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Two particle hadron correlations with higher harmonic flow in Au+Au 200 GeV collisions at RHIC-PHENIX

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Measurements of two particle correlations in high-energy heavy-ion collisions are important tools to diagnose the initial collisions and thermalization process, and the response of medium to energetic partons in Quark Gluon Plasma (QGP). In this report, the recent results are presented on two particle azimuthal correlations after subtracting the contributions from higher harmonic flow and on two particle pseudo-rapidity correlations with pseudo-rapidity selection imposed on trigger particles in Au + Au collisions at $\sqrt{s_{NN}} = 200$ GeV. We discuss the modification of away side double hump structure by higher harmonic flow subtraction and dependence on third harmonic event plane in azimuthal correlations as well as correlation shapes in trigger selected pseudo-rapidity correlations.

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1. Higher harmonic event plane and flow

In heavy ion collisions, two particle correlations have double hump structure[1] at away side in azimuthal direction and long range correlations at near side in pseudo-rapidity direction, while those are not seen in p+p collisions. Recently it is suggested via AMPT model simulations that the double hump structures at away side can be described by the triangular flow[2] originated from the fluctuations of initial collision geometry. Measurements of particle anisotropies with respect to higher harmonic event planes Φ_n and estimation of their contribution to the two particle correlations will provide rich information to understand the initial condition and space-time evolution of QGP.

The magnitude v_n of the n-th harmonics of Fourier expansion of azimuthal angular distribution with respect to Φ_n is defined as

$$v_n = < cosn(\phi - \Phi_n) >, \tag{1.1}$$

where ϕ denotes the azimuth of particle. In order to exclude the auto correlations from hard process, the rapidity gap between ϕ and Φ_n have to be sufficiently large. In the v_n measurements by the PHENIX experiment[3], Φ_n is determined at $1 < |\eta| < 2.8$ while particles are measured at $|\eta| < 0.35$.

2. Two particle $\Delta\phi$ correlations with higher harmonic flow subtractions

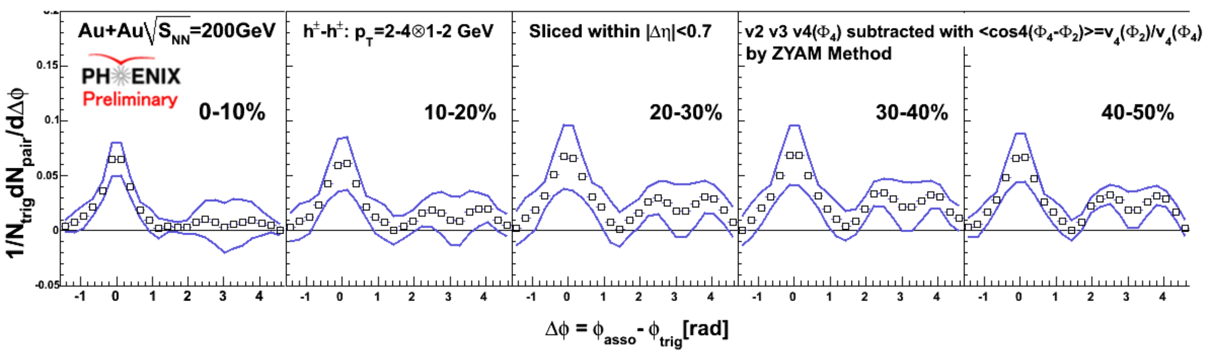

Figure 1: Two particle charged hadron correlations in $\sqrt{s_{NN}}$ =200 GeV Au+Au collisions for centrality bins from 0 to 50%. Transverse momentum ranges are 2-4 GeV/c for trigger particles and 1-2GeV/c for associated ones, respectively. Contributions from v2, v3 and v4 are subtracted by ZYAM method.

Fig. 1 shows the two particle charged hadron correlations in $\sqrt{s_{NN}}$ =200 GeV Au+Au collisions after the subtraction of contributions from v2, v3 and v4 by ZYAM method. The transverse momentum ranges of hadron pairs are 2-4 GeV/c for trigger particles and 1-2GeV/c for associated ones, respectively. The contributions to the $\Delta\phi$ correlations from flow are estimated using the measured v2, v3 and v4. It is noted that the correlation between second harmonic event plane Φ_2 and fourth harmonic event plane Φ_4 is included in the calculation, therefore it also contains the effects from $v_4(\Phi_2) =< \cos 4(\phi - \Phi_2) >$.

