

Physics

Physics Research Publications

Purdue University

Year 2008

Observation of the decay $B_c(+/-) \rightarrow J/\psi \pi(+/-)$ and measurement of the $B_c(+/-)$ mass

T. Aaltonen, J. Adelman, T. Akimoto, M. G. Albrow, B. A. Gonzalez, S. Amerio, D. Amidei, A. Anastassov, A. Annovi, J. Antos, M. Aoki, G. Apollinari, A. Apresyan, T. Arisawa, A. Artikov, W. Ashmanskas, A. Attal, A. Aurisano, F. Azfar, P. Azzi-Bacchetta, P. Azzurri, N. Bacchetta, W. Badgett, A. Barbaro-Galtieri, V. E. Barnes, B. A. Barnett, S. Baroiant, V. Bartsch, G. Bauer, P. H. Beauchemin, F. Bedeschi, P. Bednar, S. Behari, G. Bellettini, J. Bellinger, A. Belloni, D. Benjamin, A. Beretvas, J. Beringer, T. Berry, A. Bhatti, M. Binkley, D. Bisello, I. Bizjak, R. E. Blair, C. Blocker, B. Blumenfeld, A. Bocci, A. Bodek, V. Boisvert, G. Bolla, A. Bolshov, D. Bortoletto, J. Boudreau, A. Boveia, B. Brau, A. Bridgeman, L. Brigliadori, C. Bromberg, E. Brubaker, J. Budagov, H. S. Budd, S. Budd, K. Burkett, G. Busetto, P. Bussey, A. Buzatu, K. L. Byrum, S. Cabrera, M. Campanelli, M. Campbell, F. Canelli, A. Canepa, D. Carlsmith, R. Carosi, S. Carrillo, S. Carron, B. Casal, M. Casarsa, A. Castro, P. Catastini, D. Cauz, M. Cavalli-Sforza, A. Cerri, L. Cerrito, S. H. Chang, Y. C. Chen, M. Chertok, G. Chiarelli, G. Chlachidze, F. Chlebana, K. Cho, D. Chokheli, J. P. Chou, G. Choudalakis, S. H. Chuang, K. Chung, W. H. Chung, Y. S. Chung, C. I. Ciobanu, M. A. Ciocci, A. Clark, D. Clark, G. Compostella, M. E. Convery, J. Conway, B. Cooper, K. Copic, M. Cordelli, G. Cortiana, F. Crescioli, C. C. Almenar, J. Cuevas, R. Culbertson, J. C. Cully, D. Dagenhart, M. Datta, T. Davies, P. de Barbaro, S. De Cecco, A. Deisher, G. De Lentdecker, G. De Lorenzo, M. Dell'Orso, L. Demortier, J. Deng, M. Deninno, D. De Pedis, P. F. Derwent, G. P. Di Giovanni, C. Dionisi, B. Di Ruzza, J. R. Dittmann, M. D'Onofrio, S. Donati, P. Dong, J. Donini, T. Dorigo, S. Dube, J. Efron, R. Erbacher, D. Errede, S. Errede, R. Eusebi, H. C. Fang, S. Farrington, W. T. Fedorko, R. G. Feild, M. Feindt, J. P. Fernandez, C. Ferrazza, R. Field, G. Flanagan, R. Forrest, S. Forrester, M. Franklin, J. C. Freeman, I. Furic, M. Gallinaro, J. Galyardt, F. Garbersson, J. E. Garcia, A. F. Garfinkel, K. Genser, H. Gerberich, D. Gerdes, S. Giagu, V. Giakoumopolou, P. Giannetti, K. Gibson, J. L. Gimmell, C. M. Ginsburg, N. Giokaris, M. Giordani, P. Giromini, M.

Giunta, V. Glagolev, D. Glenzinski, M. Gold, N. Goldschmidt, A. Golossanov, G. Gomez, G. Gomez-Ceballos, M. Goncharov, O. Gonzalez, I. Gorelov, A. T. Goshaw, K. Goulianos, A. Gresele, S. Grinstein, C. Grosso-Pilcher, R. C. Group, U. Grundler, J. G. da Costa, Z. Gunay-Unalan, C. Haber, K. Hahn, S. R. Hahn, E. Halkiadakis, A. Hamilton, B. Y. Han, J. Y. Han, R. Handler, F. Happacher, K. Hara, D. Hare, M. Hare, S. Harper, R. F. Harr, R. M. Harris, M. Hartz, K. Hatakeyama, J. Hauser, C. Hays, M. Heck, A. Heijboer, B. Heinemann, J. Heinrich, C. Henderson, M. Herndon, J. Heuser, S. Hewamanage, D. Hidas, C. S. Hill, D. Hirschbuehl, A. Hocker, S. Hou, M. Houlden, S. C. Hsu, B. T. Huffman, R. E. Hughes, U. Husemann, J. Huston, J. Incandela, G. Introzzi, M. Iori, A. Ivanov, B. Iyutin, E. James, B. Jayatilaka, D. Jeans, E. J. Jeon, S. R. Jindariani, W. Johnson, M. Jones, K. K. Joo, S. Y. Jun, J. E. Jung, T. R. Junk, T. Kamon, D. Kar, P. E. Karchin, Y. Kato, R. Kephart, U. Kerzel, V. Khotilovich, B. Kilminster, D. H. Kim, H. S. Kim, J. E. Kim, M. J. Kim, S. B. Kim, S. H. Kim, Y. K. Kim, N. Kimura, L. Kirsch, S. Klimentenko, M. Klute, B. Knuteson, B. R. Ko, S. A. Koay, K. Kondo, D. J. Kong, J. Konigsberg, A. Korytov, A. V. Kotwal, J. Kraus, M. Kreps, J. Kroll, N. Krumnack, M. Kruse, V. Krutelyov, T. Kubo, S. E. Kuhlmann, T. Kuhr, N. P. Kulkarni, Y. Kusakabe, S. Kwang, A. T. Laasanen, S. Lai, S. Lami, S. Lammel, M. Lancaster, R. L. Lander, K. Lannon, A. Lath, G. Latino, I. Lazzizzera, T. LeCompte, J. Lee, J. Lee, Y. J. Lee, S. W. Lee, R. Lefevre, N. Leonardo, S. Leone, S. Levy, J. D. Lewis, C. Lin, C. S. Lin, J. Linacre, M. Lindgren, E. Lipeles, A. Lister, D. O. Litvintsev, T. Liu, N. S. Lockyer, A. Loginov, M. Loreti, L. Lovas, R. S. Lu, D. Lucchesi, J. Lueck, C. Luci, P. Lujan, P. Lukens, G. Lungu, L. Lyons, J. Lys, R. Lysak, E. Lytken, P. Mack, D. MacQueen, R. Madrak, K. Maeshima, K. Makhoul, T. Maki, P. Maksimovic, S. Malde, S. Malik, G. Manca, A. Manousakis, F. Margaroli, C. Marino, C. P. Marino, A. Martin, M. Martin, V. Martin, M. Martinez, R. Martinez-Ballarín, T. Maruyama, P. Mastrandrea, T. Masubuchi, M. E. Mattson, P. Mazzanti, K. S. McFarland, P. McIntyre, R. McNulty, A. Mehta, P. Mehtala, S. Menzemer, A. Menzione, P. Merkel, C. Mesropian, A. Messina, T. Miao, N. Miladinovic, J. Miles, R. Miller, C. Mills, M. Milnik, A. Mitra, G. Mitselmakher, H. Miyake, S. Moed, N. Moggi, C. S. Moon, R. Moore, M. Morello, P. M. Fernandez, J. Mulmenstadt, A. Mukherjee, T. Muller, R. Mumford, P. Murat, M. Mussini, J. Nachtman, Y. Nagai, A. Nagano, J. Naganoma, K. Nakamura, I. Nakano, A. Napier, V. Necula, C. Neu, M. S. Neubauer, J. Nielsen, L. Nodulman, M. Norman, O. Norriella, E. Nurse, S. H. Oh, Y. D. Oh, I. Oksuzian, T. Okusawa, R. Oldeman, R. Orava, K. Osterberg, S. P. Griso, C. Pagliarone, E. Palencia, V. Papadimitriou, A. Papaikonomou, A. A. Paramonov, B. Parks, S. Pashapour, J. Patrick, G. Pauletta, M. Paulini, C. Paus, D. E. Pellett, A. Penzo, T. J. Phillips, G. Piacentino, J. Piedra, L. Pinera, K. Pitts, C. Plager, L. Pondrom, X. Portell, O. Poukhov, N. Pounder, F. Prakoshyn, A. Pronko, J. Proudfoot, F. Ptohos, G. Punzi, J. Pursley, J. Rademacker, A. Rahaman, V. Ramakrishnan, N. Ranjan, I. Redondo, B. Reisert, V. Rekovic, P. Renton, M. Rescigno, S. Richter, F. Rimondi, L. Ristori, A. Robson, T. Rodrigo, E. Rogers, S. Rolli, R. Roser, M. Rossi, R. Rossin, P. Roy, A. Ruiz, J. Russ, V. Rusu, H. Saarikko, A. Safonov, W. K. Sakumoto, G. Salamanna, O. Salto, L. Santi, S. Sarkar, L. Sartori, K. Sato,

