

Measurements of the branching fraction and time-dependent CP asymmetries of $B^0 \rightarrow J/\psi\pi^0$ decays

B. Aubert,¹ R. Barate,¹ D. Boutigny,¹ F. Couderc,¹ Y. Karyotakis,¹ J. P. Lees,¹ V. Poireau,¹ V. Tisserand,¹ A. Zghiche,¹ E. Grauges,² A. Palano,³ M. Pappagallo,³ J. C. Chen,⁴ N. D. Qi,⁴ G. Rong,⁴ P. Wang,⁴ Y. S. Zhu,⁴ G. Eigen,⁵ I. Ofte,⁵ B. Stugu,⁵ G. S. Abrams,⁶ M. Battaglia,⁶ D. S. Best,⁶ D. N. Brown,⁶ J. Button-Shafer,⁶ R. N. Cahn,⁶ E. Charles,⁶ C. T. Day,⁶ M. S. Gill,⁶ A. V. Gritsan,^{6,*} Y. Groysman,⁶ R. G. Jacobsen,⁶ R. W. Kadel,⁶ J. A. Kadyk,⁶ L. T. Kerth,⁶ Yu. G. Kolomensky,⁶ G. Kukartsev,⁶ G. Lynch,⁶ L. M. Mir,⁶ P. J. Oddone,⁶ T. J. Orimoto,⁶ M. Pripstein,⁶ N. A. Roe,⁶ M. T. Ronan,⁶ W. A. Wenzel,⁶ M. Barrett,⁷ K. E. Ford,⁷ T. J. Harrison,⁷ A. J. Hart,⁷ C. M. Hawkes,⁷ S. E. Morgan,⁷ A. T. Watson,⁷ M. Fritsch,⁸ K. Goetzen,⁸ T. Held,⁸ H. Koch,⁸ B. Lewandowski,⁸ M. Pelizaeus,⁸ K. Peters,⁸ T. Schroeder,⁸ M. Steinke,⁸ J. T. Boyd,⁹ J. P. Burke,⁹ W. N. Cottingham,⁹ D. Walker,⁹ T. Cuhadar-Donszelmann,¹⁰ B. G. Fulsom,¹⁰ C. Hearty,¹⁰ N. S. Knecht,¹⁰ T. S. Mattison,¹⁰ J. A. McKenna,¹⁰ A. Khan,¹¹ P. Kyberd,¹¹ M. Saleem,¹¹ L. Teodorescu,¹¹ V. E. Blinov,¹² A. D. Bukin,¹² V. P. Druzhinin,¹² V. B. Golubev,¹² E. A. Kravchenko,¹² A. P. Onuchin,¹² S. I. Serednyakov,¹² Yu. I. Skovpen,¹² E. P. Solodov,¹² K. Yu. Todyshev,¹² M. Bondioli,¹³ M. Bruinsma,¹³ M. Chao,¹³ S. Curry,¹³ I. Eschrich,¹³ D. Kirkby,¹³ A. J. Lankford,¹³ P. Lund,¹³ M. Mandelkern,¹³ R. K. Mommsen,¹³ W. Roethel,¹³ D. P. Stoker,¹³ S. Abachi,¹⁴ C. Buchanan,¹⁴ S. D. Foulkes,¹⁵ J. W. Gary,¹⁵ O. Long,¹⁵ B. C. Shen,¹⁵ K. Wang,¹⁵ L. Zhang,¹⁵ D. del Re,¹⁶ H. K. Hadavand,¹⁶ E. J. Hill,¹⁶ H. P. Paar,¹⁶ S. Rahatlou,¹⁶ V. Sharma,¹⁶ J. W. Berryhill,¹⁷ C. Campagnari,¹⁷ A. Cunha,¹⁷ B. Dahmes,¹⁷ T. M. Hong,¹⁷ J. D. Richman,¹⁷ T. W. Beck,¹⁸ A. M. Eisner,¹⁸ C. J. Flacco,¹⁸ C. A. Heusch,¹⁸ J. Kroseberg,¹⁸ W. S. Lockman,¹⁸ G. Nesom,¹⁸ T. Schalk,¹⁸ B. A. Schumm,¹⁸ A. Seiden,¹⁸ P. Spradlin,¹⁸ D. C. Williams,¹⁸ M. G. Wilson,¹⁸ J. Albert,¹⁹ E. Chen,¹⁹ G. P. Dubois-Felsmann,¹⁹ A. Dvoretzki,¹⁹ D. G. Hitlin,¹⁹ I. Narsky,¹⁹ T. Piatenko,¹⁹ F. C. Porter,¹⁹ A. Ryd,¹⁹ A. Samuel,¹⁹ R. Andreassen,²⁰ G. Mancinelli,²⁰ B. T. Meadows,²⁰ M. D. Sokoloff,²⁰ F. Blanc,²¹ P. C. Bloom,²¹ S. Chen,²¹ W. T. Ford,²¹ J. F. Hirschauer,²¹ A. Kreisel,²¹ U. Nauenberg,²¹ A. Olivas,²¹ W. O. Ruddick,²¹ J. G. Smith,²¹ K. A. Ulmer,²¹ S. R. Wagner,²¹ J. Zhang,²¹ A. Chen,²² E. A. Eckhart,²² A. Soffer,²² W. H. Toki,²² R. J. Wilson,²² F. Winklmeier,²² Q. Zeng,²² D. D. Altenburg,²³ E. Feltresi,²³ A. Hauke,²³ H. Jasper,²³ B. Spaan,²³ T. Brandt,²⁴ M. Dickopp,²⁴ V. Klose,²⁴ H. M. Lacker,²⁴ R. Nogowski,²⁴ S. Otto,²⁴ A. Petzold,²⁴ J. Schubert,²⁴ K. R. Schubert,²⁴ R. Schwierz,²⁴ J. E. Sundermann,²⁴ A. Volk,²⁴ D. Bernard,²⁵ G. R. Bonneaud,²⁵ P. Grenier,^{25,†} E. Latour,²⁵ S. Schrenk,²⁵ Ch. Thiebaux,²⁵ G. Vasileiadis,²⁵ M. Verderi,²⁵ D. J. Bard,²⁶ P. J. Clark,²⁶ W. Gradl,²⁶ F. Muheim,²⁶ S. Playfer,²⁶ Y. Xie,²⁶ M. Andreotti,²⁷ D. Bettoni,²⁷ C. Bozzi,²⁷ R. Calabrese,²⁷ G. Cibinetto,²⁷ E. Luppi,²⁷ M. Negrini,²⁷ L. Piemontese,²⁷ F. Anulli,²⁸ R. Baldini-Ferrolì,²⁸ A. Calcaterra,²⁸ R. de Sangro,²⁸ G. Finocchiaro,²⁸ S. Pacetti,²⁸ P. Patteri,²⁸ I. M. Peruzzi,^{28,‡} M. Piccolo,²⁸ A. Zallo,²⁸ A. Buzzo,²⁹ R. Capra,²⁹ R. Contri,²⁹ M. Lo Vetere,²⁹ M. M. Macri,²⁹ M. R. Monge,²⁹ S. Passaggio,²⁹ C. Patrignani,²⁹ E. Robutti,²⁹ A. Santroni,²⁹ S. Tosi,²⁹ G. Brandenburg,³⁰ K. S. Chaisanguanthum,³⁰ M. Morii,³⁰ J. Wu,³⁰ R. S. Dubitzky,³¹ J. Marks,³¹ S. Schenk,³¹ U. Uwer,³¹ W. Bhimji,³² D. A. Bowerman,³² P. D. Dauncey,³² U. Egede,³² R. L. Flack,³² J. R. Gaillard,³² J. A. Nash,³² M. B. Nikolich,³² W. Panduro Vazquez,³² X. Chai,³³ M. J. Charles,³³ W. F. Mader,³³ U. Mallik,³³ V. Ziegler,³³ J. Cochran,³⁴ H. B. Crawley,³⁴ L. Dong,³⁴ V. Eyges,³⁴ W. T. Meyer,³⁴ S. Prell,³⁴ E. I. Rosenberg,³⁴ A. E. Rubin,³⁴ G. Schott,³⁵ N. Arnaud,³⁶ M. Davier,³⁶ G. Grosdidier,³⁶ A. Höcker,³⁶ F. Le Diberder,³⁶ V. Lepeltier,³⁶ A. M. Lutz,³⁶ A. Oyanguen,³⁶ T. C. Petersen,³⁶ S. Pruvot,³⁶ S. Rodier,³⁶ P. Roudeau,³⁶ M. H. Schune,³⁶ A. Stocchi,³⁶ W. F. Wang,³⁶ G. Wormser,³⁶ C. H. Cheng,³⁷ D. J. Lange,³⁷ D. M. Wright,³⁷ A. J. Bevan,³⁸ C. A. Chavez,³⁸ I. J. Forster,³⁸ J. R. Fry,³⁸ E. Gabathuler,³⁸ R. Gamet,³⁸ K. A. George,³⁸ D. E. Hutchcroft,³⁸ D. J. Payne,³⁸ K. C. Schofield,³⁸ C. Touramanis,³⁸ F. Di Lodovico,³⁹ W. Menges,³⁹ R. Sacco,³⁹ C. L. Brown,⁴⁰ G. Cowan,⁴⁰ H. U. Flaecher,⁴⁰ M. G. Green,⁴⁰ D. A. Hopkins,⁴⁰ P. S. Jackson,⁴⁰ T. R. McMahon,⁴⁰ S. Ricciardi,⁴⁰ F. Salvatore,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 M. P. Kelly,⁴² G. D. Lafferty,⁴² M. T. Naisbit,⁴² J. C. Williams,⁴² J. I. Yi,⁴² C. Chen,⁴³ W. D. Hulsbergen,⁴³ A. Jawahery,⁴³ D. Kovalskyi,⁴³ C. K. Lae,⁴³ D. A. Roberts,⁴³ G. Simi,⁴³ G. Blaylock,⁴⁴ C. Dallapiccola,⁴⁴ S. S. Hertzbach,⁴⁴ R. Kofler,⁴⁴ X. Li,⁴⁴ T. B. Moore,⁴⁴ S. Saremi,⁴⁴ H. Staengle,⁴⁴ S. Y. Willocq,⁴⁴ R. Cowan,⁴⁵ K. Koeneke,⁴⁵ G. Sciolla,⁴⁵ S. J. Sekula,⁴⁵ M. Spitznagel,⁴⁵ F. Taylor,⁴⁵ R. K. Yamamoto,⁴⁵ H. Kim,⁴⁶ P. M. Patel,⁴⁶ C. T. Potter,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 J. Reidy,⁴⁸ D. A. Sanders,⁴⁸ D. J. Summers,⁴⁸ H. W. Zhao,⁴⁸ S. Brunet,⁴⁹ D. Côté,⁴⁹ P. Taras,⁴⁹ F. B. Viaud,⁴⁹ H. Nicholson,⁵⁰ N. Cavallo,^{51,§} G. De Nardo,⁵¹ F. Fabozzi,^{51,§} C. Gatto,⁵¹ L. Lista,⁵¹ D. Monorchio,⁵¹ P. Paolucci,⁵¹ D. Piccolo,⁵¹ C. Sciacca,⁵¹ M. Baak,⁵² H. Bulten,⁵² G. Raven,⁵² H. L. Snoek,⁵² C. P. Jessop,⁵³ J. M. LoSecco,⁵³ T. Allmendinger,⁵⁴ G. Benelli,⁵⁴ K. K. Gan,⁵⁴ K. Honscheid,⁵⁴ D. Hufnagel,⁵⁴ P. D. Jackson,⁵⁴ H. Kagan,⁵⁴ R. Kass,⁵⁴ T. Pulliam,⁵⁴ A. M. Rahimi,⁵⁴ R. Ter-Antonyan,⁵⁴ Q. K. Wong,⁵⁴ N. L. Blount,⁵⁵

