Title

Measurement of the Time-Dependent CP Asymmetry in B;{0}-->D_{CP};{(*)}h;{0} Decays.

Journal

Physical review letters, 99(8)

ISSN

0031-9007

Authors

Aubert, B
Bona, M
Boutigny, D
et al.

Publication Date

2007-08-01

DOI

10.1103/physrevlett.99.081801

Measurement of the Time-Dependent CP Asymmetry in $B^0 \to D^{(*)}_{CP} h^0$ Decays

B. Aubert,[1] M. Bona,[1] D. Boutigny,[1] Y. Karyotakis,[1] J. P. Lees,[1] V. Poireau,[1] X. Prudent,[1] V. Tisserand,[1] A. Zghiche,[1] J. Garra Tico,[2] E. Grauges,[2] L. Lopez,[3] A. Palano,[3] G. Eigen,[4] I. Ofte,[4] B. Stugu,[4] L. Sun,[4] G. S. Abrams,[5] M. Battaglia,[5] D. N. Brown,[5] J. Button-Shafer,[5] R. N. Cahn,[5] Y. Groysman,[5] R. G. Jacobsen,[5] J. A. Kadyk,[5] L. T. Kerth,[5] Yu. G. Kolomensky,[5] G. Kukartsev,[5] D. Lopes Pegna,[5] G. Lynch,[5] L. M. Mir,[5] T. J. Orimoto,[5] M. Pripstein,[5] N. A. Roe,[5] M. T. Ronan,[5,*] K. Tackmann,[5] W. A. Wenzel,[5] P. del Amo Sanchez,[6] C. M. Hawkes,[6] A. T. Watson,[6] T. Held,[7] H. Koch,[7] B. Lewandowski,[7] M. Pelizaeus,[7] T. Schroeder,[7] M. Steinke,[7] J. T. Boyd,[8] J. P. Burke,[8] W. N. Cottingham,[8] D. Walker,[8] D. J. Asgeirsson,[9] T. Cuhadar-Donszelmann,[9] B. G. Fulsom,[9] C. Hearty,[9] N. S. Knecht,[9] T. S. Mattison,[9] J. A. McKenna,[9] A. Khan,[10] M. Saleem,[10] L. Teodorescu,[10] V. E. Blinov,[11] A. D. Bukin,[11] V. P. Druzhinin,[11] V. B. Golubev,[11] A. P. Onuchin,[11] S. I. Serednyakov,[11] Yu. I. Skovpen,[11] E. P. Solodov,[11] K. Yu. Todyshev,[11] M. Bondioli,[12] M. Bruinsma,[12] S. Curry,[12] I. Eschrich,[12] D. Kirkby,[12] A. J. Lankford,[12] P. Lund,[12] M. Mandelkern,[12] E. C. Martin,[12] D. P. Stoker,[12] S. Abachi,[13] C. Buchanan,[13] S. D. Foulkes,[14] J. W. Gary,[14] F. Liu,[14] O. Long,[14] B. C. Shen,[14] L. Zhang,[14] H. P. Paar,[15] S. Rahatlou,[15] V. Sharma,[15] J. W. Berryhill,[16] C. Campagnari,[16] A. Cunha,[16] B. Dahmes,[16] T. M. Hong,[16] D. Kovalskyi,[16] J. D. Richman,[16] T. W. Beck,[17] A. M. Eisner,[17] C. J. Flacco,[17] C. A. Heusch,[17] J. Kroseberg,[17] W. S. Lockman,[17] T. Schalk,[17] B. A. Schumm,[17] A. Seiden,[17] D. C. Williams,[17] M. G. Wilson,[17] L. O. Winstrom,[17] E. Chen,[18] C. H. Cheng,[18] A. Dvoretskii,[18] F. Fang,[18] D. G. Hitlin,[18] I. Narsky,[18] T. Piatenko,[18] F. C. Porter,[18] G. Mancinelli,[19] B. T. Meadows,[19] K. Mishra,[19] M. D. Sokoloff,[19] F. Blanc,[20] P. C. Bloom,[20] S. Chen,[20] W. T. Ford,[20] J. F. Hirschauer,[20] A. Kreisel,[20] M. Nagel,[20] U. Nauenberg,[20] A. Olivas,[20] J. G. Smith,[20] K. A. Ulmer,[20] S. R. Wagner,[20] J. Zhang,[20] A. Chen,[21] E. A. Eckhart,[21] A. Soffer,[21] W. H. Toki,[21] R. J. Wilson,[21] F. Winklmeier,[21] Q. Zeng,[21] D. D. Altenburg,[22] E. Feltresi,[22] A. Hauke,[22] H. Jasper,[22] J. Merkel,[22] A. Petzold,[22] B. Spaan,[22] K. Wacker,[22] T. Brandt,[23] V. Klose,[23] H. M. Lacker,[23] W. F. Mader,[23] R. Nogowski,[23] J. Schubert,[23] K. R. Schubert,[23] R. Schwierz,[23] J. E. Sundermann,[23] A. Volk,[23] D. Bernard,[24] G. R. Bonneaud,[24] E. Latour,[24] Ch. Thiebaux,[24] M. Verderi,[24] P. J. Clark,[25] W. Gradl,[25] F. Muheim,[25] S. Playfer,[25] A. I. Robertson,[25] Y. Xie,[25] M. Andreotti,[26] D. Bettoni,[26] C. Bozzi,[26] R. Calabrese,[26] A. Cecchi,[26] G Cibinetto,[26] P. Franchini,[26] E. Luppi,[26] M. Negrini,[26] A. Petrella,[26] L. Piemontese,[26] E. Prencipe,[26] V. Santoro,[26] F. Anulli,[27] R. Baldini-Ferroli,[27] A. Calcaterra,[27] R. de Sangro,[27] G. Finocchiaro,[27] S. Pacetti,[27] P. Patteri,[27] I. M. Peruzzi,[27,†] M. Piccolo,[27] M. Rama,[27] A. Zallo,[27] A. Buzzo,[28] R. Contri,[28] M. Lo Vetere,[28] M. M. Macri,[28] M. R. Monge,[28] S. Passaggio,[28] C. Patrignani,[28] E. Robutti,[28] A. Santroni,[28] S. Tosi,[28] K. S. Chaisanguanthum,[29] M. Morii,[29] J. Wu,[29] R. S. Dubitzky,[30] J. Marks,[30] S. Schenk,[30] U. Uwer,[30] D. J. Bard,[31] P. D. Dauncey,[31] R. L. Flack,[31] J. A. Nash,[31] M. B. Nikolich,[31] W. Panduro Vazquez,[31] P. K. Behera,[32] X. Chai,[32] M. J. Charles,[32] U. Mallik,[32] N. T. Meyer,[32] V. Ziegler,[32] J. Cochran,[33] H. B. Crawley,[33] L. Dong,[33] V. Eyges,[33] W. T. Meyer,[33] S. Prell,[33] E. I. Rosenberg,[33] A. E. Rubin,[33] A. V. Gritsan,[34] C. K. Lae,[34] A. G. Denig,[35] M. Fritsch,[35] G. Schott,[35] N. Arnaud,[36] J. Béquilleux,[36] M. Davier,[36] G. Grosdidier,[36] A. Höcker,[36] V. Lepeltier,[36] F. Le Diberder,[36] A. M. Lutz,[36] S. Pruvot,[36] S. Rodier,[36] P. Roudeau,[36] M. H. Schune,[36] J. Serrano,[36] V. Sordini,[36] A. Stocchi,[36] W. F. Wang,[36] G. Wormser,[36] D. J. Lange,[37] D. M. Wright,[37] C. A. Chavez,[38] I. J. Forster,[38] J. R. Fry,[38] E. Gabathuler,[38] R. Gamet,[38] D. E. Hutchcroft,[38] D. J. Payne,[38] K. C. Schofield,[38] C. Touramanis,[38] A. J. Bevan,[39] K. A. George,[39] F. Di Lodovico,[39] W. Menges,[39] R. Sacco,[39] G. Cowan,[40] H. U. Flaecher,[40] D. A. Hopkins,[40] P. S. Jackson,[40] T. R. McMahon,[40] F. Salvatore,[40] A. C. Wren,[40] D. N. Brown,[41] C. L. Davis,[41] J. Allison,[42] N. R. Barlow,[42] R. J. Barlow,[42] Y. M. Chia,[42] C. L. Edgar,[42] G. D. Lafferty,[42] T. J. West,[42] J. I. Yi,[42] J. Anderson,[43] C. Chen,[43] A. Jawahery,[43] D. A. Roberts,[43] G. Simi,[43] J. M. Tuggle,[43] G. Blaylock,[44] C. Dallapiccola,[44] S. S. Hertzbach,[44] X. Li,[44] T. B. Moore,[44] E. Salvati,[44] S. Saremi,[44] R. Cowan,[45] P. H. Fisher,[45] G. Sciolla,[45] S. J. Sekula,[45] M. Spitznagel,[45] F. Taylor,[45] R. K. Yamamoto,[45] H. Kim,[46] S. E. Mclachlin,[46] P. M. Patel,[46] S. H. Robertson,[46] A. Lazzaro,[47] V. Lombardo,[47] F. Palombo,[47] J. M. Bauer,[48] L. Cremaldi,[48] V. Eschenburg,[48] R. Godang,[48] R. Kroeger,[48] D. A. Sanders,[48] D. J. Summers,[48] H. W. Zhao,[48] S. Brunet,[49] D. Côté,[49] M. Simard,[49] P. Taras,[49] F. B. Viaud,[49] H. Nicholson,[50] G. De Nardo,[51] F. Fabozzi,[51,‡] L. Lista,[51] D. Monorchio,[51] C. Sciacca,[51] M. A. Baak,[52] G. Raven,[52] H. L. Snoek,[52] C. P. Jessop,[53] J. M. LoSecco,[53] G. Benelli,[54] L. A. Corwin,[54] K. K. Gan,[54] K. Honscheid,[54] D. Hufnagel,[54] H. Kagan,[54] R. Kass,[54] J. P. Morris,[54] A. M. Rahimi,[54] J. J. Regensburger,[54] R. Ter-Antonyan,[54] Q. K. Wong,[54] N. L. Blount,[55] J. Brau,[55] R. Frey,[55] O. Igonkina,[55] J. A. Kolb,[55] M. Lu,[55] R. Rahmat,[55] N. B. Sinev,[55] D. Strom,[55] J. Strube,[55] E. Torrence,[55] N. Gagliardi,[56] A. Gaz,[56] M. Margoni,[56] M. Morandin,[56] A. Pompili,[56] M. Posocco,[56] M. Rotondo,[56] F. Simonetto,[56] R. Stroili,[56] C. Voci,[56] E. Ben-Haim,[57] H. Briand,[57] J. Chauveau,[57] P. David,[57] L. Del Buono,[57] Ch. de la Vaissière,[57] O. Hamon,[57] B. L. Hartfiel,[57] Ph. Leruste,[57] J. Malclès,[57]

