Charmon-07/01 BAD 2059, version 4

Collaboration-Wide Review 3 July 2008 to 17 July 2008

Primary BAD	2059, version 4			
	Evidence for X(3872)> Psi(2S) gamma in B+> X(3872) K+			
Author list	Fulsom, Bryan			
Review Committee	comm413, members: Arnaud, Nicolas; Jackson, Paul (chair); Park, Woochun			
Target	Physical Review D			
Result type				
Supporting BAD(s)	BAD #1936 Search for B>X(3872)K(*), X(3872)>ccbar gamma			
Changes since preliminary result				
BAIS/CWR Com- ments				
Institutional Reading Groups	2b. Budker, UCLA, Colorado, Royal Holloway, McGill, MIT, Trieste3b. UC Santa Barbara, Colorado State, Dortmund, Ohio State, Oregon, IRFU, Warwick			

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Evidence for $X(3872) \rightarrow \psi(2S)\gamma$ in $B^{\pm} \rightarrow X(3872)K^{\pm}$ decays, and a study of $B \to c \overline{c} \gamma K$

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 10 E. C. Martin,¹² D. P. Stoker,¹² S. Abachi,¹³ C. Buchanan,¹³ J. W. Gary,¹⁴ F. Liu,¹⁴ O. Long,¹⁴ B. C. Shen,^{14, *} 11 G. M. Vitug,¹⁴ Z. Yasin,¹⁴ L. Zhang,¹⁴ V. Sharma,¹⁵ C. Campagnari,¹⁶ T. M. Hong,¹⁶ D. Kovalskyi,¹⁶ 12 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 13 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 14 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 15 R. Andreassen,¹⁹ G. Mancinelli,¹⁹ B. T. Meadows,¹⁹ K. Mishra,¹⁹ M. D. Sokoloff,¹⁹ P. C. Bloom,²⁰ 16 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 17 S. R. Wagner,²⁰ R. Ayad,^{21,†} A. Soffer,^{21,‡} W. H. Toki,²¹ R. J. Wilson,²¹ D. D. Altenburg,²² E. Feltresi,²² 18 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 19 W. F. Mader,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 20 21 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 22 L. Piemontese^a,²⁶ V. Santoro^{ab},²⁶ R. Baldini-Ferroli,²⁷ A. Calcaterra,²⁷ R. de Sangro,²⁷ G. Finocchiaro,²⁷ 23 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 24 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 25 A. Santroni^{ab},²⁸ S. Tosi^{ab},²⁸ K. S. Chaisanguanthum,²⁹ M. Morii,²⁹ A. Adametz,³⁰ J. Marks,³⁰ S. Schenk,³⁰ 26 U. Uwer,³⁰ 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 27 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 28 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 29 J. Béquilleux,³⁶ A. D'Orazio,³⁶ M. Davier,³⁶ J. Firmino da Costa,³⁶ G. Grosdidier,³⁶ A. Höcker,³⁶ V. Lepeltier,³⁶ 30 F. Le Diberder,³⁶ A. M. Lutz,³⁶ S. Pruvot,³⁶ P. Roudeau,³⁶ M. H. Schune,³⁶ J. Serrano,³⁶ V. Sordini,^{36, ¶} 31 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 32 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 33 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 34 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 35 M. Fritsch,⁴² W. Gradl,⁴² G. Schott,⁴² K. E. Alwyn,⁴³ D. Bailey,⁴³ R. J. Barlow,⁴³ Y. M. Chia,⁴³ C. L. Edgar,⁴³ 36 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 37 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 38 P. H. Fisher,⁴⁶ G. Sciolla,⁴⁶ M. Spitznagel,⁴⁶ F. Taylor,⁴⁶ R. K. Yamamoto,⁴⁶ M. Zhao,⁴⁶ P. M. Patel,⁴⁷ 39 S. H. Robertson,⁴⁷ A. Lazzaro^{ab},⁴⁸ V. Lombardo^a,⁴⁸ F. Palombo^{ab},⁴⁸ J. M. Bauer,⁴⁹ L. Cremaldi,⁴⁹ 40 R. Godang,^{49, **} R. Kroeger,⁴⁹ D. A. Sanders,⁴⁹ D. J. Summers,⁴⁹ H. W. Zhao,⁴⁹ M. Simard,⁵⁰ P. Taras,⁵⁰ 41 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 42 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 43 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 44 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 45 R. Rahmat,⁵⁶ N. B. Sinev,⁵⁶ D. Strom,⁵⁶ J. Strube,⁵⁶ E. Torrence,⁵⁶ G. Castelli^{ab},⁵⁷ N. Gagliardi^{ab},⁵⁷ 46 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 47 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 48

