Enhanced Jet Quenching in Strongly Interacting Quark Gluon Plasma

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Abstract

We investigate the possibility of enhanced jet quenching in the vicinity of the critical temperature similar to the scenario proposed by Liao and Shuryak [1]. We discuss the consequences of the fact that the "shells" of such enhanced, critical quenching grow thinner as a function of the center-of-mass energy $\sqrt{S}$ of the collision.

A systematic scan of jet quenching as a function of $\sqrt{S}$ can put constraints on such critical enhancement scenarios. Lastly, we compare results from a numerical calculation using critical enhancement against high transverse momentum data from RHIC and LHC.

Introduction

Collisions of nuclei at RHIC and LHC produce a very hot and dense fireball with temperatures large enough to form a deconfined quark gluon plasma (QGP). From inside this fireball, jets and hadrons at high transverse momentum P_T emerge . They come from hard processes involving quarks and gluons. These high-P_T partons interact with the QGP. The resultant energy loss can be observed in the suppression of observed hadron spectra at high P_T. One way to quantify this suppression is by using the **nuclear modification factor** R_{AA}:

$$R_{AA}(P_T, b) = \frac{d^2N^{AA}/dP_T d\eta}{T_{AA}\cdot d^2N^{NN}/dP_T d\eta} \quad (1)$$

A second observable that plays an important role in the quantification of the QGP and gives us a look at the original geometry is the **azimuthal anisotropy** v_2. It is defined as the second Fourier coefficient of the yield distribution $d^2N^{AA}/dP_T d\phi$ in azimuthal angle ϕ with respect of the reaction plane:

$$v_2(P_T, b) \equiv \frac{\int_0^{2\pi} d\phi\, \cos(2\phi)\left[d^2N^{AA}/dP_T d\phi\right]}{\int_0^{2\pi} d\phi\left[d^2N^{AA}/dP_T d\phi\right]} \quad (2)$$

Liao and Shuryak Model of Energy Loss

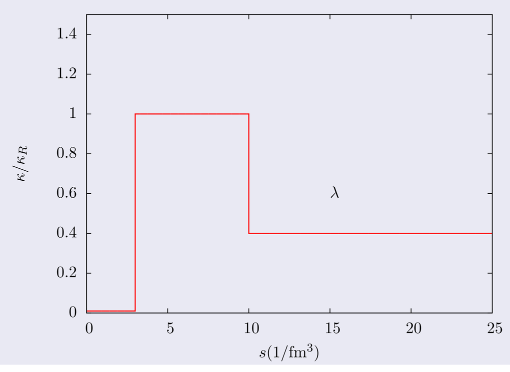
L&S proposed [1] that **quenching is a non monotonic function of matter density**. They also suggested the following quenching function $\kappa(s)$ with two parameters: one in the near-T_c region and the other for the QGP phase:

$$\kappa(s) = \kappa_R \times w(s) \quad (3)$$

where the profile function $w(s)$ is defined as:

$$w(s) \equiv \theta(s - s_1^c)\cdot\theta(s_2^c - s) + \lambda\cdot\theta(s - s_2^c) \quad (4)$$

with $s_1^c = 3/\mathrm{fm}^3$ and $s_2^c = 11/\mathrm{fm}^3$ bracketing the near-T_c region. The parameter κ_R is globally fitted from $R_{AA}(N_{part})$ (for a given λ), while λ characterizes a suppression of the quenching above T_c-region and the QGP with its best value to be determined from a global fitting for $v_2(N_{part})$. The value found by L&S for λ is 0.4.



Enhanced Jet Quenching

We use the profile function (4) to define the energy loss of a parton inside the fireball:

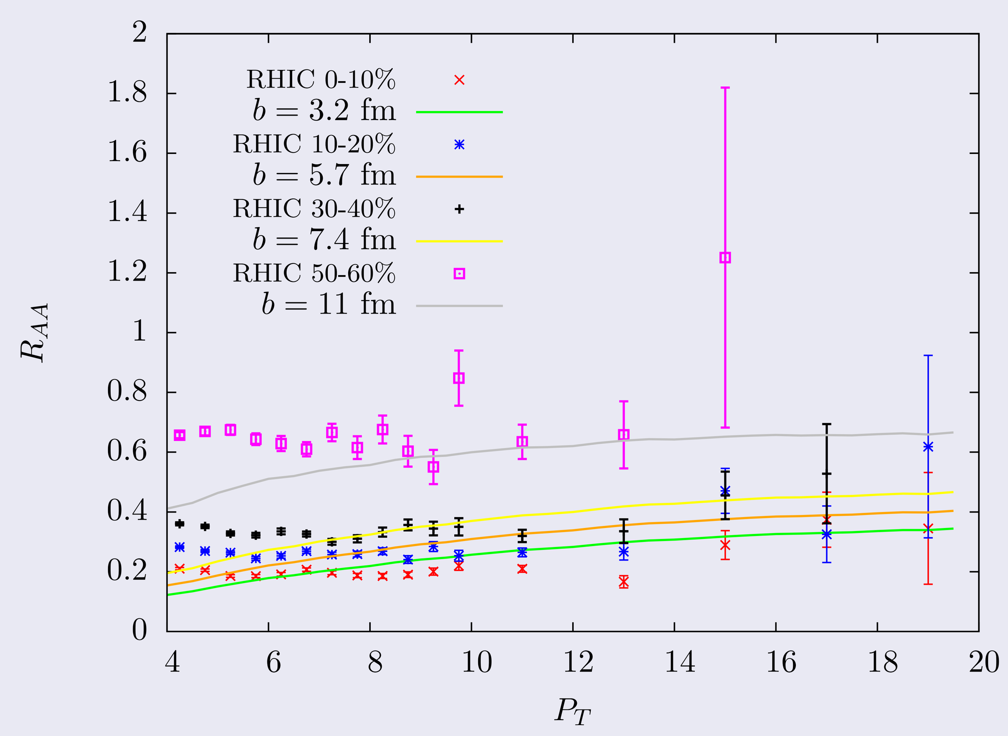
$$\Delta E = k\int dl\,(l - l_0)w(s)s \quad (5)$$

where l is the distance along the path, $l_0 = 0.15\,\mathrm{fm}$ and $s(l)$ is the local entropy density. Observe here that the extra l corresponds to the LPM effect. Once λ has been chosen, the parameter k is fitted to experimental neutral pion R_{AA} data from four centralities: $0-10\%$, $20-30\%$, $30-40\%$ and $50-60\%$ at RHIC energies [2].
k represents the quenching strength per entropy density.

