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Nuclear Physics A 932 (2014) 99–104
NUCLEAR PHYSICS A
www.elsevier.com/locate/nuclphysa

Jet propagation within a Linearized Boltzmann Transport model ☆

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Received 3 April 2014; received in revised form 15 September 2014; accepted 16 September 2014

Available online 24 September 2014

Abstract

A Linearized Boltzmann Transport (LBT) model has been developed for the study of parton propagation inside quark–gluon plasma. Both leading and thermal recoiled partons are tracked in order to include the effect of jet-induced medium excitation. In this talk, we present a study within the LBT model in which we implement the complete set of elastic parton scattering processes. We investigate elastic parton energy loss and their energy and length dependence. We further investigate energy loss and transverse shape of reconstructed jets. Contributions from the recoiled thermal partons and jet-induced medium excitations are found to have significant influences on the jet energy loss and transverse profile.

Keywords: Jet quenching; Jet transport; Parton energy loss; Quark–gluon plasma

1. Introduction

Interaction between energetic jet shower partons and thermal partons in a quark–gluon plasma (QGP) is expected to lead to jet quenching [1] in high-energy heavy-ion collisions. The observed

☆ Talk presented by T. Luo at HP2013.

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http://dx.doi.org/10.1016/j.nuclphysa.2014.09.052
0375-9474/

jet quenching has been considered as one of the most striking phenomena observed in heavy-ion collisions at the Relativistic Heavy-ion Collider (RHIC) [2,3] and at the Large Hadron Collider (LHC) [4,5]. The jet shower partons produced at the very early stage of a heavy-ion collision will suffer both collisional energy loss in the elastic $2 \to 2$ scattering processes and radiative energy loss through induced gluon radiation. Induced gluon radiation has been considered as the dominant source of the parton energy loss for an energetic parton. However, many other studies also pointed out that the energy carried away by the recoiled partons in the binary elastic scattering could not be neglected [6–9] in order to account for the observed pattern of jet quenching in high-energy heavy-ion collisions at RHIC and LHC. The estimate of the elastic energy loss of a quark in the hot dense medium was first made by Bjorken [10], and detailed studies were later carried out within the framework of finite temperature QCD [11]. In addition to the energy transfer through elastic scattering, one should also consider change of flavor for the propagating parton which can only be taken into account systematically in a Monte Carlo transport model. We have therefore implemented the complete set of $2 \to 2$ elastic processes in QCD in the Linearized Boltzmann Transport (LBT) Monte Carlo model.

At the partonic level, jets defined by a jet-finding algorithm are composed by collimated showers of partons inside a jet cone of radius $R = \sqrt{(\phi - \phi_C)^2 + (\eta - \eta_C)^2}$. Previous work [12] within the Linearized Boltzmann Transport model [14] with small angle approximation for all parton elastic scattering processes has shown that inclusion of the recoiled medium partons has a significant influence on the energy loss of reconstructed jets. For a more accurate and complete description, however, one needs to implement the complete set of elastic scattering processes including flavor changing annihilation and creation processes. We present here test simulations of jet propagation and jet-induced medium excitation within a static and homogeneous quark gluon plasma, and their effects on reconstructed jets. We consider only elastic processes here while inclusion of inelastic processes is still in development. A modified version of the anti-k_t algorithm in FASTJET [13] is used to reconstruct the leading jet. The influence on the jet energy loss and jet transverse profile by the recoiled thermal partons will be studied in detail.

2. The model

Simulations of interaction among leading, recoiled and thermal partons in LBT model are based on the Boltzmann transport equation,

$$\begin{aligned} p_1 \cdot \partial f_1(p_1) = -\frac{1}{2} \int \frac{d^3 p_2}{(2\pi)^3 2E_2} \int \frac{d^3 p_3}{(2\pi)^3 2E_3} \int \frac{d^3 p_4}{(2\pi)^3 2E_4} \\ \times (f_1 f_2 - f_3 f_4) |M_{12\to 34}|^2 S_2(s,t,u) \\ \times (2\pi)^4 \delta^4(p_1 + p_2 - p_3 - p_4), \end{aligned} \quad (1)$$

for partonic processes $1 + 2 \to 3 + 4$, where the matrix elements $|M_{12\to 34}|^2$ are given by pQCD in terms of standard Mandelstam variables. As a jet shower parton 1 traverses the QGP, it can scatter with parton 2 (light quark, antiquark or gluon) sampled from the medium. The parton phase-space distributions in a thermal medium with local temperature T and the fluid velocity $u = (1, \vec{v})/\sqrt{1 - \vec{v}^2}$ are denoted as $f_{i=2,4}(p_i)$, which are Bose–Einstein distributions for gluons and Fermi–Dirac distributions for quarks and antiquarks. The phase-space densities for the jet shower partons before and after scattering assume the form of a point-like particle $f_i = (2\pi)^3 \delta^3(\vec{p} - \vec{p}_i) \delta^3(\vec{x} - \vec{x}_i - \vec{v}_i t)$ $(i = 1, 3)$ and we neglect Bose enhancement and Pauli