Study of the Multiplicity Dependence of Strange and Multi-Strange Particles in pp Collisions

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Introduction

Several effects typical of heavy-ion phenomenology have been observed in high-multiplicity proton-proton (pp) collisions[1]. Recent ALICE results on enhanced production of multi-strange particles in high-multiplicity proton-proton collisions show that, the enhancement increases with strangeness content rather than with mass or baryon number of the hadron. This opens up challenges for a thorough understanding of such novel behaviour which can not be reproduced by any of the commonly used Monte Carlo (MC) models. There are various phenomena which are attributed to such type of behaviour. One of them is the effect of multipartonic interactions. At higher center-of-mass energies the probability of multipartonic interactions increases, where there is more than one hard scatterings take place, which lead to high-multiplicity pp collisions. Due to the high multiplicities produced in pp collisions, one can use the statistical models to describe the particle production mechanism. As thermodynamically consistent Tsallis statistics has been successful in describing the transverse momentum (p_T) spectra of identified particles at RHIC and the LHC , we use this distribution to fit the entire p_T spectra and study the Tsallis parameters as a function of multiplicity as well as mass for the strange (K^0_s, $\Lambda + \bar{\Lambda}$) and multi-strange particles ($\Xi^- + \bar{\Xi}^+$, $\Omega^- + \bar{\Omega}^+$) in pp collisions at $\sqrt{s} = 7$ TeV [2].

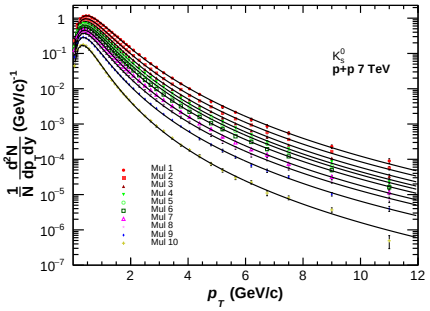

FIG. 1: (Color online) Fitting of p_T-spectra of K^0_s [1] with Tsallis distribution for pp collisions at $\sqrt{s}$= 7 TeV.

Ressults and Discussion

At LHC energies, where $\mu \simeq 0$, the Tsallis distribution function at mid-rapidity is given by,

$$\frac{1}{p_T}\frac{d^2N}{dp_T dy}\bigg|_{y=0} = \frac{gVm_T}{(2\pi)^2}\left[1 + (q-1)\frac{m_T}{T}\right]^{\frac{-q}{q-1}} \quad (1)$$

where, m_T is the transverse mass of a particle given by $\sqrt{p_T^2 + m^2}$, g is the degeneracy, V is the system volume and μ is the chemical potential of the system.

For extraction of the Tsallis parameters of identified strange and multi-strange particles Eq. 1 has been used.

The p_T-spectra for strange and multi-strange particles in pp collisions at $\sqrt{s} = 7$ TeV [1] are fitted with the thermodynamically consistent Tsallis distribution function given by Eq. 1 for different multiplicity classes [2]. For K^0_s, it is shown in Fig. 1 and rest are shown in [2]. In Fig. 2 (upper panel) we show

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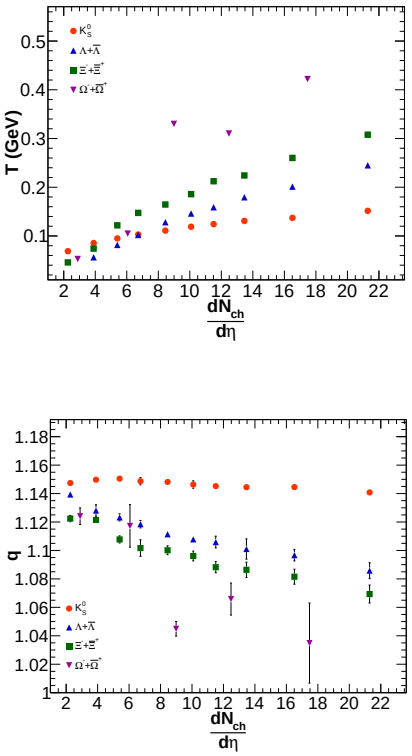

FIG. 2: (color online) Multiplicity dependence of T (upper panel) and q (lower panel) for pp collisions at $\sqrt{s}$= 7 TeV.

the variation of the temperature parameter, T as a function of event multiplicity. This shows a monotonic increase with increase in particle multiplicity. For particles with higher strangeness T is seen to be higher. This indicates an early freeze-out of the multi-strange particles. In Fig. 2 (lower panel), the variation of the non-extensive parameter, q with charged particle multiplicity is shown. The value of q decreases monotonically for higher multiplicity classes for all the particles. However, the q-value for K^0_s is almost independent of the charged particle multiplicity density. This indicates that K^0_s hardly interacts with the medium formed in the collision and thus it shows a minimal tendency for equilibration. The fact that the q-values go on decreasing with multiplicity is indicative of the tendency of the produced systems towards thermodynamic equilibrium.

Summary

Tsallis statistics provides a very good description of the transverse momentum distributions of strange and multi-strange particles produced in pp collisions at $\sqrt{s} = 7$ TeV.

- The extracted non-extensive parameter "q" decreases towards 1 for high multiplicity event classes except for K^0_s, this shows the tendency of the produced system to equilibrate with higher multiplicities.
- Similarly, T shows a systematic increase with multiplicity, the heaviest baryons showing the largest increase.
- This is an indication of a mass hierarchy in particle freeze-out. This goes inline with the expected multipartonic interactions, which increase for higher multiplicities in pp collisions and are thus responsible for bringing the system towards thermodynamic equilibrium.

These results show that the Tsallis distribution is an excellent tool to analyze high-energy pp collisions and are important to understand particle production, freeze-out and equilibration.

ST acknowledges DST-INSPIRE program of Govt. of India.

References

[1] ALICE Collaboration (J. Adam et al.), Nature Phys. **13**, 535 (2017).
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