New experiment using the existing detector system @ K1.8BR

$^{3}_{\Lambda}$H lifetime measurement with ^{3}He(K^{-}, π^{0})$^{3}_{\Lambda}$H Reaction

RIKEN

F.Sakuma, RIKEN

RIKEN NiSHiNA CENTER

on behalf of the P73 Collaboration

“Strange Matter Workshop - Strangeness studies in Italy and Japan“

Laboratori Nazionali di Frascati INFN

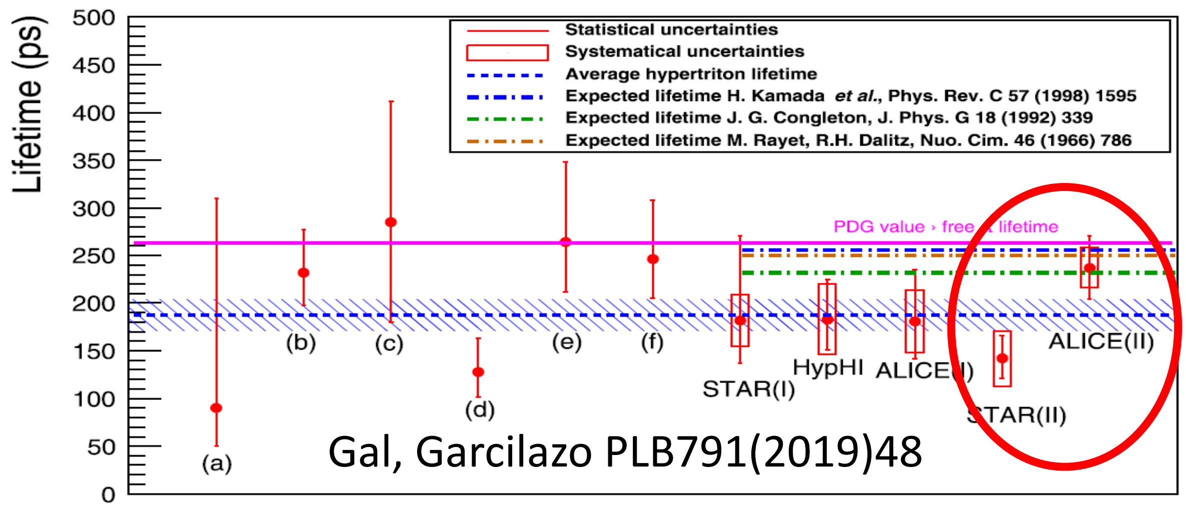
16-17 October 2019

Lifetime of Hyper-triton

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

STAR (2018)	ALICE (2019)	free Λ
$142^{+24}_{-21} \pm 29$ ps	$242^{+34}_{-38} \pm 17$ ps	263 ± 2 ps

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

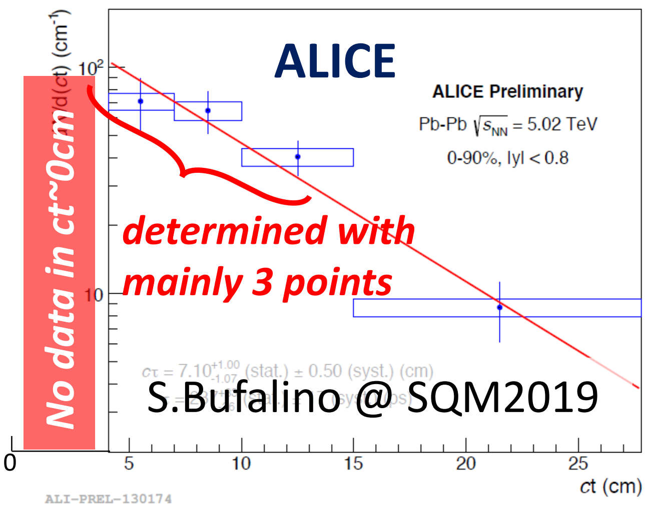


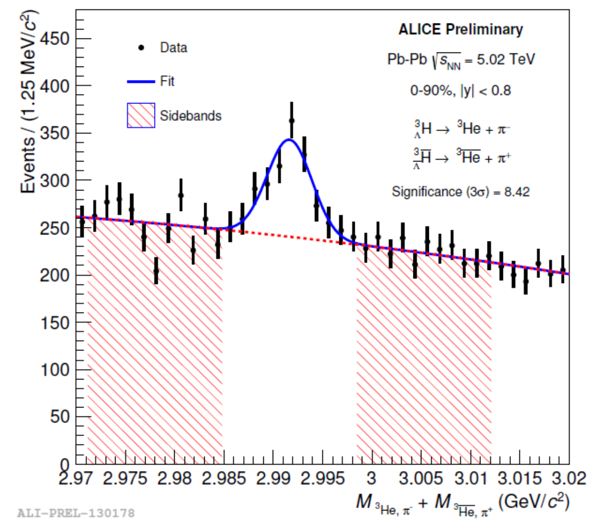
→ need to clarify the situation using different experimental technique