Considering cone radius of jets, these correlations measured without the pseudo-rapidity gap between pairs ($|\Delta\eta| < 0.7$) preserve jet like component in itself. On the other hand, v_n are measured with large rapidity gaps and they contain much less jet components. Therefore, possible medium-energized parton interplay is not compensated by the flow contribution subtractions process.

In most central collisions, the subtractions of contributions from v_3 and v_4 significantly reduces the double hump structure and away side general yield. However in mid-central collisions, the structures remains clearly even after the contribution rejection from higher harmonics and yield at away side also remains.

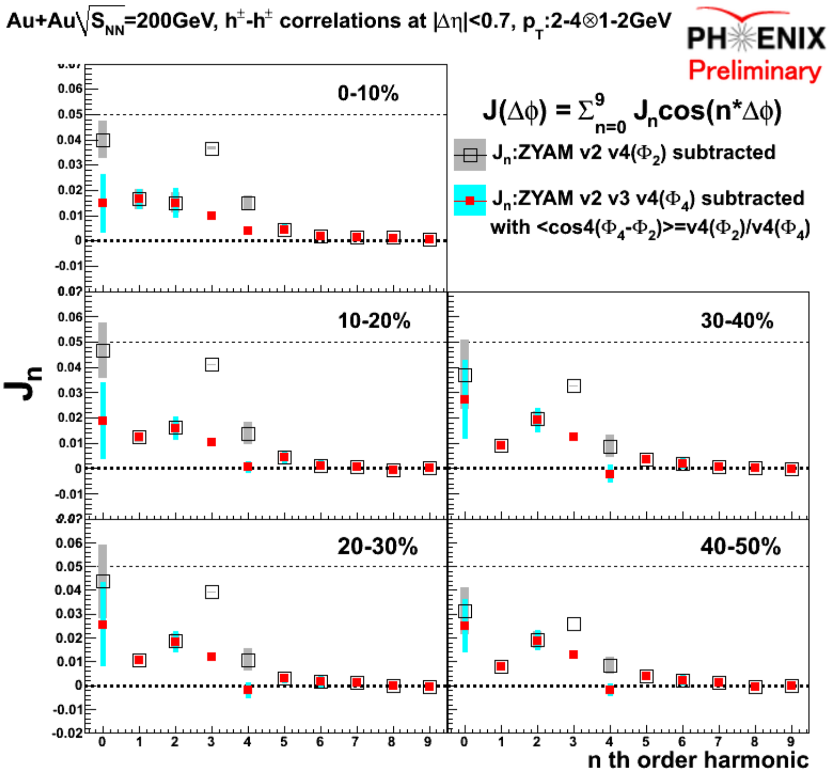

Figure 2: Two particle charged hadron correlations shown in Fig.1 decomposed by cosine terms of Fourier series centrality 0 to 50%.

Fourier series decomposition is applied to the correlation functions $J(\Delta\Phi)$ shown in Fig.1 to obtain the cosine terms up to 9th harmonics as follows;

$$J(\Delta\Phi) = \sum_{n=0}^{9} J_n \cos n\Delta\phi. \tag{2.1}$$

The obtained amplitude J_n is shown in Fig. 2.

The amplitude of collective flow $v_n =< cosn(\phi - \Phi_n) >$ in single particle level is reflected in correlations as $v_n^{trig} v_n^{asso} cosn\Delta\phi$. After the subtractions of contributions from v_3 and v_4, $\cos 3\Delta\phi$ and $\cos 4\Delta\phi$ components in correlation functions are reduced, however still $\cos 3\Delta\phi$ terms can be seen in all centrality ranges. The degree of remaining $\cos 4\Delta\phi$ components after flow subtractions are depending on centrality, they have positive amplitude in centrality 0-20% but negative one in centrality 20-50%. The $\cos 3\Delta\phi$ and $\cos 4\Delta\phi$ components are balanced in most central collisions while they are imbalanced in mid-central collisions, this results in the disappearance or remaining of double hump structures in most central or mid central collisions.

