SLAC-PUB-12316
hep-ex/0701044
January 2007

Measurements of $\sin 2\beta$ and $\cos 2\beta$ from $b \to c\bar{c}s$ decays at *BABAR*.

Katherine A. George*
Department of Physics, Queen Mary, University of London, Mile End Road, London, E1 4NS, UK.

Recent measurements of $\sin 2\beta$ and $\cos 2\beta$ using $b \to c\bar{c}s$ decays are presented using data collected by the *BABAR* experiment at the PEP-II asymmetric-energy B-factory.

I. INTRODUCTION.

The Standard Model (SM) of particle physics describes charge conjugation-parity (CP) violation as a consequence of a complex phase in the three-generation Cabibbo-Kobayashi-Maskawa (CKM) quark-mixing matrix [1]. In this framework, measurements of CP asymmetries in the proper-time distribution of neutral B decays to CP eigenstates containing a charmonium and K^0 meson provide a direct measurement of $\sin 2\beta$ [2]. The unitarity triangle angle β is $\arg\left[-V_{\rm cd}V_{\rm cb}^*/V_{\rm td}V_{\rm tb}^*\right]$ where the V_{ij} are CKM matrix elements. CP violation in the B-meson system was established by the *BABAR* [3] and Belle [4] collaborations in 2001.

The *BABAR* detector [5] is located at the SLAC PEP-II e^+e^- asymmetric energy B-factory [6] where data is collected on or just below the $\Upsilon(4S)$ resonance. A small fraction ($\approx 10\%$) is collected at approximately 40 MeV below the $\Upsilon(4S)$ resonance, and is used to study background from $e^+e^- \to q\bar{q}$ ($q = u, d, s, c$) continuum events. The *BABAR* experimental program includes the measurement of the angle β through the measurement of time-dependent CP-asymmetries, A_{CP} as discussed in Ref. [7]. A_{CP} is defined as

$$A_{CP}(t) \equiv \frac{N(\overline{B}^0(t) \to f) - N(B^0(t) \to f)}{N(\overline{B}^0(t) \to f) + N(B^0(t) \to f)} = S\sin(\Delta m_d t) - C\cos(\Delta m_d t), \quad (1)$$

where $N(\overline{B}^0(t) \to f)$ is the number of $\overline{B}^0$ that decay into the CP-eigenstate f after a time t and Δm_d is the difference between the B mass eigenstates. The sinusoidal term describes interference between mixing and decay and the cosine term is the direct CP asymmetry. In Eq. 1, $A(\overline{B}^0(t) \to \overline{f})$ ($A(B^0(t) \to \overline{f})$) is the decay amplitude of $\overline{B}^0$ (B^0) to the final state $\overline{f}$ (f).

In this article, the current status of measurements of $\sin 2\beta$ and $\cos 2\beta$ from $b \to c\bar{c}s$ decays at *BABAR* are discussed. All results are final unless otherwise stated. Additional results on CP violation measurements in B to charm decays at *BABAR* can be found in Ref. [8].

II. $\sin 2\beta$ FROM $B^0 \to$ CHARMONIUM + K^0

The determination of β from $b \to c\bar{c}s$ decay modes currently provides the most stringent constraint on the unitarity triangle. For these decay modes, the CP violation parameters S and C are $S_{b\to c\bar{c}s} = -\eta_f \sin 2\beta$ and $C_{b\to c\bar{c}s} = 0$, where η_f is -1 for $(c\bar{c})K^0_S$ decays (e.g. $J/\psi K^0_S$, $\psi(2S)K^0_S$, $\chi_{c1}K^0_S$, $\eta_c K^0_S$ [9]) and η_f is $+1$ for the $(c\bar{c})K^0_L$ (e.g. $J/\psi K^0_L$) state. We use the value $\eta_f = 0.504 \pm 0.033$ for the $J/\psi K^{*0}(K^{*0} \to K^0_S\pi^0)$ final state since it can be both CP even and CP odd due to the presence of even and odd orbital angular momentum contributions [10]. These modes have most recently been used to measure $\sin 2\beta$ using a sample of $347.5 \times 10^6\, \Upsilon(4S) \to B\overline{B}$ decays [11]. This result is preliminary.

