CKM fitter LP 2005

UPDATED RESULTS ON THE CKM MARTIX AND THE UNITARITY TRIANGLE

Including experimental results presented at Lepton-Photon 2005, Uppsala

Preliminary - to be completed

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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
(J. Charles, A. Höcker, H. Lacker, S. Laplace, F.R. Le Diberder, J. Malcles, J. Ocariz, M. Pivk, L. Roos)
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The CKMfitter Group

A. Bret [a], J. Charles [b], D. Decamp [a], O. Deschamps [c], A. Höcker [d], H. Lacker [e], S. Laplace [a], F.R. Le Diberder [d], J. Malclès [f], S. Monteil [c], J. Ocariz [f], M. Pivk [g], S. Pruvot [d], L. Roos [f], S. T'Jampens [a], K. Trabelsi [h],

[a] *Laboratoire d'Annecy-Le-Vieux de Physique des Particules*
9 Chemin de Bellevue, BP 110, F-74941 Annecy-le-Vieux Cedex, France
(UMR 5814 du CNRS-IN2P3 associée à l'Université de Savoie)
e-mail: anais.bret@lapp.in2p3.fr, Daniel.Decamp@lapp.in2p3.fr, laplace@lapp.in2p3.fr, tjamp@lapp.in2p3.fr

[b] *Centre de Physique Théorique,*
Campus de Luminy, Case 907, F-13288 Marseille Cedex 9, France
(UMR 6207 du CNRS associée aux Universités d'Aix-Marseille I et II et Université du Sud Toulon-Var; laboratoire affilié à la FRUMAM-FR2291)
e-mail: charles@cpt.univ-mrs.fr

[c] *Laboratoire de Physique Corpusulaire de Clermont-Ferrand*
Université Blaise Pascal
24, avenue des Landais F-63177 Aubiere Cedex
(UMR 6533 du CNRS-IN2P3 associée à l'Université Blaise Pascal)
e-mail: odescham@in2p3.fr, monteil@clermont.in2p3.fr

[d] *Laboratoire de l'Accélérateur Linéaire,*
Bât. 200 BP34 F-91898 Orsay, France
(UMR 8607 du CNRS-IN2P3 associée à l'Université Paris XI)
e-mail: hoecker@lal.in2p3.fr, diberder@in2p3.fr, pruvot@lal.in2p3.fr

[e] *Technische Universität Dresden,*
Institut für Kern- und Teilchenphysik, D-01062 Dresden, Germany
e-mail: h.lacker@physik.tu-dresden.de

[f] *Laboratoire de Physique Nucléaire et de Hautes Energies*
4 place Jussieu, F-75252 Paris Cedex 05, France
(UMR 7585 du CNRS-IN2P3 associée aux Universités Paris VI et VII)
e-mail: malcles@lpnhep.in2p3.fr, ocariz@in2p3.fr, lroos@lpnhep.in2p3.fr

[g] *CERN, PH Department*
CH-1211 Geneva 23, Switzerland
e-mail: muriel.pivk@cern.ch

[h] *University of Hawaii*
Honolulu, Hawai, 96822
e-mail: karim@phys.hawaii.edu

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Inputs that have been used for fit comparisons at the CKM05 workshop. Some of them might change in the complete write-up.

