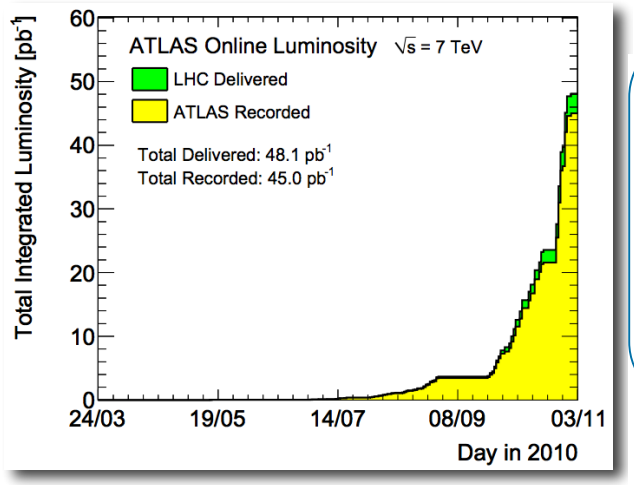
Gauge Boson Measurements and PDF fits in the DESY ATLAS Group

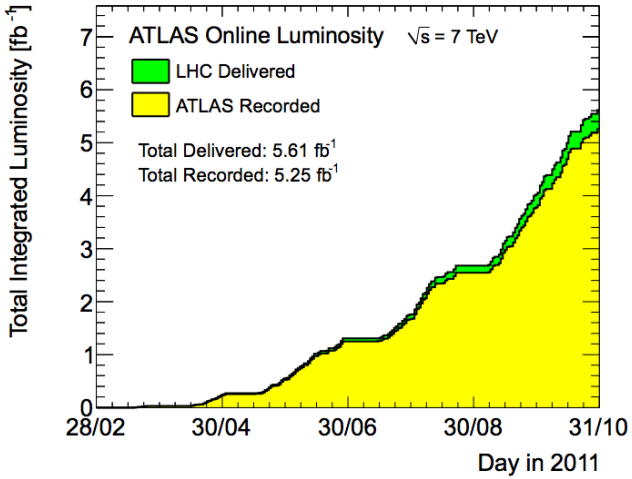
OUTLINE

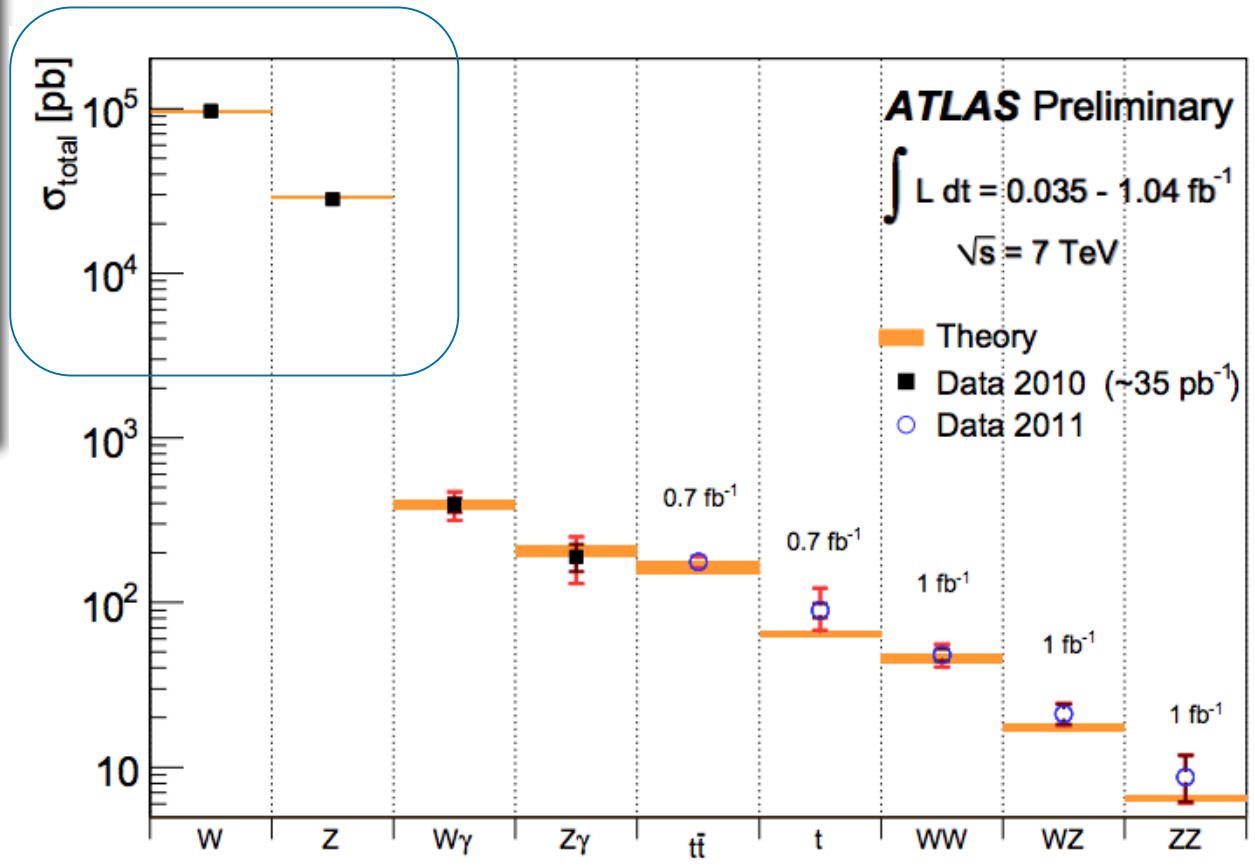
- W and Z production at LHC
  - o electron and muon channels
- QCD analysis and sensitivity to the strange PDF
  - o HERAFitter framework
- Prospects and concluding remarks

ATLAS Performance

- Successful run in 2010 and 2011 enabled a rediscovery of SM processes at the LHC







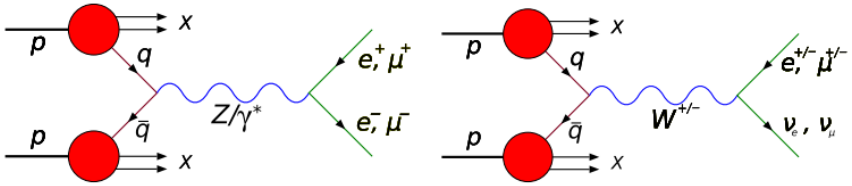
W, Z 2010: arXiv:1109.5141 https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PAPERS/STDM-2011-06/

QCD analysis: submitted to archive https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PAPERS/STDM-2011-43/

W and Z production at LHC

- Drell-Yan production of W and Z bosons calculable to high orders in pQCD
  - Cross sections are given by a convolution of the parton densities and coefficient functions

