Strangeness Enhancement at FAIR

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Introduction

The Quantum Chromodynamics calculations predicted, the high density matter to be produced in the relativistic collisions of nuclei (A+A) will comprise of deconfined state of quarks and gluons, namely the Quark Gluon Plasma (QGP). It is argued that the strangeness production from a deconfined partonic matter is more energy efficient than in a hadron gas. As a result, one may expect a relative enhancement of strange particles over the non-strange ones in central A+A collisions with respect to peripheral A+A or proton-proton(p+p) interactions at same collision energy. This makes strangeness enhancement, a diagnostic probe of the properties of the partonic matter and hence regarded as one of the potential signatures of the QGP formation.

Strangeness enhancement was extensively studied at RHIC and SPS. A non-monotonic variation in K/π as function of beam energy, popular as horn structure, was reported unanimously from both the experimental facilities. This non-monotonic increase in the K over π ratio was considered as the first confirmatory evidence of strangeness enhancement. At low energy collisions, as in AGS, a baryon rich QGP is expected to be produced. In a baryon dense QGP, production of light anti-quarks are also suppressed, therefore a large enhancement in strange anti-baryons over the ordinary anti-baryons were expected. This is not only because of strangeness enhancement but also due to suppression of light anti-quark production. Similar signature was also observed in the baryon sector, where an enhancement in anti-lambda($\bar{\Lambda}$) to anti-proton ($\bar{p}$) was reported [1,2]. Since anti-particles are made-of quarks produced in the reactions only, they are regarded as a cleaner channel to probe strangeness enhancement than the usual K/π ratio. Indeed a large enhancement $\bar{\Lambda}$ over $\bar{p}$ ratio ($\sim$3.5) was reported by the E917 experiment at AGS. Also a significant increase from 0.25 in p+p collisions to 1.5 for A+A collisions was published by the NA35 experiment at CERN SPS. However, what has remained unclear, whether this enhancement is uniquely associated with the strangeness enhancement in QGP. The main reason of this ambiguity was the modification of particle yields in the later stages of a collision, mostly during the hadronic rescattering phase, prior to freeze-out. Based on the hadronic transport model calculations it was inferred, $\bar{p}$ yields may reduce in the rescattering phase because of anti-baryon absorbtion processes, resulting in an apparent rise in $\bar{\Lambda}/\bar{p}$.

In this work, our goal is to quantitatively demonstrate how baryon anti-baryon annihilation processes can affect the potential interpretation of an enhanced $\bar{\Lambda}$ to $\bar{p}$ ratio as a possible indication of strangeness enhancement in high energy heavy ion collisions. To address this issue we have studied $\bar{\Lambda}$ to $\bar{p}$ ratio in Au+Au (Pb+Pb) at different collision energies, corresponding to beam energies of AGS (SPS), using a hadronic version of a multi phase transport (AMPT) model. The hadronic version of AMPT , also known as default mode, well reproduce several aspects of data at these energy ranges.

AMPT model

AMPT is a hybrid Monte Carlo model, that has three main parts. An initial condition, which is obtained from HIJING. A partonic transport, where the partons (quarks) are scattered elastically. The scattering cross section is calculated perturbatively from the strong coupling constant (α) and gluon screening mass (μ). These two are the main input

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parameters to the model and have been constrained with wide range experimental data.

At the end of the scattering, partons are hadronized. In the default mode, the hadronization scheme is the Lund string fragmentation. Later to hadronization, the hadronic rescattering phase is modeled via A Relativistic Transport (ART) model. For our model calculation we have set the scattering cross section to 10 mb, with the following choice of input parameters: $\alpha = 0.47$, $\mu = 1.8\ \text{fm}^{-1}$

Results and Discussion

$\bar{\Lambda}/\bar{p}$ was calculated at six different energies of central collisions (b $\leq$ 3.5 fm), with 4.7 GeV Au+Au collisions and rest 6.3 GeV, 7.6 GeV, 8.8 GeV, 12.3 GeV ,17.3 GeV are Pb+Pb collisions and the calculation was restricted to mid-rapidity region, $|y| \leq 0.4$ and over the momentum range $0 < p < 0.5$ GeV/c. At the first place we calculate the ratio with full model simulations, i.e, baryon-anti-baryon absorbtion processes are included. AMPT uses a data driven parametrization of the absorbtion cross section as $\sigma = 67\ p_{lab}\ ^{(-0.7)}$.

Later, we repeat our calculation by turning off the annihilation processes. In Fig 1. we compare the results from model calculation to the SPS data. It is clearly seen when annihilation processes are included in the simulation, a rise in the ratio can be noticed, reaching upto 1.2 around 9 GeV. However, when the annihilation process are turned-off ratio remains below unity over the entire measured range. This indicate that interpretation of an enhancement in $\bar{\Lambda}/\bar{p}$ as a signature of strangeness enhancement in QGP is not straightforward. Rather it may be effect of two contributions both from partonic and hadronic processes. So exploration of hadronic processes is needed for better understanding of the final yield of the particles from the data.In the presentation we also plan to report the results obtained from an improved parameterization of B-$\bar{\text{B}}$ annihilation cross sections.

At present, data has large uncertainty, we foresee, in the upcoming second phase of beam energy scan program (BES II) at

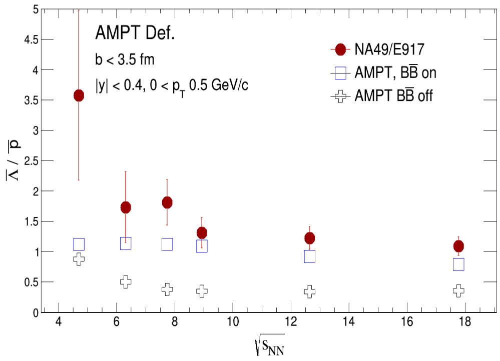

FIG. 1: $\bar{\Lambda}/\bar{p}$ calculated at beam energy: 4.7 GeV (Au+Au), 6.3 GeV, 7.6 GeV, 8.8 GeV, 12.3 GeV and 17.3 GeV (Pb+Pb) from hadronic version of AMPT model with and without B-$\bar{\text{B}}$ annihilation. Compared with NA49 data for similar kinematic conditions.

RHIC or in future experimental facilities like the Compressed Baryonic Matter (CBM) at FAIR, these measurements may play an important roles in the context of studying the strangeness production dynamics and the properties of the bulk partonic matter.

References

[1] B. B. Back et al. (The E917 Collaboration) Phys. Rev. Lett. 87 (2001), 242301.

[2] C. Alt et al. (NA49 Collaboration) Phys. Rev. C 73 (2006), 044910.