V_{cb} and V_{ub} CKM Matrix Elements

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V_{cb} MEASUREMENTS

For the discussion of V_{cb} measurements, which is not repeated here, see the review on "Determination of $|V_{cb}|$ and $|V_{ub}|$."

The CKM matrix element $|V_{cb}|$ can be determined by studying the rate of the semileptonic decay $B \rightarrow D^{(*)}\ell\nu$ as a function of the recoil kinematics of $D^{(*)}$ mesons. Taking advantage of theoretical constraints on the normalization and a linear ω dependence of the form factors provided by Heavy Quark Effective Theory (HQET), the $|V_{cb}|\times F(\omega)$ and ρ^2 (a^2) can be simultaneously extracted from data, where ω is the scalar product of the two-meson four velocities, $F(1)$ is the form factor at zero recoil (ω=1) and ρ^2 is the slope, sometimes denoted as a^2. Using the theoretical input of $F(1)$, a value of $|V_{cb}|$ can be obtained.

"OUR EVALUATION" is an average using rescaled values of the data listed below. The average and rescaling were performed by the Heavy Flavor Averaging Group (HFAG) and are described at http://www.slac.stanford.edu/xorg/hfag/. The averaging/rescaling procedure takes into account correlations between the measurements.

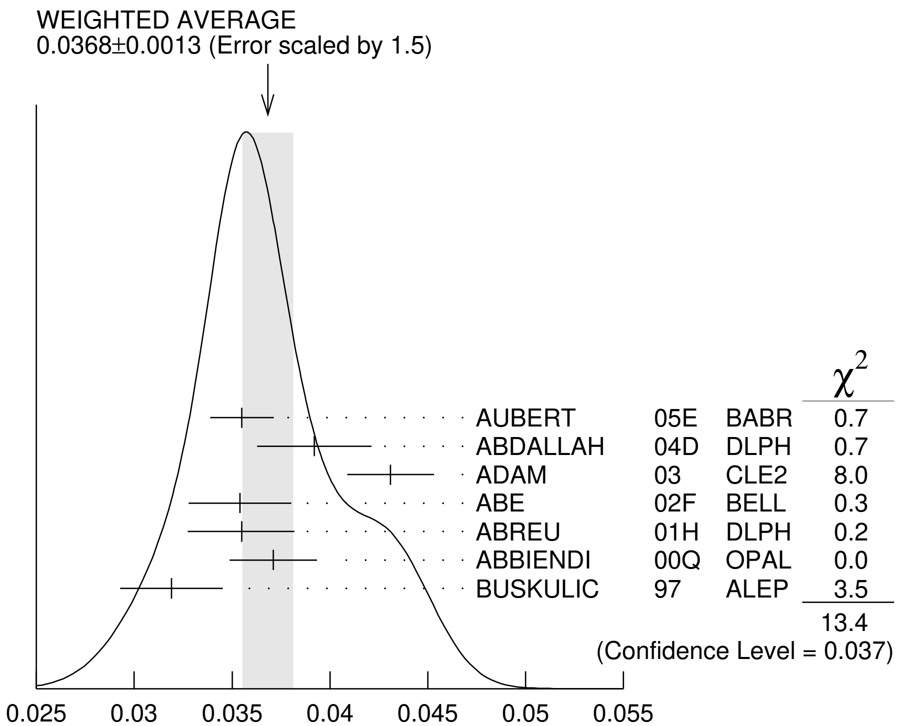
$|V_{cb}| \times F(1)$ (from $B^0 \rightarrow D^{*-}\ell^+\nu$)

0.036 ±0.006 OUR EVALUATION with ρ^2=1.13 ± 0.03 ± 0.06 and a correlation 0.65. The fitted χ^2 is 34 for 14 degrees of freedom.

0.0368±0.0013 OUR AVERAGE Error includes scale factor of 1.5. See the ideogram below.

