E73 status report

Apply for Stage-2 approval

Yue MA from RIKEN

y.ma@riken.jp

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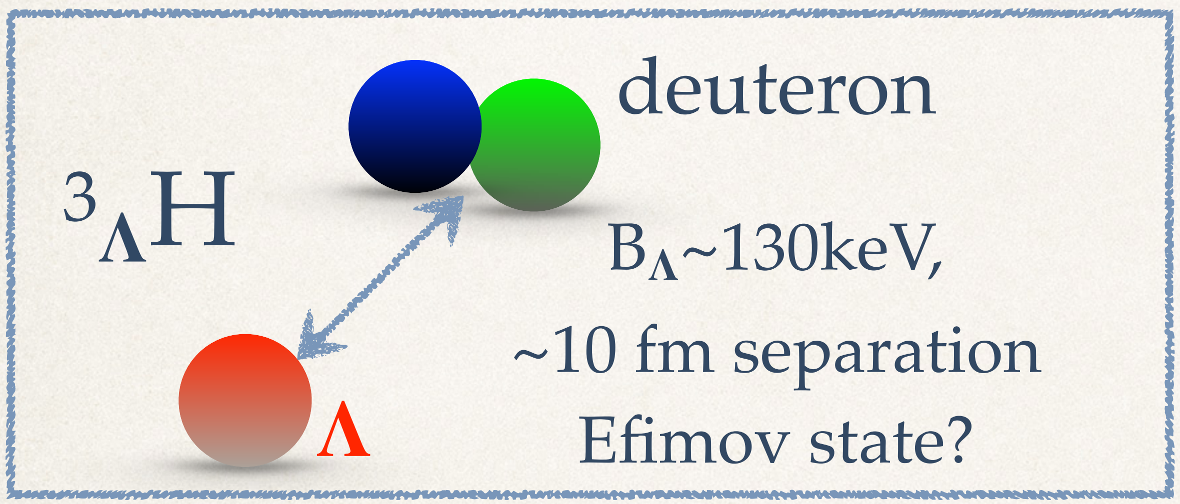
Outline

- Introduction to J-PARC E73:
  - The first direct measurement for ${}^{3}_{\Lambda}H$ lifetime
- J-PARC E73 staging & status
  - Phase-0: ${}^{4}_{\Lambda}H$ lifetime as feasibility study, June, 2020
  - Phase-1: ${}^{3}_{\Lambda}H$ production cross section measurement, May, 2021
  - Phase-2: ${}^{3}_{\Lambda}H$ lifetime measurement in early 2023
    - Request for Stage-2 approval in this talk
- 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.



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…

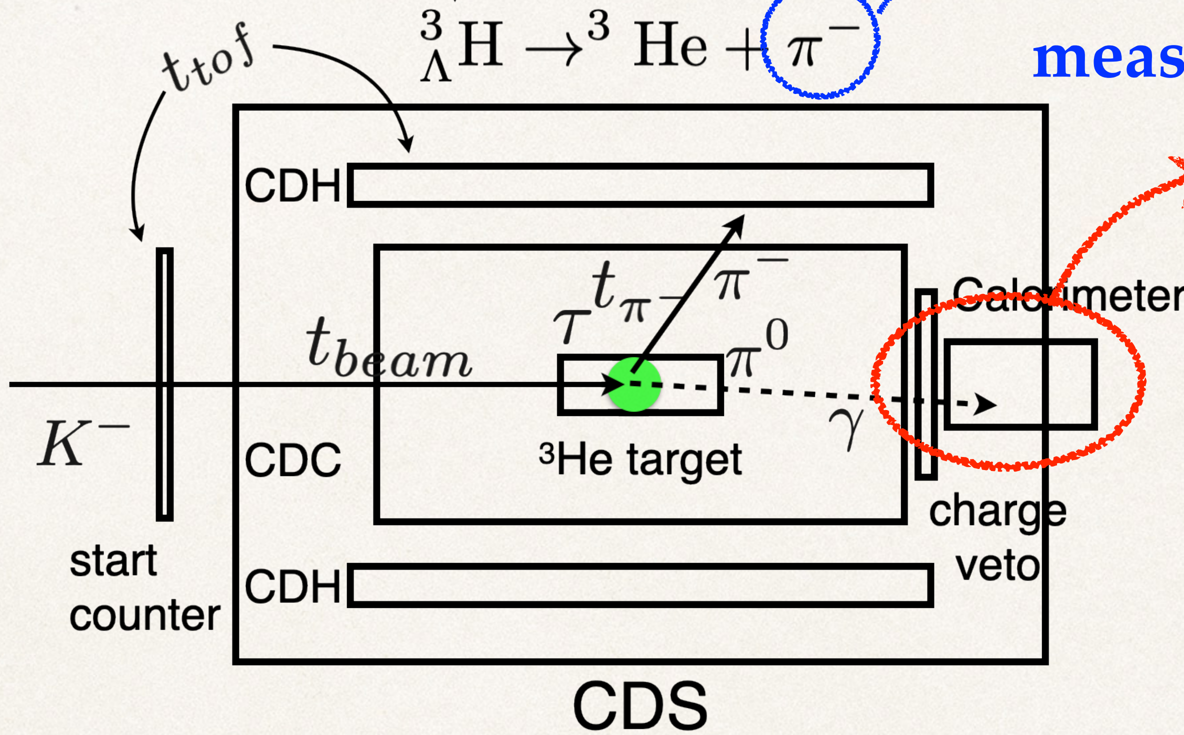
$^3_\Lambda H \longrightarrow {}^3He + \pi^-$ decay probability:
kinematics$\times|$transition matrix$|^2$
~ phase space$\times$wave function overlap

a small term
(separation of ~10fm)

E73 experimental setup

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

very forward π0 projectile;
tagged with decayed high energy γ



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}+$t_{\pi-}$+τ;

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

J-PARC E73 staging & status

Staging:	Phase-0 (June, 2020)	Phase-1 (May, 2021)	Phase-2
Task:	Background study with $^{4}He(K-,pi0)^{4}{}_{\Lambda}H$	First measurement for $^{3}He(K-, pi0)^{3}{}_{\Lambda}H$ 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	Fully ready for beam time from now on	Request for Stage-2 approval

Request from the 33rd PAC meeting

The PAC understands the importance of the measurement as well as the readiness of the experiment. The earliest beam time will be in the fourth quarter of 2022. Before granting the stage-2 status to E73, the PAC suggests to the experiment: (1) complete the analysis of $^{4}He(K^{-},\pi^{0})^{4}{}_{\Lambda}He$ reaction and determine the systematic uncertainties and (2) Prepare a detailed document on the analysis procedure for the lifetime measurement and submit the material before the next PAC meeting.

