

Jet suppression measurement with the ATLAS detector

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Abstract. A hot medium with a high density of unscreened color charges is produced in relativistic heavy-ion collisions. Jets are produced at the early stages of these collisions and are known to become attenuated as they propagate through the hot matter. One manifestation of this energy loss is a lower yield of jets emerging from the medium than expected in the absence of medium effects. Another manifestation of the energy loss is the modification of the dijet balance and the modification of fragmentation functions. In these proceedings, the latest ATLAS results on single jet suppression, dijet suppression, and modification of the jet internal structure in Pb+Pb collisions are presented.

Relativistic heavy-ion collisions provide a unique opportunity to study the most intriguing aspects of the strong interaction in the laboratory. In high energy ion-ion collisions studied at RHIC and the LHC, the energy densities are sufficiently high to produce a new form of matter referred to as the quark-gluon plasma.

In the past few years, since the beginning of LHC Run 1, the ATLAS collaboration [1] has published several measurements showing strong modification of jet and hadron yields in lead-lead (Pb+Pb) collisions. Measurements of production of asymmetric dijets, single jets, measurement of jet fragmentation and production of neighbouring jets should provide new information on the mechanism of jet energy loss and modification of the jet substructure [2][3][4][5].

1. Nuclear modification factor of jets

The observable quantity that expresses the magnitude of suppression or enhancement of jets is the nuclear modification factor R_{AA} , which is defined as

$$R_{AA} = \frac{\frac{1}{N_{\text{evt}}} \frac{d^2 N_{\text{jet}}}{dp_T dy} \big|_{\text{central}}}{\langle T_{AA} \rangle \frac{d^2 \sigma_{\text{jet}}^{pp}}{dp_T dy}} \quad (1)$$

where T_{AA} is the nuclear overlap function.

For jet R_{AA} measurement, Pb+Pb data collected in 2011 (luminosity $L_{\text{int}}^{\text{PbPb}}=0.14 \text{ nb}^{-1}$) and pp data collected in 2013 ($L_{\text{int}}^{\text{pp}}=4.0 \text{ pb}^{-1}$) at $\sqrt{s_{\text{NN}}} = 2.76 \text{ TeV}$ were used. Minimum bias (MB) and jet triggered samples were combined to get jet spectra in the interval of $32 < p_T^{\text{jet}} < 500 \text{ GeV}$. Jets were reconstructed using the anti- k_t algorithm [6] with parameter $R=0.4$. Background contribution to the jet energy from the underlying event (UE) was estimated and subtracted on the event-by-event basis by the iterative procedure. This procedure was used in both pp and



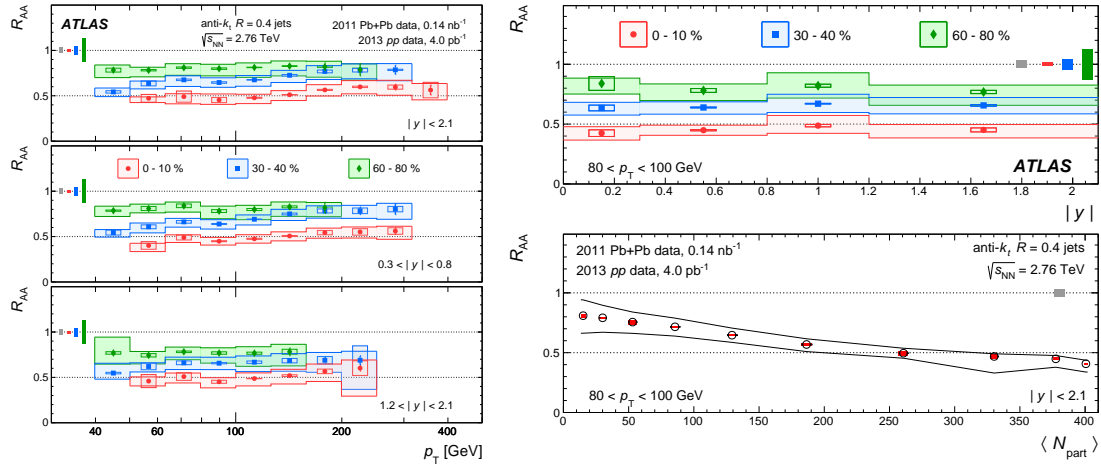


Figure 1. Left: Jet R_{AA} as a function of p_T in three centrality bins with each panel showing a different range in $|y|$. Right: The R_{AA} for jets with $80 < p_T < 100$ GeV as a function of y for different centrality bins (top) and as a function of N_{part} for $|y| < 2.1$ range (bottom) [7].

