PROCEEDINGS OF SCIENCE

Measurement of $R_2(\Delta\eta, \Delta\varphi)$ and $P_2(\Delta\eta, \Delta\varphi)$ correlation functions in pp collisions at $\sqrt{s}$ = 13 TeV with ALICE

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Two-particle normalized cumulants of particle number correlations (R_2) and transverse momentum correlations (P_2) [1], measured as a function of relative pseudorapidity and azimuthal angle difference ($\Delta\eta, \Delta\varphi$), provide key information about particle production mechanisms, diffusivity, and conservation of charge and momentum in high-energy collisions. To complement the recent ALICE measurements in Pb–Pb collisions, as well as for better understanding of the jet contribution and nature of collectivity in small systems, these observables are measured in pp collisions at $\sqrt{s}$ = 13 TeV with similar transverse momentum range, $0.2 \leq p_{\mathrm{T}} \leq 2.0$ GeV/c. The R_2 and P_2 results on the near- and away-side are qualitatively similar, but differ quantitatively. A much narrower near-side peak is observed for P_2 compared to R_2 for both charge-independent and charge-dependent combinations, as in the recently published ALICE results for p–Pb and Pb–Pb collisions [2]. Since these results are sensitive to the interplay between the underlying event and mini-jets in pp collisions, they not only establish a baseline for heavy-ion collisions, but also allow a better understanding of signals that are compatible with the presence of collective effects in small systems.

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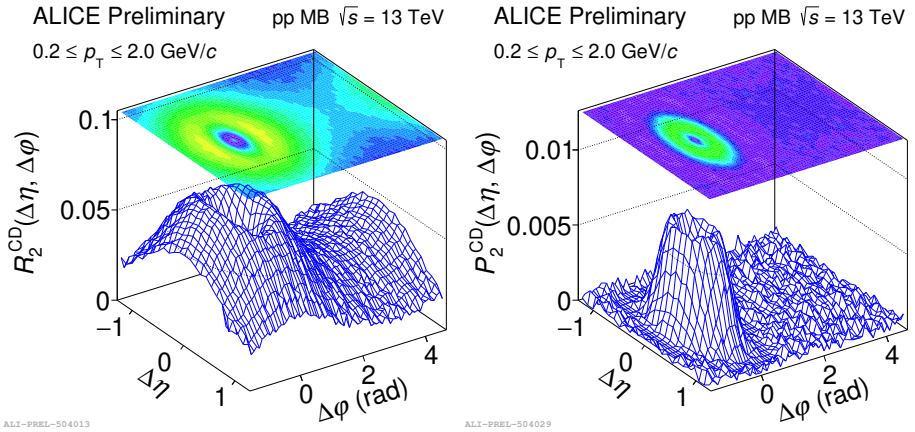

Figure 1: Correlation functions R_2^{CD} (left panel) and P_2^{CD} (right panel) of charged hadrons obtained in the selected p_{T} range in pp collisions at $\sqrt{s}$ = 13 TeV.

Motivation

The robust observables $R_2(\Delta\eta, \Delta\varphi)$ and $P_2(\Delta\eta, \Delta\varphi)$ are sensitive to the particle production mechanisms and transverse momentum fluctuations, respectively. The comparative study of R_2 and P_2 will provide valuable insights into the understanding of particle production in pp collisions and will also serve as a baseline for the interpretation of similar measurements performed in heavy ion collisions [2].

Analysis details

The R_2 and P_2 correlation functions are measured for unidentified charged hadrons in the transverse momentum range $0.2 \leq p_{\mathrm{T}} \leq 2.0$ GeV/c and $|\eta| < 0.8$ in pp collisions at $\sqrt{s}$ = 13 TeV recorded by ALICE. The analysis of the R_2 and P_2 correlation functions are carried out for charge combination pairs $(+-)$, $(-+)$, $(++)$, and $(--)$ to obtain charge-independent, $R^{\mathrm{CI}} = \frac{1}{2}[R^{+-} + R^{++} + R^{-+} + R^{--}]$, and charge-dependent, $R^{\mathrm{CD}} = \frac{1}{2}[R^{+-} - R^{++} + R^{-+} - R^{--}]$, correlation functions and similarly for P_2 [3].

