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.

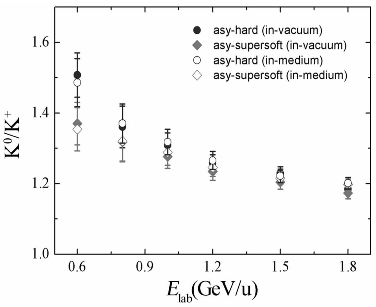

Fig. 3 Comparison of excitation functions of the K^0/K^+ yields for central $^{197}Au+^{197}Au$ collisions for the cases of hard and supersoft symmetry energies.

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 $N\triangle \rightarrow NYK$ contributes the main part for the kaon yields due to the larger production cross sections and the higher invariant energy, and the $NN \rightarrow NYK$ as well as $\pi N \rightarrow YK$ 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

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

with the free mass m_τ at Fermi momentum $\boldsymbol{p}=\boldsymbol{p}_F$. Therefore, the nucleon effective mass only depends on the momentum-dependent term of the nucleon optical potential[1].

Shown in Fig. 1 is a comparison of the momentum dependence of single-nucleon optical potential with the mass splittings of $m_n^* > m_p^*$ in the left window and $m_n^* < m_p^*$ in the right window for the hard and super-soft symmetry energies, respectively. One should note that a cross of neutron and proton single-nucleon potentials appears in the case of $m_n^* > m_p^*$ at high momentum, but which does not take place in the mass splitting of $m_n^* < m_p^*$ and a broader separation exists with increasing the nucleon momentum. The difference of single-particle potentials for both mass splitting affects the isospin emission in heavy-ion collisions, in particular, in the domain of high-baryon densities.

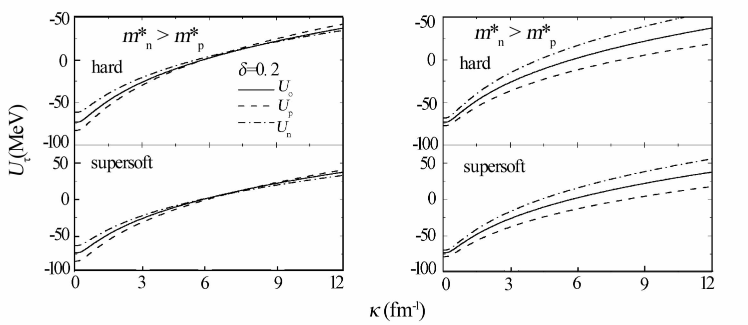

Fig. 1 Momentum dependence of single-nucleon optical potential for isospin symmetric matter ($\delta=0$) and neutron-rich matter ($\delta=0.2$) with the mass splittings of $m_n^* > m_p^*$ (left panel) and $m_n^* < m_p^*$ (right panel), respectively.

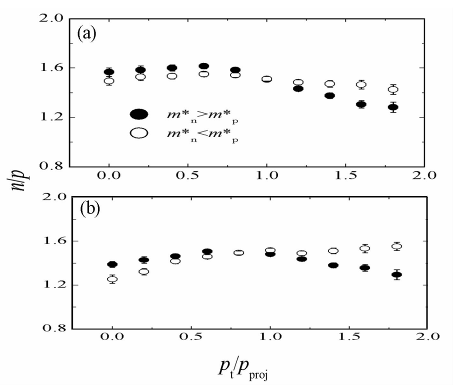

Fig. 2 Transverse momentum distributions of neutron/proton within the rapidity bin $|y/y_{proj}|<0.25$ in the $^{197}Au+^{197}Au$ reaction at the incident energy of 400 MeV/u for the near central ($b=1$ fm) and semi-central ($b=6$ fm) collisions with different mass splitting.

The preequilibrium nucleons in high-energy heavy-ion collisions are mostly produced during a compression stage of two colliding partners within a very short time. Therefore, the high-density information of nuclear phase diagram is expected to be extracted from the nucleons or light complex particles, which can be constrained from the longitudinal rapidity distributions and the azimuthal emissions[2]. Shown in Fig. 2 is a comparison of transverse emission ratios of neutron/proton within the rapidity selection of $|y/y_{proj}|<0.25$ in the $^{197}Au+^{197}Au$ reaction at the incident energy of 400 AMeV for the near central ($b=1$ fm) and semi-central ($b=6$ fm) collisions, but with different mass splittings. One can see that the influence of the symmetry energy appears at low transverse momentum and the situation does not be changed with the mass splitting. A hard symmetry energy enforces a strongly repulsive force on neutrons in the high-density domain, furthermore, squeezes out more neutrons in the preequilibrium stage of dynamical evolution. From the negative contribution of the momentum- dependent interaction of $m_n^* > m_p^*$ to the potential part of the symmetry energy in Ref. [1], one notices that the momentum-dependent potential leads to an attractive force on neutrons, in particular at high densities, which reduces the n/p yields at high transverse momentum. Opposite contributions take place and a flat distribution appears in the case of $m_n^* < m_p^*$. More sensitive observable can be seen from the flow difference between neutron and proton as shown in Fig. 3. The $m_n^* > m_p^*$ case is always larger, in particular in the domain of high transverse momentum. Basically, the symmetry energy does not change the spectrum structure.

