UPDATED RESULTS ON THE CKM MARTIX AND THE UNITARITY TRIANGLE

Including results presented up to
FPCP 06, Vancouver, Canada

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)	0.97377 ± 0.00027	[1]	$\star$	-
$\|V_{us}\|$ ($K_{\ell 3}$ and $K_{\mu 2}$)	0.2257 ± 0.0021	[10]	$\star$	-
$\|V_{ub}\|$ (incl.)	$(4.45 \pm 0.23 \pm 0.39) \times 10^{-3}$	[2, 3]	$\star$	$\star$
$\|V_{ub}\|$ (excl.)	$(3.94 \pm 0.28 \pm 0.51) \times 10^{-3}$	[10]	$\star$	$\star$
$\|V_{cb}\|$ (incl.)	$(41.70 \pm 0.70) \times 10^{-3}$	[10]	$\star$	-
$\|V_{cb}\|$ (excl.)	$(41.18 \pm 1.71) \times 10^{-3}$	[2]	$\star$	-
$\|\varepsilon_K\|$	$(2.221 \pm 0.008) \times 10^{-3}$	[5]	$\star$	-
Δm_d	(0.507 ± 0.004) ps^{-1}	[2]	$\star$	-
Δm_s	Amplitude spectrum+CDF -LogL	[6]	$\star$	-
$\sin(2\beta)_{[c\bar{c}]}$	0.687 ± 0.032	[2]	$\star$	-
$S^{+-}_{\pi\pi}$	-0.50 ± 0.12	[2]	$\star$	-
$C^{+-}_{\pi\pi}$	-0.37 ± 0.10	[2]	$\star$	-
$C^{00}_{\pi\pi}$	-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	[7]	$\star$	-
$B^- \to D^{(*)}K^{(*)-}$	Inputs to GLW analysis	[2]	$\star$	-
$B^- \to D^{(*)}K^{(*)-}$	Inputs to ADS analysis	[2]	$\star$	-
$B^- \to D^{(*)}K^{(*)-}$	GGSZ Dalitz analyses	[2]	$\star$	-
$\mathcal{B}(B^- \to \tau^- \overline{\nu}_\tau)$	Experimental likelihoods	[9]	$\star$	-
$\overline{m}_c(m_c)$	$(1.24 \pm 0.037 \pm 0.095)$ GeV	[4]	$\star$	$\star$
$\overline{m}_t(m_t)$	(162.3 ± 2.2) GeV	[8]	$\star$	-
m_{K^+}	(493.677 ± 0.016) MeV	[10]	-	-
Δm_K	$(3.4833 \pm 0.0066) \times 10^{-12}$ MeV	[10]	-	-
m_{B_d}	(5.2794 ± 0.0005) GeV	[10]	-	-
m_{B_s}	(5.3696 ± 0.0024) GeV	[10]	-	-
m_W	(80.423 ± 0.039) GeV	[10]	-	-
G_F	1.16639×10^{-5} GeV^{-2}	[10]	-	-
f_K	(159.8 ± 1.5) MeV	[10]	-	-
B_K	$0.79 \pm 0.04 \pm 0.09$	[1]	$\star$	$\star$
$\alpha_s(m_Z^2)$	0.1176 ± 0.0020	[10]	-	$\star$
η_{ct}	0.47 ± 0.04	[11]	-	$\star$
η_{tt}	0.5765 ± 0.0065	[11, 12]	-	$\star$
$\eta_B(\overline{\rm MS})$	0.551 ± 0.007	[13]	-	$\star$
f_{B_d}	(191 ± 27) MeV	[1]	$\star$	-
B_d	1.37 ± 0.14	[1]	$\star$	-
$\xi^{(a)}$	$1.24 \pm 0.04 \pm 0.06$	[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 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.*

