Journal of Physics: Conference Series **612** (2015) 012009 doi:10.1088/1742-6596/612/1/012009

Measurement of W-boson production in p–Pb collisions at $\sqrt{s_{\rm NN}} = 5.02$ TeV with ALICE at the LHC

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Abstract. In hadronic collisions, electroweak bosons are produced in initial hard scattering processes and they are not affected by the strong interaction. In proton–proton collisions, they have been suggested as standard candles for luminosity monitoring and their measurement can improve the evaluation of detector performances. In nucleus-nucleus and proton–nucleus collisions, W-bosons allow one to check at first order the validity of binary collision scaling, while small deviations allow to study the nuclear modifications of parton distribution functions. The W-boson production in p–Pb collisions at $\sqrt{s_{\rm NN}} = 5.02$ TeV is measured via the contribution of W-boson decays to the inclusive p_T-differential muon yield reconstructed with the ALICE muon spectrometer at forward ($2.03 < y^{\mu}_{\rm cms} < 3.53$) and backward ($-4.46 < y^{\mu}_{\rm cms} < -2.96$) rapidity. This paper reports the production cross section of muons from W-boson decays for $p^{\mu}_{\rm T} > 10$ GeV/c and the yields normalised to the average number of binary nucleon-nucleon collisions as a function of the event activity.

1. Introduction

The high collision energies available at the Large Hadron Collider (LHC) at CERN allow for an abundant production of hard probes, such as quarkonia, high $p_{\rm T}$ jets and intermediate vector bosons ($W^{\pm}$, Z^0). The W bosons are produced in initial hard parton scattering processes, with a formation time of the order of $1/M_{\rm W} \sim 0.003$ fm/c and, having a lifetime of 0.09 fm/c, they decay before the formation of the quark-gluon plasma (QGP), which is a deconfined phase of QCD matter that is formed in high-energy heavy-ion collisions. Furthermore, their leptonic decay products do not interact strongly with the hot and dense QCD medium. In proton-proton collisions, due to precise theoretical predictions, one can use W-boson production to cross check the luminosity. In proton-nucleus and nucleus-nucleus collisions, precise measurements of W-boson and Z-boson production can constrain the modification of the Parton Distribution Functions (PDFs) in the nucleus [1] and they can be used to test the scaling of hard particle production with the number of binary nucleon-nucleon collisions at first order [2].

2. Experimental setup and data taking

The ALICE experiment is equipped with various detectors for triggering, tracking and particle identification [3]. Muons are reconstructed in the muon spectrometer, which covers the pseudo-rapidity range $-4 < \eta_{\rm lab} < -2.5$, consists of a thick front absorber, a dipole magnet, five tracking stations, a muon filter and two trigger stations. Other detectors are used for event

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selection and characterization. The inner tracking system consists of six layers of silicon detectors covering the range $|\eta_{\rm lab}| < 0.9$. In this analysis, the interaction vertex is measured with the two innermost layers, which are equipped with Silicon Pixel Detectors (SPD). The number of clusters in the outer layer of the SPD (CL1) can be used to characterize the event activity. An array of scintillators placed at both sides of the interaction point, the VZERO detector (V0A, V0C), provides the trigger and event activity estimation. A third estimation of the event activity is obtained with the Zero Degree Calorimeters (ZNA, ZNC) located at both sides of the detector at 112.5 m distance from the interaction point along the beam line. Due to the energy asymmetry of the two colliding beams, the centre-of-mass system of nucleon-nucleon collisions is shifted by $\Delta y = 0.465$ in the direction of the proton beam, with respect to the laboratory frame. Experimental data have been collected with two beam configurations (p-Pb and Pb-p) by inverting the orbits of the two particle species. The rapidity regions covered by the muon spectrometer in the two cases are $2.03 < y^{\mu}_{\rm cms} < 3.53$ (forward, p-Pb) and $-4.46 < y^{\mu}_{\rm cms} < -2.96$ (backward, Pb-p), where positive rapidities refer to the situation where the proton beam is moving towards the muon spectrometer. The data have been collected at $\sqrt{s_{\rm NN}} = 5.02$ TeV with minimum bias (MB) and single muon triggers. The former is defined requiring hits in both sides of the VZERO detector in coincidence with the beam counters. The latter is defined by asking, in addition to the MB condition, for a high transverse momentum muon in the trigger system of the spectrometer. The trigger selection is not sharp in momentum, but roughly corresponds to $p_{\rm T} > 4$ GeV/c. The integrated luminosities for the forward and backward rapidity measurements are 4.9 nb^{-1} and 5.8 nb^{-1}, respectively. Events are selected by requiring that the timing in VZERO and ZDC detectors are compatible with a nominal p-Pb interaction and that the interaction vertex is reconstructed. The track in the muon tracking system is required to be in the geometrical acceptance ($-4 < \eta_{\rm lab} < -2.5$), to have a polar angle measured at the end of the absorber of $170^\circ < \theta_{\rm abs} < 178^\circ$ and match a tracklet in the trigger system in order to reject the remaining contamination from hadrons. Furthermore, the correlation between momentum and distance of closest approach (DCA) to the interaction vertex was used to remove beam-gas collisions and secondary particles produced in the absorber.

