UPDATED RESULTS ON THE CKM MATRIX AND THE UNITARITY TRIANGLE

Including results presented up to
ICHEP 10

P r e l i m i n a r y

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The CKMfitter Group

Abstract

This document provides the collection of up-to-date inputs to the global CKM analysis, and numerical results obtained with the use of the fit package CKMfitter. The statistical method employed is the frequentist approach *R*fit. Detailed background information on the methodology and the treatment of experimental and theoretical uncertainties is provided in:

CP VIOLATION AND THE CKM MATRIX:
ASSESSING THE IMPACT OF THE ASYMMETRIC *B* FACTORIES
By CKMfitter Group
Eur. Phys. J. **C41**, 1-131, 2005 [hep-ph/0406184]

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Parameter	Value ± Error(s)	Reference	Errors GS	Errors TH
$\|V_{ud}\|$ (nuclei)	0.97425 ± 0.00022	[1]	$\star$	-
$\|V_{us}\|$ ($K_{\ell 3}$)	0.2254 ± 0.0013	[2]	$\star$	-
$\|V_{ub}\|$	$(3.92 \pm 0.09 \pm 0.45) \times 10^{-3}$	[3, 4]	$\star$	$\star$
$\|V_{cb}\|$	$(40.89 \pm 0.38 \pm 0.59) \times 10^{-3}$	[3]	$\star$	$\star$
$\|\varepsilon_K\|$	$(2.229 \pm 0.010) \times 10^{-3}$	[5]	$\star$	-
Δm_d	(0.507 ± 0.005) ps^{-1}	[3]	$\star$	-
Δm_s	(17.77 ± 0.12) ps^{-1}	[6]	$\star$	-
$\sin(2\beta)_{[c\bar{c}]}$	0.673 ± 0.023	[3]	$\star$	-
$S^{+-}_{\pi\pi}$, $C^{+-}_{\pi\pi}$, $C^{00}_{\pi\pi}$	Inputs to isospin analysis	[3]	$\star$	-
$\mathcal{B}_{\pi\pi}$ all charges	Inputs to isospin analysis	[3]	$\star$	-
$S^{+-}_{\rho\rho,L}$, $C^{+-}_{\rho\rho,L}$, $S^{00}_{\rho\rho}$, $C^{00}_{\rho\rho}$	Inputs to isospin analysis	[3]	$\star$	-
$\mathcal{B}_{\rho\rho,L}$ all charges	Inputs to isospin analysis	[3]	$\star$	-
$B^0 \to (\rho\pi)^0 \to 3\pi$	Time-dependent Dalitz analysis	[7, 8]	$\star$	-
$B^- \to D^{(*)}K^{(*)-}$	Inputs to GLW analysis	[3]	$\star$	-
$B^- \to D^{(*)}K^{(*)-}$	Inputs to ADS analysis	[3]	$\star$	-
$B^- \to D^{(*)}K^{(*)-}$	GGSZ Dalitz analysis	[3]	$\star$	-
$\mathcal{B}(B^- \to \tau^- \overline{\nu}_\tau)$	$(1.68 \pm 0.31) \times 10^{-4}$	[9]	$\star$	-
$\overline{m}_c(m_c)$	$(1.286 \pm 0.013 \pm 0.040)$ GeV	[12]	$\star$	$\star$
$\overline{m}_t(m_t)$	$(165.02 \pm 1.16 \pm 0.11)$ GeV	[10]	$\star$	$\star$
B_K	$0.723 \pm 0.004 \pm 0.067$	[16]	$\star$	$\star$
$\alpha_S(m_Z^2)$	0.1176 ± 0.0020	[5]	-	$\star$
η_{cc}	Calculated from $\overline{m}_c(m_c)$ and α_S	[17]	-	$\star$
η_{ct}	0.47 ± 0.04	[18]	-	$\star$
η_{tt}	0.5765 ± 0.0065	[17, 18]	-	$\star$
$\eta_B(\overline{\rm MS})$	0.551 ± 0.007	[19]	-	$\star$
f_{B_s}	$(228 \pm 3 \pm 17)$ MeV	[16]	$\star$	$\star$
B_s	$1.28 \pm 0.02 \pm 0.03$	[16]	$\star$	$\star$
f_{B_s}/f_{B_d}	$1.199 \pm 0.008 \pm 0.023$	[16]	$\star$	$\star$
B_s/B_d	$1.05 \pm 0.01 \pm 0.03$	[16]	$\star$	$\star$

