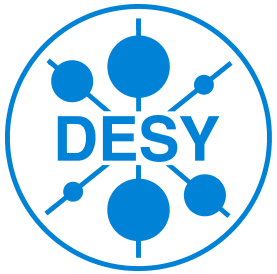
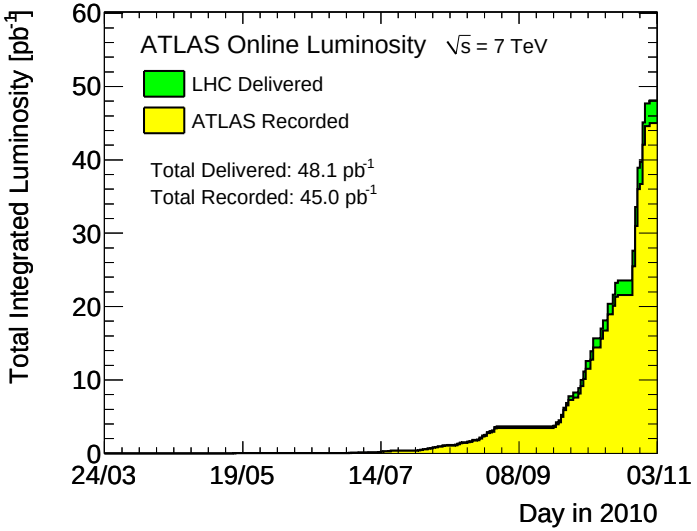
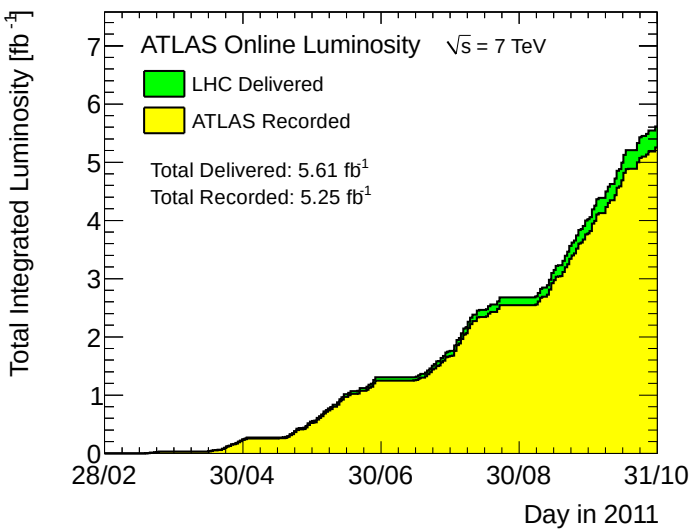


Electroweak Results from ATLAS

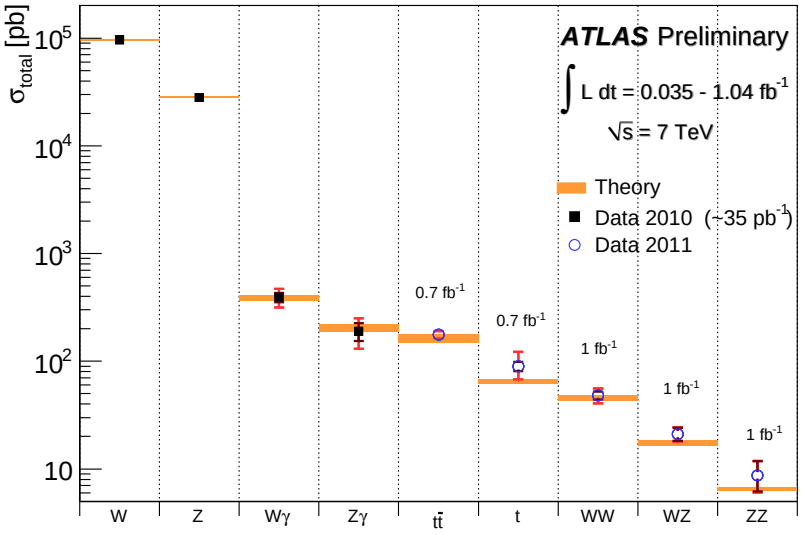
S. Glazov
On behalf of the ATLAS collaboration
La Thuile 2012.

Electroweak cross sections at the LHC

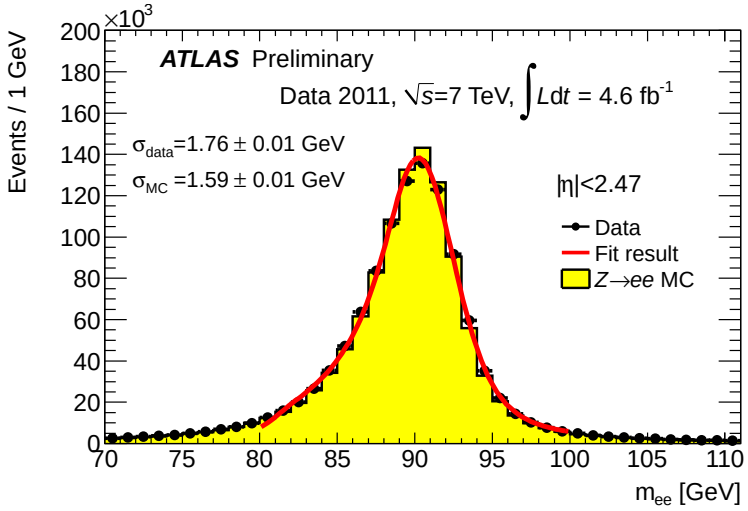


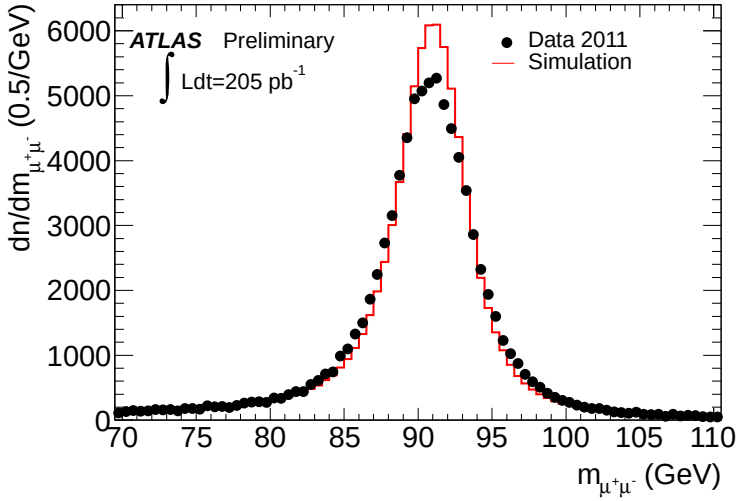


Successful start and continuous delivery of the luminosity enabled rediscovery of the standard model processes at the LHC.



ATLAS detector performance

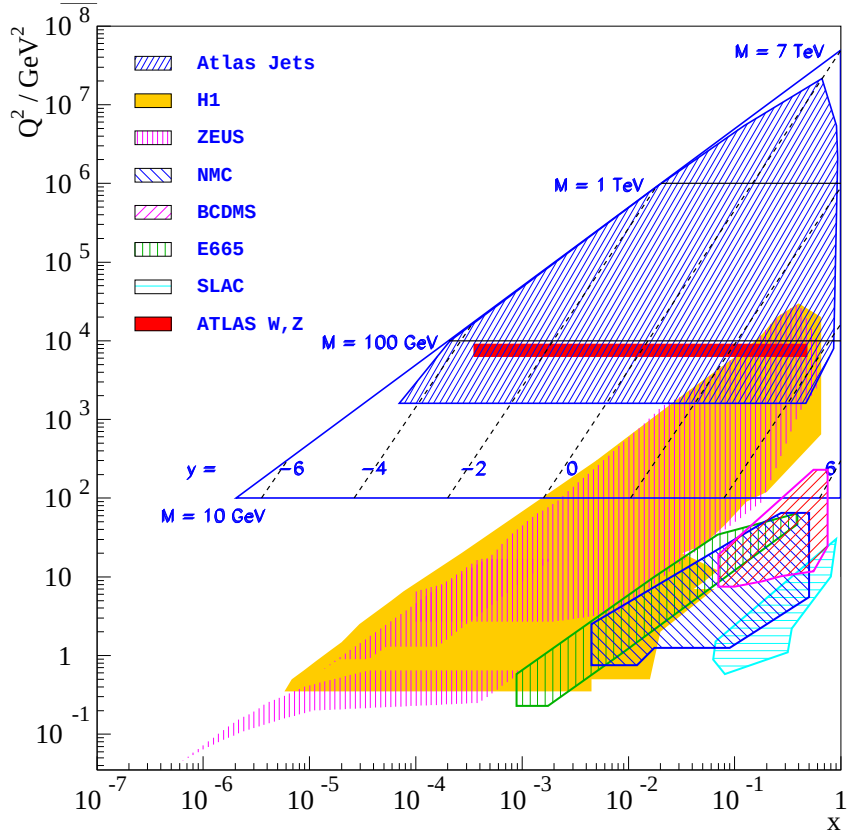




Precision tests of the standard model are enabled by an excellent performance of the ATLAS detector.

- e, μ identification efficiency is understood to ~ 1% accuracy with high background suppression.
- Calorimeter calibration / spectrometer scale are known to better than 1% precision.
- Jet energy scale known to better 2.5% for central jets with $60 < p_t < 800$ GeV
- LHC luminosity is known to 3.4% accuracy.