$$\sim x_1 f_1(x_1,\mu)\, x_2 f_2(x_2,\mu)\, \hat{\sigma}(x_1,x_2,\mu)$$

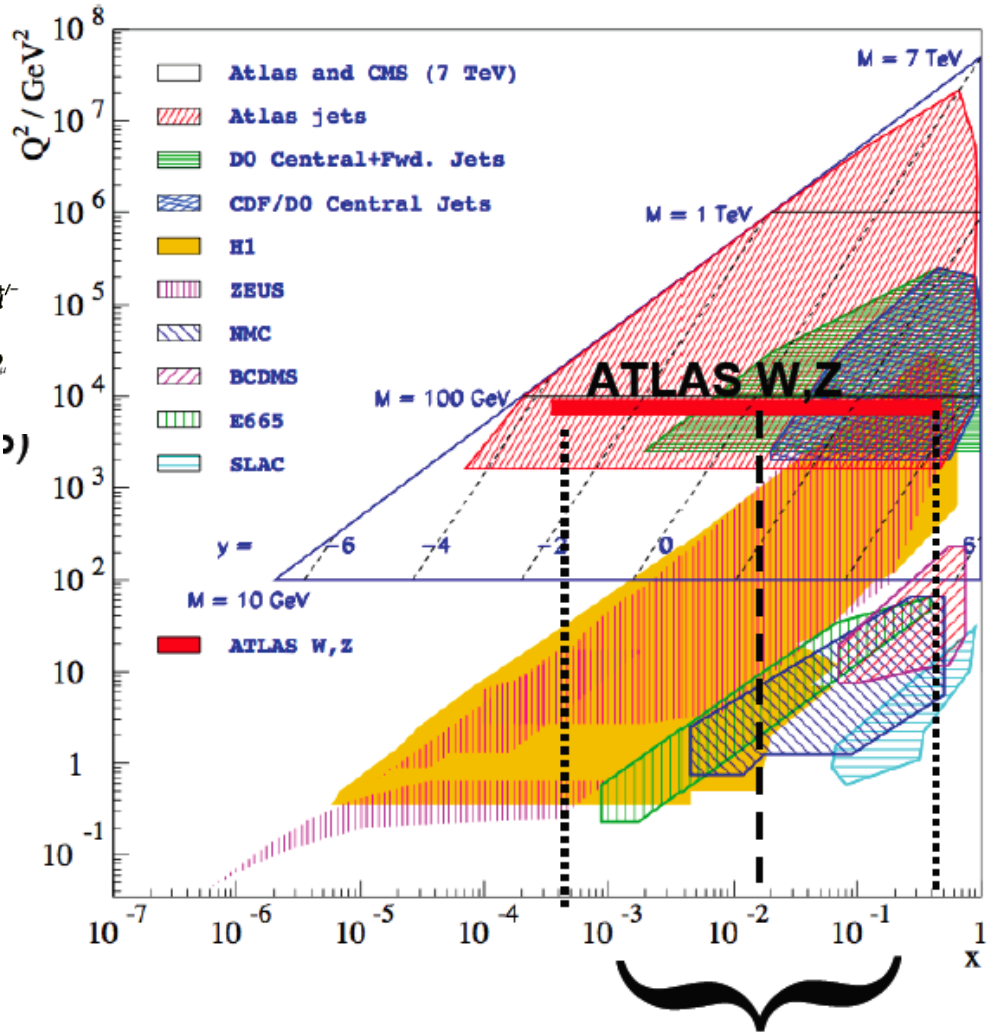


- ATLAS data in kinematic range given by boson masses W, Z and the Ep=3.5 TeV
- Kinematic variables are related via

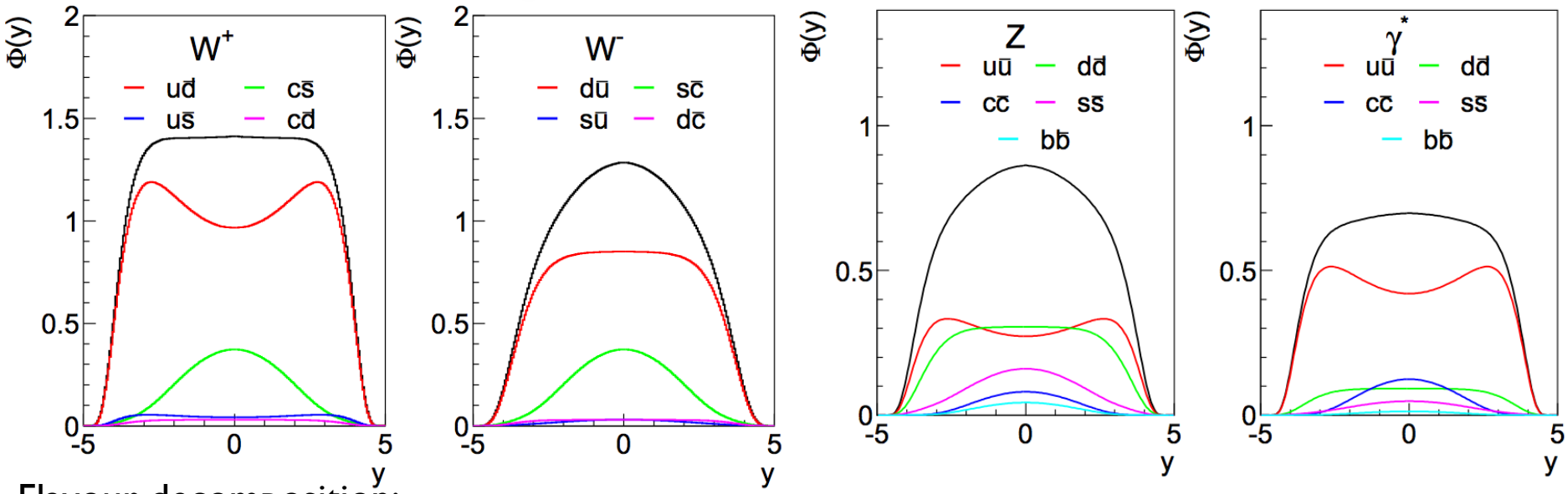
$$x_{1,2} = \frac{M_{\ell\ell}}{\sqrt{S}} e^{\pm y_{\ell\ell}}$$

  - Corresponds to $Q^2=M_Z^2$ and $0.001<x<0.1$

- Interpretation of EW physics results at the LHC requires an accurate theory predictions to match experimental precision
  - An interesting testing ground of PDFs



Flavour decomposition of W and Z and the LHC



Flavour decomposition:

For Ws:

- ud dominates for W
  - u_{val} peaks at large rapidity
- sc important at mid y

$$W^+ \sim 0.95(u\bar{d} + c\bar{s}) + 0.05(u\bar{s} + c\bar{d})$$
$$W^- \sim 0.95(d\bar{u} + s\bar{c}) + 0.05(d\bar{c} + s\bar{u})$$

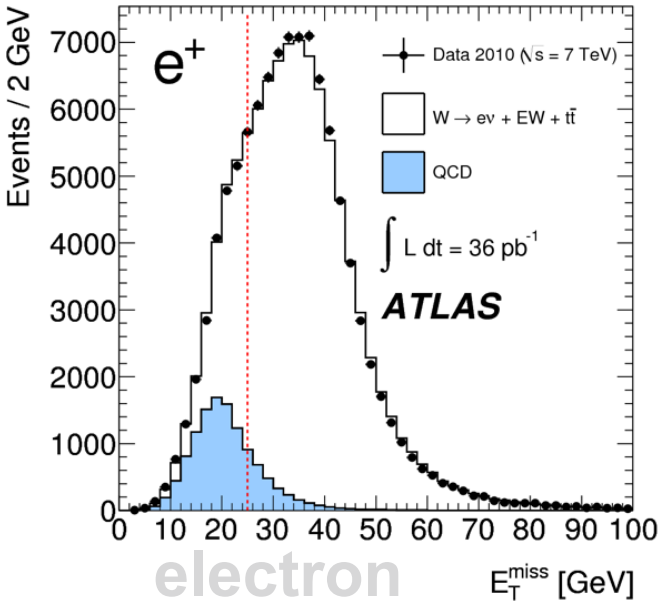
For Z:

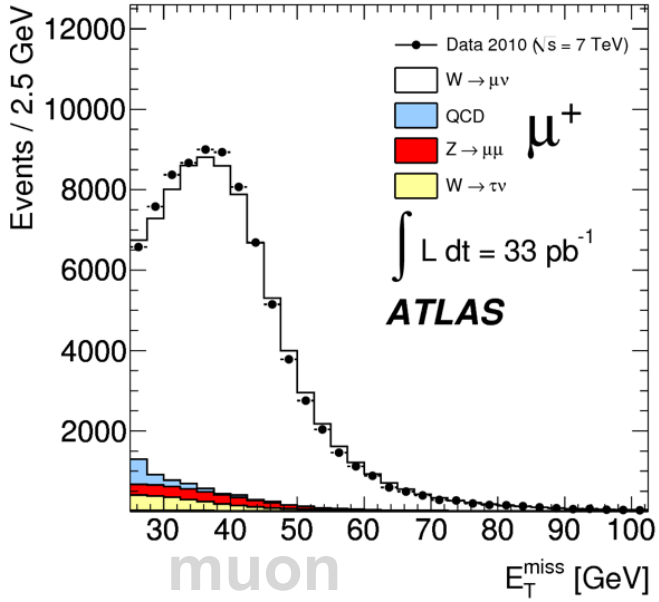
- all flavours contribute, even b is significant
- larger coupling to d compared to u vs γ^* due to different couplings

$$Z \sim 0.29(u\bar{u} + c\bar{c}) + 0.37(d\bar{d} + s\bar{s} + b\bar{b})$$
$$\gamma^* \sim 0.44(u\bar{u} + c\bar{c}) + 0.11(d\bar{d} + s\bar{s} + b\bar{b})$$

