Symmetry energy investigation with pion production from Sn + Sn systems†

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In the last couple of decades, pions produced in the high density regions of heavy ion collisions have been considered to be one of sensitive probes to investigate the symmetry energy term in the nuclear equation of state at high densities, a key property to understand neutron stars. In our new experiment designed to study the symmetry energy, the multiplicities of negatively and positively charged pions have been measured with high accuracy for central ^{132}Sn + ^{124}Sn, ^{112}Sn + ^{124}Sn, and ^{108}Sn + ^{112}Sn collisions at $E/A = 270$ MeV with the SπRIT Time Projection Chamber[2,3] placed inside the SAMURAI spectrometer[4] at RIBF. While individual pion multiplicities are measured to 4% accuracy, those of the charged pion multiplicity ratios are measured to 2% accuracy. We compare these data to predictions from seven major transport models which have taken part in the Transport Model Evaluation Project (TMEP).[5–7] The calculations reproduce qualitatively the dependence of the multiplicities and their ratios on the total neutron and proton number in the colliding systems.

As shown in Fig. 1, however, the predictions of the transport models from different codes differ too much to allow extraction of reliable constraints on the symmetry energy from the data even using the double pion ratio. This finding may explain previous contradictory conclusions on symmetry energy constraints obtained from pion data in Au + Au system.[8–12] These new results call for still better understanding of the differences among transport codes, and new observables that are more sensitive to the density dependence of the symmetry energy.

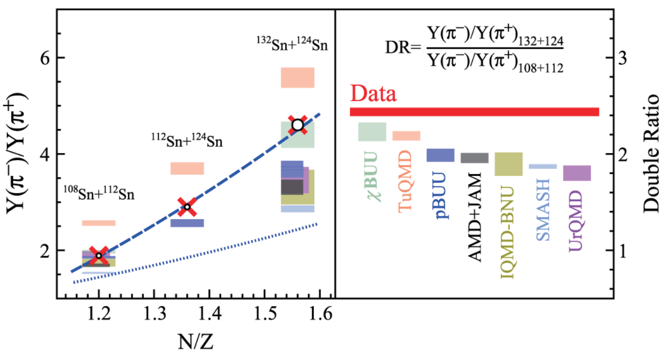

Fig. 1. (Left panel) Experimental charged pion yield ratios as a function of N/Z together with the results of seven transport-model predictions for the soft and stiff symmetry energies (the difference of predictions are presented by the height of colored boxes). The dashed blue line is a power-law fit with the function $(N/Z)^{3.6}$, while the dotted blue line represents $(N/Z)^2$ of the system. (Right panel) Double pion yield ratios for ^{132}Sn + ^{124}Sn and ^{108}Sn + ^{112}Sn. The data and their uncertainty are given by the red horizontal bar and the results of the transport models are shown by the colored boxes, in a similar way as in the left panel. Taken from Ref. 1).

† Condensed from the article in Phys. Lett. B **813**, 136016 (2021)[1]

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