Cross sections at the LHC

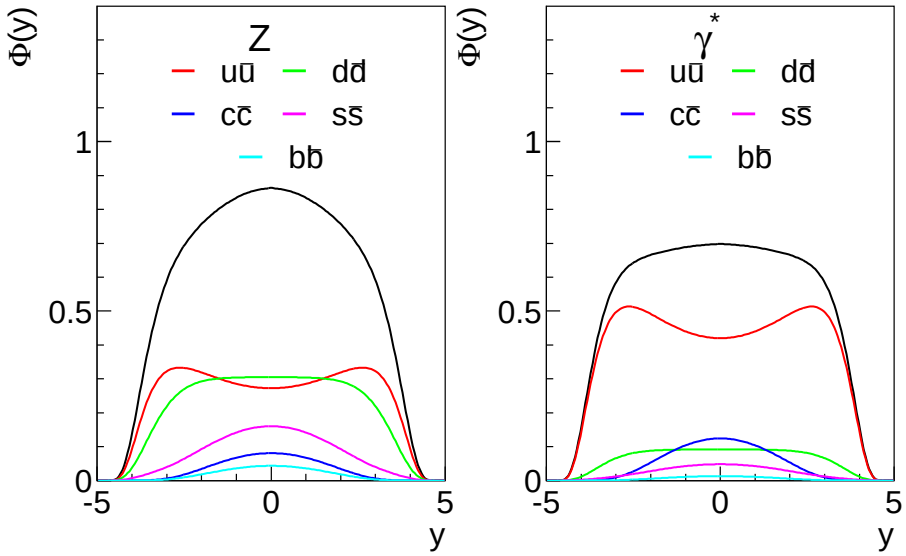


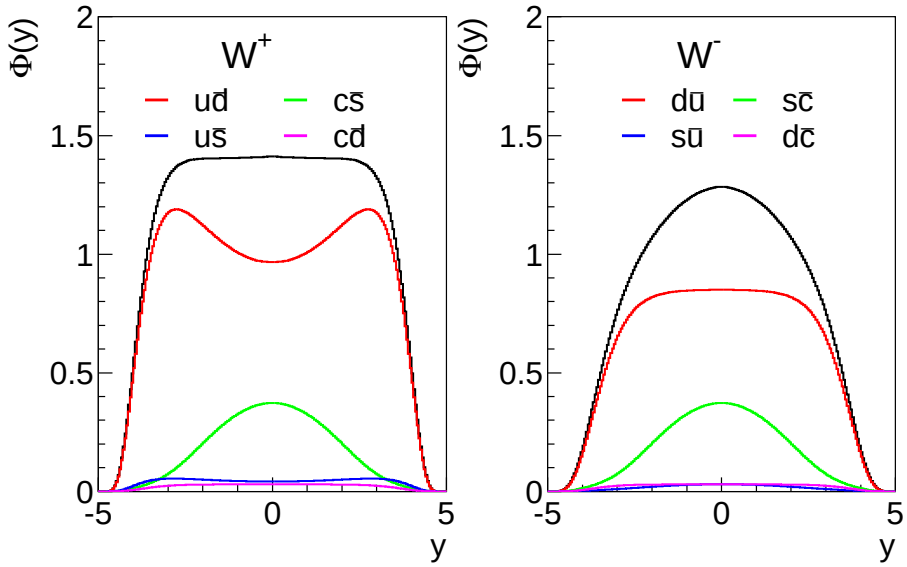
The cross sections are given by a convolution of the parton densities and coefficient functions, $\sim x_1 f_1(x_1,\mu)\, x_2 f_2(x_2,\mu)\, \hat{\sigma}(x_1,x_2,\mu)$.
Leading order relation between rapidity y and x_1, x_2: $x_{1,2} = \frac{M_{\ell\ell}}{\sqrt{S}} e^{\pm y_{\ell\ell}}$.

Interpretation of EW physics results at the LHC requires PDFs and (N)LO QCD.

$W^{\pm}, Z(\gamma)$ rapidity dependence flavour decomposition

Z production is more sensitive to d-type quarks while photon production is more sensitive to u-type quarks. Different in y-shapes for $u\bar{u}$ vs $d\bar{d}$ vs $s\bar{s}$ because of the $2u_v$, d_v quarks.

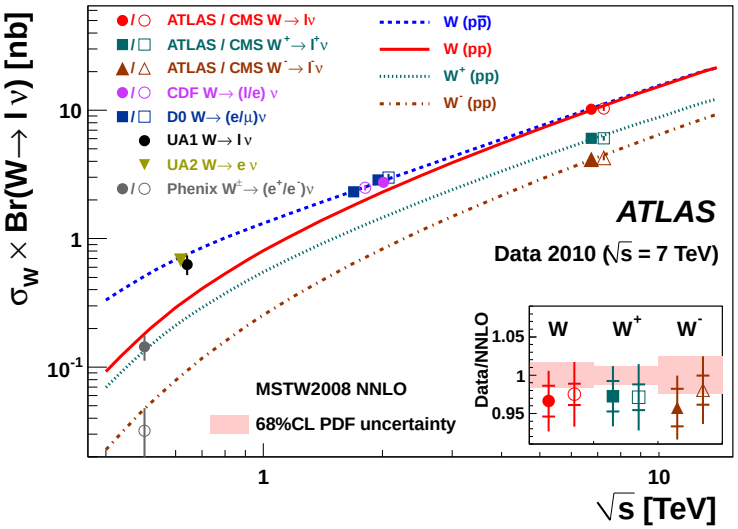


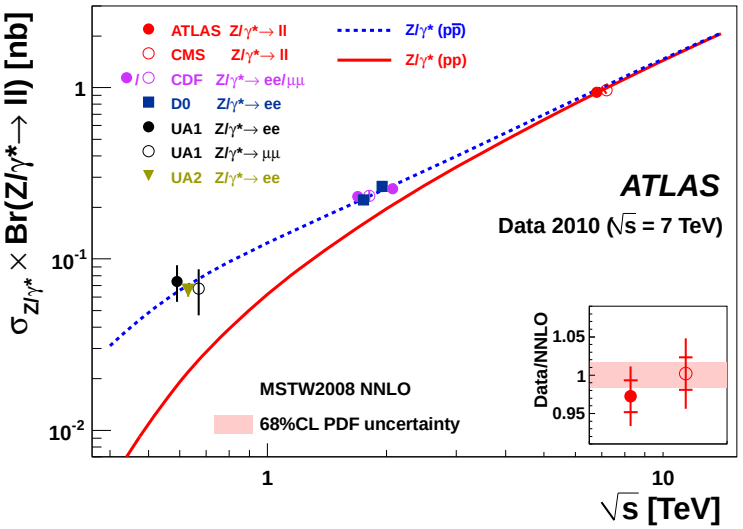


W^+, W^- production is more sensitivity to Cabbibo favored ud and cs combinations.

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

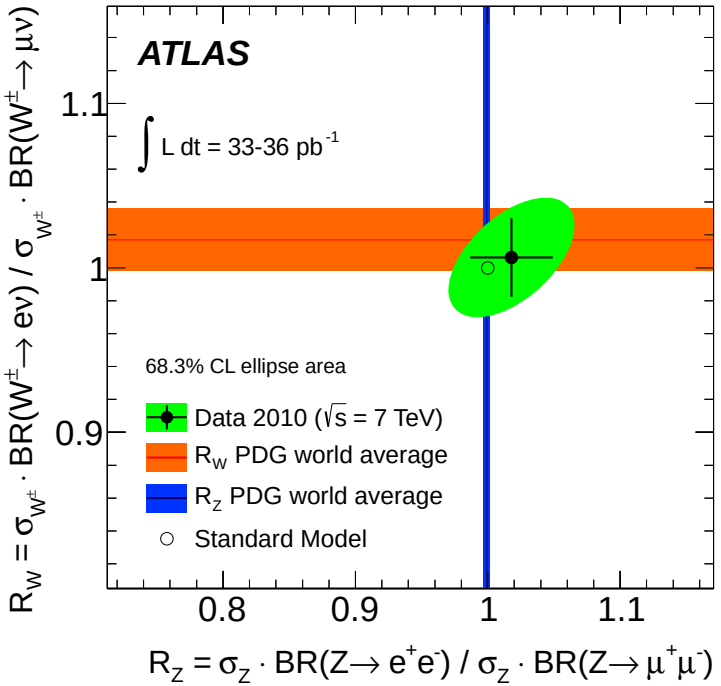
W, Z Total cross section results





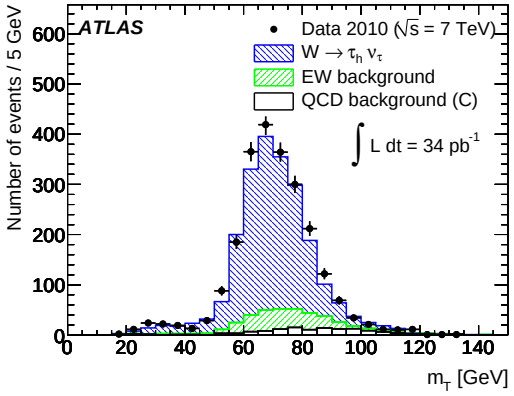
The *e* and *μ* cross-section measurements are combined and extrapolated from the fiducial volume to the full phase space.

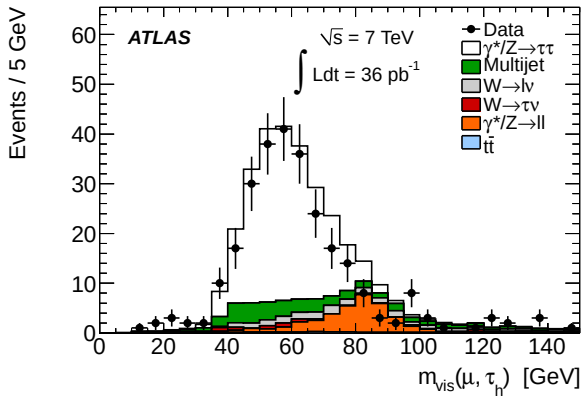
Ratio of cross-section measurements in *e* and *μ* channel provides lepton universality check.



(arXiv:1109.5141)

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

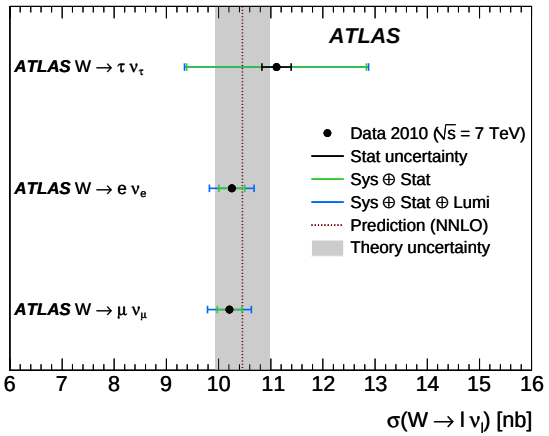


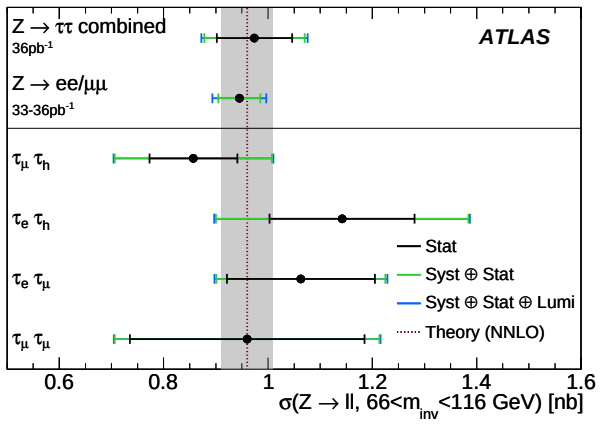


Measurements of $W \to \tau\nu$ and $Z \to \tau\tau$ provide check of τ identification performance.

