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A Search for the Decay $B^+ \to \overline{D}^0 K^+$

CLEO Collaboration

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Abstract

Using 3.3×10^6 charged B mesons collected with the CLEO detector at CESR, we have searched for the Cabbibo-suppressed decay $B^+ \to \overline{D}^0 K^+$. We find no evidence for signal and set the 90% confidence level upper limit $\mathcal{B}(B^+ \to \overline{D}^0 K^+) < 4.4 \times 10^{-4}$.

J. P. Alexander,[1] C. Bebek,[1] B. E. Berger,[1] K. Berkelman,[1] K. Bloom,[1] D. G. Cassel,[1] H. A. Cho,[1] D. M. Coffman,[1] D. S. Crowcroft,[1] M. Dickson,[1] P. S. Drell,[1] R. Ehrlich,[1] R. Elia,[1] A. D. Foland,[1] P. Gaidarev,[1] B. Gittelman,[1] S. W. Gray,[1] D. L. Hartill,[1] B. K. Heltsley,[1] P. I. Hopman,[1] S. L. Jones,[1] J. Kandaswamy,[1] N. Katayama,[1] P. C. Kim,[1] D. L. Kreinick,[1] T. Lee,[1] Y. Liu,[1] G. S. Ludwig,[1] J. Masui,[1] J. Mevissen,[1] N. B. Mistry,[1] C. R. Ng,[1] E. Nordberg,[1] M. Ogg,[1,*] J. R. Patterson,[1] D. Peterson,[1] D. Riley,[1] A. Soffer,[1] C. Ward,[1] P. Avery,[2] M. Athanas,[2] C. D. Jones,[2] M. Lohner,[2] C. Prescott,[2] S. Yang,[2] J. Yelton,[2] J. Zheng,[2] G. Brandenburg,[3] R. A. Briere,[3] D. Y.-J. Kim,[3] T. Liu,[3] M. Saulnier,[3] R. Wilson,[3] H. Yamamoto,[3] T. E. Browder,[4] F. Li,[4] Y. Li,[4] J. L. Rodriguez,[4] T. Bergfeld,[5] B. I. Eisenstein,[5] J. Ernst,[5] G. E. Gladding,[5] G. D. Gollin,[5] E. Johnson,[5] I. Karliner,[5] M. Palmer,[5] M. Selen,[5] J. J. Thaler,[5] K. W. Edwards,[6] A. Bellerive,[7] D. I. Britton,[7] R. Janicek,[7] D. B. MacFarlane,[7] K. W. McLean,[7] P. M. Patel,[7] A. J. Sadoff,[8] R. Ammar,[9] P. Baringer,[9] A. Bean,[9] D. Besson,[9] D. Coppage,[9] C. Darling,[9] R. Davis,[9] N. Hancock,[9] S. Kotov,[9] I. Kravchenko,[9] N. Kwak,[9] S. Anderson,[10] Y. Kubota,[10] M. Lattery,[10] J. J. O'Neill,[10] S. Patton,[10] R. Poling,[10] T. Riehle,[10] A. Smith,[10] V. Savinov,[10] M. S. Alam,[11] S. B. Athar,[11] Z. Ling,[11] A. H. Mahmood,[11] H. Severini,[11] S. Timm,[11] F. Wappler,[11] A. Anastassov,[12] S. Blinov,[12,†] J. E. Duboscq,[12] R. Fulton,[12] D. Fujino,[12] K. K. Gan,[12] T. Hart,[12] K. Honscheid,[12] H. Kagan,[12] R. Kass,[12] J. Lee,[12] M. Sung,[12] A. Undrus,[12,†] R. Wanke,[12] A. Wolf,[12] M. M. Zoeller,[12] B. Nemati,[13] S. J. Richichi,[13] W. R. Ross,[13] P. Skubic,[13] M. Wood,[13] M. Bishai,[14] J. Fast,[14] E. Gerndt,[14] J. W. Hinson,[14] D. H. Miller,[14] E. I. Shibata,[14] I. P. J. Shipsey,[14] M. Yurko,[14] L. Gibbons,[15] S. D. Johnson,[15] Y. Kwon,[15] S. Roberts,[15] E. H. Thorndike,[15] C. P. Jessop,[16] K. Lingel,[16] H. Marsiske,[16] M. L. Perl,[16] S. F. Schaffner,[16] D. Ugolini,[16] R. Wang,[16] X. Zhou,[16] T. E. Coan,[17] V. Fadeyev,[17] I. Korolkov,[17] Y. Maravin,[17] I. Narsky,[17] V. Shelkov,[17] R. Stroynowski,[17] J. Staeck,[17] I. Volobouev,[17] J. Ye,[17] M. Artuso,[18] A. Efimov,[18] M. Gao,[18] M. Goldberg,[18] R. Greene,[18] F. Frasconi,[18] D. He,[18] S. Kopp,[18] G. C. Moneti,[18] R. Mountain,[18] Y. Mukhin,[18] S. Schuh,[18] T. Skwarnicki,[18] S. Stone,[18] X. Xing,[18] J. Bartelt,[19] S. E. Csorna,[19] V. Jain,[19] S. Marka,[19] A. Freyberger,[20] R. Godang,[20] D. Gibaut,[20] K. Kinoshita,[20] I. C. Lai,[20] P. Pomianowski,[20] S. Schrenk,[20] G. Bonvicini,[21] D. Cinabro,[21] L. Perera,[21] B. Barish,[22] M. Chadha,[22] S. Chan,[22] G. Eigen,[22] J. S. Miller,[22] C. O'Grady,[22] M. Schmidtler,[22] J. Urheim,[22] A. J. Weinstein,[22] F. Würthwein,[22] D. M. Asner,[23] D. W. Bliss,[23] W. S. Brower,[23] G. Masek,[23] H. P. Paar,[23] J. Gronberg,[24] C. M. Korte,[24] D. J. Lange,[24] R. Kutschke,[24] S. Menary,[24] R. J. Morrison,[24] S. Nakanishi,[24] H. N. Nelson,[24] T. K. Nelson,[24] C. Qiao,[24] J. D. Richman,[24] D. Roberts,[24] A. Ryd,[24] H. Tajima,[24] M. S. Witherell,[24] R. Balest,[25] B. H. Behrens,[25] K. Cho,[25] W. T. Ford,[25] H. Park,[25] P. Rankin,[25] J. Roy,[25] and J. G. Smith[25]

