Multiparton interactions in pp collisions using charged-particle flattenicity

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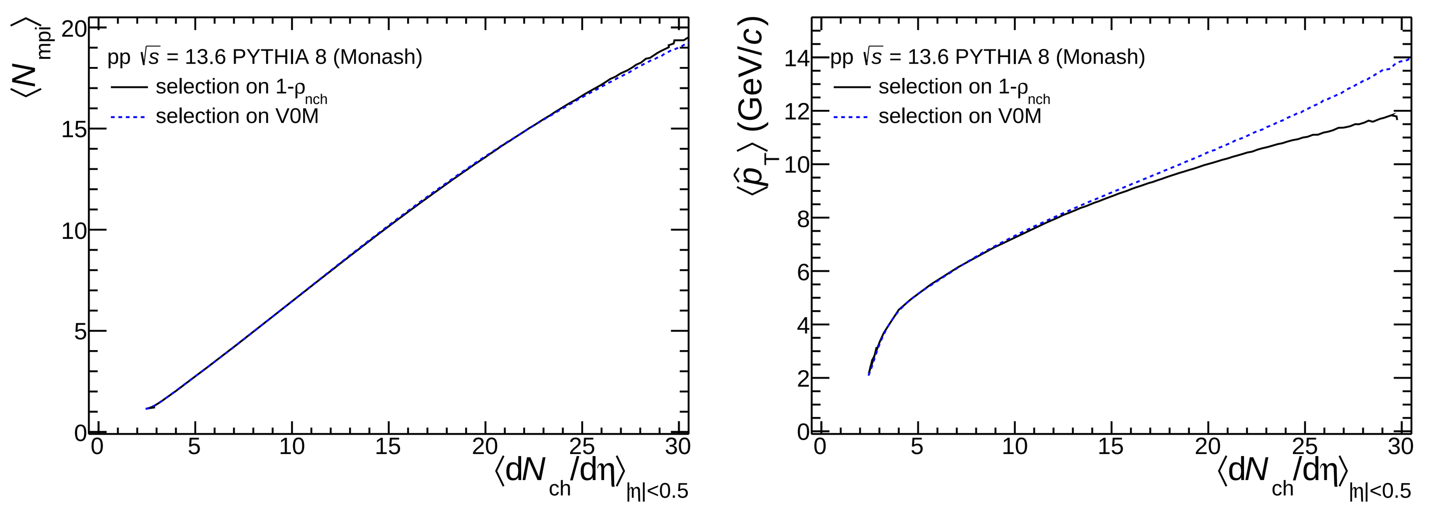
Introduction

The study of pp collisions is relevant given the discovery of collective-like effects and strangeness enhancement in high-multiplicity events. The origin of the effects is not fully understood yet because of several reasons:

- Medium-induced jet modifications have not been observed.
- The existing multiplicity estimators strongly bias the sample towards multijet final states.

The present work discusses that combining charged particle multiplicity ($N_{\rm ch}$) and flattenicity (ρ), both measured at forward pseudorapidity (η), it is possible to control the bias [1]. The figure below shows that they are correlated with multiparton interactions (MPI: several parton-parton scatterings involving momentum transfers of a few GeV/c occurring in the same pp collision); however, the pp collisions tagged with $N_{\rm ch}$ are harder than those selected with ρ.



What is flattenicity?

Flattenicity, ρ:

$$\rho = \sqrt{\sum_{i}^{N_{\rm cell}} \left(N_{\rm ch}^{{\rm cell},i} - \langle N_{\rm ch}^{\rm cell}\rangle\right)^2 / N_{\rm cell}^2} \,/\, \langle N_{\rm ch}^{\rm cell}\rangle, \quad (1)$$

is measured in the V0 detector of the Run 2 ALICE configuration, which consists of V0A ($2.8 < \eta < 5.1$) and V0C ($-3.6 < \eta < -1.7$) covering the full azimuth. Each subdetector has four rings along η and eight equidistant sectors in φ. This leads to a grid with 64 cells ($N_{\rm cell} = 64$). In Eq. 1, $N_{\rm ch}^{{\rm cell},i}$ is the multiplicity in the i-th cell and $\langle N_{\rm ch}^{\rm cell}\rangle$ is the event-by-event average multiplicity in the V0 cells. Figure 1 shows two event displays for high-multiplicity pp collisions produced with PYTHIA 8 [2] event generator.

