K中間子ビームによる 軽いハイパー核の生成断面積測定
Measurement of production cross-section of light hypernucleus using K meson beam

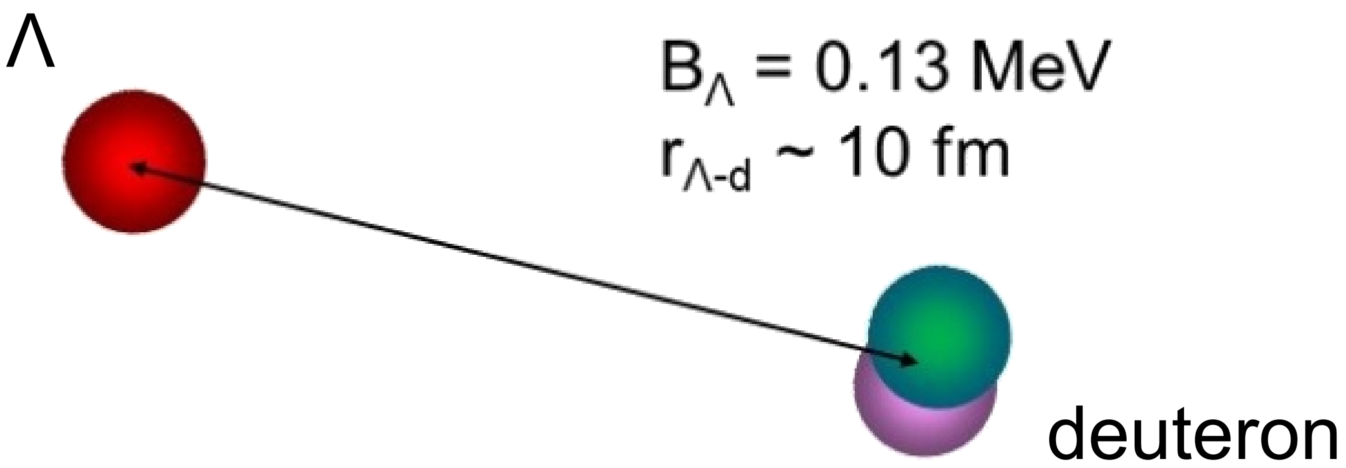
1

Osaka Univ.
Takaya Akaishi
For the J-PARC E73 collaboration

Introduction

- Hypertriton ($^{3}_{\Lambda}H$): Lightest hypernucleus with p, n and Λ
  - Benchmark for hypernuclear physics
  - Small binding energy by emulsion data has been generally accepted.

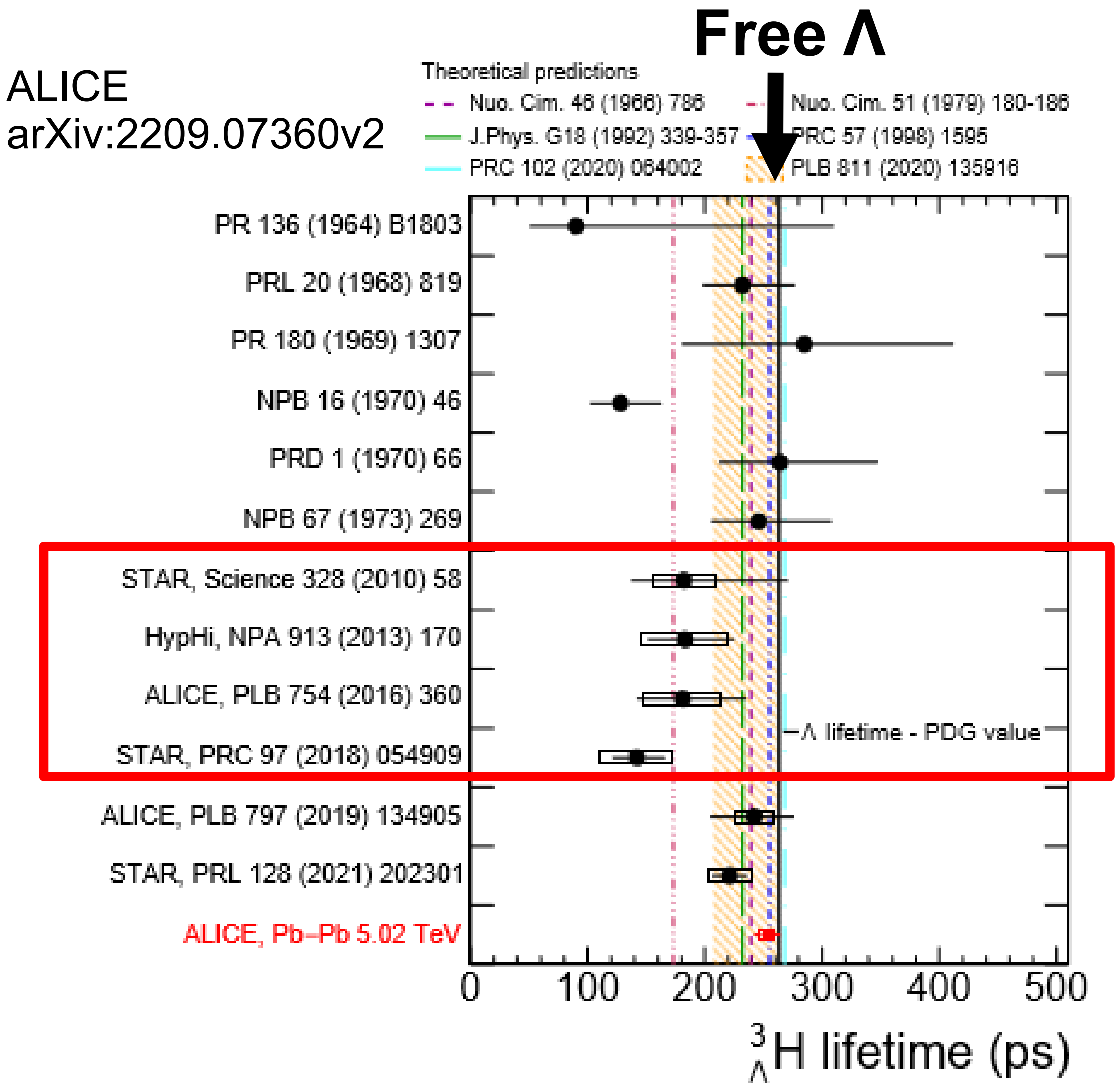
    $B_\Lambda = 130 \pm 50$ keV



✓Small B_Λ → large separation between Λ & d

→ **lifetime τ ~ free Λ is naively expected**

Hypertriton lifetime



Exp.	Lifetime
HypHI(2013)	$183^{+42}_{-32} \pm 37$ ps
ALICE(2016)	$181^{+54}_{-39} \pm 33$ ps
STAR(2018)	$142^{+24}_{-21} \pm 29$ ps

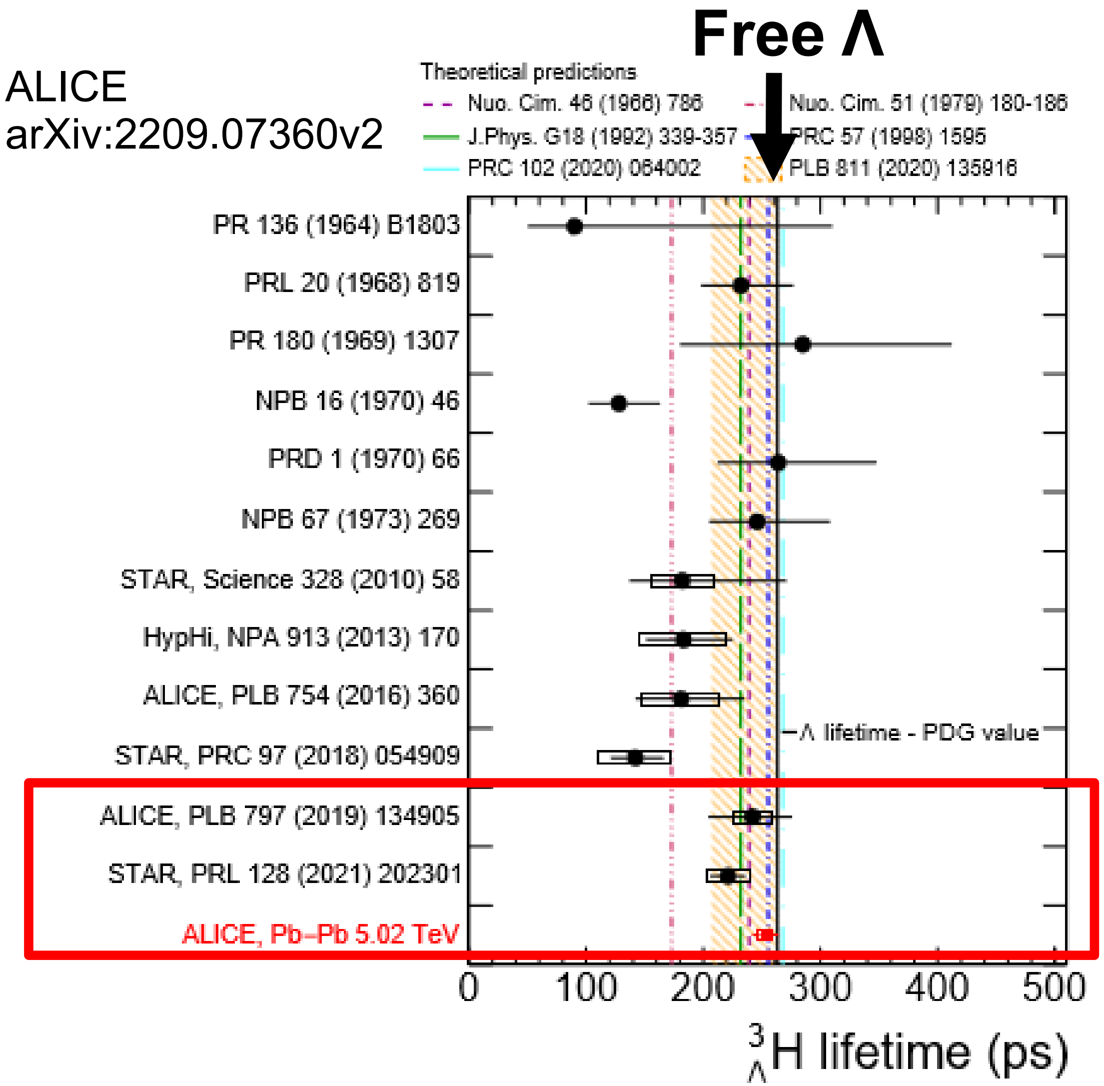
Free Λ(263 ps)

"Hypertriton Lifetime Puzzle"

- **Short lifetimes** from heavy ion experiments in 2010's

Hypertriton lifetime

ALICE
arXiv:2209.07360v2



➢updated result was reported recently

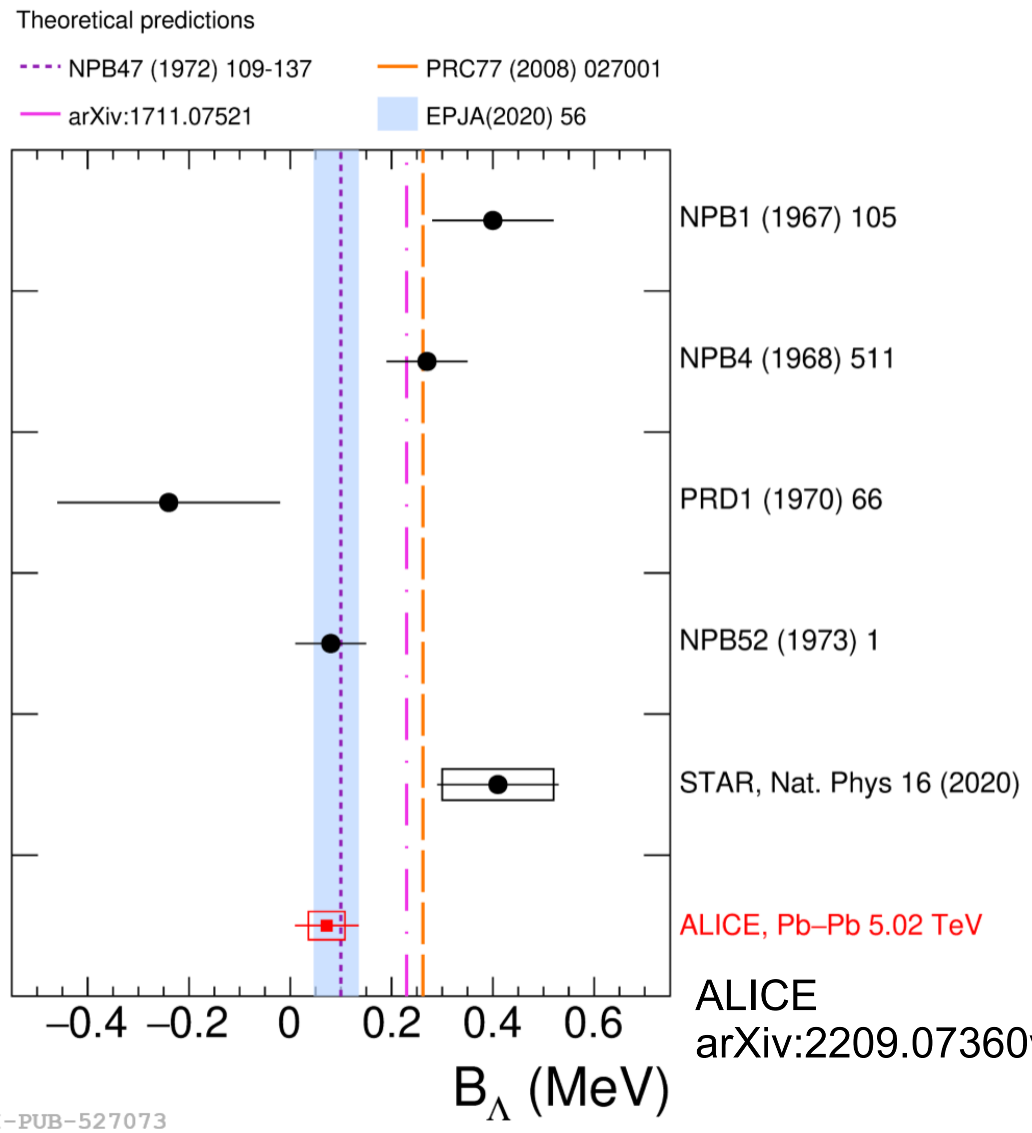
STAR
PRL 128, 202301 (2022)

Exp.	Lifetime
STAR(2021)	$221 \pm 15 \pm 19$ ps
ALICE(2022)	$253 \pm 11 \pm 6$ ps

ALICE
arXiv:2209.07360v2

Comparable with Free Λ

Hypertriton Binding energy



ALICE
arXiv:2209.07360v2

Exp.	Binding energy
Emulsion	0.13 ± 0.05 MeV
STAR(2020)	$0.41 \pm 0.12 \pm 0.11$ MeV
ALICE(2022)	$0.072 \pm 0.063 \pm 0.036$ MeV

The binding energy is still not determined

Need Lifetime and binding energy measurements by a different method
⇒Promoting direct measurement of $^3_\Lambda H$ lifetime at J-PARC

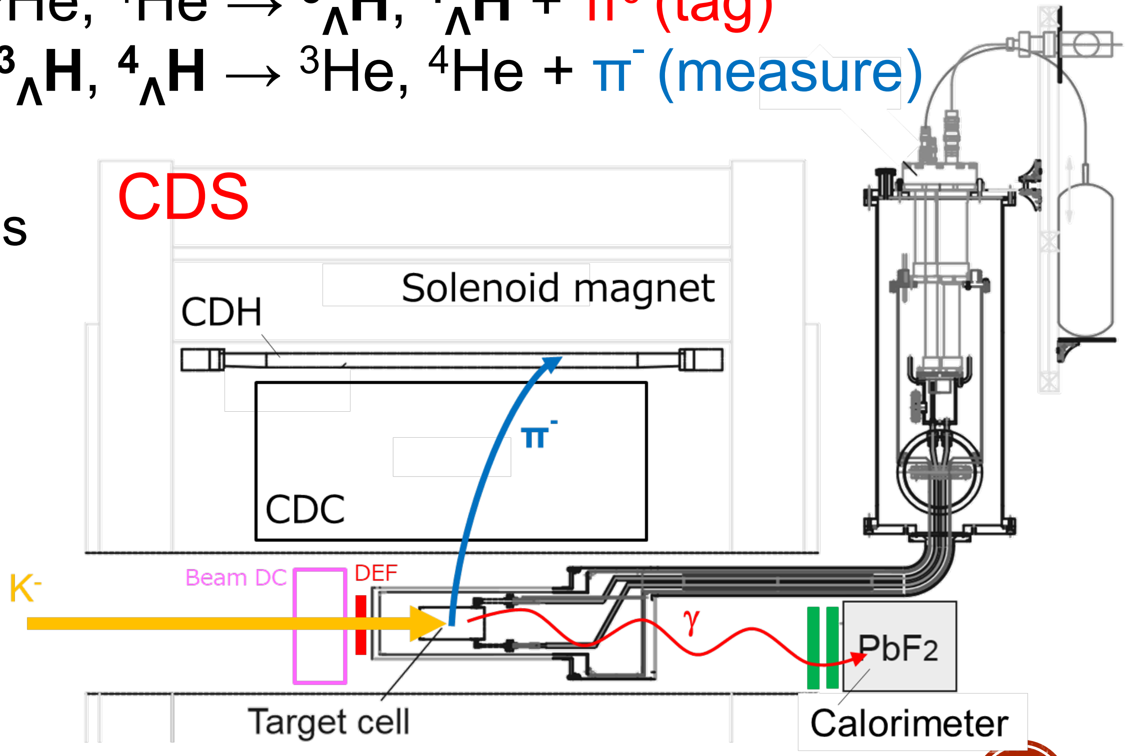
J-PARC E73 experiment

- $^{3}_{\Lambda}$H lifetime direct measurement
  - ➢Hypernuclear production via (K^{-}, π^{0}) reaction
    - ✓Reaction marked by a single forward high energy gamma ray
    - ✓Identification of single momentum π^{-} decaying from resting hypernucleus

$K^{-} + {}^{3}He, {}^{4}He \rightarrow {}^{3}_{\Lambda}\mathbf{H}, {}^{4}_{\Lambda}\mathbf{H} + \pi^{0}$ (tag)

${}^{3}_{\Lambda}\mathbf{H}, {}^{4}_{\Lambda}\mathbf{H} \rightarrow {}^{3}He, {}^{4}He + \pi^{-}$ (measure)

  - ➢Characteristics
    - ✓Strangeness exchange reaction
      Selective production of ground-state hypernucleus
    - ✓Reduction of background
      Y decay and multi-pion production

