Reference: hep-ph/0104062

UPDATED RESULTS ON THE CKM MARTIX

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Abstract

This document provides a collection of updated plots and numerical results from the global CKM analysis, using the framework package *CkmFitter* and the frequentist approach *R*fit. We also give the input parameters used.

Detailed background information on the methodology and the inputs is provided in:

A NEW APPROACH TO A GLOBAL FIT OF THE CKM MATRIX
A. Höcker, H. Lacker, S. Laplace and F. Le Diberder
Eur. Phys. J. **C21/2** (2001) 225-259
LAL 01-06; [hep-ph/0104062]

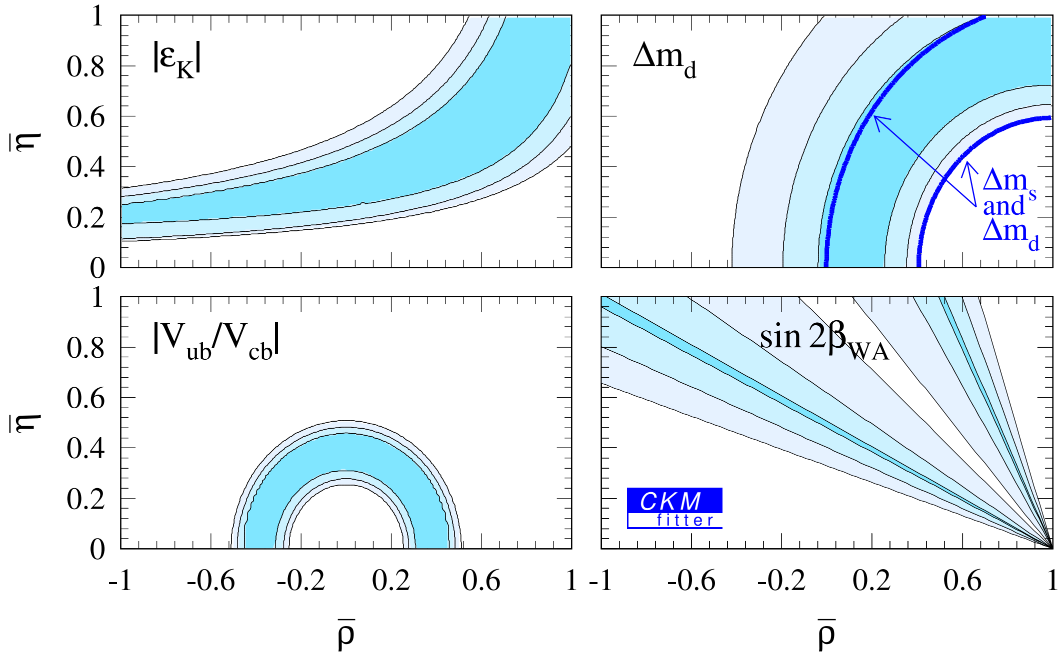

Figure 1: Confidence levels in the $(\bar{\rho}, \bar{\eta})$ plane for the individual constraints. The upper right hand plot shows in addition to Δm_d the improved constraint from Δm_s via ξ on Δm_d. The shaded areas indicate the regions of $\geq 90\%$, $\geq 32\%$ and $\geq 5\%$ CLs, respectively. Shown in the lower right hand plot is the world average of $\sin 2\beta$.

