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# CHERENKOV RADIATION OF GLUON CURRENTS

M.N. Alfimov, A.V. Leonidov

P.N. Lebedev Physical Institute

# Quantum picture for the Cherenkov radiation

- In the medium the dispersion relation (as seen from the propagator's poles) for excitations changes:

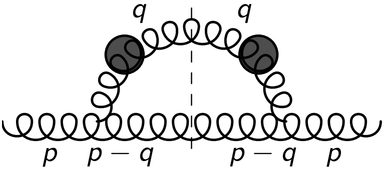
$$\frac{1}{\omega^2 - \mathbf{k}^2} \Longrightarrow \frac{1}{\omega^2 - \epsilon(\omega, \mathbf{k})\mathbf{k}^2}$$

- Of special interest are the nonlinear interactions of excitations. The leading nonlinear effect is a three-wave interaction corresponding to the decay of a quasiparticle into two quasiparticles

$$(\omega_1, \mathbf{k}_1) \rightarrow (\omega_2, \mathbf{k}_2) \oplus (\omega_3, \mathbf{k}_3)$$

- Cherenkov radiation is a decay of a free vacuum particle into a quasiparticle and a free particle possible for certain special values of the permittivity $\epsilon(\omega, \mathbf{k}) > 1$.

# Decay kinematics




- Cherenkov decay can happen only for special angles between the decaying particle and its quasiparticle successor (Cherenkov angle)

$$\cos\theta = \frac{1}{\sqrt{\epsilon(\omega)}}\left(1 + \frac{\epsilon(\omega) - 1}{2}\,\frac{\omega}{E}\right)$$

- QFT calculation is possible only for real $\epsilon(\omega)$ $\Rightarrow$ restriction on $\omega/E$ :

$$\frac{\omega}{E} < 1 - \sin\theta$$

# Model for chromopermittivity

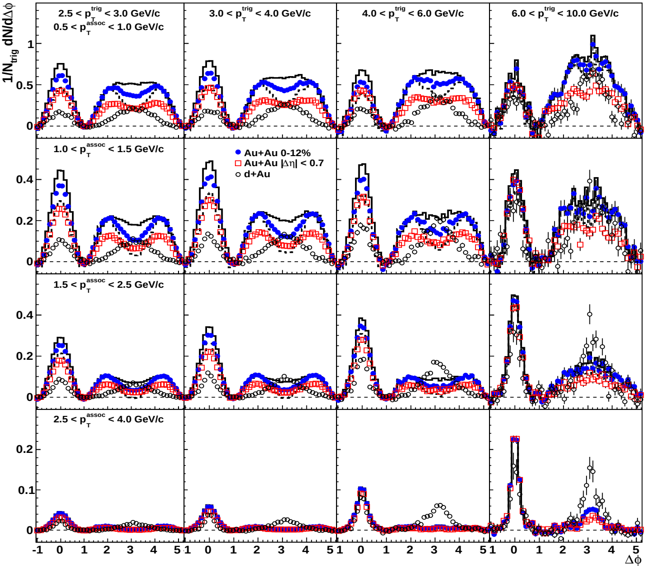
- Generically the colored medium is characterized by chromopermittivity
$$\epsilon^{ab}(\omega, \mathbf{k})$$
- We shall consider the quasiabelian case and neglect the spatial dispersion:
$$\epsilon^{ab}(\omega, \mathbf{k}) \to \delta^{ab}\epsilon(\omega)$$
- Experimental data from RHIC suggest the step-like model for $\epsilon(\omega)$:
$$\epsilon(\omega) = \epsilon_0 \cdot \theta(\omega_0 - \omega) + 1 \cdot \theta(\omega - \omega_0)$$
with
$$\epsilon_0 \simeq 5, \quad \omega_0 \simeq 3\ \mathrm{GeV}$$

# Experimental setup

- How does a two-jet pattern in $pp$ change in $AA$ ?
- First jet (trigger) should ideally be the same as in $pp$
- Partner jet (associated) should ideally evolve in the medium
- Cherenkov gluon radiation corresponds to the conical structure around the associated jet direction.

# Experimental data on two-particle azimuthal correlations

STAR Collaboration, arXiv:1004.2377



# Decay calculation

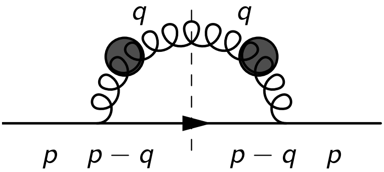
- Basic decay spectrum

$$P(\omega) = \frac{\omega}{2E} \int d\Pi_f \delta \left( \omega - \frac{|\overrightarrow{q}|}{\sqrt{\epsilon(\omega)}} \right) \frac{1}{2} \sum_{i,j,k=1,2} |\mathcal{M}_{i \to jk}|^2$$

- After integration

$$P(\omega) = \frac{\epsilon(\omega)\omega}{16\pi^2 E^2} \frac{1}{2} \sum_{i,j,k=1,2} |\mathcal{M}_{i \to jk}|^2$$

# Cherenkov radiation by quarks



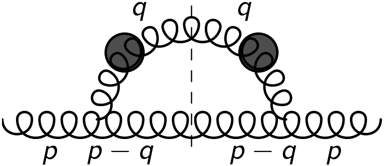

Full spectrum

$$P(\omega) = 4\pi\alpha_s \, \frac{(N_c^2 - 1)}{2N_c} \, \omega \left(1 - \frac{1}{\epsilon(\omega)}\right) \left(1 - \frac{\omega}{E} + \frac{\epsilon(\omega) - 1}{2} \, \frac{\omega^2}{E^2}\right)$$

Soft limit

$$P(\omega)\big|_{\omega \to 0} \simeq 4\pi\alpha_s \, \frac{(N_c^2 - 1)}{2N_c} \, \omega \left(1 - \frac{1}{\epsilon(\omega)}\right)$$

# Cherenkov radiation by gluons




## Full spectrum

$$
\begin{aligned}
P(\omega) &= 4\pi\alpha_s N_c \omega \left(1 - \frac{1}{\epsilon}\right)\left(1 - \frac{\omega}{E} - \frac{\epsilon - 1}{4}\frac{\omega^2}{E^2}\right) \\
&\times \left[1 + \frac{1}{2}\left(\epsilon + \frac{\epsilon + 1}{1 - \frac{\omega}{E}} + \frac{\epsilon}{\left(1 - \frac{\omega}{E}\right)^2}\right)\frac{\omega^2}{E^2} + \frac{(\epsilon + 1)^2}{8\left(1 - \frac{\omega}{E}\right)^2}\frac{\omega^4}{E^4}\right]
\end{aligned}
$$

## Soft limit

$$
P(\omega)|_{\omega \to 0} \simeq 4\pi\alpha_s \, N_c \, \omega \left(1 - \frac{1}{\epsilon(\omega)}\right)
$$

# Conclusions

- Quantum Cherenkov radiation of gluon current computed
- Meaningful comparision with experimental data at RHIC require introducing explicit mechanisms responsible for absorption because of $\omega/E > 1 - \sin\theta$ in the kinematic region covered by RHIC