Search for Factorization-Suppressed $B \to \chi_c K^{(*)}$ Decays

B. Aubert,[1] R. Barate,[1] D. Boutigny,[1] F. Couderc,[1] Y. Karyotakis,[1] J. P. Lees,[1] V. Poireau,[1] V. Tisserand,[1] A. Zghiche,[1] E. Grauges-Pous,[2] A. Palano,[3] A. Pompili,[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] A. W. Borgland,[6] A. B. Breon,[6] D. N. Brown,[6] J. Button-Shafer,[6] R. N. Cahn,[6] E. Charles,[6] C. T. Day,[6] M. S. Gill,[6] A. V. Gritsan,[6] Y. Groysman,[6] R. G. Jacobsen,[6] R. W. Kadel,[6] J. Kadyk,[6] L. T. Kerth,[6] Yu. G. Kolomensky,[6] G. Kukartsev,[6] G. Lynch,[6] L. M. Mir,[6] P. J. Oddone,[6] T. J. Orimoto,[6] M. Pripstein,[6] N. A. Roe,[6] M. T. Ronan,[6] W. A. Wenzel,[6] M. Barrett,[7] K. E. Ford,[7] T. J. Harrison,[7] A. J. Hart,[7] C. M. Hawkes,[7] S. E. Morgan,[7] A. T. Watson,[7] M. Fritsch,[8] K. Goetzen,[8] T. Held,[8] H. Koch,[8] B. Lewandowski,[8] M. Pelizaeus,[8] T. Schroeder,[8] M. Steinke,[8] J. T. Boyd,[9] N. Chevalier,[9] W. N. Cottingham,[9] M. P. Kelly,[9] T. E. Latham,[9] F. F. Wilson,[9] T. Cuhadar-Donszelmann,[10] C. Hearty,[10] N. S. Knecht,[10] T. S. Mattison,[10] J. A. McKenna,[10] D. Thiessen,[10] A. Khan,[11] P. Kyberd,[11] L. Teodorescu,[11] A. E. Blinov,[12] V. E. Blinov,[12] V. P. Druzhinin,[12] V. B. Golubev,[12] V. N. Ivanchenko,[12] E. A. Kravchenko,[12] A. P. Onuchin,[12] S. I. Serednyakov,[12] Yu. I. Skovpen,[12] E. P. Solodov,[12] A. N. Yushkov,[12] D. Best,[13] M. Bruinsma,[13] M. Chao,[13] I. Eschrich,[13] D. Kirkby,[13] A. J. Lankford,[13] M. Mandelkern,[13] R. K. Mommsen,[13] W. Roethel,[13] D. P. Stoker,[13] C. Buchanan,[14] B. L. Hartfiel,[14] A. J. R. Weinstein,[14] S. D. Foulkes,[15] J. W. Gary,[15] O. Long,[15] B. C. Shen,[15] K. Wang,[15] D. del Re,[16] H. K. Hadavand,[16] E. J. Hill,[16] D. B. MacFarlane,[16] H. P. Paar,[16] Sh. Rahatlou,[16] V. Sharma,[16] J. W. Berryhill,[17] C. Campagnari,[17] A. Cunha,[17] B. Dahmes,[17] T. M. Hong,[17] A. Lu,[17] M. A. Mazur,[17] J. D. Richman,[17] W. Verkerke,[17] T. W. Beck,[18] A. M. Eisner,[18] C. A. Heusch,[18] J. Kroseberg,[18] W. S. Lockman,[18] G. Nesom,[18] T. Schalk,[18] B. A. Schumm,[18] A. Seiden,[18] P. Spradlin,[18] D. C. Williams,[18] M. G. Wilson,[18] J. Albert,[19] E. Chen,[19] G. P. Dubois-Felsmann,[19] A. Dvoretskii,[19] D. G. Hitlin,[19] I. Narsky,[19] T. Piatenko,[19] F. C. Porter,[19] A. Ryd,[19] A. Samuel,[19] S. Yang,[19] S. Jayatilleke,[20] G. Mancinelli,[20] B. T. Meadows,[20] M. D. Sokoloff,[20] F. Blanc,[21] P. Bloom,[21] S. Chen,[21] W. T. Ford,[21] U. Nauenberg,[21] A. Olivas,[21] P. Rankin,[21] W. O. Ruddick,[21] J. G. Smith,[21] K. A. Ulmer,[21] J. Zhang,[21] L. Zhang,[21] A. Chen,[22] E. A. Eckhart,[22] J. L. Harton,[22] A. Soffer,[22] W. H. Toki,[22] R. J. Wilson,[22] Q. Zeng,[22] B. Spaan,[23] D. Altenburg,[24] T. Brandt,[24] J. Brose,[24] M. Dickopp,[24] E. Feltresi,[24] A. Hauke,[24] H. M. Lacker,[24] R. Nogowski,[24] S. Otto,[24] A. Petzold,[24] J. Schubert,[24] K. R. Schubert,[24] R. Schwierz,[24] J. E. Sundermann,[24] D. Bernard,[25] G. R. Bonneaud,[25] P. Grenier,[25] S. Schrenk,[25] Ch. Thiebaux,[25] G. Vasileiadis,[25] M. Verderi,[25] D. J. Bard,[26] P. J. Clark,[26] F. Muheim,[26] S. Playfer,[26] Y. Xie,[26] M. Andreotti,[27] V. Azzolini,[27] D. Bettoni,[27] C. Bozzi,[27] R. Calabrese,[27] G. Cibinetto,[27] E. Luppi,[27] M. Negrini,[27] L. Piemontese,[27] A. Sarti,[27] F. Anulli,[28] R. Baldini-Ferroli,[28] A. Calcaterra,[28] R. de