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Lifetime measurements of light hypernuclei in Au+Au collisions from the STAR experiment

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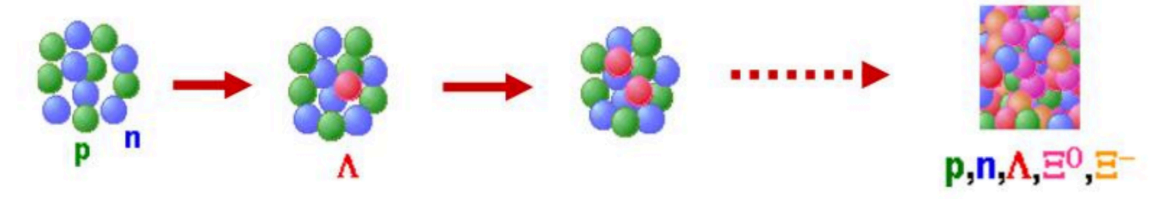
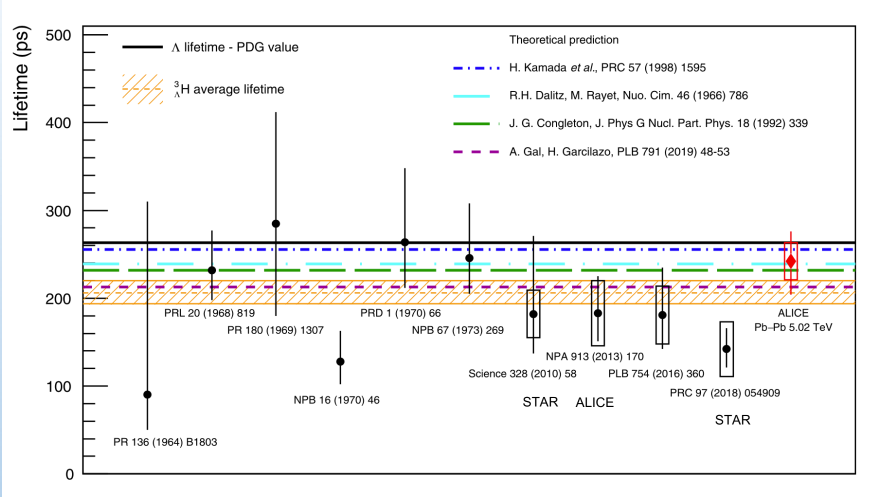
Introduction



- ➢Hypernuclei: bound nuclear systems of non-strange and strange baryons
  - ➢Probe hyperon-nucleon(Y-N) interaction
    - ➢Help understand inner structure of neutron stars
- ➢$^{3}_{\Lambda}\mathrm{H}$ lifetime “puzzle”
  - ➢Assuming Λ and deuteron weakly bound in $^{3}_{\Lambda}\mathrm{H}$
    - →Indicate the lifetime of $^{3}_{\Lambda}\mathrm{H}$ will be close to that of Λ.
  - ➢ Large uncertainties in experimental measurements
    - ➢ Tension between STAR and ALICE