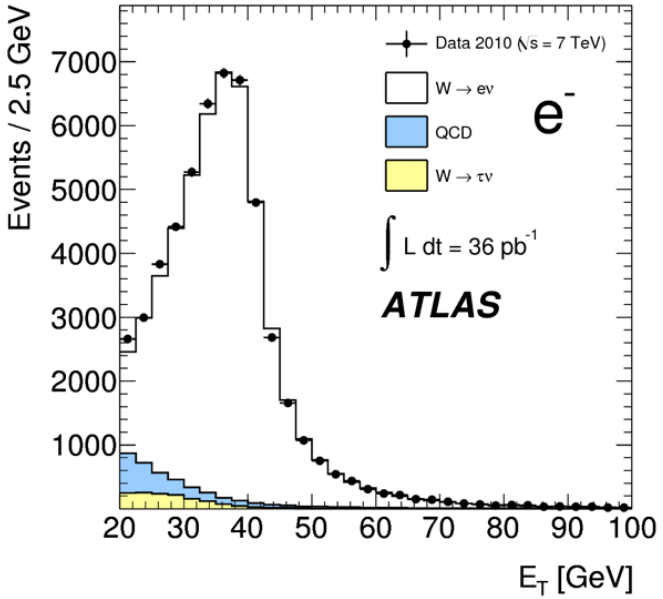
Measurements of W, Z production differentially in y_Z and η_ℓ provide information on light sea decomposition

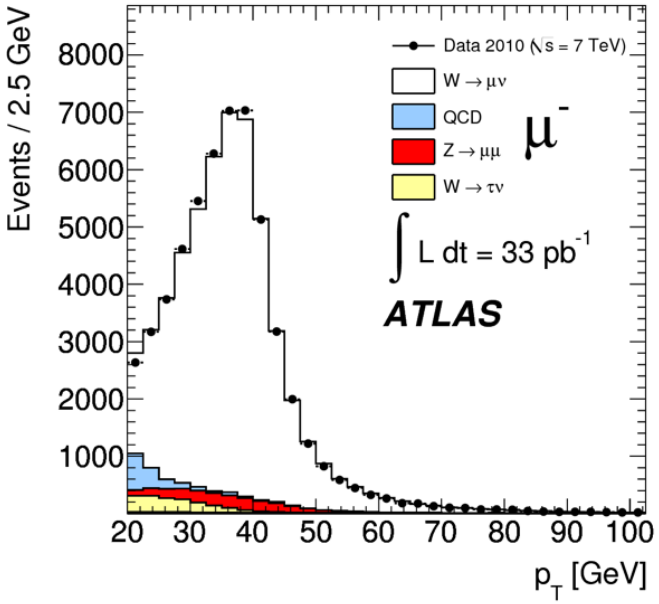
W→lν selection



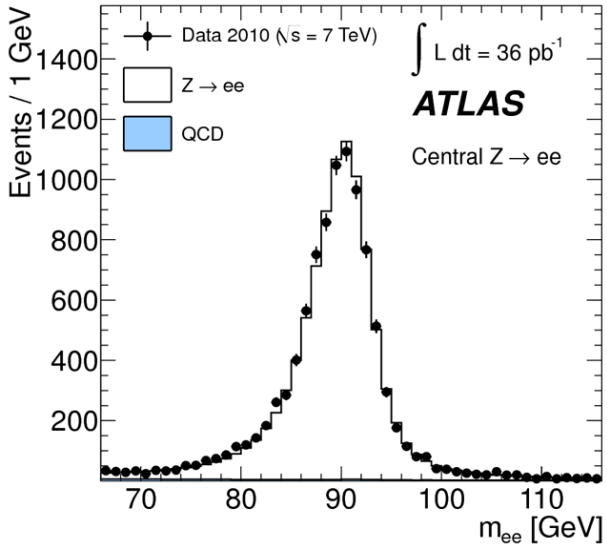


- Single lepton triggers with high efficiency:
  - $p_{T,l}$ > 20 GeV
  - $|\eta_e|$ <2.47, $|\eta_\mu|$ <2.4
  - Isolated leptons
  - $E_T$miss >25 GeV,
  - m_T > 40 GeV
- 131-140 K candidates with 7~9 % background

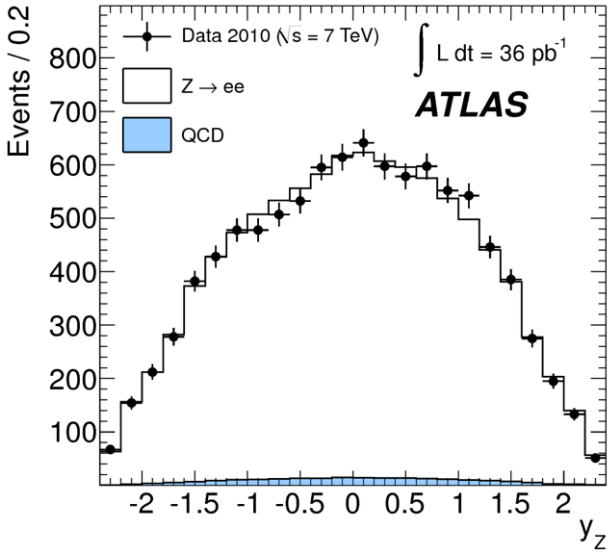




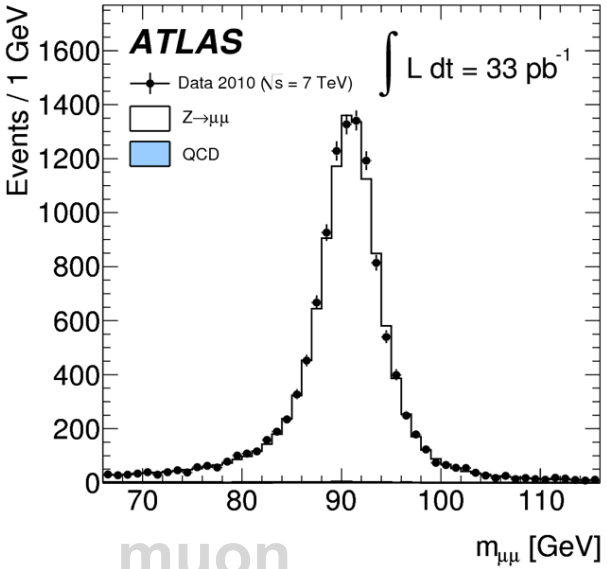
Z→ll selection (central region)



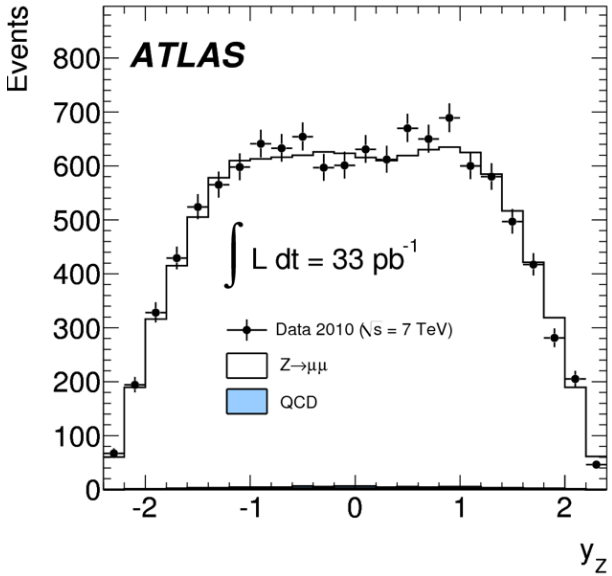
Central elec



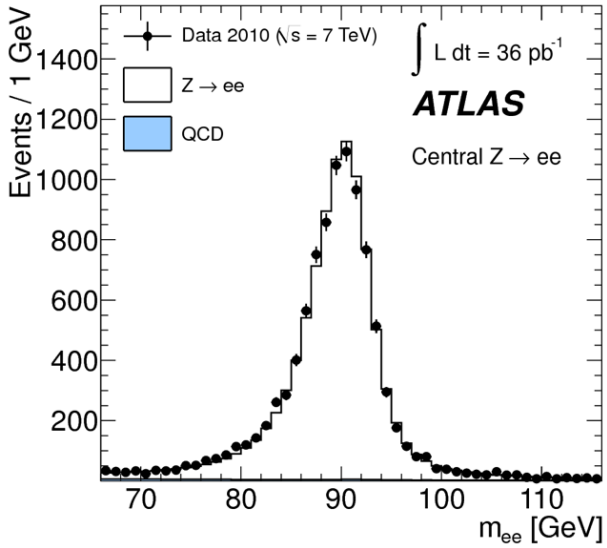
- Single lepton triggers with high efficiency:
  - $p_{T,l}$ > 20 GeV
  - Central Z:
    - Both $|\eta_e|$ <2.47, $|\eta_\mu|$ <2.4
  - Forward Z:
    - One $|\eta_e|$ <2.47
    - Other 2.5<$|\eta_e|$ <4.9
  - Opposite charge leptons
  - 66<mll <116 GeV
- 10-12 K candidates with 1~2 % background