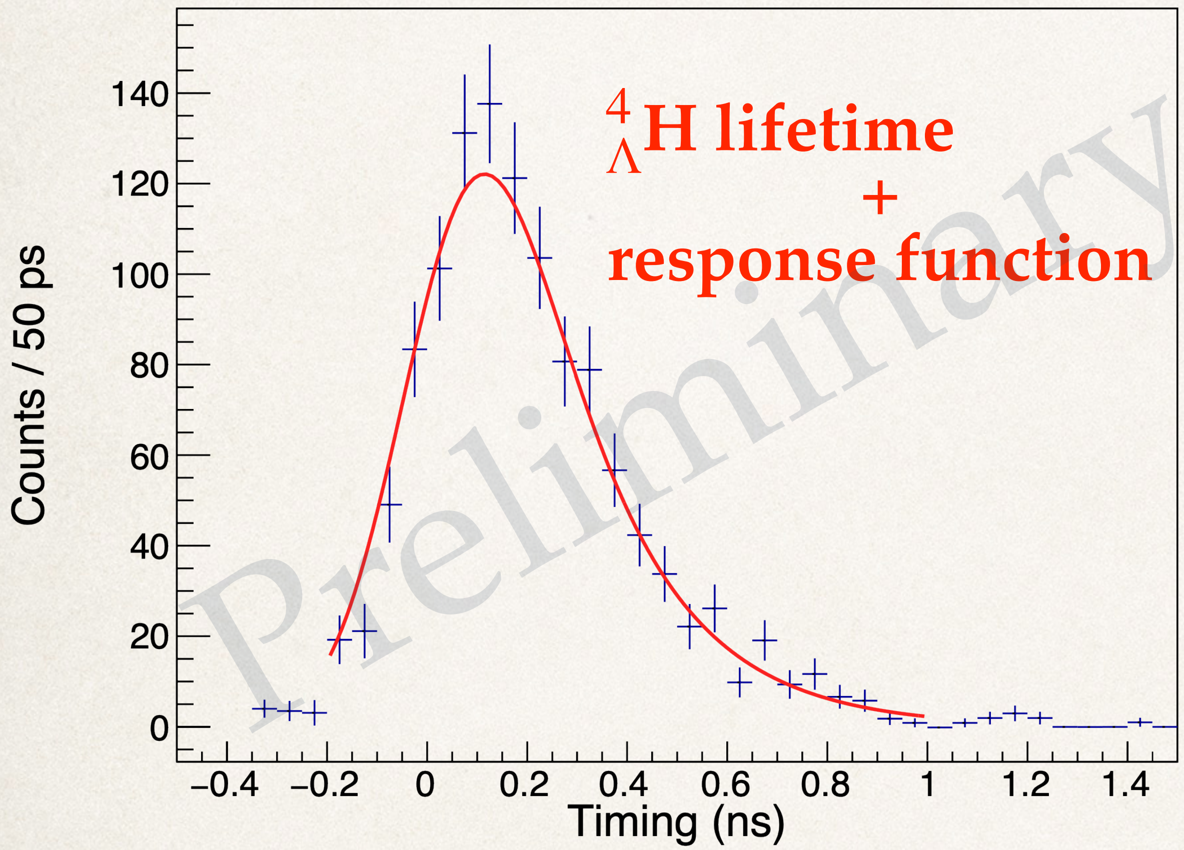
Homework assigned by the last PAC:

1, accomplished, will be covered by this talk

2, a detailed analysis report has been submitted

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

$190 \pm 8(\text{stat.}) \pm 17(\text{sys.})$ ps



194^{+24}_{-26} ps @ KEK stop K-

H. Outa, et al., Nucl. Phys. A 547, (1992), 109c-114c

$218 \pm 6(\text{stat.}) \pm 13(\text{sys.})$ ps

@ STAR, Au-Au collision

arXiv:2110.09513

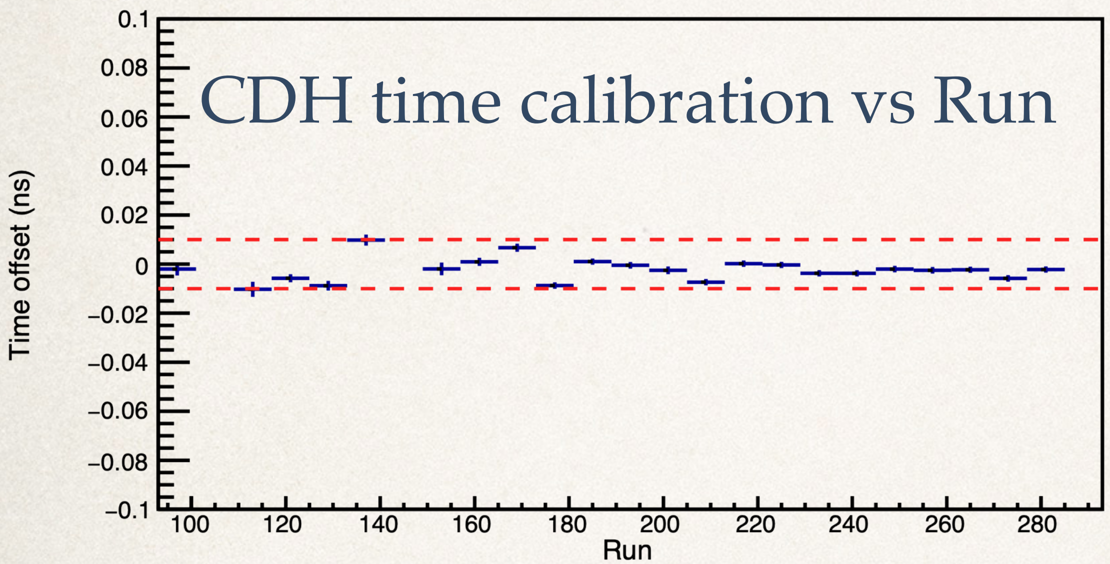
Contribution	Value
Uncertainty of time calibration	±10 ps
Intrinsic bias of T77(E73) approach	-5 ±5 ps
Uncertainty induced by background subtraction	±8 ps
Uncertainty induced by fitting range	±10 ps

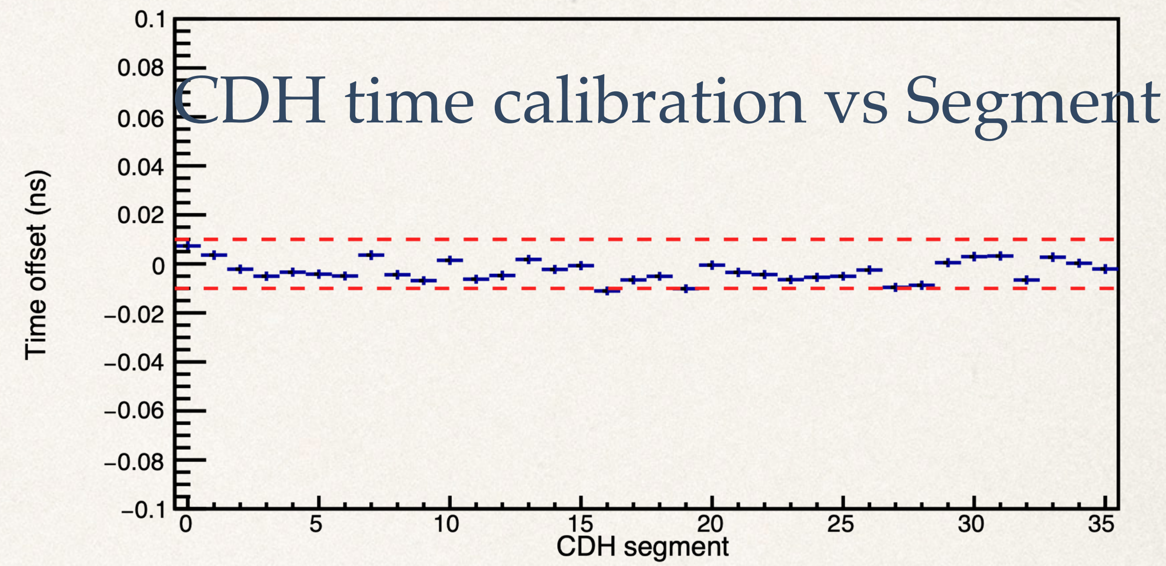
We will go through these numbers in this talk.

