

Measurement of the CP -Violating Asymmetries in $B^0 \rightarrow K_S^0 \pi^0$ and of the Branching Fraction of $B^0 \rightarrow K^0 \pi^0$

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 M. Pappagallo,³ G. Eigen,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 I. L. Osipenkov,⁵ M. T. Ronan,^{5,*} K. Tackmann,⁵ T. Tanabe,⁵ W. A. Wenzel,⁵
P. del Amo Sanchez,⁶ C. M. Hawkes,⁶ A. T. Watson,⁶ T. Held,⁷ H. Koch,⁷ M. Pelizaeus,⁷ T. Schroeder,⁷
M. Steinke,⁷ D. Walker,⁸ D. J. Asgeirsson,⁹ T. Cuhadar-Donszelmann,⁹ B. G. Fulsom,⁹ C. Hearty,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
M. G. Wilson,¹⁷ L. O. Winstrom,¹⁷ E. Chen,¹⁸ C. H. Cheng,¹⁸ F. Fang,¹⁸ D. G. Hitlin,¹⁸ I. Narsky,¹⁸ T. Piatenko,¹⁸
F. C. Porter,¹⁸ R. Andreassen,¹⁹ 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 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 V. Klose,²³ M. J. Kobel,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. Thiebaux,²⁴ M. Verderi,²⁴ P. J. Clark,²⁵ W. Gradl,²⁵ F. Muheim,²⁵ S. Playfer,²⁵
A. I. Robertson,²⁵ J. E. Watson,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-Ferrolì,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 W. Panduro Vazquez,³¹ M. Tibbetts,³¹ P. K. Behera,³² X. Chai,³²
M. J. Charles,³² U. Mallik,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 Y. Y. Gao,³⁴ 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 A. D'Orazio,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 I. Bingham,³⁸
J. P. Burke,³⁸ 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 S. Paramesvaran,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 D. Dujmic,⁴⁵ P. H. Fisher,⁴⁵ K. Koeneke,⁴⁵ G. Sciolla,⁴⁵ S. J. Sekula,⁴⁵ M. Spitznagel,⁴⁵
F. Taylor,⁴⁵ R. K. Yamamoto,⁴⁵ M. Zhao,⁴⁵ Y. Zheng,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 K. J. Knoepfel,⁵³ J. M. LoSecco,⁵³ G. Benelli,⁵⁴ L. A. Corwin,⁵⁴ K. Honscheid,⁵⁴

Submitted to *Physical Review D*

Work supported in part by US Department of Energy contract DE-AC02-76SF00515
SLAC, Stanford University, Stanford, CA 94025

H. Kagan,⁵⁴ R. Kass,⁵⁴ J. P. Morris,⁵⁴ A. M. Rahimi,⁵⁴ J. J. Regensburger,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 G. Calderini,⁵⁷ J. Chauveau,⁵⁷ P. David,⁵⁷ L. Del Buono,⁵⁷ Ch. de la Vaissière,⁵⁷ O. Hamon,⁵⁷ Ph. Leruste,⁵⁷ J. Malclès,⁵⁷ J. Ocariz,⁵⁷ A. Perez,⁵⁷ J. Prendki,⁵⁷ L. Gladney,⁵⁸ M. Biasini,⁵⁹ R. Covarelli,⁵⁹ E. Manoni,⁵⁹ C. Angelini,⁶⁰ G. Batignani,⁶⁰ S. Bettarini,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 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 T. Hartmann,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 S. Emery,⁶⁶ M. Escalier,⁶⁶ A. Gaidot,⁶⁶ S. F. Ganzhur,⁶⁶ G. Hamel de Monchenault,⁶⁶ W. Kozanecki,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 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 J. Kaminski,⁶⁸ M. H. Kelsey,⁶⁸ H. Kim,⁶⁸ P. Kim,⁶⁸ M. L. Kocian,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 I. Ofte,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 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 P. F. Harrison,⁷⁸ J. Ilic,⁷⁸ T. E. Latham,⁷⁸ G. B. Mohanty,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 and H. Neal⁸⁰

(The 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 1, 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

- 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-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*

We present a measurement of the time-dependent CP -violating asymmetries in $B^0 \rightarrow K_S^0 \pi^0$ decays based on 383 million $\Upsilon(4S) \rightarrow B\bar{B}$ events collected by the BABAR experiment at the PEP-II asymmetric-energy B Factory at SLAC. We measure the direct CP -violating asymmetry $C_{K_S^0 \pi^0} = 0.24 \pm 0.15 \pm 0.03$ and the CP -violating asymmetry in the interference between mixing and decay

$S_{K_S^0\pi^0} = 0.40 \pm 0.23 \pm 0.03$, where the first errors are statistical and the second are systematic. On the same sample, we measure the decay branching fraction, obtaining $\mathcal{B}(B^0 \rightarrow K^0\pi^0) = (10.3 \pm 0.7 \pm 0.6) \times 10^{-6}$.

