An up-to-date determination of the CKM matrix elements and of the unitarity triangle on the basis of the available experimental results

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Summary. — The results of a critical review of the experimental sources that provide information on the CKM matrix are presented. Direct determinations of the matrix elements and indirect constraints (*B*-meson mixing, CP violation measurements, $b \to s\gamma$ Penguin decays) updated taking into account the most recent experimental results are included in a unitarity-constrained fit to determine the shape of the unitarity triangle. The following best values are found for the parameters describing the observable CP asymmetries which are expected in *B* decays: $\sin 2\alpha = -0.11^{+0.20}_{-0.22}$, $\sin 2\beta = 0.725^{+0.044}_{-0.046}$, $\gamma = \left(63.7^{+5.3}_{-7.0}\right)^{\circ}$.

PACS 12.15.Hh – Determination of CKM matrix elements.

1 Introduction

The Cabibbo-Kobayashi-Maskawa[1] (CKM, or V_{CKM}) matrix extends the Cabibbo[2] model, preserving the weak coupling universality while explaining the existing priority scale among the transitions occurring inside one quark family and those connecting two neighbouring families, or the first with the third one. Its structure incorporates the GIM[3] mechanism, which suppresses the flavour-changing neutral current (FCNC) processes. Finally, with a suitable quark phase choice, the imaginary part of the CKM matrix is the source of all the CP-violating phenomena which the Standard Model is able to account for.

We present here an up-to-date determination of the CKM matrix elements, obtained on the basis of the available experimental results. A procedure similar to that proposed in Ref. 4 has been followed to draw the favoured profile of the *unitarity triangle*, which parametrizes the CP violation expected in the *b* quark sector.
A short outline of the CKM structure is given in Sect. 2. The experimental frame on which this analysis is based and the results obtained are presented in Sects. 3 and 4.

2 Notations

The CKM matrix parametrizes the unitary transformation connecting the quark weak eigenstates, which enter into the expression of the Lagrangian density term representing the flavour-changing processes, to the mass eigenstates. Of the nine real parameters that are peculiar to the 3×3 unitary matrix, five are phases which can be arbitrarily redefined through a suitable choice of the phase of the quark fields. The matrix thus depends on four physically meaningful parameters. Several parametrizations are expressed in terms of three Euler angles (ϑ_i) and one phase (δ); the one suggested by the PDG[5] (currently considered the canonical parametrization),

$$V_{CKM}=\begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix}=\begin{pmatrix} c_1c_3 & s_1c_3 & s_3e^{-i\delta} \\ -s_1c_2-c_1s_2s_3e^{i\delta} & c_1c_2-s_1s_2s_3e^{i\delta} & s_2c_3 \\ s_1s_2-c_1c_2s_3e^{i\delta} & -c_1s_2-s_1c_2s_3e^{i\delta} & c_2c_3 \end{pmatrix} \quad (1)$$

($c_i=\cos\vartheta_i$, $s_i=\sin\vartheta_i$, ϑ_1 is the Cabibbo angle), will be used in the present analysis as well as Wolfenstein's parametrization[6] (λ, A, ρ, η), which is obtained from the former by defining

$$\lambda=s_1\cong|V_{us}|\cong|V_{cd}|\cong 0.22\,,\qquad s_2=A\lambda^2\,,\qquad s_3e^{-i\delta}=A\lambda^3(\rho-i\eta) \quad (2)$$

(with $\tan\delta=\eta/\rho$). The following expression is true up to the fifth order in λ:

$$V_{CKM}=\begin{pmatrix} 1-\frac{\lambda^2}{2}-\frac{\lambda^4}{8} & \lambda & A\lambda^3(\rho-i\eta) \\ -\lambda\left[1-A^2\lambda^4\left(\frac{1}{2}-\rho\right)+iA^2\lambda^4\eta\right] & 1-\frac{\lambda^2}{2}-\frac{\lambda^4}{8}\left(1+4A^2\right) & A\lambda^2 \\ A\lambda^3\left[(1-\rho)+\lambda^2\frac{\rho}{2}-i\eta\left(1-\frac{\lambda^2}{2}\right)\right] & -A\lambda^2\left[1-\lambda^2\left(\frac{1}{2}-\rho\right)+i\eta\lambda^2\right] & 1-\frac{A^2\lambda^4}{2} \end{pmatrix}. \quad (3)$$

