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Abstract

Using the ARGUS detector at the e^+e^-storage ring DORIS II, we have determined the lepton and dilepton rates in $\Upsilon(4S)$ decays. From this measurement we derive the lifetime ratio of charged and neutral B mesons and obtain $\tau(B^+)/\tau(B^0)= 1.00^{+0.49}_{-0.32}$.

Weak decays of D and B mesons are described by decays of free c or b quarks in the simple spectator model. The lifetime ratio for charged and neutral D mesons has been measured to be 2.52 ± 0.09 [1] in contradiction with the value of 1.0 expected by this model. QCD corrections at the c-quark decay vertex lead to destructive interference in D^+ decays which brings the expected lifetime ratio very close to its observed value [2]. In the heavier B meson system, these QCD corrections have a much smaller influence; one expects $\tau(B^+)/\tau(B^0)$ to be unity within 10% [3].

Until now, direct measurements of $\tau(B^+)/\tau(B^0)$ have still very uncertain results. The average lifetime of b-flavoured hadrons is known to be $(1.18 \pm 0.11)ps$ [1] and the B^0 lifetime has been found to be $(1.20^{+0.52}_{-0.36}{}^{+0.16}_{-0.14})ps$ by MARK-II [4]. Neglecting the small influence of B_s mesons and b-flavoured baryons, these two results yield $\tau(B^+)/\tau(B^0)= 0.97^{+0.9}_{-0.6}$.

There are, however, indirect methods which give more information on $\tau(B^+)/\tau(B^0)$. Most of them rely on the assumption $\Gamma(B^+ \to l^+\nu X) = \Gamma(B^0 \to l^+\nu X)$ which is expected with very good precision even in QCD-corrected spectator models. In the K meson system, where $\tau(K^+)/\tau(K^0_S) = 139$, the semileptonic rates are experimentally equal within $\pm 1.5\%$. The equality of the semileptonic rates leads to

$$\tau(B^+)/\tau(B^0) = b_+/b_0 \, , \tag{1}$$

where b_+ and b_0 are the inclusive branching fractions $BR(B^+ \to l^+\nu X)$ and $BR(B^0 \to l^+\nu X)$, respectively.

In a previous ARGUS publication [5], we have determined f_+b_+/f_0b_0 by detecting coincidences between leptons and charmed mesons, where f_+ and f_0 are $BR(\Upsilon(4S) \to B^+B^-)$ and $BR(\Upsilon(4S) \to B^0\overline{B^0})$ respectively. As pointed out in this publication, the result depends on δ, the fraction of semileptonic B decays into final states different from $Dl\nu$ and $D^*(2010)l\nu$.

Because of this dependence it is very desirable to study an alternative method with different systematics. In this paper, we present the result of a method pioneered by CLEO [6] using lepton and di-lepton events in inclusive $\Upsilon(4S)$ decays [7]. The obtained result for b_+/b_0 is independent of δ and to a large extent also independent of f_+/f_0. The expected numbers of leptons and lepton pairs from $\Upsilon(4S)$ decays are:

$$\begin{aligned} N_l &= 2 \cdot (f_0b_0 + f_+b_+) \cdot N_{B\overline{B}} \, , \\ N_{ll} &= (f_0b_0^2 + f_+b_+^2) \cdot N_{B\overline{B}} \, , \end{aligned} \tag{2}$$

Since the semileptonic branching fractions b_0 and b_+ enter linearly into N_l and quadratically into N_{ll}, the ratio b_+/b_0 is given by:

$$\frac{b_+}{b_0} = \frac{f_0 - \alpha f_0^2}{\alpha f_0 f_+ \pm \sqrt{f_0 f_+(\alpha - 1)}} \, , \tag{3}$$

where the parameter α is defined by:

$$\alpha = \frac{f_0 b_0^2 + f_+ b_+^2}{(f_0 b_0 + f_+ b_+)^2} = 4N_{B\bar{B}} \cdot \frac{N_{ll}}{N_l^2} \,. \tag{4}$$

Assuming $N_{B\bar{B}} = N_{\Upsilon(4S)}$ we have $f_0 + f_+ = 1.0$. The relation between b_+/b_0 and α therefore depends on only one parameter f_0. Figures 1 and 2 show that this relation is very insensitive to f_0 values around 0.5 if α is close to unity and that $\alpha \geq 1.0$ for any b_+/b_0 and any f_0. The CLEO measurement of α [6] led to $0.43 \leq \tau(B^+)/\tau(B^0) \leq 2.3$ at 90% CL.

