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Charm jet and correlation measurements with ALICE in pp and p–Pb collisions at the LHC

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The recent results about charm jet and correlation measurements by the ALICE experiment are presented in this contribution. The measurements of the D^0 parallel jet momentum fraction in pp collisions at $\sqrt{s}$ = 5.02 and 13 TeV are shown and compared with Monte Carlo model predictions. Λ_c-tagged jets in pp collisions at $\sqrt{s}$ = 13 TeV, including their jet momentum fraction measurements, are shown. Measurements of the radial displacement in D^0 and Λ_c jets in pp collisions at $\sqrt{s}$ = 13 TeV are also illustrated. The nuclear modification factor of jets tagged with electrons from heavy-flavour hadron decays in p–Pb collisions at $\sqrt{s}$ = 5.02 TeV is then discussed. Finally, the new results about azimuthal correlations between heavy-flavour decay electrons and hadrons in pp collisions at $\sqrt{s}$ = 5.02 TeV are introduced.

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1. Introduction

In hadronic collisions heavy flavour quarks, beauty and charm, due to their large masses, can be only produced by a hard interaction between the elementary constituents of the colliding hadrons. Therefore, their production cross section can be described by pQCD calculations. In this context, studies of azimuthal correlations between D mesons and charged particles, and charm jet measurements provide a complementary description of the charm showering: the former are sensitive to the production mechanisms and allow the characterization of the charm fragmentation process by means of the angular distribution of its products with respect to the direction of the tagged meson, the latter give a direct access to the parton kinematics. Measurements in pp collisions are useful tools for testing pQCD calculations, as well as for tuning Monte Carlo event generators. Differences between the results in pp and p–Pb collisions can shed light on the modifications induced by cold nuclear matter effects in both the charm quark production and in the hadronization stage.

2. Experimental apparatus and results

Thanks to the excellent performances in terms of particle identification, low-p_{T} track reconstruction and vertexing of the ALICE detector [1], heavy-flavour particles can be identified with great precision down to p_{T}=0. The reconstruction of heavy-flavour hadrons is performed by looking at their displaced decay topology, exploiting the possibility of separating the primary from the secondary vertices with the Inner Tracking System (ITS). Furthermore, the identification of the daughter particles by means of the energy loss in the Time Projection Chamber (TPC) and in the time-of-flight (TOF) detectors furtherly improves the selection of the candidates. Thus, D mesons, such as D^0, D^+, D^*, D_s^+ can be reconstructed at midrapidity ($|y| < 0.5$) from their hadronic decay channels $\mathrm{D}^0 \to \mathrm{K}^-\pi^+$ (BR = 3.95%), $\mathrm{D}^+ \to \mathrm{K}^-\pi^+\pi^+$(BR = 9.38%), $\mathrm{D}^* \to \mathrm{D}^0\pi^+ \to \mathrm{K}^-\pi^+\pi^+$ (BR = 2.67%), and $\mathrm{D}_s^+ \to \mathrm{K}^-\mathrm{K}^+\pi^+$(BR = 5.50%) as well as a wide set of baryons including the $\Lambda_c \to \mathrm{pK}_s^0$(BR = 1.59%). Electrons from the semileptonic decay of heavy-flavour hadrons can be also reconstructed at central rapidity: their identification is then demanded to the TPC and TOF in the low-p_{T} and to the Electromagnetic Calorimeter (EMCal) in the high-p_{T} region.

2.1 Charm-tagged jets: D^0- and Λ_c- jets

Charm jets are identified by the presence of a charmed hadron among their constituents. After the topological reconstruction of the D^0 (Λ_c) candidates through their hadronic decay channel, charm-hadron yields are evaluated from an invariant mass spectra analysis and the anti-k_{T} algorithm [2] is performed to identify the spray of particles correlated to the charm fragmentation. A Bayesian unfolding procedure is then applied to the feed-down corrected heavy-flavour jet signal to recover the charm-jet momentum [3]. In Fig. 1, the probability density of the jet parallel momentum fraction carried by the D^0 meson $z_{||}^{ch} = \frac{\vec{p}_{\mathrm{D}}\cdot\vec{p}_{\mathrm{ch,jet}}}{\vec{p}_{\mathrm{ch,jet}}\cdot\vec{p}_{\mathrm{ch,jet}}}$ is shown in the transverse momentum interval $2 < p_{\mathrm{T,D^0}} < 7$ GeV/c and $5 < p_{\mathrm{T,ch.jet}} < 7$ GeV/c, in pp collisions at $\sqrt{s}$ = 5.02 and 13 TeV respectively. A softer fragmentation is observed with respect to POWHEG+PYTHIA 6[4, 5] expectations, at both $\sqrt{s}$ = 5.02 and 13 TeV. Similarly, the Λ_c-jets fragmentation functions, in Fig.2 (left), are compared with two different parametrization of PYTHIA8[6]: a better description

