

Open heavy-flavour and electroweak boson measurements via the (di-)muonic decay channel with ALICE at the LHC

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Abstract. Heavy flavours (charm and beauty) and electroweak bosons (W and Z) are produced in initial hard partonic scatterings. The former interact strongly with the medium formed in ultra-relativistic heavy-ion collisions throughout its evolution, thus making them well suited to investigate its properties. Furthermore, heavy-flavour measurements in proton-nucleus collisions can be used to investigate initial-state effects whereas in proton-proton (pp) collisions they are considered an important test for perturbative Quantum ChromoDynamics (pQCD) predictions. In addition, open heavy-flavour measurements in pp collisions are used as a reference for proton-lead (p-Pb) and lead-lead (Pb-Pb) collisions. On the other hand, electroweak bosons and their leptonic decay products only interact weakly with the QCD matter and thus are suitable probes to test the validity of binary-collision scaling of hard processes. Moreover, their measurements in p-Pb collisions could help to constrain nuclear parton distribution functions. The ALICE muon spectrometer allows the measurement of open heavy flavour, W- and Z-boson production at forward rapidity ($-4.0 < \eta < -2.5$) exploiting their (di)muonic decay channel. In this talk the results obtained with the LHC Run I data in pp, p-Pb and Pb-Pb collisions will be discussed and compared with theoretical predictions.

1. Introduction

Due to their large masses, open heavy flavours (charm and beauty) and electroweak bosons (W and Z) are produced in initial hard partonic processes. The former traverse and interact strongly with the medium formed in heavy-ion collisions and their energy is reduced. The modification of the transverse momentum (p_T) distribution is quantified via nuclear modification factor (R_{AA} or R_{pPb}) as a function of p_T [1]. The R_{AA} value is equal to unity if no nuclear modification is present while R_{AA} smaller than unity can be due to partonic energy loss such as radiative energy loss (medium induced gluons radiation) [2, 3, 4] and elastic scattering (collisional energy loss) [2, 5]. Initial-state effects [6, 7] or cold nuclear matter (CNM) effects, studied in proton-lead (p-Pb) collisions, complicate the interpretation of any deviation from unity of the R_{AA} in terms of energy loss effects, therefore, for a thorough treatment, heavy-ion collisions need to be studied in conjunction with proton-proton and p-Pb collisions. In proton-proton collisions, open heavy flavour production is used to test theoretical models based on perturbative Quantum ChromoDynamics (pQCD) and they are used as reference measurement for heavy-ion collisions. Since open heavy flavours experience the whole evolution of the medium, the question is whether they participate in the collective expansion of the medium or do they have a non-zero azimuthal anisotropy (v_2).



The isospin dependent production of W- and Z-bosons makes them good probes to constrain parton distribution functions (PDFs) at high momentum transfer (Q) [12]. In high-energy heavy-ion collisions, these electroweak bosons decay before the formation of the QGP. Their weak coupling nature in the leptonic decay channel makes them good probes to study CNM effects. Therefore, they give access to the initial-state properties in nuclear collisions and their yields provide a benchmark to validate the binary-scaling of hard processes [12]. This scaling was verified by the CMS [8, 9] and ATLAS [10, 11] collaborations for photons, W and Z bosons at mid-rapidity.

The production of open heavy flavours, W- and Z-bosons in proton-lead collisions (p-Pb) provides an excellent tool to study cold nuclear matter (CNM) effects [6, 7, 12]. This control experiment (p-Pb) is used to understand whether the effects seen in heavy-ion collisions are a combination of initial and final state effects.

ALICE (A Large Ion Collider Experiment) collected data in pp, Pb-Pb and p-Pb collisions at center-of-mass energies of 7 and 2.76, 5.02 and 2.76 TeV, respectively, at the CERN Large Hadron Collider (LHC). Details of the ALICE detector can be found in ref. [13, 14]. The analysis procedure of open heavy flavour measurement at forward rapidity can be found in [15] and [16] for pp collisions at 2.76 TeV and 7 TeV, in [17] for Pb-Pb collisions at 2.76 TeV and in [18] for p-Pb collisions at 5.02 TeV. The analysis procedure of electroweak bosons is detailed in [19].

