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Measurements of collectivity in the forward region at LHCb

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Abstract.
Due to its unique pseudorapidity coverage ($2 < \eta < 5$) and excellent performance at low p_{T}, the LHCb detector provides measurements of two-particle correlation in a complementary region to other LHC experiments. Ongoing studies in flow at different collision systems and energies, pPb collisions at $\sqrt{s_{NN}}$ = 8 TeV, PbPb collisions at $\sqrt{s_{NN}}$ = 5 TeV, and Bose-Einstein correlations of identical pions for pPb collisions at $\sqrt{s_{NN}}$ = 5 TeV, are summarised.

1 Introduction

Particle correlations are a fundamental observable in heavy-ion studies. Since the discovery of the long-range near side ridge in pp collisions [1], the characterization of this effect in different collision systems and pseudorapidity ranges has become crucial. Due to the different acceptance of the LHCb experiment [2], it is possible to measure this observable in an unexplored region where the partons involved have a Bjorken-x value in the range $10^{-6} - 10^{-1}$. Previously at LHCb, two-particle correlations of charged hadrons have been measured in pPb collisions at $\sqrt{s_{NN}}$ = 5 TeV providing the correlation function and the 1D yield for different activity classes [3]. This analysis will serve as a baseline to introduce ongoing analyses where the Fourier coefficients are extracted from the yield in order to measure directed (v_1), elliptic (v_2) and triangular (v_3) flow. Moreover, for PbPb collisions, the results will be displayed in different centrality classes. Finally, following a previous Bose-Einstein correlation measurement in pp collisions [4], an upcoming analysis on the same observable in pPb collisions will be detailed.

2 Near side long-range corrrelations

2.1 Two-particle angular correlations in pPb collisions at $\sqrt{s_{NN}}$ = 5 TeV

Two-particle angular correlations of prompt charged particles have been measured in LHCb for both pPb and Pbp collisions [3]. This observable is widely motivated by the discovery of long-range near-side correlations ("ridge") in pp collisions by the CMS experiment [1]. The correlations are measured for events with one primary vertex and minimum bias trigger. The results have been displayed as a function of p_{T} and event-activity. The event activity is defined as percentiles of the number of VELO hits distribution, where VELO is the LHCb vertex detector. Five event-activity classes, from low (50-100%) to very high (0-3%) activity have been defined.

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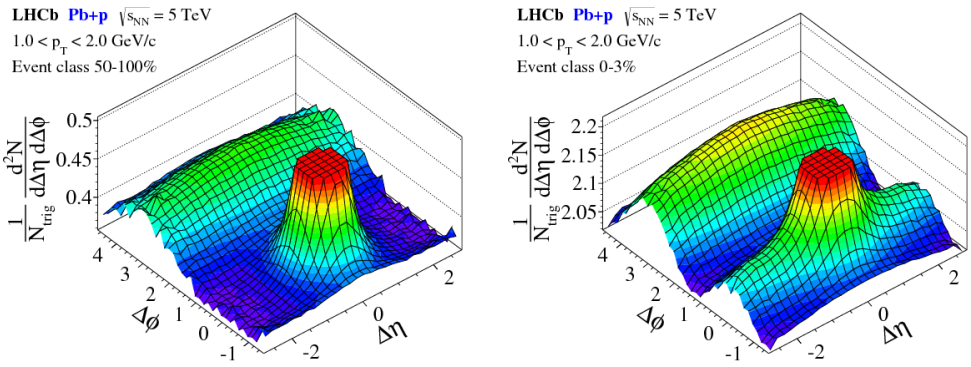

Figure 1. Correlation functions for Pbp collisions at low (left) and high (right) activity.

The correlation function is constructed as a ratio of signal over background,

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

Where the signal, $S(\Delta\eta,\Delta\phi)$, is the density of particle pairs within the same event and the background, $B(\Delta\eta,\Delta\phi)$, the density of pairs from mixed events. Finally, this ratio is normalized by the value of the background contribution at the origin.

To quantify the correlation function, and study its evolution, a 1D-yield, $Y(\Delta\phi)$, is computed by integrating over a $\Delta\eta$ range,

$$Y(\Delta\phi) = \frac{1}{N_{trig}}\frac{dN_{pair}}{d\Delta\phi} = B(0,\,0)\frac{S(\Delta\phi)}{B(\Delta\phi)}. \tag{2}$$

In order to exclude short-range correlations the integration is limited to $2.0 < |\Delta\eta| < 2.8$. The correlation functions for Pbp collisions can be seen in Fig. 1 for low and high activity events. The appearance of a ridge is visible in the high activity regime. This effect is consistent with the one observed by other experiments.

Furthermore, the underlying events have been subtracted by the zero yields at minimum (ZYAM) method. It is observed that the near side ridge yield increases when increasing event activity, as shown in Fig.2. Moreover, yields at pPb and Pbp collisions are compatible when comparing events with the same activity in the forward region. This is the first observation of near-side long-range correlation in the forward region.

2.2 Charged hadrons v_n in PbPb collisions at $\sqrt{s_{NN}}$ = 5 TeV

The LHCb collaboration is going a step forward in measuring flow coefficients for charged hadrons in PbPb collisions. In this work, v_n coefficients will be extracted by fitting the 1D yield with a Fourier series. In that way, the directed, elliptic and triangular flow will be measured in the forward region.

In this study, a centrality classification is made according to Ref.[5] using calorimeter information and fitting to the Glauber model.