CP symmetry is violated if the equivalent conditions $\delta\neq 0,\pi$ and $\eta\neq 0$ are satisfied. The relation $V_{ud}V_{ub}^*+V_{cd}V_{cb}^*+V_{td}V_{tb}^*=0$ is used to define the so-called *unitarity triangle* represented in Figure 1, where the angles are indicated with the letters α, β, γ and the co-ordinates of the vertex are (neglecting corrections of the fourth order in λ)

$$\bar{\rho}=\rho\left(1-\frac{\lambda^2}{2}\right)\quad\text{and}\quad\bar{\eta}=\eta\left(1-\frac{\lambda^2}{2}\right). \quad (4)$$

The area of the triangle, which vanishes in the absence of CP violation, is equal to $\bar{\eta}/2$.

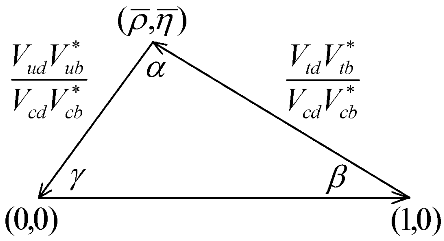

Figure 1: *The unitarity triangle*

The angles α, β and γ, which are in direct relation to the CP asymmetries peculiar to *B*-meson decays, are about to be measured in forthcoming experiments. The angle γ is equal to the phase δ of the canonical parametrization: $\gamma = \arctan(\overline{\eta}/\overline{\rho}) = \arctan(\eta/\rho) = \delta$; the observables $\sin 2\alpha$ and $\sin 2\beta$, which will be measured directly, are expressed as functions of $\overline{\rho}$ and $\overline{\eta}$ in the following way:

$$\sin 2\alpha = \frac{2\overline{\eta}\left(\overline{\eta}^2 + \overline{\rho}^2 - \overline{\rho}\right)}{\left(\overline{\eta}^2 + \overline{\rho}^2 - \overline{\rho}\right)^2 + \overline{\eta}^2} ; \qquad \sin 2\beta = \frac{2\overline{\eta}(1-\overline{\rho})}{(1-\overline{\rho})^2 + \overline{\eta}^2} . \tag{5}$$

3 The experimental frame

The possibility of fully exploiting independent measurements for the determination of the CKM matrix elements and other observables connected with weak-decay amplitudes is due to the great precision with which the Fermi constant G_F was determined by measuring the muon lifetime. The latter was the object of nearly half a century of experimental research[7], which began in the early forties. The first accurate measurement was carried out at CERN in 1962[8], when for the first time an inconsistency with the coupling constant of the nuclear transition $^{14}\mathrm{O} \to {}^{14}\mathrm{N} + e^+ + \nu_e$ clearly emerged. One year later, this evidence led Cabibbo[2] to the new formulation of the weak universality principle. The present level of precision was achieved in 1984 by the Saclay-CERN-Bologna (SCB)[9] and by the TRIUMPH[10] group. The SCB group also provided one of the most meaningful tests of CPT invariance through a determination of the ratio $\tau_{\mu^+}/\tau_{\mu^-}$. From the world average of these measurements, the following value of G_F is obtained[5] taking into account the radiative corrections:

$$G_F/(\hbar c)^3 = (1.16639 \pm 0.00001)\cdot 10^{-5}\, GeV^{-2} . \tag{6}$$

A detailed analysis of the experimental and theoretical information which can be used to constrain the CKM matrix has been carried out. The direct determinations of the CKM matrix elements which have been used in the present analysis are listed in Table I. In most cases, a reduction in the experimental uncertainties has been obtained by taking into account the most recent measurements. A sensible improvement has been made in the determination of $|V_{ub}/V_{cb}|$, since now independent measurements of $|V_{ub}|$, $|V_{cb}|$ and $|V_{ub}/V_{cb}|$ make it possible to discriminate between the disagreeing predictions of the theoretical model which were used in the inclusive analyses of CLEO[11,12] (1990,1993) and ARGUS[13] (1991). Further information on the CKM matrix (see Table II) is drawn from the measurement of $|\varepsilon_K|$, from the oscillation frequency Δm_{B_d} of the $B_d^0 - \overline{B}_d^0$ system and from the amplitude spectrum of the still unresolved $B_s^0 - \overline{B}_s^0$ oscillations. The CP violation parameter $\sin 2\beta$ recently measured by CDF[30] is also considered in this analysis.

