

## Characterizing system dynamics with two-particle transverse momentum correlations in pp collisions at $\sqrt{s} = 7$ TeV and p–Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV

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The two-particle differential transverse momentum correlator  $G_2$  recently measured in Pb–Pb collisions, emerged as a powerful tool to gain insight into particle production mechanisms and to infer transport properties such as the ratio of shear viscosity to entropy density of the medium created in Pb–Pb collisions. In this poster, recent ALICE measurements of this correlator in pp collisions at  $\sqrt{s} = 7$  and p–Pb collisions at  $\sqrt{s_{NN}} = 5.02$  TeV are presented to search, in particular, for viscous effects expected to arise in fluid-like systems produced in these collisions. The strength and shape of the correlator are studied as a function of produced particle multiplicity to look for longitudinal broadening that might reveal the presence of viscous effects in these smaller systems. The measured correlators and their evolution from pp and p–Pb to Pb–Pb are additionally compared to predictions from Monte Carlo models, and the potential presence of viscous effects is discussed.

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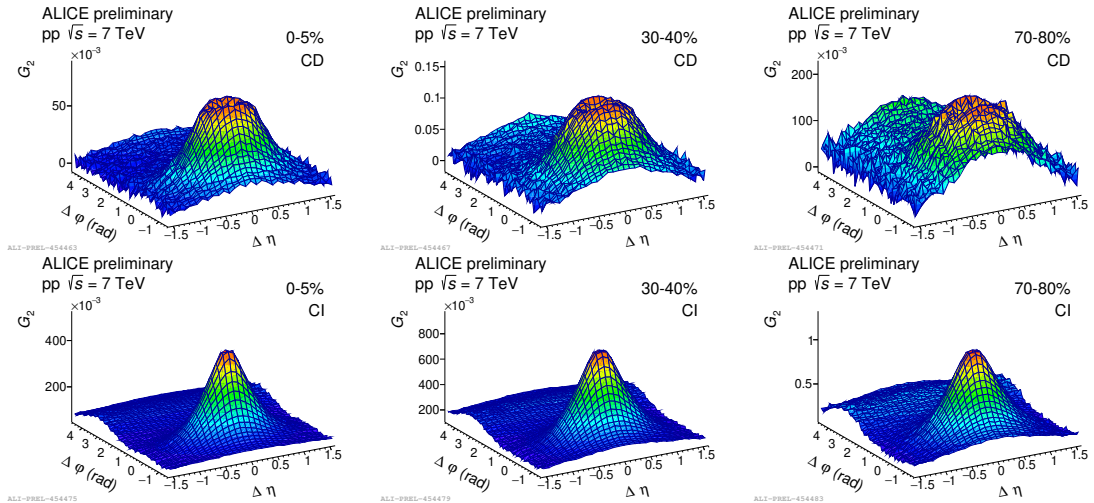
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## 1. Introduction

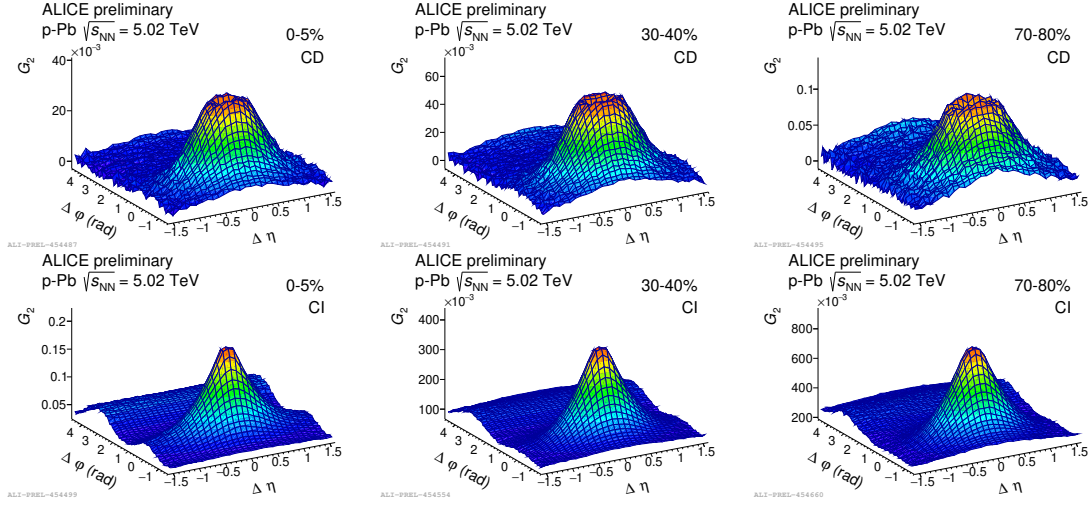
The specific shear viscosity,  $\eta/s$ , is the transport coefficient that most directly controls the expansion of viscous systems. Recent measurements of the longitudinal broadening of the  $G_2$  correlator [1] by the ALICE Collaboration [2] yield a QGP  $\eta/s$  range compatible with estimations based on anisotropic flow. This work measures the same correlator in pp and p–Pb collisions seeking for evidence of longitudinal broadening that may indicate the presence of viscous effects.

