PROCEEDINGS OF SCIENCE

Measurement of W boson production in Pb+Pb collisions at 5.02 TeV with the ATLAS detector

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The W boson is a short lived particle which does not interact strongly. Thus its production rate measured in lepton decay channels can be compared between lead-lead and proton-proton collisions as a direct test of both binary collision scaling and the possible modification of parton distribution functions due to nuclear effects (nPDF). In Run 2 the ATLAS experiment has recorded 0.49 nb^{-1} of lead-lead collision data at the center-of-mass energy of 5.02 TeV. The available W boson sample is increased by a factor of eight relative to the Run 1 data sample collected at 2.76 TeV. This study presents W^{+} and W^{-} boson production yields measured differentially in lepton pseudorapidity and as a function of centrality.

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1. Introduction

One of the direct way to study the initial stage of nucleus–nucleus collisions is a measurement of production of $W^{\pm}$ bosons, which are created at the very beginning stage of collision in the hard parton-parton interaction. Also the leptonic decay products of $W^{\pm}$ are expected not to interact strongly with a produced medium in the later stages of collision therefore the carried information is not modified. This unique feature makes them sensitive to the initial geometry of the nuclei and nuclear modifications of parton distribution function (nPDF) can be studied. Measurements of electroweak vector bosons in lead-lead (Pb+Pb) collisions performed by the ATLAS and CMS experiments [1–3] showed that their rates scale with the nuclear thickness function (T_{AA}). It means that their production rates were found to be independent of presence of Quark Gluon Plasma (QGP). Furthermore, the $W^{\pm}$ bosons production in Pb+Pb collisions may differ from *pp* system. There are two main sources of these differences. The first one is related to the presence of neutrons in the lead ions, which have different quark composition comparing to protons. Secondly, its production can be affected by effects arising from the presence of nucleus where the PDF of free nucleon might be modified [4].

This report covers measurement on $W^{\pm}$ production in the Pb+Pb system at $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV based on data collected in 2015 [5] by the ATLAS experiment at the LHC [6].

2. Data analysis

The W bosons selection requires events containing at least one muon with $p_{\mathrm{T}} > 15$ GeV accepted by the ATLAS trigger system. Simulated Monte Carlo (MC) samples are used to calculate acceptances and to model the properties of signal and background processes. The production of W bosons and their decays are modelled with the Powheg [7] event generator at NLO QCD using the CT10 [8] PDF set, which is interfaced to Pythia8 [9]. The centrality determination for the 2015 Pb+Pb data set follows similar procedures to those used for lower-energy Pb+Pb data in ATLAS and is described in Ref. [10]. The background from muons originating from heavy-flavour decays is reduced by requiring muons to be isolated. The isolation criterion relies on the sum of transverse momenta of tracks in the cone in $\eta - \phi$ space of the size $\Delta R = 0.2$ around the muon candidate divided by the muon p_{T}, and its exact value depends on centrality. The missing transverse momentum $p_{\mathrm{T}}^{\mathrm{miss}}$ is defined as a vector sum of transverse momenta of tracks which pass a minimum p_{T} requirement (4 GeV), taken with negative sign. At the reconstruction level, the transverse mass of the muon and neutrino system is defined as:

$$m_{\mathrm{T}}^{\mathrm{miss}} = \sqrt{2 p_{\mathrm{T}}^{\mu} p_{\mathrm{T}}^{\mathrm{miss}} (1 - \cos\Delta\phi)}, \quad (2.1)$$

where $\Delta\phi$ is the difference between the direction of the muon and the $p_{\mathrm{T}}^{\mathrm{miss}}$ vector (a proxy for p_{T}^{ν}) in the azimuthal plane. Finally, the W boson production yields are measured in the following fiducial region: $p_{\mathrm{T}}^{\mu} > 25$ GeV, $0.1 < |\eta_{\mu}| < 2.4$, $p_{\mathrm{T}}^{\nu} > 25$ GeV and $m_{\mathrm{T}} > 40$ GeV. The range of η_{μ} reflects the coverage of the Muon Spectrometers (MS) chambers and the acceptance of the muon trigger system. The background contribution from Z boson decays is suppressed by imposing a Z-veto requirement, which means that events with a pair of opposite-charge muons with the invariant mass greater than 66 GeV are rejected. After imposing all W boson selection cuts 25245 W^+ and 23123 W^- candidates are selected for further analysis.

