

**LOW ENERGY CONSTANTS FROM THE MILC
COLLABORATION***

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*Talk presented by C. Bernard at Chiral Dynamics 2006, Duke University, Sept. 18-22.

Santa Barbara, California 93106, USA

We present preliminary updates of results for QCD low energy constants.

Keywords: chiral dynamics, lattice QCD

The MILC Collaboration is in the process of updating its simulations¹ of QCD using three dynamical light flavors (u, d, s) of improved staggered quarks. New lattice data² includes a complete ensemble with average u, d mass $\hat{m} = 0.1m_s$ and lattice spacing $a \approx 0.09$ fm, and a partial ensemble at $\hat{m} = 0.4m_s$ and $a \approx 0.06$ fm, as well as several new coarser ensembles at $a \approx 0.15$ fm, with a range of sea quark masses.

Some of our preliminary results are:

$$\begin{aligned}
 f_\pi &= 128.6 \pm 0.4 \pm 3.0 \text{ MeV}; & f_K &= 155.3 \pm 0.4 \pm 3.1 \text{ MeV}; \\
 f_K/f_\pi &= 1.208(2)({}_{-14}^{+7}) \Rightarrow |V_{us}| = 0.2223({}_{-14}^{+26}); \\
 f_\pi/f_2 &= 1.050(3)(10); & f_2/f_3 &= 1.09(4)(4); \\
 2L_6 - L_4 &= 0.5(1)(2); & 2L_8 - L_5 &= -0.1(1)(1); \\
 L_4 &= 0.1(2)(3); & L_5 &= 2.0(3)(2); \\
 \langle \bar{u}u \rangle_2 &= -(276(2)(7)(5) \text{ MeV})^3; & \langle \bar{u}u \rangle_3 &= -(247(10)(15)(4) \text{ MeV})^3; \\
 \langle \bar{u}u \rangle_2 / \langle \bar{u}u \rangle_3 &= 1.38(15)(22); \\
 m_s^{\overline{\text{MS}}} &= 90(0)(5)(4)(0) \text{ MeV}; & \hat{m}^{\overline{\text{MS}}} &= 3.3(0)(2)(2)(0) \text{ MeV}; \\
 m_u^{\overline{\text{MS}}} &= 2.0(0)(1)(2)(1) \text{ MeV}; & m_d^{\overline{\text{MS}}} &= 4.6(0)(2)(2)(1) \text{ MeV}; \\
 m_s/\hat{m} &= 27.2(0)(4)(0)(0); & m_u/m_d &= 0.42(0)(1)(0)(4).
 \end{aligned}$$

The errors are statistical, systematic (from the simulations), and, where relevant, perturbative (from two-loop perturbation theory³) and electromagnetic. The quantity f_2 (f_3) represents the three-flavor decay constant in the two (three) flavor chiral limit, and $\langle \bar{u}u \rangle_2$ ($\langle \bar{u}u \rangle_3$) is the corresponding condensate. The low energy constants L_i are evaluated at chiral scale m_η , and the condensates and masses are in the $\overline{\text{MS}}$ scheme at scale 2 GeV.

Our computations use the “fourth root trick” to reduce the staggered degrees of freedom. While this gives an action that is non-local at non-zero lattice spacing,⁴ recent work⁵⁻⁷ indicates that the desired local QCD theory is obtained in the continuum limit. In addition, the complicated effects of the non-locality at non-zero lattice spacing can be controlled and extrapolated away with “rooted staggered chiral perturbation theory.”^{6,7}

More work is still required to check the assumptions and arguments in Refs. 5–7; for a comprehensive review of the status and prospects, see Ref. 8.

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