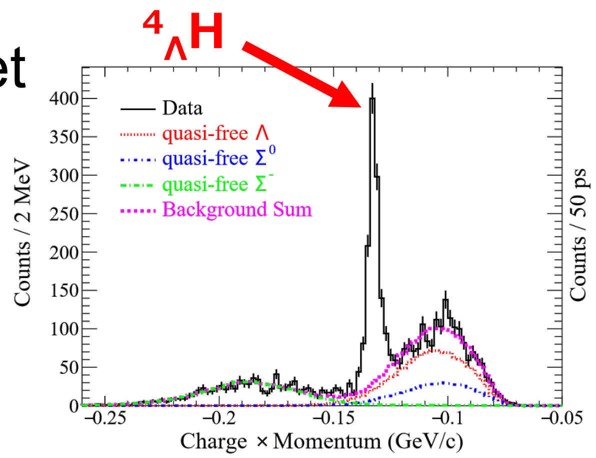


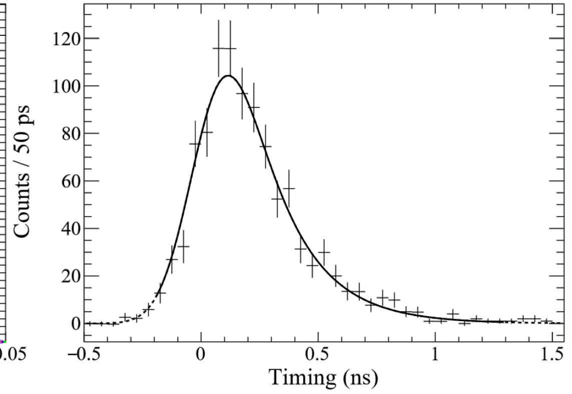
using a new method unique
Identification, Lifetime Measurement

Current status of J-PARC E73

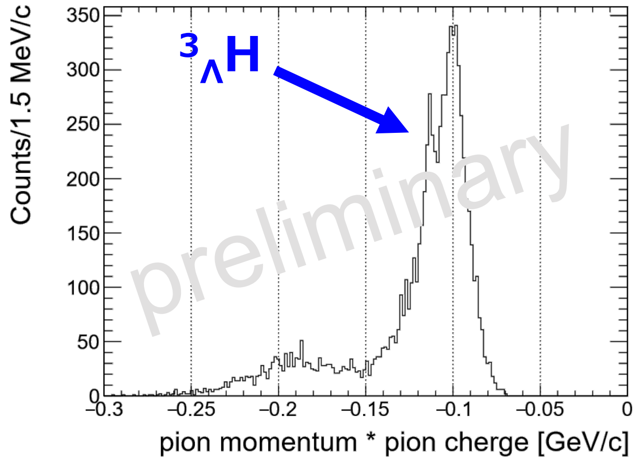
- Phase-0
  - Feasibility study of (K^-, π^0) reaction @^{4}He target
    - ✓Data taking in June 2020 (3 d)
    - ⇒ Establishment of the method, $^4{}_\Lambda$H lifetime

    now being submitted:
    https://arxiv.org/abs/2302.07443





- Phase-1
  - measurement of production cross section of $^3{}_\Lambda$H
    - ✓Data taking in May 2021(4.5 d)
    - ⇒Confirmation and derivation of production cross section (this presentation)

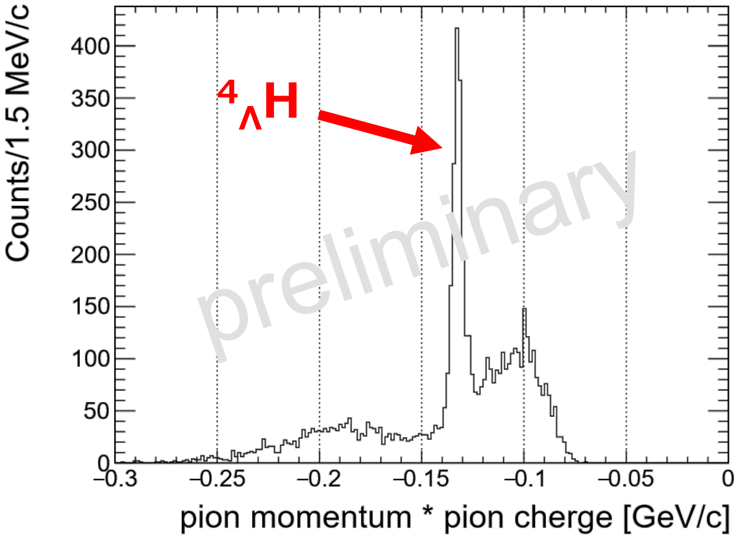


- Phase-2
  - $^3{}_\Lambda$H lifetime measurement
    - ✓planned in JFY2023 (1 month)
    - ⇒**Upgrade to increase the solid angle of forward γ-ray**

    東北大 鶴田(講演番号 24aV2-4)

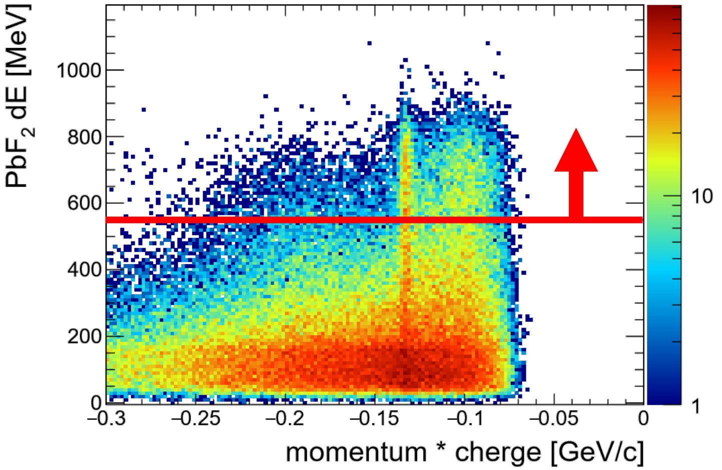
Event selection

- Trigger: Kaon beam ⊗ $\overline{\text{charged particle}}$ ⊗ PbF2 dE
- Offline analysis
  - ➢Pion 1 track
  - ➢PbF2 dE > 550 MeV
  - ➢DCA between beam and pion track < 0.5 cm
  - ➢CDC inner layer multi <=1

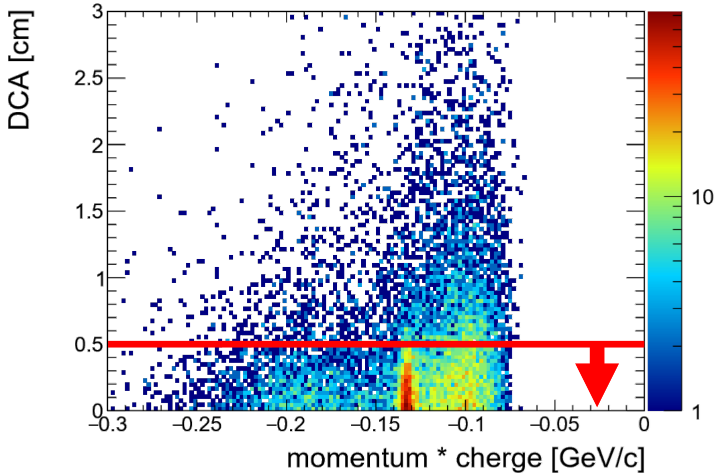


4He target

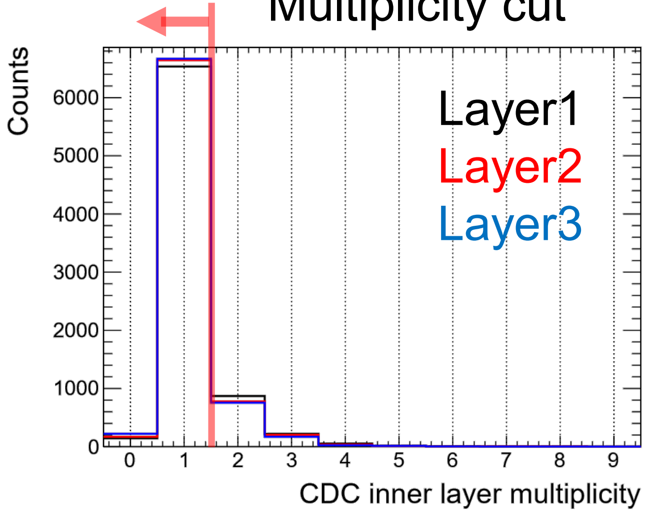
PbF2 dE cut



DCA cut



Multiplicity cut

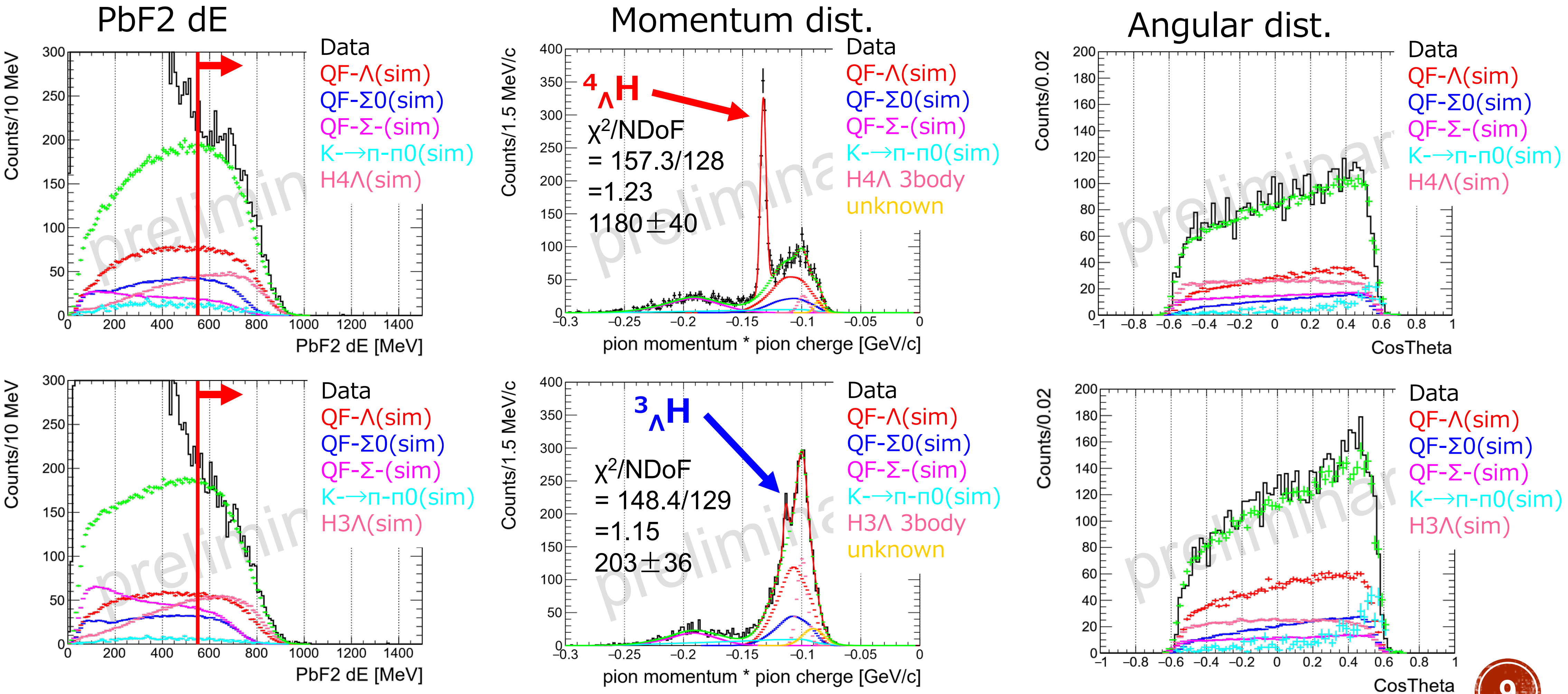


Background estimation

- Reproduction by Geant4 simulation
  - ✓Energy deposit of calorimeter, momentum, and angular distributions

Production (^{4}He target)

Production (^{3}He target)



Integrated production cross section

- $\sigma = \dfrac{N_{signal}}{Luminosity \times A_{CDS} \times A_{PbF2} \times Br \times \epsilon}$
  - A_{PbF2}: π^0 acceptance by PbF2
    Angular distribution $\theta^{lab}_{0°\text{-}20°}$ of the reaction is assumed by theoretical calculation by Prof. Harada (Osaka EC Univ.)
    T. Harada and Y. Hirabayashi
    Nuclear Physics A 1015 (2021) 122301
  - A_{CDS}: π^- acceptance by CDS
  - Br: Calculate Branching ratio to 2-body based on previous experiments
    - ✓Ref: Suplemento de la Revista Mexicana de Fısica30308069 (2022) 1–6

target	Helium-4	Helium-3
# of signal	1180	203
Luminosity(μb^{-1})	928	1020
A_{CDS}	0.523	0.503
A_{PbF2}	0.183	0.189
Br(2-body)	0.507	0.259
ϵ_{CDC}	0.981	0.977
ϵ_{DCA}	0.947	0.914
ϵ_{PbF2dE}	0.549	0.558
ϵ_{DAQ}	0.918	0.926

Result

- $\theta^{lab}_{0°\text{-}20°}$ Integrated cross section(preliminary)

	Experiment	Theory
$\sigma({}^{4}_{\Lambda}H)$	**56 ± 2(stat.) ± 6(syst.) μb**	63.1 μb
$\sigma({}^{3}_{\Lambda}H)$	**18 ± 3(stat.) ± 5(syst.) μb**	25.9 μb (E_Λ= 0.13 MeV) 41.0 μb (E_Λ= 0.41 MeV)

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

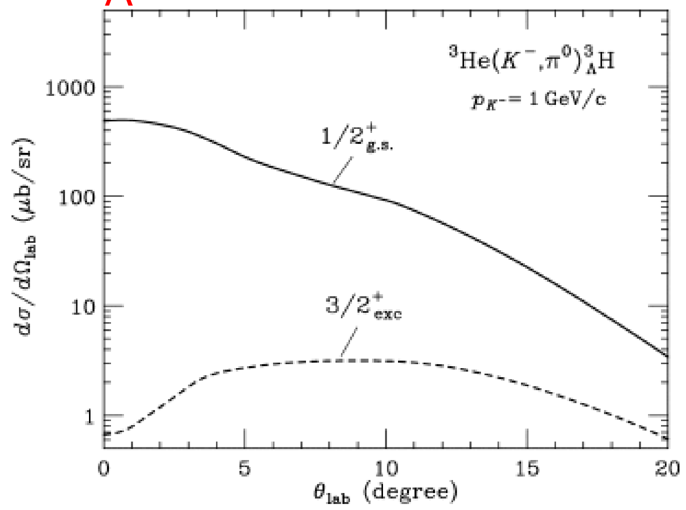
- Main components of systematic error
  - ✓Background subtraction, Uncertainty of gamma-ray selection, Branching ratio(2-body)

Value will be finalized soon!

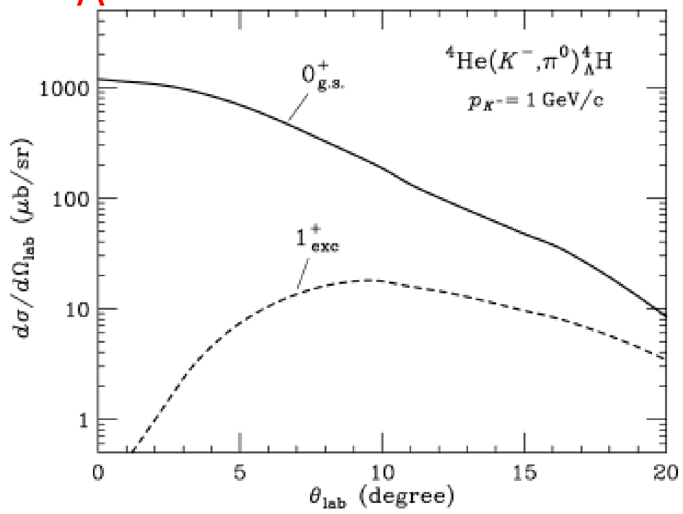
Discussion

- Information of the value of the binding energy of $^{3}_{\Lambda}H$ by the production cross section ratio $\sigma(^{3}_{\Lambda}H)/\sigma(^{4}_{\Lambda}H)$

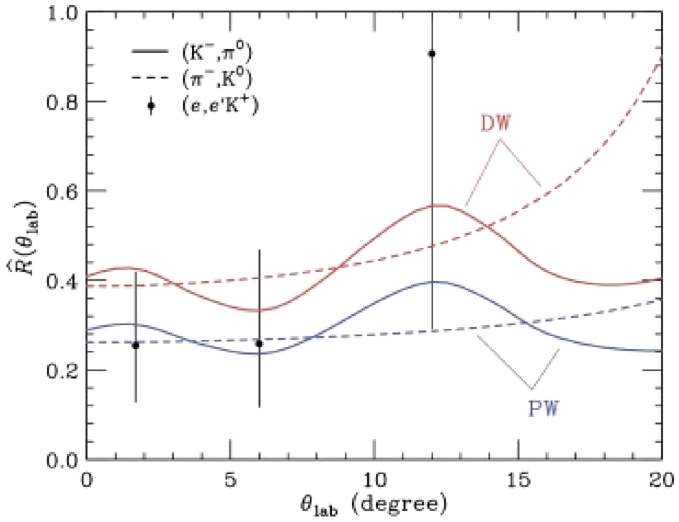
$^{3}_{\Lambda}H$ @B_{Λ}=0.13 MeV



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



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



Emulsion: B_{Λ}=0.13 MeV ⇒ $\sigma(^{3}_{\Lambda}H)/\sigma(^{4}_{\Lambda}H)$ ~ 0.4

heavy ion collision(STAR): B_{Λ}=0.41 MeV ⇒ $\sigma(^{3}_{\Lambda}H)/\sigma(^{4}_{\Lambda}H)$ ~ 0.65

T. Harada and Y. Hirabayashi, NPA 1015 (2021) 122301

➢ **Experimental result: R = 0.31 ± 0.06(stat.) ± 0.09(syst.) (preliminary)**

⇒ Hypertriton prefer loosely bound system

Summary

- Toward Solving the Hypertriton Lifetime Puzzle
  - ➢Lifetime and binding energy must be measured by a method different from heavy-ion collision experiments

- J-PARC E73 experiment
  - ➢Direct Measurement of Hypertriton Lifetime
    - ✓Selective production of the ground state of hypernucleus by the (K^-, π^0) reaction

- Integrated production cross section of $^4_\Lambda H$, $^3_\Lambda H$
  - ➢**$\sigma(^4_\Lambda H)$ = 56 ± 2(stat.) ± 6(syst.) μb**
  - ➢**$\sigma(^3_\Lambda H)$ = 18 ± 3(stat.) ± 5(syst.) μb**

  (preliminary)

