Drell-Yan and vector boson plus jets measurements with the ATLAS detector

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On behalf of the ATLAS collaboration

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Symmetry Breaking

PRISMA Cluster of Excellence

Test of perturbative QCD

W+jets cross sections (Eur. Phys. J. C (2015) 75:82)

Z+jets cross sections (JHEP 07 (2013) 032)

Rjets (W+jets/Z+jets ratio) cross sections (Eur. Phys. J. C (2014) 74:3168)

W boson in association with b-jets (JHEP 06 (2013) 084)

Event Selection

W→lν

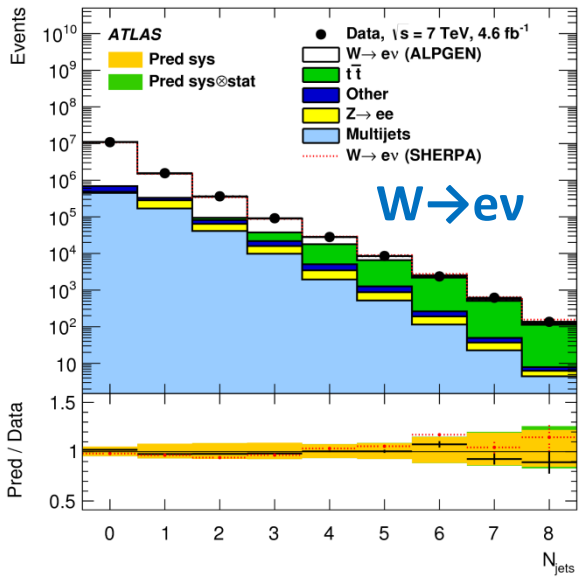
- Exactly 1 lepton
  - → p_T > 25 GeV, |η| < 2.4 / 2.47 (μ/e)
- E_T^{miss} > 25 GeV
- m_T > 40 GeV

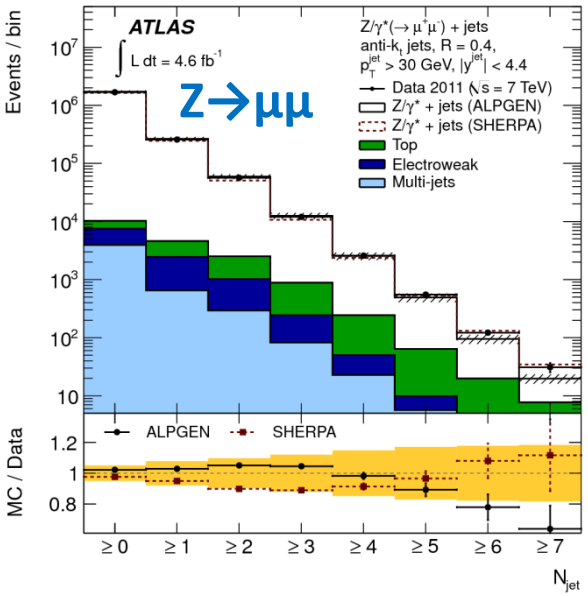
Z→ll

- Exactly 2 leptons with opposite charge
  - → p_T > 25 GeV, |η| < 2.4 / 2.47 (μ/e)
- ΔR(l,l) > 0.2
- 66 GeV < m_{ll} < 116 GeV

Jets

- Anti-k_T algorithm, R=0.4
- p_T > 30 GeV
- |y| < 4.4
- Removed if overlapping with lepton
- ΔR > 0.5



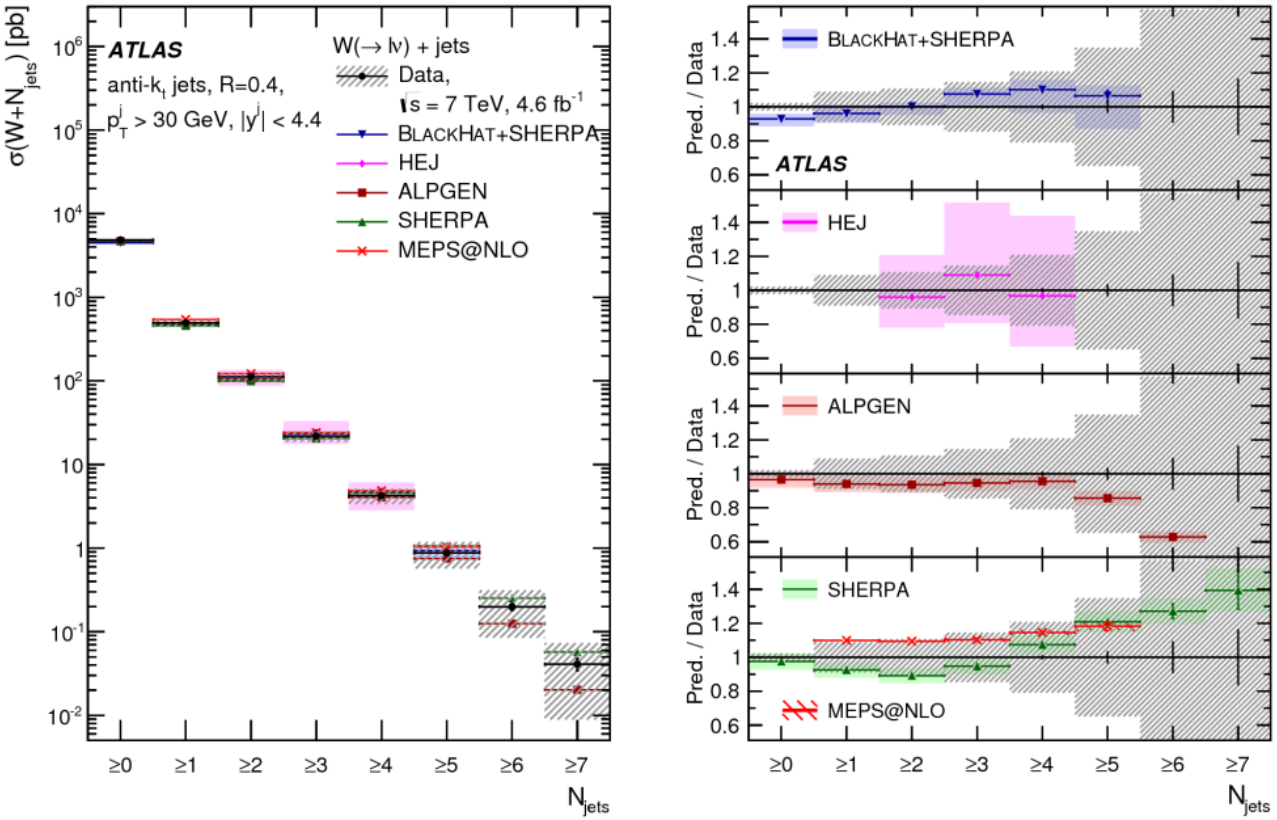


Eur. Phys. J. C (2015) 75:82 & JHEP 07 (2013) 032

W+jets: Inclusive number of jets

- Thorough analysis of ~40 distributions
  - → Valuable to Monte Carlo developers
- Good agreement with BlackHat, Sherpa shows some differences for $N_{jets} > 5$
- Trend towards large N_{jets} (Alpgen & Sherpa)
  - → Still compatible within the large uncertainties

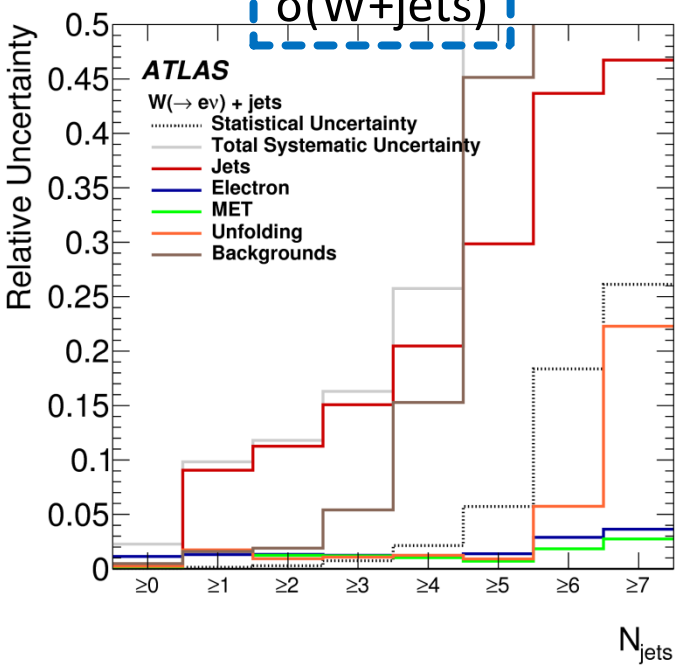
Eur. Phys. J. C (2015) 75:82



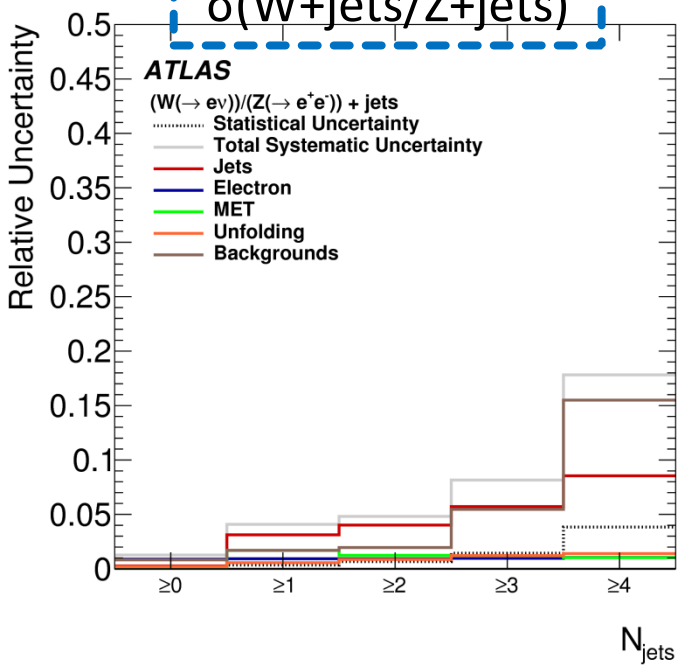
Motivation: Ratio W+jets/Z+jets

- Probes kinematic differences of jet-system recoiling against W or Z
- Significant cancellation of the uncertainties in the ratio
  - → Experimental
    - Positively correlated uncertainties: Energy scales, Backgrounds, Jet uncertainties
  - → Prediction
    - Scale & PDF uncertainties, Parton shower / Hadronization

σ(W+jets)



