ATLAS measurements of vector boson production, inclusive and with associated jets

QCD I4

Montpellier (France), 30 June - 4 July, 2014

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Outline

- Inclusive gauge boson production
 - ☑ Z transverse momentum ([arXiv:1406.3660](#))
 - ☑ Low mass Drell-Yan ([arXiv:1404.1212](#))
- Gauge boson production in association with jets
 - ☑ Z +jets ([JHEP07\(2013\)032](#))
- Gauge boson production in association with heavy flavors
 - ☑ W +charm ([JHEP 1405 \(2014\) 068](#))
 - ☑ W + b ([JHEP 06 \(2013\) 084](#))
 - ☑ Z + b -jets (**Preliminary**)
- Summary

Inclusive gauge boson production

- ❑ Experimental final state with high purity
- ❑ Z transverse momentum measurement to access to QCD radiation in all kinematics regimes
- ❑ Di-lepton pair production at the Z pole is known to constrain the quark parton density functions
- ☑ Explore out of peak regions to probe different different ranges of (x, Q^2) and quark mixtures
- ❑ Available theoretical tools provide accuracy up to NNLO QCD and can include EW corrections up to NLO or resummation of QCD radiation up to NNLL
- ☑ MC based on LO matrix element +PS, NLO+PS also used

$p_T(l\bar{l})$ at the Z peak

Drell-Yan at low mass

arXiv:1406.3660

arXiv:1404.1212

Z boson transverse momentum

- Fixed order NNLO QCD underestimate the measured cross section by about 10% in the intermediate $p_T(Z)$ region
- Transverse momentum shape reasonably well described above ~ 30 GeV
- NLO EW corrections affect the high $p_T(Z)$ tail only
- Experimental precision of about $\sim 0.5\%$

Z boson transverse momentum

- Data compared to other predictions, including NLL or NNLL resummation
- ☑ Low $p_T(Z)$ region well described
- ☑ Residual data-theory differences almost covered by theory errors

Low mass neutral current Drell-Yan

- Access to di-lepton invariant mass down to 12 GeV
- Fixed order NNLO QCD + NLO EW + PI (photon induced di-lepton pair production) describes well the data

Gauge bosons production in association with jets

- Probe of high p_T QCD radiation description, background for Higgs measurements and New Physics searches
- Z+jets cross section: good statistics ($\sim 10^5$ candidate events), small background
- Measurements also motivated by continuous theoretical progresses
 - ✓ State-of-the-art predictions include LO multileg+PS, NLO, NLO+PS, fixed order NLO (for V+Njets)

Z+jets

- In a nutshell: the data are well described by theory predictions using multileg MC or NLO multileg calculations

- ☑ Some expected limitations or some small “features” of the currently used MC

Gauge bosons production in association with heavy flavors

- The associated production of gauge bosons and heavy flavors has a rich phenomenology at LHC
- ☑ Sensitive to parton distribution functions
- ☑ Interesting for testing various aspects of MC modeling
- Exploiting dedicated analysis strategies to face the large backgrounds
- Available theoretical predictions: NLO+PS, LO multileg +PS, fixed order NLO

W+charm: total fiducial cross sections

- Comparing W+charm-jets and W+D measurements to NLO+PS interfaced to several PDF sets
- ☑ Testing suppressed vs unsuppressed scenarios for the strange quark PDF
- ☑ Testing $s-\bar{s}$ PDF asymmetry

W+charm: differential cross sections and strange quark PDF

- Measured also the lepton $|\eta|$ spectrum
- Total fiducial cross sections used to test the strange quark content of the proton
- ☑ Results consistent with unsuppressed strangeness scenario

Wb

- Excess in the one jet bin more evident at high transverse momentum
- Experimental precision increase with a suitable signal definition (including the single top in the W+b cross section)

Z+b and Z+bb: total fiducial cross sections

- Testing various implementations of QCD predictions
 - ☑ Flavor number scheme (b-quark vs gluon initial state partons), parton-shower, multileg LO vs NLO, b-quark mass sensitivity, ...
- Z+b data favor NLO implementation in the 5FN scheme, Z+bb data favor 4FNS NLO

(*) Leading order for Z+bb final state

Z+b and Z+bb: differential cross sections

- Comprehensive study of Z and b-jets kinematics as well as Z-b and b-jets angular correlations
- Evidence for limitations of the current theory predictions

Summary

- ❑ Fruitful studies of inclusive vector bosons and vector boson plus jets recently published or under publication
- ❑ Improving experimental constraints on parton distribution functions
- ❑ Increasing knowledge on Monte Carlo generators
- ❑ Systematic use of the data to validate/improve the theoretical predictions to be used in view of the physics reach of Run 2 at LHC

Full list of Standard Model measurements in ATLAS
<https://twiki.cern.ch/twiki/bin/view/AtlasPublic/StandardModelPublicResults>

Backup

Z boson transverse momentum

- Data compared also to several MC generators
- Performed a tuning of parton shower parameters for $p_T(Z) \lesssim 25$ GeV

Data versus nominal MC predictions

Comparison of the data with LO and NLO predictions using the base Pythia8 tune and the tune with the $p_T(Z)$ and Φ^* 2011 ATLAS data

$p_T(Z)$: extra information

High compatibility of
electron and muon channels

Purity

Low mass neutral current Drell-Yan

Before the QCD fit

Prediction	χ^2 (8 points) Nominal	χ^2 (6 points) Extended
POWHEG NLO+LLPS	22.4 (19.8)	22.3 (18.6)
FEWZ NLO	48.7 (28.6)	139.7 (133.7)
FEWZ NNLO	13.9 (12.9)	7.1 (7.1)

After the QCD fit

Prediction	χ^2 (8 points) Nominal	χ^2 (6 points) Extended
NLO Fit	40.7	117.1
NNLO Fit	8.5	7.8

- Performed a QCD fit to the nominal and extended invariant mass spectra
- Comparison data-NNLO improves, especially in the nominal analysis mass range