

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 ($\omega=1$) 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 $B^0 \rightarrow D^{*-} \ell^+ \nu$)

VALUE	DOCUMENT ID	TECN	COMMENT
0.03618 ± 0.00055 OUR EVALUATION	with $\rho^2=1.17 \pm 0.05$ and a correlation 0.24. The fitted χ^2 is 33.9 for 17 degrees of freedom.		
0.0360 ± 0.0013 OUR AVERAGE	Error includes scale factor of 1.6. See the ideogram below.		
$0.0344 \pm 0.0003 \pm 0.0011$	¹ AUBERT	08R	BABR $e^+ e^- \rightarrow \Upsilon(4S)$
$0.0392 \pm 0.0018 \pm 0.0023$	² ABDALLAH	04D	DLPH $e^+ e^- \rightarrow Z^0$
$0.0431 \pm 0.0013 \pm 0.0018$	³ ADAM	03	CLE2 $e^+ e^- \rightarrow \Upsilon(4S)$
$0.0354 \pm 0.0019 \pm 0.0018$	⁴ ABE	02F	BELL $e^+ e^- \rightarrow \Upsilon(4S)$
$0.0355 \pm 0.0014 \begin{smallmatrix} +0.0023 \\ -0.0024 \end{smallmatrix}$	⁵ ABREU	01H	DLPH $e^+ e^- \rightarrow Z$
$0.0371 \pm 0.0010 \pm 0.0020$	⁶ ABBIENDI	00Q	OPAL $e^+ e^- \rightarrow Z$
$0.0319 \pm 0.0018 \pm 0.0019$	⁷ BUSKULIC	97	ALEP $e^+ e^- \rightarrow Z$
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●			
$0.0355 \pm 0.0003 \pm 0.0016$	⁸ AUBERT	05E	BABR Repl. by AUBERT 08R
$0.0377 \pm 0.0011 \pm 0.0019$	⁹ ABDALLAH	04D	DLPH $e^+ e^- \rightarrow Z^0$
$0.0431 \pm 0.0013 \pm 0.0018$	¹⁰ BRIERE	02	CLE2 $e^+ e^- \rightarrow \Upsilon(4S)$
$0.0328 \pm 0.0019 \pm 0.0022$	ACKERSTAFF	97G	OPAL Repl. by ABBIENDI 00Q
$0.0350 \pm 0.0019 \pm 0.0023$	¹¹ ABREU	96P	DLPH Repl. by ABREU 01H
$0.0351 \pm 0.0019 \pm 0.0020$	¹² BARISH	95	CLE2 Repl. by ADAM 03
$0.0314 \pm 0.0023 \pm 0.0025$	BUSKULIC	95N	ALEP Repl. by BUSKULIC 97

- ¹ Measured using fully reconstructed D^* sample and a simultaneous fit to the Caprini-Lellouch-Neubert form factor parameters: $\rho^2 = 1.191 \pm 0.048 \pm 0.028$, $R_1(1) = 1.429 \pm 0.061 \pm 0.044$, and $R_2(1) = 0.827 \pm 0.038 \pm 0.022$.
- 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 $B^+ \rightarrow \bar{D}^*(2007) \ell^+ \nu$ 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 Measurement using fully reconstructed D^* sample with a $\rho^2 = 1.29 \pm 0.03 \pm 0.27$.
- ⁹ Combines with previous partial reconstructed D^* measurement with a $\rho^2 = 1.39 \pm 0.10 \pm 0.33$.
- ¹⁰ BRIERE 02 result is based on the same analysis and data sample reported in ADAM 03.
- ¹¹ ABREU 96P: measured using both inclusively and exclusively reconstructed $D^{*\pm}$ samples.
- ¹² 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.