Sangro,[28] G. Finocchiaro,[28] P. Patteri,[28] I. M. Peruzzi,[28] M. Piccolo,[28] A. Zallo,[28] A. Buzzo,[29] R. Capra,[29] R. Contri,[29] G. Crosetti,[29] M. Lo Vetere,[29] M. Macri,[29] M. R. Monge,[29] S. Passaggio,[29] C. Patrignani,[29] E. Robutti,[29] A. Santroni,[29] S. Tosi,[29] S. Bailey,[30] G. Brandenburg,[30] K. S. Chaisanguanthum,[30] M. Morii,[30] E. Won,[30] R. S. Dubitzky,[31] U. Langenegger,[31] J. Marks,[31] U. Uwer,[31] W. Bhimji,[32] D. A. Bowerman,[32] P. D. Dauncey,[32] U. Egede,[32] J. R. Gaillard,[32] G. W. Morton,[32] J. A. Nash,[32] M. B. Nikolich,[32] G. P. Taylor,[32] M. J. Charles,[33] G. J. Grenier,[33] U. Mallik,[33] J. Cochran,[34] H. B. Crawley,[34] J. Lamsa,[34] W. T. Meyer,[34] S. Prell,[34] E. I. Rosenberg,[34] A. E. Rubin,[34] J. Yi,[34] N. Arnaud,[35] M. Davier,[35] X. Giroux,[35] G. Grosdidier,[35] A. Höcker,[35] F. Le Diberder,[35] V. Lepeltier,[35] A. M. Lutz,[35] T. C. Petersen,[35] S. Plaszczynski,[35] M. H. Schune,[35] G. Wormser,[35] C. H. Cheng,[36] D. J. Lange,[36] M. C. Simani,[36] D. M. Wright,[36] A. J. Bevan,[37] C. A. Chavez,[37] J. P. Coleman,[37] I. J. Forster,[37] J. R. Fry,[37] E. Gabathuler,[37] R. Gamet,[37] D. E. Hutchcroft,[37] R. J. Parry,[37] D. J. Payne,[37] C. Touramanis,[37] C. M. Cormack,[38] F. Di Lodovico,[38] C. L. Brown,[39] G. Cowan,[39] R. L. Flack,[39] H. U. Flaecher,[39] M. G. Green,[39] P. S. Jackson,[39] T. R. McMahon,[39] S. Ricciardi,[39] F. Salvatore,[39] M. A. Winter,[39] D. Brown,[40] C. L. Davis,[40] J. Allison,[41] N. R. Barlow,[41] R. J. Barlow,[41] M. C. Hodgkinson,[41] G. D. Lafferty,[41] J. C. Williams,[41] C. Chen,[42] A. Farbin,[42] W. D. Hulsbergen,[42] A. Jawahery,[42] D. Kovalskyi,[42] C. K. Lae,[42] V. Lillard,[42] D. A. Roberts,[42] G. Blaylock,[43] C. Dallapiccola,[43] S. S. Hertzbach,[43] R. Kofler,[43] V. B. Koptchev,[43] T. B. Moore,[43] S. Saremi,[43] H. Staengle,[43] S. Willocq,[43] R. Cowan,[44] K. Koeneke,[44] G. Sciolla,[44] S. J. Sekula,[44] F. Taylor,[44] R. K. Yamamoto,[44] P. M. Patel,[45] S. H. Robertson,[45] A. Lazzaro,[46] V. Lombardo,[46] F. Palombo,[46] J. M. Bauer,[47] L. Cremaldi,[47] V. Eschenburg,[47] R. Godang,[47] R. Kroeger,[47] J. Reidy,[47] D. A. Sanders,[47] D. J. Summers,[47] H. W. Zhao,[47] S. Brunet,[48] D. Côté,[48] P. Taras,[48] H. Nicholson,[49] N. Cavallo,[50,*] F. Fabozzi,[50,*] C. Gatto,[50] L. Lista,[50] D. Monorchio,[50] P. Paolucci,[50] D. Piccolo,[50] C. Sciacca,[50] M. Baak,[51] H. Bulten,[51] G. Raven,[51] H. L. Snoek,[51] L. Wilden,[51] C. P. Jessop,[52] J. M. LoSecco,[52] T. Allmendinger,[53] G. Benelli,[53] K. K. Gan,[53] K. Honscheid,[53] D. Hufnagel,[53] H. Kagan,[53] R. Kass,[53] T. Pulliam,[53] A. M. Rahimi,[53] R. Ter-Antonyan,[53] Q. K. Wong,[53] J. Brau,[54] R. Frey,[54] O. Igonkina,[54] M. Lu,[54] C. T. Potter,[54] N. B. Sinev,[54] D. Strom,[54] E. Torrence,[54] F. Colecchia,[55] A. Dorigo,[55] F. Galeazzi,[55] M. Margoni,[55] M. Morandin,[55] M. Posocco,[55] M. Rotondo,[55] F. Simonetto,[55]

