PRL **94,** 182002 (2005) PHYSICAL REVIEW LETTERS week ending 13 MAY 2005

Observation of a Near-Threshold $\omega J/\psi$ Mass Enhancement in Exclusive $B \to K\omega J/\psi$ Decays

S.-K. Choi,[6] S. L. Olsen,[7] K. Abe,[8] K. Abe,[39] I. Adachi,[8] H. Aihara,[41] Y. Asano,[45] S. Bahinipati,[4] A. M. Bakich,[36] Y. Ban,[31] I. Bedny,[1] U. Bitenc,[12] I. Bizjak,[12] A. Bondar,[1] A. Bozek,[25] M. Bračko,[8,18,12] J. Brodzicka,[25] T. E. Browder,[7] M.-C. Chang,[24] P. Chang,[24] A. Chen,[22] W. T. Chen,[22] B. G. Cheon,[3] R. Chistov,[11] Y. Choi,[35] A. Chuvikov,[48] S. Cole,[36] J. Dalseno,[19] M. Danilov,[11] M. Dash,[46] A. Drutskoy,[4] S. Eidelman,[1] Y. Enari,[20] F. Fang,[7] S. Fratina,[12] N. Gabyshev,[1] T. Gershon,[8] G. Gokhroo,[37] B. Golob,[17,12] T. Hara,[29] N. C. Hastings,[8] K. Hayasaka,[20] H. Hayashii,[21] M. Hazumi,[8] L. Hinz,[16] T. Hokuue,[20] Y. Hoshi,[39] S. Hou,[22] W.-S. Hou,[24] Y. B. Hsiung,[24] T. Iijima,[20] A. Imoto,[21] K. Inami,[20] A. Ishikawa,[8] M. Iwasaki,[41] Y. Iwasaki,[8] J. H. Kang,[47] J. S. Kang,[14] S. U. Kataoka,[21] N. Katayama,[8] H. Kawai,[2] T. Kawasaki,[27] H. R. Khan,[42] H. Kichimi,[8] H. J. Kim,[15] S. M. Kim,[35] K. Kinoshita,[4] S. Korpar,[18,12] P. Križan,[17,12] P. Krokovny,[1] C. C. Kuo,[22] A. Kuzmin,[1] Y.-J. Kwon,[47] J. S. Lange,[5] S. E. Lee,[34] S. H. Lee,[34] T. Lesiak,[25] J. Li,[33] S.-W. Lin,[24] D. Liventsev,[11] G. Majumder,[37] T. Matsumoto,[43] A. Matyja,[25] W. Mitaroff,[10] K. Miyabayashi,[21] H. Miyata,[27] R. Mizuk,[11] D. Mohapatra,[46] G. R. Moloney,[19] E. Nakano,[28] M. Nakao,[8] H. Nakazawa,[8] S. Nishida,[8] O. Nitoh,[44] S. Ogawa,[38] T. Ohshima,[20] T. Okabe,[20] S. Okuno,[13] W. Ostrowicz,[25] H. Palka,[25] C. W. Park,[35] N. Parslow,[36] R. Pestotnik,[12] L. E. Piilonen,[46] M. Rozanska,[25] H. Sagawa,[8] Y. Sakai,[8] N. Sato,[20] T. Schietinger,[16] O. Schneider,[16] C. Schwanda,[10] H. Shibuya,[38] B. Shwartz,[1] A. Somov,[4] N. Soni,[30] S. Stanič,[45,*] M. Starič,[12] T. Sumiyoshi,[43] S. Suzuki,[32] S. Y. Suzuki,[8] O. Tajima,[8] F. Takasaki,[8] K. Tamai,[8] N. Tamura,[27] Y. Teramoto,[28] X. C. Tian,[31] K. Trabelsi,[7] S. Uehara,[8] T. Uglov,[11] S. Uno,[8] G. Varner,[7] K. E. Varvell,[36] S. Villa,[16] C. H. Wang,[23] M.-Z. Wang,[24] M. Watanabe,[27] B. D. Yabsley,[46] A. Yamaguchi,[40] Y. Yamashita,[26] M. Yamauchi,[8] Heyoung Yang,[34] Y. Yuan,[9] Y. Yusa,[40] C. C. Zhang,[9] J. Zhang,[8] L. M. Zhang,[33] Z. P. Zhang,[33] D. Žontar,[17,12] and D. Zürcher[16]

