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The ARGUS Collaboration

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Abstract

Using the ARGUS detector at the e^+e^- storage ring DORIS II at DESY, a study of $B^0\overline{B}^0$ oscillations has been performed using three different techniques. Besides the standard dilepton method, charge correlations between D^* mesons and one or two leptons have also been investigated. The mixing parameter r is determined to be $(20.6 \pm 7.0)\%$.

1 Introduction

Particle-antiparticle oscillations in the neutral B meson system probe the Standard Model at a mass scale which is presently out of reach by direct measurements. The strength of these oscillations is very sensitive to parameters of yet undiscovered particles, in particular the mass and weak couplings of the top quark. The first observation of $B^0\overline{B}^0$ mixing, reported by the ARGUS collaboration in 1987 [1], yielded an unexpectedly large mixing rate, with $r = \Gamma(B^0 \to \overline{B}^0)/\Gamma(B^0 \to B^0) = (21 \pm 8)\%$. This measurement provided indirect proof of the existence of the top quark and led to the conclusion that, within the standard electroweak theory, its mass had to be larger than about 50 GeV/c^2. Experimental searches for the top quark at the hadron colliders [2] and at LEP [3] have subsequently confirmed that mass is at least this large. Thus, lacking direct observation of the top quark, $B^0\overline{B}^0$ mixing provides the best available information about the Cabibbo-Kobayashi-Maskawa (CKM) matrix element $|V_{td}|$.

In our original publication $B^0\overline{B}^0$ oscillations were discovered by two methods using like sign dilepton events and coincidences between a fully reconstructed B meson and a lepton. Based on a data sample that has more than doubled the present paper presents an update of this first publication. In addition, a new technique for determining the mixing strength is also introduced. The analysis is performed with B mesons produced in 200000 $\Upsilon(4S)$ decays, corresponding to an integrated luminosity of 234 pb^{-1} at the $\Upsilon(4S)$ energy. For background determination, an additional 104 pb^{-1} of data is available from the continuum between 9.4 and 10.5 GeV. A detailed description of the ARGUS detector can be found in [4]. Charged particles are identified by measurement of the specific ionisation in the drift chamber (dE/dx) and the time of flight. For lepton identification, additional information from the electromagnetic calorimeter and the muon chamber system is used, and all measurements are combined into an overall likelihood ratio [5]. A lepton is deemed to be well-identified if this ratio exceeds 70% for either the electron or the muon hypothesis.

$B^0\overline{B}^0$ mixing on the $\Upsilon(4S)$ resonance manifests itself in the production of B^0B^0 or $\overline{B}^0\overline{B}^0$ mesons in the final state. Hence the observation of oscillations requires flavor identification of both B mesons at the time of their decay. Due to the low efficiency for complete reconstruction of $B\overline{B}$ events, the present methods for measuring the $B^0\overline{B}^0$ mixing rate are based on partial B^0 reconstruction [1], referred to as flavor tagging.

[1] Unless otherwise stated references in this paper to a specific charged state are to be interpreted as implying the charged-conjugate state as well.

2 $B^0\overline{B}^0$ Mixing in $\overline{B}^0 l^\pm$ Events

The first approach presented here uses events where both B mesons decay via semileptonic channels. One B meson is observed in the decay mode $\overline{B}^0 \to D^{*+} l^- \overline{\nu}$, while the other is flavor tagged using only the charge of the lepton. $\overline{B}^0$ reconstruction in the channel $D^{*+} l^- \overline{\nu}$ is performed by applying the recoil mass technique, a method which has been successfully used to measure the branching ratio and the D^{*+} polarization [6]. The technique relies on the fact that B mesons produced in the decay of the $\Upsilon(4S)$ resonance are nearly at rest. The neutrino, which is not seen in the detector, can be inferred if the mass squared of the system recoiling against the D^{*+} meson and the lepton is consistent with zero:

$$M_{rec}^2 = [E_{Beam} - (E_{D^*} + E_l)]^2 - [\vec{p}_{D^*} + \vec{p}_l]^2 . \quad (1)$$

Those $D^{*+} l^-$ combinations in the signal region $|M_{rec}^2| \leq 1.5$ GeV^2/c^4 are referred to as $\overline{B}^0$ mesons. Using an additional energetic lepton to tag the second B meson in the event, mixed and unmixed events are seen as $\overline{B}^0 l^-$ and $\overline{B}^0 l^+$ combinations respectively. The $B^0\overline{B}^0$ oscillation strength, expressed in terms of the mixing parameter r, is determined by the ratio

