Measurements of the Vector boson production with the ATLAS Detector

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for

ATLAS Collaboration
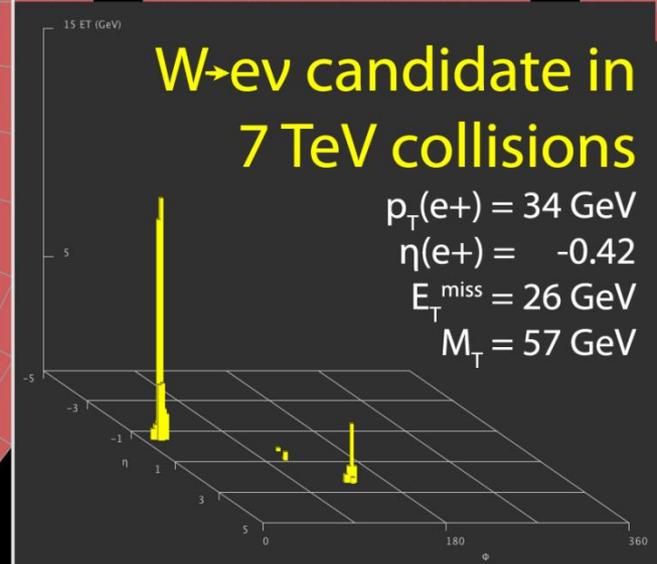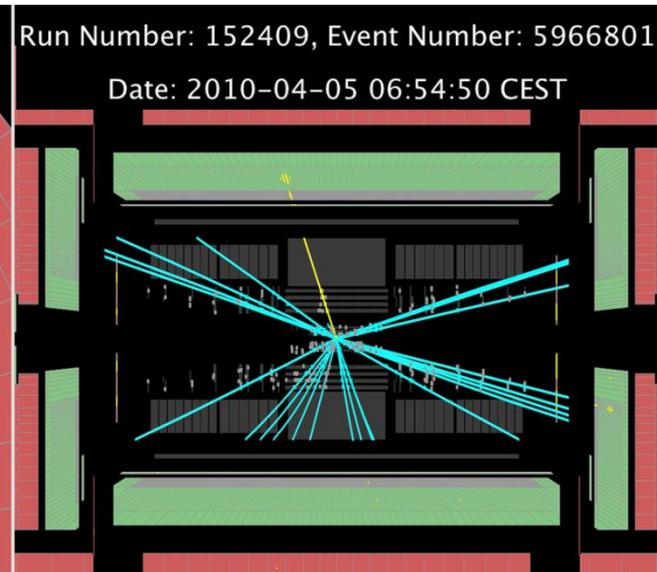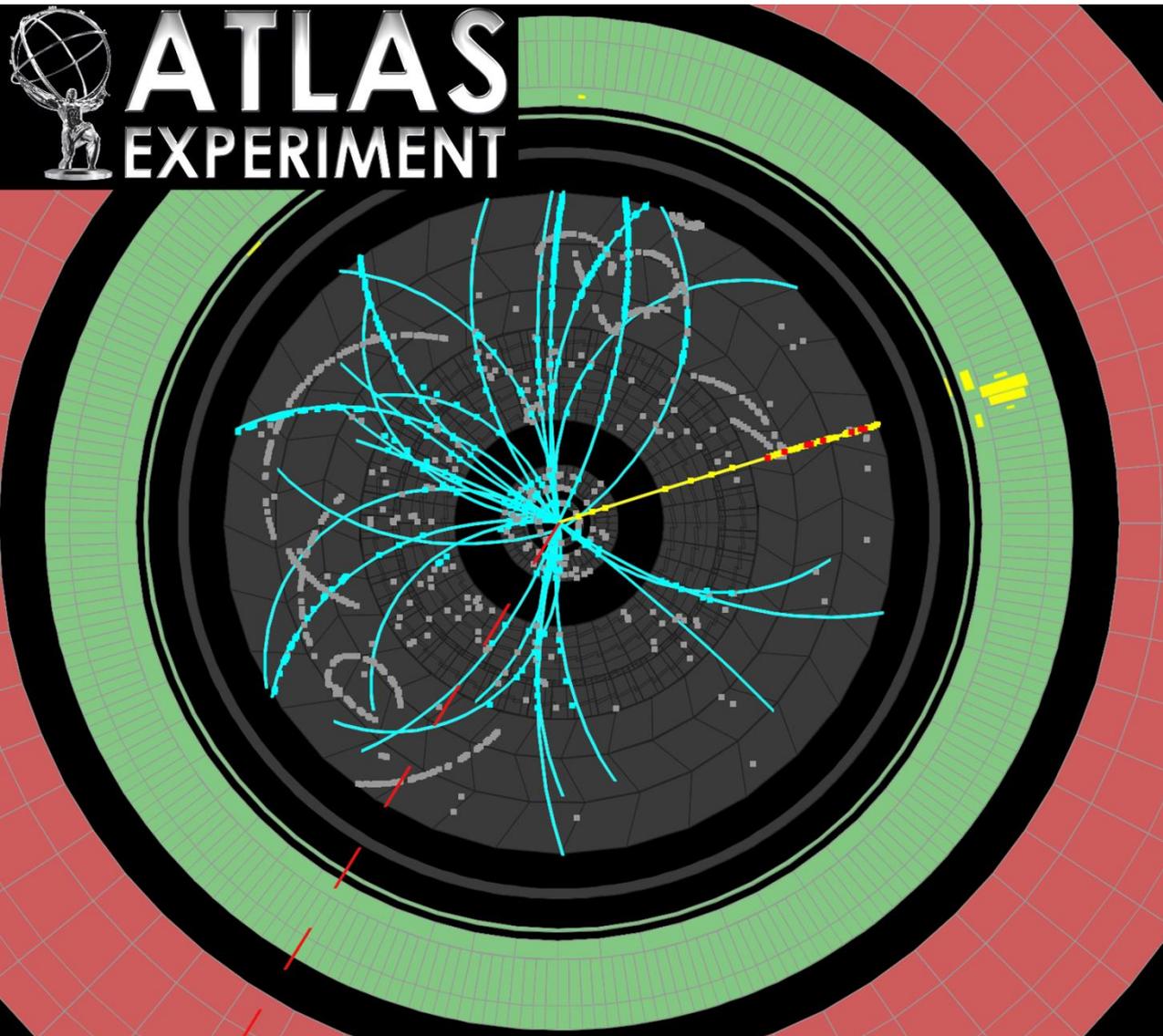
W/Z measurements at **ATLAS**

