Observation of the $D_{sJ}(2317)$ and $D_{sJ}(2457)$ in B Decays

P. Krokovny,[1] K. Abe,[7] K. Abe,[38] T. Abe,[7] I. Adachi,[7] H. Aihara,[40] K. Akai,[7] M. Akatsu,[20] M. Akemoto,[7] Y. Asano,[45] T. Aso,[44] T. Aushev,[11] A. M. Bakich,[35] I. Bedny,[1] P. K. Behera,[46] I. Bizjak,[12] A. Bondar,[1] M. Bračko,[18,12] T. E. Browder,[6] B. C. K. Casey,[6] Y. Chao,[24] B. G. Cheon,[34] R. Chistov,[11] S.-K. Choi,[5] Y. Choi,[34] Y. K. Choi,[34] A. Chuvikov,[30] L. Y. Dong,[9] J. Dragic,[19] S. Eidelman,[1] V. Eiges,[11] Y. Enari,[20] J. Flanagan,[7] N. Gabyshev,[7] A. Garmash,[1,7] T. Gershon,[7] B. Golob,[17,12] R. Guo,[22] C. Hagner,[47] F. Handa,[39] N. C. Hastings,[7] H. Hayashii,[21] M. Hazumi,[7] L. Hinz,[16] T. Hokuue,[20] Y. Hoshi,[38] W.-S. Hou,[24] H.-C. Huang,[24] Y. Igarashi,[7] H. Ikeda,[7] A. Ishikawa,[20] R. Itoh,[7] H. Iwasaki,[7] M. Iwasaki,[40] H. K. Jang,[33] T. Kamitani,[7] J. H. Kang,[49] N. Katayama,[7] H. Kawai,[2] T. Kawasaki,[27] H. Kichimi,[7] E. Kikutani,[7] D.W. Kim,[34] H. J. Kim,[49] Hyunwoo Kim,[14] J. H. Kim,[34] K. Kinoshita,[3] H. Koiso,[7] P. Koppenburg,[7] S. Korpar,[18,12] P. Križan,[17,12] A. Kuzmin,[1] Y.-J. Kwon,[49] J. S. Lange,[4,31] S. H. Lee,[33] T. Lesiak,[25] A. Limosani,[19] S.-W. Lin,[24] J. MacNaughton,[10] G. Majumder,[36] F. Mandl,[10] M. Masuzawa,[7] T. Matsumoto,[42] S. Michizono,[7] Y. Mikami,[39] W. Mitaroff,[10] H. Miyata,[27] D. Mohapatra,[47] G. R. Moloney,[19] T. Nagamine,[39] Y. Nagasaka,[8] T. Nakadaira,[40] T. T. Nakamura,[7] E. Nakano,[28] M. Nakao,[7] H. Nakazawa,[7] J.W. Nam,[34] Z. Natkaniec,[25] S. Nishida,[7] O. Nitoh,[43] T. Nozaki,[7] S. Ogawa,[37] Y. Ogawa,[7] Y. Ohnishi,[7] T. Ohshima,[20] N. Ohuchi,[7] K. Oide,[7] T. Okabe,[20] S. Okuno,[13] S. L. Olsen,[6] W. Ostrowicz,[25] H. Ozaki,[7] H. Palka,[25] C.W. Park,[14] H. Park,[15] K. S. Park,[34] N. Parslow,[35] L. E. Piilonen,[47] N. Root,[1] M. Rozanska,[25] H. Sagawa,[7] S. Saitoh,[7] Y. Sakai,[7] T. R. Sarangi,[46] A. Satpathy,[7,3] O. Schneider,[16] C. Schwanda,[7,10] A. J. Schwartz,[3] S. Semenov,[11] M. E. Sevior,[19] H. Shibuya,[37] T. Shidara,[7] V. Sidorov,[1] J. B. Singh,[29] N. Soni,[29] S. Stanič,[45,*] A. Sugi,[20] K. Sumisawa,[7] T. Sumiyoshi,[42] S. Suzuki,[48] F. Takasaki,[7] K. Tamai,[7] N. Tamura,[27] J. Tanaka,[40] M. Tanaka,[7] M. Tawada,[7] Y. Teramoto,[28] T. Tomura,[40] K. Trabelsi,[6] T. Tsuboyama,[7] T. Tsukamoto,[7] S. Uehara,[7] K. E. Varvell,[35] C. H. Wang,[23] Y. Watanabe,[41] E. Won,[14] B. D. Yabsley,[47] Y. Yamada,[7] A. Yamaguchi,[39] N. Yamamoto,[7] Y. Yamashita,[26] M. Yamauchi,[7] H. Yanai,[27] Y. Yuan,[9] C. C. Zhang,[9] Z. P. Zhang,[32] V. Zhilich,[1] and D. Žontar[17,12]

