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In-medium effects on strangeness production

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Abstract

We discuss the strangeness production close to threshold in heavy-ion collisions based on two independent microscopic transport approaches – HSD and IQMD – employing different in-medium scenarios for the modification of particle properties (strange mesons and hyperons) in the dense and hot medium following either from the chiral models or from a coupled-channel G-matrix approach using a meson-exchange model for strange mesons. The comparison of available kaon, antikaon and Λ data with the HSD and IQMD models shows a good agreement for the large majority of observables when incorporating the in-medium effects. The investigation of the reactions with help of transport models reveals the complicated multiple interactions of the strange particles with hadronic matter which shows that strangeness production in heavy-ion collisions is very different from that in elementary interactions. We discuss how a variety of strange particle observables can be used to study the different facets of this interaction (production, rescattering and potential interaction) which finally merge into a comprehensive understanding of these reactions.

Keywords: In-medium effects; Strangeness production; Heavy-ion collisions

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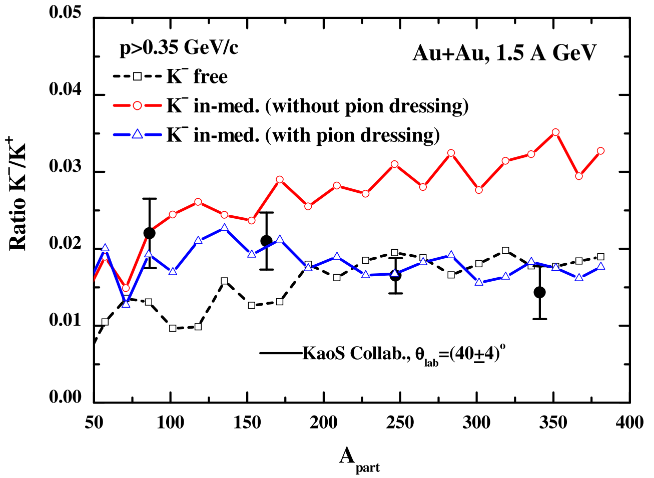

Fig. 1. The K^-/K^+ ratio as a function of centrality, expressed in terms of the number of participating nucleons A_{part}, for the system Au + Au at 1.5 A GeV and $\theta_{cm} = (90 \pm 10)^\circ$ including a cut in momentum $p_{cm} \geqslant 0.35$ GeV/c versus the experimental data [18]. The dashed line corresponds to the HSD results with 'free' spectral function of antikaons, the solid line with open triangles to a G-matrix calculation including pion dressing whereas the solid line with open circles results from a G-matrix calculation without pion dressing.

The in-medium properties of kaons have been primarily investigated due to their relevance for the neutron star phenomenology and for kaonic atoms. In the interior of a neutron star a strongly attractive kaon–nucleon interaction may lead to kaon condensation as suggested by Kaplan and Nelson [1]. The theoretical research work on the topic of in-medium properties of hadrons was triggered in part by the early suggestion of Brown and Rho [2], that the modifications of hadron masses should scale with the scalar quark condensate $\langle q\bar{q}\rangle$ at finite density. The first attempts to extract the real part of the antikaon–nucleus potential from the analysis of kaonic-atom data were in favor of very strong attractive potentials of the order of −150 to −200 MeV close to normal nuclear matter density ρ_0 [3]. However, in-medium self-consistent calculations based on a chiral Lagrangian [4,5] or coupled-channel G-matrix theory (within meson-exchange potentials) [6] predicted an only moderate attractive depths of −50 to −80 MeV at density ρ_0.

The in-medium modification of kaon/antikaon properties can be explored experimentally in relativistic heavy-ion collisions. The comparison of transport model calculations [7–11] with experimental results on $K^\pm$ production in $A + A$ collisions at SIS energies of 1–2 A GeV [12,13] allowed for a quantitative determination of these modifications for kaons whereas for antikaons the situation is still much more uncertain. This is due to a broad and structured spectral function of the antikaon because the antikaon–nucleon amplitude in the isospin channel $I = 0$ is dominated by the $\Lambda(1405)$ resonant structure and influences strongly the antikaon dynamics since $\pi Y \to \bar{K}N$ is the dominant channel for the antikaon production in heavy-ion collisions.

In this contribution we present the highlights of the results of the two models – the off-shell Hadron String Dynamics (HSD) transport approach [8] and the Isospin Quantum Molecular Dynamics (IQMD) model [14] – for different observables. This allows us to assess possible uncertainties of the theoretical approaches and the consequences of different ingredients. Here we employ different in-medium scenarios for the modification of strange particle properties in the dense and hot medium: in HSD – the chiral perturbation theory [15] for kaons and antikaons and a coupled-channel G-matrix approach [9] for antikaons; in IQMD – the relativistic mean-