BEAUTY PRODUCTION IN HEAVY-ION COLLISIONS WITH ALICE AT THE LHC*

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In this contribution, the final measurements of the centrality dependence of the nuclear modification factor (R_{AA}) of non-prompt D^0 in Pb–Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV will be presented. These measurements provide important constraints to the mass dependence of in-medium energy loss and hadronisation of the beauty quark. The p_{T}-integrated non-prompt D^0 R_{AA} will be presented for the first time and will be compared to the prompt D^0 one. This comparison will shed light on possible different shadowing effects between charm and beauty quarks. In addition, the first measurements of non-prompt D_s^+ production in central and semi-central Pb–Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV will be discussed. The non-prompt D_s^+ measurements provide additional information on the hadronisation of beauty quarks and the production yield of B_s^0 mesons. Finally, the first measurement of non-prompt D-meson elliptic flow in Pb–Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV will also be discussed. These measurements can constrain the degree of thermalisation of beauty quarks in the hot and dense QCD medium.

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1. Introduction

Heavy quarks (charm and beauty) are produced in hard-scattering processes over short time scales compared to the quark–gluon plasma (QGP). They probe the whole system evolution interacting with the medium constituents. In particular, due to the larger mass, beauty quarks are expected to lose less energy [1, 2] and diffuse less than the charm quarks [3, 4]. Therefore, the comparison between charm and beauty nuclear modification factor (R_{AA}) and elliptic flow (v_2) provides insight into the quark mass-dependence of energy loss, as well as heavy-quark diffusion properties.

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The D mesons from beauty hadron decays (non-prompt D) are excellent probes for beauty properties. Existing data on the production of B mesons [5], and J/ψ from beauty decays [6–8] at midrapidity are limited by large uncertainties, while the broad correlation between the transverse momenta (p_{T}) of the lepton and the parent beauty hadron reduces the effectiveness of beauty decay lepton measurements [9, 10].

In these proceedings, the measurement of open-beauty production in Pb–Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV from ALICE at midrapidity is reported.

2. *D*-meson reconstruction

The non-prompt D mesons are reconstructed via their hadronic decay channels $D^0 \to K^-\pi^+$ and $D_s^+ \to \pi^+\phi \to \pi^+K^+K^-$. A multi-classification BDT algorithm [11], trained using variables sensitive to the decay topology and particle identification, is utilised to simultaneously increase the non-prompt ($b \to D$) fraction and suppress the combinatorial background. After extracting the yield via an invariant mass analysis, the $b \to D$ fraction is estimated by a χ^2-minimisation approach based on a variation of ML-based selections [11]. The measurement of the non-prompt D^0 v_2 is performed with the scalar-product (SP) method [12]. In order to obtain non-prompt D^0 v_2 ($v_2^{\mathrm{non-prompt}}$), a linear fit of v_2^{sum} is performed as a function of $b \to D$ fraction, and extrapolated to $f_{\mathrm{non-prompt}} = 1$, as described in [13].

3. Results

The left panel of Fig. 1 shows the R_{AA} of non-prompt D^0 mesons [14] as a function of p_{T} measured in the 0–10% most central Pb–Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV. The result is compared with the prompt D^0-meson R_{AA} [15]. The non-prompt D^0-meson R_{AA} is significantly higher than the prompt D^0 one for $p_{\mathrm{T}} > 5$ GeV/c, indicating that non-prompt D^0 mesons are less suppressed than prompt D^0 mesons, and supporting the expectation that beauty quarks lose less energy than charm quarks due to their larger mass. An extrapolation of the measured spectrum is performed. The resulting non-prompt D^0-meson R_{AA} for $p_{\mathrm{T}} > 0$ is 1.00 ± 0.10 (stat.) $\pm$ 0.13 (syst.)$^{+0.08}_{-0.09}$ (extr.) $\pm$ 0.02 (norm.) [14] in the 0–10% centrality class, which is compatible with unity within uncertainties, and larger than the prompt one [15] within less than 1.5σ.

The non-prompt-to-prompt D^0-meson R_{AA} ratio as a function of p_{T} in the 0–10% central Pb–Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV is presented in the right panel of Fig. 1. The ratio can be well described by model predictions [16–20] that include collisional and radiative processes (top panel). In order to further understand the data pattern at low p_{T} and the enhancement with respect to unity at high p_{T} for the data, the ratio is compared with different LGR model [17, 18] calculations (bottom panel), highlighting the

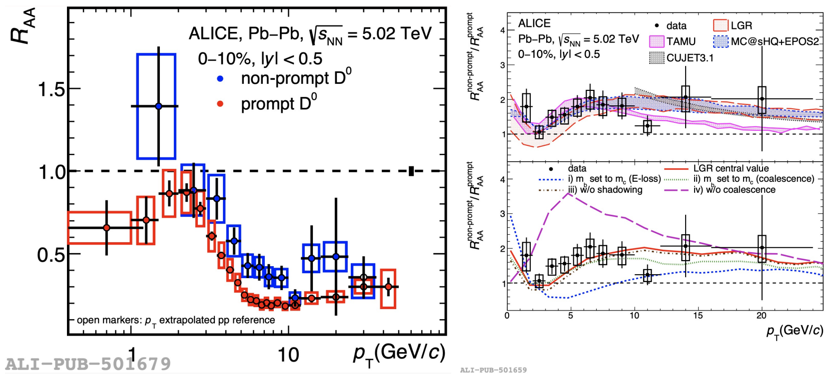

Fig. 1. Left: the R_{AA} of non-prompt D^0 mesons [14] as a function of p_T in the 0–10% centrality classes, compared with the R_{AA} of prompt D^0 mesons [15]. Right: non-prompt-to-prompt D^0-meson R_{AA} ratio as a function of p_T in the 0–10% central Pb–Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV, compared to model predictions [16–20] (top) and to different modifications of LGR calculations [17, 18] (bottom).

role of coalescence, shadowing, and mass dependence of energy loss. The LGR model suggests that the "valley" structure at low p_T is mainly due to the formation of prompt D mesons via charm-quark coalescence (case iv), and the significant enhancement of the ratio at high p_T is interpreted as the effect of the mass dependence of the in-medium energy loss (case i).

