RECONSTRUCTION OF B MESONS

ARGUS Collaboration

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0370-2693/87/$ 03.50 © Elsevier Science Publishers B.V.
(North-Holland Physics Publishing Division)

Received 30 October 1986

B mesons have been reconstructed in five decay channels of the type $B\to D^{*\pm}n\pi$ ($n=1,2,3$) using data accumulated by the ARGUS experiment at the e^+e^- storage ring DORIS II at DESY. In total, we find 40 neutral B mesons above a background of 15 ± 6 events with a mass of $(5278.2\pm1.0\pm3.0)$ MeV/c^2 and 32 charged B mesons above a background of 17 ± 6 events with a mass of $(5275.8\pm1.3\pm3.0)$ MeV/c^2. The decays $\bar{B}^0\to D^{*+}\pi^-\pi^0$, $\bar{B}^0\to D^{*+}\pi^-\pi^-\pi^+$, and $B^-\to D^{*+}\pi^-\pi^-\pi^0$ have been observed for the first time. We find substantially smaller branching ratios for the decay modes $\bar{B}^0\to D^{*+}\pi^-$ and $B^-\to D^{*+}\pi^-\pi^-$ than previously published by the CLEO collaboration.

The reconstruction of exclusive hadronic decays of B mesons is an important step toward understanding the properties of b quarks. Scaling from charm decay widths [1] leads to the expectation that hadronic ratios for the B are quite small. Recent calculations [2] confirm this picture in detail. On the other hand, first experimental indications yielded rather larger values. By reconstructing B hadronic decays involving a D^{*+} and therefore with minimal combinatorial background, we find branching ratios more in line with theoretical expectation than with previously published values [3].

The results reported here are based on data taken with the ARGUS detector at the e^+e^- storage ring DORIS II at DESY. A total luminosity of 59/pb has been collected at a centre-of-mass energy corresponding to the mass of the $\Upsilon(4S)$. The data contain about 50 000 decays of the $\Upsilon(4S)$.

Since b quarks decay mainly into c quarks, B mesons will decay predominantly into final states containing charmed mesons. The reconstruction of the decay $B\to D^{*+}n\pi$ is especially favourable since kinematical constraints can be used to efficiently suppress the combinatorial background arising from high decay multiplicities. Specifically, the following channels[‡1] have been studied:

$$\bar{B}^0\to D^{*+}\pi^-,$$

$$\bar{B}^0\to D^{*+}\pi^-\pi^0,$$

$$\bar{B}^0\to D^{*+}\pi^-\pi^-\pi^+,$$

$$B^-\to D^{*+}\pi^-\pi^-,$$

$$B^-\to D^{*+}\pi^-\pi^-\pi^0.$$

The D^{*+} is detected via its decay into $D^0\pi^+$, where the D^0 is reconstructed in the channels

$$D^0\to K^-\pi^+,$$

$$D^0\to K^0_s\pi^+\pi^-,$$

$$D^0\to K^-\pi^+\pi^0,$$

$$D^0\to K^-\pi^+\pi^+\pi^-,$$

Thus five B decay channels have been investigated, comprising, with the four D^0 decay modes, a total of 20 decay chains. Up to 9 reconstructed tracks are combined in order to form a B meson candidate.

Charged pions and kaons are required to point to the reconstructed interaction point (to the K^0 decay vertex in the decay $K^0_s\to\pi^+\pi^-$) with $\chi^2<36$. Particle identification is made on the basis of specific ionisation in the drift chamber and of time of flight [4]. For the reconstruction of π^0's, we combine two photons with an energy of at least 40 MeV each [5]. To improve the resolution on the mass of the B mesons

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[2] Supported by the Minerva Stiftung.
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[10] Supported by Raziskovalna skupnast Slovenije, the Internationales Büro KfA, Jülich and DESY, Hamburg.
[11] Supported by the Swedish Research Council.
[12] Supported by the US Department of Energy, under contract DE-AS09-80ER 10690.