J. Ocariz,[57] A. Perez,[57] L. Gladney,[58] M. Biasini,[59] R. Covarelli,[59] E. Manoni,[59] C. Angelini,[60] G. Batignani,[60] S. Bettarini,[60] G. Calderini,[60] M. Carpinelli,[60] R. Cenci,[60] F. Forti,[60] M. A. Giorgi,[60] A. Lusiani,[60] G. Marchiori,[60] M. A. Mazur,[60] M. Morganti,[60] N. Neri,[60] E. Paoloni,[60] G. Rizzo,[60] J. J. Walsh,[60] M. Haire,[61] J. Biesiada,[62] P. Elmer,[62] Y. P. Lau,[62] C. Lu,[62] J. Olsen,[62] A. J. S. Smith,[62] A. V. Telnov,[62] E. Baracchini,[63] F. Bellini,[63] G. Cavoto,[63] A. D'Orazio,[63] D. del Re,[63] E. Di Marco,[63] R. Faccini,[63] F. Ferrarotto,[63] F. Ferroni,[63] M. Gaspero,[63] P. D. Jackson,[63] L. Li Gioi,[63] M. A. Mazzoni,[63] S. Morganti,[63] G. Piredda,[63] F. Polci,[63] F. Renga,[63] C. Voena,[63] M. Ebert,[64] H. Schröder,[64] R. Waldi,[64] T. Adye,[64] G. Castelli,[65] B. Franek,[65] E. O. Olaiya,[65] S. Ricciardi,[65] W. Roethel,[65] F. F. Wilson,[65] R. Aleksan,[66] S. Emery,[66] M. Escalier,[66] A. Gaidot,[66] S. F. Ganzhur,[66] G. Hamel de Monchenault,[66] W. Kozanecki,[66] M. Legendre,[66] G. Vasseur,[66] Ch. Yèche,[66] M. Zito,[66] X. R. Chen,[67] H. Liu,[67] W. Park,[67] M. V. Purohit,[67] J. R. Wilson,[67] M. T. Allen,[68] D. Aston,[68] R. Bartoldus,[68] P. Bechtle,[68] N. Berger,[68] R. Claus,[68] J. P. Coleman,[68] M. R. Convery,[68] J. C. Dingfelder,[68] J. Dorfan,[68] G. P. Dubois-Felsmann,[68] D. Dujmic,[68] W. Dunwoodie,[68] R. C. Field,[68] T. Glanzman,[68] S. J. Gowdy,[68] M. T. Graham,[68] P. Grenier,[68] V. Halyo,[68] C. Hast,[68] T. Hryn'ova,[68] W. R. Innes,[68] M. H. Kelsey,[68] P. Kim,[68] D. W. G. S. Leith,[68] S. Li,[68] S. Luitz,[68] V. Luth,[68] H. L. Lynch,[68] D. B. MacFarlane,[68] H. Marsiske,[68] R. Messner,[68] D. R. Muller,[68] C. P. O'Grady,[68] V. E. Ozcan,[68] A. Perazzo,[68] M. Perl,[68] T. Pulliam,[68] B. N. Ratcliff,[68] A. Roodman,[68] A. A. Salnikov,[68] R. H. Schindler,[68] J. Schwiening,[68] A. Snyder,[68] J. Stelzer,[68] D. Su,[68] M. K. Sullivan,[68] K. Suzuki,[68] S. Swain,[68] J. M. Thompson,[68] J. Va'vra,[68] N. van Bakel,[68] A. P. Wagner,[68] M. Weaver,[68] W. J. Wisniewski,[68] M. Wittgen,[68] D. H. Wright,[68] A. K. Yarritu,[68] K. Yi,[68] C. C. Young,[68] P. R. Burchat,[69] A. J. Edwards,[69] S. A. Majewski,[69] B. A. Petersen,[69] L. Wilden,[69] S. Ahmed,[70] M. S. Alam,[70] R. Bula,[70] J. A. Ernst,[70] V. Jain,[70] B. Pan,[70] M. A. Saeed,[70] F. R. Wappler,[70] S. B. Zain,[70] W. Bugg,[71] M. Krishnamurthy,[71] S. M. Spanier,[71] R. Eckmann,[72] J. L. Ritchie,[72] A. M. Ruland,[72] C. J. Schilling,[72] R. F. Schwitters,[72] J. M. Izen,[73] X. C. Lou,[73] S. Ye,[73] F. Bianchi,[74] F. Gallo,[74] D. Gamba,[74] M. Pelliccioni,[74] M. Bomben,[75] L. Bosisio,[75] C. Cartaro,[75] F. Cossutti,[75] G. Della Ricca,[75] L. Lanceri,[75] L. Vitale,[75] V. Azzolini,[76] N. Lopez-March,[76] F. Martinez-Vidal,[76] D. A. Milanes,[76] A. Oyanguren,[76] J. Albert,[77] Sw. Banerjee,[77] B. Bhuyan,[77] K. Hamano,[77] R. Kowalewski,[77] I. M. Nugent,[77] J. M. Roney,[77] R. J. Sobie,[77] J. J. Back,[78] P. F. Harrison,[78] T. E. Latham,[78] G. B. Mohanty,[78] M. Pappagallo,[78,§] H. R. Band,[79] X. Chen,[79] S. Dasu,[79] K. T. Flood,[79] J. J. Hollar,[79] P. E. Kutter,[79] Y. Pan,[79] M. Pierini,[79] R. Prepost,[79] S. L. Wu,[79] Z. Yu,[79] and H. Neal[80]

