

First Measurement of Antideuteron Number Fluctuations at Energies Available at the Large Hadron Collider

Original

First Measurement of Antideuteron Number Fluctuations at Energies Available at the Large Hadron Collider / Acharya, S.; Adamová, D.; Adler, A.; Aglieri Rinella, G.; Agnello, M.; Agrawal, N.; Ahammed, Z.; Ahmad, S.; Ahn, S. U.; Ahuja, I.; Akindinov, A.; Al-Turany, M.; Aleksandrov, D.; Alessandro, B.; Alfanda, H. M.; Alfaro Molina, R.; Ali, B.; Ali, Y.; Alici, A.; Alizadehvandchali, N.; Alkin, A.; Alme, J.; Alocco, G.; Alt, T.; Altsybeev, I.; Anaam, M. N.; Andrei, C.; Andronic, A.; Anguelov, V.; Antinori, F.; Antonioli, P.; Anuj, C.; Apadula, N.; Aphecetche, L.; Appelshäuser, H.; Arcelli, S.; Araldi, R.; Arsene, I. C.; Arslanok, M.; Augustinus, A.; Auerbach, R.; Aziz, S.; Azmi, M. D.; Badalà, A.; Baek, Y. W.; Bai, X.; Bailache, R.; Bailung, Y.; Bala, R.; Balbino, A.; Baldisseri, A.; Balis, B.; Banerjee, D.; Banoo, Z.; Barbera, R.; Barioglio, L.; Barlou, M.; Barnafoldi, G. G.; Barnby, L. S.; Barfét, V.; Barreto, L.; Bartels, C.; Barth, K.; Bartsch, E.; Baruffaldi, F.; Bastid, N.; Basu, S.; Batigne, G.; Battistini, D.; Batyunya, B.; Bauri, D.; Bazo Alba, J. L.; Bearden, I. G.; Beattie, C.; Becht, P.; Behera, D.; Belikov, I.; Bell Hechavarria, A. D. C.; Bellwied, R.; Belokurova, S.; Belyaev, V.; Bencedi, G.; Beole, S.; Bercuci, A.; Berdnikov, Y.; Berdnikova, A.; Bergmann, L.; Besoiu, M. G.; Betev, L.; Bhaduri, P. P.; Bhasin, A.; Bhat, I. R.; Bhat, M. A.; Bhattacharjee, B.; Bianchi, L.; Bianchi, N.; Bielík, J.; Bielíková, J.; Biernat, J.; Bilandzic, A.; Biro, P.; Biswas, S.; Blair, J. T.; Blau, D.; Blidaru, M. B.; Bluhme, N.; Blume, C.; Boca, G.; Bock, F.; Bodova, T.; Bogdanov, A.; Boli, S. B.; Bork, P.; Borvič, I.; Borvičová, A.; Borwina, A.; Bombara, M.; Bond, P. M.; Bonomi, G.; Borel, H.; Borissov, A.; Bossi, H.; Botta, E.; Bratrud, L.; Braun-Munzinger, P.; Bregant, M.; Broz, M.; Bruno, G. E.; Buckland, M. D.; Budnikov, D.; Buesching, H.; Bufalino, S.; Bugnon, O.; Buhler, P.; Buthelezi, Z.; Butt, J. B.; Bylinkin, A.; Bysiak, S. A.; Cai, M.; Caines, H.; Caliva, A.; Calvo Villar, E.; Camacho, J. M. M.; Camacho, R. S.; Camerini, P.; Canedo, F. D. M.; Carabas, M.; Carnesecchi, F.; Caron, R.; Castillo Castellanos, J.; Catalano, F.; Ceballos Sanchez, C.; Chakaberia, I.; Chakraborty, P.; Chandra, S.; Chapevalais, C.; Chatterjee, M.; Chatterjee, S.; Chatterjee, G.; Chaudhury, G.; Chaudhury, T.; Chaudhury, T.; Chiesi, M.; Chibante Barroso, V.; Chinellato, D. D.; Chizzali, E. S.; Cho, S.; Chochula, P.; Christakoglou, P.; Christensen, C. H.; Christiansen, P.; Chujo, T.; Ciaccio, M.; Cicalo, C.; Cifarelli, L.; Cindolo, F.; Ciupek, M. R.; Clai, G.; Colamaria, F.; Colburn, J. S.; Colella, D.; Collu, A.; Colocci, M.; Concas, M.; Conesa Balbastre, G.; Conesa del Valle, Z.; Contín, G.; Contreras, J. G.; Coquet, M. L.; Cormier, T. M.; Cortese, P.; Cosentino, M. R.; Costa, F.; Costanza, S.; Crochet, P.; Cruz-Torres, R.; Cuautle, E.; Cui, P.; Cunqueiro, L.; Dainese, A.; Danisch, M. C.; Danu, A.; Das, P.; Das, P.; Das, S.; Dash, S.; De Caro, A.; de Cataldo, G.; De Cilladi, L.; de Cuveland, J.; De Falco, A.; De Gruttola, D.; De Marco, N.; De Martin, C.; De Pasquale, S.; Deb, S.; Degenhardt, H. F.; Deja, K. R.; Del Grande, R.; Dello Stritto, L.; Deng, W.; Dhankher, P.; Di Bari, D.; Di Mauro, A.; Diaz, R. A.; Dietel, T.; Ding, Y.; Divià, R.; Dixit, D. U.; Djuvsland, Ø.; Dmitrieva, U.; Dobrin, A.; Dönigus, B.; Dubey, A. K.; Dubinski, J. M.; Dubla, A.; Dudi, S.; Dupieux, P.; Durkac, M.; Dzalaiova, N.; Eder, T. M.; Ehlers, R. J.; Eikeland, V. N.; Eisenhut, F.; Elia, D.; Erazmus, B.; Ercolessi, F.; Erhardt, F.; Erokhin, A.; Ersdal, M. R.; Espagnon, B.; Eulisse, G.; Evans, D.; Evdokimov, S.; Fabbietti, L.; Faggin, M.; Faivre, J.; Fan, F.; Fan, W.; Fantoni, A.; Fasel, M.; Fecchio, P.; Feliciello, A.; Feofilov, G.; Fernández Téllez, A.; Ferrer, M. B.; Ferrero, A.; Ferretti, A.; Feuillard, V. J. G.; Figiel, J.; Filova, V.; Finogeev, D.; Fiorenza, G.; Flor, F.; Flores, A. N.; Foertsch, S.; Fokin, I.; Fokin, S.; Fragiaco, E.; Frajna, E.; Fuchs, U.; Funicello, N.; Furget, C.; Furs, A.; Gaardhøje, J. J.; Gagliardi, M.; Gago, A. M.; Gal, A.; Galvan, C. D.; Ganoti, P.; Garabatos, C.; Garcia, J. R. A.; Garcia-Solis, E.; Garg, K.; Gargiulo, C.; Garibli, A.; Garner, K.; Gauger, E. F.; Gautam, A.; Gay Ducati, M. B.; Germain, M.; Ghosh, S. K.; Giacalone, M.; Gianotti, P.; Giubellino, P.; Giubilato, P.; Glaenger, A. M. C.; Glässel, P.; Glimos, E.; Goh, D. J. Q.; Gonzalez, V.; González-Trueba, L. H.; Gorbunov, S.; Gorgon, M.; Görlich, L.; Gotovac, S.; Grabski,

