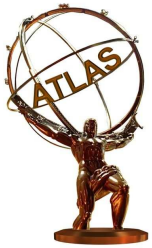

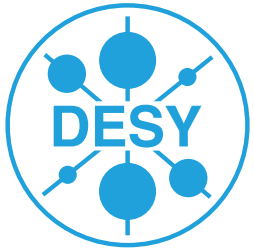

ATLAS W/Z measurements and strange-quark density determination

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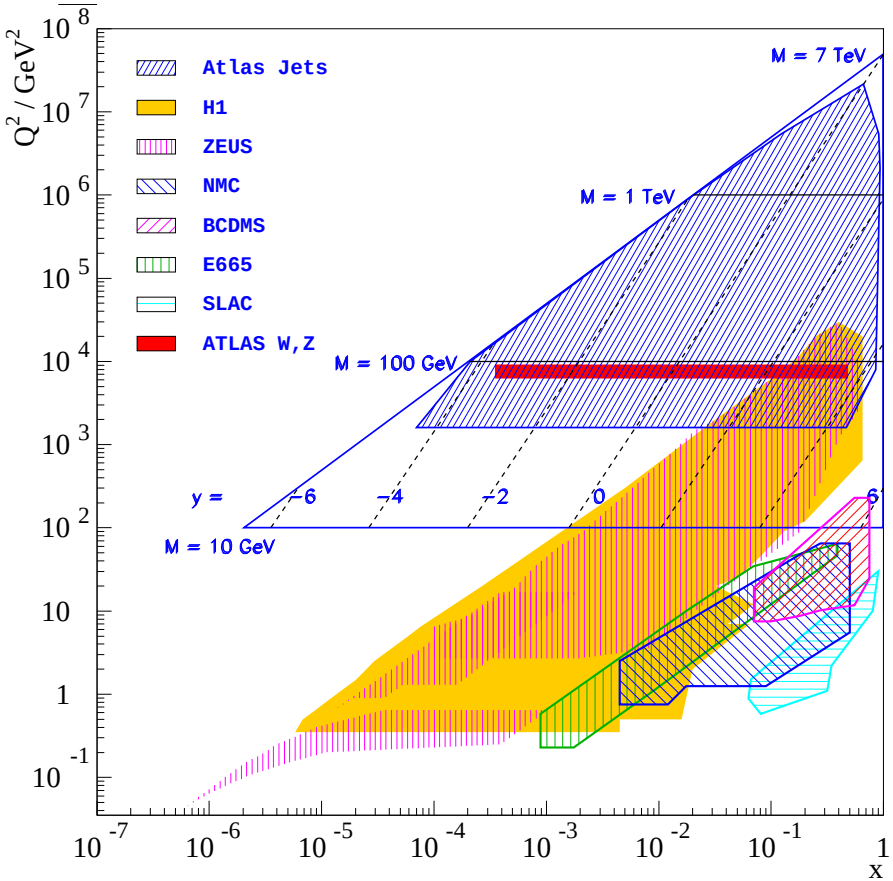
29.05.2012, Cyprus, Low x 2012

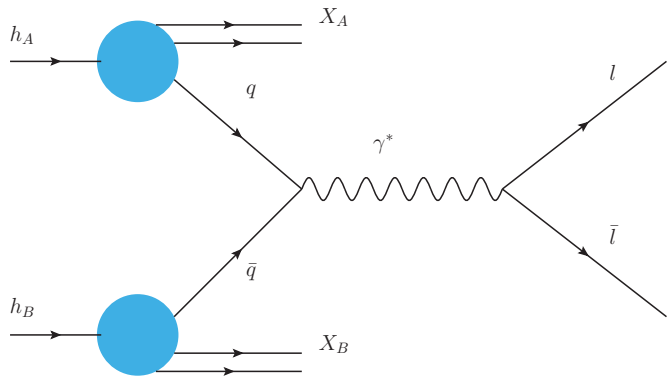
On behalf of the ATLAS collaboration

Motivation of the W/Z measurement at the LHC

- Production of W, Z bosons is theoretically well understood
- Clear experimental signature in the leptonic decay



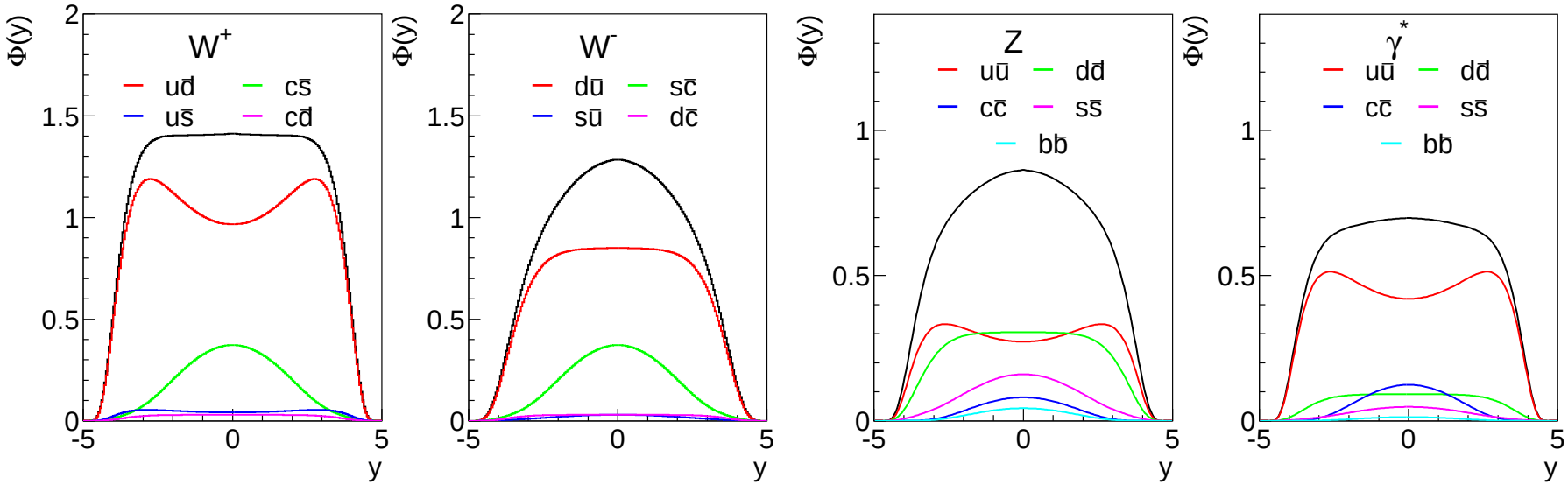
$Q^2 = M^2_{W/Z}$ and $x_{1,2} = e^{\pm y} \frac{M_{W/Z}}{\sqrt{s}}$



Motivation:

