Measurements of W/Z production with the ATLAS detector

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Jean-Baptiste Sauvan
Université Paris-Sud, LAL
On behalf of the ATLAS collaboration

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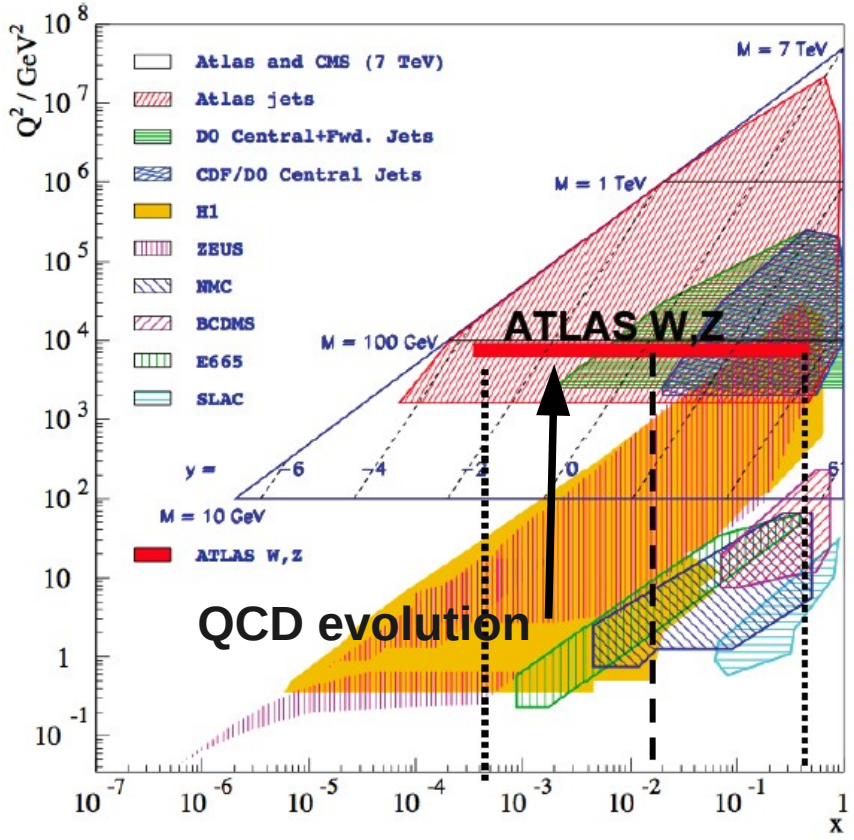
W/Z measurements in ATLAS

- QCD sector
  - ↳ W, Z integrated cross sections
  - ↳ W, Z cross-section ratios
  - ↳ W, Z differential cross sections
- Electroweak sector
  - ↳ Cross section ratios in e/μ decay channels → lepton universality
  - ↳ W polarisation
  - ↳ τ polarisation

Motivations

- Low x → dominance of gluon and sea quark scattering
  - ↳ Can contribute to further constrain this region
- Support the validity of QCD evolution from low scales to higher scales

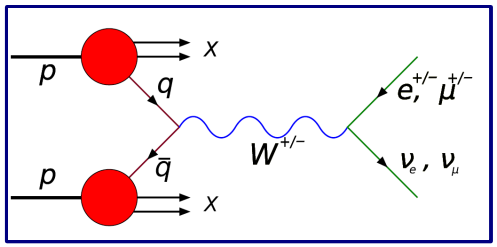


- Test pQCD predictions
  - ↳ Up to NNLO
- And phenomenological models:
  - ↳ Matrix elements + Parton shower
  - ↳ Soft gluon resummations

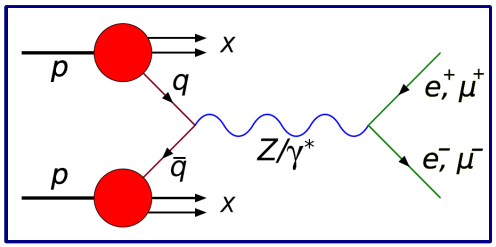
- Test lepton universality
- τ polarisation in W → τν
  - ↳ Important for characterization of new phenomena

