Available online at www.sciencedirect.com

ScienceDirect

Nuclear Physics A 982 (2019) 667–670

www.elsevier.com/locate/nuclphysa

XXVIIth International Conference on Ultrarelativistic Nucleus-Nucleus Collisions (Quark Matter 2018)

Non-strange and strange D-meson and charm-baryon production in heavy-ion collisions measured with ALICE at the LHC

Xinye Peng, for the ALICE collaboration

Central China Normal University, China,
Università degli Studi di Padova & INFN, Padova, Italy

Abstract

We present recent results on strange and non-strange D-meson production measured with ALICE in Pb–Pb collisions at the LHC. In addition, the measurements of the Λ_c^+-baryon production and of the Λ_c^+/D^0 ratio in pp, p–Pb, and, for the first time ever, Pb–Pb collisions are reported.

Keywords: Quark Gluon Plasma, Relativistic heavy-ion collisions, Open heavy-flavour, Charm-baryon

1. Introduction

Heavy quarks are produced in hard-scattering processes over short time scales compared to the Quark Gluon Plasma (QGP) formation time. They probe the whole system evolution via interact with the medium constituents. The investigation of charm production in Pb-Pb collisions helps understand the colour-charge and quark-mass dependence of in-medium energy loss, the sensitivity of charm quarks to the medium collective motion, whether they reach thermal equilibrium, and charm-hadron production mechanism. For the latter a possible enhancement of D_s/D^0 and Λ_c/D^0 ratios is predicted by models including charm-hadron formation via coalescence [1]. In pp and p–Pb collisions, the aforementioned particle ratios allow investigating further the charm hadronisation mechanism at LHC energies. In p–Pb collisions the study of the Λ_c/D^0 ratio allows investigating whether nuclear matter effects on charm hadronisation could enhance the baryon-to-meson ratio with respect to pp collisions also in small systems, as observed in the light flavour sector.

2. Heavy-flavour reconstruction strategy

The analysis data sample consists of $370 \cdot 10^6$ pp at $\sqrt{s} = 7$ TeV (corresponding to $L_{\rm int} = 6.0$/nb), $600 \cdot 10^6$ p–Pb (corresponding to $L_{\rm int} = 292$/nb) and $100 \cdot 10^6$ Pb–Pb at $\sqrt{s_{\rm NN}} = 5.02$ TeV (corresponding to $L_{\rm int} = 13.4$/nb) minimum-bias collisions, collected by ALICE [2] in 2010, 2016 and 2015, respectively. Charmed

https://doi.org/10.1016/j.nuclphysa.2018.09.017
0375-9474/© 2018 Published by Elsevier B.V.
This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

hadrons are reconstructed at mid-rapidity via the hadronic decay channels $D^0 \to K^-\pi^+$, $D^+ \to K^-\pi^+\pi^+$, $D^{*+} \to D^0\pi^+$, $D_s^+ \to \phi\pi^+$, $\Lambda_c^+ \to pK^-\pi^+$ and $\Lambda_c^+ \to pK_s^0$. To reduce the combinatorial background, selections on the decay topology and particle identification are applied. In the case of Λ_c^+ analysis, a second approach based on multivariate approach (BDTs) to select decay topology is used. The signal is extracted via an invariant-mass analysis. The feed-down from beauty-hadron decays is subtracted according to expectations based on FONLL calculations, and in p-Pb and Pb-Pb collisions, with further assumptions of feed-down nuclear modification factor ($R_{AA}^{\text{feed-down}}/R_{AA}^{\text{prompt}} = 1$ in p–Pb, and ranges from 1 to 2 in Pb–Pb collisions depending on p_T, centrality classes and particle species).

