$^{3}_{\Lambda}\mathrm{H}$ and $^{4}_{\Lambda}\mathrm{H}$ mesonic weak decay lifetime measurement with $^{3,4}\mathrm{He}(K^{-}, \pi^{0})^{3,4}_{\Lambda}\mathrm{H}$ Reaction

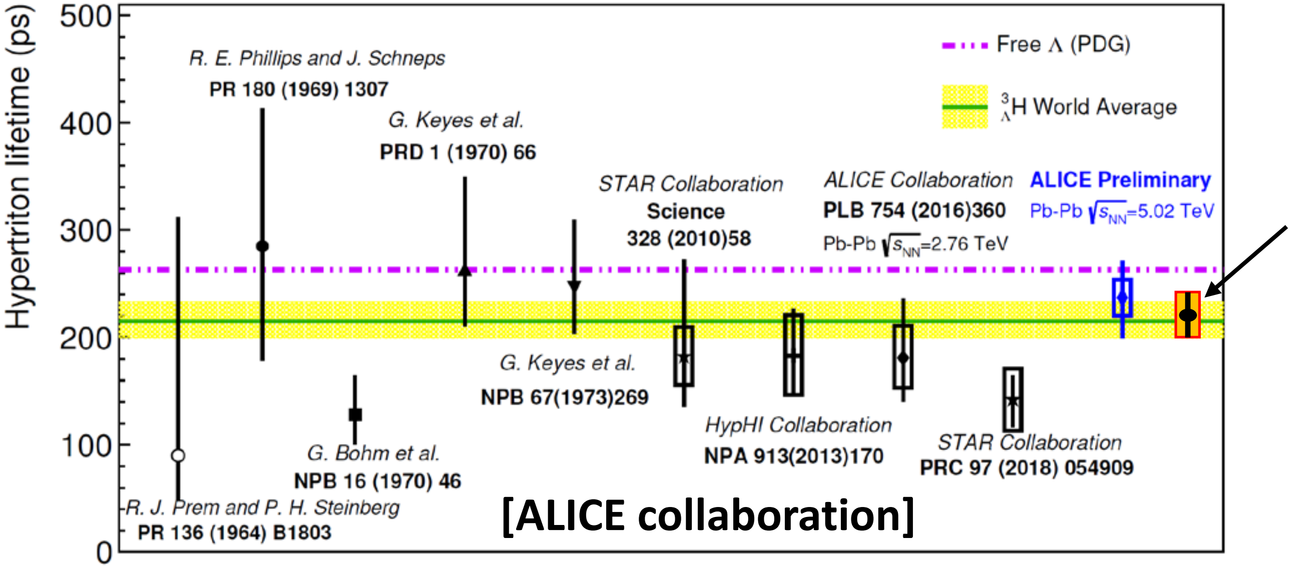
Apply for stage-1 approval

F.Sakuma, RIKEN

on behalf of the P73 Collaboration

Summary of the P73 Experiment

- Direct measurement of the **hypertriton ($^{3}_{\Lambda}$H) lifetime** using **(K$^-$,π^0)** reactions.
- The experiment will be **ready at K1.8BR** in early 2020.
- We request **1 week** (1d+6d, 50kW equiv.) beamtime for **$^{4}_{\Lambda}$H** as **a pilot run in 2020**.
  - ➢after feasibility study with $^{4}_{\Lambda}$H, we would like to request **the $^{3}_{\Lambda}$H physics run (~4 weeks, 50kW equiv.)**.



[ALICE collaboration]

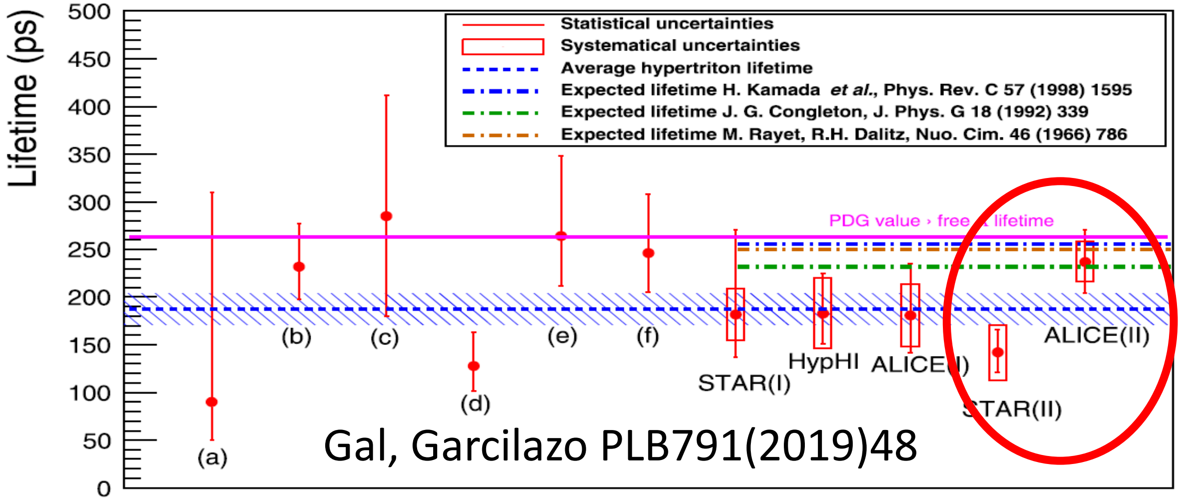
P73 expected

Physics Motivation

- Recent heavy-ion experiments reported different lifetime of **hyper-triton, $^{3}_{\Lambda}\mathrm{H}$**:

STAR (2018)	ALICE (2018)	free Λ
$142^{+24}_{-21} \pm 29$ ps	$237^{+33}_{-36} \pm 17$ ps	263 ± 2 ps

- $\tau(^{3}_{\Lambda}\mathrm{H}) \sim \tau(\text{free }\Lambda)$ is naively expected, because $^{3}_{\Lambda}\mathrm{H}$ is known to be very loosely bound system (~0.13MeV)



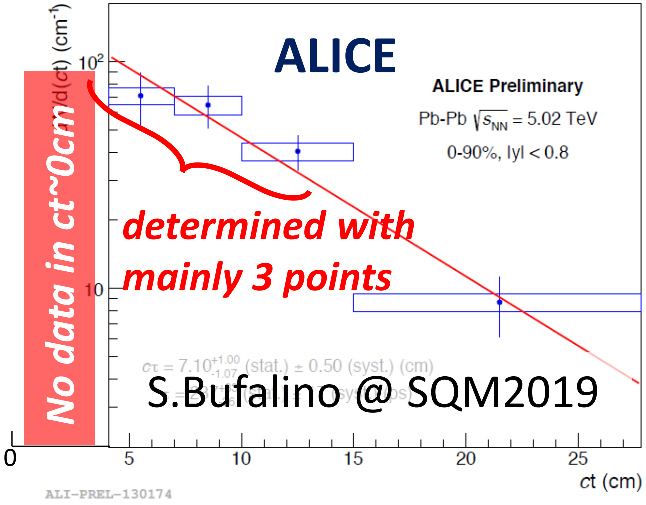
Gal, Garcilazo PLB791(2019)48

→ need to clarify the situation using different experimental technique

Heavy-Ion Experiment

Heavy-ion experiment STAR, ALICE, HypHI

- **Invariant mass reconstruction**
  - Difficult to use ${}^{3}_{\Lambda}$H information in ct~0cm region
  - Huge combinatorial BG

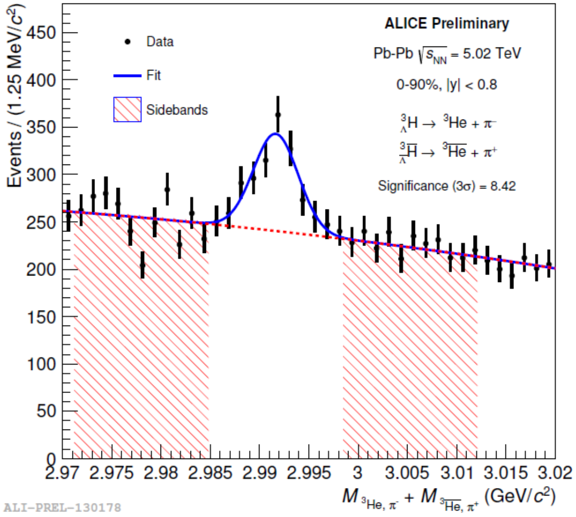


ALICE

No data in ct~0cm

determined with mainly 3 points

S.Bufalino @ SQM2019

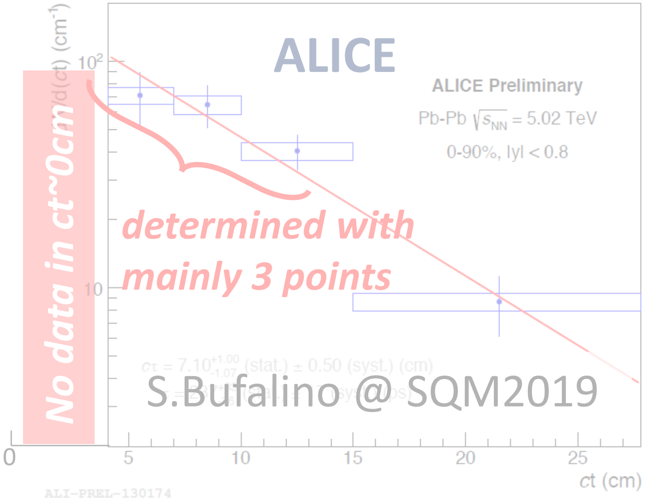


Direct Lifetime Measurement

Heavy-ion experiment STAR, ALICE, HypHI

complementary

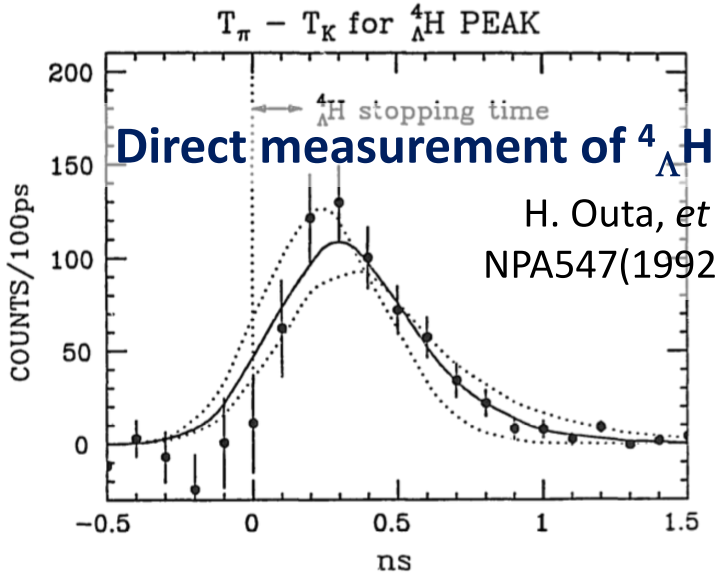
- **Invariant mass reconstruction**
  - Difficult to use ${}^{3}_{\Lambda}$H information in ct~0cm region
  - Huge combinatorial BG



No data in ct~0cm

determined with mainly 3 points

S.Bufalino @ SQM2019



Direct measurement of ${}^{4}_{\Lambda}$H

H. Outa, *et al.*, NPA547(1992)109c

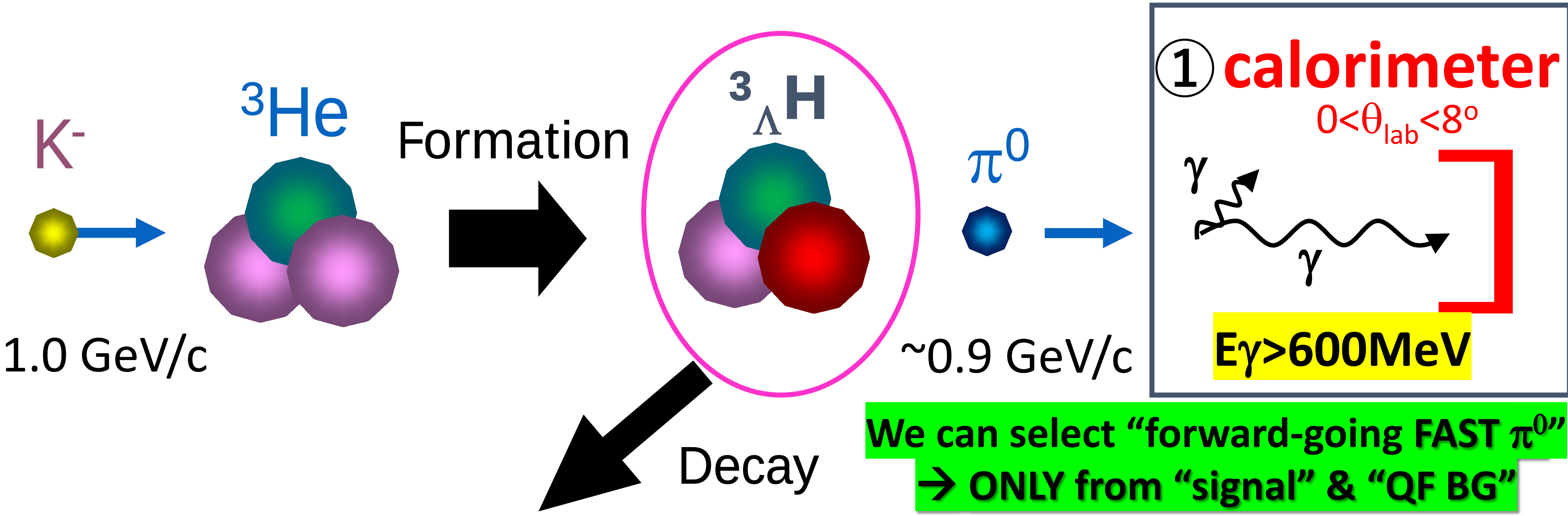
Direct measurement ***NO counter experiment so far*** → **P73,** **P74**

- **Delayed time of π^- in mesonic weak decay ~ at rest**
  - Wide-range fitting is possible
  - Quasi-free Y→π^-N is dominant BG

(K^-,π^0) and (π^-,K^0)

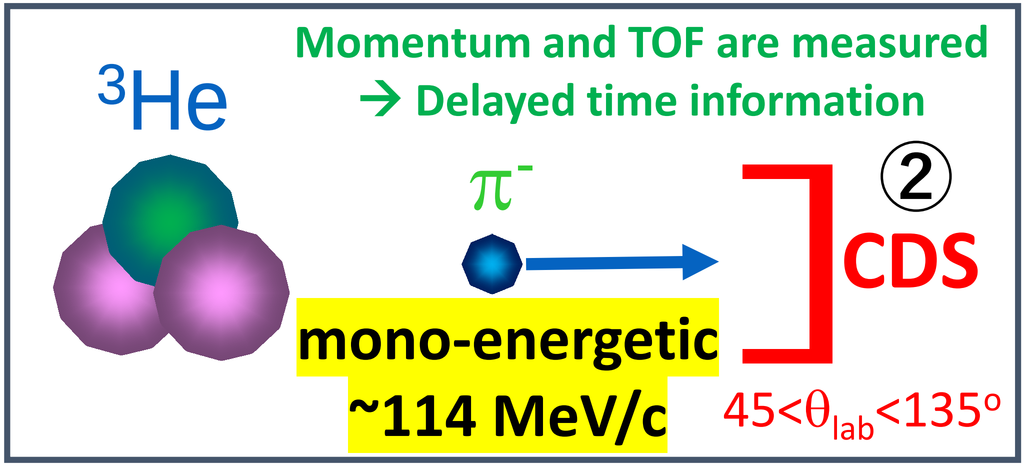
	P73	P74
Reaction	**$^3He(K^-,\pi^0)^3_\Lambda H$**	$^3He(\pi^-,K^0)\,^3_\Lambda H$
Measurement	**Delayed π^- from $^3_\Lambda H$ decay**	
Decay mode	**2-body**	2- and 3-body
$^3_\Lambda H$ identification	**mono-energetic π^-**	(π^-,K^0) missing mass ☺
Beamline	**K1.8BR** ☺	K1.1
Beam	**$2x10^5$ 1.0 GeV/c K^-**	$1x10^7$ 1.05 GeV/c π^-
main spectrometer	**CDS** ☺	SKS + vertex
L^3He target	**In hand** ☺	-
Expected yield	**~1k/month**	~0.6k/month
Trigger tag	**γ from π^0 for BG suppression**	$\pi^+\pi^-$ from K^0 for $^3_\Lambda H$ identification
Main BG	**QF**	QF + K^0-reconst.