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 49 R. Covarelli^{ab}, ⁶⁰ E. Manoni^{ab}, ⁶⁰ C. Angelini^{ab}, ⁶¹ G. Batignani^{ab}, ⁶¹ S. Bettarini^{ab}, ⁶¹ M. Carpinelli^{ab}, ⁶¹, ^{††} 50 A. Cervelli^{ab},⁶¹ F. Forti^{ab},⁶¹ M. A. Giorgi^{ab},⁶¹ A. Lusiani^{ac},⁶¹ G. Marchiori^{ab},⁶¹ 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 51 52 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 53 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 54 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 55 T. Adye,⁶⁵ B. Franck,⁶⁵ E. O. Olaiya,⁶⁵ F. F. Wilson,⁶⁵ S. Emery,⁶⁶ M. Escalier,⁶⁶ L. Esteve,⁶⁶ S. F. Ganzhur,⁶⁶ 56 G. Hamel de Monchenault,⁶⁶ W. Kozanecki,⁶⁶ G. Vasseur,⁶⁶ Ch. Yèche,⁶⁶ M. Zito,⁶⁶ X. R. Chen,⁶⁷ H. Liu,⁶⁷ 57 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 58 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 59 G. P. Dubois-Felsmann,⁶⁸ W. Dunwoodie,⁶⁸ R. C. Field,⁶⁸ A. M. Gabareen,⁶⁸ S. J. Gowdy,⁶⁸ M. T. Graham,⁶⁸ 60 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 61 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 62 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 63 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 64 65 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 66 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 67 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 68 S. M. Spanier,⁷¹ B. J. Wogsland,⁷¹ R. Eckmann,⁷² J. L. Ritchie,⁷² A. M. Ruland,⁷² C. J. Schilling,⁷² 69 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 70 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 71 N. Lopez-March,⁷⁶ F. Martinez-Vidal,⁷⁶ D. A. Milanes,⁷⁶ A. Oyanguren,⁷⁶ J. Albert,⁷⁷ Sw. Banerjee,⁷⁷ 72 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 73 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 74 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. Wu⁷⁹ 75 (The BABAR Collaboration) 76 ¹Laboratoire de Physique des Particules, IN2P3/CNRS et Université de Savoie, F-74941 Annecy-Le-Vieux, France 77 ²Universitat de Barcelona, Facultat de Fisica, Departament ECM, E-08028 Barcelona, Spain 78 ³INFN Sezione di Bari^a; Dipartmento di Fisica, Università di Bari^b, I-70126 Bari, Italy 79 ⁴University of Bergen, Institute of Physics, N-5007 Bergen, Norway 80 ⁵Lawrence Berkeley National Laboratory and University of California, Berkeley, California 94720, USA 81 ⁶University of Birmingham, Birmingham, B15 2TT, United Kingdom 82 7 Ruhr Universität Bochum, Institut für Experimentalphysik 1, D-44780 Bochum, Germany 83 ⁸University of Bristol, Bristol BS8 1TL, United Kingdom 84 ⁹University of British Columbia, Vancouver, British Columbia, Canada V6T 1Z1 85 ¹⁰Brunel University, Uxbridge, Middlesex UB8 3PH, United Kingdom 86 ¹¹Budker Institute of Nuclear Physics, Novosibirsk 630090, Russia 87 ¹²University of California at Irvine, Irvine, California 92697, USA 88 ¹³University of California at Los Angeles, Los Angeles, California 90024, USA 89 ¹⁴ University of California at Riverside, Riverside, California 92521, USA 90 ¹⁵University of California at San Diego, La Jolla, California 92093, USA 91 ¹⁶ University of California at Santa Barbara, Santa Barbara, California 93106, USA 92 ¹⁷University of California at Santa Cruz, Institute for Particle Physics, Santa Cruz, California 95064, USA 93 ¹⁸California Institute of Technology, Pasadena, California 91125, USA 94 ¹⁹University of Cincinnati, Cincinnati, Ohio 45221, USA 95 ²⁰ University of Colorado, Boulder, Colorado 80309, USA 96 ²¹Colorado State University, Fort Collins, Colorado 80523, USA 97 ²² Technische Universität Dortmund, Fakultät Physik, D-44221 Dortmund, Germany 98 ²³ Technische Universität Dresden, Institut für Kern- und Teilchenphysik, D-01062 Dresden, Germany 99 ²⁴Laboratoire Leprince-Rinquet, CNRS/IN2P3, Ecole Polytechnique, F-91128 Palaiseau, France 100 ²⁵University of Edinburgh, Edinburgh EH9 3JZ, United Kingdom 101 ²⁶INFN Sezione di Ferrara^a; Dipartimento di Fisica, Università di Ferrara^b, I-44100 Ferrara, Italy 102 ²⁷INFN Laboratori Nazionali di Frascati, I-00044 Frascati, Italy 103 ²⁸INFN Sezione di Genova^a; Dipartimento di Fisica, Università di Genova^b, I-16146 Genova, Italy 104 ²⁹Harvard University, Cambridge, Massachusetts 02138, USA 105