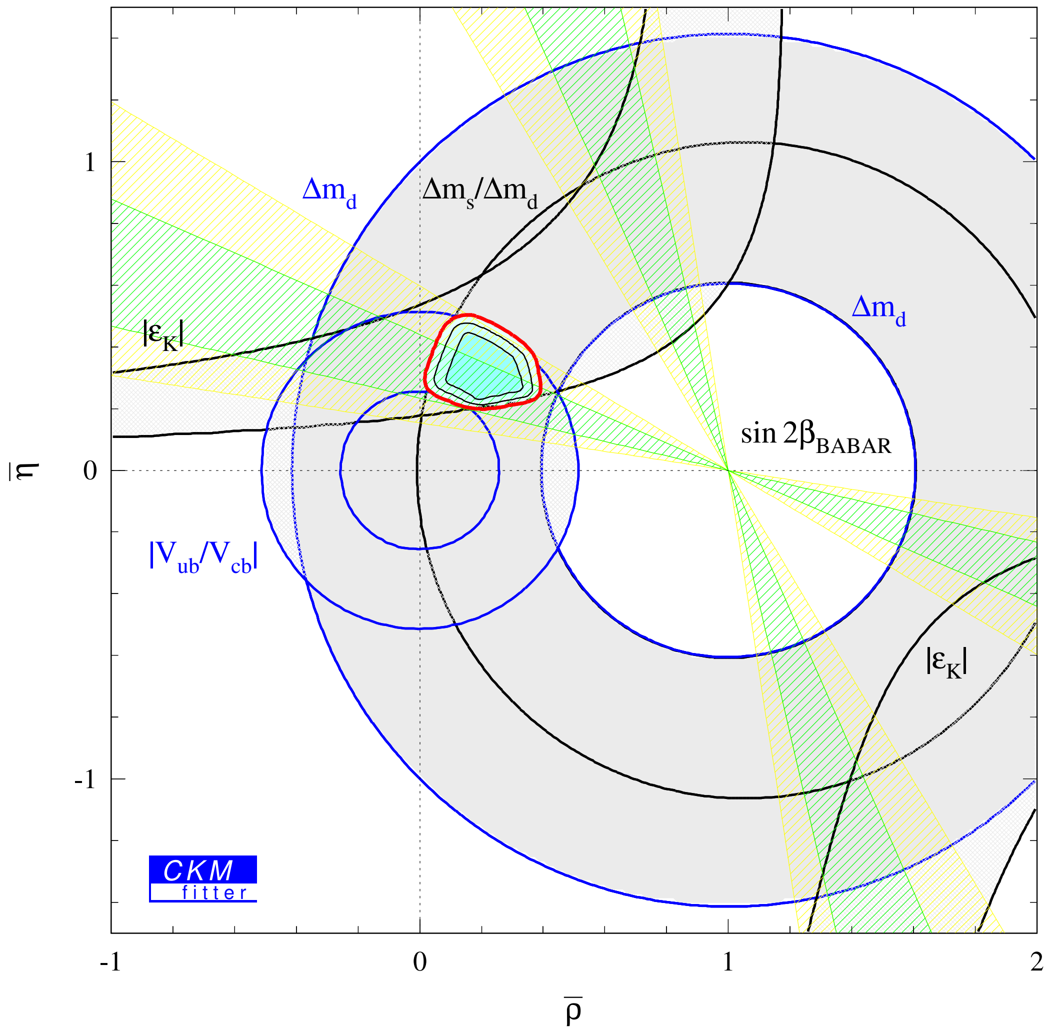

Figure 2: Present Standard Model constraints and the result from the global CKM fit (not using sin2β) in the $\bar{\rho}-\bar{\eta}$ plane compared to the newest BABAR measurement of $\sin 2\beta$.

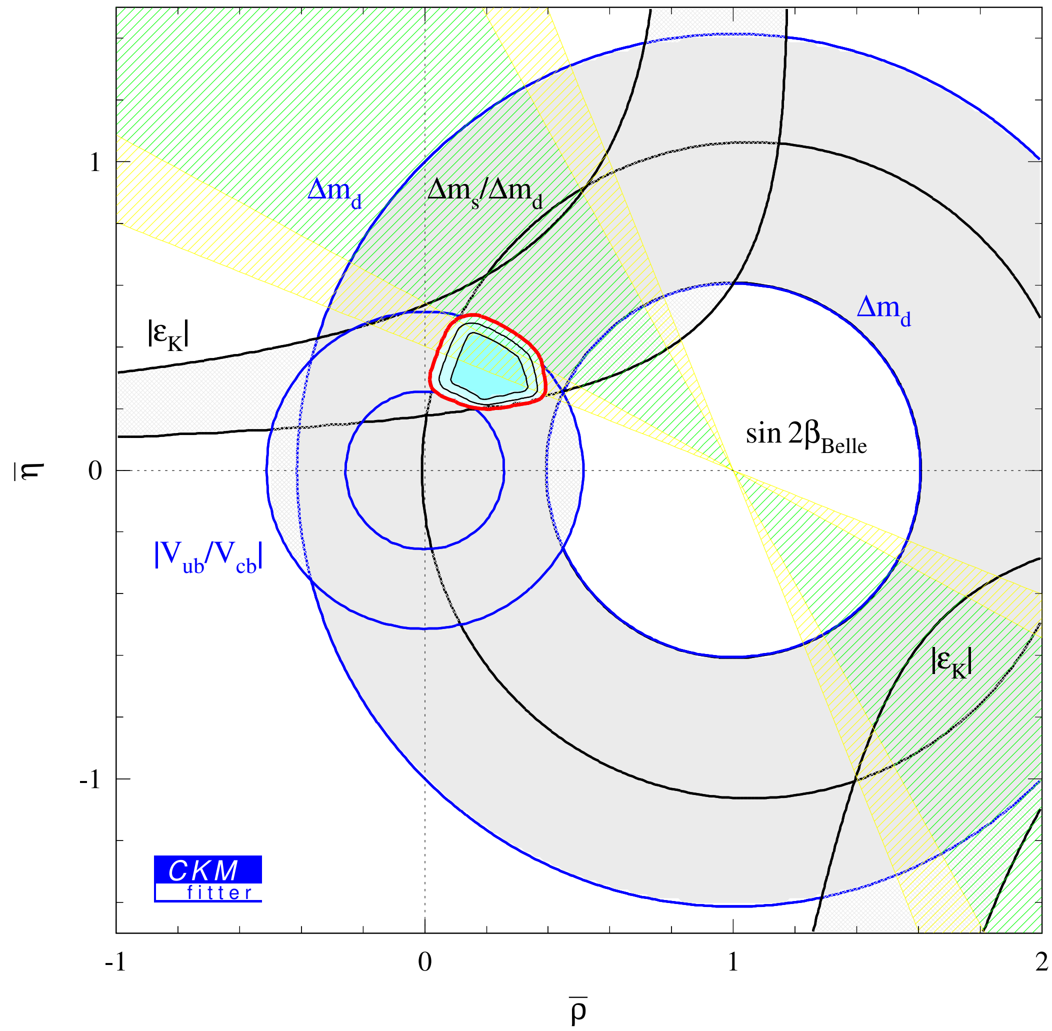

Figure 3: Present Standard Model constraints and the result from the global CKM fit (not using $\sin 2\beta$) in the $\bar{\rho} - \bar{\eta}$ plane compared to the newest Belle measurement of $\sin 2\beta$.

