# New results on W/Z measurements from ATLAS

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FSP 101 ATLAS

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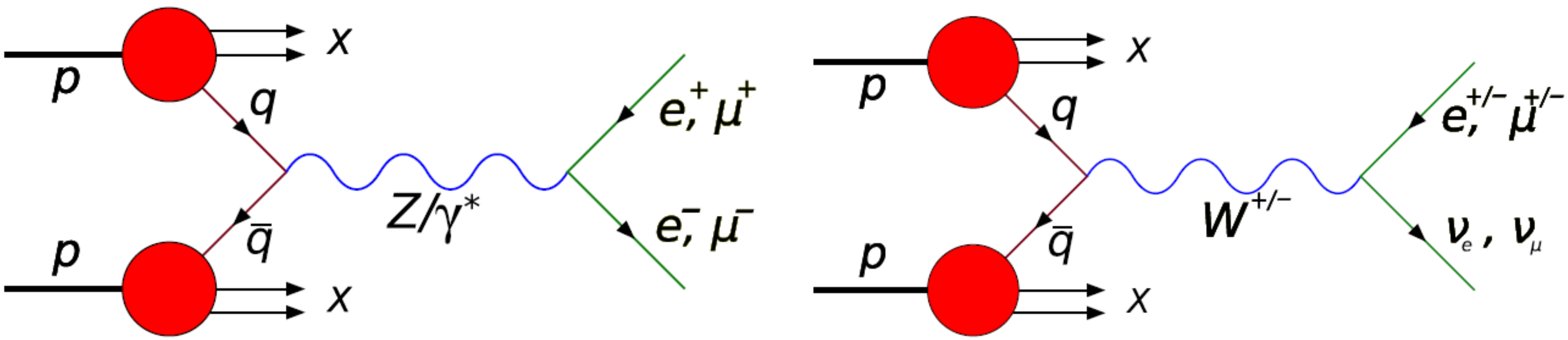
PRISMA

# W/Z production at LHC

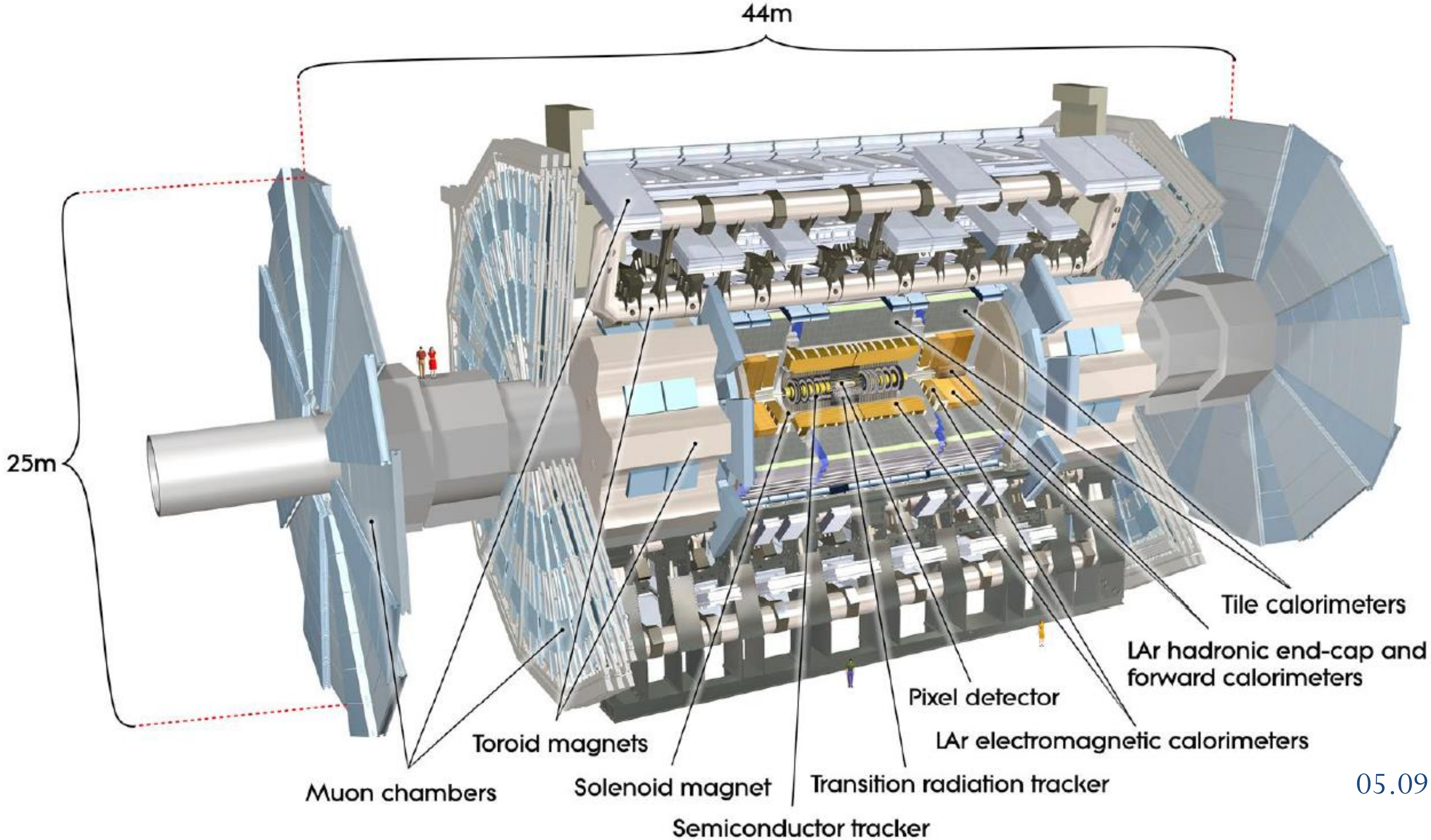
Drell-Yan production of W and Z calculable to high orders in pQCD (diagramm only LO)




- High-mass Drell-Yan cross-sections arXiv:1305.4192
  - Test of perturbative QCD (pQCD), EW corrections, $\gamma$-induced processes, sensitive to poorly known $\bar{q}$ PDF at large x-Bjorken
- $Z/\gamma^* \rightarrow ll$ cross-section vs. $\Phi^*_\eta$ Phys. Lett. B 720 (2013) 32-51
  - Test of pQCD, resummation
- W production in association with a charm hadron ATLAS-CONF-2013-045
  - Sensitive to s-quark PDF for high $Q^2$
- Forward-backward Z asymmetry measurement ATLAS-CONF-2013-043
  - Measurement of $\sin^2 \Theta_W^{eff}$

# The ATLAS Detector

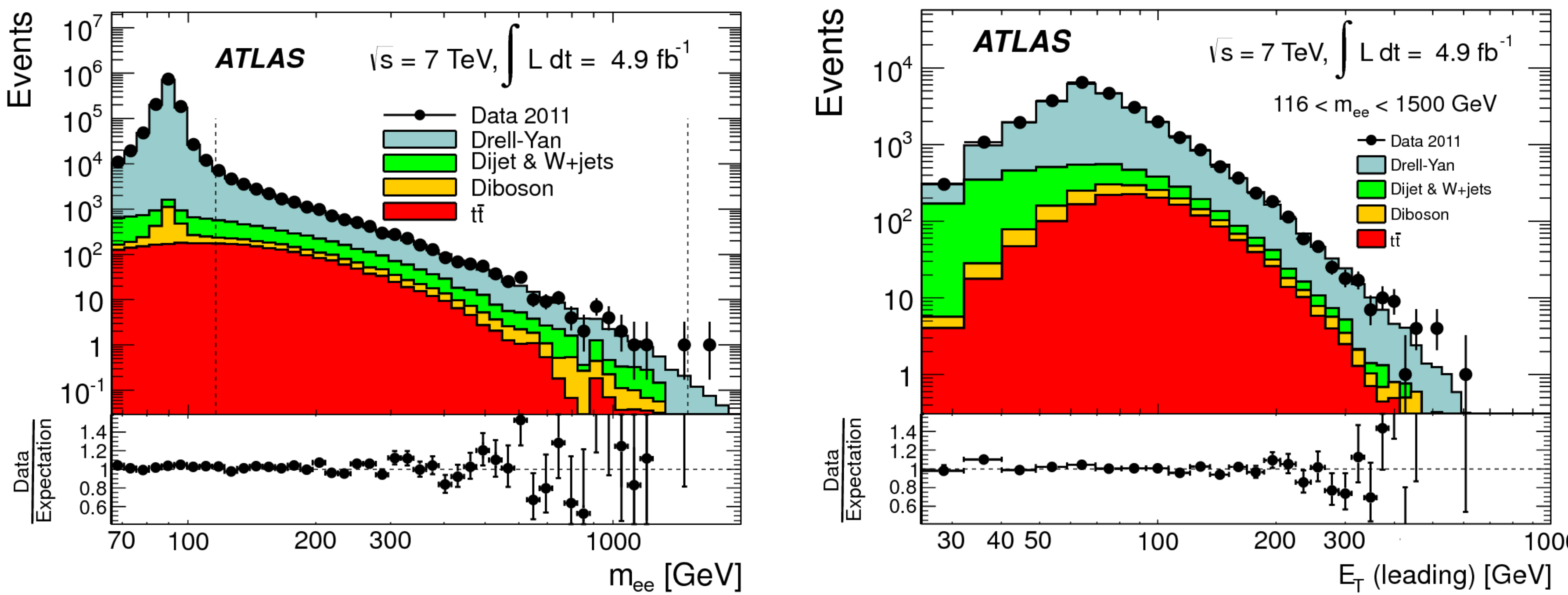
- EM calorimeter and tracking system up to $|\eta|< 2.5$ → electrons
- Muon spectrometer up to $|\eta|< 2.7$ , trigger up to $|\eta| < 2.4$ → muons
- Calorimetric coverage up to $|\eta| < 4.9$ → jets, MET, forward electrons