(Belle Collaboration)

[1]*Budker Institute of Nuclear Physics, Novosibirsk*
[2]*Chiba University, Chiba*
[3]*University of Cincinnati, Cincinnati, Ohio 45221*
[4]*University of Frankfurt, Frankfurt*
[5]*Gyeongsang National University, Chinju*
[6]*University of Hawaii, Honolulu, Hawaii 96822*
[7]*High Energy Accelerator Research Organization (KEK), Tsukuba*
[8]*Hiroshima Institute of Technology, Hiroshima*
[9]*Institute of High Energy Physics, Chinese Academy of Sciences, Beijing*
[10]*Institute of High Energy Physics, Vienna*
[11]*Institute for Theoretical and Experimental Physics, Moscow*
[12]*J. Stefan Institute, Ljubljana*
[13]*Kanagawa University, Yokohama*
[14]*Korea University, Seoul*
[15]*Kyungpook National University, Taegu*
[16]*Institut de Physique des Hautes Énergies, Université de Lausanne, Lausanne*
[17]*University of Ljubljana, Ljubljana*
[18]*University of Maribor, Maribor*
[19]*University of Melbourne, Victoria*
[20]*Nagoya University, Nagoya*
[21]*Nara Women's University, Nara*
[22]*National Kaohsiung Normal University, Kaohsiung*
[23]*National Lien-Ho Institute of Technology, Miao Li*
[24]*Department of Physics, National Taiwan University, Taipei*
[25]*H. Niewodniczanski Institute of Nuclear Physics, Krakow*
[26]*Nihon Dental College, Niigata*
[27]*Niigata University, Niigata*
[28]*Osaka City University, Osaka*
[29]*Panjab University, Chandigarh*
[30]*Princeton University, Princeton, New Jersey 08545*

 0031-9007/03/91(26)/262002(6)$20.00

[31]RIKEN BNL Research Center, Upton, New York 11973
[32]University of Science and Technology of China, Hefei
[33]Seoul National University, Seoul
[34]Sungkyunkwan University, Suwon
[35]University of Sydney, Sydney NSW
[36]Tata Institute of Fundamental Research, Bombay
[37]Toho University, Funabashi
[38]Tohoku Gakuin University, Tagajo
[39]Tohoku University, Sendai
[40]Department of Physics, University of Tokyo, Tokyo
[41]Tokyo Institute of Technology, Tokyo
[42]Tokyo Metropolitan University, Tokyo
[43]Tokyo University of Agriculture and Technology, Tokyo
[44]Toyama National College of Maritime Technology, Toyama
[45]University of Tsukuba, Tsukuba
[46]Utkal University, Bhubaneswer
[47]Virginia Polytechnic Institute and State University, Blacksburg, Virginia 24061
[48]Yokkaichi University, Yokkaichi
[49]Yonsei University, Seoul
(Received 8 August 2003; published 31 December 2003)

We report the first observation of the $B \to \bar{D}D_{sJ}(2317)$ and $B \to \bar{D}D_{sJ}(2457)$ decays based on 123.8×10^6 $B\bar{B}$ events collected with the Belle detector at KEKB. We observe the $D_{sJ}(2317)$ decay to $D_s\pi^0$ and the $D_{sJ}(2457)$ decay to the $D_s^*\pi^0$ and $D_s\gamma$ final states. We also set 90% C.L. upper limits for the decays $D_{sJ}(2317) \to D_s^*\gamma$, $D_{sJ}(2457) \to D_s^*\gamma$, $D_{sJ}(2457) \to D_s\pi^0$, and $D_{sJ}(2457) \to D_s\pi^+\pi^-$.

