Azimuthal correlations in Pb–Pb and pp collisions measured with the ALICE detector

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Abstract: We present results from the measurements of azimuthal correlations of charged particles in √sNN = 2.76 TeV Pb–Pb collisions and √sNN = 7 TeV pp collisions. In addition, the comparison of the experimental measurements in pp collisions with those from Pythia and Phojet simulations are presented.

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1. Introduction

The study of azimuthal correlations is one of the most important tools to probe the properties of the medium generated in heavy–ion collisions. Experimentally, these azimuthal correlations are not determined solely by anisotropic flow [1] but also have other contributions, usually referred to as non–flow which are not correlated to the participant plane [2]. Anisotropic flow, especially the second order harmonic $v_2$ (elliptic flow), has been systematically studied from SPS to LHC energies [3–5]. Recently it has been argued that fluctuations in the initial matter distribution give rise to odd harmonics like $v_3$ (triangular flow) [6]. In this contribution, we report the anisotropic flow for charged particles measured in √sNN = 2.76 TeV Pb–Pb collisions. We also discuss azimuthal correlation measurements in pp collisions compared to simulations from Pythia and Phojet.

2. Anisotropic flow in Pb–Pb collisions

In this contribution, we report on the study the azimuthal correlations via 2– and 4–particle cumulants [7]. In Fig. 1 we observe that the $v_3$ measurements from the 2– and 4–particle cumulants differ from zero; the $v_3\{4\}$

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Figure 1. $v_2$, $v_3$ and $v_4$ $p_t$-integrated flow as a function of centrality. Full and open blue squares show the $v_3$ (2) and $v_3$ (4), respectively. The full circle and full diamond are symbols for $v_3/p_{t,RP}$ and $v_3^2/\Psi_2$. In addition, the hydrodynamic calculations [11] for $v_3$ and AMPT simulations [12] for $v_2$, $v_3$ and $v_4$ are shown by dash lines and full gray markers. ALICE data points taken from [8].

Figure 2. $v_2$, $v_3$, $v_4$, $v_5$ 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% centrality percentile compared to hydrodynamic model calculations [9], (b) 0-5% centrality percentile, (c) 0-2% centrality percentile. Figures taken from [8].

is a factor of 2 smaller than $v_3(2)$ which can be understood if $v_3$ originates predominantly from event–by–event fluctuations of the initial spatial geometry [10]. At the same time, we investigate the correlation between $\Psi_3$ and the reaction plane $\Psi_{RP}$ as well as the correlations between $\Psi_3$ and $\Psi_2$, evaluated by $v_3/p_{t,RP} = \langle \cos(3\phi - 3\Psi_{RP}) \rangle$ and $v_3^2/\Psi_2 = \langle \cos(3\phi_1 + 3\phi_2 - 2\phi_3 - 2\phi_4 - 2\phi_5) \rangle/v_3^2$, respectively. We observe that $v_3/p_{t,RP}$ and $v_3^2/\Psi_2$ are consistent with zero within uncertainties. Based on these results, we conclude that $v_3$ develops as a correlation of all particles with respect to the third order participant plane $\Psi_3$, while there is no (or very weak) correlation between $\Psi_{RP}$ (or $\Psi_2$) and $\Psi_3$. The centrality dependence of $v_3$ is compared to hydrodynamic calculations. The data are described well by calculations based on Glauber initial conditions and $\eta/s = 0.08$, while underestimated by the MC–KLN initial conditions and $\eta/s = 0.16$ [11]. The comparison suggests that $\eta/s$ of the produced matter is small. Finally,
the data are described well by the AMPT model calculations, with only a slight overestimation of $v_2(2)$ in the most central collisions [12].

To further constrain the properties of the system, we compare the $p_t$–differential flow of $v_2$ and $v_3$ to hydrodynamic calculations in Fig. 2(a). We find that the hydrodynamic calculations with Glauber initial conditions can describe the elliptic and triangular differential flow measurements, although not for higher $p_t$. However, the $v_2(p_t)$ measurements seem to suggest $\eta/s=0$ while for $v_3(p_t)$ the hydrodynamic calculations with $\eta/s=0.08$ provide a better description. Currently there is no hydrodynamic calculation which simultaneously describes the $p_t$–differential $v_2$ and $v_3$ measurements at LHC energies with the same value for $\eta/s$. In central collisions 0-5% we observe that the higher harmonics $v_3$ and $v_4$ exceed $v_2$ and become the dominant harmonics at intermediate $p_t$. This occurs already at lower $p_t$ for more central collisions 0-2%. In AMPT simulations, it is observed that the initial geometrical fluctuations leads to anisotropic collective expansions even at an impact parameter of $b=0$ [13].

Figure 3. Cumulants for charged particles in 7 TeV pp collisions. (a) 2-particle cumulant ; (b) 4-particle cumulant. The shadow areas represent the results for Pythia (purple) and Phojet (pink).

3. Anisotropic flow or non–flow in pp collisions?

At LHC energies relatively high multiplicity events are observed in pp collisions [14]. Some theoretical work predict elliptic flow magnitudes up to 0.2 in pp collisions at LHC energies [15]. It is interesting to investigate whether collective effects appear in such events and if we can test those predictions. The 2– and 4–particle cumulant when dominated by anisotropic flow, correspond to: $Q{C}{2} = v^2$, $Q{C}{4} = -v^4$. Therefore if the measured azimuthal correlations are dominated by anisotropic flow, they should show the typical flow signature $(+,−)$ which has been observed in Pb–Pb collisions [16]. Figure 3 presents the 2– and 4–particle cumulant as a function of the measured uncorrected multiplicity, defined as the number of charged particle tracks which pass our track selection. We observe that the measured $Q{C}{4}$ is positive in the currently measured multiplicity range,
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which suggests that its dominant contribution is not coming from anisotropic flow. Also we find that both QC\(\{2\}\) and QC\(\{4\}\) decrease with increasing multiplicity, which is a typical behaviour for non–flow. In addition, we notice that both Pythia and Phojet can qualitatively describe the trend and sign of the QC\(\{2\}\) and QC\(\{4\}\). However, both of them do overestimate the strength of the azimuthal correlation measurements.

4. Conclusion

The azimuthal correlations of charged particles measured in \(\sqrt{s_{NN}} = 2.76\) TeV Pb–Pb collisions are presented. Our results constrain the corresponding models. The analyses with 2– and 4–particle cumulant in \(\sqrt{s_{NN}} = 7\) TeV pp collisions show that such azimuthal correlations are not dominated by anisotropic flow in the multiplicity range presented.

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