

Exploring strangeness enhancement in proton-proton collisions at the LHC with event shapes

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Introduction

Strangeness enhancement is one of the important signatures to probe the formation of a thermalised and deconfined medium of partons in high-energy heavy-ion collisions, where proton-proton (pp) collisions are taken as the baseline. Recently, an enhancement of strange hadron production with respect to pions is observed in high multiplicity pp collisions [1]. Several theoretical and phenomenological models have been proposed to explain the observed signatures of QGP in small systems. In fact, p-QCD based models such as PYTHIA8, with a multi-partonic interaction (MPI) based picture of colour reconnection (CR) and rope hadronisation (RH), can reproduce the experimental features of strangeness production [1]. Figure 1 shows the self-normalised yield ratios to pions as a function of average charged-particle multiplicity ($\langle dN_{ch}/d\eta \rangle$) in pp collisions at $\sqrt{s} = 13$ TeV using PYTHIA8 with CR and RH. Here, a large value of $\langle dN_{ch}/d\eta \rangle$ corresponds to a large value of the number of multi-partonic interactions (N_{mpi}). As one approaches high N_{mpi} events, the self-normalised yield ratios of strange hadrons to pions increase. The increment is higher for hadrons having larger valence strange quarks and is higher for baryons than for mesons with a similar number of valence strange quarks. However, MPI is a phenomenological mechanism that explains different experimental measurements and direct measurement of N_{mpi} is not viable in the experiments. Thus, we define event shapes, such

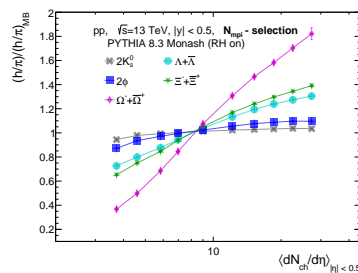


FIG. 1: Strange hadron production ratio to pions normalised to minimum bias events as a function of average charged particle multiplicity at midrapidity in pp collisions at $\sqrt{s} = 13$ TeV using PYTHIA 8 [6].

as charge particle multiplicity in the midrapidity (N_{ch}^{mid}) and forward rapidity (N_{ch}^{fwd}), unweighted transverse sphericity ($S_0^{pT=1}$) [2], transverse sphericity (S_T) [3], relative transverse activity classifier (R_T) [4] and charged particle flattenicity (ρ_{ch}) [5], that are capable of selecting the soft-QCD-dominated isotropic events from the jetty events and possess large correlations with N_{mpi} . The details for event shape definition, event generation, and event and track selection cuts can be found in Ref. [6]. In this study, we show the feasibility of probing the strange hadron production with different event shapes in pp collisions at $\sqrt{s} = 13$ TeV using PYTHIA8.

Results

Figure 2 shows self-normalised yield ratios to pions as a function of $\langle dN_{ch}/d\eta \rangle$ measured in different percentiles of N_{ch}^{mid} (upper left), N_{ch}^{fwd} (upper middle), $S_0^{pT=1}$ (upper right), S_T (lower left), R_T (lower middle), and $1 - \rho_{ch}$ (lower right) in pp collisions at

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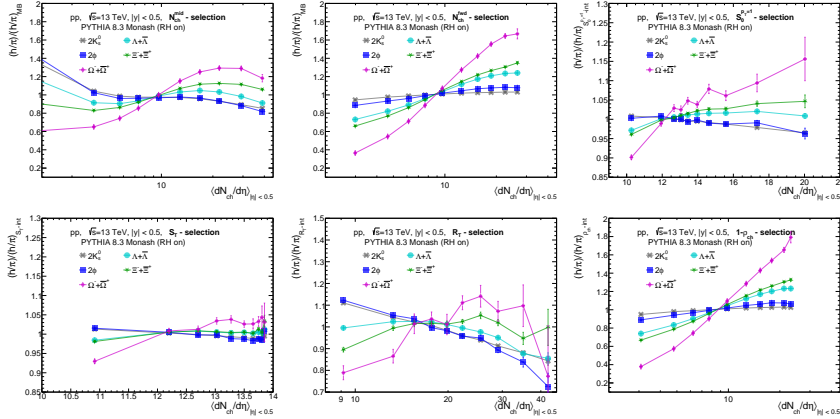


FIG. 2: Self-normalised yield ratios to pions as a function of $\langle dN_{ch}/d\eta \rangle$ for different percentiles of N_{ch}^{mid} (upper left), N_{ch}^{fwd} (upper middle), $S_0^{pT=1}$ (upper right), S_T (lower left), R_T (lower middle), and $1 - \rho_{ch}$ (lower right) in pp collisions at $\sqrt{s} = 13$ TeV using PYTHIA8 [6].

$\sqrt{s} = 13$ TeV using PYTHIA8. Similar to Fig. 1, in Fig. 2, we find a distinction in the self-normalised yield ratios to pions for the strange baryons having different numbers of valence strange quarks. Here, the increment of self-normalised yield ratios with $\langle dN_{ch}/d\eta \rangle$ for all event shapes is higher for Ω having three valence strange quarks as compared to Λ , having only one valence strange quark. Further, one finds a close resemblance between the self-normalised yield ratios to pions for the hidden strange meson, ϕ and K_S^0 possessing one valence strange quark. The self-normalised yield ratios of ϕ and K_S^0 mesons to pions are observed to decrease with an increase in $\langle dN_{ch}/d\eta \rangle$ for the event shapes measured in the midrapidity which includes N_{ch}^{mid} , $S_0^{pT=1}$, S_T and R_T . This is an autocorrelation bias caused by defining the event shapes in a rapidity region where one measures the identified particles. In contrast, this selection bias is absent when event selection is performed using the event shapes measured in a different rapidity region, which includes N_{ch}^{fwd} and $1 - \rho_{ch}$. Here, the self-normalised yield ratios to pions for the strange hadrons are all distinct for events selected with N_{ch}^{fwd} and $1 - \rho_{ch}$, representing their sensitivity to probe the strangeness production. However,

one finds $1 - \rho_{ch}$ very closely mimics the event selection with N_{mpi} shown in Fig. 1, making $1 - \rho_{ch}$ an ideal choice among the currently available event shapes to study strangeness production at the LHC.

Summary

In summary, we show the self-normalised yield ratios of different strange hadrons to pions with event selection based on different event shapes in pp collisions at $\sqrt{s} = 13$ TeV using PYTHIA 8. We find that charged particle flatnecity is one of the best among the currently available event shapes for studying strangeness production at the LHC energies.

References

- [1] S. Acharya *et al.* [ALICE], Eur. Phys. J. C **80**, 693 (2020).
- [2] S. Acharya *et al.* [ALICE], JHEP **05**, 184 (2024).
- [3] B. Abelev *et al.* [ALICE], Eur. Phys. J. C **72**, 2124 (2012).
- [4] T. Martin, P. Skands and S. Farrington, Eur. Phys. J. C **76**, 299 (2016).
- [5] A. Ortiz *et al.* Phys. Rev. D **107**, 076012 (2023).
- [6] S. Prasad, B. Sahoo, S. Tripathy, N. Mallick and R. Sahoo, [arXiv:2409.05454 [hep-ph]].