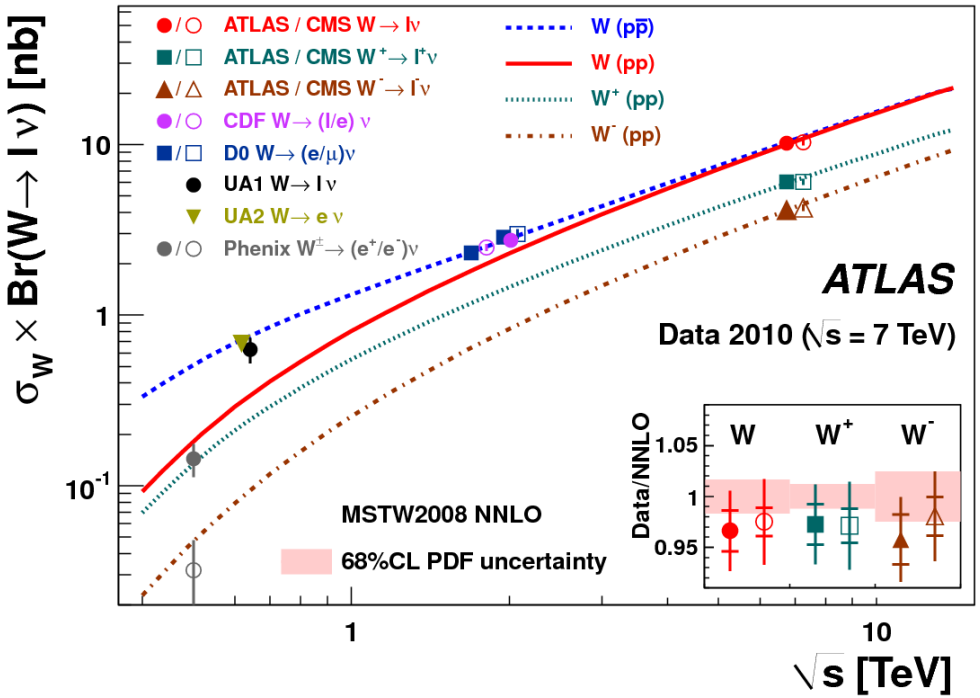
W, Z cross section measurements

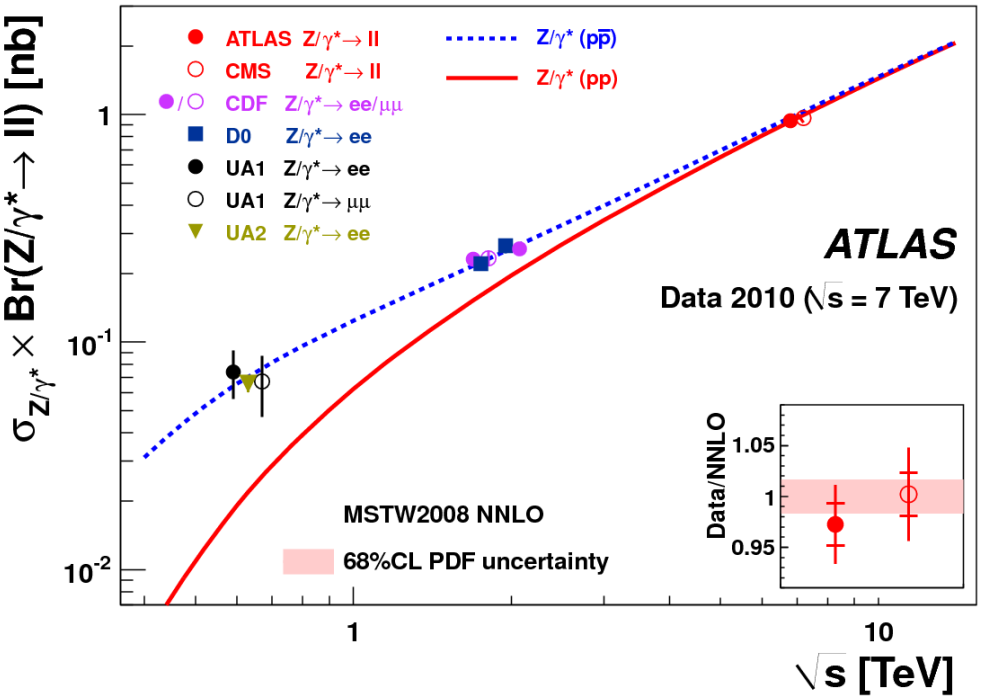
- W, Z cross sections measured with ~35pb^{-1} (2010 dataset)
  - ↳ Integrated over the fiducial regions and extrapolated to the full kinematic range
  - ↳ Differential cross sections as a function of the lepton η and the Z boson rapidity:
    - W: $|\eta_l| \leq 2.5$
    - Z: $|y_Z| \leq 2.4$, with and extension to $|y_Z| \leq 3.6$ using forward electrons