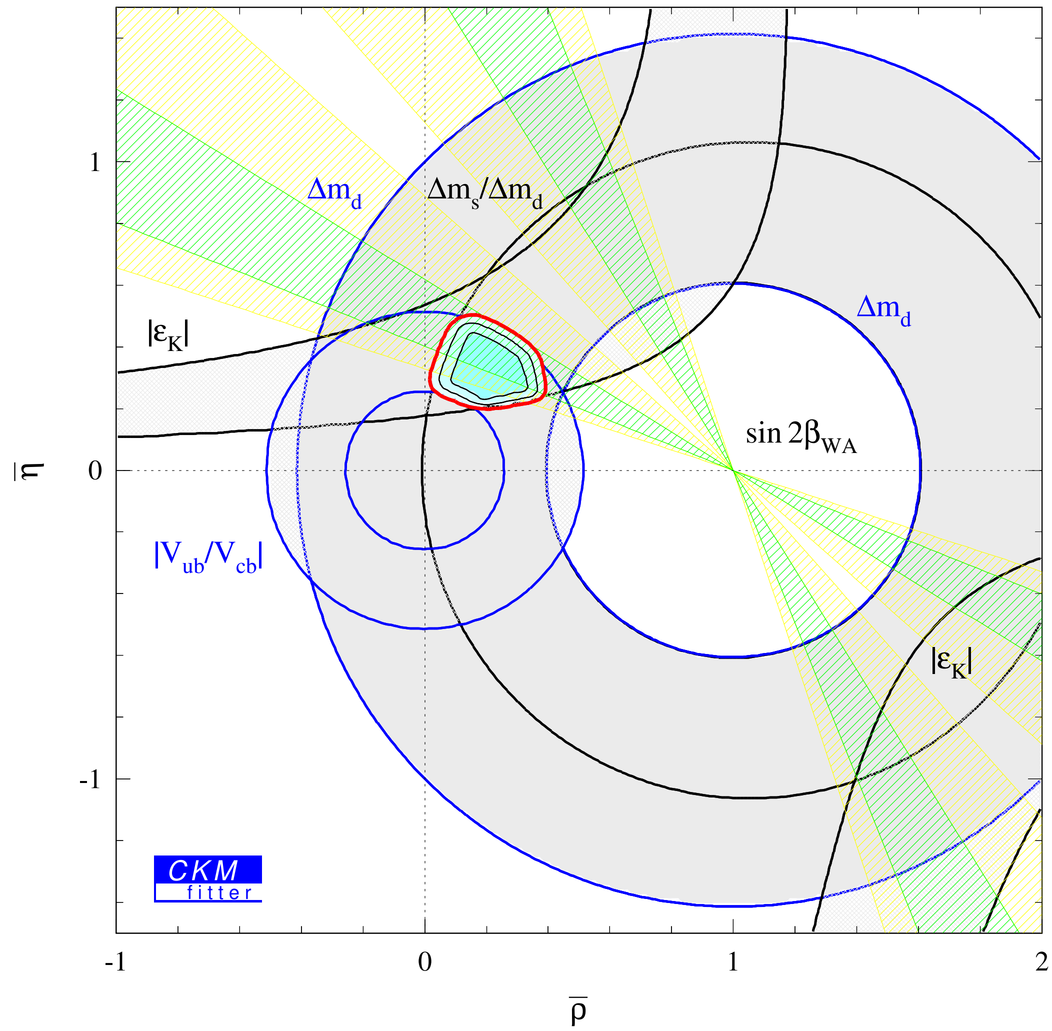

Figure 4: Present Standard Model constraints and the result from the global CKM fit (not using $\sin 2\beta$) in the $\bar{\rho} - \bar{\eta}$ plane compared to the world average of $\sin 2\beta$.

