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Search for the Isospin Violating Decay Y(4260)→J/ 0 Postprint

Authors: Ablikim, M. and others

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Abstract

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Full Text

Preamble

Search for the isospin violating decay Y(4260) → J/ 0

M. Ablikim, M. N. Achasov, X. C. Ai, O. Albayrak, M. Albrecht, D. J. Ambrose, A. Amoroso, F. F. An, Q. An, J. Z. Bai, R. Baldini Ferroli, Y. Ban, D. W. Bennett, J. V. Bennett, M. Bertani, D. Bettoni, J. M. Bian, F. Bianchi, E. Boger, I. Boyko, R. A. Briere, H. Cai, X. Cai, O. Cakir, A. Calcaterra, G. F. Cao, S. A. Cetin, J. F. Chang, G. Chelkov, G. Chen, H. S. Chen, H. Y. Chen, J. C. Chen, M. L. Chen, S. J. Chen, X. Chen, X. R. Chen, Y. B. Chen, H. P. Cheng, X. K. Chu, G. Cibinetto, H. L. Dai, J. P. Dai, A. Dbeyssi, D. Dedovich, Z. Y. Deng, A. Denig, I. Denysenko, M. Destefanis, F. De Mori, Y. Ding, C. Dong, J. Dong, L. Y. Dong, M. Y. Dong, S. X. Du, P. F. Duan, E. E. Eren, J. Z. Fan, J. Fang, S. S. Fang, X. Fang, Y. Fang, L. Fava, F. Feldbauer, G. Felici, C. Q. Feng, E. Fioravanti, M. Fritsch, C. D. Fu, Q. Gao, X. Y. Gao, Y. Gao, Z. Gao, I. Garzia, C. Geng, K. Goetzen, W. X. Gong, W. Gradl, M. Greco, M. H. Gu, Y. T. Gu, Y. H. Guan, A. Q. Guo, L. B. Guo, Y. Guo, Y. P. Guo, Z. Haddadi, A. Hafner, S. Han, Y. L. Han, X. Q. Hao, F. A. Harris, K. L. He, Z. Y. He, T. Held, Y. K. Heng, Z. L. Hou, C. Hu, H. M. Hu, J. F. Hu, T. Hu, Y. Hu, G. M. Huang, G. S. Huang, H. P. Huang, J. S. Huang, X. T. Huang, Y. Huang, T. Hussain, Q. Ji, Q. P. Ji, X. B. Ji, X. L. Ji, L. L. Jiang, L. W. Jiang,

