Inputs used in
Predictions of selected flavour observables within the SM

J. Charles et al. [arXiv:1106.4041 [hep-ph]]

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We have presented predictions of selected flavour observables within the Standard Model in ref. [1]. We gather here the inputs used for these predictions, including those that could not be listed for lack of space. Most of them come from lattice gauge theories and are obtained following our usual averaging method, described in more detail in Sec. 3.

1 Inputs for the CKM fit

In tables 1 and 2, we provide the experimental and theoretical inputs required for the global fit described in Sec. I of ref. [1].

Observable	Value and uncertainties	Reference
$\lvert V_{ud}\rvert_{\rm nucl}$	0.97425 ± 0.00022	[2]
$\lvert V_{us}\rvert_{\rm semi} f_+(0)$	0.2163 ± 0.0005	[3]
$\mathcal{B}(K \to e\nu_e)$	$(1.584 \pm 0.0020) \cdot 10^{-5}$	[4]
$\mathcal{B}(K \to \mu\nu_\mu)$	0.6347 ± 0.0018	[3]
$\mathcal{B}(\tau \to K\nu_\tau)$	0.00696 ± 0.00023	[4]
$\frac{\mathcal{B}(K\to\mu\nu_\mu)}{\mathcal{B}(\pi\to\mu\nu_\mu)}$	$(1.3344 \pm 0.0041) \cdot 10^{-2}$	[3]
$\frac{\mathcal{B}(\tau\to K\nu_\tau)}{\mathcal{B}(\tau\to\pi\nu_\tau)}$	$(6.53 \pm 0.11) \cdot 10^{-2}$	[5]
$\mathcal{B}(D \to \mu\nu)$	$(3.82 \pm 0.32 \pm 0.09) \cdot 10^{-4}$	[6]
$\mathcal{B}(D_s \to \tau\nu)$	$(5.29 \pm 0.28) \cdot 10^{-2}$	[7]
$\mathcal{B}(D_s \to \mu\nu_\mu)$	$(5.90 \pm 0.33) \cdot 10^{-3}$	[7]
$\lvert V_{ub}\rvert_{\rm semi}$	$(3.92 \pm 0.09 \pm 0.45) \cdot 10^{-3}$	[7]
$\mathcal{B}(B \to \tau\nu)$	$(1.68 \pm 0.31) \cdot 10^{-4}$	[8]
$\lvert V_{cb}\rvert_{\rm semi}$	$(40.89 \pm 0.38 \pm 0.59) \cdot 10^{-3}$	[7]
$B \to \pi\pi,\ \rho\pi,\ \rho\rho$	Branching ratios, CP asymmetries	[7]
$\sin(2\beta)_{[c\bar{c}]}$	0.678 ± 0.020	[7]
$B \to D^{(*)}K^{(*)}$	Inputs for GGSZ, GLW, ADS methods	[7]
Δm_d	0.507 ± 0.005 ps^{-1}	[7]
Δm_s	17.77 ± 0.12 ps^{-1}	[9]
$\lvert\epsilon_K\rvert$	$(2.229 \pm 0.010) \cdot 10^{-3}$	[4]

Table 1: Experimental inputs used for the global fit of ref. [1]. The errors were treated as Gaussian (if there is only a statistical uncertainty) or using the Rfit scheme (if both statistical and systematic uncertainties are present).

Theoretical parameter	Value and uncertainties	Reference
$f_+(0)$	$0.9632 \pm 0.0028 \pm 0.0051$	Sec. 3
f_K	$156.3 \pm 0.3 \pm 1.9$ MeV	Sec. 3
f_K/f_π	$1.205 \pm 0.001 \pm 0.010$	Sec. 3
f_{D_s}/f_D	$1.186 \pm 0.005 \pm 0.010$	Sec. 3
f_{D_s}	$251.3 \pm 1.2 \pm 4.5$ MeV	Sec. 3
f_{B_s}	$231 \pm 3 \pm 15$ MeV	Sec. 3
f_{B_s}/f_B	$1.209 \pm 0.007 \pm 0.023$	Sec. 3
$\hat{B}_{B_s}/\hat{B}_{B_d}$	$1.01 \pm 0.01 \pm 0.03$	Sec. 3
$\hat{B}_{B_s}$	$1.28 \pm 0.02 \pm 0.03$	Sec. 3
$\hat{B}_K$	$0.730 \pm 0.004 \pm 0.036$	Sec. 3
κ_ϵ	$0.940 \pm 0.013 \pm 0.023$	[10]
$\overline{m}_c(\overline{m}_c)$	$(1.286 \pm 0.013 \pm 0.040)$ GeV	[10]
$\overline{m}_t(\overline{m}_t)$	$(165.017 \pm 1.156 \pm 0.11)$ GeV	[10]
$\alpha_s(M_Z)$	0.1176 ± 0.0020	[4]
η_{cc}	computed from $\overline{m}_c(\overline{m}_c)$ and α_s	[11]
η_{ct}	0.47 ± 0.04	[12]
η_{tt}	0.5765 ± 0.0065	[13]
$\hat{\eta}_B$	0.8393 ± 0.0034	[10]

