

UC Berkeley

UC Berkeley Previously Published Works

Title

Improved measurement of CP violation in neutral B decays to $cc[\overline{c}]s$.

Permalink

<https://escholarship.org/uc/item/70h7z4fz>

Journal

Physical review letters, 99(17)

ISSN

0031-9007

Authors

Aubert, B
Bona, M
Boutigny, D
[et al.](#)

Publication Date

2007-10-01

DOI

10.1103/physrevlett.99.171803

Copyright Information

This work is made available under the terms of a Creative Commons Attribution License, available at <https://creativecommons.org/licenses/by/4.0/>

Peer reviewed

Improved Measurement of CP Violation in Neutral B Decays to $c\bar{c}s$

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. Groyzman,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 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 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. Dvoretzkii,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. M. Gabareen,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 V. Lombardo,²⁴ Ch. Thiebaut,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-Ferrolli,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 Z. J. Guo,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 S. E. Mclachlin,⁴⁶ P. M. Patel,⁴⁶ S. H. Robertson,⁴⁶ A. Lazzaro,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 A. Cervelli,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,⁶⁵ 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. Bechtel,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 C. Hast,⁶⁸ T. Hryn'ova,⁶⁸ W. R. Innes,⁶⁸ M. H. Kelsey,⁶⁸ H. Kim,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 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. K. 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,^{78,8} 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. Neal⁸⁰

(BABAR Collaboration)

¹Laboratoire de Physique des Particules, IN2P3/CNRS et Université de Savoie, F-74941 Annecy-Le-Vieux, France

²Universitat de Barcelona, Facultat de Física, Departament ECM, E-08028 Barcelona, Spain

³Università di Bari, Dipartimento di Fisica and INFN, I-70126 Bari, Italy

⁴University of Bergen, Institute of Physics, N-5007 Bergen, Norway

⁵Lawrence Berkeley National Laboratory and University of California, Berkeley, California 94720, USA

⁶University of Birmingham, Birmingham, B15 2TT, United Kingdom

⁷Ruhr Universität Bochum, Institut für Experimentalphysik I, D-44780 Bochum, Germany

⁸University of Bristol, Bristol BS8 1TL, United Kingdom

⁹University of British Columbia, Vancouver, British Columbia, Canada V6T 1Z1

¹⁰Brunel University, Uxbridge, Middlesex UB8 3PH, United Kingdom

¹¹Budker Institute of Nuclear Physics, Novosibirsk 630090, Russia

¹²University of California at Irvine, Irvine, California 92697, USA

¹³University of California at Los Angeles, Los Angeles, California 90024, USA

¹⁴University of California at Riverside, Riverside, California 92521, USA

¹⁵University of California at San Diego, La Jolla, California 92093, USA

¹⁶University of California at Santa Barbara, Santa Barbara, California 93106, USA

¹⁷University of California at Santa Cruz, Institute for Particle Physics, Santa Cruz, California 95064, USA

¹⁸California Institute of Technology, Pasadena, California 91125, USA

¹⁹University of Cincinnati, Cincinnati, Ohio 45221, USA

²⁰University of Colorado, Boulder, Colorado 80309, USA

²¹Colorado State University, Fort Collins, Colorado 80523, USA

²²Universität Dortmund, Institut für Physik, D-44221 Dortmund, Germany

²³Technische Universität Dresden, Institut für Kern- und Teilchenphysik, D-01062 Dresden, Germany

²⁴Laboratoire Leprince-Ringuet, CNRS/IN2P3, Ecole Polytechnique, F-91128 Palaiseau, France

²⁵University of Edinburgh, Edinburgh EH9 3JZ, United Kingdom

²⁶Università di Ferrara, Dipartimento di Fisica and INFN, I-44100 Ferrara, Italy

²⁷Laboratori 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-Paris6, Université Denis Diderot-Paris7, 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 12 March 2007; published 25 October 2007)

We present updated measurements of time-dependent CP asymmetries in fully-reconstructed neutral B decays to several CP eigenstates containing a charmonium meson. The measurements use a data sample of $(383 \pm 4) \times 10^6 Y(4S) \rightarrow B\bar{B}$ decays collected with the BABAR detector at the PEP-II B factory. We determine $\sin 2\beta = 0.714 \pm 0.032(\text{stat}) \pm 0.018(\text{syst})$ and $|\lambda| = 0.952 \pm 0.022(\text{stat}) \pm 0.017(\text{syst})$.

DOI: 10.1103/PhysRevLett.99.171803

PACS numbers: 13.25.Hw, 11.30.Er, 12.15.Hh

The standard model (SM) of electroweak interactions describes CP violation as a consequence of an irreducible phase in the three-family Cabibbo-Kobayashi-Maskawa (CKM) quark-mixing matrix [1]. In the CKM framework, neutral B decays to CP eigenstates containing a charmonium and a $K^{(*)0}$ meson through tree-diagram dominated processes provide a direct measurement of $\sin 2\beta$ [2], where the angle β is defined in terms of the CKM matrix elements V_{ij} as $\arg[-(V_{cd}V_{cb}^*)/(V_{td}V_{tb}^*)]$.

We report updated measurements, based on a sample of $(383 \pm 4) \times 10^6 Y(4S) \rightarrow B\bar{B}$ decays, of $\sin 2\beta$ and of the parameter $|\lambda|$. Here $\lambda = (q/p)(\bar{A}/A)$ [3], q and p are complex constants that relate the B -meson flavor eigenstates to the mass eigenstates, and \bar{A}/A is the ratio of amplitudes of the decay of a \bar{B}^0 or B^0 to the final state under study. We reconstruct B^0 decays to the final states $J/\psi K_S^0$, $J/\psi K_L^0$, $\psi(2S)K_S^0$, $\chi_{c1}K_S^0$, $\eta_c K_S^0$, and $J/\psi K^{*0}$ [4]. Since our previously published result [5], we have added $157 \times 10^6 B\bar{B}$ decays and applied improved event reconstruction algorithms to the entire data set. We have also developed a new $\eta_c K_S^0$ event selection based on the Dalitz plot structure of the $\eta_c \rightarrow K_S^0 K^+ \pi^-$ decay, and have performed a more detailed study of the CP properties of the background events, which results in reduced systematic errors. We now include the $J/\psi K_L^0$ and $J/\psi K^{*0}$ modes in the sample to measure $|\lambda|$, and we report individual measurements of $\sin 2\beta$ and $|\lambda|$ for each of the CP decay modes used in the analysis. Finally, we present separate results for the $J/\psi K_S^0(\pi^+ \pi^- + \pi^0 \pi^0)$ [6], and $J/\psi K^0(K_S^0 + K_L^0)$ modes.

We identify (tag) the initial flavor of the reconstructed B candidate, B_{rec} , using information from the other B meson, B_{tag} , in the event. The decay rate g_+ (g_-) for a neutral B meson decaying to a CP eigenstate accompanied by a B^0 (\bar{B}^0) tag can be expressed as

$$g_{\pm}(\Delta t) = \frac{e^{-|\Delta t|/\tau_{B^0}}}{4\tau_{B^0}} \left\{ (1 \mp \Delta w) \pm (1 - 2w) \left[\frac{2\text{Im}\lambda}{1 + |\lambda|^2} \times \sin(\Delta m_d \Delta t) - \frac{1 - |\lambda|^2}{1 + |\lambda|^2} \cos(\Delta m_d \Delta t) \right] \right\}, \quad (1)$$

where $\Delta t \equiv t_{\text{rec}} - t_{\text{tag}}$ is the difference between the proper decay times of the reconstructed and tag B mesons, τ_{B^0} is the neutral B lifetime and Δm_d is the mass difference of the B meson mass eigenstates determined from B^0 - \bar{B}^0 oscillations [7]. We assume that the corresponding decay-width difference $\Delta\Gamma_d$ is zero. The average mistag probability w describes the effect of incorrect tags, and Δw is the difference between the mistag probabilities for B^0 and \bar{B}^0 . The sine term in Eq. (1) results from the interference between direct decay and decay after B^0 - \bar{B}^0 oscillation. A non-zero cosine term arises from the interference between

decay amplitudes with different weak and strong phases (direct CP violation) or from CP violation in B^0 - \bar{B}^0 mixing. In the SM, CP violation in mixing and direct CP violation in $b \rightarrow c\bar{c}s$ decays are both negligible [3]. Under these assumptions, $\lambda = \eta_f e^{-2i\beta}$, where $\eta_f = \pm 1$ is the CP eigenvalue of the final state f . Thus, the time-dependent CP -violating asymmetry is

$$A_{CP}(\Delta t) \equiv \frac{g_+(\Delta t) - g_-(\Delta t)}{g_+(\Delta t) + g_-(\Delta t)} = -(1 - 2w)\eta_f \sin 2\beta \sin(\Delta m_d \Delta t). \quad (2)$$

The BABAR detector is described in detail elsewhere [8]. We select a sample of neutral B mesons (B_{CP}) decaying to the $\eta_f = -1$ final states $J/\psi K_S^0$, $\psi(2S)K_S^0$, $\chi_{c1}K_S^0$, and $\eta_c K_S^0$, and to the $\eta_f = +1$ final state $J/\psi K_L^0$. We reconstruct $K_S^0 \rightarrow \pi^+ \pi^-$, except in $J/\psi K_S^0$, where we also include $K_S^0 \rightarrow \pi^0 \pi^0$. The charmonium mesons are reconstructed in the decays $J/\psi \rightarrow e^+ e^-$, $\mu^+ \mu^-$; $\psi(2S) \rightarrow e^+ e^-$, $\mu^+ \mu^-$, $J/\psi \pi^+ \pi^-$; $\chi_{c1} \rightarrow J/\psi \gamma$ and $\eta_c \rightarrow K_S^0 K^+ \pi^-$. We also reconstruct the $J/\psi K^{*0}(K^{*0} \rightarrow K_S^0 \pi^0)$ final state, which can be CP even or CP odd due to the presence of even ($L = 0, 2$) and odd ($L = 1$) orbital angular momentum contributions. Ignoring the angular information in $J/\psi K^{*0}$ results in a dilution of the measured CP asymmetry by a factor $|1 - 2R_{\perp}|$, where R_{\perp} is the fraction of the $L = 1$ contribution. In Ref. [9] we have measured $R_{\perp} = 0.233 \pm 0.010(\text{stat}) \pm 0.005(\text{syst})$, which gives an effective $\eta_f = 0.504 \pm 0.033$ for $f = J/\psi K^{*0}$, after acceptance corrections.

In addition to the CP modes described above, we use a sample of B^0 mesons (B_{flav}) decaying to the flavor eigenstates $D^{(*)-} h^+$ ($h^+ = \pi^+$, ρ^+ , a_1^+) and $J/\psi K^{*0}(K^{*0} \rightarrow K^+ \pi^-)$ to calibrate the flavor-tagging performance and Δt resolution. We also perform studies to measure apparent CP violation arising from CP -conserving processes using a control sample of B^+ mesons decaying to the final states $J/\psi K^{(*)+}$, $\psi(2S)K^+$, $\chi_{c1}K^+$, and $\eta_c K^+$. The event selection and candidate reconstruction remain unchanged from those described in Refs. [5,10,11], with the exception of modes containing η_c mesons. In Ref. [5] we reconstructed the $B^0 \rightarrow \eta_c K_S^0$ and $B^{\pm} \rightarrow \eta_c K^{\pm}$ modes using the $\eta_c \rightarrow K_S^0 K^+ \pi^-$ decay, with the requirement $2.91 < m_{K_S^0 K^+ \pi^-} < 3.05 \text{ GeV}/c^2$. We now exploit the fact that the η_c decays predominantly through a $K\pi$ resonance at around $1430 \text{ MeV}/c^2$ and a $K_S^0 K$ resonance close to threshold, and require that either $m_{K_S^0 \pi^-}$ or $m_{K^+ \pi^-}$ be in the mass-range $[1.26, 1.63] \text{ GeV}/c^2$, or that $m_{K^+ K_S^0} \in [1.0, 1.4] \text{ GeV}/c^2$.

We calculate the time interval Δt between the two B decays from the measured separation Δz between the decay vertices of B_{rec} and B_{tag} along the collision (z) axis

[10]. The z position of the B_{rec} vertex is determined from the charged daughter tracks. The B_{tag} decay vertex is determined by fitting tracks not belonging to the B_{rec} candidate to a common vertex, while employing constraints from the beamspot location and the B_{rec} momentum [10]. Events are accepted if the calculated Δt uncertainty is less than 2.5 ps and $|\Delta t|$ is less than 20 ps. The fraction of all events satisfying these requirements is 95%.