X. S. Jiang, X. Y. Jiang, J. B. Jiao, Z. Jiao, D. P. Jin, S. Jin, T. Johansson, A. Julin, N. Kalantar-Nayestanaki, X. L. Kang, X. S. Kang, M. Kavatsyuk, B. C. Ke, P. Kiese, R. Kliemt, B. Kloss, O. B. Kolcu, B. Kopf, M. Kornicer, W. Kühn, A. Kupsc, J. S. Lange, M. Lara, P. Larin, C. Leng, C. Li, Cheng Li, D. M. Li, F. Li, G. Li, H. B. Li, J. C. Li, Jin Li, K. Li, K. Li, Lei Li, P. R. Li, T. Li, W. D. Li, W. G. Li, X. L. Li, X. M. Li, X. N. Li, X. Q. Li, Z. B. Li, H. Liang, Y. F. Liang, Y. T. Liang, G. R. Liao, D. X. Lin, B. J. Liu, C. X. Liu, F. H. Liu, Fang Liu, Feng Liu, H. B. Liu, H. H. Liu, H. H. Liu, H. M. Liu, J. Liu, J. B. Liu, J. P. Liu, J. Y. Liu, K. Liu, K. Y. Liu, L. D. Liu, P. L. Liu, Q. Liu, S. B. Liu, X. Liu, X. X. Liu, Y. B. Liu, Z. A. Liu, Zhiqiang Liu, Zhiqing Liu, H. Loehner, X. C. Lou, H. J. Lu, J. G. Lu, R. Q. Lu, Y. Lu, Y. P. Lu, C. L. Luo, M. X. Luo, T. Luo, X. L. Luo, M. Lv, X. R. Lyu, F. C. Ma, H. L. Ma, L. L. Ma, Q. M. Ma, T. Ma, X. N. Ma, X. Y. Ma, F. E. Maas, M. Maggiora, Y. J. Mao, Z. P. Mao, S. Marcello, J. G. Messchendorp, J. Min, T. J. Min, R. E. Mitchell, X. H. Mo, Y. J. Mo, C. Morales Morales, K. Moriya, N. Yu. Muchnoi, H. Muramatsu, Y. Nefedov, F. Nerling, I. B. Nikolaev, Z. Ning, S. Nisar, S. L. Niu, X. Y. Niu, S. L. Olsen, Q. Ouyang, S. Pacetti, P. Patteri, M. Pelizaeus, H. P. Peng, K. Peters, J. Pettersson, J. L. Ping, R. G. Ping, R. Poling, V. Prasad, Y. N. Pu, M. Qi, S. Qian, C. F. Qiao, L. Q. Qin, N. Qin, X. S. Qin, Y. Qin, Z. H. Qin, J. F. Qiu, K. H. Rashid, C. F. Redmer, H. L. Ren, M. Ripka, G. Rong, Ch. Rosner, X. D. Ruan, V. Santoro, A. Sarantsev, M. Savrié, K. Schoenning, S. Schumann, W. Shan, M. Shao, C. P. Shen, P. X. Shen, X. Y. Shen, H. Y. Sheng, W. M. Song, X. Y. Song, S. Sosio, S. Spataro, G. X. Sun, J. F. Sun, S. S. Sun, Y. J. Sun, Y. Z. Sun, Z. J. Sun, Z. T. Sun, C. J. Tang, X. Tang, I. Tapan, E. H. Thorndike, M. Tiemens, M. Ullrich, I. Uman, G. S. Varner, B. Wang, B. L. Wang, D. Wang, D. Y. Wang, K. Wang, L. L. Wang, L. S. Wang, M. Wang, P. Wang, P. L. Wang, S. G. Wang, W. Wang, X. F. Wang, Y. D. Wang, Y. F. Wang, Y. Q. Wang, Z. Wang, Z. G. Wang, Z. H. Wang, Z. Y. Wang, T. Weber, D. H. Wei, J. B. Wei, P. Weidenkaff, S. P. Wen, U. Wiedner, M. Wolke, L. H. Wu, Z. Wu, L. G. Xia, Y. Xia, D. Xiao, Z. J. Xiao, Y. G. Xie, Q. L. Xiu, G. F. Xu, L. Xu, Q. J. Xu, Q. N. Xu, X. P. Xu, L. Yan, W. B. Yan, W. C. Yan, Y. H. Yan, H. J. Yang, H. X. Yang, L. Yang, Y. Yang, Y. X. Yang, H. Ye, M. Ye, M. H. Ye, J. H. Yin, B. X. Yu, C. X. Yu, H. W. Yu, J. S. Yu, C. Z. Yuan, W. L. Yuan, Y. Yuan, A. Yuncu, A. A. Zafar, A. Zallo, Y. Zeng, B. X. Zhang, B. Y. Zhang, C. Zhang, C. C. Zhang, D. H. Zhang, H. H. Zhang, H. Y. Zhang, J. J. Zhang, J. L. Zhang, J. Q. Zhang, J. W. Zhang, J. Y. Zhang, J. Z. Zhang, K. Zhang, L. Zhang, S. H. Zhang, X. Y. Zhang, Y. Zhang, Y. N. Zhang, Y. H. Zhang, Y. T. Zhang, Yu Zhang, Z. H. Zhang, Z. P. Zhang, Z. Y. Zhang, G. Zhao, J. W. Zhao, J. Y. Zhao, J. Z. Zhao, Lei Zhao, Ling Zhao, M. G. Zhao, Q. Zhao, Q. W. Zhao, S. J. Zhao, T. C. Zhao, Y. B. Zhao, Z. G. Zhao, A. Zhemchugov, B. Zheng, J. P. Zheng, W. J. Zheng, Y. H. Zheng, B. Zhong, L. Zhou, Li Zhou, X. Zhou, X. K. Zhou, X. R. Zhou, X. Y. Zhou, K. Zhu, K. J. Zhu, S. Zhu, X. L. Zhu, Y. C. Zhu, Y. S. Zhu, Z. A. Zhu, J. Zhuang, L. Zotti, B. S. Zou, J. H. Zou