Experimental Principle



We can select "forward-going FAST π^0"
→ ONLY from "signal" & "QF BG"

charged 2-body decay "almost" at rest



Momentum and TOF are measured
→ Delayed time information

mono-energetic
~114 MeV/c

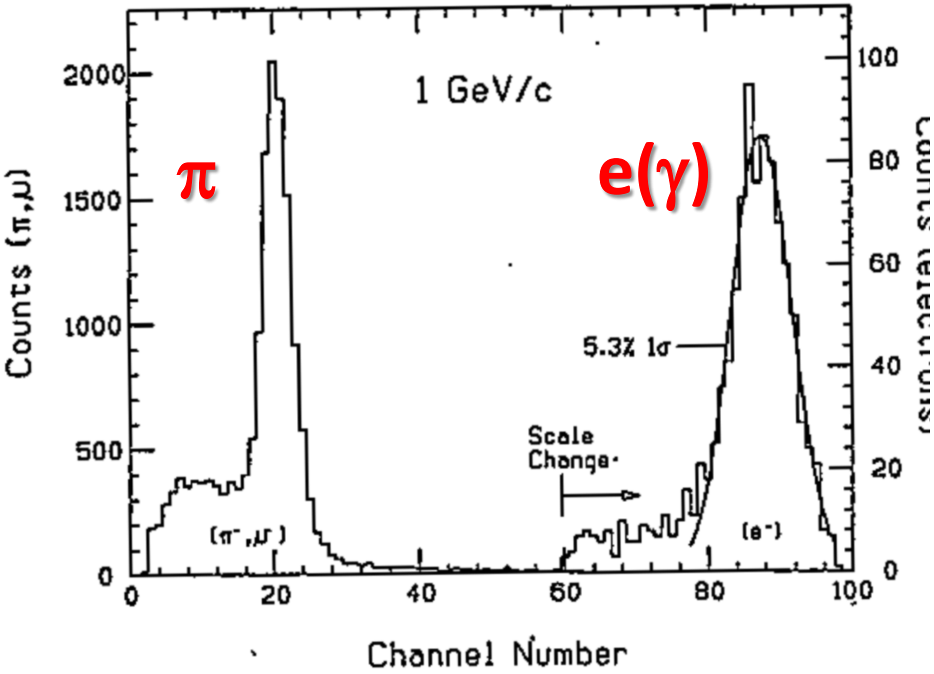
①Tag high-energy γ

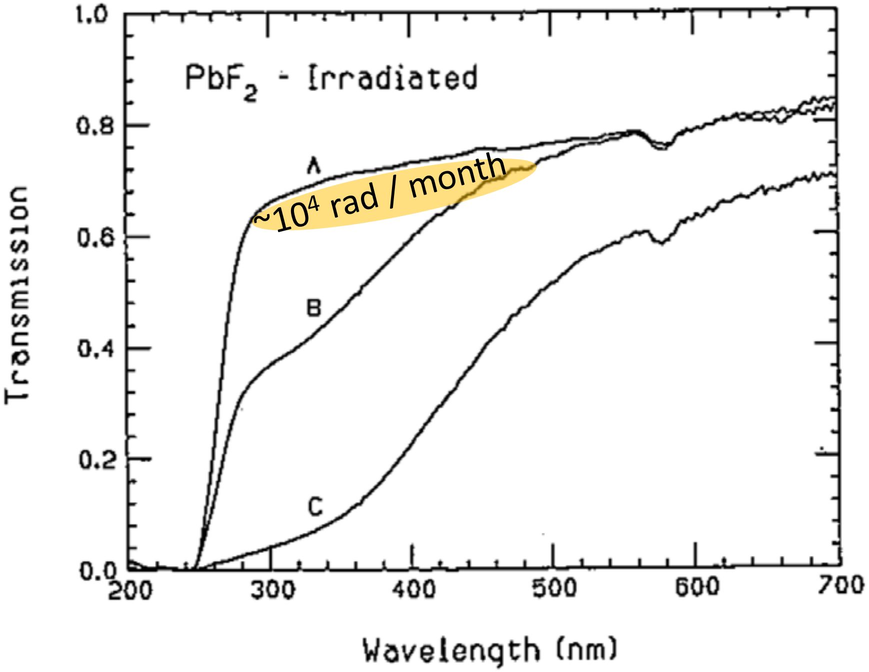
②Detect mono-energic π^-

③Measure $^3_\Lambda$H lifetime
via π^- delay time

PbF_2 Calorimeter

- we can perform on-line discrimination of γ and π
  - **Hadron blind** with ΔE cut
  - Radiation hardness (x10 times more resistive than Pb glass)

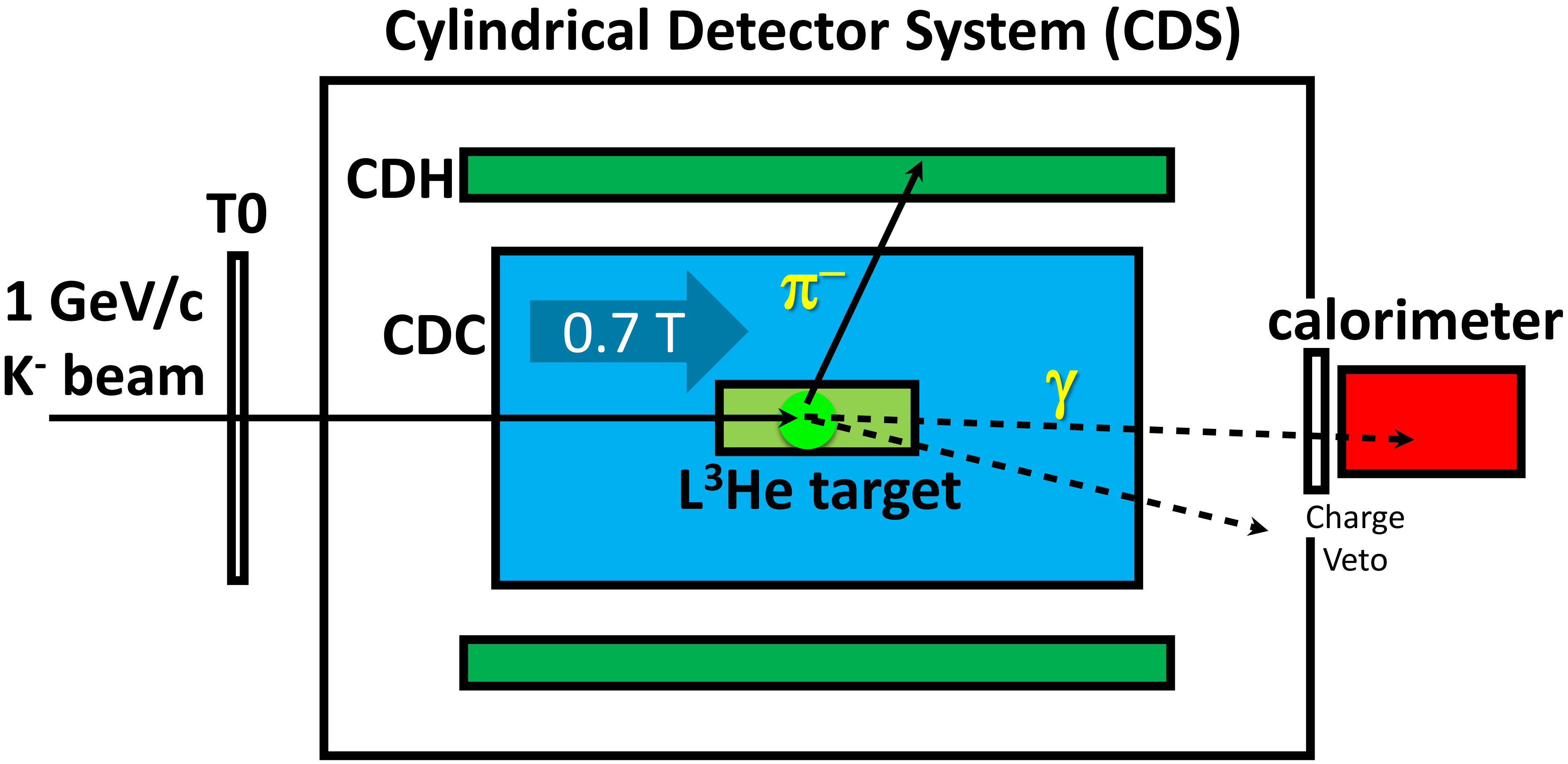




Radiation length	Moliere radius	Density	Resolution	Signal length
0.93 cm	2.22 cm	7.77 g/cm^3	5%	2ns

A: before radiation
B: after 3x10^5 rad n and 1x10^5 rad γ
C: after 3x10^6 rad n and 1x10^6 rad γ

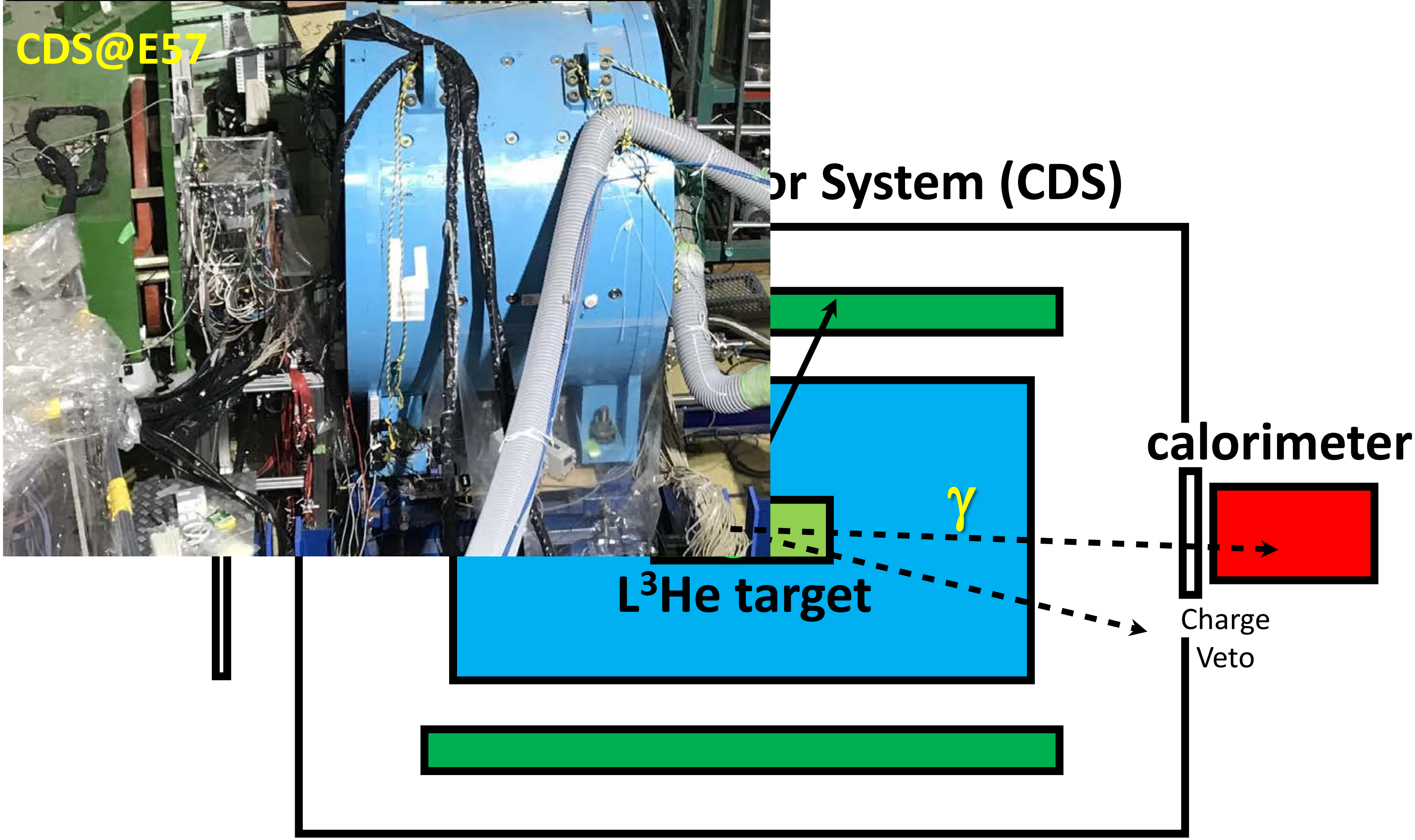
Experimental Setup



Beam spectrometer & CDS
→ Ready

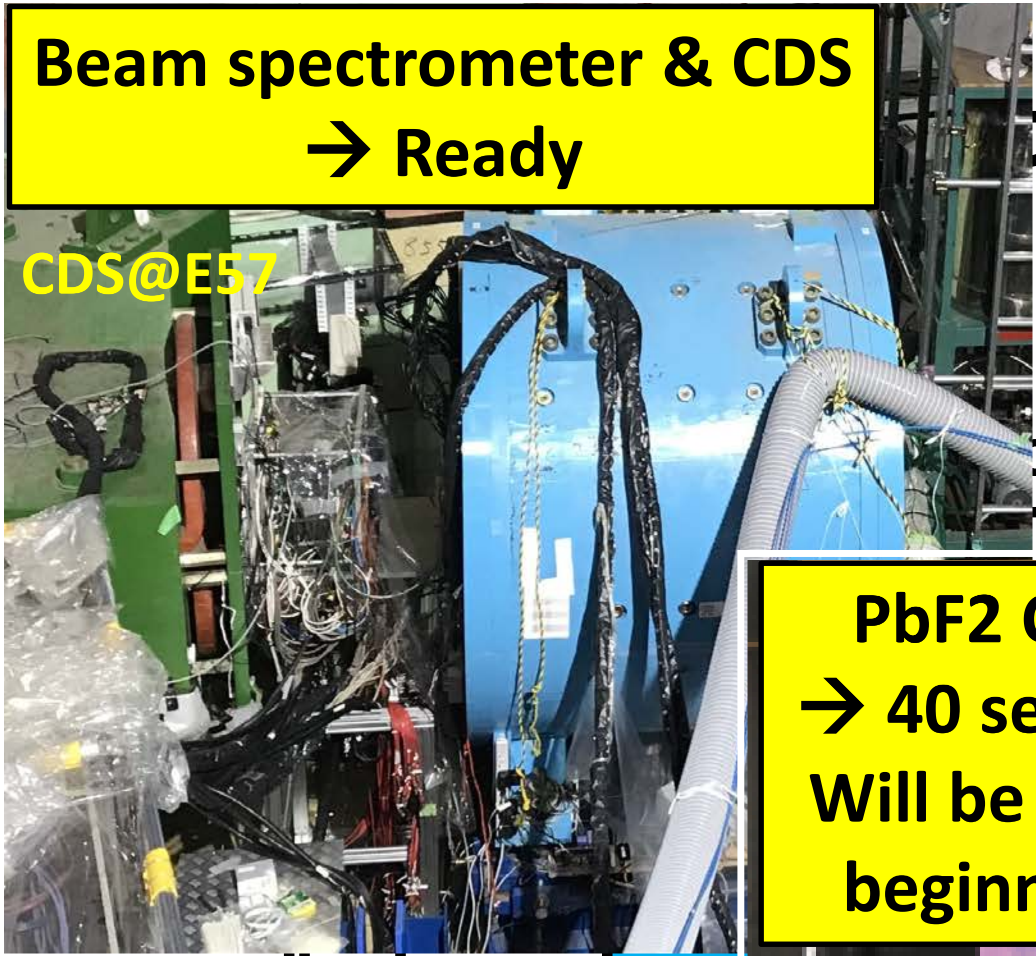
tal Setup

or System (CDS)



tal Setup

Beam spectrometer & CDS
→ Ready



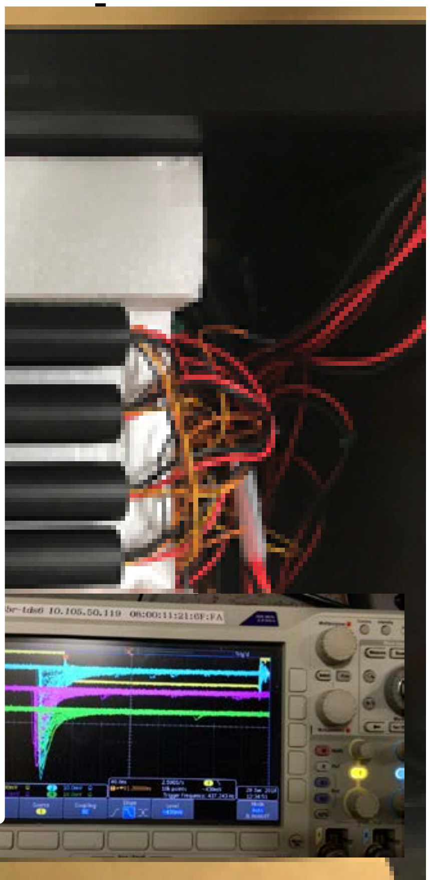
or System (CDS)

PbF2 Calorimeter
→ 40 sets on hand &
Will be ready by the
beginning of 2020

Beam spectr & CDS

→ I

L^{3}He target system
→ 500l ^{3}He in hand &
Will be ready by the
beginning of 2020

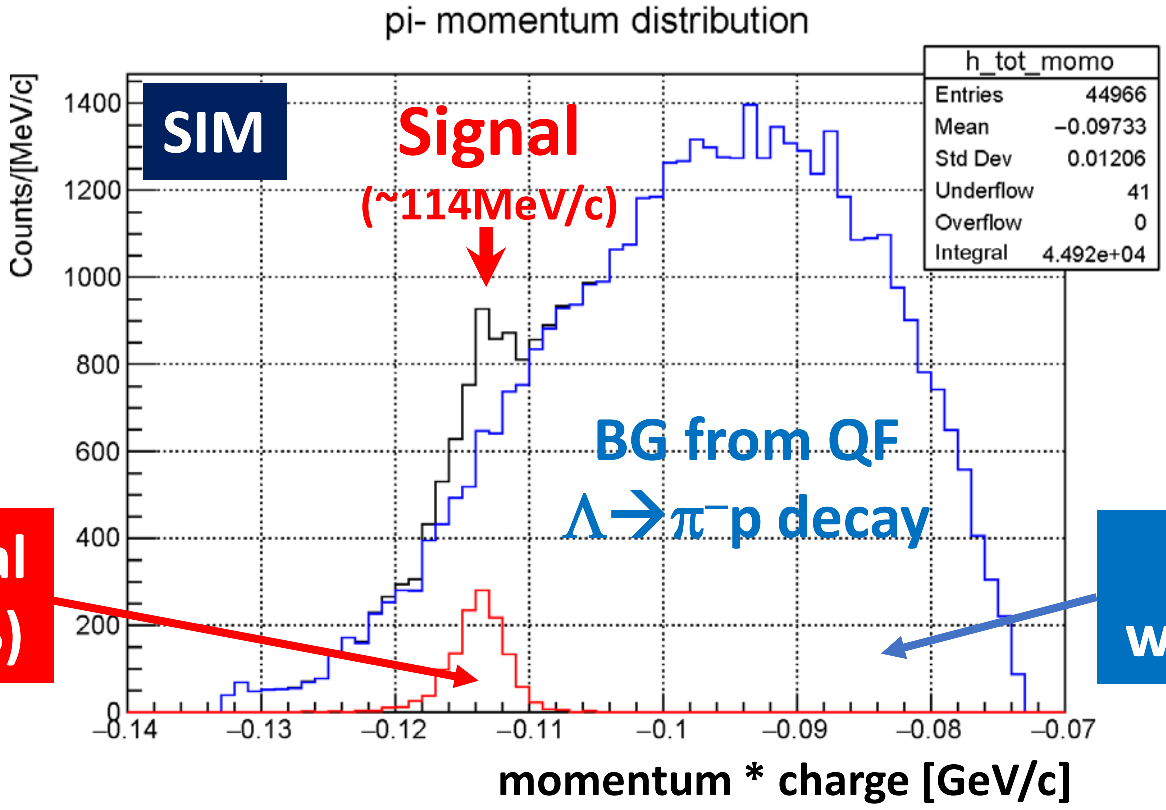


Reported Issues in the Previous (27th) PAC

(based on 26th PAC comments)

