probability increases while the proton occupation decreases almost linearly as a function of asymmetry. At low densities around and below the nuclear saturation density, the TBF effect on the predicted momentum distributions is found to be negligibly weak. At high densities well above the saturation density, the TBF is expected to induce strong enough extra short-range correlations and its effect turns out to become noticeable. In dense asymmetric nuclear matter, inclusion of the TBF effect may lead to an overall enhancement of both the depletion of the neutron and proton Fermi seas for all the asymmetries considered. Although the TBF affects sizably the neutron and proton momentum distributions at high densities well above the saturation density, its effect on the isodepletion of the nuclear Fermi sea (i. e. , the difference of the neutron and proton occupation probabilities) in asymmetric nuclear matter is shown to be quite small in the density region up to two times saturation density.

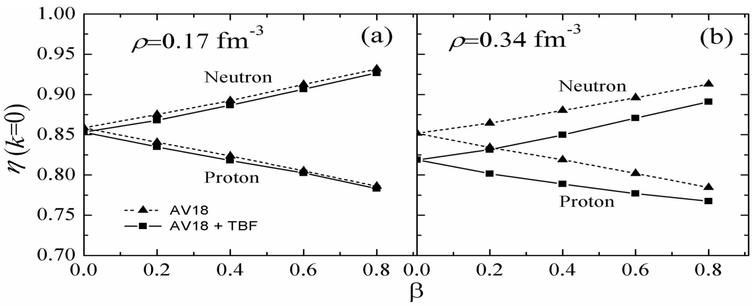

Fig. 1 Neutron and proton momentum distributions at zero momentum in asymmetric nuclear matter vs isospin asymmetry. The results are obtained for the two cases of including the TBF (solid curves) and excluding the TBF (dashed curves).

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1 - 4 Isospin Effects on Subthreshold Kaon Production in Heavy Ion Collisions

Feng Zhaoqing

Kaon producted in relativistic heavy-ion collisions has been investigated as a useful tool to constrain the high-density information of isospin symmetric nuclear equation of state (EoS) both experimentally and theoretically. Kaons (K^0 and K^+) as a probe of EoS are produced in the high-density domain without subsequent reabsorption in nuclear medium. The K^0/K^+ ratio was proposed as a sensitive probe to extract the high-density behavior of the nuclear symmetry energy (isospin asymmetric part of EoS)[1], which is poorly known up to now but has an important application in astrophysics, such as the structure of neutron star, the cooling of protoneutron stars, the nucleo synthes is during supernova explosion of massive stars etc. Kaon dynamics in heavy-ion collisions is investigated with an isospin and momentum dependent transport model (Lanzhou quantum molecular dynamics (LQMD)), in which strangeness production is contributed from channels of baryon-baryon and pion-baryon collisions[2,3]. The momentum dependence of the symmetry potential was also implemented in the model, which results in an isospin splitting of proton and neutron effective mass in nuclear medium[4].

In the LQMD model, the time evolutions of the baryons (nucleons and resonances), hyperons and mesons in reaction system under a self-consistently generated mean-field are governed by Hamilton's equations of motion[2-4]. A density, isospin and momentum dependent single-nucleon potential is used in the LQMD model as follows:

$$U_\tau(\rho,\delta,\boldsymbol{p}) = \alpha\frac{\rho}{\rho_0} + \beta\left(\frac{\rho}{\rho_0}\right)^\gamma + \frac{8}{3}g_\tau\left(\frac{\rho}{\rho_0}\right)^{5/3} + E_{\rm sym}^{\rm loc}(\rho)\delta^2 + \frac{\partial E_{\rm sym}^{\rm loc}(\rho)}{\partial\rho}\rho\delta^2 + \partial E_{\rm sym}^{\rm loc}(\rho)\rho\frac{\partial\delta^2}{\partial\rho_\tau} + \frac{1}{\rho_0}C_{\tau\tau}\int d\boldsymbol{p}' f_\tau(\boldsymbol{r},\boldsymbol{p})[\ln(\varepsilon(\boldsymbol{p}-\boldsymbol{p}')^2)+1)]^2 + \frac{1}{\rho_0}C_{\tau\tau'}\int d\boldsymbol{p}' f_\tau(\boldsymbol{r},\boldsymbol{p})[\ln(\varepsilon(\boldsymbol{p}-\boldsymbol{p}')^2)+1)]^2 \quad (1)$$

