RIKEN/Japan. Such studies may help one to constrain the density-dependent symmetry energy by pion production using a wide variety of advanced new facilities, such as the Facility for Rare Isotope Beams (FRIB) in the US, the Facility for Antiproton and Ion Research (FAIR) at GSI in Germany, the Radioactive Isotope Beam Facility (RIBF) at RIKEN in Japan, the Cooling Storage Ring on the Heavy Ion Research Facility at IMP (HIRFL-CSR) in China, the Korea Rare Isotope Accelerator (KoRIA) in Korea.

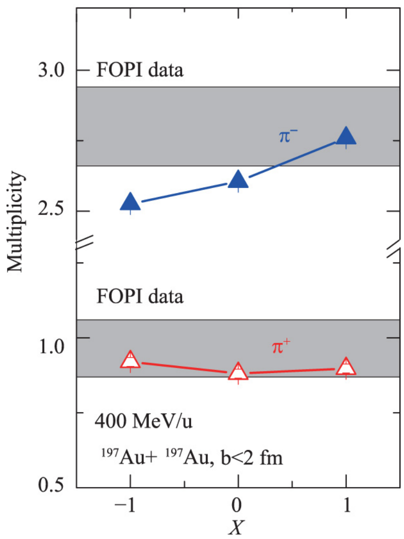

Fig. 1 (color online) Charged pion yields in Au+Au reaction at 400 MeV/nucleon with different symmetry energies. The shadow region denotes the FOPI data.

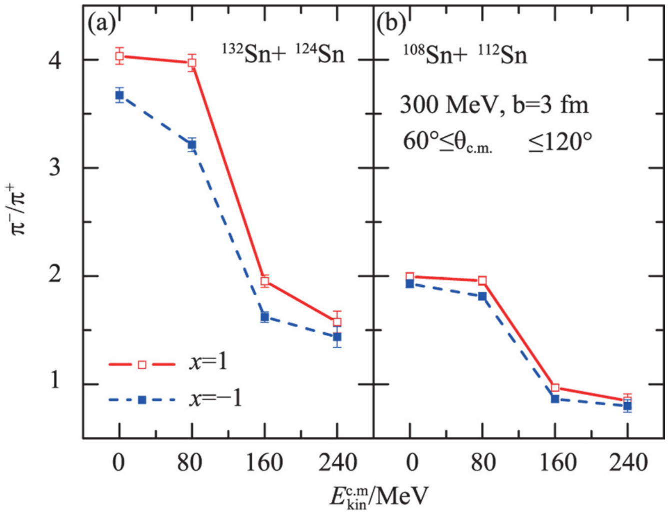

Fig. 2 (color online) The ratios of π^-/π^+ as a function of kinetic energy in isotope reaction systems of ^{132}Sn+^{124}Sn and ^{108}Sn+^{112}Sn at 300 MeV/nucleon incident beam energy with stiff (x= -1) and soft (x= 1) symmetry energies. $\theta_{\rm cm}$ is polar angle relative to the incident beam direction.

Reference

[1] G. C. Yong, Phys. Rev. C, 6(2017)044605.

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1 - 4 Interplay of Short-range Correlations and Nuclear Symmetry Energy in Hard Photon Productions from Heavy-ion Reactions at Fermi Energies*

Yong Gaochan

Within an isospin- and momentum-dependent transport model for nuclear reactions at intermediate energies, we investigate the interplay of the nucleon-nucleon short-range correlations (SRC) and nuclear symmetry energy $E_{\rm sym}(\rho)$ on hard photon spectra in collisions of several Ca isotopes on ^{112}Sn and ^{124}Sn targets at a beam energy of 45 MeV/u. It is found that over the whole spectra of hard photons studied, the effects of the SRC overwhelm those due to the $E_{\rm sym}(\rho)$. The energetic photons come mostly from the high-momentum tails (HMT) of single-nucleon momentum distributions in the target and projectile. Since the underlying physics of SRC and $E_{\rm sym}(\rho)$ are closely correlated, a better understanding of the SRC will in turn help to constrain the nuclear symmetry energy more precisely in a broad density range[1].

Figure. 1 shows the nucleon momentum distribution of Ca isotopes with or without the HMT. Compared with the ideal gas case, for the neutron-rich nucleus $^{48}_{20}$Ca, protons have a larger probability than neutrons to have momenta greater than the nuclear Fermi momentum. This feature is a consequence of the n-p dominance model where equal numbers of neutrons and protons are required to be in the HMT[1].