More than 50 publications in total. Wide range of topics is covered.

Recent analyses selected for this presentation:

- W/Z cross sections at 7 TeV using the full 2011 dataset

- W mass at 7 TeV using the full 2011 dataset

Run Number: 152409, Event Number: 5966801

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W→eν candidate in
7 TeV collisions

$p_T(e+) = 34$ GeV
$\eta(e+) = -0.42$
$E_T^{miss} = 26$ GeV
$M_T = 57$ GeV

Precision measurement and interpretation of inclusive W^+, W^- and Z production cross sections with the ATLAS detector

1) Inclusive cross sections
2) Test of lepton universality
3) Differential cross sections
4) Interpretation of data in NNLO QCD analysis
5) Ratio of strange-to-light sea quarks densities determined
6) New measurement of the CKM matrix element |Vcs|

Measurements are performed in electron and muon channels and finally they are combined.

Fiducial phase space definitions

$$l = e, \mu$$

$W^{\pm} \to l^{\pm}\nu:$ $P_{T,l} > 25\ GeV, |\eta_l| < 2.5,\ P_{T,\nu} > 25\ GeV, m_T > 40\ GeV$

$Central\ Z \to ll:$ $P_{T,l} > 20\ GeV, |\eta_l| < 2.5, 46\ GeV < m_{ll} < 150\ GeV$

$Forward\ Z \to ll:$ $P_{T,l} > 20\ GeV, |\eta_{l_1}| < 2.5, 2.5 < |\eta_{l_2}| < 4.9$
$66\ GeV < m_{ll} < 150\ GeV$

Theoretical predictions:
QCD NNLO : DYNNLO 1.5, FEWZ 3.1.b2
EW   NLO: MCSANC 1.20
PDF: ATLAS-epWZ12

Improved precision

0.6%, 0.5% and 0.32%, precision reached for W^+, W^- and Z, respectively, appart of the common 1.8% normalization uncertainty due to the luminosity specification. The differential measurements are nearly as precise except the edges of the phase space.

	$\sigma^{tot}_{W \to \ell\nu}$ [pb]
$W^+ \to \ell^+\nu$	$6350 \pm 2\,(\text{stat}) \pm 30\,(\text{syst}) \pm 110\,(\text{lumi}) \pm 100\,(\text{acc})$
$W^- \to \ell^-\bar{\nu}$	$4376 \pm 2\,(\text{stat}) \pm 25\,(\text{syst}) \pm 79\,(\text{lumi}) \pm 90\,(\text{acc})$
$W \to \ell\nu$	$10720 \pm 3\,(\text{stat}) \pm 60\,(\text{syst}) \pm 190\,(\text{lumi}) \pm 130\,(\text{acc})$
	$\sigma^{tot}_{Z/\gamma^* \to \ell\ell}$ [pb]
$Z/\gamma^* \to \ell\ell$	$990 \pm 1\,(\text{stat}) \pm 3\,(\text{syst}) \pm 18\,(\text{lumi}) \pm 15\,(\text{acc})$

