Phase structure of the Quark-Meson model

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I. INTRODUCTION

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II. 2 FLAVOR QUARK MESON MODEL

The effective action of the 2 flavor quark-meson model reads [1]

$$\Gamma_k[\Phi] = \int_x \{Z_{q,k}\bar{q}(\gamma_\mu\partial_\mu - \gamma_0\mu)q + \frac{1}{2}Z_{\phi,k}(\partial_\mu\phi)^2$$

$$+ h_k\bar{q}(T^0\sigma + i\gamma_5\vec{T}\cdot\vec{\pi})q + V_k(\rho) - c\sigma\} \tag{1}$$

with the integral $\int_x = \int_0^{1/T} d_{x_0}\int d^3x$. T and μ denote the temperature and quark chemical potential, respectively. The meson/quark wave function $Z_{\phi,k}/Z_{q,k}$ are scale and field dependent. Moreover, in this work we ignore the longitudinal and transversal splitting of Z_k, i.e., $Z_k^{\parallel}$ and $Z_k^{\perp}$, respectively, and an interesting discussion is presented in Ref. [2]. T^0 and $\vec{T}$ are generators of $SU(N_f = 2)$ with $\mathrm{Tr}(T^iT^j) = \frac{1}{2}\delta^{ij}$ and $T^0 = \frac{1}{\sqrt{N_f}}\mathbb{1}_{N_f\times N_f}$. Quark and meson interaction is encoded in Yukawa coupling h_k in Eq. (1). The effective potential $V_k(\rho)$ is scale and field dependent and chirally invariant with chirally invariant variable $\rho = \frac{1}{2}\phi^2$. $\phi = (\sigma, \vec{\pi})$ is the meson field and its vacuum expectation value $\phi_0 = (\sigma, 0)$. The linear sigma term $-c\sigma$ explicitly breaks the chiral symmetry.

We introduce the renormalized field and renormalized coupling parameters

$$\bar{\phi} = Z_\phi^{1/2}\phi, \quad \bar{h} = \frac{h}{Z_\phi^{1/2}Z_q} \tag{2}$$

And the field dependent renormalized dimensionless meson and quark masses are obtained by

$$\bar{m}_\pi = \frac{V_k'(\rho)}{k^2 Z_{\phi,k}} \tag{3}$$

$$\bar{m}_\sigma = \frac{V_k'(\rho) + 2\rho V_k''(\rho)}{k^2 Z_{\phi,k}} \tag{4}$$

$$\bar{m}_q = \frac{h_k^2\rho}{2k^2 Z_{q,k}^2} \tag{5}$$

the masses given above are curvature masses which distinguish from the pole and screening masses [3, 4]..

The QM model at various truncations have been investigated in Ref. [1, 2, 5–7]. However, all of these investigation are based on Taylor expansion technology which only consider field dependent at the neighborhood of vacuum expectation value ϕ_0, while the full field dependent is not included. In [5], they show a good match of chiral phase diagram between Taylor expansion solution and grid solution within LPA truncations at low chemical potential. However, the Taylor expansion technology disables to resolve the problem at high chemical potential and low temperature.

Due to the Matsubara

Then with the Wetterich equation

$$\partial_t\Gamma_k[\Phi] = \frac{1}{2}\mathrm{Tr}\, G_{\phi\phi}[\Phi]\partial_t R_k^\phi - \mathrm{Tr}\, G_{q\bar{q}}[\Phi]\partial_t R_k^q \tag{6}$$

with the regulators R_k^ϕ, R_k^q are defined in Eq...

$$\partial_t V_k(\rho) = \frac{k^4}{4\pi^2}\{(N_f^2 - 1)l_0^B(m_{\pi,k}, \eta_{\phi,k}; T)$$

$$+ l_0^B(m_{\sigma,k}, \eta_{\phi,k}; T)$$

$$- 4N_cN_f l_0^F(m_{q,k}, \eta_{q,k}; T, \mu)\} \tag{7}$$

here $l_0^{B/F}$ are threshold functions which are defined in A

$$\eta_{\phi,k} = \frac{1}{6\pi^2}\Big\{\frac{4}{k^2}\rho(V_k'(\rho))^2 \tag{8}$$

III. RESULTS

A. phase diagram at chiral limit

IV. SUMMARY AND DISCUSSIONS

In this work, we have studied

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Appendix A: Threshold Functions

$$l_0^B(\bar{m}_{\phi,k}^2,\eta_{\phi,k}) = \frac{2}{3}\frac{1}{\sqrt{1+\bar{m}_{\phi,k}^2}}\Big(1-\frac{\eta_{\phi,k}}{5}\Big)$$
$$\Big(\frac{1}{2}+n_B(\bar{m}_{\phi,k}^2,T)\Big) \tag{A1}$$
$$l_0^F(\bar{m}_{q,k}^2,\eta_{q,k}) = \frac{1}{3}\frac{1}{\sqrt{1+\bar{m}_{q,k}^2}}\Big(1-\frac{\eta_{q,k}}{4}\Big)$$
$$\Big(1-n_F(E-\mu)-n_F(E+\mu)\Big) \tag{A2}$$

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