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



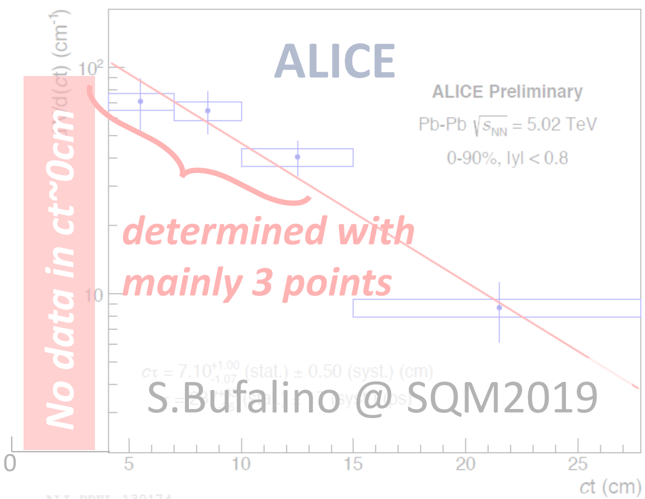


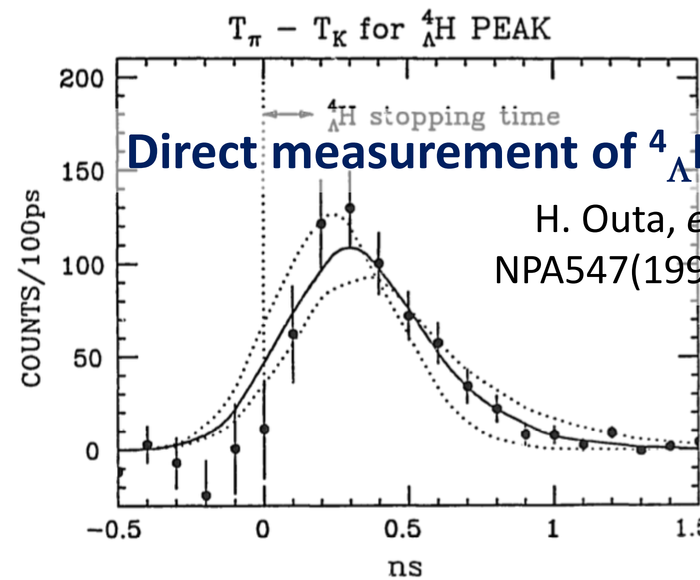
Direct Lifetime Measurement

Heavy-ion experiment STAR, ALICE, HypHI

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

complementary

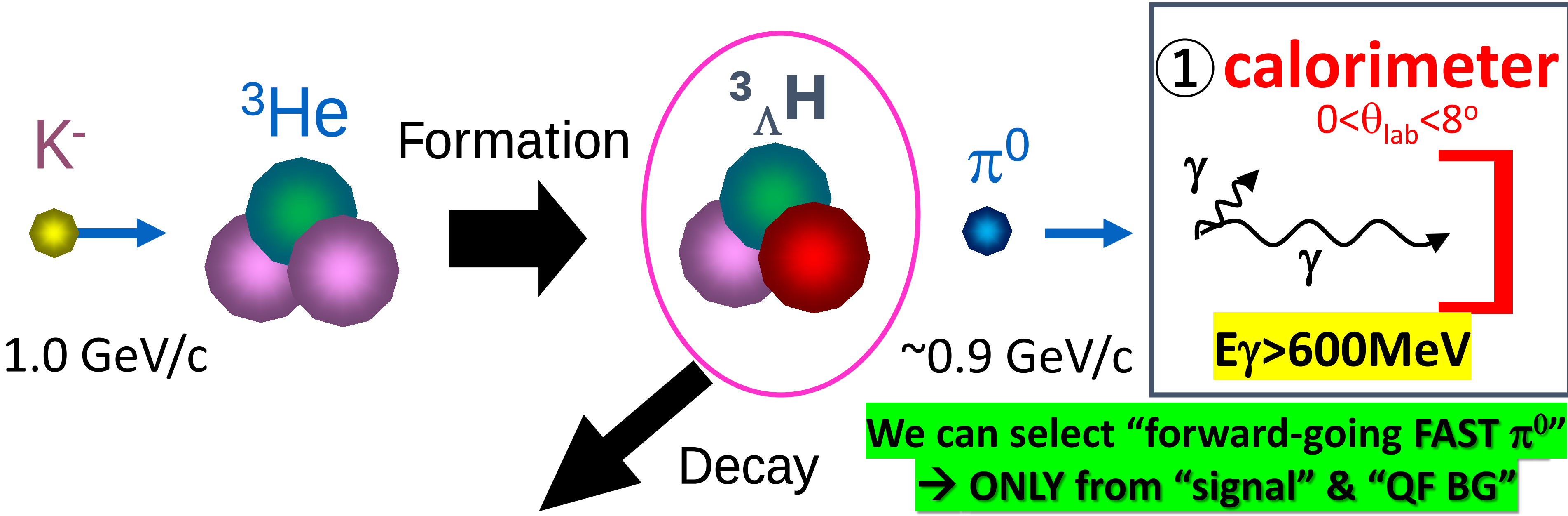




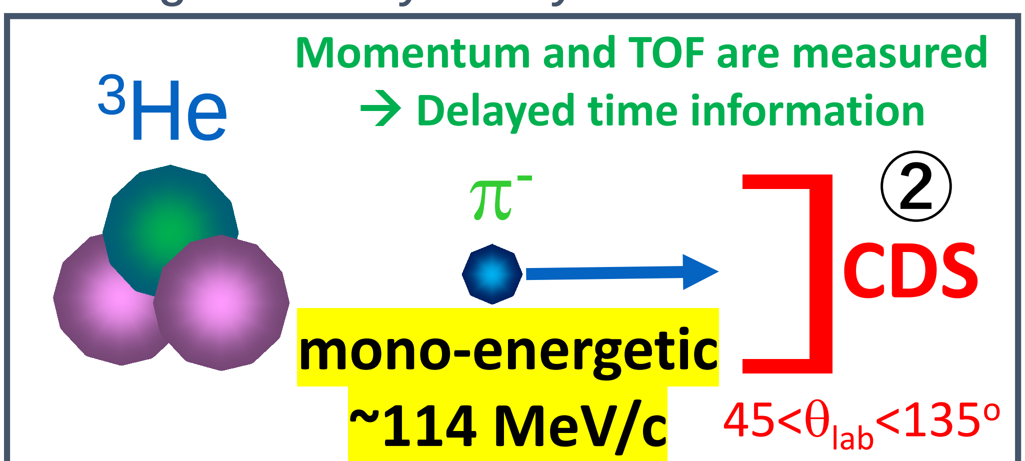
Direct measurement ***NO counter experiment so far*** → **P73**

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

Experimental Principle



charged 2-body decay "almost" at rest



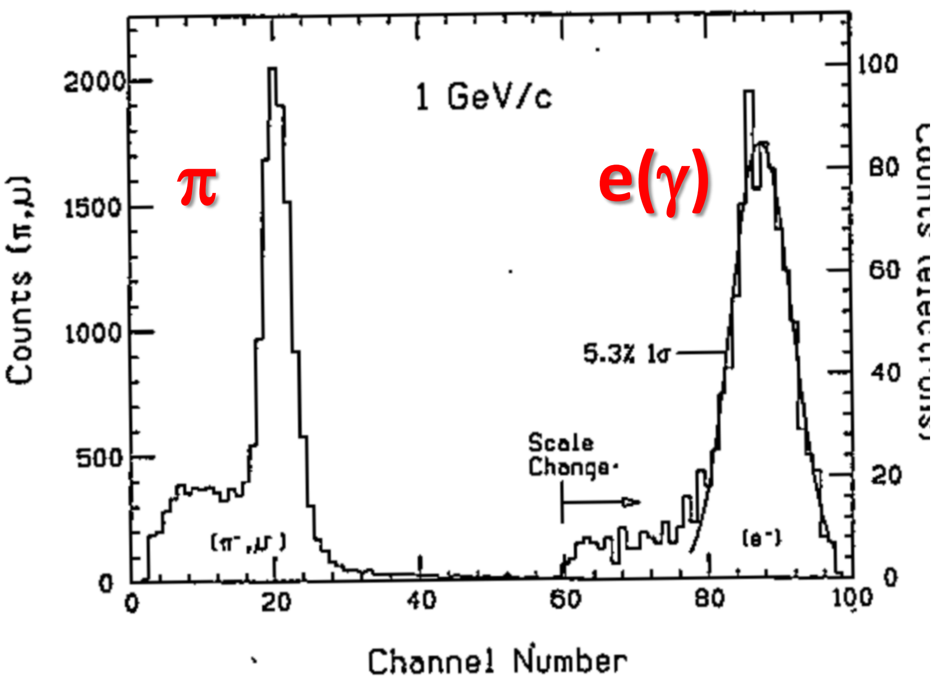
① Tag high-energy γ

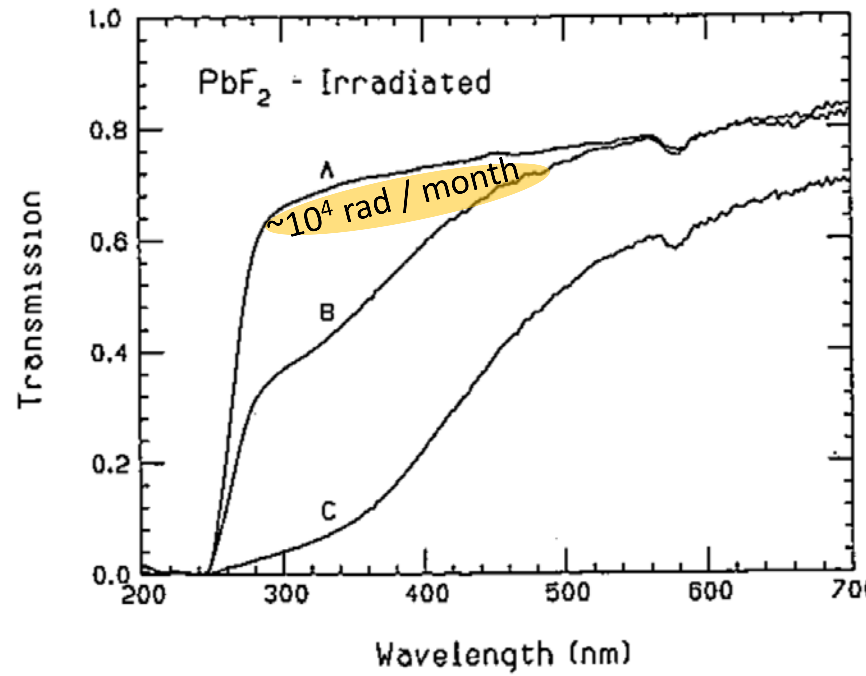
② Detect mono-energic π^-

③ Measure $^3_\Lambda H$ 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)

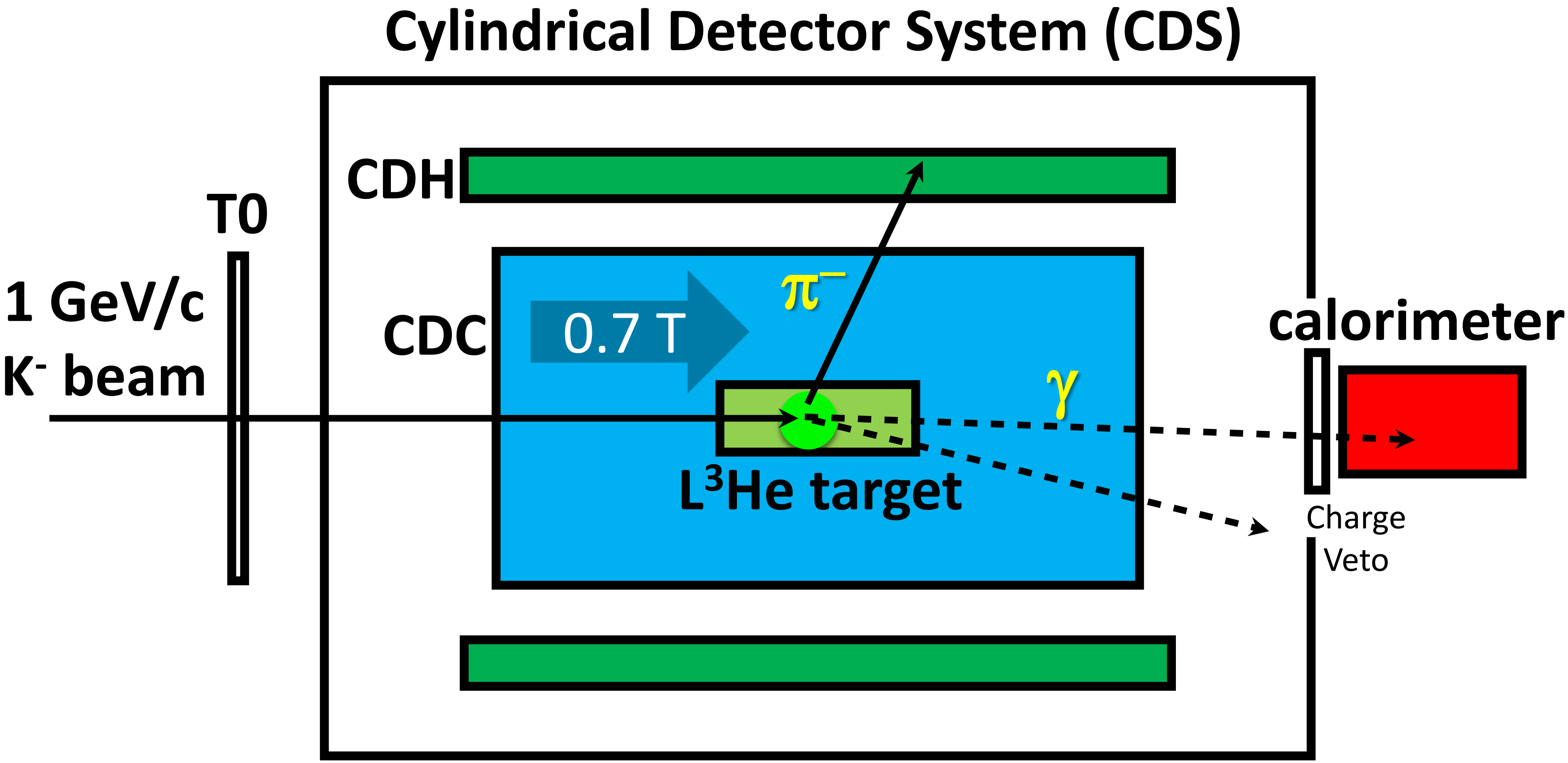




Radiation length	Moliere radius	Density	Resolution	Signal length
0.93 cm	2.22 cm	7.77 g/cm^3	5%	2ns