3. Results

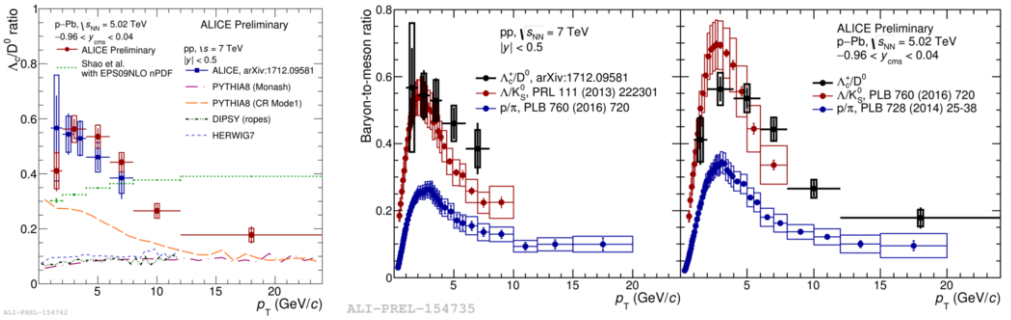

Fig. 1. The Λ_c/D^0 raito in pp collisions at $\sqrt{s}$ = 7 TeV and in p–Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV, compared with model predictions (left) and Λ/K_s^0, p/π ratios in pp (middle) and p–Pb (right) collisions.

In this contribution, new results on the p_T-differential cross section of the Λ_c^+-baryon, measured in p–Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV with the data collected in 2016 are presented. The precision is improved and p_T coverage is extended with respect to the previous measurement [3]. Figure 1 shows the updated baryon-to-meson ratio Λ_c^+/D^0. The ratios obtained in pp and p–Pb collisions are compatible within the larger uncertainties of the pp measurements. On the left panel of Figure 1, the measured Λ_c^+/D^0 ratios are compared with models. The results are higher than the expectation from theoretical models including PYTHIA8 with Monash tune and with a tune with enhanced colour reconnection [4], DIPSY with ropes [5], HERWIG7 with a cluster hadronisation mechanism [6], and a calculation [7] tuned on LHCb pp data [8] at forward rapidity, note that this calculations is higher than data at high p_T. PYTHIA8 with enhanced colour reconnection gets closer to the data, hinting the importance of understanding the role of colour reconnection in charm hadronisation. On the right panel, the baryon-to-meson ratio in the charm sector (Λ_c^+/D^0) is compared with the same ratios in the light flavour sectors [9, 10, 11](Λ/K_s^0 and p/π). A similar trend is observed with decreasing values from $p_T = 4$ GeV/c.

At this conference, ALICE presented the first measurement of the Λ_c^+/D^0 ratio in Pb–Pb collisions. The measurement is performed at $\sqrt{s_{NN}}$ = 5.02 TeV in the centrality class 0-80% for $6 < p_T < 12$ GeV/c. On the left panel of Figure 2, the comparison of the Λ_c^+/D^0 ratios in the three colliding systems is reported. It shows a hint of enhancement in Pb–Pb with respect to pp and p–Pb collisions. The value is similar to that measured by STAR at lower p_T in Au–Au collisions at 200 GeV [12]. The models [1, 13, 14, 15] tend to underestimate the data for the same p_T interval. The right panel of Figure 2 shows the Λ_c^+-baryon R_{AA} measured in 0-80% Pb–Pb collisions at 5.02 TeV compared to the average non-strange D-meson [16], D_s^+-meson [16], $\pi^\pm$ and charged particle [17] R_{AA} in 0-10% centrality class. A hint of hierarchy is observed: Λ_c^+-baryon R_{AA} > D_s^+-meson R_{AA} > non-strange D-meson R_{AA}, which reflects the enhancement of baryon and strange-particle production expected by models including charm hadronisation via coalescence of charm quarks with the surrounding quarks in the QGP. For $p_T > 10$ GeV/c, non-strange D-meson R_{AA} is similar to

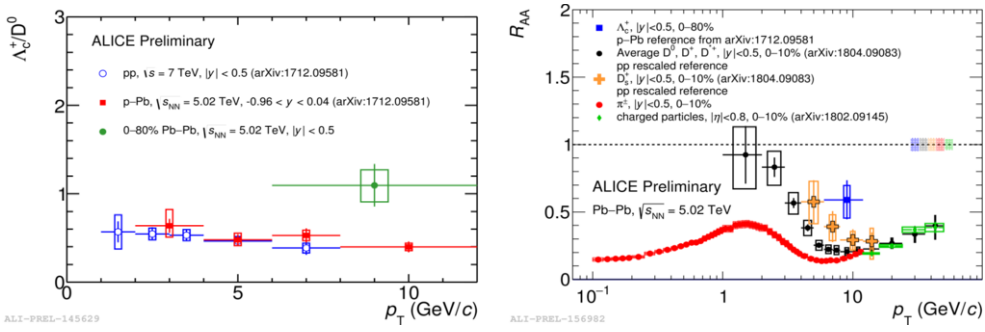

Fig. 2. The Λ_c^+/D^0 ratio in Pb–Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV, compared with that in pp and p–Pb collisions (left), and Λ_c^+-baryon R_{AA} in 0-80% Pb–Pb collisions at 5.02 TeV compared to average non-strange D-meson, D_s^+-meson, $\pi^\pm$ and charged particle R_{AA} in 0-10% centrality class