In addition to the CP modes described above, a large sample $B_{\rm flav}$ of B^0 decays to the flavor eigenstates $D^{(*)-}h^+(h^+ = \pi^+, \rho^+$, and $a_1^+)$ and $J/\psi K^{*0}(K^{*0} \to K^+\pi^-)$ is used for calibrating the flavor tagging performance and Δt resolution. Studies are performed to measure apparent CP violation from unphysical sources using a control sample of B^+ mesons decaying to the final states $J/\psi K^{(*)+}$, $\psi(2S)K^+$, $\chi_{c1}K^+$, and $\eta_c K^+$. The event selection and candidate reconstruction are unchanged from those described in Refs. [7, 12, 13] with the exception of a new $\eta_c K^0_S$ event selection based on the Dalitz structure of the $\eta_c \to K^0_S K^+\pi^-$ decay. We calculate the time interval Δt between the two B decays from the measured separation Δz between the decay vertices of $B_{\rm rec}$ and $B_{\rm tag}$ along the collision (z) axis [7]. The z position of the $B_{\rm rec}$ vertex is determined from the charged daughter tracks. The $B_{\rm tag}$ decay vertex is determined by fitting tracks not belonging to the $B_{\rm rec}$ candidate to a common vertex, employing constraints from the beam spot location and the $B_{\rm rec}$ momentum [7]. Events are accepted if the calculated Δt uncertainty is less than 2.5 ps and $|\Delta t|$ is less than 20 ps. The fraction of events satisfying these requirements is 95%.

At the $\Upsilon(4S)$ resonance, A_{CP} is extracted from the distribution of the difference of the proper decay times, $t \equiv t_{CP} - t_{tag}$, where t_{CP} refers to the decay time of the signal B meson (B_{CP}) and t_{tag} refers to the decay time of the other B meson in the event (B_{tag}). Multivariate algorithms are used to identify signatures of B decays that determine ("tag") the flavor of the $B_{\rm tag}$ at decay to be either a B^0 or $\overline{B}^0$ candidate. These algorithms account for

*Electronic address: katherine.george@slac.stanford.edu

Invited talk presented at 4th International Workshop On The CKM Unitarity Triangle (CKM 2006), 12-16 Dec 2006, Nagoya, Japan

Work supported in part by the US Department of Energy contract DE-AC02-76SF00515

SLAC, Stanford Univesity, Stanford, CA 94309

correlations among different sources of flavor information and provide an estimate of the mistag probability for each event. Each event whose estimated mistag probability is less than 45% is assigned to one of six tagging categories. The `Lepton` category contains events with an identified lepton; the remaining events are divided into the `Kaon I`, `Kaon II`, `Kaon-Pion`, `Pion`, or `Other` categories based on the estimated mistag probability. For each category i, the tagging efficiency ε_i and fraction w_i of events having the wrong tag assignment are measured from data. The figure of merit for tagging is the effective tagging efficiency $Q \equiv \sum_i \varepsilon_i(1-2w_i)^2 = (30.4 \pm 0.3)\,\%$, where the error shown is statistical only.

With the exception of the $J/\psi\, K^0_L$ mode, we use the beam-energy substituted mass $m_{ES} = \sqrt{(E^*_{\rm beam})^2 - (p^*_B)^2}$ to determine the composition of our final sample, where $E^*_{\rm beam}$ and p^*_B are the beam energy and B momentum in the e^+e^- center-of-mass frame. For the $J/\psi\, K^0_L$ mode we use the difference ΔE between the candidate center-of-mass energy and $E^*_{\rm beam}$. We use events with $m_{ES} > 5.2\,{\rm GeV}/c^2$ ($\Delta E < 80\,{\rm MeV}$ for $J/\psi\, K^0_L$) in order to determine the properties of the background contributions. We define a signal region $5.27 < m_{ES} < 5.29\,{\rm GeV}/c^2$ ($|\Delta E| < 10\,{\rm MeV}$ for $J/\psi\, K^0_L$) that contains CP candidate events that satisfy the tagging and vertexing requirements as listed in Table I.

