

Evidence for $B^0 \rightarrow \rho^0 \rho^0$ Decay and Implications for the CKM Angle α

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 E. Grauges,² A. Palano,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. N. Brown,⁶ J. Button-Shafer,⁶ R. N. Cahn,⁶ Y. Groysman,⁶ R. G. Jacobsen,⁶ J. A. Kadyk,⁶ L. T. Kerth,⁶ Yu. G. Kolomensky,⁶ G. Kukartsev,⁶ D. Lopes Pegna,⁶ G. Lynch,⁶ L. M. Mir,⁶ T. J. Orimoto,⁶ I. Osipenkov,⁶ M. Pripstein,⁶ N. A. Roe,⁶ M. T. Ronan,^{6,*} K. Tackmann,⁶ W. A. Wenzel,⁶ P. del Amo Sanchez,⁷ M. Barrett,⁷ T. J. Harrison,⁷ A. J. Hart,⁷ C. M. Hawkes,⁷ A. T. Watson,⁷ T. Held,⁸ H. Koch,⁸ B. Lewandowski,⁸ M. Pelzaeus,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 D. J. Asgeirsson,¹⁰ 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 D. J. Sherwood,¹¹ L. Teodorescu,¹¹ V. E. Blinov,¹² A. D. Bukin,¹² V. P. Druzhinin,¹² V. B. Golubev,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 E. C. Martin,¹³ D. P. Stoker,¹³ S. Abachi,¹⁴ C. Buchanan,¹⁴ S. D. Foulkes,¹⁵ J. W. Gary,¹⁵ F. Liu,¹⁵ O. Long,¹⁵ B. C. Shen,¹⁵ L. Zhang,¹⁵ 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 D. Kovalskyi,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 T. Schalk,¹⁸ B. A. Schumm,¹⁸ A. Seiden,¹⁸ D. C. Williams,¹⁸ M. G. Wilson,¹⁸ L. O. Winstrom,¹⁸ E. Chen,¹⁹ C. H. Cheng,¹⁹ A. Dvoretzki,¹⁹ F. Fang,¹⁹ D. G. Hitlin,¹⁹ I. Narsky,¹⁹ T. Piatenko,¹⁹ F. C. Porter,¹⁹ G. Mancinelli,²⁰ B. T. Meadows,²⁰ K. Mishra,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 M. Nagel,²¹ U. Nauenberg,²¹ A. Olivas,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 J. Merkel,²³ A. Petzold,²³ B. Spaan,²³ K. Wacker,²³ T. Brandt,²⁴ V. Klose,²⁴ H. M. Lacker,²⁴ W. F. Mader,²⁴ R. Nogowski,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 E. Latour,²⁵ Ch. Thiebaux,²⁵ M. Verderi,²⁵ P. J. Clark,²⁶ W. Gradl,²⁶ F. Muheim,²⁶ S. Playfer,²⁶ A. I. Robertson,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 A. Petrella,²⁷ L. Piemontese,²⁷ E. Prencipe,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 M. Rama,²⁸ A. Zallo,²⁸ A. Buzzo,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 K. S. Chaisanguanthum,³⁰ M. Morii,³⁰ J. Wu,³⁰ R. S. Dubitzky,³¹ J. Marks,³¹ S. Schenk,³¹ U. Uwer,³¹ D. J. Bard,³² P. D. Dauncey,³² R. L. Flack,³² J. A. Nash,³² M. B. Nikolich,³² W. Panduro Vazquez,³² P. K. Behera,³³ X. Chai,³³ M. J. Charles,³³ U. Mallik,³³ N. T. Meyer,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 A. V. Gritsan,³⁵ C. K. Lae,³⁵ A. G. Denig,³⁶ M. Fritsch,³⁶ G. Schott,³⁶ N. Arnaud,³⁷ M. Davier,³⁷ G. Grosdidier,³⁷ A. Höcker,³⁷ V. Lepeltier,³⁷ F. Le Diberder,³⁷ A. M. Lutz,³⁷ S. Pruvot,³⁷ S. Rodier,³⁷ P. Roudeau,³⁷ M. H. Schune,³⁷ J. Serrano,³⁷ A. Stocchi,³⁷ W. F. Wang,³⁷ G. Wormser,³⁷ D. J. Lange,³⁸ D. M. Wright,³⁸ C. A. Chavez,³⁹ I. J. Forster,³⁹ J. R. Fry,³⁹ E. Gabathuler,³⁹ R. Gamet,³⁹ D. E. Hutchcroft,³⁹ D. J. Payne,³⁹ K. C. Schofield,³⁹ C. Touramanis,³⁹ A. J. Bevan,⁴⁰ K. A. George,⁴⁰ F. Di Lodovico,⁴⁰ W. Menges,⁴⁰ R. Sacco,⁴⁰ G. Cowan,⁴¹ H. U. Flaecher,⁴¹ D. A. Hopkins,⁴¹ P. S. Jackson,⁴¹ T. R. McMahon,⁴¹ F. Salvatore,⁴¹ A. C. Wren,⁴¹ D. N. Brown,⁴² C. L. Davis,⁴² J. Allison,⁴³ N. R. Barlow,⁴³ R. J. Barlow,⁴³ Y. M. Chia,⁴³ C. L. Edgar,⁴³ G. D. Lafferty,⁴³ T. J. West,⁴³ J. I. Yi,⁴³ C. Chen,⁴⁴ W. D. Hulsbergen,⁴⁴ A. Jawahery,⁴⁴ D. A. Roberts,⁴⁴ G. Simi,⁴⁴ G. Blaylock,⁴⁵ C. Dallapiccola,⁴⁵ S. S. Hertzbach,⁴⁵ X. Li,⁴⁵ T. B. Moore,⁴⁵ E. Salvati,⁴⁵ S. Saremi,⁴⁵ R. Cowan,⁴⁶ G. Sciolla,⁴⁶ S. J. Sekula,⁴⁶ M. Spitznagel,⁴⁶ F. Taylor,⁴⁶ R. K. Yamamoto,⁴⁶ H. Kim,⁴⁷ S. E. Mclachlin,⁴⁷ P. M. Patel,⁴⁷ S. H. Robertson,⁴⁷ A. Lazzaro,⁴⁸ V. Lombardo,⁴⁸ F. Palombo,⁴⁸ J. M. Bauer,⁴⁹ L. Cremaldi,⁴⁹ V. Eschenburg,⁴⁹ R. Godang,⁴⁹

