Observation of near-side angular correlations in pPb collisions at 5.02TeV with CMS

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Abstract.
The first measurement of two-particle correlations in pPb collisions at a center-of-mass energy of 5.02 TeV is presented. The correlations are studied in azimuth, ϕ , and pseudorapidity, η , as a function of charged-particle transverse momentum, p_{T} , and multiplicity. A total of two million collisions are used in this analysis. A long range ($2 < |\Delta\eta| < 4$), near-side ($\Delta\phi \approx 0$) ridge-like structure emerges in the two-particle $\Delta\eta-\Delta\phi$ correlation functions of high-multiplicity events. This is the first time such a correlation has been seen in proton-nucleus collisions, which which resembles the correlations seen in a broad energy range of nucleus-nucleus collisions and in high-multiplicity proton-proton collisions at $\sqrt{s} = 7$ TeV. The correlation strength rises approximately linearly with multiplicity and has a maximum in the range of $p_{\mathrm{T}} = 1 - 1.5$ GeV/c .

1. Introduction

These proceedings present two-particle correlations in pPb collisions at $\sqrt{s_{NN}} = 5.02$ TeV with the Compact Muon Solenoid (CMS) detector at the Large Hadron Collider (LHC). Collective behavior in the medium can give rise to two-particle correlations. These can be studied using two-dimensional $\Delta\eta - \Delta\phi$ correlation functions. Of particular interest are the long-range (large $\Delta\eta$) correlations that are less affected by correlations such as fragmentations from jets and resonance decays. These long-range correlations are related to the medium properties and its evolution and have been studied at many collision energies in proton-proton (pp), proton-nucleus (pA), and nucleus-nucleus collisions (AA). Recently measurements of 7 TeV pp collisions have revealed the existence of long-range, near-side ($\Delta\phi \approx 0$) correlations in high multiplicity collisions [1]. Diverse theoretical models have been proposed to explain the origin of the ridge in pp collisions (see Ref. [2] for a recent review). The first comparison of pPb and pp correlations, presented in these proceedings, provides information for understanding the ridge correlation signal observed in high-multiplicity pp collisions. In section 2 the two-particle correlation function is described, then in section 3 the quantitative ridge measurements are presented.

2. The Two-Particle Correlation Function

The two-particle correlations analysis was performed in bins of track multiplicity in order to match the analysis strategy in high-multiplicity pp collisions [1], and using the procedure established in [3, 4]. Charged particles, which have their trajectories reconstructed in the silicon tracker, are denoted as "tracks", and multiplicity, $N_{\mathrm{trk}}^{\mathrm{offline}}$, is defined as the number of tracks having $|\eta| < 2.4$ and $p_{\mathrm{T}} > 0.4$ GeV/c and passing a set of quality cuts described in more detail in [5]. For each multiplicity bin, the "trigger" particles are defined to be all charged particles in a given p_{T} range originating from the primary vertex. Charged-particle pairs are formed by associating all other tracks in the same p_{T} range as the trigger particle, where a minimum of two particles is required in each p_{T} interval for each collision. The definition of per-trigger-particle associated yield is

$$\frac{1}{N_{\mathrm{trig}}}\frac{\mathrm{d}^2\mathrm{N}^{\mathrm{pair}}}{\mathrm{d}\Delta\eta\,\mathrm{d}\Delta\phi} = B(0,0) \times \frac{S(\Delta\eta,\Delta\phi)}{B(\Delta\eta,\Delta\phi)}, \tag{1}$$

where $\Delta\eta$ and $\Delta\phi$ are the pair differences in η and ϕ. The signal distribution, $S(\Delta\eta, \Delta\phi)$, is the per-trigger-particle yield of same event particle pairs,

$$S(\Delta\eta,\Delta\phi) = \frac{1}{N_{\mathrm{trig}}}\frac{\mathrm{d}^2\mathrm{N}^{\mathrm{same}}}{\mathrm{d}\Delta\eta\,\mathrm{d}\Delta\phi}\ . \tag{2}$$

The background distribution is constructed the same way as the signal, except associating particles from different events than the trigger particle, but from events with the same longitudinal position along the beam axis and multiplicity range.

