Hypertriton lifetime

Jean-Marc Richard

Institut de Physique des 2 Infinis de Lyon
Université Claude Bernard (Lyon 1)–IN2P3-CNRS
Villeurbanne, France

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Origin of nuclear clusters in hadronic collisions
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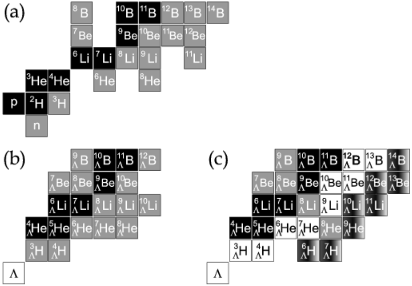
Content

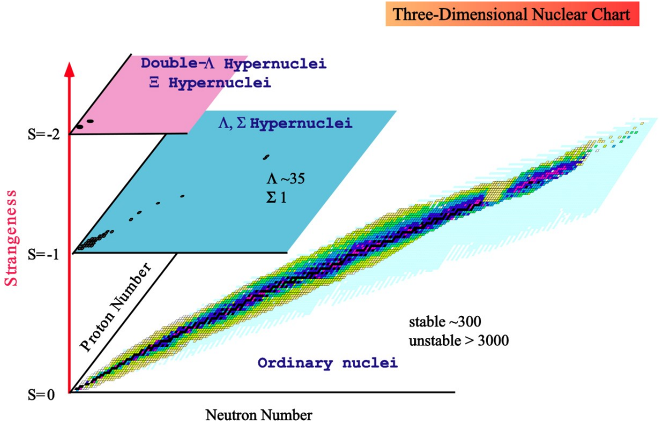
Collaboration

- Qiang Zhao (IHEP)
- Qian Wang (Guangzhou)
- Jean-Marc Richard (IP2I, Lyon)

Overview of Hypernuclei

- Hypernuclei studied almost immediately after the discovery of hyperons (K discovered earlier)
- Many contributions Dalitz, Gibson, Millener, Dover, Gal, Suzuki, Hiyama, Alberico, etc., etc.
- 

- Stimulated studies of the YN and YY interaction, (Y = hyperon)


Three-Dimensional Nuclear Chart
Double-Λ Hypernuclei
Ξ Hypernuclei
Λ, Σ Hypernuclei
Λ ~35
Σ 1
S=-2
S=-1
S=0
Strangeness
Proton Number
stable ~300
unstable > 3000
Ordinary nuclei
Neutron Number

Baryon-baryon

- Baryon-baryon: analogy with *NN* using $\pm$ $\mathrm{SU(3)_F}$
- Meson-exchanges (Nijmegen group, Rijken et al., . . .)
- Quark models (Tübingen group, Japanese groups, . . .)
- Lattice QCD (several groups)
- Chiral effective theories, LO, NLO, NNLO, . . .
- Mostly ΛN, but more recently $\Lambda\Lambda$ also for double-hypernuclei
- Coupled-channel dynamics, e.g., $\Lambda\Lambda \leftrightarrow \Xi N$ either absorbed into an effective one-channel or treated explicitly
- Short-range uncertainties tuned to $pn\Lambda$ or ${}^{6}_{\Lambda\Lambda}\mathrm{He}$
- $pn\Lambda$ re-measured recently (STAR)
- $\Lambda\Lambda$ also revisited (ALICE)

Light hypernuclei

- Many systems at the edge between stability and instability
- Predictions can change with refinements of the models (tuned to new data!), or a better treatment of the few-body dynamics
- For instance, in *some* models, the fully Borromean $\Lambda\Lambda nn$ is predicted to be bound, while none of its subsystems is stable
- Namely, models with small effective range for ΛN and large medium corrections for $\Lambda\Lambda$ (the true $\Lambda\Lambda$ being rather attractive, but if measured in, e.g., ${}^{6}_{\Lambda\Lambda}\mathrm{He}$, it looks weaker)
- Other examples: spin or isospin partners of Λnp

