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Multiparticle correlation studies in *p*Pb collisions at $\sqrt{s_{NN}} = 8.16$ TeV

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The second- and third-order azimuthal anisotropy Fourier harmonics of charged particles produced in *p*Pb collisions, at $\sqrt{s_{NN}} = 8.16$ TeV, are studied over a wide range of event multiplicities. Multiparticle correlations are used to isolate global properties stemming from the collision overlap geometry. The second-order "elliptic" harmonic moment is obtained with high precision through four-, six-, and eight-particle correlations and, for the first time, the third-order "triangular" harmonic moment is studied using four-particle correlations. A sample of peripheral PbPb collisions at $\sqrt{s_{NN}} = 5.02$ TeV that covers a similar range of event multiplicities as the *p*Pb results is also analyzed. Model calculations of initial-state fluctuations in *p*Pb and PbPb collisions can be directly compared to the high-precision experimental results. This work provides new insight into the fluctuation-driven origin of the v_3 coefficients in *p*Pb and PbPb collisions, and into the dominating overall collision geometry in PbPb collisions at the earliest stages of heavy ion interactions.

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I. INTRODUCTION

In collisions of ultrarelativistic heavy ions, two-particle azimuthal correlations between the large number of particles created over a broad range in pseudorapidity were first observed in gold-gold and copper-copper collisions at the BNL Relativistic Heavy Ion Collider (RHIC) [1–4], and have subsequently been studied in lead-lead (PbPb) collisions at the CERN Large Hadron Collider (LHC) [5–11]. These correlations are thought to reflect the collective motion of a strongly interacting and expanding medium with quark and gluon degrees of freedom, namely, the quark-gluon plasma [12]. The observed azimuthal correlation structure can be characterized by Fourier harmonics, with the second (v_2) and third (v_3) harmonics referred to as "elliptic" and "triangular" flow, respectively. Within a hydrodynamic picture, the Fourier harmonics are related to the initial geometry of the colliding system and provide insight into the transport properties of the produced medium [13–15]. Fluctuations can also arise from the discrete substructure of the interaction region at the parton level [16,17] and can have a significant effect on the observed higher-order harmonic coefficients.

Two-particle azimuthal correlations, which are long range in pseudorapidity, are also found in small systems for collisions leading to high final-state particle densities. At the LHC, long-range correlations have been observed in proton-proton (*pp*) [18–20] and proton-lead (*p*Pb) [21–24] collisions. Similar results have been obtained at RHIC in studies of deuteron-gold, proton-gold, and helium-3–gold collisions [25–28]. The origin of the long-range correlations in systems involving only a small number of participating nucleons is still under active discussion [29]. One possibility is that fluctuation-driven asymmetries in the initial-state nucleon locations within the overlap region are transferred to the final-state particle distributions through the hydrodynamic evolution of an expanding plasma [30–32]. Alternatively, it has been proposed that the observed behavior arises from the transfer of initial-state gluon correlations to the produced particles [33–35].

Studies of azimuthal correlations in small systems using two or more particles, as achieved through the use of a multiparticle cumulant expansion [36], show that the *pp* [37] and *p*Pb [38] systems develop similar collective behavior to that found in heavier systems [39]. The cumulants quantify an *n*th-order contribution of the azimuthal correlation that is irreducible to lower-order correlations. By requiring correlations among multiple particles, correlations that are not related to a bulk property of the medium, such as back-to-back jet correlations and resonance decays, are strongly suppressed [40]. The v_n harmonics based on different orders of the multiparticle expansion provide information on the event-by-event fluctuation of the observed anisotropy [41]. Previous v_2 multiparticle cumulant results for *p*Pb collisions at a nucleon-nucleon center-of-mass energy of $\sqrt{s_{NN}} = 5.02$ TeV suggest a direct correlation of the final-state asymmetry with the initial-state eccentricity of the participating nucleons [38,42]. The v_3 harmonic is expected to be dominated by fluctuations in the initial-state geometry. The multiparticle correlations of the v_3 harmonic are then expected to reflect these fluctuations. An earlier multiparticle correlation measurement by the ATLAS Collaboration found evidence for a finite v_3 harmonic amplitude in the *p*Pb system [43]. With precise measurements of