The 2-D two-particle correlation function for low (a) and high (b) multiplicity pPb events is shown in Figure 1 for charged-particle pairs with $1 < p_{\mathrm{T}} < 3$ GeV/c.

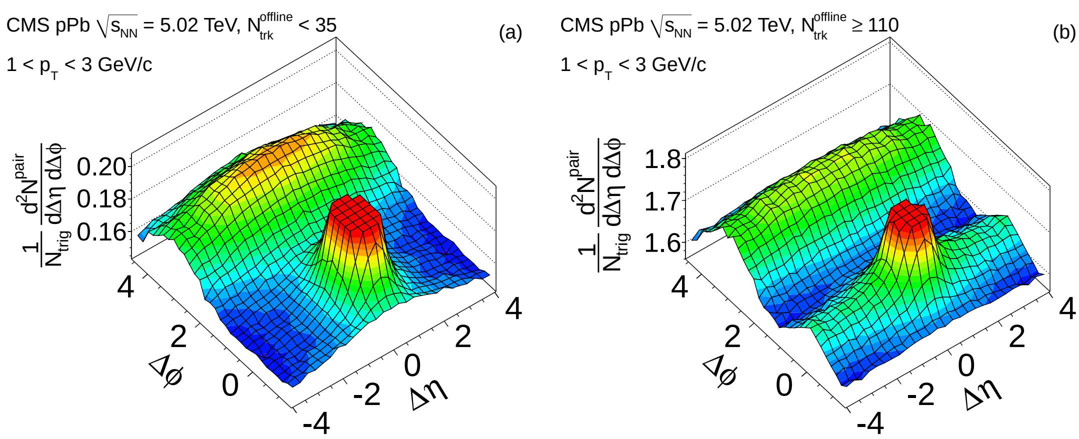

Figure 1. 2-D two-particle correlation functions for charged-particle pairs with $1 < p_{\mathrm{T}} < 3$ GeV/c from 5.02 TeV pPb collisions are shown with low-multiplicity ($N_{\mathrm{trk}}^{\mathrm{offline}} < 35$) (a) and high-multiplicity ($N_{\mathrm{trk}}^{\mathrm{offline}} \geq 110$) (b). The near side jet peak is truncated.

Both the high and low multiplicity correlation functions exhibit a peak at $(\Delta\eta, \Delta\phi) = (0, 0)$ originating from particle pairs produced by a jet, and an elongated structure at $\Delta\phi \approx \pi$ from particle pairs produced by back-to-back jets. However, the high-multiplicity correlation function also has a pronounced ridge at $\Delta\phi \approx 0$ extending at least 4 units in $|\Delta\eta|$.

3. Results

To further investigate these long-range near-side pA correlations and to provide a quantitative comparison to measurements in pp collisions, one-dimensional (1D) $\Delta\phi$ distributions are formed by averaging the two-dimensional signal and background distributions over the range of $2 < |\Delta\eta| < 4$ [1, 3, 4]. The minimum of the correlation function in the azimuthal range of

0.1 < $|\Delta\phi|$ < 2 is first found and the corresponding value, C_{ZYAM}, is subtracted from the 1-D correlation function [6].