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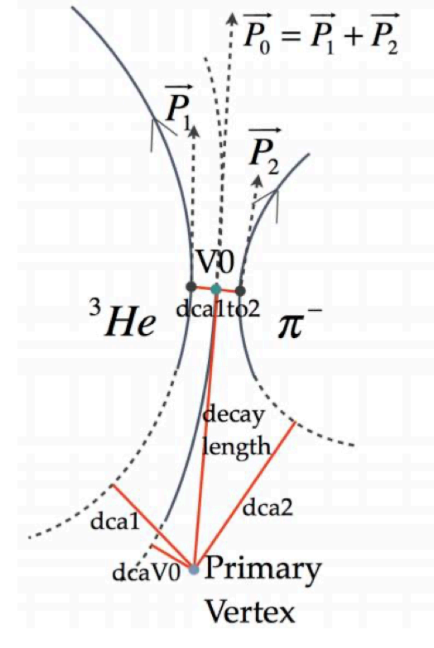
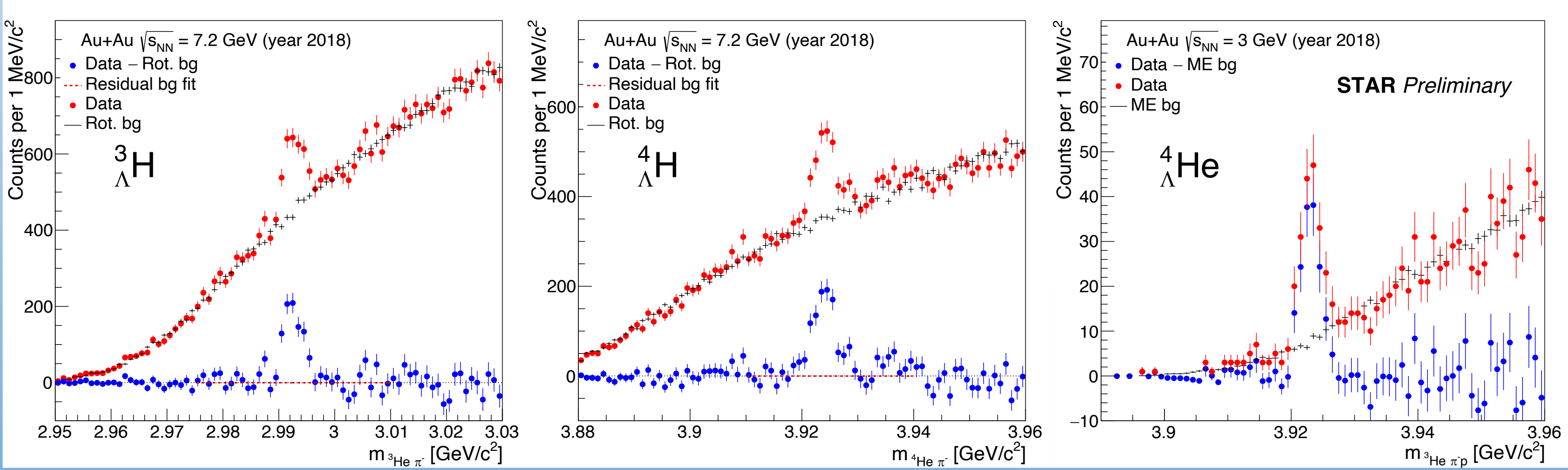
- ➢Light hypernuclei abundantly produced at low collision energies due to the high baryon density.
  - ➢Great opportunity to study hypernuclei production using STAR BES-II data.

Particle reconstruction



- Decay channels:
  - ${}^3_\Lambda\mathrm{H} \rightarrow {}^3\mathrm{He} + \pi^-$, ${}^4_\Lambda\mathrm{H} \rightarrow {}^4\mathrm{He} + \pi^-$, ${}^4_\Lambda\mathrm{He} \rightarrow {}^3\mathrm{He} + p + \pi^-$
- Background reconstruction:
  - For ${}^3_\Lambda\mathrm{H}$ and ${}^4_\Lambda\mathrm{H}$, estimated by rotating the daughter particle π^- in the transverse plane.
  - For ${}^4_\Lambda\mathrm{He}$, estimated by mixed-event method.
    - Mix ${}^3\mathrm{He}$ and $p\pi^-$ pairs.