The ARGUS detector, its trigger requirements, and lepton identification capabilities have been described in detail in ref. [8]. The analyzed data sample corresponds to an integrated luminosity of $234/pb$ taken on the $\Upsilon(4S)$ and $92/pb$ in the continuum just below the $\Upsilon(4S)$ resonance. After continuum subtraction and acceptance correction we obtain $N_{\Upsilon(4S)} = 197600 \pm 2500 \pm 7900$.

Continuum and background events are suppressed by requiring a charged multiplicity $n_{ch} \geq 5$ and by rejecting events containing a track with momentum $p \geq 2.5$ GeV/c or an energy deposition in the shower counters $E \geq 3.5$ GeV. In the remaining events, leptons (e and μ) are counted for $|cos\theta| < 0.9$ and $p_l > 1.4$ GeV/c. Events with three or more lepton candidates above 1.4 GeV/c are rejected. These cuts supress most of the events with leptons originating from charmed meson decays. The lepton identification criteria are described in ref. [9]. The fake rates for these criteria have been determined to be (0.5 ± 0.2)% per track for electrons and (1.8 ± 0.5)% for muons. Electrons from photon conversion are suppressed by eliminating electron candidates which, when combined with an oppositely charged electron candidate, have an invariant mass of less than 100 MeV/c^2.

To remove lepton pairs from continuum and decay cascades, we require the opening angle between the leptons θ_{ll} to satisfy $-0.85 < \cos\theta_{ll} < 0.95$ and the invariant mass of e^+e^- and $\mu^+\mu^-$ pairs not to coincide with the mass of the J/ψ or the $\psi(2S)$ within ±150 or ±100 MeV/c^2, respectively. The obtained numbers of leptons and lepton pairs on the resonance and in the continuum are given in Table 1 together with the remaining background from misidentification and from secondary decays. The latter was obtained from a full-detector Monte Carlo simulation [10] using the modified spectator model following Wirbel et al. [2, 11].

A factorisation ansatz for the acceptances of leptons and dileptons into single lepton identification efficiencies and event acceptances η_l and η_{ll} leads to

$$\frac{N_{ll}}{N_l^2} = \frac{\eta_l^2}{\eta_{ll}} \cdot \frac{\tilde{N}_{ll}}{\tilde{N}_l^2} \tag{5}$$

where $\tilde{N}_l$ and $\tilde{N}_{ll}$ are the observed numbers of leptons and lepton pairs. The lepton identification efficiencies cancel in this ratio. The different event acceptances due to the charged multiplicity cut $n_{ch} \geq 5$ were determined by the Monte Carlo simulation and lead to $\eta_l^2/\eta_{ll} = 0.95 \pm 0.02$.

Assuming $N_{B\bar{B}} = N_{\Upsilon(4S)}$ and inserting the sum of electrons and muons from table 1 into eq. 4, we obtain

$$\alpha = 0.962 \pm 0.055 \pm 0.037 \tag{6}$$

where the first error is statistical and the second systematic. The systematic error is the quadratic sum of the uncertainties in the luminosity ratio (0.032), the fake rates of electrons (0.001) and muons (0.005), the secondary leptons (0.010), and the event acceptance ratio (0.015).

Using eq. 3 with f_0 between 0.4 and 0.6 and combining statistical and systematic errors quadratically, this result for α can be transformed into a likelihood function ($\mathcal{L}$) for b_+/b_0 which is shown in fig. 3. Defining errors by the decrease of $\mathcal{L}$ to $e^{-1/2}$ of its maximum value, we obtain

$$\frac{\tau(B^+)}{\tau(B^0)} = \frac{b_+}{b_0} = 1.00^{+0.49}_{-0.32}. \tag{7}$$

As in the previous ARGUS publication [5], using D-lepton coincidences, the result obtained here is well compatible with 1.0 but has not yet reached the wanted precision of around 10%.

