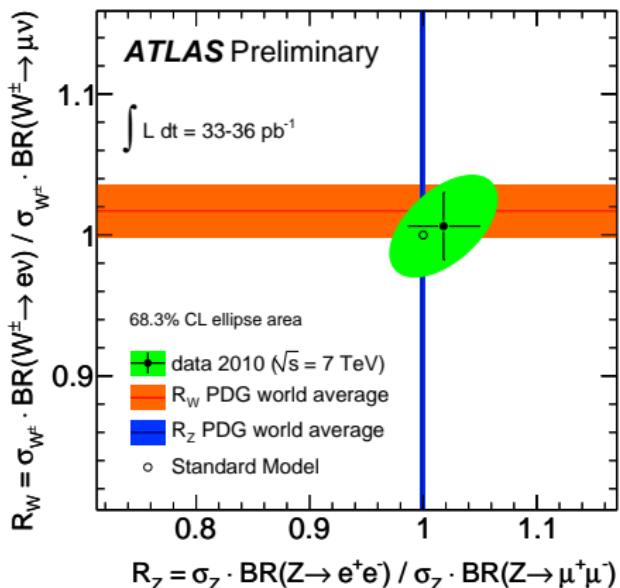
Theory comparisons - lepton universality

- New measurements of the ratios of the e and μ branching fractions

$$R_W = \frac{\sigma_W^e}{\sigma_W^\mu} = \frac{Br(W \rightarrow e\nu)}{Br(W \rightarrow \mu\nu)} = 1.006 \pm 0.004 \text{ (sta)} \pm 0.006 \text{ (unc)} \pm 0.023 \text{ (cor)} = 1.006 \pm 0.024$$
$$R_Z = \frac{\sigma_Z^e}{\sigma_Z^\mu} = \frac{Br(Z \rightarrow ee)}{Br(Z \rightarrow \mu\mu)} = 1.018 \pm 0.014 \text{ (sta)} \pm 0.016 \text{ (unc)} \pm 0.028 \text{ (cor)} = 1.018 \pm 0.031$$

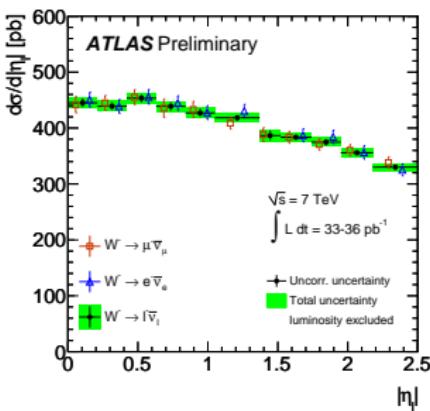
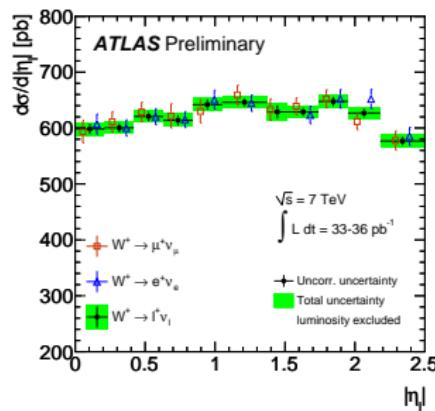
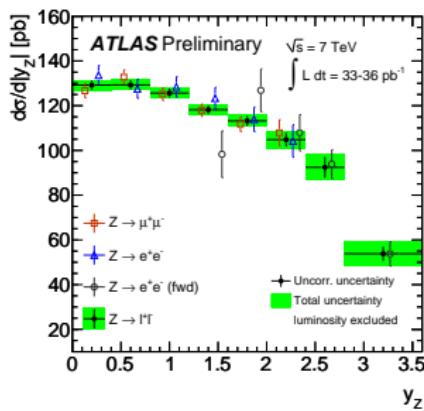
- Inserting R_Z PDG value into the present measurement for a combined cross section analysis

⇒ reduction of correlated R_W systematic uncertainty
⇒ improved result of
 $R_W = 0.999 \pm 0.021$.