PACS numbers: 13.25.Hw, 11.30.Er

The *BABAR* and Belle experiments have measured the weak phase β [1, 2] of the Cabibbo-Kobayashi-Maskawa (CKM) quark mixing matrix [3] with a better precision than the Standard Model (SM) prediction [4] derived from measurements of other CP-conserving and CP-violating processes. The agreement between the theoretical and experimental results has shown that the CKM matrix correctly describes these measurements of β to good precision.

A major goal of the *B* Factory experiments is now to search for indirect evidence of New Physics (NP). One strategy is to compare the measured value of the CP violation (CPV) parameters from $b \rightarrow sc\bar{c}$ to independent determinations of the same quantities using processes that are sensitive to the contributions of NP effects through loop diagrams.

CPV in *B* decays to a final state f can be parameterized by C_f , measuring direct CPV, and S_f , measuring CPV in the interference between decays with and without mixing. In the Standard Model for penguin-dominated processes $b \rightarrow sq\bar{q}$ ($q = u, d, s$) [19], S_f and C_f are expected to be consistent with the values from $b \rightarrow sc\bar{c}$ decays (namely $C_f \sim 0$ and $S_f \sim \sin 2\beta$). Additional CKM suppressed contributions to the amplitude can induce only small deviations from this expectation. On the other hand, additional loop contributions from NP processes may produce observable deviations [5, 6].

In addition, it is possible to combine the direct CP asymmetries and the branching fractions of the four $B \rightarrow K\pi$ modes to test precise sum rules [7–9]. The experimental uncertainty on these sum rules is dominated by the error on the direct CP asymmetry in $B^0 \rightarrow K^0\pi^0$. Therefore a precise measurement of both the direct CP asymmetry, and the branching fraction, in this decay channel represents an important consistency test of the SM.

In this work, we present an updated measurement of the time-dependent CP asymmetries and branching fraction of the decay $B^0 \rightarrow K_S^0\pi^0$ ($K_S^0 \rightarrow \pi^+\pi^-$) [10, 11]. The CKM and color suppression of the tree-level $b \rightarrow su\bar{u}$ transition leads to the expectation that this decay is dominated by a top quark mediated $b \rightarrow sd\bar{d}$ penguin diagram, which carries a weak phase $\arg(V_{tb}V_{ts}^*)$. If non-leading contributions are small, the time-dependent CP asymmetry is expected to be equal to $\sin 2\beta$.

The results presented here are based on 383 million $\Upsilon(4S) \rightarrow B\bar{B}$ decays collected with the *BABAR* detector at the PEP-II e^+e^- collider, located at the Stanford Linear Accelerator Center. The *BABAR* detector, which is

described elsewhere [12], provides charged particle tracking through a combination of a five-layer double-sided silicon micro-strip detector (SVT) and a 40-layer central drift chamber, both operating in a 1.5 T magnetic field to provide momentum measurements. Charged kaon and pion identification is achieved through measurements of particle energy loss in the tracking system and Cherenkov cone angle in a detector of internally reflected Cherenkov light. A segmented CsI(Tl) electromagnetic calorimeter (EMC) provides photon detection and electron identification. Finally, the instrumented flux return of the magnet allows discrimination between muons and pions.