The algorithm used to determine the flavor of the B_{tag} at its decay to be either B^0 or \bar{B}^0 is described in detail in Ref. [5]. In brief, we define six mutually exclusive tagging categories in order of decreasing tag purity: *lepton*, *kaon I*, *kaon II*, *kaon-pion*, *pion*, and *other*. The figure of merit for tagging is the effective tagging efficiency $Q \equiv \sum_i \varepsilon_i (1 - 2w_i)^2$, where ε_i is the tagging efficiency of tagging category i . We measure $Q = (30.5 \pm 0.3)\%$, consistent with the results in Ref. [5].

We determine the composition of our final sample using the variable $m_{\text{ES}} = \sqrt{(E_{\text{beam}}^*)^2 - (p_B^*)^2}$, where E_{beam}^* and p_B^* are the beam energy and B momentum in the e^+e^- center-of-mass (c.m.) frame. For the $J/\psi K_L^0$ mode we instead use the difference ΔE between the candidate c.m. energy and E_{beam}^* . The composition of our final sample is shown in Fig. 1. We use events with $m_{\text{ES}} > 5.2$ GeV/ c^2 ($|\Delta E| < 80$ MeV for $J/\psi K_L^0$) to determine the properties of the background contributions. We define a signal region $5.27 < m_{\text{ES}} < 5.29$ GeV/ c^2 ($|\Delta E| < 10$ MeV for

$J/\psi K_L^0$), which contains 12 677 CP candidate events that satisfy the tagging and vertexing requirements (see Table I). For all modes except $\eta_c K_S^0$ and $J/\psi K_L^0$, we use simulated events to estimate the fractions of events that peak in the m_{ES} signal region due to cross-feed from other decay modes (peaking background). For the $\eta_c K_S^0$ mode, the cross-feed fraction is determined from a fit to the $m_{KK\pi}$ and m_{ES} distributions in data. For the $J/\psi K_L^0$ decay mode, the sample composition, effective η_f , and ΔE distribution of the individual background sources are determined either from simulation (for $B \rightarrow J/\psi X$) or from the $m_{\ell^+\ell^-}$ sidebands in data (for non- J/ψ background).

We determine $\sin 2\beta$ and $|\lambda|$ from a simultaneous maximum likelihood fit to the Δt distribution of the tagged B_{CP} and B_{flav} samples. The Δt distributions of the B_{CP} sample are modeled by Eq. (1). Those of the B_{flav} sample evolve according to Eq. (1) with $\lambda = 0$. The observed amplitudes for the CP asymmetry in the B_{CP} sample and for flavor oscillation in the B_{flav} sample are reduced by the same factor, $1-2w$, due to flavor mistags. The Δt distributions for the signal are convolved with a resolution function common to both the B_{flav} and B_{CP} samples, modeled by the sum of three Gaussian functions [10]. The combinatorial background is incorporated with an empirical description of its Δt spectra, containing prompt and nonprompt lifetime components convolved with a resolution function [10] distinct from that of the signal. The peaking background is assigned the same Δt distribution as the signal but with no CP violation, with the same Δt resolution function.

In addition to $\sin 2\beta$ and $|\lambda|$, there are 68 free parameters in the CP fit. For the signal, these are the parameters of the Δt resolution (7), the average mistag fractions w and the differences Δw between B^0 and \bar{B}^0 mistag fractions for each tagging category (12), and the difference between B^0 and \bar{B}^0 reconstruction and tagging efficiencies (7). The background is described by mistag fractions (24), parameters of the Δt resolution (3) and B_{flav} time dependence (3), and parameters for the CP background (8), including the apparent CP asymmetry of nonpeaking events in each tagging category. Finally, we allow for the possibility of direct CP violation in the $\chi_{c1} K_S^0$ background to $J/\psi K^{*0}$ (1), and in the main backgrounds to the $J/\psi K_L^0$ mode, coming from $J/\psi K_S^0$, $J/\psi K^{*0}$, and the remaining J/ψ background (3 parameters). The effective $|\lambda|$ of the non- J/ψ background is fixed from a fit to the J/ψ -candidate sidebands in $J/\psi K_L^0$. We fix $\tau_{B^0} = 1.530$ ps and $\Delta m_d = 0.507$ ps $^{-1}$ [7]. The determination of the mistag fractions and Δt resolution function parameters for the signal is dominated by the B_{flav} sample, about 10 times more abundant than the CP sample.

