Pseudoscalar-meson-octet-baryon coupling constants in two-flavor lattice QCD

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We evaluate the πNN, $\pi \Sigma \Sigma$, $\pi \Lambda \Sigma$, $K \Lambda N$ and $K \Sigma N$ coupling constants and the corresponding monopole masses in lattice QCD with two flavors of dynamical quarks. The parameters representing the SU(3)-flavor symmetry are computed at the point where the three quark flavors are degenerate at the physical s-quark mass. In particular, we obtain $\alpha \equiv F/(F + D) = 0.395(6)$. The quark-mass dependences of the coupling constants are obtained by changing the u- and the d-quark masses. We find that the SU(3)-flavor parameters have weak quark-mass dependence and thus the SU(3)-flavor symmetry is broken by only a few percent at each quark-mass point we consider.

Meson-baryon coupling constants are important ingredients for hadron physics as they provide a measure of baryon-baryon interactions in terms of one boson exchange (OBE) models, and production of mesons off the baryons. In phenomenological potential models, the meson-baryon coupling constants are determined so as to reproduce the nucleon-nucleon, hyperon-nucleon, and the hyperon-hyperon interactions in terms of, *e.g.*, OBE models. On the other hand, it is an important issue to determine the coupling constants at the hadronic vertices directly from QCD, the underlying theory of the strong interactions. The only method we know that provides a first-principles calculation of hadronic phenomena is lattice QCD, which serves as a valuable tool to determine the hadron couplings in a model-independent way.

Among other meson-baryon coupling constants, the πNN coupling constant, $g_{\pi NN}$, which enters as a fundamental quantity in low-energy dynamics of nucleon-nucleon and pion-nucleon, has been a subject of intense investigation. It is defined as the πNN form factor, $g_{\pi NN}(q^2)$, at zero momentum transfer, $q^2 = 0$. The value of the coupling constant at the pion pole is relatively well-known from experiment: $g_{\pi NN}^2(m_\pi^2)/4\pi \simeq 13.6$ (see, *e.g.*, Ref. [1,2] for a review). The value at zero-momentum transfer can be extracted from the Goldberger-Treimann relation (GTR), $g_{\pi NN} \equiv g_A m_N/f_\pi \sim 12.8$, where f_π is the pion decay constant and m_N and g_A are the mass and the axial-vector coupling constant of the nucleon, respectively. An earlier determination of the πNN coupling constant from a quenched-lattice QCD calculation, which reports $g_{\pi NN} = 12.7 \pm 2.4$ [3], is in agreement with the phenomenological value. In the SU(3)-flavor [SU(3)$_F$] symmetric limit, one can classify the pseudoscalar-meson–octet-baryon coupling constants in terms of two parameters: the πNN coupling constant and the $\alpha = F/(F + D)$ ratio of the pseudoscalar octet [4]. This systematic classification is expected to govern all the meson-baryon couplings, however as we move from the symmetric case to the

realistic one, the SU(3)$_F$ breaking occurs as a result of the s-quark mass and the physical masses of the baryons and mesons. The broken symmetry no longer provides a pattern for the meson-baryon coupling constants, and therefore they should be individually calculated based on the underlying theory, QCD.

In this work we extract the coupling constants $g_{\pi NN}$, $g_{\pi \Sigma \Sigma}$, $g_{\pi \Lambda \Sigma}$, $g_{K \Lambda N}$, and $g_{K \Sigma N}$ (denoted by $g_{MBB'}$ hereafter) by employing lattice QCD with two flavors of dynamical quarks. The evaluation of the coupling constants allows us to check the following SU(3)$_F$ relations:

$$g_{\pi NN} = g, \qquad g_{\pi \Sigma \Sigma} = 2g\alpha, \qquad g_{\pi \Lambda \Sigma} = \frac{2}{\sqrt{3}} g(1 - \alpha),$$

$$g_{K \Lambda N} = -\frac{1}{\sqrt{3}} g(1 + 2\alpha), \qquad g_{K \Sigma N} = g(1 - 2\alpha), \quad (1)$$

which phenomenologically work rather well but are not known *a priori* to hold.

