BABAR-PUB-08/046
SLAC-PUB-13461
February 2009

Search for the decay $B^+ \to K^0_S K^0_S \pi^+$

B. Aubert,[1] M. Bona,[1] Y. Karyotakis,[1] J. P. Lees,[1] V. Poireau,[1] E. Prencipe,[1] X. Prudent,[1] V. Tisserand,[1]
J. Garra Tico,[2] E. Grauges,[2] L. Lopez[ab],[3] A. Palano[ab],[3] M. Pappagallo[ab],[3] G. Eigen,[4] B. Stugu,[4] L. Sun,[4]
G. S. Abrams,[5] M. Battaglia,[5] D. N. Brown,[5] R. N. Cahn,[5] R. G. Jacobsen,[5] L. T. Kerth,[5] Yu. G. Kolomensky,[5]
G. Lynch,[5] I. L. Osipenkov,[5] M. T. Ronan,[5, *] K. Tackmann,[5] T. Tanabe,[5] C. M. Hawkes,[6] N. Soni,[6] A. T. Watson,[6]
H. Koch,[7] T. Schroeder,[7] D. Walker,[8] D. J. Asgeirsson,[9] B. G. Fulsom,[9] C. Hearty,[9] T. S. Mattison,[9]
J. A. McKenna,[9] M. Barrett,[10] A. Khan,[10] V. E. Blinov,[11] A. D. Bukin,[11] A. R. Buzykaev,[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] H. Atmacan,[14] J. W. Gary,[14] F. Liu,[14] O. Long,[14]
G. M. Vitug,[14] Z. Yasin,[14] L. Zhang,[14] V. Sharma,[15] C. Campagnari,[16] T. M. Hong,[16] D. Kovalskyi,[16]
M. A. Mazur,[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] A. J. Martinez,[17] T. Schalk,[17] B. A. Schumm,[17] A. Seiden,[17] M. G. Wilson,[17] L. O. Winstrom,[17]
C. H. Cheng,[18] D. A. Doll,[18] B. Echenard,[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] P. C. Bloom,[20] W. T. Ford,[20]
A. Gaz,[20] J. F. Hirschauer,[20] M. Nagel,[20] U. Nauenberg,[20] J. G. Smith,[20] K. A. Ulmer,[20] S. R. Wagner,[20]
R. Ayad,[21, †] A. Soffer,[21, ‡] W. H. Toki,[21] R. J. Wilson,[21] E. Feltresi,[22] A. Hauke,[22] H. Jasper,[22] M. Karbach,[22]
J. Merkel,[22] A. Petzold,[22] B. Spaan,[22] K. Wacker,[22] M. J. Kobel,[23] R. Nogowski,[23] K. R. Schubert,[23] R. Schwierz,[23]
A. Volk,[23] D. Bernard,[24] G. R. Bonneaud,[24] E. Latour,[24] M. Verderi,[24] P. J. Clark,[25] S. Playfer,[25] J. E. Watson,[25]
M. Andreotti[ab],[26] D. Bettoni[a],[26] C. Bozzi[a],[26] R. Calabrese[ab],[26] A. Cecchi[ab],[26] G. Cibinetto[ab],[26] P. Franchini[ab],[26]
E. Luppi[ab],[26] M. Negrini[ab],[26] A. Petrella[ab],[26] L. Piemontese[a],[26] V. Santoro[ab],[26] R. Baldini-Ferroli,[27]
A. Calcaterra,[27] R. de Sangro,[27] G. Finocchiaro,[27] S. Pacetti,[27] P. Patteri,[27] I. M. Peruzzi,[27, §] M. Piccolo,[27]
M. Rama,[27] A. Zallo,[27] A. Buzzo[a],[28] R. Contri[ab],[28] M. Lo Vetere[ab],[28] M. M. Macri[a],[28] M. R. Monge[ab],[28]
S. Passaggio[a],[28] C. Patrignani[ab],[28] E. Robutti[a],[28] A. Santroni[ab],[28] S. Tosi[ab],[28] K. S. Chaisanguanthum,[29]
M. Morii,[29] A. Adametz,[30] J. Marks,[30] S. Schenk,[30] U. Uwer,[30] F. U. Bernlochner,[31] V. Klose,[31] H. M. Lacker,[31]
D. J. Bard,[32] P. D. Dauncey,[32] J. A. Nash,[32] M. Tibbetts,[32] P. K. Behera,[33] X. Chai,[33] M. J. Charles,[33]
