# Centrality dependence of jet-quenching at RHIC

Somnath De* and Dinesh K. Srivastava
*Variable Energy Cyclotron Centre, 1/AF Bidhan Nagar, Kolkata - 700064, India*

## Introduction

The phenomenon of *jet-quenching* is defined as the suppression of the transverse momentum spectra of high momentum particles emitted in the collisions of heavy nuclei compared to NN collisions at the same center of mass energy. This arises due to the energy loss suffered by fast partons as they traverse the quark gluon plasma (QGP). A quantative measure we get, through the nuclear modification factor $R_{AA}$, given by:

$$R_{\rm AA}(p_T, b) = \frac{d^2N_{\rm AA}(b)/dp_Tdy}{T_{\rm AA}(b)(d^2\sigma_{\rm NN}/dp_Tdy)} \ , \quad (1)$$

where $T_{AA}(b)$ is the nuclear overlap function for the collisions having impact parameter b. We have carried out a systematic study of parton energy loss by analyzing the nuclear modification of neutral pion production for Au+Au collisions at $\sqrt{s_{\rm NN}}$=200 GeV for six different centralities [1]. The partons produced after initial hard scattering are subjected to multiple collisions over an average path length $\langle L \rangle$, lose energy by radiating gluons and finally fragment into hadrons outside the medium. The effect of muliple scatterings and energy loss are included by modifying the fragmentation function. The average path length $\langle L \rangle$ is calculated in a Glauber model approach [1]. The nuclear shadowing is also taken into account.

We follow the formalism of Baier et. al. [2] where the energy loss per collision ($\varepsilon$) depends on the gluon formation time ($\approx \omega/k_T^2$) is less than mean free path ($\lambda$) (Bethe-Heitler regime), greater than mean free path but less than path length L (LPM regime) and greater than path length L (Complete Coherence regime). Here $\omega$ is the energy of the radiated gluon and $k_T$ is the transverse momentum. Thus energy loss per unit length in the BH regime becomes:

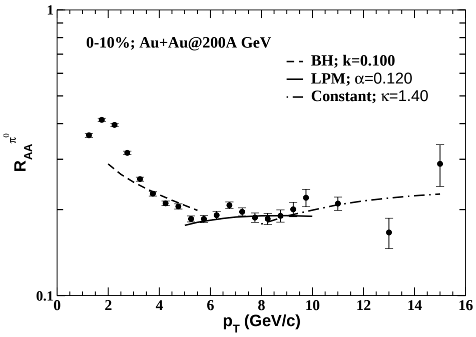


FIG. 1: Nuclear modification of neutral pion production [3] for Au-Au collisions at 200 AGeV for 0–10% centrality for the three energy loss schemes.

$$-\frac{dE}{dx} \approx \frac{\alpha_s}{\pi} N_c \frac{1}{\lambda} E \ , \quad (2)$$

where $N_c$=3 and E is the energy of the parton. We write this as, $\varepsilon$=kE.

For LPM regime of coherent energy loss, $\varepsilon$ is found proportional to $\sqrt{E}$

$$-\frac{dE}{dx} \approx \frac{\alpha_s}{\pi} \frac{N_c}{\lambda} \sqrt{\lambda k_T^2 E} \ , \quad (3)$$

we write $\varepsilon = \sqrt{\alpha E}$. Finally for the complete coherence regime, the energy loss per collision is constant($\kappa$), independent of parton energy.

$$-\frac{dE}{dx} \approx \frac{\alpha_s}{\pi} N_c \frac{\langle k_T^2 \rangle}{\lambda} L \ . \quad (4)$$

A more rigorous calculation leads to:

$$-\frac{dE}{dx} \approx \frac{\alpha_s}{4} N_c \widehat{q} L \ , \quad (5)$$

where $\widehat{q}$ is the average momentum transport coefficient for a given centrality of collision.

