

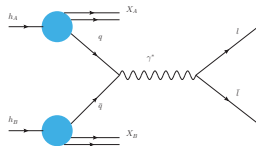
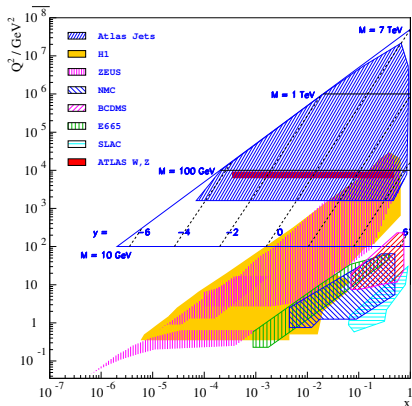
# Measurements of inclusive vector boson production from ATLAS

Mikhail Karnevskiy

Uni. Mainz.  
on behalf of the ATLAS collaboration.

5.08.2014

# Cross-section as function of di-lepton invariant mass



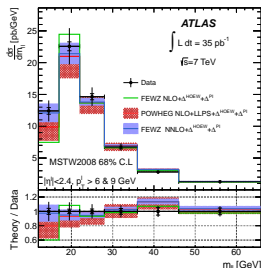
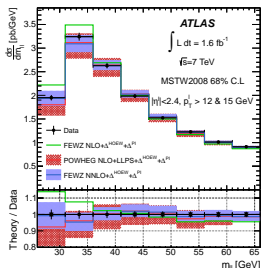
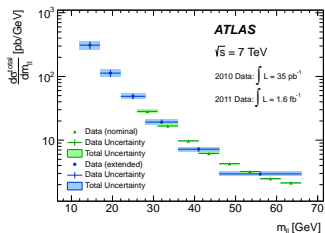
- Production of  $W, Z$  bosons is theoretically well understood and provide clear experimental signature in the leptonic decay
- The differential cross-section  $d\sigma/dm_{ll}$  is described by perturbative QCD (pQCD) calculations at next-to-next-to-leading order (NNLO).
- Studies of invariant mass shape at higher masses is interesting for searching of new resonances.
- Combined measurements are compared with NNLO theory predictions with different PDFs.

The mass spectrum is sensitive to the parton distribution functions (PDFs) for a wide kinematic range.

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

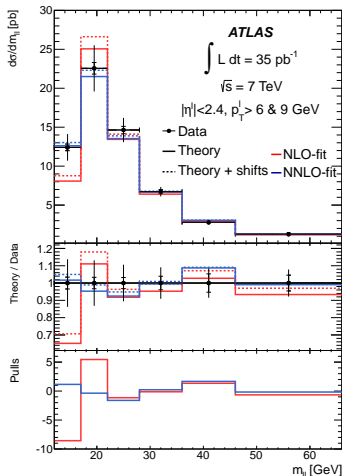
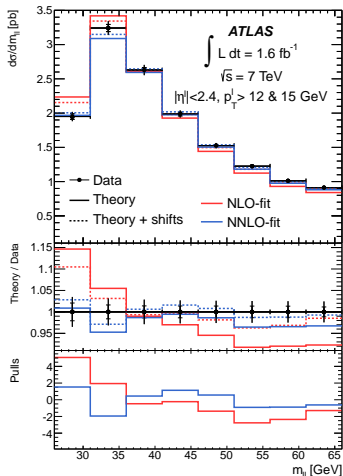
# Low Mass DY at 7 TeV

- $m_{ll}$  shape was measured down to 25 GeV in  $e$  channel and 12 GeV in  $\mu$  channels.
- Dominant uncertainty is due to imperfect knowledge of background (vary from 3.9% to 1.6% from lowest to highest mass bin in electron channel)
- Combined data are in agreement with measurements performed with 2010 and 2011 data sets and with NNLO theory predictions.



