Multi-strange Baryon Productions at LHC Energy

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Introduction

The study of strange hadrons plays a significant role in probing the hot and dense matter formed in relativistic nuclear collisions at SPS, RHIC and LHC energies. Enhanced production of multi strange baryons(Y) are observed recently which led to intense theoretical activities. The measurements of Ξ and Ω by ALICE collaborations from Pb-Pb, p-Pb and p-p collisions, respectively at $\sqrt{s_{NN}}$=2.76, 5.02 and 7 TeV [1] for various multiplicities motivate to carry out the present work. It is observed that the ratios of the yields of multi strange hadrons, Ξ and Ω to Pion increase with multiplicity like single strange hadrons. However the productions of multi strange are enhanced (compared to single strange with respect to Pion multiplicity) when one goes from lower multiplicity($dN_{ch}/d\eta$) to higher.

In this work, the yields of Ξ and Ω are evaluated using SH-THIC(Strange Hadron Transport in Heavy Ion Collisions), a numerical code developed at VECC based on the frame work of momentum integrated Boltzmann equation or rate equation. The yields are then normalised with thermal pions and results are compared with experimental observations for various initial conditions. The analysis has been done for the yields at various multiplicities from Pb-Pb collisions at $\sqrt{s_{NN}}$=2.76 TeV, LHC energy.

1. Formalism: evolution and rate equation

The production of Ξ and Ω for a hadronic medium is calculated from various hadronic interactions using following rate equations.

$$\begin{aligned}
\frac{dn_\Xi}{dt} &= n_\Lambda n_\Lambda \langle\sigma v\rangle_{\Lambda\Lambda\to N\Xi} - n_N n_\Xi \langle\sigma v\rangle_{N\Xi\to\Lambda\Lambda} \\
&+ n_\Lambda n_\Sigma \langle\sigma v\rangle_{\Lambda\Sigma\to N\Xi} - n_N n_\Xi \langle\sigma v\rangle_{N\Xi\to\Lambda\Sigma} \\
&+ n_\Sigma n_\Sigma \langle\sigma v\rangle_{\Sigma\Sigma\to N\Xi} - n_N n_\Xi \langle\sigma v\rangle_{N\Xi\to\Sigma\Sigma} \\
&+ n_{\bar{K}} n_N \langle\sigma v\rangle_{\bar{K}N\to K\Xi} - n_K n_\Xi \langle\sigma v\rangle_{K\Xi\to\bar{K}N} \\
&+ n_{\bar{K}} n_\Lambda \langle\sigma v\rangle_{\bar{K}\Lambda\to\pi\Xi} - n_\pi n_\Xi \langle\sigma v\rangle_{\pi\Xi\to\bar{K}\Lambda} \\
&+ n_{\bar{K}} n_\Sigma \langle\sigma v\rangle_{\bar{K}\Sigma\to\pi\Xi} - n_\pi n_\Xi \langle\sigma v\rangle_{\pi\Xi\to\bar{K}\Sigma} \\
&+ n_p n_{\bar{p}} \langle\sigma v\rangle_{p\bar{p}\to\Xi\bar{\Xi}} - n_\Xi n_{\bar{\Xi}} \langle\sigma v\rangle_{\Xi\bar{\Xi}\to p\bar{p}} \\
&+ n_\Omega n_K \langle\sigma v\rangle_{\Omega K\to\pi\Xi} - n_\pi n_\Xi \langle\sigma v\rangle_{\pi\Xi\to\Omega K} \\
&- \frac{n_\Xi}{t}
\end{aligned}$$

$$\begin{aligned}
\frac{dn_\Omega}{dt} &= n_p n_{\bar{p}} \langle\sigma v\rangle_{p\bar{p}\to\Omega\bar{\Omega}} - n_\Omega n_{\bar{\Omega}} \langle\sigma v\rangle_{\Omega\bar{\Omega}\to p\bar{p}} \\
&+ n_\pi n_\Xi \langle\sigma v\rangle_{\pi\Xi\to\Omega K} - n_\Omega n_K \langle\sigma v\rangle_{\Omega K\to\pi\Xi} \\
&+ n_{\bar{K}} n_\Lambda \langle\sigma v\rangle_{\bar{K}\Lambda\to K\Omega} - n_K n_\Omega \langle\sigma v\rangle_{K\Omega\to\bar{K}\Lambda} \\
&+ n_{\bar{K}} n_\Sigma \langle\sigma v\rangle_{\bar{K}\Sigma\to K\Omega} - n_K n_\Omega \langle\sigma v\rangle_{K\Omega\to\bar{K}\Sigma} \\
&- \frac{n_\Omega}{t} \qquad (1)
\end{aligned}$$