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the v_2 and v_3 multiparticle cumulants, it becomes possible to make direct comparison of calculations based on eccentricity fluctuations in the initial-state geometry to the higher-order moments of the fluctuation distributions. The measurements provide key input for models that explore the hydrodynamic expansion of the medium [44,45], as well as for models that propose that final-state asymmetries in light systems arise from partons scattering off localized domains of color charge in the initial state [34]. In the hydrodynamic picture, the v_2 and v_3 values are dominated by fluctuations in *p*Pb collisions. In PbPb collisions, the v_2 value is dominated by the lenticular shape of the overlap geometry, while the v_3 value is dominated by initial-state fluctuations of the nucleon locations [16].

In this work, the results from *p*Pb collisions at $\sqrt{s_{NN}} = 8.16$ TeV are studied with a significant improvement in the precision of the v_2 results compared to the earlier measurements at $\sqrt{s_{NN}} = 5.02$ TeV. For the first time, the v_3 harmonic is determined by multiparticle correlations. The *p*Pb results are also compared to those found for PbPb collisions at $\sqrt{s_{NN}} = 5.02$ TeV to explore the dependence on the overlap geometry. The ratios between the four-particle and two-particle v_n values provide information on the relative importance of the global geometry and the fluctuation-driven asymmetries [46]. These ratios are explored for both the v_2 and v_3 harmonics and are compared between the *p*Pb and PbPb systems.

II. EXPERIMENTAL SETUP AND DATA SAMPLE

The CMS detector comprises a number of subsystems [47]. The results in this paper are mainly based on the silicon tracker information. The silicon tracker, located in the 3.8 T field of a superconducting solenoid, consists of 1 440 silicon pixel and 15 148 silicon strip detector modules. The silicon tracker measures charged particles within the laboratory pseudorapidity range $|\eta| < 2.5$, and provides an impact parameter resolution of $\approx 15\,\mu$m and a transverse momentum (p_T) resolution better than 1.5% up to 100 GeV/*c* [47]. The electromagnetic (ECAL) and hadron (HCAL) calorimeters are also located inside the solenoid and cover the pseudorapidity range $|\eta| < 3.0$. The HCAL barrel and endcaps are sampling calorimeters composed of brass and scintillator plates. The ECAL consists of lead tungstate crystals arranged in a quasiprojective geometry. Iron and quartz-fiber Čerenkov hadron forward (HF) calorimeters cover the range $3.0 < |\eta| < 5.2$ on either side of the interaction region. These HF calorimeters are azimuthally subdivided into 20° modular wedges and further segmented to form 0.175×0.175 rad ($\Delta\eta \times \Delta\phi$) cells. The ECAL and HCAL cells are grouped to form "towers." The detailed Monte Carlo (MC) simulation of the CMS detector response is based on GEANT4 [48].

The analysis is performed using data recorded by CMS during the LHC *p*Pb run in 2016 and corresponds to an integrated luminosity of 186 nb^{-1} [49]. The beam energies were 6.5 TeV for protons and 2.56 TeV per nucleon for lead nuclei, resulting in $\sqrt{s_{NN}} = 8.16$ TeV. The beam directions were reversed during the run, allowing a check of potential detector related systematic uncertainties. No significant differences were detected and the merged results are reported. The nucleon-nucleon center-of-mass in the *p*Pb collisions is not at rest with respect to the laboratory frame because of the energy difference between the colliding particles. Massless particles emitted at $\eta_{\rm cm} = 0$ in the nucleon-nucleon center-of-mass frame will be detected at $\eta = -0.465$ (clockwise proton beam) or 0.465 (counterclockwise proton beam) in the laboratory frame. In this paper, an unsubscripted η symbol is used to denote the laboratory frame pseudorapidity. A sample of $\sqrt{s_{NN}} = 5.02$ TeV PbPb data collected during the 2015 LHC heavy ion run, corresponding to an integrated luminosity of 1.2 μb^{-1}, is also analyzed for comparison purposes. The triggers and event selection, as well as track reconstruction and selection, are identical to those used in Ref. [50] and are summarized below.

