fragmentation are emitted preferentially towards the midrapidity domain on a short timescale in comparison to PLFs and TLFs. The isospin ratios depend on the stiffness of symmetry energy and the effects increase with softening the symmetry energy, in particular in neutron-rich nuclear reactions.

References

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1 - 5 Constraining Nucleon High Momentum in Nuclei*

Yong Gaochan

Recent studies at Jefferson Lab show that there are a certain proportion of nucleons in nuclei have momenta greater than the so-called nuclear Fermi momentum p_F. Based on the transport model of nucleus-nucleus collisions at intermediate energies, nucleon high momentum caused by the neutron-proton short-range correlations in nuclei is constrained by comparing with π and photon experimental data. The high momentum cutoff value $p_{max} \leq 2p_F$ is obtained[1].

Fig. 1 shows π^+ production as a function of high-momentum cutoff parameter λ (= p_{max}/p_F, *i.e.*, the ratio of the maximal nucleon momentum over the nuclear Fermi momentum) of colliding nuclei in the Au + Au collisions at 0.4 and 1 GeV/u incident beam energies, respectively. One can clearly see that as the high-momentum cutoff parameter λ increases, more π^+'s are produced. Larger high-momentum cutoff parameter λ causes larger nucleon average kinetic energy, especially proton average kinetic energy, thus the average center-of-mass energy of proton-proton collision also becomes larger. As a consequence more π^+'s are produced in nucleus-nucleus collision. This is the reason why one sees in the upper panel of Fig. 1 more π^+'s are produced with larger high-momentum cutoff parameter λ. As incident beam energy increases, the initial motion of nucleons in nuclei becomes less important in nucleus-nucleus collisions. We thus see, in the lower panel of Fig. 1, at 1 GeV/u incident beam energy, π^+ production is less sensitive to the high-momentum cutoff parameter λ (At 0.4 GeV/u, the sensitivity of π^+ production to λ is about 10 times larger than that of π^+ at 1 GeV/u). Fig. 1 indicates $\lambda \leq 2$ is favored by the FOPI data.

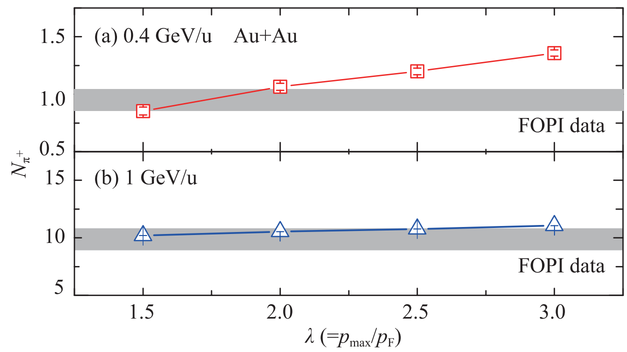

Fig. 1 (color online) The number of produced π^+ meson as a function of high-momentum cutoff parameter λ in the Au + Au collisions at, respectively, 0.4 and 1 GeV/u beam energies.

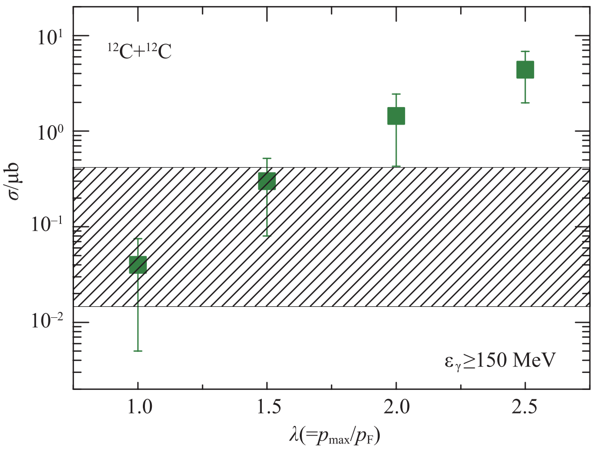

Fig. 2 (color online) Inclusive photon production cross sections ($\varepsilon_\gamma \geq 150$ MeV) in $^{12}C+^{12}C$ collisions at the beam energy of 60 MeV/u. The symbols stand for BUU calculations with, respectively, $\lambda = 1$ (*i.e.*, without high-momentum tail), 1.5, 2, 2.5. The shadow region denotes experimental data.