[‡1] References in this paper to a specific charged state are to be interpreted as implying the charge-conjugate state also.

we perform mass constraint fits to the intermediate states, i.e., D^{*+}, D^0, K^0_s, and π^0.

In the search for B candidates, two principal cuts are used:

(1) We require the probability for the sum of all χ^2 contributions from particle identification and from kinematical fits to exceed 1%.

(2) We perform an energy constraint fit for those B candidates for which $|E(\mathrm{B})-E(\mathrm{Beam})|<3\sigma$, exploiting the fact that the B must have the energy of the beam.

Through particle identification and good mass resolution for short-lived intermediate states, particularly for the D^{*+}–D^0 mass difference, a sharp reduction in combinatorial background can be achieved. The probability cut on total χ^2 is a means of using this detector information in a coherent and efficient fashion. The energy constraint fit translates good momentum resolution for the B candidate into good mass resolution, without biasing the background distribution. The mass scale after this fit is strongly correlated with the energy scale of the DORIS beams.

Combinations passing these cuts and, in addition, fulfilling the condition that their mass lies in the allowed region between 1/2 the mass of the $\Upsilon(3S)$ and 1/2 the mass of the $\Upsilon(4S)$ are considered to be B meson candidates. There are events containing more than one candidate. The number, compared to all selected events, depends strongly on the decay chain and can be as large as 40%. There are two reasons for the occurrence of multiple candidates, both of which arise from the fact that the number of reconstructed tracks forming a B meson candidate is very large:

(1) Two B candidates consist of the same contributing stable particles. Two of these particles, however, exchange their position in the decay chain.

(2) Combinatorial background.

The first contribution tends to artificially enhance the signal in the B mass spectrum, whereas the second contribution increases the background. Only one candidate is accepted per event and per decay chain. This is achieved by choosing the candidate with the largest probability calculated for the sum of all χ^2 contributions from particle identification, kinematical fits, and the beam energy constraint. This procedure does not bias the mass distribution of the combinatorial background.

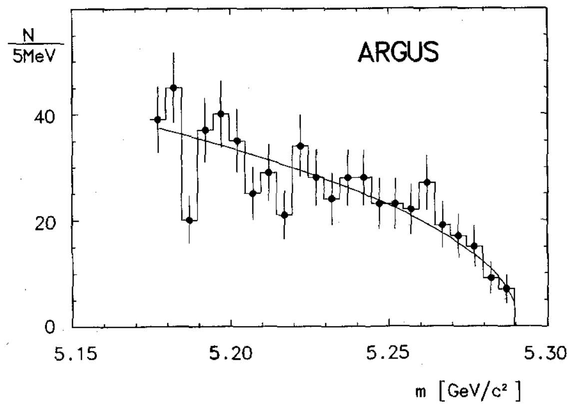

Fig. 1. Mass distribution of background candidates obtained by event mixing.

The shape of the combinatorial background is determined from event mixing (fig. 1), from wrong charge combinations, and from data taken in the continuum below the $\Upsilon(4S)$. It can be described by the form

$$\mathrm{d}N/\mathrm{d}M \sim M\sqrt{1-M^2/E^2_{\mathrm{beam}}},$$

which is derived by assuming that the background is uniformly distributed in phase space.

The mass spectrum for candidates satisfying the requirements described above is shown in fig. 2. From a fit of a gaussian above the background we observe a signal of 71 events at a mass of (5277.1 ± 0.8) MeV/c^2 with a width, consistent with expectation, of $\sigma=(4.5\pm1.0)$ MeV/c^2. The mass values are obtained

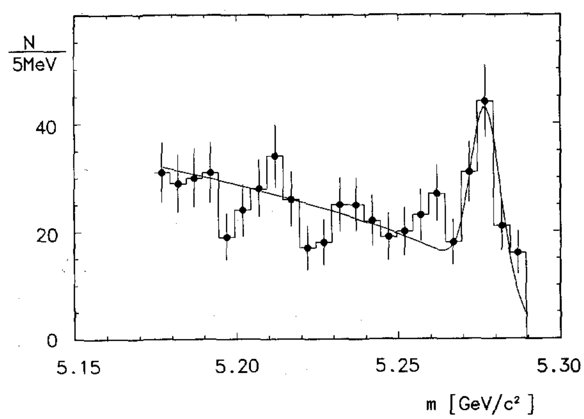

Fig. 2. Mass distribution of B meson candidates.

