



HAL
open science

Observation of the decay $B_c \rightarrow J/\psi K^+ K^- \pi^+$

R. Aaij, B. Adeva, M. Adinolfi, C. Adrover, A. Affolder, Ziad Zj Ajaltouni, J. Albrecht, F. Alessio, M. Alexander, S. Ali, et al.

► **To cite this version:**

R. Aaij, B. Adeva, M. Adinolfi, C. Adrover, A. Affolder, et al.. Observation of the decay $B_c \rightarrow J/\psi K^+ K^- \pi^+$. *Journal of High Energy Physics*, 2013, 11, pp.094. 10.1007/JHEP11(2013)094 . in2p3-00857748

HAL Id: in2p3-00857748

<https://in2p3.hal.science/in2p3-00857748v1>

Submitted on 18 Jul 2023

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Distributed under a Creative Commons Attribution 4.0 International License



Observation of the decay $B_c^+ \rightarrow J/\psi K^+ K^- \pi^+$

The LHCb collaboration[†]

Abstract

The decay $B_c^+ \rightarrow J/\psi K^+ K^- \pi^+$ is observed for the first time, using proton-proton collisions collected with the LHCb detector corresponding to an integrated luminosity of 3 fb^{-1} . A signal yield of 78 ± 14 decays is reported with a significance of 6.2 standard deviations. The ratio of the branching fraction of $B_c^+ \rightarrow J/\psi K^+ K^- \pi^+$ decays to that of $B_c^+ \rightarrow J/\psi \pi^+$ decays is measured to be $0.53 \pm 0.10 \pm 0.05$, where the first uncertainty is statistical and the second is systematic.

Submitted to JHEP

[†]Authors are listed on the following pages.

LHCb collaboration

R. Aaij⁴⁰, B. Adeva³⁶, M. Adinolfi⁴⁵, C. Adrover⁶, A. Affolder⁵¹, Z. Ajaltouni⁵, J. Albrecht⁹, F. Alessio³⁷, M. Alexander⁵⁰, S. Ali⁴⁰, G. Alkhazov²⁹, P. Alvarez Cartelle³⁶, A.A. Alves Jr²⁴, S. Amato², S. Amerio²¹, Y. Amhis⁷, L. Anderlini^{17,f}, J. Anderson³⁹, R. Andreassen⁵⁶, J.E. Andrews⁵⁷, R.B. Appleby⁵³, O. Aquines Gutierrez¹⁰, F. Archilli¹⁸, A. Artamonov³⁴, M. Artuso⁵⁸, E. Aslanides⁶, G. Auriemma^{24,m}, M. Baalouch⁵, S. Bachmann¹¹, J.J. Back⁴⁷, A. Badalov³⁵, C. Baesso⁵⁹, V. Balagura³⁰, W. Baldini¹⁶, R.J. Barlow⁵³, C. Barschel³⁷, S. Barsuk⁷, W. Barter⁴⁶, Th. Bauer⁴⁰, A. Bay³⁸, J. Beddow⁵⁰, F. Bedeschi²², I. Bediaga¹, S. Belogurov³⁰, K. Belous³⁴, I. Belyaev³⁰, E. Ben-Haim⁸, G. Bencivenni¹⁸, S. Benson⁴⁹, J. Benton⁴⁵, A. Berezhnoy³¹, R. Bernet³⁹, M.-O. Bettler⁴⁶, M. van Beuzekom⁴⁰, A. Bien¹¹, S. Bifani⁴⁴, T. Bird⁵³, A. Bizzeti^{17,h}, P.M. Bjørnstad⁵³, T. Blake³⁷, F. Blanc³⁸, J. Blouw¹⁰, S. Blusk⁵⁸, V. Bocci²⁴, A. Bondar³³, N. Bondar²⁹, W. Bonivento¹⁵, S. Borghi⁵³, A. Borgia⁵⁸, T.J.V. Bowcock⁵¹, E. Bowen³⁹, C. Bozzi¹⁶, T. Brambach⁹, J. van den Brand⁴¹, J. Bressieux³⁸, D. Brett⁵³, M. Britsch¹⁰, T. Britton⁵⁸, N.H. Brook⁴⁵, H. Brown⁵¹, A. Bursche³⁹, G. Busetto^{21,q}, J. Buytaert³⁷, S. Cadeddu¹⁵, O. Callot⁷, M. Calvi^{20,j}, M. Calvo Gomez^{35,n}, A. Camboni³⁵, P. Campana^{18,37}, D. Campora Perez³⁷, A. Carbone^{14,c}, G. Carboni^{23,k}, R. Cardinale^{19,i}, A. Cardini¹⁵, H. Carranza-Mejia⁴⁹, L. Carson⁵², K. Carvalho Akiba², G. Casse⁵¹, L. Castillo Garcia³⁷, M. Cattaneo³⁷, Ch. Cauet⁹, R. Cenci⁵⁷, M. Charles⁵⁴, Ph. Charpentier³⁷, P. Chen^{3,38}, S.-F. Cheung⁵⁴, N. Chiapolini³⁹, M. Chrzaszcz^{39,25}, K. Ciba³⁷, X. Cid Vidal³⁷, G. Ciezarek⁵², P.E.L. Clarke⁴⁹, M. Clemencic³⁷, H.V. Cliff⁴⁶, J. Closier³⁷, C. Coca²⁸, V. Coco⁴⁰, J. Cogan⁶, E. Cogneras⁵, P. Collins³⁷, A. Comerma-Montells³⁵, A. Contu^{15,37}, A. Cook⁴⁵, M. Coombes⁴⁵, S. Coquereau⁸, G. Corti³⁷, B. Couturier³⁷, G.A. Cowan⁴⁹, D.C. Craik⁴⁷, M. Cruz Torres⁵⁹, S. Cunliffe⁵², R. Currie⁴⁹, C. D'Ambrosio³⁷, P. David⁸, P.N.Y. David⁴⁰, A. Davis⁵⁶, I. De Bonis⁴, K. De Bruyn⁴⁰, S. De Capua⁵³, M. De Cian¹¹, J.M. De Miranda¹, L. De Paula², W. De Silva⁵⁶, P. De Simone¹⁸, D. Decamp⁴, M. Deckenhoff⁹, L. Del Buono⁸, N. Déléage⁴, D. Derkach⁵⁴, O. Deschamps⁵, F. Dettori⁴¹, A. Di Canto¹¹, H. Dijkstra³⁷, M. Dogaru²⁸, S. Donleavy⁵¹, F. Dordei¹¹, A. Dosil Suárez³⁶, D. Dossett⁴⁷, A. Dovbnya⁴², F. Dupertuis³⁸, P. Durante³⁷, R. Dzhelyadin³⁴, A. Dziurda²⁵, A. Dzyuba²⁹, S. Easo⁴⁸, U. Egede⁵², V. Egorychev³⁰, S. Eidelman³³, D. van Eijk⁴⁰, S. Eisenhardt⁴⁹, U. Eitschberger⁹, R. Ekelhof⁹, L. Eklund^{50,37}, I. El Rifai⁵, Ch. Elsasser³⁹, A. Falabella^{14,e}, C. Färber¹¹, C. Farinelli⁴⁰, S. Farry⁵¹, D. Ferguson⁴⁹, V. Fernandez Albor³⁶, F. Ferreira Rodrigues¹, M. Ferro-Luzzi³⁷, S. Filippov³², M. Fiore^{16,e}, C. Fitzpatrick³⁷, M. Fontana¹⁰, F. Fontanelli^{19,i}, R. Forty³⁷, O. Francisco², M. Frank³⁷, C. Frei³⁷, M. Frosini^{17,37,f}, E. Furfaro^{23,k}, A. Gallas Torreira³⁶, D. Galli^{14,c}, M. Gandelman², P. Gandini⁵⁸, Y. Gao³, J. Garofoli⁵⁸, P. Garosi⁵³, J. Garra Tico⁴⁶, L. Garrido³⁵, C. Gaspar³⁷, R. Gauld⁵⁴, E. Gersabeck¹¹, M. Gersabeck⁵³, T. Gershon⁴⁷, Ph. Ghez⁴, V. Gibson⁴⁶, L. Giubega²⁸, V.V. Gligorov³⁷, C. Göbel⁵⁹, D. Golubkov³⁰, A. Golutvin^{52,30,37}, A. Gomes², P. Gorbounov^{30,37}, H. Gordon³⁷, M. Grabalosa Gándara⁵, R. Graciani Diaz³⁵, L.A. Granado Cardoso³⁷, E. Graugés³⁵, G. Graziani¹⁷, A. Greco²⁸, E. Greening⁵⁴, S. Gregson⁴⁶, P. Griffith⁴⁴, O. Grünberg⁶⁰, B. Gui⁵⁸, E. Gushchin³², Yu. Guz^{34,37}, T. Gys³⁷, C. Hadjivasiliou⁵⁸, G. Haefeli³⁸, C. Haen³⁷, S.C. Haines⁴⁶, S. Hall⁵², B. Hamilton⁵⁷, T. Hampson⁴⁵, S. Hansmann-Menzemer¹¹, N. Harnew⁵⁴, S.T. Harnew⁴⁵, J. Harrison⁵³, T. Hartmann⁶⁰, J. He³⁷, T. Head³⁷, V. Heijne⁴⁰, K. Hennessy⁵¹, P. Henrard⁵, J.A. Hernando Morata³⁶, E. van Herwijnen³⁷, M. Heß⁶⁰, A. Hicheur¹, E. Hicks⁵¹, D. Hill⁵⁴, M. Hoballah⁵, C. Hombach⁵³, W. Hulsbergen⁴⁰, P. Hunt⁵⁴, T. Huse⁵¹, N. Hussain⁵⁴, D. Hutchcroft⁵¹, D. Hynds⁵⁰, V. Iakovenko⁴³, M. Idzik²⁶, P. Ilten¹², R. Jacobsson³⁷, A. Jaeger¹¹,