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Parameter	Value ± Error(s)	Reference	Errors GS	Errors TH
$\lvert V_{ud}\rvert$ (nuclei)	0.9739 ± 0.0003	[1]	$\star$	$\star$
$\lvert V_{us}\rvert$ ($K_{\ell 3}$ and $K_{\mu 2}$)	0.2248 ± 0.0016	[1]	$\star$	$\star$
$\lvert V_{ub}\rvert$ (average)	$(4.05 \pm 0.13 \pm 0.50) \times 10^{-3}$	[2], our average	$\star$	$\star$
$\lvert V_{cb}\rvert$ (incl.)	$(41.4 \pm 0.7 \pm 0.6) \times 10^{-3}$	[1]	$\star$	$\star$
$\lvert V_{cb}\rvert$ (excl.)	$(41.4 \pm 1.0 \pm 1.8) \times 10^{-3}$	[1]	$\star$	-
$\lvert\varepsilon_K\rvert$	$(2.282 \pm 0.017) \times 10^{-3}$	[3]	$\star$	-
Δm_d	$(0.509 \pm 0.004)\ \mathrm{ps}^{-1}$	[2]	$\star$	-
Δm_s	Amplitude spectrum	[1]	$\star$	-
$\sin(2\beta)_{[c\bar{c}]}$	0.687 ± 0.032	[2]	$\star$	-
$S_{\pi\pi}^{+-}$	-0.50 ± 0.12	[2]	$\star$	-
$C_{\pi\pi}^{+-}$	-0.37 ± 0.10	[2]	$\star$	-
$C_{\pi\pi}^{00}$	-0.28 ± 0.39	[2]	$\star$	-
$\mathcal{B}_{\pi\pi}$ all charges	Inputs to isospin analysis	[2]	$\star$	-
$S_{\rho\rho,L}^{+-}$	-0.22 ± 0.22	[2]	$\star$	-
$C_{\rho\rho,L}^{+-}$	-0.02 ± 0.17	[2]	$\star$	-
$\mathcal{B}_{\rho\rho,L}$ all charges	Inputs to isospin analysis	[2]	$\star$	-
$B^0 \to (\rho\pi)^0 \to 3\pi$	Time-dependent Dalitz analysis	[5]	$\star$	-
$B^- \to D^{(*)}K^-$	Inputs to GLW analysis	[2]	$\star$	-
$B^- \to D^{(*)}K^-$	Inputs to ADS analysis	[2]	$\star$	-
$B^- \to D^{(*)}K^{(*)-}$	GGSZ Dalitz analysis	[2]	$\star$	-
$\mathcal{B}(B^- \to \tau^-\overline{\nu}_\tau)$	Experimental likelihoods	[11]	$\star$	-
$\overline{m}_c(m_c)$	(1.3 ± 0.1) GeV	[6]	-	$\star$
$\overline{m}_t(m_t)$	(168.5 ± 4.1) GeV	[1]	$\star$	-
m_{K^+}	(493.677 ± 0.016) MeV	[6]	-	-
Δm_K	$(3.490 \pm 0.006) \times 10^{-12}$ MeV	[6]	-	-
m_{B_d}	(5.2794 ± 0.0005) GeV	[6]	-	-
m_{B_s}	(5.3696 ± 0.0024) GeV	[6]	-	-
m_W	(80.423 ± 0.039) GeV	[6]	-	-
G_F	$1.16639 \times 10^{-5}\ \mathrm{GeV}^{-2}$	[6]	-	-
f_K	(159.8 ± 1.5) MeV	[6]	-	-
B_K	$0.79 \pm 0.04 \pm 0.09$	[1]	$\star$	$\star$
$\alpha_s(m_Z^2)$	0.1187 ± 0.0020	[6]	-	$\star$
η_{ct}	0.47 ± 0.04	[7]	-	$\star$
η_{tt}	0.5765 ± 0.0065	[7, 8]	-	-
$\eta_B(\overline{\mathrm{MS}})$	0.551 ± 0.007	[9]	-	$\star$
$f_{B_d}\sqrt{B_d}$	$(223 \pm 33 \pm 12)$ MeV	[1]	$\star$	$\star$
$\xi^{(a)}$	$1.24 \pm 0.04 \pm 0.06$	[1]	$\star$	$\star$

$^{(a)}$anticorrelated theory error with $f_{B_d}\sqrt{B_d}$.