DOI: 10.1103/PhysRevLett.91.262002 PACS numbers: 14.40.Lb, 13.25.Hw

Recently a new $D_s\pi^0$ resonance with a mass of 2317 MeV$/c^2$ and a very narrow width was observed by the *BABAR* Collaboration [1]. A natural interpretation is that this is a P-wave $c\bar{s}$ quark state that is below the DK threshold, which accounts for the small width [2]. This interpretation is supported by the observation of a $D_s^*\pi^0$ resonance [3] by the CLEO Collaboration [4] and Belle Collaboration [5]. All groups observe these states in inclusive e^+e^- processes. The mass difference between the two observed states is consistent with the expected hyperfine splitting of the P wave D_s meson doublet with total light-quark angular momentum $j = 1/2$ [2]. However, the masses of these states are considerably below potential model expectations [6] and are nearly the same as those of the corresponding $c\bar{u}$ states recently measured by Belle [7]. The low mass values have caused speculation that these states may be more exotic than a simple $q\bar{q}$ meson system [8–13]. To clarify the nature of these states, it is necessary to determine their quantum numbers and decay branching fractions, particularly those for radiative decays. In this context it is useful to search for these states, which we refer to as D_{sJ}, in exclusive B meson decay processes.

We search for decays of the type $B \to \bar{D}D_{sJ}$, which are expected to be the dominant exclusive D_{sJ} production mechanism in B decays. Because of the known properties of the parent B meson, angular analyses of these decays can unambiguously determine the D_{sJ} quantum numbers. Moreover, since QCD sum rules in the heavy quark effect theory predict that P-wave mesons with $j = 1/2$ should be more readily produced in B decays than mesons with $j = 3/2$ [14], the observation of $B \to \bar{D}D_{sJ}$ would provide additional support for the P-wave nature of these states as well as serving as a check of these predictions.

In this Letter we report on a search for the $B \to \bar{D}D_{sJ}(2317)$ and $B \to \bar{D}D_{sJ}(2457)$ decays based on a sample of 123.8×10^6 $B\bar{B}$ pairs produced at the KEKB asymmetric energy e^+e^- collider [15]. The inclusion of charge conjugate states is implicit throughout this paper.

The Belle detector has been described elsewhere [16]. Charged tracks are selected with a set of requirements based on the average hit residual and impact parameter relative to the interaction point (IP). The transverse momentum of at least 0.05 GeV$/c$ is required for each track in order to reduce the combinatorial background.

For charged particle identification (PID), the combined information from specific ionization in the central drift chamber (dE/dx), time-of-flight scintillation counters, and aerogel Čerenkov counters is used. Charged kaons are selected with PID criteria that have an efficiency of 88%, a pion misidentification probability of 8%, and negligible contamination from protons. All charged tracks with PID responses consistent with a pion hypothesis that are not positively identified as electrons are considered as pion candidates.

Neutral kaons are reconstructed via the decay $K_S^0 \to \pi^+\pi^-$ with no PID requirements for the daughter pions. The two-pion invariant mass is required to be within 9 MeV$/c^2$ ($\sim 3\sigma$) of the K^0 mass and the displacement of the $\pi^+\pi^-$ vertex from the IP in the transverse ($r - \varphi$)

plane is required to be between 0.2 and 20 cm. The direction in the $r - \varphi$ plane from the IP to the $\pi^+\pi^-$ vertex is required to agree within 0.2 rad with the combined momentum of the two pions.

Photon candidates are selected from calorimeter showers not associated with charged tracks. An energy deposition of at least 30 MeV and a photonlike shape are required for each candidate. A pair of photons with an invariant mass within 12 MeV$/c^2$ ($\sim 2.5\sigma$) of the π^0 mass is considered as a π^0 candidate.

