Observation of the Decay $\overline{B}^0 \to \Lambda_c^+ \overline{p}$

N. Gabyshev,[8] H. Kichimi,[8] K. Abe,[8] K. Abe,[41] R. Abe,[28] T. Abe,[42] I. Adachi,[8] H. Aihara,[43] M. Akatsu,[22] Y. Asano,[48] T. Aso,[47] V. Aulchenko,[1] T. Aushev,[12] A. M. Bakich,[38] Y. Ban,[32] E. Banas,[26] A. Bay,[18] I. Bedny,[1] I. Bizjak,[13] A. Bondar,[1] A. Bozek,[26] M. Bračko,[20,13] J. Brodzicka,[26] T. E. Browder,[7] B. C. K. Casey,[7] M.-C. Chang,[25] P. Chang,[25] Y. Chao,[25] K.-F. Chen,[25] B. G. Cheon,[37] R. Chistov,[12] S.-K. Choi,[6] Y. Choi,[37] Y. K. Choi,[37] M. Danilov,[12] L. Y. Dong,[10] J. Dragic,[21] A. Drutskoy,[12] S. Eidelman,[1] V. Eiges,[12] Y. Enari,[22] F. Fang,[7] C. Fukunaga,[45] A. Garmash,[1,8] T. Gershon,[8] B. Golob,[19,13] J. Haba,[8] C. Hagner,[50] F. Handa,[42] T. Hara,[30] K. Hasuko,[33] H. Hayashii,[23] M. Hazumi,[8] I. Higuchi,[42] L. Hinz,[18] T. Hojo,[30] T. Hokuue,[22] Y. Hoshi,[41] W.-S. Hou,[25] Y. B. Hsiung,[25] H.-C. Huang,[25] T. Igaki,[22] Y. Igarashi,[8] T. Iijima,[22] K. Inami,[22] A. Ishikawa,[22] R. Itoh,[8] H. Iwasaki,[8] Y. Iwasaki,[8] H. K. Jang,[36] J. H. Kang,[52] J. S. Kang,[15] P. Kapusta,[26] S. U. Kataoka,[23] N. Katayama,[8] H. Kawai,[2] H. Kawai,[43] T. Kawasaki,[28] D.W. Kim,[37] H. J. Kim,[52] H. O. Kim,[37] Hyunwoo Kim,[15] J. H. Kim,[37] S. K. Kim,[36] K. Kinoshita,[4] S. Kobayashi,[34] S. Korpar,[20,13] P. Križan,[19,13] P. Krokovny,[1] R. Kulasiri,[4] A. Kuzmin,[1] Y.-J. Kwon,[52] J. S. Lange,[5,33] G. Leder,[11] S. H. Lee,[36] J. Li,[35] S.-W. Lin,[25] D. Liventsev,[12] R.-S. Lu,[25] J. MacNaughton,[11] G. Majumder,[39] F. Mandl,[11] T. Matsuishi,[22] S. Matsumoto,[3] T. Matsumoto,[45] W. Mitaroff,[11] Y. Miyabayashi,[22] H. Miyake,[30] H. Miyata,[28] G. R. Moloney,[21] T. Mori,[3] T. Nagamine,[42] Y. Nagasaka,[9] T. Nakadaira,[43] E. Nakano,[29] M. Nakao,[8] J.W. Nam,[37] Z. Natkaniec,[26] S. Nishida,[16] O. Nitoh,[46] S. Noguchi,[23] T. Nozaki,[8] S. Ogawa,[40] T. Ohshima,[22] T. Okabe,[22] S. Okuno,[14] S. L. Olsen,[7] Y. Onuki,[28] W. Ostrowicz,[26] H. Ozaki,[8] P. Pakhlov,[12] H. Palka,[26] C.W. Park,[15] H. Park,[17] K. S. Park,[37] L. S. Peak,[38] J.-P. Perroud,[18] L. E. Piilonen,[50] M. Rozanska,[26] K. Rybicki,[26] H. Sagawa,[8] S. Saitoh,[8] Y. Sakai,[8] T. R. Sarangi,[49] M. Satapathy,[49] A. Satpathy,[8,4] O. Schneider,[18] S. Schrenk,[4] J. Schümann,[25] A. J. Schwartz,[4] S. Semenov,[12] K. Senyo,[22] R. Seuster,[7] M. E. Sevior,[21] H. Shibuya,[40] B. Shwartz,[1] V. Sidorov,[1] J. B. Singh,[31] N. Soni,[31] S. Stanič,[48,*] M. Starič,[13] A. Sugi,[22] A. Sugiyama,[22] K. Sumisawa,[8] T. Sumiyoshi,[45] S. Suzuki,[51] S. Y. Suzuki,[8] S. K. Swain,[7] T. Takahashi,[29] F. Takasaki,[8] K. Tamai,[8] N. Tamura,[28] J. Tanaka,[43] M. Tanaka,[8] G. N. Taylor,[21] Y. Teramoto,[29] S. Tokuda,[22] T. Tomura,[43] T. Tsuboyama,[8] T. Tsukamoto,[8] S. Uehara,[8] Y. Unno,[2] S. Uno,[8] G. Varner,[7] K. E. Varvell,[38] C. C. Wang,[25] C. H. Wang,[24] J. G. Wang,[50] M.-Z. Wang,[25] Y. Watanabe,[44] E. Won,[15] B. D. Yabsley,[50] Y. Yamada,[8] A. Yamaguchi,[42] Y. Yamashita,[27] Y. Yamashita,[43] M. Yamauchi,[8] H. Yanai,[28] Y. Yuan,[10] Y. Yusa,[42] C. C. Zhang,[10] Z. P. Zhang,[35] Y. Zheng,[7] V. Zhilich,[1] and D. Žontar[19,13]

