Enhancement of $\phi$ meson production in p-p and Pb-Pb collisions at SPS energy

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Abstract The $\phi$ meson yield, rapidity and transverse mass distributions in p-p and Pb-Pb collisions at 158 $A$ GeV were studied by the hadron-string cascade model, LUCIAE. By adjusting the width parameter in $q\bar{q}$ Gaussian like transverse momentum distribution in string fragmentation to fit the NA49 data of $\phi$ meson transverse mass distribution in p-p collisions, the obtained $\phi$ meson rapidity distribution in p-p collisions, the rapidity and transverse mass distributions in Pb-Pb collisions, and the $\phi$ meson enhancement factor in Pb-Pb relative to p-p collisions were compatible with corresponding NA49 data, which might be attributed to the collective effect in gluon emission of string and the reduction of strange quark suppression mechanisms involved in the LUCIAE model.

Keywords: p-p and Pb-Pb collisions, transverse-mass distribution, $\phi$ meson production, LUCIAE model.

One goal of relativistic heavy-ion collisions is to explore the new phase of matter, quark-gluon-plasma (QGP), which mainly consists of deconfined quarks and gluons. Since QGP cannot be detected directly, a variety of hadronic signatures have been proposed theoretically.

Strangeness enhancement is one of the most promising signatures for the creation of QGP$^{[1]}$. Strangeness enhancement means that the ratio of $\phi$ meson yield to negatively charged multiplicity in A-A collisions is larger than the ones in, for instance, p-A or p-p collisions, and is stemming from the energy, centrality, and system size dependences of strange quark suppression factor in string fragmentation. Strange quark suppression factor is defined as

$$\lambda = \frac{2s\bar{s}}{u\bar{u} + d\bar{d}},$$

where $s\bar{s}$, $u\bar{u}$ and $d\bar{d}$ refer to the production probability of $q\bar{q}$ pair with corresponding flavor in string fragmentation. It has been observed that $\lambda$ is not a constant but increases from a value of 0.2 at ISR (Intersecting-Storage–Rings) energy to about 0.3 at the top of the SPS (Su-
The first experimental result of the enhanced production of strange particles in sulphur-sulphur collisions at 200 $A$ GeV was reported in 1990\cite{3}. More experimental data of strangeness enhancement have been reported by NA49 and WA97 recently\cite{4-6}. NA49 reported especially the experimental data of $\phi$ meson yield, rapidity and transverse-mass distributions in p-p and Pb-Pb collisions at 158 $A$ GeV\cite{5}, which have to be understood.

Strangeness enhancement could be explained either in QGP scenario as a result of fast flavor equilibrium or in hadronic scenario as results of rescattering, etc. The hadron and string cascade model, LUCIAE\cite{7-10}, is employed to study NA49 data of $\phi$ meson production in this paper. The corresponding preliminary results have been published elsewhere\cite{11}. In this paper, we first run LUCIAE and adjust the width parameter in $q\bar{q}$ Gaussian like transverse momentum distribution to fit the data of $\phi$ meson transverse mass distribution in p-p collisions. The $\phi$ meson rapidity distribution in p-p collisions, the rapidity and transverse mass distributions in Pb-Pb collisions, and the $\phi$ meson enhancement factor in Pb-Pb relative to p-p collisions obtained from the LUCIAE calculations with fixed width parameter above were compatible with corresponding NA49 data.

1 LUCIAE model and JETSET parameters

LUCIAE model is a hadron and string cascade model based on the FRITIOF model. In the FRITIOF model the nucleus-nucleus collision is depicted simply as a superposition of nucleon-nucleon collisions and the nuclear geometry plays an important role. What characterizes LUCIAE beyond FRITIOF are as follows: First, the rescattering among participant and spectator nucleons and the produced particles is taken into account\cite{12}. Secondly, the collective effect in gluon emission of strings is considered by the firecracker model\cite{13,14}. Thirdly, the reduction of strange quark suppression\cite{2} in string fragmentation is added.

In the mechanism of reduction of strange quark suppression, the effective string tension and the relevant parameters in the JETSET model, which is run together with LUCIAE model, are varying with energy, centrality and size of reaction system automatically. Those JETSET parameters are PARJ(1), PARJ(2), PARJ(3) and PARJ(21). PARJ(1) is equal to $P(q\bar{q})/P(q)$ where $P(q\bar{q})$ is diquark-antidiquark pair production probability in string fragmentation and $P(q)$ is probability of quark-antiquark pair, thus PARJ(1) is the suppression of diquark-antidiquark pair production relative to the quark-antiquark pair production. PARJ(2)=$P(s)/P(u)$ is the suppression of $s$ quark pair production relative to $u$ or $d$ quark pair, i.e. $\lambda$ in eq. (1). PARJ(3) = $(P(us)/P(ud))/(P(s)/P(d))$ is the extra suppression of strange diquark production with respect to the normal suppression of strange quark pair. PARJ(21) refers to the width of Gaussian like transverse momentum distribution of $q\bar{q}$ pair in string fragmentation. If PARJ(21) is denoted as $\sigma$ for simplicity, then a relation of