Measurements of vector bosons and vector bosons plus jet production with the ATLAS detector

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on behalf of the ATLAS Collaboration

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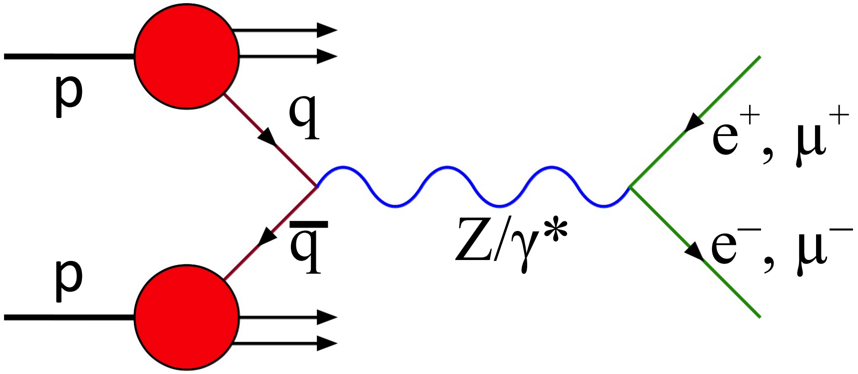
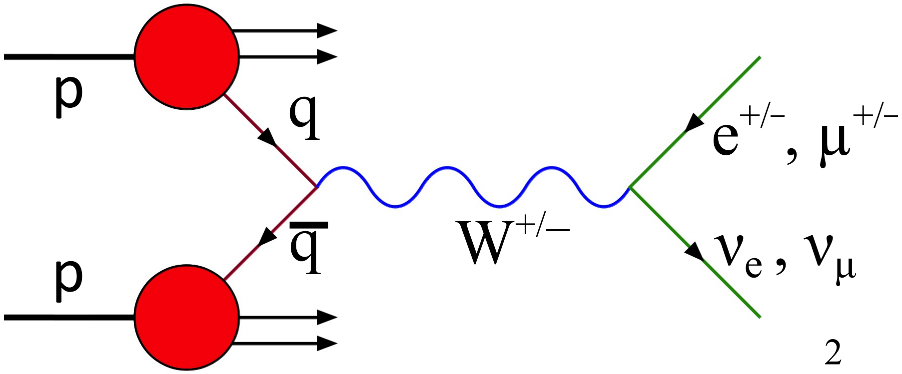
Motivation

- Drell-Yan production of W and Z bosons can be used to test perturbative QCD calculations
- W+jets a Z+jets production represents important source of background to SM measurements including Higgs physics and searches
- Testing ground for parton distribution functions (PDFs)
- Test of Monte-Carlo modeling (Parton Shower and Matrix Element)

Neutral-current DY process



Charged-current DY process



Overview of ATLAS results

Results produced by ATLAS experiment at LHC in proton-proton collisions

- at centre-of-mass energy of $\sqrt{s}$ = 7 TeV
- data correspond to an integrated luminosity of 5 fb^{-1}

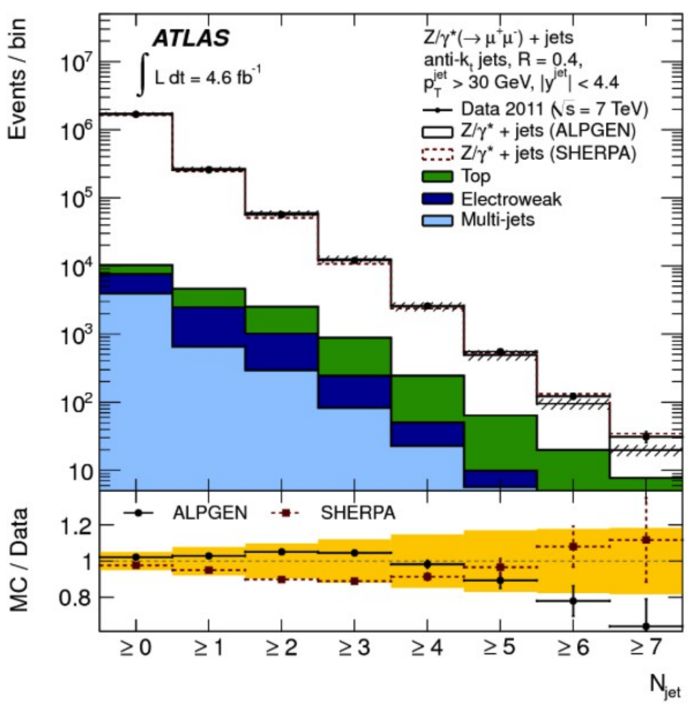
JHEP07(2013)032	Phys. Lett. B 725 (2013) 223–242
Z+jets	**DY at high masses**
Phys. Lett. B 720 (2013) 32-51	ATLAS-CONF-2013-045
ϕ^* in Z/γ^*	**Forward-backward asymmetry in Z/γ^***
ATLAS-CONF-2013-045	JHEP 06 (2013) 084
W+c	**W+b**

Z+jets

- test of pQCD calculations with large higher order corrections
- background for SM and BSM processes
- Increased statistics allow to measure production up to 7 jets in association with Z boson

Measurements (chosen for the presentation):

- cross section as a function of inclusive jet multiplicity
- ratio of cross sections for successive inclusive and exclusive jet multiplicities
- differential cross section as a function of jet and Z transverse momentum, jet rapidity, scalar pT sum of leptons and jets (H_T)

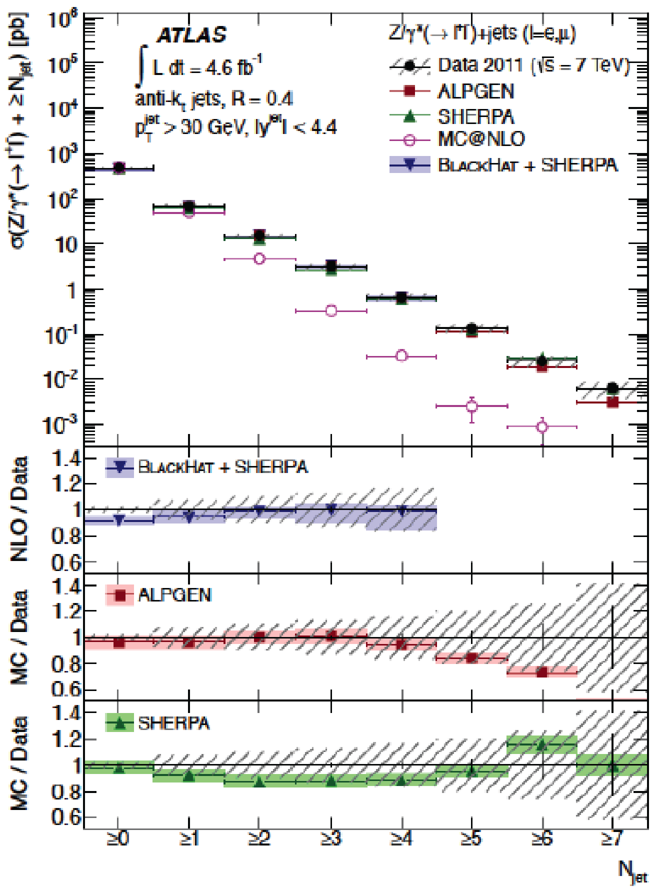


Backgrounds:

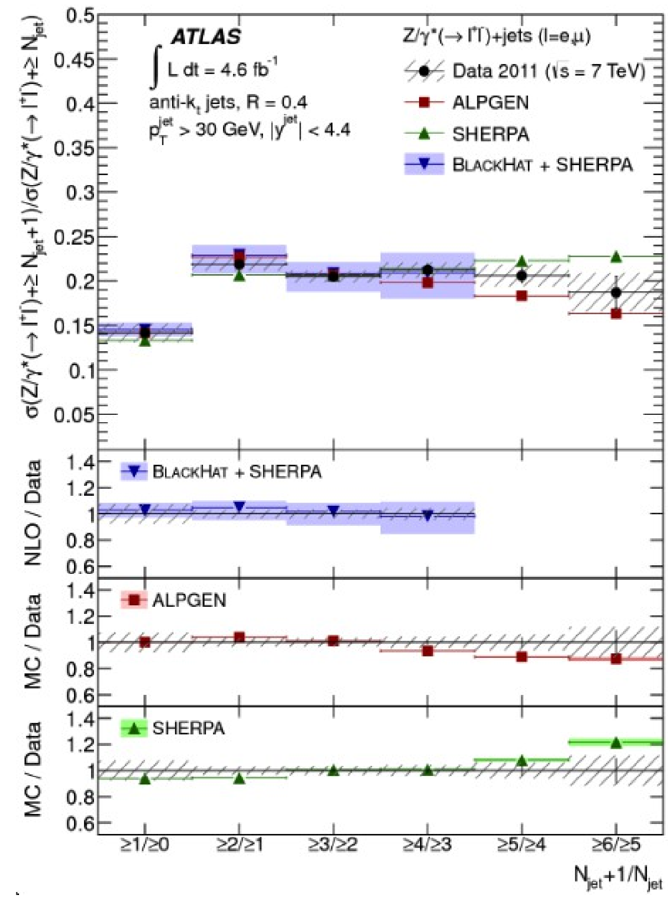
- For jet multiplicity ≥ 2 dominate $t\bar{t}$ production
  - derived from $t\bar{t}$-enriched sample in data
- Increasing with with jet multiplicity from 2% to 20%

Z+jets

Cross section for inclusive jet multiplicities



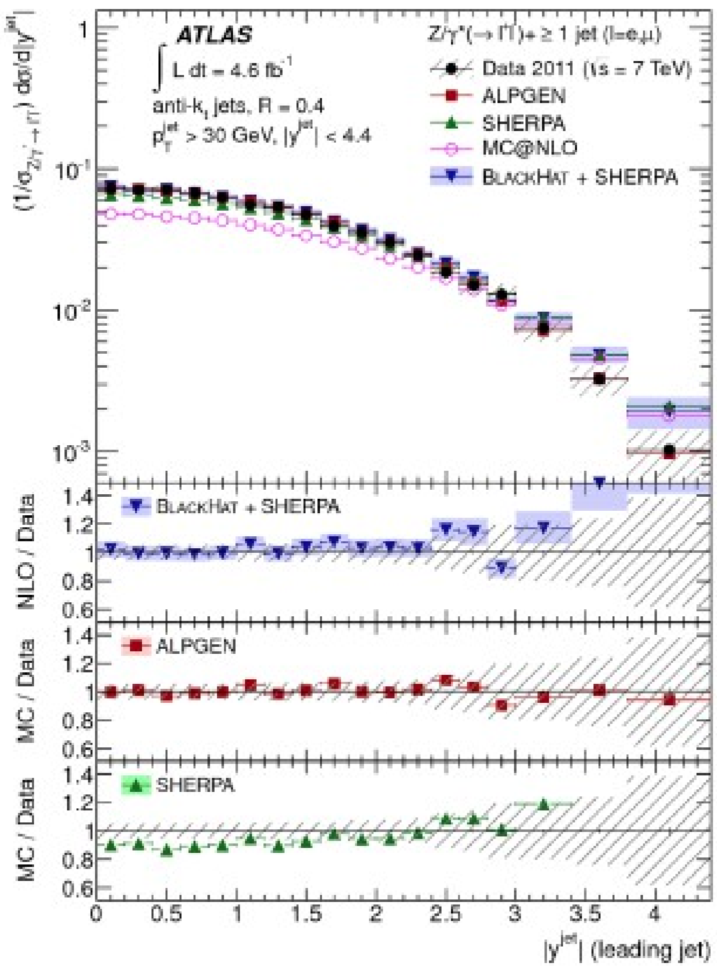
Ratio of cross sections for successive inclusive jet multiplicities



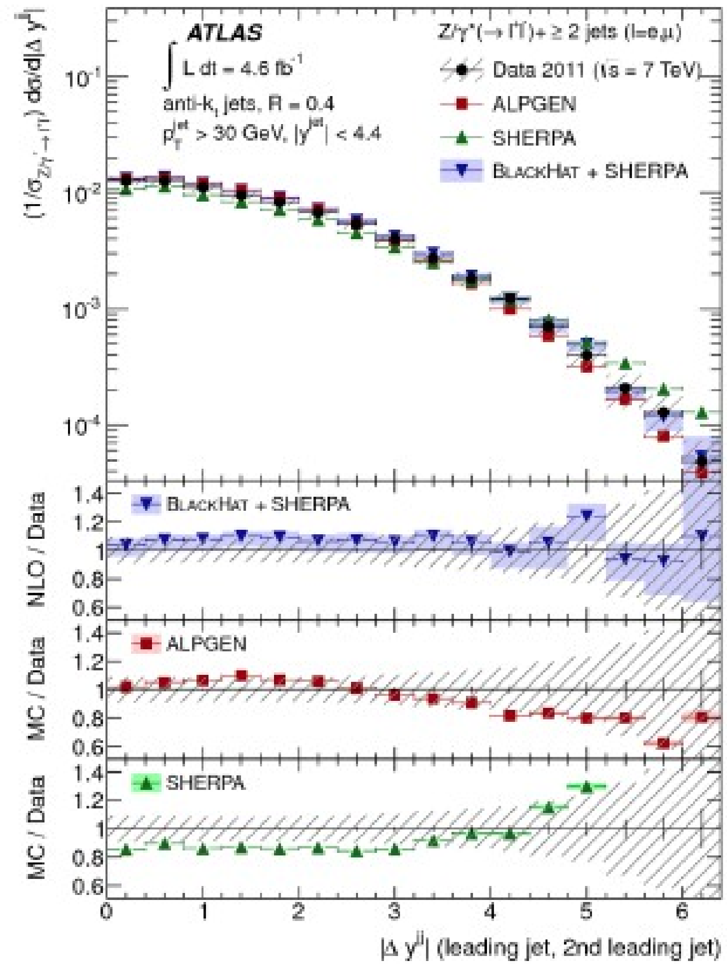
- The MC@NLO models higher jet multiplicities by parton shower → expected offsets to the data
- Good agreement with **BlackHat+Sherpa** calculations and with predictions from ALPGEN, **SHERPA**
- Ratio of successive multiplicities gives a more precise result due to cancelations in syst. uncertainties

Z+jets - angular distributions

Leading Jet Rapidity (Z+≥1jet)



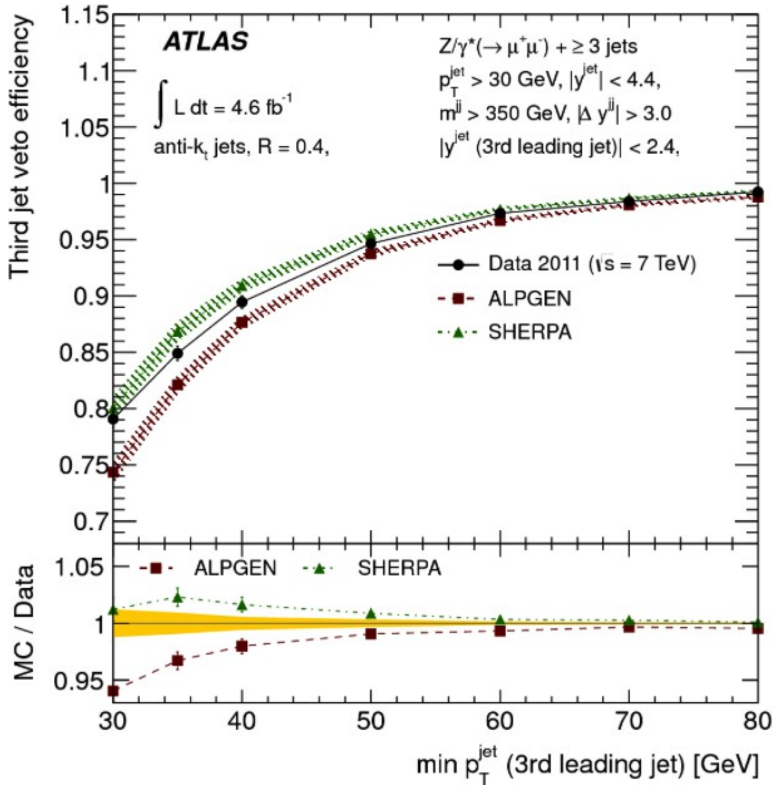
Δ|y|(leading,2nd leading jet) (Z+≥2jet)