# High-mass Drell-Yan cross-sections

arXiv:1305.4192

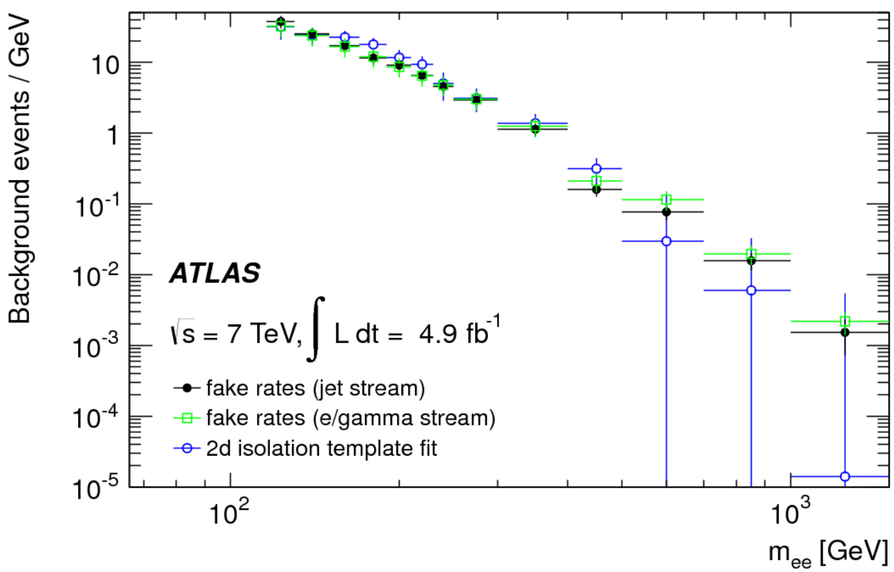
- Cross-sections measured for leptons with $P_T^l$ > 25 GeV, $|\eta^l|$< 2.5
- As function of the invariant mass in the region 116 GeV < $m_{ll}$ < 1500 GeV
- Measured in the electron-positron channel

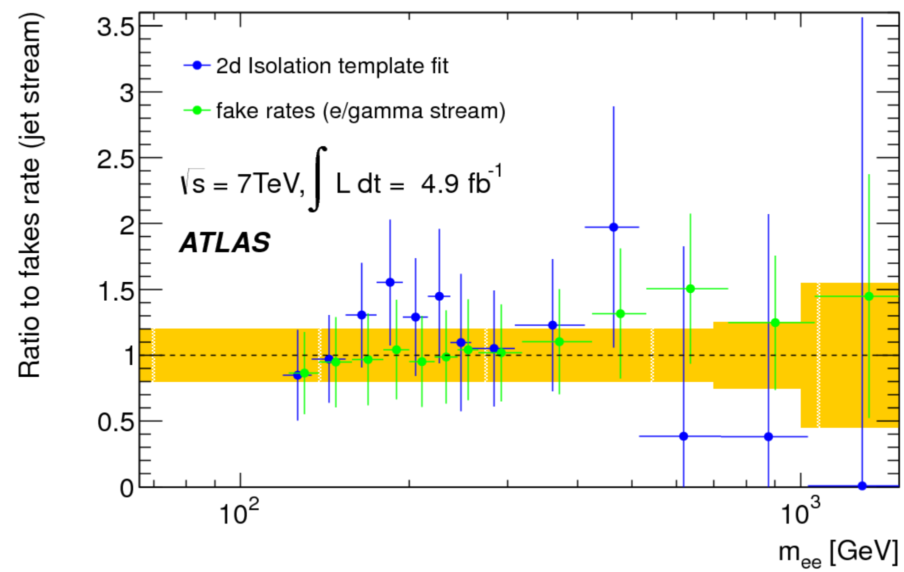


# High-mass Drell-Yan cross-sections

arXiv:1305.4192

- Dominant background (6-16% depending on $m_{ee}$) by particles misidentified as electrons (DiJet (QCD) and jet+real electron (e.g. pp→W(e$\nu$)+jets))
- This background estimated with a data driven matrix-method
- Fake rate calculated in a jet enriched control sample




- Smaller irreversible background (up to 5% and 9%) from other processes with two real electrons in the final state estimated from MC samples

# High-mass Drell-Yan cross-sections

arXiv:1305.4192

- Measurement dominated by systematic uncertainty up to $m_{ee}$ ~400 GeV

| Source of uncertainty | Uncertainty [%] in $m_{ee}$ bin 116–130 GeV | Uncertainty [%] in $m_{ee}$ bin 1000–1500 GeV |
|---|---|---|
| Total background estimate (Stat.) | 0.1 | 7.6 |
| Total background estimate (Syst.) | 1.3 | 3.1 |
| Electron energy scale & resolution | 2.1 | 3.3 |
| Electron identification | 2.3 | 2.5 |
| Electron reconstruction | 1.6 | 1.7 |
| Bin-by-bin correction | 1.5 | 1.5 |
| Trigger efficiency | 0.8 | 0.8 |
| MC statistics ($C_{DY}$ stat.) | 0.7 | 0.4 |
| MC modelling | 0.2 | 0.3 |
| Theoretical uncertainty | 0.3 | 0.4 |
| Total systematic uncertainty | 4.2 | 9.8 |
| Luminosity uncertainty | 1.8 | 1.8 |
| Data statistical uncertainty | 1.1 | 50 |

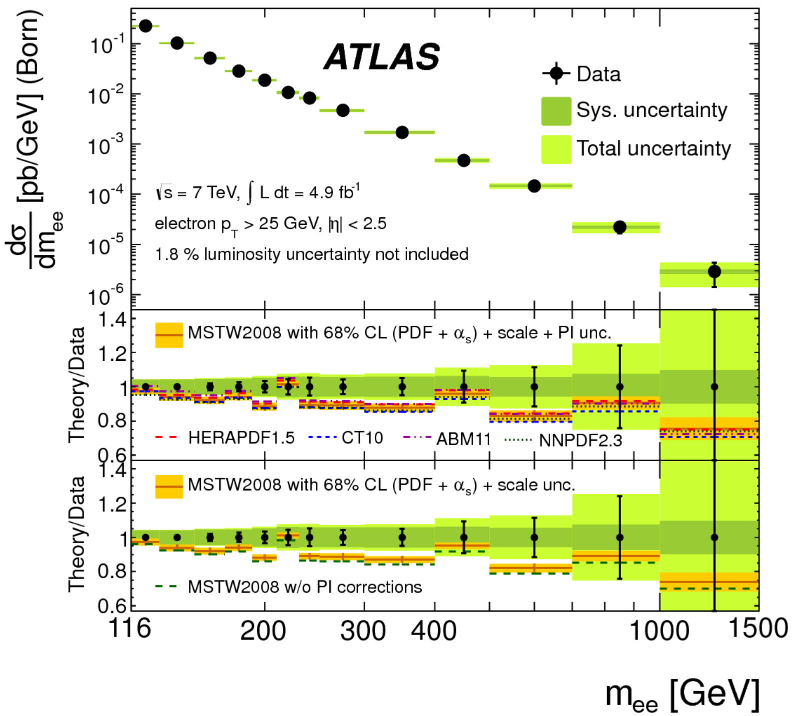
- Complete results with all uncertanties, seperated as correlated and uncorrelated are availabe at HepData

