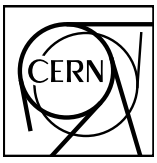
EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH



CERN-EP-2021-084
10 May 2021

Supplemental figures: Measurement of the cross sections of Ξ_c^0 and Ξ_c^+ baryons and of the branching-fraction ratio $\mathrm{BR}(\Xi_c^0 \to \Xi^- e^+ \nu_e)/\mathrm{BR}(\Xi_c^0 \to \Xi^- \pi^+)$ in pp collisions at $\sqrt{s} = 13$ TeV

The ALICE Collaboration*

Abstract

The following public note presents supplemental figures for the paper "Measurement of the production cross sections of Ξ_c^0 and Ξ_c^+ baryons and of the $\mathrm{BR}(\Xi_c^0 \to \Xi^- e^+ \nu_e)/\mathrm{BR}(\Xi_c^0 \to \Xi^- \pi^+)$ ratio in pp collisions at $\sqrt{s}$ = 13 TeV" [1]. The p_T-differential production cross sections of prompt charm-strange baryons Ξ_c^0 and Ξ_c^+ were measured at midrapidity in proton–proton (pp) collisions at $\sqrt{s}$ = 13 TeV with the ALICE detector at the LHC. The Ξ_c^0 baryon was reconstructed via both its semileptonic decay ($e^+\Xi^-\nu_e$) and, for the first time, also via its hadronic decay ($\Xi^-\pi^+$). The Ξ_c^+ baryon was also reconstructed for the first time via the hadronic decay ($\Xi^-\pi^+\pi^+$). The ratio $\mathrm{BR}(\Xi_c^0 \to \Xi^- e^+ \nu_e)/\mathrm{BR}(\Xi_c^0 \to \Xi^- \pi^+)$ = 1.38 $\pm$ 0.14 (stat) $\pm$ 0.22 (syst) was measured.

*See Appendix A for the list of collaboration members

1 Invariant mass distributions

The Ξ_c^0 baryon, and its charge conjugate, was reconstructed via its decay into $e^+\Xi^-\nu_e$ (BR = (1.8 ± 1.2)% [2]) and for the first time via its decay into $\Xi^-\pi^+$ (BR = (1.43 ± 0.32)% [2]) in the interval $1 < p_T < 12$ GeV/c. The Ξ_c^+ baryon, and its charge conjugate, was also reconstructed for the first time via its decay into $\Xi^-\pi^+\pi^+$ (BR = (2.86 ± 1.21 ± 0.38)% [3]) in the interval $4 < p_T < 12$ GeV/c as reported in Ref. [1].

Examples of invariant-mass distributions of candidate Ξ_c baryons together with the result of the fits are reported in Fig. 1. For the semileptonic decay channel of the Ξ_c^0, the candidates are defined from $e^+\Xi^-$ pairs. Due to the undetected neutrino, the invariant-mass distribution of $e^+\Xi^-$ pairs does not show a peak at the Ξ_c^0 mass (shown in the left panel of Fig. 1). The background contributions are estimated exploiting the fact that Ξ_c^0 baryons and their antiparticles decay only into eΞ pairs with opposite charge sign ($e^+\Xi^-$ and $e^-\Xi^+$), denoted as right-sign (RS), and not into same-sign pairs ($e^-\Xi^-$ and $e^+\Xi^+$), denoted as wrong-sign (WS), while combinatorial background candidates contribute equally to both RS and WS pairs. The raw yield is obtained from the invariant-mass distribution of RS pairs after subtracting the WS contribution. For the two hadronic decay channels the invariant mass can be reconstructed and it is shown and the signal is extracted via fits (middle and right panel of Fig. 1). The fit function was composed of a Gaussian for the description of the signal and a linear function for the background. The widths of the signal peaks were fixed to the value obtained from simulations to make the fits more stable. The widths of the signal peaks were observed to be compatible within the uncertainties between data and simulations.

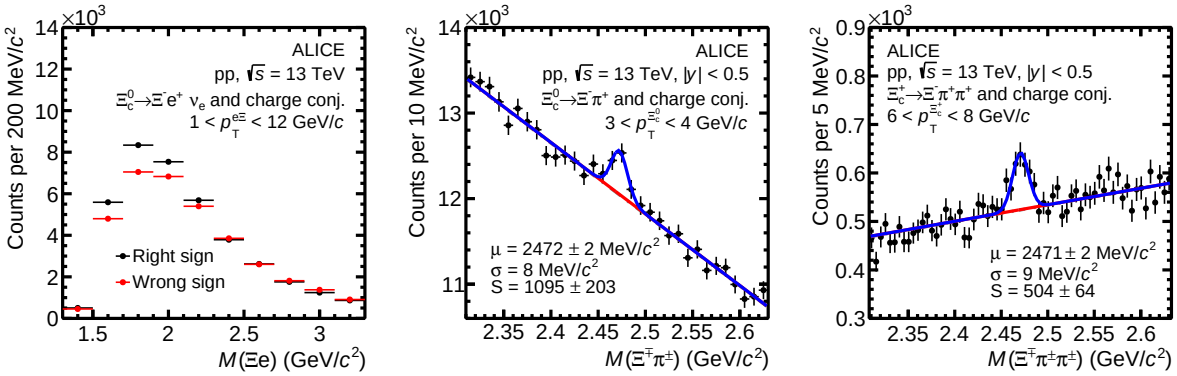


Figure 1: Left panel: invariant-mass distributions of right-sign ($e^\pm\Xi^\mp$) and wrong-sign ($e^\pm\Xi^\pm$) pairs with $1 < p_T < 12$ GeV/c for the analysis of $\Xi_c^0 \to e^+\Xi^-\nu_e$. Middle and right panels: invariant-mass distributions of $\Xi_c^0 \to \pi^+\Xi^-$ and $\Xi_c^+ \to \pi^+\pi^+\Xi^-$ candidates and charge conjugates in $3 < p_T < 4$ GeV/c and $4 < p_T < 6$ GeV/c, respectively. The blue lines show the total fit functions and the red lines represent the combinatorial background.

The $p_T^{e\Xi}$-differential raw yield is corrected for the missing neutrino momentum to obtain the Ξ_c^0 raw yield in intervals of Ξ_c^0 p_T. The correction for the missing momentum of the neutrino is performed by using an unfolding technique with a response matrix which represents the correlation between the p_T of the Ξ_c^0 baryon and that of the reconstructed $e^+\Xi^-$ pair. The response matrix is determined through a simulation with the PYTHIA 8.2 event generator and the GEANT 3 transport code, including a realistic description of the detector conditions and alignment during the data taking period. The response matrix needs to be determined using a realistic Ξ_c^0-baryon p_T distribution which is not known a priori. Therefore, a two-step iterative procedure is adopted. In the first step, the response matrix is obtained with the p_T distribution generated with PYTHIA 8.2. This matrix is used to calculate a first estimate of the Ξ_c^0 p_T-differential spectrum from the measured p_T distribution of $e^+\Xi^-$ pairs. The Ξ_c^0 p_T distribution from this first iteration is used to reweight the response matrix, which is then used for the second iteration. The response matrix obtained from this procedure is shown in the left panel of Fig. 2, while the raw yield before and after the

unfolding is applied is shown in the right panel of Fig. 2. The Bayesian unfolding technique implemented in the RooUnfold package is used. In this analysis the Bayesian procedure required three iterations to converge.

