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High p_T Harmonics in PbPb Collisions at 5.02 TeV

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Abstract

Studies of azimuthal anisotropies for very high p_T particles in relativistic heavy ion collisions provide crucial information on the path length dependence of the parton energy loss mechanism in the quark-gluon plasma. Final high-precision data on the elliptic (v_2) and triangular (v_3) anisotropy harmonics of charged particles, obtained with the scalar product method, are presented up to $p_T \sim 100$ GeV/c in PbPb collisions at $\sqrt{s_{NN}} = 5.02$ TeV, using data recorded during the LHC run 2 with the CMS detector. In particular, the v_3 harmonic is explored to a very high p_T regime for the first time, allowing for an improved understanding of the effect of initial-state fluctuations on the parton energy loss. The v_2 values reaching up $p_T \sim 100$ GeV/c are also determined using 4-, 6- and 8-particle cumulants, shedding new light on the origin of the observed high-p_T azimuthal anisotropies. These new results are compared to theoretical calculations and provide stringent constraints on the parton energy loss mechanisms and the influence of initial-state fluctuations.

Keywords: heavy ion, flow, high p_T, quark-gluon plasma, scalar product, multiparticle cumulant

1. Introduction

It has been observed that energetic partons lose a significant fraction of their energies when traversing through the quark-gluon plasma (QGP), the hot and dense matter created in AuAu collisions at center-of-mass energy per nucleon pair $\sqrt{s_{NN}} = 200$ GeV at RHIC [1, 2, 3, 4] and in PbPb collisions at $\sqrt{s_{NN}} =$ 2.76 TeV and 5.02 TeV at the LHC [5, 6, 7, 8]. The nuclear modification factor (R_{AA}), a ratio of the produced particle spectrum between the heavy ion and pp collisions, has shown a large suppression of the charged particles with high transverse momentum (p_T) at both RHIC [9] and LHC [8] energies. In addition, the strong dijets asymmetry in PbPb collisions [5, 6] suggests that jets are quenched in the QGP. These observations trigger strong interests of studying the detailed high energy parton energy loss mechanisms and the interplay between the hard and soft sector of the QGP. The azimuthal anisotropy of the emitted charged particles can be described by the n-th Fourier expansion coefficient v_n. The low-p_T charged hadron v_2 and v_3 reflect the hydrodynamic conversion of the initial state geometry into a final momentum space anisotropy. Studying such coefficients of the high-p_T particle can provide strigent constraints on the model calculations and reveal information that is complementary to previous measurements.

In this talk, the Fourier coefficients of the azimuthal anisotropy are presented using the scalar product (for v_2 and v_3) and multiparticle cumulant (for v_2) methods for PbPb $\sqrt{s_{NN}} = 5.02$ TeV collisions collected in 2015 with the CMS detector [10]. The p_T region up to 14 GeV/c is covered by a minimum-bias trigger. To extend the measurement to higher p_T, a dedicated trigger that selects events with at least one high-p_T particle is used, which results in the p_T reach up to 100 GeV/c. To ensure high tracking efficiency and

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reduce the misreconstructed tracks, the particles to be studied are restricted to the pseudorapidity coverage of $|\eta| < 1$.

2. Method

The scalar product method [11] is used to measure the flow harmonic $v_2\{SP\}$ and $v_3\{SP\}$. We take advantage of the long-range behavior by establishing an event-plane angle in the forward range of pseudorapidity and then measuring the correlations of particles in the midrapidity with respect to the reference angle. The v_n coefficients can be expressed in terms of event-averaged Q-vectors,

$$v_n\{SP\} \equiv \frac{\left\langle Q_n Q_{nA}^* \right\rangle}{\sqrt{\frac{\langle Q_{nA} Q_{nB}^* \rangle \langle Q_{nA} Q_{nC}^* \rangle}{\langle Q_{nB} Q_{nC}^* \rangle}}}, \text{ with } Q_n \equiv \sum_{k=1}^{M} \omega_k \cdot e^{in\phi_k}, \tag{1}$$

where M represents the number of tracks or hadronic forward (HF) calorimeter towers ($3 < |\eta| < 5$) with energy above a certain threshold in each event, ϕ_k is the azimuthal angle of each k track (Q_{nB}) or HF tower (Q_{nA} and Q_{nC}), and ω_k is a weighting factor equal to p_T for the tracks and E_T for the HF towers. Benefit from the large pseudorapidity coverage, a gap of at least 3 unit in η is guaranteed between the HF detector and the particles being studied. Such large η gap is sufficient to suppress non-flow effects, such as back-to-back jets and resonance decay etc., which have been simulated using event generators.

The multiparticle correlations are measured using the Q-cumulant method [12]. The reference $v_2\{m\}$ values, $m = 4, 6, 8$, are firstly evaluated by correlating m particles within the reference phase space of $|\eta| < 2.4$ and p_T range of $1 < p_T < 5$ GeV/c. The p_T dependent $v_2(p_T)$ are then calculated with respect to the reference by replacing one of the m particles with a particle from certain p_T range within the midrapidity, $|\eta| < 1$.

3. Results

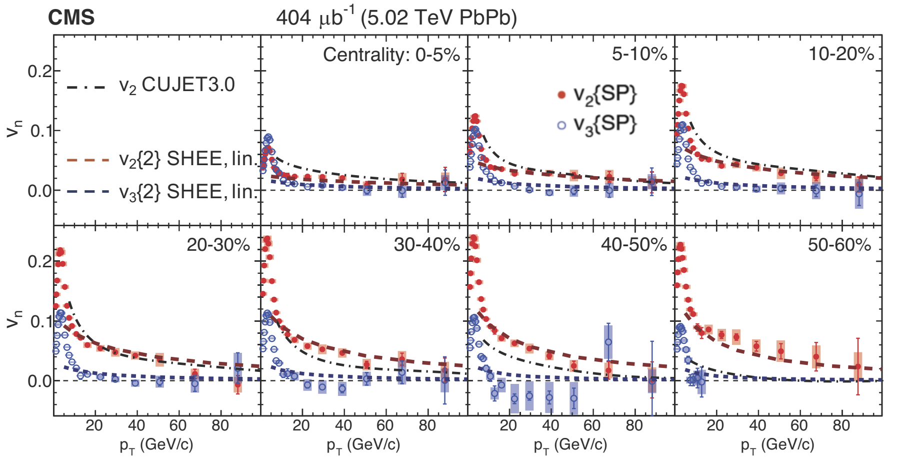

Fig. 1. The v_2 and v_3 results [13] from the SP method as a function of p_T, in seven collision centrality ranges from 0–5% to 50–60%. The vertical bars (shaded boxes) represent the statistical (systematic) uncertainties. The curves represent calculations made with the CUJET3.0 [14] and the SHEE models [15] (see text).

The p_T-dependent $v_2(p_T)$ and $v_3(p_T)$ using the SP method are shown in Figure 1 for seven collision centrality ranges from the most central (0–5%) to peripheral (50–60%) [13]. For the first time, we measure