Intra-jet correlations of high-\( p_t \) hadrons from STAR

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Abstract.

Systematic measurements of pseudorapidity (\( \Delta \eta \)) and azimuthal (\( \Delta \phi \)) correlations between high-\( p_t \) charged hadrons in \( \sqrt{s_{NN}}=200 \text{ GeV} \) Au+Au collisions are presented. An enhancement of correlated yield at large \( \Delta \eta \) on the near-side is observed. This effect persists up to trigger \( p_t^{\text{trig}} \sim 9 \text{ GeV/c} \), indicating that it is associated with jet production. More detailed analysis suggests distinct short-range and long-range components in the correlation.

Dihadron azimuthal correlation studies in nuclear collisions have shown that hard partons interact strongly with the matter that is generated and provide a sensitive probe of the medium [1, 2, 3]. Enhanced near-side (\( \Delta \phi \sim 0 \)) correlated yield at large \( \Delta \eta \) (the ridge) has been observed in measurements with trigger particles at intermediate \( p_t \) (4 < \( p_t^{\text{trig}} < 6 \text{ GeV} \)) [4, 5] and for dihadron pairs having \( p_t < 2 \text{ GeV/c} \) but no trigger requirement [6]. However, inclusive hadron production at \( p_t < \sim 6 \text{ GeV/c} \) exhibits large differences between nuclear collisions and more elementary collisions [7, 8]. It is therefore unclear from these existing measurements whether the ridge is associated with hard partonic scattering and jet production. In these proceedings we extend the near-side correlation measurement to \( p_t^{\text{trig}} \sim 9 \text{ GeV/c} \), well into the kinematic region where inclusive hadron production is similar in nuclear and elementary collisions and where jet fragmentation is thought to dominate. We observe the persistence of the ridge effect to the highest measured trigger \( p_t \), suggesting that it is indeed associated with jet production. We further characterize the ridge, to gain insights into its origin.

To illustrate the analysis method, Fig. 1 shows the \( \Delta \eta \times \Delta \phi \) distribution of hadrons with \( p_t^{\text{assoc}} > 2 \text{ GeV} \), associated with trigger hadrons 3 < \( p_t^{\text{trig}} < 4 \text{ GeV} \) in central Au+Au collisions. The yields are corrected for single-particle tracking efficiency and the finite pair acceptance in \( \Delta \eta \) and \( \Delta \phi \). The near-side yield shows a clear peak around (\( \Delta \eta, \Delta \phi \) = (0,0)), as expected from jet fragmentation. In addition a prominent enhancement of correlated yield in \( \Delta \eta \) on the near-side is clearly visible above the flow modulated background (the ridge). To better understand the ridge phenomenon we decompose the near-side into a jet-like peak and a \( \Delta \eta \) independent ridge component. This ansatz assumes distinct underlying physical processes in the different \( \Delta \eta \) regions. We examine this assumption below.
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Figure 1. Raw \(\Delta \eta \times \Delta \phi\) dihadron correlation function in central Au+Au collisions for \(3 < p_t^{\text{trig}} < 4\) GeV and \(p_t^{\text{assoc}} > 2\) GeV.

Figure 2. Near-side yield of associated particles in \(\Delta \eta\) and \(\Delta \phi\) with \(p_t^{\text{assoc}} > 2\) GeV as a function of \(N_{\text{part}}\) in Au+Au for \(3 < p_t^{\text{trig}} < 4\) GeV (details see text).

To extract the ridge yield from dihadron measurements we project the two dimensional \((\Delta \eta \times \Delta \phi)\) correlation function (Fig. 1) onto \(\Delta \phi\) and \(\Delta \eta\) in different \(\Delta \eta \times \Delta \phi\) regions. Three methods were used to characterize the small \(\Delta \eta\) jet-like \((J)\) and the large \(\Delta \eta\) ridge-like \((R)\) contributions to the near-side jet yield in \(\Delta \eta\) and \(\Delta \phi\):

- \(\Delta \phi(J + R)\): Projecting onto \(\Delta \phi\) with the full experimental \(\Delta \eta\) acceptance (\(|\Delta \eta| < 1.7\) was used in this analysis) and subtracting the elliptic flow \((v_2)\) modulated background.

- \(\Delta \phi(J)\): Subtracting the \(\Delta \phi\) projection for \(0.7 < |\Delta \eta| < 1.4\) from the \(\Delta \phi\) projection \(|\Delta \eta| ≤ 0.7\) (near-side).

