Available online at www.sciencedirect.com

ScienceDirect

Nuclear Physics A 00 (2020) 1–4

Nuclear Physics A

www.elsevier.com/locate/procedia

XXVIIIth International Conference on Ultrarelativistic Nucleus-Nucleus Collisions (Quark Matter 2019)

Latest results on Λ_c^+ and D production in pp and Pb-Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV with ALICE at the LHC

Gian Michele Innocenti

CERN, Espl. des Particules 1, 1211 Meyrin, Switzerland

Abstract

The measurement of heavy-flavour production represents a powerful tool to study the medium formed in high-energy heavy-ion collisions. Produced in hard scattering processes on a timescale shorter than the QGP formation time, they experience the whole evolution of the medium interacting with its constituents. The measurements of charm-hadron production allows testing the mechanisms of in-medium parton energy loss. Moreover, the study of charm-baryon production in heavy-ion collisions and in particular the baryon-to-meson ratio, provides unique information on hadronisation mechanisms, constraining the role of coalescence. In this contribution, the ALICE results on open charmed meson and baryon production in large and small systems will be presented with a focus on the recent measurements of Λ_c^+/D^0 and D_s^+/D^0 ratios in central and peripheral PbPb collisions and on the new results obtained for the same ratios in proton-proton collisions as a function of the charged particle multiplicity. The prospects for Ξ_c and Σ_c analyses will also be discussed.

Keywords: Heavy ions, heavy flavours, energy loss, quark recombination

1. Introduction

Charm and beauty quarks are produced in hard scattering processes at the very early stages of heavy-ion collisions. As a consequence of the large momentum transferred in these processes, their production can be effectively described by perturbative QCD calculations. Once produced, these probes traverse the hot and dense medium and interact with the medium constituents via inelastic and elastic processes. Therefore, by studying their suppression in heavy-ion collisions relative to the vacuum, one can investigate the microscopic nature of energy loss processes and constrain fundamental parameters of the system, such as the charm diffusion coefficient. Alternatively, measurements of heavy-flavour hadrochemistry can be used to constrain the relevance of of quark recombination processes in the medium. The study of heavy-flavour production can also play an important role in understanding the nature of the systems created in proton-proton and proton-lead collisions. Measurements of heavy-particle ratios can highlight the presence of recombination processes in small systems and shed new light into the medium-like phenomena that have been observed over the last years, both at RHIC and at the LHC. A more detailed description of heavy-flavour physics in large and small systems can be found in [1, 2, 3].

2. Heavy-quark energy loss

With the large statistics collected at the end of 2018, ALICE was able to update its measurements of the nuclear modification factors of non-strange D mesons in central and peripheral Pb–Pb collisions. In Fig. 1 (left), the R_{AA} of non-strange D mesons in the centrality interval of 0–10% is presented as a function of the transverse momentum, p_T. For the first time at the LHC, the D^0 production is measured in central collisions down to 0 GeV/c. Thanks to its high accurcay, this measurement is now capable of challenging energy-loss calculations in a wide transverse momentum region [4, 5, 6, 7, 8]. In addition, the new data point obtained in the 0–1 GeV/c bin provides new experimental constraints on the relevance of shadowing in the charm sector. A new measurement of beauty suppression via the analysis of non-prompt D^0 hadrons was also presented. In the middle panel of Fig. 1, the ratio of the R_{AA} of non-prompt and prompt D^0 mesons is shown as a function of p_T. The ratio shows a maximum for $p_T \sim$10 GeV/c and decreases at higher transverse momenta. This trend is well described by theoretical calculations which include a different energy loss for charm and beauty quarks [5, 7, 9].

3. Charm recombination

Stronger constraints on the role of charm recombination were obtained thanks to new measurements of the D_s^+/D^0 and Λ_c^+/D^0 ratios in central Pb–Pb collisions. In Fig. 1 (right), the double ratio of D_s^+/D^0 measured in Pb–Pb and pp collisions is presented as a function of p_T. An enhancement of a factor of approximately 2 is observed in central Pb–Pb collisions at p_T of $\approx$5 GeV/c. The p_T-dependence and magnitude of this enhancement are well described by theoretical calculations, like TAMU, that adopt a Langevin approach to describe the charm evolution in the medium whilst also including charm recombination [5]. The first measurement of the Λ_c^+/D^0 ratio in central Pb–Pb collisions was also presented. In the left panel of Fig. 2, the Pb–Pb measurement performed in the centrality region of 0–10% is presented and compared to the same ratio measured in semi-peripheral Pb–Pb and pp collisions. A moderate enhancement is observed in central and peripheral collisions with respect to pp for p_T of about 5–8 GeV/c, as expected in the presence of charm recombination. In the right panel of the same plot, the central Pb–Pb measurement is compared to different theoretical calcuations [8, 10, 11]. More precise measurements will be needed in order to be able to discriminate amongst different theoretical descriptions of this observable.