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References

[1] Particle Data Group, Phys.Lett. **B 239** (1990) 1.

[2] M. Wirbel, B. Stech und M. Bauer, Z.Phys. **C29** (1985) 637.
M. Bauer, B. Stech und M. Wirbel, Z.Phys. **C34** (1987) 103.

[3] I.I. Bigi and B. Stech, in Proceedings of the Workshop on High Sensitivity Beauty Physics at Fermilab, Batavia, Illinois 1987, ed. by A.J. Slaughter, N. Lockyer and M. Schmidt, p. 239.

[4] S.R. Wagner et al. (MARK II-Collab.), Phys.Rev.Lett. **64** (1990) 1095.

[5] H. Albrecht et al. (ARGUS-Collab.), Phys.Lett. **B232** (1989) 554.

[6] M. Artuso et al. (CLEO-Collab.), Phys.Rev.Lett. **58** (1987) 183.
E. H. Thorndike and R. A. Poling, Phys.Rep. **157** (1988) 183.

[7] S. Schael (ARGUS-Collab.), Dr.rer.nat. Thesis,
Karlsruhe University, 1990, **IEKP-KA/90-1**

[8] H. Albrecht et al. (ARGUS-Collab.), Nucl. Instr. and Meth. **A275** (1989) 1.

[9] H. Albrecht et al. (ARGUS-Collab.), Phys.Lett. **B192** (1987) 245.

[10] H. Gennow, **DESY F15-85-02** (1985)

[11] T. Ruf, "Description of a B-Meson Decay Generator Program", **IEKP-KA/89-8**

		$e^\pm$	$\mu^\pm$
$\Upsilon(4S)$		20817	23694
background:	continuum (scaled)	7247	9143
	$b \to c \to l$	533	484
	$J/\psi \to l^+l^-$	252	213
	fakes	270	971
total background:		8302 ± 137	10811 ± 154
Signal		12515 ± 199	12883 ± 218

		ee	$\mu\mu$	$e\mu$
$\Upsilon(4S)$		222	255	494
background:	continuum (scaled)	25	17	22
	$b \to c \to l$	16	9	37
	$J/\psi \to l^+l^-$	7	6	20
	fakes	11	42	50
total background:		59 ± 9	74 ± 8	129 ± 10
Signal		163 ± 17	181 ± 18	365 ± 24
corrected for ll-cuts		197 ± 21	228 ± 23	405 ± 27

Table 1: Observed numbers, expected background, and derived signals for leptons and dileptons in the momentum interval $1.4 \leq p_l \leq 2.5\ GeV/c$. The quoted errors are statistical only.

