Modeling pion physics in the $\epsilon$-regime of two-flavor QCD using lattice field theory

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In order to model pions of two-flavor QCD we consider lattice field theory involving two flavors of staggered quarks interacting strongly with $U(1)$ gauge fields. For massless quarks, this theory has an $SU_L(2) \times SU_R(2) \times U_A(1)$ symmetry. By adding a four-fermion term we can break the $U_A(1)$ symmetry and thus incorporate the physics of the QCD anomaly. We can also tune the pion decay constant $F_\pi$, to be small compared to the lattice cutoff by starting with an extra fictitious dimension, thus allowing us to model low energy pion physics in a setting similar to lattice QCD from first principles. However, unlike lattice QCD, a major advantage of our model is that we can easily design efficient algorithms to compute a variety of quantities in the chiral limit. Here we show that the model reproduces the predictions of chiral perturbation theory in the $\epsilon$-regime.