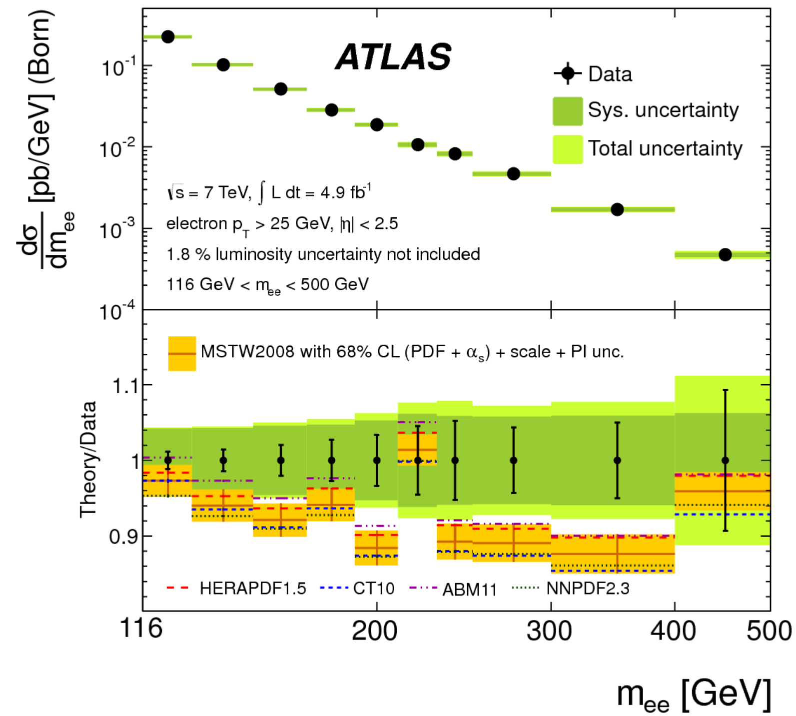
  → http://hepdata.cedar.ac.uk/view/ins1234228

# High-mass Drell-Yan cross-sections

arXiv:1305.4192

- Born cross-section compared to NNLO QCD FEWZ calculation with different NNLO PDFs, NLO EW corrections
- Photon induced contribution (1-8%) and real W/Z FSR (0.1-2%) are included




- Data generally lies above the FEWZ calculations
- $X^2$ fits over the full mass yield, taking all uncertainties into account gives values between 13.5 (HERAPDF) and 18.9 (CT10) for 13 data points

# $Z/\gamma^* \to ll$ cross-section vs. $\Phi^*_\eta$

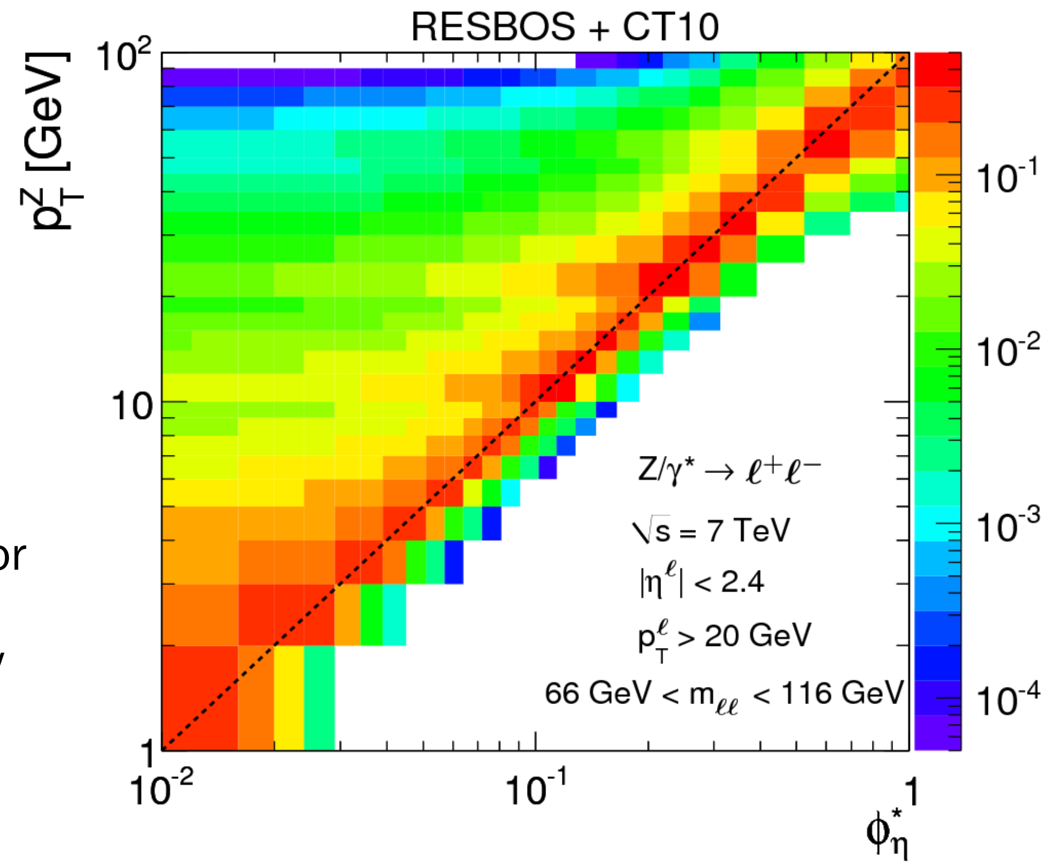
Phys. Lett. B 720 (2013) 32-51

- Measurement of angle correlations $\Phi^*_\eta$ probes the same physics as measurement of $P_T^Z$
- Depends only on direction of tracks → Better experimental resolution

$$\Phi^*_\eta = \tan\left(\frac{\Phi_{acop}}{2}\right) * \sin(\Theta^*_\eta)$$

$$\Phi_{acop} = \pi - \Delta\Phi$$
$$\cos(\Theta^*_\eta) = \tanh[((\eta^- - \eta^+))/2]$$

- Correlation matrix between $\Phi^*$ and $P_T^Z$ variables, at born level, for $Z/\gamma^* \to l^+l^-$
- $\Phi^*_\eta$ of 1 is equal to $P_T^Z$ of 100 GeV

