University of Chinese Academy of Sciences

Production of Light Nuclei and Hypernuclei in Heavy-Ion Collisions

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Workshop on extreme nuclear matter frontiers, Yichang 2026

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- Introduction
- Experimental Facilities
- (Hyper)Nuclei yields
    - Stable nuclei
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    - Unstable nuclei
- Correlation functions
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Light Nuclei & Hypernuclei (What)

- Hypernuclei are nuclei containing at least one hyperon
- Light (hyper)nuclei show strong structural diversity

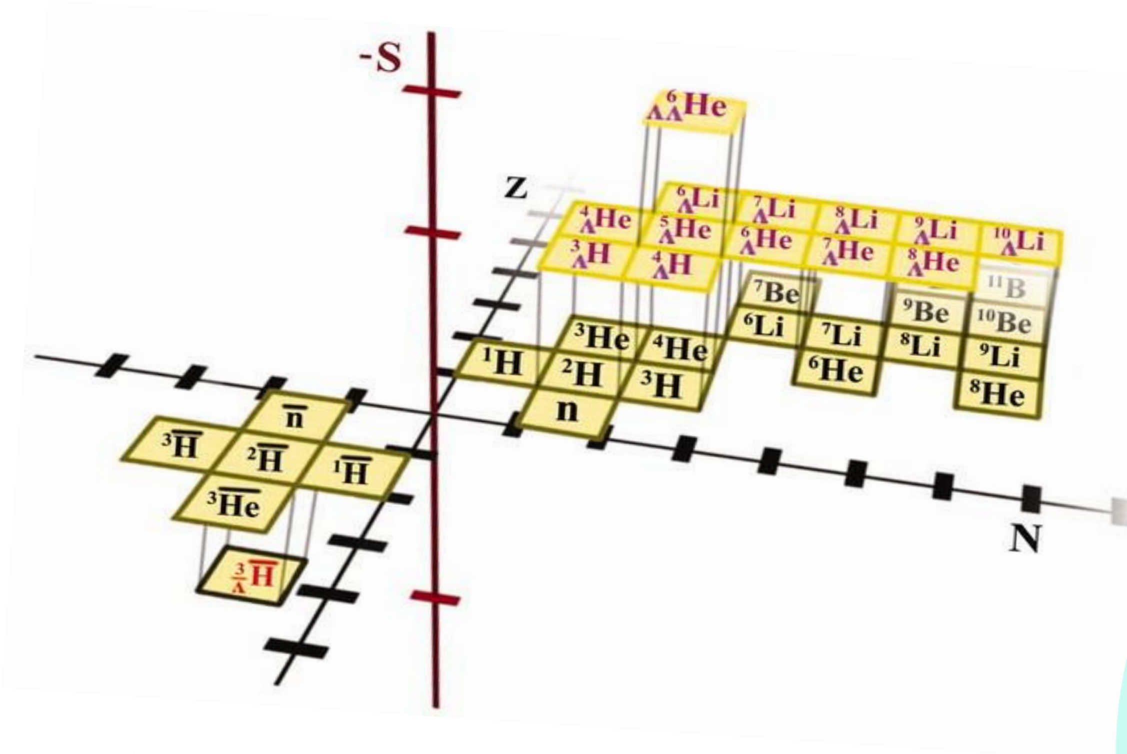


Figure from Science 328 (2010) 58-62

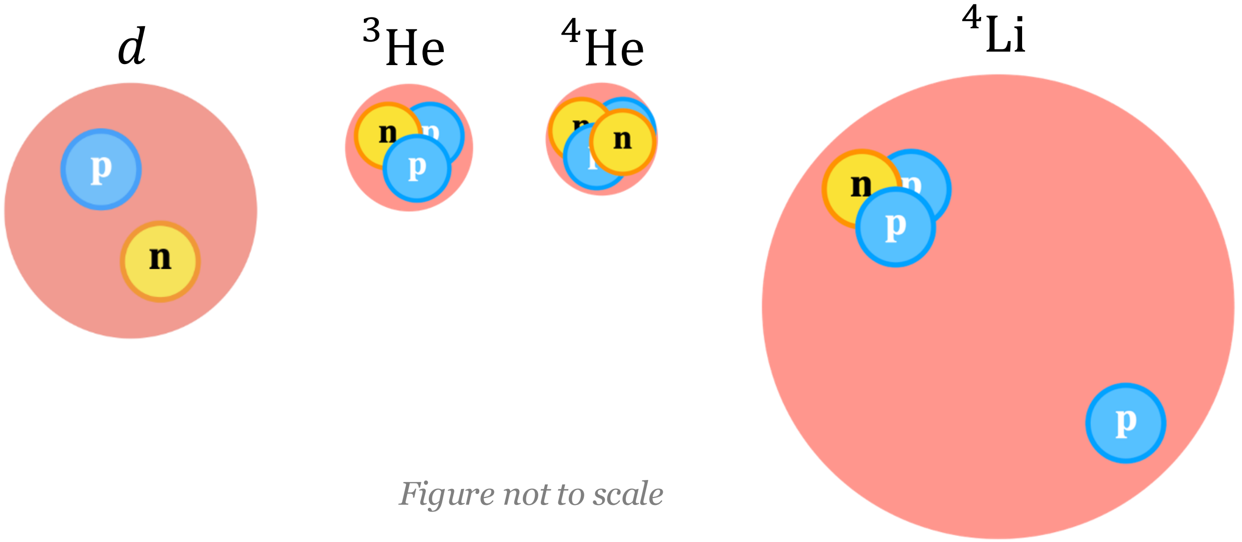
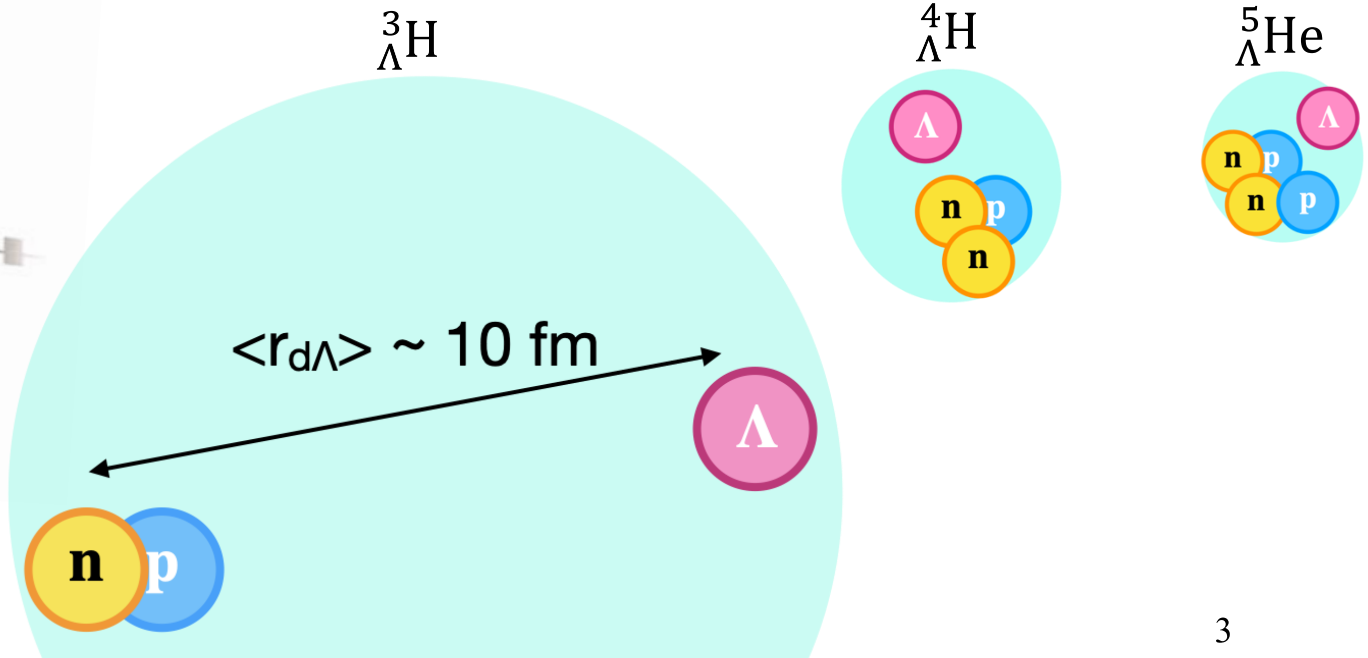


Figure not to scale



Light Nuclei & Hypernuclei (Why)

1. What can (hyper)nuclei production in heavy-ion collisions tell us about the QCD phase diagram and the nuclear equation-of-state?

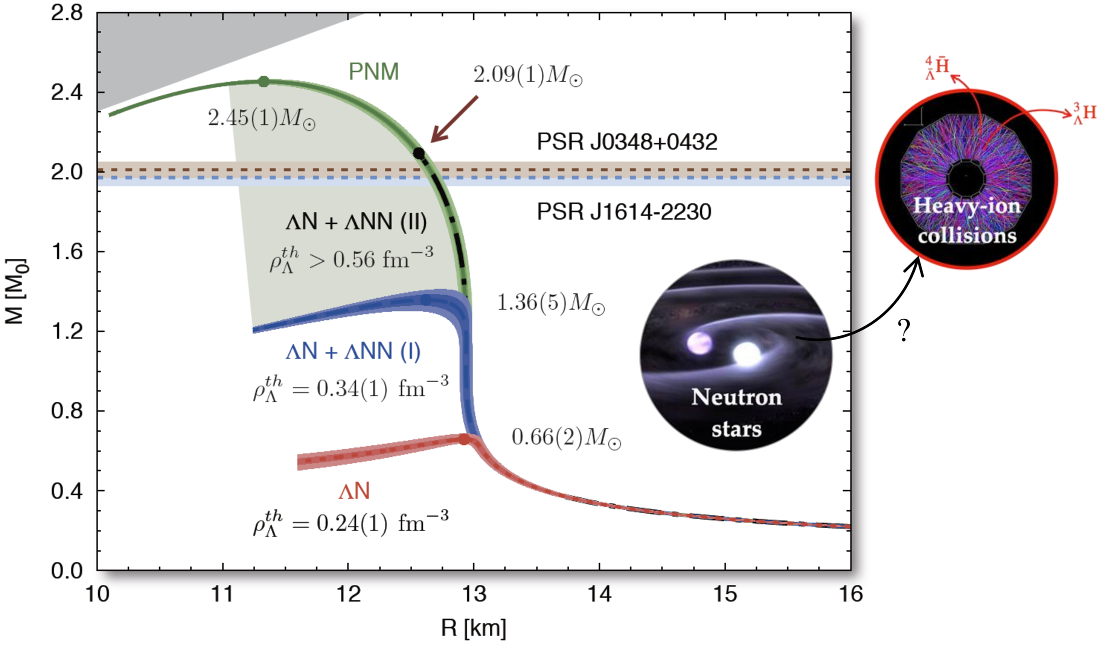
S. Zhang et al., Phys. Lett. B 684 (2010) 224
K. Sun et al., Phys. Lett. B 781 (2018) 499

- Sensitive to critical fluctuations and the onset of deconfinement

$$\frac{t \times p}{d^2} \qquad \frac{{}^{3}_{\Lambda}\mathrm{H}}{{}^{3}\mathrm{He} \times \frac{\Lambda}{p}}$$

2. What is the role of hyperon-nucleon (Y-N, Y-N-N) and hyperon-hyperon (Y-Y) interaction in the equation-of-state of high baryon density matter?

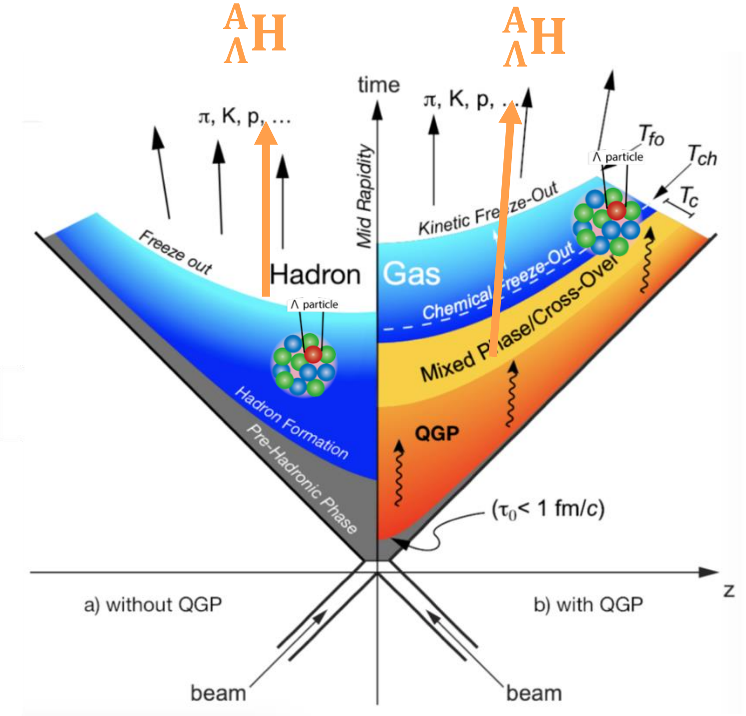
- Hyperon Puzzle: difficulty to reconcile the measured masses of neutron stars with the presence of hyperons in their interiors



D Lonardoni et al., Phys. Rev. Lett. 114, 092301 (2015)

Light Nuclei & Hypernuclei (How)

1. When and how are (hyper)nuclei formed?



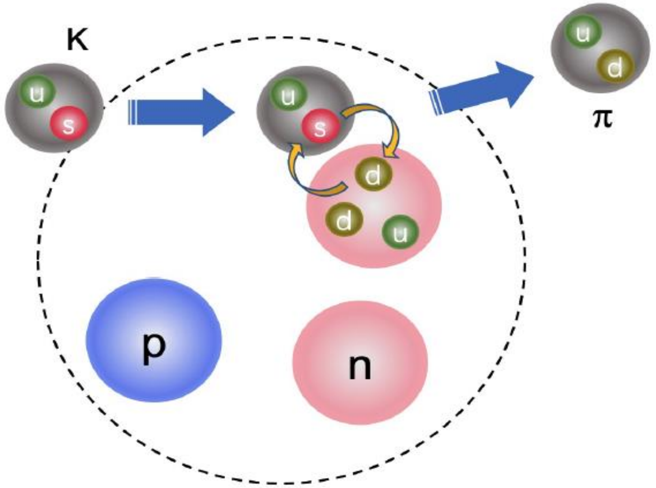
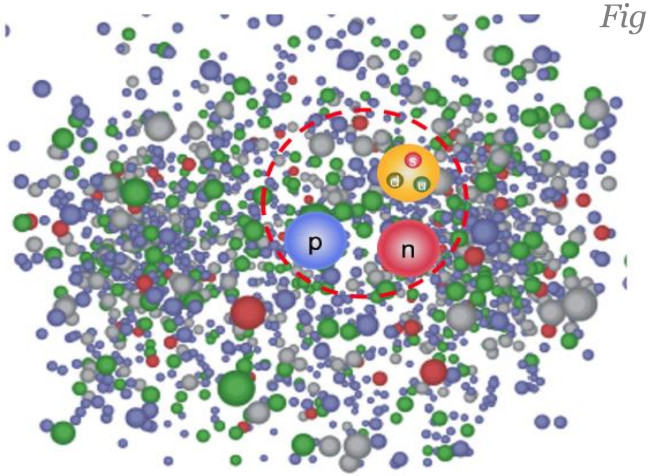


Fig. from Yifei Zhang



- Observables related to nuclei production:
  p_T spectra, yields, flow, **correlation functions**

Light Nuclei & Hypernuclei (How)

2. Is the production yield of (hyper)nuclei sensitive to their internal structure?

- Observables related to hypernuclear structure: Binding energy, lifetime, … **(yield?)**
- Compare production yields of (hyper)nuclei with large and small radii, e.g.:

1. $^{3}_{\Lambda}$H vs ^{3}He
2. ^{4}Li vs ^{4}He

Jiaxing Zhao, Yuehang Leung SQM26

Cluster	d	t	^{3}He	$^{3}_{\Lambda}$H	^{4}He	$^{4}_{\Lambda}$He	$^{4}_{\Lambda}$H	$^{5}_{\Lambda}$He	$^{5}_{\Lambda\Lambda}$He
Constitutes	pn	pnn	ppn	pnΛ	ppnn	ppnΛ	pnnΛ	ppnnΛ	ppn$\Lambda\Lambda$
J^P	1^+	$\frac{1}{2}^+$	$\frac{1}{2}^+$	$\frac{1}{2}^+$	0^+	0^+	0^+	$\frac{1}{2}^+$	$\frac{1}{2}^+$
$M_{exp.}$(GeV)	1.875	2.809	2.808	2.991	3.727	3.923	3.923	4.731	-
$M_{theo.}$(GeV)	1.873	2.813	2.812	2.993	3.746	3.927	3.929	4.847	5.028
rms(fm)	2.790	1.561	1.567	4.332	1.590	1.810	1.809	1.509	1.595

Jiaxing Zhao et al., Phys.Rev.C 112 (2025) 6, 064902

Clusterization mechanism

Kaijia Sun, April 26

Ruiqin Wang, April 27

- **Statistical hadronization model**
  - Nuclei are in thermal equilibrium on the chemical freeze-out surface $dN/dp^3 \sim \exp(-\frac{E-\mu_B}{T})$
  - **Yields not related to nuclear structure**

A. Andronic, et al. Phys.Lett.B 697 (2011) 203-207
J. Steinheimer, et al. Phys.Lett.B 714 (2012) 85-91

- **Coalescence model**
  - Nuclei are formed from nucleons (hyperons) that are close together in phase space.
  - In the Wigner Function formalism, formation probability given by overlap b/w:
    - Nucleon distributions at freeze-out
    - **Nuclear wave function**

J. I. Kapusta Phys.Rev.C 21 (1980) 1301
R. Scheibl and U. Heinz, Phys. Rev. C 59, 1585 (1999)
K. Sun and C. Ko, Phys. Rev. C 103, 064909 (2021)
F. Bellini, et al. Phys. Rev. C 103, 014907 (2021)

- **“Potential” model**
  - Nuclei are identified during the dynamical evolution of the system by the Minimum Spanning Tree (MST and aMST)