VALUE	DOCUMENT ID		TECN	COMMENT
$0.0355\pm0.0003\pm0.0016$	[1] AUBERT	05E	BABR	$e^+e^- \rightarrow \Upsilon(4S)$
$0.0392\pm0.0018\pm0.0023$	[2] ABDALLAH	04D	DLPH	$e^+e^- \rightarrow Z^0$
$0.0431\pm0.0013\pm0.0018$	[3] ADAM	03	CLE2	$e^+e^- \rightarrow \Upsilon(4S)$
$0.0354\pm0.0019\pm0.0018$	[4] ABE	02F	BELL	$e^+e^- \rightarrow \Upsilon(4S)$
$0.0355\pm0.0014^{+0.0023}_{-0.0024}$	[5] ABREU	01H	DLPH	$e^+e^- \rightarrow Z$
$0.0371\pm0.0010\pm0.0020$	[6] ABBIENDI	00Q	OPAL	$e^+e^- \rightarrow Z$
$0.0319\pm0.0018\pm0.0019$	[7] BUSKULIC	97	ALEP	$e^+e^- \rightarrow Z$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
$0.0377\pm0.0011\pm0.0019$	[8] ABDALLAH	04D	DLPH	$e^+e^- \rightarrow Z^0$
$0.0431\pm0.0013\pm0.0018$	[9] BRIERE	02	CLE2	$e^+e^- \rightarrow \Upsilon(4S)$
$0.0328\pm0.0019\pm0.0022$	ACKERSTAFF	97G	OPAL	Repl. by ABBIENDI 00Q
$0.0350\pm0.0019\pm0.0023$	[10] ABREU	96P	DLPH	Repl. by ABREU 01H
$0.0351\pm0.0019\pm0.0020$	[11] BARISH	95	CLE2	Repl. by ADAM 03
$0.0314\pm0.0023\pm0.0025$	BUSKULIC	95N	ALEP	Repl. by BUSKULIC 97

[1] Measurement using fully reconstructed D^* sample with a $\rho^2 = 1.29 \pm 0.03 \pm 0.27$.
[2] Measurement using fully reconstructed D^* sample with a $\rho^2 = 1.32 \pm 0.15 \pm 0.33$.
[3] Average of the $B^0 \rightarrow D^*(2010)^- \ell^+ \nu$ and $B^+ \rightarrow \overline{D}^*(2007))\ell^+ \nu$ modes with $\rho^2 = 1.61 \pm 0.09 \pm 0.21$ and $f_{+-} = 0.521 \pm 0.012$.
[4] Measured using exclusive $B^0 \rightarrow D^*(892)^- e^+ \nu$ decays with $\rho^2 = 1.35 \pm 0.17 \pm 0.19$ and a correlation of 0.91.
[5] ABREU 01H measured using about 5000 partial reconstructed D^* sample with a $\rho^2 = 1.34 \pm 0.14^{+0.24}_{-0.22}$.
[6] ABBIENDI 00Q: measured using both inclusively and exclusively reconstructed $D^{*\pm}$ samples with a $\rho^2 = 1.21 \pm 0.12 \pm 0.20$. The statistical and systematic correlations between $|V_{cb}| \times F(1)$ and ρ^2 are 0.90 and 0.54 respectively.
[7] BUSKULIC 97: measured using exclusively reconstructed $D^{*\pm}$ with a $a^2 = 0.31 \pm 0.17 \pm 0.08$. The statistical correlation is 0.92.
[8] Combines with previous partial reconstructed D^* measurement with a $\rho^2 = 1.39 \pm 0.10 \pm 0.33$.
[9] BRIERE 02 result is based on the same analysis and data sample reported in ADAM 03.
[10] ABREU 96P: measured using both inclusively and exclusively reconstructed $D^{*\pm}$ samples.
[11] BARISH 95: measured using both exclusive reconstructed $B^0 \rightarrow D^{*-} \ell^+ \nu$ and $B^+ \rightarrow D^{*0} \ell^+ \nu$ samples. They report their experiment's uncertainties $\pm 0.0019 \pm 0.0018 \pm 0.0008$, where the first error is statistical, the second is systematic, and the third is the uncertainty in the lifetimes. We combine the last two in quadrature.



