Evolution of the Away-Side Jet Shapes in $\pi^0 - h^\pm$ Correlations in 200 GeV Au+Au Collisions with RHIC-PHENIX

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1. Introduction

The studies of hard scattering processes in the heavy ion environment, previously uncharted before the advent of RHIC, have resulted in very dramatic results. Initial results, and the most cited, were the single particle studies where a suppressed production of high-$p_T$ particles compared to binary-scaled $p + p$ collisions was observed[1]. Two-particle studies, via the azimuthal correlation between two high-$p_T$ particles, have extended these single particle studies to infer properties of the jets themselves responsible for the particle production. At $p_T$ of 2-5 GeV/c, where hard scattering production dominates in $p + p$ collisions, there are strong modifications to the structure of the two-particle correlations in Au+Au collisions. In both the near-side and away-side the jets show yields which are enhanced compared to $p + p$ at low-$p_{T,assoc}$ and suppressed at the highest $p_{T,assoc}$[2]. The shape of the away-side correlations at these intermediate $p_T$ are also broader and show a humped structure compared to those in $p + p$ collisions[3]. Another difference in particle production between $p + p$ and $Au + Au$ at these $p_T$ is the observation of enhanced baryon production. The $p/\pi^+$ ratio is a factor of $\sim 5$ larger than that measured in $p + p$[4]. These ratios and spectra are consistent with models of recombination of partons from the medium and partons from jet fragments[4]. Recent results indicate that

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*For the full list of PHENIX authors and acknowledgements, see Appendix 'Collaborations' of this volume
the structure of the away-side seems to be dependent on the flavor of the associated particle \[6\].

This contribution focuses on \(\pi^0 - h^\pm\) correlations at high trigger \(p_T\) (>5 GeV/c). This is motivated for several reasons. First, given a high-\(p_T\) \(\pi^0\), the effects on these correlations from recombination is small \[7\] and less than the effects from using an unidentified hadron trigger. Next, it is instructive to measure the away-side structure of these correlations at high-\(p_T\) to determine if the structure is similar to the lobed structure observed in lower-\(p_T\) correlations. Finally, since the away-side parton on average travels through a longer medium path length, effects of energy loss should be more evident on the away-side. Whatever away-side structure exists, it is important to measure the yield and shape to quantify this modification compared to \(p+p\).

2. High-\(p_T\) Azimuthal Correlations

Azimuthal correlations are a well-established tool to measure jet fragments in all RHIC collisions. Details of the method used to measure correlations are found in reference \[8\]. Briefly, azimuthal correlations are measured with events containing a trigger particle. Detector acceptance and efficiency correlations are measured by correlating particles from different events. These are then removed from the real pair correlations to reveal the physical correlations.

The \(\pi^0\) trigger particles are measured in PHENIX by their \(\gamma\gamma\) decay channel in the electromagnetic calorimeter. One experimental advantage of using \(\pi^0\) triggers is the ability to measure the signal-to-background (S/B) of the triggers and to measure the correlations due to these fake \(\pi^0\) triggers from combinatoric photon

Fig. 1. Di-photon invariant mass distributions for 0-20% Au+Au collisions and photon pair \(p_T\) from 5-7 GeV/c (left) and 7-20 GeV/c (right). Dashed line is a Gaussian and polynomial fit to describe the signal and background.
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Fig. 2. Correlations between π⁰ triggers from 5-7 GeV/c and associated hadrons from 1-2 GeV/c (upper row), 2-3 GeV/c (second row), 3-5 GeV/c (third row), and 5-10 GeV/c (lower row) in Au+Au collisions in 0-20% central (left column), 20-40% central (middle column), and 40-70% (right column). Statistical errors are indicated by the error bars on the points. The systematic error on the normalization is given as the dashed line bracketing zero. The systematic error due to the v₂ uncertainty is the solid histogram around the data points. Not shown is a systematic error of 10% due to the single hadron efficiency and 5% from the combinatoric contribution under the π⁰ peak.

Once the physical correlations are measured, the interest is in the correlations due to jets. In A + A collisions the elliptic flow results in a physical two-particle correlation. This is removed by assuming that the correlations can be decomposed pairs within the π⁰ mass. Example di-photon invariant mass peaks are shown in Fig. 1 for 0-20% Au+Au collisions for the two trigger ranges considered here, 5-7 GeV/c and 7-20 GeV/c. The S/B is 3.6 for the 5-7 GeV/c and 8.6 for 7-20 GeV/c triggers. To measure the effect on the correlations due to the fake π⁰ triggers, correlations with di-photon triggers in mass ranges below and above the π⁰ peak are measured. The correlations from these combinatoric photon triggers within the π⁰ mass window are then extrapolated. In this analysis since the S/B is sufficiently large the effect of the background correlations is 5% nearly independent of ∆φ and as such we assign a 5% systematic error on the correlations.
Fig. 3. Correlations between $\pi^0$ triggers from 7-20 GeV/c and associated hadrons from 1-2 GeV/c (upper row), 2-3 GeV/c (second row), 3-5 GeV/c (third row), and 5-10 GeV/c (lower row) in Au+Au collisions in 0-20% central (left column), 20-40% central (middle column), and 40-70% (right column). Statistical errors are indicated by the error bars on the points. The systematic error on the normalization is given as the dashed line bracketing zero. The systematic error due to the $v_2$ uncertainty is the solid histogram around the data points. Not shown is a systematic error of 10% due to the single hadron efficiency and 5% from the combinatoric contribution under the $\pi^0$ peak.

into two sources

$$\frac{1}{N_{\text{trig}}} \frac{dN}{d\Delta\phi} = B \left( 1 + 2v_2^{\text{trig}} v_2^{\text{assoc}} \cos(2\Delta\phi) \right) + J(\Delta\phi)$$  \hspace{1cm} (1)$$

The $v_2$ of the trigger and associated particles are measured independently from an analysis of the single $\pi^0$ and charged hadrons with respect to the reaction plane. The background level $B$ must be determined in order to subtract the elliptic flow contribution. This is done by the Zero Yield At Minimum (ZYAM) method. In the end the jet correlations have errors due to background determination from ZYAM and the uncertainties in the measured $v_2$ values.
3. Results and Discussion

The resulting jet correlations between $\pi^0$ triggers and associated hadrons are shown in Fig. 2 and Fig. 3 for $\pi^0$ triggers from 5-7 GeV/c and 7-20 GeV/c, respectively. The associated hadron $p_T$ varies top to bottom in the bins 1-2 GeV/c, 2-3 GeV/c, 3-5 GeV/c and 5-10 GeV/c, respectively. The centrality of the collisions varies left to right in bins of 0-20%, 20-40%, and 40-70%, respectively. The dashed lines on the correlations around the zero line indicate the uncertainty in the background level from the ZYAM procedure. The solid lines around the points indicate the error on the $v_2$. All errors are 1σ.

From these jet correlations no obvious lobed structure is observed as in lower trigger $p_T$ correlations. A statistically significant away-side distribution is observed at all $p_T$ and centrality. What is not clear from these data alone are any systematic trends in centrality, associated $p_T$, or trigger $p_T$ for yield at $\Delta \phi \sim 2$ rad.

In the future it will be necessary to compare directly to the correlations in p+p and to quantify whatever yield exists in Au+Au compared to p+p to search for the existence of conical structure at these $p_T$. Further, it will be important to extend the $\pi^0$ trigger $p_T$ reach down to 2-5 GeV/c where the strong modifications are seen in unidentified hadron triggered correlations.

References

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