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Supplemental figures: “Search for a common baryon source in high-multiplicity pp collisions at the LHC”

The ALICE Collaboration*

Abstract

Femtoscopy studies make use of momentum correlations between pairs of particles to access the properties of particle emission (source function) and interaction (wave function). Small collision systems, such as pp, result in very small ($\sim$ 1 fm) source sizes, leading to a strong correlation signal due to the interaction. To study the latter, the emission source has been extensively investigated by ALICE, concluding that a common baryon emission source is present in high-multiplicity pp collisions at $\sqrt{s} = 13$ TeV. This observation is based on measurement of p–p and p–Λ correlations. Further, a strong dependence of the source size on the transverse mass (m_{T}) of the particles has been observed. The current work shows the measured p–p (p–Λ) correlation functions in all 7 (6) m_{T} bins, as well as the corresponding mixed-event (phase space) distributions of the measured pairs. Further, the experimental momentum resolution matrices are provided for both systems.

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*See Appendix 4 for the list of collaboration members

1 Introduction

Femtoscopy is a method to use two-particle momentum correlations to access the properties of the strong interaction. The relevant observable is the single particle momentum evaluated in the pair rest frame (k^*). In small collision systems the correlation functions exhibit a strong femtoscopic signal in the range $k^* < 200$ MeV$/c$. Experimentally, the correlation function is measured by pairing particles from same-events and building their corresponding relative momentum (k^*) distribution $N(k^*)$, and dividing it by a correlation free reference sample, constructed from pairing particles stemming from different (mixed) events. The distribution of the latter is denoted as $M(k^*)$. The asterisk denotes the rest momentum frame of the pair. The Koonin-Pratt relation

$$C(k^*) = \frac{N(k^*)}{M(k^*)} = 1 + \int S(r^*) \left[\left| \Psi(\vec{k}^*, \vec{r}^*) \right|^2 - 1 \right] \mathrm{d}^3 r^* \tag{1}$$

connects the measured distributions to the effective two-particle emission source function $S(r^*)$ and the two-particle wave function $\Psi(\vec{k}^*, \vec{r}^*)$, where r^* denotes the relative distance between the particles [1].

The ALICE collaboration measured p–p and p–Λ correlations in high-multiplicity (HM) pp collisions at $\sqrt{s} = 13$ TeV as a benchmark to study the baryon–baryon emission source function [2]. This is possible as the pp interaction is modeled with high precision using the Argonne V18 potential [3], while the existing pΛ scattering data can be successfully described using chiral effective field theory (χEFT) [4, 5]. The published ALICE results on p–p and p–Λ correlations demonstrate that the emission sources in both systems are similar and show a scaling as a function of the transverse mass m_{T} [2]. The proper treatment of particle production through short lived (strongly decaying) resonances leads to a direct access of the primordial (core) source, which is identical for both p–p and p–Λ.

The momentum resolution effects are required to transform the "true" correlation function $C_{\mathrm{true}}(k^*_{\mathrm{true}})$ into the measured $C(k^*)$ using the relation

$$C(k^*) = \int_0^\infty P(k^*, k^*_{\mathrm{true}}) \cdot C_{\mathrm{true}}(k^*_{\mathrm{true}}) \mathrm{d}k^*_{\mathrm{true}}, \tag{2}$$

where $P(k^*, k^*_{\mathrm{true}})$ is the probability that a pair of measured relative momentum k^* had a true value of k^*_{true} [6]. This relation is only approximate, as the resolution matrix has to be applied to the same- and mixed-event samples separately, using

$$C(k^*) = \frac{\int_0^\infty P(k^*, k^*_{\mathrm{true}}) \cdot N_{\mathrm{true}}(k^*_{\mathrm{true}}) \mathrm{d}k^*_{\mathrm{true}}}{\int_0^\infty P(k^*, k^*_{\mathrm{true}}) \cdot M_{\mathrm{true}}(k^*_{\mathrm{true}}) \mathrm{d}k^*_{\mathrm{true}}}. \tag{3}$$

Substituting $C_{\mathrm{true}}(k^*_{\mathrm{true}}) = N_{\mathrm{true}}(k^*_{\mathrm{true}})/M_{\mathrm{true}}(k^*_{\mathrm{true}})$ and assuming $M_{\mathrm{true}}(k^*_{\mathrm{true}}) \approx M(k^*_{\mathrm{true}})$, Eq. 3 transforms to

$$C(k^*) = \int_0^\infty P(k^*, k^*_{\mathrm{true}}) \cdot \frac{M(k^*_{\mathrm{true}})}{M(k^*)} \cdot C_{\mathrm{true}}(k^*_{\mathrm{true}}) \mathrm{d}k^*_{\mathrm{true}}. \tag{4}$$

The ALICE collaboration recommends using Eq. 4 to include momentum resolution effects in order to make comparissons to models with predicted correlation $C_{\mathrm{true}}(k^*_{\mathrm{true}})$.

2 Results

In this section the ALICE measurements of the correlation functions used in the aforementioned m_{T} differential analysis [2] are presented (Figs. 1, 4). These are uncorrected correlations, implying that they contain momentum resolution effects, feed-down contributions from weakly decaying particles and impurities. The details on accounting for these effects, as well as other relevant information on the methodology of modelling the data, are described in [2, 7]. The correlation functions have been normalized by rescaling the mixed event distribution to match the integrated value of the same-events within the region $k^* \in [240, 340]$ MeV$/c$. For an accurate comparison to models, both the momentum smearing functions (Figs. 3, 6) and mixed event distributions (Figs. 2, 5) are required. The former have been obtained from a full scale Monte-Carlo simulation of ALICE, using Pythia 8.2 [8] as an event generator and GEANT3 [9] to simulate the detector response. Figures 3 and 6 show several projections of the p–p and p–Λ momentum smearing matrices, evaluated at $k^* =$10, 20, 50, 100, 200, 400 MeV$/c$. The shapes at intermediate values can be obtained through interpolation.