$$r = \frac{N_{\overline{B}^0 l^-}}{N_{\overline{B}^0 l^+}} . \quad (2)$$

Event selection is performed by requiring one well identified electron or muon in the event with momentum, p_l, greater than 1.4 GeV/c; due to contamination with leptons from $b \to c$ transitions, where the charmed hadron subsequently undergoes a semileptonic decay (cascade decays), flavor tagging with leptons only works at high momentum. For $\overline{B}^0$ reconstruction in these events, we find D^{*+} mesons in the decay chain $D^{*+} \to D^0\pi^+$, followed by $D^0 \to K^-\pi^+$, $K^-\pi^+\pi^-\pi^+$, $K^-\pi^+\pi^0$, or $K_S^0\pi^-\pi^+$. The D^0 decay products are required to lie within ± 80 MeV/c^2 of the nominal D^0 mass for the $K^-\pi^+$ and the $K^-\pi^+\pi^0$ channels and ± 50 MeV/c^2 for the other two channels, and are then subject to a mass-constraint fit. In order to reduce the e^+e^- continuum contribution, the scaled momentum, $x_p = p/p_{max}$, of the $D^0\pi^+$ candidate is required to be less than 0.5, which is the kinematic limit for charmed meson production in B decays on the $\Upsilon(4S)$. Semileptonic B^0 decays are then selected by examining the recoil mass spectrum obtained by combining the D^{*+} mesons with negatively-charged electrons or muons in the momentum region 1.0 to 2.4 GeV/c. The upper value is close to the kinematic limit for $b \to c$ transitions while the lower limit is chosen to reject much of the cascade background. Figure 1a shows the invariant $D^0\pi^+$ mass distribution for events containing two leptons.

For events satisfying these requirements, the recoil mass spectrum, $M_{rec}^2(D^{*+}l^-)$, shown in Figure 1b is obtained. The sample is divided into $\overline{B}^0 l^+$ (points with errors) and $\overline{B}^0 l^-$ (shaded histogram) combinations. In the signal region there are 10 mixed events and 33 unmixed events; an analogous procedure finds no events in our continuum data sample.

There are several sources of backgrounds in this selected data sample:

(a) Random or combinatorial D^{*+} candidates

(b) Contributions from higher mass charmed states (D^{**})

(c) $D^{*+} l^- l^\pm$ combinations where one or both leptons arise from a semileptonic D decay

(d) Misidentification of hadrons as leptons (fakes).

The contribution from the combinatorial background is determined from $D^0\pi^+$ candidates with masses above the D^{*+} signal. Secondary lepton backgrounds as well as the background from higher mass charmed states are studied using a Monte Carlo simulation. Fake lepton sources are evaluated from the hadron misidentification rate folded with the observed hadron momentum spectrum in events containing a D^{*+} and one well-identified lepton. The probability to misidentify a hadron as an electron or a muon has been determined using hadronic $\Upsilon(1S)$ decays as lepton free source. In addition, the fake rate per track has been studied with clean samples of pions from K_S^0 decays and kaons produced in the decay chain $D^{*+} \to D^0\pi^+$ followed by $D^0 \to K^-\pi^+$. Both methods yield consistent values for the misidentification rate of $(0.4 \pm 0.2)\%$ for electrons and $(1.4 \pm 0.4)\%$ for muons. From the total event rates listed in Table 1, a value for the mixing parameter:

$$r_{\overline{B}^0 l} = (23.1 \pm 11.8 \pm 3.4)\% \quad (3)$$

is derived, where the first error is statistical and the second systematic. This result, although statistically limited, does not suffer from assumptions concerning the production fraction and semileptonic branching ratios of charged and neutral B mesons.

3 Dilepton Analysis

The second method used to measure the $B^0 \leftrightarrow \overline{B}^0$ transition rate is based on tagging both B^0 mesons with fast leptons. In this case, mixing on the $\Upsilon(4S)$ resonance manifests itself through production of like-sign lepton pairs. The strength of $B^0\overline{B}^0$ oscillations is determined by the ratio of like-sign to opposite-sign lepton pairs produced in neutral B decays:

$$r = \frac{N_{l^+l^+} + N_{l^-l^-}}{N_{l^+l^-}} . \quad (4)$$

Events are selected which contain exactly two well-identified leptons with momenta between 1.4 and 2.4 GeV/c and polar angles in the range $|\cos\vartheta| \leq 0.9$ for electrons and $|\cos\vartheta| \leq 0.7$ for muons. The more restrictive selection for muons removes the endcap regions, which have a higher hadron misidentification rate. In order to suppress background contributions from QED and continuum processes, a cut on the charged multiplicity of $N_{ch} \geq 5$ and on the total multiplicity of $N_{tot} = N_{ch} + N_\gamma/2 \geq 7$ is applied. Converted photons are identified by their secondary vertex and by the requirement that the invariant mass of the e^+e^- pair be less than 100 MeV/c^2. Decays of the J/Ψ (Ψ') meson into e^+e^- are eliminated by demanding that the invariant mass of the e^+e^- combination lie more than 190 MeV/c^2 below or 150 MeV/c^2 above the J/Ψ (Ψ') mass, where the asymmetric cut accounts for the radiative tail. For the $J/\Psi(\Psi') \to \mu^+\mu^-$ mode, a symmetric mass region of ± 150 MeV/c^2 is eliminated. For uncorrelated production of the two leptons, as in the decays of two B mesons nearly at rest, the distribution of the opening angle ϑ_{ll} between the pair should be uniform.