Pb+Pb collisions. Jet energies were calibrated by the procedure based on the MC. To account for the resolution effects an unfolding based on the Singular Value Decomposition (SVD) method was used.

Various dependencies of jet R_{AA} are shown in Fig.1. Left panel shows suppression of jet production in central Pb+Pb collisions by a factor of approximately two which is weakly dependent on the jet p_T . Size of suppression gradually decreases from central to peripheral collisions but is significant even in 60-80% centrality bin. This is depicted in the lower right panel where number of participants N_{part} dependence of R_{AA} in one p_T and one rapidity (y) bin is shown. The upper right panel shows rapidity dependence of R_{AA} for three different centralities in $80 < p_T < 100$ GeV bin. No rapidity dependence is observed in the measured y range.

2. Measurements of production of asymmetric dijets

ATLAS has also performed new measurements of dijet p_T correlations in Pb+Pb and pp collisions at $\sqrt{s_{NN}} = 2.76$ TeV [10]. The momentum balance of the dijet system was expressed in terms of the variable $x_J = p_{T1}/p_{T2}$, where p_{T1} and p_{T2} are the transverse momenta of the jets with the highest and second highest p_T in the event, respectively. Measurements of $\frac{1}{N} \frac{dN}{dx_J}$ were performed as a function of p_{T1} and collision centrality. Previous experimental results [8][9][11] were not corrected to account for detector-specific experimental effects, in particular the resolution on the measured jet p_T , which lead to distortions of the distributions. To account for these effects two-dimensional Bayesian unfolding procedure was used. The new measurement of dijet asymmetry is free from such distortions and can be directly compared to theoretical calculations.

The $\frac{1}{N} \frac{dN}{dx_J}$ distributions obtained in central Pb+Pb and pp collisions are shown in Fig.2 for different intervals of p_{T1} . The distributions in pp collisions have the most probable value near $x_J \sim 1$ corresponding to the dijet pairs having nearly the same p_T . In contrast, Pb+Pb event with $100 < p_T < 126$ GeV, the distributions develop a large peak at $x_J \sim 0.5$, corresponding to the subleading jet with half the p_T of the leading jet. The modifications observed in the Pb+Pb data are smaller with larger p_{T1} . This evolution is much more abrupt than the p_T dependence of the single jet R_{AA} , which is approximately logarithmic [12]. The modifications are also smaller in more peripheral centrality bins.

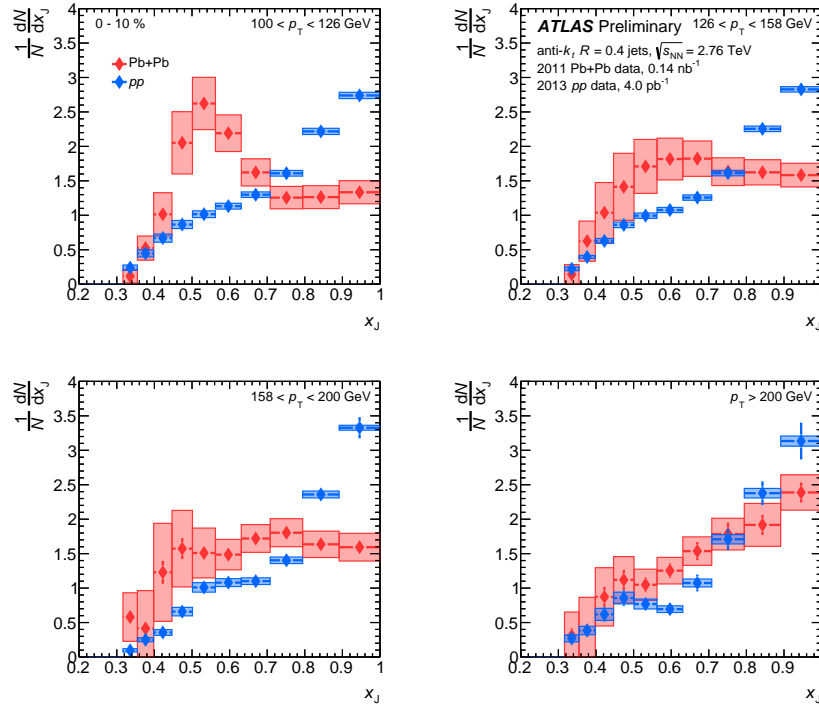


Figure 2. The $\frac{1}{N} \frac{dN}{dx_j}$ distributions for different selections on p_{T1} , shown for the 0-10% centrality bin in Pb+Pb collisions (red) and pp (blue). Statistical uncertainties are indicated by the error bars while systematic uncertainties are shown with shaded boxes [10].

