Study of medium modified jet shape observables in Pb-Pb collisions at $\sqrt{s_{NN}}$=2.76 TeV using EPOS and JEWEL event generators

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Physics Motivation:

In high energy heavy ion collisions at the RHIC and the LHC energies, a medium with partonic degrees of freedom is formed.One of the early observables that probed the gluon-density of the medium had been the fragments of highly energetic partons in terms of high p_T leading particles and reconstruction of full jets at the RHIC and LHC energies. Initially, global jet-observables in the form of suppression of both the leading particles and jets, commonly known as jet-quenching have been used to probe the gluon-density of the medium.

Now, energy loss of partons by radiation or collision is expected to modify the fragmentation function of the incoming partons. It is expected that during the process of energy loss and hadronization, the internal structure of jet also undergoes modification. Measurements of observables like transverse spread of energy and momentum of the jet fragments in central heavy ion collisions and its comparison to pp collisions lead to a conclusion that the core of the jet gets harder and the periphery gets extended to a larger radii with softer fragments due to jet-medium interaction. As per theoretical descriptions of jet quenching, high energetic partons suffer energy loss due to interactions with thermal partons in the medium and these scattered medium partons can have an effect on the final jet-shape parameters.

Main motivation of this work: (a) Sensitivity of JEWEL on jet-shape at lower p_T region without considering the recoiled partons. The difference in the pattern compared to the experimental data may help to better understand the effect of the recoiled medium partons on the jet-shape observables (b) Study the jet-shape observables in the same p_T range using EPOS-3 with a simplistic partonic energy loss mechanism and secondary hard-soft interactions during hadronization and hadronic cascade phase.

Observables:

Two observables are studied : differential jet-shape (ρ(r)) and angularity (g) or girth

The differential jet shape describes the radial distribution of the jet transverse momentum density inside the jet cone and is defined as:

$$\rho_r = \frac{1}{\delta r}\frac{1}{N_{jet}}\sum_{jets}\frac{\sum_{tracks\epsilon[r_a,r_b]} p_T^{track}}{p_T^{jet}}$$

The jet cone is divided into several annuli with radial width of δr and each annular ring has an inner radius of r_a = r - δr/2 and outer radius of r_b = r + δr/2.

$$r = \sqrt{(\phi^{track}-\phi^{jet})^2 + (\eta^{track}-\eta^{jet})^2} \leq R$$

r is the radial distance of the track from the jet axis.
The angularity is defined as,

$$g = \sum_{i\epsilon jet}\frac{p_T^i}{p_T^{jet}}|\Delta R_{jet}^i|$$

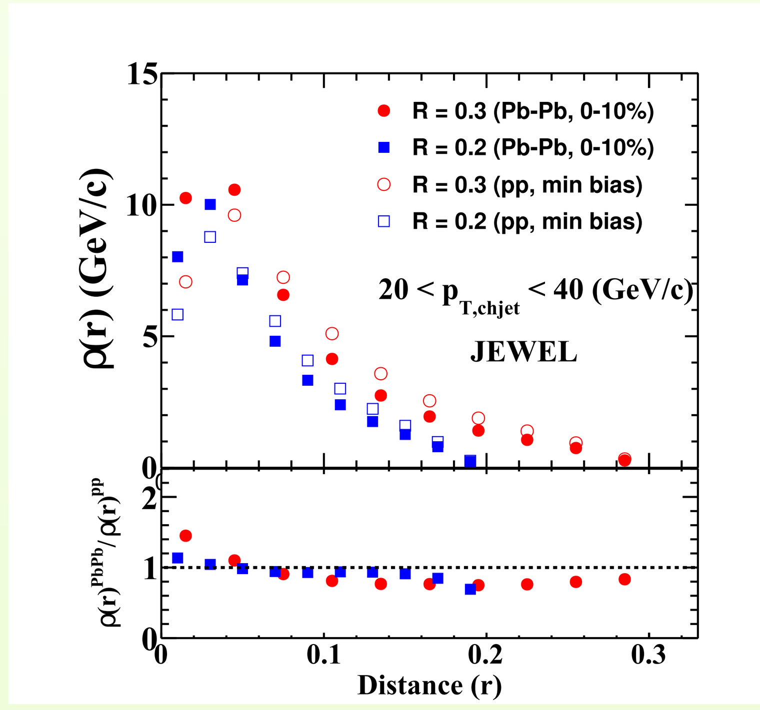
ΔR is the distance between i-th constituent and the jet axis in (η,φ) space. These shape observables describes the radial distribution of the jet energy inside the jet cone