Jet production via QCD processes (referred to as "QCD multi-jet background") is a dominant background contribution to this analysis. It is evaluated using a data-driven approach used in W boson measurements in pp collisions [11]. The electroweak background processes considered in this analysis include $W \to \tau\nu$, $Z \to \mu^+\mu^-$, $Z \to \tau^+\tau^-$ and $t\bar{t}$ events in which at least one top quark decays semileptonically into a muon. The above electroweak backgrounds are estimated using Powheg MC samples.

Several sources of systematic uncertainties are considered in the analysis. The most significant systematic uncertainties originates from the muon trigger efficiency and normalization of the QCD multi-jet background. Their impact is around 3% and 5%, respectively. Other non-negligible systematic sources are related to $p_{\mathrm{T}}^{\mathrm{miss}}$ reconstruction, isolation requirement, muon reconstruction efficiency and misalignment of the tracking detectors in the Pb+Pb data. The total systematic uncertainty is the sum in quadrature of all individual contributions and it varies between 3% and 9% for W bosons yields in η.

3. Results

Figure 1 presents differential production yields per minimum bias event divided by $\langle T_{\mathrm{AA}} \rangle$ for $W^+ \to \mu^+\nu$ and $W^- \to \mu^-\bar{\nu}$ as a function of η_μ.

The data are compared to Powheg (with NNLO effects taken into account to the scaling factor $\mathrm{k_{NNLO}}$) using CT10 PDF and MCFM [12] using the most recent nPDF, EPPS16 [13] and nCTEQ15 [14]. Data agree well with Powheg calculations while predictions including nuclear modifications to PDF underestimate the data.

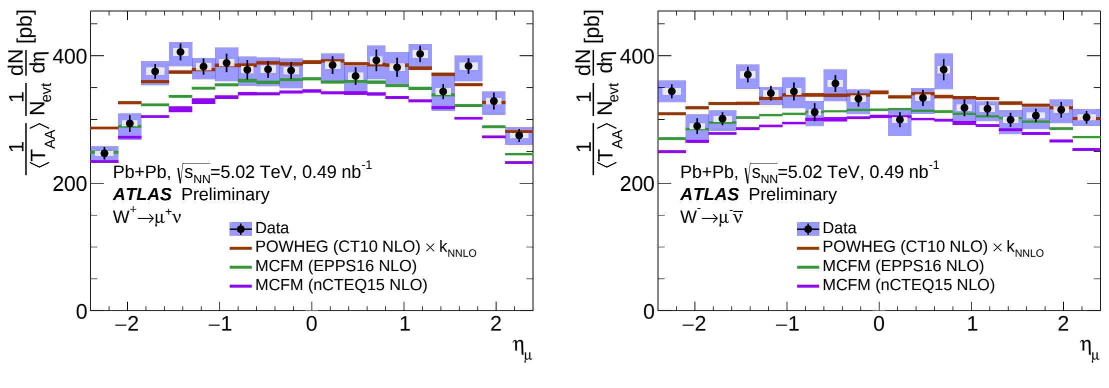

Figure 1: Differential production yields per minimum bias event divided by $\langle T_{\mathrm{AA}} \rangle$ for $W^+ \to \mu^+\nu$ (left) and $W^- \to \mu^-\bar{\nu}$ (right) extracted from the $0-80\%$ centrality range as a function of the muon pseudorapidity compared with several models. The error bars correspond to the statistical uncertainties, error boxes correspond to the total systematic uncertainties. The uncertainties on the models are only statistical [5].

