Measurements of Hypertriton Production in Au+Au Collisions from 3 to 7.7 GeV

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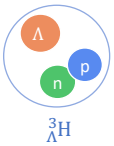
Abstract

Hypernuclei are bound states of nuclei with one or more hyperons. Precise measurements of hypernuclei properties and their production yields in heavy-ion collisions are crucial for the understanding of their production mechanisms. The STAR Beam Energy Scan II program offers us a great opportunity to investigate collision energy and system size dependence of hypernuclei production.

In this poster, we present new measurements on transverse momentum (p_T), rapidity (y), and centrality dependence of ${}^3_\Lambda$H production yields in Au+Au collisions from $\sqrt{s_{NN}}$ = 3 to 7.7 GeV. These results are compared with phenomenological model calculations, and physics implications on the hypernuclei production mechanism are also discussed.

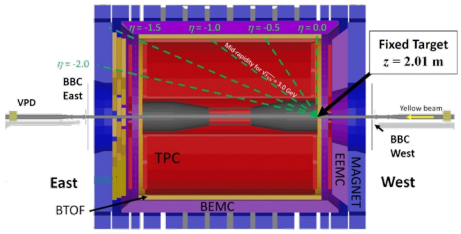
Motivation

- Production mechanism of hypernuclei in heavy ion collisions.
  - Role and strength of hyperon-nucleon (Y-N) interaction in nuclei formation.
- Energy dependence of hypernuclei yields.
  - When and how are loosely bound hypernuclei formed in heavy ion collisions.
- Rapidity dependence
  - Coalescence mechanism (mid-rapidity) and nuclear fragmentation (target rapidity).

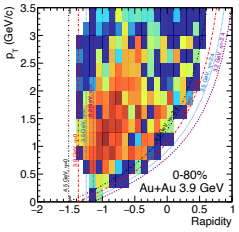


${}^3_\Lambda$H

STAR Fixed-target setups



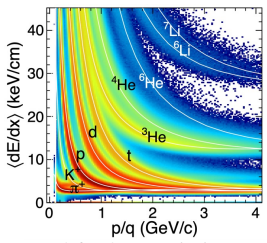
${}^3_\Lambda$H acceptance



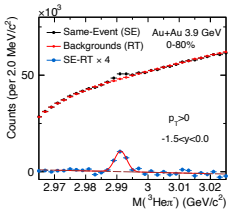
p_T spectra in Au+Au $\sqrt{s_{NN}}$ = 3.9 and 4.5 GeV

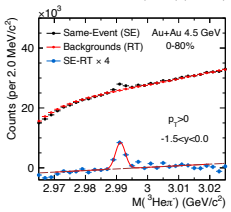
- Hypertritons are reconstructed via the ${}^3_\Lambda\text{H} \rightarrow {}^3\text{He}\,\pi^-$ channel utilizing KFParticle package.
- ${}^3\text{He}/\pi^-$ are identified by dE/dx information provided by TPC.
- p_T spectra are fitted by:

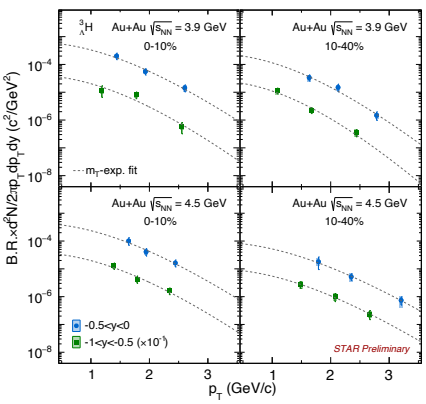
$$\frac{d^2N}{2\pi p_T dp_T dy} = C \cdot e^{\frac{-m_T}{T_{eff}}}$$



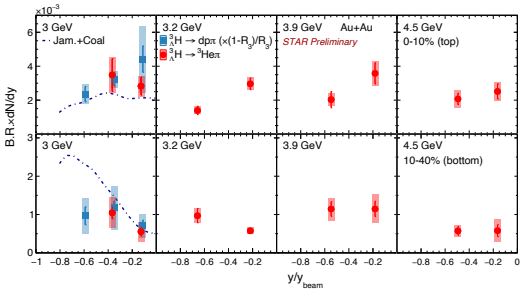
PID plot from: Phys. Lett. B 827 (2022) 136941



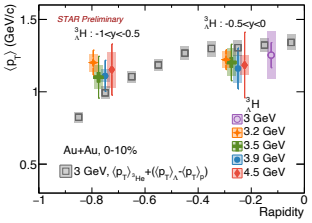




Rapidity dependence of yields and <p_T>



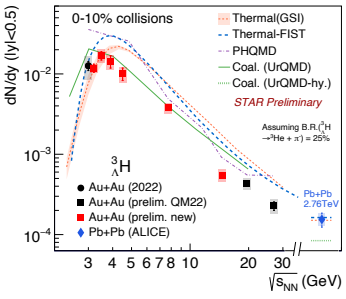
- Hypertriton yields at 3-4.5GeV are close in 0-10% at mid-rapidity.
- JAM+Coal. can describe the tendency of ${}^3_\Lambda$H yields as a function of rapidity at 0-10% centrality; while fails to describe the trend in 10-40% centrality.



R₃ takes STAR preliminary R₃ = 0.272±0.030±0.042, (EPJ Web Conf. 276 (2023) 04003) Uncertainty from R₃ is not included in the plot.
STAR 3 GeV ${}^3_\Lambda\text{H} \rightarrow {}^3\text{He}\,\pi^-$: Phys. Rev. Lett. 128 (2022) 202301

- ${}^3_\Lambda$H <p_T> are comparable in Au+Au collisions at $\sqrt{s_{NN}}$ = 3-4.5 GeV within uncertainties.
- The radial flow behavior of ${}^3_\Lambda$H is similar as light nuclei.

Energy dependence of ${}^3_\Lambda$H yields



- ${}^3_\Lambda$H yields peak at 3-4 GeV, then decrease with higher energy.
- Thermal model fails to describe the trend at RHIC energies.
  - Contrast to LHC energies, hypernuclei maybe dominantly produced after the hadron chemical freeze-out at RHIC.
- Coalescence calculation consistent with data at 3.5<$\sqrt{s_{NN}}$<10 GeV, while still significantly higher than data at higher energies.
- PHQMD predicts decreasing tendency while systematically higher than data.

Thermal (GSI): A. Andronic et al. PLB 697,203-207 (2011)
Thermal-FIST, Coal.+UrQMD: Phys.Rev.C 107 (2023) 1, 014912
PHQMD: Susanne Gläßel et al. PRC 105, 014908 (2022), V. Kireyeu et al. arXiv:1911.09496
Pb+Pb: ALICE, PLB 754, 360 (2016)
STAR at 3 GeV: PRL 128, 202301 (2022)

Summary and outlook

- Rapidity dependence of ${}^3_\Lambda$H yields and <p_T> in Au+Au $\sqrt{s_{NN}}$ = 3-4.5 GeV are presented.
- Energy dependence of ${}^3_\Lambda$H production at RHIC cannot be well described by model calculations.
- 2×10^9 events in Au+Au collisions at 3GeV taken at RHIC Run 2021.
  - Enable precise measurements on centrality and rapidity dependence of hypernuclei (${}^3_\Lambda$H, ${}^4_\Lambda$H, ${}^4_\Lambda$He) yields in the future.

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The STAR Collaboration

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Link to STAR presentations: