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 ($\langle dN_{\rm ch}/d\eta\rangle$) in pp collisions at $\sqrt{s}$ = 13 TeV using PYTHIA8 with CR and RH. Here, a large value of $\langle dN_{\rm ch}/d\eta\rangle$ corresponds to a large value of the number of multi-partonic interactions ($N_{\rm mpi}$). As one approaches high $N_{\rm mpi}$ 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 $N_{\rm mpi}$ is not viable in the experiments. Thus, we define event shapes, such as charge particle multiplicity in the midrapidity ($N_{\rm ch}^{\rm mid}$) and forward rapidity ($N_{\rm ch}^{\rm fwd}$), unweighted transverse spherocity ($S_0^{p_{\rm T}=1}$) [2], transverse sphericity ($S_{\rm T}$) [3], relative transverse activity classifier ($R_{\rm T}$) [4] and charged particle flattenicity ($\rho_{\rm ch}$) [5], that are capable of selecting the soft-QCD-dominated isotropic events from the jetty events and possess large correlations with $N_{\rm mpi}$. 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.

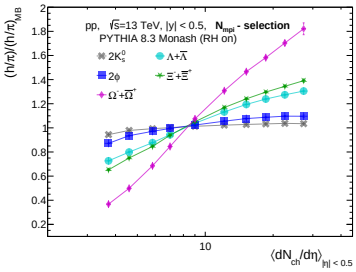

FIG. 1: Strange hadron production ratio to pions normalised to minimum bias events as a function of average charged particle multiplicity at midrapidity in pp collisions at $\sqrt{s}$ = 13 TeV using PYTHIA 8 [6].

Results

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

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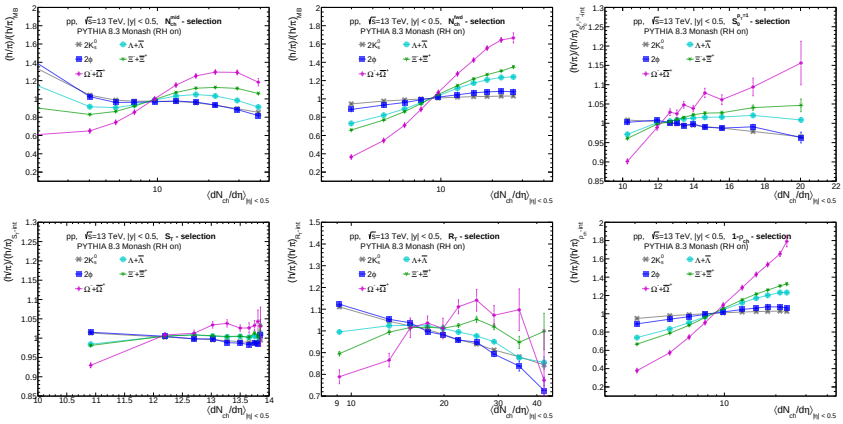

FIG. 2: Self-normalised yield ratios to pions as a function of $\langle dN_{\rm ch}/d\eta\rangle$ for different percentiles of $N_{\rm ch}^{\rm mid}$ (upper left), $N_{\rm ch}^{\rm fwd}$ (upper middle), $S_0^{p_{\rm T}=1}$ (upper right), $S_{\rm T}$ (lower left), $R_{\rm T}$ (lower middle), and $1-\rho_{\rm ch}$ (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 $\langle dN_{\rm ch}/d\eta\rangle$ 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 $\langle dN_{\rm ch}/d\eta\rangle$ for the event shapes measured in the midrapidity which includes $N_{\rm ch}^{\rm mid}$, $S_0^{p_{\rm T}=1}$, $S_{\rm T}$ and $R_{\rm T}$. 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 $N_{\rm ch}^{\rm fwd}$ and $1-\rho_{\rm ch}$. Here, the self-normalised yield ratios to pions for the strange hadrons are all distinct for events selected with $N_{\rm ch}^{\rm fwd}$ and $1-\rho_{\rm ch}$, representing their sensitivity to probe the strangeness production. However, one finds $1-\rho_{\rm ch}$ very closely mimics the event selection with $N_{\rm mpi}$ shown in Fig. 1, making $1-\rho_{\rm ch}$ 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 flattenicity is one of the best among the currently available event shapes for studying strangeness production at the LHC energies.

References

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