Test of electron-muon universality
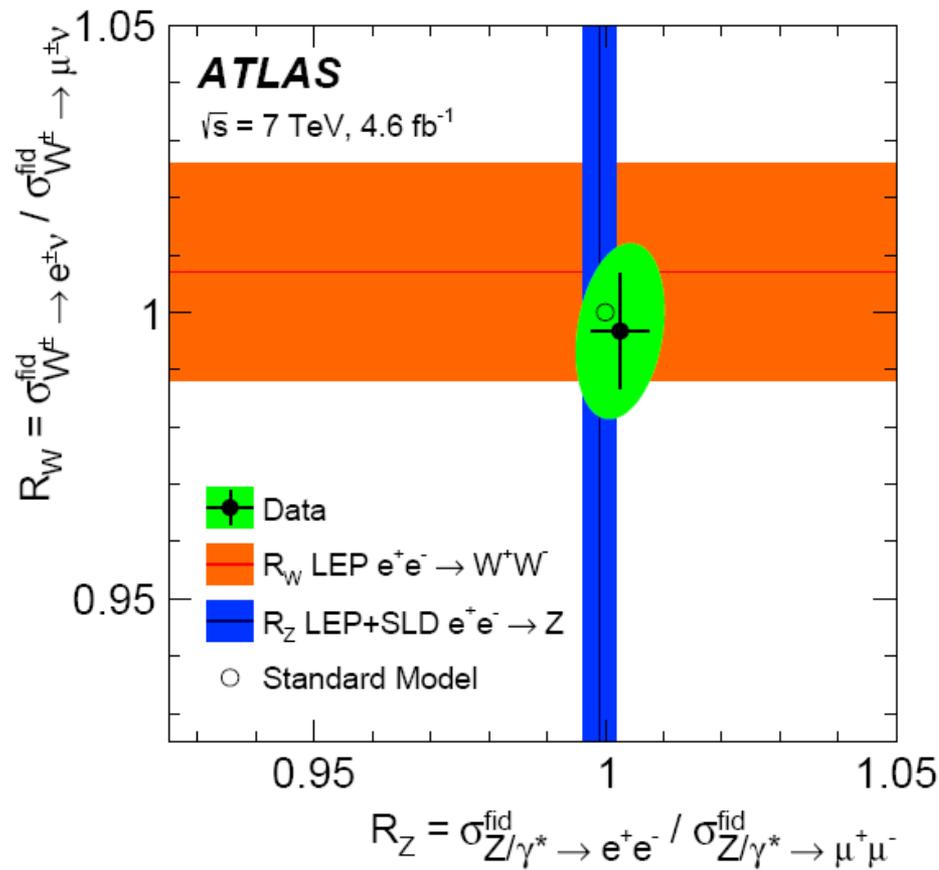
Many systematic uncertainties cancel in the ratio.

$$R_W = \frac{\sigma_{W \to e\nu}^{fid}}{\sigma_{W \to \mu\nu}^{fid}} = \frac{BR(W \to e\nu)}{BR(W \to \mu\nu)} = 0.9967 \pm 0.0004(stat) \pm 0.0101(syst)$$

This measurement is more precise than the combination of **LEP** results, **CDF** and **LHCb Collaboration**. It also significantly improves the previous **ATLAS** measurement.

$$R_Z = \frac{\sigma_{Z \to ee}^{fid}}{\sigma_{Z \to \mu\mu}^{fid}} = \frac{BR(W \to ee)}{BR(W \to \mu\mu)} = 1.0026 \pm 0.0013(stat) \pm 0.0048(syst)$$
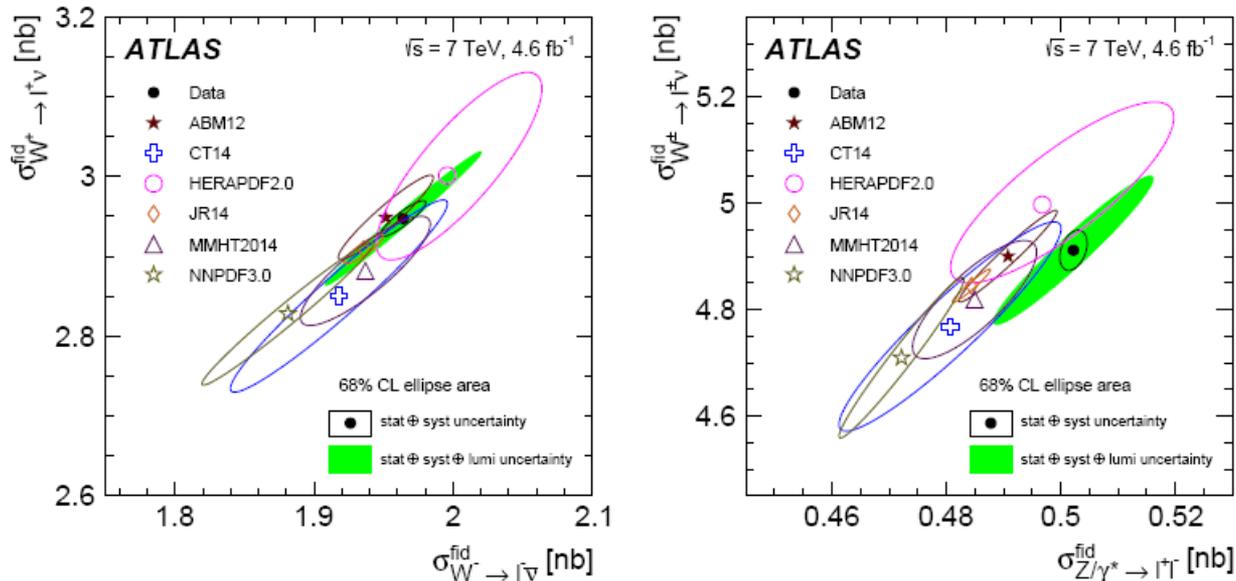
This measurement is in agreement with the combined result of **LEP** and **SLC** data and again, significantly more precise than the **ATLAS** measurements with the 2010 and 2015 data.