LO production



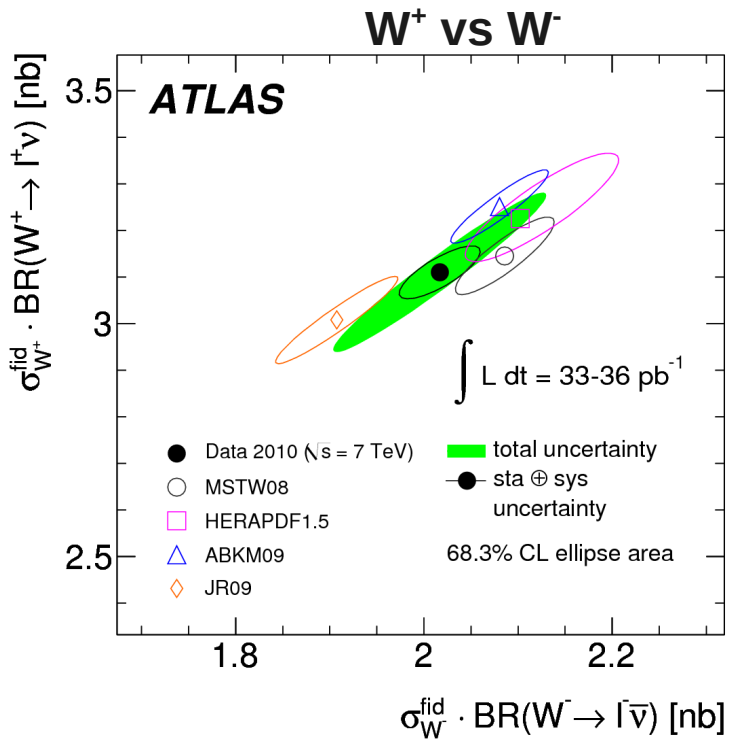


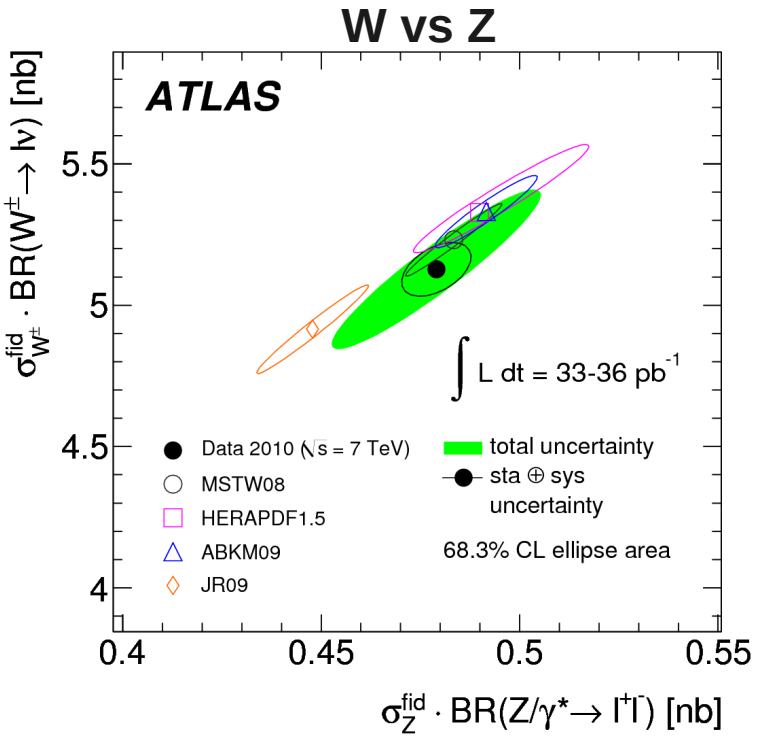


W and Z inclusive cross-sections

arXiv:1109.5141

- Assuming lepton universality, e and μ cross sections are combined.
  - ↳ Reach accuracy of a few % dominated by luminosity measurement (3.4%)
- Comparison with NNLO predictions (FEWZ) with various PDF sets
  - ↳ Good agreement
  - ↳ Some differences visible between different PDFs (68% CL)
  - ↳ Validity of QCD evolution from low scales (mainly DIS from HERA) to W, Z scales