3. Two particle $\Delta\phi$ correlations relative to third order event plane Φ_3

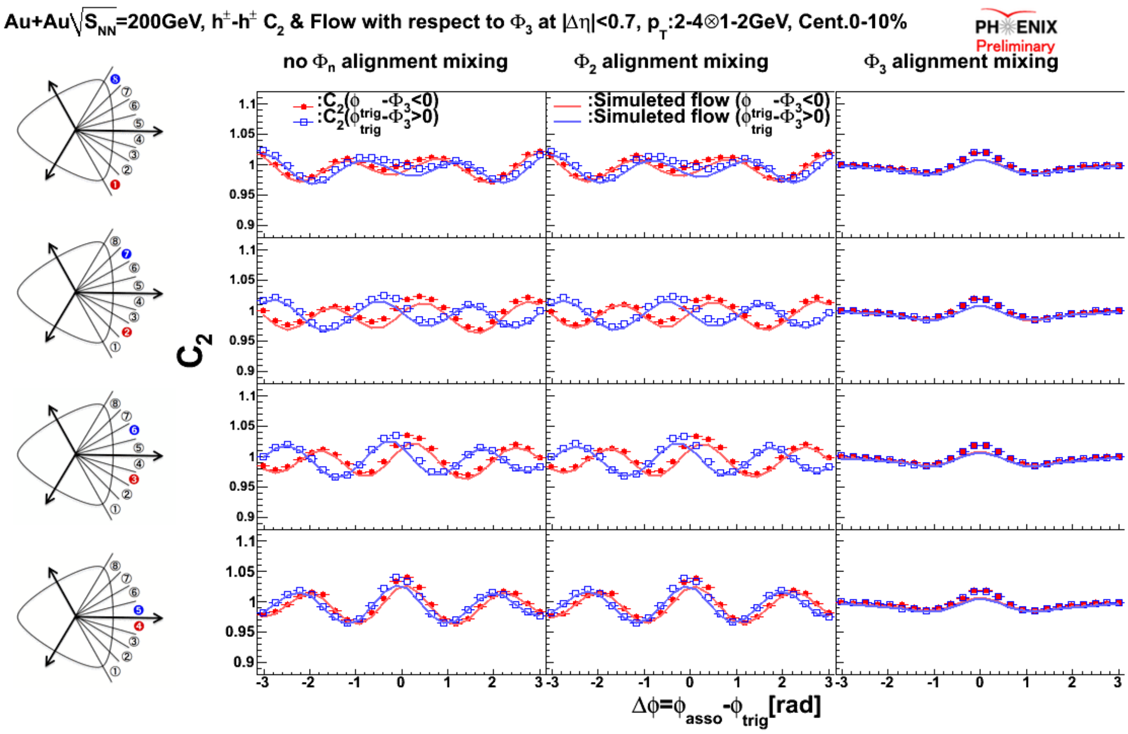

Figure 3: Φ_3 dependent correlations without flow subtractions and pure flow contribution simulated with measured v_n at centrality 0-10%. Results under no Φ_n,Φ_2 and Φ_3 alignment mixing methods are presented. The transverse momentum ranges are 2-4 GeV/c for trigger particles and 1-2GeV/c for associate particles. The direction of solid circle in left figures indicate the direction of trigger particle relative to Φ_3.

Measurements of two particle correlations with trigger particle selection relative to third order event plane Φ_3 is performed to test the parton path length dependence of correlations with respect to triangular component of fluctuating collision geometry, as done in correlation measurements relative to second order event plane Φ_2 to survey path length dependence on elliptic shape of collision geometry [4].

Fig.(3) shows Φ_3 dependent correlations without flow subtractions and pure flow contribution simulated with measured v_n in most central collisions, where the couple of Φ_n alignment selection in laboratory frame on event mixing process are performed. The transverse momentum ranges are 2-4 GeV/c for trigger particles and 1-2GeV/c for associate particles. The direction of trigger particle relative to Φ_3 is divide into 8 different ranges as small images in Fig.(3). Red and blue square marker indicate the correlations with trigger in right or left side relative to Φ_3. Red and blue curves show the pure flow distribution with same trigger selection as correlations.

The most right column in Fig.(3) shows the correlations and flow contributions under the Φ_3 alignment event mixing. These represent the results in which v_3 contributions are to some degree reduced because alignment of event plane direction in laboratory frame on the process of event mixing provides similar flow distribution to pairs in both real and mixed events and loses $\cos n\Delta\phi$ components in correlations. Both correlations and flow distribution seem to be independent of Φ_3, therefore it would be telling us that flow subtracted correlations are also independent of or weakly dependent on third harmonic event plane.

