Color coherence in multiple antenna medium radiation

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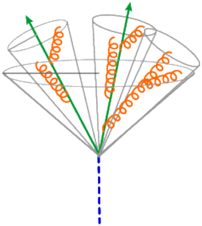
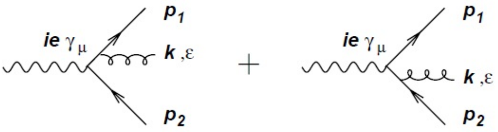
Motivation: jet substructure



- Ideal techniques for heavy ion collisions.
- More direct access to the underlying dynamics:
  - QGP properties.
  - Energy loss.
  - Coherence.

Color coherence in vacuum

- Is radiation independent?: $q\bar{q}$ antenna as a laboratory.

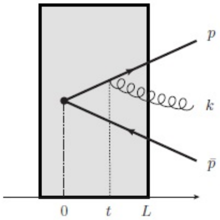
$\mathcal{M}_{q\bar{q}g} =$ 

$$dN = \frac{d\omega}{\omega}\frac{d\Omega}{2\pi}\frac{\alpha_s C_F}{2\pi}\left[R_q + R_{\bar{q}} - 2\mathcal{J}\right]$$

- The spectrum is suppressed at large angles due to the presence of destructive inteferences (coherence).
- Angular ordering.

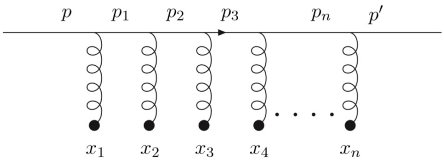
Color coherence in a medium

- How does the medium change this picture?



- A parton can change color through interaction with the medium, breaking the correlation between emitted gluons.

Particle propagation in matter

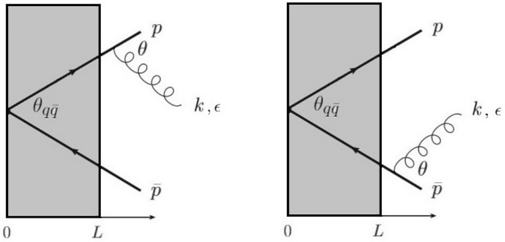


$$W(\vec{x}) = \mathcal{P}\ exp\left[ig \int dx_+ A_-(x_+, \vec{x})\right]$$

- The effect of the medium is to induce color rotation at each scattering center.
- The quark (a high energy quark) loses a negligible amount of energy and propagates in straight lines (*eikonal* propagation).

In-medium antenna radiation

- To study the degree of coherence we a take a very soft gluon $\omega \to 0$ (out-out radiation).



The decoherence parameter

- The interaction of the $q\bar{q}$ pair with the medium is described by the survival probability $\mathcal{S}$.

$$\mathcal{S} \equiv \frac{1}{N_c^2 - 1} \left\langle W(\vec{x}_\perp) W^\dagger(\vec{y}_\perp) \right\rangle$$

$$\mathcal{S} \equiv 1 - \Delta_{med}(t)$$

$$\Delta_{med} \equiv 1 - exp\left[-\frac{1}{4} \hat{q} L (\vec{x}_\perp - \vec{\bar{x}}_\perp)^2 \right]$$

- This factor determines a characteristic time-scale for decoherence of the $q\bar{q}$ pair.

The resulting spectrum

$$dN = \frac{d\omega}{\omega}\frac{d\Omega}{2\pi}\frac{\alpha_s C_F}{2\pi}\left[R_q + R_{\bar{q}} - (1-\Delta_{med})\, 2\mathcal{J}\right]$$

$$\begin{cases} \Delta_{med} \to 0 : dN \sim R_q + R_{\bar{q}} - 2\mathcal{J} \\ \boxed{Dilute\ \ medium : coherence\ (angular\ ordering)} \\ \\ \Delta_{med} \to 1 : dN \sim R_q + R_{\bar{q}} \\ \boxed{Opaque\ \ medium : decoherence\ (two\ \ independent\ \ emitters)} \end{cases}$$

[The radiation pattern of a QCD antenna in a diluite/dense medium, Yacine Mehtar-Tani, Carlos A. Salgado and Konrad Tywoniuk]

Main limitations

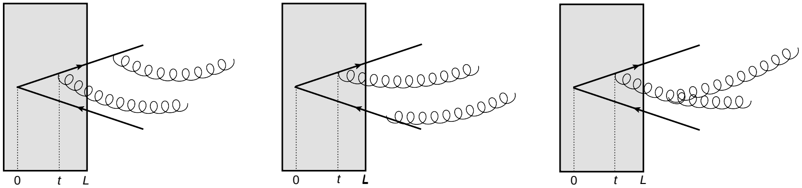
- We have to deal with more realistic settings:
  - Non-eikonal antenna.
  - Multiple emissions.
  - Finite formation time.