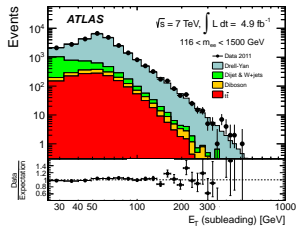
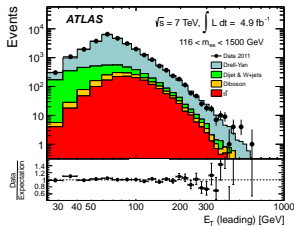
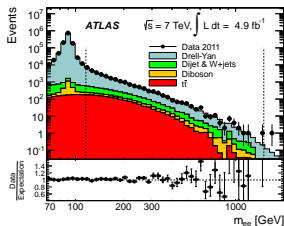
# Low Mass DY at 7 TeV JHEP 06 (2014) 112

- Fitting of the PDFs was performed using deep inelastic scattering data from HERA and the new measurements presented here.
- The QCD analysis performed at NNLO is in a good fit with a total  $\chi^2$  value of 16.3 for 14 measurements.



# High Mass DY at 7 TeV

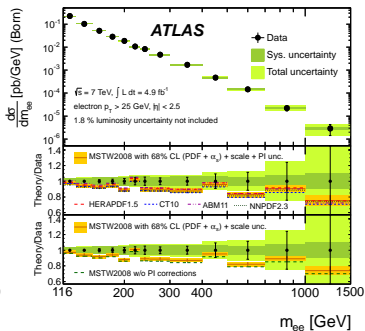
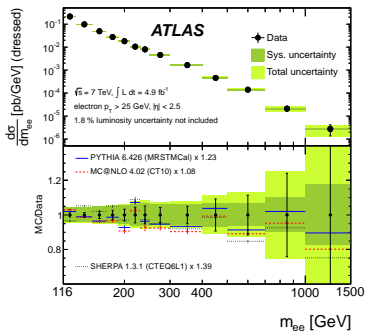
- The measurement is performed in electron channel and covers the mass region 166-1500 GeV
- Dominant systematic uncertainties is due to electron identification for the lower mass bins and background subtraction in the higher mass bins
- Statistical uncertainties is larger than systematic for  $m_{ee} > 400$  GeV



Phys. Lett. B 719 (2013) 242-260

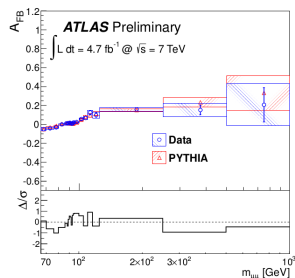
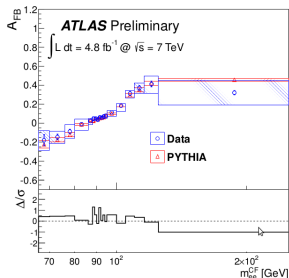
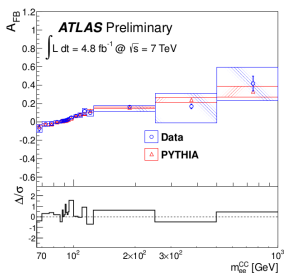
# High Mass DY at 7 TeV

- The measurement was compared to the predictions of the PYTHIA, MC@NLO and SHERPA MC generators.
- The deviations between predictions based on different PDFs are within the total uncertainty band assigned to the MSTW2008 prediction. The predictions show a good compatibility with data points.



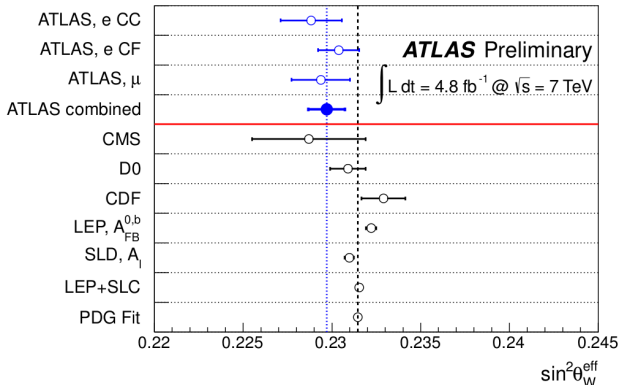
# Measurement forward-backward asymmetry $A_{FB}$

- The leptons produced in the annihilation process are asymmetric with respect to the quark direction in the rest frame of the di-lepton system.
- The forward-backward asymmetry  $A_{FB}$  was measured using angles in the Collins–Soper frame in electron (both central-central and central-forward) and muon channels.
- Electron central-forward ( $|\eta_{e_1}| < 2.5, |\eta_{e_2}| > 2.5$ ) measurement is most sensitive to forward-backward asymmetry.