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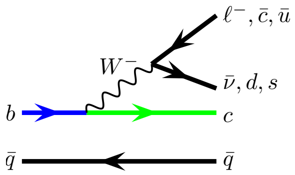
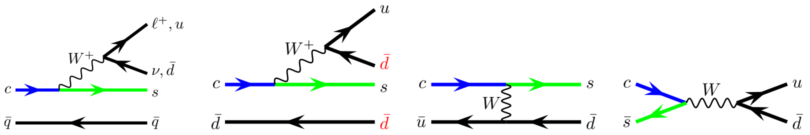
Beauty decay

- Rather “normal”, with an overall lifetime of about 1.5 ps and normal SL BR.
- Suggests a dominance of mere *W* emission
- B_c of course rather peculiar $\tau \sim 0.5$ ps
- *bbq* expected to have the same $\tau \sim 1.5$ ps
- $bb\bar{u}\bar{d}$, which is predicted to be stable (Ader et al., 1981), might have a much longer lifetime (Hernandez et al., Phys.Lett.B 800 (2020) 135073). This might help its identification in HE production.



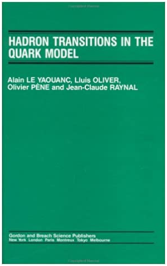
Charm decay

- Shock when it was discovered that $\tau(D^+) \neq \tau(D^0)$
- Differences from the hadronic sector, i.e., $\neq$ SLBR
- A variety of effects
- Extrapolation to the baryon sector rather successful
- Observed spread of lifetimes and SLBR larger than predicted
- Hadronic effects also present. E.g., $\Lambda_c \to \pi\Sigma$ influenced by poles in intermediate states.

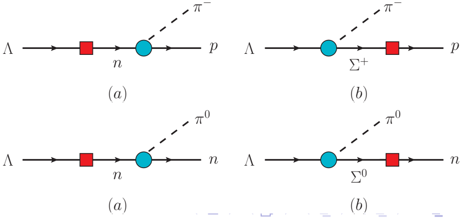


Strangeness decay

- Most famous for K decay, with mixing, CP violation, etc.
- Also very intriguing properties for baryons
- Very small SLBR
- More precisely, very strong enhancement of the hadronic modes
- Well documented, 70s, 80s, $\to$ e.g. 1988 book



- $\Lambda \to n \to p + \pi^-$
- $\Lambda \to \Sigma^+\pi^- \to p + \pi^-$
- With a striking cancellation



Weak decay of hypernuclei

- Several effects, with often some cancelations.
- For instance, Polykanov et al. (PS177 at LEAR) observed heavy hypernuclei (e.g. ${}^{238}_{\Lambda}\mathrm{U}$) with a lifetime of the order of 100 ps.
- Phase-space corrections
- Potential felt by the pion
- Pion-less decay
- Etc. For a review, see, e.g., Alberico et al. (Phys. Rpt.)

Hypertriton-1

- Experiment results
- Renewed interest with measurements at heavy-ion experiements

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On the measured lifetime of light hypernuclei ${}^{3}_{\Lambda}$H and ${}^{4}_{\Lambda}$H

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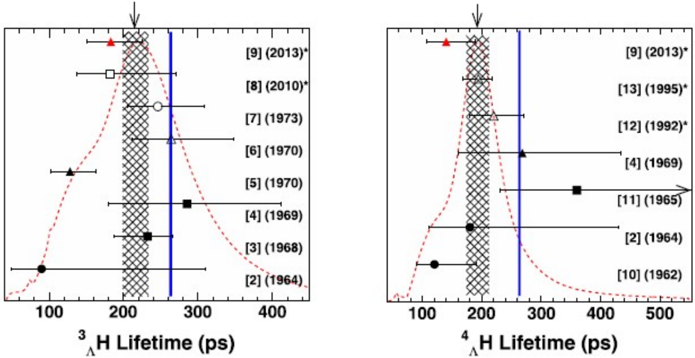
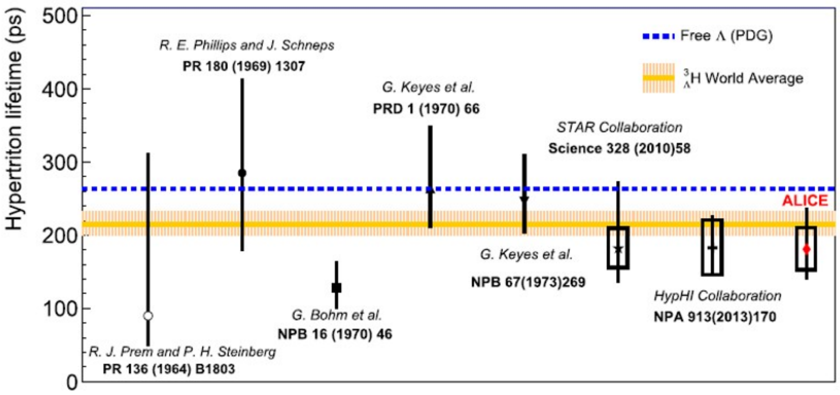
C. Rappold [a,b,*], T.R. Saito [a,c,d], O. Bertini [a,c], S. Bianchin [a], V. Bozkurt [a,e], M. Kavatsyuk [f], E. Kim [a,g], Y. Ma [a,c], F. Maas [a,c,d], S. Minami [a], D. Nakajima [a,h], B. Özel-Tashenov [a], K. Yoshida [a,d,i]