V.; Graczykowski, L. K.; Grecka, E.; Greiner, L.; Grelli, A.; Grigoras, C.; Grigoriev, V.; Grigoryan, S.; Grosa, F.; Grosse-Oetringhaus, J. F.; Grosso, R.; Grund, D.; Guardiano, G. G.; Guernane, R.; Guilbaud, M.; Gulbrandsen, K.; Gunji, T.; Guo, W.; Gupta, A.; Gupta, R.; Guzman, S. P.; Gyulai, L.; Habib, M. K.; Hadjidakis, C.; Hamagaki, H.; Hamid, M.; Han, Y.; Hannigan, R.; Haque, M. R.; Harlenderova, A.; Harris, J. W.; Harton, A.; Hasenbichler, J. A.; Hassan, H.; Hatzifotiadou, D.; Hauer, P.; Havener, L. B.; Heckel, S. T.; Hellbär, E.; Helstrup, H.; Herman, T.; Herrera Corral, G.; Herrmann, F.; Hetland, K. F.; Heybeck, B.; Hillemanns, H.; Hills, C.; Hippolyte, B.; Hofman, B.; Hohlweger, B.; Honermann, J.; Hong, G. H.; Horak, D.; Horzyk, A.; Hosokawa, R.; Hou, Y.; Hristov, P.; Hughes, C.; Huhn, P.; Huhta, L. M.; Hulse, C. V.; Humanic, T. J.; Hushnud, H.; Hutson, A.; Hutter, D.; Iddon, J. P.; Ilkaev, R.; Ilyas, H.; Inaba, M.; Innocenti, G. M.; Ippolitov, M.; Isakov, A.; Isidori, T.; Islam, M. S.; Ivanov, M.; Ivanov, V.; Izucheev, V.; Jablonski, M.; Jacak, B.; Jacazio, N.; Jacobs, P. M.; Jadlovská, S.; Jadlovsky, J.; Jaffe, L.; Jahnke, C.; Janik, M. A.; Janson, T.; Jercic, M.; Jevons, O.; Jimenez, A. A. P.; Jonas, F.; Jones, P. G.; Jowett, J. M.; Jung, J.; Jung, M.; Junique, A.; Jusko, A.; Kabus, M. J.; Kaewjai, J.; Kalinak, P.; Kalteyer, A. S.; Kalweit, A.; Kaplin, V.; Karasu Uysal, A.; Karatovic, D.; Karavichev, O.; Karavicheva, T.; Karczmarczyk, P.; Karpechev, E.; Kashyap, V.; Kazantsev, A.; Kebschull, U.; Keidel, R.; Keijdener, D. L. D.; Keil, M.; Ketzer, B.; Khan, A. M.; Khan, S.; Khanzadeev, A.; Kharlov, Y.; Khatun, A.; Khuntia, A.; Kileng, B.; Kim, B.; Kim, C.; Kim, D. J.; Kim, E. J.; Kim, J.; Kim, J. S.; Kim, J.; Kim, J.; Kim, M.; Kim, S.; Kim, T.; Kirsch, S.; Kisel, I.; Kiselev, S.; Kisiel, A.; Kitowski, J. P.; Klay, J. L.; Klein, J.; Klein, S.; Klein-Bösing, C.; Kleiner, M.; Klemen, T.; Kluge, A.; Knospe, A. G.; Kobdaj, C.; Kollegger, T.; Kondratyev, A.; Kondratyeva, N.; Kondratyuk, E.; König, J.; Königstorfer, S. A.; Konopka, P. J.; Kornakov, G.; Koryciak, S. D.; Kotliarov, A.; Kovalenko, O.; Kovalenko, V.; Kowalski, M.; Králik, I.; Kraváková, A.; Kreis, L.; Krivda, M.; Krizek, F.; Krizkova Gajdosova, K.; Kroesen, M.; Krüger, M.; Krupova, D. M.; Kryshen, E.; Krzewicki, M.; Kuera, V.; Kuhn, C.; Kuijter, P. G.; Kumaoka, T.; Kumar, D.; Kumar, L.; Kumar, N.; Kundu, S.; Kurashvili, P.; Kurepin, A.; Kurepin, A. B.; Kuryakin, A.; Kushpil, S.; Kvapil, J.; Kweon, M. J.; Kwon, J. Y.; Kwon, Y.; La Pointe, S. L.; La Rocca, P.; Lai, Y. S.; Lakrathok, A.; Lamanna, M.; Langoy, R.; Larionov, P.; Laudi, E.; Lautner, L.; Lavicka, R.; Lazareva, T.; Lea, R.; Lehrbach, J.; Lemmon, R. C.; León Monzón, I.; Lesch, M. M.; Lesser, E. D.; Lettrich, M.; Lévai, P.; Li, X.; Li, X. L.; Lien, J.; Lietava, R.; Lim, B.; Lim, S. H.; Lindenstruth, V.; Lindner, A.; Lippmann, C.; Liu, A.; Liu, D. H.; Liu, J.; Lofnes, I. M.; Loginov, V.; Loizides, C.; Loncar, P.; Lopez, J. A.; Lopez, X.; López Torres, E.; Lu, P.; Luhder, J. R.; Lunardon, M.; Luparello, G.; Ma, Y. G.; Maevskaya, A.; Mager, M.; Mahmoud, T.; Maire, A.; Malaev, M.; Malik, N. M.; Malik, Q. W.; Malik, S. K.; Malinina, L.; Mal'Kevich, D.; Mallick, D.; Mallick, N.; Mandaglio, G.; Manko, V.; Manso, F.; Manzari, V.; Mao, Y.; Margagliotti, G. V.; Margotti, A.; Marín, A.; Markert, C.; Marquard, M.; Martin, N. A.; Martinengo, P.; Martinez, J. L.; Martinez, M. I.; Martínez García, G.; Masciocchi, S.; Maser, M.; Masoni, A.; Massacrier, L.; Mastroserio, A.; Mathis, A. M.; Matonoha, O.; Matuoka, P. F. T.; Matyja, A.; Mayer, C.; Mazuecos, A. L.; Mazzaschi, F.; Mazzilli, M.; Mdhluli, J. E.; Mechler, A. F.; Melikyan, Y.; Menchaca-Rocha, A.; Meninno, E.; Menon, A. S.; Meres, M.; Mhlanga, S.; Miake, Y.; Micheletti, L.; Migliorin, L. C.; Mihaylov, D. L.; Mikhaylov, K.; Mishra, A. N.; Mikowiec, D.; Modak, A.; Mohanty, A. P.; Mohanty, B.; Mohisin Khan, M.; Molander, M. A.; Moravcova, Z.; Mordasini, C.; Moreira De Godoy, D. A.; Morozov, I.; Morsch, A.; Mrnjavac, T.; Muccifora, V.; Mudnic, E.; Muhuri, S.; Mulligan, J. D.; Mulliri, A.; Munhoz, M. G.; Munzer, R. H.; Murakami, H.; Murray, S.; Musa, L.; Musinsky, J.; Myrcha, J. W.; Naik, B.; Nair, R.; Nandi, B. K.; Nania, R.; Nappi, E.; Nassirpour, A. F.; Nath, A.; Natrass, C.; Nayak, T. K.; Neagu, A.; Negru, A.; Nellen, L.; Nesbo, S. V.; Neskovic, G.; Nesterov, D.; Nielsen, B. S.; Nielsen, E. G.; Nikolaev, S.; Nikulin, S.; Nikulin, V.; Noferini, F.; Noh, S.; Nomokonov, P.; Norman, J.; Novitzky, N.; Nowakowski, P.; Nyanin, A.; Nystrand, J.; Ogino, M.; Ohlson, A.; Okorokov, V. A.; Oleniacz, J.; Oliveira Da Silva, A. C.; Oliver, M. H.; Onnerstad, A.; Oppedisano, C.; Ortiz Velasquez, A.; Oskarsson, A.; Otwinowski, J.; Oya, M.; Oyama, K.; Pachmayer, Y.; Padhan, S.; Pagano, D.; Pai, G.; Palasciano, A.; Panebianco, S.; Park, J.; Parkkila, J. E.; Pathak, S. P.; Patra, R. N.; Paul, B.; Pei, H.; Peitzmann, T.; Peng, X.; Pereira, L. G.; Pereira Da Costa, H.; Peresunko, D.; Perez, G. M.; Perrin, S.; Pestov, Y.; Petráek, V.; Petrov, V.; Petrovici, M.; Pezzi, R. P.; Piano, S.; Pikna, M.; Pillot, P.; Pinazza, O.; Pinsky, L.; Pinto, C.; Pisano, S.; Posko, M.; Planinic, M.; Pliquet, F.; Poghosyan, M. G.; Polichtchouk, B.; Politano, S.; Poljak, N.; Pop, A.; Porteboeuf-Houssais, S.; Porter, J.; Pozdniakov, V.; Prasad, S. K.; Prasad, S.; Preghenella, R.; Prino, F.; Pruneau, C. A.; Pshenichnov, I.; Puccio, M.; Qiu, S.; Quaglia, L.; Quishpe, R. E.; Ragoni, S.; Rakotozafindrabe, A.; Ramello, L.; Rami, F.; Ramirez, S. A. R.; Rancien, T. A.; Raniwala, R.; Raniwala, S.; Räsänen, S. S.; Rath, R.; Ravasenga, I.; Read, K. F.; Redelbach, A. R.; Redlich, K.; Rehman, A.; Reichelt, P.; Reidt, F.; Reme-Ness, H. A.; Rescakova, Z.; Reygers, K.; Riabov, A.; Riabov, V.; Ricci, R.; Richert, T.; Richter, M.; Riegler, W.; Riggi, F.; Ristea, C.; Rodríguez Cahuantzi, M.; Røed, K.; Rogalev, R.; Rogochaya, E.; Rogoschinski, T. S.; Rohr, D.; Röhrich, D.; Rojas, P. F.; Rojas Torres, S.; Rokita, P. S.; Ronchetti, F.; Rosano, A.; Rosas, E. D.; Rossi, A.; Roy, A.; Roy, P.; Roy, S.; Rubini, N.; Rueda, O. V.; Ruggiano, D.; Rui, R.; Rumyantsev, B.; Russek, P. G.; Russo, R.; Rustamov, A.; Ryabinkin, E.; Ryabov, Y.; Rybicki, A.; Rytönen, H.; Rzeska, W.; Saarimaki, O. A. M.; Sadek, R.; Sadovsky, S.; Saetre, J.; Šafaík, K.; Saha, S. K.; Saha, S.; Sahoo, B.; Sahoo, P.; Sahoo, R.; Sahoo, S.; Sahu, D.; Sahu, P. K.; Saini, J.; Sakai, S.; Salvan, M. P.; Sambyal, S.; Saramela, T. B.; Sarkar, D.; Sarkar, N.; Sarma, P.; Sarti, V. M.; Sas, M. H. P.; Schambach, J.; Scheid, H. S.; Schiaua, C.; Schicker, R.; Schmah, A.; Schmidt, C.; Schmidt, H. R.; Schmidt, M. O.; Schmidt, M.; Schmidt, N. V.; Schmier, A. R.; Schotter, R.; Schukraft, J.; Schwarz, K.; Schweda, K.; Scioli, G.; Scomarini, E.; Seger, J. E.; Sekiguchi, Y.; Sekihata, D.; Selyuzhenkov, I.; Senyukov, S.; Seo, J. J.; Serebryakov, D.; Šerkšnyt, L.; Sevcenco, A.; Shaba, T. J.; Shabanov, A.; Shabetai, A.; Shahoyan, R.; Shaikh, W.; Shangaraev, A.; Sharma, A.; Sharma, D.; Sharma, H.; Sharma, M.; Sharma, N.; Sharma, S.; Sharma, U.; Shatat, A.; Sheibani, O.; Shigaki, K.; Shimomura, M.; Shirinkin, S.; Shou, Q.; Sibiriak, Y.; Siddhanta, S.; Siemiarzuk, T.; Silva, T. F.; Silvermyr, D.; Simantathammakul, T.; Simonetti, G.; Singh, B.; Singh, B.; Singh, R.; Singh, R.; Singh, R.; Singh, V. K.; Singhal, V.; Sinha, T.; Sitar,

B.; Sitta, M.; Skaali, T. B.; Skorodumovs, G.; Slupecki, M.; Smirnov, N.; Snellings, R. J. M.; Solheim, E. H.; Soncco, C.; Song, J.; Songmoolnak, A.; Soramel, F.; Sorensen, S.; Spijkers, R.; Sputowska, I.; Staa, J.; Stachel, J.; Stan, I.; Steffanic, P. J.; Stiefelmaier, S. F.; Stocco, D.; Storehaug, I.; Storetvedt, M. M.; Stratmann, P.; Strazzi, S.; Stylianidis, C. P.; Suaide, A. A. P.; Suire, C.; Sukhanov, M.; Suljic, M.; Sumberia, V.; Sumowidagdo, S.; Swain, S.; Szabo, A.; Szarka, I.; Tabassam, U.; Taghavi, S. F.; Taillepiet, G.; Takahashi, J.; Tambave, G. J.; Tang, S.; Tang, Z.; Tapia Takaki, J. D.; Tapus, N.; Tarasovicova, L. A.; Tarzila, M. G.; Tauro, A.; Tejeda Muñoz, G.; Telesca, A.; Terlizzi, L.; Terrevoli, C.; Tersimonov, G.; Thakur, S.; Thomas, D.; Tieulent, R.; Tikhonov, A.; Timmins, A. R.; Tkacik, M.; Tkacik, T.; Toia, A.; Topilskaya, N.; Toppi, M.; Torales-Acosta, F.; Tork, T.; Torres Ramos, A. G.; Trifiró, A.; Triolo, A. S.; Tripathy, S.; Tripathy, T.; Trogolo, S.; Trubnikov, V.; Trzaska, W. H.; Trzcinski, T. P.; Tumkin, A.; Turrisi, R.; Tveter, T. S.; Ullaland, K.; Ulukutlu, B.; Uras, A.; Urioni, M.; Usai, G. L.; Vala, M.; Valle, N.; Vallero, S.; van Doremalen, L. V. R.; van Leeuwen, M.; van Veen, C. A.; van Weelden, R. J. G.; Vande Vyvre, P.; Varga, D.; Varga, Z.; Varga-Kofarago, M.; Vasileiou, M.; Vasiliev, A.; Vázquez Doce, O.; Vechernin, V.; Vercellin, E.; Vergara Limón, S.; Vermunt, L.; Vértesi, R.; Verweij, M.; Vickovic, L.; Vilakazi, Z.; Villalobos Baillie, O.; Vino, G.; Vinogradov, A.; Virgili, T.; Vislavicius, V.; Vodopyanov, A.; Volkel, B.; Völkl, M. A.; Voloshin, K.; Voloshin, S. A.; Volpe, G.; von Haller, B.; Vorobyev, I.; Vozniuk, N.; Vrláková, J.; Wagner, B.; Wang, C.; Wang, D.; Weber, M.; Wegrzynek, A.; Weiglhofer, F. T.; Wenzel, S. C.; Wessels, J. P.; Weyhmilller, S. L.; Wiechula, J.; Wikne, J.; Wilk, G.; Wilkinson, J.; Willems, G. A.; Windelband, B.; Winn, M.; Wright, J. R.; Wu, W.; Wu, Y.; Xu, R.; Yadav, A. K.; Yalcin, S.; Yamaguchi, Y.; Yamakawa, K.; Yang, S.; Yano, S.; Yin, Z.; Yoo, I. - K.; Yoon, J. H.; Yuan, S.; Yuncu, A.; Zaccolo, V.; Zampolli, C.; Zanolli, H. J. C.; Zanone, F.; Zardoshti, N.; Zarochentsev, A.; Závada, P.; Zaviyalov, N.; Zhalov, M.; Zhang, B.; Zhang, S.; Zhang, X.; Zhang, Y.; Zhao, M.; Zhrebchevskii, V.; Zhi, Y.; Zhigareva, N.; Zhou, D.; Zhou, Y.; Zhu, J.; Zhu, Y.; Zinovjev, G.; Zurlo, N.; Null, Null. - In: PHYSICAL REVIEW LETTERS. - ISSN 0031-9007. - ELETTRONICO. - 131:4(2023), pp. 1-12. [10.1103/physrevlett.131.041901]

First Measurement of Antideuteron Number Fluctuations at Energies Available at the Large Hadron Collider

S. Acharya *et al.**
(ALICE Collaboration)

 (Received 5 May 2022; revised 1 July 2022; accepted 15 September 2022; published 25 July 2023)

The first measurement of event-by-event antideuteron number fluctuations in high energy heavy-ion collisions is presented. The measurements are carried out at midrapidity ($|\eta| < 0.8$) as a function of collision centrality in Pb-Pb collisions at $\sqrt{s_{\text{NN}}} = 5.02$ TeV using the ALICE detector. A significant negative correlation between the produced antiprotons and antideuterons is observed in all collision centralities. The results are compared with a state-of-the-art coalescence calculation. While it describes the ratio of higher order cumulants of the antideuteron multiplicity distribution, it fails to describe quantitatively the magnitude of the correlation between antiproton and antideuteron production. On the other hand, thermal-statistical model calculations describe all the measured observables within uncertainties only for correlation volumes that are different with respect to those describing proton yields and a similar measurement of net-proton number fluctuations.

DOI: [10.1103/PhysRevLett.131.041901](https://doi.org/10.1103/PhysRevLett.131.041901)

The production of nuclei and antinuclei in heavy-ion collisions has been extensively studied in the last two decades. Nevertheless, this wealth of results is still not able to clarify the mechanism behind nuclei and antinuclei formation in heavy-ion collisions. Indeed, the two best fitting models, the coalescence [1–3] and the statistical hadronization models (SHM) [4,5], give very similar predictions for the production rates of nuclei and antinuclei in heavy-ion collisions. This similarity calls for new observables to decisively discriminate between these two approaches.

