# Appendix D **Numerical Input**

In Table D.1 we collect the experimental values of most important parameters used in the numerical estimates in the book. If in certain cases other values are used, we warn the reader about it. In any case, these values change with time, and in doing phenomenology the readers should consult PDG, FLAG, and HFLAV.

**Table D.1** Values of the experimental and theoretical quantities used as input parameters as of December 2018 based on PDG, FLAG, and HFLAV.

| | | |
|---|---|---|
| $G_F = 1.16637(1) \times 10^{-5}\,\text{GeV}^{-2}$ | $M_Z = 91.188(2)\,\text{GeV}$ | $M_W = 80.385(15)\,\text{GeV}$ |
| $\sin^2\theta_W = 0.23116(13)$ | $\alpha(M_Z) = 1/127.9$ | $\alpha_s(M_Z) = 0.1184(7)$ |
| $m_e = 0.511\,\text{MeV}$ | $m_\mu = 105.66\,\text{MeV}$ | $m_\tau = 1776.9(1)$ |
| $m_u(2\,\text{GeV}) = 2.16(11)\,\text{MeV}$ | $m_c(m_c) = 1.279(13)\,\text{GeV}$ | $m_t(m_t) = 163(1)\,\text{GeV}$ |
| $m_d(2\,\text{GeV}) = 4.68(15)\,\text{MeV}$ | $m_s(2\,\text{GeV}) = 93.8(24)\,\text{MeV}$ | $m_b(m_b) = 4.19^{+0.18}_{-0.06}\,\text{GeV}$ |
| $m_{\pi^\pm} = 139.57\,\text{MeV}$ | $m_{\pi^0} = 134.98\,\text{MeV}$ | $m_\eta = 547.86(2)\,\text{MeV}$ |
| $m_{K^\pm} = 493.68(2)\,\text{MeV}$ | $m_{K^0} = 497.61(1)\,\text{MeV}$ | $m_{K^*} = 895.81(19)\,\text{MeV}$ |
| $m_{D^\pm} = 1869.58(0.09)\,\text{MeV}$ | $m_{D^0} = 1864.83(05)\,\text{MeV}$ | $m_{D_s^\pm} = 1968.27(10)\,\text{MeV}$ |
| $m_{B_d} = 5279.62(15)\,\text{MeV}$ | $m_{B_s} = 5366.82(22)\,\text{MeV}$ | $m_{B^+} = 5279.31(15)\,\text{MeV}$ |
| $\tau_\mu = 2.197\,10^{-6}\,(s)$ | $\tau_\tau = 2.903(5)\,10^{-13}\,(s)$ | |
| $\tau_{\pi^\pm} = 2.603\,10^{-8}\,(s)$ | $\tau_{\pi^0} = 8.52(18)\,10^{-17}\,(s)$ | |
| $\tau_{K^\pm} = 1.238(2)\,10^{-8}\,(s)$ | $\tau_{K_L} = 5.116(21)\,10^{-8}\,(s)$ | $\tau_{K_S} = 0.895\,10^{-10}\,(s)$ |
| $\tau_{D^\pm} = 10.4(1)\,10^{-13}\,(s)$ | $\tau_{D^0} = 4.10(2)\,10^{-13}\,(s)$ | $\tau_{D_s^\pm} = 5.0(1)\,10^{-13}\,(s)$ |
| $\tau_{B_d} = 1.520(4)\,\text{ps}$ | $\tau_{B_s} = 1.510(5)\,\text{ps}$ | $\tau_{B^\pm} = 1.638(4)\,\text{ps}$ |
| $\Delta M_K = 0.5292(9) \times 10^{-2}\,\text{ps}^{-1}$ | $\Delta M_d = 0.5055(20)\,\text{ps}^{-1}$ | $\Delta M_s = 17.757(21)\,\text{ps}^{-1}$ |
| $\lvert\varepsilon_K\rvert = 2.228(11) \times 10^{-3}$ | $S_{\psi K_S} = 0.699(17)$ | $S_{\psi\phi} = 0.054(20)$ |