$\left|V_{cb}\right| \times F(1)$ (from $B^0 \rightarrow D^{*-} \ell^+ \nu$)

$|V_{cb}| \times F(1)$ (from $B \to D^- \ell^+ \nu$)

VALUE	DOCUMENT ID		TECN	COMMENT
0.0423±0.0045 OUR EVALUATION with ρ^2=1.17 ± 0.18 and a correlation of 0.93. The fitted χ^2 is 0.3 for 4 degrees of freedom.				
0.039 ±0.004 OUR AVERAGE				
$0.0411 \pm 0.0044 \pm 0.0052$	[12] ABE	02E	BELL	$e^+ e^- \to \Upsilon(4S)$
$0.0416 \pm 0.0047 \pm 0.0037$	[13] BARTELT	99	CLE2	$e^+ e^- \to \Upsilon(4S)$
$0.0278 \pm 0.0068 \pm 0.0065$	[14] BUSKULIC	97	ALEP	$e^+ e^- \to Z$
• • • We do not use the following data for averages, fits, limits, etc. • • •				
$0.0337 \pm 0.0044 {}^{+0.0072}_{-0.0049}$	[15] ATHANAS	97	CLE2	Repl. by BARTELT 99

[12] Using the missing energy and momentum to extract kinematic information about the undetected neutrino in the $B^0 \to D^- \ell^+ \nu$ decay.

[13] BARTELT 99: measured using both exclusive reconstructed $B^0 \to D^- \ell^+ \nu$ and $B^+ \to D^0 \ell^+ \nu$ samples.

[14] BUSKULIC 97: measured using exclusively reconstructed $D^\pm$ with a $a^2 = -0.05 \pm 0.53 \pm 0.38$. The statistical correlation is 0.99.

[15] ATHANAS 97: measured using both exclusive reconstructed $B^0 \to D^- \ell^+ \nu$ and $B^+ \to D^0 \ell^+ \nu$ samples with a $\rho^2 = 0.59 \pm 0.22 \pm 0.12^{+0.59}_{-0}$. They report their experiment's uncertainties $\pm 0.0044 \pm 0.0048^{+0.0053}_{-0.0012}$, where the first error is statistical, the second is systematic, and the third is the uncertainty due to the form factor model variations. We combine the last two in quadrature.

V_{ub} MEASUREMENTS

For the discussion of V_{ub} measurements, which is not repeated here, see the review on "Determination of $|V_{cb}|$ and $|V_{ub}|$."

The CKM matrix element $|V_{ub}|$ can be determined by studying the rate of the charmless semileptonic decay $b \to u \ell \nu$. Measurements based on exclusive decay channels and on inclusive techniques can be found in the previous B Listings, which will not repeat here.

V_{cb} and V_{ub} CKM Matrix Elements REFERENCES

AUBERT	05E	PR D71 051502R	B. Aubert *et al.*	(BABAR Collab.)
ABDALLAH	04D	EPJ C33 213	J. Abdallah *et al.*	(DELPHI Collab.)
ADAM	03	PR D67 032001	N.E. Adam *et al.*	(CLEO Collab.)
ABE	02E	PL B526 258	K. Abe *et al.*	(BELLE Collab.)
ABE	02F	PL B526 247	K. Abe *et al.*	(BELLE Collab.)
BRIERE	02	PRL 89 081803	R. Briere *et al.*	(CLEO Collab.)
ABREU	01H	PL B510 55	P. Abreu *et al.*	(DELPHI Collab.)
ABBIENDI	00Q	PL B482 15	G. Abbiendi *et al.*	(OPAL Collab.)
BARTELT	99	PRL 82 3746	J. Bartelt *et al.*	(CLEO Collab.)
ACKERSTAFF	97G	PL B395 128	K. Ackerstaff *et al.*	(OPAL Collab.)
ATHANAS	97	PRL 79 2208	M. Athanas *et al.*	(CLEO Collab.)
BUSKULIC	97	PL B395 373	D. Buskulic *et al.*	(ALEPH Collab.)
ABREU	96P	ZPHY C71 539	P. Abreu *et al.*	(DELPHI Collab.)
BARISH	95	PR D51 1014	B.C. Barish *et al.*	(CLEO Collab.)
BUSKULIC	95N	PL B359 236	D. Buskulic *et al.*	(ALEPH Collab.)