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Quantify phenomenological effects of causality constraints in the hydrodynamic description of relativistic heavy-ion collisions

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We study theoretical uncertainties in the hydrodynamic description of relativistic heavy-ion collisions by examining the full nonlinear causality conditions [1] and quantifying their effects on flow observables [2]. The causality conditions impose physical constraints on the maximum allowed values of inverse Reynolds numbers during the hydrodynamic evolution. We develop a new numerical scheme to impose the necessary and sufficient causality conditions on individual fluid cells during the evolution. We find that the necessary causality condition can effectively stabilize event-by-event hydrodynamic simulations with large pressure gradients. Performing systematic simulations with and without the necessary and sufficient causality conditions, we quantify their effects on flow observables in p+Au and Au+Au collisions at the top RHIC energy and p+Pb and Pb+Pb collisions at LHC. Their impacts on the global Bayesian extraction of the QGP transport properties will be discussed.

[1] F. S. Bemfica, M. M. Disconzi, V. Hoang, J. Noronha, and M. Radosz, "Nonlinear Constraints on Relativistic Fluids Far from Equilibrium,"Phys. Rev. Lett. 126, 222301 (2021)
[2] C. Chiu and C. Shen, "Exploring theoretical uncertainties in the hydrodynamic description of relativistic heavy-ion collisions,"Phys. Rev. C 103, 064901 (2021)

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