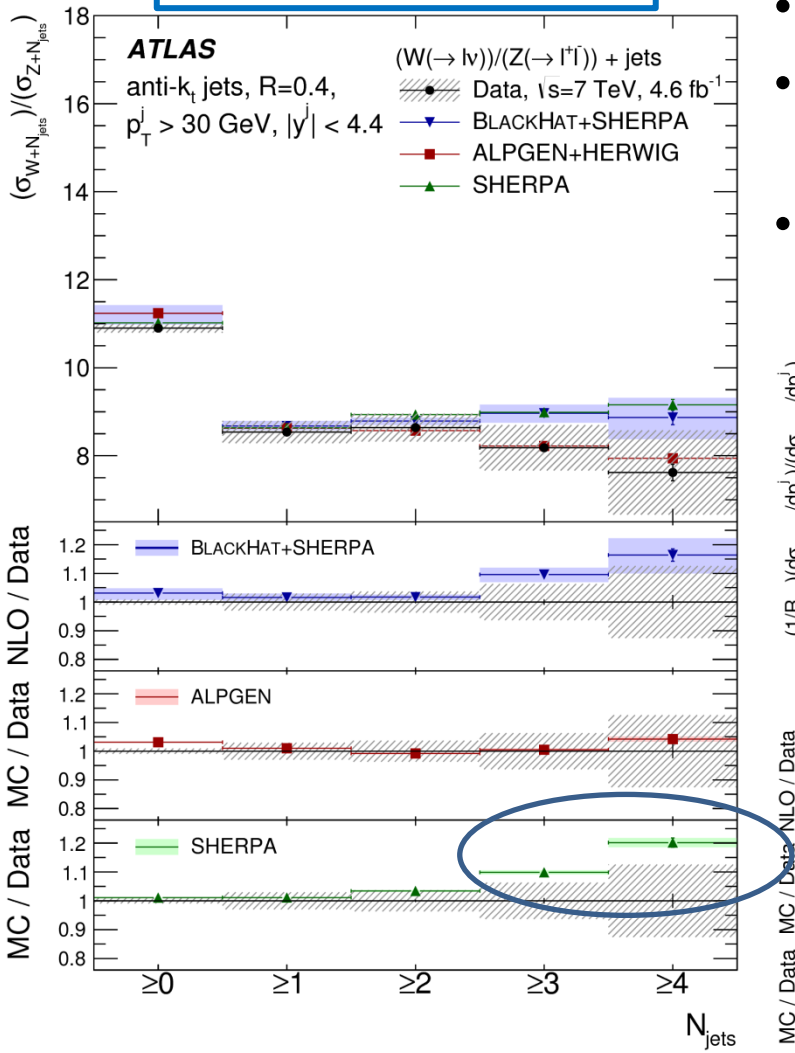
σ(W+jets/Z+jets)



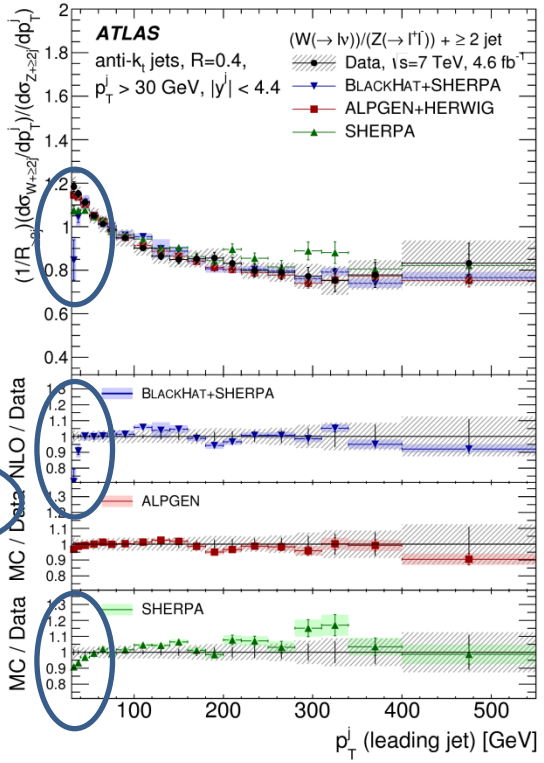
Eur. Phys. J. C (2015) 75:82 &
Eur. Phys. J. C (2014) 74:3168

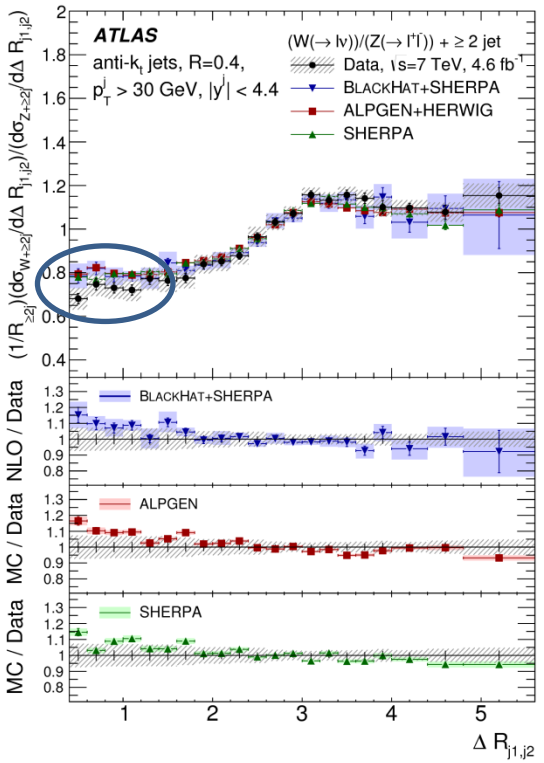
Results: Ratio W+jets/Z+jets

Eur. Phys. J. C (2014) 74:3168



- Inclusive jets: Deviation of Sherpa for large N_{jets}
- p_T leading jet (≥2jets): Well modeled, except very low p_T
- Angular separation of jets: Small trend at low separation





- ATLAS data has been used to improve MC description of the data

Test of non-perturbative QCD

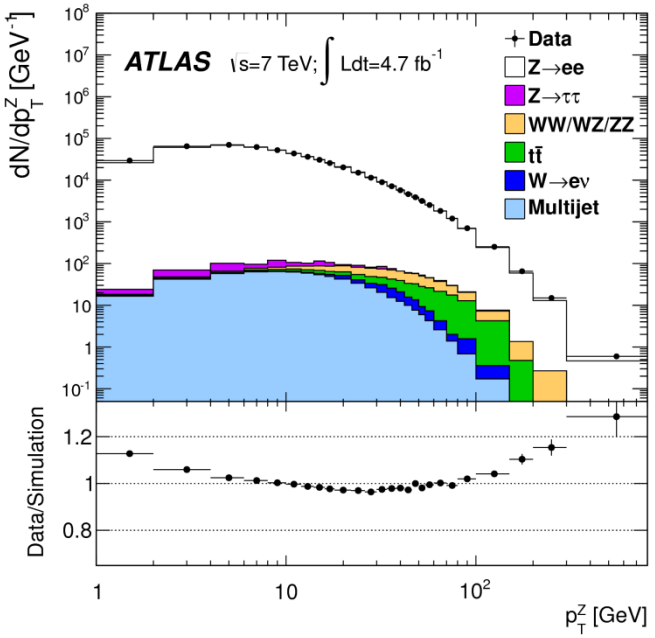
Z transverse momentum distribution (JHEP09 (2014) 145)

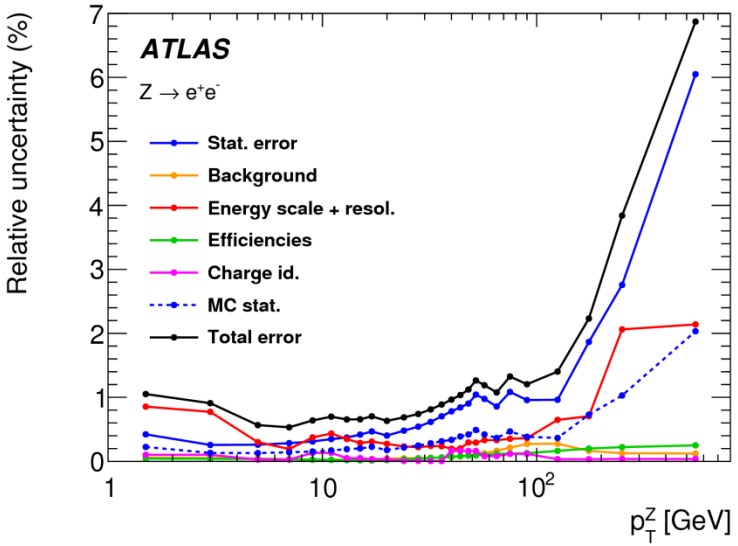
Phi* distribution of Drell-Yan lepton pairs (Phys. Lett. B 720 (2013) 32-51)

Z-p_T Measurement

JHEP09 (2014) 145

- Probes QCD ISR, p_T distributions of partons, gluon PDF, higher order pQCD
- Important input for searches with W and Z backgrounds and in particular for W mass measurement due to improved shower tunes
- Normalized cross section measurement
  - → Three different rapidity regions
  - → Three different final state kinematics: born, bare, dressed
- Uncertainties ~ 1% below Z-p_T 100 GeV

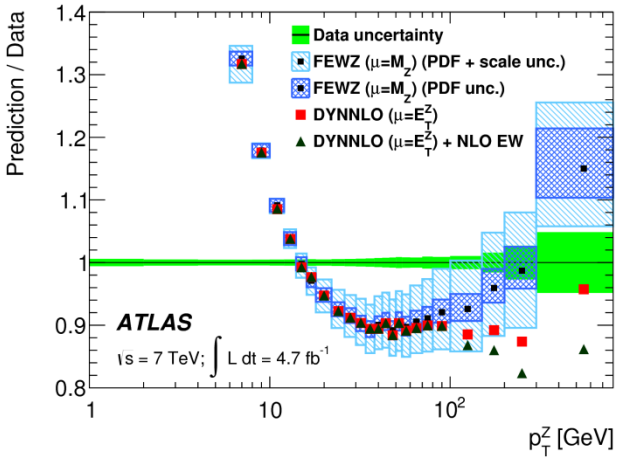


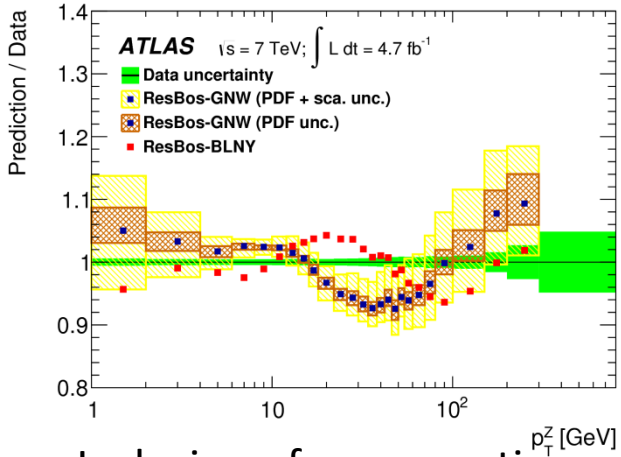


Results: Z-p_T

- Combined cross section compared with predictions from
  - → FEWZ and DYNNLO: Fixed-order calculation, CT10 PDF
  - → ResBos (NNLL): Resummed multiple and collinear gluon emission, CT10 PDF
- Combined cross section used to tune Monte Carlo

Divergence at low p_T expected from lack of resummation; dynamic scale choice improves shape at high p_T