(Belle Collaboration)

[1]*Budker Institute of Nuclear Physics, Novosibirsk,*
[2]*Chiba University, Chiba*
[3]*Chuo University, Tokyo*
[4]*University of Cincinnati, Cincinnati, Ohio 45221*
[5]*University of Frankfurt, Frankfurt*
[6]*Gyeongsang National University, Chinju*
[7]*University of Hawaii, Honolulu, Hawaii 96822*
[8]*High Energy Accelerator Research Organization (KEK), Tsukuba*
[9]*Hiroshima Institute of Technology, Hiroshima*
[10]*Institute of High Energy Physics, Chinese Academy of Sciences, Beijing*
[11]*Institute of High Energy Physics, Vienna*
[12]*Institute for Theoretical and Experimental Physics, Moscow*
[13]*J. Stefan Institute, Ljubljana*
[14]*Kanagawa University, Yokohama*
[15]*Korea University, Seoul*
[16]*Kyoto University, Kyoto*
[17]*Kyungpook National University, Taegu*
[18]*Institut de Physique des Hautes Énergies, Université de Lausanne, Lausanne*
[19]*University of Ljubljana, Ljubljana*
[20]*University of Maribor, Maribor*
[21]*University of Melbourne, Victoria*
[22]*Nagoya University, Nagoya*
[23]*Nara Women's University, Nara*
[24]*National Lien-Ho Institute of Technology, Miao Li*
[25]*National Taiwan University, Taipei*
[26]*H. Niewodniczanski Institute of Nuclear Physics, Krakow*