A. Savoy-Navarro, T. Scheidle, P. Schlabach, E. E. Schmidt, M. A. Schmidt, M. P. Schmidt, M. Schmitt, T. Schwarz, L. Scodellaro, A. L. Scott, A. Scribano, F. Scuri, A. Sedov, S. Seidel, Y. Seiya, A. Semenov, L. Sexton-Kennedy, A. Sfyria, S. Z. Shalhout, M. D. Shapiro, T. Shears, P. F. Shepard, D. Sherman, M. Shimojima, M. Shochet, Y. Shon, I. Shreyber, A. Sidoti, P. Sinervo, A. Sisakyan, A. J. Slaughter, J. Slaunwhite, K. Sliwa, J. R. Smith, F. D. Snider, R. Snihur, M. Soderberg, A. Soha, S. Somalwar, V. Sorin, J. Spalding, F. Spinella, T. Spreitzer, P. Squillacioti, M. Stanitzki, R. S. Denis, B. Stelzer, O. Stelzer-Chilton, D. Stentz, J. Strologas, D. Stuart, J. S. Suh, A. Sukhanov, H. Sun, I. Suslov, T. Suzuki, A. Taffard, R. Takashima, Y. Takeuchi, R. Tanaka, M. Tecchio, P. K. Teng, K. Terashi, J. Thom, A. S. Thompson, G. A. Thompson, E. Thomson, P. Tipton, V. Tiwari, S. Tkaczyk, D. Toback, S. Tokar, K. Tollefson, T. Tomura, D. Tonelli, S. Torre, D. Torretta, S. Tournear, W. Trischuk, Y. Tu, N. Turini, F. Ukegawa, S. Uozumi, S. Vallecorsa, N. van Remortel, A. Varganov, E. Vataga, F. Vazquez, G. Velez, C. Vellidis, V. Veszpremi, M. Vidal, R. Vidal, I. Vila, R. Vilar, T. Vine, M. Vogel, I. Volobouev, G. Volpi, F. Wurthwein, P. Wagner, R. G. Wagner, R. L. Wagner, J. Wagner-Kuhr, W. Wagner, T. Wakisaka, R. Wallny, S. M. Wang, A. Warburton, D. Waters, M. Weinberger, W. C. Wester, B. Whitehouse, D. Whiteson, A. B. Wicklund, E. Wicklund, G. Williams, H. H. Williams, P. Wilson, B. L. Winer, P. Wittich, S. Wolbers, C. Wolfe, T. Wright, X. Wu, S. M. Wynne, A. Yagil, K. Yamamoto, J. Yamaoka, T. Yamashita, C. Yang, U. K. Yang, Y. C. Yang, W. M. Yao, G. P. Yeh, J. Yoh, K. Yorita, T. Yoshida, G. B. Yu, I. Yu, S. S. Yu, J. C. Yun, L. Zanello, A. Zanetti, I. Zaw, X. Zhang, Y. Zheng, and S. Zucchelli

This paper is posted at Purdue e-Pubs.

http://docs.lib.purdue.edu/physics_articles/830

Observation of the Decay $B_c^\pm \rightarrow J/\psi\pi^\pm$ and Measurement of the B_c^\pm Mass

