Effects of parton radiative processes on Quark-Gluon Plasma thermalization

Bin Zhang and Warner A. Wortman, Arkansas State University, bzhang@astate.edu

Abstract

A hot and dense partonic system can be produced in the early stage of a relativistic heavy ion collision. How it equilibrates is important for the extraction of Quark-Gluon Plasma properties. We study the effects of inclusion of the simplest parton number changing processes. They affect not only chemical equilibration but also kinetic equilibration. In particular, thermal and Color Glass Condensate motivated initial conditions are shown to share the same asymptotic evolution toward pressure isotropization when these processes are included.

1. Introduction

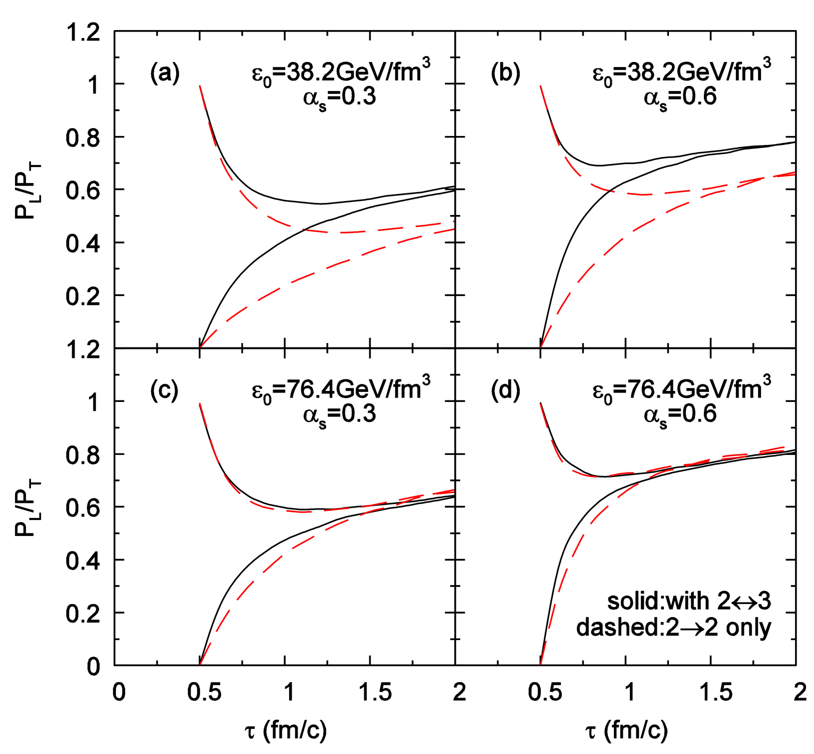
● We will focus on the system of gluons in the central cell in central heavy ion collisions and start with exponential initial momentum distributions characterized by temperature parameters.

● The 2-body collision cross section is taken to be the perturbative QCD cross section regulated by a Debye screening mass. The 2 to 3 cross section is set to be 50% of the 2 to 2 cross section. The 3 to 2 collision rate is determined by detailed balance.

● Kinetic equilibration can be characterized by the longitudinal to transverse pressure ratio, P_L/P_T, which is also called the pressure anisotropy. Different from thermalization in a box, longitudinal expansion tends to decrease the pressure anisotropy. Even when the initial pressure anisotropy equals 1, free streaming can lead to a decrease of the pressure anisotropy toward 0.

2. Pressure isotropization

● In a fixed box, pressure isotropization is determined by the initial anisotropy and the collision rate. When the system undergoes longitudinal expansion, how fast the pressure anisotropy evolves toward 0 depends on the initial pressure anisotropy and the expansion rate. The competition between collision and expansion determines whether pressure isotropization can happen. With dynamical screening, equilibration will eventually take over and lead to pressure isotropization.