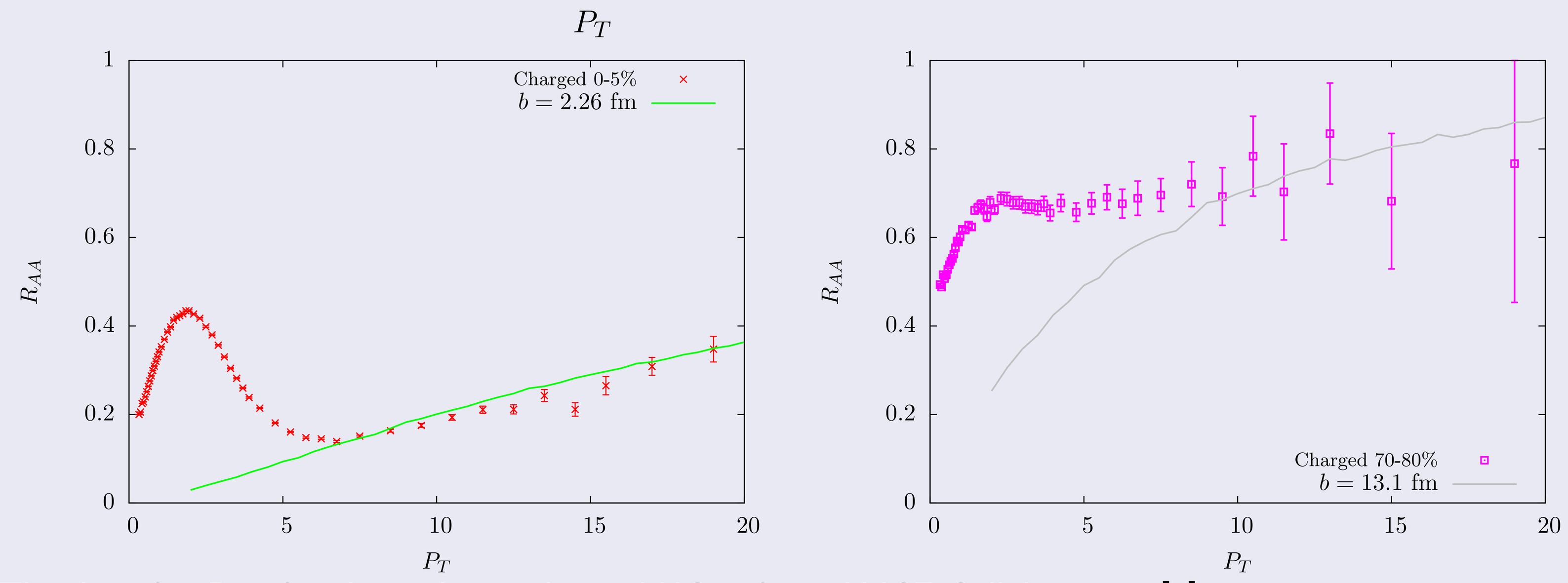
Numerical Study

For the initial condition of the fireball we use Monte Carlo Glauber profiles of the N_{part} density produced in *AuAu* and *PbPb* collisions. For the parton production points we use N_{bin} density profiles. Both profiles are produced by GLISSANDO [3]. We also implement a 1-D Bjorken expansion. We feed the input files into PPM [4], that follows samples of hard partons on eikonal trajectories through the background fireball. PPM then, calculates the nuclear modification factor and the azimuthal anisotropy.

Results



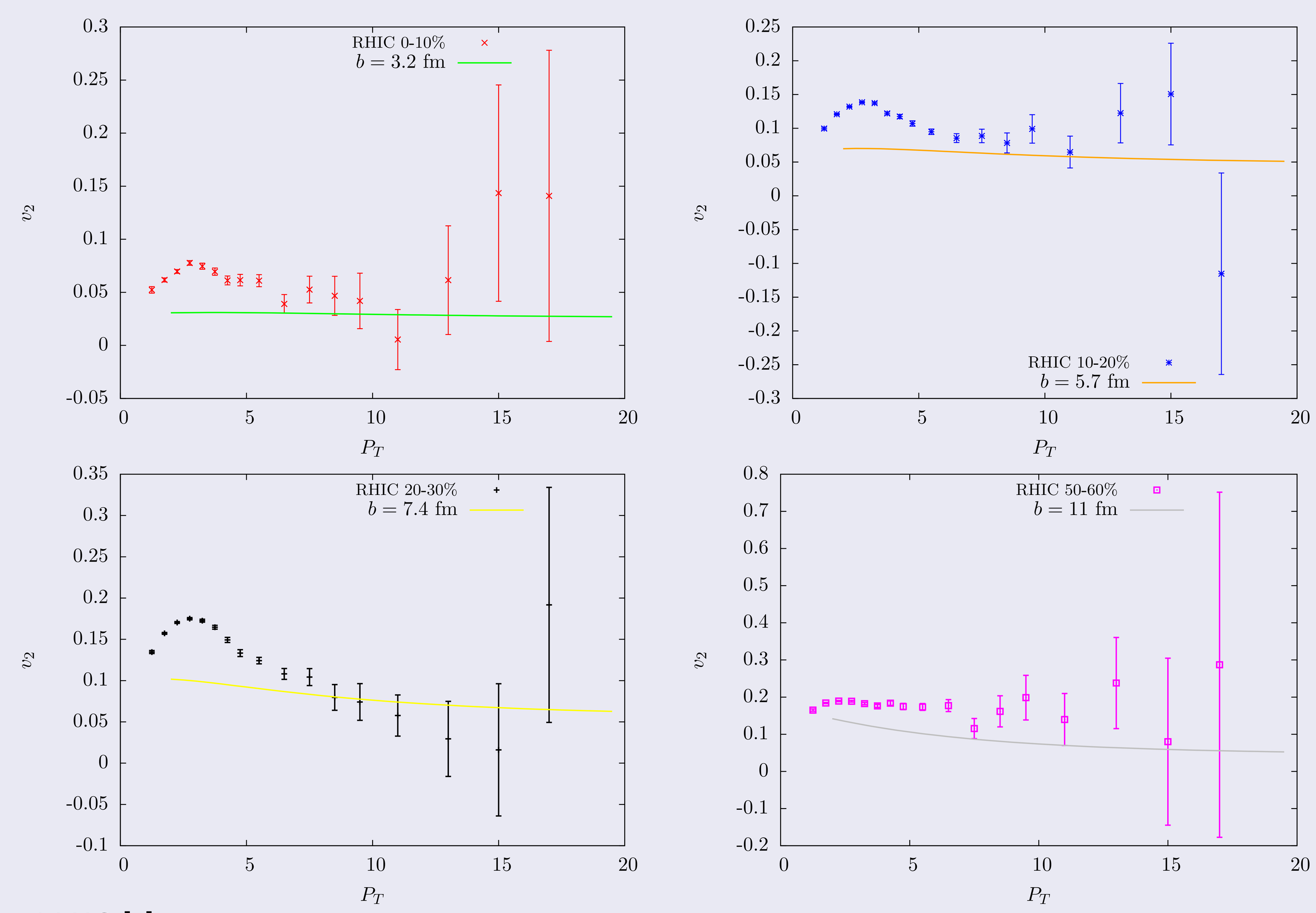
After a scan in λ we look for the fit to R_{AA} data that minimizes the $\chi^2/D.o.F.$ We found the best fit with $\lambda = 0.333$ and $k = 0.035\,\mathrm{GeV}\cdot\mathrm{fm}$. R_{AA} data is from the PHENIX collaboration [2]. We then proceed to observe what are the "predictions" of the model for v_2 at RHIC and for R_{AA} and the asymmetry at LHC.