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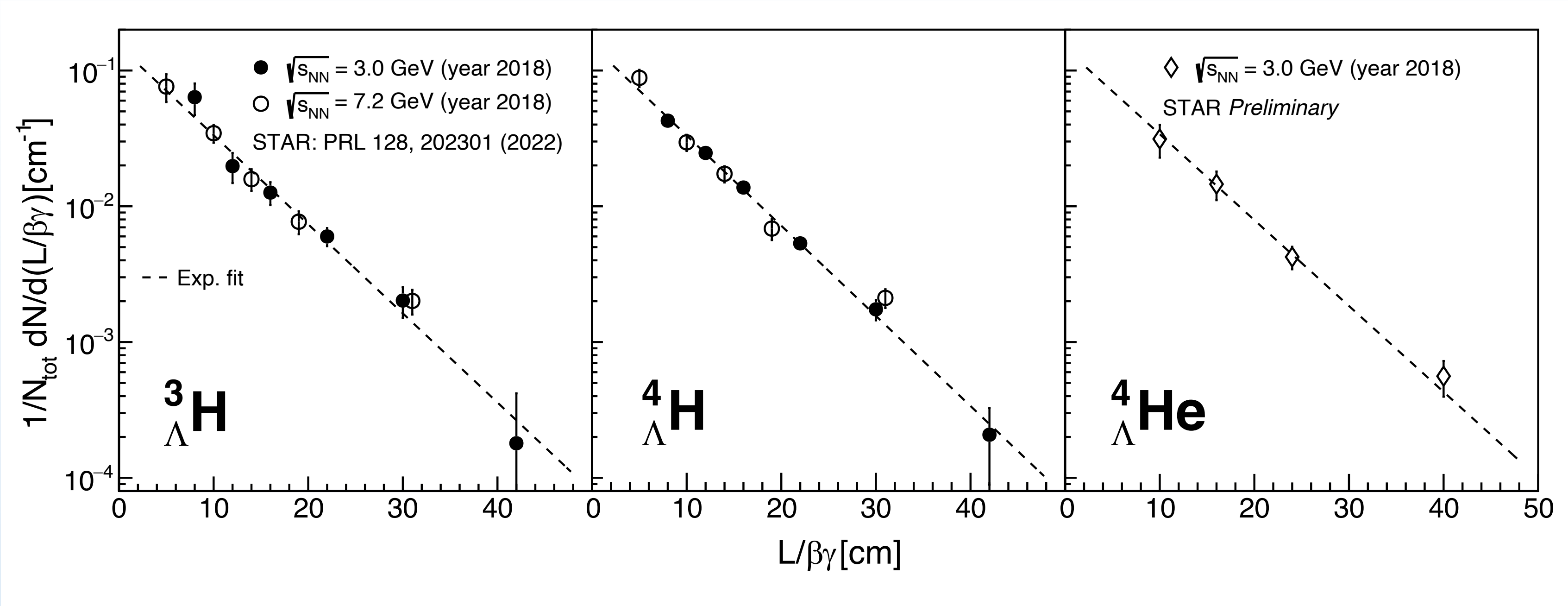
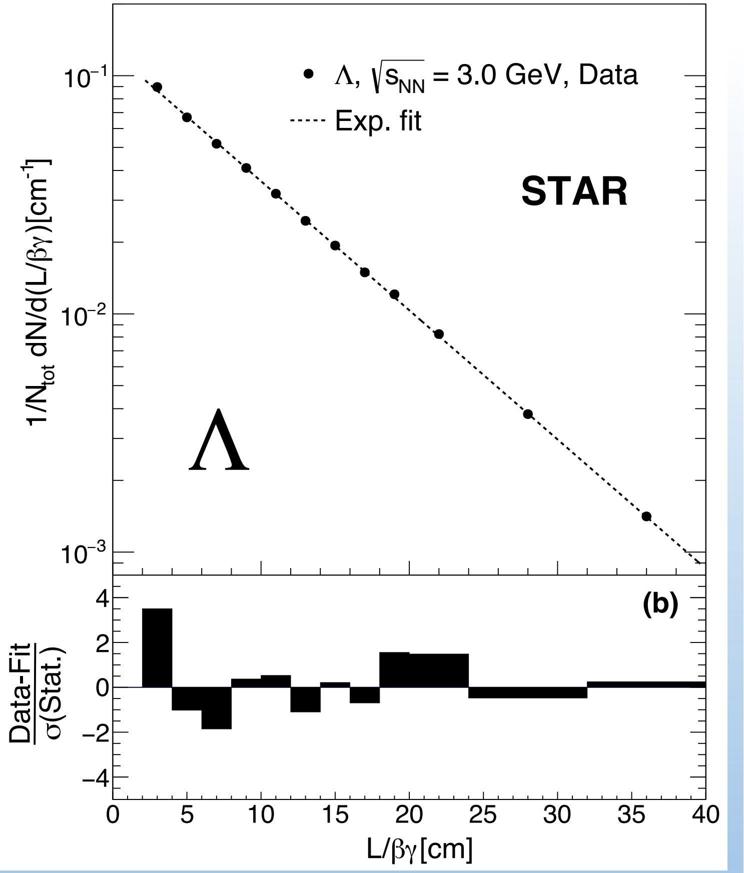
Lifetime of ${}^{3}_{\Lambda}\mathrm{H}$, ${}^{4}_{\Lambda}\mathrm{H}$ and ${}^{4}_{\Lambda}\mathrm{He}$