[1]Cornell University, Ithaca, New York 14853
[2]University of Florida, Gainesville, Florida 32611
[3]Harvard University, Cambridge, Massachusetts 02138

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[*]Permanent address: University of Texas at Austin.

[†]Permanent address: BINP, RU-630090 Novosibirsk, Russia.

[4]University of Hawaii at Manoa, Honolulu, Hawaii 96822
[5]University of Illinois, Champaign-Urbana, Illinois 61801
[6]Carleton University, Ottawa, Ontario, Canada K1S 5B6
and the Institute of Particle Physics, Canada
[7]McGill University, Montréal, Québec, Canada H3A 2T8
and the Institute of Particle Physics, Canada
[8]Ithaca College, Ithaca, New York 14850
[9]University of Kansas, Lawrence, Kansas 66045
[10]University of Minnesota, Minneapolis, Minnesota 55455
[11]State University of New York at Albany, Albany, New York 12222
[12]Ohio State University, Columbus, Ohio 43210
[13]University of Oklahoma, Norman, Oklahoma 73019
[14]Purdue University, West Lafayette, Indiana 47907
[15]University of Rochester, Rochester, New York 14627
[16]Stanford Linear Accelerator Center, Stanford University, Stanford, California 94309
[17]Southern Methodist University, Dallas, Texas 75275
[18]Syracuse University, Syracuse, New York 13244
[19]Vanderbilt University, Nashville, Tennessee 37235
[20]Virginia Polytechnic Institute and State University, Blacksburg, Virginia 24061
[21]Wayne State University, Detroit, Michigan 48202
[22]California Institute of Technology, Pasadena, California 91125
[23]University of California, San Diego, La Jolla, California 92093
[24]University of California, Santa Barbara, California 93106
[25]University of Colorado, Boulder, Colorado 80309-0390

I. INTRODUCTION

The decays $B^{\pm} \to D^0 K^{\pm}$, $B^{\pm} \to \overline{D}^0 K^{\pm}$ and $B^{\pm} \to D_{cp} K^{\pm}$, where $D^0_{cp} = \frac{1}{\sqrt{2}}(D^0 \pm \overline{D}^0)$, provide a way to measure the CKM phase $\gamma \approx \mathrm{Arg}(V^*_{ub})$, even in the absence of a decay rate asymmetry [1]. Resonant kaon final states can be used in similar measurements [2] [3]. Here we report on the search for one of these decay modes, $B^+ \to \overline{D}^0 K^+$.

