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Multiplicity dependence of intra-jet properties in small collision systems with ALICE

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Measurements of jet fragmentation and jet properties in pp collisions provide a test of perturbative quantum chromodynamics (pQCD) and form a baseline for similar measurements in heavy ion (AA) collisions. In addition, jet measurements in pA collisions are sensitive to cold nuclear matter effects. Recent studies of high-multiplicity final states of small collision systems exhibit signatures of collective effects that could be associated with hot and dense, color-deconfined QCD matter, which is known to be formed in collisions of heavier nuclei. The modification of the jet fragmentation pattern and jet properties is expected in the presence of such QCD matter. Measurements of jet fragmentation patterns and other jet properties in pA collisions are needed in order to establish whether deconfined QCD matter is indeed generated in such small systems. In this contribution, we present measurements of intra-jet properties for leading charged-particle jets in minimum bias p–Pb collisions at $\sqrt{s_{\rm NN}}$ = 5.02 TeV and in minimum bias and high multiplicity pp collisions at $\sqrt{s}$ = 13 TeV. Results are compared with theoretical model predictions.

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1. Introduction

Jets are the key ingredients to test perturbative quantum chromodynamics (pQCD) predictions and jet properties are sensitive to the details of the parton showering process that are expected to get modified in the presence of a dense partonic medium. Measurements of intra-jet properties in p–Pb collisions are useful to investigate cold nuclear matter effects [1] and to enrich our current understanding of particle production in such collision systems. In addition, jet measurement in small collision system, particularly at high-multiplicity, is important to understand the onset of QGP-like effects in such systems. In this work, we report measurements of charged-particle jet properties, including mean charged-particle multiplicity and fragmentation distribution for leading jets, in minimum bias pp collisions at $\sqrt{s}$ = 13 TeV and p–Pb collisions at $\sqrt{s_{\mathrm{NN}}}$ = 5.02 TeV. In addition, the multiplicity dependence of these jet properties in pp collisions at $\sqrt{s}$ = 13 TeV is also presented. We also compare the results with different Monte Carlo models.

2. Analysis details

The data presented here were recorded with the ALICE detector during 2016, 2017 and 2018. Events with a primary vertex within 10 cm from the nominal interaction point along the beam direction ($|z_{\mathrm{vertex}}| = 0$) are considered. A trigger condition that requires the coincidence of signals in the V0A and V0C forward scintillator arrays [2] in ALICE is used to select minimum bias (MB) events whereas high multiplicity (HM) events in pp collisions are selected using a trigger condition requiring the sum of V0A and V0C amplitudes to be more than 5 times the mean MB signal.

Charged tracks with $p_{\mathrm{T}} > 0.15$ GeV/c within a pseudorapidity range $|\eta| < 0.9$ over the full azimuth are used to reconstruct charged-particle jets using the anti-k_{T} jet finding algorithm [3] with the p_{T}-recombination scheme of the FastJet package [4] with jet resolution parameter $R = 0.4$. The mean charged-particle multiplicity within charged-particle jets ($\langle N_{\mathrm{ch}} \rangle$) and jet fragmentation function ($1/N_{\mathrm{jets}} dN/dz^{\mathrm{ch}}$ with $z^{\mathrm{ch}} = p_{\mathrm{T,track}}/p^{\mathrm{ch}}_{\mathrm{T,jet}}$, where $p_{\mathrm{T,track}}$ is the p_{T} of jet constituent inside the leading-jet cone) are studied for leading jets (highest p_{T} jet in an event) in the interval of jet p_{T} = 5–110 GeV/c for pp and 10–100 GeV/c for p–Pb collisions.

The contribution from the underlying event (UE; coming from sources other than the hard-scattered partons) in the jet observables ($\langle N_{\mathrm{ch}} \rangle$ and z^{ch}) is estimated using the perpendicular-cone method [5–7] and subtracted on a statistical basis after unfolding. To correct for instrumental effects, a 2-D Bayesian unfolding technique [8] implemented in the RooUnfold [9] package is applied. Systematic uncertainties from various sources such as tracking efficiency, modelling of the jet properties and the detector response in the MC simulation, choice of regularization parameter or number of iterations in Bayesian unfolding, change in prior distribution, and underlying event contribution are estimated and added in quadrature to calculate the total systematic uncertainty.

