E73 status report

Request for beam time allocation

$(80kW \times 25days)$

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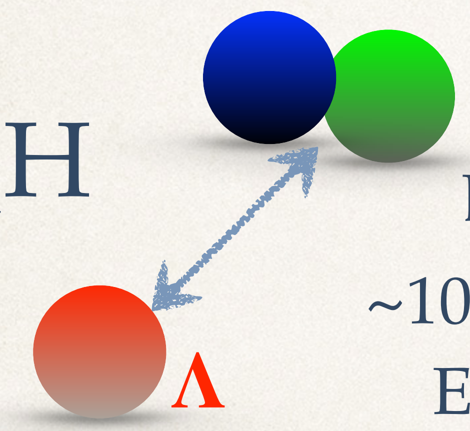
Aug. 4th, 2022

Outline

- Introduction to J-PARC E73:
  - The first direct measurement for ${}^{3}_{\Lambda}H$ lifetime
- J-PARC E73 review
  - Pilot run: ${}^{4}_{\Lambda}H$ lifetime as feasibility study, June, 2020
  - Stage-1: ${}^{3}_{\Lambda}H$ production cross section measurement, May, 2021
  - Stage-2: ${}^{3}_{\Lambda}H$ lifetime measurement
    - Stage-2 approved by the 33rd PAC with $80kW \times 25days$ beam time;
    - Ready for data taking from January 2023
- Summary

Introduction: hypertriton lifetime puzzle

As the lightest hypernucleus, $^3_\Lambda H$ serves as the cornerstone for hypernuclear physics just as deuteron for nuclear physics.



$^3_\Lambda H$

B_Λ~130keV,
~10 fm separation
Efimov state?

Hypertriton lifetime puzzle challenges the very foundation of our knowledge for hypernucleus.

Up to a few years ago, we believe:
$\tau \approx 263$ ps ($B_\Lambda = 130 \pm 50$ keV);
However, heavy ion experiments suggest $\tau \approx 180$ ps…

$^3_\Lambda H \longrightarrow {}^3He + \pi^-$ decay probability:
kinematics× | transition matrix | ^{2}
~ phase space×wave function overlap

a small term (separation of ~10fm)

E73 experimental setup

$$K^- + {}^3\text{He} \rightarrow {}^3_\Lambda\text{H} + \pi^0$$

very forward π0 projectile;