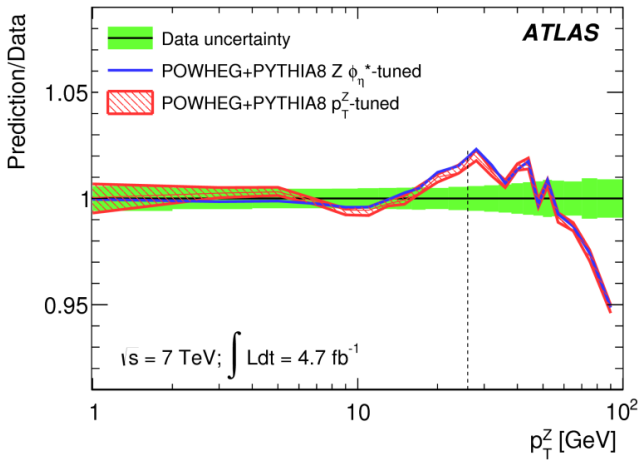




Inclusion of resummation improves agreement of data and theory prediction significantly

JHEP09 (2014) 145

After tuning: agreement within 2% below 50 GeV



Input for PDF fits & test of pQCD

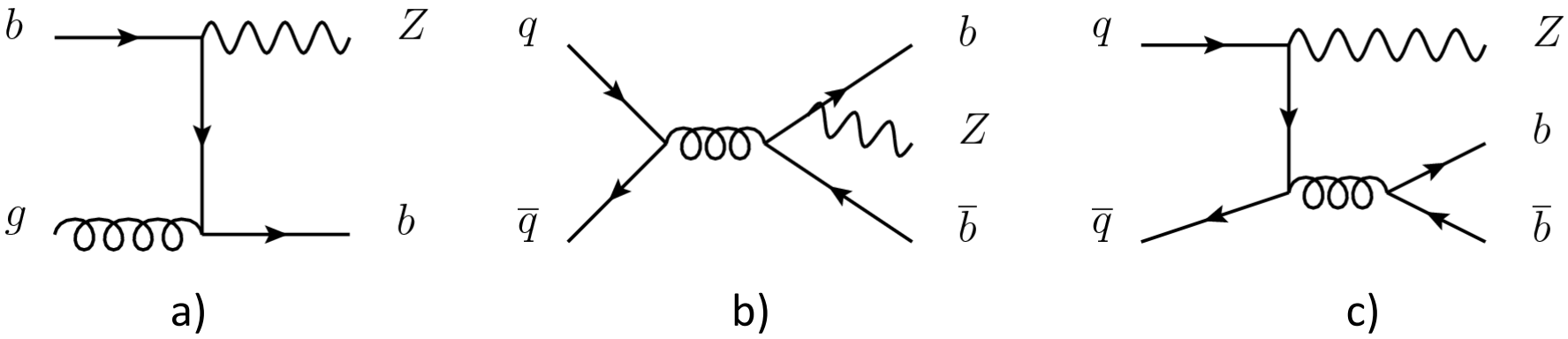
Z boson in association with b-jets (JHEP10 (2014) 141)

Low-mass Drell-Yan differential cross section (JHEP06 (2014) 112)

W plus D/D* and c-jet (JHEP05 (2014) 068)

High-mass Drell-Yan differential cross section (Phys. Lett. B 725 (2013) 223-242)

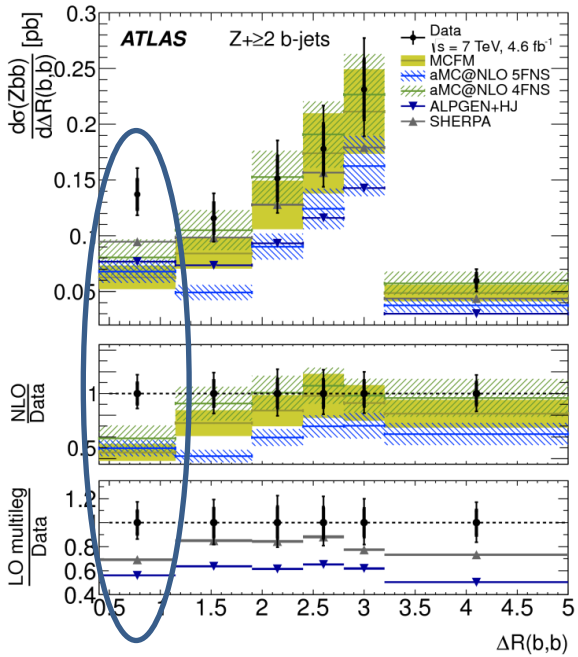
Motivation: Z+b(b)



- Important background for associated Higgs production with H→bb and BSM models
- Two schemes used in pQCD calculations: 4 and 5 flavor initial state
  - → a) only exists in 5 flavor scheme
  - → Can be sensitive to b-quark PDF

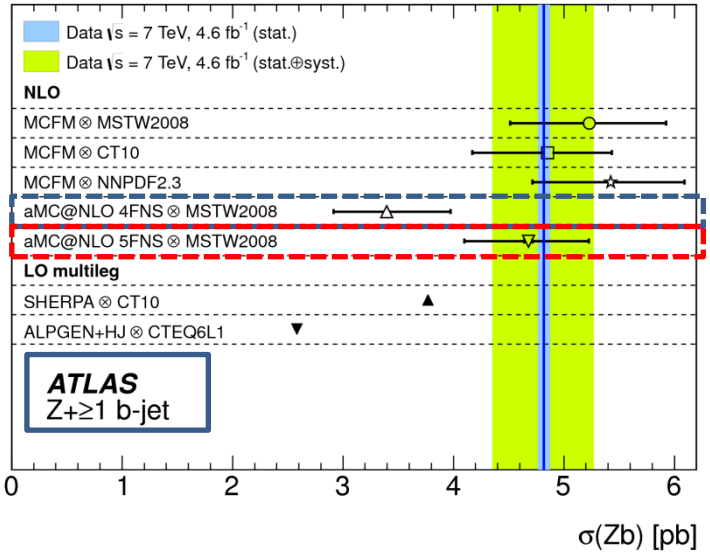
Measurement: Z+b(b)

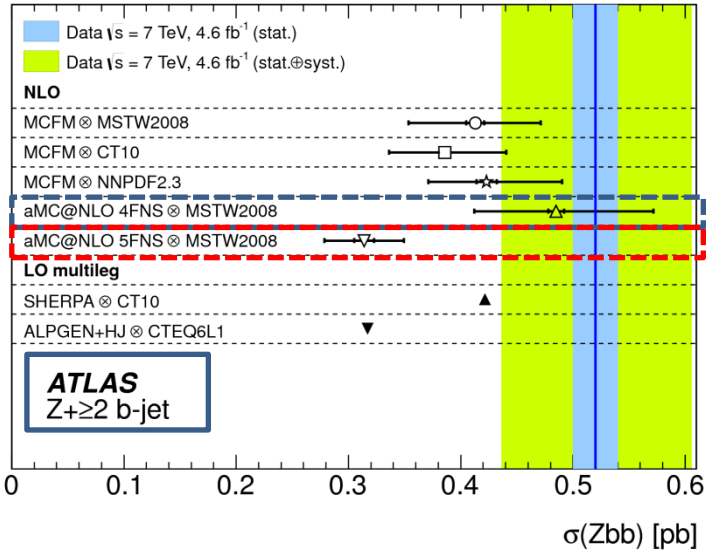
- Z+b can not yet constrain b-PDF due to large scale uncertainty
- Z+bb sensitive to gluon splitting



Good agreement in 5 FNS (≥ 1b)

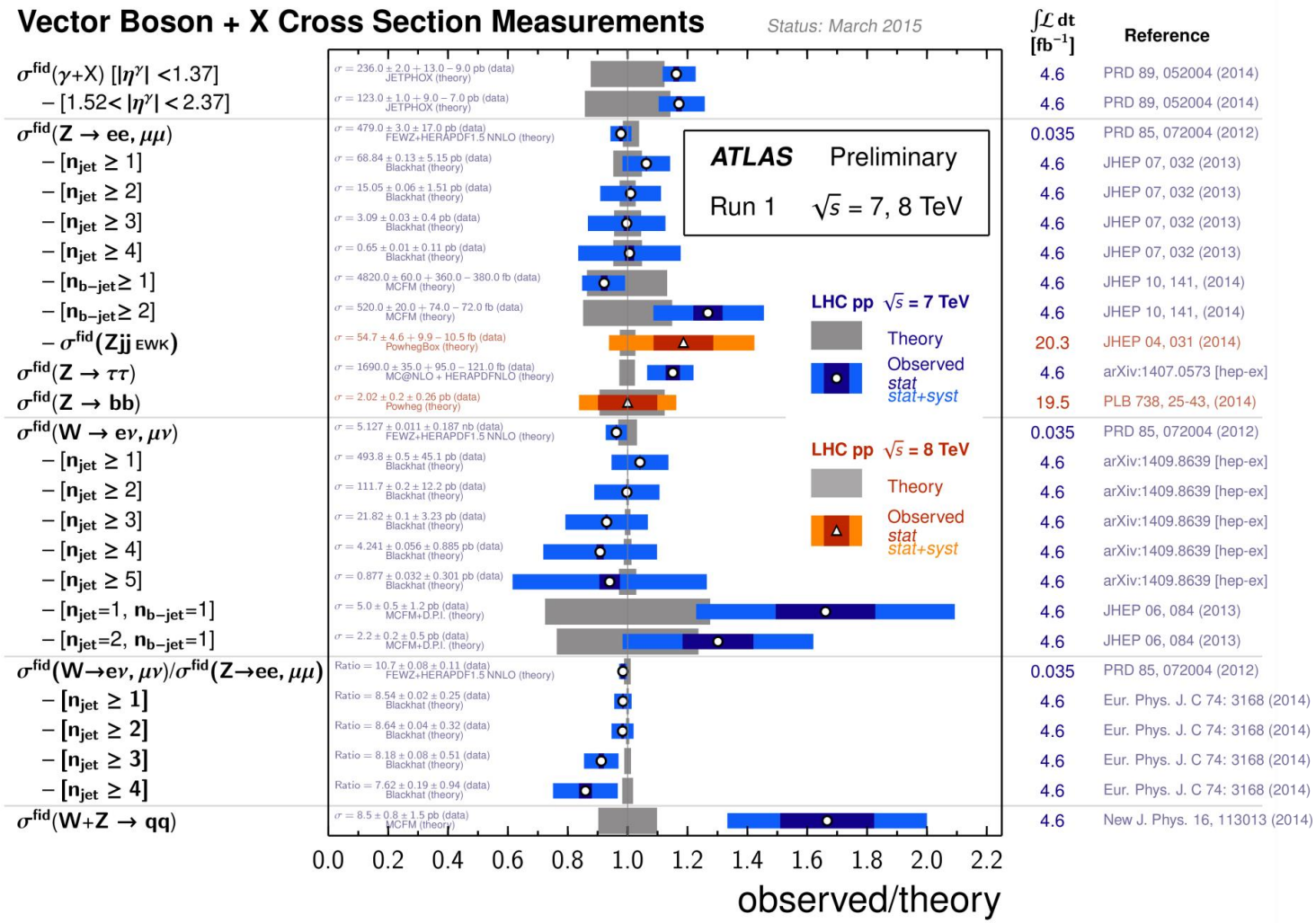
Good agreement in 4 FNS (≥ 2b)





JHEP10 (2014) 141

Run I Summary



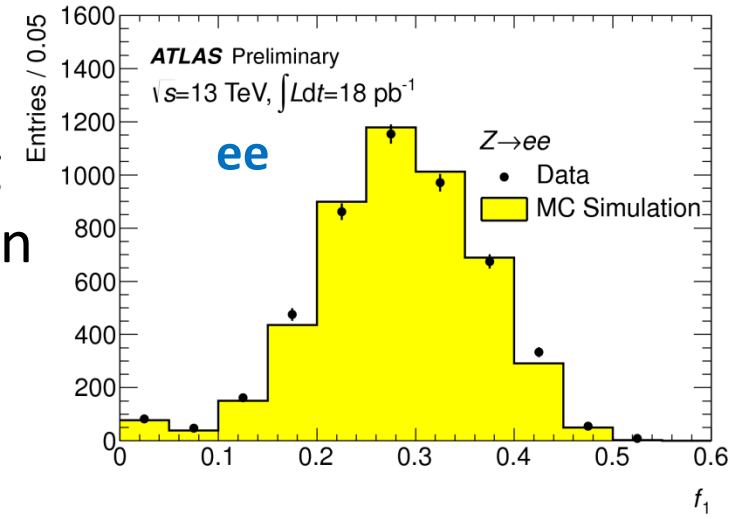
A lot more 8 TeV results still in the pipeline!

