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Early thermal and chemical equilibration of quarks and gluons

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Local equilibration of a QCD medium has been a long-standing issue in hadron physics since the discovery of a nearly-perfect fluid in heavy-ion collisions at RHIC and LHC. The pre-collision state is considered to be described as color glass condensate, which has a relatively large number of high-momentum gluons but almost no quarks. The success of hydrodynamic approaches, on the other hand, indicate that the medium should quickly turn into an equilibrated quark-gluon plasma in less than 1 fm/c.

Equilibration of a heavy-ion system requires (i) isotropization, (ii) thermalization and (iii) chemical equilibration of partons. In this work we focus on the latter two and aim to provide an efficient description for producing low-momentum quarks and gluons by modeling collinear parton splitting and recombination processes. Parton-medium interaction, which is required for creating off-shell partons, is embedded in the model by drag and diffusion effects in relativistic Fokker-Planck equation. We perform numerical simulation in a transverse direction for qualitative analyses to find that the gluon distribution approaches the thermal one in a very short time, and quark thermal/chemical equilibration is slower than the gluon thermalization though it is reasonably fast. The recombination is suggested to be essential in chemical equilibration as quark production from over-populated low-momentum gluons would be suppressed by Pauli exclusion principle. The results imply that the collinear processes play an important role in early thermal and chemical equilibration of the QCD matter produced in high-energy heavy-ion collisions.

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