Comparing pion production in transport simulations of heavy-ion collisions at 270A MeV under controlled conditions

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Within the Transport Model Evaluation Project (TMEP), we have carried out a detailed study of the performance of different transport models in Sn + Sn collisions at 270*A* MeV, which are representative reactions used to study the equation of state at supra-saturation densities [1]. We have put particular emphasis on the production of pion and Delta resonance, which have been used as probes of the nuclear symmetry energy. Our study aims to understand the differences in the results of different codes for a given physics model to estimate the uncertainties of transport model studies in the intermediate energy range. With a common and rather simple physics model, we have followed in detail the results of four Boltzmann-Uehling-Uhlenbeck (BUU) models [2-5] and six quantum molecular dynamics (QMD) models [6-11]. It is found that the nucleonic evolution of the collision and the nucleonic observables in these codes do not completely converge, but the differences among the codes can be understood as being due to several reasons: the basic differences between BUU and QMD models in the representation of the phase-space distributions, computational differences in the mean-field evaluation, and differences in the adopted strategies for the Pauli blocking in the collision integrals. For pion observables, we have found that a higher maximum density leads to an enhanced pion yield and a reduced π^-/π^+ yield ratio, while a more effective Pauli blocking generally leads to a slightly suppressed pion yield and an enhanced π^-/π^+ yield ratio. We have specifically investigated the effect of the Coulomb force and found that it increases the total π^-/π^+ yield ratio but reduces the ratio at high pion energies, although differences in its implementations do not have a dominating role in the differences among the codes. Considering only the results of codes that strictly follow the homework specifications, we have found a convergence of the codes in the final charged-pion yield ratio to a 1σ deviation of about 5%. However, the uncertainty is expected to be reduced to about 1.6% if the same or similar strategies and ingredients, i.e., an improved Pauli blocking and calculation of the nonlinear term in the mean-field potential, are similarly used in all codes. As a result of this work, we have identified the sensitive aspects of a simulation with respect to the pion observables and suggested optimal procedures in some cases. Our study has provided benchmark calculations of heavy-ion collisions to be complemented in the future by simulations with more realistic physics models, which include the momentum-dependence of isoscalar and isovector mean-field potentials and pion in-medium effects.

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