Hadronic identification for W decays, combination of hadronic and leptonic for Z. Manageable level of background, cross section accuracy reaches $\sim 10\%$ for the combined Z result.

Production cross sections in different leptonic decays are consistent.



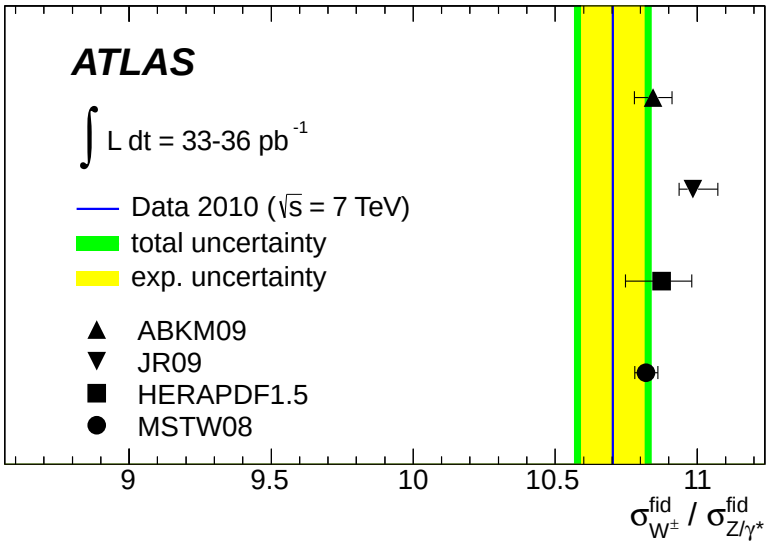


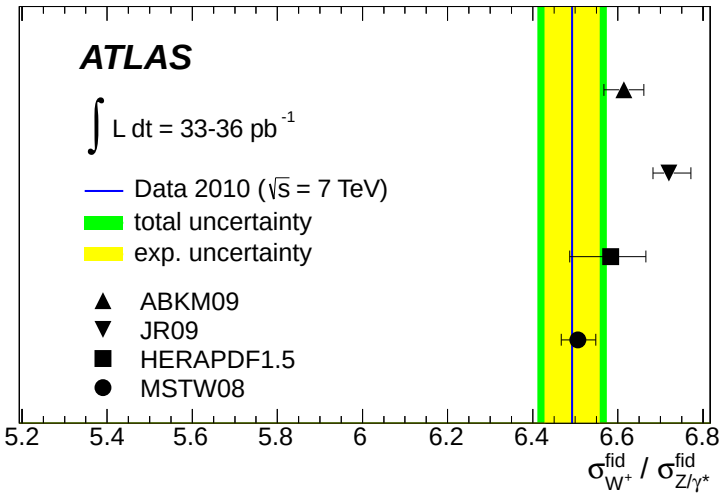
(PLB 706 (2011) 276, PRD 84 (2011) 112006)

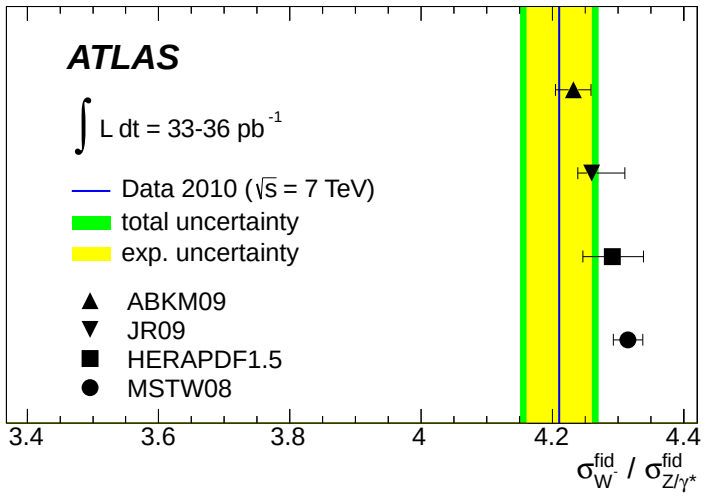
Ratios of W, Z cross sections

Correlation due to luminosity measurement cancels in the ratio of the cross sections. For σ_W/σ_Z PDF errors are reduced, the ratio is sensitive to $\bar{s}/\bar{d}$ densities ratio.

Ratios σ_{W^+}/σ_Z and σ_{W^-}/σ_Z are sensitive to u/d at $x \sim 0.01$.

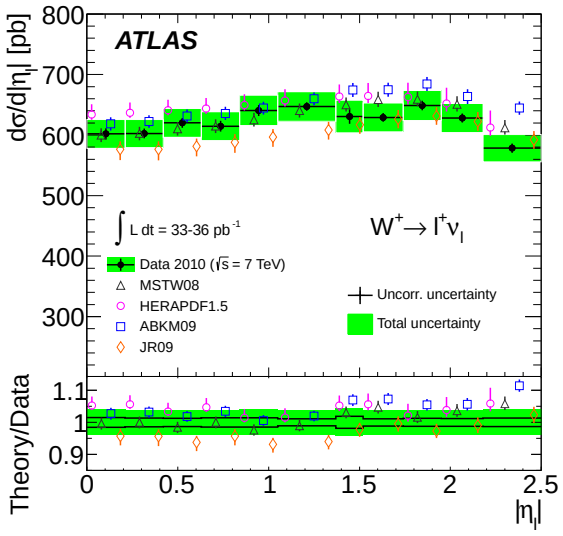


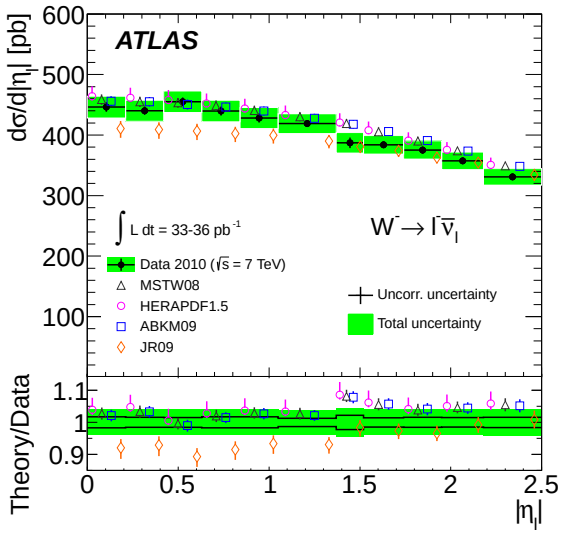


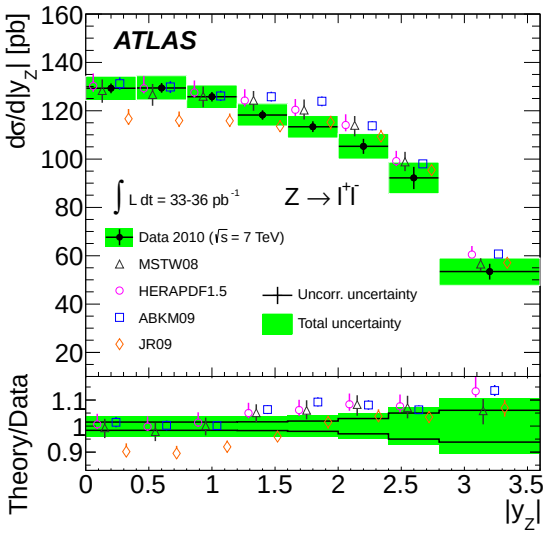


(arXiv:1109.5141)

Differential cross-section measurements







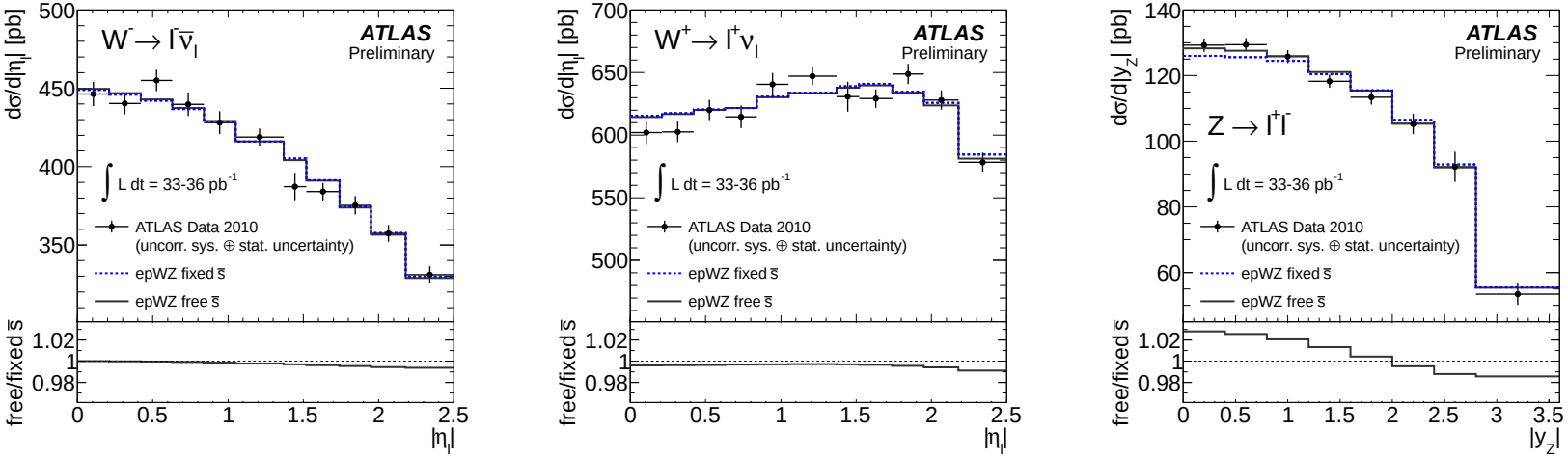
Measurement of differential $d\sigma/dy_Z$ and $d\sigma/d\eta_\ell$ cross sections compared to NNLO predictions based on NNLO PDF sets.

