Radial Flow in Au + Au Central Collisions at RHIC Energy *

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Abstract Using the dynamical transport approach RQMD, the radial collective expansion in relativistic heavy-ion collisions is studied at RHIC energy. The prediction of the radial flow is presented by analyzing the transverse mass spectra for Au + Au central collisions at the center of mass energy $\sqrt{s} = 200A\text{GeV}$. We conclude that the average radial flow velocity is $0.6c$ and the freeze-out temperature is 160MeV in Au + Au reactions.

Key words heavy-ion collisions, radial flow, transverse mass spectra

Relativistic heavy-ion collisions offer a unique opportunity to study hot and dense matter under controlled laboratory conditions[1,2]. In the past years, the transverse mass spectra of single particles have been measured in heavy-ion collisions from LBL Bevalac energies to BNL AGS and CERN SPS energies[3,4]. These experimentally measured distributions are well reproduced by hydrodynamical and dynamical transport calculations in which the collective degrees of freedom, such as the average freeze-out temperature and mean transverse velocity are unambiguously identified[5,6]. During the Spring 2001 run, the BNL RHIC delivered Au + Au collisions at its full energy[7,8], and it is necessary to study the dynamical transport simulations for RHIC[9].

In this letter, we study the radial collective expansion in relativistic heavy-ion collisions. The predictions for the transverse mass spectra of emitted particles are presented in heavy-ion collisions and elementary collisions at RHIC energy. For our investigation we employ the Relativistic Quantum Molecular Dynamics (RQMD) model[10]. The model is well established and has been used successfully to describe many observable measured at AGS and SPS energies. Recently, a new version of RQMD (v2.4) model has been available which can deal with collisions at RHIC energies. In this study, the simulating events are generated by RQMD (v2.4) for Au + Au and Si + Si as well as p + p collisions at RHIC energy $\sqrt{s} = 200A\text{GeV}$. With a centrality cut, we choose Au + Au and Si + Si central events according to the range of impact parameter $0 < b < 3$ fm and $0 < b < 0.7$ fm, respectively.

In symmetric collision system, the fireball expands essentially at rest in the center of mass frame. The transverse mass spectra of particles resemble the effect of transverse motion in the cleanest possible way. Fig.1 shows the transverse mass spectra of pions, kaons and protons from Au + Au and Si + Si central collisions at the center of mass energy $\sqrt{s} = 200A\text{GeV}$. The distributions are

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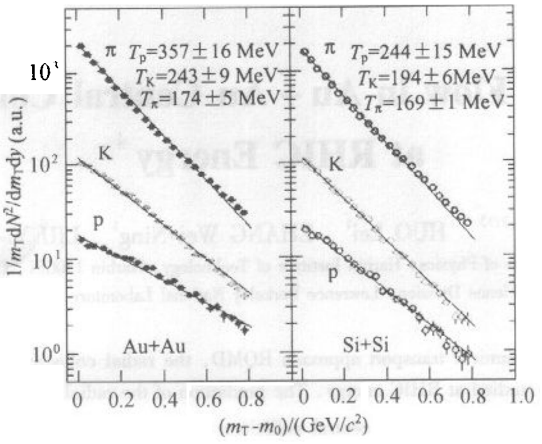

Fig.1. The transverse mass spectra for pions, kaons and protons in Au + Au and Si + Si central collisions at $\sqrt{s}$ = 200AGeV.

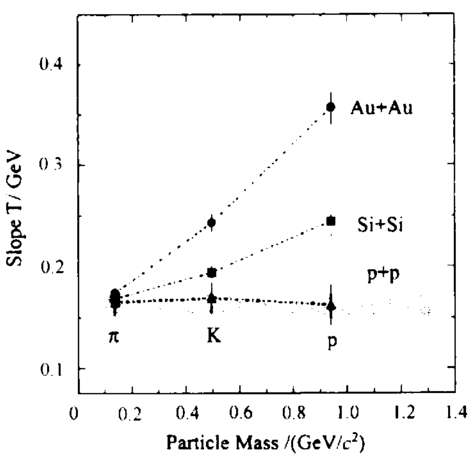

Fig.2. The inverse slope parameters of pions, kaons and protons in Au + Au, Si + Si and p + p collisions at $\sqrt{s}$ = 200AGeV.

extracted from midrapidity $-0.5 < y < 0.5$. In order to clear the collective features the spectra are fitted with simple Boltzmann distributions,

$$\frac{1}{m_T}\frac{d^2N}{dm_T dy} \propto \exp\left(-\frac{m_T}{T}\right), \qquad (1)$$

here m_T is the transverse mass of emitted particles and T is the inverse slope parameter, often interpreted as the apparent temperature of the emitting source. The fitted inverse slope parameters are indicated in Fig.1. From the comparison of the different reaction systems, it is clear that (a) the spectra of pions have similar slopes, (b) with increasing mass of the emitted particles, the spectra become harder, and (c) with increasing system size, spectra of the particles heavier than pions become increasingly stiffer. To make this point clear, we summarize the inverse slope parameters of pions, kaons and protons from heavy-ion collisions and elementary collisions in Fig.2.