(Belle Collaboration)

[1]*Budker Institute of Nuclear Physics, Novosibirsk*
[2]*Chiba University, Chiba*
[3]*Chonnam National University, Kwangju*
[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]*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]*Swiss Federal Institute of Technology of Lausanne, EPFL, 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 Central University, Chung-li*
[23]*National United University, 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]*Osaka University, Osaka*
[30]*Panjab University, Chandigarh*
[31]*Peking University, Beijing*
[32]*Saga University, Saga*
[33]*University of Science and Technology of China, Hefei*

[34]*Seoul National University, Seoul*
[35]*Sungkyunkwan University, Suwon*
[36]*University of Sydney, Sydney NSW*
[37]*Tata Institute of Fundamental Research, Bombay*
[38]*Toho University, Funabashi*
[39]*Tohoku Gakuin University, Tagajo*
[40]*Tohoku University, Sendai*
[41]*Department of Physics, University of Tokyo, Tokyo*
[42]*Tokyo Institute of Technology, Tokyo*
[43]*Tokyo Metropolitan University, Tokyo*
[44]*Tokyo University of Agriculture and Technology, Tokyo*
[45]*University of Tsukuba, Tsukuba*
[46]*Virginia Polytechnic Institute and State University, Blacksburg, Virginia 24061*
[47]*Yonsei University, Seoul*
[48]*Princeton University, Princeton, New Jersey 08545*

(Received 23 December 2004; published 12 May 2005)

We report the observation of a near-threshold enhancement in the $\omega J/\psi$ invariant mass distribution for exclusive $B \rightarrow K\omega J/\psi$ decays. The results are obtained from a 253 fb^{-1} data sample that contains 275×10^6 $B\bar{B}$ pairs that were collected near the $\Upsilon(4S)$ resonance with the Belle detector at the KEKB asymmetric energy e^+e^- collider. The statistical significance of the $\omega J/\psi$ mass enhancement is estimated to be greater than 8σ.

DOI: 10.1103/PhysRevLett.94.182002 PACS numbers: 14.40.Gx, 12.39.Mk, 13.25.Hw

Recently there has been a revival of interest in the possible existence of mesons with a more complex structure than the simple $q\bar{q}$ bound states of the original quark model. There are long-standing predictions of four-quark $q\bar{q}q\bar{q}$ meson-meson resonance states [1] and for *$q\bar{q}$-gluon* hybrid states [2]. Searches for these types of particles in systems that include a charmed-anticharmed quark pair ($c\bar{c}$) are particularly effective because for at least some of these cases, the states are expected to have clean experimental signatures as well as relatively narrow widths, thereby reducing the possibility of overlap with standard $c\bar{c}$ mesons.

B meson decays are a prolific source of $c\bar{c}$ pairs and the large B meson samples produced at B factories are providing opportunities to search for missing $c\bar{c}$ charmonium mesons as well as more complex states. From studies of $K_S^0 K^- \pi^+$ systems produced in exclusive $B \rightarrow K K_S^0 K^- \pi^+$ decays with a 45×10^6 $B\bar{B}$ event sample, the Belle group made the first observation of the $\eta_c(2S)$ [3]. This state was subsequently seen in two-photon reactions by other experiments [4] and in the exclusive $e^+e^- \rightarrow J/\psi \eta_c(2S)$ production process by Belle [5]. With a larger sample of 152×10^6 $B\bar{B}$ events, Belle discovered the $X(3872)$ as a narrow peak in the $\pi^+\pi^- J/\psi$ mass spectrum from exclusive $B \rightarrow K\pi^+\pi^- J/\psi$ decays [6]. This observation has been confirmed by other experiments [7]. The properties of the $X(3872)$ do not match well to any $c\bar{c}$ charmonium state [8]. This, together with the close proximity of the $X(3872)$ mass with the $m_{D^0} + m_{D^{*0}}$ mass threshold, have led some authors to interpret the $X(3872)$ as a $D^0\bar{D}^{*0}$ resonant state [9].