We reconstruct $K_S^0 \rightarrow \pi^+\pi^-$ candidates from pairs of oppositely charged tracks. The two-track combinations must form a vertex with a χ^2 probability greater than 0.001 and a $\pi^+\pi^-$ invariant mass within $11.2 \text{ MeV}/c^2$ (3.7σ) of the K_S^0 mass [13]. We form $\pi^0 \rightarrow \gamma\gamma$ candidates from pairs of energy depositions in the EMC that are isolated from any charged tracks, carry a minimum energy of 50 MeV per photon, fall within the mass window $110 < m_{\gamma\gamma} < 160 \text{ MeV}/c^2$, and have the expected lateral shower shapes. Finally, we construct $B^0 \rightarrow K_S^0\pi^0$ candidates by combining K_S^0 and π^0 candidates in the event using kinematic and geometric information of the decay which constraints the B^0 decay vertex to originate in the e^+e^- interaction region. We extract the flight length of the K_S^0 from the fit and require that the reconstructed proper lifetime be greater than five times its uncertainty. We require that the χ^2 probability of the fit be greater than 0.001.

For each B^0 candidate two, independent kinematic variables are computed. The first one is m_B , the invariant mass of the reconstructed *B* meson, B_{CP} . The second one is m_{miss} , the invariant mass of the other *B*, B_{tag} , computed from the known beam energy, applying a mass constraint to B_{CP} [10]. For signal decays, m_B (m_{miss}) peaks near the B^0 mass with a resolution of $\sim 36 \text{ MeV}/c^2$ ($\sim 5.3 \text{ MeV}/c^2$). Both the m_{miss} and m_B distributions exhibit a low-side tail from leakage of energy deposits out of the EMC. We select candidates within the window $5.11 < m_{\text{miss}} < 5.31 \text{ GeV}/c^2$ and $5.13 < m_B < 5.43 \text{ GeV}/c^2$, which includes the signal peak and a “sideband” region for background characterization. For the 0.8% of events with more than one reconstructed candidate, we select the combination with the smallest $\chi^2 = \sum_{i=\pi^0, K_S^0} (m_i - m'_i)^2 / \sigma_{m_i}^2$, where m_i (m'_i) is the measured (nominal) mass and σ_{m_i} is the estimated uncertainty on the measured mass of particle i .

We exploit topological observables, computed in the

$\Upsilon(4S)$ rest frame, to discriminate jet-like e^+e^- to $q\bar{q}$ events ($q = u, d, s, c$) from more spherical $B\bar{B}$ events. We compute the value of L_2/L_0 , where $L_j \equiv \sum_i |\mathbf{p}_i^*| |\cos \theta_i^*|^j$. Here, \mathbf{p}_i^* is the momentum of particle i and θ_i^* is the angle between \mathbf{p}_i^* and the sphericity axis [14] of the B_{CP} candidate, and the sum does not include the decay tree of the B_{tag} . In order to reduce the number of background events, we require $L_2/L_0 < 0.55$. We compute $\cos \theta_B^*$, the cosine of the angle between the direction of the B meson and the nominal direction of the magnetic field (z axis). This variable is distributed as $1 - \cos^2 \theta_B^*$ for signal events and nearly flat for background events. We select events with $|\cos \theta_B^*| < 0.9$. We also use the distribution of L_2/L_0 and of $\cos \theta_B^*$ to discriminate the signal from the residual background in a maximum likelihood fit. Using a full detector simulation, we estimate that our selection retains $(33.6 \pm 1.6)\%$ of the signal events, where this error includes statistical and systematic contributions. The selected sample of $B^0 \rightarrow K_S^0 \pi^0$ candidates is dominated by random $K_S^0 \pi^0$ combinations from $e^+e^- \rightarrow q\bar{q}$ ($q = u, d, s, c$) fragmentation. Using large samples of simulated $B\bar{B}$ events, we find that backgrounds from other B meson decays can be generally neglected, but we include some specific B decay channels in our study of the systematic errors.

For each $B^0 \rightarrow K_S^0 \pi^0$ candidate, we examine the remaining tracks and neutral candidates in the event to determine if the B_{tag} meson decayed as a B^0 or a \bar{B}^0 (flavor tag). We use a neural network to determine the flavor of the B_{tag} meson from kinematic and particle identification information [15]. Each event is assigned to one of six mutually exclusive tagging categories, designed to combine flavor tags with similar performance and vertex resolution. We measure the performance of this algorithm in a data sample (B_{flav}) of fully reconstructed $B^0 \rightarrow D^{(*)-} \pi^+ / \rho^+ / a_1^+$ decays. The average effective tagging efficiency obtained from this sample is $Q = \sum_c \epsilon_S^c (1 - 2w^c)^2 = (30.5 \pm 0.3)\%$, where ϵ_S^c and w^c are the signal efficiency and mistag probability, respectively, for events tagged in category c , and the error is statistical only. We take into account differences in tagging efficiency (for signal and background) and mistag (only for signal) for B^0 and \bar{B}^0 events, in order to exclude any source of fake CPV effects. For the background, the fraction of events (ϵ_B^c) and the asymmetry in the rate of B^0 versus \bar{B}^0 tags in each tagging category are extracted from the fit to the B_{flav} data.