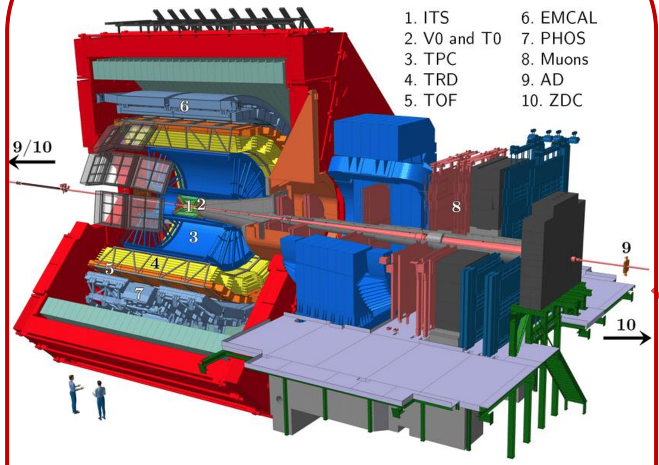
J. Aichelin, Phys. Rept. 202, 233 (1991)
J. Aichelin, et al, Phys. Rev. C 101, 044905 (2020) (PHQMD)

- **Kinetic model**
  - Nuclei are formed dynamically via reactions e.g.: $NNN \rightarrow dN$; $NN\pi \rightarrow d\pi$

D. Oliinychenko, et al. Phys.Lett.B 714 (2012) 85-91 (SMASH)
G. Coci et al. Phys. Rev. C 108, 014902 (2023) (PHQMD)

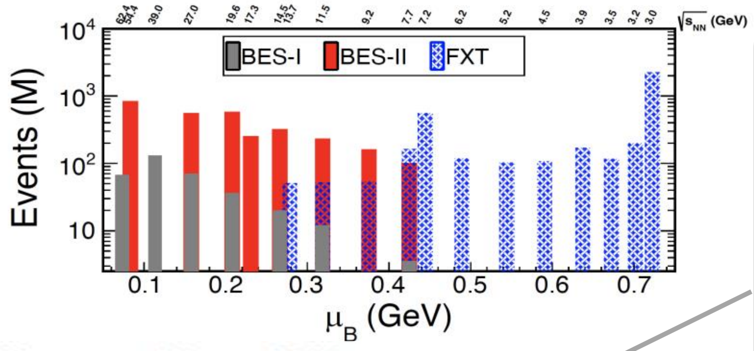
Experimental Facilities

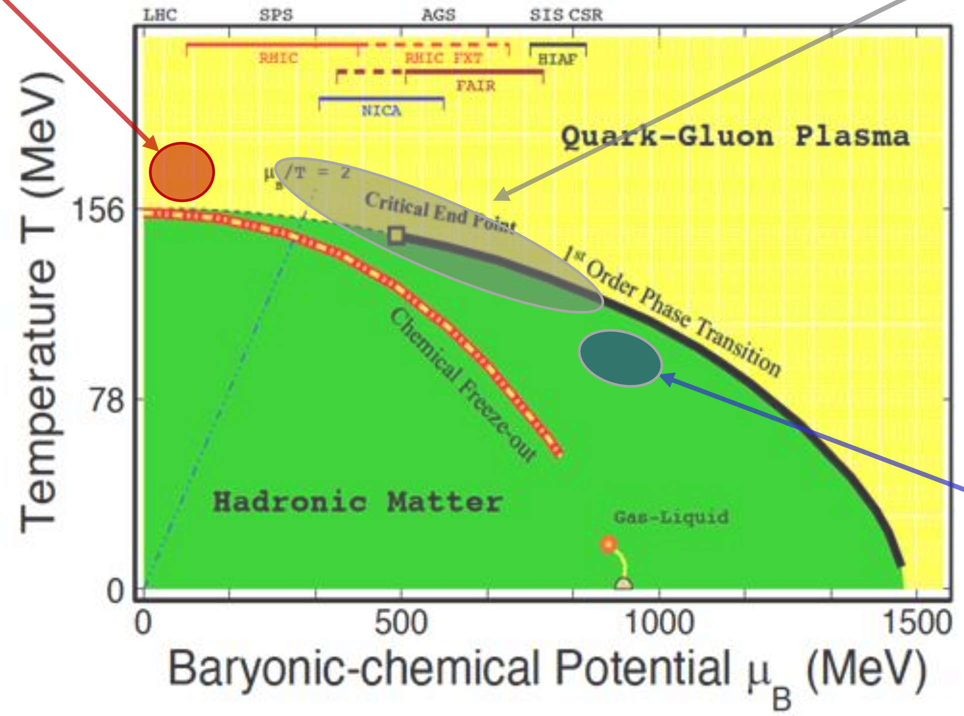
ALICE LHC, CERN



- Pb+Pb, p+p, p+Pb, …
- $\sqrt{s_{NN}}$ = 2.76 – 5.02 TeV (Pb+Pb)

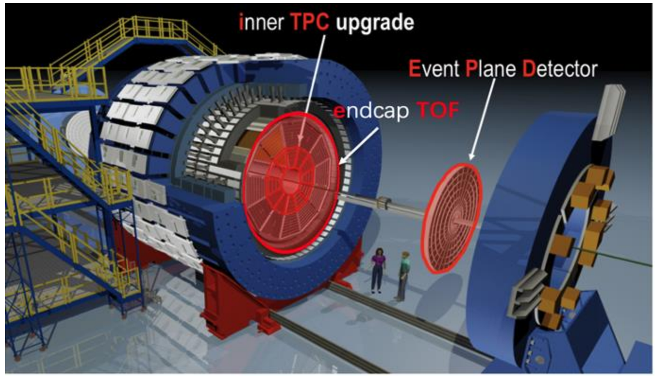
RHIC BES-II, $3 < \sqrt{s_{NN}} < 200$ GeV





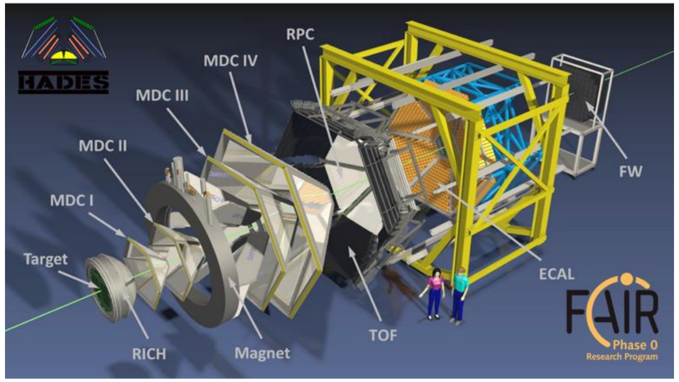
- Advantage at low $\sqrt{s_{NN}}$: high μ_B → enhanced yields
- Advantage at high $\sqrt{s_{NN}}$: anti-particles

STAR RHIC, BNL



- Au+Au,p+p, p+Au, …
- $\sqrt{s_{NN}}$ = 3.0 – 200 GeV (Au+Au)

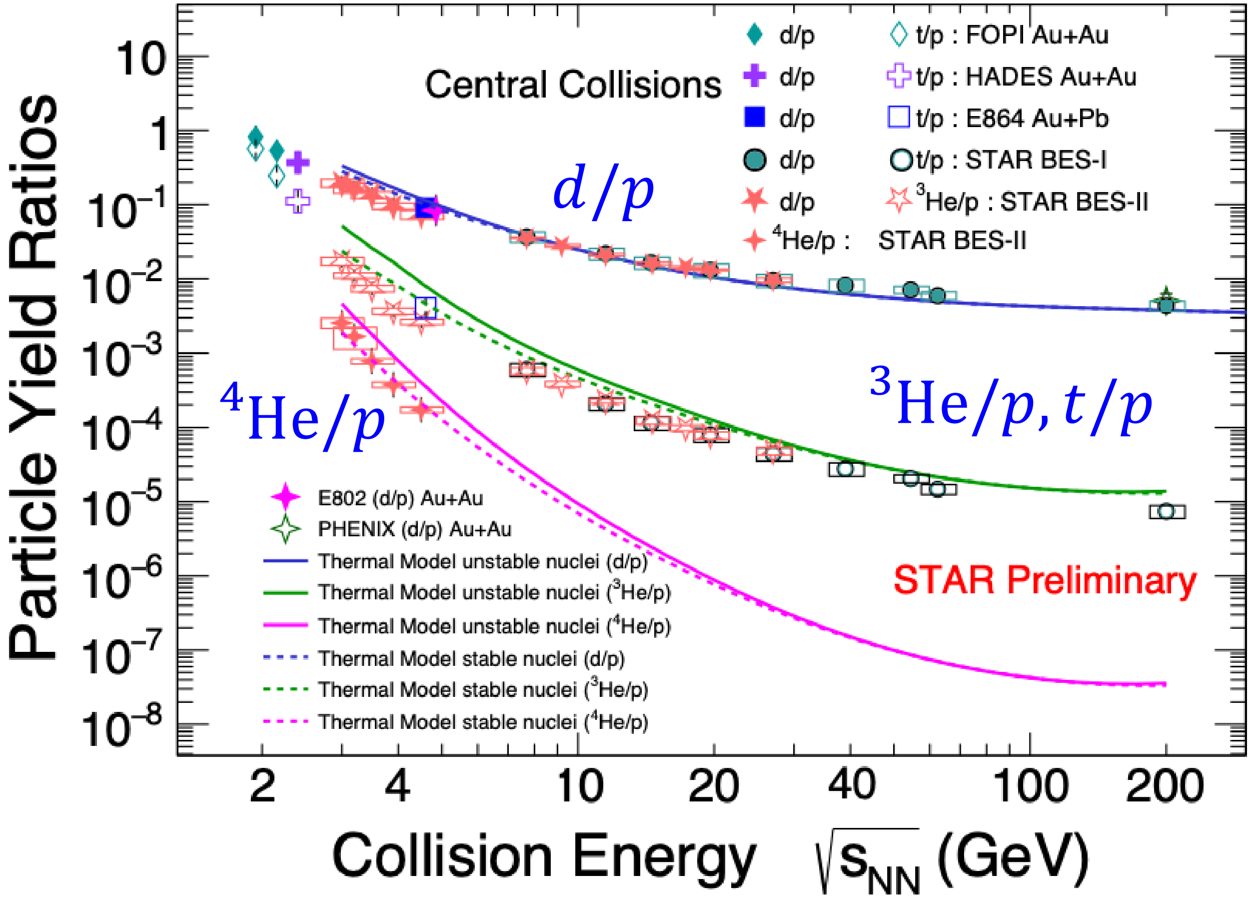
HADES SIS18, GSI



- Au+Au, Ag+Ag, …
- $\sqrt{s_{NN}}$ = 2.55 GeV (Ag+Ag)

Nuclei Yield Ratios from RHIC-BES

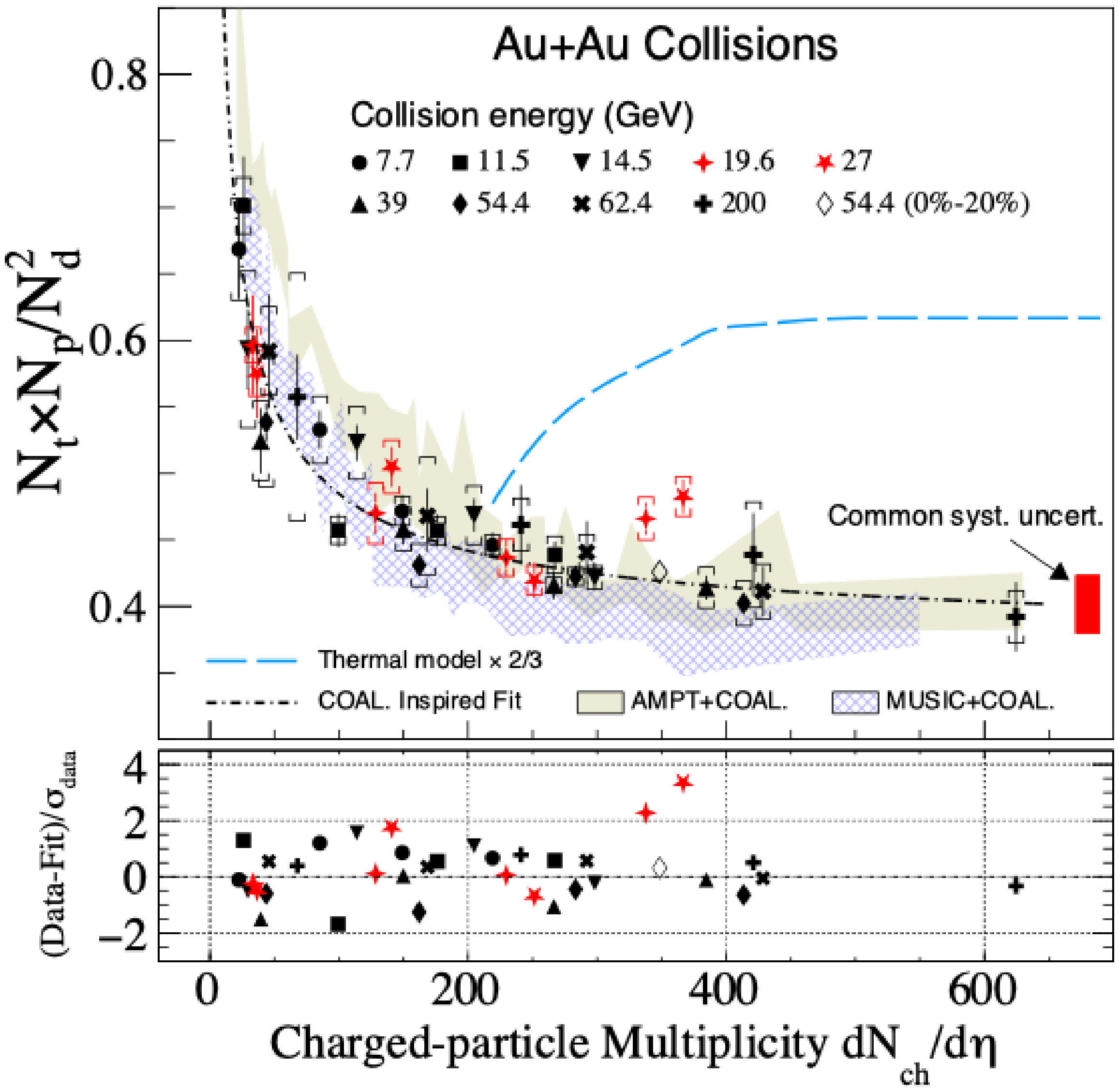
Y. Jin, STAR, QM2025
Thermal-FIST: V. Vovchenko, Comput. Phys. Commun. 244, 295 (2019)



- d/p fairly well described by thermal model
- $^{3}\mathrm{He}/p, t/p$ overestimated by approx. factor of 2
- For $^{4}\mathrm{He}/p$, the results depend on whether we consider unstable nuclei feed-down decays

Compound Ratio (tp/d^2)

STAR, Phys. Rev. Lett. 130 (2023) 202301
K. Sun et al., Phys. Lett. B 781 (2018) 499

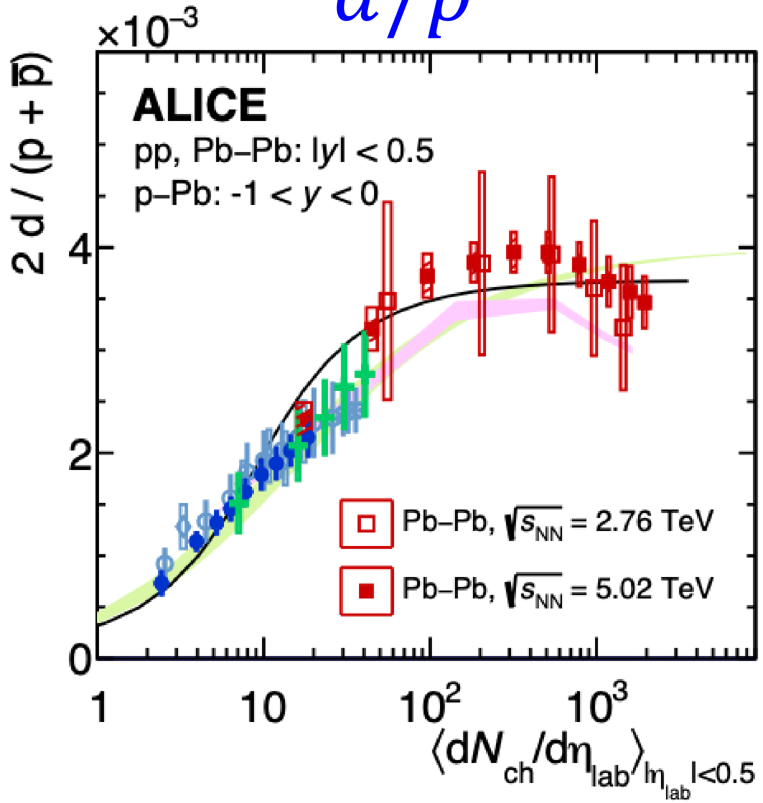


- Data follows a common decreasing trend
- Thermal model predicts an increasing trend and is inconsistent with data
- Compound ratio can be described by coalescence calculations