Analysis preserves correlation information bin-to-bin and among different reactions, provides more information/constraining power compared to simple asymmetry measurement.

Some tensions with all PDF sets, in particular for $d\sigma/dy_Z$ distribution, where all sets considered have suppressed strange quark density.

(arXiv:1109.5141)

Determination of the strange sea density



A QCD analysis of HERA+ATLAS data, using HERAFitter.

Perform two NNLO fits: with fixed strangeness fraction $r_s = 0.5(s + \bar{s})/\bar{d}$, $r_s = 0.5$ and free strange density parametrized as

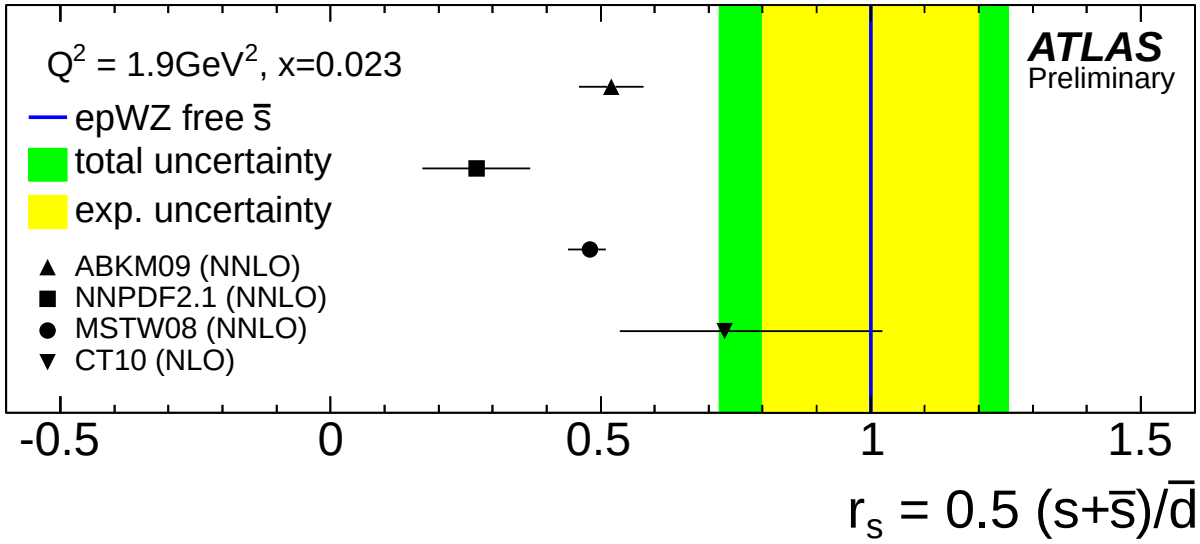
$$x\bar{s}(x) = A_s x^{B_{\bar{d}}}(1 - x)^{C_s}$$

For $x = 0.023$ and $Q^2 = 1.9\ \mathrm{GeV}^2$, corresponding to the maximum of ATLAS data sensitivity extrapolated to low Q^2

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

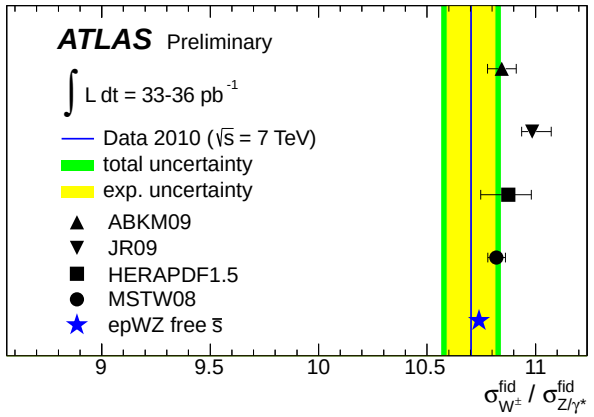
consistent with sea quark flavour democracy at low x.

ATLAS strange sea determination results

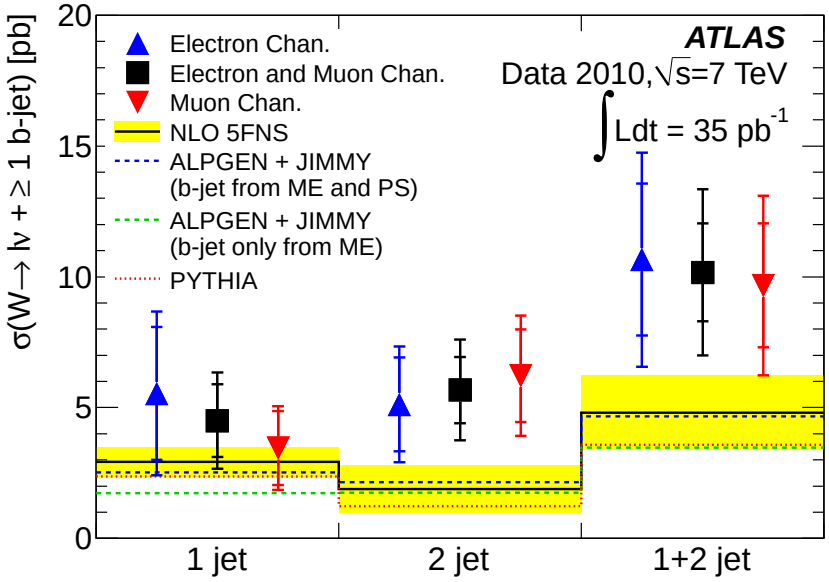


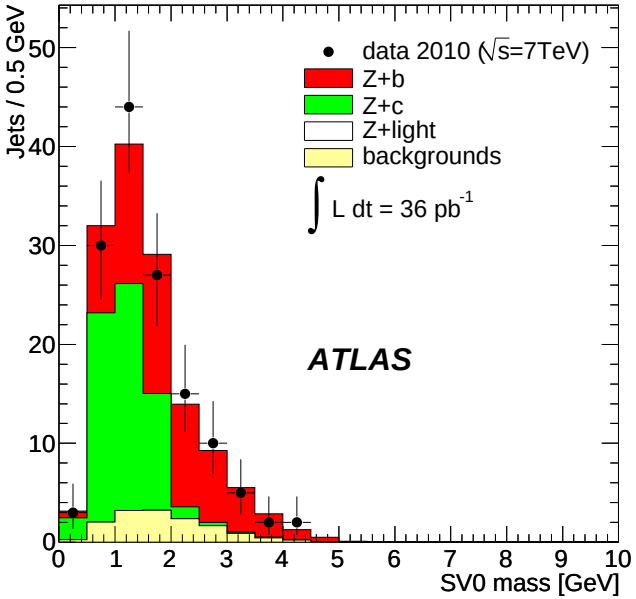
ATLAS result is consistent with CTEQ6.6 (NLO) and is above MSTW08, ABKM09 and NNPDF2.1 determinations.

The free $\bar{s}$ fit provides the best description of the measured W/Z cross sections ratio.



$W, Z + b$ jet production





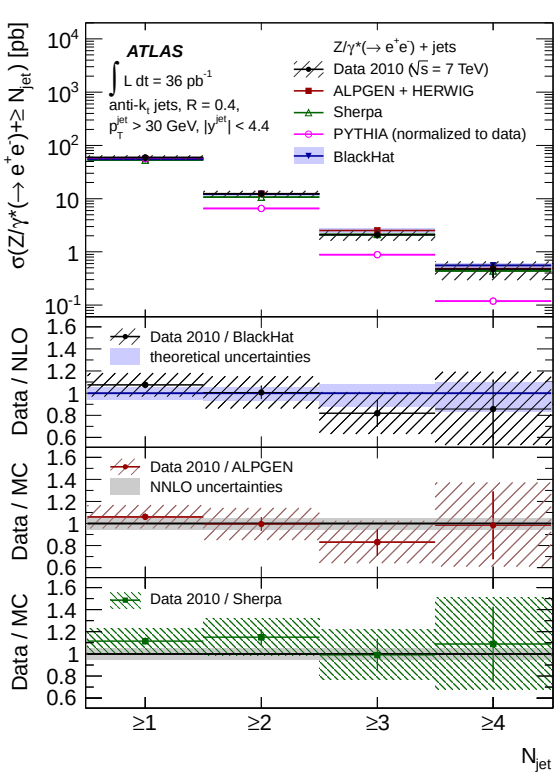
$W, Z + b$ production are sensitive to (N)LO QCD corrections and (for Z production) b-quark parton density.

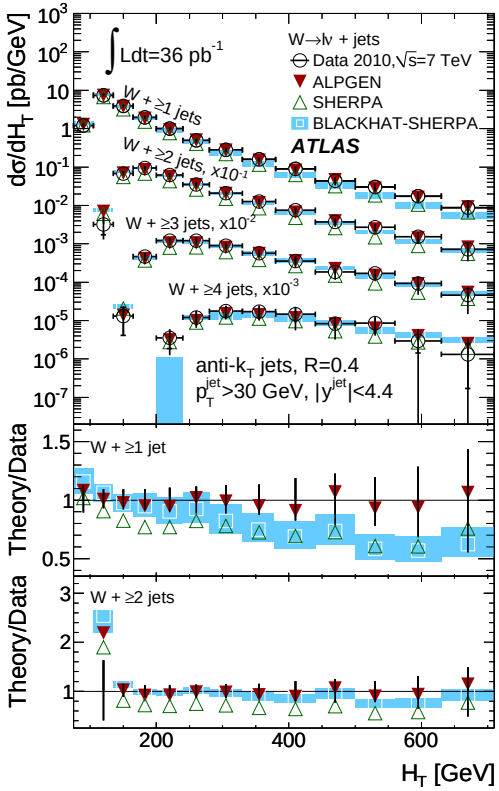
Measured using secondary vertex reconstruction.

For ≥ 2 jets, ATLAS results are somewhat above the NLO prediction and ALPGEN, PYTHIA MC generators, consistent at 2σ level.