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 fourth and fifth columns indicate the treatment of the input parameters within* R*fit: 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, treated as ranges in* R*fit, are marked in the "TH" column by an asterisk.* <u>*Upper part:*</u> *experimental determinations of the CKM matrix elements.* <u>*Middle upper part:*</u> *CP-violation and mixing observables.* <u>*Middle lower part:*</u> *parameters used in SM predictions that are obtained from experiment.* <u>*Lower part:*</u> *parameters of the SM predictions obtained from theory.*

Observable	central ± CL ≡ 1σ	± CL ≡ 2σ	± CL ≡ 3σ
λ	$0.2261\,^{+0.0010}_{-0.0010}$	$^{+0.0020}_{-0.0020}$	$^{+0.0030}_{-0.0030}$
A	$0.804\,^{+0.026}_{-0.013}$	$^{+0.051}_{-0.026}$	$^{+0.067}_{-0.039}$
$\bar{\rho}$	$0.183\,^{+0.035}_{-0.043}$	$^{+0.092}_{-0.087}$	$^{+0.142}_{-0.129}$
$\bar{\eta}$	$0.324\,^{+0.024}_{-0.018}$	$^{+0.049}_{-0.041}$	$^{+0.076}_{-0.063}$
J $[10^{-5}]$	$2.80\,^{+0.26}_{-0.17}$	$^{+0.60}_{-0.33}$	$^{+0.85}_{-0.45}$
$\sin(2\alpha)$	$-0.27\,^{+0.25}_{-0.17}$	$^{+0.50}_{-0.41}$	$^{+0.71}_{-0.56}$
$\sin(2\alpha)$ (meas. not in fit)	$-0.17\,^{+0.46}_{-0.31}$	$^{+0.69}_{-0.58}$	$^{+0.86}_{-0.70}$
$\sin(2\beta)$	$0.686\,^{+0.031}_{-0.021}$	$^{+0.062}_{-0.044}$	$^{+0.093}_{-0.070}$
$\sin(2\beta)$ (meas. not in fit)	$0.685\,^{+0.115}_{-0.027}$	$^{+0.176}_{-0.065}$	$^{+0.197}_{-0.111}$
α (deg)	$97.8\,^{+5.4}_{-7.3}$	$^{+13.8}_{-14.4}$	$^{+20.2}_{-20.9}$
α (deg) (meas. not in fit)	$94.9\,^{+9.6}_{-13.3}$	$^{+19.3}_{-20.5}$	$^{+25.6}_{-26.6}$
β (deg)	$21.65\,^{+1.27}_{-0.78}$	$^{+2.58}_{-1.66}$	$^{+3.95}_{-2.61}$
β (deg) (meas. not in fit)	$21.6\,^{+4.9}_{-1.1}$	$^{+8.1}_{-2.4}$	$^{+9.3}_{-4.1}$
$\gamma \simeq \delta$ (deg)	$60.6\,^{+7.1}_{-5.4}$	$^{+14.4}_{-13.8}$	$^{+21.0}_{-20.1}$
$\gamma \simeq \delta$ (deg) (meas. not in fit)	$59.8\,^{+7.8}_{-5.7}$	$^{+16.1}_{-16.2}$	$^{+23.5}_{-21.4}$
$\sin(2\beta_s)$	$0.0346\,^{+0.0026}_{-0.0020}$	$^{+0.0054}_{-0.0044}$	$^{+0.0084}_{-0.0068}$
β_s (deg)	$0.993\,^{+0.074}_{-0.058}$	$^{+0.154}_{-0.129}$	$^{+0.239}_{-0.198}$
$\sin\theta_{12}$	$0.22613\,^{+0.00098}_{-0.00104}$	$^{+0.00198}_{-0.00204}$	$^{+0.00298}_{-0.00305}$
$\sin\theta_{13}$ $[10^{-3}]$	$3.56\,^{+0.21}_{-0.11}$	$^{+0.47}_{-0.22}$	$^{+0.77}_{-0.33}$
$\sin\theta_{23}$ $[10^{-3}]$	$41.11\,^{+1.29}_{-0.56}$	$^{+2.41}_{-1.12}$	$^{+3.07}_{-1.68}$
R_u	$0.373\,^{+0.020}_{-0.013}$	$^{+0.041}_{-0.027}$	$^{+0.067}_{-0.040}$
R_t	$0.879\,^{+0.047}_{-0.036}$	$^{+0.094}_{-0.096}$	$^{+0.137}_{-0.147}$
Δm_d (ps^{-1}) (meas. not in fit)	$0.453\,^{+0.172}_{-0.090}$	$^{+0.458}_{-0.157}$	$^{+0.723}_{-0.206}$
Δm_s (ps^{-1})	$17.9\,^{+3.6}_{-1.4}$	$^{+8.6}_{-2.4}$	$^{+13.3}_{-3.3}$
Δm_s (ps^{-1}) (meas. not in fit)	$18.8\,^{+4.8}_{-2.9}$	$^{+8.4}_{-4.7}$	$^{+12.8}_{-6.3}$
ϵ_K $[10^{-3}]$ (meas. not in fit)	$1.72\,^{+1.24}_{-0.22}$	$^{+1.77}_{-0.41}$	$^{+2.25}_{-0.62}$
$f_{B_d}\sqrt{B_d}$ (MeV) (lattice value not in fit)	$213\,^{+21}_{-12}$	$^{+47}_{-23}$	$^{+61}_{-31}$
B_K (lattice value not in fit)	$0.86\,^{+0.19}_{-0.18}$	$^{+0.34}_{-0.28}$	$^{+0.54}_{-0.35}$
m_c (GeV/c^2) (meas. not in fit)	$1.67\,^{+0.24}_{-0.88}$	$^{+0.41}_{-0.88}$	$^{+0.62}_{-0.88}$
m_t (GeV/c^2) (meas. not in fit)	$155\,^{+38}_{-21}$	$^{+92}_{-37}$	$^{+133}_{-49}$