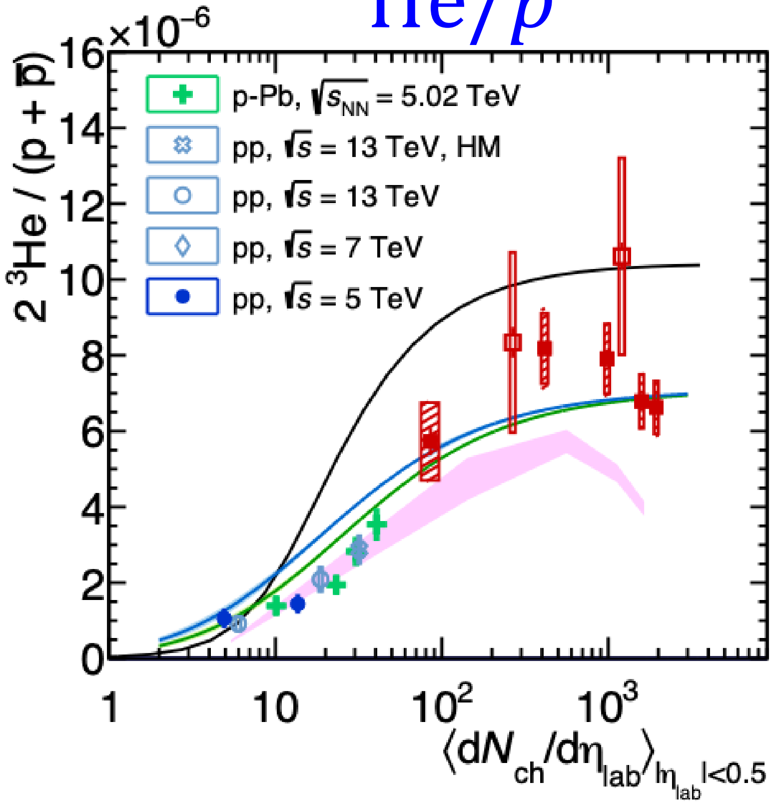
Nuclei Ratios from LHC

ALICE, Phys. Lett. B 858 (2024) 138943

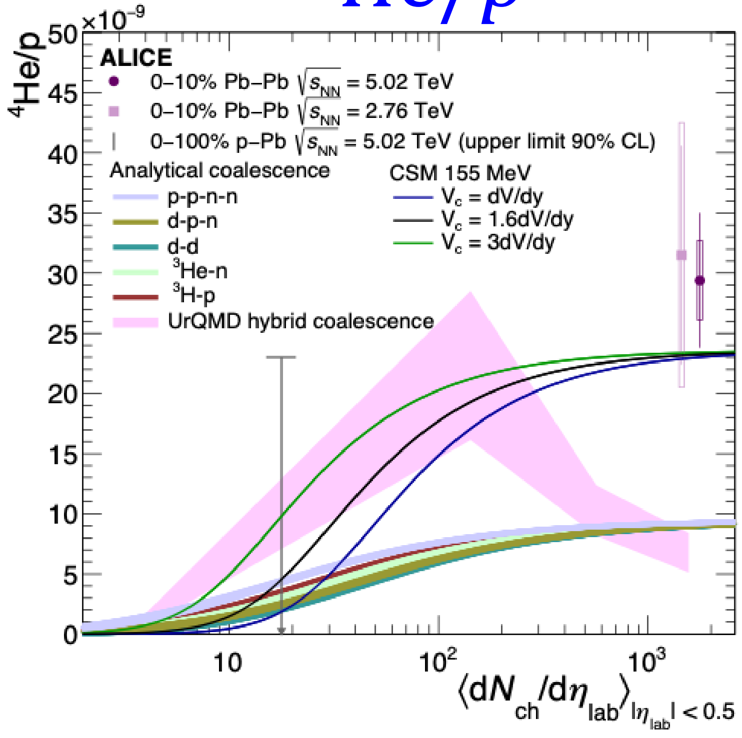
d/p



$^3\text{He}/p$



$^4\text{He}/p$



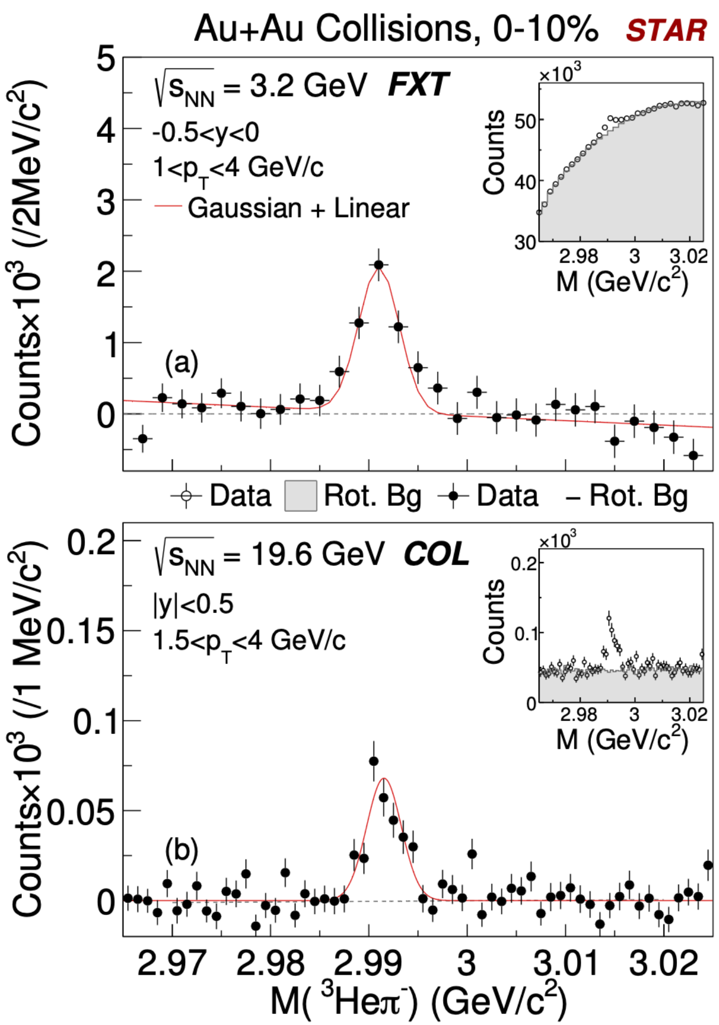
- Thermal: $A = 2{,}4$: fairly well described; A=3: strongly overpredicted
- Coalescence: $A = 2{,}3$: fairly well described; A=4: underpredicted
- Similar trends in data–model comparisons across RHIC and LHC

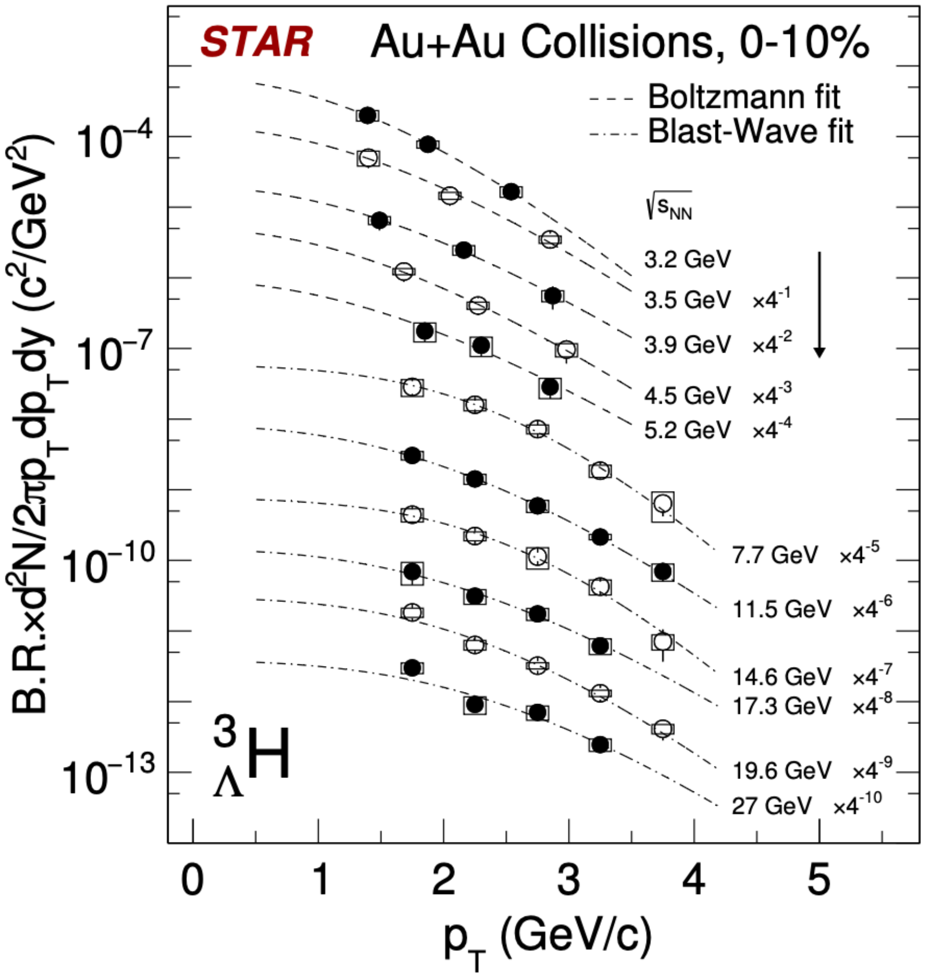
For nuclei with A < 4, coalescence models provide a good description, while thermal models do not consistently describe all species

Hypernuclei ${}^{3}_{\Lambda}H$ Reconstruction

STAR, arXiv:2604.18214

$${}^{3}_{\Lambda}\mathrm{H} \rightarrow {}^{3}\mathrm{He}\,\pi^{-}$$





- Hypernuclei reconstructed from 2-body mesonic decay channels from 11 (5 FXT+6 COL) energies at BES-II

Energy Dependence of ${}^{3}_{\Lambda}H$ $\langle \mathrm{p_T} \rangle$

STAR, arXiv:2604.18214

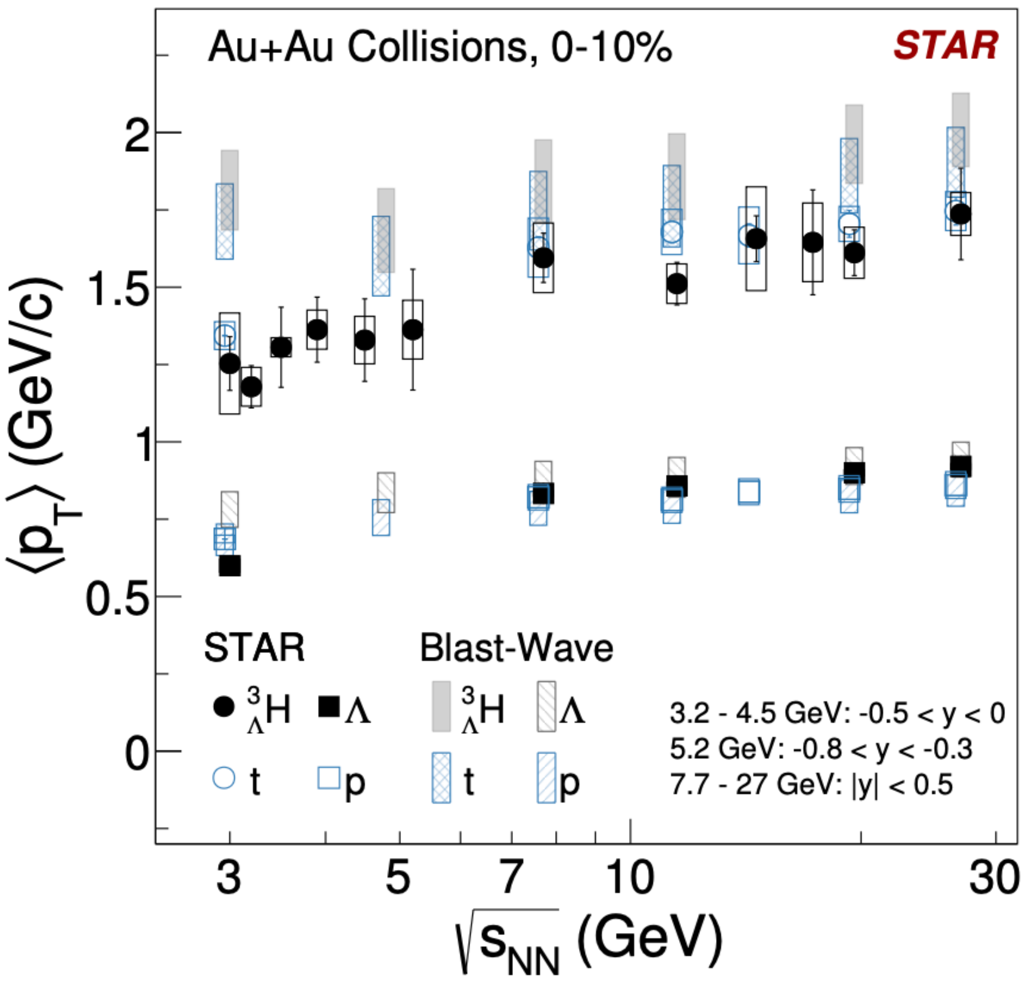
- Hydrodynamic-inspired blast-wave model: common $T_{kin}, \langle \beta_T \rangle$

- At $\geq$ 7.7 GeV, ${}^{3}_{\Lambda}H$ $\langle \mathrm{p_T} \rangle$ tends to approach the blast-wave prediction with proton freeze-out parameters

  - *May be due to increasing effective volume for coalescence with increasing energy*

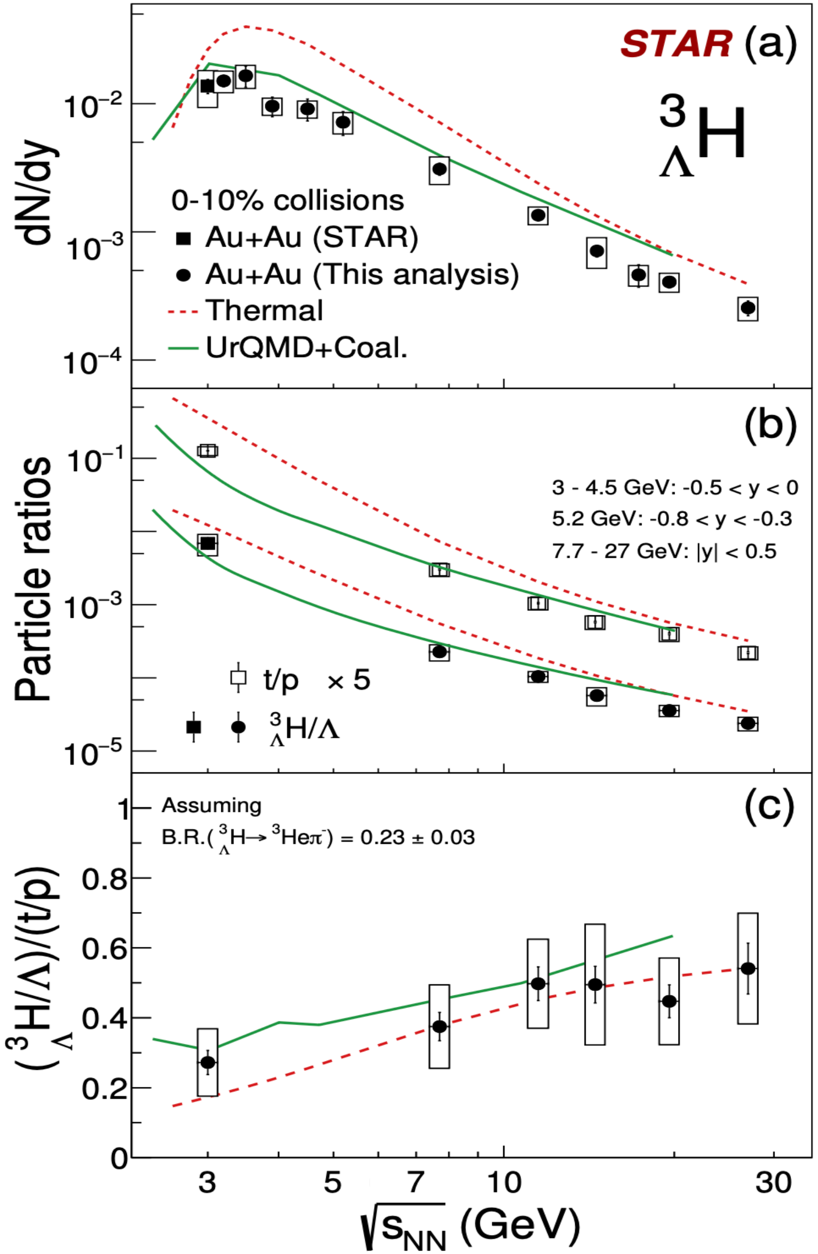
- Different trend for $\sqrt{s_{NN}}$ =3-4.5 GeV and $\sqrt{s_{NN}}$ = 7.7-27 GeV

Suggest different expansion dynamics or medium properties?



${}^{3}_{\Lambda}H$ Excitation Functions in Au+Au collisions

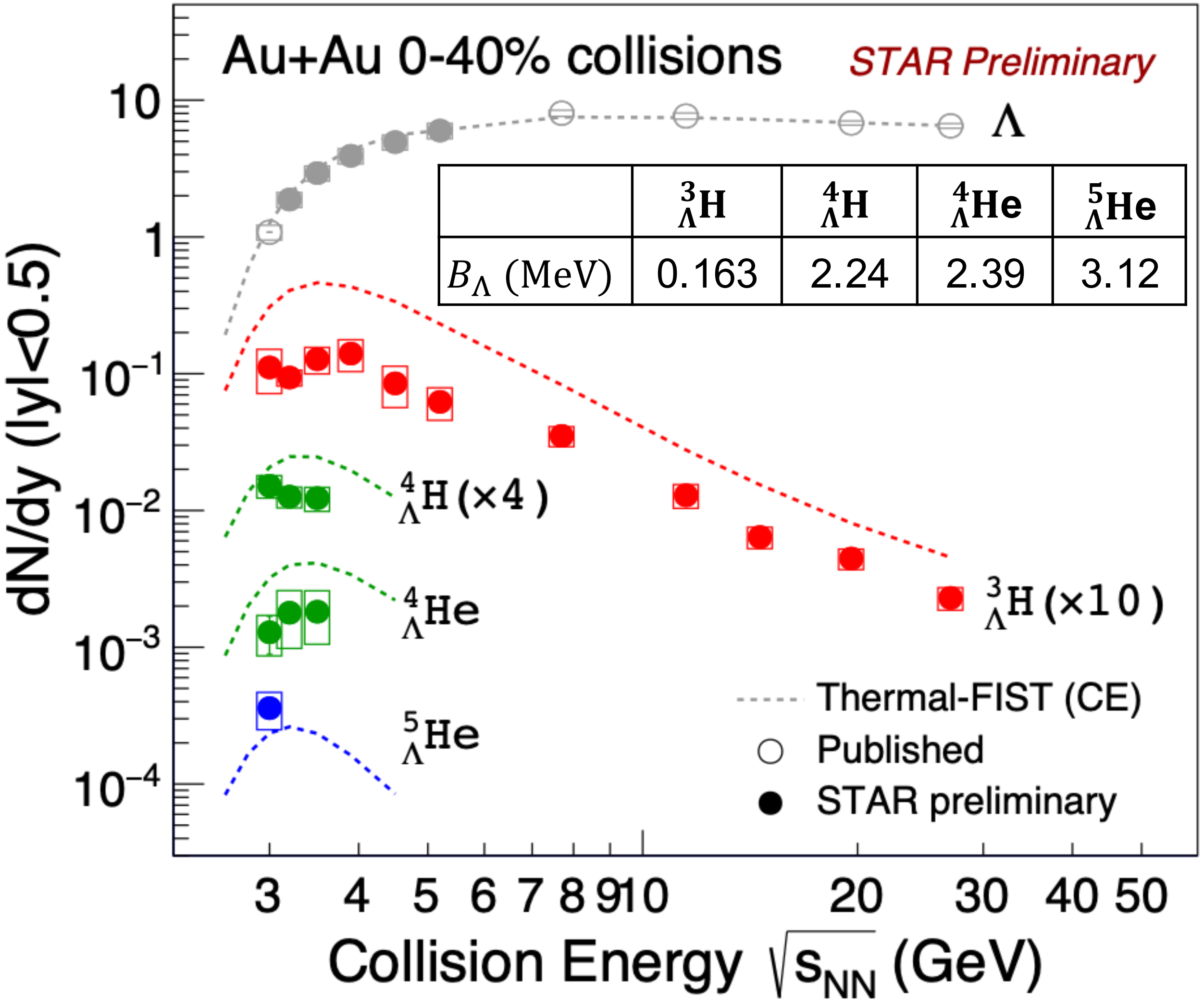
STAR, arXiv:2604.18214



- ${}^{3}_{\Lambda}$H yields peak at $\sqrt{s_{NN}}$= 3-4 GeV then decrease toward higher energies
  - Increasing baryon density at lower energies ↑
  - Stronger strangeness canonical suppression at low energies ↓

