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Exploring the freeze-out hypersurface with a rapidity-dependent thermal model

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The success of thermal models in extracting freeze-out parameters from particle yields near midrapidity is well known. However, it is essential to investigate their performance with rapidity-dependent measurements at low collision energies, where boost-invariance is expected to be strongly violated. In this study, we calibrate a (3+1)-dimensional multistage hydrodynamic framework using rapidity distributions of charged particles and net protons for Au+Au collisions at $\sqrt{s_{NN}} = 7.7$–200 GeV. We observe significant rapidity dependences in thermodynamic properties at the hadronization process near the chemical freeze-out. The effects on the rapidity dependence of particle production due to longitudinal flow and system size are also highlighted. A rapidity-dependent thermal model is developed, incorporating the dynamical features of the multistage framework. We evaluate the performance of different thermal model scenarios in extracting the freeze-out profiles, using the rapidity-dependent yields of the multistage framework and comparing them to the hydrodynamic freeze-out hypersurface as a closure test [1]. Bayesian analysis is applied to constrain the longitudinal flow, system size in rapidity space, and thermodynamic properties for nuclear matter created at low beam energies. Our Bayesian model selection analysis reveals a longitudinal flow stronger than Bjorken in the experimental measurements as beam energy decreases. Our study provides a simple numerical approach for extracting rapidity-dependent thermodynamic parameters at freeze-out for low-beam energy collisions. Furthermore, analyzing freeze-out profiles through data-driven methods using this model offers quantitative guidance to computationally-demanding hybrid approaches [2].

[1] Lipei Du, Han Gao, Sangyong Jeon, and Charles Gale, "Rapidity scan with multistage hydrodynamic and statistical thermal models,"arXiv: 2302.13852.
[2] Han Gao, Lipei Du, Sangyong Jeon, and Charles Gale, "Constraining longitudinal dynamics and freeze-out thermodynamics with Bayesian Analysis in a hydrodynamics-inspired thermal model,"in preparation.

Category

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