The Compact Muon Solenoid Experiment

Conference Report

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Charged hadron azimuthal anisotropy (v_2) in $\sqrt{s_{NN}} = 2.76$ TeV PbPb collisions from CMS

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Abstract. During the past decade, azimuthal correlation measurements have played a pivotal role in our understanding of the properties of high density QCD matter through their sensitivity to the early stage evolution of relativistic heavy-ion collisions. The CMS experiment has measured the anisotropy parameter, v_2 , using four different methods: event-plane, two and four particle cumulants, and Lee-Yang Zeros. Consistent results are found for the different methods after considering their respective sensitivities to non-flow correlations and event-by-event fluctuations in the initial conditions. The anisotropy is studied as a function of transverse momentum, pseudorapidity and centrality in a broad kinematic range: $0.3 < p_T < 12$ GeV/ c , $|\eta| < 2.4$, and in 12 centrality classes in the range 0-80%.

1. Introduction

In non-central collisions of two heavy-ions there is an azimuthal anisotropy of the emitted particles associated with the spatially asymmetric overlap region. This anisotropy can be described by a Fourier expansion of the observed yield with respect to the reaction plane. The second coefficient, v_2 , in this expansion characterizes elliptic flow. The observation of v_2 values approaching the hydrodynamic limit is one of the most significant results of the RHIC program. The center-of-mass energy achieved in heavy ion collisions at the LHC is increased by approximately a factor of 14 in comparison to the highest RHIC energy. Predictions for the elliptic flow include scenarios that lead to both increases and decreases of the azimuthal asymmetry as compared to RHIC results. Determining the elliptic flow for the energy regime accessible using the LHC should help in establishing the shear viscosity to entropy ratio achieved in the produced, strongly interacting matter. Our goal is to measure this anisotropy in the broad kinematic range ($0 < p_T < 12$ GeV/ c) with a large pseudorapidity coverage ($|\eta| < 2.4$) and in multiple centrality classes. Four different methods with different sensitivities to non-flow effects were employed to study the magnitude of these effects and to facilitate comparisons with other measurements.

The data were obtained using Compact Muon Solenoid (CMS) [1] detector at the LHC. Silicon pixel and strip detectors are located within the field volume and were used

for tracking and event plane reconstruction. Pseudorapidity coverage of these detectors extends up to $|\eta| < 2.5$. Minimum bias triggers were achieved using beam scintillation counters (BSCs) and forward hadron calorimeters (HFs) with an efficiency of $97 \pm 3\%$ of the single diffractive cross section. Additional off-line event selection was applied to remove beam-halo and beam-gas collisions. The total number of the events after applying all the cuts is slightly above $2.3 M$.

2. Methods

Comparing methods based on two-particle and multi-particle correlations can provide a quantitative estimate of the non-flow effect on v_2 [2], with the multi-particle methods being the least sensitive to non-flow. In the event plane method [3] particles are correlated with an event plane. The experimental event plane is only an estimate of the reaction plane due to finite resolution of the detector. A 3-subevent method was used to establish the event plane resolution with the subevents defined in the pseudorapidity intervals: $-2 < \eta < -1$, $-0.75 < \eta < 0.75$, $1 < \eta < 2$. To minimize jet contribution in the estimation of the event planes only tracks with the momentum in the range $0.3 < p_T < 2.6$ GeV/ c were used. The standard flattening procedure [4] based on a Fourier expansion was applied to account for non-uniform azimuthal acceptance. To avoid auto-correlations at least one unit of pseudorapidity separation was required between the tracks to extract v_2 and the tracks to estimate event plane.

The cumulant method [5], using either two or four particle correlations, is based on constructing a generating function in a complex plane. To avoid auto-correlations the tracks that are used to determine the differential flow are excluded from the integral calculation. The multiplicity for each centrality class was fixed to avoid multiplicity fluctuation effects on the extracted v_2 signal.

The Lee-Yang Zeros method [6] correlates all particles in the event and is the least sensitive to non-flow contributions. The idea of the method is to find the first minimum in a generating function, which is directly related to the magnitude of the flow signal. The differential signal is determined with respect to the integral v_2 .

3. Results

Fig. 1 shows a comparison of $v_2(p_T)$ between CMS and PHENIX using event plane method in mid-rapidity range. Despite a dramatic energy increase from RHIC to LHC, the v_2 is only slightly larger than that at RHIC. The observed increase is within the systematic uncertainties. $v_2(p_T)$ behavior changes $< 5\%$ ($< 10\%$) going from mid-rapidity to $\eta = 2.4$ for central (peripheral) events.

To better understand the pseudorapidity dependence of v_2 as a function of centrality, the results for the event plane method in each centrality class were symmetrized in positive and negative pseudorapidity and plotted in Fig. 2. The more peripheral collisions plotted in the right panel seem to indicate a stronger pseudorapidity

dependence.

Figure 1. Comparison of v_2 using the event plane method as a function of p_T from CMS (closed symbols) at $\sqrt{s_{NN}} = 200$ GeV at mid-rapidity ($|\eta| < 0.8$, and $|\eta| < 0.35$, respectively)

Figure 2. Dependence of v_2 on $|\eta|$ for the event plane method in 12 centrality classes. The error bars show the statistical uncertainties, and boxes give the systematic uncertainties.

The $v_2(p_T)$ values were integrated to obtain integral v_2 measurements as a function of centrality at mid-rapidity. The integration range of $0.3 < p_T < 3.0$ GeV/ c was chosen to maximize the contribution from soft processes. v_2 increases from central to peripheral events achieving the maximum value at 50% centrality. This is consistent with previous RHIC results. As expected from non-flow contributions and sensitivity to initial-state fluctuations, the results for the second order cumulant and event plane are higher as shown in Fig. 3.

Figure 3. Top panel: Integrated v_2 as a function of centrality at mid-rapidity $|\eta| < 0.8$ for the four methods. Bottom panel: Comparison of results: the values from three of the methods are divided by the results from the event plane method. The error bars show the statistical uncertainties only.

4. Conclusions

We have presented detailed measurements of charged hadron azimuthal anisotropies in $\sqrt{s_{NN}} = 2.76$ TeV PbPb collisions. The results cover a broad kinematic range $0.3 < p_T < 12.0$ GeV/c, $|\eta| < 2.4$, and in 12 centrality classes covering the range 0-80%, extending beyond previously published LHC results. The measurements employ four different methods which have different sensitivities to the initial conditions of the system and the interplay between soft-particle production and jet quenching effects. These differences provide a systematic check between the methods, as well as the possibility to explore underlying physics processes which cause them. The data indicates that the collective flow at mid-rapidity at LHC energies is similar to that at RHIC. These results will provide an important basis for future detailed comparisons to models and give insights into the transport properties of the strongly coupled Quark-Gluon Plasma.

References

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