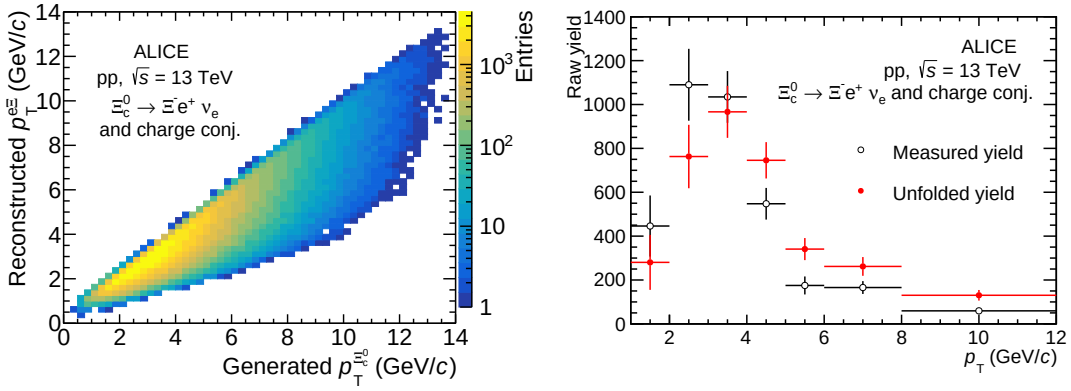


Figure 2: Left panel: correlation matrix between the generated Ξ_c^0-baryon p_T and the reconstructed $e^+\Xi^-$ pair p_T. Right panel: The $p_T^{e\Xi}$-differential raw yield before (black open markers) and after (red solid markers) the unfolding is applied.

2 Prompt Ξ_c^0-baryon production cross section comparison

The measurement of the production cross section of prompt Ξ_c^0 baryons not corrected by the BRs in both the semileptonic and hadronic decays channels are shown in the upper panel of Fig. 3. The error bars and empty boxes represent the statistical and systematic uncertainties, respectively. The lower panel of Fig. 3 shows the p_T-dependent ratio of the two measurements and, as explained in [1], its weighted average was used to calculate the ratio $\mathrm{BR}(\Xi_c^0 \to \Xi^- e^+ \nu_e)/\mathrm{BR}(\Xi_c^0 \to \Xi^- \pi^+)$ with an improved precision by a factor of 3 with respect to the global average value reported by the PDG [2]. The average was calculated using as weights the sum in quadrature of the relative statistical and the p_T-uncorrelated part of the systematic uncertainties. The p_T-correlated systematic uncertainties were propagated by recomputing the average ratio after shifting up and down the p_T-dependent ratios by the corresponding p_T-correlated systematic uncertainty. The final systematic uncertainty on the ratio was obtained by summing in quadrature the p_T-correlated and uncorrelated systematic uncertainties.

The prompt Ξ_c^0-baryon cross section measurements in the two decay channels corrected with BR are shown in Fig. 4 and agree within the statistical uncertainties in the common p_T interval of the measurement. The results from the two decay channels were combined to obtain a more precise measurement of the prompt p_T-differential Ξ_c^0-baryon production cross section. The error bars and empty boxes represent the statistical and systematic uncertainties, respectively. The systematic uncertainties on the BRs and on the luminosity are not included in the boxes but their values are listed in the figures.

Acknowledgements

The ALICE Collaboration would like to thank all its engineers and technicians for their invaluable contributions to the construction of the experiment and the CERN accelerator teams for the outstanding performance of the LHC complex. The ALICE Collaboration gratefully acknowledges the resources and support provided by all Grid centres and the Worldwide LHC Computing Grid (WLCG) collaboration. The ALICE Collaboration acknowledges the following funding agencies for their support in building and running the ALICE detector: A. I. Alikhanyan National Science Laboratory (Yerevan Physics Institute) Foundation (ANSL), State Committee of Science and World Federation of Scientists (WFS),

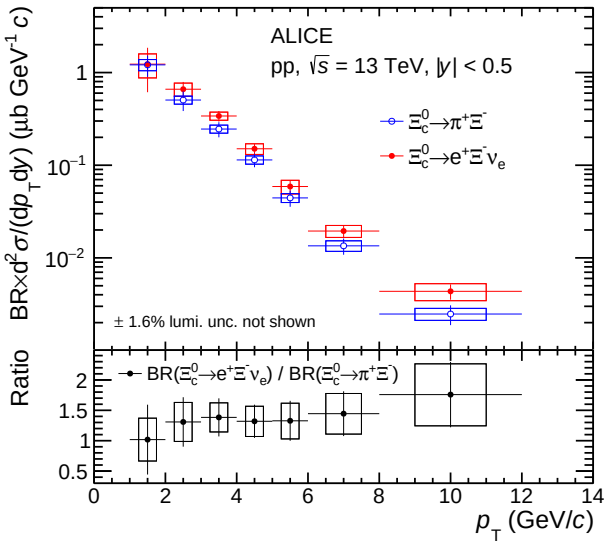


Figure 3: Upper panel: BR × cross sections of prompt $\Xi_c^0 \to e^+\Xi^-\nu_e$ (full red circles) and $\Xi_c^0 \to \pi^+\Xi^-$ (open blue circles) as a function of the transverse momentum p_T. Lower panel: ratio of BR × cross sections of prompt $\Xi_c^0 \to e^+\Xi^-\nu_e$ and $\Xi_c^0 \to \pi^+\Xi^-$ as a function of p_T.

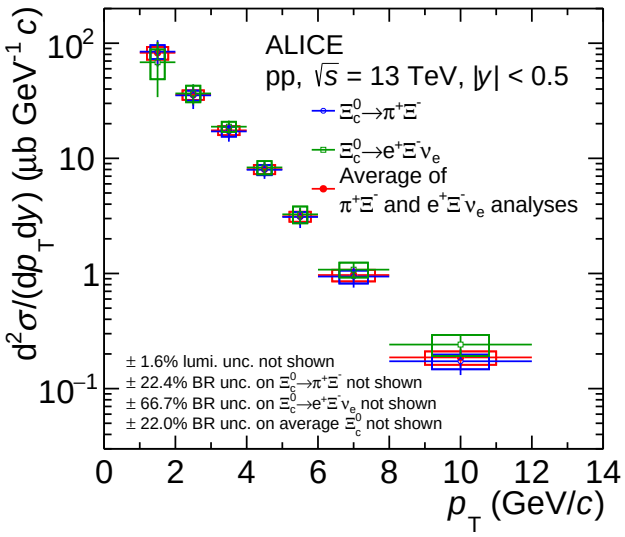


Figure 4: Cross sections of prompt $\Xi_c^0 \to e^+\Xi^-\nu_e$ (empty green squares) and $\Xi_c^0 \to \pi^+\Xi^-$ (open blue circles) and the average of the cross section values (full red markers) as a function of the transverse momentum p_T.