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

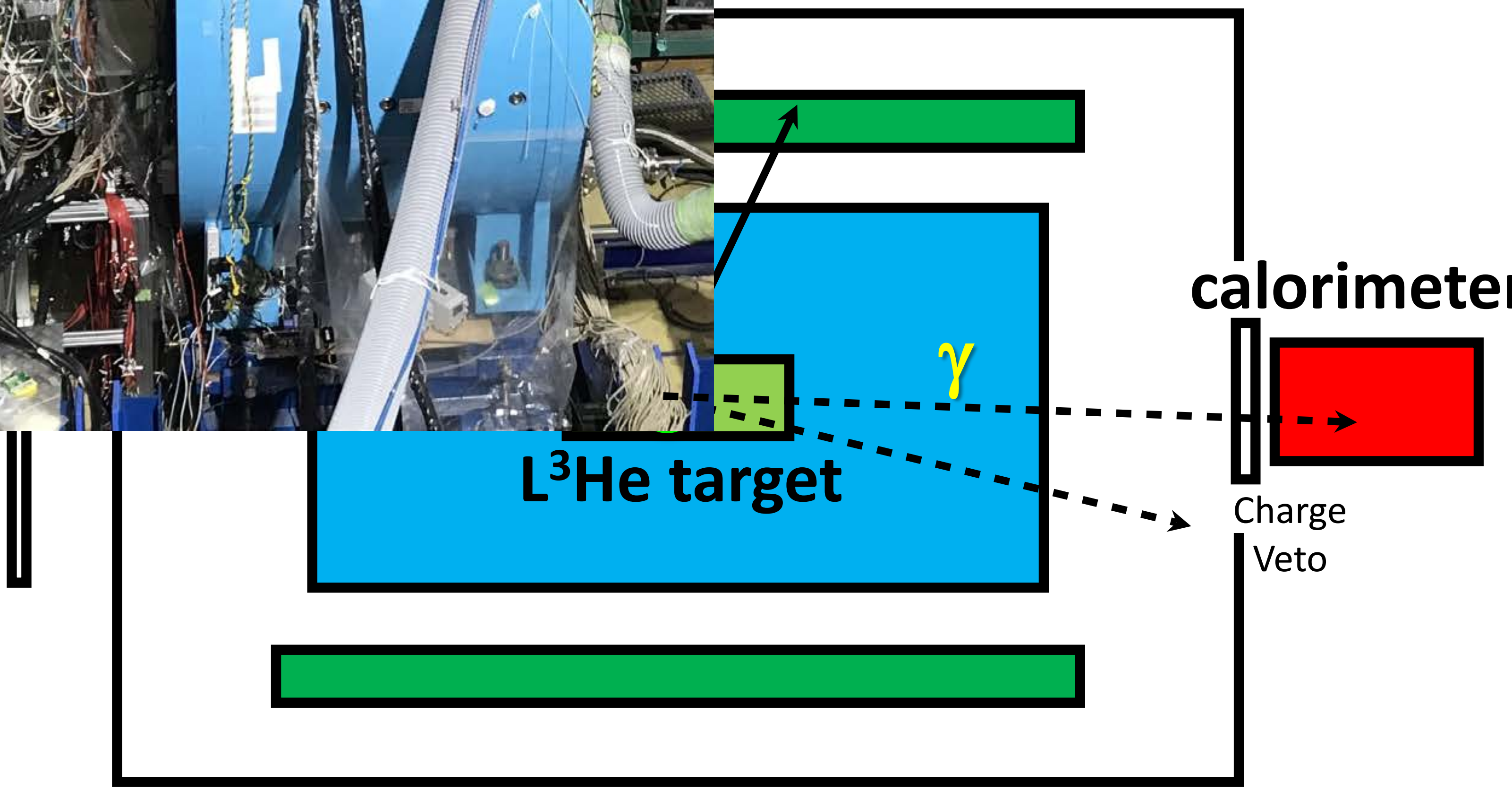
Experimental Setup



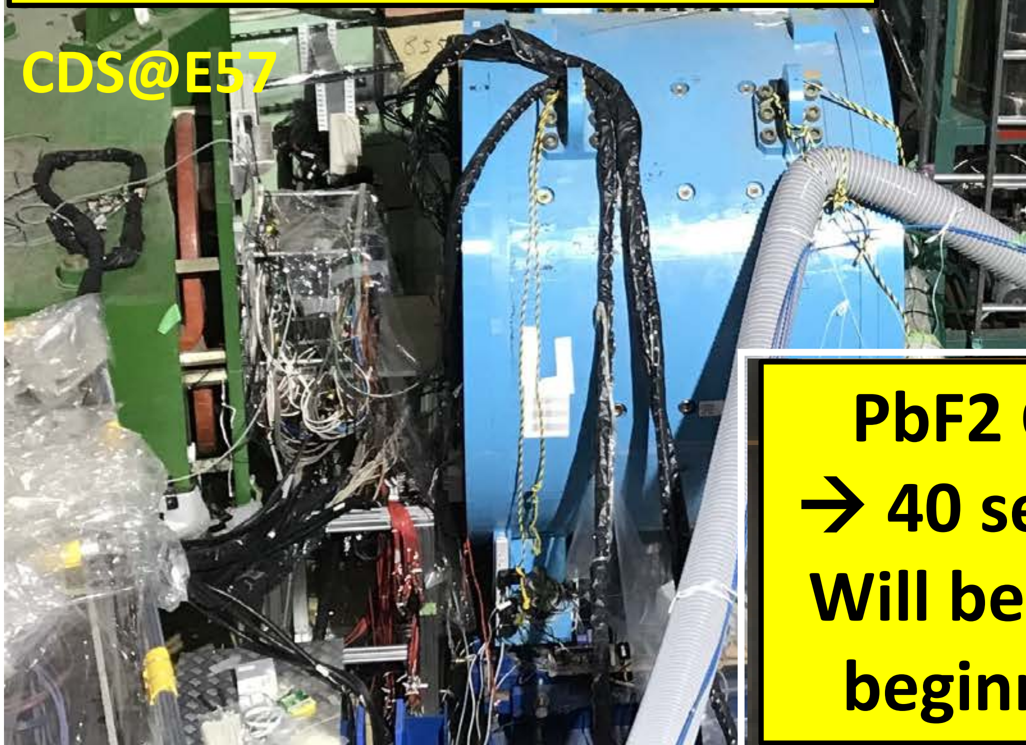
Beam spectrometer & CDS
→ Ready

al Setup

or System (CDS)

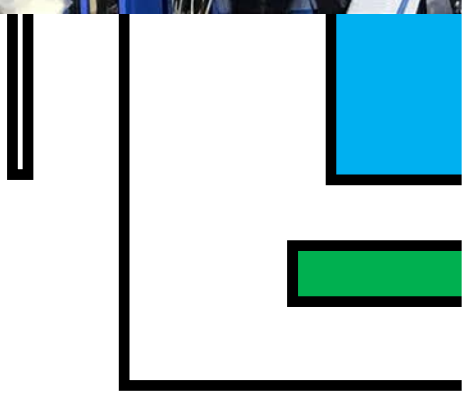


Beam spectrometer & CDS
→ Ready



tal Setup

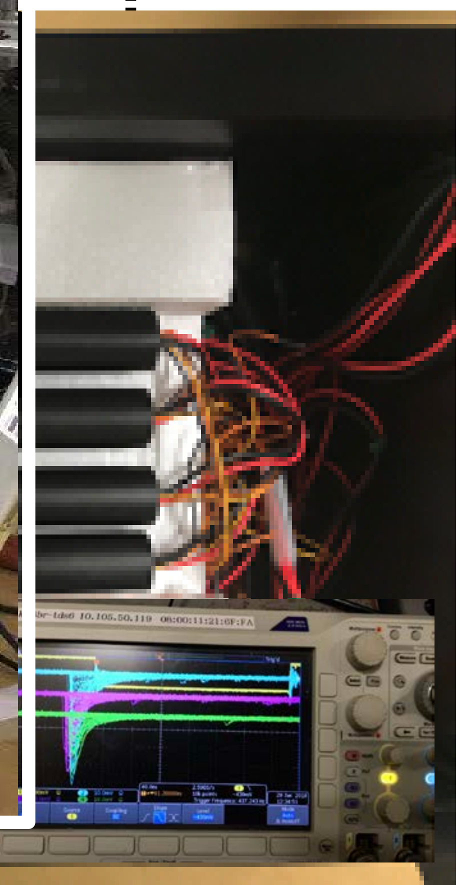
or System (CDS)