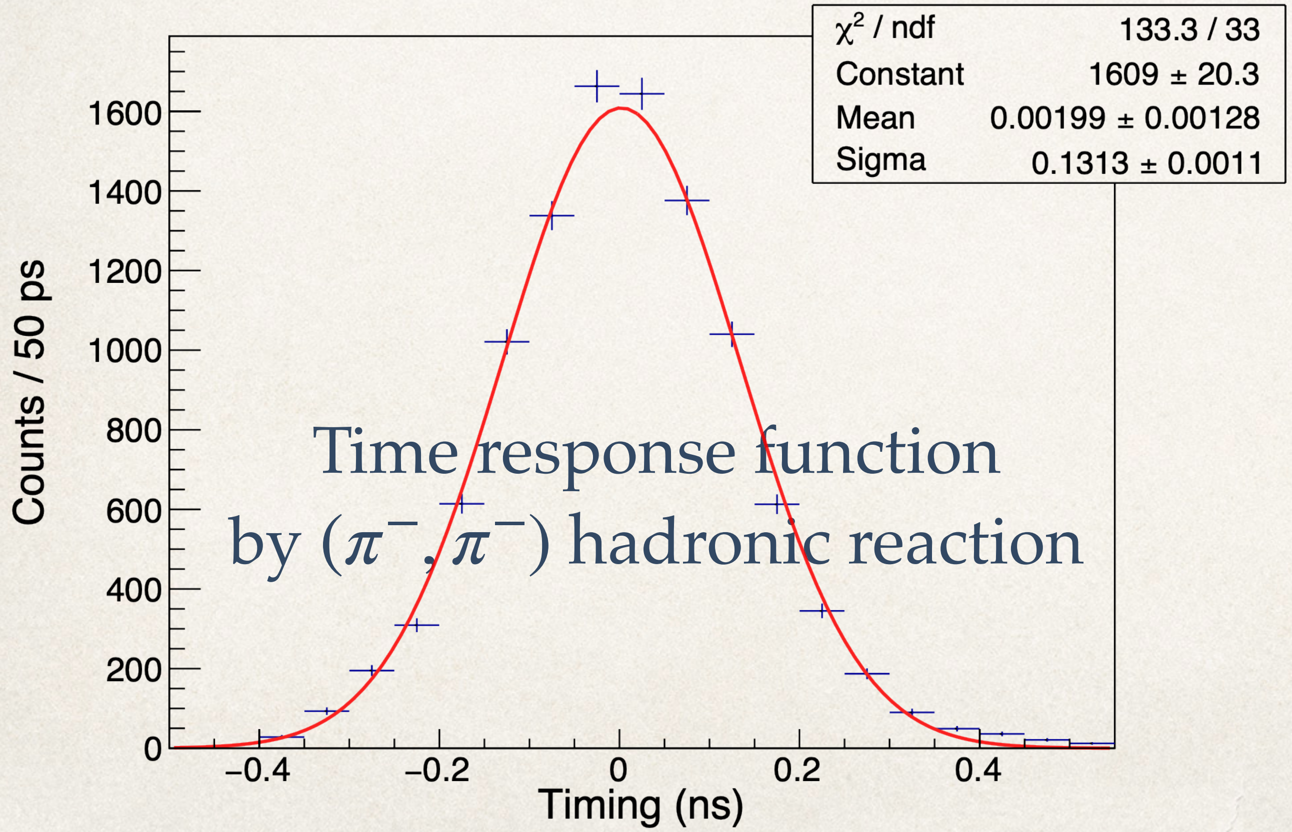
verified by tuning fitting range

Uncertainty of time calibration: ±10 ps

±10 ps systematic uncertainty



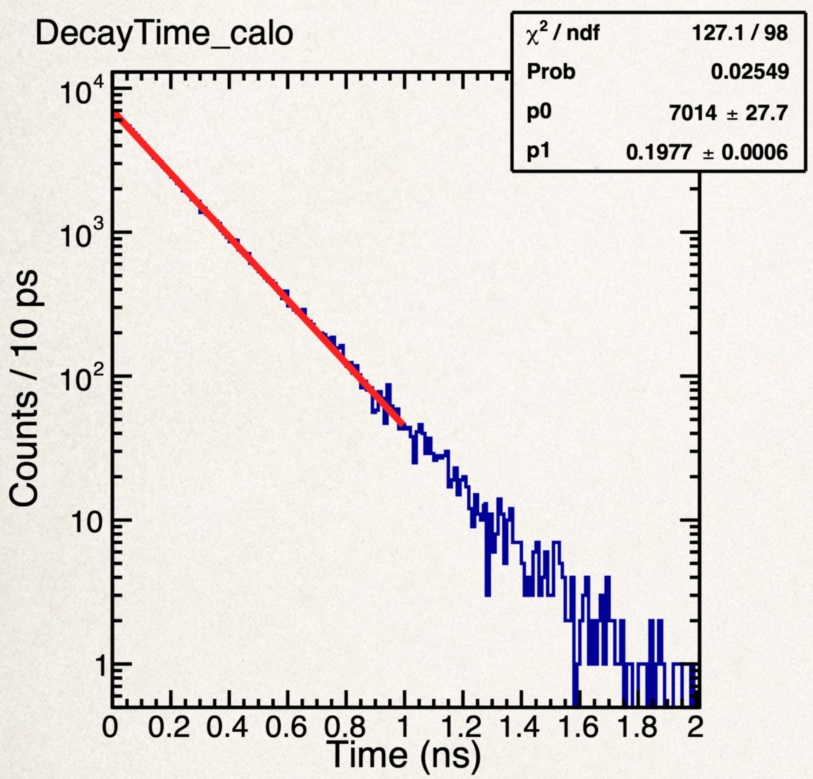




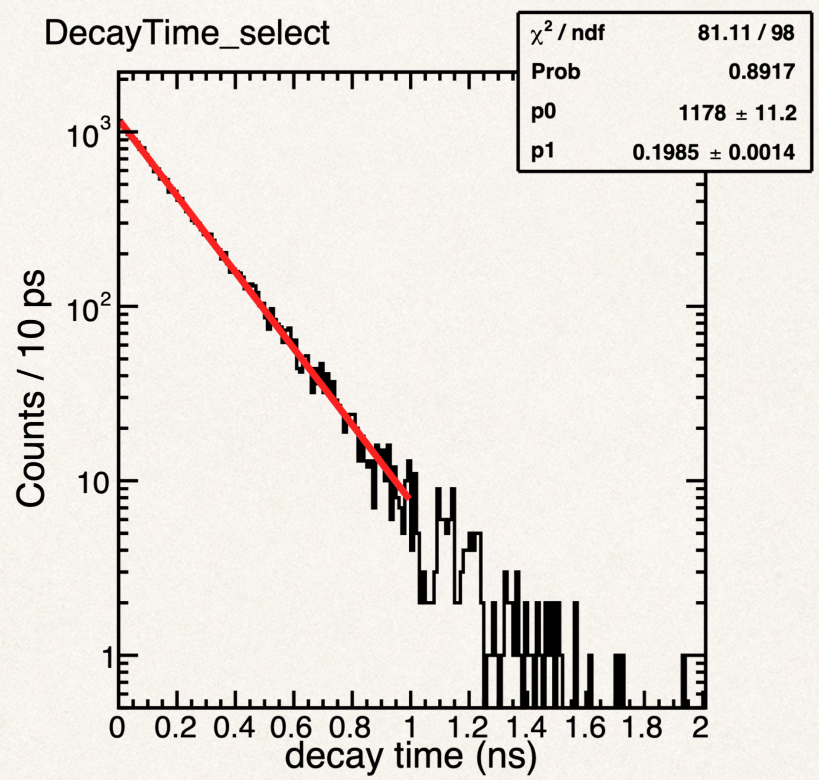
- CDH time calibration performed run-by-run & segment-by-segment;
- Calibration precision < 10ps;
- (π^-, π^-) hadronic events used to obtain time response function;
- Time resolution: $\sigma_t \sim 130$ ps

