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Measurement of two- and four-particle correlations in pPb collisions with CMS

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Measurements of two- and four-particle angular correlations for inclusive charged particles in pPb collisions at $\sqrt{s_{NN}} = 5.02$ TeV are presented over a wide pseudorapidity range, $|\eta| < 2.5$ and full azimuth from the CMS experiment. Results from 2.76 TeV semi peripheral PbPb collision data, recorded during 2011 PbPb running is compared to 31 nb^{-1} of pPb data, collected during the 2013 LHC running, having similar multiplicities. The two-particle azimuthal correlation technique and a four-particle cumulant method is used to extract the second-order (v_2) and third-order (v_3) anisotropy harmonics. The four-particle cumulant method is used to further explore the multi-particle nature of correlations in pPb collisions. We observe a remarkable similarity in the v_3 signal as a function of multiplicity between pPb and PbPb systems.

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PoS(EPS-HEP 2013)194

1. Introduction

Studies of multi-particle correlations play a major role in characterizing the underlying mechanism of particle production in high-energy collisions of protons and nuclei. Long-range (large $|\Delta\eta|$) correlations, observed in two-dimensional (2D) $\Delta\eta$-$\Delta\phi$ co-ordinates in nucleus-nucleus (AA) collisions are of particular interest, where $\Delta\eta$ and $\Delta\phi$ are the relative pseudorapidity and azimuthal differences between two particles. The term "elliptic flow" (v_2), which is the second harmonic in the Fourier expansion of the azimuthal anisotropy of the produced particles is attributed to be the major source of such long-range correlations [1]. Elliptic flow contributes a $\cos(2\Delta\phi)$ type modulation to the two-particle correlation function over a broad range in $\Delta\eta$ [2]. Higher-order anisotropic flow components arising due to initial-state geometry fluctuations also play a major role in contributing to these long-range correlations, in particular the "triangular flow" which contributes a $\cos(3\Delta\phi)$ component [3, 4]. The CMS collaboration recently reported a similar long-range near-side ($\Delta\phi \sim 0$) correlation structure in the highest multiplicity proton-proton (pp) [5] and proton-lead (pPb) [6] collisions at the LHC. Evidence of such correlations was also reported in deuteron-gold collisions at $\sqrt{s_{NN}}$ = 200 GeV at RHIC [7]. In AA collisions the prevailing interpretation of the long-range correlations is the collective flow in the produced system. However, collective flow phenomenon is generally not expected to be present in small-size systems because in a hydrodynamic evolution the mean free path between the produced particles must be small compared to the size of the collision volume. However, we do see similar correlations in small systems such as pPb collisions. It is therefore natural to ask if multi-particle correlations exist. If so, it will yield further support to the hydrodynamic picture. Since hydrodynamic flow is intrinsically a multi-particle phenomenon, it can be probed more directly using multi-particle correlation (or cumulant) techniques [8] besides two-particle correlations.

We present a detailed analysis of two- and four particle angular correlations in pPb collisions at $\sqrt{s_{NN}} = 5.02$ TeV. These results are based on dedicated high-multiplicity triggers, which enabled access to very high multiplicity pPb events. The correlation measurements from pPb collisions are compared to mid-central ($\sim$ 55% centrality) PbPb collisions with similar multiplicities. The two-particle long-range correlation data are presented in terms of anisotropy harmonics (v_2 and v_3), which provide a measure of relative correlation magnitude w.r.t. the uncorrelated background. We also measured the second harmonic using a 4-particle cumulant method that suppress any non flow correlations.

2. Experimental Setup

The results presented here are primarily based on CMS silicon tracker information. The tracker is located in the 3.8T field of the superconducting solenoid, and it consists of 1440 silicon pixel and 15148 silicon strip detector modules. The silicon tracker measures charged particles within the 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 $p_T \approx 100$ GeV/c.

3. Selections of Events and Tracks

The pPb data set corresponds to an integrated luminosity of about 31 nb^{-1}, assuming an inter-

PoS(EPS-HEP 2013)194

action cross section of 2.1 barns. Because of the asymmetric collision system and the requirement of the LHC to have identical magnetic rigidity of both particle beams, the nucleon-nucleon center-of-mass in pPb collisions is not at rest with respect to the laboratory frame. Particles emitted at η_{cm} = 0 in the nucleon-nucleon center-of-mass frame with be detected at η = -0.465 (clockwise proton beam) or 0.465 (counterclockwise proton beam) in the laboratory frame. Hadronic collisions were selected by requiring a coincidence of at least one HF (Hadron Forward, having an acceptance of $2.9 < |\eta| < 5.2$) calorimeter tower with more than 3 GeV of total energy in each of the HF detectors. Events were also required to contain at least one reconstructed primary vertex within 15 cm of the nominal interaction point along the beam axis and within 0.15 cm transverse to the beam trajectory. At least two reconstructed tracks were required to be associated with the primary vertex. In order to select high-multiplicity pPb collisions, a dedicated high-multiplicity trigger was implemented using the CMS level-1 (L1) and high-level trigger (HLT) systems. Data were taken with thresholds of $N_{\mathrm{trk}}^{\mathrm{online}} > 100, 130$ and 160, 190. For more details, please refer to the CMS publication [9].