3. Fragmentation functions

Modifications of the jet internal structure can be directly accessed by measuring jet fragmentation functions [9]. ATLAS measured two sets of fragmentation functions, $D(p_T)$ and $D(z)$ which are defined as

$$D(p_T) = \frac{1}{N_{\text{jet}}} \frac{dN_{\text{ch}}}{dp_T} \quad D(z) = \frac{1}{N_{\text{jet}}} \frac{dN_{\text{ch}}}{dz} \quad (2)$$

where p_T is transverse momentum of charged particles and longitudinal momentum fraction $z = (p_T \cos \Delta R) / p_T^{\text{jet}}$ and ΔR is the distance between jet axis and track in $\eta - \phi$ space. Jet triggered Pb+Pb and pp data taken in 2011 and 2013 were used in this analysis. Jets used in this analysis were clustered with anti- k_t algorithm, from UE background subtracted and fully calibrated. Jets with $100 < p_T < 398$ GeV were used in the analysis and tracks with $p_T > 1$ GeV that match the jet within $\Delta R < 0.4$ were used. Tracks were corrected for reconstruction efficiency. Because of the large contribution from UE η -dependent subtraction procedure was applied on the event-by-event basis to tracks with p_T less than 6 GeV. To correct for detector effects 2D Bayesian unfolding was used.

Ratios of jet fragmentation functions in Pb+Pb to pp jet fragmentation functions are shown in Fig.3. Jet fragmentation functions in Pb+Pb collisions exhibit enhancement in low and high p_T region and depletion at intermediate p_T compared to pp . Magnitude of the modification decreases for peripheral collisions. No significant difference between different η intervals at low p_T is observed but a hint of smaller enhancement in forward region ($1.2 < |\eta| < 2.1$) compared to barrel region ($|\eta| < 1.2$) is observed at high p_T .

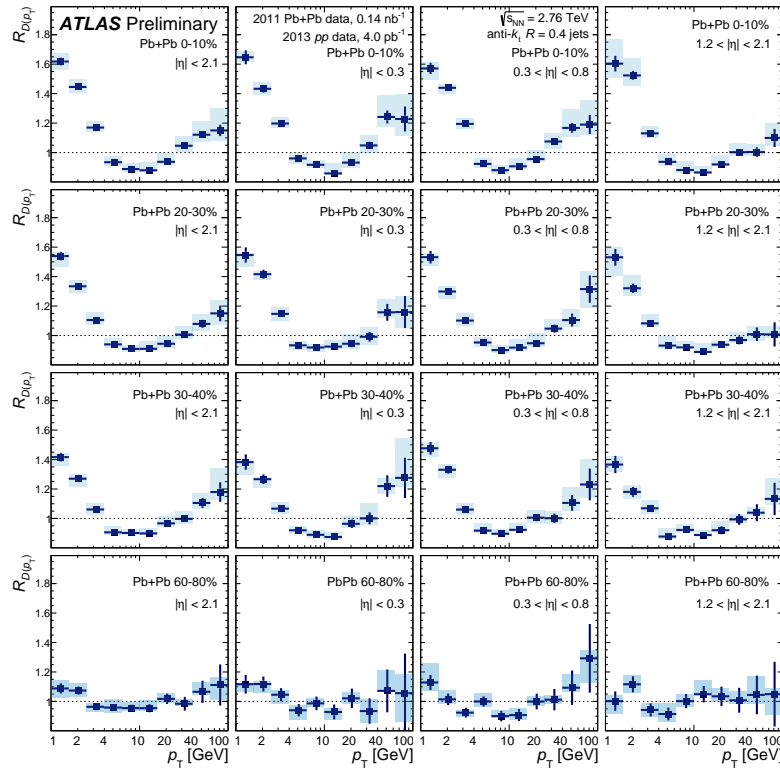


Figure 3. The ratios of $D(p_T)$ distributions measured in Pb+Pb collisions to $D(p_T)$ measured in pp collisions. Ratios are evaluated in four centrality bins (rows) and four selections on jet pseudorapidity (columns) [13].

4. Summary

Three presented measurements provide complex view on the jet quenching phenomenon. Measurements of single hadron and single jet R_{AA} show strong suppression of hadrons and jets in Pb+Pb collisions which is y independent. Dijets with $p_{T1} > 100$ GeV in the most central Pb+Pb collisions, the typical configurations are strongly asymmetric compared to that in pp collisions at the same collision energy. However, in peripheral collisions or at higher p_{T1} (>200 GeV), the distributions are qualitatively similar to those in pp collisions. Measurement of jet fragmentation functions show modification of jet fragmentation in Pb+Pb collisions which is η independent except high p_T region where a hint of η dependence is observed.

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