The orange and blue bands correspond to the measurements for on-shell **W** and **Z** production as obtained at **LEP** and **SLC**. The **SM** expectation is indicated with an open circle.
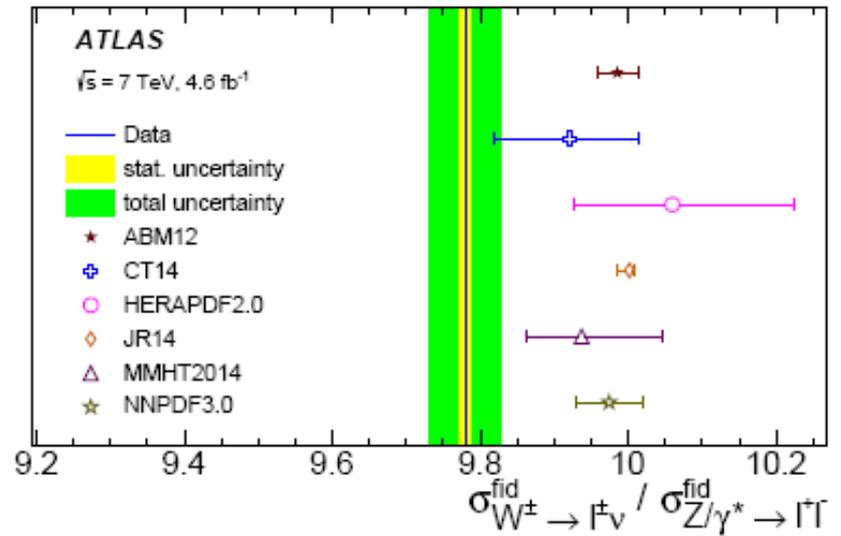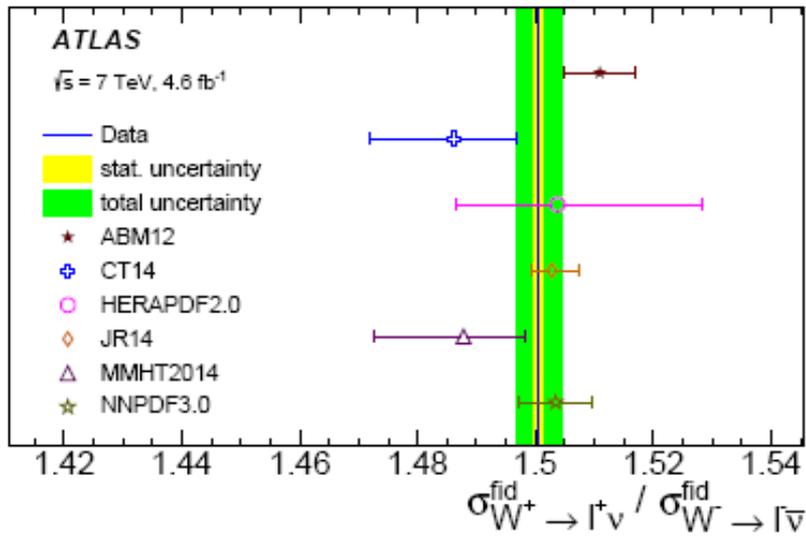
Fiducial cross sections discriminate between PDFs

NNLO QCD predictions with **NLO EW** corrections based on the **ABM12**, **CT14**, **HERAPDF2.0**, **JR14**, **MMHT2014** and **NNPDF3.0** PDF sets are compared to the data. PDF sets **CT14**, **MMHT2014** and **NNPDF3.0** give predictions that are lower both for the **W** positive and the **W** negative, and the same trend is observed also for **Z**.
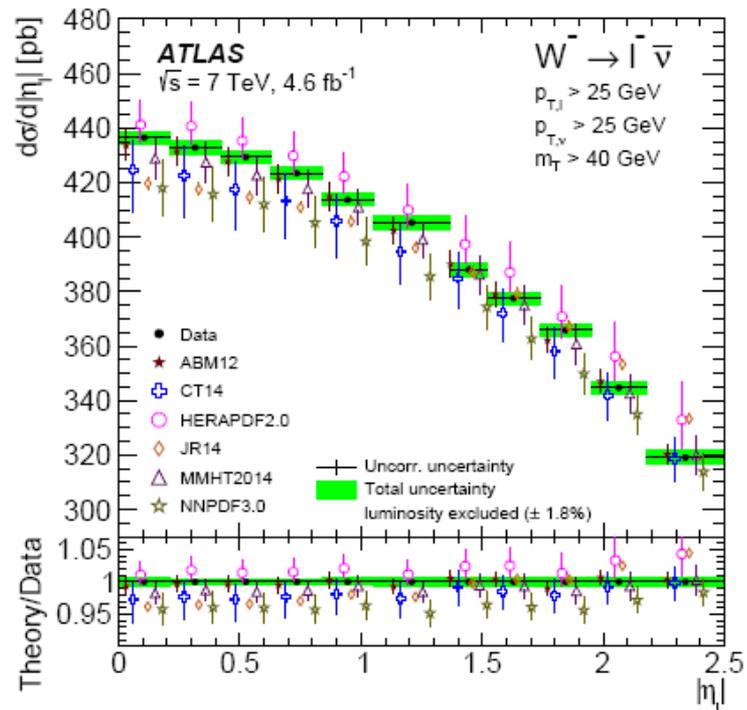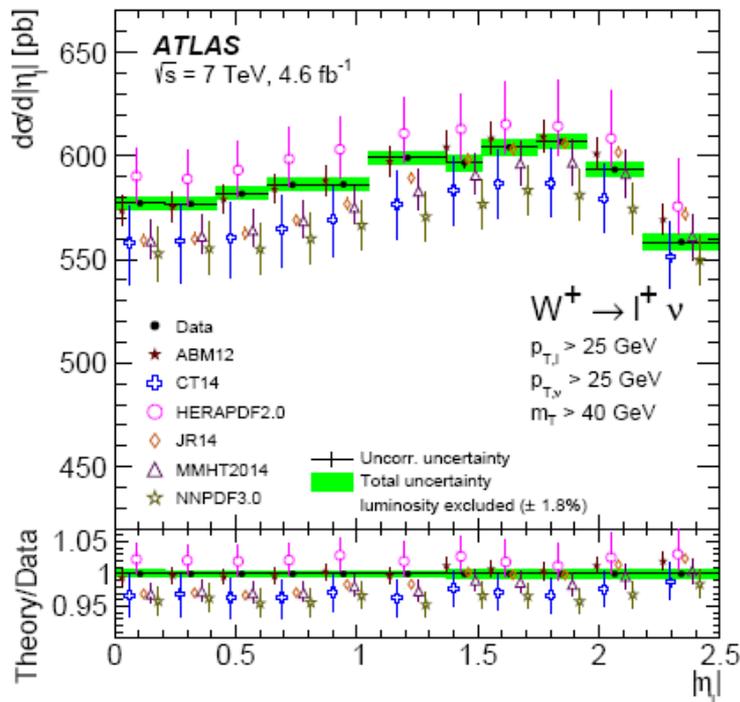
Cross section ratios