The pseudoscalar current matrix element is written as

$$\langle \mathcal{B}(\mathbf{p}) | P(0) | \mathcal{B}'(\mathbf{p}') \rangle = g_P(q^2) \bar{u}(\mathbf{p}) i \gamma_5 u(\mathbf{p}'), \qquad (2)$$

where $g_P(q^2)$ is the pseudoscalar form factor, $q_\mu = p'_\mu - p_\mu$ is the transferred four-momentum and $P(x) = \bar{\psi}(x) i \gamma_5 \frac{\tau_3}{2} \psi(x)$ is the pseudoscalar current. We compute this matrix element using the ratio [5,6]

$$R(t_2, t_1; \mathbf{p}', \mathbf{p}; \Gamma; \mu)$$
$$= \frac{\langle G^{\mathcal{B}P\mathcal{B}'}(t_2, t_1; \mathbf{p}', \mathbf{p}; \Gamma) \rangle}{\langle G^{\mathcal{B}'}(t_2; \mathbf{p}'; \Gamma_4) \rangle}$$
$$\times \left[\frac{\langle G^{\mathcal{B}}(t_2 - t_1; \mathbf{p}; \Gamma_4) \rangle}{\langle G^{\mathcal{B}'}(t_2 - t_1; \mathbf{p}'; \Gamma_4) \rangle} \right.$$
$$\times \left. \frac{\langle G^{\mathcal{B}'}(t_1; \mathbf{p}'; \Gamma_4) \rangle \langle G^{\mathcal{B}'}(t_2; \mathbf{p}'; \Gamma_4) \rangle}{\langle G^{\mathcal{B}}(t_1; \mathbf{p}; \Gamma_4) \rangle \langle G^{\mathcal{B}}(t_2; \mathbf{p}; \Gamma_4) \rangle} \right]^{1/2}, \qquad (3)$$

where the baryonic two- and three-point correlation functions are, respectively, defined as

$$\langle G^{\mathcal{B}}(t;\mathbf{p};\Gamma_4)\rangle = \sum_{\mathbf{x}} e^{-i\mathbf{p}\cdot\mathbf{x}}\Gamma_4^{\alpha\alpha'}\langle \text{vac}|T[\eta_{\mathcal{B}}^{\alpha}(x)\bar{\eta}_{\mathcal{B}'}^{\alpha'}(0)]|\text{vac}\rangle,$$

$$(4)$$

$$\langle G^{\mathcal{B}P\mathcal{B}'}(t_2, t_1;\mathbf{p}',\mathbf{p};\Gamma)\rangle$$
$$= -i\sum_{\mathbf{x_2},\mathbf{x_1}} e^{-i\mathbf{p}\cdot\mathbf{x_2}}e^{i\mathbf{q}\cdot\mathbf{x_1}}\Gamma^{\alpha\alpha'}\langle \text{vac}|T[\eta_{\mathcal{B}}^{\alpha}(x_2)P(x_1)\bar{\eta}_{\mathcal{B}'}^{\alpha'}(0)]$$
$$\times |\text{vac}\rangle, \qquad (5)$$

with $\Gamma \equiv \gamma_3\gamma_5\Gamma_4$ and $\Gamma_4 \equiv (1+\gamma_4)/2$. The baryon interpolating fields are given as

$$\eta_N(x) = \epsilon^{abc}[u^{Ta}(x)C\gamma_5 d^b(x)]u^c(x),$$

$$\eta_\Sigma(x) = \epsilon^{abc}[s^{Ta}(x)C\gamma_5 u^b(x)]u^c(x),$$

$$\eta_\Lambda(x) = \frac{1}{\sqrt{6}}\epsilon^{abc}\{[u^{Ta}(x)C\gamma_5 s^b(x)]d^c(x) \qquad (6)$$
$$- [d^{Ta}(x)C\gamma_5 s^b(x)]u^c(x)$$
$$+ 2[u^{Ta}(x)C\gamma_5 d^b(x)]s^c(x)\},$$

where $C = \gamma_4\gamma_2$ and a, b, c are the color indices. t_1 is the time when the meson interacts with a quark and t_2 is the time when the final baryon state is annihilated. The ratio in Eq. (3) reduces to the desired pseudoscalar form factor when $t_2 - t_1$ and $t_1 \gg a$, viz.

$$R(t_2, t_1;\mathbf{0},\mathbf{p};\Gamma;\mu) \xrightarrow[t_2-t_1\gg a]{t_1\gg a} \frac{g_P^L(q^2)}{[2E(E+m)]^{1/2}}q_3, \qquad (7)$$

where m and E are the mass and the energy of the initial baryon, respectively, and $g_P^L(q^2)$ is the lattice pseudoscalar form factor. Since the ratio in (7) is proportional to the transferred momentum q_3, it cannot be used directly to obtain $g_P^L(q^2)$ at $q^2 = 0$. We apply a procedure (similarly to the one in Ref. [3]) of seeking plateau regions as a function of t_1 in the ratio (7) and calculating $g_P^L(q^2)$ at the momentum transfers $\mathbf{q}^2a^2 = n(2\pi/L)^2$ (for the lowest nine n points), where L is the spatial extent of the lattice. We then obtain the meson-baryon form factor via the relation

$$g_P^L(q^2) = \frac{G_M g_{MBB'}(q^2)}{m_M^2 - q^2}, \qquad (8)$$

assuming that the pseudoscalar form factors are dominated

TABLE I. The fitted values of m_π, m_K, m_N, m_Λ, and m_Σ in lattice units.

