PROCEEDINGS OF SCIENCE

ALICE measurements of inclusive untagged and heavy flavor-tagged jets in pp, p–Pb and Pb–Pb collisions

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In these proceedings we report on heavy-flavour jet measurements performed by the ALICE Collaboration in pp and p–Pb collisions at $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV. While the presented pp results will focus on discussion of the dead cone effect and production of D^0 and Λ_c^+ hadrons in a jet, the new b-jet results constrain the magnitude of cold nuclear matter effects in p–Pb down to charged-particle jet transverse momentum 10 GeV/c. Finally, recent measurements of leading subjet fragmentation functions of inclusive charged-particle jets in pp and Pb–Pb collisions at $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV will be presented.

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Quarks and gluons produced by processes with high-Q^2 transfer lose their initial virtuality by fragmentation and create partonic showers. These showers subsequently hadronize into collimated sprays of hadrons, the so-called jets. In order to recover the four-momentum of the original parton, produced particles are grouped into jets using infrared and collinear safe algorithms (anti-k_{T}, Cambridge/Aachen, k_{T}) [1]. Jets originating from c- or b-quark fragmentation are referred to as heavy-flavour (HF) jets. They are usually identified by means of topological selection criteria that are sensitive to the presence of a displaced secondary decay vertex from a HF-hadron decay, or the presence of a HF-decay electron in the jet. The production rate of HF jets is calculable using perturbative quantum chromodynamics (QCD). In contrast to the production of inclusive untagged jets, which stem predominantly from gluon fragmentation in the LHC energy regime, the large mass of the HF quarks allows for calculating the HF jet production to lower transverse momenta. These proceedings present recent measurements of HF jets and inclusive untagged jets by ALICE. The ALICE detector is described in detail in [2]. Jets were reconstructed from charged-particle tracks measured in the ALICE central barrel, where the Inner Tracking System detector (ITS) performs precise localization of HF-hadron decay vertices.

Production of b jets in p–Pb and pp collisions at $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV

The ALICE collaboration uses two independent methods for b-jet tagging [3]. The impact parameter method identifies a b-jet candidate by looking for a jet with a constituent track having a large distance of closest approach from the primary vertex. The secondary vertex method searches for a well defined and displaced secondary vertex constructed out of a triplet of jet constituent tracks. After correcting the raw transverse momentum (p_{T}) spectrum of b-jet candidates for efficiency and purity of the b-jet tagging, and momentum smearing due to detector effects and local background fluctuations, both methods yield consistent results. The resulting p_{T} differential cross-section spectra of b jets from pp and p–Pb collisions are shown in Fig. 1. The spectra are compared with the prediction of the next to leading order generator POWHEG [4] with PYTHIA 8 fragmentation [5].

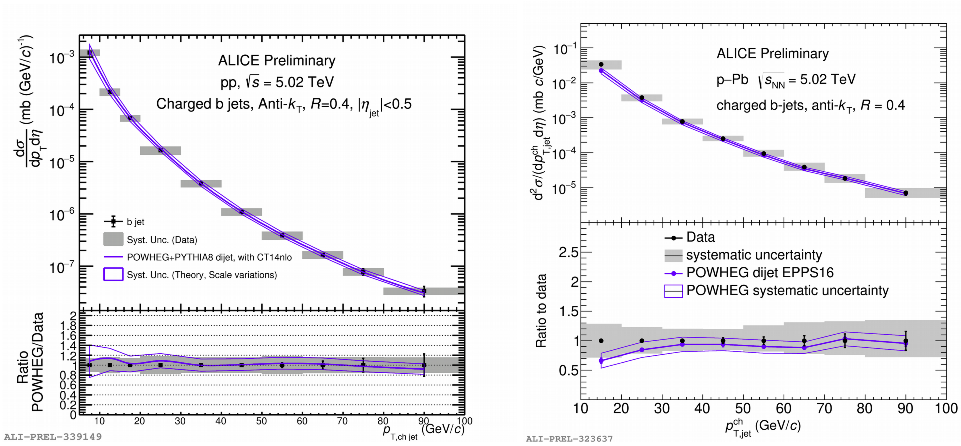

Figure 1: Top panels: The differential production cross section of charged-particle anti-k_{T} $R = 0.4$ b jets measured in pp (left) and p–Pb (right) collisions at $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV. The data are compared with a NLO pQCD prediction by the POWHEG dijet tune with PYTHIA 8 fragmentation. Systematic and statistical uncertainties are shown as boxes and error bars, respectively. Bottom panels: Ratio of the theory calculations to the data.