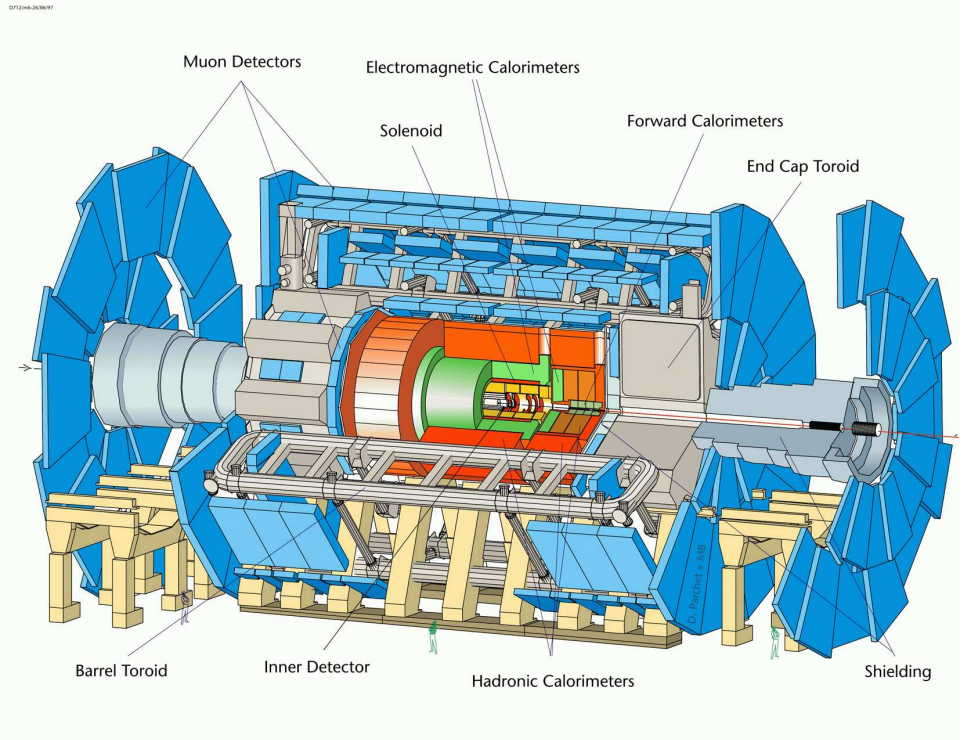
- Test of the validity of the QCD evolution into the region of high Q^2 at low Bjorken x
- Check of the PDFs estimated using HERA data

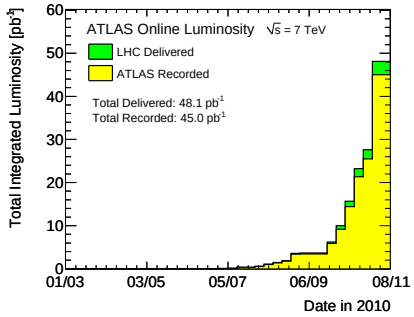
PDFs sensitivity



- For the Z exchange the d-quark distribution is higher than u for the central rapidity region
- A contribution of s quarks to the Z cross section for the central rapidity is not negligible
- W^+ cross section is dominated by the $u_v\bar{d}$ contribution and expected to exceed the W cross section, which is dominated by the $\bar{u}d_v$ part
- Measurement of the W/Z production at the LHC and structure functions at HERA allow for PDF decomposition determination

The ATLAS detector





Eur.Phys.J. C 72 1849

Integrated Luminosity:

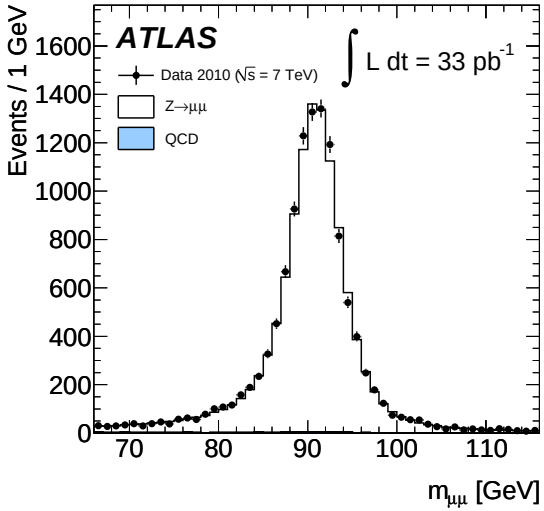
- 20 μb^{-1} in 2009
- 45 pb^{-1} in 2010
- 5.2 fb^{-1} in 2011
- > 4 fb^{-1} in 2012

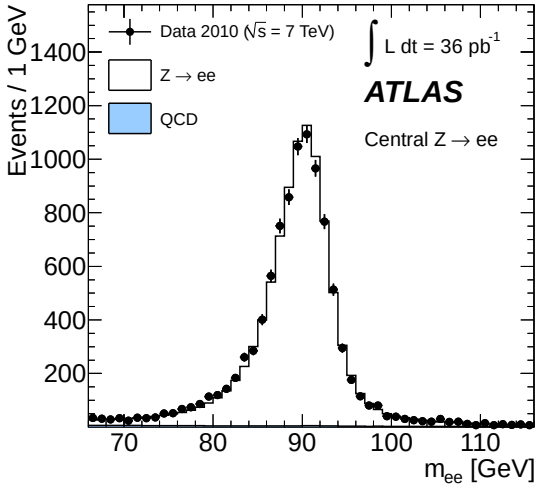
Detector structure:

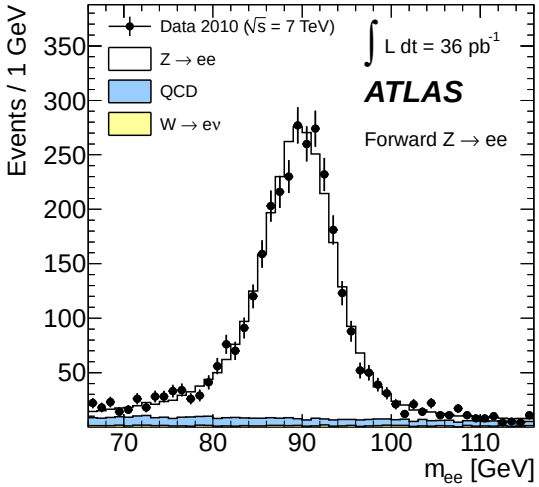
- Inner detector $|\eta| < 2.5$
- Calorimeter system $|\eta| < 4.9$
- Muon system $|\eta| < 2.7$