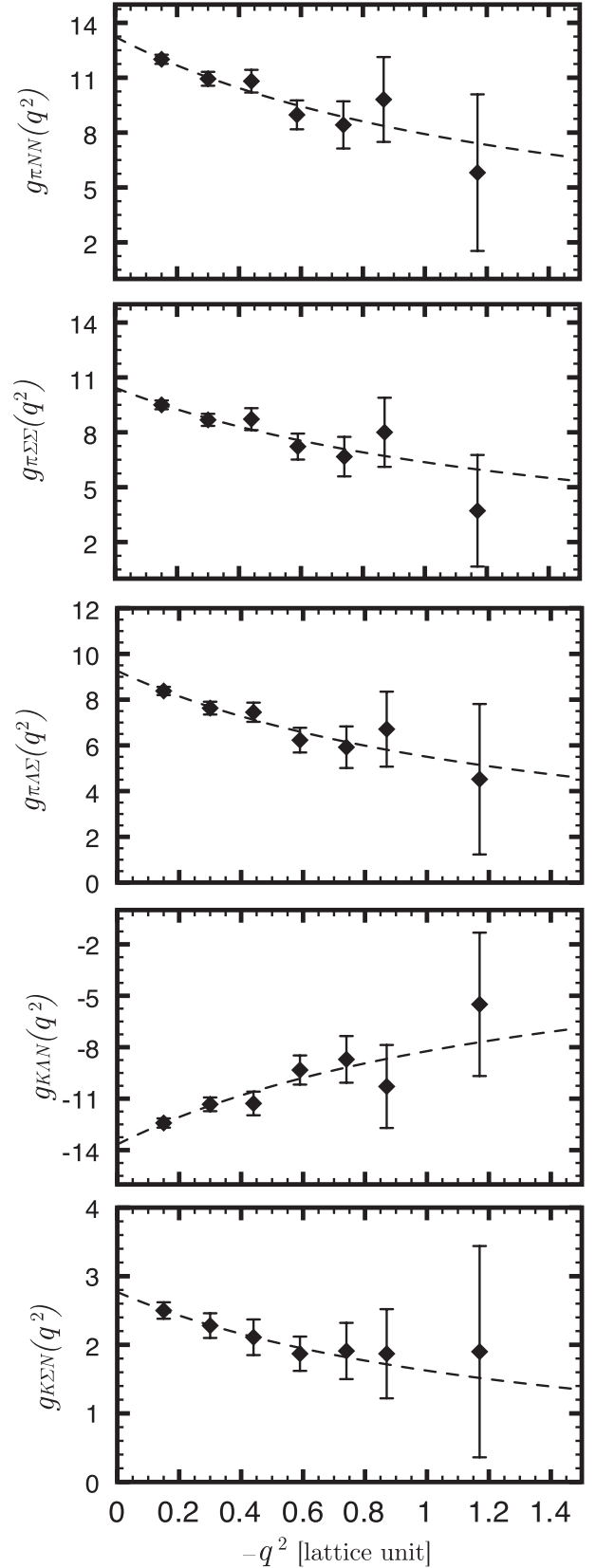| $\kappa_{\text{val}}^{u,d}$	m_π	m_K	m_N	m_Λ	m_Σ
0.1375	0.899(1)	0.834(1)	1.707(06)	1.658(06)	1.648(06)
0.1390	0.737(1)	0.725(1)	1.475(05)	1.466(06)	1.464(06)
0.1393	0.713(1)	0.713(1)	1.455(06)	1.455(06)	1.455(06)
0.1400	0.603(1)	0.635(1)	1.289(05)	1.312(04)	1.318(05)
0.1410	0.440(1)	0.533(1)	1.051(08)	1.114(06)	1.134(07)

FIG. 1. The q^2 dependence of the form factors, $g_{MBB'}$ for $\kappa_{\text{val}}^{u,d} = 0.1393$. The diamonds show the lattice data, and the solid curves denote the fitted form factors.

by the pseudoscalar-meson poles. Here $G_M \equiv \langle \text{vac}|P(0)|M\rangle$ is extracted from the two-point mesonic correlator $\langle P(x)P(0)\rangle$. Finally we extract the meson-baryon coupling constants $g_{MBB'} = g_{MBB'}(0)$ by means of a monopole form factor:

$$g_{MBB'}(q^2) = g_{MBB'} \frac{\Lambda^2_{MBB'}}{\Lambda^2_{MBB'} - q^2}. \qquad (9)$$