In summary, within the transport model (LQMD) we have investigated the impact of the momentum-dependent interaction on fast nucleon emissions in heavy-ion collisions. Two different mass splittings, i. e., $m_n^* > m_p^*$ and $m_n^* < m_p^*$, are chosen in the calculations. The momentum-dependent potential plays a significant role on the fast nucleon emissions. Specifically, the neutron/proton ratio at high transverse momenta is influenced, in which a flat spectrum appears in the case of $m_n^* < m_p^*$. The elliptic flow difference between neutron and proton sensitively depends on the mass splitting, in particular at high transverse momenta.

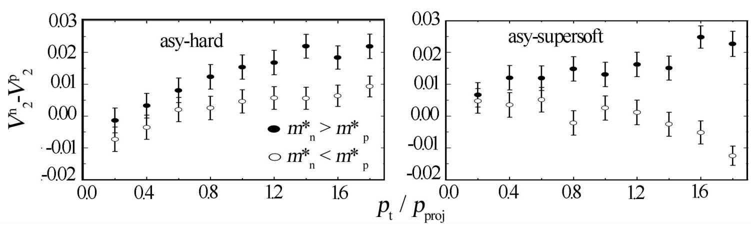

Fig. 3 Comparison of the difference between neutron and proton elliptic flows with the rapidity bin $|y/y_{proj}|<0.25$ for the different mass splitting in the semi-central ^{197}Au+^{197}Au collisions.

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1 - 6 Two Charged Strangeonium-like Structures Observable in Y(2175)→φ(1020)π⁺π⁻ Process

Chen Dianyong

As one of the newly observed *XYZ* states, Y(2175) was first reported by the BaBar Collaboration, where an enhancement structure with mass $M=2175\pm10\pm15$ MeV and width $\Gamma=58\pm16\pm20$ MeV was observed in the $\phi f_0(980)$ invariant mass spectrum of $e^+e^-\to\phi(1020)\, f_0(980)$ via the initial state radiation (ISR) mechanism[1]. Furthermore, Y(2175) was confirmed by BES-II in $J/\psi\to\eta\phi f_0(980)$[2] and by Belle in the $e^+e^-\to\phi(1020)\pi^+\pi^-$ and $e^+e^-\to\phi f_0(980)$ processes[3]. The observation of Y(2175) have stimulated theorists' interest in revealing its underlying structures. By a relativized quark model with chromodynamics, Godfrey and Isgur predicted the masses of $2\,^3D_1$ and $3\,^3S_1$ states close to the mass of Y(2175), which seems to support Y(2175) as a vector strangeonium. However, vector strangeonium assignment with $3\,^3S_1$ can be fully excluded since the calculated total width of this state is about 380 MeV, which is far larger than the width of Y(2175). Right after the observation of Y(2175), Ding and Yan studied the decay behavior of Y(2175) assuming it as a $2\,^3D_1$ strangeonium state[4] and calculated the total width of Y(2175) to be 167.21 MeV by the $^3P_0$ model or 211.9 MeV by the flux tube model, which are larger than the width of Y(2175) to some extent.

The observation of Y(2175) is tempting us to relate it to the observed Y(4260) and Υ(10860) due to some common peculiarities existing in the experiments of Y(2175), Y(4260) and Υ(10860). Before observing Y(2175), the BaBar Collaboration once reported an enhancement named as Y(4260) in the $J/\psi\pi^+\pi^-$ invariant mass spectrum of $e^+e^-\to J/\psi\pi^+\pi^-$[5]. In 2007, the Belle Collaboration found anomalous partial width of $\Upsilon(10860)\to\Upsilon(1S,2S)\pi^+\pi^-$, which is 2~3 orders larger than those of $\Upsilon(nS)\to\Upsilon(mS)\,\pi^+\pi^-$ ($n=2,3,4$ and $m<n$)[6]. Comparing the experimental phenomena of Y(2175), Y(4260) and Υ(10860), we notice the similarities among these particles. Y(2175), Y(4260) and Υ(10860). Firstly, Y(2175), Y(4260) and Υ(10860) are produced from the e^+e^- collision, which indicates that their quantum numbers are $J^{PC}=1^{--}$. Secondly, the dipion transitions of Y(2175), Y(4260) and Υ(10860) were observed. Thirdly, there exist some anomalous phenomena in the e^+e^- collisions at several typical energies 2175 MeV, 4260 MeV and 10860 MeV, which correspond to the relevant observations of Y(2175), Y(4260) and Υ(10860). These properties seem to show a complete series of flavors. Thus, the ideas that arise when studying Y(2175), Y(4260) and Υ(10860) can be shared with each other, which provides new insight into these peaks and further reveals the properties of Y(2175), Y(4260) and Υ(10860).

Recently, the Belle Collaboration announced two charged bottomonium-like structures $Z_b(10610)$ and $Z_b(10650)$ observed in the $\Upsilon(1S,2S,3S)\pi^\pm$ and $h_b(1P,2P)\pi^\pm$ invariant mass spectra of $\Upsilon(10860)\to\Upsilon(1S,2S,3S)\,\pi^+\pi^-$, $h_b(1P,2P)\,\pi^+\pi^-$[7]. In Ref. [8], the Initial Single Pion Emission (ISPE) mecha-