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Chiral Magnetic Effect and Isobar Collisions

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Gauge fields provide the fundamental interactions in the Standard Model of particle physics. Gauge field configurations with nontrivial topological windings are known to play crucial roles in many important phenomena, from matter-anti-matter asymmetry of today's universe and the permanent quark confinement to topological phases in condensed matter. Their presence is however elusive for direct detection in experiments. It turns out that measurements of the so-called chiral magnetic effect (CME) can be used to access and manifest gauge field topology in quantum chromo matter created by heavy ion collisions. The CME is a nontrivial macroscopic transport phenomena arising from microscopic quantum anomaly of underlying fermions in a chiral material (e.g. a Dirac/Weyl semimetal or a quark-gluon plasma), which has been in the spotlight lately across different disciplines of physics. Potential discovery of CME in heavy ion collisions is of utmost significance, with extensive experimental searches carried out over the past decade. In particular a dedicated experiment of isobar collisions was performed and the first set of blind analysis results were publicly released in late 2021 based an amazingly large data sample of about 2 billion events. Such data have already shown unprecedented precision in CME-motivated correlation measurements, whose interpretation however has so far been complicated by the difference in the bulk matter properties such as multiplicity and elliptic flow between the isobar systems. In this talk, we report our recent efforts to address such pressing issue and discuss our progress in understanding these isobar data. In particular, three aspects will be presented: (1) the event-by-event anomalous-viscous fluid dynamics (EBE-AVFD) as an essential tool for CME modeling and its application for characterizing various observables'responses to CME signals as well as backgrounds; (2) the quantitative description of the multiplicity and flow difference between isobar systems and the sensitivity to their respective nuclear geometry inputs (in particular the neutron skin and shape deformations); (3) the identification of a new baseline of CME observables for the isobar comparison after taking into account the above known bulk differences as well as an attempt to extract/constrain CME signals in isobar collisions. References: PRL125(2020)242301; Nature Reviews Physics 3(2021)55-63; arXiv:2106.10847; PRC104(2021)064906; CPC46(2022)014101.

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Primary author: LIAO, Jinfeng

Presenter: LIAO, Jinfeng

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