(The *BaBar* Collaboration)

[1]*Laboratoire de Physique des Particules, IN2P3/CNRS et Université de Savoie, F-74941 Annecy-Le-Vieux, France*
[2]*Universitat de Barcelona, Facultat de Fisica, Departament ECM, E-08028 Barcelona, Spain*
[3]*Università di Bari, Dipartimento di Fisica and INFN, I-70126 Bari, Italy*
[4]*University of Bergen, Institute of Physics, N-5007 Bergen, Norway*
[5]*Lawrence Berkeley National Laboratory and University of California, Berkeley, California 94720, USA*
[6]*University of Birmingham, Birmingham, B15 2TT, United Kingdom*
[7]*Ruhr Universität Bochum, Institut für Experimentalphysik 1, D-44780 Bochum, Germany*
[8]*University of Bristol, Bristol BS8 1TL, United Kingdom*
[9]*University of British Columbia, Vancouver, British Columbia, Canada V6T 1Z1*
[10]*Brunel University, Uxbridge, Middlesex UB8 3PH, United Kingdom*
[11]*Budker Institute of Nuclear Physics, Novosibirsk 630090, Russia*
[12]*University of California at Irvine, Irvine, California 92697, USA*
[13]*University of California at Los Angeles, Los Angeles, California 90024, USA*
[14]*University of California at Riverside, Riverside, California 92521, USA*
[15]*University of California at San Diego, La Jolla, California 92093, USA*
[16]*University of California at Santa Barbara, Santa Barbara, California 93106, USA*
[17]*University of California at Santa Cruz, Institute for Particle Physics, Santa Cruz, California 95064, USA*
[18]*California Institute of Technology, Pasadena, California 91125, USA*
[19]*University of Cincinnati, Cincinnati, Ohio 45221, USA*
[20]*University of Colorado, Boulder, Colorado 80309, USA*
[21]*Colorado State University, Fort Collins, Colorado 80523, USA*
[22]*Universität Dortmund, Institut für Physik, D-44221 Dortmund, Germany*
[23]*Technische Universität Dresden, Institut für Kernund Teilchenphysik, D-01062 Dresden, Germany*
[24]*Laboratoire Leprince-Ringuet, CNRS/IN2P3, Ecole Polytechnique, F-91128 Palaiseau, France*
[25]*University of Edinburgh, Edinburgh EH9 3JZ, United Kingdom*
[26]*Università di Ferrara, Dipartimento di Fisica and INFN, I-44100 Ferrara, Italy*
[27]*Laboratori Nazionali di Frascati dell'INFN, I-00044 Frascati, Italy*

