

# RETROSPECTIVE RESULTS ON THE CKM MATRIX AND THE UNITARITY TRIANGLE

Based on results available  
around 1995

*P r e l i m i n a r y*

July 15th, 2010

The CKMfitter Group

## Abstract

This document provides a retrospective collection of inputs to the global CKM analysis, and numerical results obtained with the use of the CKMfitter fit package. Experimental and theoretical information available at the time of the first observation of the top quark, are used. The statistical method employed is the frequentist approach *Rfit*. 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]

## The CKMfitter Group

J. Charles<sup>b</sup>, O. Deschamps<sup>c</sup>, S. Descotes-Genon<sup>f</sup>, R. Itoh<sup>e</sup>, H. Lacker<sup>d</sup>, S. Monteil<sup>c</sup>,  
V. Niess<sup>c</sup>, J. Ocariz<sup>h</sup>, S. T'Jampens<sup>a</sup>, V. Tisserand<sup>a</sup>, K. Trabelsi<sup>e</sup>

<sup>a</sup>*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: tisserav@lapp.in2p3.fr, tjamp@lapp.in2p3.fr*

<sup>b</sup>*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*

<sup>c</sup>*Laboratoire de Physique Corpusculaire 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*

<sup>d</sup>*Humboldt-Universität zu Berlin,  
Institut für Physik, Newtonstr. 15,  
D-12489 Berlin, Germany  
e-mail: lacker@physik.hu-berlin.de*

<sup>e</sup>*High Energy Accelerator Research Organization, KEK  
1-1 Oho, Tsukuba, Ibaraki 305-0801 Japan  
e-mail: ryosuke.itoh@kek.jp, karim.trabelsi@kek.jp*

<sup>f</sup>*Laboratoire de Physique Théorique  
Bâtiment 210, Université Paris-Sud 11, F-91405 Orsay Cedex, France  
(UMR 8627 du CNRS associée à l'Université de Paris-Sud 11)  
e-mail: Sebastien.Descotes-Genon@th.u-psud.fr*

<sup>h</sup>*Laboratoire de Physique Nucléaire et de Hautes Energies,  
IN2P3/CNRS, Université Pierre et Marie Curie Paris 6  
et Université Denis Diderot Paris 7, F-75252 Paris, France  
e-mail: Ocariz@in2p3.fr*

Parameter	Value $\pm$ Error(s)	Reference	Errors	
			GS	TH
$ V_{ud} $	$0.9736 \pm 0.0010$	[1]	*	-
$ V_{us} $	$0.2205 \pm 0.0018$	[1]	*	-
$ V_{ub} $	$(3.3 \pm 0.4 \pm 0.7) \times 10^{-3}$	[2, 3]	*	*
$ V_{cd} $	$(0.224 \pm 0.016)$	[1]	*	-
$ V_{cs} $	$(1.01 \pm 0.18)$	[1]	*	-
$ V_{cb} $	$(41 \pm 3 \pm 2) \times 10^{-3}$	[1]	*	*
$ \varepsilon_K $	$(2.265 \pm 0.023) \times 10^{-3}$	[1]	*	-
$\Delta m_d$	$(0.471 \pm 0.031) \text{ ps}^{-1}$	[1]	*	-
$\Delta m_s$	$> 6.5 \text{ ps}^{-1}$	[4]	*	-
$\bar{m}_c(m_c)$	$(1.3 \pm 0.3) \text{ GeV}$	[1]	-	*
$\bar{m}_t(m_t)$	$(174 \pm 16) \text{ GeV}$	[5, 6]	-	*
$B_K$	$0.8 \pm 0.2$	[7]	-	*
$\eta_{cc}$	$1.38 \pm 0.53$	[8]	-	*
$\eta_{ct}$	$0.47 \pm 0.04$	[9]	-	*
$\eta_{tt}$	$0.574 \pm 0.004$	[10]	-	*
$\eta_B(\overline{\text{MS}})$	$0.551 \pm 0.007$	[10]	-	*
$f_{B_d} \sqrt{B_d}$	$(200 \pm 40) \text{ MeV}$	[11]	-	*
$\xi$	$1.14 \pm 0.20$	[11]	-	*

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 Rfit 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.*