Submitted to Physical Review Letters

R. Kroeger,⁴⁹ D. A. Sanders,⁴⁹ D. J. Summers,⁴⁹ H. W. Zhao,⁴⁹ S. Brunet,⁵⁰ D. Côté,⁵⁰ M. Simard,⁵⁰ P. Taras,⁵⁰
 F. B. Viaud,⁵⁰ H. Nicholson,⁵¹ N. Cavallo,^{52, †} G. De Nardo,⁵² F. Fabozzi,^{52, †} C. Gatto,⁵² L. Lista,⁵²
 D. Monorchio,⁵² P. Paolucci,⁵² D. Piccolo,⁵² C. Sciacca,⁵² M. A. Baak,⁵³ G. Raven,⁵³ H. L. Snoek,⁵³ C. P. Jessop,⁵⁴
 J. M. LoSecco,⁵⁴ G. Benelli,⁵⁵ L. A. Corwin,⁵⁵ K. K. Gan,⁵⁵ K. Honscheid,⁵⁵ D. Hufnagel,⁵⁵ H. Kagan,⁵⁵ R. Kass,⁵⁵
 J. P. Morris,⁵⁵ A. M. Rahimi,⁵⁵ J. J. Regensburger,⁵⁵ R. Ter-Antonyan,⁵⁵ Q. K. Wong,⁵⁵ N. L. Blount,⁵⁶ J. Brau,⁵⁶
 R. Frey,⁵⁶ O. Igonkina,⁵⁶ J. A. Kolb,⁵⁶ M. Lu,⁵⁶ C. T. Potter,⁵⁶ R. Rahmat,⁵⁶ N. B. Sinev,⁵⁶ D. Strom,⁵⁶
 J. Strube,⁵⁶ E. Torrence,⁵⁶ A. Gaz,⁵⁷ M. Margoni,⁵⁷ M. Morandin,⁵⁷ A. Pompili,⁵⁷ M. Posocco,⁵⁷ M. Rotondo,⁵⁷
 F. Simonetto,⁵⁷ R. Stroili,⁵⁷ C. Voci,⁵⁷ E. Ben-Haim,⁵⁸ H. Briand,⁵⁸ J. Chauveau,⁵⁸ P. David,⁵⁸ L. Del Buono,⁵⁸
 Ch. de la Vaissière,⁵⁸ O. Hamon,⁵⁸ B. L. Hartfiel,⁵⁸ Ph. Leruste,⁵⁸ J. Malclès,⁵⁸ J. Ocariz,⁵⁸ L. Gladney,⁵⁹
 M. Biasini,⁶⁰ R. Covarelli,⁶⁰ C. Angelini,⁶¹ G. Batignani,⁶¹ S. Bettarini,⁶¹ G. Calderini,⁶¹ M. Carpinelli,⁶¹
 R. Cenci,⁶¹ F. Forti,⁶¹ M. A. Giorgi,⁶¹ A. Lusiani,⁶¹ G. Marchiori,⁶¹ M. A. Mazur,⁶¹ M. Morganti,⁶¹ N. Neri,⁶¹
 E. Paoloni,⁶¹ G. Rizzo,⁶¹ J. J. Walsh,⁶¹ M. Haire,⁶² J. Biesiada,⁶³ P. Elmer,⁶³ Y. P. Lau,⁶³ C. Lu,⁶³ J. Olsen,⁶³
 A. J. S. Smith,⁶³ A. V. Telnov,⁶³ F. Bellini,⁶⁴ G. Cavoto,⁶⁴ A. D’Orazio,⁶⁴ D. del Re,⁶⁴ E. Di Marco,⁶⁴ R. Faccini,⁶⁴
 F. Ferrarotto,⁶⁴ F. Ferroni,⁶⁴ M. Gaspero,⁶⁴ P. D. Jackson,⁶⁴ L. Li Gioi,⁶⁴ M. A. Mazzoni,⁶⁴ S. Morganti,⁶⁴
 G. Piredda,⁶⁴ F. Polci,⁶⁴ C. Voena,⁶⁴ M. Ebert,⁶⁵ H. Schröder,⁶⁵ R. Waldi,⁶⁵ T. Adye,⁶⁶ G. Castelli,⁶⁶ B. Franek,⁶⁶
 E. O. Olaiya,⁶⁶ S. Ricciardi,⁶⁶ W. Roethel,⁶⁶ F. F. Wilson,⁶⁶ R. Aleksan,⁶⁷ S. Emery,⁶⁷ M. Escalier,⁶⁷ A. Gaidot,⁶⁷
 S. F. Ganzhur,⁶⁷ G. Hamel de Monchenault,⁶⁷ W. Kozanecki,⁶⁷ M. Legendre,⁶⁷ G. Vasseur,⁶⁷ Ch. Yèche,⁶⁷