Time-dependent CP asymmetries are determined from the distribution of the difference of the proper decay times, $\Delta t \equiv t_{CP} - t_{\text{tag}}$, where the t_{CP} refers to the B_{CP} and t_{tag} to the B_{tag} . At the $\Upsilon(4S)$ resonance, the Δt distribution follows

$$\mathcal{P}(\Delta t) = \frac{e^{-|\Delta t|/\tau}}{4\tau} \times \{ 1 \pm [S_f \sin(\Delta m_d \Delta t) - C_f \cos(\Delta m_d \Delta t)] \}, \quad (1)$$

where the $+(-)$ sign corresponds to B_{tag} decaying as B^0 (\bar{B}^0), τ is the neutral B lifetime, Δm_d is the mixing angular frequency, C_f is the magnitude of direct CP violation in the decay to final state f , and S_f is the magnitude of CP violation in the interference between mixing and decay. To account for flavor mistags we reduce S_f by the factor $1 - 2w^c$. For the case of penguin dominance, we expect $S_{K_S^0 \pi^0} \simeq \sin 2\beta$, and $C_{K_S^0 \pi^0} \simeq 0$.

The reconstructed proper time difference Δt_r is computed from the measured $\Delta z = z_{CP} - z_{\text{tag}}$, the difference of the reconstructed decay vertex positions of the B_{CP} and B_{tag} candidates along the boost direction, and the known boost of the e^+e^- system. A description of the inclusive reconstruction of the B_{tag} vertex is given in [16]. For the $B^0 \rightarrow K_S^0 \pi^0$ decay, where no charged particles are present at the decay vertex, we identify the vertex of the B_{CP} using the single K_S^0 trajectory from the $\pi^+\pi^-$ momenta and the knowledge of the average interaction point (IP) [11], which is determined several times per hour from the spatial distribution of vertices from two-track events. We compute Δt_r and its uncertainty from a geometric fit to the $\Upsilon(4S) \rightarrow B^0 \bar{B}^0$ system that takes this IP constraint into account. We further improve the sensitivity to Δt_r by constraining the sum of the two B decay times ($t_{CP} + t_{\text{tag}}$) to be equal to 2τ with an uncertainty $\sqrt{2}\tau$, which effectively constrains the two vertices to be near the $\Upsilon(4S)$ line of flight. We have verified in a full detector simulation that this procedure provides an unbiased estimate of Δt .

The per-event estimate of the uncertainty on Δt_r reflects the strong dependence of the Δt resolution on the K_S^0 flight direction and on the number of SVT layers traversed by the K_S^0 decay daughters. In about 60% of the selected events, each pion track is reconstructed from at least one ϕ hit and one z hit in the first three layers, leading to a sufficient resolution for the time-dependent CPV measurement. The average Δt resolution in these events is about 1.0 ps. For events which fail this criterion or for which $\Delta t_r > 20$ ps or the error on Δt_r satisfies $\sigma_{\Delta t_r} > 2.5$ ps, the Δt_r information is not used. However, since C_f can also be extracted from flavor tagging information alone, these events still contribute to the measurement of C_f and to the signal yield.

We obtain the probability density function (PDF) for the time-dependence of signal decays from the convolution of Eq. 1 with a resolution function $\mathcal{R}(\delta t \equiv \Delta t_r - \Delta t, \sigma_{\Delta t_r})$, where Δt is the true value of the proper time difference from Monte Carlo. The resolution function is parameterized as the sum of a core and a tail Gaussian, each with a width proportional to the reconstructed $\sigma_{\Delta t_r}$, and a third Gaussian centered at zero with a fixed width of 8 ps [16]. We have verified in simulation that the parameters of $\mathcal{R}(\delta t, \sigma_{\Delta t_r})$ for $B^0 \rightarrow K_S^0 \pi^0$ decays are similar to those obtained from the B_{flav} sample, even though the distributions of $\sigma_{\Delta t_r}$ differ considerably. Therefore, we extract these parameters from a fit to the B_{flav} sam-

ple. We find that the Δt_τ distribution of background candidates is well described by a δ function convolved with a resolution function with the same functional form as used for signal events. The parameters of the background function are determined together with the CPV parameters and the signal yield.