4. Analysis Technique

Please refer to Refs. [10] for details on constructing a correlation function. The per-trigger-particle associated yield is defined as

$$\frac{1}{N_{trig}} \frac{d^2N^{pair}}{d\Delta\eta d\Delta\phi} = B(0,0) \times \frac{S(\Delta\eta,\Delta\phi)}{B(\Delta\eta,\Delta\phi)}, \tag{4.1}$$

where $\Delta\eta$ and $\Delta\phi$ are the differences in η and ϕ of the pair. The signal pair distribution, $S(\Delta\eta,\Delta\phi)$, represents the yield of particle pairs normalized by N_{trig} from the same event, $S(\Delta\eta,\Delta\phi) = \frac{1}{N_{\mathrm{trig}}} \frac{d^2N^{same}}{d\Delta\eta d\Delta\phi}$ and the mixed-event pair distribution defined as, $B(\Delta\eta,\Delta\phi) = \frac{1}{N_{\mathrm{trig}}} \frac{d^2N^{Mix}}{d\Delta\eta d\Delta\phi}$, is constructed by pairing the trigger particles in each event with the associated particles from 10 different random events in the same 2 cm wide z_{vtx} range and from the same track multiplicity class.

5. Results

Figure 1 shows the 2D two-particle correlation functions measured in 2.76 TeV PbPb (a) and 5.02 TeV pPb (b) collisions, for pairs of charged particles with $1 \leq p_{\mathrm{T}}^{\mathrm{trig}} < 3$ GeV/c and $1 \leq p_{\mathrm{T}}^{\mathrm{assoc}} < 3$ GeV/c, and with the track multiplicity in the range $220 \leq N_{\mathrm{trk}}^{\mathrm{offline}} < 260$. For both colliding systems, in addition to the correlation peak near ($\Delta\eta$, $\Delta\phi$) = (0,0) due to jet fragmentation, a pronounced long-range structure is seen at $\Delta\phi \approx 0$ extending at least 4.8 units in $|\Delta\eta|$. This structure has been widely reported in AA collisions also [10, 11, 12, 13]. To compare with hydrodynamic predictions of the long-range correlations in pPb collisions, the elliptic (v_2) and triangular (v_3) flow harmonics are extracted from a Fourier decomposition of 1D $\Delta\phi$ correlation functions, $v_2\{2\}$ and $v_3\{2\}$ for long-range region, $|\Delta\eta| > 2$ as shown in Figs. 2 and 3. A four particle cumulant method is also used to extract the $v_2\{4\}$ signal. Figure 2 shows the magnitude of the v_2 signal is found to be larger in PbPb than in pPb by about 30% for $p_{\mathrm{T}} < 2$ GeV/c both for $v_2\{2,|\Delta\eta| > 2\}$ and $v_2\{4\}$ in the same multiplicity range. The differences between the $v_2\{2,|\Delta\eta| > 2\}$ and $v_2\{4\}$ could be attributed to different sensitivity to fluctuations in the initial conditions. It is argued that with the large $\Delta\eta$

PoS(EPS-HEP 2013)194

gap the nonflow is minimized. The main difference is due to fluctuations that increase $v_2\{2\}$ and decrease $v_2\{4\}$. The multiplicity dependence of v_3 for PbPb and pPb collisions, averaged over the