In this Letter we report on an analysis of $\omega J/\psi$ systems produced in exclusive $B \rightarrow K\omega J/\psi$ decays. The study is based on a 253 fb^{-1} data sample that contains 275×10^6 $B\bar{B}$ pairs collected with the Belle detector operating at the KEKB asymmetric energy e^+e^- collider [10]. KEKB operates at the $\Upsilon(4S)$ resonance ($\sqrt{s} = 10.58$ GeV) with a peak luminosity of $1.5 \times 10^{34}\ \text{cm}^{-2}\ \text{s}^{-1}$.

The Belle detector is a large-solid-angle magnetic spectrometer that consists of a silicon vertex detector, a 50-layer cylindrical drift chamber (CDC), an array of aerogel threshold Cherenkov counters (ACC), a barrel-like arrangement of time-of-flight scintillation counters (TOF), and an electromagnetic calorimeter (ECL) comprised of CsI(Tl) crystals located inside a superconducting solenoid coil that provides a 1.5 T magnetic field. An iron flux return located outside of the coil is instrumented to detect K_L mesons and to identify muons (KLM). The Belle detector is described in Ref. [11].

We select events of the type $B \rightarrow K\pi^+\pi^-\pi^0 J/\psi$, where we use both charged and neutral kaons [12]. We use the charged kaon, pion, and J/ψ requirements described in Ref. [6]. For neutral kaons we use $\pi^+\pi^-$ pairs with invariant mass within 15 MeV of m_{K_S} and a displaced vertex that is consistent with $K_S^0 \rightarrow \pi^+\pi^-$ decay. We identify a π^0 as a $\gamma\gamma$ pair that fits the $\pi^0 \rightarrow \gamma\gamma$ hypothesis with $\chi^2 < 6$. We further require the energy asymmetry $|E_{\gamma_1} - E_{\gamma_2}|/|E_{\gamma_1} + E_{\gamma_2}| < 0.9$ and the π^0 laboratory-frame momentum to be greater than 180 MeV. Events with a $\pi^+\pi^- J/\psi$ invariant mass within 3σ of $m_{\psi'}$ are rejected in order to eliminate $B \rightarrow K\pi^0\psi'$; $\psi' \rightarrow \pi^+\pi^- J/\psi$ decays. The level of $e^+e^- \rightarrow q\bar{q}$ ($q = u, d, s,$

or c quark) continuum events in the sample is reduced by the requirements $R_2 < 0.4$, where R_2 is the normalized Fox-Wolfram moment [13], and $|\cos\theta_B| < 0.8$, where θ_B is the polar angle of the B-meson direction in the center-of-mass (c.m.) system.

At the $\Upsilon(4S)$ each B meson has a total c.m. energy that is equal to $E_{\rm beam}$, the c.m. beam energy. We identify B mesons using the beam-constrained mass $M_{\rm bc} = \sqrt{E_{\rm beam}^2 - p_B^2}$ and the energy difference $\Delta E = E_{\rm beam} - E_B$, where p_B is the vector sum of the c.m. momenta of the B meson decay products and E_B is their c.m. energy sum. For the final state used in this analysis, the experimental resolutions for $M_{\rm bc}$ and ΔE are approximately 3 MeV and 13 MeV, respectively.

We select events with $M_{\rm bc} > 5.20$ GeV and $|\Delta E| < 0.2$ GeV for further analysis. For events with multiple π^0 entries in this region, we select the $\gamma\gamma$ combination with the best χ^2 value for the $\pi^0 \to \gamma\gamma$ hypothesis. Multiple entries caused by multiple charged particle assignments are small (~4%) and are tolerated. The signal region is defined as $5.2725\ {\rm GeV} < M_{\rm bc} < 5.2875$ GeV and $|\Delta E| < 0.030$ GeV, corresponding to $\pm 2.5\sigma$ from the central values. We identify three-pion combinations with $0.760\ {\rm GeV} < M(\pi^+\pi^-\pi^0) < 0.805$ GeV as candidate ω mesons. To suppress events of the type $B \to K_X J/\psi$; $K_X \to K\omega$, where K_X denotes strange meson resonances such as $K_1(1270)$, $K_1(1400)$, and $K_2^*(1430)$ that are known to decay to $K\omega$, we restrict the analysis to events in the region $M(K\omega) > 1.6$ GeV.

