Proceedings

Multiplicity dependence of heavy-flavour hadron decay electron production in p–Pb collisions at $\sqrt{s_{\mathrm{NN}}}$ = 8.16 TeV measured with ALICE at the LHC†.

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Abstract: A Large Ion Collider Experiment (ALICE) at the Large Hadron collider (LHC) is a heavy-ion dedicated experiment designed to study nuclear matter at extreme condition of high temperature and high density at which quarks are deconfined and give rise to a new state of matter known as Quark Gluon Plasma (QGP). Heavy flavours (charm and beauty), are produced in the initial stages of hadronic collisions in hard scattering processes and therefore are effective probes to study the QGP. In this contribution, recent measurements of the production of electrons from heavy-flavour hadron decays, their nuclear modification factor and the self-normalised yield measured up to 14 GeV/c in p–Pb collisions at $\sqrt{s_{\mathrm{NN}}}$ = 8.16 TeV collected in LHC Run2 in 2016 are presented.

Keywords: Heavy-ion experiment; Quark gluon plasma; Heavy-flavour; Cold Nuclear Matter

1. Introduction

Heavy quarks (charm and beauty), due to their large masses ($m_q >> \lambda_{QCD}$), are produced in the initial stages of hadronic collisions in hard scattering processes, provide an important testing ground for perturbative QCD calculations and are also effective probes to investigate the properties of the hot and dense QCD matter produced in the heavy-ion collisions. A deeper understanding of heavy-flavour production in Pb–Pb collisions requires the detailed studies of Cold Nuclear Matter (CNM) effects in order to clarify the role of initial- and final-state effects on their production. Furthermore, measurements of heavy-flavour hadron production as a function of the charged-particle multiplicity in pp and p–Pb collisions have recently gained interest for investigating the interplay between hard and soft mechanisms of particle production as well as the connection between open and hidden production of heavy-flavour [1].

The aforementioned effects on heavy-quark production can be studied in p–Pb collisions by measuring electrons from heavy-flavour hadron decays (HFE) where the formation and the kinematic properties of heavy-flavour hadrons can be influenced at all stages by CNM effects and by concurrent Multiple Parton Interactions (MPI).

In this proceedings, we present the new results on the production of electrons from heavy-flavour hadron decays, their nuclear modification factor and the self-normalised yield measured up to 14 GeV/c in p–Pb collisions at $\sqrt{s_{\mathrm{NN}}}$ = 8.16 TeV collected in LHC Run2 in 2016. The high-p_{T} measurements are particularly interesting because the contribution of electrons from beauty-hadron decays is expected to dominate.

2. Experimental setup and data samples

The detailed description of the ALICE detector can be found in [2]. With the excellent particle identification capabilities of the ALICE apparatus, the heavy-flavour hadrons are either detected directly via the reconstruction of hadronic decays of D mesons (D^0, D^+, D^{*+} and D_s^+) and λ_c^+ baryon at mid-rapidity, or indirectly by finding a single electron at mid-rapidity or muon produced at forward rapidity via a semi-leptonic decay channel. In addition, λ_c and Ξ_c are also reconstructed via semi-leptonic decays at mid-rapidity. For this analysis, electrons at mid rapidity $|\eta| < 1$ are identified using the ITS (Inner Tracking System) [3], TPC (Time Projection Chamber) [4] and EMCal (Electromagnetic Calorimeter) [5]. The charged particle tracks are reconstructed in the central barrel using the ITS, followed by TPC in radial direction and then matched to the EMCal clusters.

The analyses presented in these proceedings have been performed on 2016 p–Pb collisions at $\sqrt{s_{NN}}$ = 8.16 TeV collected with ALICE detector at the LHC. The EMCal triggered data are used to select events with high p_T particles based on the energy deposited in the EMCal. For efficiency correction, a Monte Carlo simulation is used which is generated using the HIJING [6] event generator and transported using GEANT3.

3. Analysis Details

The measurement of HFE is performed using the combination of signal from TPC and EMCal shown in figure 1. The particle identification in TPC is done using the information of specific ionisation energy loss dE/dx and by E/p ratio ($E/p \sim 1$ for electrons) in EMCal shown in figure 2, where E is the energy deposited in the calorimeter and p is the track momentum measured by the TPC. The charged-particle multiplicities at mid-rapidity is estimated using the information of SPD tracklet which is reconstructed by connecting the hits in both Silicon Pixel Detector (SPD) layers pointing to the vertex.