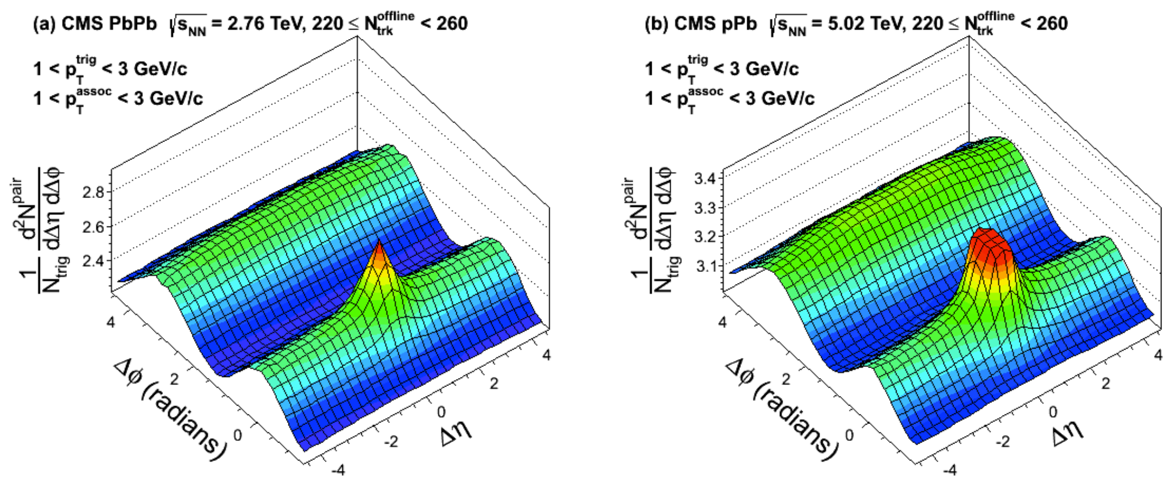

Figure 1: The 2D two-particle correlation functions for (a) 2.76 TeV PbPb and (b) 5.02 TeV pPb collisions for pairs of charged particles with $1 \leq p_T^{trig} < 3$ GeV/c and $1 \leq p_T^{assoc} < 3$ GeV/c within the $220 \leq N_{trk}^{offline} < 260$ multiplicity bin. The sharp near-side peak at $\Delta\phi = \Delta\eta = 0$, from jet correlations is truncated to emphasize the structure outside that region.

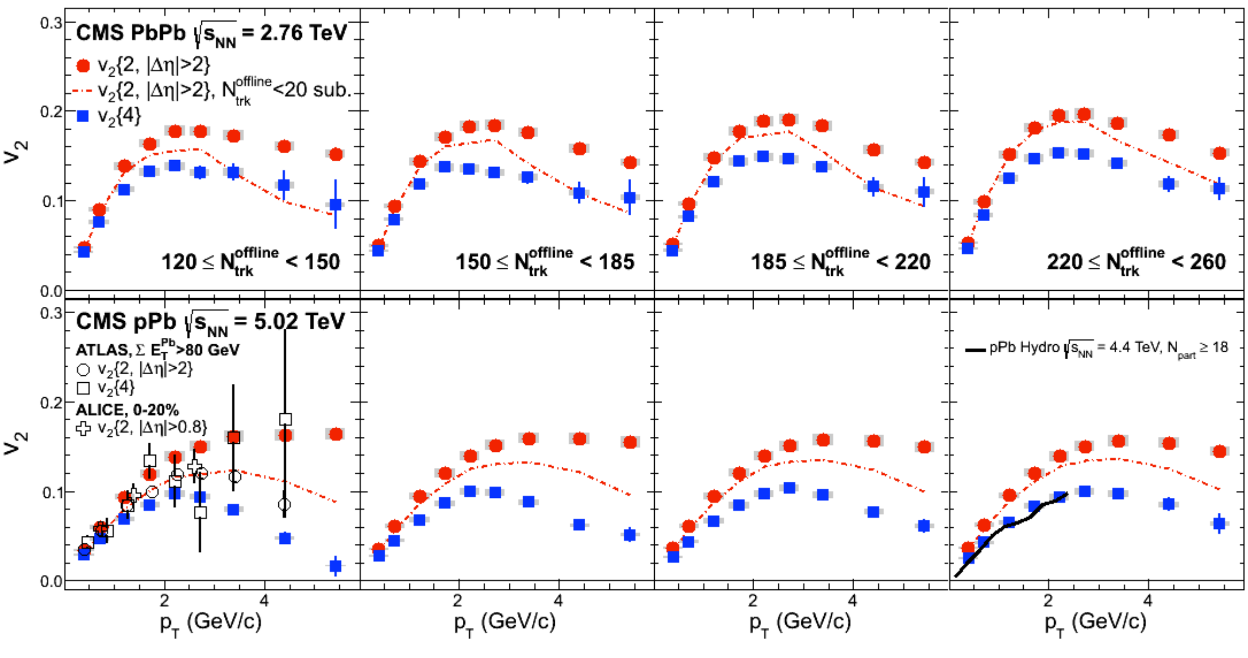

Figure 2: The differential $v_2\{2, |\Delta\eta| > 2\}$ (closed circles) and $v_2\{4\}$ (closed squares) values for four multiplicity ranges obtained with $|\eta| < 2.4$ and a p_T^{ref} range of 0.3-3 GeV/c. The results are for 2.76 TeV PbPb collisions (top) and for 5.02 TeV pPb collisions (bottom).

