PROCEEDINGS OF SCIENCE

PoS(EPS-HEP2023)282

Collective effects in PYTHIA 8 simulations of pp and p–Pb collisions

C. D. Brandibur,* A. Danu, A. F. Dobrin and A. Manea

Institute of Space Science – INFLPR Subsidiary,
409 Atomistilor, Magurele, Romania

E-mail: diana.catalina.brandibur@cern.ch

Measurements of two- and multi-particle azimuthal correlations (cumulants) provide valuable information on the properties of the system created in collisions of hadrons and nuclei at high energy. In particular, they revealed an unexpected collective behavior in small collision systems similar to the one exhibited by the quark–gluon plasma in heavy-ion collisions. The origin of collectivity in small collision systems is still not understood.

Measurements of the second order two- and four-particle cumulants of unidentified charged particles are reported from PYTHIA 8 simulations of pp collisions at $\sqrt{s}$ = 13.6 TeV and p–Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV. The second order two-particle cumulants decrease with charged-particle multiplicity and pseudorapidity gap, $|\Delta\eta|$, introduced to suppress the contribution from few-particle correlations ("nonflow"). A weak dependence on the $|\Delta\eta|$ gap is still observed at high multiplicity. The second order four-particle cumulants exhibit a strong dependence on multiplicity for $N_{ch} < 50$ in both collision systems, while they are consistent with zero at high multiplicity. However, when a $|\Delta\eta|$ gap is placed, the second order four-particle cumulants are consistent with zero over the entire multiplicity range. This is expected for Gaussian fluctuations of the sources. In addition, the second order Fourier coefficient of $\pi^{\pm}$, $K^{\pm}$, $p+\overline{p}$, $\Lambda+\overline{\Lambda}$, K^0_S, and $\Xi^{-}+\overline{\Xi}^{+}$ obtained using the scalar product method exhibits a weak mass ordering at low transverse momenta when a $|\Delta\eta| > 2$ gap is employed. This is qualitatively similar to the elliptic-flow pattern observed in heavy-ion collisions.

The European Physical Society Conference on High Energy Physics (EPS-HEP2023)
21-25 August 2023
Hamburg, Germany

*Speaker

1. Introduction

In the last decade striking similarities have been found in proton–proton (pp), p–Pb, and Pb–Pb collisions at the Large Hadron Collider by studying azimuthal correlations of produced particles. The first result was the observation of a near-side ridge (elongated structure at $\Delta\varphi \sim 0$ in the two-particle correlation function versus the difference in azimuth, $\Delta\varphi$, and pseudorapidity, $\Delta\eta$) in high-multiplicity pp collisions [1]. It was followed by the discovery of a symmetric double ridge structure on both the near- and the away-side in p–Pb collisions [2]. The studies were extended to measurements of identified hadrons which reveal a mass ordering in the transverse momentum, p_{T}, dependence of v_2 for different species, with a crossing of p+$\overline{\mathrm{p}}$ and $\pi^{\pm}$ at intermediate p_{T} [3]. This is qualitatively similar to the elliptic-flow pattern observed in heavy-ion collisions. The elliptic flow, v_2, is the second order coefficient in a Fourier series expansion of the particle azimuthal distribution.

The origin of collectivity in small collision systems is still under debate as different models incorporating various physics mechanisms explain qualitatively the measurements. In these proceedings, the collective behaviour is investigated using two- and multi-particle azimuthal correlations of inclusive and identified particles in PYTHIA 8 [4] simulations of pp collisions at $\sqrt{s}$ = 13.6 TeV and p–Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV. Different configurations (default version based on string fragmentation [5] with and without color reconnection, rope hadronization [6], and Monash tune [7]) are used in pp simulations, while the Angantyr model [8] is employed to generate p–Pb collisions. The version 8.309 is used for both systems.

The second order Fourier coefficient of charged particles is extracted using the two- and four-particle cumulant technique [9], while the one of $\pi^{\pm}$, $\mathrm{K}^{\pm}$, p+$\overline{\mathrm{p}}$, Λ+$\overline{\Lambda}$, $\mathrm{K}^0_{\mathrm{S}}$, and Ξ^-+$\overline{\Xi}^+$ is determined employing the scalar product method [10]. Different $|\Delta\eta|$ gaps are placed in order to suppress contributions from short-range correlations ("nonflow"), such as those due to resonances and jets.

2. Results

Figures 1 and 2 present the second order two- and four-particle cumulants of unidentified charged particles as a function of charged-particle multiplicity from different configurations of pp collisions and Angantyr model for p–Pb collisions, respectively. Although there are quantitative differences between the various configurations, the trends are qualitatively similar in all cases. The second order two-particle cumulants decrease with charged-particle multiplicity and $|\Delta\eta|$ gap introduced to suppress nonflow. A weak dependence on the $|\Delta\eta|$ gap is still observed at high multiplicity. The second order four-particle cumulants exhibit a strong dependence on multiplicity for $\mathrm{N}_{\mathrm{ch}} < 50$ in both collision systems, while they are consistent with zero at high multiplicity. However, when a $|\Delta\eta|$ gap is placed, the second order four-particle cumulants are consistent with zero over the entire multiplicity range. This is expected for Gaussian fluctuations of the sources.