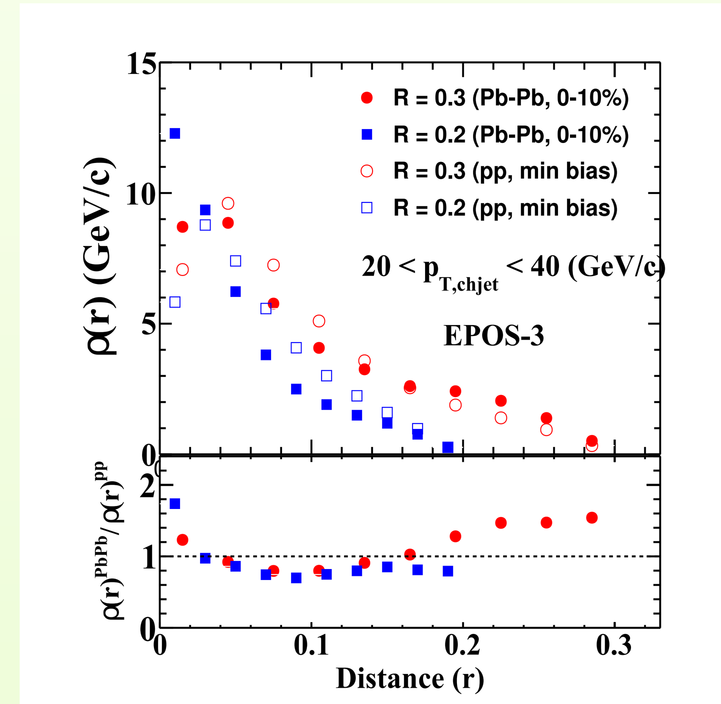
Analysis Strategy:

Charged jets are reconstructed with anti−k_T jet finding algorithm using Fastjet package with two resolution parameters R = 0.2 and R = 0.3 for 20 < $p_{T,ch}^{jet}$ <40 GeV/c. $p_{T,min}$ of the tracks for jet reconstruction is 0.15 GeV/c. Tracks with |η|<0.9 and jets with $|\eta_{jet}|$<0.7 and $|\eta_{jet}|$<0.6 for R = 0.2 and R = 0.3 respectively are selected. The jets having at least one particle with p_T>5 GeV/c are considered to reduce the contribution of the combinatorial jets in the selected jet sample.

We have used pp collisions in JEWEL to represent no medium effect and have compared with Pb-Pb results from both the models. For making the observables on the same footing as of experimental data, we have used JEWEL recoil OFF data without background subtraction and in EPOS, only corona (jet) particles are considered to construct the jet.

Results & discussions:

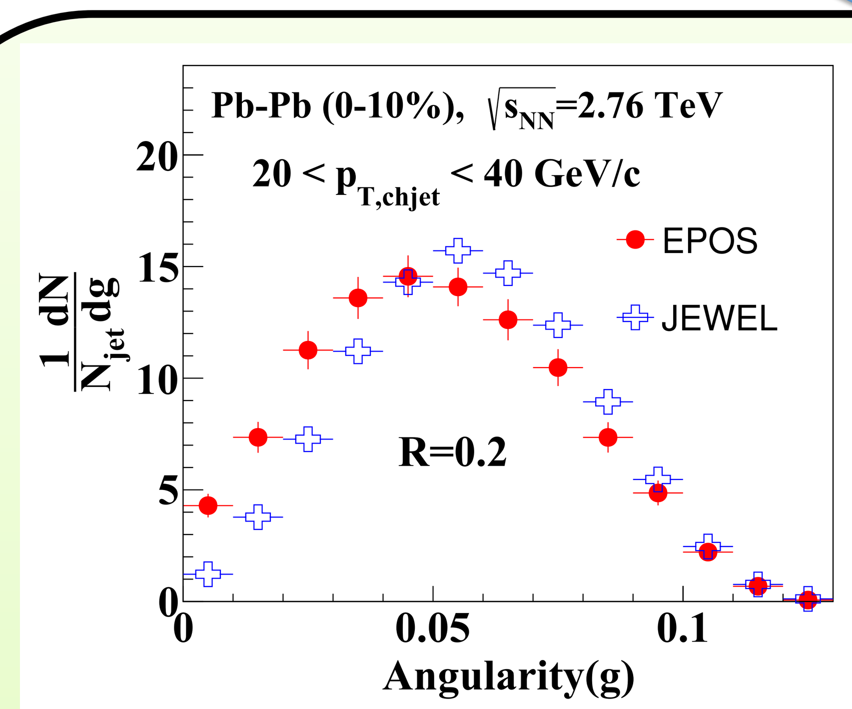


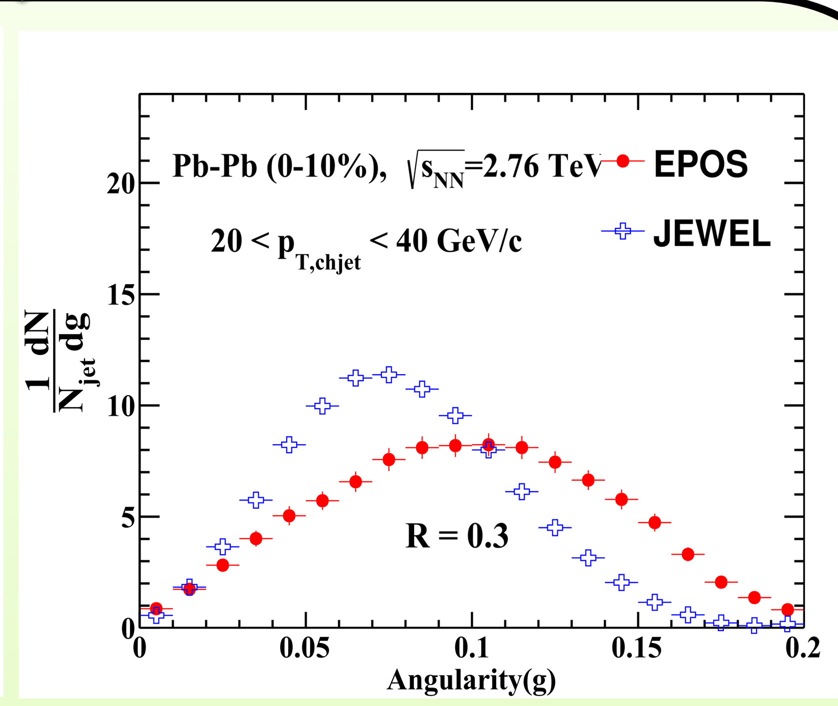


For both the models while going radially outward from the jet-axis, the relative difference in ρ(r) distribution between 0-10% Pb-Pb and minimum bias pp collisions changes ---- indicates a modification in distribution of energy inside jet cone ---- deviation of the ratio from unity indicates a modification to the jet structure in presence of the medium. Compared to the jet-shape in pp, a narrowing of the jet core (at r<0.02) with higher momentum density has been observed in central Pb-Pb collisions for both the models.

Due to in-medium energy loss, jets reconstructed with a fixed R in central Pb-Pb collisions may originate from higher energy initial parton compared to that in pp. As the jet core gets harder with increase in jet momentum and is less affected by the medium, the jet core in central heavy ion collisions can be harder compared to the peripheral and minimum bias pp collisions.
Interestingly, the ratio becomes less than unity at intermediate radii indicating the in-medium energy loss in central PbPb collisions.

Increasing the R to 0.3 includes the energy carried away by softer particles at larger angles from the jet axis. At higher radial distances, while the ratio remains below unity for JEWEL (recoil OFF) but goes above unity for EPOS-3 indicating a moderate broadening of jets at the periphery in EPOS-3. The broadening of jets at the periphery in EPOS-3 is qualitatively consistent with the experimental observations which indicate that the energy lost due to jet-medium interaction is distributed at larger distances from the jet axis and represents a clear signature of medium induced modification to the internal jet structure. These hard-soft interactions in EPOS-3 contribute to the redistribution of the jet energy inside the jet cone and qualitatively describe the jet-shape broadening in heavy ion collisions.





The jet core in EPOS-3 is more collimated than JEWEL. For R=0.2. For large radius(R = 0.3), the medium induced modifications lead to the broadening of thejets at the periphery for both models as shown in Fig.4. The jet in EPOS-3 isharder at core and broader at periphery compared to JEWEL and is consistentwith the differential jet shape measurements shown earlier.

Summary

JEWEL with recoil OFF has been used primarily as a reference system as that has been found to explain the global jet observables satisfactorily but lacks in jet-shape variables at higher jet-radii. EPOS-3 that explains the bulk properties in such collisions quite well takes into account a hydrodynamically evolving bulk matter, jets and hard-soft interactions. A comparison between the results from these models shows that while JEWEL (recoil OFF) does not explain the distribution of lost energy at higher radii with respect to the jet-axis,EPOS-3 explains the effect quite well. However, in EPOS-3, the partonic energy loss mechanism and secondary hard-soft interactions during hadronization and hadronic cascade phase are different from the conventional jet energy loss models

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