Results

The charge-dependent (CD) charge combination pairs of R_2 and P_2 correlation functions are shown in the left and right panels of Fig. 1, respectively. Due to the Hanbury Brown-Twiss (HBT) effect, both R_2^{CD} and P_2^{CD} have a dip around $(\Delta\eta, \Delta\varphi) = (0, 0)$. The away-side of R_2^{CD} features a saddle-shape structure, whereas P_2^{CD} has a flat away-side.

Figure 2 shows the projections of R_2^{CD} and P_2^{CD} on $\Delta\eta$ and $\Delta\varphi$ in the left and right panels, respectively, where the width of $P_2^{\mathrm{CD}}(\Delta\eta)$ is much smaller than that of $R_2^{\mathrm{CD}}(\Delta\eta)$. Similarly, the width of the near side of the $P_2^{\mathrm{CD}}(\Delta\varphi)$ correlator is also significantly smaller than that of the $R_2^{\mathrm{CD}}(\Delta\varphi)$ correlator. This difference is expected due to the angular and transverse momentum ordering [4].

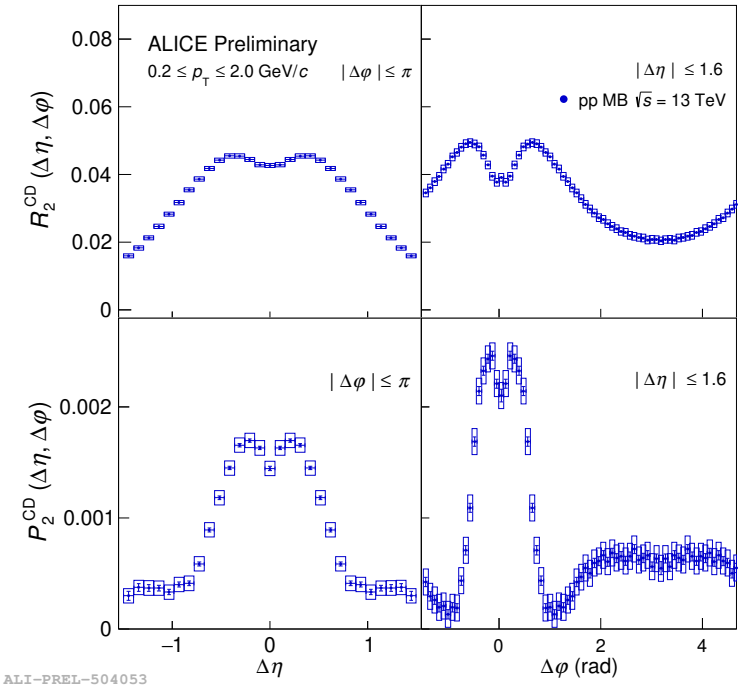

Figure 2: Projections on $\Delta\eta$ (top row) and $\Delta\varphi$ (bottom row) of R_2^{CD} (left column) and P_2^{CD} (right column) correlation functions of charged hadrons in pp collisions at $\sqrt{s}$ = 13 TeV. The $\Delta\eta$ and $\Delta\varphi$ projections are calculated as averages of the two-dimensional correlations in the ranges of $|\Delta\varphi| \leq \pi$ and $|\Delta\eta| \leq 1.6$, respectively. Vertical bars and boxes represent statistical and systematic uncertainties, respectively.

