

Status of the measurements of the lifetimes of the hydrogen hyperisotopes

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Outline

Lifetime of ${}^3_{\Lambda}\text{H}$ and ${}^4_{\Lambda}\text{H}$ in 2013

Lifetime of ${}^3_{\Lambda}\text{H}$ in 2015

Conclusion

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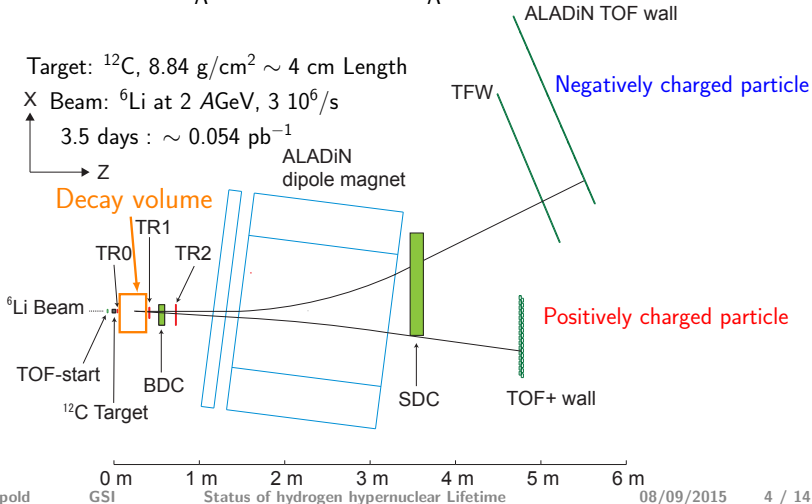
Lifetime of ${}^3_{\Lambda}\text{H}$ and ${}^4_{\Lambda}\text{H}$ in 2013

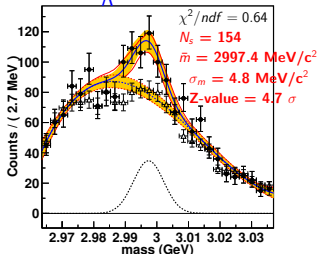
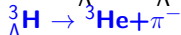
Lifetime of ${}^3_{\Lambda}\text{H}$ in 2015

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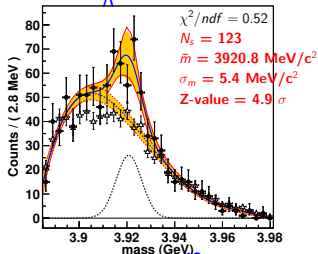
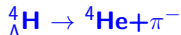
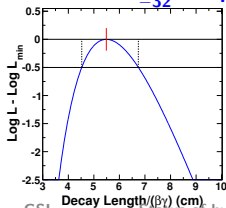
Results from HypHI experiment: Phase 0 @ GSI

Fixed target, Reaction : ${}^6\text{Li} + {}^{12}\text{C} @ 2 \text{ AGeV}$ or $\sqrt{s_{NN}} = 2.7 \text{ GeV}$
 ${}^3_{\Lambda}\text{H} \rightarrow \pi^- + {}^3\text{He}$ ${}^4_{\Lambda}\text{H} \rightarrow \pi^- + {}^4\text{He}$ ${}^5_{\Lambda}\text{He} \rightarrow \pi^- + {}^4\text{He} + p$

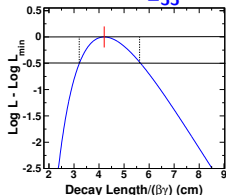


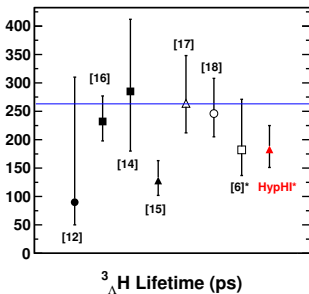
${}^3_{\Lambda}\text{H}$ and ${}^4_{\Lambda}\text{H}$ Lifetime extraction[C. Rappold *et al.*, Nucl. Phys. A. **913**, 170 (2013)]Evidence of ${}^3_{\Lambda}\text{H}$ et ${}^4_{\Lambda}\text{H}$ & Lifetime measurements

$$\tau = 183^{+42}_{-32} \pm 37 \text{ ps}$$

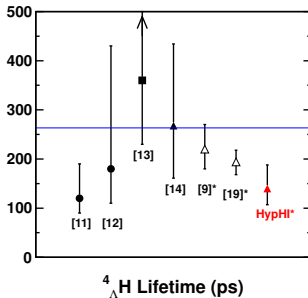


$$\tau = 140^{+48}_{-33} \pm 35 \text{ ps}$$



Status of ${}^3_{\Lambda}\text{H}$ and ${}^4_{\Lambda}\text{H}$ lifetime in 2013[C. Rappold *et al.*, Nucl. Phys. A. **913**, 170 (2013)] ${}^3_{\Lambda}\text{H}$