(PLB 707 (2012) 418; PLB 706 (2012) 295)

W, Z+ jet results

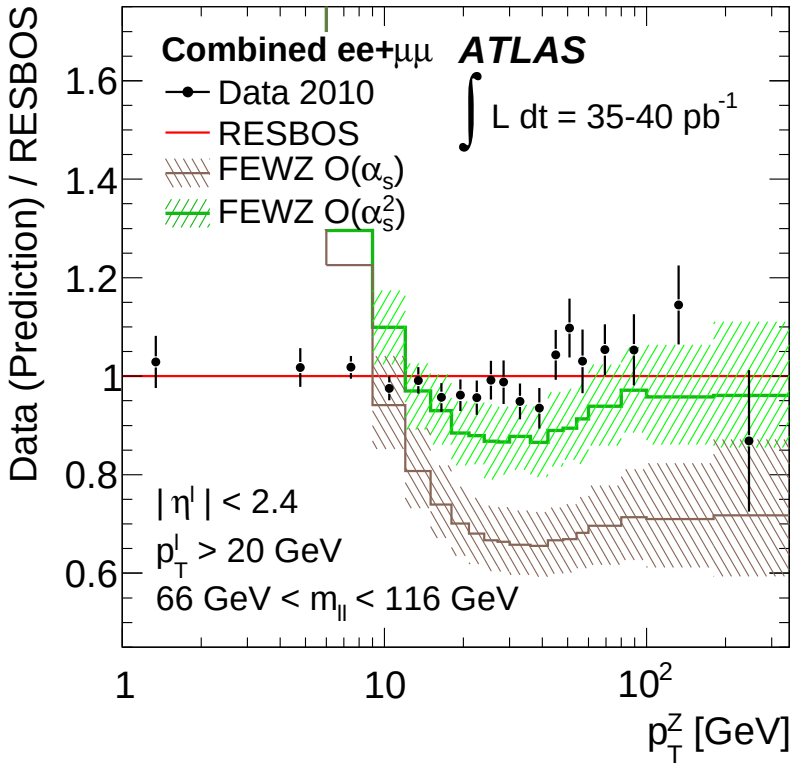


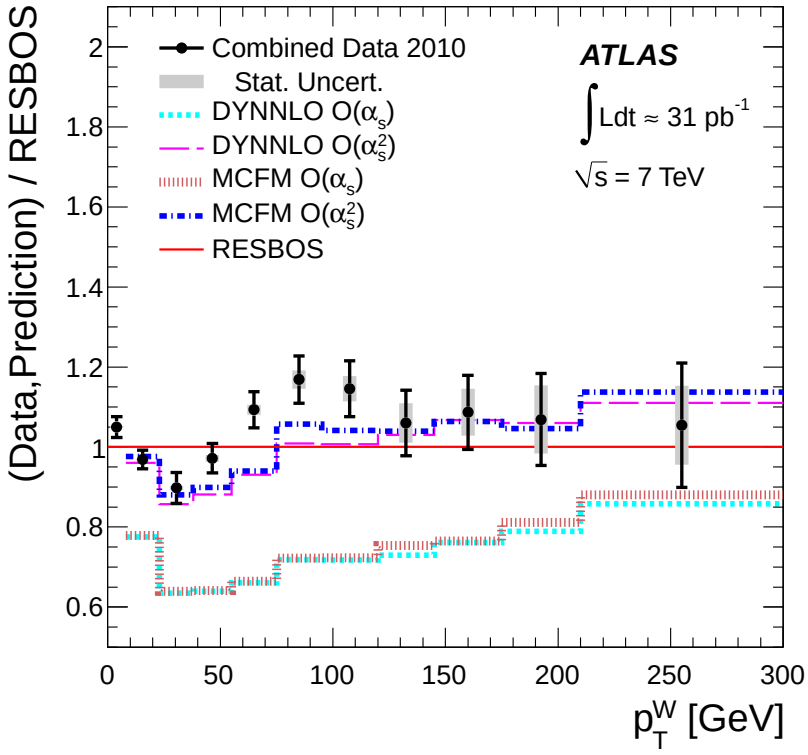


ATLAS performed detailed studies of *W, Z*+jet production cross sections, with up to four jets in the final state. Results are compared to NLO QCD calculations and MC generators with LO matrix element supplemented by parton showers. Uncertainties are dominated by the knowledge of the jet energy scale.

(arXiv:1201.1276, arXiv:1111.2690)

W, Z transverse momentum measurements





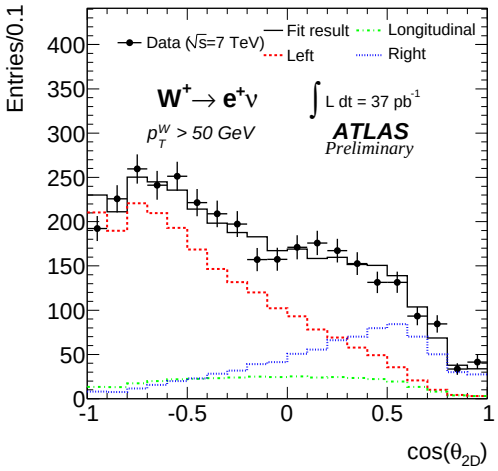
Measurement of *Z, W* transverse momentum allows one to study hadronic recoil inclusively, without need to reconstruct jets.

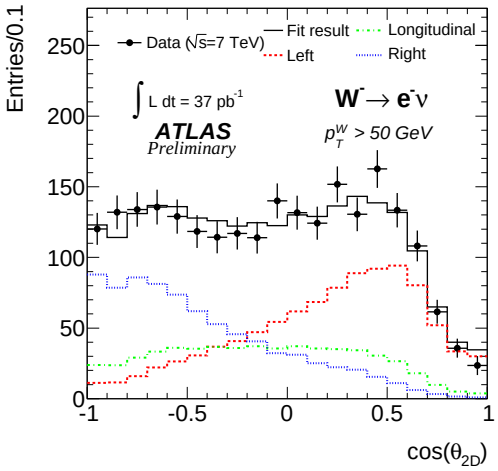
Z measurement has good resolution at low p_T, *W* reaches high p_T with higher statistics.

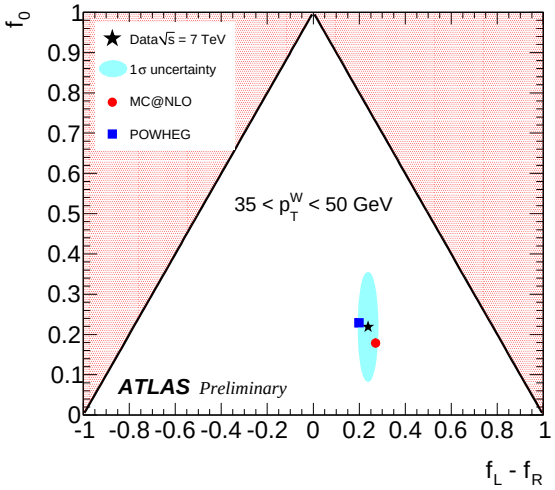
Data agree well with RESBOS predictions, some differences are observed for NNLO calculations.

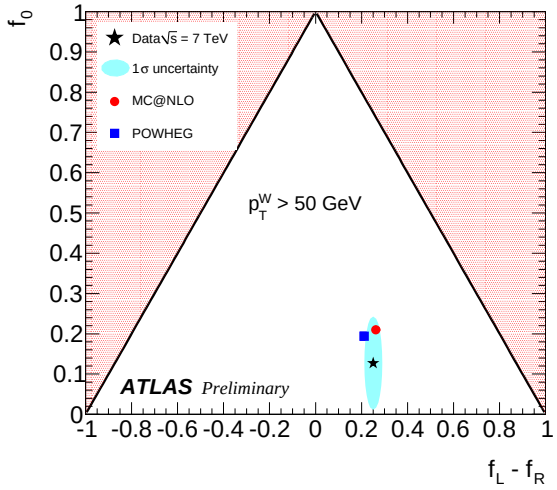
(PLB 705(2011)415,PRD 85 (2012) 012005)

W polarisation measurements





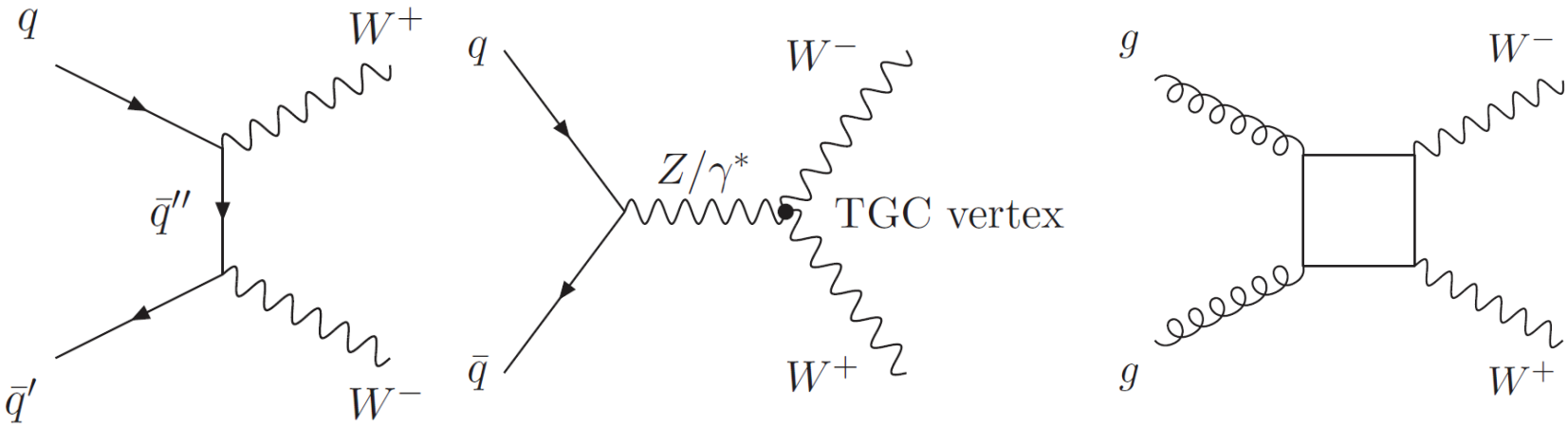




At LO, W-bosons are left- (f_L) or right-handed (f_R) and for large rapidity they are mostly left-handed (left-handed valence quark carries larger momentum vs sea anti-quark). At NLO, for significant transverse momenta, longitudinal polarisation (f_0) is also possible. Measure using "transverse helicity", $\cos\theta_{2D} \sim \boldsymbol{p}_T^{\ell *} \cdot \boldsymbol{p}_T^W$ Since $f_L + f_R + f_0 = 1$, express results in terms $f_L - f_R$ and f_0. Charge averaged $f_L - f_R$ is measured accurately, f_0 is more challenging. Measurements are consistent with NLO QCD.