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

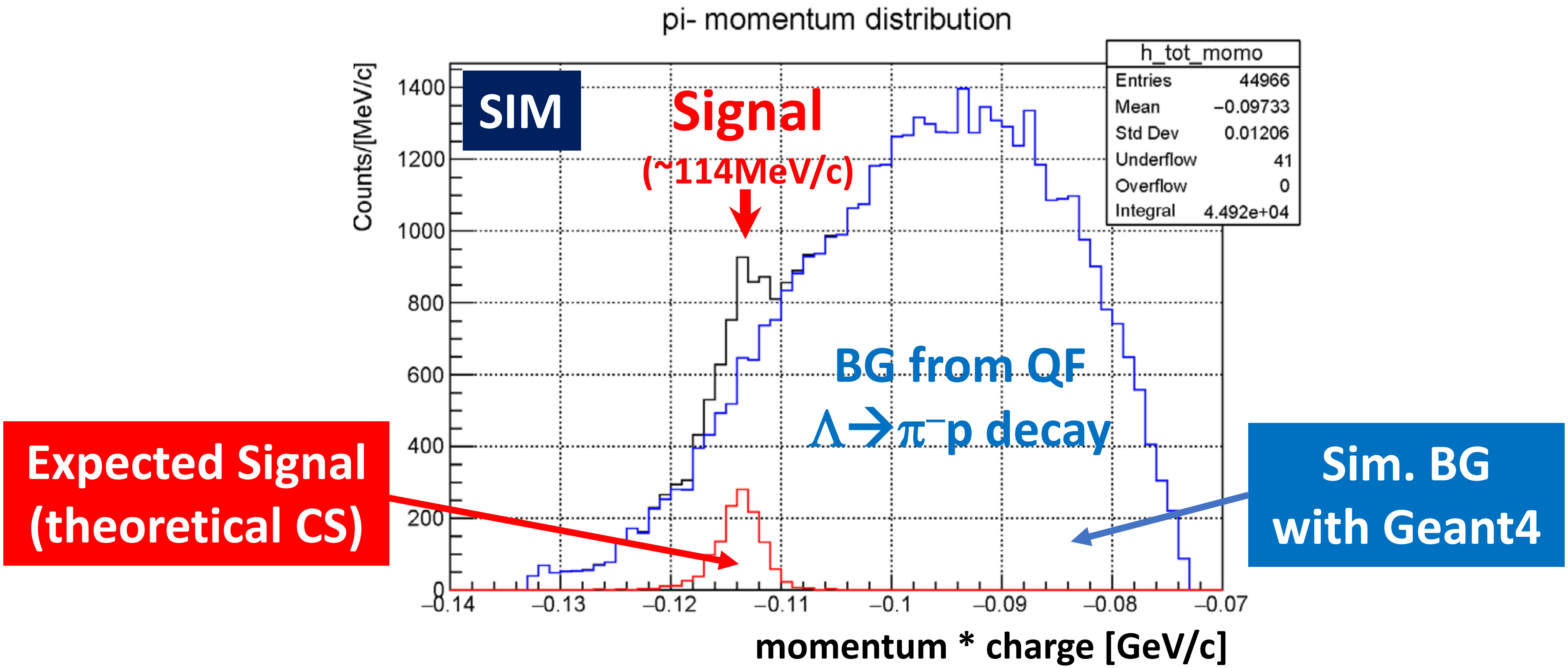
Beam spectr

→



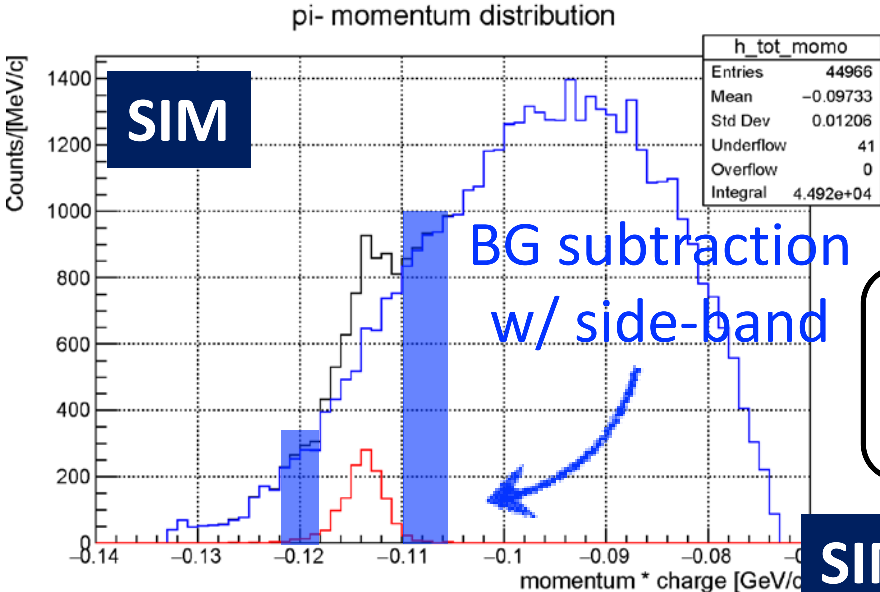
L^3He target system
→ 500l ^3He in hand &
Will be ready by the
beginning of 2020

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



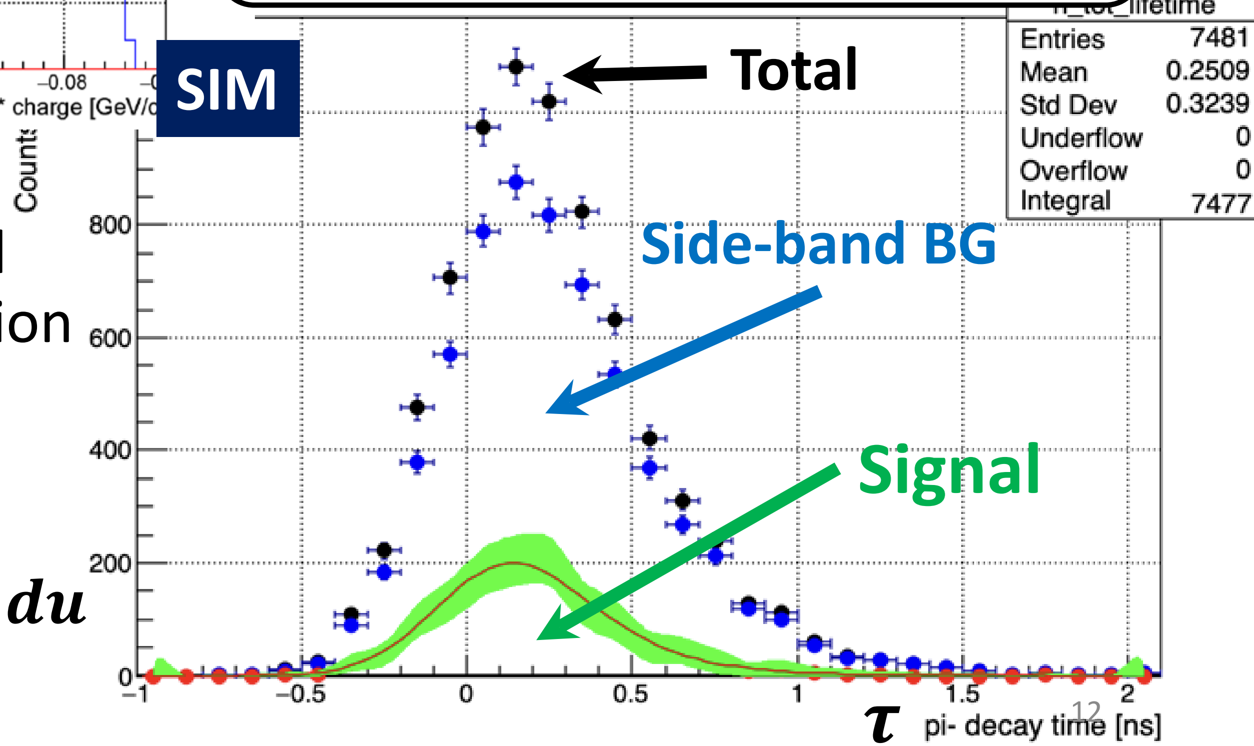
- The spectrum with **~4 weeks** data taking at **50kW**
  - # of expected signal is ~1k
  - BG is estimated with MC based on Geant4 using K^- + p reactions.
    - **$K^-p \to \Lambda\pi^0$ ~ 3.5 mb is dominant**
    - $K^-p \to \Sigma^0\pi^0$ ~ 0.9 mb and $K^-n \to \Sigma^-\pi^0$ ~ 0.9 mb are suppressed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

Lifetime Evaluation



delayed decay time τ:

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



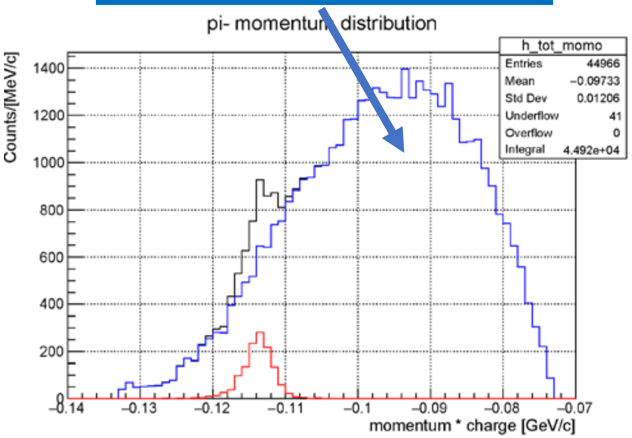
The **lifetime** τ_0 is derived with the **exp(-τ/τ_0)** function convoluted with the CDS response function $R()$

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

Expected S/BG Ratio with Different Models

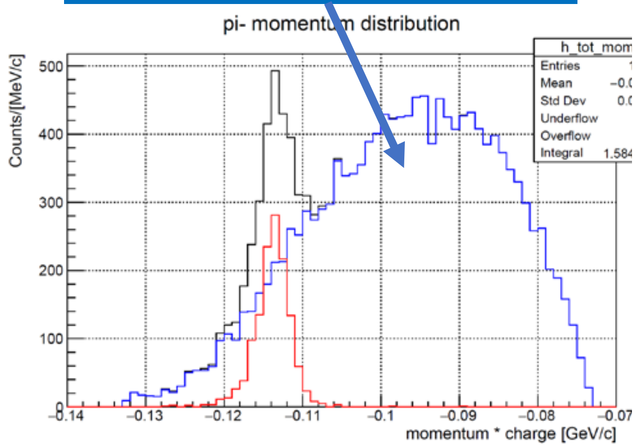
Signal yield is assumed to be ~ 1k in all cases (4w, 50kW)

