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Novel Effects of Rotational Polarization in Relativistic Nuclear Collisions

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In a non-central nucleus-nucleus collision, the colliding system carries large orbital angular momentum, part of which remains within the hot dense matter created by the collision. This angular momentum turns into complex fluid vorticity structures in the bulk fluid, and eventually manifests itself through nontrivial rotational polarization effects. Such quantum phenomena were known in condensed matter physics long ago and have renewed interests in the so-called spintronics research. In the subatomic regime, the STAR Collaboration reported in 2017 the experimental discovery of global hyperon spin polarization in heavy ion collisions. A crucial feature in establishing the interpretation is the predicted beam energy dependence, specifically a strong increase of fluid vorticity (and thus the polarization) when the collision beam energy is decreased from O(100) GeV to O(10) GeV range. Very recently, these measurements have been pushed toward GeV-beam-energy range in the RHIC Beam Energy Scan II as well as HADES experiment, showing an even stronger signal for hyperon global polarization. These results suggest the creation of a highly polarized strong interaction matter with substantial angular momentum transport in low energy collisions, thus offering a unique environment for exploring novel effects of rotational polarization. In this talk, we report a number of studies on this topic, including: (1) quantitative simulations to understand the hyperon production and its (somewhat surprisingly) strong polarization as well as the implications for angular momentum transport in the bulk matter along rapidity; (2) the progress and pressing issues in the development of a viscous hydrodynamic framework for relativistic fluids with finite angular momentum; (3) possible new phase structures under rotation and in particular the emergence of a new rho-superfluid phase due to interplay of isospin density and rotation, which are both available in low energy collisions. References: PRC104(2021)L041902; arXiv:2105.04060; CPC44(2020)111001; Scientific Reports 10(2020)2196; PLB798(2019)134929; Lect. Notes Phys 987(2021)1.

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Primary author: LIAO, Jinfeng

Presenter: LIAO, Jinfeng

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