T. Aaltonen,²³ J. Adelman,¹³ T. Akimoto,⁵⁴ M. G. Albrow,¹⁷ B. Álvarez González,¹¹ S. Amerio,⁴² D. Amidei,³⁴ A. Anastassov,⁵¹ A. Annovi,¹⁹ J. Antos,¹⁴ M. Aoki,²⁴ G. Apollinari,¹⁷ A. Apresyan,⁴⁷ T. Arisawa,⁵⁶ A. Artikov,¹⁵ W. Ashmanskas,¹⁷ A. Attal,³ A. Aurisano,⁵² F. Azfar,⁴¹ P. Azzi-Bacchetta,⁴² P. Azzurri,⁴⁵ N. Bacchetta,⁴² W. Badgett,¹⁷ A. Barbaro-Galtieri,²⁸ V. E. Barnes,⁴⁷ B. A. Barnett,²⁵ S. Baroiant,⁷ V. Bartsch,³⁰ G. Bauer,³² P.-H. Beauchemin,³³ F. Bedeschi,⁴⁵ P. Bednar,¹⁴ S. Behari,²⁵ G. Bellettini,⁴⁵ J. Bellinger,⁵⁸ A. Belloni,²² D. Benjamin,¹⁶ A. Beretvas,¹⁷ J. Beringer,²⁸ T. Berry,²⁹ A. Bhatti,⁴⁹ M. Binkley,¹⁷ D. Bisello,⁴² I. Bizjak,³⁰ R. E. Blair,² C. Blocker,⁶ B. Blumenfeld,²⁵ A. Bocci,¹⁶ A. Bodek,⁴⁸ V. Boisvert,⁴⁸ G. Bolla,⁴⁷ A. Bolshov,³² D. Bortoletto,⁴⁷ J. Boudreau,⁴⁶ A. Boveia,¹⁰ B. Brau,¹⁰ A. Bridgeman,²⁴ L. Brigliadori,⁵ C. Bromberg,³⁵ E. Brubaker,¹³ J. Budagov,¹⁵ H. S. Budd,⁴⁸ S. Budd,²⁴ K. Burkett,¹⁷ G. Busetto,⁴² P. Bussey,²¹ A. Buzatu,³³ K. L. Byrum,² S. Cabrera,^{16,r} M. Campanelli,³⁵ M. Campbell,³⁴ F. Canelli,¹⁷ A. Canepa,⁴⁴ D. Carlsmith,⁵⁸ R. Carosi,⁴⁵ S. Carrillo,^{18,l} S. Carron,³³ B. Casal,¹¹ M. Casarsa,¹⁷ A. Castro,⁵ P. Catastini,⁴⁵ D. Cauz,⁵³ M. Cavalli-Sforza,³ A. Cerri,²⁸ L. Cerrito,^{30,p} S. H. Chang,²⁷ Y. C. Chen,¹ M. Chertok,⁷ G. Chiarelli,⁴⁵ G. Chlachidze,¹⁷ F. Chlebana,¹⁷ K. Cho,²⁷ D. Chokheli,¹⁵ J. P. Chou,²² G. Choudalakis,³² S. H. Chuang,⁵¹ K. Chung,¹² W. H. Chung,⁵⁸ Y. S. Chung,⁴⁸ C. I. Ciobanu,²⁴ M. A. Ciocci,⁴⁵ A. Clark,²⁰ D. Clark,⁶ G. Compostella,⁴² M. E. Convery,¹⁷ J. Conway,⁷ B. Cooper,³⁰ K. Copic,³⁴ M. Cordelli,¹⁹ G. Cortiana,⁴² F. Crescioli,⁴⁵ C. Cuenca Almenar,^{7,r} J. Cuevas,^{11,o} R. Culbertson,¹⁷ J. C. Cully,³⁴ D. Dagenhart,¹⁷ M. Datta,¹⁷ T. Davies,²¹ P. de Barbaro,⁴⁸ S. De Cecco,⁵⁰ A. Deisher,²⁸ G. De Lentdecker,^{48,d} G. De Lorenzo,³ M. Dell'Orso,⁴⁵ L. Demortier,⁴⁹ J. Deng,¹⁶ M. Deninno,⁵ D. De Pedis,⁵⁰ P. F. Derwent,¹⁷ G. P. Di Giovanni,⁴³ C. Dionisi,⁵⁰ B. Di Ruzza,⁵³ J. R. Dittmann,⁴ M. D'Onofrio,³ S. Donati,⁴⁵ P. Dong,⁸ J. Donini,⁴² T. Dorigo,⁴² S. Dube,⁵¹ J. Efron,³⁸ R. Erbacher,⁷ D. Errede,²⁴ S. Errede,²⁴ R. Eusebi,¹⁷ H. C. Fang,²⁸ S. Farrington,²⁹ W. T. Fedorko,¹³ R. G. Feild,⁵⁹ M. Feindt,²⁶ J. P. Fernandez,³¹ C. Ferrazza,⁴⁵ R. Field,¹⁸ G. Flanagan,⁴⁷ R. Forrest,⁷ S. Forrester,⁷ M. Franklin,²² J. C. Freeman,²⁸ I. Furic,¹⁸ M. Gallinaro,⁴⁹ J. Galyardt,¹² F. Garbersson,¹⁰ J. E. Garcia,⁴⁵ A. F. Garfinkel,⁴⁷ K. Genser,¹⁷ H. Gerberich,²⁴ D. Gerdes,³⁴ S. Giagu,⁵⁰ V. Giakoumopolou,^{45,a} P. Giannetti,⁴⁵ K. Gibson,⁴⁶ J. L. Gimmell,⁴⁸ C. M. Ginsburg,¹⁷ N. Giokaris,^{15,a} M. Giordani,⁵³ P. Giromini,¹⁹ M. Giunta,⁴⁵ V. Glagolev,¹⁵ D. Glenzinski,¹⁷ M. Gold,³⁶ N. Goldschmidt,¹⁸ A. Golossanov,¹⁷ G. Gomez,¹¹ G. Gomez-Ceballos,³² M. Goncharov,⁵² O. González,³¹ I. Gorelov,³⁶ A. T. Goshaw,¹⁶ K. Goulianos,⁴⁹ A. Gresele,⁴² S. Grinstein,²² C. Grosso-Pilcher,¹³ R. C. Group,¹⁷ U. Grundler,²⁴ J. Guimaraes da Costa,²² Z. Gunay-Unalan,³⁵ C. Haber,²⁸ K. Hahn,³² S. R. Hahn,¹⁷ E. Halkiadakis,⁵¹ A. Hamilton,²⁰ B.-Y. Han,⁴⁸ J. Y. Han,⁴⁸ R. Handler,⁵⁸ F. Happacher,¹⁹ K. Hara,⁵⁴ D. Hare,⁵¹ M. Hare,⁵⁵ S. Harper,⁴¹ R. F. Harr,⁵⁷ R. M. Harris,¹⁷ M. Hartz,⁴⁶ K. Hatakeyama,⁴⁹ J. Hauser,⁸ C. Hays,⁴¹ M. Heck,²⁶ A. Heijboer,⁴⁴ B. Heinemann,²⁸ J. Heinrich,⁴⁴ C. Henderson,³² M. Herndon,⁵⁸ J. Heuser,²⁶ S. Hewamanage,⁴ D. Hidas,¹⁶ C. S. Hill,^{10,c} D. Hirschbuehl,²⁶ A. Hocker,¹⁷ S. Hou,¹ M. Houlden,²⁹ S.-C. Hsu,⁹ B. T. Huffman,⁴¹ R. E. Hughes,³⁸ U. Husemann,⁵⁹ J. Huston,³⁵ J. Incandela,¹⁰ G. Introzzi,⁴⁵ M. Iori,⁵⁰ A. Ivanov,⁷ B. Iyutin,³² E. James,¹⁷ B. Jayatilaka,¹⁶ D. Jeans,⁵⁰ E. J. Jeon,²⁷ S. Jindariani,¹⁸ W. Johnson,⁷ M. Jones,⁴⁷ K. K. Joo,²⁷ S. Y. Jun,¹² J. E. Jung,²⁷ T. R. Junk,²⁴ T. Kamon,⁵² D. Kar,¹⁸ P. E. Karchin,⁵⁷ Y. Kato,⁴⁰ R. Kephart,¹⁷ U. Kerzel,²⁶ V. Khotilovich,⁵² B. Kilminster,³⁸ D. H. Kim,²⁷ H. S. Kim,²⁷ J. E. Kim,²⁷ M. J. Kim,¹⁷ S. B. Kim,²⁷ S. H. Kim,⁵⁴ Y. K. Kim,¹³ N. Kimura,⁵⁴ L. Kirsch,⁶ S. Klimenko,¹⁸ M. Klute,³² B. Knuteson,³² B. R. Ko,¹⁶ S. A. Koay,¹⁰ K. Kondo,⁵⁶ D. J. Kong,²⁷ J. Konigsberg,¹⁸ A. Korytov,¹⁸ A. V. Kotwal,¹⁶ J. Kraus,²⁴ M. Kreps,²⁶ J. Kroll,⁴⁴ N. Krumnack,⁴ M. Kruse,¹⁶ V. Krutelyov,¹⁰ T. Kubo,⁵⁴ S. E. Kuhlmann,² T. Kuhr,²⁶ N. P. Kulkarni,⁵⁷ Y. Kusakabe,⁵⁶ S. Kwang,¹³ A. T. Laasanen,⁴⁷ S. Lai,³³ S. Lami,⁴⁵ S. Lammel,¹⁷ M. Lancaster,³⁰ R. L. Lander,⁷ K. Lannon,³⁸ A. Lath,⁵¹ G. Latino,⁴⁵ I. Lazzizzera,⁴² T. LeCompte,² J. Lee,⁴⁸ J. Lee,²⁷ Y. J. Lee,²⁷ S. W. Lee,^{52,q} R. Lefèvre,²⁰ N. Leonardo,³² S. Leone,⁴⁵ S. Levy,¹³ J. D. Lewis,¹⁷ C. Lin,⁵⁹ C. S. Lin,²⁸ J. Linacre,⁴¹ M. Lindgren,¹⁷ E. Lipeles,⁹ A. Lister,⁷ D. O. Litvintsev,¹⁷ T. Liu,¹⁷ N. S. Lockyer,⁴⁴ A. Loginov,⁵⁹ M. Loreti,⁴² L. Lovas,¹⁴ R.-S. Lu,¹ D. Lucchesi,⁴² J. Lueck,²⁶ C. Luci,⁵⁰ P. Lujan,²⁸ P. Lukens,¹⁷ G. Lungu,¹⁸ L. Lyons,⁴¹ J. Lys,²⁸ R. Lysak,¹⁴ E. Lytken,⁴⁷ P. Mack,²⁶ D. MacQueen,³³ R. Madrak,¹⁷ K. Maeshima,¹⁷ K. Makhoul,³² T. Maki,²³ P. Maksimovic,²⁵ S. Malde,⁴¹ S. Malik,³⁰ G. Manca,²⁹ A. Manousakis,^{15,a} F. Margaroli,⁴⁷ C. Marino,²⁶ C. P. Marino,²⁴ A. Martin,⁵⁹ M. Martin,²⁵ V. Martin,^{21,j} M. Martínez,³ R. Martínez-Ballarín,³¹ T. Maruyama,⁵⁴ P. Mastrandrea,⁵⁰ T. Masubuchi,⁵⁴ M. E. Mattson,⁵⁷ P. Mazzanti,⁵ K. S. McFarland,⁴⁸ P. McIntyre,⁵² R. McNulty,^{29,i} A. Mehta,²⁹ P. Mehtala,²³ S. Menzemer,^{11,k} A. Menzione,⁴⁵ P. Merkel,⁴⁷ C. Mesropian,⁴⁹ A. Messina,³⁵ T. Miao,¹⁷ N. Miladinovic,⁶ J. Miles,³² R. Miller,³⁵ C. Mills,²² M. Milnik,²⁶ A. Mitra,¹ G. Mitselmakher,¹⁸ H. Miyake,⁵⁴ S. Moed,²² N. Moggi,⁵ C. S. Moon,²⁷ R. Moore,¹⁷ M. Morello,⁴⁵ P. Movilla Fernandez,²⁸ J. Mülmenstädt,²⁸ A. Mukherjee,¹⁷ Th. Muller,²⁶ R. Mumford,²⁵ P. Murat,¹⁷ M. Mussini,⁵ J. Nachtman,¹⁷ Y. Nagai,⁵⁴ A. Nagano,⁵⁴ J. Naganoma,⁵⁶ K. Nakamura,⁵⁴

