Very High-$p_T$ Triggered Dihadron Correlations in PbPb Collisions at 2.76 TeV with CMS

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Abstract. Measurements of dihadron correlations triggered by very high-$p_T$ particles in 2.76 TeV PbPb collisions are shown. The data set, which corresponds to an integrated luminosity of 150 $\mu$b$^{-1}$, collected by the CMS detector is utilized. Long-range correlations are measured up to $p_T \sim 50$ GeV/c. These correlations are driven by single-particle azimuthal anisotropies and characterized by the Fourier harmonics, $v_n$. Once the $v_2 - v_4$ harmonic components are subtracted the associated particle yields on the near and away side of the jet-like correlations are studied. These measurements are done over a wide kinematic range in the associated and trigger particle $p_T$ and as a function of centrality. The data are compared to pp collisions at the same energy. A suppression of about 50% from the pp reference in the away-side associated yield is observed for $p_{assoc}^T > 3$ GeV/c. For lower momentums, $p_{assoc}^T \sim 0.5$ GeV/c, the yield is found to be enhanced significantly by up to a factor of 3-4 on the away-side. On the near side, there is some evidence of a moderate enhancement.

1. Introduction
Opaqueness to high-energy quarks and gluons, known as jet quenching, is one of the key signatures of the Quark Gluon Plasma (QGP). This effect can be measured using dihadron correlations by comparing the integrated-yields in pp to PbPb collision for the near and away-side regions. The contributions from flow and anisotropies in the interaction region must be subtracted in order to isolate the underlying jet-like correlations. The $I_{AA}$ modification factor is used to quantify the amount of suppression/enhancement with respect to a pp reference and is described in more detail in the next section. These measurements provide important constraints on energy-loss models of a QGP medium.

2. Methods
The measurements described in this section were all done using the CMS detector, which is described in detail in Ref. [1]. Two-particle associated yield distributions are constructed by dividing the signal distribution by the background distribution and integrating across the range $|\Delta\eta| < 1$ and from 0 < $\Delta\phi$ < 1 for the near-side and 1 < $\Delta\phi$ < $\pi$ for the away-side. The procedure is described in more detail in Refs. [2, 3]. The contributions from single-particle anisotropies in the measured correlation function need to be subtracted. These single-particle anisotropies are given by the Fourier harmonics, $v_n$, and were measured out to very high-$p_T$ using the event plane method in Refs. [3, 4]. The $I_{AA}$ modification factor, which is the ratio of the integrated associated yields in PbPb to that in pp collisions as a function of $p_T^{trig}$ and $p_T^{assoc}$,
used to quantify the amount of suppression observed in the near and away sides, as in Ref. [5]. A cross check was done by calculating the near-side $I_{AA}$ values using a long-range $\Delta \eta$ subtraction method, which is described in more detail in Ref. [3]. In this method the correlations from single-particle azimuthal anisotropies are estimated from the two-particle correlation functions averaged over “long-range” region, $1 < |\Delta \eta| < 4$, and then subtracted from the full correlation function, $|\Delta \eta| < 4$. The single-particle anisotropies are expected to extend to large values of $\Delta \eta$ and the jet-correlations on the near-side do not. This is a good alternative approach to estimating and then subtracting the background correlations. Since the jet-correlations extend to large $\Delta \eta$ value on the away-side, the long-range $\Delta \eta$ subtraction method can only be applied to the near side.

Figure 1. The per-trigger-particle associated yield of charged particles in (a) two-dimensions (2-D) as a function of $\Delta \eta$ and $\Delta \phi$ and (b) one-dimension (1-D) as a function of $|\Delta \phi|$ averaged over $0 < |\Delta \eta| < 1$ for $p_T^{trig} > 20$ GeV/c and $1 < p_T^{assoc} < 3$ GeV/c from the 0-30% centrality range of PbPb collisions at $\sqrt{s_{NN}} = 2.76$ TeV. The near-side peak in (a) is truncated to better display the surrounding structure.

