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Azimuthal anisotropy of charged hadrons at very high p_T in PbPb collisions at 2.76 TeV with CMS

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Abstract

Measurements of the azimuthal anisotropy of charged hadrons are presented for PbPb collisions at 2.76 TeV over an extended transverse momentum range up to approximately 60 GeV/c. The data were collected with the CMS detector at the LHC. Utilizing a novel and unique high-p_T single-track high-level trigger, the analysis explores the full 2011 PbPb data set corresponding to an integrated luminosity of 150 μb^{-1}. Anisotropy parameters (v_2, v_3 and v_4) are extracted by correlating charged tracks with the event plane reconstructed using the energy deposited in the forward calorimeters. The results presented in this talk significantly improve on the statistical precision of previous v_2 measurements for $p_T > 12$ GeV/c, and explore for the first time the harmonic components of the azimuthal dependence in the very high p_T region beyond 20 GeV/c. These new data can impose quantitative constraints on the details of in-medium parton energy loss models, particularly the influence of the path length and the shape of the interaction region.

1. Introduction

Recent measurements of nuclear modification factors [1] and momentum imbalance of back-to-back jets [2, 3] provide evidence for a more significant energy loss by partons propagating through the dense QCD medium at LHC than at RHIC. Due to the ellipsoidal shape of the interaction region in a non-central heavy ion collision partons lose different amount of energy depending on the direction they propagate. This leads to a non-zero v_2. Different theoretical predictions suggest different parton energy loss scenarios, $\delta E \propto L^{\alpha}$ [4, 5, 6, 7] with $\alpha = 1$ for collisional energy loss scenario and $\alpha = 2$ for radiative energy loss scenario, while $\alpha = 3$ is predicted by the AdS/CFT gravity-gauge dual model. The signficance of this measurement is that it can provide further constraints on the modeling of parton energy loss.

2. Experimental Details

The data set of 150 μb^{-1} of total integrated luminosity of PbPb collisions at $\sqrt{s_{NN}} = 2.76$ TeV was collected using the CMS detector [8]. Central feature of the CMS detector is a magnetic solenoid of 3.8 T magnetic field. The inner tracker that was used for particle reconstruction

[1] A list of members of the CMS Collaboration and acknowledgements can be found at the end of this issue.

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in the pseudo rapidity range of $|\eta| < 2$ is located within the field volume. The set of two Forward Hadronic (HF) calorimeters with the pseudo rapidity coverage of $3 < |\eta| < 5$ was used to determine event planes.

Azimuthal anisotropy measurement below 12 GeV/c in p_T was performed based on minimum bias data. To extract v_2 above 12 GeV/c in p_T, a special single track trigger was implemented. This triggered required a presence of at least one track above the threshold. Total of 20 million events with at least one track with p_T above 20 GeV/c were collected using this trigger.

Azimuthal anisotropy was measured using the event-plane method. The observed v_2 signal was obtained by correlating produced hadrons with the event plane. To account for the reconstruction of the event planes, the observed v_2 values were scaled by the resolution correction factor, R. Resolution correction values varied from 0.55 to 0.84 with the peak value corresponding to 20-30% bin. Further details of the method for this measurement can be found in the documentation for the lower p_T azimuthal anisotropy results in Ref. [9].

3. Results

Pseudorapidity gap between the tracks and event plane they are correlated with was introduced to suppress dijet contribution to the v_2 signal. This was done by correlating the tracks on one of the pseudorapidity sides,$\eta > 0$ ($\eta < 0$), with the event plane obtained on the opposite pseudo rapidity side, $-5 < \eta < -3$ ($3 < \eta < 5$). Fig. 1 shows a complete systematic study of v_2 as a function of the pseudo rapidity gap in 6 centrality classes (as shown in different panels) for different p_T bins (as shown by different colors). Based on this study a systematic uncertainty of ±2.5% (central events) and ±10% (peripheral events) was assigned to the final v_2 values.

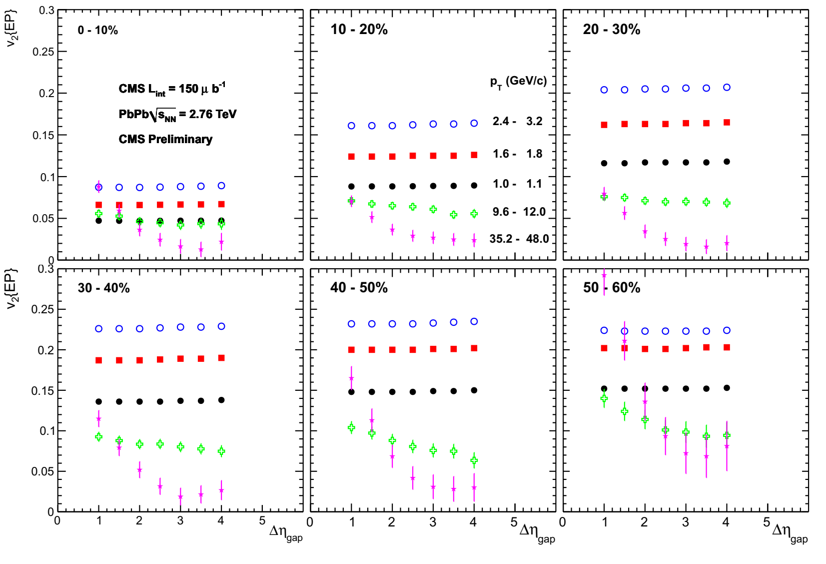

Figure 1: Systematic study of v_2 as a function of the pseudorapidity gap size between tracks and event plane for 5 selected p_T bins shown on each panel, where each panel corresponds to a different centrality range.

