Heavy quark systems in anisotropic lattice QCD

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Recent experimental progress in flavor physics to look for the effect of new physics requires precise theoretical predictions from the standard model. For calculations of the hadronic matrix elements, the lattice QCD simulation is one of most promising approaches in which the systematic uncertainties can be reduced systematically. For the heavy-light systems, however, a precision less than 10% is hard to achieve with previously adopted frameworks for heavy quark such as effective theories and extrapolation from the region where the standard relativistic framework is applicable. The goal of this work is to construct a framework for lattice calculations of heavy-light matrix elements in a few percent systematic accuracy, as required by the experiments in progress.
For this purpose, we propose a systematic program making use of the anisotropic lattice, whose temporal lattice spacing, a_τ, is finer than the spatial one, a_σ [1-3]. The required characters of a framework for precision computations are as follows. (i) The continuum limit can be taken; (ii) A systematic improvement program, such as the nonperturbative renormalization technique, can be applied not only to the parameters in the action but also to the operators; (iii) A modest size of computational cost is required for systematic computation of matrix elements. We study the $O(a)$ improved Wilson quark action on the anisotropic lattice as a potential framework which fulfills these conditions.
Firstly, we examine the relativity relations in the dispersion relations of heavy-light mesons as well as of heavy quarkonium [1]. The tuning of bare anisotropy parameter is performed for the massless quark [3]. We investigate to which heavy quark mass the relativity relation is satisfied by this tuned parameter. In this region, we consider that we can also adopt the other parameters tuned at massless quark limit, with systematic errors under control. This is a crucial point of our approach, since for massless quark the nonperturbative renormalization technique is applicable to proper $O(a)$ improvement, while our present calculation adopt the mean-field improved tree-level values for $O(a)$ improving coefficients. The simulation is performed on a quenched lattice with the spatial lattice cutoff $a_\sigma^{-1} \simeq 1.6$ GeV and the anisotropy $\xi \equiv a_\sigma/a_\tau = 4$. We find that the bare anisotropy parameter tuned for the massless quark describes both the heavy-heavy and heavy-light mesons within 2% accuracy for the quark mass $a_\sigma m_Q < 0.8$, which covers the charm quark mass. This bare anisotropy parameter also successfully describes the heavy-light mesons in the quark mass region $a_\sigma m_Q \leq 1.2$ within the same accuracy. With this encouraging result, we calculate the spectrum and decay constants of heavy-light mesons in the charm quark mass region on quenched lattices [4].

References

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