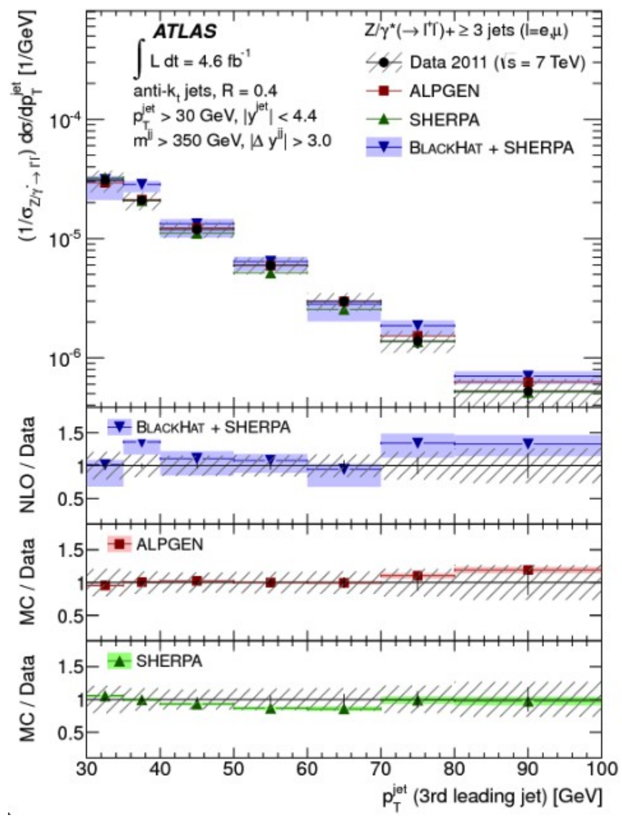
- BlackHat and SHERPA overestimate cross section in the forward region
- Effect reproduced in distribution of leading and second leading jet separation in Z+≥2jets

Z + forward jets

- A veto on a third jet is used to reject Z+jets background in VBF Higgs analysis
- VBF signature: Two forward jets (large Δy(j,j) separation), high di-jet mass, central jet gap
- Study of Z+jets events with VBF selection allows to estimate 3rd jet veto efficiency



Fraction of events passing veto on 3rd jet in central region, as function of the third jet p_T threshold



p_T distribution of the 3rd jet after VBF-like selection

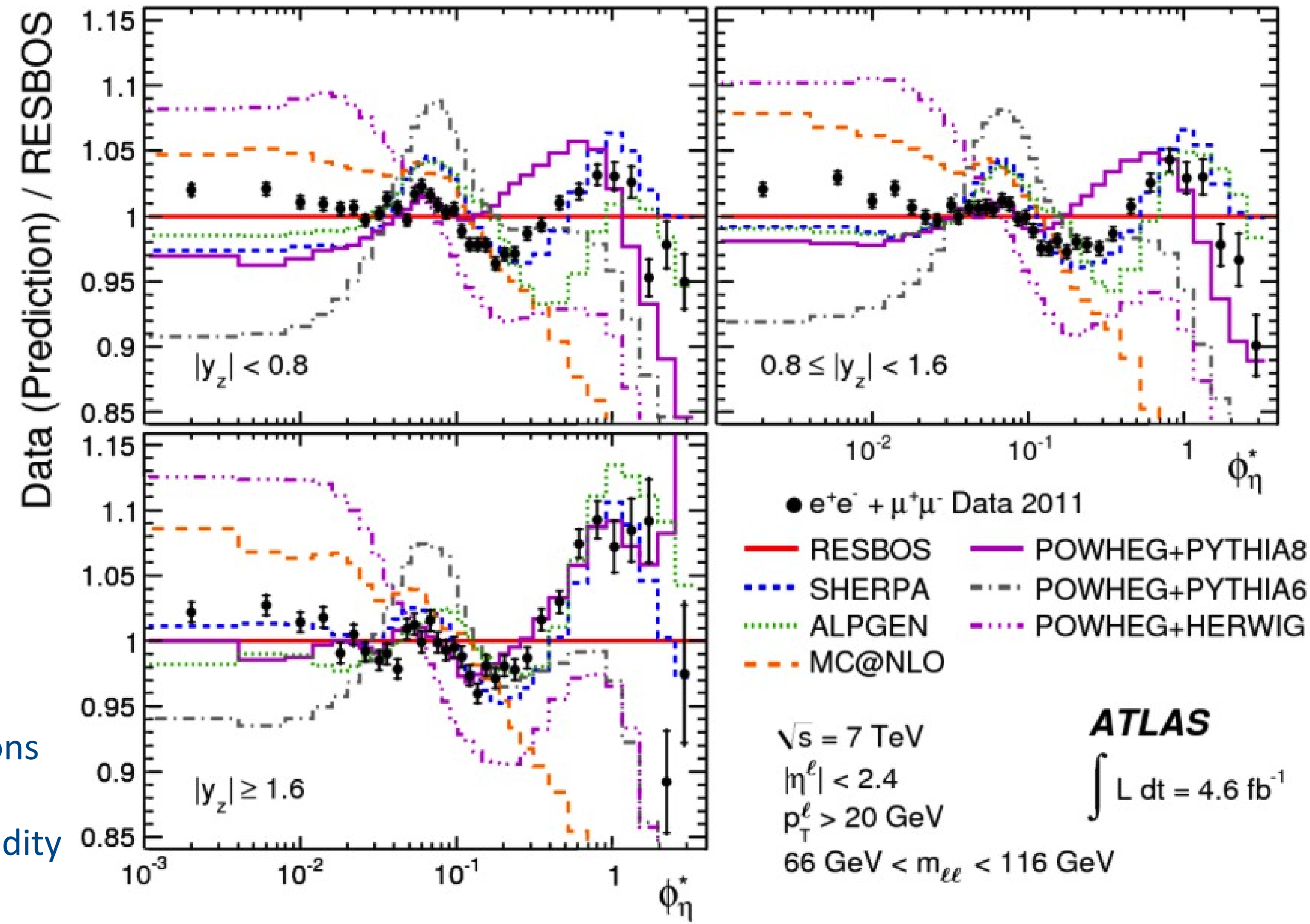
ϕ^* in Z/γ^*

- ϕ^* is optimal observable to probe low p_T domain of Z/γ^* production
- Depends exclusively on the directions of the leptons → reduce experimental uncertainties
- The results are compared to QCD calculations and to predictions from different MCs

