JET QUENCHING AND RADIATIVE ENERGY LOSS IN DENSE NUCLEAR MATTER *

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In this report we reviewed two recent approaches to the problem of non-Abelian radiative energy energy loss in dense but finite QCD matter. In the first section, we highlighted some of the striking new high p_T phenomena observed for the first time in $A+A$ reactions at RHIC with $\sqrt{s} > 100$ AGeV. An interesting pattern of hadron suppression, already beginning at moderate $p_T > 3$ GeV, was seen in the hadron flavor dependence of single inclusive spectra, in the large azimuthal asymmetry, and in the preliminary two-hadron correlations. We interpret these phenomena as manifestations of jet quenching in ultra-dense matter produced in such reactions. Our predictions for these phenomena in both approaches are reviewed in later sections and depend on the energy loss, $\Delta E = \int dx\, dE/dx$, of fast quarks and gluons propagating through rapidly expanding QCD matter. The two approaches, GLV and WW/WOGZ reviewed here, provide a systematic way to compute ΔE via an opacity or higher twist expansion in finite nuclear matter. The phenomenological applications of the asymptotic expressions tend to overpredict quenching at RHIC and lead to a too rapid variation of the suppression factor with p_T, inconsistent with the RHIC data. In our approach, on the other hand, the opacity series is computed to arbitrary order in opacity for applications to finite opacity systems where the non-Gaussian (Rutherford) tails of distributions are not yet eclipsed by the approximate Gaussian small p_T component. In addition, our expressions can be applied to arbitrary 3D expanding and time dependent media such as created in nuclear collisions.

Several recent works were combined (referred to as the WOGZ approach to elaborate on a general twist-expansion of multiple parton scattering beyond the GW model of the medium. In that approach one can calculate explicitly the modified parton fragmentation function up to twist 4 thus far. The LPM interference effect is then embedded in the twist-four parton matrix elements of the nucleus which also contains the fundamental properties of the nuclear medium – parton density correlations inside a nucleus. These matrix elements replace the Debye screened interactions used in the GLV approach. One can demonstrate explicitly that the quadratic dependence of the modification of fragmentation functions and the effective parton energy loss on the nuclear size R_A is caused both by the LPM interference and the specific form of gluon radiation spectra in QCD. The predicted nuclear modification of the fragmentation function, both the energy and nuclear dependence, is found to agree well with the recent experimental data on jet fragmentation in $e+A$. This is an important test of both the twist or opacity expansions since it shows the dominance of the twist 4 (first order in opacity) contribution to the energy loss in finite nuclear systems as found numerically in the GLV expansion up to twist 8. Extending the results to a parton propagating in a hot QCD medium, we have shown that the twist expansion to order 4 is equivalent to the first order opacity GLV result under certain simplifying assumptions about the form of the twist 4 matrix elements. The phenomenological application of WOGZ to both DIS on cold nuclear targets and high-energy heavy-ion collisions suggests that the parton energy loss in an expanding system at RHIC would be equivalent to $(dE/dx)_0 \approx 7.3$ GeV/fm in a static medium, which is almost 15 times higher than that in a cold Au nucleus.

If the jet quenching pattern is confirmed by further measurements and theoretical refinements, current RHIC data may have already provided the first tomographic evidence that initial parton densities on the order of 100 times nuclear matter density were achieved in $Au+Au$ collisions. The full analysis of the flavor composition, shape, and azimuthal moments of the high p_T spectra appears to be a promising diagnostic probe of the evolution of the produced quark-gluon plasma.

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