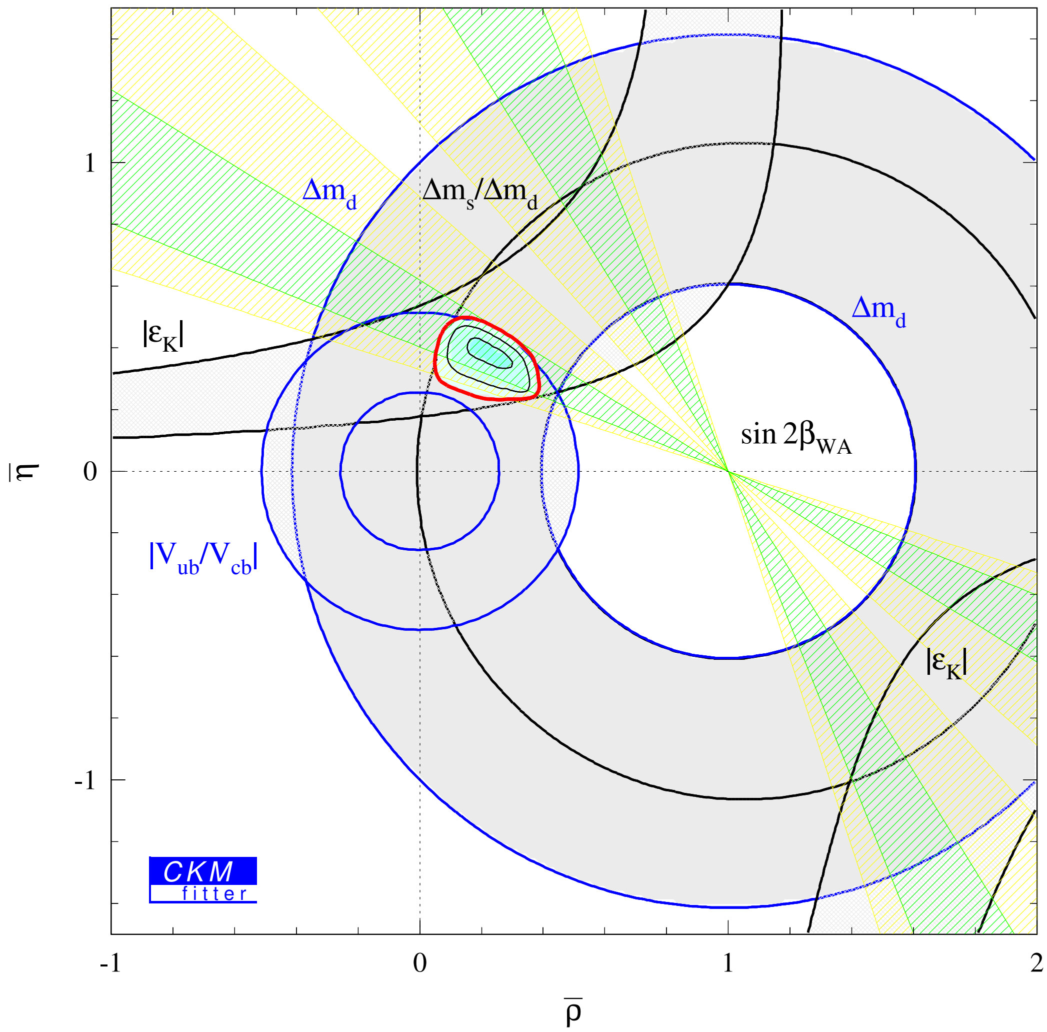

Figure 5: Present Standard Model constraints and the result from the global CKM fit in the $\bar{\rho} - \bar{\eta}$ plane, including the world average of $\sin 2\beta$ in the fit.