The SHM describes the system as a hadron-resonance gas in thermal equilibrium at hadron emission, hence it predicts particle yields starting from the volume (V) and the temperature of the system at chemical freeze-out (T_{chem}). The grand canonical ensemble (GCE) formulation of the SHM fits the measured production yields of light hadrons and nuclei in central Pb-Pb collisions at center-of-mass energy ($\sqrt{s_{\text{NN}}}$) of 2.76 TeV with $T_{\text{chem}} = 156.5$ MeV [6]. The coalescence model uses a different approach to explain the production of nuclei: the size of the nucleon-emitting source, accessible through the analysis of femtosopic correlations [7], the momentum distribution of the nucleons, as well as the nuclear wave function, are inputs that determine the formation probability of bound states [3,8].

While using statistical hadronization it is possible to compute directly the absolute yields of particles, in the hadron coalescence model the yield of bound states can be computed only relative to the production of its components and as a function of system size.

In a recent model study [9], it is shown that the higher order cumulants of the deuteron yield distribution and correlation between proton (p) and deuteron (d) production can be used to distinguish between coalescence and SHM. Higher order cumulants κ_m of the multiplicity distribution for $m < 4$ and the Pearson correlation coefficient (ρ_{ab}) between different identified particles a and b can be expressed as

$$\kappa_1 = \langle n \rangle, \quad (1)$$

$$\kappa_m = \langle (n - \langle n \rangle)^m \rangle, \quad (2)$$

$$\rho_{\text{ab}} = \langle (n_a - \langle n_a \rangle)(n_b - \langle n_b \rangle) \rangle / \sqrt{\kappa_{2a}\kappa_{2b}}, \quad (3)$$

where n , $\langle n \rangle$, and m are the event-by-event particle numbers, event average of particle numbers, and order of the cumulants, respectively. The $\langle n_a \rangle$ ($\langle n_b \rangle$) and κ_{2a} (κ_{2b}) are the first and second order cumulants of the multiplicity distribution of particle a (b). In the GCE formulation of the SHM, the event-by-event deuteron multiplicity distribution is expected to follow the Poisson distribution [10]. Therefore various ratios between cumulants of different order of the deuteron multiplicity distribution such as κ_2/κ_1 , κ_3/κ_2 are equal to unity in the GCE SHM. In a simple coalescence scenario, if deuterons are produced by the coalescence of thermally produced protons and

*Full author list given at the end of the Letter.

Published by the American Physical Society under the terms of the [Creative Commons Attribution 4.0 International license](https://creativecommons.org/licenses/by/4.0/). Further distribution of this work must maintain attribution to the author(s) and the published article's title, journal citation, and DOI.

neutrons, then the event-by-event deuteron distribution is expected to deviate from the Poisson baseline [9]. By definition, the coalescence model also introduces a negative correlation between the measured proton and deuteron numbers in the absence of any initial correlation between proton and neutron. On the other hand, one does not expect any correlation between the measured p and d in the GCE SHM as the baryon productions from a thermal source are independent from each other. However, in the canonical ensemble (CE) formulation of the SHM, particle production is constrained by the conservation of the net baryon numbers on an event-by-event basis, which can also introduce a negative correlation between measured proton and deuteron in SHM and a deviation of cumulant ratios from the Poisson baseline [10,11].

In this Letter, the first measurements of the κ_2/κ_1 ratio of antideuteron (antiparticles are used throughout the analysis to avoid the contamination from secondary deuterons coming from spallation processes in the beam pipe) multiplicity distribution and correlation ($\rho_{\bar{p}\bar{d}}$) between measured antideuterons (\bar{d}) and antiprotons (\bar{p}) are presented. Measurements are compared with predictions from the SHM and coalescence model in order to shed light on the deuteron synthesis mechanism. The results presented in this Letter are obtained using data collected during the 2015 Pb-Pb LHC run at $\sqrt{s_{NN}} = 5.02$ TeV.

The ALICE detector and its performance are described in detail in Refs. [12,13]. Collision events are selected by using the information from the V0C and V0A scintillator arrays [14], located on both sides of the interaction point, covering the pseudorapidity intervals $-3.7 < \eta < -1.6$ and $2.8 < \eta < 5.1$, respectively. Events are selected with a minimum-bias (MB) trigger which requires at least one hit in both the V0A and the V0C detectors. In addition, only events with the primary vertex position within 10 cm along the beam axis to the nominal interaction point are selected to benefit from the full acceptance of the detector. Furthermore, to ensure the best possible performance of the detector and proper normalisation of the results, events with more than one reconstructed primary interaction vertex (pile-up events) are rejected. In total, about 100×10^6 MB events are selected for analysis. Furthermore, the selected events are divided into centrality classes based on the measured amplitude distribution in the V0A and V0C counters as described in Ref. [15]. Central Pb-Pb collisions (head-on collisions) are obtained from the top 10% of the amplitude distribution corresponding to hadronic interactions and peripheral Pb-Pb collisions are obtained from the 70%–80% region of the same distribution.

The charged-particle tracks are reconstructed in the ALICE central barrel with the inner tracking system (ITS) [13] and the time projection chamber (TPC) [16], which are located within a solenoid that provides a homogeneous magnetic field of up to 0.5 T in the direction of the beam axis. These two subsystems provide full

azimuthal coverage for charged-particle trajectories in the pseudorapidity interval $|\eta| < 0.8$. The transverse momentum range is restricted to $0.4 < p_T < 1.8$ GeV/ c to select the \bar{p} and \bar{d} with high purity. Moreover, to guarantee a track-momentum resolution of 2% in the relevant p_T range and an energy loss (dE/dx) resolution in the TPC of 5%, the selected tracks are required to have at least 70 out of a maximum possible 159 reconstructed space points in the TPC, and at least one hit in the two innermost layers of the ITS. This selection also assures a resolution better than 300 μm [13] on the distance of the closest approach to the primary vertex in the plane perpendicular (DCA_{xy}) and parallel (DCA_z) to the beam axis for the selected tracks. In addition, the χ^2 per space point in the TPC and the ITS from the track fit are required to be less than 4 and 36, respectively. Daughter tracks from reconstructed secondary weak-decay kink topologies were rejected and a suppression of the weak-decay particles are obtained by selecting tracks with $|DCA_z|$ and $|DCA_{xy}|$ less than 1.0 and 0.1 cm, respectively.

The \bar{d} and \bar{p} are identified via the specific energy loss dE/dx in the gas volume of the TPC and the flight time of a particle from the primary vertex of the collision to the time-of-flight (TOF) detector. The $n(\sigma_i^{\text{TPC}})$ variable represents the particle identification (PID) response in the TPC expressed in terms of the deviation between the measured and the expected dE/dx for a particle species i , normalized by the detector resolution σ . The expected dE/dx is computed with a parameterised Bethe-Bloch function [13]. The \bar{p} and \bar{d} are identified using $-2 < |n(\sigma_i^{\text{TPC}})| < 4$ in the range $0.4 < p_T < 0.6$ GeV/ c and $0.8 < p_T < 1.0$ GeV/ c , respectively. Particle identification on a track-by-track basis using the TPC is limited to low momenta. Therefore, to identify \bar{d} (\bar{p}) in the range $1.0 < p_T < 1.8$ GeV/ c ($0.6 < p_T < 0.9$ GeV/ c), an additional selection of $3.0 < m^2 < 4.2$ GeV $^2/c^4$ ($0.6 < m^2 < 1.2$ GeV $^2/c^4$) using the Time-of-Flight (TOF) [17] detector is applied, where the square of the particle mass, m^2 , is obtained by combining the information of the flight time with the trajectory length of the particle. The selection of \bar{d} is restricted to the range $0.8 < p_T < 1.8$ GeV/ c in order to keep the overall \bar{d} purity above 90%. The \bar{p} selection is restricted to exactly half of the p_T range of \bar{d} according to the coalescence mechanism. This selection results in a purity of the selected \bar{p} sample above 95%. The impurity in \bar{d} selection can lead to an autocorrelation with the selected \bar{p} and affect the $\rho_{\bar{p}\bar{d}}$. The effect is negligible in our measurement as the \bar{d} and \bar{p} are mostly selected in separated p_T regions and in the common p_T interval the \bar{d} purity is $\sim 99\%$. Selected \bar{d} and \bar{p} numbers in each event are further used to obtain the higher order cumulants and correlation.

Measured cumulants are corrected for the \bar{d} and \bar{p} efficiencies assuming a binomial response of the detectors.

The binomial-based method of efficiency correction [18] is a two-step method. First, the efficiency of \bar{d} and \bar{p} reconstruction in the ALICE detector is obtained using a simulation based on GEANT4, which correctly describes the interaction of \bar{p} and \bar{d} with the material of the detectors [19]. Then, the cumulants and correlation coefficient are corrected for the reconstruction efficiencies using analytic expressions as discussed in Ref. [18]. Typical reconstruction efficiencies of both \bar{p} and \bar{d} in the studied p_T ranges are about 70% and 25% in the TPC and TOF, respectively. The efficiency-corrected cumulants and correlation are further corrected for the centrality bin width effect [20] to suppress the initial volume fluctuations which arise from the initial state (size and shape) fluctuations.

The statistical uncertainties on the efficiency corrected κ_2/κ_1 ratio and $\rho_{\bar{p}\bar{d}}$ are obtained by the subsample method [21]. The systematic uncertainties on the observables are estimated by varying the track selection and PID criteria. The systematic uncertainties due to track selection include the variation of the selection criteria on DCA_{xy} , DCA_z , the number of reconstructed space points in the TPC, and the quality of the track fit from their nominal values. The systematic uncertainties due to PID are calculated by varying the default $n(\sigma^{\text{TPC}_i})$ and m^2 criteria. Systematic uncertainties due to each of these sources are considered as uncorrelated and the total systematic uncertainty on the observables is obtained by adding all the contributions in quadrature.

The resulting ratio of the second to first order cumulant for \bar{d} is shown in Fig. 1 for different centrality classes. The data is found to be consistent with unity within uncertainties as expected from a Poisson distribution and does not exhibit a significant centrality dependence. Measurements are also compared with estimations from the CE version of the SHM [22] for two different correlation volumes (V_c) for baryon number conservation, $V_c = 4.8 dV/dy$ (orange band in figures) and $V_c = 1.6 dV/dy$ (green band in figures). The choice of two different V_c is discussed below. In the SHM model the temperature is fixed to $T = 155$ MeV [5], the volume fitted to the published pion, kaon, and proton yields at midrapidity [23], and the net-baryon number set to 0. Measurements are found to be consistent with the SHM model for both of the V_c . In contrast to the corresponding ratio for p and \bar{p} [24,25], no strong dependence on the V_c is seen due to the fact that only a small fraction of the total antibaryon number is carried by \bar{d} [10,26]. Remarkably, the data differs from the calculations of the coalescence model, which predicts a deviation larger than 1% from the Poisson baseline as explained in Ref. [9]. Two shaded bands are shown for the coalescence model: the purple one assumes full correlation among protons and neutrons produced in the collision (model A), while the blue one assumes completely independent proton and neutron production fluctuations (model B). On the other hand, a state of art model

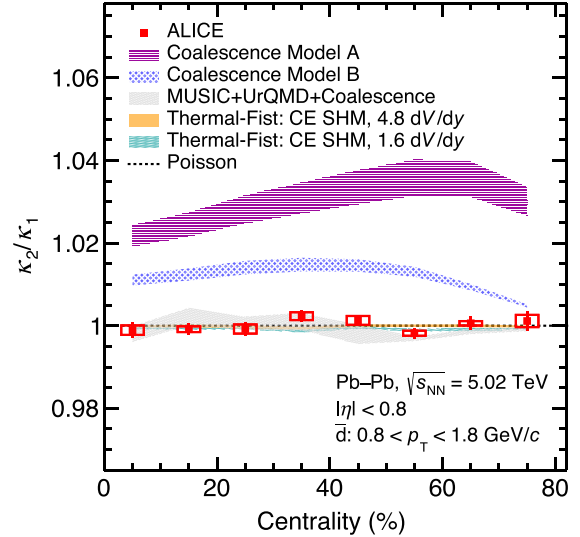


FIG. 1. Second order to first order cumulant ratio of the \bar{d} multiplicity distribution as a function of collision centrality in Pb-Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV. Statistical and systematic uncertainties are shown by the bars and boxes, respectively. Measured cumulant ratios are compared with estimations from the CE version of the SHM, from a simple coalescence model and from a MUSIC + UrQMD + Coalescence simulation. The width of the SHM model and MUSIC + UrQMD + Coalescence bands corresponds to the statistical uncertainty of the model estimation, whereas the width of the bands for the coalescence model corresponds to the uncertainty coming from the variation of the coalescence parameters.

calculation coupling coalescence to a hydrodynamical model with hadronic interactions in the final state (MUSIC + UrQMD + COAL) [27] predicts κ_2/κ_1 ratio ~ 1 , in agreement with the experimental data (note that these predictions were updated after acceptance of this Letter). As discussed in [27], the main difference between the coalescence predictions in Fig. 1 and the MUSIC + UrQMD + COAL calculation is due to the different method of implementing baryon number conservation.