We employ a $16^3 \times 32$ lattice with two flavors of dynamical quarks and use the gauge configurations generated by the CP-PACS collaboration [7] with the renormalization group improved gauge action and the mean-field improved clover quark action. We use the gauge configurations at $\beta = 1.95$ with the clover coefficient $c_{SW} = 1.530$, which give a lattice spacing of $a = 0.1555(17)$ fm ($a^{-1} = 1.267$ GeV), which is determined from the ρ-meson mass. The simulations are carried out with four different hopping parameters for the sea and the u,d valence quarks, κ_{sea}, $\kappa^{u,d}_{val} = 0.1375, 0.1390, 0.1400,$ and 0.1410, which correspond to quark masses of $\sim 150, 100, 65,$ and 35 MeV, and we use 490, 680, 680, and 490 such gauge configurations, respectively. The hopping parameter for the s valence quark is fixed to $\kappa^s_{val} = 0.1393$ so that the Kaon mass is reproduced [7], which corresponds to a quark mass of ~ 90 MeV. We employ smeared source and smeared sink, which are separated by 8 lattice units in the temporal direction. Source and sink operators are smeared in a gauge-invariant manner with the root mean square radius of 0.6 fm. All the statistical errors are estimated via the jackknife analysis.

In Table I, we give the fitted values of the meson and baryon masses as obtained from the two-point correlation function in Eq. (4). We extract the meson-baryon coupling constants, $g_{MBB'}$, and the corresponding monopole masses, $\Lambda_{MBB'}$, for each $\kappa^{u,d}_{val}$. In Fig. 1, the q^2 dependence of the form factors, $g_{MBB'}$, for $\kappa^{u,d}_{val} = 0.1393$ is given. Our complete results are presented in Table II: We give the fitted value of the πNN coupling constant and the corresponding monopole mass in lattice unit, as well as the fitted values of the $\pi\Sigma\Sigma$, $\pi\Lambda\Sigma$, $K\Lambda N$ and $K\Sigma N$ coupling constants and the corresponding monopole masses normalized with $g_{\pi NN}$ and $\Lambda_{\pi NN}$, respectively. In Table II, $g^R_{MBB'}$ and $\Lambda^R_{MBB'}$ denote $g_{MBB'}/g_{\pi NN}$ and $\Lambda_{MBB'}/\Lambda_{\pi NN}$, respectively. We

expect that the systematic errors cancel out to some degree in the ratios of the coupling constants and those of the monopole masses. We give a graphical representation of our results in Figs. 2–4. In Fig. 2 we plot $g_{\pi NN}$ and $\Lambda_{\pi NN}$ as a function of the pion-mass squared. The ratios of the $\pi\Sigma\Sigma$, $\pi\Lambda\Sigma$, $K\Lambda N$, and $K\Sigma N$ coupling constants to the πNN coupling constant, and the corresponding monopole masses normalized with $\Lambda_{\pi NN}$ are shown in Fig. 3. $g_{\pi NN}$ is consistent with the experimental value at $\kappa \leq 0.1393$ and $\Lambda_{\pi NN}$ decreases towards the chiral limit. Note that, in addition to the monopole form, we have tried fitting the form factors to dipole and exponential forms, which have produced coupling-constant ratios consistent with those given in Table II.

Having discussed the results for $g_{\pi NN}$, we proceed with the octet-meson–baryon coupling constants. We first concentrate on the SU(3)-flavor symmetric case, where $\kappa^{u,d}_{val} \equiv \kappa^s_{val} = 0.1393$ and the SU(3)$_F$ relations in Eq. (1) are exact. (Here we take $\kappa^{u,d}_{sea} = 0.1390$ and neglect the difference in the sea-quark effects.) As expected, all the coupling ratios, $g^R_{\pi\Sigma\Sigma}$, $g^R_{\pi\Lambda\Sigma}$, $g^R_{K\Lambda N}$, and $g^R_{K\Sigma N}$ are well reproduced with $\alpha = 0.395(6)$, which is obtained by a global fit. The ratios of the monopole masses, $\Lambda^R_{\pi\Sigma\Sigma}$, $\Lambda^R_{\pi\Lambda\Sigma}$, $\Lambda^R_{K\Lambda N}$, and $\Lambda^R_{K\Sigma N}$, are consistent with unity. The obtained value of α is consistent with that in the SU(6) spin-flavor symmetry ($\alpha = 2/5$) [8], which is the symmetry based on the nonrelativistic quark model. We have also tried fixing all the quark masses at $\kappa^{u,d,s}_{val} = 0.1390$. $g_{\pi NN}$ and the ratios of the coupling constants obtained in this case are as follows: $g_{\pi NN} = 12.769(495)$, $g^R_{\pi\Sigma\Sigma} = 0.785(10)$, $g^R_{\pi\Lambda\Sigma} = 0.704(6)$, $g^R_{K\Lambda N} = -1.003(6)$, and $g^R_{K\Sigma N} = 0.211(10)$. We have found that the coupling constants again satisfy SU(3)$_F$ and the resulting $\alpha = 0.387(5)$ is consistent with that obtained at $\kappa^{u,d,s}_{val} = 0.1393$. In Fig. 5 we plot the ratio in Eq. (3) for $g_{\pi NN}$ as a function of current-insertion point, in order to show the plateau regions. We present the data at $\kappa^{u,d,s}_{val} = 0.1393$ for the first three momentum-transfer values.