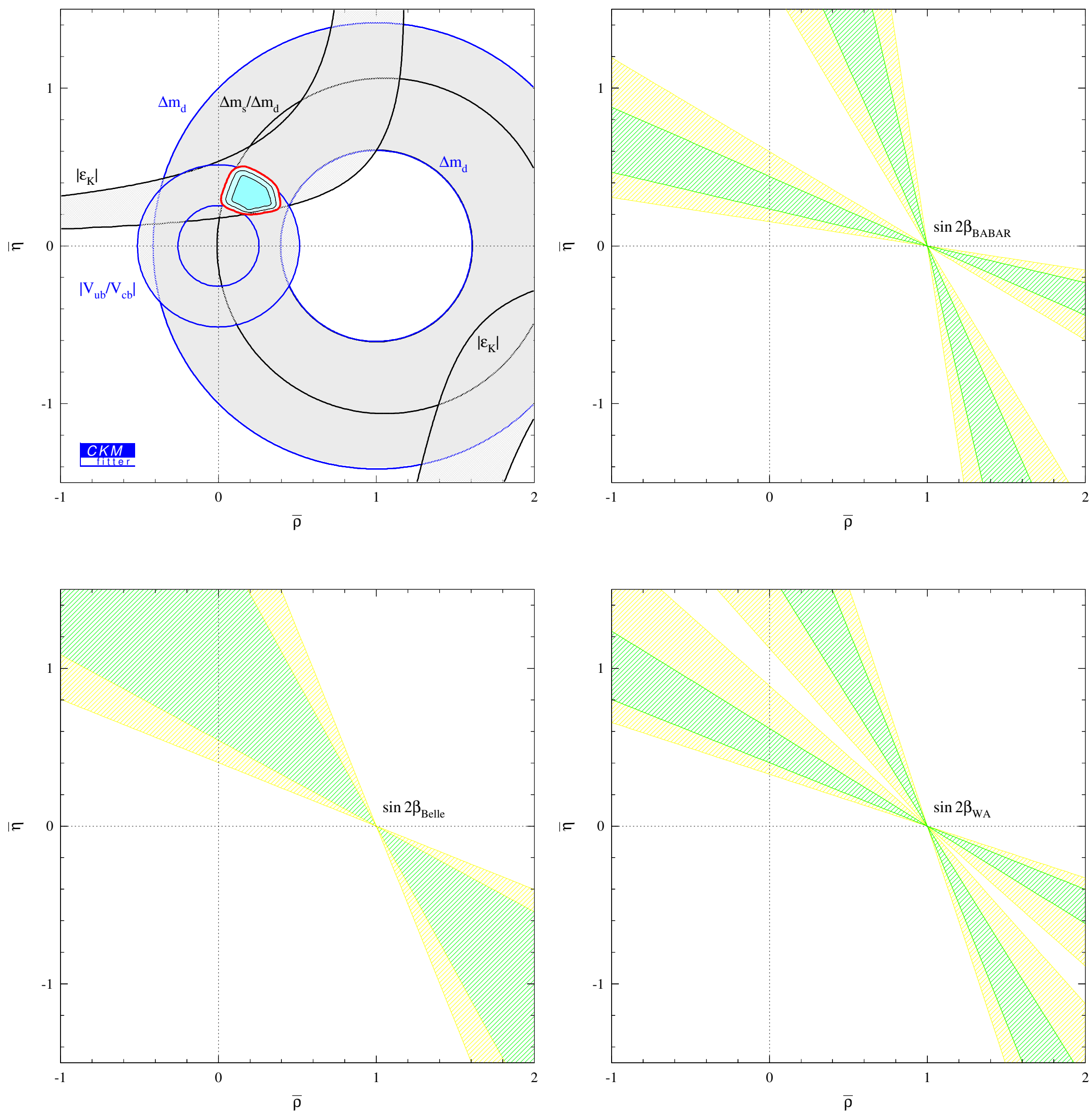

Figure 6: Present Standard Model constraints and the result from the global CKM fit (not using sin2β) in the $\bar{\rho}-\bar{\eta}$ plane (upper left hand plot). The following three plots show the constraints from sin2β using BABAR, Belle and the world average, respectively.

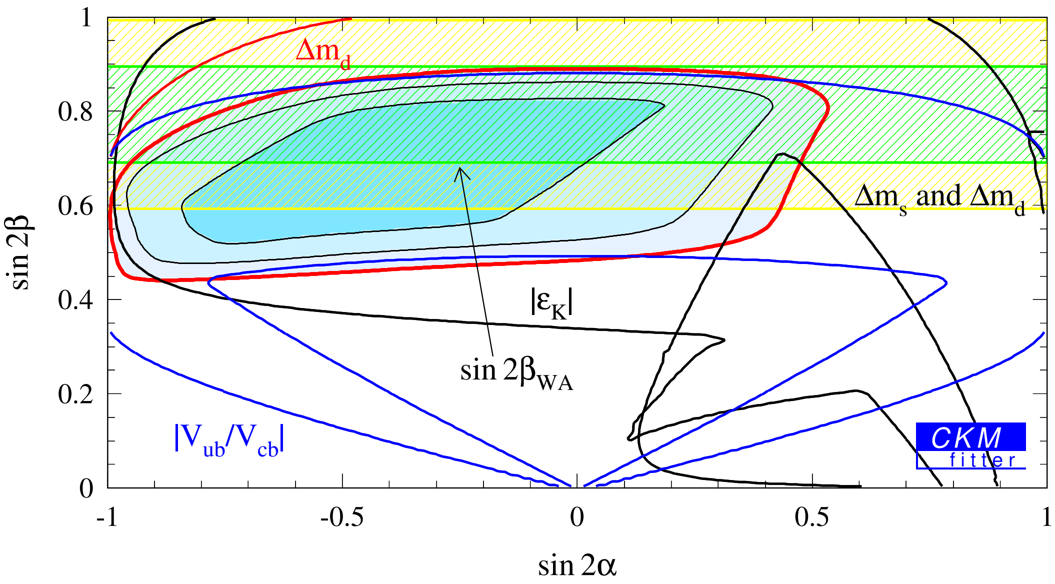

Figure 7: *Confidence levels in the* $(\sin 2\alpha, \sin 2\beta)$ *plane for the global CKM fit. The shaded areas indicate the regions of* $\geq 90\%$, $\geq 32\%$ *and* $\geq 5\%$ *CLs, respectively. Also shown are the 5% CL contours of the individual constraints. The* $\geq 32\%$ *and* $\geq 5\%$ *CL constraints from the world average of the* $\sin 2\beta$ *measurements, not entering the global fit, are given by the hatched areas.*

