COLOR DECOHERENCE IN IN-MEDIUM QCD CASCADES

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Abstract

The talk, based on [1], analyzes the consequences of the assumption that the effects of quantum coherence and the resulting angular ordering in QCD cascades are disrupted within the hot fireball created in ultrarelativistic heavy ion collisions.

Studying modifications of intrajet properties of high energy jets in nuclear collisions has drawn considerable theoretical [2, 3, 4, 5] and experimental [6, 7] attention. All of the listed MC generators take into account the medium-induced radiative energy loss that is believed to be a major source of jet quenching. In addition, JEWEL [3] also takes into account the effects of rescattering of cascade particles on those in the medium assuming, in particular, that such a scattering destroys angular ordering among the corresponding gluon emission angles.

The focus of the present work is on analyzing the consequences of the assumption that due to the violent color environment created in heavy ion collisions the interference effects requiring precise color matching between the different contributing diagrams, in particular the one leading to the angular ordering, get disrupted within the hot fireball having some finite size. The assumption in question is supported by the fact [8] that rotation of the color spin of the hard mode is the fastest process in quark-gluon plasma. In particular, it is faster than the rate of the change of the energy-momentum of the hard mode. The resulting decoherence has a significant effect on the spatiotemporal pattern of the part of cascade that evolves inside the hot fireball and on the properties of the final cascade-generated configuration. A detailed comparison of globally angular ordered and non-angular ordered cases was made in [9]. In distinction to [3] we do not take into account the energy-momentum exchange with the medium accompanying randomization of color leading to decoherence and in distinction to [9, 3] explicitly take into account the finite size of the hot zone.

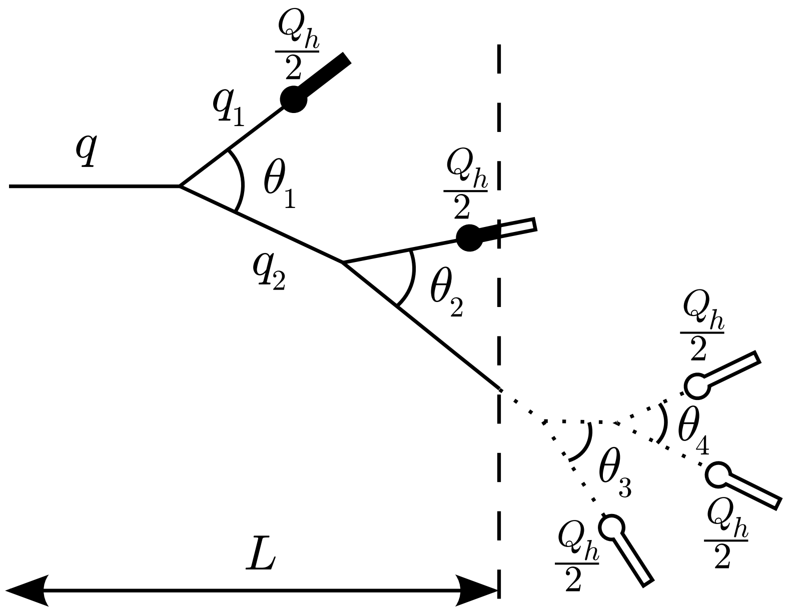

Figure 1: A sketch of the in-medium QCD cascade. The angles θ_3 and θ_4 of in-vacuum decays are ordered, $\theta_4 < \theta_3$, while those of in-medium decays θ_1 and θ_2 are not.

The key elements of the model used in the present work are illustrated in Fig. 1.

To determine whether a given line is still inside the medium or has already left it, one needs to set up a clock counting time along the cascade. The only possibility of associating a spatiotemporal pattern with the cascade is to use the lifetime τ of a virtual parton which, for a parton with the energy E and virtuality Q^2 that has been created in the decay of its parent parton with the virtuality $Q^2_{\rm par}$, reads

$$\tau = E\left(\frac{1}{Q^2} - \frac{1}{Q^2_{\rm par}}\right) \tag{1}$$

The lifetime of the initial parton is taken to be $\tau_{\rm in} = E_{\rm in}/Q^2_{\rm in}$. For decays taking place inside the medium such as those of gluons with the momenta q and q_1 the quantum coherence effects resulting in the angular ordering are assumed to be destroyed. The effect is taken into account by switching off angular ordering for the decay vertices inside the hot fireball.