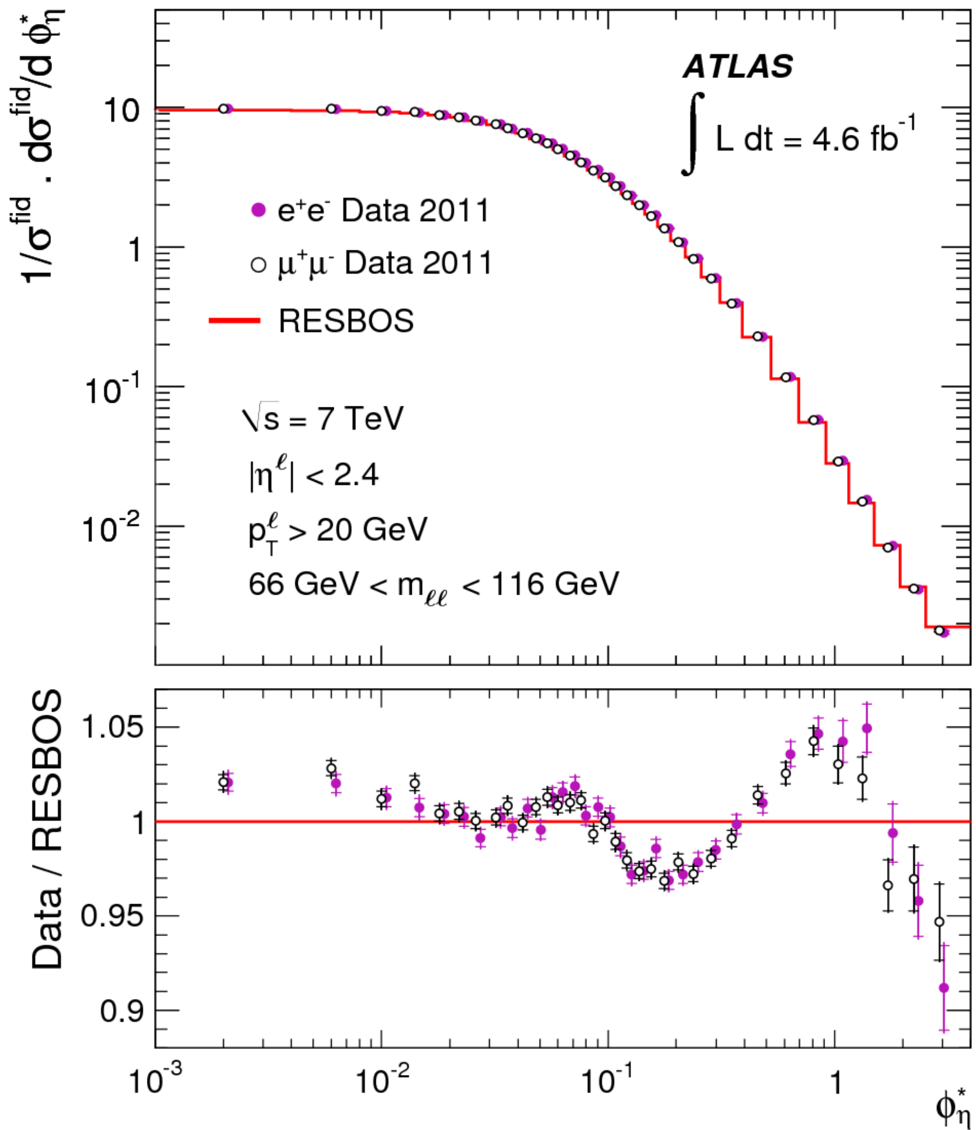


# $Z/\gamma^* \rightarrow ll$ cross-section vs. $\Phi_\eta^*$

Phys. Lett. B 720 (2013) 32-51

- Measurements done in electron and muon channels
- Cross-sections are measured for $P_T^l > 20\text{GeV}$, $|\eta_l| < 2.4$ and 66 < $m_{ll}$ < 116 GeV
- Multi-jet background derived from data fitting the Z lineshape
- Total background is only in the order of 0.6%

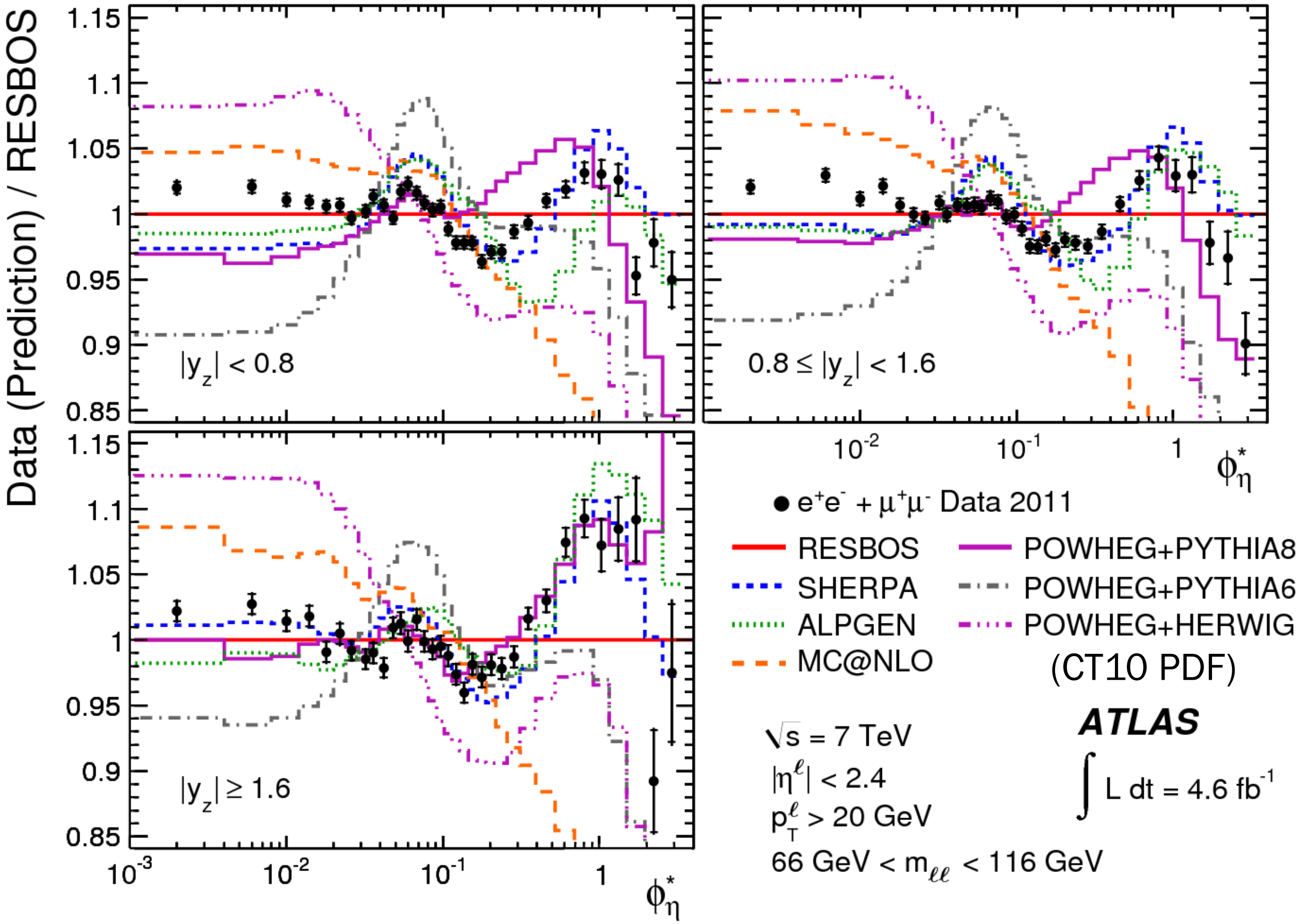
  → high-precision measurement
- Systematics (0.1-0.3%) smaller than statistical uncertainty (0.3%)



# $Z/\gamma^* \to ll$ cross-section vs. $\Phi^*_\eta$

Phys. Lett. B 720 (2013) 32-51

Comparison to predictions of different MC generators and NNLL calculations




Very important input for MC tuning (ISR parameters)