$\pi^\pm$ R_{AA}, in agreement with what expected from the combination of the colour charge and mass dependence of energy loss with the different fragmentation and initial spectra of charm and light partons [18]. For $p_T < 8$ GeV/c, non-strange D-meson R_{AA} is higher than that of $\pi^\pm$. This difference does not prove per se a smaller energy loss for charm quarks than light quarks: other effects must be considered, like N_{part} scaling of pion production at very low p_T, the different impact of radial flow, coalescence, as well as different initial-state effects.

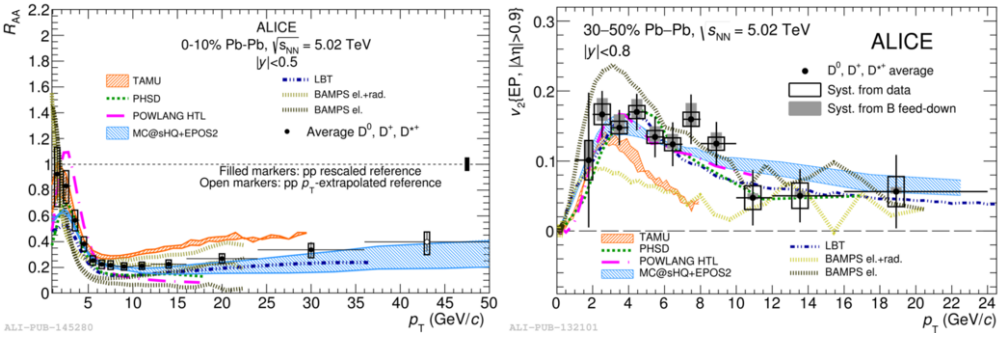

Fig. 3. Non-strange D-meson R_{AA} in the 0-10% centrality class [16] (left) and elliptic flow v_2 in the 30-50% centrality class [19] (right), compared with models predictions [20, 21, 22, 23, 24, 25].

The simultaneous comparison of both R_{AA} and elliptic flow (v_2) can provide important constraints on the theoretical models and help to extract information about the medium properties. Figure 3 shows the non-strange D-meson R_{AA} in the 0-10% centrality class (left) and elliptic flow v_2 in the 30-50% centrality class (right) [19], compared with the models. Models (LBT [20], MC@sHQ [21], PHSD [22], POWLANG [23]) in which charm quarks pick up collective flow via recombination or subsequent elastic collision in the expanding QGP medium can better describe both R_{AA} and v_2 at low p_T. The models which can reasonably describe the data use a diffusion coefficient $2\pi T D_s(T)$ in the range of 1.5-7, corresponding to a charm thermalisation time τ_{charm} in the range of 3-14 fm/c at T_c.

4. Summary

The ALICE results on charm-meson and charm-baryon production have been reported. The Λ_c^+/D^0 baryon-to-meson ratio in pp and p–Pb collisions is higher than theoretical predictions, and a similar p_T-trend is observed compared to Λ/K_s^0 and p/π ratios. The first LHC measurement of Λ_c^+/D^0 ratio in Pb–Pb collision at 5.02 TeV shows a hint of enhancement with respect to pp and p-Pb collisions. Finally, the D_s^+-meson R_{AA} is higher than non-strange D-meson R_{AA} supporting the possibility of charm hadronisation via recombination. A significant positive D-meson v_2 confirms that charm quark is sensitive to the medium collective motion.

5. Acknowledgement

This work was partly supported by the National Key Research and Development Program of China under Grant No. 2016YFE0100900 and the NSFC (Grant Nos. 11775095 and 11475068) and Grant No. CCNU18ZDPY04.