## 2. Experimental measurements

The presented results correspond to measurements based on  $6.4 \times 10^7$  selected minimum bias (MB) pp collisions at center-of-mass energy  $\sqrt{s} = 7$  TeV and  $5.4 \times 10^7$  MB p–Pb collisions at center-of-mass energy per nucleon–nucleon collision  $\sqrt{s_{NN}} = 5.02$  TeV recorded with the ALICE detector in the years 2010 and 2013, respectively [3]. Results are reported in nine multiplicity classes corresponding to 0–5% (highest multiplicity), 5–10%, ..., 70–80% (lowest multiplicity) of the total interaction cross section. The analysis uses tracks of charged particles reconstructed in the kinematic acceptance of  $0.2 \leq p_T \leq 2.0$  GeV/ $c$  and  $|\eta| < 0.8$ . The charge-dependent (CD =  $1/4[(+-) + (-+) - (++) - (--) ]$ ) and charge-independent (CI =  $1/4[(+-) + (-+) + (++) + (--) ]$ ) correlators,  $G_2^{\text{CD}}$  and  $G_2^{\text{CI}}$ , respectively, are measured as a function of pair longitudinal,  $\Delta\eta$ , and azimuthal,  $\Delta\phi$ , separation [2]. Figures 1 and 2 present  $G_2^{\text{CD}}$  and  $G_2^{\text{CI}}$  correlators for the pp and p–Pb systems, respectively, while Fig. 3 shows their longitudinal and azimuthal projections. The amplitudes of the correlations decrease monotonically with the collision multiplicity. The CD correlators feature a flat away side associated with the absence of charge-dependent effects, while the CI correlators exhibit a long-range ridge which might be related to momentum conservation. Both correlators show a prominent near side peak, whose longitudinal and azimuthal widths are extracted using the same procedure described in Ref. [2].



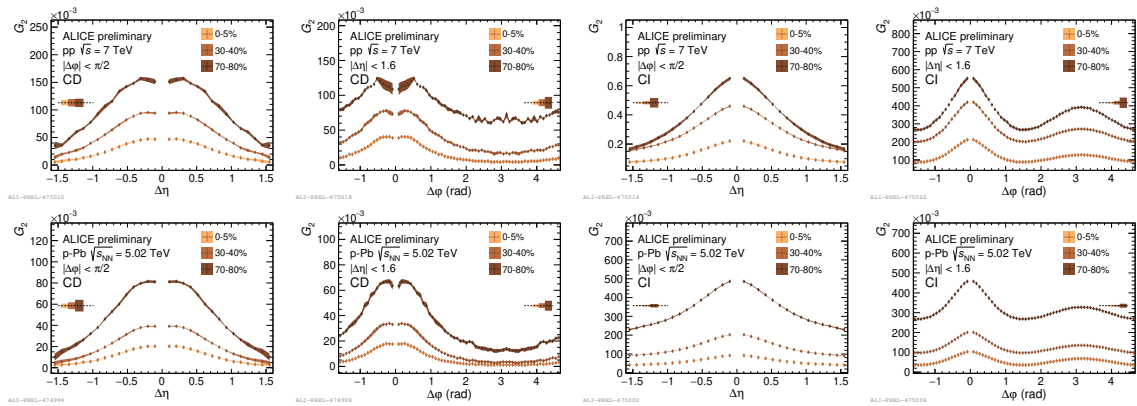
**Figure 1:** Two-particle transverse momentum correlators  $G_2^{\text{CD}}$  (top row) and  $G_2^{\text{CI}}$  (bottom row) for selected multiplicity classes in pp collisions at  $\sqrt{s} = 7$  TeV.