- Information of the value of the binding energy of $^3_\Lambda H$
  - ➢**R = 0.31 ± 0.06(stat.) ± 0.09(syst.) (preliminary)**

    ⇒ Hypertriton prefer loosely bound system

J-PARC E73 collaboration

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Backup

Experiments on Hypertriton

- Heavy ion-based experiments
  - ALICE Run 3(2021~2024), Run 4 (2027~2030): ~50 times yield expected
  - GSI (WASA-FRS experiment) data taking performed in 2022

- Counter experiments for lifetime
  - ELPH, Tohoku-U, Japan: (γ, K^{+})
  - J-PARC P74: (π^{-}, K^{0})
  - J-PARC E73: $(K^{-}, \pi^{0}) \leftarrow$ Our project

- Binding energy measurement
  - MAMI (e, e'K) decay pion spectroscopy data taking performed in 2022
  - JLab (e, e'K)
  - J-PARC E07: Emulsion full scan

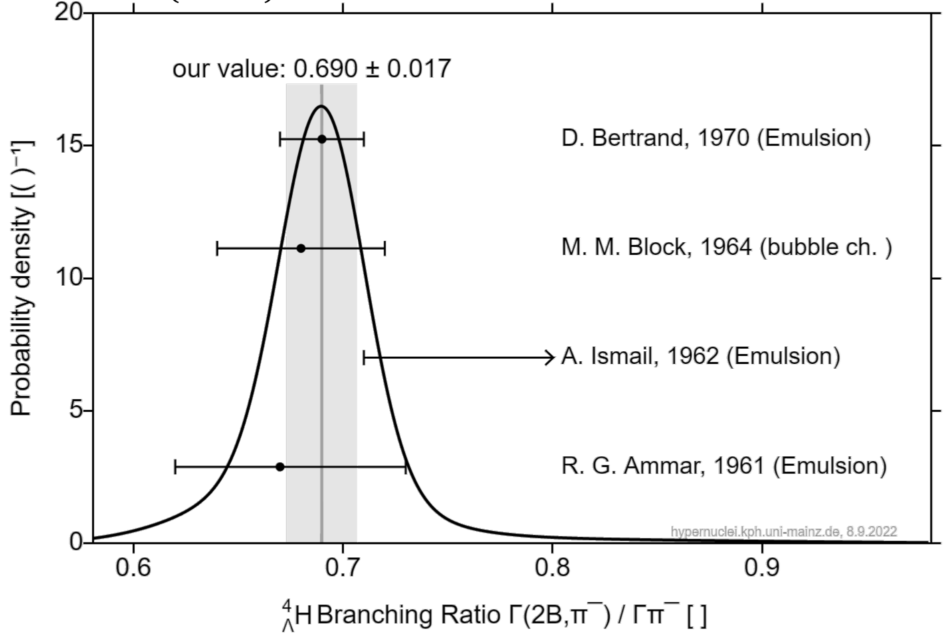
${}^{4}_{\Lambda}\mathrm{H}$ 2 body decay branching ratio

$$\frac{\Gamma({}^{4}_{\Lambda}\mathrm{H} \to \pi^- + {}^{4}\mathrm{He})}{\Gamma(all)} = \frac{\Gamma({}^{4}_{\Lambda}\mathrm{H} \to \pi^- + {}^{4}\mathrm{He})}{\Gamma(\pi^-\ all)} \times \frac{1}{(\Gamma(\pi^-\ all) + \Gamma(\pi^0\ all) + \Gamma(nm\ all))/\Gamma(\pi^-\ all)}$$

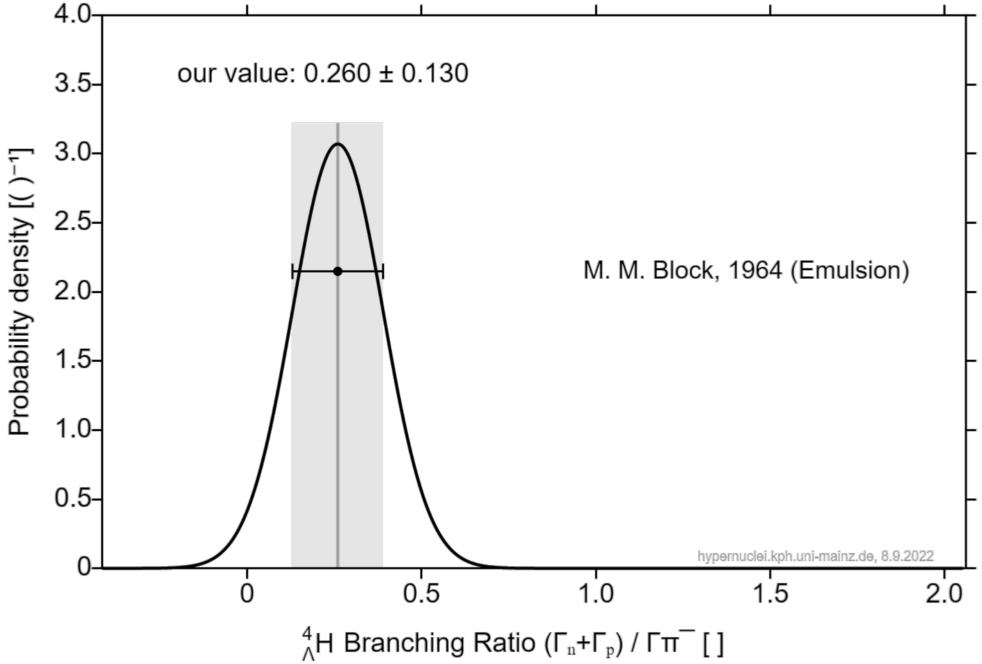
$$= \frac{0.690 \pm 0.017}{1 + 0.1 + (0.260\ \pm 0.130)}$$

$$= 0.51 \pm 0.05$$

$$\frac{\Gamma({}^{4}_{\Lambda}\mathrm{H} \to \pi^- + {}^{4}\mathrm{He})}{\Gamma(\pi^-\ all)}$$



$$\frac{\Gamma(non\ mesonic)}{\Gamma(\pi^-\ all)}$$



https://arxiv.org/pdf/2201.02368.pdf

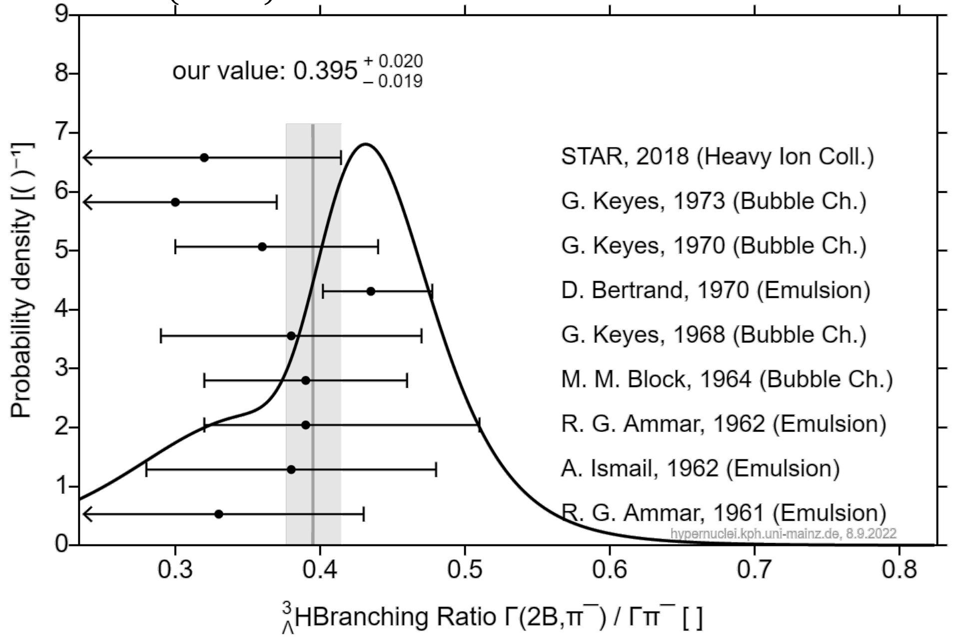
${}^{3}_{\Lambda}$H 2 body decay branching ratio

$$\frac{\Gamma({}^{3}_{\Lambda}\mathrm{H} \to \pi^- + {}^{3}\mathrm{He})}{\Gamma(all)} = \frac{\Gamma({}^{3}_{\Lambda}\mathrm{H} \to \pi^- + {}^{3}\mathrm{He})}{\Gamma(\pi^-\ all)} \times \frac{1}{\left(\Gamma(\pi^-\ all) + \Gamma(\pi^0\ all) + \Gamma(nm\ all)\right)/\Gamma(\pi^-\ all)}$$

$$= \frac{0.395^{+0.020}_{-0.019}}{1 + 0.5 + 0.025}$$

$$= 0.259\ {}^{+0.013}_{-0.012}$$

$$\frac{\Gamma({}^{3}_{\Lambda}\mathrm{H} \to \pi^- + {}^{3}\mathrm{He})}{\Gamma(\pi^-\ all)}$$



https://arxiv.org/pdf/2201.02368.pdf

- 分母は鎌田さんの理論計算

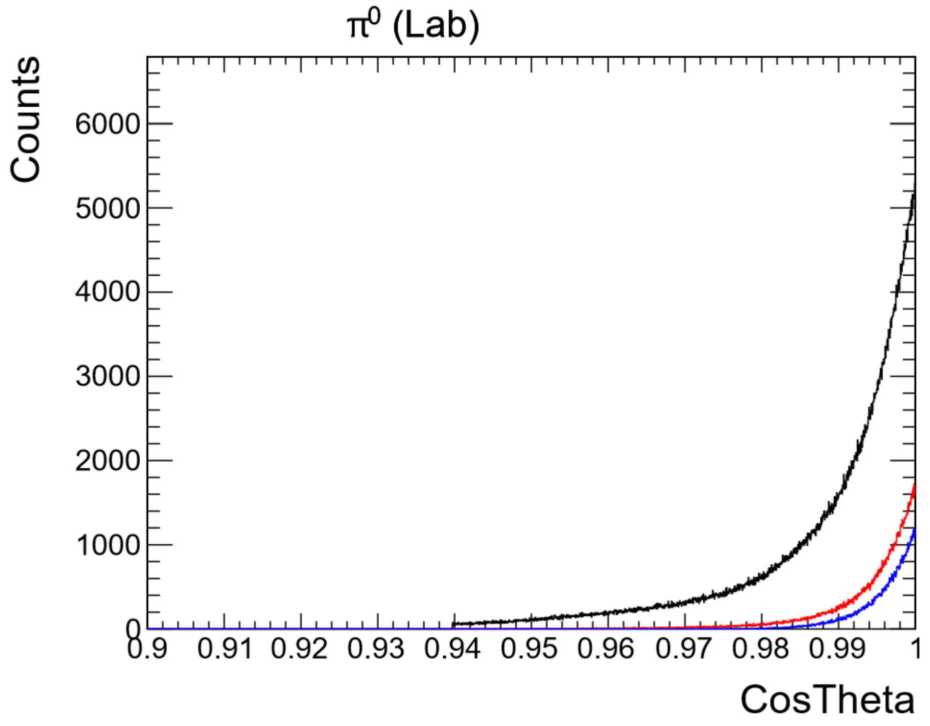
https://doi.org/10.1103/PhysRevC.57.1595

π^0 acceptance by PbF2

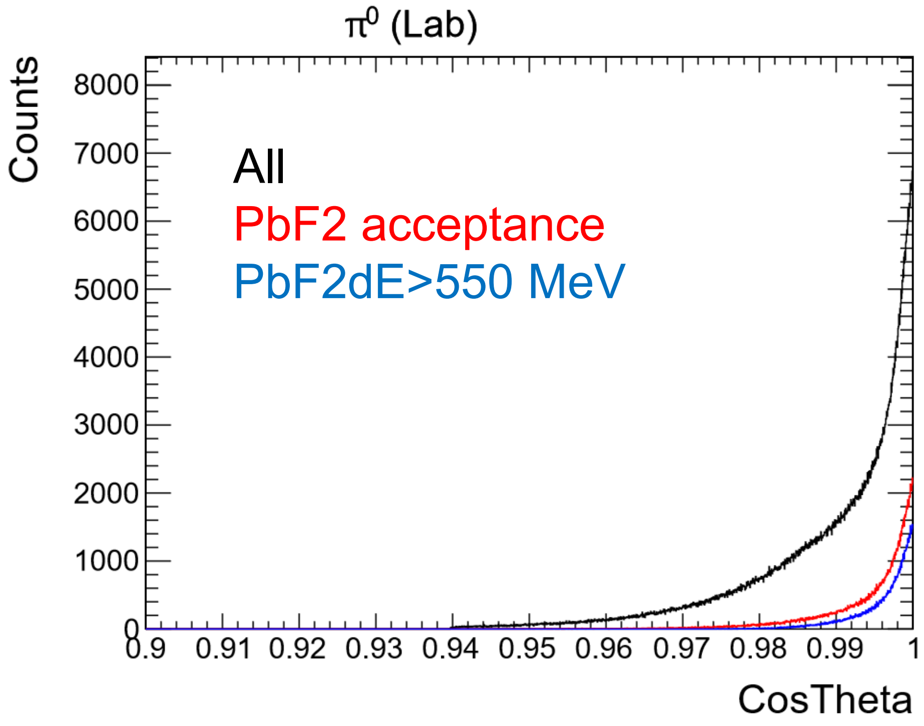
Angular distribution $\theta^{lab}_{0°\text{-}20°}$ of the reaction is assumed by theoretical calculation by Prof. Harada (Osaka EC Univ.)

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

$^4_\Lambda H$



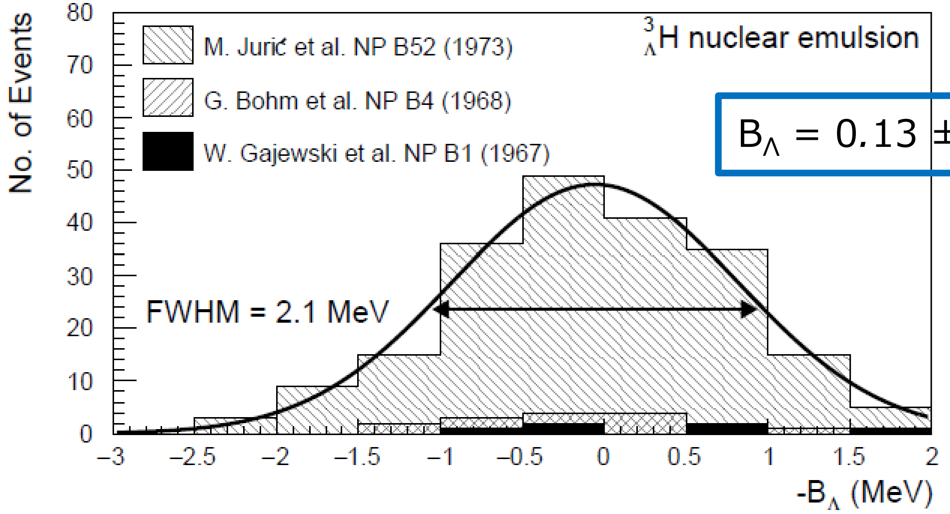
$^3_\Lambda H$@B_Λ=0.13 MeV



Binding energy

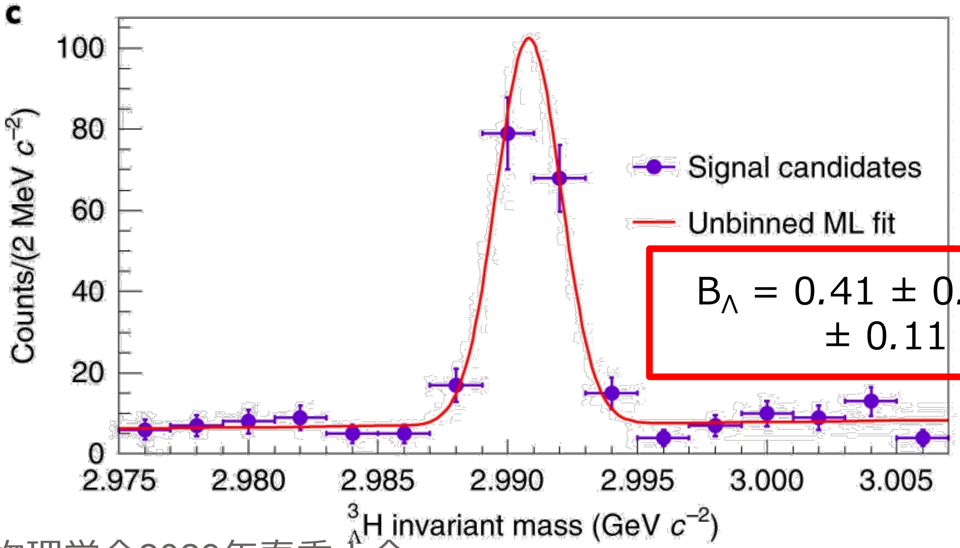
Emulsion measurement

P. Achenbach, *et al*, *PoS(Hadron2017)207*



B_{Λ} = 0.13 ± 0.05 MeV

Heavy-ion experiment – STAR in Au-Au collisions

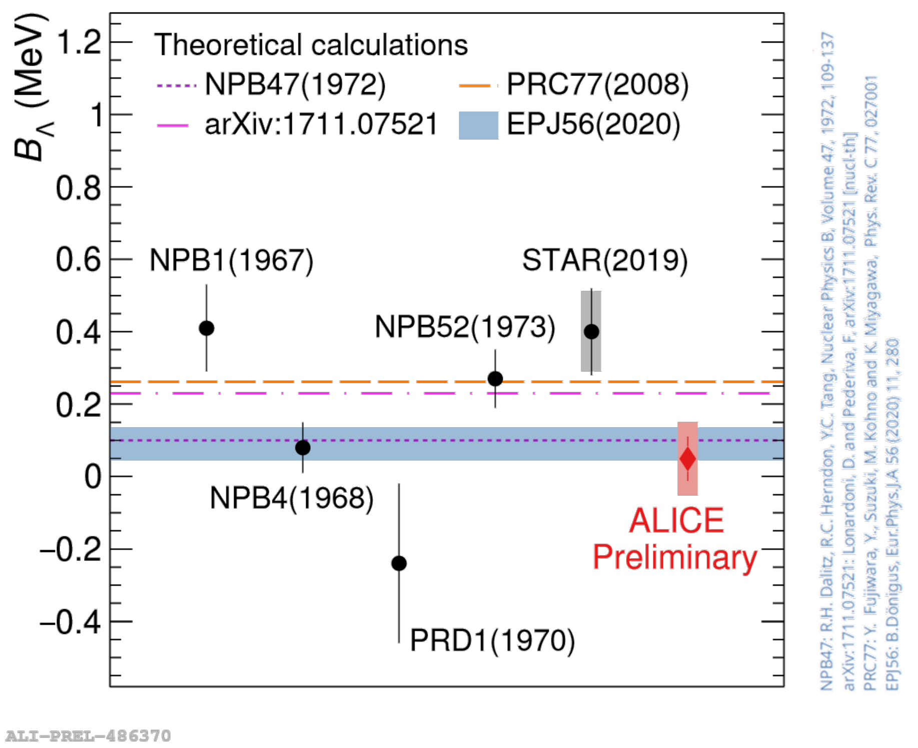


B_{Λ} = 0.41 ± 0.12 (stat.)
± 0.11 (syst.) MeV

STAR collaboration
Nature Physics **volume 16**,
pages409–412 (2020)