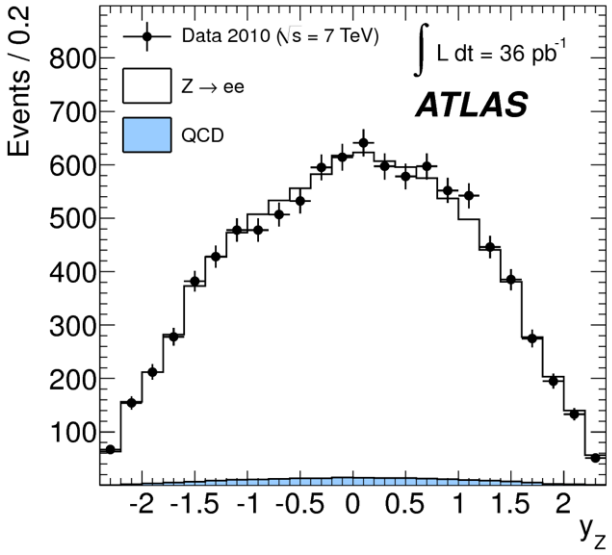
muon



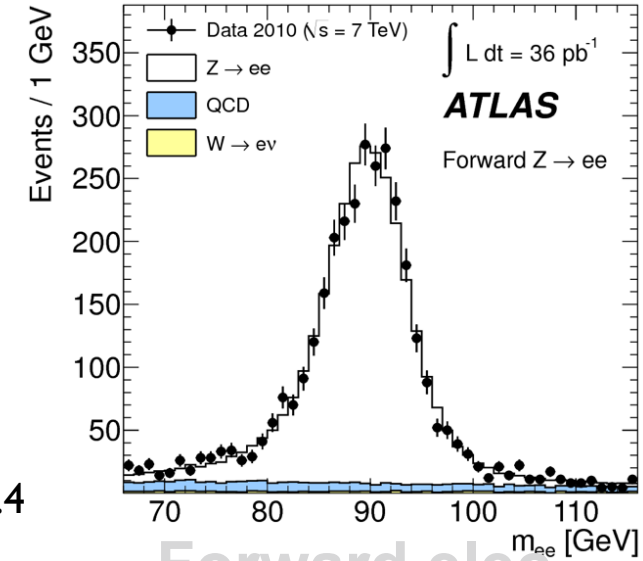
Z→ll selection (forward region)



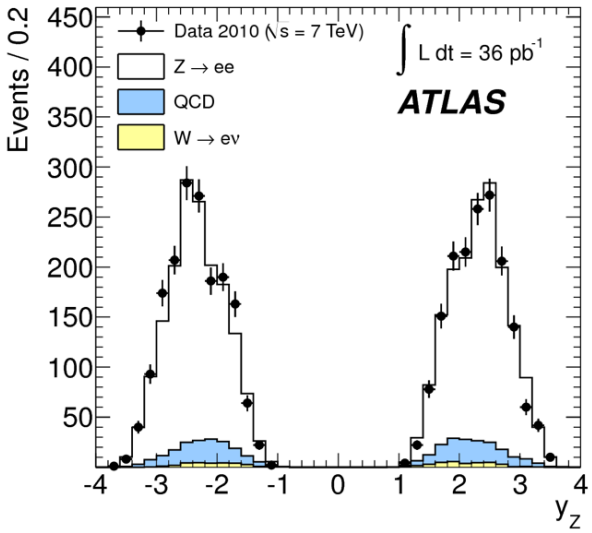
Central elec



- Single lepton triggers with high efficiency:
  - $p_{T,l}$ > 20 GeV
  - Central Z:
    - Both $|\eta_e|$ <2.47, $|\eta_\mu|$ <2.4
  - Forward Z:
    - One $|\eta_e|$ <2.47
    - Other 2.5<$|\eta_e|$ <4.9
  - Opposite charge leptons
  - 66<mll <116 GeV
- 10-12 K candidates with 1~2 % background

