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Correlations in small systems with ALICE

Igor Lakomov (for the ALICE Collaboration)
European Organization for Nuclear Research (CERN), CH-1211, Geneva 23, Switzerland
E-mail: igor.lakomov@cern.ch

ALICE is dedicated to the study of the strongly interacting matter, the so-called Quark-Gluon Plasma (QGP), formed in heavy-ion collisions at the LHC. In addition, ALICE also actively participated in the pp and p–Pb collision programs. In particular, the measurements of the two-particle azimuthal correlations in pp collisions at $\sqrt{s} = 7$ TeV and in p–Pb collisions at $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV have been performed by the ALICE Collaboration during Run I of the LHC. Similar long-range correlations in p–Pb and Pb–Pb collisions have been observed on the near and away side — also known as the double ridge. Further investigations showed the importance of the Multi-Parton Interactions (MPI) in high-multiplicity collisions in small systems. In this work the ALICE results on the correlations in small systems are presented including MPI measurements in pp collisions.

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1. Introduction

In last few years all the four main LHC experiments performed many studies of azimuthal two-particle correlations in different collisions systems, from pp to Pb–Pb. It was seen that a near-side (around $\Delta\phi = 0$) ridge is present in the data not only in Pb–Pb collisions but also at high multiplicity in small systems. While in Pb–Pb collisions it is a well-known feature which is usually explained by the presence of the anisotropic flow, appearance of this ridge in small systems raises a question about its origin: is it a result of initial or final state effects? While studying the multiplicity dependence of two-particle correlations in p–Pb collisions, ALICE showed that peripheral p–Pb collisions are similar to minimum bias pp collisions, where no near-side ridge is seen [1]. The associated-particle yield in peripheral p–Pb collisions is then subtracted from that in central p–Pb collisions to isolate the ridge from jet. After this procedure a "double-ridge" structure was observed which is shown in the right panel of the Fig. 1. This ridge was quantified in terms of v_{n} coefficients of the Fourier decomposition, and a clear mass ordering was found for v_2 which resembled Pb–Pb case [2]. Such similar behaviour of central p–Pb and Pb–Pb collisions yields to further discussion on the possible collective effects in p–Pb collisions. In this work we show a selection of the ALICE measurements on the correlations in small systems.

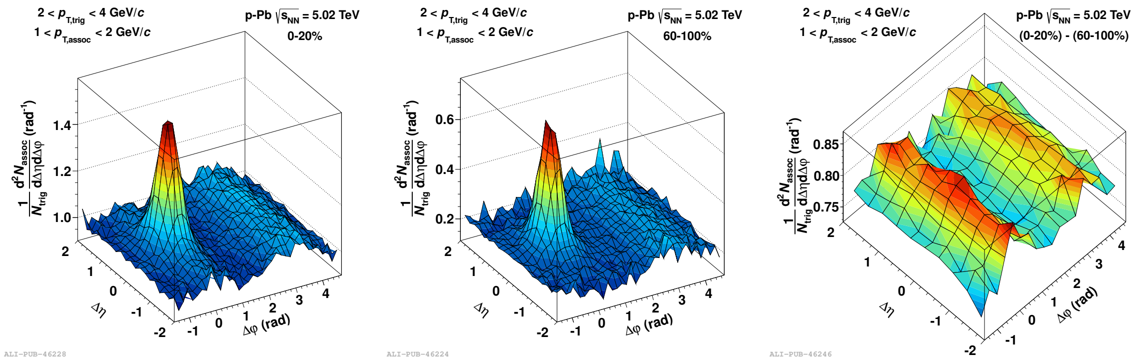

Figure 1: Double-ridge in p–Pb collisions. The right panel with the double-ridge structure is the result of the subtraction of the scaled associated-particle yield for peripheral p–Pb collisions (middle) from that for central p–Pb collisions (left).

2. Long-range correlations in p–Pb collisions

In order to understand the origin of the observed double-ridge in p–Pb collisions ALICE performed the study of the correlations between particles with a large pseudorapidity gap in p–Pb collisions at $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV [3]. For this study the muons detected by the ALICE forward muon spectrometer in pseudorapidity range $2.5 < |\eta| < 4$ were used as trigger particles, and associated particles were chosen from central barrel in pseudorapidity range $|\eta| < 1.0$. The measurements have been performed in two configurations (p–Pb, or p-going direction, and Pb–p, or Pb-going direction) which differ by the direction of the proton and lead beams with respect to the muon spectrometer. A double-ridge structure was observed in both configurations and it thus extends to large pseudorapidity, with η reaching ±4. The left and right panels of Fig. 2 show the Fourier decomposition of the observed double-ridge for p–Pb and Pb–p configurations, respectively. Second-order

