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Exploring jet profiles in Pb-Pb collisions at 5.02 TeV with the ALICE detector

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Abstract

In this contribution, we present measurements of inclusive jet production with the ALICE detector in Pb-Pb collisions at $\sqrt{s_{\rm NN}}$ = 5.02 TeV. Production cross sections of charged particle jets and fully reconstructed jets are measured with jet resolution parameters $R = 0.2$ and 0.3. To quantify the medium induced parton energy loss, jet nuclear modification factors ($R_{\rm AA}$) are measured by utilizing POWHEG+Pythia8 predictions as reference cross section in pp collisions. We also calculate the ratio of jet production cross sections for jets reconstructed with different cone radii to explore the jet radial profile in Pb-Pb collisions. The ratios of jet cross sections are compared to a pp reference predicted by POWHEG+Pythia8 and in-medium energy loss model prediction by the JEWEL Monte Carlo event generator.

Keywords:
jet; heavy-ion; parton energy loss

1. Introduction

Jets, collimated sprays of high momentum particles originating from initial hard scattered partons, are well calibrated probes to study the properties of the Quark-Gluon Plasma (QGP) formed in ultra relativistic heavy ion collisions. They allow to probe the entire evolution of the QGP since they stem from partons created at the very early stages of the collisions. Futhermore, their production cross section and profiles in elementary pp collisions are calculable within the framework of perturbative QCD (pQCD). Hence, any modification observed in heavy-ion collisions compared to an incoherent sum of individual pp collisions could be attributed to in-medium effects. Such modifications, called jet quenching, have been measured in high-energy heavy-ion collisions [1], and were interpreted as partonic energy loss in the QGP. Jet quenching effects have been explored with charged hadrons and jet observables in Pb-Pb collisions at $\sqrt{s_{\rm NN}}$ = 2.76 TeV at the LHC [2, 3, 4]. To quantify the partonic energy loss in the QGP in Pb-Pb collisions at the currently highest available centre-of-mass energy $\sqrt{s_{\rm NN}}$ = 5.02 TeV, we measured the nuclear modification factors ($R_{\rm AA}$) for charged particle jets and fully reconstructed jets including neutral components as a function of jet $p_{\rm T}$. $R_{\rm AA}$ is the ratio of inclusive jet yields per event in Pb-Pb collisions over binary scaled jet yields per

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event in pp collisions, and it can be fomulated as

$$R_{\mathrm{AA}} = \frac{\mathrm{d}N^{\mathrm{AA}}/\mathrm{d}p_{\mathrm{T}}}{\langle N_{coll}\rangle\,\mathrm{d}N^{\mathrm{pp}}/\mathrm{d}p_{\mathrm{T}}} = \frac{\mathrm{d}N^{\mathrm{AA}}/\mathrm{d}p_{\mathrm{T}}}{\langle T_{\mathrm{AA}}\rangle\,\mathrm{d}\sigma^{\mathrm{pp}}/\mathrm{d}p_{\mathrm{T}}} \tag{1}$$

where, N^{AA} and N^{pp} are the jet yields in AA collisions and pp collisions, and σ^{pp} is the jet cross section in pp collisions. $\langle N_{coll}\rangle$ is the average number of binary nucleon-nucleon collisions in AA collisions. The average nuclear overlap function $\langle T_{\mathrm{AA}}\rangle$ is calculated from the ratio of $\langle N_{coll}\rangle$ to the total inelastic cross section in pp colisions. The R_{AA} deviation from unity quantifies the strength of nuclear effects and can be interpreted as the effect of the jet quenching if the R_{AA} is less than unity. Jet production cross section ratios for jets reconstructed with different cone radii is also calculated to explore jet shape modifications in AA collisions. Cross section ratios can provide information about jet shape modifications due to energy re-distributions caused by jet quenching effects [5, 6].