- Kaon in-flight decay background
  - **Negligible** effect on $^{3}_{\Lambda}$H lifetime
    - Most of in-flight decays are out of the CDS acceptance
- Reaction induced background
  - Almost of all π^{-} BG are originated from **QF Λ/Σ^{-} decays**
    - QF $K^{-}p \rightarrow \Lambda\pi^{0}/\Sigma^{0}\pi^{0}$ and $K^{-}n \rightarrow \Sigma^{-}\pi^{0}$ reactions
  - **BG evaluation with ^{4}He target is absolutely essential**
- Setup optimization
  - The target and the calorimeter positions were **optimized**
- Statistical and systematics error estimation
  - Statistical error: ~$\pm$**20 ps** (with 4 weeks data taking)
  - Systematic error: ~$\pm$**20 ps**

Expected π^- Spectrum of ${}^{3}_{\Lambda}\mathrm{H}$



Signal (~114MeV/c)

BG from QF $\Lambda \rightarrow \pi^- p$ decay

Expected Signal (theoretical CS)

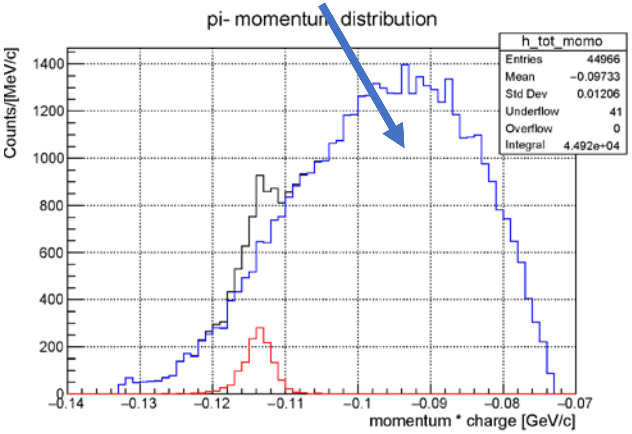
Sim. BG with Geant4

- The spectrum with **~4 weeks** data taking at **50kW**
  - # of expected signal is ~1k
  - BG is estimated with MC based on Geant4 using K^- + p reactions.
    - **$K^- p \rightarrow \Lambda \pi^0$ ~ 3.5 mb is dominant**
    - $K^- p \rightarrow \Sigma^0 \pi^0$ ~ 0.9 mb and $K^- n \rightarrow \Sigma^- \pi^0$ ~ 0.9 mb are suppressed by ΔE cut of the calorimeter (>600MeV)

Expected S/BG Ratio with Different Models

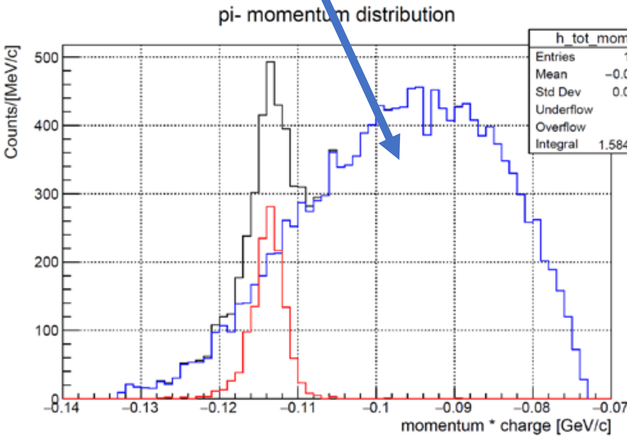
Signal yield is assumed to be ~ 1k in all cases (4w, 50kW)

from Geant4 CS



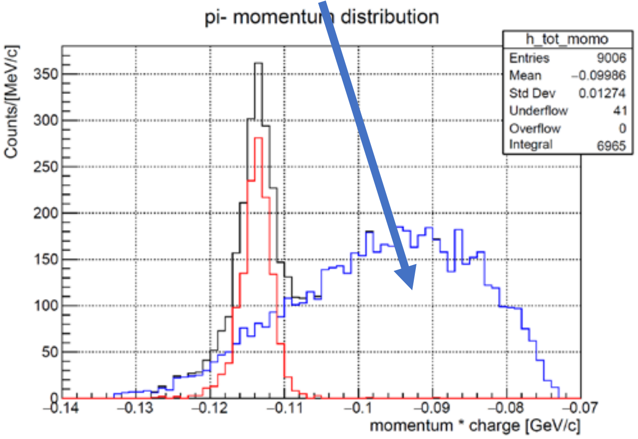
S/BG ~ 1/42

from BNL E905 CS



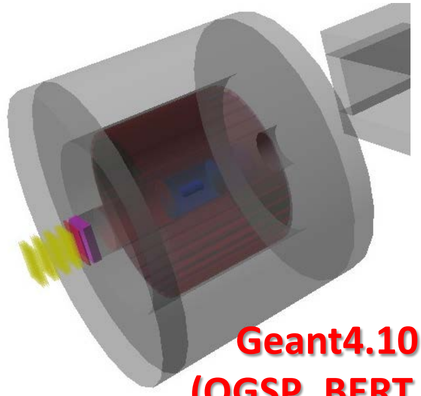
S/BG ~ 1/16

from theoretical CS



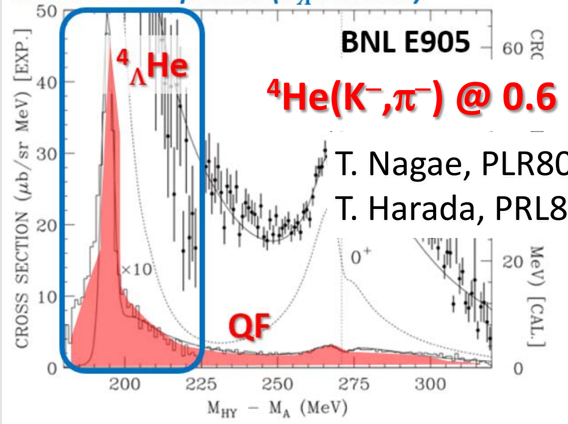
S/BG ~ 1/6

Worst case *S/BG ~ 1/20 will be realistic estimation* **Best case**



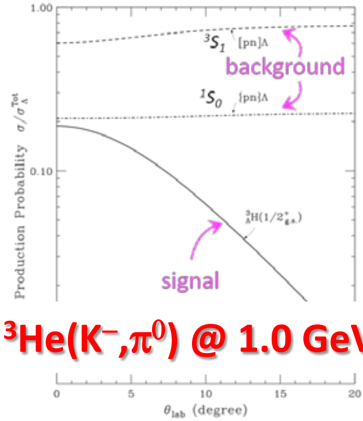
Geant4.10.0 (QGSP_BERT_HP)

detector acceptance (T_Λ<20MeV)



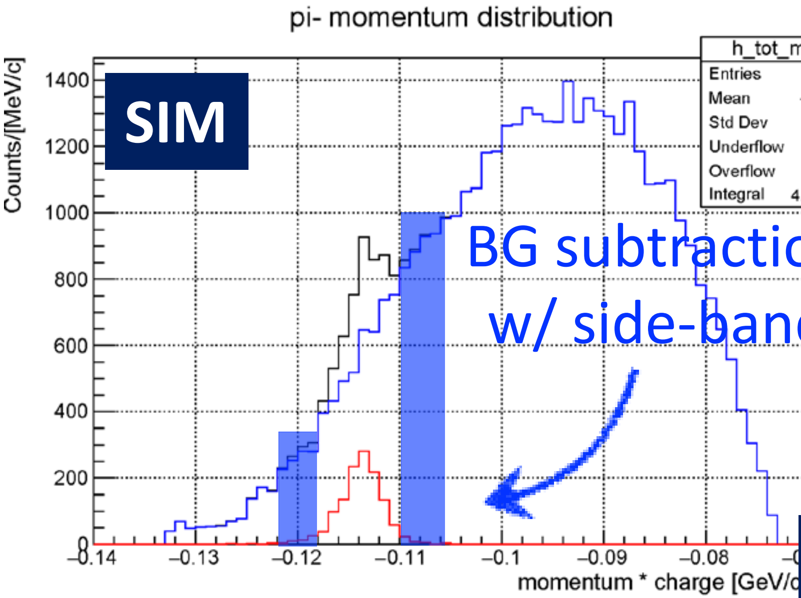
^{4}He(K^-,π^-) @ 0.6 GeV/c

T. Nagae, PLR80(98)1605
T. Harada, PRL81(98)5287



^{3}He(K^-,π^0) @ 1.0 GeV/c

Lifetime Evaluation



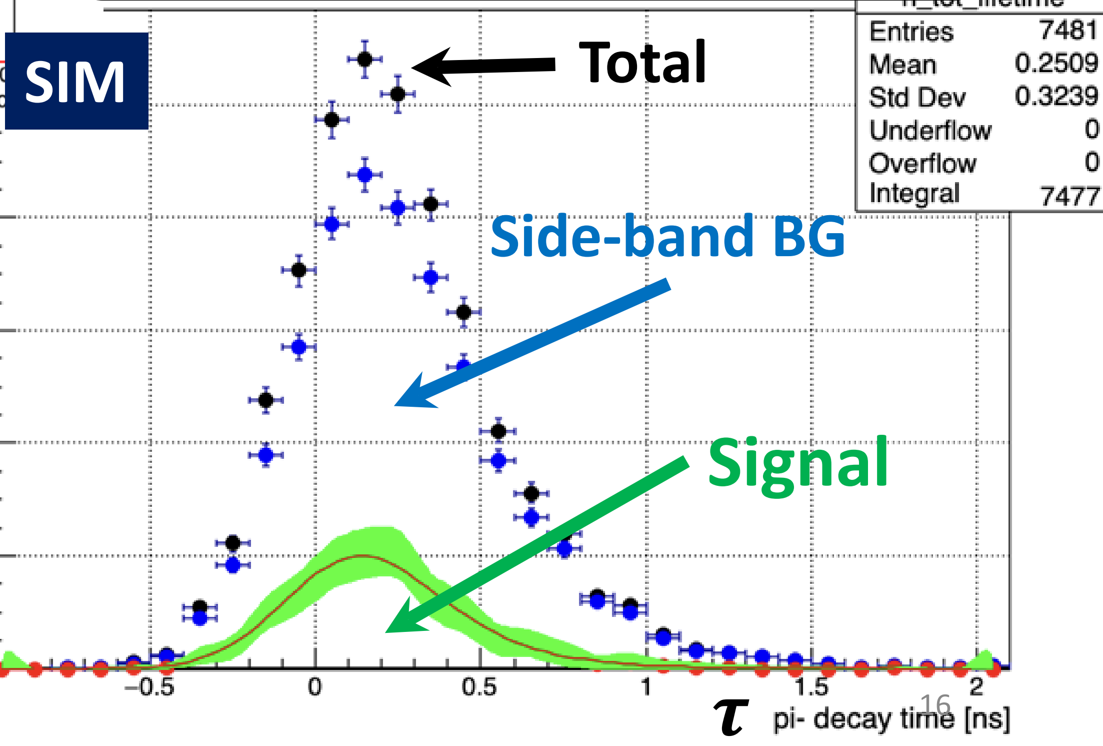
BG subtraction
w/ side-band

delayed decay time τ:

$$T_{CDH} - T_0 = t_{beam} + t_{\pi^-} + \tau$$

The **lifetime** τ_0 is derived with the **exp(-**τ/τ_0**)** function convoluted with the CDS response function $R()$

$$f(\tau) = \int_{-\infty}^{\infty} e^{-\frac{\tau - u}{\tau_0}} R(u) du$$



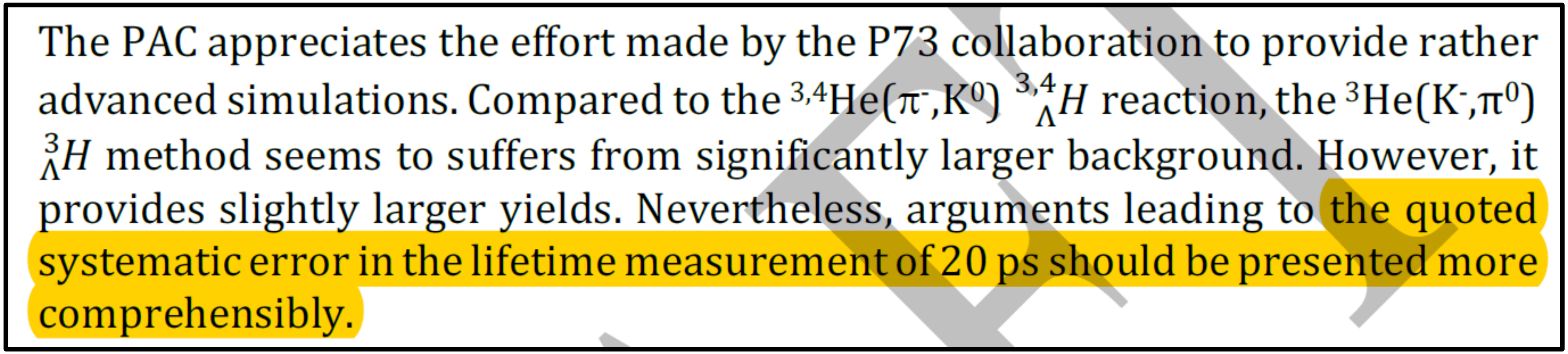
Total

Side-band BG

Signal

τ

Answer to the 27th PAC Comments

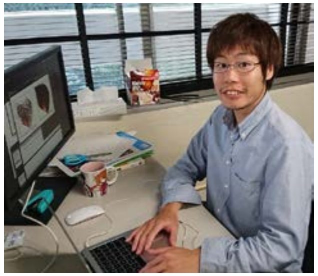


The PAC appreciates the effort made by the P73 collaboration to provide rather advanced simulations. Compared to the $^{3,4}\mathrm{He}(\pi^-,\mathrm{K}^0)$ $^{3,4}_{\Lambda}H$ reaction, the $^{3}\mathrm{He}(\mathrm{K}^-,\pi^0)$ $^{3}_{\Lambda}H$ method seems to suffers from significantly larger background. However, it provides slightly larger yields. Nevertheless, arguments leading to the quoted systematic error in the lifetime measurement of 20 ps should be presented more comprehensibly.

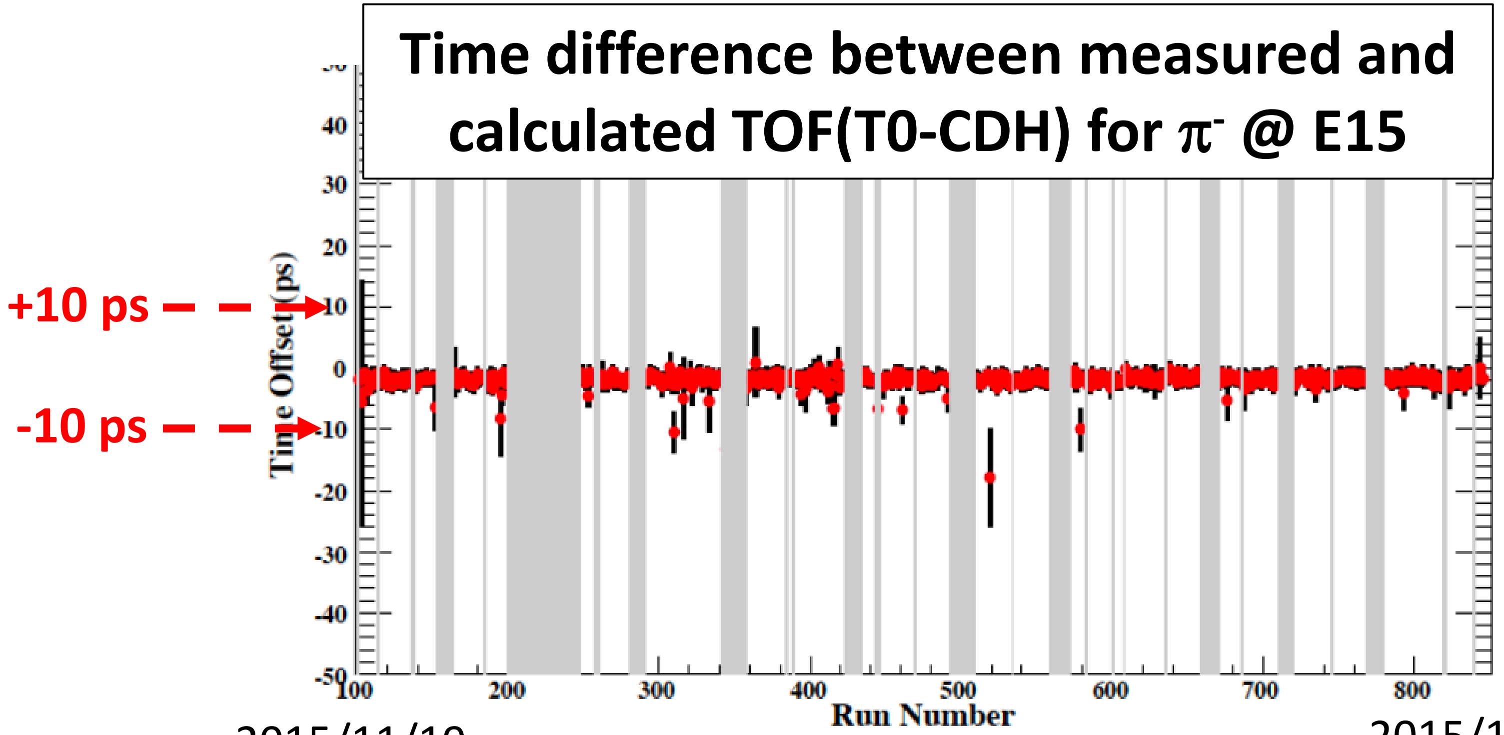
Syst. err. will be mainly originated from two types of errors:

- Time Zero Alignment **<5 ps**
  - Estimated with the E15 (K^- + ^{3}He) data **← Next page**
- Background subtraction **~20 ps**
  - Guesstimated from the previous experiment of $^{4}_{\Lambda}$H at KEK
  - **Have to be confirmed with real data analysis with the pilot-run data of K- + ^{4}He**

Time Zero Alignment Estimation with the E15 Data



Dr. Yamaga, RIKEN



Time difference between measured and calculated TOF(T0-CDH) for π^- @ E15

2015/11/19

2015/12/18

- E15-2nd data (Run65, ^{3}He(K$^-$,π^-)X)
  - Time zero can be determined **within 5 ps**
- Error propagated from the time zero alignment is estimated to be **<5 ps** with MC simulation

Answer to the 27th PAC Comments

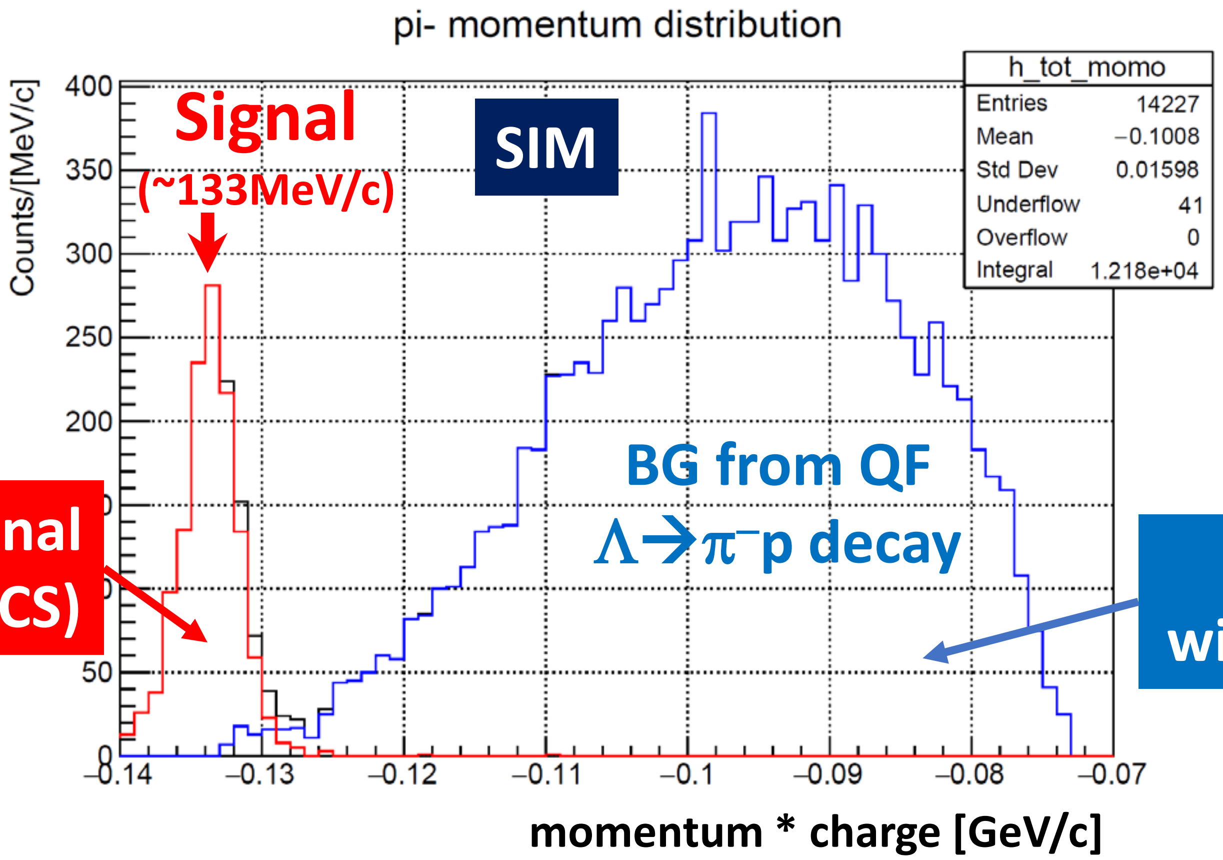
> The PAC appreciates the effort made by the P73 collaboration to provide rather advanced simulations. Compared to the ^{3,4}He(π^-,K^0) ${}^{3,4}_{\Lambda}H$ reaction, the ^{3}He(K$^-$,π^0) ${}^{3}_{\Lambda}H$ method seems to suffers from significantly larger background. However, it provides slightly larger yields. Nevertheless, arguments leading to the quoted systematic error in the lifetime measurement of 20 ps should be presented more comprehensibly.

We strongly request the ^{4}He pilot run for (K$^-$,π^0) background investigation

Syst. err. will be mainly originated from two types of errors:

- Time Zero Alignment <5 ps
  - Estimated with the E15 (K^- + ^{3}He) data set ← Next page
- Background subtraction **~20 ps**
  - Guesstimated from the previous experiment of ${}^4_{\Lambda}$H at KEK
  - **Have to be confirmed with real data analysis with the pilot-run data of K- + ^{4}He**

Expected π^- Spectrum of ${}^{4}_{\Lambda}\mathrm{H}$



Signal
(~133MeV/c)

SIM

BG from QF
$\Lambda \rightarrow \pi^- p$ decay

Expected Signal
(~ BNL E905 CS)

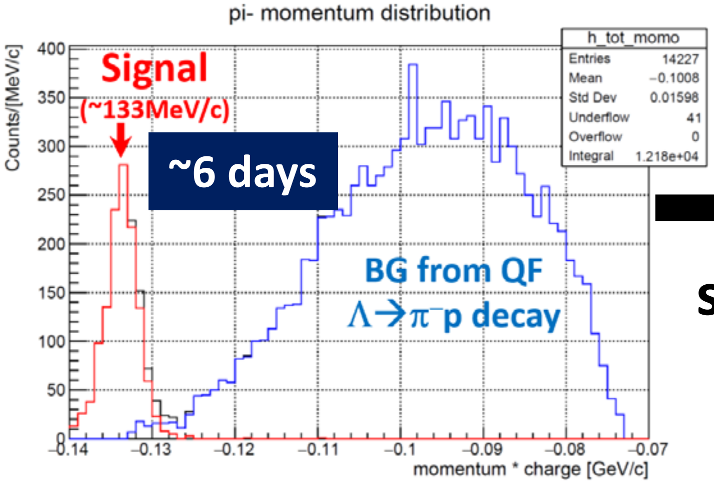
Sim. BG
with Geant4

- The spectrum with **~6 days** data taking at **50kW**
  - # of expected signal is ~1k
    - N(${}^{3}_{\Lambda}\mathrm{H}$) is expected to be ~ N(${}^{4}_{\Lambda}\mathrm{H}$) x1/3 [CS] x1/2 [Br(2-body)]
  - BG is estimated as with ${}^{3}\mathrm{He}$.

Based on theoretical CS
& BNL E905 results

Realistic Estimation using ^{4}He Data

K^{-} + ^{4}He

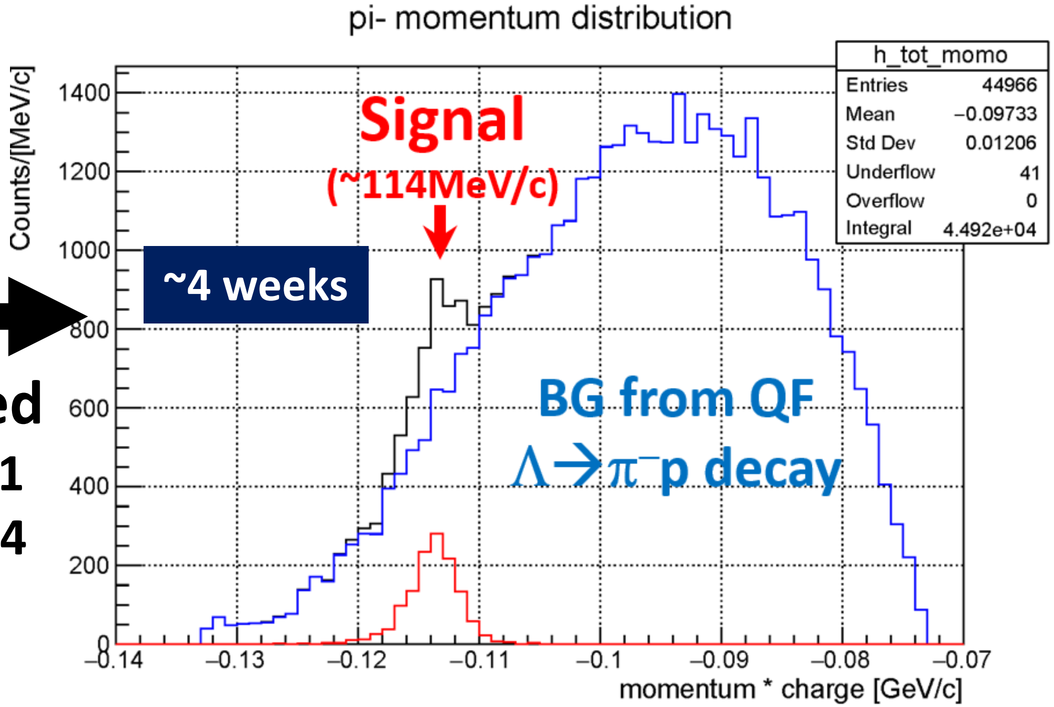


scaled

S x ~1

B x ~4

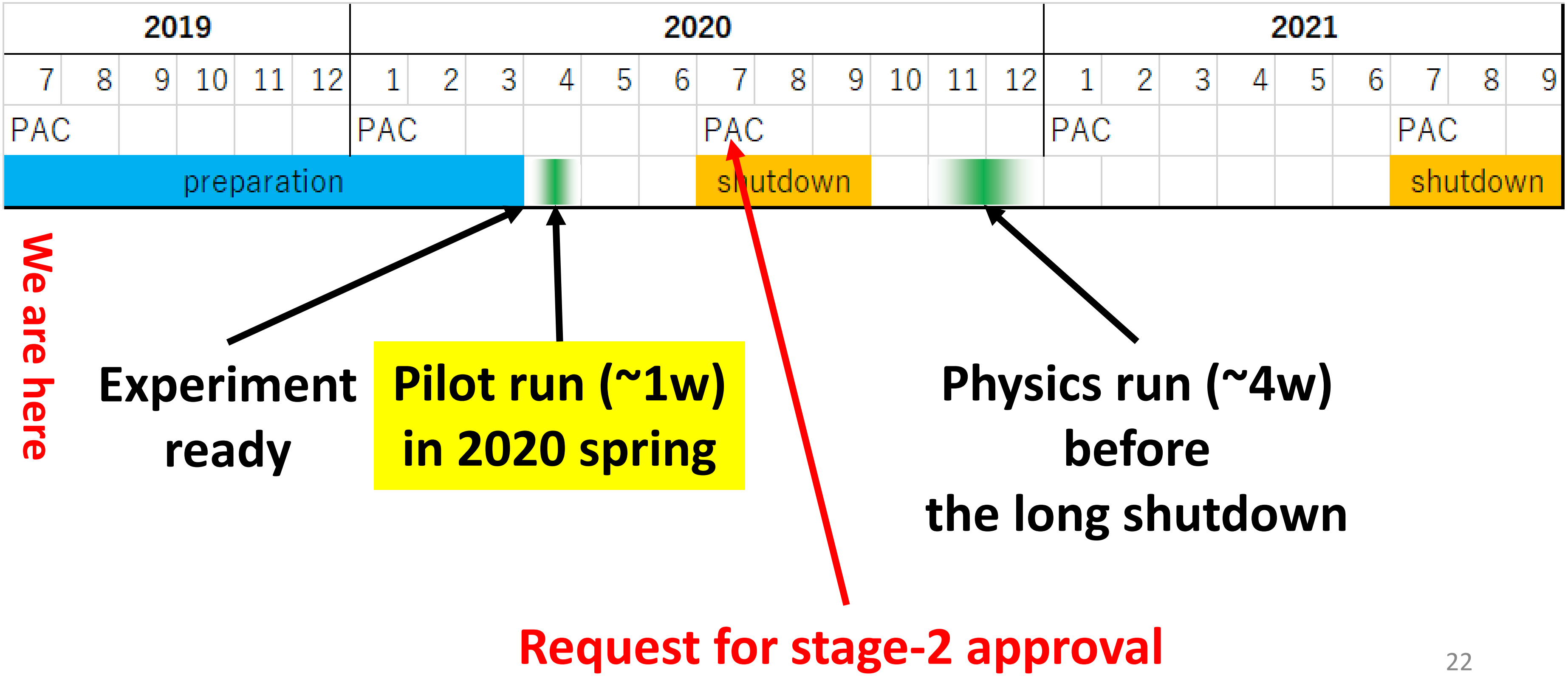
K^{-} + ^{3}He



- **We can do an realistic estimation of the $^{3}_{\Lambda}$H measurement using the BG in K^{-} + ^{4}He data**
  - BG will be almost the same between ^{3}He and ^{4}He
  - A sensitivity study can be possible with various $\sigma(^{3}_{\Lambda}\mathrm{H})$

Schedule

- To perform the experiment before the long shutdown scheduled in 2021, we would like to conduct the pilot run in 2020.



2019						2020												2021								
7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9
PAC						PAC						PAC						PAC						PAC		
preparation									🟩			shutdown				🟩	🟩							shutdown		

We are here

Experiment ready

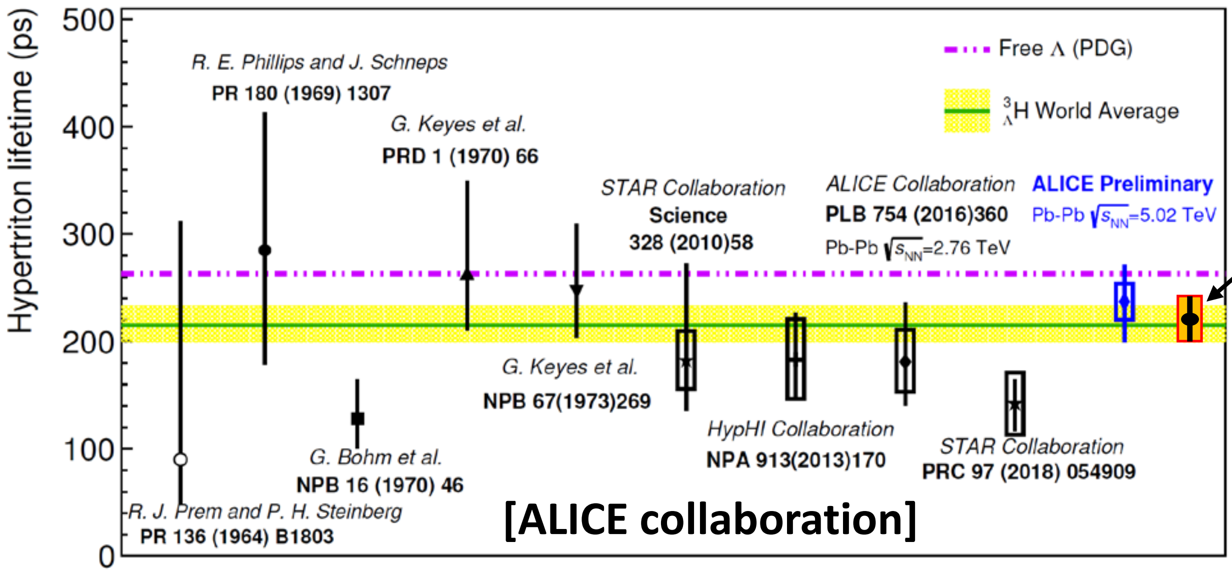
Pilot run (~1w) in 2020 spring

Physics run (~4w) before the long shutdown

Request for stage-2 approval

Summary of the P73 Experiment

- Direct measurement of the **hypertriton ($^{3}_{\Lambda}$H) lifetime** using **(K^{-},π^{0})** reactions.
- The experiment will be **ready at K1.8BR** in early 2020.
- We request **1 week** (1d+6d, 50kW equiv.) beamtime for **$^{4}_{\Lambda}$H** as **a pilot run in 2020**.
  - after feasibility study with $^{4}_{\Lambda}$H, we would like to request **the $^{3}_{\Lambda}$H physics run (~4 weeks, 50kW equiv.)**.