Figure 2 shows $\rho_{\bar{p}\bar{d}}$ as a function of the collision centrality. A small negative correlation of $O(0.1\%)$ is observed, i.e., in events with at least one \bar{d} , there are $O(0.1\%)$ less \bar{p} observed than in an average event. A negative correlation as observed in data is expected by the coalescence model (shown by the blue band in Fig. 2) where \bar{p} and \bar{n} from two independent sources coalesce to produce \bar{d} . The same behavior is observed for the MUSIC + UrQMD + COAL calculation. It has to be noted that models based on fully correlated proton and neutron fluctuations (Model A in Ref. [9]) predict values of ρ around 6% and are ruled out by data. On the other hand, the measured negative correlation between \bar{p} and \bar{d} is also expected by the CE version of the SHM which introduces a negative correlation between \bar{p} and \bar{d} through the conservation of a fixed net-baryon number. The predicted

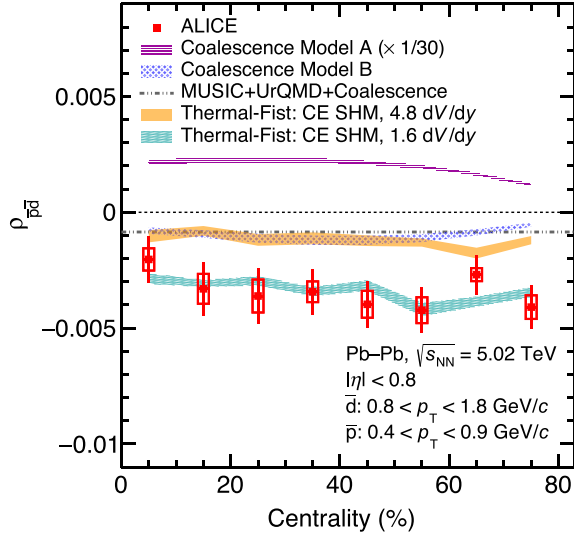


FIG. 2. Pearson correlation between the measured \bar{p} and \bar{d} as a function of collision centrality in Pb-Pb collisions at $\sqrt{s_{\text{NN}}} = 5.02$ TeV. Bars and boxes represent statistical and systematic uncertainties, respectively. Measured correlations are compared with estimations from the CE version of the SHM for two different baryon number conservation volumes, from coalescence model and from MUSIC + UrQMD + COAL.

correlation in the SHM increases with decreasing correlation volume V_c for baryon number conservation which is used in the following for a determination of V_c . In order to determine the correlation volume for the baryon quantum number, a χ^2 minimization is performed by varying the V_c parameter in the SHM model and comparing the result to the measured correlation as a function of centrality. The V_c interval probed in this case spans from 1 to 5 units of rapidity, and the value that describes best the measurement is $V_c = 1.6 \pm 0.3$ dV/dy with a fit probability of 85%. The SHM configuration with $V_c = 4.8$ dV/dy that correctly

describes the net-proton number fluctuations in central Pb-Pb collisions [26,28] is compatible within uncertainties with the measured $\rho_{\bar{p}\bar{d}}$ only in central collisions. Conversely, this configuration is excluded with a 4σ confidence level when compared with the measurements in all centrality classes.

Several consistency checks such as the correlation between \bar{p} and \bar{d} from different events, the correlation between antibaryon (\bar{d}) and baryon (p) were performed for a better understanding of the observed correlation. The correlation between \bar{p} and \bar{d} from mixed events is served as a null hypothesis test of the measurements and the obtained results are consistent with zero as expected. However, a positive correlation is observed between antibaryon and baryon. This positive correlation is expected due to baryon number conservation [10], whereas in simple coalescence model no correlation between baryon and antibaryon is expected as \bar{d} is not produced from the coalescence of p .

Figure 3 shows the same Pearson correlation coefficient in three centrality intervals as a function of the η acceptance of \bar{p} and \bar{d} selection. The observed anticorrelation is increasing with acceptance, and the effect is more pronounced for peripheral collisions. Simple coalescence calculations do not capture this trend. On the other hand, this measurement should motivate further calculations with more refined coalescence models. The decreasing trend seen in the SHM with $V_c = 1.6$ dV/dy describes the experimental data. In the CE version of SHM model, anticorrelation between antibaryons depends on the fraction of antibaryon number in the acceptance out of the total conserved antibaryon numbers [10,11,25,28]. Therefore, the increased negative correlation magnitude with increasing acceptance can be understood as a consequence of baryon number conservation.

In summary, the measurement of \bar{d} production fluctuation is a valuable tool to challenge the nucleosynthesis

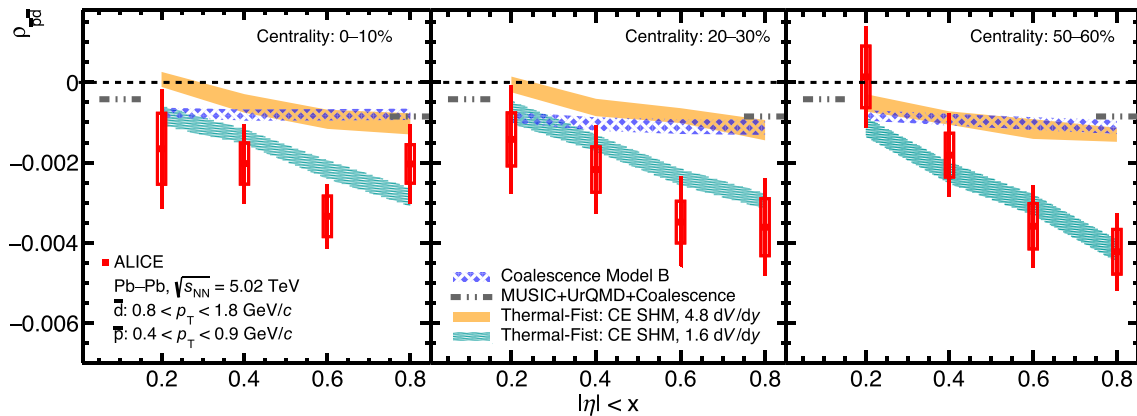


FIG. 3. Dependence of \bar{p} - \bar{d} correlation on pseudorapidity acceptance of \bar{p} and \bar{d} selection in Pb-Pb collisions at $\sqrt{s_{\text{NN}}} = 5.02$ TeV for three different centrality classes. Measurements are compared with calculations from the CE version of the SHM, coalescence model and MUSIC + UrQMD + COAL.

models used for hadronic collisions. Simple coalescence models, as well as state-of-the-art MUSIC + UrQMD + COAL calculations, fail to fit simultaneously the measurement of the cumulant ratios and the correlation coefficient $\rho_{p\bar{a}}$. These models show a great sensitivity to the initial correlation between the proton and the neutron production, hence further theoretical developments might improve the comparison with the measurement. In recent studies, state-of-the-art CE SHM models are describing simultaneously proton yields and net-proton fluctuation measurements finding large $V_c \approx 3-5dV/dy$ [26,28,29]. Surprisingly, deuteron production measurements [5] as well as the fluctuation measurements presented here indicate a significantly smaller correlation volume for the baryon number. Under the assumption that V_c is independent of collision centrality, the value $V_c = 1.6 \pm 0.3 dV/dy$ is obtained. This discrepancy might indicate a different production mechanism for light flavored hadrons and light nuclei. However, more sophisticated approaches including partial chemical equilibrium [30] or the implementation of the interaction of hadrons through phase shift [31,32] could help in resolving this conundrum. The results of this Letter present a severe challenge to the current understanding of nuclei production in heavy-ion collisions at the LHC energies.

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), 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; National Research and Innovation Agency—BRIN, Indonesia; Istituto Nazionale di Fisica Nucleare (INFN), Italy; 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 Académico (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, Ministry of Research and Innovation and Institute of Atomic Physics and University Politehnica of Bucharest, Romania; 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 (NSTDA), Thailand Science Research and Innovation (TSRI) and National Science, Research and Innovation Fund (NSRF), 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), USA. In addition, individual groups or members have received support from Marie Skłodowska Curie, Strong 2020—Horizon 2020 (Grants No. 824093, No. 896850), European Union; Academy of Finland (Center of Excellence in Quark Matter) (Grants No. 346327, No. 346328), Finland; Programa de Apoyos para la Superación del Personal Académico, UNAM, Mexico.

-
- [1] S. Mrowczynski, Deuteron formation mechanism, *J. Phys. G* **13**, 1089 (1987).
- [2] R. Scheibl and U. W. Heinz, Coalescence and flow in ultrarelativistic heavy ion collisions, *Phys. Rev. C* **59**, 1585 (1999).
- [3] K.-J. Sun, C. M. Ko, and B. Dönigus, Suppression of light nuclei production in collisions of small systems at the Large Hadron Collider, *Phys. Lett. B* **792**, 132 (2019).
- [4] A. Andronic, P. Braun-Munzinger, J. Stachel, and H. Stoecker, Production of light nuclei, hypernuclei and their antiparticles in relativistic nuclear collisions, *Phys. Lett. B* **697**, 203 (2011).
- [5] V. Vovchenko, B. Dönigus, and H. Stoecker, Multiplicity dependence of light nuclei production at LHC energies in the canonical statistical model, *Phys. Lett. B* **785**, 171 (2018).
- [6] A. Andronic, P. Braun-Munzinger, K. Redlich, and J. Stachel, Decoding the phase structure of QCD via particle production at high energy, *Nature (London)* **561**, 321 (2018).
- [7] S. Acharya *et al.* (ALICE Collaboration), Search for a common baryon source in high-multiplicity pp collisions at the LHC, *Phys. Lett. B* **811**, 135849 (2020).
- [8] K. Blum, Kenny Chun Yu Ng, R. Sato, and M. Takimoto, Cosmic rays, antihelium, and an old navy spotlight, *Phys. Rev. D* **96**, 103021 (2017).
- [9] Z. Fecková, J. Steinheimer, B. Tomášik, and M. Bleicher, Formation of deuterons by coalescence: Consequences for deuteron number fluctuations, *Phys. Rev. C* **93**, 054906 (2016).
- [10] P. Braun-Munzinger, B. Friman, K. Redlich, A. Rustamov, and J. Stachel, Relativistic nuclear collisions: Establishing a non-critical baseline for fluctuation measurements, *Nucl. Phys. A* **1008**, 122141 (2021).
- [11] M. Barej and A. Bzdak, Factorial cumulants from global baryon number conservation, *Phys. Rev. C* **102**, 064908 (2020).
- [12] K. Aamodt *et al.* (ALICE Collaboration), The ALICE experiment at the CERN LHC, *J. Instrum.* **3**, S08002 (2008).
- [13] B. B. Abelev *et al.* (ALICE Collaboration), Performance of the ALICE Experiment at the CERN LHC, *Int. J. Mod. Phys. A* **29**, 1430044 (2014).
- [14] E. Abbas *et al.* (ALICE Collaboration), Performance of the ALICE VZERO system, *J. Instrum.* **8**, P10016 (2013).
- [15] B. Abelev *et al.* (ALICE Collaboration), Centrality determination of Pb-Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV with ALICE, *Phys. Rev. C* **88**, 044909 (2013).
- [16] J. Alme *et al.*, The ALICE TPC, a large 3-dimensional tracking device with fast readout for ultra-high multiplicity events, *Nucl. Instrum. Methods Phys. Res., Sect. A* **622**, 316 (2010).
- [17] A. Akindinov *et al.*, Performance of the ALICE time-of-flight detector at the LHC, *Eur. Phys. J. Plus* **128**, 44 (2013).
- [18] T. Nonaka, M. Kitazawa, and S. I. Esumi, More efficient formulas for efficiency correction of cumulants and effect of using averaged efficiency, *Phys. Rev. C* **95**, 064912 (2017); **103**, 029901(E) (2021).
- [19] S. Acharya *et al.* (ALICE Collaboration), Measurement of the Low-Energy Antideuteron Inelastic Cross Section, *Phys. Rev. Lett.* **125**, 162001 (2020).
- [20] X. Luo, J. Xu, B. Mohanty, and N. Xu, Volume fluctuation and auto-correlation effects in the moment analysis of net-proton multiplicity distributions in heavy-ion collisions, *J. Phys. G* **40**, 105104 (2013).
- [21] S. Acharya *et al.* (ALICE Collaboration), Relative particle yield fluctuations in Pb-Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV, *Eur. Phys. J. C* **79**, 236 (2019).
- [22] V. Vovchenko and H. Stoecker, Thermal-FIST: A package for heavy-ion collisions and hadronic equation of state, *Comput. Phys. Commun.* **244**, 295 (2019).
- [23] S. Acharya *et al.* (ALICE Collaboration), Production of charged pions, kaons, and (anti-)protons in Pb-Pb and inelastic pp collisions at $\sqrt{s_{NN}} = 5.02$ TeV, *Phys. Rev. C* **101**, 044907 (2020).
- [24] M. Abdallah *et al.* (STAR Collaboration), Cumulants and correlation functions of net-proton, proton, and antiproton multiplicity distributions in Au + Au collisions at energies available at the BNL Relativistic Heavy Ion Collider, *Phys. Rev. C* **104**, 024902 (2021).
- [25] V. Vovchenko, V. Koch, and C. Shen, Proton number cumulants and correlation functions in Au-Au collisions at sNN = 7.7–200 GeV from hydrodynamics, *Phys. Rev. C* **105**, 014904 (2022).
- [26] S. Acharya *et al.* (ALICE Collaboration), Global baryon number conservation encoded in net-proton fluctuations measured in Pb-Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV, *Phys. Lett. B* **807**, 135564 (2020).
- [27] K.-J. Sun and C. M. Ko, Event-by-event anti-deuteron multiplicity fluctuation in Pb + Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV, *Phys. Lett. B* **840**, 137864 (2023).
- [28] V. Vovchenko and V. Koch, Particlization of an interacting hadron resonance gas with global conservation laws for event-by-event fluctuations in heavy-ion collisions, *Phys. Rev. C* **103**, 044903 (2021).
- [29] V. Vovchenko, B. Dönigus, and H. Stoecker, Canonical statistical model analysis of p-p, p-Pb, and Pb-Pb collisions at energies available at the CERN Large Hadron Collider, *Phys. Rev. C* **100**, 054906 (2019).
- [30] T. Neidig, K. Gallmeister, C. Greiner, M. Bleicher, and V. Vovchenko, Towards solving the puzzle of high temperature light (anti-)nuclei production in ultra-relativistic heavy ion collisions, *Phys. Lett. B* **827**, 136891 (2022).