(*)	*Experimental sources*	*Latest results*
$\lvert V_{ud}\rvert = 0.9743 \pm 0.0008$	super-allowed nuclear β decays; neutron decay; pion decay	
$\lvert V_{us}\rvert = 0.2200 \pm 0.0025$	semileptonic decays of kaons	
$\lvert V_{ub}\rvert = (3.6 \pm 0.5)\cdot 10^{-3}$	exclusive and inclusive $b\to u$ semileptonic decays	ALEPH[14], L3[15] (1998); CLEO[16] (1999)
$\lvert V_{ub}/V_{cb}\rvert = 0.090 \pm 0.008$	inclusive $b\to u$ semileptonic decays	DELPHI[17] (1998)
$\lvert V_{cd}\rvert = 0.225^{+0.013}_{-0.011}$	deep inelastic neutrino-nucleon scattering	
$\lvert V_{cs}\rvert = 0.996 \pm 0.024$	semileptonic decays of D mesons; deep inelastic neutrino-nucleon scattering; hadronic W decays	CCFR[18] (1998); CHARM II[19] (1998) DELPHI[20] (1998); ALEPH[21] (1999); L3[22] (1999); OPAL[23] (1999)
$\lvert V_{cb}\rvert = (39.5 \pm 1.7)\cdot 10^{-3}$	exclusive and inclusive $b\to c$ semileptonic decays	DELPHI[24] (1999)
$\lvert V_{ts}\rvert\,\lvert V_{tb}\rvert/\lvert V_{cb}\rvert = 0.96 \pm 0.09$	electromagnetic Penguin decays	CLEO[25], ALEPH[26] (1998)
$\lvert V_{tb}\rvert = 0.96^{+0.16}_{-0.12}$ (**)	top quark decays	CDF[27] (1999)

Table I: *measurements of the CKM matrix elements (the errors quoted correspond to one standard deviation). (*) values updated with respect to the Review of Particle Physics 1998[5] (the details of this analysis will be the subject of a forthcoming article; for the present, they can be found in Ref. 28). (**) to obtain this result, the hypothesis of unitarity was invoked.*

Δm_{B_d}	$(0.473 \pm 0.016)\,ps^{-1}$	results averaged by the LEP B Oscillations Working group[29], 1999
Δm_{B_s}	$> 14.3\,ps^{-1}$ 95% $C.L.$	
$\lvert\varepsilon_K\rvert$	$\lvert\varepsilon_K\rvert = (2.279 \pm 0.018)\cdot 10^{-3}$	[5]
$\sin 2\beta$	$0.79^{+0.41}_{-0.44}$	CDF[30] 1999

Table II: *additional information used in the determination of the CKM matrix.*

4 Results of the present analysis

A unitarity-constrained fit, based on the χ^2 minimization, has then been performed with the help of the MINUIT[31] libraries. All the collected experimental information have been taken into account. The results for the CKM parameters (canonical and Wolfenstein's parametrizations) are summarized in Table III. Figure 2 shows the effect of the single constraints (at the 68% C.L.) on the determination of the unitarity triangle (a) and the contours of the 68 and 95% confidence regions for the vertex $(\bar{\rho},\bar{\eta})$ (b).

The predictions listed in Table IV have been obtained for the observables that are to be measured in the experiments at the *B* factories.