We next discuss the SU(3)$_F$ broken case. The quark-mass dependences we find for $g^R_{MBB'}$ and $\Lambda^R_{MBB'}$ are not large. The ratios of the coupling constants, $g^R_{MBB'}$, are similar in value to those in the SU(3)$_F$ symmetric limit, and the monopole-mass ratios, $\Lambda^R_{MBB'}$, are almost unity

TABLE II. The fitted value of the πNN coupling constant and the corresponding monopole mass (given in lattice units), together with the fitted values of the $\pi\Sigma\Sigma$, $\pi\Lambda\Sigma$, $K\Lambda N$ and $K\Sigma N$ coupling constants and the corresponding monopole masses normalized with $g_{\pi NN}$ and $\Lambda_{\pi NN}$, respectively. Here, we define $g^R_{MBB'} = g_{MBB'}/g_{\pi NN}$ and $\Lambda^R_{MBB'} = \Lambda_{MBB'}/\Lambda_{\pi NN}$.

| $\kappa^{u,d}_{val}$	$g_{\pi NN}$	$\Lambda_{\pi NN}$	$g^R_{\Sigma\Sigma}$	$g^R_{\pi\Lambda\Sigma}$	$g^R_{K\Lambda N}$	$g^R_{K\Sigma N}$	$\Lambda^R_{\pi\Sigma\Sigma}$	$\Lambda^R_{\pi\Lambda\Sigma}$	$\Lambda^R_{K\Lambda N}$	$\Lambda^R_{K\Sigma N}$
0.1375	13.953(412)	1.053(123)	0.759(11)	0.698(11)	−1.038(07)	0.231(14)	1.074(065)	0.908(039)	1.011(27)	0.714(118)
0.1390	13.257(448)	1.228(189)	0.785(12)	0.697(07)	−1.034(07)	0.209(12)	1.020(066)	0.988(042)	1.006(28)	0.978(223)
0.1393	13.236(478)	1.223(202)	0.789(13)	0.699(08)	−1.033(08)	0.209(13)	1.020(068)	0.989(044)	1.009(30)	0.970(236)
0.1400	13.098(393)	1.013(111)	0.781(13)	0.723(08)	−1.017(07)	0.242(15)	1.034(053)	0.970(033)	1.026(24)	0.802(124)
0.1410	12.834(1.092)	0.719(123)	0.781(38)	0.756(28)	−1.007(30)	0.260(30)	1.083(106)	0.985(074)	1.032(58)	0.958(191)
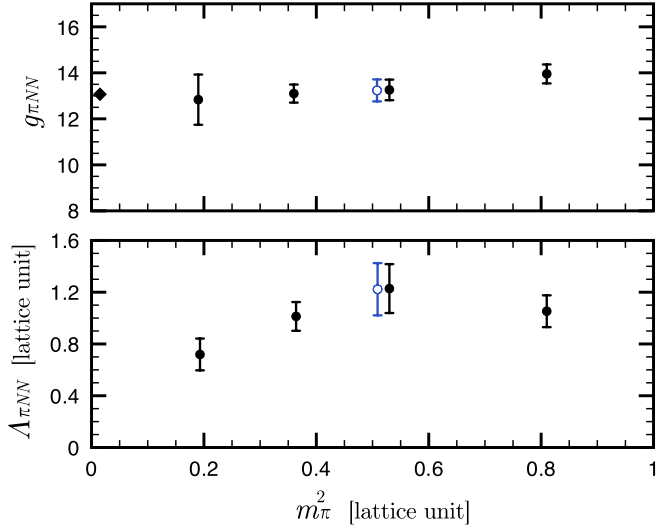
FIG. 2 (color online). $g_{\pi NN}$ and $\Lambda_{\pi NN}$ as a function of m_π^2. The empty circle denotes the $SU(3)_F$ limit and the diamond marks the experimental result.