- [31] A. Andronic, P. Braun-Munzinger, B. Friman, P. M. Lo, K. Redlich, and J. Stachel, The thermal proton yield anomaly in Pb-Pb collisions at the LHC and its resolution, *Phys. Lett. B* **792**, 304 (2019).
- [32] J. Cleymans, P. M. Lo, K. Redlich, and N. Sharma, Multiplicity dependence of (multi)strange baryons in the canonical ensemble with phase shift corrections, *Phys. Rev. C* **103**, 014904 (2021).
-
- S. Acharya^{123,130} D. Adamová⁸⁵ A. Adler⁶⁸ G. Aglieri Rinella³² M. Agnello²⁹ N. Agrawal⁴⁹ Z. Ahammed¹³⁰ S. Ahmad¹⁵ S. U. Ahn⁶⁹ I. Ahuja³⁶ A. Akindinov¹³⁸ M. Al-Turany⁹⁷ D. Aleksandrov¹³⁸ B. Alessandro⁵⁴ H. M. Alfanda⁶ R. Alfaro Molina⁶⁵ B. Ali¹⁵ Y. Ali¹³ A. Alici²⁵ N. Alizadehvandchali¹¹² A. Alkin³² J. Alme²⁰ G. Alocco⁵⁰ T. Alt⁶² I. Altsybeev¹³⁸ M. N. Anaam⁶ C. Andrei⁴⁴ A. Andronic¹³³ V. Anguelov⁹⁴ F. Antinori⁵² P. Antonioli⁴⁹ C. Anuj¹⁵ N. Apadula⁷³ L. Aphecetche¹⁰² H. Appelshäuser⁶² S. Arcelli²⁵ R. Arnaldi⁵⁴ I. C. Arsene¹⁹ M. Arslandok¹³⁵ A. Augustinus³² R. Averbeck⁹⁷ S. Aziz⁷¹ M. D. Azmi¹⁵ A. Badalà⁵¹ Y. W. Baek³⁹ X. Bai⁹⁷ R. Bailhache⁶² Y. Bailung⁴⁶ R. Bala⁹⁰ A. Balbino²⁹ A. Baldisseri¹²⁶ B. Balis² D. Banerjee⁴ Z. Banoo⁹⁰ R. Barbera²⁶ L. Barioglio⁹⁵ M. Barlou⁷⁷ G. G. Barnaföldi¹³⁴ L. S. Barnby⁸⁴ V. Barret¹²³ L. Barreto¹⁰⁸ C. Bartels¹¹⁵ K. Barth³² E. Bartsch⁶² F. Baruffaldi²⁷ N. Bastid¹²³ S. Basu⁷⁴ G. Batigne¹⁰² D. Battistini⁹⁵ B. Batyunya¹³⁹ D. Bauri⁴⁵ J. L. Bazo Alba¹⁰⁰ I. G. Bearden⁸² C. Beattie¹³⁵ P. Becht⁹⁷ D. Behera⁴⁶ I. Belikov¹²⁵ A. D. C. Bell Hechavarría¹³³ R. Bellwied¹¹² S. Belokurova¹³⁸ V. Belyaev¹³⁸ G. Bencedi^{63,134} S. Beole²⁴ A. Bercuci⁴⁴ Y. Berdnikov¹³⁸ A. Berdnikova⁹⁴ L. Bergmann⁹⁴ M. G. Besoiu⁶¹ L. Betev³² P. P. Bhaduri¹³⁰ A. Bhasin⁹⁰ I. R. Bhat⁹⁰ M. A. Bhat⁴ B. Bhattacharjee⁴⁰ L. Bianchi²⁴ N. Bianchi⁴⁷ J. Bielčík³⁵ J. Bielčíková⁸⁵ J. Biernat¹⁰⁵ A. Bilandzic⁹⁵ G. Biro¹³⁴ S. Biswas⁴ J. T. Blair¹⁰⁶ D. Blau¹³⁸ M. B. Blidaru⁹⁷ N. Bluhme³⁷ C. Blume⁶² G. Boca^{21,53} F. Bock⁸⁶ T. Bodova²⁰ A. Bogdanov¹³⁸ S. Boi²² J. Bok⁵⁶ L. Boldizsár¹³⁴ A. Bolozdynya¹³⁸ M. Bombara³⁶ P. M. Bond³² G. Bonomi^{53,129} H. Borel¹²⁶ A. Borissov¹³⁸ H. Bossi¹³⁵ E. Botta²⁴ L. Bratrud⁶² P. Braun-Munzinger⁹⁷ M. Bregant¹⁰⁸ M. Broz³⁵ G. E. Bruno^{96,31} M. D. Buckland¹¹⁵ D. Budnikov¹³⁸ H. Buesching⁶² S. Bufalino²⁹ O. Bugnon¹⁰² P. Buhler¹⁰¹ Z. Buthelezi^{66,119} J. B. Butt¹³ A. Bylinkin¹¹⁴ S. A. Bysiak¹⁰⁵ M. Cai^{6,27} H. Caines¹³⁵ A. Caliva⁹⁷ E. Calvo Villar¹⁰⁰ J. M. M. Camacho¹⁰⁷ R. S. Camacho⁴³ P. Camerini²³ F. D. M. Canedo¹⁰⁸ M. Carabas¹²² F. Carnesecchi²⁵ R. Caron^{124,126} J. Castillo Castellanos¹²⁶ F. Catalano²⁹ C. Ceballos Sanchez¹³⁹ I. Chakaberia⁷³ P. Chakraborty⁴⁵ S. Chandra¹³⁰ S. Chapeland³² M. Chartier¹¹⁵ S. Chattopadhyay¹³⁰ S. Chattopadhyay⁹⁸ T. G. Chavez⁴³ T. Cheng⁶ C. Cheshkov¹²⁴ B. Cheynis¹²⁴ V. Chibante Barroso³² D. D. Chinellato¹⁰⁹ E. S. Chizzali^{95,b} S. Cho⁵⁶ P. Chochula³² P. Christakoglou⁸³ C. H. Christensen⁸² P. Christiansen⁷⁴ T. Chujo¹²¹ M. Ciacco²⁹ C. Cicalo⁵⁰ L. Cifarelli²⁵ F. Cindolo⁴⁹ M. R. Ciupek⁹⁷ G. Clai^{49,c} F. Colamaria⁴⁸ J. S. Colburn⁹⁹ D. Colella^{96,31} A. Collu⁷³ M. Colocci³² M. Concas^{54,d} G. Conesa Balbastre⁷² Z. Conesa del Valle⁷¹ G. Contin²³ J. G. Contreras³⁵ M. L. Coquet¹²⁶ T. M. Cormier^{86,a} P. Cortese^{54,128} M. R. Cosentino¹¹⁰ F. Costa³² S. Costanza^{21,53} P. Crochet¹²³ R. Cruz-Torres⁷³ E. Cuautle⁶³ P. Cui⁶ L. Cunqueiro⁸⁶ A. Dainese⁵² M. C. Danisch⁹⁴ A. Danu⁶¹ P. Das⁷⁹ P. Das⁴ S. Das⁴ S. Dash⁴⁵ A. De Caro²⁸ G. de Cataldo⁴⁸ L. De Cilladi²⁴ J. de Cuveland³⁷ A. De Falco²² D. De Gruttola²⁸ N. De Marco⁵⁴ C. De Martin²³ S. De Pasquale²⁸ S. Deb⁴⁶ H. F. Degenhardt¹⁰⁸ K. R. Deja¹³¹ R. Del Grande⁹⁵ L. Dello Stritto²⁸ W. Deng⁶ P. Dhankher¹⁸ D. Di Bari³¹ A. Di Mauro³² R. A. Diaz^{139,7} T. Dietel¹¹¹ Y. Ding^{6,124} R. Divià³² D. U. Dixit¹⁸ Ø. Djuvsland²⁰ U. Dmitrieva¹³⁸ A. Dobrin⁶¹ B. Dönigus⁶² A. K. Dubey¹³⁰ J. M. Dubinski¹³¹ A. Dubla⁹⁷ S. Dudi⁸⁹ P. Dupieux¹²³ M. Durkac¹⁰⁴ N. Dzalaiova¹² T. M. Eder¹³³ R. J. Ehlers⁸⁶ V. N. Eikeland²⁰ F. Eisenhut⁶² D. Elia⁴⁸ B. Erasmus¹⁰² F. Ercolessi²⁵ F. Erhardt⁸⁸ A. Erokhin¹³⁸ M. R. Ersdal²⁰ B. Espagnon⁷¹ G. Eulisse³² D. Evans⁹⁹ S. Evdokimov¹³⁸ L. Fabbietti⁹⁵ M. Faggin²⁷ J. Faivre⁷² F. Fan⁶ W. Fan⁷³ A. Fantoni⁴⁷ M. Fasel⁸⁶ P. Fedchio²⁹ A. Feliciello⁵⁴ G. Feofilov¹³⁸ A. Fernández Téllez⁴³ M. B. Ferrer³² A. Ferrero¹²⁶ A. Ferretti²⁴ V. J. G. Feuillard⁹⁴ J. Figiel¹⁰⁵ V. Filova³⁵ D. Finogeev¹³⁸ G. Fiorenza⁹⁶ F. Flor¹¹² A. N. Flores¹⁰⁶ S. Foertsch⁶⁶ I. Fokin⁹⁴ S. Fokin¹³⁸ E. Fragiaco⁵⁵ E. Frajna¹³⁴ U. Fuchs³² N. Funicello²⁸ C. Furget⁷² A. Furs¹³⁸ J. J. Gaardhøje⁸² M. Gagliardi²⁴ A. M. Gago¹⁰⁰ A. Gal¹²⁵ C. D. Galvan¹⁰⁷ P. Ganoti⁷⁷ C. Garabatos⁹⁷ J. R. A. Garcia⁴³ E. Garcia-Solis⁹ K. Garg¹⁰² C. Gargiulo³² A. Garibli⁸⁰ K. Garner¹³³