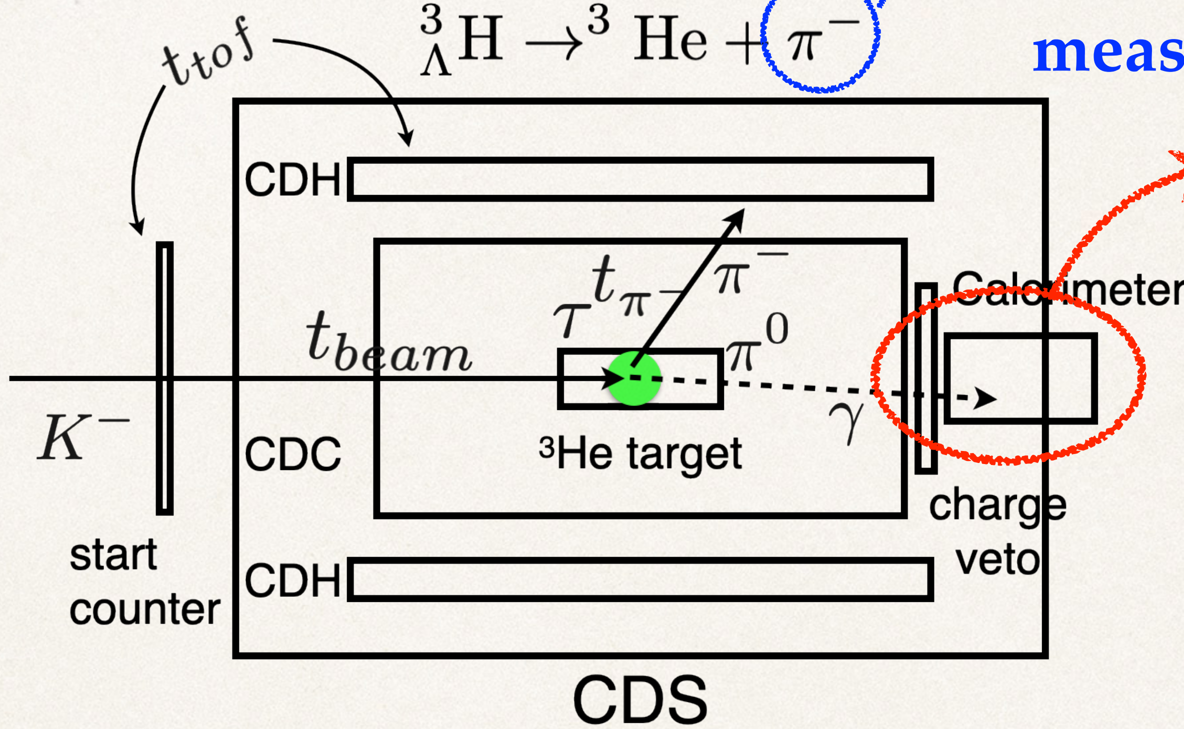
tagged with decayed high energy γ

slows down inside ³He target
and decays at rest

$${}^3_\Lambda\text{H} \rightarrow {}^3\text{He} + \pi^-$$

mono-energetic, ~114MeV/c;

measured with CDS



5x8 PbF2 Cherenkov Calo

Fully ready

$^3{}_\Lambda$H decay time can be derived by TOF and CDS tracking

The idea of ***direct measurement***: $T_{CDH}-T_0=t_{beam}+t_{\pi^-}+\tau$;

1. A complementary measurement for Heavy Ion results
2. Achievable precision: $\sigma/\sqrt{N} < 30$ps
3. *Direct lifetime measurement with fixed J=1/2 state*

$^{3}He(K^{-}, \pi^{0})^{3}_{\Lambda}H$ vs heavy ion production

Experiment	J-PARC E73	BNL STAR
Production method	$^{3}He(K^{-}, \pi^{0})^{3}_{\Lambda}H$	Au+Au
Microscopic process	Strangeness exchange	Thermal model; Coalescence model
PID	pi- momentum	Invariant mass;
Quantum number	spin=1/2 dominant	1/2 and 3/2 mixture?
Lifetime derivation	Time of flight	Decay length

J-PARC E73 staging & status

Staging:	Pilot (June, 2020)	Stage-1 (May, 2021)	Stage-2
Task:	Background study with $^{4}He(K^{-},\pi^{0})^{4}_{\Lambda}H$	First measurement for $^{3}He(K^{-}, \pi^{0})^{3}_{\Lambda}H$ reaction	Direct lifetime measurement for $^{3}_{\Lambda}H$
Output:	Established a new method as: (K-,pi0) + decay spectrum	Production cross section study for $^{3}_{\Lambda}H$ @ 1GeV/c	Pin down Hypertriton lifetime puzzle
Status:	$^{4}_{\Lambda}H$ lifetime publication under preparation	Successfully observed $^{3}_{\Lambda}H$ from mesonic weak decay	Request for beam time allocation (80kWx25days)

