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

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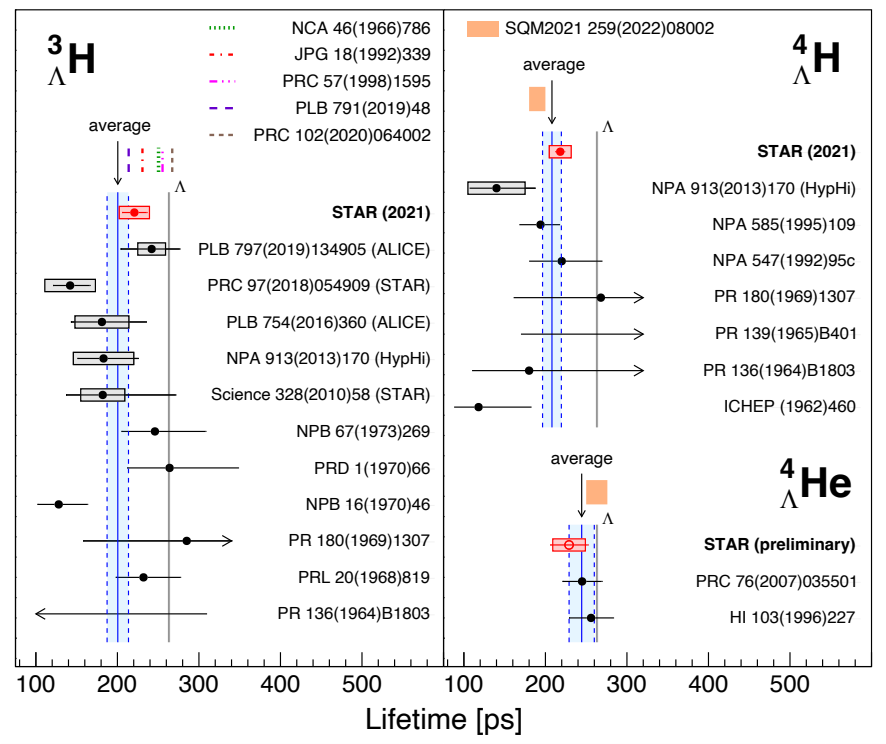
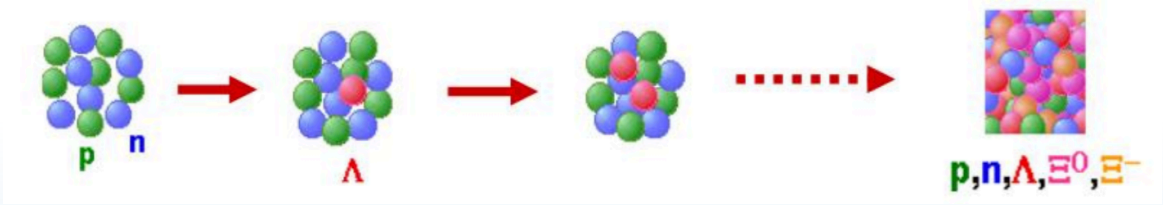


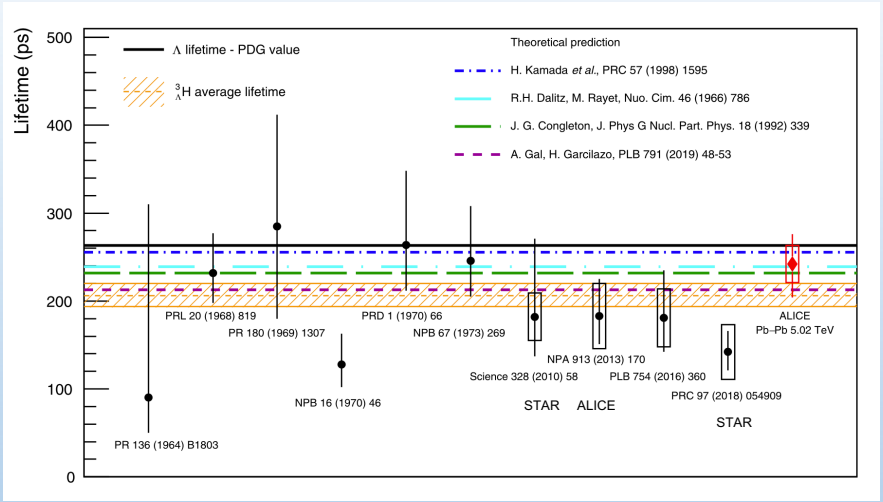
STAR, arXiv 2110.09513 (2021)
Accepted by PRL