Intrinsic bias of T77(E73) approach: -5 ± 5 ps

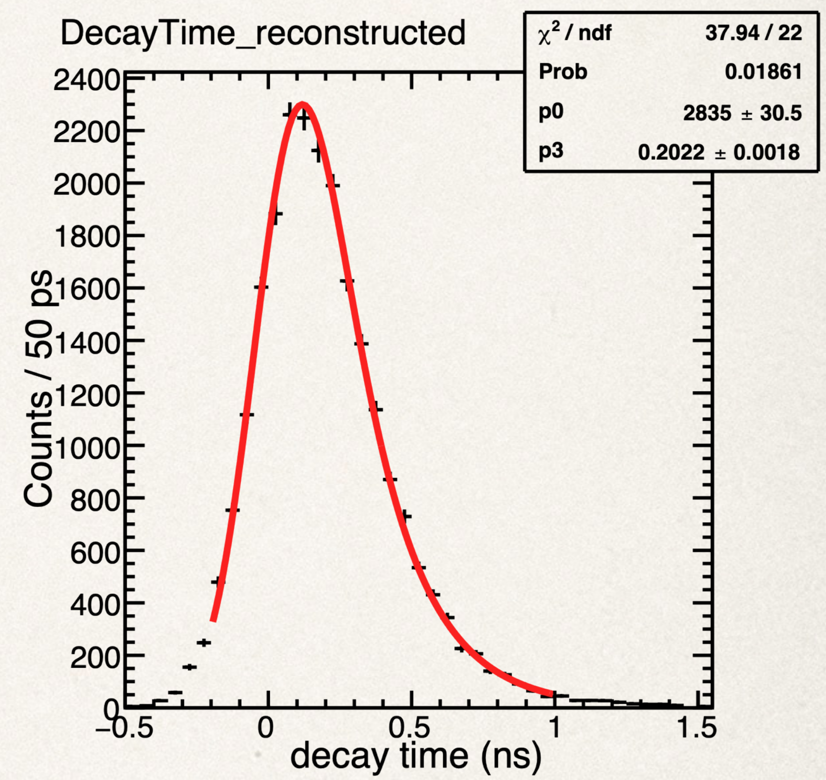
MC input:
$\tau = 197.7$ ps



MC true W/ cuts:
$\tau = 198.5$ ps



Analyzer output:
$\tau = 202.2$ ps

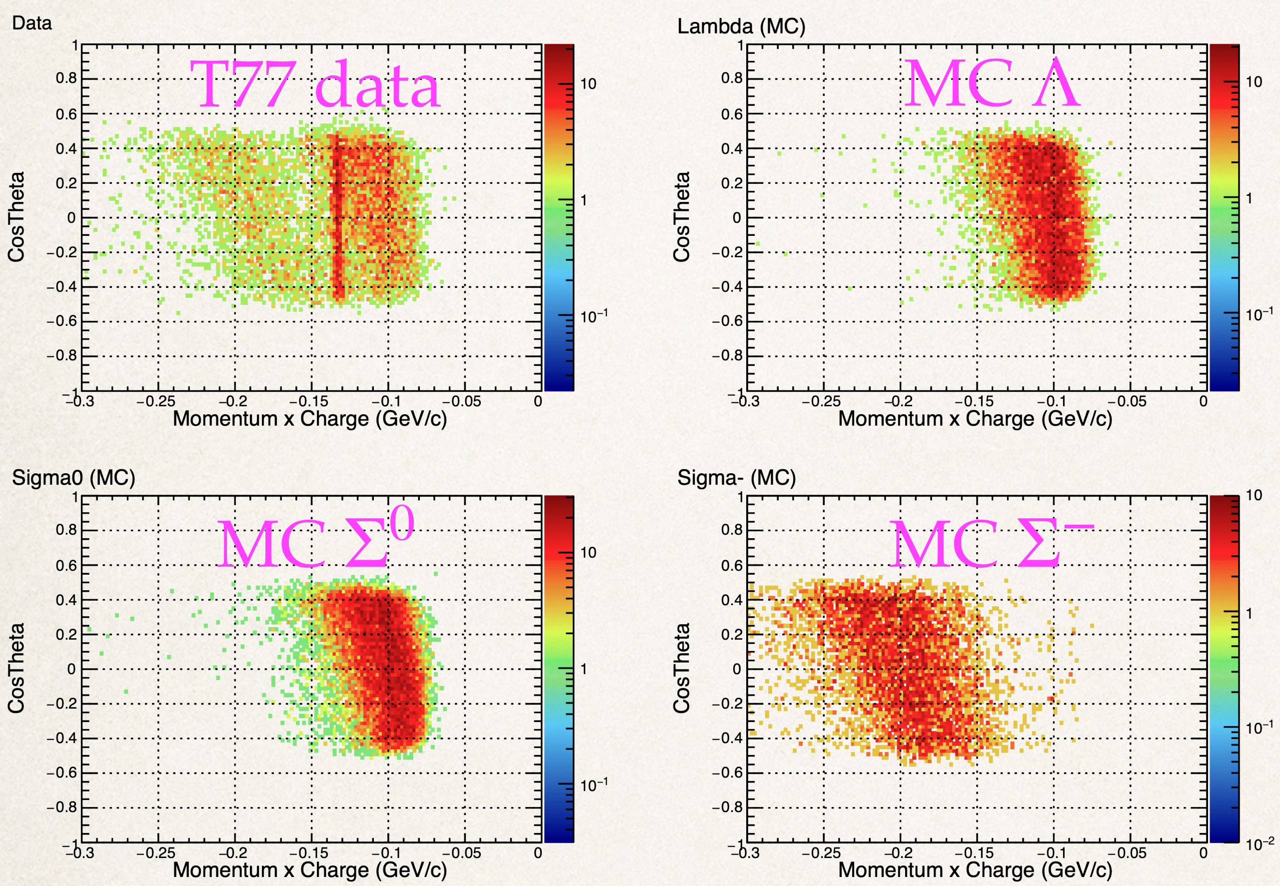


- ${}^{4}_{\Lambda}$H differential cross section from Prof. T. Harada;
- Assuming reaction vertex is the same as the decay vertex;
  - Vertex determined by connecting K^- and π^- track;
  - A systematic bias studied with MC data

