Di-jet Shape Modification in Heavy Ion Collisions

Paul Constantin (for the PHENIX Collaboration)
Los Alamos National Laboratory, Los Alamos, NM 87545, USA

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Abstract. We present preliminary results from intermediate $p_T$ (1-5\,GeV/c) di-hadron azimuthal correlations induced by hadronic di-jets produced in AuAu collisions at $\sqrt{s_{NN}} = 200$\,GeV. The near-side ($\Delta \phi \sim 0$) has a typical single-peaked structure which broadens with the centrality of the collision. A qualitatively new phenomenon shows up in the shape of the away-side ($\Delta \phi \sim \pi$): it has a symmetric, double-peaked structure in central and mid-central collisions.

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1. Introduction

The AuAu data collected during the 2002 RHIC run established several new exciting results in the area of hadronic jet modification by a hot and dense QCD medium: leading hadron suppression [1], away-side disappearance at high $p_T$ [2], and the strong (non-Gaussian) modification of the away-side at intermediate $p_T$ [3].

The goal of the much higher statistics 2004 RHIC run is a systematic study of these effects. This paper addresses the particular issue of how the di-jet shape is modified by interacting with the medium formed in AuAu collisions at high energy.

2. Di-jet Shapes from Di-hadron Azimuthal Correlations

In order to correct for the limited acceptance of the PHENIX detector, we build our statistical di-hadron azimuthal correlations by dividing with mixed event azimuthal distributions [1, 3].

An example of such azimuthal correlations is shown in the left panel of Figure 1 for (2-3)\,GeV/c trigger hadrons and (1-2)\,GeV/c associated hadrons in the 0-2\% and 2-5\% most central AuAu collisions at $\sqrt{s_{NN}} = 200$\,GeV. A striking feature is the wide flat plateau around $\Delta \phi \sim \pi$, before background subtraction. Considering the $\cos(2\Delta \phi)$ shape of the background (see Equation 1), it is obvious that the
resulting di-jet shape will have a local minimum at $\Delta \phi \sim \pi$ after subtraction. This can be seen indeed in the extracted di-jet induced correlation function shown in the right panel of the same figure.

Two sources contribute to angular correlations in this $p_T$ range - a global correlation of all hadrons with the collision reaction plane \cite{7}, and the di-jet induced correlation $J(\Delta \phi)$:

$$C(\Delta \phi) = \xi (1 + 2v_2(p_T^{\text{true}})v_2(p_T^{\text{assoc}})\cos(2\Delta \phi)) + J(\Delta \phi)$$  \hspace{1cm} (1)

The presence of a momentum conservation source proportional to $-\cos(\Delta \phi)$, observed at much lower associated hadron momenta \cite{3}, is under study.

We use the measured $v_2$ of charged hadrons in the PHENIX central arms ($|\eta| < 0.35$) with respect to the reaction plane orientation in the BBCs (Beam-Beam Counters with $3 < |\eta| < 3.9$) from \cite{7}.

We then fit the correlation functions with the right hand side of Equation (1), where the di-jet term is parameterized as a Gaussian for the near side and a symmetric double Gaussian for the away side, hence $J(\Delta \phi)$ has the functional form:

$$A_N \exp \left( -\frac{\Delta \phi^2}{2w_N^2} \right) + A_A \left( \exp \left( -\frac{(\Delta \phi - \pi - D)^2}{2w_A^2} \right) + \exp \left( -\frac{(\Delta \phi - \pi + D)^2}{2w_A^2} \right) \right)$$  \hspace{1cm} (2)

with six free parameters: the background level $\xi$, the near/away di-jet amplitudes $A_N,A_A$, and the di-jet shape parameters $w_N$ (near width), $w_A$ (away width), and $D$ (away splitting). This functional form provides an excellent description of the di-jet correlation functions for a wide selection of centralities and momenta.

The main source of systematic errors comes from the background estimation, with its two components: the $v_2$ error, which is propagated from the published measurement \cite{7}, and the $\xi$ error. The latter is estimated by using an independent method, called the ZYAM (Zero di-jet Yield At Minimum) method \cite{4,6}.

3. Di-jet Shape Parameters at Intermediate $p_T$

Using the above method, we extract the di-jet induced correlation functions for AuAu and dAu collisions at $\sqrt{s_{NN}} = 200$GeV in various centrality classes and $p_T$ regions. The qualitatively new feature, shown in the right panel of Figure 1 and present only for di-jet induced correlation functions in relativistic heavy ion collisions, is the splitting of the away side into a symmetric, double-peaked structure.

The position of the away side peaks is parameterized by $D$. Its centrality and momentum dependence are shown in Figure 2. $D$ rapidly increases in mid-peripheral collisions and then has a slower increase towards more central collisions. It also slowly decreases with both the trigger and associated hadron momenta.

Several theoretical models to explain this result have been proposed already. In one of them, partons with velocities larger than the speed of sound in a liquid QGP produce shock waves propagating in a Mach cone with respect to parton’s
momentum; $D$ is then the Mach angle, hence it measures the QGP speed of sound \cite{8}. In another model, partons with velocities larger than the speed of light in a QGP with bound partonic states produce gluon radiation in a Cherenkov cone with respect to parton’s momentum. $D$ is then the Cherenkov angle, hence it measures the QGP index of refraction \cite{9}.

The left panel of Figure 3 shows the centrality dependence of the near side width $w_N$ (triangles) and of the away side width $w_A$ (circles). Both widths broaden with collision centrality at intermediate $p_T$. The right panel of this figure shows the momentum dependence of the away width $w_A$. A trend from broadening at intermediate $p_T$ towards centrality independence at higher trigger and associated momenta can be observed, but higher statistics is needed.

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Fig. 2. Centrality and momentum dependence of the splitting parameter $D$.

Fig. 3. Left: centrality dependence of the near width $w_N$ (triangles) and of the away width $w_A$ (circles). Right: momentum dependence of the away width $w_A$. 