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Hadron Azimuthal Correlations and Mach-like Structures in a Partonic/Hadronic Transport Model

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Abstract

With a multi-phase transport model (AMPT) with both partonic and hadronic interactions, two- and three-particle azimuthal correlations in Au + Au collisions at $\sqrt{s_{NN}}$ = 200 GeV have been studied by the mixing-event technique. A Mach-like structure has been observed in two- and three-particle correlations in central collisions. It has been found that both partonic and hadronic dynamical mechanisms contribute to the Mach-like structure. However, only hadronic rescattering is unable to reproduce experimental amplitude of Mach-like structure, and parton cascade process is indispensable. The results of three-particle correlation indicate a partonic Mach-like shock wave can be produced by strong parton cascade in central Au+Au collisions.

1 Introduction

Recent RHIC experimental results indicated an exotic partonic matter may be created in central Au + Au collisions at $\sqrt{s_{NN}}$=200 GeV. It is very interesting that Mach-like structure (the splitting of the away side peak in two-particle correlation) has been observed in azimuthal di-hadron correlations in central Au + Au collisions at $\sqrt{s_{NN}}$ = 200 GeV [1]. It was proposed that the Mach-like structure is due to the generation of a Mach-cone shock wave , when jets travel faster than sound in the new medium [2,3]. However a Cherenkov radiation model can be also used to explain the Mach-like structure [4]. In Refs. [5], it was interpreted that the sideward peaks can stem from medium dragging effect. In this talk, we will demonstrate the strong parton cascade based on a multi-phase transport model (AMPT) [6], which includes both partonic and hadronic interactions, can explain the production mechanism of

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Mach-like structure. Two versions of AMPT model were used in our simulations, which are called as the *default* AMPT model and the *melting* AMPT model respectively. Because the *melting* version includes a melting mechanism that excitations of strings melt strings into partons, more partons take part in parton cascade process in *melting* version than in *default* one.

2 Two-particle azimuthal correlations

Figure. 1(a) presents the $\Delta\phi$ correlations in Au + Au collisions (0-10%) at $\sqrt{s_{NN}} = 200$ GeV under different conditions. We can see that hadronic rescattering increases $\Delta\phi$ correlation yields for both versions (*melting* and *default*). A very strong Mach-like structure is observed before hadronic rescattering in the *melting* AMPT version, which indicates that Mach-like structure has been formed in parton cascade process. The effect of hadronic rescattering does not kill the Mach-like structure even slightly enhance the effect, which seems to be in qualitatively agreement with the effect of time-dependent speed of sound on the development of the conical wave in expanding QCD matter [7].

The splitting parameter D is defined as half distance between two Gaussian peaks on away side of $\Delta\phi$ correlations. Figure 1 (b) gives the impact parameter dependence of D, which shows the result from the *melting* AMPT version can roughly fit the experimental data. However, D values from the *default* AMPT version are obviously smaller than experimental data. It indicates that only hadronic rescattering mechanism is not enough to produce Mach-like cone amplitudes on away side and parton cascade mechanism is necessary[8].

3 Three-particle azimuthal correlations

On the other hand, the mixing-event technique has been used in our three-particle correlation analysis. The cuts are selected as $2.5 < p_T^{trig} < 4$ GeV/c, $1.0 < p_T^{assoc} < 2.5$ GeV/c and $|\eta^{trig,assoc}| < 1.0$ in Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV for the AMPT model with the string melting mechanism. One can find the detailed techniques of extracting signals in our recent paper [9].

In a three-particle correlation picture, we will mainly pay our attention to three regions: *'center'* region, *'cone'* regions, *'deflected'* regions. The *'center'* correlations quantify penetration ability of away-jet. It was predicted that *'cone'* correlations may be caused by Mach-cone shock wave effect that when a jet goes faster than sound in the medium, shock wave would appear on away side. The *'deflected'* region may be due to the sum of away-side jets deflected by radial flow and Mach-cone shock wave effect.

Figure 3 gives segmental areas ($1 < \Delta\phi_{1,2} < 5.28$) in different centralities in the *melting* AMPT model before and after hadronic rescattering, which reflects three-particle correlations on away side. Figure 2(a) shows the corresponding correlation densities ρ ($\rho = \frac{\int\int_{region} \frac{d^2N}{N_{trig} d\Delta\phi_1 d\Delta\phi_2} d\Delta\phi_1 d\Delta\phi_2}{\int\int_{region} d\Delta\phi_1 \Delta\phi_2}$) in different

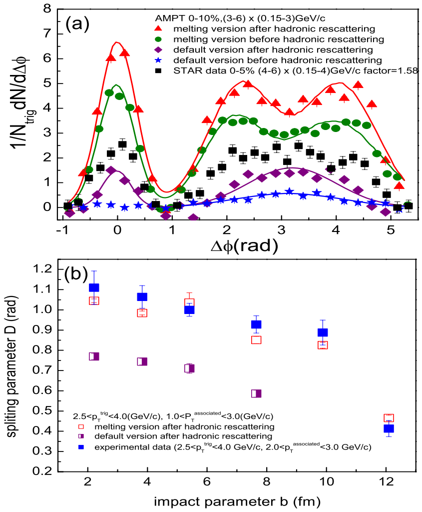

Fig. 1. (color online) $\Delta\phi$ correlations (a) and splitting parameter D vs impact parameter (b) in Au + Au collisions $\sqrt{s_{NN}}$ = 200 GeV in different AMPT model sets.