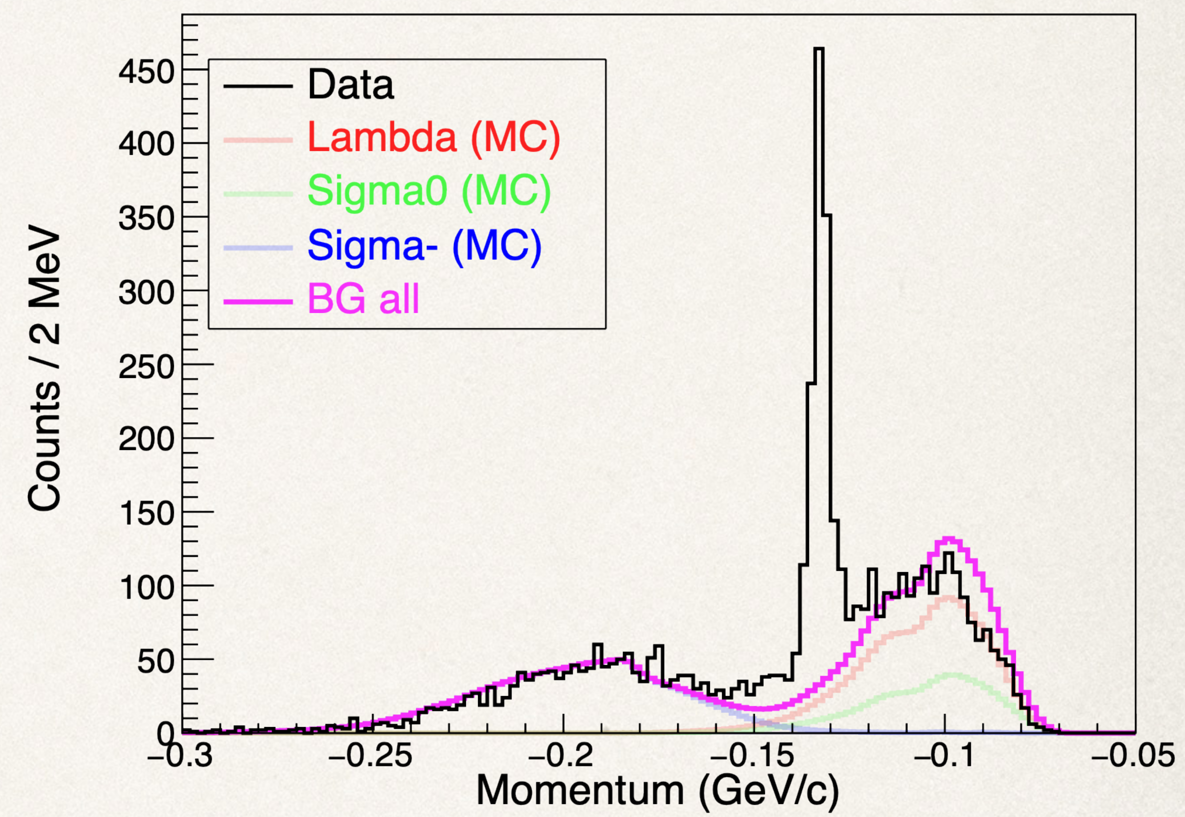
T. Harada, Y. Hirabayashi, Nucl. Phys. A, 1015, 122301 (2021)

Simulation validation

decay π^- momentum vs angle



MC yield tuned to match data



GEANT4 based simulation for quasi-free Λ/Σ in-flight decay;

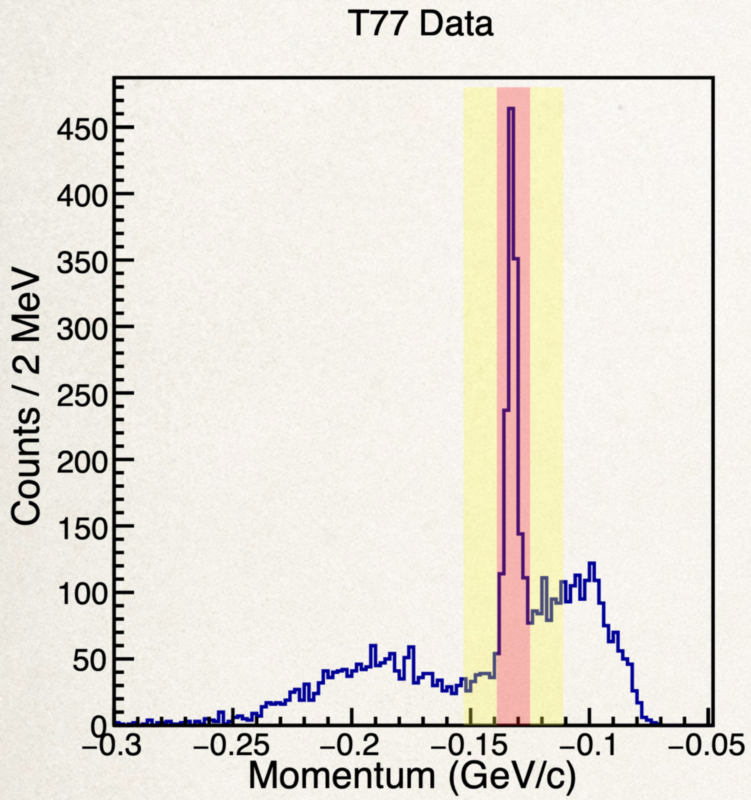
$N(K^-, \pi^0)$Y elementary reaction with published data +

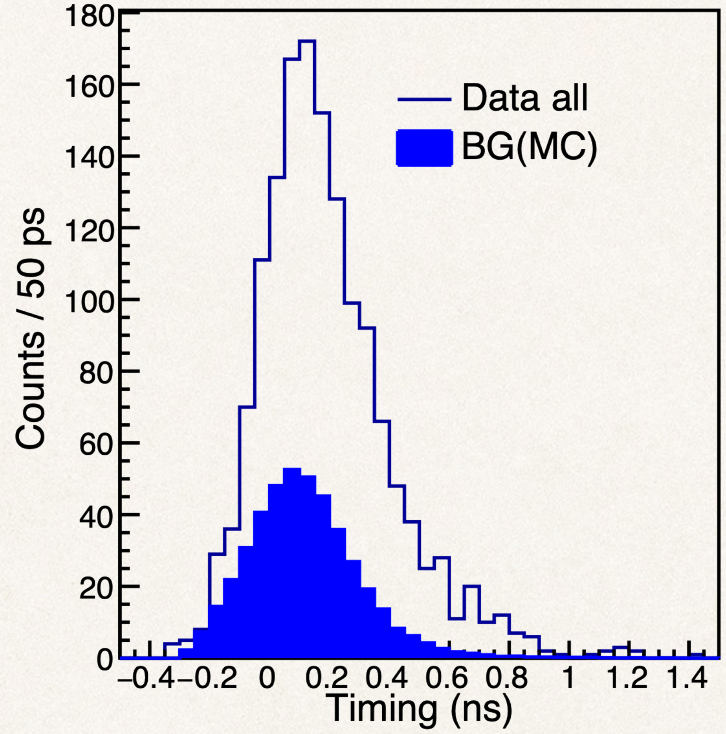
convoluted with Argonne AV18+UX Fermi motion