independently of the quark masses. This suggests that the $SU(3)_F$ breaking is small at the quark masses we consider. Our data do not allow a direct determination of $SU(3)_F$ breaking in the chiral limit, as we have flavor-symmetric data only at $\kappa_{val}^{u,d} \equiv \kappa_{val}^s = 0.1393$. On the other hand, the value of $g_{\pi NN}$ at the chiral point is well-known, which may serve as a reference point for us to obtain a measure of $SU(3)_F$ breaking. For this purpose, we construct the following three sets of relations:

$$A_1 \equiv \frac{1}{2}(\sqrt{3}g^R_{\pi\Lambda\Sigma} + g^R_{\pi\Sigma\Sigma}), \qquad A_2 \equiv g^R_{K\Sigma N} + g^R_{\pi\Sigma\Sigma},$$

$$A_3 \equiv \frac{1}{2}(g^R_{K\Sigma N} - \sqrt{3}g^R_{K\Lambda N}), \qquad A_4 \equiv -g^R_{\pi\Sigma\Sigma} - \sqrt{3}g^R_{K\Lambda N},$$

$$A_5 \equiv \frac{1}{\sqrt{3}}(g^R_{\pi\Lambda\Sigma} - g^R_{K\Lambda N}), \qquad A_6 \equiv \sqrt{3}g^R_{\pi\Lambda\Sigma} - g^R_{K\Sigma N},$$

$$(10)$$

$$B_1 \equiv \frac{1}{4}(\sqrt{3}g^R_{\pi\Lambda\Sigma} + 3g^R_{\pi\Sigma\Sigma} + 2g^R_{K\Sigma N}),$$

$$B_2 \equiv \frac{1}{4}(2g^R_{\pi\Sigma\Sigma} + 3g^R_{K\Sigma N} - \sqrt{3}g^R_{K\Lambda N}),$$

$$(11)$$

$$B_3 \equiv \frac{1}{\sqrt{12}}(g^R_{\pi\Lambda\Sigma} - 4g^R_{K\Lambda N} - \sqrt{3}g^R_{\pi\Sigma\Sigma}),$$

$$B_4 \equiv \frac{1}{\sqrt{12}}(4g^R_{\pi\Lambda\Sigma} - \sqrt{3}g^R_{K\Sigma N} - g^R_{K\Lambda N}),$$

and

$$C_1 \equiv \frac{1}{2}(\sqrt{3}g^R_{\pi\Lambda\Sigma} - \sqrt{3}g^R_{K\Lambda N} - g^R_{\pi\Sigma\Sigma} - g^R_{K\Sigma N}), \quad (12)$$

which can be readily obtained from those in Eq. (1). In the $SU(3)_F$ symmetric limit, the above equations satisfy $A_1 \equiv$
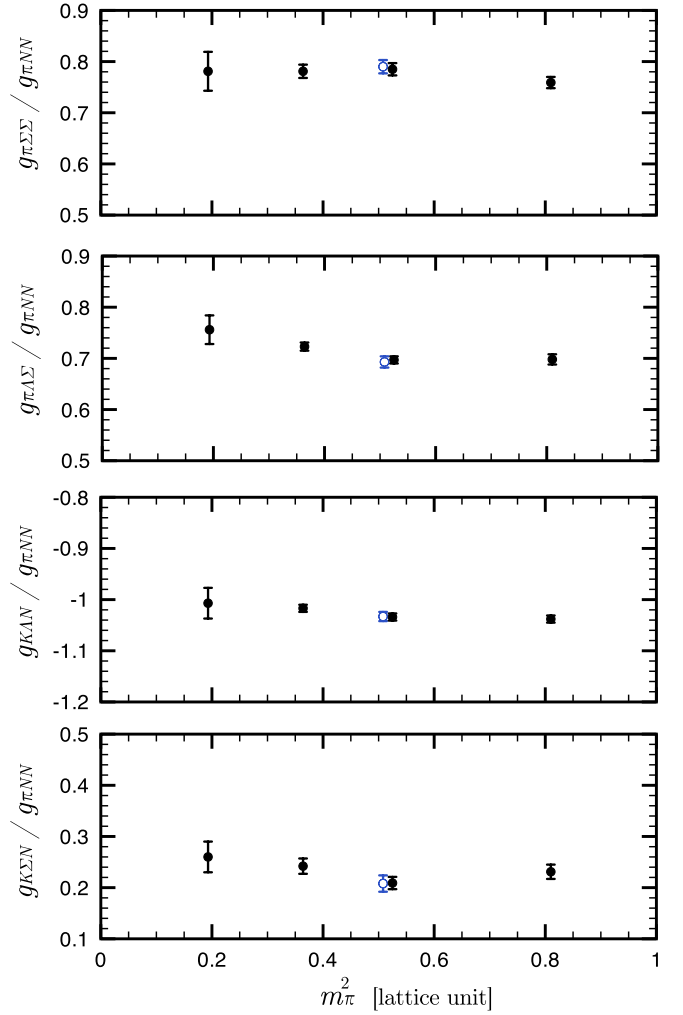

FIG. 3 (color online). The $\pi\Sigma\Sigma$, $\pi\Lambda\Sigma$, $K\Lambda N$ and $K\Sigma N$ coupling constants normalized with $g_{\pi NN}$ as a function of m_π^2. The empty circle denotes the $SU(3)_F$ limit.

