Scalar σ meson at finite temperature in nonlocal quark model [1]

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Abstract

Properties and temperature behavior of π and σ bound states are studied in the framework of the nonlocal model with a separable interaction kernel based on the quark Dyson-Schwinger and the meson Bethe-Salpeter equations. $M_\pi(T)$, $f_\pi(T)$, $M_\sigma(T)$ and $\Gamma_{\sigma\to\pi\pi}(T)$ are considered above and below the deconfinement and chiral restoration transitions.

1 Introduction

Understanding the behavior of matter under extreme conditions is nowadays a challenge in the physics of strong interactions. Different regions of the QCD phase diagram are an object of interest, and major theoretical and experimental efforts have been dedicated to the physics of relativistic heavy–ion collisions looking for signatures of the quark gluon plasma (QGP) [1, 2, 3]. Restoration of symmetries and deconfinement are expected to occur at high density and/or temperature. In this regard, the study of observables of pseudoscalar and scalar mesons is particularly important. Since the origin of these mesons is associated with the phenomena of spontaneous and explicit chiral symmetry breaking, its temperature behavior is expected to carry relevant signs of a possible restoration of symmetries. Usually, the restoration of chiral symmetry at high temperature is connected to the transition from hadronic matter to the quark-gluon plasma. Effective chiral quark models are useful tools to explore the behavior of matter at nonzero temperatures. Nambu–Jona-Lasinio (NJL) [4] type models have been extensively used over the past years to describe low-energy features of hadrons and also to investigate the restoration of chiral symmetry in a hot medium [5]-[8]. This paper is devoted to the investigation of pseudoscalar and scalar mesons in hot matter within the framework of an effective nonlocal model. This work is the continuation of [9]. In Ref. [9], a special separable form of the effective gluon

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propagator is used in the quark Dyson - Schwinger equation (DSE) and the Bethe - Salpeter equation (BSE) for bound states. Only pseudoscalar and vector mesons are considered in that paper. Here we concentrate on the properties of the scalar σ meson at finite temperature.

2 Dyson - Schwinger equation with separable interaction

The dressed quark propagator $S(p)$ and meson Bethe - Salpeter (BS) amplitude $\Gamma(p,P)$ are solutions of the DSE

$$S(p)^{-1} = i\hat{p} + m_0 + \frac{4}{3}\int \frac{d^4q}{(2\pi)^4} g^2 D^{\rm eff}_{\mu\nu}(p-q)\gamma_\mu S(q)\gamma_\nu \qquad (1)$$

and the BSE

$$\Gamma(p,P) = \frac{4}{3}\int \frac{d^4q}{(2\pi)^4} g^2 D^{\rm eff}_{\mu\nu}(p-q)\gamma_\mu S(q_+)\Gamma(q,P)S(q_-)\gamma_\nu, \qquad (2)$$

where[2] $D^{\rm eff}_{\mu\nu}(p-q)$ is an "effective gluon propagator", m_0 is the current quark mass, P is the total momentum, and $q_\pm = q \pm P/2$. The form of equations (1) and (2) corresponds to the rainbow - ladder truncations of DSE and BSE.

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