[28]Università di Genova, Dipartimento di Fisica and INFN, I-16146 Genova, Italy
[29]Harvard University, Cambridge, Massachusetts 02138, USA
[30]Universität Heidelberg, Physikalisches Institut, Philosophenweg 12, D-69120 Heidelberg, Germany
[31]Imperial College London, London, SW7 2AZ, United Kingdom
[32]University of Iowa, Iowa City, Iowa 52242, USA
[33]Iowa State University, Ames, Iowa 50011-3160, USA
[34]Johns Hopkins University, Baltimore, Maryland 21218, USA
[35]Universität Karlsruhe, Institut für Experimentelle Kernphysik, D-76021 Karlsruhe, Germany
[36]Laboratoire de l'Accélérateur Linéaire, IN2P3/CNRS et Université Paris-Sud 11, Centre Scientifique d'Orsay, B. P. 34, F-91898 ORSAY Cedex, France
[37]Lawrence Livermore National Laboratory, Livermore, California 94550, USA
[38]University of Liverpool, Liverpool L69 7ZE, United Kingdom
[39]Queen Mary, University of London, E1 4NS, United Kingdom
[40]University of London, Royal Holloway and Bedford New College, Egham, Surrey TW20 0EX, United Kingdom
[41]University of Louisville, Louisville, Kentucky 40292, USA
[42]University of Manchester, Manchester M13 9PL, United Kingdom
[43]University of Maryland, College Park, Maryland 20742, USA
[44]University of Massachusetts, Amherst, Massachusetts 01003, USA
[45]Massachusetts Institute of Technology, Laboratory for Nuclear Science, Cambridge, Massachusetts 02139, USA
[46]McGill University, Montréal, Québec, Canada H3A 2T8
[47]Università di Milano, Dipartimento di Fisica and INFN, I-20133 Milano, Italy
[48]University of Mississippi, University, Mississippi 38677, USA
[49]Université de Montréal, Physique des Particules, Montréal, Québec, Canada H3C 3J7
[50]Mount Holyoke College, South Hadley, Massachusetts 01075, USA
[51]Università di Napoli Federico II, Dipartimento di Scienze Fisiche and INFN, I-80126, Napoli, Italy
[52]NIKHEF, National Institute for Nuclear Physics and High Energy Physics, NL-1009 DB Amsterdam, The Netherlands
[53]University of Notre Dame, Notre Dame, Indiana 46556, USA
[54]Ohio State University, Columbus, Ohio 43210, USA
[55]University of Oregon, Eugene, Oregon 97403, USA
[56]Università di Padova, Dipartimento di Fisica and INFN, I-35131 Padova, Italy
[57]Laboratoire de Physique Nucléaire et de Hautes Energies, IN2P3/CNRS, Université Pierre et Marie Curie-Paris 6, Université Denis Diderot-Paris 7, F-75252 Paris, France
[58]University of Pennsylvania, Philadelphia, Pennsylvania 19104, USA
[59]Università di Perugia, Dipartimento di Fisica and INFN, I-06100 Perugia, Italy
[60]Università di Pisa, Dipartimento di Fisica, Scuola Normale Superiore and INFN, I-56127 Pisa, Italy
[61]Prairie View A&M University, Prairie View, Texas 77446, USA
[62]Princeton University, Princeton, New Jersey 08544, USA
[63]Università di Roma La Sapienza, Dipartimento di Fisica and INFN, I-00185 Roma, Italy
[64]Universität Rostock, D-18051 Rostock, Germany
[65]Rutherford Appleton Laboratory, Chilton, Didcot, Oxon, OX11 0QX, United Kingdom
[66]DSM/Dapnia, CEA/Saclay, F-91191 Gif-sur-Yvette, France
[67]University of South Carolina, Columbia, South Carolina 29208, USA
[68]Stanford Linear Accelerator Center, Stanford, California 94309, USA
[69]Stanford University, Stanford, California 94305-4060, USA
[70]State University of New York, Albany, New York 12222, USA
[71]University of Tennessee, Knoxville, Tennessee 37996, USA
[72]University of Texas at Austin, Austin, Texas 78712, USA
[73]University of Texas at Dallas, Richardson, Texas 75083, USA
[74]Università di Torino, Dipartimento di Fisica Sperimentale and INFN, I-10125 Torino, Italy
[75]Università di Trieste, Dipartimento di Fisica and INFN, I-34127 Trieste, Italy
[76]IFIC, Universitat de Valencia-CSIC, E-46071 Valencia, Spain
[77]University of Victoria, Victoria, British Columbia, Canada V8W 3P6
[78]Department of Physics, University of Warwick, Coventry CV4 7AL, United Kingdom
[79]University of Wisconsin, Madison, Wisconsin 53706, USA
[80]Yale University, New Haven, Connecticut 06511, USA

(Received 9 March 2007; published 21 August 2007)

We report a measurement of the time-dependent CP-asymmetry parameters $\mathcal{S}$ and $\mathcal{C}$ in color-suppressed $B^0 \to D^{(*)0}h^0$ decays, where h^0 is a π^0, η, or ω meson, and the decays to one of the CP eigenstates K^+K^-, $K^0_S\pi^0$, or $K^0_S\omega$. The data sample consists of 383×10^6 $\Upsilon(4S) \to B\bar{B}$ decays collected with the *BABAR* detector at the PEP-II asymmetric-energy B factory at SLAC. The results are

$\mathcal{S} = -0.56 \pm 0.23 \pm 0.05$ and $\mathcal{C} = -0.23 \pm 0.16 \pm 0.04$, where the first error is statistical and the second is systematic.

DOI: 10.1103/PhysRevLett.99.081801 PACS numbers: 13.25.Hw, 11.30.Er, 12.15.Hh

Measurements of time-dependent CP asymmetries in B^0 meson decays, through the interference between decays with and without B^0–$\bar{B}^0$ mixing, have provided stringent tests on the mechanism of CP violation in the standard model (SM). The time-dependent CP asymmetry amplitude $\sin 2\beta$ has been measured with high precision in the $b \to c\bar{c}s$ decay modes [1], where $\beta = -\arg(V_{cd}V_{cb}^*/V_{td}V_{tb}^*)$ is a phase in the Cabibbo-Kobayashi-Maskawa (CKM) quark-mixing matrix [2].