E. Jans⁴⁰, P. Jaton³⁸, A. Jawahery⁵⁷, F. Jing³, M. John⁵⁴, D. Johnson⁵⁴, C.R. Jones⁴⁶,
 C. Joram³⁷, B. Jost³⁷, M. Kaballo⁹, S. Kandybei⁴², W. Kanso⁶, M. Karacson³⁷, T.M. Karbach³⁷,
 I.R. Kenyon⁴⁴, T. Ketel⁴¹, B. Khanji²⁰, O. Kochebina⁷, I. Komarov³⁸, R.F. Koopman⁴¹,
 P. Koppenburg⁴⁰, M. Korolev³¹, A. Kozlinskiy⁴⁰, L. Kravchuk³², K. Kreplin¹¹, M. Kreps⁴⁷,
 G. Krocker¹¹, P. Krokovny³³, F. Kruse⁹, M. Kucharczyk^{20,25,37,j}, V. Kudryavtsev³³, K. Kurek²⁷,
 T. Kvaratskheliya^{30,37}, V.N. La Thi³⁸, D. Lacarrere³⁷, G. Lafferty⁵³, A. Lai¹⁵, D. Lambert⁴⁹,
 R.W. Lambert⁴¹, E. Lanciotti³⁷, G. Lanfranchi¹⁸, C. Langenbruch³⁷, T. Latham⁴⁷,
 C. Lazzeroni⁴⁴, R. Le Gac⁶, J. van Leerdam⁴⁰, J.-P. Lees⁴, R. Lefèvre⁵, A. Leflat³¹,
 J. Lefrançois⁷, S. Leo²², O. Leroy⁶, T. Lesiak²⁵, B. Leverington¹¹, Y. Li³, L. Li Gioi⁵, M. Liles⁵¹,
 R. Lindner³⁷, C. Linn¹¹, B. Liu³, G. Liu³⁷, S. Lohn³⁷, I. Longstaff⁵⁰, J.H. Lopes²,
 N. Lopez-March³⁸, H. Lu³, D. Lucchesi^{21,q}, J. Luisier³⁸, H. Luo⁴⁹, O. Lupton⁵⁴, F. Machefert⁷,
 I.V. Machikhiliyan³⁰, F. Maciuc²⁸, O. Maev^{29,37}, S. Malde⁵⁴, G. Manca^{15,d}, G. Mancinelli⁶,
 J. Maratas⁵, U. Marconi¹⁴, P. Marino^{22,s}, R. Märki³⁸, J. Marks¹¹, G. Martellotti²⁴, A. Martens⁸,
 A. Martín Sánchez⁷, M. Martinelli⁴⁰, D. Martinez Santos^{41,37}, D. Martins Tostes²,
 A. Martynov³¹, A. Massafferri¹, R. Matev³⁷, Z. Mathe³⁷, C. Matteuzzi²⁰, E. Maurice⁶,
 A. Mazurov^{16,37,e}, J. McCarthy⁴⁴, A. McNab⁵³, R. McNulty¹², B. McSkelly⁵¹, B. Meadows^{56,54},
 F. Meier⁹, M. Meissner¹¹, M. Merk⁴⁰, D.A. Milanes⁸, M.-N. Minard⁴, J. Molina Rodriguez⁵⁹,
 S. Monteil⁵, D. Moran⁵³, P. Morawski²⁵, A. Mordà⁶, M.J. Morello^{22,s}, R. Mountain⁵⁸, I. Mous⁴⁰,
 F. Muheim⁴⁹, K. Müller³⁹, R. Muresan²⁸, B. Muryn²⁶, B. Muster³⁸, P. Naik⁴⁵, T. Nakada³⁸,
 R. Nandakumar⁴⁸, I. Nasteva¹, M. Needham⁴⁹, S. Neubert³⁷, N. Neufeld³⁷, A.D. Nguyen³⁸,
 T.D. Nguyen³⁸, C. Nguyen-Mau^{38,o}, M. Nicol⁷, V. Niess⁵, R. Niet⁹, N. Nikitin³¹, T. Nikodem¹¹,
 A. Nomerotski⁵⁴, A. Novoselov³⁴, A. Oblakowska-Mucha²⁶, V. Obraztsov³⁴, S. Oggero⁴⁰,
 S. Ogilvy⁵⁰, O. Okhrimenko⁴³, R. Oldeman^{15,d}, M. Orlandea²⁸, J.M. Otalora Goicochea²,
 P. Owen⁵², A. Oyanguren³⁵, B.K. Pal⁵⁸, A. Palano^{13,b}, M. Palutan¹⁸, J. Panman³⁷,
 A. Papanestis⁴⁸, M. Pappagallo⁵⁰, C. Parkes⁵³, C.J. Parkinson⁵², G. Passaleva¹⁷, G.D. Patel⁵¹,
 M. Patel⁵², G.N. Patrick⁴⁸, C. Patrignani^{19,i}, C. Pavel-Nicorescu²⁸, A. Pazos Alvarez³⁶,
 A. Pearce⁵³, A. Pellegrino⁴⁰, G. Penso^{24,l}, M. Pepe Altarelli³⁷, S. Perazzini^{14,c}, E. Perez Trigo³⁶,
 A. Pérez-Calero Yzquierdo³⁵, P. Perret⁵, M. Perrin-Terrin⁶, L. Pescatore⁴⁴, E. Pesen⁶¹,
 G. Pessina²⁰, K. Petridis⁵², A. Petrolini^{19,i}, A. Phan⁵⁸, E. Picatoste Olloqui³⁵, B. Pietrzyk⁴,
 T. Pilar⁴⁷, D. Pinci²⁴, S. Playfer⁴⁹, M. Plo Casasus³⁶, F. Polci⁸, G. Polok²⁵, A. Poluektov^{47,33},
 I. Polyakov³⁰, E. Polcarpo², A. Popov³⁴, D. Popov¹⁰, B. Popovici²⁸, C. Potterat³⁵, A. Powell⁵⁴,
 J. Prisciandaro³⁸, A. Pritchard⁵¹, C. Prouve⁷, V. Pugatch⁴³, A. Puig Navarro³⁸, G. Punzi^{22,r},
 W. Qian⁴, B. Rachwal²⁵, J.H. Rademacker⁴⁵, B. Rakotomiaramanana³⁸, M.S. Rangel²,
 I. Raniuk⁴², N. Rauschmayr³⁷, G. Raven⁴¹, S. Redford⁵⁴, S. Reichert⁵³, M.M. Reid⁴⁷,
 A.C. dos Reis¹, S. Ricciardi⁴⁸, A. Richards⁵², K. Rinnert⁵¹, V. Rives Molina³⁵,
 D.A. Roa Romero⁵, P. Robbe⁷, D.A. Roberts⁵⁷, A.B. Rodrigues¹, E. Rodrigues⁵³,
 P. Rodriguez Perez³⁶, S. Roiser³⁷, V. Romanovsky³⁴, A. Romero Vidal³⁶, J. Rouvinet³⁸,
 T. Ruf³⁷, F. Ruffini²², H. Ruiz³⁵, P. Ruiz Valls³⁵, G. Sabatino^{24,k}, J.J. Saborido Silva³⁶,
 N. Sagidova²⁹, P. Sail⁵⁰, B. Saitta^{15,d}, V. Salustino Guimaraes², B. Sanmartin Sedes³⁶,
 R. Santacesaria²⁴, C. Santamarina Rios³⁶, E. Santovetti^{23,k}, M. Sapunov⁶, A. Sarti¹⁸,
 C. Satriano^{24,m}, A. Satta²³, M. Savrie^{16,e}, D. Savrina^{30,31}, M. Schiller⁴¹, H. Schindler³⁷,
 M. Schlupp⁹, M. Schmelling¹⁰, B. Schmidt³⁷, O. Schneider³⁸, A. Schopper³⁷, M.-H. Schune⁷,
 R. Schwemmer³⁷, B. Sciascia¹⁸, A. Sciubba²⁴, M. Seco³⁶, A. Semennikov³⁰, K. Senderowska²⁶,
 I. Sepp⁵², N. Serra³⁹, J. Serrano⁶, P. Seyfert¹¹, M. Shapkin³⁴, I. Shapoval^{16,42,e}, Y. Shcheglov²⁹,
 T. Shears⁵¹, L. Shekhtman³³, O. Shevchenko⁴², V. Shevchenko³⁰, A. Shires⁹,
 R. Silva Coutinho⁴⁷, M. Sirendi⁴⁶, N. Skidmore⁴⁵, T. Skwarnicki⁵⁸, N.A. Smith⁵¹, E. Smith^{54,48},