3. Results and discussion

It is observed that $\langle N_{\mathrm{ch}} \rangle$ increases with jet p_{T} in both minimum bias pp (Fig. 1: top left) and p–Pb (Fig. 1: bottom left) collisions. For p–Pb collisions, DPMJET [10] (GRV94 [11]) explains the $\langle N_{\mathrm{ch}} \rangle$ distributions within systematic uncertainties except at low jet p_{T} and for pp

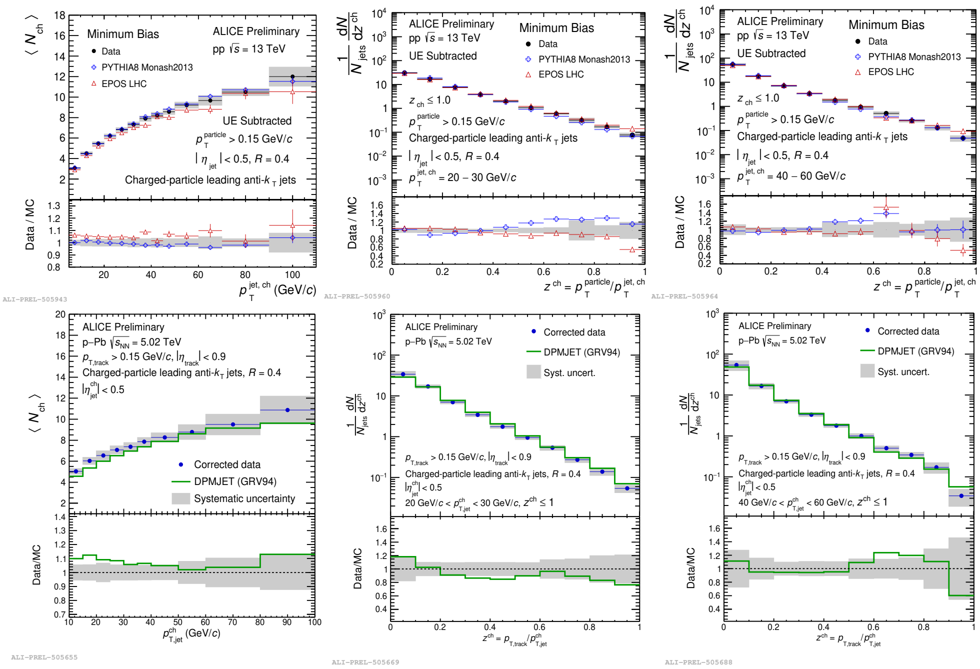

Figure 1: $\langle N_{\rm ch}\rangle$ as a function of jet $p_{\rm T}$ (left) and $z^{\rm ch}$ distributions for different jet $p_{\rm T}$ (middle, right) in minimum bias pp (top) and p–Pb (bottom) collisions.