 M. Zito,⁶⁷ X. R. Chen,⁶⁸ H. Liu,⁶⁸ W. Park,⁶⁸ M. V. Purohit,⁶⁸ J. R. Wilson,⁶⁸ M. T. Allen,⁶⁹ D. Aston,⁶⁹
 R. Bartoldus,⁶⁹ P. Bechtle,⁶⁹ N. Berger,⁶⁹ R. Claus,⁶⁹ J. P. Coleman,⁶⁹ M. R. Convery,⁶⁹ J. C. Dingfelder,⁶⁹
 J. Dorfan,⁶⁹ G. P. Dubois-Felsmann,⁶⁹ D. Dujmic,⁶⁹ W. Dunwoodie,⁶⁹ R. C. Field,⁶⁹ T. Glanzman,⁶⁹ S. J. Gowdy,⁶⁹
 M. T. Graham,⁶⁹ P. Grenier,⁶⁹ V. Halyo,⁶⁹ C. Hast,⁶⁹ T. Hryn’ova,⁶⁹ W. R. Innes,⁶⁹ M. H. Kelsey,⁶⁹ P. Kim,⁶⁹
 D. W. G. S. Leith,⁶⁹ S. Li,⁶⁹ S. Luitz,⁶⁹ V. Luth,⁶⁹ H. L. Lynch,⁶⁹ D. B. MacFarlane,⁶⁹ H. Marsiske,⁶⁹ R. Messner,⁶⁹
 D. R. Muller,⁶⁹ C. P. O’Grady,⁶⁹ V. E. Ozcan,⁶⁹ A. Perazzo,⁶⁹ M. Perl,⁶⁹ T. Pulliam,⁶⁹ B. N. Ratcliff,⁶⁹
 A. Roodman,⁶⁹ A. A. Salnikov,⁶⁹ R. H. Schindler,⁶⁹ J. Schwiening,⁶⁹ A. Snyder,⁶⁹ J. Stelzer,⁶⁹ D. Su,⁶⁹
 M. K. Sullivan,⁶⁹ K. Suzuki,⁶⁹ S. K. Swain,⁶⁹ J. M. Thompson,⁶⁹ J. Va’vra,⁶⁹ N. van Bakel,⁶⁹ A. P. Wagner,⁶⁹
 M. Weaver,⁶⁹ W. J. Wisniewski,⁶⁹ M. Wittgen,⁶⁹ D. H. Wright,⁶⁹ H. W. Wulsin,⁶⁹ A. K. Yarrity,⁶⁹ K. Yi,⁶⁹
 C. C. Young,⁶⁹ P. R. Burchat,⁷⁰ A. J. Edwards,⁷⁰ S. A. Majewski,⁷⁰ B. A. Petersen,⁷⁰ L. Wilden,⁷⁰ S. Ahmed,⁷¹
 M. S. Alam,⁷¹ R. Bula,⁷¹ J. A. Ernst,⁷¹ V. Jain,⁷¹ B. Pan,⁷¹ M. A. Saeed,⁷¹ F. R. Wappler,⁷¹ S. B. Zain,⁷¹
 W. Bugg,⁷² M. Krishnamurthy,⁷² S. M. Spanier,⁷² R. Eckmann,⁷³ J. L. Ritchie,⁷³ C. J. Schilling,⁷³
 R. F. Schwitters,⁷³ J. M. Izen,⁷⁴ X. C. Lou,⁷⁴ S. Ye,⁷⁴ F. Bianchi,⁷⁵ F. Gallo,⁷⁵ D. Gamba,⁷⁵ M. Pelliccioni,⁷⁵
 M. Bomben,⁷⁶ L. Bosisio,⁷⁶ C. Cartaro,⁷⁶ F. Cossutti,⁷⁶ G. Della Ricca,⁷⁶ L. Lanceri,⁷⁶ L. Vitale,⁷⁶ V. Azzolini,⁷⁷
 N. Lopez-March,⁷⁷ F. Martinez-Vidal,⁷⁷ A. Oyanguren,⁷⁷ J. Albert,⁷⁸ Sw. Banerjee,⁷⁸ B. Bhuyan,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 M. Pappagallo,^{79, §} H. R. Band,⁸⁰ X. Chen,⁸⁰ S. Dasu,⁸⁰ K. T. Flood,⁸⁰ J. J. Hollar,⁸⁰
 P. E. Kutter,⁸⁰ B. Mellado,⁸⁰ Y. Pan,⁸⁰ M. Pierini,⁸⁰ R. Prepost,⁸⁰ S. L. Wu,⁸⁰ Z. Yu,⁸⁰ and H. Neal⁸¹

