Radiative correction from the Wigner's little group perspective

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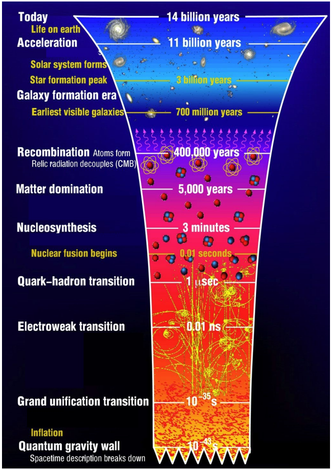
Outline

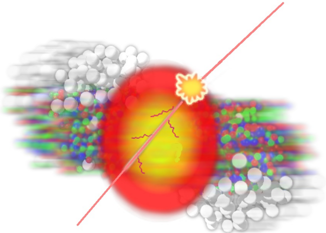
- ▷ Introduction
  - – Heavy ion collision
  - – Aim of the work
- ▷ Wigner's Little group W
  - – Action of a W on a state
  - – Helicity representation
- ▷ Radiative calculation
  - – Kinematic setup
  - – Soft factor radiation
- ▷ Conclusion



Introduction

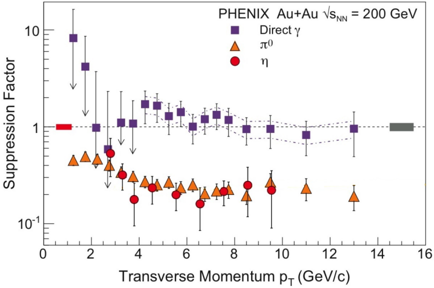
Relativistic heavy ion collision

- ▷ Heavy Ion Collision:
  - Study collectivity and thermodynamics of QCD.
  - Collide heavy nuclei at relativistic energies (RHIC, LHC).
  - Creating a small volume of matter with extreme density and temperature.
- ▷ Experimental Observation:
  - Thermalized system: collective response to pressure gradients.
  - High transverse momentum processes: predicted from pQCD.



Jet suppression

- ▷ Hard Probes:
  - ○ The outgoing partons propagates through the medium.
  - ○ Understand the properties of hot and dense QCD matter.
  - ○ A dramatic decrease of the jet energy, jet quenching.
- ▷ Nuclear modification R_{AA}
  - ○ Ratio: σ_{AuAu} and σ_{pp}.
  - ○ Deviation from 1?
  - ○ R^{γ}_{AA} vs R^{jet}_{AA}



Jet suppression

▷ Hard Probes:

- The outgoing partons propagates through the medium.
- Understand the properties of hot and dense QCD matter.
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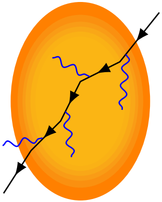
▷ Energy loss mechanisms:

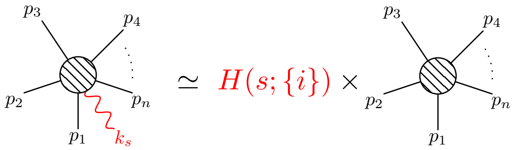
- Collisionnal energy loss: multiple scattering center, drag coefficient.
- Radiative energy loss: soft/collinear photon and gluon radiation.



Objectives

▷ Radiative calculation:

- Effects of radiation (γ, g) on a jet through the medium.
- Radiation without explicit details on the hard collisions!
- Soft contributions can be factorized from hard collisions.

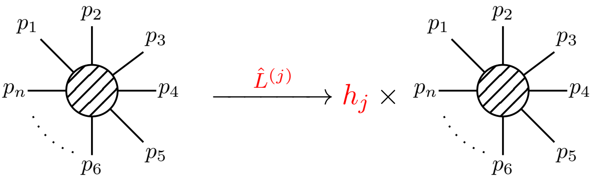


- Hard collision $\sim 2 \to 2$ collisions between the probe and the constituents of the bulk.

Wigner’s Little Group

Wigner's little group (W)

- ▷ Little group W: is a subgroup of the Lorentz group that leave a momentum p invariant ($Wp = p$).
- ▷ Single particle state ($m = 0$): $\hat{U}(W) |p, h\rangle = e^{i\theta h} |p, h\rangle$.
- ▷ Massless: $W \cong U(1)$ generated by $\hat{L} |p, h\rangle = h |p, h\rangle$.
- ▷ Scattering amplitudes



Spinor representation of W

- Massless spinor representation

$$p_\mu \xrightarrow{p^2=0} \lambda_a \bar{\lambda}_{\dot{a}}$$

- The little group W becomes a simple scaling of λ and $\bar{\lambda}$

$$W : \begin{cases} \lambda \longrightarrow t\,\lambda \\ \bar{\lambda} \longrightarrow t^{-1}\bar{\lambda} \end{cases}$$

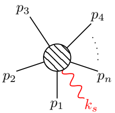
- Spinor representation of the generator $\hat{L}$

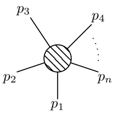
$$\hat{L} = -\frac{1}{2}\left(\lambda_a \frac{\partial}{\partial \lambda_a} - \bar{\lambda}_{\dot{a}} \frac{\partial}{\partial \bar{\lambda}_{\dot{a}}}\right)$$

- $\hat{L}$ act on any function $f(\lambda, \bar{\lambda})$ as a simple derivative.

