

Measurement of electrons from charm and beauty-hadron decays in p-Pb collisions at $\sqrt{s_{\text{NN}}} = 5.02$ TeV with ALICE at the LHC

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Abstract. The p_T -differential production cross section of electrons from heavy-flavour hadron decays in the rapidity range $-1.06 < y_{\text{cms}} < 0.14$ in p-Pb collisions at $\sqrt{s_{\text{NN}}} = 5.02$ TeV has been measured with ALICE. The cross section of electrons from beauty-hadron decays, isolated based on their larger average displacement from the interaction vertex, is presented as well as the nuclear modification factor R_{pPb} of heavy-flavour and beauty-hadron decay electrons. Theoretical predictions including the effects due to the nuclear modification of the parton distribution functions are discussed with the results.

1. Introduction

The characterization of the Quark-Gluon Plasma (QGP), the deconfined state of strongly-interacting matter produced in high-energy heavy-ion collisions, is one of the main purposes of ALICE at the LHC. The medium can be probed by charm and beauty quarks since they are produced in initial hard partonic interactions and experience its complete evolution. The transverse momentum (p_T) distribution of heavy-flavour hadrons and of their decay leptons is an observable sensitive to the energy loss of heavy quarks in the hot and dense medium [1]. Furthermore, a quark-mass dependence of the in-medium energy loss is predicted by theory [2]. By separating leptons from charm-hadron and beauty-hadron decays it is possible to study their in-medium modification and to compare to theoretical predictions.

A significant suppression of electrons from heavy-flavour hadron decays has been observed in heavy-ion collisions at $\sqrt{s_{\text{NN}}} = 2.76$ TeV with ALICE [3]. In addition to the QGP, the presence of cold nuclear matter in the initial state may affect the production of heavy-flavour hadrons through e.g. shadowing/saturation effects and could contribute to the suppression observed in Pb-Pb collisions. This can be investigated by studying the nuclear modification factor R_{pPb} measured in p-Pb collisions, where an extended hot medium is not expected to form:

$$R_{\text{pPb}} = \frac{1}{\langle T_{\text{pPb}} \rangle} \frac{dN_{\text{pPb}}/dp_T}{d\sigma_{\text{pp}}/dp_T}$$

where dN_{pPb}/dp_T is the invariant yield in p-Pb collisions, $d\sigma_{\text{pp}}/dp_T$ is the reference cross section measured from pp collisions and $\langle T_{\text{pPb}} \rangle$ is the nuclear overlap function [4]. Using the tracking



and electron identification capabilities of ALICE, it is possible to measure electrons from heavy-flavour hadron decays over a wide momentum range. By taking advantage of the resolution of the silicon vertex detectors, electrons from charm and beauty-hadron decays can be discriminated based on their displacement from the interaction vertex.

2. Analysis

In 2013 ALICE recorded p-Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV. In this analysis about 10^8 events corresponding to an integrated luminosity $L_{int} = (48.6 \pm 1.6) \mu b^{-1}$ were selected using a minimum bias (MB) trigger condition and requiring an event vertex within ± 10 cm from the detector center. The MB trigger for the p-Pb data taking was set to require at least one hit in both of the forward scintillator arrays V0A and V0C [5]. The central barrel of ALICE in the rapidity range $-0.6 < y_{lab} < 0.6$ was used to measure electrons coming from charm and beauty-hadron decays.

For tracking and particle identification (PID) the Time Projection Chamber (TPC) was used. Exploiting the particle specific energy loss dE/dx in the TPC, electron identification is possible over a large momentum range. The dE/dx is similar for electrons and hadrons at specific momenta, thus other detectors are also required. At low momentum ($p_T < 2.5$ GeV/c) electrons are required to be within 3σ of the electron hypothesis in the Time Of Flight detector (TOF). At high momentum ($p_T > 6$ GeV/c) the energy deposit E in the electromagnetic calorimeter (EMCal) relative to the momentum p is required to be $0.8 < E/p < 1.2$. The remaining hadron contamination is estimated and subtracted by fitting the TPC dE/dx distributions to a superposition of the expected shapes for the various hadrons and then subtracting them.

Two methods are used to distinguish electrons from heavy-flavour hadron decays and electrons from other sources.

