

Charmed meson and baryon measurements in pp and p–Pb collisions with ALICE at the LHC

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Abstract. We present here recent open heavy-flavour results from the ALICE experiment, including measurements of D-meson, Λ_c baryon and Ξ_c^0 baryon production in pp collisions at $\sqrt{s} = 7$ TeV and p–Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV.

1 Introduction

The measurement of charm production in pp collisions is an important test of perturbative QCD, and in p–Pb collisions the study of charm production can help disentangle cold nuclear matter effects from the effects modifying the p_T spectrum of charmed hadrons in Pb–Pb collisions due to the high-temperature and high energy-density medium formed. The relative abundance of baryons and mesons can shed light on the process of fragmentation - a non-perturbative process - and deviations from measurements made at e^+e^- colliders may hint at specific processes occurring in the higher partonic density environment of pp and p–Pb collisions. In addition, these measurements also provide a reference for future measurements in nucleus-nucleus collisions, where the baryon-to-meson ratio is expected to be sensitive to modified hadronisation mechanisms such as coalescence [1]. Preliminary results from STAR [2] hint at an enhanced Λ_c^+/D^0 ratio in Au–Au collisions.

2 Heavy-flavour reconstruction at ALICE

Heavy-flavour decays are reconstructed at ALICE in the central barrel, which consists of the Inner Tracking System (ITS), the Time Projection Chamber (TPC) and the Time-of-Flight detector (TOF), covering the entire azimuthal range and designed to track and identify charged particles over a wide momentum range. Charmed hadrons are reconstructed at mid-rapidity ($|y| < 0.8$) via their hadronic decays including $D^0 \rightarrow K^-\pi^+$, $D^+ \rightarrow K^-\pi^+\pi^+$, $D^{*+} \rightarrow D^0\pi^+$, $D_s^+ \rightarrow \phi\pi^+$, $\Lambda_c^+ \rightarrow pK^-\pi^+$ and $\Lambda_c^+ \rightarrow pK_S^0$. Selection is made on the hadron decay topology, the signal is extracted via an invariant mass analysis, and corrections are made for the efficiency, acceptance, and the fraction of non-prompt hadrons in the signal sample. The semileptonic decays of Λ_c^+ and Ξ_c^0 baryons are also reconstructed via the decay channels $\Lambda_c^+ \rightarrow e^+\nu_e\Lambda$ and $(\Xi_b^0 \rightarrow)\Xi_c^0 \rightarrow e^+\nu_e\Xi^-$. Here the analyses are not based on topological selections, and are instead based on subtracting the ‘wrong-sign’ $e^-\Lambda(e^-\Xi^-)$ pair spectra from the ‘right-sign’ $e^+\Lambda(e^+\Xi^-)$ spectra. Additional corrections include correcting for contributions to the wrong-sign spectra from $\Lambda_b(\Xi_b^0)$, and unfolding the $e^-\Lambda(e^-\Xi^-)$ p_T spectra to obtain the $\Lambda_c^+(\Xi_c^0)$ p_T spectrum. A correction for feed-down from $\Xi_c^{+,0}$ is also included for the Λ_c^+ measurement.

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3 Results

The nuclear modification factor (R_{pPb}) of D^0 , D^+ , D^{*+} and D_s^+ mesons was measured in p–Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV [3]. Figure 1 (left) shows the p_T -differential averaged D^0 , D^+ and D^{*+} R_{pPb} in comparison with models that include cold nuclear matter effects and models that assume a Quark-Gluon Plasma is formed and include hydrodynamical effects [3]. The statistical precision of the measurements has been improved by approximately a factor of 2 with respect to the previous measurement [4] due to an increased integrated luminosity. The models describe the data well, although a suppression larger than 15-20% for $p_T > 5$ GeV/c, expected from the POWLANG(HTL) and Duke models, is slightly disfavoured by the data. D-meson production has also been measured as a function of centrality in p–Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV [3]. Figure 1 (right) shows the D^0 Q_{CP} calculated as the ratio of the D^0 -meson nuclear modification factor in central (0-10%) and peripheral (60-100%) centrality intervals. The Q_{CP} tends to increase in the interval $1 < p_T < 4$ GeV/c and reaches about 1.25, and then decreases in the interval $7 < p_T < 24$ GeV/c. The average value of the D^0 Q_{CP} is larger than unity in the interval $3 < p_T < 8$ GeV/c by 1.7 standard deviations of the statistical and systematic uncertainty.