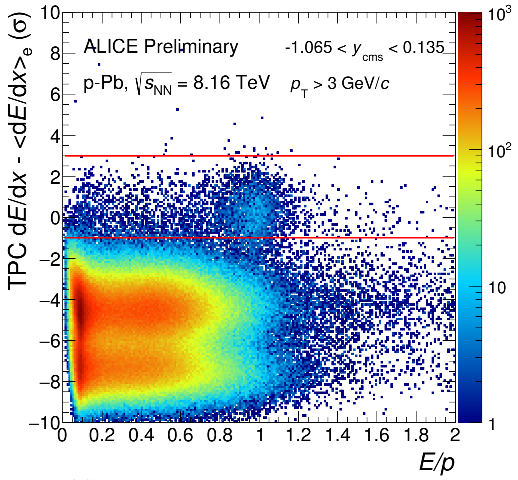

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Figure 1. TPC n_σ as a function of E/p in minimum-bias events.

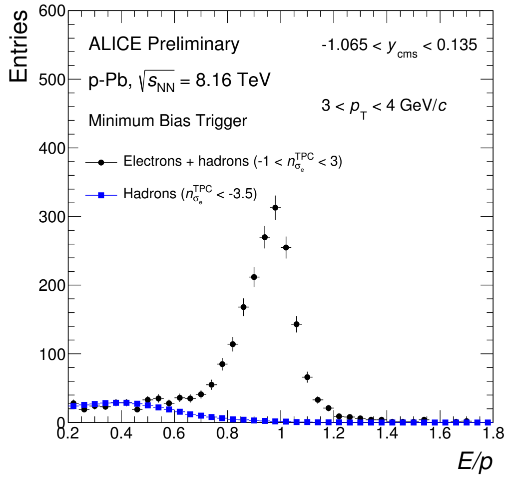

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Figure 2. E/p distribution in $3 < p_T < 4$ GeV/c in minimum-bias events.

Apart from electrons from heavy-flavour hadron decays, there are electrons from the dalitz decay of light neutral mesons or decay photons and from W-boson decay which have a significant contribution to inclusive electrons yield. The most dominant background is photonic conversion which is reconstructed by combining an electron with other electron candidates and selecting pairs with a small invariant mass with a method known as the invariant mass technique. The contribution to the background of electrons from W-boson decay is estimated using POWHEG [7] event generator. Then the heavy-flavour decay electrons yield is obtained by subtracting statistically the background from the inclusive electron yield.

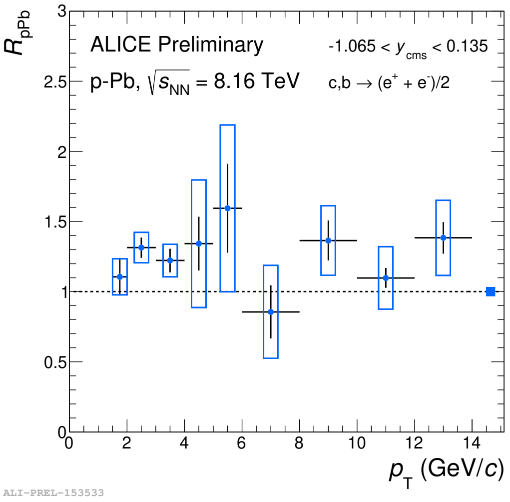

Figure 3. The nuclear modification factors of electrons from heavy-flavour hadron decays in p–Pb collisions at $\sqrt{s_{\mathrm{NN}}}$ = 8.16 TeV.