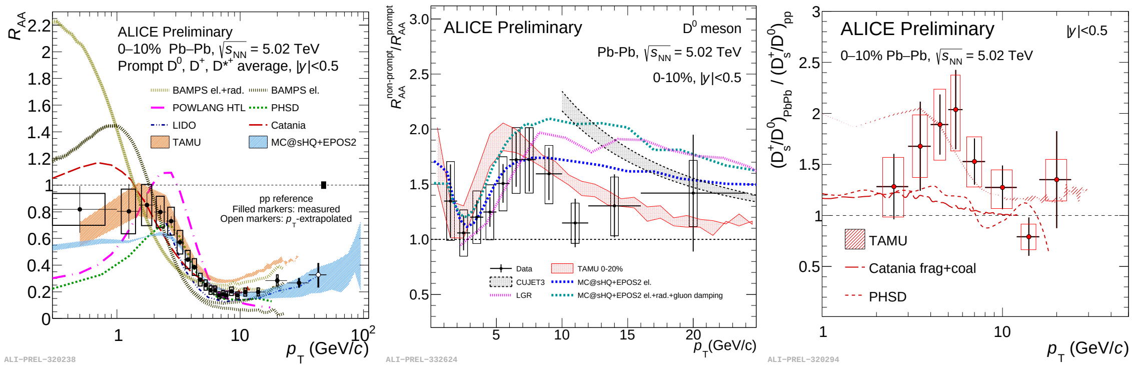

Fig. 1. (Left) R_{AA} of non-strange D mesons in the centrality interval of 0–10% is compared to various theoretical calculations. (Middle) Ratio of the R_{AA} of non-prompt and prompt D^0 mesons as a function of p_T. (Right) Double ratio of D_s^+/D^0 measured in central Pb–Pb and pp collisions.

4. Heavy-flavour hadronization in small systems

The comparison between the D_s^+/D^0 and Λ_c^+/D^0 ratios in pp and central Pb–Pb collisions, despite the limited statistical precision, supports the hypothesis of baryon/meson ehancement due to charm recombination inside the QGP. The natural extension was to therefore understand whether these phenomena could also play a role in small systems. In this conference, the first measurements of the D_s^+/D^0 and Λ_c^+/D^0 ratios as a function of multiplicity in pp collisions were presented. For these measurements, the multiplicity was sampled according to the number of tracklets measured in the two innermost layers of the Inner Tracking System (ITS). The lowest multiplicity range considered corresponds to an average $dN_{ch}/d\eta$ of 3.9, well below the average pp multiplicity, whilst the highest interval has an average $dN_{ch}/d\eta$ of about 2.5 times that of the minimum-bias one. In the left panel of Fig. 3, the D_s^+/D^0 ratios as a function of p_T in different ranges of charged particle multiplicity are presented. For this ratio, a mild increase still not statistically significant is observed at intermediate p_T. However, as shown in the right panel of the same figure, a much stronger multiplicity dependence is observed for the Λ_c^+/D^0 ratio. At a theoretical level no framework for recombination in pp is available. However, the comparison with PYTHIA calculations provides some very interesting information. Even at the lowest multiplicities, the ratio in data is already enhanced compared to the standard PYTHIA Monash tune which describes the $^{+}$e^{-} measurements. To capture the multiplicity dependence seen in data the PYTHIA tune is varied to include more processes of colour reconnection beyond leading colour [12]. In this formalism, the enhancement compared to the $^{+}$e^{-} baseline could be attributed to final state colour reconnection processes that do not strictly require the presence of a QGP. New and higher precision measurements along with further comparisons to theoretical calculations are still needed in order to draw a firm conclusion. One such measurement is the ratio of Ξ_c^0/D^0 in pp collisions, which was also presented (Fig. 4). Here the measured ratio is largely underestimated by PYTHIA even when colour recombination effects are enhanced, suggesting that such a variable could have a stronger discrimination power to study these phenomena.

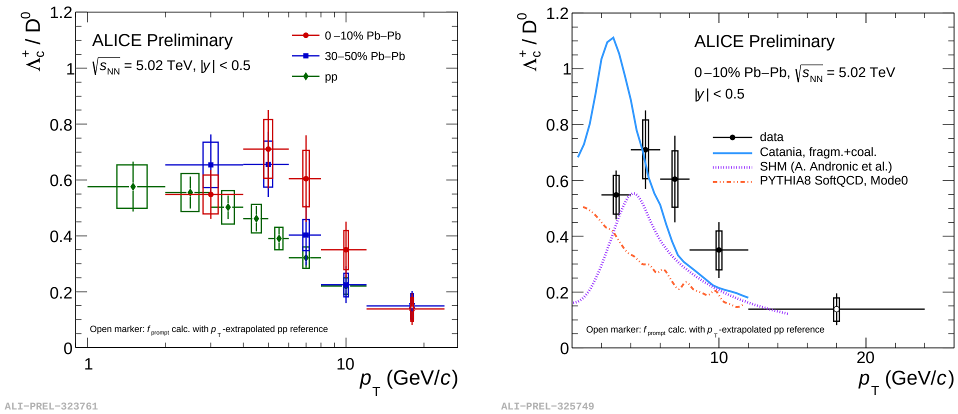

Fig. 2. (Left) Ratio of the R_{AA} of Λ_c^+ and D^0 mesons as a function of p_T in pp, central and semipheripheral PbPb collisions. (Right) Ratio of the R_{AA} of Λ_c^+ and D^0 mesons in central PbPb collisions compared to theoretical calculations.