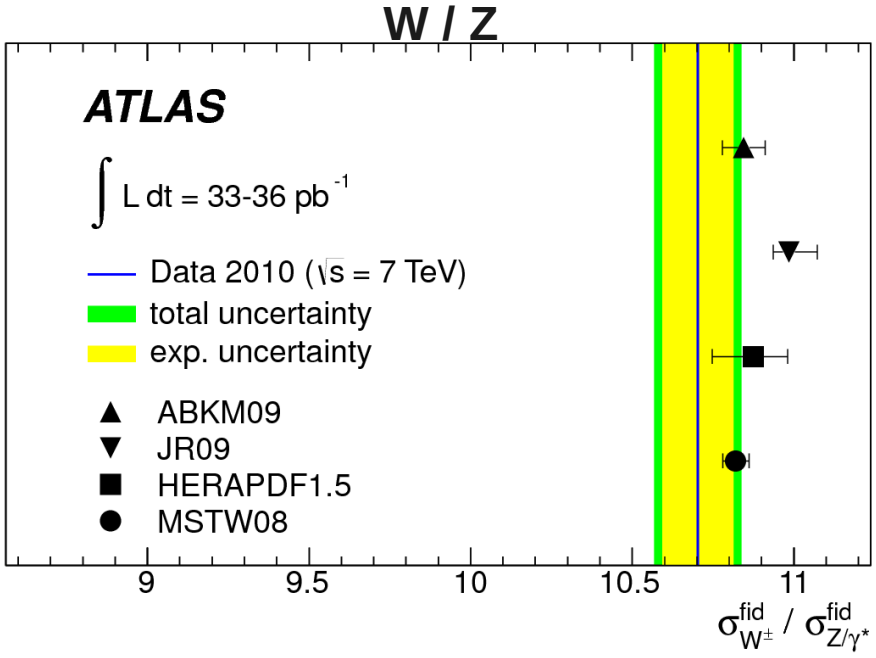


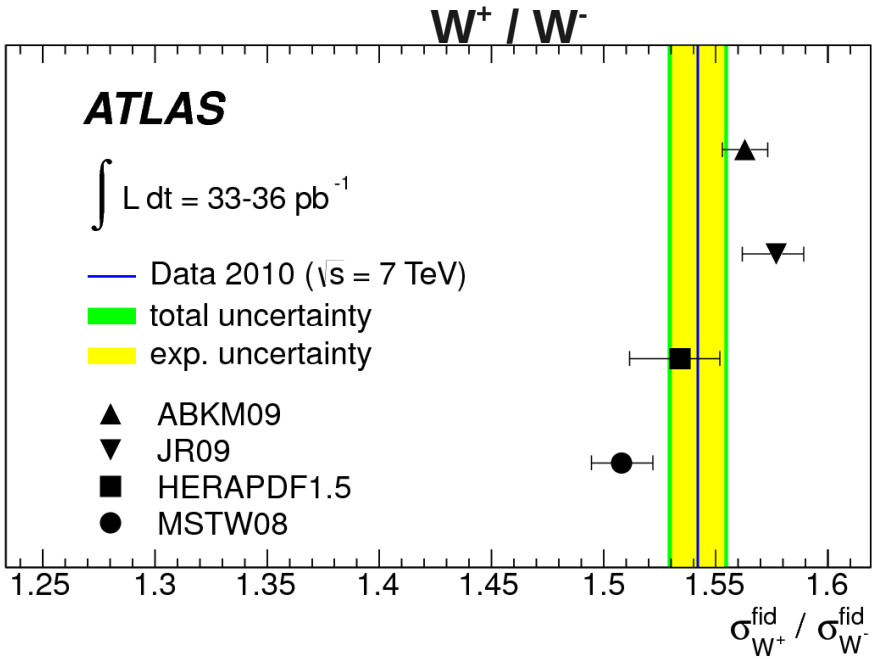


Cross section ratios

arXiv:1109.5141

- Correlation due to luminosity measurement cancels in the ratio of the cross sections
- $(W^+ + W^-)/Z$ ratio rather insensitive to PDFs (provided that the sea is flavour symmetric)
  - ↳ Agreement with measurement → flavour-independent light-quark sea (at high scale, x~0.01)
- Charge-dependent ratios (e.g. W^+/W^-) more sensitive to u/d differences
  - ↳ More significant deviations between PDF sets





$Z \to \tau\tau$ & $W \to \tau\nu$

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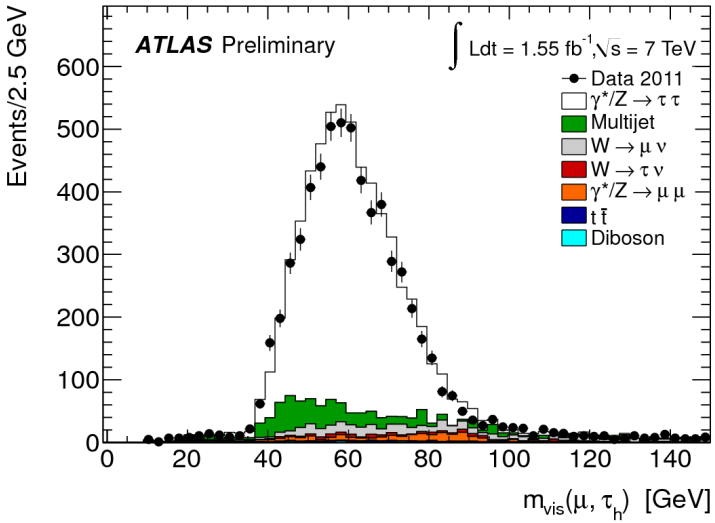
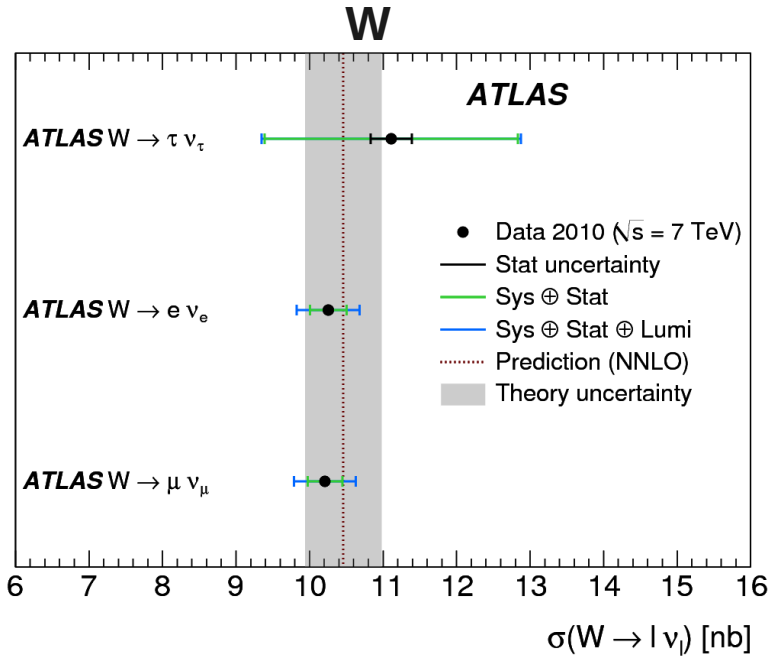
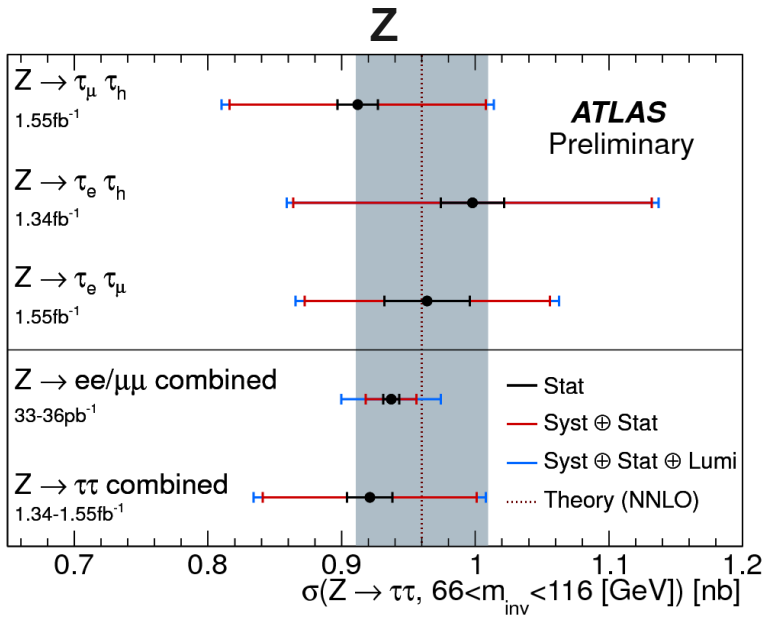
PLB 706 (2011) 276-294