The way in which the removal of the main constraints (with special regard to those involving some peculiar kind of theoretical assumption) alters the determination of the unitarity triangle and of the CKM matrix has been ascertained by subtracting in turn the corresponding terms from the total χ^2 of the fit. The results are shown in Table V and in Figure 3. In particular, it has been found that, even when the constraints which are based on the present experimental evidence for CP violation (essentially $|\varepsilon_K|$, since the measurement of $\sin 2\beta$ is still too imprecise to be effective) are released, the predictions for the observables which parametrize the magnitude of CP violation ($\overline{\eta}$, γ, $\sin 2\beta$) remain incompatible with zero. The current precision in the determination of the phase is almost entirely due to the much more effective $|V_{ub}/V_{cb}|$ and $|V_{ub}|$ constraints: when these are removed, the error in $\sin 2\beta$, for example, is nearly tripled. However, the imaginary part of the CKM matrix becomes totally undetermined after the removal of the constraints $|\varepsilon_K|$, Δm_{B_d}, Δm_{B_s}, $\sin 2\beta$ and $|V_{ts}||V_{tb}|/|V_{cb}|$ (see the last row of Table V).

5 Conclusions

An accurate determination of the CKM matrix and of the unitarity triangle has been obtained by exploiting the currently available experimental information (a more comprehensive account of the present analysis is about to appear). In addition, the following predictions have been made available:

$$\sin 2\alpha = -0.11^{+0.20}_{-0.22}, \quad \sin 2\beta = 0.725^{+0.044}_{-0.046}, \quad \gamma = \left(63.7^{+5.3}_{-7.0}\right)^{\circ}, \quad \Delta m_{B_s} = 15.4^{+3.0}_{-0.7}\, ps^{-1}. \qquad (7)$$

A comparatively small error affects the predicted value of $\sin 2\beta$, thanks to the improved measurements of $|V_{ub}|$, $|V_{cb}|$ and $|V_{ub}/V_{cb}|$. The first years of running of the *B* factories should already bring results of comparable precision. For example, it is expected that a combined precision better than 10% in the measurement of $\sin 2\beta$ will be reached by HERA-B[32], BaBar[33] and Belle[34] after one year. The primary interest in the results of these experiments is the verification of the Standard Model predictions, which may provide useful indications in the search for new physics. However, even if the present scenario will be confirmed, the improved knowledge of the unitarity triangle will certainly give us important clues for a better understanding of the quark weak interactions.

	68% C.L.	95% C.L.
λ	$0.2219^{+0.0020}_{-0.0021}$	$0.2179 < \lambda < 0.2258$
A	0.798 ± 0.029	$0.743 < A < 0.868$
$\overline{\rho}$	$0.175^{+0.046}_{-0.034}$	$0.103 < \overline{\rho} < 0.288$
$\overline{\eta}$	$0.354^{+0.031}_{-0.032}$	$0.275 < \overline{\eta} < 0.415$
δ	$\left(63.7^{+5.3}_{-7.0}\right)^{\circ}$	$45.4^{\circ} < \delta < 74.4^{\circ}$
ϑ_1	$(12.82 \pm 0.12)^{\circ}$	$12.58^{\circ} < \vartheta_1 < 13.05^{\circ}$
ϑ_2	$\left(2.250^{+0.074}_{-0.071}\right)^{\circ}$	$2.12^{\circ} < \vartheta_2 < 2.43^{\circ}$
ϑ_3	$\left(0.202^{+0.014}_{-0.013}\right)^{\circ}$	$0.176^{\circ} < \vartheta_3 < 0.230^{\circ}$
$\lvert V_{CKM} \rvert = \begin{pmatrix} 0.97508\left(^{+45}_{-46}\right) & 0.2218(20) & 0.00353\left(^{+25}_{-24}\right) \\ 0.2217(20) & 0.97432(46) & 0.0393\left(^{+12}_{-13}\right) \\ 0.00782\left(^{+32}_{-33}\right) & 0.0386\left(^{+13}_{-12}\right) & 0.999223\left(^{+48}_{-51}\right) \end{pmatrix}$		(68%)

Table III: *CKM parameters and matrix elements, as determined by the present analysis.*

