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MULTIPLICITY DEPENDENCE OF TWO-PARTICLE CORRELATION IN *pp* AND *p*Pb AT THE LHCb*

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This paper shows that two-particle correlation function depends on multiplicity in proton–proton (pp) collisions at $\sqrt{s} = 13$ TeV and proton–lead (pPb) collisions at $\sqrt{s_{NN}} = 5.02$ TeV using results from the LHCb experiment. Results show azimuthal anisotropies in the event shape, the so-called near-side ridge in long-range $\Delta\eta$. The near-side ridge in a small system has been understood as the collective behaviour of emitted particles in the collisions.

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1. Introduction

Particle correlation measurements play a great role in studying particle production in high-energy collisions. This paper presents results of two-particle angular correlation of charged particles in pp collisions $\sqrt{s} = 13$ TeV and pPb collisions $\sqrt{s_{NN}} = 5.02$ TeV in the LHCb detector. Previous results of azimuthal anisotropies were presented in heavy-ion collisions in the STAR experiment [1] and the PHOBOS experiment [2] at the Relativistic Heavy Ion Collider (RHIC). These anisotropies are well-described by the hydrodynamic model [3]. In the case of small system, another model is called colour-glass condensate (CGC) [4], where the initial state is connected to colour relation between particles after collision. In a third model, ridge structure can be formed due to the local fluctuation caused by jets crossing through the created medium [5]. There is also a multi-parton interaction model [6] where a few interactions take place at partonic level in a single event.

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2. The LHCb detector

The LHCb detector [7] is a single-arm forward spectrometer covering the pseudorapidity range of $2 < \eta < 5$. It contains ring-imaging Cherenkov detectors, hadronic and electromagnetic calorimeters, muon identification system and tracking detectors of high precision (shown in Fig. 1). This tracking system is composed of the vertex locator (VELO) surrounding the beam interaction region, a tracking station located upstream of the dipole magnets and three tracking stations located downstream of the dipole magnets. Particles inside the LHCb detector experience a bending field of around 4 Tm. The online event selection is formed by a trigger which consists of two stages: hardware stage, based on informations from the calorimeters and muon system, and software stage, which applies a full event reconstruction.

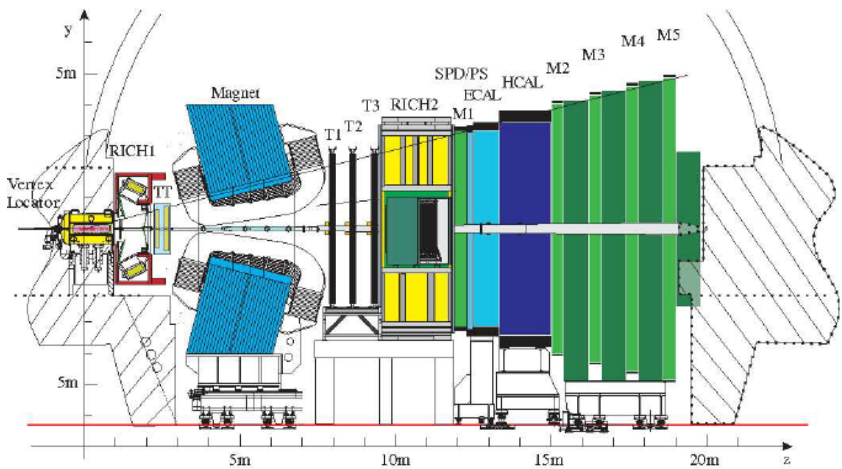

Fig. 1. The LHCb detector [7].

3. Two-particle correlation

Two-particle correlation is shown by pseudorapidity separation $\Delta\eta$ and relative azimuthal angle $\Delta\varphi$ of particle pairs. These two particles are called trigger particle and associated particle. Trigger particles are charged particles originating from the primary vertex within a given p_{T} range. To form a particle pair, one has to associate every trigger particle with the remaining particles in the same p_{T} interval as the trigger particle.

Angular correlation between two particles is given by the formula

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

where $N_{\rm trig}$ is a number of trigger particles and $N_{\rm pair}$ is a number of particle pairs found in a $(\Delta\eta, \Delta\varphi)$ bin. $S(\Delta\eta, \Delta\varphi)$ refers to signal distribution where particles are associated within the same event. In the background distribution $B(\Delta\eta, \Delta\varphi)$, trigger particles are combined with particles from another event. $B(0, 0)$ is for normalization of the background distribution, which describes the associated yield for particles of a pair travelling in approximately the same direction and thus having the maximum pair acceptance.