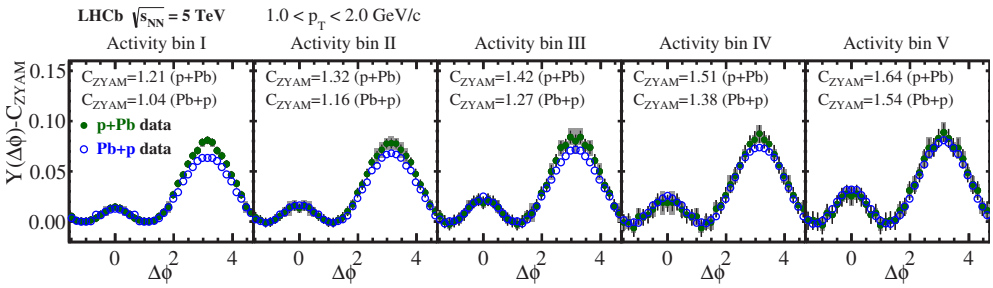

Figure 2. 1D yield from correlation function integration. The ZYAM normalization method is applied. An emergence of long-range near-side correlations can be observed in high activity events.

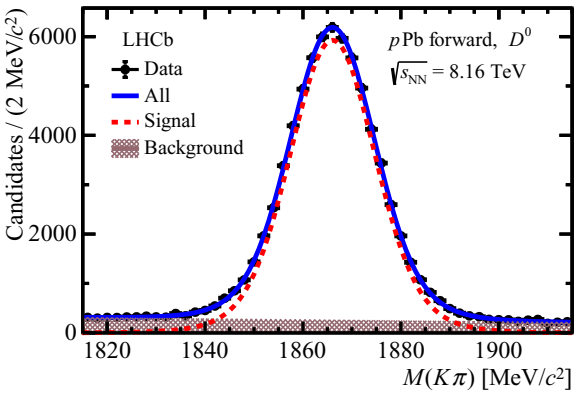

Figure 3. Fit to the invariant mass distribution of D^0 candidates from pPb collisions at $\sqrt{s_{NN}}$ = 8 TeV, [6].

2.3 Charged hadrons and charm meson v_n in pPb collisions at $\sqrt{s_{NN}}$ = 8 TeV

Using the same method as explained in Sec.2.2 to extract Fourier coefficients, a new analysis is being performed with pPb data at $\sqrt{s_{NN}}$ = 8 TeV. Additionally, the flow coefficients of charm mesons will be also measured. Thanks to LHCb's excellent hadron reconstruction capabilities, outstanding precision could be expected from this work. Fig.3 shows the excellent D^0 signals seen in the pPb dataset [6].

3 Bose-Einstein correlations of identical pions in pPb collisions

Following a previous LHCb work using pp collisions [4], a Bose-Einstein correlation analysis is ongoing at the LHCb collaboration using pPb data at $\sqrt{s_{NN}}$ = 5 TeV.

The correlation function, C_2, is computed by dividing the signal over the background. The signal corresponds to the pair density of the same sign pions in the same event while the background is constructed using pions from different events. An event-activity classification is also made. Moreover, the correlation function can be parameterized as a function of two parameters, R and Q,

$$C_2(Q) = 1 + e^{-|RQ|}. \tag{3}$$

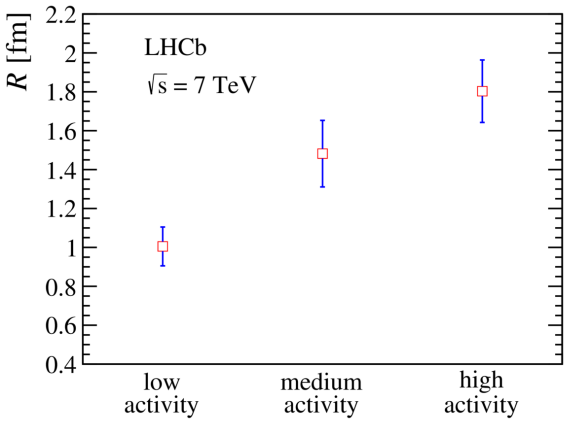

Figure 4. Correlation radius as a function of event-activity from pp data [4].

Where R is the correlation radius and $Q \equiv \sqrt{-q^2} = \sqrt{-(k_1 - k_2)^2}$, a Lorentz invariant quantity that gives a measure of the phase-space separation of the two-particle system. Fitting the correlation function with Eq.3 the correlation radius, R, can be extracted. In Fig.4 an example from the published measurement [4] can be seen.

4 Summary

Ongoing analyses in two-particle correlations at LHCb have been summarised. Thanks to its unique pseudorapidity coverage, LHCb detector can provide measurements in a complementary coverage to other LHC experiments. Three measurements have been detailed in this work. First, the already published long-range correlations functions of charged hadrons in pPb/Pbp collisions, in which LHCb has confirmed the "ridge" effect emergence in high activity events. Secondly, two ongoing measurements, one with PbPb data at $\sqrt{s_{NN}} = 5$ TeV, and the other with pPb data at $\sqrt{s_{NN}} = 8$ TeV, are extending the analysis method to the computation of the Fourier coefficients. Additionally, flow coefficients of charm mesons will also be measured. Finally, a measurement of the Bose-Einstein correlation of identical pions in pPb collisions is being performed. In this work, the activity dependency of the correlation radius will be studied in pPb collisions.

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