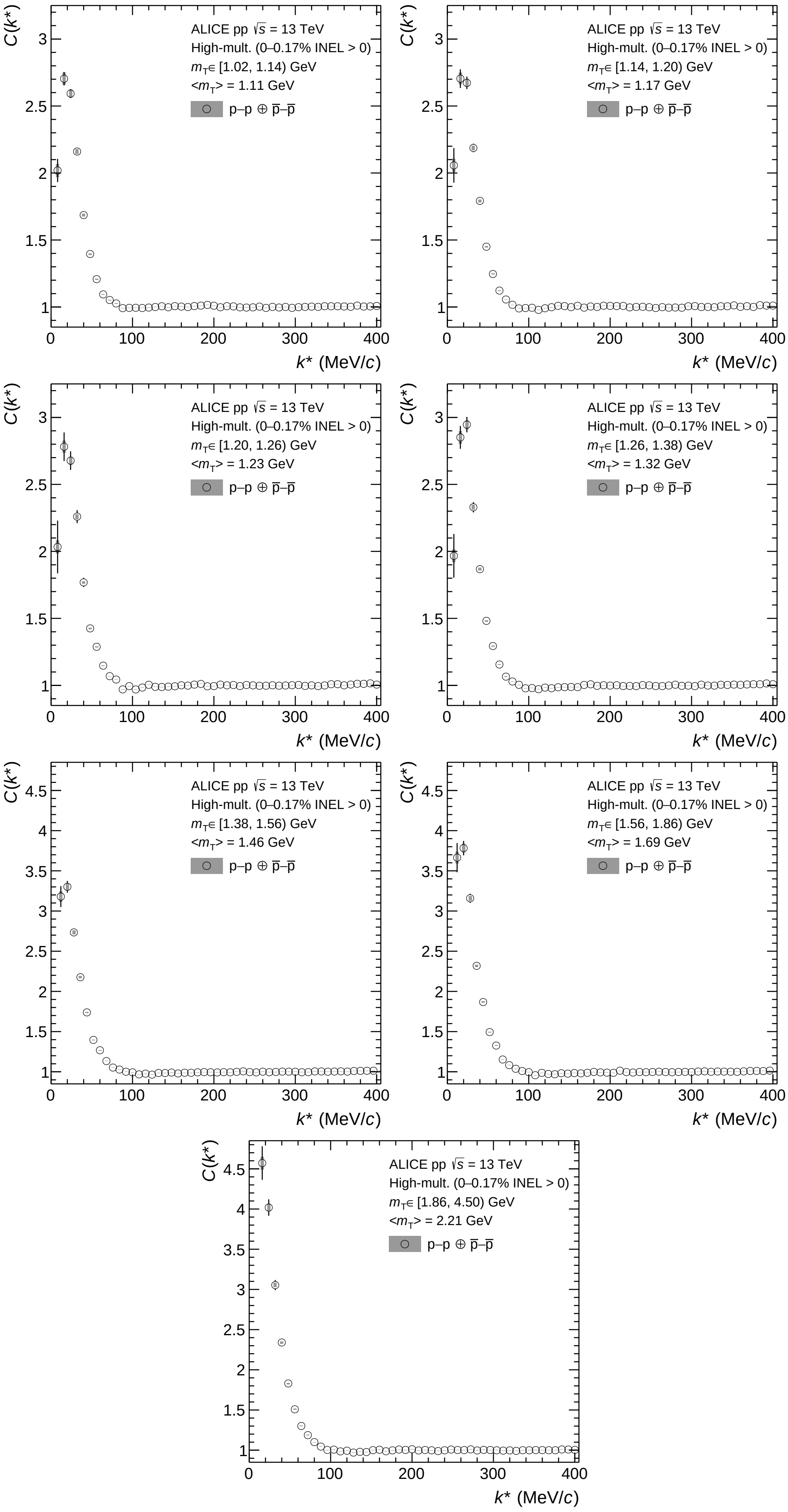

Figure 1: The p–p correlation functions measured by ALICE in pp collisions at $\sqrt{s}$ = 13 TeV in seven m_T differential bins. The vertical lines (grey boxes) correspond to the statistical (systematic) uncertainty.

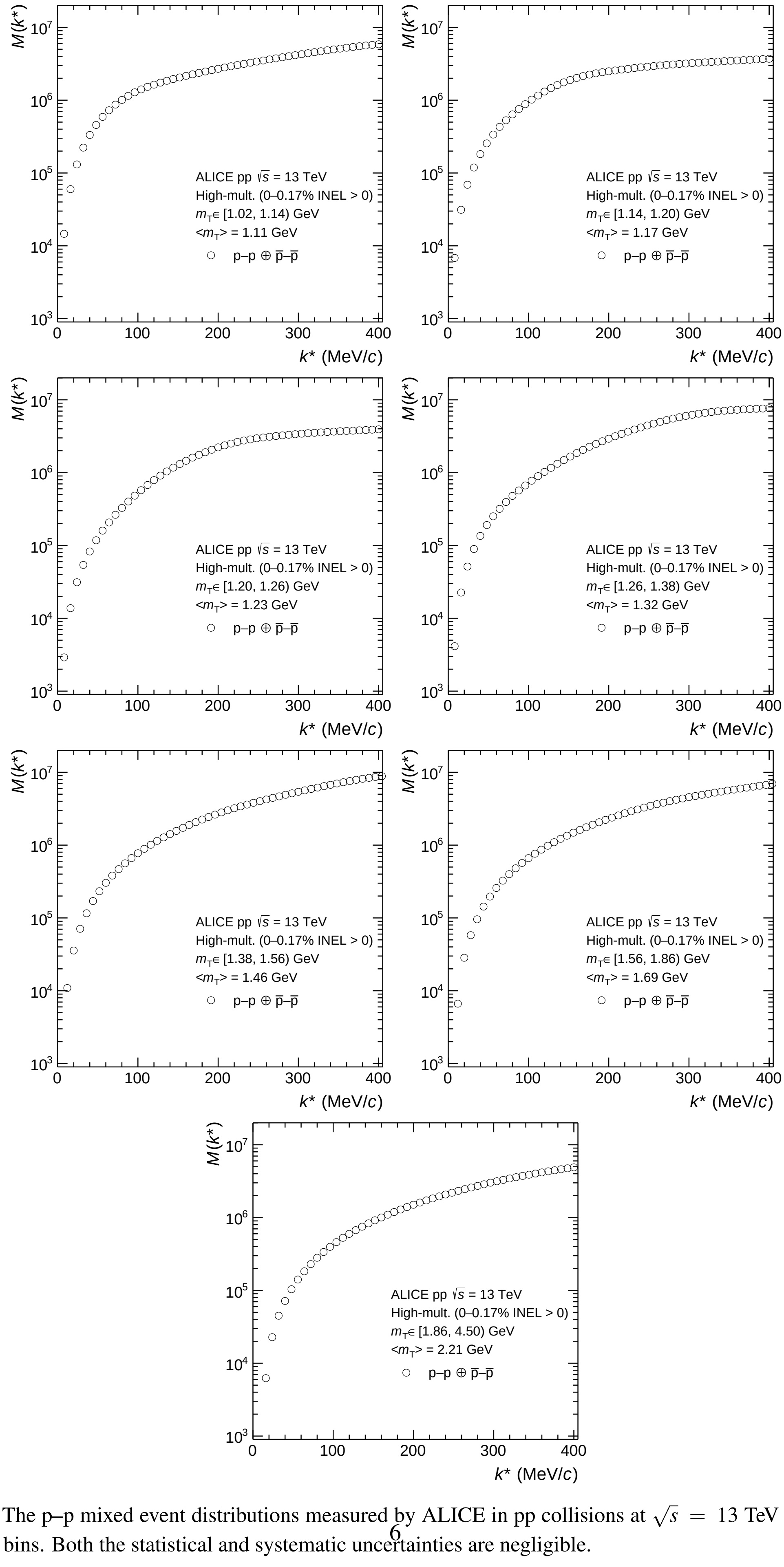

Figure 2: The p–p mixed event distributions measured by ALICE in pp collisions at $\sqrt{s}$ = 13 TeV in seven m_T differential bins. Both the statistical and systematic uncertainties are negligible.