Therefore, only candidates satisfying the requirement $-0.85 \leq \cos\vartheta_{ll} \leq 0.95$ are accepted, thereby reducing dilepton candidates from backgrounds such as jet-like continuum events. cascade decays from a single B meson or fake events.

The observed numbers of events fulfilling these conditions are summarized in Table 2. There are 105 candidates for mixing, i.e., events containing two leptons of the same charge. The majority of the background contained in the dilepton sample arises from $B\overline{B}$ events (charged and neutral), with either one primary semileptonic beauty decay and the other B meson producing secondary leptons in the decay chain $B \to XX_c \to l\nu X$, or the pairing of a primary lepton candidate with a misidentified hadron.

Cascade backgrounds produce lepton pairs with the same charge and thus contribute to the mixing signal. The observed single lepton spectrum in B decays [7] is used to make a quantitative determination of the contribution from this source. Opposite-sign dileptons, comprising one primary and one secondary lepton, arise either from mixed events or from the decay $\overline{B} \to l^-\overline{\nu}l^+\nu X$; the number of such events in the sample can be calculated from the known branching ratios and efficiencies. The absolute number of faked dilepton pairs is evaluated from the hadron momentum spectrum in events containing one well identified lepton. A small background arising from asymmetric photon conversion and from leptonic $J/\Psi(\Psi')$ decays, where only one track is seen in the detector, can be reliably estimated using a Monte Carlo simulation.

After subtraction of these backgrounds, which are strongly correlated for the three dilepton samples, there remains a total of $48.1 \pm 11.4 \pm 13.3$ like-sign and $505.1 \pm 25.4 \pm 17.1$ opposite-sign lepton pairs, where the first error is statistical and the second systematic. The latter mainly reflects the uncertainty in the determination of the cascade background resulting from fitting the inclusive lepton spectrum with different theoretical models [8].

In order to calculate the mixing parameter r from these rates the observed l^+l^- sample has to be corrected for contributions from B^+B^- decays. This is achieved by applying a correction factor $\lambda = (f_\pm/f_0)\cdot(\tau^\pm/\tau^0)^2$, where $f_\pm/f_0$ is the ratio of charged to neutral $B\overline{B}$ production on the $\Upsilon(4S)$ resonance and $\tau^\pm/\tau^0$ is the corresponding lifetime ratio. The number of l^+l^- events originating from $B^0\overline{B}^0$ decays is then given by:

$$N_{l^+l^-} \;=\; N^{obs}_{l^+l^-} - \frac{\lambda}{1+\lambda}(N^{obs}_{l^+l^-} + N^{obs}_{l^+l^+} + N^{obs}_{l^-l^-})\,. \qquad (5)$$

The fraction $f_\pm/f_0$ has not been experimentally determined; based on the small mass difference between charged and neutral B mesons [9] a conservative estimate [10] for $f_\pm/f_0$ is 1.0 ± 0.05. The lifetime ratio has been measured by ARGUS and CLEO [11], and the average result is $\tau_{B^\pm}/\tau_{B^0} = (0.95 \pm 0.14)(f_0/f_\pm)$. Using these values λ is found to be 0.90 ± 0.27.

From the combined electron and muon dilepton rates the mixing parameter is determined to be:

$$\langle r_{ll}\rangle \;=\; (19.8 \pm 5.2 \pm 6.7)\%, \qquad (6)$$

where the first error is statistical and the second systematic. The uncertainty on the correction factor λ is included in the systematic error.

The number of lepton pairs (N_{ll}) in combination with the number of leptons (N_l) from B decays can also be used to measure the lifetime ratio between charged and neutral B mesons [12]. From the measured value $4N_{\Upsilon(4S)}\cdot N_{ll}/N_l^2 \;=\; 0.962 \pm 0.055 \pm 0.037$ we obtain [13] a lifetime ratio

$$\frac{\tau(B^+)}{\tau(B^0)} \;=\; 1.00^{+0.49}_{-0.32}\,. \qquad (7)$$

4 D^*-Lepton Charge Correlations

A third method for measuring the $B^0\overline{B}^0$ mixing rate uses charged D^* mesons to identify the b quark content of one of the B mesons in the event. This approach relies on the dominance of exclusive D and D^* production through the spectator mechanism which predicts that only neutral B mesons produce charged D or D^* mesons. Thus, the reconstruction of D^{*+} mesons not only tags the B flavor but also allows a separation of charged and neutral B decays. Tagging the second B meson in the event with an energetic lepton, the mixing parameter r can be measured by the ratio of opposite-sign to like-sign $D^{*+}l$ combinations:

$$r = \frac{N_{D^{*+}l^-}}{N_{D^{*+}l^+}}. \qquad (8)$$

Restricting the recoil mass of the D^{*+}-lepton system to the region $M^2_{rec} \leq -2.0$ GeV^2/c^4 ensures that the two particles emerge from different B decays.