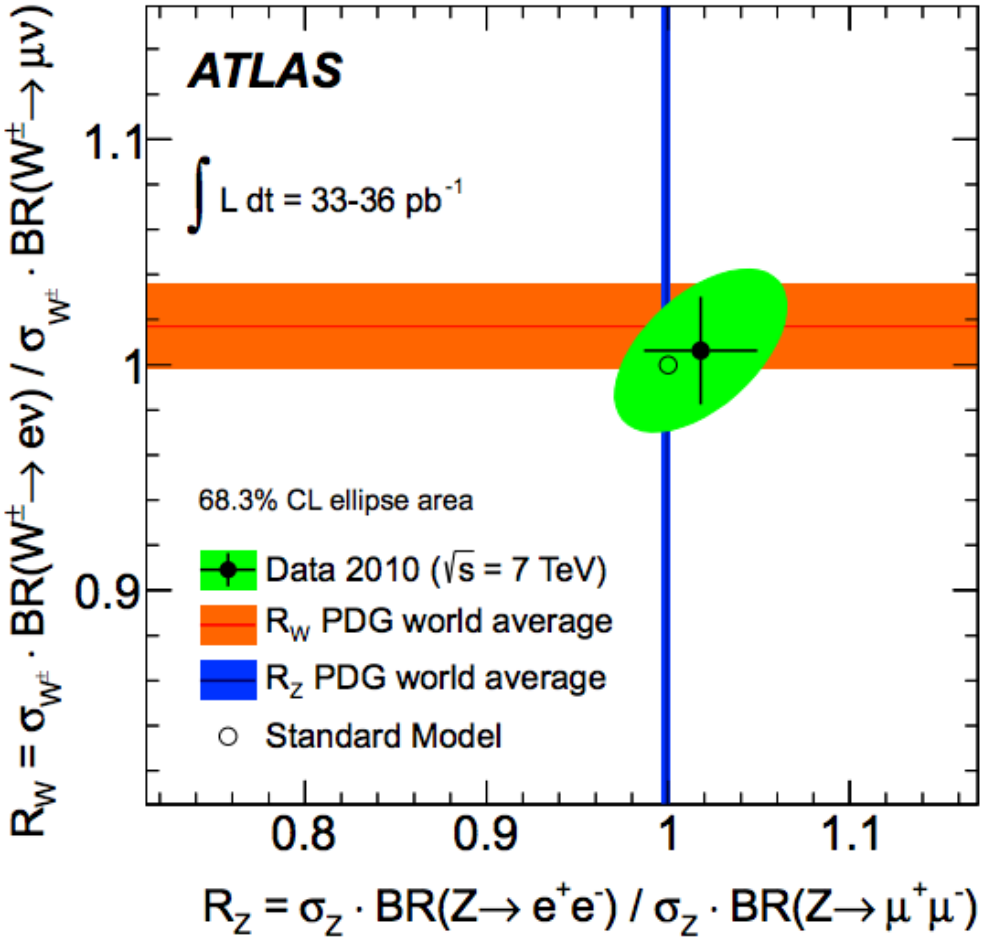


Forward elec



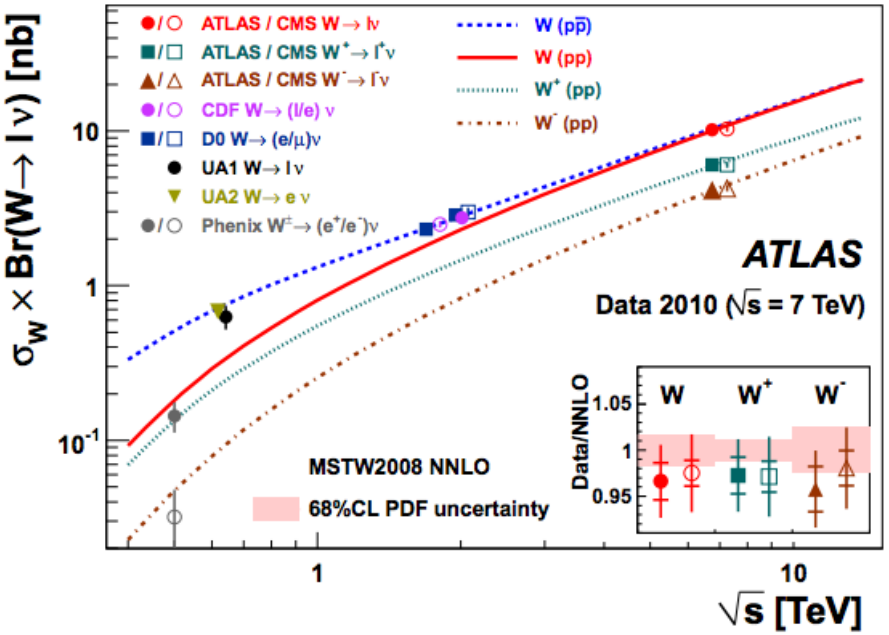
Electron-Muon Universality

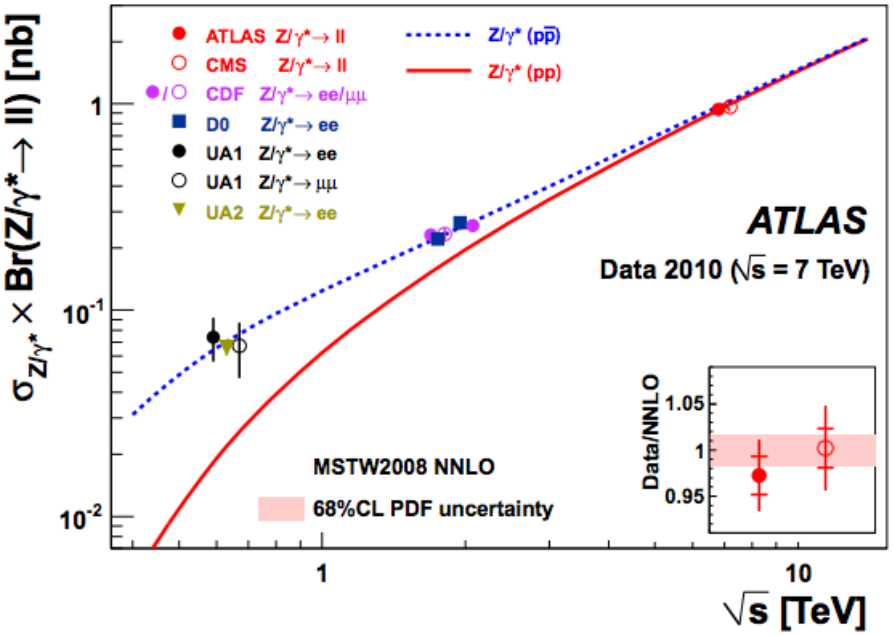
- The e and μ cross-section measurements are extrapolated from the fiducial volume to the common phase space.
- Ratio of cross-section measurements in e and μ channel provides lepton universality check.



Comparison to World Data

- The measured values of σ_W (xBR) and σ_Z (xBR) are combined for electron-muon channels and extrapolated to the full space
- Measurements are compared to other data and theory predictions at NNLO (MSTW2008) for both pp and ppbar colliders

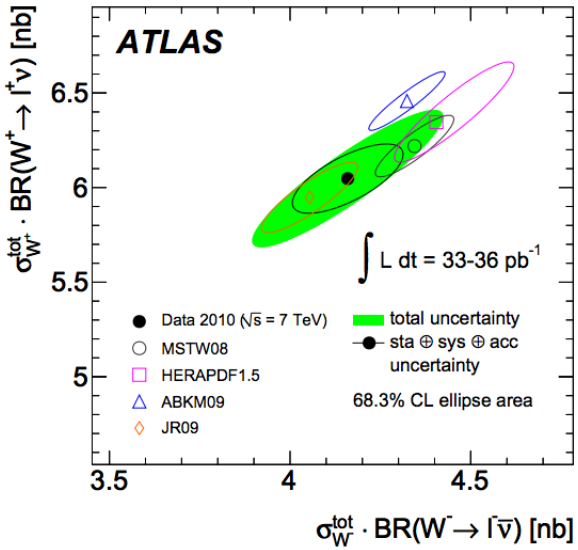


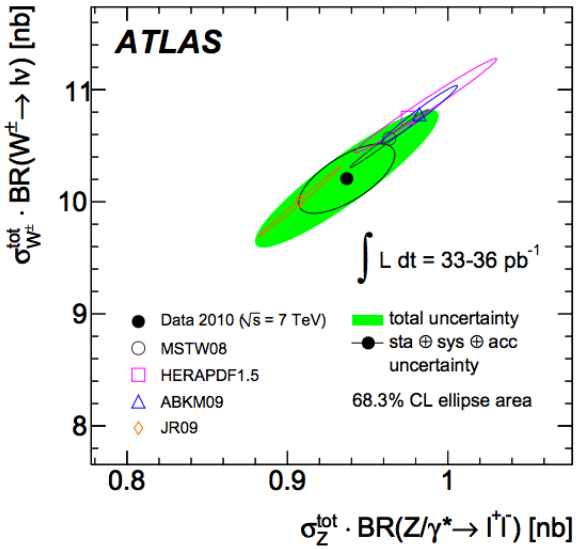


Total vs Fiducial Volume Cross Sections Results

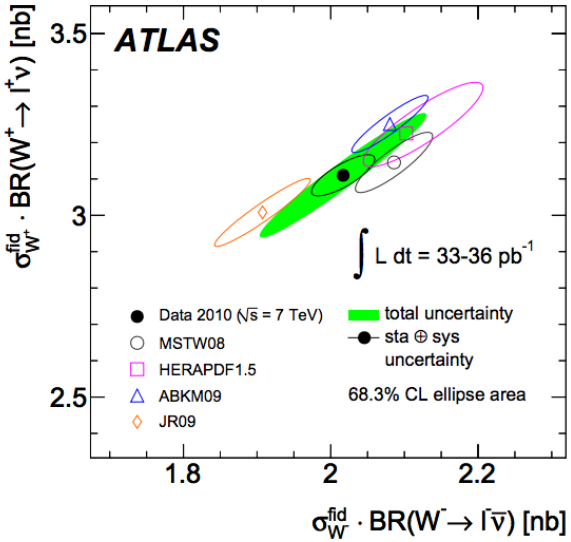
- NNLO Theory comparison in remarkable agreement
- Comparison to total cross sections requires extrapolation from the fiducial volume:
  - ~ 2% uncertainty in extrapolation which is larger than experimental uncertainty
- Comparison in the fiducial region disentangle theory and experimental effects
  - ~1% uncertainty enables more interesting comparison to PDFs

