Observation of a $\chi_{c2}$ candidate in $\gamma\gamma \to D\bar{D}$ production in Belle

K. Abe,9 K. Abe,47 I. Adachi,9 H. Aihara,49 K. Aoki,23 K. Arinstein,2 Y. Asano,54 T. Aso,53 V. Aulchenko,2 T.Aushev,13 T. Aziz,45 S. Bahinipati,5 A. M. Bakich,44 V. Balagura,13 Y. Ban,36 S. Banerjee,45 E. Barberio,22 M. Barbero,8 A. Bay,19 I. Bedny,2 U. Bitenc,14 I. Bizjak,14 S. Blyth,25 A. Bondar,2 A. Bozek,29 M. Bračko,9,21,14 J. Brodzicka,29 T. E. Browder,8 M.-C. Chang,48 P. Chang,28 Y. Chao,28 A. Chen,25 K.-F. Chen,28 W. T. Chen,25 B. G. Cheon,4 C.-C. Chiang,28 R. Chistov,13 S.-K. Choi,7 Y. Choi,43 Y. K. Choi,43 A. Chuvikov,37 S. Cole,44 J. Dalseno,22 M. Danilov,13 M. Dash,56 L. Y. Dong,11 R. Dowd,22 J. Dragic,9 A. Drutskoy,5 S. Eidelman,2 Y. Enari,23 D. Epifanov,2 F. Fang,8 S. Fratina,14 H. Fujii,9 N. Gabyshev,2 A. Garmshev,37 T. Gershon,9 A. Go,25 G. Gokhroo,45 P. Goldenzweig,5 B. Goloh,20,14 A. Gorišek,14 M. Grosse Perdekamp,38 H. Guler,8 R. Guo,26 J. Haba,9 K. Hara,9 T. Hara,34 Y. Hasegawa,42 N. C. Hastings,49 K. Hasuko,38 K. Hayasaka,23 H. Hayashii,24 M. Hazumi,9 T. Higuchi,9 L. Hinz,19 T. Hojo,34 T. Hokusee,23 Y. Hoshi,47 K. Hoshina,52 S. Hou,25 W.-S. Hou,28 Y. B. Hsiung,28 Y. Igarashi,9 T. Iijima,23 K. Ikado,23 A. Imoto,24 K. Inami,23 A. Ishikawa,9 H. Ishino,50 K. Itoh,49 R. Itoh,9 M. Iwasaki,49 Y. Iwasaki,9 C. Jacoby,19 C.-M. Jen,28 R. Kagan,13 M. Kakuno,49 J. H. Kang,57 J. S. Kang,16 P. Kapusta,29 S. U. Kataoka,24 N. Katayama,9 H. Kawai,3 N. Kawamura,1 T. Kawasaki,31 S. Kazi,5 N. Kent,8 H. R. Khan,50 A. Kidbayeri,50 H. Khichi,9 H. J. Kim,48 H. O. Kim,43 J. H. Kim,43 S. K. Kim,41 S. M. Kim,43 T. H. Kim,57 K. Kinoshita,50 N. Kishimoto,23 S. Korpar,21,14 Y. Kozakai,23 P. Krizan,20,14 P. Krokovny,9 T. Kubota,23 R. Kulasiri,5 C. C. Kuo,25 H. Kurashiro,50 E. Kurilova,9 A. Kusaka,49 A. Kubmin,2 Y.-J. Kwon,57 J. S. Lange,6 G. Leder,12 S. E. Lee,41 Y.-J. Lee,28 T. Lesiak,29 J. Li,40 A. Limosani,9 S.