Heavy-ion experiment
– ALICE in 2018 Pb-Pb collisions

Michael Hartung,
PANIC2021



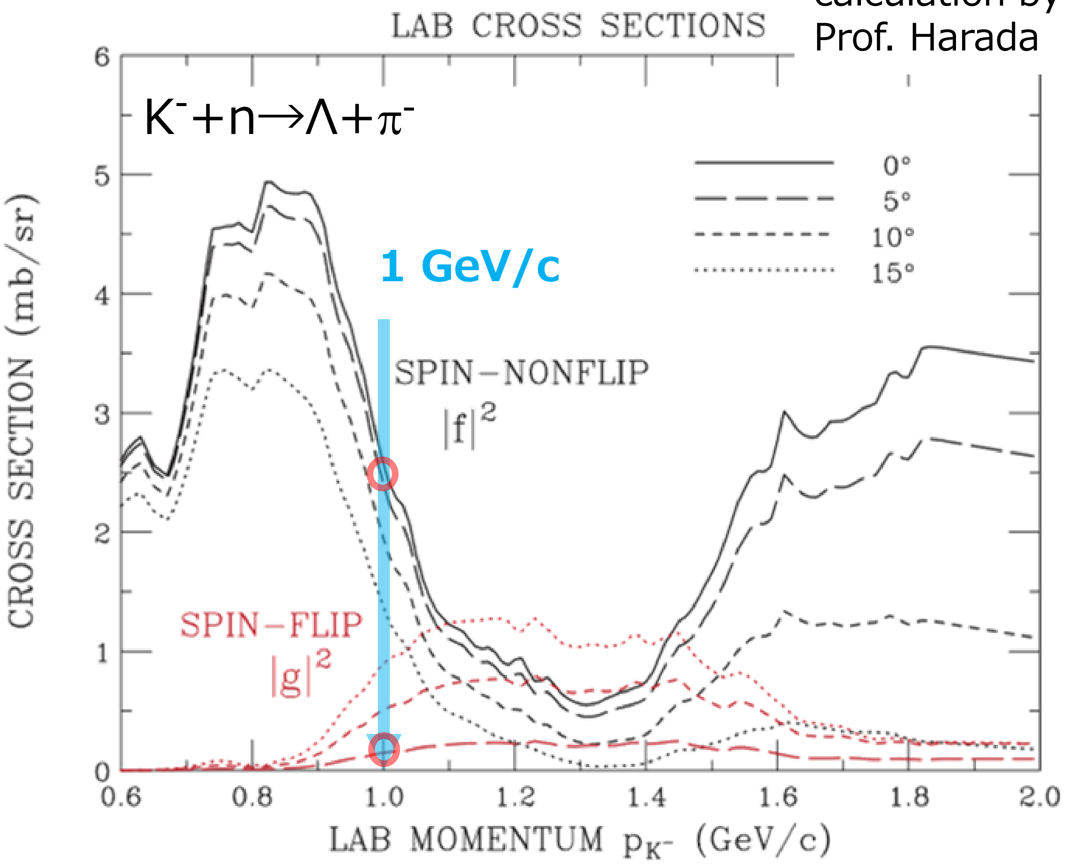
**The binding energy
is still not determined**

Toward solving hypertriton lifetime puzzle

- an independent experimental approach is needed
  ⇒ **Measurement using strangeness exchange reaction (J-PARC E73)**

Experiment	ALICE, STAR	J-PARC E73
Production method	Heavy ion collision	$^3He(K^-, \pi^0)^3_\Lambda H$
Microscopic process	Thermal model; Coalescence model	**Strangeness exchange**
Quantum number	1/2 and 3/2 mixture?	**spin=1/2 dominant**

calculation by Prof. Harada

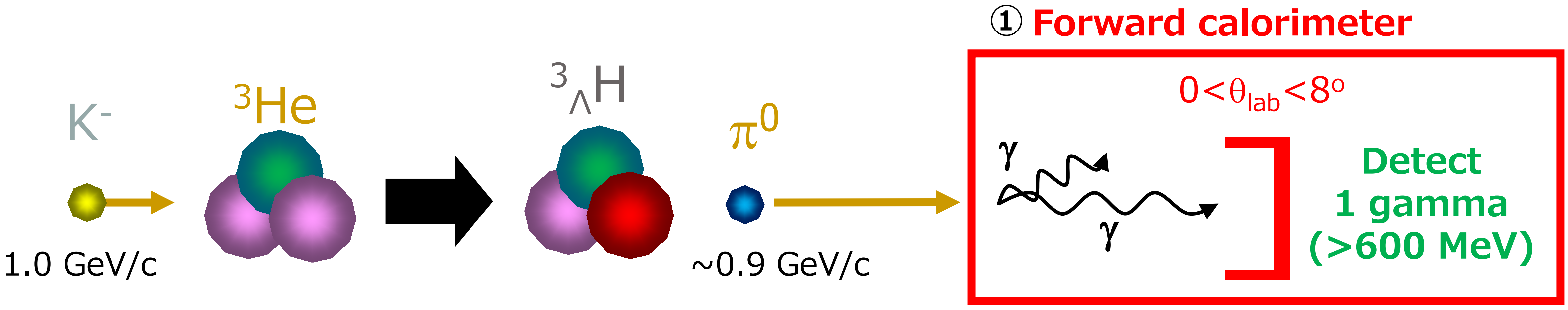


- ➢ produce the ground state of $^3_\Lambda H(1/2^+)$
- ➢ **provide important data on the hypertriton lifetime puzzle**

J-PARC E73 experiment with (K^-,π^0) reaction

J-PARC E73: Experimental principle

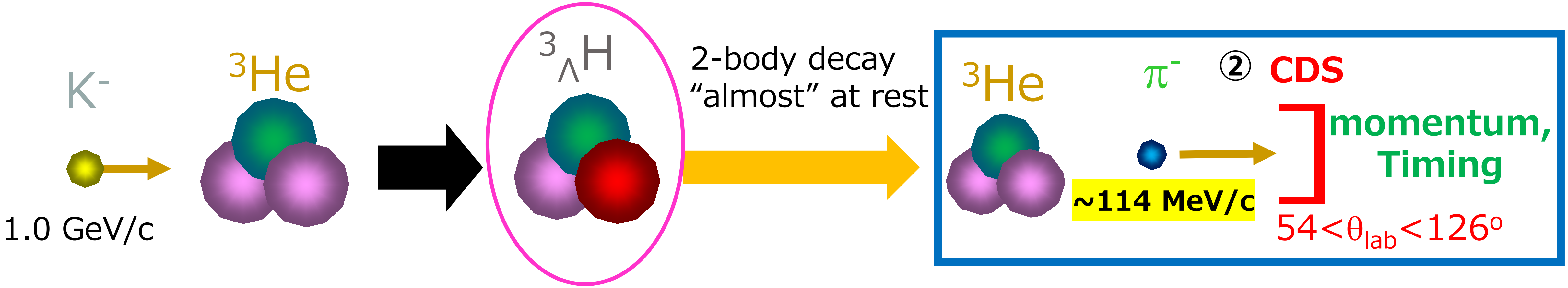
✓^{3}He(K^{-}, π^{0})$^{3}_{\Lambda}$H reaction



①tag (K^{-}, π^{0}) reaction by detecting
forward single high-energy gamma with calorimeter
→almost 100% detection efficiency for forward going π^{0} (0< $\theta_{lab}^{\pi^0}$ <10)
⇒tag Λ production with low recoil momentum
Reduce BG from Y decays and multi pion production

J-PARC E73: Experimental principle

✓^{3}He(K^{-}, π^{0})$^{3}_{\Lambda}$H reaction



②Measure Momentum and Timing with Cylindrical Detector System (CDS)

select the mono-momentum of π- after 2-body decay

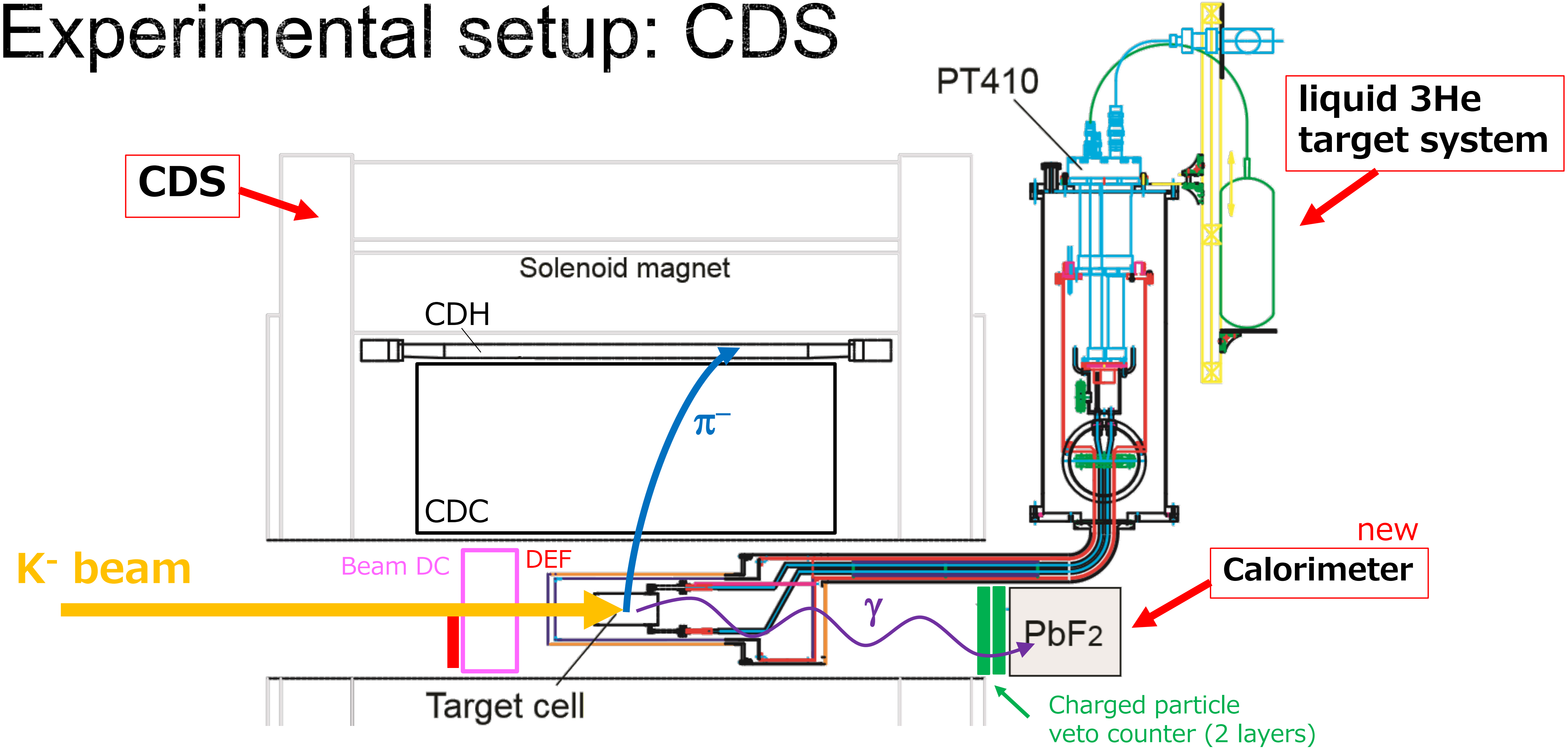
low recoil momentum (~100 MeV/c)

→Hypertriton stops immediately inside the target

⇒2-body decay "almost" at rest

Identify $^{3}_{\Lambda}$H and derive lifetime from decay timing

Experimental setup: CDS



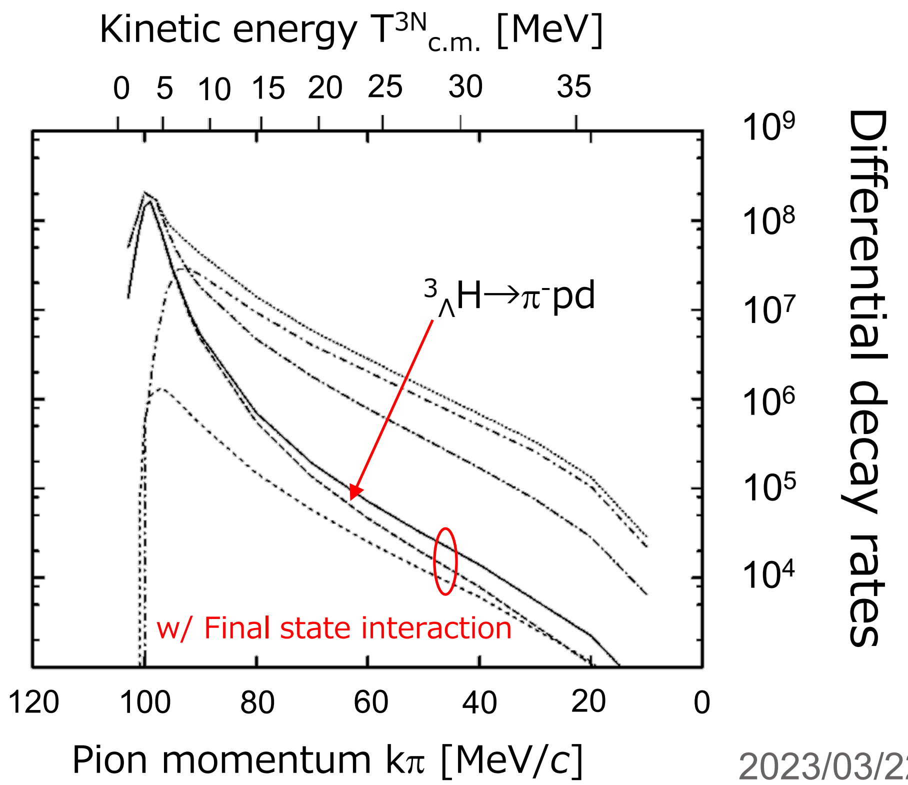
CDS has worked well in K1.8BR Beamline

Used in E15(K^-pp)/E31(Λ1405)/E57(K^-d atom)

$^{3}_{\Lambda}H$ 3-body decay

- Why be seen peak structure of 3-body decay
  - Qualitative
    - ✓$^{3}_{\Lambda}H$ 3-body decay
    - ✓large separation between Λ & d → fermi motion of Λ is small
    - ✓Small effect to pion momentum
  - Theorical
    - ✓Based on hypertriton wave function and scattering states
    - ✓H. Kamada, et al., Phys. Rev. C57, 1595 (1998)

From 3-body events,
Can understand
the structure of the hypertriton ?



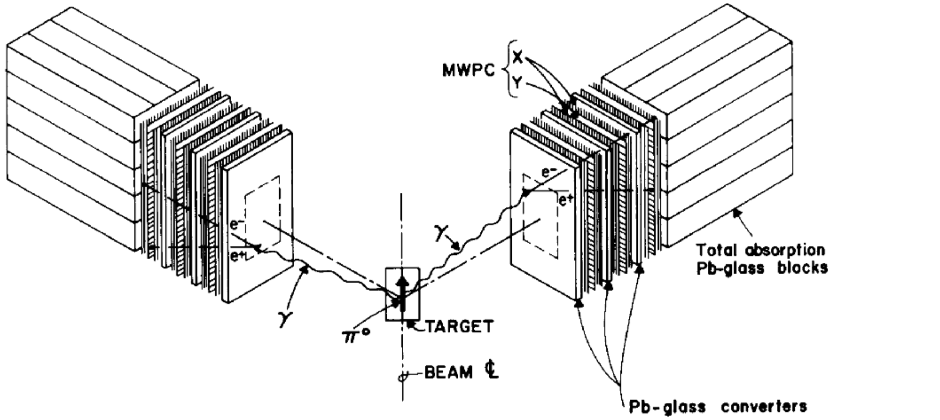
Previous Experiment using (K⁻,π^0) reaction

- Neutral Meson Spectroscopy @BNL (1997)
  - Reaction: $^{12}C(\text{stop } K^-, \pi^0)^{12}_{\Lambda}B$
  - Measured π^0 energy

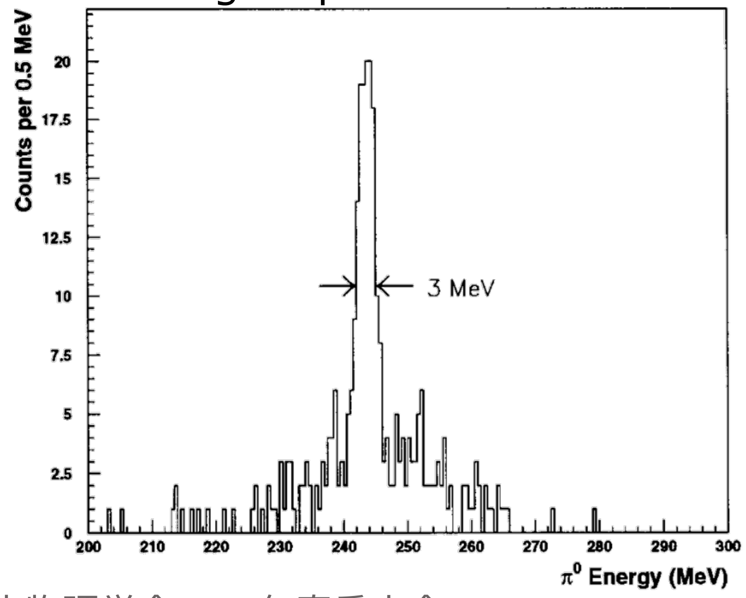
✓ $$E_{\pi^0} = E_1 + E_2 = m_{\pi^0}\sqrt{\frac{2}{(1-\cos\eta)(1-X^2)}},\ X = \frac{E_1-E_2}{E_1+E_2}$$