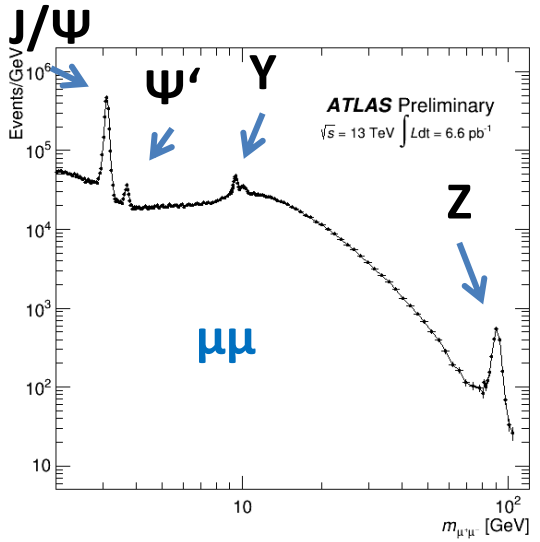
Run II Preview

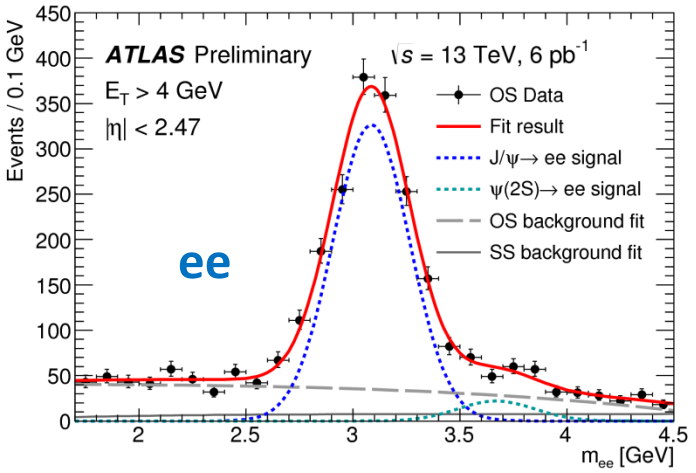
- Very early results of the first data from LHC √s=13 TeV pp-collisions
  - → Results shown for dataset collected from 13th of June to 14th of July
  - → Corresponds to integrated luminosity of 6.4 pb^{-1} to 78 pb^{-1}
  - → Current luminosity uncertainty: 9%
- W and Z production at 13 TeV is ideal for validating early detector performance
  - → Object reconstruction
  - → Analysis software chain
- Uncertainties from both very early and statistics limited data/MC studies as well as studies using Run1 knowledge and MC extrapolation
  - → Luminosity uncertainty not included

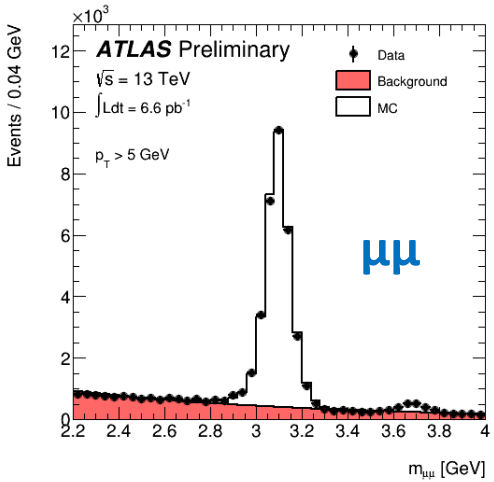
Run II Preview: Performance

- Good understanding of electron and muon performance
  - → Good description of electron shower shapes
  - → "Rediscovery" of SM particles at 13 TeV









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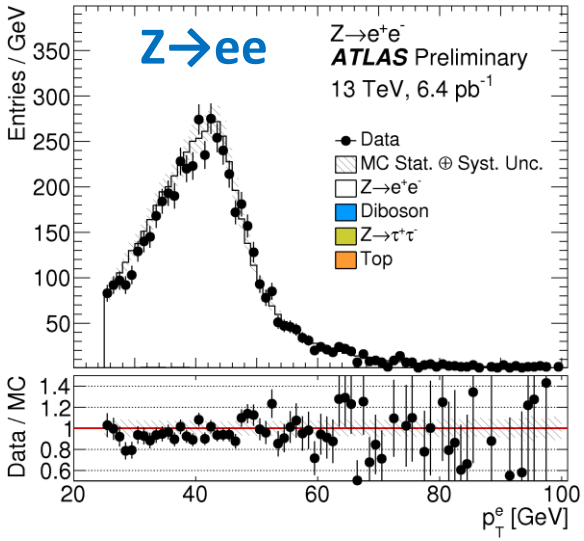
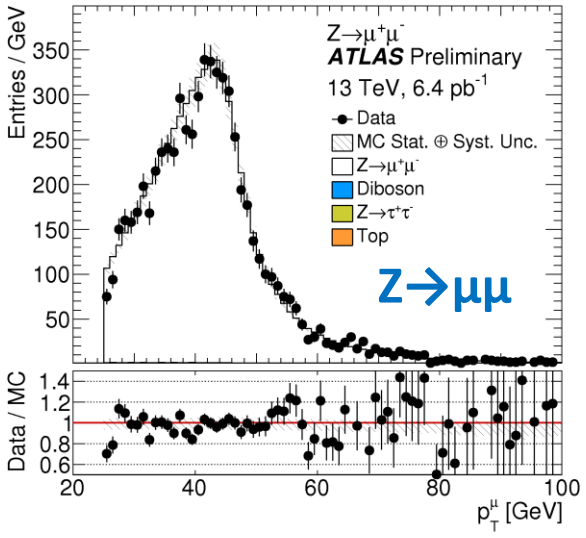
https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PLOTS/MUON-2015-001/

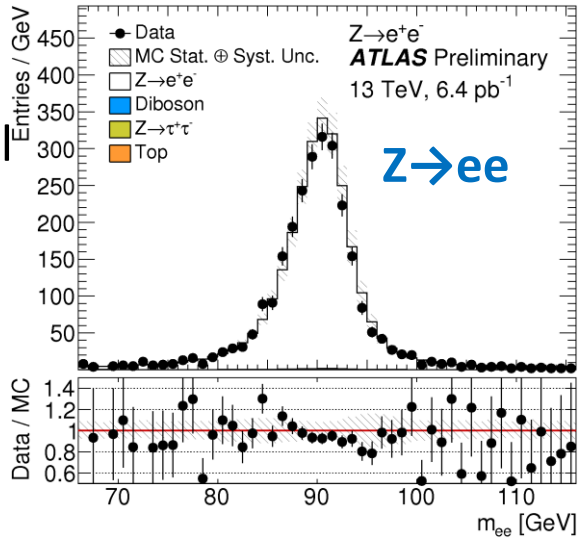
Run II Preview: Z

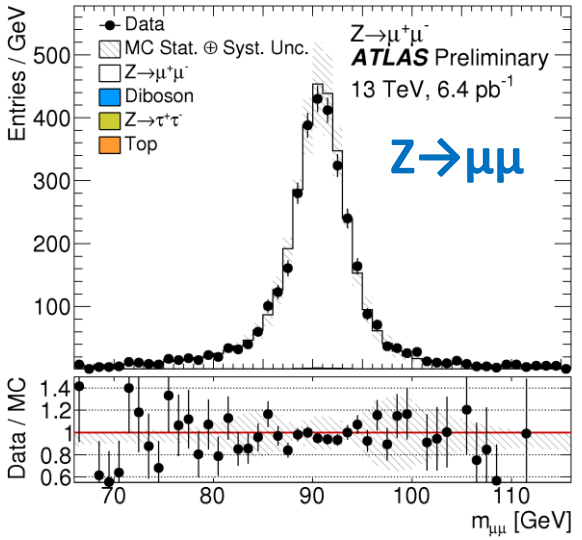
- Exactly 2 leptons with opposite charge
  - → p_T > 25 GeV,
  - → |η| < 2.4 / 2.47 (μ/e)
- 66 GeV < m_{ll} < 116 GeV





- Yield and shapes agree well with the SM expectation within systematic uncertainties

