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Measurement of in-medium modification of energy-space structure of jets via γ and π^0 triggered hadrons in Au+Au collisions at RHIC

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Abstract. Since the discovery of the jet quenching at RHIC, the in-medium interaction of hard scattered partons with the nuclear medium created by high-energy heavy-ion collisions has been an excellent tool to understand not only the transport properties of the medium but also its time evolution towards hadronization. The multi-differential measurement of the high momentum two-particle correlations can probe a particular space-time window as a function of energy transfer. Comparing the correlations with the prompt photon-triggered hadron spectra, one can extract the property of the medium from various aspects and contribute to distinct models. The PHENIX experiment at RHIC has collected its highest statistics of the γ and π^0 triggered hadron events in Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV in the RHIC Year-2014 run, and measured not only the inclusive spectra of the triggered hadrons but also the angle and energy dependent I_{AA} and D_{AA}. We will discuss the in-medium modification of the energy-space structure of the jets at the RHIC energies with the results obtained.

1 Introduction

By colliding gold nuclei at $\sqrt{s_{NN}}$ = 200 GeV, the Relativistic Heavy Ion Collider (RHIC) creates the quark gluon plasma (QGP), a state of nuclear matter in which quarks and gluons are not confined within hadrons. In the initial stages of the collision, hard scatterings can produce energetic partons which then lose energy as they traverse the QGP before fragmenting into a spray of particles known as a jet. Comparing jet measurements in heavy-ion collisions to jets in p+p collisions reveals suppression of high energy hadrons and jets, and modifications to the spatial and momentum distributions of particles within the jet. These jet quenching effects and the medium's response to the lost energy are useful tools for testing our understanding of partonic energy loss in the QGP by comparing experimental observables to expectations from theoretical models.

Direct photons, which do not interact via the strong force, are not suppressed in the QGP [1]. At high momentum, direct photons are predominately produced via quark-gluon scatterings that result in a quark initiated jet opposite the direct photon. Since the direct photon is not modified its energy balances the initial energy of the opposing quark. Therefore, direct photon-tagged jet measurements have long been considered a golden channel for measuring energy loss in the QGP. PHENIX has published results for direct photon-hadron correlations

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in data collected from Au+Au collisions in 2004, 2007, 2010 and 2011 [2–4]. These results show a suppression of high momentum hadrons due to the energy loss and an enhancement of low momentum hadrons attributed to enhanced lower momentum particle production [5] or medium response [6, 7]. However, due to the rarity of this scattering and the large contribution of decay photons which need to be removed, the statistical and systematic uncertainties remain large. In 2014 and 2016, PHENIX collected a significantly larger sample of Au+Au events which have yet to be fully analyzed. This talk presented the status of various components for extracting the direct photon-hadron correlations from the 2014 data including π^0-hadron correlations which quantify the modifications of dijet events and can also be compared to energy loss models. The increased statistics from 2014 enables more differential measurements including the angular distribution of modifications.

2 Direct Photon Analysis

Photons are measured in the PHENIX electromagnetic calorimeter (EMCal) which consists of six sectors of lead scintillator towers and two sectors of lead glass towers. Charged hadrons are measured by selecting tracks in the PHENIX drift and pad chambers and using the RICH to exclude electrons. The azimuthal angle $\Delta\phi$ between the photon and the hadrons is measured to extract the photon-hadron correlations. Mixed events and GEANT3 simulations are used to correct for the detector effects and tracking efficiency. Since a large fraction of the photons measured are actually from the decay of neutral pions, their contribution to the inclusive photon-hadron correlations must be removed using Equation 1.

$$Y_{direct} = \frac{R_\gamma Y_{inclusive} - Y_{decay}}{R_\gamma - 1}, \tag{1}$$

where Y refers to the per trigger yield from the photon-hadron correlations with the type of photon indicated in the subscript and $R_\gamma = N_{inclusive}/N_{decay}$ which is the ratio of the number of inclusive photons to the number of decay photons. PHENIX has measured R_γ using the 2014 data [8]. The decay photon-hadron correlations are determined by weighting the π^0-hadron correlations. Due to the fine segmentation of the PHENIX EMCal, π^0s can be measured up to 20 GeV by measuring the invariant mass of photon pairs. Before extracting the per trigger yield, the flow modulated underlying event needs to be subtracted from the correlations according to

$$\frac{dN_{\gamma-h}}{d\Delta\phi} = \frac{1}{N_\gamma}\frac{N_{\gamma-h}}{\epsilon\int d\Delta\phi}\left\{\frac{dN^{same}_{\pi^0-h}/d\Delta\phi}{dN^{mix}_{\gamma-h}/d\Delta\phi} - b_0\left[1 + 2\sum_{n=2}^{4}\langle v_n^{\pi^0} v_n^h\rangle\cos(n\cdot\Delta\phi)\right]\right\}.$$

The second order Fourier term, v_2, has recently been measured by PHENIX for inclusive and decay photons using the Run 14 data and are shown in Figure 1. To extract Y_{decay}, one must first measure π^0-hadron correlations.