U. Mallik,[33] J. Cochran,[34] H. B. Crawley,[34] L. Dong,[34] W. T. Meyer,[34] S. Prell,[34] E. I. Rosenberg,[34] A. E. Rubin,[34]
Y. Y. Gao,[35] A. V. Gritsan,[35] Z. J. Guo,[35] C. K. Lae,[35] N. Arnaud,[36] J. Béquilleux,[36] A. D'Orazio,[36] M. Davier,[36]
J. Firmino da Costa,[36] G. Grosdidier,[36] F. Le Diberder,[36] V. Lepeltier,[36] A. M. Lutz,[36] S. Pruvot,[36] P. Roudeau,[36]
M. H. Schune,[36] J. Serrano,[36] V. Sordini,[36, ¶] A. Stocchi,[36] G. Wormser,[36] D. J. Lange,[37] D. M. Wright,[37]
I. Bingham,[38] J. P. Burke,[38] C. A. Chavez,[38] J. R. Fry,[38] E. Gabathuler,[38] R. Gamet,[38] D. E. Hutchcroft,[38]
D. J. Payne,[38] C. Touramanis,[38] A. J. Bevan,[39] C. K. Clarke,[39] K. A. George,[39] F. Di Lodovico,[39] R. Sacco,[39]
M. Sigamani,[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] A. G. Denig,[42] M. Fritsch,[42] W. Gradl,[42] K. E. Alwyn,[43] D. Bailey,[43] R. J. Barlow,[43]
Y. M. Chia,[43] C. L. Edgar,[43] G. Jackson,[43] G. D. Lafferty,[43] T. J. West,[43] J. I. Yi,[43] J. Anderson,[44] C. Chen,[44]
A. Jawahery,[44] D. A. Roberts,[44] G. Simi,[44] J. M. Tuggle,[44] C. Dallapiccola,[45] X. Li,[45] E. Salvati,[45] S. Saremi,[45]
R. Cowan,[46] D. Dujmic,[46] P. H. Fisher,[46] S. W. Henderson,[46] G. Sciolla,[46] M. Spitznagel,[46] F. Taylor,[46]
R. K. Yamamoto,[46] M. Zhao,[46] P. M. Patel,[47] S. H. Robertson,[47] A. Lazzaro[ab],[48] V. Lombardo[a],[48] F. Palombo[ab],[48]
J. M. Bauer,[49] L. Cremaldi,[49] R. Godang,[49, **] R. Kroeger,[49] D. A. Sanders,[49] D. J. Summers,[49] H. W. Zhao,[49]
M. Simard,[50] P. Taras,[50] F. B. Viaud,[50] H. Nicholson,[51] G. De Nardo[ab],[52] L. Lista[a],[52] D. Monorchio[ab],[52]
G. Onorato[ab],[52] C. Sciacca[ab],[52] G. Raven,[53] H. L. Snoek,[53] C. P. Jessop,[54] K. J. Knoepfel,[54] J. M. LoSecco,[54]
W. F. Wang,[54] G. Benelli,[55] L. A. Corwin,[55] K. Honscheid,[55] H. Kagan,[55] R. Kass,[55] J. P. Morris,[55] A. M. Rahimi,[55]
J. J. Regensburger,[55] S. J. Sekula,[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] R. Rahmat,[56] N. B. Sinev,[56] D. Strom,[56] J. Strube,[56] E. Torrence,[56] G. Castelli[ab],[57]
N. Gagliardi[ab],[57] M. Margoni[ab],[57] M. Morandin[a],[57] M. Posocco[a],[57] M. Rotondo[a],[57] F. Simonetto[ab],[57] R. Stroili[ab],[57]
C. Voci[ab],[57] P. del Amo Sanchez,[58] E. Ben-Haim,[58] H. Briand,[58] G. Calderini,[58] J. Chauveau,[58] P. David,[58]
L. Del Buono,[58] O. Hamon,[58] Ph. Leruste,[58] J. Ocariz,[58] A. Perez,[58] J. Prendki,[58] S. Sitt,[58] L. Gladney,[59]
M. Biasini[ab],[60] R. Covarelli[ab],[60] E. Manoni[ab],[60] C. Angelini[ab],[61] G. Batignani[ab],[61] S. Bettarini[ab],[61]
M. Carpinelli[ab],[61, ††] A. Cervelli[ab],[61] F. Forti[ab],[61] M. A. Giorgi[ab],[61] A. Lusiani[ac],[61] G. Marchiori[ab],[61]

