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A Comparative Study of Nuclei/Hyper Nuclei Formation Phenomena in Heavy Ion Collisions

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Abstract. In this study, we present the results of our recent theoretical analyses and compare them with existing experimental data. Starting with the initial production of baryons, their clustering to form unstable and exotic nuclei, then examine the subsequent decay of the fragments to the stable nuclei. Rapidity distributions for initial baryons, hot and cold ^{3}H and $^3_\Lambda$H nuclei are investigated to understand the phenomena of nucleus formation.

1 Introduction

Multifragmentation of nuclei and statistical approach is used in nuclear reactions at intermadiate and high energies as theoretically [1, 2] and multifragmentation reactions [3–10] are analyzed successfully by using the statistical approach in the literature. In this study we have focused on the products of the central Au+Au collisions to describe formation of nuclei and hypernuclei using hybrid models [1, 11–13] at $\sqrt{s_{NN}}$=3 GeV. The results of the Dubna Cascade Model (DCM) [14], the Ultra-relativistic Quantum Molecular Dynamic (UrQMD) Model [15, 16] and the Statistical Multifragmentation Model (SMM) [11, 12] are especially compared in three steps as follows: generation of the initial nucleon/baryon distribution(s), identification of clusters, and statistical decay of excited clusters. The initial nucleon distributions are determined using the PSG method as in [11, 12], DCM [14] and UrQMD [16]. For the UrQMD model, "freeze-out version" is used as baryon generator. Conservation of total energy and momentum and produce nucleon momenta strongly correlated with nucleon coordinates. In the second stage, hot clusters are "identified" based on nucleon relative velocities $v_c = 0.22c$ via coalescence of baryons (CB). In the third stage, SMM is employed to obtain the final nuclei and hypernuclei (as in Refs. [12, 13, 17]). Kinetic energy spectra, excitation energies, mass and charge distributions and flow properties are discussed in our recent studies [12, 13, 17, 18].

2 Rapidity Distributions

First, after the central collisions of Au+Au nuclei to describe nuclei and hypernuclei formation, we have investigated the rapidity distributions to understand the distribution of initial protons and Λ particles. Figure 1 shows the results of the DCM (triangles), UrQMD (squares) and PSG (circles) calculations. While the full lines with full symbols show the proton distributions, the dotted lines with open symbols show the distributions of Λ particles. In all cases, Gaussian type distributions can be seen changing smoothly and centered on the collision centre.

As next step, we have investigated rapidity distributions of produced ^{3}H nuclei and $^3_\Lambda$H hypernuclei as shown in Figure 2. Calculations are done over hundred thousand events. Top panel shows the results for the distributions of hot primary ^{3}H nuclei, calculated using UrQMD+CB and the distributions of cold stable ^{3}H nuclei, calculated using UrQMD+SMM. Similarly, the botttom panel shows results for $^3_\Lambda$H hypernuclei for the hot (UrQMD+CB) and cold

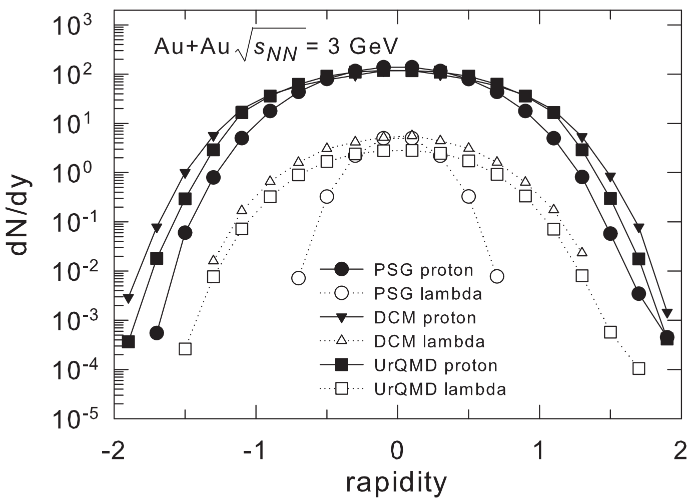

Figure 1. Rapidity distributions of initial protons and Λ's. The calculations are performed with the PSG method, UrQMD and DCM models for initial nucleon generation of the initial sources with $A_0 = 197$ and $Z_0 = 79$ at $\sqrt{s_{NN}}$=3 GeV

