Initial fluctuation and dihadron and γ-hadron correlations in high-energy heavy ion collisions

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Abstract. Fluctuations in initial parton density give rise to fluctuating geometrical shapes and hot spots in high energy heavy ion collisions. Hydrodynamic evolution of these initial fluctuations lead to the final anisotropic dihadron azimuthal correlation. We remove the harmonic flow background, and separately study the effects from different sources of initial fluctuation with different initial conditions within AMPT model. We also study γ-hadron correlation which is only influenced by jet-medium interaction.

1. Introduction

A strongly interacting partonic matter could be created in heavy-ion collisions at RHIC and LHC energy. Jets, produced in hard processes in the initial state, loss much energy into the formed medium when they propagate through [1]. Recent experimental data show dihadron azimuthal correlation with double-peak [2] and ridge [3] structures, which were thought as medium excitation by or response to jet propagation [4]. However, initial state is not smooth and calm, but fluctuates. There exists hot spots in the geometrical shapes of the fireball because of the large fluctuations in the initial state. These initial fluctuations lead to many final observables, such as harmonic flow and dihadron correlation. Whether the observed double-peak and ridge structures in dihadron correlation are caused only by harmonic flow (such as triangular flow background) [5]or hot spots [6] is still under debate.

2. Initial fluctuation and harmonic flow

A Multi-Phase Transport (AMPT) model [7] is employed to simulate b=0 fm Au+Au 200 GeV collisions (with a partonic interaction cross section of 10 mb) in this study [8]. The initial conditions of AMPT model, including the spatial and momentum distributions of minijet partons and soft string excitations, are obtained from HIJING model [9]. Within HIJING, Glauber model for multiple nucleon scattering is used to describe the initial parton production in heavy-ion collisions. Nucleon-nucleon scatterings contain

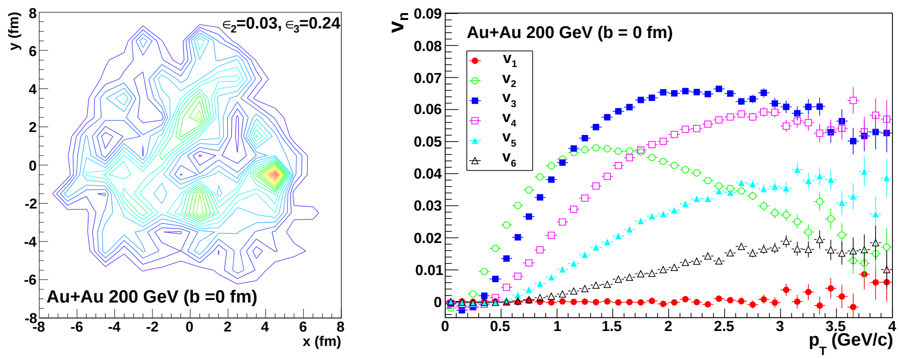

Figure 1. (Color online) Left panel: Contour plot of initial parton density (in arbitrary unit) $dN/dxdy$ in transverse plane in a AMPT event; Right panel: Azimuthal anisotropies of hadron spectra $v_n(p_T)$ $(n = 1-6)$ from AMPT model calculation.

both independent hard parton scattering and coherent soft interaction that is modeled by string formation for each participant nucleon. Strings are then converted into soft partons via string melting scheme in AMPT. Such multiple parton production mechanism leads to fluctuation in local parton number density or hot spots. The left panel in Fig. 1 shows a contour plot of initial parton density in the transverse plane $dN/dxdy$ for a Au+Au event with eccentricity ϵ_2=0.03 and triangularity ϵ_3=0.24 of the initial transverse parton distribution. It shows the possibility that the initial partons are distributed in a triangular area with many hot spots even for an event with b = 0 fm. The initial geometry asymmetry can be translated into final momentum space by final state interactions, which contribute to all orders of harmonic flow. The right panel in Fig. 1 shows the initial fluctuation can leads to the different orders of harmonic flow (v_n, n=1-6), even for b=0 fm Au+Au 200 GeV collisions.

3. Dihadron correlation

To find contribution to dihadron correlation from other mechanisms such as jet-medium interaction, it is very important to remove the background contribution from all orders of harmonic flow. We subtract the flow contributions, $f(\Delta\phi) = B\left(1 + \sum_{n=1}^{\infty} 2\langle v_n^{\rm trig} v_n^{\rm asso}\rangle \cos n\Delta\phi\right)$ from dihadron correlation, where B is a normalization factor determined by the ZYAM scheme, v_n^{trig} and v_n^{asso} are harmonic flow coefficients for trigger and associated hadrons. The left panel in Fig. 2 shows dihadron correlations before (dot-dashed) and after (solid) the removal of contributions from harmonic flow [v_n, n = 2-6 (dashed)]. As shown in the right panel in Fig. 2, the dihadron correlations with different initial geometric triangularity ϵ_3 become identical after the harmonic flow background subtraction, which indicates that we have removed the complete harmonic flow background.