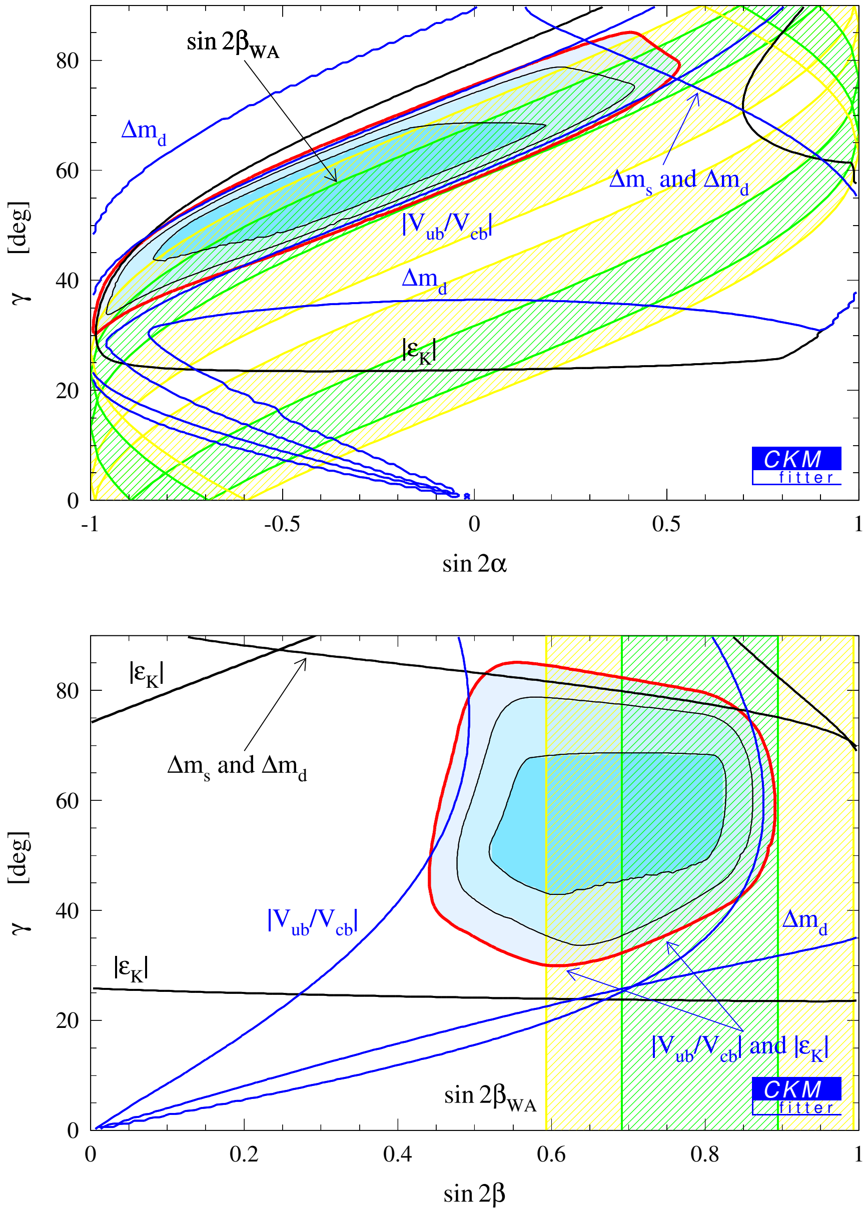

Figure 8: *Confidence levels in the* $(\sin 2\alpha,\, \gamma)$ *(upper plot) and the* $(\sin 2\beta,\, \gamma)$ *plane (lower plot), obtained from the global CKM fit. The shaded areas indicate the regions of* $\geq 90\%$, $\geq 32\%$ *and* $\geq 5\%$ *CLs, respectively. Shown in addition are the 5% CL contours of the individual constraints. The* $\geq 32\%$ *and* $\geq 5\%$ *CL constraints from the world average of the* $\sin 2\beta$ *measurements are given by the hatched areas. It does not enter the global fit.*

Parameter	Value ± Error(s)	Reference(s)	Error treatment in *R*fit: Gauss.	Theo.	Prop.	Float.
$\lvert V_{ud}\rvert$	0.97394 ± 0.00089	[hep-ph/0104062]	*	-	-	-
$\lvert V_{us}\rvert$	0.2200 ± 0.0025	[hep-ph/0104062]	*	-	-	-
$\lvert V_{ub}\rvert$	$(3.49 \pm 0.23 \pm 0.55) \times 10^{-3}$	[hep-ph/0104062]	*	*	-	*
$\lvert V_{cd}\rvert$	0.224 ± 0.014	[hep-ph/0104062]	*	-	-	-
$\lvert V_{cs}\rvert$	0.969 ± 0.058	[hep-ph/0104062]	*	-	-	-
$\lvert V_{cb}\rvert$	$(40.76 \pm 0.50 \pm 2.0) \times 10^{-3}$	[hep-ph/0104062]	*	*	-	*
$\lvert\epsilon_K\rvert$	$(2.271 \pm 0.017) \times 10^{-03}$	[hep-ph/0104062]	*	-	-	-
Δm_d	(0.487 ± 0.014) ps^{-1}	[hep-ph/0104062]	*	-	-	-
Δm_s	Amplitude spectrum	[hep-ph/0104062]	*	-	-	-
$\sin 2\beta_{\rm WA}$	0.79 ± 0.10	[Lepton-Photon'01]	*	-	-	-
m_c	(1.3 ± 0.1) GeV	[PDG'00]	-	*	-	*
$m_t(\overline{\rm MS})$	(166.0 ± 5.0) GeV	[PDG'00]	*	-	-	*
m_K	(493.677 ± 0.016) MeV	[PDG'00]	-	-	*	-
Δm_K	$(3.4885 \pm 0.0008) \times 10^{-15}$ GeV	[PDG'00]	-	-	*	-
m_{B_d}	(5.2794 ± 0.0005) GeV	[PDG'00]	-	-	*	-
m_{B_s}	(5.3696 ± 0.0024) GeV	[PDG'00]	-	-	*	-
m_W	(80.419 ± 0.056) GeV	[PDG'00]	-	-	*	-
G_F	$(1.16639 \pm 0.00001) \times 10^{-5}$ GeV^{-2}	[PDG'00]	-	-	-	-
f_K	(159.8 ± 1.5) MeV	[PDG'00]	-	-	*	-
B_K	$0.87 \pm 0.06 \pm 0.13$	[hep-ph/0104062]	*	*	-	*
η_{cc}	1.38 ± 0.53	[hep-ph/0104062]	-	*	-	*
η_{ct}	0.47 ± 0.04	[hep-ph/0104062]	-	-	*	-
η_{tt}	0.574 ± 0.004	[hep-ph/0104062]	-	-	*	-
$\eta_B(\overline{\rm MS})$	0.55 ± 0.01	[hep-ph/0104062]	-	*	-	*
$f_{B_d}\sqrt{B_d}$	$(230 \pm 28 \pm 28)$ MeV	[hep-ph/0104062]	*	*	-	*
ξ	$1.16 \pm 0.03 \pm 0.05$	[hep-ph/0104062]	*	*	-	*

