Constituent Quarks and Enhancement of Multi-Strange Baryons in Heavy-ion Collisions

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Introduction

Heavy-ion collisions at relativistic energies aim to produce a state of matter which is governed by partonic degrees of freedom, known as Quark-Gluon Plasma (QGP). In the central rapidity region, strangeness enhancement has been proposed as a potential signature of QGP [1]. This enhancement is due to high production rate of $gg \rightarrow s\bar{s}$ in the QGP phase and it can be explained in the framework of statistical mechanics. It has been observed that multi-strange baryons are formed and decouple from the system earlier [2] 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 $1GeV/fm^3$ [2] 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 have shown the dependence of particle production on the participating quarks. For this, we have chosen multi-strange particles as they are of special interest in QGP formation.

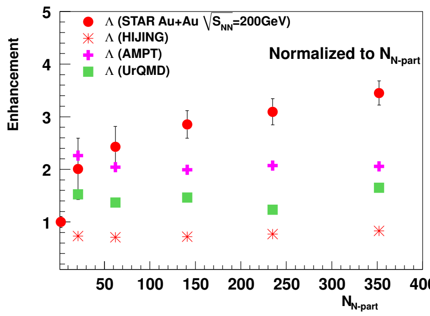

FIG. 1: Mid-rapidity N_{N-part} normalized Λ enhancement for Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV as a function of collision centrality. Data are compared with HIJING, AMPT and UrQMD models.

To study the constituent quarks dependence of strangeness enhancement, we have estimated the number of participant quarks in the framework of a nuclear overlap model [4].

Results and Discussion

We have analysed the centrality dependence of enhanced strange baryon data measured by STAR experiment for Au+Au and p+p collisions at $\sqrt{s_{NN}} = 200$ GeV in contrast to different models like Hijing, AMPT and UrQMD. In FIG.1, we show the centrality dependence of Λ enhancement normalized to the number of participating nucleons. The enhancement is defined as:
Enhancement $= \frac{(\text{Yield in Au+Au})<N_{part}^{pp}>}{(\text{Yield in p+p})<N_{part}^{AuAu}>}$.
The enhancement in data rises linearly as a function of centrality, where as that estimated

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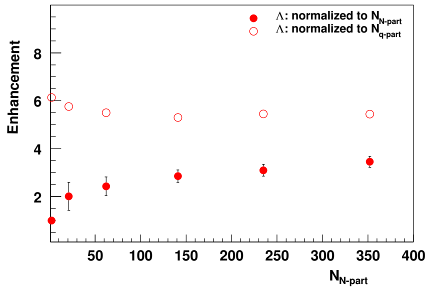

FIG. 2: Mid-rapidity N_{N-part} and N_{q-part} normalized Λ enhancement for Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV as a function of collision centrality.

from the above models are centrality independent (although the data for Λ are shown here, we have seen this trend for Ξ and Ω and their anti-particles, which will be presented). This clearly shows that we need partonic degrees of freedom to describe the data. In other words, we must observe a quark-participant scaling, if we normalize the enhancement taking quarks as the participants in the collision. In FIG. 2, we have shown that the enhancement when normalized to number of quark participants shows a centrality independent scaling, which is absent when we normalize it to nucleon participants. A 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. In FIG.3, the linear rise of the quark participant normalized enhancement (for top central collision) of various multi-strange baryons (upper panel) is further converted to a strangeness scaling (lower panel), when further divided by the strangeness content.

We will present our analysis of SPS Pb+Pb collision data at $\sqrt{s_{NN}}$ = 17.3 GeV and the comparison to different models and our nuclear overlap model.

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 is playing a major role in the particle production mechanism and may therefore significantly determine the formation of QGP in heavy ion collisions [5].

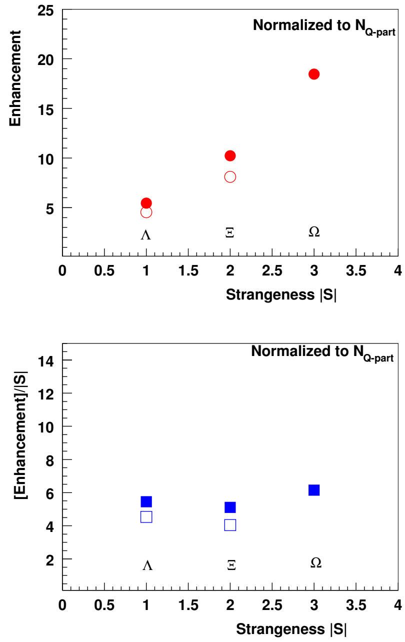

FIG. 3: Quark participant normalized strange particle enhancement as a function of strangeness content. Filled symbols are for the particles and open symbols are for the anti-particles.

References

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