Light Nuclei Production in Au+Au Collisions at $\sqrt{s_{NN}}$ = 14.6 and 19.6 GeV from RHIC BES-II

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Abstract

In high-energy nuclear collisions, the light nuclei production is sensitive to the temperature and density of the system at freeze-out. It is also predicted to be sensitive to local baryon density fluctuations and can be used to probe the QCD phase transition. The second phase of Beam Energy Scan (BES-II) program at RHIC was completed in 2021. The high-statistics data recorded by the STAR experiment provide a unique opportunity to carry out high-precision measurements on the light nuclei production.

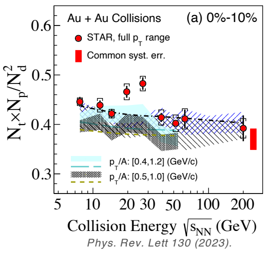
In this poster, we will report the results of the centrality and transverse momentum dependence of proton (p), deuteron (d) and ^{3}He production in Au+Au collisions at $\sqrt{s_{NN}}$ = 14.6 and 19.6 GeV measured by the STAR experiment. We will also present the centrality dependence of coalescence parameters (B_2(d)and B_3(^{3}He)) and particle ratios (N_d/N_p and $N_{^3He}/N_p$), and discuss their physics implications.

Introduction

- QCD Phase transition
  - Low baryon density: crossover.
  - High baryon density: 1st order phase boundary and critical point.
- Light nuclei, such as deuteron and ^{3}He, are loosely bound objects with small binding energies. Those are formed via coalescence of nucleons [1, 2].

$$E_A\frac{d^3N_A}{d^3p_A} = B_A\left(E_p\frac{d^3N_p}{d^3p_p}\right)^Z\left(E_n\frac{d^3N_n}{d^3p_n}\right)^{A-Z} \approx B_A\left(E_p\frac{d^3N_p}{d^3p_p}\right)^A.$$

- Due to the increasing correlation length and a formation of an instability in the spinodal domain, both the critical fluctuations and first-order phase transition can induce large baryon density fluctuations [3, 4].



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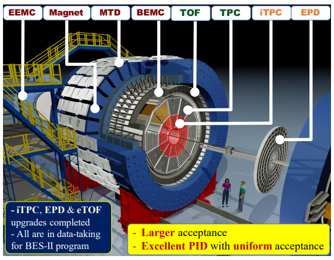
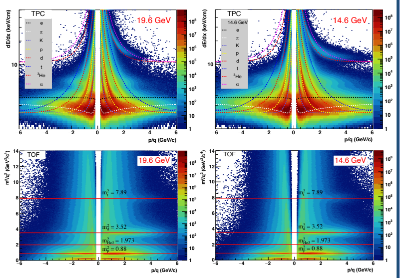
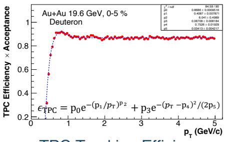
STAR Detector and Particle Identification

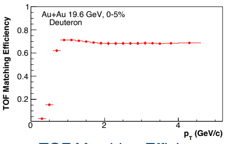




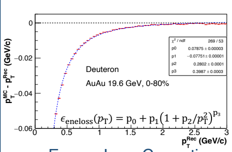
Detector Corrections



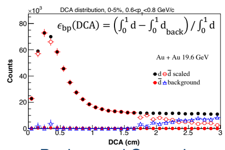
TPC Tracking Efficiency



TOF Matching Efficiency

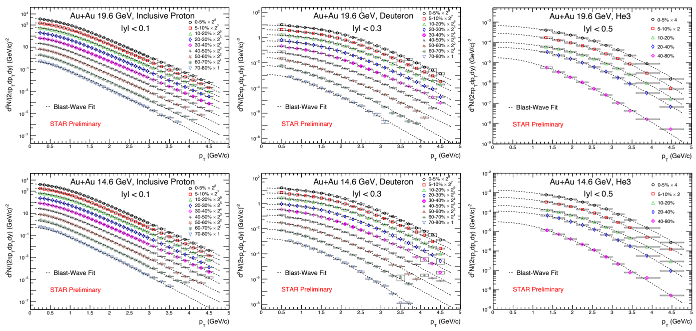


Energy Loss Correction

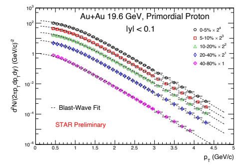


Background Correction

Transverse Momentum Spectra

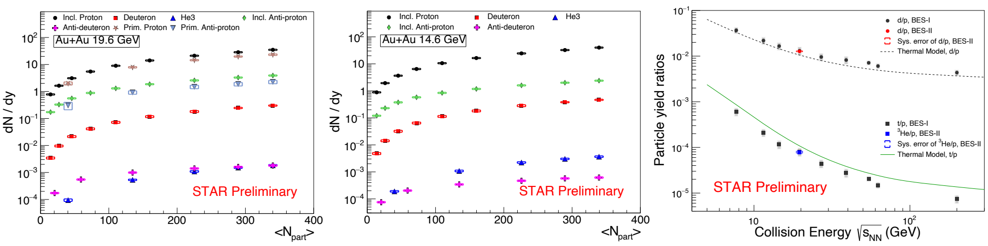


Primordial Spectra



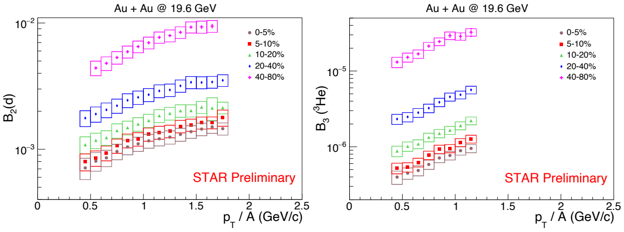
- The primordial spectra were obtained by subtracting the (anti-)proton decayed from strange hadrons.
- Data driven method:
  Use STAR published strange particle ($\Lambda, \Sigma^+, \Xi^-, \Xi^0$) yield and embedding simulation samples.

dN/dy and Particle Ratios



- dN/dy for light nuclei increase from peripheral to central collisions; dN/dy for positive particle decrease with increasing energy, dN/dy for antiparticles are the opposite.
- The particle ratios show a monotonic decrease with collision energy; d/p ratio [2] can be described well by the thermal model [5], but the model over-predicts t/p and ^{3}He/p by a factor of about 2.

Coalescence Parameters



- B_A changes as a function of collision centrality and transverse momentum is due to collective expansion [2, 3].

Summary

- We report the centrality dependence of proton, deuteron, Helium-3, and anti-proton, anti-deuteron productions in Au+Au collisions at $\sqrt{s_{NN}}$ = 14.6 and 19.6 GeV from RHIC STAR BES-II.
- The particle ratios N_d/N_p and $N_{^3He}/N_p$ have been calculated for Au+Au collisions at 19.6 GeV in BES-II.
- Due to collective expansion, coalescence parameter B_A is found to increase from central to peripheral collisions and from low to high p_T bins.

References

[1] F. Bellini, et al., Phys. Rev. C 99 (2019) 054905
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[3] K. J. Sun, et al., Phys. Lett. B 774 (2017) 103-107; Phys. Lett. B 781(2018) 499-504
[4] H. Abdulhamid, et al. [STAR Collaboration], Phys. Rev. Lett 130 (2023)
[5] A. Andronic, et al., Nucl. Phys. A772 (2006) 167-199; Phys. Lett. B 697 (2011) 203-207

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The STAR Collaboration
https://drupal.star.bnl.gov/STAR/presentations

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