CKM fitter CKM 2005

UPDATED RESULTS ON THE CKM MARTIX AND THE UNITARITY TRIANGLE

(Including all experimental results presented at Moriond 2005 and CKM 2005, San Diego)

March 30, 2005

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)
Accepted for publication by Eur. Phys. J. C
e-Print Archive: hep-ph/0406184

References

[1] http://ckm2005.ucsd.edu/
Inputs that have been used for fit comparisons at the CKM05 workshop. Some of them might change in the complete write-up.

[2] The Heavy Flavor Averaging Group, http://www.slac.stanford.edu/xorg/hfag/ (Winter 2005 averages)

[3] T. Trippe, private communication (2004)

[4] B. Aubert *et al.*, hep-ex/0503049

[5] B. Aubert *et al.*, BABAR-CONF-04/038, hep-ex/0408099

[6] Particle Data Group (K. Hagiwara *et al.*), Phys. Rev. **D66**, 010001 (2002 and 2003 update)

[7] S. Herrlich and U. Nierste, Nucl. Phys. **B419**, 292 (1994)

[8] U. Nierste, Ref. [10] and private communication (2003)

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

[10] M. Battaglia *et al.*, CERN-2003-002, Cern Yellow Report, Based on the Workshop on CKM Unitarity Triangle (CERN 2002-2003), Geneva, Switzerland, 13-16 Feb 2002, hep-ph/0304132

Parameter	Value ± Error(s)	Reference	Errors GS	TH
$\lvert V_{ud}\rvert$ (nuclei)	0.9739 ± 0.0003	[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	$(0.502 \pm 0.006)\ \mathrm{ps}^{-1}$	[2]	$\star$	-
Δm_s	Amplitude spectrum	[1]	$\star$	-
$\sin 2\beta_{[c\bar{c}]}$	0.726 ± 0.037	[2]	$\star$	-
$S_{\pi\pi}^{+-}$	-0.50 ± 0.12	[2]	$\star$	-
$C_{\pi\pi}^{+-}$	-0.37 ± 0.10	[2]	$\star$	-
$C_{\pi^0\pi^0}$	0.28 ± 0.39	[2]	$\star$	-
$\mathcal{B}_{\pi\pi}$ all charges	Inputs to isospin analysis	[2]	$\star$	-
$S_{\rho\rho,L}^{+-}$	$-0.33^{+0.25}_{-0.28}$	[4]	$\star$	-
$C_{\rho\rho,L}^{+-}$	-0.03 ± 0.20	[4]	$\star$	-
$\mathcal{B}_{\rho\rho,L}$ 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]	$\star$	-
$\overline{m}_c(m_c)$	$(1.3 \pm 0.1)\ \mathrm{GeV}$	[6]	-	$\star$
$\overline{m}_t(m_t)$	$(168.5 \pm 4.1)\ \mathrm{GeV}$	[1]	$\star$	-
m_{K^+}	$(493.677 \pm 0.016)\ \mathrm{MeV}$	[6]	-	-
Δm_K	$(3.490 \pm 0.006) \times 10^{-12}\ \mathrm{MeV}$	[6]	-	-
m_{B_d}	$(5.2794 \pm 0.0005)\ \mathrm{GeV}$	[6]	-	-
m_{B_s}	$(5.3696 \pm 0.0024)\ \mathrm{GeV}$	[6]	-	-
m_W	$(80.423 \pm 0.039)\ \mathrm{GeV}$	[6]	-	-
G_F	$1.16639 \times 10^{-5}\ \mathrm{GeV}^{-2}$	[6]	-	-
f_K	$(159.8 \pm 1.5)\ \mathrm{MeV}$	[6]	-	-
B_K	$0.79 \pm 0.04 \pm 0.09$	[1]	$\star$	$\star$
$\alpha_s(m_Z^2)$	0.1172 ± 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]	-	$\star$
$f_{B_d}\sqrt{B_d}$	$(223 \pm 33 \pm 12)\ \mathrm{MeV}$	[1]	$\star$	$\star$
ξ	$1.24 \pm 0.04 \pm 0.06$	[1]	$\star$	$\star$

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 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. 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.*