I. Nakano,³⁹ A. Napier,⁵⁵ V. Neclula,¹⁶ C. Neu,⁴⁴ M. S. Neubauer,²⁴ J. Nielsen,^{28,f} L. Nodulman,² M. Norman,⁹ O. Norniella,²⁴ E. Nurse,³⁰ S. H. Oh,¹⁶ Y. D. Oh,²⁷ I. Oksuzian,¹⁸ T. Okusawa,⁴⁰ R. Oldeman,²⁹ R. Orava,²³ K. Osterberg,²³ S. Pagan Griso,⁴² C. Pagliarone,⁴⁵ E. Palencia,¹⁷ V. Papadimitriou,¹⁷ A. Papaikonomou,²⁶ A. A. Paramonov,¹³ B. Parks,³⁸ S. Pashapour,³³ J. Patrick,¹⁷ G. Pauletta,⁵³ M. Paulini,¹² C. Paus,³² D. E. Pellett,⁷ A. Penzo,⁵³ T. J. Phillips,¹⁶ G. Piacentino,⁴⁵ J. Piedra,⁴³ L. Pinares,¹⁸ K. Pitts,²⁴ C. Plager,⁸ L. Pondrom,⁵⁸ X. Portell,³ O. Poukhov,¹⁵ N. Pounder,⁴¹ F. Prakoshyn,¹⁵ A. Pronko,¹⁷ J. Proudfoot,² F. Ptohos,^{17,h} G. Punzi,⁴⁵ J. Pursley,⁵⁸ J. Rademacker,^{41,c} A. Rahaman,⁴⁶ V. Ramakrishnan,⁵⁸ N. Ranjan,⁴⁷ I. Redondo,³¹ B. Reisert,¹⁷ V. Rekovic,³⁶ P. Renton,⁴¹ M. Rescigno,⁵⁰ S. Richter,²⁶ F. Rimondi,⁵ L. Ristori,⁴⁵ A. Robson,²¹ T. Rodrigo,¹¹ E. Rogers,²⁴ S. Rolli,⁵⁵ R. Roser,¹⁷ M. Rossi,⁵³ R. Rossin,¹⁰ P. Roy,³³ A. Ruiz,¹¹ J. Russ,¹² V. Rusu,¹⁷ H. Saarikko,²³ A. Safonov,⁵² W. K. Sakumoto,⁴⁸ G. Salamanna,⁵⁰ O. Saltó,³ L. Santi,⁵³ S. Sarkar,⁵⁰ L. Sartori,⁴⁵ K. Sato,¹⁷ A. Savoy-Navarro,⁴³ T. Scheidle,²⁶ P. Schlabach,¹⁷ E. E. Schmidt,¹⁷ M. A. Schmidt,¹³ M. P. Schmidt,⁵⁹ M. Schmitt,³⁷ T. Schwarz,⁷ L. Scodellaro,¹¹ A. L. Scott,¹⁰ A. Scribano,⁴⁵ F. Scuri,⁴⁵ A. Sedov,⁴⁷ S. Seidel,³⁶ Y. Seiya,⁴⁰ A. Semenov,¹⁵ L. Sexton-Kennedy,¹⁷ A. Sfyria,²⁰ S. Z. Shalhout,⁵⁷ M. D. Shapiro,²⁸ T. Shears,²⁹ P. F. Shepard,⁴⁶ D. Sherman,²² M. Shimojima,^{54,n} M. Shochet,¹³ Y. Shon,⁵⁸ I. Shreyber,²⁰ A. Sidoti,⁴⁵ P. Sinervo,³³ A. Sisakyan,¹⁵ A. J. Slaughter,¹⁷ J. Slaunwhite,³⁸ K. Sliwa,⁵⁵ J. R. Smith,⁷ F. D. Snider,¹⁷ R. Snihur,³³ M. Soderberg,³⁴ A. Soha,⁷ S. Somalwar,⁵¹ V. Sorin,³⁵ J. Spalding,¹⁷ F. Spinella,⁴⁵ T. Spreitzer,³³ P. Squillacioti,⁴⁵ M. Stanitzki,⁵⁹ R. St. Denis,²¹ B. Stelzer,⁸ O. Stelzer-Chilton,⁴¹ D. Stentz,³⁷ J. Strologas,³⁶ D. Stuart,¹⁰ J. S. Suh,²⁷ A. Sukhanov,¹⁸ H. Sun,⁵⁵ I. Suslov,¹⁵ T. Suzuki,⁵⁴ A. Taffard,^{24,e} R. Takashima,³⁹ Y. Takeuchi,⁵⁴ R. Tanaka,³⁹ M. Tecchio,³⁴ P. K. Teng,¹ K. Terashi,⁴⁹ J. Thom,^{17,g} A. S. Thompson,²¹ G. A. Thompson,²⁴ E. Thomson,⁴⁴ P. Tipton,⁵⁹ V. Tiwari,¹² S. Tkaczyk,¹⁷ D. Toback,⁵² S. Tokar,¹⁴ K. Tollefson,³⁵ T. Tomura,⁵⁴ D. Tonelli,¹⁷ S. Torre,¹⁹ D. Torretta,¹⁷ S. Tourneur,⁴³ W. Trischuk,³³ Y. Tu,⁴⁴ N. Turini,⁴⁵ F. Ukegawa,⁵⁴ S. Uozumi,⁵⁴ S. Vallecorsa,²⁰ N. van Remortel,²³ A. Varganov,³⁴ E. Vataga,³⁶ F. Vázquez,^{18,l} G. Velev,¹⁷ C. Vellidis,^{45,a} V. Veszpremi,⁴⁷ M. Vidal,³¹ R. Vidal,¹⁷ I. Vila,¹¹ R. Vilar,¹¹ T. Vine,³⁰ M. Vogel,³⁶ I. Volobouev,^{28,q} G. Volpi,⁴⁵ F. Würthwein,⁹ P. Wagner,⁴⁴ R. G. Wagner,² R. L. Wagner,¹⁷ J. Wagner-Kuhr,²⁶ W. Wagner,²⁶ T. Wakisaka,⁴⁰ R. Wallny,⁸ S. M. Wang,¹ A. Warburton,³³ D. Waters,³⁰ M. Weinberger,⁵² W. C. Wester III,¹⁷ B. Whitehouse,⁵⁵ D. Whiteson,^{44,e} A. B. Wicklund,² E. Wicklund,¹⁷ G. Williams,³³ H. H. Williams,⁴⁴ P. Wilson,¹⁷ B. L. Winer,³⁸ P. Wittich,^{17,g} S. Wolbers,¹⁷ C. Wolfe,¹³ T. Wright,³⁴ X. Wu,²⁰ S. M. Wynne,²⁹ A. Yagil,⁹ K. Yamamoto,⁴⁰ J. Yamaoka,⁵¹ T. Yamashita,³⁹ C. Yang,⁵⁹ U. K. Yang,^{13,m} Y. C. Yang,²⁷ W. M. Yao,²⁸ G. P. Yeh,¹⁷ J. Yoh,¹⁷ K. Yorita,¹³ T. Yoshida,⁴⁰ G. B. Yu,⁴⁸ I. Yu,²⁷ S. S. Yu,¹⁷ J. C. Yun,¹⁷ L. Zanello,⁵⁰ A. Zanetti,⁵³ I. Zaw,²² X. Zhang,²⁴ Y. Zheng,^{8,b} and S. Zucchelli⁵

