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Measurement of high-p[subscript T] azimuthal anisotropy in charged hadron production from 2.76 Tev PbPb collisions at CMS

Measurement of high-p_T azimuthal anisotropy in charged hadron production from 2.76 Tev PbPb collisions at CMS

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Abstract

Measurements of the azimuthal anisotropy of charged hadrons are presented for PbPb collisions at $\sqrt{s_{NN}} = 2.76$ TeV over an extended transverse momentum range. The data were collected with the CMS detector at the LHC. The anisotropy parameter (v_2) is extracted up to a significantly higher p_T region than previously achieved, by correlating charged tracks with respect to the event plane reconstructed using the energy deposited in forward-angle calorimeters. 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 observations on dijets from the LHC suggest there is a significant energy loss by partons traversing dense QCD medium known as "jet quenching", quantitatively shown in the measurement of nuclear modification factors [1] and momentum imbalance of back-to-back jets [2, 3]. In non-central heavy ion collisions partons lose more energy along the long axis of the overlap ellipsoid rather than the short axis. This anisotropic energy loss leads to a non-zero v_2. The magnitude of the azimuthal anisotropy is sensitive to the path-length (L) dependence and can be used to quantify the path-length dependence of parton energy loss, $\delta E \propto L^{\alpha}$. Different theoretical models predict different scenarios for this dependence [4, 5, 6, 7]. The perturbative QCD calculations suggest $\alpha = 1$ 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. Therefore, this measurement can provide an additional constraint for further dynamical modeling of parton energy loss, in particular the influence of the path length and the collisional geometry on the energy loss.

2. Experimental Details

The data for this measurement was collected using the general purpose CMS detector at the LHC with PbPb collisions at $\sqrt{s_{NN}} = 2.76$ TeV and corresponds to 150 μb^{-1} of total integrated luminosity. Detailed description of the CMS detector can be found here [8]. The inner tracker that is located within the volume of the field of 3.8 T magnetic field, was used for charged track particle reconstruction in the pseudo rapidity range of $|\eta| < 2$. Event plane determination was based on on the set of two Forward Hadronic (HF) calorimeters located on each side of the interaction region. These calorimeters have a pseudorapidity coverage of $3 < |\eta| < 5$. The coincidence of either HFs

or Beam Scintillator Counters (BSCs) was used for minimum bias trigger. This trigger was used to extract azimuthal anisotropy below 12 GeV/c in p_T.

In order to increase statistics in the high-p_T region a dedicated single track trigger was used. This trigger required the presence of at least one track above p_T of 12 GeV/c. With the help of this special trigger it was possible to record 20 million events containing at least one charged particle with p_T above 20 GeV/c.

The azimuthal anisotropy measurement was based on the event-plane method previously exploited for the lower p_T results. The detailed description of the method for this measurement can be found in Ref. [9]. The final v_2 results were obtained by dividing the observed v_2 by the resolution correction factor, R. Based on the "three-subevent" technique R values for the HF event planes varied from 0.55 to 0.84 with the maximum for the events that fall into the 20-30% centrality bin.

3. Results

To minimize the systematic effect on the v_2 signal that results from other correlations such as dijets, a pseudora-pidity gap was introduced between the tracks that are used to extract v_2 and event planes. To calculate v_2 particles with $\eta > 0$ ($\eta < 0$) were correlated with the event plane defined in the opposite pseudorapidity region, $-5 < \eta < -3$ ($3 < \eta < 5$). This way a minimum gap of 3 units in pseudorapidity is introduced. This gap allows to suppress other types of correlations such as those that might come from back-to-back dijets. A complete systematic check was done for different p_T bins as a function of the gap size [10]. The multipanel plot in Fig. 1 shows that by varying the mini-mum gap size between 3 and 4 units in pseudorapidity the final v_2 values are consistent within ±2.5%(central events) and ±10% (peripheral events).
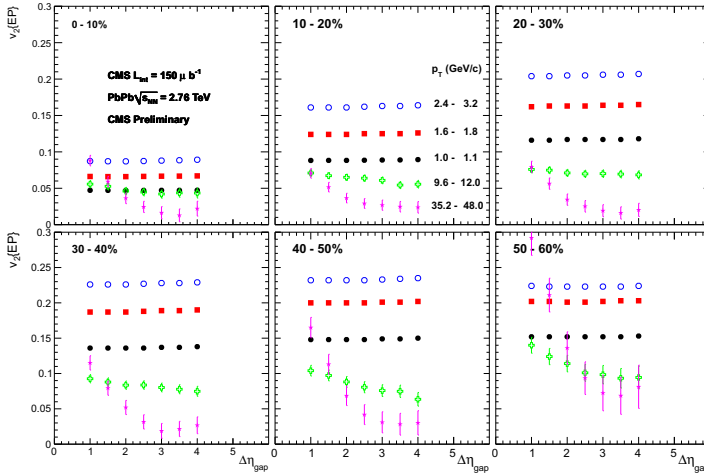

Figure 1: Systematic study of v_2 as a function of the pseudorapidity gap size between tracks and event plane for 5 selected p_T bins shown on each panel, where each panel corresponds to a different centrality range.