Figure 1(a) shows the $M_{\rm bc}$ distribution for selected events that are in the ΔE and ω signal regions. The curve in the figure is the result of a binned likelihood fit that uses a single Gaussian for the signal and an ARGUS function [14] for the background. The fit gives a signal yield of 219 ± 23 events. Figure 1(b) shows the ΔE distribution for events in the $M_{\rm bc}$ and ω signal regions. Here the curve is the result of a fit that represents the signal with a single Gaussian and the background with a first-order polynomial. The signal yield is 196 ± 21 events. Figure 1(c) shows the $M(\pi^+\pi^-\pi^0)$ distribution for all events in the $M_{\rm bc}$-ΔE signal region. The peak is well fitted with a Breit-Wigner function with the mass and width of the $\omega(780)$, broadened by an experimental resolution of 8 MeV. Here the signal yield is 204 ± 20 events. The reasonable consistency in the signal yield from all three distributions indicates that $K\omega J/\psi$ is the dominant component of $B \to K\pi^+\pi^-\pi^0 J/\psi$ decays with $M(3\pi)$ in the ω mass range and $M(K\omega) > 1.6$ GeV. The arrows in the figures indicate the signal regions for the plotted quantity.

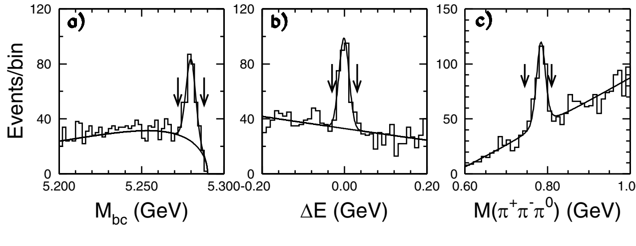

FIG. 1. (a) $M_{\rm bc}$ distributions for $B \to K\omega J/\psi$ candidates in the ΔE and $\omega \to \pi^+\pi^-\pi^0$ signal regions. (b) ΔE distribution for events in the $M_{\rm bc}$ and ω signal regions. (c) $M(\pi^+\pi^-\pi^0)$ distribution for events in the $M_{\rm bc}$ and ΔE signal regions. The curves are the results of fits described in the text; the arrows indicate the signal region for each quantity.

Figure 2 shows the Dalitz plot of $M^2(\omega J/\psi)$ (vertical) vs $M^2(\omega K)$ (horizontal) for $B \to K\omega J/\psi$ candidates in the signal regions. Here the $M(K\omega) > 1.6$ GeV requirement has been relaxed. The clustering of events near the left side of the plot are attributed to $B \to K_X J/\psi$; $K_X \to K\omega$ decays. There is an additional clustering of events with low $\omega J/\psi$ invariant masses near the bottom of the Dalitz plot; this is the subject of the analysis reported here.

The fits to the $M_{\rm bc}$ and ΔE distributions of Figs. 1(a) and 1(b) indicate that about half of the entries with $M(\omega K) > 1.6$ GeV in the Dalitz plot of Fig. 2 are background. To determine the level of $B \to K\omega J/\psi$ signal events, we bin the data into 40 MeV-wide bins of $M(\omega J/\psi)$ and fit for B meson signals. The histograms in Figs. 3(a)–3(l) show the $M_{\rm bc}$ distributions for the 12 lowest $M(\omega J/\psi)$ bins for events in the ΔE and ω signal regions. Here there are distinct $B \to K\omega J/\psi$ signals for low $\omega J/\psi$ invariant mass bins, especially those covered by Figs. 3(b) and 3(c). We establish the $B \to K\omega J/\psi$ signal level for each $M(\omega J/\psi)$ bin by performing binned, one-dimensional fits to the $M_{\rm bc}$ and ΔE distributions for events in that interval using the same signal and background functions that are used to fit the integrated distributions of Figs. 1(a) and 1(b). For these fits, the peak positions, resolution values and background shape parameters are all fixed at the values that are determined from the fits to the integrated distributions, and the areas of the $M_{\rm bc}$ and ΔE signal functions are constrained to