We reconstruct $\bar{D}^0(D^-)$ mesons in the $K^+\pi^-$, $K^+\pi^-\pi^-\pi^+$, and $K^+\pi^-\pi^0$ ($K^+\pi^-\pi^-$) decay channels and require the invariant mass to be within 12 MeV$/c^2$ (1.5σ for $K^+\pi^-\pi^0$ and 2.5σ for other modes) of the $\bar{D}^0(D^-)$ mass. For the π^0 from the $\bar{D}^0 \to K^+\pi^-\pi^0$ decay, we require that the π^0 momentum in the $\Upsilon(4S)$ center-of-mass (c.m.) frame be greater than 0.4 GeV$/c$ in order to reduce combinatorial backgrounds. We reconstruct D_s^+ mesons in the $\phi\pi^+$, $\bar{K}^{*0}K^+$, and $K_S^0K^+$ decay channels. ϕ mesons are reconstructed from K^+K^- pairs with an invariant mass within 10 MeV$/c^2$ (2.5Γ) of the ϕ mass. $\bar{K}^{*0}$ mesons are reconstructed from $K^-\pi^+$ pairs with an invariant mass within 75 MeV$/c^2$ (1.5Γ) of the $\bar{K}^{*0}$ mass. After calculating the invariant mass of the corresponding set of particles, we define the D_s^+ signal region as being within 12 MeV$/c^2$ ($\sim 2.5\sigma$) of the D_s mass. D_s^* mesons are reconstructed in the $D_s^* \to D_s\gamma$ decay channel. The mass difference between D_s^* and D_s candidates is required to be within 8 MeV$/c^2$ of its nominal value ($\sim 2.5\sigma$). The D_{sJ} candidates are reconstructed from $D_s^{(*)}$ mesons and a π^0, γ, or $\pi^+\pi^-$ pair. The mass difference $M(D_{sJ}) - M(D_s^{(*)})$ is used to select D_{sJ} candidates. We use central mass values of 2317 and 2460 MeV$/c^2$ for $D_{sJ}(2317)$ and $D_{sJ}(2457)$, respectively, and define signal regions within 12 MeV$/c^2$ for the corresponding mass difference.

We combine $\bar{D}$ and D_{sJ} candidates to form B mesons. Candidate events are identified by their c.m. energy difference, $\Delta E = (\sum_i E_i) - E_{\rm beam}$, and the beam constrained mass, $M_{\rm bc} = \sqrt{E_{\rm beam}^2 - (\sum_i \vec{p}_i)^2}$, where $E_{\rm beam}$ is the beam energy and $\vec{p}_i$ and E_i are the momenta and energies of the decay products of the B meson in the c.m. frame. We select events with $5.272 < M_{\rm bc} < 5.288$ GeV$/c^2$ and $|\Delta E| < 0.2$ GeV, and define a B signal region of $|\Delta E| < 0.03$ GeV. In cases with more than one candidate in an event, the one with D and $D_s^{(*)+}$ masses closest to the nominal values is chosen. We use a Monte Carlo (MC) simulation to model the response of the detector and determine the efficiency [17].

Variables that characterize the event topology are used to suppress background from the two-jet-like $e^+e^- \to q\bar{q}$ continuum process. We require $|\cos\theta_{\rm thr}| < 0.80$, where $\theta_{\rm thr}$ is the angle between the thrust axis of the B candidate and that of the rest of the event; this eliminates 77% of the continuum background while retaining 78% of the signal events. To suppress combinatorial background we apply a restriction on the invariant mass of the D meson and the π^0 or γ from D_{sJ} decay: $M(D\pi^0) > 2.3$ GeV$/c^2$, $M(D\gamma) > 2.2$ GeV$/c^2$.

The ΔE and D_{sJ} candidate's invariant mass $[M(D_{sJ})]$ distributions for $B \to \bar{D}D_{sJ}$ candidates are presented in Fig. 1, where all $\bar{D}^0$ and D^- decay modes are combined. Each distribution is the projection of the signal

