Dependence of multiplicity and transverse energy distributions on nuclear geometry at RHIC*

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Abstract We study the dependence of multiplicity and transverse energy on nuclear geometry at RHIC at $\sqrt{s_{\rm NN}}=19.6$, 130, and 200 GeV basing on ellipsoidal decay model. It is found that the ellipsoidal decay model can describe the data well.

Key words Ellipsoidal decay model, centrality

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1 Introduction

One of the central questions at the Relativistic Heavy-Ion Collider (RHIC) is the extent to which the quanta produced in collisions interact and thermalize. Nuclear collisions generate enormous multiplicity and transverse energy, but to what extent does the collision generate matter in local equilibrium that can be characterized by the thermodynamic parameters temperature, pressure, and energy density? Only if thermalization has been established can more detailed questions be asked about the equation of state of the matter.

Recently, RHIC experiments study the distributions of $\frac{{\rm d}E_{\rm T}}{{\rm d}\eta}$ and $\frac{{\rm d}N_{\rm ch}}{{\rm d}\eta}$ at mid-rapidity at center-of mass energies $\sqrt{s_{\rm NN}}=19.6$, 130, and 200 GeV[1—4]. The centrality dependence on the distributions of the and is characterized by the number of participants and is studied as a function of the incident energy. The data taken at 19.6 GeV are particularly interesting because they can be compared with data taken at lower energies by the CERN Super Proton Synchrotron (SPS) program. It is believed that the detailed study of the dependence of $\frac{{\rm d}E_{\rm T}}{{\rm d}\eta}$ and $\frac{{\rm d}N_{\rm ch}}{{\rm d}\eta}$ per pair of participants with centrality with different energies, can provide stringent constraints on the reaction dynamics of heavy-ion collisions at ultra-relativistic energies.

The paper is organized as follows. The ellipsoidal decay model (EDM)are described in Sec.2. The comparisons of EDM calculations with experimental data and the summary are given in Sec. 3.

2 The ellipsoidal decay model

The Ellipsoidal Decay Model (EDM) we considered[5, 6] contains distinct assumptions some of which are rather different from those usually contained in other models. We assume the transverse energy is proportional to the total excited energy at very fixed impact parameter,

$$E_{\rm T}=\lambda_{\perp}E^{*}\ , \tag{1}$$

where $\lambda_{\perp}$ is the ratio of the transverse part to the total excited energy, which measures the efficiency of the deposition of initial energy. It is given by the following equation[5]:

$$\lambda_{\perp}=\frac{\int_{\Omega}\varepsilon\sin\Theta{\rm d}x{\rm d}y{\rm d}z}{\int_{\Omega}\varepsilon{\rm d}x{\rm d}y{\rm d}z} \tag{2}$$

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where ε is the average energy density. This implies that all participants have lost historical memories after collisions. In fact, due to the transparency of the nucleus at high energies all participants will not lose historical vestiges and some of the produced hadrons will carry their parent's memories of motion. This picture will lead to the un-equivalence in longitudinal and transverse directions. So we assume that the excited system decays elliptically. In terms of the ellipsoidal coordinates

$$\begin{aligned} x &= \mu\rho\sin\vartheta\cos\varphi, \\ y &= \mu\rho\sin\vartheta\sin\varphi, \\ z &= \nu\rho\cos\vartheta, \end{aligned} \tag{3}$$

where μ and ν are elliptical major and minor axes,respectively, and the integral range Ω is $0<\rho<1$, $0<\vartheta<\pi$. The ratio defined by Eq. (2) can be given with:

$$\lambda_{\perp} = \frac{1}{2}\int_0^{\pi} \frac{\sin^2\vartheta}{\sin^2\vartheta + e^{-2}\cos^2\vartheta}, \tag{4}$$

where we have defined an ellipticity $e=\mu/\nu$. We assume that the ellipticity e is related to impact parameter b as $e=e_0 e^{-\beta b}$, where β is a parameter to express the correlative degree of the phase space with the impact parameter. At a certain impact parameter, the transverse energy distribution or the rapidity distribution is related to the charged hadron multiplicities $N_{\rm ch} \propto E_{\rm T}$, and also $N_{\rm ch} = \lambda_{\perp}(e) N_{\rm part}$. The distributions of $\frac{{\rm d}E_{\rm T}}{{\rm d}\eta}$ and $\frac{{\rm d}N_{\rm ch}}{{\rm d}\eta}$ at a central rapidity is proportionate to $N_{\rm part}$,

$$\left.\frac{{\rm d}X}{{\rm d}\eta}\right|_{\rm mid} = \kappa N_{\rm ch} = \kappa\lambda_{\perp}(e) N_{\rm part}, \quad X = E_{\rm T}, N_{\rm ch}. \tag{5}$$