η: opening angle

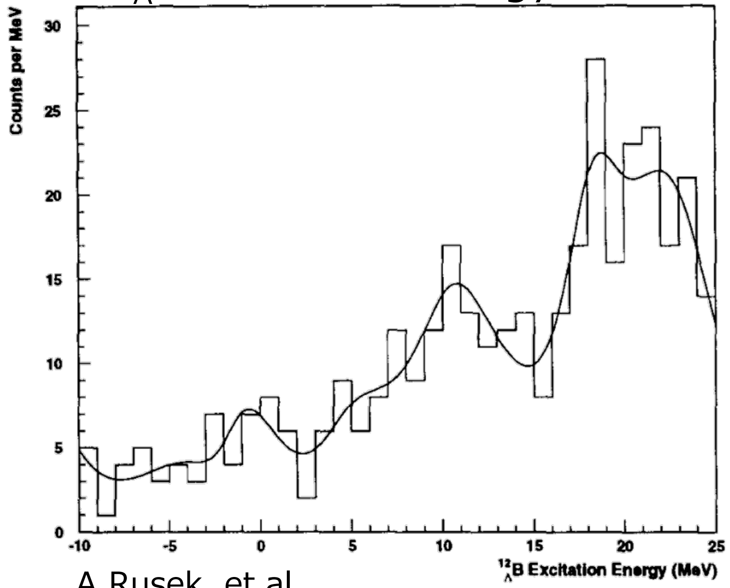
H.W. Baer, et al.,
Nucl. Inst. Meth. 180(1981)445



Energy resolution
using stop $K^+ \to \pi^+ + \pi^0$



$^{12}C(\text{stop } K^-, \pi^0)$ reaction
$^{12}_{\Lambda}B$ excitation energy



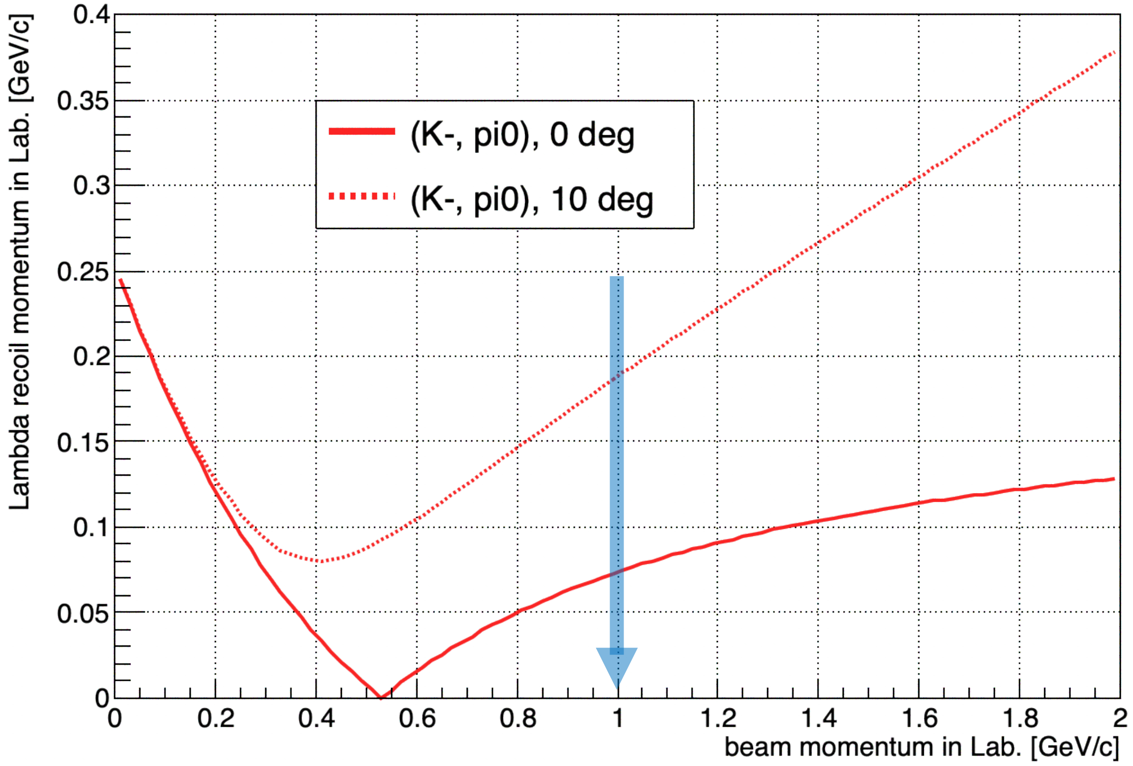
A.Rusek, et al.,
Nucl. Phys. A 639(1998)111c

Difficult method

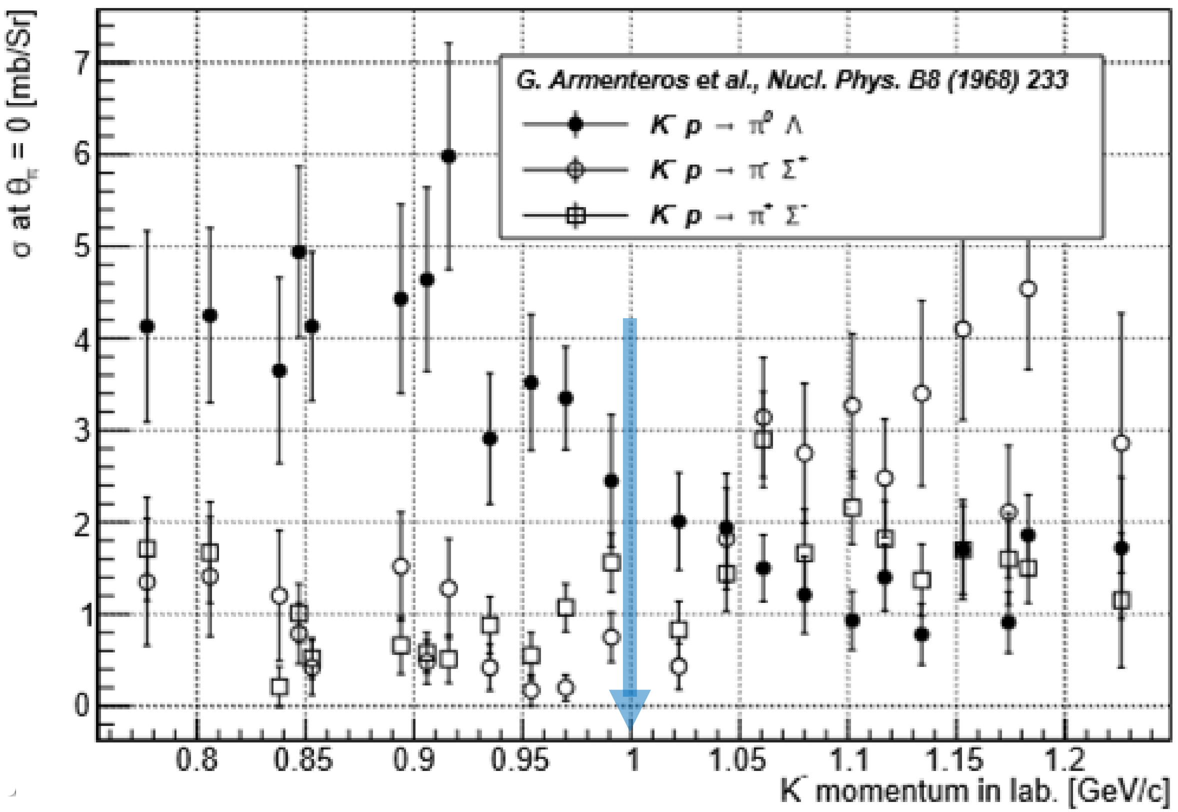
Experiment concept

Beam Momentum selection

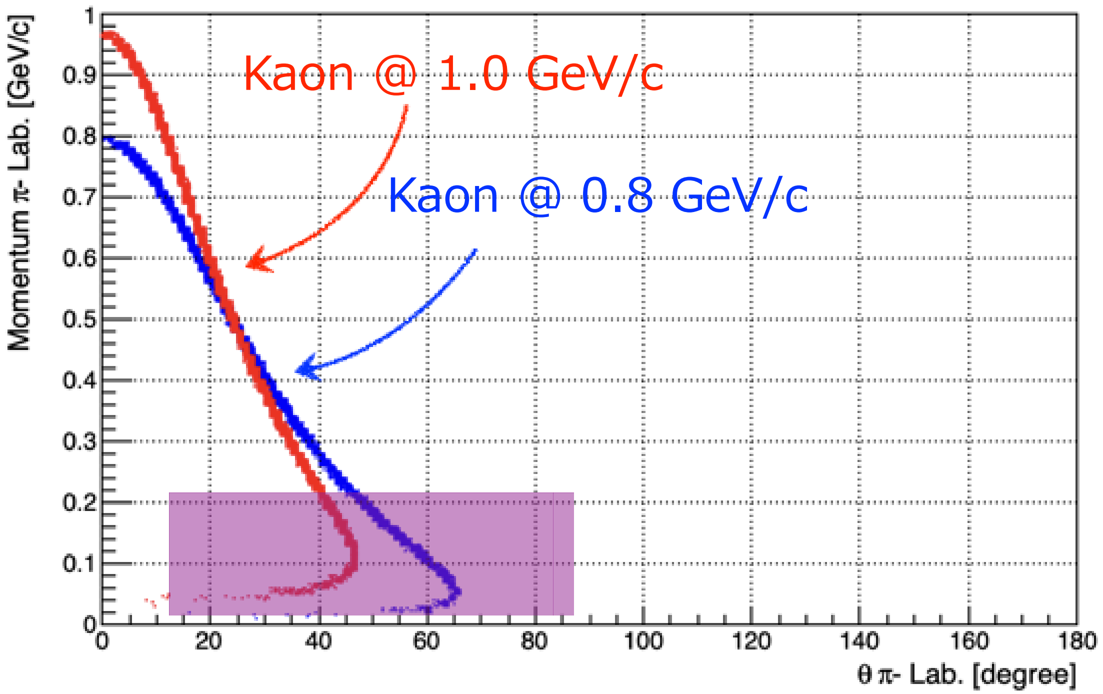
Lambda recoil momentum vs meson scattering angle



Elementary cross section

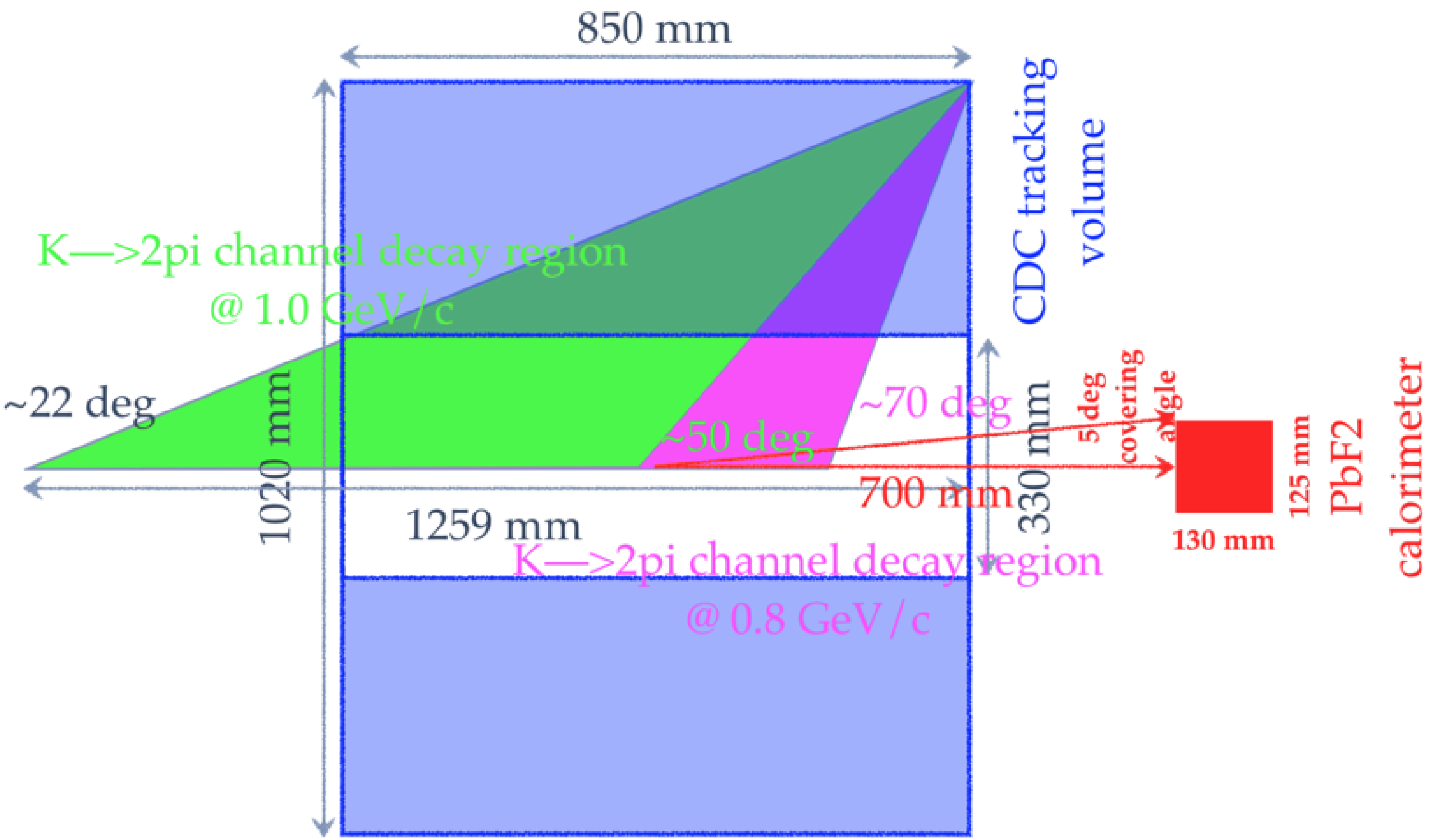


Background events from Kaon in-flight decay



- For setup like SKS dipole magnet spectrometer, there are severe BG from K- inflight decay.
- But in our case, a conjunction measurement of both pi- and pi0, the kaon decay backgrounds can be suppressed by using the pi- decay angle and decay vertex.

CDC acceptance vs Kaon decay background



- Most of the 1.0 GeV/c K- beam in-flight decay background is out of the acceptance of CDS spectrometer.

Reaction and final states

out of
pi0⊕pi-
acceptance

Reaction(decay) and final states		Charged particle timing structure	Branching ratio	σ [mb/Sr] for p_{K^-}=0.9GeV/c and θ_{π^0}=0
$K^- {}^3He \to \pi^0 {}^3_\Lambda H \to$	$\pi^0 \pi^- {}^3He \to 2\gamma \pi^- {}^3He$	delayed π^-	?%	?%
	$\pi^0 p n n_s \to 2\gamma p n n$	delayed p	?%	?%
$K^- \to$	$\pi^0 \mu^- \bar{\nu}_\mu \to 2\gamma \mu^- \bar{\nu}_\mu$	prompt μ^-	3.32%	Not included
	$\pi^0 \pi^- \to 2\gamma \pi^-$	prompt π^-	20.92%	
	$\pi^0 \pi^0 \pi^- \to 4\gamma \pi^-$	prompt π^-	1.76%	
$K^- p \to \pi^0 \Lambda \to$	$\pi^0 \pi^0 n \to 4\gamma n$	N. A.	35.8%	4.5
	$\pi^0 \pi^- p \to 2\gamma \pi^- p$	delayed π^-, p	63.9%	
$K^- p \to \pi^0 \Sigma^0 \to \pi^0 \gamma \Lambda \to$	$\pi^0 \gamma \pi^0 n \to 5\gamma n$	N. A.	35.8%	0.36 (scaled)
	$\pi^0 \gamma \pi^- p \to 3\gamma \pi^- p$	delayed π^-, p	63.9%	
$K^- p \to \pi^- \Sigma^+ \to$	$\pi^- \pi^0 p \to 2\gamma \pi^- p$	prompt π^-, delayed p	51.57%	0.9
	$\pi^- \pi^+ n$	N. A.	48.31%	
$K^- p \to \pi^+ \Sigma^- \to \pi^+ \pi^- n$		N. A.	100%	Not included
$K^- n \to \pi^- \Lambda \to$	$\pi^- \pi^0 n \to 2\gamma \pi^- n$	prompt π^-	35.8%	Not included
	$\pi^- \pi^- p \to 2\pi^- p$	N. A.	63.9%	
$K^- n \to \pi^- \Sigma^0 \to \pi^- \gamma \Lambda \to$	$\pi^- \gamma \pi^0 n \to 3\gamma \pi^- n$	prompt π^-	35.8%	Not included
	$\pi^- \gamma \pi^- p \to \gamma 2\pi^- p$	N. A.	63.9%	
$K^- n \to \pi^0 \Sigma^- \to$	$\pi^0 \pi^- n \to 2\gamma \pi^- n$	delayed π^-	100%	0.9 (scaled)

Table 4: Survey for $K^- + {}^3He \to$ forward π^0 + delayed π^-.