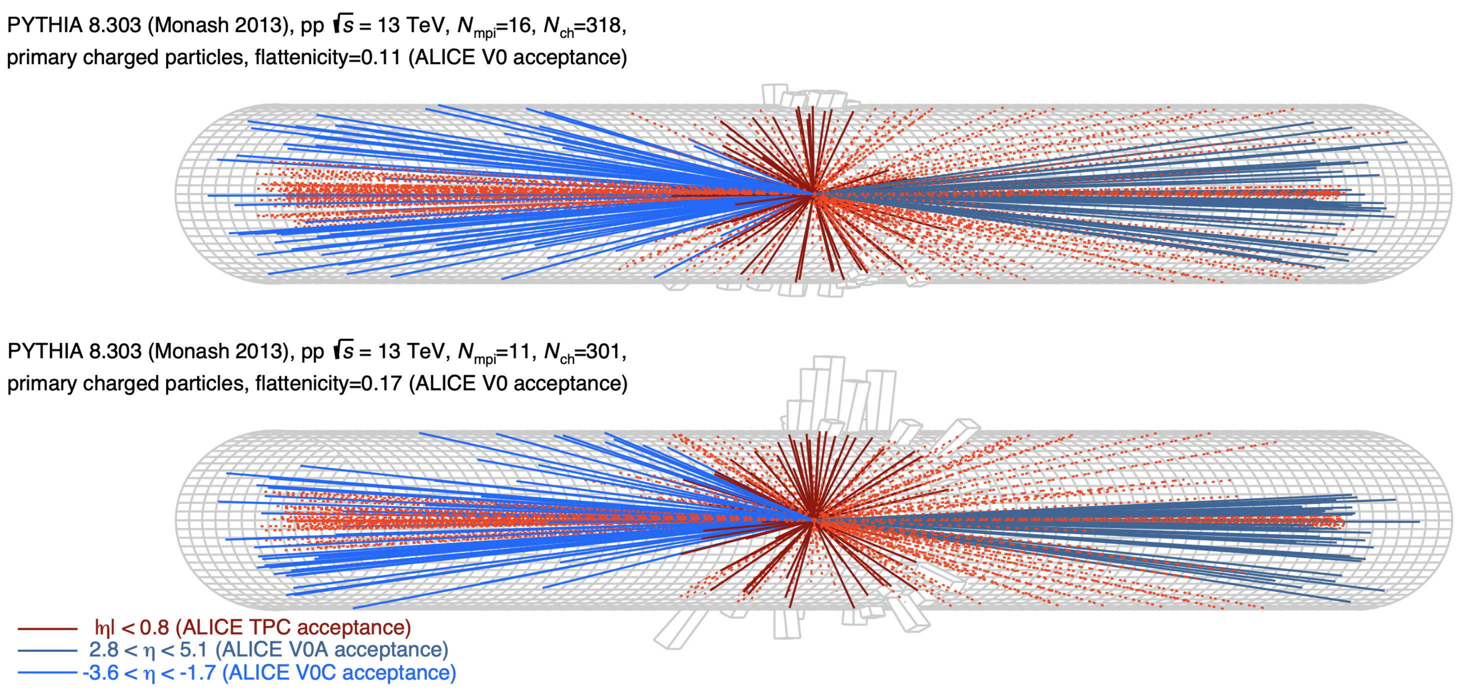


Figure 1: Event displays for "low ρ" (top) and "high ρ" (bottom) pp collisions simulated with PYTHIA 8.