E. F. Gauger¹⁰⁶ A. Gautam¹¹⁴ M. B. Gay Ducati⁶⁴ M. Germain¹⁰² S. K. Ghosh,⁴ M. Giacalone²⁵ P. Gianotti⁴⁷
P. Giubellino^{54,97} P. Giubilato²⁷ A. M. C. Glaenger¹²⁶ P. Glässel⁹⁴ E. Glimos,¹¹⁸ D. J. Q. Goh,⁷⁵ V. Gonzalez¹³²
L. H. González-Trueba⁶⁵ S. Gorbunov,³⁷ M. Gorgon² L. Görlich¹⁰⁵ S. Gotovac,³³ V. Grabski⁶⁵
L. K. Graczykowski¹³¹ E. Grecka⁸⁵ L. Greiner⁷³ A. Grelli⁵⁷ C. Grigoras³² V. Grigoriev¹³⁸ S. Grigoryan^{1,139}
F. Grosa⁵⁴ J. F. Grosse-Oetringhaus³² R. Grosso⁹⁷ D. Grund³⁵ G. G. Guardiano¹⁰⁹ R. Guernane⁷²
M. Guilbaud¹⁰² K. Gulbrandsen⁸² T. Gunji¹²⁰ W. Guo⁶ A. Gupta⁹⁰ R. Gupta⁹⁰ S. P. Guzman⁴³
L. Gyulai¹³⁴ M. K. Habib,⁹⁷ C. Hadjidakis⁷¹ H. Hamagaki⁷⁵ M. Hamid,⁶ Y. Han¹³⁶ R. Hannigan¹⁰⁶
M. R. Haque¹³¹ A. Harlenderova,⁹⁷ J. W. Harris¹³⁵ A. Harton⁹ J. A. Hasenbichler,³² H. Hassan⁸⁶
D. Hatzifotiadou,⁴⁹ P. Hauer⁴¹ L. B. Havener¹³⁵ S. T. Heckel⁹⁵ E. Hellbär⁹⁷ H. Helstrup³⁴ T. Herman³⁵
G. Herrera Corral⁸ F. Herrmann,¹³³ K. F. Hetland³⁴ B. Heybeck⁶² H. Hillemanns³² C. Hills¹¹⁵ B. Hippolyte¹²⁵
B. Hofman⁵⁷ B. Hohlweger⁸³ J. Honermann¹³³ G. H. Hong¹³⁶ D. Horak³⁵ A. Horzyk² R. Hosokawa,¹⁴
Y. Hou⁶ P. Hristov³² C. Hughes¹¹⁸ P. Huhn,⁶² L. M. Huhta¹¹³ C. V. Hulse⁷¹ T. J. Humanic⁸⁷ H. Hushnud,⁹⁸
A. Hutson¹¹² D. Hutter³⁷ J. P. Iddon¹¹⁵ R. Ilkaev,¹³⁸ H. Ilyas¹³ M. Inaba¹²¹ G. M. Innocenti³²
M. Ippolitov¹³⁸ A. Isakov⁸⁵ T. Isidori¹¹⁴ M. S. Islam⁹⁸ M. Ivanov⁹⁷ V. Ivanov¹³⁸ V. Izucheev,¹³⁸
M. Jablonski² B. Jacak⁷³ N. Jacazio³² P. M. Jacobs⁷³ S. Jadlovská,¹⁰⁴ J. Jadlovsky,¹⁰⁴ L. Jaffe,³⁷ C. Jahnke,¹⁰⁹
M. A. Janik¹³¹ T. Janson,⁶⁸ M. Jercic,⁸⁸ O. Jevons,⁹⁹ A. A. P. Jimenez⁶³ F. Jonas^{86,133} P. G. Jones,⁹⁹ J. M. Jowett^{32,97}
J. Jung⁶² M. Jung⁶² A. Junique³² A. Jusko⁹⁹ M. J. Kabus¹³¹ J. Kaewjai,¹⁰³ P. Kalinak⁵⁸ A. S. Kalteyer⁹⁷
A. Kalweit³² V. Kaplin¹³⁸ A. Karasu Uysal⁷⁰ D. Karatovic⁸⁸ O. Karavichev¹³⁸ T. Karavicheva¹³⁸
P. Karczmarczyk¹³¹ E. Karpechev¹³⁸ V. Kashyap,⁷⁹ A. Kazantsev,¹³⁸ U. Keschull⁶⁸ R. Keidel¹³⁷
D. L. D. Keijdener,⁵⁷ M. Keil³² B. Ketzer⁴¹ A. M. Khan⁶ S. Khan¹⁵ A. Khanzadeev¹³⁸ Y. Kharlov¹³⁸
A. Khatun¹⁵ A. Khuntia¹⁰⁵ B. Kileng³⁴ B. Kim¹⁶ C. Kim¹⁶ D. J. Kim¹¹³ E. J. Kim⁶⁷ J. Kim¹³⁶
J. S. Kim³⁹ J. Kim⁹⁴ J. Kim⁶⁷ M. Kim⁹⁴ S. Kim¹⁷ T. Kim¹³⁶ S. Kirsch⁶² I. Kisel³⁷ S. Kiselev¹³⁸
A. Kisel¹³¹ J. P. Kitowski² J. L. Klay⁵ J. Klein³² S. Klein⁷³ C. Klein-Bösing¹³³ M. Kleiner⁶²
T. Klemenz⁹⁵ A. Kluge³² A. G. Knospe¹¹² C. Kobdaj¹⁰³ T. Kollegger,⁹⁷ A. Kondratyev¹³⁹ N. Kondratyeva¹³⁸
E. Kondratyuk¹³⁸ J. König⁶² S. A. Königstorfer⁹⁵ P. J. Konopka³² G. Kornakov¹³¹ S. D. Koryciak²
A. Kotliarov⁸⁵ O. Kovalenko⁷⁸ V. Kovalenko¹³⁸ M. Kowalski¹⁰⁵ I. Králik⁵⁸ A. Kravčáková³⁶ L. Kreis,⁹⁷
M. Krivda^{58,99} F. Krizek⁸⁵ K. Krizkova Gajdosova³⁵ M. Kroesen⁹⁴ M. Krüger⁶² D. M. Krupova³⁵
E. Kryshen¹³⁸ M. Krzewicki,³⁷ V. Kučera³² C. Kuhn¹²⁵ P. G. Kuijer⁸³ T. Kumaoka,¹²¹ D. Kumar,¹³⁰ L. Kumar⁸⁹
N. Kumar,⁸⁹ S. Kundu³² P. Kurashvili⁷⁸ A. Kurepin¹³⁸ A. B. Kurepin¹³⁸ A. Kuryakin¹³⁸ S. Kushpil⁸⁵
J. Kvapil⁹⁹ M. J. Kweon⁵⁶ J. Y. Kwon⁵⁶ Y. Kwon¹³⁶ S. L. La Pointe³⁷ P. La Rocca²⁶ Y. S. Lai,⁷³
A. Lakrathok,¹⁰³ M. Lamanna³² R. Langoy¹¹⁷ P. Larionov⁴⁷ E. Laudi³² L. Lautner^{32,95} R. Lavicka¹⁰¹
T. Lazareva¹³⁸ R. Lea^{53,129} J. Leibrach³⁷ R. C. Lemmon⁸⁴ I. León Monzón¹⁰⁷ M. M. Lesch⁹⁵ E. D. Lesser¹⁸
M. Lettrich,⁹⁵ P. Lévai¹³⁴ X. Li,¹⁰ X. L. Li,⁶ J. Lien¹¹⁷ R. Lietava⁹⁹ B. Lim¹⁶ S. H. Lim¹⁶ V. Lindenstruth³⁷
A. Lindner,⁴⁴ C. Lippmann⁹⁷ A. Liu¹⁸ D. H. Liu⁶ J. Liu¹¹⁵ I. M. Lofnes²⁰ V. Loginov,¹³⁸ C. Loizides⁸⁶
P. Loncar³³ J. A. Lopez⁹⁴ X. Lopez¹²³ E. López Torres⁷ P. Lu^{97,116} J. R. Lühder¹³³ M. Lunardon²⁷
G. Luparello⁵⁵ Y. G. Ma³⁸ A. Maevskaya,¹³⁸ M. Mager³² T. Mahmoud,⁴¹ A. Maire¹²⁵ M. Malaev¹³⁸
N. M. Malik⁹⁰ Q. W. Malik,¹⁹ S. K. Malik⁹⁰ L. Malinina^{139,g} D. Mal'Kevich¹³⁸ D. Mallick⁷⁹ N. Mallick⁴⁶
G. Mandaglio^{30,51} V. Manko¹³⁸ F. Manso¹²³ V. Manzari⁴⁸ Y. Mao⁶ G. V. Margagliotti²³ A. Margotti⁴⁹
A. Marín⁹⁷ C. Markert¹⁰⁶ M. Marquard,⁶² N. A. Martin,⁹⁴ P. Martinengo³² J. L. Martinez,¹¹² M. I. Martínez⁴³
G. Martínez García¹⁰² S. Masciocchi⁹⁷ M. Masera²⁴ A. Masoni⁵⁰ L. Massacrier⁷¹ A. Mastroserio^{48,127}
A. M. Mathis⁹⁵ O. Matonoha⁷⁴ P. F. T. Matuoka,¹⁰⁸ A. Matyja¹⁰⁵ C. Mayer¹⁰⁵ A. L. Mazuecos³²
F. Mazzaschi²⁴ M. Mazzilli³² J. E. Mdhuli¹¹⁹ A. F. Mechler,⁶² Y. Melikyan¹³⁸ A. Menchaca-Rocha⁶⁵
E. Meninno^{101,28} A. S. Menon¹¹² M. Meres¹² S. Mhlanga,^{66,111} Y. Miake,¹²¹ L. Micheletti⁵⁴ L. C. Migliorin,¹²⁴
D. L. Mihaylov⁹⁵ K. Mikhaylov^{138,139} A. N. Mishra¹³⁴ D. Miśkowiec⁹⁷ A. Modak⁴ A. P. Mohanty⁵⁷
B. Mohanty⁷⁹ M. Mohisin Khan^{15,e} M. A. Molander⁴² Z. Moravcova⁸² C. Mordasini⁹⁵
D. A. Moreira De Godoy¹³³ I. Morozov¹³⁸ A. Morsch³² T. Mrnjavac³² V. Muccifora⁴⁷ E. Mudnic,³³
S. Muhuri¹³⁰ J. D. Mulligan⁷³ A. Mulliri,²² M. G. Munhoz¹⁰⁸ R. H. Munzer⁶² H. Murakami¹²⁰ S. Murray¹¹¹
L. Musa³² J. Musinsky⁵⁸ J. W. Myrcha¹³¹ B. Naik¹¹⁹ R. Nair⁷⁸ B. K. Nandi⁴⁵ R. Nania⁴⁹ E. Nappi⁴⁸
A. F. Nassirpour⁷⁴ A. Nath⁹⁴ C. Nattrass¹¹⁸ T. K. Nayak⁷⁹ A. Neagu,¹⁹ A. Negro,¹²² L. Nellen⁶³ S. V. Nesbo,³⁴