Supported in part by the U.S. DEPARTMENT OF ENERGY Office of Science

Introduction



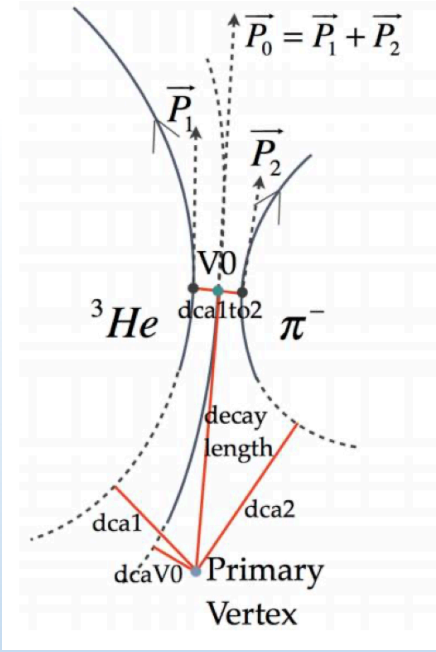
- Hypernuclei: bound nuclear systems of non-strange and strange baryons
  - Probe hyperon-nucleon(Y-N) interaction
    - Help understanding inner structure of neutron stars
- ${}^{3}_{\Lambda}\mathrm{H}$ lifetime "puzzle"
  - Assuming Λ and deuteron weakly bound in ${}^{3}_{\Lambda}\mathrm{H}$
    - → 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
- 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.

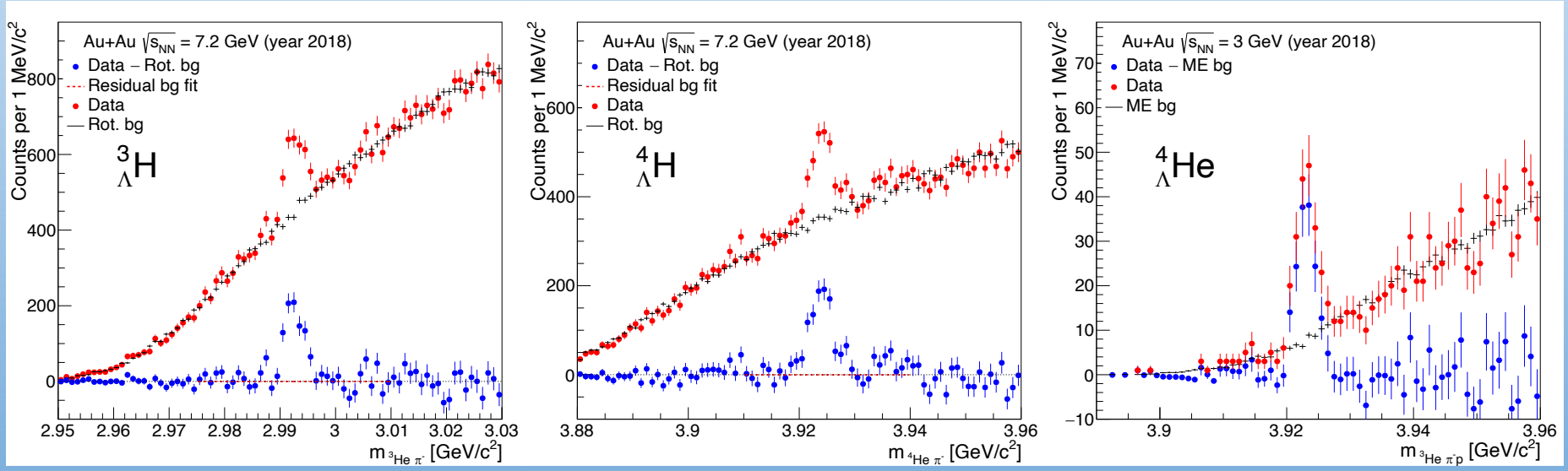


PLB 797,134905 (2019)