Observable	central $\pm$ CL $\equiv 1\sigma$	$\pm$ CL $\equiv 2\sigma$	$\pm$ CL $\equiv 3\sigma$
λ	$0.2272\,^{+0.0010}_{-0.0010}$	$^{+0.0020}_{-0.0020}$	$^{+0.0030}_{-0.0030}$
A	$0.809\,^{+0.014}_{-0.014}$	$^{+0.029}_{-0.028}$	$^{+0.044}_{-0.042}$
$\bar{\rho}$	$0.197\,^{+0.026}_{-0.030}$	$^{+0.050}_{-0.087}$	$^{+0.074}_{-0.133}$
$\bar{\eta}$	$0.339\,^{+0.019}_{-0.018}$	$^{+0.047}_{-0.037}$	$^{+0.075}_{-0.057}$
J $[10^{-5}]$	$3.05\,^{+0.18}_{-0.18}$	$^{+0.45}_{-0.36}$	$^{+0.69}_{-0.54}$
$\sin(2\alpha)$	$-0.25\,^{+0.17}_{-0.15}$	$^{+0.49}_{-0.28}$	$^{+0.71}_{-0.42}$
$\sin(2\alpha)$ (meas. not in fit)	$-0.23\,^{+0.55}_{-0.16}$	$^{+0.72}_{-0.32}$	$^{+0.83}_{-0.45}$
$\sin(2\beta)$	$0.716\,^{+0.024}_{-0.024}$	$^{+0.048}_{-0.049}$	$^{+0.074}_{-0.075}$
$\sin(2\beta)$ (meas. not in fit)	$0.752\,^{+0.057}_{-0.035}$	$^{+0.105}_{-0.073}$	$^{+0.135}_{-0.112}$
α (deg)	$97.3\,^{+4.5}_{-5.0}$	$^{+8.7}_{-14.0}$	$^{+13.7}_{-20.7}$
α (deg) (meas. not in fit)	$96.5\,^{+4.9}_{-16.0}$	$^{+9.9}_{-21.2}$	$^{+14.6}_{-25.3}$
α (deg) (dir. meas.)	$100.2\,^{+15.0}_{-8.8}$	$^{+22.7}_{-18.2}$	$^{+32.0}_{-28.1}$
β (deg)	$22.86\,^{+1.00}_{-1.00}$	$^{+2.03}_{-1.97}$	$^{+3.22}_{-2.93}$
β (deg) (meas. not in fit)	$24.4\,^{+2.6}_{-1.5}$	$^{+5.1}_{-3.0}$	$^{+6.9}_{-4.5}$
β (deg) (dir. meas.)	$21.7\,^{+1.3}_{-1.2}$	$^{+2.6}_{-2.4}$	$^{+4.1}_{-3.6}$
$\gamma \simeq \delta$ (deg)	$59.8\,^{+4.9}_{-4.1}$	$^{+13.9}_{-7.9}$	$^{+20.8}_{-12.1}$
$\gamma \simeq \delta$ (deg) (meas. not in fit)	$59.8\,^{+4.9}_{-4.2}$	$^{+14.1}_{-8.0}$	$^{+21.0}_{-12.3}$
$\gamma \simeq \delta$ (deg) (dir. meas.)	$63\,^{+35}_{-25}$	$^{+62}_{-40}$	$^{+100}_{-54}$
β_s (deg)	$1.045\,^{+0.061}_{-0.057}$	$^{+0.151}_{-0.114}$	$^{+0.238}_{-0.177}$
$\sin(2\beta_s)$	$0.0365\,^{+0.0021}_{-0.0020}$	$^{+0.0053}_{-0.0040}$	$^{+0.0083}_{-0.0062}$
$\sin\theta_{12}$	$0.2272\,^{+0.0010}_{-0.0010}$	$^{+0.0020}_{-0.0020}$	$^{+0.0030}_{-0.0030}$
$\sin\theta_{13}$ $[10^{-3}]$	$3.82\,^{+0.15}_{-0.15}$	$^{+0.31}_{-0.30}$	$^{+0.49}_{-0.44}$
