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Hadronic contributions to rare kaon decays

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The amplitudes of the rare kaon decays $K \rightarrow \pi \ell^+ \ell^-$, $(K, \pi) = (K^+, \pi^+), (K_S, \pi^0), \ell = e, \mu$, are dominated by their long-distance component. The latter is given by the exchange of a virtual photon between the lepton pair and the four-quark operators of the $\Delta S = 1$ weak effective Lagrangian. The corresponding $K - \pi - \gamma^*$ form factor is described as a sum of three contributions. At large Euclidian virtualities, it behaves as powers of the logarithm of the photon momentum squared. The one-loop correction of this type is easily computed, and the two-loop one is almost entirely determined by a renormalization-group argument combined with existing calculations of the two-loop anomalous dimensions of the $\Delta S = 1$ four-quark operators. At long distances, the form factor is written as an unsubtracted dispersion relation. The absorptive part, when restricted to two-pion intermediate states, is given by the product of the electromagnetic form factor of the pion times the P -wave projection of the amplitude for $K\pi \rightarrow \pi^+\pi^-$ scattering. Finally, the intermediate region is described by an infinite sum of zero-width resonances, with residues tuned such as to reproduce the correct short-distance behaviour. Predictions of the amplitudes based on this description are presented and compared to experiment. Possibilities to improve this phenomenological description are also discussed.

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