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

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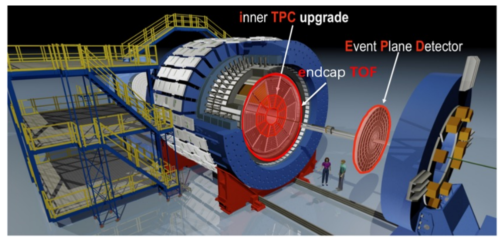
Abstract

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 the QCD phase-diagram. In this poster, we 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) are shown and compared with results from collider energies.

Introduction

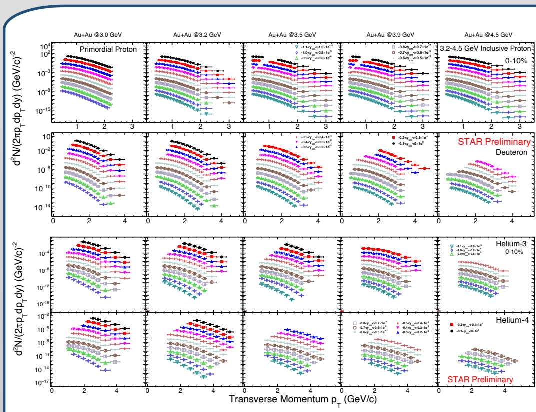
- ***QCD Phase Transition***
  - High Temperature: QGP properties
  - High Baryon Density: Critical Point and 1^{st} order phase boundary
- ***Light Nuclei Production Mechanism***
  - Thermal[1] and Coalescence[2] approach

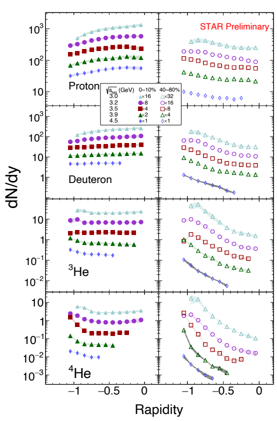
The Solenoidal Tracker At RHIC (STAR)

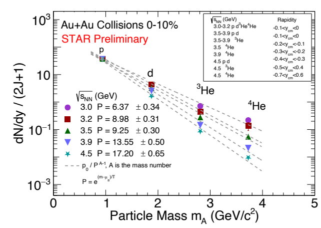


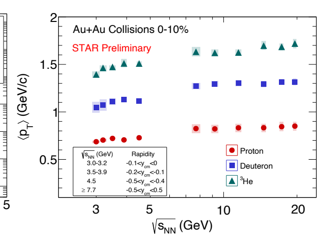
- **BES-II detector upgrade**
  - iTPC
    cover full area, $-1.5 < \eta < 1.5$
    better dE/dx, p_T > 60 MeV/c.
  - eTOF
    at the east end of STAR,
    $-2 < \eta < -1$
  - EPD $2.3 < \eta < 5.0$

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



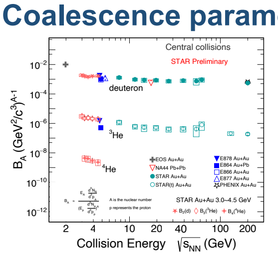


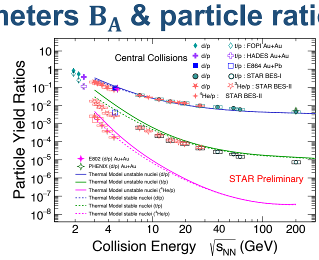




- Light nuclei with larger nuclear numbers show more sensitive dN/dy distributions from target to mid-rapidity and from central to peripheral collisions, implying fragment impacts on light nuclei production.
- The penalty factor P in dN/dy/(2j+1) grows with beam energy, indicated suppressed formation of high-mass objects at higher energies.
- Proton, deuteron and ^{3}He $< p_T >$ growth with energy flattens out as the energy increases.

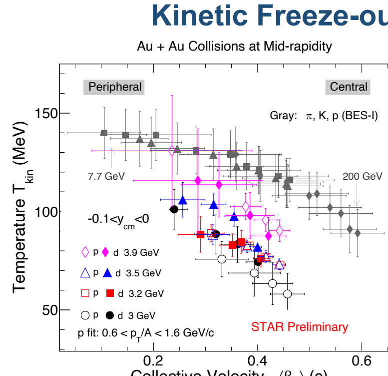
Coalescence parameters B_A & particle ratio





- As the energy increases, B_A becomes smaller, reflecting that the effective volume of the system[4] becomes larger.
- For d/p and ^{3}He/p, thermal model[5] overestimate regardless of whether feed-down from unstable nuclei is included or not. For ^{4}He/p, considering only stable nuclei, thermal is consistent with the experiment data.

Kinetic Freeze-out Dynamics



- The differing trends in T_{kin} and $< \beta_T >$ for protons and deuterons (3.0–3.9 GeV) imply they share distinct kinetic freeze-out surfaces.
- For 3.0–3.9 GeV, proton T_{kin} increases with energy while $< \beta_T >$ stays approximately constant with $\sqrt{s_{NN}} \geq$ 7.7 GeV trends, implying EoS evolution.

Summary

- We presented light nuclei production (p_T spectra, dN/dy, $< p_T >$, particle ratio and B_A) and freeze-out parameters (T_{kin}, $< \beta_T >$) in Au + Au collisions at $\sqrt{s_{NN}}$ = 3.0 - 4.5 GeV by STAR experiment, studying their rapidity and energy dependence.
- The thermal model overestimated light nuclei ratio d/p and t/p, but consisted with ^{4}He/p only considering stable nuclei .
- The measured kinetic freeze-out parameters (T_{kin}, $< \beta_T >$) may imply that the equation of state describing the hot, dense nuclear matter at low collision energies ($\sqrt{s_{NN}}$ = 3.0-3.9 GeV) differs from that observed at higher energies.

References

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