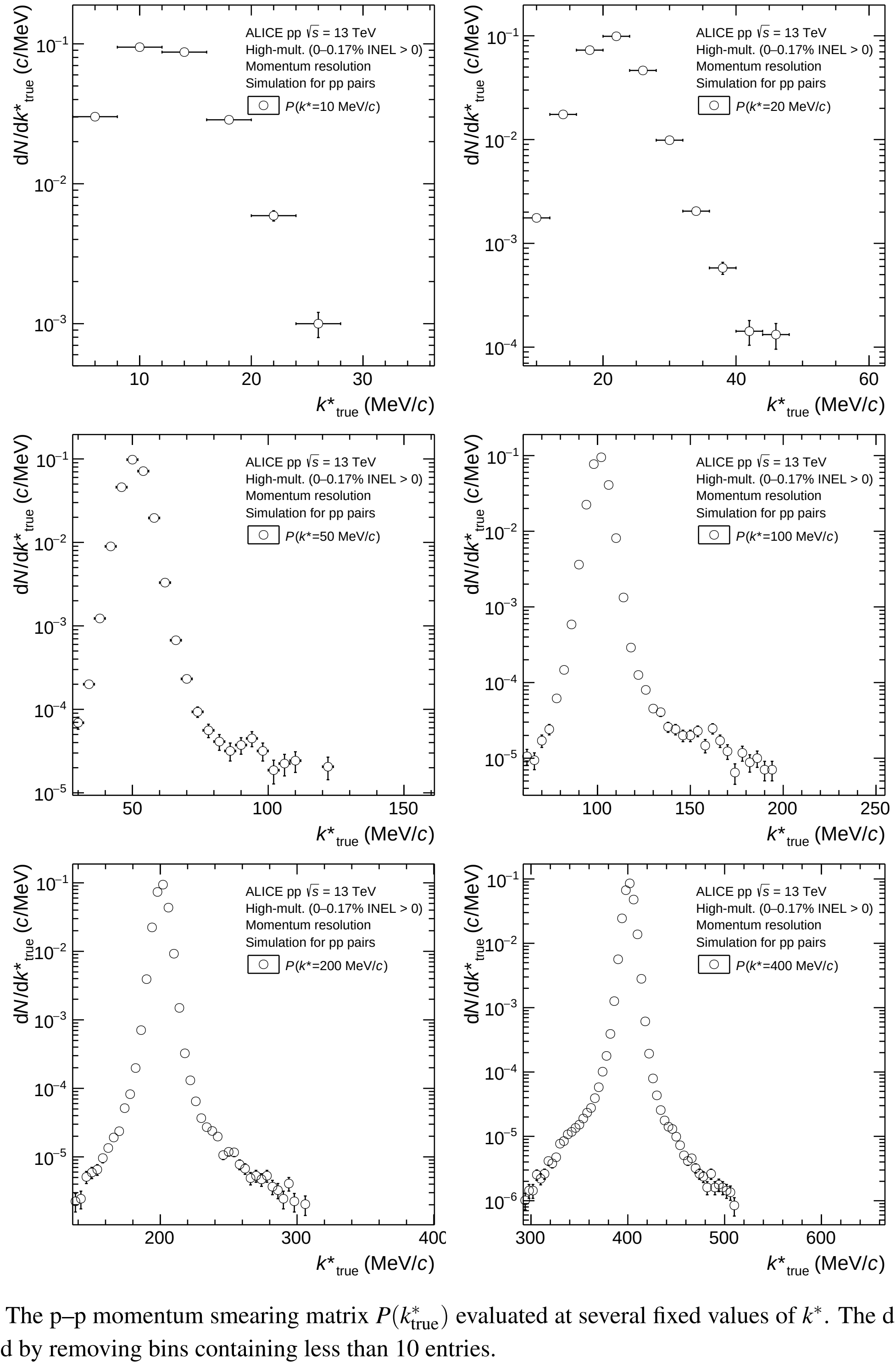

Figure 3: The p–p momentum smearing matrix $P(k^*_{\text{true}})$ evaluated at several fixed values of k^*. The distributions are trimmed by removing bins containing less than 10 entries.