References

[1] Y. Oh, C. M. Ko, S. H. Lee, and S. Yasui *Phys. Rev.* **C79** (2009) 044905, arXiv:0901.1382 [nucl-th].
[2] **ALICE** Collaboration, K. Aamodt *et al. JINST* **3** (2008) S08002.
[3] **ALICE** Collaboration, S. Acharya *et al. JHEP* **04** (2018) 108, arXiv:1712.09581 [nucl-ex].
[4] J. R. Christiansen and P. Z. Skands *JHEP* **08** (2015) 003, arXiv:1505.01681 [hep-ph].
[5] C. Bierlich and J. R. Christiansen *Phys. Rev.* **D92** no. 9, (2015) 094010, arXiv:1507.02091 [hep-ph].
[6] M. Bahr *et al. Eur. Phys. J.* **C58** (2008) 639–707, arXiv:0803.0883 [hep-ph].
[7] J.-P. Lansberg and H.-S. Shao *Eur. Phys. J.* **C77** no. 1, (2017) 1, arXiv:1610.05382 [hep-ph].
[8] **LHCb** Collaboration, R. Aaij *et al. Nucl. Phys.* **B871** (2013) 1–20, arXiv:1302.2864 [hep-ex].
[9] **ALICE** Collaboration, B. B. Abelev *et al. Phys. Rev. Lett.* **111** (2013) 222301, arXiv:1307.5530 [nucl-ex].
[10] **ALICE** Collaboration, J. Adam *et al. Phys. Lett.* **B760** (2016) 720–735, arXiv:1601.03658 [nucl-ex].
[11] **ALICE** Collaboration, B. B. Abelev *et al. Phys. Lett.* **B728** (2014) 25–38, arXiv:1307.6796 [nucl-ex].
[12] **STAR** Collaboration, G. Xie *Nucl. Phys.* **A967** (2017) 928–931, arXiv:1704.04353 [nucl-ex].
[13] S. Ghosh, S. K. Das, V. Greco, S. Sarkar, and J.-e. Alam *Phys. Rev.* **D90** no. 5, (2014) 054018, arXiv:1407.5069 [nucl-th].
[14] S. K. Das, J. M. Torres-Rincon, L. Tolos, V. Minissale, F. Scardina, and V. Greco *Phys. Rev.* **D94** no. 11, (2016) 114039, arXiv:1604.05666 [nucl-th].
[15] S. Plumari, V. Minissale, S. K. Das, G. Coci, and V. Greco *Eur. Phys. J.* **C78** no. 4, (2018) 348, arXiv:1712.00730 [hep-ph].
[16] **ALICE** Collaboration, S. Acharya *et al. Submitted to: JHEP* (2018) , arXiv:1804.09083 [nucl-ex].
[17] **ALICE** Collaboration, S. Acharya *et al.* arXiv:1802.09145 [nucl-ex].
[18] M. Djordjevic *Phys. Rev. Lett.* **112** no. 4, (2014) 042302, arXiv:1307.4702 [nucl-th].
[19] **ALICE** Collaboration, S. Acharya *et al. Phys. Rev. Lett.* **120** no. 10, (2018) 102301, arXiv:1707.01005 [nucl-ex].
[20] S. Cao, T. Luo, G.-Y. Qin, and X.-N. Wang *Phys. Lett.* **B777** (2018) 255–259, arXiv:1703.00822 [nucl-th].
[21] M. Nahrgang, J. Aichelin, P. B. Gossiaux, and K. Werner *Phys. Rev.* **C89** no. 1, (2014) 014905, arXiv:1305.6544 [hep-ph].
[22] T. Song, H. Berrehrah, D. Cabrera, W. Cassing, and E. Bratkovskaya *Phys. Rev.* **C93** no. 3, (2016) 034906, arXiv:1512.00891 [nucl-th].
[23] A. Beraudo, A. De Pace, M. Monteno, M. Nardi, and F. Prino *Eur. Phys. J.* **C75** no. 3, (2015) 121, arXiv:1410.6082 [hep-ph].
[24] J. Uphoff, O. Fochler, Z. Xu, and C. Greiner *J. Phys.* **G42** no. 11, (2015) 115106, arXiv:1408.2964 [hep-ph].
[25] M. He, R. J. Fries, and R. Rapp *Phys. Lett.* **B735** (2014) 445–450, arXiv:1401.3817 [nucl-th].