(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

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 1, 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

- ²⁰ University of Cincinnati, Cincinnati, Ohio 45221, USA
- ²¹ University of Colorado, Boulder, Colorado 80309, USA
- ²² Colorado 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 Laboratoire Leprince-Ringuet, CNRS/IN2P3, Ecole Polytechnique, 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 Johns Hopkins University, Baltimore, Maryland 21218, USA
- ³⁶ Universität Karlsruhe, Institut für Experimentelle Kernphysik, D-76021 Karlsruhe, Germany
- ³⁷ Laboratoire de l'Accélérateur Linéaire, IN2P3/CNRS et Université Paris-Sud 11, Centre Scientifique d'Orsay, B. P. 34, F-91898 ORSAY Cedex, France
- ³⁸ Lawrence Livermore National Laboratory, Livermore, California 94550, USA
- ³⁹ University of Liverpool, Liverpool L69 7ZE, United Kingdom
- ⁴⁰ Queen Mary, University of London, E1 4NS, United Kingdom
- ⁴¹ University of London, Royal Holloway and Bedford New College, Egham, Surrey TW20 0EX, United Kingdom
- ⁴² University of Louisville, Louisville, Kentucky 40292, USA
- ⁴³ University of Manchester, Manchester M13 9PL, United Kingdom
- ⁴⁴ University of Maryland, College Park, Maryland 20742, USA
- ⁴⁵ University of Massachusetts, Amherst, Massachusetts 01003, USA
- ⁴⁶ Massachusetts Institute of Technology, Laboratory for Nuclear Science, Cambridge, Massachusetts 02139, USA
- ⁴⁷ McGill University, Montréal, Québec, Canada H3A 2T8
- ⁴⁸ Università di Milano, Dipartimento di Fisica and INFN, I-20133 Milano, Italy
- ⁴⁹ University of Mississippi, University, Mississippi 38677, USA
- ⁵⁰ Université de Montréal, Physique des Particules, Montréal, Québec, Canada H3C 3J7
- ⁵¹ Mount Holyoke College, South Hadley, Massachusetts 01075, USA
- ⁵² Università di Napoli Federico II, Dipartimento di Scienze Fisiche and INFN, I-80126, Napoli, Italy
- ⁵³ NIKHEF, National Institute for Nuclear Physics and High Energy Physics, NL-1009 DB Amsterdam, The Netherlands
- ⁵⁴ University of Notre Dame, Notre Dame, Indiana 46556, USA
- ⁵⁵ Ohio State University, Columbus, Ohio 43210, USA
- ⁵⁶ University of Oregon, Eugene, Oregon 97403, USA
- ⁵⁷ Università di Padova, Dipartimento di Fisica and INFN, I-35131 Padova, Italy
- ⁵⁸ Laboratoire de Physique Nucléaire et de Hautes Energies, IN2P3/CNRS, Université Pierre et Marie Curie-Paris6, Université Denis Diderot-Paris7, F-75252 Paris, France
- ⁵⁹ University of Pennsylvania, Philadelphia, Pennsylvania 19104, USA
- ⁶⁰ Università di Perugia, Dipartimento di Fisica and INFN, I-06100 Perugia, Italy
- ⁶¹ Università di Pisa, Dipartimento di Fisica, Scuola Normale Superiore and INFN, I-56127 Pisa, Italy
- ⁶² Prairie View A&M University, Prairie View, Texas 77446, USA
- ⁶³ Princeton University, Princeton, New Jersey 08544, USA
- ⁶⁴ Università di Roma La Sapienza, Dipartimento di Fisica and INFN, I-00185 Roma, Italy
- ⁶⁵ Universität Rostock, D-18051 Rostock, Germany
- ⁶⁶ Rutherford Appleton Laboratory, Chilton, Didcot, Oxon, OX11 0QX, United Kingdom
- ⁶⁷ DSM/Dapnia, CEA/Saclay, F-91191 Gif-sur-Yvette, France
- ⁶⁸ University of South Carolina, Columbia, South Carolina 29208, USA
- ⁶⁹ Stanford Linear Accelerator Center, Stanford, California 94309, USA
- ⁷⁰ Stanford University, Stanford, California 94305-4060, USA
- ⁷¹ State University of New York, Albany, New York 12222, USA
- ⁷² University of Tennessee, Knoxville, Tennessee 37996, USA
- ⁷³ University of Texas at Austin, Austin, Texas 78712, USA
- ⁷⁴ University of Texas at Dallas, Richardson, Texas 75083, USA
- ⁷⁵ Università di Torino, Dipartimento di Fisica Sperimentale and INFN, I-10125 Torino, Italy
- ⁷⁶ Università di Trieste, Dipartimento di Fisica and INFN, I-34127 Trieste, Italy
- ⁷⁷ IFIC, Universitat de Valencia-CSIC, E-46071 Valencia, Spain
- 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

⁸¹Yale University, New Haven, Connecticut 06511, USA

(Dated: December 11, 2006)

We search for the decays $B^0 \rightarrow \rho^0 \rho^0$, $B^0 \rightarrow \rho^0 f_0(980)$, and $B^0 \rightarrow f_0(980) f_0(980)$ in a sample of about 384 million $\Upsilon(4S) \rightarrow B\bar{B}$ decays collected with the BABAR detector at the PEP-II asymmetric-energy e^+e^- collider at SLAC. We find evidence for $B^0 \rightarrow \rho^0 \rho^0$ with 3.5σ significance and measure the branching fraction $\mathcal{B} = (1.07 \pm 0.33 \pm 0.19) \times 10^{-6}$ and longitudinal polarization fraction $f_L = 0.87 \pm 0.13 \pm 0.04$, where the first uncertainty is statistical, and the second is systematic. The uncertainty on the CKM unitarity angle α due to penguin contributions in $B \rightarrow \rho\rho$ decays is 18° at the 1σ level. We also set upper limits on the $B^0 \rightarrow \rho^0 f_0(980)$ and $B^0 \rightarrow f_0(980) f_0(980)$ decay rates.

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

Measurements of CP -violating asymmetries in the $B^0\bar{B}^0$ system test the flavor structure of the standard model by over-constraining the Cabibbo-Kobayashi-Maskawa (CKM) quark-mixing matrix [1]. The time-dependent CP asymmetry in the decays of B^0 or \bar{B}^0 mesons to a CP eigenstate dominated by the tree-level amplitude $b \rightarrow u\bar{u}d$ measures $\sin 2\alpha_{\text{eff}}$, where α_{eff} differs from the CKM unitarity triangle angle $\alpha \equiv \arg[-V_{td}V_{tb}^*/V_{ud}V_{ub}^*]$ by a quantity $\Delta\alpha$ accounting for the contributions from loop (penguin) amplitudes. The value of $\Delta\alpha$ can be extracted from an analysis of the branching fractions of the B decays into the full set of isospin-related channels [2].