Since $B^+ \to \overline{D}^0 K^+$ is identical to $B^+ \to \overline{D}^0 \pi^+$ with the $\overline{d}$-quark replaced by an $\overline{s}$-quark, we expect the ratio between the branching fractions of these two decays to be $\left(\tan\theta_c \frac{f_K}{f_\pi}\right)^2 \approx$ 0.075. This gives the expected $B^+ \to \overline{D}^0 K^+$ branching fraction of 4.0×10^{-4}.

II. DATA SAMPLE AND EVENT SELECTION

The data used in this analysis were produced in e^+e^- annihilations at the Cornell Electron Storage Ring and collected with the CLEO II detector. A detailed description of the detector is given elsewhere [4]. The data sample consists of 3.1 fb^{-1} taken at the $\Upsilon(4s)$ center of mass energy, corresponding to $(3.32 \pm 0.06) \times 10^6$ charged B mesons, and 1.6 fb^{-1} taken just below the threshold for $B\overline{B}$ production.

π^0 candidates are formed by combining two showers whose invariant mass is within 2.5σ of the π^0 mass and which are consistent with originating from photons. $\overline{D}^0$ candidates are reconstructed in the decay modes $K^+\pi^-$, $K^+\pi^-\pi^0$ or $K^+\pi^-\pi^+\pi^-$, using good tracks originating from the interaction point and π^0 candidates. The invariant mass of $\overline{D}^0$ candidates is required to be within 2.5σ of the nominal mass. B^+ candidates are formed by combining a $\overline{D}^0$ candidate with a candidate kaon track. The beam-constrained mass of the B^+, $M_B \equiv \sqrt{E^2_{\mathrm{beam}} - P^2_{\mathrm{candidate}}}$, is required to be within 6 MeV ($\sim 2.5\sigma$) of the B-meson mass.

The primary source of background in this analysis is the Cabbibo-allowed decay $B^+ \to \overline{D}^0\pi^+$, where the pion is mistaken for a kaon. The only variables that give significant separation of signal from this background are the energy difference, $\Delta E \equiv E_{\mathrm{candidate}} - E_{\mathrm{beam}}$, and the specific ionization of the candidate kaon, $\sigma_K \equiv (dE/dx_{\mathrm{measured}} - dE/dx_{\mathrm{expected}})/\sigma_{dE/dx}$, where $dE/dx_{\mathrm{expected}}$ is the mean specific ionization of kaons at the measured track momentum. The distribution of signal events is centered at 0 in both ΔE and σ_K, while $B^+ \to \overline{D}^0\pi^+$ events are distributed around $\Delta E = 48$ MeV, $\sigma_K = 1.6$. The ΔE separation is between 1.8σ and 2.3σ, depending on the $\overline{D}^0$ decay mode, and the σ_K separation is 1.6σ. For initial selection we apply the cuts $-50 < \Delta E < 130$ MeV, $-3 < \sigma_K < 4$.

So as not to degrade the dE/dx resolution, we require that the dE/dx measurement of the candidate kaon track be made with at least twenty hits. The σ_K distributions were studied in clean kaon and pion data samples tagged in the decay chain

$$\begin{array}{l} D^{*+} \to D^0\ \pi^+ \\ \qquad\quad \hookrightarrow K^-\pi^+. \end{array} \tag{1}$$

The σ_K distributions are shown in Figure 1.

Additional background sources include $B\overline{B}$ events which do not contain a $B^+ \to \overline{D}^0\pi^+$ decay, and $q\overline{q}$ events produced in the continuum, both of which are dominated by candidates

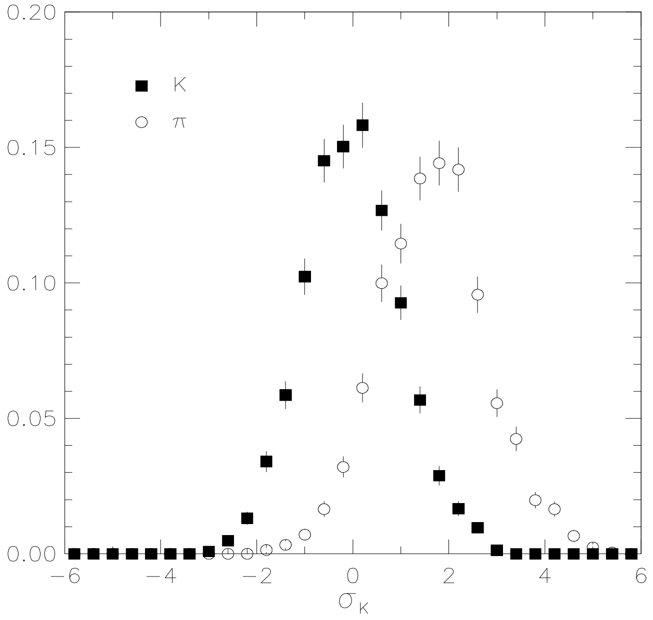

FIG. 1. The normalized σ_K distributions of tracks in clean data samples of kaons and pions between 2.1 and 2.5 GeV.