Table 2: Preliminary numerical results of the global CKM fit (I).

Observable	central ± CL ≡ 1σ	± CL ≡ 2σ	± CL ≡ 3σ
$\mathcal{B}(K^0_{\rm L} \to \pi^0\nu\overline{\nu})$ $[10^{-11}]$	$2.26\,^{+0.45}_{-0.28}$	$^{+1.10}_{-0.50}$	$^{+1.60}_{-0.66}$
$\mathcal{B}(K^+ \to \pi^+\nu\overline{\nu})$ $[10^{-11}]$	$7.39\,^{+0.87}_{-0.51}$	$^{+2.00}_{-1.00}$	$^{+2.77}_{-1.44}$
$\mathcal{B}(B^+ \to \tau^+\nu_\mu)$ $[10^{-5}]$	$8.2\,^{+1.7}_{-1.3}$	$^{+5.0}_{-2.2}$	$^{+8.6}_{-3.0}$
$\mathcal{B}(B^+ \to \mu^+\nu_\mu)$ $[10^{-7}]$	$3.63\,^{+0.75}_{-0.58}$	$^{+2.21}_{-0.97}$	$^{+3.83}_{-1.31}$
$\|V_{ud}\|$	$0.97409\,^{+0.00024}_{-0.00023}$	$^{+0.00047}_{-0.00047}$	$^{+0.00070}_{-0.00070}$
$\|V_{us}\|$	$0.22611\,^{+0.00100}_{-0.00101}$	$^{+0.00200}_{-0.00202}$	$^{+0.00300}_{-0.00303}$
$\|V_{ub}\|$ $[10^{-3}]$	$3.55\,^{+0.21}_{-0.11}$	$^{+0.47}_{-0.22}$	$^{+0.77}_{-0.33}$
$\|V_{ub}\|$ $[10^{-3}]$ (meas. not in fit)	$3.55\,^{+0.21}_{-0.20}$	$^{+0.47}_{-0.39}$	$^{+0.77}_{-0.39}$
$\|V_{cd}\|$	$0.22597\,^{+0.00102}_{-0.00100}$	$^{+0.00202}_{-0.00200}$	$^{+0.00302}_{-0.00301}$
$\|V_{cs}\|$	$0.97326\,^{+0.00024}_{-0.00023}$	$^{+0.00047}_{-0.00047}$	$^{+0.00070}_{-0.00071}$
$\|V_{cb}\|$ $[10^{-3}]$	$41.12\,^{+1.29}_{-0.57}$	$^{+2.41}_{-1.13}$	$^{+3.06}_{-1.68}$
$\|V_{cb}\|$ $[10^{-3}]$ (meas. not in fit)	$40.9\,^{+4.7}_{-2.0}$	$^{+7.0}_{-3.3}$	$^{+9.2}_{-4.6}$
$\|V_{td}\|$ $[10^{-3}]$	$8.17\,^{+0.48}_{-0.35}$	$^{+1.06}_{-0.85}$	$^{+1.49}_{-1.21}$