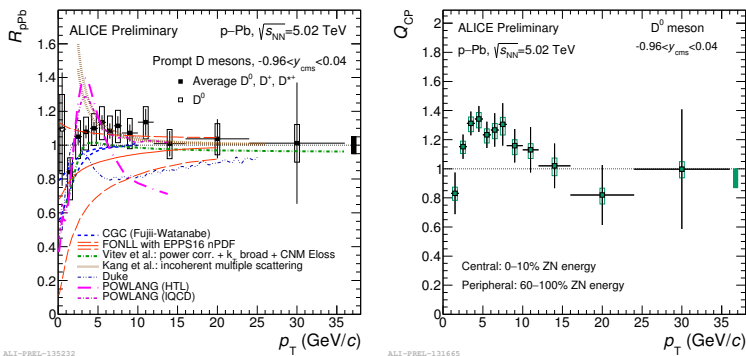


Figure 1. Left: averaged D^0 , D^+ and D^{*+} R_{pPb} in p–Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV compared to model calculations. Right: prompt D^0 Q_{CP} in p–Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV.

The p_T -differential cross section of the Λ_c^+ baryon was measured in pp collisions at $\sqrt{s} = 7$ TeV and in p–Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV, and is reported in figure 2. The cross section is compared to perturbative calculations at NLO using the GM-VFNS [5, 6] scheme in pp collisions, and at NLO with POWHEG [7] matched with PYTHIA 6.4.25 [8] in pp and p–Pb collisions. For the p–Pb POWHEG the EPS09 nuclear PDF was used [9]. GM-VFNS underpredicts the data by a factor of 2.5 on average, and POWHEG underpredicts the data by a factor of 18(4) at low(high) p_T in pp collisions, and by a similar amount in p–Pb collisions. Figure 3 (left) shows the baryon-to-meson ratio Λ_c^+/D^0 measured using the Λ_c^+ cross sections presented in this paper and the D^0 cross sections measured by ALICE [4, 10]. In the same figure theoretical predictions in pp collisions are shown including PYTHIA8 with and without a tune including enhanced colour reconnection [11], DIPSY [12] with rope hadronisation and HERWIG7 [13] with hadronisation via clusters. The Λ_c^+/D^0 ratio in pp collisions is compatible with the same ratio in p–Pb collisions within uncertainties. While all models underpredict the data, PYTHIA8 with enhanced colour reconnection brings the prediction closer to data. Figure 3 (right) shows the nuclear modification factor R_{pPb} for the Λ_c^+ baryon in p–Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV, in comparison to the averaged D-meson (D^0 , D^+ , D^{*+}) R_{pPb} [4], and predictions including POWHEG+PYTHIA with EPS09

nuclear PDF [9] and a prediction for charmed hadrons which assumes a small-size QGP is formed [14]. The R_{pPb} of Λ_c^+ is consistent with unity and with the D-meson R_{pPb} , and does not allow to distinguish between the models presented within the current experimental uncertainties.

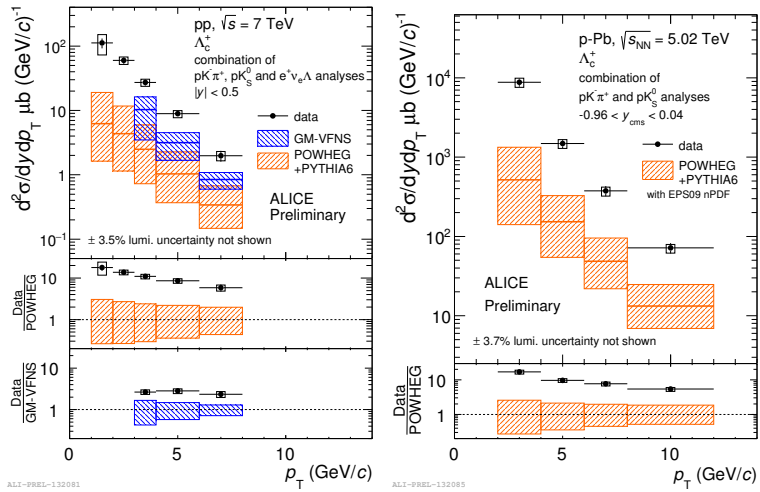


Figure 2. Left: the p_T -differential cross section of prompt Λ_c^+ in pp collisions at $\sqrt{s} = 7$ TeV. Right: the p_T -differential cross section of prompt Λ_c^+ in p-Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV. Both measurements are compared with theoretical predictions.