A distinct difference between the results of the elementary p + p collision and heavy-ion collisions can be seen in Fig.2. While the slope parameters of p + p collision remain flat as a function of the particle mass, these parameters from heavy-ion collisions increase as the mass increases. Furthermore, for a given mass, the heavier the colliding system, the higher the slope parameter. It is also interesting to observe that all curves converge to a point about $T \approx 160 \pm 10$MeV, as indicated by the shaded bars in Fig.2. In hydrodynamical picture, matter flows developed, i.e., all particles flow at a same collective velocity. Classically, the collective kinetic energy will then depend on the particle mass: particles with higher mass will have higher energy. The slope parameter is a measure of the particle energy induced by the transverse motion. Roughly speaking, the transverse motion contains both thermal and collective modes,

$$T = T_{f_0} + m_T\langle\beta_T\rangle^2, \qquad (2)$$

here T_{f_0} is the freeze-out temperature determined by the thermal motion and $\langle\beta_T\rangle$ is the average radial flow velocity. For the p + p collision, one does not expect any rescattering, and the slope parameter reflects the true freeze-out temperature. For heavy-ion collisions, rescattering becomes more important and collective motion gradually develops.

Within the above discussion, once the parameters T and $\langle\beta_T\rangle$ are fixed, it is possible to study the evolution of the flow velocity with radius, i.e. the flow profile. Given the distribution shown in Fig.1, one may discuss the physics in terms of collectivity. To proceed, we evaluate the average transverse velocities of pions, koans, and protons. The collective velocity is defined as $\langle\beta_T(r_T)\rangle = \langle(p_T \cdot r_T)/m_T/r_T\rangle$. Here p_T and r_T is the transverse momentum and radius of a particle, respectively. And $\langle\cdots\rangle$ means the average for the particles in a cell located at the same radial parameter. Fig.3 shows the transverse flow velocities of pions, kaons, and protons from Au + Au central collisions at the center of mass energy $\sqrt{s} = 200A\,\text{GeV}$. In order to get the velocity profile, a parameterized function fits to those simulations,

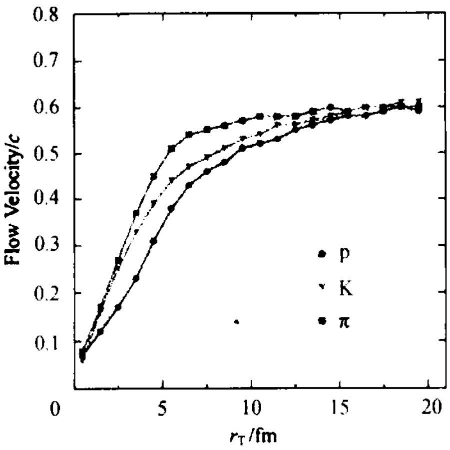

Fig.3. The transverse flow velocity profiles of pions, kaons and protons in Au + Au central collisions at $\sqrt{s} = 200A\,\text{GeV}$.

$$\beta_T(r_T) = \frac{\beta_T^{max}}{1 + \exp[-a(r_T - b)]},$$

where the parameters are $a = 0.55$, $b = 3.8$ and $\beta_T^{max} = 0.58c$. It is seen from Fig.3 that on the av-

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In summary, we has studied the transverse mass spec

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strong radial flow are developed in the reaction studie

perature is 160MeV and average radial flow velocity is

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RHIC能区Au+Au碰撞中集合径向流的研究*

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摘要 利用相对论量子分子动力学模型RQMD,对RHIC能区$\sqrt{s}=200A$GeV Au+Au碰撞的集体膨胀效应进行了研究,对散射粒子的横质量谱进行了分析.研究表明,在RHIC能区的重离子反应中存在有强的集合径向流.对单粒子谱的拟合结果给出Au+Au的源冻结温度为160MeV,平均径向流速度为0.6c.

关键词 重离子碰撞 径向流 横质量谱

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