J. Brau,⁵⁵ R. Frey,⁵⁵ O. Igonkina,⁵⁵ M. Lu,⁵⁵ R. Rahmat,⁵⁵ N. B. Sinev,⁵⁵ D. Strom,⁵⁵ J. Strube,⁵⁵ E. Torrence,⁵⁵ F. Galeazzi,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 M. Benayoun,⁵⁷ J. Chauveau,⁵⁷ P. David,⁵⁷ L. Del Buono,⁵⁷ Ch. de la Vaissière,⁵⁷ O. Hamon,⁵⁷ B. L. Hartfiel,⁵⁷ M. J. J. John,⁵⁷ Ph. Leruste,⁵⁷ J. Malclès,⁵⁷ J. Ocariz,⁵⁷ L. Roos,⁵⁷ G. Therin,⁵⁷ P. K. Behera,⁵⁸ L. Gladney,⁵⁸ J. Panetta,⁵⁸ M. Biasini,⁵⁹ R. Covarelli,⁵⁹ M. Pioppi,⁵⁹ C. Angelini,⁶⁰ G. Batignani,⁶⁰ S. Bettarini,⁶⁰ F. Bucci,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 M. Rama,⁶⁰ G. Rizzo,⁶⁰ J. Walsh,⁶⁰ M. Haire,⁶¹ D. Judd,⁶¹ D. E. Wagoner,⁶¹ J. Biesiada,⁶² N. Danielson,⁶² P. Elmer,⁶² Y. P. Lau,⁶² C. Lu,⁶² J. Olsen,⁶² A. J. S. Smith,⁶² A. V. Telnov,⁶² F. Bellini,⁶³ G. Cavoto,⁶³ A. D'Orazio,⁶³ E. Di Marco,⁶³ R. Faccini,⁶³ F. Ferrarotto,⁶³ F. Ferroni,⁶³ M. Gaspero,⁶³ L. Li Gioi,⁶³ M. A. Mazzoni,⁶³ S. Morganti,⁶³ G. Piredda,⁶³ F. Polci,⁶³ F. Safai Tehrani,⁶³ C. Voena,⁶³ H. Schröder,⁶⁴ R. Waldi,⁶⁴ T. Adye,⁶⁵ N. De Groot,⁶⁵ B. Franek,⁶⁵ E. O. Olaiya,⁶⁵ F. F. Wilson,⁶⁵ S. Emery,⁶⁶ A. Gaidot,⁶⁶ S. F. Ganzhur,⁶⁶ G. Hamel de Monchenault,⁶⁶ W. Kozanecki,⁶⁶ M. Legendre,⁶⁶ B. Mayer,⁶⁶ G. Vasseur,⁶⁶ Ch. Yèche,⁶⁶ M. Zito,⁶⁶ W. Park,⁶⁷ M. V. Purohit,⁶⁷ A. W. Weidemann,⁶⁷ J. R. Wilson,⁶⁷ M. T. Allen,⁶⁸ D. Aston,⁶⁸ R. Bartoldus,⁶⁸ N. Berger,⁶⁸ A. M. Boyarski,⁶⁸ R. Claus,⁶⁸ J. P. Coleman,⁶⁸ M. R. Convery,⁶⁸ M. Cristinziani,⁶⁸ J. C. Dingfelder,⁶⁸ D. Dong,⁶⁸ J. Dorfan,⁶⁸ D. Dujmic,⁶⁸ W. Dunwoodie,⁶⁸ R. C. Field,⁶⁸ T. Glanzman,⁶⁸ S. J. Gowdy,⁶⁸ V. Halyo,⁶⁸ C. Hast,⁶⁸ T. Hryn'ova,⁶⁸ W. R. Innes,⁶⁸ M. H. Kelsey,⁶⁸ P. Kim,⁶⁸ M. L. Kocian,⁶⁸ D. W. G. S. Leith,⁶⁸ J. Libby,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 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 M. Weaver,⁶⁸ A. J. R. Weinstein,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 C. Roat,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. Satpathy,⁷² R. F. Schwitters,⁷² J. M. Izen,⁷³ I. Kitayama,⁷³ X. C. Lou,⁷³ S. Ye,⁷³ F. Bianchi,⁷⁴ M. Bona,⁷⁴ F. Gallo,⁷⁴ D. Gamba,⁷⁴ M. Bomben,⁷⁵ L. Bosisio,⁷⁵ C. Cartaro,⁷⁵ F. Cossutti,⁷⁵ G. Della Ricca,⁷⁵ S. Dittongo,⁷⁵ S. Grancagnolo,⁷⁵ L. Lanceri,⁷⁵ L. Vitale,⁷⁵ V. Azzolini,⁷⁶ F. Martinez-Vidal,⁷⁶ R. S. Panvini,⁷⁷ Sw. Banerjee,⁷⁸ B. Bhuyan,⁷⁸ C. M. Brown,⁷⁸ D. Fortin,⁷⁸ K. Hamano,⁷⁸ R. Kowalewski,⁷⁸ I. M. Nugent,⁷⁸ J. M. Roney,⁷⁸ R. J. Sobie,⁷⁸ J. J. Back,⁷⁹ P. F. Harrison,⁷⁹ T. E. Latham,⁷⁹ G. B. Mohanty,⁷⁹ H. R. Band,⁸⁰ X. Chen,⁸⁰ B. Cheng,⁸⁰ S. Dasu,⁸⁰ M. Datta,⁸⁰ A. M. Eichenbaum,⁸⁰ K. T. Flood,⁸⁰ M. T. Graham,⁸⁰ J. J. Hollar,⁸⁰ J. R. Johnson,⁸⁰ P. E. Kutter,⁸⁰ H. Li,⁸⁰ R. Liu,⁸⁰ B. Mellado,⁸⁰ A. Mihalyi,⁸⁰ A. K. Mohapatra,⁸⁰ Y. Pan,⁸⁰ M. Pierini,⁸⁰ R. Prepost,⁸⁰ P. Tan,⁸⁰ S. L. Wu,⁸⁰ Z. Yu,⁸⁰ and H. Neal⁸¹