P73 expected

[ALICE collaboration]

P73 Collaboration

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

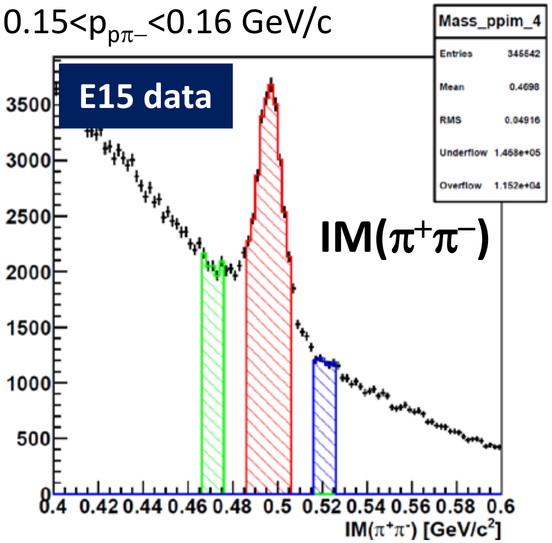
[1]RIKEN, Wako, 351-0198, Japan
[2]High Energy Accelerator Research Organization (KEK), Tsukuba, 305-0801, Japan
[3]Japan Atomic Energy Agency, Ibaraki 319-1195, Japan
[4]Institute of Modern Physics, Gansu 730000, China
[5]School of Nuclear Science and Technology, Lanzhou University, Gansu 730000, China
[6]Laboratori Nazionali di Frascati dell' INFN, I-00044 Frascati, Italy
[7]Horia Hulubei National Institute of Physics and Nuclear Engineering (IFIN-HH), Magurele, Romania
[8]CENTRO FERMI - Museo Storico della Fisica e Centro Studi e Ricerche "Enrico Fermi", 00184 Rome, Italy
[9]Osaka University, Osaka, 567-0047, Japan
[10]Tohoku University, Miyagi, 982-0826, Japan

Backup Slides

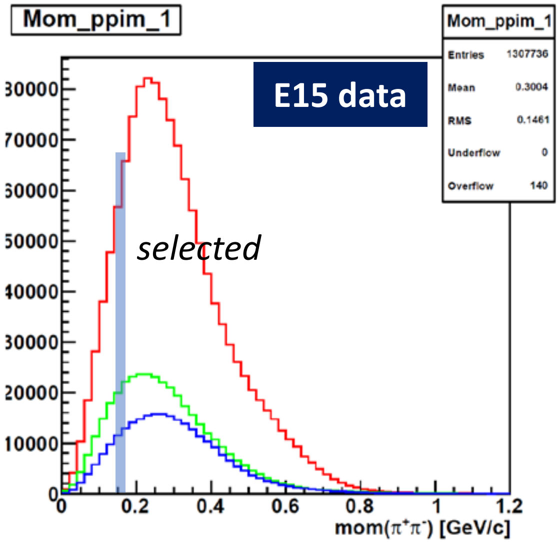
“free K^0_S” Lifetime with the E15 Data

In stead of Λ, we evaluated K^0_S lifetime with $K^0_S \rightarrow \pi^+\pi^-$ reconstruction

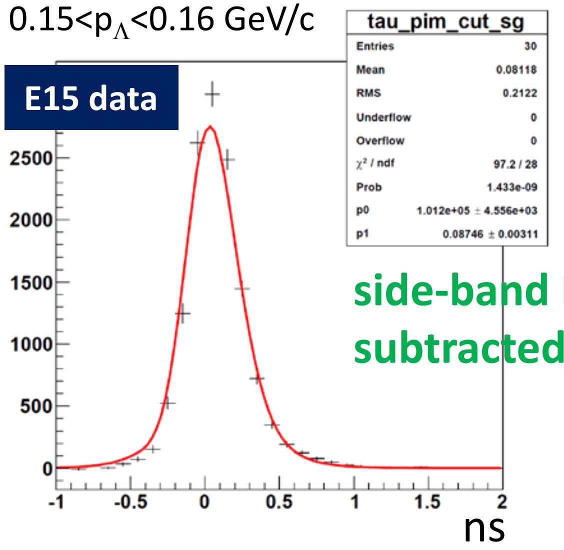
K^0_S selection



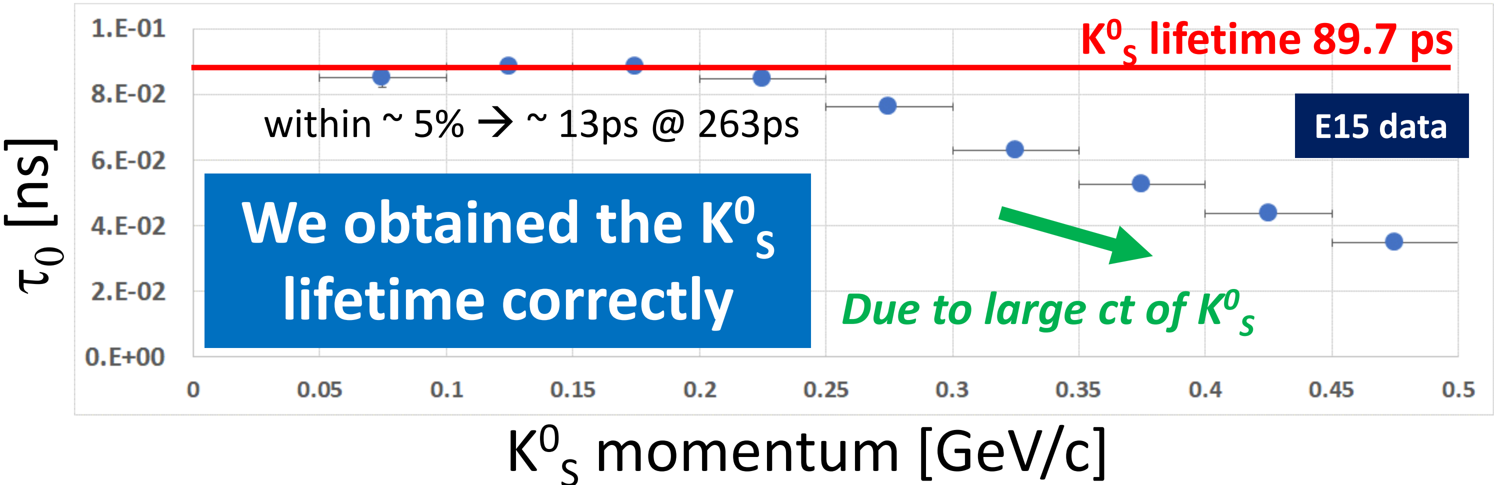
p_{K0s} distribution



π^- delay time fitting



side-band BG subtracted



K^0_S lifetime 89.7 ps

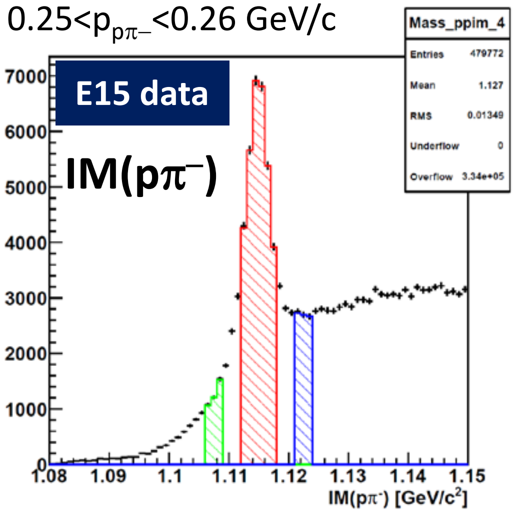
within ~ 5% → ~ 13ps @ 263ps

We obtained the K^0_S lifetime correctly

Due to large ct of K^0_S

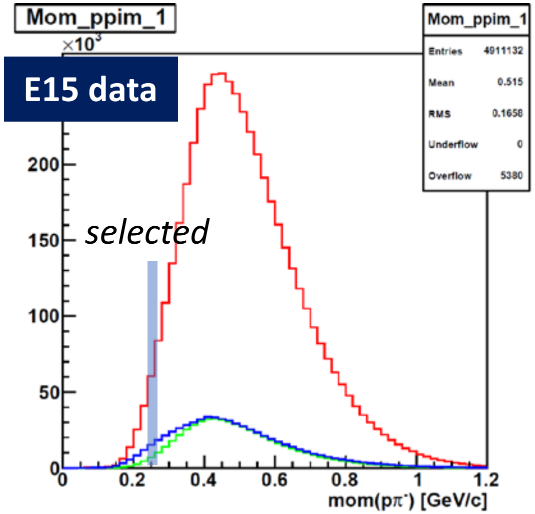
“free Λ” Lifetime Evaluation with the E15 Data

The main BG in P73 is ~100 MeV/c Λ, whose decay p CANNOT be detected by the CDS.

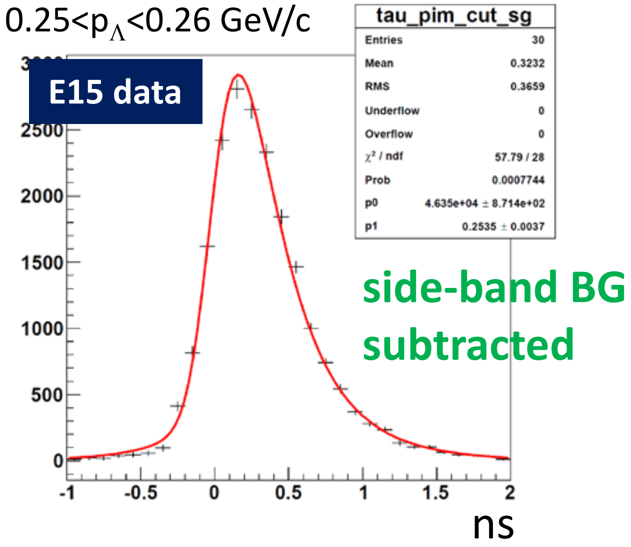


Λ selection

$0.25 < p_{p\pi^-} < 0.26$ GeV/c



p_Λ distribution



π^- delay time fitting

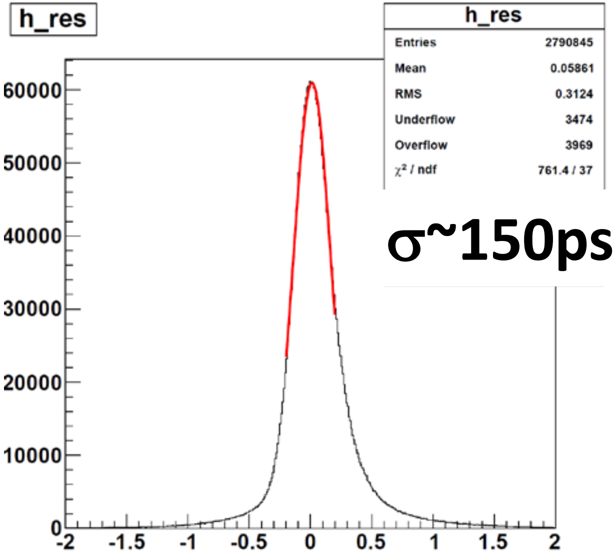
$0.25 < p_\Lambda < 0.26$ GeV/c

side-band BG subtracted

- We tried to obtain the lifetime using $\Lambda \rightarrow p\pi^-$ event sample
- However, we found that there are difficulties after $\Lambda \rightarrow p\pi^-$ reconstruction with the proposed method **at this moment**
  - low “proton” efficiency in low p_Λ region → large τ_0 ←*need efficiency correction*
  - large *ct* in high p_Λ region → small τ_0

Trigger Scheme

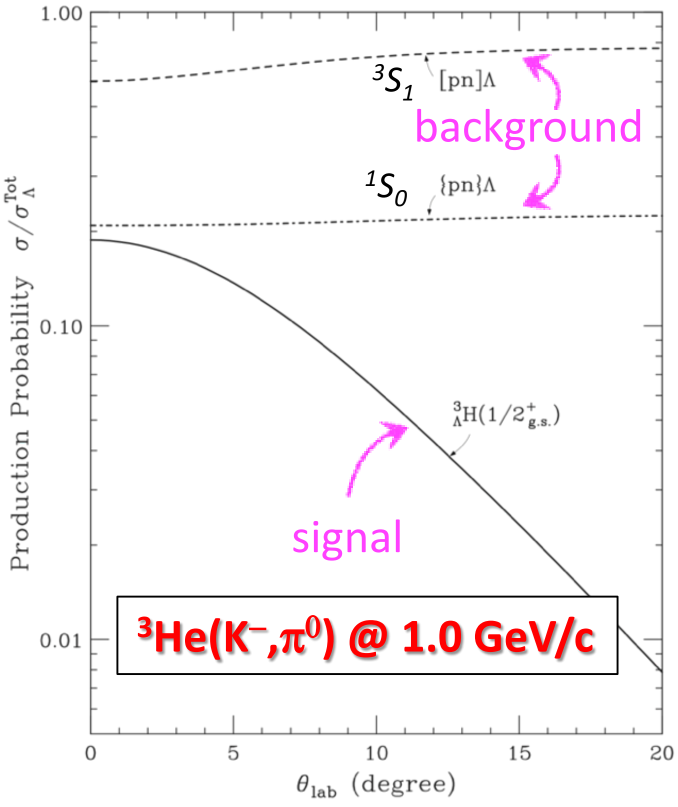
- **Main trigger is “K^--beam* CDH-1hit * E-cal”**
  - will be <<1k/spill estimated from E15 trigger (“K*CDH1*γ/n”)
  - up to ~5k/spill is acceptable by keeping ~95% eff. (HUL & HD-DAQ)
- **R(τ) is obtained with calibration trigger of (π^-,π^-)**
  - “π^--barm * CDH-1hit” trigger **← “prompt” π^- is dominant**



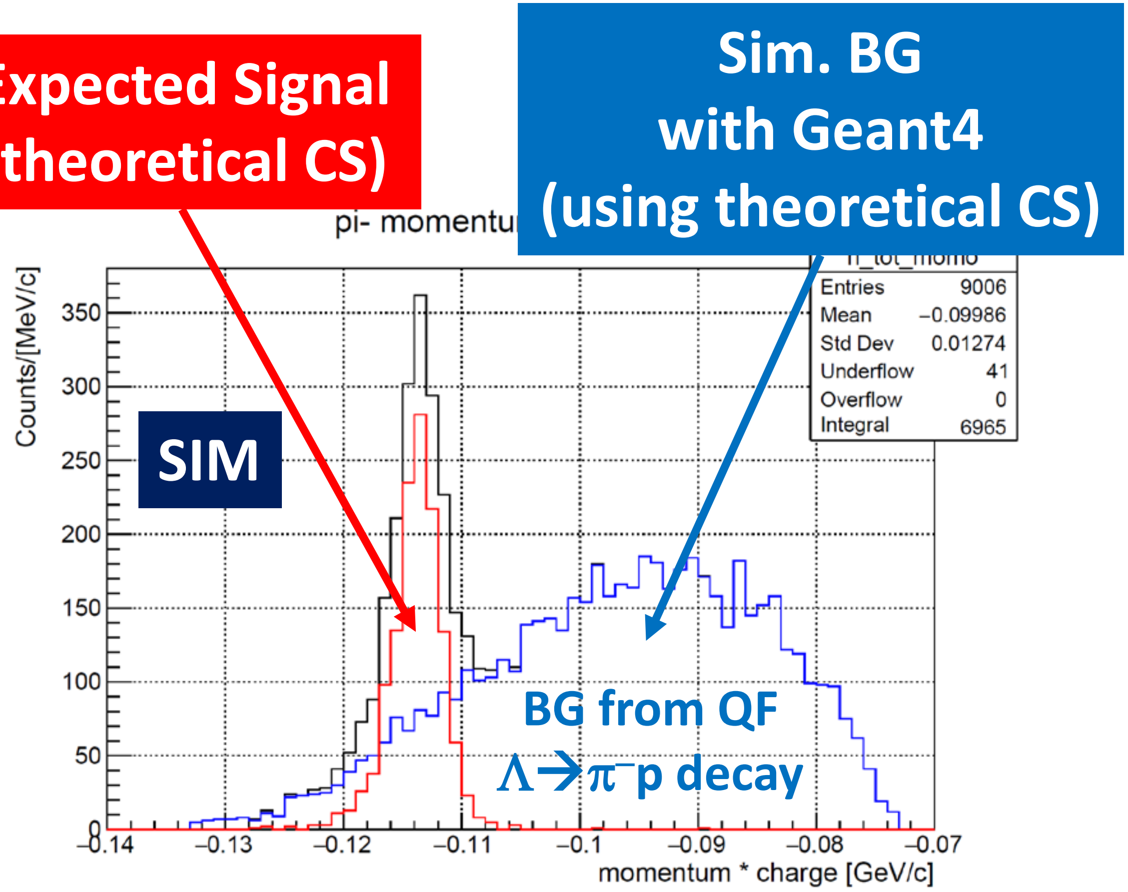
σ~150ps

R(τ) obtained with the E15 data
[ΔTOF(T0-CDH) using (K^-,π^-)]

Background from Theoretical Calculation



^{3}He(K$^-$,π^0) @ 1.0 GeV/c



Expected Signal (theoretical CS)

Sim. BG with Geant4 (using theoretical CS)

SIM

BG from QF
$\Lambda \rightarrow \pi^- p$ decay

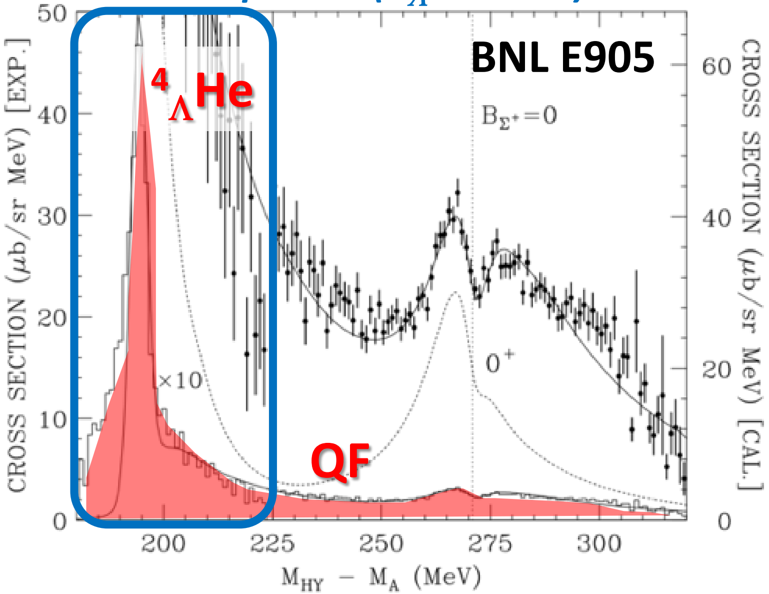
- Expected BG yield is much different btw “Geant4-CS” and “theoretical-CS”

Background from BNL ^{4}He(K^{-},π^{-}) Exp.