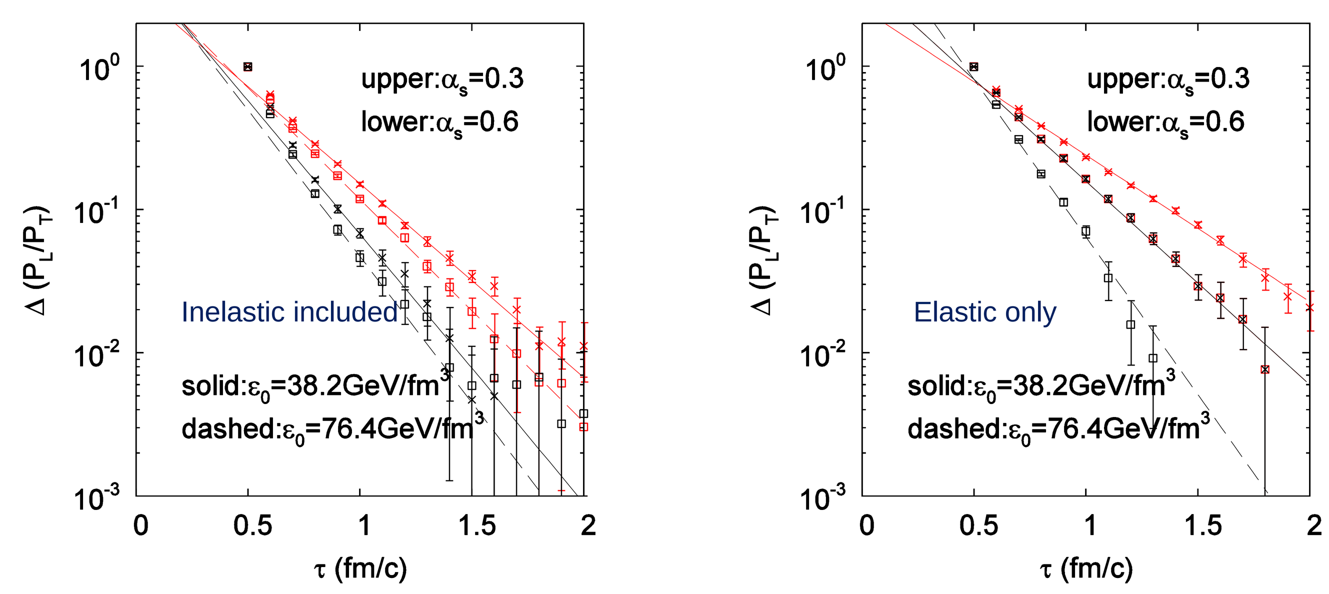


● It is interesting to note that the pressure anisotropy evolution is not sensitive to the initial energy density when radiative processes are included. As the energy density is increased, the screening mass decreases, increasing the cross section and collision rate. However, this is counteracted by the additional particle production. As the system falls below chemical equilibrium, additional particle production tends to increase the screening mass and reduce the collision rate. Lacking this balancing factor, the elastic only case needs to compensate for the increase in pressure anisotropy due to the energy density increase by decreasing the coupling constant.

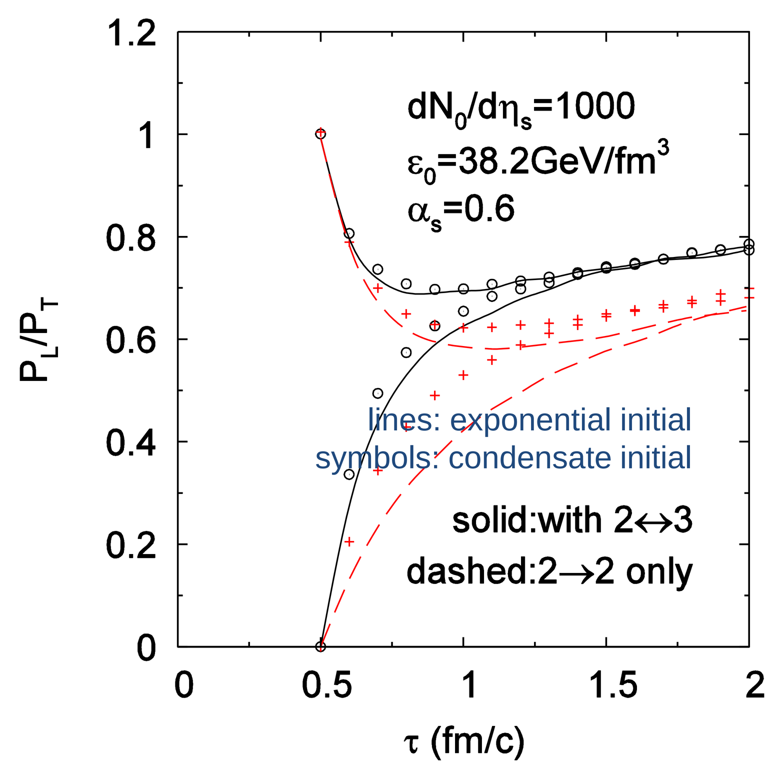
3. Memory effect

● The pressure anisotropy evolution loses memory of the initial pressure anisotropy. This can be studied more carefully by looking at the difference between the evolutions for systems with different initial pressure anisotropies but otherwise identical initial setups.

● After a very short period of time, the pressure anisotropy evolution becomes exponential. When the evolutions are traced back in time, they appear to have come from the same point, even though the point for the radiative case appears to be quite different from the point for the elastic only case.



● The memory of the initial momentum distribution can be studied by comparing results starting from exponential initial momentum distributions and those from step function initial momentum distributions. Radiative processes lead to faster thermalization and almost identical pressure anisotropy evolution.



4. Summary and outlook

● When there is chemical equilibration (radiative processes), kinetic equilibration (pressure anisotropy evolution) depends mainly on the coupling constant. The asymptotic evolution is not sensitive to the initial pressure anisotropy, energy density, or momentum distribution. More realistic studies can be done for the effects of radiative processes on many experimental observables.

This work was supported by the U.S. National Science Foundation under grant Nos. PHY-0554930 and PHY-0970104. We thank the National Energy Research Scientific Computing Center for providing computing resources.