The fit to the B_{CP} and B_{flav} samples yields $\sin 2\beta = 0.714 \pm 0.032$ and $|\lambda| = 0.952 \pm 0.022$, where the errors are statistical only. The correlation between these two parameters is -1.5% . We also perform a separate fit in which we allow different $\sin 2\beta$ and $|\lambda|$ values for each

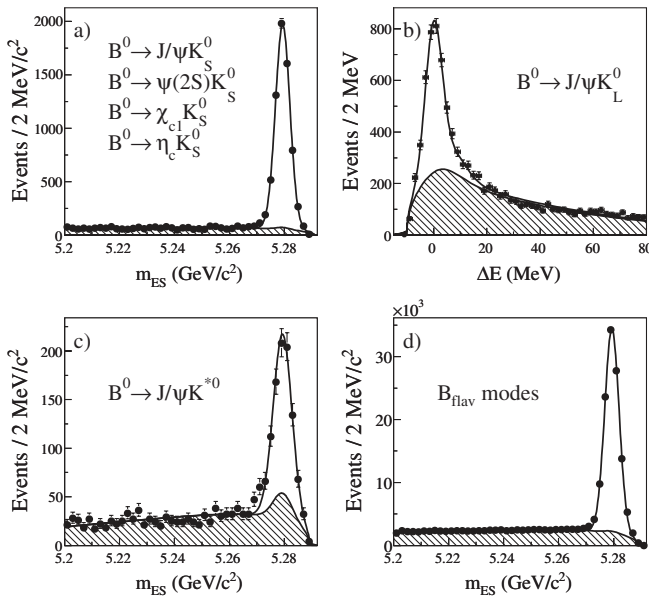


FIG. 1. Distributions for B_{CP} and B_{flav} candidates satisfying the tagging and vertexing requirements: (a) m_{ES} for the final states $J/\psi K_S^0$, $\psi(2S) K_S^0$, $\chi_{c1} K_S^0$, and $\eta_c K_S^0$, (b) ΔE for the final state $J/\psi K_L^0$, (c) m_{ES} for $J/\psi K^{*0}$ ($K^{*0} \rightarrow K_S^0 \pi^0$), and (d) m_{ES} for the B_{flav} sample. In each plot, the shaded region is the estimated background contribution.

TABLE I. Number of events N_{tag} and signal purity P in the signal region after tagging and vertexing requirements, and results of fitting for CP asymmetries in the B_{CP} sample and various subsamples. In addition, fit results for the B_{flav} and B^+ control samples demonstrate that no artificial CP asymmetry is found where we expect no CP violation ($\sin 2\beta = 0$, $|\lambda| = 1$). Errors are statistical only.

Sample	N_{tag}	$P(\%)$	$\sin 2\beta$	$ \lambda $
Full CP sample	12 677	75	0.714 ± 0.032	0.952 ± 0.022
$J/\psi K_S^0(\pi^+ \pi^-)$	4459	96	0.702 ± 0.042	0.976 ± 0.030
$J/\psi K_S^0(\pi^0 \pi^0)$	1086	88	0.617 ± 0.103	0.812 ± 0.058
$\psi(2S)K_S^0$	687	83	0.947 ± 0.112	0.867 ± 0.079
$\chi_{c1}K_S^0$	313	89	0.759 ± 0.170	0.804 ± 0.102
$\eta_c K_S^0$	328	69	0.778 ± 0.195	0.948 ± 0.141
$J/\psi K_L^0$	4748	55	0.734 ± 0.074	1.061 ± 0.063
$J/\psi K^{*0}$	1056	66	0.477 ± 0.271	0.954 ± 0.083
$J/\psi K^0$	10 275	76	0.697 ± 0.035	0.966 ± 0.025
$J/\psi K_S^0$	5547	94	0.686 ± 0.039	0.950 ± 0.027
$\eta_f = -1$	6873	92	0.711 ± 0.036	0.935 ± 0.024
1999–2002 data	3084	79	0.735 ± 0.063	0.987 ± 0.045
2003–2004 data	4850	77	0.728 ± 0.052	0.940 ± 0.035
2005–2006 data	4725	74	0.681 ± 0.054	0.940 ± 0.037
<i>Lepton</i>	1349	80	0.728 ± 0.066	0.901 ± 0.043
<i>Kaon I</i>	1843	76	0.689 ± 0.063	0.986 ± 0.046
<i>Kaon II</i>	2948	72	0.751 ± 0.071	0.880 ± 0.044
<i>Kaon-Pion</i>	2321	73	0.654 ± 0.112	0.999 ± 0.075
<i>Pion</i>	2551	76	0.671 ± 0.167	0.927 ± 0.104
<i>Other</i>	1665	73	0.705 ± 0.504	1.506 ± 0.483
B_{flav} sample	123 893	85	0.018 ± 0.010	0.995 ± 0.007
B^+ sample	29598	94	0.012 ± 0.017	1.010 ± 0.012