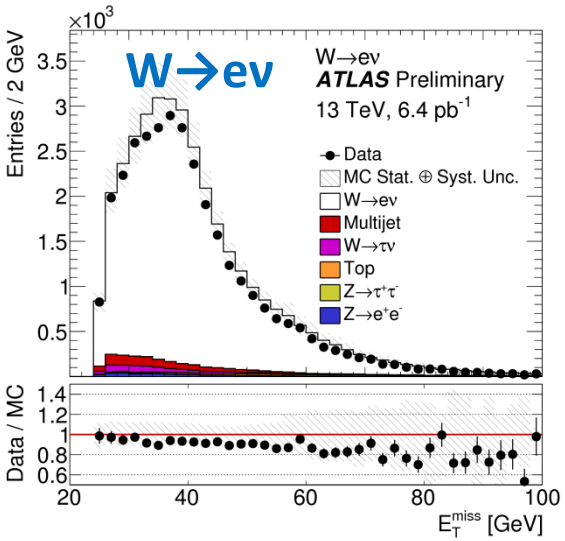


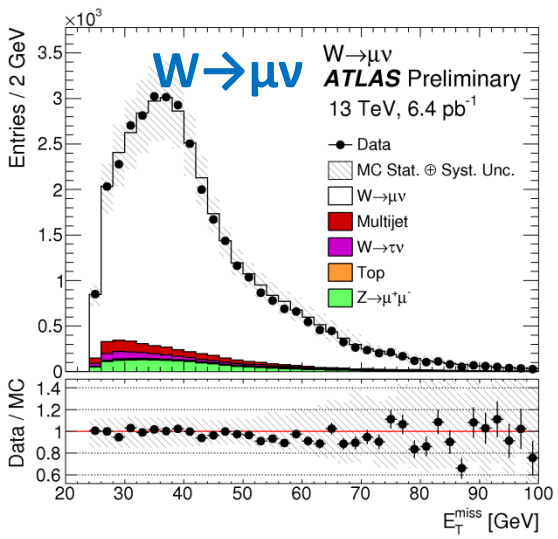


ATL-PHYS-PUB-2015-021

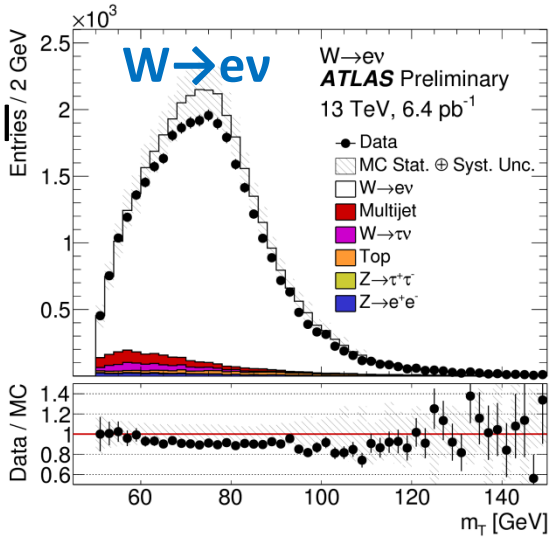
Run II Preview: W

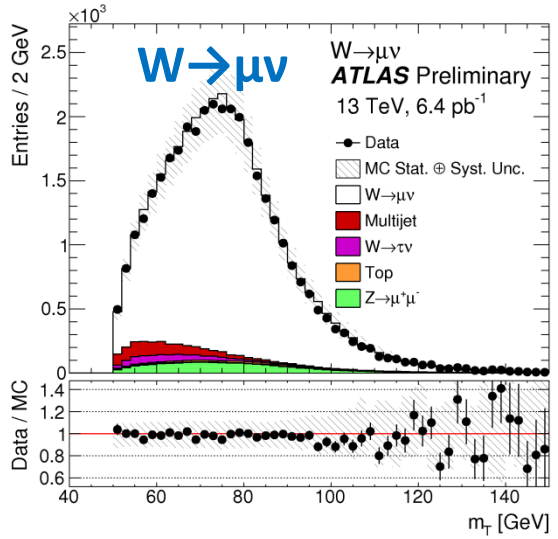
- Exactly 1 lepton
  - → p_T > 25 GeV
  - → |η| < 2.4 / 2.47 (μ/e)
- E_T^{miss} > 25 GeV
- m_T > 50 GeV





- Yield and shapes agree well with the SM expectation within systematic uncertainties





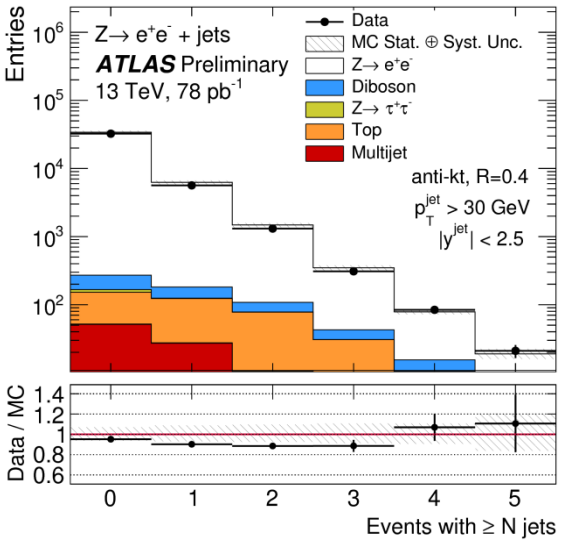
ATL-PHYS-PUB-2015-021

Run II Preview: Z+jets

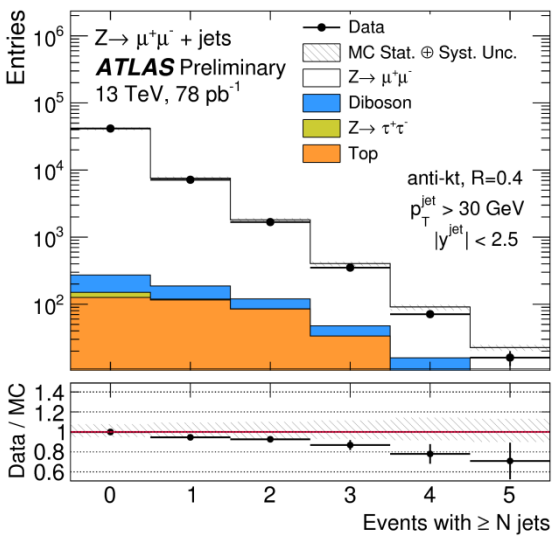
- Anti-k_T R=0.4 Jets
  - → p_T > 30 GeV
  - → |η| < 4.4, |y| < 2.5
- Comparison to Sherpa v2.1
- Yield and shapes agree well with the SM expectation within systematic uncertainties

ATL-PHYS-PUB-2015-021

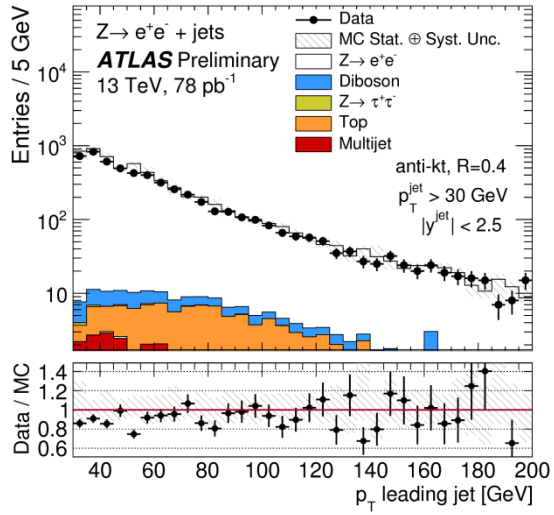
Z→ee+jets



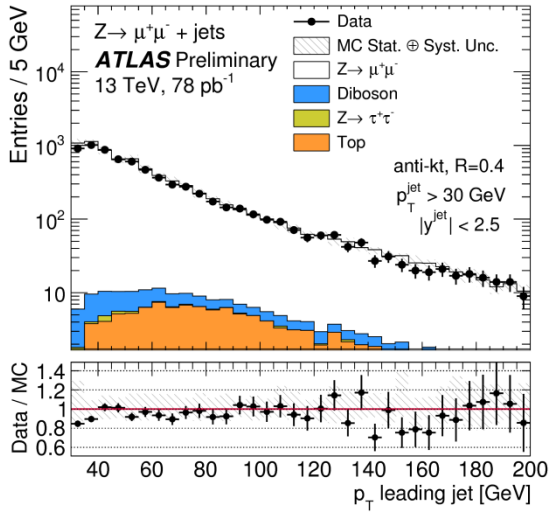
Z→μμ+jets



Z→ee+jets

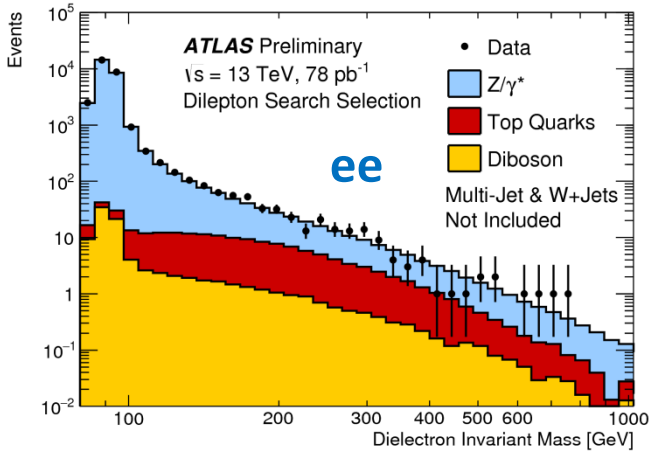


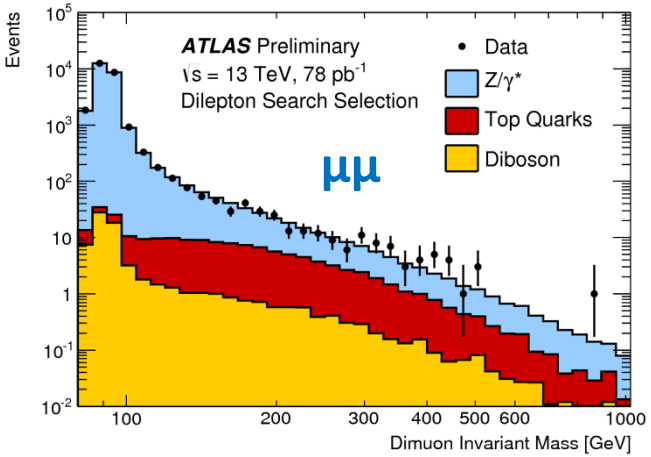
Z→μμ+jets



Run II Preview: High p_T Regime

- Dilepton
  - → p_T > 30 GeV





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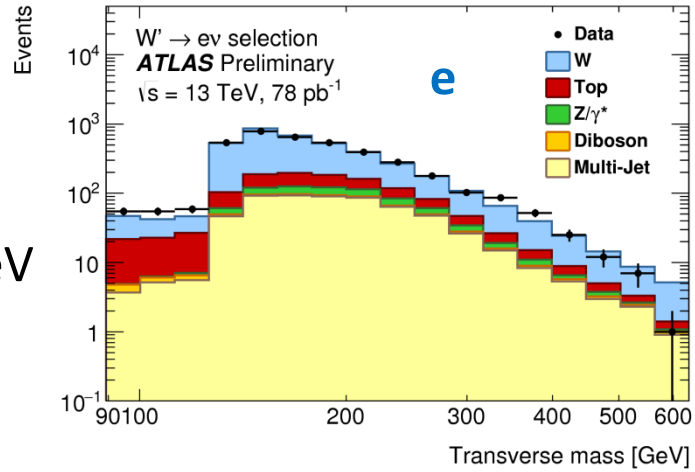
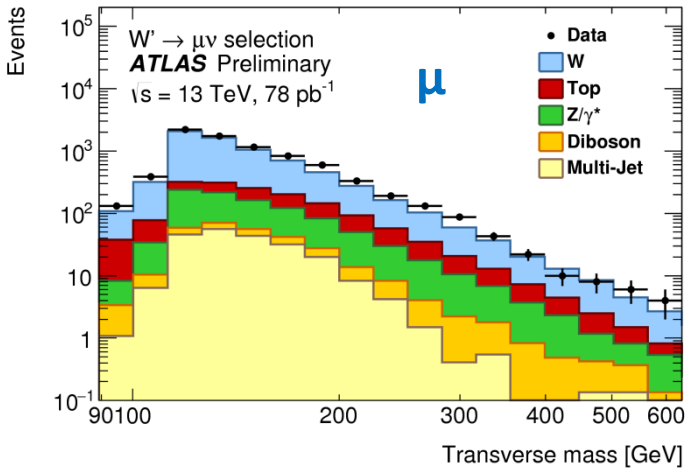
- Lepton + E_T^{miss}
  - → pT > 65 GeV
  - → E_T^{miss} > 65 GeV





