

Probing the nuclear equation of state by K^+ production in heavy ion collisions

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From the very beginning kaons have been considered as one of the best probes to study dense and hot nuclear matter formed in relativistic heavy ion collisions. In particular at incident energies below the corresponding production thresholds in free space K^+ mesons are created in the early and high density phase of such reactions and – due to strangeness conservation – are not reabsorbed by the nuclear environment. Furthermore, there exist strong evidences that kaons change their properties inside the nuclear medium as predicted by effective chiral models. The aim of the present work is to study if decisive information on the nuclear EOS can be extracted from subthreshold kaon production by new high precision data [1]. The KaoS Collaboration has performed systematic measurements of the K^+ production far below threshold in heavy ($Au + Au$) and light ($C + C$) systems [2]. Looking at the ratios built from heavy and light systems possible uncertainties which might still exist in the theoretical calculations should cancel out to a large extent which allows to draw reliable conclusions. Furthermore, far below threshold the kaon production is a highly collective process and a particular sensitivity to the compression of the participant matter is expected. The present investigations are based on the Quantum Molecular Dynamics (QMD) transport model. For the nuclear EOS we adopt soft and hard Skyrme forces corresponding to a compression modulus of $K=200$ MeV and 380 MeV, respectively, and with a momentum dependence adjusted to the empirical optical nucleon-nucleus potential.

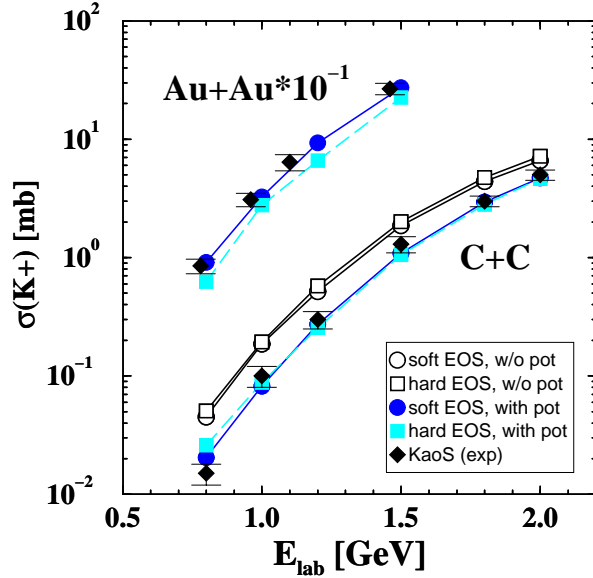


Figure 1: Excitation function of the K^+ cross section in $C + C$ and $Au + Au$ reactions. The calculations are performed with in-medium kaon potential and using a hard/soft nuclear EOS. For $C + C$ also results without in-medium kaon potential are shown.

In Fig. 1 the K^+ excitation function for $Au + Au$ and $C + C$ reactions starting from 0.8 A·GeV which is far below threshold ($E_{thr} = 1.58$ GeV) are shown. The calculations are performed for a soft/hard EOS including the in-medium kaon potential. For both systems the agreement with the KaoS data [3, 2] is very good when a soft EOS is used. In the large system

there is a visible EOS effect which is absent in the light system. To estimate the influence of the in-medium kaon potential for $C + C$ also calculations without potential are shown. Already in the light system the K^+ yield is reduced by about 50% by the influence of the potential which is essential to reproduce the yields [3]. The comparison to the new KaoS data [2] is made

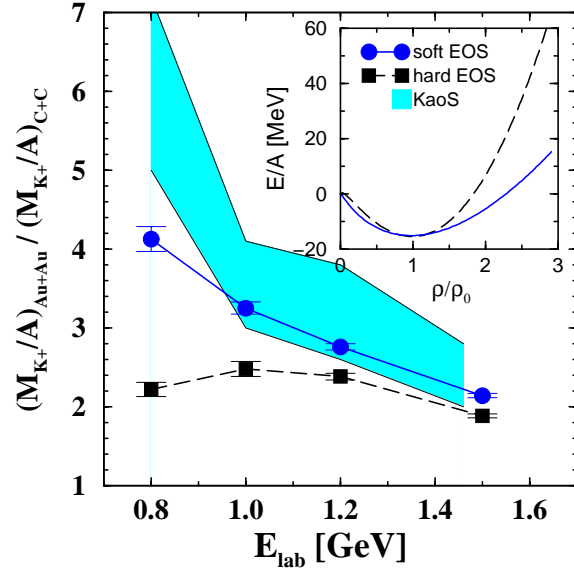


Figure 2: Excitation function of the ratio R of K^+ multiplicities obtained in inclusive $Au + Au$ over $C + C$ reactions. The calculations are performed with in-medium kaon potential and using a hard/soft nuclear EOS and compared to the experimental range of R (shaded area) given by the data from the KaoS Collaboration [2].

in Fig. 2. Here only calculations including the kaon potential are shown since it is already clear from Fig. 1 that without the potential one is not able to reproduce the experimental yields. The calculations are performed under minimal bias conditions with $b_{max} = 11$ fm for $Au + Au$ and $b_{max} = 5$ fm for $C + C$ and normalised to the experimental reaction cross sections [3, 2]. Both calculations show an increase of R with decreasing incident energy down to 1.0 A·GeV. However, this increase is much less pronounced using the stiff EOS. In the latter case R even drops for 0.8 A·GeV whereas the soft EOS leads to an unrelieved increase of R . Using the light system as reference frame there is a visible sensitivity on the EOS. Results for the K^+ excitation function in $Au + Au$ over $C + C$ reactions as measured by the KaoS Collaboration, strongly support the scenario with a soft EOS. The ratio itself is rather independent on the existence of the in-medium potential, but the potential is necessary to reproduce the total yields.

References

- [1] C. Fuchs, A. Faessler, E. Zabrodin, Y.-M. Zheng, Phys. Rev. Lett. (2001) in press.
- [2] C. Sturm *et al.*, Phys. Rev. Lett. **86**, 39 (2001).
- [3] F. Laue *et al.*, Phys. Rev. Lett. **82**, 1640 (1998).