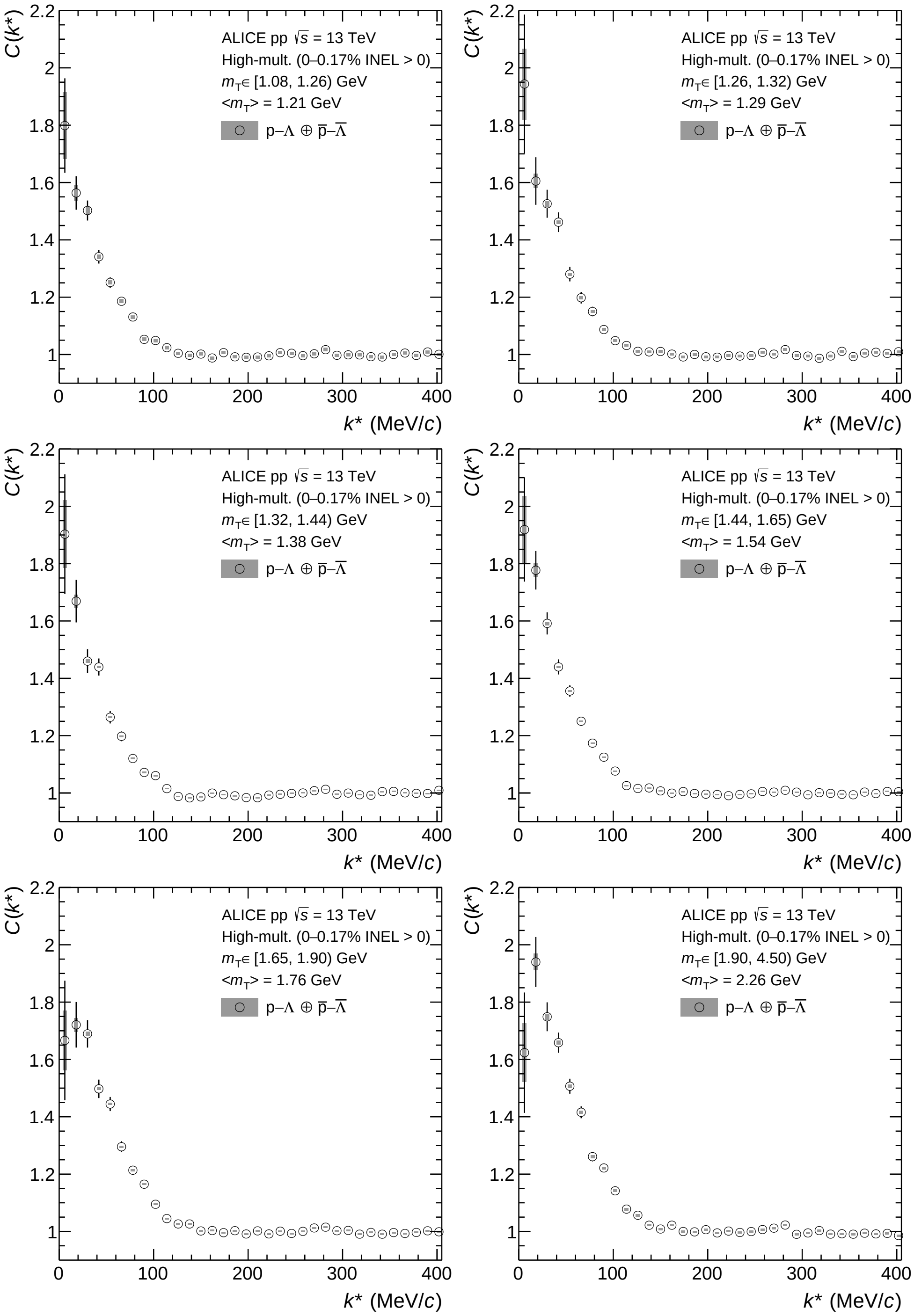

Figure 4: The p–Λ correlation functions measured by ALICE in pp collisions at $\sqrt{s}$ = 13 TeV in six m_T differential bins.

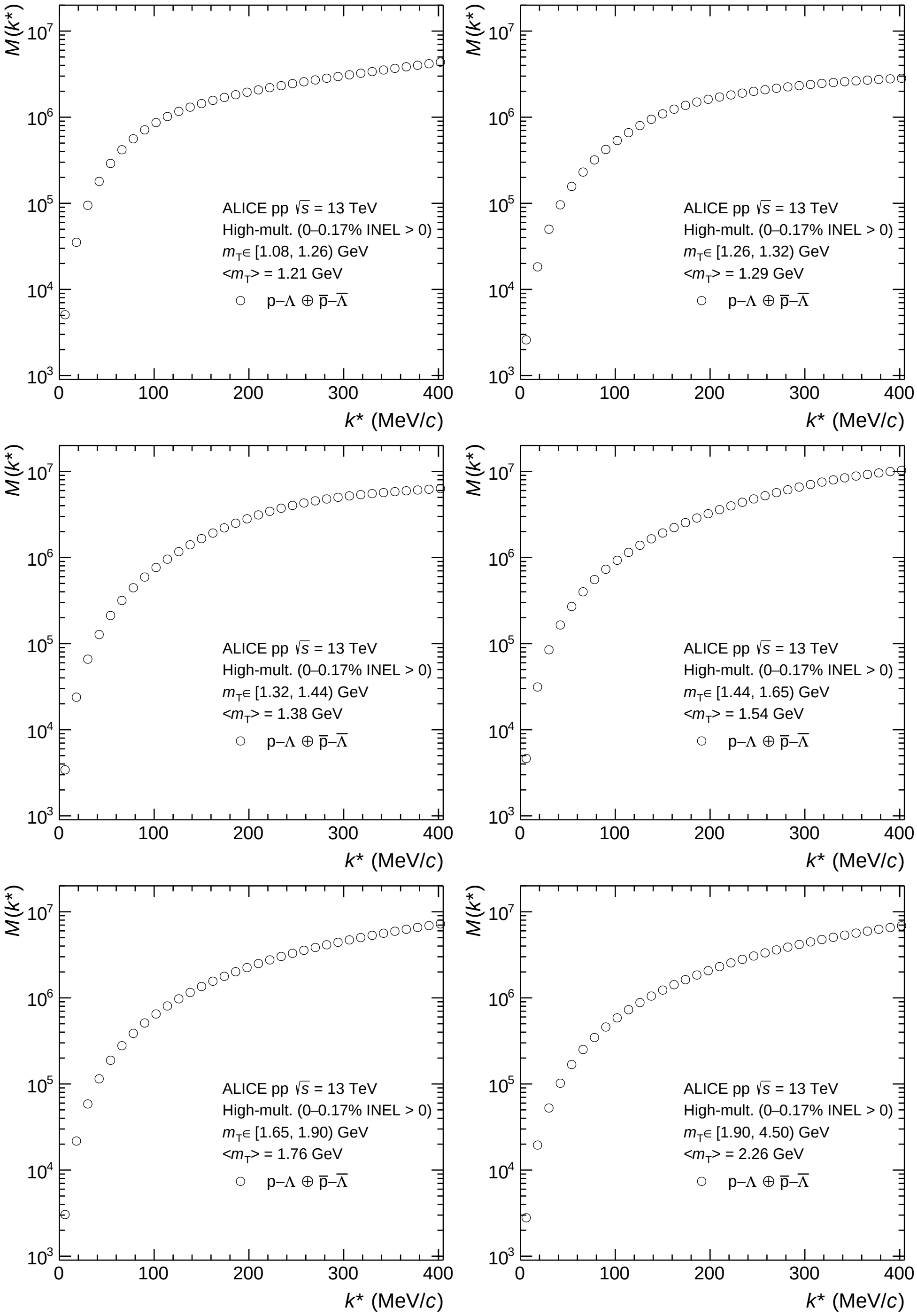

Figure 5: The p–Λ mixed event distributions measured by ALICE in pp collisions at $\sqrt{s}$ = 13 TeV in six m_T differential bins. Both the statistical and systematic uncertainties are negligible.