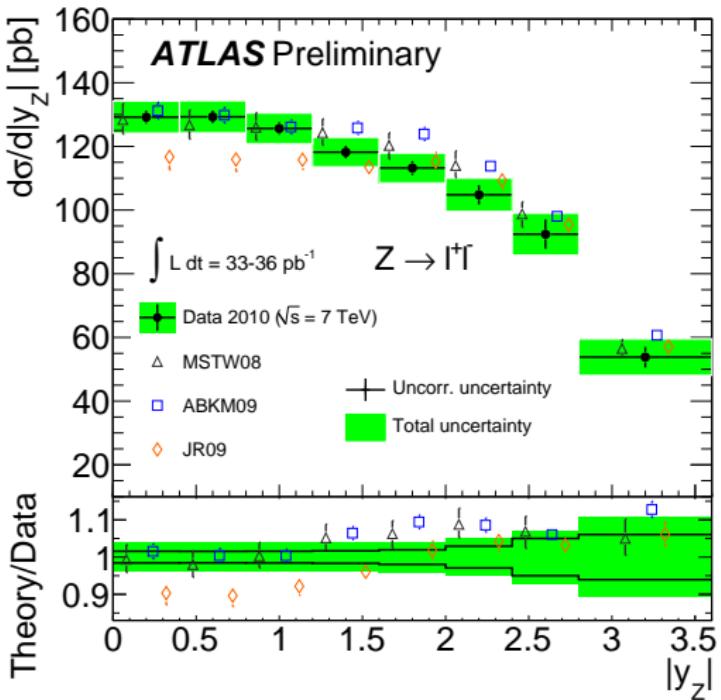
W and Z differential cross sections

- Differential σ_{W^\pm} and σ_Z measured vs. lepton η and boson rapidity
- Electron and muon measurements combined together with full covariance (meas., bins, channels) matrix available ($\chi^2/ndf = 33.9/29$)
- Z rapidity coverage up to $|y| = 3.5$ including the forward $Z \rightarrow ee$ measurement
- Accuracy of $\sim 2\%$ in central y_Z and W meas, of 6 (10) % at $y_Z = 2.6$ (3.2)



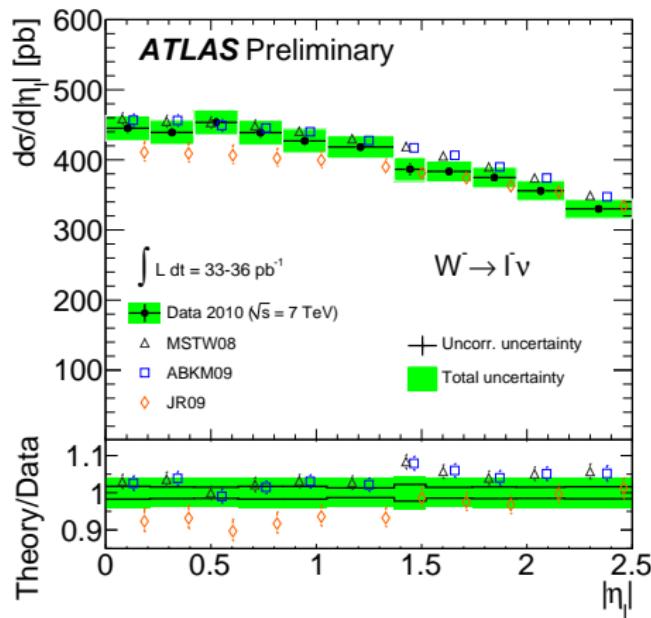
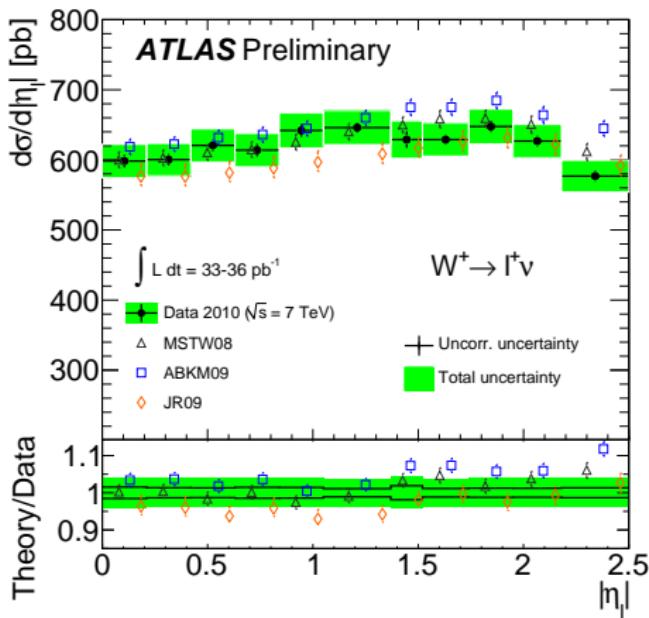
Combined e-mu $d\sigma_Z/dy_Z$ vs PDF predictions to NNLO

- Overall broadly described by predictions of NNLO PDF sets considered
- Measurements can impact on PDF central values and uncertainties



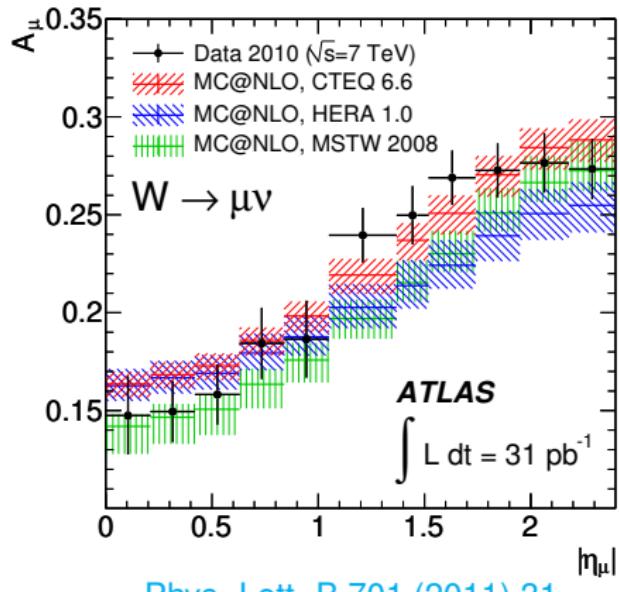
Combined e-mu $d\sigma_{W^\pm}/d\eta_l$ vs PDF predictions to NNLO