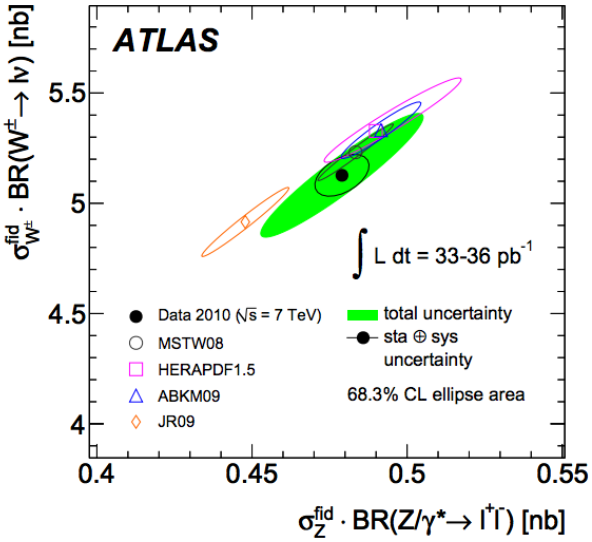
TOTAL





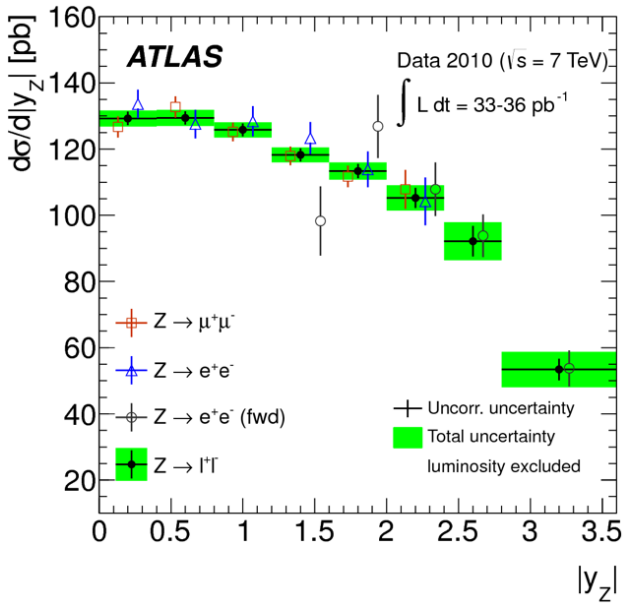
Fiducial

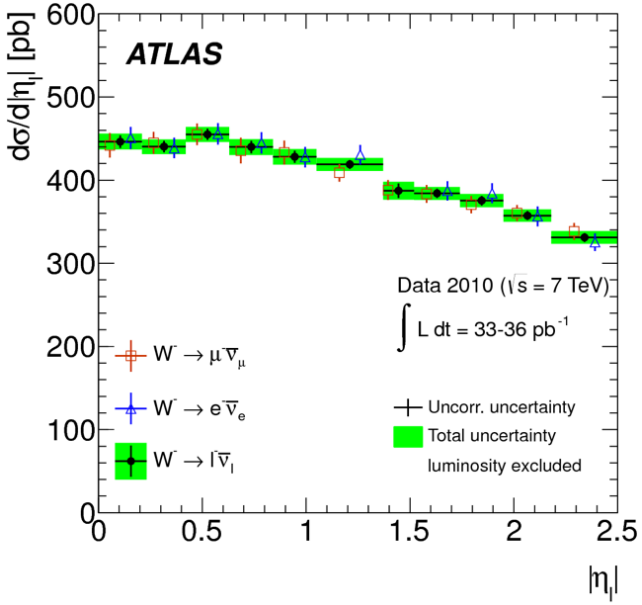


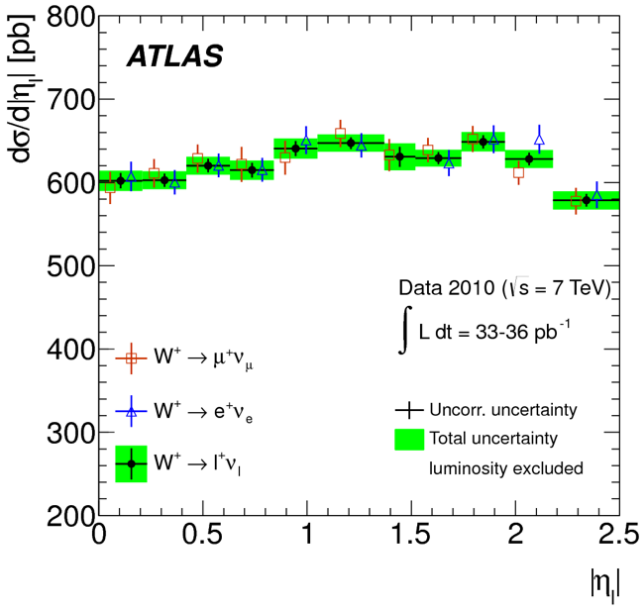


W and Z (pseudo)-rapidity Differential Cross Section

- The electron and muon measurements are found to be consistent in the three channels: W+, W-, Z
- Data sets are therefore combined using a method which accounts for the different systematic error correlations (developed at DESY)
  - Combination yields an accurate rapidity dependent cross sections with a precision in the fiducial region of 2% (apart from very forward region)

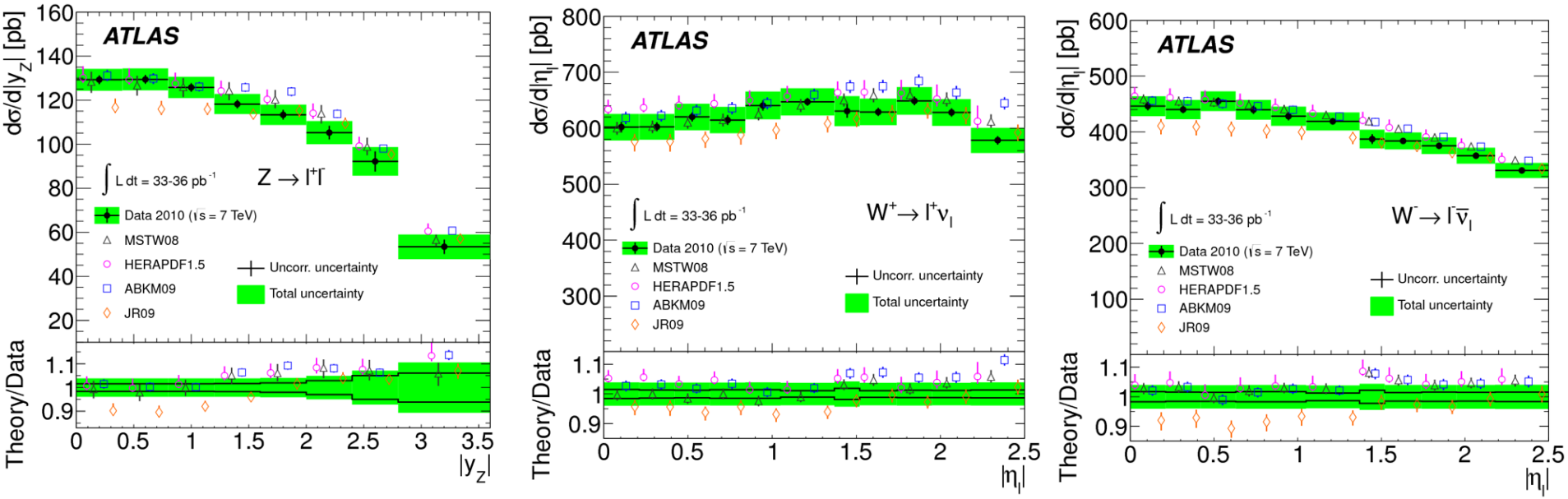






Comparison with PDF predictions at NNLO

- Measurements of differential cross sections are compared to NNLO predictions based on NNLO PDFs:
  - have the potential to bring impact on PDFs, as there is some tension among PDF sets, especially for the Z cross sections where all PDF considered have a suppressed strange quark density.



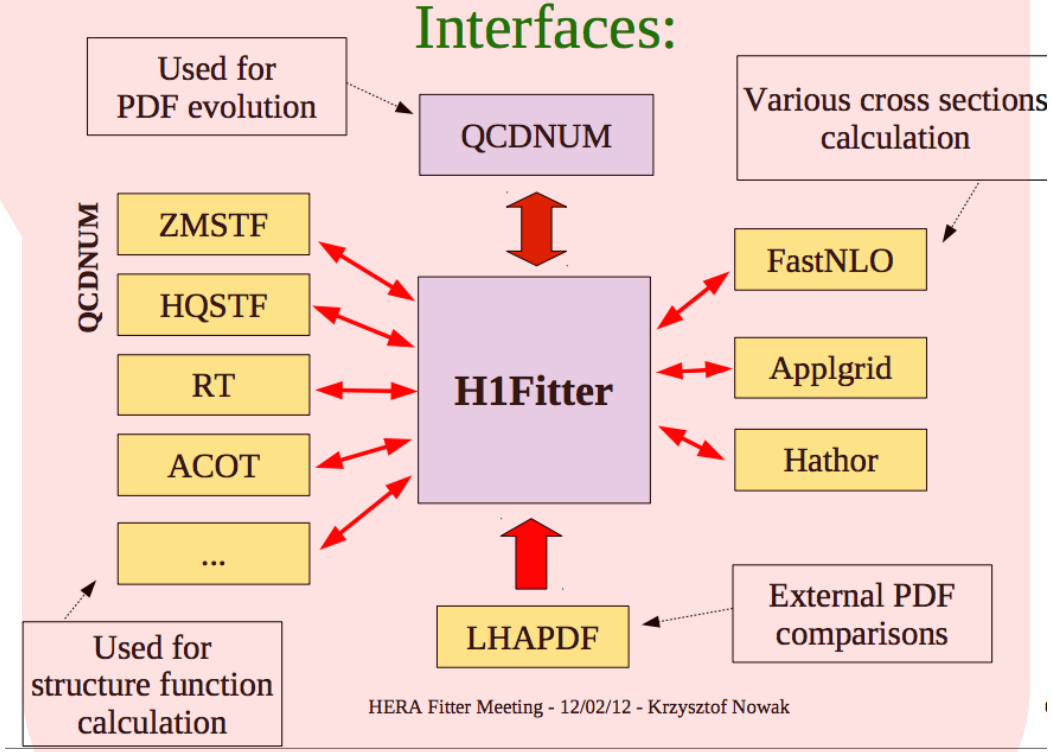
→ ratio of W/Z cross sections may give a handle on s-quark density.