^{4}He(K^{-},π^{-}) @ 0.6 GeV/c

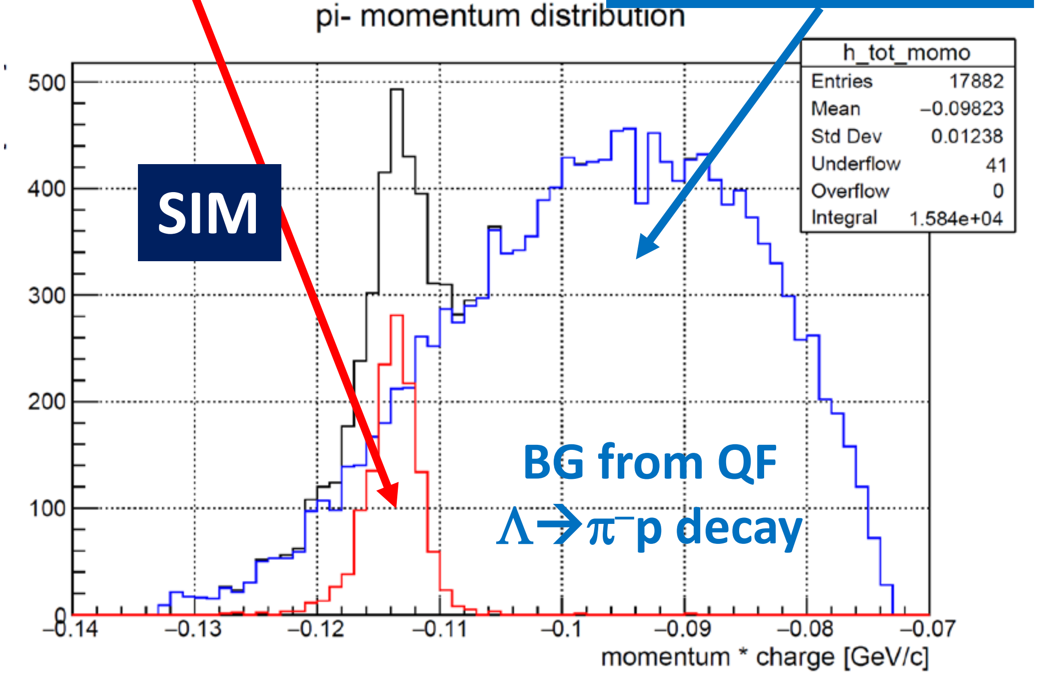
T. Nagae, PLR80(98)1605
T. Harada, PRL81(98)5287

detector acceptance (T_{Λ}<20MeV)



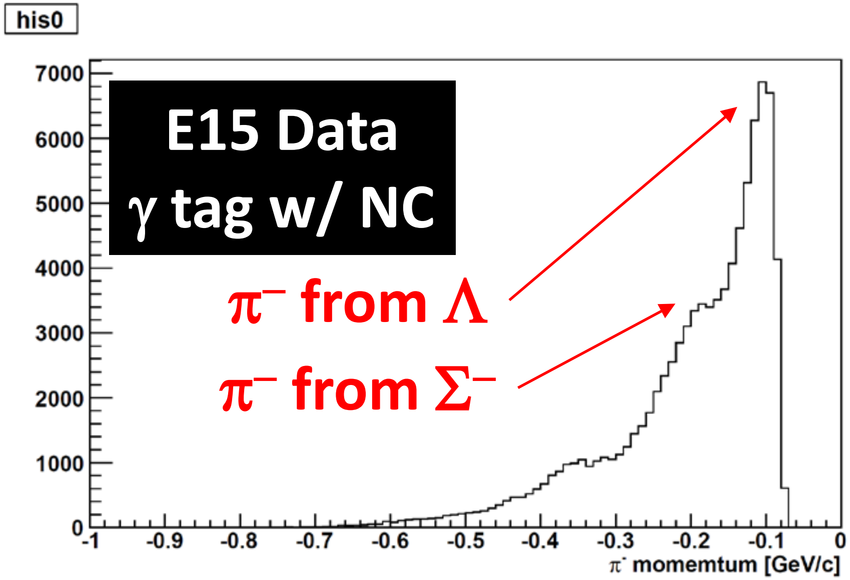
Expected Signal (theoretical CS)

Sim. BG with Geant4 (using Exp. CS)



- Expected BG yield is less than that based on “Geant4-CS”
  - S/BG~1/0.5 @ ^{4}He(K^{-},π^{-}), 0.6 GeV/c
  - S/BG~1/2 @ ^{4}He(K^{-},π^{0}), 1.0 GeV/c
    - mom-transfer 50→100 MeV (x~1/4)
  - **S/BG~1/16 @ ^{3}He(K^{-},π^{0}), 1.0 GeV/c**
    - **$\sigma(^{3}_{\Lambda}H)$ ~ 1/3 x $\sigma(^{4}_{\Lambda}H)$**
    - **BR($^{3}_{\Lambda}$H-2body) ~ 1/4, BR($\Lambda \rightarrow p\pi^{-}$) ~ 2/3**

Background Estimation w/o ΔE cut

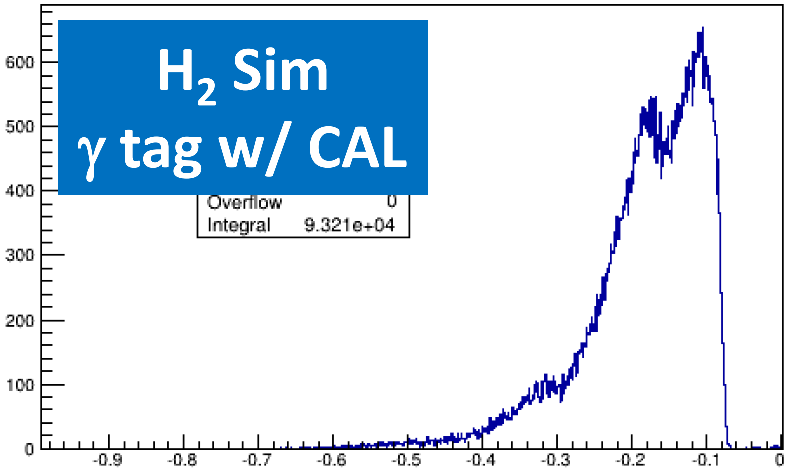

E15 Data

γ tag w/ NC

π^- from Λ

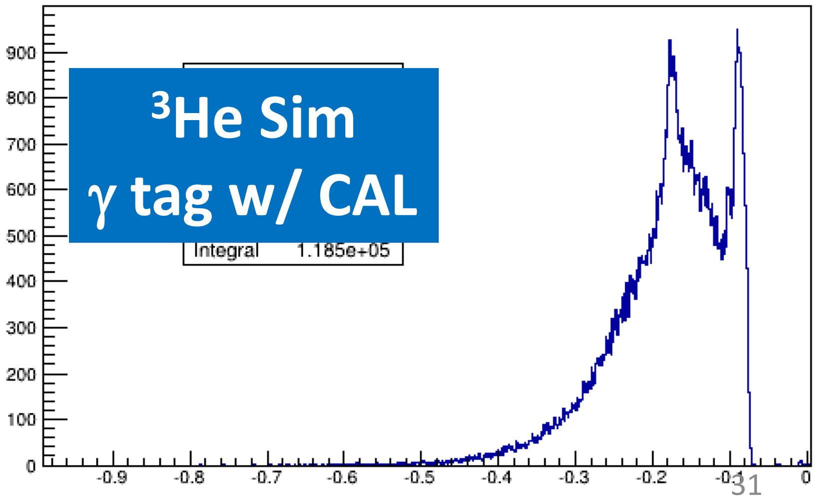
π^- from Σ^-

momentum tracked with CDS


H_2 Sim

γ tag w/ CAL

momentum tracked with CDS

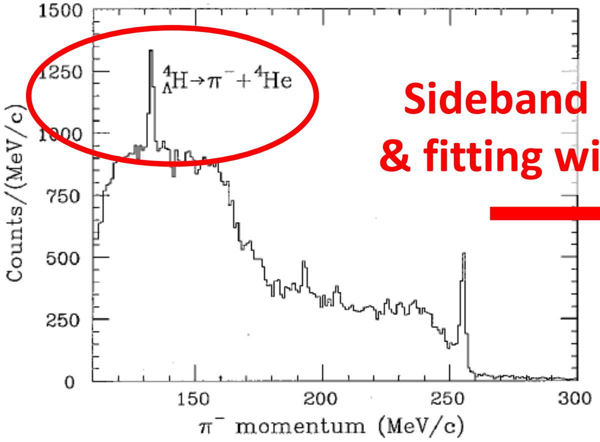

^{3}He Sim

γ tag w/ CAL

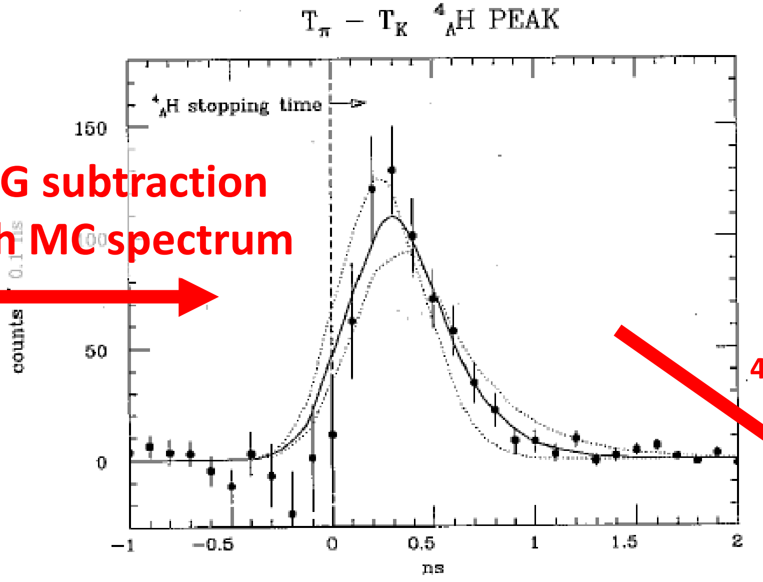
- including low-energy γ (π^0)
  - can be reject with ΔE cut
- **E15 data favors H_2 simulation**
  - **thus we employ H_2 sim.**

$^{4}{}_{\Lambda}$H Lifetime @ KEK

- ^{4}He(stopped K^-, π^-)$^{4}{}_{\Lambda}$H reaction
- The lifetime was obtained from a fitting with a simulated spectrum

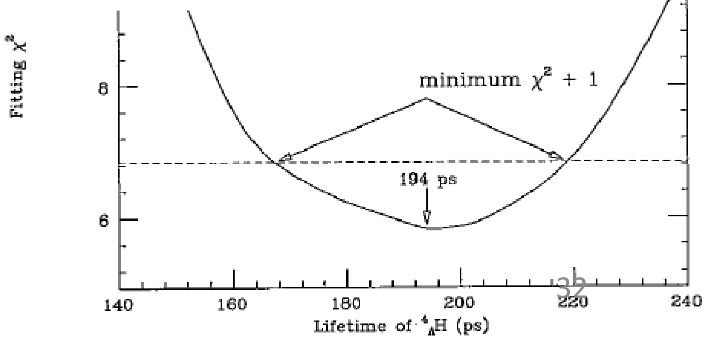


Sideband BG subtraction & fitting with MC spectrum



H. Outa, D-thesis

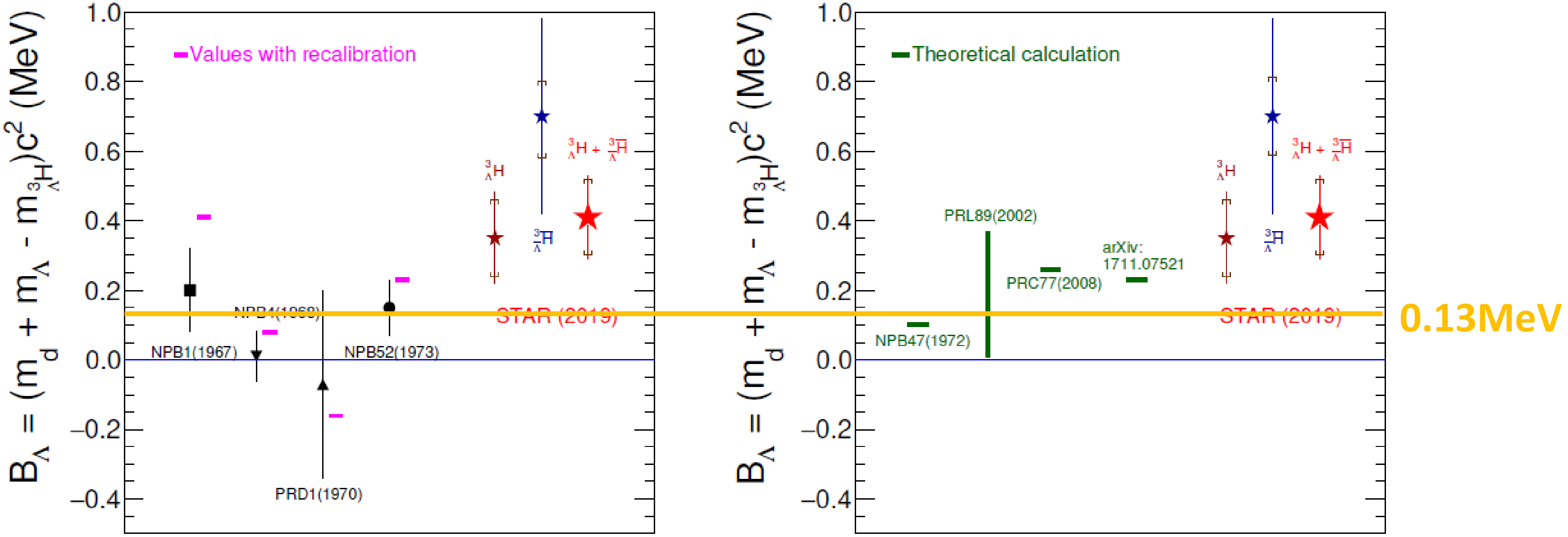
$^{4}{}_{\Lambda}$H lifetime



For cross-check, we will apply the same procedure to the $^{3}{}_{\Lambda}$H analysis.

Binding Energy of $^{3}_{\Lambda}$H?

- The STAR experiment also reported rather large binding energy of ~0.4 MeV
- However, the lifetime is expected not to be shorten so much, even if the binding energy is as large as the START reported



STAR, arXiv:1904.10520

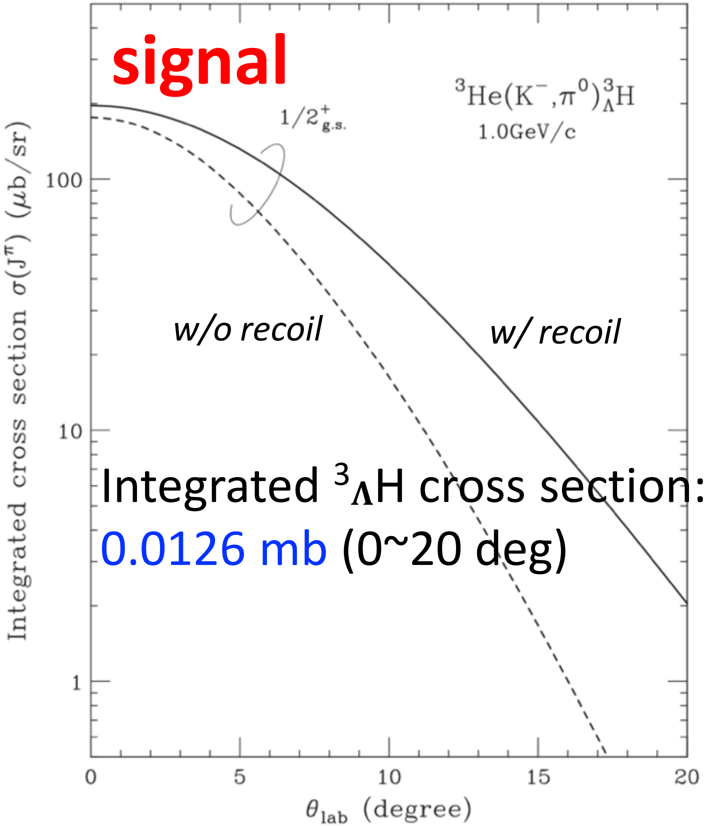
Slides from the 27th PAC

Performance estimation: yield estimation

Target: liquid 3He, 10cm	$1.6\times10^{23}/\mathrm{cm}^2$
K- intensity @ 1GeV/c	$2\times10^{5}/5.2\mathrm{s}$
σ of ${}^{3}_{\Lambda}$H g.s.	0.0126 mb
Accelerator up time	80%
Beam acceptance	60%
DAQ efficiency	90%
${}^{3}_{\Lambda}\mathrm{H}\rightarrow{}^{3}\mathrm{He}+\pi^-$ b.r.	25%
π- & π0 acceptance	6%
${}^{3}_{\Lambda}$H signal yield	***~1000 events/4 weeks***

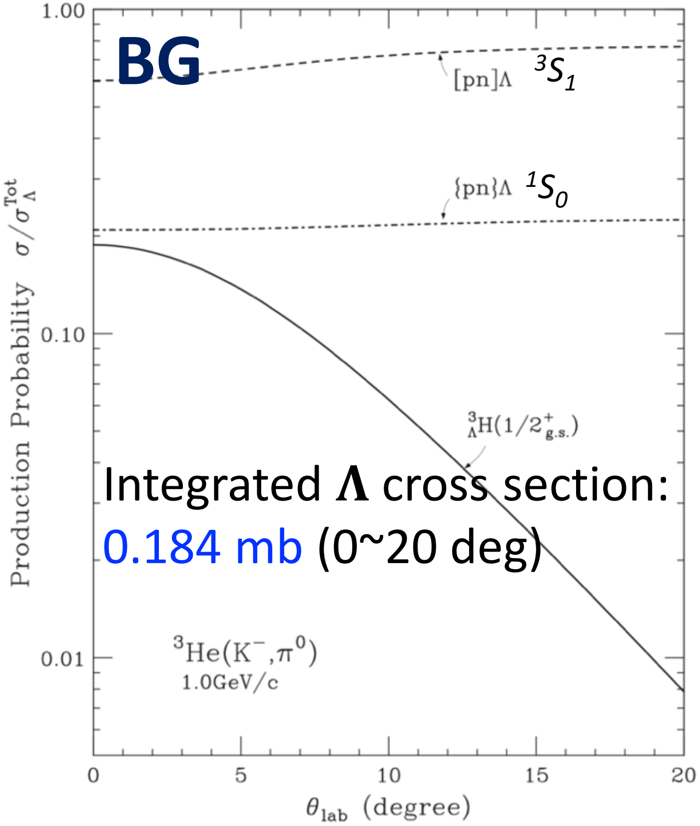
${}^{4}_{\Lambda}$H signal yield (same target cell):
~3(cross section)×2(π^- branching ratio)×${}^{3}_{\Lambda}$H signal yield
==> ***~1000 events/1 week***

Performance estimation: $^{3}_{\Lambda}\mathrm{H}$ cross section



signal

Integrated $^{3}_{\Lambda}\mathrm{H}$ cross section:
0.0126 mb (0~20 deg)



