Role of Axial-Vector Mesons near the Chiral Phase Transition ◇

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In the presence of hot matter the vector and axial-vector current correlators are mixed due to pions in the heat bath. At low temperatures this process is described in a model-independent way in terms of a low-energy theorem based on chiral symmetry and consequently the vector spectral function is modified by axial-vector mesons through the mixing theorem [1]. The validity of the theorem is, however, limited to temperatures $T \ll 2f_\pi$, where f_π is the pion decay constant in vacuum. At higher temperatures one needs in-medium correlators systematically involving hadronic excitations other than pions. Using an effective field theory, we have explored the effects of the mixing (hereafter V-A mixing), and how the axial-vector mesons affect the vector spectral function near the chiral phase transition [2].

A model based on the generalized hidden local symmetry (GHLS) describes a system including the axial-vector meson explicitly, in addition to the pion and the vector meson, consistently with the chiral symmetry of QCD. We use the GHLS Lagrangian as a reliable basis which describes the spectral function sum rules [3].

The critical temperature T_c for the restoration of chiral symmetry in its Wigner-Weyl realization is defined as the temperature at which the vector and axial-vector current correlators, G_V and G_A, coincide and their spectra become degenerate. Thus, chiral symmetry restoration implies $\delta G = G_A - G_V = 0$ at T_c. Let us consider δG changing with temperature intrinsically. To achieve $\delta G = 0$ at the critical temperature, we assume non-dropping ρ mass at T_c and adopt the following ansatz of the temperature dependence of the *bare* axial-vector meson mass, $M_{a_1}^2(T) = M_\rho^2 + \delta M^2(T)$.

Figure 1 shows the temperature dependence of the vector spectral function in the chiral limit. One observes a systematic downward shift of the a_1 enhancement with increasing temperature, while the peak position corresponding to the ρ pole mass moves upward. At $T/T_c = 0.9$ the two bumps begin to overlap: the lower one corresponds to the ρ pole, and the upper one to the a_1-π contribution. Finally at $T = T_c$, M_{a_1} becomes degenerate with M_ρ around $\sqrt{s} \simeq 1\,\mathrm{GeV}$ and the two bumps are on top of each other. The V-A mixing eventually vanishes there. This feature is a direct consequence of vanishing coupling of a_1 to ρ-π.

Figure 2 shows the effect of finite pion mass in the vector spectrum. For finite m_π the energy of the time-like virtual ρ meson splits into two branches corresponding to the processes, $\rho + \pi \to a_1$ and $\rho \to a_1 + \pi$, with thresholds $\sqrt{s} = M_{a_1} - m_\pi$ and $\sqrt{s} = M_{a_1} + m_\pi$. This results in the threshold effects seen as a shoulder at $\sqrt{s} = M_{a_1} - m_\pi$ and a bump above $\sqrt{s} = M_{a_1} + m_\pi$. Below T_c one observes the threshold effects moving downward with increasing temperature. It is remarkable that at T_c the spectrum shows almost no traces of a_1-ρ-π threshold effects. This indicates that at T_c *the* a_1 *meson mass nearly equals the* ρ *meson mass and the* a_1-ρ-π *coupling almost vanishes even in the presence of explicit chiral symmetry breaking.*

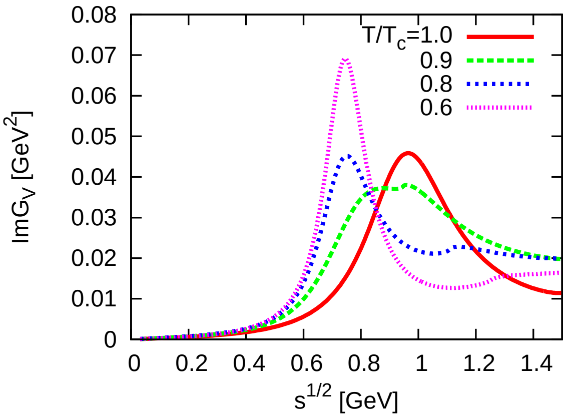

Fig. 1: The vector spectral function for $m_\pi = 0$ (left) at several temperatures $T/T_c = 0.6$-1.0.

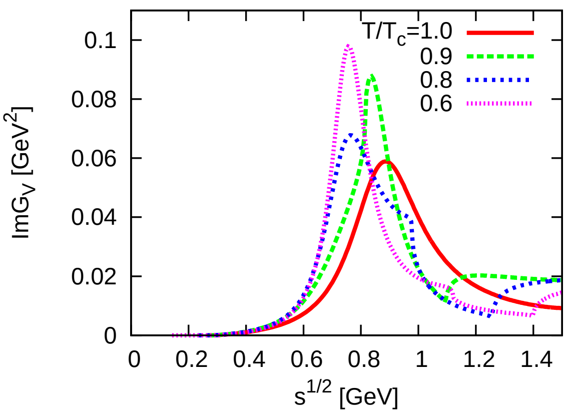

Fig. 2: Same as in Fig. 1 but for $m_\pi = 0$.

Studying dilepton production in relativistic heavy-ion collisions is an interesting application. The present investigation may be of some relevance for the high temperature and low baryon density scenarios encountered at RHIC and LHC.

References

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