-W. Lin,28 D. Liventsev,13 J. MacNaughton,12 G. Majumder,45 F. Maudi,12 D. Marlow,37 H. Matsumoto,31 T. Matsumoto,51 A. Matyja,29 Y. Mikami,48 W. Mitaroff,12 K. Miyabayashi,24 H. Miyake,34 H. Miyata,31 Y. Miyazaki,23 R. Mizuk,13 D. Mohapatra,56 G. R. Moloney,22 T. Mori,50 A. Murakami,39 T. Nagamine,48 Y. Nagaoka,32 T. Nakagawa,25 I. Nakamura,49 E. Nakano,33 M. Nakao,9 H. Nakazawa,9 Z. Natsukanie,29 K. Neichi,47 S. Nishida,9 O. Nitoh,52 S. Noguchi,24 T. Nozaki,9 A. Ogawa,38 S. Ogawa,46 T. Ohshima,23 T. Okabe,23 S. Okuno,15 S. L. Olsen,8 Y. Omukai,31 W. Ostrowicz,29 H. Ozaki,9 P. Pakhlov,13 H. Palka,29 C. W. Park,43 H. Park,18 K. S. Park,13 N. Parslow,44 L. S. Peak,44 M. Pernicka,12 R. Pestotnik,44 M. Peters,8 L. E. Piilonen,56 A. Poluektov,2 F. J. Ronga,9 N. Root,2 M. Rozanska,29 H. Sahoo,6 M. Snaigo,38 S. Saitoh,9 Y. Sakai,9 H. Sakamoto,17 H. Sakaue,33 T. R. Sarangi,56 S. Satpathy,55 N. Sato,23 N. Satoyama,42 T. Schietinger,19 O. Schneider,19 P. Schönherr,48 J. Schimann,28 C. Schwanda,12 A. J. Schwartz,5 T. Seki,51 K. Senyo,23 R. Seuster,8 M. E. Sevior,22 T. Shibata,31 H. Shibuya,46 J.-G. Shiu,28 B. Shwartz,2 V. Sidorov,2 J. B. Singh,35 A. Somov,5 N. Soni,35 R. Stam,9 S. Stanic,14 A. Starić,14 A. Sugiyama,39 K. Sumisawa,9 T. Sumiyoshi,51 S. Suzuki,39 Y. S. Suzuki,9 O. Tajima,9 N. Takada,42 F. Takasawa,25 K. Tani,25 T. Tamura,21 N. Tanabe,49 M. Tanaka,9 G. N. Taylor,22 Y. Teramoto,34 X. C. Tian,36 K. Trabelsi,8 Y. F. Tse,22 T. Tsuoyama,9 T. Tsukamoto,9 K. Uchida,8 Y. Uchida,9 S. Uehara,9 T. Uglov,13 K. Ueno,28 Y. Unno,9 S. Uno,9 P. Urquijo,22 Y. Ushiroda,9 G. Varner,8 K. E. Varvell,44 S. Villa,19 C. C. Wang,28 C. H. Wang,27 M.-Z. Wang,28 M. Watanabe,31 Y. Watanabe,50 L. Widhalm,12 C.-H. Wu,28 Q. L. Xie,11 B. D. Yabsley,56 A. Yamaguchi,48 H. Yamamoto,48 S. Yamamoto,51 Y. Yamashita,30 M. Yamamura,3 Heyoung Yang,41 J. Ying,36 S. Yoshino,23 Y. Yuan,11 Y. Yusa,48 H. Yuta,1 S. L. Zang,11 C. C. Zhang,11 J. Zhang,9 L. M. Zhang,40 Z. P. Zhang,40 V. Zhilich,2 T. Ziegler,37 and D. Zürcher19