- Similar to ^{3}He, ${}^{3}_{\Lambda}$H is overestimated by thermal model across all energies

Hypernuclei Excitation Functions in Au+Au collisions



	${}^{3}_{\Lambda}$H	${}^{4}_{\Lambda}$H	${}^{4}_{\Lambda}$He	${}^{5}_{\Lambda}$He
B_Λ (MeV)	0.163	2.24	2.39	3.12

STAR, Phys. Rev. Lett 128, 202301 (2022)

- ${}^{3}_{\Lambda}$H yields peak at $\sqrt{s_{NN}}$= 3-4 GeV then decrease toward higher energies
  - Increasing baryon density at lower energies ↑
  - Stronger strangeness canonical suppression at low energies ↓

- Similar to ^{3}He, ${}^{3}_{\Lambda}$H is overestimated by thermal model across all energies
- As the mass number increases, the discrepancy with the thermal model decreases

May indicate larger survival probability for more tightly bound hypernuclei

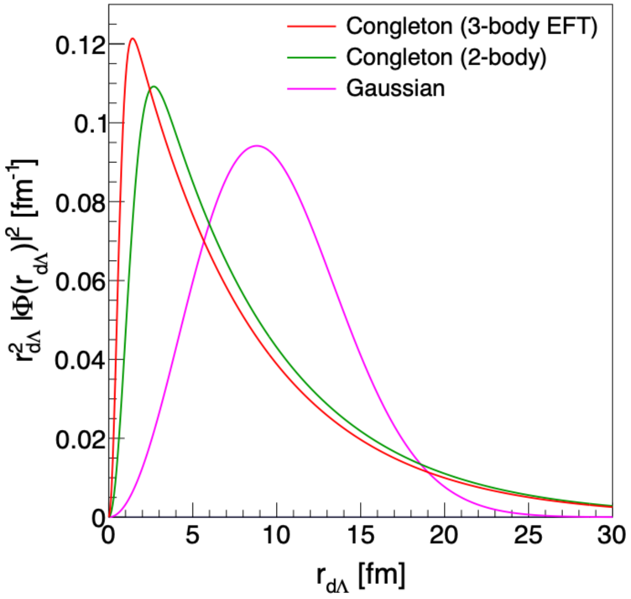
- Need dynamical models coupling formation and dissociation of (hyper)nuclei

Strangeness Population Factor S_3 vs. $dN_{ch}/d\eta$

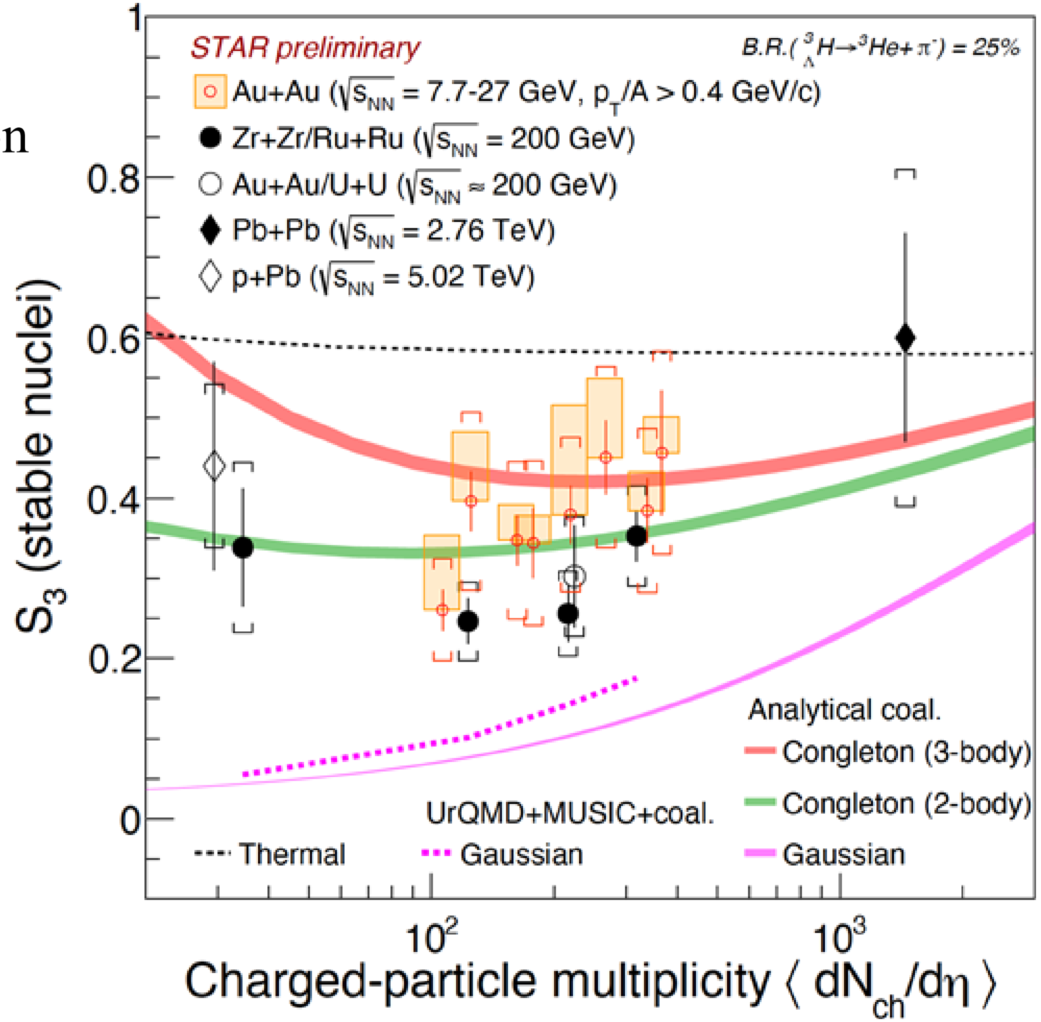
$$S_3 = \frac{{}^{3}_{\Lambda}\mathrm{H}}{{}^{3}\mathrm{He} \times \frac{\Lambda}{p}}$$

removes the difference of Λ and proton density
→ direct comparison b/w ${}^{3}_{\Lambda}$H and ^{3}He production

	${}^{3}_{\Lambda}$**H**	^{3}**He**
Mass (GeV)	2.991	2.809
rms (fm)	4.332	1.567



- $S_3 < 1$ → suppression of ${}^{3}_{\Lambda}$H relative to ^{3}He due to wider wave function in coalescence
- Coalescence using Gaussian wave function underestimates the data
- Coalescence using Congleton wave function describes across different energies/systems



F. Bellini et al., Phys. Rev. C 103 (2021) 1, 014907
YHL et al., Phys.Rev.C 113 (2026) 3, 034912
K. Sun et al., PLB 820(2021)136571
V .Vovchenko et al., Phys. Let. B 809 (2020) 135746
ALICE, Phys. Rev. Lett. 128 (2022) 252003
ALICE, Phys. Lett. B 754 (2016) 360

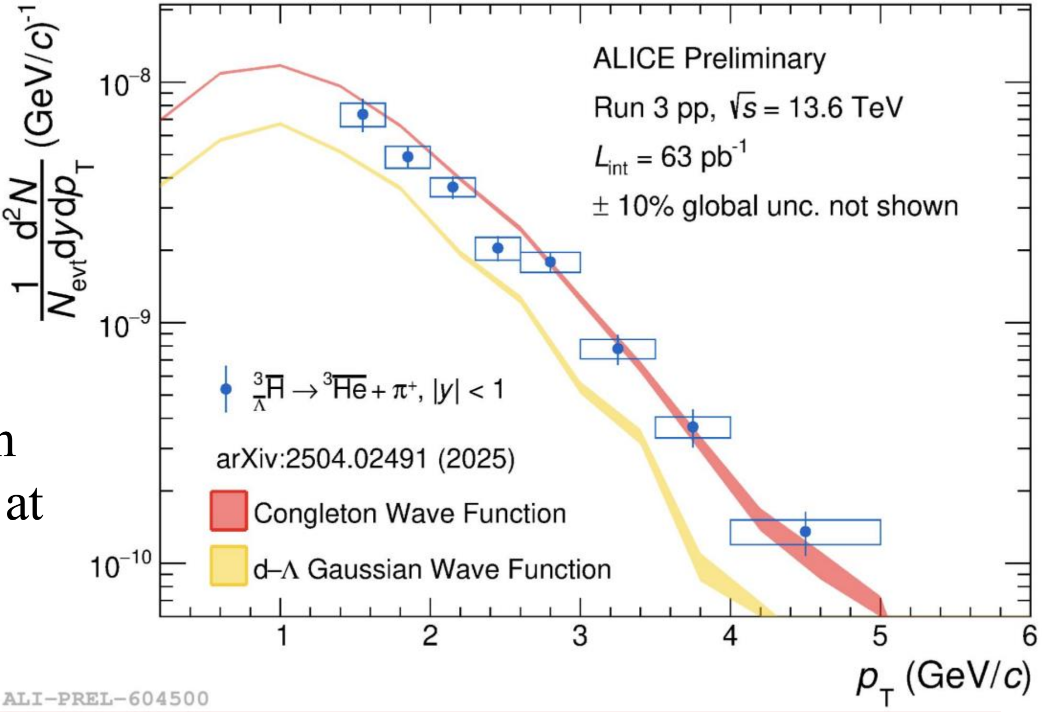
Strangeness Population Factor S_3 vs. $dN_{ch}/d\eta$

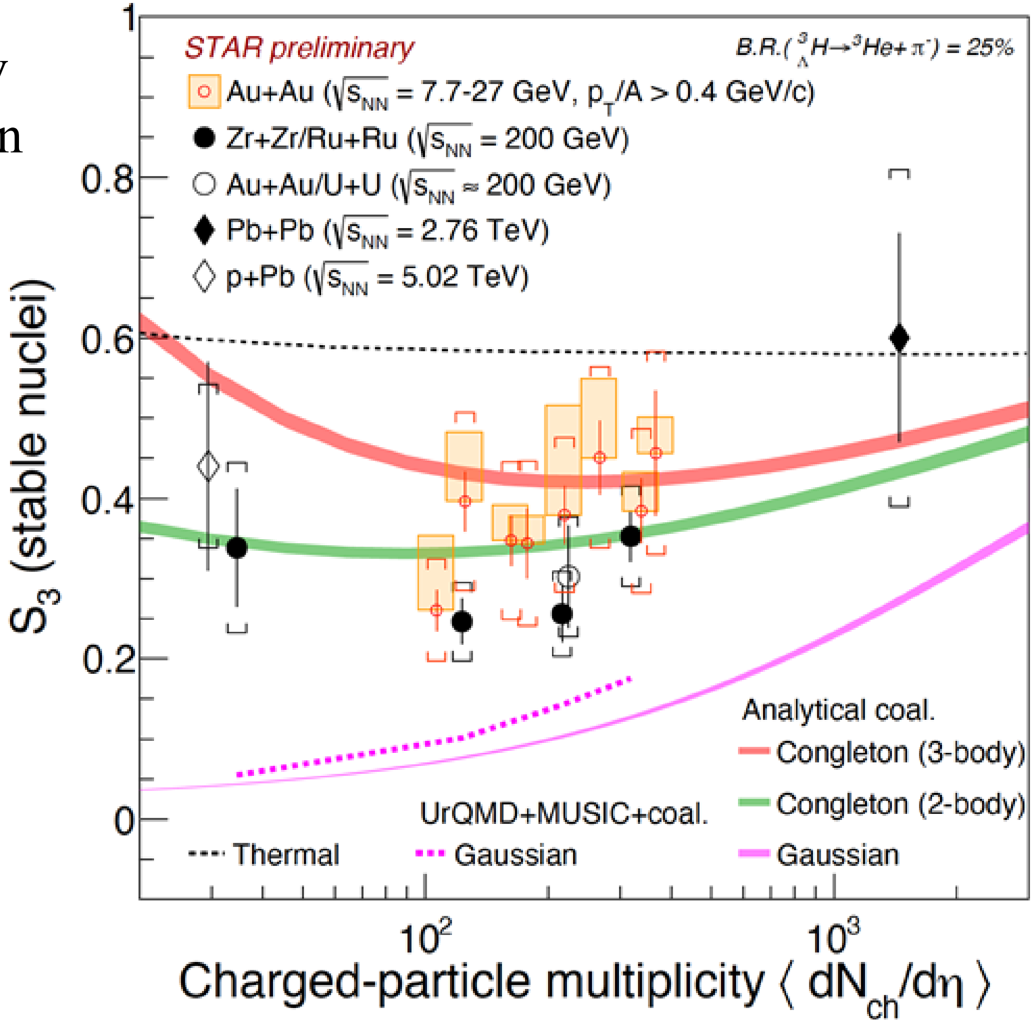
$$S_3 = \frac{^3_\Lambda\mathrm{H}}{^3\mathrm{He} \times \frac{\Lambda}{p}}$$

removes the difference of Λ and nucleon density
→ direct comparison b/w $^3_\Lambda$H and ^{3}He production

- Similar observations in p+p collisions at 13.6 TeV

ALICE, QM2025





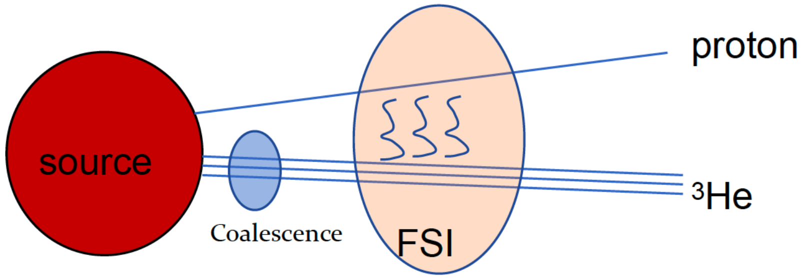
S_3 provides access to the short distance behavior of the $^3_\Lambda$H wave function

F. Bellini et al., Phys. Rev. C 103 (2021) 1, 014907
YHL et al., Phys.Rev.C 113 (2026) 3, 034912
K. Sun et al., PLB 820(2021)136571
V .Vovchenko et al., Phys. Let. B 809 (2020) 135746
ALICE, Phys. Rev. Lett. 128 (2022) 252003
ALICE, Phys. Lett. B 754 (2016) 360

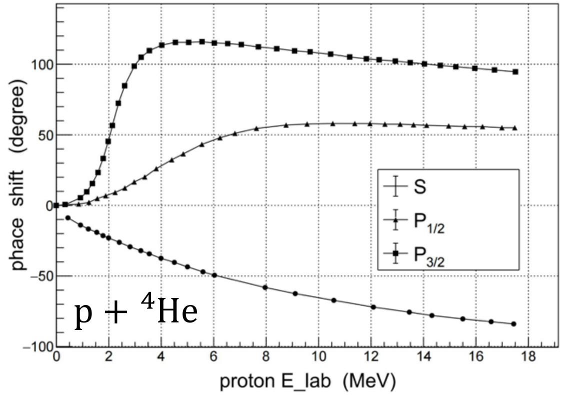
$^{4}\boldsymbol{Li}\ (^{3}P_{2}) \rightarrow \boldsymbol{p} + {}^{3}He$
$^{5}\boldsymbol{Li}\ (P_{3/2}) \rightarrow \boldsymbol{p} + {}^{4}He$

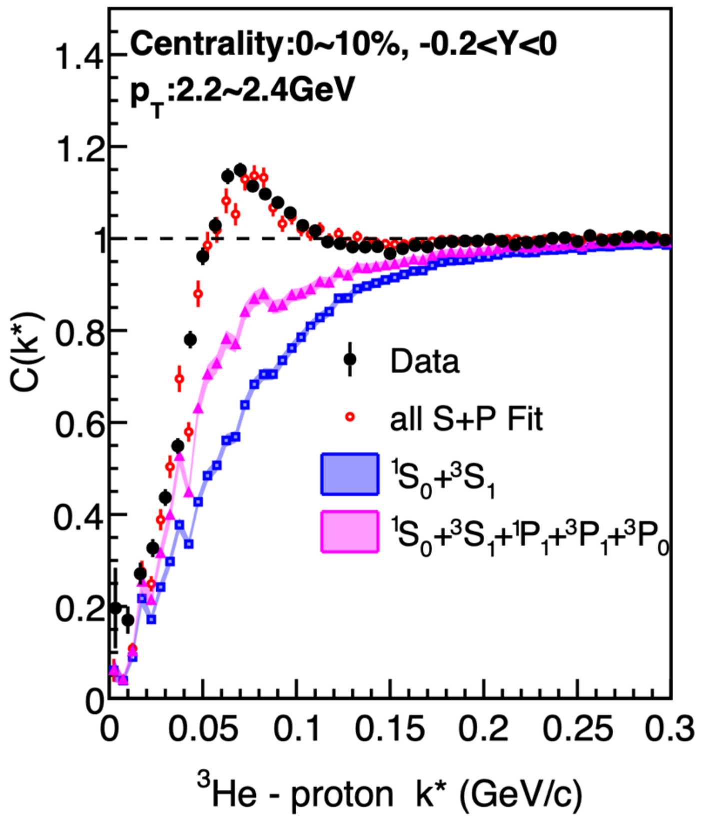
Unstable Light Nuclei (^{4}Li &^{5}Li)