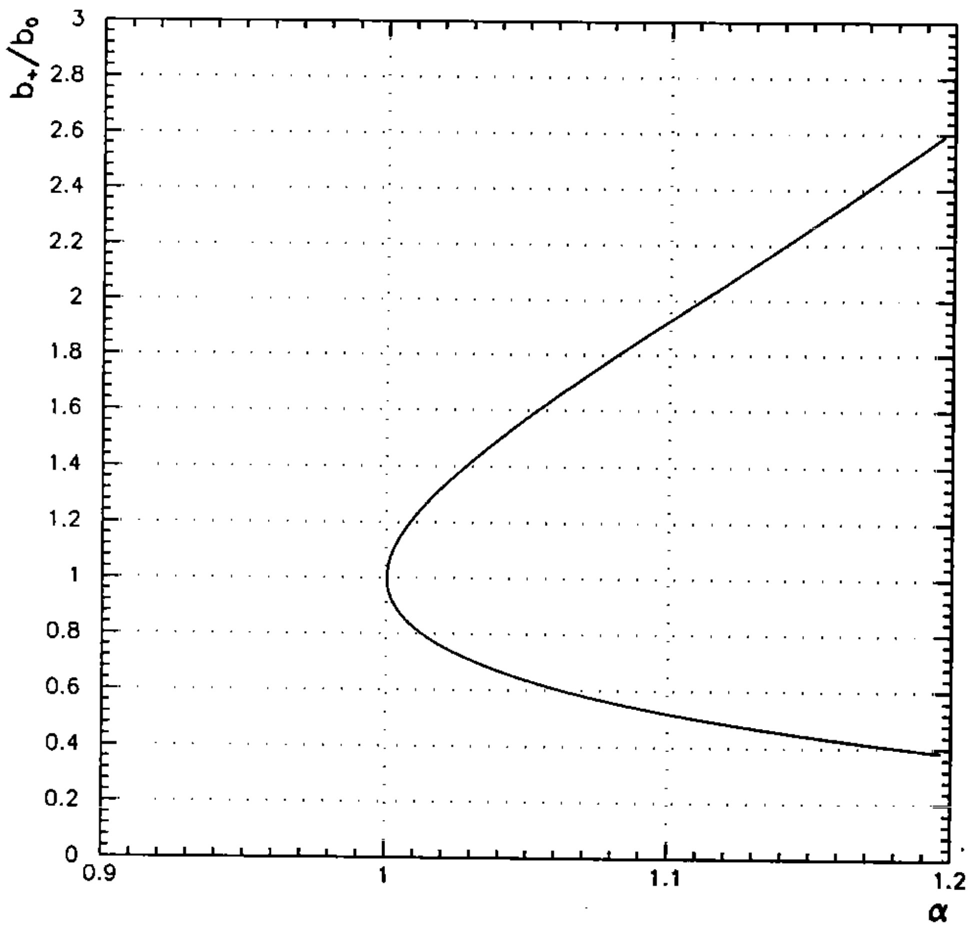

Figure 1: $\tau(B^+)/\tau(B^0)$ as a function of α taking $f_0 = 0.5$

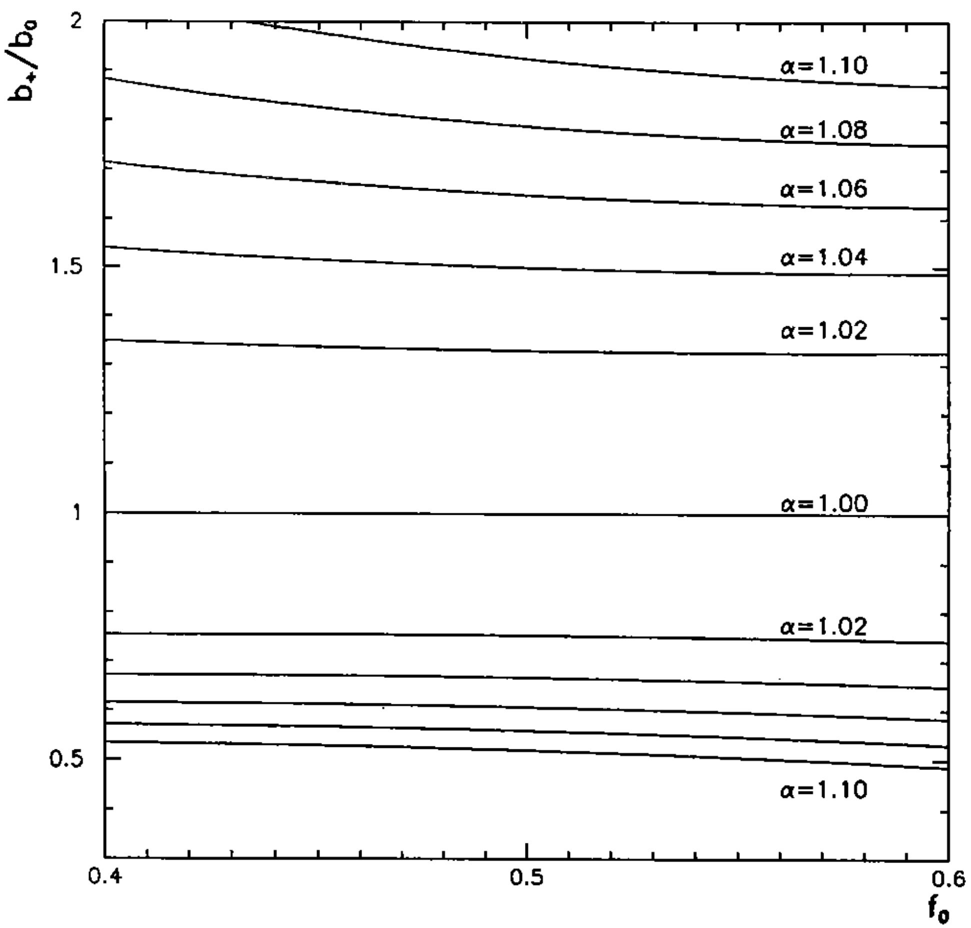

Figure 2: $\tau(B^+)/\tau(B^0)$ as a function of f_0 for different values of α