(BESIII Collaboration)

Affiliations

7 China Center of Advanced Science and Technology, Beijing 100190, People' s Republic of China

8 COMSATS Institute of Information Technology, Lahore, Defence Road, Off Raiwind Road, 54000 Lahore, Pakistan

19 Indiana University, Bloomington, Indiana 47405, USA

20 (A)INFN Laboratori Nazionali di Frascati, I-00044, Frascati, Italy; (B)INFN and University of Perugia, I-06100, Perugia, Italy

21 (A)INFN Sezione di Ferrara, I-44122, Ferrara, Italy; (B)University of Ferrara, I-44122, Ferrara, Italy

23 Joint Institute for Nuclear Research, 141980 Dubna, Moscow region, Russia

24 Justus Liebig University Giessen, II. Physikalisches Institut, Heinrich-Buff-Ring 16, D-35392 Giessen, Germany

39 Tsinghua University, Beijing 100084, People' s Republic of China

40 (A)Istanbul Aydin University, 34295 Sefakoy, Istanbul, Turkey; (B)Dogus University, 34722 Istanbul, Turkey; (C)Uludag University, 16059 Bursa, Turkey

47 University of the Punjab, Lahore-54590, Pakistan

48 (A)University of Turin, I-10125, Turin, Italy; (B)University of Eastern Piedmont, I-15121, Alessandria, Italy; (C)INFN, I-10125, Turin, Italy

52 Zhengzhou University, Zhengzhou 450001, People' s Republic of China

Also at State Key Laboratory of Particle Detection and Electronics, Beijing 100049, Hefei 230026, People' s Republic of China

Also at Ankara University, 06100 Tandogan, Ankara, Turkey

Also at Bogazici University, 34342 Istanbul, Turkey

Also at the Moscow Institute of Physics and Technology, Moscow 141700, Russia

Also at the Functional Electronics Laboratory, Tomsk State University, Tomsk, 634050, Russia

Also at the Novosibirsk State University, Novosibirsk, 630090, Russia

Also at the NRC "Kurchatov Institute", PNPI, 188300, Gatchina, Russia

Also at University of Texas at Dallas, Richardson, Texas 75083, USA

Present address: Istanbul Arel University, 34295 Istanbul, Turkey

(Dated: December 8, 2015)

Abstract

Using data samples collected at center-of-mass energies of √s = 4.009, 4.226, 4.257, 4.358, 4.416, and 4.599 GeV with the BESIII detector operating at the BEPCII storage ring, we search for the isospin violating decay Y(4260) → J/ 0. No signal is observed, and upper limits on the cross section (e e → J/ 0) at the 90% confidence level are determined to be 3.6, 1.7, 2.4, 1.4, 0.9, and 1.9 pb, respectively.

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Introduction

The Y(4260) charmonium-like state was first observed in its decay to J/ and has a small coupling to open charm decay modes. As a vector (J^PC = 1^-) state, it is only barely observable as an s-channel resonance in e e collisions and appears at an energy where no conventional charmonium state is expected. Since its discovery, many theoretical studies have been carried out considering the Y(4260) as a tetraquark state, D D or D D* hadronic molecule, hybrid charmonium, baryonium state, etc.

Recently, in the study of Y(4260) → J/ , a charged charmonium-like structure, the Z_c(3900)^±, was observed in the ^±J/ invariant mass spectrum by the BESIII and Belle experiments and confirmed shortly thereafter with CLEO-c data. In the molecule model, the Y(4260) is proposed to have a large D D̄ component, while Z_c(3900)^± has a D̄D* component.