Branching fractions and time-dependent CP asymmetries in $B \rightarrow \pi\pi$, $\rho\pi$, and $\rho\rho$ have already provided information on α . Since the tree contribution to the $B^0 \rightarrow \rho^0 \rho^0$ decay is color-suppressed, the decay rate is sensitive to the penguin amplitude. The $B^0 \rightarrow \rho^0 \rho^0$ decay has a much smaller branching fraction than $B^0 \rightarrow \rho^+ \rho^-$ and $B^+ \rightarrow \rho^+ \rho^0$ channels [4–9], and therefore a stringent limit on $\Delta\alpha$ can be set [2, 7, 10]. This makes the $\rho\rho$ system particularly effective for measuring α .

In $B \rightarrow \rho\rho$ decays the final state is a superposition of CP -odd and CP -even states. An isospin-triangle relation [2] holds for each of the three helicity amplitudes, which can be separated through an angular analysis. The helicity angles θ_1 and θ_2 are defined as the angles between the direction of π^+ and the direction of the B in the rest system of each of the ρ^0 candidates. The resulting angular distribution $d^2\Gamma/(\Gamma d\cos\theta_1 d\cos\theta_2)$ is

$$\frac{9}{4} \left\{ \frac{1}{4} (1 - f_L) \sin^2 \theta_1 \sin^2 \theta_2 + f_L \cos^2 \theta_1 \cos^2 \theta_2 \right\}, \quad (1)$$

where $f_L = |A_0|^2/(\sum |A_\lambda|^2)$ is the longitudinal polarization fraction and $A_{\lambda=-1,0,+1}$ are the helicity amplitudes.

In this paper we present the first evidence for the $B^0 \rightarrow \rho^0 \rho^0$ decay, the measurement of the longitudinal polarization fraction in this decay, and updated constraints on the penguin contribution to the measurement of the unitarity angle α .

These results are based on data collected with the BABAR detector [11] at the PEP-II asymmetric-energy e^+e^- collider [12]. A sample of 383.6 ± 4.2 million

$B\bar{B}$ pairs was recorded at the $\Upsilon(4S)$ resonance with the center-of-mass (c.m.) energy $\sqrt{s} = 10.58$ GeV. Charged-particle momenta and trajectories are measured in a tracking system consisting of a five-layer double-sided silicon vertex tracker and a 40-layer drift chamber, both within a 1.5-T solenoidal magnetic field. Charged-particle identification is provided by measurements of the energy loss in the tracking devices and by a ring-imaging Cherenkov detector.

We select $B \rightarrow M_1 M_2 \rightarrow (\pi^+ \pi^-)(\pi^+ \pi^-)$ candidates, with $M_{1,2}$ standing for ρ^0 or f_0 candidate, from neutral combinations of four charged tracks that are consistent with originating from a single vertex near the e^+e^- interaction point. We veto tracks that are positively identified as kaons or electrons. The identification of signal B candidates is based on several kinematic variables. The beam-energy-substituted mass, $m_{\text{ES}} = [(s/2 + \mathbf{p}_i \cdot \mathbf{p}_B)^2 / E_i^2 - \mathbf{p}_B^2]^{1/2}$, where the initial e^+e^- four-momentum (E_i, \mathbf{p}_i) and the B momentum \mathbf{p}_B are defined in the laboratory frame, is centered near the B mass with a resolution of 2.6 MeV for signal candidates. The difference $\Delta E = E_B^{\text{cm}} - \sqrt{s}/2$ between the reconstructed B energy in the c.m. frame and its known value $\sqrt{s}/2$ has a maximum near zero with a resolution of 20 MeV for signal events. Four other kinematic variables describe two possible $\pi^+ \pi^-$ pairs: invariant masses m_1, m_2 and helicity angles θ_1, θ_2 .

The selection requirements for signal candidates are the following: $5.245 < m_{\text{ES}} < 5.290$ GeV, $|\Delta E| < 85$ MeV, $550 < m_{1,2} < 1050$ MeV, and $|\cos\theta_{1,2}| < 0.98$. The last requirement removes a region with low reconstruction efficiency. In addition, we veto the copious decays $B^0 \rightarrow D^{(*)-} \pi^+ \rightarrow (h^+ \pi^- \pi^-) \pi^+$, where h^+ refers to a pion or kaon, by requiring the invariant mass of the three-particle combination to differ from the D -meson mass by more than 13.2 MeV, or 40 MeV if one of the particles is consistent with a kaon hypothesis.

We reject the dominant $e^+e^- \rightarrow q\bar{q}$ ($q = u, d, s, c$) (continuum) background by requiring $|\cos\theta_T| < 0.8$, where θ_T is the angle between the B -candidate thrust axis and that of the remaining tracks and neutral clusters in the event, calculated in the c.m. frame. We further suppress continuum background using a neural network

discriminant \mathcal{E} , which combines a number of topological variables calculated in the c.m. frame. Among those are the polar angles of the B momentum vector and the B -candidate thrust axis with respect to the beam axis. Other discriminating variables include the two Legendre moments L_0 and L_2 of the energy flow around the B -candidate thrust axis [13] and the sum of the transverse momenta of all particles in the rest of the event, calculated with respect to the B direction.

After application of all selection criteria, $N_{\text{cand}} = 64843$ events are retained. On average, each selected background event has 1.05 signal candidates, while in Monte Carlo [14] samples of longitudinally and transversely polarized $B^0 \rightarrow \rho^0 \rho^0$ decays we find 1.15 and 1.03 candidates, respectively. When more than one candidate is present in the same event, the candidate having the best χ^2 consistency with a single four-pion vertex is selected. Simulation shows that 18% of longitudinally and 4% of transversely polarized $B^0 \rightarrow \rho^0 \rho^0$ events are misreconstructed with one or more tracks not originating from the $B^0 \rightarrow \rho^0 \rho^0$ decay. These are mostly due to combinatorial background from low-momentum tracks from the other B meson in the event.