D^{*+} mesons are reconstructed in the decay $D^{*+} \to D^0\pi^+$ with subsequent decay $D^0 \to K^-\pi^+$. Electrons and muons are accepted with momenta in the interval from 1.0 to 2.4 GeV/c. The recoil mass distribution for the $D^{*+}l$ pairs selected by these conditions is shown in Figure 2. The opposite-sign spectrum contains a mixing signal in the search region indicated by the shaded portion of the histogram, along with a prominent contribution near zero recoil mass from semileptonic $\overline{B}^0$ decays. In the search region, 12 candidates for mixed events are observed and 33 for unmixed.

The background in these data samples can be attributed to the same sources as described in the first analysis and is determined in an analogous fashion. The rates, summarized in Table 3, lead to a value for the mixing parameter of:

$$r_{D^*l} \;=\; (19.4 \pm 14.8 \pm 4.3)\%. \qquad (9)$$

This result agrees, within large errors, with the determinations obtained by the other two methods.

Corrections to this result due to deviations from the assumed spectator decay mechanism affect both the mixed and the unmixed event samples. Possible contributions arise mainly from the production of D^{*+} mesons in the fragmentation of the $c\bar{s}$ system produced in the decay $W^+ \to c\bar{s}$, or through decay modes leading to higher-mass charmed mesons states. These contributions have been estimated [14] to be roughly equal for $D^{*+}l^-$ and $D^{*+}l^+$ combinations, and so cancel from the ratio in the mixing determination.

Due to strong correlations between the event sample of this analysis and the data sample of the first method, and also because of the uncertainties described above, we will not average the mixing parameter of Equation 8 with the results of the other methods.

5 Conclusions

Combining the results of the dilepton and the $\overline{B}^0 l$ methods and taking into account three mixed events and 13 unmixed events which are present in both data samples, a mixing rate of

$$\langle r \rangle = (20.6 \pm 7.0)\% \tag{10}$$

is derived, which is in excellent agreement with previous results [1], [15]. For comparison with experiments where both B^0 and B_S^0 mixing contributions are possible, the corresponding value for $\chi = r/(1+r)$ is:

$$\chi = (17.1 \pm 4.8)\%. \tag{11}$$

The parameter χ is linearly dependant on the correction factor λ (see Equation 5) and increases to 17.7% for $\lambda = 1$.

$B^0\overline{B}^0$ oscillations are expected to proceed via a second-order weak interaction process [16] involving the exchange of virtual top quarks. By this means, the mixing strength provides information about the the CKM element $|V_{td}|$, which is otherwise not currently available from other direct or indirect sources. The ratio, x, of the transition rate $\triangle M$ to the decay rate Γ is given by [17],

$$x = \frac{\triangle M}{\Gamma} = \frac{\tau_B G_F^2 m_B}{6\pi^2} B_B f_B^2 |V_{td} V_{tb}^*|^2 m_t^2 F(\frac{m_t^2}{M_W^2}) \eta_{QCD} \tag{12}$$

which is related to r by

$$r = \frac{x^2}{2+x^2} . \tag{13}$$

Our result for the mixing parameter r (Equation 10) translates into a value for x of

$$x = (0.72 \pm 0.15) . \tag{14}$$

In Equation 12 the B meson lifetime τ_B and mass m_B, as well as the function F and the QCD correction factor η_{QCD} are well known [18],[19],[20]. Within the three generation standard theory $|V_{tb}|$ is close to one. The largest uncertainty arises from the hadron structure contained in the B meson decay constant f_B and the bag parameter B_B. Neither quantity is known experimentally; in the vacuum insertion approximation $B_B = 1$ and theoretical estimates for f_B range between 100 and 300 MeV [21]. In this paper we choose as an example a value $\sqrt{B_B} f_B = (160 \pm 40) MeV$ [22]. The mass of the top quark determined from a fit to electroweak data is $m_t = (126 \pm 35)$ GeV/c^2 [23].