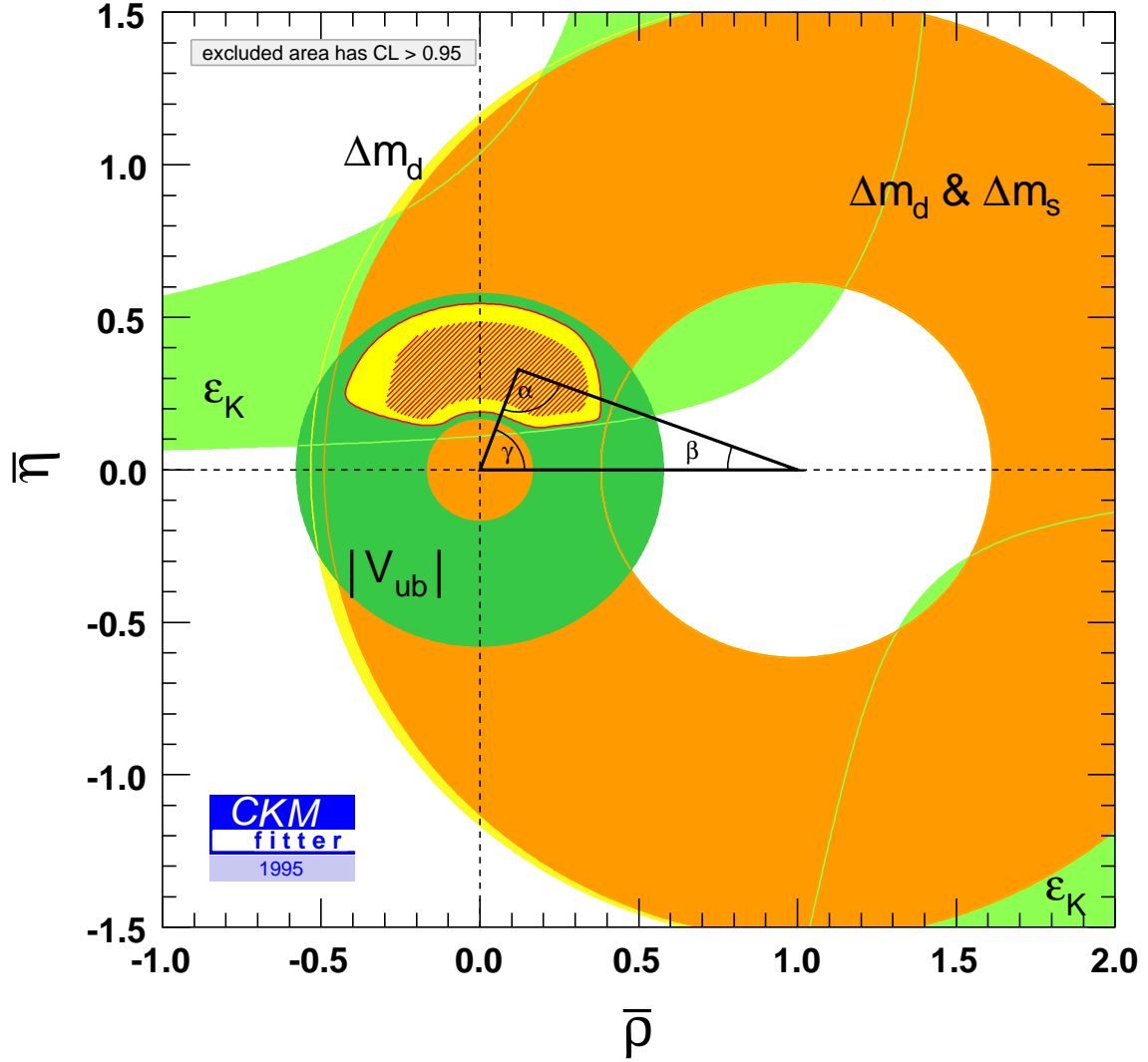


Figure 1: Constraints on the  $(\bar{\rho}, \bar{\eta})$  plane including results available by 1995 in the global CKM fit. These are: the first measurement of the top quark mass, the first evidence for exclusive  $b \rightarrow u$  decays, and a limit on the  $B_s$  mixing, with numerical values summarised in Table 1. The red hashed region of the global combination corresponds to 68%CL.

## References

- [1] L. Montanet *et al.* [Particle Data Group], Phys. Rev. D **50**, 1173 (1994) and 1995 off-year partial update for the 1996 edition.
- [2] H. Albrecht *et al.* [ARGUS Collaboration], Phys. Lett. B **255**, 297 (1991).
- [3] J. E. Bartelt *et al.* [CLEO Collaboration], Phys. Rev. Lett. **71**, 4111 (1993).
- [4] D. Buskulic *et al.* [ALEPH Collaboration], Phys. Lett. B **356**, 409 (1995).
- [5] F. Abe *et al.* [CDF Collaboration], Phys. Rev. Lett. **74**, 2626 (1995) [arXiv:hep-ex/9503002].
- [6] S. Abachi *et al.* [D0 Collaboration], Phys. Rev. Lett. **74**, 2632 (1995) [arXiv:hep-ex/9503003].
- [7] S. Aoki *et al.* [JLQCD Collaboration], Nucl. Phys. Proc. Suppl. **47**, 465 (1996) [arXiv:hep-lat/9510012].
- [8] S. Herrlich and U. Nierste, Nucl. Phys. B **419**, 292 (1994) [arXiv:hep-ph/9310311].
- [9] S. Herrlich and U. Nierste, Phys. Rev. D **52**, 6505 (1995) [arXiv:hep-ph/9507262].
- [10] A. J. Buras, M. Jamin and P. H. Weisz, Nucl. Phys. B **347**, 491 (1990).
- [11] S. Aoki *et al.* [JLQCD Collaboration], Nucl. Phys. Proc. Suppl. **47**, 433 (1996) [arXiv:hep-lat/9510033].