0031-9007/05/94(17)/171801(7)$23.00

R. Stroili,[55] C. Voci,[55] M. Benayoun,[56] H. Briand,[56] J. Chauveau,[56] P. David,[56] Ch. de la Vaissière,[56] L. Del Buono,[56] O. Hamon,[56] M. J. J. John,[56] Ph. Leruste,[56] J. Malcles,[56] J. Ocariz,[56] L. Roos,[56] G. Therin,[56] P. K. Behera,[57] L. Gladney,[57] Q. H. Guo,[57] J. Panetta,[57] M. Biasini,[58] R. Covarelli,[58] M. Pioppi,[58] C. Angelini,[59] G. Batignani,[59] S. Bettarini,[59] M. Bondioli,[59] F. Bucci,[59] G. Calderini,[59] M. Carpinelli,[59] F. Forti,[59] M. A. Giorgi,[59] A. Lusiani,[59] G. Marchiori,[59] M. Morganti,[59] N. Neri,[59] E. Paoloni,[59] M. Rama,[59] G. Rizzo,[59] G. Simi,[59] J. Walsh,[59] M. Haire,[60] D. Judd,[60] K. Paick,[60] D. E. Wagoner,[60] N. Danielson,[61] P. Elmer,[61] Y. P. Lau,[61] C. Lu,[61] V. Miftakov,[61] J. Olsen,[61] A. J. S. Smith,[61] A. V. Telnov,[61] F. Bellini,[62] G. Cavoto,[61,62] A. D'Orazio,[62] E. Di Marco,[62] R. Faccini,[62] F. Ferrarotto,[62] F. Ferroni,[62] M. Gaspero,[62] L. Li Gioi,[62] M. A. Mazzoni,[62] S. Morganti,[62] M. Pierini,[62] G. Piredda,[62] F. Polci,[62] F. Safai Tehrani,[62] C. Voena,[62] S. Christ,[63] H. Schröder,[63] G. Wagner,[63] R. Waldi,[63] T. Adye,[64] N. De Groot,[64] B. Franek,[64] G. P. Gopal,[64] E. O. Olaiya,[64] R. Aleksan,[65] S. Emery,[65] A. Gaidot,[65] S. F. Ganzhur,[65] P.-F. Giraud,[65] G. Hamel de Monchenault,[65] W. Kozanecki,[65] M. Legendre,[65] G. W. London,[65] B. Mayer,[65] G. Schott,[65] G. Vasseur,[65] Ch. Yèche,[65] M. Zito,[65] M. V. Purohit,[66] A. W. Weidemann,[66] J. R. Wilson,[66] F. X. Yumiceva,[66] T. Abe,[67] M. Allen,[67] D. Aston,[67] R. Bartoldus,[67] N. Berger,[67] A. M. Boyarski,[67] O. L. Buchmueller,[67] R. Claus,[67] M. R. Convery,[67] M. Cristinziani,[67] G. De Nardo,[67] J. C. Dingfelder,[67] D. Dong,[67] J. Dorfan,[67] D. Dujmic,[67] W. Dunwoodie,[67] S. Fan,[67] R. C. Field,[67] T. Glanzman,[67] S. J. Gowdy,[67] T. Hadig,[67] V. Halyo,[67] C. Hast,[67] T. Hryn'ova,[67] W. R. Innes,[67] M. H. Kelsey,[67] P. Kim,[67] M. L. Kocian,[67] D. W. G. S. Leith,[67] J. Libby,[67] S. Luitz,[67] V. Luth,[67] H. L. Lynch,[67] H. Marsiske,[67] R. Messner,[67] D. R. Muller,[67] C. P. O'Grady,[67] V. E. Ozcan,[67] A. Perazzo,[67] M. Perl,[67] B. N. Ratcliff,[67] A. Roodman,[67] A. A. Salnikov,[67] R. H. Schindler,[67] J. Schwiening,[67] A. Snyder,[67] A. Soha,[67] J. Stelzer,[67] J. Strube,[54,67] D. Su,[67] M. K. Sullivan,[67] J. Thompson,[67] J. Va'vra,[67] S. R. Wagner,[67] M. Weaver,[67] W. J. Wisniewski,[67] M. Wittgen,[67] D. H. Wright,[67] A. K. Yarritu,[67] C. C. Young,[67] P. R. Burchat,[68] A. J. Edwards,[68] S. A. Majewski,[68] B. A. Petersen,[68] C. Roat,[68] M. Ahmed,[69] S. Ahmed,[69] M. S. Alam,[69] J. A. Ernst,[69] M. A. Saeed,[69] M. Saleem,[69] F. R. Wappler,[69] W. Bugg,[70] M. Krishnamurthy,[70] S. M. Spanier,[70] R. Eckmann,[71] H. Kim,[71] J. L. Ritchie,[71] A. Satpathy,[71] R. F. Schwitters,[71] J. M. Izen,[72] I. Kitayama,[72] X. C. Lou,[72] S. Ye,[72] F. Bianchi,[73] M. Bona,[73] F. Gallo,[73] D. Gamba,[73] L. Bosisio,[74] C. Cartaro,[74] F. Cossutti,[74] G. Della Ricca,[74] S. Dittongo,[74] S. Grancagnolo,[74] L. Lanceri,[74] P. Poropat,[74,†] L. Vitale,[74] G. Vuagnin,[74] F. Martinez-Vidal,[2,75] R. S. Panvini,[76] Sw. Banerjee,[77] B. Bhuyan,[77] C. M. Brown,[77] D. Fortin,[77] P. D. Jackson,[77] R. Kowalewski,[77] J. M. Roney,[77] R. J. Sobie,[77] J. J. Back,[78] P. F. Harrison,[78] G. B. Mohanty,[78] H. R. Band,[79] X. Chen,[79] B. Cheng,[79] S. Dasu,[79] M. Datta,[79] A. M. Eichenbaum,[79] K. T. Flood,[79] M. Graham,[79] J. J. Hollar,[79] J. R. Johnson,[79] P. E. Kutter,[79] H. Li,[79] R. Liu,[79] A. Mihalyi,[79] Y. Pan,[79] R. Prepost,[79] P. Tan,[79] J. H. von Wimmersperg-Toeller,[79] J. Wu,[79] S. L. Wu,[79] Z. Yu,[79] M. G. Greene,[80] and H. Neal[80]

(*BABAR* Collaboration)

[1]*Laboratoire de Physique des Particules, F-74941 Annecy-le-Vieux, France*
[2]*Universitad Autonoma de Barcelona, E-08193 Bellaterra, Barcelona, Spain*
[3]*Dipartimento di Fisica and INFN, Università di Bari, I-70126 Bari, Italy*
[4]*Institute of High Energy Physics, Beijing 100039, China*
[5]*University of Bergen, Institute of Physics, N-5007 Bergen, Norway*
[6]*Lawrence Berkeley National Laboratory and University of California, Berkeley, California 94720, USA*
[7]*University of Birmingham, Birmingham, B15 2TT, United Kingdom*
[8]*Ruhr Universität Bochum, Institut für Experimentalphysik 1, D-44780 Bochum, Germany*
[9]*University of Bristol, Bristol BS8 1TL, United Kingdom*
[10]*University of British Columbia, Vancouver, British Columbia, Canada V6T 1Z1*
[11]*Brunel University, Uxbridge, Middlesex UB8 3PH, United Kingdom*
[12]*Budker Institute of Nuclear Physics, Novosibirsk 630090, Russia*
[13]*University of California at Irvine, Irvine, California 92697, USA*
[14]*University of California at Los Angeles, Los Angeles, California 90024, USA*
[15]*University of California at Riverside, Riverside, California 92521, USA*
[16]*University of California at San Diego, La Jolla, California 92093, USA*
[17]*University of California at Santa Barbara, Santa Barbara, California 93106, USA*
[18]*University of California at Santa Cruz, Institute for Particle Physics, Santa Cruz, California 95064, USA*
[19]*California 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 fur Physik, D-44221 Dortmund, Germany*