Table 1: *Inputs to the standard CKM fit. If not stated otherwise: for two errors given, the first is statistical and accountable systematic and the second stands for systematic theoretical uncertainties. The last two columns indicate* R*fit treatment of the input parameters: measurements or parameters that have statistical errors (we include here experimental systematics) are marked in the "GS" column by an asterisk; measurements or parameters that have systematic theoretical errors are marked in the "TH" column by an asterisk. Upper part: experimental determinations of the CKM matrix elements. Middle upper part: CP-violation and mixing observables. Middle lower part: parameters used in SM predictions that are obtained from experiment. Lower part: parameters of the SM predictions obtained from theory.*

References

[1] I.S. Towner and J.C. Hardy, Phys. Rev. **C 79**, 055502 (2009), arXiv:0812.1202 [nucl-ex].

[2] FlaviaNet Working Group on Kaon Decays, arXiv:1005.2323 [hep-ph].

[3] The Heavy Flavor Averaging Group (HFAG),
Summer 2010 averages, http://www.slac.stanford.edu/xorg/hfag, and references therein.
For V_{ub} and V_{cb}, our averages are based on "End of 2009" preliminary results.

[4] For the inclusive average we are taking the BLNP number. (The DGE result is very close to the BLNP result. The uncertainties between BLNP and DGE are hard to compare.) The theoretical error on the inclusive average is obtained by adding linearly the contributions from weak annihilation, subleading shape functions and the HQE uncertainty on m_b.
We use only branching fractions measured for $B \to \pi\ell\nu$. We average the results obtained from the two unquenched Lattice calculations and the LCSR calculation for the form factor quoted by HFAG [3] in such a way that the smallest theoretical error is kept.
Also for the average between the inclusive and exclusive result we keep the smallest theoretical error.

[5] Particle Data Group (C. Amsler *et al.*), Phys. Lett. **B 667**, 1 (2008).

[6] For this only the CDF measurement (Phys. Rev. Lett. **97**, 242003 (2006)) has been used as it currently dominates the world average which still needs to be determined by HFAG.

[7] B. Aubert *et al.*, Phys. Rev. **D 76**, 012004 (2007), hep-ex/0703008.

[8] A. Kusaka *et al.*, Phys. Rev. Lett. **98**, 221602 (2007), hep-ex/0701015.

[9] P. del Amo Sanchez *et al.*, ICHEP 2010
B. Aubert *et al.*, Phys. Rev. **D 81**, 051101(R) (2010)
K. Ikado *et al.*, Phys. Rev. Lett. **97**, 251802 (2006), hep-ex/0604018.
K. Hara *et al.*, arXiv:1006.4201 [hep-ex].

[10] The world average of the top quark mass measurements performed at the Tevatron [11] interpreted as a pole mass is translated into $m_t(m_t)$ in the $\overline{\rm MS}$ at 1-loop order.

[11] The Tevatron Electroweak Working Group and for the CDF and D0 collaborations, "Combination of CDF and D0 Results on the Mass of the Top Quark", arXiv:0808.1089v1 [hep-ex].

[12] We take $\overline{m}_c(m_c) = (1.286 \pm 0.013)$ GeV from an analysis by Kuhn and Steinhauser [13]. We assign an additional theoretical uncertainty of 0.040 GeV in order to take into account: a) an observed difference in analyses with participation of the same authors for the central value when using a somehow different extraction method [14, 15], and b) in order to take into account a likely over-optimistic error range for the gluon condensate in this analysis.
This input is consistent with $\overline{m}_c(m_c) = (1.265 \pm 0.060 \pm 0.050)$ GeV translated from the kinetic charm mass obtained from fits to data from lepton energy and hadronic mass moments in $B \to X_c\ell\nu$ decays combined with photon energy moments measured in $B \to X_s\gamma$ decays: $m_c^{kin} = (1.165 \pm 0.050)$ GeV [3].

[13] J. H. Kuhn, M. Steinhauser and C. Sturm, Nucl. Phys. B **778** (2007) 192 [arXiv:hep-ph/0702103].

[14] I. Allison *et al.* [HPQCD Collaboration], Phys. Rev. D **78** (2008) 054513 [arXiv:0805.2999 [hep-lat]].

[15] M. Steinhauser, "Precise Determinations of the Charm Quark Mass, arXiv:0809.1925 [hep-ph].

[16] CKMfitter group FPCP10 average (April, 26 2010).

[17] U. Nierste, private communication (2003).

[18] S. Herrlich and U. Nierste, Nucl. Phys. **B 419**, 292 (1994).

[19] G. Buchalla, A.J. Buras and M.E. Lautenbacher, Rev. Mod. Phys. **68**, 1125 (1996).