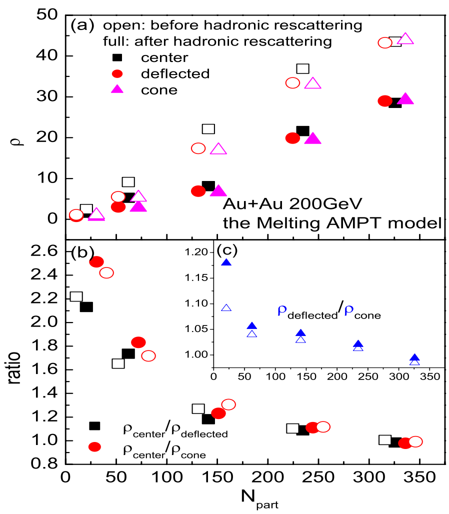

Fig. 2. (a): Average three-particle correlation densities (ρ) as a function of N_{part} in different regions ; (b): ratios of ($\rho_{center}/\rho_{deflected}$ and $\rho_{center}/\rho_{cone}$) as a function of N_{part}; (c): ratio of ($\rho_{deflected}/\rho_{cone}$) as a function of N_{part}.

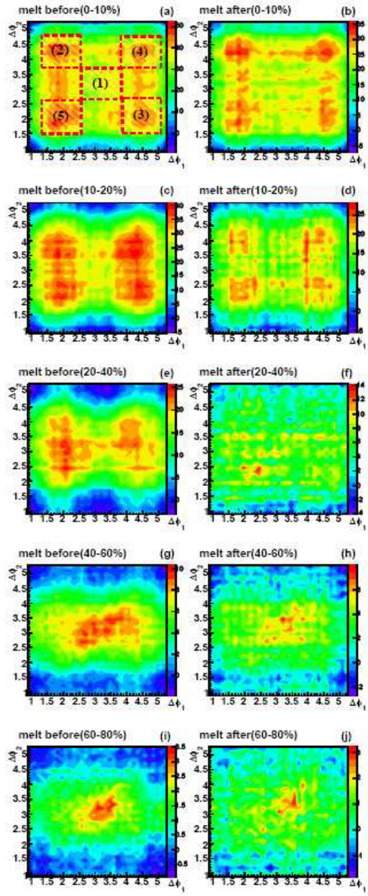

Fig. 3. (color online)Background subtracted segmental 3-particle correlation areas ($1 < \Delta\phi_{1,2} < 5.28$) in different centralities. The left column is for the *melting* AMPT model before hadronic rescattering and the right column is for the *melting* AMPT model after hadronic rescattering . (a) and (b): 0-10%; (c) and (d): 10-20%; (e) and (f): 20-40%; (g) and (h): 40-60%; (i) and (j): 60-80%. (In panel(a), (1): $'center'$ region;(2) and (3): $'cone'$ regions;(4) and (5): $'deflected'$ regions;)

regions as a function of N_{part}. (Note: the N_{part} of some points has been shifted slightly for clarity.) The results show that hadronic rescattering can weaken three-particle correlation strength partially. However di-hadron correlations are almost unchanged in this p_T window selection in our previous work [8], which indicates that three-particle correlation is more sensitive to the hadronic rescattering process than two-particle correlation. The N_{part} dependences of $\rho_{center}/\rho_{deflected}$ and $\rho_{center}/\rho_{cone}$ (figure 2(b)) indicate away jets can eject from reaction system more easily in more peripheral collisions.

Figure 2(c) shows the ratio of $\rho_{deflected}/\rho_{cone}$ slightly decreases with N_{part} and approach 1.0 in central collisions, which supports that three-particle correlations in central collisions are mainly from a Mach-like shock wave mechanism, while the observed correlations can be partially from deflected jets in peripheral collisions. It can be understood that this Mach-cone like behavior is due to many partons experience sequential partonic interactions which could couple many partons together to exhibit a collective behavior, i.e. partonic Mach-like shock wave [8–10].

4 Summary

Two- and three-particle correlations have been extracted by using mix event technique in a multi-phase transport model with both partonic and hadronic interactions. It has been shown that the associated particle correlation and Mach-like structure have been formed before hadronic rescattering, which indicates that Mach-like structures are born in the partonic process and further developed in later-on hadronic rescattering process. However, only hadronic rescattering mechanism is unable to give big enough splitting parameters D for Mach-like structures, and parton cascade process is very essential. The corresponding results of three-particle correlation support that Mach-like structure is due to a partonic Mach-like shock wave which can be produced by significant and continuous partonic interactions in dense partonic matter.

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