QCD Analysis Framework: HERAFitter

PDFs are extracted through QCD Fit analysis:

- Open source HERAFitter framework
  http://projects.hepforge.org/herafitter/
- Fits performed at NNLO
- W, Z cross sections are calculated via APPLGRID interfaced to MCFM at NLO and then applied kfactors from NLO to NNLO calculated with the parton-level programs DYNNLO and FEWZ
- Electroweak parameters are calculated in the G_mu scheme, where remaining HO EW and QCD corrections are included in the definitions of the couplings/widths

- HERAFitter is a modular platform:
  (developed at DESY)



ATLAS determination of the strange sea density

- To assess the impact of ATLAS data, a minimum set of input data are used to allow PDF determination:
  - HERA I combined data [JHEP 01, 109, 2010] ATLAS W, Z data [CERN-PH-EP-2011-06]
    - NC, CC e+p and e-p $1<Q^2<10000$ and $0.0001<x<0.65$
- Two types of fit are performed with different treatments of strangeness:
  - Fixed Strange fit: At the starting scale, strange is fully coupled to down sea

$$r_s = 0.5(s+\bar{s})/\bar{d},\ r_s = 0.5$$

  - Free Strange fit: parametrise strange distribution as done with other individual PDFs

$$x\bar{s} = xs = r_s A_{\bar{d}} x^{B_{\bar{d}}}(1-x)^{C_s}$$

- For the region at the maximum of ATLAS data sensitivity extrapolated to low Q^2

$$r_s = 1.00 \pm 0.20_{\text{exp}} \pm 0.07_{\text{mod}}{}^{+0.10}_{-0.15}{}_{\text{par}}{}^{+0.06}_{-0.07}\alpha_S \pm 0.08_{\text{th.}}$$

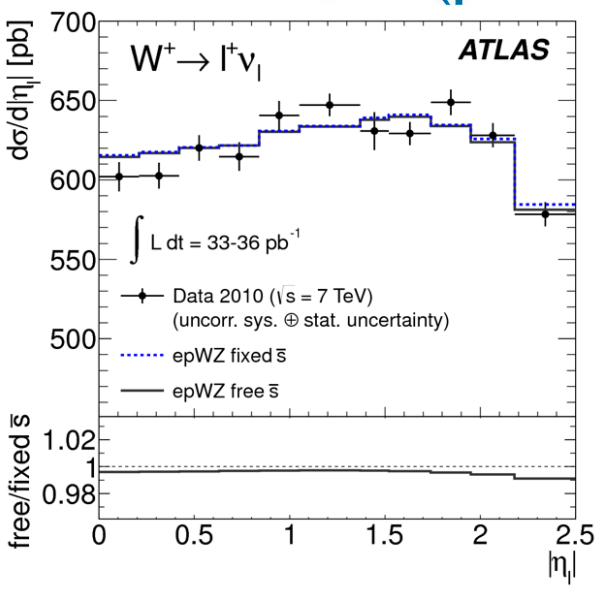
Fit with fixed $r_s = 0.5$

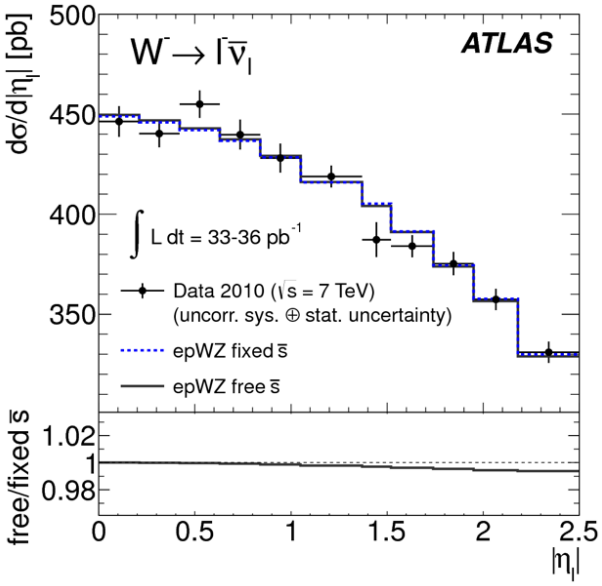
Channel	Partial χ^2/N_{DF}
Systematics	5.4
Total ATLAS	44.2/30
Total ATLAS+HERA	477.1/567

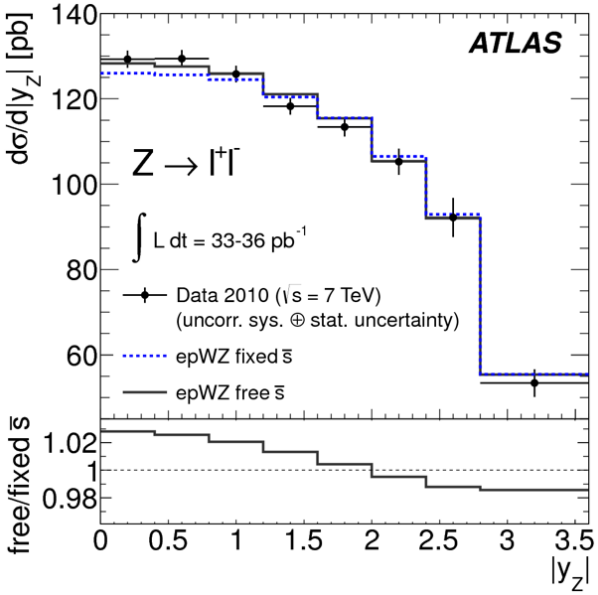
Fit with free strange

Channel	Partial χ^2/N_{DF}
Systematics	2.3
Total ATLAS	33.9/30
Total ATLAS+HERA	470.3/565

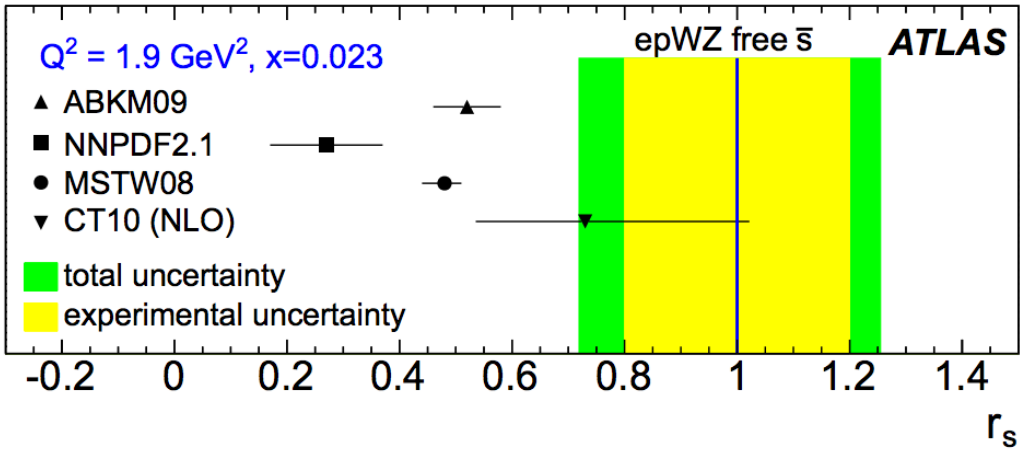
$W^{\pm}$, Z (pseudo-)rapidity Cross Sections and Rs