(BABAR Collaboration)

¹Laboratoire de Physique des Particules, F-74941 Annecy-le-Vieux, France

²IFAE, Universitat Autònoma de Barcelona, E-08193 Bellaterra, Barcelona, Spain

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

⁴Institute of High Energy Physics, Beijing 100039, China

⁵University of Bergen, Institute of Physics, N-5007 Bergen, Norway

⁶Lawrence Berkeley National Laboratory and University of California, Berkeley, California 94720, USA

⁷University of Birmingham, Birmingham, B15 2TT, United Kingdom

⁸Ruhr Universität Bochum, Institut für Experimentalphysik I, D-44780 Bochum, Germany

⁹University of Bristol, Bristol BS8 1TL, United Kingdom

¹⁰University of British Columbia, Vancouver, British Columbia, Canada V6T 1Z1

¹¹Brunel University, Uxbridge, Middlesex UB8 3PH, United Kingdom

¹²Budker Institute of Nuclear Physics, Novosibirsk 630090, Russia

¹³University of California at Irvine, Irvine, California 92697, USA

¹⁴University of California at Los Angeles, Los Angeles, California 90024, USA

¹⁵University of California at Riverside, Riverside, California 92521, USA

¹⁶University of California at San Diego, La Jolla, California 92093, USA

¹⁷University of California at Santa Barbara, Santa Barbara, California 93106, USA