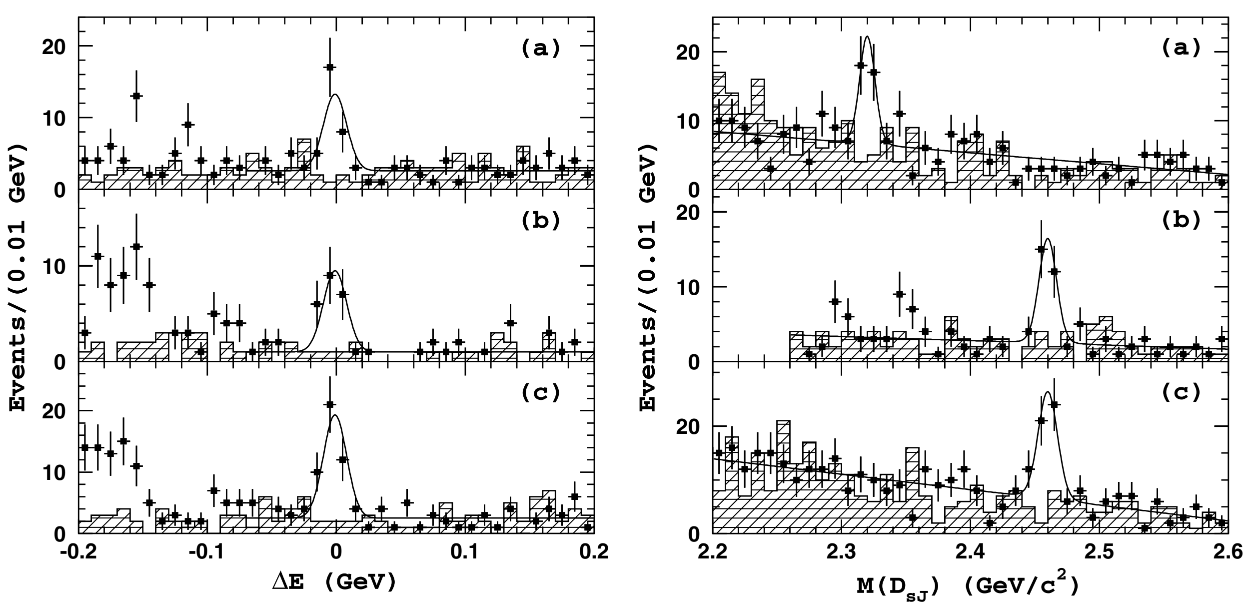

FIG. 1. ΔE (left) and $M(D_{sJ})$ (right) distributions for the $B \to \bar{D}D_{sJ}$ candidates: (a) $D_{sJ}(2317) \to D_s\pi^0$, (b) $D_{sJ}(2457) \to D_s^*\pi^0$, and (c) $D_{sJ}(2457) \to D_s\gamma$. Points with errors represent the experimental data, crosshatched histograms show the sidebands, and curves are the results of the fits.

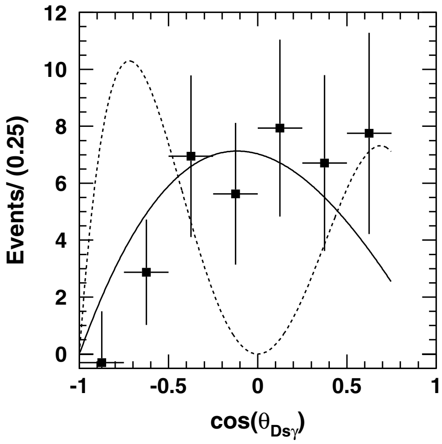

FIG. 2. The $D_{sJ}(2457) \to D_s\gamma$ helicity distribution. The points with error bars are the results of fits to the ΔE spectra for experimental events. Solid and dashed curves are MC predictions for the $J = 1$ and $J = 2$ hypotheses, respectively. The highest bin has no events because of the cut on the $D\gamma$ invariant mass.

region of the other parameter; distributions for events in the $M(D_{sJ})$ and ΔE sidebands are shown as cross-hatched histograms. Clear signals are observed for the $DD_{sJ}(2317)[D_s\pi^0]$ and $DD_{sJ}(2457)[D_s^*\pi^0, D_s\gamma]$ final states. The measured masses for the $D_{sJ}(2317)$ and $D_{sJ}(2457)$ are $(2319.8 \pm 2.1 \pm 2.0)$ MeV/c^2 and $(2459.2 \pm 1.6 \pm 2.0)$ MeV/c^2, respectively. The fitted widths are consistent with those expected for D_{sJ} mesons of zero intrinsic width. The systematic error in the D_{sJ} mass is expected to come from the photon energy scale.

We also study the helicity distribution for the $D_{sJ}(2457) \to D_s\gamma$ decay. The helicity angle $\theta_{D_s\gamma}$ is defined as the angle between the $D_{sJ}(2457)$ momentum in the B meson rest frame and the D_s momentum in the $D_{sJ}(2457)$ rest frame. The $\theta_{D_s\gamma}$ distribution in the data (Fig. 2) is consistent with MC expectations for the $J = 1$ hypothesis for the $D_{sJ}(2457)$ (χ^2/n.d.f. = 5/6, where n.d.f represents number of dimensions of freedom), and contradicts the $J = 2$ hypothesis (χ^2/n.d.f. = 44/6). The $J = 0$ hypothesis is already ruled out by the conservation of angular momentum and parity in $D_{sJ}(2457) \to D_s\gamma$.