Minimum bias (MB) *p*Pb events were triggered by requiring at least one track with $p_T > 0.4$ GeV/*c* in the pixel tracker during a *p*Pb bunch crossing and the presence of at least one tower in one of the two HF detectors having an energy above 1 GeV. To select high-multiplicity *p*Pb collisions, a dedicated high-multiplicity trigger was implemented using the CMS level-1 (L1) and high-level trigger (HLT) systems [51]. At L1, the total number of ECAL and HCAL towers with the transverse energies above a threshold of 0.5 GeV is required to exceed 120 and 150 in ECAL and HCAL, respectively. The events which pass the L1 trigger are then subsequently filtered in the HLT. The track reconstruction that is performed online, as part of the HLT trigger, uses the identical reconstruction algorithm as employed in the offline processing [52]. For each event, the vertex reconstructed with the highest number of pixel detector tracks was selected. The number (multiplicity) of pixel tracks ($N_{\rm trk}^{\rm online}$) with $|\eta| < 2.4$, $p_T > 0.4$ GeV/*c*, and a distance of closest approach to this vertex of 0.4 cm or less, was determined for each event. Several multiplicity ranges were defined with prescale factors that were reduced with increasing particle multiplicity until, for the highest-multiplicity events, no prescale was applied.

In the offline analysis, hadronic collisions are selected by the requirement of a coincidence of at least one HF calorimeter tower containing more than 3 GeV of total energy in each of the HF detectors within $3.0 < |\eta| < 5.2$. Events are also required to contain at least one reconstructed primary vertex within 15 cm from the nominal interaction point along the beam axis and within 0.15 cm transverse to the beam trajectory. At least two reconstructed tracks are required to be associated with the primary vertex. Beam-related background is suppressed by rejecting events for which less than 25% of all reconstructed tracks pass the track selection criteria.

Tracks are used that pass the high-purity selection criteria described in Ref. [52]. In addition, a reconstructed track is only considered as a candidate track from the primary vertex if the separation along the beam axis (z) between the track and the best vertex, and the track-vertex impact parameter measured transverse to the beam, are each less than three times their respective uncertainties. The relative uncertainty in the p_T measurement is required to be less than 10%. To restrict the analysis to a kinematic region of high tracking efficiency and a low rate of incorrectly reconstructed tracks, only tracks with $|\eta| < 2.4$ and $0.3 < p_T < 3.0$ GeV/*c* are used.

The entire *p*Pb data set is divided into classes of reconstructed track multiplicity, $N_{\mathrm{trk}}^{\mathrm{offline}}$, where primary tracks passing the high-purity criteria and with $|\eta| < 2.4$ and $p_{\mathrm{T}} > 0.4\,\mathrm{GeV}/c$ are counted. The HLT p_{T} cutoff, which is only applied on determination of $N_{\mathrm{trk}}^{\mathrm{offline}}$, is higher than that used for the analysis because of online processing time constraints. The absence of the time constraints in the offline process allows extending the p_{T} coverage down to $0.3\,\mathrm{GeV}/c$ in the cumulant calculation. The multiplicity classification in this analysis is identical to that used in Ref. [40], where more details are provided, including a table relating $N_{\mathrm{trk}}^{\mathrm{offline}}$ to the fraction of MB triggered events. The PbPb sample is reprocessed using the same event selection and track reconstruction as for the present *p*Pb analysis. A description of the analysis of 2015 PbPb data can be found in Ref. [50].

III. ANALYSIS TECHNIQUES

The analysis is done using the *Q*-cumulant method [41]. Here it is possible to determine the *n*th harmonic moment based on correlations among all possible grouping of m particles, where m also corresponds to the cumulant order. The multiparticle correlations for cumulant orders 2 through 8 can be expressed as

$$\begin{aligned}
\langle\langle 2\rangle\rangle &\equiv \langle\langle e^{in(\phi_1-\phi_2)}\rangle\rangle,\\
\langle\langle 4\rangle\rangle &\equiv \langle\langle e^{in(\phi_1+\phi_2-\phi_3-\phi_4)}\rangle\rangle,\\
\langle\langle 6\rangle\rangle &\equiv \langle\langle e^{in(\phi_1+\phi_2+\phi_3-\phi_4-\phi_5-\phi_6)}\rangle\rangle,\\
\langle\langle 8\rangle\rangle &\equiv \langle\langle e^{in(\phi_1+\phi_2+\phi_3+\phi_4-\phi_5-\phi_6-\phi_7-\phi_8)}\rangle\rangle,
\end{aligned}$$

