Contribution ID: **603** Type: **Poster**

Tachyonic instability of the scalar mode prior to the QCD critical point based on the functional renormalization-group method in the two-flavor case

Tuesday 15 May 2018 19:20 (20 minutes)

We investigate spectral properties of the collective excitations around the QCD critical point (CP) by applying the functional renormalization-group (FRG) method to the two-flavor quark-meson model with current quark mass m_q being varied. The nature of the CP such as the soft modes is known to be affected by the value of m_q: We first determine the whole phase structure in the three-dimensional space $(T, , m_q)$ consisting of temperature T, quark chemical potential μ and m_q, with the tricritical point, $\mathrm{O}(4)$ and Z_2 critical lines being located; they altogether make a winglike shape quite reminiscent of those known in the condensed matters with a tricritical point. We then calculate the spectral functions in the scalar and pseudoscalar channel around the critical points. We find that the sigma mesonic mode becomes tachyonic with a superluminal velocity at finite momenta before the system reaches the Z_2 point from the lower density, even for m_q smaller than the physical value. One of the possible implications of the appearance of such a tachyonic mode at finite momenta is that the assumed equilibrium state with a uniform chiral condensate is unstable toward a state with an inhomogeneous σ condensate. No such anomalous behavior is found in the pseudoscalar channel. We find that the σ-to-2σ coupling due to finite m_q plays an essential role for the drastic modification of the spectral function.

Content type

Theory

Collaboration

Centralised submission by Collaboration

Presenter name already specified

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Session Classification: Poster Session

Track Classification: Phase diagram and search for the critical point