from Geant4 CS



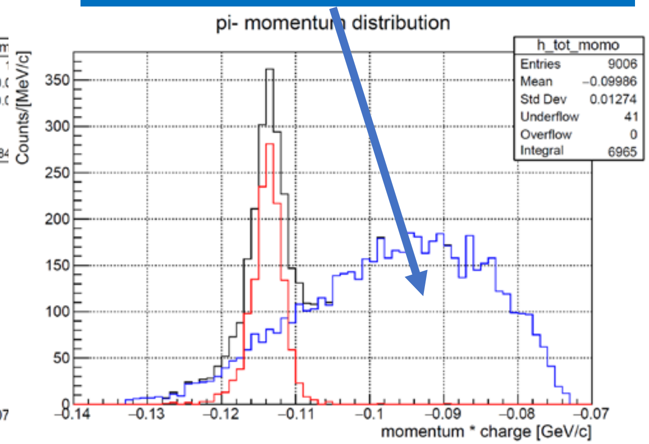
S/BG ~ 1/42

from BNL E905 CS



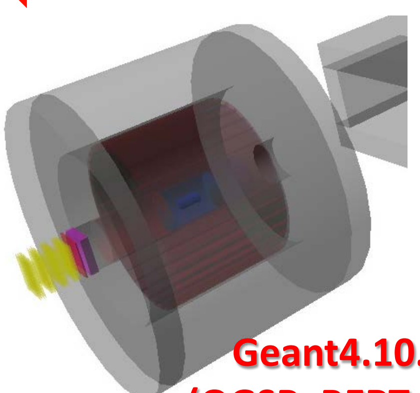
S/BG ~ 1/16

from theoretical CS

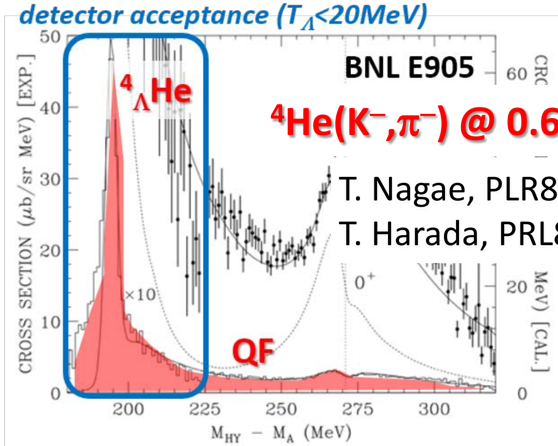


S/BG ~ 1/6

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

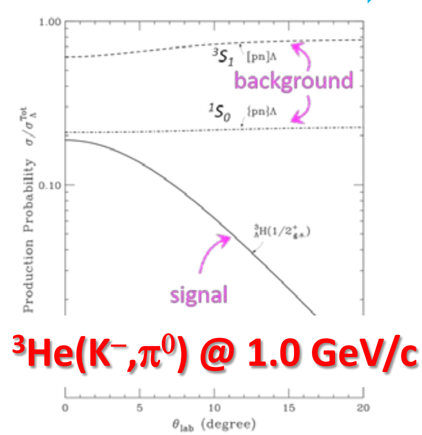


Geant4.10.0 (QGSP_BERT_HP)



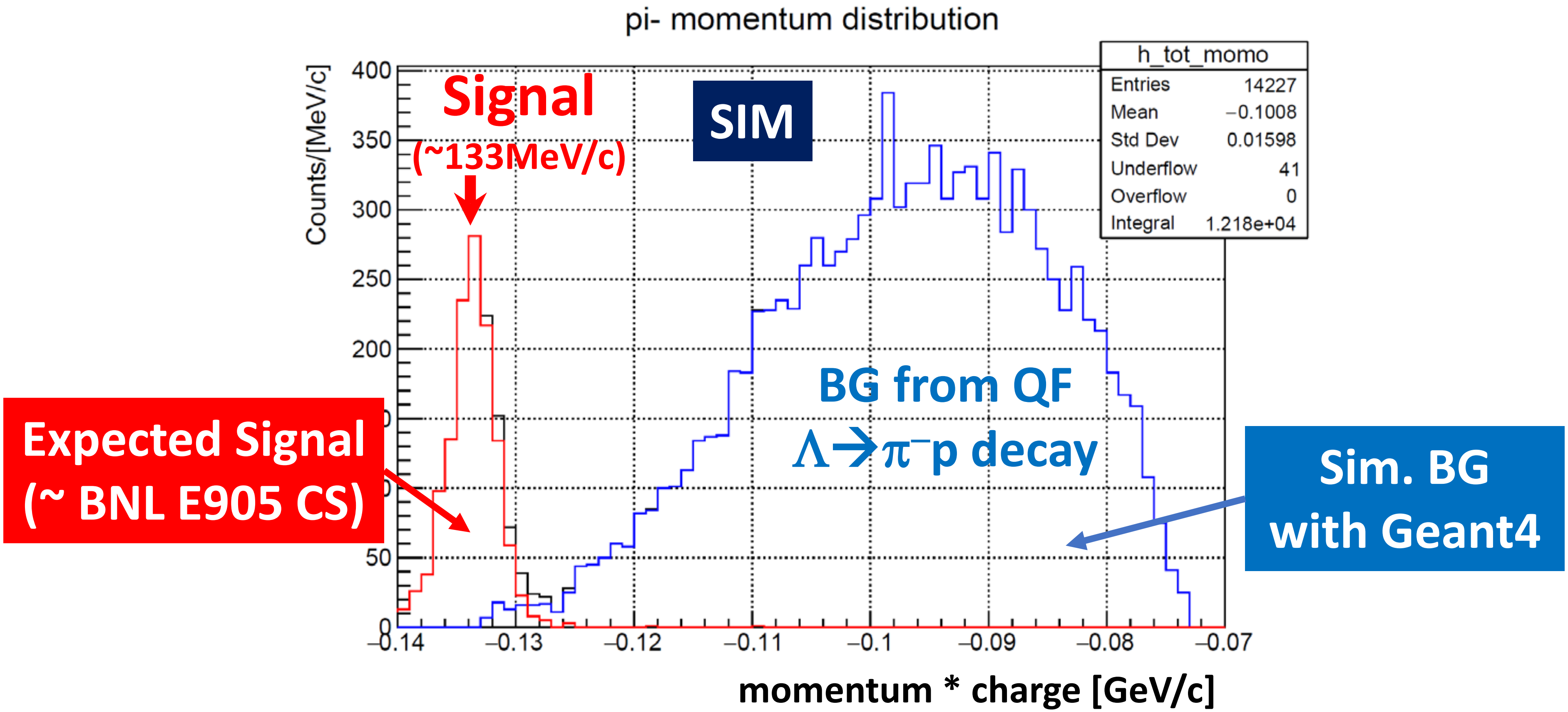
^{4}He(K^-,π^-) @ 0.6 GeV/c

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



^{3}He(K^-,π^0) @ 1.0 GeV/c

$^{4}_{\Lambda}$H pilot run for BG evaluation

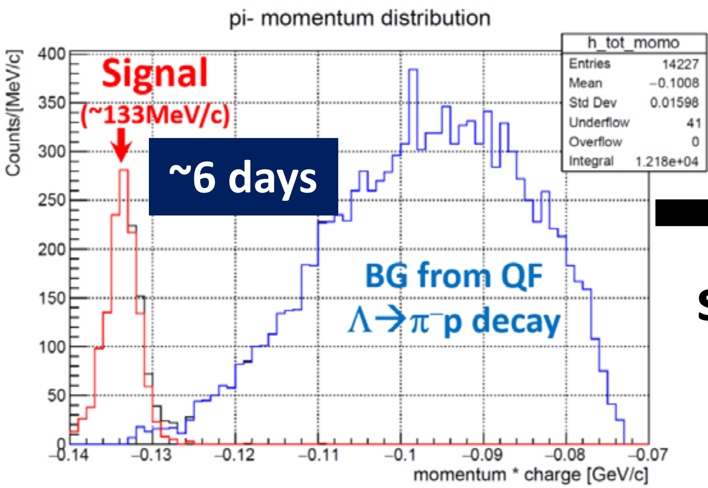


- The spectrum with **~6 days** data taking at **50kW**
  - # of expected signal is ~1k
    - N($^{3}_{\Lambda}$H) is expected to be ~ N($^{4}_{\Lambda}$H) x1/3 [CS] x1/2 [Br(2-body)]
  - BG is estimated as with ^{3}He.