In this Letter, we present a measurement of the time-dependent CP asymmetry in B^0 meson decays to a neutral D meson and a light neutral meson through a $b \to c\bar{u}d$ color-suppressed tree amplitude. Interference between decay amplitudes with and without B^0–$\bar{B}^0$ mixing contribution occurs if the neutral D meson decays to a CP eigenstate. The measured time-dependent asymmetry is expected to be different from $\sin 2\beta$ measured in the charmonium modes due to the subleading amplitude $b \to u\bar{c}d$, which has a different weak phase. This amplitude is suppressed by $V_{ub}V_{cd}^*/V_{cb}V_{ud}^* \simeq 0.02$ relative to the leading diagram. Therefore, the deviation is expected to be small in the SM [3,4].

Many other decay modes that have significant contribution from loop diagrams have been studied [5] to constrain or discover new physics due to unobserved heavy particles in the loop diagrams in B decays. This kind of new physics would not affect the decays presented in this Letter because only tree diagrams contribute to these modes. However, R-parity-violating ($\not{R}_p$) supersymmetric processes [3,7] could enter at tree level in these decays, leading to a deviation from the SM prediction.

The analysis uses a data sample of 348 fb^{-1}, which corresponds to $(383 \pm 4) \times 10^6$ $\Upsilon(4S)$ decays into $B\bar{B}$ pairs collected with the *BABAR* detector at the asymmetric-energy e^+e^- PEP-II collider. The *BABAR* detector is described in detail elsewhere [8]. We use the GEANT4 simulation toolkit [9] to simulate interactions of particles traversing the *BABAR* detector and to take into account the varying detector conditions and beam backgrounds.

We fully reconstruct B^0 mesons [10] decaying into a CP eigenstate in the following channels: $D^{(*)0}\pi^0$ ($D^0 \to K^+K^-$, $K_S^0\omega$) [11], $D^{(*)0}\eta$ ($D^0 \to K^+K^-$) with $D^{*0} \to D^0\pi^0$, and $D^0\omega$ ($D^0 \to K^+K^-$, $K_S^0\omega$, $K_S^0\pi^0$). From the remaining particles in the event, the vertex of the other B meson, B_{tag}, is reconstructed, and its flavor is identified (tagged). The proper decay time difference $\Delta t = t_{CP} - t_{tag}$ between the signal B (t_{CP}) and B_{tag} (t_{tag}) is determined from the measured distance between the two B decay vertices projected onto the boost axis and the boost ($\beta\gamma = 0.56$) of the center-of-mass (c.m.) system. The Δt distribution is given by

$$F_{\pm}(\Delta t) = \frac{e^{-|\Delta t|/\tau}}{4\tau}\{1 \mp \Delta w \pm (1-2w) \times [\eta_f \sin(\Delta m \Delta t) - \mathcal{C}\cos(\Delta m \Delta t)]\}, \quad (1)$$

where the upper (lower) sign is for events with B_{tag} being identified as a B^0 ($\bar{B}^0$), η_f is the CP eigenvalue of the final state, Δm is the B^0–$\bar{B}^0$ mixing frequency, τ is the mean lifetime of the neutral B meson, the mistag parameter w is the probability of incorrectly identifying the flavor of B_{tag}, and Δw is the difference of w for B^0 and $\bar{B}^0$. The neural-network based tagging algorithm [12] has six mutually exclusive categories and a measured total effective tagging efficiency of $(30.4 \pm 0.3)\%$. Neglecting CKM-suppressed decay amplitudes, we expect the CP violating parameters $\mathcal{S} = -\sin 2\beta$ and $\mathcal{C} = 0$ in the SM.

The event selection criteria are determined by maximizing the expected signal significance based on the simulation of signal and generic decays of $B\bar{B}$ and $e^+e^- \to q\bar{q}$ ($q = u, d, s, c$) continuum events. The selection requirements vary by mode due to different signal yields and background levels.

A pair of energy clusters in the electromagnetic calorimeter (EMC), isolated from any charged tracks and with a lateral shower shape consistent with photons, is considered as a π^0 candidate if both cluster energy deposits exceed 30 MeV and the invariant mass of the pair is between 100 and 160 MeV$/c^2$. Charged tracks are considered as pions, except for those used in $D^0 \to K^+K^-$ reconstruction, where the kaons must be consistent with the kaon hypothesis [13]. We reconstruct η mesons in $\gamma\gamma$ and $\pi^+\pi^-\pi^0$ modes. Each photon is required to have an energy exceeding 100 MeV and, when combined with any other photon in the event, to not have an invariant mass within 5 MeV$/c^2$ of the π^0 nominal mass [14]. The invariant mass is required to be within approximately 30 MeV$/c^2$ (8 MeV$/c^2$) of the η nominal mass for $\eta \to \gamma\gamma$ ($\eta \to \pi^+\pi^-\pi^0$). Both π^0 and $\eta \to \gamma\gamma$ candidates are kinematically fitted with their invariant masses constrained at their respective nominal values. The $\omega \to \pi^+\pi^-\pi^0$ candidates are accepted if the invariant mass is within approximately 22 MeV$/c^2$ of the nominal ω mass, depending on the D^0 decay mode. The $K_S^0 \to \pi^+\pi^-$ candidates are required to have an invariant mass within 10 MeV$/c^2$ of the K_S^0 nominal mass and χ^2 probability of forming a common vertex greater than 0.1%. The distance between the K_S^0 decay vertex and the primary interaction point projected on the plane perpendicular to the beam axis is required to be greater than twice its measurement uncertainty.

The vector meson ω is fully polarized in $D^0 \to K_S^0\omega$ decays. Two angular distributions of the ω decay are used to discriminate against background: (a) $\cos\theta_N^D$, defined in the ω rest frame, the cosine of the angle between the D^0 direction and the normal to the decay plane of $\omega \to \pi^+\pi^-\pi^0$, and (b) $\cos\theta_D^D$, the cosine of the angle between the direction of one pion in the rest frame of the remaining pion pair and the direction of the pion pair. The signals are distributed according to $\cos^2\theta_N^D$ and $1 - \cos^2\theta_D^D$, while the background distributions are nearly uniform. We require $|\cos\theta_N^D| > 0.4$ and $|\cos\theta_D^D| < 0.9$.