- \(\Delta \eta(J)\): Projecting onto \(\Delta \eta\) in a \(\Delta \phi\) window \(|\Delta \phi| < 0.7\) (near-side). A constant fit to the measurements was used to subtract the background.

In Fig. 2 the near-side yield is shown as a function of the number of participants \(N_{\text{part}}\) for all three methods. The agreement of the measured jet-like yield between the \(\Delta \eta(J)\) and \(\Delta \phi(J)\) method for all centrality bins, within the sensitivity of this analysis, supports the assumption that the ridge-like correlation is uniform in the \(\Delta \eta\) acceptance. Further detailed studies of the ridge shape in the high statistics Au+Au central data set, especially at high \(p_t^{\text{trig}}\), will be pursued. Note that the jet-like correlated yield is independent of centrality and agrees with the p+p reference measurements. In contrast the \(\Delta \phi(J + R)\) yield shows a significant increase with centrality due to the inclusion of the correlated yield at large \(\Delta \eta\) (ridge).

For the purpose of this analysis one can define the (absolute) ridge yield = \(\text{yield}(\Delta \phi(J + R)) - \text{yield}(\Delta \eta(J))\). The main systematic error is the uncertainty in the elliptic flow measurement for the \(\Delta \phi(J + R)\) method. The \(v_2\) value used in this analysis

\(^{\ddagger}\) The yields are extracted from bin-counting in the interval \(|\Delta \phi| = |\Delta \eta| < 1\)

\(^{\S}\) Not corrected for the finite \(\Delta \eta\) pair-acceptance.

\(||\) The ridge yield depends on the \(\Delta \eta\) integration window used in the \(\Delta \phi(J + R)\) method.
is the mean of the reaction plane ($v_2\{RP\}$) and four-particle cumulant method ($v_2\{4\}$) in Au+Au collisions [9]. The systematic uncertainties were estimated using $v_2\{RP\}$ as maximum and $v_2\{4\}$ as minimum $v_2$ values (represented as lines in all figures).

Fig. 8 shows that a significant (absolute) ridge yield persists up to the highest $p_t^{\text{trig}}$, with yield increasing with centrality. The finite ridge yield at $p_t^{\text{trig}}$ up to 9 GeV, where parton fragmentation is expected to be the dominant hadron production mechanism [7,8], indicates that the ridge is associated with jet production.

To characterize in more detail the properties of particles associated to the ridge-like or jet-like near-side correlation we use the $p_t^{\text{assoc}}$ spectrum in different $p_t^{\text{trig}}$ windows, as shown in Fig. 4. An exponential function $\frac{dN}{dp_t} \propto p_t e^{-p_t/T}$ is fitted to the data to extract the inverse slope parameter $T$. A clear difference between the slopes of the jet-like yield, using the $\Delta \eta(J)$ method, and the ridge-like yield is seen: while the $p_t$ dependence of the ridge yield is similar to the inclusive particle production, the jet-like associated yield has a significantly harder $p_t$-spectrum, increasing with $p_t^{\text{trig}}$, as expected from jet fragmentation. The slope of the ridge-like yield is largely independent of $p_t^{\text{trig}}$ and only slightly harder than the inclusive spectrum with a slope difference $\Delta T \approx 40$-50 MeV.

Fig. 5 a) shows the $p_t^{\text{trig}}$ dependence of the near-side $z_T$ di-hadron fragmentation function ($z_T = p_t^{\text{assoc}}/p_t^{\text{trig}}$) in central Au+Au collisions (for details see [11]). Subtracting the ridge-like contributions, using the $\Delta \phi(J)$ method, one observes a near-side fragmentation that is approximately independent of $p_t^{\text{trig}}$ (Fig. 5 b)). The $z_T$ distributions in central Au+Au collisions after subtracting the ridge contribution are comparable to the d+Au reference measurements (Fig. 5 c)) in contrast to the non-ridge subtracted distributions [11].
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These observations support the ansatz that the near-side $\Delta\eta \times \Delta\phi$ correlation consists of two distinct components: a jet contribution, consistent with the p+p and d+Au dihadron reference measurements \cite{4,5}, and the ridge contribution with properties similar to the medium. This could arise from partonic energy loss followed by fragmentation in vacuum, with the lost energy appearing dominantly in the ridge.

Several models are qualitatively able to describe the presented phenomena: coupling of induced radiation to longitudinal flow \cite{12}, a combination of jet-quenching and strong radial flow \cite{13} and recombination of locally thermal enhanced partons due to partonic energy loss in the recombination framework \cite{14}. A comparison of quantitative theoretical calculations to the measurements are needed in order to understand the origin of the ridge.

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