Fig. 2 shows v_2 as a function of p_T extending the previosly measured kinematic range up to 60 GeV/c for 6 central-ity classes at midrapidity(η). CMS results of 2011 are compared to the 2010 minimum bias data obtained in a slightly smaller pseudorapidity range(η). CMS results are also compared with the results from ATLAS experiment [11] us-ing the event-plane method. Good agreement is observed between the experiments. The v_2 values gradually decrease above p_T 10 GeV/c and they remain finite up to 40 GeV/c. A similar multipanel plot is shown for the slightly forward pseudorapidity region (η) in Fig. 2. No significant pseudorapidity depenedence of v_2 is present.
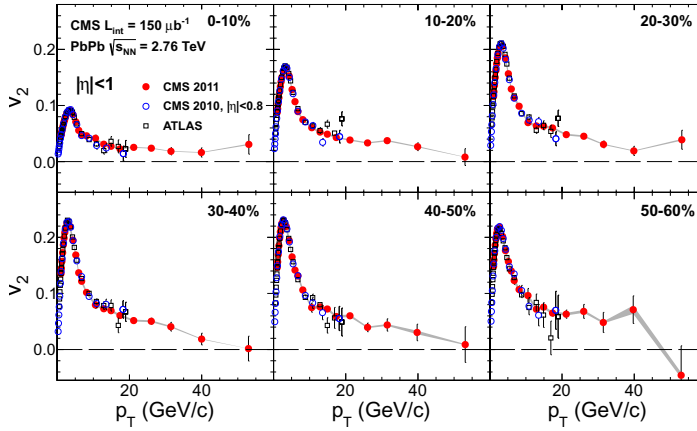
Figure 2: Azimuthal anisotropy, v_2, as a function of transverse momentum, p_T, of charged hadrons detected by the CMS detector in PbPb collisions at $\sqrt{s_{NN}}$ = 2.76TeV in 0 − 60% centrality range for $|\eta| < 1$. Error bars show statistical uncertainties, while the gray bands represent systematic uncertainties. The CMS results (open circles) are compared to ATLAS results (open squares) and to the 2010 results from CMS.
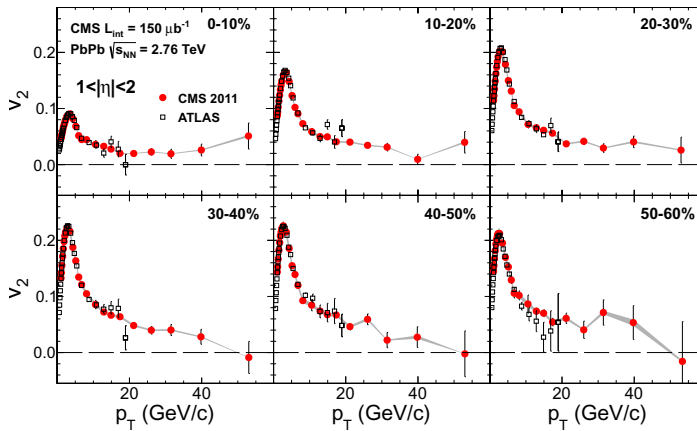

Figure 3: Azimuthal anisotropy, v_2, as a function of transverse momentum, p_T, of charged hadrons detected by the CMS detector in PbPb collisions at $\sqrt{s_{NN}}$ = 2.76TeV in 0 − 60% centrality range for $1 < |\eta| < 2$. Error bars show statistical uncertainties, while the gray bands represent systematic uncertainties. The CMS results (open circles) are compared to ATLAS results (open squares).

The centrality dependence of v_2 is shown in Fig. 4. The number of participants that is associated with each centrality bin was calculated using Glauber model. Different panels correspond to different p_T bins comparing the two pseudorapidity regions as well: $|\eta| < 1$ and $1 < |\eta| < 2$. No pseudorapidity dependence is observed for all the p_T bins within the statistical uncertainties. v_2 values decrease as the number of participants increases. This trend for the particles with p_T less than a few GeV/c is well understood by the interplay between the hydrodynamic flow and eccentricity values associated with the initial geometry of the collision. A similar trend is observed up to $p_T \approx 48$ GeV/c. This is a direct indication that azimuthal anisotropy at high p_T is also sensitive to the initial geometry.
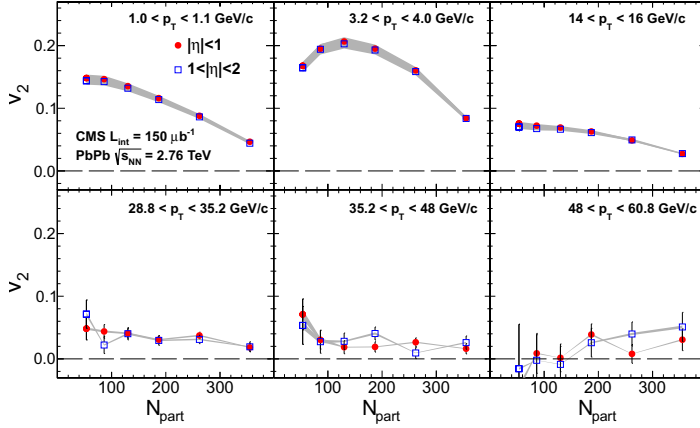

Figure 4: Azimuthal anisotropy, v_2, as a function of the number of participating nucleons, (N_{part}) for $|\eta| < 1$(red solid circles) and $1 < |\eta| < 2$(blue open squares) in $\sqrt{s_{NN}} = 2.76$ TeV PbPb collisions with the CMS detector. Different panels correspond to 6 selected p_T bins. Gray bands represent systematic uncertainties.

4. Conclusions

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. This is the first time this measurement extends 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. Beyond $p_T \approx 10$ GeV/c there is a moderate decrease of v_2 with p_T. Azimuthal anisotropy remains finite up to $p_T \approx 40$ GeV/c for all the centralities and pseudorapidity regions. The centrality dependence of v_2 is similar for all the p_T bins up to 48 GeV/c, indicating a potential initial geometry connection. These high precision data will provide important input for parton energy loss models.

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