 0031-9007/03/90(12)/121802(5)$20.00

[27]Nihon Dental College, Niigata
[28]Niigata University, Niigata
[29]Osaka City University, Osaka
[30]Osaka University, Osaka
[31]Panjab University, Chandigarh
[32]Peking University, Beijing
[33]RIKEN BNL Research Center, Upton, New York 11973
[34]Saga University, Saga
[35]University of Science and Technology of China, Hefei
[36]Seoul National University, Seoul
[37]Sungkyunkwan University, Suwon
[38]University of Sydney, Sydney New South Wales
[39]Tata Institute of Fundamental Research, Bombay
[40]Toho University, Funabashi
[41]Tohoku Gakuin University, Tagajo
[42]Tohoku University, Sendai
[43]University of Tokyo, Tokyo
[44]Tokyo Institute of Technology, Tokyo
[45]Tokyo Metropolitan University, Tokyo
[46]Tokyo University of Agriculture and Technology, Tokyo
[47]Toyama National College of Maritime Technology, Toyama
[48]University of Tsukuba, Tsukuba
[49]Utkal University, Bhubaneswer
[50]Virginia Polytechnic Institute and State University, Blacksburg, Virginia 24061
[51]Yokkaichi University, Yokkaichi
[52]Yonsei University, Seoul
(Received 20 December 2002; published 26 March 2003)

We report the measurement of the charmed baryonic decay $\bar{B}^0 \to \Lambda_c^+ \bar{p}$ with a branching fraction of $(2.19^{+0.56}_{-0.49} \pm 0.32 \pm 0.57) \times 10^{-5}$ and a statistical significance of 5.8σ. The errors are statistical, systematic, and the error of the $\Lambda_c^+ \to pK^-\pi^+$ decay branching fraction. This is the first observation of a two-body baryonic B decay. The analysis is based on 78.2 fb^{-1} of data accumulated at the $\Upsilon(4S)$ resonance with the Belle detector at the KEKB asymmetric e^+e^- collider.

DOI: 10.1103/PhysRevLett.90.121802 PACS numbers: 13.25.Hw, 14.20.Lq

Although the four- and three-body baryonic B decays $\bar{B}^0 \to \Lambda_c^+ \bar{p} \pi^+ \pi^-$ and $B^- \to \Lambda_c^+ \bar{p} \pi^-$ are experimentally well established [1,2], there has been, until now, no reported observation of any two-body mode, such as $\bar{B}^0 \to \Lambda_c^+ \bar{p}$. In a previous Belle analysis, based on a 29.1 fb^{-1} data sample [2], we obtained the following branching fractions for four-, three- and two-body decays:

$$\mathcal{B}(\bar{B}^0 \to \Lambda_c^+ \bar{p} \pi^+ \pi^-) = (11.04^{+1.22}_{-1.17} \pm 1.98 \pm 2.87) \times 10^{-4},$$

$$\mathcal{B}(B^- \to \Lambda_c^+ \bar{p} \pi^-) = (1.87^{+0.43}_{-0.40} \pm 0.28 \pm 0.49) \times 10^{-4},$$

$$\mathcal{B}(\bar{B}^0 \to \Lambda_c^+ \bar{p}) < 0.31 \times 10^{-4} \quad \text{(90\% confidence level)}.$$

The measured branching fractions decrease rapidly with decreasing decay multiplicity. This suppression of lower multiplicity decays is a key issue in the understanding of the mechanism behind charmed baryonic B decays.

There are several different theoretical calculations for the $\bar{B}^0 \to \Lambda_c^+ \bar{p}$ branching fraction, based on a diquark model [3], a QCD sum rule model [4], and pole models [5,6]. They differ by an order of magnitude. Thus, a measurement of the two-body decay $\bar{B}^0 \to \Lambda_c^+ \bar{p}$ branching fraction would distinguish between these different theoretical approaches and provide important insight into the underlying physics.

In this Letter we report the first observation of the two-body decay $\bar{B}^0 \to \Lambda_c^+ \bar{p}$. The analysis is based on a data sample of 78.2 fb^{-1} accumulated at the $\Upsilon(4S)$ resonance with the Belle detector at the KEKB 8 GeV e^- on 3.5 GeV e^+ asymmetric collider.

The Belle detector is a large-solid-angle magnetic spectrometer that consists of a three-layer silicon vertex detector (SVD), a 50-layer cylindrical drift chamber (CDC), a mosaic of aerogel threshold Čerenkov counters (ACC), a barrel-like array of time-of-flight scintillation counters (TOF), and an array of CsI(Tl) crystals (ECL) located inside a superconducting solenoidal coil that provides a 1.5 T magnetic field. An iron flux return located outside the coil is instrumented to detect muons and K_L mesons (KLM). The detector is described in detail elsewhere [7]. We use a GEANT based Monte Carlo (MC) simulation to model the response of the detector and determine its acceptance [8].