Ressumed calculation
- RESBOS

LO calculation + PS
- ALPGEN
- SHERPA

NLO calculation + PS
- POWHEG
- MC@NLO

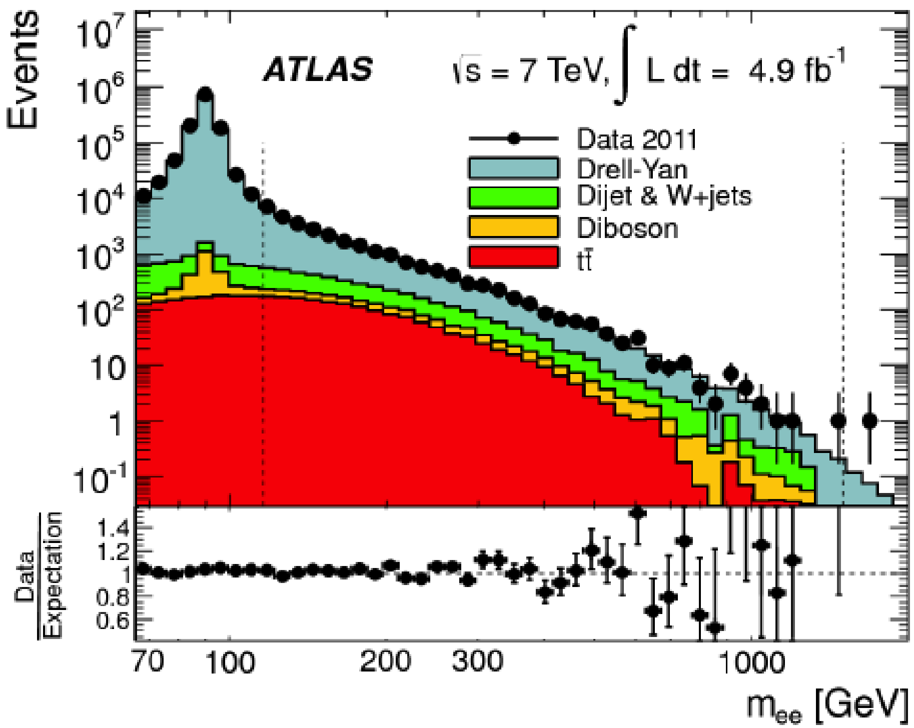


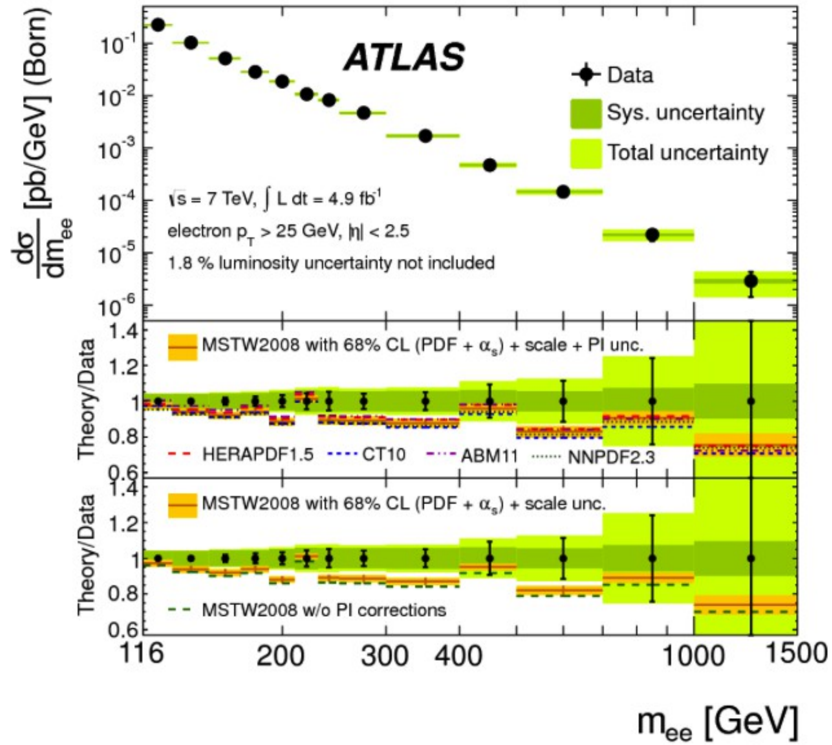
Total background ~ 0.6%

Statistical unc. ~ 0.3%

Comparison of results to the QCD calculations and predictions of different MC generators in three ranges of Z boson rapidity

High-mass Drell-Yan

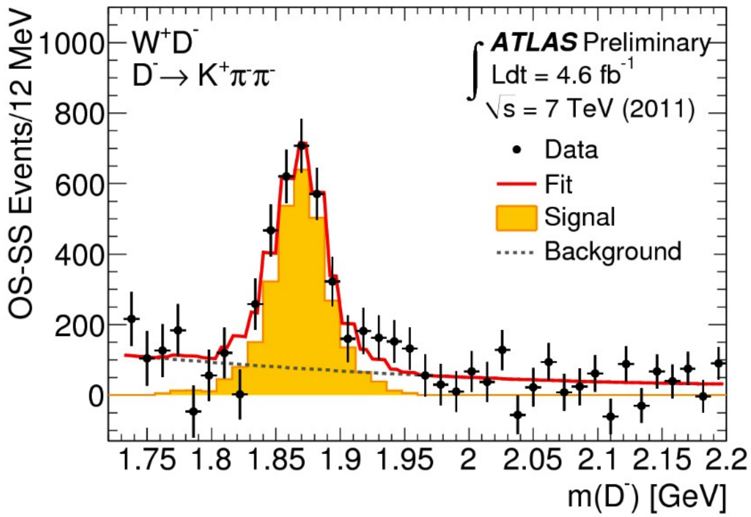




- Cross-sections are measured for $p_T > 25$ GeV, $|\eta| < 2.5$ and $116 < M < 1500$ GeV
- Results compared to NNLO QCD calculations using FEWZ framework, including NLO EW corrections and with different NNLO PDFs
- Resulting predictions for all PDFs are consistent with the measured cross sections
- With more statistics and measurement precision the data have potential to constrain PDFs for large x

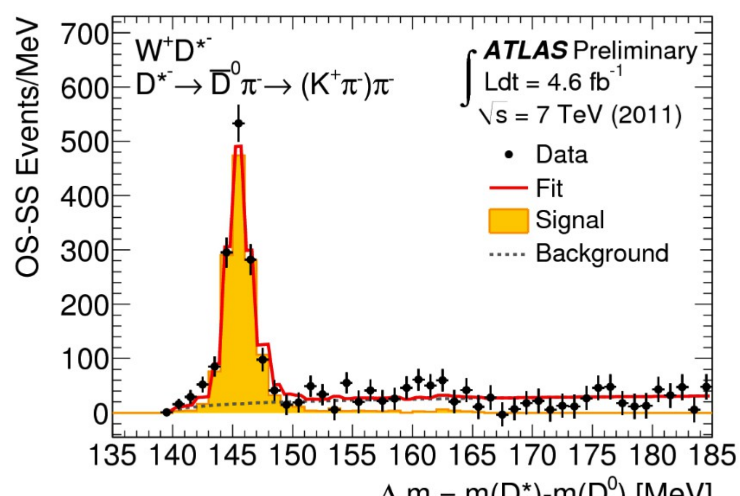
W+c

- Sensitive to strange quark distribution function
- Probe potential $s/\bar{s}$ asymmetry
- Charge correlation between $W^{\pm}$ and $D^{(*)\mp}$ used to extract single-charm component
- subtracted same-sign contribution (OS-SS)

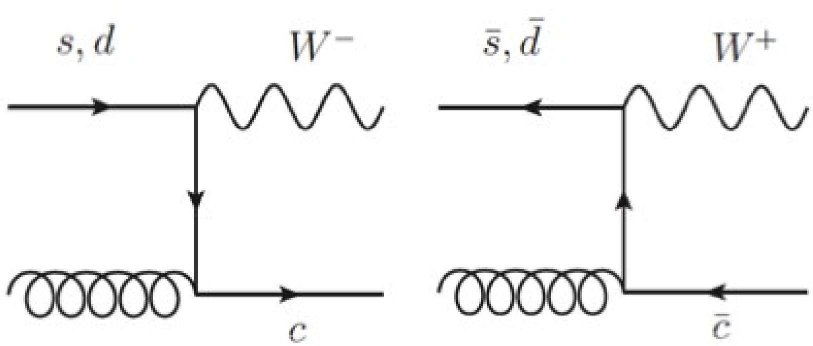


Measurements:

- Integrated measurement by W charge
- W charge ratio
- Differential cross sections as function of pT of D meson and η of lepton

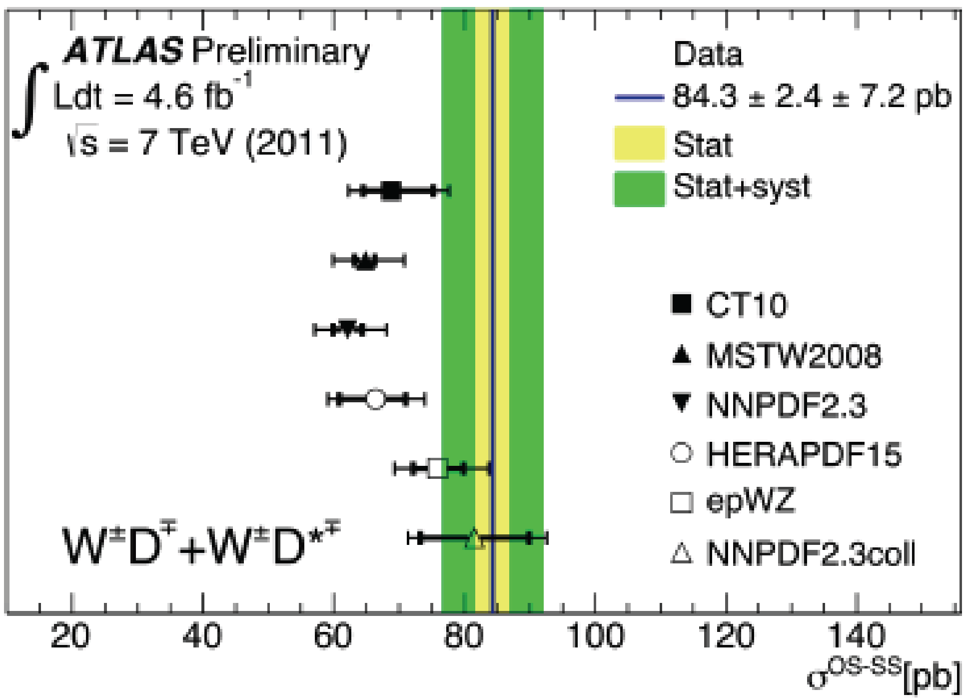


Example of production processes:

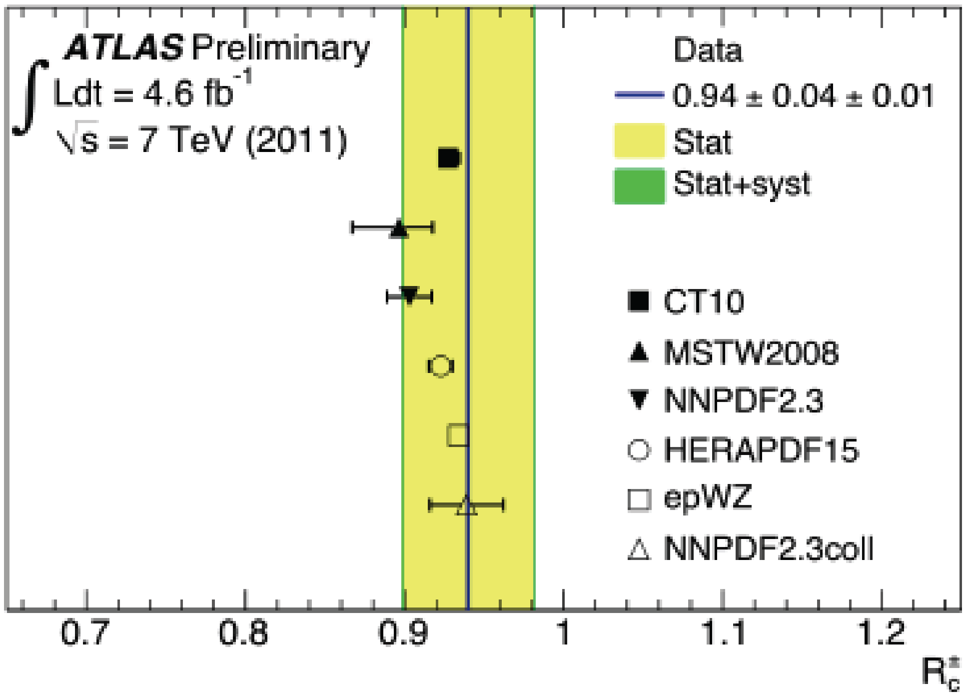


W+c

Sum of cross section $\sigma(W^{\pm}D^{\mp}) + \sigma(W^{\pm}D^{*\mp})$



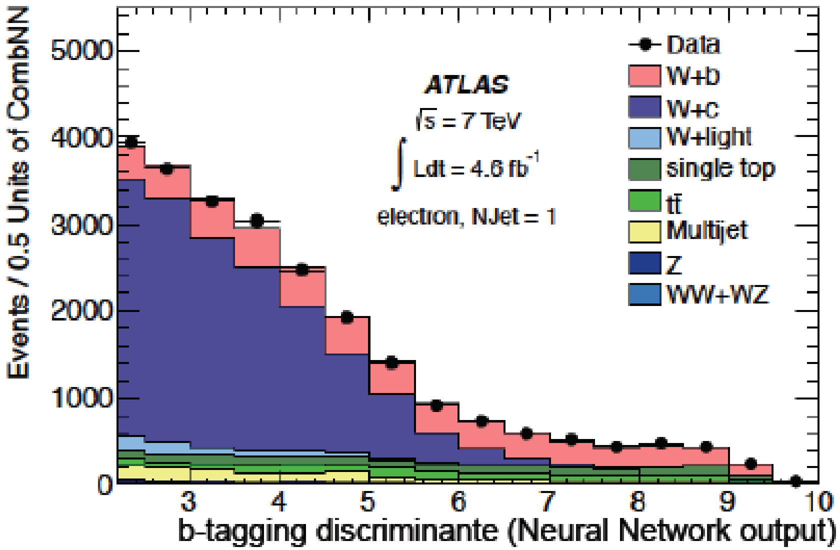
Asymmetry ratio $R_c^{\pm} = \sigma(W^+D^{(*)-})/\sigma(W^-D^{(*)+})$



- The measurements agree well with epWZ and NNPDF2.3coll (s-quark enhanced PDFs)
- Larger discrepancies are seen with MSTW2008, HERAPDF15 and NNPDF2.3 (1.5σ - 2.7σ)
- Experimental uncertainty dominated by tracking efficiency systematics (7%)
- Studies of dependence of the NLO prediction on the choice of μ_F and μ_R: +8%/-6% uncert.
- Asymmetry ratio $R_C^{\pm}$ sensitive to $s / \bar{s}$ ratio, results consistent with all PDFs

W+b

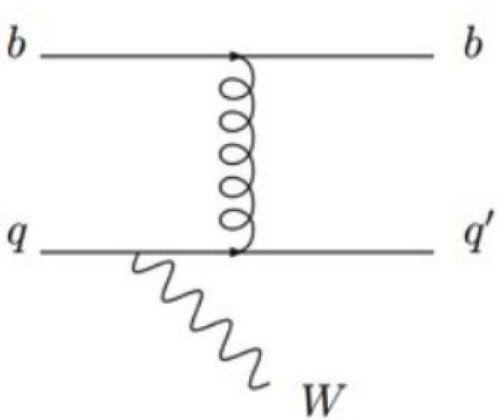
- Important test for pQCD in presence of HF quarks
- Background to Higgs (WH, ZH), single-top
- b-tagging used to discriminate signal processes
- Large Backgrounds: ~ 85% after selection

