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Bayesian calibration of viscous anisotropic hydrodynamic simulations of heavy-ion collisions*

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Due to large pressure gradients at early times, standard hydrodynamic model simulations of relativistic heavy-ion collisions do not become reliable until $O(1)$ fm/c after the collision. To address this one often introduces a pre-hydrodynamic stage that models the early evolution microscopically, typically as a conformal, weakly interacting gas. In such an approach the transition from the pre-hydrodynamic to the hydrodynamic stage is discontinuous, introducing considerable theoretical model ambiguity. Alternatively, fluids with large anisotropic pressure gradients can be handled macroscopically using the recently developed Viscous Anisotropic Hydrodynamics (VAH). In high-energy heavy-ion collisions VAH is applicable already at very early times, and at later times transitions smoothly into conventional second-order viscous hydrodynamics (VH). We present a Bayesian calibration of a multi-stage dynamical evolution model built around a VAH fluid dynamic core with experimental data for p_T-integrated observables from Pb-Pb collisions at the LHC at $\sqrt{s_{\rm NN}} = 2.76$ TeV. We find that the VAH model has the unique capability of constraining the specific viscosities of the QGP at higher temperatures than other previously used models [1]. We also find that the model has fewer tensions with the p_T-integrated input data than the previously calibrated JETSCAPE SIMS model [2]. Finally, we use the calibrated VAH and JETSCAPE SIMS models, with the four different particlization models studied in [2], to predict a number of p_T- *differential* observables, including p_T-spectra and anisotropic flow coefficients $v_{2,3,4}\{2\}(p_T)$ for several identified hadron hadron species. We find [3] that the p_T-dependence of the anisotropic flow coefficients is *very sensitive* to the choice of particlization model, and that the VAH predictions agree with available data much better than all available calibrated variants of the JETSCAPE SIMS model. We therefore propose the VAH approach as a superior framework for describing the dynamical evolution of heavy-ion collisions at LHC energies.

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[1] D. Liyanage et al., arXiv:2302.14184 [nucl-th]
[2] D. Everett et al., PRL 126, 242301 (2021); and PRC 103, 054904 (2021).
[3] C. Gantenberg, research honors thesis, The Ohio State University, April 2023

Category

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Author: HEINZ, Ulrich

Co-authors: GANTENBERG, Cullen (The Ohio State University); Dr LIYANAGE, Dananjaya (The Ohio State University)

Presenter: HEINZ, Ulrich

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