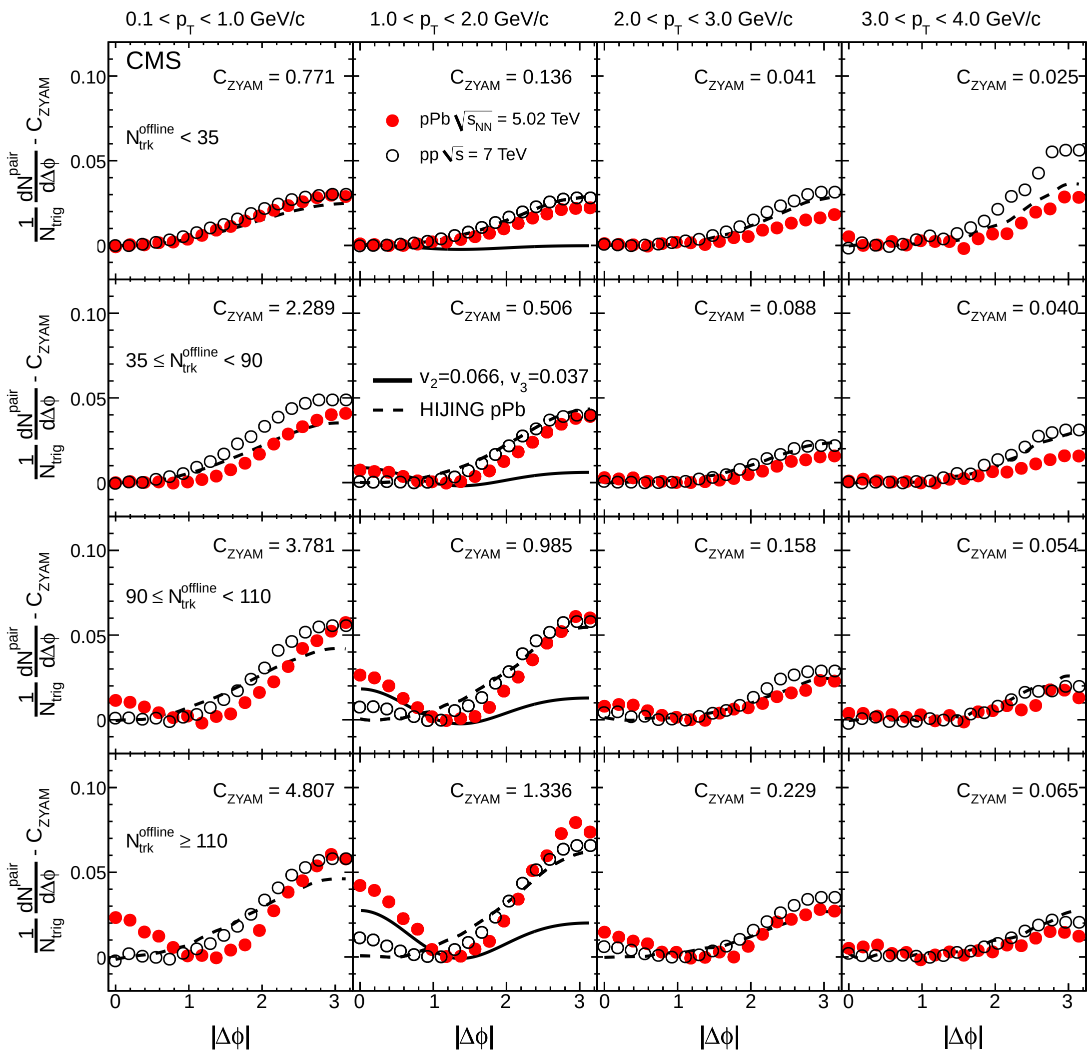

Figure 2. Zero-yield-at-minimum (ZYAM) correlated yield in different p_T and multiplicity bins averaged over $2 < |\Delta\eta| < 4$ as a function of $|\Delta\phi|$. Shown are 5.02 TeV pPb data (solid circles) and 7 TeV pp data (open circles). Statistical uncertainties are smaller than the marker size. The subtracted ZYAM constant is listed in each panel.

Figure 2 shows the 1D distributions for $\sqrt{s_{NN}}$ = 5.02 TeV pPb (solid), $\sqrt{s_{NN}}$ = 7 TeV pp (open), with p_T increasing horizontally and multiplicity increasing from top to bottom. Also shown are predictions, for pPb collisions modeled by HIJING [7] (dashed curves), and by hydrodynamics [8] (solid curves) in the multiplicity bins that best match the bins of the theoretical predictions. The color-glass condensate framework also predicted a ridge structure, but in this case it arises from initial state gluon correlations rather than from collective behavior in the produced matter [9].

In low multiplicity events the correlation functions from both pPb and pp collisions have minima at $\Delta\phi = 0$ and a maximum at $\Delta\phi = \pi$ for all p_T ranges. However in high-multiplicity collisions a second maximum emerges at $\Delta\phi = 0$, corresponding to the two-dimensional ridge, for both the pp and pPb collisions systems, which is most pronounced in the $1 < p_{\mathrm{T}} < 2$ GeV/c range.