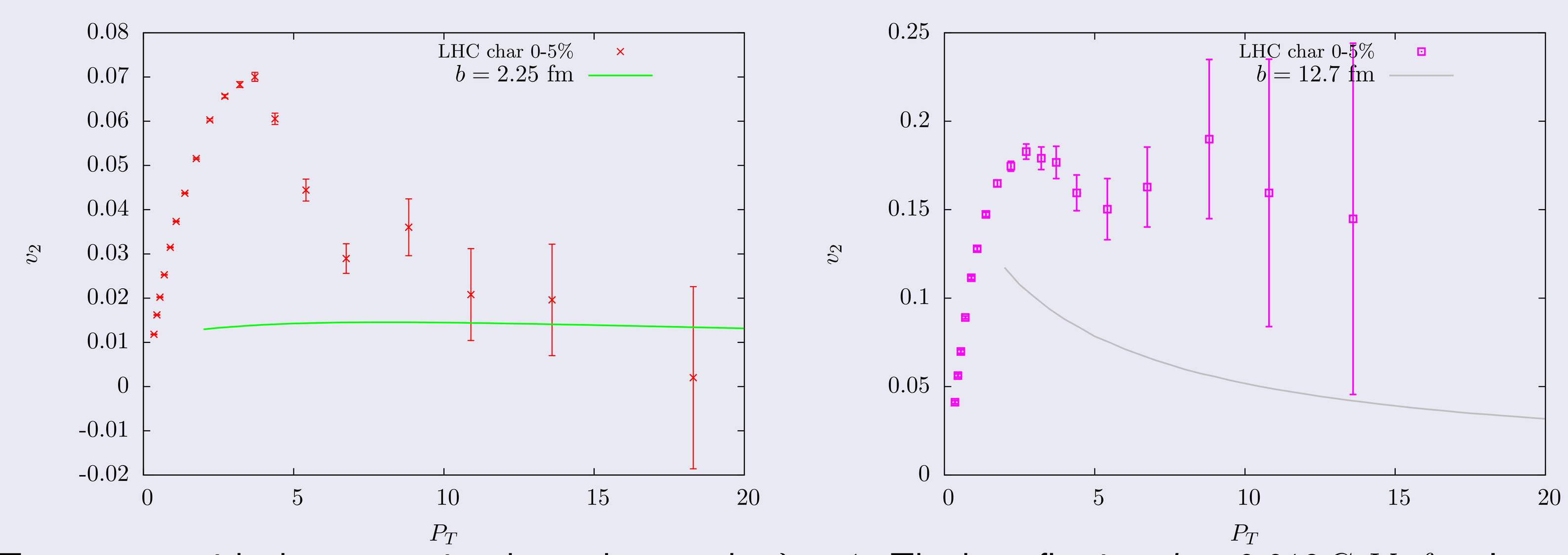
The data for R_{AA} for charged particles at LHC is from ALICE Collaboration [5].