2. Experimental setup and analysis method

The minimum bias data samples of Pb-Pb collisions collected with the ALICE detector in 2015 is used for this analysis. 68×10^6 Pb-Pb collisions of 0-80% centrality are analyzed for the charged particle jet measurement and 4.5×10^6 Pb-Pb collisions of 0-10% centrality are analyzed for full jet measurement. Charged particle jets were reconstructed with charged tracks detected by the Time Projection Chamber (TPC) and Inner Tracking System (ITS) which consists of three different types of silicon detectors. The tracks with $p_{\mathrm{T}} > 0.15\mathrm{GeV}/c$ in $|\eta| < 0.9$ over full azimuth are used for jet reconstruction. For full jets, neutral components are mesured with the ElectroMagnetic Calorimeter (EMCal) covering $|\eta| < 0.7$ and $80^\circ < \phi < 188^\circ$. To avoid double counting of the charged energy, each EMCal clusters were corrected for hadronic contamination. Charged tracks are propergated to the EMCal surface and the sum of momenta of matched tracks are subtracted from the cluster energy. Signal jets are reconstructed with the anti-k_{T} clustering algorithm utilizing the FastJet software package [7, 8]. Jet resolution parameters $R = 0.2, 0.3$ are chosen for this study. In heavy-ion collisions, a large background from soft interactions has to be subtracted. The event-by-event average background p_{T} density, ρ, is subtracted from each anti-k_{T} jet as follows

$$p_{\mathrm{T,jet}}^{Corr} = p_{\mathrm{T,jet}}^{Raw} - \rho \cdot A_{\mathrm{jet}} \tag{2}$$

where, A_{jet} is the reconstructed jet area and $p_{\mathrm{T,jet}}^{Raw}$ is the jet p_{T} before background subtraction. ρ is calculated as the median value of k_{T} clusters transverse momentum densities reconstructed in an event. A minimum leading track p_{T} cut of 5 GeV/c is also applied to reduce the combinatorial fake jet contamination. The measured jet spectra are smeared by detector and background fluctuation effects. These effects are corrected by SVD unfolding [9]. The detector response is evaluated by a GEANT3-based full simulation with the Pythia8 as the primary particle generator [10, 11]. Background fluctuations are evaluated by a random cone method for charged particle jets and by embedding Pythia events into Pb-Pb collisions for full jets.

3. Results

3.1. Nuclear modification factor for charged particle jets

Fig.1 shows the R_{AA} for $R = 0.2$ and 0.3 charged particle jets as a function of jet transverse momenta and for four centrality classes. The R_{AA} are calculated by using POWHEG+Pythia8 [12] simulations as a pp reference. We observe a strong jet suppression for central collisions which vanished for more peripheral collisions. No significant cone radii dependence is observed for charged particle jet R_{AA} within current uncertainties.

3.2. Cross sectio ratios for charged particle jets

Cross section ratios for charged particle jet production are shown in Fig.2. The ratios in Pb-Pb collisions are compared to a pp reference predicted by POWHEG+Pythia8. A small descrepancy between the pp reference and Pb-Pb collisions are seen especially for central collisions at lower p_{T}.

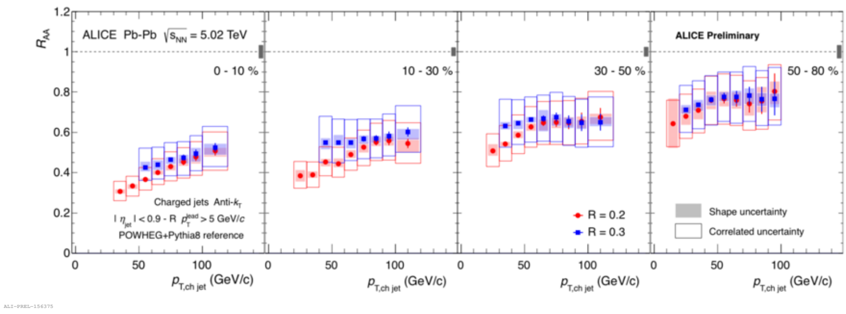

Fig. 1: Nuclear modification factor (R_{AA}) of $R = 0.2$ and 0.3 charged particle jets for four centrality intervals (0-10%, 10-30%, 30-50%, 50-80%).