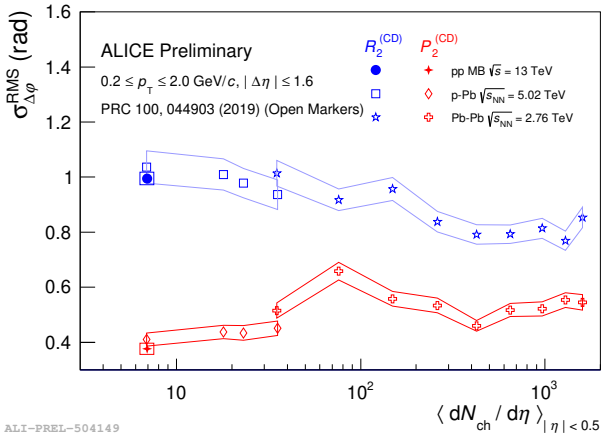

Figure 3: The widths of $R_2^{\mathrm{CD}}(\Delta\varphi)$ (blue markers) and $P_2^{\mathrm{CD}}(\Delta\varphi)$ (red markers) correlation functions along $\Delta\varphi$ measured within $|\Delta\eta| \leq 1.6$ in pp, p–Pb, and Pb–Pb collisions as a function of $\langle \mathrm{d}N_{\mathrm{ch}}/\mathrm{d}\eta \rangle_{|\eta|<0.5}$. Vertical bars represent statistical uncertainties; boxes and bands represent systematic uncertainties.

Note that balance functions (BF) [3] are related to R_2^{CD}, so the width of the near-side peak of R_2^{CD} may be used to understand BF. The widths of the CD pairs of R_2 and P_2 correlation functions along $\Delta\varphi$ measured in pp, p–Pb, and Pb–Pb collisions are shown in Fig. 3 as a function of the average charged-particle multiplicity density. Due to the radial flow and diffusivity in Pb–Pb

collisions, the widths of R_2^{CD} and P_2^{CD} vary with centrality. In p–Pb collisions, the widths of R_2^{CD} decrease, while the widths of P_2^{CD} increase. This is related to the angular ordering [4] of the p_{T} of the jet constituents, which leads to a narrowing of the width of R_2^{CD}. In pp collisions, the widths of $R_2^{\mathrm{CD}}(\Delta\varphi)$ and $P_2^{\mathrm{CD}}(\Delta\varphi)$ are in good agreement with the peripheral p–Pb collisions.

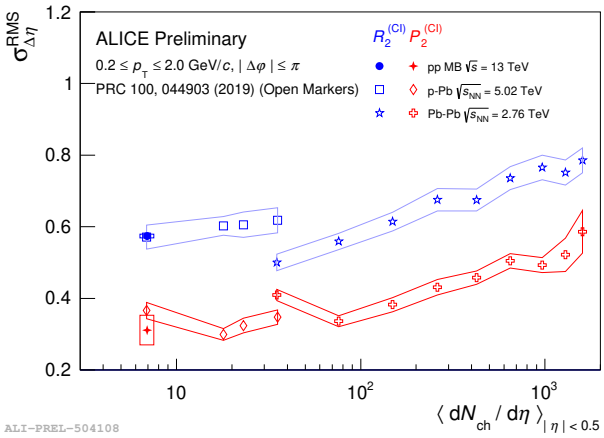

Figure 4: The widths of $R_2^{\mathrm{CI}}(\Delta\eta)$ (blue markers) and $P_2^{\mathrm{CI}}(\Delta\eta)$ (red markers) correlation functions along $\Delta\eta$ measured within $|\Delta\varphi| \leq \pi$ in pp, p–Pb, and Pb–Pb collisions as a function of $\langle \mathrm{d}N_{\mathrm{ch}}/\mathrm{d}\eta \rangle_{|\eta|<0.5}$. Vertical bars represent statistical uncertainties; boxes and bands represent systematic uncertainties.

The widths along $\Delta\eta$ increase monotonically as a function of multiplicity for both $R_2^{\mathrm{CI}}(\Delta\eta)$ and $P_2^{\mathrm{CI}}(\Delta\eta)$, except for $P_2^{\mathrm{CI}}(\Delta\eta)$ for low multiplicities, as shown in Fig. 4. The observed trend in Pb–Pb collisions is mainly due to the anisotropic flow. The widths in pp collisions are comparable to those measured for p–Pb collisions, where the dependence is rather weak compared to Pb–Pb.

Summary

The two-particle correlation functions $R_2(\Delta\eta, \Delta\varphi)$ and $P_2(\Delta\eta, \Delta\varphi)$ have been measured for unidentified charged hadrons in the p_{T} range of 0.2–2.0 GeV/c in pp collisions at $\sqrt{s}$ = 13 TeV recorded by ALICE. The widths of the charge-independent and charge-dependent R_2 and P_2 correlation functions are compared with previously published results in p–Pb and Pb–Pb collisions [2]. The widths show a consistent trend among the three collision systems.

References

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