Particle and Jet Production in Heavy-Ion Collisions with the ATLAS Detector at LHC

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Abstract. The ATLAS Collaboration is embarked in a detailed study of the dense and opaque extended system formed in Pb-Pb collisions at LHC. Comparisons of jet yields obtained in different classes of events confirm the presence of strong energy loss of partons in the medium at this energy. The study of jet shapes provides detailed information on the flow of energy as partons traverse the medium.

Keywords: Relativistic Heavy Ion, Jet Energy loss

PACS: 25.75.Dw, 25.75.Ld

INTRODUCTION AND ANALYSIS

The collision of relativistic heavy ions at RHIC and LHC forms and extended partonic system that has been characterized as being strongly coupled and dissipative to quarks and gluons moving through it [1]. Hard partonic scatterings at the time of the collision produce probes that traverse this new medium. The higher energy of the collisions at LHC and the hermetic feature of the ATLAS detectors allow, for the first time, a systematic study of the newly formed system with jets. Partons with high transverse momentum lose energy as they move through the opaque medium [2]. Medium induced gluon radiation is one possible mechanism for the energy loss. The distribution of particles in the jet should then be a handle to study the presence and strength of coupling between the medium constituents [3]. Such measurements have been performed by the ATLAS Collaboration and are reported here.

A minimum bias dataset with integrated luminosity of 7µb$^{-1}$ was collected with the ATLAS detector. Jets with transverse momentum $p_T$ higher the 40 GeV were identified and reconstructed using the anti-$k_t$ algorithm once the underlying soft particle background and the presence of azimuthal anisotropies were subtracted event by event. The centrality of the collisions was characterized by the total transverse energy deposited in the Forward calorimeter (FCal). A standard Glauber Monte-Carlo analysis was used to estimate the average number of participating nucleons $<N_{\text{part}}>$ and their number of binary collisions $<N_{\text{coll}}>$. The effects of bin migration in the jet spectra were removed using the singular value decomposition (SVD) technique [4]. Bin migration can be produced by uncertainties in the jet energy resolution and the jet energy scale. This unfolding also provides good estimates of associated systematic uncertainties. The $R_{cp}$ ratio expressed as a function of $p_T$ of the jet is defined as:
FIGURE 1. Unfolded $R_{cp}$ values as a function of $N_{\text{part}}$ for $R = 0.4$ anti-$k_t$ jets in six $p_T$ bins. The error bars indicate statistical errors from the unfolding; the shaded boxes show point-to-point systematic uncertainties. The solid lines indicate fully correlated systematic errors [6].

$$R_{cp}^{\text{cent}}(p_T) = \frac{1}{R_{\text{coll}}} \left( \frac{\tilde{N}_{\text{cent}}^{\text{jet}}(p_T)}{\epsilon'_{\text{cent}}N_{\text{cent}}^{\text{jet}}(p_T)} \right)$$,

where $\tilde{N}_{\text{cent}}^{\text{jet}}(p_T)$ and $\tilde{N}_{60-80}^{\text{jet}}(p_T)$ are the unfolded yield of jets in a given centrality bin and in the most peripheral centrality bin respectively. The $\epsilon'$ terms are the corresponding jet reconstruction efficiencies and $R_{\text{coll}}$ is the ratio of the corresponding $<N_{\text{coll}}>$.

Figure 1 shows the fully corrected $R_{cp}$ ratio as a function of the number of participant nucleons $<N_{\text{part}}>$ for several bins of the jet $p_T$. As the ions collide almost head-on, $(N_{\text{part}}$ reaches 350) the normalized jet yield in central collisions drops approximately to half of the yield measured in the peripheral events (60-80%)%.

The study of jet shapes and their evolution with collision centrality has also been performed. This study involves the reconstruction of the charge and momentum for charged particles that form jets. The energy and main axis of those jets is measured with the ATLAS calorimeters using the same background subtraction and reconstruction algorithm as the study on $R_{cp}$ reported above. Two quantities are measured to study the changes in the jets structures. The first one is a distribution of $z$, the fraction of transverse momentum or energy of the jet carried by each charged particle detected within the jet boundaries. This quantity provides a measure of the longitudinal distribution of energy inside a jet. It is often referred to as the fragmentation function $D(z)$. The second observable focuses on the distribution of energy transverse to the jet axis. Space limitations do not permit the discussion of this variable. More details about these measurements can be found in [7].

Figure 2 shows the ratios of the fragmentation function $D(z)$ extracted from different centrality samples for jets with $p_T$ greater than 100 GeV. For such high energy jets a modification of the longitudinal distribution of energy within the jet is clear in the most central events and almost disappears in the peripheral ones. The modification has three features: an enhancement at low values of $z$, together with a depression at intermediate
FIGURE 2. Ratios of fragmentation functions for jets of size $R=0.2$ measured in events with different centralities. Yellow boxes show partially correlated uncertainties. Error bars show statistical errors [7].

values and no change above $z=0.2$.

SUMMARY

The ATLAS Collaboration has performed studies of energy loss in lead-lead collisions as well as jet shape modifications with a minimum bias sample using reconstructed charged particles and jets. The strength of the energy loss measured with the $R_{cp}$ ratio shows a factor of two reduction in normalized yields at all measured jet $p_T$ bins. For the first time a detailed and fully corrected measurement of the jet shapes as a function of the centrality of the events is performed. It shows a difference between central and peripheral events, the difference appears mainly at low values of $z$ consistent with soft gluon radiation.

REFERENCES