51st International Symposium on Multiparticle Dynamics (ISMD2022)



Contribution ID: 12

Type: Talk

Local thermalization of gluons

Wednesday 3 August 2022 09:50 (25 minutes)

Fast local thermalization of gluons and quarks characterizes the initial stages of relativistic heavy-ion collisions. For a theoretical description, effective weakly-coupled kinetic theories that rely on the quantum Boltzmann equation have been proposed and solved numerically. In the present work, I aim to account for the time evolution during the rapid equilibration of partons through a nonlinear diffusion equation for the occupationnumber distributions in the full momentum range. It is shown that in case of constant transport coefficients, the equation can be solved analytically in closed form through a nonlinear transformation. The occupationnumber distribution is then obtained via the logarithmic derivative of a generalized (time-dependent) partition function.

Although the nonlinear boson diffusion equation (NBDE) for the thermalization of gluons had been proposed in [1], the analytical solution had initially been derived only for the free case. In order to obtain the full Bose-Einstein distribution in the stationary limit, however, one has to consider the IR boundary condition [2] at the singularity $p = \mu$ with the initial chemical potential $\mu_i < 0$ for number-conserving elastic gluon scatterings, and $\mu = 0$ for inelastic scatterings. It is shown that analytical solutions of the NBDE can still be obtained [2].

The model is applied to the equilibration of gluons in heavy-ion collisions at LHC energies, where initial central temperatures of 500 - 600 MeV are reached in the course of local thermalization. Equilibrium is attained through the nonlinear evolution of the distribution functions at short times t < 0.1 fm/c in the infrared, whereas it takes more time in the large-momentum region to approach the Maxwell-Boltzmann tail of the distribution function. Thermalization in the IR occurs much faster through inelastic as compared to elastic gluon scatterings, thus preventing the formation of a gluon condensate via number-conserving elastic collisions. These results are consistent with QCD-based numerical findings in [3].

[1] Wolschin, G.: Equilibration in finite Bose systems. Physica A 499, 1 (2018).

[2] Wolschin, G.: Nonlinear diffusion of gluons. Physica A 597, 127299 (2022) .

[3] Blaizot, J.P., Liao, J., Mehtar-Tani, Y.: The thermalization of soft modes in non-expanding isotropic quark gluon plasmas. Nucl. Phys. A 961, 37 (2017).

Preferred track

High-temperature QCD

Subfield

Heavy-ion theory

Attending in-person?

Yes

On behalf of collaboration?

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Session Classification: High-temperature QCD 1

Track Classification: High-temperature QCD