(The Belle Collaboration)

1Aomori University, Aomori
2Budker Institute of Nuclear Physics, Novosibirsk
3Chiba University, Chiba
4Chonnam National University, Kwangju
5University of Cincinnati, Cincinnati, Ohio 45221
6University of Frankfurt, Frankfurt
7Gyeongsang National University, Chinju
8University of Hawaii, Honolulu, Hawaii 96822
We report on a search for the production of new resonance states in the process $\gamma\gamma \rightarrow D\bar{D}$. A candidate $C$-even charmonium state is observed in the vicinity of 3.93 GeV/$c^2$. The production rate and the angular distribution in the $\gamma\gamma$ center-of-mass frame suggest that this state is the previously unobserved $\chi_{c2}^\prime$, the $2^3S_2$ charmonium state.

PACS numbers: 13.66.Bc, 14.40.Gx

**INTRODUCTION**

The masses and other properties of the radial-ground and radially excited states of charmonium provide valuable input to QCD models that describe heavy quarkonium systems. To date, radial excitation states of charmonium have been found only for the $^{2S+1}L_J = 3S_1$ states ($\psi$) and $1^3S_0$ states ($\eta_c$). No radially excited $3P_J$ states ($\chi_{cJ}$) have yet been found, even though the three radial ground states have been already well established.
The first radially excited $\chi_{cJ}$ states are predicted to have masses between 3.9 and 4.0 GeV/$c^2$ [1, 2], which is considerably above $D\bar{D}$ threshold. If the masses of these states lie between the $D\bar{D}$ and $D^*\bar{D}^*$ thresholds, the $\chi_{c0}(2P)$ ($\chi_{cJ}'$) and $\chi_{c2}(2P)$ ($\chi_{cJ}''$) are expected to decay primarily into $D\bar{D}$, although the $\chi_{c2}$ could also decay to $D^*\bar{D}^*$ if it is energetically allowed. (The inclusion of charge-conjugated reactions is implied throughout this paper.) Recently, two new charmonium-like states in this mass region, the $X(3940)$ [3] and $Y(3940)$ [4], were reported by Belle. Decays of either of these states to $D\bar{D}$ have not been observed [3].

In this paper we report on a search for the $\chi_{cJ}'$ ($J = 0$ or 2) states and other $C$-even charmonium states in the mass range of 3.73 - 4.3 GeV/$c^2$ produced via the $\gamma\gamma \rightarrow D\bar{D}$ process. The results presented here are preliminary.

**DATA AND DETECTOR**

The analysis uses data recorded in the Belle detector at the KEKB asymmetric $e^+e^-$ collider [5]. The data sample corresponds to an integrated luminosity of 280 fb$^{-1}$, accumulated on the $\Upsilon(4S)$ resonance ($\sqrt{s} = 10.58$ GeV) and 60 MeV below the resonance. Since the beam energy dependence of two-photon processes is small, we combine both samples. We study the two-photon process $e^+e^- \rightarrow e^+e^-D\bar{D}$ in the “no-tag” mode, i.e. where neither the final-state electron nor positron is detected. We restrict the virtuality of the incident photons to be small by imposing a strict requirement on the transverse-momentum balance of the final-state hadronic system with respect to the beam axis.

A comprehensive description of the Belle detector is given elsewhere [6]. We mention here only the detector components essential for the present measurement.

Charged tracks are reconstructed from hit information in a central drift chamber (CDC) located in a uniform 1.5 T solenoidal magnetic field. The $z$ axis of the detector and the solenoid are along the positron beam, with the positrons moving in the $-z$ direction. The CDC measures the longitudinal and transverse momentum components (along the $z$ axis and in the $r\phi$ plane, respectively). Track trajectory coordinates near the collision point are measured by a silicon vertex detector (SVD). Photon detection and energy measurements are provided by a CsI(Tl) electromagnetic calorimeter (ECL). Species of charged hadron are identified by means of information from time-of-flight counters (TOF) and a silica-aerogel Cherenkov counters (ACC). The ACC provides separation between kaons and pions for momenta above 1.2 GeV/$c$. The TOF system consists of a barrel of 128 plastic scintillation counters, and is effective for $K/\pi$ separation for tracks with momenta below 1.2 GeV/$c$. Low energy kaons are also identified by specific ionization ($dE/dx$) measurements in the CDC.