 ³⁷Immbolde Universitä en Berlin, Fusikis Iför Physik, Nestenser, 15, D-12480 Berlin, Germang ³⁷Umiersekty of Iowa, Jona Gily, Jonas 3224, USA ³⁸Umiersekty of Iowa, Jonas Gily, Jonas 3224, USA ³⁵Johns Hopkins University, Maltimore, Maryland 21218, USA ³⁶Johns Hopkins University, Baltimore, Maryland 21218, USA ³⁶University of Liverpool, Licerpool, Licerpool, Leorograv, California 4JSAO, USA ³⁶University of Liverpool, Licerpool, Leorograv, California 4JSAO, USA ³⁷Umiersetty of Liverpool, Licerpool, Leorograv, Licerpool, Kongolom ³⁶University of Liverpool, Licerpool, Leorograv, Liverpool, Kongolom ³⁶University of Liverpool, Licerpool, Leorograv, Way, United Kingdom ³⁶University of Liversity, Indiana, Kinkitä Jör Kenryhpsik, D-55009 Mains, Germany ⁴⁴University of Maryland, College Park, Maryland 20748, USA ⁴⁴University of Maryland, College Park, Maryland 20748, USA ⁴⁵University of Maryland, College Park, Maryland 20748, USA ⁴⁶University of Maryland, College, Connol Halley, Massachastis 00139, USA ⁴⁶Massachusets, Antherst, Massachusets 10013, UIAA ⁴⁷Massachusets, Mantrid, Quebec, Connol HAJ 219 ⁴⁸INFN Secione & Napoli, Peliciro J, Jourison K, Maryland J, Leola J, Jourison Laboratory, Markaley, Massachusets 10013, USA ⁴⁶INFN Secione & Napoli, Peliciro J, Jourison Laboratory, Markaley, Massachusets 10013, USA ⁴⁶INFN Secione & Napoli, Peliciro J, Jourison Markaley, Massachusets 10013, USA ⁴⁶INFN Secione & Napoli, Peliciro J, Jourison Markaley, Massachusets 10013, USA ⁴⁶INFN S	³⁰ Universität Heidelberg, Physikalisches Institut, Philosophenweg 12, D-69120 Heidelberg, Germany	106
 ¹⁰ ¹⁰ ¹⁰ ¹⁰ ¹⁰ ¹⁰ ¹⁰ ¹⁰	³¹ Humboldt-Universität zu Berlin, Institut für Physik, Newtonstr. 15. D-12/489 Berlin, Germany	107
 ⁴⁰ Diversity of Lows Jones (2014). USA ⁴¹ Jones State University, Markano Lowa Jones Jone Jones Jones Jones Jones Jones Jones Jones Jones Jone Jones J	³² Imperial College London, London, SW7 2AZ, United Kingdom	108
 ³⁴Itona State University, Ames, Towa 50011-5160, USA ³⁵Johos Hopkins University, Billimore, Maryland 21218, USA ³⁶Laboratoire de l'Accilérateur Lindeire, IN2P3/CNRS et Université Paris-Sul II, ³⁷Causrence Inversors National Laboratory, Livermore, California 94530, USA ³⁶University of London, F.J. (ANS, University of London, National Laboratory, Livermore, California 94530, USA ³⁷Causrence Inversors National Laboratory, Livermore, California 94530, USA ⁴⁹University of London, London, P.I. (ANS, United Kingdom ⁴⁹University of London, London, RI (ANS, United Kingdom ⁴⁰University of Maryland, College Park, Maryland 20742, USA ⁴⁴Johannes Gatenberg-Universitäl Mainz, Institut für Kernphysik, D-50099 Maina, Germany ⁴⁴University of Maryland, College Park, Maryland 20742, USA ⁴⁵University of Maryland, College Park, Maryland 20742, USA ⁴⁶Massachusetts, Aniheester, Manerst, Massachusetts Aniheester Mis 2014, United Kingdom ⁴⁷Massachusetts Intersity, Manerst, Massachusetts Aniheester Mis 2014, USA ⁴⁸Massachusetts Aniheester, Manerst, Massachusetts 01219, USA ⁴⁹Intersity of Massachusetts, Aniheest, Massachusetts 01219, USA ⁴⁹Intersity of Massachusetts, Montrida, Québec, Canada HSO 217 ⁴⁹Intersity of Massachusetts, Montrida, Québec, Canada HSO 217 ⁴⁰Diversity of Oxore, Bagen, Orago 1705, USA ⁴⁰INT Besione di Napoli?, Dipartimento di Science, Fisiche, University of Nabassisty, University, Manerico IF, I-S012 Napoli, Italy ⁴³INFN Secione di Napoli?, Colange, South Jana, 40550, USA ⁴⁴INFN Secione di Napoli?, Dipartimento di Science, Pisiche, University of Nabaschusetts 0173 ⁴⁵INFN Secione di Napoli?, Dipartimento di Science, Pisiche, USA ⁴⁶INFN Secione di Napoli?, Dipartimen	³³ University of Iowa, Iowa City, Iowa 52242, USA	109
 ⁴⁰ Johns Hopkins University, Baltimore, Maryland 2218, USA ⁴⁰ Ilaboratione de l'Accélicateur Lincánu, INP39/CINRS et University Pars-Sud 11, un Centre Scientifique d'Orsay, B. P. 34, F-91898 Orsay Cedez, France ⁴⁰ University of Linemool, Lincerpool L69 72E, United Kingdom ⁴⁰ University of London, Royal Bolloway and Belford New College, Falsam, Surry TW20 0EX, United Kingdom ⁴⁰ University of London, Royal Bolloway and Belford New College, Falsam, Surry TW20 0EX, United Kingdom ⁴¹ University of Manchester. Manchester M13 9FL, United Kingdom ⁴² University of Maryland, College Park, Maryland 2012, USA ⁴⁴ University of Maryland, College Park, Maryland 2012, USA ⁴⁵ University of Maryland, College Park, Maryland 2014, USA ⁴⁶ University, of Maryland, College Park, Maryland 2014, USA ⁴⁷ University