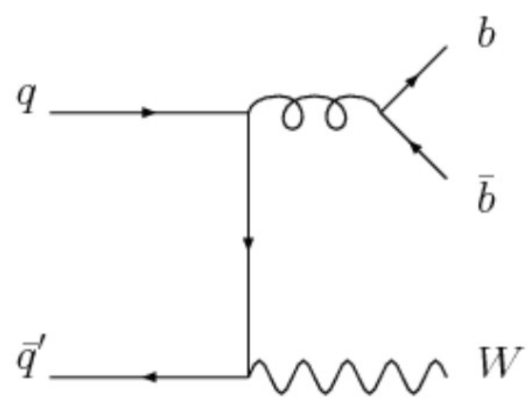


Measurement:

- inclusive cross section (1,2 jets)
- differential cross section in b-jet pT

Example of production processes:



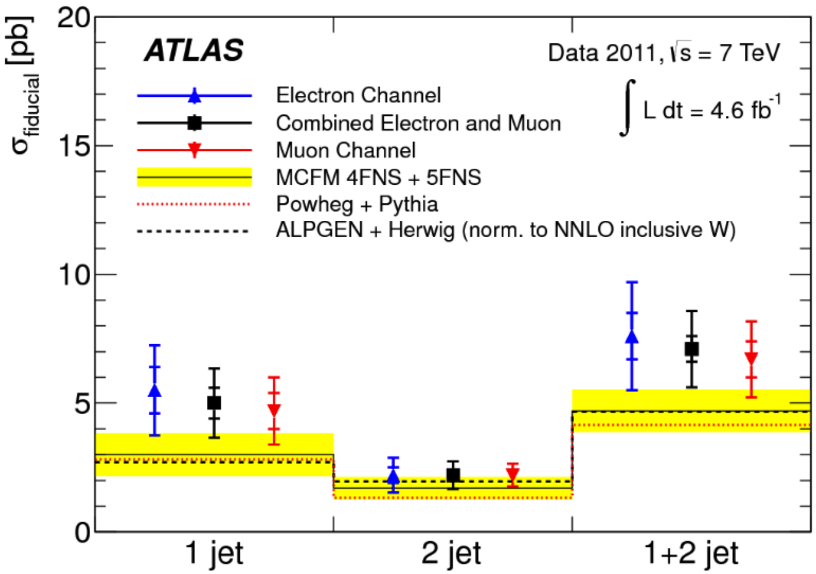


+ double parton interaction (DPI)

- W and b-jets are produced from different parton–parton interactions within the same pp collision

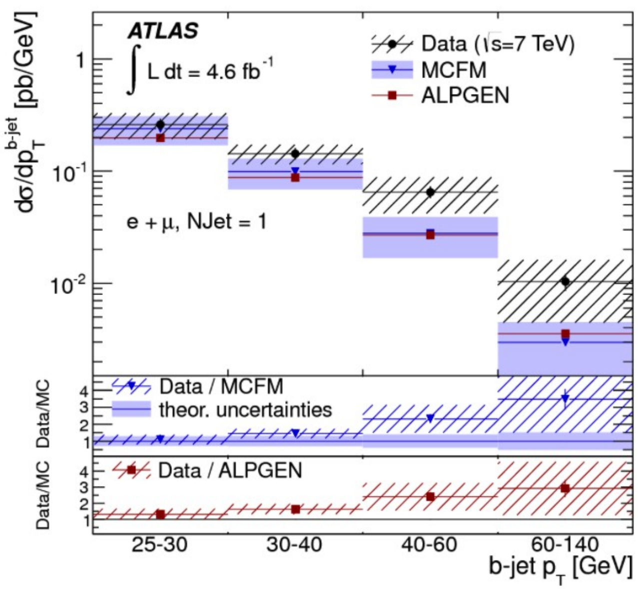
W+b

Measured fiducial cross-sections

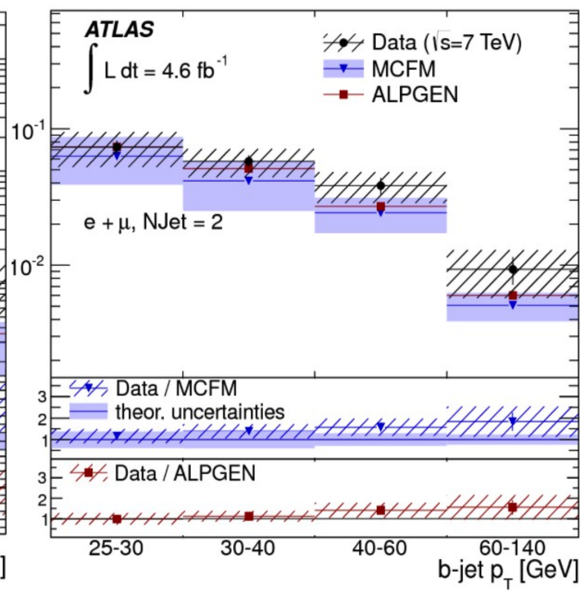


W+b-jets cross-section as a function of b-jet p_T in

1-jet fiducial region



2-jet fiducial region



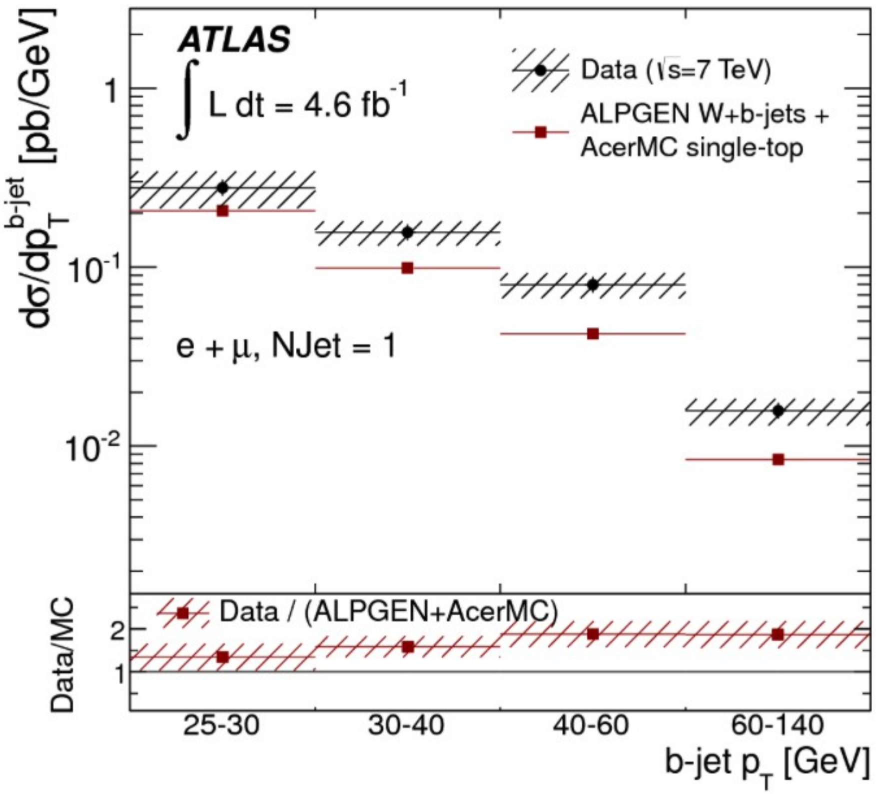
- Comparison to LO prediction (ALPGEN)
  - scaled to NNLO (for inclusive W)
- Comparison to NLO prediction (MCFM and Powheg)
  - MCFM corrected for hadronization effects and DPI
  - Powheg corrected for DPI