3. W-boson signal extraction

The present analysis is based on the extraction of the W-boson contribution from the transverse momentum distribution of inclusive muons. At high $p_{\rm T}$, the main contributions to the yield of inclusive muons come from the muonic decays of W-bosons, the di-muon decays of Z^0/γ^* bosons and the semi-muonic decays of beauty hadrons. The yield of muons from W-boson decays can be obtained through a fit based on suitable parameterizations of the different components. The distribution of muons from intermediate vector boson decays is described by MC templates obtained from POWHEG simulations [4]. The isospin dependence of the W-boson differential cross-section [5] is accounted for by simulating separately p-p and p-n collisions and then summing the results together according to:

$$\frac{1}{N_{\text{p-Pb}}} \cdot \frac{\mathrm{d}N_{\text{p-Pb}}}{\mathrm{d}p_{\rm T}} = \frac{Z_{\rm Pb}}{A_{\rm Pb}} \cdot \frac{1}{N_{\text{p-p}}} \cdot \frac{\mathrm{d}N_{\text{p-p}}}{\mathrm{d}p_{\rm T}} + \frac{A_{\rm Pb} - Z_{\rm Pb}}{A_{\rm Pb}} \cdot \frac{1}{N_{\text{p-n}}} \cdot \frac{\mathrm{d}N_{\text{p-n}}}{\mathrm{d}p_{\rm T}} \tag{1}$$

where $A_{\rm Pb} = 208$ and $Z_{\rm Pb} = 82$. The generation of muons from Z^0/γ^* decays is performed in an equivalent way. For the description of the background at low $p_{\rm T}$ ($10 < p_{\rm T} < 40$ GeV/c), which originates from the decays of beauty hadrons, three approaches are adopted: MC templates based on pQCD calculations with FONLL [6], functional form which was already successfully adopted for analogous measurements by the ATLAS experiment at the LHC [7] and another function adapted from the second term of the function used by ATLAS, which can be written as $f(p_{\rm T}) = a \cdot \frac{e^{b\cdot\sqrt{p_{\rm T}}}}{p_{\rm T}^{c}}$. The different contributions are summed together in the final fit function:

$$f(p_{\mathrm{T}}) = N_{\mathrm{bkg}} \cdot f_{\mathrm{bkg}}(p_{\mathrm{T}}) + N_{\mu\leftarrow \mathrm{W}} \cdot f_{\mu\leftarrow \mathrm{W}}(p_{\mathrm{T}}) + N_{\mu\leftarrow \mathrm{Z}^0/\gamma^*} \cdot f_{\mu\leftarrow \mathrm{Z}^0/\gamma^*}(p_{\mathrm{T}}) \quad (2)$$

where f_{bkg} can be either a functional form or the MC template for muons from heavy-flavour decays, and $f_{\mu\leftarrow \mathrm{W}}$ and $f_{\mu\leftarrow \mathrm{Z}^0/\gamma^*}$ are the MC templates for muons from W and Z^0/γ^* boson decays, respectively. The number of muons from W decays ($N_{\mu\leftarrow \mathrm{W}}$) is a free parameter, while the ratio $N_{\mu\leftarrow \mathrm{Z}^0/\gamma^*}/N_{\mu\leftarrow \mathrm{W}}$ is fixed to the value obtained with POWHEG. Two examples of combined fit are shown in figure 1.

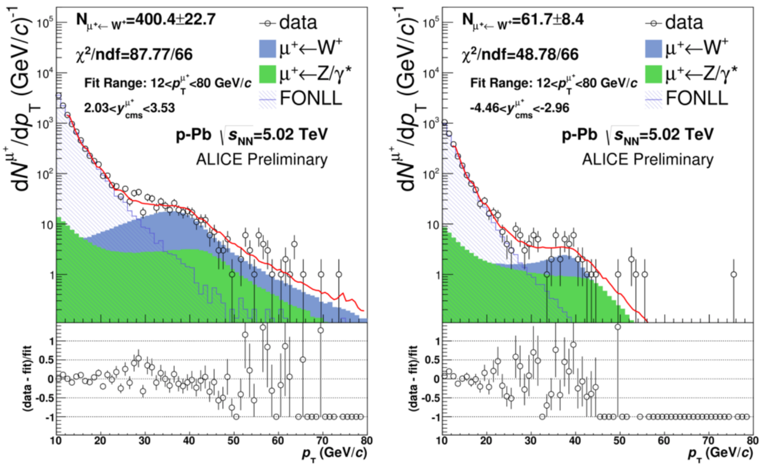

Figure 1. Examples of signal extraction at forward (left) and backward (right) rapidity using a FONLL-based MC template to describe the background

The signal extraction is affected by the uncertainties in the description of the shapes of signal and background. The effect of the detector alignment is taken into account by producing the templates in simulations using different residual alignment assumptions. The uncertainty on the background description is determined by using either FONLL-based MC templates or functional forms and by varying the p_{T} range in the fit. The relative contribution of Z^0/γ^* is varied based on POWHEG and PYTHIA [8] predictions. The signal was extracted many times by varying the above conditions and the final result is chosen as the weighted average of all of the trials. The systematic uncertainties is given by the RMS of the trials. It is worth noting that POWHEG does not account for the nuclear modification of the PDFs. Hence, the signal extraction using PYTHIA with EPS09 parameterization of nuclear PDFs [9] was included in the calculation of the systematic uncertainties.