- Provides a validation of τ reconstruction and identification
- Latest Z cross-section results use lh and ll channels:
  - ↳ ~10% systematic uncertainty
- Production cross section in the different W/Z leptonic decays are consistent



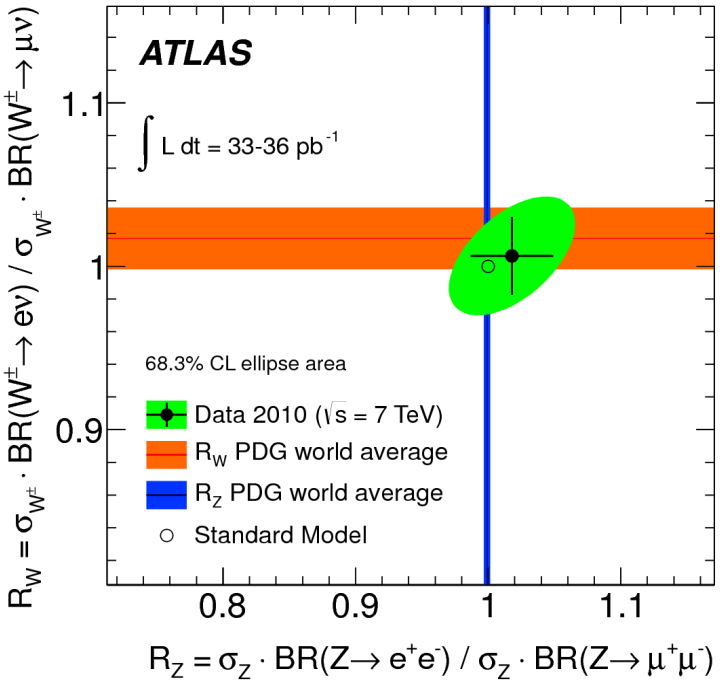




Lepton universality

arXiv:1109.5141

- Ratios of e and μ cross sections evaluated in a common fiducial region
- R_W = 1.006 ± 0.024 to be compared with the world average 1.017 ± 0.019
- e-μ universality is also confirmed in Z decays:
  - ↳ 1.018 ± 0.031
  - ↳ World average (dominated by LEP): 0.9991 ± 0.0024



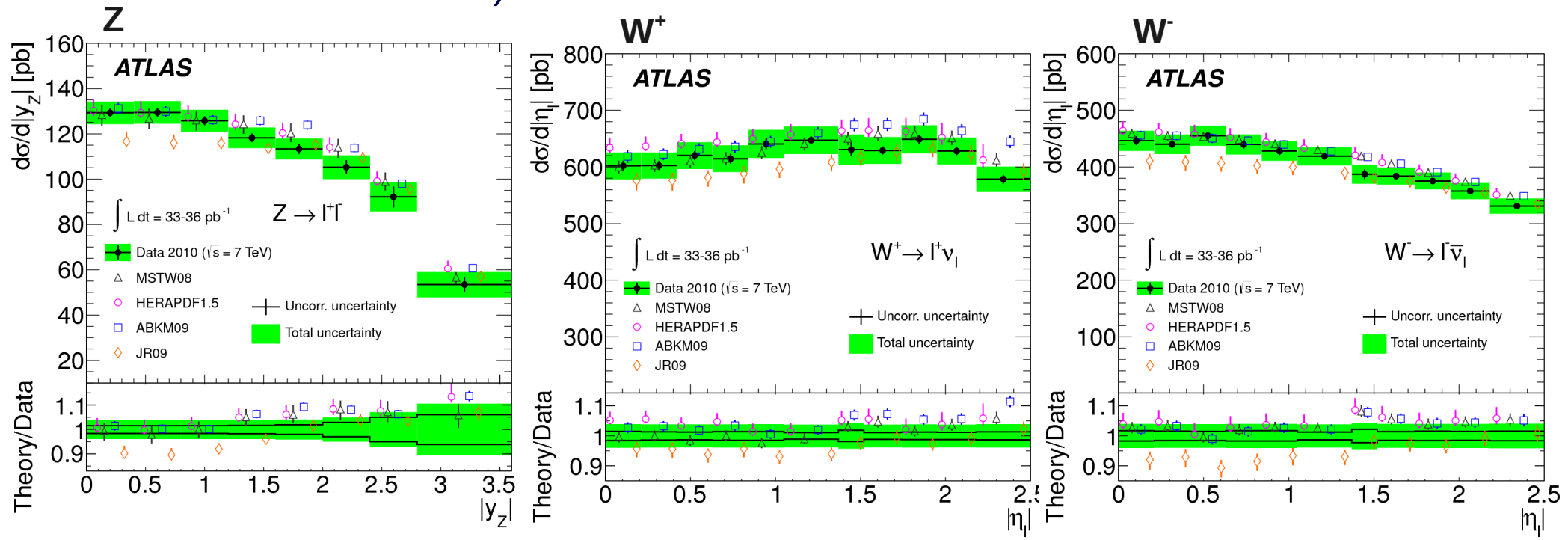
W & Z rapidity differential measurement

arXiv:1109.5141

- Boson rapidity y directly linked to parton momentum fractions

$$x_{1,2} = M_{W,Z} / \sqrt{s} \cdot e^{\pm y}$$

- For W, the pseudo-rapidity of the charged lepton is used
- Comparison with NNLO predictions using NNLO PDF sets.
  - ↳ Some tension with all PDF sets (especially JR09 and ABKM09)
  - ↳ W/Z LHC measurements can provide additional constraints on PDFs, especially on the strange quark density (see talk by U. Klein in “Structure functions” session).