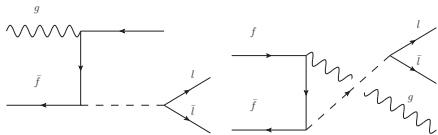
# Measurement of weak mixing angle. ATL-CONF-2013-043

- Measurements of the leptonic effective weak mixing angle,  $\sin^2 \theta_W^{\text{eff}}$ , have been made using the raw  $A_{FB}$  spectra.
- The dominant uncertainty is due to the limited knowledge of the proton parton density function.
- Presented measurement is in agreement with with SM and most precise measurements.



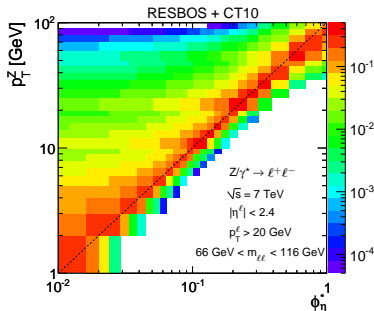


# Transverse momentum measurement



- The transverse momentum characterises the initial state radiation of the Drell-Yan process.
- Measurements of the  $p_T$  cross section tests therefore perturbative QCD calculations (higher-order corrections, resummation technique).
- These measurements are used to tune parton shower algorithm.

- Probe of  $p_T^Z$  spectrum can be studied by the reconstructed  $p_T^H$  and alternatively by the  $\phi^* = \tan((\pi - \Delta\phi)/2) \sin(\theta^*)$ , where  $\cos(\theta^*) = \tanh((\eta^- - \eta^+)/2)$  is a complementary to  $p_T^Z$  measurement but have smaller uncertainties.

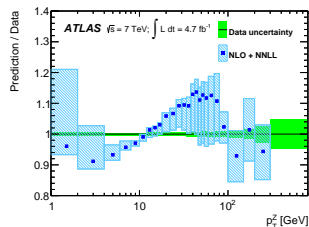
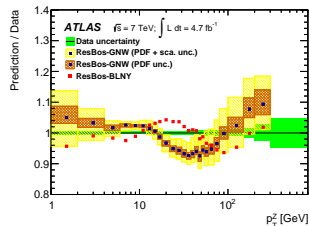
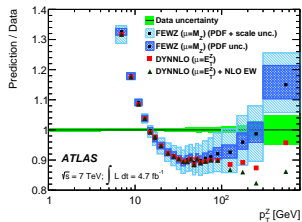


arXiv:1406.3660, Phys. Lett. B 720 (2013) 32-51

# $Z_{pT}$ at 7 TeV

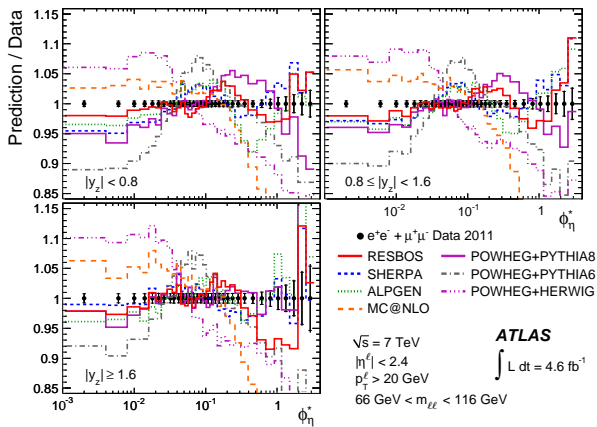
- The ResBos-GNW prediction agrees with the data within 5–7%, NLO+NNLL calculation matches the data within 10–12%. The prediction uncertainties are almost sufficient to cover the difference with the data.
- Born-level combined result was compared to theoretical predictions from Fewz, Dynnlo, ResBos (all with CT10 PDFs) and NLO+NNLL (with CTEQ6m PDFs) calculation.