where ϕ_i $(i = 1,\ldots,m)$ are the azimuthal angles of one unique combination of m particles in an event, n is the harmonic number (2 for elliptic and 3 for triangular flow, respectively), and $\langle\langle\cdots\rangle\rangle$ represents the average over all combinations from all events within a given $N_{\mathrm{trk}}^{\mathrm{offline}}$ range. The higher-order cumulants, $c_n\{m\}$, are calculated as [41]

$$\begin{aligned}
c_n\{4\} &= \langle\langle 4\rangle\rangle - 2\langle\langle 2\rangle\rangle^2,\\
c_n\{6\} &= \langle\langle 6\rangle\rangle - 9\langle\langle 4\rangle\rangle\langle\langle 2\rangle\rangle + 12\langle\langle 2\rangle\rangle^3,\\
c_n\{8\} &= \langle\langle 8\rangle\rangle - 16\langle\langle 6\rangle\rangle\langle\langle 2\rangle\rangle - 18\langle\langle 4\rangle\rangle^2\\
&\quad + 144\langle\langle 4\rangle\rangle\langle\langle 2\rangle\rangle^2 - 144\langle\langle 2\rangle\rangle^4.
\end{aligned}$$

The Fourier harmonics $v_n\{m\}$ that characterize the global azimuthal behavior can be related to the m-particle correlations using a generic framework discussed in Ref. [53], with

$$\begin{aligned}
v_n\{4\} &= \sqrt[4]{-c_n\{4\}},\\
v_n\{6\} &= \sqrt[6]{\frac{1}{4}c_n\{6\}},\\
v_n\{8\} &= \sqrt[8]{-\frac{1}{33}c_n\{8\}}.
\end{aligned}$$

Each reconstructed track is weighted by a correction factor to account for the reconstruction efficiency, the detector acceptance, and the fraction of misreconstructed tracks. This factor is based on HIJING 1.383 [54] MC simulations, and is determined as a function of p_{T}, η, and ϕ, as described in Refs. [5,8]. The $c_n\{4\}$ and $c_n\{8\}$ values need to be negative, and the $c_n\{6\}$ value needs to be positive, in order to have real values for the $v_n\{m\}$ coefficients. The same method was used in previous CMS analyses [38,40,55]. The two-particle correlation $v_n\{2\}$ can be measured as described in Ref. [50]. Increasing the numbers of particles used to determine the correlations for a given harmonic reduces the sensitivity of the results to few-particle correlations that are not related to a global behavior. The ratios between v_n harmonics involving different numbers of particles can be used to test the system independence of fluctuation-driven initial-state anisotropies in the hydrodynamic picture. In particular, the triangular flow ratio $v_3\{4\}/v_3\{2\}$, which is dominated by fluctuations, can be used to confirm this expectation.

A number of potential sources of systematic uncertainties affecting the experimental $v_n\{m\}$ values are considered. The sensitivity of the results to the selection criteria for valid tracks was studied by varying the criteria. The sensitivity to the primary vertex position was explored by performing the analysis for different vertex z ranges. The potential for an HLT trigger bias was investigated by changing the trigger thresholds. Pileup effects, where two or more interactions occur in the same bunch crossing, were studied by comparing results obtained during different beam differential luminosity periods. For the *p*Pb results, the beam directions were reversed, allowing for potential detector acceptance effects to be explored. No evident $N_{\mathrm{trk}}^{\mathrm{offline}}$-dependent systematic effects are observed. The total systematic uncertainties, obtained by combining the individual uncertainties in quadrature, are found to be 1–2.4% for the v_2 coefficients for both *p*Pb and PbPb collisions and 5% (2.6%) for the *p*Pb (PbPb) v_3 results. The *p*Pb (PbPb) $v_n\{4\}/v_n\{2\}$ ratios systematic uncertainties are found to be 3% (1%). The *p*Pb $v_2\{6\}/v_2\{4\}$ and $v_2\{8\}/v_2\{6\}$ ratio systematic uncertainties are found to be 3%.