¹⁸University of California at Santa Cruz, Institute for Particle Physics, Santa Cruz, California 95064, USA

¹⁹California Institute of Technology, Pasadena, California 91125, USA

²⁰University of Cincinnati, Cincinnati, Ohio 45221, USA

²¹University of Colorado, Boulder, Colorado 80309, USA

²²Colorado State University, Fort Collins, Colorado 80523, USA

- ²³*Universität Dortmund, Institut für Physik, D-44221 Dortmund, Germany*
- ²⁴*Technische Universität Dresden, Institut für Kern- und Teilchenphysik, D-01062 Dresden, Germany*
- ²⁵*Ecole Polytechnique, LLR, F-91128 Palaiseau, France*
- ²⁶*University of Edinburgh, Edinburgh EH9 3JZ, United Kingdom*
- ²⁷*Università di Ferrara, Dipartimento di Fisica and INFN, I-44100 Ferrara, Italy*
- ²⁸*Laboratori Nazionali di Frascati dell'INFN, I-00044 Frascati, Italy*
- ²⁹*Università di Genova, Dipartimento di Fisica and INFN, I-16146 Genova, Italy*
- ³⁰*Harvard University, Cambridge, Massachusetts 02138, USA*
- ³¹*Universität Heidelberg, Physikalisches Institut, Philosophenweg 12, D-69120 Heidelberg, Germany*
- ³²*Imperial College London, London, SW7 2AZ, United Kingdom*
- ³³*University of Iowa, Iowa City, Iowa 52242, USA*
- ³⁴*Iowa State University, Ames, Iowa 50011-3160, USA*
- ³⁵*Universität Karlsruhe, Institut für Experimentelle Kernphysik, D-76021 Karlsruhe, Germany*
- ³⁶*Laboratoire de l'Accélérateur Linéaire, F-91898 Orsay, 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*Universités Paris VI et VII, Laboratoire de Physique Nucléaire et de Hautes Energies, 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*Vanderbilt University, Nashville, Tennessee 37235, USA*
- ⁷⁸*University of Victoria, Victoria, British Columbia, Canada V8W 3P6*
- ⁷⁹*Department of Physics, University of Warwick, Coventry CV4 7AL, United Kingdom*
- ⁸⁰*University of Wisconsin, Madison, Wisconsin 53706, USA*
- ⁸¹*Yale University, New Haven, Connecticut 06511, USA*

(Received 6 March 2006; published 10 July 2006)

We present measurements of the branching fraction and time-dependent CP asymmetries in $B^0 \rightarrow J/\psi\pi^0$ decays based on $(231.8 \pm 2.6) \times 10^6$ $Y(4S) \rightarrow B\bar{B}$ decays collected with the *BABAR* detector at the SLAC PEP-II asymmetric-energy B factory. We obtain a branching fraction $\mathcal{B}(B^0 \rightarrow J/\psi\pi^0) = (1.94 \pm 0.22(\text{stat}) \pm 0.17(\text{syst})) \times 10^{-5}$. We also measure the CP asymmetry parameters $C = -0.21 \pm 0.26(\text{stat}) \pm 0.06(\text{syst})$ and $S = -0.68 \pm 0.30(\text{stat}) \pm 0.04(\text{syst})$.

DOI: [10.1103/PhysRevD.74.011101](https://doi.org/10.1103/PhysRevD.74.011101)

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

Charge conjugation-parity (CP) violation in the B meson system has been established by the *BABAR* [1] and Belle [2] collaborations. The standard model (SM) of electroweak interactions describes CP violation as a consequence of a complex phase in the three-generation Cabibbo-Kobayashi-Maskawa (CKM) quark-mixing matrix [3]. Measurements of CP asymmetries in the proper-time distribution of neutral B decays to CP eigenstates containing a charmonium and K^0 meson provide a precise measurement of $\sin 2\beta$ [4], where β is $\arg[-V_{cd}V_{cb}^*/V_{td}V_{tb}^*]$ and the V_{ij} are CKM matrix elements.

The decay $B^0 \rightarrow J/\psi\pi^0$ is a CP -even Cabibbo-suppressed $b \rightarrow c\bar{c}d$ transition whose tree amplitude has the same weak phase as the $b \rightarrow c\bar{c}s$ modes *e.g.* the CP -odd decay $B^0 \rightarrow J/\psi K_S^0$. The $b \rightarrow c\bar{c}d$ penguin amplitude has a different weak phase than the tree amplitude. The tree and penguin amplitudes expected to dominate this decay are shown in Fig. 1.

If there is a significant penguin amplitude in $B^0 \rightarrow J/\psi\pi^0$, then one will measure values of the CP asymmetry coefficients S and C that are different from $-\sin 2\beta$ and 0, respectively [5]. The coefficient S denoting the interference between mixing and decay, and the direct CP asymmetry coefficient C are defined as

$$S \equiv \frac{2\text{Im}\lambda}{1 + |\lambda|^2} \quad \text{and} \quad C \equiv \frac{1 - |\lambda|^2}{1 + |\lambda|^2}, \quad (1)$$

where λ is a complex parameter that depends on both the $B^0 - \bar{B}^0$ oscillation amplitude and the amplitudes describing B^0 and \bar{B}^0 decays to the $J/\psi\pi^0$ final state. An additional motivation for measuring S and C from $B^0 \rightarrow J/\psi\pi^0$ is that they can provide a model-independent constraint on the penguin dilution within $B^0 \rightarrow J/\psi K_S^0$ [6].

In this publication, we present an update of previous *BABAR* branching fraction and time-dependent CP violating asymmetry measurements of the decay $B^0 \rightarrow J/\psi\pi^0$ [7,8], which had been performed using 20.7 fb^{-1} and

81.1 fb^{-1} of integrated luminosity, respectively. Belle has also studied this mode and has published a branching fraction and later a time-dependent CP -violating asymmetry result using 29.4 fb^{-1} and 140.0 fb^{-1} of integrated luminosity, respectively [9,10].