Table 2: Theoretical inputs used for the global fit of ref. [1]. The errors were treated using the Rfit scheme.

Theoretical parameter	Value and uncertainties	Reference
$\tilde{\mathcal{B}}_{S,B_s}/\tilde{\mathcal{B}}_{S,B_d}$	$1.01 \pm 0 \pm 0.03$	[14]
$\tilde{\mathcal{B}}_{S,B_s}(m_b)$	$0.91 \pm 0.03 \pm 0.12$	[14]
$\overline{m}_s(\overline{m}_b)$	(0.085 ± 0.017) GeV	[16]
$\overline{m}_b(\overline{m}_b)$	(4.248 ± 0.051) GeV	[7]
m_b^{pow}	$(4.7 \pm 0 \pm 0.1)$ GeV	[16]
$\mathcal{B}_{R_0}$	1.0 ± 0.5	[16]
$\mathcal{B}_{\tilde{R}_1}$	1.0 ± 0.5	[16]
$\mathcal{B}_{R_1}$	1.0 ± 0.5	[16]
$\mathcal{B}_{\tilde{R}_2}$	$1.0 \pm 0 \pm 0.5$	[16]
$\mathcal{B}_{\tilde{R}_3}$	$1.0 \pm 0 \pm 0.5$	[16]

Table 3: Theoretical inputs used for the predictions of ref. [1] concerning neutral-meson mixing. The errors were treated using the Rfit scheme.

2 Inputs for the predictions in the Standard Model

In tables 3 and 4, we collect the additional theoretical inputs required for the predictions of flavour quantities in the Standard Model described in Sec. I of ref. [1]. We do not recall the elements for the parametrisation of $B \to X_s\gamma$, which is described in detailed in ref. [15].

3 Lattice inputs

3.1 Averaging method

Several hadronic inputs are required for the fits presented by CKMfitter, and we mostly rely on lattice QCD simulations to estimate these quantities. The presence of results from different collaborations with various statistics and systematics make it all the more necessary to combine them in a careful way.

We collect the relevant calculations of the quantity that we are interested in: we take only unquenched results with 2 or 2+1 dynamical fermions, even those from proceedings without a companion article. In these results, we separate the error estimates into a Gaussian part and a flat part that is treated à la Rfit. The Gaussian part collects the uncertainties from purely statistical origin, but also the systematics that can be controlled and treated in a similar way (e.g., interpolation or fitting in some cases). The remaining systematics constitute the Rfit error. If there are several sources of error in the Rfit category, we add them linearly [1].

The Rfit model is simple but also very strict. It amounts to assuming that the theoretical uncertainty is rigorously constrained by a mathematical bound that is our only piece of information. If Rfit is taken stricto sensu and the individual likelihoods are combined in the usual way (by multiplication), the final uncertainty can be underestimated, in particular in the case of marginally compatible values. We correct this effect by adopting the following averaging recipe. The central value is obtained by combining the whole likelihoods. Then we combine the Gaussian uncertainties by combining likelihoods restricted to their Gaussian part. Finally we assign to this combination the smallest of the individual Rfit uncertainties. The underlying idea is twofold:

[1] keeping in mind that in many papers in the literature, this combination is done in quadrature and the splitting between different sources is not published.