- Trigger:
  - electrons: $|\eta| < 2.5$
  - muons: $|\eta| < 2.4$

Electron and Muon performance







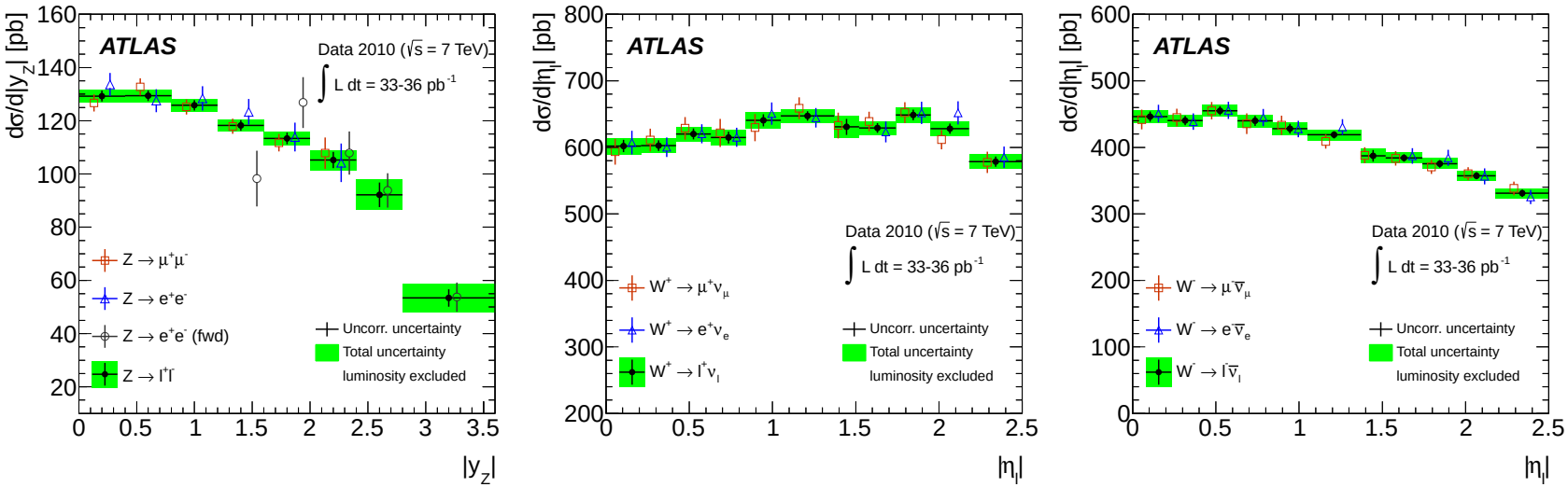
Phys. Rev. D85, 072004

- Various components of the **electron and muon efficiency** were measured with high accuracy
- **Energy calibration** of the EM calorimeter was measured with 1% uncertainty for almost all pseudo-rapidity regions
- Muon **momentum scale and resolution** are determined with $\sim$ 0.3% and $\sim$ 0.5% uncertainty respectively
- QCD background is studied using data-driven methods, while EW background are taken from MC samples.
- The total uncertainty of the luminosity measurement is 3.4 %

W/Z measurement

- Inclusive W/Z cross-section measurements in each leptonic channel
- Differential measurement in the electron and muon channel in bins of boson rapidity and transverse momentum.
- W boson polarization and charge asymmetry ($\sim 1\ \mathrm{fb}^{-1}$)

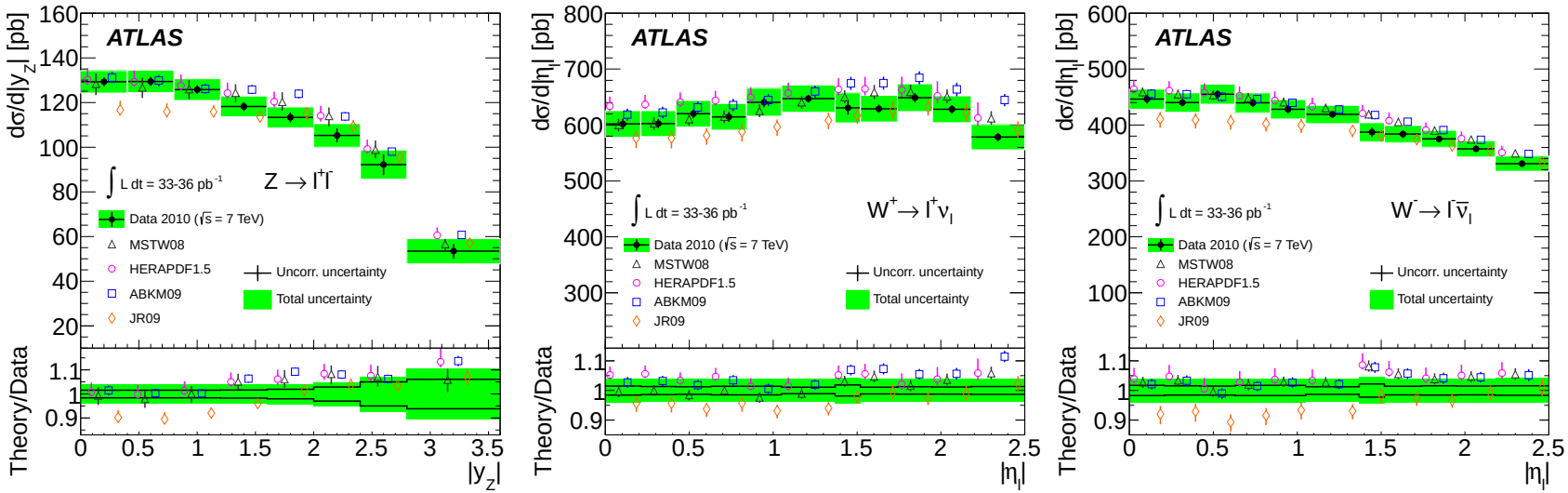
Differential cross-section combination ($e + \mu$)



Phys. Rev. D85, 072004

- The combination increases precision of the measurements and provides a test of compatibility
- Combinations of several cross sections are performed taking into account all sources of correlated and uncorrelated uncertainties
- The data show good compatibility, with the total $\chi^2/dof = 33.9/29$