2. Results: open heavy flavour

Shown in Figure 1 are plots of the R_{AA} (left) and azimuthal anisotropy (right) of open heavy flavour decay muons as function of p_T in the most central and semi-central collisions, compared to transport models: MC@sHQ+EPOS, BAMPs and TAMU which include radiative and collisional energy loss (for details see Ref. [17] and references therein). It is seen in Figure 1 that open heavy flavour production is effectively modified/reduced in the medium (left plot) and also a non-zero v_2 suggests that they participate in the collective expansion of the medium (right plot).

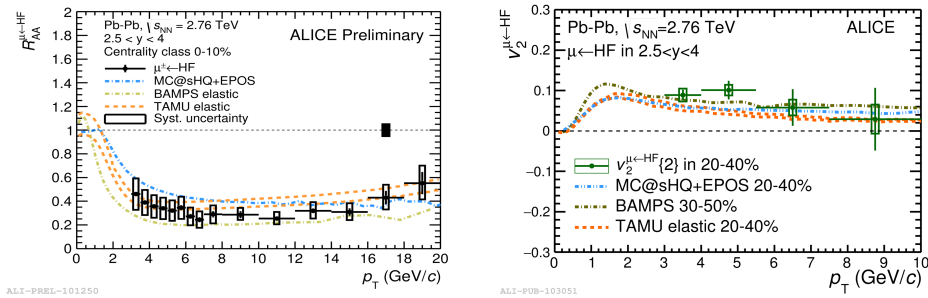


Figure 1. The R_{AA} (left) and azimuthal anisotropy (right) of open heavy flavour muons as functions of p_T in the most central and semi-central Pb-Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV compared to theoretical models [17].

The R_{pPb} of open heavy flavour decay muons in p-Pb collisions is shown in Figure 2 at backward (left) and forward (right) rapidity. The R_{pPb} is consistent with unity in both rapidity intervals indicating that the effects seen in Pb-Pb collisions are dominated by final state or medium effects.

3. Results: electroweak bosons

In Figure 3 (left), the measured cross sections of W bosons ($\sigma_{\mu^\pm \leftarrow W^\pm}$) at forward and backward rapidity in p-Pb collisions are compared with pQCD predictions with CT10 PDFs [20],

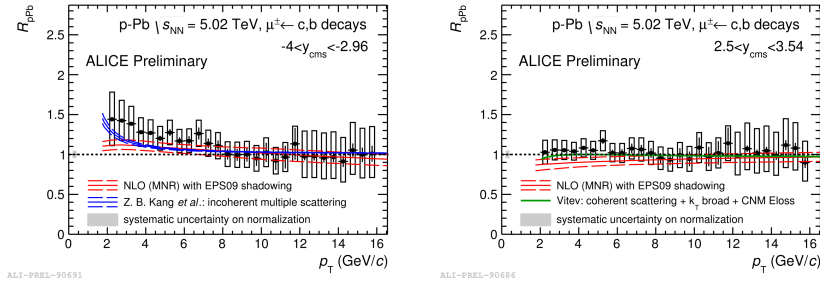


Figure 2. The R_{pPb} of open heavy flavour decay muons at backward (left) and forward (right) rapidity in p-Pb collisions. The measurements are compared with theoretical calculations [18].

with and without EPS09 parametrization [21] for nuclear shadowing. Theoretical calculations agree with the measured cross sections within uncertainties. In Figure 3 (right),