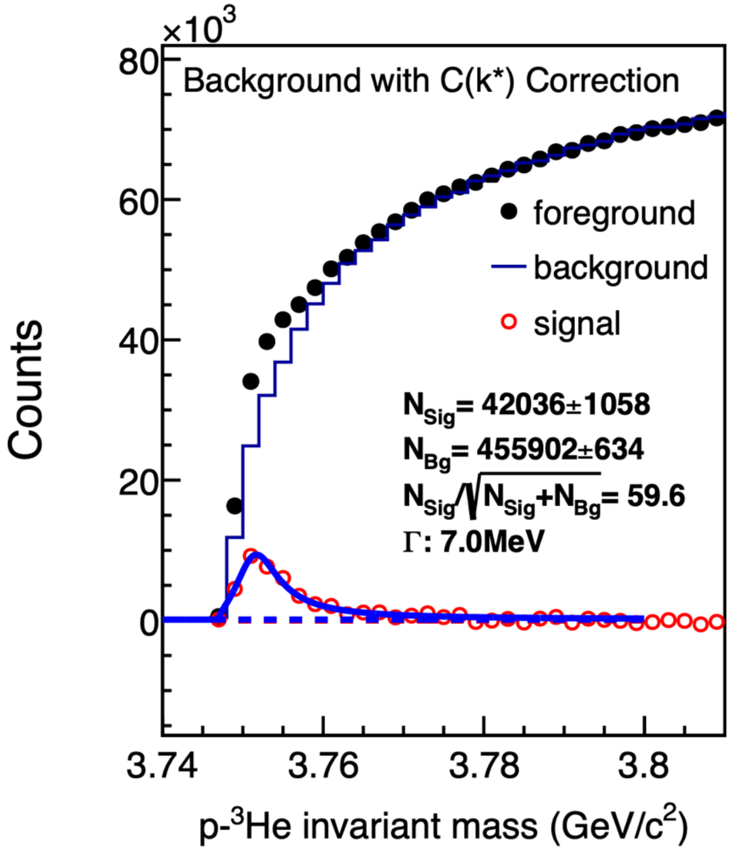
STAR, Junlin Wu, sQM26



Nuclear Physics A163 (1971) 432-448







- Femtoscopy correlations provide a unique bridge between heavy-ion collisions and low-energy nuclear scattering.
- Novel method: Partial-wave + phase-shift data + LL model enables the extraction of near-threshold resonance, ^{4}Li &^{5}Li

^{4}Li & ^{5}Li yields in $\sqrt{s_{NN}} = 3$ GeV Au+Au collisions

STAR, Junlin Wu, sQM26

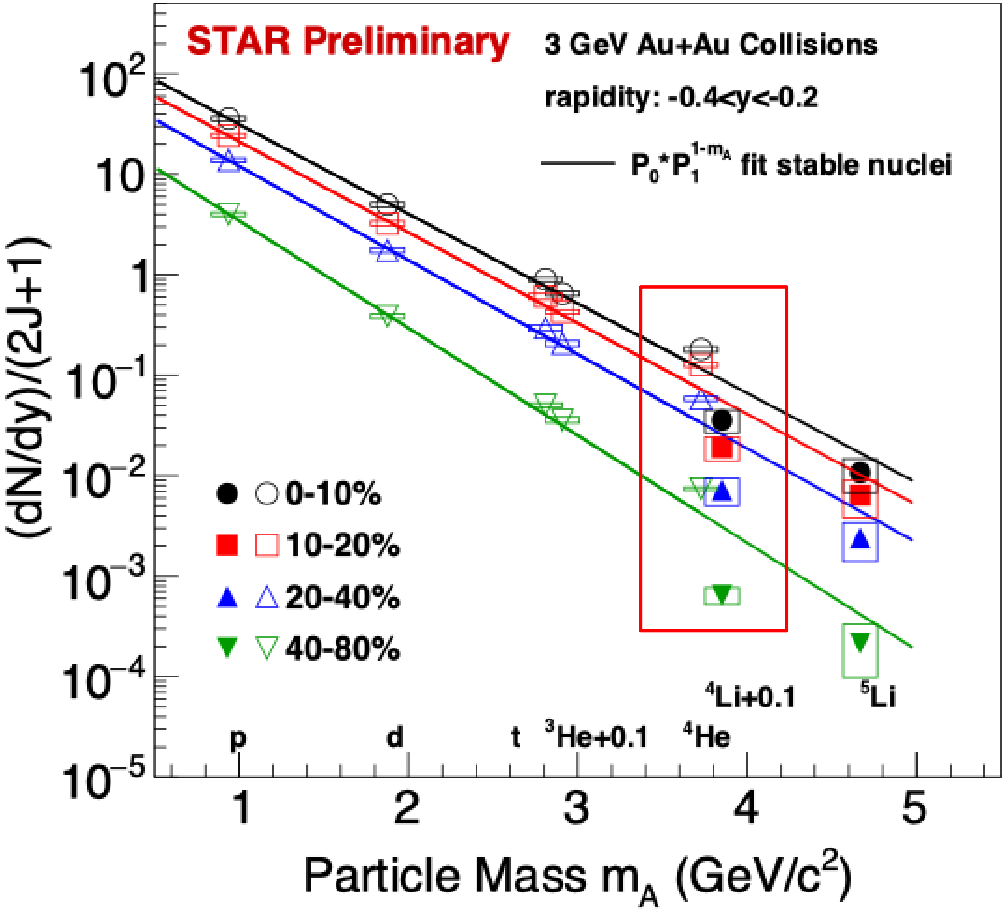
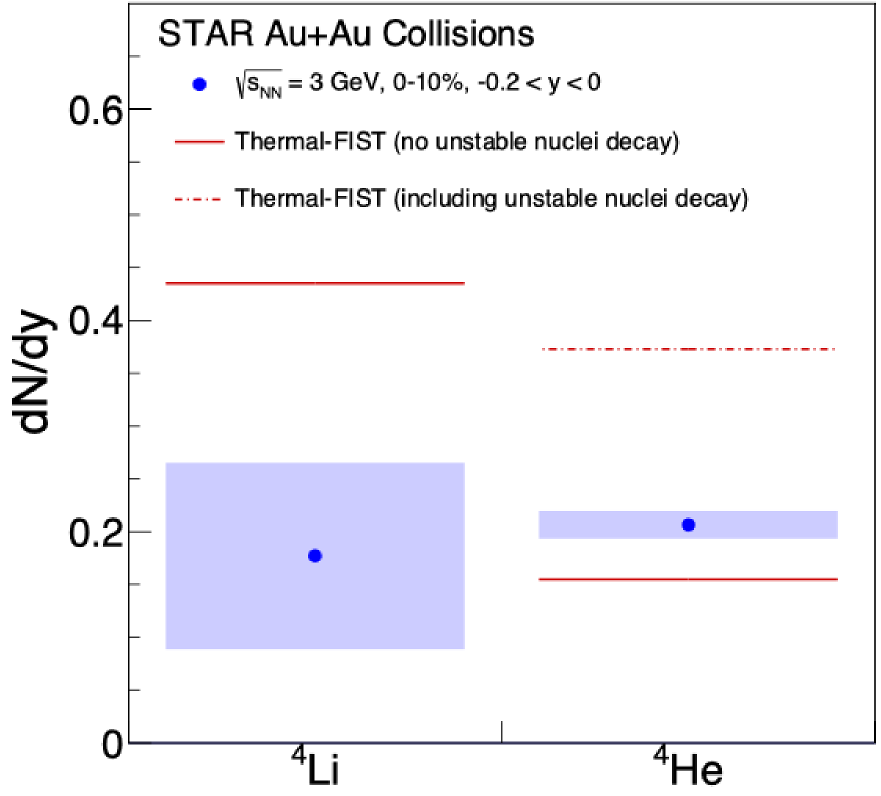


Fig. from STAR preliminary + STAR, Phys. Rev. C 110 (2024) 54911

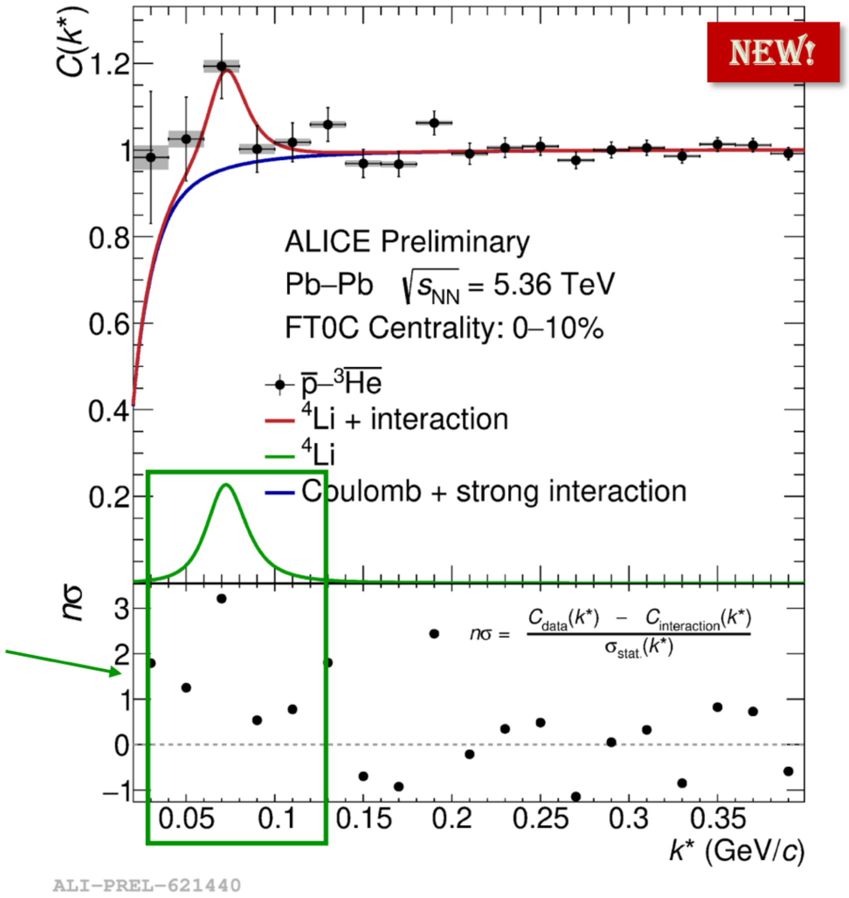


	^{4}Li	^{4}He
Mass (GeV)	3.749	3.727
rms (fm)	?	1.590

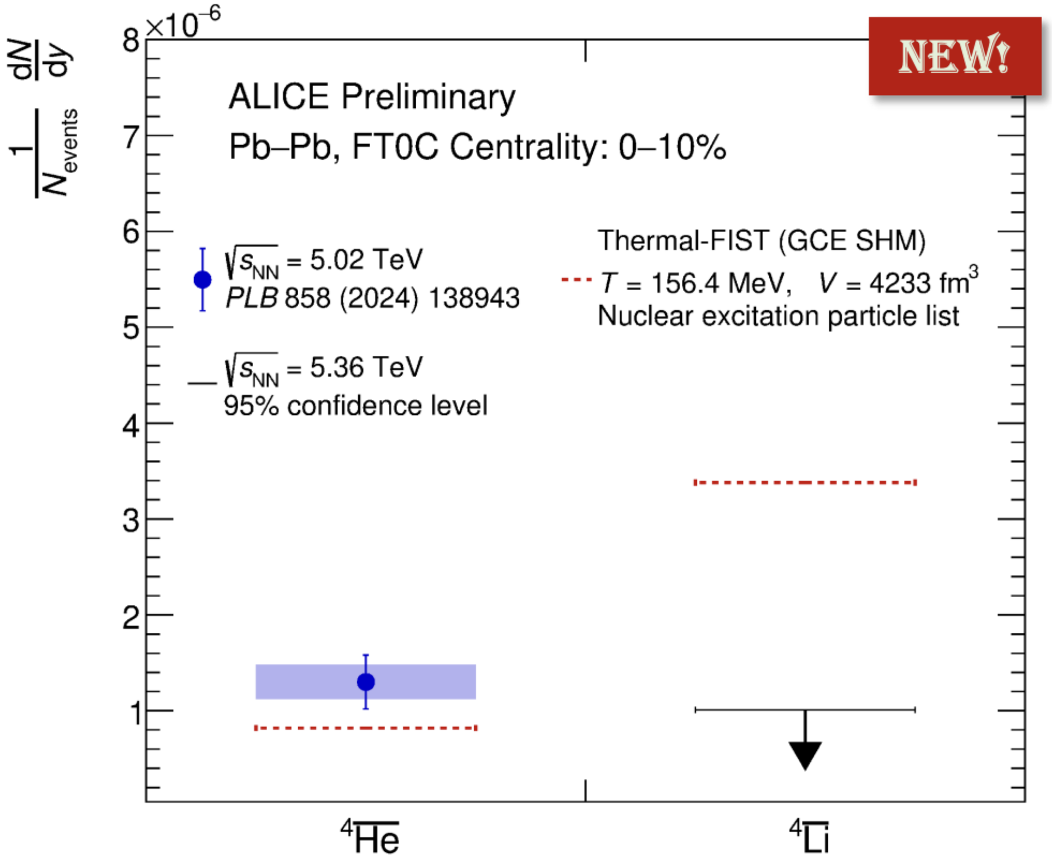
- Yield of ^{4}Li /(2J+1) is significantly lower than that of ^{4}He
- Thermal model overestimates ^{4}Li yield
- Thermal model (including unstable nuclei feed-down) overestimates ^{4}He yield

Search for $^4\overline{\text{Li}}$ in Pb+Pb collisions at 5.36 TeV

ALICE, new ,sQM26



Significance:
2.1σ

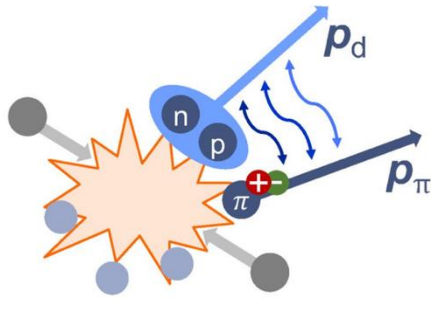


- Search for $^4\overline{\text{Li}}$ in Pb+Pb at $\sqrt{s_{NN}}$ = 5.36 TeV
- Upper limit on $^4\overline{\text{Li}}$ yield obtained, significantly below SHM prediction

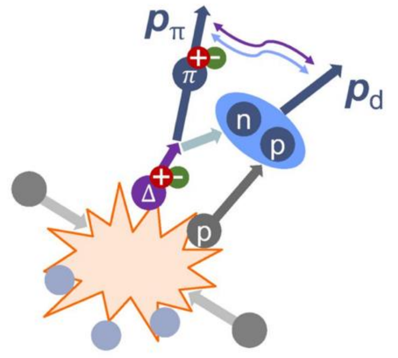
^{4}Li suppressed relative to ^{4}He , possibly reflecting its resonant nature and extended spatial structure

Studying deuteron production via femtoscopy

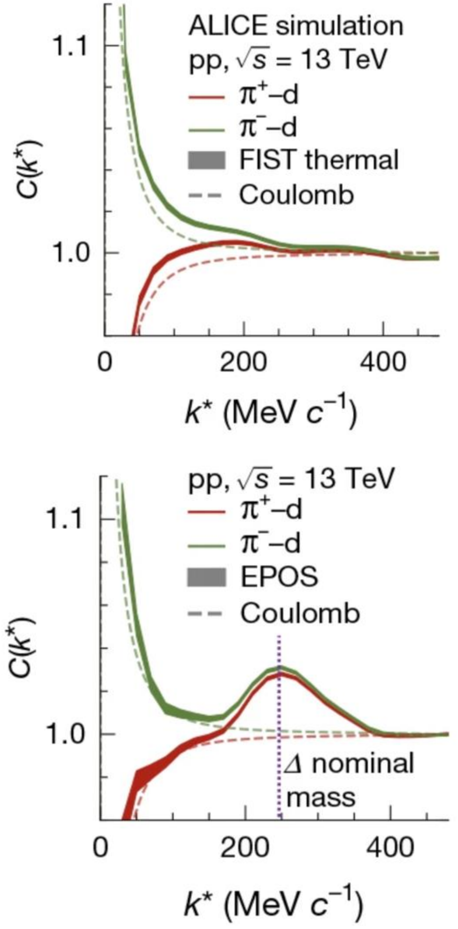
Kaijia Sun, April 26



1. Prompt production

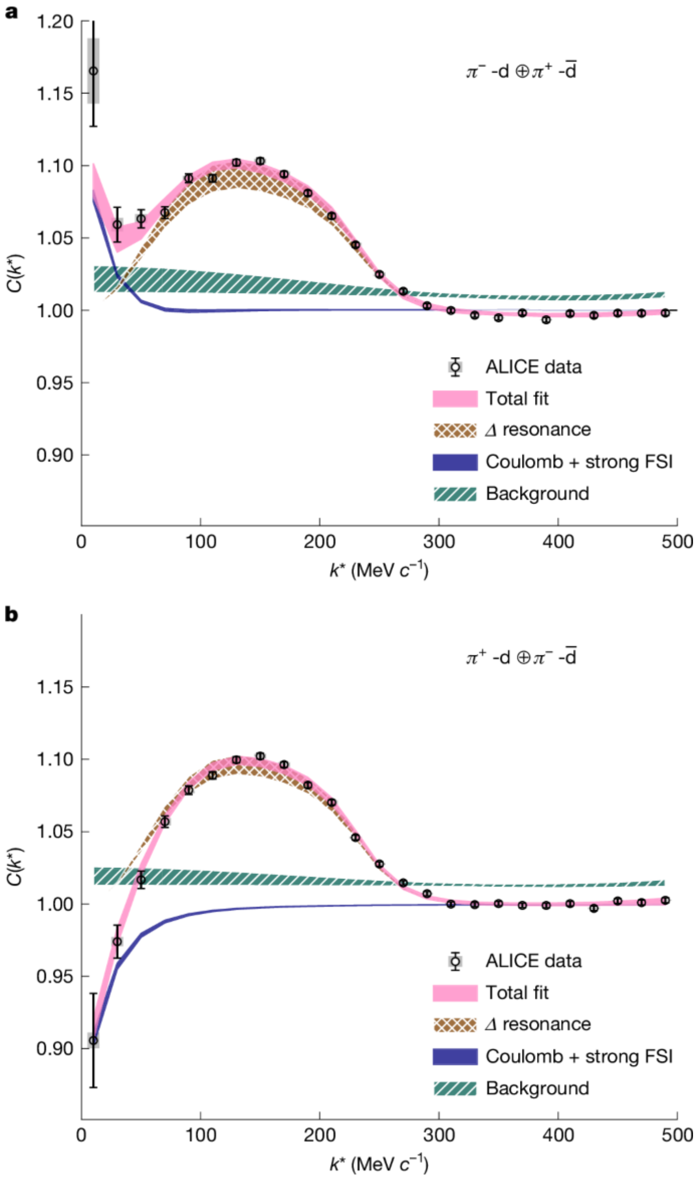


2. Coalescence



- The correlation function of π-d can provide information about deuteron production