G. Neskovic³⁷ D. Nesterov¹³⁸ B. S. Nielsen⁸² E. G. Nielsen⁸² S. Nikolaev¹³⁸ S. Nikulin¹³⁸ V. Nikulin¹³⁸
 F. Noferini⁴⁹ S. Noh¹¹ P. Nomokonov¹³⁹ J. Norman¹¹⁵ N. Novitzky¹²¹ P. Nowakowski¹³¹ A. Nyanin¹³⁸
 J. Nystrand²⁰ M. Ogino⁷⁵ A. Ohlson⁷⁴ V. A. Okorokov¹³⁸ J. Oleniacz¹³¹ A. C. Oliveira Da Silva¹¹⁸
 M. H. Oliver¹³⁵ A. Onnerstad¹¹³ C. Oppedisano⁵⁴ A. Ortiz Velasquez⁶³ A. Oskarsson⁷⁴ J. Otwinowski¹⁰⁵
 M. Oya⁹² K. Oyama⁷⁵ Y. Pachmayer⁹⁴ S. Padhan⁴⁵ D. Pagano^{53,129} G. Paic⁶³ A. Palasciano⁴⁸
 S. Panebianco¹²⁶ J. Park⁵⁶ J. E. Parkkila^{32,113} S. P. Pathak¹¹² R. N. Patra⁹⁰ B. Paul²² H. Pei⁶ T. Peitzmann⁵⁷
 X. Peng⁶ L. G. Pereira⁶⁴ H. Pereira Da Costa¹²⁶ D. Peresunko¹³⁸ G. M. Perez⁷ S. Perrin¹²⁶ Y. Pestov¹³⁸
 V. Petráček³⁵ V. Petrov¹³⁸ M. Petrovici⁴⁴ R. P. Pezzi⁶⁴ S. Piano⁵⁵ M. Pikna¹² P. Pillot¹⁰² O. Pinazza^{32,49}
 L. Pinsky¹¹² C. Pinto^{95,26} S. Pisano⁴⁷ M. Płoskoń⁷³ M. Planinic⁸⁸ F. Pliquett⁶² M. G. Poghosyan⁸⁶
 B. Polichtchouk¹³⁸ S. Politano²⁹ N. Poljak⁸⁸ A. Pop⁴⁴ S. Porteboeuf-Houssais¹²³ J. Porter⁷³
 V. Pozdniakov¹³⁹ S. K. Prasad⁴ S. Prasad⁴⁶ R. Preghenella⁴⁹ F. Prino⁵⁴ C. A. Pruneau¹³² I. Pshenichnov¹³⁸
 M. Puccio³² S. Qiu⁸³ L. Quaglia²⁴ R. E. Quishpe¹¹² S. Ragoni⁹⁹ A. Rakotozafindrabe¹²⁶ L. Ramello^{54,128}
 F. Rami¹²⁵ S. A. R. Ramirez⁴³ T. A. Rancien⁷² R. Raniwala⁹¹ S. Raniwala⁹¹ S. S. Räsänen⁴² R. Rath⁴⁶
 I. Ravasenga⁸³ K. F. Read^{86,118} A. R. Redelbach³⁷ K. Redlich^{78,f} A. Rehman²⁰ P. Reichelt⁶² F. Reidt³²
 H. A. Reme-Ness³⁴ Z. Rescakova³⁶ K. Reygers⁹⁴ A. Riabov¹³⁸ V. Riabov¹³⁸ R. Ricci²⁸ T. Richert⁷⁴
 M. Richter¹⁹ W. Riegler³² F. Riggi²⁶ C. Ristea⁶¹ M. Rodríguez Cahuantzi⁴³ K. Røed¹⁹ R. Rogalev¹³⁸
 E. Rogochaya¹³⁹ T. S. Rogoschinski⁶² D. Rohr³² D. Röhrich²⁰ P. F. Rojas⁴³ S. Rojas Torres³⁵ P. S. Rokita¹³¹
 F. Ronchetti⁴⁷ A. Rosano^{30,51} E. D. Rosas⁶³ A. Rossi⁵² A. Roy⁴⁶ P. Roy⁹⁸ S. Roy⁴⁵ N. Rubini²⁵
 O. V. Rueda⁷⁴ D. Ruggiano¹³¹ R. Rui²³ B. Rumyantsev¹³⁹ P. G. Russek² R. Russo⁸³ A. Rustamov⁸⁰
 E. Ryabinkin¹³⁸ Y. Ryabov¹³⁸ A. Rybicki¹⁰⁵ H. Rytönen¹¹³ W. Rzesza¹³¹ O. A. M. Saarimäki⁴² R. Sadek¹⁰²
 S. Sadovsky¹³⁸ J. Saetre²⁰ K. Šafařík³⁵ S. K. Saha¹³⁰ S. Saha⁷⁹ B. Sahoo⁴⁵ P. Sahoo⁴⁵ R. Sahoo⁴⁶
 S. Sahoo⁵⁹ D. Sahu⁴⁶ P. K. Sahu⁵⁹ J. Saini¹³⁰ S. Sakai¹²¹ M. P. Salvan⁹⁷ S. Sambyal⁹⁰ T. B. Saramela¹⁰⁸
 D. Sarkar¹³² N. Sarkar¹³⁰ P. Sarma⁴⁰ V. M. Sarti⁹⁵ M. H. P. Sas¹³⁵ J. Schambach⁸⁶ H. S. Scheid⁶²
 C. Schiaua⁴⁴ R. Schicker⁹⁴ A. Schmah⁹⁴ C. Schmidt⁹⁷ H. R. Schmidt⁹³ M. O. Schmidt³² M. Schmidt⁹³
 N. V. Schmidt^{62,86} A. R. Schmier¹¹⁸ R. Schotter¹²⁵ J. Schukraft³² K. Schwarz⁹⁷ K. Schweda⁹⁷ G. Scioli²⁵
 E. Scomparin⁵⁴ J. E. Seger¹⁴ Y. Sekiguchi¹²⁰ D. Sekihata¹²⁰ I. Selyuzhenkov^{97,138} S. Senyukov¹²⁵ J. J. Seo⁵⁶
 D. Serebryakov¹³⁸ L. Šerkšnytė⁹⁵ A. Sevcenco⁶¹ T. J. Shaba⁶⁶ A. Shabanov¹³⁸ A. Shabetai¹⁰² R. Shahoyan³²
 W. Shaikh⁹⁸ A. Shangaraev¹³⁸ A. Sharma⁸⁹ D. Sharma⁴⁵ H. Sharma¹⁰⁵ M. Sharma⁹⁰ N. Sharma⁸⁹ S. Sharma⁹⁰
 U. Sharma⁹⁰ A. Shatat⁷¹ O. Sheibani¹¹² K. Shigaki⁹² M. Shimomura⁷⁶ S. Shirinkin¹³⁸ Q. Shou³⁸
 Y. Sibiriak¹³⁸ S. Siddhanta⁵⁰ T. Siemiarczuk⁷⁸ T. F. Silva¹⁰⁸ D. Silvermyr⁷⁴ T. Simantathammakul¹⁰³
 G. Simonetti³² B. Singh⁹⁰ B. Singh⁹⁵ R. Singh⁷⁹ R. Singh⁹⁰ R. Singh⁴⁶ V. K. Singh¹³⁰ V. Singhal¹³⁰
 T. Sinha⁹⁸ B. Sitar¹² M. Sitta^{54,128} T. B. Skaali¹⁹ G. Skorodumovs⁹⁴ M. Słupecki⁴² N. Smirnov¹³⁵
 R. J. M. Snellings⁵⁷ E. H. Solheim¹⁹ C. Soncco¹⁰⁰ J. Song¹¹² A. Songmoolnak¹⁰³ F. Soramel²⁷ S. Sorensen¹¹⁸
 R. Spijkers⁸³ I. Sputowska¹⁰⁵ J. Staa⁷⁴ J. Stachel⁹⁴ I. Stan⁶¹ P. J. Steffanic¹¹⁸ S. F. Stiefelmaier⁹⁴
 D. Stocco¹⁰² I. Storehaug¹⁹ M. M. Storetvedt³⁴ P. Stratmann¹³³ S. Strazzi²⁵ C. P. Stylianidis⁸³
 A. A. P. Suaide¹⁰⁸ C. Suire⁷¹ M. Sukhanov¹³⁸ M. Suljic³² V. Sumberia⁹⁰ S. Sumowidagdo⁸¹ S. Swain⁵⁹
 A. Szabo¹² I. Szarka¹² U. Tabassam¹³ S. F. Taghavi⁹⁵ G. Taillepieid^{97,123} J. Takahashi¹⁰⁹ G. J. Tambave²⁰
 S. Tang^{6,123} Z. Tang¹¹⁶ J. D. Tapia Takaki¹¹⁴ N. Tapus¹²² L. A. Tarasovicova¹³³ M. G. Tazila⁴⁴ A. Tauro³²
 G. Tejada Muñoz⁴³ A. Telesca³² L. Terlizzi²⁴ C. Terrevoli¹¹² G. Tersimonov³ S. Thakur¹³⁰ D. Thomas¹⁰⁶
 R. Tieulent¹²⁴ A. Tikhonov¹³⁸ A. R. Timmins¹¹² M. Tkacik¹⁰⁴ T. Tkacik¹⁰⁴ A. Toia⁶² N. Topilskaya¹³⁸
 M. Toppi⁴⁷ F. Torales-Acosta¹⁸ T. Tork⁷¹ A. G. Torres Ramos³¹ A. Trifiró^{30,51} A. S. Triolo^{30,51} S. Tripathy⁴⁹
 T. Tripathy⁴⁵ S. Trogolo³² V. Trubnikov³ W. H. Trzaska¹¹³ T. P. Trzcinski¹³¹ A. Tumkin¹³⁸ R. Turrisi⁵²
 T. S. Tveter¹⁹ K. Ullaland²⁰ B. Ulukutlu⁹⁵ A. Uras¹²⁴ M. Urioni^{53,129} G. L. Usai²² M. Vala³⁶ N. Valle²¹
 S. Vallerio⁵⁴ L. V. R. van Doremalen⁵⁷ M. van Leeuwen⁸³ C. A. van Veen⁹⁴ R. J. G. van Weelden⁸³
 P. Vande Vyvre³² D. Varga¹³⁴ Z. Varga¹³⁴ M. Varga-Kofarago¹³⁴ M. Vasileiou⁷⁷ A. Vasiliev¹³⁸
 O. Vázquez Doce⁹⁵ V. Vechernin¹³⁸ E. Vercellin²⁴ S. Vergara Limón⁴³ L. Vermunt⁵⁷ R. Vértesi¹³⁴
 M. Verweij⁵⁷ L. Vickovic³³ Z. Vilakazi¹¹⁹ O. Villalobos Baillie⁹⁹ G. Vino⁴⁸ A. Vinogradov¹³⁸ T. Virgili²⁸
 V. Vislavicius⁸² A. Vodopyanov¹³⁹ B. Volkel³² M. A. Völkl⁹⁴ K. Voloshin¹³⁸ S. A. Voloshin¹³² G. Volpe³¹
 B. von Haller³² I. Vorobyev⁹⁵ N. Vozniuk¹³⁸ J. Vrláková³⁶ B. Wagner²⁰ C. Wang³⁸ D. Wang³⁸ M. Weber¹⁰¹

A. Wegrzynek¹⁹, F. T. Weiglhofer³⁷, S. C. Wenzel¹⁶, J. P. Wessels¹³³, S. L. Weyhmiller¹³⁵, J. Wiechula⁶², J. Wikne¹⁹, G. Wilk⁷⁸, J. Wilkinson⁹⁷, G. A. Willems¹³³, B. Windelband⁹⁴, M. Winn¹²⁶, J. R. Wright¹⁰⁶, W. Wu³⁸, Y. Wu¹¹⁶, R. Xu⁶, A. K. Yadav¹³⁰, S. Yalcin⁷⁰, Y. Yamaguchi⁹², K. Yamakawa⁹², S. Yang²⁰, S. Yano⁹², Z. Yin⁶, I.-K. Yoo¹⁶, J. H. Yoon⁵⁶, S. Yuan²⁰, A. Yuncu⁹⁴, V. Zaccolo²³, C. Zampolli³², H. J. C. Zanoli⁵⁷, F. Zanone⁹⁴, N. Zardoshti^{32,99}, A. Zarochentsev¹³⁸, P. Závada⁶⁰, N. Zaviyalov¹³⁸, M. Zhalov¹³⁸, B. Zhang⁶, S. Zhang³⁸, X. Zhang⁶, Y. Zhang¹¹⁶, M. Zhao¹⁰, V. Zhrebchevskii¹³⁸, Y. Zhi¹⁰, N. Zhigareva¹³⁸, D. Zhou⁶, Y. Zhou⁸², J. Zhu^{6,97}, Y. Zhu⁶, G. Zinovjev^{3,a} and N. Zurlo^{53,129}

(ALICE Collaboration)