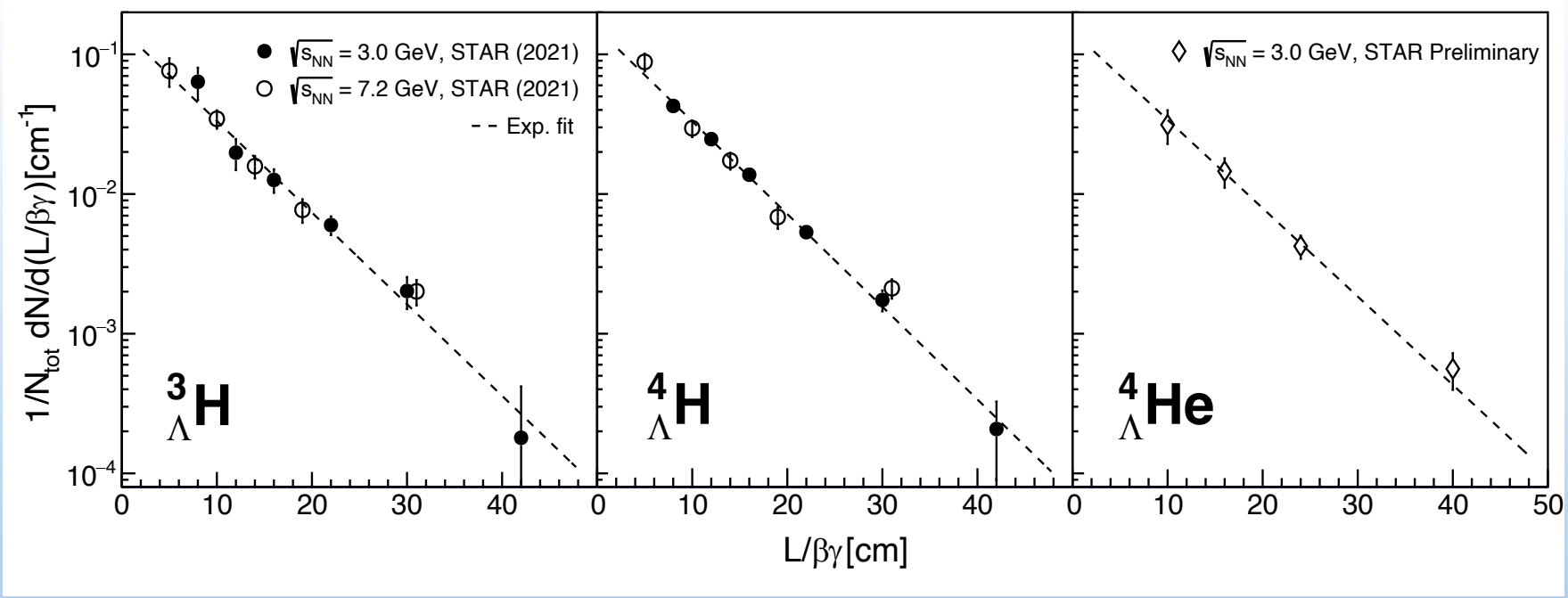
Particle reconstruction

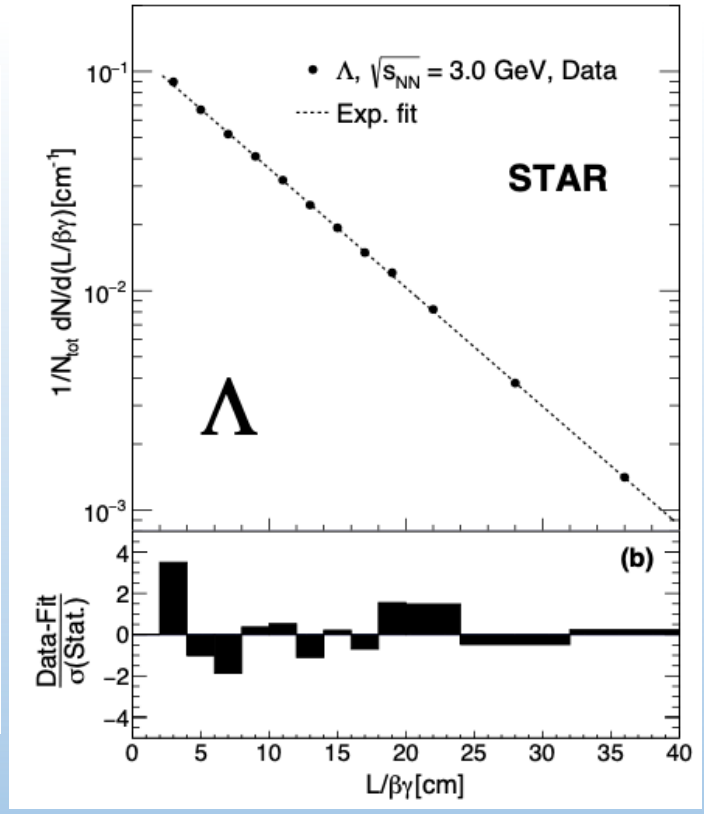
- Decay channels:
  - ${}^{3}_{\Lambda}\mathrm{H} \rightarrow {}^{3}\mathrm{He} + \pi^{-}$, ${}^{4}_{\Lambda}\mathrm{H} \rightarrow {}^{4}\mathrm{He} + \pi^{-}$, ${}^{4}_{\Lambda}\mathrm{He} \rightarrow {}^{3}\mathrm{He} + p + \pi^{-}$
- Background reconstruction:
  - For ${}^{3}_{\Lambda}\mathrm{H}$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





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





- 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

- **Most precise lifetime measurements of $^{3}_{\Lambda}\mathrm{H}$ and $^{4}_{\Lambda}\mathrm{H}$ to date**
  - Lead to world average values shorter by (24±5)% and (21±4)% than τ_Λ for $\tau_{^{3}_{\Lambda}\mathrm{H}}$ and $\tau_{^{4}_{\Lambda}\mathrm{H}}$
  - Consistent with world average values
- **Compare the results with theoretical calculations.**
  - $\tau_{^{3}_{\Lambda}\mathrm{H}}$ result consistent with calculation including pion FSI(2019) and calculation under Λd 2-body picture(1992) within 1σ.
  - $\frac{\tau_{^{4}_{\Lambda}\mathrm{H}}}{\tau_{^{4}_{\Lambda}\mathrm{He}}} = 0.85 \pm 0.07$, consistent with theoretical prediction applying the $\Delta I = \frac{1}{2}$ rule(2022): 0.74 ± 0.04
- **Precision lifetime measurements provide constrains on theoretical models, which will lead to better determination of the Y-N interaction.**