Higher Harmonic Anisotropic Flow Measurements of Charged Particles in Pb-Pb Collisions at $\sqrt{s_{NN}} = 2.76$ TeV

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We report on the first measurement of the triangular v_3, quadrangular v_4, and pentagonal v_5 charged particle flow in Pb-Pb collisions at $\sqrt{s_{\rm NN}} = 2.76$ TeV measured with the ALICE detector at the CERN Large Hadron Collider. We show that the triangular flow can be described in terms of the initial spatial anisotropy and its fluctuations, which provides strong constraints on its origin. In the most central events, where the elliptic flow v_2 and v_3 have similar magnitude, a double peaked structure in the two-particle azimuthal correlations is observed, which is often interpreted as a Mach cone response to fast partons. We show that this structure can be naturally explained from the measured anisotropic flow Fourier coefficients.

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The quark-gluon plasma is a state of matter whose existence at high-energy density is predicted by quantum chromodynamics. The creation of this state of matter in the laboratory and the study of its properties are the main goals of the ultrarelativistic nuclear collision program. One of the experimental observables that is sensitive to the properties of this matter is the azimuthal distribution of particles in the plane perpendicular to the beam direction. When nuclei collide at nonzero impact parameter (noncentral collisions), the geometrical overlap region is anisotropic. This initial spatial asymmetry is converted via multiple collisions into an anisotropic momentum distribution of the produced particles [1].

The azimuthal anisotropy is usually characterized by the Fourier coefficients [2,3]:

$$v_n = \langle \cos[n(\phi - \Psi_n)] \rangle, \tag{1}$$

where ϕ is the azimuthal angle of the particle, Ψ_n is the angle of the initial state spatial plane of symmetry, and n is the order of the harmonic. Because the planes of symmetry Ψ_n are not known experimentally, the anisotropic flow coefficients are estimated from measured correlations between the observed particles. The second Fourier coefficient v_2 is called elliptic flow and has been studied in detail in recent years [4]. Large values of elliptic flow at the LHC were recently observed by the ALICE Collaboration [5].

In a noncentral heavy ion collision the beam axis and the impact parameter define the reaction plane $\Psi_{\rm RP}$. Assuming a smooth matter distribution in the colliding nuclei, the plane of symmetry is the reaction plane $\Psi_n = \Psi_{\rm RP}$ and the odd Fourier coefficients are zero by symmetry. However, due to fluctuations in the matter distribution, including contributions from fluctuations in the positions of the participating nucleons in the nuclei, the plane of symmetry fluctuates event by event around the reaction plane. This plane of symmetry is determined by the participating nucleons and is therefore called the participant plane $\Psi_{\rm PP}$ [6]. Event-by-event fluctuations of the spatial asymmetry generate additional odd harmonic symmetry planes Ψ_n, which are predicted to give rise to the odd harmonics like v_3 and v_5 [7–13].

The large elliptic flow at the Relativistic Heavy Ion Collider (RHIC) [14,15] and at the LHC [5] provides compelling evidence for strongly interacting matter which appears to behave like an almost perfect (inviscid) fluid [16]. Deviations from this ideal case are controlled by the ratio η/s of shear viscosity to entropy density. Because the effect of shear viscosity is to dampen all coefficients, with a larger decrease for higher order coefficients [12,17], it has been argued that the magnitude and transverse momentum dependence of the coefficients v_3 and v_5 is a more sensitive measure of η/s [11]. Therefore a measurement of these Fourier coefficients at the LHC provides strong constraints on the initial geometry, its fluctuations, as well as on the shear viscosity to entropy density ratio.

In this Letter we report the first measurement of the anisotropic flow coefficients v_3, v_4, and v_5 of charged particles in Pb-Pb collisions at the center of mass energy per nucleon pair $\sqrt{s_{NN}} = 2.76$ TeV, with the ALICE detector [18–20]. The data were recorded in November 2010 during the first run with heavy ions at the LHC.