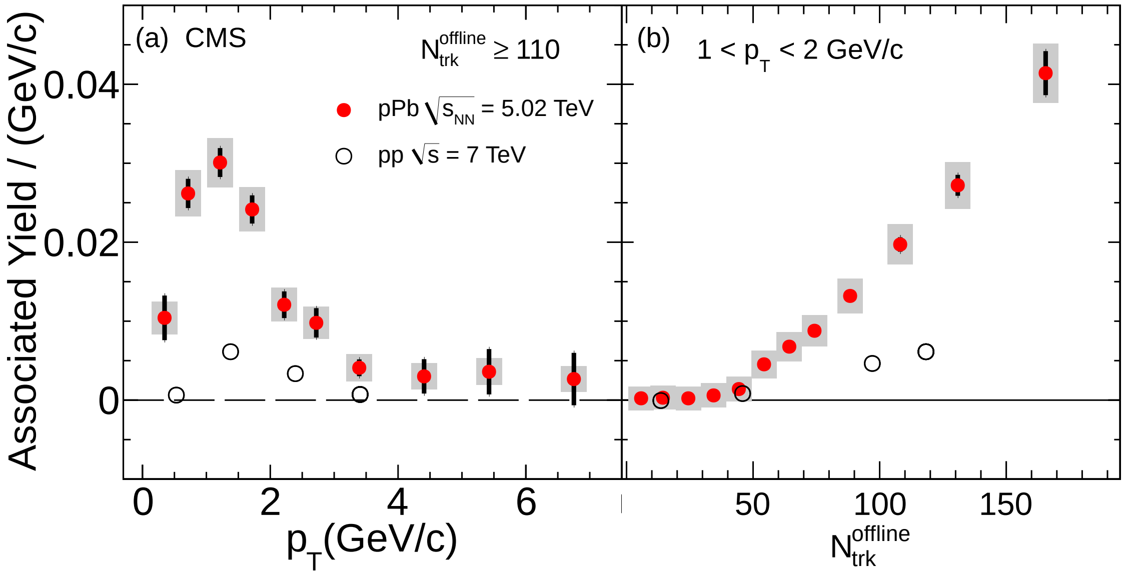

Figure 3. Ridge associated yield in different p_{T} and multiplicity bins averaged over $2 < |\Delta\eta| < 4$ and integrated over $|\Delta\phi| < 1.2$. Shown are 5.02 TeV pPb data (solid circles) and 7 TeV pp data (open circles). Panel (a) shows the p_{T} dependence of the associated yield in high-multiplicity events. Panel (b) shows the multiplicity dependence of the associated yield in the $1 < p_{\mathrm{T}} < 2$ GeV/c range. The error bars are statistical uncertainties and the shaded areas are systematic uncertainties.

The strength of the ridge yield can be further quantified in finer multiplicity and p_{T} bins by integrating the correlated yield from Fig. 2 over $|\Delta\phi| < 1.2$ and normalizing by the width of the p_{T} interval. The resulting pPb ridge-yield is shown in Fig. 3 in ten p_{T} bins for high-multiplicity collisions 3(a) and in twelve multiplicity classes fixing $1 < p_{\mathrm{T}} < 2$ GeV/c in 3(b). The corresponding pp data (open circles) is also shown. The error bars show the statistical uncertainties and the shaded boxes the systematic.

Both pp and pPb data show a maximum ridge yield in the range of $1 < p_{\mathrm{T}} < 2$ GeV/c. At low multiplicity the ridge yield is zero due to the ZYAM procedure, indicating the ridge correlations are absent or smaller than other negative correlations. At high-multiplicity the yield rises almost linearly with multiplicity once it turns on at a multiplicity of around $N_{\mathrm{trk}}^{\mathrm{offline}} = 50$, which is slightly higher than the mean multiplicity in minimum bias events..

4. Summary

A ridge-like structure has been observed in two-particle angular correlations in high-multiplicity pPb collisions with the CMS experiment at the LHC. This structure is qualitatively similar to the ridge observed in high-multiplicity pp collisions at $\sqrt{s} = 7$ TeV and in AA collisions for a wide range range of center-of-mass energies. The effect is strongest in the intermediate transverse momentum range $1 < p_{\mathrm{T}} < 1.5$ GeV/c. The dependence of the effect on multiplicity and p_{T} in pPb collisions is similar to that seen in pp data, but the magnitude of the ridge yield is significantly larger.

References

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