The data used in this analysis were collected with the *BABAR* detector at the PEP-II asymmetric e^+e^- storage ring. This represents a total integrated luminosity of 210.6 fb^{-1} collected on or just below the $Y(4S)$ resonance (on-peak), corresponding to a sample of 231.8 ± 2.6 million $B\bar{B}$ pairs. An additional 21.6 fb^{-1} of data, collected at approximately 40 MeV below the $Y(4S)$ resonance, is used to study background from $e^+e^- \rightarrow q\bar{q}$ ($q = u, d, s, c$) continuum events.

The *BABAR* detector is described in detail elsewhere [11]. Surrounding the interaction point is a 5 layer double-sided silicon vertex tracker (SVT) which measures the impact parameters of charged particle tracks in both the plane transverse to, and along the beam direction. A 40 layer drift chamber (DCH) surrounds the SVT and provides measurements of the transverse momenta for charged particles. Both the SVT and the DCH operate in the magnetic field of a 1.5 T solenoid. Charged hadron identification is achieved through measurements of particle energy loss (dE/dx) in the tracking system and the Čerenkov angle obtained from a detector of internally reflected Čerenkov light (DIRC). This is surrounded by a segmented CsI(Tl) electromagnetic calorimeter (EMC) which is used to pro-

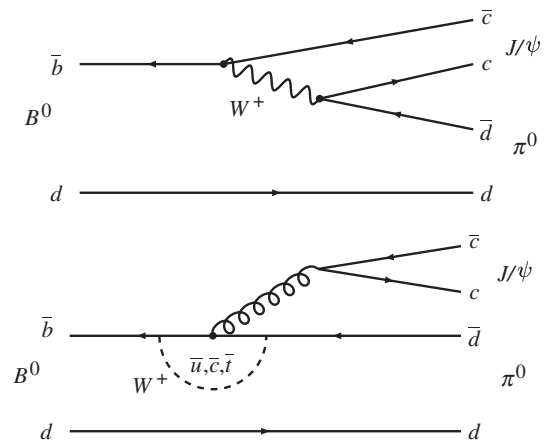


FIG. 1. Feynman diagrams of the color suppressed tree (top) and gluonic penguin (bottom) amplitudes contributing to the $B^0 \rightarrow J/\psi\pi^0$ decay.

*Also with the Johns Hopkins University, Baltimore, MD 21218, USA.

†Also at Laboratoire de Physique Corpusculaire, Clermont-Ferrand, France.

‡Also with Università di Perugia, Dipartimento di Fisica, Perugia, Italy.

§Also with Università della Basilicata, Potenza, Italy.

||Deceased.

vide photon detection and electron identification, and is used to reconstruct neutral hadrons. Finally, the instrumented flux return (IFR) of the magnet allows discrimination of muons from pions.

We reconstruct $B^0 \rightarrow J/\psi \pi^0$ decays in $B\bar{B}$ candidate events from combinations of $J/\psi \rightarrow \ell^+ \ell^-$ ($\ell = e, \mu$) and $\pi^0 \rightarrow \gamma\gamma$ candidates. A detailed description of the charged particle reconstruction and identification can be found elsewhere [7]. For the $J/\psi \rightarrow e^+ e^-$ ($J/\psi \rightarrow \mu^+ \mu^-$) channel, the invariant mass of the lepton pair is required to be between 3.06 and 3.12 GeV/ c^2 (3.07 and 3.13 GeV/ c^2). Each lepton candidate must also be consistent with the electron (muon) hypothesis. We form $\pi^0 \rightarrow \gamma\gamma$ candidates from clusters in the EMC with an invariant mass, $m_{\gamma\gamma}$ satisfying $100 < m_{\gamma\gamma} < 160$ MeV/ c^2 . These clusters are required to be isolated from any charged tracks, carry a minimum energy of 30 MeV, and have a lateral energy distribution consistent with that of a photon. Each π^0 candidate is required to have a minimum energy of 200 MeV and is constrained to the nominal mass [12]. Finally the $B^0 \rightarrow J/\psi \pi^0$ candidates (B_{rec}) are constrained to originate from the $e^+ e^-$ interaction point using a geometric fit.

We use two kinematic variables, m_{ES} and ΔE , in order to isolate the signal: $m_{\text{ES}} = \sqrt{(E_{\text{beam}}^*)^2 - (p_B^*)^2}$ is the beam-energy substituted mass and $\Delta E = E_B^* - E_{\text{beam}}^*$ is the difference between the B -candidate energy and the beam energy. E_{beam}^* and p_B^* (E_B^*) are the beam energy and B -candidate momentum (energy) in the center-of-mass (CM) frame. We require $m_{\text{ES}} > 5.2$ GeV/ c^2 and $|\Delta E| < 0.3$ GeV.

A significant source of background is due to $e^+ e^- \rightarrow q\bar{q}$ ($q = u, d, s, c$) continuum events. We combine several kinematic and topological variables into a Fisher discriminant (\mathcal{F}) [13] to provide additional separation between signal and continuum. The three variables L_0 , L_2 and $\cos(\theta_H)$ are inputs to \mathcal{F} . L_0 and L_2 are the zeroth- and second-order Legendre polynomial moments; $L_0 = \sum_i |\mathbf{p}_i^*|$ and $L_2 = \sum_i |\mathbf{p}_i^*|^2 / (2(3\cos^2\theta_i - 1))$, where \mathbf{p}_i^* are the CM momenta of the tracks and neutral calorimeter clusters that are not associated with the signal candidate. The θ_i are the angles between \mathbf{p}_i^* and the thrust axis of the signal candidate and θ_H is the angle between the positively charged lepton and the B candidate in the J/ψ rest frame.

We use multivariate algorithms to identify signatures of B decays that determine (tag) the flavor of the decay of the other B in the event (B_{tag}) to be either a B^0 or \bar{B}^0 . The flavor tagging algorithm used is described in more detail elsewhere [14]. In brief, we define seven mutually exclusive tagging categories. These are (in order of decreasing signal purity) Lepton, KaonI, KaonII, Kaon-Pion, Pion, Other, and No-Tag. The total effective tagging efficiency of this algorithm is $(30.5 \pm 0.4)\%$.

The decay rate f_+ (f_-) of neutral decays to a CP eigenstate, when B_{tag} is a B^0 (\bar{B}^0), is

$$f_{\pm}(\Delta t) = \frac{e^{-|\Delta t|/\tau_{B^0}}}{4\tau_{B^0}} [1 \pm S \sin(\Delta m_d \Delta t) \mp C \cos(\Delta m_d \Delta t)], \quad (2)$$

where Δt is the difference between the proper decay times of the B_{rec} and B_{tag} mesons, $\tau_{B^0} = 1.536 \pm 0.014$ ps is the B^0 lifetime and $\Delta m_d = 0.502 \pm 0.007$ ps $^{-1}$ is the $B^0 - \bar{B}^0$ oscillation frequency [12]. The decay width difference between the B^0 mass eigenstates is assumed to be zero.

