The Compact Muon Solenoid Experiment

Conference Report

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14 October 2011 (v2, 27 October 2011)

Elliptic flow in heavy-ion collisions with the CMS detector at the LHC: first results

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Presented at *LOMONOSOV11: 15th Lomonosov Conference on Elementary Particle Physics*

ELLIPTIC FLOW IN HEAVY-ION COLLISIONS WITH THE CMS DETECTOR AT THE LHC: FIRST RESULTS

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Abstract. We report on CMS measurements of charged hadron anisotropic azimuthal distributions from PbPb collisions at $\sqrt{s_{NN}} = 2.76$ TeV and their decomposition into a Fourier series up to the 6th coefficient. The results are presented as a function of transverse momentum, centrality and pseudorapidity and cover a broad kinematic range. The relation between the different harmonic coefficients and the scaling with the respective participant eccentricity are studied. These results could provide constraints on the theoretical description of the early dynamics in the hot and dense medium and its transport properties.

1 Introduction

In non-central collisions between two nuclei the beam direction and the impact parameter vector define a reaction plane for each event. A measurement of the azimuthal anisotropy of particle production with respect to the reaction plane is one of the important tools for studying the properties of the dense matter created in ultrarelativistic heavy-ion collisions [1, 2]. As it was shown before, CMS detector at the LHC [3] has a good possibility to provide a precise measurement of global event characteristics [4]. This report is dedicated to CMS measurements of charged hadron anisotropic azimuthal distributions from PbPb at the energy in c.m.s. $\sqrt{s} = 2.76$ TeV per nucleon pair.

2 Methods

The elliptic flow parameter, v_2 , is defined as the second harmonic coefficient in the Fourier expansion of the particle azimuthal distribution with respect to the reaction plane:

$$\frac{dN}{d\varphi} = \frac{N_0}{2\pi} [1 + 2v_1 \cos(\varphi - \Psi_R) + 2v_2 \cos 2(\varphi - \Psi_R) + \dots], \quad (1)$$

where Ψ_R is the true reaction plane angle and N_0 stands for full multiplicity. Then v_2 is the average over particles of $\cos(2(\varphi - \Psi_R))$. The higher-order coefficients of interest are v_3 (triangular flow), v_4 (quadrangular flow), v_5 (pentagonal flow), and v_6 (hexagonal flow).

There exists a wealth of anisotropic flow measurement methods, each of which has its advantages and limitations. Here we have used the methods: based on the measurement of the reaction plane angle — event plane (EP) [5], 2- and 4-particle cumulants (2, 4) [6, 7], and the Lee-Yang zeros (LYZ) [8, 9].

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3 Results and discussion

The v_n coefficients were measured using the high-granularity CMS tracker composed of silicon pixel and strip detectors covering the pseudorapidity range of $|\eta| < 2.4$. The analysis was performed using 2.31 million PbPb events selected with a minimum bias trigger. A Glauber model MC is used to connect the centrality classes as determined from the data with the number of nucleons participating in the collision, N_{part} , and the respective eccentricity of the initial nuclear overlap region, ϵ_{part} .

The main results of the analysis are as follows:

- $v_n(p_T)$ at $|\eta| < 0.8$ for up to 12 centrality classes in the range 0-80%, where p_T is the transverse momentum of charged particle;
- $v_2(\eta)$ for 12 centrality classes;
- integrated v_n at $|\eta| < 0.8$, and v_n/ϵ_{part} as a function of N_{part} .

The systematic uncertainties include those common to all methods, as well as method-specific ones [10, 11].

The results of $v_2(p_T)$ obtained by four methods at mid-rapidity are presented in Figure 1, for 12 centrality classes. The value of v_2 increases from central to peripheral collisions as expected if the anisotropy is driven by the spatial anisotropy in the initial state. The transverse momentum dependence shows a rise of v_2 up to $p_T \sim 3$ GeV/ c and then a decrease. This behavior is expected if hydrodynamic flow dominates up to $p_T = 2 \div 3$ GeV/ c .