The extraction of $|V_{td}|$ from the measurement of $B^0\overline{B}^0$ mixing is thus restricted by lack of knowledge of the parameters $\sqrt{B_B} f_B$ and m_t; it is therefore convenient to embody both quantities into a scaling factor C:

$$C = \frac{(B_B f_B^2)}{(0.16\ GeV)^2} \frac{m_t^2}{(126\ GeV/c^2)^2} \frac{F(m_t^2/M_W^2)}{0.63} . \tag{15}$$

With this definition we obtain

$$|V_{td}| = (0.0123 \pm 0.0014) \frac{1}{C} , \tag{16}$$

where the error reflects just the experimental precision of the mixing measurement. Figure 3 shows the relation between the measured mixing strength x (solid line), together with 1σ error contours (dashed lines), and $|V_{td}|$ for three different values of the parameter C. Further progress in the determination of $|V_{td}|$ strongly depends on a better knowledge of the top quark mass and the B meson decay constant; a measurement of f_B can be expected from experiments at a future B factory.

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References

[1] H.Albrecht et al., (ARGUS Collaboration), Phys.Lett. **B 192** (1987), 245.
A superposition of $B^0\overline{B}^0$ and $B_s^0\overline{B}_s^0$ mixing has been reported at the same time by C.Albajar et al., (UA1 Collaboration), Phys.Lett. **B 186** (1987), 247.

[2] C.Albajar et al., (UA1 Collaboration), Z.Phys. **C48** (1990), 1.
T.Akesson et al., (UA2 Collaboration), Z.Phys. **C46** (1990), 179.
F.Abe et al., (CDF Collaboration), Phys.Rev.Lett. **64** (1990), 142.

[3] M.Akwary et al., (OPAL Collaboration), Phys.Lett. **B 236** (1990), 364;
D.Decamp et al., (ALEPH Collaboration), Phys.Lett. **B 236** (1990), 511.

[4] H.Albrecht et al.,(ARGUS Collaboration), Nucl. Instr. and Meth. **A 275** (1989), 1.

[5] S.Weseler, (ARGUS Collaboration), Ph.D.Thesis, University of Heidelberg, 1986, IHEP-HD/86-2.

[6] H.Albrecht et al., (ARGUS Collaboration), Phys.Lett. **B 197** (1987), 452.
H.Albrecht et al., (ARGUS Collaboration), Phys.Lett. **B 219** (1989), 121.

[7] H.Albrecht et al., (ARGUS Collaboration), Phys.Lett. **B 249** (1990), 359.

[8] G.Altarelli, N.Cabibbo, G.Corbo, L.Maiani, G.Martinelli, Nucl.Phys. **B 208** (1982), 365.
M.Wirbel, B.Stech, M.Bauer, Z.Phys. **C 29** (1985), 637.

[9] H.Albrecht et al., (ARGUS Collaboration), Z.Phys. **C48** (1990), 543.

[10] G.P.Lepage, Cornell Preprint, CLNS 90/1007.

[11] H.Albrecht et al., (ARGUS Collaboration), Phys.Lett. **B 232** (1989), 554.
M.Danilov, (ARGUS Collaboration), reported at the LP-EPS Conf. Geneva 1991.
K.Berkelman and S.Stone, (CLEO Collaboration), Cornell preprint CLNS 91-1044 (1991).
R.Fulton et al., (CLEO Collaboration), Phys.Rev. **D43** (1991) 651.

[12] A.Bean et al., (CLEO Collaboration), Phys.Rev.Lett. **58** (1987) 183.
E.H.Thorndike and R.A.Poling, Phys.Rep. **157** (1988) 183.

[13] S.Schael, (ARGUS Collaboration), Ph.D.Thesis, University of Karlsruhe, 1990, IEKP-KA/90-1.
H.Albrecht et al., (ARGUS Collaboration), DESY preprint 91-056 (1991).

[14] M.Schäfer, (ARGUS Collaboration), Ph.D.Thesis, University of Hamburg, 1990, DESY F15-91-02.

[15] M.Artuso et al., (CLEO Collaboration), Phys.Rev.Lett. **62** (1989), 2233.

[16] M.K.Gaillard and B.W.Lee, Phys.Rev. **D10** (1974), 897.

[17] J.S.Hagelin, Nucl.Phys. **B 193** (1981), 123.

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

[19] M.Vysotsky, Sov.J.Nucl.Phys., **31** (1980), 797.
T.Inami, C.S.Kim, Progr.Theor.Phys. **65** (1981), 297.

[20] A.J.Buras, W.Slominski, H.Steger, Nucl.Phys. **B 245** (1984), 369.

[21] G.Martinelli,XXVIth Rencontre de Moriond, Les Arcs, Savoie, France, 1991, and references therein.

[22] G.Altarelli,*Phenomenology of $M - \overline{M}$ Mixing*, Int. Symposium on Heavy Quark Physics, Cornell University, Ithaca NY, 1989, and private communication.

