In terms of $|q/p|$,

$$a_{\rm sl} = \frac{1 \Leftrightarrow |q/p|^4}{1 + |q/p|^4}, \tag{1.54}$$

which follows from

$$\langle \ell^- \nu X | H | B^0_{\rm phys}(t) \rangle = (q/p) g_-(t) A^*, \quad \langle \ell^+ \nu X | H | \overline{B}^0_{\rm phys}(t) \rangle = (p/q) g_-(t) A. \tag{1.55}$$

As can be seen from the discussion in Section 1.2.3, effects of CP violation in mixing in neutral B_d decays, such as the asymmetries in semileptonic decays, are expected to be small, $\mathcal{O}(10^{-2})$. Moreover, to calculate the deviation of q/p from a pure phase, one needs to calculate Γ_{12} and M_{12}. This involves large hadronic uncertainties, in particular in the hadronization models for Γ_{12}. The overall uncertainty is easily a factor of 2–3 in $|q/p| \Leftrightarrow 1$ [10]. Thus even if such asymmetries are observed, it will be difficult to relate their rates to fundamental CKM parameters.

1.3.3 CP Violation in the Interference Between Decays With and Without Mixing

Finally, consider neutral B decays into final CP eigenstates, f_{CP} [14, 15, 16]. Such states are accessible in both B^0 and $\overline{B}^0$ decays. The quantity of interest here that is independent of phase conventions and physically meaningful is λ of Eq. (1.42), $\lambda = \eta_{f_{CP}} \frac{q}{p} \frac{\overline{A}_{\overline{f}_{CP}}}{A_{f_{CP}}}$. When CP is conserved, $|q/p| = 1$, $|\overline{A}_{\overline{f}_{CP}}/A_{f_{CP}}| = 1$, and furthermore, the relative phase between (q/p) and $(\overline{A}_{\overline{f}_{CP}}/A_{f_{CP}})$ vanishes. Therefore, Eq. (1.42) implies

$$\lambda \neq \pm 1 \quad \Longrightarrow \quad CP \text{ violation}. \tag{1.56}$$

Note that both CP violation in decay (1.47) and CP violation in mixing (1.52) lead to (1.56) through $|\lambda| \neq 1$. However, it is possible that, to a good approximation, $|q/p| = 1$ and $|\overline{A}/A| = 1$, yet there is CP violation:

$$|\lambda| = 1, \quad \mathcal{I}m\, \lambda \neq 0. \tag{1.57}$$

This type of CP violation is called *CP violation in the interference between decays with and without mixing* here; sometimes this is abbreviated as "interference between mixing and decay." As explained in Section 1.6, this type of CP violation has also been observed in the neutral kaon system.

For the neutral B system, CP violation in the interference between decays with and without mixing can be observed by comparing decays into final CP eigenstates of a time-evolving neutral B state that begins at time zero as B^0 to those of the state that begins as a $\overline{B}^0$:

$$a_{f_{CP}} = \frac{\Gamma(B^0_{\rm phys}(t) \to f_{CP}) \Leftrightarrow \Gamma(\overline{B}^0_{\rm phys}(t) \to f_{CP})}{\Gamma(B^0_{\rm phys}(t) \to f_{CP}) + \Gamma(\overline{B}^0_{\rm phys}(t) \to f_{CP})}. \tag{1.58}$$