The measured **W** positive / **W** negative ratio is well reproduced, but all PDF sets predict a higher **W/Z** ratio than measured in the data.
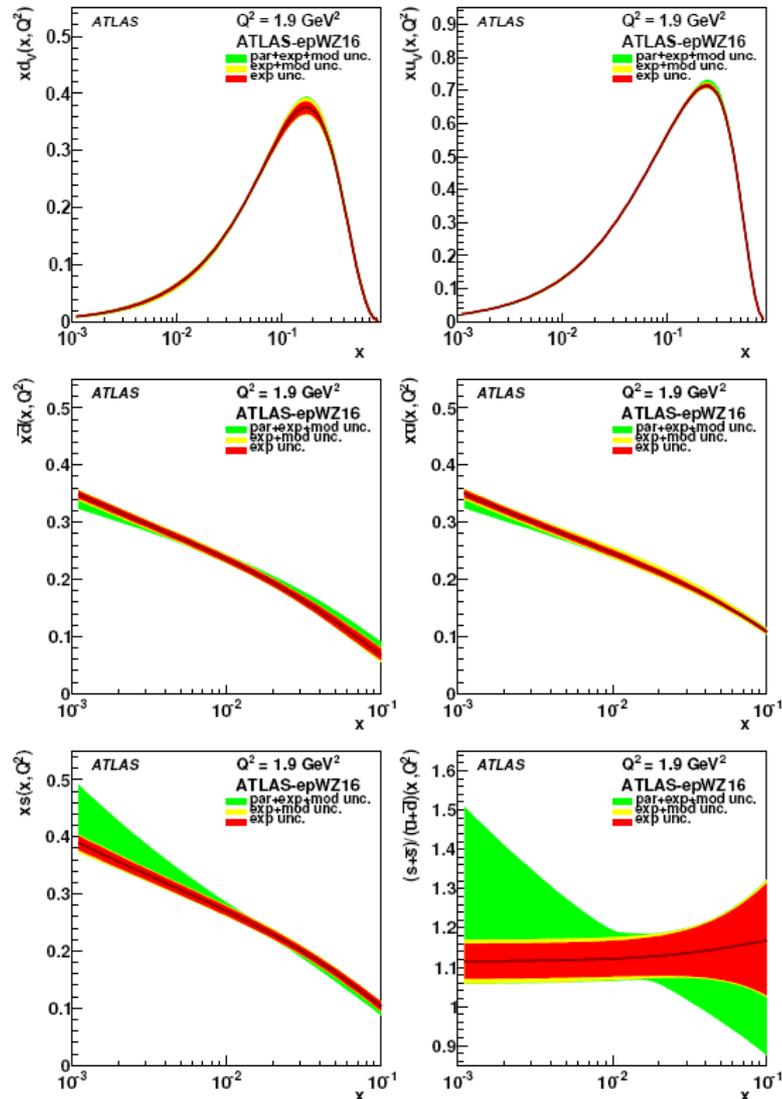
Differential distributions