Figure 2 presents the $W^\pm$ yields per minimum bias event divided by $\langle T_{\mathrm{AA}} \rangle$ as a function of $\langle N_{\mathrm{part}} \rangle$ separately for both charges. Yields are observed to be independent of centrality. Similarly to η differential production yields the good agreement was found with Powheg calculations using CT10 PDF scaled by k_{NNLO}.

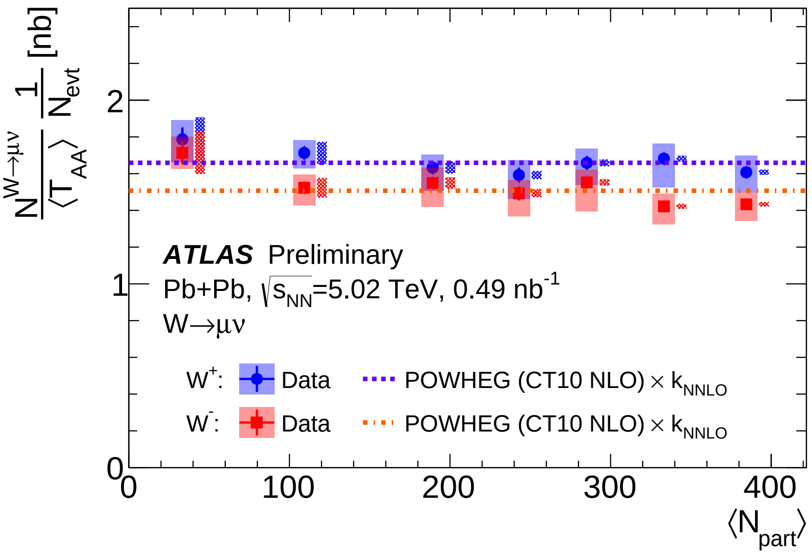

Figure 2: Fiducial $W \to \mu\nu$ yields per minimum bias event divided by $\langle T_{AA} \rangle$ as a function of $\langle N_{part} \rangle$ for W^+ and W^-. The error bars correspond to the statistical uncertainties, error boxes correspond to the total systematic uncertainties [5].

4. Summary

Measurements of $W^{\pm}$ bosons production have been reported based on Pb+Pb data collected at 5.02 TeV by the ATLAS experiment at the LHC. Predictions based on perturbative QCD calculations describe the data well. Good agreement was found with Powheg calculations using CT10 PDF scaled by k_{NNLO}, while MCFM using EPPS16 and nCTEQ15 nPDF underestimate the global normalization of the data.

References

[1] ATLAS Collaboration, Phys. Rev. Lett. 110 (2013) 022301.
[2] ATLAS Collaboration, Eur. Phys. J. C75 (2015) 23.
[3] CMS Collaboration, Phys. Lett. B715 (2012) 66.
[4] R. Vogt, Phys. Rev. C64 (2001) 044901.
[5] ATLAS Collaboration, ATLAS-CONF-2017-067, http://cds.cern.ch/record/2285571.
[6] ATLAS Collaboration, JINST 3 (2008) S08003.
[7] S. Alioli, P. Nason, C. Oleari and E. Re, JHEP 06 (2010) 043.
[8] H.-L. Lai et al., Phys. Rev. D82 (2010) 074024.
[9] T. Sjostrand, S. Mrenna and P. Z. Skands, Comput. Phys. Commun. 178 (2008) 852.
[10] ATLAS Collaboration, ATLAS-CONF-2016-110, https://cds.cern.ch/record/2220772.
[11] ATLAS Collaboration, Eur. Phys. J. C 78 (2018) 110.
[12] J. M. Campbell, R. K. Ellis and W. T. Giele, Eur. Phys. J. C75 (2015) 246.
[13] K. J. Eskola, P. Paakkinen, H. Paukkunen and C. A. Salgado, Eur. Phys. J. C77 (2017) 163.
[14] K. Kovarik et al., Phys. Rev. D93 (2016) 085037.