We detect the Λ_c^+ via the $\Lambda_c^+ \to pK^-\pi^+$ decay channel. Inclusion of charge conjugate states is implicit unless otherwise stated. The particle identification (PID) information from the CDC, ACC, and TOF is used to construct likelihood functions L_p, L_K, and L_π for the proton, kaon, and pion assignment for all charged tracks, respectively. Likelihood ratios $LR(A/B) = L_A/(L_A + L_B)$ are required to be greater than 0.6 to identify a particle from Λ_c^+ decay as type A, where B denotes the other two possible assignments among kaon, pion, or proton. In order to maintain high efficiency for the high momentum prompt antiproton that comes directly from the primary $\bar{B}^0$ meson decay, we rely more heavily on the kinematic reconstruction and loosen the PID requirement to $LR(A/B) > 0.2$, which improves the efficiency by a factor of about 20%. Electron and muon candidates are removed if their combined likelihood ratios from the ECL, CDC, and KLM information are greater than 0.95. A Λ_c^+ candidate is selected if the invariant mass $M(pK^-\pi^+)$ is within 0.010 GeV$/c^2$ (2.5 σ) of the 2.285 GeV$/c^2$ Λ_c^+ mass. A Λ_c^+ mass constrained fit is carried out at the reconstructed Λ_c^+ decay vertex to remove background including secondary particles from Λ or K_S decay.

The $\bar{B}^0 \to \Lambda_c^+ \bar{p}$ events are identified by their energy difference $\Delta E = (\sum E_i) - E_{\rm beam}$, and the beam-energy constrained mass $M_{\rm bc} = \sqrt{E_{\rm beam}^2 - (\sum \vec{p}_i)^2}$, where $E_{\rm beam}$ is the beam energy, and $\vec{p}_i$ and E_i are the three-momenta and energies of the B meson decay products, all defined in the center-of-mass system of the e^+e^- collision. We select events with $M_{\rm bc} > 5.20$ GeV$/c^2$ and $|\Delta E| < 0.20$ GeV. The prompt antiproton track and the virtual Λ_c^+ track are required to form a common B mass constrained decay vertex. To suppress continuum background, we impose requirements on event-shape variables. We require $|\cos\theta_{\rm thr}| < 0.80$, where $\theta_{\rm thr}$ is the angle between the thrust axis of the B candidate tracks and that of the other tracks. This requirement eliminates 80% of the continuum background and retains 80% of the signal events. We also require $R_2 < 0.35$, where R_2 is the ratio of the second to the zeroth Fox-Wolfram moments [9]. This requirement rejects 50% of the remaining continuum background and retains 90% of the signal. If there are multiple candidates in an event, the candidate with the best χ_B^2 for the B vertex fit is selected.

Figure 1 shows a scatter plot of ΔE versus $M_{\rm bc}$ and their projections for selected events. The ΔE projection is shown for $M_{\rm bc} > 5.270$ GeV$/c^2$ and the $M_{\rm bc}$ projection is shown for $|\Delta E| < 0.030$ GeV. The widths determined from single Gaussian fits to signal MC events are 2.7 MeV$/c^2$ and 10.3 MeV for $M_{\rm bc}$ and ΔE, respectively. A two-dimensional binned maximum likelihood fit is performed to determine the signal yield. For this fit, the ΔE distribution is represented by a double Gaussian for the signal plus a first order polynomial for the background, and the $M_{\rm bc}$ distribution is represented by a single Gaussian for the signal plus the ARGUS function [10] for the background. The region $\Delta E < -0.1$ GeV is excluded from the fit to avoid feed down from modes including extra pions, which produces the bump structure observed in the region $\Delta E \leq -0.15$ GeV. In the fit, the signal shape parameters are fixed to the values fitted to the