We determine sin2β with a simultaneous maximum likelihood fit to the Δt distribution of the tagged B_{CP} and $B_{\rm flav}$ samples. There are 65 free parameters in the fit: sin2β (1), the average mistag fractions w and the differences Δw between B^0 and $\overline{B}^0$ mistag fractions for each tagging category (12), parameters for the signal Δt resolution (7), parameters for CP background time dependence (8), and the difference between B^0 and $\overline{B}^0$ reconstruction and tagging efficiencies (7); for $B_{\rm flav}$ background, time dependence (3), Δt resolution (3), and mistag fractions (24). For the CP modes (except for $J/\psi\, K^0_L$), the apparent CP asymmetry of the non-peaking background in each tagging category is allowed to be a free parameter in the fit. We fix $\tau_{B^0} = 1.530$ ps, $\Delta m_d = 0.507$ ps^{-1} [14], $|\lambda| = 1$, and $\Delta\Gamma_d = 0$. The fit to the B_{CP} and $B_{\rm flav}$ samples yields sin2$\beta = 0.710 \pm 0.034 \pm 0.019$ [15]. Figure 1 shows the Δt distributions and asymmetries in yields between events with B^0tags and $\overline{B}^0$tags for the $\eta_f = -1$ and $\eta_f = +1$ samples as a function of Δt overlaid with the projection of the likelihood fit result.

We perform a separate fit with only the cleanest $\eta_f = -1$ sample, in which we treat both $|\lambda|$ and sin2β as free parameters. We do not use the modes $J/\psi K^{*0}$ and $J/\psi K^0_L$ to minimize the dependence of the results on the background parametrization. We obtain $|\lambda| = 0.932 \pm 0.026 \pm 0.017$. The updated value of sin2β is consistent with the current world average [16] and the theoretical estimates of the magnitudes of CKM matrix elements in the context of the SM [17].

Ref. [18] presents a model-independent study of this shift using the measurements of $B^0 \to J/\psi\pi^0$ [19] to quantify the effect of contributions from penguin operators and long-distance contributions from penguin contractions. They find that the deviation of the measured S_{CP} term from sin2β, $\Delta S_{J/\psi\, K^0_S} \equiv S_{J/\psi\, K^0_S} - \sin 2\beta = 0.000 \pm 0.017$ which is comparable to the systematic error from our previous publication [12]. The theoretical estimates of $\Delta S_{J/\psi\, K^0_S}$ are $\mathcal{O}(10^{-3})$ [20] and $\mathcal{O}(10^{-4})$ [21].

TABLE I: Number of events $N_{\rm tag}$ in the signal region after tagging and vertexing requirements, signal purity P including the contribution from peaking background, and results of fitting for CP asymmetries in the B_{CP} sample and various subsamples. In addition, results on the $B_{\rm flav}$ and charged B control samples test that no artificial CP asymmetry is found where we expect no CP violation (sin2$\beta = 0$). Errors are statistical only. The signal region is $5.27 < m_{ES} < 5.29\,{\rm GeV}/c^2$ ($|\Delta E| < 10\,{\rm MeV}$ for $J/\psi\, K^0_L$).