For the D^0 in $D^{*0} \to D^0\pi^0$, the invariant mass of the D^0 candidate is required to be within 30 MeV$/c^2$ of the world-average D^0 mass. For the D^0 in $B^0 \to D^0h^0$, the invariant mass window is tightened, ranging from ±14 to ±29 MeV$/c^2$, depending on the mode. In both cases, the D^0 is kinematically fitted with its mass constrained at its nominal value. The invariant mass difference between D^{*0} and D^0 candidates is required to be within ±2.7 MeV$/c^2$ of the nominal value. For $B^0 \to D^{*0}\pi^0$ with $D^0 \to K_S^0\omega$, we require $|\cos\theta_H^*| > 0.4$, where θ_H^* is the angle between the momenta of the B^0 and the π^0 from the D^{*0} in the D^{*0} rest frame.

The signal is characterized by the kinematic variables $m_{\rm ES} = \sqrt{(s/2 + \mathbf{p}_0 \cdot \mathbf{p}_B)^2/E_0^2 - \mathbf{p}_B^2}$ and $\Delta E = E_B^* - E_{\rm beam}^*$, where the asterisk denotes the values evaluated in the c.m. frame, the subscripts 0, beam, and B denote the e^+e^- system, the beam, and the B candidate, respectively, and $\sqrt{s}$ is the c.m. energy. We require $m_{\rm ES} > 5.23$ GeV$/c^2$. The ΔE distribution for signal events is asymmetric and varies by decay mode. Depending on the mode, the lower (upper) boundary of the ΔE selection window varies from -95 to -35 MeV (+ 35 to +85 MeV). The reconstructed $|\Delta t|$, and its uncertainty $\sigma_{\Delta t}$ are required to satisfy $|\Delta t| < 15$ ps and $\sigma_{\Delta t} < 2.5$ ps.

The background from continuum $q\bar{q}$ production is suppressed based on the event topology. In the c.m. frame, the B mesons are produced nearly at rest and decay isotropically, while the quarks in the process $e^+e^- \to q\bar{q}$ are produced with large relative momentum and result in a jetlike topology. The ratio of the second to zeroth order Fox-Wolfram moments [15], determined from all charged tracks and clusters in the EMC with energy greater than 30 MeV, must be less than 0.5. The $q\bar{q}$ background is further suppressed by a Fisher discriminant $\mathcal{F}$ [16], constructed with the following variables, evaluated in the c.m. frame: (a) L_2/L_0 where $L_i = \sum_j p_j^* |\cos\theta_j^*|^i$, summed over the remaining particles in the event after removing the daughter particles from the B^0, p_j^* is the momentum of particle j, and θ_j^* is the angle of the momentum with respect to the B^0 thrust axis [17]; (b) $|\cos\theta_T^*|$, where θ_T^* is the angle between the B^0 thrust axis and the thrust axis of the rest of the event; (c) $|\cos^2\theta_B^*|$, where θ_B^* is the angle between the beam direction and the direction of the B^0; (d) total event thrust magnitude; and (e) total event sphericity [18].

For $B^0 \to D^0\omega$ decays, we add two angular variables to $\mathcal{F}$: $\cos\theta_N^B$ and $\cos\theta_D^B$, analogous to $\cos\theta_N^D$ and $\cos\theta_D^D$ in $D^0 \to K_s^0\omega$. The signal distributions for the B^0 system are the same as those in the D^0 system. The background distributions are close to $2 - \cos^2\theta_N^B$ and uniform in $\cos\theta_D^B$. The requirement on $\mathcal{F}$ depends on the background level in each mode; the signal selection (background rejection) efficiency is 60%–86% (72%–94%).

Within each reconstructed decay chain, the fraction of events that have more than one candidate ranges from less than 1% to about 10%, depending on the mode. We select one candidate with the most signal-like Fisher discriminant value for each mode. A total of 1128 events are selected, of which 751 are tagged (the absolute value of the flavor-tagging neural-network output greater than 10% of the maximum).

The signal and background yields are determined by a fit to the $m_{\rm ES}$ distribution using a Gaussian distribution for the signal peak and a threshold function [19] for the combinatorial background. We obtain 340 ± 32 signal events (259 ± 27 tagged). The contribution from each mode is shown in Table I, and the $m_{\rm ES}$ distributions are shown in Fig. 1. We investigate potential backgrounds that might peak in the $m_{\rm ES}$ signal region by studying data in the D^0 mass sideband (outside a window of ±3 standard deviations of the mass peak) and simulated $e^+e^- \to B\bar{B}$ events. We estimate that $(0.8 \pm 2.6)\%$ of the CP-even signal yield and $(5.4 \pm 2.2)\%$ of the CP-odd signal yield are background, based on the simulation. Approximately half of the peaking background found in simulation is from $B^- \to D^0\rho^-(\to \pi^0\pi^-)$ with a low momentum π^-. Other sources include $B^0 \to \pi^+\pi^-\pi^0$ and $B^0 \to D^{(*)0}h^0$, with D^0 decaying to a flavor eigenstate, e.g., $K^-\pi^+$. We find that the peaking background from the D^0 mass sideband data in

TABLE I. Signal yields. Uncertainties are statistical only. The CP parity of the D^0 is indicated in the column of D_{CP}. The combined value is from a simultaneous fit to all modes.