The time interval Δt is calculated from the measured separation Δz between the decay vertices of B_{rec} and B_{tag} along the collision axis (z). The vertex of B_{rec} is reconstructed from the lepton tracks that come from the J/ψ ; the vertex of B_{tag} is constructed from the remaining tracks in the event that do not belong to B_{rec} , with constraints from the beam spot location and the B_{rec} momentum. We accept events with $|\Delta t| < 20$ ps whose uncertainty are less than 2.5 ps.

After all of the selection criteria mentioned above have been applied, the average number of candidates per event is approximately 1.1, indicating some events still have multiple candidates. In these events, we randomly choose one candidate to be used in the fit. This selection is unbiased. Overall, the true signal candidate is correctly identified 91.7% of the time. After this step, the signal efficiency is 22.0% and a total of 1318 on-peak events are selected.

In addition to signal and continuum background events, there are also $B\bar{B}$ -associated backgrounds present in the data. We divide the B backgrounds into the following types: (i) $B^0 \rightarrow J/\psi K_S^0$, where $K_S^0 \rightarrow \pi^0 \pi^0$ (ii) inclusive neutral B meson decays, and (iii) inclusive charged B meson decays. When normalized to the integrated luminosity, Monte Carlo (MC) studies predict 153 ± 9 , 68 ± 14 and 314 ± 63 events of these background types, respectively. The inclusive neutral B meson decays exclude signal and $B^0 \rightarrow J/\psi K_S^0$ events. The inclusive B decay backgrounds are dominated by contributions from $B \rightarrow J/\psi X$ (inclusive charmonium final states). In particular the inclusive charged B meson decay backgrounds are dominated by $B^+ \rightarrow J/\psi \rho^+$ decays. The $B^0 \rightarrow J/\psi K_S^0$ background was studied separately since it contributes a significant amount of neutral B background, has a large asymmetry, and has the almost same tagging efficiency and resolution as the signal.

The signal yield, S and C are simultaneously extracted from an unbinned maximum-likelihood (ML) fit to the B candidate sample, where the discriminating variables used in the fit are m_{ES} , ΔE , \mathcal{F} , and Δt . The signal yield is fitted using known tagging efficiencies [14]. The continuum yield for the seven mutually-exclusive tagging categories, is also allowed to vary in the ML fit.

The probability density function (PDF) for signal m_{ES} distribution takes the form of a Gaussian with a low side exponential tail [15]. We parameterize the m_{ES} distribution

for continuum and neutral inclusive B background with an Argus phase space distribution [16]. As there are significant correlations between m_{ES} and ΔE for the charged inclusive B and the $B^0 \rightarrow J/\psi K_S^0$ backgrounds, we parameterize these variables with two-dimensional nonparametric PDFs as described in Ref. [17]. The ΔE distribution for signal events is modeled by a Gaussian with an exponential tail on the negative side to account for energy leakage in the EMC, plus a polynomial contribution. The ΔE distributions for the continuum and the neutral inclusive B background are described by second and third-order polynomials, respectively. The \mathcal{F} distributions for the signal and the backgrounds are described by bifurcated Gaussians with different widths above and below the peak value.

The signal decay rate distribution of Eq. (2) is modified to account for dilution coming from incorrectly assigning the flavor of B_{tag} and is convolved with a triple Gaussian resolution function, whose core width is about 1.1 ps [18]. The decay rate distribution for B backgrounds is similar to that for signal. The inclusive B backgrounds are assigned an effective lifetime instead of their respective B lifetimes to account for their misreconstruction. This effective lifetime is determined from MC simulated data. The potential CP asymmetry of the inclusive B background is evaluated by allowing the parameters of S and C for this background to vary. The decay rate distribution for $B^0 \rightarrow J/\psi K_S^0$ is the same as that for signal and reflects the known level of CP violation in that decay. The continuum background is modeled with a prompt lifetime component convolved with a triple Gaussian resolution function. The core Gaussian parameters and fractions are allowed to vary in the ML fit. The other two Gaussians have means fixed to zero, and widths of 0.85 ps and 8.0 ps, respectively.

The results from the ML fit are $109 \pm 12(\text{stat})$ signal events, with $S = -0.68 \pm 0.30(\text{stat})$ and $C = -0.21 \pm 0.26(\text{stat})$. The fit yields the following numbers of continuum events: $N_{\text{Lepton}} = 17 \pm 5$, $N_{\text{KaonI}} = 38 \pm 8$, $N_{\text{KaonII}} = 101 \pm 12$, $N_{\text{KaonPion}} = 102 \pm 12$, $N_{\text{Pion}} = 115 \pm 12$, $N_{\text{Other}} = 94 \pm 11$, and $N_{\text{NoTag}} = 227 \pm 17$. Figure 2 shows the distributions of m_{ES} , ΔE , and \mathcal{F} for the data. In these plots the signal has been enhanced by selecting $|\Delta E| < 0.1$ GeV for the m_{ES} plot, $m_{ES} > 5.275$ GeV/ c^2 for the ΔE plot and by applying both of these criteria for the \mathcal{F} plot. After applying these requirements to the signal (background) samples that are used in the fit, they are reduced to a relative size of 83.1% (24.3%), 85.0% (21.1%) and 73.1% (2.8%) for the m_{ES} , ΔE , and \mathcal{F} distributions, respectively.

Figure 3 shows the Δt distribution for signal B^0 and \bar{B}^0 tagged events. The signal has been enhanced using the same m_{ES} and ΔE cuts as for Fig. 2. The time-dependent decay rate asymmetry $[N(\Delta t) - \bar{N}(\Delta t)]/[N(\Delta t) + \bar{N}(\Delta t)]$ is also shown, where N (\bar{N}) is the decay rate for B^0 (\bar{B}^0) tagged events and the decay rate takes the form of Eq. (2).