(CDF Collaboration)^a¹*Institute of Physics, Academia Sinica, Taipei, Taiwan 11529, Republic of China*²*Argonne National Laboratory, Argonne, Illinois 60439, USA*³*Institut de Física d'Altes Energies, Universitat Autònoma de Barcelona, E-08193, Bellaterra (Barcelona), Spain*⁴*Baylor University, Waco, Texas 76798, USA*⁵*Istituto Nazionale di Fisica Nucleare, University of Bologna, I-40127 Bologna, Italy*⁶*Brandeis University, Waltham, Massachusetts 02254, USA*⁷*University of California, Davis, Davis, California 95616, USA*⁸*University of California, Los Angeles, Los Angeles, California 90024, USA*⁹*University of California, San Diego, La Jolla, California 92093, USA*¹⁰*University of California, Santa Barbara, Santa Barbara, California 93106, USA*¹¹*Instituto de Física de Cantabria, CSIC-University of Cantabria, 39005 Santander, Spain*¹²*Carnegie Mellon University, Pittsburgh, Pennsylvania 15213, USA*¹³*Enrico Fermi Institute, University of Chicago, Chicago, Illinois 60637, USA*¹⁴*Comenius University, 842 48 Bratislava, Slovakia; Institute of Experimental Physics, 040 01 Kosice, Slovakia*¹⁵*Joint Institute for Nuclear Research, RU-141980 Dubna, Russia*¹⁶*Duke University, Durham, North Carolina 27708*¹⁷*Fermi National Accelerator Laboratory, Batavia, Illinois 60510, USA*¹⁸*University of Florida, Gainesville, Florida 32611, USA*¹⁹*Laboratori Nazionali di Frascati, Istituto Nazionale di Fisica Nucleare, I-00044 Frascati, Italy*²⁰*University of Geneva, CH-1211 Geneva 4, Switzerland*²¹*Glasgow University, Glasgow G12 8QQ, United Kingdom*²²*Harvard University, Cambridge, Massachusetts 02138, USA*²³*Division of High Energy Physics, Department of Physics, University of Helsinki and Helsinki Institute of Physics, FIN-00014, Helsinki, Finland*

- ²⁴University of Illinois, Urbana, Illinois 61801, USA
²⁵The Johns Hopkins University, Baltimore, Maryland 21218, USA
²⁶Institut für Experimentelle Kernphysik, Universität Karlsruhe, 76128 Karlsruhe, Germany
²⁷Center for High Energy Physics: Kyungpook National University, Daegu 702-701, Korea;
 Seoul National University, Seoul 151-742, Korea;
 Sungkyunkwan University, Suwon 440-746, Korea;
 Korea Institute of Science and Technology Information, Daejeon, 305-806, Korea;
 Chonnam National University, Gwangju, 500-757, Korea
²⁸Ernest Orlando Lawrence Berkeley National Laboratory, Berkeley, California 94720, USA
²⁹University of Liverpool, Liverpool L69 7ZE, United Kingdom
³⁰University College London, London WC1E 6BT, United Kingdom
³¹Centro de Investigaciones Energeticas Medioambientales y Tecnologicas, E-28040 Madrid, Spain
³²Massachusetts Institute of Technology, Cambridge, Massachusetts 02139, USA
³³Institute of Particle Physics: McGill University, Montréal, Canada H3A 2T8;
 and University of Toronto, Toronto, Canada M5S 1A7
³⁴University of Michigan, Ann Arbor, Michigan 48109, USA
³⁵Michigan State University, East Lansing, Michigan 48824, USA
³⁶University of New Mexico, Albuquerque, New Mexico 87131, USA
³⁷Northwestern University, Evanston, Illinois 60208, USA
³⁸The Ohio State University, Columbus, Ohio 43210, USA
³⁹Okayama University, Okayama 700-8530, Japan
⁴⁰Osaka City University, Osaka 588, Japan
⁴¹University of Oxford, Oxford OX1 3RH, United Kingdom
⁴²University of Padova, Istituto Nazionale di Fisica Nucleare, Sezione di Padova-Trento, I-35131 Padova, Italy
⁴³LPNHE, Universite Pierre et Marie Curie/IN2P3-CNRS, UMR7585, Paris, F-75252 France
⁴⁴University of Pennsylvania, Philadelphia, Pennsylvania 19104, USA
⁴⁵Istituto Nazionale di Fisica Nucleare Pisa, Universities of Pisa, Siena
 and Scuola Normale Superiore, I-56127 Pisa, Italy
⁴⁶University of Pittsburgh, Pittsburgh, Pennsylvania 15260, USA
⁴⁷Purdue University, West Lafayette, Indiana 47907, USA
⁴⁸University of Rochester, Rochester, New York 14627, USA
⁴⁹The Rockefeller University, New York, New York 10021, USA
⁵⁰Istituto Nazionale di Fisica Nucleare, Sezione di Roma 1, University of Rome "La Sapienza," I-00185 Roma, Italy
⁵¹Rutgers University, Piscataway, New Jersey 08855, USA
⁵²Texas A&M University, College Station, Texas 77843, USA
⁵³Istituto Nazionale di Fisica Nucleare, University of Trieste/Udine, Italy
⁵⁴University of Tsukuba, Tsukuba, Ibaraki 305, Japan
⁵⁵Tufts University, Medford, Massachusetts 02155, USA
⁵⁶Waseda University, Tokyo 169, Japan
⁵⁷Wayne State University, Detroit, Michigan 48201, USA
⁵⁸University of Wisconsin, Madison, Wisconsin 53706, USA
⁵⁹Yale University, New Haven, Connecticut 06520, USA
 (Received 11 December 2007; published 8 May 2008)

The B_c^\pm meson is observed through the decay $B_c^\pm \rightarrow J/\psi\pi^\pm$, in data corresponding to an integrated luminosity of 2.4 fb^{-1} recorded by the Collider Detector at Fermilab II detector at the Fermilab Tevatron. A signal of 108 ± 15 candidates is observed, with a significance that exceeds 8σ . The mass of the B_c^\pm meson is measured to be $6275.6 \pm 2.9(\text{stat}) \pm 2.5(\text{syst}) \text{ MeV}/c^2$.