Based on theoretical CS & BNL E905 results

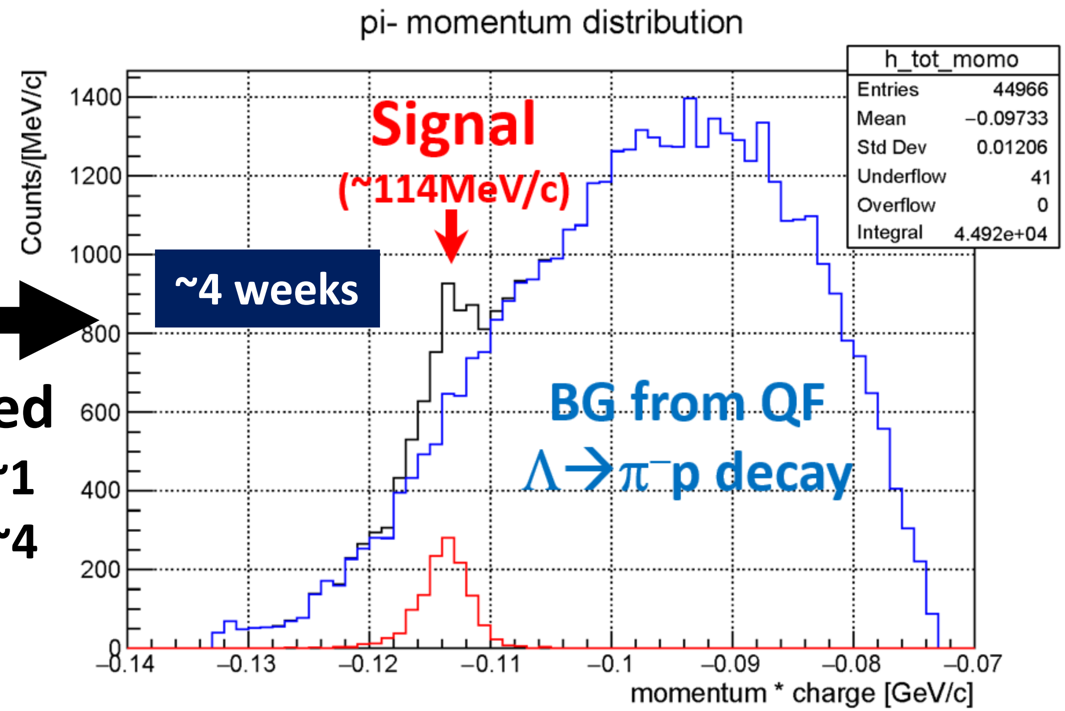
Realistic Estimation using ^{4}He Data

$K^- + {}^4He$



scaled
S x ~1
B x ~4

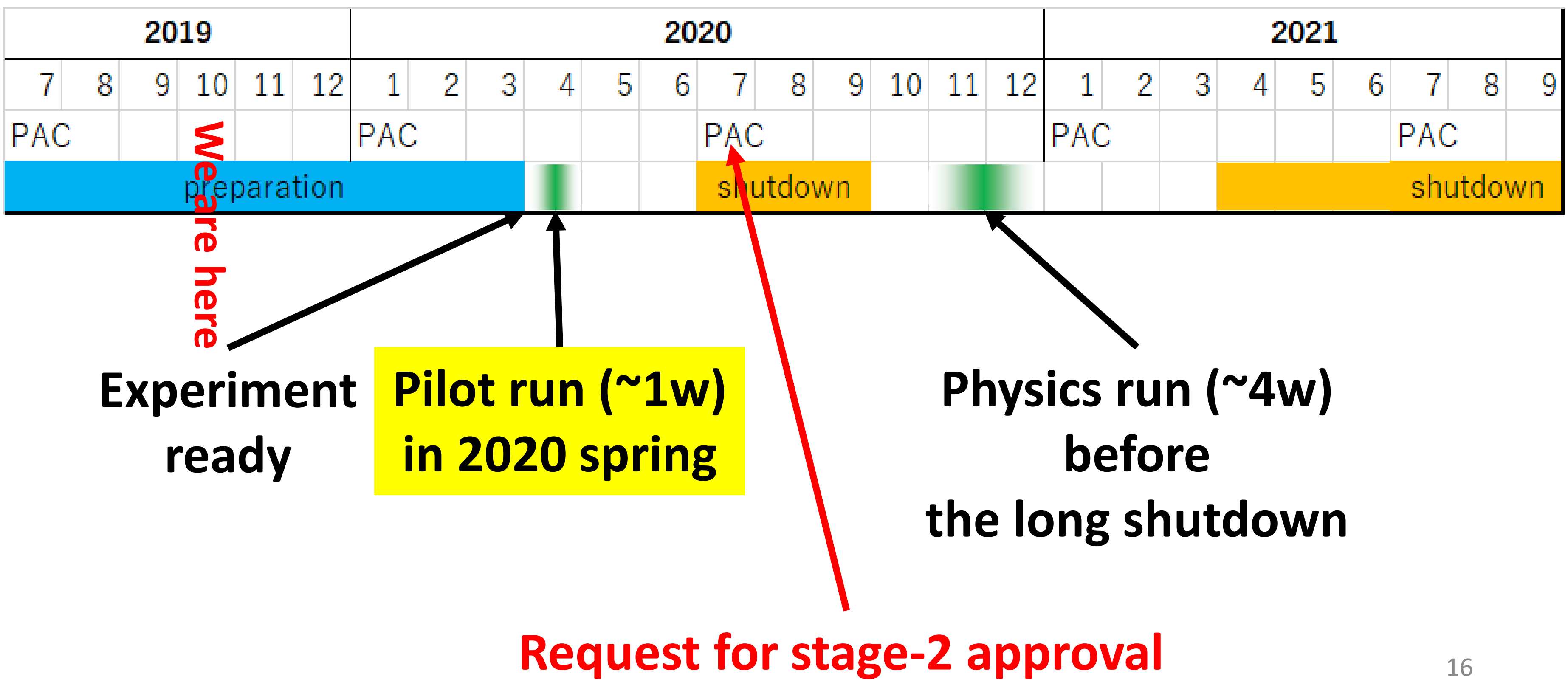
$K^- + {}^3He$



- **We can do an realistic estimation of the $^3_\Lambda H$ measurement using the BG in K^- + ^4He data**
  - BG will be almost the same between ^3He and ^4He

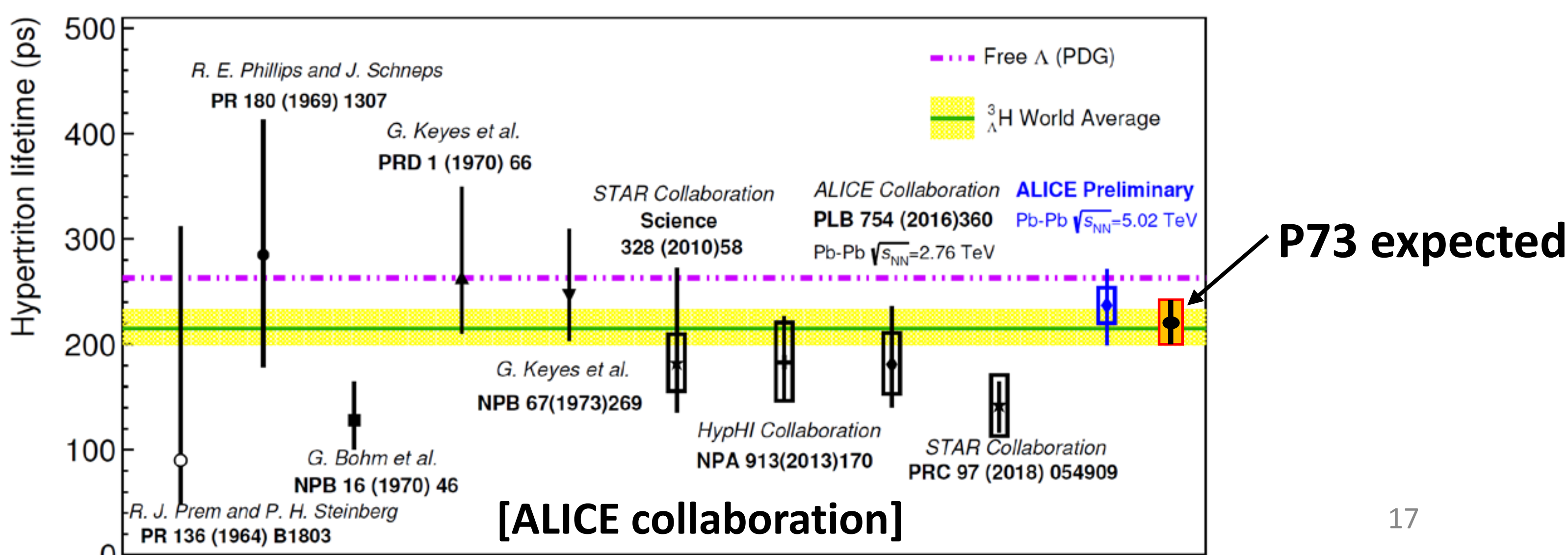
Schedule

- To perform the experiment before the long shutdown scheduled in 2021, we would like to conduct the pilot run in 2020 (= accepted as “test run” at the previous PAC).



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.
- **1 week** beamtime for **$^{4}_{\Lambda}$H** has been accepted as **"test run"**.
  - after feasibility study with $^{4}_{\Lambda}$H, we would like to request **the $^{3}_{\Lambda}$H physics run (~4 weeks, 50kW equiv.)**.



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

(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.

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**

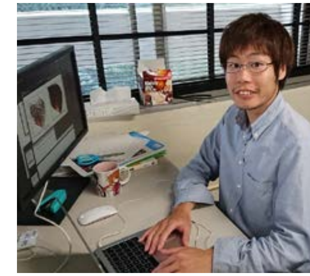
Answer to the 27th PAC Comments

> The PAC appreciates the effort made by the P73 collaboration to provide rather advanced simulations. Compared to the $^{3,4}He(\pi^-,K^0)$ $^{3,4}_{\Lambda}H$ reaction, the $^3He(K^-,\pi^0)$ $^3_{\Lambda}H$ 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.

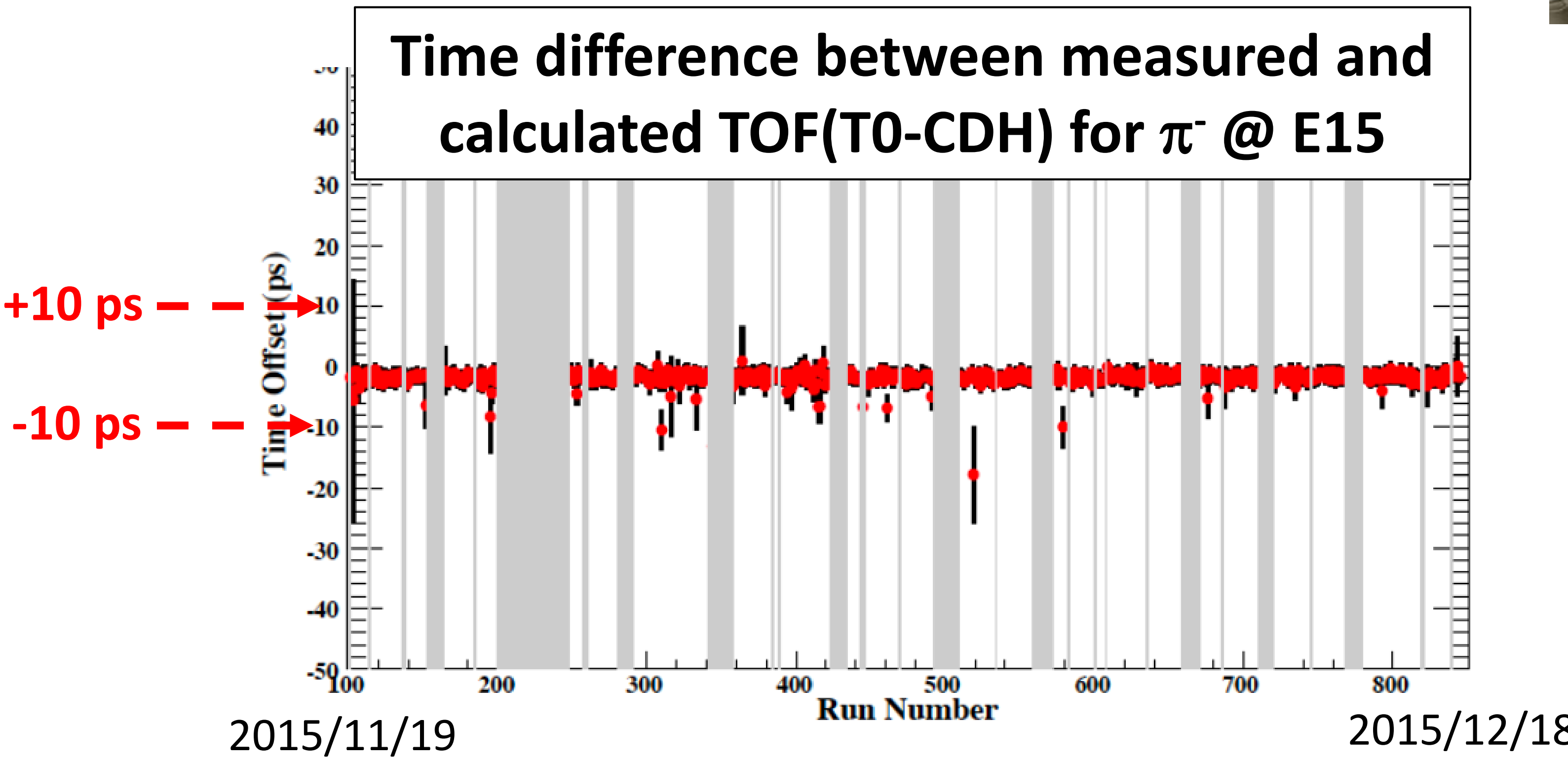
Syst. err. will be mainly originated from two types of errors:

- Time Zero Alignment **<5 ps**
  - Estimated with the E15 (K^- + ^3He) 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- + ^4He**

Time Zero Alignment Estimation with the E15 Data



Dr. Yamaga, RIKEN



- E15-2nd data (Run65, $^{3}He(K^{-},\pi^{-})X$)
  - 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:

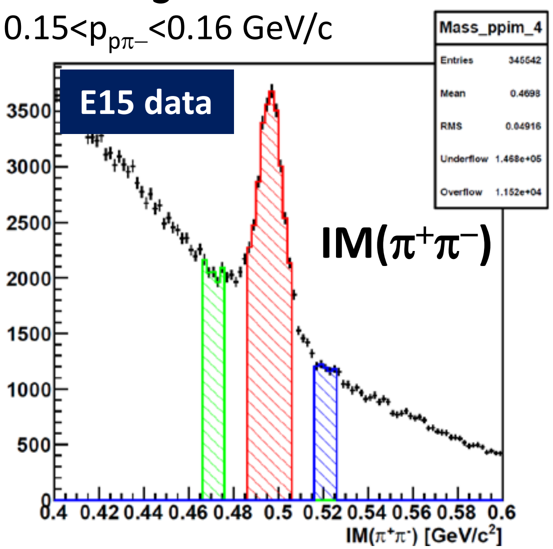
- Time Zero Alignment <5 ps
  - Estimated with the E15 (K$^-$ + ^{3}He) data set ← Next page

- 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**

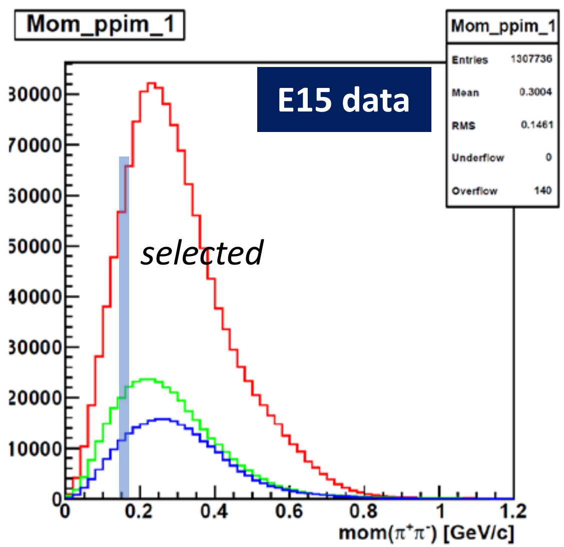
"free K^0_S" Lifetime with the E15 Data

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

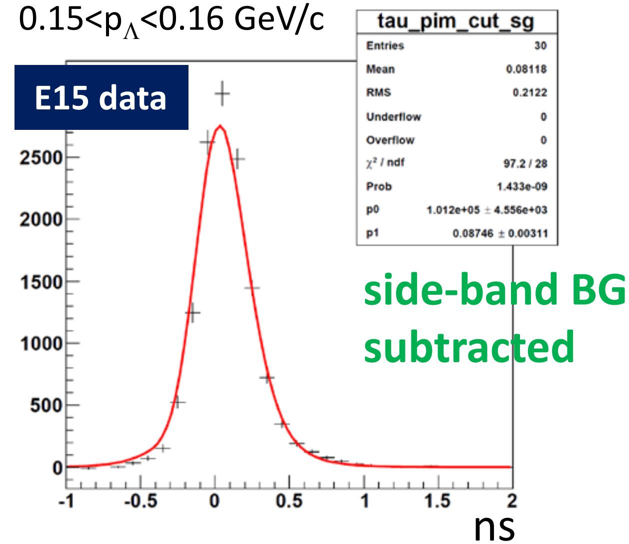
K^0_S selection

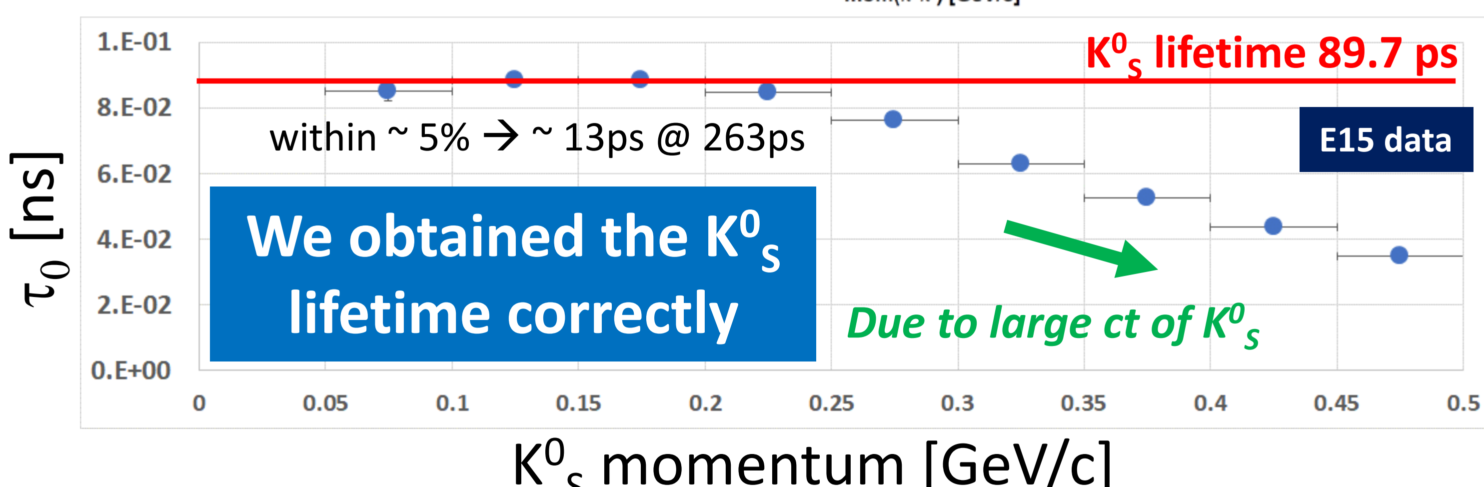


p_{K0s} distribution



π^- delay time fitting



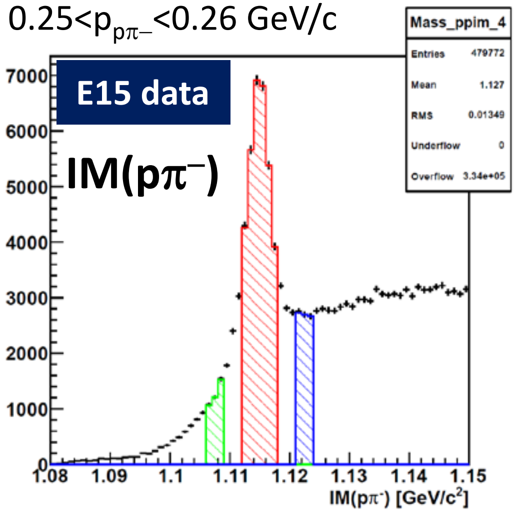


"free Λ" Lifetime Evaluation with the E15 Data

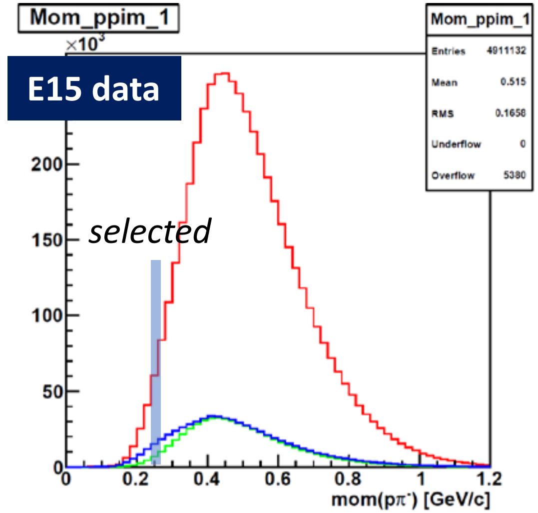
The main BG in P73 is ~100 MeV/c Λ, whose decay p CANNOT be detected by the CDS.