Published in the Physical Review D

Work supported in part by US Department of Energy contract DE-AC02-76SF00515

M. Morganti[ab],[61] N. Neri[ab],[61] E. Paoloni[ab],[61] G. Rizzo[ab],[61] J. J. Walsh[a],[61] D. Lopes Pegna,[62] C. Lu,[62] J. Olsen,[62] A. J. S. Smith,[62] A. V. Telnov,[62] F. Anulli[a],[63] E. Baracchini[ab],[63] G. Cavoto[a],[63] D. del Re[ab],[63] E. Di Marco[ab],[63] R. Faccini[ab],[63] F. Ferrarotto[a],[63] F. Ferroni[ab],[63] M. Gaspero[ab],[63] P. D. Jackson[a],[63] L. Li Gioi[a],[63] M. A. Mazzoni[a],[63] S. Morganti[a],[63] G. Piredda[a],[63] F. Polci[ab],[63] F. Renga[ab],[63] C. Voena[a],[63] M. Ebert,[64] T. Hartmann,[64] H. Schröder,[64] R. Waldi,[64] T. Adye,[65] B. Franek,[65] E. O. Olaiya,[65] F. F. Wilson,[65] S. Emery,[66] M. Escalier,[66] L. Esteve,[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] R. M. White,[67] J. R. Wilson,[67] M. T. Allen,[68] D. Aston,[68] R. Bartoldus,[68] P. Bechtle,[68] J. F. Benitez,[68] R. Cenci,[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] A. M. Gabareen,[68] S. J. Gowdy,[68] M. T. Graham,[68] P. Grenier,[68] C. Hast,[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] B. Lindquist,[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] H. Neal,[68] S. Nelson,[68] C. P. O'Grady,[68] I. Ofte,[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] D. Su,[68] M. K. Sullivan,[68] K. Suzuki,[68] S. K. Swain,[68] J. M. Thompson,[68] J. Va'vra,[68] A. P. Wagner,[68] M. Weaver,[68] C. A. West,[68] W. J. Wisniewski,[68] M. Wittgen,[68] D. H. Wright,[68] H. W. Wulsin,[68] A. K. Yarritu,[68] K. Yi,[68] C. C. Young,[68] V. Ziegler,[68] P. R. Burchat,[69] A. J. Edwards,[69] S. A. Majewski,[69] T. S. Miyashita,[69] B. A. Petersen,[69] L. Wilden,[69] S. Ahmed,[70] M. S. Alam,[70] J. A. Ernst,[70] B. Pan,[70] M. A. Saeed,[70] S. B. Zain,[70] S. M. Spanier,[71] B. J. Wogsland,[71] R. Eckmann,[72] J. L. Ritchie,[72] A. M. Ruland,[72] C. J. Schilling,[72] R. F. Schwitters,[72] B. W. Drummond,[73] J. M. Izen,[73] X. C. Lou,[73] F. Bianchi[ab],[74] D. Gamba[ab],[74] M. Pelliccioni[ab],[74] M. Bomben[ab],[75] L. Bosisio[ab],[75] C. Cartaro[ab],[75] G. Della Ricca[ab],[75] L. Lanceri[ab],[75] L. Vitale[ab],[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] H. H. F. Choi,[77] K. Hamano,[77] R. Kowalewski,[77] M. J. Lewczuk,[77] I. M. Nugent,[77] J. M. Roney,[77] R. J. Sobie,[77] T. J. Gershon,[78] 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] Y. Pan,[79] M. Pierini,[79] R. Prepost,[79] C. O. Vuosalo,[79] and S. L. Wu[79]

(The *BABAR* Collaboration)

[1]*Laboratoire de Physique des Particules, IN2P3/CNRS et Université de Savoie, F-74941 Annecy-Le-Vieux, France*
[2]*Universitat de Barcelona, Facultat de Fisica, Departament ECM, E-08028 Barcelona, Spain*
[3]*INFN Sezione di Bari*[a]*; Dipartmento di Fisica, Università di Bari*[b]*, I-70126 Bari, Italy*
[4]*University of Bergen, Institute of Physics, N-5007 Bergen, Norway*
[5]*Lawrence Berkeley National Laboratory and University of California, Berkeley, California 94720, USA*
[6]*University of Birmingham, Birmingham, B15 2TT, United Kingdom*
[7]*Ruhr Universität Bochum, Institut für Experimentalphysik 1, D-44780 Bochum, Germany*
[8]*University of Bristol, Bristol BS8 1TL, United Kingdom*
[9]*University of British Columbia, Vancouver, British Columbia, Canada V6T 1Z1*
[10]*Brunel University, Uxbridge, Middlesex UB8 3PH, United Kingdom*
[11]*Budker Institute of Nuclear Physics, Novosibirsk 630090, Russia*
[12]*University of California at Irvine, Irvine, California 92697, USA*
[13]*University of California at Los Angeles, Los Angeles, California 90024, USA*
[14]*University of California at Riverside, Riverside, California 92521, USA*
[15]*University of California at San Diego, La Jolla, California 92093, USA*
[16]*University of California at Santa Barbara, Santa Barbara, California 93106, USA*
[17]*University of California at Santa Cruz, Institute for Particle Physics, Santa Cruz, California 95064, USA*
[18]*California Institute of Technology, Pasadena, California 91125, USA*
[19]*University of Cincinnati, Cincinnati, Ohio 45221, USA*
[20]*University of Colorado, Boulder, Colorado 80309, USA*
[21]*Colorado State University, Fort Collins, Colorado 80523, USA*
[22]*Technische Universität Dortmund, Fakultät Physik, D-44221 Dortmund, Germany*
[23]*Technische Universität Dresden, Institut für Kern- und Teilchenphysik, D-01062 Dresden, Germany*
[24]*Laboratoire Leprince-Ringuet, CNRS/IN2P3, Ecole Polytechnique, F-91128 Palaiseau, France*
[25]*University of Edinburgh, Edinburgh EH9 3JZ, United Kingdom*
[26]*INFN Sezione di Ferrara*[a]*; Dipartimento di Fisica, Università di Ferrara*[b]*, I-44100 Ferrara, Italy*
[27]*INFN Laboratori Nazionali di Frascati, I-00044 Frascati, Italy*
[28]*INFN Sezione di Genova*[a]*; Dipartimento di Fisica, Università di Genova*[b]*, I-16146 Genova, Italy*
[29]*Harvard University, Cambridge, Massachusetts 02138, USA*
[30]*Universität Heidelberg, Physikalisches Institut, Philosophenweg 12, D-69120 Heidelberg, Germany*
[31]*Humboldt-Universität zu Berlin, Institut für Physik, Newtonstr. 15, D-12489 Berlin, 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]*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, 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]*Johannes Gutenberg-Universität Mainz, Institut für Kernphysik, D-55099 Mainz, Germany*
[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]*INFN Sezione di Milano*[a]*; Dipartimento di Fisica, Università di Milano*[b]*, 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]*INFN Sezione di Napoli*[a]*; Dipartimento di Scienze Fisiche,*
Università di Napoli Federico II[b]*, 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]*INFN Sezione di Padova*[a]*; Dipartimento di Fisica, Università di Padova*[b]*, 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]*INFN Sezione di Perugia*[a]*; Dipartimento di Fisica, Università di Perugia*[b]*, I-06100 Perugia, Italy*
[61]*INFN Sezione di Pisa*[a]*; Dipartimento di Fisica,*
Università di Pisa[b]*; Scuola Normale Superiore di Pisa*[c]*, I-56127 Pisa, Italy*
[62]*Princeton University, Princeton, New Jersey 08544, USA*
[63]*INFN Sezione di Roma*[a]*; Dipartimento di Fisica,*
Università di Roma La Sapienza[b]*, I-00185 Roma, Italy*
[64]*Universität Rostock, D-18051 Rostock, Germany*
[65]*Rutherford Appleton Laboratory, Chilton, Didcot, Oxon, OX11 0QX, United Kingdom*
[66]*CEA, Irfu, SPP, Centre de 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]*INFN Sezione di Torino*[a]*; Dipartimento di Fisica Sperimentale, Università di Torino*[b]*, I-10125 Torino, Italy*
[75]*INFN Sezione di Trieste*[a]*; Dipartimento di Fisica, Università di Trieste*[b]*, 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*