Theoretical parameter	Value and uncertainties	Reference
$\mu_{B\to\ell\ell}$	200 ± 120 GeV	[17]
$m_s(2\text{ GeV})$	0.1 ± 0.02 GeV	[18]
μ_b	6 ± 3.6 GeV	[18]
$\bar{m}_b$	4.2	[18]
$\lambda_B(\mu_h)$	0.51 ± 0.12 GeV	[18]
$\lambda_{B_s}(\mu_h)$	0.6 ± 0.2	[18]
$f_{\perp,K^*}$	0.185 ± 0.010	[18]
$a_{1,\perp,K^*}$	0.04 ± 0.03	[18]
$a_{2,\perp,K^*}$	0.15 ± 0.1	[18]
$T_1^{B\to K^*}(0)$	0.31 ± 0.04	[18]
$f_{\perp,\phi}$	0.186 ± 0.009	[18]
$a_{2,\perp,\phi}$	0.2 ± 0.2	[18]
$\xi_{B_s\to\phi}$	1.01 ± 0.13	[18]
$G_V + G_A$	-0.24 ± 0.06	[18]
$G_V - G_A$	-0.03 ± 0.015	[18]
$l_c - \tilde{l}_c(B \to K^*)$	0.000242 ± 0.000370	[18]
$l_c + \tilde{l}_c(B \to K^*)$	-0.000952 ± 0.000800	[18]
$l_c - \tilde{l}_c(B_s \to \phi)$	0.000306 ± 0.000320	[18]
$l_c + \tilde{l}_c(B_s \to \phi)$	-0.000930 ± 0.000750	[18]
$l_u - \tilde{l}_u(B \to K^*)$	-0.000099 ± 0.000300	[18]
$l_u + \tilde{l}_u(B \to K^*)$	0.001172 ± 0.000821	[18]
$l_u - \tilde{l}_u(B_s \to \phi)$	-0.000581 ± 0.000300	[18]
$l_u + \tilde{l}_u(B_s \to \phi)$	0.000893 ± 0.000625	[18]
δP_{cu}	0.04 ± 0.02	[19]
Δ_{EM}	-0.003	[19]
κ_+	$(0.5173 \pm 0.0025) \cdot 10^{-10}$	[19]
κ_L	$(2.231 \pm 0.013) \cdot 10^{-10}$	[19]
κ_{10}	1.6624	[20]
κ_{01}	-2.3537	[20]
κ_{11}	-1.5862	[20]
κ_{20}	1.5036	[20]
κ_{02}	-4.3477	[20]

Table 4: Theoretical inputs used for the predictions of ref. [1] concerning radiative B decays and rare K decays. The errors were treated using the Rfit scheme.

- the present state of art cannot allow us to reach a better theoretical accuracy than the best of all estimates
- this best estimate should not be penalized by less precise methods (as it would happen be the case if one would take the dispersion of the individual central values as a guess of the combined theoretical uncertainty).

It should be stressed that the concept of a theoretical uncertainty is ill-defined, and the combination of them even more. Thus our approach is only one among the alternatives that can be found in the literature. In contrast to some of the latter, ours is algorithmic and can be reproduced.

3.2 Decay constants and form factors

f_K

Reference	Article	N_f	Mean	Stat	Syst
ETMC09	[21]	2	158.1	0.8	3.1
MILC07	[22]	2+1	156.5	0.4	$^{+1.0}_{-2.7}$
HPQCD07	[23]	2+1	157	0.6	3.3
ALVdW08	[24]	2+1	153.9	1.7	6.5
Our average			156.3	0.3	1.9

f_K/f_π

Reference	Article	N_f	Mean	Stat	Syst
ETMC09	[21]	2	1.210	0.006	0.024
MILC07	[22]	2+1	1.197	0.003	$^{+0.006}_{-0.013}$
NPLQCD07	[25]	2+1	1.218	0.002	$^{+0.024}_{-0.011}$
HPQCD07	[23]	2+1	1.189	0.002	0.014
ALVdW08	[24]	2+1	1.191	0.016	0.026
BMW10	[26]	2+1	1.192	0.010	0.019
Our average			1.205	0.0012	0.0095

f_{D_s}

Reference	Article	N_f	Mean	Stat	Syst
CP-PACS00	[27]	2	267	13	$^{+27}_{-17}$
MILC02	[28]	2	241	5	$^{+41}_{-30}$
ETMC09	[21]	2	244	3	9
HPQCD03	[29]	2+1	290	20	64
FNAL-MILC09	[30]	2+1	260	6.8	14
HPQCD10	[47]	2+1	248.0	1.4	4.5
Our average			251.3	1.2	4.5