Further background separation is achieved by the use of multivariate B -flavor-tagging algorithms trained to identify primary leptons, kaons, soft pions, and high-momentum charged particles from the other B [15]. The discrimination power arises from the difference between the tagging efficiencies for signal and background in seven tagging categories ($c_{\text{tag}} = 1..7$).

We use an unbinned extended maximum likelihood fit to extract the $B^0 \rightarrow \rho^0 \rho^0$ event yield and fraction of longitudinal polarization f_L . We also fit for the event yields of $B^0 \rightarrow \rho^0 f_0$ and $B^0 \rightarrow f_0 f_0$ decays, as well as of several background categories. The likelihood function is

$$\mathcal{L} = \exp\left(-\sum_k n_k\right) \prod_{i=1}^{N_{\text{cand}}} \left(\sum_j n_j \mathcal{P}_j(\vec{x}_i)\right), \quad (2)$$

where n_j is the unconstrained number of events for each event type j ($B^0 \rightarrow \rho^0 \rho^0$, $B^0 \rightarrow \rho^0 f_0(980)$, $B^0 \rightarrow f_0(980) f_0(980)$, three background components from B decays, and continuum), and $\mathcal{P}_j(\vec{x}_i)$ is the probability density function (PDF) of the variables $\vec{x}_i = \{m_{\text{ES}}, \Delta E, \mathcal{E}, m_1, m_2, \cos \theta_1, \cos \theta_2, c_{\text{tag}}\}_i$ for the i th event.

We use simulated events to parameterize the background contributions from B decays. The charmless modes are grouped into two classes with similar kinematic and topological properties: $B^0 \rightarrow a_1^\pm \pi^\mp$ and a combination of other charmless modes, including $B^0 \rightarrow \rho^0 K^{*0}$, $B^+ \rightarrow \rho^+ \rho^0$, $B \rightarrow \rho \pi$, and $B^0 \rightarrow \rho^+ \rho^-$. One additional class accounts for the remaining neutral and charged B decays to charm modes. We ignore any other four-pion final states whose contributions are expected to be small in our invariant mass window.

Since the statistical correlations among the variables are found to be small, we take each \mathcal{P}_j as the product of the PDFs for the separate variables. Exceptions are the kinematic correlation between the two helicity angles in signal, and mass-helicity correlations in other B -decay classes and misreconstructed signal.

We use double-Gaussian functions to parameterize the m_{ES} and ΔE PDFs for signal, and a relativistic Breit-Wigner functions for the resonance masses of ρ^0 and $f_0(980)$ [16]. The angular distribution at production for $B^0 \rightarrow \rho^0 \rho^0$, $B^0 \rightarrow \rho^0 f_0$, and $B^0 \rightarrow f_0 f_0$ modes (expressed as a function of the longitudinal polarization in Eq. (1) for $B^0 \rightarrow \rho^0 \rho^0$) is multiplied by a detector acceptance function $\mathcal{G}(\cos \theta_1, \cos \theta_2)$, determined from Monte Carlo. The distributions of misreconstructed signal events are parameterized with empirical shapes in a way similar to that used for B background. The neural network discriminant \mathcal{E} is described by three asymmetric Gaussian functions with different parameters for signal and background distributions.

The PDFs for non-signal B decay modes are generally modeled with empirical analytical distributions. Several variables have distributions identical to those for signal, such as m_{ES} when all four tracks come from the same B , or $\pi^+ \pi^-$ invariant mass $m_{1,2}$ when both tracks come from a ρ^0 meson. Also for some of the modes the two $\pi^+ \pi^-$ pairs can have different mass and helicity distributions, *e.g.* when only one of the two combinations comes from a genuine ρ^0 or f_0 meson, or when one of the two pairs contains a high-momentum pion (as in $B \rightarrow a_1 \pi$). In such cases, we use a four-variable correlated mass-helicity PDF.

The signal and B -background PDF parameters are extracted from simulation. The Monte Carlo parameters for m_{ES} , ΔE , and \mathcal{E} PDFs are adjusted by comparing data and simulation in control channels with similar kinematics and topology, such as $B^0 \rightarrow D^- \pi^+$ with $D^- \rightarrow K^+ \pi^- \pi^-$. The continuum background PDF parameters are left free in the fit. Finally, the discrete B -flavor tagging PDFs for signal modes are obtained in dedicated fits to events with identified exclusive B decays. The tagging PDFs for inclusive B backgrounds are determined by Monte Carlo and their systematic uncertainties are studied in data.

Table I shows the results of the fit. The $B^0 \rightarrow \rho^0 \rho^0$ decay is observed with a significance of 3.5σ , as determined by the quantity $\sqrt{-2 \log(\mathcal{L}_0/\mathcal{L}_{\text{max}})}$, where \mathcal{L}_{max} is the maximum likelihood value, and \mathcal{L}_0 is the likelihood for a fit with the signal contribution set to zero. It corresponds to a probability of background fluctuation to the observed signal yield of 2×10^{-4} , including systematic uncertainties, which are assumed to be Gaussian-distributed. We do not observe significant event yields for $B^0 \rightarrow \rho^0 f_0(980)$ and $B^0 \rightarrow f_0(980) f_0(980)$ decays. Background yields are found to be consistent with expectations. In Fig. 1 we show the projections of the fit

