Enhanced production of multi-strange hadrons in proton-proton collisions

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Introduction

The production of strange hadrons in high-energy hadronic interactions provides a tool to investigate the properties of quark-gluon plasma (QGP) [1]. In fact, strangeness enhancement is proposed as a signature of QGP formation in nuclear collisions. Ordinary matter is formed of up (u) and down (d) quarks. The strange (s) quarks are not present as valence quarks in a nucleon, but they may be among the sea quarks in the form of $s\bar{s}$ pairs.As they are sufficiently light, they can be created in large amount in high energy hadronic collisions. Strangeness is produced in hard partonic scattering processes by flavour creation, flavour excitation and gluon splittings. These processes tend to dominate the production of strange hadrons in the higher transverse momentum (p_{T}) region. The non-perturbative processes, like string fragmentation, dominate the production at low p_{T} region. The relative yields of strange particles to pions in heavy-ion collisions from top RHIC (Relativistic Heavy-Ion Collider) to LHC (Large Hadron Collider) energies are found to be compatible with those of a hadron gas in thermal and chemical equilibrium and can be described using a grand-canonical statistical model [2]. In peripheral collisions the relative yields of strange particles to pions decrease and tend toward those observed in proton-proton (pp) collisions. This behaviour can be described by a statistical-mechanics approach [3]. Statistical models implementing strangeness canonical suppression [4] and core-corona superposition [5] models, can predict a suppression of strangeness production in small systems.

Recently, ALICE has published results on strangeness enhancement in high-multiplicity pp collisions [6]. In that letter, ALICE has shown the multiplicity dependence of the production of primary strange (K^0_s, Λ) and multi-strange (Ξ, Ω) (with their anti-particles) hadrons in pp collisions at the energy of $\sqrt{s}$ = 7 TeV. It has shown that in pp collisions the p_{T}-integrated yields of strange and multi-strange particles relative to pions increase significantly with multiplicity. The observed enhancement increases with strangeness content, but not with mass or baryon number of the hadron. To understand this behaviour we have studied on the simulations, like AMPT [7] and EPOS [8]. AMPT itself has two versions; default and string melting (SM). In default model the hadron production is dealt by string fragmentation process and in SM, there is a provision for deconfined quarks and gluons and through coalescence model they hadronize. EPOS is based on 3+1D viscous hydrodynamic model. For the transport of its hadronic medium, it uses UrQMD [9].

Results and Discussion

Fig. 1 shows the yield ratios of strange hadrons to pions divided by the values measured in the inclusive INEL > 0 pp sample, for pp collisions at $\sqrt{s}$ = 7 TeV. There, ALICE is showing a multiplicity-dependent enhancement with respect to the INEL > 0 sample follows a hierarchy determined by the hadron strangeness. The red solid lines show fitting to the data by an empirical function [6] of the

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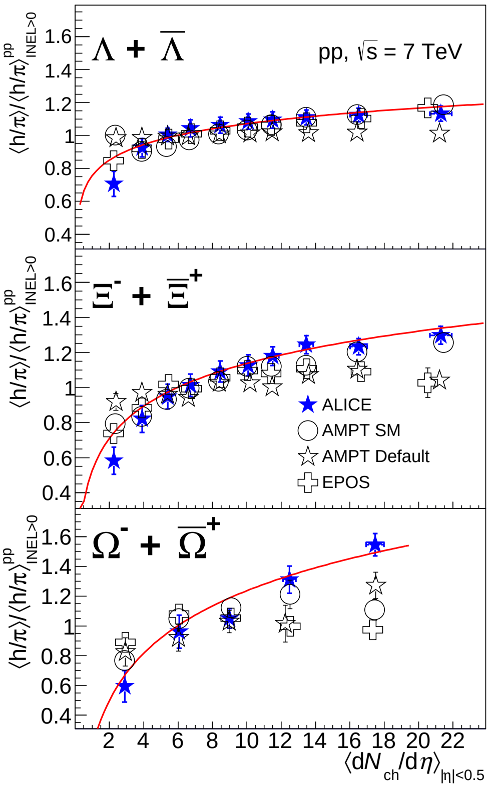

FIG. 1: (Color online) Yield ratios of hadrons to pions normalized to the values measured in the inclusive INEL > 0 pp collisions at $\sqrt{s} = 7$ TeV. The lines represent a individual fit of the results with the empirical scaling formula in equation (1) [6]. The open circles, open stars and open crosses represent AMPT SM, AMPT default and EPOS results, simultaneously.

form

$$\frac{(h/\pi)}{(h/\pi)^{pp}_{INEL>0}} = 1 + aS^b \log\left[\frac{\langle dN_{ch}/d\eta \rangle}{\langle dN_{ch}/d\eta \rangle^{pp}_{INEL>0}}\right], \tag{1}$$

here a and b are free parameters and S is the number of strange or anti-strange valence quarks in the hadron. The results from AMPT default model show the normalised Λ to pion ratios has no effect of charge particle multiplicty, but in case of Ξ and Ω, the model shows a little enhancement towards the high multiplicity events. Still it is not enough to describe the ALICE results. In case of AMPT SM, the model approaches the ALICE results. In case of Λ, AMPT SM approaches to AMPT default in the lowest multiplicity bin. Though EPOS shows an enhancement of yields in high multiplicity events, still it lacks to distinguish the behaviours of single strange and multi-strange hadrons.

Summary and Conclusion

Though models can explain the yield enhancement of strange hadrons, yet they are insufficient to explain the behaviour of multi-strange particles. The models may not be able to explain simultaneously the effects of strangeness canonical suppression in low multiplicity events and QGP like effect in high multiplicity pp collisions at LHC energies. To separately study these effects we have analysed both experimental data and simulation models at low energies and our results will be presented in the conference.

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