Azimuthal correlations of high-p_T photons and hadrons in Au+Au collisions at RHIC

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The measurement of γ+jet events with a direct photon in coincidence with an energetic parton can provide unique insights into the propagation and fragmentation of the parton in the presence of the hot and dense medium created in heavy-ion collisions. One way to explore these effects is the study of azimuthal correlations between the direct photon and hadrons produced in the fragmentation.

We present azimuthal correlations between photons with a transverse momentum of more than 10 GeV and charged hadrons with a transverse momentum of more than 2 GeV in Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV that have been measured with the STAR detector at RHIC. The separation of correlations with direct photons and photons from hadronic decays will be discussed.

1. INTRODUCTION

Photon-tagged jets in heavy ion collisions provide the ideal framework to study the interaction of energetic partons traversing a strongly interacting, hot and dense medium like the Quark-Gluon Plasma [1]. Annihilation ($q\overline{q} \rightarrow g\gamma$) or Compton scattering ($qg \rightarrow q\gamma$) results in γ+jet events with a prompt photon, which does not interact strongly, and a parton, which is subject to energy loss in the medium and subsequent fragmentation into a jet of hadrons [2]. As the photon escapes the medium without interactions, the analysis of these events will provide the best possible determination of the initial kinematics of the parton, and therefore all modifications of the jet can be attributed to the interaction of the parton or the emerging jet with the medium [3,4]. Azimuthal correlations with prompt photons as trigger particles reflect these interactions and provide information about the energy loss mechanism during the propagation of the parton through the medium [5].

2. ANALYSIS

The data presented here has been taken by the STAR experiment during a long Au+Au run at top energy of $\sqrt{s_{NN}} = 200$ GeV at the RHIC collider. Events triggered on a high tower ($E_T > 9$ GeV) in the Barrel Electromagnetic Calorimeter (BEMC) were selected for fast analysis. In the configuration used for this analysis, about 180 million events were offered to the trigger, corresponding to an integrated luminosity of $25\,\mu\mathrm{b}^{-1}$.

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This analysis studies azimuthal correlations between neutral clusters in the BEMC [7] and charged tracks reconstructed with the Time Projection Chamber (TPC) [8].

Neutral trigger particles are reconstructed by adding the energy of the three neighboring towers with the highest energy deposition to a trigger tower. For each event, only the trigger cluster with the largest transverse energy is used and only if $E_T > 10\,\mathrm{GeV}$. The cluster position is defined as the center of the highest energy tower of the cluster. Clusters with a matching TPC track with $p_T > 1\,\mathrm{GeV}$ within 0.03 in η and ϕ are vetoed to remove charged particles with large energy deposition.

Charged particles with high transverse momenta are then associated with these neutral trigger particles. Due to large acceptance losses near the TPC edges, the acceptance has been limited to $|\eta| < 0.9$.

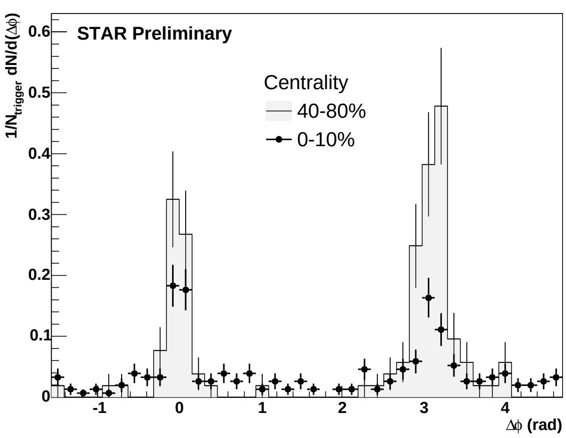

Figure 1: $\Delta\phi$ correlation of trigger BEMC clusters with $E_T^{trigger} > 10\,\mathrm{GeV}$ and associated charged particles with $4\,\mathrm{GeV} < p_T^{assoc} < E_T^{trigger}$. The correlation function is corrected for tracking efficiency. Combinatorial background has not been subtracted.