Several structures can be distinguished in two-particle correlation function. Near-side jet fragmentation peak in $(\Delta\eta, \Delta\varphi) \approx (0, 0)$ dominates in correlation function. It comes from particles which originate from the same jet-like hard process. Away-side ridge in $\Delta\varphi \approx \pi$, which covers a broad range in $\Delta\eta$, refers to momentum conservation. Near-side ridge in $\Delta\varphi \approx 0$ in long-range $\Delta\eta$ appears not only in PbPb [8] collisions but also in *pp* [9] and *p*Pb [10] collisions with high-multiplicity and for medium-$p_{\rm T}$ range.

3.1. pp and pPb system at LHCb

This chapter is dedicated to present results of two-particle correlation in *pp* collisions at the center-of-mass energy of 13 TeV [11] and *p*Pb collisions at the center-of-mass energy of 5 TeV [12] using data from the LHCb experiment.

Figure 2 shows two-particle correlation function for three different activity classes which refers to multiplicity for medium $p_{\rm T}$ range. All histograms in this paper are dominated by the jet peak around $(\Delta\eta, \Delta\varphi) \approx (0, 0)$ which is due to correlations of particles originating from the same jet-like objects. For better visualization, in all 2D-histograms, the jet peak is truncated. With increasing multiplicity, associated particle yield becomes bigger, as shown in Fig. 2 (a)–(c), and for high-activity class near-side ridge in $\Delta\varphi \approx 0$ arises in about $|\Delta\eta| > 1.5$, as shown in Fig. 2 (c). The ridge is not visible in the corresponding low- and medium-activity class.

Figure 3 demonstrates $p_{\rm T}$ dependence of two-particle correlation for high-multiplicity events. For medium $p_{\rm T}$ interval, as shown in Fig. 3 (b), near-side ridge structure is enhanced, however, for particles with low $p_{\rm T}$, as shown in Fig. 3 (a), is a concave shape in $\Delta\varphi \approx 0$ in about $|\Delta\eta| > 1.5$.

Two-particle correlation functions of *p*Pb collisions at the center-of-mass energy of 5 TeV [12] are shown in Fig. 4. The correlation for particles with $1 < p_{\rm T} < 2$ GeV/c is shown for low (events of the 50–100% class, (a)) and very high (events of the 0–3%, (b)) event activities, respectively. The ridge structure is observed in high multiplicity and $1 < p_{\rm T} < 2$ GeV/c, as shown in Fig. 4 (b), and is not visible in the corresponding low-activity class.