Fourier coefficient dominates in both cases. ALICE also measured v_2 of muons which is presented in Fig. 3. A sizeable muon v_2 is found for both p–Pb and Pb–p beam configurations which is larger in the latter case. The AMPT model shows a fair agreement with low-p_T measurements for p–Pb, while at higher p_T it fails to describe the data. The ratio of these two results is consistent with no p_T-dependence. A possible mismatch of the AMPT compared to the data might be partly explained by the fact that the measurements are sensitive to the parent particle v_2 and composition of reconstructed muon tracks, where the contribution from heavy flavour decays are expected to dominate at $p_T > 2$ GeV$/c$.

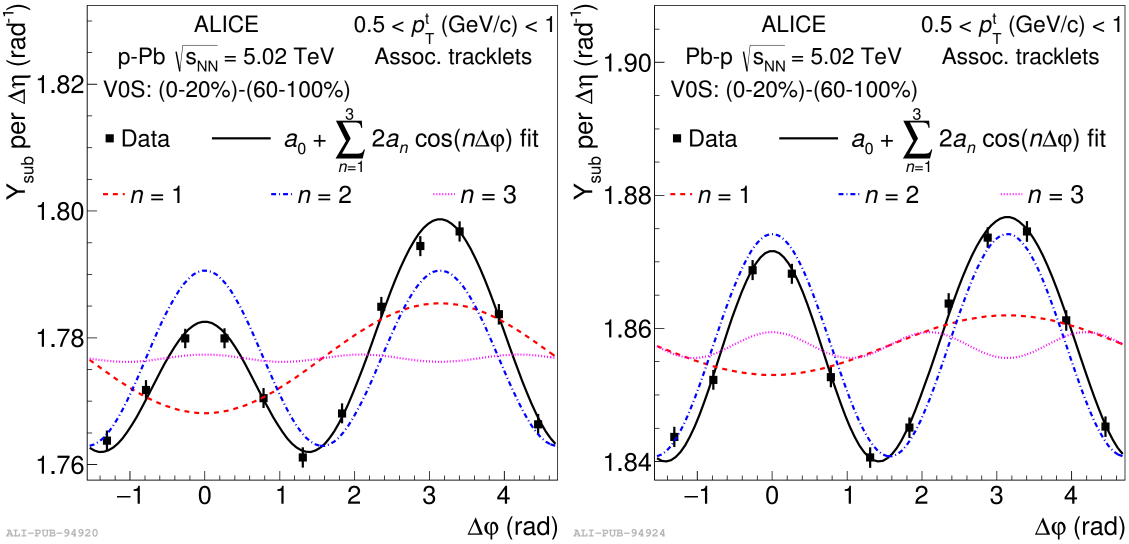

Figure 2: Fourier decomposition of the double-ridge in p–Pb collisions for two configurations of the beams: p–Pb (left) and Pb–p (right).

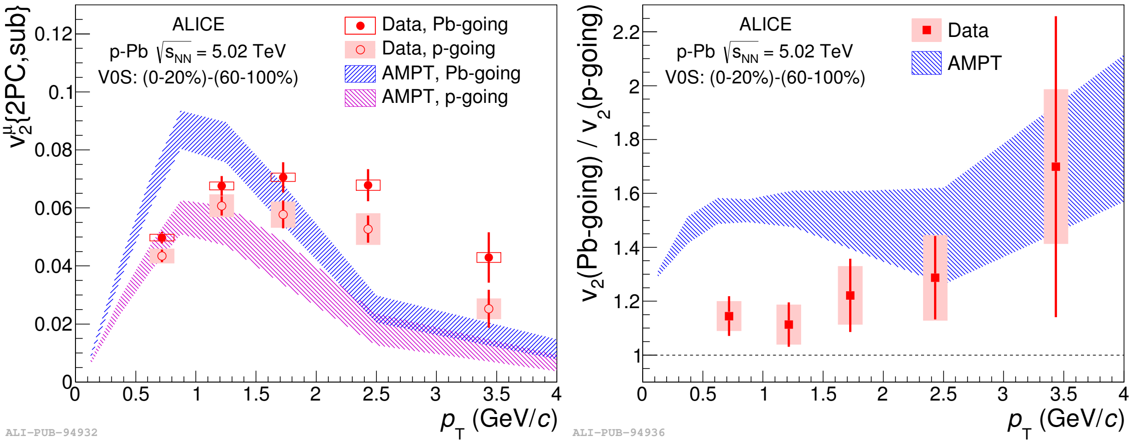

Figure 3: Muon v_2 in p–Pb collisions as a function of p_T for 2 beam configurations (left) and their ratio (right). Open points in left panel represent the p-going configuration, while the filled points are for the Pb-going configuration.