Kaon candidates are separated from pions based on normalized kaon and pion likelihood functions obtained from the particle identification system ($L_K$ and $L_\pi$, respectively) with a criterion, $L_K/(L_K + L_\pi) > 0.8$. All tracks that are not identified as kaons are treated as pions.

Signal candidates are triggered by a variety of track-triggers that require two or more CDC tracks with associated TOF hits, ECL clusters or a minimum sum of energy in the ECL. For the four and six charged track topologies used in this analysis, the trigger conditions are complementary to each other and, in combination, provide a high trigger efficiency ($\sim 95\%$).

**EVENT SELECTION**

We search for exclusive $D\bar{D}$ production in the following four combinations of decays:

\[
\begin{align*}
\gamma\gamma & \rightarrow D^0\bar{D}^0, \quad D^0 \rightarrow K^-\pi^+, \quad \bar{D}^0 \rightarrow K^+\pi^- \quad \text{(N4)}, \\
\gamma\gamma & \rightarrow D^0\bar{D}^0, \quad D^0 \rightarrow K^-\pi^+, \quad \bar{D}^0 \rightarrow K^+\pi^-\pi^0 \quad \text{(N5)}, \\
\gamma\gamma & \rightarrow D^0\bar{D}^0, \quad D^0 \rightarrow K^-\pi^+, \quad \bar{D}^0 \rightarrow K^+\pi^-\pi^+\pi^- \quad \text{(N6)}, \\
\gamma\gamma & \rightarrow D^+D^-, \quad D^+ \rightarrow K^-\pi^+\pi^+, \quad D^- \rightarrow K^+\pi^-\pi^- \quad \text{(C6)}. 
\end{align*}
\]

The symbols in parentheses are used to designate each of the final states. For the four-prong processes (N4 and N5) the selection criteria are: four charged tracks, each one with (L) a transverse momentum in the laboratory frame of $p_t > 0.1$ GeV/$c$ and a distance of closest approach to the nominal collision point of $|dr| < 5$ cm and $|dz| < 5$ cm; the absolute value of the average $dz$ for all of the tracks, $\langle dz \rangle < 3$ cm; two or more of the four tracks must have (S) $p_t > 0.4$ GeV/$c$, $|dr| < 1$ cm, and $-0.8660 < \cos \theta < +0.9563$, where $\theta$ is the laboratory frame polar angle; no photon clusters with an energy greater than 400 MeV; the charged track system consists of a $K^+K^-\pi^-\pi^-$ combination; the larger of the two neutral $K\pi$ invariant masses should lie within $\pm 15$ MeV/$c^2$ of the nominal $D^0$ mass. For the N4 process, we require that the smaller neutral $K\pi$ mass is within $\pm 20$ MeV/$c^2$ of the nominal $D^0$ mass. For the N5 process, we require that the remaining $K\pi$ combination, when combined with a $\pi^0$ candidate, has an invariant mass in the range $1.83 < M(K^+\pi^-\pi^0) < 1.89$ GeV/$c^2$. A $\pi^0$ candidate is any pair of photons in the event that fits the $\pi^0 \rightarrow \gamma\gamma$ hypothesis with $\chi^2 < 4$. If there are multiple $\pi^0$ candidates, we select the one that results in $M(K^+\pi^-\pi^0)$ closest to the nominal $D^0$ mass.

For the six-prong processes (N6 and C6), we require exactly six tracks with particle assignments $K^+K^-\pi^-\pi^-\pi^+\pi^-$, where all six pass the looser and two to four pass the more stringent track criteria that are indicated by (L) and (S) above, respectively. For the N6 process, one combination is required to have $|\Delta M|_1 = \ldots$
$|M(K^+\pi^-) - m_D^0| < 15$ MeV/$c^2$ while the remaining tracks have $|\Delta M|_2 = |M(K^-\pi^+\pi^-\pi^+) - m_D^0| < 30$ MeV/$c^2$. When there are multiple combinations, we take the one with the smallest $|\Delta M|_1 + |\Delta M|_2$. For the $C6$ process, we require $|M(K^+\pi^+\pi^-) - m_D^+| < 30$ MeV/$c^2$ for each of the charge combinations, where $m_D^0$ is the nominal $D^+$ mass.