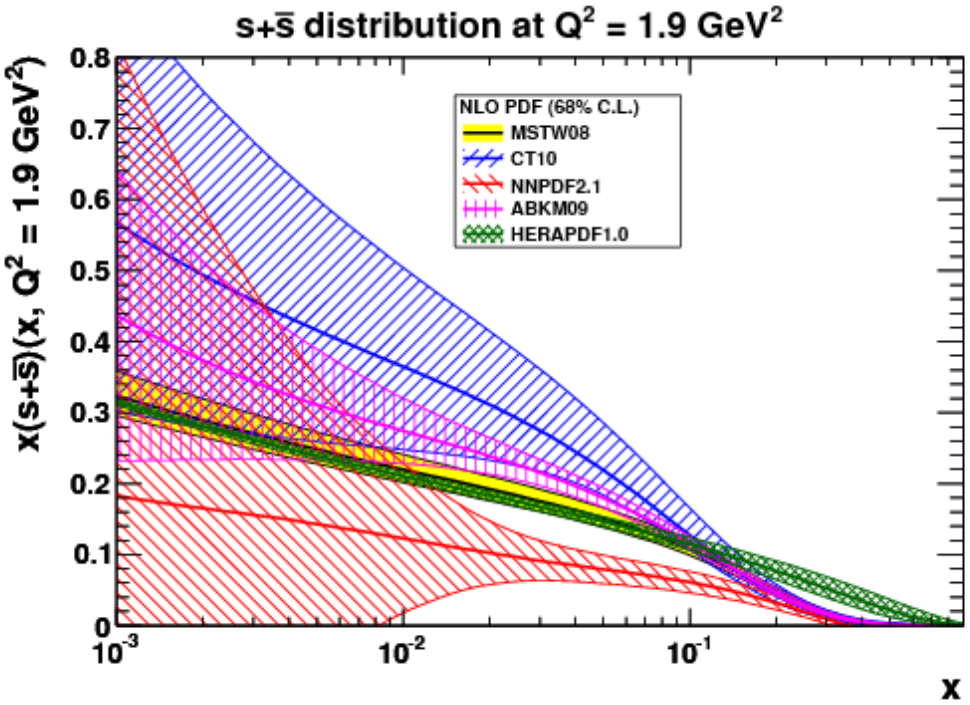
Comparison with theory prediction



Phys. Rev. D85, 072004

- The combined data are compared to theoretical calculations performed with FEWZ and DYNNLO programs using recent NNLO PDFs (JR09, ABKM09, HERAPDF1.5 and MSTW08).
- Overall there is reasonable agreement, however none of the PDF sets describe all features of the ATLAS data. Thus it can be expected that the differential cross sections will reduce the uncertainties of PDFs and also influence the central values.

Strange quark density. Motivation.

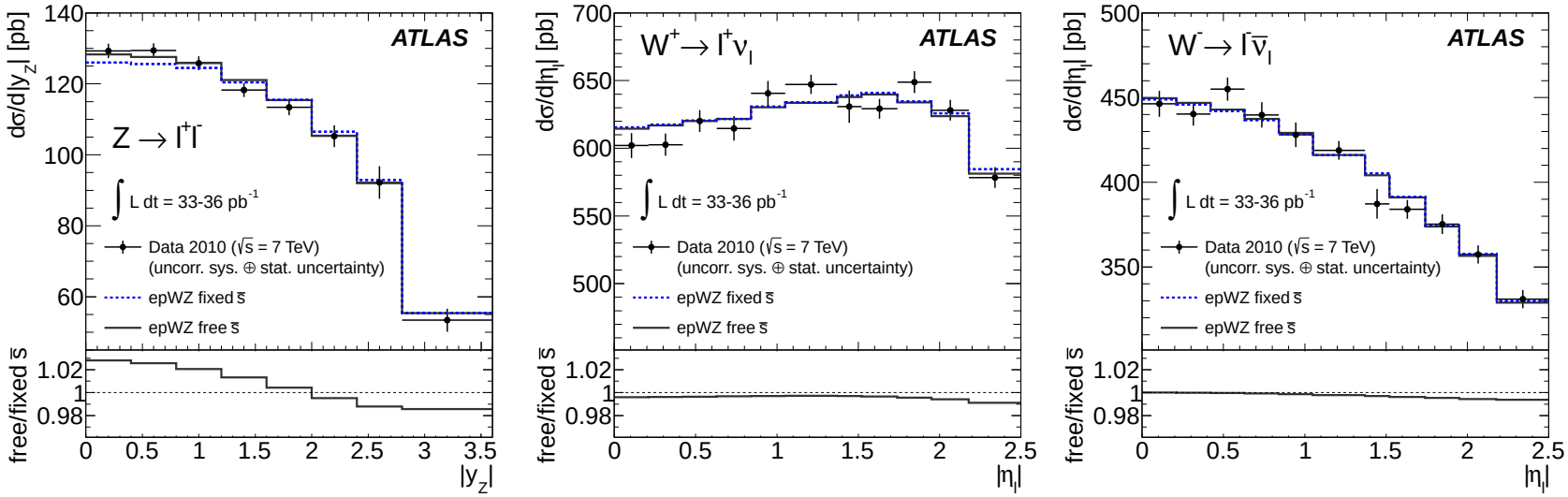


- Little is known about the strange quark distribution
- Flavor $SU(3)$ symmetry suggests that the three light sea quark distributions are equal
- Strange quark density is suppressed in many PDFs due to their larger mass

Set-up of the QCD analysis

- The QCD analysis uses the HERAFitter framework
- The APPLGRID package interfaced to MCFM program was used for fast calculation of the differential W/Z boson cross section at NLO level and the K-factor technique to correct NLO to NNLO prediction.
- The data are compared to the theory using χ^2 function
- The following parameters were chosen for analysis:
  - $Q_0^2 = 1.9\ \mathrm{GeV}^2$
  - $m_c = 1.4\ \mathrm{GeV}$
  - $m_b = 4.75\ \mathrm{GeV}$
  - $\alpha_S(M_Z) = 0.1176$
  - $Q^2_{min} > 7.5$ for HERA data
- The standard parametrization is used:
  - $xq_i(x) = A_i x^{B_i}(1-x)^{C_i} P_i(x)$ for $u_v, d_v, \bar{u}, \bar{d}, \bar{s} = s$
  - $xg(x) = A_g x^{B_g}(1-x)^{C_g} - A'_g x^{B'_g}(1-x)^{C'_g}$

Result of the PDF fit



arXiv:1203.4051

- The measurement uses ATLAS and HERA data

χ^2/dof for PDF fit:

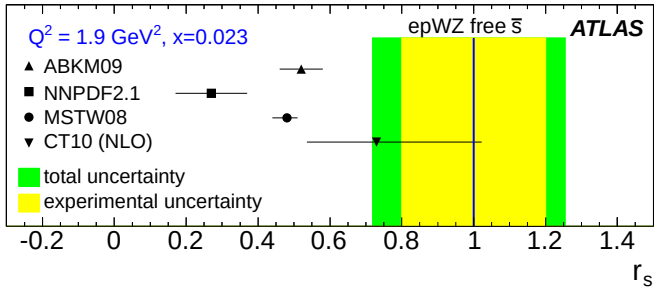
data	fixed $\bar{s}/\bar{d} = 0.5$	free $\bar{s}/\bar{d}$
All	546.1/567	538.4/565
ATLAS	45.0/30	33.9/30