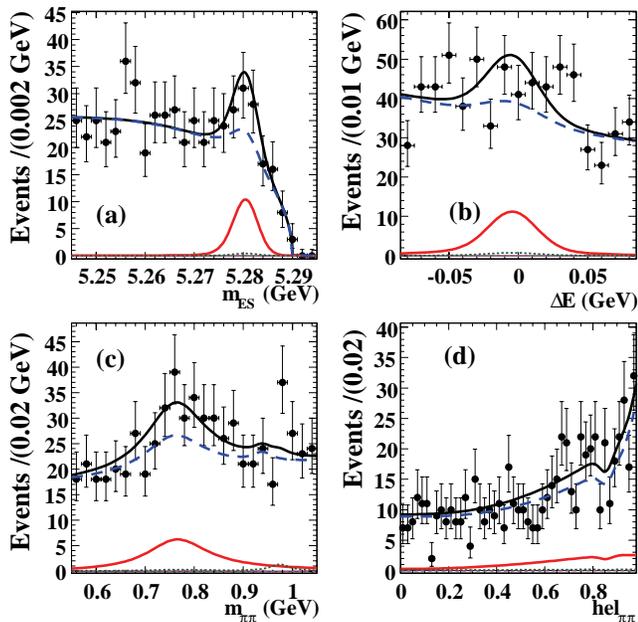


FIG. 1: Projections of the multidimensional fit onto (a) m_{ES} , (b) ΔE , (c) di-pion invariant mass (m_1 is shown, distribution of m_2 is similar), and (d) cosine of the helicity angle ($\cos \theta_1$ is shown), after a requirement on the signal-to-background probability ratio with the plotted variable excluded. This requirement enhances the fraction of signal events in the sample. The data points are overlaid by the solid (dashed) line, which shows the full (background only) PDF projection. The individual $B^0 \rightarrow \rho^0 \rho^0$ PDF component is also shown with a solid line.

results onto m_{ES} , ΔE , m_1 , and $\cos \theta_1$ variables.

Dominant systematic uncertainties in the fit originate from statistical errors in the PDF parameterizations, due to the limited number of events in the control samples. The PDF parameters are varied by their respective uncertainties to derive the corresponding systematic errors (± 10 , ${}^{+6}_{-9}$, ± 4 events for $\rho^0 \rho^0$, $\rho^0 f_0$, and $f_0 f_0$ respectively, and 0.03 for f_L). We also assign a systematic error of 2 events for $\rho^0 \rho^0$, 3 events for $\rho^0 f_0$, and 1 event for $f_0 f_0$ (0.01 for f_L) to account for a possible fit bias, evaluated with Monte Carlo experiments. The above systematic uncertainties do not scale with event yield and are included in the calculation of the significance of the result.

We estimate the systematic uncertainty due to the interference between the $B^0 \rightarrow \rho^0 \rho^0$ and $a_1^\pm \pi^\mp$ decays using simulated samples in which the decay amplitudes for $B^0 \rightarrow \rho^0 \rho^0$ are generated according to this measurement and those for $B^0 \rightarrow a_1^\pm \pi^\mp$ correspond to a branching fraction of $(33.2 \pm 4.8) \times 10^{-6}$ [17]. Their amplitudes are modeled with a Breit-Wigner function for all $\rho \rightarrow \pi\pi$ and $a_1 \rightarrow \rho\pi$ combinations and their relative phase is assumed to be constant across the phase space. The strong phases and CP content of the interfering state $a_1^\pm \pi^\mp$ are varied between zero and a maximum value using uniform

TABLE I: Summary of results: event yields (n); fraction of longitudinal polarization (f_L); selection efficiency (Eff) corresponding to measured polarization; branching fraction (\mathcal{B}_{sig}); branching fraction upper limit (UL) at 90% CL; and significance including systematic uncertainties. The systematic errors are quoted last. We also show the background event yields for $a_1\pi$, $q\bar{q}$, charmless, and other $B\bar{B}$ components (statistical uncertainties only).

Quantity	Value
$n(B^0 \rightarrow \rho^0 \rho^0)$	$100 \pm 32 \pm 17$
f_L	$0.87 \pm 0.13 \pm 0.04$
Eff (%)	24.2 ± 1.0
$\mathcal{B}_{\text{sig}} (\times 10^{-6})$	$1.07 \pm 0.33 \pm 0.19$
Significance, stat. only (σ)	3.7
Significance, syst. included (σ)	3.5
$n(B^0 \rightarrow \rho^0 f_0)$	$20 \pm 21 \begin{smallmatrix} +7 \\ -10 \end{smallmatrix}$
Eff (%)	26.1 ± 1.0
$\mathcal{B}_{\text{sig}} \times \mathcal{B}(f_0 \rightarrow \pi^+ \pi^-) (\times 10^{-6})$	$0.19 \pm 0.21 \begin{smallmatrix} +0.07 \\ -0.10 \end{smallmatrix}$
UL $\times \mathcal{B}(f_0 \rightarrow \pi^+ \pi^-) (\times 10^{-6})$	0.53
$n(B^0 \rightarrow f_0 f_0)$	$-3 \pm 9 \pm 5$
Eff (%)	28.6 ± 1.1
$\mathcal{B}_{\text{sig}} \times \mathcal{B}^2(f_0 \rightarrow \pi^+ \pi^-) (\times 10^{-6})$	$-0.03 \pm 0.08 \pm 0.04$
UL $\times \mathcal{B}^2(f_0 \rightarrow \pi^+ \pi^-) (\times 10^{-6})$	0.16
$n(B^0 \rightarrow a_1^\pm \pi^\mp)$	81 ± 25
$n(\text{charmless})$	$-17 \begin{smallmatrix} +107 \\ -96 \end{smallmatrix}$
$n(B\bar{B})$	3198 ± 224
$n(q\bar{q})$	61469 ± 311

prior distributions. We take the RMS variation of the average signal yield (14 events for the $\rho^0 \rho^0$ yield, or 0.03 for f_L) as a systematic uncertainty.

Uncertainties in the reconstruction efficiency arise from track finding (2%), particle identification (2%), and other selection requirements, such as vertex probability (2%), track multiplicity (1%), and thrust angle (1%).