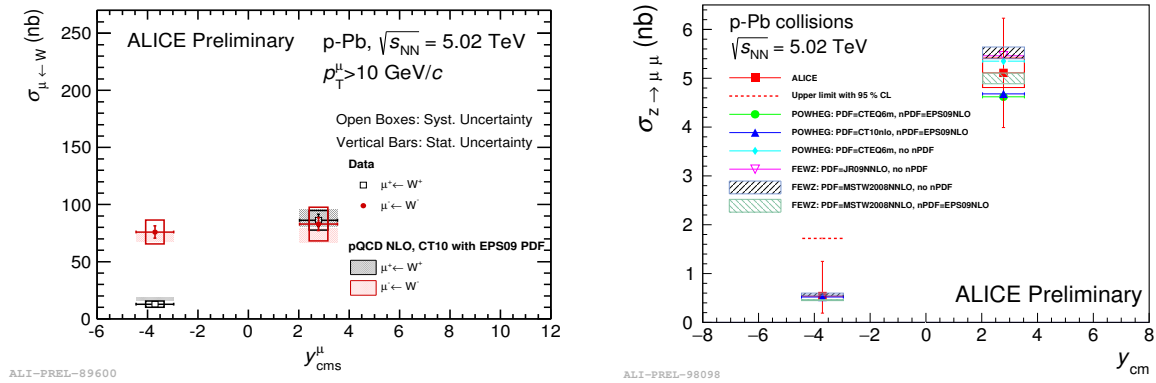


Figure 3. The measured production cross section of muons from W-boson (left) and Z-boson (right) compared with theoretical predictions with and without nuclear PDFs.

the Z-boson cross sections at forward and backward rapidity are compared with next-to-next-to leading order (NNLO) Fully Exclusive W and Z (FEWZ) [22] predictions with CT10, CTEQ6m [23], JR09NNLO [24] and MSTW2008NNLO [25] with and without nuclear PDFs. Theoretical calculations agree with the measured cross sections within uncertainties.

In ALICE the binary scaling of hard processes is tested by evaluating the yield of muons from W-boson decays per event in selected event activity (or centrality) intervals, renormalized by $\langle N_{coll} \rangle$ [26]. The values of $\langle N_{coll} \rangle$ are obtained using methods described in [26]. Figure 4 shows the results for yield normalized to $\langle N_{coll} \rangle$ for both backward (right) and forward (left) rapidity in p-Pb collisions. The $\langle N_{coll} \rangle$ -normalized yield is independent of event activity and compatible among estimators within uncertainties which is consistent with the results by CMS and ATLAS, indicating binary scaling of hard processes in heavy ion collisions.

4. Conclusions

The $R_{AA/pPb}$ of open heavy flavour decay muons has been measured in Pb-Pb and p-Pb collisions, respectively, and the results show that the effects seen in Pb-Pb are due to final state effects. The azimuthal anisotropy of open heavy flavour decay muons shows that these

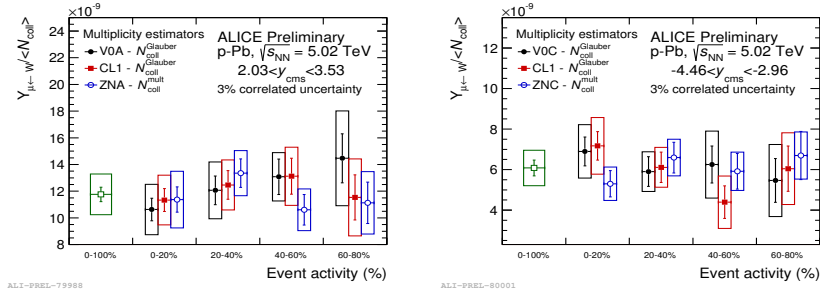


Figure 4. Yield of muons from W-boson decays at forward (left) and backward (right) rapidity as a function of event activity in p-Pb collisions. The green points represent event activity integrated points while black, red and blue represent cases where event activity is estimated with information from V0A, SPD and ZDC, respectively [26].

heavy particles participate in collective expansion of the medium. Theoretical calculations describe the measurements within uncertainties. The production cross sections of W and Z bosons in p-Pb collisions have been measured in two rapidity intervals and compared with theoretical calculations with and without nuclear PDFs parametrized by EPS09. These theoretical calculations agree with the measurements within uncertainties. The measured yield of muons from W-boson decays normalized to $\langle N_{\text{coll}} \rangle$ as function of event-activity shows that the W-boson production scales with $\langle N_{\text{coll}} \rangle$.

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