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Supplemental figures: Multipion Bose-Einstein correlations in pp, p–Pb and Pb–Pb collisions at the LHC

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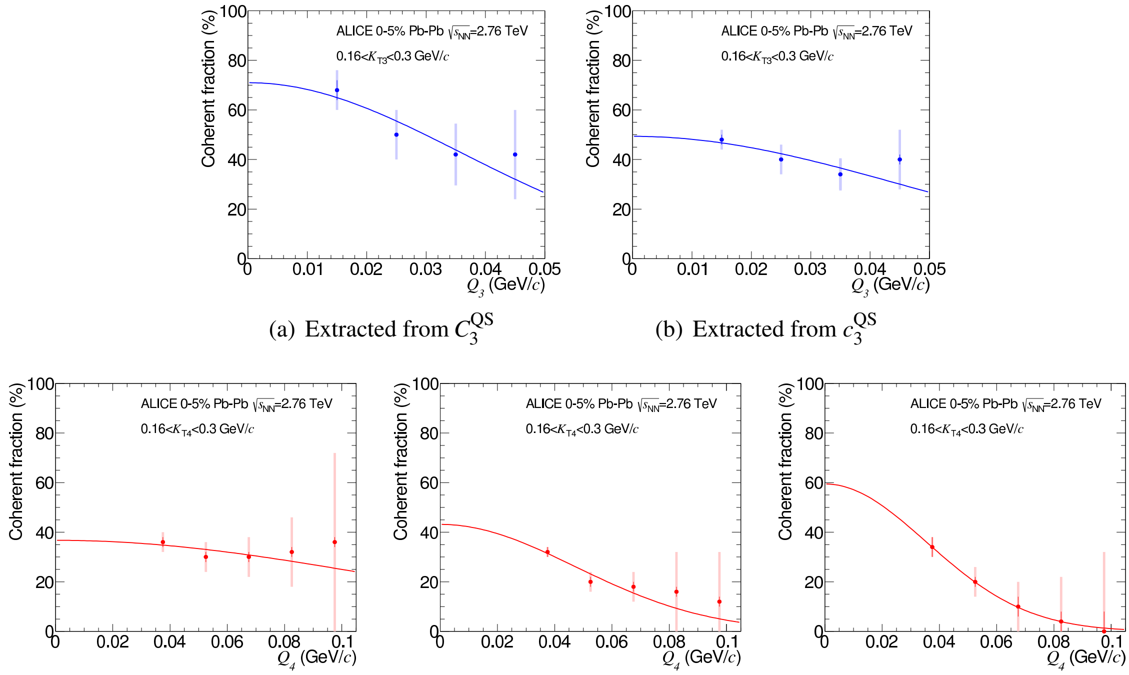
Abstract

Supplemental figures for the Pb–Pb part of the analysis on "Multipion Bose-Einstein correlations in pp, p–Pb and Pb–Pb collisions at the LHC" [1] are provided. The Q_3 and Q_4 dependence of the coherent fractions is extracted from several types of same-charge correlation functions. Further studies pertaining to the mixed-charge cumulant correlation functions are also presented.

*The author list is given in arXiv:1512.08902.



(a) Extracted from C_3^{QS} (b) Extracted from c_3^{QS}

(c) Extracted from C_4^{QS} (d) Extracted from a_4^{QS} (e) Extracted from b_4^{QS}