The invariant mass distributions for $D$-meson candidates reconstructed according to the above selection procedure are shown in Fig. 1. For all processes, we require that there are no extra $\pi^0$ candidates with transverse momenta larger than 100 MeV/$c$. We also apply the following kinematical requirements to reject initial-state radiation or pseudo-Compton processes (ISR veto). The invariant mass constructed from all of the tracks accepted by the more stringent criteria is less than 4.5 GeV/$c^2$ (here a zero rest mass is assigned to each charged track), and the missing mass squared of the system recoiling against the detected tracks is larger than 2 (GeV/$c^2$)$^2$. The $DD$ candidate system is also required to satisfy: $P_z(DD) > (M(DD)^2 - 49$ GeV/$c^2^2)/(14$ GeV/$c^2^2) + 0.6$ GeV/$c$, where $P_z(DD)$ and $M(DD)$ are the momentum component in the $z$ direction in the laboratory frame and the invariant mass, respectively. This condition eliminates the ISR events from $e^+e^- \rightarrow D^{(*)}\bar{D}^{(*)}\gamma$ efficiently, in case the photon is emitted in the forward direction with respect to the incident electron. We compute the invariant mass of the $DD$ system using the measured 3-momenta of each $D$ candidate ($P_D$) and energy determined from $E_D = \sqrt{P_D^2 + m_D^2}$, where $m_D$ is the nominal mass of the neutral or charged $D$.

We calculate $P_t(DD)$, the total transverse momentum in the $e^+e^-$ center-of-mass (c.m.) frame with respect to the incident $e^+e^-$ axis that approximates the direction of the two-photon collision axis. In the two-dimensional region $M(DD) < 4.3$ GeV/$c^2$ and $P_t(DD) < 0.2$ GeV/$c$, we find 159 $N4$-process events, 110 $N5$-process events, 240 $N6$-process events and 86 $C6$-process events.

**DISTRIBUTIONS OF THE $DD$ CANDIDATES**

In Fig. 2 we show the $M(DD)$ distributions separately for $D^0\bar{D}^0$ (sum of $N4$, $N5$ and $N6$) (Fig. 2(a)) and $D^+D^-$ (Fig. 2(b)) and for the combined charged and neutral channels (Fig. 2(c)). In the figures, two event concentrations are evident: one near $3.80$ GeV/$c^2$ and another near $3.93$ GeV/$c^2$. Here, we have applied the requirement $P_t(DD) < 0.05$ GeV/$c$ to enhance exclusive two-photon $\gamma\gamma \rightarrow DD$ production.

The invariant-mass distribution for the combined $D^0\bar{D}^0$ and $D^+D^-$ channels is shown for 10-MeV/$c^2$ bins in Fig. 3. The curve is the result of an unbinned likelihood fit to the data in the region $3.80 < M(DD) < 4.10$ GeV/$c^2$ using a relativistic Breit-Wigner signal function plus a background of the form $\sim M(DD)^{-\alpha}$, where $\alpha$ is a free parameter. The mass dependence of the efficiency and the two-photon luminosity function is taken into account in the fit. These are computed using the TREPS Monte-Carlo (MC) program [7] for $e^+e^- \rightarrow e^+e^- DD$ production together with JETSET7.3 decay routines [8] for the $D$ meson decays (using PDG2004 [9] values for the decay branching fractions). The $M(DD)$ dependence of this product is not large. (At $M(DD) = 3.93$ GeV/$c^2$, there is a $\sim 13\%$ decrease in this product for a 0.1 GeV/$c^2$ increase in $M(DD)$.)