E. Smith⁵², J. Smith⁴⁶, M. Smith⁵³, M.D. Sokoloff⁵⁶, F.J.P. Soler⁵⁰, F. Soomro³⁸, D. Souza⁴⁵, B. Souza De Paula², B. Spaan⁹, A. Sparkes⁴⁹, P. Spradlin⁵⁰, F. Stagni³⁷, S. Stahl¹¹, O. Steinkamp³⁹, S. Stevenson⁵⁴, S. Stoica²⁸, S. Stone⁵⁸, B. Storaci³⁹, M. Straticiu²⁸, U. Straumann³⁹, V.K. Subbiah³⁷, L. Sun⁵⁶, W. Sutcliffe⁵², S. Swientek⁹, V. Syropoulos⁴¹, M. Szczekowski²⁷, P. Szczypka^{38,37}, D. Szilard², T. Szumlak²⁶, S. T'Jampens⁴, M. Teklishyn⁷, E. Teodorescu²⁸, F. Teubert³⁷, C. Thomas⁵⁴, E. Thomas³⁷, J. van Tilburg¹¹, V. Tisserand⁴, M. Tobin³⁸, S. Tolk⁴¹, D. Tonelli³⁷, S. Topp-Joergensen⁵⁴, N. Torr⁵⁴, E. Tournefier^{4,52}, S. Tourneur³⁸, M.T. Tran³⁸, M. Tresch³⁹, A. Tsaregorodtsev⁶, P. Tsopelas⁴⁰, N. Tuning^{40,37}, M. Ubeda Garcia³⁷, A. Ukleja²⁷, A. Ustyuzhanin^{52,p}, U. Uwer¹¹, V. Vagnoni¹⁴, G. Valenti¹⁴, A. Vallier⁷, R. Vazquez Gomez¹⁸, P. Vazquez Regueiro³⁶, C. Vázquez Sierra³⁶, S. Vecchi¹⁶, J.J. Velthuis⁴⁵, M. Veltri^{17,g}, G. Veneziano³⁸, M. Vesterinen³⁷, B. Viaud⁷, D. Vieira², X. Vilasis-Cardona^{35,n}, A. Vollhardt³⁹, D. Volynskyy¹⁰, D. Voong⁴⁵, A. Vorobyev²⁹, V. Vorobyev³³, C. Voß⁶⁰, H. Voss¹⁰, R. Waldi⁶⁰, C. Wallace⁴⁷, R. Wallace¹², S. Wandernoth¹¹, J. Wang⁵⁸, D.R. Ward⁴⁶, N.K. Watson⁴⁴, A.D. Webber⁵³, D. Websdale⁵², M. Whitehead⁴⁷, J. Wicht³⁷, J. Wiechczynski²⁵, D. Wiedner¹¹, L. Wiggers⁴⁰, G. Wilkinson⁵⁴, M.P. Williams^{47,48}, M. Williams⁵⁵, F.F. Wilson⁴⁸, J. Wimberley⁵⁷, J. Wishahi⁹, W. Wislicki²⁷, M. Witek²⁵, G. Wormser⁷, S.A. Wotton⁴⁶, S. Wright⁴⁶, S. Wu³, K. Wyllie³⁷, Y. Xie^{49,37}, Z. Xing⁵⁸, Z. Yang³, X. Yuan³, O. Yushchenko³⁴, M. Zangoli¹⁴, M. Zavertyaev^{10,a}, F. Zhang³, L. Zhang⁵⁸, W.C. Zhang¹², Y. Zhang³, A. Zhelezov¹¹, A. Zhokhov³⁰, L. Zhong³, A. Zvyagin³⁷.

¹ Centro Brasileiro de Pesquisas Físicas (CBPF), Rio de Janeiro, Brazil

² Universidade Federal do Rio de Janeiro (UFRJ), Rio de Janeiro, Brazil

³ Center for High Energy Physics, Tsinghua University, Beijing, China

⁴ LAPP, Université de Savoie, CNRS/IN2P3, Annecy-Le-Vieux, France

⁵ Clermont Université, Université Blaise Pascal, CNRS/IN2P3, LPC, Clermont-Ferrand, France

⁶ CPPM, Aix-Marseille Université, CNRS/IN2P3, Marseille, France

⁷ LAL, Université Paris-Sud, CNRS/IN2P3, Orsay, France

⁸ LPNHE, Université Pierre et Marie Curie, Université Paris Diderot, CNRS/IN2P3, Paris, France

⁹ Fakultät Physik, Technische Universität Dortmund, Dortmund, Germany

¹⁰ Max-Planck-Institut für Kernphysik (MPIK), Heidelberg, Germany

¹¹ Physikalisches Institut, Ruprecht-Karls-Universität Heidelberg, Heidelberg, Germany

¹² School of Physics, University College Dublin, Dublin, Ireland

¹³ Sezione INFN di Bari, Bari, Italy

¹⁴ Sezione INFN di Bologna, Bologna, Italy

¹⁵ Sezione INFN di Cagliari, Cagliari, Italy

¹⁶ Sezione INFN di Ferrara, Ferrara, Italy

¹⁷ Sezione INFN di Firenze, Firenze, Italy

¹⁸ Laboratori Nazionali dell'INFN di Frascati, Frascati, Italy

¹⁹ Sezione INFN di Genova, Genova, Italy

²⁰ Sezione INFN di Milano Bicocca, Milano, Italy

²¹ Sezione INFN di Padova, Padova, Italy

²² Sezione INFN di Pisa, Pisa, Italy

²³ Sezione INFN di Roma Tor Vergata, Roma, Italy

²⁴ Sezione INFN di Roma La Sapienza, Roma, Italy

²⁵ Henryk Niewodniczanski Institute of Nuclear Physics Polish Academy of Sciences, Kraków, Poland

²⁶ AGH - University of Science and Technology, Faculty of Physics and Applied Computer Science, Kraków, Poland

²⁷ National Center for Nuclear Research (NCBJ), Warsaw, Poland

²⁸ Horia Hulubei National Institute of Physics and Nuclear Engineering, Bucharest-Magurele, Romania

