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Simulating collectivity in dense baryon matter with multiple fluids

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Fluid-dynamical modelling of heavy-ion collisions in the region of RHIC Beam Energy Scan (BES) and FAIR experiments poses notable challenges. Contraction of the incoming nuclei is much weaker, which results in a long inter-penetration phase and a complex initial-state geometry. Conventional hydrodynamic models, where the fluid phase starts at a fixed proper time $\tau 0$, therefore miss the compression stage of the collision. Hence, they miss the key sensitivity to the EoS of the dense medium.
We present a novel multi-fluid approach to simulate heavy-ion collisions in the region of RHIC BES and FAIR. In our approach, we circumvent the issue above by representing the incoming nuclei as two cold, baryon-rich fluids with appropriate energy and baryon densities. The newly produced matter is represented by a third baryon-free fluid, which is generated by the friction between the two colliding fluids. Our MUlti Fluid simulation for Fast IoN collisions (MUFFIN) model is implemented from scratch using a versatile 3+1 dimensional relativistic viscous hydrodynamic code vHLLE. We present benchmark calculations for Au-Au collisions at different RHIC BES energies, discuss the challenges in constructing the approach, and present a study [2] of flow and hyperon polarization observables at RHIC BES energies in MUFFIN. We discuss underlying vorticity development in multi-fluid approach, hyperon - anti-hyperon splitting, and compare our results to the recent data for hyperon polarization from HADES experiment at GSI, and a measurement from fixed-target program at RHIC, in addition to previous measurements within RHIC BES program. We examine directed flow observable at different collision energies, and show its equation-of-state dependence and the effects of final-state hadronic cascade, in a full-fledged dynamical model.

[1] Jakub Cimerman, Iurii Karpenko, Boris Tomášik, and Pasi Huovinen, Phys. Rev. C 107, 044902 (2023)
[2] Iu. Karpenko, J. Cimerman, arXiv:2312.11325

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