with a misreconstructed $\overline{D}^0$ and a pion misidentified as the kaon. The continuum background is suppressed by combining event shape variables with the π^0 and $\overline{D}^0$ masses into a Fisher discriminant [5], whose coefficients are optimized to give the best separation between signal and background.

We find 198 events that passed the initial cuts in the $K^+\pi^-$ mode, 288 events in the $K^+\pi^-\pi^0$ mode and 320 in the $K^+\pi^-\pi^+\pi^-$ mode. None of the events contribute more than one B candidate.

III. RESULTS

The ΔE distributions of $B^+ \to \overline{D}^0 K^+$ candidates which pass the initial cuts and whose kaon candidate satisfies $-3 < \sigma_K < 0.75$ are shown in Figure 2. The prominent feature in these distributions is the broad $B^+ \to \overline{D}^0 \pi^+$ peak centered at 48 MeV. In addition, there are events due to continuum and combinatoric $B\overline{B}$ events, and possible signal, which would appear as a $\sim$ 24 MeV-wide peak centered at $\Delta E = 0$.

In order to search for signal in these distributions, we fit them, varying the contributions of three sources of events. The first source represents background from pions misidentified as kaons, the second describes continuum background with real kaons and the third simulates the $B^+ \to \overline{D}^0 K^+$ signal. The shapes of the three contributions are fixed in the fit, but their relative normalizations are allowed to float. The misidentified-pion background is due to $B^+ \to \overline{D}^0 \pi^+$ and most continuum and $B\overline{B}$ processes, and its shape is obtained from the ΔE distribution in the sideband $1 < \sigma_K < 4$. Continuum events with real kaons are represented by data taken below the $\Upsilon(4s)$ resonance. This background is expected to be small, with

1.7 ± 1.0 events in the $K^+\pi^-$ and $K^+\pi^-\pi^0$ modes and 3.9 ± 1.5 events in the $K^+\pi^-\pi^+\pi^-$ mode. The fit procedure does not allow this background to vary more than $\pm 2\sigma$ around the expected values. The expected signal shape is generated using a GEANT based simulation of the detector. The fit results are summarized in Table I.

From the σ_K distribution of pions tagged in the decay chain (1), we expect the sideband distribution to be scaled by 0.304 ± 0.011 in the fit, where the error comes from the statistics in the tagged pion data sample. The ratios between the sideband scale factors found in the fits and this expected value (see Table I), are consistent with the value 1.

From the σ_K distribution of tagged kaons, we expect 0.1547 ± 0.0076 of the signal events to appear in the sideband, reducing the signal yield in the fit. We correct for this small effect by adding 0.41 ± 0.67 events to the yield in the $K^+\pi^-$ mode, 0.45 ± 0.71 events in the $K^+\pi^-\pi^0$ mode and 0.26 ± 0.52 events in the $K^+\pi^-\pi^+\pi^-$ mode. The yields in Table I include these corrections.

To calculate $\mathcal{B}(B^+ \to \overline{D}^0 K^+)$ we use the PDG96 [6] $\overline{D}^0$ branching fractions $(3.83 \pm 0.12)\%$, $(13.9 \pm 0.9)\%$ and $(7.5 \pm 0.4)\%$ to the final states $K^+\pi^-$, $K^+\pi^-\pi^0$ and $K^+\pi^-\pi^+\pi^-$, respectively.

The fits yield the average branching fraction $(2.7 \pm 1.2 \pm 0.2) \times 10^{-4}$, where the first error is statistical and the second is systematic, dominated by the uncertainty in tracking efficiency. The χ^2 is 2.1 for two degrees of freedom. This result implies the 90% confidence level upper limit $\mathcal{B}(B^+ \to \overline{D}^0 K^+) < 4.4 \times 10^{-4}$.

mode	efficiency(%)	yield	$\mathcal{B} \times 10^4$	sideband scale ratio
$K^+\pi^-$	25.08 ± 0.44	5.6 ± 4.8	1.8 ± 1.5	1.07 ± 0.22
$K^+\pi^-\pi^0$	7.43 ± 0.18	7.3 ± 9.0	2.1 ± 2.6	1.08 ± 0.24
$K^+\pi^-\pi^+\pi^-$	11.36 ± 0.38	16.3 ± 6.7	5.8 ± 2.4	0.76 ± 0.15

TABLE I. Results of the fits. Sideband scale ratio is the ratio between the sideband scaling found in the fit and its expected value.