(UrQMD+SMM) cases. Our results are within the limits of experimental data, symbols as red stars show STAR experimental data [19, 20]. Here, B.R. is the branching ratio and is taken from the experimental data for ${}^{3}_{\Lambda}$H. Since the rapidity distributions show similar trends for all model calculations, we have not presented other model results here. In the calculations, the production of light nuclei and hypernuclei is described at kinetic freeze-out via the clusterization of baryons and with a statistical multi-fragmentation calculation.

We should point out that our future aim is to investigate the rapidity distributions of double hypernuclei. Due to the lower statistics, it is neccessary to

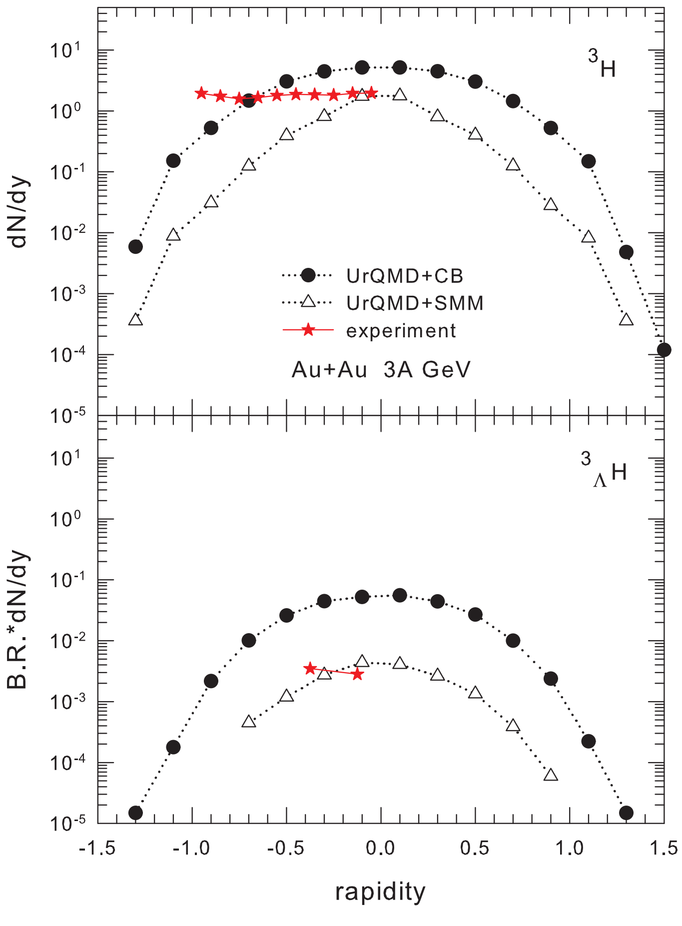

Figure 2. Rapidity distributions of ^{3}H and ${}^{3}_{\Lambda}$H nuclei of the central Au+Au collisions at $\sqrt{s_{NN}}$=3 GeV. The calculations are performed with the UrQMD+CB and UrQMD+SMM models. Symbols as red stars show STAR experimental data [19, 20].

perform calculations over a longer computational time. This is the subject of ongoing investigation. As a preliminary study, cross-section predictions for some double hypernuclei have already been published in our recent work [13].

3 Conclusion

We have investigated the formation of initial hardrons by using different modelling approaches, such as DCM, freeze-out version of UrQMD and the SMM with the PSG method version. Even though these models use different approaches for the production of hadrons after central collision of Au nuclei at $\sqrt{s_{NN}} = 3$ GeV, results show similar trends in the formation of hot primary fragments during the clusterization of baryons and for cold nuclei after their decay. STAR experimental data results are within the limits of our predictions. We believe that many more experimental results should be obtained in the near future to further understanding of hypernuclei formation.

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