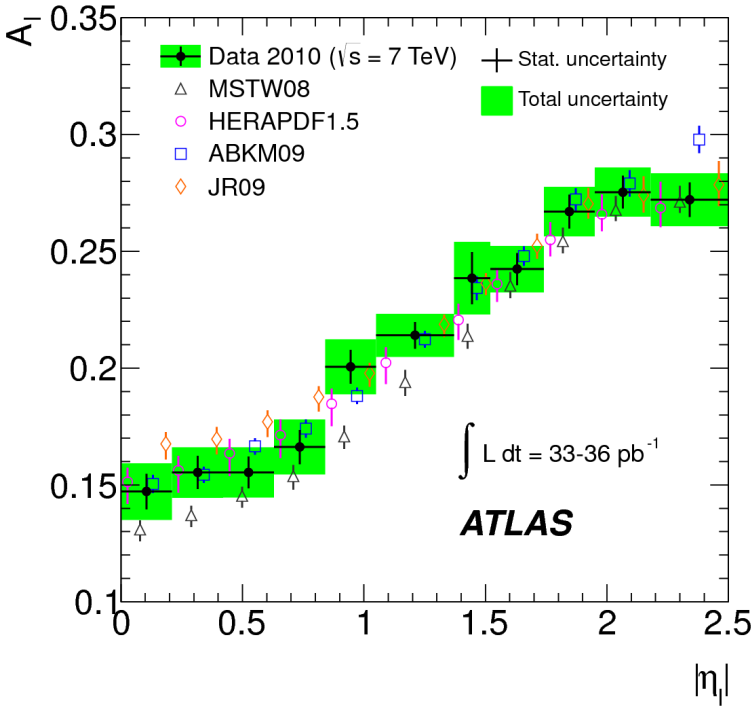


W charge asymmetry

arXiv:1109.5141

- Cannot reconstruct the W kinematics completely: the charge lepton asymmetry is used
- Some tension with MSTW08 and JR09
- Good agreement with ABKM09
  - ↳ But discrepancies for individual cross-sections (previous slide)
  - ↳ Points to fortuitous cancellation in the asymmetry measurement
  - ↳ More information in the individual cross sections (with correlations)

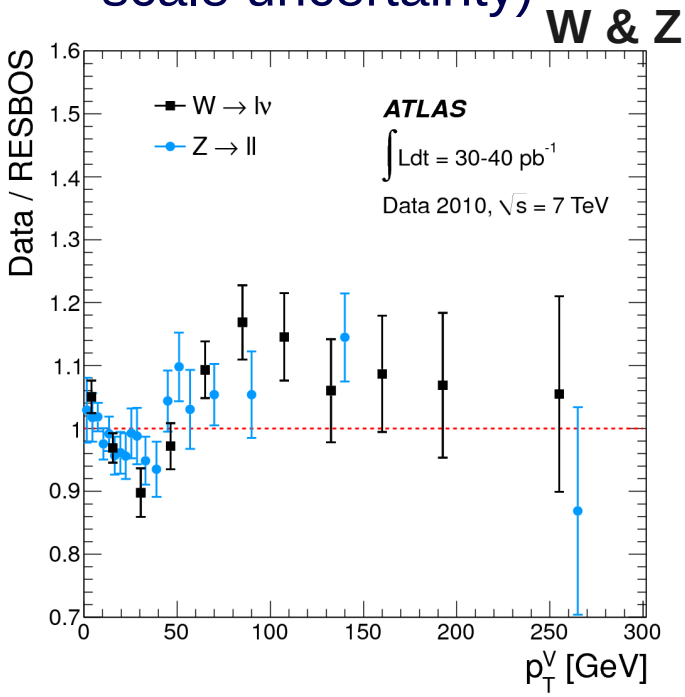
$$A_l = \frac{\sigma^{\text{fid}}_{W+} - \sigma^{\text{fid}}_{W-}}{\sigma^{\text{fid}}_{W+} + \sigma^{\text{fid}}_{W-}}$$