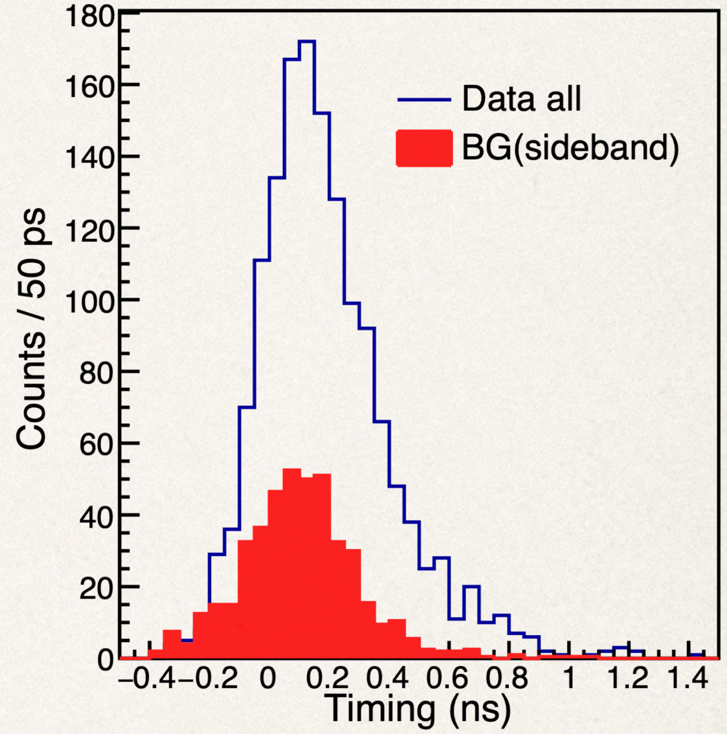
R.B. Wiringa et al, Phys. Rev. C **89**, 024305

Uncertainty due to background subtraction: ±8 ps

MC yield was tuned up to $\pm 5\sigma$ from the best fit:
${}^{4}_{\Lambda}$H lifetime converges within ±8 ps







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R.B. Wiringa et al, Phys. Rev. C **89**, 024305

Request for Stage-2 approval

273kW*Day executed in May, 2021

- Request for E73 Stage-2 approval with 25days @ 80kW beam time for ~1k 2-body decay events scaled with Phase-1 data

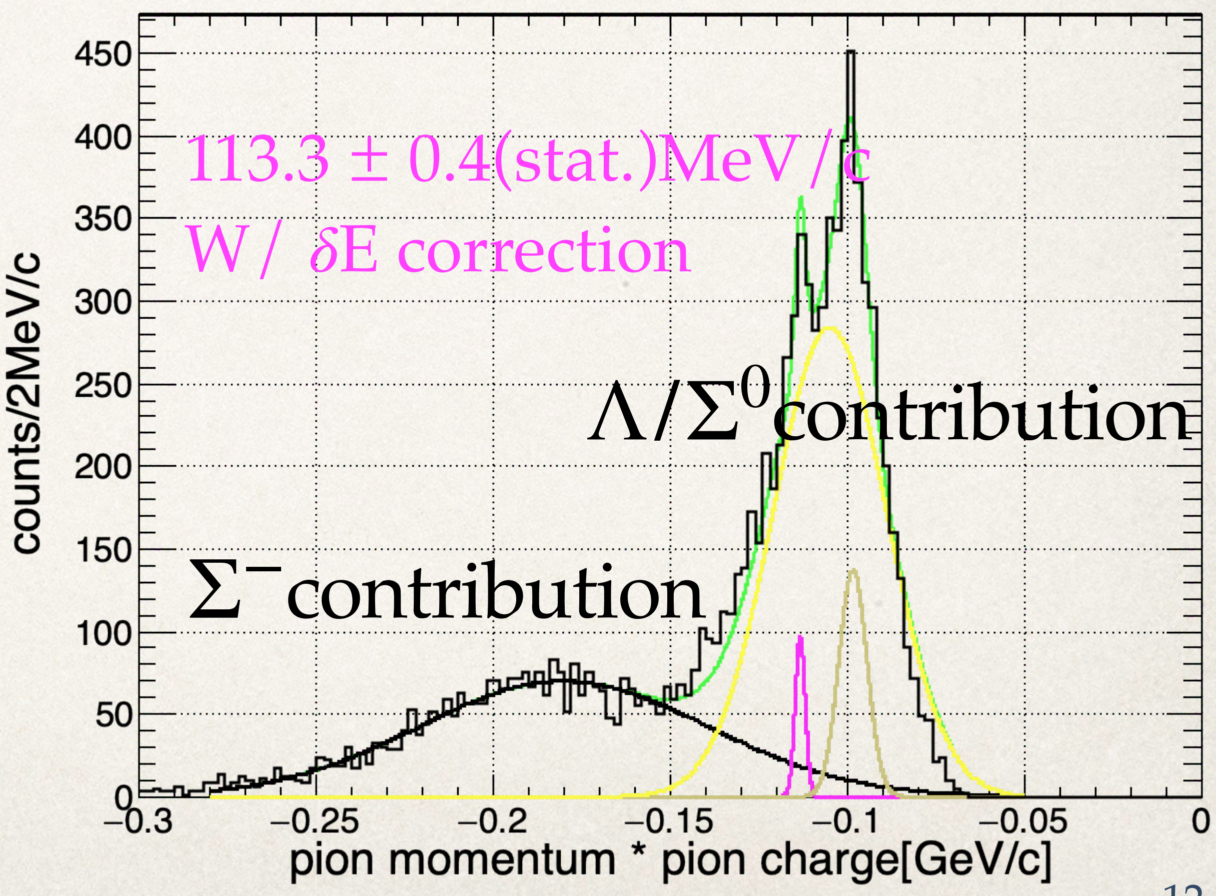
$$K^- + {}^3He \rightarrow {}^3_\Lambda H + \pi^0$$

slows down and decays at rest

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

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

- Expected precision for ${}^3_\Lambda H$ lifetime:
  - statistical error ~20 ps;
  - systematic error ~30 ps based on the ${}^4_\Lambda H$ result



