Measurement of elliptic flow and higher-order flow harmonics from the event plane and two particle correlation methods in $\sqrt{s_{NN}} = 2.76$ TeV Pb+Pb collisions with the ATLAS detector at the LHC

Adam Trzupek on behalf of the ATLAS Collaboration

The H. Niewodniczański Institute of Nuclear Physics Polish Academy of Sciences Radzikowskiego 152, 31-342 Kraków, Poland

E-mail: Adam.Trzupek@ifj.edu.pl

Abstract. The measurement of elliptic flow of charged particles in Pb+Pb collisions with the ATLAS detector at the Large Hadron Collider (LHC) is presented in a wide range of transverse momentum (p_T), pseudorapidity (η) and collision centrality. For the first time at this energy, elliptic flow v_2 is measured over 5 units of pseudorapidity, from -2.5 to 2.5, and over a broad range in transverse momentum, 0.5-20 GeV. Measurement of higher-order flow harmonics, up to v_6 , using both the event plane and the two-particle correlation methods over a broad p_T and centrality range is also presented.

PACS numbers: 25.75.-q, 25.75.Gz, 25.75.Ld

Submitted to: *J. Phys. G: Nucl. Phys.*

1. Introduction

The properties of the hot and dense medium created in Pb+Pb collisions at the LHC energy, 14 times higher than the energy available at RHIC, are now under extensive theoretical and experimental scrutiny. A particularly interesting observable is the azimuthal anisotropy of produced particles which, being sensitive to system conditions at the very early stage of evolution, became one of the main signatures of the strongly coupled Quark-Gluon Plasma (sQGP) discovered at RHIC [1]. It is expected that the observed azimuthal anisotropy results from an approximately elliptical shape of the initial interaction region of colliding nuclei. The initial asymmetry leads to additional pressure gradients in the QGP, which result in a significant azimuthal anisotropy in particle emission with respect to the reaction plane, defined by the impact parameter and the beam axis. The distribution of particle azimuthal angles relative to the reaction plane is decomposed into a Fourier series with the second harmonics, called elliptic flow (v_2), and higher-order flow harmonics both characterizing the “elliptical” shape of the initial interaction region and its higher modes related to event-by-event fluctuations.

The design of the ATLAS detector makes it an excellent tool for the measurement of the azimuthal anisotropy of charged particles in a wide range of transverse momentum (p_T), pseudorapidity (η) and centrality. In ATLAS, flow harmonics are measured using the event plane method [2] by correlating azimuthal angles of

Figure 1. $v_2(p_T)$ of charged particles in Pb+Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV. Error bars show statistical and systematic uncertainties added in quadrature. An overall scale uncertainty due to centrality uncertainties, ranging from 2% for central collisions up to 4% for peripheral events, is not shown.

reconstructed particle tracks in the inner tracker ($|\eta| < 2.5$) with the event plane angle obtained from forward calorimeters ($3.2 < |\eta| < 4.9$), as well as by using the two-particle correlation method [3, 4]. A large pseudorapidity gap (> 3.2) between the tracking system and forward calorimeters in the event plane method significantly reduces contributions from short-range non-flow effects.

2. Elliptic Flow

The results on elliptic flow of charged particles in Pb+Pb collisions in p_T range of 0.5-20 GeV and in $|\eta| < 1$ in eight 10% centrality bins are presented in Figure 1. For a given centrality interval, after a rapid rise of $v_2(p_T)$ up to $p_T \approx 3$ GeV and a decrease within the range of 3-8 GeV, a weak p_T -dependence is observed at the highest momenta. The strongest peak elliptic flow is found in mid-central (30-40% and 40-50%) Pb+Pb collisions. The p_T -dependence of elliptic flow was also measured in pseudorapidity ranges of $1 < |\eta| < 2$ and $2 < |\eta| < 2.5$. At larger pseudorapidities the same trends are observed as for the midrapidity results. For the centrality bin 40-50% the p_T -dependence of elliptic flow was found to be similar when compared to the measurement by ALICE at the same energy, and to the PHENIX [7] and STAR [8] results at RHIC, both at low and high p_T . The pseudorapidity dependence of elliptic flow in different p_T slices is shown in Figure 2. No substantial η -dependence of v_2 is observed. This is in contrast to the PHOBOS measurement at RHIC [5] which shows a 30% decrease within the same pseudorapidity range. However, it should be noted that the PHOBOS result was obtained for almost all particles including particles at very low p_T while the measurement described here is restricted to $p_T > 0.5$ GeV.

