EPJ Web of Conferences **276**, 02007 (2023)
SQM 2022
https://doi.org/10.1051/epjconf/202327602007

Heavy-flavour jet properties and correlations from small to large systems measured by ALICE

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Abstract. The early production of heavy-flavour partons makes them an excellent probes for investigating the evolution of QCD systems. Jets tagged by the presence of a heavy-flavour hadron give access to the kinematics of the heavy partons and allow for comparisons of their production, propagation and fragmentation across different systems. Whilst traversing the quark-gluon plasma (QGP), charm and bottom quarks lose energy through interactions with the medium, at a different rate relative to light quarks and gluons. To constrain the energy loss in the QGP, the nuclear modification factor of D^0-tagged jets is measured in the 0–10% most central Pb–Pb collisions at $\sqrt{s_{\mathrm{NN}}} = 5.02$ GeV/c. The properties of charm fragmentation are also investigated in pp collisions at $\sqrt{s} = 5.02$ GeV/c through measurements of the production and the momentum fraction of the D^0 with respect to its jet.

1 Introduction

Heavy-flavour quarks are created in hard-scatterings in high-energy collisions. These heavy quarks can lose energy via gluon radiation forming a parton shower. The original heavy quark produced in this process finally hadronizes into a heavy hadron. ALICE is capable of fully reconstructing the heavy hadron and using it to tag jets that originated from the hard-scatterings and heavy quark parton shower.

In heavy-ion collisions, since heavy quarks are produced in hard scattering and, therefore, in the early stages of the collision, they will experience the whole evolution of the system. This makes heavy quarks ideal tools to study properties of the QGP in large systems.

2 Analysis methods and results

The D^0 meson is fully reconstructed through the hadronic decay channel $\mathrm{D}^0 \to \mathrm{K}^-\pi^+$ exploiting the particle identification provided by the ALICE detector[1]. The main strategy for D^0-jet reconstruction is the replacement of the D^0 decay daughters by the 4-momentum vector of the reconstructed D^0. After that, the D^0 and charged particles in the event are processed by the FastJet package for jet finding using the anti-k_T algorithm [2].

D^0-jets are fully corrected for reconstruction efficiency and detector effects. The contribution of non-prompt D^0, originating from the decay of hadrons containing bottom quarks, is subtracted using POWHEG [3] simulations.

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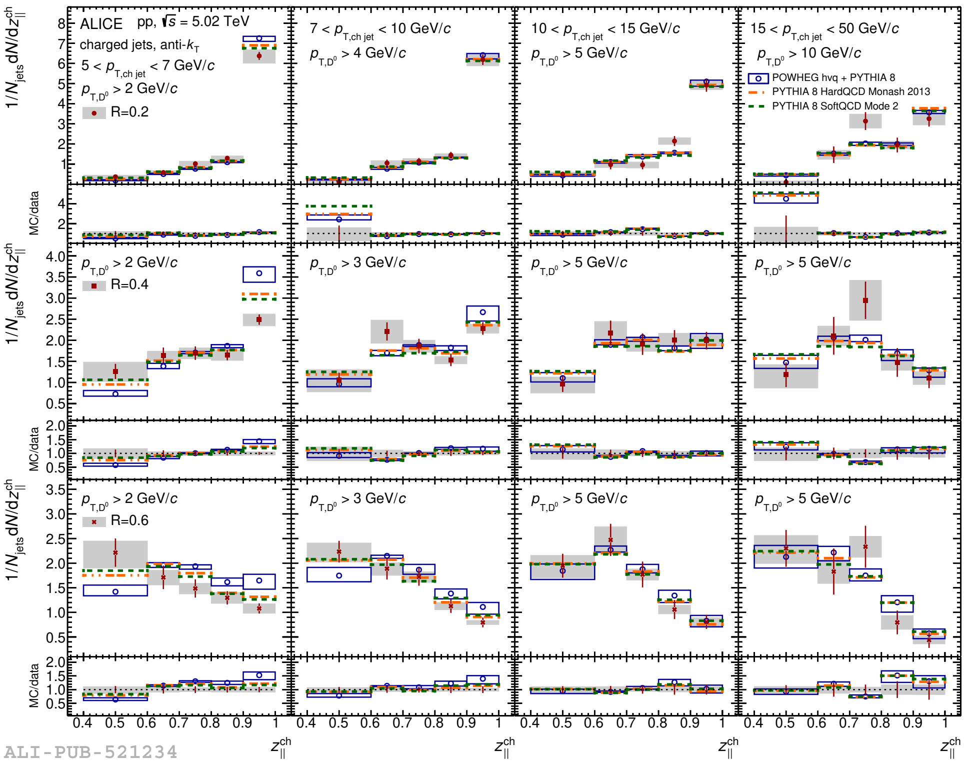