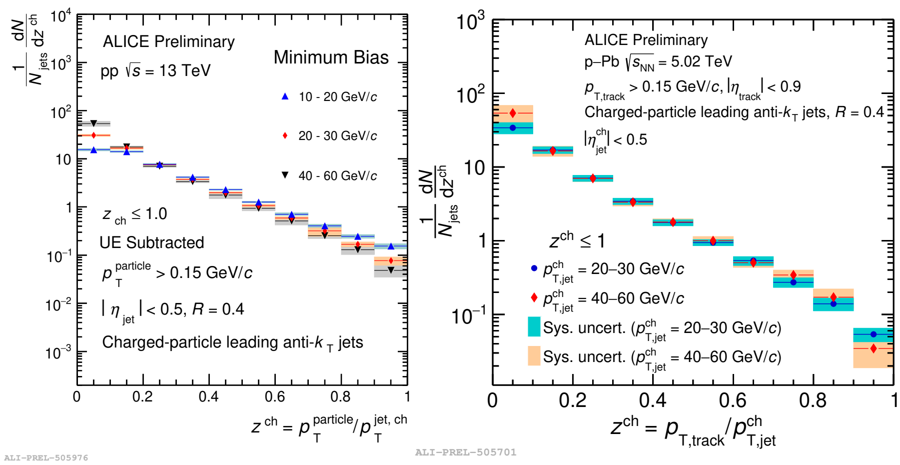

Figure 2: $z^{\rm ch}$ distributions for different jet $p_{\rm T}$ in minimum bias pp (left) and p–Pb (right) collisions.

collisions, EPOS LHC [12] underestimate the data whereas PYTHIA8 Monash 2013 [13] explains the data within systematic uncertainties. For the $z^{\rm ch}$ distributions in p–Pb collisions (Fig. 1: bottom middle and bottom right), DPMJET (GRV94) explains the measured distributions within systematic uncertainties. Both EPOS LHC and PYTHIA8 Monash 2013 are able to explain the $z^{\rm ch}$ distributions in pp collisions (Fig. 1: top middle and top right), however, EPOS LHC describes the data better than PYTHIA8 Monash 2013 for $20 < p_{\rm T,jet}^{\rm ch} < 30$ GeV/c at low $z^{\rm ch}$ values (Fig. 1: top middle). A

z^{ch} scaling is observed for different jet p_{T} in minimum bias pp (Fig. 2: left) and p–Pb (Fig. 2: right) collisions (except for very high and low z^{ch} values in pp collisions).

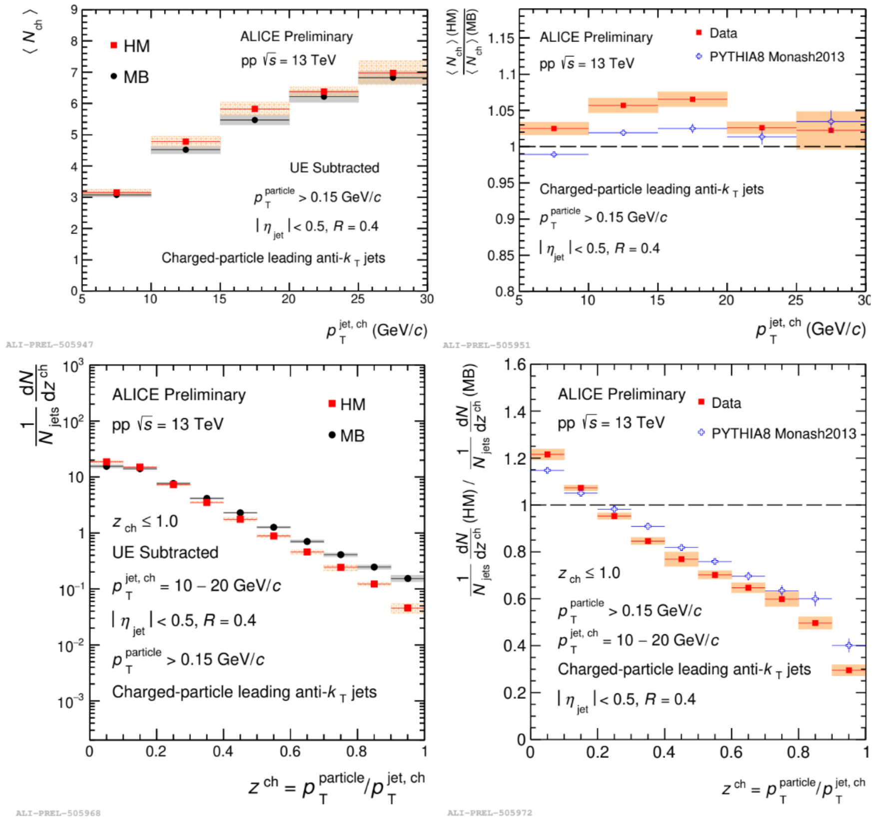

Figure 3: $\langle N_{\mathrm{ch}} \rangle$ as a function of jet p_{T} (top left) and z^{ch} (bottom left) distributions for HM and MB events in pp collisions and their corresponding ratios (top right and bottom right).

