Jet Tomography of Hot and Cold Nuclear Matter *

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Energetic partons produced via hard processes provide an excellent tool that enables tomographic studies of both hot dense and cold nuclear matter. By measuring the attenuation of these partons as they propagate through the medium, one would be able to study the properties such as the geometry and the gluon density of the medium. The attenuation will suppress the final leading hadron distribution giving rise to modified parton fragmentation functions. Such a modified fragmentation function inside a nucleus has been derived recently in a pQCD approach with a systematic expansion of higher-twist corrections to the fragmentation processes. In this letter, we will compare the predicted nuclear modification to the recent HERMES experimental data and extract the effective parton energy loss. We will further extend the study to the case of a hot QCD medium including the dynamics of expansion. We will then analyze within this framework the π^0 spectra as measured by the PHENIX experiment in central $Au+Au$ collisions at $\sqrt{s} = 130$ GeV, which have shown significant suppression at large transverse momentum. The extracted effective parton energy loss will be compared with that in a cold nucleus, and discussions will be given about the implications of the PHENIX data on the gluon density in the early stage of central $Au+Au$ collisions at the RHIC energy. We will also provide predictions for π^0 spectra in central $Au+Au$ collisions at $\sqrt{s} = 200$ GeV.

To extract the parton energy loss, we compare the data with the calculated hadron p_T spectra in heavy-ion collisions using the above effective model for medium modified jet fragmentation functions. Parton shadowing and nuclear broadening of the intrinsic k_T are also taken into account in the calculation which decrsibes pA data for energies up to $\sqrt{s} = 40$ GeV [**?**]. The nuclear k_T-broadening gives the so-called Cronin enhancement at large p_T in pA collisions, where there is no parton energy loss induced by a hot medium. Fitting the PHENIX data yields $\langle dE/dL \rangle_{1d} \approx 0.34 \ln E/\ln 5$ GeV/fm, including the factor of 1.6 from the unitarity correction effect. We consider only π^0 data here, since at large p_T the charged hadrons are dominated by baryons, which could be influenced mainly by non-perturbative dynamics.

Taking into account the expansion, the averaged parton energy loss extracted from the PHENIX data would be equivalent to $(dE/dL)_0 = 0.34(R_A/2\tau_0)\ln E/\ln 5$ in a static system with the same gluon density as the initial value of the expanding system at τ_0. With $R_A \sim 6$ fm and $\tau_0 \sim 0.2$ fm, this would give $(dE/dL)_0 \approx 7.3$ GeV/fm for a 10-GeV parton, which is about 15 times of that in a cold Au nucleus as extracted from the HERMES data. Since the parton energy loss is directly proportional to gluon density of the medium, this implies that the gluon density in the initial stage of $Au+Au$ collisions at $\tau_0 = 0.2$ fm/c is about 15 times higher than that inside a cold nucleus. we can predict the π^0 spectra at $\sqrt{s} = 200$ GeV as given by the dashed lines in Fig. **??**, assuming that the initial parton density in central $Au+Au$ collisions at $\sqrt{s} = 200$ GeV is about 10% higher than at 130 GeV.

The nuclear modification of parton fragmentation function predicted in a pQCD study describes well the HERMES experimental data. The extracted energy loss is $dE/dL \approx 0.5$ GeV/fm for a quark with $E = 10$ GeV in a Au nucleus. Analysis of the PHENIX data of π^0 spectra suppression in central $Au+Au$ collisions yields an averaged parton energy loss in an expanding system that would be equivalent to $(dE/dL)_0 \approx 7.3$ GeV/fm in a static medium. This would imply that the initial gluon density at $\tau_0 = 0.2$ fm/c is about 15 times higher than that in a cold Au nucleus.

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