Figure 1. D^0-jet momentum fraction distribution measured in pp collisions at $\sqrt{s}$ = 5.02 TeV. Vertical lines and boxes are, respectively, statistical and systematic uncertainties [4]. Jet and D^0 p_T increase in panels from left to right and R increases in panels from top to bottom. Data are compared to predictions from models [3, 7–9].

The fraction of the D^0 momentum with respect to its jet is defined as $z_{||}^{\text{ch,jet}} = \frac{\vec{p}_D \cdot \vec{p}_{\text{ch,jet}}}{||\vec{p}_{\text{ch,jet}}||^2}$, where $\vec{p}_D$ and $\vec{p}_{ch,jet}$ are the momenta of the D^0 and the jet, respectively. Fig. 1 presents the D^0-jet momentum fraction in pp collisions at $\sqrt{s}$ = 5.02 TeV for jet resolution parameters R = 0.2, 0.4, and 0.6 in four jet p_T intervals.

The shape of the D^0-jet momentum fraction for R = 0.2 is peaked around $z_{||}^{\text{ch,jet}} \approx 1$ for the first three jet p_T intervals and minimum D^0 p_T. This changes in the largest jet p_T interval ($15 < p_{\text{T,ch jet}} < 50$ GeV/c), where the peak is not clearly defined. This is also a consequence of the dead-cone effect [5, 6], which suppresses gluon emission at small angles. When the heavy-quark energy becomes larger, the dead-cone angle becomes smaller and the effect also gets smaller. For larger jet resolution parameters, the distributions are not dominated by larger $z_{||}^{\text{ch,jet}}$ because the jet recovers a large fraction of the gluon emissions. The measurements are compared with POWHEG-hvq + PYTHIA 8, POWHEG-hvq is a generator for heavy-flavour hadroproduction at next-to-leading order in QCD [7]; PYTHIA 8 HardQCD Monash 2013 [8]; and PYTHIA 8 SoftQCD Mode 2, which includes colour reconnection beyond the leading-colour approximation [9]. The bottom panels in Fig. 1 present the ratios of the Monte Carlo simulations to data and all models presented are in agreement with the measurements.

The charm interaction with the QGP was studied by measuring the p_T-differential yields and nuclear modification factor (R_{AA}) of D^0-jets in central (0–10%) Pb–Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV.