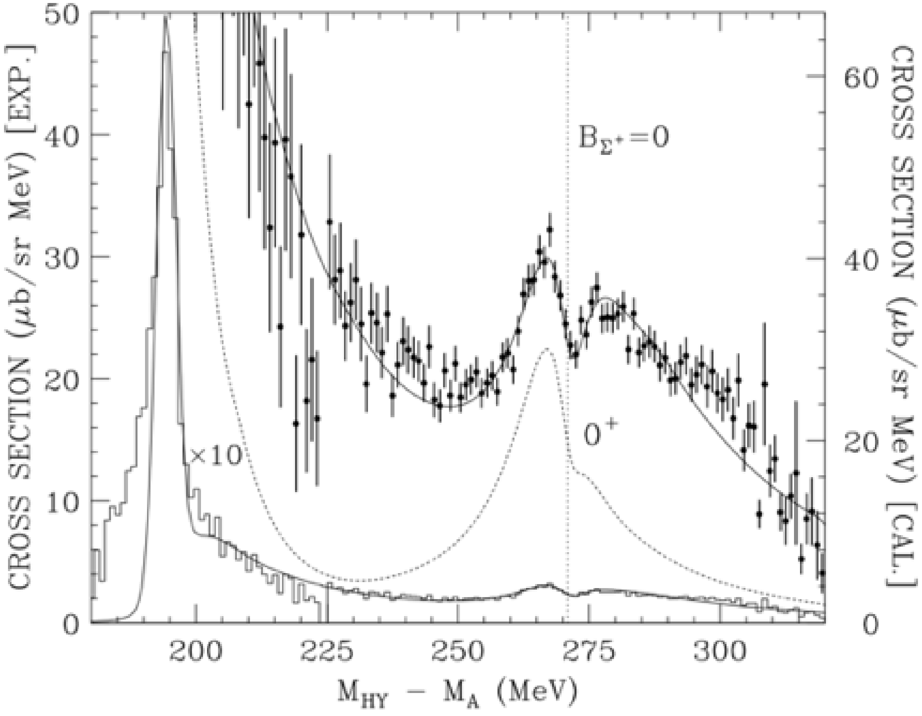
BG

Integrated **Λ** cross section:
0.184 mb (0~20 deg)

$^{3}\mathrm{He}(K^{-},\pi^{0})^{3}_{\Lambda}\mathrm{H}$ cross section calculated by Prof. Harada, using the CDCC (continuum discretized coupled-channels) method and DWIA

Private communication with Prof. T. Harada

Performance estimation: $^{4}_{\Lambda}\mathrm{H}$ cross section



T. Harada, Phys. Rev. Lett., 81, 5287, (1998)

No direct calculation available

for $^{4}\mathrm{He}(K^-, \pi^0)^{4}_{\Lambda}\mathrm{H}$ reaction at 1GeV/c

1, for $^{4}\mathrm{He}(K^-, \pi^-)^{4}_{\Lambda}\mathrm{He}$ reaction, σ~3.5mb/sr at 0.6GeV/c, 4deg

2, taking into account isospin coupling factor of ½

3, considering recoiling momentum and $n(K^-, \pi^-)\Lambda$ elementary cross section between 0.6 and 1.0 GeV/c K- beam

$^{4}\mathrm{He}(K^-, \pi^0)^{4}_{\Lambda}\mathrm{H}$ @ 1.0 GeV, 4deg: ~0.44mb (scaled)
$^{3}\mathrm{He}(K^-, \pi^0)^{3}_{\Lambda}\mathrm{H}$ @ 1.0 GeV, 4deg: ~0.15mb (calc.)

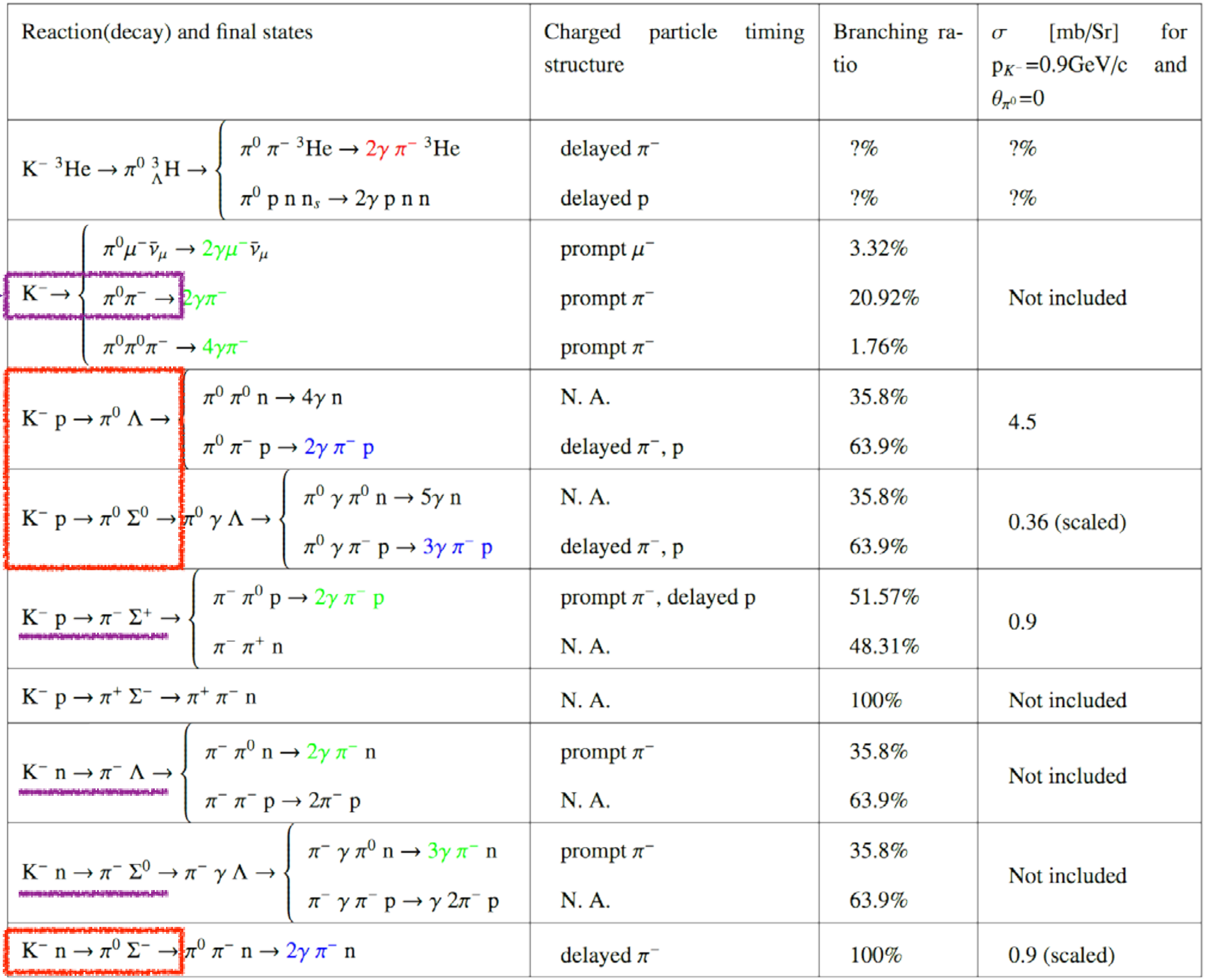
Elementary CS @ 0 degree is almost the same

- $K^- n \rightarrow \Lambda\pi^-$: ~2.5mb @ 0.6GeV/c ($q$~50MeV/c)
- $K^- p \rightarrow \Lambda\pi^0$: ~2.5mb @ 1.0GeV/c ($q$~100MeV/c)

$^{4}_{\Lambda}\mathrm{H}$ cross section *estimated* to be ~3 times of $^{3}_{\Lambda}\mathrm{H}$

Part I: Performance estimation

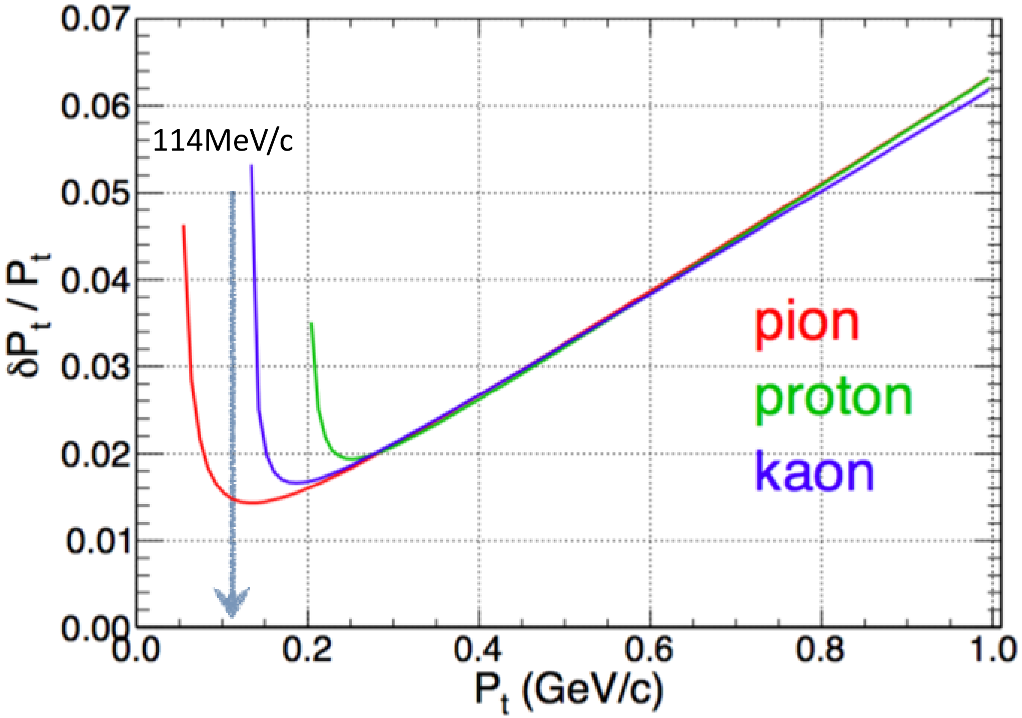
out of pi0⊕pi- acceptance



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^-.

Performance estimation: pi- resolution



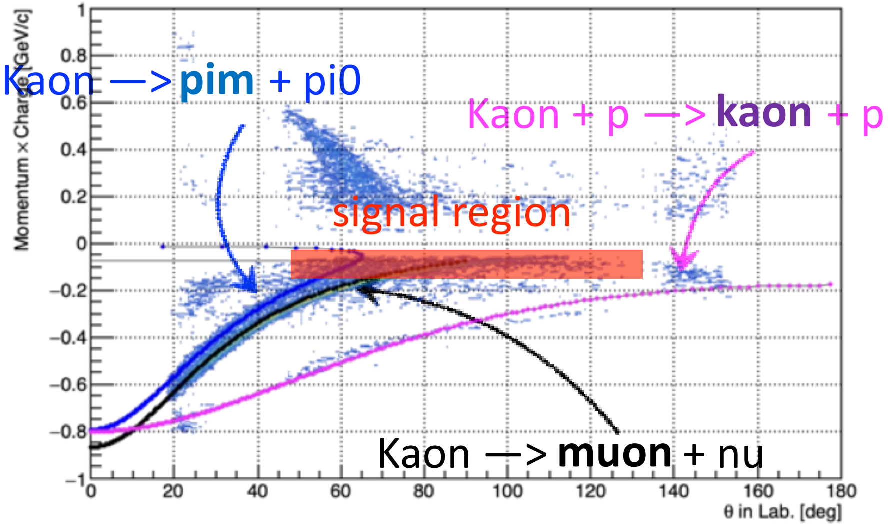
According to GEANT4 simulation,
~2% momentum resolution is achieved for total π^- momentum (pt + pl) after energy loss correction.

T. Hashimoto PhD thesis, University of Tokyo, 2013

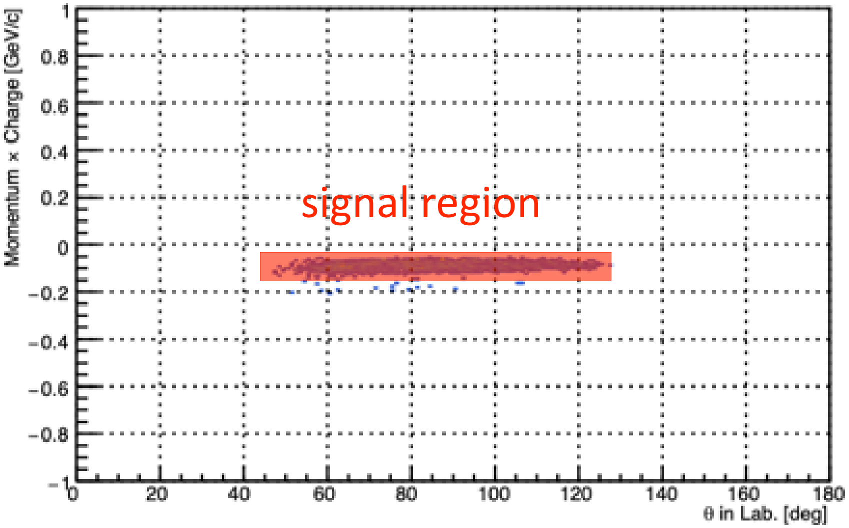
Kaon in-flight decay background

- dE veto counter <= 0.2 MeV && PbF2 calorimeter >= 600 MeV
- IH == 1 && CDS charged track == 1
- CDS tracking mass >= 0 && <= 0.3 GeV/c^2
- DCA <= 5mm && fiducial cut

From Monte Carlo information, only hyperon and hypernucleus events survived the event selection --> effective trigger and analysis method