For this analysis the ALICE inner tracking system (ITS) and the time projection chamber (TPC) were used to reconstruct charged particle tracks. The VZERO counters and the silicon pixel detector (SPD) were used for the trigger. The VZERO counters are two scintillator arrays providing both amplitude and timing information, covering

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the pseudorapidity range $2.8 < \eta < 5.1$ (VZERO-A) and $-3.7 < \eta < -1.7$ (VZERO-C). The SPD is the innermost part of the ITS, consisting of two cylindrical layers of hybrid silicon pixel assemblies covering the range of $|\eta| < 2.0$ and $|\eta| < 1.4$ for the inner and outer layer, respectively. The minimum-bias interaction trigger required the following three conditions [21]: (i) two pixel chip hits in the outer layer of the silicon pixel detectors, (ii) a signal in VZERO-A, and (iii) a signal in VZERO-C. Deflection of neutral recoils, which is sensitive to the directed flow of spectators, is measured with two neutron zero degree calorimeters (ZDCs) installed on each side, 114 m from the interaction point. Only events with a vertex found within 7 cm from the center of the detector along the beam line were used in the analysis. This is to ensure a uniform acceptance in the central pseudorapidity region $|\eta| < 0.8$. An event sample of 5×10^6 Pb-Pb collisions passed the selection criteria and was analyzed as a function of collision centrality, determined by cuts on the VZERO multiplicity as described in [21]. Based on the strong correlation between the collision centrality determined by the ZDC, TPC, SPD, and VZERO detectors, the resolution in centrality is found to be <0.5% rms for the most central collisions (0%–5%), increasing towards 2% rms for peripheral collisions (e.g., 70%–80%). This resolution is also in agreement with our Monte Carlo (MC) Glauber [22] studies.

The analysis was, as in [5], performed using tracks measured with only the TPC and for tracks using the ITS and TPC. These two measurements have very different acceptance and efficiency corrections, and provide an estimate of a possible residual bias which may be present, after correction, for small values of the harmonics [23]. For both measurements, charged particles were selected with high reconstruction efficiency and minimal contamination from photon conversions and secondary charged particles produced in the detector material as described in [5]. From Monte Carlo simulations of HIJING [24] events using a GEANT3 [25] detector simulation and event reconstruction, the estimated contamination is less than 6% at $p_t = 0.2$ GeV/c and drops below 1% at $p_t > 1$ GeV/c. In this Letter we present the results obtained using the TPC standalone tracks, because of the smaller corrections for the azimuthal acceptance.

We report the anisotropic flow coefficients v_n obtained from two-particle correlations and from a four-particle cumulant method [26], denoted $v_n\{2\}$ and $v_n\{4\}$, respectively. To calculate the four-particle cumulants we used the method proposed in [23]. The $v_n\{2\}$ and $v_n\{4\}$ measurements have different sensitivity to flow fluctuations and contributions from nonflow. The nonflow contribution arises from correlations between the particles unrelated to the initial geometry. The contribution from flow fluctuations is positive for $v_n\{2\}$ while it is negative for $v_n\{4\}$ [27]. Because the odd harmonics are expected to be completely due to event-by-event fluctuations in the initial spatial geometry, the comparison of these two- and four-particle cumulants provides a strong constraint on the initial spatial geometry fluctuations.

The nonflow contribution to the two-particle correlations is not known and might be significant. We utilize four methods to study and correct for nonflow contributions to the $v_n\{2\}$ coefficients. First, we compare $v_n\{2\}$ for like and unlike charge-sign combinations since they have different contributions from resonance decay and jet fragmentation. Second, we used different pseudorapidity gap requirements between the two particles since larger gaps reduce the nonflow contributions. Third, we utilize HIJING (a perturbative quantum chromodynamics inspired model which does not include flow) to estimate these contributions, and, finally, we estimate the nonflow from the correlations measured in proton-proton collisions. All of these methods indicate that nonflow effects are smaller than 10%. In this Letter we use the dependence of the correlations on pseudorapidity distance between particles as an estimate of nonflow.