²⁹ Petersburg Nuclear Physics Institute (PNPI), Gatchina, Russia

- ³⁰*Institute of Theoretical and Experimental Physics (ITEP), Moscow, Russia*
- ³¹*Institute of Nuclear Physics, Moscow State University (SINP MSU), Moscow, Russia*
- ³²*Institute for Nuclear Research of the Russian Academy of Sciences (INR RAN), Moscow, Russia*
- ³³*Budker Institute of Nuclear Physics (SB RAS) and Novosibirsk State University, Novosibirsk, Russia*
- ³⁴*Institute for High Energy Physics (IHEP), Protvino, Russia*
- ³⁵*Universitat de Barcelona, Barcelona, Spain*
- ³⁶*Universidad de Santiago de Compostela, Santiago de Compostela, Spain*
- ³⁷*European Organization for Nuclear Research (CERN), Geneva, Switzerland*
- ³⁸*Ecole Polytechnique Fédérale de Lausanne (EPFL), Lausanne, Switzerland*
- ³⁹*Physik-Institut, Universität Zürich, Zürich, Switzerland*
- ⁴⁰*Nikhef National Institute for Subatomic Physics, Amsterdam, The Netherlands*
- ⁴¹*Nikhef National Institute for Subatomic Physics and VU University Amsterdam, Amsterdam, The Netherlands*
- ⁴²*NSC Kharkiv Institute of Physics and Technology (NSC KIPT), Kharkiv, Ukraine*
- ⁴³*Institute for Nuclear Research of the National Academy of Sciences (KINR), Kyiv, Ukraine*
- ⁴⁴*University of Birmingham, Birmingham, United Kingdom*
- ⁴⁵*H.H. Wills Physics Laboratory, University of Bristol, Bristol, United Kingdom*
- ⁴⁶*Cavendish Laboratory, University of Cambridge, Cambridge, United Kingdom*
- ⁴⁷*Department of Physics, University of Warwick, Coventry, United Kingdom*
- ⁴⁸*STFC Rutherford Appleton Laboratory, Didcot, United Kingdom*
- ⁴⁹*School of Physics and Astronomy, University of Edinburgh, Edinburgh, United Kingdom*
- ⁵⁰*School of Physics and Astronomy, University of Glasgow, Glasgow, United Kingdom*
- ⁵¹*Oliver Lodge Laboratory, University of Liverpool, Liverpool, United Kingdom*
- ⁵²*Imperial College London, London, United Kingdom*
- ⁵³*School of Physics and Astronomy, University of Manchester, Manchester, United Kingdom*
- ⁵⁴*Department of Physics, University of Oxford, Oxford, United Kingdom*
- ⁵⁵*Massachusetts Institute of Technology, Cambridge, MA, United States*
- ⁵⁶*University of Cincinnati, Cincinnati, OH, United States*
- ⁵⁷*University of Maryland, College Park, MD, United States*
- ⁵⁸*Syracuse University, Syracuse, NY, United States*
- ⁵⁹*Pontifícia Universidade Católica do Rio de Janeiro (PUC-Rio), Rio de Janeiro, Brazil, associated to ²*
- ⁶⁰*Institut für Physik, Universität Rostock, Rostock, Germany, associated to ¹¹*
- ⁶¹*Celal Bayar University, Manisa, Turkey, associated to ³⁷*

^a*P.N. Lebedev Physical Institute, Russian Academy of Science (LPI RAS), Moscow, Russia*

^b*Università di Bari, Bari, Italy*

^c*Università di Bologna, Bologna, Italy*

^d*Università di Cagliari, Cagliari, Italy*

^e*Università di Ferrara, Ferrara, Italy*

^f*Università di Firenze, Firenze, Italy*

^g*Università di Urbino, Urbino, Italy*

^h*Università di Modena e Reggio Emilia, Modena, Italy*

ⁱ*Università di Genova, Genova, Italy*

^j*Università di Milano Bicocca, Milano, Italy*

^k*Università di Roma Tor Vergata, Roma, Italy*

^l*Università di Roma La Sapienza, Roma, Italy*

^m*Università della Basilicata, Potenza, Italy*

ⁿ*LIFAEELS, La Salle, Universitat Ramon Llull, Barcelona, Spain*

^o*Hanoi University of Science, Hanoi, Viet Nam*

^p*Institute of Physics and Technology, Moscow, Russia*

^q*Università di Padova, Padova, Italy*

^r*Università di Pisa, Pisa, Italy*

^s*Scuola Normale Superiore, Pisa, Italy*

1 Introduction

The B_c^+ meson is of special interest, as it is the only meson consisting of two heavy quarks of different flavours. It is the heaviest meson that decays through weak interactions, with either the c or \bar{b} quark decaying or through their weak annihilation [1, 2]. Although the B_c^+ meson was discovered in 1998 by the CDF collaboration [3], relatively few decay channels were observed [4] prior to LHCb measurements [5–9].

In the factorisation approximation [10], the $B_c^+ \rightarrow J/\psi K^+ K^- \pi^+$ decay¹ is characterised by the form factors of the $B_c^+ \rightarrow J/\psi W^+$ transition and the spectral functions for the subsequent hadronisation of the virtual W^+ boson into light hadrons [2]. A measurement of the branching fractions of exclusive B_c^+ meson decays into final states consisting of charmonium and light hadrons allows the validity of the factorisation theorem to be tested. Similar studies of factorisation have been performed on $B \rightarrow D^{(*)} K^- K^{*0}$ decays [11]. The predictions for the ratio of branching fractions $\mathcal{B}(B_c^+ \rightarrow J/\psi K^+ K^- \pi^+) / \mathcal{B}(B_c^+ \rightarrow J/\psi \pi^+)$ are 0.49 and 0.47 [12], using form factor contributions from Refs. [13] and [14], respectively.

In this article, the first observation of the decay $B_c^+ \rightarrow J/\psi K^+ K^- \pi^+$ and a measurement of $\mathcal{B}(B_c^+ \rightarrow J/\psi K^+ K^- \pi^+) / \mathcal{B}(B_c^+ \rightarrow J/\psi \pi^+)$ are reported. The analysis is based on proton-proton (pp) collision data, corresponding to an integrated luminosity of 1 fb^{-1} at a centre-of-mass energy of 7 TeV and 2 fb^{-1} at 8 TeV, collected with the LHCb detector.

2 Detector and software

The LHCb detector [15] is a single-arm forward spectrometer covering the pseudorapidity range $2 < \eta < 5$, designed for the study of particles containing b or c quarks. The detector includes a high-precision tracking system consisting of a silicon-strip vertex detector surrounding the pp interaction region, a large-area silicon-strip detector located upstream of a dipole magnet with a bending power of about 4 Tm, and three stations of silicon-strip detectors and straw drift tubes placed downstream. The combined tracking system provides a momentum measurement with relative uncertainty that varies from 0.4% at 5 GeV/ c to 0.6% at 100 GeV/ c , and impact parameter resolution of 20 μm for tracks with high transverse momentum. Charged hadrons are identified using two ring-imaging Cherenkov detectors [16]. Muons are identified by a system composed of alternating layers of iron and multiwire proportional chambers [17]. The trigger [18] consists of a hardware stage, based on information from the calorimeter and muon systems, followed by a software stage, which applies a full event reconstruction.

This analysis uses events collected by triggers that select the $\mu^+ \mu^-$ pair from the J/ψ meson decay with high efficiency. At the hardware stage either one or two muon candidates are required. In the case of single muon triggers, the transverse momentum, p_T , of the candidate is required to be greater than 1.5 GeV/ c . For dimuon candidates, the product of the p_T of muon candidates is required to satisfy $\sqrt{p_{T1} p_{T2}} > 1.3 \text{ GeV}/c$. At the subsequent software trigger stage, two muons with invariant mass in the interval

¹The inclusion of charge conjugate modes is implicit throughout this paper.

39 $2.97 < m_{\mu^+\mu^-} < 3.21 \text{ GeV}/c^2$, and consistent with originating from a common vertex, are
 40 required.

41 Simulated pp collisions are generated using PYTHIA 6.4 [19] with the configura-
 42 tion described in Ref. [20]. Final-state QED radiative corrections are included using
 43 the PHOTOS package [21]. The B_c^+ mesons are produced by a dedicated generator,
 44 BCVEGPY [22]. The decays of all hadrons are performed by EVTGEN [23], and a specific
 45 model is implemented to generate the decays of $B_c^+ \rightarrow J/\psi K^+ K^- \pi^+$, assuming factorisa-
 46 tion [12]. The model has different $B_c^+ \rightarrow J/\psi$ form factors implemented, calculated using
 47 QCD sum rules [13] or using a relativistic quark model [14]. These model predictions are
 48 very similar and those based on the latter are used in the simulation. The coupling of
 49 $K^+ K^- \pi^+$ to the virtual W^+ is taken from τ decays [24], following Refs. [2, 25, 26], and
 50 modelled through the intermediate $a_1^+ \rightarrow \bar{K}^{*0} K^+ (\bar{K}^{*0} \rightarrow K^- \pi^+)$ decay chain. The interac-
 51 tion of the generated particles with the detector and its response are implemented using
 52 the GEANT4 toolkit [27] as described in Ref. [28].

53 3 Candidate selection

54 The signal $B_c^+ \rightarrow J/\psi K^+ K^- \pi^+$ and normalisation $B_c^+ \rightarrow J/\psi \pi^+$ decays are reconstructed
 55 using the $J/\psi \rightarrow \mu^+ \mu^-$ channel. Common selection criteria are used in both channels with
 56 additional requirements to identify kaon candidates in the signal channel.

57 Muons are selected by requiring that the difference in logarithms of the muon hypothesis
 58 likelihood with respect to the pion hypothesis likelihood, $\Delta \ln \mathcal{L}_{\mu/\pi}$ [17, 29], is greater than
 59 zero. To select kaons (pions) the corresponding difference in the logarithms of likelihoods
 60 of the kaon and pion hypotheses [16] is required to satisfy $\Delta \ln \mathcal{L}_{K/\pi} > 2$ (< 0).