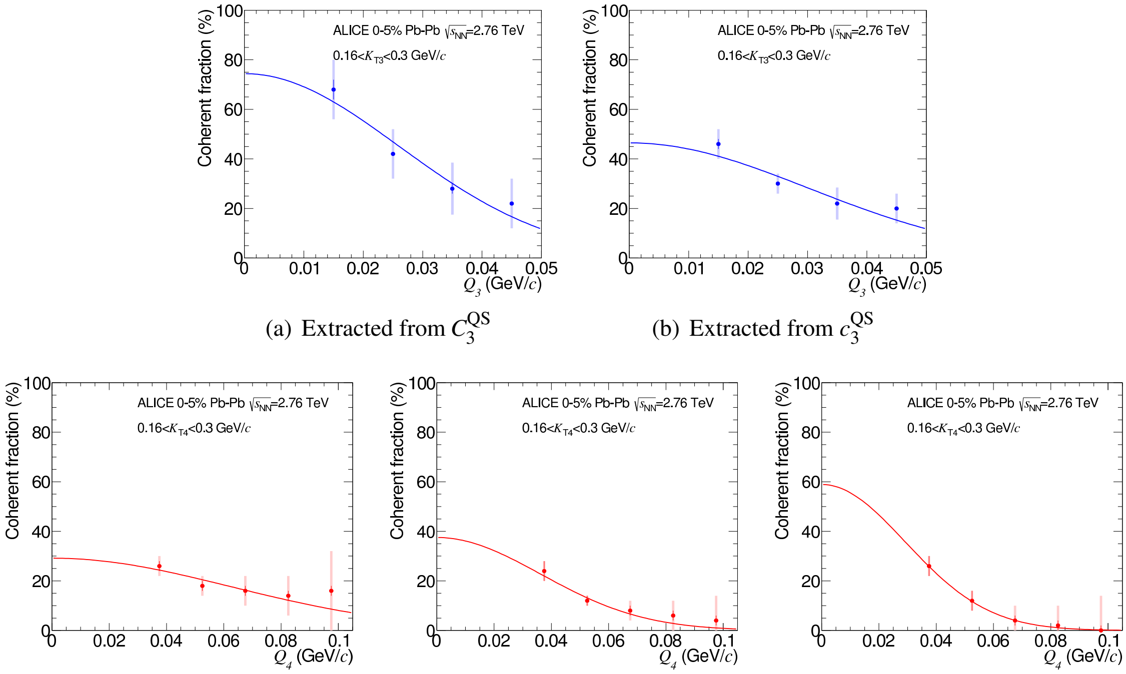
Fig. 1: The coherent fractions extracted for each Q_3 and Q_4 bin. Four different extraction procedures are shown. $R_{coh} = R_{ch}$ is assumed. The fit parameters are shown in Tab. 1.

G from	C_3^{QS}	$\mathbf{c}_3^{QS}$	C_4^{QS}	a_4^{QS}	b_4^{QS}
$R_{\rm coh} = R_{\rm ch}$					
α	71 ± 12	49 ± 6	37 ± 7	43 ± 9	59 ± 24
β	20 ± 6	16 ± 5	6 ± 6	15 ± 4	20 ± 5

Table 1: Gaussian fit parameters ($\alpha e^{-(\beta Q_n)^2}$) for G versus Q_3 and Q_4 at low K_{T3} and K_{T4} for 0-5% Pb–Pb collisions. G was extracted from five different correlation functions and with the assumption that $R_{\rm coh} = R_{\rm ch}$ (full size). The uncertainties on the fit parameters are dominated by systematic but include statistical uncertainties as well.

In this supplementary note we investigate the Q_3 and Q_4 dependence of the suppression of multipion Bose-Einstein correlations. We also further investigate the residues observed with mixed-charge cumulant correlation functions. The coherent fractions in our main article [1] were extracted using the full four-pion QS correlation function, C_4^{QS}, while assuming that the possible coherent component has a radius equal to that of the chaotic component, $R_{\rm coh} = R_{\rm ch}$. Here we extract the coherent fractions with four additional multipion correlation functions and also with the assumption that the possible coherent component is point-like, $R_{\rm coh} = 0$. In total, the coherent fractions are extracted from C_3^{QS}, c_3^{QS}, C_4^{QS}, a_4^{QS}, and b_4^{QS}. The four-pion cumulant correlation, c_4^{QS}, was found to be too unstable to perform the extraction. We fit the coherent fractions with a simple Gaussian parametrization: $\alpha e^{-(\beta Q_n)^2}$. The coherent fractions in the 0-5% Pb–Pb centrality interval at low K_{T4} are shown in Figs. 1(a)-1(e) under the assumption that $R_{\rm coh} = R_{\rm ch}$. The corresponding Gaussian fit parameters are shown in Tab. 1

Another extreme for the possible coherent component is the case where $R_{coh} = 0$. The coherent fractions extracted with such an assumption are shown in Figs. 2(a)-2(d). The Gaussian fit parameters for the case that $R_{\rm coh} = 0$ are shown in Tab. 2