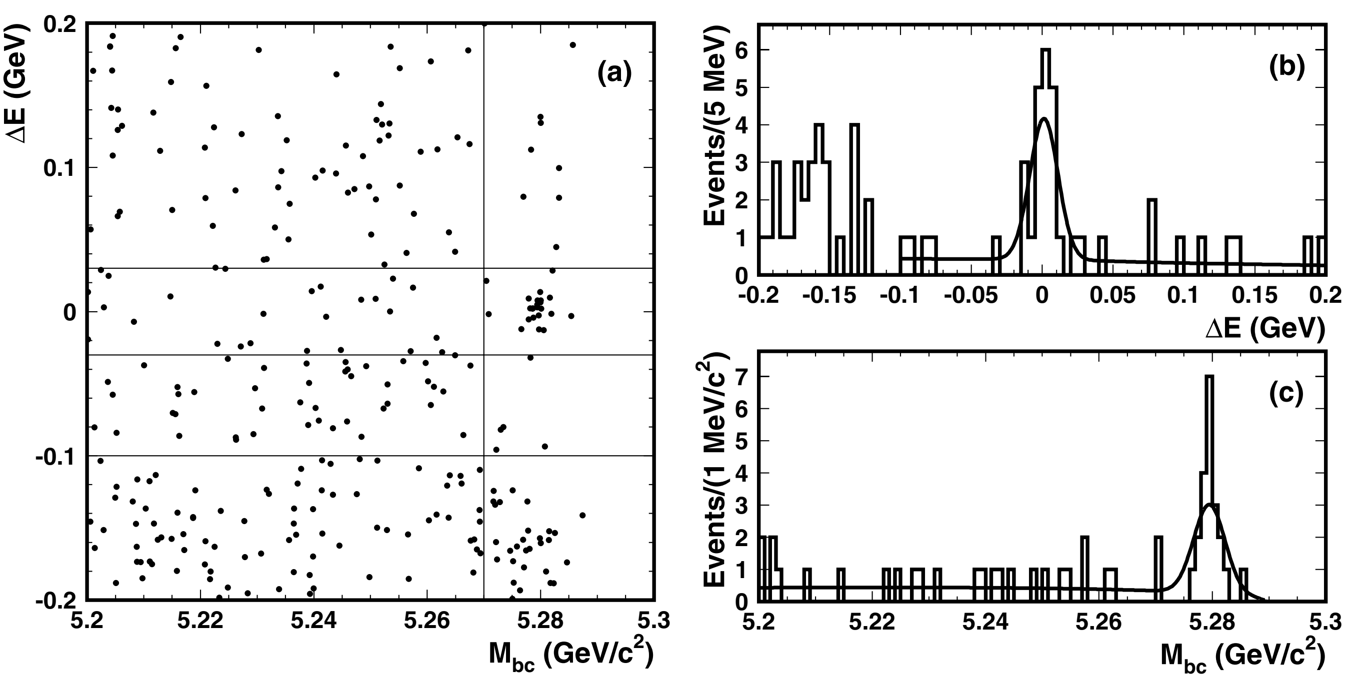

FIG. 1. Candidate $\bar{B}^0 \to \Lambda_c^+ \bar{p}$ events: (a) scatter plot of ΔE versus $M_{\rm bc}$, (b) ΔE distribution for $M_{\rm bc} > 5.270$ GeV$/c^2$, and (c) $M_{\rm bc}$ distribution for $|\Delta E| < 0.030$ GeV. The curves indicate the result of a two-dimensional fit.

signal MC, and the signal yield and the background parameters are allowed to float. The curves in Fig. 1(b) and 1(c) indicate the results of this two-dimensional fit.

