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Explore the high-density QCD medium via particle correlations in pPb collisions at CMS

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ABSTRACT

The observation of a long-range, near-side two-particle correlation ("ridge") in very high multiplicity proton–proton and proton–lead collisions has opened up new opportunity of studying novel QCD phenomena in small collision systems. In 2013, high luminosity pPb data were collected by the CMS experiment at the LHC. New results of two- and multi-particle correlations in pPb collisions from CMS are presented over a wide event multiplicity and transverse momentum range. A direct comparison of pPb and PbPb systems is provided. Physics implications, especially in the context of color glass condensate and hydrodynamics models are also discussed.

1. Introduction

In recent years, CMS collaboration observed a long-range near-side correlation structure in the highest particle multiplicity proton–proton (pp) [1] and proton–lead (pPb) [2] collisions at the LHC. The finding details a phenomenon that final-state particles produced over a wide range of pseudorapidity (η) from the collisions are emitted at a similar azimuthal angle (ϕ), known as the "Ridge". Similar phenomenon was seen before in high-energy collisions of heavy nuclei (AA), which is attributed to the hydrodynamic flow effect of a strongly interacting medium created in the overlap collision region. While hydrodynamic flow is the commonly accepted explanation of such long-range correlations in the AA collision systems, a variety of theoretical models have been proposed to explain the origin of this phenomenon in small collision systems like pp (see Ref. [3] for a recent review) and pPb. Such models include gluon saturation in the initial interaction of the protons and nuclei [4,5] and hydrodynamic effects in the high-density systems possibly formed in these collisions at TeV energies [6–8].

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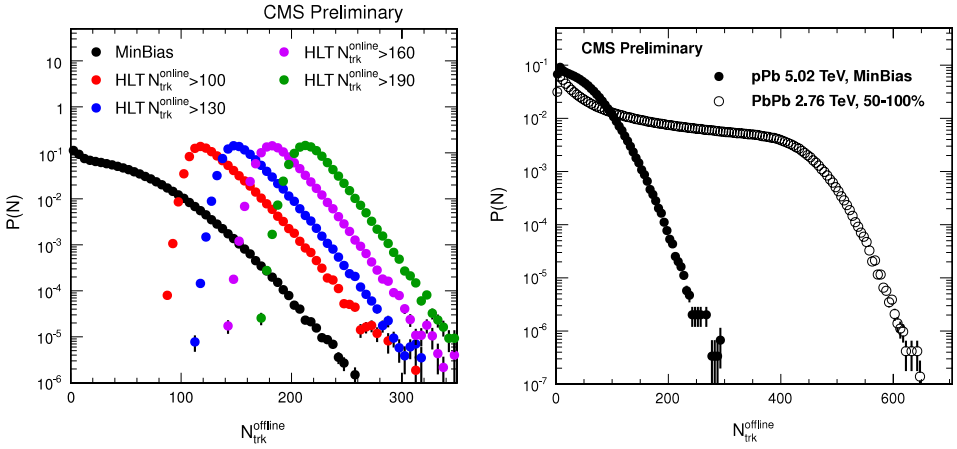

Fig. 1. Left: multiplicity distributions of 2.76 TeV pPb collision collected by high-multiplicity triggers with different thresholds. Right: multiplicity distributions of 2.76 TeV minimum bias pPb and 2.76 TeV 50%–100% centrality PbPb collisions. All distributions are normalized to unit integral.

The LHC recently delivered a high luminosity pPb run in 2013, enabling further investigation of the particle production mechanism in pPb collisions, particularly to provide new insights on the origin of the novel long-range ridge correlations. This paper presents new results of two- and four-particle angular correlations in pPb collisions at $\sqrt{s_{NN}} = 5.02$ TeV from the CMS experiment. This 2013 data set, especially with the implementation of a dedicated high-multiplicity trigger, provides a much larger sample of very-high-multiplicity pPb events. Therefore, correlations can be explored up to a multiplicity comparable to that in mid-central PbPb collisions.

2. Experimental setup

The CMS detector comprises a number of subsystems and a detailed description can be found in Ref. [9]. The results in this paper are mainly based on the silicon tracker information. This analysis is performed using data recorded by CMS during the LHC pPb run in 2013 at a center-of-mass energy per nucleon pair ($\sqrt{s_{NN}}$) of 5.02 TeV. The data set corresponds to an integrated luminosity of about 31 nb^{-1}, assuming a pPb interaction cross section of 2.1 barns. A dedicated high-multiplicity trigger was implemented in order to select high-multiplicity pPb collisions. Fig. 1 (left) shows the multiplicity distributions from various thresholds of high-multiplicity triggers. Here, the reconstructed track multiplicity, $N_{\text{trk}}^{\text{offline}}$, is defined as the number of primary tracks with $|\eta| < 2.4$ and $p_{\text{T}} > 0.4$ GeV/c. A comparison of multiplicity distributions for minimum bias pPb and 50%–100% PbPb collisions can be found in Fig. 1. As one can see, with implemented high-multiplicity triggers, the pPb events can be investigated in a multiplicity regime that is comparable to mid-central PbPb collisions, where collective medium effect has been unambiguously established.

3. Azimuthal anisotropy harmonics from two- and four-particle correlations

Technique of two-particle correlations at CMS has been established in several previous publications from CMS [10,11,2,12]. The azimuthal anisotropy harmonics are determined from a Fourier decomposition of long-range two-particle $\Delta\phi$ correlation functions,

$$\frac{1}{N_{\text{trig}}}\frac{dN^{\text{pair}}}{d\Delta\phi} = \frac{N_{\text{assoc}}}{2\pi}\left[1 + \sum_n 2V_{n\Delta}\cos(n\Delta\phi)\right], \tag{1}$$

where $V_{n\Delta}$ are the Fourier coefficients and N_{assoc} represents the total number of pairs per trigger particle for a given $(p_{\text{T}}^{\text{trig}}, p_{\text{T}}^{\text{assoc}})$ bin. A minimum $|\Delta\eta|$ of 2 units is applied to remove short-range