Table 1: *Inputs to the global 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, fifth and sixth columns indicate the treatment of the parameters within R*fit*: measurements dominated by experimental errors (or statistical components of theoretical parameters) are marked as "Gauss." by an asterisk; parameters dominated by systematic theoretical uncertainties, treated as ranges in R*fit*, are marked as "Theo."; for parameters that have experimental and systematic theoretical errors, treated in the fit according to Eq. (61), both fields, "Exp." and "Theo.", are marked; parameters with small errors, marked as "Prop.", have their uncertainties propagated to the corresponding measurements to whose errors they are added in quadrature. The last column indicates whether or not the parameter is floating in the fit. In general, measurements with non-vanishing systematic theoretical errors have a floating theoretical component. Theoretical parameters with significant errors are necessarily floating. Upper part: experimental determinations of the CKM matrix elements. Middle upper part: CP-violating and mixing observables. Middle lower part: parameters of the SM predictions obtained from experimental data. Lower part: parameters of the SM predictions obtained from theory.*

Parameter	$\geq$ 32% CL	half width	$\geq$ 5% CL	half width
λ	0.2221 ± 0.0021		0.2221 ± 0.0041	
A	0.770 - 0.888	0.059	0.754 - 0.906	0.076
$\bar{\rho}$	0.08 - 0.35	0.14	0.04 - 0.38	0.17
$\bar{\eta}$	0.22 - 0.46	0.12	0.21 - 0.49	0.14
J $[10^{-5}]$	2.0 - 3.5	0.8	1.9 - 3.7	0.9
sin2α	-0.91 - 0.34	0.63	-0.96 - 0.49	0.73
sin2β	0.50 - 0.86	0.18	0.47 - 0.89	0.21
α	80° - 123°	22°	75° - 127°	26°
β	15.0° - 29.7°	7.4°	14.0° - 31.4°	8.7°
$\gamma = \delta$	37° - 75°	19°	34° - 82°	24°
sinθ_{12}	0.2221 ± 0.0021		0.2221 ± 0.0041	
sinθ_{13} $[10^{-3}]$	2.70 - 4.31	0.81	2.49 - 4.55	1.03
sinθ_{23} $[10^{-3}]$	38.4 - 43.2	2.4	37.9 - 43.6	2.8
$\lvert V_{ud}\rvert$	0.97504 ± 0.00049		0.97504 ± 0.00094	
$\lvert V_{us}\rvert$	0.2221 ± 0.0021		0.2221 ± 0.0042	
$\lvert V_{ub}\rvert$ $[10^{-3}]$	2.70 - 4.31	0.81	2.49 - 4.55	1.03
$\lvert V_{cd}\rvert$	0.2220 ± 0.0021		0.2220 ± 0.0042	
$\lvert V_{cs}\rvert$	0.97422 ± 0.00056		0.97422 ± 0.00102	
$\lvert V_{cb}\rvert$ $[10^{-3}]$	38.4 - 43.2	2.4	37.9 - 43.6	2.8
$\lvert V_{td}\rvert$ $[10^{-3}]$	6.6 - 9.2	1.3	6.3 - 9.6	1.6
$\lvert V_{ts}\rvert$ $[10^{-3}]$	37.7 - 42.8	2.6	37.3 - 43.2	3.0
$\lvert V_{tb}\rvert$	0.99907 - 0.99927	10×10^{-5}	0.99905 - 0.99929	12×10^{-5}
Δm_s (ps^{-1})	15.5 - 30.0	7.1	14.8 - 34.0	9.4
BR($K_L^0 \to \pi^0 \nu\bar{\nu}$) $[10^{-11}]$	1.3 - 4.0	1.4	1.2 - 4.4	1.6
BR($K^+ \to \pi^+ \nu\bar{\nu}$) $[10^{-11}]$	5.1 - 9.6	2.3	4.8 - 10.5	2.9
BR($B^+ \to \tau^+ \nu_\tau$) $[10^{-5}]$	4.6 - 20.0	7.7	3.6 - 23.6	10.0
BR($B^+ \to \mu^+ \nu_\mu$) $[10^{-7}]$	1.8 - 7.9	3.1	1.5 - 9.3	3.9
$f_{B_d}\sqrt{B_d}$ (MeV)	193 - 271	39	184 - 284	50
B_K	$>$ 0.55		$>$ 0.50	
m_t (GeV)	106 - 406	150	93 - 565	236