61 To ensure that they do not originate from a pp interaction vertex (PV), hadrons must
 62 have $\chi_{\text{IP}}^2 > 4$, where χ_{IP}^2 is defined as the difference in χ^2 of a given PV reconstructed with
 63 and without the considered hadron. When more than one PV is reconstructed, that with
 64 the smallest value of χ_{IP}^2 is chosen.

65 Oppositely-charged muons that have a transverse momentum greater than $0.55 \text{ GeV}/c$
 66 and that originate from a common vertex are paired to form J/ψ candidates. The quality
 67 of the vertex is ensured by requiring that the χ^2 of the vertex fit (χ_{vtx}^2) is less than 20. The
 68 vertex is required to be well-separated from the reconstructed PV by selecting candidates
 69 with decay length significance greater than 3. The invariant mass of the J/ψ candidate is
 70 required to be between 3.020 and $3.135 \text{ GeV}/c^2$.

71 The selected J/ψ candidates are then combined with a π^+ meson candidate or
 72 a $K^+ K^- \pi^+$ combination to form B_c^+ candidates. The quality of the common vertex
 73 is ensured by requiring $\chi_{\text{vtx}}^2 < 35$ (16) for the signal (normalisation) channel, and that
 74 the χ^2 values for the distance of closest approach for the $K^+ K^-$, $K^- \pi^+$ and $K^+ \pi^+$ combi-
 75 nations are less than 9. To suppress the combinatorial background, the kaons (pions) are
 76 required to have $p_{\text{T}} > 0.8$ (0.5) GeV/c . To improve the invariant mass resolution a kine-
 77 matic fit [30] is performed. The invariant mass of the J/ψ candidate is constrained to
 78 the known value of J/ψ mass [31], the decay products of the B_c^+ candidate are required to

79 originate from a common vertex, and the momentum vector of the B_c^+ candidate is required
 80 to point to the PV. When more than one PV is reconstructed, that with the smallest
 81 value of χ_{IP}^2 is chosen. The χ^2 per degree of freedom for this fit is required to be less
 82 than 5. This requirement also reduces the potential contamination from decay chains with
 83 intermediate long-lived particles, namely $B_c^+ \rightarrow J/\psi D_s^+$, $B_c^+ \rightarrow B_s^0 \pi^+$ and $B_c^+ \rightarrow B^+ K^- \pi^+$,
 84 followed by $D_s^+ \rightarrow K^+ K^- \pi^+$, $B_s^0 \rightarrow J/\psi K^+ K^-$ and $B^+ \rightarrow J/\psi K^+$, respectively. To reduce
 85 contributions from the known $B_c^+ \rightarrow J/\psi D_s^+$ [7] and $B_c^+ \rightarrow B_s^0 \pi^+$ decays [8] to a negligible
 86 level, the invariant masses of the $K^+ K^- \pi^+$ and $J/\psi K^+ K^-$ systems are required to differ
 87 from the known D_s^+ and B_s^0 masses [31, 32] by more than 18 and 51 MeV/c^2 , respectively,
 88 corresponding to $\pm 3\sigma$, where σ is the mass resolution of the intermediate state. The decay
 89 time of the B_c^+ candidate (ct) is required to be between 150 μm and 1 mm. The upper
 90 limit corresponds to approximately 7 lifetimes of the B_c^+ meson.

91 4 Signal and normalisation yields

92 The invariant mass distribution of the selected $B_c^+ \rightarrow J/\psi K^+ K^- \pi^+$ candidates is shown in
 93 Fig. 1(a). To estimate the signal yield, N_S , an extended unbinned maximum likelihood
 94 fit to the mass distribution is performed. The B_c^+ signal is modelled by a Gaussian
 95 distribution and the background by an exponential function. The values of the signal
 96 parameters obtained from the fit are summarised in Table 1 and the result is shown
 97 in Fig. 1(a). The statistical significance of the observed signal yield is calculated as
 98 $\sqrt{2\Delta \ln \mathcal{L}}$, where $\Delta \ln \mathcal{L}$ is the change in the logarithm of the likelihood function when
 99 the signal component is excluded from the fit, relative to the default fit, and is found to
 100 be 6.3 standard deviations.

101 The invariant mass distribution of the selected $B_c^+ \rightarrow J/\psi \pi^+$ candidates is shown
 102 in Fig. 1(b). To estimate the signal yield, an extended unbinned maximum likelihood fit
 103 to the mass distribution is performed, where the B_c^+ signal is modelled by a Gaussian
 104 distribution and the background by an exponential function. The fit gives a yield of
 105 2099 ± 59 events.

106 For $B_c^+ \rightarrow J/\psi K^+ K^- \pi^+$ candidates, the resonant structures in the $K^- \pi^+$, $K^+ K^-$,
 107 $K^+ K^- \pi^+$, $J/\psi K^+ K^-$, $J/\psi K^- \pi^+$ and $J/\psi K^+$ systems are studied and the possible contri-
 108 butions from the decays $B_c^+ \rightarrow B^0 K^+$ and $B_c^+ \rightarrow B^+ K^- \pi^+$, followed by subsequent decays
 109 $B^0 \rightarrow J/\psi K^- \pi^+$ and $B^+ \rightarrow J/\psi K^+$ are investigated. The *sPlot* technique [33] is used to

Table 1: Parameters of the signal function of the fit to the $J/\psi K^+ K^- \pi^+$ mass distribution. Uncertainties are statistical only.

Parameter	Value
$m_{B_c^+}$ [MeV/c^2]	6274.8 ± 1.7
$\sigma_{B_c^+}$ [MeV/c^2]	8.8 ± 1.5
N_S	78 ± 14

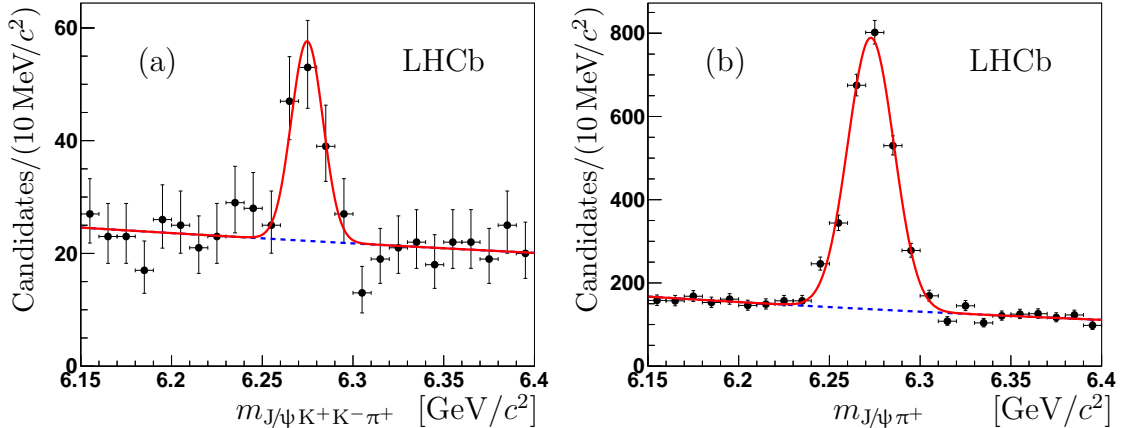


Figure 1: Mass distribution for selected (a) $B_c^+ \rightarrow J/\psi K^+ K^- \pi^+$ and (b) $B_c^+ \rightarrow J/\psi \pi^+$ candidates. The result of the fit described in the text is superimposed (solid line) together with the background component (dashed line).

110 subtract the estimated background contribution from the corresponding mass distributions.
 111 The results are shown in Fig. 2.

112 The binned $K^- \pi^+$ invariant mass distribution, presented in Fig. 2(a), is fitted with
 113 the sum of two components, one representing the \bar{K}^{*0} resonance and a non-resonant
 114 component modelled with the LASS parametrisation [34]. The resonant component is
 115 described by a relativistic P-wave Breit-Wigner function. The form factor for the $(1^-) \rightarrow$
 116 $(0^-)(0^-)$ decay is taken from lowest order perturbation theory [35], while the peak position
 117 and the natural width are fixed to their known values [31]. The resulting resonant yield is
 118 44 ± 10 decays, where the uncertainty is statistical only.

119 Figures 2(b)–(f) show the invariant mass distributions for the $K^+ K^-$, $K^+ K^- \pi^+$,
 120 $J/\psi K^+ K^-$, $J/\psi K^- \pi^+$ and $J/\psi K^+$ final states. In contrast to Fig. 2(a), no narrow structures
 121 are visible. The predictions from the model of Ref. [12] are also presented in Fig. 2, and
 122 are found to give an acceptable description of the data.