DOI: [10.1103/PhysRevLett.100.182002](https://doi.org/10.1103/PhysRevLett.100.182002)

PACS numbers: 14.40.Nd, 13.20.He, 13.25.Hw

The B_c^- meson [1] is composed of a bottom quark, b , and an anticharm quark, \bar{c} , the heaviest quark flavors expected to form mesons. The presence of two relatively heavy quarks is unique in the B_c^\pm system, and affects the theoretical calculation of the decay properties and mass of the B_c^\pm meson. Either quark in the B_c^\pm meson can decay weakly, which suggests a large number of possible decay

modes [2] and an expected lifetime much shorter than that of other B mesons [3]. The mass of the B_c^\pm meson has been predicted using a variety of theoretical techniques. Nonrelativistic potential models have been used to predict a mass of the B_c^\pm in the range of 6247–6286 MeV/c^2 [4], and a slightly higher value is found for a perturbative QCD calculation [5]. Recent lattice QCD calculations

provide a B_c^\pm mass prediction of $6304 \pm 12_{-0}^{+18}$ MeV/ c^2 [6]. Precision measurements of the properties of the B_c^\pm are needed to test these calculations.

The B_c^\pm meson is too massive to be produced at e^+e^- colliders operating near the $Y(4S)$ center of mass energy, and only a few candidate events, which were consistent with background processes, were observed at LEP [7]. With a large b -quark production cross section and powerful multipurpose detectors, the Fermilab Tevatron is well-suited to the study of all species of B hadrons, including the B_c^\pm meson. In particular, this collaboration observed the B_c^\pm meson in semileptonic decays and used these candidates to measure the lifetime of the B_c^\pm to be $0.463_{-0.065}^{+0.073} \pm 0.036$ ps [8]. In addition, we have previously presented evidence for a $B_c^\pm \rightarrow J/\psi\pi^\pm$ signal [9].

In this Letter, an analysis is presented which observes the decay mode $B_c^\pm \rightarrow J/\psi\pi^\pm$, with $J/\psi \rightarrow \mu^+\mu^-$, and precisely measures the B_c^\pm mass. This result provides the first observation of the B_c^\pm meson in a fully reconstructed mode. This observation is made in $p\bar{p}$ collisions at a center of mass energy of 1.96 TeV using the Collider Detector at Fermilab (CDF II) [10]. The results presented here are based on a data sample with an integrated luminosity of 2.4 fb^{-1} , and supersede our earlier measurement [9], which was based on an integrated luminosity of 360 pb^{-1} .

This analysis makes use of the tracking and muon identification systems. The tracking system consists of double-sided silicon detectors [11] and a 96 layer open-cell drift chamber (COT) [12] that operate inside a solenoid with a 1.4 T field oriented along the beam axis. Charged particles with $p_T > 250 \text{ MeV}/c^2$ [13] that originate from the collision point are measured in the tracking system with a momentum resolution of $\sigma(p_T)/p_T \sim 0.0015 p_T \text{ (GeV}/c)^{-1}$. Muon candidates from the decay $J/\psi \rightarrow \mu^+\mu^-$ are identified by two sets of drift chambers located radially outside the electromagnetic and hadronic calorimeters. The central muon chambers cover the pseudorapidity region $|\eta| < 0.6$ and are sensitive to muons with transverse momentum $p_T > 1.4 \text{ GeV}/c$. A second muon system covers the region $0.6 < |\eta| < 1.0$ and detects muons having $p_T > 2.0 \text{ GeV}/c$. Muon triggering and identification are based on matching tracks measured in the muon system to COT tracks. This analysis is based on events recorded with a trigger that is dedicated to the collection of a $J/\psi \rightarrow \mu^+\mu^-$ sample. The first level of the three-level trigger system requires two muon candidates with tracks in the COT and muon chamber systems that match in the transverse view. The track trigger system identifies tracks with $p_T > 1.4 \text{ GeV}/c$ and a 1.25° resolution in the transverse view. The presence of muon chamber hits that are consistent with trigger tracks is required to satisfy the lowest level trigger. The second level imposes the requirement that muon candidates have opposite charge and limits the accepted range of opening angle between the two muon candidates. The highest level of the J/ψ trigger

reconstructs the muon pair in software, and requires that the invariant mass of the pair falls within the range 2.7–4.0 GeV/ c^2 .

The analysis of the data begins with a selection of well-measured $J/\psi \rightarrow \mu^+\mu^-$ candidates. Events are required to contain two oppositely charged muon candidates that satisfy restrictive matching requirements, consistent with the full measurement precision of the COT and muon chamber systems. The tracks reconstructed in the COT are extrapolated to the position of the muon chambers. Both the position and slope measurements made in the muon system are required to be within 3σ of the extrapolated tracks. We also require that both muon tracks have associated measurements in at least three of the six layers of the silicon detector within 10 cm of the beam line, and a two-track invariant mass within 70 MeV/ c^2 of the world-average J/ψ mass [14]. This data sample provides approximately 17×10^6 events containing J/ψ candidates, measured with an average mass resolution of 13 MeV/ c^2 .

Both $B^\pm \rightarrow J/\psi K^\pm$ and $B_c^\pm \rightarrow J/\psi\pi^\pm$ combinations are reconstructed in this analysis. The relatively plentiful B^\pm sample serves as a reference signal and is used to develop criteria for the B_c^\pm selection. These final states are identified by assigning the π^\pm or K^\pm mass to all tracks not used in the J/ψ reconstruction. In order to provide the measurement resolution sufficient to discriminate between directly produced tracks and B -hadron decay products, the π^\pm and K^\pm candidate tracks are required to have measurements in at least three layers of the silicon detector. Each three-track combination must satisfy a fit in which the tracks are required to originate from a single vertex and the invariant mass of the muon pair is constrained to the world-average J/ψ mass. Approximately 65 000 B^\pm candidates are identified in this loosely selected sample.

The selection requirements are further improved to give a large $B^\pm \rightarrow J/\psi K^\pm$ signal with very small background, in order to increase the significance of the B_c^\pm observation. Since the B_c^\pm lifetime is significantly shorter than the lifetime of the B^\pm , each selection variable under consideration has been studied for its effect on preserving signal and removing background only for $J/\psi K^\pm$ combinations with $80 < ct < 300 \mu\text{m}$, where t is the proper decay time of the B^\pm determined from $t \equiv \vec{L}_T \cdot \vec{p}_T(B) \frac{M(B)}{|p_T(B)|^2}$, $M(B)$ is the mass of the combination, $\vec{p}_T(B)$ is the transverse momentum of the combination, and \vec{L}_T is the transverse displacement of the $J/\psi K^\pm$ decay vertex from the beam line. Each selection quantity considered is evaluated for its efficiency in retaining the B^\pm signal and reducing the combinatorial background in the 5.4–5.5 GeV/ c^2 mass range. This range was chosen to avoid lower mass backgrounds from partially reconstructed decays and the Cabibbo-suppressed process $B^\pm \rightarrow J/\psi\pi^\pm$.

Several characteristics of the $J/\psi K^\pm$ candidates are considered for selection requirements. Minimum p_T requirements on the K^\pm and B^\pm candidates are used to

suppress backgrounds from $J/\psi K^\pm$ combinations that are not related to the B^\pm decay. Reasonable vertex quality is assured by placing a minimum value on the accepted probability $P(\chi^2)$ of the mass- and vertex-constrained fit used to obtain the B^\pm candidate. The trajectory of the K^\pm is required to originate from the B^\pm decay vertex by placing a requirement on its distance of closest approach $d_{sv}(K)$ and associated uncertainty $\sigma_{dsv}(K)$ (typically $40 \mu\text{m}$) with respect to the vertex found in the J/ψ fit. Similar quantities, $d_{pv}(K)$ and $\sigma_{dpv}(K)$ (typically $30 \mu\text{m}$), measured with respect to the primary vertex are used to remove tracks that originate from direct production processes. We suppress the promptly produced combinatorial background by rejecting candidates with small ct . A requirement on σ_{ct} removes poorly-reconstructed combinations and other backgrounds. We also reject $J/\psi K^\pm$ combinations that are inconsistent with having originated from the beam line by requiring a small magnitude for the transverse impact of the candidate, $\vec{d}_{pv}(B) \equiv \vec{L}_T \times \vec{p}_T(B)/|p_T(B)|$, and a small angle β between \vec{L}_T and $\vec{p}_T(B)$.