- [12] Phys. Rev. 136 (1964) B1803
- [16] Phys. Rev. Lett. 20 (1968) 819
- [14] Phys. Rev. 180 (1969) 1307
- [15] Nucl. Phys. B 16 (1970) 46
- [17] Phys. Rev. D 1 (1970) 66
- [18] Nucl. Phys. B 67 (1973) 269
- [6] Science 328 (2010) 58
- [9] Nucl. Phys. A. 913 (2013) 170

 ${}^4_{\Lambda}\text{H}$

- [11] Proc. 11th Int. Conf. on HEP (1962) 460
- [12] Phys. Rev. 136 (1964) B1803
- [13] Phys. Rev. 139 (1965) B401
- [14] Phys. Rev. 180 (1969) 1307
- [9] Nucl. Phys. A 547 (1992) 95c
- [19] Nucl. Phys. A 585 (1995) 109
- [9] Nucl. Phys. A. 913 (2013) 170

Meta analysis: What can we learn from all measurements ?

- ▶ From PDG : Combination of measurements with symmetric error :

- ▶ standard weighted least-squares procedure

$$\bar{x} \pm \delta\bar{x} = \frac{\sum_i w_i x_i}{\sum_i w_i} \pm \left(\sum_i w_i \right)^{-1/2}$$

- ▶ When asymmetric errors are involved :

- ▶ standard weighted least-squares procedure

- ▶ It is deduced from the combination of likelihood function of Gaussian distributed data.

- ▶ \rightarrow Back the definition : The likelihood function !

- ▶ Problem : Results quoted by only the mean value and the 1 standard deviation.
- ▶ Must parametrize the likelihood functions of published results.
 - ▶ Variable Gaussian Form (up to 5σ interval)
- ▶ R.Barlow [arXiv:physics/0406120] & C. Rappold *et al* Phys. Lett. B **728**, 543 (2014)

Application to the ${}^3_{\Lambda}\text{H}$ and ${}^4_{\Lambda}\text{H}$ lifetime result sets[C. Rappold *et al.*, Phys. Lett. B **728**, 543 (2014)]

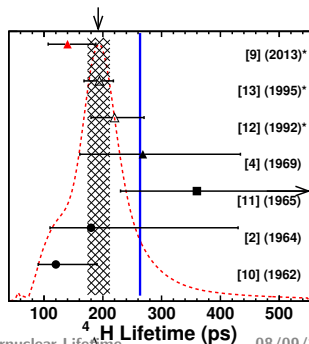
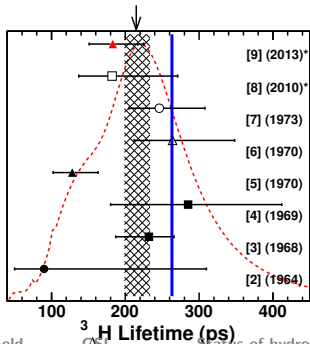
- ▶ Average combined lifetime :

$${}^3_{\Lambda}\text{H} : 216^{+19}_{-16} \text{ ps} \quad \& \quad {}^4_{\Lambda}\text{H} : 192^{+20}_{-18} \text{ ps}$$

- ▶ Theory side :

$${}^3_{\Lambda}\text{H} \text{ [H. Kamada } et al. \text{ PRC 57 1595 (1998)]} : 256 \text{ ps}$$

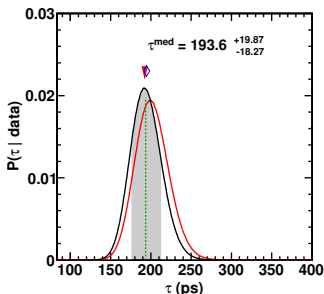
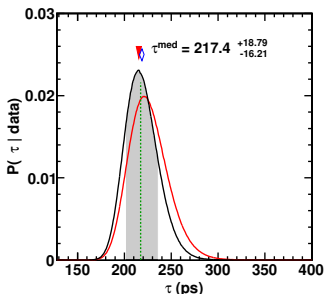
$${}^4_{\Lambda}\text{H} \text{ [T. Motoba } et al. \text{ NPA 34 597 (1991)]} : 233 \text{ ps} / 244 \text{ ps}$$



Meta analysis via Bayesian analysis : Additional approach

[C. Rappold *et al.*, Phys. Lett. B **728**, 543 (2014)]

Bayes formulation : $P(\tau|\vec{D}) \sim \mathcal{L}(\vec{D}|\vec{\tau}) \pi(\vec{\tau})$



- ▶ Upper Limit 95% : ${}^3_{\Lambda}\text{H}$: 250 ps & ${}^4_{\Lambda}\text{H}$: 227 ps
- ▶ Bayes Factor :

$$B_{10} = \int \mathcal{L}(\tau | \text{data}) \pi^{\text{Comb}}(\tau) d\tau / \int \mathcal{L}(\tau | \text{data}) \pi^{\Lambda}(\tau) d\tau$$

