evidence for CP violation in decays. (As explained in 1.6.3, a measurement of $\mathcal{R}e\ \varepsilon'_K \neq 0$ would constitute such evidence.)

The magnitude and strong phase of any amplitude involve long distance strong interaction physics, and cannot be calculated from first principles. Thus quantities that depend only on the weak phases are much cleaner than those that require knowledge of the relative magnitudes or strong phases of various amplitude contributions. There is however a large literature and considerable theoretical effort that goes into the calculation of amplitudes and strong phases. In many cases one can only relate experiment to Standard Model parameters through such calculations. The techniques that are used are expected to be more accurate for B decays than for K decays because of the larger B mass, but theoretical uncertainty remains significant. The calculations generally contain two parts. First, the operator product expansion and QCD perturbation theory are used to write any underlying quark process as a sum of local quark operators with well-determined coefficients. Second, the matrix elements of the operators between the initial and final hadron states must be calculated. This is where the theory is weakest and the results most model dependent. Ideally lattice calculations should be able to provide accurate determinations for the matrix elements, and in certain cases this is already true, but much remains to be done. In the following chapter an overview of the principal methods used in such calculations is given. Further details on the status of various theoretical approaches are presented in relevant chapters and in the appendices.

1.3.2 *CP* Violation in Mixing

A second quantity that is independent of phase conventions and physically meaningful is

$$\left|\frac{q}{p}\right|^2 = \left|\frac{M_{12}^* \Leftrightarrow \frac{i}{2}\Gamma_{12}^*}{M_{12} \Leftrightarrow \frac{i}{2}\Gamma_{12}}\right|. \tag{1.51}$$

When CP is conserved, the mass eigenstates must be CP eigenstates. In that case the relative phase between M_{12} and Γ_{12} vanishes. Therefore, Eq. (1.51) implies

$$|q/p| \neq 1 \quad \Longrightarrow \quad CP \text{ violation.} \tag{1.52}$$

This type of CP violation is here called *CP violation in mixing*; it is often referred to as *indirect CP violation*. It results from the mass eigenstates being different from the CP eigenstates. CP violation in mixing has been observed unambiguously in the neutral kaon system.

For the neutral B system, this effect could be observed through the asymmetries in semileptonic decays:

$$a_{\text{sl}} = \frac{\Gamma(\overline{B}^0_{\text{phys}}(t) \to \ell^+\nu X) \Leftrightarrow \Gamma(B^0_{\text{phys}}(t) \to \ell^-\nu X)}{\Gamma(\overline{B}^0_{\text{phys}}(t) \to \ell^+\nu X) + \Gamma(B^0_{\text{phys}}(t) \to \ell^-\nu X)}. \tag{1.53}$$