Pseudorapidity and transverse spherocity dependence of particle production in proton+proton collisions at the LHC

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Introduction

Recent observations of strangeness enhancement, ridge-like structure and radial flow behaviour at the LHC indicate the formation of QGP-droplets in high multiplicity proton+proton (pp) collisions. While the applicability of hydrodynamics in high multiplicity pp collisions is still under investigation, certain perturbative QCD (pQCD) inspired models such as PYTHIA can imitate radial flow-like effects by implementing color reconnection (CR) with multi-partonic interactions (MPI). Also, the event classifier, transverse spherocity (S_0), is found to be capable of disentangling events based on their geometrical shapes. It can segregate the soft-QCD-dominated isotropic events from the pQCD-dominated jetty events, helping us identify the rare events that mimic heavy-ion-like behaviour in pp collisions. In addition, recent studies show that transverse radial flow velocity depends upon both transverse spherocity and pseudorapidity [1, 2]. In this work, we attempt to study the observables that are sensitive to the radial flow, such as the particle ratios, mean transverse momentum, and kinetic freeze-out parameters, as a function of transverse spherocity and pseudorapidity in pp collisions at $\sqrt{s} = 13$ TeV using PYTHIA8. Here, for the estimation of transverse spherocity, we consider all charged hadrons having $|\eta| < 2.0$ and $p_T > 0.15$ GeV/c. Events having the lowest and the highest 20% value of S_0 are referred to as jetty and isotropic events, respectively.

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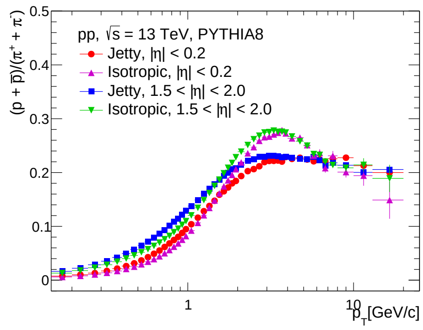

FIG. 1: The ratio of proton to pion yield ($(p + \bar{p})/(\pi^+ + \pi^-)$) versus transverse momentum (p_T) for different transverse spherocity and pseudorapidity selections in pp collisions at $\sqrt{s} = 13$ TeV using PYTHIA8 [3].

Results and Discussions

Radial flow is assumed to give a boost to all the particles and it depends upon the particle mass and transverse momentum (p_T), resulting in the broadening of particle p_T spectra. Thus, a different degree of broadening in p_T spectra is expected for different species of particles, which is reflected in p_T dependent yield ratio of the particles [2]. Consequently, for a system with larger radial flow, the ratio of proton to pion yield ($(p+\bar{p})/(\pi^+ + \pi^-)$ or simply p/π) would show a larger peak which shifts towards a higher p_T value as compared to the system having less radial flow. Figure 1 shows p/π ratio as a function of transverse momentum for different regions of transverse spherocity and pseudorapidity in pp collisions at $\sqrt{s} = 13$ TeV using PYTHIA8. As expected, for a given pseudorapidity class, the isotropic

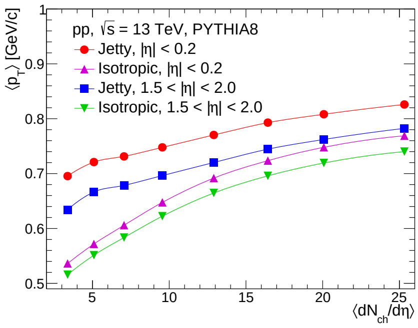

FIG. 2: Mean transverse momentum ($\langle p_{\mathrm{T}}\rangle$) versus mean charged particle density ($\langle dN_{\mathrm{ch}}/d\eta\rangle_{\mathrm{V0M}}$) for different transverse spherocity and pseudorapidity selections in pp collisions at $\sqrt{s}$ = 13 TeV [3].

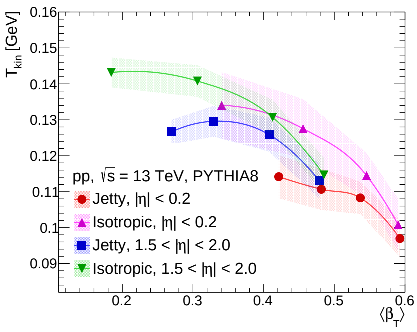

FIG. 3: Kinetic freezeout temperature (T_{kin}) versus mean transverse radial flow velocity ($\langle\beta_T\rangle$), extracted from simultaneous Boltzmann Gibbs Blastwave fit to identified particle spectra, for different transverse spherocity and pseudorapidity selections in pp collisions at $\sqrt{s} = 13$ TeV [3].

events are found to show larger signatures of radial flow compared to the jetty events due to a larger number of partons and partonic interactions. Furthermore, for a given transverse spherocity class, the p/π ratio shows faint pseudorapidity dependence. The system in the mid-pseudorapidity class is found to mimic a more radially boosted system compared to the system having higher pseudorapidity.

Another consequence of radial flow is the enhanced value of mean transverse momentum ($\langle p_{\mathrm{T}}\rangle$). Figure 2 shows $\langle p_{\mathrm{T}}\rangle$ as a function of mean charged particle density ($\langle dN_{\mathrm{ch}}/d\eta\rangle_{\mathrm{V0M}}$) for different transverse spherocity and pseudorapidity selections. As expected, $\langle p_{\mathrm{T}}\rangle$ increases with an increase in $\langle dN_{\mathrm{ch}}/d\eta\rangle_{\mathrm{V0M}}$; however, the $\langle p_{\mathrm{T}}\rangle$ is larger for the jetty events compared to the isotropic events. This is expected as, by nature, jets carry particles with high transverse momentum. Additionally, $\langle p_{\mathrm{T}}\rangle$ is larger for the mid-pseudorapidity case compared to the forward pseudorapidity case.

Figure 3 shows kinetic freeze-out temperature (T_{kin}) as a function of mean transverse radial flow velocity ($\langle\beta_T\rangle$) for different transverse spherocity and pseudorapidity selections. For a particular transverse spherocity class, the particles in the mid-pseudorapidity possess higher $\langle\beta_T\rangle$ and smaller T_{kin} than those in the higher pseudorapidity class. In addition, the jetty events show a larger $\langle\beta_T\rangle$ compared to the isotropic events for both the pseudorapidity classes. We suspect this to have originated and contributed due to large non-flow effects in the jetty events.

Summary

In summary, we have studied p/π ratios, $\langle p_{\mathrm{T}}\rangle$ and kinetic freeze-out parameters such as T_{kin} and $\langle\beta_T\rangle$ as a function of pseudorapidity and transverse spherocity. It is observed that the particles in the mid-pseudorapidity region mimic a system with larger radial flow compared to the higher pseudorapidity regions. In addition, some of the signals for radial flow are enhanced in isotropic events. The studies presented in this contribution using PYTHIA8 can serve as a baseline for future experimental studies.

References

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