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Probing charm-quark fragmentation by correlation and jet measurements in pp collisions with ALICE

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Introduction

Heavy-flavor measurements in ultra-relativistic hadronic collisions hold significance in validating perturbative QCD. The recent observation of an enhanced baryon-to-meson ratio at the low transverse momenta in hadronic collisions compared to e^+e^- and e^-p collisions has disproven the universality of fragmentation fractions across colliding systems [1, 2]. Discrepancies between experimental measurements in hadronic collisions and models that rely on fragmentation functions constrained to e^+e^- and e^-p data have also been obsereved. Charm-tagged jets measurements and azimuthal correlations between charmed hadrons and other charged particles offer supplementary insights into charm fragmentation mechanisms.

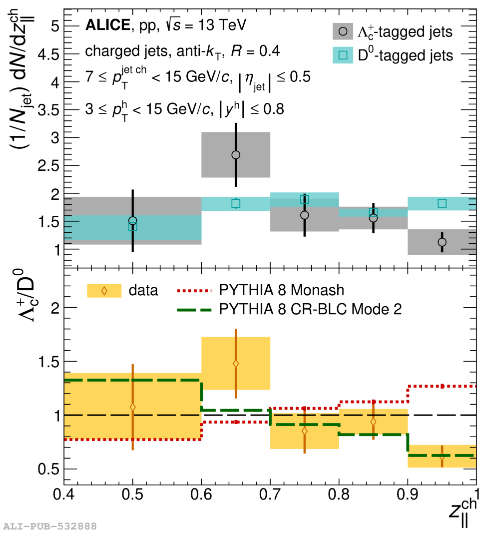

FIG. 1: Jet parallel-momentum fraction distribution for D^0 and Λ_c^+.

Heavy-flavour tagged jets

Measurements of heavy-flavour tagged jets provide a unique sensitivity to explore the mechanisms involved in the production of heavy quarks and contributions from higher-order processes, such as gluon splitting and flavour excitation. The hardness of the fragmentation of charm quarks into hadrons can be accessed by investigating the relation between the hadron momentum along the jet direction with respect to the momentum of the charged jets by introducing the parallel jet momentum fraction $z_{||}^{\text{ch}}$, as defined in Eq. 1.

$$z_{||}^{\text{ch}} = \frac{\vec{p}^{\,\text{HF}} . \vec{p}^{\,\text{ch jet}}}{\vec{p}^{\,\text{ch jet}} . \vec{p}^{\,\text{ch jet}}} \tag{1}$$

Fig. 1 compares the $z_{||}^{\text{ch}}$ distribution of jets containing fully reconstructed D^0 mesons and Λ_c^+ baryons, suggesting a softer fragmentation of charm quarks in baryons than in mesons [3] as predicted by hadronization models which include colour correlations beyond leading-colour in the string formation.

In the realm of Quantum Chromodynamics (QCD), the features of parton showers is contingent upon the mass of the emitting parton. This dependence arises from the presence of the dead-cone effect, which predicts a suppression of the gluon spectrum emitted by a

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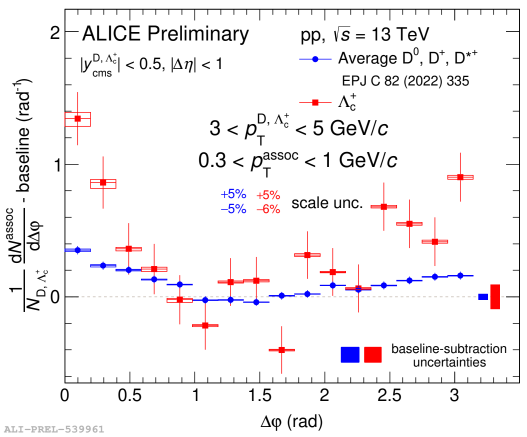

FIG. 2: Distribution of azimuthal correlations between Λ_c^+/D^0 and charged particles.

heavy quark of mass m and energy E, within a cone of angular size m/E around the emitter. ALICE has observed for the first time the dead-cone effect's impact on heavy-flavour parton showers through the measurement of D^0-tagged jets in pp collisions [4] confirming a fundamental feature of QCD. Furthermore, the measurement of a dead-cone angle constitutes a direct experimental observation of the non-zero mass of the charm quark, which is a fundamental constant in the standard model of particle physics..

Azimuthal correlations between charm hadrons and charged particles

To gain a more profound understanding of charm-quark fragmentation, ALICE has measured the azimuthal correlations between charm hadrons and charged particles. [5].

For the first time, ALICE has measured azimuthal correlation distributions of Λ_c^+ baryons and charged particles in pp collisions at $\sqrt{s} = 13$ TeV. Comparing these measurements with previous measurements of D meson-charged particles in the same collision system can offer insights into potential modifications of charm fragmentation and provide clues regarding different hadronization mechanisms when the final state comprises either mesons or baryons. A notable discrepancy for $3 < p_T^{D,\Lambda_c^+} < 5$ GeV/c and $0.3 < p_T^{asssoc} < 1$ GeV/c can be observed, as illustrated in Fig. 2, suggesting a larger multiplicity of low-momentum associated particles produced either collimated or in the opposite direction to the Λ_c^+ baryon. Besides effects induced by different charm hadronization mechanisms, this enhancement could potentially be explained by assuming a softer fragmentation of Λ_c^+ baryons compared to that into D mesons. This translates to a higher initial energy of the charm parton and, consequently, a larger phase space available for the production of other fragmenting particles.

Acknowledgments

The author expresses gratitude for the financial support provided by DST-INDIA project.

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