Here $\tau \neq \tau'$, $\partial\delta^2/\partial\rho_{\rm n} = 4\delta\rho_{\rm p}/\rho^2$, and $\partial\delta^2/\partial\rho_{\rm p} = 4\delta\rho_{\rm n}/\rho^2$. The coefficients α, β, γ, g_τ and ρ_0 are set to be the values of −296.6 MeV, 197 MeV, 1.143, 9.9 MeV and 0.16 $\rm fm^{-3}$, respectively. The primary products in nucleon-nucleon (NN) collisions in the region of 1 *A*GeV energies are the resonances of Δ(1232), N^*(1440), N^*(1535) and the pions. The strangeness is created as the secondary products in inelastic hadron-hadron collisions. Shown in Fig. 1 is a comparison of the total kaon yields produced in the central ^{197}Au+^{197}Au collisions with and without KN potential for the hard and supersoft symmetry energies, respectively. Inclusion of the KN potential in the model leads to about 30% reduction of the total kaon yields in the subthreshold domain. Once kaons are produced in the compression stage, the subsequent reabsorption by the surrounding baryons almost does not take place although the distributions of kaons in phase space can be deviated by the in-medium potential.

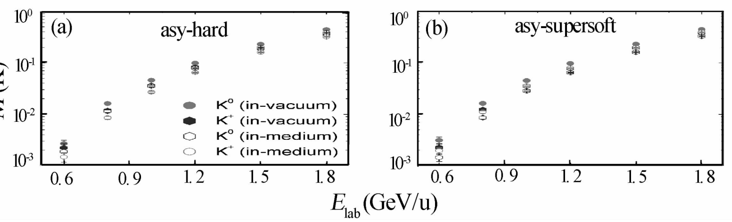

Fig. 1 Total multiplicities of K^0 and K^+ as a function of incident energy in central ^{197}Au+^{197}Au collisions at the cases of hard and supersoft symmetry energies.

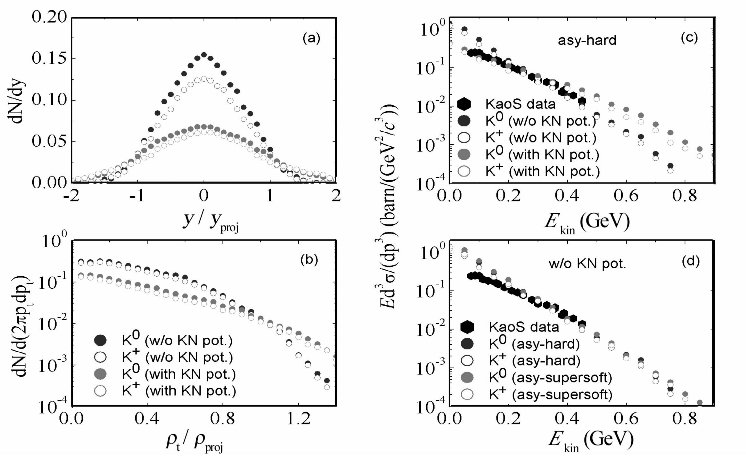

Fig. 2 Longitudinal rapidity and transverse momentum distributions of isospin kaons (left panels) and the kinetic energy spectra of inclusive invariant cross sections at mid-rapidity (right panels) in the ^{197}Au+^{197}Au reaction at the incident energy of 1.5 AGeV. The mid-rapidity condition is a selection of $\theta_{\rm cm} = 90^\circ \pm 10^\circ$ both for the data and the calculations.