[24]Technische Universität Dresden, Institut für Kern- und Teilchenphysik, D-01062 Dresden, Germany
[25]Ecole Polytechnique, LLR, F-91128 Palaiseau, France
[26]University of Edinburgh, Edinburgh EH9 3JZ, United Kingdom
[27]Dipartimento di Fisica and INFN, Università di Ferrara, I-44100 Ferrara, Italy
[28]Laboratori Nazionali di Frascati dell'INFN, I-00044 Frascati, Italy
[29]Dipartimento di Fisica and INFN, Università di Genova, 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]Laboratoire de l'Accélérateur Linéaire, F-91898 Orsay, France
[36]Lawrence Livermore National Laboratory, Livermore, California 94550, USA
[37]University of Liverpool, Liverpool L69 72E, United Kingdom
[38]Queen Mary, University of London, E1 4NS, United Kingdom
[39]University of London, Royal Holloway and Bedford New College, Egham, Surrey TW20 0EX, United Kingdom
[40]University of Louisville, Louisville, Kentucky 40292, USA
[41]University of Manchester, Manchester M13 9PL, United Kingdom
[42]University of Maryland, College Park, Maryland 20742, USA
[43]University of Massachusetts, Amherst, Massachusetts 01003, USA
[44]Laboratory for Nuclear Science, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139, USA
[45]McGill University, Montréal, Quebec, Canada H3A 2T8
[46]Dipartimento di Fisica and INFN, Università di Milano, I-20133 Milano, Italy
[47]University of Mississippi, University, Mississippi 38677, USA
[48]Laboratoire René J. A. Lévesque, Université de Montréal, Montréal, Quebec, Canada H3C 3J7
[49]Mount Holyoke College, South Hadley, Massachusetts 01075, USA
[50]Dipartimento di Scienze Fisiche and INFN, Università di Napoli Federico II, I-80126, Napoli, Italy
[51]NIKHEF, National Institute for Nuclear Physics and High Energy Physics, NL-1009 DB Amsterdam, The Netherlands
[52]University of Notre Dame, Notre Dame, Indiana 46556, USA
[53]The Ohio State University, Columbus, Ohio 43210, USA
[54]University of Oregon, Eugene, Oregon 97403, USA
[55]Dipartimento di Fisica and INFN, Università di Padova, I-35131 Padova, Italy
[56]Laboratoire de Physique Nucléaire et de Hautes Energies, Universités Paris VI et VII, F-75252 Paris, France
[57]University of Pennsylvania, Philadelphia, Pennsylvania 19104, USA
[58]Dipartimento di Fisica and INFN, Università di Perugia, I-06100 Perugia, Italy
[59]Dipartimento di Fisica, Scuola Normale Superiore and INFN, Università di Pisa, I-56127 Pisa, Italy
[60]Prairie View A&M University, Prairie View, Texas 77446, USA
[61]Princeton University, Princeton, New Jersey 08544, USA
[62]Dipartimento di Fisica and INFN, Università di Roma La Sapienza, I-00185 Roma, Italy
[63]Universität Rostock, D-18051 Rostock, Germany
[64]Rutherford Appleton Laboratory, Chilton, Didcot, Oxon, OX11 0QX, United Kingdom
[65]DSM/Dapnia, CEA/Saclay, F-91191 Gif-sur-Yvette, France
[66]University of South Carolina, Columbia, South Carolina 29208, USA
[67]Stanford Linear Accelerator Center, Stanford, California 94309, USA
[68]Stanford University, Stanford, California 94305-4060, USA
[69]State University of New York, Albany, New York 12222, USA
[70]University of Tennessee, Knoxville, Tennessee 37996, USA
[71]University of Texas at Austin, Austin, Texas 78712, USA
[72]University of Texas at Dallas, Richardson, Texas 75083, USA
[73]Dipartimento di Fisica Sperimentale and INFN, Università di Torino, I-10125 Torino, Italy
[74]Dipartimento di Fisica and INFN, Università di Trieste, I-34127 Trieste, Italy
[75]Universidad de Valencia, E-46100 Burjassot, Valencia, Spain
[76]Vanderbilt University, Nashville, Tennessee 37235, USA
[77]University of Victoria, Victoria, British Columbia, Canada V8W 3P6
[78]Department of Physics, University of Warwick, Coventry CV4 7AL, United Kingdom
[79]University of Wisconsin, Madison, Wisconsin 53706, USA
[80]Yale University, New Haven, Connecticut 06511, USA

(Received 24 January 2005; published 4 May 2005)

We search for the factorization-suppressed decays $B \to \chi_{c0} K^{(*)}$ and $B \to \chi_{c2} K^{(*)}$, with χ_{c0} and χ_{c2} decaying into $J/\psi\gamma$, using a sample of 124×10^6 $B\bar{B}$ events collected with the *BABAR* detector at the

PEP-II storage ring of the Stanford Linear Accelerator Center. We find no significant signal and set upper bounds for the branching fractions.

