First indication on self-similarity of strangeness production in $Au+Au$ collisions at RHIC: Search for signature of phase transition in nuclear matter

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Abstract

New results of analysis of K_S^0—meson spectra measured over a wide range of energy $\sqrt{s_{NN}} = 7.7-200$ GeV and centrality in $Au+Au$ collisions by the STAR Collaboration at RHIC using the z-scaling approach are presented. Indication on self-similarity of fractal structure of nuclei and fragmentation processes with K_S^0 probe is demonstrated. The energy loss as a function of the collision energy, centrality and transverse momentum of the inclusive strange meson is estimated.

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1 Introduction

We use the z-scaling concept [1] to search for signatures of phase transition in nuclear matter created at RHIC energies and verify self-similarity of K_S^0-meson production in $Au+Au$ collisions. The data on K_S^0-meson yields obtained by the STAR Collaboration during BES-I program over a wide range of collision energy $\sqrt{s_{NN}} = 7.7$, 11.5, 19.6, 27, 39, 62.4 and 200 GeV for different centrality classes $(0-5)\%$, $(5-10)\%$, $(10-20)\%$, $(20-30)\%$, $(30-40)\%$, $(40-60)\%$ and $(60-80)\%$ at $|y| < 0.5$ were used in the present analysis. The centrality classes are characterized by different multiplicity densities $dN_{\rm neg}^{AA}/d\eta|_0$ of negative particles. Depending on the energy and centrality of the collisions, this quantity varied from 4 to 350 particles per unit of rapidity. It regulates the state of nuclear medium in which the inclusive particles are produced. Scaling features of K_S^0-meson production in $Au+Au$ system are compared with the corresponding characteristics of strange hadron spectra found in $p+p$ interactions [2]. Based on this study, we consider strange identified probes, such as K_S^0 mesons, to be suitable for revealing more specific properties of nuclear matter than can be found in processes with non-strange particles [3].

A more detailed description of the z-scaling concept based on the fundamental principles of self-similarity, locality, and fractality of particle production in $p+p$ and $A+A$ interactions at the constituent level and its applicability for data analysis of inclusive spectra of different hadron species are presented in [4,5].

2 Self-similarity of K_S^0-meson production in $Au+Au$ collisions

Figure 1 shows the dependence of the scaling function $\psi(z)$ on the variable z for K_S^0 mesons produced in the $(0-5)\%$ central (a) and $(60-80)\%$ peripheral (b) $Au+Au$ collisions for different energies. The symbols correspond to p_T-distributions measured in the Au+Au system. The solid line is the z-scaling curve for $p+p$ interactions. Reasonable coincidence of the symbols and the solid curve in the interval $z = 0.1-7$ was found. One can see from Fig. 1 (a,b) that the scaling function is independent of centrality. It gives specific dependencies of model parameters on energy and multiplicity. There are no irregularities in the behavior of $\psi(z)$ over a wide range of collision energy $\sqrt{s_{NN}} = 7.7$ - 200 GeV. An indication on a flattening of the scaling function at low z and a power law at high z is clearly observed. Similar scaling of K_S^0-spectra was obtained for other collision centralities. This result is interpreted as a self-similar modification of the constituent sub-processes by the created medium.