Figure 1(a) shows v_2, v_3, and v_4 integrated over the p_t range $0.2 < p_t < 5.0$ GeV/c as a function of centrality. The $v_2\{2\}$, $v_3\{2\}$, and $v_4\{2\}$ are shown for particles with $|\Delta\eta| > 1.0$ and corrected for the estimated remaining nonflow contribution based on the correlation measured in HIJING. The total systematic uncertainty is shown as a band and fully includes this residual correction. The measured v_3 is smaller than v_2 and does not depend strongly on centrality. The v_3 is compatible with predictions for Pb-Pb collisions from a hydrodynamic model calculation with Glauber initial conditions and $\eta/s = 0.08$ and larger than for MC-KLN (Kharzeev-Levin-Nardi) color glass condensate (CGC) [28] initial conditions with $\eta/s = 0.16$ [11], suggesting a small value of η/s for the matter created in these collisions. The $v_3\{4\}$ is about a factor 2 smaller than the two-particle measurement which can, as explained in [29], be understood if v_3 originates predominantly from event-by-event fluctuations of the initial spatial geometry. For these event-by-event fluctuations of the spatial geometry, the symmetry plane Ψ_3 is expected to be uncorrelated (or correlated very weakly [30]) with the reaction plane Ψ_{RP} and with Ψ_2. We evaluate the correlations between Ψ_3 and Ψ_{RP} using the first-order event plane from the ZDC via $v_{3/\Psi_{\mathrm{RP}}} = \langle\cos(3\phi_1 - 3\Psi_{\mathrm{RP}})\rangle$ and the correlation between Ψ_3 and Ψ_2 with a five-particle correlator $\langle\cos(3\phi_1 + 3\phi_2 - 2\phi_3 - 2\phi_4 - 2\phi_5)\rangle/v_2^3 = v^2_{3/\Psi_2}$. In Fig. 1(a) $v_{3/\Psi_{\mathrm{RP}}}$ and v^2_{3/Ψ_2} are shown as a function of centrality. These correlations are indeed, within uncertainties, consistent with zero, as expected from a triangular flow that originates predominantly from event-by-event fluctuations of the initial spatial geometry.

To investigate the role of viscosity further we calculate the ratios v_2/ε_2 and v_3/ε_3, where ε_2 and ε_3 are the ellipticity and triangularity of the initial spatial geometry, defined by

$$\varepsilon_n = -\frac{\langle r^2 \cos n(\phi - \Psi_n)\rangle}{\langle r^2 \rangle}, \tag{2}$$

where the brackets denote an average which traditionally is taken over the position of participating (wounded) nucleons in a Glauber model [22].

Under the assumption that v_n is proportional to ε_n, $v_n\{2\}$ is proportional to $\varepsilon_n\{2\}$ [27]. Figure 1(b) shows the ratios v_n/ε_n for eccentricities calculated with a Glauber and a MC-KLN CGC [28] model, denoted by $\varepsilon_n^W\{2\}$ and $\varepsilon_n^{\rm CGC}\{2\}$, respectively. We find that for a Glauber model the magnitude of $v_3\{2\}/\varepsilon_3\{2\}$ is smaller than $v_2\{2\}/\varepsilon_2\{2\}$, which would indicate significant viscous corrections. For MC-KLN CGC calculations the ratios $v_2\{2\}/\varepsilon_2\{2\}$ and $v_3\{2\}/\varepsilon_3\{2\}$ are almost equal for the most central collisions, as expected for an almost ideal fluid [11]. In addition, we notice that the ratio $v_3\{2\}/\varepsilon_3\{2\}$ decreases faster than $v_2\{2\}/\varepsilon_2\{2\}$ toward more peripheral collisions, which is expected due to larger viscous corrections to v_3.