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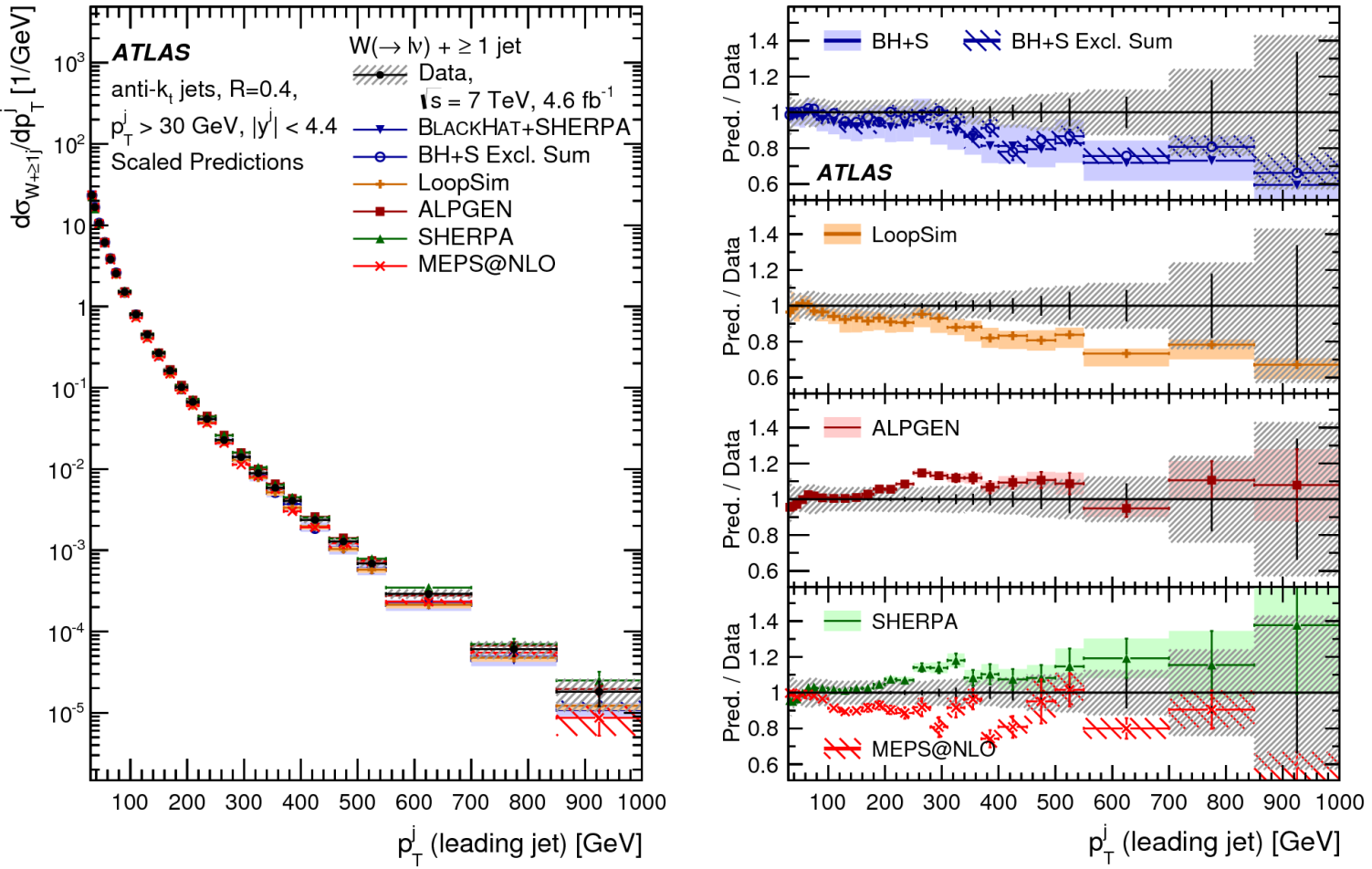
Conclusion

- Run I measurements being finalized as Run II dataset is coming
  - →Precise Run I results are still coming!
- Probes of pQCD, n-pQCD, PDFs, consistency of the SM
  - →In general good agreement with SM predictions
  - →A lot of measurements theorist can dig into
- Run II will continue to provide precision measurements in new kinematic regions
  - →Good understanding of the detector
  - →Yield and shapes agree well with the SM expectation
  - →ATLAS ready for first W,Z cross section measurements and detailed follow-up studies