4. Two particle $\Delta\eta$ correlations with trigger η selection

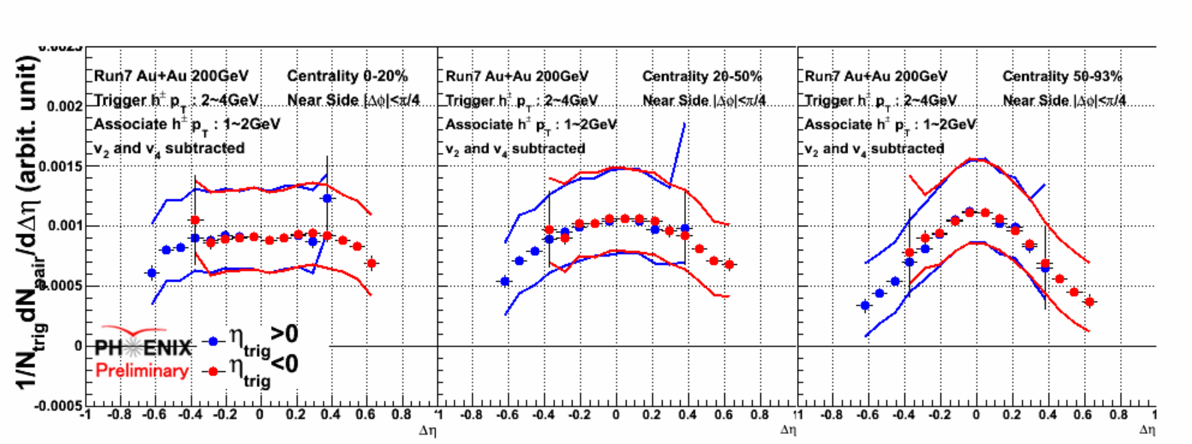

Figure 4: Two particle $\Delta\eta$ correlations with trigger η selection in positive(blue) or negative(red) region. Contributions from v_2 and $v_4(\Phi_2) = < cos4(\phi - \Phi_2) >$ are subtracted. Near side($|\Delta\phi| < \pi/4$) results are presented.

Possible medium response in pseudo-rapidity direction could also be discussed via two particle $\Delta\eta$ correlations with trigger particle selection in pseudo-rapidity direction as previously performed in $\Delta\phi$ correlations, since correlations would have trigger rapidity dependence if there are evolution mechanisms of medium such as density profile depending on pseudo-rapidity and longitudinal flow.

Fig.4 shows the $\Delta\eta$ correlations with trigger particle selection in positive or negative η region, where contributions from v_2 and $v_4(\Phi_2) = < \cos 4(\phi - \Phi_2) >$ are subtracted. The transverse momentum range of trigger particle is 2-4 GeV/c and that of associate particle is 1-2GeV/c. Blue marker show the positive triggered case, red marker show the negative triggered case, respectively. The discrepancy of plot range between positive and negative trigger cases is due to the limited acceptance of detector in pseudo-rapidity direction. PHENIX central arm has $|\eta| < 0.35$ coverage, this restricts the plot range as $-0.70 < \Delta\eta < 0.35$ or $-0.35 < \Delta\eta < 0.7$ for positive or negative triggered case, respectively.

Positive and negative triggered cases seem to be consistent with in all centrality at $\Delta\eta$ range common to both triggered case, the effect of trigger selections could not be seen in this pair momentum region. We here note that the experimental sensitivity of these correlation measurements for

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medium dynamics in pseudo rapidity direction might be insufficient due to limited pseudo rapidity range for trigger selections.

5. Summary

We have measured two particle correlations in both azimuthal and pseudo-rapidity direction. In azimuthal correlations, rejection of contributions from higher harmonic flow make double hump structure disappeared only in most central collisions, reduced structure still remain in mid central collisions. Measurements of triggered correlations tell us that correlations would be independent of or weakly dependent on third harmonic event plane. In pseudo-rapidity correlations, both of positive and negative triggered correlations seem to be consistent with. It could be thought that the effect of trigger selections is not seen, or this might be due to not sufficient experimental sensitivity in current detector configurations.

References

[1] A. Adler et. al., *Dihadron azimuthal correlations in Au+Au collisions at* $\sqrt{s_{NN}}$*=200 GeV*, Phys. Rev. C. 78, 014901 (2008).

[2] B. Alver *Collision-geometry fluctuations and triangular flow in heavy-ion collisions*, Phys. Rev. C 81, 054905 (2010).

[3] A. Adare et. al., *Measurements of Higher-Order Flow Harmonics in Au+Au Collisions at* $\sqrt{s_{NN}}$ = *200 GeV*, Phys. Rev. Lett. 107, 252301 (2011).

[4] H. Agakishiev et. al., *Measurements of Dihadron Correlations Relative to the Event Plane in Au+Au Collisions at* $\sqrt{s_{NN}} = 200$ *GeV*, arXiv:1010.0690v1 [nucl-ex] (2011).