3 π^0-hadron Analysis

The π^0-hadron correlations are an important part of the direct photon-hadron analysis but they also contain interesting jet physics. These high momentum π^0s select on dijet events. The modification of these jets in Au+Au collisions can be compared to p+p collisions by taking the ratio, $I_{AA} = Y_{AA}/Y_{pp}$, or the difference, $D_{AA} = Y_{AA} - Y_{pp}$, of the yields in the two collision systems. The I_{AA} is shown as a function of associated hadron p_T in Figure 2

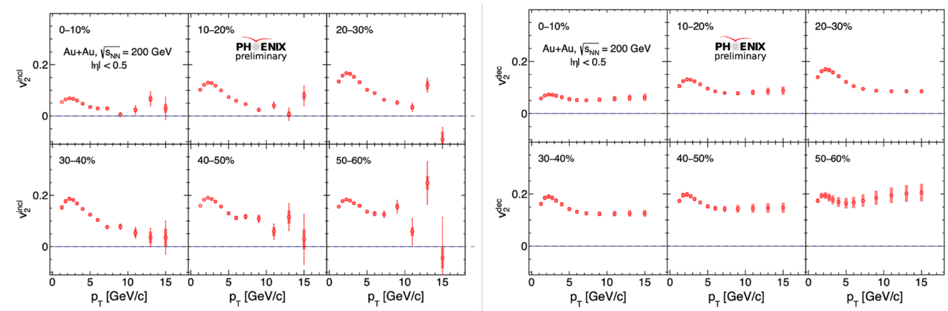

Figure 1. The v_2 for inclusive photons (left) and decay photons (right) measured in the PHENIX 2014 Au+Au dataset.

for four π^0 p_T bins (4–5, 5–7, 7–9, 9–12 GeV/c). Hadrons are measured from 0.5–7 GeV/c. At low momentum there is an enhancement in Au+Au compared to p+p as indicated by $I_{AA} > 1$ while a suppression ($I_{AA} < 1$) is observed for the high momentum hadrons. This observation is consistent with previous direct photon-hadron correlations. To further explore where this enhancement occurs spatially, D_{AA} vs $\Delta\phi$ is extracted for the awayside ($|\Delta\phi| > \pi/2$) jet. Figure 3 shows D_{AA} for a p_T bin where I_{AA} showed enhancement and one where I_{AA} shows suppression. For the 3–5 GeV/c bin, suppression of the jet peak is observed around $\Delta\phi = \pi$. For the 0.5–1 GeV/c bin, enhancement is observed over a broad range of $\Delta\phi$ which is consistent with previous observations that indicate enhancement at wide angles relative to the jet axis. These effects are captured in the hybrid model that includes medium response (red band in Figure 3) [6]. This suggests that the enhancement is a result of the response of the medium to energy lost by the hard scattered parton.

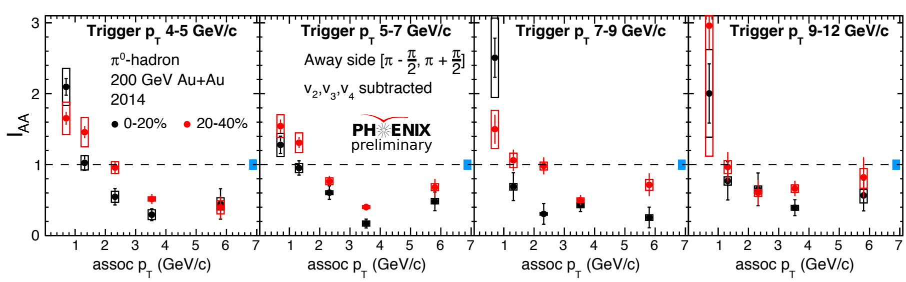

Figure 2. I_{AA} as a function of associated hadron p_T for four different π^0 p_T bins in 0–20% (black) and 20-40% (red) centrality bins.

4 Conclusion

The measurements for the inclusive and decay photon v_2, R_γ, and π^0-hadron correlations all from the high statistics Run 14 PHENIX Au+Au data were highlighted. These are all crucial for extracting the direct photon-hadron correlations from this dataset. In addition, the modification of the π^0-hadron correlations in Au+Au with respect to p+p was quantified and shown as a function of $\Delta\phi$. The results indicate that the enhancement for low momentum hadrons occurs over a broad azimuthal range opposite the pi^0. This is consistent with expectations for

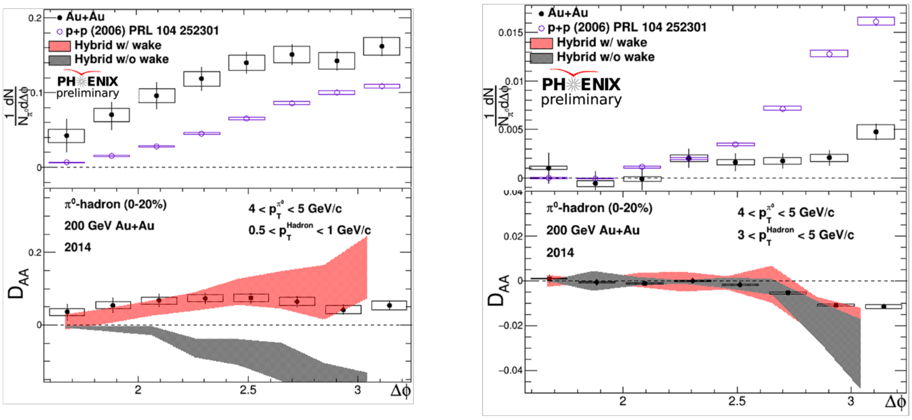

Figure 3. The Y_{AA} (top, black), Y_{pp} (top, purple) and D_{AA} as a function of $\Delta\phi$ for two associated hadron p_T bins, 0.5-1 GeV/c (left) and 3-5 GeV/c (right) for π^0-hadron correlations measured in PHENIX compared to Hybrid model expectations with (red band) and without (gray band) medium response.

medium response as demonstrated by the Hybrid model [6]. The next steps for these studies is to extract the D_{AA} as a function of $\Delta\phi$ for direct photon-hadron correlations using the Run 14 data. Comparisons of those results to the π^0 triggered results presented here as well as to a variety of models will further constrain the medium response description.

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