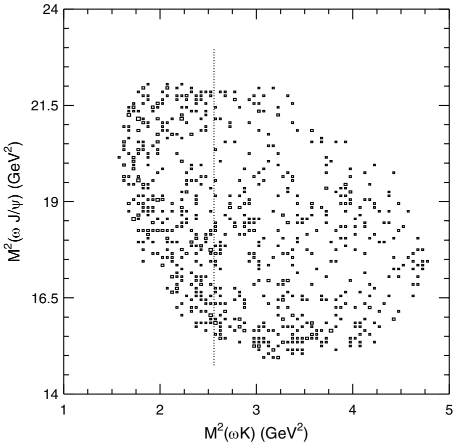

FIG. 2. Dalitz-plot distribution for $B \to K\omega J/\psi$ candidate events. The dotted line indicates the boundary of the $M(K\omega) > 1.6$ GeV selection requirement.

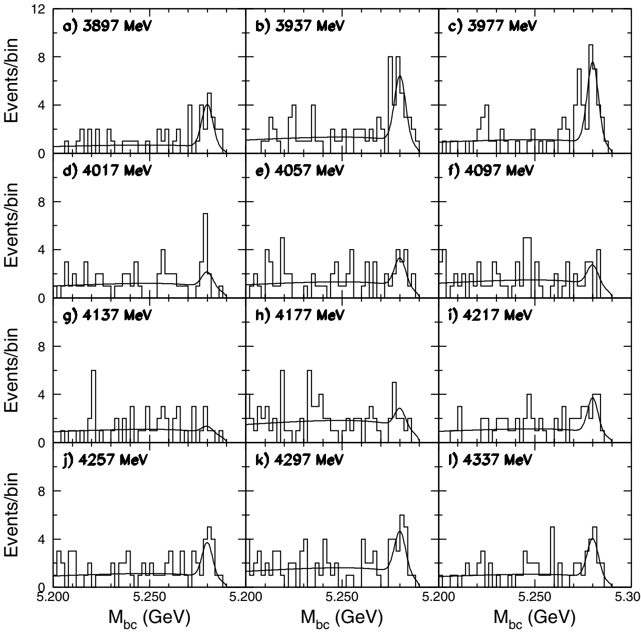

FIG. 3. M_{bc} distributions for $B^- \to K^- \omega J/\psi$ candidates in the ΔE signal region for 40 MeV-wide $\omega J/\psi$ invariant mass intervals. The curves are the results of fits described in the text.

be equal. The curves in Fig. 3 indicate the results of the M_{bc} fits.

The fitted B-meson signal yields are plotted vs $M(\omega J/\psi)$ in Figs. 4(a) and 4(b). An enhancement is evident around $M(\omega J/\psi) = 3940$ MeV. The curve in Fig. 4(a) is the result of a fit with a threshold function of the form $f(M) = A_0 q^*(M)$, where $q^*(M)$ is the momentum of the daughter particles in the $\omega J/\psi$ rest frame. This functional form accurately reproduces the threshold behavior of Monte Carlo simulated $B \to K\omega J/\psi$ events that are generated uniformly over phase space. The fit quality to the observed data points is poor ($\chi^2/\mathrm{d.o.f.} = 115/11$), indicating a significant deviation from phase space; the integral of $f(M)$ over the first three bins is 16.8 events, where the data total is 55.6 events.