IV. CONCLUSIONS

Using a data sample of $(3.32 \pm 0.06) \times 10^6$ charged B mesons, we searched for the decay $B^+ \to \overline{D}^0 K^+$ in three $\overline{D}^0$ decay modes. We set the 90% confidence level upper limit

$$\mathcal{B}(B^+ \to \overline{D}^0 K^+) < 4.4 \times 10^{-4}, \ 90\% \ \ \text{CL}. \tag{2}$$

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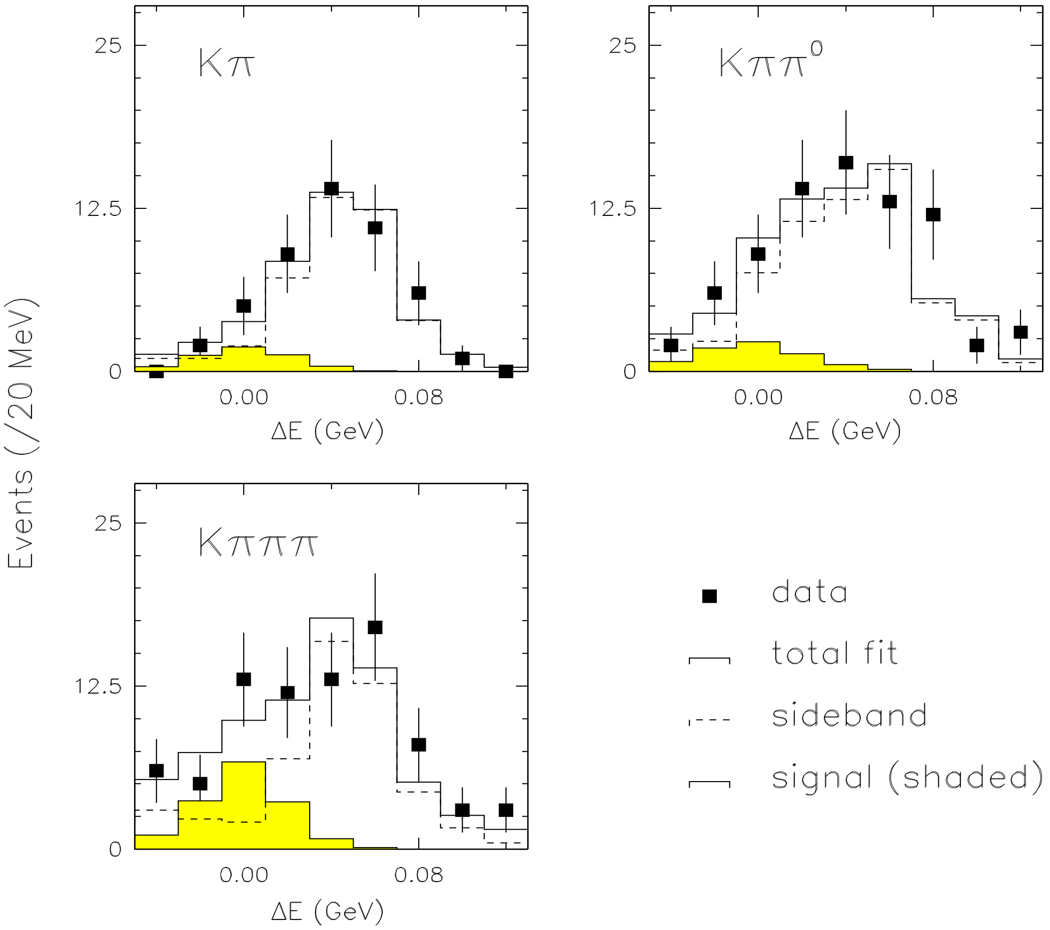

FIG. 2. The ΔE distribution of events in the $K^+\pi^-$ (top left), $K^+\pi^-\pi^0$ (top right) and $K^+\pi^-\pi^+\pi^-$ (bottom left) modes. The data points with error bars are the data, and the histograms represent components of the fit described in the text: signal (shaded), sideband data (dashed), and the sum of the fit components (solid), which includes the small contribution from continuum kaon events.

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