Pilot run results: ${}^{4}_{\Lambda}\mathrm{H}$ lifetime

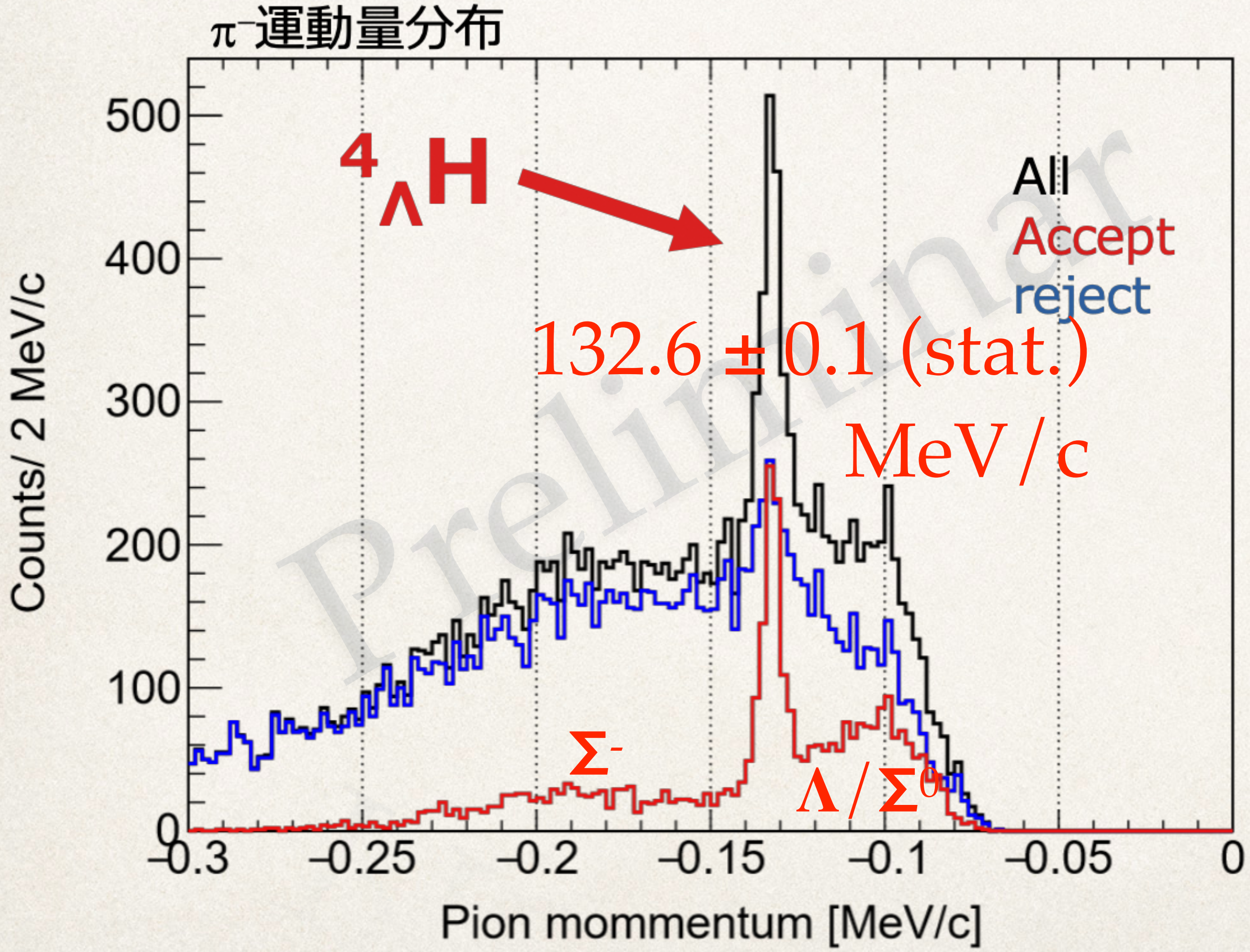
$$K^- + {}^4He \rightarrow {}^4_\Lambda H + \pi^0$$