[23] H.Burkhardt and J.Steinberger, CERN-PPE/91-50, March 1991.

Figure Captions

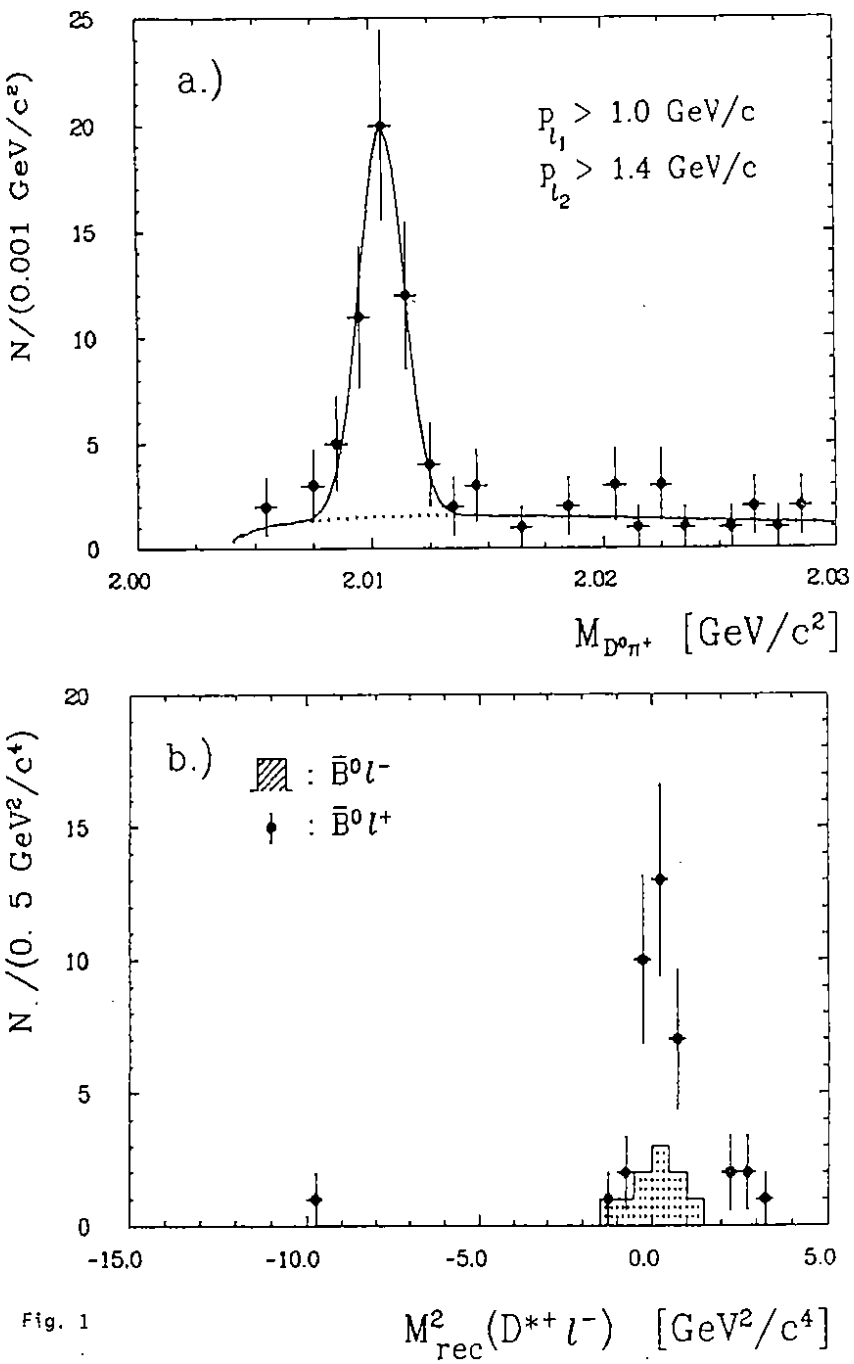
Figure 1.

(a) Invariant $D^0\pi^+$ mass in events containing two energetic leptons.

(b) Recoil mass spectrum for $D^{*+}l^-$ combinations in events with an additional lepton of $p_l > 1.4$ GeV/c.