Sample	$N_{\rm tag}$	$P(\%)$	sin2β
Full CP sample	11496	76	0.710 ± 0.034
$J/\psi\, K^0_S$,$\psi(2S)K^0_S$,$\chi_{c1}K^0_S$,$\eta_c K^0_S$	6028	92	0.713 ± 0.038
$J/\psi\, K^0_L$	4323	55	0.716 ± 0.080
$J/\psi\, K^{*0}(K^{*0} \to K^0_S\pi^0)$	965	68	0.526 ± 0.284
1999-2002 data	3084	79	0.755 ± 0.067
2003-2004 data	4850	77	0.724 ± 0.052
2005-2006 data	3562	74	0.663 ± 0.062
$J/\psi\, K^0_S$ ($K^0_S \to \pi^+\pi^-$)	4076	96	0.715 ± 0.044
$J/\psi\, K^0_S$ ($K^0_S \to \pi^0\pi^0$)	988	88	0.581 ± 0.105
$\psi(2S)K^0_S$ ($K^0_S \to \pi^+\pi^-$)	622	83	0.892 ± 0.120
$\chi_{c1}K^0_S$	279	89	0.709 ± 0.174
$\eta_c K^0_S$	243	75	0.717 ± 0.229
`Lepton` category	703	97	0.754 ± 0.068
`Kaon I` category	900	93	0.713 ± 0.066
`Kaon II` category	1437	91	0.711 ± 0.075
`Kaon-Pion` category	1107	89	0.635 ± 0.117
`Pion` category	1238	91	0.587 ± 0.175
`Other` category	823	89	0.454 ± 0.469
$B_{\rm flav}$ sample	112878	83	0.016 ± 0.011
B^+ sample	27775	93	0.008 ± 0.017

III. cos2β FROM $b \to c\bar{c}s$ DECAYS.

The analysis of $b \to c\bar{c}s$ decay modes imposes a constraint on sin2β only, leading to a four-fold ambiguity in the determination of β. This ambiguity can leave possible new physics undetected even with very high precision measurements of sin2β. Additional constraints are obtained from the ambiguity-free measurement of cos2β using the angular and time-dependent asymmetry in $B^0 \to J/\psi\, K^*$ decays and the time-dependent Dalitz plot analyses of $B^0 \to D^{*0}h^0$ and $B^0 \to D^{*+}D^{*-}K^0_S$. The *BABAR* $B^0 \to D^{*0}h^0$ analysis is described in Refs. [22] and [23].

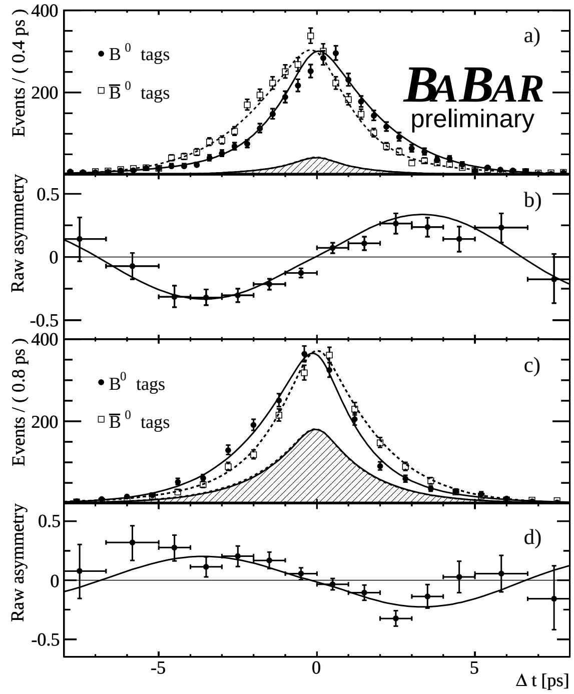

FIG. 1: a) Number of $\eta_f = -1$ candidates ($J/\psi K^0_S$, $\psi(2S)K^0_S$, $\chi_{c1}K^0_S$, and $\eta_c K^0_S$) in the signal region with a B^0tag (N_{B^0}) and with a $\overline{B}^0$tag ($N_{\overline{B}^0}$), and b) the raw asymmetry ($N_{B^0} - N_{\overline{B}^0})/(N_{B^0} + N_{\overline{B}^0}$), as functions of Δt. Figures c) and d) are the corresponding distributions for the $\eta_f = +1$ mode $J/\psi K^0_L$. All distributions exclude `Other`-tagged events. The solid (dashed) curves represent the fit projections in $\Delta t$for $B^0(\overline{B}^0)$ tags. The shaded regions represent the estimated background contributions.