BESIII recently reported the observation of e e → X(3872) → J/ . The cross section measurements strongly support the existence of the radiative transition Y(4260) → X(3872). One significant feature of the X(3872) that differs from conventional charmonium is that the decay branching fraction of X(3872) → J/ is comparable to J/ , indicating that the isospin violating process occurs on a large scale.

Isospin violating decays can be used to probe the nature of heavy quarkonium. The hadro-charmonium model and tetraquark models predict that the reaction ϒ(5S) → + bottomonium should be observable. The tetraquark model also predicts that Z_c can be produced in Y(4260) decaying into J/ and possibly J/ in the presence of sizable isospin violation. The molecular model predicts a J/ peak in the cross section of Y(4260) at the D D̄ threshold and a narrow peak in the J/ invariant mass spectrum at the D̄D* threshold.

In this paper, we present results on a search for the isospin violating decay Y(4260) → J/ 0, with J/ → e e / , → , and → (the other decay modes of are not used due to much lower detection efficiency and branching fraction), based on e e annihilation data collected with the BESIII detector operating at the BEPCII storage ring at center-of-mass energies of √s = 4.009, 4.226, 4.257, 4.358, 4.416, and 4.599 GeV.

BESIII Detector and Monte Carlo Simulation

The BESIII detector, described in detail in Ref. [19], has a geometrical acceptance of 93% of 4 . A small-cell helium-based main drift chamber (MDC) provides a charged particle momentum resolution of 0.5% at 1 GeV/c in a 1 T magnetic field and supplies energy-loss (dE/dx) measurements with a resolution of 6% for minimum-ionizing pions. The electromagnetic calorimeter (EMC) measures photon energies with a resolution of 2.5% (5%) at 1.0 GeV in the barrel (end caps). Particle identification is provided by a time-of-flight system with a time resolution of 80 ps (110 ps) for the barrel (end caps). The muon system (MUC), located in the iron flux return yoke of the magnet, provides 2 cm position resolution and detects muon tracks with momentum greater than 0.5 GeV/c.

The GEANT4-based Monte Carlo (MC) simulation software BOOST includes the geometric description of the BESIII detector and a simulation of the detector response. It is used to optimize event selection criteria, estimate backgrounds, and evaluate the detection efficiency. For each energy point, we generate large signal MC samples of e e $\rightarrow$ e e / , , and $\rightarrow$ uniformly in phase space. Effects of initial state radiation (ISR) are simulated with KKMC, where the Born cross section of e e $\rightarrow$ J/ is assumed to follow a Y(4260) Breit-Wigner line shape with resonance parameters taken from the Particle Data Group (PDG). Final state radiation effects associated with charged particles are handled with PHOTOS.

To study possible backgrounds, a MC sample of inclusive Y(4260) decays, equivalent to an integrated luminosity of 825.6 pb [1], is also generated at $\sqrt{s} = 4.260$ GeV. In these simulations, the Y(4260) is allowed to decay generically, with the main known decay channels being generated using EVTGEN with branching fractions set to world average values. The remaining events associated with charmonium decays are generated with LUNDCHARM, while continuum hadronic events are generated with PYTHIA. QED events (e e $\rightarrow$ e e , , and) are generated with KKMC. Backgrounds at other energy points are expected to be similar.

Event Selection

Events with two charged tracks with a net charge of zero are selected. For each good charged track, the polar angle in the MDC must satisfy $|\cos| < 0.93$, and the point of closest approach to the e e interaction point must be within 10 cm in the beam direction and within 1 cm in the plane perpendicular to the beam direction.

The momenta of leptons from the J/ decays in the laboratory frame are required to be larger than 1.0 GeV/c. E/p is used to separate electrons from muons, where E is the energy deposited in the EMC and p is the momentum measured by the MDC. For electron candidates, E/p should be larger than 0.7, while for muons it should be less than 0.3. To suppress background from events with pion tracks

in the final state, at least one of the two muons is required to have at least five layers with valid hits in the MUC.

Showers identified as photon candidates must satisfy fiducial and shower quality as well as timing requirements. The minimum EMC energy is 25 MeV for barrel showers ($|\cos| < 0.80$) and 50 MeV for end cap showers ($0.86 < |\cos| < 0.92$). To eliminate showers produced by charged particles, a photon must be separated by at least 5° from any charged track. The time information from the EMC is also used to suppress electronic noise and energy deposits unrelated to the event. At least four good photon candidates in each event are required.