Figure 1: Comparison of all four methods for determining v_2 as a function of p_T at $|\eta| < 0.8$ for the 12 centrality classes. The error bars show the statistical uncertainties only.

The four methods show differences consistent with their expected sensitivities to non-flow contributions. The method which is most affected by these is the 2-particle cumulant, because the integral and differential v_2 were determined in the same η -range. For the event plane method we have applied the separation between the particles used in the event plane determination and the particles used to measure the flow. The 4th-order cumulant and the Lee-Yang zeros method are much less affected by such non-flow contributions.

The pseudorapidity dependence of the anisotropy parameter is of interest because it provides constraints on the description of the system evolution in the longitudinal direction. The $v_2(\eta)$ results presented in Figure 2 cover a broad pseudorapidity range of $|\eta| < 2.4$ for the tracks with $0.3 < p_T < 3.0$ GeV/c. Only a weak η -dependence is observed, except in the most peripheral events, which are more affected by non-flow correlations.

Figure 2: Pseudorapidity dependence of v_2 for all four methods in 12 centrality classes. The error bars show the statistical uncertainties, and boxes give the systematic uncertainties.

Figures 3 and 4 display integrated v_n and the eccentricity scaled value, v_n/ϵ_{part} as a function of N_{part} at mid-rapidity. The v_3 value is weakly dependent on N_{part} and remains sizable even in the most central collisions. This is in contrast to the behavior of v_2 , which rapidly decreases with N_{part} . The higher order even harmonics, v_4 and v_6 , show similar trends as v_2 , although this is less pronounced in the case of v_6 . These measurements may be used in conjunction with hydrodynamics calculations as a test of the theoretical models of the initial eccentricities.

Figure 3: Integrated v_n as a function of N_{part} for $|\eta| < 0.8$. The error bars show the statistical uncertainties, the colored bands — the systematic ones.

Figure 4: Integrated v_n/ϵ_{part} as a function of N_{part} for $|\eta| < 0.8$. The error bars show the statistical uncertainties, the colored bands — the systematic ones.

4 Summary

We have presented the detailed measurements of the harmonic flow coefficients from PbPb collisions at $\sqrt{s_{NN}} = 2.76$ TeV as a function of p_T , pseudorapidity and N_{part} for a broad range of collision centralities, and obtained with several methods. These measurements taken together may aid in the systematic validation of different approaches to the modeling of heavy-ion collisions and lead to a reliable determination of the properties of the produced hot QCD matter.

Acknowledgments

I would like to thank the members of the CMS collaboration for providing the materials. Many thanks for the Organizers of 15th Lomonosov Conference on Elementary Particle Physics for possibility to present the talk.

References

- [1] J.Y.Ollitrault, *Phys.Rev.* **D 46**, 229 (1992).
- [2] H.Sorge, *Phys. Rev.Lett.* **82**, 2048 (1999).
- [3] CMS Collaboration, *JINST* **3**, S08004 (2008).
- [4] D.d’Enterria et al., *J.Phys.* **G 34**, 2307 (2007).
- [5] A.M.Poskanzer, S.A.Voloshin, *Phys.Rev.* **C 58**, 1671 (1998).
- [6] N.Borghini, P.M.Dinh, J.Y.Ollitrault, *Phys.Rev.* **C 64**, 054901 (2001).
- [7] N.Borghini, P.M.Dinh, J.Y.Ollitrault, arXiv:nucl-ex/0110016.
- [8] R.S.Bhalerao, N.Borghini, J.Y.Ollitrault, *Nucl.Phys.* **A 727**, 373 (2003).
- [9] N.Borghini, R.S.Bhalerao, J.Y.Ollitrault, *J.Phys.* **G 30**, S1213 (2004).
- [10] CMS Collaboration, CMS PAS HIN-10-002, CERN CDS 1347788 (2011).
- [11] CMS Collaboration, CMS PAS HIN-11-005, CERN CDS 1361385 (2011).