${}^3_{\Lambda}\text{H}$: $B_{10} = 2.7$ & ${}^4_{\Lambda}\text{H}$: $B_{10} = 3.8$

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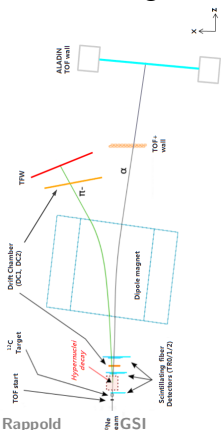
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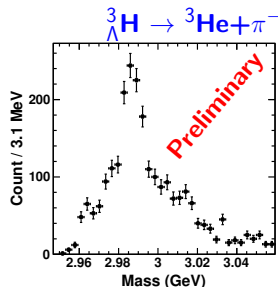
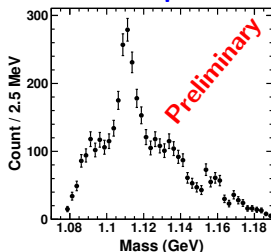
Most recent lifetime results

- ▶ STAR: Au+Au @ 200 GeV [Y.G. Ma, STAR collaboration, EPJ Conf. 66, 04020 (2014)]
- ▶ ALICE: Pb+Pb @ 2.7 TeV [ALICE collaboration, arXiv:1506.08453 (2015)]
- ▶ HypHI: Second experiment in 2010
Fixed target, Reaction : ${}^{20}\text{Ne} + {}^{12}\text{C} @ 2 \text{ AGeV}$
 $\Lambda \rightarrow p + \pi^-$



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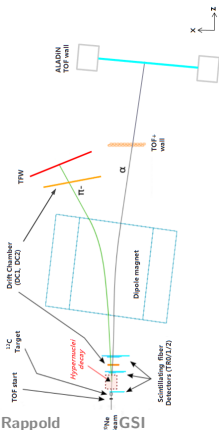
HGI



- ▶ good signals for Λ and ${}^3_{\Lambda}\text{H}$
- ▶ Analysis of $d + \pi^-$ and $t + \pi^-$ on-going
- ▶ Analysis of ${}^7_{\Lambda}\text{Li}$ and ${}^6_{\Lambda}\text{He}$ on-going

Most recent lifetime results

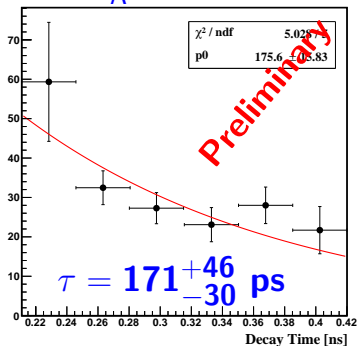
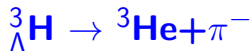
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C. Rappold

HypHI GSI

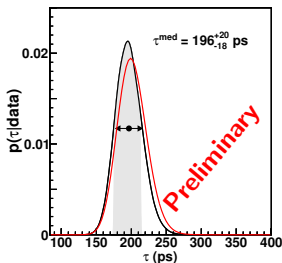
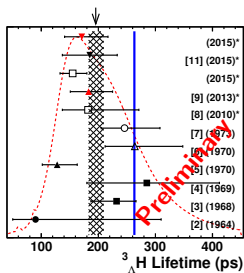
Status of hydrogen hypernuclear Lifetime



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Combination with the most recent available lifetime results:



- ▶ PDG says need to rescale errors if $\chi^2 > 1$
 - ▶ initial $\chi^2=1.18$, $197.5^{+12.4}_{-11.2}$ ps
 - ▶ scaled $\chi^2=0.98$, $195.9^{+13.8}_{-12.5}$ ps
- ▶ Upper Limit at 95% : 223.9 ps & at 99% : 234.0 ps
- ▶ Bayesian :
 - ▶ $195.9^{+19.7}_{-18}$ ps & Upper Limit 95% : 229 ps
 - ▶ Bayes Factor : $B_{10} = 3.0$

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- ▶ in 2013 : with STAR & HypHI published results
 - ▶ first evidence that ${}^3_{\Lambda}\text{H}$ has effectively shorter lifetime than Λ
 - ▶ From combined analysis upper limit at 95% CL : 250 ps
 - ▶ Most recent ${}^3_{\Lambda}\text{H}$ theoretical model : 256 ps
 - ▶ Similarly ${}^4_{\Lambda}\text{H}$ has shorter lifetime: 227 ps at 95% CL upper limit
 - ▶ ${}^4_{\Lambda}\text{H}$ theoretical models : 233 ps / 244 ps
- ▶ in 2015 : with new available/preliminary results :
 - ▶ Strong evidence that ${}^3_{\Lambda}\text{H}$ lifetime is shorter than Λ
 - ▶ upper limit at 95% CL : 226 ps & at 99% CL : 240 ps
- ▶ Experimental results show :
 - the structure of light hyper-hydrogens is still not well understood !