# Event topology studies at the Large Hadron Collider with ALICE

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## Introduction

Measurements of Identified particle production as a function of charged-particle multiplicity in proton-proton (pp) and proton-lead (p-Pb) collisions have unveiled results that are similar to heavy-ion collisions. The origin of these effects in small collision systems is still an open question in the heavy-ion physics community, as there is no evidence of jet quenching in such collisions to date. Event classifiers based either on the charged-particle multiplicity or on event topologies, such as spherocity and underlying event activity variable, have been extensively used in pp collisions by the ALICE Collaboration at the LHC. These event classifiers are very useful tools to understand the fluid-like behavior in high multiplicity pp collisions, for example, radial and anisotropic flow. Furthermore, the study as a function of the charged-particle multiplicity in the forward V0 ALICE detector allowed for the discovery of strangeness enhancement in high-multiplicity pp collisions [1]. However, one drawback of the multiplicity-based event classifiers is that requiring a high charged-particle multiplicity biases the sample towards hard processes like multijet final states. These biases soften the effects of multi-parton (MPI) interactions and make it difficult to pin down the origins of fluid-like effects. Event-shape observables like transverse spherocity, and the relative transverse activity classifier have been studied to isolate the soft-particle production. However, these observables are still sensitive to biases originating due to hard gluon radiation which makes it difficult to interpret the results. Recently, a new event classifier, flattenicity , evaluated from the multiplicity calculated in the forward pseudorapidity region is introduced. It is intended to be sensitive to soft multipartonic interactions, and it is measurable with the current detector acceptance of experiments at the LHC.

The calculation of both the event classifiers and the observable of interest within the same narrow pseudorapidity interval introduces selection biases. The biases are reduced if the event classifiers are determined at forward pseudorapidity. As most of the collider experiments can measure the charged-particle multiplicity at forward pseudorapidity, the flattenicity ($\rho_{\mathrm{nch}}$) is defined using the charged-particle multiplicity [2] in such a way that it can be measured using the existing detectors and given as

$$\rho_{\mathrm{nch}} = \frac{\sqrt{\sum_i (N_{\mathrm{ch}}^{\mathrm{cell},i} - \langle N_{\mathrm{ch}}^{\mathrm{cell}} \rangle)^2 / \mathrm{N}_{\mathrm{cell}}^2}}{\langle N_{\mathrm{ch}}^{\mathrm{cell}} \rangle}, \qquad (1)$$

which is measured in the V0 detector of the Run 2 ALICE.

## Results and discussion

For all these measurements, the ALICE detector is employed, and its comprehensive description can be found in Ref. [3]. The relevant subdetectors contributing to the results include the Time Projection Chamber (TPC), the Time-of-Flight detector (TOF), the Inner Tracking System (ITS) with $|\eta| < 0.9$, and the V0A (2.8 <

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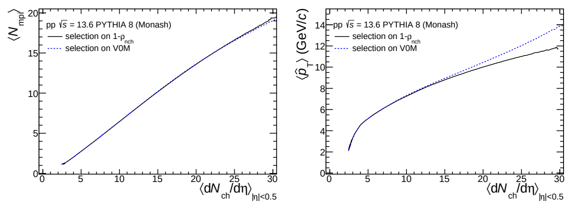


Figure 1: The average number of MPI (transverse momentum of the main partonic scattering) as a function of the charged-particle multiplicity is shown in the left (right) side panel.

$\eta < 5.1$) and V0C ($-3.7 < \eta < -1.7$) detectors. The TPC and ITS play a vital role in tracking and primary vertex determination, while particle identification relies on the TPC and TOF. The V0 detectors are used for triggering and estimating multiplicity at forward rapidities.

The correlation between the average number of multi-partonic interactions and the charged-particle multiplicity density ($|\eta| < 0.5$) with PYTHIA 8 are shown in Fig. 1 (left) using an event selection based on selection with flattenicity or with multiplicity in V0 detectors. Slightly higher $\langle N_{\rm mpi}\rangle$ values at high charged-particle multiplicity are observed when the event selection is done with flattenicity. However, the selection in terms of V0M gives a steeper rise of $\langle \hat{p}_{\rm T}\rangle$ with the charged-particle density than that observed for the selection based on flattenicity. These results suggest that V0M and flattenicity are nearly equally sensitive to MPI, while flattenicity reduces the bias towards hard pp collisions.

The spectral shape modification is studied with $Q_{\rm pp}$, which is defined as the the ratio of $[{\rm d}^2N/\langle N_{\rm ch}\rangle {\rm d}y{\rm d}p_{\rm T}]^{1-\rho_{\rm nch}\ {\rm class}}$ to $[{\rm d}^2N/\langle N_{\rm ch}\rangle {\rm d}y{\rm d}p_{\rm T}]^{\rm min.\ bias.}$ is shown in Fig. 2. By definition, for independent parton-parton scatterings occurring in the same pp collision, $Q_{\rm pp}$ should converge to 1. In min. bias, $Q_{\rm pp}$ is higher (lower) than unity above $p_{\rm T} > 1$ GeV/$c$ for 0-1% (50-100%) 1-$\rho_{\rm nch}$ event classes, which approaches towards unity for large transverse momentum. By restricting the charged particle multiplicity to the top 1%, we observe the bump structure

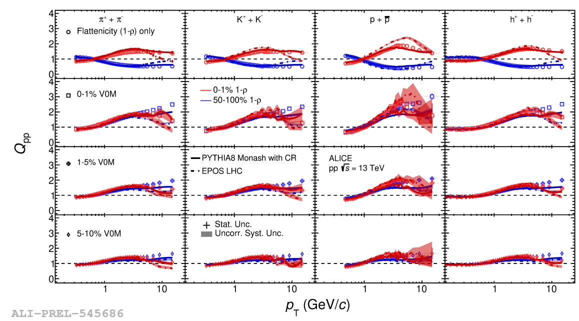


Figure 2: $Q_{\rm pp}$ as a function of charged-particle flattenicity class for different selection of multiplicity classes [4].

in the intermediate $p_{\rm T}$ for the 0-1% 1-$\rho_{\rm nch}$ event class which approaches towards unity at higher $p_{\rm T}$, whereas, for 50-100% 1-$\rho_{\rm nch}$ event class, $Q_{\rm pp}$ is enhanced for high $p_{\rm T}$. These results show that in a high multiplicity environment, selection with flattenicity could isolate the soft and hard QCD processes and hence provide an opportunity to understand the particle production dynamics in small collision systems.

In this contribution, the overview of light flavour particle production with the event classifiers will be discussed and new results on flattenicity will be presented looking into the possibility of measuring multi-differential particle production with the large statistics pp Run 3 data collected by the ALICE Collaboration.

# References

[1] J. Adam *et al.* [ALICE Collaboration], Nature Phys. **13**, 535 (2017).

[2] A. Ortiz, A. Khuntia ..*et. al.*, Phys. Rev. D **107**, 076012 (2023) and references therein.

[3] B. B. Abelev *et al.* [ALICE Collaboration], Int. J. Mod. Phys. A **29**, 1430044 (2014).

[4] Antonio Ortiz; Multiparton interactions in pp collisions using charged-particle flattenicity; Quark Matter (2023).