Is $\hat{q}$ a physical quantity or just a parameter? and other unanswered questions in High-p_T Physics

Michael J. Tannenbaum[1]

[1] *Physics Department, Brookhaven National Laboratory, Upton, NY 11973-5000, USA*

Contact email: *mjt@bnl.gov*

The many different theoretical studies of energy loss of a quark or gluon with their color charges fully exposed passing through a medium with a large density of similarly exposed color charges (i.e. a QGP), have one thing in common: the transport coefficient of a gluon in the medium, denoted $\hat{q}$, which is defined from the mean 4-momentum transfer^2/collision but is expressed as the mean 4-momentum transfer^2 per mean free path of a gluon in the medium. Thus the mean 4-momentum transfer^2 for a gluon traversing length L in the medium is, $\langle q^2(L)\rangle = \hat{q}\,L = \mu^2\,L/\lambda_{\rm mfp}$, where $\lambda_{\rm mfp}$ is the mean free path for a gluon interaction in the medium, and μ, the mean momentum transfer per collision, is the Debye screening mass acquired by gluons in the medium. In this, the original BDMPSZ formalism, the energy loss of an outgoing parton due to coherent gluon bremsstrahlung per unit length (x) of the medium, $-dE/dx$, takes the form:

$$\frac{-dE}{dx} \simeq \alpha_s \left\langle q^2(L)\right\rangle = \alpha_s\,\hat{q}\,L = \alpha_s\,\mu^2\,L/\lambda_{\rm mfp} \qquad , \tag{1}$$

so that the total energy loss in the medium goes like L^2. Also the accumulated transverse momentum^2, $\langle k_\perp^2\rangle$, for a gluon traversing a length L in the medium is well approximated by $\langle k_\perp^2\rangle \approx \langle q^2(L)\rangle = \hat{q}\,L$.

A simple estimate shows that the $\langle k_\perp^2\rangle \approx \hat{q}\,L$ should be observable at RHIC via the broadening of di-hadron azimuthal correlations. For a trigger particle with p_{T_t}, assume that the away-parton traverses slightly more than half the diameter of the QGP for central collisions of Au+Au, say 8 fm. This corresponds to $\langle k_\perp^2\rangle = \hat{q}\,L = 8$ GeV^2, for $\hat{q} = 1$ GeV^2/fm, compared to the measured $\langle k_T^2\rangle = 8.0 \pm 0.2$ (GeV/c)^2 for di-hadrons in $p-p$ collisions at $\sqrt{s_{_{NN}}}$ =200 GeV, which should be visible as an azimuthal width $\sim\sqrt{2}$ larger in Au+Au than in $p-p$ collisions . Measurements relevant to this issue will be discussed including recent STAR jet results presented at QM2014.

Other topics to be discussed include the danger of using forward energy to define centrality in $p(d)$+A collisions for high p_T measurements, the danger of not using comparison $p-p$ data at the same $\sqrt{s}$ in the same detector for R_{AA} or lately for R_{pA} measurements. Also, based on a comment at last year's 9th workshop that the parton energy loss is proportional to $dN_{\rm ch}/d\eta$, results on the depencence of the shift in the p_T spectra in A+A collisions from the T_{AA}-scaled $p-p$ spectrum (to be presented in detail in another talk) will be further discussed.