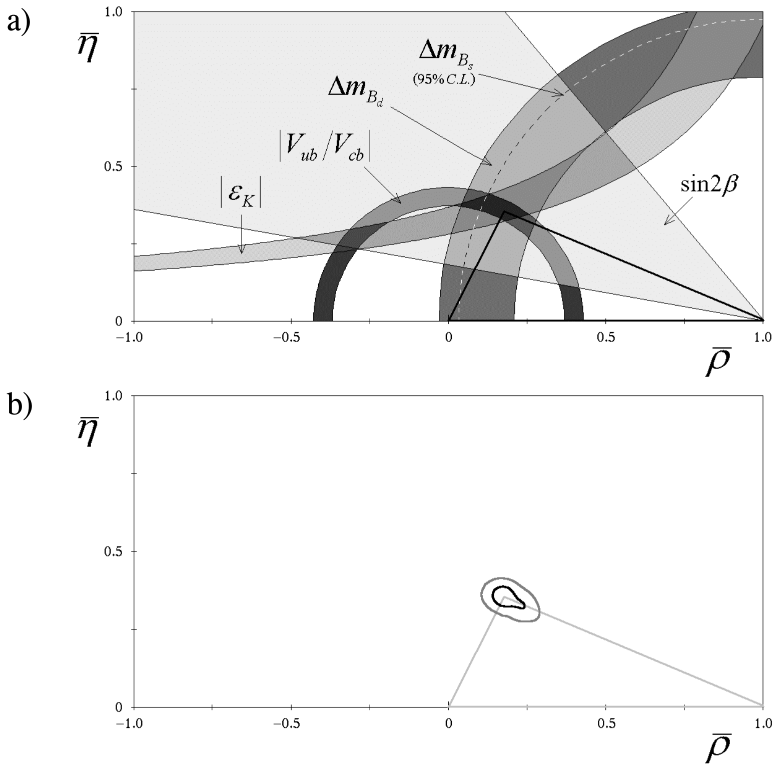

Figure 2. a) *Graphic representation of the main experimental constraints (68% probability contours)*. b) *Regions of maximum probability (68 and 95% C.L.) for the vertex* $(\overline{\rho},\overline{\eta})$ *of the unitarity triangle.*

	68% C.L.	95% C.L.
$\sin 2\alpha$	$-0.11^{+0.20}_{-0.22}$	$-0.73 < \sin 2\alpha < +0.26$
$\sin 2\beta$	$0.725^{+0.044}_{-0.046}$	$0.632 < \sin 2\beta < 0.809$
$\gamma = \delta$	$\left(63.7^{+5.3}_{-7.0}\right)^{\circ}$	$45.4^{\circ} < \gamma < 74.4^{\circ}$
Δm_{B_s}	$15.4^{+3.0}_{-0.7}\ ps^{-1}$	$14.1\ ps^{-1} < \Delta m_{B_s} < 21.5\ ps^{-1}$

Table IV: *predictions for the angles of the unitarity triangle and the $B_s^0 - \overline{B}_s^0$ oscillation frequency.*