(Dated: February 13, 2009)

We search for charmless decays of charged B mesons to the three-body final state $K^0_S K^0_S \pi^+$. Using a data sample of 423.7 fb^{-1} collected at the $\Upsilon(4S)$ resonance with the *BABAR* detector, corresponding to $(465.1 \pm 5.1) \times 10^6$ $B\overline{B}$ pairs, we find no significant signal and determine a 90 % confidence level upper limit on the branching fraction of 5.1×10^{-7}.

PACS numbers: 13.25.Hw, 11.30.Er

---

[*] Deceased

[†] Now at Temple University, Philadelphia, Pennsylvania 19122,

Charmless decays of B mesons to final states with even numbers of strange quarks or antiquarks, such as $B^+ \to K^0_S K^0_S \pi^+$ [1], are suppressed in the standard model. Such decays proceed mainly via the $\overline{b} \to \overline{d}$ loop (penguin) transition. Hadronic $\overline{b} \to \overline{d}$ penguin transitions have been observed in the decays $B^0 \to K^0 \overline{K}^0$ and $B^+ \to \overline{K}^0 K^+$ [2, 3], and their effects have also been seen through direct CP violation in charmless B decays, such as $B^0 \to \pi^+\pi^-$ [4, 5] and $B^0 \to \pi^+\pi^-\pi^0$ [6, 7]. In contrast to B^0-$\overline{B}^0$ mixing, which is a $\overline{b} \to \overline{d}$ process with a change of beauty-flavor quantum number of $\Delta F = 2$, little experimental information exists on $\Delta F = 1$ $\overline{b} \to \overline{d}$ decay amplitudes. There is still potential for new physics effects to be uncovered in these decays.

The decay $B^+ \to K^0_S K^0_S \pi^+$ has not yet been observed. The upper limit on the branching fraction at 90 % confidence level (CL) is 3.2×10^{-6} [8]. A model based on the factorization approximation, which makes use of heavy-quark and chiral symmetries, predicts a nonresonant branching fraction for $B^+ \to K^0 \overline{K}^0 \pi^+$ of order 10^{-6} [9]. Decays via intermediate resonant states can also lead to the $K^0_S K^0_S \pi^+$ final state. This motivates an inclusive analysis incorporating both nonresonant and resonant modes. Based on the measured branching fraction $\mathcal{B}[B^+ \to f_2(1270)\pi^+] = (8.2 \pm 2.5) \times 10^{-6}$ [10–12], the product branching fraction for $B^+ \to f_2(1270)\pi^+$ with $f_2(1270) \to K^0_S K^0_S$ should be around 10^{-7}. Similarly, $B^+ \to f_0(980)\pi^+$ and $B^+ \to K^{*+}(892)\overline{K}^0$ decays could contribute to the $K^0_S K^0_S \pi^+$ channel. The branching fraction for $B^+ \to K^{*+}(892)\overline{K}^0$ is predicted to be of order 10^{-6} or less [13–18].