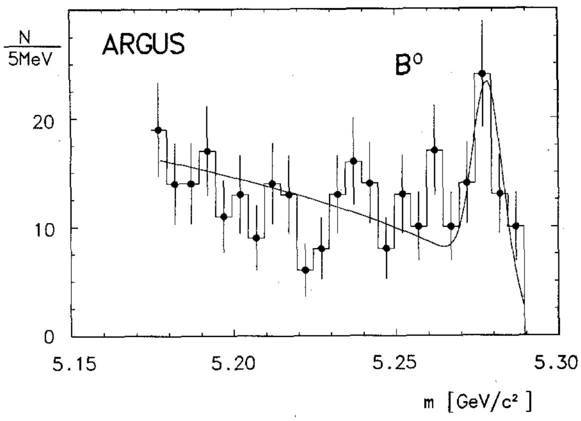

Fig. 3. Mass distribution of B^0 candidates.

by using an energy scale which is set by fixing the mass of the $\Upsilon(4S)$ to 10 577 MeV/c^2 [6]. A separate fit to the background was performed, excluding the signal region. Extending the result of this fit, the background in a $\pm 1.5\sigma$ region around the signal is determined to be 32 ± 8 events. Thus, the excess of events in the signal region represents an 8σ deviation from the average background level.

The sample can be divided into neutral and charged B mesons (figs. 3 and 4). From separate fits to these distributions, we find 40 B^0 mesons above a background of 15 ± 6 with a mass of $(5278.2 \pm 1.0 \pm 3.0)$ MeV/c^2 and 32 B^- mesons above a background of 17 ± 6 with a mass of $(5275.8 \pm 1.3 \pm 3.0)$ MeV/c^2.

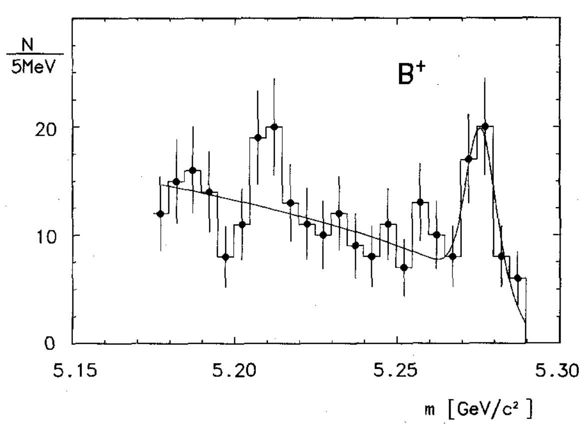

Fig. 4. Mass distribution of $B^{\pm}$ candidates.