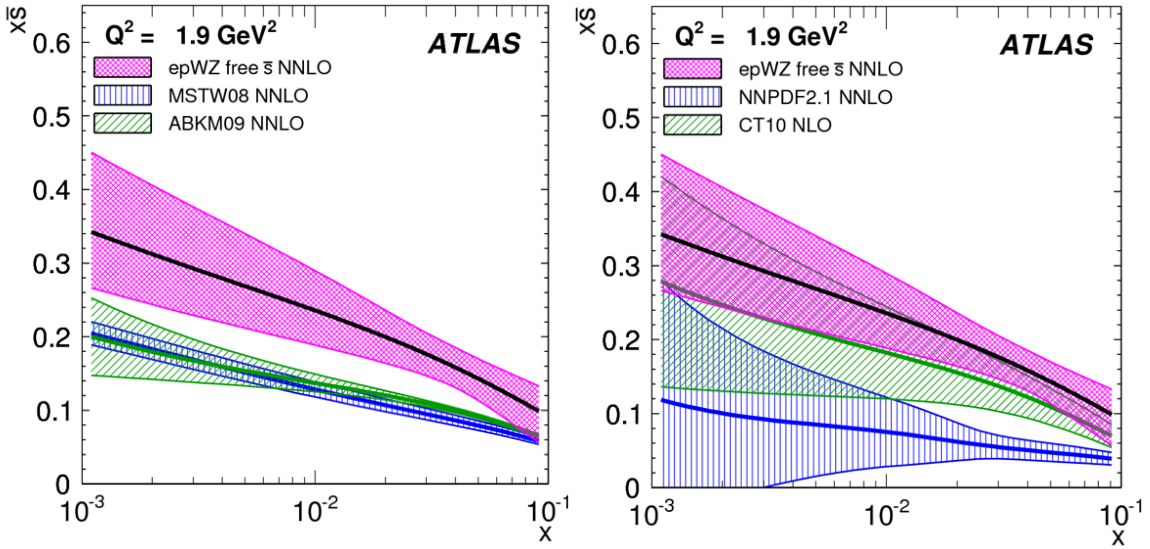


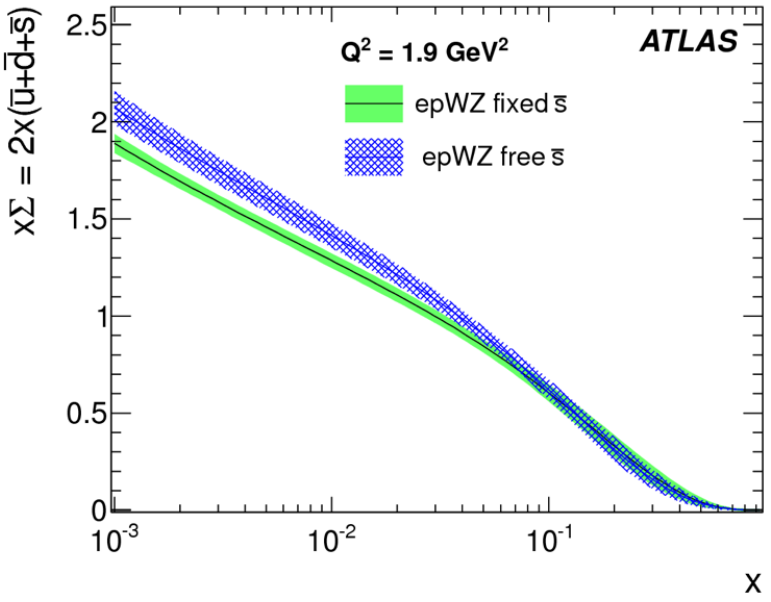
- The results for NNLO fits with free and fixed strangeness
  - For W+ and W- there is little difference
  - For Z instead, the total cross section is increased and the shape is modified.



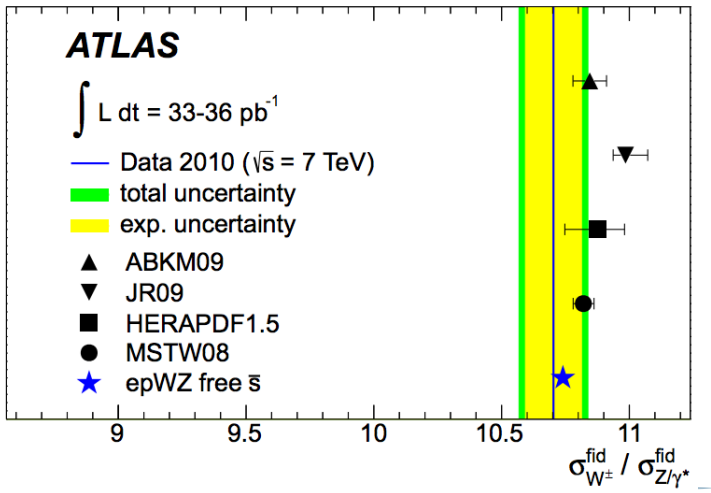
ATLAS result is consistent with CT10 (NLO) and is above MSTW08, ABKM09 and NNPDF2.1 (NNLO) determinations

Strange distribution





- Comparisons of the strange quark density resulting from the present free strangeness epWZ fit with the predictions of different PDF sets.
- A change of the strange density with fixed F2 measured by HERA must affect the light sea xΣ.
  - Enhancement by about 8% at the starting scale
- The free strange fit provides the best description of the measured W/Z cross sections ratio.



Concluding Remarks

- Precision standard model results already with 2010 data.
  - W and Z inclusive cross section in electron and muon channels measured in 2010 dataset with ~ 1% experimental precision and 1.5 – 2% theoretical uncertainty for the extrapolation to full phase-space
  - Absolute rapidity differential cross sections are measured in electron and muon channels and combined with accuracy of ~ 2 % for bulk of measurement bins (central yZ and all W) and of 6 – 10 % for forward Z region

- The first differential $W^{\pm}$, Z cross section data of ATLAS, jointly analysed with $e^{\pm}p$ cross sections from HERA, suggest that the light quark sea is flavour symmetric and increased by ~8%.

- More is to come:
  - 2011 data have ample of statistics for differential W, Z and low/high mass γ^* analyses.

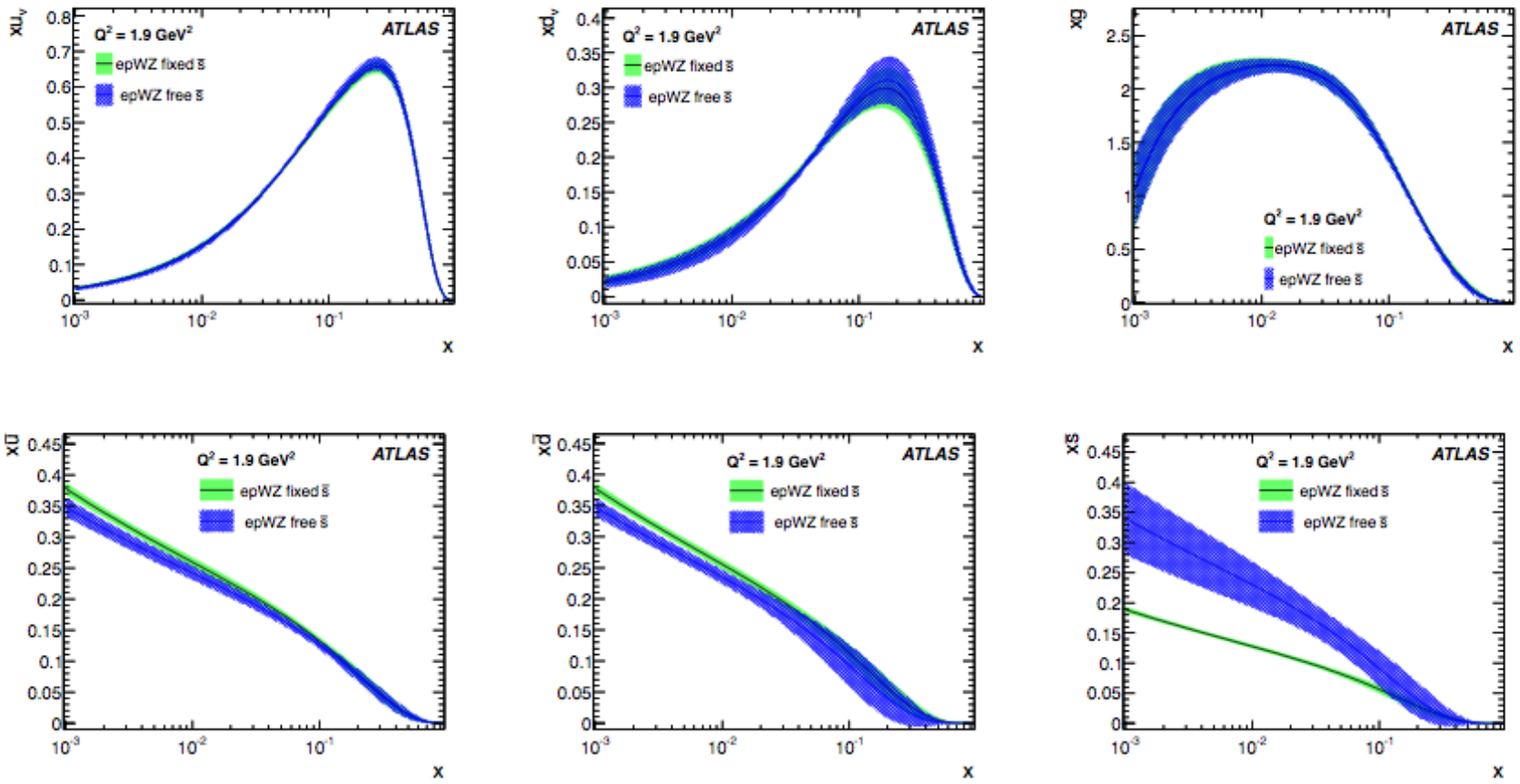


FIG. 4. Comparison of $xu_v(x)$, $xd_v(x)$, $xg(x)$, $x\bar{u}(x)$, $x\bar{d}(x)$ and $x\bar{s}(x)$ distributions and their experimental uncertainty for the epWZ fixed $\bar{s}$ and free $\bar{s}$ NNLO fits at the starting scale $Q^2 = 1.9$ GeV^2.