For similar multiplicities, pp collisions are dominated by:

- **Multijet-final states: high ρ ("hard" pp collisions)**
- **Minijets (MPI): low ρ ("soft" pp collisions)**

Analysis details

- The $p_{\rm T}$ spectra of charged particles, pions, kaons and (anti)protons are measured as a function of forward multiplicity (V0M) and flattenicity in pp collisions at $\sqrt{s} = 13$ TeV.
- For $p_{\rm T}$ below 2-3 GeV/c, particle identification (PID) is done exploiting the dE/dx provided by the Time Projection Chamber, and the particle velocity measured with the Time-Of-Flight detector. For higher $p_{\rm T}$, the PID is performed deconvoluting the dE/dx spectrum measured in the relativistic rise regime of the Bethe-Bloch curve.
- The analysis follows the well established methods described in several ALICE publications [3].

Results

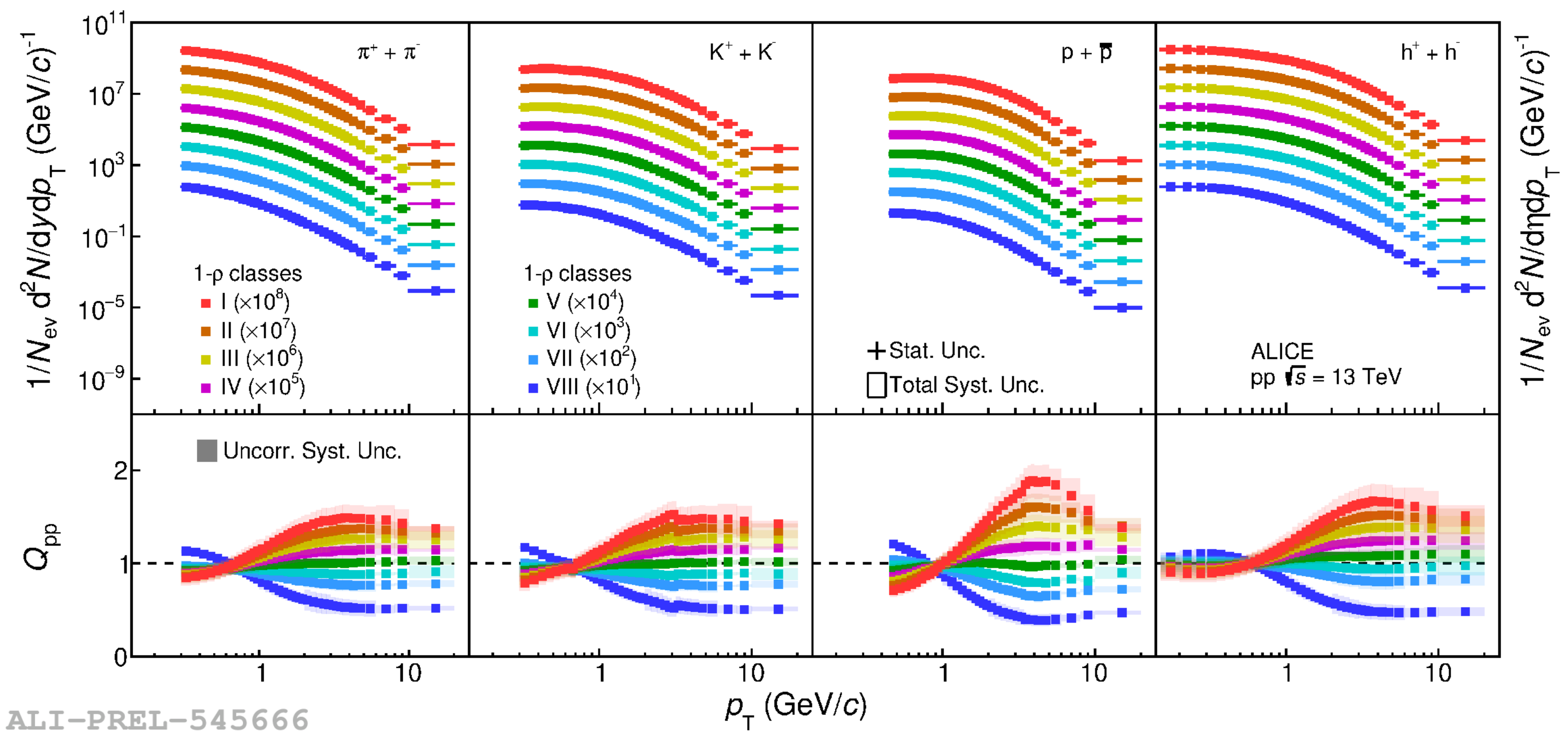
The sample is divided into event classes based on flattenicity. The table below lists the average charged-particle pseudorapidity densities $\langle {\rm d}N_{\rm ch}/{\rm d}\eta\rangle$ within $|\eta| < 0.8$ for the different flattenicity classes, it shows the implicit multiplicity dependence of flattenicity.