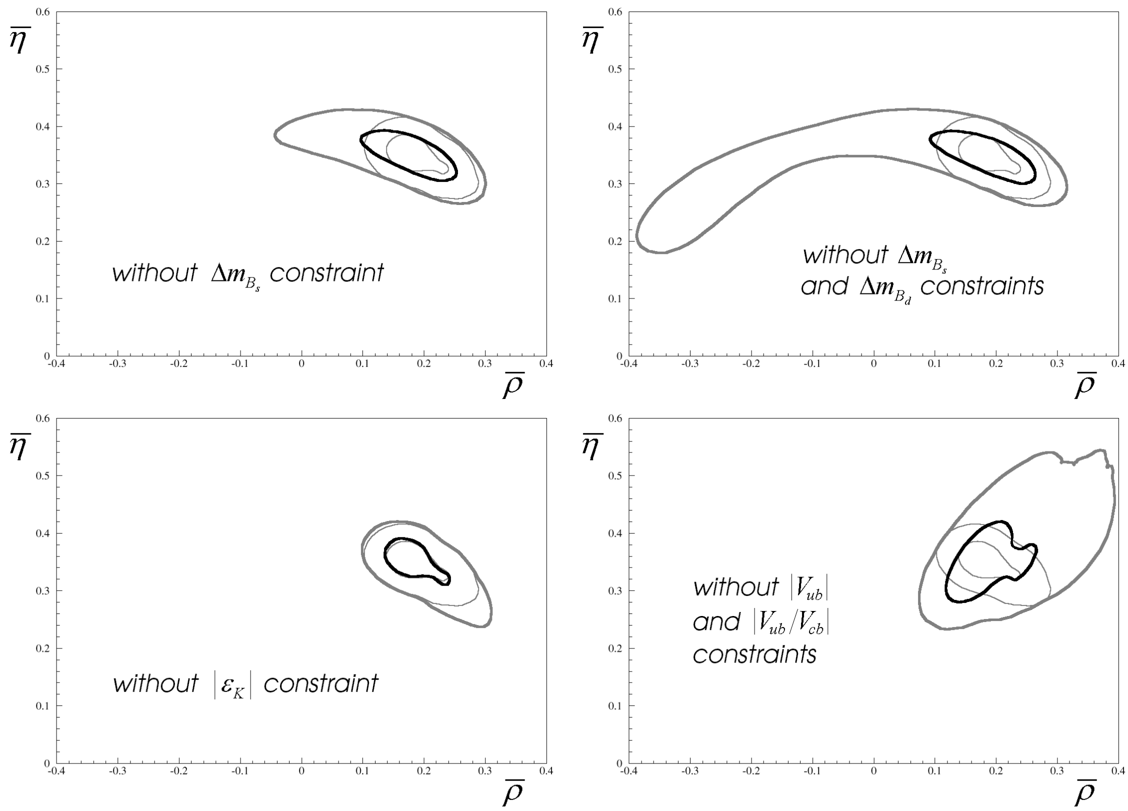

Figure 3: *the regions of maximum probability (68% and 95%) for the vertex $(\overline{\rho},\overline{\eta})$ of the unitarity triangle, as determined by four different sets of constraints. Each graph has been superimposed over the contours obtained in the complete fit (see Figure 2).*

	$\bar{\rho}$	$\bar{\eta}$	$\sin 2\alpha$	$\sin 2\beta$	γ	$\lvert V_{CKM}\rvert$
all the constraints	$0.175^{+0.046}_{-0.034}$	$0.354^{+0.031}_{-0.032}$	$-0.11^{+0.20}_{-0.22}$	$0.725^{+0.044}_{-0.046}$	$\left(63.7^{+5.3}_{-7.0}\right)^{\circ}$	$\begin{pmatrix} 0.97508({}^{+45}_{-46}) & 0.2218(20) & 0.00353({}^{+25}_{-24}) \\ 0.2217(20) & 0.97432(46) & 0.0393({}^{+12}_{-13}) \\ 0.00782({}^{+32}_{-33}) & 0.0386({}^{+13}_{-12}) & 0.999223({}^{+48}_{-51}) \end{pmatrix}$
without Δm_{B_s}	$0.186^{+0.064}_{-0.090}$	$0.350^{+0.042}_{-0.044}$	$-0.17^{+0.47}_{-0.36}$	$0.725^{+0.044}_{-0.048}$	$\left(62^{+14}_{-10}\right)^{\circ}$	$\begin{pmatrix} 0.97508(46) & 0.2218(20) & 0.00355({}^{+28}_{-27}) \\ 0.2217(20) & 0.97431({}^{+47}_{-46}) & 0.0394({}^{+17}_{-16}) \\ 0.00775({}^{+62}_{-49}) & 0.0388(17) & 0.999216({}^{+62}_{-66}) \end{pmatrix}$
without Δm_{B_d} and Δm_{B_s}	$0.196^{+0.068}_{-0.104}$	0.346 ± 0.045	$-0.22^{+0.53}_{-0.37}$	$0.726^{+0.045}_{-0.049}$	$\left(60^{+16}_{-10}\right)^{\circ}$	$\begin{pmatrix} 0.97508(46) & 0.2218(20) & 0.00357({}^{+29}_{-28}) \\ 0.2217(20) & 0.97431({}^{+46}_{-47}) & 0.0395(16) \\ 0.00767({}^{+73}_{-53}) & 0.0389(17) & 0.999213({}^{+64}_{-66}) \end{pmatrix}$
without $\lvert\varepsilon_K\rvert$	$0.172^{+0.046}_{-0.035}$	$0.358^{+0.032}_{-0.035}$	$-0.08^{+0.20}_{-0.24}$	$0.728^{+0.045}_{-0.048}$	$\left(64.3^{+5.3}_{-7.6}\right)^{\circ}$	$\begin{pmatrix} 0.97508(46) & 0.2218(20) & 0.00357({}^{+29}_{-28}) \\ 0.2217(20) & 0.97431({}^{+46}_{-47}) & 0.0395({}^{+16}_{-15}) \\ 0.00791(45) & 0.0389({}^{+16}_{-15}) & 0.999211({}^{+61}_{-64}) \end{pmatrix}$
without $\lvert V_{ub}\rvert$ and $\lvert V_{ub}/V_{cb}\rvert$	$0.166^{+0.065}_{-0.048}$	$0.340^{+0.081}_{-0.060}$	$-0.13^{+0.23}_{-0.25}$	$0.70^{+0.10}_{-0.11}$	$\left(64.0^{+5.6}_{-7.2}\right)^{\circ}$	$\begin{pmatrix} 0.97508(46) & 0.2218(20) & 0.00339({}^{+74}_{-54}) \\ 0.2217(20) & 0.97432({}^{+46}_{-47}) & 0.0394({}^{+16}_{-15}) \\ 0.00788({}^{+44}_{-43}) & 0.0388(15) & 0.999216({}^{+60}_{-63}) \end{pmatrix}$
only $\lvert V_{ij}\rvert$ and $\lvert V_{ub}/V_{cb}\rvert$	$-0.427 \div 0.427$	$-0.427 \div 0.427$	undetermined	$-0.773 \div 0.773$	undetermined	$\begin{pmatrix} 0.97508(46) & 0.2218(20) & 0.00357(29) \\ 0.2217({}^{+21}_{-20}) & 0.97431({}^{+50}_{-46}) & 0.0395({}^{+17}_{-16}) \\ 0.00782({}^{+50}_{-29}) & 0.0389({}^{+21}_{-27}) & 0.999212({}^{+64}_{-67}) \end{pmatrix}$