$\|V_{ts}\|$ $[10^{-3}]$	$40.46\,^{+1.26}_{-0.56}$	$^{+2.37}_{-1.11}$	$^{+3.03}_{-1.66}$
$\|V_{tb}\|$	$0.999148\,^{+0.000023}_{-0.000054}$	$^{+0.000046}_{-0.000103}$	$^{+0.000068}_{-0.000132}$
$\|V_{ud}V^*_{ub}\|$ $[10^{-3}]$	$3.46\,^{+0.21}_{-0.11}$	$^{+0.46}_{-0.21}$	$^{+0.75}_{-0.32}$
$\arg\,[V_{ud}V^*_{ub}]$ (deg)	$60.6\,^{+7.2}_{-5.3}$	$^{+14.4}_{-13.7}$	$^{+21.1}_{-20.0}$
$\|V_{cd}V^*_{cb}\|$ $[10^{-3}]$	$9.29\,^{+0.29}_{-0.13}$	$^{+0.56}_{-0.26}$	$^{+0.71}_{-0.39}$
$\arg\,[-V_{cd}V^*_{cb}]$ (deg)	$0.0314\,^{+0.0029}_{-0.0018}$	$^{+0.0067}_{-0.0037}$	$^{+0.0095}_{-0.0050}$
$\|V_{td}V^*_{tb}\|$ $[10^{-3}]$	$8.16\,^{+0.49}_{-0.35}$	$^{+1.07}_{-0.85}$	$^{+1.49}_{-1.20}$
$\arg\,[V_{td}V^*_{tb}]$ (deg)	$-21.62\,^{+0.78}_{-1.27}$	$^{+1.66}_{-2.57}$	$^{+2.60}_{-3.95}$
$\|V_{td}/V_{ts}\|$	$0.2020\,^{+0.0112}_{-0.0087}$	$^{+0.0225}_{-0.0231}$	$^{+0.0330}_{-0.0351}$
$\arg\,[-V_{ts}V^*_{tb}]$ (deg)	$0.990\,^{+0.075}_{-0.056}$	$^{+0.155}_{-0.127}$	$^{+0.240}_{-0.196}$
${\rm Re}\lambda_c$	$-0.21994\,^{+0.00093}_{-0.00092}$	$^{+0.00186}_{-0.00185}$	$^{+0.00279}_{-0.00276}$
${\rm Im}\lambda_c$ $[10^{-4}]$	$-1.272\,^{+0.076}_{-0.117}$	$^{+0.150}_{-0.271}$	$^{+0.203}_{-0.383}$
${\rm Re}\lambda_t$ $[10^{-4}]$	$-3.05\,^{+0.15}_{-0.25}$	$^{+0.32}_{-0.54}$	$^{+0.48}_{-0.75}$
${\rm Im}\lambda_t$ $[10^{-4}]$	$1.271\,^{+0.118}_{-0.075}$	$^{+0.272}_{-0.149}$	$^{+0.383}_{-0.202}$

Table 3: Preliminary numerical results of the global CKM fit (II).