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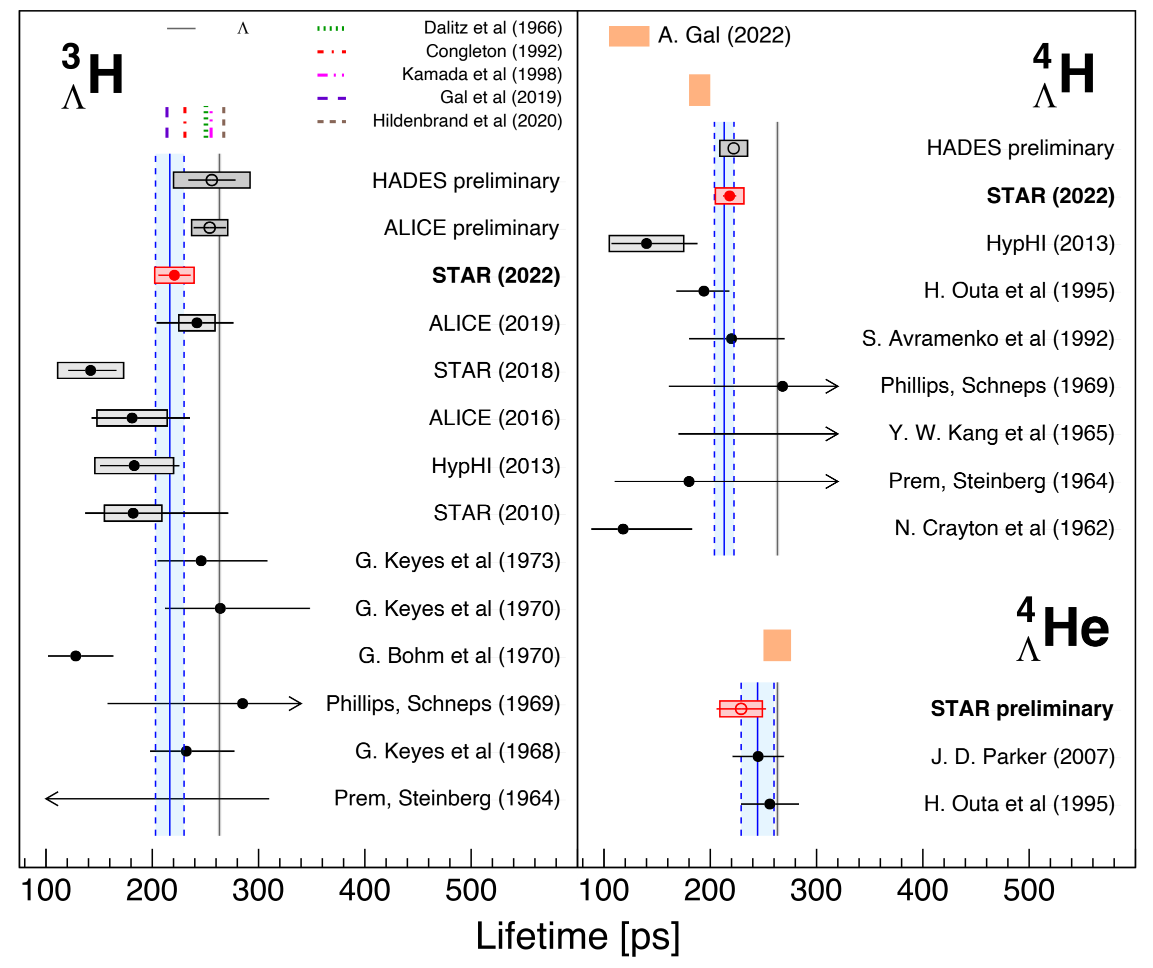
- Extract lifetime τ from an exponential fit to the corrected signal counts dN/d(L/$\beta\gamma$) vs. L/$\beta\gamma$
  - $\mathrm{N(t)} = \mathrm{N_0 e^{-L/\beta\gamma c\tau}}$, L: decay length
- Λ lifetime crosscheck
  - τ_{Λ} = 267±4 ps, consistent with PDG value(263±2 ps)
- ${}^{3}_{\Lambda}\mathrm{H}$, ${}^{4}_{\Lambda}\mathrm{H}$ lifetimes from 3.0 GeV consistent with 7.2 GeV results

$\tau_{{}^{3}_{\Lambda}H}$ = 221 ± 15(stat.) ± 19(syst.) ps
$\tau_{{}^{4}_{\Lambda}H}$ = 218 ± 6(stat.) ± 13(syst.) ps
$\tau_{{}^{4}_{\Lambda}He}$ = 229 ± 23(stat.) ± 20(syst.) ps

Summary

- **${}^{3}_{\Lambda}$H and ${}^{4}_{\Lambda}$H lifetimes with improved precision**
  - World average lifetimes of ${}^{3}_{\Lambda}$H and ${}^{4}_{\Lambda}$H are shorter than τ_{Λ} by (24±5)% and (21±4)%
  - $\tau_{{}^{3}_{\Lambda}H}$ and $\tau_{{}^{4}_{\Lambda}H}$ (STAR 2022) are shorter than τ_{Λ} with 1.8σ and 3σ respectively
  - $\tau_{{}^{3}_{\Lambda}H}$ and $\tau_{{}^{4}_{\Lambda}H}$ (STAR 2022) are consistent with all former measurements within 2.5σ
- **Compare the results with theoretical calculations.**
  - $\tau_{{}^{3}_{\Lambda}H}$ result consistent with calculation including pion FSI (2019) and calculation under Λd 2-body picture (1992) within 1σ.
  - $\frac{\tau_{{}^{4}_{\Lambda}H}}{\tau_{{}^{4}_{\Lambda}He}} = 0.85 \pm 0.07$, consistent with theoretical prediction applying the $\Delta I = \frac{1}{2}$ rule(2022): 0.74 ± 0.04
- **Precision lifetime measurements provide constraints on theoretical models, which will lead to better determination of the Y-N interaction.**



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