Parton Interactions and Two Particle Transverse Momentum Correlations in Au+Au Collisions at $\sqrt{s_{\rm NN}}=130$GeV

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Abstract Partonic effects on two-particle transverse momentum correlations are studied for Au+Au collisions at $\sqrt{s_{\rm NN}}=130$GeV in the Monte Carlo model, AMPT. This study demonstrates that in these collisions partonic interactions contribute significantly to the correlations. Additionally, model calculations are compared with data of the two-particle transverse momentum correlations measured by the STAR Collaboration at RHIC, and it is found that AMPT with string melting can well reproduce the measured centrality dependence of the two-particle transverse momentum correlations in Au+Au collisions at $\sqrt{s_{\rm NN}}=130$GeV.

Key words parton interaction, two particle transverse momentum correlation, AMPT, relativistic heavy-ion collision

1 Introduction

A new form of nuclear matter with partonic degree of freedom may be produced through relativistic heavy-ion collisions. To detect the production and to study the properties of the nuclear matter, two particle transverse momentum correlations in Au+Au collisions at $\sqrt{s_{\rm NN}}=130$GeV have been measured[1] by the STAR Collaboration at BNL RHIC and compared with HIJING model[2] predictions. The comparison shows that jets/minijets contribute non-trivially to the correlations. However, HIJING cannot reproduce the data. Therefore in addition to jets/minijets, there might exist other sources of the two particle transverse momentum correlations that fill the gap between HIJING predictions and the measurement made at RHIC. HIJING includes neither partonic nor hadronic cascade processes. Could parton interactions, a characteristic of the parton cascade processes, add to the correlations? Is the AMPT model[3] with string melting, which takes into account the parton cascade, together with the hadronic cascade, able to reproduce STAR data on the two particle transverse momentum correlations? In the following these questions will be addressed, using the AMPT model with string-melting[4].

2 The AMPT model and analysis method

The AMPT model with string-melting is a hybrid model and it is able to reproduce the elliptic flow[4] and pion interferometry[5] measured in Au+Au collisions at RHIC[6, 7]. Recently, it has been used for studying charm flow[8]. It uses minijet partons from hard processes and strings from soft processes in HIJING as the initial conditions and the initial excited strings are allowed to melt into partons[4]. Interactions among partons are described by the ZPC parton cascade model[9]. At present, it includes only parton-parton elastic scatterings with an in-medium cross section

$$\sigma_{\rm p}\approx\frac{9\pi\alpha_{\rm s}^2}{2\mu^2}, \tag{1}$$

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where μ is a Debye screening mass generated by medium effects and α_s is the strong coupling constant. The μ and the α_s are used as two parameters to obtain the cross section σ_p. The transition from the partonic matter to the hadronic matter in AMPT is achieved using a simple coalescence model[3, 4], in which two nearest quark and antiquark combine into a meson and three nearest quarks or antiquarks into baryon or anti-baryon whose masses are close to the invariant mass of these partons. Hadronic scatterings are modeled by a relativistic transport model (ART)[10].

As in Ref. [1], the measure for two particle transverse momentum correlations $\langle\Delta p_{t,i}\Delta p_{t,j}\rangle$ is defined as follows

$$\langle\Delta p_{t,i}\Delta p_{t,j}\rangle=\frac{1}{\varepsilon}\sum_{k=1}^{\varepsilon}\frac{C_k}{n_k(n_k-1)}, \tag{2}$$

where

$$C_k=\sum_{i=1}^{n_k}\sum_{j=1,i\neq j}^{n_k}(p_{t,i}-\langle\langle p_t\rangle\rangle)\ (p_{t,j}-\langle\langle p_t\rangle\rangle), \tag{3}$$

and ε is the number of events, n_k is the number of particles in the kth event. In Eq. (3), $p_{t,i}$ is the transverse momentum of the ith particle in each event, $\langle\langle p_t\rangle\rangle$ is the overall event average transverse momentum given by

$$\langle\langle p_t\rangle\rangle=\left(\sum_{k=1}^{\varepsilon}\langle p_t\rangle_k\right)\Big/\varepsilon, \tag{4}$$

where $\langle p_t\rangle_k$ is the average transverse momentum per event for the kth event

$$\langle p_t\rangle_k=\frac{1}{n_k}\sum_{i=1}^{n_k}p_{t,i}. \tag{5}$$

3 Partonic effects on two particle transverse momentum correlation $\langle\Delta p_{t,i}\ \Delta p_{t,j}\rangle$

We generated three classes of AMPT events for Au+Au collisions at $\sqrt{s_{NN}}$=130GeV: class Ⅰ—events with both partonic interactions and hadronic cascade processes, class Ⅱ—events with the partonic interactions but without the hadronic cascade processes, class Ⅲ—events without both the partonic interactions and the hadronic cascade processes. Events of class Ⅲ are physically HIJING events with jets/minijets production but without jet quenching.

