Parton Energy Loss in a Medium with a Chromomagentic Background Field

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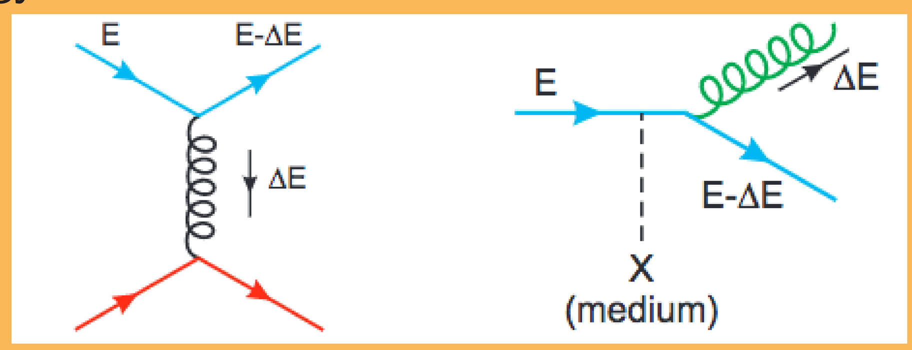
Introduction

- During Pb-Pb collisions at the LHC a hot and dense medium of deconfined quarks and gluons is created (QGP).
- In Cosmology, a QGP is expected to have been the state of matter up to few microseconds after the Big Bang.
- Jet suppression in Pb-Pb collisions is expected if a QGP is formed.
- The main energy loss mechanisms are radiative and collisional energy loss.



- The medium consists of colored particles with color charges, creating a chromomagnetic background field.
- A fast parton passing through the QGP will feel the effect of the background field while undergoing multiple scatterings with other particles of the medium.
- This kind of energy loss is called synchrotron like gluon emission.
- This description contains both radiative and collisional energy loss.

Objectives

1. Finding the gluon emission spectrum.
2. Finding the energy loss dependence on the intial energy E and the medium length L.

Color Charge representation

- The coupling between the partons and the chromomagnetic background field is characterized by a color charge.
- This color charge can be obtained from the QCD Lagrangian.
  - ▷ This can be done by splitting the gauge field into a quantum fluctuation and a classical background field.
  - ▷ Then regrouping the terms that couple to a given background color index.
- Another method for extracting the color charge from the SU(3) representation:
  - ▷ The chromomagnetic field will be considered with color components A=3 and B=8.
  - ▷ The radiated gluons will use the color state $Q = (Q_A, Q_B)$ with definite color isospin Q_A and color hypercharge Q_B.
  - ▷ Simple calculation will give two neutral gluons G_3 and G_8 and six color charged gluons:
    $(1,0)$, $(-1,0)$, $(-\frac{1}{2}, \frac{\sqrt{3}}{2})$, $(\frac{1}{2}, -\frac{\sqrt{3}}{2})$, $(\frac{1}{2}, \frac{\sqrt{3}}{2})$, $(-\frac{1}{2}, -\frac{\sqrt{3}}{2})$

Formalism

- The propagation of a parton in an external field can be understood in terms of wave functions.
- So using the path integral approach the evolution of the wave function can be written as

$$\phi(\tau_f, z_f) = \int d^2\tau_i K_F(\tau_f, z_f; \tau_i, z_i)\phi(\tau_i, z_i)$$

- The probability distribution for gluon emission can be written as:

$$dP = 2\mathrm{Re}\int d^2\tau_i d^2\tau_f \phi_q^*(\tau_f, z_f)\phi_q(\tau_i, z_i)\delta K(\tau_f, z_f; \tau_i, z_i)$$

  - ▷ The δK term is the radiation corrected propagator.
- After expansion and simplifications the gluon emission probability becomes:

$$\frac{dP}{dx} = \int_0^L dz\, n(z)\frac{d\sigma_{eff}(x,z)}{dx}$$

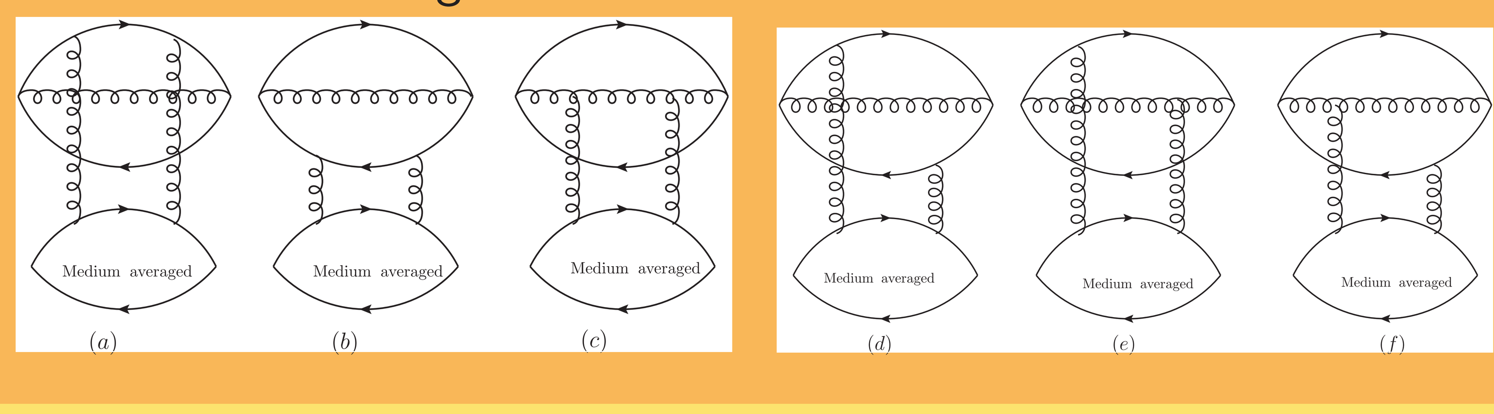
  - ▷ $n(z)$ is the medium density, and $\frac{d\sigma_{eff}(x,z)}{dx}$ is the effective cross section.

Formalism

- The effective cross section is approximated by:

$$\frac{d\sigma_{eff}(x,z)}{dx} = Re\int d^2\rho \sum_{color,helicity} \psi_m^*(\rho, x)\sigma_3\psi_f(\rho, x, z)$$

  - ▷ where ψ_f is the light-cone wave function of the three body system qgq' in the background field.
  - ▷ ψ_m is the three body light-cone medium modified wave function.
  - ▷ σ_3 is the three body scattering (with medium) cross section.
- The medium was treated as a collection of random scattering centers.
- σ_3 was determined averaging over all the scattering centers taking into account all the following interactions:



Results

- The background field was approximated by an impulse field, i.e it gives the particle a "kick" at an instant of time z_s.
- So the effective force becomes $f(z) = f_o\delta(z - z_s)$.
- Two background field configurations were considered:
  - ▷ Background field in the transverse plane $f_o = g[(1-x)Q - xq']e_z \wedge H_o$.
  - ▷ Background field in the longitudinal direction $f_o = (1-x)q_g - xq_{q'}$
- Two assumptions were made:
  - ▷ First, the impulse point and the scattering point were considered to be very close, $z \approx z_s$.
  - ▷ Second, the impulse point and the scattering point are widely separated, $z - z_s \to \infty$.
- In the first assumption the gluon emission probability was found to be:

$$x\frac{dP}{dx} \approx \frac{2xG(x)\alpha_s}{\alpha_s}\frac{A(x)}{\pi\, A(0)}\frac{L}{\lambda_g} ln\left(1 + \frac{\mu^2}{f^2}\right)$$

- From $x\frac{dP}{dx}$, the energy loss can be determined by taking the small $\frac{\mu}{q'_\perp}$ limit:

$$\Delta E = E\int_0^1 dx\, x\frac{dP}{dx} = C\alpha_s\frac{L}{\lambda_g}\frac{\mu}{q'_\perp}E \text{ (For the Transverse case)}$$

- The above equation is linear in L and E.
- In the second assumption, the background field will be turned off $f_o = 0$. The energy loss will be:

$$\Delta E = \frac{C_F\alpha_s}{4}\frac{L^2\mu^2}{\lambda_g} ln\left(\frac{E}{\omega_{cr}}\right)$$

  which is logarithmic in E and quadratic in L.
- The above equation is the same equation obtained by [2].

Conclusion

- In this poster the energy loss by the synchrotron gluon radiation with scattering was presented.
- In the impulse field configuration the energy loss is linearly dependent on L and E.
- In the zero field case the energy loss is logarithmically dependent on E and quadratically dependent on L.

References

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