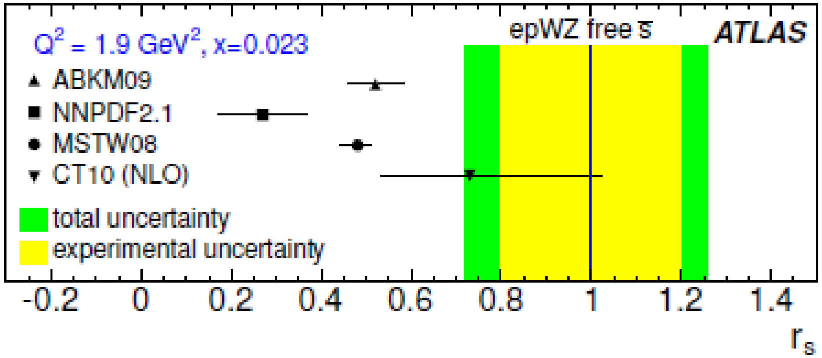
# Short reminder

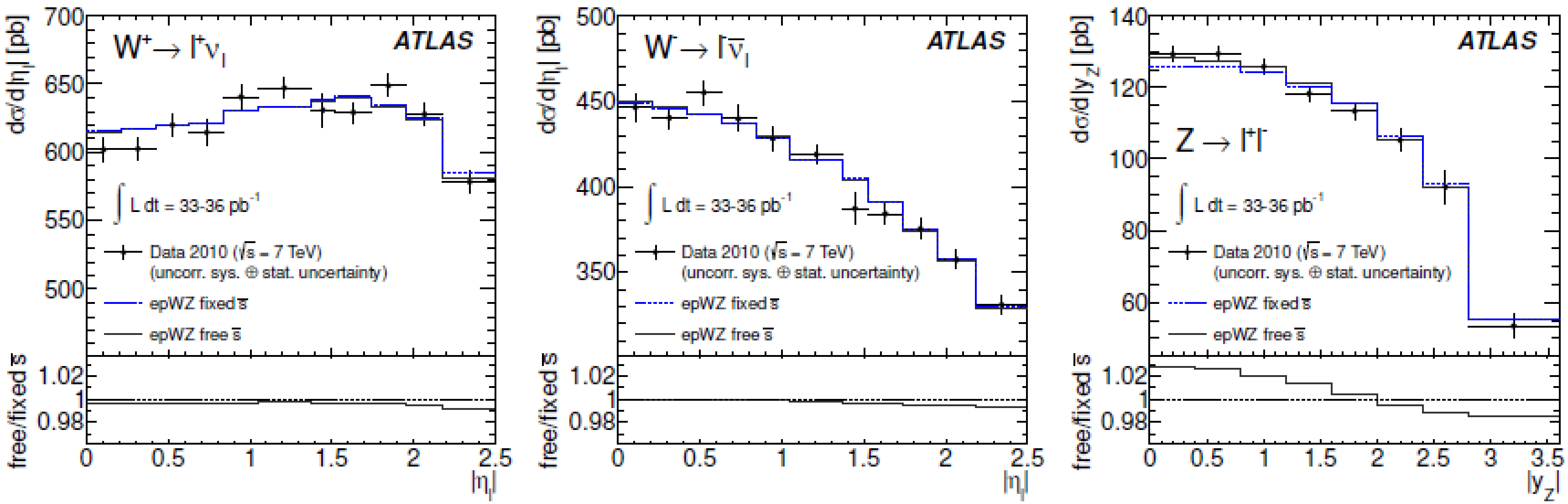
Phys. Rev. D 85, 072004 ; Phys. Rev. Lett. 109, 012001

- ATLAS W, Z data from 2010 was fitted together with HERA data with the HERAFITTER framework $(Q_0^2 = 1.9\ GeV^2, m_c = 1.4\ GeV, m_b = 4.75\ GeV, \alpha_s(M_Z) = 0.1176)$

- Fits are run with fixed $\bar{s}/\bar{d}$= 0.5 and leaving $\bar{s}(x)$ free (with s = $\bar{s}$)
- The „free $\bar{s}$ fit“ leads to better $X^2$ to ATLAS data and determines

$$r_s = 0.5\,(s+\bar{s})/\bar{d} = 1.00^{+0.25}_{-0.28}$$



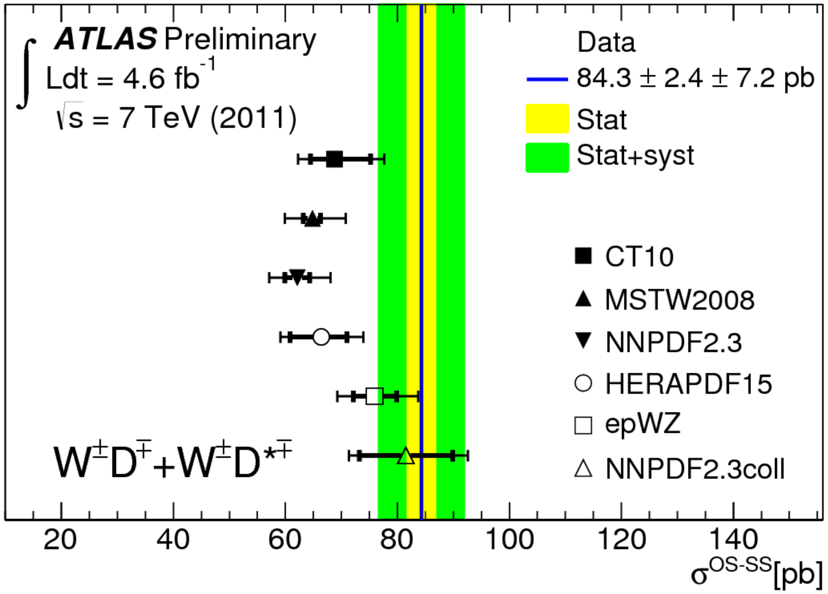
# W in association with a charm hadron

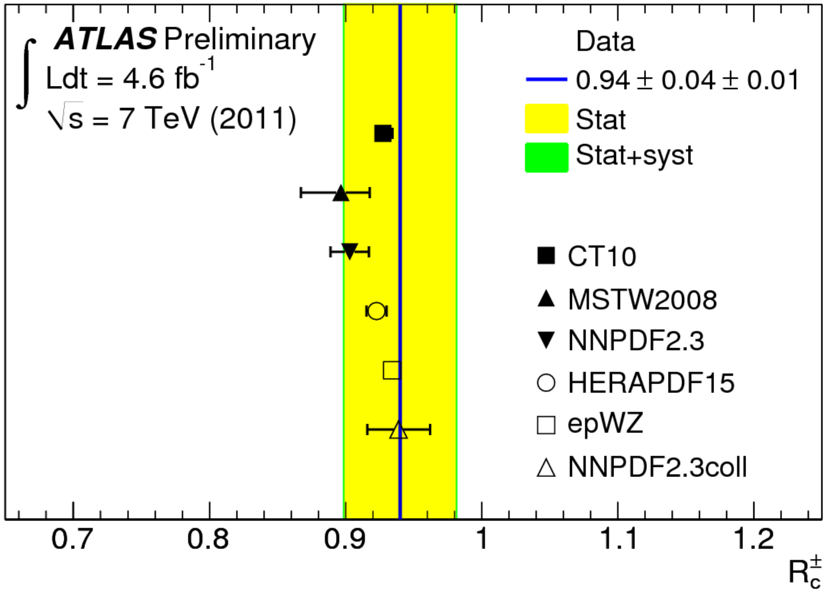
ATLAS-CONF-2013-045

Details of the analysis: see talks of Vargas Trevino in PDF + PDF4LHC session and Ishitsuka in Hard QC: NLO, NNLO, EW session

Left plot: Sum of measured cross-sections compared to different PDF predictions

Right plot: Measured asymmetry ratios $R_c^{\pm} = \sigma(W^+D^{*-})/\sigma(W^-D^{*+})$ compared to different PDF predictions