Armenia; Austrian Academy of Sciences, Austrian Science Fund (FWF): [M 2467-N36] and Nationalstiftung für Forschung, Technologie und Entwicklung, Austria; Ministry of Communications and High Technologies, National Nuclear Research Center, Azerbaijan; Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq), Financiadora de Estudos e Projetos (Finep), Fundação de Amparo à Pesquisa do Estado de São Paulo (FAPESP) and Universidade Federal do Rio Grande do Sul (UFRGS), Brazil; Ministry of Education of China (MOEC) , Ministry of Science & Technology of China (MSTC) and National Natural Science Foundation of China (NSFC), China; Ministry of Science and Education and Croatian Science Foundation, Croatia; Centro de Aplicaciones Tecnológicas y Desarrollo Nuclear (CEADEN), Cubaenergía, Cuba; Ministry of Education, Youth and Sports of the Czech Republic, Czech

Republic; The Danish Council for Independent Research | Natural Sciences, the VILLUM FONDEN and Danish National Research Foundation (DNRF), Denmark; Helsinki Institute of Physics (HIP), Finland; Commissariat à l'Energie Atomique (CEA) and Institut National de Physique Nucléaire et de Physique des Particules (IN2P3) and Centre National de la Recherche Scientifique (CNRS), France; Bundesministerium für Bildung und Forschung (BMBF) and GSI Helmholtzzentrum für Schwerionenforschung GmbH, Germany; General Secretariat for Research and Technology, Ministry of Education, Research and Religions, Greece; National Research, Development and Innovation Office, Hungary; Department of Atomic Energy Government of India (DAE), Department of Science and Technology, Government of India (DST), University Grants Commission, Government of India (UGC) and Council of Scientific and Industrial Research (CSIR), India; Indonesian Institute of Science, Indonesia; Istituto Nazionale di Fisica Nucleare (INFN), Italy; Institute for Innovative Science and Technology , Nagasaki Institute of Applied Science (IIST), Japanese Ministry of Education, Culture, Sports, Science and Technology (MEXT) and Japan Society for the Promotion of Science (JSPS) KAKENHI, Japan; Consejo Nacional de Ciencia (CONACYT) y Tecnología, through Fondo de Cooperación Internacional en Ciencia y Tecnología (FONCICYT) and Dirección General de Asuntos del Personal Academico (DGAPA), Mexico; Nederlandse Organisatie voor Wetenschappelijk Onderzoek (NWO), Netherlands; The Research Council of Norway, Norway; Commission on Science and Technology for Sustainable Development in the South (COMSATS), Pakistan; Pontificia Universidad Católica del Perú, Peru; Ministry of Education and Science, National Science Centre and WUT ID-UB, Poland; Korea Institute of Science and Technology Information and National Research Foundation of Korea (NRF), Republic of Korea; Ministry of Education and Scientific Research, Institute of Atomic Physics and Ministry of Research and Innovation and Institute of Atomic Physics, Romania; Joint Institute for Nuclear Research (JINR), Ministry of Education and Science of the Russian Federation, National Research Centre Kurchatov Institute, Russian Science Foundation and Russian Foundation for Basic Research, Russia; Ministry of Education, Science, Research and Sport of the Slovak Republic, Slovakia; National Research Foundation of South Africa, South Africa; Swedish Research Council (VR) and Knut & Alice Wallenberg Foundation (KAW), Sweden; European Organization for Nuclear Research, Switzerland; Suranaree University of Technology (SUT), National Science and Technology Development Agency (NSDTA) and Office of the Higher Education Commission under NRU project of Thailand, Thailand; Turkish Energy, Nuclear and Mineral Research Agency (TENMAK), Turkey; National Academy of Sciences of Ukraine, Ukraine; Science and Technology Facilities Council (STFC), United Kingdom; National Science Foundation of the United States of America (NSF) and United States Department of Energy, Office of Nuclear Physics (DOE NP), United States of America.

References

[1] **ALICE** Collaboration, S. Acharya *et al.*, "Measurement of the cross sections of Ξ_c^0 and Ξ_c^+ baryons and branching-fraction ratio BR($\Xi_c^0 \to \Xi^- e^+ \nu_e$)/BR($\Xi_c^0 \to \Xi^- \pi^+$) in pp collisions at 13 TeV", arXiv:2105.05187 [nucl-ex].

[2] **Particle Data Group** Collaboration, P. Zyla *et al.*, "Review of Particle Physics", *PTEP* **2020** no. 8, (2020) 083C01.

[3] **Belle** Collaboration, Y. Li *et al.*, "First measurements of absolute branching fractions of the Ξ_c^+ baryon at Belle", *Phys. Rev. D* **100** (2019) 031101.