Another motivation comes from the recent observation of $B^+ \to K^+K^-\pi^+$ by *BABAR*, with an inclusive branching fraction of $\mathcal{B}(B^+ \to K^+K^-\pi^+) = [5.0 \pm 0.5(\text{stat.}) \pm 0.5(\text{syst.})] \times 10^{-6}$ [19]. An unexpected peak seen near 1.5 GeV/c^2 in the K^+K^- invariant-mass spectrum, which we dub the $f_{\rm X}(1500)$, accounts for approximately half of the total event rate. If the decay of the $f_{\rm X}(1500)$ follows isospin symmetry, then equal rates would be expected to K^+K^- and to $K^0\overline{K}^0$. If the $f_{\rm X}(1500)$ has even spin, then $f_{\rm X}(1500) \to K^0\overline{K}^0$ decays would result in 50 % $K^0_S K^0_S$ and 50 % $K^0_L K^0_L$ final states, whereas if the $f_{\rm X}(1500)$ has odd spin, then the $K^0_S K^0_S$ final state is forbidden by Bose symmetry. Observation of the decay $f_{\rm X}(1500) \to K^0_S K^0_S$ in $B^+ \to K^0_S K^0_S \pi^+$ could therefore provide information on the spin or the quark content of the $f_{\rm X}(1500)$ and could help to elucidate the relationship between this state and similar unexplained structures seen in $B^+ \to K^+K^-K^+$ decays [20, 21]. Structures in the $K^0_S K^0_S$ mass spectrum have also been observed in two-photon [22] and electron-proton collisions [23].

We report a search for the decay $B^+ \to K^0_S K^0_S \pi^+$. The analysis is based on data collected at the PEP-II asymmetric-energy e^+e^- collider [24] at SLAC. The data sample consists of an integrated luminosity of 423.7 fb^{-1} recorded at the $\Upsilon(4S)$ resonance (on-peak) and 43.9 fb^{-1} collected 40 MeV below the resonance (off-peak). The on-peak data sample contains $(465.1 \pm 5.1) \times 10^6$ $B\overline{B}$ pairs [25].

The *BABAR* detector is described in detail elsewhere [26]. Charged particles are detected and their momenta measured with a five-layer silicon vertex tracker (SVT) and a 40-layer drift chamber (DCH) located inside a 1.5 T solenoidal magnet. Surrounding the DCH is a detector of internally reflected Cherenkov radiation (DIRC), designed for charged particle identification. Energy deposited by electrons and photons is measured by a CsI(Tl) crystal electromagnetic calorimeter (EMC). Muons and long-lived neutral hadrons are identified in the flux return of the solenoid instrumented with resistive plate chambers and limited streamer tubes.

We reconstruct a $B^+ \to K^0_S K^0_S \pi^+$ candidate by combining a pair of K^0_S mesons and a charged pion. A $K^0_S \to \pi^+\pi^-$ candidate is formed from a pair of oppositely charged tracks with an invariant mass that lies within 15 MeV/c^2 of the nominal K^0_S mass [11], which corresponds to five times the K^0_S mass resolution. We require the ratio of measured K^0_S lifetime and its uncertainty to be greater than 20, the cosine of the angle between the line connecting the B and K^0_S decay vertices and the K^0_S momentum vector to be greater than 0.999, and the K^0_S vertex probability to be greater than 10^{-6}. Charged pions coming from the B decay are identified with the energy loss (dE/dx) information from the SVT and DCH, and the Cherenkov angle and the number of photons measured by the DIRC. The efficiency for pion selection is approximately 76 % including geometrical acceptance, while the probability for misidentification of kaons as pions is less than 15 %, up to a momentum of 4 GeV/c. We require pion candidates not to be consistent with the electron hypothesis, based on information from the dE/dx, the shower shape in the EMC, and the ratio of the shower energy and track momentum.

Continuum $e^+e^- \to q\overline{q}$ $(q = u, d, s, c)$ events are the dominant background. To discriminate this type of event from signal we use a boosted decision tree (BDT) [27] that combines five discriminating variables. The first of these is the ratio of L_2 to L_0, with $L_j = \Sigma_i p_i |\cos\theta_i|^j$, where θ_i is the angle, with respect to the B thrust axis, of the track or neutral cluster i, and p_i is its momentum. The sum excludes the daughters of the B candidate and all quantities are calculated in the e^+e^- center-of-mass (CM) frame. The other four variables are the absolute

---

USA

[‡] Now at Tel Aviv University, Tel Aviv, 69978, Israel

[§] Also with Università di Perugia, Dipartimento di Fisica, Perugia, Italy

[¶] Also with Università di Roma La Sapienza, I-00185 Roma, Italy

[**] Now at University of South Alabama, Mobile, Alabama 36688, USA

[††] Also with Università di Sassari, Sassari, Italy

value of the cosine of the angle between the B direction and the beam (z) axis, the magnitude of the cosine of the angle between the B thrust axis and the z axis, the product of the B candidate's charge and the flavor of the recoiling B as reported by a multivariate tagging algorithm [28], and the proper time difference between the decays of the two B mesons divided by its uncertainty. The BDT is trained using off-peak data as well as simulated signal events that pass the selection criteria. We make a requirement on the BDT output ($\mathrm{BDT_{out}}$) such that approximately 96 % of the signal is retained and 60 % of the continuum background is rejected.