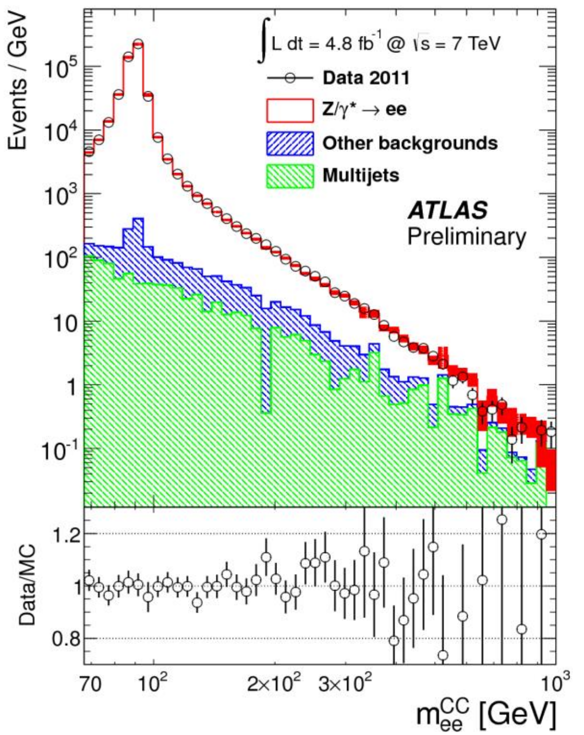




→ Good agreement with epWZ (see last slide) and NNPDF2.3coll

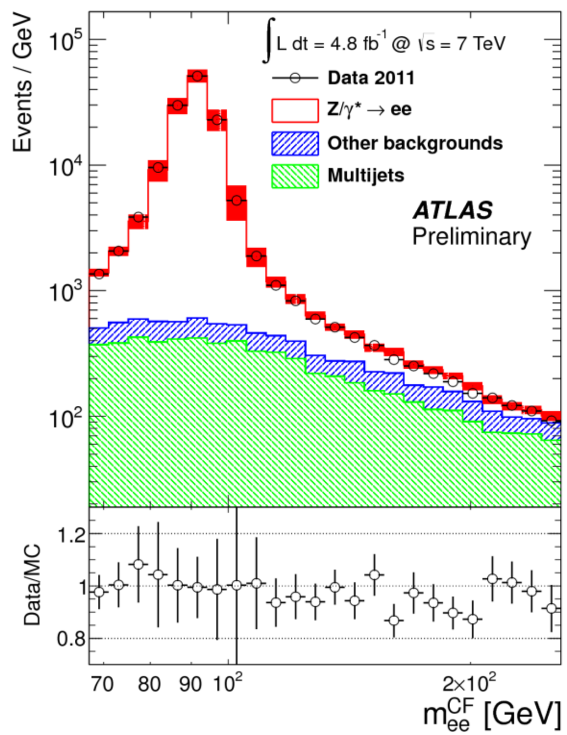
# Forward-backward Z asymmetry

ATLAS-CONF-2013-043

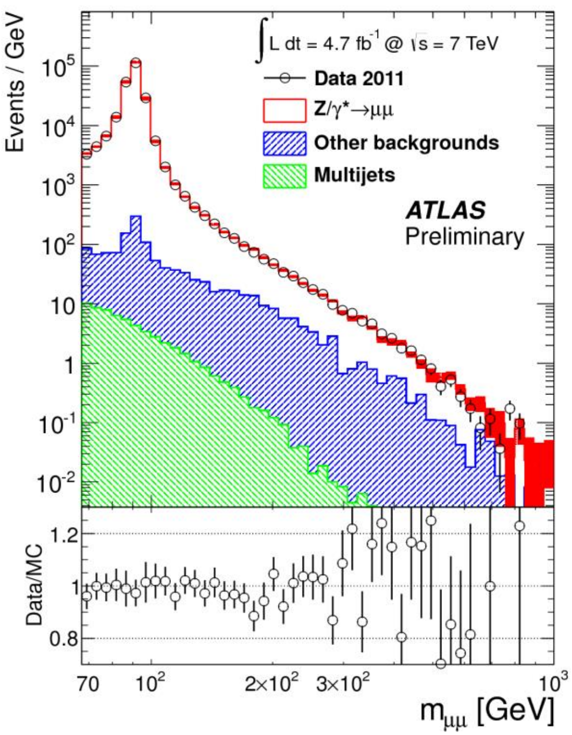
- Measurement of $A_{FB}$ in $Z \to ll$ decays to determine $\sin^2 \Theta_W^{eff}$
- Electrons with $P_T$ > 25 GeV selected from central ($|\eta|$< 2.47) and forward (2.5 <$|\eta|$< 4.9) region
- Muons from inner tracker and muon –spectrometer measurements selected with $P_T$ > 20 GeV and $|\eta|$ < 2.4




Both elec from central region




One central, one forward

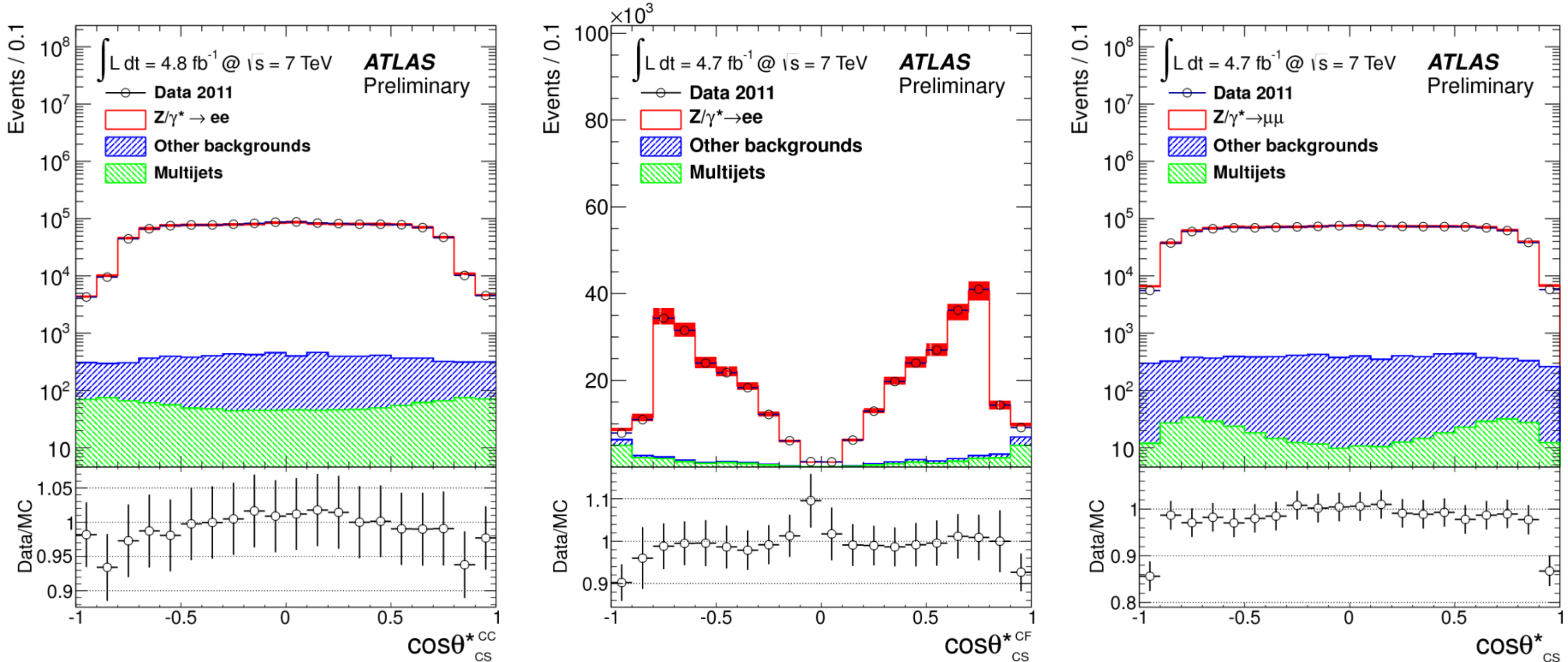



Muon channel

# Forward-backward Z asymmetry

ATLAS-CONF-2013-043

- Very important to include „forward“ electrons ($2.5 < |\eta| < 4.9$) to reconstruct Z events at large rapidity
- For these events the direction of the incoming quark is better determined
- For CF (one central, one forward electron) $A_{FB}$ is already visible from the reco-level distribution

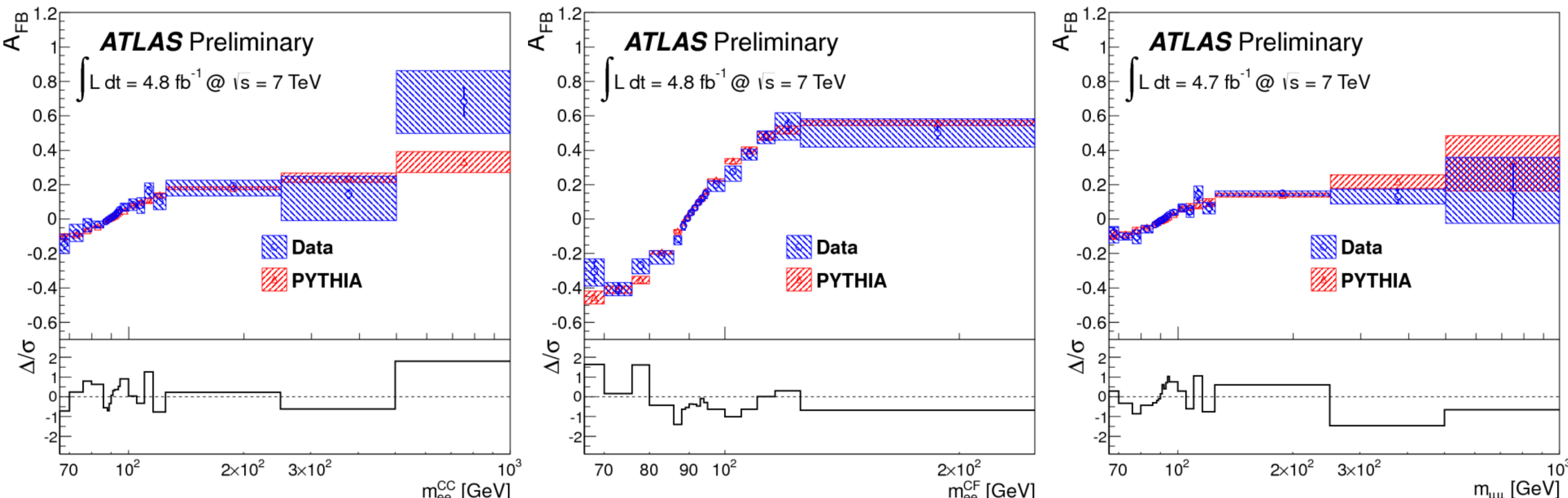



cos $\Theta^*$ is in the Collins-Soper (CS) frame

# Forward-backward Z asymmetry

ATLAS-CONF-2013-043

- Unfolded $A_{FB}$ distribution to Born-level compared to PYTHIA prediction including QED FSR NLO QCD corrections
    - $A_{FB}$ corrected for detector effects, QED corrections
- For data the boxed shaded region represents the total uncertainty
    - Systematic uncertainty from unfolding, MC dependence, PDFs, backgrounds and other experimental effects
- MC is only shown with the statistical uncertainty



