The non-Abelian feature of parton energy loss in energy dependence of jet quenching in high-energy heavy-ion collisions[1]

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The radiative parton energy loss incoporated in previous studies within a leading order (LO) perturbative QCD (pQCD) model has two basic non-Abelian features. One of them is the quadratic dependence on the total distance traversed by the propagating parton due to the non-Abelian Landau-Pomeranchuk-Midal (LPM) interference effect in gluon bremsstrahlung induced by mulitple scatterings in a *static* medium. The second feature of the parton energy loss is its dependence on the color representation of the propagating parton. Therefore, energy loss for a gluon is 9/4 times larger than a quark. Previous works have investigated the consequences of the second non-Abelian feature in the flavor dependence of the high-p_T hadron suppression. In this paper we study the effect of the non-Abelian parton energy loss on the energy dependence of the inclusive hadron spectra suppression. We exploit the well-known feature of the initial parton distributions in nucleons (or nuclei) that quarks dominate at large fractional momentum (x) while gluons dominate at small x. Jet or large p_T hadron production as a result of hard scatterings of initial partons will be dominated by quarks at large $x_T = 2p_T/\sqrt{s}$ and by gluons at small x_T. Since gluons lose 9/4 times as more energy as quarks, the energy dependence of the large (and fixed) p_T hadron spectra suppression due to parton energy loss should reflect the transition from quark-dominated jet production at low energy to gluon-dominated jet production at high energy. Such a unique energy dependence of the high-p_T hadron suppression can be tested by combining $\sqrt{s} = 200$ AGeV data with lower energy data or future data from LHC experiments.

We study in this paper [1] within a LO pQCD parton model incorporating the non-Abelian QCD parton energy loss in high-energy heavy-ion collisions. We will study the energy dependence of the high-p_T hadron suppression and compare the effect of QCD energy loss with that of a non-QCD one where gluons and quarks are chosen to have the same amount of energy loss. In both cases, we will assume that parton energy loss is proportional to the initial gluon density of the system which in turn is assumed to be proportional to the measured total charge hadron multiplicity in the central rapidity region.

In order to demonstrate the colliding energy dependence of the nuclear modification factor and illustrate the difference between QCD and non-QCD energy loss, we compute the R_{AA} for neutral pions at fixed $p_T = 6$ GeV in Au+Au collisions as a function of $\sqrt{s}$ from 20 AGeV to 5500 AGeV. Shown in Fig. 1 are the calculated results with both the QCD energy loss and a non-QCD case where the energy loss is set to be identical for quarks and gluons. Two parameters ϵ_0 and λ_0 which are relevant to the energy loss are determined according to the gluon number or the charged particle multiplicity per rapidity. One can see that due to the dominant gluon bremstrahlung or gluon energy loss at high energy the R_{AA} for the QCD case is more suppressed than the non-QCD case where the gluon energy loss is assumed to take an equal role as the quark one. In the calculation, we have assumed that the lifetime of the dense matter is equal or longer than the parton propagation time which is essentially determined by the system size. This might not be the case for heavy-ion collisions at lower energies, in particular at around $\sqrt{s} = 20$ AGeV. If one takes short lifetime, the suppression factor R_{AA} is much larger than 1 due to strong Cronin effect. The dashed box around $\sqrt{s} = 20$ AGeV in the Fig. 3 assumes a lifetime $\tau_f = 0-2$ fm/c and thus provides an estimate of the uncerntaintty due to lifetime of the dense matter. Since finite lifetime reduce the effect of full parton energy loss, the difference between QCD and non-QCD energy loss effect in R_{AA} should be smaller. The difference in Fig. 1 is therefore the upper limit.

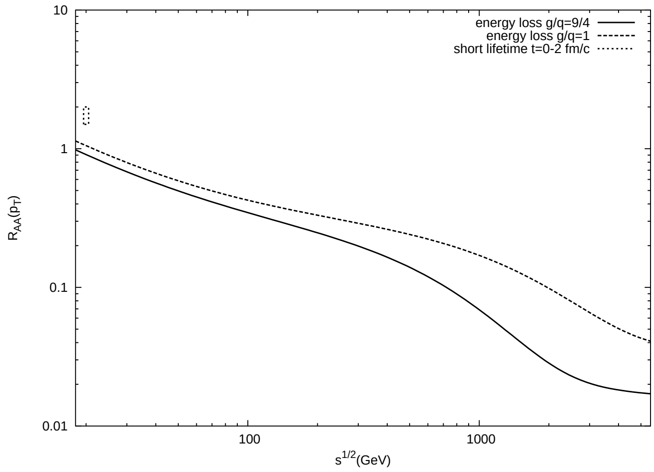

FIG. 1: Nuclear modification factor R_{AuAu} for neutral pions as function of collision energy at fixed $p_T = 6$ GeV in most central collisions (with centrality 10%). Here we compare the QCD energy loss and a non-QCD one where the energy loss is identical for quarks and gluons.

[1] Q. Wang and X.-n. Wang, Phys. Rev. **C71**, 014903 (2005), nucl-th/0410049.