Measurements of Hypernuclei Production in Au+Au Collisions from 3.2 to 4.5 GeV from STAR

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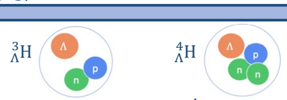
Abstract

Hypernuclei, bound states of nuclei with one or more hyperons, serve as a natural laboratory to investigate the hyperon-nucleon (Y-N) interaction, an important ingredient for the equation-of-state (EoS) of nuclear matter. Precise measurements of hypernuclei properties and their production yields in heavy-ion collisions are crucial for the understanding of their production mechanisms and the strength of the Y-N interaction.

The STAR Beam Energy Scan II program and isobar collisions offer a great opportunity to investigate energy and system size dependence of hypernuclei production. In this poster, we present new measurements on ${}^{3}_{\Lambda}\mathrm{H}$ production yields in Au+Au collisions from 3.2 to 4.5 GeV. The measurements of ${}^{4}_{\Lambda}\mathrm{H}$ at these energies will be brought out in the future. The prospect of strangeness population factor (S_3) with isobar dataset is also discussed.

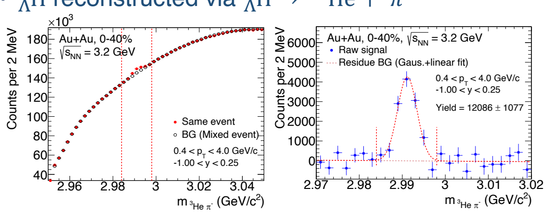
Motivation



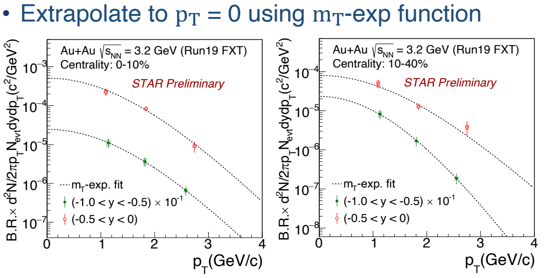
- What are hypernuclei?
  - Bound nuclear system of non-strange and strange baryons
- Why study hypernuclei?
  - Probe Y-N interactions
  - Production mechanism of hypernuclei in heavy-ion collisions are not well understood.

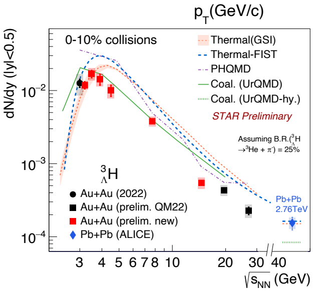
${}^{3}_{\Lambda}\mathrm{H}$ p_T Spectra in Au+Au $\sqrt{s_{NN}}$ = 3.2 GeV and Energy Dependence of ${}^{3}_{\Lambda}\mathrm{H}$ Yields

- Dataset : 201M events, year 2019 FXT
- Daughter particle identification: dE/dx using TPC
- KFparticle package for hypernuclei reconstruction
- ${}^{3}_{\Lambda}\mathrm{H}$ reconstructed via ${}^{3}_{\Lambda}\mathrm{H} \rightarrow {}^{3}\mathrm{He} + \pi^-$



- Extrapolate to $p_T = 0$ using m_T-exp function



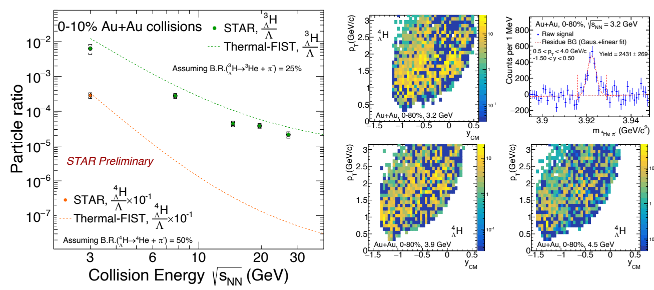


Thermal (GSI): Phys.Lett.B 697 (2011)203-207
Thermal-FIST, UrQMD: Phys.Rev.C 107 (2023) , 014912
PHQMD Phys.Rev.C 105 (2022) , 014908
ALICE: Phys.Lett.B 754 (2016) 360–372
STAR at 3GeV: Phys.Rev.Lett. 128 (2022), 202301

- High production yields of ${}^{3}_{\Lambda}\mathrm{H}$ around 3-4 GeV and decrease towards higher energies
- None of the production models can describe the energy dependence quantitatively

Towards ${}^{4}_{\Lambda}\mathrm{H}$ Production Measurements

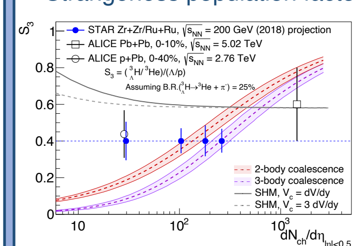
- Thermal model can describe ${}^{4}_{\Lambda}\mathrm{H}/\Lambda$, but overestimates ${}^{3}_{\Lambda}\mathrm{H}/\Lambda$
- $B_\Lambda({}^{4}_{\Lambda}\mathrm{H})$~ 2 MeV, much larger than $B_\Lambda({}^{3}_{\Lambda}\mathrm{H})$~ 150 keV
  → Does B_Λ play a role in hypernuclei production yields?



- Mid-rapidity coverage of ${}^{4}_{\Lambda}\mathrm{H}$ in FXT with inner TPC upgrade
  - ${}^{4}_{\Lambda}\mathrm{H}$ reconstructed via ${}^{4}_{\Lambda}\mathrm{H} \rightarrow {}^{4}\mathrm{He} + \pi^-$
  - ${}^{4}_{\Lambda}\mathrm{H}$ yield measurements from 3.2 to 4.5 GeV are ongoing

Statistical Projections of S_3 with Isobar Dataset

- Strangeness population factor $S_3 = \dfrac{{}^{3}_{\Lambda}\mathrm{H}/{}^{3}\mathrm{He}}{\Lambda/p}$



- Relative suppression of hypernuclei production compared to light nuclei production
- Double ratio S_3 cancels out effects from the difference in the proton and hyperon densities involved

Coalescence: Phys.Lett.B 792 (2019)132-137
SHM(Thermal-FIST): Phys.Lett.B 785 (2018)171-174
ALICE: arXiv:2107.10627, Phys.Lett.B 754 (2016) 360–372

- The S_3 predicted by thermal and coalescence model deviates strongly in the low multiplicity region
- Good statistical significance using 2018 data from isobar collisions (2 billion events per system) provides differentiation capability b/w thermal and coalescence models

Summary

- High production yields of ${}^{3}_{\Lambda}\mathrm{H}$ around 3-4 GeV and decrease towards higher energies
  - Cannot be quantitatively described by production models
- Thermal model can describe ${}^{4}_{\Lambda}\mathrm{H}/\Lambda$, but overestimates ${}^{3}_{\Lambda}\mathrm{H}/\Lambda$
  - Explore the role of B_Λ in hypernuclei formation process
  - ${}^{4}_{\Lambda}\mathrm{H}$ measurements from 3.2 to 4.5 GeV are ongoing
- Future S_3 with isobar dataset will help to distinguish models

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