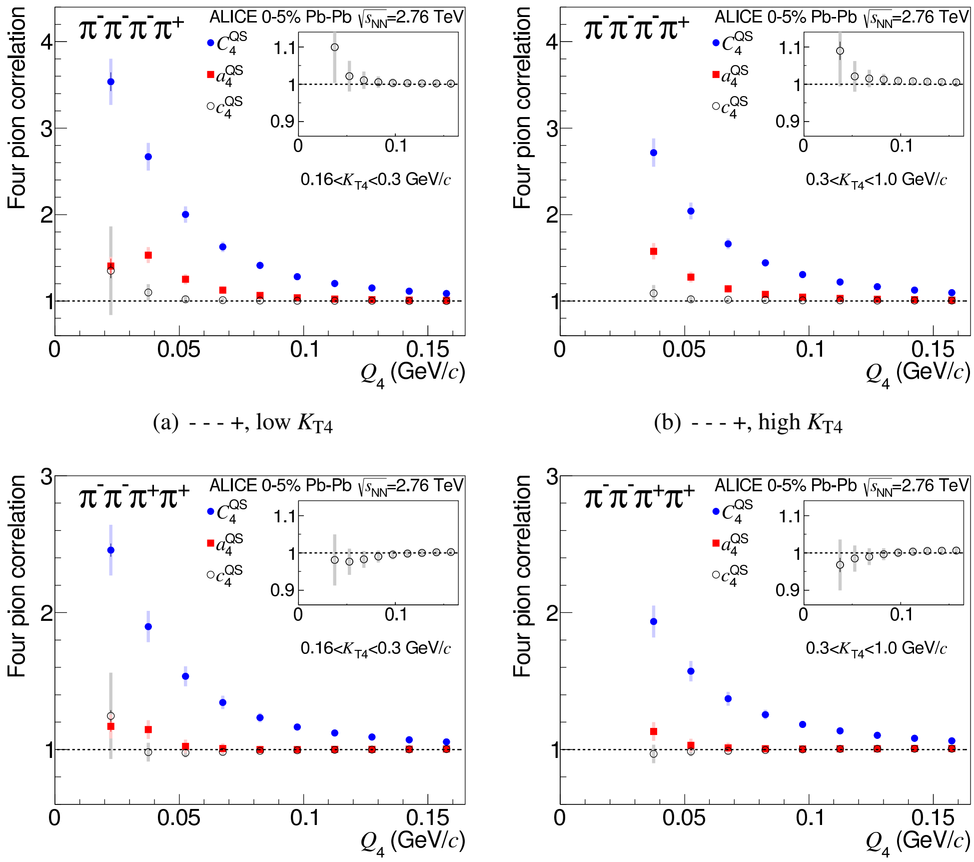
(a) Extracted from C_3^{QS} (b) Extracted from c_3^{QS}

(c) Extracted from C_4^{QS} (d) Extracted from a_4^{QS} (e) Extracted from b_4^{QS}

Fig. 2: The coherent fractions extracted for each Q_3 and Q_4 bin for the case when $R_{coh} = 0$ is assumed. Four different extraction procedures are shown. The fit parameters are shown in Tab. 2.

G from	C_3^{QS}	$\mathbf{c}_3^{\mathrm{QS}}$	C_4^{QS}	a_4^{QS}	b_4^{QS}
$R_{\mathrm{coh}} = 0$					
α	74 ± 17	46 ± 8	29 ± 8	38 ± 19	59 ± 33
β	27 ± 6	23 ± 5	11 ± 4	20 ± 5	24 ± 7

Table 2: Gaussian fit parameters ($\alpha e^{-(\beta Q_n)^2}$) for G versus Q_3 and Q_4 at low K_{T3} and K_{T4} for 0-5% Pb–Pb collisions. G was extracted from five different correlation functions and with the assumption that $R_{\mathrm{coh}} = 0$ (point source). The uncertainties on the fit parameters are dominated by systematic but include statistical uncertainties as well.



(a) - - - +, low K_{T4}

(b) - - - +, high K_{T4}

(c) - - + +, low K_{T4}

(d) - - + +, high K_{T4}

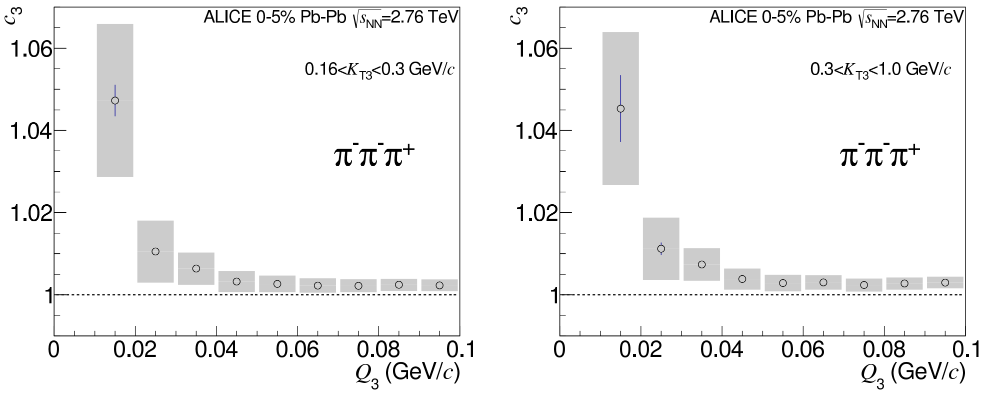
Fig. 3: Mixed-charge four-pion correlations. The cumulant correlation function, $\mathbf{c}_4^{QS}$, has been constructed in an alternative way.