The energy loss $\Delta E_q/E_q = (1-y_a)$ is characterized by the fraction y_a in the z-scaling scheme. This quantity is sensitive characteristic of the nuclear medium. Figure 1 shows the dependence of the momentum fraction y_a on the transverse momentum p_T of K_S^0 mesons produced in the $(0-5)\%$ central (c) and $(60-80)\%$ peripheral (d) $Au+Au$ collisions at different energies. A monotonic growth of y_a with p_T is found for all energies and all collision centralities. This means that the relative energy dissipation associated with a high-p_T particle is smaller than for processes with lower transverse momenta. The energy loss becomes larger as the collision energy increases. It is larger in the central $Au+Au$ collisions than in the peripheral ones. For example, it can be seen from Fig.1 (c) and (d) that the relative energy loss for the most central events at $p_T = 2.5$ GeV/c is about 32% and 90% at $\sqrt{s_{NN}} = 7.7$ and 200 GeV, respectively. For $(60-80)\%$ peripheral collisions, the quantity is estimated to be about 23% and 78%. At the highest collision energy $\sqrt{s_{NN}} = 200$ GeV and momentum $p_T = 8$ GeV/c, the energy loss is found to be about 83% and 64% for $(0-5)\%$ and $(60-80)\%$ centrality, respectively. The energy losses alone, which have been estimated for the production of K_S^0 mesons in Au+Au collisions over a wide range of collision energy, centrality and p_T, show no sign of a phase transition.

3 Conclusion

We analyzed data on transverse momentum spectra of K_S^0 mesons measured in $Au+Au$ collisions at mid-rapidity by the STAR Collaboration in BES-I program at RHIC in the z-scaling approach. Self-similarity of K_S^0-meson production in the gold-gold collisions over a wide kinematic and centrality range was found. The relative energy loss as a function of the collision energy, centrality and transverse momentum of K_S^0 mesons was estimated. The method of analysis is extended for systematic description of $A+A$ collisions with production of identified hadrons.

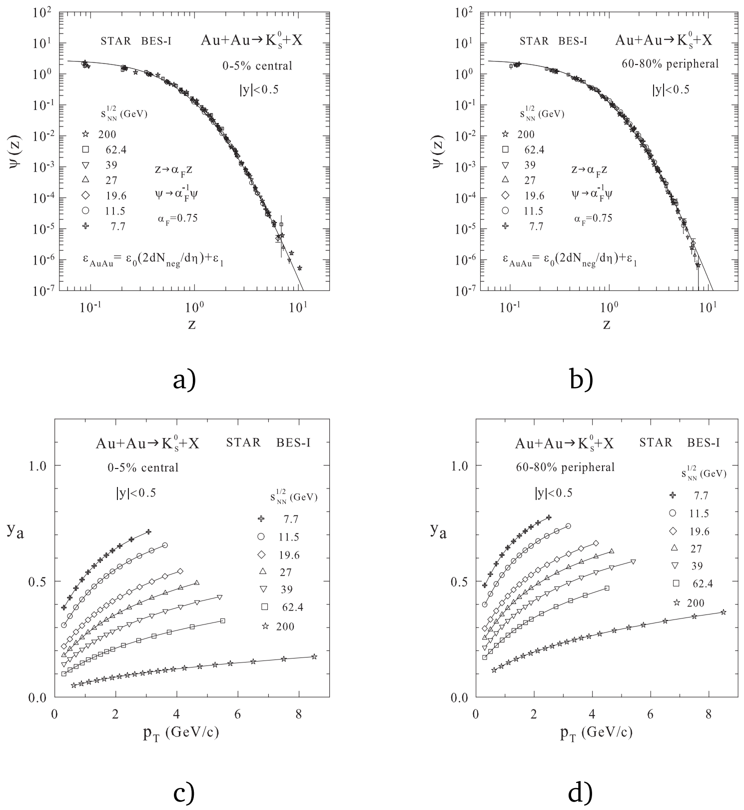

Figure 1: The scaling function $\psi(z)$ (a,b) and the momentum fraction y_a (c,d) for K_S^0 mesons produced in $(0-5)\%$ central and $(60-80)\%$ peripheral $Au+Au$ collisions at $\sqrt{s_{NN}} = 7.7, 11.5, 19.6, 27, 39, 62.4, 200$ GeV in the rapidity interval $|y| < 0.5$. The symbols in (a) and (b) correspond to data obtained by the STAR Collaboration at RHIC. The solid line is a reference curve for $p+p$ interactions.

Acknowledgements

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