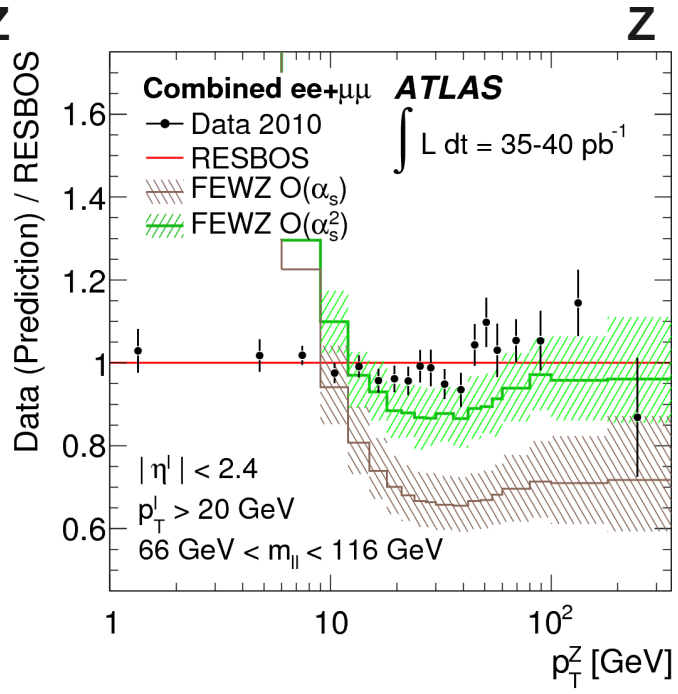


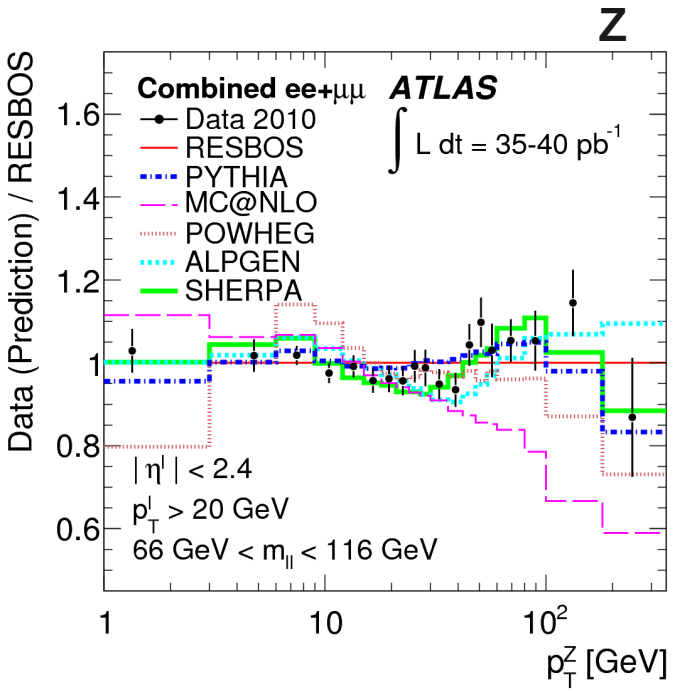
W & Z p_T differential measurement

PLB 705 (2011) 415-434
arXiv:1108.6308

- Non-zero p_T generated through ISR
  - ↳ Low p_T : multiple soft/collinear partons → logarithmic resummations, PS
  - ↳ High p_T : ≥ 1 hard partons → test $O(\alpha_s^2)$ calculations, NLO ME, tree-level LO ME
- Good description for RESBOS, ALPGEN, SHERPA, and also PYTHIA
- MC@NLO (interfaced with HERWIG+JIMMY) and POWHEG (interfaced with PYTHIA) deviate at low and high p_T
- Z p_T: pQCD prediction at $O(\alpha_s^2)$ undershoots the data by ~10% (similar to the scale uncertainty)