Backup

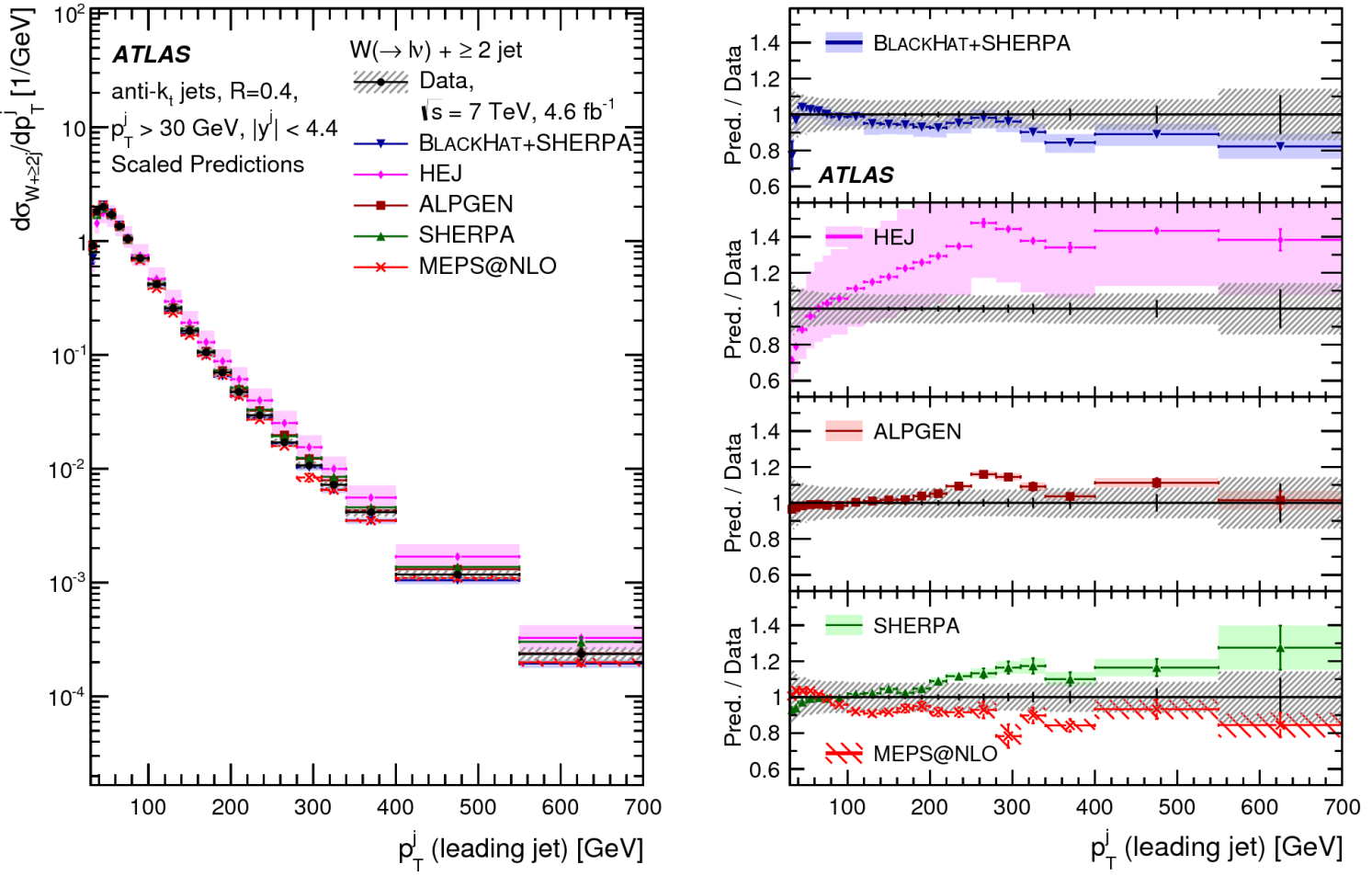
W+jets

Eur. Phys. J. C (2015) 75:82



W+jets

Eur. Phys. J. C (2015) 75:82



W+jets

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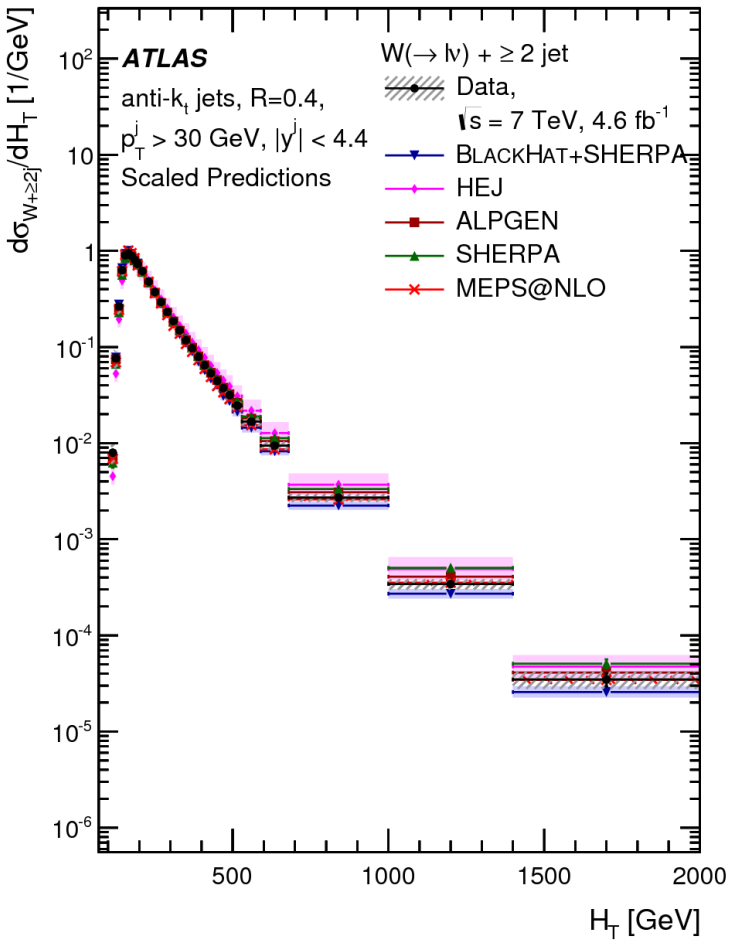
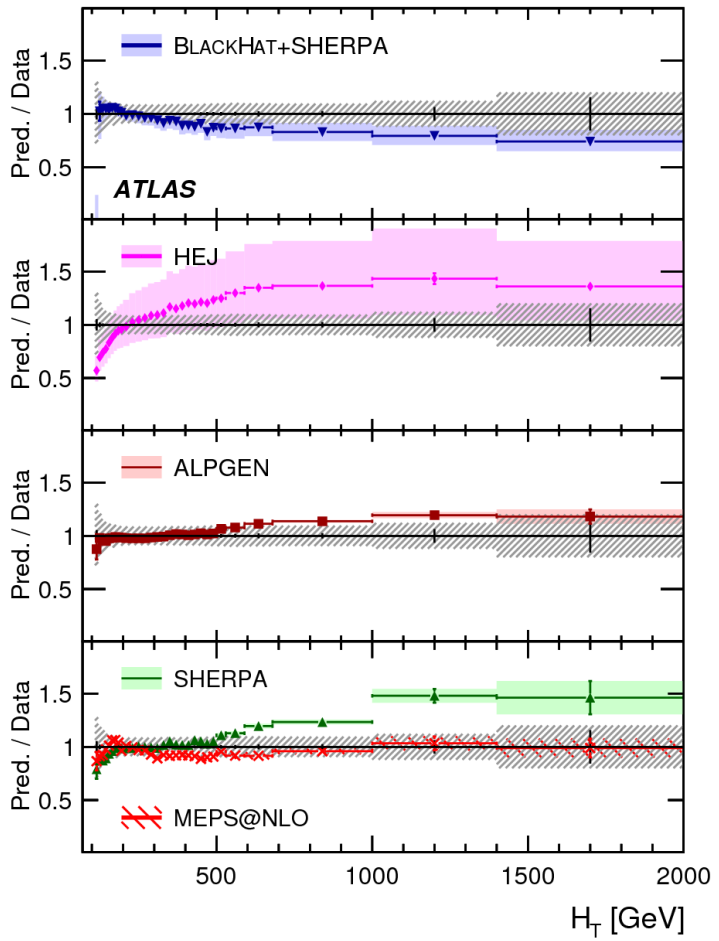
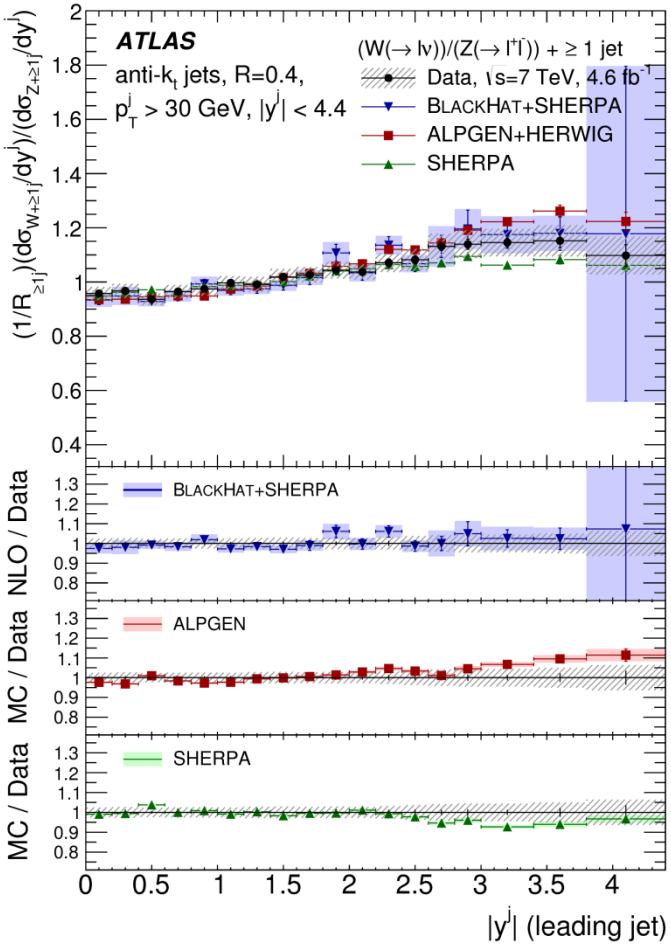
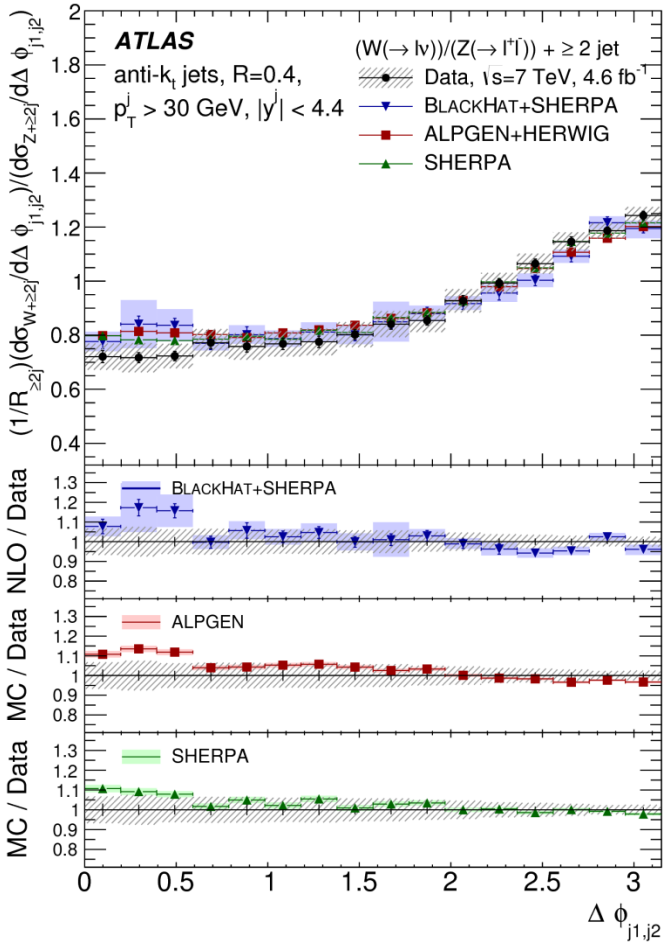




Ratio W+jets/Z+jets

Eur. Phys. J. C (2014) 74:3168





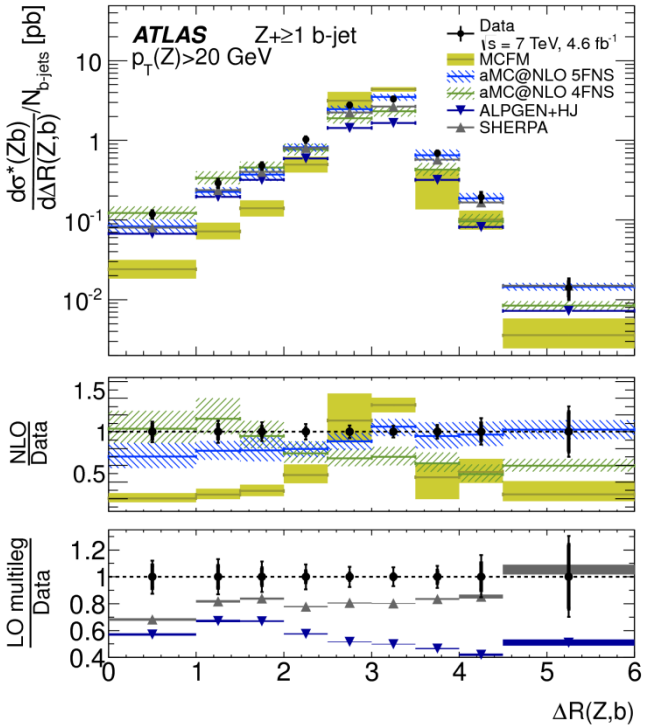
Ratio W+jets/Z+jets

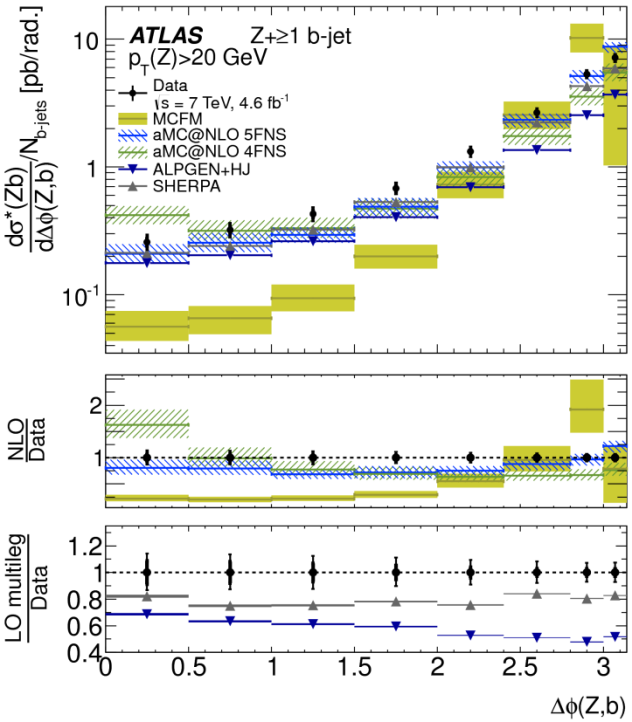
Eur. Phys. J. C (2014) 74:3168

$(W \to e\nu)/(Z \to ee)$					
N_{jets}	≥ 0	≥ 1	≥ 2	≥ 3	≥ 4
Electron	0.89	0.92	0.93	0.97	1.0
JES	0.094	2.0	2.0	3.5	5.7
JER	0.25	2.4	3.5	4.3	6.4
$E_{\text{T}}^{\text{miss}}$	0.19	1.7	1.2	1.2	1.0
$t\bar{t}$	0.024	0.23	1.0	4.9	14
Multi-jet	0.81	1.6	1.5	2.2	6.2
Other backgrounds	0.12	0.57	0.58	0.76	1.0
Unfolding	0.20	0.56	0.86	1.2	1.4
Luminosity	0.062	0.26	0.27	0.34	0.44
Total	1.3	4.1	4.8	8.2	18

$(W \to \mu\nu)/(Z \to \mu\mu)$					
N_{jets}	≥ 0	≥ 1	≥ 2	≥ 3	≥ 4
Muon	1.1	1.2	1.1	0.86	0.87
JES	0.10	0.84	0.71	1.8	2.6
JER	0.094	1.6	1.8	2.6	4.2
$E_{\text{T}}^{\text{miss}}$	0.30	1.0	0.94	0.97	0.99
$t\bar{t}$	0.018	0.18	0.87	4.3	12
Multi-jet	0.20	0.60	1.1	1.7	2.7
Other backgrounds	0.21	0.24	0.28	0.42	0.60
Unfolding	0.22	0.59	0.90	1.2	1.2
Luminosity	0.10	0.12	0.11	0.088	0.023
Total	1.2	2.5	3.0	5.9	13

Z+b(b)