charmonium decay mode, a fit to the $J/\psi K_S^0(\pi^+ \pi^- + \pi^0 \pi^0)$ mode, and a fit to the $J/\psi K^0(K_S^0 + K_L^0)$ sample. We split the data sample by run period and by tagging category. We perform the CP measurements on control samples with no expected CP asymmetry. The results of these fits are summarized in Table I. The difference in the $\eta_c K_S^0 \sin 2\beta$ value with respect to our previous publication [5] is partly due to the slightly different reconstruction algorithms and partly to the different selection; the two measurements are consistent when the systematic error is taken into account.

Figure 2 shows the Δt distributions and asymmetries in yields between events with B^0 tags and \bar{B}^0 tags for the $\eta_f = -1$ and $\eta_f = +1$ samples as a function of Δt , overlaid with the projection of the likelihood fit result. We also performed the CP fit fixing $|\lambda| = 1$, which yields $\sin 2\beta = 0.713 \pm 0.032(\text{stat})$.

The dominant systematic errors on $\sin 2\beta$ are due to limited knowledge of various background properties, including uncertainties in $J/\psi K_L^0$ -specific backgrounds and in the amounts of peaking backgrounds and their CP asymmetries (0.010), to possible differences between the B_{flav} and B_{CP} tagging performances (0.009), to the descrip-

tion of the Δt resolution functions (0.008), to the knowledge of the event-by-event beam spot position (0.005). The only sizeable systematic uncertainties on $|\lambda|$ are due to the possible interference between the suppressed $\bar{b} \rightarrow \bar{u}c\bar{d}$ amplitude with the favored $b \rightarrow c\bar{u}d$ amplitude for some tag side B decays [12] (0.015), and to the CP content of the peaking backgrounds (0.006). The total systematic error on $\sin 2\beta(|\lambda|)$ is 0.018 (0.017). We detail in [13] the main systematic uncertainties on both $\sin 2\beta$ and $|\lambda|$ for the full sample, for the seven individual modes, and for the fits to the $J/\psi K^0$ and $J/\psi K_S^0$ samples.

The large B_{CP} sample allows a number of consistency checks, including separation of the data by decay mode and tagging category. The results of those checks, all consistent within the errors, are listed in Table I. We observe no statistically significant asymmetry from fits to the control samples of non- CP decay modes.

In summary, we report improved measurements of $\sin 2\beta$ and $|\lambda|$ that supersede our previous results [5]. We measure $\sin 2\beta = 0.714 \pm 0.032(\text{stat}) \pm 0.018(\text{syst})$ and $|\lambda| = 0.952 \pm 0.022(\text{stat}) \pm 0.017(\text{syst})$, providing an improved model-independent constraint on the position of the apex of the unitarity triangle [14]. Our measurements agree