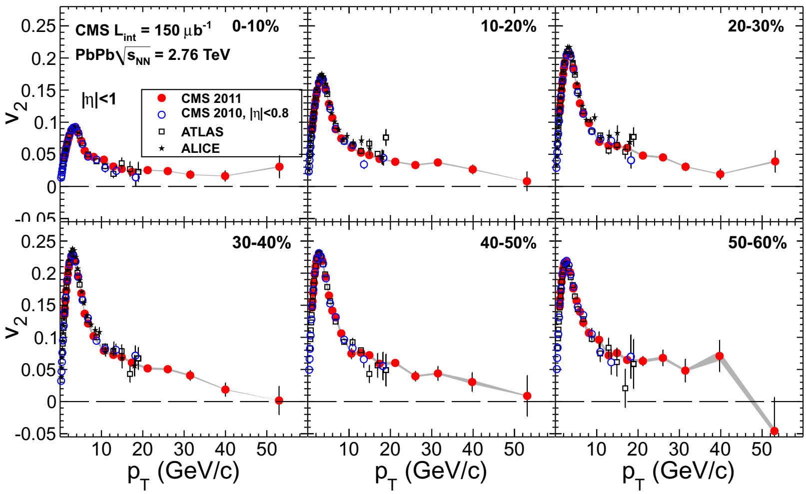

Figure 2: Azimuthal anisotropy, v_2, as a function of transverse momentum, p_T, of charged hadrons detected by the CMS detector in PbPb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV in 0 – 60% centrality range for $|\eta| < 1$. Error bars show statistical uncertainties, while the gray bands represent systematic uncertainties.

Fig. 2 shows the p_T dependence of v_2 in 6 centrality classes at mid rapidity ($|\eta| < 1$). CMS results of 2010 based just on minimum bias data in a slightly different pseudo rapidity range ($|\eta| < 0.8$) are shown on the same plot. Good agreement is observed across the experiments when comparing with ATLAS [11] and ALICE [12] results. There is a gradual decrease of v_2 above p_T 10 GeV/c. v_2 remains finite up to 40 GeV/c. p_T dependence of v_2 was also studied in the slightly forward pseudo rapidity region ($1 < |\eta| < 2$). Similar trends are observed between the two pseudo rapidity regions. Higher harmonics results (v_3 and v_4) were also measured as a function of p_T. Within the statistical uncertainties the results are consistent with zero above $p_T \approx 20$ GeV/c.

Fig. 3 shows the centrality dependence of v_2. The number of participating nucleons for each centrality bin was calculated based on the Glauber model. Different p_T bins are shown in different panels. Each panel also compares the two pseudorapidity regions: $|\eta| < 1$ and $1 < |\eta| < 2$. Within the statistical uncertainties no pseudorapidity dependence is observed for all the p_T bins. As the number of participants increases azimuthal anisotropy, v_2, decreases. This trend persists up to $p_T \approx 48$ GeV/c. At p_T less than a few GeV/c this dependence is well understood by the interplay between eccentricity values (geometry of the collision) and the hydrodynamic flow. This is a direct indication that azimuthal anisotropy at high p_T is also sensitive to the initial geometry.

4. Summary

In summary, the azimuthal anisotropy of charged hadrons using the event-plane method has been measured in PbPb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV with the CMS detector. The measurements (v_2, v_3 and v_4) extend beyond p_T = 20 GeV/c up to approximately 60 GeV/c. A rapid rise up to $p_T \approx 3$ GeV/c is observed, followed by a rapid fall up to $p_T \approx 10$ GeV/c for the second harmonic. Azimuthal anisotropy is finite up to $p_T \approx 40$ GeV/c for all the centralities independent

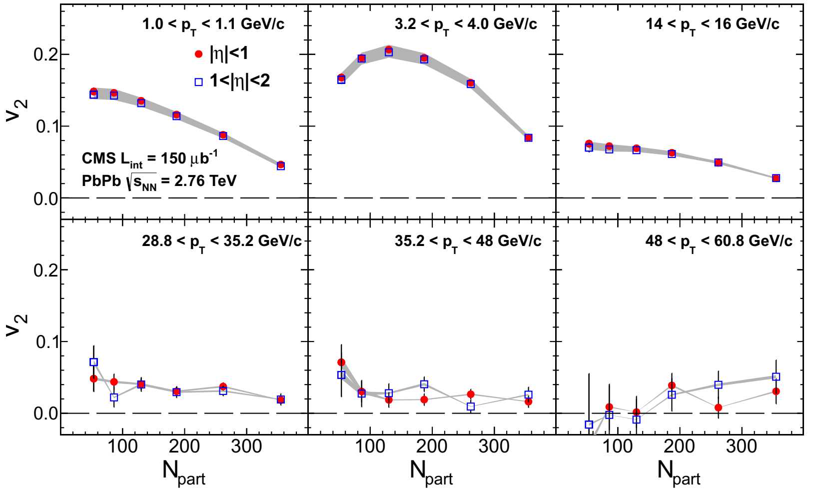

Figure 3: Azimuthal anisotropy, v_2, as a function of the number of participating nucleons, (N_{part}) for $|\eta| < 1$ (red solid circles) and $1 < |\eta| < 2$ (blue open squares) in $\sqrt{s_{NN}} = 2.76$ TeV PbPb collisions with the CMS detector. Different panels correspond to 6 selected p_T bins. Gray bands represent systematic uncertainties.

of pseudorapidity. The centrality dependence of v_2 suggests a connection to the initial geometry of the collision. These high precision data will provide an important input for the parton energy loss models.

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