The signal peak positions determined from fits to the data, $(5279.5 \pm 0.3)\,\mathrm{MeV}/c^2$ for M_{bc} and $(0.9 \pm 1.8)\,\mathrm{MeV}$ for ΔE, are consistent with the world average B^0 mass [11] and zero, respectively. When we use single Gaussians for M_{bc} and ΔE signal functions and fit with the widths as free parameters, the fitted values in the data are found to be $(1.3 \pm 0.3)\,\mathrm{MeV}/c^2$ and $(6.9 \pm 1.5)\,\mathrm{MeV}$, respectively, which are narrower than those determined with the signal MC. The probability of obtaining such narrow widths is $\mathcal{O}(1\%)$ and is attributed to a statistical fluctuation. We also investigate the decays $\bar{B}^0 \to \Lambda_c^+ \bar{p} \pi^+ \pi^-$, $B^- \to \Lambda_c^+ \bar{p} \pi^-$ and $\bar{B}^0 \to J/\psi \bar{K}^*(892)^0$, $J/\psi \to p\bar{p}$ as control samples, and find that for these modes M_{bc} and ΔE widths are consistent between the data and signal MC. The effect of the narrow widths to the signal yield is investigated by applying fits where single Gaussians with widths allowed to float are used for the signal shapes. The difference in the fitted yields is taken into account in a systematic error as discussed below.

From the fit we obtain $19.6^{+5.0}_{-4.4}$ signal events. From separate fits to the charge conjugate modes we obtain signal yields of $6.4^{+3.0}_{-2.4}$ and $13.3^{+4.2}_{-3.5}$ events for $\bar{B}^0 \to \Lambda_c^+ \bar{p}$ and $B^0 \to \bar{\Lambda}_c^- p$, respectively. These are consistent within statistical errors.

The branching fraction is calculated as $N_{\mathrm{S}}/[\varepsilon \times N_{B\bar{B}} \times \mathcal{B}(\Lambda_c^+ \to pK^-\pi^+)]$, using the measured signal yield N_{S} and the decay branching fraction $\mathcal{B}(\Lambda_c^+ \to pK^-\pi^+) = (5.0 \pm 1.3)\%$ [11]. The detection efficiency ε is evaluated to be 21.1% from the signal MC. The number of $B\bar{B}$ pairs $N_{B\bar{B}}$ is $(85.0 \pm 0.5) \times 10^6$. The fractions of charged and neutral B mesons are assumed to be the same.

We obtain a branching fraction of

$$\mathcal{B}(\bar{B}^0 \to \Lambda_c^+ \bar{p}) = (2.19^{+0.56}_{-0.49} \pm 0.32 \pm 0.57) \times 10^{-5},$$

where the first and the second errors are statistical and systematic, respectively. The last error of 26% is due to uncertainty in the branching fraction $\mathcal{B}(\Lambda_c^+ \to pK^-\pi^+)$.

The total systematic error of 14.8% is determined as follows. The tracking systematic error is estimated to be 8% in total, assuming a correlated systematic error of 2% per charged track, based on tracking efficiency studies with $\eta \to \gamma\gamma$ and $\eta \to \pi^+\pi^-\pi^0$ samples. The PID systematic error is 10% in total, assuming a correlated systematic error of 3% per proton and 2% per pion or kaon, based on studies with a $\Lambda \to p\pi^-$ sample for protons; and with a $D^{*+} \to D^0\pi^+$, $D^0 \to K^-\pi^+$ sample for kaons and pions. The systematic error in the fitting procedure and signal shape is estimated to be 7.3%, which is half of the maximum deviation in the branching fractions obtained with various modifications to the fitting functions: with a single or a double Gaussian for the ΔE signal, with the widths and means for both M_{bc} and ΔE signals fixed to MC determined values or fitted in the data. Finally, the systematic error in the detection efficiency due to MC statistics is 1.3%.

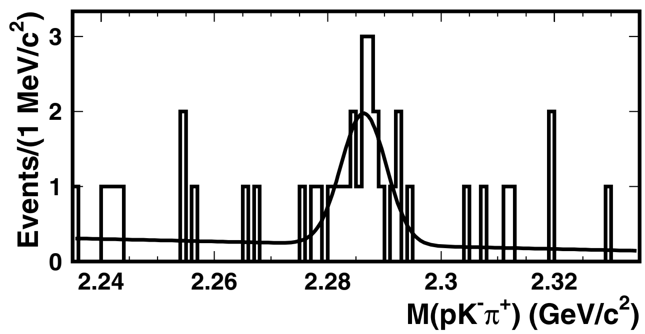

FIG. 2. Invariant mass $M(pK^-\pi^+)$ distribution for $\bar{B}^0 \to \Lambda_c^+ \bar{p}$ candidates in the B signal region.