(CERN-PH-EP-2012-016)

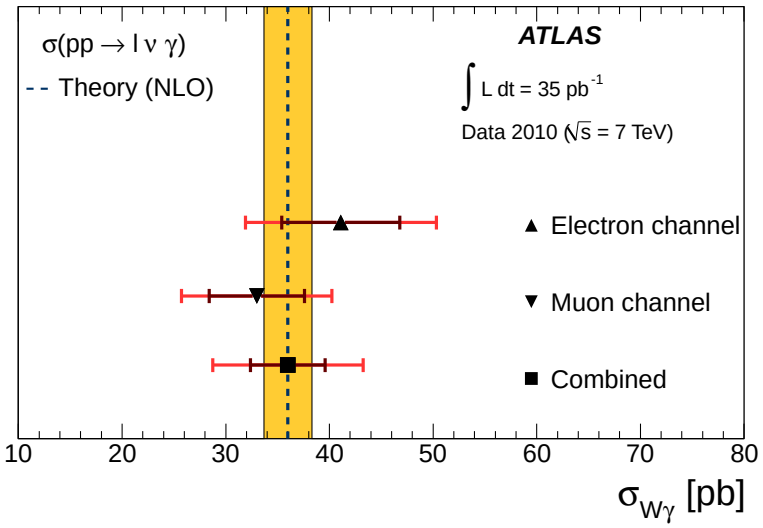
Diboson production at the LHC

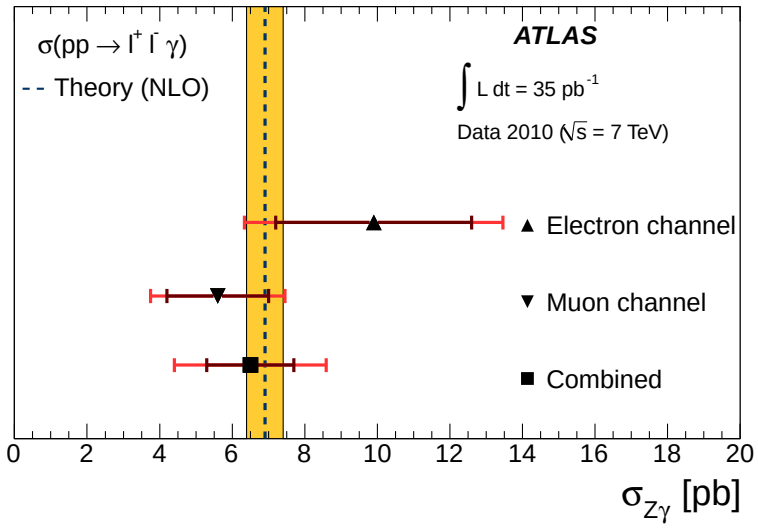


The main production diagrams for the W^+W^- pairs are the t-channel quark exchange and the s-channel diagram containing triple gauge coupling (TGC) vertex. The gluon-gluon fusion diagrams contribute $< 10\%$ for $\sqrt{S} = 7$ TeV. In the standard model, the TGC diagrams are zero for ZZ and WZ production.

→ measuring of the diboson production cross sections provide stringent tests of the standard model.

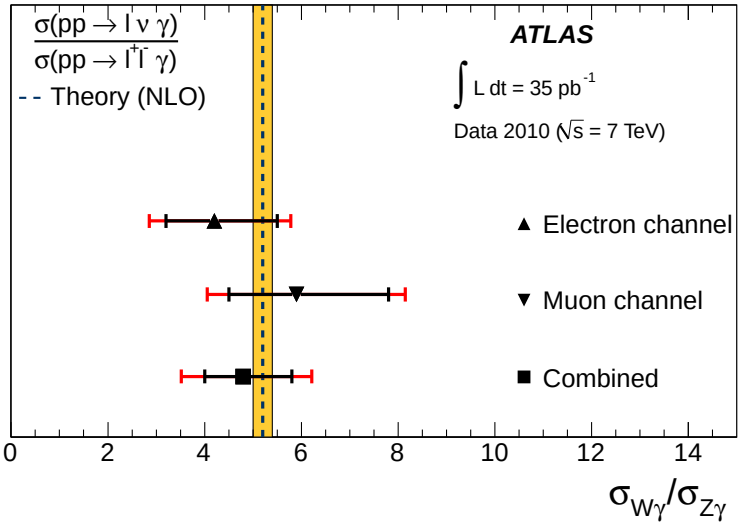
$W\gamma$ and $Z\gamma$ production





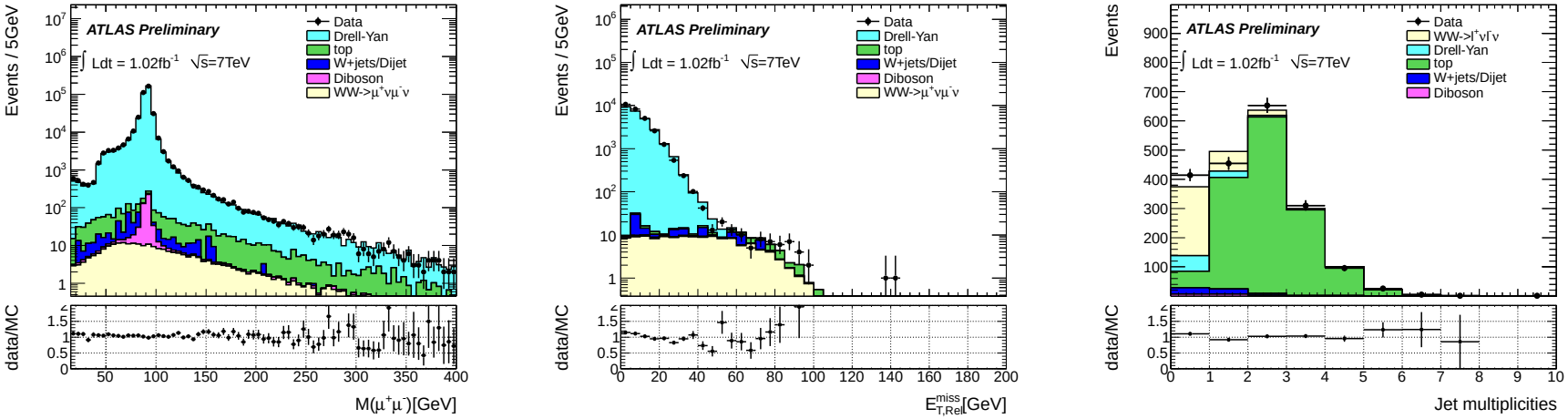
Measurement of $W + \gamma$ and $Z + \gamma$ production cross section with a high $p_T > 15$ GeV isolated from the leptons, $\Delta_R > 0.7$ photon.

The measurements are found to be in a good agreement with NLO calculations.



(JHEP 09 (2011) 072)

W^+W^- analysis



Analysis of W^+W^- events is performed in e^+e^-, $\mu^+\mu^-$ and $e^\pm\mu^\mp$ channels.

Main selection criteria: $p_{T,\ell}^{\max} > 25$ GeV, $M_{\ell\ell} > 15$ GeV, $M_{e\mu} > 10$ GeV, Z veto, $E_{T,Ref}^{miss} > 40, 45, 25$ GeV for ee, $\mu\mu$ and $e\mu$ channel. Here

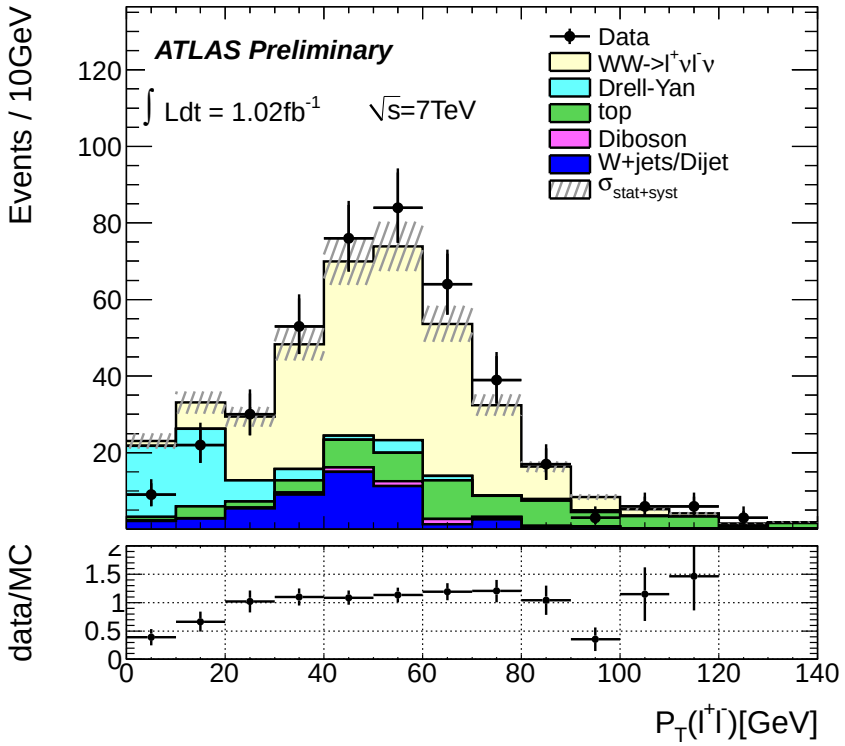
$$E_{T,Ref}^{miss} = \begin{cases} E_T^{miss} \times \sin\Delta\phi & \text{if} \quad \delta\phi < \pi/2 \\ E_T^{miss} & \text{if} \quad \delta\phi \geq \pi/2 \end{cases}$$