We extract the CPV parameters from an extended unbinned maximum-likelihood (ML) fit to kinematic, event shape, flavor tag, and decay time variables. We have verified that all correlations are negligible, so we construct the likelihood from the product of one-dimensional PDFs. Residual correlations are taken into account in the systematic uncertainty, as explained below.

The PDFs for signal events are parameterized from a large sample of fully-reconstructed B decays in data and from simulated events. For background PDFs, we select the functional form from the background-dominated sideband regions in our data.

The likelihood function is defined as:

$$\begin{aligned} \mathcal{L}(S_f, C_f, N_S, N_B, f_S, f_B, \vec{\alpha}) &= \frac{e^{-(N_S+N_B)}}{N!} \\ &\times \prod_{i \in g} [N_S f_S \epsilon_S^c \mathcal{P}_S(\vec{x}_i, \vec{y}_i; S_f, C_f) + N_B f_B \epsilon_B^c \mathcal{P}_B(\vec{x}_i, \vec{y}_i; \vec{\alpha})] \\ &\times \prod_{i \in b} [N_S (1 - f_S) \epsilon_S^c \mathcal{P}'_S(\vec{x}_i; C_f) + N_B (1 - f_B) \epsilon_B^c \mathcal{P}'_B(\vec{x}_i; \vec{\alpha})], \end{aligned} \quad (2)$$

where the N selected events are partitioned into two subsets: $i \in g$ events have Δt_τ information, while $i \in b$ events do not. f_S (f_B) is the fraction of signal (background) events $\in g$, and the complement to one is the fraction of events $\in b$. The probabilities \mathcal{P}_S and \mathcal{P}_B are products of PDFs for signal (S) and background (B) hypotheses evaluated for the measurements $\vec{x}_i = \{m_B, m_{\text{miss}}, L_2/L_0, \cos \theta_B^*, \text{flavor tag, tagging category}\}$ and $\vec{y}_i = \{\Delta t_\tau, \sigma_{\Delta t_\tau}\}$. \mathcal{P}'_S and \mathcal{P}'_B are the corresponding probabilities for events without Δt_τ information. In the formula, $\vec{\alpha}$ represents the set of parameters that define the shape of the PDFs. Along with the CP asymmetries S_f and C_f , the fit extracts the yields N_S and N_B , the fraction of events f_S and f_B , and the parameters $\vec{\alpha}$ which describe the background PDFs.

Fitting the data sample of 18111 $B^0 \rightarrow K_S^0 \pi^0$ candidates, we find $N_S = 459 \pm 29$ signal decays with $S_{K_S^0 \pi^0} = 0.40 \pm 0.23$ and $C_{K_S^0 \pi^0} = 0.24 \pm 0.15$, where the uncertainties are statistical only. The linear correlation coefficient between the CPV parameters is -7.3% . Taking into account the selection efficiency and the total number of $B\bar{B}$ pairs in the data sample, we obtain the branching fraction $\mathcal{B}(B^0 \rightarrow K_S^0 \pi^0) = (10.4 \pm 0.7) \times 10^{-6}$ which does not include systematic corrections on the yield.

Fig. 1 shows distributions for signal (background) events, where background (signal) is subtracted using an event weighting technique [17]. Figure 2 shows distributions of Δt_τ for B^0 and \bar{B}^0 -tagged events, and the asymmetry $\mathcal{A}_{K_S^0 \pi^0}(\Delta t_\tau) = [N_{B^0} - N_{\bar{B}^0}] / [N_{B^0} + N_{\bar{B}^0}]$ as a