To improve the momentum resolution and reduce the background, the event is subjected to a four-constraint (4C) kinematic fit under the hypothesis e e → (= e/), and the ² is required to be less than 40. For events with more than four photons, the four photons with the smallest ² from the 4C fit are assigned as the photons from and .

After selecting the candidate, scatter plots of M( ) with all six combinations of photon pairs for events in the J/ signal region ($3.067 < M(\ ) < 3.127$ GeV/c²) for data at $\sqrt{s} = 4.226$ and 4.257 GeV are shown in the left two panels of Fig. 1 [Figure 1: see original paper]. Distributions of M( ) for events in the signal region (both photon pairs satisfy $|M(\ ) - m_{\ }| < 10$ MeV/c²) for data at $\sqrt{s} = 4.226$ and 4.257 GeV are shown in the right two panels of Fig. 1. Clear J/ peaks are observed, corresponding to J/ events. To remove this J/ background, events with any combination of photon pairs in the region of the scatter plot are rejected.

After rejecting the J/ background, we choose the combination of photon pairs closest to the signal region by minimizing $\sqrt{[(M(\ ) - m_{\ })^2/\ _{\ }^2 + (M(\ ) - m_{\ })^2/\ _{\ }^2]}$, where _ and _ are the and resolutions obtained from the signal MC, respectively. The scatter plots of M( ) with the combination closest to the signal region for events in the J/ signal region for data at $\sqrt{s} = 4.226$ and 4.257 GeV are shown in the top two panels of Fig. 2 [Figure 2: see original paper]. No cluster of events is observed in the J/ signal region, with a vertical band for → clearly visible, but no prominent band for → is observed. The projections of the scatter plots on M( ) with M( ) in the signal region ($|M(\ ) - m_{\ }| < 10$ MeV/c²) and projections on M( ) with M( ) in the signal region ($|M(\ ) - m_{\ }| < 30$ MeV/c²) for data are shown in the middle and bottom panels of Fig. 2, respectively.

The background for e e → J/ is studied using the inclusive MC sample at $\sqrt{s} = 4.260$ GeV. After imposing all event selection requirements, there are two background events from e e → J/ and nine background events arising from e e → _ISR ' , _ISR ' ' , and _ISR (4040). No other background survives. The background can be evaluated with sideband events.

Distributions of M( ) for events in the signal region for data at $\sqrt{s} = 4.226$ and 4.257 GeV are shown in Fig. 3 [Figure 3: see original paper]. Distributions of M( ) for events corresponding to the normalized two-dimensional side-

bands are shown as shaded histograms. The sideband regions are defined as 0.3978 < M( ) < 0.4578 GeV/c² and 0.6378 < M( ) < 0.6978 GeV/c². The sideband regions are defined as 0.0849 < M( ) < 0.1049 GeV/c² and 0.1649 < M( ) < 0.1849 GeV/c². The number of observed events in the J/ signal region N_obs and number of background events estimated from sidebands N_bkg are listed in Table I .

Cross Section Upper Limits

Since no J/ signal above the background is observed, upper limits on the Born cross section of e e → J/ at the 90% C.L. are determined using the formula:

_Born < (1 + _r)(1 + _v)(_ee B_ee + _ B_) N_up / L

where N_up is the upper limit on the number of signal events; L is the integrated luminosity; (1 + _r) is the radiative correction factor, which is taken from a QED calculation assuming the e e → J/ cross section is described by a Y(4260) Breit-Wigner line shape with parameters taken from the PDG; (1 + _v) is the vacuum polarization factor including leptonic and hadronic parts and taken from a QED calculation with an accuracy of 0.5%; _ee and _ are the efficiencies for e e and modes, respectively; B_ee and B_ are the branching fractions of J/ → e e and J/ → , respectively; and B_ and B_ are the branching fractions of → and → , respectively.