A. $B^0 \to D^{*+}D^{*-}K^0_S$.

Both B^0 and $\overline{B}^0$ mesons can decay to the same final state $D^{*+}D^{*-}K^0_S$ via a process dominated by the single weak phase W-emission $b \to c\bar{c}s$ transition. Possible penguin contributions are neglected and it is therefore assumed that there is no direct CP violation. According to Ref. [24], the decay can be divided into two half Dalitz planes $s^+ \leq s^-$ and $s^+ \geq s^-$, where $s^+ \equiv m^2(D^{*+}K^0_S)$ and $s^- \equiv m^2(D^{*-}K^0_S)$, such that the time-dependent decay rate asymmetry of $B^0 \to D^{*+}D^{*-}K^0_S$ is

$$A(t) \equiv \frac{\Gamma_{\overline{B}^0} - \Gamma_{B^0}}{\Gamma_{\overline{B}^0} + \Gamma_{B^0}} = \eta_y \frac{J_c}{J_0}\cos(\Delta m_d t) - \left(\frac{2J_{s1}}{J_0}\sin 2\beta + \eta_y \frac{2J_{s2}}{J_0}\cos 2\beta\right)\sin(\Delta m_d t),$$

where $\eta_y = -1(+1)$ for $s^+ \leq s^-(s^+ \geq s^-)$. The parameters J_0,J_c,J_{s1} and J_{s2} are the integrals over the half Dalitz phase space with $s^+ < s^-$ of the functions $|a|^2 + |\bar{a}|^2$, $|a|^2 - |\bar{a}|^2$, $\mathcal{R}e(\bar{a}a^*)$ and $\mathcal{I}m(\bar{a}a^*)$, where a and $\bar{a}$ are the decay amplitudes of $B^0 \to D^{*+}D^{*-}K^0_S$ and $\overline{B}^0 \to D^{*+}D^{*-}K^0_S$, respectively. If the decay $B^0 \to D^{*+}D^{*-}K^0_S$ has only a non-resonant component, the parameters $J_{s2} = 0$ and J_c are at the few percent level [24]. The CP asymmetry can be extracted by fitting the B^0 time-dependent decay distribution. The measured CP asymmetry is sin2β multiplied by a factor of $2J_{s1}/J_0$ because the final state is an admixture of CP eigenstates with different CP parities. In this case, the value of the dilution factor $2J_{s1}/J_0$ is estimated to be large [24], similar to the decay $B^0 \to D^{*+}D^{*-}$. The situation is more complicated if intermediate resonances such as D^+_{sJ} are present. In this case, the parameter J_{s2} is non-zero and J_c can be large. The resonant components are expected to be dominated by two P-wave excited D_{s1} states [24]. One such state is $D^+_{s1}(2536)$ that has a narrow width and does not contribute much to J_{s2}. The other D^+_{s1} resonant state is predicted in the quark model [25] to have a mass above the $D^{*+}K^0_S$ mass threshold with a large width. In this case, the J_{s2} can be large. Therefore by studying the time-dependent asymmetry of $B^0 \to D^{*+}D^{*-}K^0_S$ in two different Dalitz regions, the sign of $\cos 2\beta$ can be determined for a sufficiently large data set using the method described in Refs. [24, 26]. This would allow the resolution of the $\beta \to \pi/2 - \beta$ ambiguity despite the large theoretical uncertainty of $2J_{s2}/J_0$. However, one of the expected P-wave D^+_{s1} may be the newly discovered $D^+_{sJ}(2317)$ or $D^+_{sJ}(2460)$. These states are below the $D^{*+}K^0_S$ mass threshold, so they will not contribute to the decay $B^0 \to D^{*+}D^{*-}K^0_S$. The fits to $208.7 \times 10^6\, \Upsilon(4S) \to B\overline{B}$ decays yield: $J_c/J_0 = 0.76 \pm 0.18 \pm 0.07$, $(2J_{s1}/J_0)\sin 2\beta = 0.10 \pm 0.24 \pm 0.06$, and $(2J_{s2}/J_0)\cos 2\beta = 0.38 \pm 0.24 \pm 0.05$ [27]. The measured value of J_c/J_0 is significantly different from zero, which, according to Ref. [24], may indicate that there is a sizable broad resonant contribution to the decay $B^0 \to D^{*+}D^{*-}K^0_S$ from an unknown D^+_{s1} state with an unknown width. Under this assumption then the measured value of $2J_{s2}/J_0$ implies that the sign of cos2β is preferred to be positive at a 94% confidence level.

