Measurements on Proton and Light Nuclei Production in Au+Au Collisions by RHIC-STAR in the High Baryon Density Region

Liubing Chen (liubingchen@mails.ccnu.edu.cn) *for the STAR Collaboration*

Central China Normal University

Quark Matter 2025

Abstract

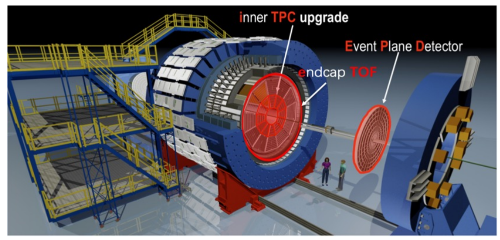
Light nuclei, such as deuteron and triton, are loosely bound objects, and their yields are expected to be sensitive to baryon density fluctuations. They may be used to probe the signature of a first-order phase transition and/or critical point in heavy-ion collisions. In this poster, we will present the collision centrality and rapidity dependence of proton and light nuclei production in Au+Au collisions at $\sqrt{s_{NN}}$ = 3.0, 3.2, 3.5, 3.9 and 4.5 GeV recorded by the STAR experiment in fixed-target mode. The transverse momentum (p_T) spectra, coalescence parameters (B_A), particle ratios, kinetic freeze-out temperature (T_{kin}), and collective velocity (β_T) will be shown and compared with results from collider energies.

Introduction

- ***QCD Phase Transition***
- High Temperature: QGP properties
- High Baryon Density: Critical Point and 1st order phase boundary

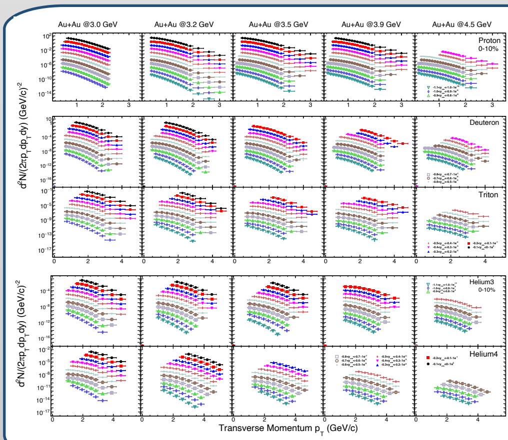
- ***Light Nuclei Production Mechanism***
- Thermal[1] and Coalescence[2] approach

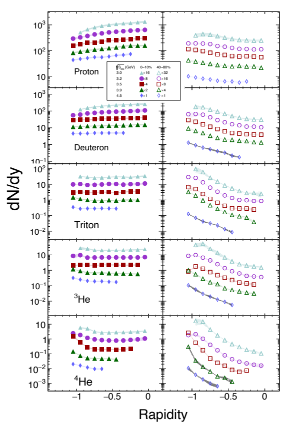
The Solenoidal Tracker At RHIC (STAR)

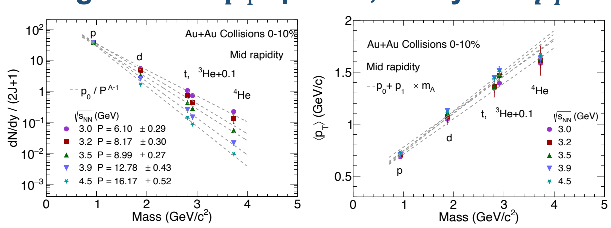


- **BES-II detector upgrade**
- iTPC
  cover full area, $-1.5 < \eta < 1.5$
  better dE/dx, $p_T > 60$ MeV/c.
- eTOF
  at the east end of STAR,
  $-2 < \eta < -1$
- EPD $2.3 < \eta < 5.0$

Light Nuclei p_T spectra, dN/dy & $< p_T >$

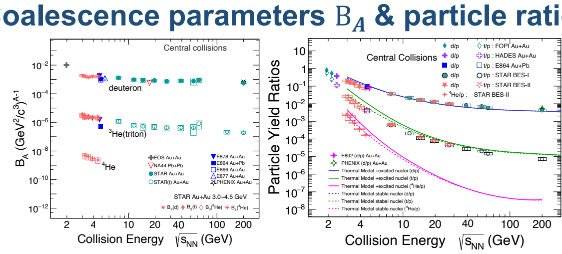






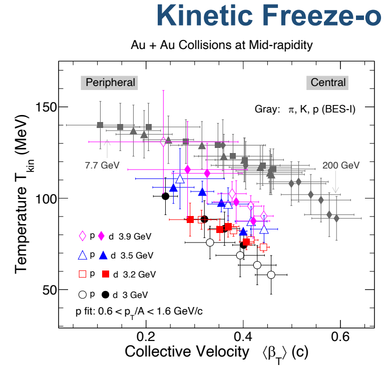
- Light nuclei p_T spectra in 0-10% centrality for each rapidity.
- Light nuclei dN/dy and $< p_T >$ distribution in 0-10% centrality with energy and mass.

Coalescence parameters B_A & particle ratio



- As the energy increases, B_A becomes smaller, reflecting that the effective volume of the system[4] is larger.
- For d/p and t/p, thermal model[5] overestimate no matter the nuclei will excited or not. For ^{4}He/p, stable nuclei in thermal is consistent with the experiment data.

Kinetic Freeze-out Dynamics



- The freeze-out temperature T_{kin} and average radial flow velocity $< \beta_T >$ show a monotonically trend from central to peripheral collisions.
- In the fixed-target energy region, proton is different from that at high energy, which implies a different equation of state.

Summary

- We report light nuclei production with rapidity and energy dependence in Au + Au collisions at $\sqrt{s_{NN}}$ = 3.0 - 4.5 GeV by STAR experiment.
- Present the particle ratio and B_A with energy dependence, and compare with thermal model, which overestimate d/p and t/p, but consist with ^{4}He/p by stable nuclei .
- Calculate the freeze-out temperature T_{kin} and average radial flow velocity $< \beta_T >$, the kinematic dynamics difference indicated that EoS of the hot and dense medium in the low energy collisions seems different from that of high energy collisions.

References

[1] A. Andronic et al, Nature 561 (2018) 7723,321-330

[2]K.J.Sun et al, Phys.Lett.B 792(2019)132-137

[3] NA49 Collaboration, Phys. Rev. C 94, 044906 (2016)

[4] V.Gaebel et al, arXiv:2006.12951

[5] V. Vovchenko et al, Phys. Rev. C 93 (2016) 064906

Supported in part by the U.S. DEPARTMENT OF ENERGY Office of Science

華中師範大學 CENTRAL CHINA NORMAL UNIVERSITY
Central China Normal University

The STAR Collaboration