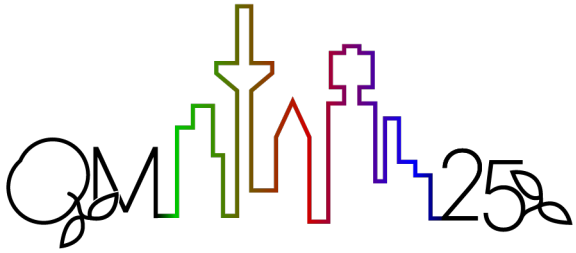

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An end-to-end generative model for heavy-ion collisions

Tuesday 8 April 2025 11:10 (20 minutes)

The multistage approach based on hydrodynamics has achieved remarkably success in modeling heavy-ion physics, providing an accurate description of experimental particle spectra as well as various signatures of collective flow, flow correlations, and fluctuations. However, traditional numerical simulations of hydrodynamics are challenged by recent high-precision measurements: to probe the finer details in the system via statistics-demanding observables, 10ˆ9-10ˆ10 collisions events are commonly required. As heavy-ion collision physics enters a high-precision era, theoretical modeling needs to evolve to meet growing computational demands.

In this work, we introduce DiffHIC, a generative diffusion model designed to bridge this gap. The model simulates ultra-relativistic heavy-ion collisions from end to end, taking initial entropy density profiles as input and producding two-dimensional final particle spectra. By comparing observables derived from particle spectra generated by both traditional numerical simulations and our trained generative model, we demonstrate that DiffHIC not only accurately replicates integrated and differential observables but also effectively captures higher-order fluctuations and correlations. These results indicate that DiffHIC successfully learns the intricate mapping from initial entropy density profiles to final particle spectra, governed by a set of nonlinear hydrodynamic and Boltzmann transport equations. While preserving the fine details of the underlying physical processes, DiffHIC significantly accelerates end-to-end heavy-ion collision simulations. For example, DiffHIC can simulate a single central collision event in just 0.1 seconds on a GeForce GTX 4090 GPU.

The code and trained model are available at https://huggingface.co/Jing-An/DiffHIC/tree/main.

[1]arxiv:2410.13069

Category

Theory

Collaboration (if applicable)

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