Summary

- Based on previous results, E73 is ready for the Stage-2 approval
  - Phase-0 (June, 2020): ${}^{4}_{\Lambda}$H lifetime has been obtained to demonstrate the feasibility of our approach
  - Phase-1 (May, 2021): ${}^{3}_{\Lambda}$H production cross section has been measured as a reference for Stage-2 beam time request
- Request for E73 Stage-2 approval with 25days @ 80kW beam time for ~1k 2-body decay events (scaled with Phase-1 data)

E73/T77 collaborator list

T. Akaishi[1], H. Asano[2], X. Chen[5], A. Clozza[7], C. Curceanu[7], R. Del Grande[7], C. Guaraldo[7], C. Han[5], T. Hashimoto[4], M. Iliescu[7], K. Inoue[1], S. Ishimoto[3], K. Itahashi[2], M. Iwasaki[2], Y. Ma[2], M. Miliucci[7], R. Murayama[2], H. Noumi[1], H. Ohnishi[10] S. Okada[2], H. Outa[2], K. Piscicchia[7,9], A. Sakaguchi[1], F. Sakuma[2], M. Sato[3], A. Scordo[7], K. Shirotori[1], D. Sirghi[7,8], F. Sirghi[7,8], S. Suzuki[3] K. Tanida[4], T. Toda[1], M. Tokuda[1], T. Yamaga[2], X. Yuan[5], P. Zhang[5], Y. Zhang[5], H. Zhang[6]

[1]Osaka University, Toyonaka, 560-0043, Japan
[2]RIKEN, Wako, 351-0198, Japan
[3]High Energy Accelerator Research Organization (KEK), Tsukuba, 305-0801, Japan
[4]Japan Atomic Energy Agency, Ibaraki 319-1195, Japan
[5]Institute of Modern Physics, Gansu 730000, China
[6]School of Nuclear Science and Technology, Lanzhou University, Gansu 730000, China
[7]Laboratori Nazionali di Frascati dell' INFN, I-00044 Frascati, Italy
[8]Horia Hulubei National Institute of Physics and Nuclear Engineering (IFIN-HH), Magurele, Romania
[9]CENTRO FERMI - Museo Storico della Fisica e Centro Studi e Ricerche Enrico Fermi, 00184 Rome, Italy
[10]Tohoku University, 982-0826, Sendai, Japan

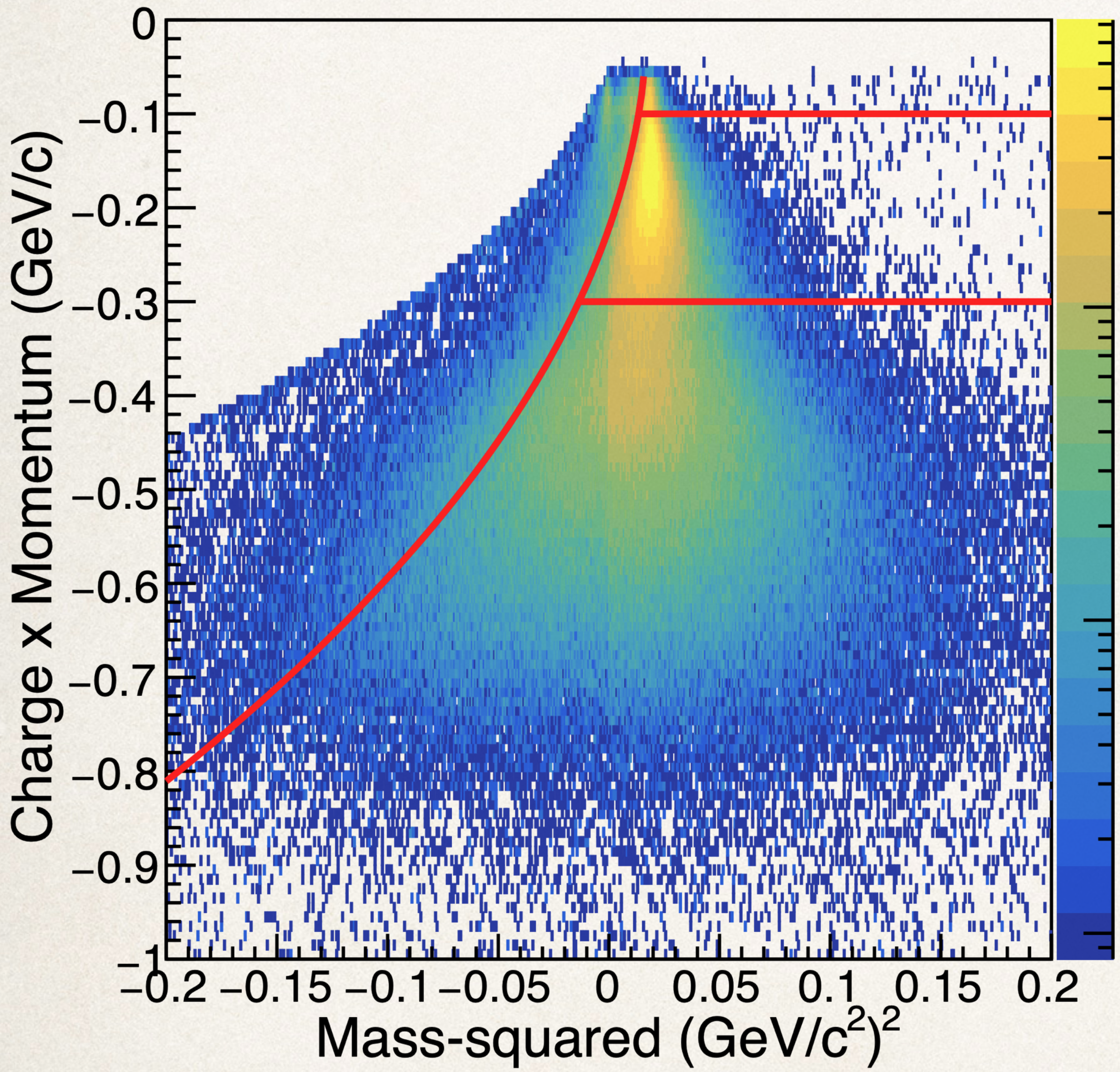
backup

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

Experiment	J-PARC E73	BNL STAR
Production method	$^3He(K\text{-}, pi0)^3{}_\Lambda H$	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

