Nonet meson properties in Nambu Jona-Lasinio model with dimensional regularization

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The Nambu Jona-Lasinio (NJL) model is one of the useful models of quantum chromodynamics, and it describes observed meson properties nicely. In this article, we study the nonet meson properties by using the NJL model with dimensional regularization at finite temperature and chemical potential. We find that the results show reasonable behaviors, which are similar to the ones seen in the model with the frequently used cutoff regularization. This may indicate that the model predictions are not drastically affected by the difference between the regularization procedures in the NJL model.

1 Introduction

The investigation of the meson properties has attracted a lot of attention in particle physics. To study them, we employ the Nambu Jona-Lasinio model [1] which is an useful effective model of QCD. The Lagrangian of our 3 flavor NJL model is written by

$$\begin{aligned}\mathcal{L}_{\rm NJL} = &\sum_{i,j}\bar{q}_i\left(i\partial\!\!\!/ - \hat{m}\right)_{ij} q_j + G\sum_a\Big[\big(\sum_{i,j}\bar{q}_i\lambda_a q_j\big)^2 + \big(\sum_{i,j}\bar{q}_i\, i\gamma_5\lambda_a q_j\big)^2\Big] \\ &- K\left[\det\bar{q}_i(1-\gamma_5)q_j + \text{h.c.}\,\right].\end{aligned}$$

Here the subscripts i, j represent the flavor indices, $\hat{m}$ is the current quark mass matrix $\mathrm{diag}(m_u, m_d, m_s)$, and λ_a are the Gell-Mann matrices in flavor space. G and K are the effective coupling constants for 4- and 6-fermion interactions.

Since the model is not renormalizable, the physical predictions depend on the regularization procedures. The most frequently used one is the three momentum cutoff method, and the model predicts the meson properties well (for reviews, see [2]). To test the other possible regularization method, we shall use the dimensional regularization here.

2 Nonet meson properties

Before performing the calculation for the meson properties, we have to set the model parameters. The model has 7 free parameters: current quark masses m_u, m_d, m_s, 4- and 6-point couplings G, K, dimension D, and the renormalization scale M_0 which are fixes so as to reproduce the meson properties. Here we use the following parameter set [3],

$$m_{u,d} = 5.5\text{MeV}, \quad m_s = 148\text{MeV}, \quad G = 0.023, \quad K = 8.4 \times 10^{-9}, \quad D = 2.78, \quad M_0 = 62.4\text{MeV}.$$

Having fixed the parameters, we are ready to study the nonet meson properties. Fig. 1

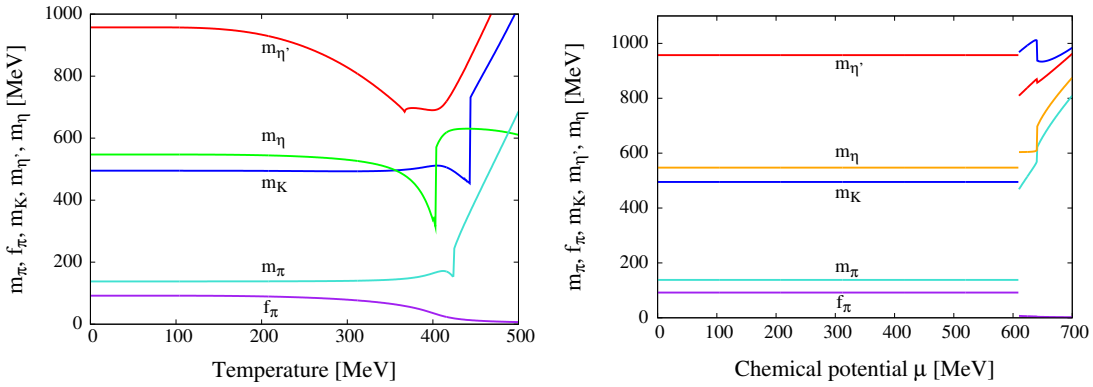

Figure 1: Meson properties. Left: finite T and $\mu = 0$. Right: $T = 10$MeV and finite μ.

shows the numerical results of the meson properties for finite temperature T and zero chemical potential μ (left), and low temperature $T = 10$MeV and finite μ (right). As we can see from the figure, the resulting meson properties show the similar behavior with the frequently used cutoff case. Thus the NJL model predicts the nonet meson properties nicely within the cutoff and dimensional regularizations. This may indicate that the model has regularization independent aspects, which is intriguing to study.

References

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