- Overall broadly described by predictions of NNLO PDF sets considered
- Measurements can impact on PDF central values and uncertainties

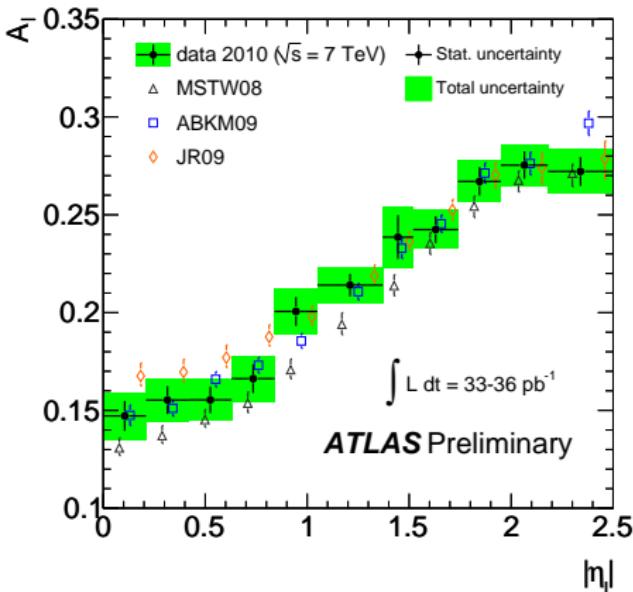


W differential charge asymmetry

- W differential charge asymmetry : $A(\eta_l) = \frac{\sigma^{W^+}(\eta_l) - \sigma^{W^-}(\eta_l)}{\sigma^{W^+}(\eta_l) + \sigma^{W^-}(\eta_l)}$
- Update of recent ATLAS muon measurement combining electron and muon channels together



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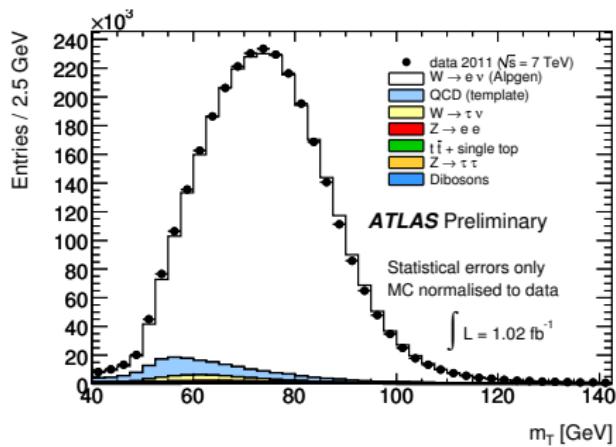
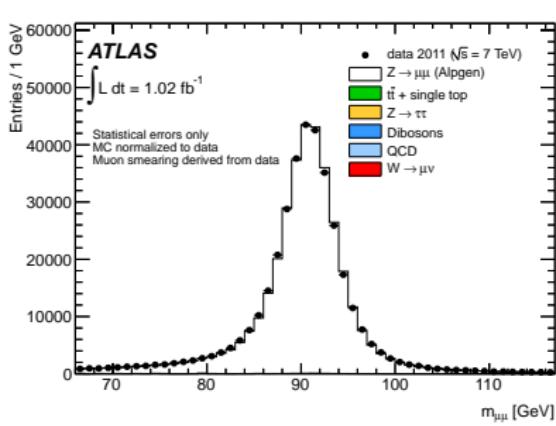


Summary

- **W and Z inclusive cross section in electron and muon channels measured with complete 2010 dataset**
- Total and fiducial integrated cross sections presented with $1 - 2\%$ level experimental precision (apart from the 3.4% luminosity uncertainty)
- First rapidity differential cross sections are measured in electron and muon channels and combined with accuracy of $\sim 2\%$ for bulk of measurement bins (central y_Z and all W) and of $6 - 10\%$ for forward Z region
⇒ Full systematics covariance matrices available for PDF fitters
- Lepton W charge asymmetry updated with improved precision
- *Integrated fiducial and rapidity differential cross sections allow for interesting comparison to theory and will impact proton PDF determinations*

Outlook

- A publication presenting 2010 analysis results is going to be released soon
- Preview of W, Z inclusive analysis with 2011 data



- Very nice data/MC agreement already achieved!
- $3.1 - 4.3 M$ W boson and $260 - 330 K$ Z boson samples in $e - \mu$ channels
- LHC $W-Z$ boson factory \Rightarrow high precision differential measurements enabled!