Table 2: *Fit results for the unitary CKM parameters, the CKM matrix elements, branching ratios of some rare K and B meson decays and theoretical quantities, not using* sin2β *in the fit. Ranges are given for the quantities that are limited by systematic theoretical errors. The theoretical quantities (last three lines) are constrained without using the prior information available from lattice, or experiment (m_t).*

Parameter	$\geq 32\%$ CL	half width	$\geq 5\%$ CL	half width	δ_{32}	δ_5
λ	0.2221 ± 0.0021		0.2221 ± 0.0041		0	0
A	0.769 - 0.885	0.058	0.753 - 0.904	0.075	2	1
$\bar{\rho}$	0.12 - 0.34	0.11	0.07 - 0.37	0.15	21	12
$\bar{\eta}$	0.29 - 0.45	0.08	0.24 - 0.48	0.12	33	14
J $[10^{-5}]$	2.4 - 3.5	0.6	2.2 - 3.7	0.8	25	11
sin2α	-0.77 - 0.34	0.56	-0.93 - 0.48	0.71	12	3
sin2β	0.69 - 0.85	0.08	0.59 - 0.88	0.14	56	33
α	$80°$ - $115°$	$18°$	$76°$ - $124°$	$24°$	27	12
β	$21.8°$ - $29.1°$	$3.7°$	$18.1°$ - $30.8°$	$6.9°$	59	25
$\gamma = \delta$	$41°$ - $73°$	$16°$	$35°$ - $79°$	$22°$	16	8
sinθ_{12}	0.2221 ± 0.0021		0.2221 ± 0.0041		0	0
sinθ_{13} $[10^{-3}]$	3.29 - 4.29	0.50	2.85 - 4.53	0.84	38	18
sinθ_{23} $[10^{-3}]$	38.3 - 43.1	2.4	38.0 - 43.5	2.8	0	0
$\|V_{ud}\|$	0.97504 ± 0.00049		0.97504 ± 0.00094		0	0
$\|V_{us}\|$	0.2221 ± 0.0021		0.2221 ± 0.0042		0	0
$\|V_{ub}\|$ $[10^{-3}]$	3.29 - 4.29	0.50	2.85 - 4.53	0.84	38	18
$\|V_{cd}\|$	0.2220 ± 0.0021		0.2220 ± 0.0041		0	0
$\|V_{cs}\|$	0.97423 ± 0.00054		0.97423 ± 0.00101		13	4
$\|V_{cb}\|$ $[10^{-3}]$	38.4 - 43.2	2.4	37.9 - 43.6	2.8	0	0
$\|V_{td}\|$ $[10^{-3}]$	6.6 - 8.8	1.1	6.3 - 9.3	1.5	15	6
$\|V_{ts}\|$ $[10^{-3}]$	37.7 - 42.7	2.5	37.3 - 43.1	2.9	4	3
$\|V_{tb}\|$	0.99907 - 0.99927	10×10^{-5}	0.99905 - 0.99929	12×10^{-5}	0	0
Δm_s (ps^{-1})	15.5 - 27.5	6.0	14.8 - 32.2	8.7	15	7
BR($K_L^0 \to \pi^0 \nu\bar{\nu}$) $[10^{-11}]$	1.8 - 3.9	1.1	1.5 - 4.4	1.5	21	6
BR($K^+ \to \pi^+ \nu\bar{\nu}$) $[10^{-11}]$	5.1 - 8.8	1.9	4.8 - 9.7	2.5	17	14
BR($B^+ \to \tau^+ \nu_\tau$) $[10^{-5}]$	8.4 - 20.0	5.8	5.7 - 23.7	9.0	25	10
BR($B^+ \to \mu^+ \nu_\mu$) $[10^{-7}]$	3.3 - 7.8	2.2	2.3 - 9.3	3.5	29	10
$f_{B_d}\sqrt{B_d}$ (MeV)	201 - 271	35	190 - 286	48	10	4
B_K	0.55 - 1.38	0.42	0.49 - 1.77	0.64	-	-
m_t (GeV)	107 - 312	103	92 - 403	155	31	34

Table 3: *Fit results including the world average* sin$2\beta_{\rm WA}$. *As in Tabale 2, ranges are given for the quantities that are limited by systematic theoretical errors. The theoretical quantities (last three lines) are constrained without using the prior information available from lattice, or experiment (m_t). The two right columns give the relative improvements (in percent) of the* $\geq 32\%$ CL *and* $\geq 5\%$ CL *half widths with respect to the fit results without* sin2β *given in Tab. 2.*