DOI: 10.1103/PhysRevLett.94.171801 PACS numbers: 13.25.Hw, 11.30.Er, 12.15.Hh, 12.39.St

Nonleptonic decays of heavy mesons are not easily described because the process involves quarks whose hadronization is not yet well understood. The factorization hypothesis allows one to make some predictions [1] by assuming that a weak decay matrix element can be described as the product of two independent hadronic currents. Under the factorization hypothesis, $B \to c\bar{c}K^{(*)}$ decays are allowed when the $c\bar{c}$ pair hadronizes to J/ψ, $\psi(2S)$, or χ_{c1}, but are suppressed when the $c\bar{c}$ pair hadronizes to χ_{c0} or χ_{c2} [2]. Here, $K^{(*)}$ represents either K or K^*. In the lowest-order heavy quark effective theory, there is no $J \geq 2$ current to create the tensor χ_{c2} from the vacuum. The decay rate to the scalar χ_{c0} is zero due to charge conjugation invariance [3].

Belle has recently observed $B^+ \to \chi_{c0}K^+$ decays with a branching fraction (BF) of $(6.0^{+2.1}_{-1.8} \pm 1.1) \times 10^{-4}$ [4] using χ_{c0} decays to $\pi^+\pi^-$ or K^+K^-. *BABAR* has confirmed the observation using the same decays with a branching fraction of $(2.7 \pm 0.7) \times 10^{-4}$ [5], somewhat lower than, but compatible with, the Belle measurement. These results are of the same order of magnitude as the BF of the decay $B^+ \to \chi_{c1}K^+$ and are surprisingly large given the expectation from factorization. Using the hadronic χ_{c0} decays, CLEO has obtained an upper limit on $B^0 \to \chi_{c0}K^0$ of 5.0×10^{-4} [6]. Nonfactorizable contributions to $B^+ \to \chi_{c0}K^+$ decays due to the rescattering of intermediate charm states have been considered theoretically [7], and similar branching fractions are predicted for decays to χ_{c0} and χ_{c2}. No predictions are available for B decays to $\chi_{c(0,2)}K^*$, but the branching fraction of decays to K^* may be expected to be similar to the branching fraction of decays to K. The measurement of $B \to \chi_{c(0,2)}K^{(*)}$ should improve our understanding of the limitations of factorization and of models that violate factorization.

In this Letter we report a search for the decays $B \to \chi_{cJ}K^{(*)}$, $J = 0, 2$, using the radiative decays $\chi_{cJ} \to J/\psi\gamma$, with branching fractions of $(1.18 \pm 0.14)\%$ and $(20.2 \pm 1.7)\%$, respectively [8]. Since the radiative branching fraction for the χ_{c0} decay (including subsequent J/ψ decay to $\ell^+\ell^-$) is much smaller than the corresponding $\pi^+\pi^-$ or K^+K^- branching fractions, the search for the $B^+ \to \chi_{c0}K^+$ decay is less sensitive than previous searches, but it is free from the interference with the nonresonant decays to three mesons that affect the latter. The data used in this analysis were obtained with the *BABAR* detector at the PEP-II storage ring, comprising an integrated luminosity of 112 fb^{-1} of data taken at the $\Upsilon(4S)$ resonance.

The *BABAR* detector is described elsewhere [9]. Surrounding the interaction point, a five-layer double-sided silicon vertex tracker (SVT) provides precise reconstruction of track angles and B-decay vertices. A 40-layer drift chamber (DCH) provides measurements of the transverse momenta of charged particles. An internally reflecting ring-imaging Cherenkov detector (DIRC) is used for particle identification (PID). A CsI(Tl) crystal electromagnetic calorimeter detects photons and electrons. The calorimeter is surrounded by a solenoidal magnet providing a 1.5 T field. The flux return is instrumented with resistive plate chambers used for muon and neutral-hadron identification.

The channels considered here are $B \to \chi_c K^{(*)}$ with $\chi_c \to J/\psi\gamma$ and $J/\psi \to \ell^+\ell^-$, where ℓ is e or μ, K is K^+ or K^0_S $(\to \pi^+\pi^-)$, $K^{*0} \to K^+\pi^-$ or $K^0_S\pi^0$, $K^{*+} \to K^+\pi^0$ or $K^0_S\pi^+$, and $\pi^0 \to \gamma\gamma$. Charge-conjugate modes are included implicitly throughout this Letter. Event selection is optimized by maximizing $\epsilon/\sqrt{N_b}$, where ϵ is the signal efficiency after all selection requirements and N_b the number of background events, estimated with $\Upsilon(4S) \to B\bar{B}$ and $e^+e^- \to q\bar{q}$ Monte Carlo (MC) samples.

Candidate J/ψ mesons are reconstructed from a pair of oppositely charged lepton candidates that form a good vertex. Muon (electron) candidates are identified with a neural-network (cut-based) selector and loose selection criteria. Electromagnetic depositions in the calorimeter in the polar-angle range $0.410 < \theta_{\text{lab}} < 2.409$ rad that are not associated with charged tracks have an energy larger than 30 MeV, and a shower shape consistent with a photon are taken as photon candidates. For $J/\psi \to e^+e^-$ decays, electron candidates are combined with nearby photon candidates in order to recover some of the energy lost through bremsstrahlung. The lepton-pair invariant mass must be in the range $[2.95, 3.18]$ GeV/c^2 for both lepton flavors. The small remaining background is mainly due to J/ψ mesons not originating from χ_c decays.

We form K^0_S candidates from oppositely charged tracks originating from a common vertex with invariant mass in the range $[487, 510]$ MeV/c^2. The K^0_S flight length must be greater than 1 mm, and its direction in the plane perpendicular to the beam line must be within 0.2 rad of the K^0_S momentum vector. Charged kaon candidates are identified with a likelihood selector, based on information from the DIRC, and dE/dx in the SVT and in the DCH.

A π^0 candidate is formed from a pair of photon candidates with invariant mass in the interval $[117, 152]$ MeV/c^2 and momentum greater than 350 MeV/c. K^* candidates are formed from $K\pi$ combinations with an invariant mass in the range $[0.85, 0.94]$ GeV/c^2.