To constrain the penguin contributions to $B \rightarrow \rho\rho$ decays, we perform an isospin analysis, by minimizing a χ^2 term that includes the measured quantities expressed as the lengths of the sides of the isospin triangles. We use the measured branching fractions and fractions of longitudinal polarization of the $B^+ \rightarrow \rho^+ \rho^0$ [6] and $B^0 \rightarrow \rho^+ \rho^-$ [7] decays, the CP -violating parameters S_L^{+-} and C_L^{+-} determined from the time evolution of the longitudinally polarized $B^0 \rightarrow \rho^+ \rho^-$ decay [8], and the branching fraction and polarization of $B^0 \rightarrow \rho^0 \rho^0$ from this analysis. We assume uncertainties to be Gaussian and neglect $I = 1$ isospin contributions, electroweak loop amplitudes, non-resonant and isospin-breaking effects.

With the $B^0 \rightarrow \rho^0 \rho^0$ measurement we obtain a 68% (90%) CL limit on $|\Delta\alpha| \equiv |\alpha - \alpha_{\text{eff}}| < 18^\circ$ ($< 20^\circ$). Fig. 2 shows $\Delta\chi^2$ as a function of $\Delta\alpha$. The central value of α obtained from the isospin analysis is the same as α_{eff} , which is constrained by the relation $\sin(2\alpha_{\text{eff}}) = S_L^{+-}/(1 - C_L^{+-2})^{1/2}$ and is measured with

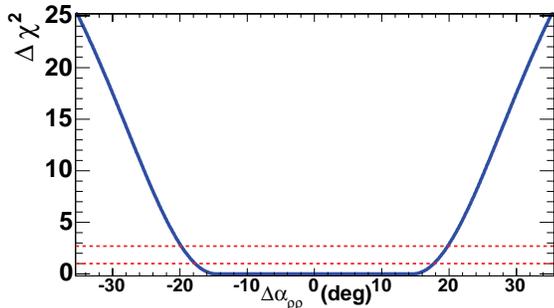


FIG. 2: $\Delta\chi^2$ as a function of $\Delta\alpha$ obtained from the isospin analysis discussed in the text. The dashed lines at $\Delta\chi^2 = 1$ and $\Delta\chi^2 = 2.7$ are taken for the 1σ (68%) and 1.64σ (90%) interval estimates.

the $B^0 \rightarrow \rho^+\rho^-$ decay [8].

The error due to the penguin contribution becomes the dominant uncertainty in the measurement of α using $B \rightarrow \rho\rho$ decays. However, once the sample of $B^0 \rightarrow \rho^0\rho^0$ decays becomes more significant, time-dependent angular analysis will allow us to measure the CP parameters S_L^{00} and C_L^{00} , analogous to S_L^{+-} and C_L^{+-} , resolving ambiguities inherent to isospin triangle orientations.

In summary, we find evidence for $B^0 \rightarrow \rho^0\rho^0$ decay with 3.5σ significance. We measure the $B^0 \rightarrow \rho^0\rho^0$ branching fraction of $(1.07 \pm 0.33 \pm 0.19) \times 10^{-6}$ and determine the longitudinal polarization fraction for these decays of $f_L = 0.87 \pm 0.13 \pm 0.04$. The measurement of this branching fraction combined with that for $B^+ \rightarrow \rho^0\rho^+$ and $B^0 \rightarrow \rho^+\rho^-$ decays provides a constraint on the penguin uncertainty in the determination of the CKM unitarity angle α . These results supersede our previous measurements [4]. We find no significant evidence for the decays $B^0 \rightarrow \rho^0 f_0$ and $B^0 \rightarrow f_0 f_0$.

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, T. Maskawa, Prog. Theor. Phys. **49**, 652 (1973).
- [2] M. Gronau, D. London, Phys. Rev. Lett. **65**, 3381 (1990).
- [3] Charge conjugate B decay modes are implied in this paper.
- [4] *BABAR* Collaboration, B. Aubert *et al.*, Phys. Rev. Lett. **91**, 171802 (2003); Phys. Rev. Lett. **94**, 131801 (2005).
- [5] Belle Collaboration, J. Zhang *et al.*, Phys. Rev. Lett. **91**, 221801 (2003).
- [6] *BABAR* Collaboration, B. Aubert *et al.*, arXiv:hep-ex/0607092 (2006), accepted to Phys. Rev. Lett. .
- [7] *BABAR* Collaboration, B. Aubert *et al.*, Phys. Rev. D **69**, 031102 (2004); Phys. Rev. Lett. **93**, 231801 (2004).
- [8] *BABAR* Collaboration, B. Aubert *et al.*, Phys. Rev. Lett. **95**, 041805 (2005).
- [9] Belle Collaboration, A. Somov *et al.*, Phys. Rev. Lett. **96**, 171801 (2006).
- [10] A.F. Falk *et al.*, Phys. Rev. D **69**, 011502 (2004).
- [11] *BABAR* Collaboration, B. Aubert *et al.*, Nucl. Instrum. Methods Phys. Res., Sect. A **479**, 1 (2002).
- [12] PEP-II Conceptual Design Report, SLAC-R-418 (1993).
- [13] *BABAR* Collaboration, B. Aubert *et al.*, Phys. Rev. D **70**, 032006 (2004).
- [14] The *BABAR* detector Monte Carlo simulation is based on GEANT4: S. Agostinelli *et al.*, Nucl. Instrum. Methods Phys. Res., Sect. A **506**, 250 (2003).
- [15] *BABAR* Collaboration, B. Aubert *et al.*, Phys. Rev. Lett. **89**, 201802 (2002).
- [16] E791 Collaboration, E. M. Aitala *et al.*, Phys. Rev. Lett. **86**, 765 (2001).
- [17] *BABAR* Collaboration, B. Aubert *et al.*, Phys. Rev. Lett. **97**, 051802 (2006).