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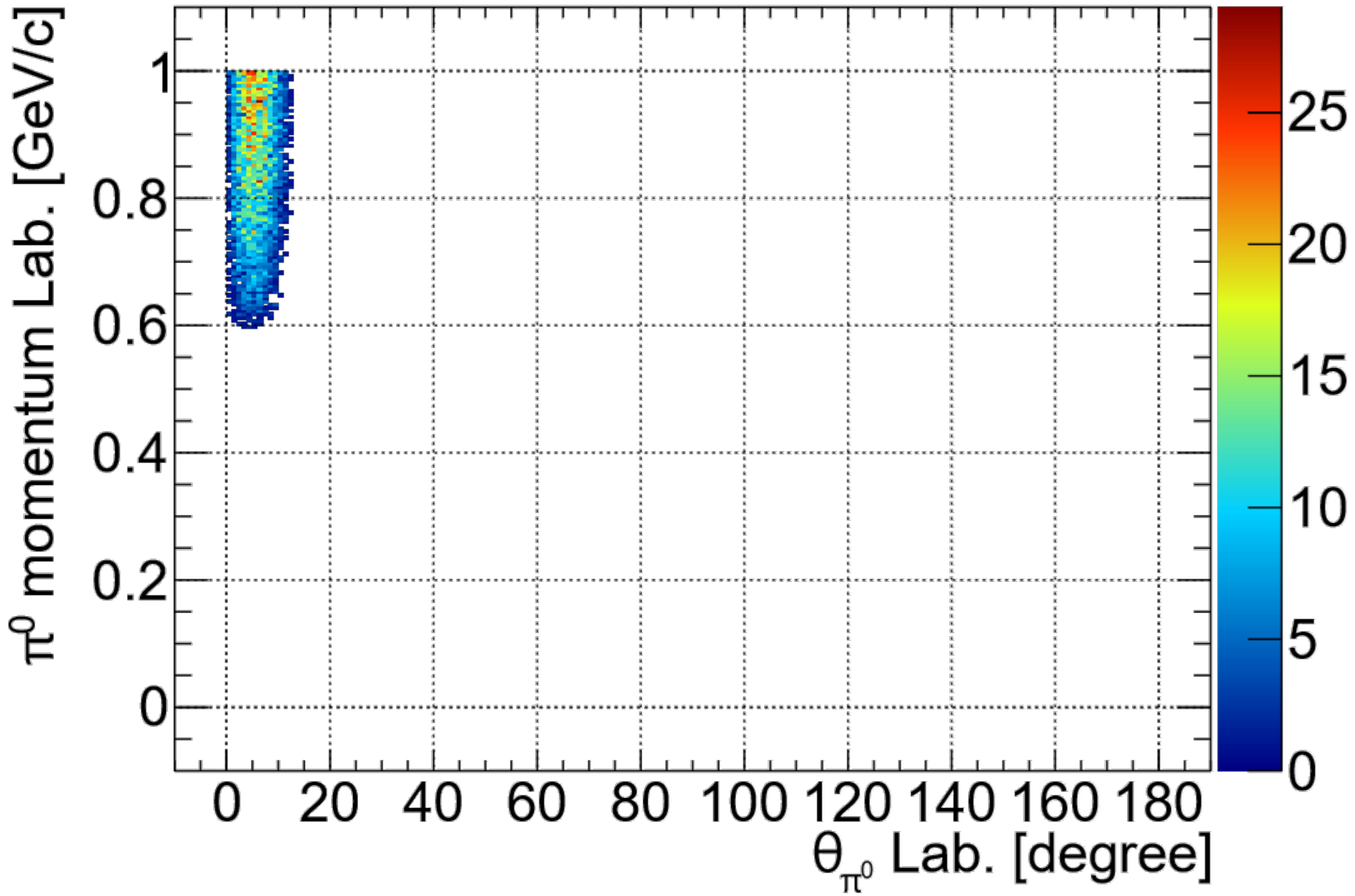
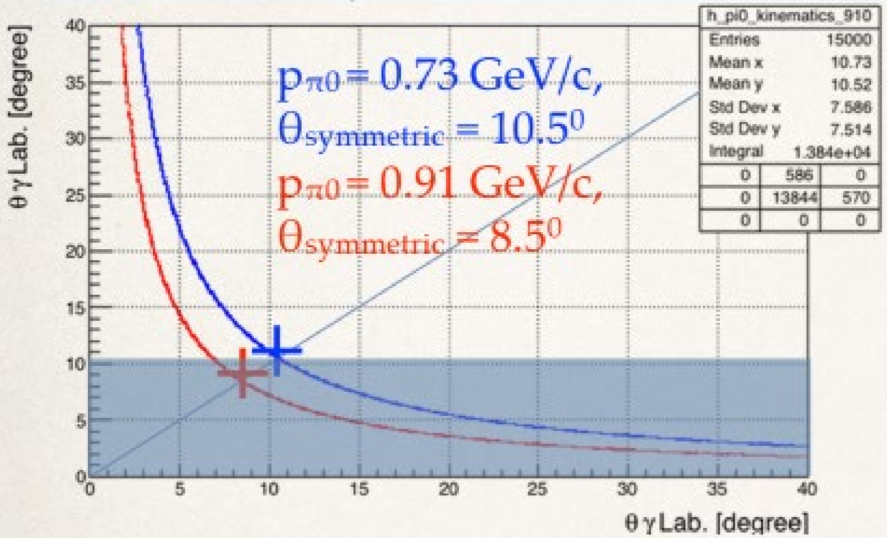
Tagging single γ-ray

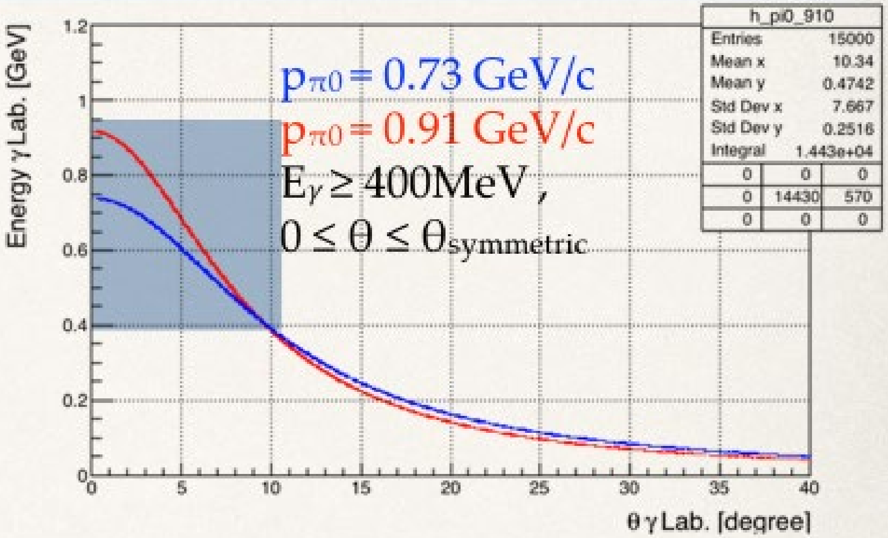
- Simulation: π^0 uniformly 0~1 GeV/c, 0~180 deg
  - Forward calorimeter energy select >0.6 GeV gamma

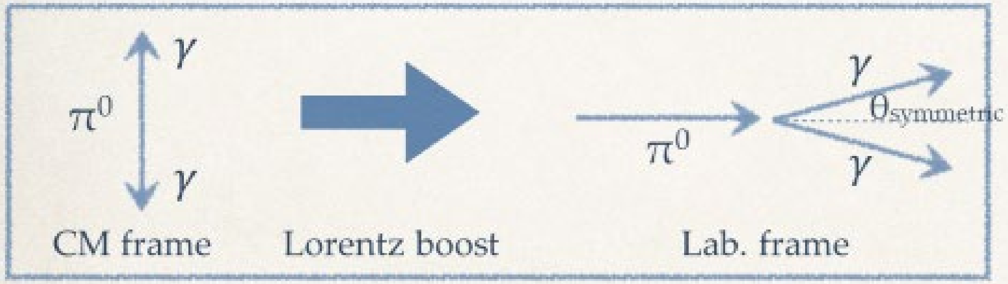


✓forward high-energy π^0 can be selected by detecting 1 gamma

Revisit π^0 decay kinematics







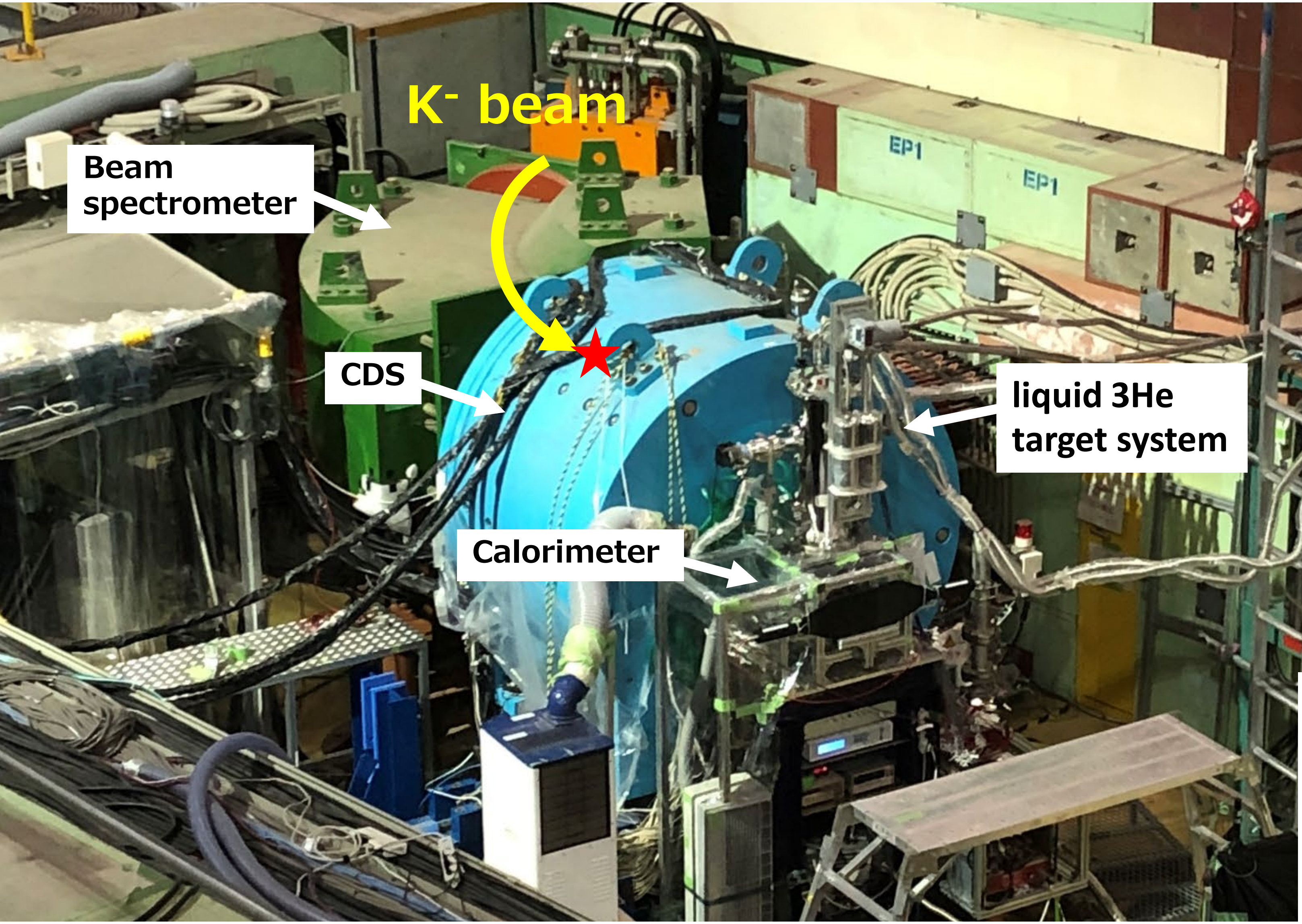
- 0.73~0.91GeV/c π^0 boosts γ forwardly;
- By covering 0~$\theta_{symmetric}$, tag the γ with higher energy ($E_\gamma \geq$ 400MeV)

- π^0 tagger needs to be ***located along beam line***
- ***Fast response, radiation hardness***

12

CDS performance

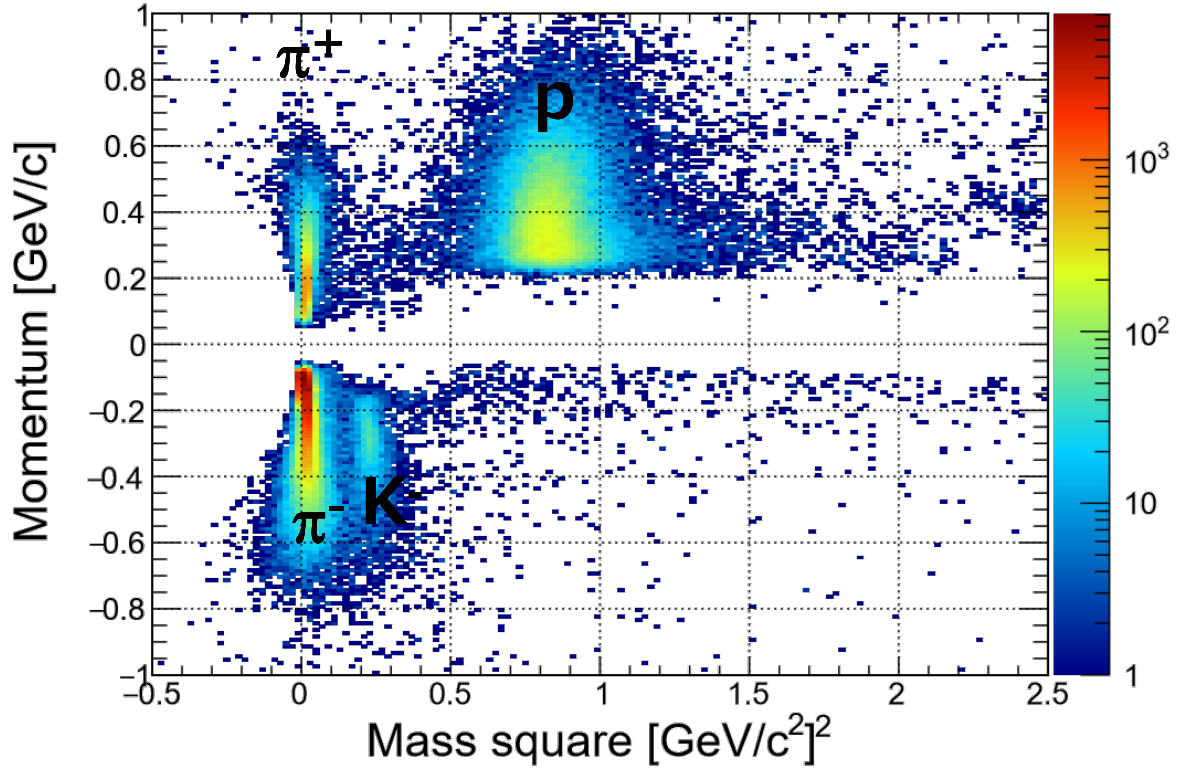
J-PARC K1.8BR Beamline



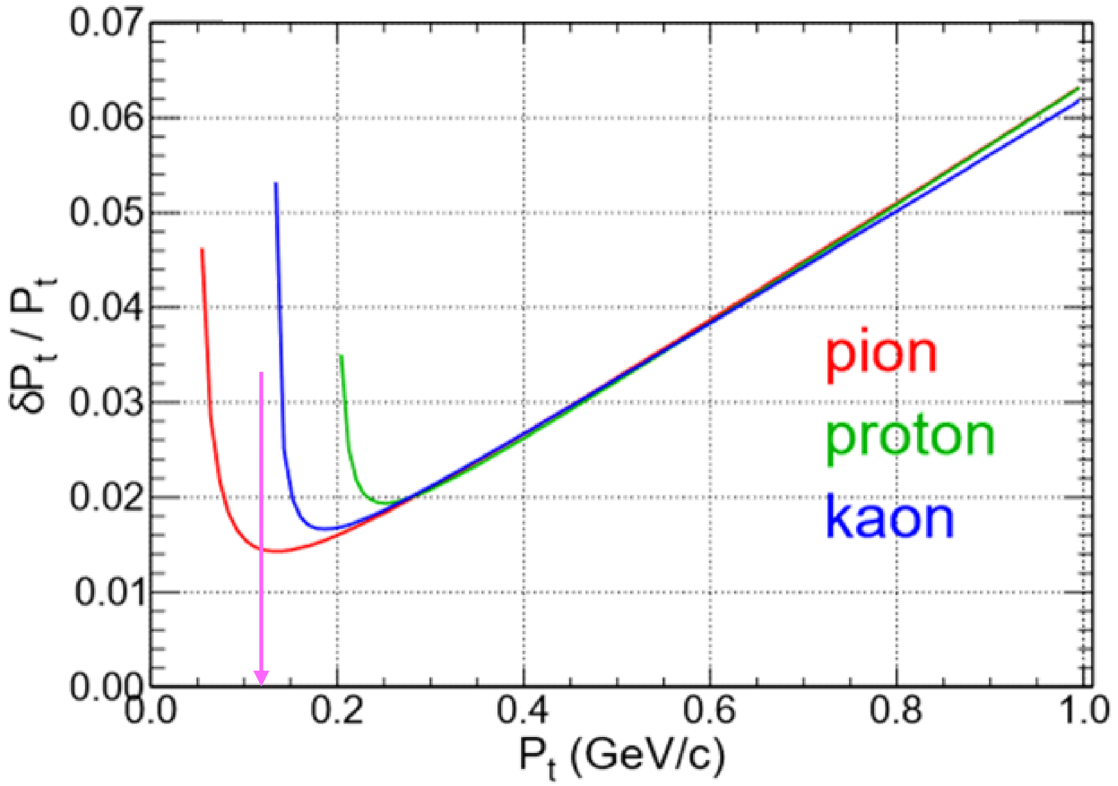
~ 2 x 10^5 K^- /spill (~70% on target)
@ 50 kW, -1.0 GeV/c
K/pi ~ 0.4
~50 kW @ T77, 2020.6
~60 kW @ E73 1st , 2021.5

CDS performance

Particle ID



Momentum resolution



✓Well working

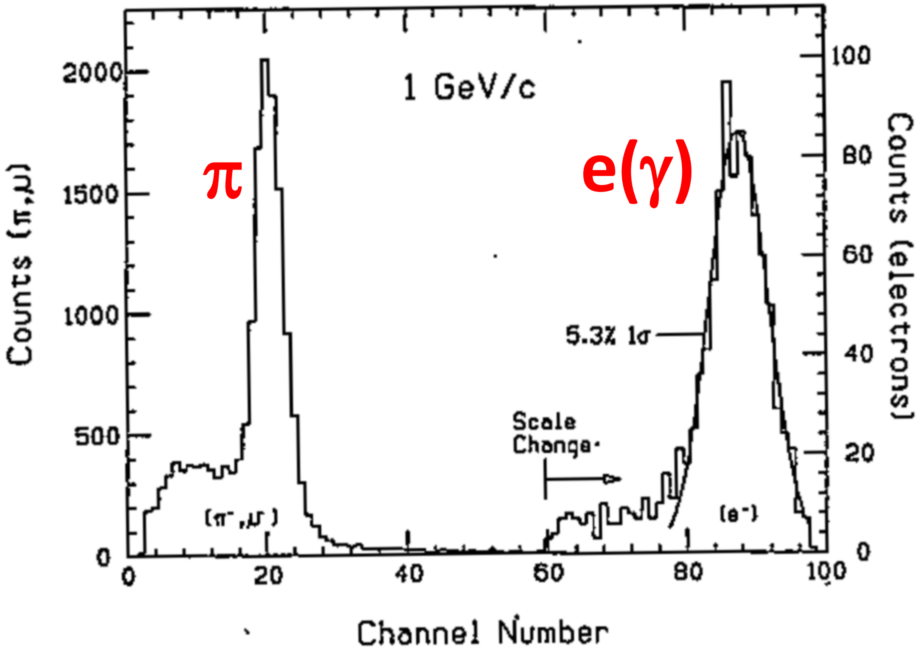
PbF2 calorimeter

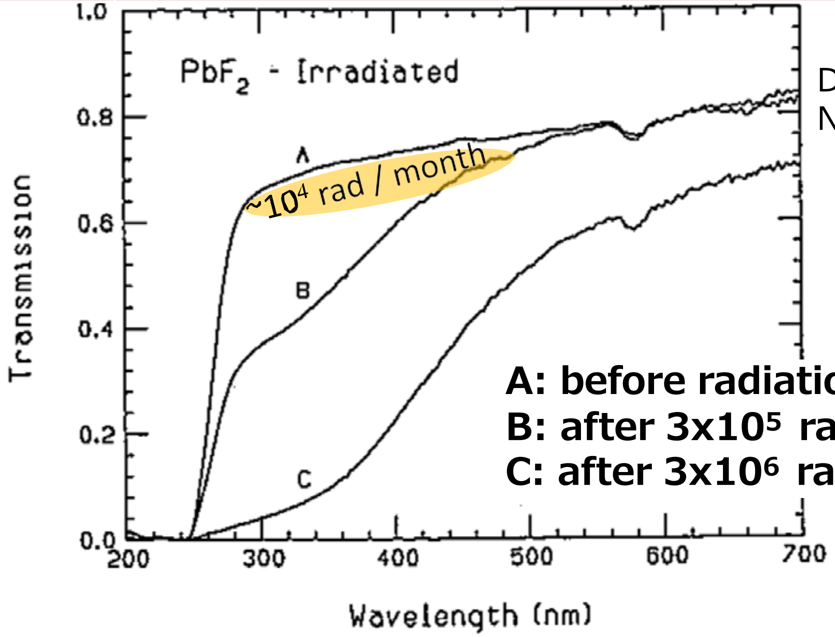
PbF_2 calorimeter

Experiment used PbF2: MAMI A4
EPJA: Hadrons and Nuclei volume 18, p.159–161(2003)

