Medium modification of jets in Quark Gluon Plasma

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Introduction

Heavy-ion collisions at ultra relativistic energies provide the opportunity to study the properties of strongly interacting matter at extreme temperatures and energy densities. The highly energetic partons produced by hard scattering in these collisions loose energy while traversing through the hot and dense medium formed in the collisions. This energy loss of partons was experimentally observed in the suppression of yields of particles with high transverse momentum (p_T) in the most central AuAu collisions as compared to pp collisions at Relativistic Heavy Ion Collider (RHIC) experiments. The suppression factor was almost an order of 5 times in most central collisions and starts to reduce from central to peripheral collisions. The suppression pattern was not observed in the controlled experiment at RHIC using the d+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV. However most of these studies at RHIC were only limited to the single particle level and could not be performed with the full jet reconstruction. The begining of pp and PbPb collisions at Large Hadron Collider (LHC), the Compact Muon Solenoid (CMS) experiment has demonstrated the capabilities of full jet reconstruction in these high energy collisions. With an excellent set of detectors, CMS experiment can identify and measure charged hadrons, neutral hadrons, electrons, muons and photons upto large pseudorapidity (η) and p_T ranges. These particles are used to reconstruct jets with appropriate clustering algorithms. Jets are reconstructed using the CMS particle flow algorithm which attempts to combine all stable particles in an event from various sub-detector systems. These particle flow objects are then clustered using the anti-k_T algorithm, with a resolution parameter of 0.3, encoded in the FastJet framework.

Inclusive jet yields

Inclusive jets spectra [1], as a function of jet p_T, for PbPb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV are shown in Fig 1. Also shown is the reference spectra obtained from pp collision at the same center of mass energy. For PbPb collisions, the spectra are are normalized by number of minimum bias events, and are scaled by $\langle T_{AA} \rangle$, with each centrality multiplied by a different factor, to seprerate the spectra for better visualization. for different collision centrality selections and scaled by

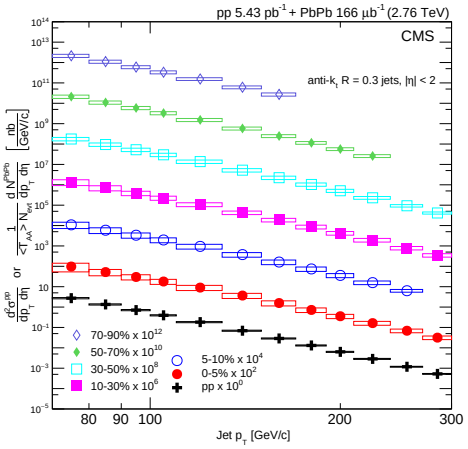

FIG. 1: Inclusive jet spectra from PbPb collisions for distance parameter R = 0.3, in different centrality classes and pp reference data. The systematic uncertainity plotted in the coloured boxes around the data points.

Nuclear modification factor

One of the most studied experimental signature of energy loss of partons in the hot and

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dense medium is the nuclear modification factor (R_{AA}). The nuclear modification factor for

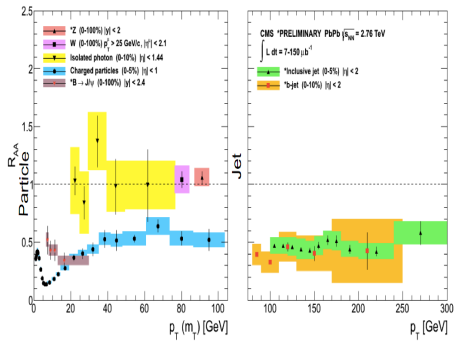

FIG. 2: Nuclear Modification factor for charged particles, b-quarks separated from secondary J/ψ particles, isolated photons, $W^{\pm}$ and Z^0 are shown in left panel. In right panel the R_{AA} for fully reconstructed anti-k_T jets and b-jets in PbPb collisions at $\sqrt{s_{NN}} = 2.76$ TeV. Statistical uncertainities are shown by verticle lines and systematic uncertainties are presented in shaded boxes around the data points.

particles or jets can be expressed by the ratio of measured yield in AA collisions to that in pp collision and scaled appropriately with the average number of nucleon-nucleon binary collisions $\langle N_{coll} \rangle$ calculated from Glauber model.

$$R_{AA} = \frac{dN^{AA}/dp_T}{\langle N_{coll} \rangle dN^{pp}/dp_T}, \qquad (1)$$

If the value of R_{AA} =1 suggests no in-medium modification of jets in PbPb collisions as compared to pp collisions. The measured $R_{AA} <$ 1 suggests parton energy loss and modification of jets in medium formed in PbPb collisions. Figure 2 shows the nuclear modification factor for different particles (in left panel) and for fully reconstructed anti-k_T jets (in right panel) for PbPb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV. The charged particles (mostly originating from the light flavor quarks and gluons) and b-quarks inferred from secondary J/ψ shows a suppression of yields in central PbPb collisions. Interestingly, the suppression factor for the charged particles and heavy-quark are of similar level indicating the independence of energy loss mechanism on the flavor of the parton. Also shown are the R_{AA} for the isolated photons (0-10%), $W^{\pm}$ and Z^0 bosons (0-100%) at $\sqrt{s_{NN}} = 2.76$ TeV PbPb collisions. The above mentioned particles do not interact strongly with the medium formed in heavy-ion collisions and hence considered to be remained unmodified during their passage through medium. As expected there is no suppression in yields observed for these particles in PbPb collisions with respect to the measured yields in the pp collisions further validating the nucleon-nucleon binary collision scaling and these particles can be used as direct probes to quantify the energy loss in PbPb collisions. The left panel shows the comparison of R_{AA} for the inclusive jets and from b-jets. Within the measured range of p_T the suppression of yields are similar for inclusive and b-jets emphasizing the flavor independence of energy loss mechanism in the most central PbPb collisions.

Summary

The inclusive jet energy spectra in PbPb collisions at $\sqrt{s_{NN}} = 2.76$ TeV are presented for various centrality classes. The nuclear modification factor for inclusive jets and b-jets are presented for central PbPb collisions. The suppression factor for light quark jets and heavy quark jets are measured for PbPb collisions and found to be similar in the studied jet p_T ranges. The inclusive and b-tagged jet yields in pPb collisions at $\sqrt{s_{NN}} = 5.02$ TeV are systematically measured as not suppressed when compared to an extrapolated pp reference. In summary, these comprehensive results for jet production in heavy-ion collisions has provided inputs for theoretical descriptions of energy loss models and established more precise experimental measurements for the energy loss mechanism in the dense medium formed in heavy-ion collisions.

References

[1] V. Khachatryan *et. al* (CMS Collaboration), Phys. Rev. C **96**, (2017), 015202.