Table V: *results (68% C. L.) obtained after releasing in turn the main constraints.*

References

[1] M. Kobayashi and T. Maskawa, *Prog. Theor. Phys.* **49** (1973) 652

[2] N. Cabibbo, *Phys. Rev. Lett.* **10** (1963) 351

[3] S.L. Glashow, J. Iliopoulos and L. Maiani, *Phys. Rev.* D **2** (1970) 1285

[4] P. Paganini, F.Parodi, P.Rondeau and A. Stocchi, *Physica Scripta* **58** (1998) 556

[5] C. Caso *et al.* (Particle Data Group), *Eur. Phys. J.* C **3** (1998) 1

[6] L. Wolfenstein, *Phys. Rev. Lett.* **51** (1983) 1945

[7] A. Bertin and A. Vitale, *Riv. Nuovo Cimento* **7** (1984) No. 7

[8] F.J.M. Farley *et al.*, *Proceedings of the International Conference on High Energy Physics, Geneva* (CERN, Geneva, 1962), p.415; A. Zichichi, *Suppl. Nuovo Cimento* **1** (1964) 11

[9] G. Bardin *et al.*, *Phys. Lett.* B **137** (1984) 135

[10] K.L. Giovanetti *et al.*, *Phys. Rev.* D **29** (1984) 343

[11] R. Fulton *et al.* (CLEO Collab.), *Phys. Rev. Lett.* **64** (1990) 16

[12] J. Bartelt *et al.* (CLEO Collab.), *Phys. Rev. Lett.* **71** (1993) 4111

[13] H. Albrecht *et al.* (ARGUS Collab.), *Phys. Lett.* B **255** (1991) 297

[14] R. Barate *et al.* (ALEPH Collab.), *Eur. Phys. J.* C **6** (1999) 555

[15] M. Acciarri *et al.* (L3 Collab.), *Phys. Lett.* B **436** (1998) 174

[16] B.H. Behrens *et al.* (CLEO Collab.), *"Measurement of $B \to \rho \ell \nu$ decay and $\lvert V_{ub}\rvert$"*, preprint hep-ex/9905056