For each decay channel, the ΔE distribution is fitted with a Gaussian signal and a linear background function. The Gaussian mean value and width are fixed to the values from a MC simulation of signal events. The region $\Delta E < -0.07$ GeV is excluded from the fit to avoid contributions from other B decays of the type $B \to \bar{D}D_{sJ}X$ where X denotes an additional particle that is not reconstructed. The $M(D_{sJ})$ distribution is fitted by the sum of a Gaussian for the signal and a linear function for the background. The Gaussian width is fixed to the value found in the MC (6–7 MeV/c^2 depending on the decay mode). The fit results are given in Table I, where the listed efficiencies include intermediate branching fractions. We use the ΔE distribution to calculate the branching fractions. The statistical significance of the signal quoted in Table I is defined as $\sqrt{-2\ln(\mathcal{L}_0/\mathcal{L}_{\max})}$, where $\mathcal{L}_{\max}$ and $\mathcal{L}_0$ denote the maximum likelihood with the nominal and with zero signal yield, respectively.

The results of combined fits of $B^+ \to \bar{D}^0 D_{sJ}^+$ and $B^0 \to D^- D_{sJ}^+$ modes assuming isospin invariance are shown in Table II. The normalization of the background in each submode is allowed to float while the signal yields are required to satisfy the constraint $N_i = N_{B\bar{B}} \cdot \mathcal{B}(B \to \bar{D}D_{sJ}) \cdot \varepsilon_i$, where the branching fraction $\mathcal{B}(B \to \bar{D}D_{sJ})$ is a fit parameter; $N_{B\bar{B}}$ is the

TABLE I. Product branching fractions for $B \to \bar{D}D_{sJ}$ decays.

Decay channel	ΔE yield	$M(D_{sJ})$ yield	Efficiency, 10^{-4}	$\mathcal{B}$, 10^{-4}	Significance
$B^+ \to \bar{D}^0 D_{sJ}^+(2317)[D_s^+\pi^0]$	$13.7^{+5.1}_{-4.5}$	$13.4^{+6.2}_{-5.4}$	1.36	$8.1^{+3.0}_{-2.7} \pm 2.4$	5.0σ
$B^0 \to D^- D_{sJ}^+(2317)[D_s^+\pi^0]$	$10.3^{+3.9}_{-3.1}$	$10.8^{+4.2}_{-3.6}$	0.97	$8.6^{+3.3}_{-2.6} \pm 2.6$	6.1σ
$B^+ \to \bar{D}^0 D_{sJ}^+(2317)[D_s^{*+}\gamma]$	$3.4^{+2.8}_{-2.2}$	$2.1^{+4.1}_{-3.4}$	1.08	$2.5^{+2.1}_{-1.6}(<7.6)$	⋯
$B^0 \to D^- D_{sJ}^+(2317)[D_s^{*+}\gamma]$	$2.3^{+2.5}_{-1.9}$	$1.6^{+2.4}_{-1.9}$	0.69	$2.7^{+2.9}_{-2.2}(<9.5)$	⋯
$B^+ \to \bar{D}^0 D_{sJ}^+(2457)[D_s^{*+}\pi^0]$	$7.2^{+3.7}_{-3.0}$	$8.9^{+4.0}_{-3.3}$	0.49	$11.9^{+6.1}_{-4.9} \pm 3.6$	2.9σ
$B^0 \to D^- D_{sJ}^+(2457)[D_s^{*+}\pi^0]$	$11.8^{+3.8}_{-3.2}$	$14.9^{+4.4}_{-3.9}$	0.42	$22.7^{+7.3}_{-6.2} \pm 6.8$	6.5σ
$B^+ \to \bar{D}^0 D_{sJ}^+(2457)[D_s^+\gamma]$	$19.1^{+5.6}_{-5.0}$	$20.2^{+7.2}_{-6.9}$	2.75	$5.6^{+1.6}_{-1.5} \pm 1.7$	5.0σ
$B^0 \to D^- D_{sJ}^+(2457)[D_s^+\gamma]$	$18.5^{+5.0}_{-4.3}$	$19.6^{+5.6}_{-4.9}$	1.83	$8.2^{+2.2}_{-1.9} \pm 2.5$	6.5σ
$B^+ \to \bar{D}^0 D_{sJ}^+(2457)[D_s^{*+}\gamma]$	$4.4^{+3.8}_{-3.3}$	$8.2^{+4.0}_{-3.4}$	1.15	$3.1^{+2.7}_{-2.3}(<9.8)$	⋯
$B^0 \to D^- D_{sJ}^+(2457)[D_s^{*+}\gamma]$	$1.1^{+1.8}_{-1.2}$	$0.2^{+1.8}_{-1.2}$	0.71	$1.3^{+2.0}_{-1.4}(<6.0)$	⋯
$B^+ \to \bar{D}^0 D_{sJ}^+(2457)[D_s^+\pi^+\pi^-]$	<4.0	$-2.2^{+2.0}_{-1.6}$	1.89	<2.2	⋯
$B^0 \to D^- D_{sJ}^+(2457)[D_s^+\pi^+\pi^-]$	<2.5	$-1.2^{+2.7}_{-2.0}$	1.35	<2.0	⋯
$B^+ \to \bar{D}^0 D_{sJ}^+(2457)[D_s^+\pi^0]$	<2.4	$1.0^{+2.7}_{-2.0}$	0.94	<2.7	⋯
$B^0 \to D^- D_{sJ}^+(2457)[D_s^+\pi^0]$	<2.4	$0.3^{+1.8}_{-1.2}$	0.68	<3.6	⋯