The predictions with the **ABM12** PDF set match data particularly well, while the predictions of **NNPDF3.0**, **CT14**, **MMHT14** and **JR14** tend to be below and the **HERAPDF2.0** set slightly above the **W** cross section data.
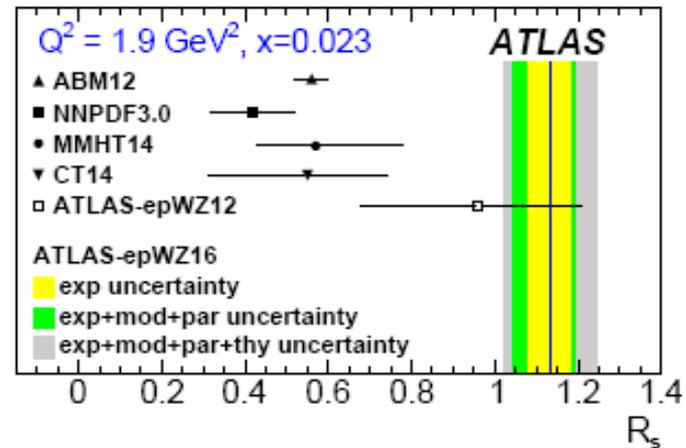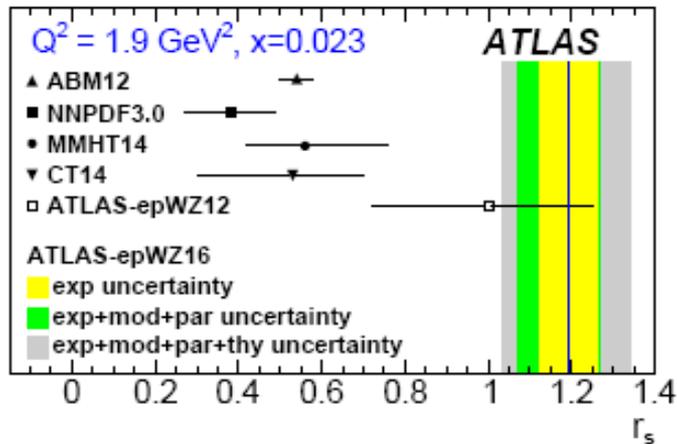
QCD analysis

Differential **Drell-Yan** production cross-sections are studied in combination with the final **NC** and **CC DIS HERA** I+II data within the framework of perturbative QCD. New set of PDFs obtained: **ATLAS-epWZ16**

Strangeness enhancement

Recent global fit analyses **ABM12**, **MMHT14**, **CT14** and **NNPDF3.0** predict both ratios to be significantly lower than unity, with values between 0.4 and 0.6. ATLAS data sees enhanced strangeness.
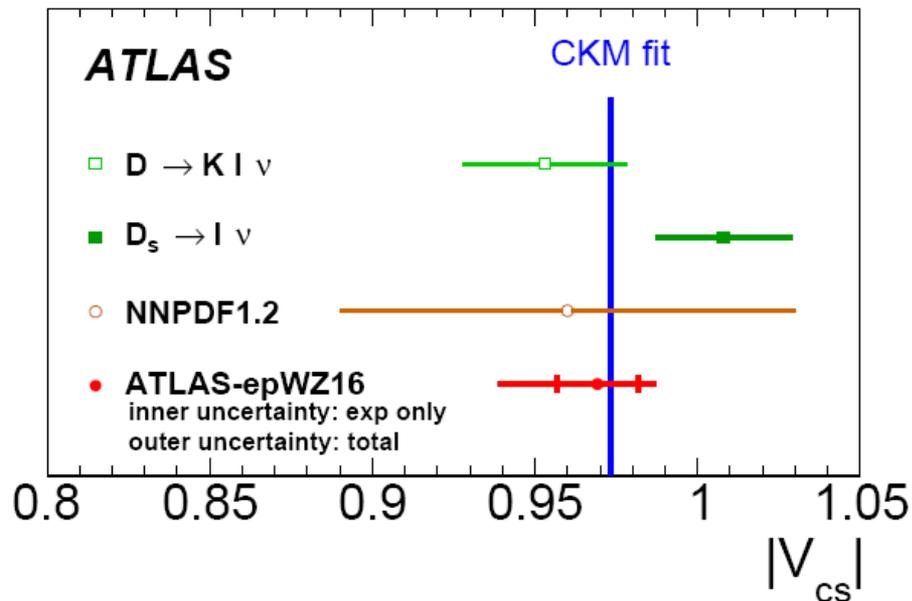