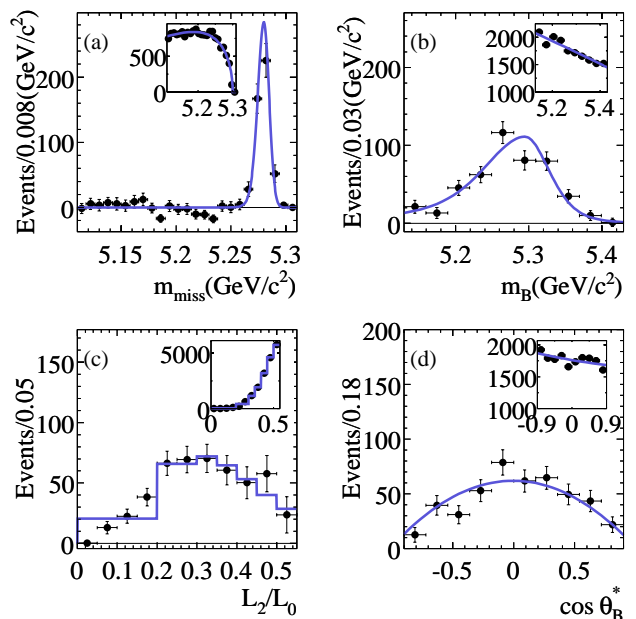


FIG. 1: Distribution of (a) m_{miss} , (b) m_B , (c) L_2/L_0 , (d) $\cos \theta_B^*$, for background subtracted events on data (dots). The solid curve represents the shape of signal PDF, as obtained from the ML fit. The insets show the distribution of the data, and the PDF, for signal subtracted events. The binning of the L_2/L_0 PDF is coarser where the signal is well separated from the background to reduce the number of free parameters.

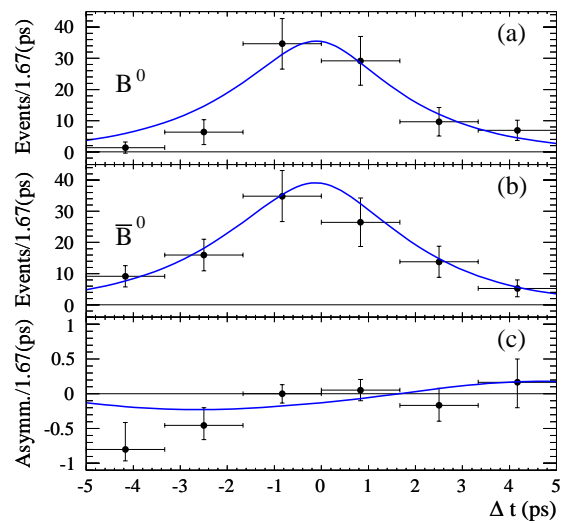


FIG. 2: Background subtracted distributions of Δt_τ for events where B_{tag} is tagged as (a) B^0 or (b) \bar{B}^0 , and (c) the asymmetry $\mathcal{A}(\Delta t_\tau)$. The points are data and the curves are the PDF projections.

function of Δt_τ , for background subtracted events. N_{B^0} ($N_{\bar{B}^0}$) represents the number of events tagged as B^0 (\bar{B}^0).

In order to validate the IP-constrained vertexing technique for CPV measurements we examine $B^0 \rightarrow J/\psi K_S^0$ decays in data, where $J/\psi \rightarrow \mu^+\mu^-$ or $J/\psi \rightarrow e^+e^-$. In these events we determine Δt_r in two ways: by fully reconstructing the B^0 decay vertex using the trajectories of charged daughters of the J/ψ and the K_S^0 mesons (standard method), or by neglecting the J/ψ contribution to the decay vertex and using the IP constraint and the K_S^0 trajectory only. This study shows that within statistical uncertainties, the IP-constrained Δt_r measurement is unbiased with respect to the standard technique and that the fit values of $S_{J/\psi K_S^0}$ and $C_{J/\psi K_S^0}$ are consistent between the two methods.

To compute the systematic error associated with the signal yield and CPV parameters, each of the input parameters to the likelihood fit is shifted by $\pm 1\sigma$ from its nominal value and the fit is repeated. Here, $\pm 1\sigma$ is the associated error, as obtained from the B_{flav} sample (for Δt and tagging) or from Monte Carlo. This contribution to the systematic error takes into account the limited statistics we used to parametrize the shape of the likelihood in Eq. 2. We find a systematic error of 0.72 events on the yield, and of 0.019 (0.010) on $S_{K_S^0\pi^0}$ ($C_{K_S^0\pi^0}$). As an additional systematic error associated with the shape of the PDF, we also quote the largest deviation observed when the parameters of the individual signal PDFs are floated in the fit. This gives a systematic error of 11 events on the yield, and of 0.019 (0.018) on $S_{K_S^0\pi^0}$ ($C_{K_S^0\pi^0}$). The output values of the PDF parameters are also used to assign a systematic error to the selection efficiency of the cuts on the likelihood variables. Comparing the efficiency to the Monte Carlo simulation we obtain a relative systematic error of 3.7%. We evaluate the systematic error coming from the neglected correlations among fit variables using a set of simulated Monte Carlo experiments, in which we embed signal events from a full detector simulation with events generated from the background PDFs. Since the shifts are small and only marginally significant we use the average shift in yield (-2.3 events) and CPV parameters (-0.003 on $S_{K_S^0\pi^0}$ and $+0.015$ on $C_{K_S^0\pi^0}$) as the associated uncertainty.