Helicity constraints

- Little group action on the factorized amplitude

$\hat{L}^{(j)}$ 

$\simeq \hat{L}^{(j)} \Big[H(s;\{i\}) \times$ 

$\Big]$

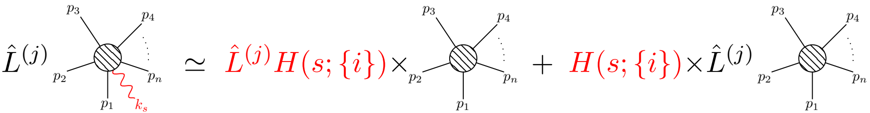
- Helicity constraints on the soft factor

$$\begin{cases} \hat{L}^{(s)} H(s;\{i\}) = h_s H(s;\{i\}) \\ \hat{L}^{(i)} H(s;\{i\}) = 0 \end{cases}$$

- Solving system of $(n+1)$ linear equations.

Helicity constraints

- ▷ Little group action on the factorized amplitude



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- ▷ Solving system of $(n+1)$ linear equations.

Radiative Calculation

Radiative calculation

▷ Kinematic setup

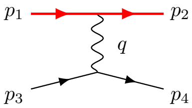
- Parton medium interactions are dominated by t-channel exchange.
- The interactions are characterized by

$$\lambda_a^{(3)} \sim \lambda_a^{(4)} \sim \lambda_a^{(q)}.$$

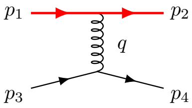
- $H(s;\{i\})$ of an helicity -1 radiation depends only on λ, i.e.

$$\langle ij \rangle = \lambda^{(i)} \cdot \lambda^{(j)}$$

- Solving the helicity constraint for a single and a double radiations.



photon exchange



gluon exchange

Radiative calculation

▷ Single soft radiation

$$H(s) = A\frac{\langle 14\rangle}{\langle 1s\rangle\,\langle s4\rangle} + B\frac{\langle 42\rangle}{\langle 4s\rangle\,\langle s2\rangle}$$

- A and B contain information on the non-kinematic dof.
- A and B can be fixed from the symmetry of the theory.
- Abelian solution: $A = B \sim e$

$$H^{\gamma}(s) \sim e\frac{\langle 12\rangle}{\langle 1s\rangle\,\langle s2\rangle} \Longleftrightarrow e\left(\frac{p_1^{\mu}}{p_1.k_s} - \frac{p_2^{\mu}}{p_2.k_s}\right)\varepsilon_{\mu}(k_s)$$

- Non-Abelian solution: color degrees of freedom

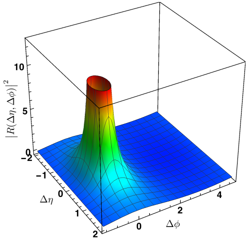
$$A(a_s) \sim gT_{a_s}\hat{C}_R \quad \text{and} \quad B(a_s) \sim g\hat{C}_R T_{a_s}$$

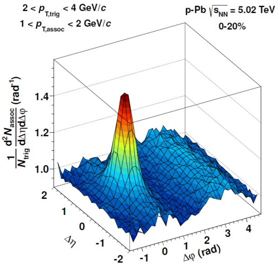
Radiative calculation

▷ Two soft radiation

$$H(s_1, s_2) = H(s_1)H(s_2) + \frac{\varepsilon_{\mathrm{NA}}}{\langle s_1 s_2 \rangle} R(s_1, s_2)$$

- $\varepsilon_{\mathrm{NA}}$ is a non-Abelian effect between the radiations.
- $R(s_1, s_2)$ leads to the correlation between the two radiations.
- Suggestive to the correlation from central $p + Pb$ collisions measured by the ALICE collaboration.





[arXiv:1212.2001]

Conclusion

Conclusion

Summary

- ▷ Jet energy loss are characterized by collisional and radiative mechanisms.
- ▷ Study the induced radiative effect on parton through a medium.
- ▷ From the scale factorization, we introduce the helicity constraints from the W action on $H(s)$.
- ▷ Presented some early result for one and two spin-1 radiations two compare to the ALICE correlation measurement.

Outlook

- ▷ Consider massive parton with $W \cong SU(2)$.
- ▷ Deep investigation on the kinematics for multiple exchange.
- ▷ Combine with the existing model (GLV, ASW, . . .)