The first method is a cocktail-based approach where the different contributions of electrons from background sources are added up and then subtracted from the electron raw yield. The main ingredient is a pion spectrum measured with ALICE, which is used to calculate a spectrum of electrons from pion decays. Contributions from other light mesons are added by applying m_T scaling. Electrons from photon conversions are simulated knowing the precise material budget of the beam pipe and the detectors. Other contributions such as weak kaon decays and di-electron charmonium decays are taken into account as well using simulations and measured spectra. A detailed description of the method can be found in published results for pp collisions at $\sqrt{s} = 7$ TeV measured with ALICE [6].

The second method is based on the measurement of the dominant background contribution from photon conversions and Dalitz decays. The contribution of this kind of background electrons, denoted 'photonic' electrons, can be quantified by reconstructing electron-positron pairs with low invariant mass. Each electron (or positron) forming with an opposite-charge partner an e^+e^- pair with an invariant mass smaller than the pion mass is tagged as background. The uncorrelated contribution to this background estimation is removed by subtracting the same-charge combinations passing the same invariant mass cut. The resulting yield of photonic electrons is corrected for the tagging efficiency for finding the partner. This "tagging" efficiency is calculated with Monte Carlo simulations by measuring the fraction of pairs which pass all selection cuts. Because the light meson kinematics in the MC generator are not necessarily the same as in nature, the meson p_T distributions were re-weighted with the pion spectrum measured with ALICE and m_T scaled spectra for the other meson species. The remaining background electron contributions (weak kaon decays and quarkonium di-electron decays) are estimated in the same way as described in the cocktail-based approach above.

To separate the contribution of electrons from beauty-hadron decays one takes advantage of the relatively large mean proper decay length of beauty hadrons ($c\tau \cong 500 \mu m$). Since these decays involve a neutrino, the decay vertex of the beauty hadron can not be determined. Instead

electron candidates with a p_T dependent minimum impact parameter (IP) to the primary vertex were selected, to enhance the signal of electrons from beauty-hadron decays. This IP cut also suppressed the electron background from conversions and Dalitz decays, since the origin of these contributions is the primary vertex. The remaining background is calculated as a cocktail consisting of electrons from conversions, light meson decays and charm hadron decays. In the cocktail simulation, the measured pion spectrum is used for the non-charm background, the measured D-meson p_T -differential cross-sections [7] are used for the charm background and the impact parameter selection is applied. A detailed description of the method can be found in published results for pp collisions at $\sqrt{s} = 7$ TeV measured with ALICE [8].

3. Results

After subtracting the electrons from background sources the spectra are corrected for the detector geometrical acceptance and efficiency to obtain a cross section. Figure 1 shows the p_T -differential cross section of electrons from heavy-flavour hadron decays (black squared markers) and the cross section of electrons from beauty-hadron decays (red circled markers). For $p_T \sim 6$ GeV/ c electrons from beauty hadron decays become the dominant contribution to the inclusive spectrum of heavy-flavour electrons. One of the main contributions to the systematic uncertainty is in the determination of the electron background due to the uncertainties of the measured light meson and charm meson spectra. To calculate the nuclear modification factor R_{pPb} a reference spectrum in pp is needed. For this analysis reference spectra for heavy-flavour decay electrons (Fig. 2) and beauty decay electrons measured at $\sqrt{s} = 7$ TeV [6, 8] are extrapolated to $\sqrt{s_{NN}} = 5.02$ TeV based on the \sqrt{s} dependence from Fixed Order Next-to-Leading Log (FONLL) pQCD calculations [9].

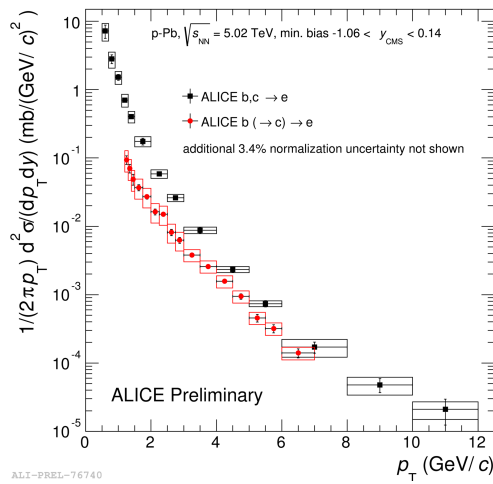


Figure 1. p_T differential cross section of electrons from heavy-flavour hadron decays (black squares) and from beauty-hadron decays only (red circles).