The J/ψ, K^0_S, and π^0 candidates are constrained to their corresponding nominal masses [8] to improve the resolution of the measurement of the four-momentum of their parent B candidate. The $\chi_c$candidates are formed from J/ψ and photon candidates. The photon is required to have an energy greater than 0.15 GeV and not to be part of π^0 candidates in the mass range $[0.125, 0.140]$ GeV$/c^2$.

Candidate B mesons are formed from χ_c and $K^{(*)}$ candidates. Two kinematic variables are used to further remove incorrectly reconstructed B candidates. The first is the difference $\Delta E \equiv E_B^* - E_{\rm beam}^*$ between the B-candidate energy and the beam energy in the $\Upsilon(4S)$ rest frame. In the absence of experimental effects, reconstructed signal candidates have $\Delta E = 0$. The typical ΔE resolution is 20 MeV for channels with only charged tracks in the final state, and 25 MeV, with a low ΔE tail due to energy leakage in the calorimeter, for channels with a π^0. The second variable is the beam-energy-substituted mass $m_{\rm ES} \equiv (E_{\rm beam}^{*2}/c^4 - p_B^{*2}/c^2)^{1/2}$, where p_B^* is the momentum of the B candidate in the $\Upsilon(4S)$ rest frame. The energy substituted mass $m_{\rm ES}$ should peak at the B meson mass, 5.279 GeV$/c^2$. Typical resolution for $m_{\rm ES}$ is 2.7 MeV$/c^2$. For the signal region, ΔE is required to be in the range $[-35, +20]$ MeV for channels involving a π^0, and within ± 20 MeV otherwise. We require $m_{\rm ES}$ to be in the range $[5.274, 5.284]$ GeV$/c^2$. If more than one B candidate is found in an event, the one having the smallest $|\Delta E|$ is retained.

The observation of χ_{c2} could be complicated by the presence of the prominent χ_{c1} peak. This is mitigated by measuring the spectrum in the variable $m_{\ell^+\ell^-\gamma} - m_{\ell^+\ell^-}$. The efficiencies obtained from fits to the mass difference distribution for exclusive MC samples, where one B decays to the final state under consideration and the other inclusively, are given in Table I. The χ_{c2} meson has a natural width of just 2 MeV [8] and is therefore fitted with a Gaussian to account for detector resolution. Since the χ_{c0} has a natural width of 10 MeV [8], comparable to the mass resolution ($\sigma \approx 10$ MeV$/c^2$), we fit the χ_{c0} peak with the convolution of Breit-Wigner and Gaussian shapes.

Studies of MC samples show that most of the background events in the $\chi_c K^*$ channels are due to nonresonant (NR) $B \to \chi_c(J/\psi\gamma)K\pi$ decays. After the NR events are removed from the MC background sample, the expected background with genuine $\chi_c \to J/\psi\gamma$ decays is the 0.2 ± 0.2 event for the $\chi_{c2}K^{*0}(K^+\pi^-)$ and $\chi_{c2}K^{*+}(K^+\pi^0)$ modes, and 0.0 ± 0.2 for all other channels. We correct for the presence of NR decays with the following procedure. The $m_{\ell^+\ell^-\gamma} - m_{\ell^+\ell^-}$ distribution for events in a nearby sideband ($1.1 < m_{K\pi} < 1.3$ GeV$/c^2$) is subtracted from the distribution for events in the signal region ($0.85 < m_{K\pi} < 0.94$ GeV$/c^2$), after scaling the sideband distribution by a factor $r = 0.26 \pm 0.04$. The quantity r, obtained from the MC simulation, is the ratio of NR events under the peak to the number in the sideband. NR-subtracted distributions of $m_{\ell^+\ell^-\gamma} - m_{\ell^+\ell^-}$ are shown in Fig. 1. These plots show the presence of the factorization-allowed χ_{c1} but no significant signals for the factorization-suppressed χ_{c0} or χ_{c2}. No χ_{c0} or χ_{c2} signal is observed in the sideband region.

The branching fractions are computed from $\mathrm{BF} = N_S/(N_B\epsilon f)$, where N_S is the number of signal events obtained from fitting the $m_{\ell^+\ell^-\gamma} - m_{\ell^+\ell^-}$ distribution (Table II), N_B is the number of produced $B\bar{B}$ events, ϵ is the selection efficiency (Table I), and f is the product of secondary branching fractions of the B daughters. The free parameters in the fits are the size of a constant background, the overall scale of $m_{\ell^+\ell^-\gamma} - m_{\ell^+\ell^-}$, and the amplitudes of the resonant peaks. The fixed parameters are the χ_{c0} natural width, the χ_{c0}–χ_{c1} and χ_{c2}–χ_{c1} mass differences (-95.4 and $+45.7$ MeV$/c^2$, respectively) all taken from Ref. [8], and the mass resolution. The mass resolution, 10.2 ± 0.4 MeV$/c^2$, is measured with χ_{c1} data and is assumed to be the same for the three χ_c states. Performing such fits to an inclusive $\Upsilon(4S) \to B\bar{B}$ MC sample, we verify that the NR events are subtracted correctly, and that the proximity of the χ_{c1} does not induce any significant bias on the measurement of the nearby χ_{c2}.

TABLE I. Efficiencies from fits of exclusive MC distributions of $m_{\ell^+\ell^-\gamma} - m_{\ell^+\ell^-}$, with statistical uncertainty.