A The ALICE Collaboration

S. Acharya[143], D. Adamová[98], A. Adler[76], J. Adolfsson[83], G. Aglieri Rinella[35], M. Agnello[31], N. Agrawal[55], Z. Ahammed[143], S. Ahmad[16], S.U. Ahn[78], I. Ahuja[39], Z. Akbar[52], A. Akindinov[95], M. Al-Turany[110], S.N. Alam[41], D. Aleksandrov[91], B. Alessandro[61], H.M. Alfanda[7], R. Alfaro Molina[73], B. Ali[16], Y. Ali[14], A. Alici[26], N. Alizadehvandchali[127], A. Alkin[35], J. Alme[21], T. Alt[70], L. Altenkamper[21], I. Altsybeev[115], M.N. Anaam[7], C. Andrei[49], D. Andreou[93], A. Andronic[146], M. Angeletti[35], V. Anguelov[107], F. Antinori[58], P. Antonioli[55], C. Anuj[16], N. Apadula[82], L. Aphecetche[117], H. Appelshäuser[70], S. Arcelli[26], R. Arnaldi[61], I.C. Arsene[20], M. Arslandok[148,107], A. Augustinus[35], R. Averbeck[110], S. Aziz[80], M.D. Azmi[16], A. Badalà[57], Y.W. Baek[42], X. Bai[131,110], R. Bailhache[70], Y. Bailung[51], R. Bala[104], A. Balbino[31], A. Baldisseri[140], B. Balis[2], M. Ball[44], D. Banerjee[4], R. Barbera[27], L. Barioglio[108,25], M. Barlou[87], G.G. Barnaföldi[147], L.S. Barnby[97], V. Barret[137], C. Bartels[130], K. Barth[35], E. Bartsch[70], F. Baruffaldi[28], N. Bastid[137], S. Basu[83], G. Batigne[117], B. Batyunya[77], D. Bauri[50], J.L. Bazo Alba[114], I.G. Bearden[92], C. Beattie[148], I. Belikov[139], A.D.C. Bell Hechavarria[146], F. Bellini[26,35], R. Bellwied[127], S. Belokurova[115], V. Belyaev[96], G. Bencedi[71], S. Beole[25], A. Bercuci[49], Y. Berdnikov[101], A. Berdnikova[107], D. Berenyi[147], L. Bergmann[107], M.G. Besoiu[69], L. Betev[35], P.P. Bhaduri[143], A. Bhasin[104], I.R. Bhat[104], M.A. Bhat[4], B. Bhattacharjee[43], P. Bhattacharya[23], L. Bianchi[25], N. Bianchi[53], J. Bielčík[38], J. Bielčíková[98], J. Biernat[120], A. Bilandzic[108], G. Biro[147], S. Biswas[4], J.T. Blair[121], D. Blau[91], M.B. Blidaru[110], C. Blume[70], G. Boca[29,59], F. Bock[99], A. Bogdanov[96], S. Boi[23], J. Bok[63], L. Boldizsár[147], A. Bolozdynya[96], M. Bombara[39], P.M. Bond[35], G. Bonomi[142,59], H. Borel[140], A. Borissov[84], H. Bossi[148], E. Botta[25], L. Bratrud[70], P. Braun-Munzinger[110], M. Bregant[123], M. Broz[38], G.E. Bruno[109,34], M.D. Buckland[130], D. Budnikov[111], H. Buesching[70], S. Bufalino[31], O. Bugnon[117], P. Buhler[116], Z. Buthelezi[74,134], J.B. Butt[14], S.A. Bysiak[120], D. Caffarri[93], M. Cai[28,7], H. Caines[148], A. Caliva[110], E. Calvo Villar[114], J.M.M. Camacho[122], R.S. Camacho[46], P. Camerini[24], F.D.M. Canedo[123], F. Carnesecchi[35,26], R. Caron[140], J. Castillo Castellanos[140], E.A.R. Casula[23], F. Catalano[31], C. Ceballos Sanchez[77], P. Chakraborty[50], S. Chandra[143], S. Chapeland[35], M. Chartier[130], S. Chattopadhyay[143], S. Chattopadhyay[112], A. Chauvin[23], T.G. Chavez[46], C. Cheshkov[138], B. Cheynis[138], V. Chibante Barroso[35], D.D. Chinellato[124], S. Cho[63], P. Chochula[35], P. Christakoglou[93], C.H. Christensen[92], P. Christiansen[83], T. Chujo[136], C. Cicalo[56], L. Cifarelli[26], F. Cindolo[55], M.R. Ciupek[110], G. Clai[II,55], J. Cleymans[I,126], F. Colamaria[54], J.S. Colburn[113], D. Colella[109,54,34,147], A. Collu[82], M. Colocci[35,26], M. Concas[III,61], G. Conesa Balbastre[81], Z. Conesa del Valle[80], G. Contin[24], J.G. Contreras[38], M.L. Coquet[140], T.M. Cormier[99], P. Cortese[32], M.R. Cosentino[125], F. Costa[35], S. Costanza[29,59], P. Crochet[137], R. Cruz-Torres[82], E. Cuautle[71], P. Cui[7], L. Cunqueiro[99], A. Dainese[58], F.P.A. Damas[117,140], M.C. Danisch[107], A. Danu[69], I. Das[112], P. Das[89], P. Das[4], S. Das[4], S. Dash[50], S. De[89], A. De Caro[30], G. de Cataldo[54], L. De Cilladi[25], J. de Cuveland[40], A. De Falco[23], D. De Gruttola[30], N. De Marco[61], C. De Martin[24], S. De Pasquale[30], S. Deb[51], H.F. Degenhardt[123], K.R. Deja[144], L. Dello Stritto[30], S. Delsanto[25], W. Deng[7], P. Dhankher[19], D. Di Bari[34], A. Di Mauro[35], R.A. Diaz[8], T. Dietel[126], Y. Ding[138,7], R. Divià[35], D.U. Dixit[19], Ø. Djuvsland[21], U. Dmitrieva[65], J. Do[63], A. Dobrin[69], B. Dönigus[70], O. Dordic[20], A.K. Dubey[143], A. Dubla[110,93], S. Dudi[103], M. Dukhishyam[89], P. Dupieux[137], N. Dzalaiova[13], T.M. Eder[146], R.J. Ehlers[99], V.N. Eikeland[21], D. Elia[54], B. Erazmus[117], F. Ercolessi[26], F. Erhardt[102], A. Erokhin[115], M.R. Ersdal[21], B. Espagnon[80], G. Eulisse[35], D. Evans[113], S. Evdokimov[94], L. Fabbietti[108], M. Faggin[28], J. Faivre[81], F. Fan[7], A. Fantoni[53], M. Fasel[99], P. Fecchio[31], A. Feliciello[61], G. Feofilov[115], A. Fernández Téllez[46], A. Ferrero[140], A. Ferretti[25], V.J.G. Feuillard[107], J. Figiel[120], S. Filchagin[111], D. Finogeev[65], F.M. Fionda[56,21], G. Fiorenza[35,109], F. Flor[127], A.N. Flores[121], S. Foertsch[74], P. Foka[110], S. Fokin[91], E. Fragiacomo[62], E. Frajna[147], U. Fuchs[35], N. Funicello[30], C. Furget[81], A. Furs[65], J.J. Gaardhøje[92], M. Gagliardi[25], A.M. Gago[114], A. Gal[139], C.D. Galvan[122], P. Ganoti[87], C. Garabatos[110], J.R.A. Garcia[46], E. Garcia-Solis[10], K. Garg[117], C. Gargiulo[35], A. Garibli[90], K. Garner[146], P. Gasik[110], E.F. Gauger[121], A. Gautam[129], M.B. Gay Ducati[72], M. Germain[117], J. Ghosh[112], P. Ghosh[143], S.K. Ghosh[4], M. Giacalone[26], P. Gianotti[53], P. Giubellino[110,61], P. Giubilato[28], A.M.C. Glaenzer[140], P. Glässel[107], D.J.Q. Goh[85], V. Gonzalez[145], L.H. González-Trueba[73], S. Gorbunov[40], M. Gorgon[2], L. Görlich[120], S. Gotovac[36], V. Grabski[73], L.K. Graczykowski[144], L. Greiner[82], A. Grelli[64], C. Grigoras[35], V. Grigoriev[96], A. Grigoryan[I,1], S. Grigoryan[77,1], O.S. Groettvik[21], F. Grosa[35,61], J.F. Grosse-Oetringhaus[35], R. Grosso[110], G.G. Guardiano[124], R. Guernane[81], M. Guilbaud[117], K. Gulbrandsen[92], T. Gunji[135], A. Gupta[104], R. Gupta[104], I.B. Guzman[46], S.P. Guzman[46], L. Gyulai[147], M.K. Habib[110], C. Hadjidakis[80], G. Halimoglu[70], H. Hamagaki[85], G. Hamar[147], M. Hamid[7], R. Hannigan[121], M.R. Haque[144,89], A. Harlenderova[110], J.W. Harris[148], A. Harton[10], J.A. Hasenbichler[35], H. Hassan[99], D. Hatzifotiadou[55], P. Hauer[44], L.B. Havener[148], S. Hayashi[135], S.T. Heckel[108], E. Hellbär[70], H. Helstrup[37], T. Herman[38], E.G. Hernandez[46], G. Herrera Corral[9], F. Herrmann[146], K.F. Hetland[37], H. Hillemanns[35], C. Hills[130], B. Hippolyte[139], B. Hofman[64], B. Hohlweger[93,108], J. Honermann[146], G.H. Hong[149], D. Horak[38], S. Hornung[110], A. Horzyk[2], R. Hosokawa[15], P. Hristov[35], C. Huang[80], C. Hughes[133], P. Huhn[70], T.J. Humanic[100],