References

[1] A. Andronic et al., Eur. Phys. J. C 76 (2016) 107, doi:10.1140/epjc/s10052-015-3819-5, arXiv:1506.03981.
[2] F. Prino, R. Rapp, Journal of Physics G: Nuclear and Particle Physics, Vol.3, Num. 9, 10.1088/0954-3899/43/9/093002, arXiv:1603.00529.
[3] X. Dong, Y-J. Lee, R. Rapp, Annual Review of Nuclear and Particle Science, Vol. 69:417-445, arXiv:1903.07709.
[4] Uphoff J, Fochler O, Xu Z, Greiner C. J. Phys. G42:115106 (2015).
[5] He M, Fries RJ, Rapp R. Phys. Lett. B735:445 (2014).
[6] Song T, et al. Phys. Rev. C93:034906 (2016).
[7] Andronic A, et al. Eur. Phys. J. C76:107 (2016).
[8] Das SK, Scardina F, Plumari S, Greco V. Phys. Lett. B747:260 (2015).
[9] A. Buzzatti, M. Gyulassy, arXiv:1207.6020.
[10] A.Andronic,P.Braun-Munzinger,K.RedlichandJ.Stachel,Nucl.Phys.A789(2007)334,arXiv:nucl-th/0611023.
[11] An introduction to PYTHIA 8.2, https://doi.org/10.1016/j.cpc.2015.01.024.
[12] J. R. Christiansen, P. Z. Skands, arXiv:1505.01681.

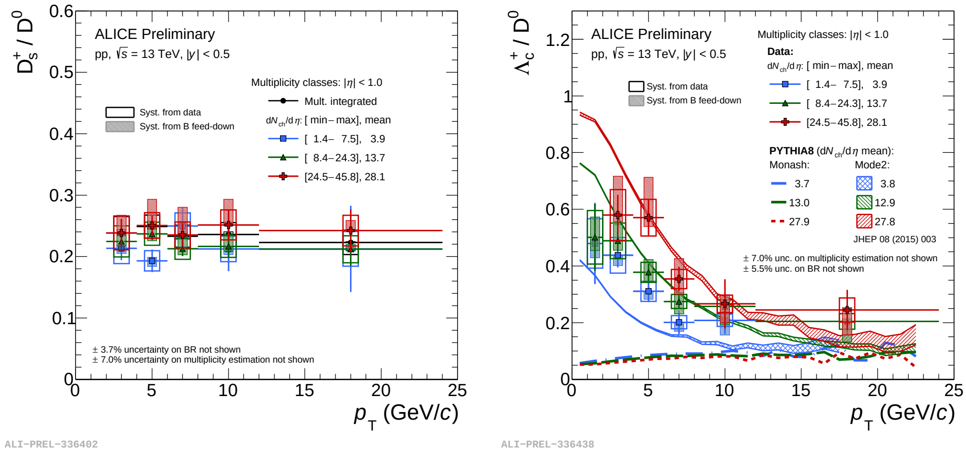

Fig. 3. (Left) D_s^+/D^0 ratio measured in pp collisions at 13 TeV in different multiplicity intervals. (Right) Λ_c^+/D^0 ratio measured in pp collisions at 13 TeV in different multiplicity intervals compared to different PYTHIA calculations.

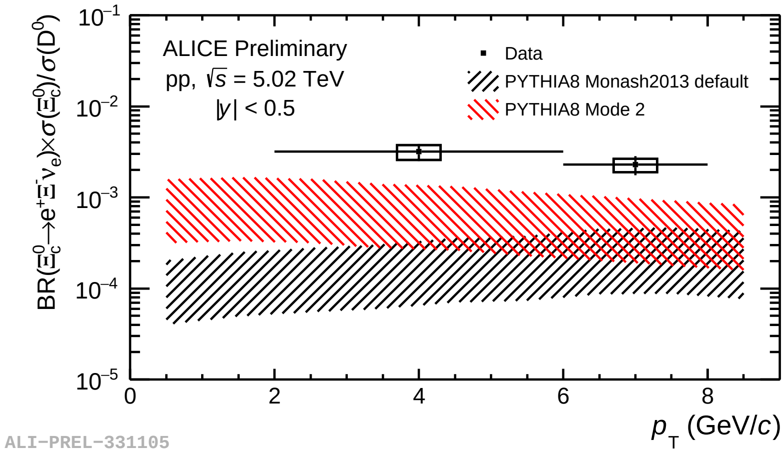

Fig. 4. Ξ_c/D^0 ratio measured in pp collisions at 5 TeV compared to PYTHIA calculations.