ELECTRONS FROM HEAVY-FLAVOUR DECAYS AT MID-RAPIDITY MEASURED IN *pp* COLLISIONS AT $\sqrt{s} = 7$ TeV AND IN Pb–Pb COLLISIONS AT $\sqrt{s_{NN}} = 2.76$ TeV WITH ALICE AT THE LHC*

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(Received January 2, 2012)

We present the production cross section of electrons from heavy-flavour hadron decays measured at mid-rapidity ($|\eta| < 0.8$) with ALICE in proton–proton collisions at $\sqrt{s} = 7$ TeV. The contribution from pure beauty decays is identified using the electron displacement from the interaction vertex. The results are compared to FONLL calculations and used as *pp* reference for Pb–Pb collisions after scaling to the same centre-of-mass energy. In Pb–Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV, the inclusive electron spectrum is measured at mid-rapidity for different centrality classes and compared to a cocktail of background electrons. The corresponding nuclear modification factor of cocktail-subtracted electrons indicates heavy-flavour suppression by a factor 1.5–5 at high p_{T} in most central Pb–Pb collisions.

DOI:10.5506/APhysPolBSupp.5.291
PACS numbers: 12.38.–t, 25.75.Cj, 14.65.Fy, 14.65.Dw

1. Introduction

In high-energy nucleus–nucleus collisions, a deconfined state of quarks and gluons, the quark-gluon plasma (QGP) is expected to be formed. Observations of how particles propagation is affected by the plasma allow to study its properties. The formation time of heavy quarks, *i.e.* charm and beauty, is much smaller than the expected lifetime of the QGP. Therefore, heavy quarks are uniquely suited to probe the QGP. In particular, they enable us to study the colour charge and quark mass dependences of parton energy loss [1]. In *pp* collisions the charm and beauty production serves as an important baseline for the nucleus–nucleus studies and allows to test

* Presented at the Conference "Strangeness in Quark Matter 2011", Kraków, Poland, September 18–24, 2011.

perturbative Quantum Chromo-Dynamics (pQCD) calculations. Both collision systems are studied with A Large Ion Collider Experiment (ALICE) [2] at the LHC. We present results of indirect measurements of charm and beauty production in pp collisions at $\sqrt{s} = 7$ TeV and Pb–Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV via the identification of single electrons at mid-rapidity ($|\eta| < 0.8$). The semi-electronic decays of hadrons carrying a charm or beauty quark have a relatively large branching ratio of the order of 10% and allow a complementary measurement to the direct reconstruction of D mesons via their hadronic decay channels.

The results are obtained from data collected during the summer 2010 with pp collisions (125 million minimum-bias events) and November 2010 with Pb–Pb collisions (17 million minimum-bias events). The data read-out was triggered by the LHC bunch-crossing signal and a minimum-bias interaction trigger based on signals from two forward scintillator hodoscopes (VZERO-A and VZERO-C) and two layers of Silicon Pixel Detectors (SPD). The summed amplitudes in the VZERO scintillator tiles are used to determine the centrality of the Pb–Pb collisions in this analysis [3].

2. Electron identification

Electrons are identified at mid-rapidity using the information provided by the Time Projection Chamber (TPC), the Transition Radiation Detector (TRD), and the Time-of-Flight (TOF) detector. The tracks are reconstructed in the TPC and ITS, and then prolonged outward to the TRD and TOF. The measured Time of Flight had to be consistent with the electron hypothesis within 3σ to suppress kaons up to $p = 1.5$ GeV/c and protons up to $p = 3$ GeV/c. Furthermore, at intermediate momenta, electrons can be separated from pions using the TRD. A cut on the likelihood value to be an electron is applied such that the TRD electron efficiency is fixed at 80%. Finally, the specific energy deposit dE/dx in the TPC is expressed as deviation from the Bethe–Bloch electron curve. Only electron candidates from the top-half of the distribution are selected. The remaining hadron contamination is determined via fits of the TPC dE/dx in momentum slices and subtracted from the electron spectra. In pp collisions, electrons are measured from $p_{\mathrm{T}} = 0.5$ GeV/c to 10 GeV/c. The hadron contamination amounts to less than 5%. In Pb–Pb collisions, electrons are measured from 1.5 GeV/c to 6 GeV/c. The TRD is not yet included in the analysis, therefore the hadron contamination is larger and reaches about 10% at 6 GeV/c.