We can get the rapidity distribution per participant as follows:

$$\frac{{\rm d}X}{{\rm d}\eta}/0.5N_{\rm part} = 2\kappa\lambda_{\perp}(e), \quad X = E_{\rm T}, N_{\rm ch}. \tag{6}$$

3 The results and conclusions

We fitted the available experimental data for the RHIC energy region with our EDM and present in Fig. 1 and Fig. 2. One can see that the EDM calculations (shown by the solid lines) are in accordance with the experimental results.

Midrapidity $E_{\rm T}$ distributions are a standard method of defining centrality[7, 8]. Thus, it is important to study the detailed relationship of transverse energy production to $N_{\rm part}$, the number of nucleons participating in the collision. The transverse energy distribution per pair are given in Fig. 2. EDM also can study the relation of transverse energy distribution with nuclear centrality.

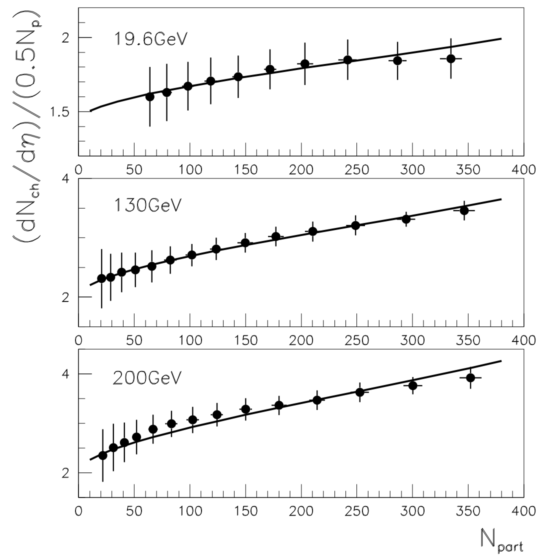

Fig. 1. PHENIX rapidity density per participant. Experimental data are given by real point given by Refs. [7, 8]. The solid lines are the results given by EDM.

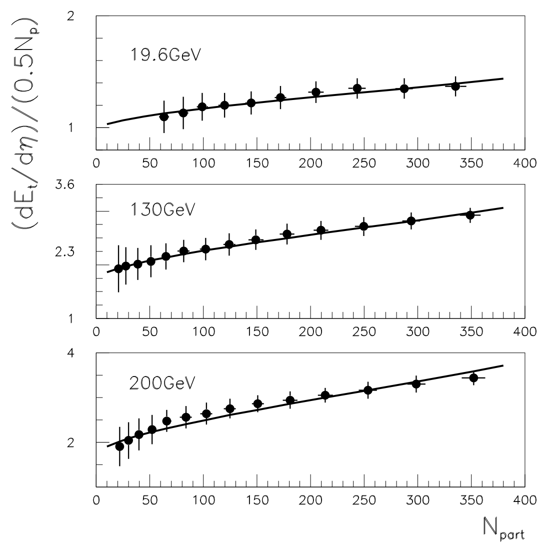

Fig. 2. Same with Fig.1 but for PHENIX transverse energy density distributions per participant. Experimental data are given by real point given by Refs. [7, 8]. The solid lines are the results given by EDM.

It has recently been emphasized that the centrality dependence of $\frac{{\rm d}E_{\rm T}}{{\rm d}\eta}$ and $\frac{{\rm d}N_{\rm ch}}{{\rm d}\eta}$ allows one to discriminate between various models of particle production. It is shown that EDM can describe the dependence of $\frac{{\rm d}E_{\rm T}}{{\rm d}\eta}$ and $\frac{{\rm d}N_{\rm ch}}{{\rm d}\eta}$ per participant pair as a function of the number of participants Np of RHIC energy region.

In conclusions, a mainly geometrical description model (EDM) for heavy-ion collisions can be suited to the RHIC energy region. The utility of the correlation between transverse energy with nuclear geometry as a valuable probe for the study of the dominant multi-particle production processes in high-energy heavy-ion collisions.

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