In high multiplicity pp collisions, $\langle N_{\mathrm{ch}} \rangle$ is slightly larger than that in minimum bias pp collisions (Fig. 3: top). A significant modification in z^{ch} distributions in HM events compared to MB events in pp collisions indicates softening of jets in HM events (Fig. 3: bottom). The amount of modification is beyond the effect one would obtain due to only the change in the shape of jet p_{T} spectra in high multiplicity events compared to the minimum bias ones.

4. Summary

We have measured intra-jet properties for leading charged-particle jets in minimum bias p–Pb collisions at $\sqrt{s_{\mathrm{NN}}}$ = 5.02 TeV and in minimum bias and high multiplicity pp collisions at $\sqrt{s}$ = 13 TeV in ALICE. Results are compared with different theoretical MC predictions. We have observed significantly softer jet fragmentation in HM events compared to MB events in pp collisions. Jet fragmentation scaling is also observed for different jet p_{T} in both minimum bias pp and p–Pb collisions.

References

[1] N. Armesto, *Small collision systems: Theory overview on cold nuclear matter effects*, *EPJ Web Conf.* **171** (2018) 11001.

[2] ALICE collaboration, *ALICE technical design report on forward detectors: FMD, T0 and V0*, .

[3] M. Cacciari, G.P. Salam and G. Soyez, *The anti-k_t jet clustering algorithm*, *JHEP* **04** (2008) 063 [0802.1189].

[4] M. Cacciari, G.P. Salam and G. Soyez, *FastJet User Manual*, *Eur. Phys. J. C* **72** (2012) 1896 [1111.6097].

[5] CDF collaboration, *Charged Jet Evolution and the Underlying Event in $p\bar{p}$ Collisions at 1.8 TeV*, *Phys. Rev. D* **65** (2002) 092002.

[6] ALICE collaboration, *Charged jet cross sections and properties in proton-proton collisions at $\sqrt{s}$ = 7 TeV*, *Phys. Rev. D* **91** (2015) 112012 [1411.4969].

[7] ALICE collaboration, *Measurement of charged-particle jet properties in p–Pb collisions at $\sqrt{s_{\rm NN}}$ = 5.02 TeV with ALICE*, in *Hot QCD Matter 2022*, 8, 2022 [2208.01389].

[8] G. D'Agostini, *A Multidimensional unfolding method based on Bayes' theorem*, *Nucl. Instrum. Meth. A* **362** (1995) 487.

[9] "Roounfold package." https://gitlab.cern.ch/RooUnfold/RooUnfold.

[10] S. Roesler, R. Engel and J. Ranft, *The Monte Carlo event generator DPMJET-III*, in *International Conference on Advanced Monte Carlo for Radiation Physics, Particle Transport Simulation and Applications (MC 2000)*, pp. 1033–1038, 12, 2000, DOI [hep-ph/0012252].

[11] A. Vogt, *On dynamical parton distributions of hadrons and photons*, in *3rd Workshop on Deep Inelastic Scattering and QCD (DIS 95)*, pp. 261–264, 7, 1995 [hep-ph/9507241].

[12] T. Pierog, I. Karpenko, J.M. Katzy, E. Yatsenko and K. Werner, *EPOS LHC: Test of collective hadronization with data measured at the CERN Large Hadron Collider*, *Phys. Rev. C* **92** (2015) 034906 [1306.0121].

[13] P. Skands, S. Carrazza and J. Rojo, *Tuning PYTHIA 8.1: the Monash 2013 Tune*, *Eur. Phys. J. C* **74** (2014) 3024 [1404.5630].