- ¹A.I. Alikhanyan National Science Laboratory (Yerevan Physics Institute) Foundation, Yerevan, Armenia
²AGH University of Science and Technology, Cracow, Poland
³Bogolyubov Institute for Theoretical Physics, National Academy of Sciences of Ukraine, Kiev, Ukraine
⁴Bose Institute, Department of Physics and Centre for Astroparticle Physics and Space Science (CAPSS), Kolkata, India
⁵California Polytechnic State University, San Luis Obispo, California, USA
⁶Central China Normal University, Wuhan, China
⁷Centro de Aplicaciones Tecnológicas y Desarrollo Nuclear (CEADEN), Havana, Cuba
⁸Centro de Investigación y de Estudios Avanzados (CINVESTAV), Mexico City and Mérida, Mexico
⁹Chicago State University, Chicago, Illinois, USA
¹⁰China Institute of Atomic Energy, Beijing, China
¹¹Chungbuk National University, Cheongju, Republic of Korea
¹²Comenius University Bratislava, Faculty of Mathematics, Physics and Informatics, Bratislava, Slovak Republic
¹³COMSATS University Islamabad, Islamabad, Pakistan
¹⁴Creighton University, Omaha, Nebraska, USA
¹⁵Department of Physics, Aligarh Muslim University, Aligarh, India
¹⁶Department of Physics, Pusan National University, Pusan, Republic of Korea
¹⁷Department of Physics, Sejong University, Seoul, Republic of Korea
¹⁸Department of Physics, University of California, Berkeley, California, USA
¹⁹Department of Physics, University of Oslo, Oslo, Norway
²⁰Department of Physics and Technology, University of Bergen, Bergen, Norway
²¹Dipartimento di Fisica, Università di Pavia, Pavia, Italy
²²Dipartimento di Fisica dell'Università and Sezione INFN, Cagliari, Italy
²³Dipartimento di Fisica dell'Università and Sezione INFN, Trieste, Italy
²⁴Dipartimento di Fisica dell'Università and Sezione INFN, Turin, Italy
²⁵Dipartimento di Fisica e Astronomia dell'Università and Sezione INFN, Bologna, Italy
²⁶Dipartimento di Fisica e Astronomia dell'Università and Sezione INFN, Catania, Italy
²⁷Dipartimento di Fisica e Astronomia dell'Università and Sezione INFN, Padova, Italy
²⁸Dipartimento di Fisica 'E.R. Caianiello' dell'Università and Gruppo Collegato INFN, Salerno, Italy
²⁹Dipartimento DISAT del Politecnico and Sezione INFN, Turin, Italy
³⁰Dipartimento di Scienze MIFT, Università di Messina, Messina, Italy
³¹Dipartimento Interateneo di Fisica 'M. Merlin' and Sezione INFN, Bari, Italy
³²European Organization for Nuclear Research (CERN), Geneva, Switzerland
³³Faculty of Electrical Engineering, Mechanical Engineering and Naval Architecture, University of Split, Split, Croatia
³⁴Faculty of Engineering and Science, Western Norway University of Applied Sciences, Bergen, Norway
³⁵Faculty of Nuclear Sciences and Physical Engineering, Czech Technical University in Prague, Prague, Czech Republic
³⁶Faculty of Science, P.J. Šafárik University, Košice, Slovak Republic
³⁷Frankfurt Institute for Advanced Studies, Johann Wolfgang Goethe-Universität Frankfurt, Frankfurt, Germany
³⁸Fudan University, Shanghai, China
³⁹Gangneung-Wonju National University, Gangneung, Republic of Korea
⁴⁰Gauhati University, Department of Physics, Guwahati, India
⁴¹Helmholtz-Institut für Strahlen- und Kernphysik, Rheinische Friedrich-Wilhelms-Universität Bonn, Bonn, Germany
⁴²Helsinki Institute of Physics (HIP), Helsinki, Finland
⁴³High Energy Physics Group, Universidad Autónoma de Puebla, Puebla, Mexico
⁴⁴Horia Hulubei National Institute of Physics and Nuclear Engineering, Bucharest, Romania
⁴⁵Indian Institute of Technology Bombay (IIT), Mumbai, India
⁴⁶Indian Institute of Technology Indore, Indore, India
⁴⁷INFN, Laboratori Nazionali di Frascati, Frascati, Italy

- ⁴⁸INFN, Sezione di Bari, Bari, Italy
- ⁴⁹INFN, Sezione di Bologna, Bologna, Italy
- ⁵⁰INFN, Sezione di Cagliari, Cagliari, Italy
- ⁵¹INFN, Sezione di Catania, Catania, Italy
- ⁵²INFN, Sezione di Padova, Padova, Italy
- ⁵³INFN, Sezione di Pavia, Pavia, Italy
- ⁵⁴INFN, Sezione di Torino, Turin, Italy
- ⁵⁵INFN, Sezione di Trieste, Trieste, Italy
- ⁵⁶Inha University, Incheon, Republic of Korea
- ⁵⁷Institute for Gravitational and Subatomic Physics (GRASP), Utrecht University/Nikhef, Utrecht, Netherlands
- ⁵⁸Institute of Experimental Physics, Slovak Academy of Sciences, Košice, Slovak Republic
- ⁵⁹Institute of Physics, Homi Bhabha National Institute, Bhubaneswar, India
- ⁶⁰Institute of Physics of the Czech Academy of Sciences, Prague, Czech Republic
- ⁶¹Institute of Space Science (ISS), Bucharest, Romania
- ⁶²Institut für Kernphysik, Johann Wolfgang Goethe-Universität Frankfurt, Frankfurt, Germany
- ⁶³Instituto de Ciencias Nucleares, Universidad Nacional Autónoma de México, Mexico City, Mexico
- ⁶⁴Instituto de Física, Universidade Federal do Rio Grande do Sul (UFRGS), Porto Alegre, Brazil
- ⁶⁵Instituto de Física, Universidad Nacional Autónoma de México, Mexico City, Mexico
- ⁶⁶iThemba LABS, National Research Foundation, Somerset West, South Africa
- ⁶⁷Jeonbuk National University, Jeonju, Republic of Korea
- ⁶⁸Johann-Wolfgang-Goethe Universität Frankfurt Institut für Informatik, Fachbereich Informatik und Mathematik, Frankfurt, Germany
- ⁶⁹Korea Institute of Science and Technology Information, Daejeon, Republic of Korea
- ⁷⁰KTO Karatay University, Konya, Turkey
- ⁷¹Laboratoire de Physique des 2 Infinis, Irène Joliot-Curie, Orsay, France
- ⁷²Laboratoire de Physique Subatomique et de Cosmologie, Université Grenoble-Alpes, CNRS-IN2P3, Grenoble, France
- ⁷³Lawrence Berkeley National Laboratory, Berkeley, California, USA
- ⁷⁴Lund University Department of Physics, Division of Particle Physics, Lund, Sweden
- ⁷⁵Nagasaki Institute of Applied Science, Nagasaki, Japan
- ⁷⁶Nara Women's University (NWU), Nara, Japan
- ⁷⁷National and Kapodistrian University of Athens, School of Science, Department of Physics, Athens, Greece
- ⁷⁸National Centre for Nuclear Research, Warsaw, Poland
- ⁷⁹National Institute of Science Education and Research, Homi Bhabha National Institute, Jatni, India
- ⁸⁰National Nuclear Research Center, Baku, Azerbaijan
- ⁸¹National Research and Innovation Agency - BRIN, Jakarta, Indonesia
- ⁸²Niels Bohr Institute, University of Copenhagen, Copenhagen, Denmark
- ⁸³Nikhef, National institute for subatomic physics, Amsterdam, Netherlands
- ⁸⁴Nuclear Physics Group, STFC Daresbury Laboratory, Daresbury, United Kingdom
- ⁸⁵Nuclear Physics Institute of the Czech Academy of Sciences, Husinec-Řež, Czech Republic
- ⁸⁶Oak Ridge National Laboratory, Oak Ridge, Tennessee, USA
- ⁸⁷Ohio State University, Columbus, Ohio, USA
- ⁸⁸Physics department, Faculty of science, University of Zagreb, Zagreb, Croatia
- ⁸⁹Physics Department, Panjab University, Chandigarh, India
- ⁹⁰Physics Department, University of Jammu, Jammu, India
- ⁹¹Physics Department, University of Rajasthan, Jaipur, India
- ⁹²Physics Program and International Institute for Sustainability with Knotted Chiral Meta Matter (SKCM2), Hiroshima University, Hiroshima, Japan
- ⁹³Physikalisches Institut, Eberhard-Karls-Universität Tübingen, Tübingen, Germany
- ⁹⁴Physikalisches Institut, Ruprecht-Karls-Universität Heidelberg, Heidelberg, Germany
- ⁹⁵Physik Department, Technische Universität München, Munich, Germany
- ⁹⁶Politecnico di Bari and Sezione INFN, Bari, Italy
- ⁹⁷Research Division and ExtreMe Matter Institute EMMI, GSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt, Germany
- ⁹⁸Saha Institute of Nuclear Physics, Homi Bhabha National Institute, Kolkata, India
- ⁹⁹School of Physics and Astronomy, University of Birmingham, Birmingham, United Kingdom
- ¹⁰⁰Sección Física, Departamento de Ciencias, Pontificia Universidad Católica del Perú, Lima, Peru
- ¹⁰¹Stefan Meyer Institut für Subatomare Physik (SMI), Vienna, Austria
- ¹⁰²SUBATECH, IMT Atlantique, Nantes Université, CNRS-IN2P3, Nantes, France
- ¹⁰³Suranaree University of Technology, Nakhon Ratchasima, Thailand
- ¹⁰⁴Technical University of Košice, Košice, Slovak Republic
- ¹⁰⁵The Henryk Niewodniczanski Institute of Nuclear Physics, Polish Academy of Sciences, Cracow, Poland

- ¹⁰⁶*The University of Texas at Austin, Austin, Texas, USA*
¹⁰⁷*Universidad Autónoma de Sinaloa, Culiacan, Mexico*
¹⁰⁸*Universidade de São Paulo (USP), Sao Paulo, Brazil*
¹⁰⁹*Universidade Estadual de Campinas (UNICAMP), Campinas, Brazil*
¹¹⁰*Universidade Federal do ABC, Santo Andre, Brazil*
¹¹¹*University of Cape Town, Cape Town, South Africa*
¹¹²*University of Houston, Houston, Texas, USA*
¹¹³*University of Jyväskylä, Jyväskylä, Finland*
¹¹⁴*University of Kansas, Lawrence, Kansas, USA*
¹¹⁵*University of Liverpool, Liverpool, United Kingdom*
¹¹⁶*University of Science and Technology of China, Hefei, China*
¹¹⁷*University of South-Eastern Norway, Kongsberg, Norway*
¹¹⁸*University of Tennessee, Knoxville, Tennessee, USA*
¹¹⁹*University of the Witwatersrand, Johannesburg, South Africa*
¹²⁰*University of Tokyo, Tokyo, Japan*
¹²¹*University of Tsukuba, Tsukuba, Japan*
¹²²*University Politehnica of Bucharest, Bucharest, Roma*
¹²³*Université Clermont Auvergne, CNRS/IN2P3, LPC, Clermont-Ferrand, France*
¹²⁴*Université de Lyon, CNRS/IN2P3, Institut de Physique des 2 Infinis de Lyon, Lyon, France*
¹²⁵*Université de Strasbourg, CNRS, IPHC UMR 7178, F-67000 Strasbourg, France*
¹²⁶*Université Paris-Saclay Centre d'Etudes de Saclay (CEA), IRFU, Département de Physique Nucléaire (DPnN), Saclay, France*
¹²⁷*Università degli Studi di Foggia, Foggia, Italy*
¹²⁸*Università del Piemonte Orientale, Vercelli, Italy*
¹²⁹*Università di Brescia, Brescia, Italy*
¹³⁰*Variable Energy Cyclotron Centre, Homi Bhabha National Institute, Kolkata, India*
¹³¹*Warsaw University of Technology, Warsaw, Poland*
¹³²*Wayne State University, Detroit, Michigan, USA*
¹³³*Westfälische Wilhelms-Universität Münster, Institut für Kernphysik, Münster, Germany*
¹³⁴*Wigner Research Centre for Physics, Budapest, Hungary*
¹³⁵*Yale University, New Haven, Connecticut, USA*
¹³⁶*Yonsei University, Seoul, Republic of Korea*
¹³⁷*Zentrum für Technologie und Transfer (ZTT), Worms, Germany*
¹³⁸*Affiliated with an institute covered by a cooperation agreement with CERN*
¹³⁹*Affiliated with an international laboratory covered by a cooperation agreement with CERN*

^aDeceased.

^bAlso at Max-Planck-Institut für Physik, Munich, Germany.

^cAlso at Italian National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA), Bologna, Italy.

^dAlso at Dipartimento DET del Politecnico di Torino, Turin, Italy.

^eAlso at Department of Applied Physics, Aligarh Muslim University, Aligarh, India.

^fAlso at Institute of Theoretical Physics, University of Wrocław, Poland.

^gAlso at An institution covered by a cooperation agreement with CERN.