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Two and Three Particle Flavor Dependent Correlations

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The PHENIX collaboration has developed novel methodologies for reliable extraction of jet functions from two and three particle azimuthal correlation functions measured at mid-rapidity in Au+Au collisions at $\sqrt{s} = 200$ GeV. The extracted jet shape and the yield of jet-associated partner hadrons (per trigger hadron) are found to vary with particle type and collision centrality, indicating a significant effect of the nuclear collision medium on the (di)jet fragmentation process.

1. Introduction

It is well known that the high energy density achieved in semi-central Au + Au collisions at RHIC, far exceeds the lattice QCD estimate for creating a de-confined phase of quarks and gluons (QGP)[1]. It's rapid thermalization gives rise to large pressure gradients evidenced by the sizable azimuthal anisotropy (v_2) observed for particle emissions from the collision zone [2]. The magnitude of this anisotropy is compatible with the predictions of the hydrodynamic model which in turn implies the creation of a strongly interacting medium and essentially full local thermal equilibrium. In addition to the soft processes giving rise to the formation of the medium, there are relatively rare hard parton-parton collisions. The scattered partons may propagate through the medium radiating gluons and interacting with the medium till they finally fragment into jet-like clusters. Since such interactions can modify jet fragmentation, jets provide a powerful probe of the medium, provided one can reliably extract the jet signal from the relatively large background which exist in RHIC collisions. Possible medium associated modifications of the jet properties are a shock wave induced conical flow or "sonic boom" [3] and "bending" induced by interactions between the propagating partons and the flowing medium [4].

2. Methodology and results:

Correlation Functions: To study jet properties we use two- and three-particle azimuthal correlation functions. These azimuthal correlation functions were built by pairing a leading hadron in a specified transverse momentum range p_T(trig), with an associated hadron also in a specified range p_T(assoc). For two-particle correlations, the correlation function $C\,(\Delta\phi)$ is given by:

$$C\,(\Delta\phi) = \frac{N_{real}\,(\Delta\phi)}{N_{mix}\,(\Delta\phi)},$$

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where $\Delta\phi$ is the difference of the azimuthal angles of the pair. The real distribution $(N_{real}(\Delta\phi))$ is built from pair members belonging to the same event and the mixed distribution $(N_{mix}(\Delta\phi))$ is made of pair members belonging to different events. Thus the correlation function is free of geometric acceptance effects and carries only the combined correlations from flow and jets. Decomposition of these correlations into their jet and flow contributions, constitute an important prerequisite for obtaining the jet function and hence, information about jet fragmentation.

Decomposition of the correlation function: Following a two source model ansatz, $C(\Delta\phi)$ can be written as;

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

where $H(\Delta\phi)$ is a second harmonic function having an amplitude $p_2 = v_2(\text{assoc}) \times v_2(\text{trig})$ and $J(\Delta\phi)$ is the jet function [5]. Here, $v_2(\text{assoc})$ and $v_2(\text{trig})$ are the amplitudes of the harmonic distributions of trigger and associated hadrons (respectively) relative to the azimuth of the reaction plane Ψ_{RP}, ie. $v_2(\text{assoc}, \text{trig}) = \langle cos\left(2.(\phi_{\text{assoc,trig}} - \Psi_{RP})\right)\rangle$. For these measurements, Ψ_{RP} was obtained from Beam-Beam counters having $\eta \pm 3.5$. To obtain $J(\Delta\phi)$ one simply uses the value a_0, obtained by assuming that the magnitude of the Jet function $J(\Delta\phi)$ is zero at its minimum (ZYAM assumption) [5], and subtracts the measured values of $H(\Delta\phi)$.

Extinction Method: One can also obtain $J(\Delta\phi)$ via extinction of the the harmonic function $H(\Delta\phi)$ [5]. This is done by aligning the trigger hadron within an appropriately chosen angular range $\Delta\phi_c$, perpendicular to the reaction plane. The harmonic amplitude for the trigger particle in this configuration $v_2^{out}(\text{trig})$, is given as [6]

$$v_2^{out}(\text{trig}) = \left(\frac{2v_2(\Delta\phi_c) - \sin(2\Delta\phi_c)\langle\cos(2\Delta\Psi_R)\rangle + \frac{v_2}{2}\sin(4\Delta\phi_c)\langle\cos(4\Delta\Psi_R)\rangle}{2(\Delta\phi_c) - 2v_2\sin(2\Delta\phi_c)\langle\cos(2\Delta\Psi_R)\rangle}\right).$$

Thus, it is clear that $v_2^{out}(\text{trig})$ can be made to vanish ($v_2^{out}(\text{trig}) \sim 0$) by appropriate choice of $\Delta\phi_c$ for a particular reaction plane resolution $\Delta\Psi_R$.

Results: Figures 1 and 2 show the application of these decomposition methods to meson-meson and baryon-meson correlation functions. They show that the jet-pair distributions, obtained after subtraction or extinction of the harmonic contributions, are significantly broadened on the away-side, independent of whether or not the trigger hadron is a baryon or meson. We attribute such broadening to the strong interactions between scattered partons and the high energy density medium.

It is straightforward to evaluate the conditional or per trigger yields (CY) for the near- and away-side jets via the integrated pair fractions indicated by the hatched area in Figs. 1 and 2 [5] or by building per trigger yield distributions. Fig. 3 compares proton and anti-proton jet yields obtained for near-side jets via the latter technique. The near-side yield is non-zero only for baryon-anti-baryon pairs, suggesting that baryon number conservation may play an important role in jet fragmentation.

One can also compare the baryonic and mesonic content of the near- and away-side jets by comparing the ratio CY(baryon)/CY(meson) for the near- and away-side jets. Fig. 4 shows the double ratio

$$DBR = \left(CY(baryon)/CY(meson)\right)_{away-jet} / \left(CY(baryon)/CY(meson)\right)_{near-jet}$$