[17] M. Battaglia *et al.* (DELPHI Collab.), *"Measurement of $B(b \to X_u \ell \nu)$ and determination of $\lvert V_{ub}\rvert / \lvert V_{cb}\rvert$ with DELPHI at LEP", HEP'99* #4_521, DELPHI 99-110 CONF 297, June 1999

[18] U.K. Yang *et al.* (CCFR), *"Measurement of the longitudinal structure function and $|V_{cs}|$ in the CCFR experiment"*, preprint hep-ex/9806023
[19] P. Vilain *et al.* (CHARM II Collab.), *"Leading-order QCD analysis of neutrino-induced dimuon events"*, CERN-EP/98-128, August 1998
[20] P. Abreu *et al.* (DELPHI Collab.), *Phys. Lett.* B **439** (1998) 209
[21] R. Barate *et al.* (ALEPH Collab.), *Phys. Lett.* B **453** (1999) 107; ALEPH Collaboration, *"Measurement of W-pair production in e^+e^- collisions at 189 GeV"*, *HEP'99,* ALEPH 99-064 CONF 99-038, July 1999; ALEPH Collaboration, *"A direct measurement of $|V_{cs}|$ in hadronic W decays using a charm tag"*, CERN-EP-99-124, September 1999
[22] The L3 Collaboration, *"Preliminary results on charm production in W decays"*, *ICHEP'98*, L3 Note 2232, June 1998; *"Preliminary results on the measurement of W-pair cross sections in e^+e^- interactions at $\sqrt{s} = 189$ GeV and W-decay branching fractions"*, *HEP'99*, L3 Note 2376, March 1999
[23] The OPAL Collaboration, *"W^+W^- production in e^+e^- collisions at 189 GeV"*, OPAL Physics Note PN378 March 1999; *"A measurement of charm production in $e^+e^- \to W^+W^-$ at LEP2"*, *HEP'99,* OPAL Physics Note PN402, July 1999
[24] P. Abreu *et al.* (DELPHI Collab.), *Z. Phys.* C **71** (1996) 539; DELPHI Collaboration, *"New precise measurement of V_{cb}"*, *HEP'99* #4_518, DELPHI 99-107 CONF 294, June 1999
[25] M.S. Alam *et al.* (CLEO Collab.), *Phys. Rev. Lett.* **74** (1995) 2885; S. Glenn *et al.* (CLEO Collab.), *"Improved measurement of $B(b \to s\gamma)$", ICHEP'98* #1011, CLEO CONF 98-17
[26] R. Barate *et al.* (ALEPH Collab.), *Phys. Lett.* B **429** (1998) 169
[27] The CDF Collaboration, *"First direct measurement of the ratio of branching fractions $B(t \to Wb)/B(t \to Wq)$ and of the CKM element $|V_{tb}|$ in $p\bar{p}$ collisions at $\sqrt{s} = 1.8\,TeV$ "*, CDF/PUB/TOP/CDFR/5028 (1999)
[28] P. Faccioli, Thesis (in Italian), Bologna University (1999)
[29] The LEP B Oscillations Working Group, *"Combined results on B^0 oscillations: results for Lepton-Photon 1999"*, *XIX International Symposium on Lepton and Photon Interactions at High Energies, Stanford University, August 1999*, http://www.cern.ch/LEPBOSC/
[30] CDF Collab., *"A measurement of* $\sin 2\beta$ *from $B \to J/\psi K_S^0$ with the CDF detector"*, FERMILAB-Pub-99/225-E
[31] F. James, *MINUIT – Function Minimization and Error Analysis*, CERN Program Library Long Writeup D506 (1994)
[32] T. Lohse *et al.*, HERA-B: Proposal, DESY-PRC 94/02 (1994); E. Hartouni *et al.*, HERA-B: Design Report, DESY-PRC 95/01 (1995)
[33] *The BaBar Physics Book*, edited by P.F. Harrison and H.R. Quinn, SLAC-R-504 (1998)
[34] M.T. Cheng *et al.*, Belle Technical Design Report, KEK Report 95-1 (April 1995)