of Maryland, College Park, Maryland 2014, USA ⁴⁸ Massachusetts Institute of Technology, Loboratory for Nuclear Science, Cambridge, Messachusetts 02159, USA ⁴⁴ Mussachusetts Institute of Technology, Loboratory for Nuclear Science, Cambridge, Messachusetts 02159, USA ⁴⁴ Mussachusetts Institute of Technology, Loboratory for Nuclear Science, Cambridge, Massachusetts 02159, USA ⁴⁵ University of Mississippi, University, Mississippi 38677, USA ⁴⁶ University of Mississippi, University, Mississippi, SB677, USA ⁴⁷ Mount Holyoke College, South Hadley, Massachusetts 01075, USA ⁴⁶ University of Naber Darae, Nate Dame, Indiana 46556, USA ⁴⁷ University of Naber Darae, Nate Dame, Indiana 46556, USA ⁴⁶ University of Naber Darae, Nate Dame, Indiana 46556, USA ⁴⁷ University of Dargon, Fagene, Orgon 97403, USA ⁴⁶ University of Dargon, Fagene, Orgon 97403, USA ⁴⁶ University of Dargon, Fagene, Orgon 97403, USA	³⁴ Iowa State University. Ames. Iowa 50011-3160. USA	110
 ⁴⁶Laboratorie de l'Arcidimeter Linéane, INPERJCARÉ et Université Paris-But 11, Centre Scientifique (Orsay, B. P. 34, F-9188 Drosay Celex, France ⁴⁷University of London, National Laboratory, Livermore, California 94550, USA ⁴⁸Queen, Mary, University of London, London, FI 4/85, United Kingdom ⁴⁹Queen, Mary, University of London, London, FI 4/85, United Kingdom ⁴⁰University of London, London, FI 4/85, United Kingdom ⁴¹University of Manchester, Manchester MIS 90PL, United Kingdom ⁴⁴University of Manchester, Manchester MIS 90PL, United Kingdom ⁴⁴University of Manchester, Manchester MIS 90PL, United Kingdom ⁴⁵University of Masschusetts, Amherst, Masschusetts 01005, USA ⁴⁶Massachusetts, Annherst, Masschusetts 01005, USA ⁴⁶Massachusetts, Manchester, Juneersity, Mansachusetts 02139, USA ⁴⁶Massachusetts, Manchest, Quebec, Canada USA 217, USA ⁴⁶Massachusetts, Manchest, Masschusetts 02139, USA ⁴⁶Mossichin, University, Manchest, Masschusetts 0105, USA ⁴⁶Massachusetts and Milano⁷, Dipartimento di Fisica, University di Manghane, Hally ⁴⁷INFN Sezione di Mapali', Dipartimento di Science, Evische, University of Manghali, Masschusetts 0175, USA ⁴⁶Masschusetts of Norbe Dane, Norbe Dane, Norbe Dane, Norbe Dane, Norbe Jane, Nor	³⁵ Johns Hopkins University, Baltimore, Maruland 21218, USA	111
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 ⁹⁴Lawrence Livernoft. National Laboratory. Liverstrover, California (1456), USA ⁹⁶Queen Mary, University of London, London, EI (NS, United Kingdom ⁹⁶Queen Mary, University of London, London, EI (NS, United Kingdom ⁹⁶University of London, Royal Holloway and Bedford New College, Egham, Surrey TW20 0EX, United Kingdom ⁹⁷University of Lonisville, Kentucky (J292, USA ⁹⁴University of Margland, College Park, Margland 20712, USA ⁹⁴University of Masschusetts, Nanchester M13 PPL, United Kingdom ⁹⁴University of Masschusetts, University, Minoschusetts 02139, USA ⁹⁴Messechusetts Institute of Technology, Laboratory for Nuclear Science, Canabridge, Massachusetts 0103, USA ⁹⁴Messechusetts Institute of Technology, College Science, Canaba H3A 278 ⁹⁴Mersensite de Maland': Dipartimento di Fisica, University, Minos, Hally ⁹⁴University of Mississipi, University, Mississipi, 38677, USA ⁹⁵University of Margland Kellege, South Hadley, Masschusetts 10175, USA ⁹⁵University of Napolf': Dipartimento di Scienze Fische, ⁹⁵NiKHEF, National Institute for Nuclear Physics and High Energy Physics, N-1009 DB Amsterdam, The Netherlands ⁹⁵Ohio State University, Columbus, Ohio 4210, USA ⁹⁵Ohio Sta	Centre Scientifique d'Orsay, B. P. 34, F-91898 Orsay Cedex, France	113
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In a search for $B \to c\bar{c}\gamma K$ decays, where $c\bar{c}$ includes J/ψ and $\psi(2S)$, and K includes charged, neutral and excited $(K^*(892))$ kaons, we find evidence for the radiative decays $X(3872) \to J/\psi\gamma$ and $X(3872) \to \psi(2S)\gamma$ with a statistical significance of 3.8σ and 3.2σ respectively. We measure the product of branching fractions $\mathcal{B}(B^{\pm} \to X(3872)K^{\pm}) \cdot \mathcal{B}(X(3872) \to J/\psi\gamma) = (2.9 \pm 0.8 \pm 0.2) \times 10^{-6}$ and $\mathcal{B}(B^{\pm} \to X(3872)K^{\pm}) \cdot \mathcal{B}(X(3872) \to \psi(2S)\gamma) = (8.5 \pm 2.8 \pm 1.0) \times 10^{-6}$ where the uncertainties are statistical and systematic, respectively. These results are obtained from (465 ± 5) million $B\bar{B}$ decays collected at the $\Upsilon(4S)$ resonance with the *BABAR* detector at the PEP-II *B* Factory at SLAC.