Observable	central $\pm$ CL $\equiv 1\sigma$	$\pm$ CL $\equiv 2\sigma$	$\pm$ CL $\equiv 3\sigma$
λ	$0.2265\,^{+0.0020}_{-0.0020}$	$^{+0.0040}_{-0.0040}$	$^{+0.0060}_{-0.0060}$
A	$0.801\,^{+0.029}_{-0.018}$	$^{+0.060}_{-0.035}$	$^{+0.082}_{-0.052}$
$\bar{\rho}$	$0.204\,^{+0.036}_{-0.043}$	$^{+0.120}_{-0.093}$	$^{+0.174}_{-0.137}$
$\bar{\eta}$	$0.340\,^{+0.025}_{-0.022}$	$^{+0.056}_{-0.055}$	$^{+0.088}_{-0.079}$
J $[10^{-5}]$	$2.94\,^{+0.27}_{-0.21}$	$^{+0.64}_{-0.48}$	$^{+0.88}_{-0.63}$
$\sin 2\alpha$	$-0.27\,^{+0.22}_{-0.16}$	$^{+0.49}_{-0.49}$	$^{+0.71}_{-0.62}$
$\sin 2\alpha$ (meas. not in fit)	$-0.11\,^{+0.43}_{-0.32}$	$^{+0.62}_{-0.67}$	$^{+0.76}_{-0.81}$
$\sin 2\beta$	$0.722\,^{+0.036}_{-0.036}$	$^{+0.072}_{-0.064}$	$^{+0.108}_{-0.091}$
$\sin 2\beta$ (meas. not in fit)	$0.682\,^{+0.125}_{-0.028}$	$^{+0.182}_{-0.078}$	$^{+0.203}_{-0.128}$
α (deg)	$97.9\,^{+5.0}_{-6.4}$	$^{+16.8}_{-14.1}$	$^{+23.4}_{-20.9}$
α (deg) (meas. not in fit)	$93.1\,^{+9.6}_{-12.5}$	$^{+22.4}_{-18.5}$	$^{+29.8}_{-23.7}$
β (deg)	$23.1\,^{+1.5}_{-1.5}$	$^{+3.1}_{-2.6}$	$^{+4.9}_{-3.6}$
$\gamma \simeq \delta$ (deg)	$59.0\,^{+6.4}_{-4.9}$	$^{+14.2}_{-16.6}$	$^{+21.1}_{-23.1}$
$\gamma \simeq \delta$ (deg) (meas. not in fit)	$58.2\,^{+6.7}_{-5.4}$	$^{+15.6}_{-20.3}$	$^{+23.3}_{-24.6}$
$\sin\theta_{12}$	$0.2266\,^{+0.0020}_{-0.0020}$	$^{+0.0040}_{-0.0040}$	$^{+0.0060}_{-0.0060}$
$\sin\theta_{13}$ $[10^{-3}]$	$3.79\,^{+0.25}_{-0.23}$	$^{+0.56}_{-0.38}$	$^{+0.56}_{-0.50}$
$\sin\theta_{23}$ $[10^{-3}]$	$41.13\,^{+1.34}_{-0.58}$	$^{+2.42}_{-1.16}$	$^{+3.07}_{-1.73}$
R_u	$0.396\,^{+0.024}_{-0.024}$	$^{+0.050}_{-0.041}$	$^{+0.085}_{-0.057}$
R_t	$0.866\,^{+0.044}_{-0.036}$	$^{+0.097}_{-0.127}$	$^{+0.145}_{-0.183}$
Δm_d (ps^{-1}) (meas. not in fit)	$0.47\,^{+0.23}_{-0.12}$	$^{+0.51}_{-0.21}$	$^{+0.82}_{-0.26}$
Δm_s (ps^{-1})	$17.9\,^{+5.3}_{-1.3}$	$^{+11.0}_{-2.4}$	$^{+17.1}_{-3.4}$
Δm_s (ps^{-1}) (meas. not in fit)	$18.3\,^{+6.3}_{-2.3}$	$^{+11.5}_{-4.3}$	$^{+17.3}_{-6.0}$
ϵ_K $[10^{-3}]$ (meas. not in fit)	$2.09\,^{+1.14}_{-0.50}$	$^{+1.76}_{-0.79}$	$^{+2.33}_{-1.01}$
$f_{B_d}\sqrt{B_d}$ (MeV) (lattice value not in fit)	$209\,^{+27}_{-10}$	$^{+58}_{-22}$	$^{+76}_{-29}$
B_K (lattice value not in fit)	$0.85\,^{+0.14}_{-0.22}$	$^{+0.36}_{-0.32}$	$^{+0.59}_{-0.39}$
m_t (GeV/c^2) (meas. not in fit)	$171\,^{+43}_{-42}$	$^{+90}_{-59}$	$^{+146}_{-71}$