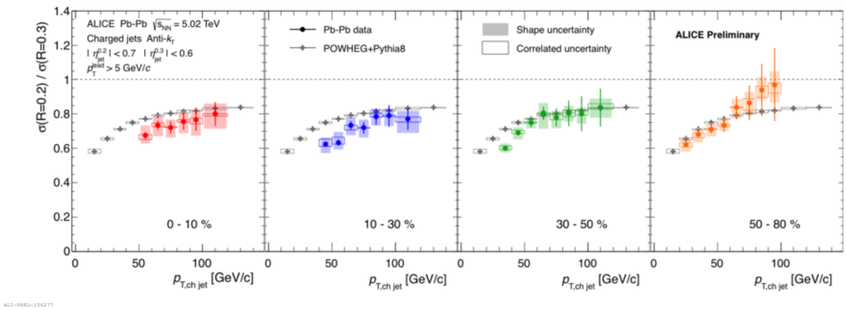

Fig. 2: Cross section ratio ($\sigma(R = 0.2)/\sigma(R = 0.3)$) of charged particle jets for four centrality intervals (0-10%, 10-30%, 30-50%, 50-80%).

3.3. Nuclear modification factor for Full jets

Fig.3 shows the R_{AA} for $R = 0.2$ and 0.3 full jets as a function of jet transverse momentum. The R_{AA} are calculated by using POWHEG+Pythia8 simulations as a pp reference. A strong jet suppression for the most central collisions (0-10%) is observed. The suppression factor is similar as that of charged particle jets over the measured p_T range. No significant cone radii depenence is observed within current uncertainties.

3.4. Cross section ratios for full jets

Cross section ratios for full jet are shown in Fig.4. The ratios in Pb-Pb collisions are compared to a pp reference predicted by POWHEG+Pythia8 and in-medium energy loss model calculations given by JEWEL [13]. JEWEL predictions are made with two options. The first one (recoils on) is taking into account the medium response by keeping recoil partons while the second (recoils off) does not. All results are consistent within uncertainties.

4. Summary

The charged particle jet and fully reconstructed jet production in Pb-Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV are measured. Nuclear modification factors are calculated for $R = 0.2$ and 0.3 jets as a function of jet transverse momentum by utilizing a POWHEG+Pythia8 prediction as pp reference. A similar jet suppression is observed in Pb-Pb collisions of 0-10% centrality for both charged particle and full jets. A significant

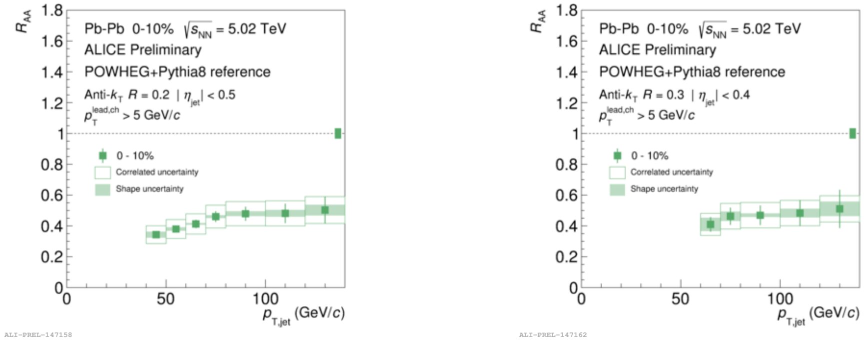

Fig. 3: Nuclear modification factor (R_{AA}) of R = 0.2 (left) and 0.3 (right) fully reconstructed jets for central collisions (0-10%).

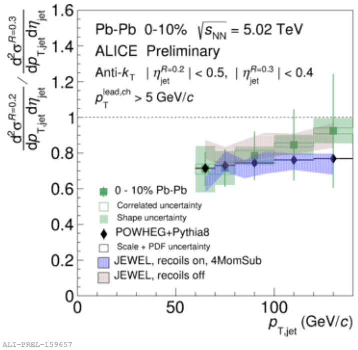

Fig. 4: Cross section ratio ($\sigma(R = 0.2)/\sigma(R = 0.3)$) of fully reconstructed jets for central collisions (0-10%).

centrality dependence of R_{AA} is observed for charged particle jets, which could be the signature of system size and/or initial energy density dependence of jet quenching. Cross section ratios ($\sigma(R = 0.2)/\sigma(R = 0.3)$) of full jets show no significant difference with the POWHEG+Pythia8 pp reference and model predictions by JEWEL over the measured transverse momentum range. On the other hand, the ratio of charged particle jets shows smaller values than the POWHEG+Pythia8 pp reference at low jet p_T in Pb-Pb collisions from 0-10% to 30-50% centrality. It may be a hint of jet broadening in Pb-Pb collisions even though the effect is not significant within current errors.

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