In addition to $\mathrm{BDT_{out}}$, we distinguish signal from background events using two kinematic variables: the beam-energy-substituted mass $m_{\mathrm{ES}} = \sqrt{s/4 - \mathbf{p}_B^2}$ and $\Delta E = E_B - \sqrt{s}/2$, where $\sqrt{s}$ is the total e^+e^- CM energy and $(E_B, \mathbf{p}_B)$ is the four-momentum of the B candidate measured in the CM frame. We select signal candidates that satisfy $5.250 < m_{\mathrm{ES}} < 5.286$ GeV$/c^2$ and $|\Delta E| < 0.1$ GeV. This region includes a sufficiently large range of m_{ES} below the signal peak to allow properties of the continuum distribution to be determined in the maximum likelihood fit.

Another source of background arises from $B^+ \to \overline{D}^0(\to K^0_S K^0_S)\pi^+$ decays, where the final state particles are identical to the signal. We reduce this background by rejecting any event containing a signal candidate with a $K^0_S K^0_S$ invariant mass in the range $1.82 < M_{K^0_S K^0_S} < 1.90$ GeV$/c^2$.

The efficiency for signal events to pass the selection criteria is 28 %, determined with a Monte Carlo (MC) simulation in which decays are generated uniformly in three-body phase space. We find that approximately 9 % of the selected $B^+ \to K^0_S K^0_S \pi^+$ events contain more than one candidate, in which case we choose that with the highest B-vertex probability. We have checked that this procedure does not bias the fit variables. In about 2 % of the signal events, the B candidate is misreconstructed because one of its daughter tracks is replaced by a track from the rest of the event. Such events are considered to be a part of the signal component.

We study possible residual backgrounds from $B\overline{B}$ events using MC event samples. These backgrounds arise from decays with similar kinematic properties to the signal or because particles get lost to, or attached from, the rest of the event in the process of reconstruction. The $B\overline{B}$ background modes can conveniently be divided into two categories, based on their shapes in m_{ES} and ΔE. The first category ($B\overline{B}_1$) contains only $B^+ \to K^0_S K^0_S K^+$ decays, which peak in m_{ES} around the B mass and in ΔE near -0.06 GeV. The second category ($B\overline{B}_2$) contains the remaining $B\overline{B}$ backgrounds and is mainly combinatorial.

We perform an unbinned extended maximum likelihood fit to the candidate events using three input variables: m_{ES}, ΔE, and $\mathrm{BDT_{out}}$. For each category j (signal, continuum background, $B\overline{B}_1$, or $B\overline{B}_2$), we define a probability density function $\mathcal{P}_j$ (PDF), and evaluate it for each event i:

$$\mathcal{P}_j^i \equiv \mathcal{P}_j(m_{\mathrm{ES}}^i, \Delta E^i) \cdot \mathcal{P}_j(\mathrm{BDT}_{\mathrm{out}}^i). \qquad (1)$$

The signal, continuum background, and $B\overline{B}_2$ background exhibit negligible correlations between m_{ES} and ΔE, and so the PDF is further factorized:

$$\mathcal{P}_j(m_{\mathrm{ES}}^i, \Delta E^i) = \mathcal{P}_j(m_{\mathrm{ES}}^i) \cdot \mathcal{P}_j(\Delta E^i)\,. \qquad (2)$$

The extended likelihood function is

$$\mathcal{L} = \prod_k e^{-n_k} \prod_i \left[\sum_j n_j \mathcal{P}_j^i \right], \qquad (3)$$

where $n_j(n_k)$ is the yield for event category $j(k)$.

The signal m_{ES} distribution is parameterized with the sum of a Gaussian and a Crystal Ball function [29] while the ΔE distribution is parameterized with a modified Gaussian function with different widths on each side, as well as with additional tails that can be different on each side. We fix the shape parameters to the values obtained from the $B^+ \to K^0_S K^0_S \pi^+$ phase-space MC sample. The continuum background m_{ES} shape is described by an empirical threshold ARGUS function, $x\sqrt{1-x^2}\exp\left[-\xi(1-x^2)\right]$, with $x \equiv 2m_{\mathrm{ES}}/\sqrt{s}$ and ξ a free parameter [30], while the continuum ΔE shape is modeled with a linear function. We describe the m_{ES} and ΔE shapes for the $B\overline{B}_1$ sample with a two-dimensional histogram determined from MC events, which accounts for correlations between these variables. One-dimensional histograms are used to describe the m_{ES} and ΔE distributions for the $B\overline{B}_2$ sample. The $\mathrm{BDT_{out}}$ distributions for all components are described by one-dimensional histograms. These are obtained from MC events for signal and the $B\overline{B}$ background categories. The continuum background $\mathrm{BDT_{out}}$ shape is determined from a combination of off-peak data and on-peak data in a continuum-dominated sideband of m_{ES}, independent of the signal region, from which the expected $B\overline{B}$ backgrounds have been subtracted.

The free parameters of our fit are the yields of the signal, continuum, and two $B\overline{B}$ background categories, together with the ξ parameter of the continuum m_{ES} shape and the slope of the continuum ΔE shape.