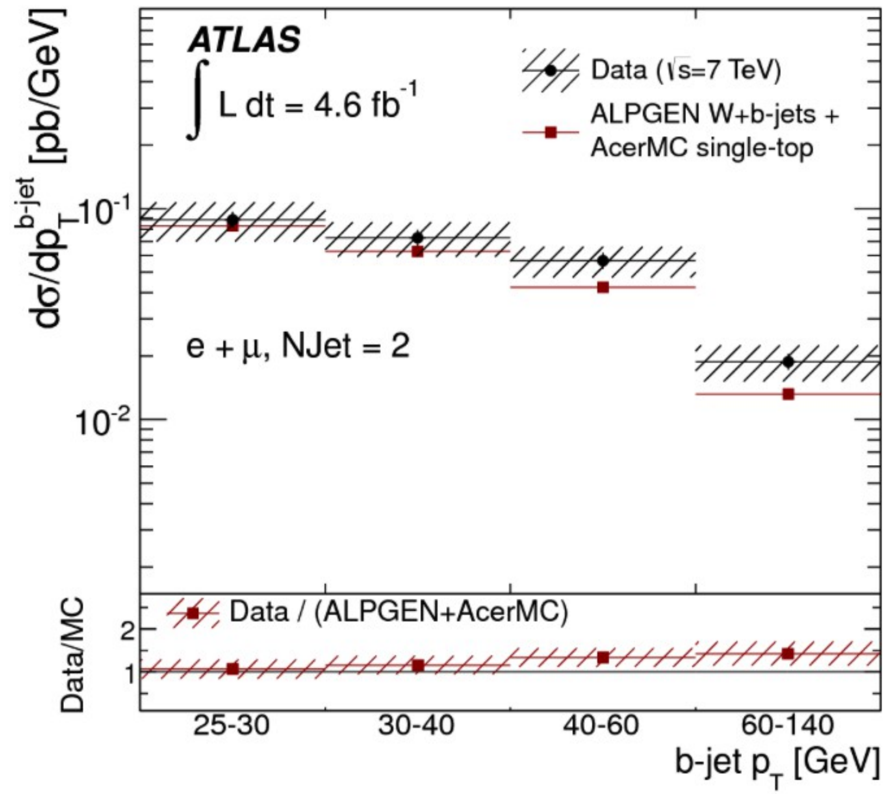
- ~ 30 % uncertainty is assigned to the DPI correction

- Data/MC increases with pT
- Total uncertainty in prediction
  - from variations of the μ_R and μ_F scales, PDF set, DPI model and nonperturbative corrections

W+b

W+b-jets cross-section without single-top subtraction as a function of b-jet p_T



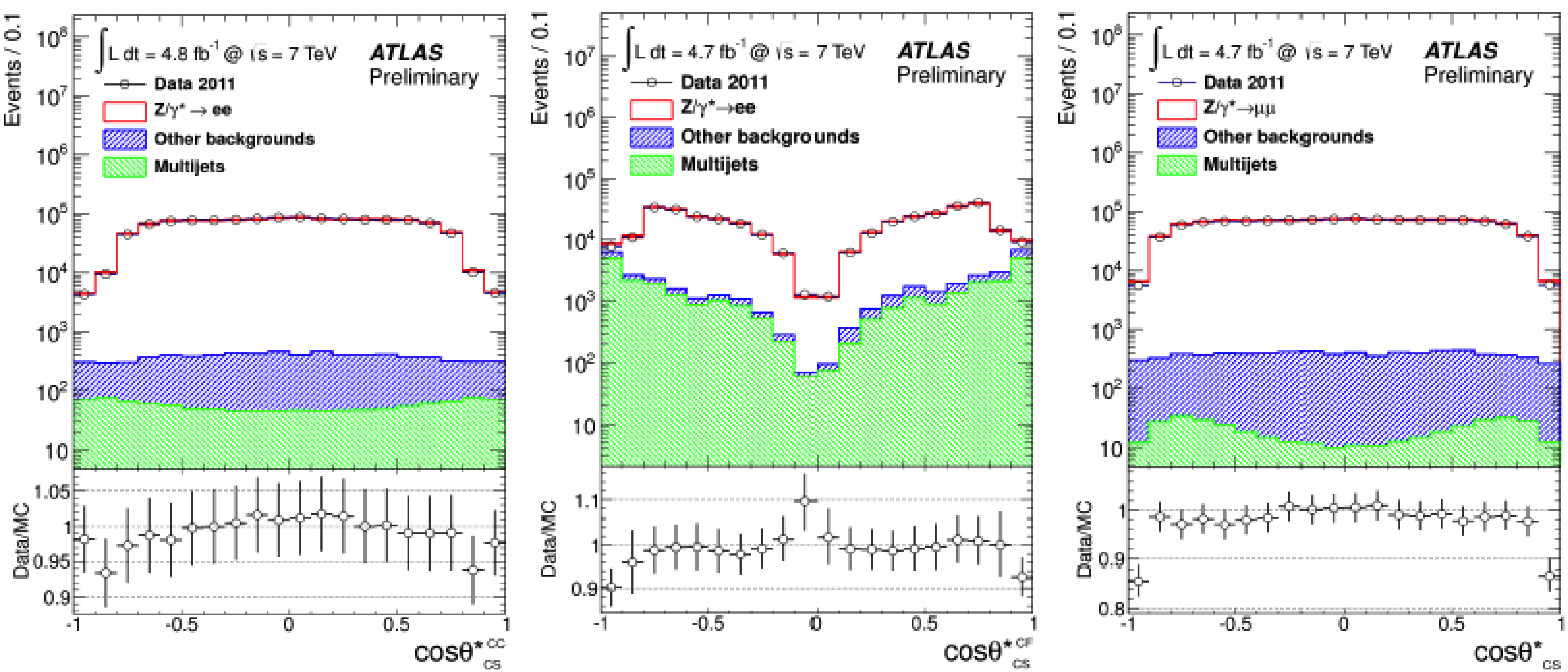


- b-jet p_T differential cross-section have significantly reduced uncertainties with respect to the single-top subtracted ones

Forward-backward asymmetry in Z/γ^*

- Measurement of forward-backward asymmetry in **ℓℓ** pairs in Z/γ^*
- The goal is to measure the weak mixing angle
- Decay angle cos ϴ* measured in the Collins-Soper (CS) frame

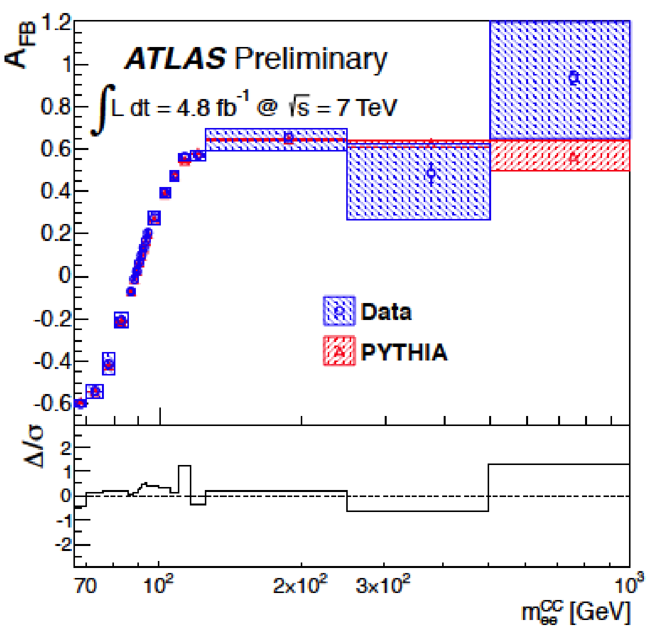
central-central ee channel central-forward ee channel central-central μμ channel