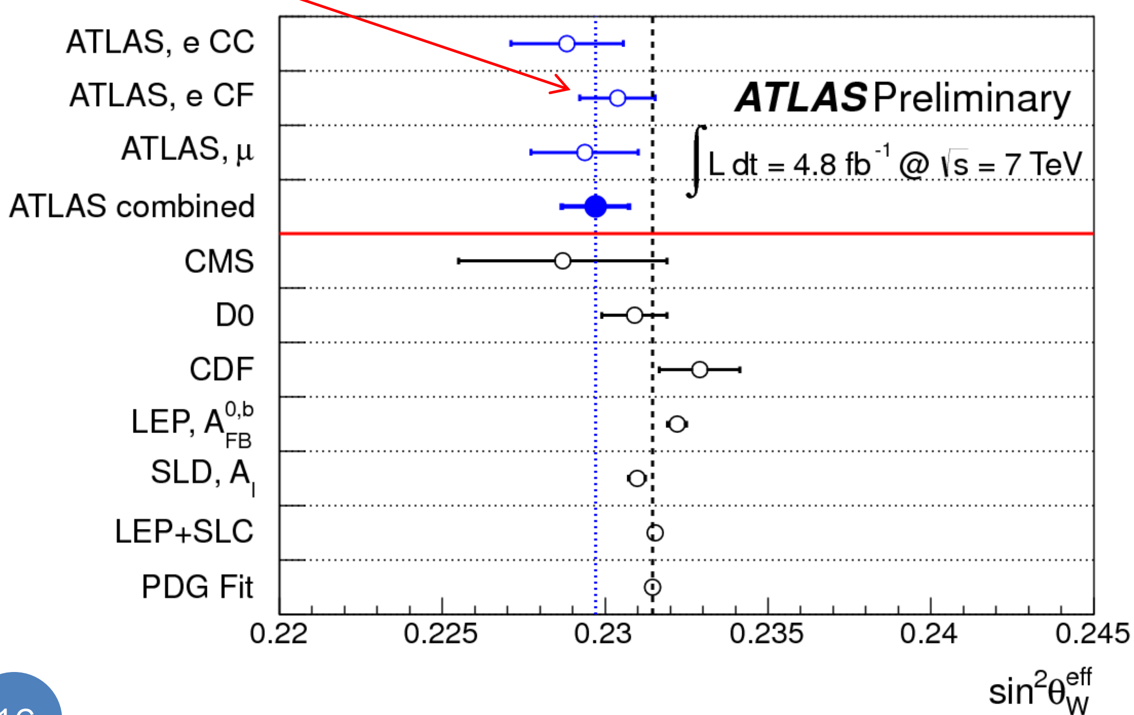
# Forward-backward Z asymmetry

ATLAS-CONF-2013-043

The value of $\sin^2 \Theta_W^{eff}$ is extracted from the raw AFB spectra by comparing it to MC predictions produced with varying initial values of the weak mixing angle

Combined result: $\sin^2 \Theta_W^{eff} = 0.2297 \pm 0.0004(\text{stat.}) \pm 0.0009(\text{sys.}) = 0.2297 \pm 0.0010(\text{tot.})$

Most precise result by including one „forward“ electron




- The systematic uncertainty is dominated by the PDF uncertainty and MC statistics
- Result is consistent with previous measurements
- Already as precise as the D0 result

# Summary & Outlook

**W and Z Physics at LHC can be measured with very high precision**

- Measurement of the high-mass Drell-Yan differential cross-section up to 1.5 TeV
  - Tests pQCD and EW corrections with sensitivity to photon induced processes
- Very presice measurement of $\Phi^*$ in $Z \rightarrow ll$ decay
  - Stringent test to resummation calculations
- High rates at LHC of Production of a W in association with a single charm hadron
  - Sensitive to the s-quark PDF
- First ATLAS measurement of $\sin^2 \Theta_W^{eff}$ analyzing $A_{FB}$ in $Z \rightarrow ll$ decays
  - already as precise as the best Tevatron result

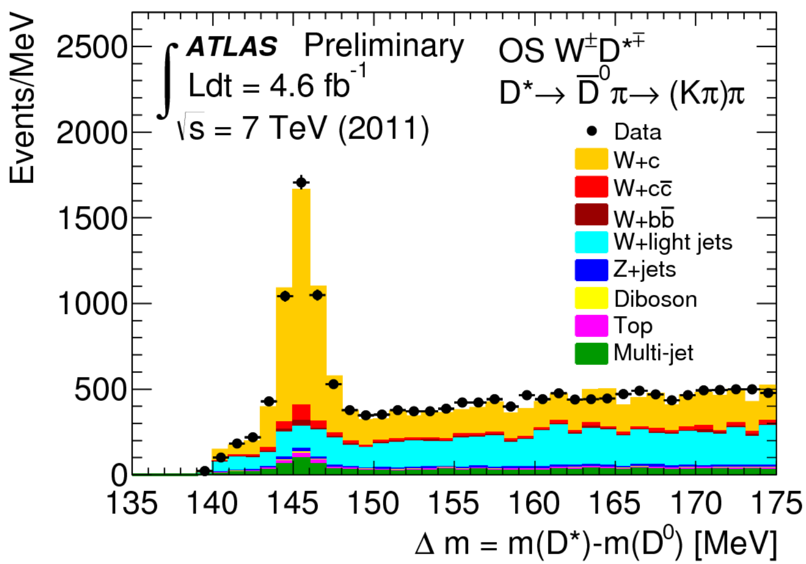
Other results with 2011 dataset will be out soon, some analysis already started to look into 2012 data

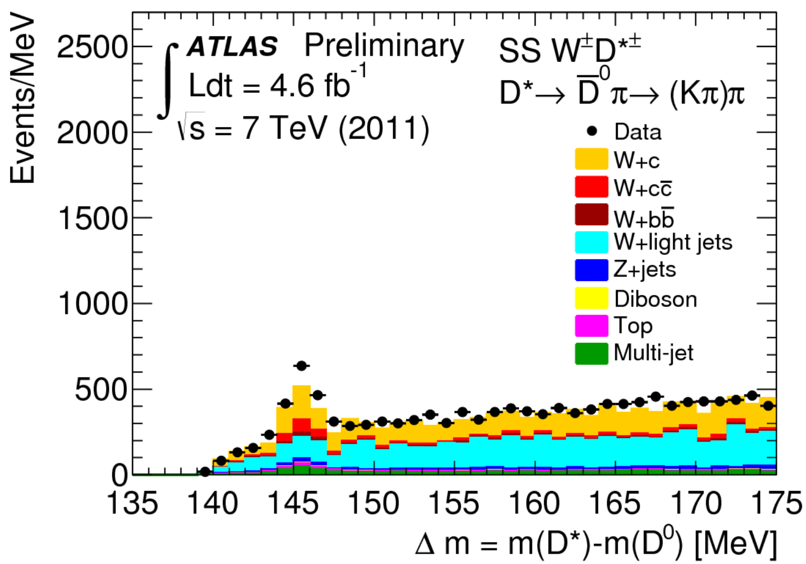
# Back-up slides

# W in association with a charm hadron

ATLAS-CONF-2013-045

- Possibility of using W + c events as probes of s-quark PDF
- Events with W leptonic decays in association with a single charm quark
- Charm hadrons are reconstructed in the decay modes into Kaons and Pions
- $P_T^l$ > 20 GeV, $|\eta|$ < 2.5, $P_T^\nu$ > 25 GeV, $m_T^W$ > 40 GeV and $P_T^D$ > 8 GeV, $|\eta^D|$ < 2.2