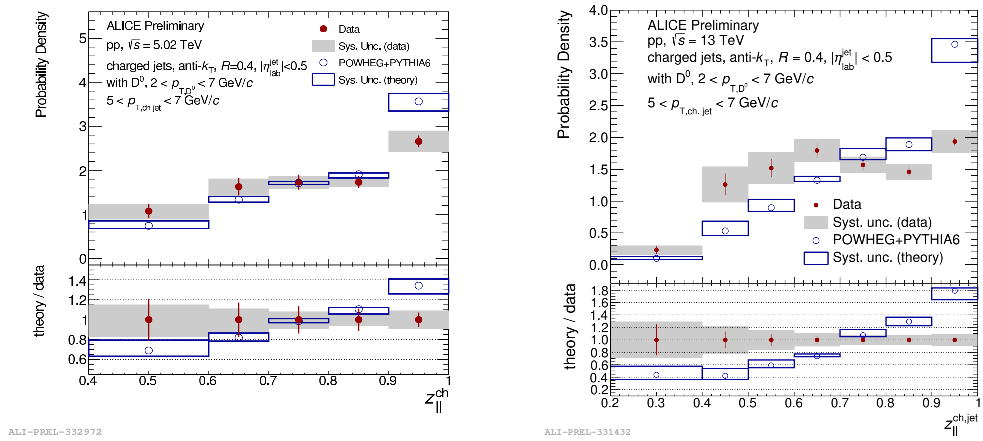

Figure 1: Comparison between the D^0 probability density distribution of the jet momentum fraction, $z_{||}^{ch}$ and the POWHEG+PYTHIA 6 predictions, in pp collisions at $\sqrt{s}$ = 5.02 TeV(left) and 13 TeV(right).

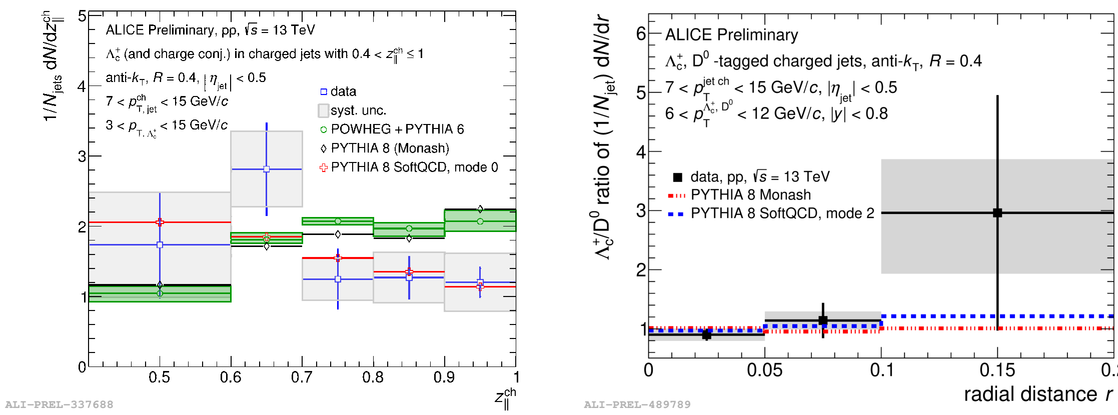

Figure 2: On the left, a comparison between the measured probability density distribution of the jet momentum fraction, $z_{||}^{ch}$, carried by the Λ_c and the POWHEG+PYTHIA 6 and PYTHIA 8 predictions, measured in pp collisions at $\sqrt{s}$ = 13 TeV. On the right, the ratio between the Λ_c/D^0 ratio of the radial displacement probability density compared with the PYTHIA 8 expectations, measured in pp collisions at $\sqrt{s}$ = 13 TeV.