The X(3872) state discovered by the Belle Collabora-163 tion in the decay $B^{\pm} \to K^{\pm}\pi^{+}\pi^{-}J/\psi$ [1] is now well 164 established [2]. It has recently been observed decaying 165 to $\overline{D}{}^{0}D^{*0}$ [3]. BABAR has also seen evidence for the de-166 cay $X(3872) \rightarrow J/\psi \gamma$, a result which implies positive 167 C-parity [4]. An angular analysis performed by CDF [5] 168 indicates that the X(3872) state has a quantum number 169 assignment $J^{PC} = 1^{++}$ or 2^{-+} . 170

A variety of theoretical interpretations [6] exist for 171 the X(3872), including exotic QCD proposals such as 172 a $\overline{D}{}^{0}D^{*0}$ molecule [7], or a diquark-antidiquark state 173 [8]. The X(3872) is not considered to be a conventional 174 charmonium state since the only two obvious options, 175 $\chi_{c1}(2^3P_1)$ or $\eta_{c2}(1^1D_2)$, are disfavored by its low mass 176 and its decay to $J/\psi\gamma$, respectively. While $\overline{D}{}^0D^{*0}$ molec-177 ular proposals can accommodate decays to $J/\psi \gamma$, decays 178 to $\psi(2S)\gamma$ are presupposed to proceed via annihilation 179 of the $u\overline{u}$ quarks, for which the branching fraction is ex-180 pected to be very small [10]. The $\chi_{c1}(2P)$ state could 181 potentially decay to $\psi(2S)\gamma$ at a rate many times higher 182 than to $J/\psi \gamma$ [9]. 183

We present a study of the decay $B \rightarrow XK$, where 184 the notation X represents any state decaying radiatively 185 to $J/\psi\gamma$ or $\psi(2S)\gamma$ (the $\chi_{c1,2}$ and X(3872) states in 186 particular), and K encompasses K^{\pm} , K_{s}^{0} , $K^{*\pm}$ (892) 187 and K^{*0} (892). We consider J/ψ decaying to e^+e^- or 188 $\mu^+\mu^-$, and $\psi(2S)$ decaying to e^+e^- , $\mu^+\mu^-$ or $J/\psi\pi^+\pi^-$. 189 Kaons are required to decay to final states consisting of 190 charged particles; $K_s^0 \to \pi^+ \pi^-, \ K^{*\pm} \to K_s^0 (\pi^+ \pi^-) \pi^{\pm},$ 191 and $K^{*0} \to K^{\pm} \pi^{\mp}$. 192

¹⁹³ The data sample for this analysis consists of (465 ± 5) ¹⁹⁴ million $B\overline{B}$ pairs collected with the BABAR detector at ¹⁹⁵ the PEP-II asymmetric e^+e^- collider. This represents ¹⁹⁶ 424 fb⁻¹ of data taken at the $\Upsilon(4S)$ resonance. The ¹⁹⁷ BABAR detector is described in detail elsewhere [11].

The choice for most of the selection criteria values is optimized using simulated Monte Carlo (MC) samples by maximizing $n_{\rm S}/\sqrt{n_{\rm S}+n_{\rm B}}$, where $n_{\rm S}$ and $n_{\rm B}$ are numbers of signal and background events, respectively. For purposes of optimization, we make the assumption that the branching fractions for X(3872) to $J/\psi\gamma$ and $\psi(2S)\gamma$ are the same and equal to the previous measurement [4].

The $J/\psi \rightarrow e^+e^-$ candidates are formed with 205 electrons (and bremsstrahlung photons) with 2.96 <206 $m(e^+e^-(\gamma)) < 3.15 \text{ GeV}/c^2$. Candidates for $J/\psi \rightarrow$ 207 $\mu^+\mu^-$ require a muon pair with 3.06 < $m(\mu^+\mu^-)$ < 208 3.13 GeV/ c^2 . The $\psi(2S) \rightarrow \ell^+ \ell^-$ candidates are 209 reconstructed in a similar manner, requiring 3.61 <210 $m(e^+e^-(\gamma)) < 3.73 \text{ GeV}/c^2 \text{ and } 3.65 < m(\mu^+\mu^-) < 3.72$ 211 GeV/ c^2 . The $\psi(2S) \rightarrow J/\psi \pi^+\pi^-$ candidates are com-212 posed of J/ψ candidates decaying as described but with 213 a tighter mass requirement of $3.01 < m(e^+e^-(\gamma)) < 3.15$ 214 GeV/c^2 . To form a $\psi(2S)$, the J/ψ candidate is mass-215

constrained to the nominal PDG value [12] and combined with a pair of oppositely charged tracks requiring 0.4 < $m(\pi^+\pi^-) < 0.6 \text{ GeV}/c^2$, 3.68 < $m(J/\psi \pi^+\pi^-) < 3.69 \text{ GeV}/c^2$, and all three particles to be constrained to the same decay vertex.

The $X \to c\overline{c}\gamma$ candidate is reconstructed from a massconstrained J/ψ ($\psi(2S)$) candidate combined with a photon with an energy E_{γ} greater than 30(100) MeV. Additional selection criteria are applied to the shape of the lateral distribution (0.001 < LAT < 0.5) [13] and azimuthal asymmetry (as measured by the Zernike moment ($A_{42} < 0.1$)[14]) of the photon-shower energy deposited in the electromagnetic calorimeter. For $X \to J/\psi\gamma$, the radiative γ candidate is rejected if, when combined with any other γ from the event, it has an invariant mass consistent with the π^0 mass, $124 < m_{\gamma\gamma} < 146 \, \text{MeV}/c^2$.

The K_s^0 candidates are reconstructed from the decay to oppositely charged tracks within $\pm 17 \text{ MeV}/c^2$ of the nominal K_s^0 mass [12], and the significance of the distance of the reconstructed vertex from the primary vertex must be > 3.7σ . The charged excited kaons, $K^{*\pm}$ (892), are reconstructed from their decay to $K_s^0\pi^{\pm}$, with K_s^0 candidates as defined above. Neutral excited kaons, K^{*0} (892), are reconstructed from their decay to $K_s^0\pi^{\pm}$, with K_s^0 candidates as defined above. Neutral excited kaons, K^{*0} (892), are reconstructed from their decay to $K^{\pm}\pi^{\mp}$. The excited kaons are required to fall within the mass range $0.7 < m(K^*) < 1.1 \text{ GeV}/c^2$. For K_s^0 , $K^{*\pm}$, and K^{*0} candidates associated with $X \to \psi(2S)\gamma$, additional requirements are placed on their χ^2 vertex probability, $P(\chi^2) > 0.001, > 0.02$ and > 0.002, respectively.