3. Results

The near-side $I_{AA}$ results are shown in Fig. 2 as a function of $p_T^{assoc}$ for various $p_T^{trig}$ bins and with $|\Delta \eta| < 1$. The red points on the top row are for the 0–10% most central collisions while the blue points on the bottom row are for the 50–60% central collisions. The black data points are from the long-range $\Delta \eta$ subtraction method while the colored points are calculated from the $v_n$ subtraction method. At low $p_T^{assoc}$ there is a noticeable enhancement of up to a factor of 2 for both methods even though they disagree slightly. This disagreement is possibly due to the fact that $v_1$ is not included in the $v_n$ subtraction method but inherently included in the long-range $\Delta \eta$ subtraction method. The away-side $I_{AA}$ are also shown as a function of $p_T^{assoc}$ in Fig. 3 with $|\Delta \eta| < 1$ and in four different $p_T^{trig}$ bins. There is a significant enhancement up to a factor of 3–4 at low $p_T^{assoc}$ and a suppression of 50% at high $p_T^{assoc}$. The near-side $I_{AA}$ values are shown as a function of $N_{part}$ in Fig. 4 for four different $p_T^{assoc}$ bins with $19.2 < p_T^{trig} < 24$ GeV/c. The blue points show the results derived from the $v_n$-subtraction method at $0 < |\Delta \eta| < 1$ while
the black points show the results derived from the long-range $\Delta \eta$ subtraction method. There is a clear correlation with $N_{part}$ at low $p_T^{assoc}$ and becomes less significant at higher $p_T^{assoc}$. The away-side $I_{AA}$ values are shown as a function of $N_{part}$ in Fig. 5 for four different $p_T^{assoc}$ bins with $19.2 < p_T^{trig} < 24 \text{ GeV/c}$ and $0 < |\Delta \eta| < 1$. Again, there is a very strong correlation with $N_{part}$ which shows a large enhancement at low $p_T^{assoc}$ and high $N_{part}$. This correlation changes to a suppression at higher $p_T^{assoc}$ and high $N_{part}$ values.

![Diagram](image.png)

**Figure 2.** Near-side $I_{AA}$ values derived from the $v_n$-subtraction method at $|\Delta \eta| < 1$ shown for four different $p_T^{trig}$ ranges as a function of $p_T^{trig}$ for PbPb collisions at $\sqrt{s_{NN}} = 2.76$ TeV, the top for 0–10% centrality and bottom row for 50–60% centrality. The black squares represent the values calculated from the long-range-$\Delta \eta$ subtraction method. The error bars represent statistical uncertainties while the brackets represent the systematic uncertainties.

4. Conclusion

The near- and away-side $I_{AA}$ values as a function of $p_T^{trig}$ and $p_T^{assoc}$ for different centrality ranges were measured in PbPb collisions at $\sqrt{s_{NN}} = 2.76$ TeV. Long-range, hydrodynamic flow-like behavior is accounted for by a separate measurement of harmonic $v_n$ coefficients using the event-plane method. There is a large enhancement of up to a factor of 3–4 in the away-side $I_{AA}$ for 0-10% central PbPb at low $p_T^{assoc}$ and a suppression of about 50% at high $p_T^{assoc}$ for all $p_T^{trig}$ ranges studied in the analysis. This is consistent with the jet-quenching picture, namely that the medium-induced energy loss from high-$p_T$ patrons is transferred to low-$p_T$ particles, especially below $p_T = 2$ GeV/c. There is a less significant enhancement, about a factor of 2, observed in the near-side associated particle yield at low-$p_T^{assoc}$ in the most central collisions. The near-side $I_{AA}$ results at intermediate and higher $p_T^{assoc}$ ranges show a significantly smaller difference between PbPb and pp collisions since high-$p_T^{trig}$ particles on the near-side are much more likely to come from the surface of the medium. These measurements can help provide qualitative constraints on parton energy loss mechanisms in a QGP medium.
Figure 3. Away-side $I_{AA}$ values derived from the $v_n$-subtraction method at $|\Delta \eta| < 1$ shown for four different $p_T^{\text{trig}}$ ranges as a function of $p_T^{\text{trig}}$ for PbPb collisions at $\sqrt{s_{NN}} = 2.76$ TeV, the top for 0–10% centrality and bottom row for 50–60% centrality. The error bars represent statistical uncertainties while the brackets represent the systematic uncertainties.

Figure 4. Near-side $I_{AA}$ shown for four different $p_T^{\text{assoc}}$ ranges as a function of $N_{\text{part}}$ for $19.2 < p_T^{\text{trig}} < 24$ GeV/c in PbPb collisions at $\sqrt{s_{NN}} = 2.76$ TeV. The solid blue circles show the results derived from the $v_n$-subtraction method at $|\Delta \eta| < 1$, while the black squares show the results derived from the long-range $\Delta \eta$ subtraction method. The error bars represent statistical uncertainties while the brackets represent the systematic uncertainties.
Figure 5. Away-side $I_{AA}$ values derived from the $v_n$-subtraction method shown for four different $p_T^{\text{assoc}}$ ranges as a function of $N_{\text{part}}$ for $19.2 < p_T^{\text{trig}} < 24$ GeV/$c$ and $|\Delta\eta| < 1$ in PbPb collisions at $\sqrt{s_{NN}} = 2.76$ TeV. The error bars represent statistical uncertainties while the brackets represent the systematic uncertainties.

5. References

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