p_T range from 0.3 to 3.0 GeV/c, are presented in Fig. 3. We find that the values of v_3 are remarkably similar for both systems at the same event multiplicity. This similarity of the triangular flow is not

PoS(EPS-HEP 2013)194

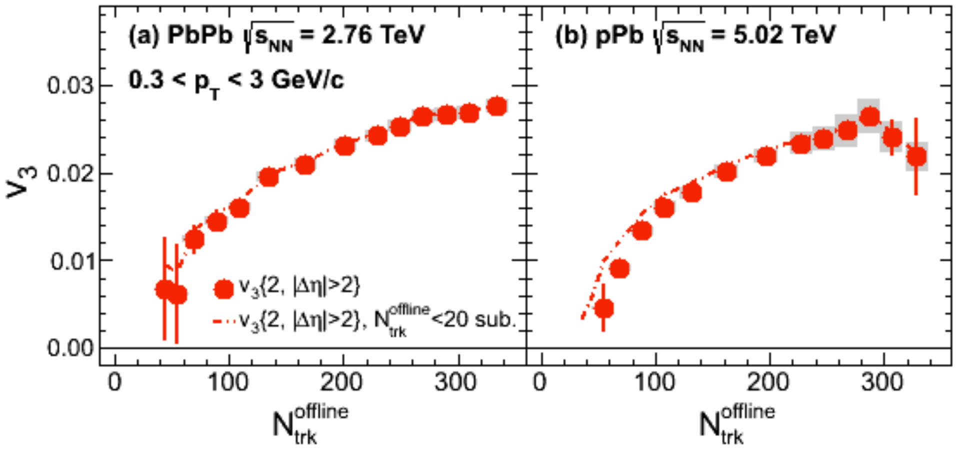

Figure 3: The $v_3\{2,|\Delta\eta| > 2\}$ values as a function of $N_{trk}^{offline}$ for $0.3 < p_T < 3$ GeV/c, in 2.76 TeV PbPb collisions (left) and 5.02 TeV pPb collisions (right).

trivially expected within a hydrodynamic picture since the initial-state collision geometry is very different for the pPb and PbPb systems.

6. Summary

Results from two- and four-particle azimuthal correlations in pPb collisions at $\sqrt{s_{NN}} = 5.02$ TeV by the CMS experiment were presented in this manuscript. A direct comparison of the correlation data between pPb and PbPb collisions were presented as a function of transverse momentum. The observed azimuthal angular two-particle correlations and four-particle azimuthal correlations were quantified in terms of the azimuthal anisotropy Fourier Harmonics (v_n). For both pPb and PbPb collision systems, elliptic (v_2) and triangular (v_3) flow Fourier harmonics were extracted from long-range two-particle correlations and four-particle cumulant method. Comparing the pPb and PbPb systems at the same multiplicity and p_T, it was found that the long-range yield and v_2 signals exhibit larger magnitude in PbPb than in pPb, while the v_3 signal has a remarkably similar magnitude in both systems. In addition, the long-range yield, v_2 obtained from the four-particle method, and v_3 all become apparent at about the same multiplicity. The comprehensive correlation data presented in this manuscript, spanning a very wide range in particle multiplicity and transverse momentum, should provide significant insights into the origin of the azimuthal correlations in small collision systems, particularly in the context of the hydrodynamic and color glass condensate models.

References

[1] J.-Y. Ollitrault, Phys. Rev. D 46 (1991) 229.

[2] PHOBOS Collaboration, Phys. Rev. C 81 (2010) 024904.

[3] B. Alver and G. Roland, Phys. Rev. C 81 (2010) 054905.

[4] B. Schenke, S. Jeon, and C. Gale, Phys. Rev. Lett. 106 (2011) 042301.

[5] CMS Collaboration, JHEP 09 (2010) 091.

[6] CMS Collaboration, Phys. Lett. B 718 (2013) 795.

PoS(EPS-HEP 2013)194

[7] PHENIX Collaboration, arXiv:1303.1794, submitted to Phys. Rev. Lett.

[8] A. Bilandzic, R. Snellings, and S. Voloshin, Phys. Rev. C 83 (2011) 044913.

[9] CMS Collaboration, Phys. Lett. B 724 (2013) 213.

[10] CMS Collaboration, JHEP 07 (2011) 076.

[11] STAR Collaboration, Phys. Rev. Lett. 95 (2005) 152301.

[12] ALICE Collaboration, Phys. Lett. B 708 (2012) 249.

[13] ATLAS Collaboration, Phys. Rev. C 86 (2012) 014907.

PoS(EPS-HEP 2013)194