Light nuclei production in Au+Au collisions at BES-II energies at RHIC-STAR

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Introduction

One of the main goals of the beam energy scan (BES) program at the Relativistic Heavy Ion Collider (RHIC) is to explore the Quantum Chromodynamics (QCD) phase structure. Lattice quantum chromodynamics (LQCD) calculations and various QCD-based models have suggested that the transition from a high-energy-density and high-temperature phase called quark-gluon plasma (QGP) phase, dominated by partonic degrees of freedom, to a phase where the relevant degrees of freedom are hadronic matter, is a smooth crossover at vanishing baryon chemical potential (μ_B), but likely changes to a first-order phase transition at large μ_B [1][2]. The point at which the first-order transition ends in the temperature versus baryon chemical potential (T, μ_B) plane of the QCD phase diagram is called the critical end-point (CEP).

Light nuclei, such as deuteron (d), triton (t), and helium-3 (^3He) are loosely bound objects with binding energies of few MeV. Their production in heavy-ion collisions is an active area of research both experimentally [3] and theoretically [4]. In heavy-ion collisions, the production mechanism of light (anti-)nuclei can be explained by either the thermal model, which assumes that their production occurs at chemical freeze-out (CFO), or the coalescence model, which tells us that their production occurs at kinetic freeze-out (KFO) by the coalescence of final state nucleons [5][6]. By studying the yields and yield ratios of the light (anti-)nuclei, we can gain a better understanding of their production mechanisms and the properties of the expanding system during freeze-out. Additionally, it has been proposed that the enhancement of light nuclei compound ratios, e.g. $N_t N_p/N_d^2$ and $N_{^4He} N_p/N_{^3He} N_d$, with respect to the coalescence baseline could serve as a probe of critical phenomena in the QCD phase diagram [6]. In the first phase of the Beam Energy Scan (BES-I) program at RHIC, an enhancement relative to the coalescence baseline of the light nuclei yield ratio $N_t N_p/N_d^2$ was observed in the most central Au+Au collisions at $\sqrt{s_{NN}} = 19.6$ and 27 GeV, with a combined significance of 4.1σ [7]. The precision of the new measurements will be significantly improved by the large data sets ($\sim 10\times$ BES-I) obtained by the STAR BES-II with upgraded detector capabilities.

In these proceedings, we will present the transverse momentum (p_T) spectra of light nuclei in Au+Au collisions at BES-II energies of $\sqrt{s_{NN}} = 7.7 - 27$ GeV. We will also report on the centrality and energy dependence of integrated particle yields (dN/dy) and mean p_T ($\langle p_T \rangle$) of light nuclei. Furthermore, we will discuss the effect of collective expansion by studying the centrality and p_T dependence of the coalescence parameters ($B_2(d)$ and $B_3(^3He)$).

Analysis details

The light nuclei identification is done by measuring the average ionization energy loss ($\langle dE/dx \rangle$) and particle velocity (β) using the Time Projection Chamber (TPC) and the Time of Flight (TOF) detectors in STAR, respectively [3]. The corrected light nuclei spectra can be obtained by implementing energy loss, TPC tracking efficiency, TOF matching efficiency, and the background (contribution

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from the beampipe) corrections. The systematic uncertainties on each p_T bin in the spectra can be estimated by considering varying the analysis cuts.

Results

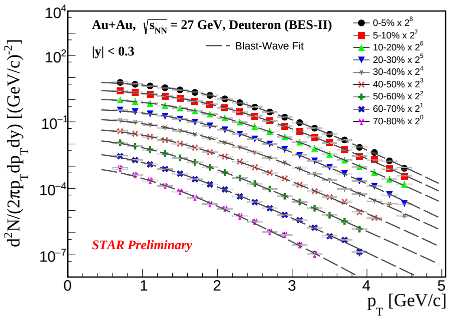

FIG. 1: The p_T spectra of the d at mid-rapidity in various centralities in Au+Au collisions at $\sqrt{s_{NN}} = 27$ GeV. The dashed lines represent the Blast-Wave fits. Statistical and systematic uncertainties are shown as vertical bars and boxes, respectively.

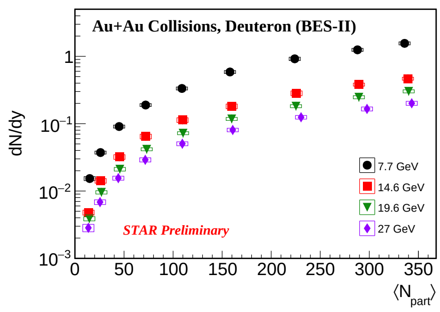

FIG. 2: The dN/dy of d in Au+Au collisions at BES-II energies. Statistical and systematic uncertainties are shown as vertical bars and boxes, respectively.

The p_T spectra of d in Au+Au collisions at $\sqrt{s_{NN}} = 27$ GeV from the STAR BES-II program is shown in Fig. 1. We observe a clear p_T and centrality dependence of p_T spectra. The dN/dy of the deuteron at BES-II energies as a function of $\langle N_{part} \rangle$ are shown in Fig. 2. The decrease in dN/dy from central to peripheral collisions suggests that the energy density is higher in central collisions. The yield decreases with increasing collision energy due to the stronger baryon stopping effect at lower collision energy as compared to higher collision energy.

Summary

The p_T spectra of light nuclei are measured in Au+Au collisions at BES-II energies of $\sqrt{s_{NN}} = 7.7 - 27$ GeV. The dN/dy of light nuclei are observed to decrease from central to peripheral collisions. Furthermore, we have observed that the dN/dy of light nuclei decreases with increasing the collision energy.

Acknowledgments

SB acknowledges the financial support from DAE-DST Project No. 3015/I/2021/Gen/RD-I/13283.

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