Measurements of $^{4}_{\Lambda}$He Lifetime in Au+Au Collisions at 3.2 and 3.5 GeV from STAR fixed target mode experiment

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June 4, 2024

Abstract

Hypernuclei are bound nuclear systems of nucleons and hyperons. They are natural hyperon-baryon correlation systems and provide direct access to the hyperon-nucleon (Y-N) interaction. The precise measurement of Λ-hypernuclei lifetimes will shed light towards the understanding of the Y-N interactions. The high statistics data, collected with the STAR fixed target mode (FXT), provides a great opportunity to measure the $^{4}_{\Lambda}$He production with good precision.

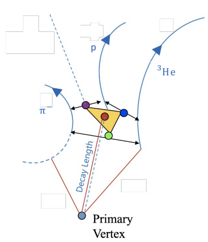
In this poster, we will present precise measurement of $^{4}_{\Lambda}$He lifetime in Au+Au collisions at $\sqrt{s_{NN}}$ = 3.2 and 3.5 GeV from STAR fixed target mode experiment.

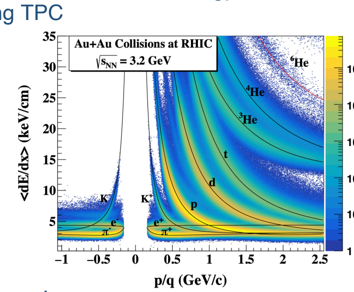
Motivation

- Lifetime of hypernuclei – probe of Y-N interaction
- Why $^{4}_{\Lambda}$He lifetime?
  - Scarcity of $^{4}_{\Lambda}$He lifetime measurements
    - Published average[1][2]: $\tau_{exp}(^{4}_{\Lambda}\mathrm{He})$=250±19 ps
    - Low production rate and low reconstruction efficiency
  - Isospin mirror hypernuclei, $^{4}_{\Lambda}$H and $^{4}_{\Lambda}$He
    - Isospin dependence of the Y-N interaction
- Large data sample and high hypernuclei production
  - Abundantly produced hypernuclei due to the high baryon density
  - STAR BES-II → great opportunity for $^{4}_{\Lambda}$He

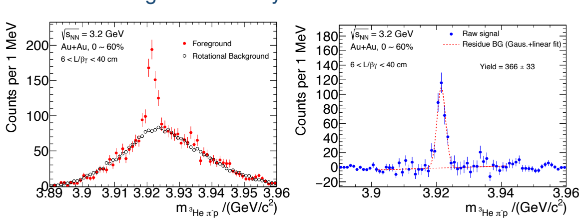
$^{4}_{\Lambda}$He Reconstruction

- $^{4}_{\Lambda}$He reconstructed via $^{4}_{\Lambda}\mathrm{He} \rightarrow {}^{3}\mathrm{He} + \pi^{-} + \mathrm{p}$
  - Daughter particle identification from energy loss measurement using TPC





- Background reconstruction
  - Combinatorial background by rotating ^{3}He between 10 to 350 degree randomly

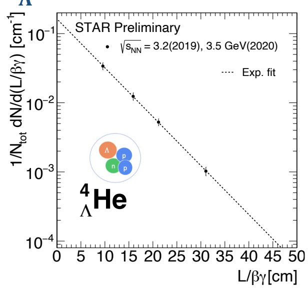


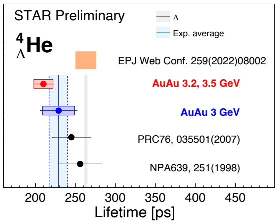
- Raw counts are calculated within a 3σ mass range determined from gaussian fit with the bin counting methods in each proper decay length $L/\beta\gamma$ (L is decay length) bin.

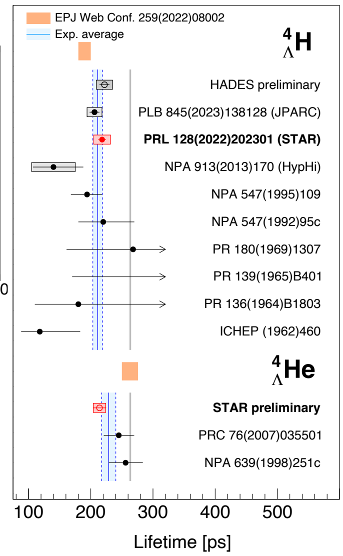
References

[1] H. Outa et al., Nucl. Phys. A 639, 251c (1998)
[2] J.D. Parker et al., Phys. Rev. C 76, 035501 (2007)
[3] A. Gal, EPJ Web Conf., 259, 08002 (2022)

$^{4}_{\Lambda}$He Lifetime Result







- After raw counts are corrected by efficiency in each $L/\beta\gamma$ bin, the counts at $\sqrt{s_{NN}}$ = 3.2 and 3.5 GeV in same $L/\beta\gamma$ bin are added together. The lifetime τ is extracted by fitting the counts with an exponential function.
  - $N(t) = N_0 e^{-L/\beta\gamma c\tau}$
- $^{4}_{\Lambda}$He lifetime from STAR FXT $\sqrt{s_{NN}}$ = 3.2 and 3.5 GeV:

$$\tau_{^{4}_{\Lambda}\mathrm{He}} = \mathbf{210 \pm 12(stat.) \pm 11(syst.)[ps]}$$

- STAR averaged result from $\sqrt{s_{NN}}$ = 3.2, 3.5, and 3 GeV:

$$\tau_{^{4}_{\Lambda}\mathrm{He}} = \mathbf{214 \pm 10(stat.) \pm 10(syst.)[ps]}$$

  - Most precise measurement of $^{4}_{\Lambda}$He to date
- World average ratio $\frac{\tau_{^{4}_{\Lambda}\mathrm{H}}}{\tau_{^{4}_{\Lambda}\mathrm{He}}}$:
  - $\frac{\tau_{^{4}_{\Lambda}\mathrm{H}}}{\tau_{^{4}_{\Lambda}\mathrm{He}}}$ = 0.92 ± 0.06, consistent within 2.5σ with theoretically estimated value 0.74 ± 0.04 applying the isospin rule [3]

Summary

- The new lifetime measurement of $^{4}_{\Lambda}$He in Au+Au collisions at $\sqrt{s_{NN}}$ = 3.2 and 3.5 GeV from the STAR experiments with the fixed-target mode.
  - Consistent with STAR 3 GeV results and previous measurements within 1.2σ.
- The averaged $^{4}_{\Lambda}$He lifetimes from measurements at $\sqrt{s_{NN}}$ = 3, 3.2 and 3.5 GeV serves as the most precise data to date.

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

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