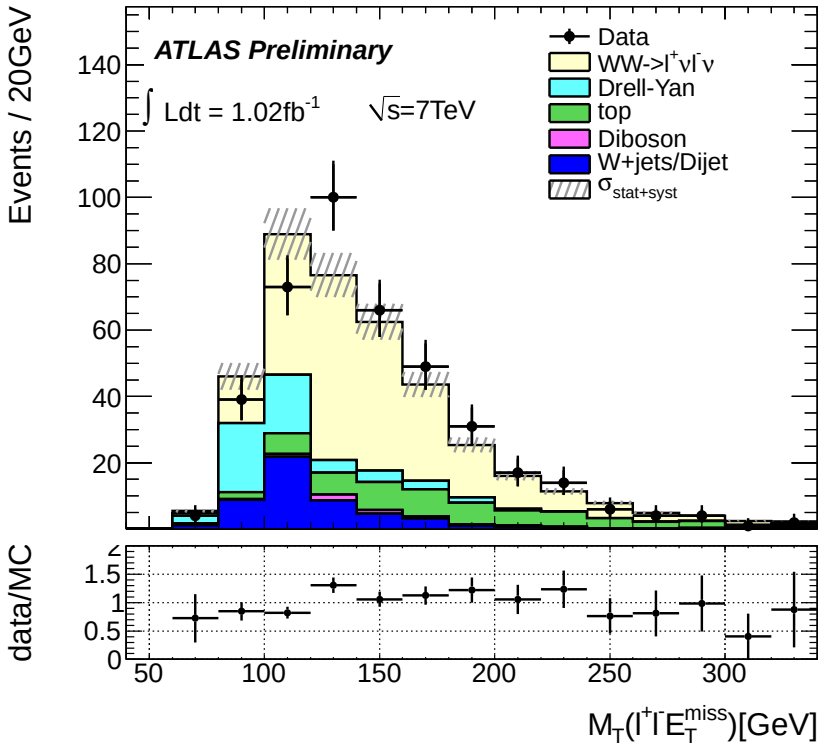
where $\Delta\phi$ is azimuthal between E_T^{miss} and nearest lepton/jet.

The Drell-Yan background is suppressed by Z veto and $E_{T,Ref}^{miss}$ cut. (the background is much smaller for $e\mu$ decay channel). The top background is reduced by the jet veto cut.

(PRL 107 (2011) 041802, ATLAS-CONF-2011-110)

W^+W^- results



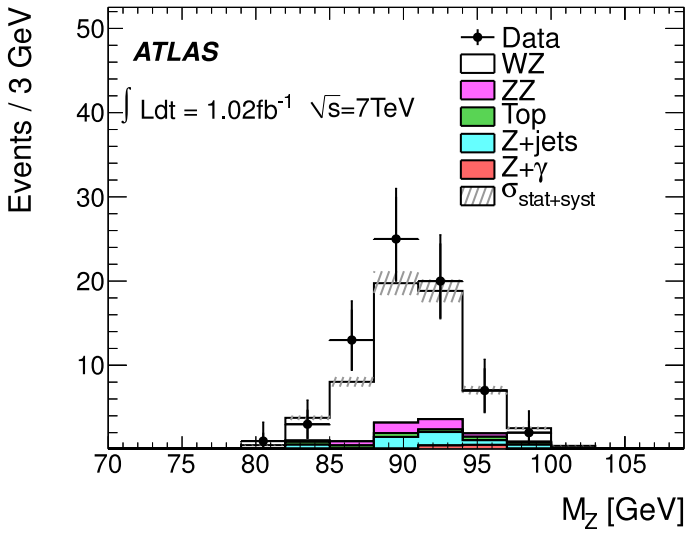


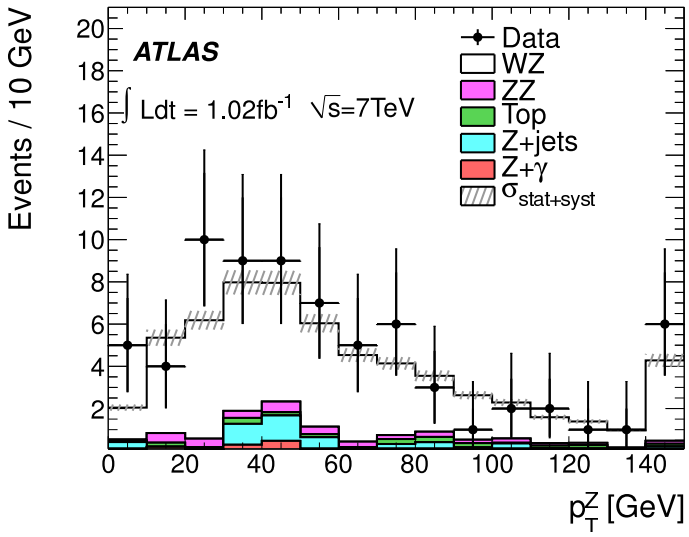
Final event yield is 414 candidate events with an estimated background of 170 ± 28 events. The measured cross section is

$$\sigma_{WW} = 48.2 \pm 4.0_{\text{stat}} \pm 6.4_{\text{syst}} \pm 1.8_{\text{lumi}} \text{ pb},$$

consistent with the standard model NLO calculation of 46 ± 3 pb.
(PRL 107 (2011) 041802, ATLAS-CONF-2011-110)

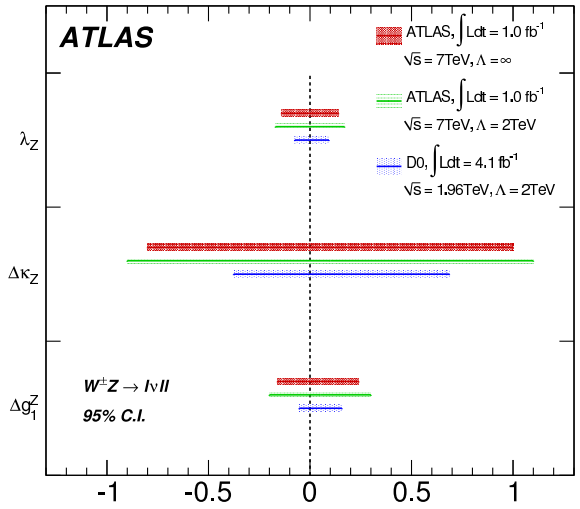
$W^{\pm}Z$ analysis





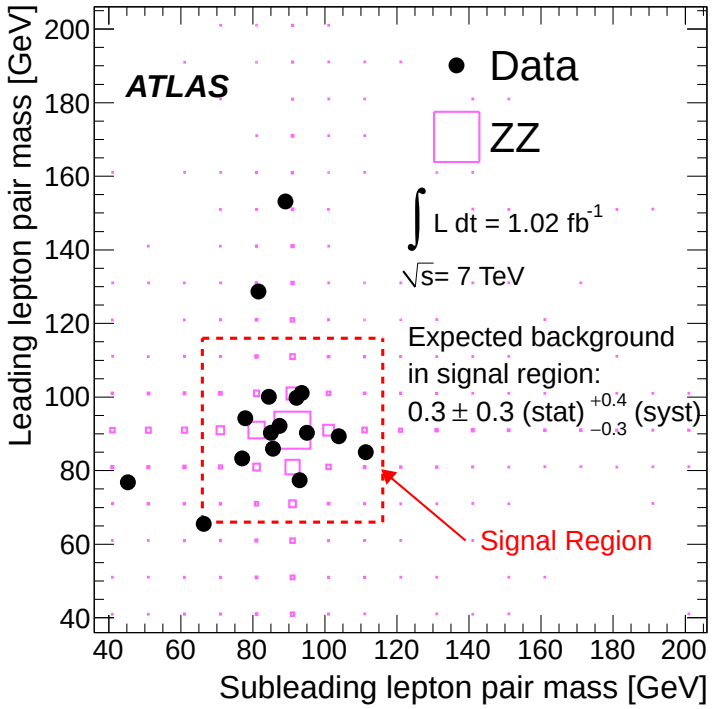
WZ analysis has significantly reduced background, 71 candidates are observed with background expectation of ~ 12 events.

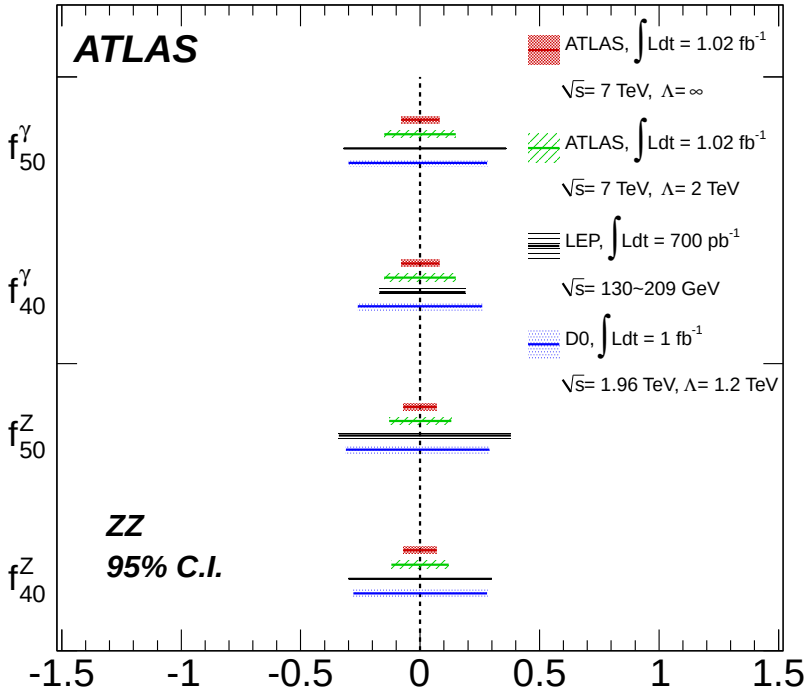
ATLAS result is consistent with the SM expectation.