We estimate the background from other B decays to be small in the nominal fit. We account for a systematic shift induced on the signal yield and a small systematic uncertainty induced on the CPV parameters by this neglected component by embedding simulated B background events in the dataset and evaluating the average shift in the fit result: $+4.5$ events on the signal yield, $+0.003$ on $S_{K_S^0\pi^0}$ and -0.002 on $C_{K_S^0\pi^0}$. We adjust the signal yield accordingly and we use half of the shift as a systematic uncertainty.

To quantify possible additional systematic effects, we examine large samples of simulated $B^0 \rightarrow K_S^0\pi^0$ and $B^0 \rightarrow J/\psi K_S^0$ decays. We employ the difference in resolution function parameters extracted from these samples to evaluate uncertainties due to the use of the resolution

function \mathcal{R} extracted from the B_{flav} sample. We also use the data-Monte Carlo difference of the resolution function in $B^0 \rightarrow J/\psi K_S^0$ decays to quantify possible problems in the reconstruction of the K_S^0 vertex. We obtain a combined systematic error from this control sample of 0.027 on $S_{K_S^0\pi^0}$ and 0.006 on $C_{K_S^0\pi^0}$.

We include a systematic uncertainty of 0.002 on $S_{K_S^0\pi^0}$ and 0.001 on $C_{K_S^0\pi^0}$ to account for possible misalignments of the SVT. We consider large variations of the IP position and resolution, which produce a systematic uncertainty of 0.004 on $S_{K_S^0\pi^0}$ and 0.001 on $C_{K_S^0\pi^0}$. Additional contributions come from the error on the known B^0 lifetime (0.0022 on both $S_{K_S^0\pi^0}$ and $C_{K_S^0\pi^0}$), the value of Δm_d (0.0017 on both $S_{K_S^0\pi^0}$ and $C_{K_S^0\pi^0}$), and the effect of interference on the tag side [18] (0.0014 on $S_{K_S^0\pi^0}$ and 0.014 on $C_{K_S^0\pi^0}$). The systematic uncertainties on $S_{K_S^0\pi^0}$ and $C_{K_S^0\pi^0}$ are summarized in Table I.

For the branching fraction, systematic errors come from the knowledge of selection efficiency, $(33.6 \pm 1.6)\%$, the counting of $B\bar{B}$ pairs in the data sample, $(383.2 \pm 4.2) \times 10^6$ $B\bar{B}$ pairs, and the branching fractions of the B decay chain $\mathcal{B}(K_S^0 \rightarrow \pi^+\pi^-) = 0.6920 \pm 0.0005$ and $\mathcal{B}(\pi^0 \rightarrow \gamma\gamma) = 0.9880 \pm 0.0003$ [13]. The systematic uncertainties on the BF are summarized in Table II.

TABLE I: Summary of contributions to the systematic error on $S_{K_S^0\pi^0}$ and $C_{K_S^0\pi^0}$.

	$\Delta S(10^{-2})$	$\Delta C(10^{-2})$
Stat. precision of PDF parameters	0.6	1.0
Shape of signal PDF	1.9	1.8
$B\bar{B}$ background	0.3	0.2
Correlation among fit observables	0.3	1.5
Vertexing method and $\mathcal{R}(\Delta t_r, \sigma_{\Delta t_r})$	2.7	0.6
SVT alignment	0.2	0.1
Beam spot position calibration	0.4	0.1
B^0 lifetime	0.2	0.2
Mixing frequency	0.2	0.2
Tag side interference	0.1	1.4
Total	3.4	3.0

TABLE II: Summary of dominant contributions to the systematic error on the branching fraction.

