Heavy-flavour jet production and charm fragmentation with ALICE* at LHC**

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Abstract. Heavy quarks, produced in hard parton scatterings in the early stage of ultra-relativistic heavy-ion collisions, are ideal probes to investigate the properties of the Quark–Gluon Plasma (QGP) produced in such collisions. Measurements of heavy-flavour jets can provide constraints on energy-loss models. In particular, they add information on how the radiated energy is dissipated in the medium. Studies of angular correlations between heavy-flavour and charged particles allow us to characterize the heavy-quark fragmentation process and its possible modification in a hot nuclear matter environment.

This manuscript will focus on the latest results on heavy-flavour jets and D-meson correlations with charged particles studied with the ALICE detector in pp, p–Pb and Pb–Pb collisions.

Keywords: Heavy-flavour, jets, nuclear modification, fragmentation function, momentum fraction

1 Physics Motivation

Fragmentation function of photon-triggered mesons was studied by Kang and Vitev [1] and a flavour dependence of energy loss in QGP medium was predicted. Measurements in pp collisions provide essential reference to interpret those in proton–nucleus (p–A) and nucleus–nucleus (A–A) collisions. They also provide an excellent test of the perturbative quantum chromodynamics (pQCD) because heavy-flavour observables are calculable in pQCD down to \( p_T \approx 0 \). Anderle et al. [2] presented a global QCD analysis of D\(|^\pm\) meson fragmentation functions in pp scatterings.

ALICE is uniquely placed to play a significant role in the low and intermediate \( p_T \) \( (p_T: \) transverse momentum) sector.

2 Procedure and Physics Results

Heavy-flavour jets are studied by means of two different methods: by reconstructing jets with a heavy-flavour tag (‘heavy-flavour jets’) and by studying correlations between heavy-flavour hadrons with other hadrons (‘D-meson-hadron correlations’).

* A Large Ion Collider Experiment
** Large Hadron Collider
2.1 Heavy-flavour jets

Jets are reconstructed using the anti-$k_T$ algorithm \[3\]. They are tagged as heavy-flavour jets if they have within their constituents: heavy-flavour electrons, D mesons, or beauty mesons (by an indirect measurement).

**Heavy-flavour electron jets.** Electrons resulting from the semi-leptonic decay of heavy-flavour hadrons are used to tag the jets, called heavy-flavour electron (HFe) jets. First, jets are reconstructed using charged tracks. Then a constituent track in each jet is searched for, having the same momentum as the heavy-flavour electrons identified separately (see Ref. \[4\] for a detailed description of the ALICE apparatus).

\[\begin{array}{c}
\text{Fig. 1. } R_{pPb}\text{ of HFe jets with } R = 0.3, 0.4, \text{ and } 0.6.
\end{array}\]

Figure 1 shows the nuclear modification factor $R_{pPb}$ of HFe jets with jet radii $R = 0.3, 0.4,$ and 0.6 in p–Pb collisions at a center of mass energy per nucleon pair, $\sqrt{s_{NN}} = 5.02$ TeV. No cold nuclear matter (CNM) effects are observed.

**D-meson tagged jets.** Jets are tagged if they contain a $D^0$ meson within the jet cone. $D^0$ mesons are reconstructed in the $D^0 \rightarrow K^- \pi^+$ channel. The daughter kaon and pion tracks are replaced by an equivalent $D^0$ constituent, which is then used together with the other charged tracks to reconstruct the jets.

Jet-$p_T$ differential cross section of $D^0$-jets was measured in pp collisions at $\sqrt{s} = 13$ TeV with $R = 0.4$. The $D^0$-jet production cross section was also measured at $\sqrt{s_{NN}} = 5.02$ TeV in pp, p–Pb, and Pb–Pb collisions in 0–20% centrality with $R = 0.3$. The nuclear modification factor is shown for p–Pb and Pb–Pb in Fig. 2 (left panel). $R_{pPb}$ is consistent with unity within uncertainties, while $R_{AA}$ is 0.2 at $p_T \sim 10$ GeV/$c$. On the right panel, it can be seen that the $R_{AA}$ of $D^0$-jets is compatible with that of D mesons.

Fractional momentum ($z_{ch}^{ch}$) carried by the constituent $D^0$ meson along the jet axis was measured for $D^0$-jets in pp collisions at $\sqrt{s} = 7$ TeV, with $R = 0.4$. Hard fragmentation is observed in $5 < p_T^{ch.\text{ jet}} < 15$ GeV/$c$, compatible with leading order (LO) and next-to-leading order (NLO) pQCD predictions, as seen on the left in Fig. 3. However, in $15 < p_T^{ch.\text{ jet}} < 30$ GeV/$c$, there is a hint of softer fragmentation observed in data, seen on the right panel.
Heavy-flavour jets with ALICE

Fig. 2. $R_{PbA}$ and $R_{AA}$ of D-jets (left) and $R_{AA}$ of D-jets, D mesons, and charged jets (right) at $\sqrt{s_{NN}} = 5.02$ TeV.

Fig. 3. $z_{ch}$ differential cross section of $D^0$-jets in pp collisions at $\sqrt{s} = 7$ TeV.

**b-tagged jets.** The property of B mesons having a longer lifetime is exploited here to identify jets originating from b quarks without explicitly reconstructing the B mesons. Jets containing a 3-pronged secondary vertex within the cone are selected since B mesons tend to decay into at least three daughters. Our measurements of jet-$p_T$ differential production cross section of b-jets in p–Pb collisions at $\sqrt{s_{NN}}=5.02$ TeV are in agreement with POWHEG+PYTHIA predictions.

### 2.2 D-meson-hadron correlations

Charm jet fragmentation is also studied using azimuthal ($\Delta\phi$) correlations between D mesons and associated charged hadrons. Two peaks are observed in the $\Delta\phi$ distribution, one at $\Delta\phi \approx 0$, called the near side, and a broader peak at the away side $\Delta\phi \approx \pi$, signifying two leading jets emitted in opposite directions in a collision. No evidence of CNM effects were found (see Fig. 4, left panel) when production of associated tracks was compared across pp and p–Pb collisions, at $\sqrt{s_{NN}} = 5.02$ TeV. No energy dependence could also be observed in pp collisions as seen on the right panel.
Fig. 4. D-meson-hadron azimuthal correlations measured in pp and p–Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV (left), and in pp collisions at $\sqrt{s} = 5.02$, 7, and 13 TeV (right).

3 Summary

ALICE obtained new measurements of HFe jets in pp and p–Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV. Also shown is a first measurement of $D^0$-jets in Pb–Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV in 0–20% centrality with a suppression by a factor of five at $p_T \sim 10$ GeV/$c$. At $\sqrt{s} = 7$ TeV, hard fragmentation for $D^0$-jets was seen in pp collisions in $5 < p_T < 15$ GeV/$c$ along with a hint of softer fragmentation in $15 < p_T < 30$ GeV/$c$ in data when compared to theoretical predictions. Our new measurements of b-tagged jets in p–Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV were also reported. No energy dependence was observed for D-meson-hadron correlations in pp collisions. And there was no evidence of CNM effects in p–Pb collisions for any study reported in this manuscript.

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