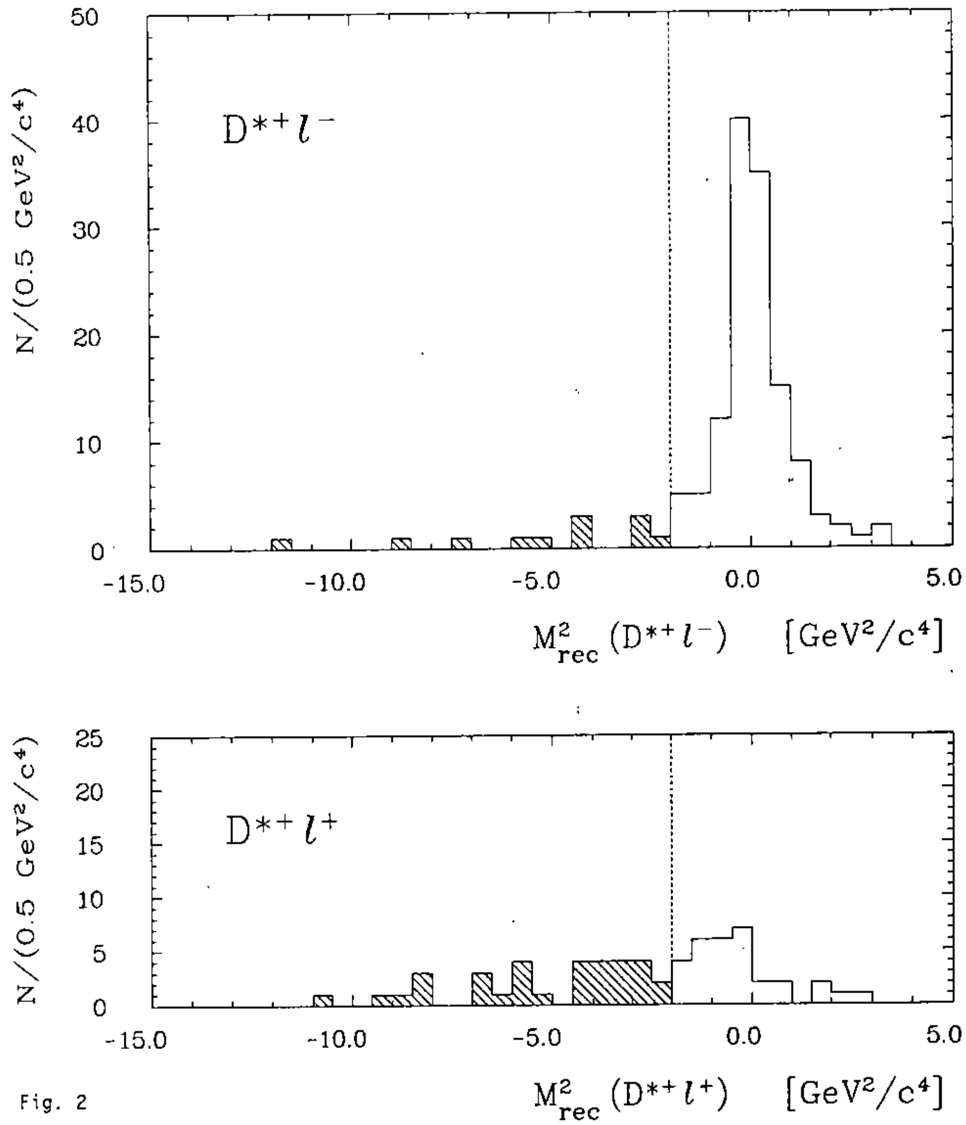
Figure 2. Recoil mass spectrum for $D^{*+}l^-$ (top) and $D^{*+}l^+$ (bottom) combinations.

Figure 3. Relation between the CKM element $|V_{td}|$ and the measured mixing parameter x together with the 1σ errors (dashed lines) for three values of the scaling factor C as defined in equation 15.



a.)
$p_{l_1} > 1.0$ GeV/c
$p_{l_2} > 1.4$ GeV/c
N/(0.001 GeV/c²)
$M_{D^0\pi^+}$ [GeV/c²]
b.)
: $\bar{B}^0 l^-$
: $\bar{B}^0 l^+$
N /(0. 5 GeV²/c⁴)
$M^2_{rec}(D^{*+} l^-)$ [GeV²/c⁴]

Fig. 1



$D^{*+} l^-$
N/(0.5 GeV²/c⁴)
$M^2_{rec}(D^{*+} l^-)$ [GeV²/c⁴]
$D^{*+} l^+$
N/(0.5 GeV²/c⁴)
$M^2_{rec}(D^{*+} l^+)$ [GeV²/c⁴]