123 5 Efficiency and systematic uncertainties

124 As the ratio of branching fractions is measured, many potential sources of systematic
 125 uncertainty cancel in the ratio of efficiencies for the normalisation and signal decays.
 126 The overall efficiency for both decays is the product of the geometrical acceptance of
 127 the detector, reconstruction, selection and trigger efficiencies. These are estimated using
 128 simulation and the ratio of the efficiencies is found to be

$$\frac{\varepsilon(B_c^+ \rightarrow J/\psi \pi^+)}{\varepsilon(B_c^+ \rightarrow J/\psi K^+ K^- \pi^+)} = 14.3 \pm 0.4,$$

129 where the uncertainty is statistical only. Systematic uncertainties that do not cancel in
 130 this ratio are discussed below and summarised in Table 2.

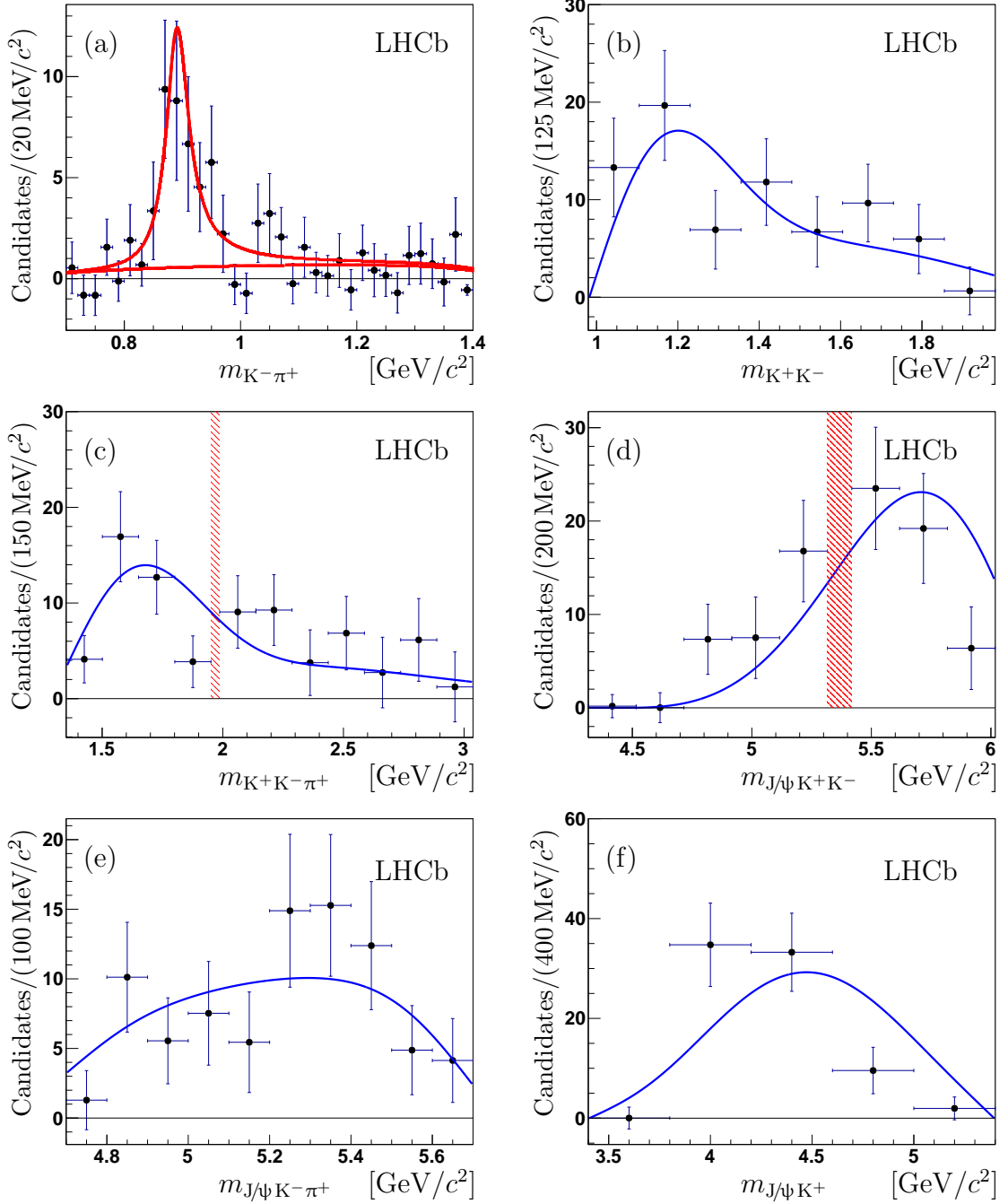


Figure 2: Background-subtracted invariant mass distributions for (a) $K^- \pi^+$, (b) $K^+ K^-$, (c) $K^+ K^- \pi^+$, (d) $J/\psi K^+ K^-$, (e) $J/\psi K^- \pi^+$ and (f) $J/\psi K^+$ in $B_c^+ \rightarrow J/\psi K^+ K^- \pi^+$ decay. The (red) full line in the $K^- \pi^+$ mass distribution (a) is composed of a resonant \bar{K}^{*0} contribution and a non-resonant component indicated by the dashed line. The (blue) full line in (b)–(f) shows the predictions of the model [12] used in the simulation. The regions $\pm 18 \text{ MeV}/c^2$ around the D_s^+ mass and $\pm 51 \text{ MeV}/c^2$ around the B_s^0 mass are excluded from the analysis and are indicated by the shaded areas on (c) and (d), respectively.

131 The main uncertainty arises from the imperfect knowledge of the shape of the signal
 132 and background components used to model the B_c^+ mass distributions. It is estimated
 133 using an alternative model to describe the $B_c^+ \rightarrow J/\psi K^+ K^- \pi^+$ and $B_c^+ \rightarrow J/\psi \pi^+$ mass
 134 distributions consisting of a Crystal Ball function [36] for the signal and a linear function
 135 for the background. The changes in the yields relative to the default fits are used to
 136 determine a 5.0% uncertainty on the number of signal candidates in both channels, and is
 137 dominated by the large background level in signal decay.

138 Other systematic uncertainties arise from differences between data and simulation in
 139 the track reconstruction efficiency for charged particles. The largest of these arises from the
 140 knowledge of the hadronic interaction probability in the detector, which has an uncertainty
 141 of 2.0% per track [37]. Further uncertainties related to the reconstruction of charged kaons
 142 contribute 0.6% per kaon [7, 38]. The differences in the kinematic properties of the charged
 143 pion in the signal and normalisation channels are also considered as a source of systematic
 144 uncertainty. The total uncertainty assigned to track reconstruction and selection is 4.2%.

145 The systematic uncertainty associated with kaon identification is studied using a kine-
 146 matically similar sample of reconstructed $B^+ \rightarrow J/\psi (K^+ K^-)_\phi K^+$ decays [7]. An uncer-
 147 tainty of 3.0% is assigned.

148 A source of systematic uncertainty arises from the potential disagreement between data
 149 and simulation in the efficiencies of the selection criteria. To study this effect, the criteria
 150 are varied to values that correspond to a 20% change in the signal yields. The variation
 151 of the relative difference between data and simulation on the number of selected signal
 152 candidates reaches 1.6%, which is assigned as a systematic uncertainty from this source,
 153 and includes effects related to pion identification criteria.

154 The dependence of the $B_c^+ \rightarrow J/\psi K^+ K^- \pi^+$ decay reconstruction and selection efficiency
 155 on the decay model implemented in the simulation is estimated from a comparison of
 156 the $K^+ K^- \pi^+$ invariant mass distributions in data and simulation, which has the greatest
 157 dependence on the decay model. This combined efficiency is recomputed after reweighting
 158 the $K^+ K^- \pi^+$ mass distribution to that observed in data. The relative difference of 2.5%
 159 observed is taken as the systematic uncertainty due to the decay model.

160 Other systematic uncertainties are related to the widths of the $K^+ K^- \pi^+$ and
 161 $J/\psi K^+ K^-$ mass regions vetoed in the analysis to reject contributions from $B_c^+ \rightarrow J/\psi D_s^+$ and
 162 $B_c^+ \rightarrow B_s^0 \pi^+$ decays. These are estimated by varying the widths of the vetoed regions
 163 and recomputing the $B_c^+ \rightarrow J/\psi K^+ K^- \pi^+$ signal yields, taking into account the changes in
 164 efficiency. A systematic uncertainty of 1.0% is assigned.

165 The efficiency of the requirement on the B_c^+ decay time depends on the value of
 166 the B_c^+ lifetime used in the simulation. The decay time distributions for simulated events
 167 are reweighted after changing the B_c^+ lifetime by one standard deviation around the
 168 known value [31], as well as using the lifetime value recently measured by the CDF
 169 collaboration [39], and the efficiencies are recomputed. The observed 2.5% variation in
 170 the ratio of efficiencies is used as the systematic uncertainty.