(arXiv:1111.5570)

ZZ measurement





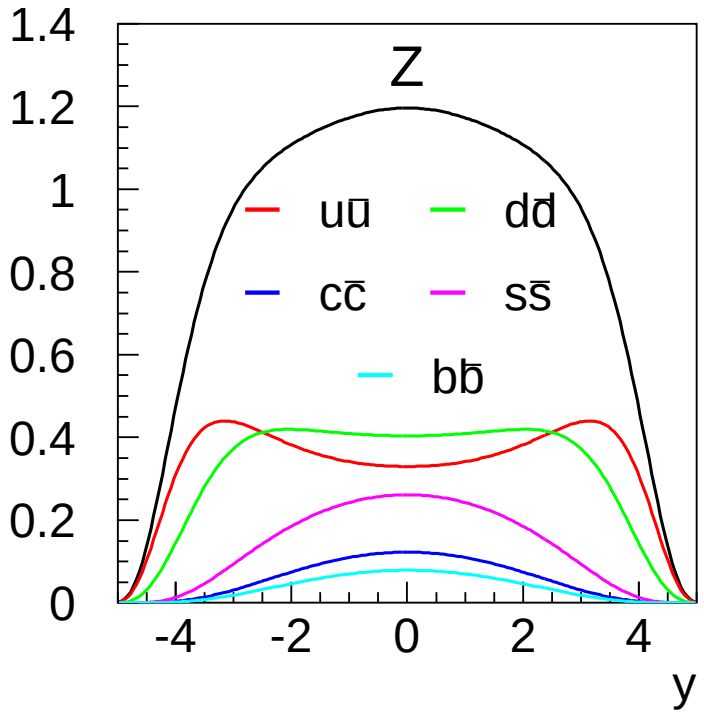
Observation of 12 events with an expected background of $0.3^{+0.05}_{-0.04}$.
The cross section for on-shell ZZ production
$\sigma^{tot}_{ZZ} = 8.5^{+2.7}_{-2.3}\,\text{stat}^{+0.4}_{-0.3}\,\text{syst} \pm 0.3\,\text{lumi}$ pb is consistent with the SM expectation $6.5^{+0.3}_{-0.2}$ pb. ATLAS limits on the forbidden TGC are competitive or exceeding other experimental results.

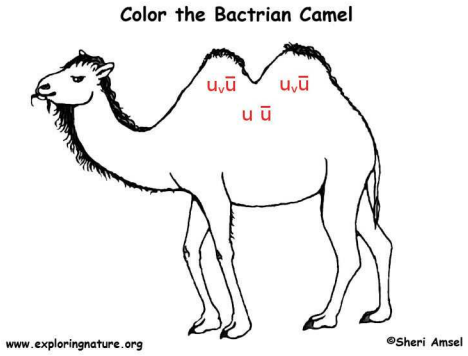
(PRL 108 (2012) 041804)

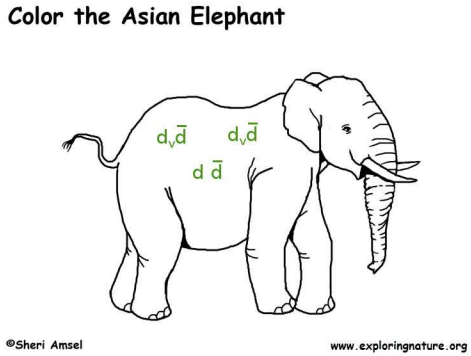
Summary

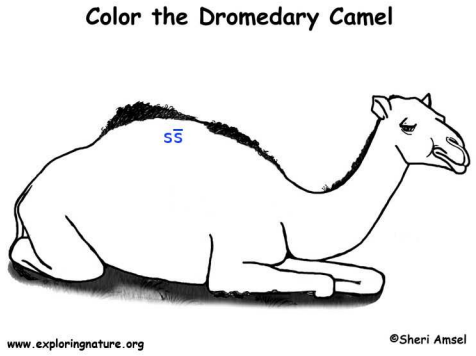
- Successful operation of the LHC and the ATLAS detector enabled precision studies of the standard model.
- Accurate measurements of the differential cross sections for W, Z production challenge our knowledge of the parton density functions. The first ATLAS analysis of the PDFs reveals novel information on the strange quark sea density which is found to be consistent with the down quark sea density at $x = 0.023$ and $Q^2 = 1.9\ \mathrm{GeV}^2$, supporting the flavour $SU(3)$ symmetry.
- Measurements of W, Z+jet production as well as of W, Z p_T spectra investigate (N)LO QCD calculations and test various MC models.
- W polarisation is found to be consistent with the NLO calculations.
- Studies of the diboson production start to impose limits on the TPG beyond the SM.

Flavor decomposition of the Z production at the LHC

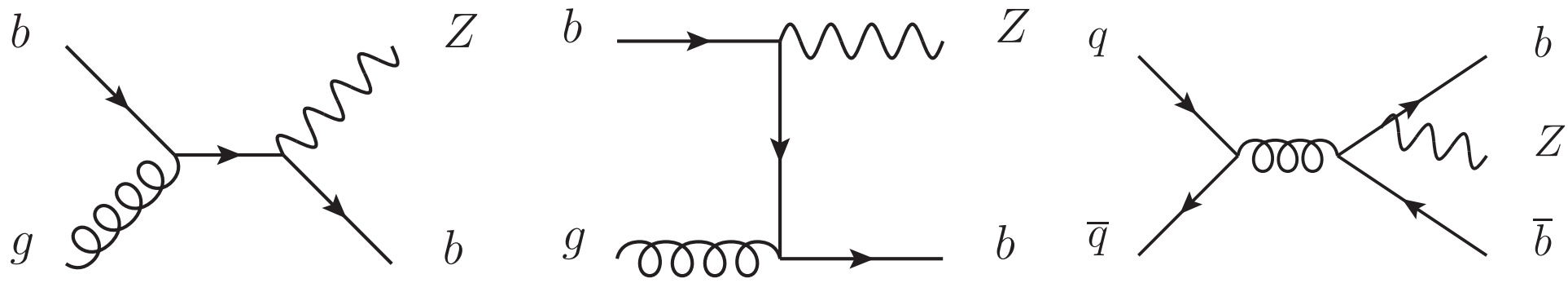


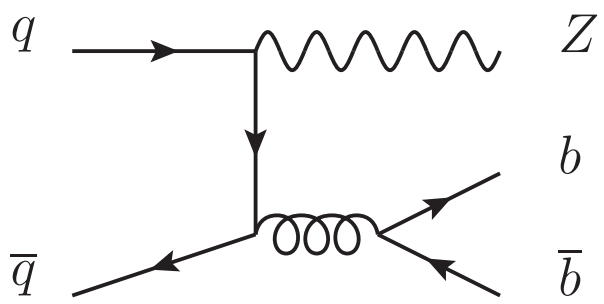






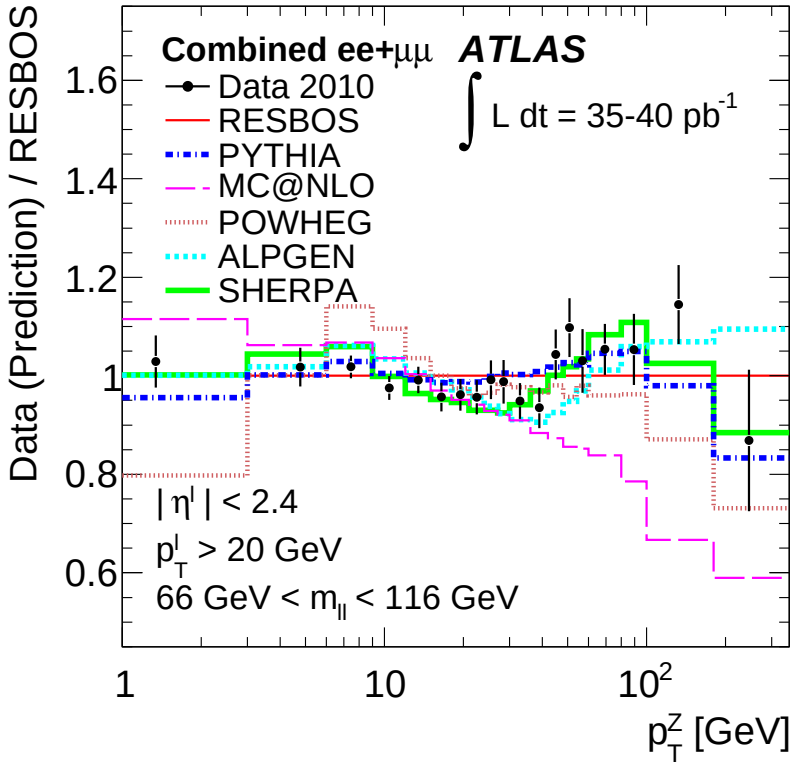
$Z + b$ jet production leading diagrams

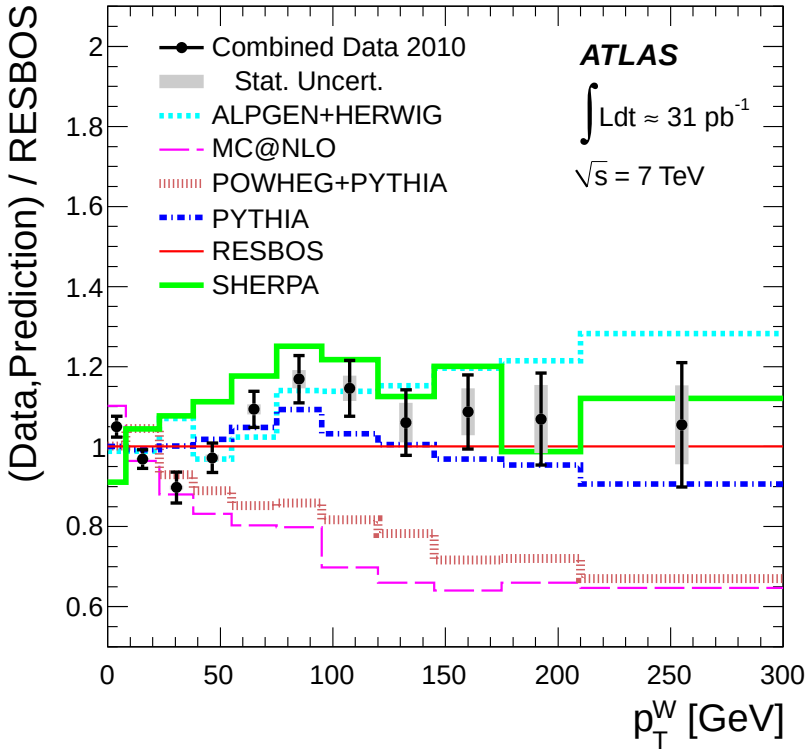




The leading processes for $Z + b$ jet production include diagrams with b-quark present in the initial state at LO as well as higher order diagrams in which b-quark is produced in the final state.

W, *Z* transverse momentum measurements





Measurements of the *Z* and *W* transverse momentum distribution are compared to various LO and NLO Monte Carlo simulations. Good agreement for PYTHIA, SHERPA and ALPGEN LO generators, however significant disagreement with NLO generators MCNLO and POWHEG with PYTHIA showering.

(PLB 705(2011)415,PRD 85 (2012) 012005)