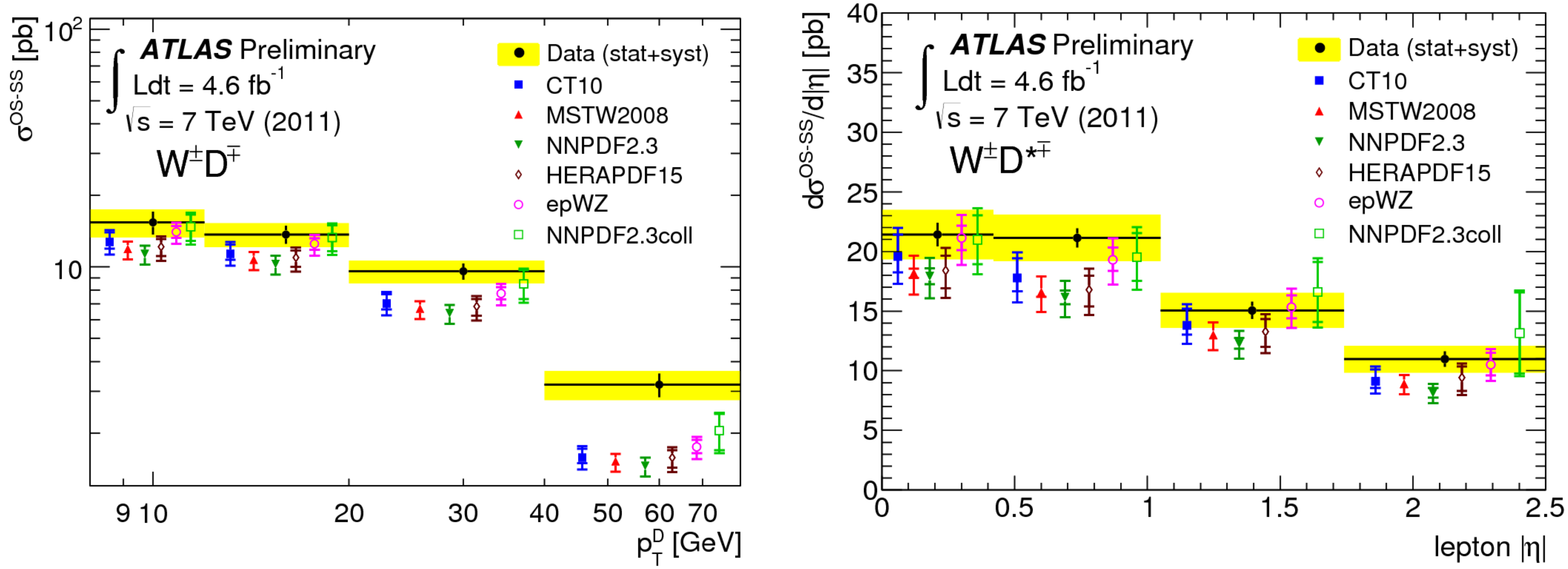


# W in association with a charm hadron

ATLAS-CONF-2013-045

- Combined measured cross-section in bins of $P_T^D$ (left side) and lepton $|\eta|$ (right side)
- Compared to cross section based on aMC@NLO simulations with different PDF sets

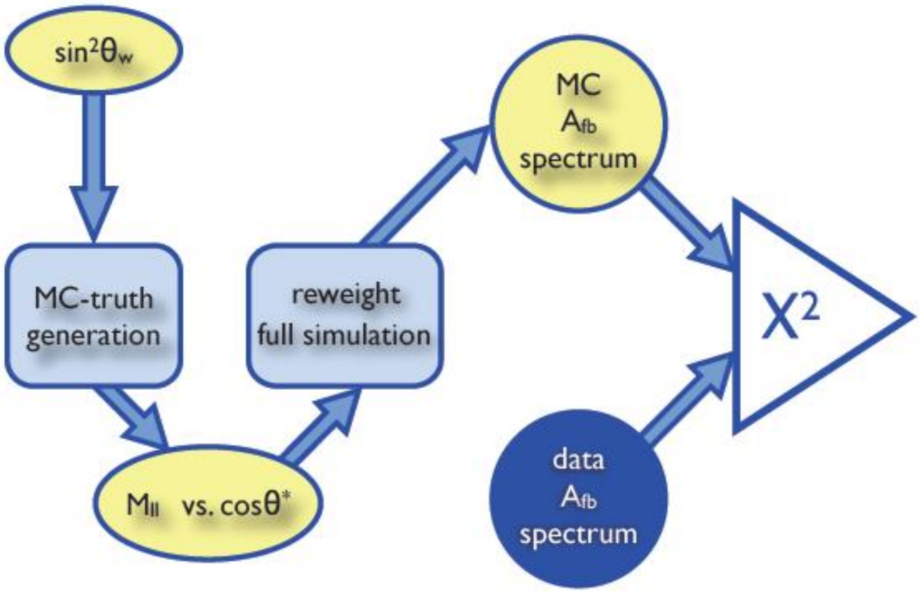



- Shapes of the different PDF sets are similar, but predicted cross-section differ as much as 25%

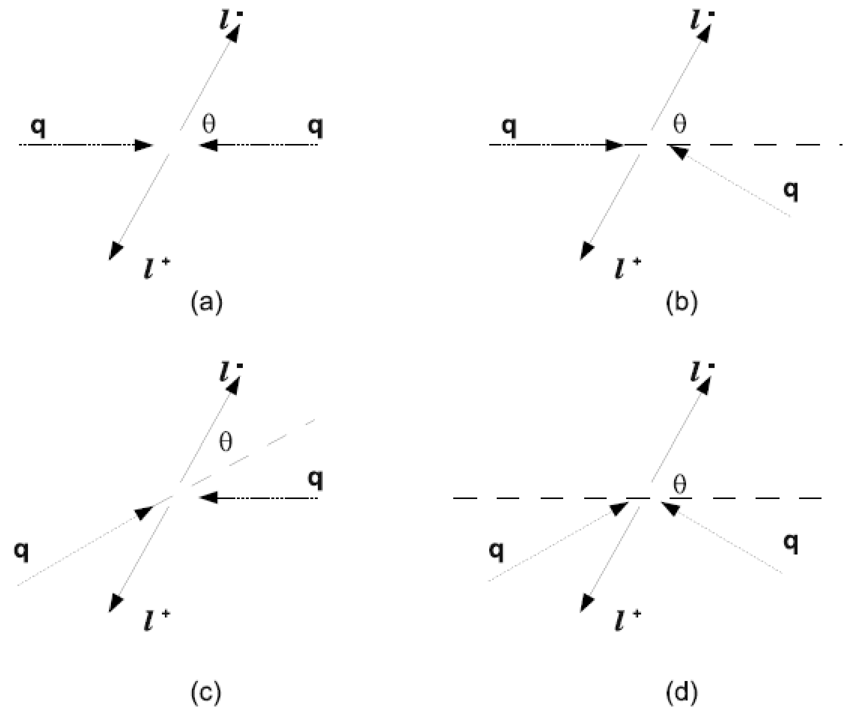
# Forward-backward Z asymmetry

ATLAS-CONF-2013-043

How $\sin^2 \Theta_W^{eff}$ was extracted




Definition of Collin-Soper Frame (CS)



# Forward-backward Z asymmetry

ATLAS-CONF-2013-043

Table of uncertainties for extraction of $\sin^2 \Theta_W^{eff}$

| Uncertainty source | CC electrons ($10^{-4}$) | CF electrons ($10^{-4}$) | Muons ($10^{-4}$) | Combined ($10^{-4}$) |
|---|---|---|---|---|
| PDF | 9 | 5 | 9 | 7 |
| MC statistics | 9 | 5 | 9 | 4 |
| Electron energy scale | 4 | 6 | – | 4 |
| Electron energy smearing | 4 | 5 | – | 3 |
| Muon energy scale | – | – | 5 | 2 |
| Higher-order corrections | 3 | 1 | 3 | 2 |
| Other sources | 1 | 1 | 2 | 2 |

- CF channel smallest total uncertainty
- Due to larger rapidity of the dilepton system reduced sensitivity to dilution
- PDF uncertainty of CF selection phasespace is smaller

# Forward-backward Z asymmetry

ATLAS-CONF-2013-043

- Fully unfolded $A_{FB}$ distribution to Born-level compared to PYTHIA prediction including QED FSR NLO QCD corrections
  - $A_{FB}$ corrected for detector effects, QED corrections and corrected for dilution