$\eta_f = +1$ (CP even)			$\eta_f = -1$ (CP odd)		
Mode	D_{CP}	$N_{\rm signal}$	Mode	D_{CP}	$N_{\rm signal}$
$D^0_{K_S^0\omega}\pi^0$	$-$	26.2 ± 6.3	$D^0_{KK}\pi^0$	$+$	104 ± 17
$D^0_{K_S^0\pi^0}\omega$	$-$	40.0 ± 8.0	$D^0_{KK}\eta_{\gamma\gamma}$	$+$	28.9 ± 6.5
$D^0_{K_S^0\omega}\omega$	$-$	23.2 ± 6.8	$D^0_{KK}\eta_{3\pi}$	$+$	14.2 ± 4.7
$D^{*0}_{KK}\pi^0$	$+$	23.2 ± 6.3	$D^0_{KK}\omega$	$+$	51.2 ± 8.5
$D^{*0}_{KK}\eta_{\gamma\gamma}$	$+$	9.8 ± 3.5	$D^{*0}_{K_S^0}\pi^0$	$-$	5.5 ± 3.3
$D^{*0}_{KK}\eta_{3\pi}$	$+$	6.8 ± 2.9			
Combined		131 ± 16			209 ± 23
Total			340 ± 32		

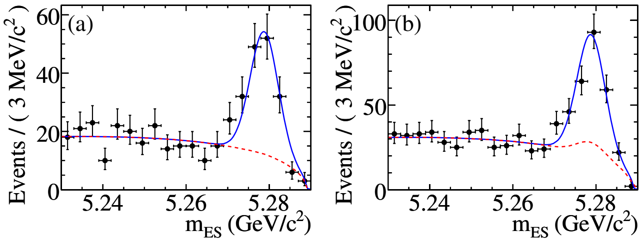

FIG. 1 (color online). The m_{ES} distributions with a fit to (a) the CP-even and (b) the CP-odd modes combined in the data. The solid curve represents the overall PDF projection, and the dashed curve represents the background.

CP-even modes is consistent with the simulation. For CP-odd modes, we find a larger peaking component in D^0 sideband data than expected from simulation. Therefore, we increase the estimated total peaking background fraction for CP-odd events to $(11 \pm 6)\%$ to account for the excess found in the D^0 sideband data. We estimate that 65% of the peaking background arises from charmless decays with potentially large CP-violating asymmetries. We account for this possibility in the systematic uncertainty.

In order to extract CP violating parameters $\mathcal{S}$ and $\mathcal{C}$, we fit the m_{ES} and Δt distributions of the 751 tagged events using a two-dimensional probability density function (PDF) that contains three components: signal, peaking background, and combinatorial background. The m_{ES} distribution is described in the previous paragraph. Its parameters are free in the fit. The peaking background is assumed to have the same m_{ES} shape as the signal. The signal decay-rate distribution shown in Eq. (1) accounts for dilution due to an incorrect assignment of the flavor of B_{tag} and is convolved with a sum of three Gaussian distributions, parameterizing the core, tail, and outlier parts of the Δt resolution function [13]. The widths and biases of the core and tail Gaussians are scaled by $\sigma_{\Delta t}$. The biases are nonzero to account for the charm meson flight from the B_{tag} vertex. The outlier Gaussian has a fixed mean (0 ps) and width (8 ps) to account for poorly-reconstructed decay vertices. The mistag parameters and the resolution function are determined from a large data control sample of $B^0 \to D^{(*)-}h^+$ decays, where h^+ is a π^+, ρ^+, or a_1^+ meson. The B^0 lifetime and mixing frequency are taken from [6].

We use an exponential decay to model the Δt PDF of the peaking background. We account for possible CP asymmetries in the systematic uncertainty. The Δt PDF for combinatorial background consists of a term with zero lifetime to account for the $q\bar{q}$ contribution, and an oscillatory term whose effective lifetime and oscillatory coefficients are free parameters in the fit to account for possible CP asymmetry in the background. The sum of a core Gaussian and an outlier Gaussian is sufficient to model the resolution function. The combinatorial background parameters are determined predominately by the events in the m_{ES} sideband. The final PDF has 25 free parameters for fitting to all modes and tagging categories simultaneously.

We obtain $\mathcal{S} = -0.56 \pm 0.23 \pm 0.05$ and $\mathcal{C} = -0.23 \pm 0.16 \pm 0.04$, where the first errors are statistical and the second are systematic. The statistical correlation between $\mathcal{S}$ and $\mathcal{C}$ is $\rho = -2.4\%$. The Δt distribution projections and the asymmetry $(A = [N_{B^0\mathrm{tag}}(\Delta t) - N_{\bar{B}^0\mathrm{tag}}(\Delta t)]/[N_{B^0\mathrm{tag}}(\Delta t) + N_{\bar{B}^0\mathrm{tag}}(\Delta t)])$ for the events in the signal region are shown in Fig. 2. We check the consistency between CP-even and CP-odd modes by fitting them separately and find (statistical errors only) $\mathcal{S}_{\mathrm{even}} = -0.17 \pm 0.37$, $\mathcal{S}_{\mathrm{odd}} = -0.82 \pm 0.28$, and $\mathcal{C}_{\mathrm{even}} = -0.21 \pm 0.25$, $\mathcal{C}_{\mathrm{odd}} = -0.21 \pm 0.21$. The difference between $\mathcal{S}_{\mathrm{even}}$ and $\mathcal{S}_{\mathrm{odd}}$ is 0.65 ± 0.46, less than 1.5 standard deviation from the expected value, zero. We also find that the differences between $h^0 \to \gamma\gamma$ and $h^0 \to \pi\pi\pi$ modes are less than 0.1 in $\mathcal{C}$ and $\mathcal{S}$.

The SM corrections due to the sub-leading-order diagrams are different for D_{CP+} and D_{CP-} [4]. Therefore, we also perform a fit allowing different CP asymmetries for D_{CP+} and D_{CP-}. We obtain $\mathcal{S}_+ = -0.65 \pm 0.26 \pm 0.06$, $\mathcal{C}_+ = -0.33 \pm 0.19 \pm 0.04$, $\rho_+ = 4.5\%$, and $\mathcal{S}_- = -0.46 \pm 0.45 \pm 0.13$, $\mathcal{C}_- = -0.03 \pm 0.28 \pm 0.07$, $\rho_- = -14\%$.