$$r_s = \frac{s + \bar{s}}{2\bar{d}}$$

$$R_s = \frac{s + \bar{s}}{\bar{u} + \bar{d}}$$

Competitive determination of the value of $|V_{cs}|$

ATLAS specification is compared with the determinations obtained from the leptonic Ds decay and semileptonic D meson decay obtained from data of **CLEO-c**, **BABAR** and **Belle Collaboration**. In addition, an early determination by the **NNPDF Collaboration** from the **QCD** fit is shown.
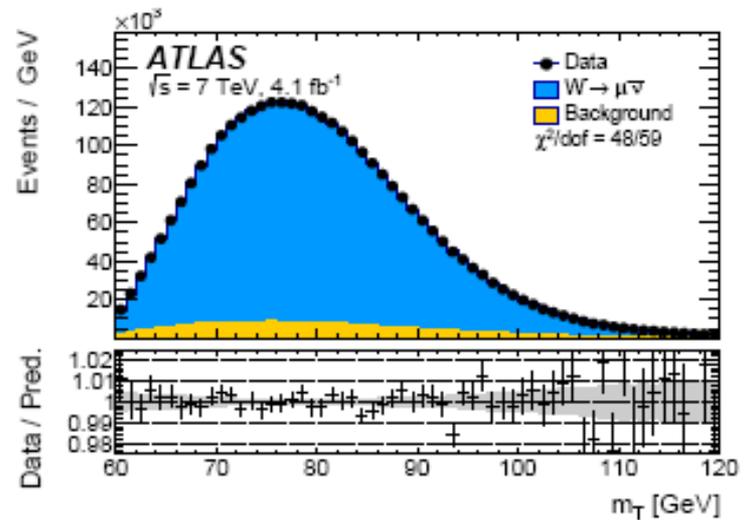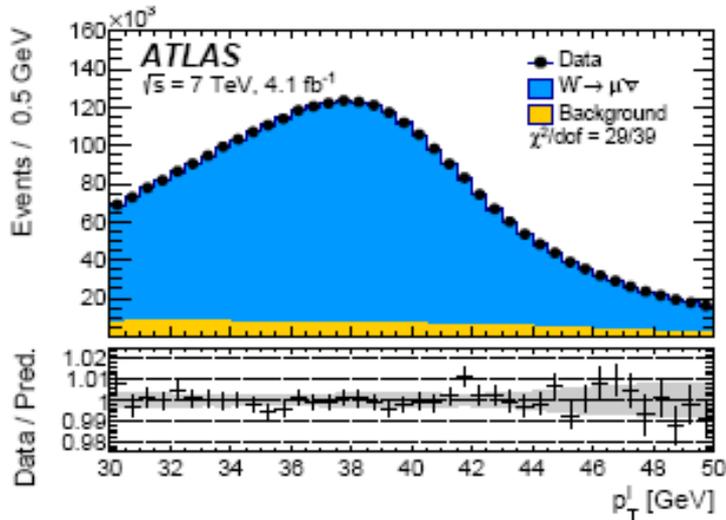
$$|V_{cs}| = 0.969 \pm 0.013(\exp)^{+0.006}_{-0.003}(\mathrm{mod})^{+0.003}_{-0.027}(par)^{+0.011}_{-0.005}(thy)$$

Measurement of the W-boson mass   in pp collisions at √s = 7 TeV with the ATLAS detector

1) The method and systematic uncertainties
2) Comparison of **ATLAS** value of **W** mass with the combined values of **LEP** and **Tevatron** experiments and with the **SM** prediction of the global electroweak fit.
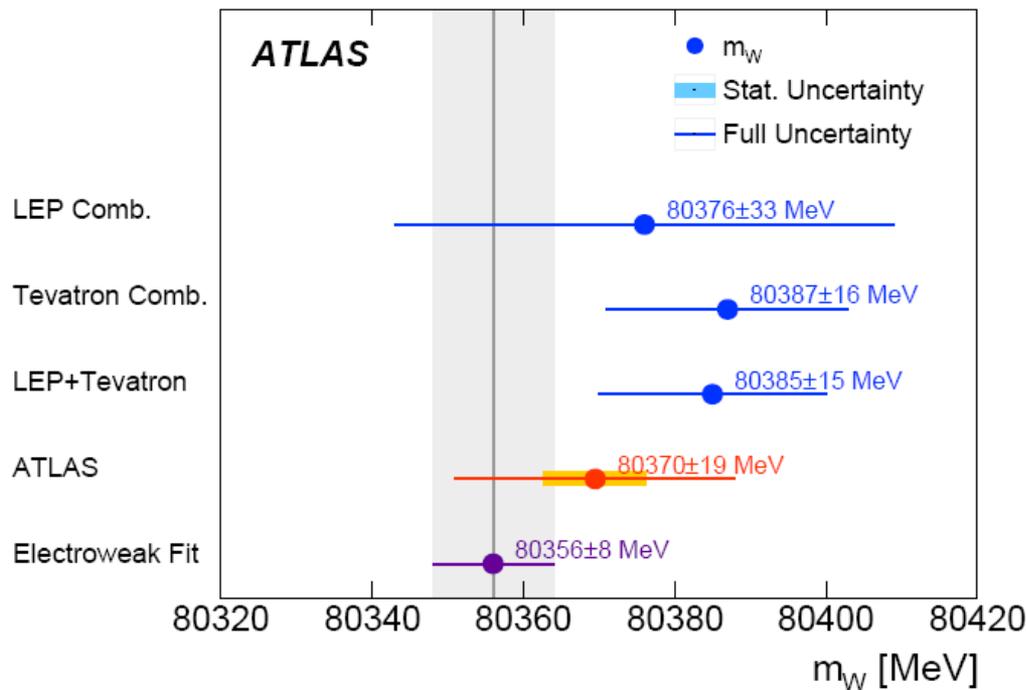3) Confidence-level contours in the plane **W** mass – **top** quark mass
4) ATLAS value

The method: m_W was obtained from the fits to the transverse momentum of the charged lepton and to the transverse mass of the W boson. Templates including signal and background were simulated for several values of W boson mass. The templates were compared to the measured distributions by means of x^2 test. The measured value of m_W is determined by the analytical minimization of the x^2 distribution.