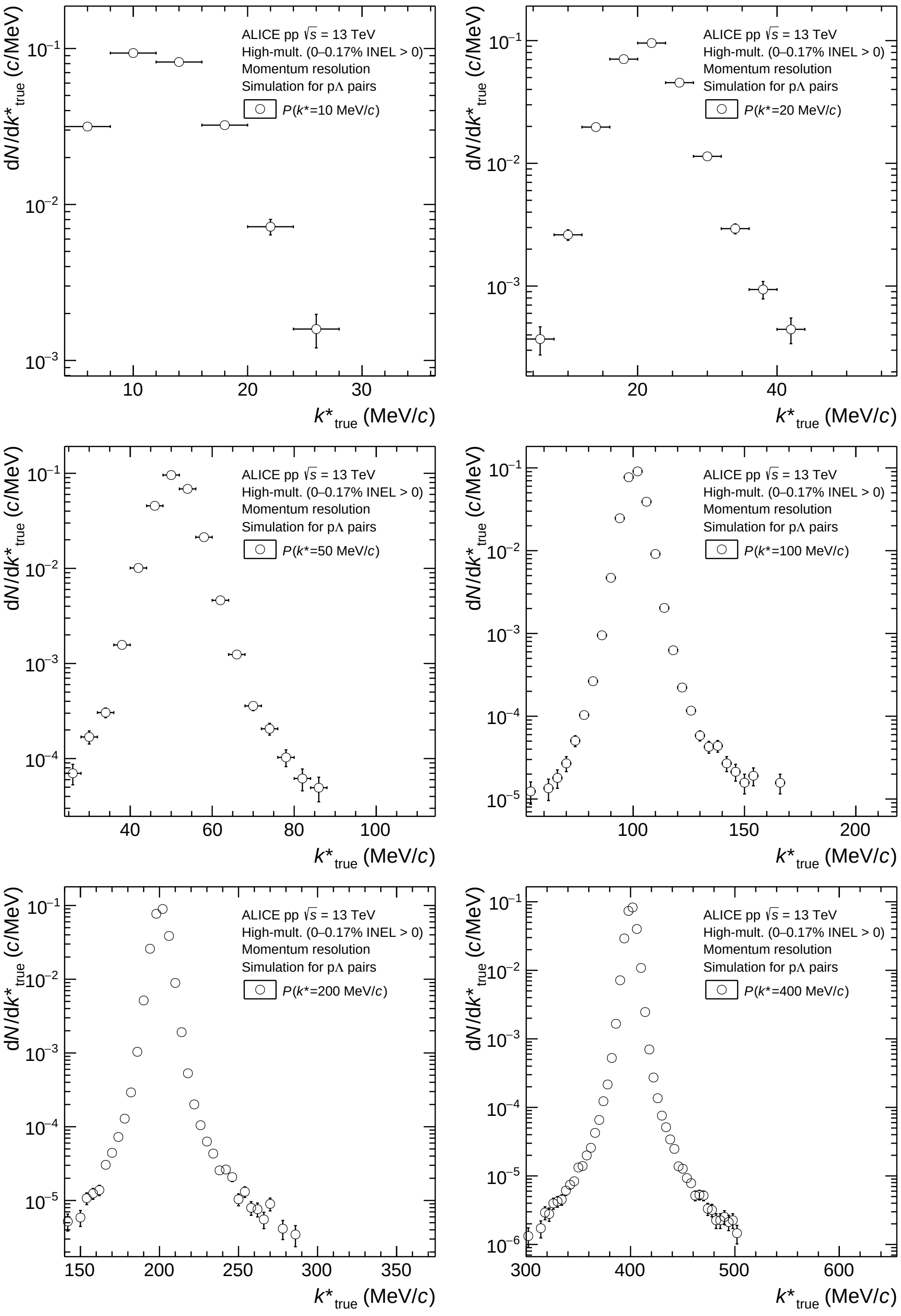

Figure 6: The p–Λ momentum smearing matrix $P(k^*_{\rm true})$ evaluated at several fixed values of k^*. The distributions are trimmed by removing bins containing less than 10 entries.