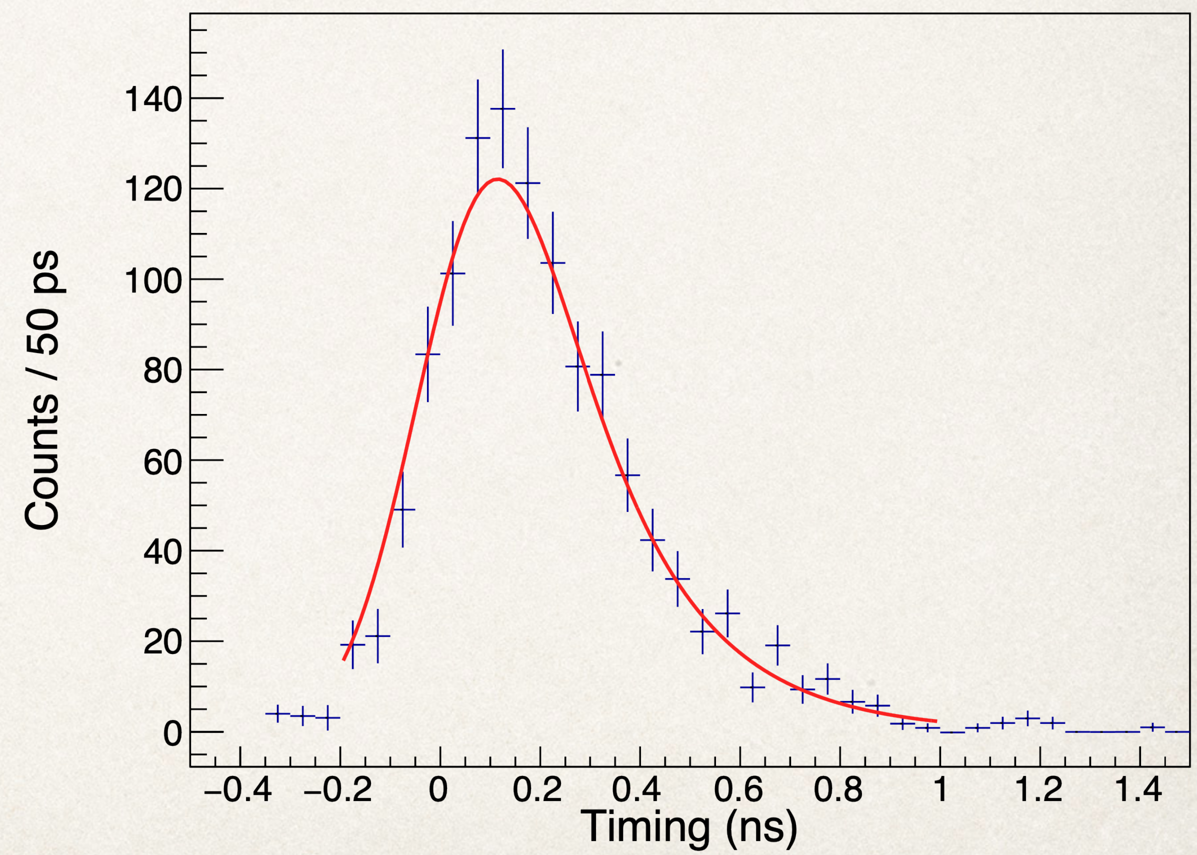
slows down inside ^{4}He target and decays at rest

$${}^4_\Lambda H \rightarrow {}^4He + \pi^-$$ 132.9 MeV/c

218 ± 6(stat.) ± 13(sys.) ps
@ STAR, Au-Au collision
arXiv:2110.09513

190 ± 8(stat.) ± 17(sys.) ps





Stage-1 results: ${}^{3}_{\Lambda}$H cross section

- First measurement for ^{3}He(K-, pi0)$^{3}_{\Lambda}$H reaction cross section; direct determination of $^{3}_{\Lambda}$H ground state spin;
- Ready for E73 Stage-2 beam time with 25days @ 80kW beam time for ~1k 2-body decay events scaled with Phase-1 data
- Expected precision for ${}^{3}_{\Lambda}$H lifetime:
  - statistical error ~20 ps;
  - systematic error ~30 ps based on the ${}^{4}_{\Lambda}$H result