Main limitations

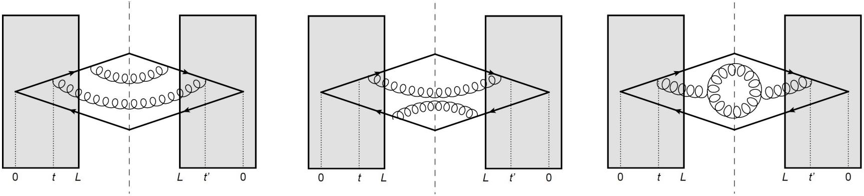
- We have to deal with more realistic settings:
    - Non-eikonal antenna.
    - **Multiple emissions.**
    - Finite formation time.

Multiple emissions

- The antenna provides a simple and intuitive picture.
- Does it hold for more than two emitters?



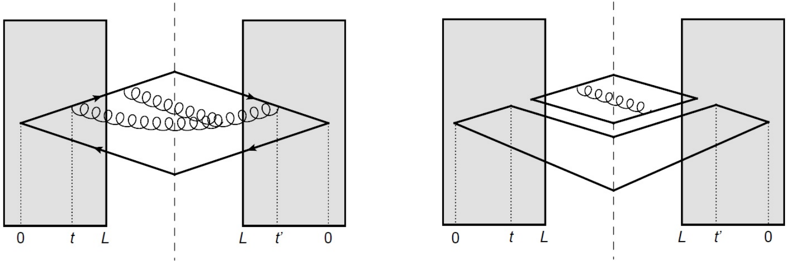
Direct terms



$|\mathcal{M}_1|^2 \propto C_F^2$ $|\mathcal{M}_2|^2 \propto C_F^2$ $|\mathcal{M}_3|^2 \propto N_c\ C_F^2$

- The direct terms are proportional to a color factor.

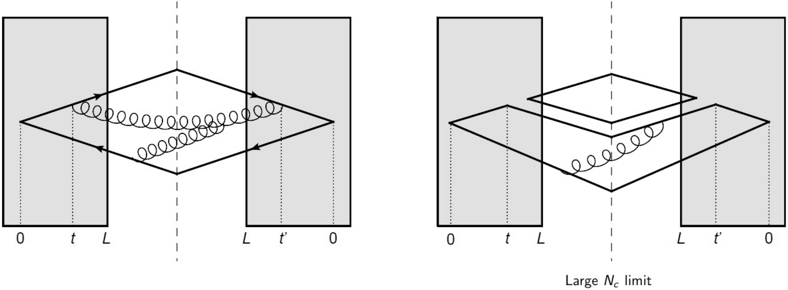
Interference terms



Large N_c limit

$$\mathcal{M}_1 \otimes \mathcal{M}_3^* \propto \mathcal{S}(t, L)$$

Interference terms



$$\mathcal{M}_2 \otimes \mathcal{M}_3^* \propto \mathcal{S}(0,t)\ \mathcal{S}(t,L)$$

Multiple emissions results

- We have considered the case of three emitters.
- **The interference terms are proportional to the survival probabilities $\mathcal{S}$ in the $(0, t)$ and (t, L) regions: the general result of the antenna is valid for each of the smaller antennas.**
- **If coherence is not preserved after the in-medium splitting, the antenna won't radiate coherently in the following emission.**
- These computations can be generalized to the problem of n emitters.

Summary

- Detailed measurements of jet substructure shed light on the intricate nature of the jet interactions with the dense, deconfined QCD matter formed in the collisions.
- Color coherence is essential to understand the jet constituents' energy loss (are they independent or not?).
- In spite of the singlet antenna limitations (eikonal propagation, zero formation time, only one splitting...), it is a very convenient *laboratory*.
- The general result of the singlet antenna is valid for the subsequent antennas in the multiple emissions case.
- These computations go a step forward to obtain a complete description of a QCD cascade.

Thanks for your attention