3. Inclusive electron spectra

The inclusive electron yield as function of p_{T} is corrected for acceptance, tracking and particle identification efficiency, derived from Monte

Carlo (MC) simulations, as well as for the imperfect momentum resolution. The inclusive electron spectrum contains contributions from electrons from heavy-flavour hadron decays, Dalitz decays of light mesons (mainly π^0), photon conversions in the material and dielectron decays of vector mesons. To reduce the contribution from photon conversions in material, the tracks used in the analysis are required to have a hit in the innermost pixel layer, positioned 3.9 cm away from the beam line. Photon conversion and π^0 Dalitz decays represent the largest background contributions. At high $p_{\rm T}$, the contribution from heavy-flavour hadron decays becomes dominant. The background sources are subtracted with a cocktail method. A MC event generator is used to calculate a cocktail of background electrons based on the yield and momentum distributions of meson spectra measured with ALICE [4].

4. Results from proton–proton collisions at $\sqrt{s} = 7$ TeV

The $p_{\rm T}$-differential cross section of electrons from heavy flavour hadron decays is shown in Fig. 1 (left). The systematic error is about 20% on the measured inclusive electron spectrum, dominated by the electron identification uncertainty, and 10% on the electron cocktail, given by the π^0 measurement. From the D meson spectra measured in ALICE [6], the charm contribution is deduced after applying PYTHIA decay kinematics [5]. Both cross sections are compared to a prediction at Fixed-Order plus Next-to-Leading Logarithms (FONLL) [7], which is found to reproduce the data within uncertainties.

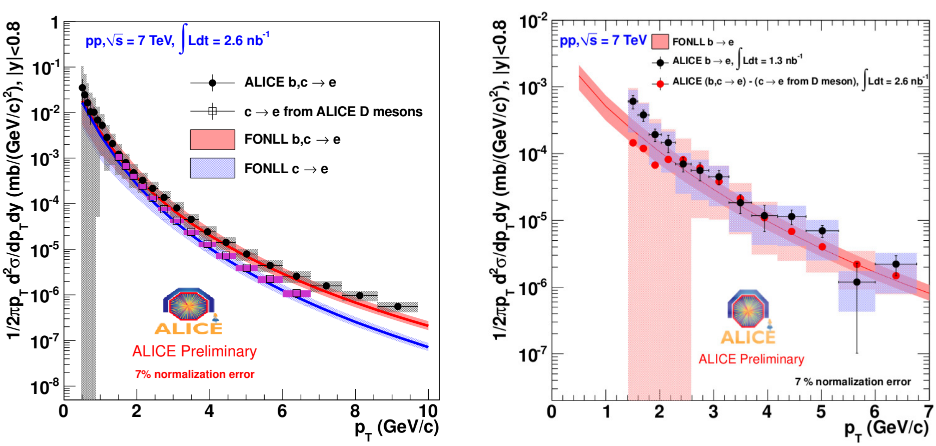

Fig. 1. Production cross section of electrons from the decay of hadrons, which carry a charm or beauty quark (on the left), or a beauty quark (on the right). The measurements are compared to FONLL predictions (see the text).

