Nonperturbative improvement of quark action on an anisotropic lattice

Hidenori Fukaya[1], Hideo Matsufuru[2], Syunsuke Negishi[3], Tetsuya Onogi[1], and Takashi Umeda[1]
[1] *Yukawa Institute for Theoretical Physics, Kyoto University, Kyoto 606-8502, Japan*
[2] *Computing Research Center, High Energy Accelerator Research Organization (KEK), Tsukuba 305-0801 Japan*
[3] *Department of Physics, Kyoto University, Kyoto 606-8502, Japan*

Determination of the CKM matrix elements is one of the most important problems in high energy physics. Although improvements in the experimental data may give indications for new physics beyond the Standard Model, at present, the bottleneck is the theoretical uncertainties in the calculations of hadronic processes including heavy quarks. The lattice QCD is a powerful tool to calculate hadronic matrix elements. In fact most of the present results are given by the lattice QCD calculations. In order to calculate the processes with high precision, e.g. a few percents level, however, we need special treatments for the heavy quarks on the lattice, since brute force calculation for heavy quarks is evidently beyond the present comutational resources. Several approaches are proposed for this purpose in the lattice study. We proposed anisotropic lattice, on which the temporal lattice spacing a_τ is finer than the spatial one a_σ, as one of the formulation for the heavy quarks on the lattice [1].

For the high precision study, the nonperturbative renormalization technique is inevitable to control $O(a)$ uncertainties [2]. Since the present technique is based on the PCAC relation, it can be applied for only massless quarks. Its mass dependent application is not yet developed. On the anisotropic lattice, however, the quark mass dependence of parameters will be suppressed, therefore the existing nonperturbative renomalization technieque will be applicable. This feature for our action is confirmed at tree-level, and some encouraging results are obtained also in numerical calculations with tree-level $O(a)$ improved action [1, 3, 4, 5].

As the next step, we are performing the nonperturbative improvement of the gauge and quark actions on the anisotropic lattice in the quenched approximation. At each lattice spacing and quark mass we have to determine, at least, the gauge anisotropy γ_G, quark anisotropy γ_F, and two clover coefficients c_E and c_B [3]. For the gauge anisotropy γ_G, we have already established the method to tune it with high precision using the Lüscher-Weise algorithm [7] and performed the determination [6]. For the quark field, we have to determined three parameters simultaneously. The γ_F is determined using the physical isotropy condition for which temporal and spatial meson correlators are measured, and the c_E is determined with the Schrëdinger functional (SF) method which is adopted in the nonperturbative improvement on isotropic lattice [2]. These procedures give sufficient precision for our purpose. However the last one, c_B, has some difficulties for its determination. It is difficult to determine the c_B using the usual SF method, where an abelian background field is adopted as the SF boundary. Therefore we investigated alternative method to determine the c_B using the self-dual background field and the constant chromo-magnetic background field. After these feasibility tests we have to investigate the relativistic properties of the action, with which the heavy-light matrix elements will be calculated.

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