H. Hushnud[112], L.A. Husova[146], A. Hutson[127], D. Hutter[40], J.P. Iddon[35,130], R. Ilkaev[111], H. Ilyas[14], M. Inaba[136], G.M. Innocenti[35], M. Ippolitov[91], A. Isakov[38,98], M.S. Islam[112], M. Ivanov[110], V. Ivanov[101], V. Izucheev[94], M. Jablonski[2], B. Jacak[82], N. Jacazio[35], P.M. Jacobs[82], S. Jadlovska[119], J. Jadlovsky[119], S. Jaelani[64], C. Jahnke[124,123], M.J. Jakubowska[144], M.A. Janik[144], T. Janson[76], M. Jercic[102], O. Jevons[113], F. Jonas[99,146], P.G. Jones[113], J.M. Jowett [35,110], J. Jung[70], M. Jung[70], A. Junique[35], A. Jusko[113], J. Kaewjai[118], P. Kalinak[66], A. Kalweit[35], V. Kaplin[96], S. Kar[7], A. Karasu Uysal[79], D. Karatovic[102], O. Karavichev[65], T. Karavicheva[65], P. Karczmarczyk[144], E. Karpechev[65], A. Kazantsev[91], U. Kebschull[76], R. Keidel[48], D.L.D. Keijdener[64], M. Keil[35], B. Ketzer[44], Z. Khabanova[93], A.M. Khan[7], S. Khan[16], A. Khanzadeev[101], Y. Kharlov[94], A. Khatun[16], A. Khuntia[120], B. Kileng[37], B. Kim[17,63], D. Kim[149], D.J. Kim[128], E.J. Kim[75], J. Kim[149], J.S. Kim[42], J. Kim[107], J. Kim[149], J. Kim[75], M. Kim[107], S. Kim[18], T. Kim[149], S. Kirsch[70], I. Kisel[40], S. Kiselev[95], A. Kisiel[144], J.P. Kitowski[2], J.L. Klay[6], J. Klein[35], S. Klein[82], C. Klein-Bösing[146], M. Kleiner[70], T. Klemenz[108], A. Kluge[35], A.G. Knospe[127], C. Kobdaj[118], M.K. Köhler[107], T. Kollegger[110], A. Kondratyev[77], N. Kondratyeva[96], E. Kondratyuk[94], J. Konig[70], S.A. Konigstorfer[108], P.J. Konopka[35,2], G. Kornakov[144], S.D. Koryciak[2], L. Koska[119], A. Kotliarov[98], O. Kovalenko[88], V. Kovalenko[115], M. Kowalski[120], I. Králik[66], A. Kravčáková[39], L. Kreis[110], M. Krivda[113,66], F. Krizek[98], K. Krizkova Gajdosova[38], M. Kroesen[107], M. Krüger[70], E. Kryshen[101], M. Krzewicki[40], V. Kučera[35], C. Kuhn[139], P.G. Kuijer[93], T. Kumaoka[136], D. Kumar[143], L. Kumar[103], N. Kumar[103], S. Kundu[35,89], P. Kurashvili[88], A. Kurepin[65], A.B. Kurepin[65], A. Kuryakin[111], S. Kushpil[98], J. Kvapil[113], M.J. Kweon[63], J.Y. Kwon[63], Y. Kwon[149], S.L. La Pointe[40], P. La Rocca[27], Y.S. Lai[82], A. Lakrathok[118], M. Lamanna[35], R. Langoy[132], K. Lapidus[35], P. Larionov[53], E. Laudi[35], L. Lautner[35,108], R. Lavicka[38], T. Lazareva[115], R. Lea[142,24,59], J. Lee[136], J. Lehrbach[40], R.C. Lemmon[97], I. León Monzón[122], E.D. Lesser[19], M. Lettrich[35,108], P. Lévai[147], X. Li[11], X.L. Li[7], J. Lien[132], R. Lietava[113], B. Lim[17], S.H. Lim[17], V. Lindenstruth[40], A. Lindner[49], C. Lippmann[110], A. Liu[19], J. Liu[130], I.M. Lofnes[21], V. Loginov[96], C. Loizides[99], P. Loncar[36], J.A. Lopez[107], X. Lopez[137], E. López Torres[8], J.R. Luhder[146], M. Lunardon[28], G. Luparello[62], Y.G. Ma[41], A. Maevskaya[65], M. Mager[35], T. Mahmoud[44], A. Maire[139], M. Malaev[101], Q.W. Malik[20], L. Malinina[IV,77], D. Mal'Kevich[95], N. Mallick[51], P. Malzacher[110], G. Mandaglio[33,57], V. Manko[91], F. Manso[137], V. Manzari[54], Y. Mao[7], J. Mareš[68], G.V. Margagliotti[24], A. Margotti[55], A. Marín[110], C. Markert[121], M. Marquard[70], N.A. Martin[107], P. Martinengo[35], J.L. Martinez[127], M.I. Martínez[46], G. Martínez García[117], S. Masciocchi[110], M. Masera[25], A. Masoni[56], L. Massacrier[80], A. Mastroserio[141,54], A.M. Mathis[108], O. Matonoha[83], P.F.T. Matuoka[123], A. Matyja[120], C. Mayer[120], A.L. Mazuecos[35], F. Mazzaschi[25], M. Mazzilli[35], M.A. Mazzoni[60], J.E. Mdhluli[134], A.F. Mechler[70], F. Meddi[22], Y. Melikyan[65], A. Menchaca-Rocha[73], E. Meninno[116,30], A.S. Menon[127], M. Meres[13], S. Mhlanga[126,74], Y. Miake[136], L. Micheletti[61,25], L.C. Migliorin[138], D.L. Mihaylov[108], K. Mikhaylov[77,95], A.N. Mishra[147], D. Miśkowiec[110], A. Modak[4], A.P. Mohanty[64], B. Mohanty[89], M. Mohisin Khan[16], Z. Moravcova[92], C. Mordasini[108], D.A. Moreira De Godoy[146], L.A.P. Moreno[46], I. Morozov[65], A. Morsch[35], T. Mrnjavac[35], V. Muccifora[53], E. Mudnic[36], D. Mühlheim[146], S. Muhuri[143], J.D. Mulligan[82], A. Mulliri[23], M.G. Munhoz[123], R.H. Munzer[70], H. Murakami[135], S. Murray[126], L. Musa[35], J. Musinsky[66], C.J. Myers[127], J.W. Myrcha[144], B. Naik[134,50], R. Nair[88], B.K. Nandi[50], R. Nania[55], E. Nappi[54], M.U. Naru[14], A.F. Nassirpour[83], A. Nath[107], C. Nattrass[133], A. Neagu[20], L. Nellen[71], S.V. Nesbo[37], G. Neskovic[40], D. Nesterov[115], B.S. Nielsen[92], S. Nikolaev[91], S. Nikulin[91], V. Nikulin[101], F. Noferini[55], S. Noh[12], P. Nomokonov[77], J. Norman[130], N. Novitzky[136], P. Nowakowski[144], A. Nyanin[91], J. Nystrand[21], M. Ogino[85], A. Ohlson[83], V.A. Okorokov[96], J. Oleniacz[144], A.C. Oliveira Da Silva[133], M.H. Oliver[148], A. Onnerstad[128], C. Oppedisano[61], A. Ortiz Velasquez[71], T. Osako[47], A. Oskarsson[83], J. Otwinowski[120], K. Oyama[85], Y. Pachmayer[107], S. Padhan[50], D. Pagano[142,59], G. Paić[71], A. Palasciano[54], J. Pan[145], S. Panebianco[140], P. Pareek[143], J. Park[63], J.E. Parkkila[128], S.P. Pathak[127], R.N. Patra[104,35], B. Paul[23], J. Pazzini[142,59], H. Pei[7], T. Peitzmann[64], X. Peng[7], L.G. Pereira[72], H. Pereira Da Costa[140], D. Peresunko[91], G.M. Perez[8], S. Perrin[140], Y. Pestov[5], V. Petráček[38], M. Petrovici[49], R.P. Pezzi[72], S. Piano[62], M. Pikna[13], P. Pillot[117], O. Pinazza[55,35], L. Pinsky[127], C. Pinto[27], S. Pisano[53], M. Płoskoń[82], M. Planinic[102], F. Pliquett[70], M.G. Poghosyan[99], B. Polichtchouk[94], S. Politano[31], N. Poljak[102], A. Pop[49], S. Porteboeuf-Houssais[137], J. Porter[82], V. Pozdniakov[77], S.K. Prasad[4], R. Preghenella[55], F. Prino[61], C.A. Pruneau[145], I. Pshenichnov[65], M. Puccio[35], S. Qiu[93], L. Quaglia[25], R.E. Quishpe[127], S. Ragoni[113], A. Rakotozafindrabe[140], L. Ramello[32], F. Rami[139], S.A.R. Ramirez[46], A.G.T. Ramos[34], T.A. Rancien[81], R. Raniwala[105], S. Raniwala[105], S.S. Räsänen[45], R. Rath[51], I. Ravasenga[93], K.F. Read[99,133], A.R. Redelbach[40], K. Redlich[V,88], A. Rehman[21], P. Reichelt[70], F. Reidt[35], H.A. Reme-ness[37], R. Renfordt[70], Z. Rescakova[39], K. Reygers[107], A. Riabov[101], V. Riabov[101], T. Richert[83,92], M. Richter[20], W. Riegler[35], F. Riggi[27], C. Ristea[69], S.P. Rode[51], M. Rodríguez Cahuantzi[46], K. Røed[20], R. Rogalev[94], E. Rogochaya[77], T.S. Rogoschinski[70], D. Rohr[35], D. Röhrich[21], P.F. Rojas[46], S. Rojas Torres[38], P.S. Rokita[144], F. Ronchetti[53], A. Rosano[33,57], E.D. Rosas[71], A. Rossi[58], A. Rotondi[29,59], A. Roy[51], P. Roy[112], S. Roy[50], N. Rubini[26], O.V. Rueda[83], R. Rui[24], B. Rumyantsev[77], P.G. Russek[2], A. Rustamov[90],