- $Z_{pT}$  was measured under the peak mass region 66–116 GeV and compared with different theory predictions.



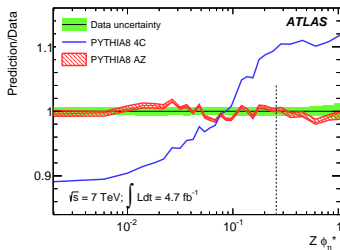
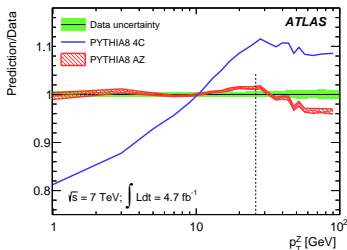
# $\phi^*$ at 7 TeV

- Measurement performed with 0.5-0.8% precision and compared with different MC predictions
- None of the tested predictions is able to reproduce the detailed shape of the measured cross section



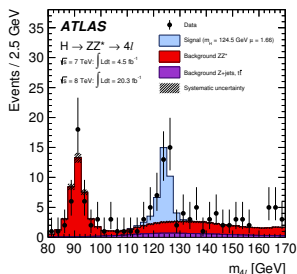
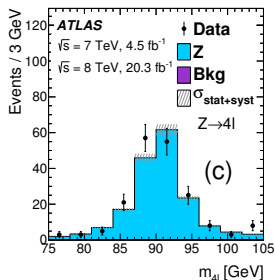
# MC tuning using $Z_{pT}$ and $\phi^*$ data.

- Comparison of the Pythia8 generator with the 4C and AZ tunes to the muon-channel  $Z_{pT}$  data and electron-channel  $\phi^*$  data are presented
- The tuned predictions agree with the measurement to better than 2% in the range used for the tuning, below  $Z_{pT} = 50$  GeV
- At higher transverse momentum, discrepancies of around 15% for Pythia8 remain, indicating the limited accuracy of the NLO signal matrix element and suggesting the need for contributions from higher parton multiplicity.



# 4-lepton at the Z resonance. 7 and 8 TeV

- Z resonance provides a test of the SM and a cross-check of the detector response to the 4 final state.
- inclusive 4l production cross-section were measured at  $4e4\mu$  and  $2e2\mu$  final states for each 7 TeV and 8 TeV datasets.
- Branching ratio:  $\Gamma_{Z \rightarrow 4l} / \Gamma_Z = (3.20 \pm 0.25(\text{stat}) \pm 0.13(\text{syst})) \times 10^{-6}$ , where  $80 < m_{4l} < 100$  GeV and  $m_{ll} > 4$  GeV
- Higgs peak appears at higher masses and not studies in this measurement



# Summary

- Several properties of  $Z/\gamma^*$  production at ATLAS were measured at higher accuracy using high statistics data (millions of  $Z$  events).
- Inclusive and differential  $Z \rightarrow \ell\ell$  cross-section measurements are sensitive to PDFs and provide new constraints for future PDF-sets
- Cross-section measurements in bins of boson transverse momentum provide precision tests of QCD dynamics from soft re-summation effects to hard multiple jet emission.
- Analysis of the 2011 data is almost finalized.
- Several 8 TeV analyses are in progress

# Backup

# $A_{FB}$ definition

The forward-backward  $A_{FB} = \frac{\sigma_{\cos \theta_{CS}^* > 0} - \sigma_{\cos \theta_{CS}^* < 0}}{\sigma_{\cos \theta_{CS}^* > 0} + \sigma_{\cos \theta_{CS}^* < 0}}$  using angles in the

Collins–Soper frame:  $\cos \theta_{CS}^* = \frac{p_{||}^z}{|p_{||}^z|} \frac{2(p_1^+ p_2^+ - p_1^- p_2^-)}{m_{||} \sqrt{m_{||}^2 + p_{T,||}^2}}$ ,  $p_i^\pm = \frac{E_i \pm p_{z,i}}{\sqrt{2}}$