We test the fitting procedure by applying it to ensembles of simulated experiments where events are generated from the PDF shapes as described above for all four categories of events. We repeat the exercise with $q\overline{q}$ events generated from the PDF while signal events are randomly extracted from the MC samples. The $B\overline{B}$ background events are either generated from PDF shapes or drawn from MC samples. In all cases, these tests confirm that our fit performs as expected. No bias is found for the value of the signal yield observed in the data.

The fit to 16 739 candidate events gives a signal yield of 15 ± 15 events, where the error is statistical only. The fit returns yields for the continuum, $B\overline{B}_1$ and $B\overline{B}_2$ background categories of $15\,500 \pm 140$, 89 ± 25 and $1\,140 \pm 70$ events, respectively. These are somewhat larger than the expected values for the first and last categories and smaller for the second, a pattern that can be explained by the correlations between these yields.

The results of the fit are shown in Fig. 1. In these plots the continuum background contribution has been suppressed by applying a requirement on the ratio of the signal likelihood to the sum of the signal and continuum likelihoods, calculated without use of the plotted variable. The value of this requirement for each plot rejects about 97 % of the continuum background while retaining 63 - 71 % of the signal, depending on the variable.

We determine the inclusive branching fraction for $B^+ \to K^0_S K^0_S \pi^+$ by dividing the observed signal yield by the reconstruction efficiency, the number of $B\overline{B}$ events in the data sample, and the square of the daughter branching fraction $\mathcal{B}(K^0_S \to \pi^+\pi^-) = 0.6920 \pm 0.0005$ [11]. We assume equal decay rates of $\Upsilon(4S)$ into B^+B^- and $B^0\overline{B}^0$ pairs. The value obtained is $\mathcal{B}(B^+ \to K^0_S K^0_S \pi^+) = (2.5 \pm 2.4) \times 10^{-7}$, where the error is statistical only. The statistical significance of the signal is 1.1 σ, which is calculated as $\sqrt{-2\ln(\mathcal{L}_0/\mathcal{L}_{\rm max})}$, where $\mathcal{L}_{\rm max}$ denotes the likelihood with the nominal signal yield of 15 events and $\mathcal{L}_0$ denotes the likelihood with the signal yield fixed at zero.

There is a significant dependence of the selection efficiency on the kinematics of the $K^0_S K^0_S \pi^+$ final state. The nominal efficiency is calculated by assuming a phase-space distribution of $K^0_S K^0_S \pi^+$ events. Since we do not know the true distribution, a systematic uncertainty of 24 % is evaluated from the RMS variation of the efficiency across the $K^0_S K^0_S \pi^+$ Dalitz plot. Smaller systematic uncertainties on the fitted yield arise from uncertainties in the PDF shapes (4 events), including possible differences between data and MC simulations, which are studied using a control sample of $B^0 \to D^-(\to K^0_S \pi^-)\pi^+$ events. We assign an uncertainty of 2 events to account for fit bias. Other uncertainties on the efficiency arise from charged particle reconstruction (0.4 %), particle identification (1.4 %), and the K^0_S selection (1.8 %). The uncertainty on the number of $B\overline{B}$ pairs is 1.1 %. The systematic uncertainties are added in quadrature to give a total of 38 %. Hence the inclusive branching fraction is $\mathcal{B}(B^+ \to K^0_S K^0_S \pi^+) = (2.5 \pm 2.4 \pm 0.9) \times 10^{-7}$, where the first (second) error is statistical (systematic).

Since our result is consistent with no signal, we determine a 90 % CL upper limit on the branching fraction ($\mathcal{B}_{\rm UL}$). This limit is calculated by integrating the likelihood in the physical region such that $\int_0^{\mathcal{B}_{\rm UL}} \mathcal{L}(x)\,dx / \int_0^{+\infty} \mathcal{L}(x)\,dx = 0.9$, where $\mathcal{L}(x)$ is the likelihood function for the signal yield x. We have confirmed that the statistical uncertainties from the fit are Gaussian, to a good approximation. We therefore assume a Gaussian behavior for the overall likelihood, with a width calculated from the sum in quadrature of the statistical and systematic uncertainties. Our result is $\mathcal{B}(B^+ \to K^0_S K^0_S \pi^+) < 5.1 \times 10^{-7}$ at 90 % CL.

The lack of signal in this decay mode contrasts with that observed for $B^+ \to K^+K^-\pi^+$ [19]. This result disfavors models in which the $f_{\rm X}(1500)$ has even spin and decays with isospin symmetry. If the $f_{\rm X}(1500)$ is confirmed to have even spin in future measurements, this may indicate a non-$q\bar{q}$ nature of this state.

In conclusion, with a data sample of 423.7 fb^{-1}, we have performed a search for the decay $B^+ \to K^0_S K^0_S \pi^+$. We observe no significant signal and set a 90 % confidence level upper limit on the branching fraction of 5.1×10^{-7}. This result provides useful information for the understanding of low energy spectroscopy.

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), MES (Russia), MEC (Spain), and STFC (United Kingdom). Individuals have received support from the Marie Curie EIF (European Union) and the A. P. Sloan Foundation.

