Lattice QCD study of hadrons at finite temperature

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Abstract

We present results for meson propagators in the temporal and the spatial directions at the temperatures below and above the deconfining transition in quenched lattice QCD.

1 Introduction

In this brief report, we introduce our investigations on the hadronic properties at finite temperature using lattice QCD simulation [1]. Increasing temperature, especially entering the deconfined phase, hadronic correlators are expected to change their nature. Forthcoming heavy-ion collision experiment will serve us the information to investigate these effects in detail. On the other hand, theoretical studies of such systems are not sufficient to predict possible effect quantitatively, because of the nonperturbative nature of QCD. Lattice QCD simulation is one of most powerful procedure to investigate such nonperturbative phenomena. However, studies of hadron structure at finite temperature encounters two difficulties. First, there is a severe limitation on the information of correlators in the (Euclidean) temporal direction unlike at $T = 0$, since the inverse of the temporal extent defines the temperature. For current computational power, it is difficult to carry out the simulation with sufficiently small lattice spacing to study the hadron structure near T_c in detail. To circumvent this problem, we use an anisotropic lattice, on which the temporal lattice spacing is smaller than the spatial one. As the second problem, the short extent in the temporal direction prevent us to distinguish the ground state from other states. We carefully choose the operator which creates the mesonic state and discuss the dependence of the correlators on these operators. We also measure the wave function of quarks inside the meson and observe the temperature effect on its shape.

2 Numerical simulations

The simulation is performed on $12^3 \times N_t$ lattice with lattice cutoffs $a_\sigma^{-1} = 0.85(3)$ GeV and $a_\tau^{-1} = 4.5(2)$ GeV, with $N_t = 72$ ($T \sim 0$), 20 ($T < T_c$), 16 and 12 ($T > T_c$). With the standard plaquette action, 60 gauge configurations are generated, and they are fixed to the Coulomb gauge. In the light quark region, the quark is described with the Wilson action. We use three types of the smearing function at the source and the sink and apply the variational analysis to the 3×3 correlators. We also measure the wave function normalized at the spatial origin and discuss their t-dependence. With these results and observing the dependence of the correlators on the quark mass, we conclude that the bound states still survive even at $T \sim 1.5T_c$. Then we extract the masses at each T and discuss the temperature dependence and chiral symmetry restoration. Although these results still suffer from large systematic uncertainties, successive investigations will give us further insight on the fate of hadrons at finite temperature.

The heavy quarkonium study with meson mass around J/ψ is also under progress. We use the Fermilab action to describe the quark field in the heavy mass region. In the effective mass plot, we find qualitatively different behavior of the correlators from the light meson case when the system enters into the deconfining phase. On the other hand, observing the wave function, there still remains the strong correlation between quark and antiquark. More detailed analyses are necessary for the argument of potential mass shift near T_c and J/ψ suppression effect in the plasma.

References

[1] QCD-TARO Collaboration (Ph. de Forcrand et al.), Nucl. Phys. B (Proc. Suppl.) **73** (1999) 420; `hep-lat/9901017`; Nucl. Phys. B (Proc. Suppl.) **83-84** (2000) 411 (`hep-lat/9911001`).