Isolation of the cumulant correlation function, c_4^{QS}, is done by subtracting several types of four-pion distributions,

$$\begin{aligned} c_4 &= [N_4^{QS}(p_1,p_2,p_3,p_4) - \varepsilon_2 N_3^{QS}(p_1,p_2,p_3)N_1(p_4) \\ &- \varepsilon_3 N_2^{QS}(p_1,p_2)N_2^{QS}(p_3,p_4) + \varepsilon_4 N_2^{QS}(p_1,p_2)N_1(p_3)N_1(p_4) \\ &+ (\varepsilon_2+\varepsilon_3-\varepsilon_4)N_1^4]/N_1^4. \end{aligned} \tag{1}$$

For mixed-charge quadruplets of type 1 ($\mp\pm\pm\pm$) the coefficients are: $\varepsilon_1 = 3, \varepsilon_2 = 1, \varepsilon_3 = 0, \varepsilon_4 = 0$. For mixed-charge quadruplets of type 2 ($\mp\mp\pm\pm$) the coefficients are: $\varepsilon_1 = 2, \varepsilon_2 = 0, \varepsilon_3 = 1, \varepsilon_4 = 0$. With exact FSI corrections and in the absence of coherent pion emission, the mixed-charge two-pion term $N_2^{QS}(+-)$ is equal to $N_1(+)N_1(-)$. In such a scenario, it is inconsequential if one subtracts $3N_2^{QS}(+-)N_1(-)N_1(-)$ from $\mp\pm\pm\pm$ quadruplets and $4N_2^{QS}(+-)N_1(+)N_1(-)$ from $\mp\mp\pm\pm$ quadruplets. By default, we subtract these FSI corrected distributions. The alternate cumulant construction, given by the above choices of ε_i, give slightly different values with respect to Ref. [1] and is shown in Figs. 3(a)-3(d). A residual correlation is still observed with c_4^{QS}. We note that c_4^{QS} constructed in the alternative way is more sensitive to f_c variations. The systematic uncertainties are therefore larger with the alternate cumulant construction.

Residues are also observed with three-pion mixed-charge cumulant correlations as previously reported in Ref. [2] and [3]. In the previous analyses, three-pion correlations were binned in interval widths of 5 MeV/c for each pair q. The mean value of q in each bin was used to compute the FSI corrections. This procedure neglects fluctuations of q within each bin. With our new procedure, the FSI corrections



(a) - - +, low K_{T3} (b) - - +, high K_{T3}

Fig. 4: The mixed-charge three-pion cumulant correlation functions in central Pb–Pb collisions.

are computed pair-by-pair. The mixed-charge three-pion cumulant correlation functions in central Pb–Pb collisions for both K_{T3} intervals are shown in Figs. 4(a)-4(a). The residual correlations are small although clearly positive.

References

[1] **ALICE** Collaboration, J. Adam *et al.*, "Multipion Bose-Einstein correlations in pp,p–Pb, and Pb–Pb collisions at energies available at the CERN Large Hadron Collider," *Phys. Rev.* **C93** no. 5, (2016) 054908, `arXiv:1512.08902 [nucl-ex]`.

[2] **ALICE** Collaboration, B. Abelev *et al.*, "Two and Three-Pion Quantum Statistics Correlations in Pb–Pb Collisions at sqrt(sNN)=2.76 TeV at the LHC," *Phys.Rev.* **C89** (2014) 024911, `arXiv:1310.7808 [nucl-ex]`.

[3] **ALICE** Collaboration, B. Abelev *et al.*, "Freeze-out radii extracted from three-pion cumulants in pp, p–Pb and Pb-Pb collisions at the LHC," *Phys.Lett.* **B739** (2014) 139–151, `arXiv:1404.1194 [nucl-ex]`.