---

[1] Inclusion of the charge conjugate mode is implied.

[2] B. Aubert *et al.* [*BABAR* Collaboration], Phys. Rev. Lett. **97**, 171805 (2006).

[3] S. W. Lin *et al.* [Belle Collaboration], Phys. Rev. Lett. **98**, 181804 (2007).

[4] H. Ishino *et al.* [Belle Collaboration], Phys. Rev. Lett. **98**, 211801 (2007).

[5] B. Aubert *et al.* [*BABAR* Collaboration], Phys. Rev. Lett. **99**, 021603 (2007).

[6] A. Kusaka *et al.* [Belle Collaboration], Phys. Rev. Lett. **98**, 221602 (2007).

[7] B. Aubert *et al.* [*BABAR* Collaboration], Phys. Rev. D **76**, 012004 (2007).

[8] A. Garmash *et al.* [Belle Collaboration], Phys. Rev. D **69**, 012001 (2004).

[9] S. Fajfer, R. J. Oakes and T. N. Pham, Phys. Rev. D **60**, 054029 (1999).

[10] E. Barberio *et al.* [Heavy Flavor Averaging Group], arXiv:0808.1297 [hep-ex] and online update at `http://www.slac.stanford.edu/xorg/hfag`.

[11] C. Amsler *et al.* [Particle Data Group], Phys. Lett. B **667**, 1 (2008).

[12] B. Aubert *et al.* [*BABAR* Collaboration], Phys. Rev. D **72**, 052002 (2005).

[13] D. S. Du and L. B. Guo, Z. Phys. C **75**, 9 (1997).

[14] A. Ali, G. Kramer and C. D. Lu, Phys. Rev. D **58**, 094009 (1998).

[15] D. S. Du, H. J. Gong, J. F. Sun, D. S. Yang and

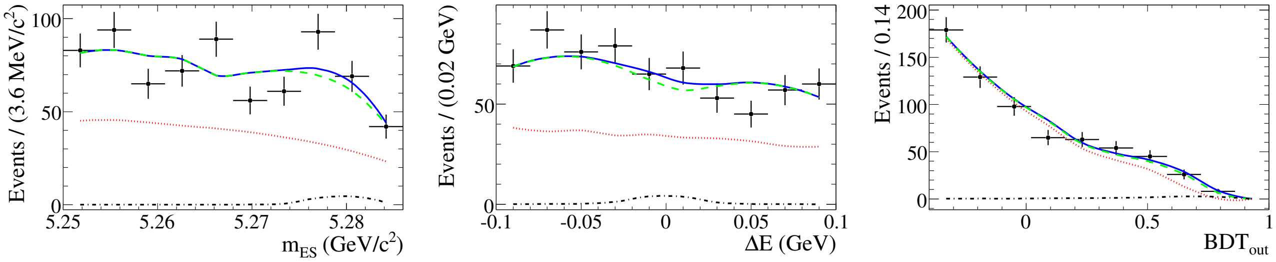

FIG. 1: Projections of candidate events with the fit results overlaid. From left to right are shown the projections onto the $m_{\rm ES}$, ΔE, and BDT$_{\rm out}$ variables. The points show the data and the solid (blue) curves show the total fit result. The dotted (red) curves show the continuum background, the dashed (green) curves the total background, and the dash-dotted (black) curves the signal distributions.

G. H. Zhu, Phys. Rev. D **65**, 094025 (2002) [Erratum-ibid. D **66**, 079904 (2002)].

[16] M. Beneke and M. Neubert, Nucl. Phys. B **675**, 333 (2003).

[17] C. W. Chiang, M. Gronau, Z. Luo, J. L. Rosner and D. A. Suprun, Phys. Rev. D **69**, 034001 (2004).

[18] L. Guo, Q. G. Xu and Z. J. Xiao, Phys. Rev. D **75**, 014019 (2007).

[19] B. Aubert *et al*. [*BABAR* Collaboration], Phys. Rev. Lett. **99**, 221801 (2007).

[20] A. Garmash *et al*. [Belle Collaboration], Phys. Rev. D **71**, 092003 (2005).

[21] B. Aubert *et al*. [*BABAR* Collaboration], Phys. Rev. D **74**, 032003 (2006).

[22] M. Acciarri *et al*. [L3 Collaboration], Phys. Lett. B **501**, 173 (2001).

[23] S. Chekanov *et al*. [ZEUS Collaboration], Phys. Rev. Lett. **101**, 112003 (2008).

[24] PEP-II Conceptual Design Report, SLAC Report No. SLAC-R-418 (1993).

[25] B. Aubert *et al.* [*BABAR* Collaboration], Phys. Rev. D **67**, 032002 (2003).

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

[27] A. Höcker *et al.*, arXiv:physics/0703039.

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

[29] M.J. Oreglia, Ph.D. Thesis, SLAC-R-236 (1980), Appendix D; J.E. Gaiser, Ph.D. Thesis, SLAC-R-255 (1982), Appendix F; T. Skwarnicki, Ph.D. Thesis, DESY F31-86-02 (1986), Appendix E.

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