Table 1. $\langle\Delta p_{t,i}\Delta p_{t,j}\rangle$, together with the total number of events(ε), in-medium parton scattering cross section(σ_p) for three classes of mid-central AMPT events($5<b<$ 7fm)—Au+Au collisions at $\sqrt{s_{NN}}=130$GeV. $\langle\Delta p_{t,i}\Delta p_{t,j}\rangle$ is calculated using charged hadrons with $|\eta|<1$ and $0.15<p_t<2$GeV/c.

event class	Ⅰ	Ⅱ	Ⅲ
σ_p/mb	10	10	N/A
ε	50686	50480	18245
$\langle\Delta p_{t,i}\Delta p_{t,j}\rangle/(\text{MeV/c})^2$	68.5	74.0	24.5

We analyzed two-particle transverse momentum correlations $\langle\Delta p_{t,i}\Delta p_{t,j}\rangle$ for the three event classes and the results are tabulated in Table 1. First of all, comparing the magnitude of $\langle\Delta p_{t,i}\Delta p_{t,j}\rangle$ for event class Ⅰ with those for class Ⅱ, one may notice that due to the hadronic cascade processes, the two particle transverse momentum correlations decrease about 8%. This is an indication that $\langle\Delta p_{t,i}\Delta p_{t,j}\rangle$ is mainly generated in the initial stage, which is characterized by jets/minijets production and partonic interactions. The hadronic cascade process happening after parton interactions tends to dilute the correlations built in the initial stage, this is the reason for the aforementioned reduction of $\langle\Delta p_{t,i}\Delta p_{t,j}\rangle$. Secondly, the large value of $\langle\Delta p_{t,i}\Delta p_{t,j}\rangle$ in events of class Ⅲ suggests that jets/minijets contribute non-trivially to two particle transverse momentum correlations. Thirdly, the magnitude of $\langle\Delta p_{t,i}\Delta p_{t,j}\rangle$ in events of class Ⅰ is almost three times the magnitude of $\langle\Delta p_{t,i}\Delta p_{t,j}\rangle$ in events of class Ⅲ. This indicates that in addition to the production of jets/minijets of partons, partonic interactions may add significantly to $\langle\Delta p_{t,i}\Delta p_{t,j}\rangle$. Therefore, one may conclude according to Table 1 that in heavy-ion collisions at RHIC energies, two particle transverse momentum correlations as studied using $\langle\Delta p_{t,i}\Delta p_{t,j}\rangle$ are generated mainly in the initial stage; in addition to jets/minijets, partonic interactions may contribute large proportion to the correlations.

In Fig. 1 we compare centrality dependence of the two particle transverse momentum correlations in AMPT for $\sigma_p=10$mb with data. AMPT results and STAR data shown in Fig. 1 are obtained for charged hadrons with transverse momentum $0.15\text{GeV}/c\leqslant$

$p_{\rm t} \leqslant 2{\rm GeV}/c$ and pseudo-rapidity $|\eta| < 1$. Fig. 1 demonstrates that with a parton scattering cross section $\sigma_{\rm p}=10$mb the AMPT model with string-melting can within error bars reproduce STAR data on two particle transverse momentum correlations.

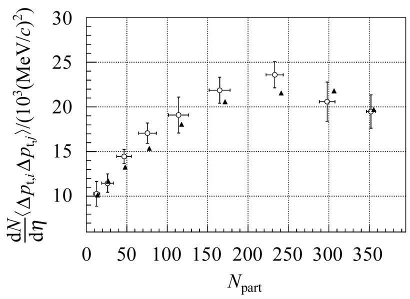

Fig. 1. $\left(\frac{{\rm d}N}{{\rm d}\eta}\right)\langle\Delta p_{{\rm t},i}\Delta p_{{\rm t},j}\rangle$ in AMPT for $\sigma_{\rm p}=10$mb(solid triangles) as a function of centrality for $\sqrt{s_{\rm NN}}=130$GeV Au+Au collisions compared with STAR data (hollowed circles with error bars) as reported in Ref. [1].

4 Conclusions

Based on AMPT model with string-melting an analysis of two particle transverse momentum correlations $\langle\Delta p_{{\rm t},i}\Delta p_{{\rm t},j}\rangle$ for Au+Au collisions at $\sqrt{s_{\rm NN}}=130$GeV is reported. It suggests that in-medium partonic interactions contribute significantly to the correlations. The centrality dependence of $\langle\Delta p_{{\rm t},i}\Delta p_{{\rm t},j}\rangle$ in the AMPT model is compared with STAR data, showing that using an in-medium parton scattering cross section $\sigma_{\rm p}=10$mb, the AMPT model can well reproduce the STAR data.

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部分子相互作用与$\sqrt{s_{\rm NN}}=130$GeV Au+Au碰撞中两粒子的横向动量关联

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摘要　采用蒙特卡罗模型AMPT研究了$\sqrt{s_{\rm NN}}=130$GeV Au+Au碰撞中部分子相互作用对两粒子横向动量关联的影响, 结果表明部分子相互作用对两粒子的横向动量关联有重要的贡献. 还计算了AMPT模型中$\sqrt{s_{\rm NN}}=130$GeV Au+Au碰撞的两粒子横向动量关联与碰撞对心性的依赖关系并与来自STAR的实验数据进行了比较, 发现AMPT的理论预言很好地符合实验数据.

关键词　部分子相互作用　两粒子的横向动量关联　AMPT　相对论重离子碰撞

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