# 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.**

## 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 $dN_{\text{neg}}^{AA}/d\eta|_0$ 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].
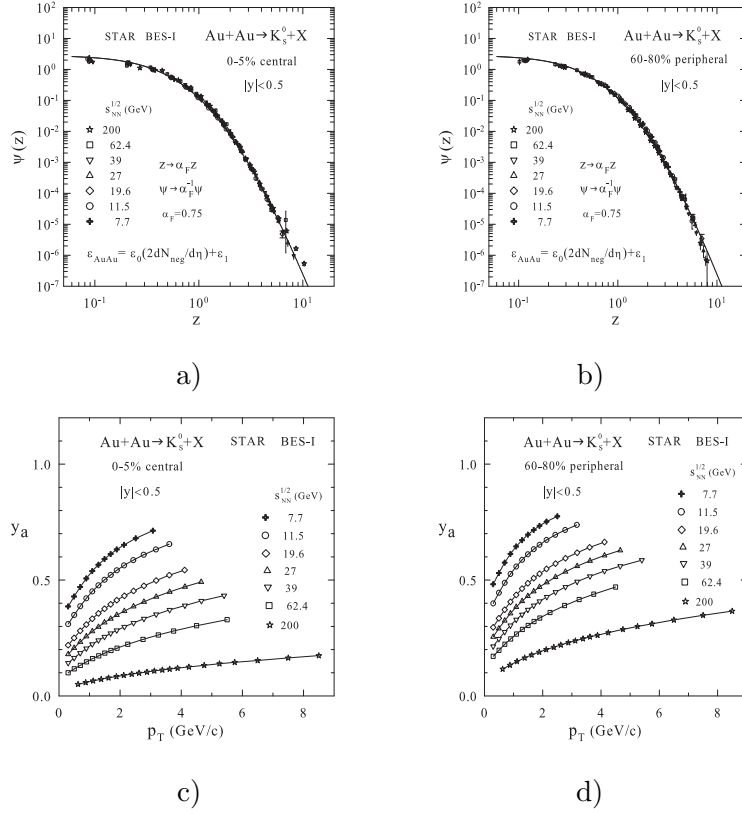
Figure 1: The scaling function $\psi(z)$ (a,b) and the momentum fraction $y_a$ (c,d) for $K_S^0$ mesons produced in $(0-5)\%$ central and $(60-80)\%$ peripheral $Au+Au$ collisions at $\sqrt{s_{NN}} = 7.7, 11.5, 19.6, 27, 39, 62.4, 200$ GeV in the rapidity interval $|y| < 0.5$. The symbols correspond to data obtained by the STAR Collaboration at RHIC. The solid line is a reference curve for $p+p$ interactions.

## 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.

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