Two sets of selection criteria based on these quantities are listed in Table I. The first step of the selection process is to impose the ‘‘standard’’ selection requirements listed above and retain all $J/\psi K^\pm$ combinations that satisfy them. However, the selection studies indicate that a substantial number of $B^\pm \rightarrow J/\psi K^\pm$ signal events fail exactly one of the standard selection requirements. To increase the overall signal efficiency, we introduce a ‘‘high- p_T ’’ selection, comprised of combinations that satisfy more restrictive p_T requirements, and pass all but one of the other high- p_T selection criteria in Table I. Figure 1 shows the reconstructed $B^\pm \rightarrow J/\psi K^\pm$ signal for candidates that satisfy the standard or high- p_T selection criteria. The additional combinations retained by the high- p_T selection increase the B^\pm yield by 28%, and the combinatorial background by 48%. The total signal of approximately 21 100 B^\pm candidates with a small background of 430 events in the B^\pm sideband region between 5.4 and

TABLE I. Selection variables and requirements for the standard selection and high- p_T selection as described in the text. Here ‘‘ Trk ’’ refers to the track combined with the J/ψ and may be a K^\pm or π^\pm candidate for the B^\pm or B_c^\pm , respectively.

Selection variable	Standard	High- p_T
$p_T(Trk)$	$>1.7 \text{ GeV}/c$	$>2.5 \text{ GeV}/c$
$p_T(J/\psi Trk)$	$>5 \text{ GeV}/c$	$>6 \text{ GeV}/c$
$P(\chi^2)$	$>0.1\%$	$>1\%$
$ d_{sv}(Trk) $	$<100 \mu\text{m}$	$<80 \mu\text{m}$
$ d_{pv}(Trk) /\sigma_{dpv}(Trk)$	>2.5	>3
$ d_{pv}(B) /\sigma_{dpv}(B)$	<2.5	<2
ct	$>80 \mu\text{m}$	$>100 \mu\text{m}$
σ_{ct}	$<30 \mu\text{m}$	$<25 \mu\text{m}$
β	$<0.4 \text{ radians}$	$<0.3 \text{ radians}$

$5.5 \text{ GeV}/c^2$ demonstrates that this selection effectively removes the background to B -hadron candidates.

The candidates used for the reconstruction of the B_c^\pm are obtained by applying the selection criteria in Table I to the sample interpreted as $J/\psi \pi^\pm$. Figure 2 shows the $B_c^\pm \rightarrow J/\psi \pi^\pm$ candidates under the combined standard and high- p_T selections. The data are also shown for a limited mass region suggested by theoretical expectations [4–6]. A clear excess of $J/\psi \pi^\pm$ combinations is evident around $6280 \text{ MeV}/c^2$.

The data shown in Fig. 2(b) are fitted using an unbinned log likelihood function that uses a Gaussian shape for the signal plus a background model that includes contributions from both combinatorial sources and contributions from Cabibbo-suppressed $B_c^\pm \rightarrow J/\psi K^\pm$ decays in the probability distribution function. Simulated events are used to estimate the mass distribution expected from the misidentified Cabibbo-suppressed process, and it is found to be approximately Gaussian, centered $60 \text{ MeV}/c^2$ below the true B_c^\pm mass and having a $30 \text{ MeV}/c^2$ width. The characteristic width for the signal in the probability distribution function is varied for each candidate in proportion to the mass uncertainty estimated from the individual track uncertainties. A similar fit performed on the B^\pm candidates finds that the mass resolution is underestimated by a factor of 1.55 with this method. Consequently, the mass uncertainties used in the $J/\psi \pi^\pm$ fit are scaled by this factor. For the central value of the fit, the Cabibbo-suppressed contribution is fixed to 0.05 of the total B_c^\pm yield, which is comparable to the measurements obtained for Cabibbo-suppressed B^\pm decays [14]. Figure 2(b) shows a projection

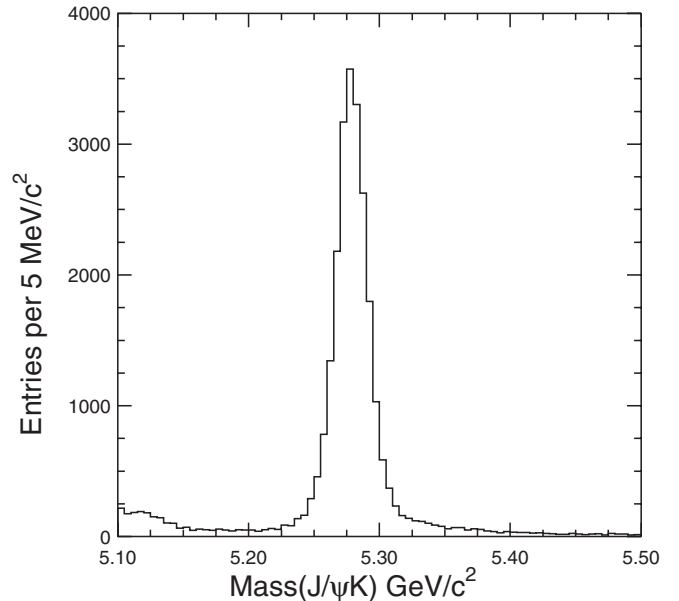


FIG. 1. The invariant mass distribution of $J/\psi K^\pm$ combinations.

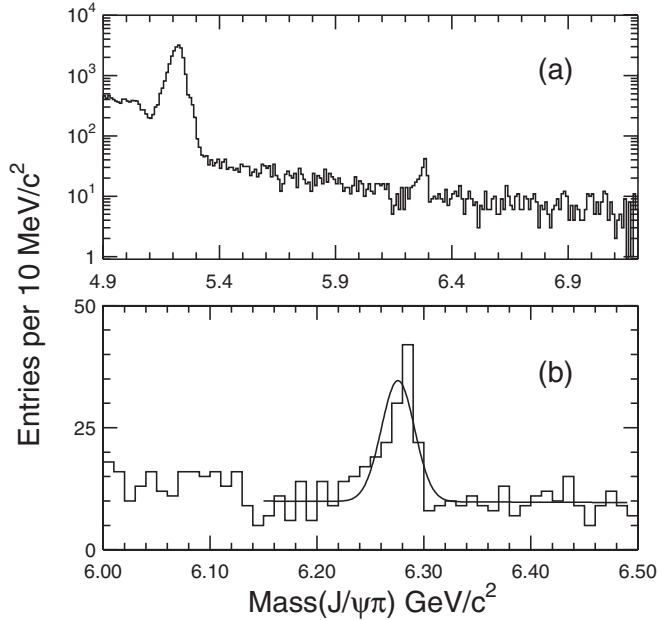


FIG. 2. (a) The invariant mass distribution of $J/\psi\pi^\pm$ combinations. The large enhancement near $5.2 \text{ GeV}/c^2$ is due to $B^\pm \rightarrow J/\psi K^\pm$ candidates, which have been reconstructed with an incorrect mass assignment for the K^\pm . (b) Identical to (a), but in a narrower mass range around the theoretically favored B_c^\pm mass. The projection of the fit to the data is indicated by the curve overlaid on (b).

of the fit overlaid on the data, which has $\chi^2/\text{DoF} = 34.6/32$ and a probability of $P(\chi^2) = 0.30$.

The result of the unbinned fit over the mass range $6150\text{--}6500 \text{ MeV}/c^2$ gives a B_c^\pm signal of 108 ± 15 candidates with a mass of $6275.6 \pm 2.9 \text{ MeV}/c^2$. The lower limit of the fitting range was chosen to avoid possible backgrounds due to partially reconstructed B_c^\pm and the upper limit is arbitrary. This fit was repeated over the same mass range with the constraint that no signal is present in order to obtain a significance. The ratio of likelihoods between the two fits yields a probability for the null hypothesis of 1.2×10^{-16} , equivalent to a fluctuation of 8σ or more in a Gaussian distribution. A second significance test was also performed, which used a Monte Carlo simulation to estimate the probability for a background-only sample to mimic a signal at least as significant as the one observed. This study confirmed the significance estimate obtained from the ratio-of-likelihoods test. We conclude that this enhancement is an observation of the process $B_c^\pm \rightarrow J/\psi\pi^\pm$.

