$\varepsilon'_K/\varepsilon_K$ IN THE CHIRAL LIMIT USING LARGE N_C

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The $K \to \pi\pi$ system is analyzed in the chiral limit and at NLO in $1/N_c$. The $\Delta I = 1/2$ rule is reproduced and we obtain a large value for $\varepsilon'_K/\varepsilon_K$.

1 Introduction

We present our calculation of $\varepsilon'_K/\varepsilon_K$ in the chiral limit.[1] Its experimental observation is the first new major CP-violation result since the original discovery.[2]

This calculation uses the large N_c approach pioneered by Bardeen et al.[3]. We used this method previously to calculate B_K[4], the $\Delta I = 1/2$-rule[5], the muon $g-2$ and electromagnetic mass differences.[6] Similar recent work is [7,8]

2 Short-distance and X-boson or fictitious gauge boson scheme

$\Delta S = 1$ weak decays are produced by the exchange of W-bosons. The resulting effective action, resumming $\alpha_S \log(M_X/\nu)$ to two-loops, is now standard. An introduction and references can be found in the lectures by Buras.[9] The resulting effective action, $\Gamma_{\Delta S=1} \sim \sum_{i=1}^{10} C_i(\nu) \int \mathrm{d}^4x\, Q_i(x) + \text{h.c.}$ with $Q_i(x)$ four-quark operators, is dependent on the various schemes chosen in its definition. This dependence should disappear in the matrix-elements of this effective action which are usually calculated in a different way.

Because currents and densities can be matched more easily across theories, we first replace the effective four-quark operator action by an equivalent one. For instance, the effective action reproducing $Q_1(x) = [\overline{s}\gamma^\mu(1-\gamma_5)d]\,[\overline{u}\gamma_\mu(1-\gamma_5)u]\,(x)$ by the exchange of the heavy fictitious X_1 is

$$\Gamma_X \equiv g_1(\mu_c, \cdots) \int \mathrm{d}^4y\, X_1^\mu \left\{ [\overline{s}\gamma_\mu(1-\gamma_5)d]\,(x) + [\overline{u}\gamma_\mu(1-\gamma_5)u]\,(x) \right\} . \quad (1)$$

The constants, like $g_1(\mu_c, \cdots)$, are determined unambiguously from matching conditions in the perturbative regime,[1,4] removing the scheme-dependence.

3 Long-distance and results

We calculate the matrix-elements of X-boson exchange by integrating over its momentum p_X in the Euclidean. The short-distance contribution, $p_X^2 > \mu^2$, is, to NLO in $1/N_c$, calculable using perturbative QCD and factorization. The long-distance part, small p_X^2, can be calculated with Chiral Perturbation Theory, also done by[7]. This fails at fairly low p_X^2 and we have chosen a reasonable hadronic model, the ENJL model, to extend the range to higher values. We find good matching for the isospin zero amplitude a_0 and for all the imaginary parts. Another improvement route is the LMD method[8].

We obtain, to NLO in $1/N_c$ and in the chiral limit,[1] a_0 within errors and

$$B_{6\chi}^{(1/2)NDR}(2\,\mathrm{GeV}) = 2.5 \pm 0.4 \qquad B_{8\chi}^{(3/2)NDR}(2\,\mathrm{GeV}) = 1.35 \pm 0.20$$
$$|\varepsilon'_K/\varepsilon_K| = (60 \pm 30)\cdot 10^{-4}\,. \tag{2}$$

Including the main isospin breaking effect and final state interactions gives[1]

$$|\varepsilon'_K/\varepsilon_K| = (34 \pm 18)\cdot 10^{-4} \tag{3}$$

in reasonable agreement with the experimental value[2] $(19.3 \pm 2.4)\ 10^{-4}$.

Acknowledgments

Work partially supported by NFR, Sweden, EU TMR Network EURO-DAPHNE (Contract No. ERBFMX-CT98-0169), CICYT, Spain (Grant No. AEN-96/1672) and the Junta de Andalucía (Grant No. FQM-101).

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