Figure 2 shows the invariant mass distribution $M(pK^-\pi^+)$ for B candidates in the signal region $|\Delta E| < 0.030$ GeV and $M_{\mathrm{bc}} > 5.27\ \mathrm{GeV}/c^2$. The curve indicates a fit result with a Gaussian over linear background. The fitted width of $(4.0 \pm 1.0)\ \mathrm{MeV}/c^2$ and the fitted mean of $(2286.4 \pm 1.3)\ \mathrm{MeV}/c^2$ are consistent with values obtained from fits to signal MC events, which are generated assuming the world average Λ_c^+ mass [11]. We obtain a Λ_c^+ yield of $17.5^{+5.2}_{-4.6}$ events, consistent with the B signal yield mentioned above.

We consider a contribution in the $\bar{B}^0 \to \Lambda_c^+ \bar{p}$ signal yield from other B decays, which gives a uniform distribution in the Λ_c^+ invariant mass. We analyze the Λ_c^+ sideband $0.015 < |M(pK^-\pi^+) - M_{\Lambda_c^+}| < 0.050\ \mathrm{GeV}/c^2$, and obtain a B signal yield of $1.2^{+3.2}_{-2.4}$ events, which is consistent with expectation of 1.4 ± 0.4 events from the $\bar{B}^0 \to \Lambda_c^+ \bar{p}$ decay MC, assuming our observed branching fraction. From this we estimate the other B decay contribution of $(-0.1^{+0.9}_{-0.7})$ events in the Λ_c^+ signal region, which is negligibly small. From a simultaneous fit of the $\bar{B}^0 \to \Lambda_c^+ \bar{p}$ signal yield and the other B decay contribution in the Λ_c^+ signal and sideband regions, we obtain a statistical significance of 5.8 σ. The significance is calculated as $\sqrt{-2\ln(\mathcal{L}_0/\mathcal{L}_{\max})}$, where $\mathcal{L}_{\max}$ and $\mathcal{L}_0$ denote the maximum likelihoods with the fitted signal yield and with the yield fixed at zero, respectively.

We investigate the $\bar{B}^0 \to \Lambda_c^+ \bar{p}$ decay in MC with all known Λ_c^+ decay modes [11]. The overall detection efficiency for the $\Lambda_c^+ \to pK^-\pi^+$ final state, including intermediate resonances, is found to be consistent with that calculated for the nonresonant $\Lambda_c^+ \to pK^-\pi^+$ decay alone. The other Λ_c^+ decays show no peaking structure in the ΔE and M_{bc} distributions.

Finally, the overall systematics are checked by analyzing the decay mode $\bar{B}^0 \to J/\psi \bar{K}^*(892)^0$ observed as $J/\psi \to p\bar{p}$ and $\bar{K}^*(892)^0 \to K^-\pi^+$, which contains the same final state particles as the mode under study. A similar analysis procedure is applied, except for the Λ_c^+ vertex fit. A J/ψ is tagged if the measured invariant mass

$M(p\bar{p})$ is within 0.019 GeV$/c^2$ of the J/ψ mass. A $\bar{K}^*(892)^0$ is tagged if the measured invariant mass $M(K^-\pi^+)$ is within 0.2 GeV$/c^2$ of the $K^*(892)^0$ mass. Vertex fits are also carried out at the J/ψ and B vertices. We obtain a signal of $23.7^{+5.6}_{-4.9}$ events and a branching fraction of $\mathcal{B}[\bar{B}^0 \to J/\psi \bar{K}^*(892)^0] = (1.02^{+0.24}_{-0.21} \pm 0.14) \times 10^{-3}$, which is consistent with previous measurements [11,12].