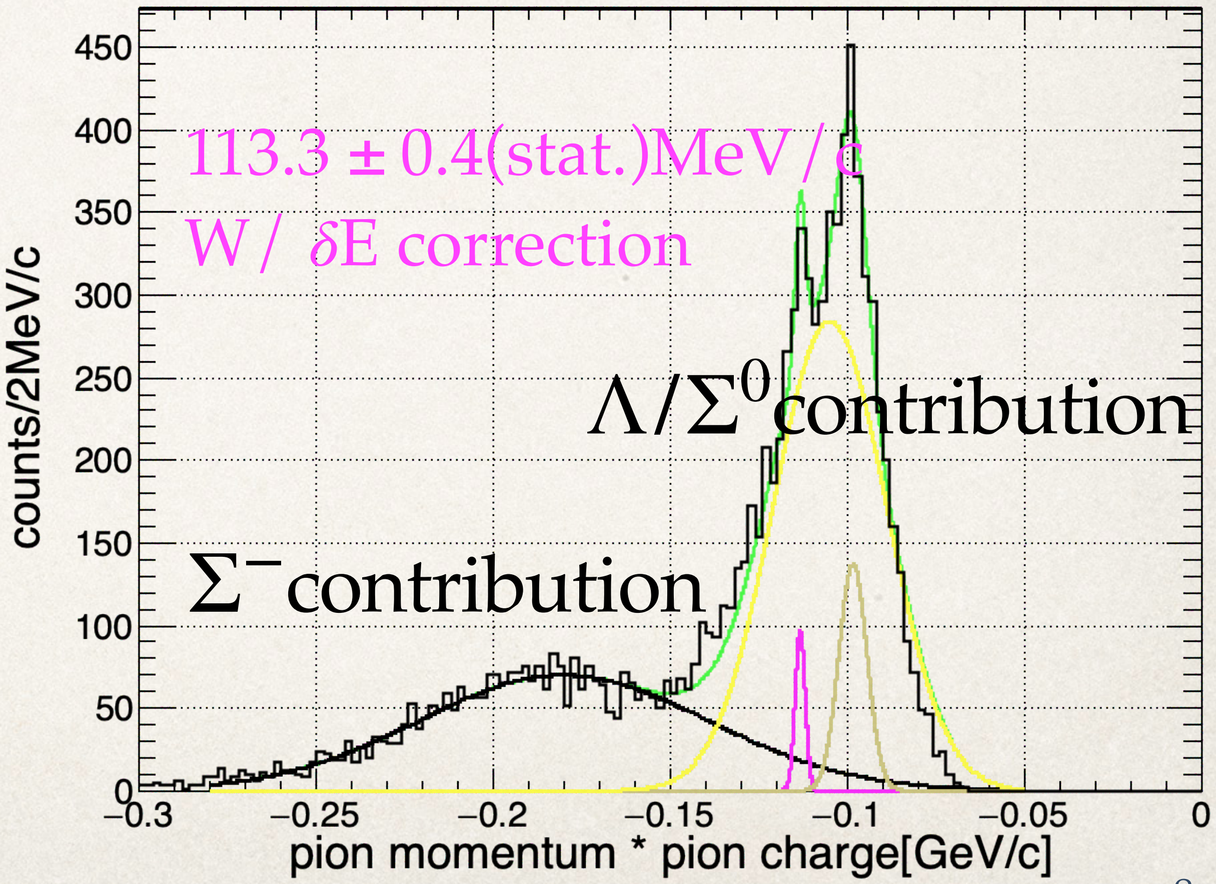
273kW*Day executed in May, 2021

$$K^- + {}^3He \rightarrow {}^3_\Lambda H + \pi^0$$

slows down and decays at rest

$${}^3_\Lambda H \rightarrow {}^3He + \pi^-$$

$${}^3_\Lambda H \rightarrow {}^2H + p + \pi^-$$



Comments from the 33rd PAC meeting

E73 (Test for ${}^{3}{}_{\Lambda}\mathrm{H}$ Decay)

The group has satisfactorily responded to all of the issues raised by the PAC. The data for ${}_{\Lambda}{}^{4}\mathrm{H}$ has been analyzed and yielded a value for the lifetime in agreement with earlier values from KEK and STAR. It is now timely to proceed with the main aim of the proposal, namely to resolve the issue of whether the lifetime of the ${}_{\Lambda}{}^{3}\mathrm{H}$ nucleus is anomalously short. While urging the group to take all measures to reduce the anticipated systematic errors, the PAC recommends stage-2 approval for data taking of 25 days (at 80kW).