The POWHEG+PYTHIA simulation also reproduces the fraction of b jets among untagged jets in pp collisions, as shown in the left panel of Fig. 2. In the range up to 100 GeV/c, b jets constitute less than 4% of all jets. The spectra from Fig. 1 were further used to evaluate the nuclear modification factor, R_{pPb}, which is for minimum bias collisions defined as the ratio of the b-jet cross section measured in p–Pb and analogous cross section measured in pp scaled by A. Here A=208 is the number of nucleons in Pb. The measured R_{pPb} indicates that the impact of the possible cold/hot nuclear matter effects on the b-jet spectrum in p–Pb is small and is below the resolution of the measurement. The nuclear modification factor of charged b jets is compatible with an analogous measurement provided by the CMS collaboration for full jets [6].

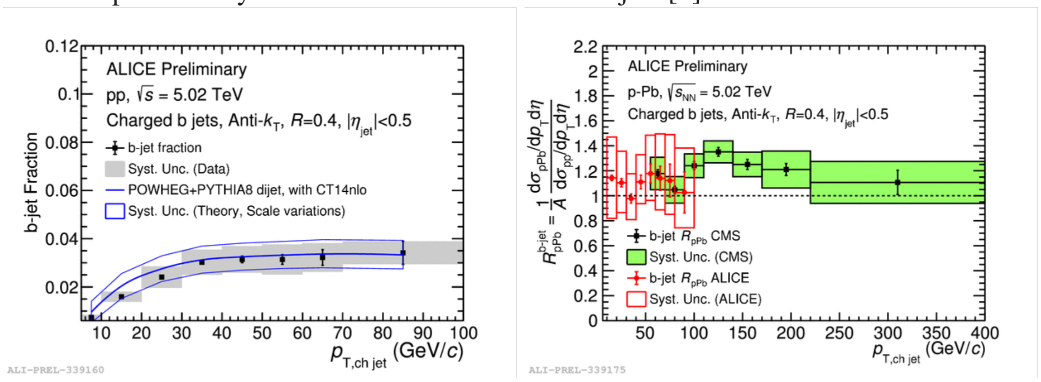

Figure 2: Left: The b-jet fraction in pp collisions at $\sqrt{s} = 5.02$ TeV compared with POWHEG NLO pQCD calculations with the PYTHIA 8 fragmentation. Right: The nuclear modification factor R_{pPb} for charged-particle b jets measured by the ALICE experiment, compared with the b-jet measurement from the CMS experiment [6]. CMS measured $R = 0.3$ full b jets in the pseudorapidity range $-2.5 < \eta_{\mathrm{jet}} < 1.5$.

Manifestation of the dead-cone effect for D^0-tagged jets

The dead-cone prevents a heavy quark to radiate gluons to a forward cone [7]. The opening angle of this cone is proportional to the ratio of quark mass and energy, therefore this effect should be more prominent for heavy quarks having low p_{T}. Using the iterative declustering technique, ALICE studied the angular distribution of splittings radiated from a charm quark in D^0 tagged jets and compared them with an equivalent distribution measured for untagged jets [8]. Figure 3 shows the ratio of both distributions in three bins of radiator energy. One can see suppression of the forward radiation in the lowest radiator energy bin, while this effect vanishes when the energy increases. This measurement represents the first direct observation of the dead-cone effect in pp.