[a] GSI Helmholtz Centre for Heavy Ion Research, Planckstrasse 1, 64291 Darmstadt, Germany
[b] Justus-Liebig-Universität Giessen, Heinrich-Buff-Ring 16, 35392 Giessen, Germany
[c] Johannes Gutenberg-Universität Mainz, J.J. Becherweg 40, 55099 Mainz, Germany
[d] The Helmholtz Institute Mainz (HIM), J.J. Becherweg 40, 55099 Mainz, Germany
[e] Nigde University, 51100 Nigde, Turkey
[f] KVI, University of Groningen, Zernikelaan 25, NL-9747 AA Groningen, The Netherlands
[g] Seoul National University, Gwanakro Sillim-dong, Gwanak-gu, Seoul 151-747, Republic of Korea

Hypertriton-2



Hypertriton-3



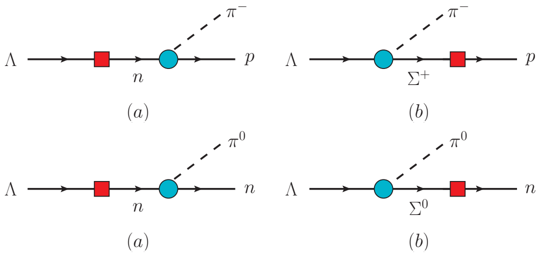
Latest analysis $\tau({}^3_\Lambda\mathrm{H}) = 242^{+34}_{-38} \pm 17\,\mathrm{ps}$
To be compared to $\tau(\Lambda) = 263 \pm 2\,\mathrm{ps}$

Hypertriton-4

- Conventional effects (nuclear corrections, pionless, etc.)
- Very small corrections
- See, e.g., Glöckle, Kamada et al.
- τ about 3% smaller than $\tau(\Lambda)$

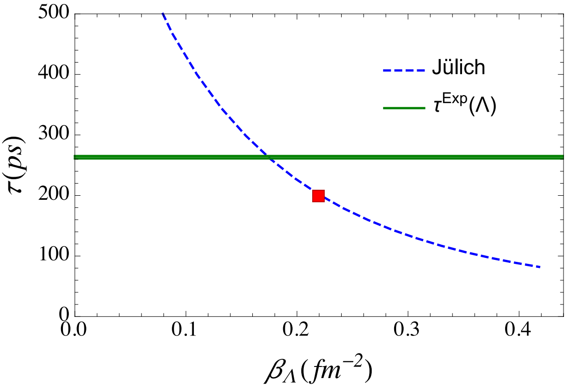
Hypertriton-5

- Neutron pole suppression
- Zhao, Wang, R.
- Intermediate *n* states suppressed by antisymmetrization
- Breaks the cancelation between the pole terms



Hypertriton-5

- Rather sensitive to the overlap between the baryons in the wave function



Outlook

- Still open problems in the physics of light hypernuclei
- New light hypernuclei might be discovered
- The shortened lifetime of ${}^{3}_{\Lambda}\mathrm{H}$ (and similar) probes of the Λ decay mecanisms and their modification in nuclei.