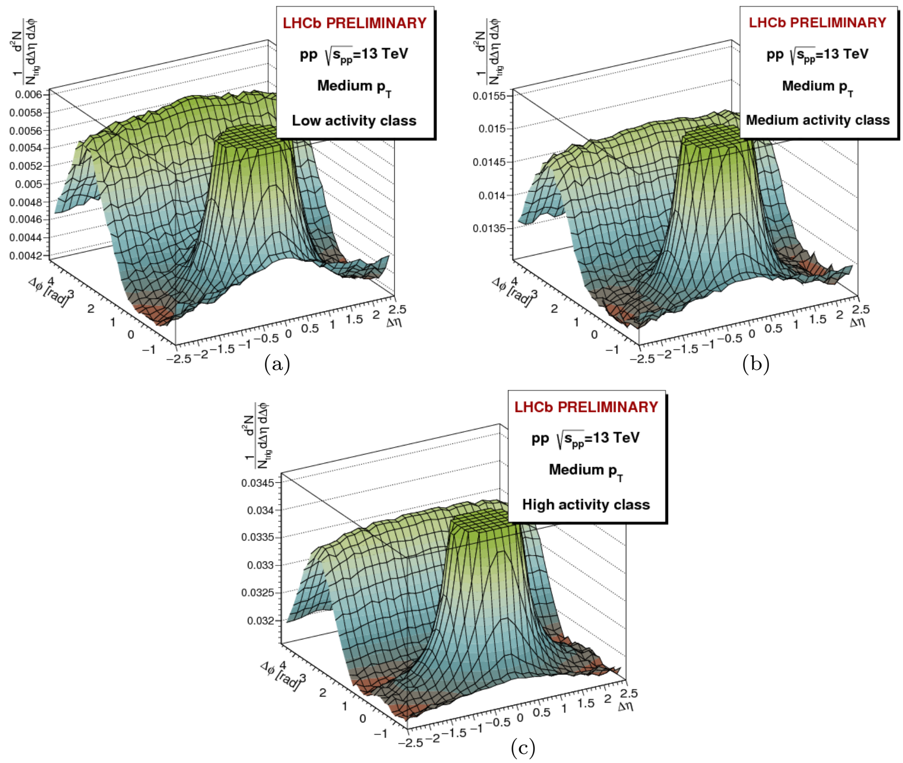

Fig. 2. Two-particle correlation functions for events in the pp collisions, showing the low (a), medium (b) and high (c) event activity classes for medium $p_{\rm T}$ range [11]. Near-side jet around $(\Delta\eta, \Delta\varphi) \approx (0, 0)$ is truncated.

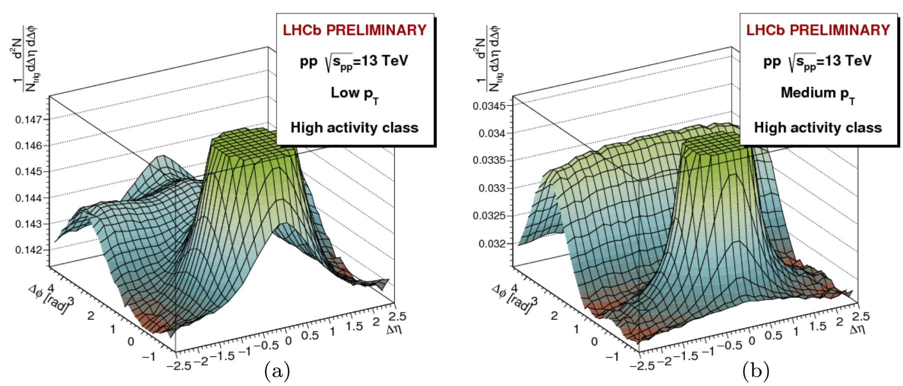

Fig. 3. Two-particle correlation functions for events in the pp collisions, showing the low (a), medium (b) $p_{\rm T}$ range in high-activity class [11]. Near-side jet around $(\Delta\eta, \Delta\varphi) \approx (0, 0)$ is truncated.

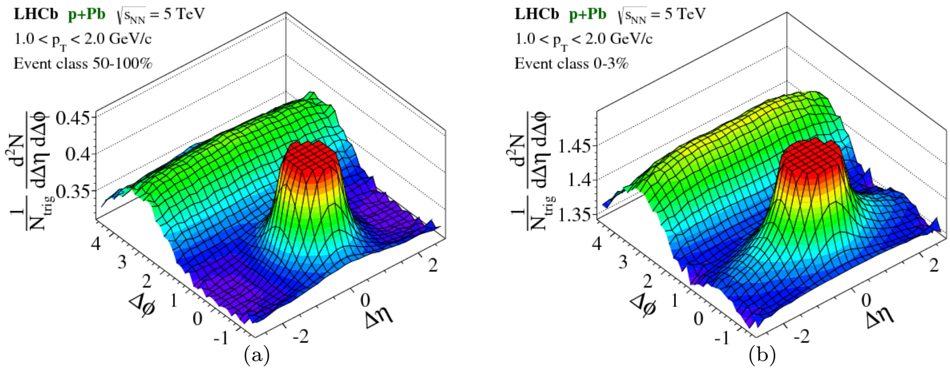

Fig. 4. Two-particle correlation functions for events in the pPb collisions, showing the low (a) and high (b) event activity classes for $1 < p_{\mathrm{T}} < 2$ GeV/c [12]. Near-side jet around $(\Delta\eta, \Delta\varphi) \approx (0, 0)$ is truncated.

4. Summary

Two-particle correlation of charged particles for two types of collision: pp collisions $\sqrt{s} = 13$ TeV and pPb collisions $\sqrt{s_{NN}} = 5.02$ TeV have been presented using results from the LHCb experiment. Near-side ridge in long-range $\Delta\eta$ is observed in both systems in high-multiplicity events for medium p_{T}.

That structure is undeniably of great importance and gives motivation to continue research.

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