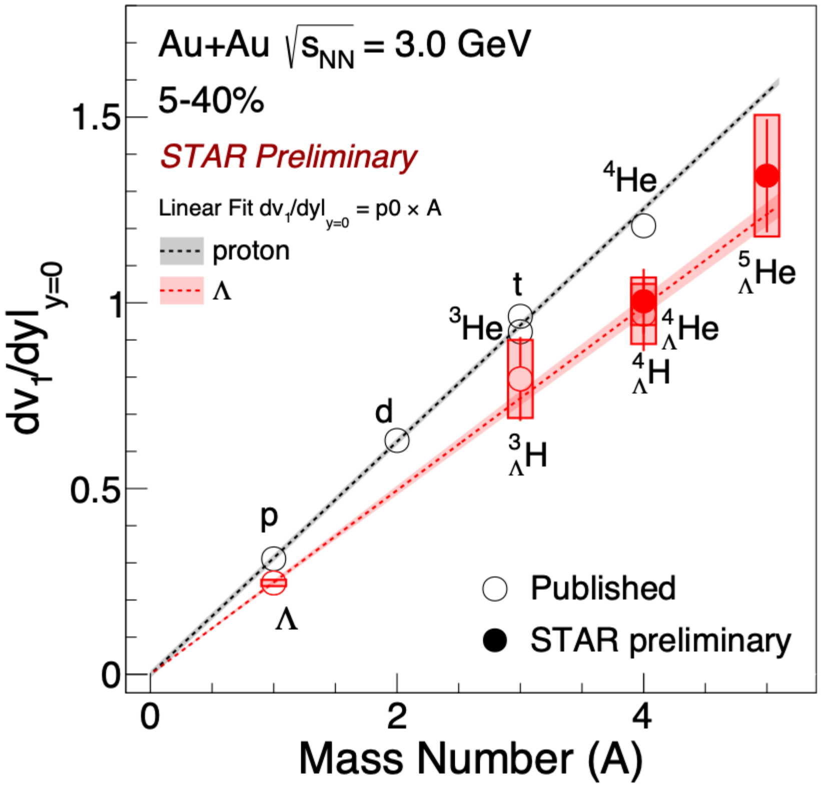
- Aim: to distinguish between two scenarios
  - Prompt production
  - Coalescence (occurs after resonance decay)

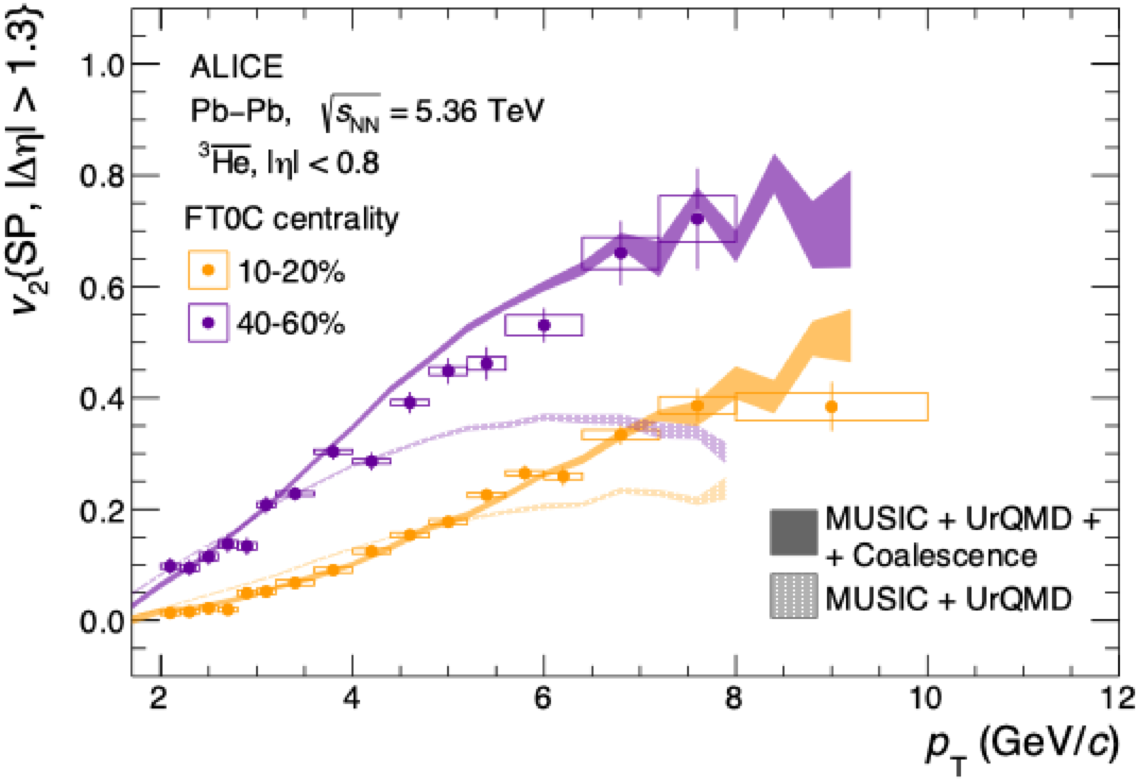


ALICE, Nature 648 (2025) 8093, 306-311

Large fraction of deuteron formed via coalescence following the strong decay of short-lived resonances

Nuclei and hypernuclei Flow





- Nuclei and hypernuclei dv_1/dy follows mass number scaling up to $A = 5$ in $\sqrt{s_{NN}} = 3$ GeV Au+Au collisions
- $^3\overline{\text{He}}$ v_2 in $\sqrt{s_{NN}} = 5.36$ TeV Pb+Pb collisions, consistent with hydrodynamic models paired with coalescence

STAR, Phys. Rev. Lett. 130 (2023) 212301, QM2025
ALICE, arXiv:2603.19398

Nuclei flow measurements support the coalescence picture

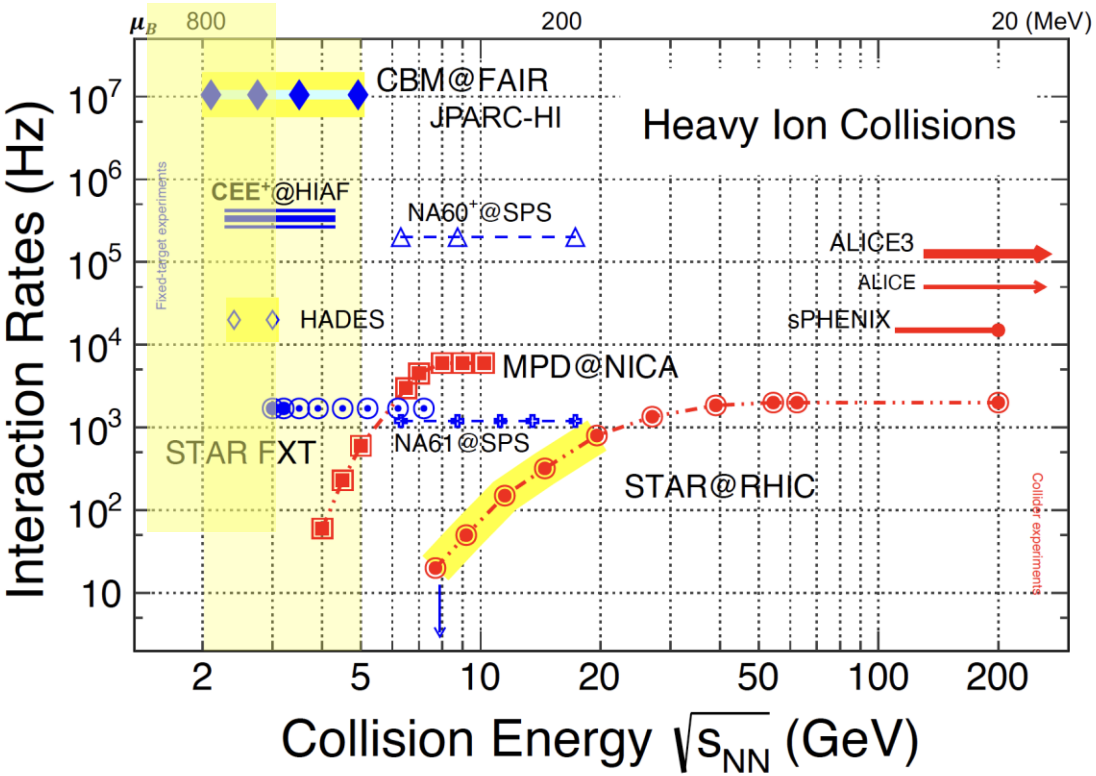
$$E\frac{d^3N}{dp^3} = \frac{1}{2\pi}\frac{d^2N}{p_T dp_T dy}\left(1 + \sum_{1}^{\infty} 2v_n \cos\left[n\left(\phi - \psi_{RP}\right)\right]\right)$$

Summary

- ✓ Data suggest that (hyper)nuclei yields are sensitive to their internal structure, and models that neglect this cannot consistently describe all observables
  - ✓ (Hyper)nuclei with larger spatial extent ($^{3}_{\Lambda}\mathrm{H}$, $^{4}\mathrm{Li}$) suppressed w.r.t. those with smaller ($^{3}\mathrm{He}$, $^{4}\mathrm{He}$)
  - ✓ $^{3}_{\Lambda}\mathrm{H}$ production is sensitive to its internal wave function.
    - ✓ Gaussian ansatz fail, while more realistic (Congleton-type) wave functions describe data

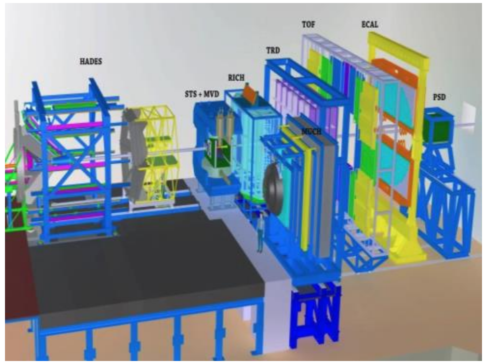
- ✓ Data for bound nuclei with $A < 4$ consistent with coalescence during late stage of collision
  - ✓ Coherent description of yield ratios, flow, and correlation observables **across datasets**
  - ✓ Correlation function indicates majority of deuterons produced after resonance decay
  - ✓ Thermal model works reasonably well for A=4–5 non-resonant (hyper)nuclei
    - ✓ May be due to stronger binding and larger survival probability in the hot medium

Future Prospects



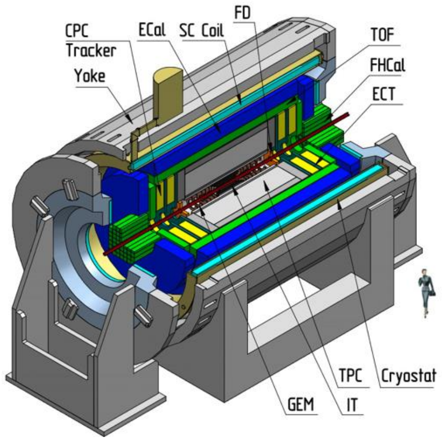
- Double-Λ hypernuclei (YY): ${}^{A}_{\Lambda\Lambda}H$?
    - Constrain ΛΛ interaction
- Heavier single-Λ hypernuclei
    - Further explore CSB, in-medium ΛN, etc.
- Hypernuclei intrinsic properties, polarization etc.

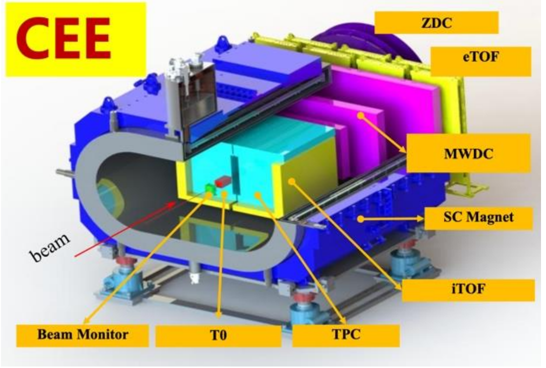
CBM@FAIR



HIAF

MPD@NICA





- ${}^{A}_{\Lambda c}H$

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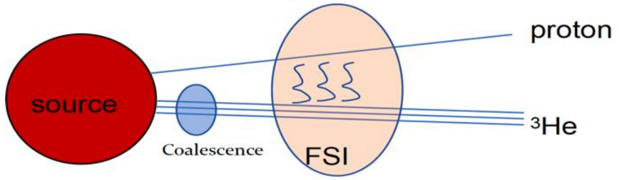
Thank you for your attention!

Backup slides follow

Unstable and Resonant Light Nuclei (^{4}Li & ^{5}Li)

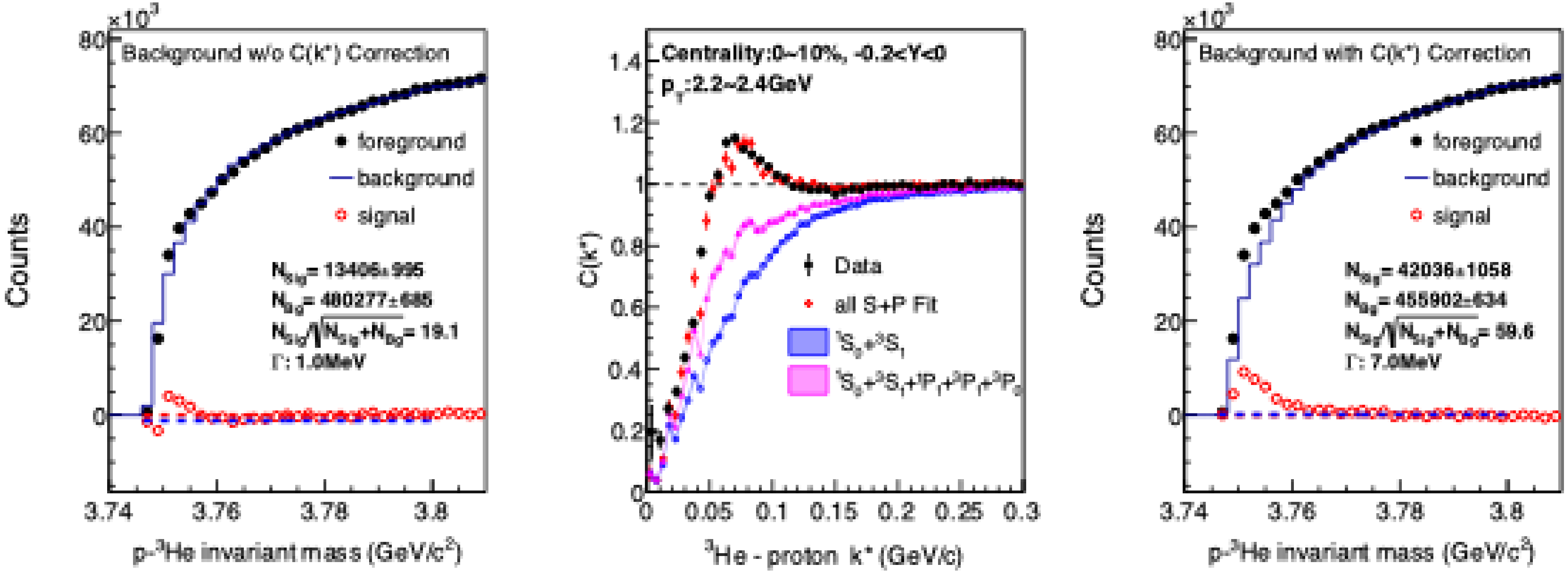
Chenlu Hu, Junlin Wu, 24/03 afternoon



$^{4}\mathbf{Li}\ (^{3}P_{2}) \rightarrow \boldsymbol{p} + {}^{3}\mathrm{He}\ (\tau \sim 30\ \mathrm{fm/c})$

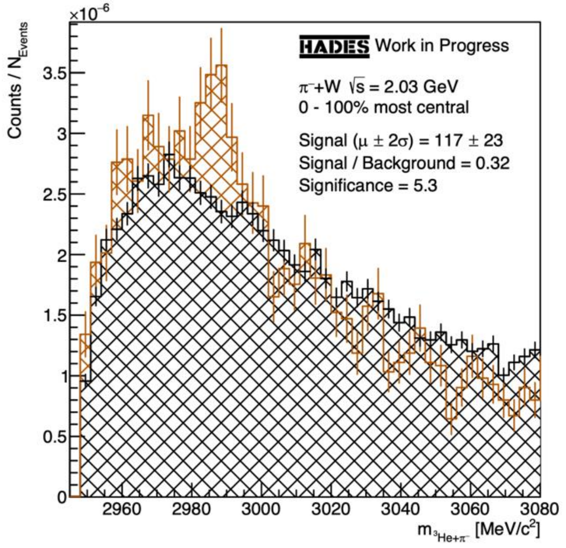
$^{5}\mathbf{Li}\ (P_{3/2}) \rightarrow \boldsymbol{p} + {}^{4}\mathrm{He}\ (\tau \sim 120\mathrm{fm/c})$

- Novel method: Partial-wave + phase-shift data + LL model enables the extraction of near-threshold resonances, ^{4}Li & ^{5}Li