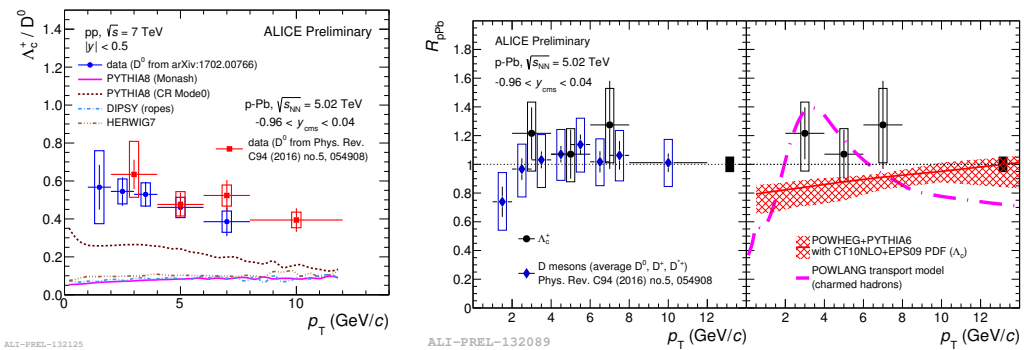


Figure 3. Left: the Λ_c^+ / D^0 ratio in pp collisions at $\sqrt{s} = 7$ TeV, and in p-Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV, compared to model predictions. Right: the nuclear modification factor R_{pPb} of Λ_c^+ compared to the R_{pPb} of D mesons, and compared with model predictions.

Figure 4 shows the p_T -differential cross section times branching ratio of the Ξ_c^0 baryon (including prompt and non-prompt contributions), and the baryon-to-meson ratio $\Xi_c^0 \rightarrow e^+ \nu_e \Xi^- / D^0$ in comparison to predictions from PYTHIA with the aforementioned tunes. The shaded band for the models spans the range of theoretical predictions for the $\Xi_c^0 \rightarrow e^+ \nu_e \Xi^-$ branching ratio [15–17]. As for the Λ_c^+ / D^0 ratio, all predictions significantly underestimate the data.

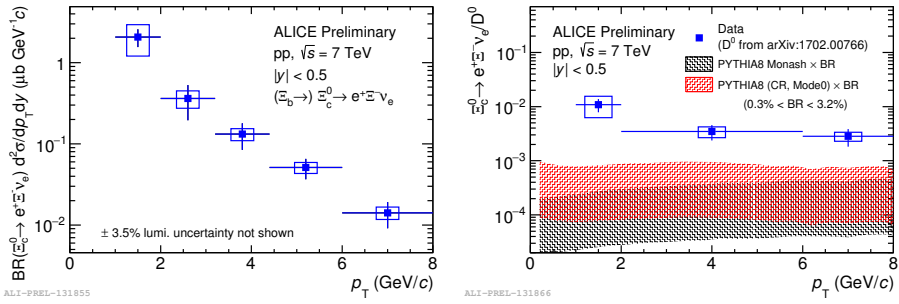


Figure 4. Left: The p_T -differential cross section times branching ratio of the Ξ_c^0 baryon in pp collisions at $\sqrt{s} = 7$ TeV. Right: The $\Xi_c^0 \rightarrow e^+ \nu_e \Xi_c^0 / D^0$ ratio compared to theoretical predictions.

4 Summary

Recent charmed meson and baryon measurements by the ALICE collaboration have been presented. The R_{pPb} of D mesons is found to be consistent with unity. The Q_{CP} of D^0 mesons shows a hint of D^0 enhancement at $3 < p_T < 8$ GeV/c in central p–Pb collisions. The cross section of the Λ_c^+ baryon and the Λ_c^+ / D^0 and $\Xi_c^0 \rightarrow e^+ \nu_e \Xi_c^0 / D^0$ ratios are found to be underpredicted by theoretical calculations. Finally the R_{pPb} of Λ_c^+ baryons is found to be consistent with unity, with the D-meson R_{pPb} and with theoretical predictions within current uncertainties.

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