Correlation of high energy photons and charged particles in p+p and d+Au collisions at $\sqrt{s} = 200$ GeV

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Abstract. Azimuthal correlations between high energy photons from $\pi^0$ decay ($p_T^{\pi^0} < 10.5$ GeV) and charged hadrons ($p_T^{\text{hadron}}$ above a threshold of 2, 3 or 4 GeV/c) have been measured in p+p and d+Au collisions at $\sqrt{s} = 200$ GeV. Clear jet-like correlations are observed at $\Delta \phi = 0$ and 180 degrees, with peak widths decreasing with increasing $p_T^{\text{hadron}}$. Jet $\langle j_T \rangle$ and $\sqrt{\langle k_T^2 \rangle}$ in d+Au collisions are deduced from the distributions. These results are presented in Quark Matter 2004 poster session.

Particles produced by fragmentation of jets are seen to be correlated in azimuth and pseudorapidity. In high energy heavy ion collisions, a measurement of dihadron correlation functions is the closest approach to obtain the properties of jets. At RHIC energy, correlation functions have been measured between leading charged particles up to $p_T$ of 6 GeV/c and the associated charged particles with $p_T > 2$ GeV for pp, dAu and AA collisions [1].

As the trigger particle energy is increased, the strength of the jet-like correlations increases and the width of the correlations gets narrower. Increasing the associated particle threshold reduces the background in the correlation functions dramatically. Thus, higher energy trigger particles allow jet properties to be inferred from two-particle correlations with much less ambiguity.

In this work, energy deposition by photons in STAR Electromagnetic Calorimeters (EMC) are used for tagging events with high energy photons, thereby enabling us to obtain correlation functions with photon as trigger particles up to very high energy. In the present study we measure the azimuthal correlation function between triggered photons and the associated charged particles for pp and dAu collisions. We study the variation of widths of the correlation functions for various energies of triggered particles and for change in $p_T$ of associated particles. We also derive mean jet fragmentation transverse momentum $\langle j_T \rangle$ and r.m.s parton transverse momentum $\sqrt{\langle k_T^2 \rangle}$ from the widths of the correlation functions.

In this analysis we used triggered events from 2003 run for pp and dAu collisions. In this run EMC covered the region of $0 < \eta < 1$ with full azimuthal coverage. Charged
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Tracks with $|\eta| < 1$ are used as associated particles for obtaining correlation functions. We used standard cuts used in STAR for selecting high transverse momentum tracks.

For every event we selected towers with highest energy deposition above selected threshold (High Tower), these towers are considered as trigger tower. We then calculated $\Delta \phi = |\phi_{\text{trig}} - \phi_{\text{associated}}|$ for all associated particles above various thresholds with $p_{T,\text{associated}} < E_T^{\text{HighTower}}$. Correlation functions are obtained by calculating, $\frac{1}{\epsilon N_{\text{trig}}} \frac{dN}{d\Delta \phi}$, where $N_{\text{trig}}$ is the number of trigger towers, $\epsilon$ is the efficiency of the associated particles at the selected $p_T$ range.

Fig. 1 shows the correlation functions for dAu collisions with $4.5 \text{ GeV} < E_{\text{trig}}^p < 6.5 \text{ GeV}$ for two sets of lower limits in $p_{T,\text{associated}}$, 2 GeV/c and 3 GeV/c. Fig. 1 shows the case of two sets of associated particles $p_T$ thresholds, (2 GeV/c and 3 GeV/c) for $4.5 \text{ GeV} < E_{\text{trig}}^p < 6.5 \text{ GeV}$. Fig. 2 shows the case for two sets of trigger particle energy, $4.5 \text{ GeV} < E_{\text{trig}}^p < 6.5 \text{ GeV}$ and $6.5 \text{ GeV} < E_{\text{trig}}^p < 8.5 \text{ GeV}$. Pedestal values of the correlation functions are obtained by taking the averages in the region of $\Delta \phi = 1$ to 2.

Two clear peaks are seen. Peaks (near angle peak and far angle peak) are fitted with gaussian functions. We have studied (a) area under the peak giving the total number of pairs per trigger tower and (b) $\sigma$ of the fitted gaussians on two peaks. Fig. 3 and fig. 4 shows the variation of above mentioned parameters for varying $p_{T,\text{associated}}$ and varying $E_{\text{trig}}^p$.

Correlation peaks get narrower with increase in $E_{\text{trig}}^p$ and $p_{T,\text{associated}}$ as expected from jets. Within error pp and dAu shows similar widths for $4.5 \text{ GeV} < E_{\text{trig}}^p < 6.5 \text{ GeV}$. Number of associated particles are larger for higher $E_{\text{trig}}^p$ and reduces with $p_{T,\text{associated}}$. This number gives idea about the number of charge particles associated to the jets in
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Figure 2. Azimuthal correlation functions for $dAu$ collisions for two sets of $E_{\text{trig}}$, $4.5$ GeV $< E_{\text{trig}} < 6.5$ GeV and $6.5$ GeV $< E_{\text{trig}} < 8.5$ GeV with same lower limit on $p_T^{\text{associated}} = 2$ GeV/c.

Figure 3. Variation of the area under peaks for near angle ($\Delta \phi = 0^0$) and far angle correlation peaks ($\Delta \phi = 180^0$) for various $p_T^{\text{associated}}$. Three sets of $E_{\text{trig}}$ bins are used with 2 GeV width and lower limits of 4.5 GeV/c, 6.5 GeV/c and 8.5 GeV/c.
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![Graph of Far Angle Correlation](image1)

![Graph of Near Angle Correlation](image2)

**Figure 4.** Variation of the fitted $\sigma$ for near angle ($\Delta \phi = 0^0$) and far angle correlation peaks ($\Delta \phi = 180^0$) in dAu and pp collisions for various $p_T^{\text{associated}}$ pp results are shown for $4.5 \text{ GeV} < E^{\text{trig}} < 6.5 \text{ GeV}$.

In order to extend the analysis for jet characterization we calculated $\langle j_T \rangle$ and $\sqrt{\langle k_T^2 \rangle}$ using the formulae,

$$\sigma_N^2 \approx \frac{\langle E_T^2 \rangle + \langle p_T^2 \rangle}{2\langle E_T^2 \rangle \langle p_T^2 \rangle} \langle j_T^2 \rangle.$$

(1)

$$\langle j_T \rangle = \frac{\sqrt{\pi}}{2} \sqrt{\langle j_T^2 \rangle}.$$

(2)

and

$$\sqrt{\langle k_T^2 \rangle} \approx \frac{\langle E_T \rangle}{\langle z \rangle} \sqrt{\sigma_F^2 - \sigma_N^2}.$$

(3)

where $\langle E_T \rangle$ represents average transverse momentum of the triggered towers and $\langle p_T \rangle$ gives average transverse momentum of the associated particles. $\sigma_F$ and $\sigma_N$ are the fitted widths of near and far angle peaks.

The values obtained for $\langle j_T \rangle$ and $\langle z \rangle \sqrt{\langle k_T^2 \rangle}$ are $450 \pm 40 \pm 150 \text{ MeV/c}$ and $1.9 \pm 0.2 \pm 0.3 \text{ GeV/c}$ respectively, where $\langle z \rangle$ is the fragmentation function for the trigger photon, and is in the range 0.6-0.8.

**References:**

1. C. Adler et.al.,(STAR Collaboration), Phys. Rev. Lett. 90 (2003)082302