The efficiency-corrected upper limit on the number of signal events N_up is estimated with N_obs and N_bkg using the profile likelihood method, which is implemented by TRolke in the ROOT framework. The calculation for obtaining N_up includes the background fluctuation and the systematic uncertainty of the cross section measurement. The background fluctuation is assumed to follow a Poisson distribution. The systematic uncertainty of the cross section is taken as a Gaussian uncertainty.

The systematic uncertainty of the cross section measurement includes the luminosity measurement, detection efficiency, and intermediate decay branching fractions. The systematic uncertainties of the luminosity, track reconstruction, and photon detection are 1.0%, 1.0% per track, and 1.0% per photon, respectively. The systematic uncertainties from the branching fraction of and decays are taken from the PDG. These sources of systematic uncertainty, which are summarized in the top part of Table II , are common for e e and modes. The following sources of systematic uncertainty, which are uncorrelated for the e e and modes, are summarized in the bottom part of Table II. The systematic uncertainty from the branching fraction of J/ decay is taken from the PDG. The systematic uncertainty from the requirement on the number of MUC hits is 3.6% and estimated by comparing the efficiency of the MUC requirement between data and MC in the control sample e e → J/ at √s = 4.257 GeV. The systematic uncertainty from the requirement of the J/ signal region is estimated by smearing the invariant mass of of the signal MC with a Gaussian

function to compensate for the resolution difference between the data and MC when calculating the efficiency. The parameters for smearing are determined by fitting the J/ distribution of data with the MC shape convoluted with a Gaussian function for the control sample e e → J/ . The difference in the detection efficiency between signal MC samples with and without the smearing is taken as the systematic uncertainty. The systematic uncertainty from the MC model is estimated by generating a MC sample with the angular distribution of leptons determined from the J/ data. The systematic uncertainty due to kinematic fitting is estimated by correcting the helix parameters of charged tracks according to the method described in Ref. [32], where the correction factors are obtained from the control sample ' → _cJ and the difference in the detection efficiency between with and without making the correction to the MC is taken as the systematic uncertainty. The uncorrelated systematic uncertainties for the electron and muon channels are combined by taking the weighted average with weights _ee and _ , respectively. The total systematic uncertainty is obtained by summing all the sources of systematic uncertainty in quadrature.

The systematic uncertainty on the size of the background is estimated by evaluating N_up with different signal and sideband regions for and . The most conservative N_up is taken as the final result, as listed in Table I. The upper limits on the Born cross section of e e → J/ (_Born^UL) assuming it follows a Y(4260) Breit-Wigner line shape are listed in Table I.

For comparison, the radiative correction factor and detection efficiency have been recalculated assuming the J/ cross section follows alternative line shapes. If the cross section follows the line shape of the Y(4040), the upper limit on the Born cross section is 4.1 pb at √s = 4.009 GeV. For a Y(4360) line shape, it is 1.6 pb at √s = 4.358 GeV. For a Y(4415) line shape, it is 1.5 pb at √s = 4.358 GeV and 1.0 pb at √s = 4.416 GeV. For a Y(4660) line shape, it is 2.0 pb at √s = 4.599 GeV.

It is also possible to set upper limits on e e → Z_c → J/ . The number of observed events and number of estimated background events in the Z_c signal region (3.850 < M(J/) < 3.940 GeV/c²) are 7 and 2, respectively, at √s = 4.226 GeV, and 8 and 3 respectively, at √s = 4.257 GeV. The upper limit on (e e → Z_c → J/) is determined to be 1.3 pb at √s = 4.226 GeV and 2.0 pb at √s = 4.257 GeV, where only the statistical uncertainty is given. Compared to the measured cross section of e e → J/ , the upper limit on the ratio of the branching fraction B(Y(4260) → J/)/B(Y(4260) → J/) at the 90% confidence level is 0.15 at √s = 4.226 GeV and 0.65 at √s = 4.257 GeV.

