Study on anomalous behavior of light and heavy flavors with event topology and multiplicity in *pp* Collisions at the LHC energies

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Hard probes or heavy-flavored hadrons are pivotal tools to study the properties of quark-gluon plasma (QGP) formed in ultra-relativistic heavy-ion collisions at RHIC and the LHC. Recent studies of multiplicity dependence of particle production in proton-proton (*pp*) collisions have gathered considerable interest in the scientific community. Enhanced baryon production over meson is also believed to indicate QGP formation in heavy-ion collisions. Recently, LHC experiments have also observed a similar signature for charmed baryon-to-meson ratio for Pb-Pb and p-Pb collisions [1]. A similar ratio is also measured in *pp* collisions [2]. In the present work, using transverse spherocity (S_0), that separates jet-rich events from isotropic events (rich in MPI), we have analysed the charmed baryon-to-meson ratio in *pp* collisions using PYTHIA8, a pQCD inspired monte-carlo generator, and looked for the existence of such enhancement in intermediate-p_T region. We have also analysed its counterpart ratio in the light flavor sector to know the production dynamics from the light flavor to the heavy flavor hadron sector.

Using PYTHIA8, we have generated around 1.6 billion events for *pp* collisions at $\sqrt{s}$ = 13 TeV with 4C tune along with MPI-based scheme of color reconnection. J/ψ is reconstructed via $e^+ + e^-$ (mid-rapidity) channel. S_0 is defined for a unit vector $\hat{n}(n_T, 0)$ that

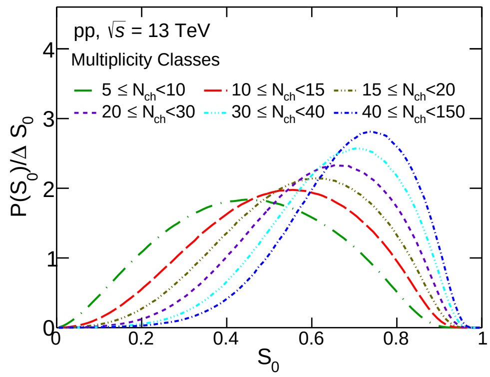

FIG. 1: (Color Online) Transverse spherocity distributions for different charged-particle multiplicity in *pp* collisions at $\sqrt{s}$ = 13 TeV using PYTHIA8 [3].

minimizes the following ratio.

$$S_0 = \frac{\pi^2}{4}\left(\frac{\Sigma_i\, |\vec{p}_{\mathrm{T_i}} \times \hat{n}|}{\Sigma_i\, p_{\mathrm{T_i}}}\right)^2. \quad (1)$$

where, S_0 becoming null are referred to as the jetty events, while unity would mean the events are isotropic. Figure 1 represents the transverse spherocity distribution in different multiplicity classes for *pp* collisions at $\sqrt{s}$ = 13 TeV. In this work, we have chosen the minimum bias collisions and events with the top (bottom) 20% of S_0 for isotropic (jetty) events.

In recent times, observations at the ALICE and LHCb show an enhancement of the

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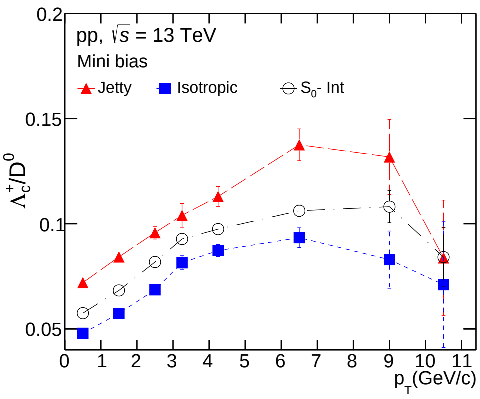

FIG. 2: (Color online) p_{T}-differential particle ratio of Λ_c^+ to D^0, for minimum bias *pp* collisions using PYTHIA8 [3].

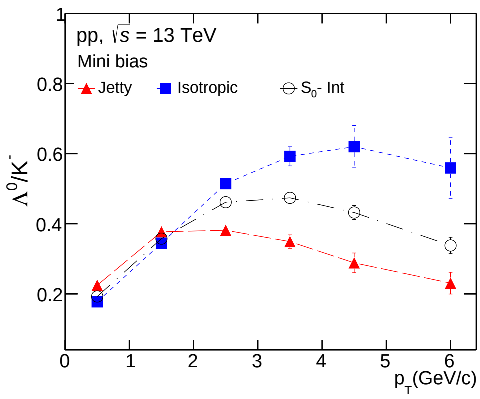

FIG. 3: (Color online) same as Fig. 2 shows p_{T}-differential particle ratio of Λ^0 to K^- using PYTHIA8 [3].

charmed baryon-to-meson ratio, which indicates charm quarks may hadronize through coalescence as well. However, minimum bias *pp* collisions do not show significant enhancement of baryon-to-meson ratio in the intermediate p_{T} region [1, 2]; Here, we have tried to unfold the possibility of such effects in *pp* collisions at different event shapes. Such enhancement would be crucial to the thermalization effect in *pp* collisions. The relative abundance of baryons and mesons can shed light on the process of fragmentation - a non-perturbative process. The formation of partonic jets into high transverse momentum hadrons described by fragmentation function, which incorporates how partons from jet combine with quarks and antiquarks from the vacuum to form hadrons. Because of MPIs, jet-partons in *pp* collisions can combine with quarks and antiquarks produced from MPIs to form hadrons via string fragmentation. Since the momenta of quarks and antiquarks from secondary MPIs are smaller than those of partons from jets, these hadrons have momenta lower than independent fragmentation of jet partons, and that is what we observe in Fig. 2.

Contrary to heavy-flavors, when we study a similar ratio in the light flavor sector (Λ^0/K^-), we observe a completely opposite trend with spherocity classes for $p_{\mathrm{T}} > 4$ GeV/c (Fig. 3): ratio is higher for isotropic samples as compared to jetty ones. This is because the former is driven predominantly by hard collisions and can have maximum contributions from the events' jettiness compared to the contributions from hadronization. However, for light flavors, most of the contributions could be MPI dominant.

We make the following conclusion based on the present study:- (1). A clear dependence of the spherocity distribution with multiplicity is observed, and (2). An observation of Λ_c^+/D^0 and Λ^0/K^- ratio is interesting as their spherocity dependence shows completely different behavior for heavy flavor compared to light flavor sector. This points to a MPI dominant contribution for Λ^0/K^- while the Λ_c^+/D^0 ratio is driven predominantly by hard collisions.

We thank the DAE-BRNS, Government of India for the financial supports from Project No. 58/14/29/2019-BRNS of Raghunath Sahoo.

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