Fig. 2 compares the theoretical inclusive hard photon production cross sections in $^{12}C+^{12}C$ collisions and the experimental data. Since the hadronic probe π^+ production constrained the high-momentum cutoff parameter λ between 1.5 ~ 2.5, we use $\lambda = 1.5$, 2, 2.5 for the BUU calculations with the high-momentum tail. As comparison, we also calculated the case without high-momentum tail ($\lambda = 1$). From Fig. 2, it is seen that the cross section of the hard photon production in heavy-ion collisions is very sensitive to the high-momentum in of nuclei. The BUU calculations with $\lambda = 2$ and 2.5 are larger than the experimental hard photon production cross section. And the case of BUU calculation without high-momentum tail is somewhat lower than the experimental data. From Fig. 2, it is seen that the electromagnetic probe (*i.e.* the hard photon production) constrains the high-momentum cutoff parameter to be $\lambda \leq 2$. Combining the constraints from hadronic probe π^+ production (shown in Fig. 1) and that from electromagnetic probe(shown in Fig. 2), we can conservatively conclude that the value of the high-momentum cutoff parameter λ in nuclei is less than 2.5 and the overlap-area is $\lambda \leq 2$.

Constraints on the high-momentum cutoff parameter λ in nuclei have implications in the studies of nuclear force at short distance, in the construction of nuclear transport model of heavy-ion collisions at intermediate energies, in the studies of equation of state of dense nuclear matter and the nuclear symmetry energy at suprasaturation densities or in the study of the physics in neutron stars, *etc*.

Reference

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1 - 6 Cross-checking the Symmetry Energy at High Densities*

Yong Gaochan

By considering both the effects of the nucleon-nucleon short-range correlations and the isospin-dependent in-medium inelastic baryon-baryon scattering cross section in the transport model, two unrelated Au + Au experimental measurements at 400 MeV/u beam energy are simultaneously analyzed, a mildly soft symmetry energy at supra-saturation densities is obtained[1].

In our transport model, by considering the effects of the nucleon-nucleon short-range correlations on the kinetic symmetry energy, a new density-dependent symmetry energy is recent obtained. Fig. 1 shows the density-dependent symmetry energy with different x parameters.

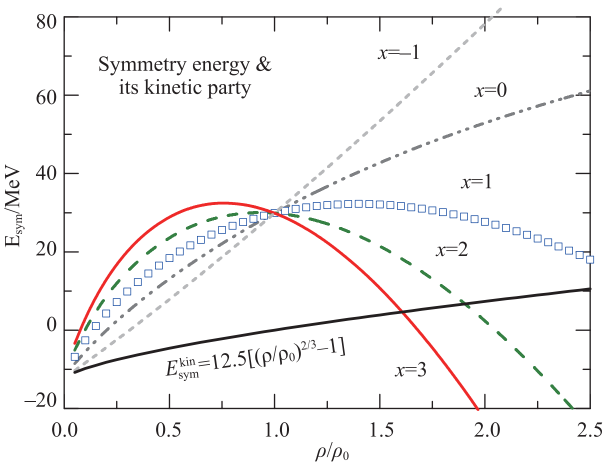

Fig. 1 (color online) Kinetic symmetry energy and density-dependent symmetry energy with different x parameters.

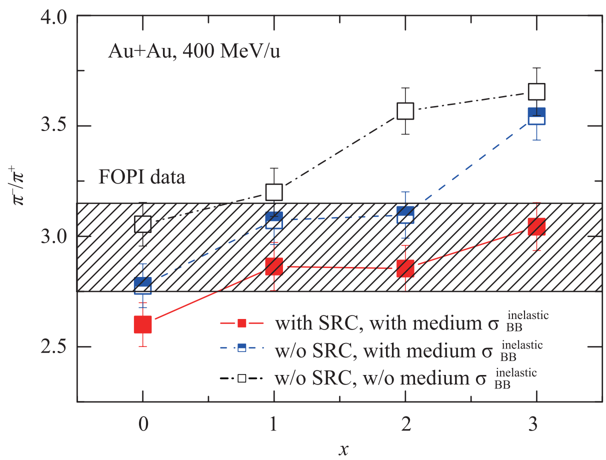

Fig. 2 (color online) π^-/π^+ ratio in Au+Au reaction at 400 MeV/u with different symmetry energies. Also shown are the effects of the SRC of nucleon-nucleon and the in-medium inelastic cross section on the π^-/π^+ ratio with same x parameters.

Fig. 2 shows the π^-/π^+ ratio predicted by our IBUU model with different symmetry energies. Because softer symmetry energy causes more neutron-rich dense matter and π^-'s are mainly from neutron-neutron collision whereas π^+'s are mainly from proton-proton collision, it is not surprising that one sees larger π^-/π^+ ratio with softer symmetry energy. To see the effects of the nucleon-nucleon SRC and the reduction of the in-medium inelastic baryon-baryon scattering cross section, with same x parameters, we made calculations by turning off the SRC and by reducting of the in-medium inelastic baryon-baryon scattering cross section, respectively. From Fig. 2, we can see that both of them affect the value of π^-/π^+ ratio evidently. Both the SRC of nucleon-nucleon and the reduction of the in-medium inelastic baryon-baryon scattering cross section decrease the value of π^-/π^+ ratio. Proton-proton