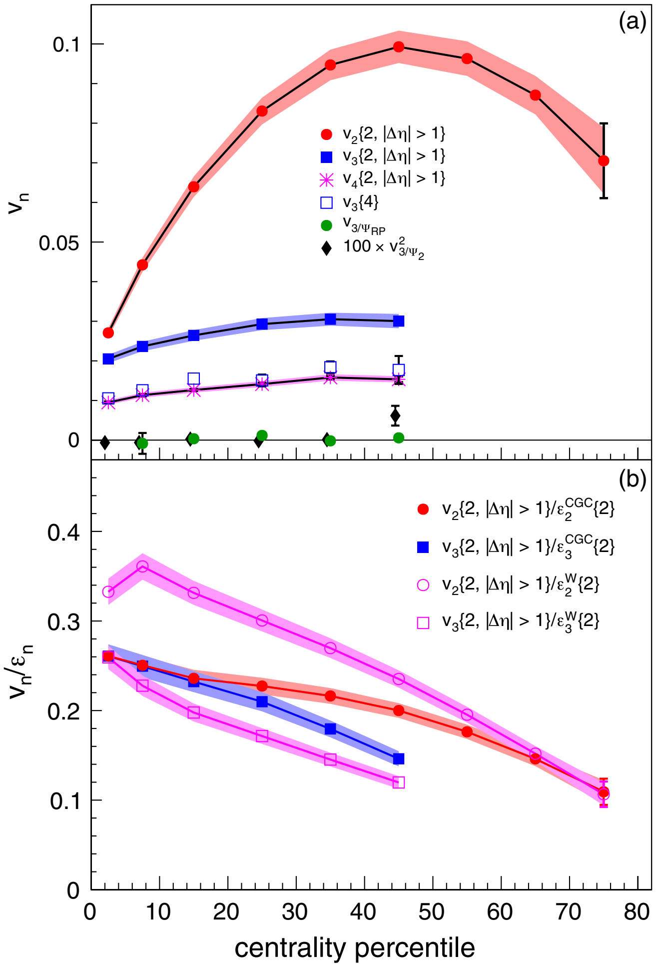

FIG. 1 (color online). (a) v_2, v_3, and v_4 integrated over the p_t range $0.2 < p_t < 5.0$ GeV/c as a function of event centrality, with the more central (peripheral) collisions shown on the left- (right-)hand side, respectively. Full and open squares show $v_3\{2\}$ and $v_3\{4\}$, respectively. In addition we show v^2_{3/Ψ_2} and $v_{3/\Psi_{\rm RP}}$, which represent the triangular flow measured relative to the second order event plane and the reaction plane, respectively (for the definitions, see text). (b) $v_2\{2, |\Delta\eta| > 1\}$ and $v_3\{2, |\Delta\eta| > 1\}$ divided by the corresponding eccentricity versus centrality percentile for Glauber [22] and MC-KLN CGC [28] initial conditions.

The centrality dependence of the triangular flow differs significantly from that of elliptic flow. This might be due to two reasons: either the centrality dependence of the spatial ellipticity and triangularity are different and/or the viscous effects are different. However, in a small centrality range, such as 0%–5%, viscous effects do not change much and there one might be directly sensitive to the change in the initial spatial geometry. Our calculations show that even in this small centrality range, the ratio $\varepsilon_2/\varepsilon_3$ changes significantly, which allows us to investigate further the geometrical origin of elliptical and triangular flow. In Fig. 2 $v_2\{2\}$ and $v_3\{2\}$ are plotted in 1% centrality bins for the 5% most central collisions. We observe that $v_3\{2\}$ does not change much versus centrality (as would be expected if v_3 is dominated by event-by-event fluctuations of the initial geometry) while $v_2\{2\}$ increases by about 60%. We compare this dependence of $v_n\{2\}$ to the centrality dependence of the eccentricities $\varepsilon_n\{2\}$ for initial conditions from MC-KLN CGC and Monte Carlo Glauber model. We observe that the weak dependence of $v_3\{2\}$ is described by both calculations while the relative strong dependence of $v_2\{2\}$ on centrality is only described for the MC-KLN CGC initial conditions.