The final B candidate is formed from an X candidate 245 and a kaon constrained to the same vertex. To identify 246 B candidates, we use two kinematic variables, m_B and 247 $m_{\rm miss}$. The unconstrained mass of the reconstructed B candidate $m_B = \sqrt{E_B^2/c^4 - p_B^2}$, where E_B and p_B are 248 249 obtained by summing the energies and momenta of the 250 particles in the candidate B meson. The missing mass is 251 defined through $m_{\text{miss}} = \sqrt{(p_{e^+e^-} - \hat{p}_B)^2}$, where $p_{e^+e^-}$ is the four-momentum of the beam e^+e^- system and \hat{p}_B 252 253 is the four-momentum of the B candidate after applying 254 a B mass constraint. These variables are uncorrelated 255 by construction, and are advantageous for analyzing B256 decays in which a particle in the final state has poorly 257 measured energy (e.g., a photon). Events with a cor-258 rectly reconstructed B decay should have values equal 259 to the nominal B mass [12] for both kinematic variables. 260 A loose requirement of $5.2 < m_{\rm miss} < 5.3 \,{\rm GeV}/c^2$ for B 261 candidates is applied. For $X \to J/\psi (\psi(2S))\gamma$ events, we require m_B to be within $^{+30}_{-36} (\pm 20) \text{ MeV}/c^2$ of the nom-262 263 inal B mass [12]. Our B candidate selection is further 264 refined by imposing criteria on the χ^2 probability for the 265 B vertex; for all $X \to J/\psi \gamma$ modes $P(\chi^2) > 0.0001$, 266 and for $X \to \psi(2S)\gamma$ modes, $P(\chi^2) > 0.01$ for the K^{\pm} 267 mode, > 0.002 for the K_s^0 mode, and > 0.05 for both K^* 268

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modes. The ratio of the second and zeroth Fox-Wolfram moments ($R_2 < 0.45$) [15] is used to separate isotropic *B* events from typically anisotropic continuum background events. Once a *B* candidate has been established, it and its daughter decays are refit with the *B* mass constrained to the known value [12].

We perform a one(two)-dimensional unbinned ex-275 tended maximum-likelihood (UML) fit to $m_{\rm miss}$ (and 276 m_{K^*} , if applicable), and then use the Plot formalism 277 [16] to project our signal events into m_X , the invariant 278 mass of the X candidate. The _sPlot of the UML fit dis-279 plays the number of $B \to XK$ signal-like events as a 280 function of m_X . We extract the number of signal events 281 for a given decay mode by fitting this resultant m_X distri-282 bution with MC-determined Gaussian shapes for signal 283 events plus a linear shape to account for peaking back-284 ground events. Only the height of the Gaussian peak 285 and the parameters of the linear component are allowed 286 to float in the fit to m_X . 287

The signal event probability density functions (PDFs) 288 are determined from MC-simulated $B \rightarrow \chi_{c1} K$ and $B \rightarrow$ 289 X(3872)K events. Only reconstructed events matching 290 the true generated decay chain particles are used to pa-291 rameterize the signal PDFs. The $m_{\rm miss}$ distribution is 292 modeled with a Crystal Ball function [17], m_X with a 293 single Gaussian for the χ_{c2} decay modes and narrower 294 "core" Gaussian plus a second wider Gaussian sharing 295 the same mean for all other signal modes, and m_{K^*} with 296 the convolution of a Breit-Wigner and a Gaussian. The 297 PDF shapes for $B \to \chi_{c2} K$ are taken to be the same as 298 χ_{c1} , with the exception of the m_X distribution. 299

The background PDFs are fitted to events from generic 300 B^+B^- , $B^0\overline{B}^0$, $q\overline{q}$ (q = u, d, s, c), and $\tau^+\tau^-$ MC samples. 301 The backgrounds are dominated by events from $B\overline{B}$ de-302 cays that include a J/ψ or $\psi(2S)$ in their decay chain. 303 Based on MC, the important backgrounds to the X(3872)304 decay modes are found to be of the type $B \to J/\psi K^{(*)}(\pi)$ 305 and $B \rightarrow \psi(2S) K^{(*)}(\pi)$, where a random photon is 306 picked up by the reconstruction and/or a pion is lost or 307 gained in the reconstruction. "Cross feed" events where 308 one signal mode is misreconstructed as another (mainly 309 K plus π to form K^* , or vice versa), are found to be 310 a negligible source of background. Background from the 311 misreconstruction of $X(3872) \rightarrow J/\psi \pi^+\pi^-$ decays is also 312 found to be negligible. 313

For the $B^{\pm} \to XK^{\pm}$ and $B^0 \to XK_s^0$ decay modes, the background in $m_{\rm miss}$ consists of two parts: a "flat" combinatoric component modeled with an ARGUS function [18], and a peaking component that shares the Crystal Ball parameterization used for signal events. These backgrounds are modeled as linear in m_X .

The K^* decay modes have three background components: events that peak in m_{miss} but are flat in m_{K^*} ("non-resonant") and vice versa (" K^* combinatoric"), and those that do not peak in either distribution ("combinatoric"). The peaking m_{miss} and m_{K^*} distributions use the same parameterization and values found by fitting for the signal modes. The non-peaking m_{miss} distributions are fit with an ARGUS function, while the non-peaking m_{K^*} distribution is modeled with a linear function. The two combinatoric background types are similarly flat in m_X , while the non-resonant backgrounds, typically $B \to XK\pi$, have both a flat and peaking component in m_X . However, because these non-resonant events are not signal-like in both m_{miss} and m_{K^*} , they are not present in the _sPlot projection in m_X .