$\ldots \equiv A_6 \equiv B_1 \equiv \ldots \equiv B_4 \equiv C_1 = 1$, which can be verified by inserting the coupling constants at $\kappa_{val}^{u,d} = 0.1393$ in Table II. At other quark masses, the deviations from unity represent the amount of $SU(3)_F$ breaking. Inserting the values of the coupling constants corresponding to the lowest quark mass we consider in Table II into (10)–(12), we find $A_1 = 1.045(29)$, $A_2 = 1.040(30)$, $A_3 = 1.002(25)$, $A_4 = 0.963(42)$, $A_5 = 1.017(22)$, $A_6 = 1.049(40)$, $B_1 = 1.043(28)$, $B_2 = 1.021(24)$, $B_3 = 0.990(28)$, $B_4 = 1.033(28)$, and $C_1 = 1.006(27)$, which indicate a breaking in $SU(3)_F$ by less than 10%. Moreover, we define the average $SU(3)_F$ breaking as follows:

$$\delta_{SU(3)} = \frac{1}{11} \sum_{n,X=A,B,C} |1 - X_n|, \quad (13)$$

which amounts to $\delta_{SU(3)} = 0.014(03)$, 0.003(02), 0.012 (02), and 0.028(17) for the quark masses at ~ 150, 100, 65, and 35 MeV, respectively. This suggests for the
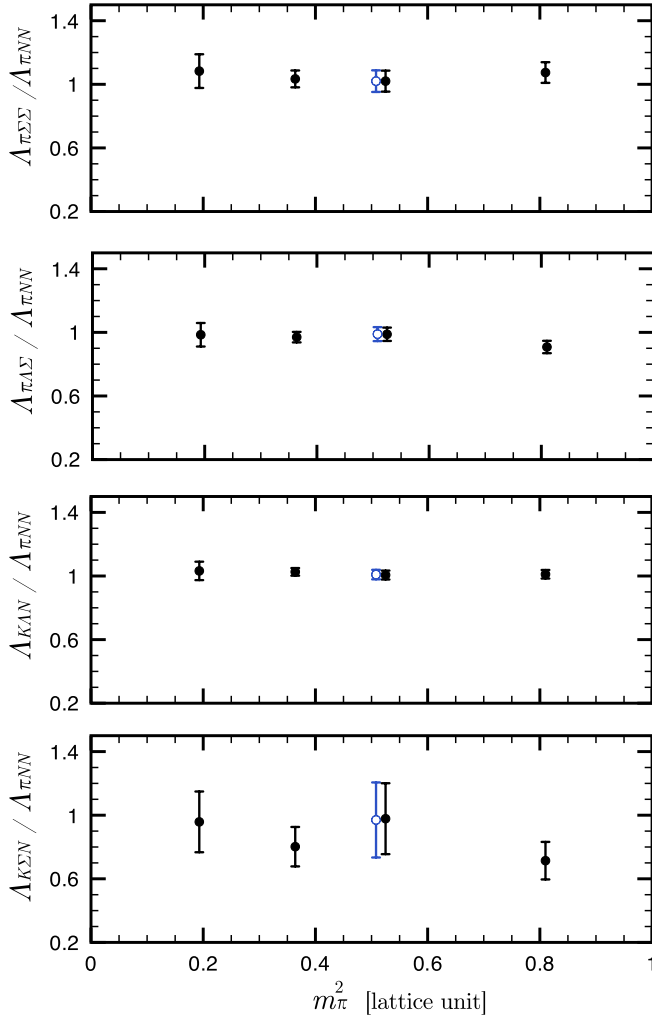
FIG. 4 (color online).   Same as Fig. 3 but for monopole masses $\Lambda_{\pi\Sigma\Sigma}$, $\Lambda_{\pi\Lambda\Sigma}$, $\Lambda_{K\Lambda N}$ and $\Lambda_{K\Sigma N}$ normalized with $\Lambda_{\pi NN}$.
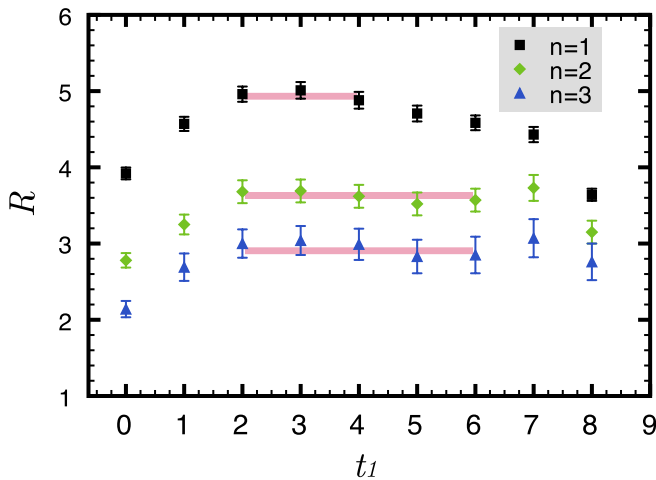