where, n_Y is the number density, $\langle\sigma v\rangle_{ab\to cY}$ is the rate of multi strange (Y) production due to interaction of particles a and b, v is the relative velocity between incoming particles. σ is the cross section for a particular channel and calculated by considering Lagrangians from [2–5]. For details, please refer[6]. Along with Ξ and Ω, rate equations are also solved for $K, \bar{K}, \Lambda$ and Σ simultaneously. As the system evolves, the temperature falls. Here we have considered Bjorken hydrodynamics for the evolution of the system. The evolution of baryon chemical potential(μ_B) is also considered for the sake of completeness although μ_B has less effect to the net production at LHC energy.

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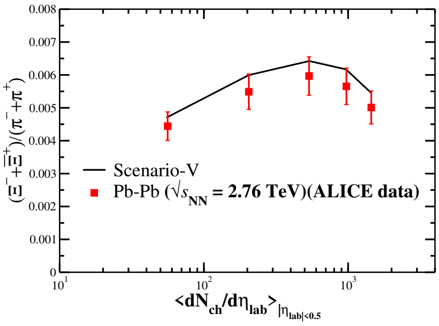

FIG. 1: Yield ratio $\frac{\Xi+\bar{\Xi}}{\pi}$ from 2.76 TeV Pb+Pb collisions. The solid points with error bar are the data points measured by ALICE collaboration. The solid line is the result of theoretical calculation with initial condition for scenario-V.

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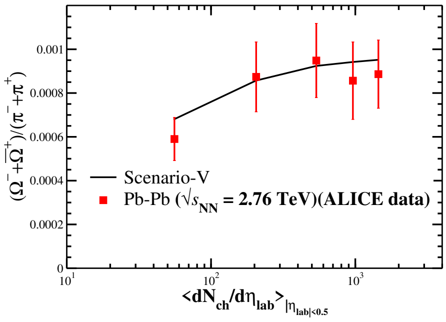

FIG. 2: Yield ratio $\frac{\Omega+\bar{\Omega}}{\pi}$ from 2.76 TeV Pb+Pb collisions. The solid points with error bar are the data points measured by ALICE collaboration. The solid line is the result of theoretical calculation with initial condition for scenario-V.

TABLE I: Freeze out temperatures, T_F for various multiplicities for various scenarios-I, II, III, IV, V

$dn_{ch}/d\eta$	N_{part}	I T_{f_1} Ξ, Ω	II T_{f_2} Ξ, Ω	III T_{f_3} Ξ, Ω	IV T_{f_4} Ξ, Ω	V T_{f_5} Ξ, Ω
1447.5	356.1	0.144	0.144	0.144	0.154	0.134, 0.145
966	260.1	0.142	0.144	0.144	0.154	0.141, 0.144
537.5	157.2	0.140	0.144	0.144	0.154	0.143, 0.143
205	68.6	0.132	0.144	0.144	0.154	0.137, 0.137
55	22.5	0.116	0.144	0.144	0.154	0.118, 0.118

Initial number densities, $n_i(T_C)$ are the parameters and $n_i(T_c) < n_i^{eq}(T_c))$. The system is allowed to start evolving from T_C=154 MeV[7], a value obtained from the first principle calculation of quantum chromo dynamics based on lattice computation. Various initial conditions are considered to analyse the yield of Cascade and Omega at various multiplicities. Then the yields are normalized with thermal pions as mentioned before. Various scenarios (scenario-I to V)considered here are tabulated in Table I.

Out of various scenarios, the one which explains both Ξ and Ω data reasonably well is scenario-V. This is displayed in Figs. 1 & 2. The ratios of the yields of multi strange baryons to Pion, $\frac{\Xi+\bar{\Xi}}{\pi}$ and $\frac{\Omega+\bar{\Omega}}{\pi}$ are plotted against $\frac{dN_{ch}}{d\eta}$. The solid lines are the theoret-

2. Summary

The present work is a microscopic calculation for multi strange productions at LHC energies. Rate equations are used to evaluate the yields for multi strange productions and compared with data. Different chemical freezeout scenarios are observed ruling out single freeze-out of hadrons. Details will be explained during the presentation.

References

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