E. Ryabinkin[91], Y. Ryabov[101], A. Rybicki[120], H. Rytkonen[128], W. Rzesa[144], O.A.M. Saarimaki[45], R. Sadek[117], S. Sadovsky[94], J. Saetre[21], K. Šafařík[38], S.K. Saha[143], S. Saha[89], B. Sahoo[50], P. Sahoo[50], R. Sahoo[51], S. Sahoo[67], D. Sahu[51], P.K. Sahu[67], J. Saini[143], S. Sakai[136], S. Sambyal[104], V. Samsonov[I,101,96], D. Sarkar[145], N. Sarkar[143], P. Sarma[43], V.M. Sarti[108], M.H.P. Sas[148], J. Schambach[99,121], H.S. Scheid[70], C. Schiaua[49], R. Schicker[107], A. Schmah[107], C. Schmidt[110], H.R. Schmidt[106], M.O. Schmidt[107], M. Schmidt[106], N.V. Schmidt[99,70], A.R. Schmier[133], R. Schotter[139], J. Schukraft[35], Y. Schutz[139], K. Schwarz[110], K. Schweda[110], G. Scioli[26], E. Scomparin[61], J.E. Seger[15], Y. Sekiguchi[135], D. Sekihata[135], I. Selyuzhenkov[110,96], S. Senyukov[139], J.J. Seo[63], D. Serebryakov[65], L. Šerkšnytė[108], A. Sevcenco[69], T.J. Shaba[74], A. Shabanov[65], A. Shabetai[117], R. Shahoyan[35], W. Shaikh[112], A. Shangaraev[94], A. Sharma[103], H. Sharma[120], M. Sharma[104], N. Sharma[103], S. Sharma[104], O. Sheibani[127], K. Shigaki[47], M. Shimomura[86], S. Shirinkin[95], Q. Shou[41], Y. Sibiriak[91], S. Siddhanta[56], T. Siemiarczuk[88], T.F. Silva[123], D. Silvermyr[83], G. Simonetti[35], B. Singh[108], R. Singh[89], R. Singh[104], R. Singh[51], V.K. Singh[143], V. Singhal[143], T. Sinha[112], B. Sitar[13], M. Sitta[32], T.B. Skaali[20], G. Skorodumovs[107], M. Slupecki[45], N. Smirnov[148], R.J.M. Snellings[64], C. Soncco[114], J. Song[127], A. Songmoolnak[118], F. Soramel[28], S. Sorensen[133], I. Sputowska[120], J. Stachel[107], I. Stan[69], P.J. Steffanic[133], S.F. Stiefelmaier[107], D. Stocco[117], I. Storehaug[20], M.M. Storetvedt[37], C.P. Stylianidis[93], A.A.P. Suaide[123], T. Sugitate[47], C. Suire[80], M. Suljic[35], R. Sultanov[95], M. Šumbera[98], V. Sumberia[104], S. Sumowidagdo[52], S. Swain[67], A. Szabo[13], I. Szarka[13], U. Tabassam[14], S.F. Taghavi[108], G. Taillepied[137], J. Takahashi[124], G.J. Tambave[21], S. Tang[137,7], Z. Tang[131], M. Tarhini[117], M.G. Tarzila[49], A. Tauro[35], G. Tejeda Muñoz[46], A. Telesca[35], L. Terlizzi[25], C. Terrevoli[127], G. Tersimonov[3], S. Thakur[143], D. Thomas[121], R. Tieulent[138], A. Tikhonov[65], A.R. Timmins[127], M. Tkacik[119], A. Toia[70], N. Topilskaya[65], M. Toppi[53], F. Torales-Acosta[19], T. Tork[80], A. Trifiró[33,57], S. Tripathy[55,71], T. Tripathy[50], S. Trogolo[35,28], G. Trombetta[34], V. Trubnikov[3], W.H. Trzaska[128], T.P. Trzcinski[144], B.A. Trzeciak[38], A. Tumkin[111], R. Turrisi[58], T.S. Tveter[20], K. Ullaland[21], A. Uras[138], M. Urioni[59,142], G.L. Usai[23], M. Vala[39], N. Valle[59,29], S. Vallero[61], N. van der Kolk[64], L.V.R. van Doremalen[64], M. van Leeuwen[93], P. Vande Vyvre[35], D. Varga[147], Z. Varga[147], M. Varga-Kofarago[147], A. Vargas[46], M. Vasileiou[87], A. Vasiliev[91], O. Vázquez Doce[108], V. Vechernin[115], E. Vercellin[25], S. Vergara Limón[46], L. Vermunt[64], R. Vértesi[147], M. Verweij[64], L. Vickovic[36], Z. Vilakazi[134], O. Villalobos Baillie[113], G. Vino[54], A. Vinogradov[91], T. Virgili[30], V. Vislavicius[92], A. Vodopyanov[77], B. Volkel[35], M.A. Völkl[107], K. Voloshin[95], S.A. Voloshin[145], G. Volpe[34], B. von Haller[35], I. Vorobyev[108], D. Voscek[119], J. Vrláková[39], B. Wagner[21], C. Wang[41], D. Wang[41], M. Weber[116], R.J.G.V. Weelden[93], A. Wegrzynek[35], S.C. Wenzel[35], J.P. Wessels[146], J. Wiechula[70], J. Wikne[20], G. Wilk[88], J. Wilkinson[110], G.A. Willems[146], B. Windelband[107], M. Winn[140], W.E. Witt[133], J.R. Wright[121], W. Wu[41], Y. Wu[131], R. Xu[7], S. Yalcin[79], Y. Yamaguchi[47], K. Yamakawa[47], S. Yang[21], S. Yano[47,140], Z. Yin[7], H. Yokoyama[64], I.-K. Yoo[17], J.H. Yoon[63], S. Yuan[21], A. Yuncu[107], V. Zaccolo[24], A. Zaman[14], C. Zampolli[35], H.J.C. Zanoli[64], N. Zardoshti[35], A. Zarochentsev[115], P. Závada[68], N. Zaviyalov[111], H. Zbroszczyk[144], M. Zhalov[101], S. Zhang[41], X. Zhang[7], Y. Zhang[131], V. Zherebchevskii[115], Y. Zhi[11], D. Zhou[7], Y. Zhou[92], J. Zhu[7,110], Y. Zhu[7], A. Zichichi[26], G. Zinovjev[3], N. Zurlo[142,59]