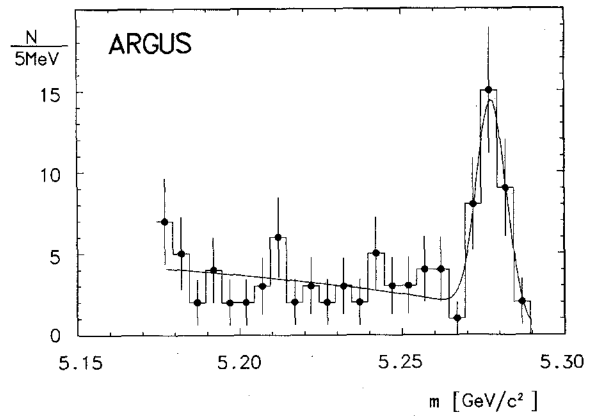

Fig. 5. Mass distribution of B candidates for those decay chains with less than 20 events containing B candidates. Specifically, the following 6 out of the 20 decay chains were discarded: $B^{-/0} \to D^{*+}\pi^-\pi^-\pi^{0/+}$, $D^{*+} \to D^0\pi^+$, $D^0 \to K^-\pi^+\pi^+\pi^-$ $B^{-/0} \to D^{*+}\pi^-\pi^-\pi^{0/+}$, $D^{*+} \to D^0\pi^+$, $D^0 \to K^-\pi^+\pi^0$ $B^{-/0} \to D^{*+}\pi^-\pi^{-/0}$, $D^{*+} \to D^0\pi^+$, $D^0 \to K^-\pi^+\pi^0$.

The mass difference between neutral and charged B mesons is found to be $(2.4 \pm 1.6 \pm 1.0)$ MeV/c^2.

If we select only decay chains with a small combinatorial background we find a clean B meson sample of 29 events (fig. 5). Since the $\Upsilon(4S)$ decay into $B\bar{B}$ pairs, the reconstruction of one B tags the other as a $\bar{B}$. This will allow more direct access to general decay properties of the B relating to Kobayashi–Maskawa matrix elements or B–$\bar{B}$ mixing. Our sample, while still small, is a start in this direction.

In order to determine branching ratios, we assume that 55% of $\Upsilon(4S)$ mesons decay into B^+B^- pairs and 45% into $B^0\bar{B}^0$ pairs. For the branching ratio of the decay $D^{*+} \to D^0\pi^+$ and the branching ratios of the D^0 decay channels are taken from ref. [6]. Their number of events observed in the five decay channels and the corresponding branching ratios are given in table 1. Where comparable, our result for the branching ratios are in good agreement with recent theoretical predictions [2].

A comparison of our results for the decays $\bar{B}^0 \to D^{*+}\pi^-$ and $B^- \to D^{*+}\pi^-\pi^-$ with those previously published [3], shows strong disagreement. The decay rates found by us for these channels are about an order of magnitude smaller than the corresponding CLEO results, where a factor of 2 can be explained as a consequence of recent changes in D^0 branching ratios. Specifically, if one considers only those decay

Table 1

Decay channel	Signal (events)	Background (events)	Branching ratio (%)
$\bar{B}^0 \to D^{*+}\pi^-$	5	1 ± 1	$(0.27\pm0.14\pm0.10)$
$\bar{B}^0 \to D^{*+}\pi^-\pi^0$	8	4 ± 3	$(1.5\pm0.8\pm0.8)$
$\bar{B}^0 \to D^{*+}\pi^-\pi^-\pi^+$	27	12 ± 5	$(3.3\pm0.9\pm1.6)$
$B^- \to D^{*+}\pi^-\pi^-$	7	3 ± 2	$(0.5\pm0.2\pm0.3)$
$B^- \to D^{*+}\pi^-\pi^-\pi^0$	24	13 ± 5	$(4.3\pm1.3\pm2.6)$

chains analysed by both groups, CLEO found 11 events while ARGUS finds one event despite the fact that, for the two groups, the integrated luminosities (40 pb^{-1} and 59 pb^{-1} respectively) and acceptances are similar.

We have confirmed two of the results presented above by independent analyses. First, the decay $\bar{B}^0 \to D^{*+}\pi^-$ has been studied using a complementary partial-reconstruction technique [7]. The branching ratio was determined to be $(0.35\pm0.20\pm0.20)\%$, in good agreement with the value reported here. Second, the B^0 mass has been measured in the decay mode $B^0 \to \psi K^-\pi^+$ using a similar analysis technique [8]. The result, $m(B^0) = (5277\pm3\pm3)$ MeV/c^2, is entirely consistent with the value given here.

To conclude, we have reconstructed B mesons in the decays $B \to D^{*+} n\pi$ ($n=1,2,3$) and have determined new values for the B masses and branching ratios.

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