I	II	III	IV	V	VI	VII	VIII
0-1%	1-5%	5-10%	10-20%	20-30%	30-40%	40-50%	50-100%
22.2±0.7	18.2±0.6	15.3±0.5	12.6±0.4	10.0±0.3	8.06±0.19	6.47±0.13	3.51±0.04

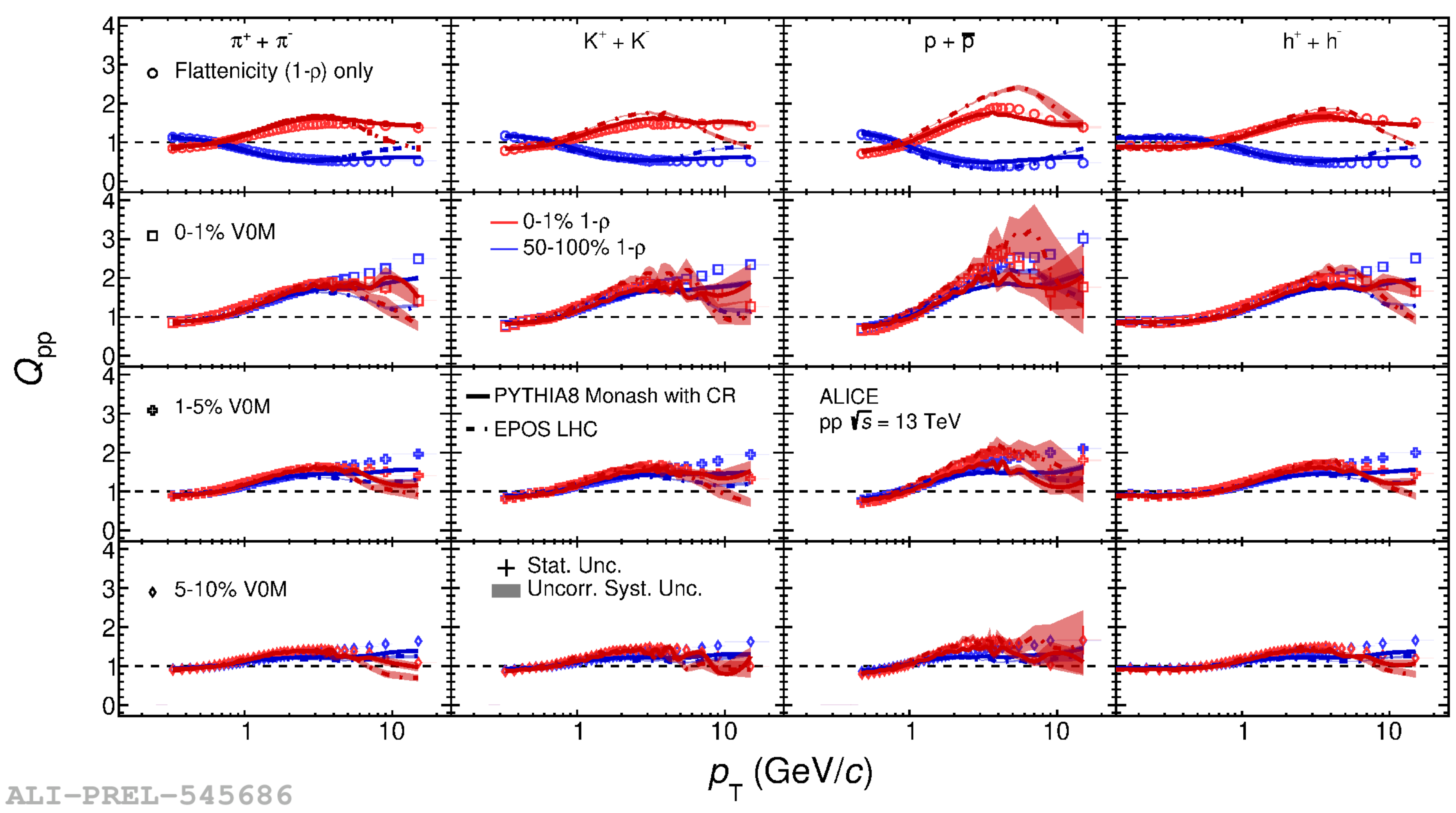
The $p_{\rm T}$ spectra as a function of flattenicity are shown in the figure below. From red (0-1% 1-ρ) to blue (50-100% 1-ρ) the spectra get harder for $p_{\rm T} > 5$ GeV/c. The spectral shape modification is studied with $Q_{\rm pp}$, which is defined as follows:

$$Q_{\rm pp} \equiv [{\rm d}^2N/\langle N_{\rm ch}\rangle {\rm d}y{\rm d}p_{\rm T}]^{\rho\,{\rm class}} / [{\rm d}^2N/\langle N_{\rm ch}\rangle {\rm d}y{\rm d}p_{\rm T}]^{\rm minimum\ bias}. \quad (2)$$

For independent parton-parton scatterings occurring in the same pp collision: $Q_{\rm pp} \to 1$. However, for all flattenicity classes $Q_{\rm pp}$ seems to converge to unity only at high $p_{\rm T}$.



The figure below shows $Q_{\rm pp}$ for pp collisions with fixed $\langle N_{\rm ch}\rangle$ values. In the highest multiplicity class (0-1% V0M), $Q_{\rm pp}$ is flattenicity independent for $p_{\rm T} < 3$ GeV/c. However, for higher $p_{\rm T}$, $Q_{\rm pp}$ keeps rising for the 50-100% 1-ρ event class. Whereas for the 0-1% 1-ρ class, $Q_{\rm pp}$ reduces with increasing $p_{\rm T}$ developing a bump structure. The other event classes exhibit a similar behaviour. Data are compared with EPOS LHC and PYTHIA 8.



Conclusions

- In contrast with previous measurements, $Q_{\rm pp}$ exhibits a reduction (bump) at low-(intermediate-)$p_{\rm T}$ going from low to high $\langle N_{\rm ch}\rangle$ values. This bump is mass dependent. At higher $p_{\rm T}$, $Q_{\rm pp}$ seems to approach to unity.
- Overall, data are better described by PYTHIA (with color reconnection).

References

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[3] **ALICE** Collaboration, S. Acharya *et al.*, "Production of charged pions, kaons, and (anti-)protons in Pb-Pb and inelastic *pp* collisions at $\sqrt{s_{NN}} = 5.02$ TeV," *Phys. Rev. C* **101** no. 4, (2020) 044907, arXiv:1910.07678 [nucl-ex].

Acknowledgment

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