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Heavy-light spectrum and decay constant from NRQCD with two flavors of dynamical quarks*

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We report on a study of B mesons on $N_f = 2$ full QCD configurations using an RG-improved gauge action, NRQCD heavy quark action and tadpole-improved clover light quark action. Results on the heavy-light spectrum and the decay constants from $16^3 \times 32$ lattices at $a^{-1} \approx 1.5$ GeV are presented, and compared with quenched results obtained with the same action combination at matching lattice spacings.

1. Introduction

The decay constant f_B is being studied extensively on the lattice because of its importance for the determination of CKM matrix elements. The spectrum of excited B mesons and b baryons is being measured in present experiments, whereas there exist only few lattice results on this subject.

In this article we report on our study of B mesons in two-flavor full QCD employing the NRQCD action for heavy quark and a tadpole-improved clover action for light quark. The dynamical configurations have been generated using the same light quark action and an RG-improved gauge action with a plaquette and a rectangular term. Details on our full QCD configurations can be found in Refs. [1]. A parallel study of B mesons using the clover action for heavy quark is presented in Ref. [5].

2. Simulation Details

We present results for two sets of dynamical lattices corresponding to the heaviest and the lightest sea quark in our configuration set at $\beta = 1.95$. The results are compared to those from quenched lattices generated with the same RG-improved gauge action at $\beta = 2.187$, the lattice spacing from the string tension matched to the dynamical lattice with $\kappa_{sea} = 0.1375$. Some details on these runs are given in Table 1.

Table 1
Parameters of lattices. The statistics for the dynamical lattices has been increased since Lattice'99. The scale is fixed by $\sqrt{\sigma} = 427$ MeV (for each sea quark for dynamical configurations)

$\kappa_{\rm sea}$	0.1375	0.1410	∞
m_{PS}/m_V	0.8048(9)	0.586(3)	–
a_σ^{-1}[GeV]	0.937(6)	1.127(10)	0.919(7)
#conf.	648	490	195

We take 5 κ values for the light valence quark corresponding to $m_{\rm PS}/m_{\rm V} \approx 0.8 - 0.5$. The strange quark mass m_s is fixed using the K and the ϕ meson. Our results for the B_s meson are obtained with m_s from the K, and the ϕ is used to estimate the systematic error.

*talk presented by A. Ali Khan

Table 2
Results for decay constants. Errors given in this table are statistical (including the statistical uncertainty in M_b), and, where applicable, the uncertainty in fixing the strange quark mass. Other systematic errors are discussed in the text.

$\kappa_{\rm sea}$	f_B[MeV]	f_{B_s}[MeV]	f_{B_s}/f_B
∞	193(4)	221(4)(+7)	1.147(10)(35)
0.1375	216(4)	250(4)(+8)	1.157(9)(+35)
0.1410	215(6)	251(6)(+6)	1.166(14)(+31)

For the heavy quarks, we use NRQCD at $O(1/M)$ with a symmetric evolution equation as defined in [2]. We employ 5 bare heavy quark masses, covering a range of roughly 2.5 − 4.5 GeV.

The heavy-light meson mass M is determined from the difference of the meson energy at finite momentum and at rest, assuming the dispersion relation, $E(\vec{p}) - E(0) = \sqrt{\vec{p}^2 + M^2} - M$. As a consistency check, we use both the B_d and the B_s meson to determine the b quark mass.

In our calculation of decay constants, the heavy-light current is corrected through $O(\alpha/M)$. The mixing coefficients between the lattice operators [2] contributing at this order to the time component of the axial vector current J_4, and the matching factor to the continuum current has been calculated [3] in one-loop perturbation theory,

$$J_4 = (1+\alpha\rho_0)J^{(0)}_{4,lat} + (1+\alpha\rho_1)J^{(1)}_{4,lat} + \alpha\rho_2 J^{(2)}_{4,lat}. \quad (1)$$

For the RG-improved gluon action, α_V has not been calculated, and we use a tadpole-improved one-loop expression for the $\overline{MS}$ coupling, $\alpha^{TI}_{\overline{MS}}(1/a)$.

3. Decay Constants

Our preliminary results for f_B, f_{B_s} and f_{B_s}/f_B are given in Table 2, along with the statistical error and, where applicable, the uncertainty in the determination of m_s. Additional systematic errors are estimated as follows: $O(\alpha^2)$ corrections, taken to be $\alpha^2 \times O(1)$, are 5%. A previous NRQCD calculation using the plaquette gluon action at $a^{-1} \sim 1$ GeV finds the tree level $O(1/M^2)$ corrections to be $\sim$ 2% [4]; we estimate our error from the truncation of the $1/M$ expansion to be $\sim$ 4%. The leading discretization effects from the light quarks and gluons of $O(\alpha a \Lambda_{QCD})$ and $O(a^2\Lambda^2_{QCD})$ are 5%. Added in quadrature, these estimates give 7%.