	χ_{c2}	χ_{c0}
K^{*0} $(K^+\pi^-)$	0.071 ± 0.001	0.066 ± 0.001
K^{*0} $(K_S^0\pi^0)$	0.031 ± 0.001	0.020 ± 0.001
K_S^0	0.158 ± 0.001	0.126 ± 0.001
K^{*+} $(K^+\pi^0)$	0.036 ± 0.001	0.031 ± 0.001
$K^{*+}(K_S^0\pi^+)$	0.065 ± 0.001	0.062 ± 0.001
K^+	0.144 ± 0.001	0.117 ± 0.002

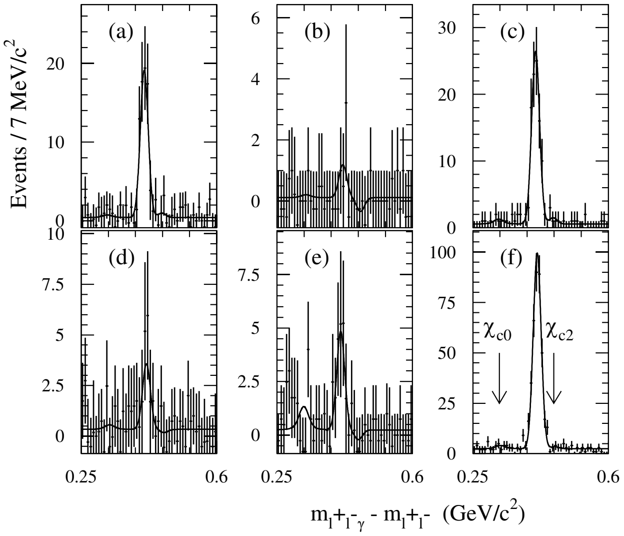

FIG. 1. Distribution of $m_{\ell^+\ell^-\gamma} - m_{\ell^+\ell^-}$ for data, with NR subtraction for final states of the strange meson (a) $K^+\pi^-$, (b) $K_S^0\pi^0$, (c) K_S^0, (d) $K^+\pi^0$, (e) $K_S^0\pi^+$, and (f) K^+. The fit is described in the text. The arrows on plot (f) show the expected positions of the χ_{c0} and χ_{c2} peaks.

TABLE II. Event yields with statistical uncertainties from the fits of Fig. 1.

	χ_{c2}	χ_{c0}
K^{*0} $(K^+\pi^-)$	2.0 ± 1.6	1.7 ± 2.1
K^{*0} $(K^0_S\pi^0)$	-1.6 ± 4.3	0.5 ± 0.3
K^0_S	3.4 ± 1.8	3.9 ± 3.8
K^{*+} $(K^+\pi^0)$	-0.5 ± 0.2	1.1 ± 2.2
K^{*+} $(K^0_S\pi^+)$	-1.9 ± 1.2	5.9 ± 3.7
K^+	3.7 ± 4.4	8.8 ± 6.6

Based on studies of $B \to J/\psi\ K^*$ decays [10], the NR $K\pi$ component appears to be in an S-wave state, with an unknown relative phase ϕ with respect to the main $K^*(892)$ P-wave peak. As no signal is found, the systematic uncertainty due to the unknown relative phase is estimated here with a MC-based method. The $K - \pi$ invariant mass is fitted with an amplitude that is the sum of a nonrelativistic Breit-Wigner function and an amplitude with a constant phase and the square of which has a quadratic dependence on $m_{K\pi}$.

$$p(m_{K\pi}) = \left| \frac{a}{m_{K^*} - m_{K\pi} - i\Gamma/2} + b(m_{K\pi})e^{i\phi} \right|^2, \quad (1)$$

where a and b are real quantities and $m_{K^*} = 892\ \mathrm{MeV}/c^2$. The slow variation of the phase of the S wave with $m_{K\pi}$ is neglected here. The free parameters in the fit are the 3 degrees of freedom of the quadratic dependence of b, the magnitude of the signal, and the relative phase ϕ. As the sideband is dominated by the NR contribution, no attempt is made to subtract the few combinatorial events. The fact that the phase ϕ is unknown is dealt with by randomly generating samples of events distributed as above for each value of ϕ, and applying NR subtraction. The number of events $N(\phi)$ thus measured is normalized to that obtained with the phase value ϕ_0 obtained in the fit. The ratio $R = N(\phi)/N(\phi_0)$ shows a sinusoidal dependence. The average value is 1.44 with a deviation of ±35%, giving an rms relative uncertainty of ±20%, which we assume is systematic uncertainty (due to the interference with the NR component).

In the case of decays to the tensor χ_{c2}, the efficiency depends on the intensity fractions to each of three polarization states. The efficiency is mainly sensitive to the value of the helicity angle θ_{K^*} of the K^* decay, because small values of θ_{K^*} occur for low momentum pions. The selection efficiency therefore depends, to first order, on the polarization of the K^* population, through the normalized differential decay rate:

$$\frac{1}{\Gamma}\frac{d\Gamma}{d\cos\theta_{K^*}} = \frac{3}{4}[(1 - \cos^2\theta_{K^*}) + A_0(3\cos^2\theta_{K^*} - 1)], \quad (2)$$

where A_0 is the fraction of longitudinal K^* polarization.

TABLE III. Coefficients for the calculation of amplitude-dependent average efficiency for the $\chi_{c2}K^*$ channels (%).

	C	D	Efficiency
K^{*0} $(K^+\pi^-)$	8.68	-1.40	7.98 ± 0.40
K^{*0} $(K^0_S\pi^0)$	4.25	-1.66	3.43 ± 0.48
K^{*+} $(K^+\pi^0)$	5.05	-1.79	4.16 ± 0.52
K^{*+} $(K^0_S\pi^+)$	7.83	-1.84	6.92 ± 0.53

The average efficiency is

$$\langle\varepsilon\rangle = \int \frac{1}{\Gamma}\frac{d\Gamma}{d\cos\theta_{K^*}}\varepsilon(\theta_{K^*})d\cos\theta_{K^*} = C + A_0 D, \quad (3)$$

where $C = \frac{3}{4}\int(1 - \cos^2\theta_{K^*})\varepsilon(\theta_{K^*})\sin\theta_{K^*}d\theta_{K^*}$, and $D = \frac{3}{4}\int(3\cos^2\theta_{K^*} - 1)\varepsilon(\theta_{K^*})\sin\theta_{K^*}d\theta_{K^*}$, where $\varepsilon(\theta_{K^*})$ is computed using MC samples. The values of C and D are shown in Table III.