IV. RESULTS

The second- and third-order harmonic multiparticle cumulant results v_2 and v_3 for charged particles with $0.3 < p_{\mathrm{T}} < 3.0\,\mathrm{GeV}/c$ and $|\eta| < 2.4$ are shown in Fig. 1 for *p*Pb collisions at $\sqrt{s_{NN}} = 8.16\,\mathrm{TeV}$ and for PbPb collisions at $\sqrt{s_{NN}} = 5.02\,\mathrm{TeV}$. The two-particle correlation results $v_2^{\mathrm{sub}}\{2\}(|\Delta\eta| > 2)$ and $v_3^{\mathrm{sub}}\{2\}(|\Delta\eta| > 2)$, with low-multiplicity subtraction to remove jet correlations, are taken from Ref. [50]. The multiparticle elliptic flow harmonics $v_2\{4\}$, $v_2\{6\}$, and $v_2\{8\}$ are found to be real and of similar magnitude. The four-particle triangular flow harmonic, $v_3\{4\}$, is also found to be real, with an amplitude consistent with the earlier ATLAS $c_3\{4\}$ results [43]. These results indicate collective behavior in high-multiplicity *p*Pb collisions at $\sqrt{s_{NN}} = 8.16\,\mathrm{TeV}$ [44,45]. Comparing the different systems, the v_2 values for PbPb collisions are higher than those for *p*Pb collisions, which is consistent with the lenticular-shaped overlap geometry dominating this harmonic for PbPb collisions. The two-particle correlation v_2 and v_3 results are systematically higher than the multiparticle results for both *p*Pb and PbPb collision. This

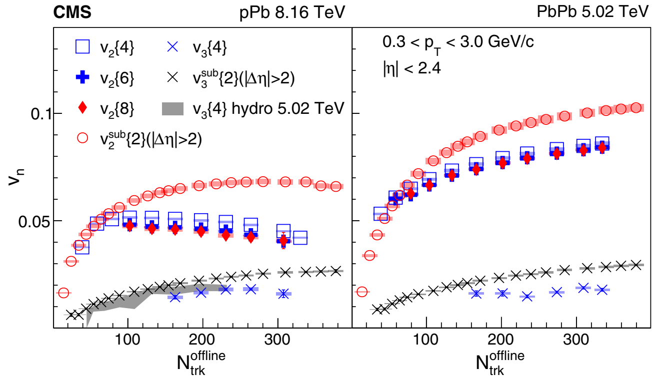

FIG. 1. The multiparticle $v_2\{4, 6, 8\}$ and $v_3\{4\}$ harmonics are shown for *p*Pb 8.16 TeV (left) and PbPb 5.02 TeV (right) collisions as a function of $N_{\mathrm{trk}}^{\mathrm{offline}}$. Two-particle results $v_2^{\mathrm{sub}}\{2\}(|\Delta\eta| > 2)$ and $v_3^{\mathrm{sub}}\{2\}(|\Delta\eta| > 2)$ are from Ref. [50]. Error bars and shaded boxes denote statistical and systematic uncertainties, respectively. The shaded area shows the hydrodynamic prediction of $v_3\{4\}$ in *p*Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV [56].

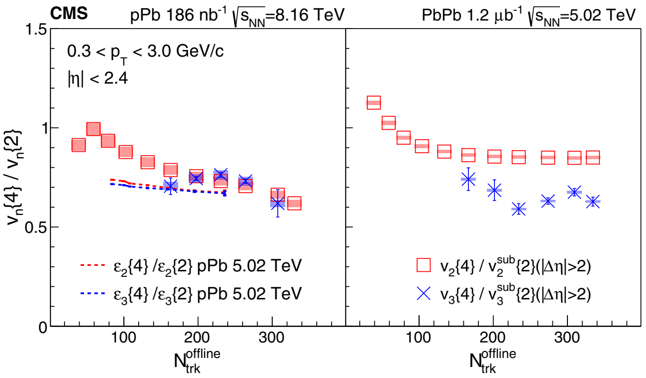

FIG. 2. The ratios of four- and two-particle harmonics ($v_2\{4\}/v_2\{2\}$ and $v_3\{4\}/v_3\{2\}$) shown for *p*Pb $\sqrt{s_{NN}} = 8.16$ TeV (left) and PbPb $\sqrt{s_{NN}} = 5.02$ TeV (right) collisions as a function of $N_{\mathrm{trk}}^{\mathrm{offline}}$. Error bars and shaded boxes denote statistical and systematic uncertainties, respectively. The dashed curves show a hydrodynamics-motivated initial-state fluctuation calculation of eccentricities $\varepsilon_n\{m\}$ for *p*Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV [45].