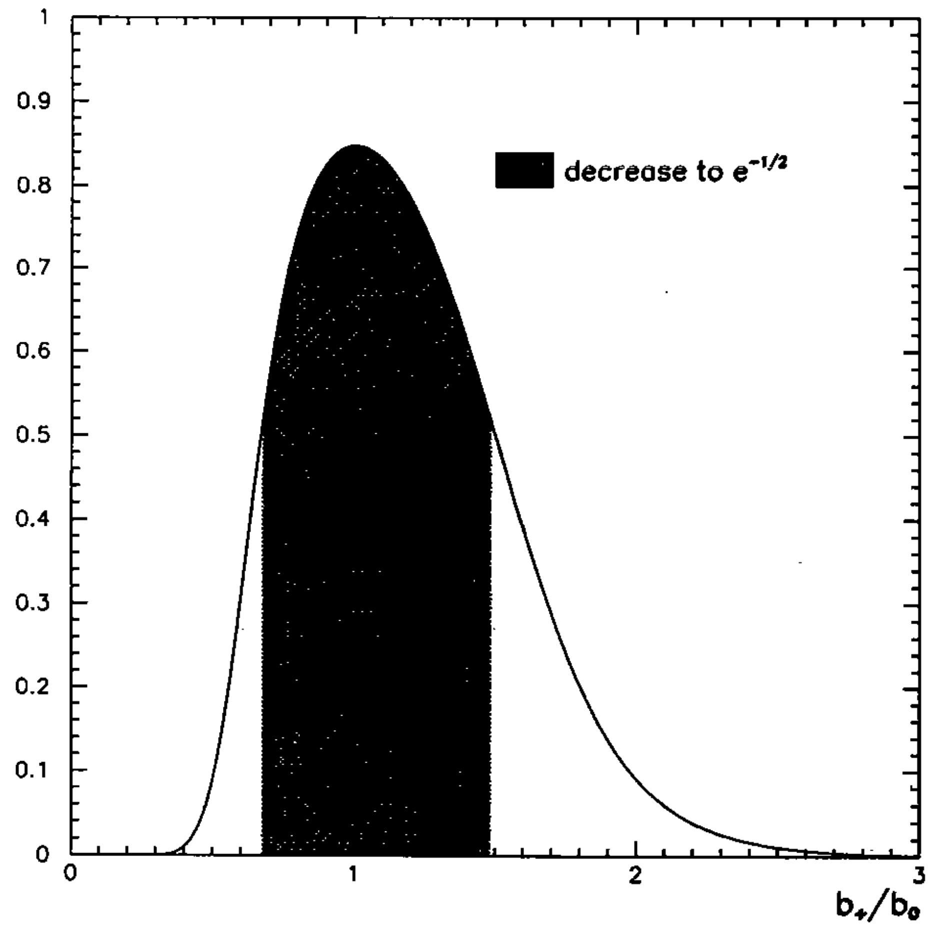

Figure 3: The likelihood function $\mathcal{L}(\tau(B^+)/\tau(B^0))$ obtained for $\alpha = 0.962 \pm 0.066$ and f_0 between 0.4 and 0.6.