The Inner Tracking System (ITS) provides a high resolution on the distance of closest approach of the tracks to the primary vertex (PV), better than 75 μm for $p_{\rm T} > 1$ GeV/c. This allows to select electrons from beauty hadron decays, which do not point to the PV due to the large lifetime of the B mesons, by requiring a minimum displacement from the interaction vertex. The impact parameter distribution of inclusive electrons is well described in the simulations. The remaining contribution from charm decays is estimated from the D meson cross section at mid-rapidity [6], and subtracted. In the right-hand side of Fig. 1, the spectrum of electrons from beauty decays is shown. As cross-check, the results from the heavy-flavour decay electron cross section is shown after subtraction of the charm contribution. The two spectra agree within uncertainties. The impact parameter analysis allows to reduce considerably the systematic uncertainties. FONLL predictions [7] are in good agreement with the data within uncertainties.

5. Results from Pb–Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV

Fig. 2 (left) shows the inclusive electron $p_{\rm T}$ spectra measured in 6 centrality bins from 1.5 GeV/c to 6 GeV/c. The systematic uncertainty is about 35% and comes mainly from the particle identification. Work is ongoing to extend the $p_{\rm T}$ range towards lower $p_{\rm T}$ using a Bayesian approach and towards higher $p_{\rm T}$ including the TRD and the Electromagnetic Calorimeter (EMCAL) in the analysis. For each centrality bin, a cocktail of background electrons is computed based on the measured ALICE $\pi^{\pm}$ spectra. The systematic uncertainty on the electron cocktail is about 25% and can be decreased in the future with an improved pion input and direct measurements

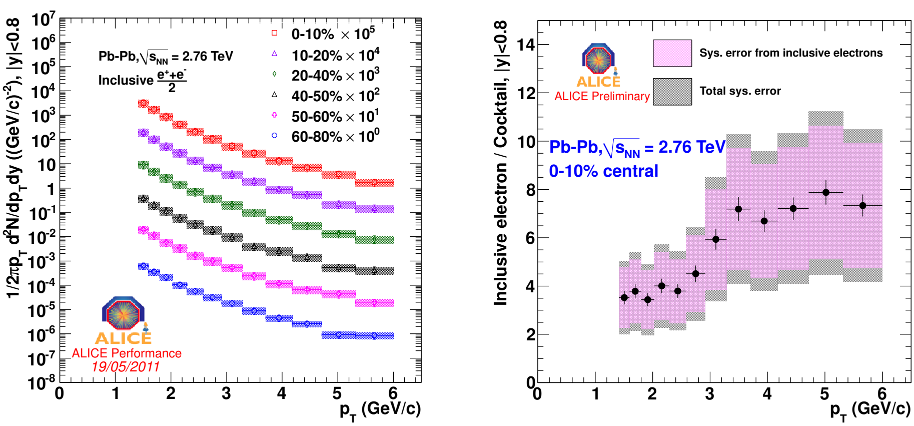

Fig. 2. Left: Inclusive corrected electron $p_{\rm T}$ spectra in Pb–Pb collisions at 2.76 TeV for different centrality bins. Right: Ratio of inclusive electron spectrum to cocktail of background electron sources for the centrality bin 0–10%.

of other background sources. Fig. 2 (right) shows the ratio of the inclusive electron spectrum to the cocktail of background electrons for the centrality 0–10%. As expected, the signal-to-background ratio increases with p_{T} due to the increasing contribution of electrons from charm and beauty decays. Above 3.5 GeV/c, the yield beyond the cocktail is attributed to electrons from heavy-flavour hadron decays. At small transverse momentum, a hint for an electron excess, increasing with the centrality of the collisions, is observed. For peripheral events, the ratio is indeed compatible with the corresponding result in *pp* collisions at 7 TeV, whereas in central events it is higher. This could point to an additional electron source at low p_{T}, *e.g.* thermal radiation, already measured at RHIC [8].