is expected if there is a significant fluctuation component, which is expected to increase the two-particle correlation results and decrease the multiparticle correlation results, as compared to case where fluctuations are absent [46]. With increasing $N_{\mathrm{trk}}^{\mathrm{offline}}$, the $v_2\{4\}$, $v_2\{6\}$, and $v_2\{8\}$ values all rise in PbPb collisions, while they fall slightly in *p*Pb collisions. This might suggest that the fluctuation-driven component of the eccentricity, as compared to the component arising from the lenticular overlap geometry, is decreasing with increasing multiplicity in the PbPb system. The v_3 values are comparable for both systems, as expected if this higher-order harmonic is dominated by fluctuation behavior. A (3+1)-dimensional event-by-event viscous hydrodynamic calculation of the four-particle cumulant $v_3\{4\}$ for *p*Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV [56] is also shown in Fig. 1 as a gray band. This calculation, with an entropy distribution taken as a two-dimensional Gaussian of width $\sigma = 0.4$ fm and having a shear viscosity-to-entropy ratio of $\eta/s = 0.08$, is found to be consistent with the data.

Figure 2 shows the ratios $v_2\{4\}/v_2\{2\}$ and $v_3\{4\}/v_3\{2\}$ for both the *p*Pb and PbPb systems. For *p*Pb collisions, the ratios for v_2 and v_3 are similar within uncertainties, which is consistent with having both the second- and third-order harmonics arising from the same initial-state fluctuation mechanism. Comparing the *p*Pb and PbPb systems, the v_3 ratios are comparable for both systems, while the v_2 ratios are higher in PbPb than in *p*Pb for higher $N_{\mathrm{trk}}^{\mathrm{offline}}$ values, again reflecting the larger geometric contribution for the heavier system collisions. The v_2 ratio for PbPb collisions saturates at large multiplicity while, for *p*Pb collisions, the ratio continues to decrease as the multiplicity increases.

Cumulants can also be constructed for the eccentricities of the matter distribution in the initial state, $\varepsilon_n\{m\}$. In the hydrodynamic picture, the $v_n\{m\}$ values are proportional to $\varepsilon_n\{m\}$, with $v_n\{m\} = k_n\varepsilon_n\{m\}$, where k_n reflects the medium properties and does not depend on the order of the cumulant. Therefore, ratios of different cumulant v_n values can directly probe properties of initial-state eccentricity. This is shown in Fig. 2 based on a Glauber model initial condition simulated using the TRENTo framework [57], and assuming a width $\sigma = 0.3$ fm of the source associated with each nucleon [45]. The calculations were done for *p*Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV by varying the geometric overlap of the colliding nuclei. It should be noted that the two-particle correlation results were obtained with a large pseudorapidity gap of $|\Delta\eta| > 2$. Earlier experimental *p*Pb results at $\sqrt{s_{NN}} = 5.02$ TeV have shown that this gap can lead to a reduction in the observed $v_2^{\mathrm{sub}}\{2\}(|\Delta\eta| > 2)$ values by 10% resulting from event-plane fluctuations [58]. This gap dependence is not directly determined in the current measurement and, consequently, the reported values are not corrected for this effect. However, assuming a 10% gap-related reduction in the two-particle $v_2\{2\}$ values with, in the absence of a gap, the $v_2\{4\}$ values not being similarly affected, the reported values of $v_2\{4\}/v_2\{2\}$ might be too high by 10%.