$\sin\theta_{23}$ $[10^{-3}]$	$41.78\,^{+0.63}_{-0.63}$	$^{+1.26}_{-1.26}$	$^{+1.90}_{-1.89}$
R_u	$0.391\,^{+0.015}_{-0.015}$	$^{+0.031}_{-0.029}$	$^{+0.049}_{-0.044}$
R_t	$0.872\,^{+0.033}_{-0.028}$	$^{+0.095}_{-0.054}$	$^{+0.143}_{-0.082}$
Δm_d (ps^{-1}) (meas. not in fit)	$0.394\,^{+0.097}_{-0.097}$	$^{+0.219}_{-0.132}$	$^{+0.361}_{-0.162}$
Δm_s (ps^{-1})	$17.34\,^{+0.49}_{-0.20}$	$^{+0.65}_{-0.35}$	$^{+0.78}_{-0.49}$
Δm_s (ps^{-1}) (meas. not in fit)	$21.7\,^{+5.9}_{-4.2}$	$^{+9.7}_{-6.8}$	$^{+13.1}_{-9.1}$
ϵ_K $[10^{-3}]$ (meas. not in fit)	$2.46\,^{+0.63}_{-0.88}$	$^{+1.05}_{-1.05}$	$^{+1.50}_{-1.20}$
f_{B_d} (MeV) (lattice value not in fit)	$183\,^{+10}_{-10}$	$^{+21}_{-20}$	$^{+34}_{-28}$
$\xi^{\Delta m_{d,s}}_{SU(3)}$ (lattice value not in fit)	$1.061\,^{+0.122}_{-0.047}$	$^{+0.213}_{-0.083}$	$^{+0.324}_{-0.119}$
B_K (lattice value not in fit)	$0.722\,^{+0.251}_{-0.084}$	$^{+0.348}_{-0.157}$	$^{+0.461}_{-0.216}$
m_c (GeV/c^2) (meas. not in fit)	$0.81\,^{+0.93}_{-0.36}$	$^{+1.08}_{-0.36}$	$^{+1.23}_{-0.81}$
m_t (GeV/c^2) (meas. not in fit)	$150\,^{+27}_{-21}$	$^{+57}_{-35}$	$^{+79}_{-46}$

Table 2: *Fit results.*

Observable	central $\pm$ CL $\equiv 1\sigma$	$\pm$ CL $\equiv 2\sigma$	$\pm$ CL $\equiv 3\sigma$
$\mathcal{B}(B^+ \to \tau^+\nu_\mu)$ $[10^{-5}]$	$9.6\,^{+1.5}_{-1.5}$	$^{+3.3}_{-2.9}$	$^{+5.4}_{-4.0}$
$\mathcal{B}(B^+ \to \mu^+\nu_\mu)$ $[10^{-7}]$	$4.32\,^{+0.58}_{-0.57}$	$^{+1.27}_{-1.12}$	$^{+2.05}_{-1.62}$
$\mathcal{B}(K^0_{\rm L} \to \pi^0\nu\overline{\nu})$ $[10^{-11}]$	$2.58\,^{+0.48}_{-0.40}$	$^{+1.01}_{-0.68}$	$^{+1.53}_{-0.93}$
$\mathcal{B}(K^+ \to \pi^+\nu\overline{\nu})$ $[10^{-11}]$	$7.5\,^{+1.8}_{-2.0}$	$^{+2.5}_{-2.4}$	$^{+3.2}_{-2.7}$
$\lvert V_{ud}\rvert$	$0.97383\,^{+0.00024}_{-0.00023}$	$^{+0.00047}_{-0.00047}$	$^{+0.00071}_{-0.00071}$
$\lvert V_{us}\rvert$	$0.2272\,^{+0.0010}_{-0.0010}$	$^{+0.0020}_{-0.0020}$	$^{+0.0030}_{-0.0030}$
$\lvert V_{ub}\rvert$ $[10^{-3}]$	$3.82\,^{+0.15}_{-0.15}$	$^{+0.31}_{-0.29}$	$^{+0.49}_{-0.44}$