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4 The ALICE Collaboration

S. Acharya[141] , D. Adamová[95] , A. Adler[74] , J. Adolfsson[81] , M.M. Aggarwal[100] , G. Aglieri Rinella[34] , M. Agnello[30] , N. Agrawal[10,54] , Z. Ahammed[141] , S. Ahmad[16] , S.U. Ahn[76] , Z. Akbar[51] , A. Akindinov[92] , M. Al-Turany[107] , S.N. Alam[40,141] , D.S.D. Albuquerque[122] , D. Aleksandrov[88] , B. Alessandro[59] , H.M. Alfanda[6] , R. Alfaro Molina[71] , B. Ali[16] , Y. Ali[14] , A. Alici[10,26,54] , A. Alkin[2,34] , J. Alme[21] , T. Alt[68] , L. Altenkamper[21] , I. Altsybeev[113] , M.N. Anaam[6] , C. Andrei[48] , D. Andreou[34] , H.A. Andrews[111] , A. Andronic[144] , M. Angeletti[34] , V. Anguelov[104] , C. Anson[15] , T. Antičić[108] , F. Antinori[57] , P. Antonioli[54] , N. Apadula[80] , L. Aphecetche[115] , H. Appelshäuser[68] , S. Arcelli[26] , R. Arnaldi[59] , M. Arratia[80] , I.C. Arsene[20] , M. Arslandok[104] , A. Augustinus[34] , R. Averbeck[107] , S. Aziz[78] , M.D. Azmi[16] , A. Badalà[56] , Y.W. Baek[41] , S. Bagnasco[59] , X. Bai[107] , R. 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A. Kalweit[34] , V. Kaplin[93] , S. Kar[6] , A. Karasu Uysal[77] , O. Karavichev[62] , T. Karavicheva[62] , P. Karczmarczyk[34] ,
E. Karpechev[62] , U. Kebschull[74] , R. Keidel[47] , M. Keil[34] , B. Ketzer[43] , Z. Khabanova[90] , A.M. Khan[6] ,
S. Khan[16] , S.A. Khan[141] , A. Khanzadeev[98] , Y. Kharlov[91] , A. Khatun[16] , A. Khuntia[118] , B. Kileng[36] , B. Kim[61] ,
B. Kim[133] , D. Kim[147] , D.J. Kim[126] , E.J. Kim[73] , H. Kim[17] , J. Kim[147] , J.S. Kim[41] , J. Kim[104] , J. Kim[147] ,
J. Kim[73] , M. Kim[104] , S. Kim[18] , T. Kim[147] , T. Kim[147] , S. Kirsch[68] , I. Kisel[39] , S. Kiselev[92] , A. Kisiel[142] ,
J.L. Klay[5] , C. Klein[68] , J. Klein[34,59] , S. Klein[80] , C. Klein-Bösing[144] , M. Kleiner[68] , A. Kluge[34] ,
M.L. Knichel[34] , A.G. Knospe[125] , C. Kobdaj[116] , M.K. Köhler[104] , T. Kollegger[107] , A. Kondratyev[75] ,
N. Kondratyeva[93] , E. Kondratyuk[91] , J. Konig[68] , S.A. Konigstorfer[105] , P.J. Konopka[34] , G. Kornakov[142] ,
L. Koska[117] , O. Kovalenko[85] , V. Kovalenko[113] , M. Kowalski[118] , I. Králik[64] , A. Kravčáková[38] , L. Kreis[107] ,
M. Krivda[64,111] , F. Krizek[95] , K. Krizkova Gajdosova[37] , M. Krüger[68] , E. Kryshen[98] , M. Krzewicki[39] ,
A.M. Kubera[97] , V. Kučera[34,61] , C. Kuhn[136] , P.G. Kuijer[90] , L. Kumar[100] , S. Kundu[86] , P. Kurashvili[85] ,
A. Kurepin[62] , A.B. Kurepin[62] , A. Kuryakin[109] , S. Kushpil[95] , J. Kvapil[111] , M.J. Kweon[61] , J.Y. Kwon[61] ,
Y. Kwon[147] , S.L. La Pointe[39] , P. La Rocca[27] , Y.S. Lai[80] , R. Langoy[129] , K. Lapidus[34] , A. Lardeux[20] ,
P. Larionov[52] , E. Laudi[34] , R. Lavicka[37] , T. Lazareva[113] , R. Lea[24] , L. Leardini[104] , J. Lee[133] , S. Lee[147] ,
F. Lehas[90] , S. Lehner[114] , J. Lehrbach[39] , R.C. Lemmon[94] , I. León Monzón[120] , E.D. Lesser[19] , M. Lettrich[34] ,
P. Lévai[145] , X. Li[12] , X.L. Li[6] , J. Lien[129] , R. Lietava[111] , B. Lim[17] , V. Lindenstruth[39] , A. Lindner[48] ,
S.W. Lindsay[127] , C. Lippmann[107] , M.A. Lisa[97] , A. Liu[19] , J. Liu[127] , S. Liu[97] , W.J. Llope[143] , I.M. Lofnes[21] ,
V. Loginov[93] , C. Loizides[96] , P. Loncar[35] , J.A. Lopez[104] , X. Lopez[134] , E. López Torres[8] , J.R. Luhder[144] ,
M. Lunardon[28] , G. Luparello[60] , Y.G. Ma[40] , A. Maevskaya[62] , M. Mager[34] , S.M. Mahmood[20] , T. Mahmoud[43] ,
A. Maire[136] , R.D. Majka[146,i], M. Malaev[98] , Q.W. Malik[20] , L. Malinina[75,iv], D. Mal'Kevich[92] ,
P. Malzacher[107] , G. Mandaglio[32,56] , V. Manko[88] , F. Manso[134] , V. Manzari[53] , Y. Mao[6] , M. Marchisone[135] ,
J. Mareš[66] , G.V. Margagliotti[24] , A. Margotti[54] , J. Margutti[63] , A. Marín[107] , C. Markert[119] , M. Marquard[68] ,
C.D. Martin[24] , N.A. Martin[104] , P. Martinengo[34] , J.L. Martinez[125] , M.I. Martínez[45] , G. Martínez García[115] ,
S. Masciocchi[107] , M. Masera[25] , A. Masoni[55] , L. Massacrier[78] , E. Masson[115] , A. Mastroserio[53,138] ,
A.M. Mathis[105] , O. Matonoha[81] , P.F.T. Matuoka[121] , A. Matyja[118] , C. Mayer[118] , F. Mazzaschi[25] ,
M. Mazzilli[53] , M.A. Mazzoni[58] , A.F. Mechler[68] , F. Meddi[22] , Y. Melikyan[62,93] , A. Menchaca-Rocha[71] ,
C. Mengke[6] , E. Meninno[29,114] , M. Meres[13] , S. Mhlanga[124] , Y. Miake[133] , L. Micheletti[25] , L.C. Migliorin[135] ,
D.L. Mihaylov[105] , K. Mikhaylov[75,92] , A.N. Mishra[69] , D. Miśkowiec[107] , A. Modak[3] , N. Mohammadi[34] ,
A.P. Mohanty[63] , B. Mohanty[86] , M. Mohisin Khan[16,v], Z. Moravcova[89] , C. Mordasini[105] , D.A. Moreira De
Godoy[144] , L.A.P. Moreno[45] , I. Morozov[62] , A. Morsch[34] , T. Mrnjavac[34] , V. Muccifora[52] , E. Mudnic[35] ,
D. Mühlheim[144] , S. Muhuri[141] , J.D. Mulligan[80] , M.G. Munhoz[121] , R.H. Munzer[68] , H. Murakami[132] ,
S. Murray[124] , L. Musa[34] , J. Musinsky[64] , C.J. Myers[125] , J.W. Myrcha[142] , B. Naik[49] , R. Nair[85] , B.K. Nandi[49] ,
R. Nania[10,54] , E. Nappi[53] , M.U. Naru[14] , A.F. Nassirpour[81] , C. Nattrass[130] , R. Nayak[49] , T.K. Nayak[86] ,
S. Nazarenko[109] , A. Neagu[20] , R.A. Negrao De Oliveira[68] , L. Nellen[69] , S.V. Nesbo[36] , G. Neskovic[39] ,
D. Nesterov[113] , L.T. Neumann[142] , B.S. Nielsen[89] , S. Nikolaev[88] , S. Nikulin[88] , V. Nikulin[98] , F. Noferini[10,54] ,
P. Nomokonov[75] , J. Norman[79,127] , N. Novitzky[133] , P. Nowakowski[142] , A. Nyanin[88] , J. Nystrand[21] ,
M. Ogino[82] , A. Ohlson[81,104] , J. Oleniacz[142] , A.C. Oliveira Da Silva[130] , M.H. Oliver[146] , C. Oppedisano[59] ,
A. Ortiz Velasquez[69] , A. Oskarsson[81] , J. Otwinowski[118] , K. Oyama[82] , Y. Pachmayer[104] , V. Pacik[89] ,
D. Pagano[140] , G. Paić[69] , J. Pan[143] , S. Panebianco[137] , P. Pareek[50,141] , J. Park[61] , J.E. Parkkila[126] , S. Parmar[100] ,
S.P. Pathak[125] , B. Paul[23] , H. Pei[6] , T. Peitzmann[63] , X. Peng[6] , L.G. Pereira[70] , H. Pereira Da Costa[137] ,
D. Peresunko[88] , G.M. Perez[8] , Y. Pestov[4] , V. Petráček[37] , M. Petrovici[48] , R.P. Pezzi[70] , S. Piano[60] , M. Pikna[13] ,
P. Pillot[115] , O. Pinazza[34,54] , L. Pinsky[125] , C. Pinto[27] , S. Pisano[10,52] , D. Pistone[56] , M. Płoskoń[80] ,
M. Planinic[99] , F. Pliquett[68] , M.G. Poghosyan[96] , B. Polichtchouk[91] , N. Poljak[99] , A. Pop[48] ,
S. Porteboeuf-Houssais[134] , V. Pozdniakov[75] , S.K. Prasad[3] , R. Preghenella[54] , F. Prino[59] , C.A. Pruneau[143] ,
I. Pshenichnov[62] , M. Puccio[34] , J. Putschke[143] , S. Qiu[90] , L. Quaglia[25] , R.E. Quishpe[125] , S. Ragoni[111] ,
S. Raha[3] , S. Rajput[101] , J. Rak[126] , A. Rakotozafindrabe[137] , L. Ramello[31] , F. Rami[136] , S.A.R. Ramirez[45] ,
R. Raniwala[102] , S. Raniwala[102] , S.S. Räsänen[44] , R. Rath[50] , V. Ratza[43] , I. Ravasenga[90] , K.F. Read[96,130] ,
A.R. Redelbach[39] , K. Redlich[85,vi], A. Rehman[21] , P. Reichelt[68] , F. Reidt[34] , X. Ren[6] , R. Renfordt[68] ,
Z. Rescakova[38] , K. Reygers[104] , V. Riabov[98] , T. Richert[81,89] , M. Richter[20] , P. Riedler[34] , W. Riegler[34] ,
F. Riggi[27] , C. Ristea[67] , S.P. Rode[50] , M. Rodríguez Cahuantzi[45] , K. Røed[20] , R. Rogalev[91] , E. Rogochaya[75] ,
D. Rohr[34] , D. Röhrich[21] , P.S. Rokita[142] , F. Ronchetti[52] , A. Rosano[56] , E.D. Rosas[69] , K. Roslon[142] ,