The effectiveness of the signal extraction method is validated on MC samples for $\chi_{c1,2}$ and X(3872) signal events, and toy samples generated from the MC background distribution. Successful performance of the fit is verified on simulated datasets assuming $n_{\rm S}$ and $n_{\rm B}$ from the known branching fractions and efficiencies. For the X(3872) and χ_{c2} modes, we test the signal extraction covering the range from a null result up to the $\mathcal{B}(B \rightarrow$ $\chi_{c2}K)$ upper limits [12] or using $\mathcal{B}(X(3872) \rightarrow \psi(2S)\gamma)$ several times higher than $\mathcal{B}(X(3872) \rightarrow J/\psi\gamma)$. Small biases found in the results of the MC fit validation are applied as a correction to the determination of the efficiency and final results.

The efficiency is determined by calculating the fraction of the events generated in MC simulation that survive the analysis selection criteria and are returned by the fitting procedure. Standard *BABAR* corrections are applied to account for particle identification differences found between simulation and data. These corrections are at the level of a few percent. The efficiencies for each mode are given in Table I.

We calculate the branching fraction for each decay mode using $\mathcal{B}(B \to XK) = N_S/(N_{B\overline{B}} \times \epsilon \times f)$ where N_S is the bias-corrected number of signal events from the fit to the m_X sPlot, $N_{B\overline{B}}$ is the number of $B\overline{B}$ pairs in the data set, ϵ is the total signal extraction efficiency, and f represents all secondary branching fractions. The fit results and derived branching fractions are summarized in Table I.

For $\mathcal{B}(B \to \chi_{c1}K)$, the largest source of systematic uncertainty is due to the uncertainties on the secondary branching fractions beyond the control of this analysis (~ 6%); the second-most is uncertainty associated with particle identification (~ 4%). In the case of $B^0 \to \chi_{c2}K^{*0}$, the largest systematic error by far comes from a lack of adequate MC for determining the fit efficiency (~ 20%). For the remaining $B \to \chi_{c2}K$ and $B \to X(3872)K$ decay modes, statistical uncertainty tends to completely dominate systematic effects. For $X(3872) \to J/\psi\gamma$, the largest source of systematic uncertainty is due to uncertainties associated with particle identification (~ 4%). The predominant systematic uncertainty for $X(3872) \to \psi(2S)\gamma$ comes from MC/data differences in modeling the background m_{miss} and m_X shapes (~ 11%).

Figure 1 shows the fit to m_X in the mass range 379 3.411 $< m_X < 3.611$ GeV/ c^2 . We observe all of the ex-

TABLE I: Summary of the analysis results. N_S is the biascorrected number of signal events extracted from the m_X $_s$ Plot, σ is the statistical significance defined as square root of the difference in χ^2 values between the fit result to the data and a result assuming zero signal events, ϵ is the total efficiency for the decay mode, and Derived \mathcal{B} is the measurement (with 90% confidence level upper limit in parentheses) of $\mathcal{B}(B \to \chi_{c1,2}K)$ or $\mathcal{B}(B \to X(3872)K) \cdot \mathcal{B}(X \to c\bar{c}\gamma)$ with statistical and systematic uncertainty.

			(0.4)	
Decay Mode	N_S	σ	$\epsilon(\%)$	Derived \mathcal{B}
χ_{c1}				$\times 10^{-4}$
$\chi_{c1}K^{\pm}$	1021 ± 35	31	11.0	$4.6 \pm 0.2 \pm 0.3$
$\chi_{c1}K^0$	242 ± 16	14	8.7	$4.1\pm0.3\pm0.3$
$\chi_{c1}K^{*\pm}$	71 ± 13	4.9	5.7	$2.7\pm0.5\pm0.3$
$\chi_{c1}K^{*0}$	255 ± 25	11	7.9	$2.5\pm0.2\pm0.2$
χ_{c2}				$\times 10^{-5}$
$\chi_{c2}K^{\pm}$	14.4 ± 7.7	1.8	12.3	$1.0 \pm 0.6 \pm 0.3 (< 1.8)$
$\chi_{c2}K^0$	6.5 ± 3.9	0.6	11.0	$1.5 \pm 0.9 \pm 0.3 (< 2.8)$
$\chi_{c2}K^{*\pm}$	1.4 ± 4.7	0.2	4.2	$1.2 \pm 4.3 \pm 6.2 (< 13)$
$\chi_{c2}K^{*0}$	40.6 ± 10.5	3.6	8.6	$6.4\pm1.7\pm1.7$
$X(J/\psi \gamma)$				$\times 10^{-6}$
$X(3872)K^{\pm}$	23.3 ± 6.4	3.8	14.5	$2.9 \pm 0.8 \pm 0.2$
$X(3872)K^{0}$	5.4 ± 3.6	1.4	11.0	$2.6 \pm 1.7 \pm 0.2 (< 4.9)$
$X(3872)K^{*\pm}$	0.6 ± 2.3	0.0	6.9	$0.7 \pm 2.6 \pm 0.1 (< 4.7)$
$X(3872)K^{*0}$	2.8 ± 5.2	0.8	10.4	$0.7 \pm 1.4 \pm 0.1 (< 2.8)$
$X(\psi(2S)\gamma)$				$\times 10^{-6}$
$X(3872)K^{\pm}$	21.9 ± 7.2	3.2	10.4	$8.5 \pm 2.8 \pm 1.0$
$X(3872)K^{0}$	8.0 ± 3.8	2.0	8.4	$11.5 \pm 5.5 \pm 1.1 (< 19)$
$X(3872)K^{*\pm}$	1.6 ± 3.0	0.6	5.0	$5.5 \pm 10.4 \pm 8.4 (< 21)$
$X(3872)K^{*0}$	-1.4 ± 3.3	—	6.7	$-1.3 \pm 3.1 \pm 0.5 (< 4.4)$

pected $B \to \chi_{c1} K$ decay modes and find good agreement with previous measurements, in all cases improving upon the existing results. We find 3.6σ statistical evidence for $B^0 \to \chi_{c2} K^{*0}$, and set upper limits for the remaining $B \to \chi_{c2} K$ decays.