171 The agreement of the absolute trigger efficiency between data and simulation has been
 172 validated to a precision of 4% using the technique described in Refs. [18, 37, 40] with a large
 173 sample of $B^+ \rightarrow J/\psi (K^+ K^-)_\phi K^+$ events [7]. A further cancellation of uncertainties in

Table 2: Relative systematic uncertainties for the ratio of branching fractions of $B_c^+ \rightarrow J/\psi K^+ K^- \pi^+$ and $B_c^+ \rightarrow J/\psi \pi^+$. The total uncertainty is the quadratic sum of the individual components.

Source	Uncertainty [%]
Fit model	5.0
Track reconstruction and selection	4.2
Kaon identification	3.0
Data and simulation disagreement	1.6
Decay model dependence	2.5
Vetoed mass intervals	1.0
B_c^+ lifetime	2.5
Trigger	1.1
Stability of data taking conditions	2.5
Geometrical acceptance	0.4
Total	8.7

174 the ratio of branching fractions has been tested with the high statistics decay modes
 175 $B^+ \rightarrow J/\psi K^+$ and $B^+ \rightarrow \psi(2S)K^+$ [41], resulting in a systematic uncertainty of 1.1 %.

176 Potential uncertainties related to the stability of the data taking conditions are tested
 177 by studying the ratio of the yields of $B^+ \rightarrow J/\psi K^+ \pi^+ \pi^-$ and $B^+ \rightarrow J/\psi K^+$ decays for
 178 different data taking periods. According to this study an additional systematic uncertainty
 179 of 2.5 % is assigned [7]. The final source of systematic uncertainty considered originates
 180 from the dependence of the geometrical acceptance on both the beam crossing angle and
 181 the position of the luminous region. The observed difference in the efficiency ratios is
 182 taken as an estimate of the systematic uncertainty and is 0.4 %. The correlation between
 183 this uncertainty and the previous one is neglected.

184 6 Results and summary

185 The decay $B_c^+ \rightarrow J/\psi K^+ K^- \pi^+$ is observed for the first time, and a signal yield of 78 ± 14
 186 is reported. This analysis uses a data sample corresponding to an integrated luminosity
 187 of 1 fb^{-1} at a centre-of-mass energy of 7 TeV and 2 fb^{-1} at 8 TeV. The significance, taking
 188 into account the systematic uncertainties due to the fit function, peak position and mass
 189 resolution in the default fit, is estimated to be 6.2 standard deviations.

190 Using the $B_c^+ \rightarrow J/\psi \pi^+$ mode as a normalisation channel, the ratio of branching
 191 fractions is calculated as

$$\frac{\mathcal{B}(B_c^+ \rightarrow J/\psi K^+ K^- \pi^+)}{\mathcal{B}(B_c^+ \rightarrow J/\psi \pi^+)} = \frac{N(B_c^+ \rightarrow J/\psi K^+ K^- \pi^+)}{N(B_c^+ \rightarrow J/\psi \pi^+)} \times \frac{\varepsilon(B_c^+ \rightarrow J/\psi \pi^+)}{\varepsilon(B_c^+ \rightarrow J/\psi K^+ K^- \pi^+)},$$

192 where N is the number of reconstructed decays obtained from the fit described in Sect. 4.

193 The ratio of branching fractions is measured to be

$$\frac{\mathcal{B}(B_c^+ \rightarrow J/\psi K^+ K^- \pi^+)}{\mathcal{B}(B_c^+ \rightarrow J/\psi \pi^+)} = 0.53 \pm 0.10 \pm 0.05,$$

194 where the first uncertainty is statistical and the second systematic. The largest contri-
195 bution to the $B_c^+ \rightarrow J/\psi K^+ K^- \pi^+$ decay is found to be from $B_c^+ \rightarrow J/\psi \bar{K}^{*0} K^+$ decays.
196 The theoretical predictions for the branching fraction ratio of 0.49 and 0.47 [12], using
197 form factors from Refs. [13] and [14], respectively, are found to be in good agreement with
198 this measurement.

199 Acknowledgements

200 We thank A.K. Likhoded and A.V. Luchinsky for fruitful discussions about the dynamics of
201 B_c^+ decays. We express our gratitude to our colleagues in the CERN accelerator departments
202 for the excellent performance of the LHC. We thank the technical and administrative
203 staff at the LHCb institutes. We acknowledge support from CERN and from the national
204 agencies: CAPES, CNPq, FAPERJ and FINEP (Brazil); NSFC (China); CNRS/IN2P3
205 and Region Auvergne (France); BMBF, DFG, HGF and MPG (Germany); SFI (Ireland);
206 INFN (Italy); FOM and NWO (The Netherlands); SCSR (Poland); MEN/IFA (Romania);
207 MinES, Rosatom, RFBR and NRC “Kurchatov Institute” (Russia); MinECo, XuntaGal
208 and GENCAT (Spain); SNSF and SER (Switzerland); NAS Ukraine (Ukraine); STFC
209 (United Kingdom); NSF (USA). We also acknowledge the support received from the ERC
210 under FP7. The Tier1 computing centres are supported by IN2P3 (France), KIT and
211 BMBF (Germany), INFN (Italy), NWO and SURF (The Netherlands), PIC (Spain),
212 GridPP (United Kingdom). We are thankful for the computing resources put at our
213 disposal by Yandex LLC (Russia), as well as to the communities behind the multiple open
214 source software packages that we depend on.

215 References

- 216 [1] C.-H. Chang and Y.-Q. Chen, *The decays of B_c meson*, Phys. Rev. **D49** (1994)
217 3399; S. S. Gershtein, V. V. Kiselev, A. K. Likhoded, and A. V. Tkabladze, *Physics*
218 *of B_c mesons*, Phys. Usp. **38** (1995) 1, arXiv:hep-ph/9504319; S. S. Gershtein
219 *et al.*, *Theoretical status of the B_c meson*, arXiv:hep-ph/9803433; P. Colangelo and
220 F. De Fazio, *Using heavy quark spin symmetry in semileptonic B_c decays*, Phys. Rev.
221 **D61** (2000) 034012, arXiv:hep-ph/9909423; V. V. Kiselev, *Decays of the B_c meson*,
222 arXiv:hep-ph/0308214.
- 223 [2] A. K. Likhoded and A. V. Luchinsky, *Light hadron production in $B_c \rightarrow J/\psi +$*
224 *X decays*, Phys. Rev. **D81** (2010) 014015, arXiv:0910.3089; A. K. Likhoded and
225 A. V. Luchinsky, *Light hadron production in $B_c \rightarrow B_s^{(*)} + X$ decays*, Phys. Rev. **D82**
226 (2010) 014012, arXiv:1004.0087.