In Fig. 2 we plot the distributions of final prehadrons in the rapidity $y = \ln(E_0/E)$ for gluon jets with the initial energy $E_0 = 100$ GeV and $L = 0.5$, 1 and 5 fm.

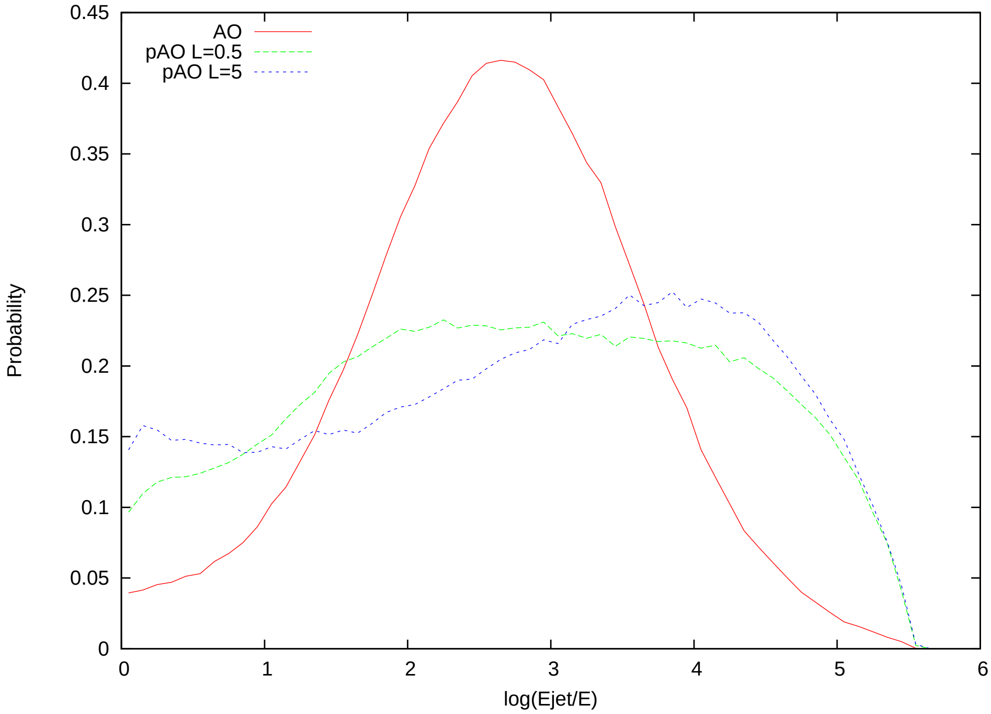

Figure 2: Rapidity distribution $P(y)$ of final prehadrons: 1) $L = 0\,\text{fm}$, full angular ordering, red, solid; 2) $L = 0.5\,\text{fm}$, partial angular ordering, green, dashed; 3) $L = 5\,\text{fm}$, partial angular ordering, blue, dotted.

From the distributions in Fig. 2 we see that the effect of color decoherence is indeed quite strong. Already at $L = 0.5$ fm the distribution is significantly different from the vacuum one and at larger L practically saturates. Thus, even in the absence of energy loss in terms of energy-momentum, the intrajet properties are significantly affected by the medium through color decoherence. The dominant effect of decoherence seen in Fig. 2 is the softening of rapidity distribution accompanied by noticeable increase in the yield of hard final particles and an overall relative flattening as compared to the in-vacuum case.

Two other results obtained in [1] are:

- Decoherence effects lead to a dramatic increase in the yield of prehadrons formed inside the hot zone.
- Taking into account collisional energy losses of partons and prehadrons leads to significant depletion of the multiplicity of final particles, noticeable overall energy loss and significant hardening of the rapidity distribution of final particles.

The problem of medium-induced effects on quantum coherence is of significant importance for working out quantitative in-medium QCD. For recent intriguing results see, e.g., [10].

Acknowledgements

The work was supported by the RFBR grants 06-02-17051, 08=02-91000, 09-02-00741 and the RAS program "Physics at the LHC collider".

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