4. Cross section of muons from W-boson decays in p-Pb collisions

After signal extraction, the yields of muons from W-boson decays are corrected for acceptance and efficiency and converted into cross sections. The measured production cross section of muons from W-boson decays at forward and backward rapidity in p-Pb collisions is shown in figure 2 and compared with theoretical predictions based on NLO pQCD calculations with CT10 [10] and EPS09 PDFs. The yield of muons from W-boson decays, corrected for acceptance and efficiency and normalised to the number of equivalent MB events can be divided by the average number of binary collisions $\langle N_{\mathrm{coll}}\rangle$ in each event activity bin, in order to obtain the yield per binary collision. $\langle N_{\mathrm{coll}}\rangle$ is determined from a Glauber-model based analysis in the case of V0A and CL1 estimators, while for the ZN estimator it is computed assuming that the particle density at mid-rapidity is proportional to N_{part}. All about $\langle N_{\mathrm{coll}}\rangle$ measurement are described in [2]. The measured yield/$\langle N_{\mathrm{coll}}\rangle$ as a function of event activity at forward and backward rapidity in p-Pb collisions are shown in figure 3.

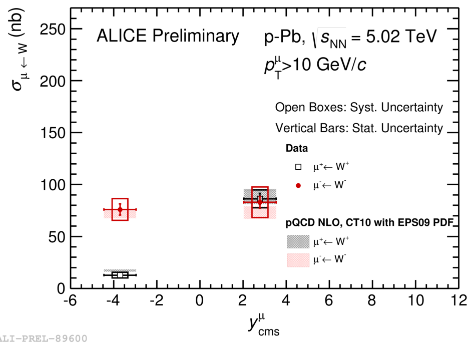

Figure 2. Cross section of muons from W-boson decays as a function of rapidity

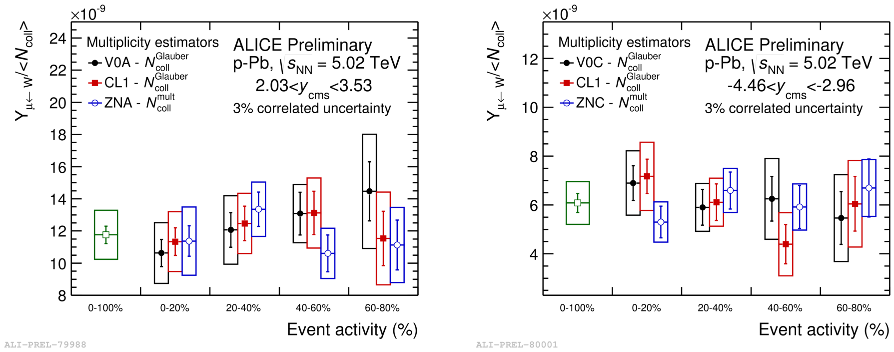

Figure 3. Yield/$\langle N_{\mathrm{coll}} \rangle$ as a function of event activity at forward and backward rapidity

5. Conclusion

The production cross section of muons from W-boson decays at forward and backward rapidity in the range $p_{\mathrm{T}}^{\mu} > 10$ GeV/c has been measured in p-Pb collisions at $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV with the ALICE muon spectrometer. Theoretical predictions based on NLO pQCD calculations with CT10 and EPS09 PDFs agree with the data within uncertainties. The yield of muons from W-boson decays in different event activity bins scales with $\langle N_{\mathrm{coll}} \rangle$ within substantial uncertainties.

Acknowledgments

This work is supported partly by the Chinese Ministry of Science and Technology 973 grant 2013CB837803, NSFC Grant 11375071 and IRG11221504, CCNU13F026 and CSC grant No. 201306770033.

References

[1] Paukkunen H and Salgado C A 2011 *J. High Energy Phys.* **03** 071
[2] Toia A 2014 *Nuclear Physics A* **926** 78-84
[3] Aamodt K *et al.* (ALICE Collaboration) 2008 *JINST* **3** S08002
[4] Alioli S, Nason P, Oleari C and Re E 2008 *J. High Energy Phys.* **07** 060
[5] Conesa del Valle Z, CERN-THESIS-2007-102
[6] Cacciari M, Greco M and Nason P 1998 *J. High Energy Phys.* **05** 007
[7] ATLAS Collaboration, ATLAS-CONF-2011-078
[8] Sjostrand T, Mrenna S and Skands P 2006 *J. High Energy Phys.* **05** 026
[9] Eskola K J, Paukkunen H and Salgado C A 2009 *J. High Energy Phys.* **04** 065
[10] Lai H L *et al.* 2010 *Phys.Rev. D* **82** 074024