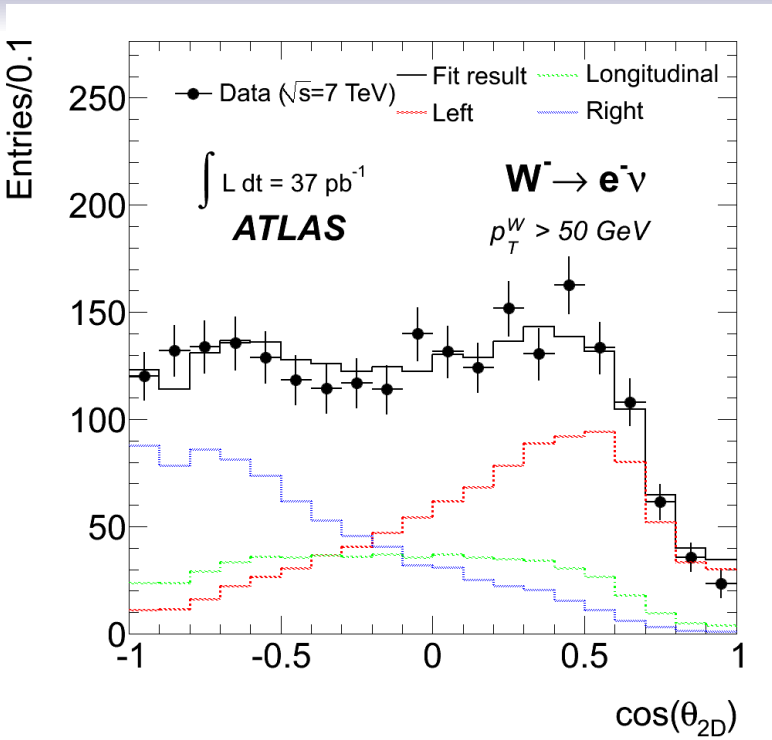
W polarisation

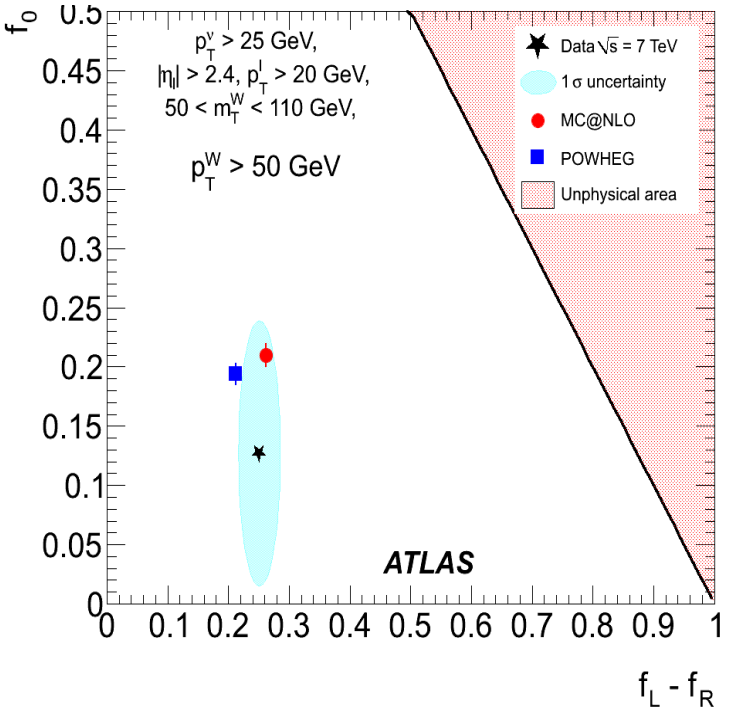
arXiv:1203.2165

- W bosons can be produced in 3 polarisation states: f_L, f_R, f_0
  - ↳ LO → right- and left-handed (predominantly left-handed)
  - ↳ NLO → longitudinal polarisation also possible
- Measured at significant p_T (sensitive to the gluon PDF): 35 GeV < p_T^W < 50 GeV & p_T^W > 50 GeV
  - ↳ Makes use of the transverse helicity angle:

$$\cos\theta_{2D} = \frac{\vec{p}_T^{\,l} \cdot \vec{p}_T^{\,W}}{|\vec{p}_T^{\,l}| \cdot |\vec{p}_T^{\,W}|}$$

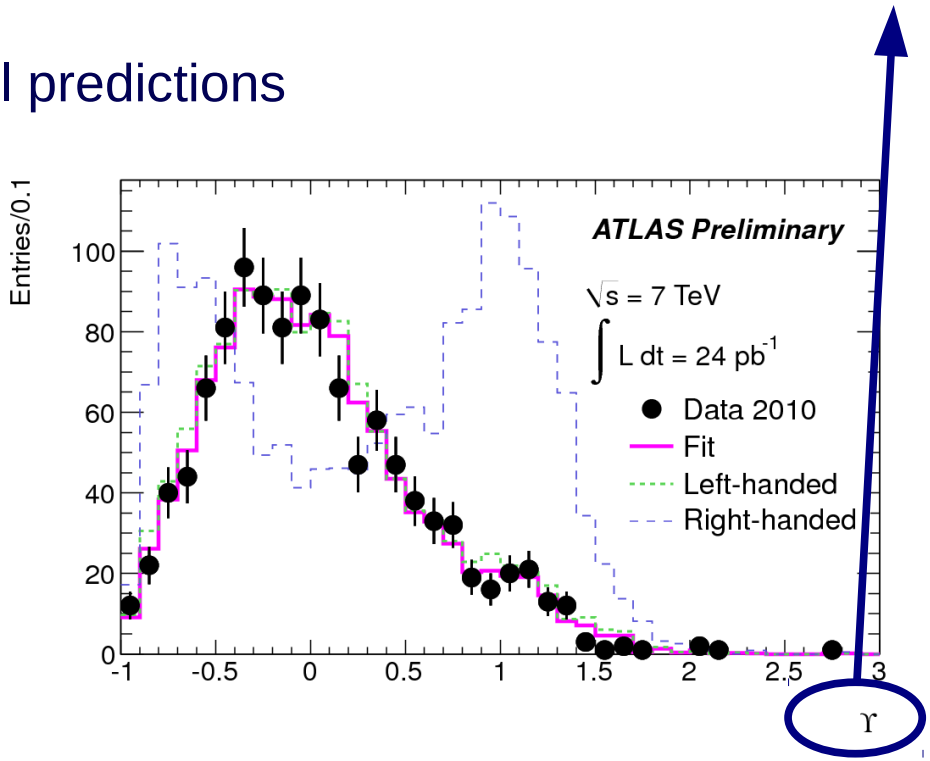
    - $\vec{p}_T^{\,l}$ in the transverse W rest frame
    - $\vec{p}_T^{\,W}$ in the laboratory frame
  - ↳ Distributions fitted with templates representing each polarisation state
- Good agreement with NLO





τ polarisation

- Measurement of τ polarisation in hadronic τ decay from W → τν
  - ↳ Degree of parity violation in the tau production mechanism
  - ↳ For W → τν, the predicted value is -1 (parity is maximally violated in the charged-current weak decays)
- Use 1-prong decays:
  - ↳ Look at energy sharing between charged an neutral pions $\Upsilon = \frac{E_{\mathrm{T}}^{\pi^-} - E_{\mathrm{T}}^{\pi^0}}{p_{\mathrm{T}}^{\mathrm{tau}}}$
  - ↳ $P_\tau = -1.06 \pm 0.04\,(stat.)^{+0.05}_{-0.07}(sys.)$
  - ↳ In agreement with the Standard Model predictions
- The method can be applied to the characterization of new phenomena
  - ↳ SM H → ττ
  - ↳ MSSM charged Higgs
  - ↳ ...



Summary & Conclusion

- High production rate of W and Z bosons enable detailed studies
  - ↳ Precise differential cross sections → impact on our knowledge of proton structure
  - ↳ Test of pQCD predictions and phenomenological models
  - ↳ W polarisation is found to be consistent with NLO calculations
- Ability to measure $Z \rightarrow \tau\tau$ and $W \rightarrow \tau\nu$
  - ↳ Integrated cross section
  - ↳ τ polarisation
- Ongoing effort for publication of W/Z results based on the full 2011 dataset