In summary, we report the measurement of the charmed baryonic B decay $\bar{B}^0 \to \Lambda_c^+ \bar{p}$ with a branching fraction of $(2.19^{+0.56}_{-0.49} \pm 0.32 \pm 0.57) \times 10^{-5}$ and a statistical significance of 5.8 σ. This is the first observation of a two-body baryonic B decay. The branching fraction is found to be about an order-of-magnitude smaller than that of the three-body decay $B^- \to \Lambda_c^+ \bar{p} \pi^-$. This suppression is a unique feature of two-body baryonic decays; in contrast, the two- and three-body mesonic B decays are comparable. A pole model [6] predicts a value of the branching fraction of $\leq (1.1 - 3.1) \times 10^{-5}$ for $\bar{B}^0 \to \Lambda_c^+ \bar{p}$, which is consistent with our measurement, while the other models [3–5] give substantially larger values. Charmless baryonic two-body decays are expected to be suppressed by an additional factor of $|V_{ub}/V_{cb}|^2$ [11]. The result reported here implies that their branching fractions should not be much above the 10^{-7} level, which are consistent with the present upper limits [13].

We wish to thank the KEKB accelerator group for their excellent operation of the KEKB accelerator. We acknowledge support from the Ministry of Education, Culture, Sports, Science, and Technology of Japan and the Japan Society for the Promotion of Science; the Australian Research Council and the Australian Department of Industry, Science and Resources; National Science Foundation of China under Contract No. 10175071; the Department of Science and Technology of India; the BK21 program of the Ministry of Education of Korea and the CHEP SRC program of the Korea Science and Engineering Foundation; the Polish State Committee for Scientific Research under Contract No. 2P03B 17017; the Ministry of Science and Technology of Russian Federation; the Ministry of Education, Science and Sport of Slovenia; the National Science Council and the Ministry of Education of Taiwan, and the U.S. Department of Energy.

*On leave from Nova Gorica Polytechnic, Nova Gorica.

[1] CLEO Collaboration, S. A. Dytman *et al.*, Phys. Rev. D **66**, 091101(R) (2002).
[2] Belle Collaboration, N. Gabyshev *et al.*, Phys. Rev. D **66**, 091102(R) (2002).
[3] P. Ball and H. G. Dosch, Z. Phys. C **51**, 445 (1991).
[4] V. Chernyak and I. Zhitnitsky, Nucl. Phys. **B345**, 137 (1990).
[5] M. Jarfi *et al.*, Phys. Lett. B **237**, 513 (1990); M. Jarfi *et al.*, Phys. Rev. D **43**, 1599 (1991); N. Deshpande, J. Trampetic, and A. Soni, Mod. Phys. Lett. A **3**, 749 (1988).
[6] H. Y. Cheng and K. C. Yang, Phys. Rev. D **65**, 054028 (2002); **65**, 099901(E) (2002).
[7] Belle Collaboration, A. Abashian *et al.*, Nucl. Instrum. Methods Phys. Res., Sect. A **479**, 117 (2002).
[8] Events are generated with the CLEO group's QQ program (http://www.lns.cornell.edu/public/CLEO/soft/QQ). The detector response is simulated using GEANT: R. Brun *et al.*, GEANT 3.21, CERN Report No. DD/EE/84-1, 1984.
[9] G. C. Fox and S. Wolfram, Phys. Rev. Lett. **41**, 1581 (1978).
[10] ARGUS Collaboration, H. Albrecht *et al.*, Phys. Lett. B **229**, 304 (1989); **241**, 278 (1990).
[11] Particle Data Group, K. Hagiwara *et al.*, Phys. Rev. D **66**, 010001 (2002).
[12] Belle Collaboration, K. Abe *et al.*, Phys. Lett. B **538**, 11 (2002).
[13] Belle Collaboration, K. Abe *et al.*, Phys. Rev. D **65**, 091103(R) (2002).