Evolution of Parton Fragmentation Functions at Finite Temperature *

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Parton production in hard processes is normally followed by final-state radiation and subsequent hadronization, giving rise to collimated jets of hadrons as observed in experiments. The hadron distributions inside a jet known as jet fragmentation functions can be defined as the vacuum expectation values of the parton fields and the hadronic interpolating fields. Though these fragmentation functions are non-perturbative and currently can only be measured experimentally, their evolution with the probing scale can be calculated within perturbative QCD. The resultant Dokshitzer-Gribov-Lipatov-Altarelli-Parisi (DGLAP) evolution equations have been stringently tested against experiments and now can even be used to measure the scale-dependence of the running strong coupling constant. If the hard parton is produced amid a thermal QCD medium, as most likely occurs in high-energy heavy-ion collisions, the subsequent final-state radiation and parton cascade must be modified by the presence of the medium. One not only has to consider parton emission but also parton absorption in describing the evolution of the fragmentation functions. Such a medium effect is closely related to the radiative parton energy loss, which also leads to modified fragmentation functions. In most of the studies of parton energy loss, one relies on a Debye-screened potential model for parton-medium interaction. One then has to introduce additional parameters such as the mean free path, which is ill-defined when the magnetic part of the one-gluon exchange interaction is included. One can replace the mean free path by a transport parameter and eliminate the infrared problem by using a hard-thermal-loop (HTL) resummed gluon propagator. However, it is still theoretically interesting to study the problem within the framework of field theory at finite temperature.

This paper is our first attempt to study medium-modified fragmentation functions within QCD field theory at finite temperature. We will first extend the definition of the fragmentation functions to include the scenario of parton propagation inside a thermal bath. We will calculate the first order corrections to the parton fragmentation functions in a thermal medium in the leading logarithmic approximation and derive the corresponding modified evolution equations. We will find that the modified evolution equation can be cast into a similar form as the DGLAP equations in the vacuum. However, the modified splitting functions depend explicitly on the temperature and the partons' initial energy. We will study the structure of different contributions and their physical interpretations. We will demonstrate that all infrared (both linear and logarithmic) divergences in radiative corrections cancel either among themselves or with the virtual corrections. We will also study the evolution of the net quark number and energy loss (or gain).

As shown in previous studies, the most important contribution to parton energy loss and modification of fragmentation functions comes from scattering induced bremsstralung. In the current study, we only consider the first order corrections to the fragmentation process in the leading logarithmic approximation. At this order, we can only consider parton emission and absorption. By solving the evolution equations, one can effectively resum radiative corrections (all ladder diagrams) associated with the leading parton. To include the scattering induced bremsstrahlung and the Landau-Pomeranchuck-Migdal (LPM) interference effect, one has to include the spectral function of the HTL resummed gluon propagator and go beyond the first order correction. Similar calculations have been performed for photon and gluon emission in the quark-gluon plasma. Calculation of modified fragmentation functions has yet to be performed. The work reported in this paper will provide a framework for such a study in the future.

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