The dominant systematic uncertainties are from the peaking background and the m_{ES} peak shape uncertainties (0.04 in $\mathcal{S}$ and 0.03 in $\mathcal{C}$). For the former, we vary the amount of the peaking background according to its estimated uncertainty and vary the CP asymmetry of the charmless component between $\pm\sin 2\beta$ of the world-

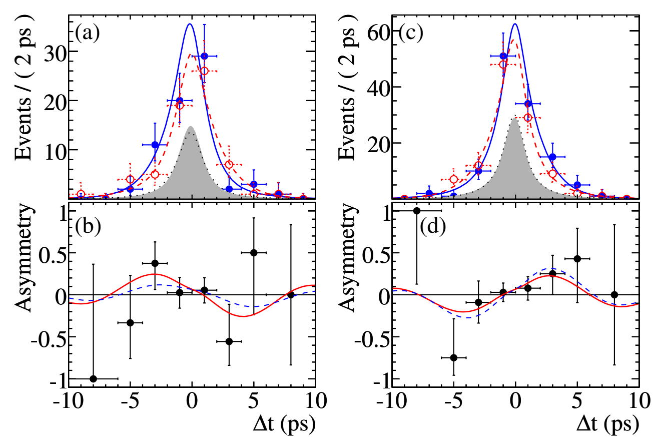

FIG. 2 (color online). The Δt distributions and asymmetries for (a,b) CP-even and (c,d) CP-odd events in the signal region ($m_{ES} > 5.27$ GeV/c^2). In (a) and (c), the solid points with error bars and solid curve (open circles with error bars and dashed curve) are B^0-tagged ($\bar{B}^0$-tagged) data points and Δt projection curves. Shaded areas (B^0-tagged) and the dotted lines ($\bar{B}^0$-tagged) are background distributions. In (b) and (d), the solid curve represents the combined fit result, and the dashed curve represents the result of the fits to CP-even and CP-odd modes separately.

average value. We study the latter effect using an alternative line shape [20] taking into account a possible non-Gaussian tail in the m_{ES} distribution. Other systematic uncertainties typically do not exceed 0.01 in $\mathcal{S}$ or $\mathcal{C}$ and come from the following sources: the assumed parameterization of the Δt resolution function; the uncertainties of the peaking background; m_{ES} width and the combinatorial background threshold function; B^0 lifetime, and mixing frequency; the beam-spot position; and the interference between the CKM-suppressed $\bar{b} \to \bar{u}c\bar{d}$ and CKM-favored $b \to c\bar{u}d$ amplitudes in some B_{tag} final states, which gives deviations from the standard time evolution function Eq. (1) [21]. Uncertainties due to the vertex tracker length scale and alignment are negligible. Summing over all systematic uncertainties in quadrature, we obtain 0.05 for $\mathcal{S}$ and 0.04 for $\mathcal{C}$.

In conclusion, we have measured the time-dependent CP asymmetry parameters $\mathcal{S} = -0.56 \pm 0.23 \pm 0.05$ and $\mathcal{C} = -0.23 \pm 0.16 \pm 0.04$ from a sample of 340 ± 32 $B^0 \to D^{(*)}_{CP} h^0$ signal events. The result is 2.3 standard deviations from the CP-conserving hypothesis $\mathcal{S} = \mathcal{C} = 0$. The parameters $\mathcal{S}$ and $\mathcal{C}$ are consistent with the SM expectation, i.e., the world average $-\sin 2\beta = -0.725 \pm 0.037$ [6] and zero, respectively.

We are grateful for the excellent luminosity and machine conditions provided by our PEP-II colleagues, and for the substantial dedicated effort from the computing organizations that support *BABAR*. The collaborating institutions wish to thank SLAC for its support and kind hospitality. This work is supported by DOE and NSF (USA), NSERC (Canada), IHEP (China), CEA and CNRS-IN2P3 (France), BMBF and DFG (Germany), INFN (Italy), FOM (The Netherlands), NFR (Norway), MIST (Russia), MEC (Spain), and PPARC (United Kingdom). Individuals have received support from the Marie Curie EIF (European Union) and the A. P. Sloan Foundation.

*Deceased

†Also with Università di Perugia, Dipartimento di Fisica, Perugia, Italy

‡Also with Università della Basilicata, Potenza, Italy

§Also with IPPP, Physics Department, Durham University, Durham DH1 3LE, United Kingdom

[1] B. Aubert *et al.* (*BABAR* Collaboration), Phys. Rev. Lett. **94**, 161803 (2005); K.-F. Chen *et al.* (Belle Collaboration), Phys. Rev. Lett. **98**, 031802 (2007).

[2] N. Cabibbo, Phys. Rev. Lett. **10**, 531 (1963); M. Kobayashi and T. Maskawa, Prog. Theor. Phys. **49**, 652 (1973).

[3] Y. Grossman and M. Worah, Phys. Lett. B **395**, 241 (1997).

[4] R. Fleischer, Phys. Lett. B **562**, 234 (2003); R. Fleischer, Nucl. Phys. **B659**, 321 (2003).

[5] See, for example, the review of CP violation in meson decays in [6] and the references therein.

[6] W.-M. Yao *et al.* (Particle Data Group), J. Phys. G **33**, 1 (2006).

[7] The $b \to c\bar{u}d$ process could be mediated by a supersymmetric $\tilde{s}_R$ in an $\not{R}_p$ tree process $b \to \bar{u}\tilde{s}_R$, $\tilde{s}_R \to cd$.

[8] B. Aubert *et al.* (*BABAR* Collaboration), Nucl. Instrum. Methods Phys. Res., Sect. A **479**, 1 (2002).

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

[10] Unless explicitly stated, charge conjugate reactions are implicitly included throughout the Letter.

[11] All neutral D mesons in this Letter decay to CP eigenstates. Therefore, the notation $D^{(*)0}$ implies $D^{(*)0}_{CP}$.

[12] B. Aubert *et al.* (*BABAR* Collaboration), Phys. Rev. Lett. **94**, 161803 (2005).

[13] B. Aubert *et al.* (*BABAR* Collaboration), Phys. Rev. D **66**, 032003 (2002).

[14] All nominal masses are from [6].

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

[16] R. Fisher, Annals of Eugenics **7**, 179 (1936).

[17] S. Brandt *et al.*, Phys. Lett. **12**, 57 (1964); E. Farhi, Phys. Rev. Lett. **39**, 1587 (1977).

[18] J. Bjorken and S. Brodsky, Phys. Rev. D **1**, 1416 (1970).

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

[20] M. J. Oreglia, Ph.D. thesis, Stanford University [Institution Report No. SLAC-236, 1980)], Appendix D; J. E. Gaiser, Ph.D. thesis, Stanford University [Institution Report No. SLAC-255, 1982], Appendix F; T. Skwarnicki, Ph.D. thesis, Institute for Nuclear Physics, Krakow [Institution Report No. DESY F31-86-02, 1986], Appendix E.

[21] O. Long *et al.*, Phys. Rev. D **68**, 034010 (2003).