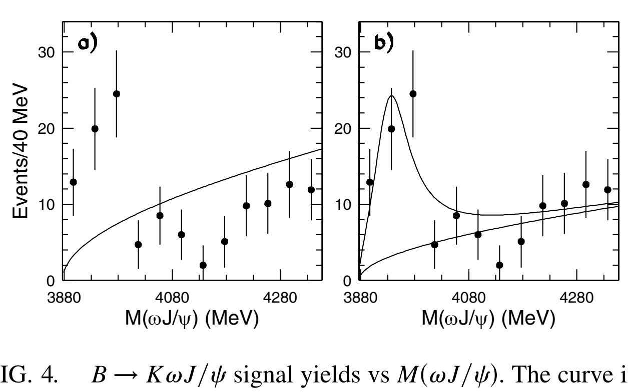

FIG. 4. $B \to K\omega J/\psi$ signal yields vs $M(\omega J/\psi)$. The curve in (a) indicates the result of a fit that includes only a phase-space-like threshold function. The curve in (b) shows the result of a fit that includes an S-wave Breit-Wigner resonance term.

In Fig. 4(b) we show the results of a fit where we include an S-wave Breit-Wigner (BW) function [15] to represent the enhancement. The fit, which has $\chi^2/\mathrm{d.o.f.} = 15.6/8$ (C.L. $= 4.8\%$), yields a Breit-Wigner signal yield of 58 ± 11 events with mass $M = 3943 \pm 11$ MeV and width $\Gamma = 87 \pm 22$ MeV (statistical errors only). The statistical significance of the signal, determined from $\sqrt{-2\ln(\mathcal{L}_0/\mathcal{L}_{\mathrm{max}})}$, where $\mathcal{L}_{\mathrm{max}}$ and $\mathcal{L}_0$ are the likelihood values for the best fit and for zero signal yield, respectively, is 8.1σ.

The $K\omega$ invariant mass distribution for M_{bc}-ΔE signal region events in the region of the $M(\omega J/\psi)$ enhancement are distributed uniformly across the available phase space and there is no evident $K\omega$ mass structure that might be producing the observed mass enhancement by a kinematic reflection. Nevertheless, the possibility that different high-mass $K\omega$ partial waves might interfere in a way that produces some peaking in the $\omega J/\psi$ mass distribution cannot be ruled out.

The $M(\pi^+\pi^-\pi^0)$ distributions for different $M(\omega J/\psi)$ mass regions exhibit $\omega \to \pi^+\pi^-\pi^0$ signals that track the M_{bc}-ΔE signal yields. There are no significant $\omega \to \pi^+\pi^-\pi^0$ signals in the ΔE or M_{bc} sidebands. A comparison of the ω signal strengths in the M_{bc}-ΔE signal region and the M_{bc} and ΔE sidebands is used to infer that $(90 \pm 18)\%$ of the $B \to K\pi^+\pi^-\pi^0 J/\psi$ events in the $M = 3943$ MeV enhancement are produced via $\omega \to \pi^+\pi^-\pi^0$ decays.

We study potential systematic errors on the yield, mass, and width by repeating the fits with different signal parametrizations, background shapes, and bin sizes. For example, when we change the background function to include terms up to third order in q^*, the yield increases to 75 ± 10 events, the mass changes to 3948 ± 9 MeV, the width changes to $\Gamma = 100 \pm 23$ MeV, and the fit quality improves: $\chi^2/\mathrm{d.o.f.} = 10.0/6$ (C.L. $= 12.4\%$). However, the resulting background shape is very different from that of phase space. For different bin sizes, fitting ranges, $M(K\omega)$ requirements, and signal line shapes we see similar variations.

For the systematic uncertainties we use the largest deviations from the nominal values for the different fits. In the following, we assume that all of the 3π systems are due to $\omega \to \pi^+\pi^-\pi^0$ decays and include the possibility of a nonresonant contribution in the systematic error. This is the main component of the negative side systematic error; the change in yield for different background shapes contributes a positive side error of comparable size. The effects of possible acceptance variation as a function of $M(\omega J/\psi)$ on the mass and width values are found to be negligibly small.