The p_{T}-differential $v_2\{2\}$ of $\pi^{\pm}$, $\mathrm{K}^{\pm}$, p+$\overline{\mathrm{p}}$, Λ+$\overline{\Lambda}$, $\mathrm{K}^0_{\mathrm{S}}$, and Ξ^-+$\overline{\Xi}^+$ for $|\Delta\eta| > 1$ and $|\Delta\eta| > 2$ is presented in Figs. 3 and 4 from pp and p–Pb simulations, respectively. A weak mass ordering at low transverse momenta is observed when a $|\Delta\eta| > 2$ gap is employed, while it is broken for $|\Delta\eta| > 1$ gap. In addition, the p+$\overline{\mathrm{p}}$ $\langle v_2\{2\}$ crosses that of $\pi^{\pm}$ at intermediate p_{T} in pp (no color reconnection) and p–Pb simulations without exhibiting any particle type grouping.

PoS(EPS-HEP2023)282

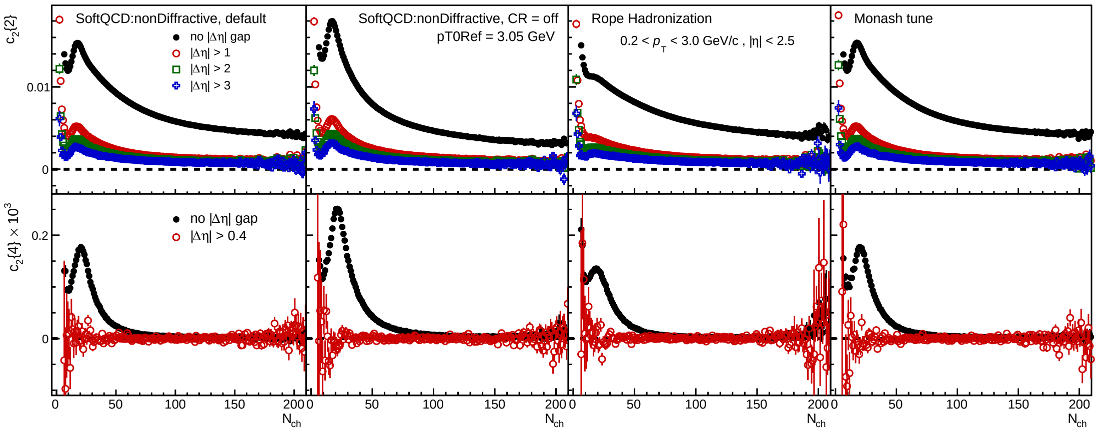

Figure 1: $c_2\{2\}$ (top) and $c_2\{4\}$ (bottom) as a function of charged-particle multiplicity from different PYTHIA 8 configurations of pp collisions at $\sqrt{s}$ = 13.6 TeV.

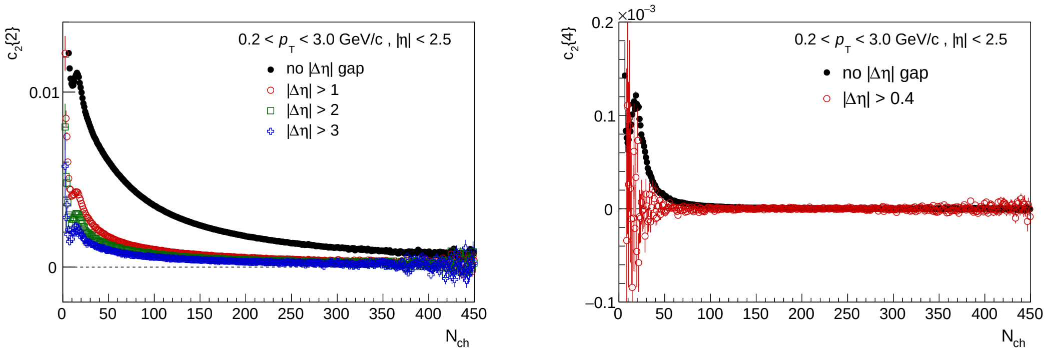

Figure 2: $c_2\{2\}$ (left) and $c_2\{4\}$ (right) as a function of charged-particle multiplicity from PYTHIA 8 Angantyr simulations of p–Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV.