- 227 [3] CDF collaboration, F. Abe *et al.*, *Observation of the B_c meson in $p\bar{p}$ collisions at*
228 $\sqrt{s} = 1.8 \text{ TeV}$, Phys. Rev. Lett. **81** (1998) 2432, [arXiv:hep-ex/9805034](#); CDF
229 collaboration, F. Abe *et al.*, *Observation of B_c mesons in $p\bar{p}$ collisions at $\sqrt{s} =$*
230 1.8 TeV , Phys. Rev. **D58** (1998) 112004, [arXiv:hep-ex/9804014](#).
- 231 [4] CDF collaboration, T. Aaltonen *et al.*, *Observation of the decay $B_c^\pm \rightarrow J/\psi \pi^\pm$ and*
232 *measurement of the B_c^\pm mass*, Phys. Rev. Lett. **100** (2008) 182002, [arXiv:0712.1506](#);
233 D0 collaboration, V. M. Abazov *et al.*, *Observation of the B_c meson in the exclusive*
234 *decay $B_c \rightarrow J/\psi \pi$* , Phys. Rev. Lett. **101** (2008) 012001, [arXiv:0802.4258](#).
- 235 [5] LHCb collaboration, R. Aaij *et al.*, *First observation of the decay $B_c^+ \rightarrow J/\psi \pi^+ \pi^- \pi^+$,*
236 Phys. Rev. Lett. **108** (2012) 251802, [arXiv:1204.0079](#).
- 237 [6] LHCb collaboration, R. Aaij *et al.*, *Observation of the decay $B_c^+ \rightarrow \psi(2S) \pi^+$,* Phys.
238 Rev. **D87** (2013) 071103(R), [arXiv:1303.1737](#).
- 239 [7] LHCb collaboration, R. Aaij *et al.*, *Observation of $B_c^+ \rightarrow J/\psi D_s^+$ and $B_c^+ \rightarrow J/\psi D_s^{*+}$ de-*
240 *cays*, Phys. Rev. **D87** (2013) 112012, [arXiv:1304.4530](#).
- 241 [8] LHCb collaboration, R. Aaij *et al.*, *Observation of the decay $B_c^+ \rightarrow B_s^0 \pi^+$,*
242 [arXiv:1308.4544](#), submitted to Phys. Rev. Lett.
- 243 [9] LHCb collaboration, R. Aaij *et al.*, *First observation of the decay $B_c^+ \rightarrow J/\psi K^+$,*
244 [arXiv:1306.6723](#), to appear in JHEP.
- 245 [10] M. Bauer, B. Stech, and M. Wirbel, *Exclusive non-leptonic decays of D, D_s^+ , and*
246 *B mesons*, Z. Phys. **C34** (1987) 103; M. Wirbel, *Description of weak decays of B and*
247 *D mesons*, Prog. Part. Nucl. Phys. **21** (1988) 33.
- 248 [11] Belle collaboration, A. Drutskoy *et al.*, *Observation of $B \rightarrow D^{(*)} K^- K^{0(*)}$ decays*, Phys.
249 Lett. **B542** (2002) 171, [arXiv:hep-ex/0207041](#).
- 250 [12] A. V. Luchinsky, *Production of K mesons in exclusive B_c decays*, [arXiv:1307.0953](#).
- 251 [13] V. V. Kiselev, A. E. Kovalsky, and A. K. Likhoded, *B_c decays and lifetime in QCD*
252 *sum rules*, Nucl. Phys. **B585** (2000) 353, [arXiv:hep-ph/0002127](#).
- 253 [14] D. Ebert, R. N. Faustov, and V. O. Galkin, *Weak decays of the B_c meson to charmo-*
254 *onium and D mesons in the relativistic quark model*, Phys. Rev. **D68** (2003) 094020,
255 [arXiv:hep-ph/0306306](#).
- 256 [15] LHCb collaboration, A. A. Alves Jr. *et al.*, *The LHCb detector at the LHC*, JINST **3**
257 (2008) S08005.
- 258 [16] M. Adinolfi *et al.*, *Performance of the LHCb RICH detector at the LHC*, Eur. Phys.
259 J. **C73** (2013) 2431, [arXiv:1211.6759](#).

- 260 [17] A. A. Alves Jr *et al.*, *Performance of the LHCb muon system*, JINST **8** (2013) P02022,
261 [arXiv:1211.1346](#).
- 262 [18] R. Aaij *et al.*, *The LHCb trigger and its performance in 2011*, JINST **8** (2013) P04022,
263 [arXiv:1211.3055](#).
- 264 [19] T. Sjöstrand, S. Mrenna, and P. Skands, *PYTHIA 6.4 physics and manual*, JHEP **05**
265 (2006) 026, [arXiv:hep-ph/0603175](#).
- 266 [20] I. Belyaev *et al.*, *Handling of the generation of primary events in GAUSS, the LHCb*
267 *simulation framework*, Nuclear Science Symposium Conference Record (NSS/MIC)
268 **IEEE** (2010) 1155.
- 269 [21] P. Golonka and Z. Was, *PHOTOS Monte Carlo: a precision tool for QED corrections*
270 *in Z and W decays*, Eur. Phys. J. **C45** (2006) 97, [arXiv:hep-ph/0506026](#).
- 271 [22] C.-H. Chang, C. Driouichi, P. Eerola, and X.-G. Wu, *BCVEGPY: an event generator*
272 *for hadronic production of the B_c meson*, Comput. Phys. Commun. **159** (2004) 192,
273 [arXiv:hep-ph/0309120](#).
- 274 [23] D. J. Lange, *The EVTGEN particle decay simulation package*, Nucl. Instrum. Meth.
275 **A462** (2001) 152.
- 276 [24] Belle collaboration, M. J. Lee *et al.*, *Measurement of the branching fractions and*
277 *the invariant mass distributions for $\tau^- \rightarrow h^- h^+ h^- \nu_\tau$ decays*, Phys. Rev. **D81** (2010)
278 113007, [arXiv:1001.0083](#).
- 279 [25] J. H. Kuhn and A. Santamaria, *Tau decays to pions*, Z. Phys. **C48** (1990) 445.
- 280 [26] A. V. Berezhnoy, A. K. Likhoded, and A. V. Luchinsky, *B_c \rightarrow J/ ψ (B_s⁰, B_s^{*}) + n π decays*,
281 PoS **QFTHEP2011** (2011) 076, [arXiv:1111.5952](#); A. V. Berezhnoy, A. K. Likhoded,
282 and A. V. Luchinsky, *BC_NPI module for the analysis of B_c \rightarrow J/ ψ + n π and*
283 *B_c \rightarrow B_s⁰ + n π decays within the EVTGEN package*, [arXiv:1104.0808](#); A. V. Luchinsky,
284 *Production of charged π -mesons in exclusive B_c \rightarrow V(P) + n π decays*, Phys. Rev. **D86**
285 (2012) 074024, [arXiv:1208.1398](#); A. K. Likhoded and A. V. Luchinsky, *Production*
286 *of a pion system in exclusive B_c \rightarrow V(P) + n π decays*, Phys. Atom. Nucl. **76** (2013)
287 787.
- 288 [27] Geant4 collaboration, J. Allison *et al.*, *GEANT4 developments and applications*, IEEE
289 Trans. Nucl. Sci. **53** (2006) 270; Geant4 collaboration, S. Agostinelli *et al.*, *GEANT4:*
290 *a simulation toolkit*, Nucl. Instrum. Meth. **A506** (2003) 250.
- 291 [28] M. Clemencic *et al.*, *The LHCb simulation application, GAUSS: design, evolution and*
292 *experience*, J. Phys. Conf. Ser. **331** (2011) 032023.
- 293 [29] F. Archilli *et al.*, *Performance of the muon identification at LHCb*, [arXiv:1306.0249](#),
294 submitted to JINST.

- 295 [30] W. D. Hulsbergen, *Decay chain fitting with a Kalman filter*, Nucl. Instrum. Meth.
296 **A552** (2005) 566, [arXiv:physics/0503191](#).
- 297 [31] Particle Data Group, J. Beringer *et al.*, *Review of particle physics*, Phys. Rev. **D86**
298 (2012) 010001, and 2013 partial update for the 2014 edition.
- 299 [32] LHCb collaboration, R. Aaij *et al.*, *Precision measurements of D meson mass differ-*
300 *ences*, JHEP **06** (2013) 65, [arXiv:1304.6865](#).
- 301 [33] M. Pivk and F. R. Le Diberder, *sPlot: a statistical tool to unfold data distributions*,
302 Nucl. Instrum. Meth. **A555** (2005) 356, [arXiv:physics/0402083](#).
- 303 [34] D. Aston *et al.*, *A study of $K^-\pi^+$ scattering in the reaction $K^-\text{p} \rightarrow K^-\pi^+\text{n}$ at*
304 *11 GeV/c*, Nucl. Phys. **B296** (1988) 493.
- 305 [35] J. D. Jackson, *Remarks on the phenomenological analysis of resonances*, Nuovo Cim.
306 **34** (1964) 1644.
- 307 [36] T. Skwarnicki, *A study of the radiative cascade transitions between the Υ' and Υ res-*
308 *onances*, PhD thesis, Institute of Nuclear Physics, Krakow, 1986, DESY-F31-86-02.
- 309 [37] LHCb collaboration, R. Aaij *et al.*, *Prompt K_S^0 production in pp collisions at*
310 *$\sqrt{s} = 0.9$ TeV*, Phys. Lett. **B693** (2010) 69, [arXiv:1008.3105](#).
- 311 [38] A. Jaeger *et al.*, *Measurement of the track finding efficiency*, LHCb-PUB-2011-025;
312 LHCb collaboration, R. Aaij *et al.*, *Measurement of track reconstruction efficiency at*
313 *LHCb*, LHCb-DP-2013-002, in preparation.
- 314 [39] CDF collaboration, F. Aaltonen *et al.*, *Measurement of the B_c^- meson lifetime in the*
315 *decay $B_c^- \rightarrow J/\psi \pi^-$* , Phys. Rev. **D87** (2013) 011101, [arXiv:1210.2366](#).
- 316 [40] LHCb collaboration, R. Aaij *et al.*, *Observation of J/ψ -pair production in pp collisions*
317 *at $\sqrt{s} = 7$ TeV*, Phys. Lett. **B707** (2012) 52, [arXiv:1109.0963](#).
- 318 [41] LHCb collaboration, R. Aaij *et al.*, *Measurement of relative branching fractions of*
319 *B decays to $\psi(2S)$ and J/ψ mesons*, Eur. Phys. J. **C72** (2012) 2118, [arXiv:1205.0918](#).