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To cite this article: N N Ajitanand and the Phenix Collaboration 2006 J. Phys.: Conf. Ser. 50 336

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Study of jet fragmentation via azimuthal correlations: a probe for the sQGP at RHIC

N N Ajitanand
For the PHENIX Collaboration
ajit@mail.chem.sunysb.edu

Abstract. Two particle azimuthal correlation functions are used to study flow and jet fragmentation in the hot QCD matter believed to be created in Au+Au collisions at RHIC ($\sqrt{s_{NN}} = 200$GeV). Detailed results on jet topologies and yields, and their flavor dependence are obtained via a novel technique for decomposition of the combined correlations from jets and flow in Au+Au collisions. The results indicate significant broadening of the away-side jet attributable to important interactions between the flowing medium and the scattered partons which fragment into jets.

1. Introduction
The RHIC experiments have been designed to recreate the first moments after the Big Bang when the universe existed as a plasma of quarks and gluons (QGP). This phase of nuclear matter is widely anticipated in the most energetic Au+Au collisions at RHIC. In fact, recent estimates of the energy density achieved in relatively central Au+Au collisions at $\sqrt{s_{NN}} = 200$GeV far exceeds that required for creating the QGP according to Lattice QCD calculations. The concomitant high matter density is expected to give rise to large pressure gradients which is evidenced in the observed large azimuthal anisotropy ($v_2$) of particle emission from the collision zone. The value of this anisotropy is close to the predictions of the hydrodynamic model which in turn implies the creation of a strongly interacting thermalized medium. In addition to the dominant soft processes giving rise to the formation of the medium, there are relatively rare hard parton-parton collisions. The scattered partons propagate through the medium radiating gluons and interacting with the medium till they finally fragment into jets. Thus jets are an ideal probe of the medium provided one can de-convolute the jet signal from the collective flow effects. Possible medium associated modifications of the jet topology are a conical emission akin to a “sonic boom” and distortions induced via interactions between scattered and flowing partons. To study jet modification it is necessary to first build two particle azimuthal correlations.

2. Azimuthal correlations
Two particle azimuthal correlations are built by pairing a leading hadron in the range 2.5<pt<4.0 with an associated hadron in the range 1.0<pt<2.5. The correlation function $C$ is given by:

$$C(\Delta \phi) = \frac{N_{\text{Real}}(\Delta \phi)}{N_{\text{mix}}(\Delta \phi)}$$
Here $\Delta \phi$ is the difference of azimuthal angles of the pair. The real distribution is built from pair members belonging to the same event and mixed distributions are made of pair members belonging to different events. Thus the correlation function is free of geometric acceptance effects and carries only the physics effects i.e. long range correlations from flow and short range correlations from jets.

2. Deconvolution Method

It is necessary to decompose the correlation function to obtain the jet function. A two source model gives

$$C(\Delta \phi) = a_0\left[H(\Delta \phi) + J(H(\Delta \phi))\right],$$

where, $H$ is a second harmonic function characterized by $p_2 = v_2^{lo} \times v_2^{hi}$.

The values $v_2^{lo}$ and $v_2^{hi}$ are simply the average of $\cos(2(\phi - \Phi_{RP}))$ for the lower and higher $p_T$ ranges and $\Phi_{RP}$ is the reaction plane azimuth obtained from the Beam-Beam counters placed at large $\eta$. To obtain $a_0$, the ZYAM assumption is made i.e. the minimum of the Jet function $J$ is zero. The following plots demonstrate the effectiveness of the de-convolution method using 3-dimensional simulations with two types of away side jets (both giving similar jet functions) in a flowing background of particles. The solid squares represent the extracted function and the solid line the input jet function. Panels (b), (c) and (d) show results for the case where the leading particle is unconstrained, constrained in the reaction plane and constrained perpendicular to the reaction plane respectively. A comparison of the input and output jet-pair distribution indicates that decomposition is robust.

Figure 1: Decomposition of simulated data. Panel (a) shows the harmonic contribution. Panels, (b), (c) and (d) show the combined correlation function (solid circles) and harmonic contribution (dashed line) and the extracted jet-pair distribution (filled squares) for inclusive and leading particle constrained in and out of plane respectively. Schematic jet shapes are indicated to the right of the figure.
4. Results

Figure 2 shows the extracted jet functions following decomposition of the measured correlation functions for 200 GeV Au+Au collisions. The points represent nominal values. The lines indicate the results of one and two sigma systematic error variation on the $v_1$ value used for decomposition. For the most peripheral collisions (panel (f)) the characteristic distribution for a di-jet is evident. For all other centralities, there is a clear broadening of the away-side jet and possibly a minimum at $\sim 180^\circ$. The latter may be the result of the predicted interaction of the away-side jet with the medium\textsuperscript{1,4}.

Figure 2: Extracted jet-pair distributions for Au+Au collisions. Results are shown for trigger particle with $2.5 < p_T < 4$ and associated particle with $1.0 < p_T < 2.5$ GeV/c for several centralities as indicated.

Figure 3: Extracted yields (a) and jet widths (b) as a function of centrality. Results are shown for the near and away-side jets.

Figure 3 shows the integrated near and away side yields and second moments of the jet widths as a function of centrality. The away side yield is generally higher than the near side yield.
The near side widths are independent of centrality while the away side values rises quickly and then remain relatively constant for mid-central to central collisions.

Similar jet extractions have been performed for flavor identified associated particles in the same pt range (1.0 < pt < 2.5 GeV/c). Figure 4 shows the ratio of baryonic yield to the mesonic yield for the near and away side jets. The away side is generally more baryon rich than the near side.

![Figure 4: Centrality dependence of the extracted ratio of associated Baryon to Meson jet yields. Results are shown for the near and away-side jets.](image)

3. Conclusions

A robust procedure for the decomposition of correlation functions has been used to extract di-jet correlations in Au+Au collisions. The observed characteristics of the near-side jet are similar to that observed in p+p and d+Au collisions. However, significant distortions of the away-side jet are observed. The flavor dependence of jet yields indicates a larger baryonic content for the away-side jet. Such information may provide more detailed information on the mechanism/s for medium induced modification to jets which traverse the strongly interacting high energy density matter produced at RHIC.

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