f_{D_s}/f_D

Reference	Article	N_f	Mean	Stat	Syst
CP-PACS00	[27]	2	1.182	0.039	$^{+0.087}_{-0.046}$
MILC02	[28]	2	1.14	0.01	$^{+0.06}_{-0.07}$
ETMC09	[21]	2	1.24	0.03	0.01
HPQCD07	[23]	2+1	1.164	0.006	0.020
FNAL-MILC09	[30]	2+1	1.200	0.016	0.025
Our average			1.186	0.005	0.010

f_{B_s}

Reference	Article	N_f	Mean	Stat	Syst
CP-PACS01	[31]	2	242	9	$^{+53}_{-34}$
MILC02	[28]	2	217	6	$^{+58}_{-31}$
JLQCD03	[32]	2	215	9	$^{+19}_{-15}$
ETMC09	[45]	2	243	6	15
HPQCD03	[29]	2+1	260	7	39
FNAL-MILC09	[33]	2+1	243	6	22
HPQCD09	[34]	2+1	231	5	30
Our average			231	3	15

f_{B_s}/f_B

Reference	Article	N_f	Mean	Stat	Syst
CP-PACS01	[31]	2	1.179	0.018	0.023
MILC02	[28]	2	1.16	0.01	$^{+0.08}_{-0.04}$
JLQCD03	[32]	2	1.13	0.03	$^{+0.17}_{-0.02}$
ETMC09	[45]	2	1.27	0.03	0.04
FNAL-MILC09	[33]	2+1	1.245	0.028	0.049
HPQCD09	[34]	2+1	1.226	0.020	0.033
RBC/UKQCD10	[46]	2+1	1.15	0.05	0.20
Our average			1.209	0.007	0.023

$f_+(0)$ for $K \to \pi\ell\nu$

Reference	Article	N_f	Mean	Stat	Syst
RBC06	[35]	2	0.968	0.009	0.006
ETMC09	[36]	2	0.9560	0.0057	0.0127
RBC-UKQCD10	[50]	2+1	0.9599	0.0034	$^{+0.0045}_{-0.0057}$
Our average			0.9632	0.0028	0.0051

3.3 Meson mixing

$B_K^{\overline{\rm MS}}(2{\rm GeV})$

Reference	Article	N_f	Mean	Stat	Syst
JLQCD08	[38]	2	0.537	0.004	0.072
ETMC 10	[51]	2	0.532	0.019	0.026
HPQCD/UKQCD06	[39]	2+1	0.618	0.018	0.179
ALVdW09	[41]	2+1	0.527	0.006	0.049
RBC/UKQCD07	[40]	2+1	0.524	0.010	0.052
BSW10	[49]	2+1	0.526	0.008	0.040
Our average for $B_K^{\overline{\rm MS}}(2{\rm GeV})$			0.532	0.003	0.026
Our average for $\hat{B}_K$			0.730	0.004	0.036

$\hat{B}_{B_s}$

Reference	Article	N_f	Mean	Stat	Syst
JLQCD03	[32]	2	1.299	0.034	$^{+0.122}_{-0.095}$
HPQCD06	[42]	2+1	1.168	0.105	0.140
RBC/UKQCD07	[43]	2+1	1.21	0.05	0.05
HPQCD09	[34]	2+1	1.326	0.04	0.03
Our average			1.28	0.02	0.03

$\hat{B}_{B_s}/\hat{B}_{B_d}$

Reference	Article	N_f	Mean	Stat	Syst
JLQCD03	[32]	2	1.017	0.016	$^{+0.076}_{-0.017}$
HPQCD09	[34]	2+1	1.053	0.02	0.03
RBC/UKQCD10	[46]	2+1	0.96	0.02	0.03
Our average			1.01	0.01	0.03

Refs. [34] and [46] provide only ξ and f_{B_s}/f_{B_d}. We have extracted $\hat{B}_{B_s}/\hat{B}_{B_d}$ in both cases assuming a total correlation in the systematics of ξ and $\hat{B}_{B_s}/\hat{B}_{B_d}$.

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