In Fig. 3, the ratios $v_2\{6\}/v_2\{4\}$ and $v_2\{8\}/v_2\{6\}$ are shown as a function of the ratio $v_2\{4\}/v_2\{2\}$ for *p*Pb collisions at $\sqrt{s_{NN}} = 8.16$ TeV and compared to calculations based on fluctuation-driven eccentricities [42] with a universal power law distribution assumed for the eccentricities instead of a two-dimensional Gaussian distribution. These results are similar to those previously reported in Ref. [38] for *p*Pb at $\sqrt{s_{NN}} = 5.02$ TeV, as shown in the figure, but with greatly reduced statistical uncertainties. Within the uncertainties, the model calculations for both the $v_2\{6\}/v_2\{4\}$ and $v_2\{8\}/v_2\{6\}$ ratios agree with the experimental results. The agreement improves if the reduced correlation resulting from the $v_2^{\mathrm{sub}}\{2\}(|\Delta\eta| > 2)$ pseudorapidity gap is also considered. The agreement of the calculations with the data shows that the differences found among the multiparticle cumulant results for the v_2 harmonic can be described by non-Gaussian initial-state fluctuations. The precise measurement of the ratio results confirms the hypothesis that the multiparticle correlations originate from the product of single-particle

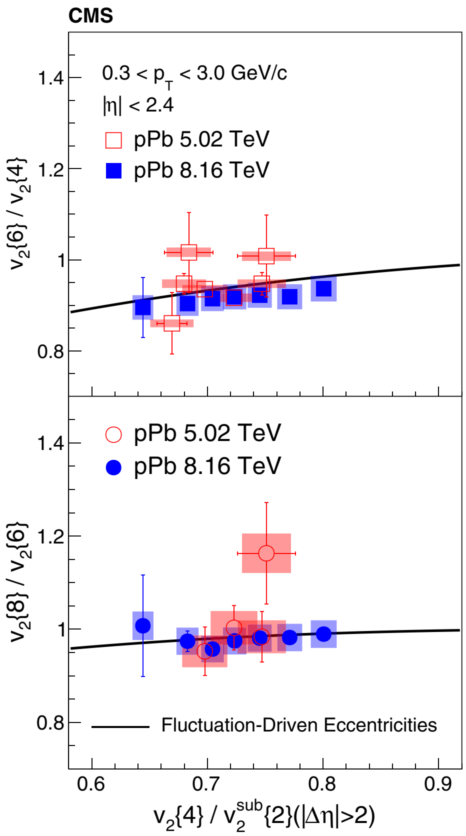

FIG. 3. Cumulant ratios $v_2\{6\}/v_2\{4\}$ (upper) and $v_2\{8\}/v_2\{6\}$ (lower) as a function of $v_2\{4\}/v_2^{\mathrm{sub}}\{2\}$ in *p*Pb collisions at $\sqrt{s_{NN}} =$ 5.02 TeV [38] and 8.16 TeV. Error bars and shaded areas denote statistical and systematic uncertainties, respectively. The solid curves show the expected behavior based on a hydrodynamics-motivated study of the role of initial-state fluctuations [42].

correlations arising from source fluctuations with respect to overall collision geometry. This is a fundamental assumption of both the hydrodynamic [45] and the color glass condensate model calculations [34].

V. SUMMARY

In summary, the azimuthal anisotropies for *p*Pb collisions at $\sqrt{s_{NN}} = 8.16$ TeV and PbPb collisions at $\sqrt{s_{NN}} =$ 5.02 TeV are studied as a function of the final-state particle multiplicities with the CMS experiment. The v_2 Fourier coefficient is determined using cumulants obtained with four-, six-, and eight-particle correlations with greatly increased precision compared to previous measurements. The higher-order $v_3\{4\}$ coefficient is reported for the first time for a small system. For *p*Pb collisions, the ratios $v_2\{4\}/v_2\{2\}$ and $v_3\{4\}/v_3\{2\}$ are comparable, consistent with a purely fluctuation-driven origin for the azimuthal asymmetry. Both the *p*Pb and PbPb systems have very similar v_3 coefficients for the cumulant orders studied, indicating a similar, fluctuation-driven initial-state geometry. In contrast, both the magnitude of the v_2 coefficients and the $v_2\{4\}/v_2\{2\}$ ratio are larger for PbPb collisions, as expected if the overall collision geometry dominates. The v_2 cumulant ratios for *p*Pb collisions are consistent with a collective flow behavior that originates from and is proportional to the initial-state anisotropy.

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