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Long-range correlations in high-multiplicity proton–proton collisions at $\sqrt{s}$ = 13 TeV with ALICE at the LHC

Abstract

The observed azimuthal modulations of long-range correlations in pseudorapidity in small systems like pp or p-Pb collisions show strikingly similar features to those seen in heavy ion collisions. Many theoretical approaches to interpreting this effect have been developed. However, it is still unclear whether these long-range correlations are due to final or initial state effects. To further investigate these effects, we studied long-range correlations as a function of transverse momentum in very high multiplicity pp collisions at $\sqrt{s} = 13$ TeV, collected with the high multiplicity event trigger during 2016 and 2017 with ALICE. In this talk, we present the near-side per-trigger yield at large pseudorapidity separation (ridge yield) as a function of transverse momentum in pp collisions at $\sqrt{s} = 13$ TeV. The results will be compared to previous measurements from CMS and ATLAS experiments. In addition, we present the ridge yield in events where harder fragmentation processes are present, to explore possible physical origins of long-range correlations.

1 Introduction

Collective effect is one of key probes to study evolution of the hot and dense matter created in heavy-ion collisions at unltra-relativistic energy. The enhancement in the associated yield of two-particle correlations at small relative azimuthal angle($\Delta\varphi$) that extends over a long-range of relative pseudorapidity($\Delta\eta$) is often referred to as the "ridge", which is one of the crucial observables of the result from the collective effect[1, 2]. In recent years, many results of unexpected observation of ridge in small systems, like proton-proton(pp) collisions and proton-nucleus(pA) collisions, has been reported([3–6]), showing similar features to those in heavy-ion collisions, where the volume and lifetime of the medium produced are expected to be small. There are many theoretical attempts[7–10] to interpret the ridge considering hydrodynamics, saturation or other mechanisms. Those attempts are not demonstrating measured data fully because the sources of the ridge is not understood quantitatively in small systems. The understanding of possible origins of the ridge in small systems may provide a hint to distinguish the mechanism of formation of ridges.

2 Experimental setup

Delivery of protons with world-highest energy by LHC at CERN makes it possible to generate various phenomena from their collisions. Recent center-of-mass energy of colliding two protons is increased up to 13 TeV during LHC Run2 period. Among data from proton-proton collisions at 13 TeV, This paper describes analysis results obtained by using 2016 to 2017 data sets.

Subsystems mainly used in the present analysis, VZERO detector, Inner Tracking System(ITS) and Time Projection Chamber(TPC), are mainly discussed in the paper while the whole ALICE detector is well described in Ref. [11]. The VZERO is separated into two plates, VZERO-A and VZERO-C, consisting of two arrays of 32 scintillator tiles each, covering the full azimuthal angle within 2.8$< \eta <$5.1 and -3.7$< \eta <$-1.7 respectively. The VZERO provides trigger and event characterization with respect to particle abundance. With higher threshold, High Multiplicity Trigger can be implemented by VZERO to acquire very high multiplicity events exclusively.

The ITS is composed of three subsystems, Silicon Pixel Detector(SPD), Silicon DriftDetector (SDD) and Silicon Strip Detector(SSD). ITS has an acceptance up to $|\eta| <$1.95 for single charged track reconstruction. The TPC, which is working inside solenoidal magnetic field of 0.5 T, has an acceptance up to $|\eta| <$0.9 for charged tracks reaching the outer radius of the TPC. The tracking of charged-particles is done with the combination of ITS and TPC, which also enable to reconstruct low transverse momentum tracks down to 0.15 GeV/c with $\sim$70% efficiency.

3 Analysis

The multiplicity class used in the present analysis is top 0-0.1%, which denotes the most particle-abundant events, to study high multiplicity events and to observe the ridge structure from the following results([3]). The present analysis uses charged tracks, whose reconstructed transverse momentum is larger than 0.2 GeV/c in a fiducial region as $|\eta| <$0.9. The efficiency and contamination from non-primary tracks are estimated from a Monte Carlo(M.C.) simulation with PYTHIA8 event generator with particle transport through the detector using GEANT simulation. The efficiency and the contamination are dependent on particle multiplicity, where the tendencies of the changes are opposite each other up to $\sim$10%, making total correction invariant.

The two-particle correlation between trigger particle and associated particle is measured as function of relative pseudorapidity($\Delta\eta$) and azimuthal angle($\Delta\varphi$). The following equation expresses the correlation as associated yield per trigger particle as function of transverse momentum($p_{\mathrm{T,trig}}$, $p_{\mathrm{T,assoc}}$) of trigger particle and associated particle with the condition of $p_{\mathrm{T,trig}} > p_{\mathrm{T,assoc}}$.

$$\frac{1}{N_{\mathrm{trig}}}\frac{\mathrm{d}^2N_{\mathrm{assoc}}}{\mathrm{d}\Delta\eta\,\mathrm{d}\Delta\varphi} = B(0,0)\frac{S(\Delta\eta,\Delta\varphi)}{B(\Delta\eta,\Delta\varphi)}, \quad (1)$$

Where the N_{trig} is the number of trigger particles in the corresponding event class. The signal distribution $S(\Delta\eta,\Delta\varphi)$ is constructed using two-particle correlation in the same event. The background distribution $B(\Delta\eta,\Delta\varphi)$ is constructed using two-particle correlation in mixed several events having same primary vertex and multiplicity class as in the events.

The quantitative study of ridge is done with $\Delta\varphi$ distribution in the large $\Delta\eta$ to allow direct comparison of ridges between different p_{T} intervals. The large $\Delta\eta$ range is defined as $1.5 < |\Delta\eta| < 1.8$ considering the limited detector acceptance. The baseline of the correlations is subtracted by implementing Zero-Yield-At-Minimum(ZYAM) procedure. The minimum yield(C_{ZYAM}) is obtained by fitting the $\Delta\varphi$ distribution with Fourier series up to the third harmonic. By subtracting C_{ZYAM} from the $\Delta\varphi$ distribution, the magnitude of long-range near-side yield is obtained and can be quantified by integrating the near-side peak of the $\Delta\varphi$ distribution. The margin of the integration(near-side) is determined as the minimum point from ZYAM procedure.

The ridge yield is further studied with various hard fragment event selections in pp collisions. The event selection is implemented by requiring that transverse momentum of leading track is larger than specific threshold. The leading track is defined as a charged track having the largest transverse momentum in a given event. Because the high transverse momentum track mainly comes from hard scattering, the requirement of the leading track can control the hardness of events, which allow one to study the ridge in hard events.

4 Results

The ridge yield as function of transverse momentum of trigger particle and associated particle has been measured with ALICE. The measured spectrum shows ....

5 Conclusions

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