Table 2: *Numerical results of the global CKM fit (I).*

Observable	central $\pm$ CL $\equiv 1\sigma$	$\pm$ CL $\equiv 2\sigma$	$\pm$ CL $\equiv 3\sigma$
$\lvert V_{ud}\rvert$	$0.97399\,^{+0.00046}_{-0.00046}$	$^{+0.00092}_{-0.00093}$	$^{+0.00137}_{-0.00141}$
$\lvert V_{us}\rvert$	$0.2265\,^{+0.0020}_{-0.0020}$	$^{+0.0040}_{-0.0040}$	$^{+0.0060}_{-0.0060}$
$\lvert V_{ub}\rvert$ $[10^{-3}]$	$3.79\,^{+0.25}_{-0.23}$	$^{+0.56}_{-0.38}$	$^{+0.89}_{-0.50}$
$\lvert V_{ub}\rvert$ $[10^{-3}]$ (meas. not in fit)	$3.79\,^{+0.25}_{-0.23}$	$^{+0.56}_{-0.46}$	$^{+0.96}_{-0.68}$
$\lvert V_{cd}\rvert$	$0.2264\,^{+0.0020}_{-0.0020}$	$^{+0.0040}_{-0.0040}$	$^{+0.0060}_{-0.0060}$
$\lvert V_{cs}\rvert$	$0.97316\,^{+0.00046}_{-0.00047}$	$^{+0.00092}_{-0.00094}$	$^{+0.00137}_{-0.00141}$
$\lvert V_{cb}\rvert$ $[10^{-3}]$	$41.13\,^{+1.34}_{-0.58}$	$^{+2.42}_{-1.16}$	$^{+3.06}_{-1.73}$
$\lvert V_{cb}\rvert$ $[10^{-3}]$ (meas. not in fit)	$40.9\,^{+4.2}_{-3.6}$	$^{+6.9}_{-4.9}$	$^{+8.7}_{-6.2}$
$\lvert V_{td}\rvert$ $[10^{-3}]$	$8.07\,^{+0.45}_{-0.35}$	$^{+1.06}_{-1.18}$	$^{+1.46}_{-1.60}$
$\lvert V_{ts}\rvert$ $[10^{-3}]$	$40.50\,^{+1.33}_{-0.57}$	$^{+2.40}_{-1.14}$	$^{+3.05}_{-1.71}$
$\lvert V_{tb}\rvert$	$0.999147\,^{+0.000024}_{-0.000057}$	$^{+0.000047}_{-0.000104}$	$^{+0.000070}_{-0.000132}$
$\lvert V_{td}/V_{ts}\rvert$	$0.1992\,^{+0.0107}_{-0.0087}$	$^{+0.0236}_{-0.0303}$	$^{+0.0350}_{-0.0438}$
$\lvert V_{ud}V_{ub}^*\rvert$ $[10^{-3}]$	$3.69\,^{+0.25}_{-0.22}$	$^{+0.55}_{-0.37}$	$^{+0.87}_{-0.49}$
$\arg\,[V_{ud}V_{ub}^*]$ (deg)	$59.1\,^{+6.3}_{-5.0}$	$^{+14.1}_{-16.7}$	$^{+21.0}_{-23.2}$
$\lvert V_{cd}V_{cb}^*\rvert$ $[10^{-3}]$	$9.31\,^{+0.31}_{-0.15}$	$^{+0.59}_{-0.30}$	$^{+0.77}_{-0.46}$
$\lvert V_{td}V_{tb}^*\rvert$ $[10^{-3}]$	$8.06\,^{+0.45}_{-0.35}$	$^{+1.06}_{-1.18}$	$^{+1.46}_{-1.60}$
$\arg\,[V_{td}V_{tb}^*]$ (deg)	$-23.1\,^{+1.5}_{-1.5}$	$^{+2.5}_{-3.2}$	$^{+3.5}_{-4.9}$
$\mathrm{Re}\lambda_c$	$-0.2203\,^{+0.0018}_{-0.0018}$	$^{+0.0037}_{-0.0037}$	$^{+0.0055}_{-0.0055}$
$\mathrm{Im}\lambda_c$ $[10^{-4}]$	$-1.334\,^{+0.092}_{-0.124}$	$^{+0.214}_{-0.285}$	$^{+0.282}_{-0.392}$
$\mathrm{Re}\lambda_t$ $[10^{-4}]$	$-2.98\,^{+0.15}_{-0.23}$	$^{+0.45}_{-0.54}$	$^{+0.62}_{-0.73}$
$\mathrm{Im}\lambda_t$ $[10^{-4}]$	$1.335\,^{+0.122}_{-0.093}$	$^{+0.284}_{-0.215}$	$^{+0.391}_{-0.283}$
$\mathcal{B}(B^+ \to \tau^+\nu_\mu)$ $[10^{-5}]$	$9.3\,^{+3.4}_{-2.3}$	$^{+7.8}_{-3.5}$	$^{+14.9}_{-4.3}$
$\mathcal{B}(B^+ \to \mu^+\nu_\mu)$ $[10^{-7}]$	$4.2\,^{+1.4}_{-1.1}$	$^{+3.4}_{-1.6}$	$^{+6.6}_{-2.0}$

Table 3: *Numerical results of the global CKM fit (II).*