To determine a branching fraction, we use the BW fit shown in Fig. 4(b) to establish the event yield of the observed enhancement. Monte Carlo simulation is used to estimate detection efficiencies of $2.4\% \pm 0.1\%$ and $0.42\% \pm 0.02\%$ for $B \to K^+\omega J/\psi$ and $K^0\omega J/\psi$, respectively. We find a product branching fraction [here we denote the enhancement as $Y(3940)$]

$$\mathcal{B}(B \to KY(3940))\mathcal{B}(Y(3940) \to \omega J/\psi) = (7.1 \pm 1.3 \pm 3.1) \times 10^{-5}, \tag{1}$$

where the second error is systematic. The latter includes uncertainties in the acceptance, the shape of the function used to parametrize the background, and the possibility of a non-ω component of the $\pi^+\pi^-\pi^0$ system added in quadrature. Here we have assumed that charged and neutral B mesons are produced in equal numbers at the $\Upsilon(4S)$ and they have the same branching fractions to the observed enhancement [16].

In summary, we have observed a strong near-threshold enhancement in the $\omega J/\psi$ mass spectrum in exclusive $B \to K\omega J/\psi$ decays. The enhancement peaks well above threshold and is broad [17]: if treated as an S-wave BW resonance, we find a mass of $3943 \pm 11(\text{stat}) \pm 13(\text{syst})$ MeV and a total width $\Gamma = 87 \pm 22(\text{stat}) \pm 26(\text{syst})$ MeV. It is expected that a $c\bar{c}$ charmonium meson with this mass would dominantly decay to $D\bar{D}$ and/or $D\bar{D}^*$; hadronic charmonium transitions should have minuscule branching fractions [18].

The peak mass of the observed enhancement is very similar to that of a peak observed by Belle in the J/ψ recoil mass spectrum for inclusive $e^+e^- \to J/\psi X$ events near $\sqrt{s} = 10.56$ GeV [19]. This latter peak is also seen to decay to $D\bar{D}^*$, and a search for it in the $\omega J/\psi$ channel is in progress. In addition, we are examining $B \to KD\bar{D}^*$ decays for a $D\bar{D}^*$ component of the enhancement reported here.

The properties of the observed enhancement are similar to those of some of the $c\bar{c}$-*gluon* hybrid charmonium states that were first predicted in 1978 [2] and are expected to be produced in B meson decays [20]. It has been shown that a general property of these hybrid states is that their decays to $D^{(*)}\bar{D}^{(*)}$ meson pairs are forbidden or suppressed, and the relevant "open charm" threshold is $m_D + m_{D^{**}} \simeq 4285$ MeV [21,22], where D^{**} refers to the $J^P = (0, 1, 2)^+$ charmed mesons. Thus, a hybrid state with a mass equal to that of the peak we observe would have large branching fractions for decays to J/ψ or ψ' plus light hadrons [23]. Moreover, lattice QCD calculations have indicated that partial widths for such decays can be comparable to the width that we measure [24]. However, these calculations predict masses for these states that are between 4300 and 4500 MeV [25], substantially higher than our measured value.

We thank the KEKB group for the excellent operation of the accelerator, the KEK cryogenics group for the efficient operation of the solenoid, and the KEK computer group and the NII for valuable computing and Super-SINET network support. We acknowledge support from MEXT and JSPS (Japan); ARC and DEST (Australia); NSFC (Contract No. 10175071, China); DST (India); the BK21 program of MOEHRD and the CHEP SRC program of KOSEF (Korea); KBN (Contract No. 2P03B 01324, Poland); MIST (Russia); MESS (Slovenia); Swiss NSF; NSC and MOE (Taiwan); and DOE (USA).

---

*On leave from Nova Gorica Polytechnic, Nova Gorica.

[1] See, for example, M. B. Voloshin and L. B. Okun, JETP Lett. **23**, 333 (1976); M. Bander, G. L. Shaw, and P. Thomas, Phys. Rev. Lett. **36**, 695 (1976); A. De Rujula, H. Georgi, and S. L. Glashow, Phys. Rev. Lett. **38**, 317 (1977); N. A. Törnqvist, Z. Phys. C **61**, 525 (1994); A. V. Manohar and M. B. Wise, Nucl. Phys. **B399**, 17 (1993).

[2] D. Horn and J. Mandula, Phys. Rev. D **17**, 898 (1978).

[3] S. K. Choi *et al.* (Belle Collaboration), Phys. Rev. Lett. **89**, 102001 (2002).