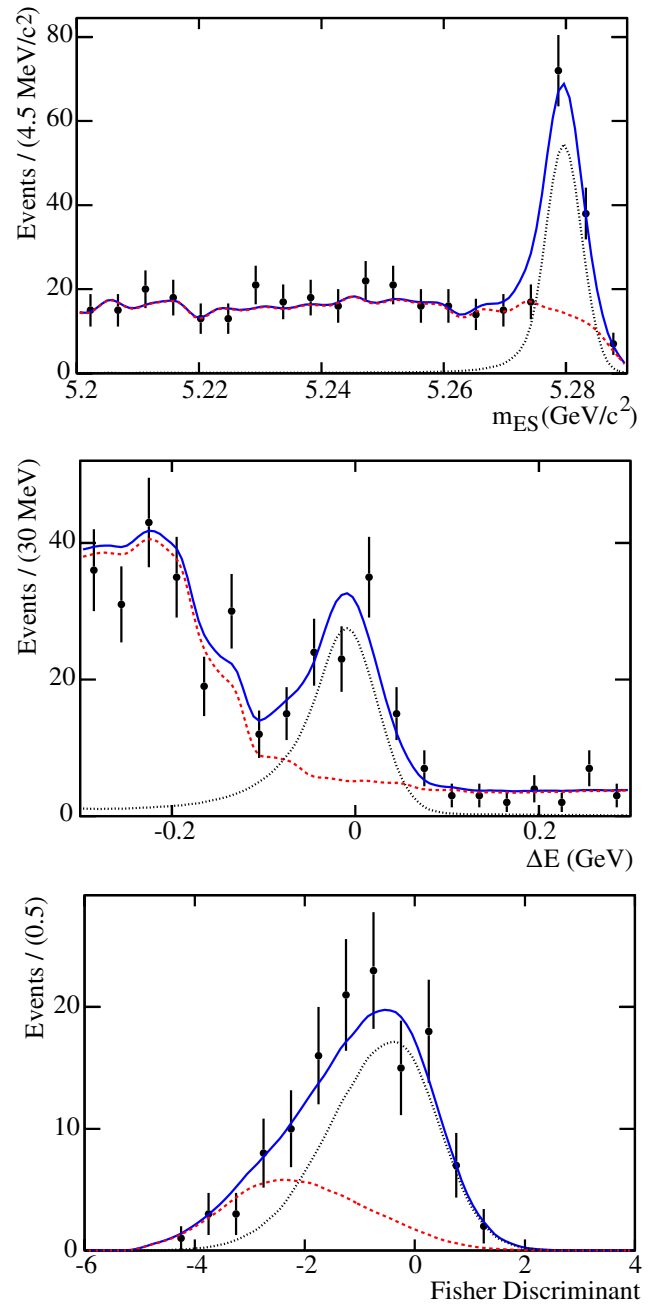


FIG. 2 (color online). Signal enhanced distributions of m_{ES} (top), ΔE (center) and \mathcal{F} (bottom) for the data (points). The solid line represents the total likelihood, the dashed line is the sum of the backgrounds and the dotted line is the signal. The undulations in the background model are the result of limited MC statistics available for defining the two-dimensional nonparametric PDFs.

Table I summarizes the systematic uncertainties on the signal yield, S and C . These include the uncertainty due to the PDF parameterization (including the resolution function), evaluated by varying the signal and the background PDF parameters within uncertainties of their nominal values. the effect of SVT misalignment; the uncertainties

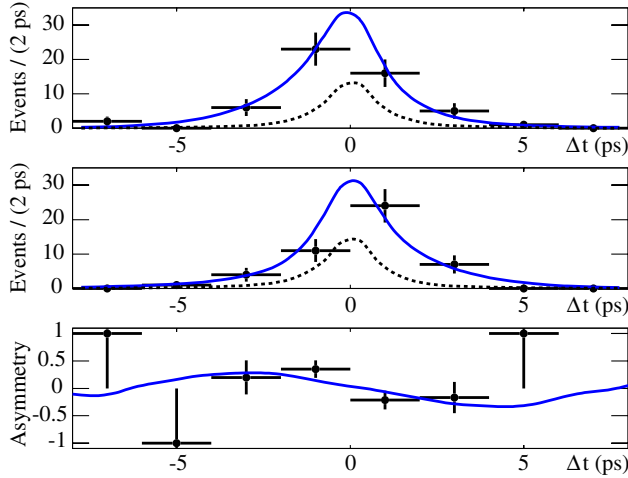


FIG. 3 (color online). The Δt distribution for a sample of signal enhanced events tagged as B^0 (top) and \bar{B}^0 (middle). The dotted lines are the sum of backgrounds and the solid lines are the sum of signal and backgrounds. The time-dependent CP asymmetry (see text) is also shown (bottom), where the curve is the measured asymmetry.

associated with the Lorentz boost, the z -scale of the tracking system, and the event-by-event beam spot position.

The uncertainty coming from the fit bias is estimated by performing ensembles of mock experiments using signal MC which is generated using the GEANT4-based [19] BABAR MC simulation, embedded into MC samples of background generated from the likelihood. The deviation from input values is added in quadrature to the error on the deviation in order to obtain a conservative fit bias uncertainty. Most, but not all of the inclusive charmonium final

TABLE I. Contributions to the systematic errors on the signal yield, S and C , where the signal yield errors are given in numbers of events. The total systematic uncertainty is the quadratic sum of the individual contributions listed. Additional systematic uncertainties that are applied only to the branching fraction are discussed in the text.

| Contribution | Signal yield | S | C |
|----------------------------------|----------------|-------------|-------------|
| PDF parameterization | $+3.21 - 2.88$ | ± 0.013 | ± 0.012 |
| SVT misalignment | — | ± 0.002 | ± 0.002 |
| Boost and z -scale | $+0.08 - 0.16$ | ± 0.004 | ± 0.001 |
| Beam spot position | — | ± 0.007 | ± 0.002 |
| Fit bias | ± 3.00 | ± 0.026 | ± 0.016 |
| Inclusive B background yields | ± 3.52 | ± 0.003 | ± 0.020 |
| $m_{ES} - \Delta E$ correlations | ± 2.92 | ± 0.020 | ± 0.002 |
| CP content of B background | $+0.13 - 0.11$ | ± 0.012 | ± 0.049 |
| CP background lifetime | ± 0.67 | ± 0.010 | ± 0.010 |
| Tagging efficiency asymmetry | ± 0.02 | ± 0.000 | ± 0.020 |
| Tag-side interference | — | ± 0.004 | ± 0.014 |
| Fisher data/MC comparison | ± 0.70 | ± 0.004 | ± 0.004 |
| Total | $+6.42 - 6.26$ | ± 0.040 | ± 0.063 |

states which dominate the inclusive B background, are precisely known from previous measurements. Their yields are then fixed in the fit. As a crosscheck, the yields for inclusive B backgrounds that are not well known are allowed to vary. The deviation from the nominal result is taken as a systematic uncertainty. We include an additional systematic uncertainty to account for neglecting the small correlation between m_{ES} and ΔE in signal and neutral inclusive B background events.