The harmonics $v_2\{2\}$, $v_3\{2\}$, $v_4\{2\}$, and $v_5\{2\}$ as a function of transverse momentum are shown for the 30%–40%, 0%–5%, and 0%–2% centrality classes in Fig. 3. For the 30%–40% centrality class the results are compared to hydrodynamic predictions using Glauber initial conditions for different values of η/s [31]. We observe that, at low p_t, the different p_t dependence of v_2 and v_3 is described well by these hydrodynamic predictions. However, the

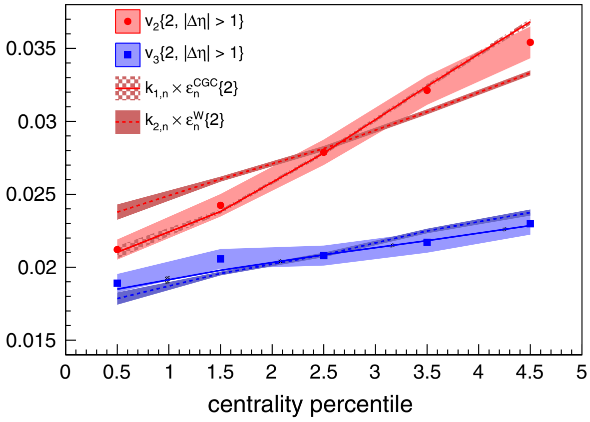

FIG. 2 (color online). v_2 and v_3 as a function of centrality for the 5% most central collisions compared to calculations of the spatial eccentricities, $\varepsilon_n^W\{2\}$ and $\varepsilon_n^{\rm CGC}\{2\}$. The eccentricities have been scaled to match the 2%–3% data using k_1 and k_2.

magnitude of $v_2(p_t)$ is better described by $\eta/s = 0$ while for $v_3(p_t)$ $\eta/s = 0.08$ provides a better description. We anticipate future comparisons utilizing MC-KLN initial conditions.

For central collisions 0%–5% we observe that at $p_t \approx 2$ GeV/c v_3 becomes equal to v_2 and at $p_t \approx 3$ GeV/c v_4 also reaches the same magnitude as v_2 and v_3. For more central collisions 0%–2%, we observe that v_3 becomes equal to v_2 at lower p_t and reaches significantly larger values than v_2 at higher p_t. The same is true for v_4 compared to v_2.

We compare the structures found with azimuthal correlations between triggered and associated particles to those described by the measured v_n components. The two-particle azimuthal correlations are measured by calculating

$$C(\Delta\phi) \equiv \frac{N_{\rm mixed}}{N_{\rm same}} \frac{dN_{\rm same}/d\Delta\phi}{dN_{\rm mixed}/d\Delta\phi}, \qquad (3)$$

where $\Delta\phi = \phi_{\rm trig} - \phi_{\rm assoc}$. $dN_{\rm same}/d\Delta\phi$ ($dN_{\rm mixed}/d\Delta\phi$) is the number of associated particles as function of $\Delta\phi$ within the same (different) event, and $N_{\rm same}$ ($N_{\rm mixed}$) the total number of associated particles in $dN_{\rm same}/d\Delta\phi$ ($dN_{\rm mixed}/d\Delta\phi$). Figure 4 shows the azimuthal correlation observed in very central collisions 0%–1%, for trigger particles in the range $2 < p_t < 3$ GeV/c with associated particles in $1 < p_t < 2$ GeV/c for pairs in $|\Delta\eta| > 1$. We observe a clear doubly peaked correlation structure centered opposite to the trigger particle. This feature has been observed at lower energies in broader centrality bins [32,33], but only after subtraction of the elliptic flow component. This two-peak structure has been interpreted as an indication for various jet-medium modifications (i.e., Mach cones) [32,33] and more recently as a manifestation of triangular flow [10–13]. We therefore compare the azimuthal correlation shape expected from v_2, v_3, v_4, and v_5 evaluated at corresponding transverse momenta with the measured two-particle azimuthal triggered correlation and find that the combination of these harmonics gives a natural description of the observed correlation structure on the away side.