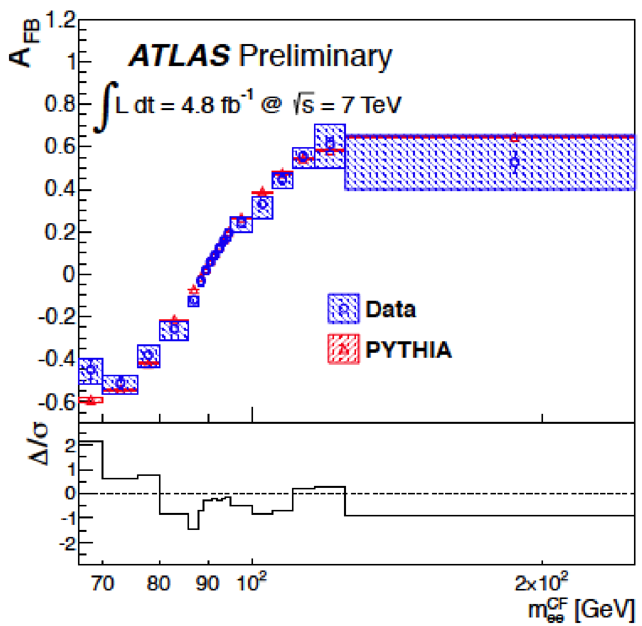
Forward-backward asymmetry in Z/γ*

- Measurement of asymmetry: $$A_{FB} = \frac{\sigma_F - \sigma_B}{\sigma_F + \sigma_B}$$
- Comparison with PYTHIA prediction of unfolded A_{FB}
- Systematic uncertainties are from unfolding, MC dependence and higher order QCD and EW corrections, PDFs, MC statistics, backrounds and others

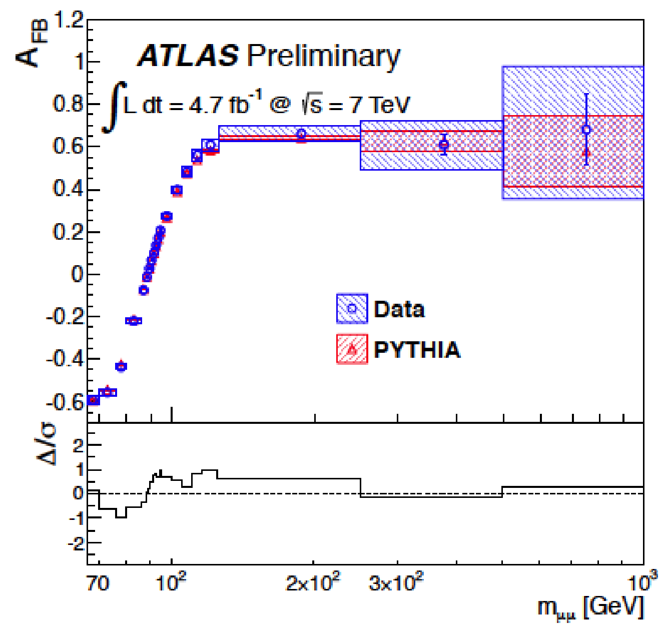
central-central ee channel



central-forward ee channel

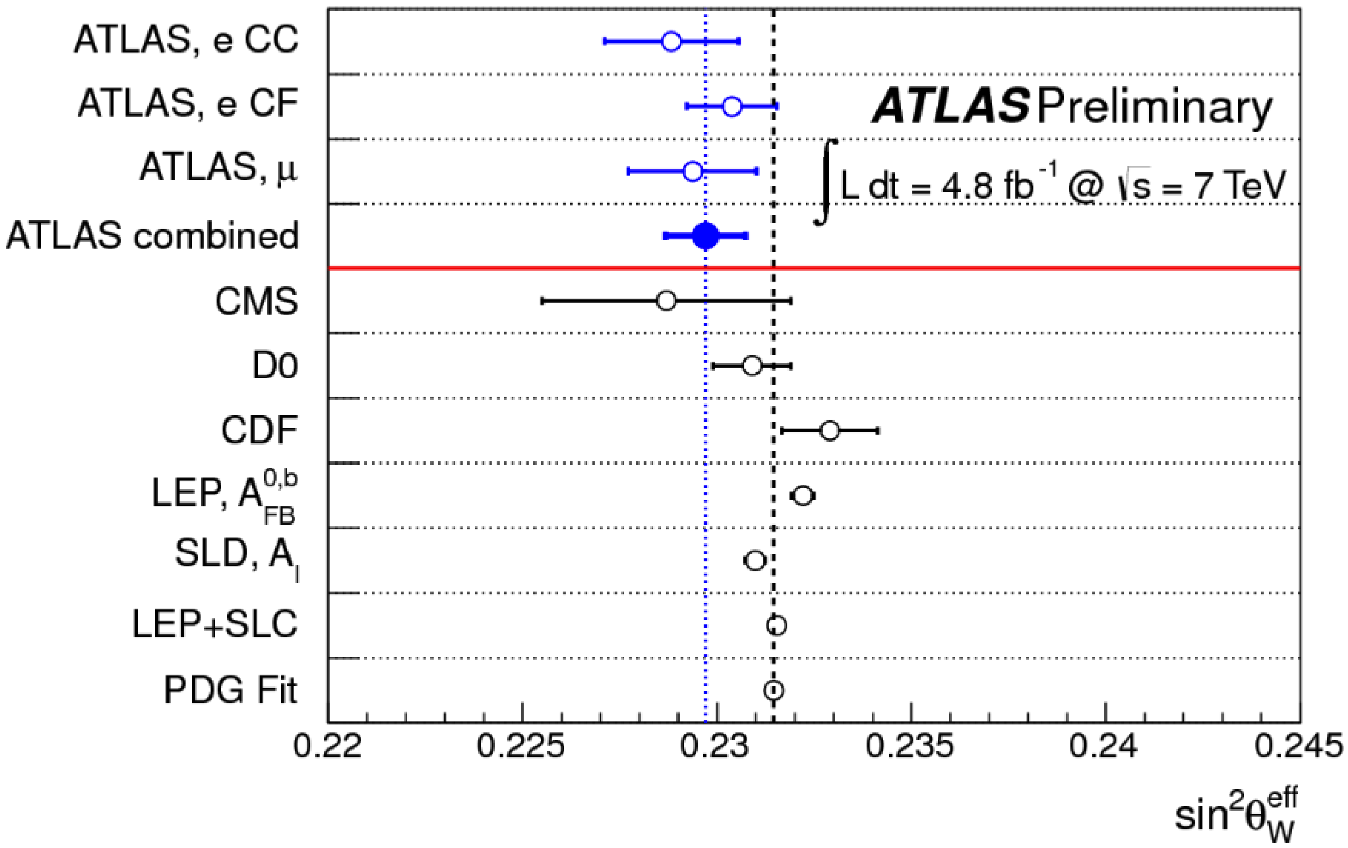


central-central μμ channel



Forward-backward asymmetry in Z/γ^*

Weak Mixing Angle: $\sin^2\Theta_W^{eff}$(combined) = 0.2297 ± 0.0004 (stat) ± 0.0009 (syst)



- Uncertainty dominated by PDFs
- $\sin^2\Theta_W^{eff}$ is extracted from A_{FB} spectra by fitting with MC templates obtained by varying the input value of the weak mixing angle

Summary

- Measurements of the production of vector bosons and vector bosons in association with jets at $\sqrt{s}$ = 7 TeV at ATLAS presented

- **Z+jets studies provide important tests of pQCD**
  - good agreement with theoretical predictions using ME+PS
- **Very precise measurements on ϕ^* in $Z \rightarrow ll$ decays presented**
- **W + heavy flavor studies presented**
  - W+b measurement consistent with NLO pQCD (4FNS+5FNS) predictions
  - W+c measurement favour enhanced s-quark PDF
- **First ATLAS measurement of weak mixing angle analyzing A_{FB} in $Z \rightarrow ll$ decays**