Instituto de Física da USP

Report

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Summary

Tasks Status

Task	**Status**	**Link**
Escrever projeto		
$\hookrightarrow$ Definir escopo e objetivos	✓	
$\hookrightarrow$ Esboçar introdução (motivação + observáveis)	✓	Projeto
$\hookrightarrow$ Listar método/dados (toy model, GP, etc.)	○	
$\hookrightarrow$ Montar bibliografia mínima	✓	

Tasks Status

Task	Status	Link
Criar toy model		
↪ Gerar dados sintéticos (correlacionados + ruído)	✓	
↪ Ajustar GP (kernel, hiperparâmetros)	○	
↪ Validar: resíduos, log-likelihood, cobertura	○	
↪ Criar 2–3 plots “de apresentação”	○	

Recent studies

Article	Status	Link
Characterizing the non-equilibrium quark-gluon plasma with photons and hadrons	◑	Thesis
Evidence for a New State of Matter	✓	Link
Bayesian parameter estimation for relativistic heavy-ion collisions	◑	Thesis
Small System Collectivity in Relativistic Hadronic and Nuclear Collisions	✓	Link
Progress and Challenges in Small Systems	✓	Link

Recent studies

Toolbox	Status	Link
2. Gaussian Processes	◑	Lecture Notes

Course	Status	Link
Statistics For Applications	◑	MIT OCW 18.650

Selected Paper

An End-to-End Generative Diffusion Model for Heavy-Ion Collisions

Jing-An Sun[1,2], *Li* Yan[1,3,*], *Charles* Gale[2], and *Sangyong* Jeon[2]

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Abstract. Heavy-ion collision physics has entered the high precision era, demanding theoretical models capable of generating huge statistics to compare with experimental data. However, traditional hybrid models, which combine hydrodynamics and hadronic transport, are computationally intensive, creating a significant bottleneck. In this work, we introduce DiffHIC, an end-to-end generative diffusion model, to emulate ultra-relativistic heavy-ion collisions. The model takes initial entropy density profiles and transport coefficients as input and directly generates two-dimensional final-state particle spectra. Our results demonstrate that DiffHIC achieves a computational speedup of approximately 10^5 against traditional simulations, while accurately reproducing a wide range of physical observables, including integrated and differential anisotropic flow, multi-particle correlations, and momentum fluctuations. This framework provides a powerful and efficient tool for phenomenological studies in the high-precision era of heavy-ion physics.

Figure: Claim of an acceleration of order 10^5 in end-to-end heavy-ion collision model evaluations when replacing the full simulation chain with a generative AI-based surrogate model.

Selected Paper

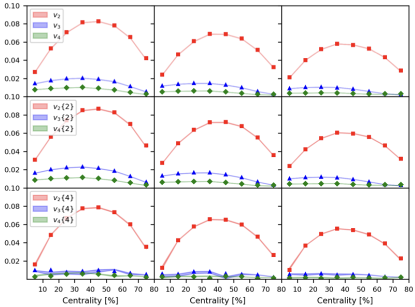

Figure 1. Centrality dependence of integrated anisotropic flow. Filled symbols represent the ground truth from the hybrid model, while colored bands show the results from DiffHIC. The agreement is excellent across different orders (n), cumulants, and shear viscosities.

Selected Paper

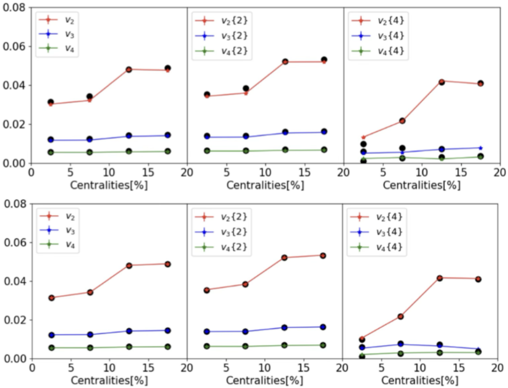

Figure 2. Symbols represent results from a hydrodynamic model, while lines show the output of a Generative AI model. The top row shows the pre-trained model, and the bottom row shows the improved results after fine-tuning with 500 new events.