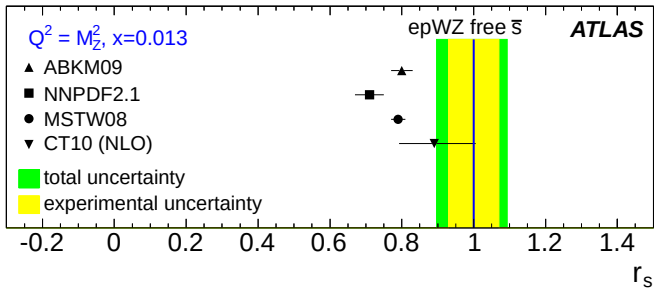
Study of uncertainties

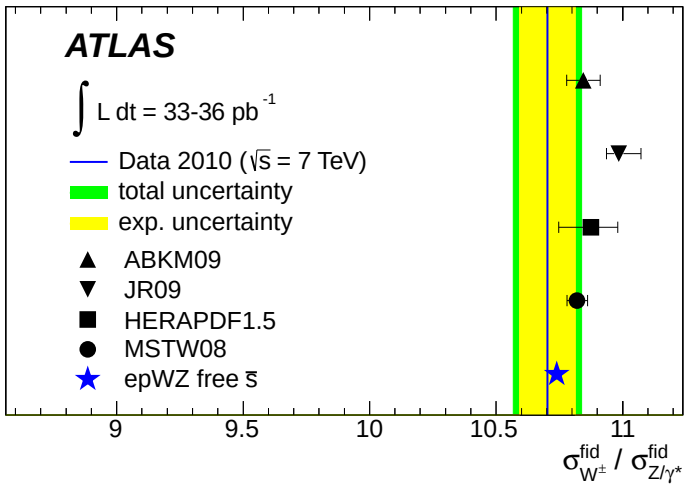
$$r_s = \frac{s(x)+\bar{s}(x)}{2d(x)} = 1.00 \pm 0.20_{\text{exp}} \pm 0.07_{\text{mod}} \pm^{+0.10}_{-0.15\text{par}} \pm^{+0.06}_{-0.07\alpha_s} \pm 0.08_{\text{th}}$$

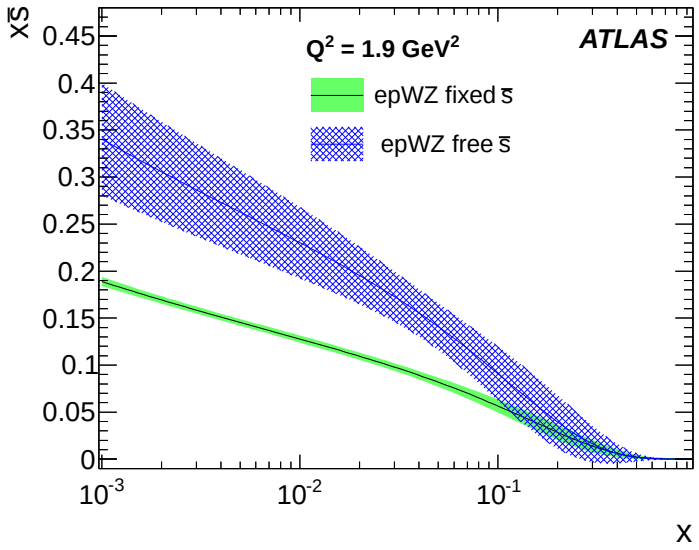
- The experimental (exp) uncertainties (both statistical and systematic uncertainties of the W/Z measurement) dominate.
- The model (mod) uncertainties arise from:
  - varying charm mass $1.25 < m_c < 1.55$ GeV
  - varying bottom mass $4.3 < m_b < 5.0$ GeV
  - varying cut on minimum Q^2 $5 < Q^2_{\text{min}} < 10$ GeV
  - varying starting scale Q^2_0 lowered to 1.5 GeV^2
- The parametrization (par) uncertainties arise from varying polynomials in the parametrization.
- The α_s uncertainty corresponds to the variation $0.114 < \alpha_s(M_Z) < 0.121$
- The theoretical (th) uncertainty is assessed by comparing the DYNNLO and FEWZ predictions.

Strange quark density. Result.









arXiv:1203.4051

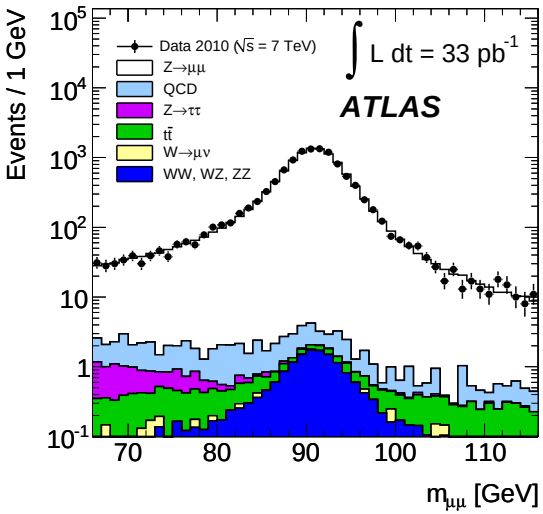
- total sea is enhanced by 8%
- $\bar{u}$, $\bar{d}$ decrease by 10%
- better agreement found in ratio $\sigma^{fid}_{W^\pm}/\sigma^{fid}_{Z}$

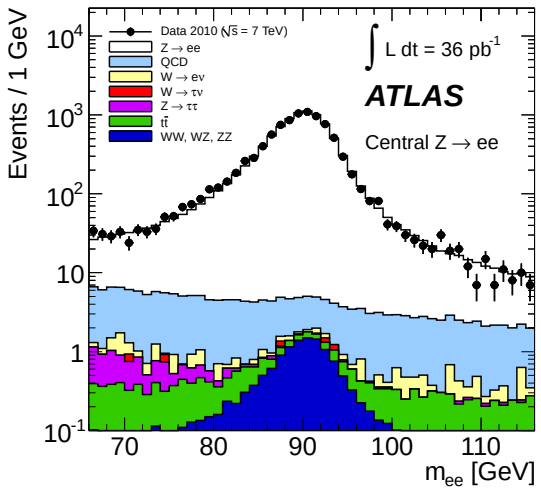
Summary

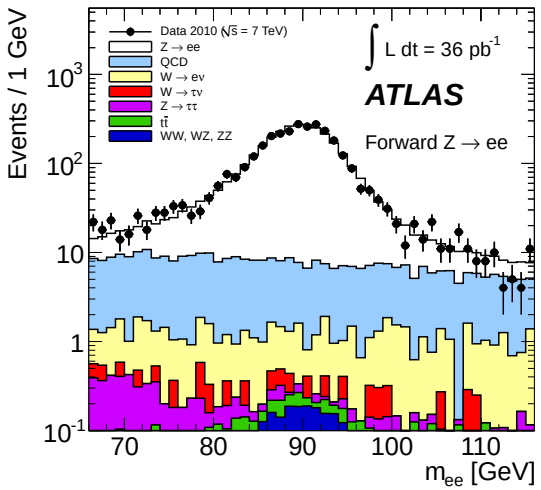
- Inclusive W/Z cross-section measurement was performed in e and μ decay channels. The total experimental uncertainty is around 1.2% and the overall normalization is 3.4 %.
- Differential measurement was performed at very high accuracy in the electron and muon channel.
- Strange quark density was determined from the differential W/Z measurement. The resulting value is consistent with no strange-density suppression.