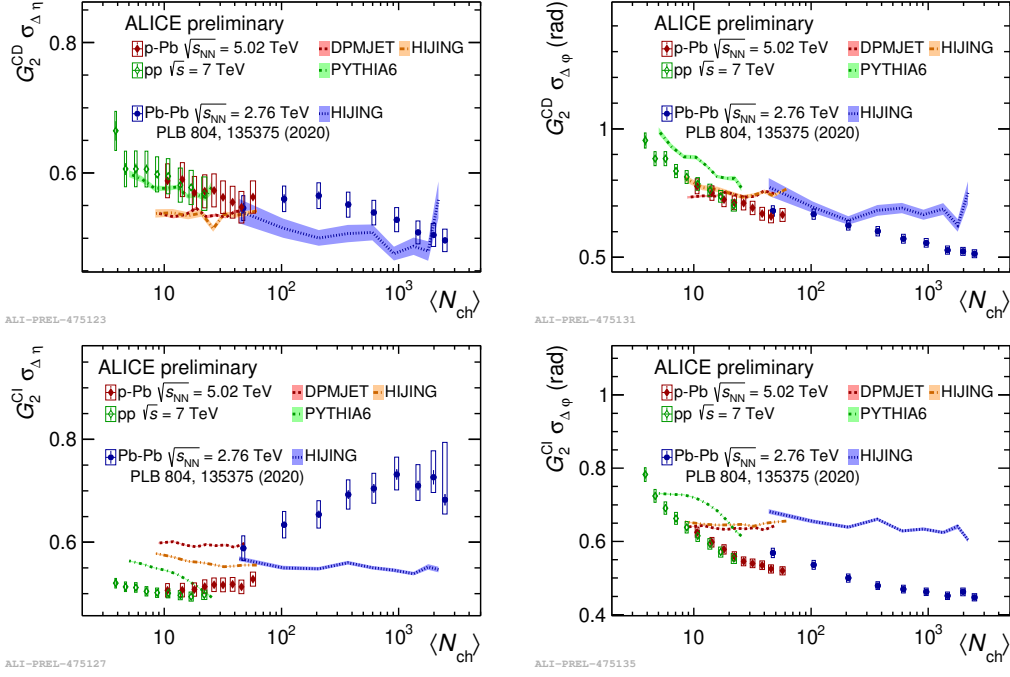
**Figure 2:** Two-particle transverse momentum correlators  $G_2^{CD}$  (top row) and  $G_2^{CI}$  (bottom row) for selected multiplicity classes in p–Pb collisions at  $\sqrt{s_{NN}} = 5.02$  TeV.

### 3. Results and discussion

The evolution of the longitudinal and azimuthal widths of the  $G_2^{CD}$  and  $G_2^{CI}$  correlators with multiplicity in pp, p–Pb, and Pb–Pb collisions systems is shown in Fig 4 in comparison with the results from the PYTHIA 6 (pp), DPMJET (p–Pb), and HIJING (p–Pb and Pb–Pb) event generators. Azimuthally, both correlators narrow with increasing multiplicity in the three systems, a behaviour reproduced only by PYTHIA 6, although its trend for the CI correlator diverges from that of the data. This azimuthal narrowing is consistent with increasing radial flow and average  $p_T$  with multiplicity. In the longitudinal direction, the CD correlator shows a narrowing from pp to the low multiplicity Pb–Pb, where the correlator undergoes some broadening that is countered toward higher multiplicities. Only PYTHIA is able to describe the behaviour shown by the data. For the CI correlator, the broadening in the Pb–Pb system, interpreted as a fingerprint of viscous effects, is



**Figure 3:** Two-particle transverse momentum correlators  $G_2^{CD}$  (two left columns) and  $G_2^{CI}$  (two right columns) longitudinal (left) and azimuthal (right) projections for selected multiplicity classes in pp collisions at  $\sqrt{s} = 7$  TeV (top row) and p–Pb collisions at  $\sqrt{s_{NN}} = 5.02$  TeV (bottom row).



**Figure 4:** Evolution with the average charged particle multiplicity of the longitudinal (left) and azimuthal (right) widths of the two-particle transverse momentum correlations  $G_2^{CD}$  (top row) and  $G_2^{CI}$  (bottom row) in pp, p–Pb, and Pb–Pb collisions at  $\sqrt{s} = 7$  TeV,  $\sqrt{s_{NN}} = 5.02$  TeV, and  $\sqrt{s_{NN}} = 2.76$  TeV, respectively, compared to models.

not seen in both the pp and p–Pb systems.

#### 4. Conclusions

There is no significant longitudinal broadening of  $G_2^{CI}$  with increasing multiplicity in pp and p–Pb, in contrast to the broadening measured in Pb–Pb collisions. Thus, based on the longitudinal broadening of  $G_2^{CI}$ , there is no evidence of viscous effects in these systems. This can also be interpreted as the system being too short-lived for viscous forces to play a significant role. Only PYTHIA reproduces the behaviour of the CD correlator, while it misses that of the CI correlator.

#### References

- [1] S. Gavin and M. Abdel-Aziz, *Measuring Shear Viscosity Using Transverse Momentum Correlations in Relativistic Nuclear Collisions*, *Phys. Rev. Lett.* **97** (2006) 162302 [[nucl-th/0606061](#)].
- [2] ALICE collaboration, *Longitudinal and azimuthal evolution of two-particle transverse momentum correlations in Pb–Pb collisions at  $\sqrt{s_{NN}} = 2.76$  TeV*, *Phys. Lett. B* **804** (2020) 135375 [[1910.14393](#)].
- [3] ALICE collaboration, *The ALICE experiment at the CERN LHC*, *Journal of Instrumentation* **3** (2008) S08002.