When no signal is observed, as is the case here, the polarization is unknown. We assume an unpolarized decay and we estimate the efficiency as $(C + 0.5D) \pm (|D|/\sqrt{12})$. The branching fraction measurements reported here are affected by the systematic uncertainties described in what follows. The relative uncertainty on the number of $B\bar{B}$ events is 1.1%. The secondary branching fractions and their uncertainty are taken from Ref. [8]. Other estimated uncertainties are as follows: tracking efficiency, 1.3% per track added linearly; K^0_S reconstruction, 2.5%; selection of the γ from the χ_c decays, 2.5%; π^0 selection, 5.0%; PID efficiency, 3.0%. For each mass peak and for ΔE, the uncertainty of the central value and of the width of the peaks are measured with the χ_{c1} channels. These quantities are used to estimate the efficiency uncertainty from this source. The ratio of B^0 to B^+ production in $\Upsilon(4S)$ decays is

TABLE IV. Summary of the multiplicative systematic uncertainties in percent. The first eight rows are in common to decays to χ_{c0} and χ_{c2}.

	$K^+\pi^-$	$K^0_S\pi^0$	$K^+\pi^0$	$K^0_S\pi^+$	K^+	K^0_S
Number of B's	1.1	1.1	1.1	1.1	1.1	1.1
Tracking	5.2	2.6	3.9	3.9	3.9	2.6
K^0_S	⋯	2.5	⋯	2.5	⋯	2.5
Neutrals	2.5	7.5	7.5	2.5	2.5	2.5
PID	3.0	3.0	3.0	3.0	3.0	3.0
Sample selection	7.7	13.1	11.6	8.2	6.5	6.3
MC statistics	1.4	2.9	1.7	1.8	1.3	1.3
S-wave phase	20.0	20.0	20.0	20.0	⋯	⋯
χ_{c0} second. BF	11.9	11.9	11.9	11.9	11.9	11.9
Total for χ_{c0}	25.4	28.3	27.6	25.5	14.8	14.6
χ_{c2} second. BF	8.5	8.5	8.5	8.5	8.5	8.5
Polarization	5.1	14.0	12.4	7.7	⋯	⋯
Total for χ_{c2}	24.5	30.5	29.1	25.3	12.2	12.0

TABLE V. Upper limits at 90% C.L. and measured branching fractions (in parentheses) in units of 10^{-4}.

	χ_{c2}		χ_{c0}	
K^{*0}	0.36	$(0.14 \pm 0.11 \pm 0.14)$	7.7	$(3.8 \pm 2.6 \pm 1.5)$
K^{*+}	0.12	$(-0.15 \pm 0.05 \pm 0.14)$	28.6	$(13.5 \pm 9.6 \pm 5.3)$
K^{+}	0.30	$(0.09 \pm 0.10 \pm 0.11)$	8.9	$(4.4 \pm 3.3 \pm 0.7)$
K^{0}	0.41	$(0.21 \pm 0.11 \pm 0.13)$	12.4	$(5.3 \pm 5.0 \pm 0.8)$

assumed to be unity. The related uncertainty is small [11] and is neglected here. A summary of the multiplicative contributions to the systematics can be found in Table IV. In addition to these multiplicative contributions, there is a small contribution from the uncertainty on r for the NR background subtraction.

Combining the measurements of the K^* submodes, and with the approximation that the multiplicative efficiencies for each K^* submode are fully correlated, we obtain the branching fractions for the factorization-suppressed modes listed in Table V. As a cross-check, the results for the allowed χ_{c1} are found to be compatible with those of a recent analysis [12] optimized for that decay. We obtain upper bounds on the BFs at 90% confidence level (C.L.) assuming Gaussian statistics for the statistical uncertainties and taking into account the systematic uncertainties. We have used a Bayesian method with uniform prior for positive BF values in the derivation of these limits. The upper limits obtained for decays to χ_{c0} are larger than for χ_{c2} due to the smaller χ_{c0} radiative BF. For $B^+ \to \chi_{c0}K^+$ they are compatible with the previous measurements [4,5].

$B \to \chi_{c(0,2)}K^{(*)}$ production requires nonfactorizable contributions. $B^+ \to \chi_{c0}K^+$ decays have been previously observed. Colangelo *et al.* [7] explain this with rescattering effects and predict a similar rate for $B \to \chi_{c2}K$. This is not observed. The upper limits obtained for decays to χ_{c2} are approximately 1 order of magnitude lower than the branching fractions of the observed $B^+ \to \chi_{c0}K^+$ decays.

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 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), and PPARC (United Kingdom). Individuals have received support from CONACyT (Mexico), A. P. Sloan Foundation, Research Corporation, and Alexander von Humboldt Foundation.

---

[*] Also with Università della Basilicata, Potenza, Italy.

[†] Deceased.

[1] M. Bauer, B. Stech, and M. Wirbel, Z. Phys. C **34**, 103 (1987).

[2] M. Suzuki, Phys. Rev. D **66**, 037503 (2002).

[3] M. Diehl and G. Hiller, J. High Energy Phys. 06 (2001) 067.

[4] Belle Collaboration, K. Abe *et al.*, Phys. Rev. Lett. **88**, 031802 (2002).

[5] *BABAR* Collaboration, B. Aubert *et al.*, Phys. Rev. D **69**, 071103 (2004).

[6] CLEO Collaboration, K. W. Edwards *et al.*, Phys. Rev. Lett. **86**, 30 (2001).

[7] P. Colangelo, F. De Fazio, and T. N. Pham, Phys. Lett. B **542**, 71 (2002).

[8] Particle Data Group Collaboration, S. Eidelman *et al.*, Phys. Lett. B **592**, 1 (2004).

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

[10] *BABAR* Collaboration, B. Aubert *et al.*, Phys. Rev. Lett. **87**, 241801 (2001).

[11] *BABAR* Collaboration, B. Aubert *et al.*, Phys. Rev. D **69**, 071101 (2004).

[12] *BABAR* Collaboration, B. Aubert, Phys. Rev. Lett. **94**, 141801 (2005).