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Event-by-Event Fluctuations in Initial Conditions in Relativistic Hydrodynamic Model

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To investigate the physics of the strongly interacting system of quarks and gluons under extreme conditions, heavy-ion collision experiments are performed at Large Hadron Collider (LHC) and Relativistic Heavy Ion Collider (RHIC). One of the major discoveries is that elliptic flow v_2 was comparable with an ideal hydrodynamic prediction and, as a result, that a new paradigm of strongly coupled quark-gluon plasma (QGP) at temperature of a few hundreds MeV was established. Recently, the higher harmonics v_n ($n > 2$) are observed at RHIC and LHC and attract a lot of theoretical and experimental interests. Initial condition with fluctuation from initial nucleon distribution in colliding nuclei is attributed to one of the major origins of the higher harmonics.

To understand detailed mechanism of how the higher harmonics develop, we construct an integrated dynamical framework based on relativistic hydrodynamics [1] and perform massive numerical simulations (10^5 minimum bias events) on an event-by-event basis [2]. In this framework, the Monte-Carlo versions of factorized Kharzeev-Levin-Nardi (fKLN) model (MC-KLN) and Glauber model (MC-Glauber) are employed as the initialization models. After describing hydrodynamic evolution of the matter using fully (3+1) dimensional ideal hydrodynamics, we treat the subsequent dynamics of hadron gas using a hadron cascade model, JAM. Using the obtained momentum distribution of the final hadrons, we finally analyze the harmonics v_n in a way that experimental people perform the flow analysis such as event plane method, multi-particle cumulant method. We compare these results with the conventional theoretically-obtained harmonics with respect to reaction plane or participant plane to investigate the systematic uncertainty in the conventional theoretical results. We found that v_n obtained in this way depends on the flow analysis model, which means the importance of consistent comparison between theoretical results with experimental data. We also calculate v_n as a function of centrality using the MC-KLN and MC-Glauber initialization and found differences of v_2 , v_4 and v_5 between these two models. This indicates the simultaneous analysis of several harmonics would discriminate between the initialization models.

[1] T. Hirano and Y. Nara, "Dynamical modeling of high energy heavy ion collisions," arXiv:1203.4418 [nucl-th].

[2] T. Hirano, P. Huovinen, K. Murase and Y. Nara, in preparation.

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