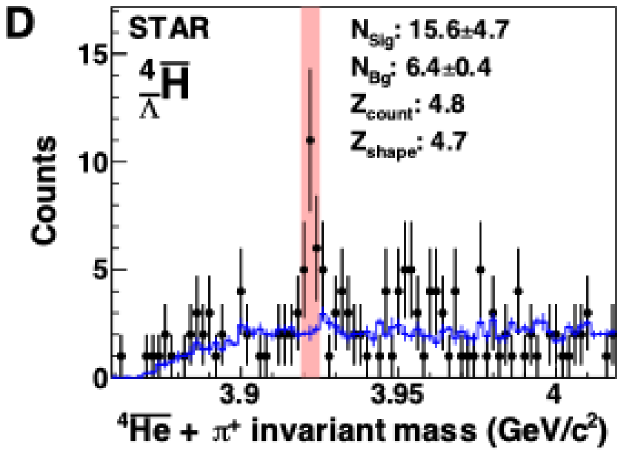
Hypernuclei Reconstruction

${}^{3}_{\Lambda}\mathrm{H}$



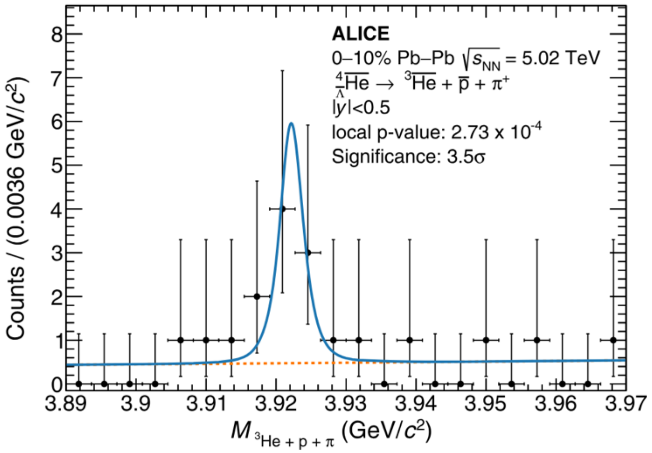
${}^{3}_{\Lambda}\mathrm{H} \rightarrow {}^{3}\mathrm{He}\,\pi^{-}$

${}^{4}_{\Lambda}\overline{\mathrm{H}}$



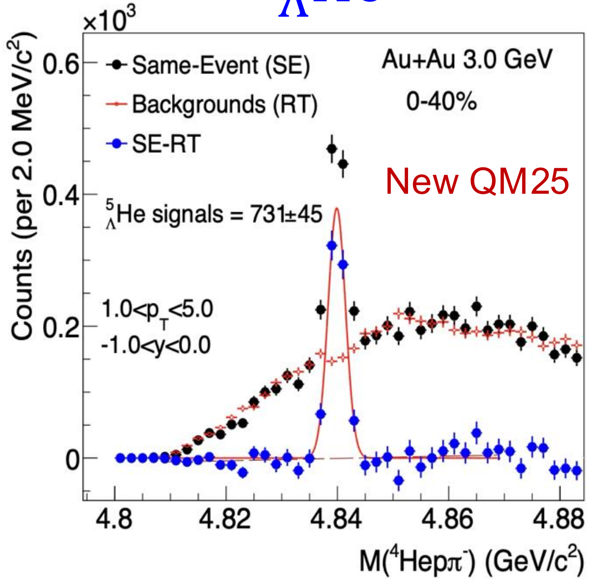
${}^{4}_{\Lambda}\overline{\mathrm{H}} \rightarrow {}^{4}\overline{\mathrm{He}}\,\pi^{+}$

${}^{4}_{\Lambda}\overline{\mathrm{He}}$



${}^{4}_{\Lambda}\overline{\mathrm{He}} \rightarrow {}^{3}\overline{\mathrm{He}}\,\bar{p}\,\pi^{+}$

${}^{5}_{\Lambda}\mathrm{He}$

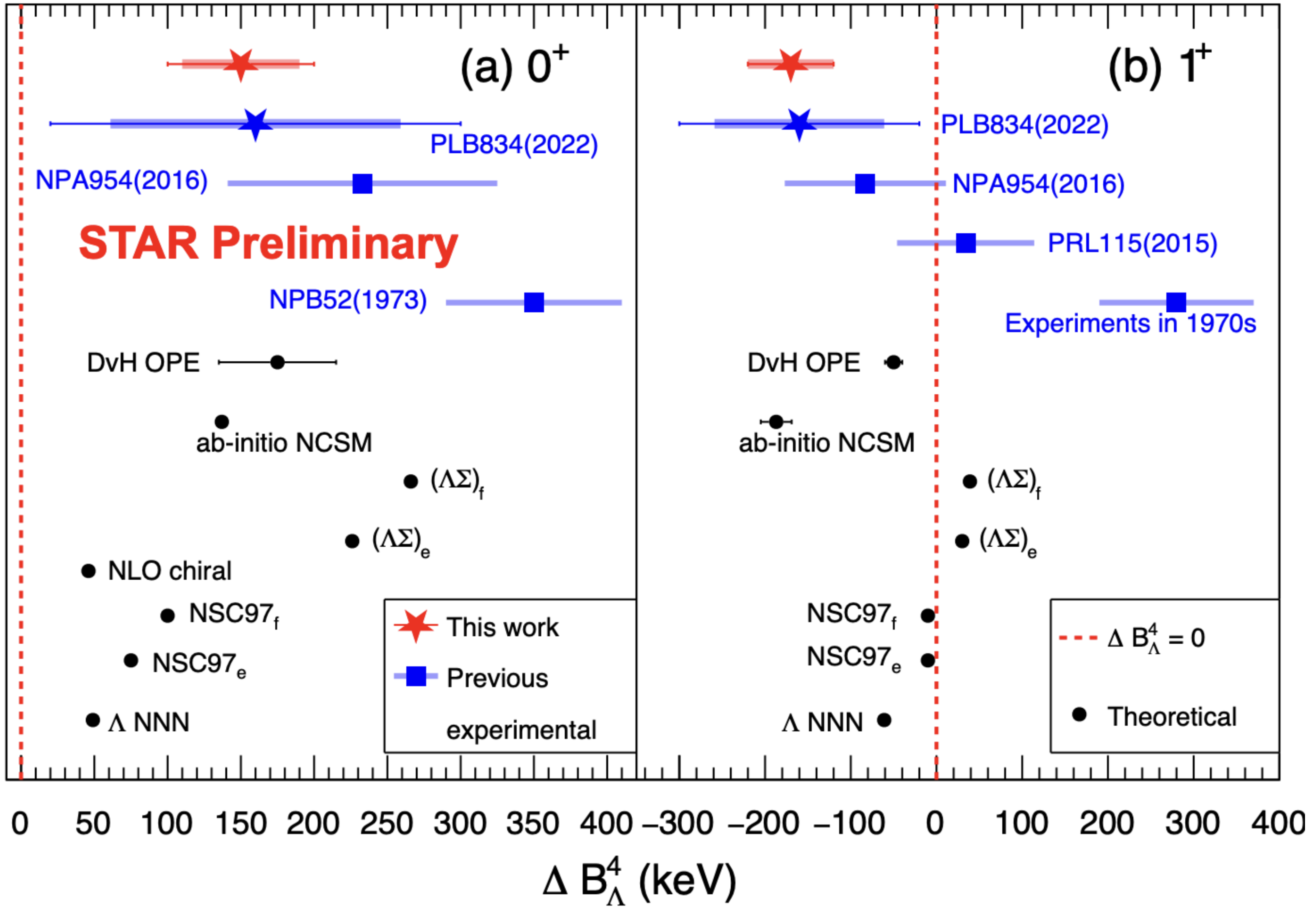


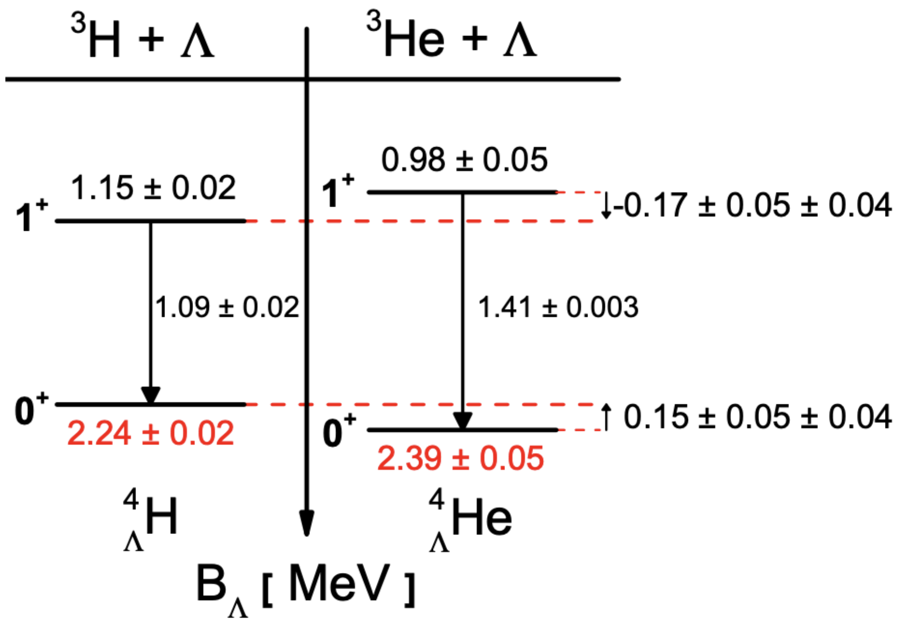
${}^{5}_{\Lambda}\mathrm{He} \rightarrow {}^{4}\mathrm{He}\,p\,\pi^{-}$

- Various hypernuclei reconstructed using 2- and 3-body mesonic decay channels
- Discovery of ${}^{4}_{\Lambda}\overline{\mathrm{H}}$ (STAR, 2024) and ${}^{4}_{\Lambda}\overline{\mathrm{He}}$ (ALICE, 2025) *STAR, Nature 632 (2024) 8027* *ALICE, Phys. Rev. Lett. 134 (2025) 16, 162301*
- Observation of the heaviest hypernucleus in heavy-ion collisions to date, ${}^{5}_{\Lambda}\mathrm{He}$ *Y. Zhou, STAR, QM2025*

Aside: Charge Symmetry Breaking in A = 4 hypernuclei

Tianhao Shao, 24/03 afternoon





Precise constraints on YN and YNN interactions

- Precise measurement of ${}^4_\Lambda$H and ${}^4_\Lambda$He ground state binding energies
- Charge Symmetry Breaking is comparable in magnitude but opposite in sign for ground and excited states
- Consistent with ab-initio no-core shell model calculation

Data-Driven Semi-Analytical Coalescence Model *(YHL et al., Phys.Rev.C 113 (2026) 3, 034912*

- Define B_3 as ratio of hypernuclei yields to the product of constituent yields:

$$B_3({}^3_\Lambda\mathrm{H}) = \boxed{\frac{E_{{}^3_\Lambda\mathrm{H}} \frac{d^3N_{{}^3_\Lambda\mathrm{H}}}{d^3p_{{}^3_\Lambda\mathrm{H}}}}{\left(E_p \frac{d^3N_p}{d^3p_p}\right)\left(E_n \frac{d^3N_n}{d^3p_n}\right)\left(E_n \frac{d^3N_\Lambda}{d^3p_\Lambda}\right)}}$$

p and Λ yields
from data

- In the Wigner-function coalescence formalism (ignoring momentum dependence of the nucleon source):

F. Bellini et al., Phys. Rev. C 103 (2021) 014907

$$B_3({}^3_\Lambda\mathrm{H}) \approx \frac{3}{m^2} \frac{2s_{{}^3_\Lambda\mathrm{H}}+1}{(2s_N+1)^3}(2\pi)^6 \int d^3r_{pn} \int d^3r_\Lambda \boxed{|\Phi_{{}^3_\Lambda\mathrm{H}}(r_{pn}, r_\Lambda)|^2} \boxed{\mathcal{S}_3(r_{pn}, r_\Lambda)}$$

nuclei wave
function

nucleon
source

- Assume an isotropic Gaussian nucleon source:

$$\mathcal{S}_3(r_{12}, r_3) = \frac{1}{(12\pi^2 R_{\mathrm{inv}}^4)^{3/2}} \exp\left(-\frac{r_{12}^2 + \frac{4}{3}r_3^2}{4R_{\mathrm{inv}}^2}\right)$$

- R_{inv} is estimated using deuteron data
- **No free parameters for once ${}^3_\Lambda$H wave function is specified**

The Hypertriton Wave Function

- ${}^{3}_{\Lambda}$H: loosely bound hypernuclei
- Gaussian: $$\Phi_{{}^{3}_{\Lambda}\mathrm{H}}(r_{pn}, r_{\Lambda}) = \left(\frac{1}{3\pi^2 b_{pn}^2 b_{\Lambda}^2}\right)^{\frac{3}{4}} e^{-\frac{r_{pn}^2}{4b_{pn}^2}-\frac{r_{\Lambda}^2}{3b_{\Lambda}^2}}$$

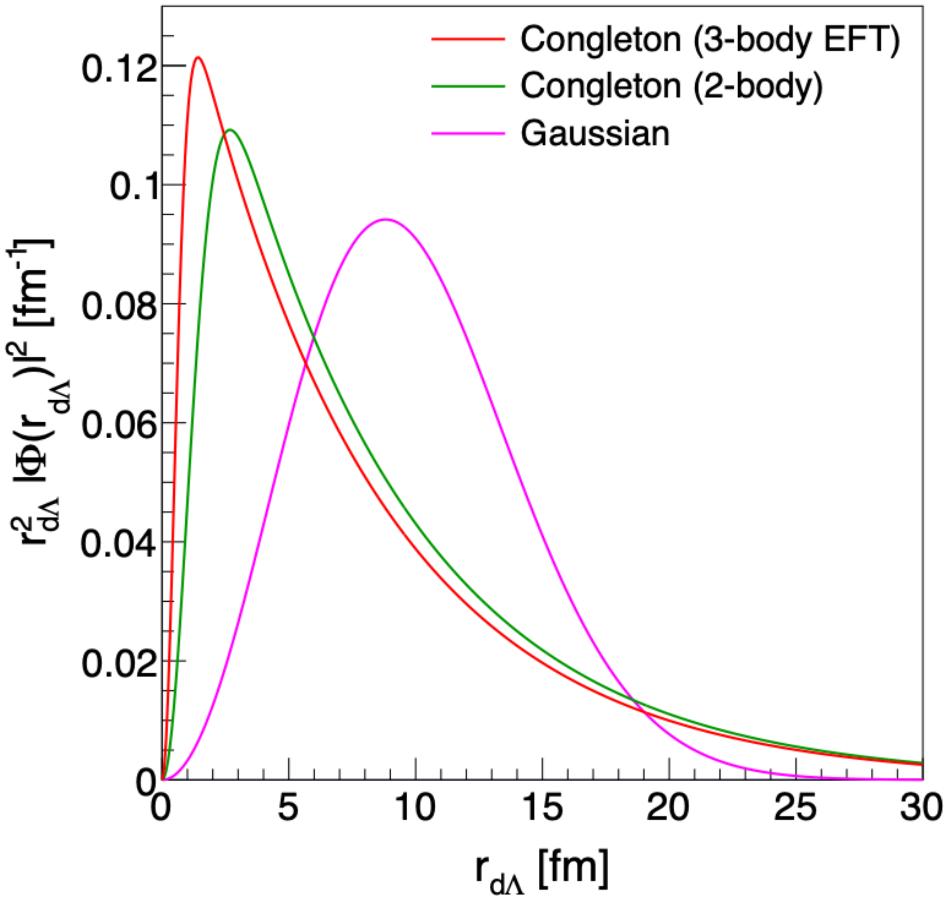
$b_{\Lambda} = 7.2\mathrm{fm}$

F. Bellini et al., Phys. Rev. C 103 (2021) 014907

- Congleton: $$\hat{\Phi}_{{}^{3}_{\Lambda}\mathrm{H}(d\Lambda)}(q) = A\frac{e^{-\frac{-q^2}{Q_{\Lambda}^2}}}{q^2+\alpha_{\Lambda}^2}$$
  - 2-body model of ${}^{3}_{\Lambda}$H: $(Q_{\Lambda}, \alpha_{\Lambda}) = (1.17, 0.068)\mathrm{fm}^{-1}$

    J. Congleton, J.Phys.G 18 (1992)339-357
  - 3-body effective field theory: $(Q_{\Lambda}, \alpha_{\Lambda}) = (2.5, 0.068)\mathrm{fm}^{-1}$

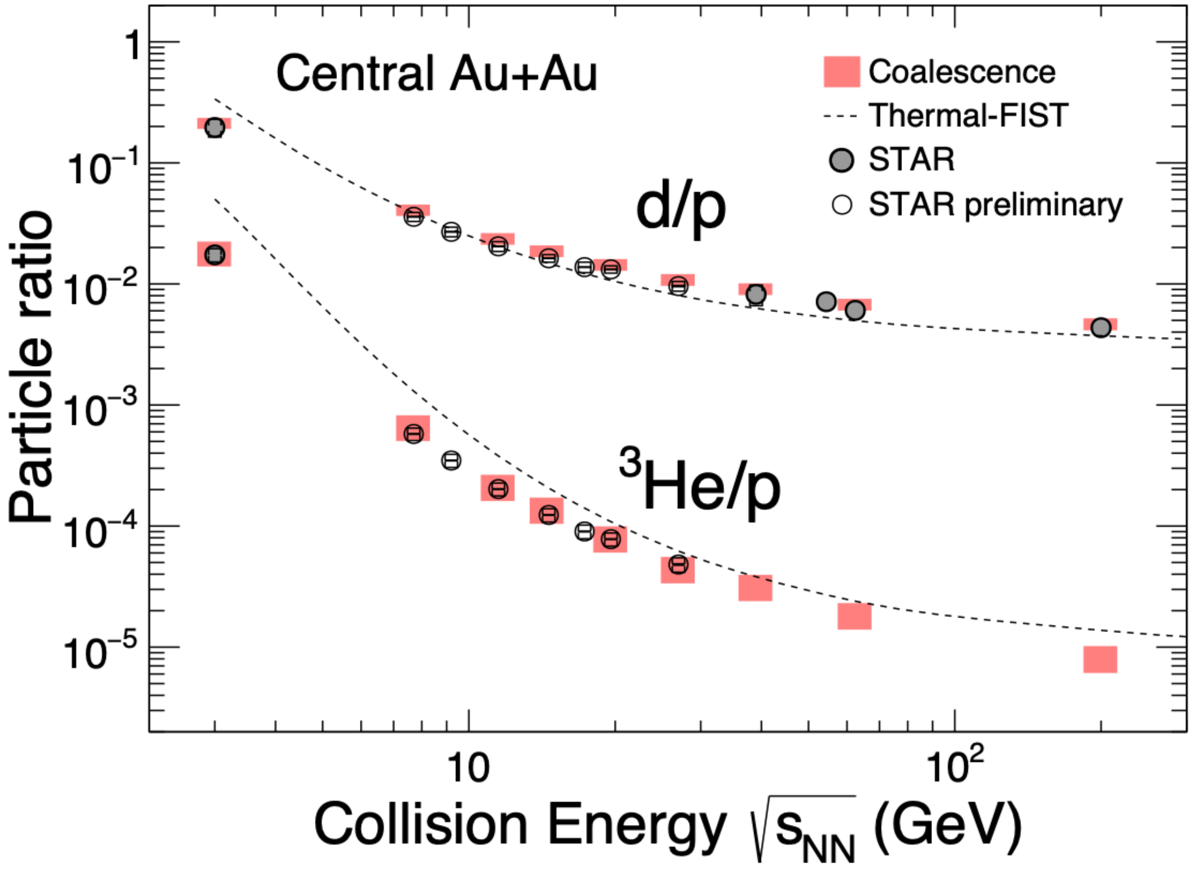
    F. Hildenbrand, H.-W. Hammer, Phys. Rev. C 100(2019)034002