Figure 1 shows the distribution of azimuthal angles between trigger clusters with $E_T = 10 - 15\,\mathrm{GeV}$, which are a mixture of neutral pions and photons, and associated particles with $4\,\mathrm{GeV} < p_T^{assoc} < E_T^{trigger}$. A correction for the tracking efficiency of the associated particle has been applied. No background has been subtracted, and the reduced near-side yield due to the charged track veto has not been corrected for. Note that the background is very low. This greatly reduces systematic uncertainties on the extracted properties (both shape and yield) of the correlation signal compared to previous analyses at lower p_T [6]. Clear near- and away-side correlations are visible in peripheral as well as central events, in contrast to the disappearance of back-to-back correlations between charged particles at lower transverse momenta in central collisions [6].

The associated yield n_{near}, n_{away} per trigger particle is determined by integration over the near- ($|\Delta\phi| < 0.3$) or away-side peaks ($|\Delta\phi - \pi| < 0.6$), subtraction of a flat background determined from the region between the peaks, and normalization with the number of trigger particles in the event sample.

Figure 2 shows the ratio of associated near-side yield per trigger particle in central and peripheral collisions as a function of centrality: $I_{CP}^{near} = n_{near}(\mathrm{central})/n_{near}(\mathrm{peripheral})$. The near-side yield for neutral BEMC trigger clusters decreases by about 40% with centrality for two different p_T^{assoc} bins (solid symbols). This feature is not visible in correlations between charged particles with similar cuts for trigger and associated particles (open symbols) [9], which are consistent with an unmodified near-side correlation. The decrease of the associated yield in correlations between neutral and charged particles can be attributed to single particle high-p_T suppression, which reduces the pion yield per binary collision, but does not affect prompt photon production [10,11]. The result is a lower fraction of π^0 triggers $N_{\pi^0}/(N_{\pi^0} + N_\gamma)$, and a proportionally lower associated near-side

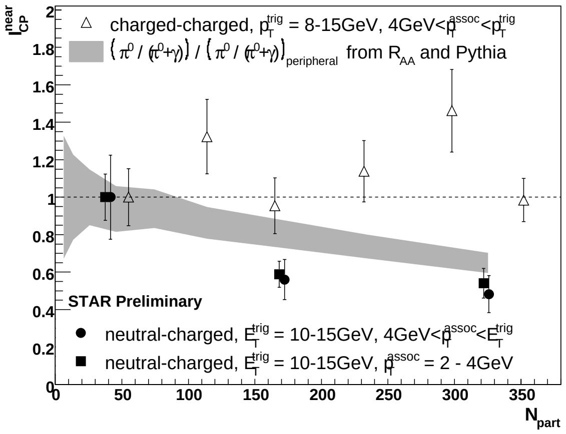

Figure 2. Ratio of the near-side yield in central and peripheral collisions I_{CP}^{near} for neutral-charged (solid symbols) and charged-charged correlations (open symbols), and expected π^0 fraction relative to peripheral collisions (grey band, see text).

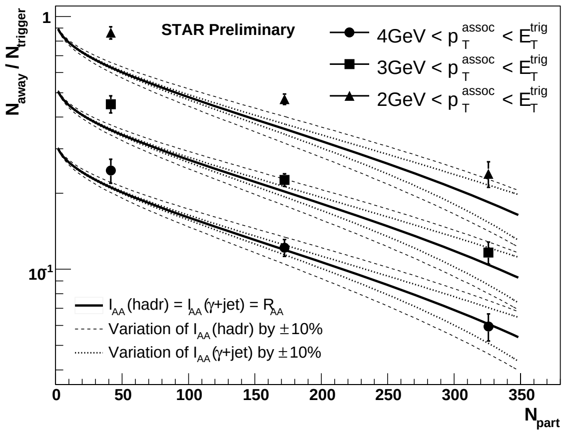

Figure 3. Away-side yield per trigger cluster for neutral-charged correlations. Solid lines are away-side yield from Pythia with a suppression of γ+jet and dijet components by R_{AA} ($I_{AA}(\text{hadr}) = I_{AA}(\gamma+\text{jet}) = R_{AA}$). The dashed and dotted lines represent 10% variations of $I_{AA}(\text{hadr})$ and $I_{AA}(\gamma+\text{jet})$.

yield per unidentified trigger particle, if a constant yield per π^0 trigger is assumed. This decrease of the π^0 fraction can be described by using the π^0 fraction from a Pythia simulation as reference, scaling N_{π^0} with R_{AA} from [10], and normalizing to the most peripheral data point to allow comparison with I_{CP}^{near} (grey band). The data is consistent with the expected decrease of the fraction of π^0 triggers from approximately 80% in peripheral to about half of all trigger particles in the most central collisions.