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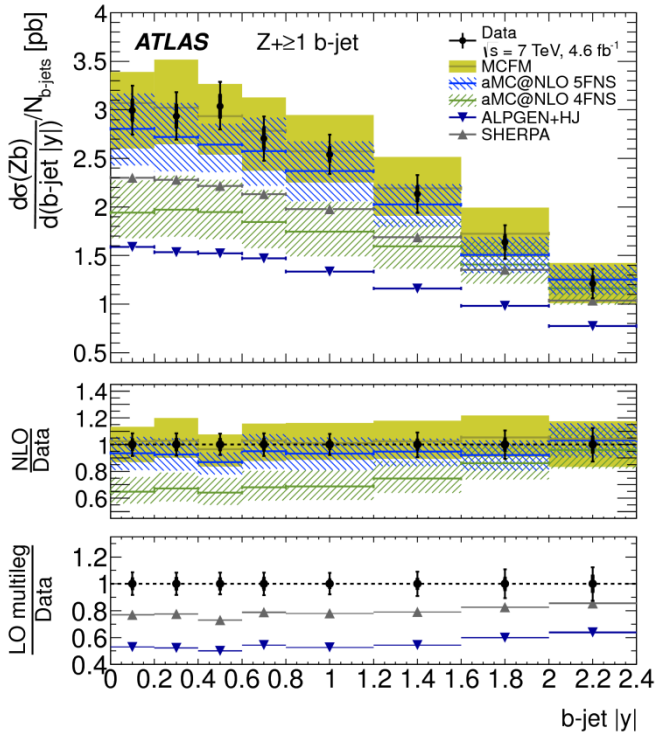
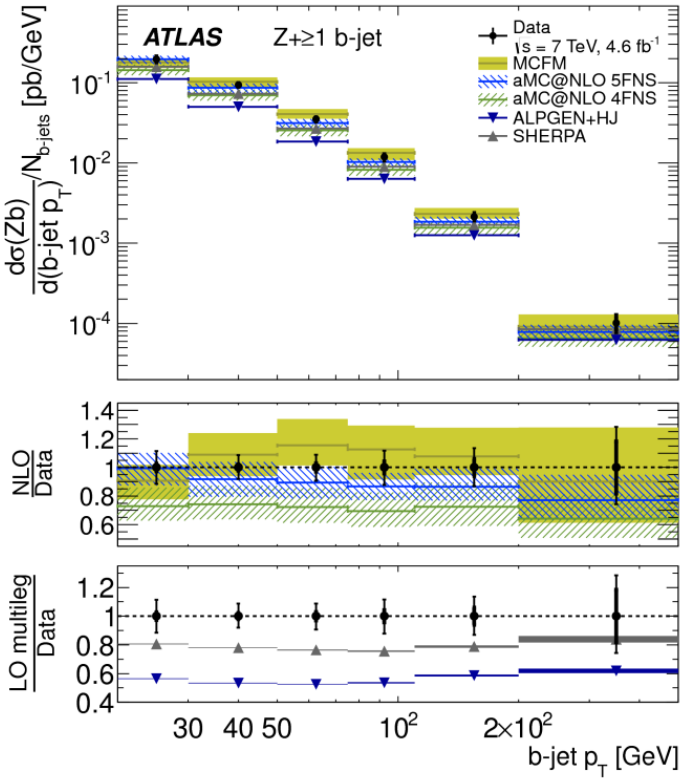
Z+b(b)





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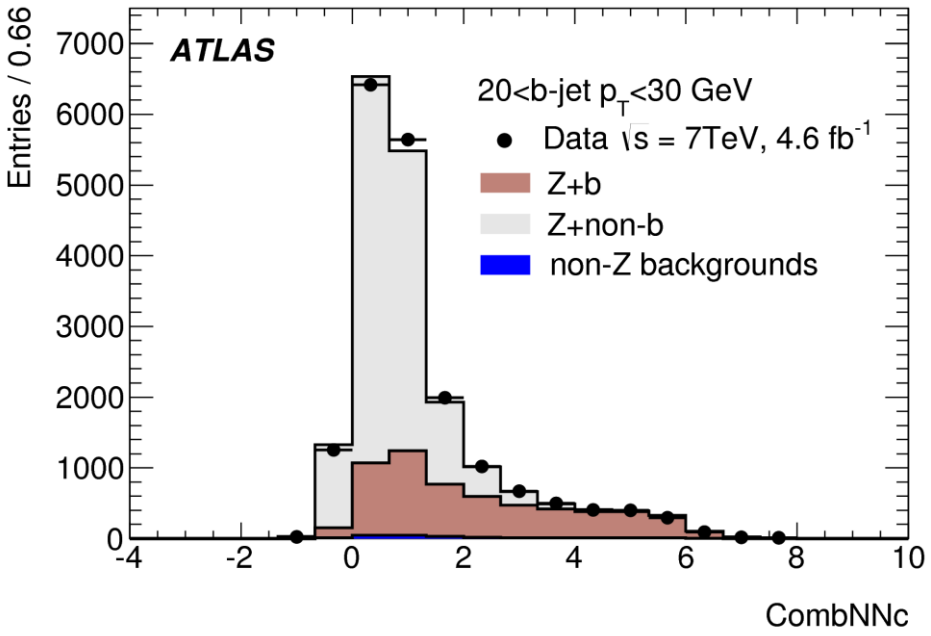
Z+b(b)

Source of uncertainty	$\sigma(Zb)$ [%]	$\sigma(Zbb)$ [%]
b-jet tagging efficiency	3.4	9.8
c-jet mistag rate	0.2	2.3
light-jet mistag rate	0.4	0.6
JES	2.9	4.7
JER	0.3	0.7
b-jet template shape	4.8	4.8
c-jet template shape	0.2	0.6
light-jet template shape	0.9	0.9
b-jet template scale factor	N/A	2.3
MPI	2.5	0.8
gluon splitting	1.2	1.5
background normalisation	1.1	3.6
$t\bar{t}$ modelling	0.0	2.9
MC sample size	1.0	1.4
lepton efficiency, scale and resolution	1.2	1.2
$E_{\mathrm{T}}^{\mathrm{miss}}$	0.1	0.6
luminosity	1.8	1.8
total	7.7	14.0



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Z-p_T

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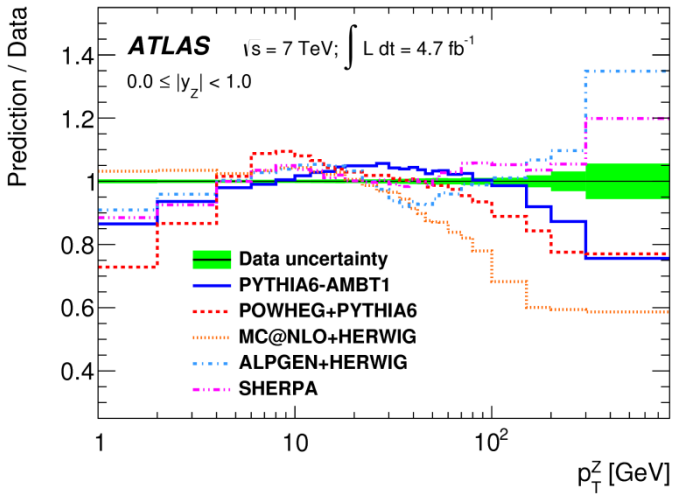
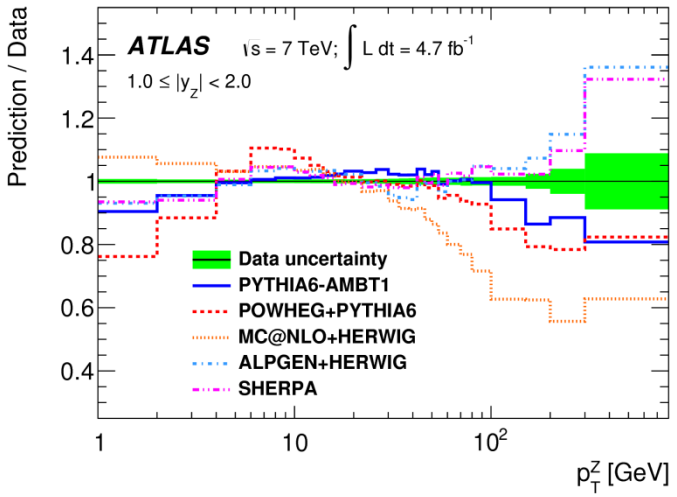
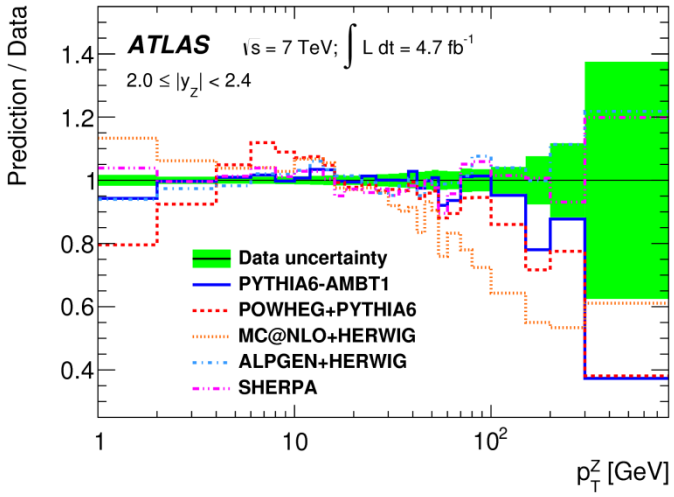
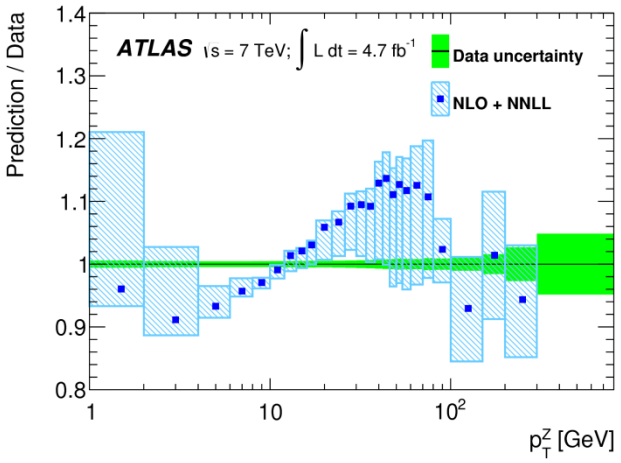
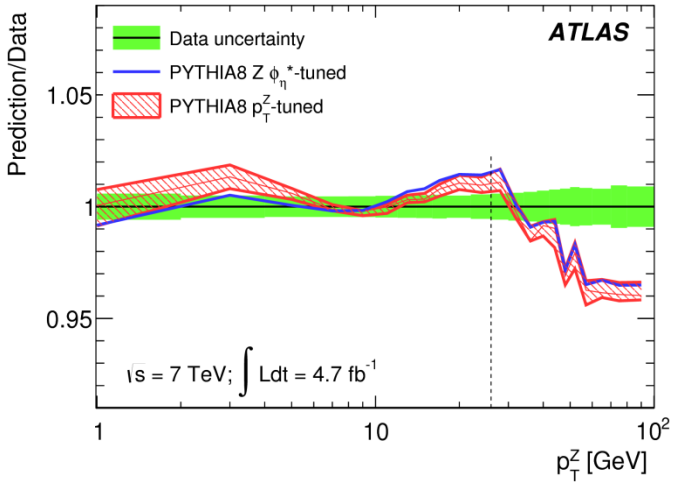






Z-p_T





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