Pion and Kaon form factors in the NJL model

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In this work we study the dressed quark mass dependence of the pion and kaon electromagnetic form factors at the quark level using the Nambu-Jona-Lasinio (NJL) model, which is a powerful chiral effective quark model of QCD[1]. We choose the proper-time regularization scheme and introduce an infrared cut-off as in previous studies[2,3] in order to include one important aspect of quark confinement. In the calculation there is one free model parameter, which we take as the dressed light quark (u and d) mass M. The constituent quark model suggests that M is about 0.3–0.4 GeV, and it is often fixed as 0.4 GeV in NJL model calculations. However, in this work we show that the description of the pion and kaon form factors, as well as other physical quantities, are sensitive to the dressed light quark mass, and can be greatly improved if the dressed light quark mass is taken to be $M \simeq 0.25$ GeV.

We first explore the quark condensates $\langle \bar{q}q \rangle$, the kaon decay constant f_K, and the light (m) and strange (m_s) current quark masses using various values of the dressed quark mass. Our results for these quantities are shown in Table I. It is revealed that our results for the three ratios m_s/m, f_K/f_π and $\langle \bar{s}s \rangle / \langle \bar{\ell}\ell \rangle$ are in excellent agreement with recent experimental analyses and lattice QCD calculations, if the mass of the dressed light quark is approximately $M \simeq 0.25$ GeV. Therefore, it is interesting to study the pion and kaon form factors for the case where M is assumed to be smaller than the usually adopted values.

Figs. 1 and 2 show our calculated results for the pion and kaon form factors for the case $M = 0.25$ GeV. In each figure the dotted line denotes the result when the quark-photon vertex is treated as point-like (bare); the dash-dotted line includes effects from the pion cloud; and the dashed line is the full result which also includes the vector mesons contributions to the quark-photon vertex. The solid line shows the monopole functions which are determined so as to reproduce the empirical charge radii. From these figures it is clear that the data and the monopole functions can be reproduced very well by choosing $M \simeq 0.25$ GeV and including both the pion cloud and vector meson contributions. Such good agreement can not be attained for the case of $M \simeq 0.4$ GeV.

Table 1. Results for the current quark masses, kaon decay constant and quark condensates, for various values of the dressed light quark mass M. Masses and f_K are in units of GeV, and quark condensates in units of GeV^3. The model parameters are chosen to reproduce $f_\pi = 0.093$ GeV, $m_\pi = 0.14$ GeV and $m_K = 0.49$ GeV.

M	m	m_s	f_K	$\langle \bar{\ell}\ell \rangle$	$\langle \bar{s}s \rangle$
0.20	0.0041	0.131	0.128	$-(0.275)^3$	$-(0.329)^3$
0.25	0.0086	0.227	0.110	$-(0.214)^3$	$-(0.224)^3$
0.30	0.0123	0.293	0.010	$-(0.190)^3$	$-(0.180)^3$
0.35	0.0150	0.331	0.094	$-(0.177)^3$	$-(0.159)^3$
0.40	0.0168	0.357	0.091	$-(0.170)^3$	$-(0.148)^3$

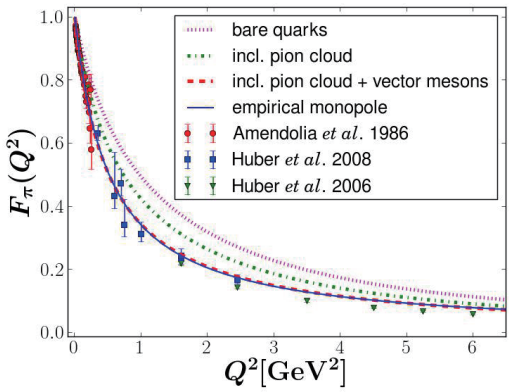

Fig. 1. Pion form factor for the case $M = 0.25$ GeV.

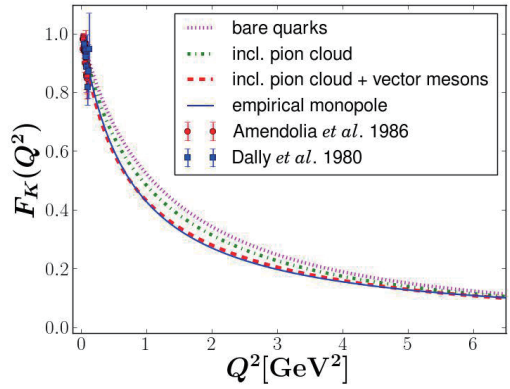

Fig. 2. Kaon form factor for the case $M = 0.25$ GeV.

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