Results (Cont.)

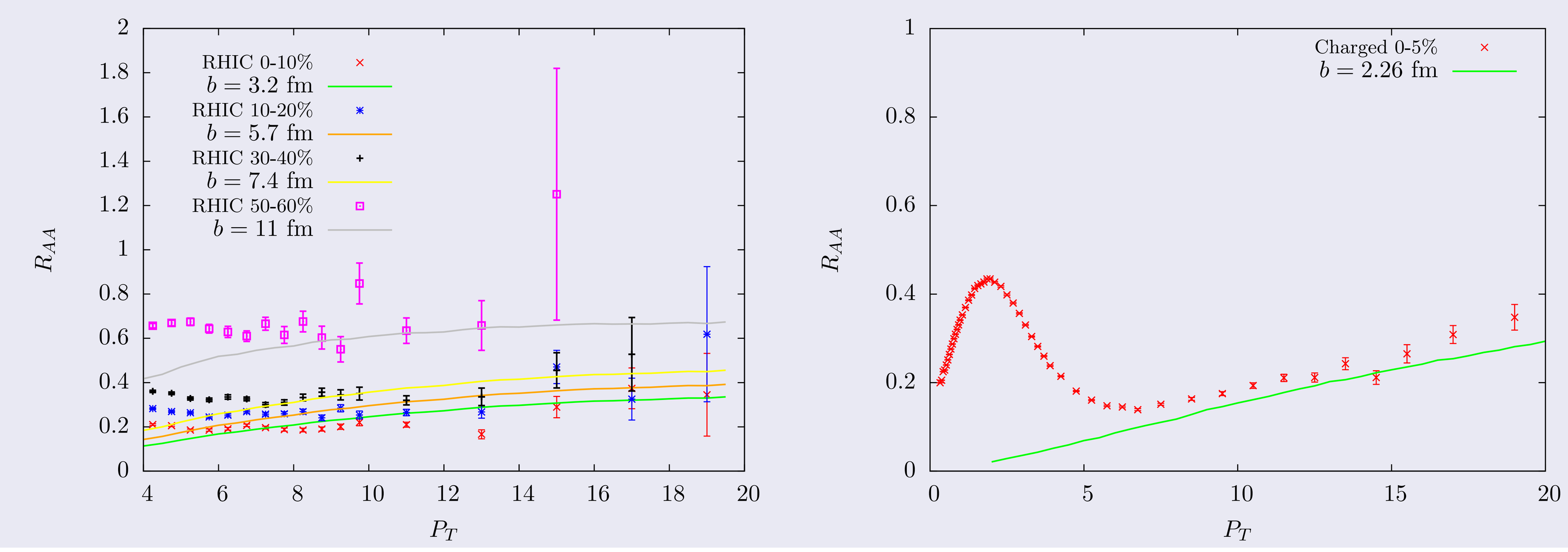
We now show the results of the fits for v_2 for RHIC [6]



and LHC [7]:



To compare with the conventional case let us take $\lambda = 1$. The best fit gives $k = 0.018\,\mathrm{GeV}\cdot\mathrm{fm}$. Let us observe the R_{AA} behavior:



Conclusions

- Our results show it is possible to produce good fits to R_{AA} at both available energies simultaneously. The best value for λ is 0.333. We have checked that RHIC data alone give us the same fit parameters.
- The v_2 fits are relatively good and in general show an improvement over other models.
- With $\lambda = 1$ fitted to RHIC data, quenching at LHC is larger than indicated by experimental data. The L&S model reduces the quenching at LHC because the quenching shells become thinner.
- Our scan over λ finds a value similar to the one found by Liao and Shuryak. This adds to our confidence that there might be enhanced jet quenching around T_c

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Acknowledgments

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