**Table D.2** Values of selected experimental branching ratios as of April 2019 based on PDG.

| | | |
|---|---|---|
| $\mathcal{B}(\pi^+ \to \mu^+\nu_\mu) = 0.9999$ | $\mathcal{B}(K^+ \to \mu^+\nu_\mu) = 0.6356(11)$ | $\mathcal{B}(\mu^- \to e^-\bar{\nu}_e\nu_\mu) \approx 1.0$ |
| $\mathcal{B}(\tau^- \to e^-\bar{\nu}_e\nu_\tau) = 0.1782(4)$ | $\mathcal{B}(\tau^- \to \mu^-\bar{\nu}_\nu\nu_\tau) = 0.1739(4)$ | $\mathcal{B}(K^+ \to \pi^0 e^+\nu_e) = 0.0507(4)$ |
| $\mathcal{B}(K^+ \to \pi^0\mu^+\nu_\nu) = 0.0335(3)$ | $\mathcal{B}(K_S^0 \to \pi^0\pi^0) = 0.3069(5)$ | $\mathcal{B}(K_S^0 \to \pi^+\pi^-) = 0.6920(5)$ |
| $\mathcal{B}(K_L^0 \to \pi^\pm e^\mp\nu_e) = 0.4055(11)$ | $\mathcal{B}(K_L^0 \to \pi^\pm\mu^\mp\nu_\mu) = 0.2704(7)$ | $\mathcal{B}(K_L^0 \to \pi^0\pi^0\pi^0) = 0.1952(12)$ |
| $\mathcal{B}(K_L^0 \to \pi^+\pi^+\pi^0) = 0.1254(5)$ | $\mathcal{B}(B^0 \to D^- l^+\nu_l) = 0.0225(8)$ | $\mathcal{B}(B^+ \to X_c l^+\nu_e) = 0.1079(37)$ |



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**Table D.3** Values of theoretical quantities used as input parameters as of April 2019 based on FLAG, HFLAV.

| | | |
|---|---|---|
| $F_\pi = 130.41(20)$ MeV | $F_K = 156.1(11)$ MeV | $\hat{B}_K = 0.766(10)$ |
| $F_{B_d} = 190.5(1.3)$ MeV | $F_{B_s} = 230.7(1.2)$ MeV | $F_{B^+} = 189.4(1.3)$ MeV |
| $\hat{B}_{B_d} = 1.27(10)$ | $\hat{B}_{B_s} = 1.33(6)$ | $\hat{B}_{B_s}/\hat{B}_{B_d} = 1.01(2)$ |
| $F_{B_d}\sqrt{\hat{B}_{B_d}} = 216(15)$ MeV | $F_{B_s}\sqrt{\hat{B}_{B_s}} = 266(18)$ MeV | $\xi = 1.21(2)$ |
| $\eta_{cc} = 1.87(76)$ | $\eta_{ct} = 0.496(47)$ | $\eta_{tt} = 0.5765(65)$ |
| $\eta_B = 0.55(1)$ | $\Delta\Gamma_s/\Gamma_s = 0.124(9)$ | $\kappa_\epsilon = 0.94(2)$ |
| $\lvert V_{us}\rvert = 0.2254(4)$ | $\lvert V_{ub}^{\rm nom}\rvert = 3.7 \times 10^{-3}$ | $\lvert V_{cb}^{\rm nom}\rvert = 42.0 \times 10^{-3}$ |

For conversion from seconds to GeV, the following relations are useful

$$6.582\,\text{ps GeV} \cdot 10^{-13} = 6.582\,\text{sec GeV} \cdot 10^{-25} = 1\,. \tag{D.1}$$

In Table D.2 we collect the values of selected experimental branching ratios used in book. Complete collection can be found in PDG. In Table D.3 we collect the values of most important parameters that we used in this book. Other, more specific, parameters are given while presenting numerical output for various observables.

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