Beam time has been granted as $80kW \times 25days$;

Full setup will be ready by January 2023;

Request for beam time allocation in early 2023;

Summary

- E73 is granted for the Stage-2 status with $80kW \times 25days$ beam time by the last (33rd) PAC
- E73 full setup will be ready by January 2023
- We request for beam time allocation in early 2023
  - Physics data taking run $80kW \times 25days$
  - An additional 1day calibration run with liquid hydrogen target for system calibration

E73/T77 collaborator list

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backup

Hydrogen calibration run

- To suppress systematic uncertainty of elementary process $p(K^-, \pi^0)\Lambda/\Sigma$ as the input for the signal channel, ${}^3\mathrm{He}(K^-, \pi^0)^3_\Lambda\mathrm{H}$

- Previous calibration run is very old with low intensity beam W/O π^0 trigger (27kW*3days, May 2015)

- New calibration run is necessary to estimate the spectrometer performance with new beam and trigger condition

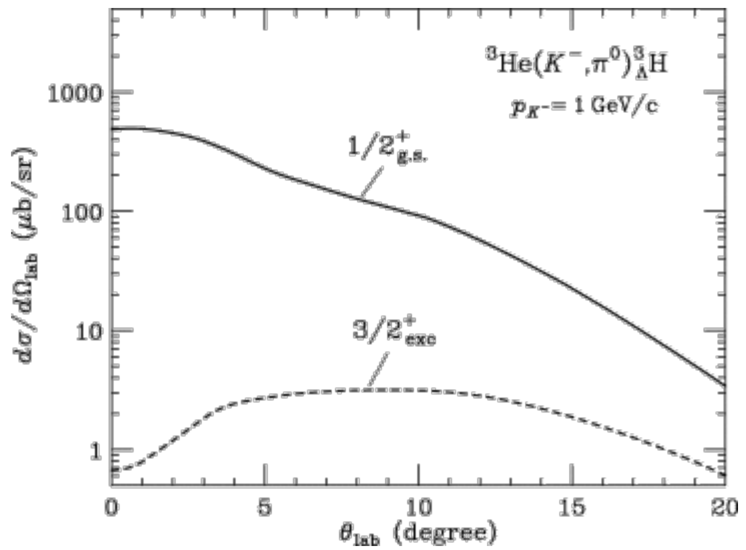
${}^{3}_{\Lambda}H/{}^{4}_{\Lambda}H$ cross section and binding energy

Ratio of production cross section

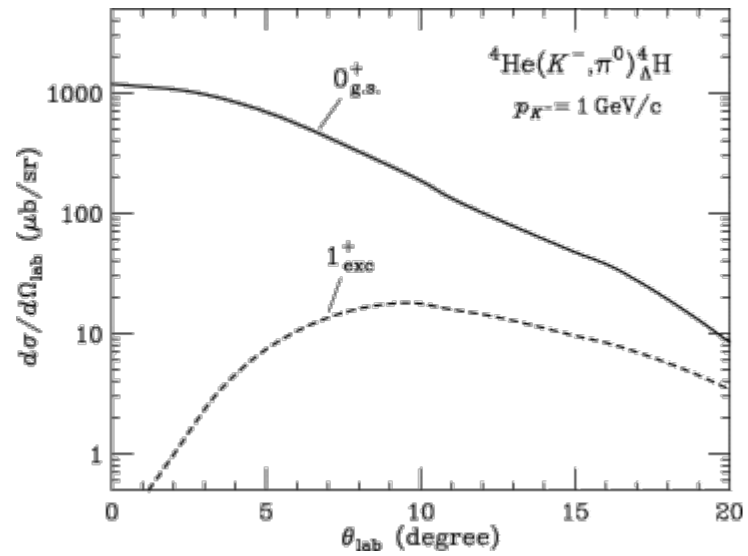
- Theoritical calculaction(DWIA)

T. Harada and Y. Hirabayashi,
Nuclear Physics A 1015 (2021) 122301

${}^{3}_{\Lambda}H$



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



$R = \sigma_{lab}({}^{3}_{\Lambda}H)/\sigma_{lab}({}^{4}_{\Lambda}H)$

R ~ 0.3—0.4 @ B_Λ=0.13 MeV(Emulsion), ~ 0.65 @ B_Λ=0.41 MeV(STAR)

→provides a better understanding of the structure of the ${}^{3}_{\Lambda}H$ bound states