Uncertainties: dominant part of the overall uncertainty of the W mass measurement is formed by the modelling uncertainties. Especially better knowledge of the PDFs and improved predictions for the Drell-Yan production is needed for future measurement of the W-boson mass at the LHC.
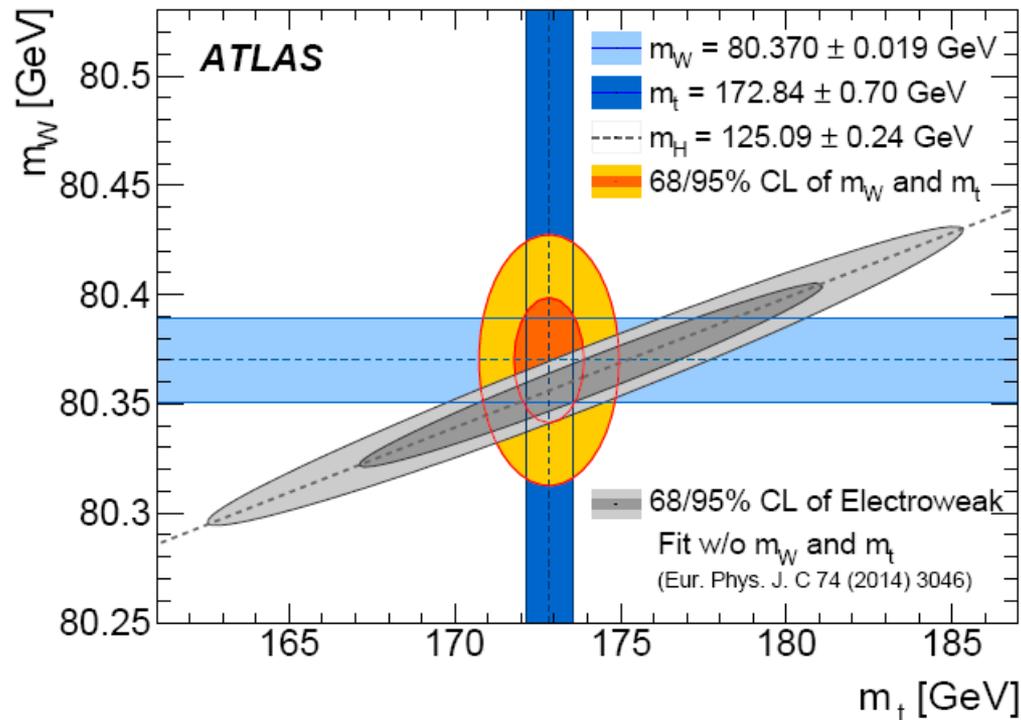
W boson mass measurement

Measured value of **W** mass is compared with the combined measurements of **LEP**, **Tevatron**, combination of **LEP** and **Tevatron** with the **SM** predictions from the **global electroweak fit**. **Electroweak fit** is updated with the **LHC** values of **top** quark and **Higgs** boson mass.

W boson mass measurement

The yellow and brown ellipses correspond to the 68% and 95% CL contours of the **ATLAS** measurement of the **top** quark and **W** boson masses. **Electroweak fit** is updated with the **LHC** values of **top** quark and **Higgs** boson mass.

W boson mass measurement

$$m_W = 80370 \pm 7(stat) \pm 11(\exp.syst.) \pm 14(\mathrm{mod}.syst.) \ MeV$$
$$= 80370 \pm 19 \ MeV$$

$$m_{W^+} - m_{W^-} = -29 \pm 28 \, MeV$$

"The **W**-boson mass measurement is compatible with the current world average **80385±15 MeV** and is similar in precision to the currently leading measurements performed by the **CDF** and **D0** collaborations."

SUMMARY
RUN 1

- ATLAS produced more than 50 publications dealing with W/Z physics
- All topics studied at hadron colliders covered
- First complex analyses testing simultaneously several predictions of SM published
- Predictions of Standard model tested in most cases at NLO accuracy or higher
- Analysis of 7 TeV data nearly completed, analysis of 8 TeV data from the year 2012 still ongoing
- Full 7 TeV dataset exploited recently. Measurement of the W mass reaches precision of the best experiments at Tevatron.
- Not including luminosity uncertainty, sub-percent precision of published values of integrated W and Z cross sections at 7 TeV achieved.

SUMMARY
RUN 2 :
STATUS, EXPECTATIONS

- New kinematic regime: $\sqrt{s}$: 8 TeV $\rightarrow$ 13 TeV (factor $\approx$ 1.6)
- Recorded luminosities : $L_{\text{int}}^{2015} = 3.9 \, fb^{-1}$, $L_{\text{int}}^{2016} = 36 \, fb^{-1}$
- Expectations: $L_{\text{int}}^{2017} \geq 50 \, fb^{-1}$, $L_{\text{int}}^{2018} \geq 50 \, fb^{-1}$
- Year 2018: $\sqrt{s}$ > 13 TeV ?
- First results based on 13 TeV data (from 2015) published: benchmark integrated cross sections.
- 140 millions of W^-, 200 millions of W^+ and 40 millions of Z expected in full 13 TeV dataset available at the end of 2017.

Backup

ATLAS Detector