is provided by the softQCD tuning, implementing colour reconnection mechanisms beyond the leading order [7]. Further information about the in-jet fragmentation mechanisms is obtained by investigating the radial distance between the charm hadron direction and the jet axis, defined as $r = \sqrt{(\theta_H - \theta_{jet})^2 + (\eta_H - \eta_{jet})^2}$, where (θ_H, η_H) and $(\theta_{jet}, \eta_{jet})$ represent, respectively, the azimuthal angle and the pseudorapity of the hadron and of the reconstructed charged jet. Fig. 2 (right) shows the ratio between the radial probability density Λ_c/D^0, computed in $7 < p_T^{\Lambda_c^+, D^0} < 12$ GeV/c and $7 < p_T^{jet\ ch} < 15$ GeV/c in pp collisions at $\sqrt{s}$ = 13 TeV. The results suggest a possible difference between the hadronization mechanism of baryons and mesons, which can be ascertained with reduced experimental uncertainties.

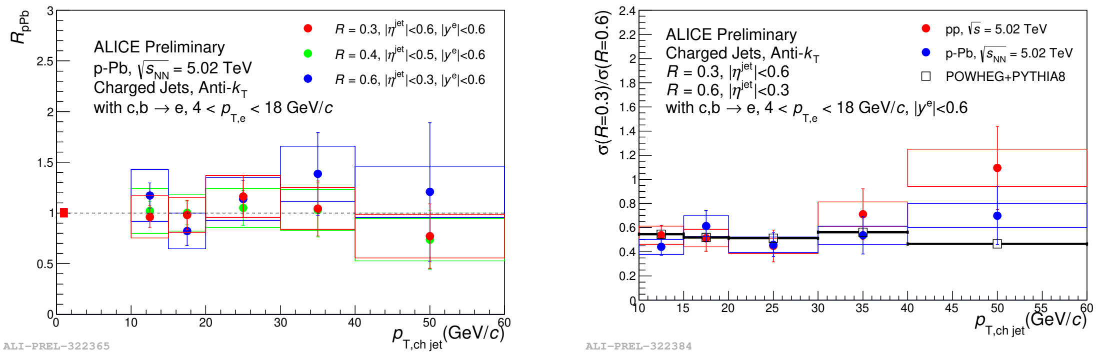

Figure 3: Left: Nuclear modification factor $R_{\rm pPb}$ with different resolution parameter R=0.3,0.4 and 0.6 in p–Pb collisions at $\sqrt{s}$ = 5.02 TeV, for HFe in $4 < p_{\rm T}^{e} < 18$ GeV/c. Right: Ratios between the $p_{\rm T}$ cross-sections computed with the jet resolution parameter R=0.3 and R=0.6, in pp and p–Pb collision.

2.2 Heavy-Flavour Jets as function of the impact parameter

The study of a possible dependence of the jet-$p_{\rm T}$ spectrum on the jet resolution parameter R can shed light on modifications induced by the presence of cold nuclear matter effects. The nuclear modification factor $R_{\rm pPb}$, defined as the ratio between the jet $p_{\rm T}$-differential yields in p–Pb and pp collisions scaled by the Pb atomic mass, is shown in Fig. 3 (left) for different values of R. Indipendently of the jet resolution R, the $R_{\rm pPb}$ is found to be consistent within uncertainties with the unity. Figure 3 (right) shows the $p_{\rm T}$ dependence of the ratio of cross section for R=0.3 and R=0.6 for both pp and p–Pb collisions at the same energy $\sqrt{s}$ = 5.02 TeV. Because of the compatibility of the results between the two systems, the presence of large final state effects on heavy-flavour decay electrons is not supported by the experimental observations.

2.3 D meson - hadron correlations

A characterization of the charm fragmentation products is achieved by studying the azimuthal correlation distribution between D mesons and the charged particles produced by the showering of the c quark. The azimuthal correlation function features two peaks, the near-side and the away-side whose properties can be directly attributed to the fragmentation and the hadronization of the $c\bar{c}$ pair produced in the hard collision. As detailed in Ref. [8] with pp and p–Pb data at $\sqrt{s_{\rm NN}}$ = 5.02 TeV, a differential study in $p_{\rm T}^{\rm D}$ and in $p_{\rm T}^{\rm assoc}$ is performed to understand the evolution of the charm jet-shape and its composition. Moreover, the comparison of the results in the two collision systems provides a good agreement within statistical uncertainties. Thus, cold nuclear matter effects are not observed with the current data sample.