Summary

In summary, using data collected with the BESIII detector, a search for the isospin violating decay Y(4260) → J/ is performed. No statistically significant signal is observed. The Born cross sections of e e → J/ at the 90%

confidence level limits at $\sqrt{s}$ = 4.009, 4.226, 4.257, 4.358, 4.416, and 4.599 GeV are determined to be 3.6, 1.7, 2.4, 1.4, 0.9, and 1.9 pb, respectively. The upper limits are well above the prediction for the molecule model.

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References

[1] B. Aubert et al. (BABAR Collaboration), Phys. Rev. Lett. 95, 142001 (2005).

[2] G. Pakhlova et al. (Belle Collaboration), Phys. Rev. Lett. 98, 092001 (2007).

[3] L. Maiani, V. Riquer, F. Piccinini, and A. D. Polosa, Phys. Rev. D 72, 031502 (2005).

[4] G. J. Ding, Phys. Rev. D 79, 014001 (2009).

[5] S. L. Zhu, Phys. Lett. B 625, 212 (2005).

[6] C. F. Qiao, Phys. Lett. B 639, 263 (2006).

[7] M. Ablikim et al. (BESIII Collaboration), Phys. Rev. Lett. 110, 252001 (2013).

[8] Z. Q. Liu et al. (Belle Collaboration), Phys. Rev. Lett. 110, 252002 (2013).

[9] T. Xiao, S. Dobbs, A. Tomaradze, and K. K. Seth, Phys. Lett. B 727, 366 (2013).

[10] Q. Wang, C. Hanhart, and Q. Zhao, Phys. Rev. Lett. 111, 132003 (2013).

[11] M. Ablikim et al. (BESIII Collaboration), arXiv:1510.06017.

[12] K. Abe (Belle Collaboration), arXiv:hep-ex/0505037.

[13] P. del Amo Sanchez et al. (BABAR Collaboration), Phys. Rev. D 82, 011101 (2010).

[14] M. B. Voloshin, Phys. Rev. D 86, 034013 (2012).

[15] A. Ali, C. Hambrock, and M. J. Aslam, Phys. Rev. Lett. 104, 162001 (2010).

[16] A. Ali, C. Hambrock, and S. Mishima, Phys. Rev. Lett. 106, 092002 (2011).

[17] L. Maiani, V. Riquer, R. Faccini, F. Piccinini, A. Pilloni, and A. D. Polosa, Phys. Rev. D 87, 111102 (2013).

[18] X. G. Wu, C. Hanhart, Q. Wang, and Q. Zhao, Phys. Rev. D 89, 054038 (2014).

[19] M. Ablikim et al. (BESIII Collaboration), Nucl. Instrum. Methods Phys. Res., Sect. A 614, 345 (2010).

[20] S. Agostinelli et al. (GEANT4 Collaboration), Nucl. Instrum. Methods Phys. Res., Sect. A 506, 250 (2003).

[21] Z. Y. Deng et al., HEP & NP 30, 371 (2006).

[22] S. Jadach, B. F. L. Ward, and Z. Was, Comput. Phys. Commun. 130, 260 (2000); Phys. Rev. D 63, 113009 (2001).

[23] K. A. Olive et al. (Particle Data Group Collaboration), Chin. Phys. C 38, 090001 (2014).

[24] P. Golonka and Z. Was, Eur. Phys. J. C 45, 97 (2006).

[25] D. J. Lange, Nucl. Instrum. Methods Phys. Res., Sect. A 462, 152 (2001).

[26] R. G. Ping, Chin. Phys. C 32, 599 (2008).

[27] T. Sjöstrand et al., arXiv:hep-ph/0108264.

[28] S. Actis et al., Eur. Phys. J. C 66, 585 (2010).

[29] W. Rolke, A. Lopez, J. Conrad, and F. James, Nucl. Instrum. Methods Phys. Res., Sect. A 551, 493 (2005).

[30] M. Ablikim et al. (BESIII Collaboration), Phys. Rev. Lett. 112, 022001 (2014).

[31] M. Ablikim et al. (BESIII Collaboration), Phys. Rev. D 83, 112005 (2011).

[32] M. Ablikim et al. (BESIII Collaboration), Phys. Rev. D 87, 012002 (2013).

[33] M. Ablikim et al. (BESIII Collaboration), arXiv:1509.02248.

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