Constituent Quarks and Multi-Strange Baryon Production in Heavy-ion Collisions

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Introduction

Relativistic heavy-ion collisions aim at creating matter at extreme conditions of energy density and temperature which is governed by the partonic degrees of freedom called Quark-Gluon Plasma (QGP). In the early phase of ultra-relativistic heavy ion collisions, when a hot and dense region is formed in the core of the reaction zone, different quark flavors are produced copiously. The produced matter then undergoes transverse expansion and the produced particles suffer multiple scattering among themselves. The formation of the hadrons from the partonic phase is accomplished through further expansion and cooling of the system.

In the central rapidity region, strangeness enhancement has been proposed as a potential signature of QGP [1, 2]. This enhancement is due to high production rate of gg $\rightarrow s\bar{s}$ in QGP and it can be explained in the language of statistical mechanics. It has been observed that multi-strange baryons are formed and decouple from the system earlier [3] in time. Due to their different reaction rates in the medium, particles with different strangeness decouple at different times. Relativistic Quantum Molecular Dynamics (RQMD) results suggest that the multi-strange baryons freeze-out at energy densities more than $1 GeV/fm^3$ [3] which corresponds to the critical energy density predicted by lattice QCD calculations. This implies that the multi-strange baryons are formed out of partonic rather than nucleonic interactions.

At lower center of mass energies, it has been found that the particle production scales with the number of participating nucleons, contrary to the case of high energies where hard processes dominate. Hard processes have much smaller cross-section than the soft collisions. However, the number of binary collisions increase with increase in collision centrality faster than the number of participants. As a result the particle production per participant nucleon increases with increase in centrality. By using constituent quark approach, we are going to show how the particle production at higher energies depend on the participating quarks. For this, we have chosen multi-strange particles as they are of special interest in QGP formation.

To study the constituent quarks dependence of strangeness enhancement, we need to estimate the number of participant quarks, which has been done in the framework of nuclear overlap model [5].

Results and Discussion

The data points are extracted from RHIC experiments at 200 GeV center of mass energy for Au+Au and p+p collisions. In FIG.1, we show the centrality dependence of Λ and $\bar{\Lambda}$ enhancement normalized to the number of nucleon and quark participants. The enhancement is defined as below.
Enhancement $= \frac{(\text{Yield in Au+Au})<N_{part}^{pp}>}{(\text{Yield in p+p})<N_{part}^{AuAu}>}$.
The enhancement per participating nucleon rises linearly as a function of centrality. But the enhancement per quark participant turns out to be centrality independent. The similar behavior has also been observed from the study of Ξ, $\bar{\Xi}$ and Ω. This indicates the partonic degrees of freedom playing dominant role in the production of the strange baryons.

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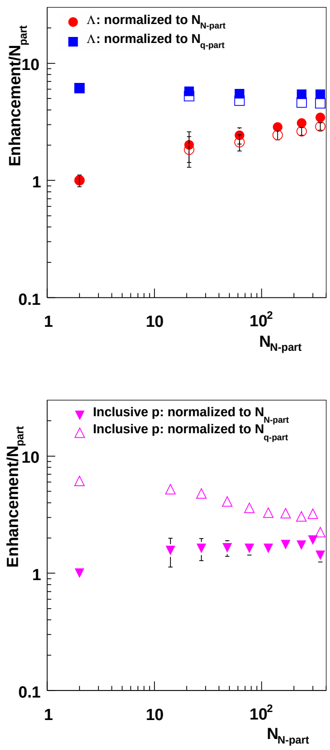

FIG. 1: N_{N-part} and N_{q-part} normalized Λ and $\bar{\Lambda}$ enhancement as a function of collision centrality. The filled squares and boxes are the data points for particles, and open boxes and circles are for the corresponding anti-particles.

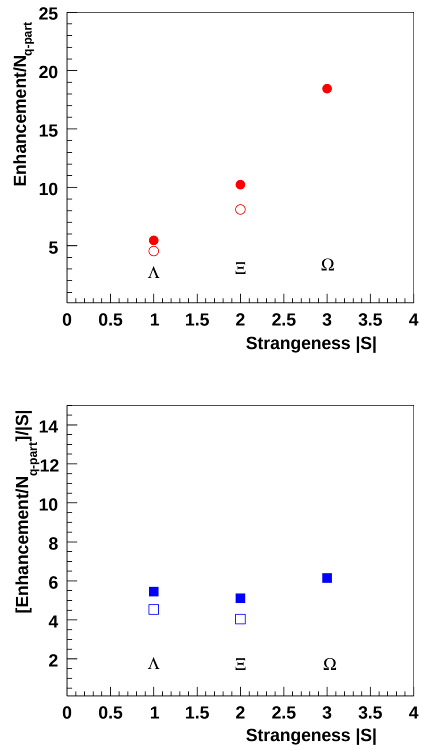

FIG. 2: Quark participant normalized strange particle enhancement as a function of strangeness content. Filled symbols are for the particles and open symbols are for the anti-particles.

In FIG.2, the linear rise of the quark participant normalized enhancement of various multi-strange baryons (upper panel) is further converted to a strangeness scaling (lower panel).

We are in the process of including the SPS data into this picture and the systematic error inclusion is underway.

Conclusion

In the constituent quarks picture, we observe a quark participant scaling of the multi-strange baryon production and also a strangeness scaling of the enhancement. This confirms that the partonic degrees of freedom are playing a major role in the particle production mechanism and may therefore significantly determine the formation of QGP in heavy ion collisions.

References

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