Studies that were performed for the mass measurement of other B mesons that contain a J/ψ in the final state [15] are used for an evaluation of some of the systematic uncertainties. The systematic uncertainty due to tracking detector misalignments and material distributions used in track fitting is assessed by varying these within reasonable limits. Based on these studies, a systematic uncertainty of

$0.6 \text{ MeV}/c^2$ is assigned to account for misalignments and material modeling. A comparison between the fitted $J/\psi K^\pm$ mass spectrum obtained in 12 independent periods of data finds the measured mass of the B^\pm meson for each subset to be within 1.8σ of the entire sample. Consequently, no systematic uncertainty is assigned for time dependent effects on this mass measurement. The momentum scale of the tracking system is calibrated with the J/ψ , $\psi(2S)$, and Y states, all of which have been well measured previously [14]. The uncertainty of the momentum scale for the decay products of the B_c^\pm which was derived from this calibration contributes an additional mass uncertainty of $0.6 \text{ MeV}/c^2$. The sensitivity of the mass measurement to the assumed Cabibbo-suppressed background process was tested with simulated events. Variations of $0.0\text{--}0.1$ for the fractional contribution correspond to mass measurement variations of $0.8 \text{ MeV}/c^2$, which is taken to be the systematic uncertainty associated with this unknown background contribution.

An additional systematic uncertainty comes from the fitting procedure. The scale factor associated with the mass uncertainty which is used in the fit was set to the best value obtained in a fit to the topologically similar $B^\pm \rightarrow J/\psi K^\pm$ final state. However, other reconstructed B hadrons that include a J/ψ in the final state have been studied as well. Scale factors in the range of $1.25\text{--}2.0$ have been suggested by these studies, so the fit for the B_c^\pm mass was repeated for this range. An uncertainty of $2.2 \text{ MeV}/c^2$ in the calculated B_c^\pm mass is indicated due to the fitting procedure. The combined systematic uncertainty is the sum in quadrature of the uncertainties in our calibration, tracking, and fitting procedure. The total systematic uncertainty in the B_c^\pm mass measurement is determined to be $2.5 \text{ MeV}/c^2$.

In conclusion, we have observed fully reconstructed B_c^\pm mesons through the decay $B_c^\pm \rightarrow J/\psi\pi^\pm$. A signal of 108 ± 15 candidates is observed with a significance greater than an 8σ fluctuation of a Gaussian distribution. The mass of the B_c^\pm meson is measured to be $6275.6 \pm 2.9(\text{stat}) \pm 2.5(\text{syst}) \text{ MeV}/c^2$.

We thank the Fermilab staff and the technical staffs of the participating institutions for their vital contributions. This work was supported by the U.S. Department of Energy and National Science Foundation; the Italian Istituto Nazionale di Fisica Nucleare; the Ministry of Education, Culture, Sports, Science and Technology of Japan; the Natural Sciences and Engineering Research Council of Canada; the National Science Council of the Republic of China; the Swiss National Science Foundation; the A.P. Sloan Foundation; the Bundesministerium für Bildung und Forschung, Germany; the Korean Science and Engineering Foundation and the Korean Research Foundation; the Science and Technology Facilities Council and the Royal Society, UK; the Institut National de Physique Nucleaire et

Physique des Particules/CNRS; the Russian Foundation for Basic Research; the Comisión Interministerial de Ciencia y Tecnología, Spain; the European Community's Human Potential Programme; the Slovak R&D Agency; and the Academy of Finland.

^aVisitor from University of Athens, 15784 Athens, Greece.

^bVisitor from Chinese Academy of Sciences, Beijing 100864, China.

^cVisitor from University of Bristol, Bristol BS8 1TL, United Kingdom.

^dVisitor from University Libre de Bruxelles, B-1050 Brussels, Belgium.

^eVisitor from University of California Irvine, Irvine, CA 92697, USA.

^fVisitor from University of California Santa Cruz, Santa Cruz, CA 95064, USA.

^gVisitor from Cornell University, Ithaca, NY 14853, USA.

^hVisitor from University of Cyprus, Nicosia CY-1678, Cyprus.

ⁱVisitor from University College Dublin, Dublin 4, Ireland.

^jVisitor from University of Edinburgh, Edinburgh EH9 3JZ, United Kingdom.

^kVisitor from University of Heidelberg, D-69120 Heidelberg, Germany.

^lVisitor from Universidad Iberoamericana, Mexico D.F., Mexico.

^mVisitor from University of Manchester, Manchester M13 9PL, United Kingdom.

ⁿVisitor from Nagasaki Institute of Applied Science, Nagasaki, Japan.

^oVisitor from University de Oviedo, E-33007 Oviedo, Spain.

^pVisitor from Queen Mary, University of London, London, E1 4NS, United Kingdom.

^qVisitor from Texas Tech University, Lubbock, TX 79409, USA.

^rVisitor from IFIC(CSIC-Universitat de Valencia), 46071 Valencia, Spain.

- [1] References to a particular charge state also imply the charge conjugate state.
- [2] E. Hernandez, J. Nieves, and J.M. Verde-Velasco, *Phys. Rev. D* **74**, 074008 (2006); M. Ivanov, J. Körner, and P. Santorelli, *Phys. Rev. D* **73**, 054024 (2006).
- [3] S. Godfrey, *Phys. Rev. D* **70**, 054017 (2004); V. V. Kiselev, arXiv:hep-ph/0308214.
- [4] E.J. Eichten and C. Quigg, *Phys. Rev. D* **49**, 5845 (1994); W.K. Kwong and J.L. Rosner, *Phys. Rev. D* **44**, 212 (1991); S. Godfrey, *Phys. Rev. D* **70**, 054017 (2004).
- [5] N. Brambilla, Y. Sumino, and A. Vairo, *Phys. Rev. D* **65**, 034001 (2002); N. Brambilla *et al.*, arXiv:hep-ph/0412158.
- [6] I.F. Allison *et al.*, *Phys. Rev. Lett.* **94**, 172001 (2005).
- [7] P. Abreu *et al.* (DELPHI Collaboration), *Phys. Lett. B* **398**, 207 (1997); R. Barate *et al.* (ALEPH Collaboration), *Phys. Lett. B* **402**, 213 (1997); K. Ackerstaff *et al.* (OPAL Collaboration), *Phys. Lett. B* **420**, 157 (1998).
- [8] A. Abulencia *et al.* (CDF Collaboration), *Phys. Rev. Lett.* **97**, 012002 (2006).
- [9] A. Abulencia *et al.* (CDF Collaboration), *Phys. Rev. Lett.* **96**, 082002 (2006).
- [10] D. Acosta *et al.* (CDF Collaboration), *Phys. Rev. D* **71**, 032001 (2005).
- [11] A. Sill *et al.*, *Nucl. Instrum. Methods Phys. Res., Sect. A* **447**, 1 (2000).
- [12] A. Affolder *et al.*, *Nucl. Instrum. Methods Phys. Res., Sect. A* **526**, 249 (2004).
- [13] The transverse momentum p_T is defined as the component of the particle momentum perpendicular to the proton beam direction. The pseudorapidity η is defined as $\eta \equiv -\ln[\tan(\theta/2)]$, where θ is the angle between the particle momentum and the proton beam direction.
- [14] W.-M. Yao *et al.* (Particle Data Group), *J. Phys. G* **33**, 1 (2006).
- [15] D. Acosta *et al.* (CDF Collaboration), *Phys. Rev. Lett.* **96**, 202001 (2006).