A. Rossi[28,57], A. Rotondi[139], A. Roy[50], P. Roy[110], O.V. Rueda[81], R. Rui[24], B. Rumyantsev[75], A. Rustamov[87], E. Ryabinkin[88], Y. Ryabov[98], A. Rybicki[118], H. Rytkonen[126], O.A.M. Saarimaki[44], S. Sadhu[141], S. Sadovsky[91], K. Šafařík[37], S.K. Saha[141], B. Sahoo[49], P. Sahoo[49], R. Sahoo[50], S. Sahoo[65], P.K. Sahu[65], J. Saini[141], S. Sakai[133], S. Sambyal[101], V. Samsonov[93,98], D. Sarkar[143], N. Sarkar[141], P. Sarma[42], V.M. Sarti[105], M.H.P. Sas[63], E. Scapparone[54], J. Schambach[119], H.S. Scheid[68], C. Schiaua[48], R. Schicker[104], A. Schmah[104], C. Schmidt[107], H.R. Schmidt[103], M.O. Schmidt[104], M. Schmidt[103], N.V. Schmidt[68,96], A.R. Schmier[130], J. Schukraft[89], Y. Schutz[136], K. Schwarz[107], K. Schweda[107], G. Scioli[26], E. Scomparin[59], J.E. Seger[15], Y. Sekiguchi[132], D. Sekihata[132], I. Selyuzhenkov[93,107], S. Senyukov[136], D. Serebryakov[62], A. Sevcenco[67], A. Shabanov[62], A. Shabetai[115], R. Shahoyan[34], W. Shaikh[110], A. Shangaraev[91], A. Sharma[100], A. Sharma[101], H. Sharma[118], M. Sharma[101], N. Sharma[100], S. Sharma[101], K. Shigaki[46], M. Shimomura[83], S. Shirinkin[92], Q. Shou[40], Y. Sibiriak[88], S. Siddhanta[55], T. Siemiarczuk[85], D. Silvermyr[81], G. Simatovic[90], G. Simonetti[34], B. Singh[105], R. Singh[86], R. Singh[101], R. Singh[50], V.K. Singh[141], V. Singhal[141], T. Sinha[110], B. Sitar[13], M. Sitta[31], T.B. Skaali[20], M. Slupecki[44], N. Smirnov[146], R.J.M. Snellings[63], C. Soncco[112], J. Song[125], A. Songmoolnak[116], F. Soramel[28], S. Sorensen[130], I. Sputowska[118], J. Stachel[104], I. Stan[67], P.J. Steffanic[130], E. Stenlund[81], S.F. Stiefelmaier[104], D. Stocco[115], M.M. Storetvedt[36], L.D. Stritto[29], A.A.P. Suaide[121], T. Sugitate[46], C. Suire[78], M. Suleymanov[14], M. Suljic[34], R. Sultanov[92], M. Šumbera[95], V. Sumberia[101], S. Sumowidagdo[51], S. Swain[65], A. Szabo[13], I. Szarka[13], U. Tabassam[14], S.F. Taghavi[105], G. Taillepied[134], J. Takahashi[122], G.J. Tambave[21], S. Tang[6,134], M. Tarhini[115], M.G. Tarzila[48], A. Tauro[34], G. Tejeda Muñoz[45], A. Telesca[34], L. Terlizzi[25], C. Terrevoli[125], D. Thakur[50], S. Thakur[141], D. Thomas[119], F. Thoresen[89], R. Tieulent[135], A. Tikhonov[62], A.R. Timmins[125], A. Toia[68], N. Topilskaya[62], M. Toppi[52], F. Torales-Acosta[19], S.R. Torres[37], A. Trifiró[32,56], S. Tripathy[50,69], T. Tripathy[49], S. Trogolo[28], G. Trombetta[33], L. Tropp[38], V. Trubnikov[2], W.H. Trzaska[126], T.P. Trzcinski[142], B.A. Trzeciak[37,63], A. Tumkin[109], R. Turrisi[57], T.S. Tveter[20], K. Ullaland[21], E.N. Umaka[125], A. Uras[135], G.L. Usai[23], M. Vala[38], N. Valle[139], S. Vallero[59], N. van der Kolk[63], L.V.R. van Doremalen[63], M. van Leeuwen[63], P. Vande Vyvre[34], D. Varga[145], Z. Varga[145], M. Varga-Kofarago[145], A. Vargas[45], M. Vasileiou[84], A. Vasiliev[88], O. Vázquez Doce[105], V. Vechernin[113], E. Vercellin[25], S. Vergara Limón[45], L. Vermunt[63], R. Vernet[7], R. Vértesi[145], L. Vickovic[35], Z. Vilakazi[131], O. Villalobos Baillie[111], G. Vino[53], A. Vinogradov[88], T. Virgili[29], V. Vislavicius[89], A. Vodopyanov[75], B. Volkel[34], M.A. Völkl[103], K. Voloshin[92], S.A. Voloshin[143], G. Volpe[33], B. von Haller[34], I. Vorobyev[105], D. Voscek[117], J. Vrláková[38], B. Wagner[21], M. Weber[114], A. Wegrzynek[34], S.C. Wenzel[34], J.P. Wessels[144], J. Wiechula[68], J. Wikne[20], G. Wilk[85], J. Wilkinson[10,54], G.A. Willems[144], E. Willsher[111], B. Windelband[104], M. Winn[137], W.E. Witt[130], J.R. Wright[119], Y. Wu[128], R. Xu[6], S. Yalcin[77], Y. Yamaguchi[46], K. Yamakawa[46], S. Yang[21], S. Yano[137], Z. Yin[6], H. Yokoyama[63], I.-K. Yoo[17], J.H. Yoon[61], S. Yuan[21], A. Yuncu[104], V. Yurchenko[2], V. Zaccolo[24], A. Zaman[14], C. Zampolli[34], H.J.C. Zanoli[63], N. Zardoshti[34], A. Zarochentsev[113], P. Závada[66], N. Zaviyalov[109], H. Zbroszczyk[142], M. Zhalov[98], S. Zhang[40], X. Zhang[6], Z. Zhang[6], V. Zherebchevskii[113], D. Zhou[6], Y. Zhou[89], Z. Zhou[21], J. Zhu[6,107], Y. Zhu[6], A. Zichichi[10,26], G. Zinovjev[2], N. Zurlo[140],