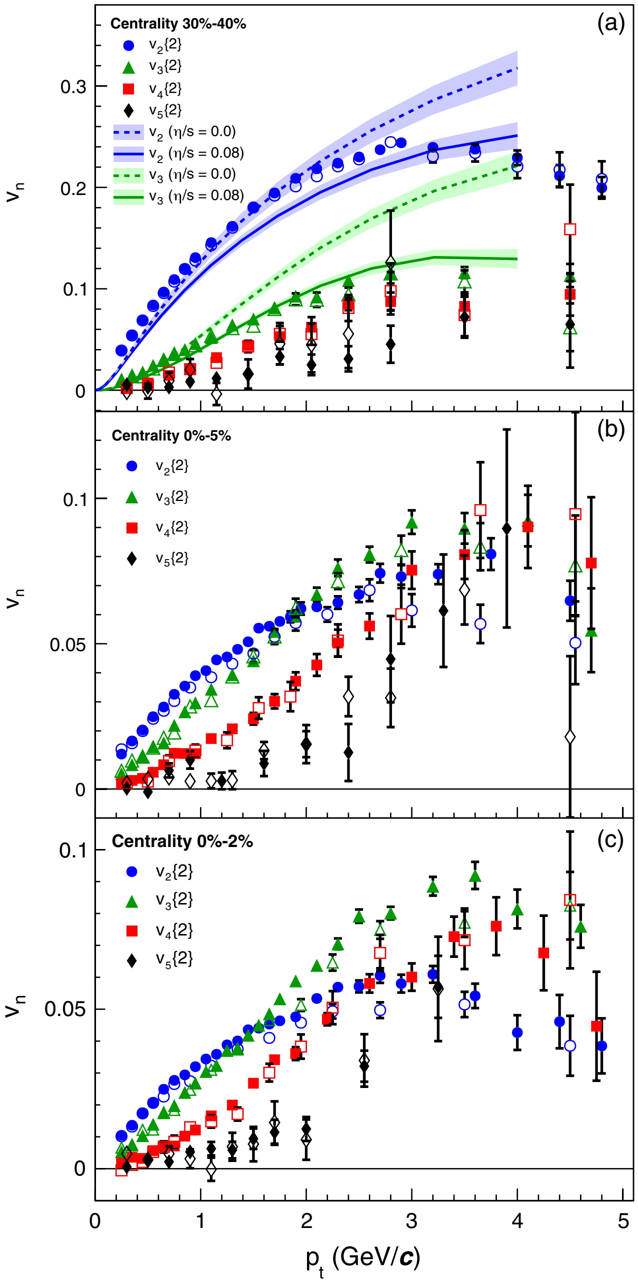

FIG. 3 (color online). v_2, v_3, v_4, v_5 as a function of transverse momentum and for three event centralities. The full and open symbols are for $\Delta\eta > 0.2$ and $\Delta\eta > 1.0$, respectively. (a) 30%–40% compared to hydrodynamic model calculations, (b) 0%–5% centrality percentile, (c) 0%–2% centrality percentile.

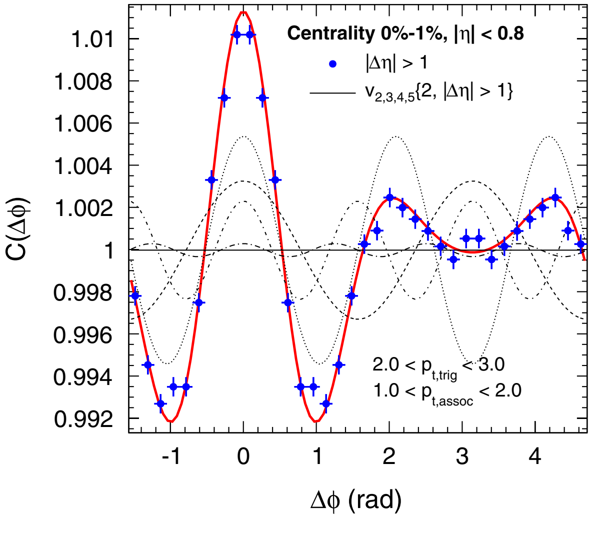

FIG. 4 (color online). The two-particle azimuthal correlation, measured in $0 < \Delta\phi < \pi$ and shown symmetrized over 2π, between a trigger particle with $2 < p_t < 3$ GeV/c and an associated particle with $1 < p_t < 2$ GeV/c for the 0%–1% centrality class. The solid red line shows the sum of the measured anisotropic flow Fourier coefficients v_2, v_3, v_4, and v_5 (dashed lines).

