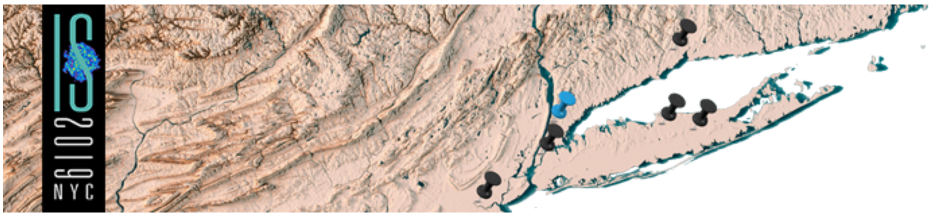

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Hydrodynamic simulations of relativistic nuclear collisions with nucleon substructure: combined analysis of p+Pb and Pb+Pb collision systems at 5.02 TeV

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Simulations of relativistic heavy-ion collisions based on viscous hydrodynamics provide an accurate description of the bulk observables measured at RHIC and LHC beam energies, including identified particle yields, mean p_T and multiparticle correlations. The success of the hydrodynamic framework, however, is naturally expected to break down in the dilute limit where discrete particle degrees of freedom dominate.

It was thus surprising when the multiparticle correlations measured in high-multiplicity proton-lead collisions were found to be similar in magnitude to those observed in lead-lead collisions. The observation suggests that hydrodynamic behavior could be manifest in small droplets of quark-gluon plasma (QGP), and that flow might develop at length scales smaller than a proton.

In this work, we assume the existence of hydrodynamic flow in small collision systems and evaluate the likelihood of our assertion using Bayesian inference. Specifically, we model the dynamics of proton-lead and lead-lead collisions at 5.02 TeV using QGP initial conditions with parametric nucleon substructure, a pre-equilibrium free-streaming stage, event-by-event viscous hydrodynamics with shear and bulk coupling, and a microscopic hadronic afterburner to simulate the dynamics of the collision below the QGP transition temperature.

The model is evaluated on a scaffolding of parameter points, and emulators are trained to interpolate the model predictions at intermediate regions of parameter space. Markov chain Monte Carlo importance sampling is then used to explore the Bayesian posterior probability distribution as a function of the model input parameters.

We use the resulting posterior distribution to sample preferred regions of parameter space and evaluate the performance of the model with optimally chosen parameter values This semi-exhaustive model validation enables us to to comment on the implied viability of hydrodynamics in small collision systems subject to the approximations of the chosen framework. We also present marginalized posterior distributions for each model input parameter, e.g. nucleon substructure degrees of freedom, which demonstrate the constraining power of global statistical analysis and reveal new insight into nuclear matter at extreme temperatures and densities.

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