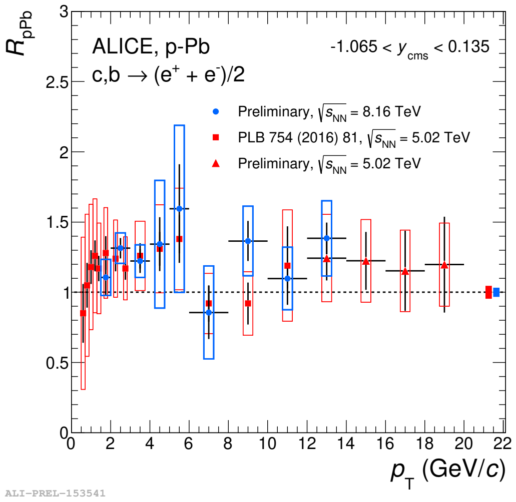

Figure 4. The nuclear modification factors of electrons from heavy-flavour hadron decays in p–Pb collisions at $\sqrt{s_{\mathrm{NN}}}$ = 8.16 TeV and $\sqrt{s_{\mathrm{NN}}}$ = 5.02 TeV.

4. Results

In this section, the measurement of heavy-flavour decay electrons nuclear modification factor R_{pPb} and their relative yield as a function of relative charged-particle multiplicity in p–Pb collisions at $\sqrt{s_{\mathrm{NN}}}$ = 8.16 TeV is shown.

4.1. Nuclear Modification Factor R_{pPb}

The nuclear modification factor R_{pPb} is measured up to 14 GeV/c in minimum-bias and EMCal triggered data using the equation [1] .

$$R_{\mathrm{pPb}} = \frac{1}{< T_{\mathrm{pPb}} >} \frac{dN_{\mathrm{pPb}}/dp_{\mathrm{T}}}{d\sigma_{\mathrm{pp}}/dp_{\mathrm{T}}} \tag{1}$$

where dN_{pPb}/dp_{T} is the particle invariant yield in p–Pb collisions, $< T_{\mathrm{pPb}} >$ is the nuclear overlap function and d$\sigma_{\mathrm{pp}}/dp_{\mathrm{T}}$ represents the invariant cross section in pp collisions. Figure 3 shows the nuclear modification factor R_{pPb} of electrons from heavy-flavour hadron decay in p–Pb collisions at $\sqrt{s_{\mathrm{NN}}}$ = 8.16 TeV. The measurement is compatible with unity in all the p_{T} intervals within uncertainty. In figure 4 the nuclear modification factors of HFE measured in p–Pb collisions at $\sqrt{s_{\mathrm{NN}}}$ = 8.16 TeV compared with the the nuclear modification factors of HFE measured in p–Pb $\sqrt{s_{\mathrm{NN}}}$ = 5.02 TeV [8] is shown.

4.2. Multiplicity dependence in heavy-flavour production: self-normalised yield

The relative yield of HFE as a function of relative charged-particle multiplicity is measured in 3 p_{T} intervals using minimum bias (3-6 GeV/c) and EMCal trigger data (6-9 GeV/c, 9-14 GeV/c). The relative yield of HFE for a given multiplicity class is obtained using the following equation 2.

$$HFE^{\mathrm{i}}_{\mathrm{norm}} = \frac{< HFE >^{\mathrm{i}}}{< HFE >^{0}}, \quad HFE = \frac{d^2N_{\mathrm{HFE}}}{N_{\mathrm{events}} * 2\pi p_{\mathrm{T}} \varepsilon^{\mathrm{total}}_{\mathrm{reco}} \Delta p_{\mathrm{T}} \Delta\eta} \tag{2}$$

where, "i" denotes the multiplicity class and the index "0" represents the integrated multiplicity. N is the number of events, $\Delta\eta$ is the rapidity range and $\varepsilon^{\mathrm{total}}_{\mathrm{reco}}$ is the total reconstruction efficiency of HFE obtained using the Monte Carlo simulations. Figure 5 shows the relative yield of HFE as a function of

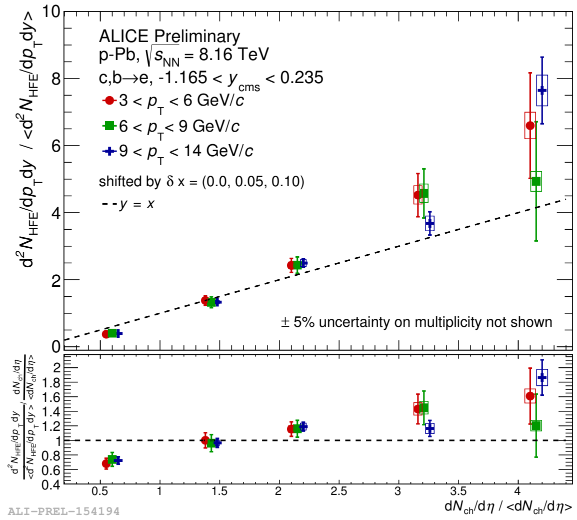

Figure 5. Relative yield of HFE as a function of relative charged-particle multiplicity in different p_T intervals measured in p–Pb collisions at $\sqrt{s_{NN}}$ = 8.16 TeV.

relative-charged particle multiplicity in p–Pb collisions at $\sqrt{s_{NN}}$ = 8.16 TeV. The measurement shows stronger than linear dependence of relative yield of HFE on the relative charged-particle multiplicity.