In summary, we have presented the first measurement at the LHC of triangular v_3, quadrangular v_4, and pentagonal particle flow v_5. We have shown that the triangular flow and its fluctuations can be understood from the initial spatial anisotropy. The transverse momentum dependence of v_2 and v_3 compared to model calculations favors a small value of the shear viscosity to entropy ratio η/s. For the 5% most central collisions we have shown that v_2 rises strongly with centrality in 1% centrality percentiles. The strong change in v_2 and the small change in v_3 as a function of centrality in these 1% centrality percentile classes follow the centrality dependence of the corresponding spatial anisotropies. The two-particle azimuthal correlation for the 0%–1% centrality class exhibits a double peak structure around $\Delta\phi \sim \pi$ (the "away side") without the subtraction of elliptic flow. We have shown that the measured anisotropic flow Fourier coefficients give a natural description of this structure.

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[1] J. Y. Ollitrault, Phys. Rev. D **46**, 229 (1992).
[2] S. Voloshin and Y. Zhang, Z. Phys. C **70**, 665 (1996).
[3] A. M. Poskanzer and S. A. Voloshin, Phys. Rev. C **58**, 1671 (1998).
[4] S. A. Voloshin, A. M. Poskanzer, and R. Snellings, in *Relativistic Heavy Ion Physics*, Landolt-Bornstein Vol. 1 (Springer-Verlag, Berlin, 2010), pp. 5–54.
[5] K. Aamodt *et al.* (ALICE Collaboration), Phys. Rev. Lett. **105**, 252302 (2010).
[6] S. Manly *et al.* (PHOBOS Collaboration), Nucl. Phys. **A774**, 523 (2006).
[7] A. P. Mishra, R. K. Mohapatra, P. S. Saumia, and A. M. Srivastava, Phys. Rev. C **77**, 064902 (2008).
[8] A. P. Mishra, R. K. Mohapatra, P. S. Saumia, and A. M. Srivastava, Phys. Rev. C **81**, 034903 (2010).
[9] J. Takahashi *et al.*, Phys. Rev. Lett. **103**, 242301 (2009).
[10] B. Alver and G. Roland, Phys. Rev. C **81**, 054905 (2010); **82**, 039903(E) (2010).
[11] B. H. Alver, C. Gombeaud, M. Luzum, and J. Y. Ollitrault, Phys. Rev. C **82**, 034913 (2010).
[12] D. Teaney and L. Yan, arXiv:1010.1876 [Phys. Rev. C (to be published)].
[13] M. Luzum, Phys. Lett. B **696**, 499 (2011).
[14] K. H. Ackermann *et al.* (STAR Collaboration), Phys. Rev. Lett. **86**, 402 (2001).
[15] S. S. Adler *et al.* (PHENIX Collaboration), Phys. Rev. Lett. **91**, 182301 (2003).
[16] P. K. Kovtun, D. T. Son, and A. O. Starinets, Phys. Rev. Lett. **94**, 111601 (2005).
[17] G.-Y. Qin, H. Petersen, S. A. Bass, and B. Muller, Phys. Rev. C **82**, 064903 (2010).
[18] ALICE Collaboration, JINST **3**, S08002 (2008).
[19] ALICE Collaboration, J. Phys. G **30**, 1517 (2004).
[20] ALICE Collaboration, J. Phys. G **32**, 1295 (2006).

[21] K. Aamodt *et al.* (ALICE Collaboration), Phys. Rev. Lett. **106**, 032301 (2011).
[22] M. L. Miller, K. Reygers, S. J. Sanders, and P. Steinberg, Annu. Rev. Nucl. Part. Sci. **57**, 205 (2007).
[23] A. Bilandzic, R. Snellings, and S. Voloshin, Phys. Rev. C **83**, 044913 (2011).
[24] M. Gyulassy and X.-N. Wang, Comput. Phys. Commun. **83**, 307 (1994); X. N. Wang and M. Gyulassy, Phys. Rev. D **44**, 3501 (1991).
[25] R. Brun *et al.*, CERN Program Library Long Write-up, W5013, GEANT Detector Description and Simulation Tool, 1994.
[26] N. Borghini, P. M. Dinh, and J. Y. Ollitrault, Phys. Rev. C **64**, 054901 (2001).
[27] M. Miller and R. Snellings, arXiv:nucl-ex/0312008.
[28] H.-J. Drescher and Y. Nara, Phys. Rev. C **76**, 041903 (2007).
[29] R. S. Bhalerao, M. Luzum, and J. Y. Ollitrault, arXiv:1104.4740.
[30] J. L. Nagle and M. P. McCumber, Phys. Rev. C **83**, 044908 (2011).
[31] B. Schenke, S. Jeon, and C. Gale, arXiv:1102.0575.
[32] A. Adare *et al.* (PHENIX Collaboration), Phys. Rev. C **78**, 014901 (2008).
[33] M. M. Aggarwal *et al.* (STAR Collaboration), Phys. Rev. C **82**, 024912 (2010).