To investigate the phase-space distribution of kaon dynamics and its correlation to the collision geometry and to the KN potential, we computed the rapidity and transverse momentum distributions of K^0 and K^+ in the near central ^{197}Au+^{197}Au reaction (b=1 fm) with a hard symmetry energy as shown in Fig. 2 in the left windows. The spectra of inclusive invariant cross sections in the mid-rapidity region for the K^+ production as measured by the KaoS collaboration[5] are compared with the LQMD calculations in the right windows. A nice agreement between the experimental data and the calculations with inclusion of the KN potential can be seen. The difference of K^0 and K^+ and the influence of nuclear symmetry energy on the kaon inclusive spectra are very small. One notices that the repulsive KN potential reduces the kaon yields in the mid-rapidity region. A broad rapidity distribution and a flat transverse momentum spectrum are found for the case with inclusion of the KN potential. It is caused from the fact that the repulsive potential enhances the energetic kaon emission and reduces the kaon yields owing to the threshold effect.

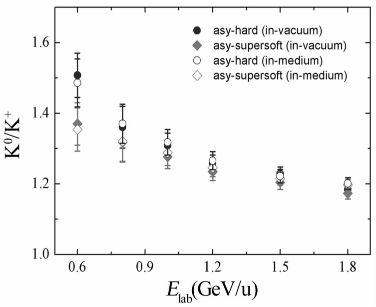

Fig. 3 Comparison of excitation functions of the K^0/K^+ yields for central $^{197}Au+^{197}Au$ collisions for the cases of hard and supersoft symmetry energies.

A pronounced effect of the stiffness of symmetry energy on kaon production can be observed from the spectrum of isospin ratio. The isospin effects appear at deep subthreshold energies as shown in Fig. 3. The in-medium potential slightly changes the K^0/K^+ value because of its influence on the kaon propagation and also on the charge-exchange reactions. At the considered energies, the channel of N△→NYK contributes the main part for the kaon yields due to the larger production cross sections and the higher invariant energy, and the NN→NYK as well as πN→YK have about one third contributions. One notices that a hard symmetry energy always has the larger values of the isospin ratios than the supersoft case in the domain of subthreshold energies ($E_{th}(K)=1.58$ GeV).

In summary, kaon dynamics in heavy-ion collisions at near threshold energies has been investigated by using an isospin- and momentum-dependent transport model (LQMD). It is found that the KN potential plays an important role on kaon emission in phase space, in particular, reducing the kaon yields in the mid-rapidity region and also at low transverse momenta, but enhancing the production at high transverse momenta. The K^0/K^+ ratio of neutron-rich heavy system in the domain of subthreshold energies is sensitive to the stiffness of nuclear symmetry energy, which is a promising probe to extract the high-density information of symmetry energy through comparison to experimental data. Precise measurements on subthreshold kaon production from neutron-rich nuclear collisions are still very necessary.

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1 - 5 Constraining Isospin Splitting of Nucleon Effective Mass from Heavy-ion Collisions at CSR Energies

Feng Zhaoqing

It has been well known that the masses of neutron and proton are equal each other in vacuum (about 1 GeV), and the effective mass in nuclear matter or finite nuclei deviates from its vacuum value. Moreover, a splitting of neutron and proton effective mass exists in neutron-rich nuclear matter, which increases with the isospin asymmetry and nucleon density. Predictions of the mass splitting based on nuclear many-body theories also differ widely. Constraints on the effective mass splitting from heavy-ion collisions are still necessary and its influence on reaction dynamics would be very interesting. In this work, we present systematic investigations of the effective mass splitting of neutron and proton and its influence on reaction dynamics within an isospin and momentum dependent transport model (LQMD). The nucleon effective (Landau) mass is calculated through the single-nucleon potential as

$$m_\tau^* = m_\tau \Big/ \left(1 + \frac{m_\tau}{|\boldsymbol{p}|}\left|\frac{dU_\tau}{d\boldsymbol{p}}\right|\right)$$