TABLE II. Combined fit results.

Decay channel	$\mathcal{B}$, 10^{-4}	Significance
$B \to \bar{D}D_{sJ}(2317)[D_s\pi^0]$	$8.5^{+2.1}_{-1.9} \pm 2.6$	6.1σ
$B \to \bar{D}D_{sJ}(2317)[D_s^*\gamma]$	$2.5^{+2.0}_{-1.8}(<7.5)$	1.8σ
$B \to \bar{D}D_{sJ}(2457)[D_s^*\pi^0]$	$17.8^{+4.5}_{-3.9} \pm 5.3$	6.4σ
$B \to \bar{D}D_{sJ}(2457)[D_s\gamma]$	$6.7^{+1.3}_{-1.2} \pm 2.0$	7.4σ
$B \to \bar{D}D_{sJ}(2457)[D_s^*\gamma]$	$2.7^{+1.8}_{-1.5}(<7.3)$	2.1σ
$B \to \bar{D}D_{sJ}(2457)[D_s\pi^+\pi^-]$	<1.6	...
$B \to \bar{D}D_{sJ}(2457)[D_s\pi^0]$	<1.8	...

number of $B\bar{B}$ pairs and ε_i is the efficiency, which includes all intermediate branching fractions. From the two $B \to \bar{D}D_{sJ}(2457)$ branching fraction measurements, we determine the ratio $\mathcal{B}(D_{sJ}(2457) \to D_s\gamma)/\mathcal{B}(D_{sJ}(2457) \to D_s^*\pi^0) = 0.38 \pm 0.11 \pm 0.04$.

The signals for the $B \to \bar{D}D_{sJ}(2317)[D_s\pi^0]$ and $B \to \bar{D}D_{sJ}(2457)[D_s^*\pi^0, D_s\gamma]$ channels have greater than 5σ statistical significance. Figure 3 shows the ΔE distributions for the other channels, where significant signals are not seen. We set 90% C.L. upper limits for these modes.

We study the possible feed across between all studied D_{sJ} decay modes using MC. We also analyze a MC sample of generic $B\bar{B}$ events corresponding to our data sample. No peaking background is found. As a check, we apply a similar procedure to decay chains with the similar final states: $B \to \bar{D}^{(*)}D_s^{(*)}$. For each mode, we measure branching fractions that are consistent with the world average values [18].

The following sources of systematic errors are considered: tracking efficiency (1%–2% per track), kaon identification efficiency (1%), π^0 efficiency (6%), K_S^0 reconstruction efficiency (6%), D branching fraction uncertainties (2%–6%), signal and background shape parametrization (4%), and MC statistics (3%). The uncertainty in the tracking efficiency is estimated using partially reconstructed $D^{*+} \to D^0[K_S^0\pi^+\pi^-]\pi^+$ decays. The kaon identification uncertainty is determined from $D^{*+} \to D^0[K^-\pi^+]\pi^+$ decays. The π^0 reconstruction uncertainty is obtained using D^0 decays to $K^-\pi^+$ and $K^-\pi^+\pi^0$. We assume equal production rates for B^+B^- and $B^0\bar{B}^0$ pairs and do not include the uncertainty related to this assumption in the total systematic error. For the calculation of the branching fractions, the errors in the D_s meson branching fractions are taken into account. These uncertainties are dominated by the error on the $D_s \to \phi\pi^+$ branching ratio of 25% [18]. The overall systematic uncertainty is 30%.