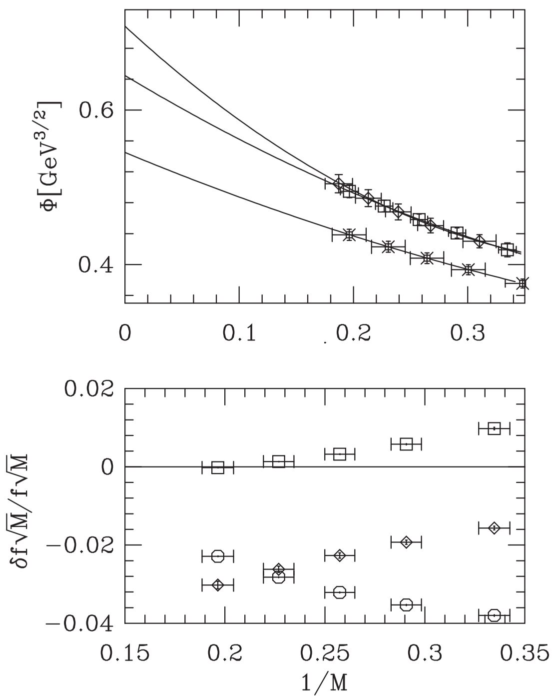

Figure 1. $\Phi \equiv (\alpha_s(M)/\alpha_s(M_B))^{(2/\beta_0)} f\sqrt{M}$ (top), and one-loop corrections to $f\sqrt{M}$ (bottom) as a function of the inverse pseudoscalar meson mass. In the upper plot, squares stand for $\kappa_{\rm sea} = 0.1375$, diamonds for $\kappa_{\rm sea} = 0.1410$ and fancy squares for quenched. In the lower plot, circles denote $\alpha\rho_0 J^{(0)}_{4,lat}/J_4$, squares, $\alpha\rho_1 J^{(1)}_{4,lat}/J_4$, and diamonds, $\alpha\rho_1 J^{(2)}_{4,lat}/J_4$.

Our two-flavor results for f_B and f_{B_s} given in Table 2 show a 10% increase compared to the quenched values (see also Fig. 1). We do not resolve any sea quark mass dependence. The dependence on the value of α_s is weaker than for the plaquette gauge action, and the difference between renormalized and bare decay constants is only about 5%.

In Fig. 1 we show the one-loop corrections to the current J_4 as a function of the heavy-light meson mass. In the B region, $1/M \sim 0.2$, we find the correction to $J^{(1)}_{4,lat}$ to be very small and the two other terms to contribute about the same amount. The $J^{(2)}_{4,lat}$ contribution also contains a discretization correction to the current first pointed out in [2]. We note that this discretization correction is considerably smaller for the RG gauge action than for the plaquette gauge action [3].

For f_{B_s}/f_B, we cannot resolve a difference between the three lattices.

In a parallel study of B mesons using clover heavy quarks [5], we have obtained f_B and f_{B_s} taking the chiral limit for sea quark at $\beta = 1.8, 1.95$ and 2.1. The results from that study at $\beta = 1.95$ agree within the estimated errors with the present results from NRQCD.

4. Spectrum

In Fig. 2, we give our results for several B splittings from the lattices with $n_f = 0$ and $n_f = 2, \kappa_{sea} = 0.1375$. The top part of the figure shows the $B^* - B$ splitting. At present, we cannot resolve any unquenching effects. For quarkonia, on the same lattices, the hyperfine splitting is found to increase from the quenched value only by a few MeV [6]. We find the $B^* - B$ splitting to be $\sim 30\%$ smaller than the experimental value. Possible sources of systematic error are the finiteness of the sea quark mass, the $O(\alpha)$ correction to the coefficient of the $\sigma \cdot B$ operator, and higher order relativistic corrections.

In the middle part of Figure 2, we show results for the $B^*_2 - B$ splitting, and in the lower part, the spin-averaged $\Lambda_b - \overline{B}$ splitting. We do not find significant unquenching effects. However, for definite conclusions, we need to study several sea quark masses and lattice spacings, which is in progress.

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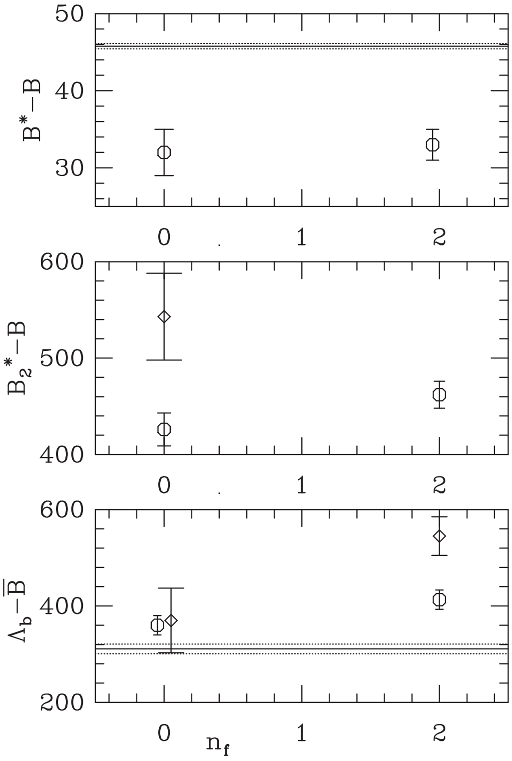

Figure 2. Meson and baryon splittings in MeV. Circles denote results from CP-PACS at $a^{-1}(\sqrt{\sigma}) \simeq 0.9$ GeV. Diamonds stand for results from [7] (quenched) and [8] ($n_f = 2$). Only statistical errors are shown. The solid line denotes the experimental value, the dashed lines, its error.

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