Detector performance: tracking and PID

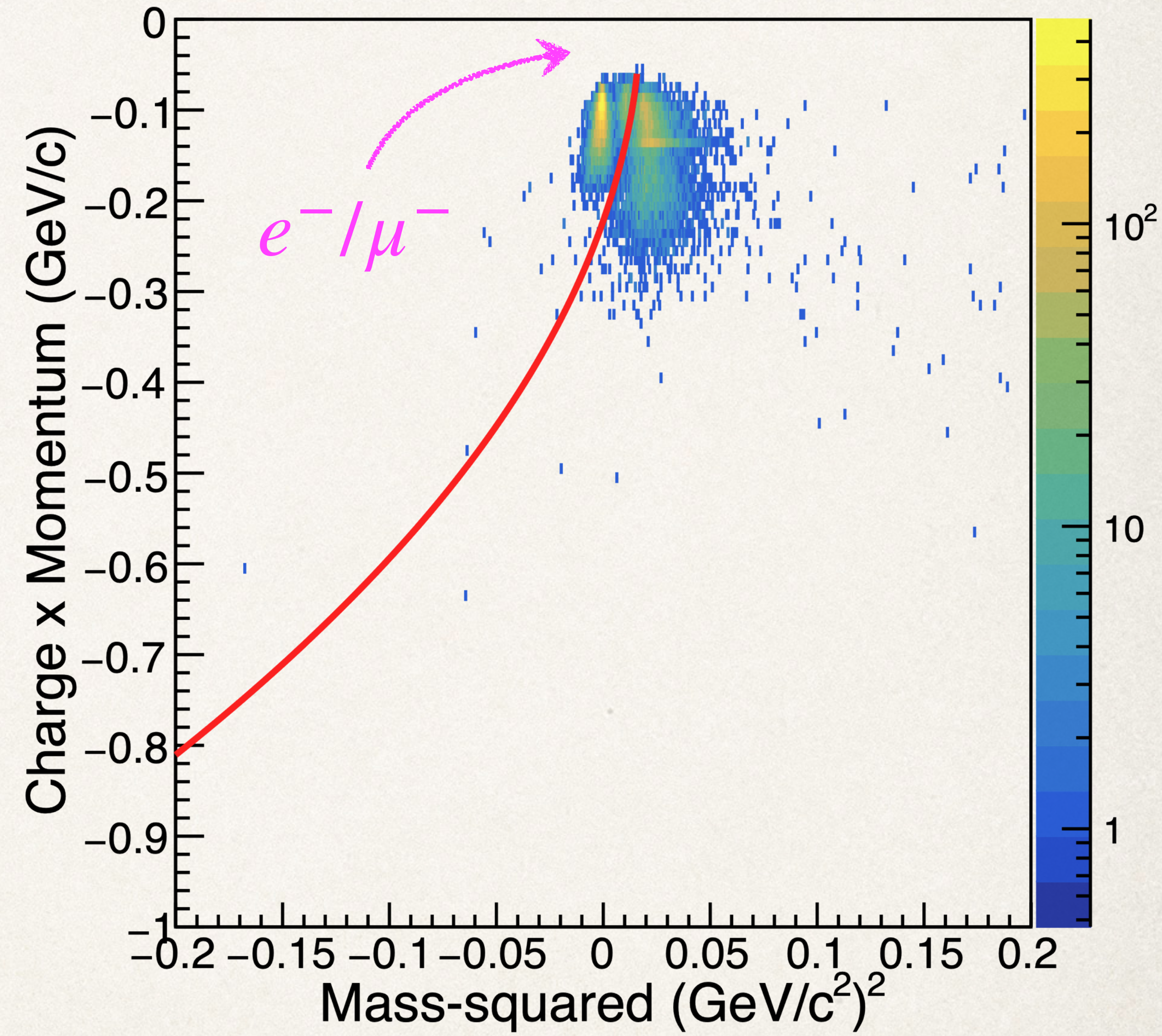
Calibration and slewing correction events



(K^-, π^-)

W/O requesting calorimeter dE

Interested physics events

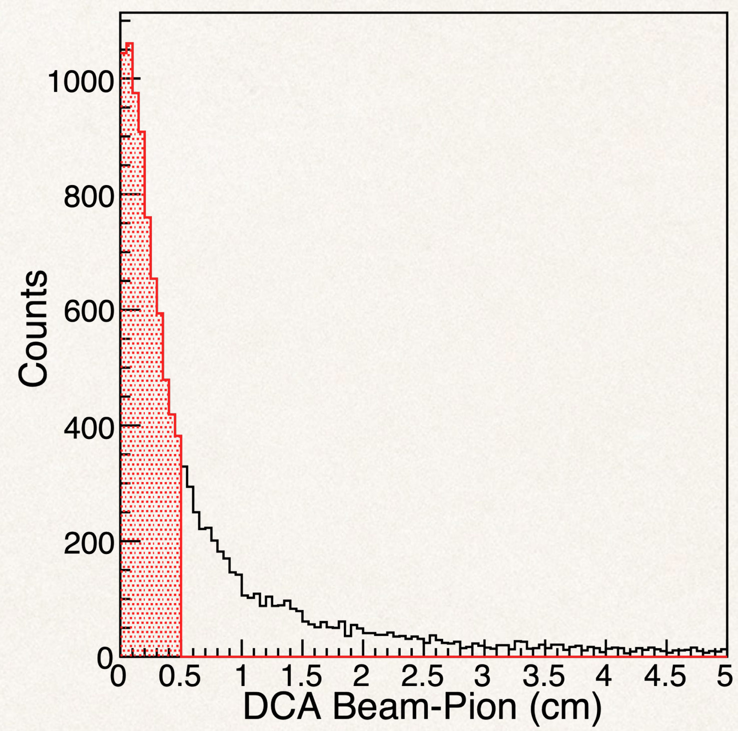


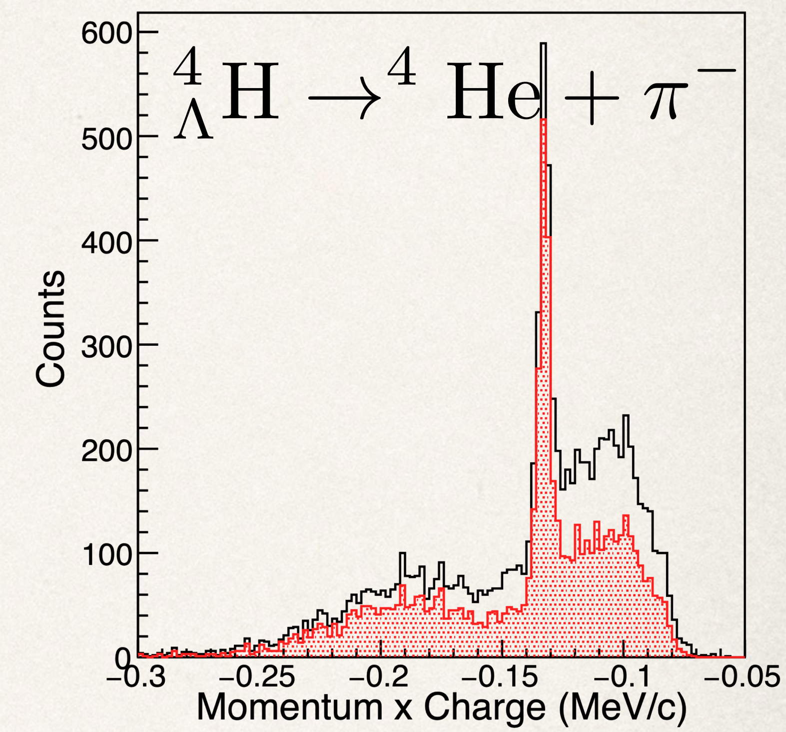
(K^-, π^-)

W/ requesting calorimeter dE > 500 MeV

Event selection: DCA & calorimeter cut

DCA < 5mm
used for event selection





Selecting $^{4}_{\Lambda}$H events by using calorimeter dE > 500MeV

--> our innovative method for selecting hypernucleus by tagging high energy gamma