In order to evaluate the uncertainty coming from CP violation in the B background, we have allowed the S and C parameters to vary in a fit for the neutral inclusive B background, and have separately allowed the C parameter to vary in a fit for the charged inclusive B background. The deviations of the fitted values of the signal S and C from the nominal fit results are assigned as systematic errors. The uncertainty from CP violation in $B^0 \rightarrow J/\psi K_S^0$ is determined by varying S and C within current experimental limits [14].

The inclusive B background uses an effective lifetime in the nominal fit and we replace this with the world-average B lifetime [12] to evaluate the systematic error due to the CP background lifetime. There is also a small asymmetry in the tagging efficiency between B^0 and \bar{B}^0 tagged events, for which a systematic uncertainty is evaluated. We study 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 tagside B decays [20]. The difference in the distribution of \mathcal{F} between data and MC is evaluated with a large sample of $B \rightarrow D^*\rho$ decays. There are additional systematic uncertainties that contribute only to the branching fraction. These come from uncertainties for charged particle identification (5.2%), π^0 meson reconstruction efficiency (3%), the $J/\psi \rightarrow \ell^+\ell^-$ branching fractions (2.4%), the tracking efficiency (1.2%) and the number of B meson pairs (1.1%). The systematic error contribution from MC statistics is negligible. The 109 ± 12 signal events correspond to a branching fraction of

$$\begin{aligned} \mathcal{B}(B^0 \rightarrow J/\psi\pi^0) \\ = (1.94 \pm 0.22(\text{stat}) \pm 0.17(\text{syst})) \times 10^{-5}. \end{aligned}$$

We determine the CP asymmetry parameters to be

$$\begin{aligned} C &= -0.21 \pm 0.26(\text{stat}) \pm 0.06(\text{syst}), \\ S &= -0.68 \pm 0.30(\text{stat}) \pm 0.04(\text{syst}), \end{aligned}$$

where the correlation between S and C is 8.3%. The value of S is consistent with SM expectations for a tree-dominated $b \rightarrow c\bar{c}d$ transition of $S = -\sin 2\beta$ and $C = 0$. All results presented here are consistent with previous measurements from the B factories [7–10].

We are grateful for the extraordinary contributions of our PEP-II colleagues in achieving the excellent luminosity and machine conditions that have made this work

possible. The success of this project also relies critically on the expertise and dedication of the computing organizations that support *BABAR*. The collaborating institutions wish to thank SLAC for its support and the kind hospitality extended to them. This work is supported by the US Department of Energy and National Science Foundation, the Natural Sciences and Engineering Research Council (Canada), Institute of High Energy Physics (China), the Commissariat à l'Energie Atomique and Institut National de Physique Nucléaire et de Physique des Particules (France), the Bundesministerium für Bildung und Forschung and Deutsche Forschungsgemeinschaft

(Germany), the Istituto Nazionale di Fisica Nucleare (Italy), the Foundation for Fundamental Research on Matter (The Netherlands), the Research Council of Norway, the Ministry of Science and Technology of the Russian Federation, and the Particle Physics and Astronomy Research Council (United Kingdom). Individuals have received support from CONACyT (Mexico), the Marie-Curie Intra European Fellowship program (European Union), the A.P. Sloan Foundation, the Research Corporation, and the Alexander von Humboldt Foundation.

-
- [1] B. Aubert *et al.* (*BABAR* Collaboration), Phys. Rev. Lett. **89**, 201802 (2002).
 - [2] K. Abe *et al.* (BELLE Collaboration), Phys. Rev. D **66**, 071102 (2002).
 - [3] N. Cabibbo, Phys. Rev. Lett. **10**, 531 (1963); M. Kobayashi and T. Maskawa, Prog. Theor. Phys. **49**, 652 (1973).
 - [4] A.B. Carter and A.I. Sanda, Phys. Rev. D **23**, 1567 (1981); I.I. Bigi and A.I. Sanda, Nucl. Phys. B **193**, 85 (1981).
 - [5] Y. Grossman and M. Worah, Phys. Lett. B **395**, 241 (1997).
 - [6] M. Ciuchini, M. Pierini, and L. Silvestrini, Phys. Rev. Lett. **95**, 221804 (2005).
 - [7] B. Aubert *et al.* (*BABAR* Collaboration), Phys. Rev. D **65**, 032001 (2002).
 - [8] B. Aubert *et al.* (*BABAR* Collaboration), Phys. Rev. Lett. **91**, 061802 (2003).
 - [9] K. Abe *et al.* (BELLE Collaboration), Phys. Rev. D **67**, 032003 (2003).
 - [10] K. Abe *et al.* (BELLE Collaboration), Phys. Rev. Lett. **93**, 261801 (2004).
 - [11] B. Aubert *et al.* (*BABAR* Collaboration), Nucl. Instr. Methods Phys. Res., Sect. A **479**, 1 (2002).
 - [12] S. Eidelman *et al.* (Particle Data Group), Phys. Lett. B **592**, 1 (2004).
 - [13] R. A. Fisher, Annals of Eugenics **7**, 179 (1936).
 - [14] B. Aubert *et al.* (*BABAR* Collaboration), Phys. Rev. Lett. **94**, 161803 (2005).
 - [15] E. D. Bloom and C. Peck, Annu. Rev. Nucl. Part. Sci. **33**, 143 (1983).
 - [16] H. Albrecht *et al.* (ARGUS Collaboration), Phys. Lett. B **241**, 278 (1990).
 - [17] K. S. Cranmer, Comput. Phys. Commun. **136**, 198 (2001).
 - [18] B. Aubert *et al.* (*BABAR* Collaboration), Phys. Rev. D **66**, 032003 (2002).
 - [19] S. Agostinelli *et al.* (GEANT4 Collaboration), Nucl. Instr. Methods Phys. Res., Sect. A **506**, 250 (2003).
 - [20] O. Long, M. Baak, R. N. Cahn, and D. Kirkby, Phys. Rev. D **68**, 034010 (2003).