2.4 Heavy-Flavour Electrons - hadron correlation

Azimuthal correlations between electrons from semi-leptonic decays of heavy-flavour hadron (HFe) and other particles are determined in pp collisions at $\sqrt{s}$ = 5.02 TeV. Hadrons and Non-HFe contaminates the inclusive spectrum of electrons identified through the PID information from the TPC and EMCal. Therefore, the hadron-hadron correlations scaled to the hadron contamination by means of an E/p distribution, are computed and subtracted from the inclusive e-h distributions.

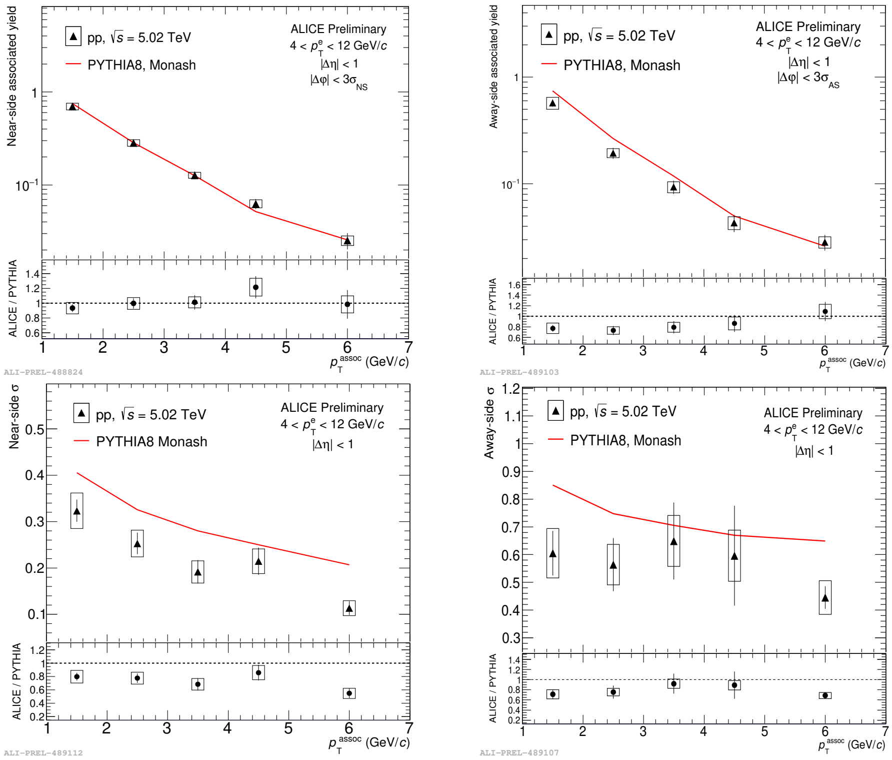

Figure 4: Near-side (left panel) and away-side (right panel) peak yields (first row) and widths (second row) obtained from a fit to the azimuthal-correlation function after the baseline subtraction and compared with the PYTHIA 8,Monash tune predictions.

Similarly, the Non-HFe contribution, dominated by electrons from gamma conversion and η and π^0 mesons Dalitz decays [9], is removed. Azimuthal correlations are evaluated in pp collisions at $\sqrt{s} = 5.02$ TeV, in the integrated transverse momentum range $4 < p_{\mathrm{T}}^{e} < 12$ GeV/c and in five disjoint $p_{\mathrm{T}}^{\mathrm{assoc}}$ intervals. From the fit of the correlation distributions quantitative results are extrapolated and compared with the PYTHIA 8 predictions, as shown in Fig. 4.

3. Conclusion

The measurements of fraction of parallel jet momentum of D^0 and Λ_{c} produced in pp collisions suggest a softer fragmentation than what is obtained from PYTHIA 8 predictions. The measurements for Λ_{c} are better described by the version of PYTHIA8 with soft QCD implementation. The new results about the radial displacement in both D^0 and Λ_{c}-jets were introduced in pp collisions at $\sqrt{s} = 13$ TeV: a deviation from the PYTHIA 8 tunes could hint at a possible difference between the baryon and meson hadronization mechanisms. The nuclear modification factor R_{pPb} measured through HFe-jets was investigated at $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV: the absence of modifications to the jet-p_{T} spectrum suggests a negligible impact by cold nuclear matter effects. The latest results about azimuthal correlations between heavy flavour electron and hadron in pp collision at $\sqrt{s} = 5.02$ TeV were also presented.

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