Backup slides

Background studies



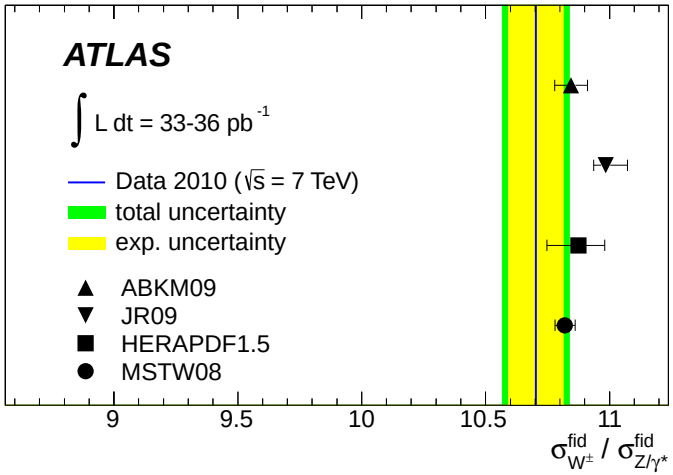


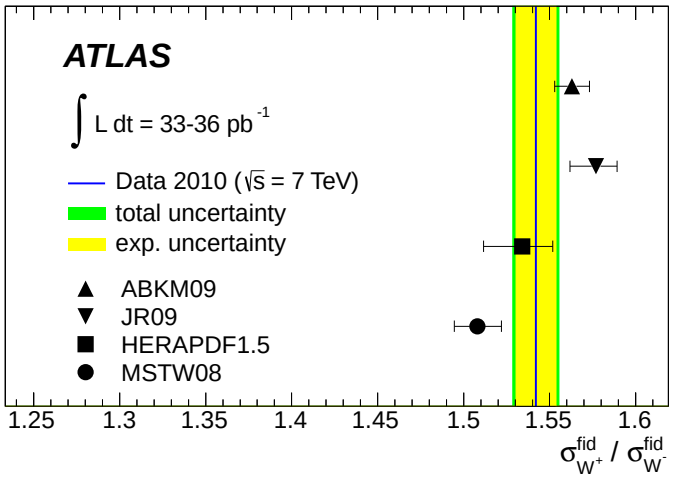


arXiv:1109.5141

- Numbers of the EW background are taken from MC samples.
- The QCD background is studied using data-driven methods. The signal and background contributions are estimated by fitting the di-electron invariant mass shape.
- $Z \to ll$ measurement was performed in a common phase space.
  - $66 < M_{ee} < 116$ GeV
  - lepton $p_T > 20$ GeV

Ratio of fiducial cross-sections

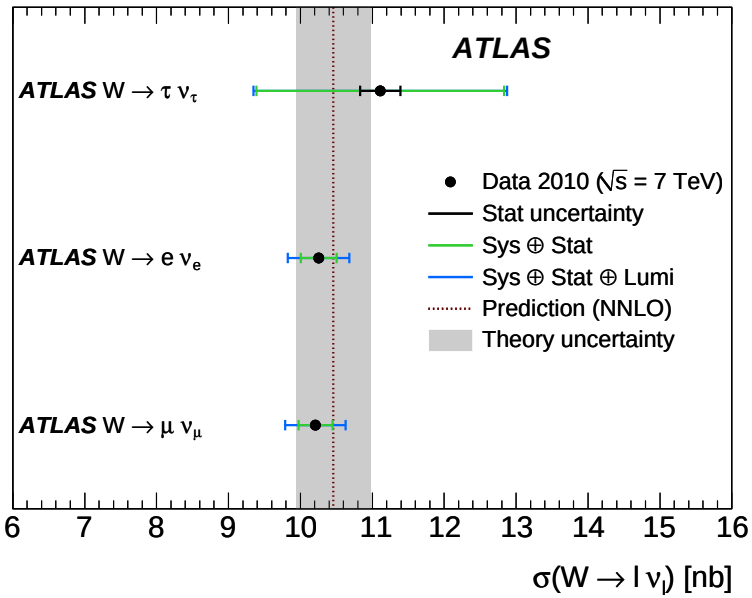


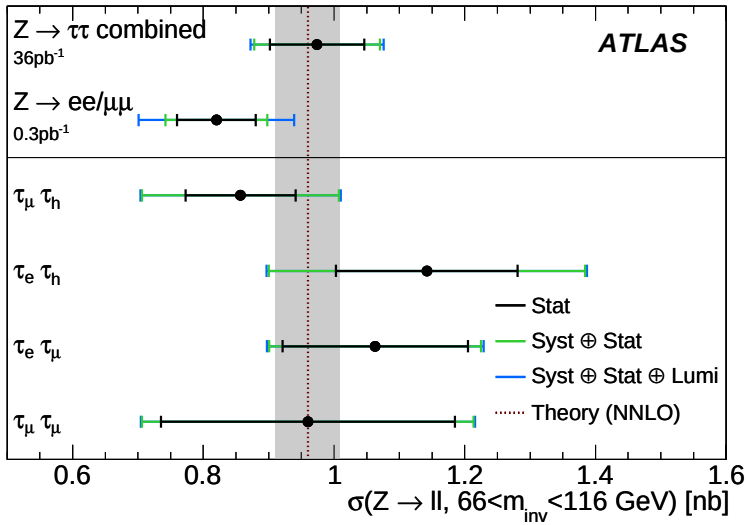


- Broad agreement with NNLO predictions, different PDF dependences:
  - W/Z – sensitive to sea quarks,
  - W^+/W^- – sensitive to up-down PDF differences.
- Ratio is obtained in the fiducial regions and combining the electron and muon final states.
- Fiducial volume is defined by the following requirements:
  - $p_{T,l} < 20$ GeV
  - $\eta_l < 2.5$
  - $66 < M_{ll} < 116$ GeV
  - $M_{T,W} > 40$ GeV
  - $E_T^{mis} > 25$ GeV

