Production of multi-strange hyperons at FAIR energies

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The enhancement of strangeness production is among the signatures of a phase transition from nuclear matter to a deconfined quark gluon plasma phase and is believed to be a powerful diagnostic tool of the quark-gluon plasma QGP, which is expected to be formed in ultra-relativistic heavy ion collisions[1]. Due to the lower energy threshold for $s\bar{s}$ quark pair production, strangeness is expected to be readily produced in a partonic system with partially restored chiral symmetry. The production of strangeness may be further increased for significant baryon densities where the chemical potential associated with the production of light quarks is raised. For these reasons it is expected that the QGP phase should reflect a high strange (anti)quark density [2]. Multi-strange baryons (and anti-baryons) due to their strange quark content, are expected to be a more sensitive probe of the QGP phase, than hadrons which contain only one strange valence quark. One important production process for multi-strange hyperons are strangeness exchange reactions like $\Lambda K^- \rightarrow \Xi^-\pi^0, \Lambda\Lambda \rightarrow \Xi^- p, \Lambda\Xi- \rightarrow \Omega^- n, \Xi^- K^- \rightarrow \Omega^-\pi^-$[3]. These multi-step processes depend on the density of the medium, and hence, the production of multi-strange hadrons, has the potential to probe the density and the Equation-of-State EOS of the medium. Also, the yield of particles carrying strange quarks is expected to be sensitive to the early phase of collision. Among particle species, strange particles freeze-out (chemically) at the early stage of system evolution, interact with quarks of different flavour and eventually appear as a strange hadron in the final state, providing information on the high density stage of the collision.

The Compressed Baryonic Matter (CBM) experiment at Facility for Antiproton and Ion Research(FAIR) at Darmstadt, Germany, has the unique capability of handling higher interaction rates(up to 10 MHz), It is therefore, likely to produce hadrons having higher numbers of strange quarks. The CBM at FAIR is a fixed target experiment aiming at exploring the properties of strongly interacting matter in the high baryon density regime, which has not yet been examined in detail. The energy range for CBM for $Au - Au$ collisions is 2-45A GeV, in this energy range in central $Au - Au$ collisions, energy densities of up to 2.5 GeV/fm^3 and baryon densities of about 7-10 times the normal nuclear matter density can be achieved in the centre of reaction zones. The CBM experiment will study nuclear reactions by measuring bulk and rare particles including their phase-space distributions, correlations and fluctuations with unprecedented precision and statistics. The research program of the CBM experiment at FAIR is focused on the measurement of diagnostic probes of the early and dense phase of the fireball evolution due to high beam luminosity and fast detector system. This approach offers the possibility to find signatures of partonic degrees-of-freedom, and to discover the conjectured first order deconfinement phase transition and its critical endpoint.

The work presents a systematic model-based study of the production of Ω^-, Ξ^- and Λ^0 in central $Au - Au$ collisions (b < 3 fm) at E_{lab} from 2-35A GeV. An investigation of the energy dependence of the yields of strange particle is carried out. The analysis is done using the particles produced in the rapidity region, $|y| < 1$. The study is carried out using two microscopic transport mod-

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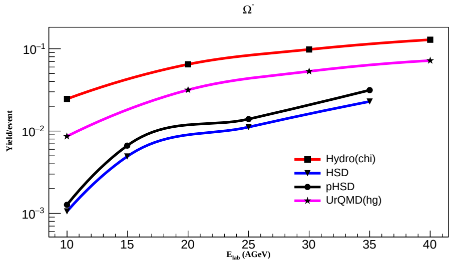

FIG. 1: Excitation function of the Ω^- particle in central $Au - Au$ collisions obtained from pHSD, HSD,UrQMD(HG), and UrQMD+HYDRO(CHI).

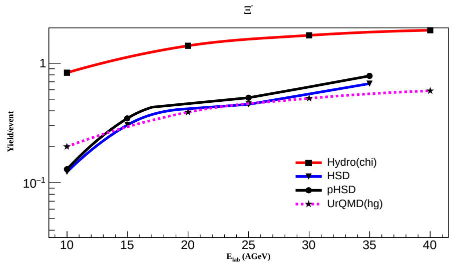

FIG. 2: Excitation function of the Ξ^- particle in central $Au - Au$ collisions obtained from pHSD, HSD,UrQMD(HG), and UrQMD+HYDRO(CHI).

els: (1)Ultra-relativistic Quantum Molecular Dynamics UrQMD in pure and hybrid mode using "hadron gas" EOS and "Chiral" EOS respectively and (2)Hydron String Dynamics HSD (hadronic and partonic mode).

The average multiplicities of Ω^-, Ξ^- and Λ^0 are plotted as a function of beam energy in Fig 1, Fig 2, and Fig 3 respectively. A comparision between the yields of different models is done. All models predict a steep excitation function up to E_{lab} = 30A GeV, from when on the increase is more moderate. The predicted values from models above a beam energy of about 30A GeV are more or less saturated and keep their relative differences. However, at beam energies below 30A GeV, these models exhibit different slopes as displayed by the figures. This is particularly true for the two versions of the UrQMD and HSD trans-

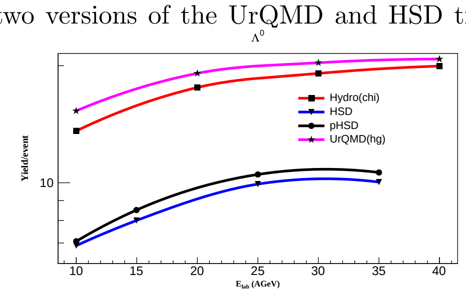

FIG. 3: Excitation function of the yields of Λ^0 in central $Au - Au$ collisions obtained from pHSD, HSD, UrQMD(HG), and UrQMD+HYDRO(CHI).

port model. Yields from UrQMD hydro (Chiral EOS) is more than UrQMD (HG EOS) for Ω^- and Ξ^- and is opposite in case of Λ^0 but the difference is narrower. Partonic version of HSD shows slighly higher yields than its hadronic version for all particles. The observation of enhanced production of multi-strange particles in the partonic mode of HSD and hydro mode with chiral EOS of UrQMD at FAIR energies suggests that these observable are sensitive to the formation of a partonic medium.

In summary, the study shows that multi-strange hyperons are very promising diagnostic probes of the density reached in the fireball and hence, of the equation-of-state of dense QCD matter.

References

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