*Electronic address: somnathde@vecc.gov.in

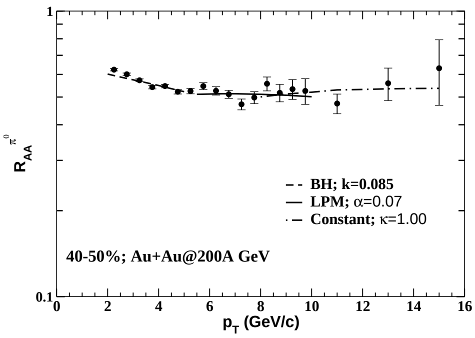


FIG. 2: Same as Fig. 1, for 40–50% centrality.

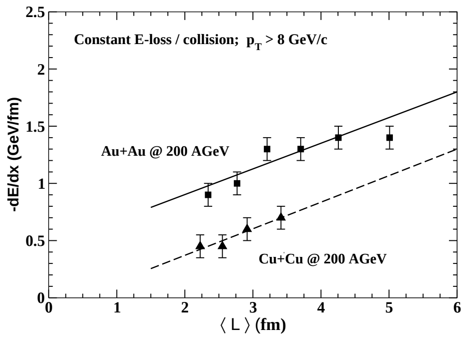


FIG. 3: Path length dependence of dE/dx at RHIC

## Results

In Fig. 1 and 2, we have shown the results for nuclear modification factor ($R_{AA}$) of neutral pions for Au+Au collisions at 200 AGeV for the most central (0-10%) and peripheral (40-50%) events using the three energy loss mechanisms discussed above. We tuned the values of energy loss per collision $\varepsilon$ to get an accurate description for $R_{AA}$. The BH mechanism is seen to describe the data for $p_T$ upto 5–6 GeV/$c$ and the k value decreases by 15% from most central to peripheral collisions, which is obvious. A change of slope of $R_{AA}$ near $p_T$ equal to 5 GeV/$c$, indicates a possible change in the energy loss mechanisms of partons. The fact is confirmed when the LPM mechanism is seen to give a good description of $R_{AA}$ in the $p_T$ range 6–10 GeV/$c$. Finally, for $p_T \geq 8$ GeV/$c$, the constant energy loss per collision works well and the $\kappa$ value drops down by 0.4 GeV from most central to mid central collisions. So we note, depending on gluon formation time (or energy), there are three distinct mechanisms of energy loss which are applicable to different $p_T$ window. A similar result is found for the collisions of copper nuclei at the same center of mass energy [1].

The energy loss of per unit length (dE/dx) for the partons of $p_T \geq 8$ GeV/$c$ can be obtained from the constant energy loss per collision ($\varepsilon = \kappa$) regime, -dE/dx=$\varepsilon/\lambda$. We take $\lambda$=1 fm. The variation of -dE/dx with $\langle L\rangle$ is given in Fig. 3 and it is seen to be linear for both Au-Au and Cu-Cu collisions. This empirical result confirms the prediction of Baier et. al. that the total energy loss $\Delta E$ is proportional to $\langle L\rangle^2$. We also see that the slopes for Au+Au and Cu+Cu collisions are quite similar, though the total energy loss $\Delta E$ is about two times higher for Au+Au system for a given $\langle L\rangle$. The average momentum transport coefficient $\widehat{q}$ for each centrality is calculated from Eq. 5. The $\widehat{q}$ for most central (0-10%) Au+Au collisions is found to be 0.25 GeV$^2$/fm and 0.32 GeV$^2$/fm for mid-central (40-50%) collisions. The decrease in value of $\widehat{q}$ reflects that the LPM suppression of gluon radiation will be less for central collision events, chiefly because of higher density and temperature at these events.

In conclusion, we have obtained a good description of nuclear modification of neutral pion production for Au+Au collisions at 200A GeV at various centralities using a simple model of parton energy loss. The energy loss per collision $\varepsilon$ varies systematically with centrality and dE/dx is found proportional to $\langle L\rangle$ for the partons in the region of $p_T \geq 8$ GeV/$c$.

## References

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