B. $B^0 \to J/\psi\, K^{*0}(K^{*0} \to K^0_S\pi^0)$.

BABAR has measured the sign of cos2β in a time-dependent angular analysis of 104 $B^0 \to J/\psi\, K^{*0}(K^* \to K^0_S\pi^0)$ decays in $88.0\times10^6\, \Upsilon(4S) \to B\overline{B}$ of data recorded between 1999 and 2002 [28]. Interference between decays to CP-even (L=0,2) and CP-odd (L=1) final states give terms proportional to cos2β in the decay rate. Strong phase differences and transversity amplitudes A, that appear also in these terms, have been separately measured in a time-integrated angular analysis of $B^\pm \to J/\psi\, K^{*\pm}$

and $J/\psi K^{*0}(K^* \to K^+\pi^-)$ decays:

$$\begin{aligned}
\delta_{\parallel} - \delta_0 &= (-2.73 \pm 0.10 \pm 0.05)\,\mathrm{rad}, \\
\delta_{\perp} - \delta_0 &= (+2.96 \pm 0.07 \pm 0.05)\,\mathrm{rad}, \\
|A_0|^2 &= 0.566 \pm 0.012 \pm 0.005, \\
|A_{\parallel}|^2 &= 0.204 \pm 0.015 \pm 0.005, \\
|A_{\perp}|^2 &= 0.230 \pm 0.015 \pm 0.004.
\end{aligned}$$

The analysis in principle allows a second solution for the strong phase differences, leading to a sign ambiguity in cos2β. This ambiguity has been resolved with the inclusion of S-wave $K\pi$ final states in the analysis. The interference between the S-wave and P-wave contributions gives additional terms in the decay rates with a clear dependence on the $K\pi$ mass due to the resonance shapes. The other solution for the strong phase differences can be excluded as leading to an unphysical dependence of the strong phase differences on the $K\pi$ mass [29]. Using the values from Eq. 2, and fixing sin2β to 0.731 [1], the fit to the $B^0 \to J/\psi K^{*0}(K^{*0} \to K^0_S\pi^0)$ sample gives cos2β = $+2.72^{+0.50}_{-0.79} \pm 0.27$. By comparing this result with the outcome of fits to 2000 data-sized Monte Carlo samples, the sign of $\cos 2\beta$ is determined to be positive at the 86% confidence level, in agreement with Standard Model expectations.

[1] This was the world average at the time - see Ref. [30].

IV. CONCLUSIONS.

When the *BABAR* measurement of sin2β using $b \to c\overline{c}s$ decays is combined with the most recent Belle result described in Ref. [31] then the world average value of sin2β from $b \to c\overline{c}s$ decays is sin2β = 0.674 ± 0.026. The combined constraint on β in the $\overline{\rho}$-$\overline{\eta}$ plane from the *BABAR* and Belle $b \to c\overline{c}s$ charmonium + K^0 meson analyses [11, 31], the $B^0 \to J/\psi K^*$ [28, 32], $B^0 \to D^{*0}h^0$ [22, 33] and $B^0 \to D^{*+}D^{*-}K^0_S$ [27] analyses strongly favour the solution β =21.1±1.0° where cos2β is positive [16].

Acknowledgments

The author wishes to thank the conference organizers for an enjoyable and well-organized workshop. This work is supported by the United Kingdom Particle Physics and Astronomy Research Council (PPARC) and the United State Department of Energy (DOE) under contract DE-AC02-76SF00515.