3. Higher-order Flow Harmonics

The results on higher-order flow harmonics of charged particles, $v_2 - v_6$, in Pb+Pb collisions in six centrality bins and in a broad transverse momentum range (0.5-

Figure 2. Pseudorapidity dependence of charged particle $v_2(\eta)$ in Pb+Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV in five p_T slices and eight 10% centrality bins.

12 GeV) from the event plane method are depicted in Figure 3. In this measurement the event plane, Ψ_n , from the full forward calorimeter was used to improve the resolution which is particularly important for the higher-order harmonics [4]. The p_T dependence of all harmonics show a similar trend and follow an interesting scaling of $v_n^{1/n}/\sqrt{v_2} \sim C(p_T)$, where $C(p_T)$ is only a function of p_t , motivated by hydrodynamic models [4]. It is also interesting to see that for the most central collisions and $p_T \approx 3$ GeV, v_3 and v_4 harmonics exceed elliptic flow.

Figure 3. Higher-order flow harmonics $v_2 - v_6$ of charged particles as a function of transverse momentum and centrality in Pb+Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV.

Figure 4. Comparison of 2-particle correlation (open symbols) and the event plane (solid symbols) results on $v_2 - v_6$ of charged particles as a function of centrality in Pb+Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV in 1-2 GeV (left) and 2-3 GeV (right) p_T bins.

Flow harmonics were also measured by the two-particle correlation method [4, 9]. Figure 4 shows a comparison of $v_2 - v_6$ as a function of centrality from the event plane and two-particle correlation method in 1-2 GeV and 2-3 GeV p_T intervals. Results from both methods agree at the 5-15% level and are consistent within systematic errors over a broad centrality range.

4. Summary

Elliptic flow v_2 and higher-order harmonics have been measured in Pb+Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV over a broad pseudorapidity, transverse momentum, and centrality range. As a function of transverse momentum, $v_2(p_T)$ reaches a maximum at p_T of about 3 GeV, then decreases and becomes weakly dependent on p_T above 7-8 GeV. A weak pseudorapidity dependence is observed up to $|\eta| < 2.5$. Similar p_T -dependent trends are seen for higher-order harmonics. Flow harmonics from the event plane and two-particle correlation methods are consistent within the p_T range 1-3 GeV.

References

- [1] RHIC White Papers, Nucl. Phys. A757 (2005).
- [2] A.M. Poskanzer, S. A. Voloshin, Phys. Rev. C58 (1998) 1671.
- [3] K. Adcox et al. The PHENIX Collaboration, Phys. Rev. Lett. 89 (2002) 212301.
- [4] G. Aad et al., The ATLAS Collaboration, ATLAS-CONF-2011-074.
- [5] B. B. Back et al., The PHOBOS Collaboration, Phys. Rev. C72 (2005) 051901.
- [6] K. Aamodt et al., The ALICE Collaboration, Phys. Rev. Lett. 105 (2010) 252302.
- [7] A. Adare et al., The PHENIX Collaboration, Phys. Rev. Lett. 105 (2010) 142301.
- [8] J. Adams et al., The STAR Collaboration, Phys. Rev. C 72 (2005) 014904.
- [9] J. Jia et al., The ATLAS Collaboration, this proceedings.