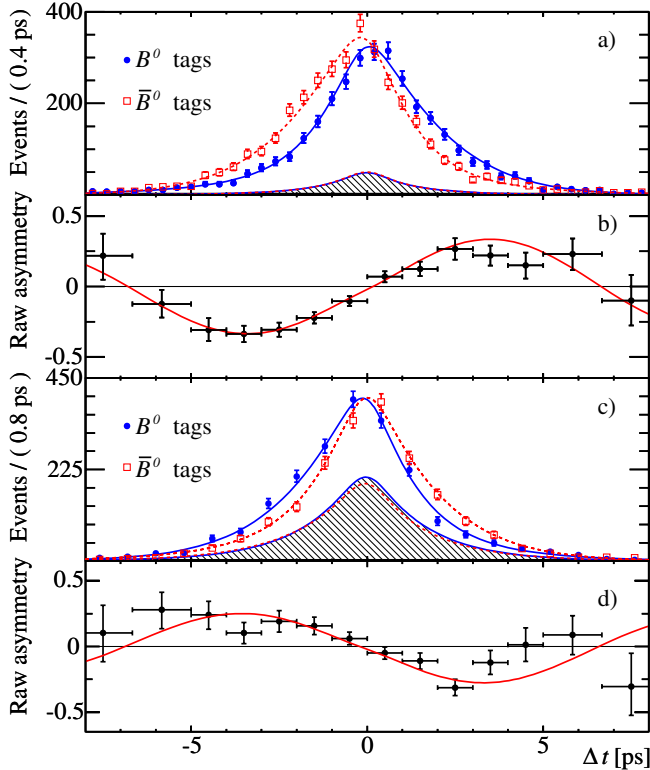


FIG. 2 (color online). (a) Number of $\eta_f = -1$ candidates ($J/\psi K_S^0$, $\psi(2S)K_S^0$, $\chi_{c1}K_S^0$, and $\eta_c K_S^0$) in the signal region with a B^0 tag (N_{B^0}) and with a \bar{B}^0 tag ($N_{\bar{B}^0}$), and (b) the raw asymmetry, $(N_{B^0} - N_{\bar{B}^0}) / (N_{B^0} + N_{\bar{B}^0})$, as functions of Δt . Figures (c) and (d) are the corresponding distributions for the $\eta_f = +1$ mode $J/\psi K_L^0$. To enhance the signal component, all distributions exclude the *other* tagging category. The solid (dashed) curves represent the fit projections in Δt for B^0 (\bar{B}^0) tags. The shaded regions represent the estimated background contributions.

within errors with the published results [15,16] and with the theoretical estimates of the magnitudes of CKM matrix elements in the context of the SM [17]. The measured value of $|\lambda|$ is consistent with no direct CP violation with a significance of 1.72 standard deviations. We report the first individual measurements of $\sin 2\beta$ and $|\lambda|$ for each of the decay modes within our CP sample, and of the $J/\psi K^0(K_S^0 + K_L^0)$ sample.

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] N. Cabibbo, Phys. Rev. Lett. **10**, 531 (1963); M. Kobayashi and T. Maskawa, Prog. Theor. Phys. **49**, 652 (1973).
- [2] A.B. Carter and A.I. Sanda, Phys. Rev. D **23**, 1567 (1981); I.I. Bigi and A.I. Sanda, Nucl. Phys. **A193**, 85 (1981).
- [3] See, for example, D. Kirkby and Y. Nir in Ref. [7].
- [4] Charge-conjugate reactions are implicitly included.
- [5] B. Aubert *et al.* (*BABAR* Collaboration), Phys. Rev. Lett. **94**, 161803 (2005).
- [6] Y. Grossman *et al.*, Phys. Lett. B **538**, 327 (2002).
- [7] W.-M. Yao *et al.* (Particle Data Group), J. Phys. G **33**, 1 (2006).
- [8] B. Aubert *et al.* (*BABAR* Collaboration), Nucl. Instrum. Methods Phys. Res., Sect. A **479**, 1 (2002).
- [9] B. Aubert *et al.* (*BABAR* Collaboration), arXiv:0704.0522v1 [Phys. Rev. D (to be published)].
- [10] B. Aubert *et al.* (*BABAR* Collaboration), Phys. Rev. D **66**, 032003 (2002).
- [11] B. Aubert *et al.* (*BABAR* Collaboration), Phys. Rev. D **70**, 011101 (2004).
- [12] O. Long, M. Baak, R. N. Cahn, and D. Kirkby, Phys. Rev. D **68**, 034010 (2003).
- [13] See EPAPS Document No. E-PRLTAO-99-075743 for a table with the main systematic uncertainties on $\sin 2\beta$ and $|\lambda|$ for the full sample, for the seven individual modes, and for the fits to the $J/\psi K^0$ and $J/\psi K_S^0$ samples. For more information on EPAPS, see <http://www.aip.org/pubservs/epaps.html>.
- [14] M. Bona *et al.* (UTfit Collaboration), Phys. Rev. Lett. **97**, 151803 (2006); J. Charles *et al.* (CKMfitter Group), Eur. Phys. J. C **41**, 1 (2005).
- [15] E. Barberio *et al.* (Heavy Flavor Averaging Group), arXiv:hep-ex/0603003.
- [16] K.-F. Chen *et al.* (Belle Collaboration), Phys. Rev. Lett. **98**, 031802 (2007).
- [17] M. Ciuchini *et al.*, Z. Phys. C **68**, 239 (1995).