Affiliation notes

[i] Deceased

[ii] Italian National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA), Bologna, Italy

[iii] Dipartimento DET del Politecnico di Torino, Turin, Italy

[iv] M.V. Lomonosov Moscow State University, D.V. Skobeltsyn Institute of Nuclear, Physics, Moscow, Russia

[v] Department of Applied Physics, Aligarh Muslim University, Aligarh, India

[vi] Institute of Theoretical Physics, University of Wroclaw, Poland

Collaboration Institutes

[1] A.I. Alikhanyan National Science Laboratory (Yerevan Physics Institute) Foundation, Yerevan, Armenia

[2] Bogolyubov Institute for Theoretical Physics, National Academy of Sciences of Ukraine, Kiev, Ukraine

[3] Bose Institute, Department of Physics and Centre for Astroparticle Physics and Space Science (CAPSS), Kolkata, India

[4] Budker Institute for Nuclear Physics, Novosibirsk, Russia

[5] California Polytechnic State University, San Luis Obispo, California, United States

[6] Central China Normal University, Wuhan, China

[7] Centre de Calcul de l'IN2P3, Villeurbanne, Lyon, France

[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] Centro Fermi - Museo Storico della Fisica e Centro Studi e Ricerche “Enrico Fermi’, Rome, Italy
[11] Chicago State University, Chicago, Illinois, United States
[12] China Institute of Atomic Energy, Beijing, China
[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.R. Caianiello’ dell’Università and Gruppo Collegato INFN, Salerno, Italy
[30] Dipartimento DISAT del Politecnico and Sezione INFN, Turin, Italy
[31] Dipartimento di Scienze e Innovazione Tecnologica dell’Università del Piemonte Orientale and INFN Sezione di Torino, Alessandria, Italy
[32] Dipartimento di Scienze MIFT, Università di Messina, Messina, Italy
[33] Dipartimento Interateneo di Fisica ‘M. Merlin’ and Sezione INFN, Bari, Italy
[34] European Organization for Nuclear Research (CERN), Geneva, Switzerland
[35] Faculty of Electrical Engineering, Mechanical Engineering and Naval Architecture, University of Split, Split, Croatia
[36] Faculty of Engineering and Science, Western Norway University of Applied Sciences, Bergen, Norway
[37] Faculty of Nuclear Sciences and Physical Engineering, Czech Technical University in Prague, Prague, Czech Republic
[38] Faculty of Science, P.J. Šafárik University, Košice, Slovakia
[39] Frankfurt Institute for Advanced Studies, Johann Wolfgang Goethe-Universität Frankfurt, Frankfurt, Germany
[40] Fudan University, Shanghai, China
[41] Gangneung-Wonju National University, Gangneung, Republic of Korea
[42] Gauhati University, Department of Physics, Guwahati, India
[43] Helmholtz-Institut für Strahlen- und Kernphysik, Rheinische Friedrich-Wilhelms-Universität Bonn, Bonn, Germany
[44] Helsinki Institute of Physics (HIP), Helsinki, Finland
[45] High Energy Physics Group, Universidad Autónoma de Puebla, Puebla, Mexico
[46] Hiroshima University, Hiroshima, Japan
[47] Hochschule Worms, Zentrum für Technologietransfer und Telekommunikation (ZTT), Worms, Germany
[48] Horia Hulubei National Institute of Physics and Nuclear Engineering, Bucharest, Romania
[49] Indian Institute of Technology Bombay (IIT), Mumbai, India
[50] Indian Institute of Technology Indore, Indore, India
[51] Indonesian Institute of Sciences, Jakarta, Indonesia
[52] INFN, Laboratori Nazionali di Frascati, Frascati, Italy
[53] INFN, Sezione di Bari, Bari, Italy
[54] INFN, Sezione di Bologna, Bologna, Italy
[55] INFN, Sezione di Cagliari, Cagliari, Italy
[56] INFN, Sezione di Catania, Catania, Italy
[57] INFN, Sezione di Padova, Padova, Italy
[58] INFN, Sezione di Roma, Rome, Italy

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

[111] School of Physics and Astronomy, University of Birmingham, Birmingham, United Kingdom
[112] Sección Física, Departamento de Ciencias, Pontificia Universidad Católica del Perú, Lima, Peru
[113] St. Petersburg State University, St. Petersburg, Russia
[114] Stefan Meyer Institut für Subatomare Physik (SMI), Vienna, Austria
[115] SUBATECH, IMT Atlantique, Université de Nantes, CNRS-IN2P3, Nantes, France
[116] Suranaree University of Technology, Nakhon Ratchasima, Thailand
[117] Technical University of Košice, Košice, Slovakia
[118] The Henryk Niewodniczanski Institute of Nuclear Physics, Polish Academy of Sciences, Cracow, Poland
[119] The University of Texas at Austin, Austin, Texas, United States
[120] Universidad Autónoma de Sinaloa, Culiacán, Mexico
[121] Universidade de São Paulo (USP), São Paulo, Brazil
[122] Universidade Estadual de Campinas (UNICAMP), Campinas, Brazil
[123] Universidade Federal do ABC, Santo Andre, Brazil
[124] University of Cape Town, Cape Town, South Africa
[125] University of Houston, Houston, Texas, United States
[126] University of Jyväskylä, Jyväskylä, Finland
[127] University of Liverpool, Liverpool, United Kingdom
[128] University of Science and Technology of China, Hefei, China
[129] University of South-Eastern Norway, Tonsberg, Norway
[130] University of Tennessee, Knoxville, Tennessee, United States
[131] University of the Witwatersrand, Johannesburg, South Africa
[132] University of Tokyo, Tokyo, Japan
[133] University of Tsukuba, Tsukuba, Japan
[134] Université Clermont Auvergne, CNRS/IN2P3, LPC, Clermont-Ferrand, France
[135] Université de Lyon, Université Lyon 1, CNRS/IN2P3, IPN-Lyon, Villeurbanne, Lyon, France
[136] Université de Strasbourg, CNRS, IPHC UMR 7178, F-67000 Strasbourg, France, Strasbourg, France
[137] Université Paris-Saclay Centre d'Etudes de Saclay (CEA), IRFU, Départment de Physique Nucléaire (DPhN), Saclay, France
[138] Università degli Studi di Foggia, Foggia, Italy
[139] Università degli Studi di Pavia, Pavia, Italy
[140] Università di Brescia, Brescia, Italy
[141] Variable Energy Cyclotron Centre, Homi Bhabha National Institute, Kolkata, India
[142] Warsaw University of Technology, Warsaw, Poland
[143] Wayne State University, Detroit, Michigan, United States
[144] Westfälische Wilhelms-Universität Münster, Institut für Kernphysik, Münster, Germany
[145] Wigner Research Centre for Physics, Budapest, Hungary
[146] Yale University, New Haven, Connecticut, United States
[147] Yonsei University, Seoul, Republic of Korea