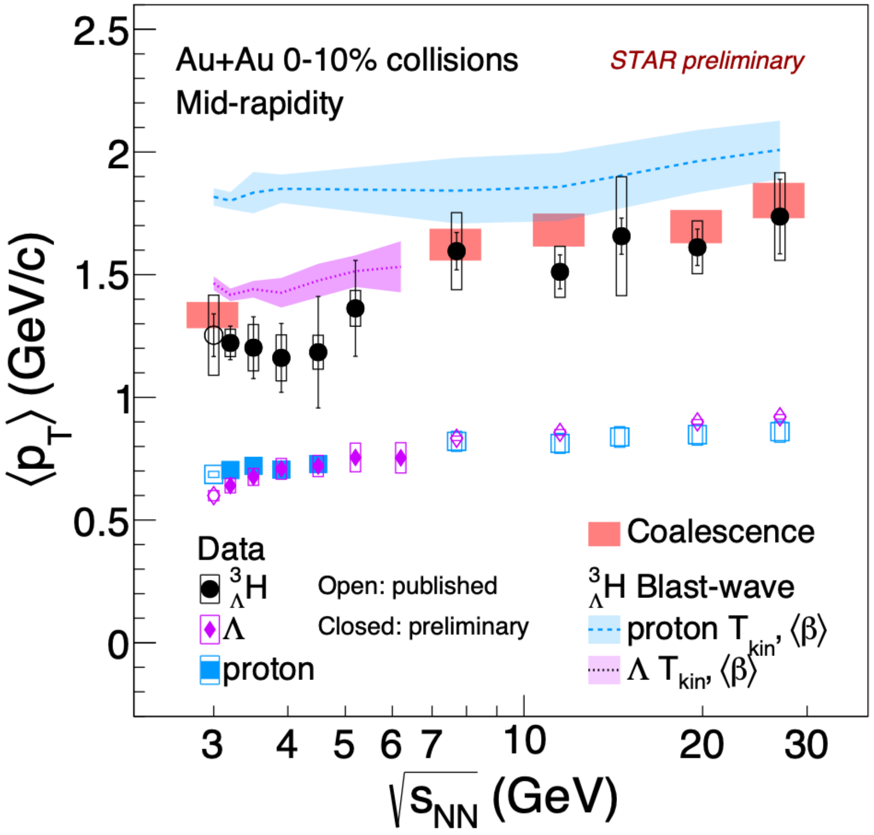


- **${}^{3}_{\Lambda}$H wave function is an active field of research**

Jiaxing Zhao et al., Phys.Rev.C 112 (2025) 6, 064902
Z. Zhang et al., Phys.Lett.B 874 (2026) 140285

Nuclei yields in BES

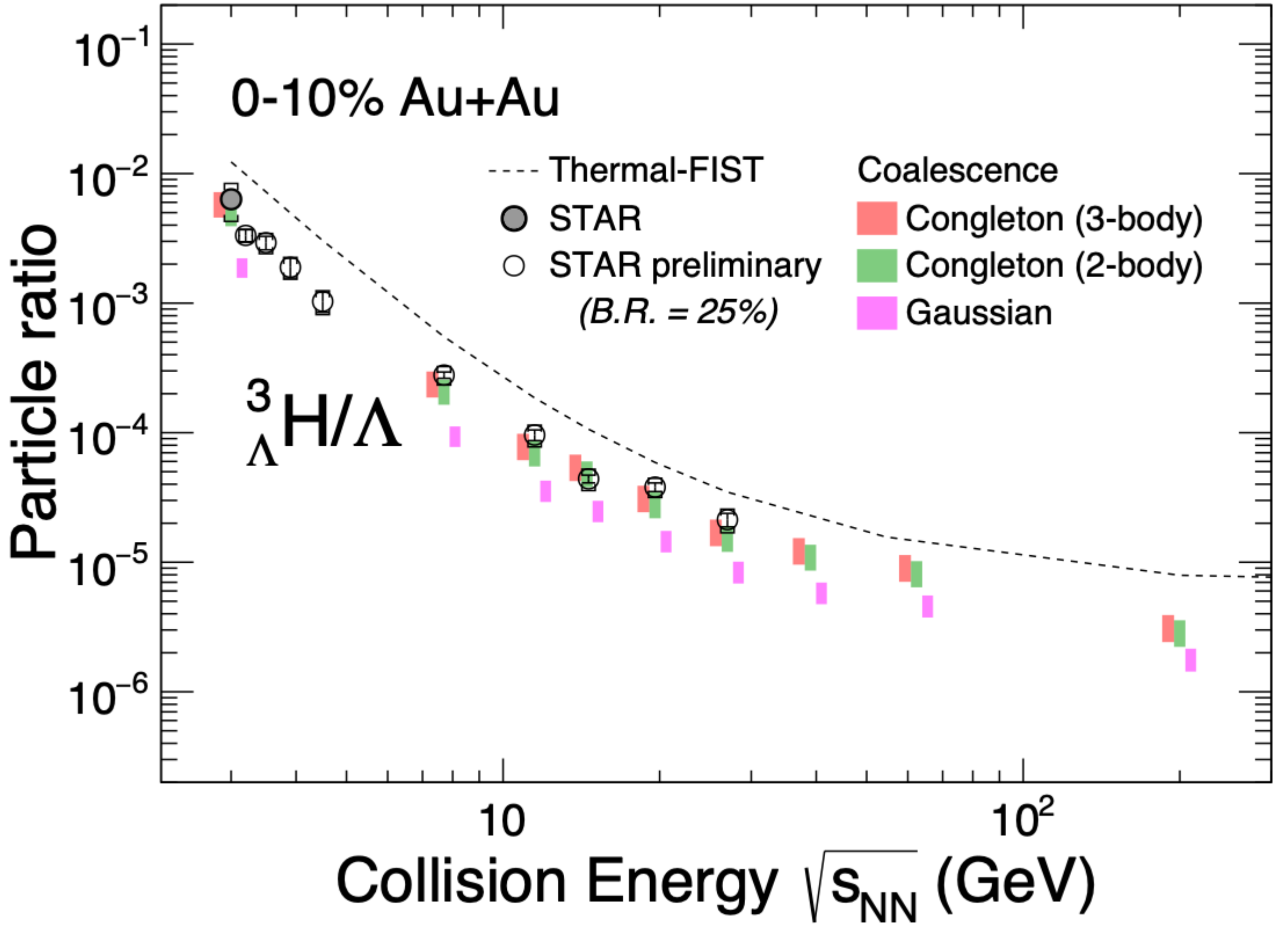


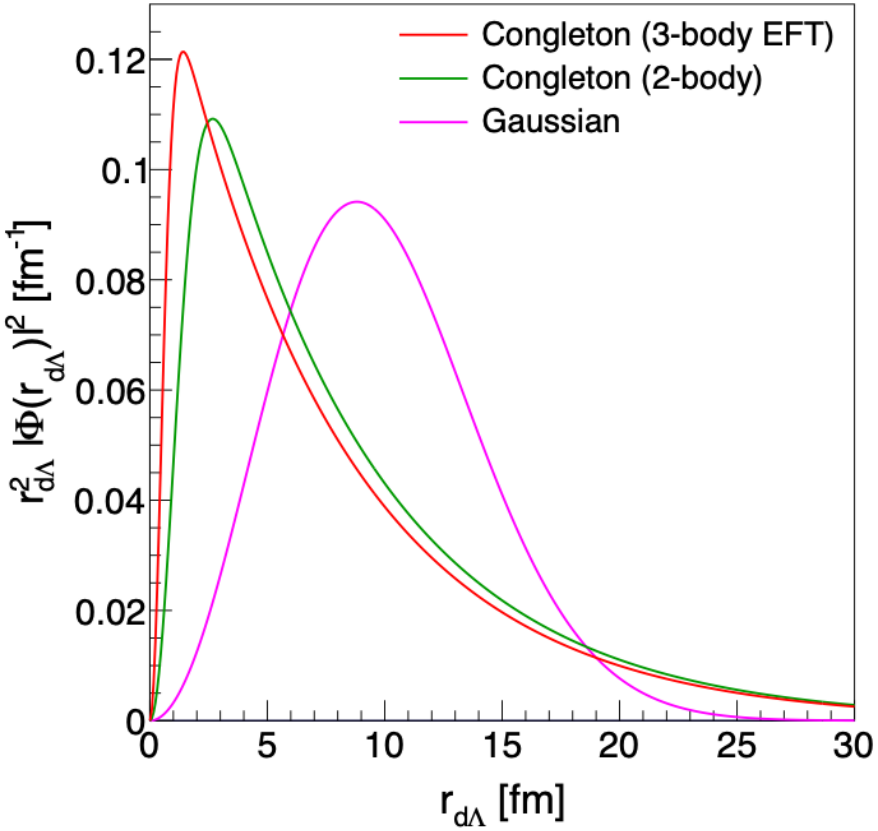


- Coalescence gives a reasonable description of $A < 4$ nuclei data

V. Vovchenko, et al, Comput. Phys. Commun. 244 (2019) 295
YHL et al., Phys.Rev.C 113 (2026) 3, 034912
STAR, Phys. Rev. Lett. 130 (2023) 202301

Hypernuclei yields in BES



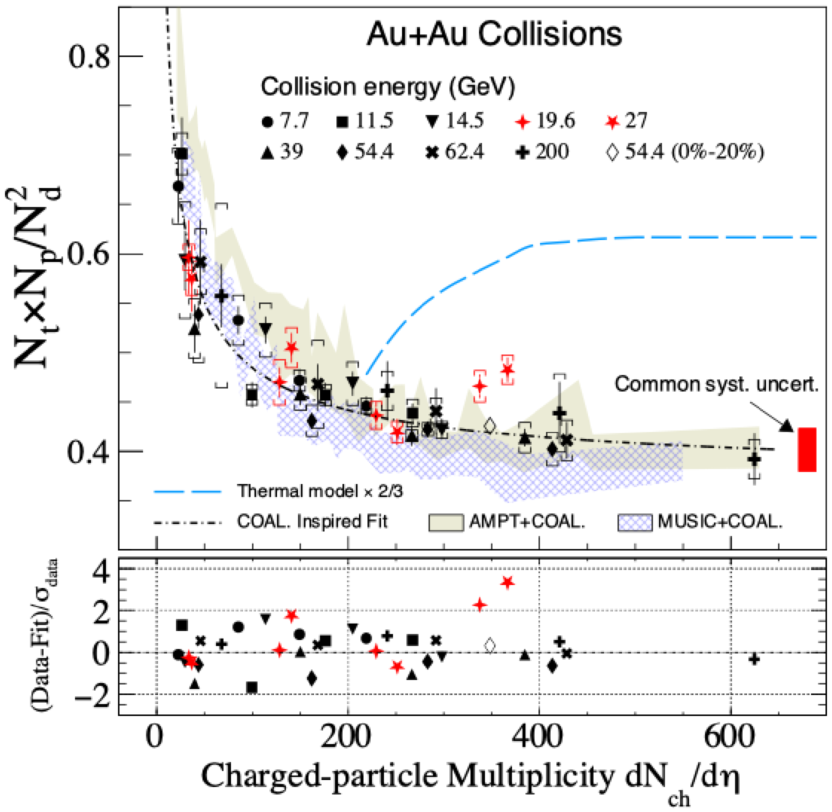


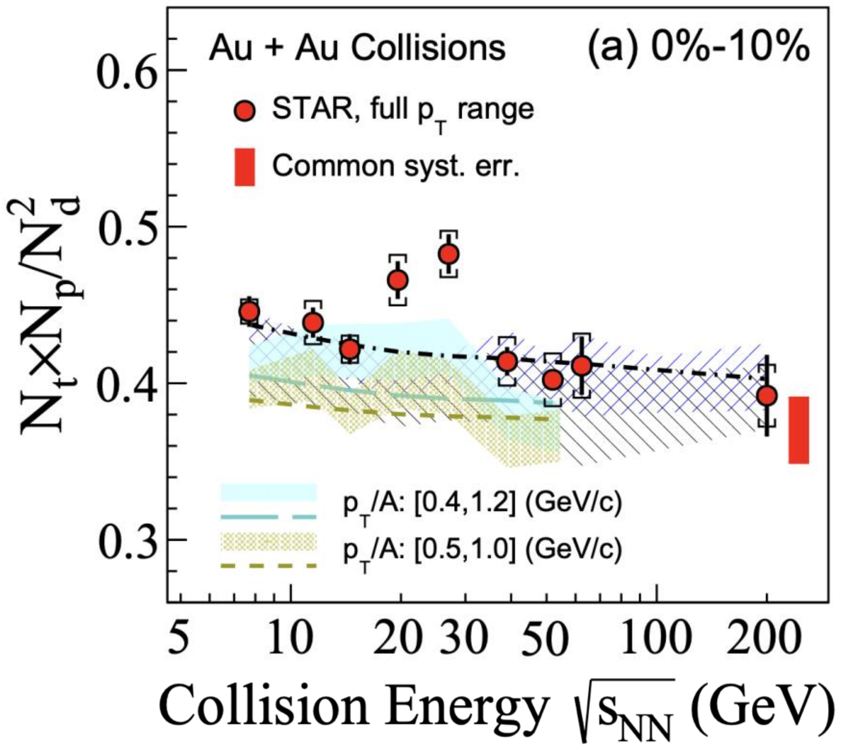
V. Vovchenko, et al, Comput. Phys. Commun. 244 (2019) 295
YHL et al., Phys.Rev.C 113 (2026) 3, 034912

- Coalescence gives a reasonable description of $A < 4$ hypernuclei data

Compound Ratio (tp/d^2) vs. $\sqrt{s_{NN}}$

STAR, Phys. Rev. Lett. 130 (2023) 202301
K. Sun et al., Phys. Lett. B 781 (2018) 499





Yield ratios have been suggested to be sensitive to neutron density fluctuations

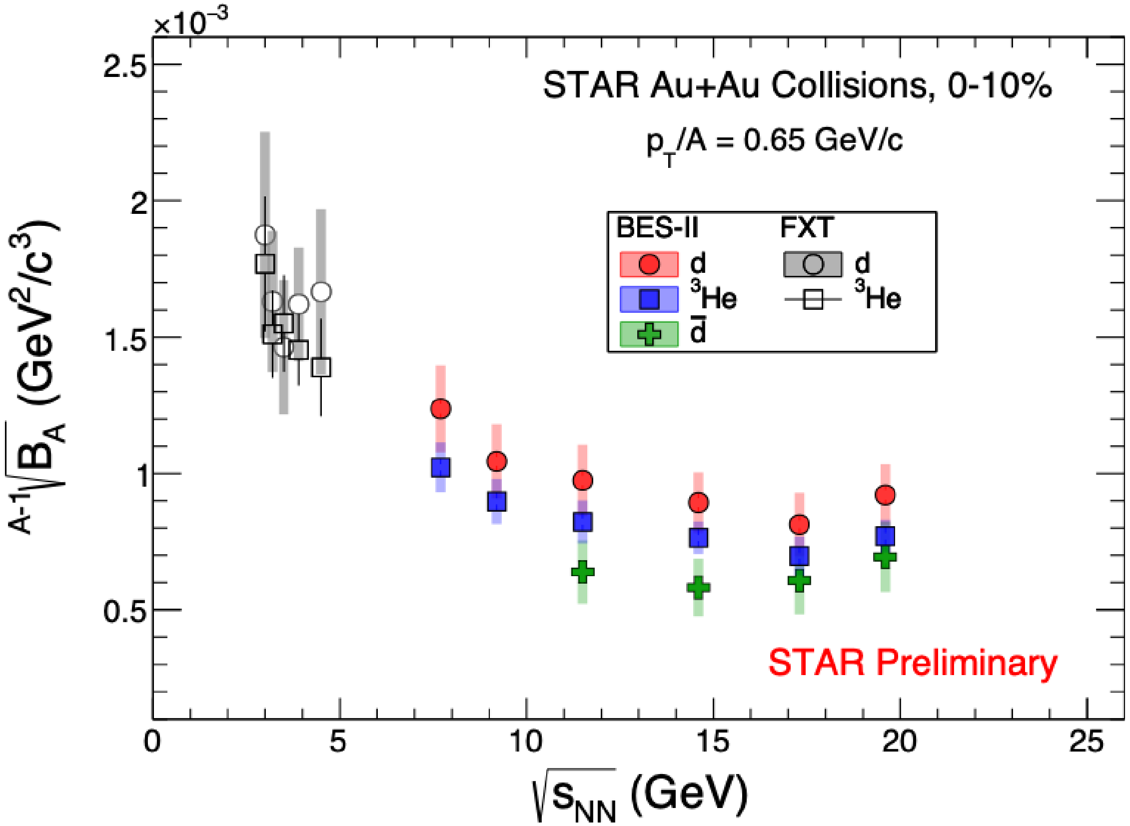
$$\boxed{\frac{t \times p}{d^2} = g(1+\Delta n)}$$

Δn: Neutron Density Fluctuation

- Compound ratio can be described by coalescence calculations
- Enhancements around 19.6/27 GeV w.r.t. baseline observed, but they decrease with decreasing p_T acceptance
- Analyses with STAR BES-II (with extended low p_T coverage) is in progress.

Nuclei Yield Ratios from RHIC-BES

$$E_A \frac{d^3N_A}{d^3p_A} = B_A\left(E_p \frac{d^3N_p}{d^3p_p}\right)^Z\left(E_n \frac{d^3N_n}{d^3p_n}\right)^{A-Z} \approx B_A\left(E_p \frac{d^3N_p}{d^3p_p}\right)^A, B_A \propto \left(\frac{1}{V_{eff}}\right)^{(A-1)}$$



- The coalescence parameters B_2, B_3 decrease with increasing energy, which indicates smaller nucleon emission source size at low energies
- $B_A \propto (1/V)^{(A-1)}$ reflects the region of homogeneity and the effective volume size