Isospin-dependent pion in-medium effects on charged pion ratio in heavy ion collisions

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We have studied [1] the dependence of the pion spectral function in asymmetric nuclear matter on the charge of the pion by using results from the chiral perturbation theory for the pion-nucleon $s$-wave interaction [2] and from the $\Delta$-hole model for the pion-nucleon $p$-wave interaction [3,4]. Because of increasing $\pi^-$ and decreasing $\pi^+$ in-medium masses due to the pion-nucleon $s$-wave interaction in neutron-rich matter, the strength of $\pi^+$ spectral function at low energies is somewhat larger than that of $\pi^-$ spectral function, and the strength around the peak of the $\Delta$ resonance mass distribution decreases while that near the threshold increases with increasing charge of the $\Delta$ resonance. In a thermal model that assumes that nucleons, pions, and $\Delta$ resonances produced in heavy ion collisions are in thermal but not chemical equilibrium, with the latter needed to maintain the final pion to nucleon ratio, the $\pi^-/\pi^+$ ratio is slightly reduced in comparison with the case without pion in-medium effects. As shown in Fig. 1, this is the case for all values of nuclear symmetry energy parameter $x=0, 0.5, 1$, corresponding to increasingly softer nuclear symmetry energy at high densities, and of the Migdal parameter $g'$ that describes the repulsive $\Delta$-hole interaction. Taking into consideration of the isospin-dependent pion in-medium effects in the transport model thus will have some, albeit not very significant, influence on the extraction of the nuclear symmetry energy from the measured $\pi^-/\pi^+$ ratio of about 3, which is also shown in Fig.1 with a large error bar, by the FOPI Collaboration [5]. Further theoretical work is needed to understand the relation between

FIG. 1. The $\pi^-/\pi^+$ ratio in Au+Au collisions at the beam energy of 0.4 AGeV for different values of nuclear symmetry energy ($x=0, 0.5, 1$) and the Migdal parameter $g'=0.3, 0.4, 0.5, 0.6$. Results for $g'=\infty$ correspond to the case without the pion medium effects.

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the $\pi^-/\pi^+$ ratio and the behavior of the nuclear symmetry energy at high densities in the transport model
description of heavy ion collisions.