Subjet fragmentation in pp and Pb–Pb

This analysis focuses on the measurements of the fraction of the momentum carried by the leading subjets, $z_r = p_{\mathrm{T,subjet}}/p_{\mathrm{T,jet}}$. The leading subjets were obtained by reclustering constituents of an original charged-particle anti-k_{T} jet with $R = 0.4$ using the anti-k_{T} algorithm with a smaller jet radius. This study is suitable to test the universality of jet fragmentation functions and to investigate differences between quark and gluon jets. Figure 4 demonstrates the first measurements of the subjet fragmentation function in pp and 0–10% central Pb–Pb collisions at $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV. In the intermediate range of the fragmentation variable, we see a hardening of the subjet fragmentation function in Pb–Pb relative to pp. Such behaviour could be explained by two effects: a larger suppression of gluon jets by the medium than quark jets, and medium-induced emissions from quark jets. The latter effect could also be responsible for a hint of depletion when $z_r \to 1$. The

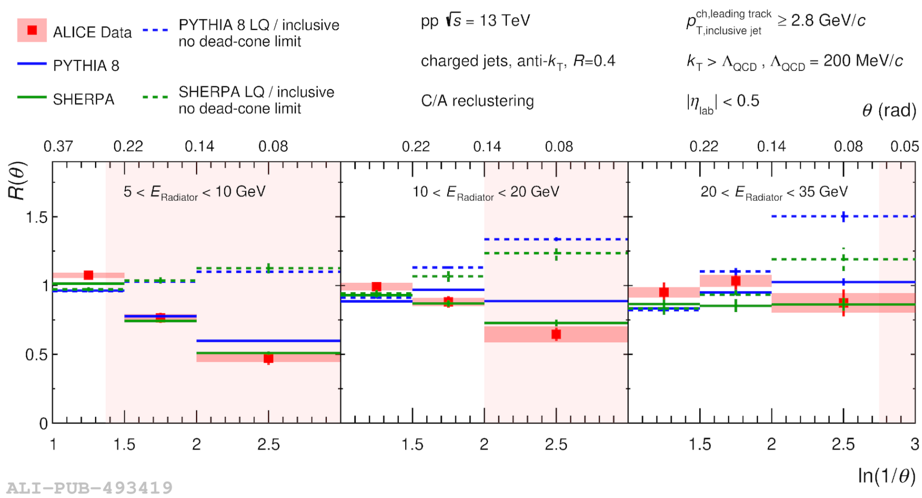

Figure 3: The ratios of the splitting-angle probability distributions for D^0-meson tagged jets to inclusive untagged jets measured in pp collisions at $\sqrt{s} = 13$ TeV. The three panels correspond to three exclusive radiator energy ranges. The measured data is compared with PYTHIA 8 and SHERPA. Taken from [8].

measured trend of the ratio is captured by medium jet functions [9] as well as by a JETSCAPE model calculation [10].

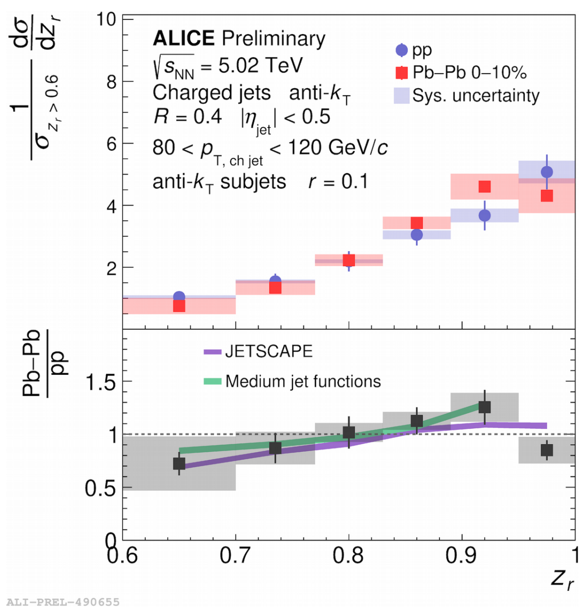

Figure 4: Top: Measurement of leading subjet z_r distributions in proton-proton and central Pb–Pb collisions. Bottom: The ratio of the measured distribution is compared with theoretical predictions by JETSCAPE and medium jet functions.

In summary, these proceedings presented several ALICE measurements of inclusive untagged and HF-tagged jets in pp, p–Pb and Pb–Pb collisions. The ALICE measurements of b-jet R_{pPb} at $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV are compatible with unity suggesting that CNM effects are smaller than the resolution of the measurement. The study of the angular distribution of splittings radiated from a charm quark in D^0-tagged jets provides the first direct observation of the dead-cone effect in pp

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collisions, and finally subjet fragmentation functions in Pb–Pb and pp collisions are shown to be affected by jet quenching.

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