[4] D. M. Asner *et al.* (CLEO Collaboration), Phys. Rev. Lett. **92**, 142001 (2004); B. Aubert *et al.* (BABAR Collaboration), Phys. Rev. Lett. **92**, 142002 (2004).

[5] K. Abe *et al.* (Belle Collaboration), Phys. Rev. Lett. **89**, 142001 (2002).

[6] S. K. Choi *et al.* (Belle Collaboration), Phys. Rev. Lett. **91**, 262001 (2003).

[7] D. Acosta *et al.* (CDF-II Collaboration), Phys. Rev. Lett. **93**, 072001 (2004); V. M. Abazov *et al.* (D0 Collaboration), Phys. Rev. Lett. **93**, 162002 (2004); B. Aubert *et al.* (BABAR Collaboration), Phys. Rev. D **71**, 071103 (2005).

[8] S. L. Olsen, Int. J. Mod. Phys. A **20**, 240 (2005); K. Abe *et al.* (Belle Collaboration), hep-ex/0408116.

[9] N. A. Törnqvist, Phys. Lett. B **590**, 209 (2004); E. S. Swanson, Phys. Lett. B **588**, 189 (2004); F. E. Close and P. R. Page, Phys. Lett. B **578**, 119 (2004); S. Pakvasa and M. Suzuki, Phys. Lett. B **579**, 67 (2004); C.-Y. Wong, Phys. Rev. C **69**, 055202 (2004); E. Braaten and M. Kusunoki, Phys. Rev. D **69**, 114012 (2004).

[10] S. Kurokawa and E. Kikutani, Nucl. Instrum. Methods Phys. Res., Sect. A **499**, 1 (2003).

[11] A. Abashian *et al.* (Belle Collaboration), Nucl. Instrum. Methods Phys. Res., Sect. A **479**, 117 (2002); Y. Ushiroda (Belle SVD2 Group), Nucl. Instrum. Methods Phys. Res., Sect. A **511**, 6 (2003).

[12] The inclusion of charge-conjugate modes is always implied.

[13] G. C. Fox and S. Wolfram, Phys. Rev. Lett. **41**, 1581 (1978).

[14] H. Albrecht *et al.* (ARGUS Collaboration), Phys. Lett. B **241**, 278 (1990).

[15] We use the form $\frac{\Gamma(q^*/q_0)}{(M^2-M_0^2)^2+[M_0\Gamma(q^*/q_0)]^2}$, where M_0 is the peak mass and $q_0 = q^*(M = M_0)$.

[16] The signal yields for the separate $K^+\omega J/\psi$ and $K_S\omega J/\psi$ channels are consistent.

[17] The $M(\omega J/\psi)$ mass resolution is $\simeq 6$ MeV and much narrower than the observed enhancement.

[18] N. Brambilla *et al.* (Quarkonium Working Group), hep-ph/0412158; T. Barnes and S. Godfrey, Phys. Rev. D **69**,

054008 (2004); E. Eichten, K. Lane, and C. Quigg, Phys. Rev. D **69**, 094019 (2004).
[19] P. Pakhlov, hep-ex/0412041.
[20] F. E. Close, I. Dunietz, P. R. Page, S. Veseli, and H. Yamamoto, Phys. Rev. D **57**, 5653 (1998); G. Chiladze, A. F. Falk, and A. A. Petrov, Phys. Rev. D **58**, 034013 (1998); F. E. Close and S. Godfrey, Phys. Lett. B **574**, 210 (2003).
[21] N. Isgur, R. Kokoski, and J. Paton, Phys. Rev. Lett. **54**, 869 (1985).
[22] F. E. Close and P. R. Page, Nucl. Phys. **B443**, 233 (1995); Phys. Lett. B **366**, 323 (1996).
[23] F. E. Close, Phys. Lett. B **342**, 369 (1995).
[24] C. McNeile, C. Michael, and P. Pennanen, Phys. Rev. D **65**, 094505 (2002).
[25] C. Banner *et al.*, Phys. Rev. D **56**, 7039 (1997); Z.-H. Mei and X.-Q. Luo, Int. J. Mod. Phys. A **18**, 5713 (2003); X. Liao and T. Manke, hep-lat/0210030.