The nuclear modification factor R_{AA} is shown in Fig. 3 (left) for central and peripheral Pb–Pb collisions. R_{AA} is defined as $R_{AA} = \frac{1}{\langle T_{AA}\rangle} \frac{dN_{AA}/dp_{\mathrm{T}}}{d\sigma_{pp}/dp_{\mathrm{T}}}$, where $\langle T_{AA}\rangle$ is the average nuclear overlap function for a given centrality bin, and dN_{AA}/dp_{T} and $d\sigma_{pp}/dp_{\mathrm{T}}$ describe the electron yield in Pb–Pb and *pp* collisions, respectively. The *pp* reference spectrum is obtained by scaling the measured spectrum of electrons from heavy-flavour decays in *pp* at 7 TeV to 2.76 TeV based on FONLL calculations [9]. In the future, the ongoing analysis of the *pp* collisions at 2.76 TeV, taken in 2011, should provide a direct measurement and allow to reduce the systematic uncertainty. In peripheral Pb–Pb collisions, R_{AA} is compatible with one, whereas a suppression by a factor 1.2–5 is observed for the most central collisions in the p_{T} region 3.5–6 GeV/c, where charm and beauty decays dominate. The suppression above 4.5 GeV/c is found to increase with centrality, as shown in Fig. 3 (right). This indicates strong coupling of heavy quarks to the medium created in central heavy-ion collisions.

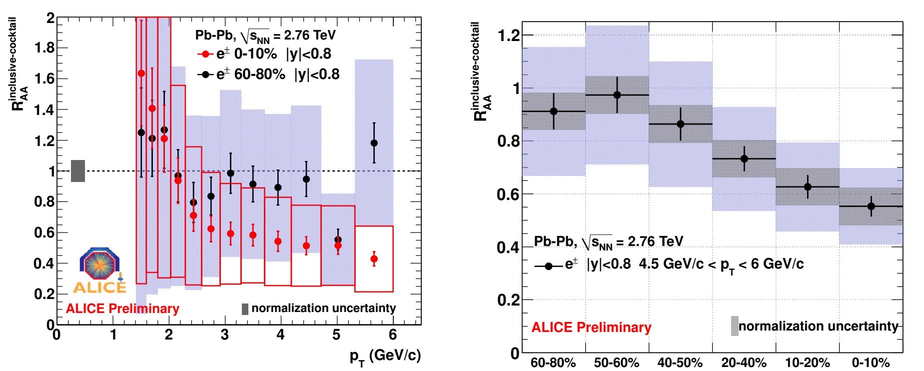

Fig. 3. Left: Comparison of the R_{AA} of background subtracted electrons for central and peripheral Pb–Pb collisions. Right: Nuclear modification factor of background subtracted electrons with $4.5 < p_{\mathrm{T}} < 6$ GeV/c as a function of the centrality of the Pb–Pb collisions.

From the D mesons measurement with ALICE in Pb–Pb collisions [10], the nuclear modification factor of electrons from charm decays can be estimated. The systematic uncertainty is still too large to conclude about the difference between the charm and beauty suppression at mid-rapidity in central Pb–Pb collisions. Nevertheless, in the future the systematic uncertainties can be reduced by extending the $p_{\rm T}$ range of the measurements and including the information of the TRD and EMCAL in the electron analysis. Moreover, electrons from beauty hadron decays will be measured via their displacement from the interaction vertex.

6. Summary

The production cross section of electrons from heavy-flavour hadron decays is measured at mid-rapidity with ALICE in pp collisions at $\sqrt{s} = 7$ TeV. Electrons from beauty hadron decays are measured via their displacement from the interaction vertex. The results are well reproduced by FONLL predictions. In Pb–Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV the inclusive electron spectra are measured and compared to a cocktail of background electrons. A hint for an excess at low $p_{\rm T}$ is observed. After subtraction of the cocktail, the nuclear modification factor of electrons, coming mostly from heavy-flavor decays for $p_{\rm T}$ larger than 3.5 GeV$/c$, is computed for different centrality bins. A suppression is found in central collisions, indicating strong coupling of heavy quarks to the medium.

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