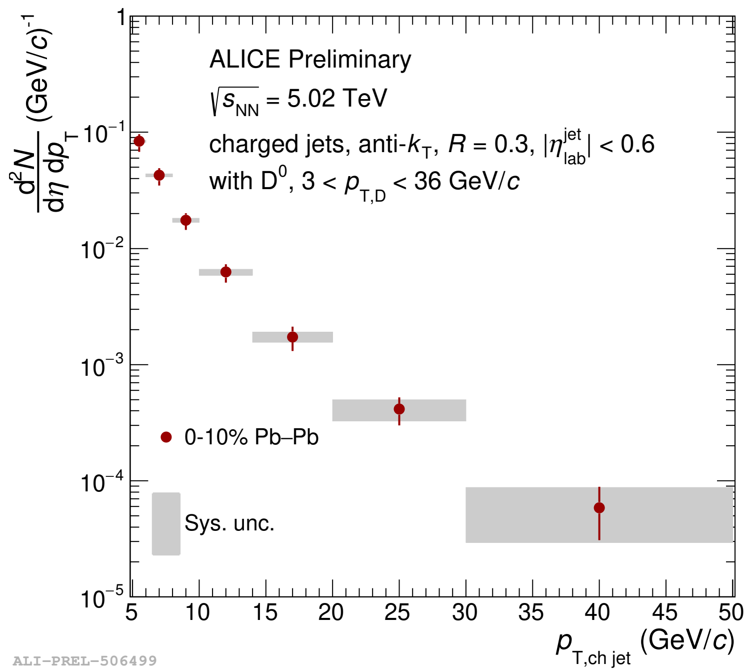

Figure 2. D^0-tagged jet p_T-differential yields in central (0–10%) Pb–Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV. The red vertical lines and gray boxes are, respectively, the statistical and systematic uncertainties.

The D^0-jet p_T-differential yields are presented in Fig. 2. The D^0 p_T interval inside the jets is $3 < p_{T,D} < 36$ GeV/c. The jet resolution parameter is $R = 0.3$ and all D^0-jets within absolute pseudorapidity $|\eta| < 0.6$ were accepted.

The R_{AA} is defined as the ratio of the p_T-differential yields of jets in Pb–Pb and pp collisions scaled by the number of binary collisions [10]. The D^0-jet R_{AA} is presented in Fig. 3 and varies from 0.3 at jet transverse momentum p_T between 5 to 8 GeV/c and grows as a function of the jet p_T. The D^0-jet R_{AA} is compared to that of inclusive charged-particle jets with R = 0.2, which is also compatible to the same measurement using R = 0.4. In the jet transverse momentum region where both measurements are available ($20 < p_{T,jet} < 50$ GeV/c), the inclusive jet R_{AA} is systematically lower than D^0-jet R_{AA}, although compatible within uncertainties in the interval $30 < p_{T,jet} < 50$ GeV/c.

The comparison between D^0-jet and inclusive charged-particle can be sensitive to different contributions of quarks and gluons energy loss mechanisms. Mass dependent effects, such as the dead-cone effect, can also play a role.

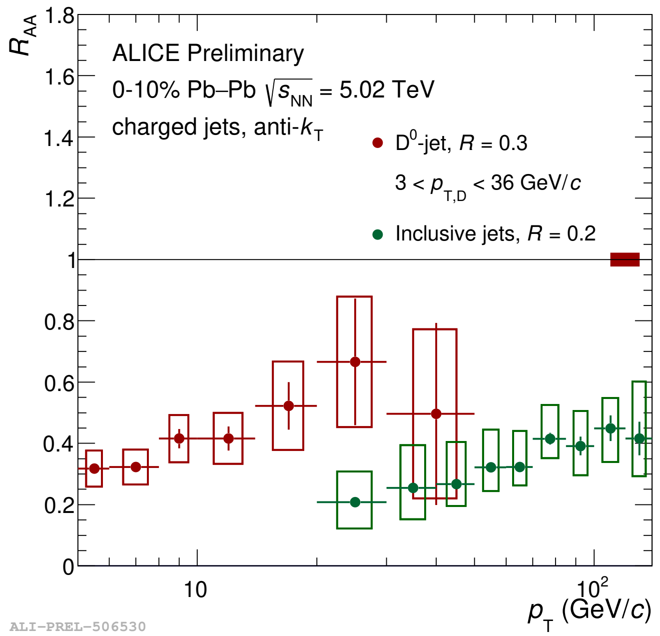

Figure 3. Nuclear modification factor of D^0-jets (red markers) and inclusive charged-particle jets (green markers) in central (0–10%) Pb–Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV. Statistical and systematic uncertainties are, respectively, presented as vertical lines and boxes.

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