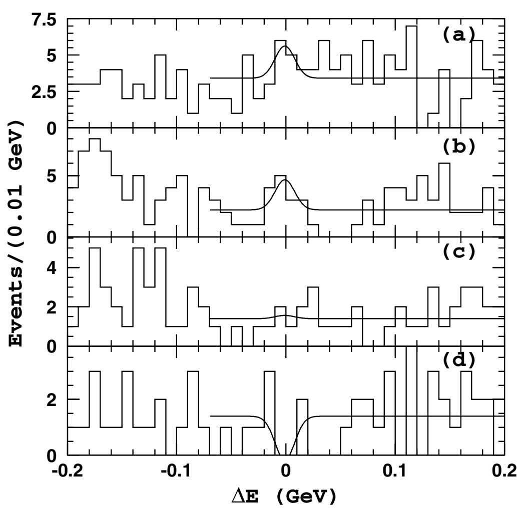

FIG. 3. ΔE distributions for the decay channels with no significant signals: (a) $DD_{sJ}(2317)[D_s^*\gamma]$, (b) $DD_{sJ}(2457) \times [D_s^*\gamma]$, (c) $DD_{sJ}(2457)[D_s\pi^+\pi^-]$, and (d) $DD_{sJ}(2457)[D_s\pi^0]$. Open histograms represent the experimental data and curves show the results of the fits.

In summary, we report the first observation of $B \to \bar{D}D_{sJ}(2317)$ and $B \to \bar{D}D_{sJ}(2457)$ decays. The measured branching fractions with the corresponding statistical significances are presented in Table II. The observation of $D_{sJ}(2457) \to D_s\gamma$ decay eliminates the zero spin of $D_{sJ}(2457)$. The angular analysis of this decay supports the hypothesis that the $D_{sJ}(2457)$ is a 1^+ state.

We wish to thank the KEKB accelerator group for the 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 Education, Science and Training; the 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 01324; the Ministry of Science and Technology of the Russian Federation; the Ministry of Education, Science and Sport of the Republic 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] *BABAR* Collaboration, B. Aubert *et al.*, Phys. Rev. Lett. **90**, 242001 (2003).
[2] W. Bardeen, E. Eichten, and C. Hill, Phys. Rev. D **68**, 054024 (2003).
[3] In the heavy c-quark mass limit, one expects two doublets of $c\bar{s}$ states with quantum numbers $J^P = 0^+, 1^+$ and $1^+, 2^+$. The second one has been observed in $D^{(*)}K$ decays.
[4] CLEO Collaboration, D. Besson *et al.*, Phys. Rev. D **68**, 032002 (2003).
[5] Belle Collaboration, K. Abe *et al.*, EPS contribution paper, BELLE-CONF-0340, hep-ex/0307052.

[6] J. Bartelt and S. Shukla, Annu. Rev. Nucl. Part. Sci. **45**, 133 (1995).
[7] Belle Collaboration, K. Abe *et al.*, hep-ex/0307021 [Phys. Rev. D (to be published)].
[8] R. Cahn and D. Jackson, Phys. Rev. D **68**, 037502 (2003).
[9] T. Barnes, F. Close, and H. Lipkin, Phys. Rev. D **68**, 054006 (2003).
[10] E. van Beveren and G. Rupp, Phys. Rev. Lett. **91**, 012003 (2003).
[11] H. Cheng and W. Hou, Phys. Lett. B **566**, 193 (2003).
[12] P. Colangelo and F. Fazio, Phys. Lett. B **570**, 180 (2003).
[13] S. Godfrey, Phys. Lett. B **568**, 254 (2003).
[14] A. Yaouanc *et al.*, Phys. Lett. B **520**, 59 (2001).
[15] S. Kurokawa and E. Kikutani, Nucl. Instrum. Methods Phys. Res., Sect. A **499**, 1 (2003).
[16] Belle Collaboration, A. Abashian *et al.*, Nucl. Instrum. Methods Phys. Res., Sect. A **479**, 117 (2002).
[17] R. Brun *et al.*, GEANT 3.21, CERN Report No. DD/EE/84-1, 1984.
[18] Particle Data Group, K. Hagiwara *et al.*, Phys. Rev. D **66**, 010001 (2002).