The R_{AA} of non-prompt D_s^+ mesons divided by that of prompt D_s^+ mesons [22] (left panel) and non-prompt D^0 mesons [14] (right panel) are shown in Fig. 2. In the 0–10% centrality class, a hint that both ratios

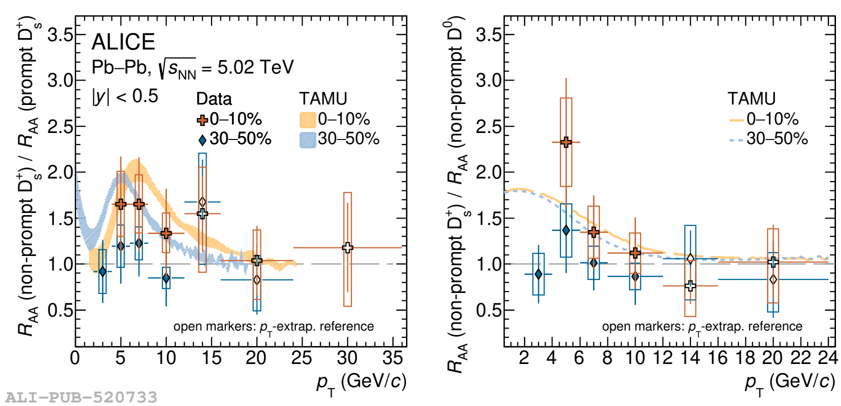

Fig. 2. The R_{AA} of non-prompt D_s^+ mesons [21] divided by the one of prompt D_s^+ mesons [22] (left) and non-prompt D^0 mesons [14] (right) as a function of p_T for the 0–10% and 30–50% centrality classes in Pb–Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV. The measurements are compared with TAMU model predictions [19].

are larger than unity in the $4 < p_{\mathrm{T}} < 12$ GeV$/c$ interval is presented, suggesting an enhancement of non-prompt D_s^+ in this interval. The trend can be explained by the interplay of mass dependence of energy loss and recombination in the QGP medium. The ratios are compatible with unity within uncertainties. The TAMU predictions [19] qualitatively describe the results for central collisions. For semi-central collisions the TAMU model overestimates the R_{AA} ratio values.

Figure 3 shows the first measurement of non-prompt D^0 v_2 in 30–50% Pb–Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV, compared to the average v_2 of prompt D mesons [23] (left panel) and to model predictions [17, 19, 24–27] (right panel). The non-prompt D^0 v_2 is found to be positive with 2.7σ significance of $2 < p_{\mathrm{T}} < 12$ GeV$/c$. The significance for the difference between non-prompt D^0 v_2 and that of prompt average non-strange D mesons is 3.2σ for $2 < p_{\mathrm{T}} < 8$ GeV$/c$, indicating a different degree of participation to collective motion between charm and beauty quarks. Theoretical predictions [17, 19, 24–27] based on beauty-quark transport in the hydrodynamically expanding medium can fairly describe the data within uncertainties. Future measurements with higher accuracy will provide important constraints to the models and allow for accurate extraction of the spatial diffusion coefficient with beauty quarks.

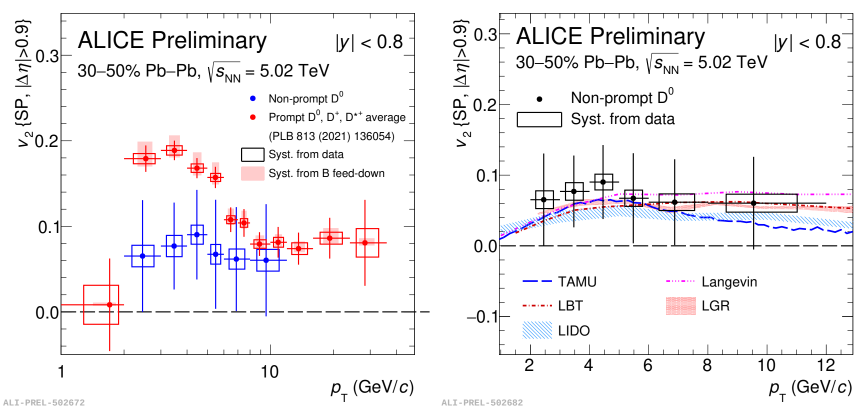

Fig. 3. The non-prompt D^0 v_2 in Pb–Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV in the 30–50% centrality class, compared to that of prompt average non-strange D mesons [23] (left) and to the model predictions [17, 19, 24–27] (right).

4. Conclusion

In this contribution, the most recent results on the production and azimuthal anisotropy of non-prompt D mesons, measured in Pb–Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV, were presented. The non-prompt D^0 R_{AA} provides an essential constraint on the mass dependence of energy loss in the medium. The non-prompt D_s^+ R_{AA} helps to further understand beauty-quark hadronisation in heavy-ion collisions. The first measurement of non-prompt D^0-meson v_2 indicates a different degree of participation in the collective motion between charm and beauty quarks. With the LHC Run3, the upgraded ITS and the increased integrated luminosity will allow for more precise beauty-hadron measurements at midrapidity with ALICE.

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