Four different initial conditions are adopted to study separately the effects of jets and hot spots on dihadron correlation within AMPT model. We first randomize

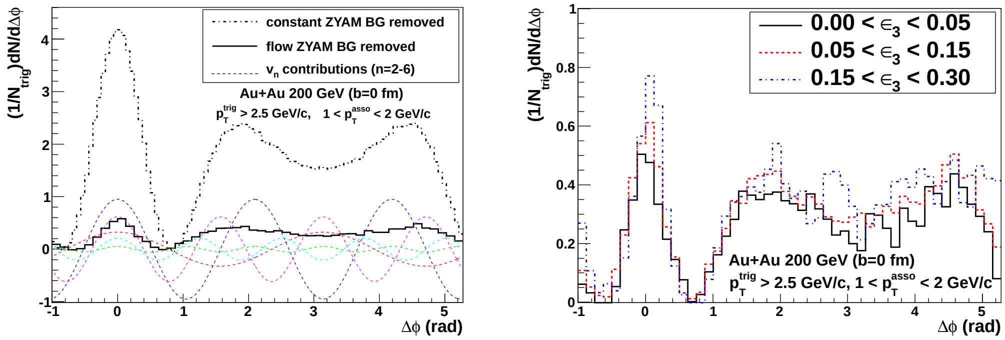

Figure 2. (Color online) Left panel: AMPT results on dihadron correlation before (dot-dashed) and after (solid) subtraction of contribution from harmonic flow $v_n(n = 2-6)$; Right panel: AMPT results on dihadron correlations after subtraction of harmonic flow with different values of geometric triangularity ϵ_3.

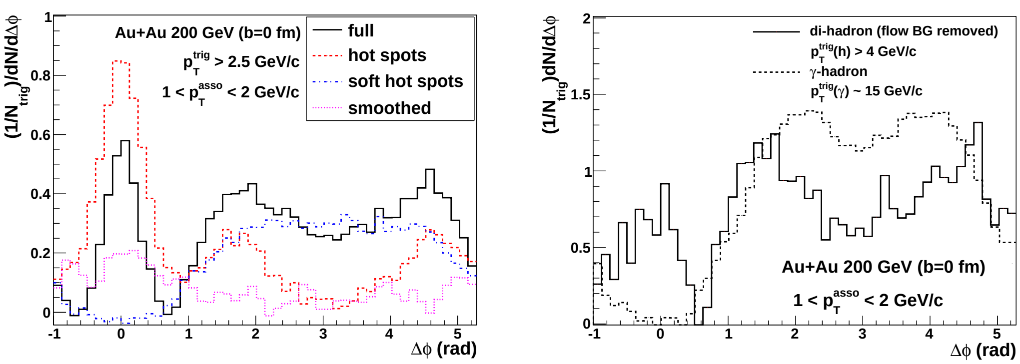

Figure 3. Left panel: (Color online) Dihadron correlation (with harmonic flow subtracted) from AMPT calculations with different initial conditions; Right panel: Dihadron correlation (solid) compared with γ-hadron correlation (dashed) from AMPT model calculations.

the azimuthal angle of each jet shower parton in the initial condition from HIJING simulations. This effectively switches off the initial back-to-back correlation of dijets. The dihadron correlation (dashed) denoted as "hot spots" in the left panel of Fig. 3 still exhibits a double-peak on the away-side that comes only from hot spots. It has roughly the same opening angle $\Delta\phi \sim 1$ (rad) as in the "full" simulation (solid). However, the magnitude of double peaks is reduced, which can be attributed to medium modified dijets and jet-induced medium excitation. When jet production is turned off in the HIJING initial condition, fluctuation in soft partons from strings can still form what we denote as "soft hot spots" that lead to a back-to-back dihadron correlation (dot-dashed) with a broadening peak. Without jets in AMPT, one can further randomize the polar angle of transverse coordinates of soft partons and therefore eliminate the "soft hot spots". The dihadron correlation from such "smoothed" initial condition becomes almost flat (dotted). We here emphasize that the above results include both short-range and long-range dihadron correlations ($\Delta\eta < 2$). We observed that hot spots are elongated in longitudinal direction as tubes, which can finally contribute to the formation of ridge structure up to $\Delta\eta \sim 2.5$.

4. γ-hadron correlation

γ-hadron correlation is a golden probe to study jet-medium interactions. Direct photons are produced isotropically, have neither strong interactions with medium nor harmonic flow, therefore the background for γ-hadron correlation is flat. Any structure in γ-hadron correlation with large p_T^γ should be only due to jet-medium interactions. The right panel in Fig. 3 shows γ-hadron correlation is comparable with dihadron correlation in magnitude but dihadron has a more pronounced double-peak which can be attributed to additional dihadrons from hot spots and the geometric bias toward surface and tangential emission that enhances deflection of jet showers and jet-induced medium excitation by radial flow [10].

5. Conclusion

The fluctuation of initial geometry leads to different orders of harmonic flow, which can significantly affects dihadron azimuthal correlation. After removing harmonic flow background, the net dihadron correlation reflects hot spots and jet-medium interactions. γ-hadron correlation is proposed as a golden probe because it only comes from jet-medium interactions.

Acknowledgments

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