Baryon-Strangeness correlations in Parton/Hadron transport model for Au + Au collisions at $\sqrt{s_{NN}} = 200$ GeV

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Abstract.

Baryon-strangeness correlation ($C_{BS}$) has been investigated with a multi-phase transport model (AMPT) in $^{197}$Au + $^{197}$Au collisions at $\sqrt{s_{NN}} = 200$ GeV. The centrality dependence of $C_{BS}$ is presented within the model, from partonic phase to hadronic matter. We find that the system still reserve partial predicted signatures $C_{BS}$ after parton coalescence. But after hadronic rescattering, the predicted signatures will be obliterated completely. So it seems that both coalescence hadronization process and hadronic rescattering are responsible for the disappearance of the $C_{BS}$ signatures.

1. Introduction

Ultra-relativistic heavy ion collision may provide sufficient conditions for the formation of a deconfined plasma of quarks and gluons [1]. Experimental results from RHIC indicate that a strongly-interacting partonic matter (termed sQGP) has been created in the early stage of central Au + Au collisions at $\sqrt{s_{NN}} = 200$ GeV at RHIC [2]. In order to uncover the nature of this matter, probes based on fluctuations have been proposed throughout the last decade [3] [4] [5]. Recently a novel event-by-event observable has been introduced by Koch et al. [6], i.e. the baryon-strangeness correlation coefficient $C_{BS}$.

The correlation coefficient $C_{BS}$ is defined as

$$C_{BS} = \frac{\langle BS \rangle - \langle B \rangle \langle S \rangle}{\sqrt{\langle BS^2 \rangle - \langle B \rangle^2 \langle S \rangle^2}}$$
where $B$ is the baryon charge and $S$ is the strangeness in a given event.

This correlation is proposed as a tool to specify the nature of the highly compressed and heated matter created in heavy-ion collisions \[7\]. The idea is from that the relation between baryon number and strangeness will be different when the phase of system is different. On the one hand, if the basic degrees of freedom are weakly interacting quarks and gluons, the strangeness is carried exclusively by the $s$ and $\bar{s}$ quarks, $B_S = \frac{-1}{3}$. Thus the correlation coefficient $C_{BS} = 1$. On the other hand, if the degrees of freedom are hadronic matter, the case is different because the baryon-strangeness correlation coefficient strictly depends on the hadronic environments. For example, in a system composed of kaons the coefficient $C_{BS} \approx 0$, but $C_{BS} \approx 1.5$ for Cascades system.

In this article, we study the correlation coefficient with the AMPT model which consists of four main components: the initial conditions, partonic interactions, hadronization and hadronic rescattering. The initial conditions, which include spatial and momentum distributions of minijet partons and soft string excitations, are obtained from HIJING model \[9\]. In the default version of AMPT model (i.e. default AMPT) \[11\], minijet partons are recombined with their parent strings when they stop interactions. Then the resulting strings and the initial excited strings are converted to hadrons using the Lund string fragmentation model \[12\]. In the string melting version of the AMPT model (i.e. the string melting AMPT) \[13\], the initial matter fragments into partons. A quark coalescence model is used to combine partons to form hadrons. In the two versions, scatterings among partons including the resultant partons and the initial minijet partons are modelled by Zhang’s parton cascade model (ZPC) \[10\], meanwhile, dynamics of the hadronic matter is described by A Relativistic Transport (ART) model \[14\]. Details of the AMPT model can be found in a recent review \[8\]. Previous studies \[15, 16\] demonstrated that the partonic effect cannot be neglected and the string melting AMPT model is much more appropriate than the default AMPT model in describing nucleus-nucleus collisions at RHIC. In the present work, the parton interaction cross section in the AMPT model is assumed to be 10, which is the same as we used in our previous publications \[15, 16, 17\].

2. Results

Because the default AMPT is based on string mechanisms it provides an estimate of $C_{BS}$ value in the case where no partonic matter is created. And the string melting AMPT is based on strong parton cascade, therefore it provides an estimate of $C_{BS}$ value where the partonic matter is created. So we can compare the values of $C_{BS}$ in the two model versions to learn information about partonic matter at RHIC. Firstly, we study the partonic phase with the string melting AMPT. we will choose appropriate pseudorapidity windows and study the effect of parton cascade.
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In an uncorrelated partonic phase, $\sigma_{us}^2 \approx 0$ and $\sigma_{ds}^2 \approx 0$, we get $C_{BS} \approx 1$. The results from the lattice QCD also predicted $C_{BS} \approx 1$ above $T_C$. So models of the deconfined matter should obey such constraints.