[1] N. Cabibbo, Phys. Rev. Lett. **10**, 531 (1963); M. Kobayashi and T. Maskawa, Prog. Th. Phys. **49**, 652 (1973).
[2] A.B. Carter and A.I. Sanda, Phys. Rev. D **23**, 1567 (1981); I.I. Bigi and A.I. Sanda, Nucl. Phys. B **193**, 85 (1981).
[3] *BABAR* Collaboration, B. Aubert *et al.*, Phys. Rev. Lett. **89**, 201802 (2002).
[4] Belle Collaboration, K. Abe *et al.*, Phys. Rev. D **66**, 071102 (2002).
[5] *BABAR* Collaboration, B. Aubert *et al.*, Nucl. Instrum. Methods Phys. Res., Sect. A **479**, 1 (2002).
[6] PEP-II Conceptual Design Report, SLAC-0418 (1993).
[7] *BABAR* Collaboration, B. Aubert *et al.*, Phys. Rev. D **66**, 032003 (2002).
[8] K.A. George (representing the *BABAR* Collaboration), arXiv:hep-ex/0610007 (2006).
[9] Charge-conjugate reactions are included implicitly unless otherwise specified.
[10] *BABAR* Collaboration, B. Aubert *et al.*, arXiv:hep-ex/0607081 (2006).
[11] *BABAR* Collaboration, B. Aubert *et al.*, arXiv:hep-ex/0607107 (2006).
[12] *BABAR* Collaboration, B. Aubert *et al.*, Phys. Rev. Lett. **94**, 161803 (2005).
[13] *BABAR* Collaboration, B. Aubert *et al.*, Phys. Rev. D **70**, 011101 (2004).
[14] W.-M. Yao *et al.*, Journal of Physics G, 33, (2006).
[15] Unless otherwise stated, all results are quoted with the first error being statistical and the second systematic.
[16] E. Barberio *et al.*, arXiv:hep-ex/0603003 and online update at `http://www.slac.stanford.edu/xorg/hfag.`
[17] See, for example, A. Ceccucci, Z. Ligeti, and Y. Sakai, in Ref. [14].
[18] M. Ciuchini, M. Pierini and L. Silvestrini, Phys. Rev. Lett. **95**, 221804 (2005).
[19] Belle Collaboration, S.U. Kataoka *et al.*, Phys. Rev. Lett. **93**, 261801 (2004); *BABAR* Collaboration, B. Aubert *et al.*, Phys. Rev. D **74**, 011101 (2006).
[20] H-n. Li, S. Mishima, arXiv:hep-ph/0610120 (2006).
[21] H. Boos, J. Reuter and T. Mannel, Phys. Rev. D **70**, 036006 (2004).
[22] *BABAR* Collaboration, B. Aubert *et al.*, arXiv:hep-ex/0607105 (2006).
[23] See talk and proceedings of A. Gaz from this workshop.
[24] T.E. Browder *et al.*, Phys. Rev. D **61**, 054009 (2000).
[25] S. Godfrey and N. Isgur, Phys. Rev. **D 32**, 189 (1985); S. Godfrey and R. Kokoski, Phys. Rev. **D 43**, 1679 (1991).
[26] J. Charles, A. Le Yaouanc, L. Oliver, O. Pene and J. C. Raynal, Phys. Lett. B **425**, 375 (1998); **433**, 441 (1998); P. Colangelo, F. De Fazio, G. Nardulli, N. Paver and Riazuddin, Phys. Rev. D **60**, 033002 (1999).
[27] *BABAR* Collaboration, B. Aubert *et al.*, arXiv:hep-ex/0608016 (2006).
[28] *BABAR* Collaboration, B. Aubert *et al.*, Phys. Rev. D **71** 032005 (2005).
[29] `http://ckm2005.ucsd.edu/WG/WG5/wed3/verderi-WG5-S2.pdf`
[30] S. Eidelman *et al.*, Phys. Lett. B **592**, (2004).
[31] Belle Collaboration, K.-F. Chen *et al.*, Phys. Rev. Lett. **98** 031802 (2007).

[32] Belle Collaboration, R. Itoh and Y. Onuki *et al.*, Phys. Rev. Lett. **95** 091601 (2005).
[33] Belle Collaboration, P. Krokovny *et al.*, Phys. Rev. Lett. **97** 081801 (2006).