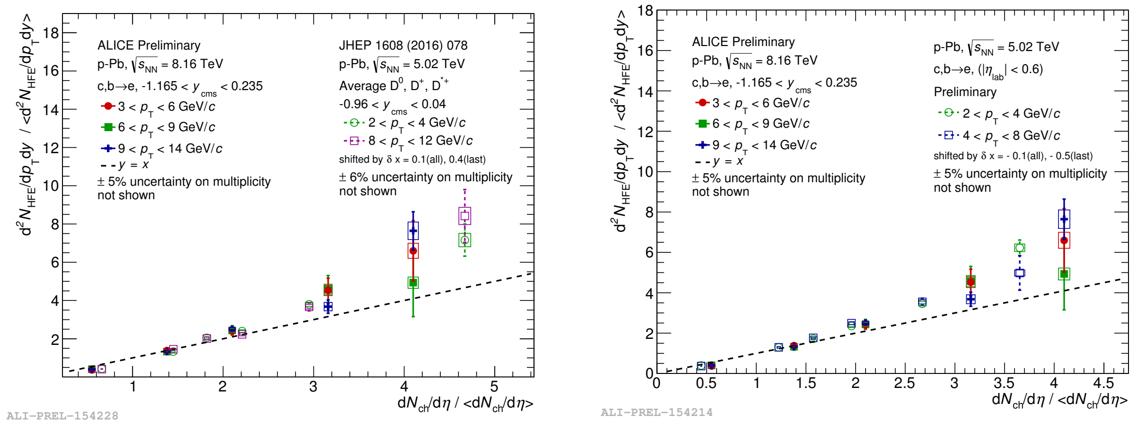

Figure 6. Relative yield of HFE as a function of the relative charged-particle multiplicity in p–Pb collisions at $\sqrt{s_{NN}}$ = 8.16 TeV compared with the average yield of D mesons in p–Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV (on the left) and with the relative yield of HFE in p–Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV (on the right).

The left panel in figure 6 shows the average relative yield of D-meson measured in p–Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV [9] compared with the relative yield of HFE in p–Pb collisions at $\sqrt{s_{NN}}$ = 8.16 TeV and the right panel in figure 6 shows a comparison of relative yield of HFE measured in p–Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV and 8.16 TeV.

5. Conclusions

In p–Pb collisions, the heavy-flavour yields are expected to be modified by the presence of CNM effects and by concurrent Multiple Parton Interactions (MPI). The CNM effects can be quantified by the nuclear modification factor R_{pPb}. Figure 3 shows the measurement of nuclear modification factor in p–Pb collisions at $\sqrt{s_{NN}}$ = 8.16 TeV which is consistent with unity within uncertainty over the whole

p_T range and also with the measurement at $\sqrt{s_{NN}}$ = 5.02 TeV shown in figure 4 which implies there is no energy dependence and the suppression observed in heavy-ion collisions yield is, from a large extent, coming from the final-state effects.
Measurement of heavy-flavour yield as a function of multiplicity can provide further insight into the MPI. Figure 5 shows the relative yield of heavy-flavour decay electron as a function of relative charged particle multiplicity. The measurement shows stronger than linear enhancement of relative yield as a function of relative charged-particle multiplicity. The factors that can contribute to this trend are contribution from Multiple Parton Interactions (MPI) and further influenced by multiple binary nucleon–nucleon interactions, and the initial conditions of the collision modified by CNM effects. In addition, no p_T dependence is observed which gives a hint that the production mechanisms of charm and beauty as a function of the multiplicity are similar as there is a significant contribution from electrons from beauty-hadron decays for $p_T > 4$ GeV/c, while at lower p_T the charm component dominates.

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