- Basic information

Radiation length	Moliere radius	Density	Refractive index	Energy resolution
0.93 cm	2.22 cm	7.77 g/cm³	1.82	5 %/√E(GeV)





D.F. Anderson et al., NIMA, 290, 385, (1990)

A: before radiation
B: after 3x10⁵ rad n and 1x10⁵ rad γ
C: after 3x10⁶ rad n and 1x10⁶ rad γ

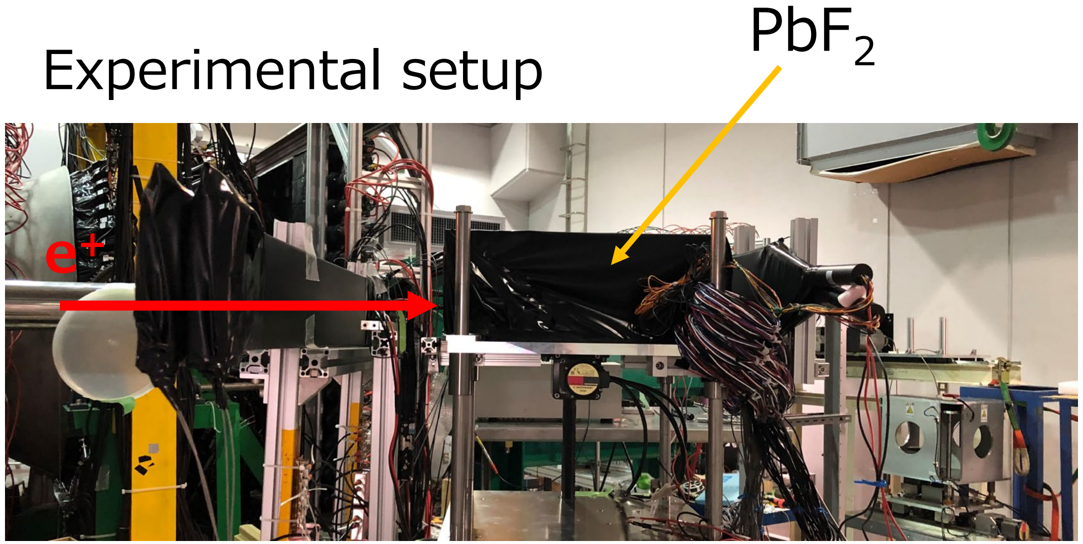
- Calorimeter with Cherenkov light
  - ✓Fast response
  - ✓Identification of hadrons and e, γ
- High radiation resistance

PbF_2 calorimeter operation

- Beam test – two pattern
  - 40 segments used

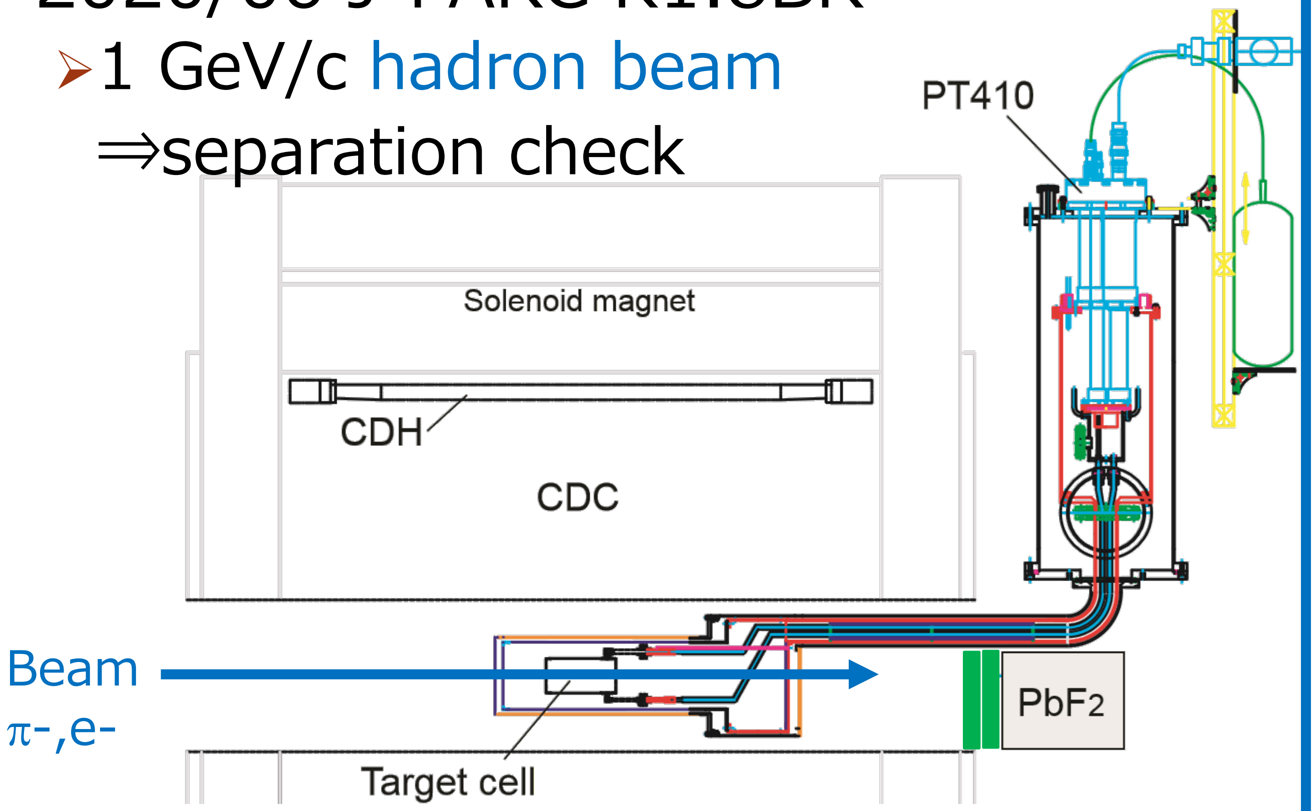
- 2019/12 ELPH
  - 100—800 MeV/c **e^+ beam**
    - ✓Basic performance test

Experimental setup



- 2020/06 J-PARC K1.8BR
  - 1 GeV/c hadron beam

  ⇒separation check

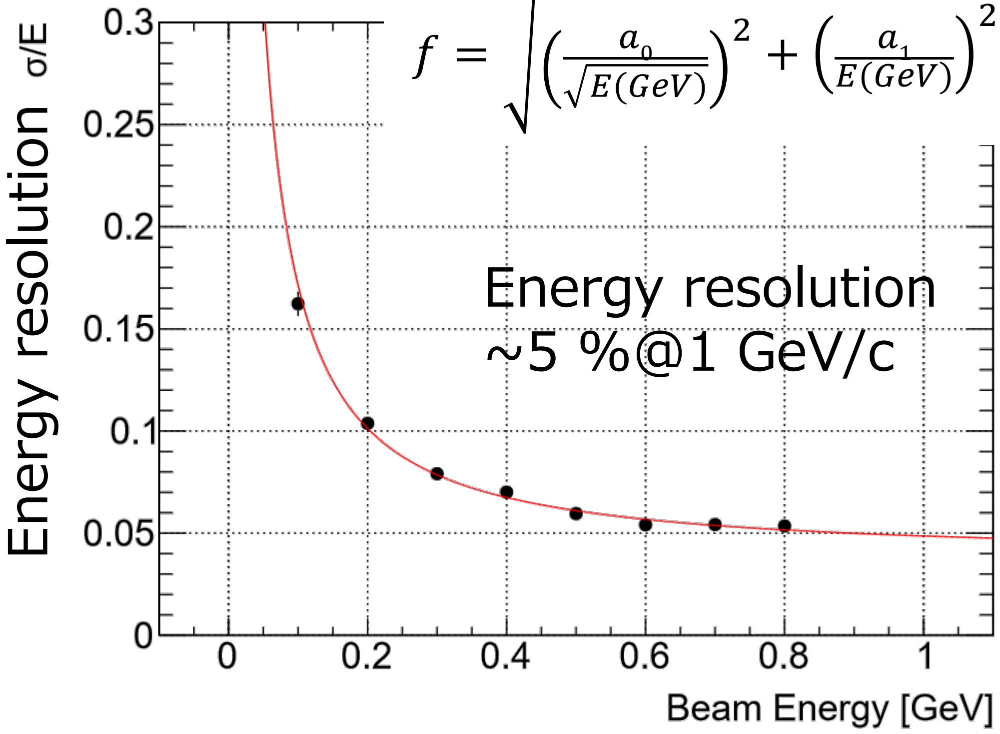


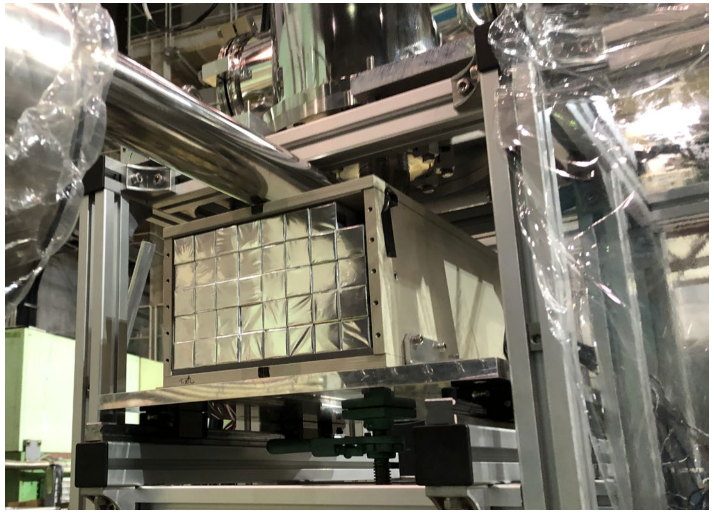
PbF_2 calorimeter performance

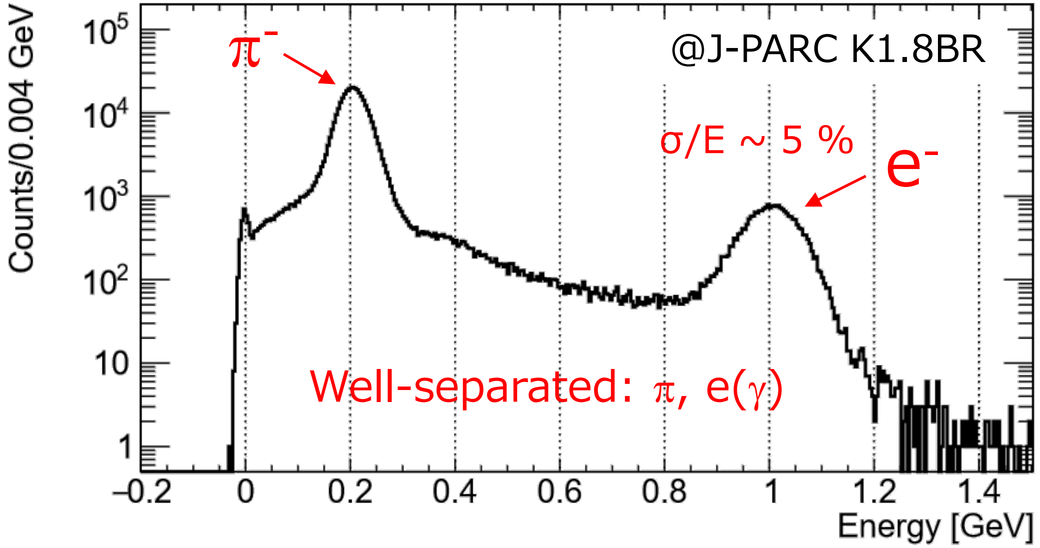
- ➢PbF2 calorimeter is installed into the meson beam line to tag fast π^0
- ➢40 segments used

2019.12: Test experiment @ ELPH e^+ beam

$$f = \sqrt{\left(\frac{a_0}{\sqrt{E(GeV)}}\right)^2 + \left(\frac{a_1}{E(GeV)}\right)^2 + b^2}$$



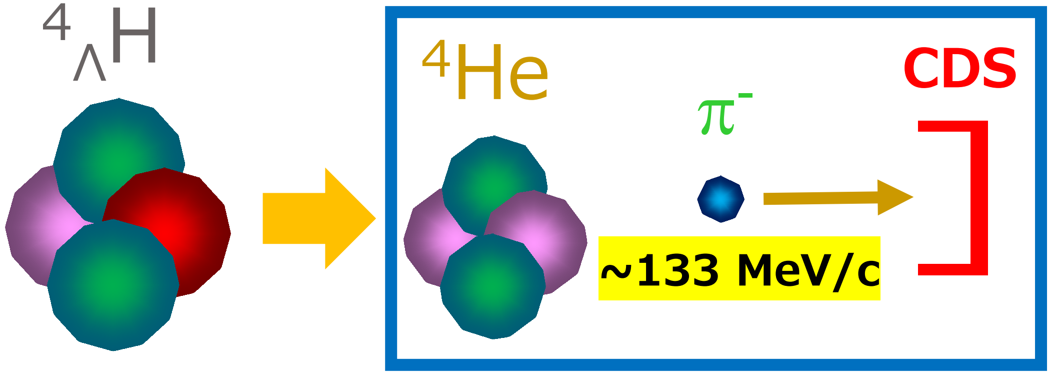




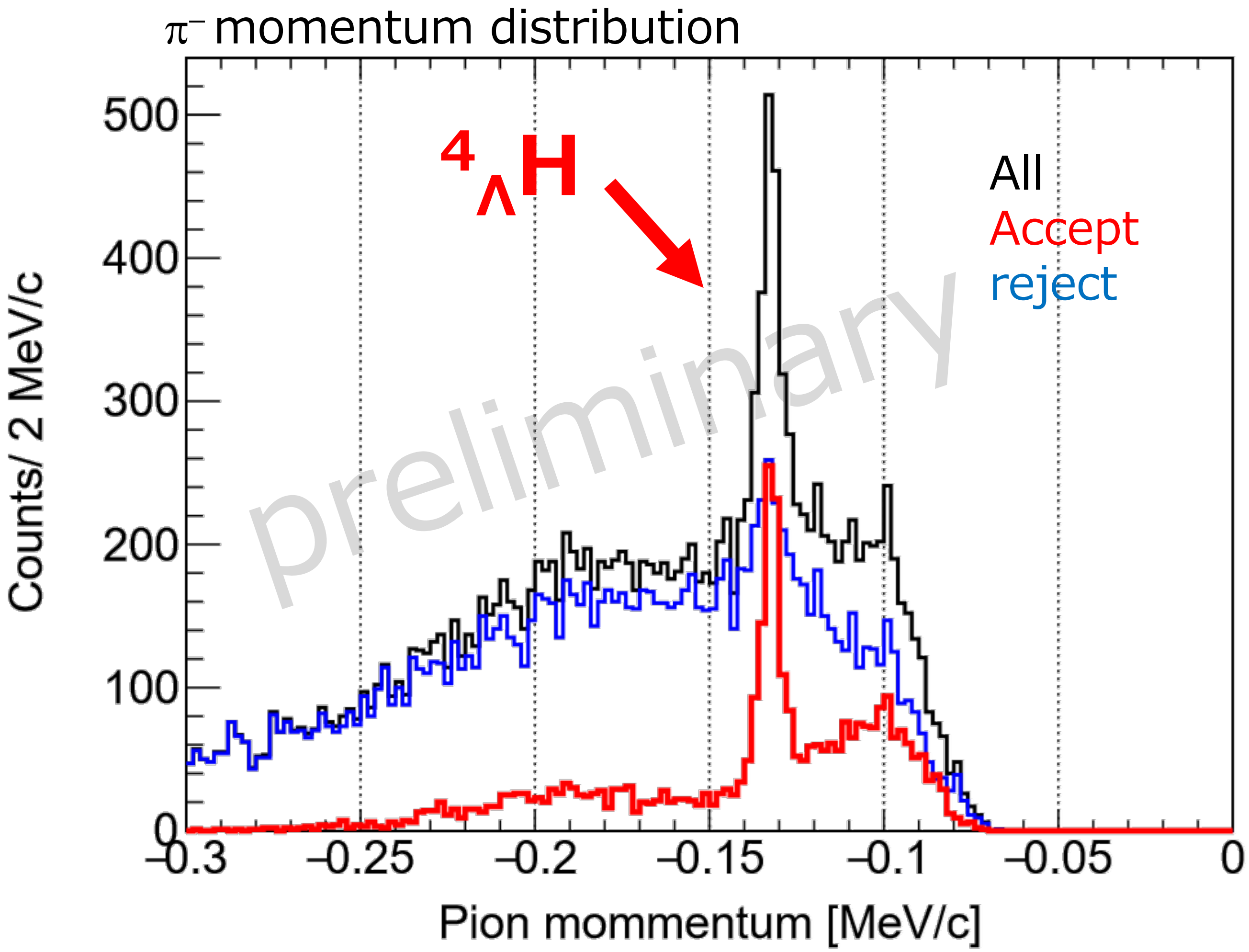
Good performance to distinguish $\pi^-/e^-,\gamma$

Feasibility study

- $^4He(K^-, \pi^0)^4{}_\Lambda H$ reaction



- select 1 gamma ray ⇒ the $^4{}_\Lambda H$ peak can be seen like the black line
- Background reduction by PbF2
  - ➢Selection of high energy γ-rays for $^4{}_\Lambda H$ production
    ⇒Improved S/N ratio(3/2 → **4/1**) Red line