FIG. 5 (color online).   The ratio in Eq. (3) for $g_{\pi NN}$ as a function of current-insertion point, t_1, at $\kappa_{\mathrm{val}}^{u,d,s} = 0.1393$ for the first three momentum-transfer values. The bands represent the adopted plateau regions.
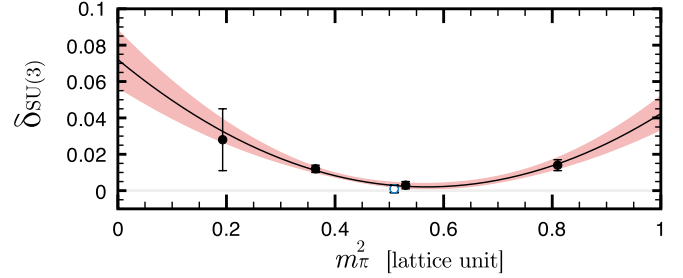

FIG. 6 (color online).   The value of $\delta_{\mathrm{SU}(3)}$ as a function of m_π^2. The curve and the shaded region denote linear chiral extrapolations with errors.

pseudoscalar-meson couplings of the octet baryons that $SU(3)_F$ is a good symmetry in the quark-mass range we consider, which is broken by only a few percent. We have also tried a quadratic fit of $\delta_{\mathrm{SU}(3)}$ and extracted $\delta_{\mathrm{SU}(3)} = 0.072(16)$ in the chiral limit. Figure 6 shows the value of $\delta_{\mathrm{SU}(3)}$ as a function of m_π^2 and the chiral extrapolations with errors. In Fig. 7, we plot the value of α as obtained from a global fit of the $SU(3)_F$ relations at each quark mass we consider. α slightly decreases toward the chiral limit. The deviation of α in the present quark-mass range is at most 10%, whereas that of $\delta_{\mathrm{SU}(3)}$ is less than 5%. We infer from this that the deviation in α should be small in the chiral limit, as we find that the ratios of the coupling constants have weak quark-mass dependence. The $SU(3)_F$ breaking effect seems to appear in α rather than in $SU(3)_F$ relations ($\delta_{\mathrm{SU}(3)}$). We have also repeated our analysis with local source and local sink for consistency check. In Fig. 7, we show the values of α as obtained from such a setup as well, where both analysis lead to consistent results with each other.

In summary, we have evaluated the pseudoscalar-meson–octet-baryon coupling constants, $g_{\pi NN}$, $g_{\pi\Sigma\Sigma}$, $g_{\pi\Lambda\Sigma}$, $g_{K\Lambda N}$ and $g_{K\Sigma N}$, in two-flavor lattice QCD with the hopping parameters κ_{sea}, $\kappa_{\mathrm{val}}^{u,d} = 0.1375$, 0.1390, 0.1400 and 0.1410, which correspond to quark masses of
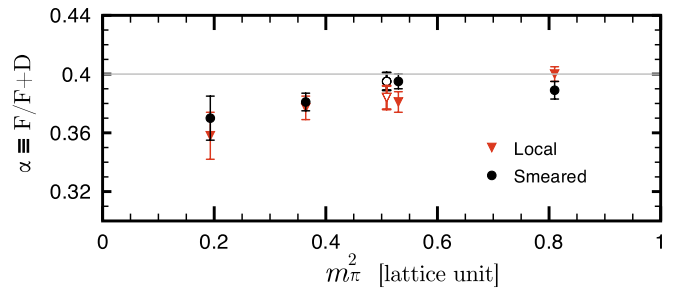

FIG. 7 (color online).   The value of α as obtained from a global fit of the $SU(3)_F$ relations at each quark mass we consider (in black filled circles). We also show our results as obtained with local source and local sink (in red triangles). The empty circle and the triangle denote the $SU(3)_F$ limit. The line at $\alpha = 0.4$ is shown for reference only.

~150, 100, 65, and 35 MeV. The parameters representing the $SU(3)_F$ symmetry have been computed at the point where the three flavors are degenerate at the physical strange-quark mass. In particular, we have obtained $\alpha \equiv F/(F+D) = 0.395(6)$, which is consistent with the prediction from SU(6) spin-flavor symmetry ($\alpha = 2/5$). The monopole mass we find leads to a πNN form factor which is softer than those typically used in the phenomenological OBE potential models. The ratios of the coupling constants, which are supposed to be less prone to systematic errors, show very weak quark-mass dependence. We have discussed to what extent the $SU(3)_F$ symmetry is broken as we approach the physical masses of the u- and the d-quarks. Our results indicate for the pseudoscalar-meson couplings of the octet baryons that $SU(3)_F$ is a good symmetry, which is broken by only a few percent (at least) in the 35 MeV to 150 MeV range of the light quark masses.

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