$\lvert V_{ub}\rvert$ $[10^{-3}]$ (meas. not in fit)	$3.64\,^{+0.19}_{-0.18}$	$^{+0.39}_{-0.36}$	$^{+0.60}_{-0.55}$
$\lvert V_{cd}\rvert$	$0.22712\,^{+0.00099}_{-0.00103}$	$^{+0.00199}_{-0.00205}$	$^{+0.00300}_{-0.00307}$
$\lvert V_{cs}\rvert$	$0.97297\,^{+0.00024}_{-0.00023}$	$^{+0.00048}_{-0.00047}$	$^{+0.00071}_{-0.00071}$
$\lvert V_{cb}\rvert$ $[10^{-3}]$	$41.79\,^{+0.63}_{-0.63}$	$^{+1.26}_{-1.27}$	$^{+1.89}_{-1.90}$
$\lvert V_{cb}\rvert$ $[10^{-3}]$ (meas. not in fit)	$44.9\,^{+1.2}_{-2.8}$	$^{+2.4}_{-5.7}$	$^{+3.8}_{-7.7}$
$\lvert V_{td}\rvert$ $[10^{-3}]$	$8.28\,^{+0.33}_{-0.29}$	$^{+0.92}_{-0.57}$	$^{+1.38}_{-0.86}$
$\lvert V_{ts}\rvert$ $[10^{-3}]$	$41.13\,^{+0.63}_{-0.62}$	$^{+1.25}_{-1.24}$	$^{+1.87}_{-1.86}$
$\lvert V_{tb}\rvert$	$0.999119\,^{+0.000026}_{-0.000027}$	$^{+0.000052}_{-0.000054}$	$^{+0.000078}_{-0.000082}$
$\lvert V_{td}/V_{ts}\rvert$	$0.2011\,^{+0.0081}_{-0.0065}$	$^{+0.0230}_{-0.0127}$	$^{+0.0345}_{-0.0195}$
$\lvert V_{ud}V^*_{ub}\rvert$ $[10^{-3}]$	$3.72\,^{+0.15}_{-0.14}$	$^{+0.30}_{-0.29}$	$^{+0.48}_{-0.43}$
$\arg\,[V_{ud}V^*_{ub}]$ (deg)	$59.8\,^{+4.9}_{-4.0}$	$^{+13.9}_{-7.8}$	$^{+20.9}_{-12.1}$
$\arg\,[-V_{ts}V^*_{tb}]$ (deg)	$1.043\,^{+0.061}_{-0.057}$	$^{+0.151}_{-0.114}$	$^{+0.238}_{-0.176}$
$\lvert V_{cd}V^*_{cb}\rvert$ $[10^{-3}]$	$9.49\,^{+0.15}_{-0.15}$	$^{+0.30}_{-0.30}$	$^{+0.45}_{-0.45}$
$\arg\,[-V_{cd}V^*_{cb}]$ (deg)	$0.0339\,^{+0.0021}_{-0.0020}$	$^{+0.0050}_{-0.0040}$	$^{+0.0077}_{-0.0060}$
$\lvert V_{td}V^*_{tb}\rvert$ $[10^{-3}]$	$8.27\,^{+0.33}_{-0.29}$	$^{+0.93}_{-0.57}$	$^{+1.38}_{-0.85}$
$\arg\,[V_{td}V^*_{tb}]$ (deg)	$-22.84\,^{+1.00}_{-0.99}$	$^{+1.98}_{-2.02}$	$^{+2.93}_{-3.21}$
${\rm Re}\lambda_c$	$-0.22098\,^{+0.00095}_{-0.00091}$	$^{+0.00188}_{-0.00184}$	$^{+0.00282}_{-0.00275}$
${\rm Im}\lambda_c$ $[10^{-4}]$	$-1.377\,^{+0.080}_{-0.084}$	$^{+0.161}_{-0.203}$	$^{+0.244}_{-0.310}$
${\rm Re}\lambda_t$ $[10^{-4}]$	$-3.11\,^{+0.13}_{-0.14}$	$^{+0.26}_{-0.36}$	$^{+0.39}_{-0.57}$
${\rm Im}\lambda_t$ $[10^{-4}]$	$1.377\,^{+0.084}_{-0.080}$	$^{+0.203}_{-0.161}$	$^{+0.310}_{-0.244}$

Table 3: *Fit results.*