Fig. 2

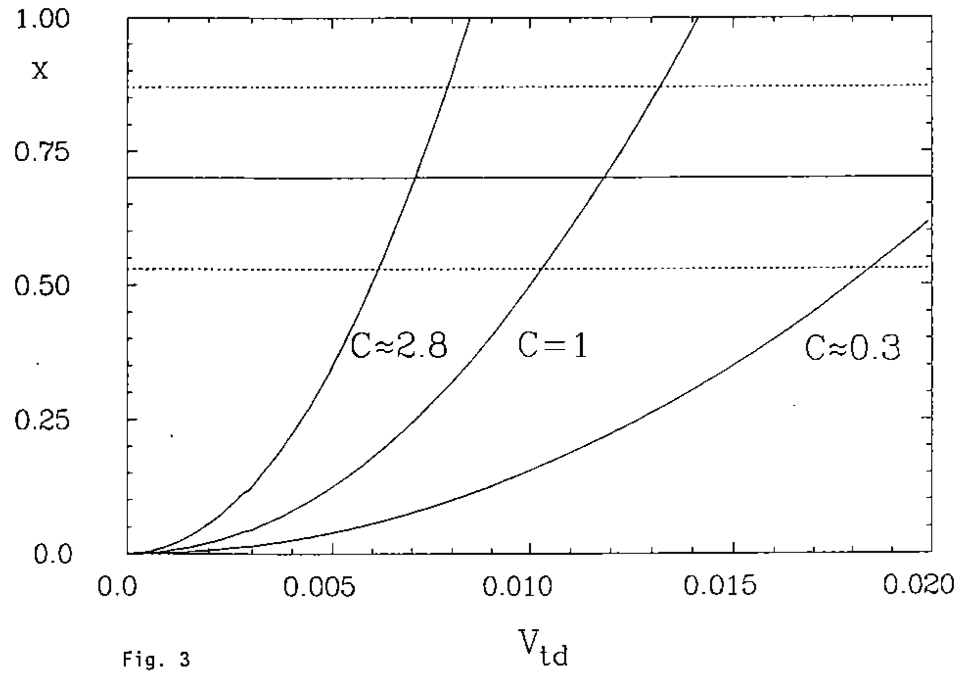


Fig. 3

	$\overline{B}^0 l^-$	$\overline{B}^0 l^+$
$\Upsilon(4S)$	10	33
Background		
D^* combinatorics, D^{**} contribution	1.9 ± 0.9	3.3 ± 1.3
Cascade decays	0.76 ± 0.3	0.15 ± 0.04
Fakes	0.6 ± 0.15	0.5 ± 0.15
Signal:	$6.7 \pm 3.2 \pm 1.0$	$29.1 \pm 5.7 \pm 1.3$

Table 1: Observed $\overline{B}^0 l^{\pm}$ rates.

Like-sign Dileptons	$e^\pm e^\pm$	$\mu^\pm \mu^\pm$	$e^\pm \mu^\pm$
$\Upsilon(4S)$	27	24	54
Continuum	-	2	2
$\Upsilon(4S)$ direct	27 ± 5.7	19.7 ± 5.8	49.7 ± 8.0
Background			
Fakes	2.1 ± 1.0	5.0 ± 1.5	7.9 ± 2.1
Cascade decays	8.7 ± 3.9	4.8 ± 2.2	14.2 ± 6.3
J/ψ decays	1.2 ± 0.3	1.1 ± 0.3	2.3 ± 0.5
γ_c conversion	0.6 ± 0.2		0.6 ± 0.2
Mixing signal :	$14.4 \pm 5.7 \pm 4.0$	$8.9 \pm 5.8 \pm 2.7$	$24.8 \pm 8.0 \pm 6.7$
Opposite-sign Dileptons	$e^+ e^-$	$\mu^+ \mu^-$	$e^\pm \mu^\mp$
$\Upsilon(4S)$	147	114	271
Continuum	6	4	4
J/ψ correction	$27.0 \pm 5.6 \pm 5.0$	$22.7 \pm 5.2 \pm 5.7$	
$\Upsilon(4S)$ direct	$161.0 \pm 14.2 \pm 5.0$	$128.1 \pm 12.5 \pm 5.7$	262.4 ± 17.0
Background			
Fakes	4.3 ± 2.1	10.9 ± 3.3	16.2 ± 4.4
Cascade decays	3.0 ± 1.4	1.9 ± 0.9	4.4 ± 2.0
J/ψ decays	1.2 ± 0.3	1.1 ± 0.3	2.3 ± 0.5
γ_c conversion	0.6 ± 0.2		0.6 ± 0.2
Signal:	$152.0 \pm 14.2 \pm 5.6$	$114.2 \pm 12.5 \pm 6.6$	$238.9 \pm 17.0 \pm 4.9$

Table 2: Observed dilepton rates.

	$D^{*+}l^-$	$D^{*+}l^+$
$\Upsilon(4S)$	12	33
Continuum	1	1
$\Upsilon(4S)$ direct	9.94	30.94
Background		
D^*-combinatorics	1.1 ± 0.4	1.6 ± 0.9
Cascade decays	2.9 ± 1.1	0.6 ± 0.2
Fakes	0.4 ± 0.2	0.6 ± 0.2
Signal:	$5.5 \pm 4.0 \pm 1.2$	$28.2 \pm 6.1 \pm 0.9$

Table 3: Observed $D^{*+}l^-$ rates.