Dilepton and Photon Production from a Coherent Pion Oscillation *

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Electromagnetic probes are known to be ideal probes of dense hadronic matter owing to the fact that they escape the strong interaction region once produced without further final state interactions and thus carry the information on the early dynamical evolution. In this work, we studied the dilepton and direct photon production from the classical pion field in the context of a disoriented chiral condensate (DCC), or most generally, a nonequilibrium pion cloud. We developed a general formalism for the dilepton and photon emissions in the presence of a classical electromagnetic current. Since the electromagnetic current coincides with the third component of the isovector current, the isospin angular oscillation of the condensate field can be a significant source of electromagnetic emission in the low mass (transverse momentum) region.

The dilepton differential distribution with respect to the lepton pair 4-momentum q can be derived as

$$\frac{dN_{\ell^+\ell^-}}{d^4q} = \frac{\alpha^2}{6\pi^3}\frac{B}{q^4}[q^\mu q^\nu - q^2 g^{\mu\nu}]J_\mu^{\rm cl}(q)J_\nu^{\rm cl*}(q)\ , \quad (1)$$

where $J_\mu^{\rm cl}(q)$ is the electromagnetic current carried by the classical pion fields, $B = [1 + 2m_\ell^2/q^2][1 - 4m_\ell^2/q^2]^{1/2}$ and m_ℓ is the lepton mass.

Given an analytical solvable model where a general class of solutions for the pion fields can be obtained, we calculate the dilepton spectrum as shown in Fig. 1.

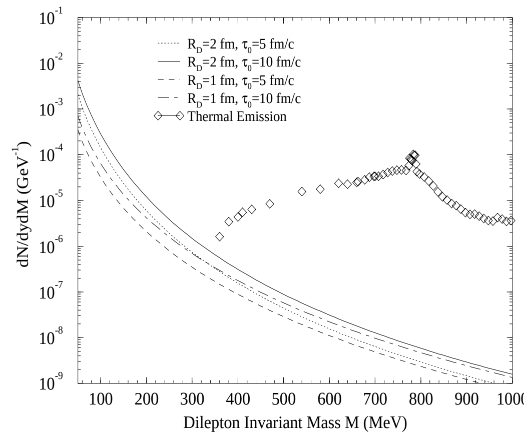

Figure 1: The dilepton invariant mass spectrum for different choices of initial time scale τ_0 and the coherent field domain size R_D. The initial energy density is assumed to be $\epsilon_0 = 0.1$ GeV/fm^3. The typical thermal spectrum due to the π-π annihilation is also plotted for a comparison

Both the dilepton and the photon spectra fall off exponentially for large transverse momentum which is characteristic of coherent production from a finite domain. The electromagnetic emission from a DCC domain is thus only important in the low momentum region where the spectra increase as some inverse power law of the momentum.

The result depends on a constant a_3 in the third component of the isospin which is conserved, $J_\mu^{(3)} = a_3 f_\pi^2 x_\mu/\tau^2$. The constant a_3 can be related to the initial energy density using the symmetry argument,

$$\langle a_3^2\rangle = \frac{1}{6}\frac{\epsilon_0\tau_0^2}{2f_\pi^2} \qquad (i = 1, 2, 3)\,. \qquad (2)$$

Most notably, there does not exist a pion mass threshold for dilepton production from a coherent field: the spectrum rises even below $M = 2m_\pi$. The finite pion mass plays no roles in the conserved isovector current whose third component directly couples to the photon. Therefore, the coherent field is most effective in producing lepton pairs in the low mass region $M < 2m_\pi$.

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