arXiv:1109.5141

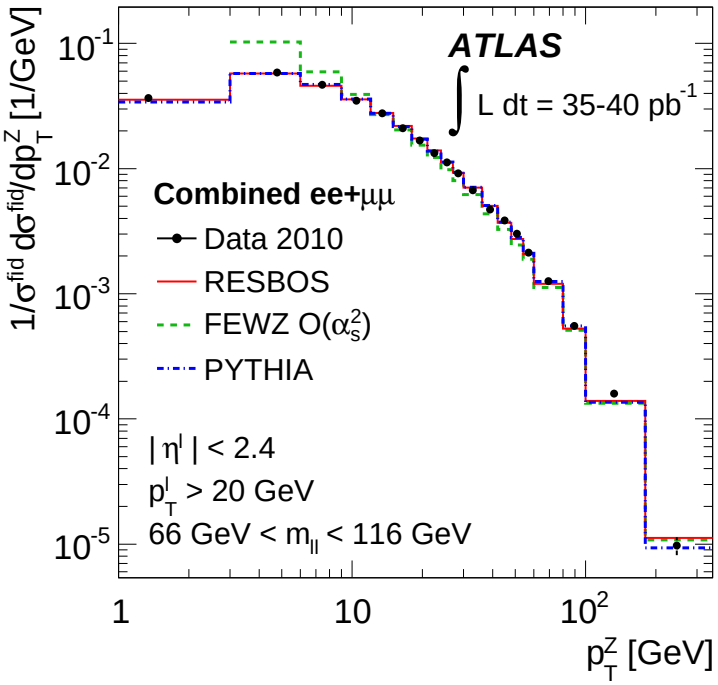
$W \to \tau\nu$ and $Z \to \tau\tau$ measurement

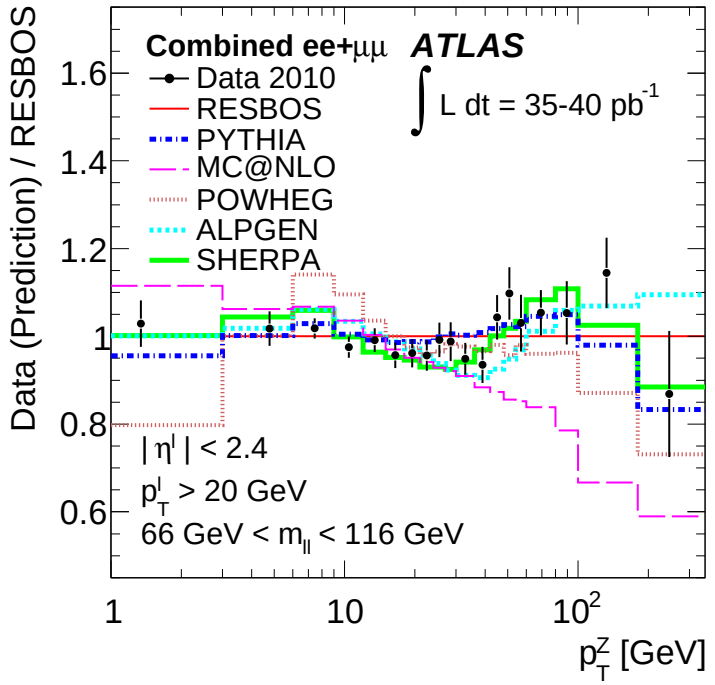




- Measurement was performed using 2010 data and shows an agreement with other leptonic decay channels
- The values are in agreement with the NNLO prediction.

$$\frac{1}{\sigma}\frac{d\sigma_{Z\to ll}}{d|p_{T,Z}|}$$



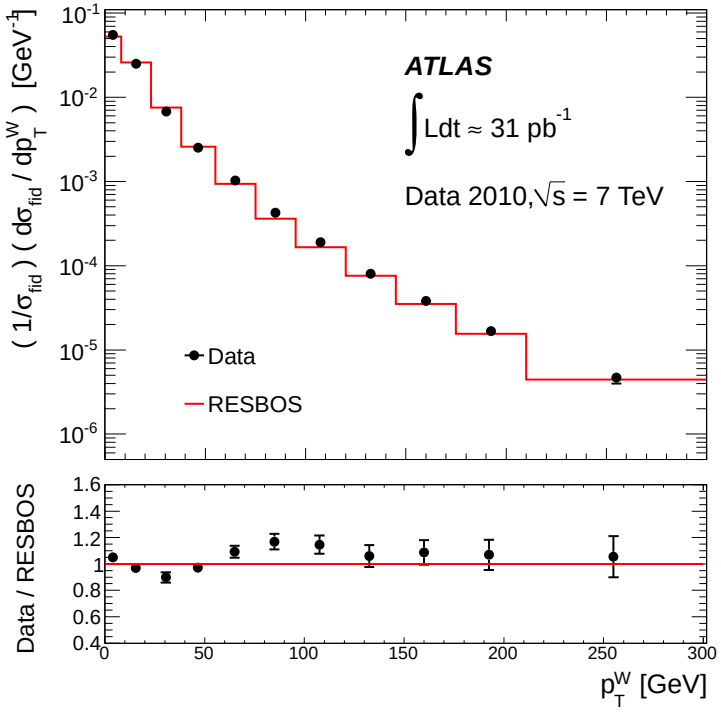


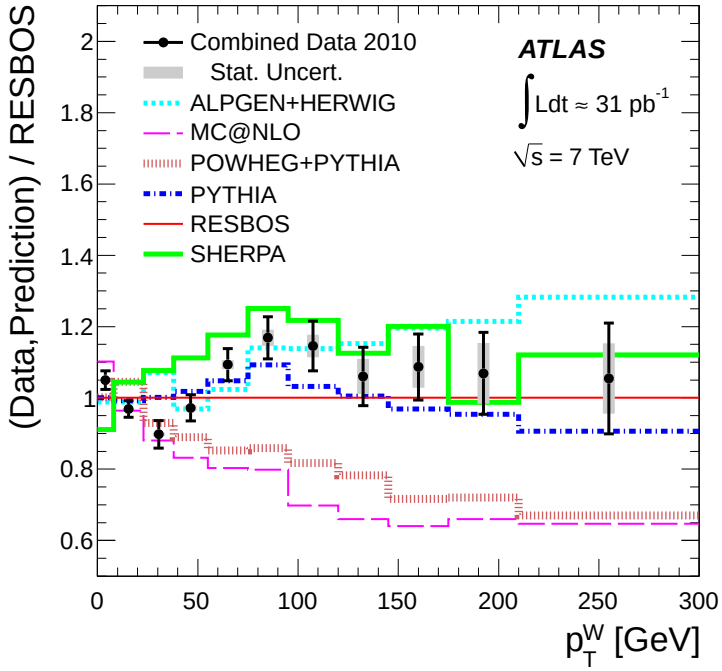
The Resbos describes the Z spectrum well for the entire $p_{T,Z}$ range.

Predictions of various event generators: Sherpa, Alpgen and Pythia show a good agreement with the measurement as well.