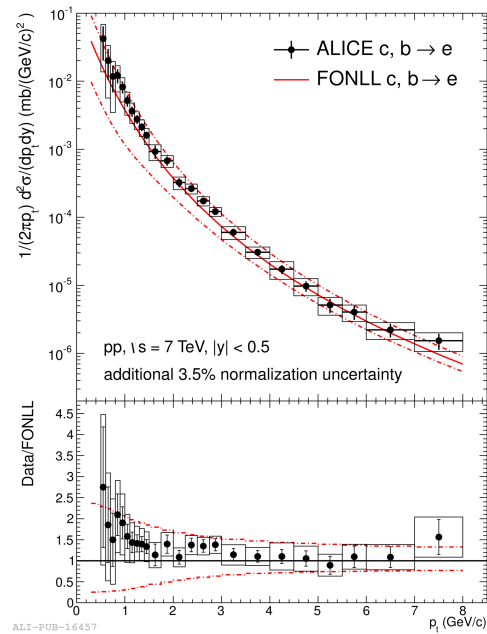


Figure 2. pp reference at $\sqrt{s} = 7$ TeV used for extrapolation to $\sqrt{s} = 5.02$ TeV and compared to FONLL calculations.

For $p_T > 8$ GeV/ c an extrapolation with FONLL calculations fitted to the spectrum was used because of the lack of a measured reference at these momenta. In Fig. 3 the measured R_{pPb} is shown as a function of p_T . It is found to be compatible with unity. Also shown in Fig. 3

is a prediction for R_{pPb} calculated using FONLL p_T -differential cross sections of heavy-flavour decay electrons and shadowing effects based on the EPS09 parametrization [10]. Uncertainties on the FONLL predictions as well as on the shadowing effects are propagated. Within the large uncertainties the measured R_{pPb} is in agreement with the shadowing calculations. The results are also compatible with measurements by the PHENIX collaboration in d-Au collisions at $\sqrt{s_{NN}} = 0.2$ TeV [11].

In Fig. 4, the nuclear modification factor of electrons from beauty-hadron decays measured from p-Pb collisions is shown to be in agreement with the inclusive (charm+beauty) R_{pPb} within the uncertainties.

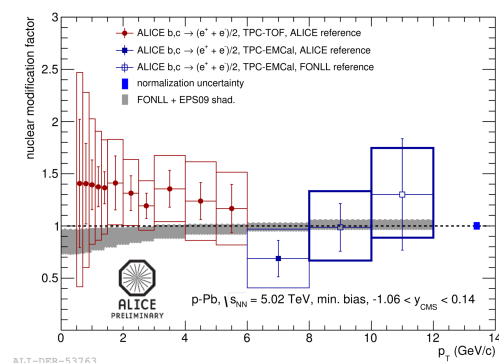


Figure 3. R_{pPb} of heavy-flavour hadron decay electrons together with EPS09 nuclear shadowing predictions [10].

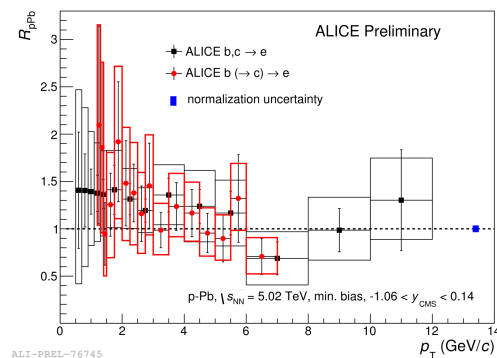


Figure 4. Inclusive (charm+beauty) R_{pPb} (black squares) together with R_{pPb} for electrons from beauty-hadron decays (red circles).

4. Summary

ALICE has measured the p_T differential cross section for electrons from heavy-flavour hadron decays as well as the cross section for electrons from beauty-hadron decays in p-Pb collisions. The nuclear modification factor R_{pPb} was measured for both cases.

As shown in Figures 3 and 4 the results are compatible with the absence of nuclear effects in the measured p_T ranges, although the experimental uncertainties are substantial. In contrast to the nuclear modification factor measured in central Pb-Pb collisions no hint for a suppression of the electron yields from heavy-flavour decays is observed at high p_T in p-Pb collisions, suggesting that in-medium energy loss of partons is responsible for the suppression in Pb-Pb collisions. A quantification of cold nuclear matter effects requires more precise data from p-Pb collisions, though.

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