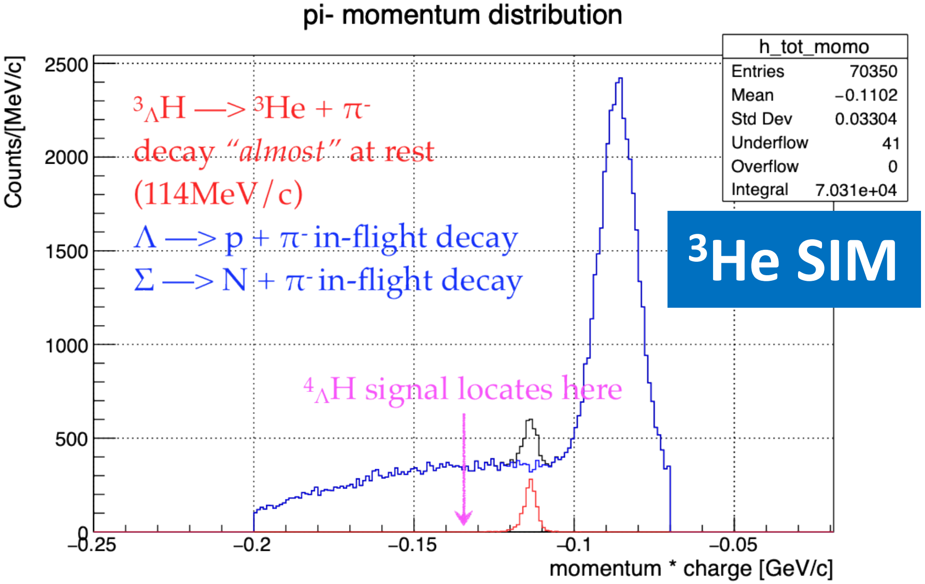


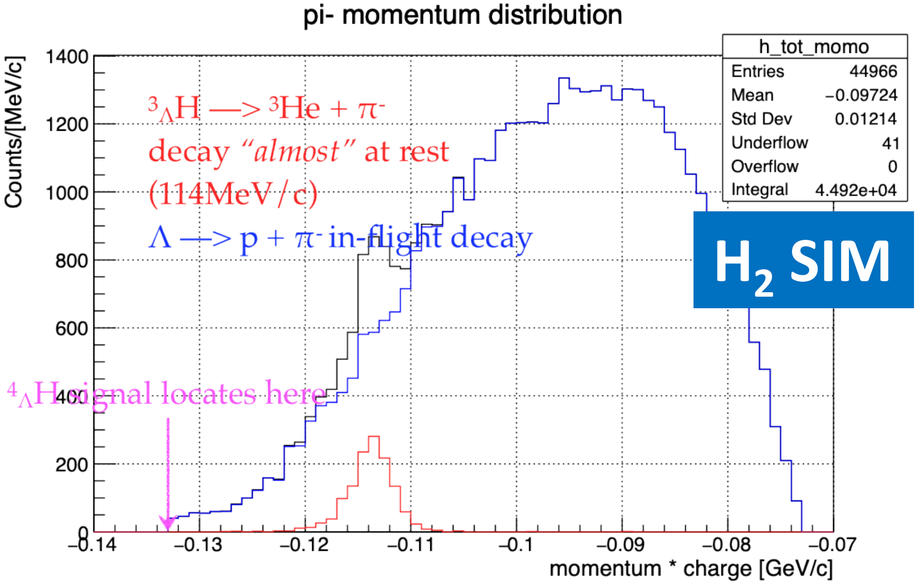
Before event selection



After event selection

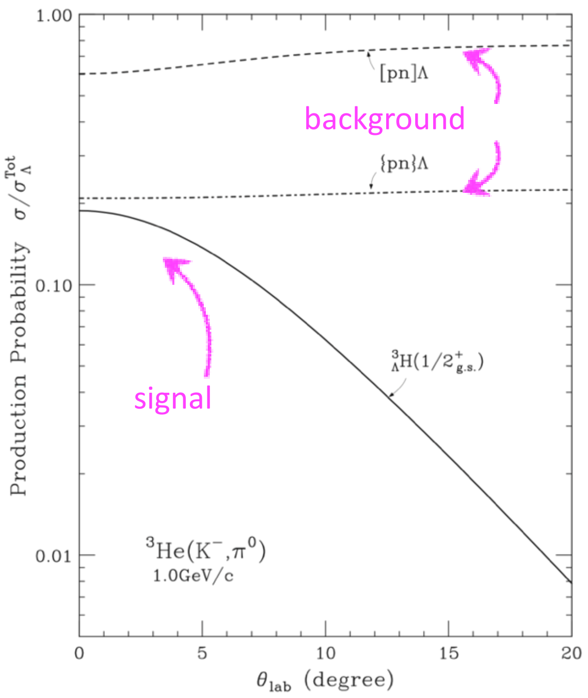
Reaction induced background

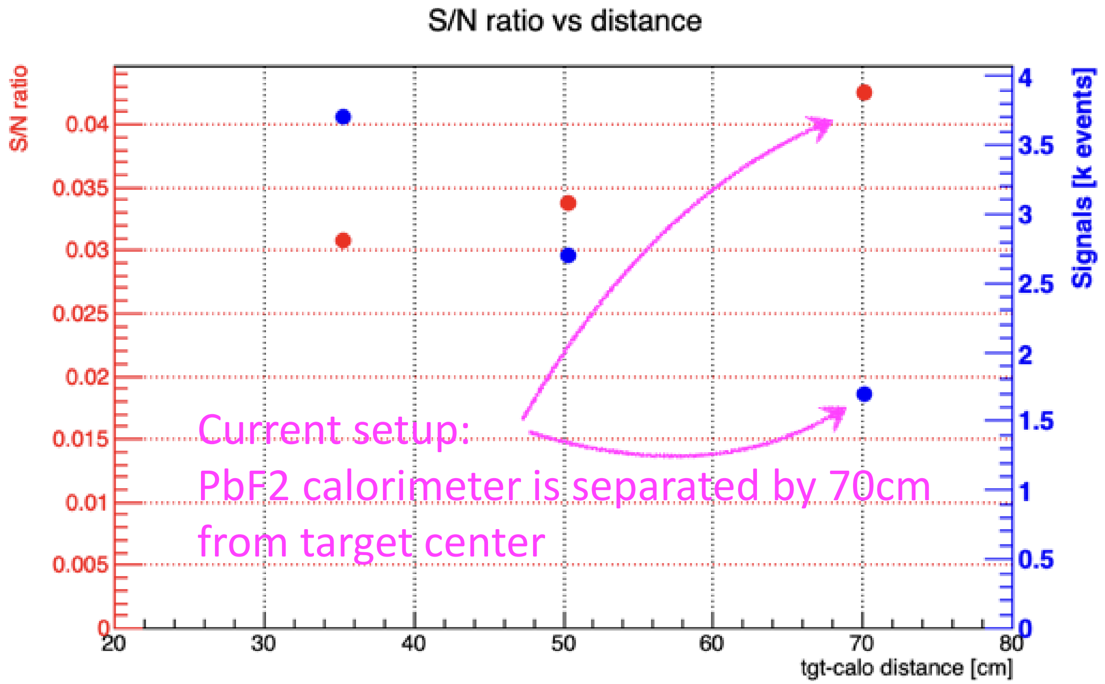




- True background shape may be somewhere in between these two cases ***(an open question)***
- Even for the high background case(Hydrogen), we still can identify the signal region
- $^{4}{}_{\Lambda}H$ signal locates ~130MeV/c, which will have better S/N ratio for both cases: ***one week beam time(50kW) with ^{4}He target*** can tell us the feasibility

Setup optimization



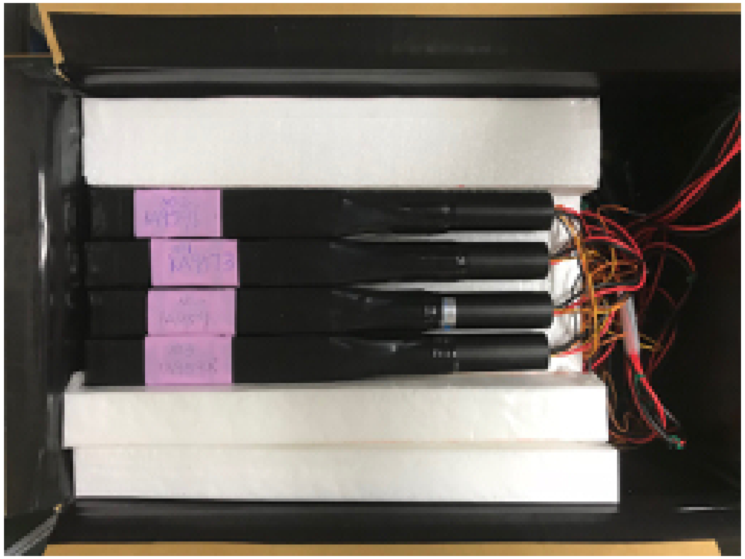


Current setup:
PbF2 calorimeter is separated by 70cm from target center

- A balance between S/N and statistical error
- Leave PbF2 calorimeter away from CDS spectrometer to avoid contamination and magnetic field effect on PMT

PbF2 calorimeter

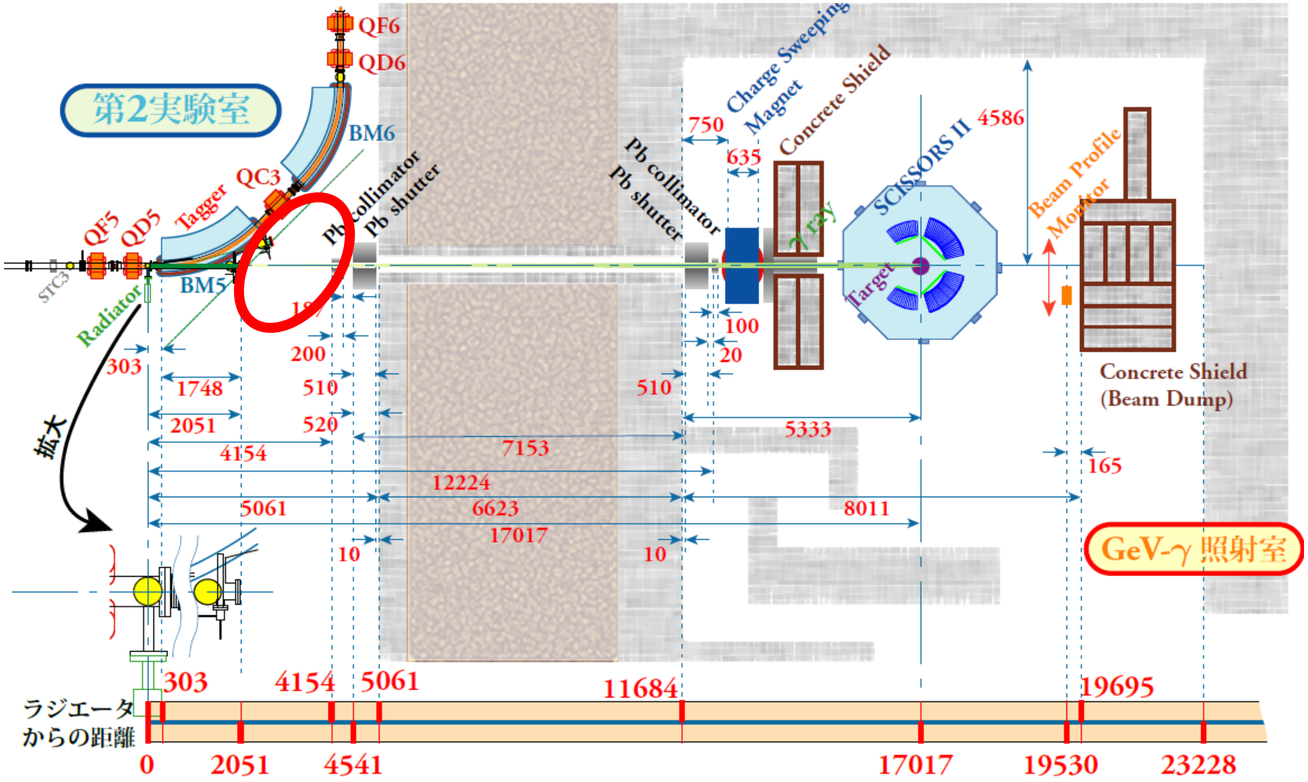
Crystal size: 2.5cm x 2.5cm x 13cm
In total: 36 segments, 6x6
--- 40 pieces in stock
PMT: H6612 (¾ inch PMT)
--- 40 pieces in stock



- Signal calibration will be performed this year (2019)
- Ready to run by the beginning of 2020

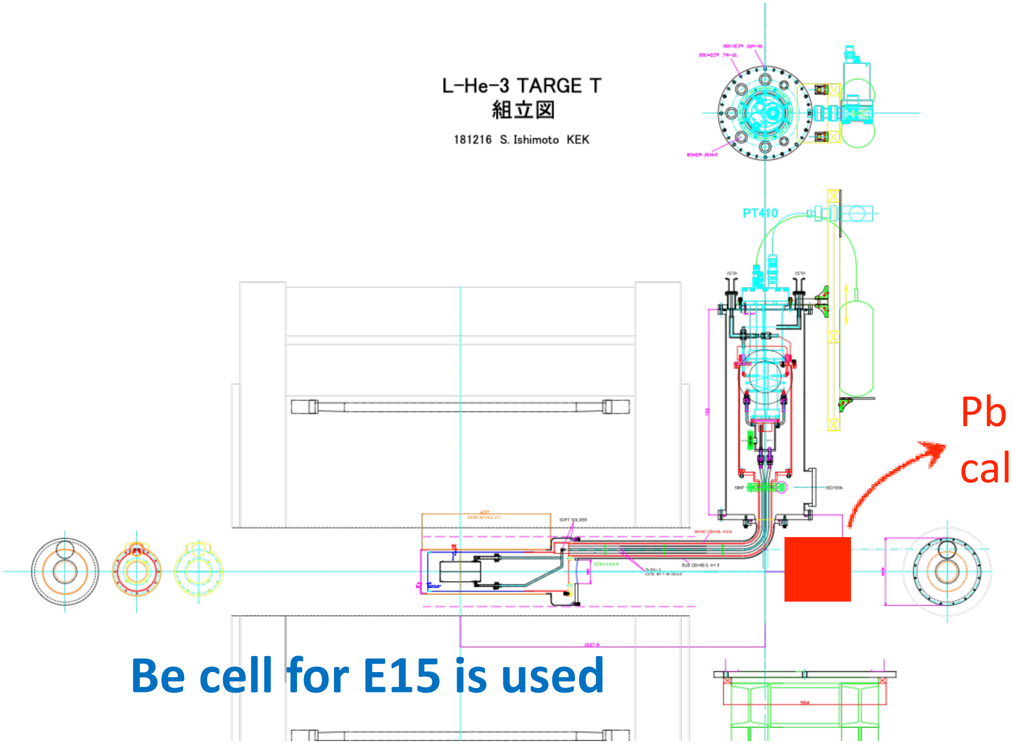
PbF2 calorimeter test @ ELPH

the 2nd experimental room in ELPH



- We are planning to conduct calorimeter test using ~ GeV γ or positron at ELPH, Tohoku-U **in the end of this year (2019)**
  - Gain-uniformity/Position-dependence/Energy-dependence/…

liquid ^{3,4}He target

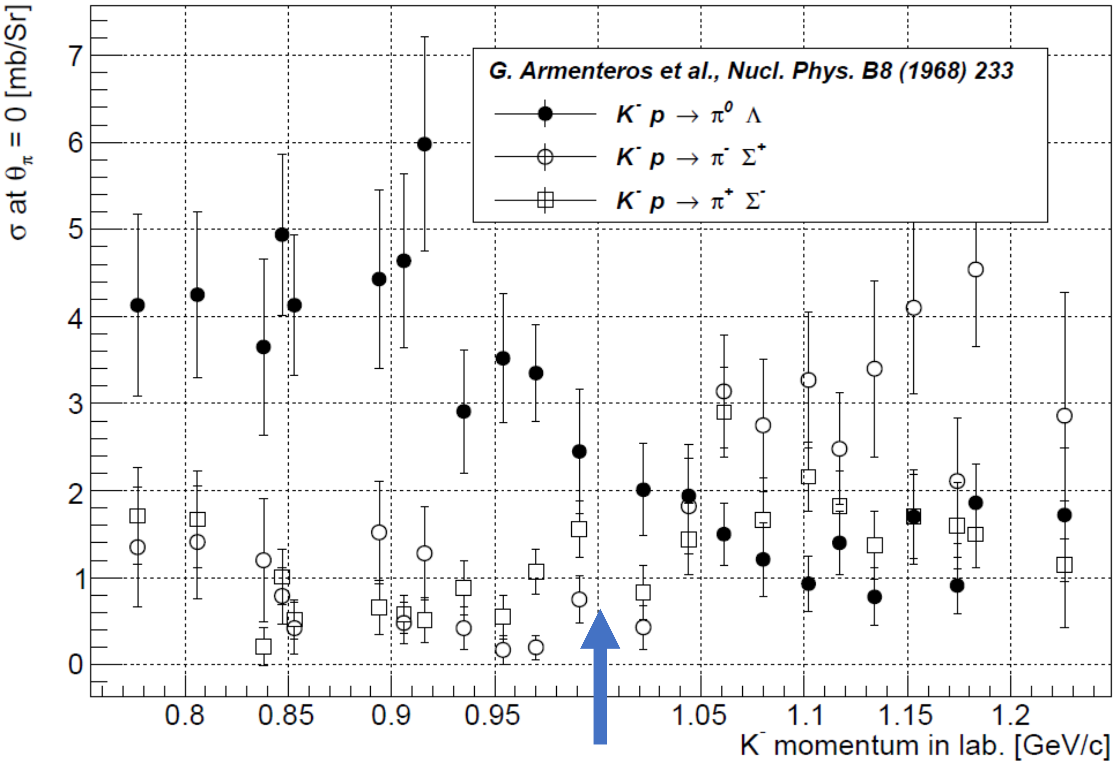


PbF2 calorimeter

Be cell for E15 is used

- Liquefaction system is changed from “syphon type with L^{4}He refrigerant” to “**Pulse tube refrigerator**”
- Designed by Dr. Ishimoto and Dr. T. Hashimoto
- Ready to run by the beginning of 2020

p(K^-,π)Y Cross Section



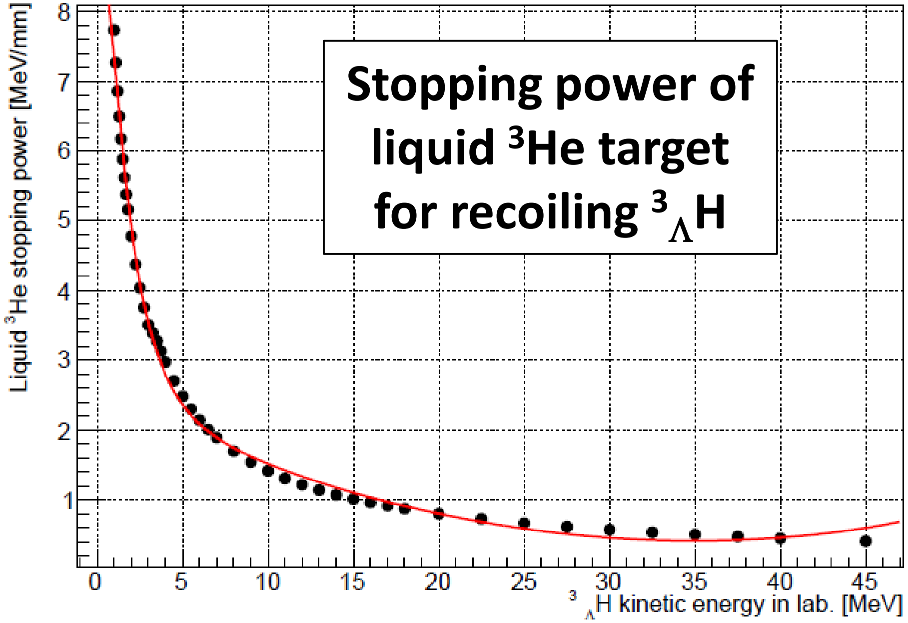
$K^-p \rightarrow \pi^0\Lambda$: ~ 2.5 mb/Sr @ 1.0 Gev/c, θ_π = 0 degree

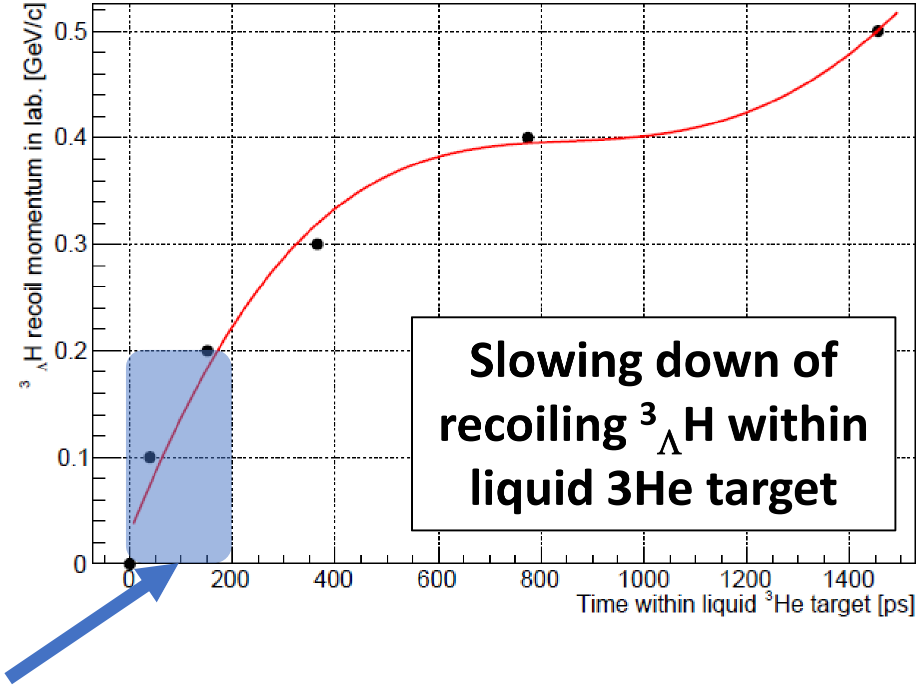
Figure 4: Production cross section for p(K^-, π)Λ,Σ reaction[10].

[10] G. Armenteros *et al.*, Nucl. Phys. B, **8**, 233, (2012)

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

calculated with the SRIM package


Stopping power of liquid ^{3}He target for recoiling $^{3}_{\Lambda}$H


Slowing down of recoiling $^{3}_{\Lambda}$H within liquid 3He target

$^{3}_{\Lambda}$H stops after 200ps within 1mm;
the recoiling effects on lifetime and
π^{-} momentum is negligible