Affiliation notes

[I] Deceased
[II] Also at: Italian National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA), Bologna, Italy
[III] Also at: Dipartimento DET del Politecnico di Torino, Turin, Italy
[IV] Also at: M.V. Lomonosov Moscow State University, D.V. Skobeltsyn Institute of Nuclear, Physics, Moscow, Russia
[V] Also at: Institute of Theoretical Physics, University of Wroclaw, Poland

Collaboration Institutes

[1] A.I. Alikhanyan National Science Laboratory (Yerevan Physics Institute) Foundation, Yerevan, Armenia
[2] AGH University of Science and Technology, Cracow, Poland
[3] Bogolyubov Institute for Theoretical Physics, National Academy of Sciences of Ukraine, Kiev, Ukraine
[4] Bose Institute, Department of Physics and Centre for Astroparticle Physics and Space Science (CAPSS), Kolkata, India
[5] Budker Institute for Nuclear Physics, Novosibirsk, Russia
[6] California Polytechnic State University, San Luis Obispo, California, United States
[7] Central China Normal University, Wuhan, China

[8] Centro de Aplicaciones Tecnológicas y Desarrollo Nuclear (CEADEN), Havana, Cuba
[9] Centro de Investigación y de Estudios Avanzados (CINVESTAV), Mexico City and Mérida, Mexico
[10] Chicago State University, Chicago, Illinois, United States
[11] China Institute of Atomic Energy, Beijing, China
[12] Chungbuk National University, Cheongju, Republic of Korea
[13] Comenius University Bratislava, Faculty of Mathematics, Physics and Informatics, Bratislava, Slovakia
[14] COMSATS University Islamabad, Islamabad, Pakistan
[15] Creighton University, Omaha, Nebraska, United States
[16] Department of Physics, Aligarh Muslim University, Aligarh, India
[17] Department of Physics, Pusan National University, Pusan, Republic of Korea
[18] Department of Physics, Sejong University, Seoul, Republic of Korea
[19] Department of Physics, University of California, Berkeley, California, United States
[20] Department of Physics, University of Oslo, Oslo, Norway
[21] Department of Physics and Technology, University of Bergen, Bergen, Norway
[22] Dipartimento di Fisica dell'Università 'La Sapienza' and Sezione INFN, Rome, Italy
[23] Dipartimento di Fisica dell'Università and Sezione INFN, Cagliari, Italy
[24] Dipartimento di Fisica dell'Università and Sezione INFN, Trieste, Italy
[25] Dipartimento di Fisica dell'Università and Sezione INFN, Turin, Italy
[26] Dipartimento di Fisica e Astronomia dell'Università and Sezione INFN, Bologna, Italy
[27] Dipartimento di Fisica e Astronomia dell'Università and Sezione INFN, Catania, Italy
[28] Dipartimento di Fisica e Astronomia dell'Università and Sezione INFN, Padova, Italy
[29] Dipartimento di Fisica e Nucleare e Teorica, Università di Pavia, Pavia, Italy
[30] Dipartimento di Fisica 'E.R. Caianiello' dell'Università and Gruppo Collegato INFN, Salerno, Italy
[31] Dipartimento DISAT del Politecnico and Sezione INFN, Turin, Italy
[32] Dipartimento di Scienze e Innovazione Tecnologica dell'Università del Piemonte Orientale and INFN Sezione di Torino, Alessandria, Italy
[33] Dipartimento di Scienze MIFT, Università di Messina, Messina, Italy
[34] Dipartimento Interateneo di Fisica 'M. Merlin' and Sezione INFN, Bari, Italy
[35] European Organization for Nuclear Research (CERN), Geneva, Switzerland
[36] Faculty of Electrical Engineering, Mechanical Engineering and Naval Architecture, University of Split, Split, Croatia
[37] Faculty of Engineering and Science, Western Norway University of Applied Sciences, Bergen, Norway
[38] Faculty of Nuclear Sciences and Physical Engineering, Czech Technical University in Prague, Prague, Czech Republic
[39] Faculty of Science, P.J. Šafárik University, Košice, Slovakia
[40] Frankfurt Institute for Advanced Studies, Johann Wolfgang Goethe-Universität Frankfurt, Frankfurt, Germany
[41] Fudan University, Shanghai, China
[42] Gangneung-Wonju National University, Gangneung, Republic of Korea
[43] Gauhati University, Department of Physics, Guwahati, India
[44] Helmholtz-Institut für Strahlen- und Kernphysik, Rheinische Friedrich-Wilhelms-Universität Bonn, Bonn, Germany
[45] Helsinki Institute of Physics (HIP), Helsinki, Finland
[46] High Energy Physics Group, Universidad Autónoma de Puebla, Puebla, Mexico
[47] Hiroshima University, Hiroshima, Japan
[48] Hochschule Worms, Zentrum für Technologietransfer und Telekommunikation (ZTT), Worms, Germany
[49] Horia Hulubei National Institute of Physics and Nuclear Engineering, Bucharest, Romania
[50] Indian Institute of Technology Bombay (IIT), Mumbai, India
[51] Indian Institute of Technology Indore, Indore, India
[52] Indonesian Institute of Sciences, Jakarta, Indonesia
[53] INFN, Laboratori Nazionali di Frascati, Frascati, Italy
[54] INFN, Sezione di Bari, Bari, Italy
[55] INFN, Sezione di Bologna, Bologna, Italy
[56] INFN, Sezione di Cagliari, Cagliari, Italy
[57] INFN, Sezione di Catania, Catania, Italy
[58] INFN, Sezione di Padova, Padova, Italy
[59] INFN, Sezione di Pavia, Pavia, Italy