- $\chi^2/dof = 17/19$
- Combination volume: $p_{T,l} > 20GeV$, $66 < m_{ll} < 116GeV$, $|\eta_l| < 2.4$.

$$\frac{1}{\sigma}\frac{d\sigma_{W\to l\nu}}{d|p_{T,W}|}$$





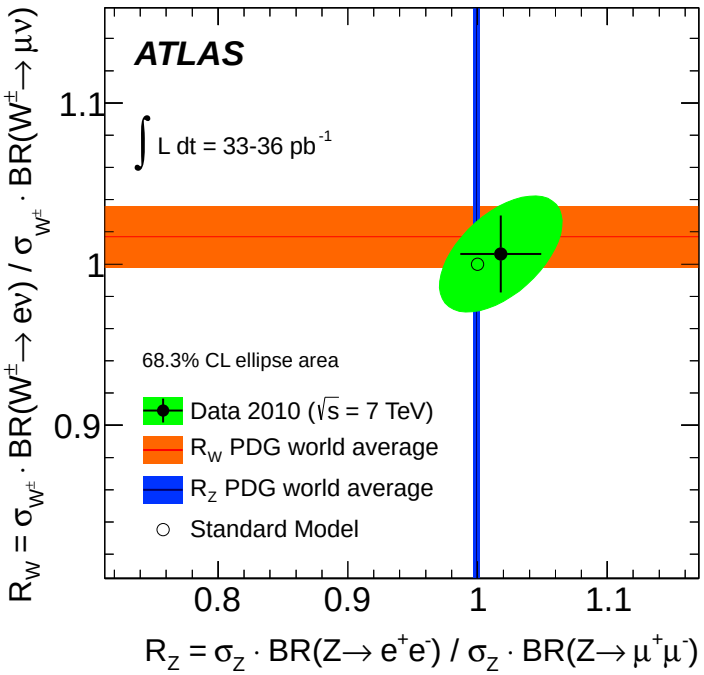
The Alpgen+Herwig, Pythia, Resbos, and Sherpa predictions match the $W \to l\nu$ cross section in $p_{T,W}$ bins within 20%.

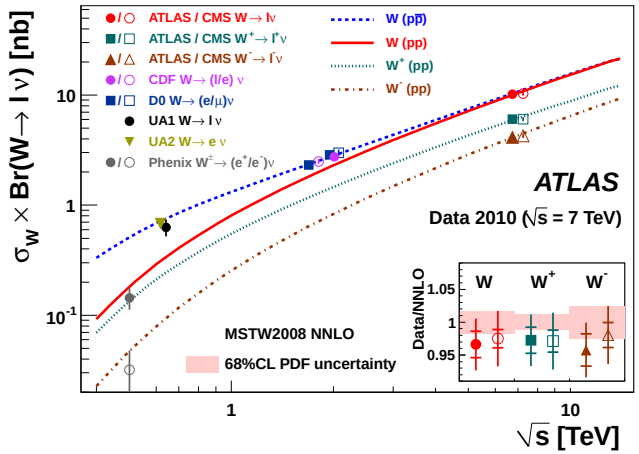
MC@NLO provides the closest description of the data for $p_{T,W} < 38GeV$

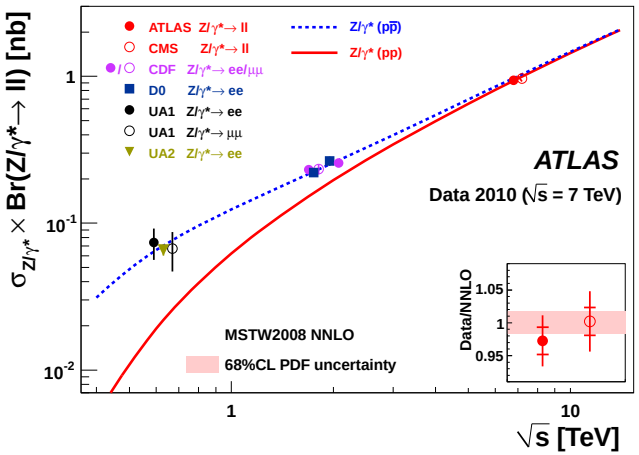
- $\chi^2/dof = 13.0/13$
- Combination volume:
  - $p_{T,l} > 20GeV$
  - $p_{T,\nu} > 25GeV$
  - $|\eta_l| < 2.4$
  - $m_T > 40GeV$

Lepton universality

The correlated measurement of the electron-to-muon cross section ratios in the W and the Z channels.

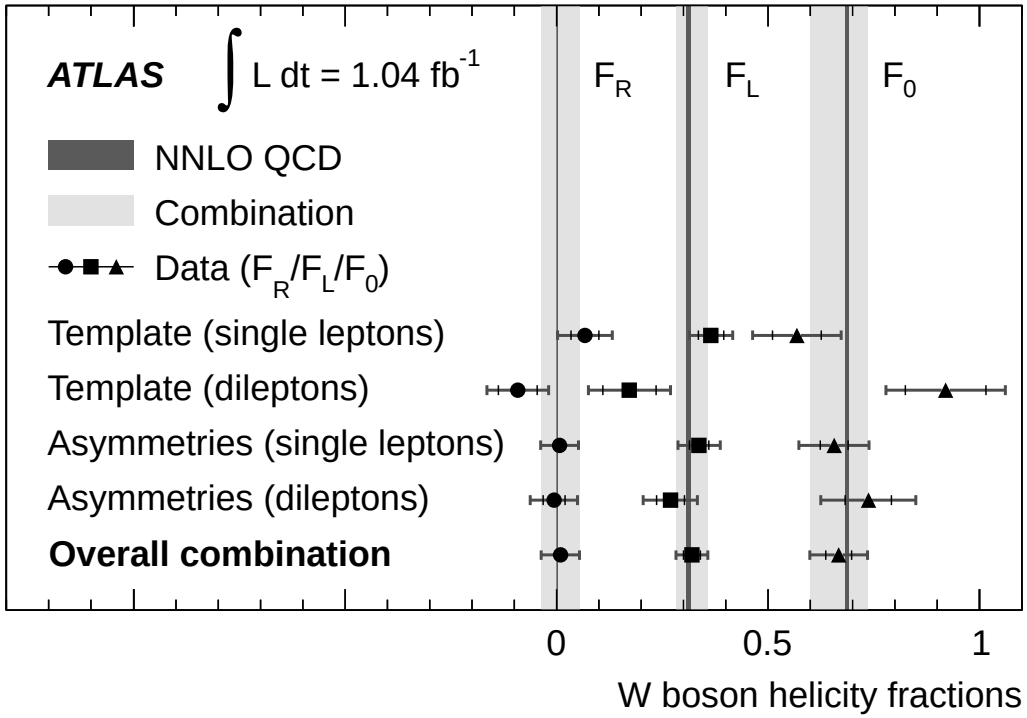






- The inclusive measurements were performed with a few % uncertainties ($\sim 35\text{pb}^{-1}$)

W boson polarization



- W polarization was derived from $t\bar{t}$ events with missing transverse momentum using 1.04fb^{-1} 2011 data
  - l + $jjjj$
  - ll + jj
- Any deviation of F_0, F_L, F_R from the Standard Model prediction could be caused by new physics contributing to the Wtb vertex