Figure. 2 shows the effects of the symmetry energy on the ratio of hard photons in neutron-rich (^{48}Ca+^{124}Sn) over neutron-poor ^{40}Ca+^{112}Sn reactions at an incident energy of 45 MeV/u with a 20% HMT using the soft and stiff

$E_{sym}(\rho)$ functions, respectively[1]. From the upper and lower panels of Fig. 2, it is clearly seen that the symmetry energy affects appreciably hard photon production in both the central and peripheral collisions. More quantitatively, about 5% more photons are produced at 100 MeV with the soft symmetry energy compared to that with the stiff $E_{sym}(\rho)$. Moreover, for peripheral collisions of neutron-rich systems, neutron-skins make the isospin asymmetry larger and the number of neutron-proton collisions smaller as well as the SRC weaker, the effects of the symmetry energy on photons are thus stronger. In the present study, the ratio of hard photon from the two reaction systems still mainly probes the symmetry energy at densities above nuclear saturation density.

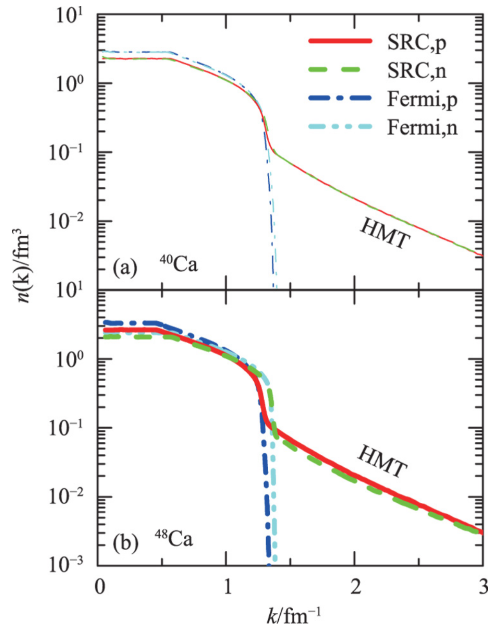

Fig. 1 (color online) Nucleon momentum distribution $n(k)$ in $^{40}_{20}$Ca and $^{48}_{20}$Ca. For a comparison, the nucleon Fermi distribution is also shown.

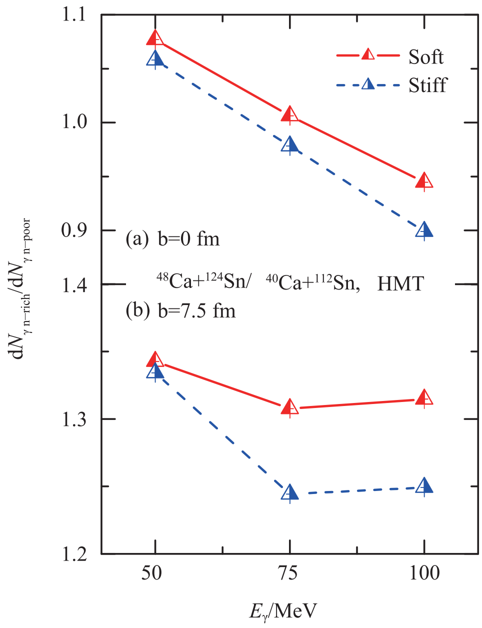

Fig. 2 (color online) Effects of the symmetry energy on the ratio of hard photon productions in neutron-rich and neutron-deficient reactions at a beam energy of 45 MeV/u with different impact parameters.

The new physics underlying both the short-range correlations and symmetry energy in neutron-rich matter is fundamentally important for both nuclear physics and astrophysics. The physics ingredients of the SRC and $E_{sym}(\rho)$ are actually closely intercorrelated. Significant efforts have been made by many people to probe both the SRC and $E_{sym}(\rho)$ using various theoretical approaches and experimental methods. Among the promising probes known, hard photons from heavy-ion collisions have the special advantages that it is basically free of the final state interactions that have been the major sources of uncertainties in interpreting some experimental findings from studying hadronic probes.

Reference

[1] G. C. Yong, B. A. Li, Phys. Rev. C, 96(2017)064614.

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