Fits to m_X in the range $3.772 < m_X < 3.972$ 386 GeV/c^2 are shown in Fig. 2 for decays to $J/\psi\gamma$. We 387 confirm evidence for the decay $X(3872) \rightarrow J/\psi \gamma$ in 388 $B^{\pm} \to X(3872)K^{\pm}$, measuring $\mathcal{B}(B^{\pm} \to X(3872)K^{\pm})$. 389 $\mathcal{B}(X(3872) \rightarrow J/\psi\gamma) = (2.9 \pm 0.8(stat.) \pm 0.2(syst.)) \times$ 390 10^{-6} with a significance of 3.8σ . This value is in good 391 agreement with the previous BABAR result [4], which it 392 supersedes, and represents the best measurement of this 393 branching fraction to date. We find no significant signal 394 for $B \to X(3872)K, X(3872) \to J/\psi \gamma$ in the other decay 395 modes. 396

Figure 3 shows the fit to the m_X distribution for $X \rightarrow$ 397 $\psi(2S)\gamma$ in the range $3.772 < m_X < 3.972$ GeV/ c^2 . In our 398 search for $X(3872) \rightarrow \psi(2S)\gamma$ in $B^{\pm} \rightarrow X(3872)K^{\pm}$, we 399 find the first evidence for this decay with a significance 400 of 3.2 σ . We derive $\mathcal{B}(B^{\pm} \to X(3872)K^{\pm}) \cdot \mathcal{B}(X(3872) \to$ 401 $\psi(2S)\gamma) = (8.5 \pm 2.8(stat.) \pm 1.0(syst.)) \times 10^{-6}$. We find 402 no significant results in any of the other decays modes in 403 this search. 404

405 Finally, in Fig. 4, we present the m_X distribution



FIG. 1: _sPlot projection of the number of signal events versus m_X for (a) $B^{\pm} \rightarrow \chi_{c1,2}K^{\pm}$, (b) $B^0 \rightarrow \chi_{c1,2}K^0_S$, (c) $B^{\pm} \rightarrow \chi_{c1,2}K^{*\pm}$, and (d) $B^0 \rightarrow \chi_{c1,2}K^{*0}$. The solid curve is the fit to the data.



FIG. 2: _sPlot projection of the number of extracted signal events versus m_X for (a) $B^{\pm} \to X(3872)K^{\pm}$, (b) $B^0 \to X(3872)K^{\$}$, (c) $B^{\pm} \to X(3872)K^{*\pm}$, and (d) $B^0 \to X(3872)K^{*0}$, where $X(3872) \to J/\psi \gamma$. The solid curve is the fit to the data.

above $3.8 \,\text{GeV}/c^2$. The results from all decay modes in this analysis have been summed together without correcting for branching fractions or efficiency. While the X(3872) signal features prominently, there are no indications of any other signals.



FIG. 3: _sPlot projection of the number of extracted signal events versus m_X for (a) $B^{\pm} \to X(3872)K^{\pm}$, (b) $B^0 \to X(3872)K_s^0$, (c) $B^{\pm} \to X(3872)K^{*\pm}$, and (d) $B^0 \to X(3872)K^{*0}$, where $X(3872) \to \psi(2S)\gamma$. The solid curve is the fit to the data.



FIG. 4: _sPlot projection for the entire m_X range above $3.8 \text{ GeV}/c^2$, summing all modes in this analysis.

In summary, we present first evidence for the decay 411 $X(3872) \rightarrow \psi(2S)\gamma$ in $B^{\pm} \rightarrow X(3872)K^{\pm}$, and updated 412 measurements of the $X(3872) \rightarrow J/\psi \gamma$, and $B \rightarrow \chi_{c1,2}K$ 413 decays. We find evidence of $B^0 \to \chi_{c2} K^{*0}$, an expect-414 edly factorization-suppressed decay [19], although we see 415 no evidence for decays of this type in the other $\chi_{c2}K$ 416 decay modes. Taking the statistical and systematic er-417 rors in quadrature, we find a ratio of $\frac{\mathcal{B}(X(38\tilde{7}2) \rightarrow \psi(2S)\gamma)}{\mathcal{B}(X(38\tilde{7}2) \rightarrow J/\psi\gamma)} =$ 418 3.0 ± 1.3 . Comparing to the branching fraction $\mathcal{B}(B^{\pm} \rightarrow$ 419 $X(3872)K^{\pm}$ [20] with the errors again in quadrature, 420 we find the ratios $\frac{\mathcal{B}(X(3872) \rightarrow J/\psi \gamma)}{\mathcal{B}(X(3872) \rightarrow J/\psi \pi^+\pi^-)} = 0.3 \pm 0.1$ and 421 $\frac{\mathcal{B}(X(3872) \rightarrow \psi(2S)\gamma)}{\mathcal{B}(X(3872) \rightarrow J/\psi \pi^+\pi^-)} = 1.0 \pm 0.4.$ This relatively large 422

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branching fraction for $X(3872) \rightarrow \psi(2S)\gamma$ is generally inconsistent with $\overline{D}{}^{0}D^{*0}$ molecular interpretations of the X(3872), and could indicate a significant amount of $c\overline{c}$ - $\overline{D}{}^{0}D^{*0}$ mixing [9].

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