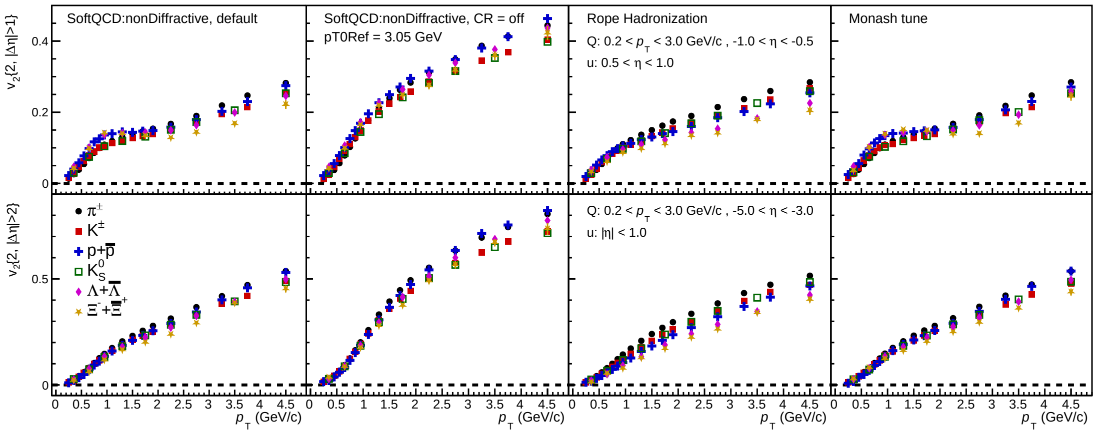

Figure 3: The p_T-differential $v_2\{2\}$ of $\pi^{\pm}$, $K^{\pm}$, $p+\bar{p}$, $\Lambda+\bar{\Lambda}$, K^0_S, and $\Xi^-+\bar{\Xi}^+$ for $|\Delta\eta| > 1$ (top) and $|\Delta\eta| > 2$ (bottom) from different PYTHIA 8 configurations of pp collisions at $\sqrt{s}$ = 13.6 TeV.

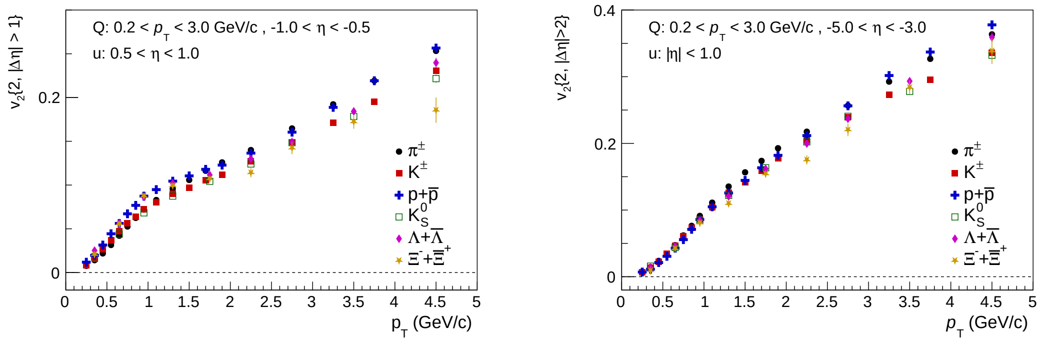

Figure 4: The p_{T}-differential $v_2\{2\}$ of $\pi^{\pm}$, $\mathrm{K}^{\pm}$, $\mathrm{p}+\overline{\mathrm{p}}$, $\Lambda+\overline{\Lambda}$, $\mathrm{K}^0_{\mathrm{S}}$, and $\Xi^-+\overline{\Xi}^+$ for $|\Delta\eta| > 1$ (left) and $|\Delta\eta| > 2$ (right) from PYTHIA 8 Angantyr simulations of p–Pb collisions at $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV.

3. Summary

The second order Fourier coefficient has been studied in pp and p–Pb collisions simulated with PYTHIA 8 event generator. The second order two-particle cumulants decrease with charged-particle multiplicity and $|\Delta\eta|$ gap, while the four-particle cumulants are consistent with zero. A weak mass ordering is observed at low p_{T} when a large $|\Delta\eta|$ gap is employed.

Acknowledgments

This research was supported by a grant of the Ministry of Research, Innovation and Digitization, CNCS – UEFISCDI, project number PN-III-P4-PCE-2021-0390, within PNCDI III.

References

[1] V. Khachatryan *et al.* [CMS], JHEP **09** (2010), 091.

[2] B. Abelev *et al.* [ALICE], Phys. Lett. B **719** (2013), 29-41.

[3] B. B. Abelev *et al.* [ALICE], Phys. Lett. B **726** (2013), 164-177.

[4] C. Bierlich *et al.*, SciPost Phys. Codebases 8 (2022).

[5] B. Andersson, G. Gustafson, G. Ingelman and T. Sjostrand, Phys. Rept. **97** (1983), 31-145.

[6] C. Bierlich, G. Gustafson, L. Lönnblad and A. Tarasov, JHEP **03** (2015), 148.

[7] P. Skands, S. Carrazza and J. Rojo, Eur. Phys. J. C **74** (2014), 3024.

[8] C. Bierlich, G. Gustafson, L. Lönnblad and H. Shah, JHEP **10** (2018), 134.

[9] A. Bilandzic, R. Snellings and S. Voloshin, Phys. Rev. C **83** (2011), 044913.

[10] C. Adler *et al.* [STAR], Phys. Rev. C **66** (2002), 034904.