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Viscous hydrodynamic evolution with non-boost invariant flow for the color glass condensate

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The heavy ion program at LHC opened up a new era in the physics of the quark-gluon plasma (QGP) at higher energies. One of the most unique properties of the hot matter is the near-perfect fluidity, which was first discovered in Au-Au collisions at RHIC [1]. Relativistic hydrodynamic analyses on the momentum anisotropy of transverse collective flow revealed that small viscosity in the QGP is essential when the initial conditions are constructed from the color glass condensate (CGC), the description of saturated gluons in the nuclei before collisions. On the other hand, the dynamics of the longitudinal flow has scarcely been discussed so far due to the numerical difficulties of the non-boost invariant viscous hydrodynamic analyses in relativistic coordinates. Since the CGC itself is considered to be successful in reproducing the observed rapidity distributions and multiplicities at RHIC, it would be indispensable to investigate the longitudinal hydrodynamic evolution for the CGC.

We develop a viscous hydrodynamic model with both shear and bulk viscosity and solve the full second-order constitutive equations [2] in the longitudinal direction with the relativistic coordinates using a novel numerical approach. The estimations are performed with the CGC-type initial distributions for both RHIC and LHC settings. The results exhibit visible and non-trivial deformations of the CGC rapidity distributions during the hydrodynamic stage due to the interplay between two factors: (i) Entropy production from non-equilibrium processes and (ii) entropy flux to the forward rapidity caused by non-boost invariance [3]. We find difference in the hydrodynamic effects at RHIC and LHC, which implies that readjustment of the CGC parameters might be necessary. This would be one of the possible explanations for the fact that the CGC predictions tend to underestimate the multiplicity at mid-rapidity observed in the Pb-Pb collisions at LHC experiments [4]. The results indicate that non-boost invariant hydrodynamic evolution together with viscosity is indispensable for understanding the physics of relativistic heavy ion collisions as a whole. We also obtain several important numerical insights towards a full (3+1)-dimensional viscous hydrodynamic model for the more quantitative analyses.

References:

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