![Figure 1](image)

Figure 1. (a) The time evolution of baryon-strangeness correlation coefficient $C_{BS}$ of partonic matter at $\eta_{max}=0.1$, 0.5 and 1.0; (b) The dependence of $C_{BS}$ on the number of participant particles in different pseudorapidity windows, namely $\eta_{max}=0.1$, 0.5 and 1.0 for an infinite lifetime of partonic matter.

Fig. 1 (a) depicts the time evolution of $C_{BS}$ of partonic matter. We find $C_{BS} \approx 1$ with increasing time of parton cascade in different pseudorapidity windows 0.1 and 0.5, even for an infinite partonic lifetime. Therefore we conclude that in the above pseudo-rapidity windows parton cascade does not influence $C_{BS}$. But Fig. 1 shows that when $\eta_{max}=1.0$, the conditions that $\sigma_{us}^2=0$ and $\sigma_{ds}^2=0$ are not perfectly satisfied after a long parton cascade period. Therefore, we will focus on the correlations only in the two pseudo-rapidity windows, namely $\eta_{max}=0.1$ or 0.5. In the following work, we present hadronic $C_{BS}$ including all hadrons with masses up to that of $\Omega^-$. In AMPT model, hadronization is described with a coalescence model, and the pseudo-rapidity distribution will change during this process. After hadronization, strangeness will be enhanced, so the $C_{BS}$ will drop. In the following work, we can observe a strange baryon to that of strange meson [18]; 0.5 for the string melting AMPT, and 0.35 for the default AMPT. In this case, it is concluded that if the deconfined phase exists, the ratio of multiplicity of strange baryon to that of strange meson will be enhanced before hadron rescattering. For $\eta_{max}=0.1$, the pseudo-rapidity windows remain...
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Figure 2. $C_{BS}$ as a function of $N_{part}$ at the $\eta_{max}=0.1$ (a) and $\eta_{max}=0.5$ (b) in the default AMPT and the string melting AMPT without hadronic rescattering, respectively.

melting AMPT because of higher baryon density. For central collisions $C_{BS}$ goes to 0.6 and becomes flat. But for the default AMPT, $C_{BS}$ still stays roughly constant because of fragmentation mechanism. The results are consistent with [7]. From Fig. 2 we can say there exists an enhanced $C_{BS}$ for central collisions if there is a partonic phase before the hadronic rescattering.

Figure 3. $C_{BS}$ as a function of $N_{part}$ at the $\eta_{max}=0.5$ in the default AMPT and the string melting AMPT (b) without hadronic rescattering and with hadronic rescattering.

We also investigate the effect of hadronic rescattering which is shown in Fig. 3(b). We find the hadronic rescattering has a larger effect on the $C_{BS}$ for the string melting AMPT simulation than that of the default AMPT from Fig. 3(b). For the default case,
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signal of partonic matter as shown in Fig. 4.

![Graph](image)

**Figure 4.** $C_{BS}$ as a function of $N_{part}$ at $\eta_{max} = 0.5$ in the default AMPT and string melting AMPT with hadronic rescattering.

Finally, we try to choose a particle subset to see how much hadronic rescattering affects the $C_{BS}$. Here, the subset only includes Kaons and Protons. We find that the value of $C_{BS}$ goes down to 0.2 from Fig. 5. But after hadronic rescattering we observe a similar result that hadronic rescattering finally obliterates the signals of partonic matter completely.

![Graph](image)

**Figure 5.** $C_{BS}$ of Kaons and Protons combination as a function of $N_{part}$ at the $\eta_{max} = 0.5$ in the default AMPT and the string melting AMPT without (a) or with hadron rescattering (b).
3. Summary

We have studied the dependence of the $C_{BS}$ as a function of the $N_{part}$ with a multi-phase transport model. At $\eta_{max} = 0.5$, we find the hadronization makes the $C_{BS}$ value drop, but we still obtain the residual signal. However, after the hadronic rescattering, the residual signal will be washed out. In order to analyze the effect of hadronic rescattering, we choose a special particle group which only includes kaons and protons, but the result does not help. Up till now, there are no powerful fluctuation probes of the deconfined matter in the experiment, perhaps both hadronization and hadronic rescattering effects may be responsible for the disappearance of the signals.

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