[60] INFN, Sezione di Roma, Rome, Italy
[61] INFN, Sezione di Torino, Turin, Italy
[62] INFN, Sezione di Trieste, Trieste, Italy
[63] Inha University, Incheon, Republic of Korea
[64] Institute for Gravitational and Subatomic Physics (GRASP), Utrecht University/Nikhef, Utrecht, Netherlands
[65] Institute for Nuclear Research, Academy of Sciences, Moscow, Russia
[66] Institute of Experimental Physics, Slovak Academy of Sciences, Košice, Slovakia
[67] Institute of Physics, Homi Bhabha National Institute, Bhubaneswar, India
[68] Institute of Physics of the Czech Academy of Sciences, Prague, Czech Republic
[69] Institute of Space Science (ISS), Bucharest, Romania
[70] Institut für Kernphysik, Johann Wolfgang Goethe-Universität Frankfurt, Frankfurt, Germany
[71] Instituto de Ciencias Nucleares, Universidad Nacional Autónoma de México, Mexico City, Mexico
[72] Instituto de Física, Universidade Federal do Rio Grande do Sul (UFRGS), Porto Alegre, Brazil
[73] Instituto de Física, Universidad Nacional Autónoma de México, Mexico City, Mexico
[74] iThemba LABS, National Research Foundation, Somerset West, South Africa
[75] Jeonbuk National University, Jeonju, Republic of Korea
[76] Johann-Wolfgang-Goethe Universität Frankfurt Institut für Informatik, Fachbereich Informatik und Mathematik, Frankfurt, Germany
[77] Joint Institute for Nuclear Research (JINR), Dubna, Russia
[78] Korea Institute of Science and Technology Information, Daejeon, Republic of Korea
[79] KTO Karatay University, Konya, Turkey
[80] Laboratoire de Physique des 2 Infinis, Irène Joliot-Curie, Orsay, France
[81] Laboratoire de Physique Subatomique et de Cosmologie, Université Grenoble-Alpes, CNRS-IN2P3, Grenoble, France
[82] Lawrence Berkeley National Laboratory, Berkeley, California, United States
[83] Lund University Department of Physics, Division of Particle Physics, Lund, Sweden
[84] Moscow Institute for Physics and Technology, Moscow, Russia
[85] Nagasaki Institute of Applied Science, Nagasaki, Japan
[86] Nara Women's University (NWU), Nara, Japan
[87] National and Kapodistrian University of Athens, School of Science, Department of Physics , Athens, Greece
[88] National Centre for Nuclear Research, Warsaw, Poland
[89] National Institute of Science Education and Research, Homi Bhabha National Institute, Jatni, India
[90] National Nuclear Research Center, Baku, Azerbaijan
[91] National Research Centre Kurchatov Institute, Moscow, Russia
[92] Niels Bohr Institute, University of Copenhagen, Copenhagen, Denmark
[93] Nikhef, National institute for subatomic physics, Amsterdam, Netherlands
[94] NRC Kurchatov Institute IHEP, Protvino, Russia
[95] NRC «Kurchatov»Institute - ITEP, Moscow, Russia
[96] NRNU Moscow Engineering Physics Institute, Moscow, Russia
[97] Nuclear Physics Group, STFC Daresbury Laboratory, Daresbury, United Kingdom
[98] Nuclear Physics Institute of the Czech Academy of Sciences, Řež u Prahy, Czech Republic
[99] Oak Ridge National Laboratory, Oak Ridge, Tennessee, United States
[100] Ohio State University, Columbus, Ohio, United States
[101] Petersburg Nuclear Physics Institute, Gatchina, Russia
[102] Physics department, Faculty of science, University of Zagreb, Zagreb, Croatia
[103] Physics Department, Panjab University, Chandigarh, India
[104] Physics Department, University of Jammu, Jammu, India
[105] Physics Department, University of Rajasthan, Jaipur, India
[106] Physikalisches Institut, Eberhard-Karls-Universität Tübingen, Tübingen, Germany
[107] Physikalisches Institut, Ruprecht-Karls-Universität Heidelberg, Heidelberg, Germany
[108] Physik Department, Technische Universität München, Munich, Germany
[109] Politecnico di Bari and Sezione INFN, Bari, Italy
[110] Research Division and ExtreMe Matter Institute EMMI, GSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt, Germany
[111] Russian Federal Nuclear Center (VNIIEF), Sarov, Russia
[112] Saha Institute of Nuclear Physics, Homi Bhabha National Institute, Kolkata, India

[113] School of Physics and Astronomy, University of Birmingham, Birmingham, United Kingdom
[114] Sección Física, Departamento de Ciencias, Pontificia Universidad Católica del Perú, Lima, Peru
[115] St. Petersburg State University, St. Petersburg, Russia
[116] Stefan Meyer Institut für Subatomare Physik (SMI), Vienna, Austria
[117] SUBATECH, IMT Atlantique, Université de Nantes, CNRS-IN2P3, Nantes, France
[118] Suranaree University of Technology, Nakhon Ratchasima, Thailand
[119] Technical University of Košice, Košice, Slovakia
[120] The Henryk Niewodniczanski Institute of Nuclear Physics, Polish Academy of Sciences, Cracow, Poland
[121] The University of Texas at Austin, Austin, Texas, United States
[122] Universidad Autónoma de Sinaloa, Culiacán, Mexico
[123] Universidade de São Paulo (USP), São Paulo, Brazil
[124] Universidade Estadual de Campinas (UNICAMP), Campinas, Brazil
[125] Universidade Federal do ABC, Santo Andre, Brazil
[126] University of Cape Town, Cape Town, South Africa
[127] University of Houston, Houston, Texas, United States
[128] University of Jyväskylä, Jyväskylä, Finland
[129] University of Kansas, Lawrence, Kansas, United States
[130] University of Liverpool, Liverpool, United Kingdom
[131] University of Science and Technology of China, Hefei, China
[132] University of South-Eastern Norway, Tonsberg, Norway
[133] University of Tennessee, Knoxville, Tennessee, United States
[134] University of the Witwatersrand, Johannesburg, South Africa
[135] University of Tokyo, Tokyo, Japan
[136] University of Tsukuba, Tsukuba, Japan
[137] Université Clermont Auvergne, CNRS/IN2P3, LPC, Clermont-Ferrand, France
[138] Université de Lyon, CNRS/IN2P3, Institut de Physique des 2 Infinis de Lyon , Lyon, France
[139] Université de Strasbourg, CNRS, IPHC UMR 7178, F-67000 Strasbourg, France, Strasbourg, France
[140] Université Paris-Saclay Centre d'Etudes de Saclay (CEA), IRFU, Départment de Physique Nucléaire (DPhN), Saclay, France
[141] Università degli Studi di Foggia, Foggia, Italy
[142] Università di Brescia, Brescia, Italy
[143] Variable Energy Cyclotron Centre, Homi Bhabha National Institute, Kolkata, India
[144] Warsaw University of Technology, Warsaw, Poland
[145] Wayne State University, Detroit, Michigan, United States
[146] Westfälische Wilhelms-Universität Münster, Institut für Kernphysik, Münster, Germany
[147] Wigner Research Centre for Physics, Budapest, Hungary
[148] Yale University, New Haven, Connecticut, United States
[149] Yonsei University, Seoul, Republic of Korea