	$\Delta\mathcal{B}/\mathcal{B}(\%)$
π^0 efficiency	3.0
K_S^0 efficiency	0.6
Cut on likelihood variables	3.7
Shape of signal PDF	2.5
$B\bar{B}$ background	0.5
Correlation among fit observables	0.5
Number of $B\bar{B}$	1.1
Resolution function	0.2
Total	5.6

In summary, we have performed a measurement of the time-dependent CP asymmetries of $B^0 \rightarrow K_S^0 \pi^0$ and the branching fraction of $B^0 \rightarrow K^0 \pi^0$. We measured the CPV parameters $C_{K_S^0 \pi^0} = 0.24 \pm 0.15 \pm 0.03$ and $S_{K_S^0 \pi^0} = 0.40 \pm 0.23 \pm 0.03$, and the branching fraction $\mathcal{B}(B^0 \rightarrow K^0 \pi^0) = (10.3 \pm 0.7 \pm 0.6) \times 10^{-6}$. The first errors are statistical and the second are systematic. These values are consistent with the Standard Model predictions and the experimental value of $\sin 2\beta$. The results presented in this work supersede previous ones [10].

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), CEA and CNRS-IN2P3 (France), BMBF and DFG (Germany), INFN (Italy), FOM (The Netherlands), NFR (Norway), MIST (Russia), MEC (Spain), and STFC (United Kingdom). Individuals have received support from the Marie Curie EIF (European Union) and the A. P. Sloan Foundation.

* Deceased

† Now at Tel Aviv University, Tel Aviv, 69978, Israel

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

§ Also with Università della Basilicata, Potenza, Italy

¶ Also with Universitat de Barcelona, Facultat de Física, Departament ECM, E-08028 Barcelona, Spain

[1] *BABAR* Collaboration, B. Aubert *et al.*, Phys. Rev. Lett. **87**, 091801 (2001); *BABAR* Collaboration, B. Aubert *et al.*, Phys. Rev. Lett. **94**, 161803 (2005).

- [2] Belle Collaboration, K. Abe *et al.*, Phys. Rev. Lett. **87**, 091802 (2001); Belle Collaboration, K. F. Chen *et al.*, Phys. Rev. Lett. **98**, 031802 (2007).
- [3] N. Cabibbo, Phys. Rev. Lett. **10**, 531 (1963); M. Kobayashi and T. Maskawa, Prog. Theor. Phys. **49**, 652 (1973).
- [4] CKMfitter Group, J. Charles *et al.*, Eur. Phys. J. C **41**, 1 (2005); UTfit Collaboration, M. Bona *et al.*, JHEP **0507** (2005) 028.
- [5] Y. Grossman and M. P. Worah, Phys. Lett. B **395**, 241 (1997).
- [6] M. Ciuchini, E. Franco, G. Martinelli, A. Masiero and L. Silvestrini, Phys. Rev. Lett. **79**, 978 (1997).
- [7] M. Gronau, Phys. Lett. B **627**, 82 (2005).
- [8] N. G. Deshpande and X. G. He, Phys. Rev. Lett. **75**, 1703 (1995).
- [9] M. Gronau and J. L. Rosner, Phys. Rev. Lett. **76**, 1200 (1996).
- [10] *BABAR* Collaboration, B. Aubert *et al.*, Phys. Rev. D **71**, 111102 (2005).
- [11] *BABAR* Collaboration, B. Aubert *et al.*, Phys. Rev. Lett. **93**, 131805 (2004).
- [12] *BABAR* Collaboration, B. Aubert *et al.*, Nucl. Instrum. Meth. A **479**, 1 (2002).
- [13] Particle Data Group, W.-M. Yao *et al.*, J. Phys. **G33**, 1 (2006).
- [14] J. D. Bjorken and S. J. Brodsky, Phys. Rev. D **1**, 1416 (1970).
- [15] *BABAR* Collaboration, B. Aubert *et al.*, Phys. Rev. Lett. **94**, 161803 (2005).
- [16] *BABAR* Collaboration, B. Aubert *et al.*, Phys. Rev. D **66**, 032003 (2002).
- [17] M. Pivk and F. R. Le Diberder, Nucl. Instrum. Meth. A **555**, 356 (2005).
- [18] O. Long, M. Baak, R.N. Cahn, and D. Kirkby, Phys. Rev. D **68**, 034010 (2003).
- [19] Unless explicitly stated, conjugate reactions are assumed throughout this paper.