3. Multi-parton interactions in pp and p–Pb collisions

Two-particle azimuthal correlations are also used to study multi-parton interactions (MPI). In PYTHIA generator [4, 5] the number of MPI is linearly proportional to the number of independent particle sources (number of uncorrelated seeds [6]), which can be measured in experiment: $\langle N_{\text{uncorr. seeds}}\rangle = \frac{\langle N_{\text{trigger}}\rangle}{1+\langle N_{\text{assoc.,near+away}}\rangle}$, where $\langle N_{\text{trigger}}\rangle$ is the average number of trigger particles per event, $\langle N_{\text{assoc.,near+away}}\rangle$ is combined associated-particle yield in near (around $\Delta\phi = 0$) and away (around $\Delta\phi = \pi$) sides. This quantity was measured by ALICE in pp at $\sqrt{s} = 0.9$, 2.76 and 7 TeV [6] and in p–Pb at $\sqrt{s_{\text{NN}}} = 5.02$ TeV [7]. The results are presented in Fig. 4 for pp (left panel) and p–Pb (right panel) collisions. In all collisions systems and for different energies the number of uncorrelated seeds seems to grow linearly with the multiplicity with a hint of slight saturation at high multiplicity in pp collisions. This confirms the importance of the MPI in small systems. In right panel results are presented for two different p_{T} cuts. The number of uncorrelated seeds is higher for the wider p_{T} cut (going to lower p_{T} values). Higher reach in multiplicity at higher collision energy from Run II of the LHC data-taking period should provide a better understanding of the MPI at large energy densities.

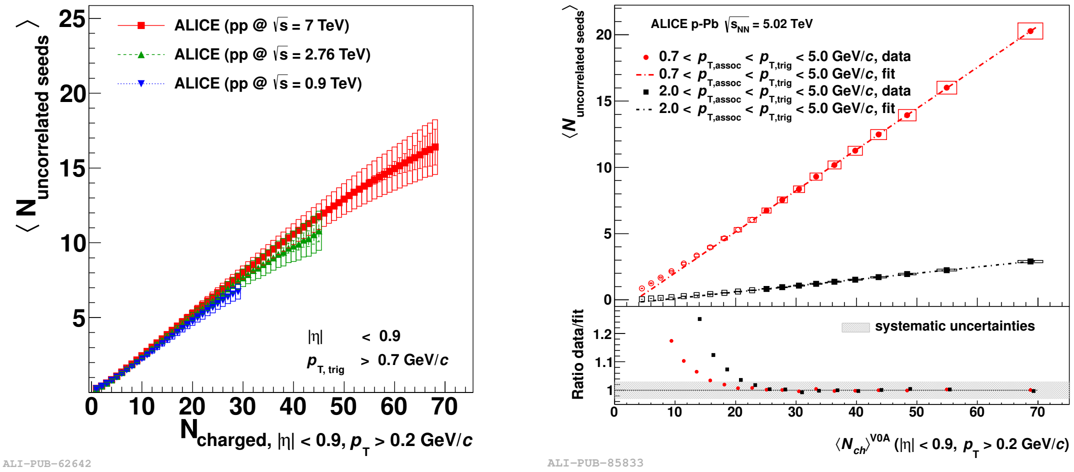

Figure 4: Uncorellated seeds as a function of multiplicity in pp (left) and in p–Pb (right) collisions. In left panel results are presented for three energies with the same p_{T} cut for both trigger and associated particles ($p_{\text{T}} > 0.7$ GeV/c). In the right panel results for p–Pb are given for two different p_{T} cuts ($0.7 < p_{\text{T}} < 5.0$ GeV/c and $2.0 < p_{\text{T}} < 5.0$ GeV/c for both trigger and associated particles).

4. Summary

ALICE has observed in p–Pb collisions a double-ridge structure and a mass ordering in v_2 measurements. This might indicate some collective effects in p–Pb collisions. Further studies of the muon-hadron correlations in p–Pb showed that the double-ridge structure extends over 10 units of pseudorapidity. Inclusive muon v_2 has been measured to be larger on Pb-going side than on p-going side. Comparison of these measurements with the AMPT calculations suggests a non-zero v_2

of muon from heavy flavour decays. Finally, the number of correlated seeds (linearly proportional to the number of MPI) was found to scale linearly with multiplicity both in pp and p–Pb collisions at different energies. Further measurement at higher energies and with higher multiplicity reach will provide better understanding of MPI in small systems.

References

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