The results of the fit for the resonance mass, width and total yield of the resonance are $M = 3931 \pm 4$ (stat) MeV/$c^2$, $\Gamma = 20 \pm 8$ (stat) MeV and $41 \pm 11$ (stat) events, respectively. The mass resolution, which is estimated by MC to be $2-3$ MeV/$c^2$, is neglected in the fit. The statistical significance of the peak is $5.5\sigma$, which is derived from the square root of the difference of the logarithmic-likelihoods for fits with and without a resonance peak component, shown in the figure as solid and dashed curves, respectively.

Systematic errors for the parameters $M$ and $\Gamma$ are 2 MeV/$c^2$ and 3 MeV, respectively. The former is dominantly due to the uncertainty in the mass of the $D$ mesons (1 MeV/$c^2$ for the resonance mass) and the choice of the Breit-Wigner function formula (1 MeV/$c^2$). We consider here several different Breit-Wigner functional forms for spin 0 and 2 resonances, phase-space and wave-function variations. In the latter, we also consider the effects of the finite invariant-mass resolution in the fit.

The $P_t(DD)$ distribution in the peak region, $3.91 < M(DD) < 3.95$ GeV/$c^2$, is shown in Fig. 4. Here the $P_t$ requirement has been relaxed. The experimental data are fitted by a shape that is expected for exclusive two-photon $DD$ production plus a linear background. We expect non-charm and non-exclusive backgrounds to be nearly linear in $P_t(DD)$. The fit uses a binned-maximum
P level, less than 6 of the 46 events observed in the selected
channel. We find that at the 90% confidence level, around 0.05 GeV/
4 events for P \( | \theta^* | < 0.5 \) and \( | \cos \theta^* | > 0.5 \), respectively,
where \( \theta^* \) is the angle of a D meson relative to the beam axis in the \( \gamma \gamma \) c.m. frame. It is apparent that the events in the 3.93 GeV/c\(^2\) peak tend to concentrate at small \( | \cos \theta^* | \) values.

The point with error bars in Fig. 5(c) show the event yields in the 3.91 GeV/c\(^2\) to 3.95 GeV/c\(^2\) region versus \( | \cos \theta^* | \). Background, estimated from events in the \( M(D\bar{D}) \) sideband, is indicated by the histogram. A MC study indicates that the efficiency is uniform in \( | \cos \theta^* | \).

For a spin-0 resonance this distribution should be flat. In contrast, a spin-2 resonance is expected to be produced with helicity-2 along the incident axis [10, 11], in which case the expected angular distribution is \( \propto \sin^4 \theta^* \).
No charmonium state that decays into $\bar{D}D$ with a mass near 3.93 GeV/$c^2$ has been previously reported. We find no corresponding event concentration in this mass region in the sample of ISR events (normally rejected by the ISR veto), which would be expected in case of production of a charmonium state.

We assign a 16% total systematic error to the present measurement. This is primarily due to uncertainties in the track reconstruction efficiency (7%), luminosity function (5%), MC statistics (7%) and the $D$-meson branching fractions (9%), added in quadrature. Using $J = 2$, the above result gives $\Gamma_{\gamma\gamma} B(Z(3930) \rightarrow \bar{D}D) = 0.23 \pm 0.06(stat) \pm 0.04(sys)$ keV.

CONCLUSION

We have observed an enhancement in $\bar{D}D$ invariant mass near 3.93 GeV/$c^2$ in $\gamma\gamma \rightarrow DD$ events. The statistical significance of the signal is 5.5$\sigma$. The observed angular distribution is consistent with two-photon production of a tensor meson. Preliminary results for the mass, width, and the product of the two-photon decay width times the branching fraction to $\bar{D}D$ are: $M = 3931 \pm 4(stat) \pm 2(sys)$ MeV/$c^2$, $\Gamma = 20 \pm 8(stat) \pm 3(sys)$ MeV and $\Gamma_{\gamma\gamma} B(\rightarrow DD) = 0.23 \pm 0.06(stat) \pm 0.04(sys)$ keV (assuming $J = 2$), respectively. The measured properties are consistent with expectations for the previously unseen $\chi'_c2$ charmonium state.