Figure 3 shows the away-side yield per neutral trigger particle with $E_T = 10 - 15\,\text{GeV}$ as a function of centrality. The away-side correlations have both γ+jet and dijet contributions. We try to describe the away-side yield by adding the expected γ+jet and dijet yields from a Pythia simulation after applying two separate suppression factors $I_{AA}(\gamma+\text{jet})$ and $I_{AA}(\text{hadr})$. The observed suppression is consistent with both parameters being similar to the nuclear modification factor: $I_{AA}(\gamma+\text{jet}) \approx I_{AA}(\text{hadr}) \approx R_{AA}$. A separation of γ+jet and dijet correlations is necessary to draw final conclusions. The measurement of either suppression factor is sufficient to determine both, as the combined I_{AA} is already known.

The absence of a near-side correlation in γ+jet events can be used to tag dijet events by requiring a charged track with $p_T > 2.5\,\text{GeV}$ in a search cone around the cluster with a radius of 0.15 in the η-ϕ-plane. The cone size and p_T cut have been chosen for high purity due to low random background, and high efficiency, which is however limited by the near-side yield per π^0 trigger. Figure 4 shows the away-side correlation for these hadron-tagged and all, i.e. tagged as well as untagged, triggers, with a common normalization to the total number of neutral trigger clusters, for two centrality bins. The tagged correlation function is not corrected for the tagging efficiency. For both centralities, about 20% of

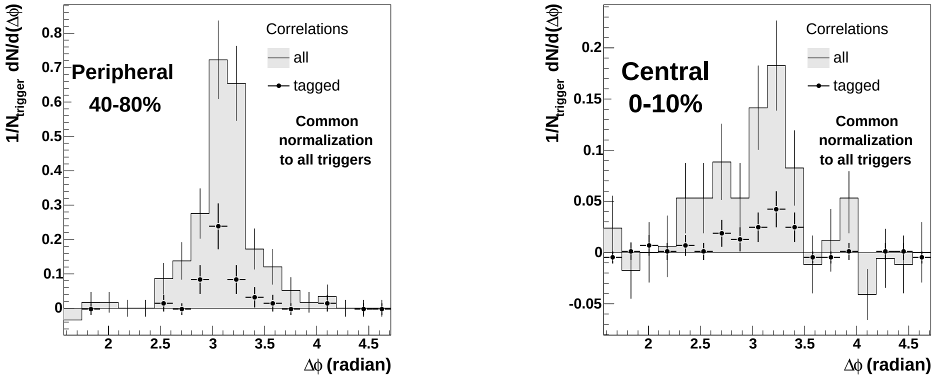

Figure 4. Inclusive (shaded) and hadron-tagged (solid markers) away-side $\Delta\phi$ correlations with $E_T^{trigger} > 10\,\text{GeV}$ and $3\,\text{GeV} < p_T^{assoc} < E_T^{trigger}$ for peripheral and central events. The hadron-tagged correlation has not been corrected for tagging efficiency.

all correlated back-to-back pairs have a tagged trigger, indicating that dijets contribute substantially to away-side correlations not only in peripheral, but also in central events. A quantitative statement about the relative contributions from γ+jet and dijets in central collisions will require a precise determination of the tagging efficiency from simulations or peripheral events, where dijet correlations dominate.

3. CONCLUSIONS

The dataset from the long Au+Au run in 2004 allows the analysis of azimuthal correlations between photonic trigger particles with energies above 10 GeV and associated particles above 4 GeV. A decrease of the near-side yield indicates a large fraction of triggers from γ+jet events (close to 50%). The centrality dependence of the away-side yield is consistent with similar values for the away-side suppression I_{AA} for dijet and γ+jet correlations and the nuclear modification factor R_{AA}. The separation of dijet and γ+jet contributions requires further analyses with better identification of these two sources.

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