K. Aamodt,[1] B. Abelev,[2] A. Abrahantes Quintana,[3] D. Adamová,[4] A. M. Adare,[5] M. M. Aggarwal,[6]
G. Aglieri Rinella,[7] A. G. Agocs,[8] A. Agostinelli,[9] S. Aguilar Salazar,[10] Z. Ahammed,[11] N. Ahmad,[12]
A. Ahmad Masoodi,[12] S. U. Ahn,[13,14] A. Akindinov,[15] D. Aleksandrov,[16] B. Alessandro,[17] R. Alfaro Molina,[10]
A. Alici,[9,7,18] A. Alkin,[19] E. Almaráz Aviña,[10] T. Alt,[20] V. Altini,[21,7] I. Altsybeev,[22] C. Andrei,[23] A. Andronic,[24]
V. Anguelov,[20,25] C. Anson,[26] T. Antičić,[27] F. Antinori,[28] P. Antonioli,[29] L. Aphecetche,[30] H. Appelshäuser,[31]
N. Arbor,[32] S. Arcelli,[9] A. Arend,[31] N. Armesto,[33] R. Arnaldi,[17] T. Aronsson,[5] I. C. Arsene,[24] M. Arslandok,[31]
A. Asryan,[22] A. Augustinus,[7] R. Averbeck,[24] T. C. Awes,[34] J. Äystö,[35] M. D. Azmi,[12] M. Bach,[20] A. Badalà,[36]
Y. W. Baek,[13,14] R. Bailhache,[31] R. Bala,[17] R. Baldini Ferroli,[18] A. Baldisseri,[37] A. Baldit,[13] J. Bán,[38] R. C. Baral,[39]
R. Barbera,[40] F. Barile,[21] G. G. Barnaföldi,[8] L. S. Barnby,[41] V. Barret,[13] J. Bartke,[42] M. Basile,[9] N. Bastid,[13]
B. Bathen,[43] G. Batigne,[30] B. Batyunya,[44] C. Baumann,[31] I. G. Bearden,[45] H. Beck,[31] I. Belikov,[46] F. Bellini,[9]
R. Bellwied,[47,48] E. Belmont-Moreno,[10] S. Beole,[49] I. Berceanu,[23] A. Bercuci,[23] E. Berdermann,[24] Y. Berdnikov,[50]
C. Bergmann,[43] L. Betev,[7] A. Bhasin,[51] A. K. Bhati,[6] L. Bianchi,[49] N. Bianchi,[52] C. Bianchin,[53] J. Bielčík,[54]
J. Bielčíková,[4] A. Bilandzic,[55] E. Biolcati,[7,49] F. Blanco,[48] F. Blanco,[56] D. Blau,[16] C. Blume,[31] M. Boccioli,[7]
N. Bock,[26] A. Bogdanov,[57] H. Bøggild,[45] M. Bogolyubsky,[58] L. Boldizsár,[8] M. Bombara,[41,59] C. Bombonati,[53]
J. Book,[31] H. Borel,[37] A. Borissov,[47] C. Bortolin,[53] S. Bose,[60] F. Bossú,[7,49] M. Botje,[55] S. Böttger,[61] B. Boyer,[62]
P. Braun-Munzinger,[24] L. Bravina,[63] M. Bregant,[30] T. Breitner,[61] M. Broz,[64] R. Brun,[7] E. Bruna,[5] G. E. Bruno,[21]
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