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 SuperSINET 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 KOSEF (Korea); KBN (contract No. 2P03B 01324, Poland); MIST (Russia); MHEST (Slovenia); SNSF (Switzerland); NSC and MOE (Taiwan); and DOE (USA).

TWO-PHOTON DECAY WIDTH

No charmonium state that decays into $\bar{D}D$ with a mass near 3.93 GeV/$c^2$ has been previously reported. We find no corresponding event concentration in this mass region in the sample of ISR events (normally rejected by the ISR veto), which would be expected in case of production of a $J^{PC}=1^{--}$ meson ($\psi'$).

Using the number of observed signal events and the branching fractions and efficiencies for the four decay channels, we determine the product of the two-photon decay width and $\bar{D}D$ branching fraction (multiplied by the spin factor) to be $\Gamma_{\gamma\gamma}(Z(3930))B(Z(3930) \rightarrow \bar{D}D) = 1.13 \pm 0.30(stat.)$ keV. Here, we define $B(Z(3930) \rightarrow \bar{D}D) = B(Z(3930) \rightarrow D^0D^0) + B(Z(3930) \rightarrow D^+D^-)$ and assume $B(Z(3930) \rightarrow D^0D^0) = B(Z(3930) \rightarrow D^+D^-)$ according to isospin invariance, where $Z(3930)$ is used as a tentative designation for the observed state.

The observed signals for the $D^0D^0$ and $D^+D^-$ modes are consistent with isospin invariance. The results on mass, decay angular distributions and $\Gamma_{\gamma\gamma}$ [12] are all consistent with expectations for the $\chi'_c2$, the $2^1P_2$ charmonium state.

FIG. 5: $M(\bar{D}D)$ distributions for (a) $|\cos \theta^*| < 0.5$ and (b) $|\cos \theta^*| > 0.5$. (c) The $|\cos \theta^*|$ distributions in the 3.91 < $M(\bar{D}D)$ < 3.95 GeV/$c^2$ region (points with error bars) and background scaled from the $M(\bar{D}D)$ sideband (solid histogram). The solid and dashed curves are expected distributions for the spin=2 (helicity=2) and spin=0 hypotheses, respectively, plus a curve that interpolates the non-peak background (dotted), with total area normalized to the observed number of events.

We have observed an enhancement in $\bar{D}D$ invariant mass near 3.93 GeV/$c^2$ in $\gamma\gamma \rightarrow DD$ events. The statistical significance of the signal is 5.5$\sigma$. The observed angular distribution is consistent with two-photon production of a tensor meson. Preliminary results for the mass, width, and the product of the two-photon decay width times the branching fraction to $\bar{D}D$ are: $M = 3931 \pm 4(stat) \pm 2(sys)$ MeV/$c^2$, $\Gamma = 20 \pm 8(stat) \pm 3(sys)$ MeV and $\Gamma_{\gamma\gamma} B(\rightarrow DD) = 0.23 \pm 0.06(stat) \pm 0.04(sys)$ keV (assuming $J = 2$), respectively. The measured properties are consistent with expectations for the previously unseen $\chi'_c2$ charmonium state.

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 SuperSINET 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); MHEST (Slovenia); SNSF (Switzerland); NSC and MOE (Taiwan); and DOE (USA).
[9] Particle Data Group, S. Eidelman et al., Phys. Lett. B 592, 1 (2004) (URL: http://pdg.lbl.gov).

[10] Belle Collaboration, K. Abe et al., Phys. Lett. B 540, 33 (2002).

[11] M. Poppe, Int. J. Mod. Phys. A 1, 545 (1986); H. Krasemann, J.A.M. Vermaseren, Nucl. Phys. B 184, 269 (1981).

[12] C.R. Münn, Nucl. Phys. A 609, 364 (1996).