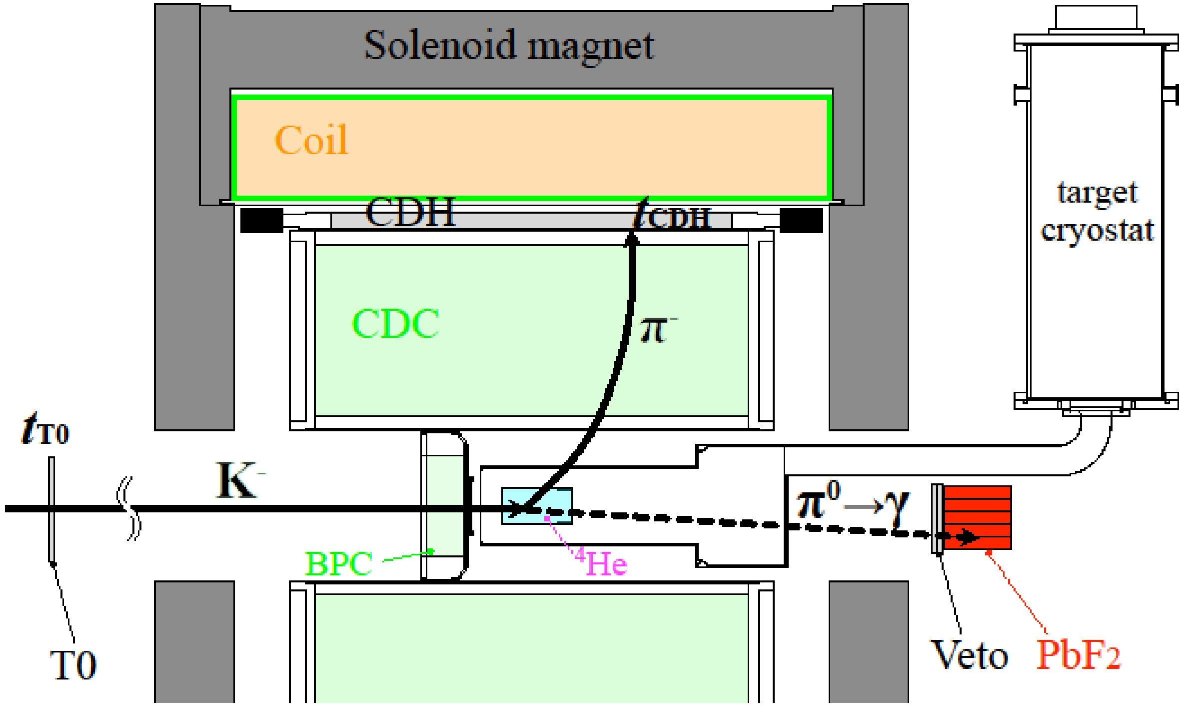


J-PARC T77 experiment
${}^{4}_{\Lambda}H$ lifetime

Derive lifetime

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

${}^4_\Lambda H \rightarrow {}^4He + \pi^-$ (measure)

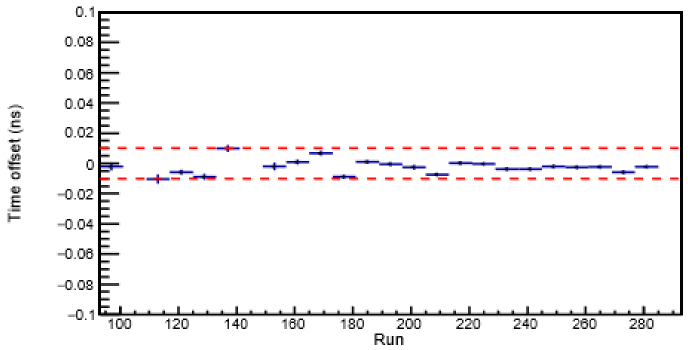


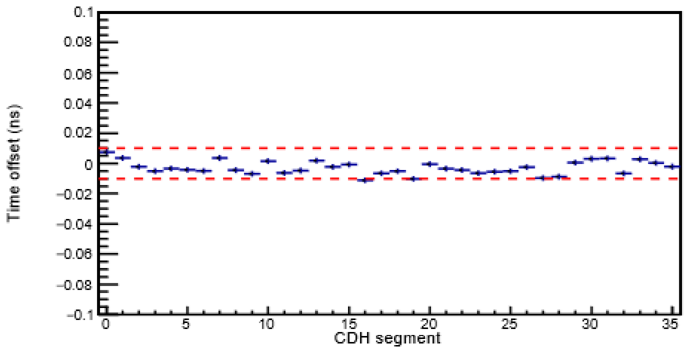
$$t_{tof} = t_{beam} + t_{\pi^-} + \tau$$

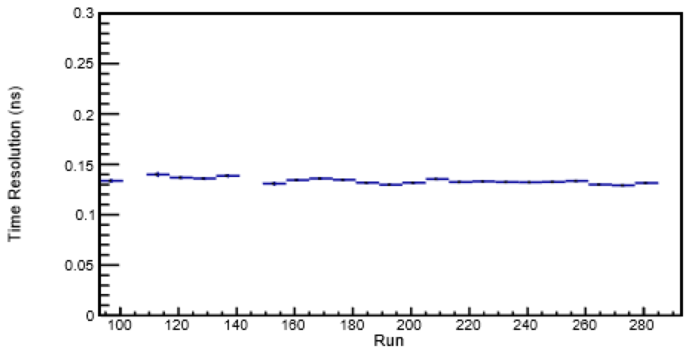
lifetime

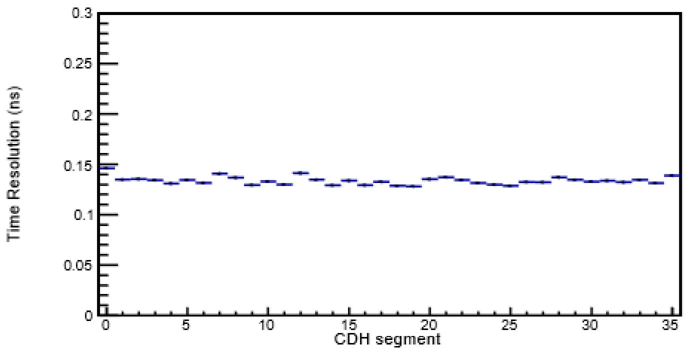
Analysis for timing

- Calibration with $\pi^-N \rightarrow \pi^-N$ scattering
  - TOF(T0-CDH)
    - ✓Select beam pion and scattering pion
    - ✓Adjusted Time offset

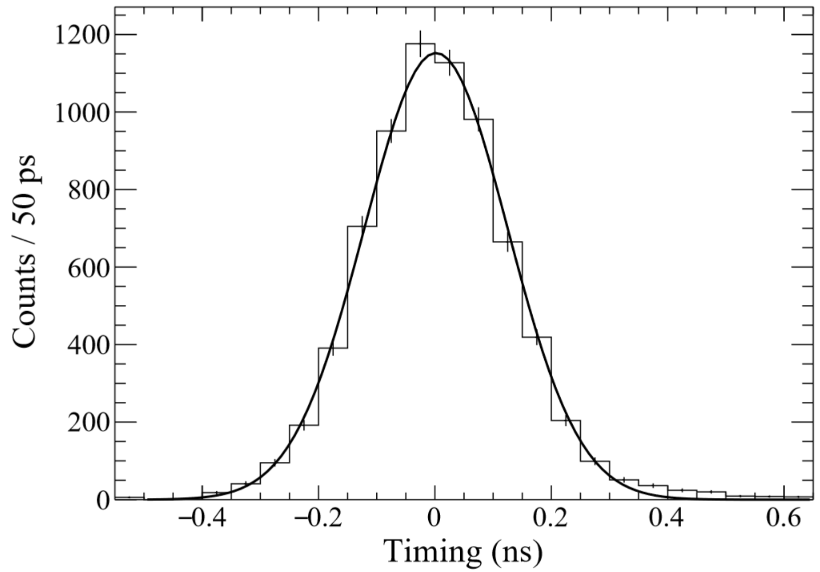








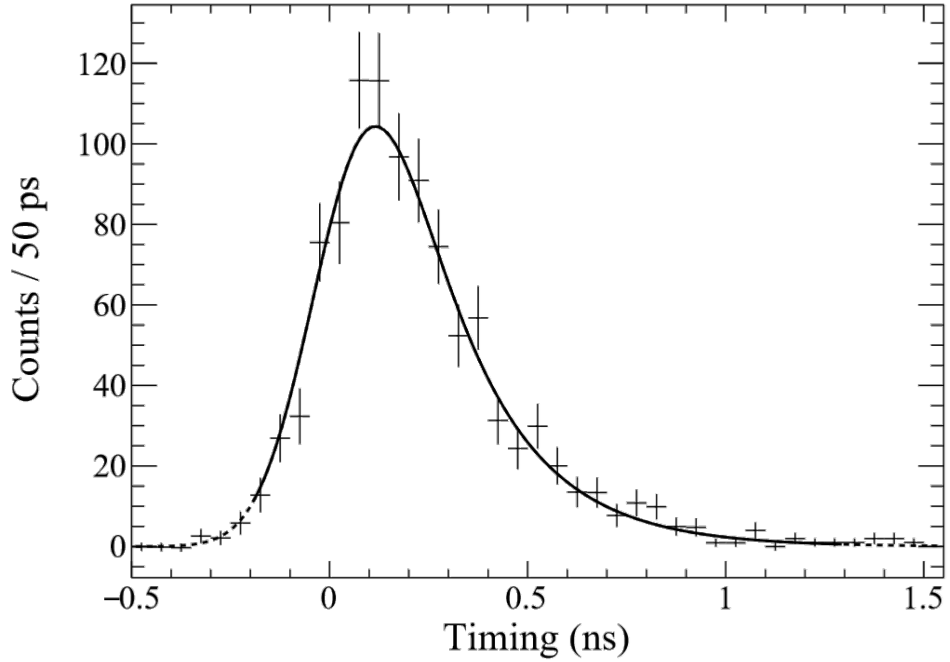
Time response function



σ = 123 ± 1 ps

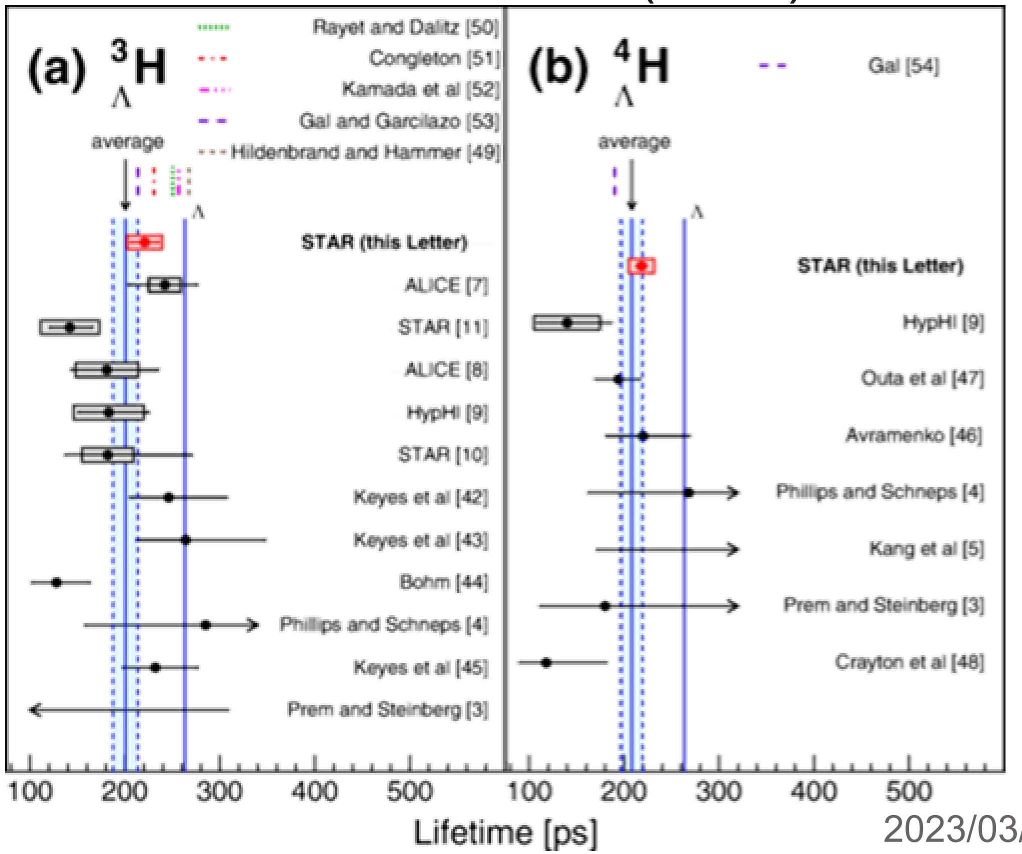
$^{4}_{\Lambda}$H lifetime

206 ± 8(stat.) ± 12(syst.) ps



Contribution	Value
Intrinsic bias of J-PARC T77 approach	±2 ps
Uncertainty from γ selection	±4 ps
Uncertainty of time calibration	±7 ps
Uncertainty of background subtraction	±5 ps
Uncertainty in fitting process	±7 ps
Total (quadratic sum)	±12 ps

- 194^{+24}_{-26} ps @KEK stop K-
  - H. Outa, et al., Nucl. Phys. A 547, (1992), 109c-114c
- 218 ± 6(stat.) ± 13(syst.) ps @STAR, Au-Au collision
  - PRL 128, 202301 (2022)

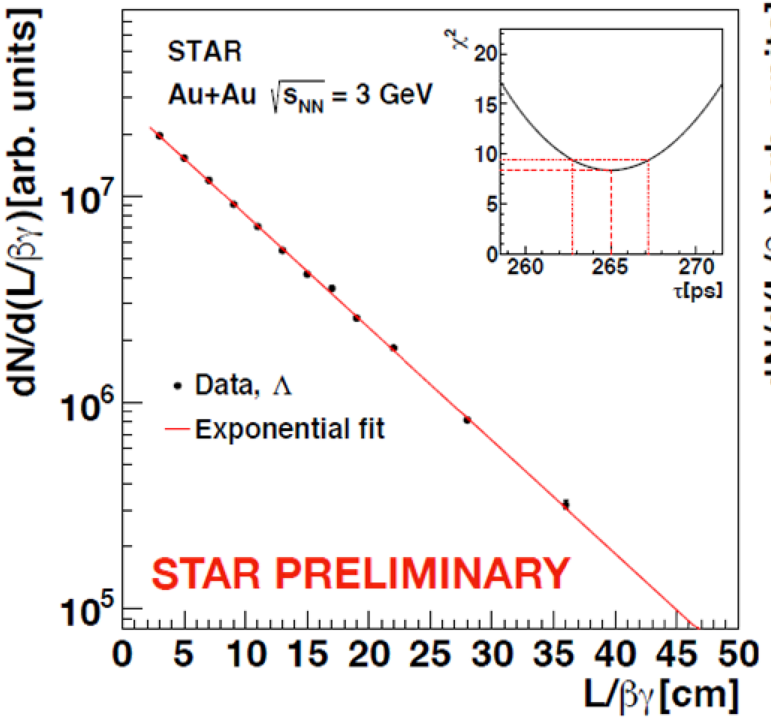


STAR new result

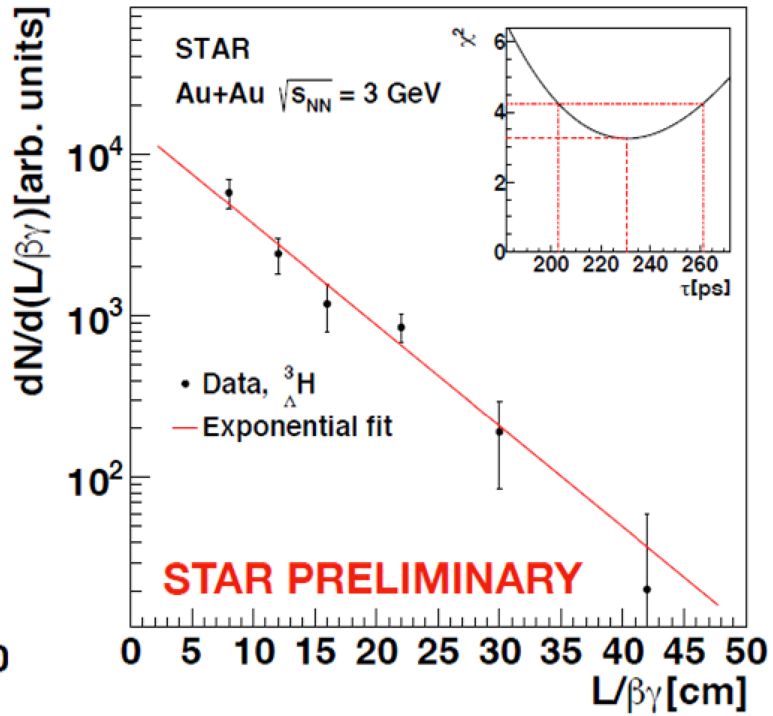
- Fixed target mode $\sqrt{S_{NN}} = 3$ GeV

Yue-Hang Leung
REIMEI-THEIA web seminar
STAR Preliminary result

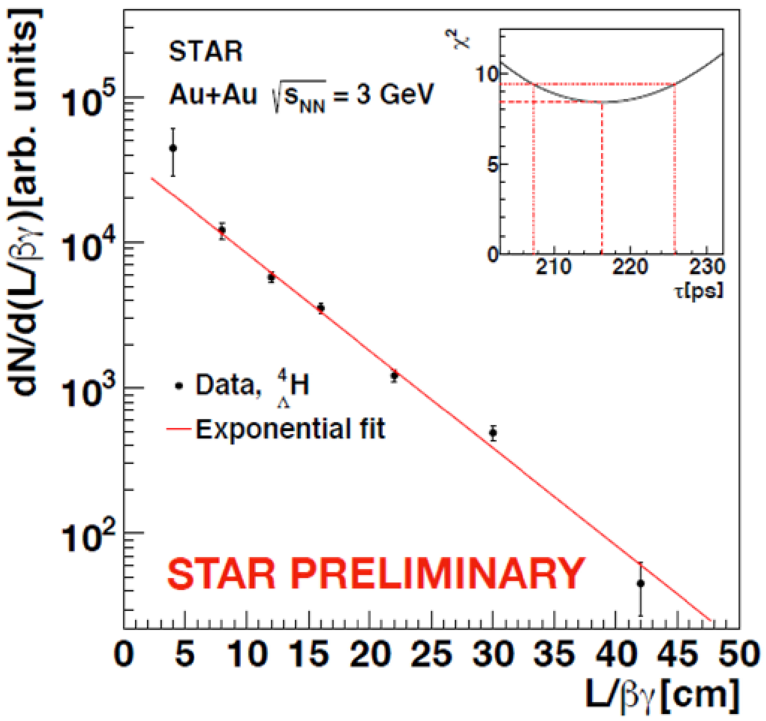
Λ



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



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



Λ **lifetime** (265.0 ± 2.2)[ps]

PDG value (263.1 ± 2.0)[ps]

$^{3}_{\Lambda}H : \tau = 232.1 \pm 29.2(stat) \pm 36.7(syst)[ps]$

$^{4}_{\Lambda}H : \tau = 218.3 \pm 7.5(stat) \pm 11.8(syst)[ps]$