Λ selection

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

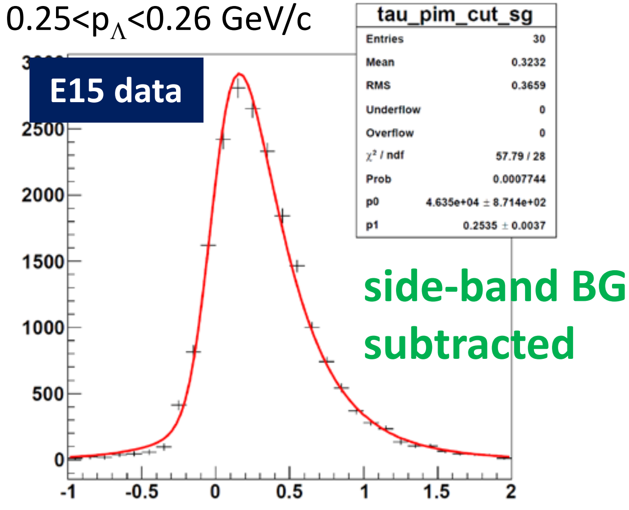


p_Λ distribution



π^- delay time fitting

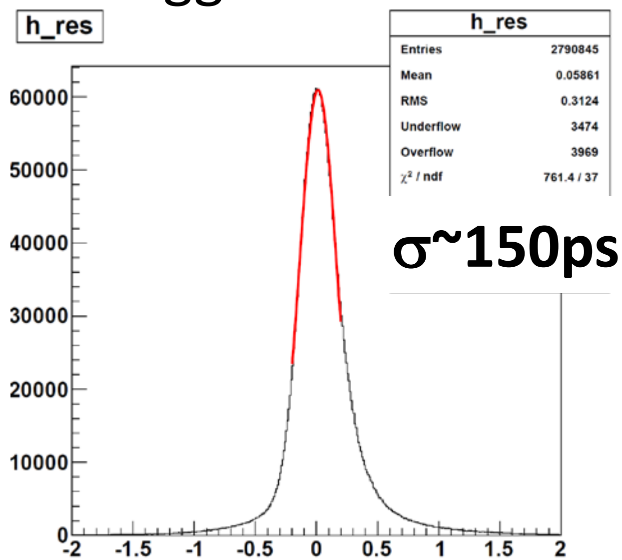
$0.25 < p_\Lambda < 0.26$ GeV/c



- We tried to obtain the lifetime using $\Lambda \to p\pi^-$ event sample
- However, we found that there are difficulties after $\Lambda \to p\pi^-$ 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

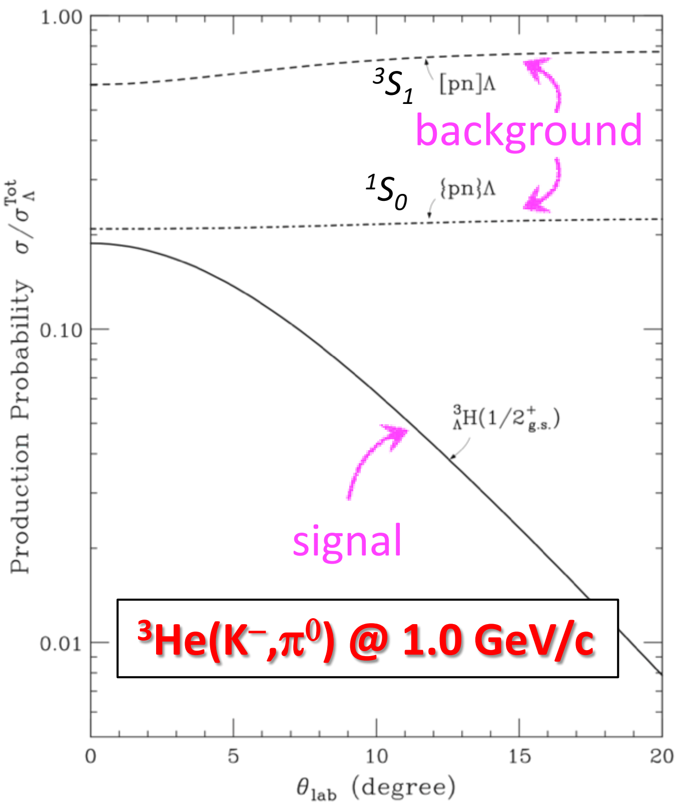
Trigger Scheme

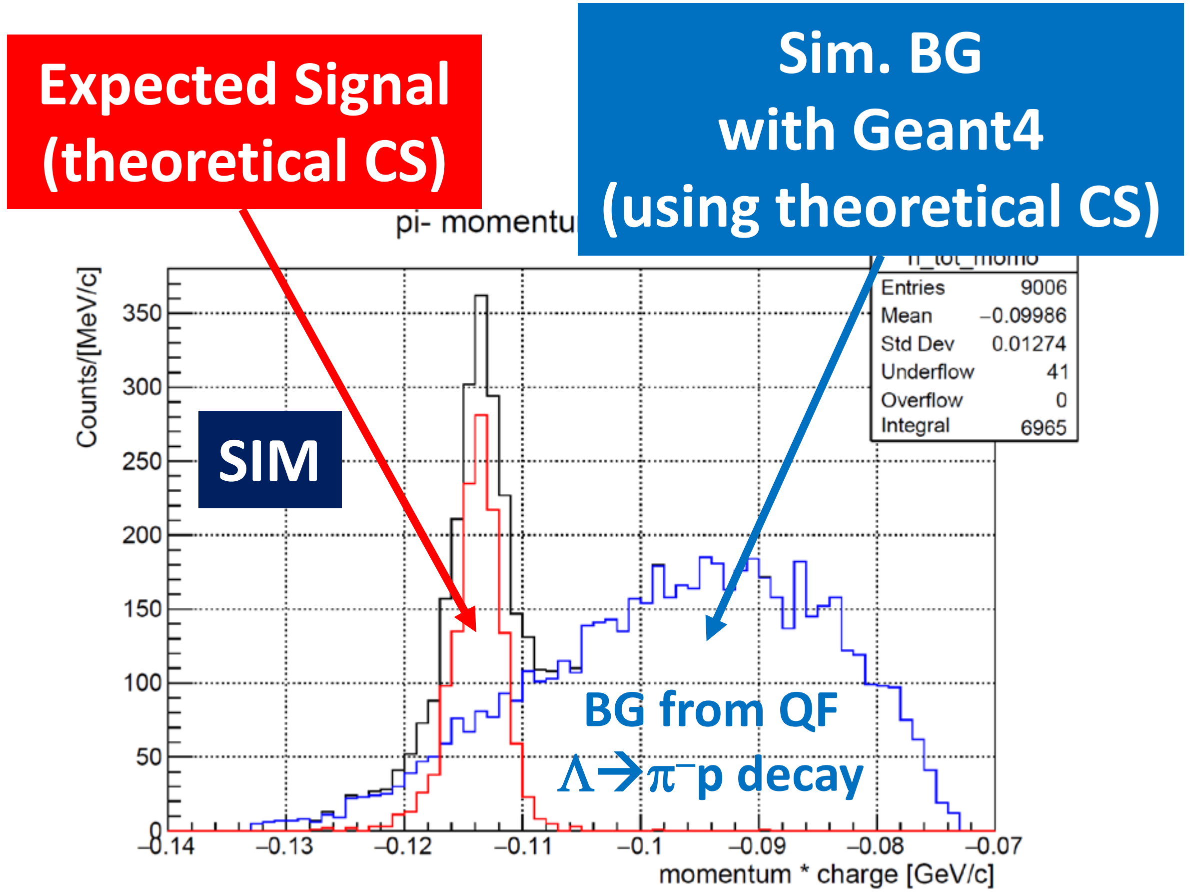
- **Main trigger is “K$^-$-beam* CDH-1hit * E-cal”**
  - will be <<1k/spill estimated from E15 trigger (“K*CDH1*γ/n”)
  - up to ~5k/spill is acceptable by keeping ~95% eff. (HUL & HD-DAQ)
- **R(τ) is obtained with calibration trigger of (π$^-$,π$^-$)**
  - “π$^-$-barm * CDH-1hit” trigger ← **“prompt”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



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

Background from Theoretical Calculation





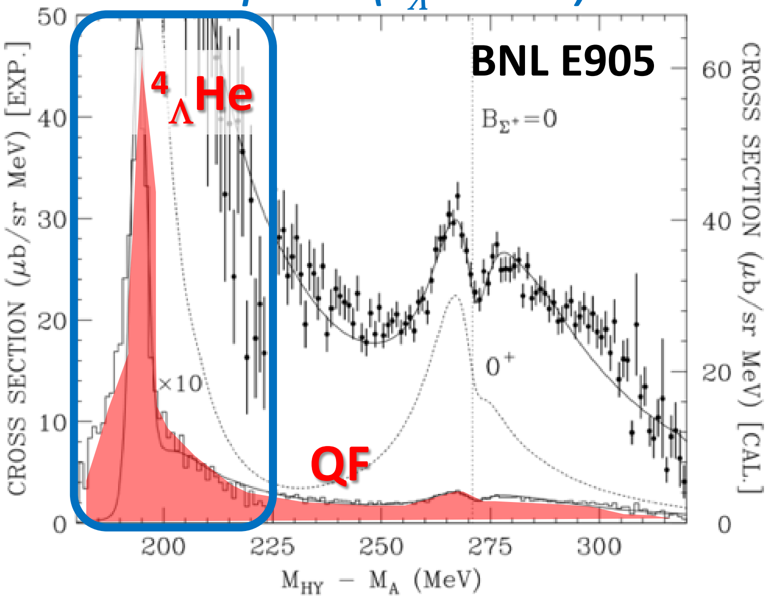
- Expected BG yield is much different btw "Geant4-CS" and "theoretical-CS"

Background from BNL $^4He(K^-,\pi^-)$ Exp.

$^4He(K^-,\pi^-)$ @ 0.6 GeV/c

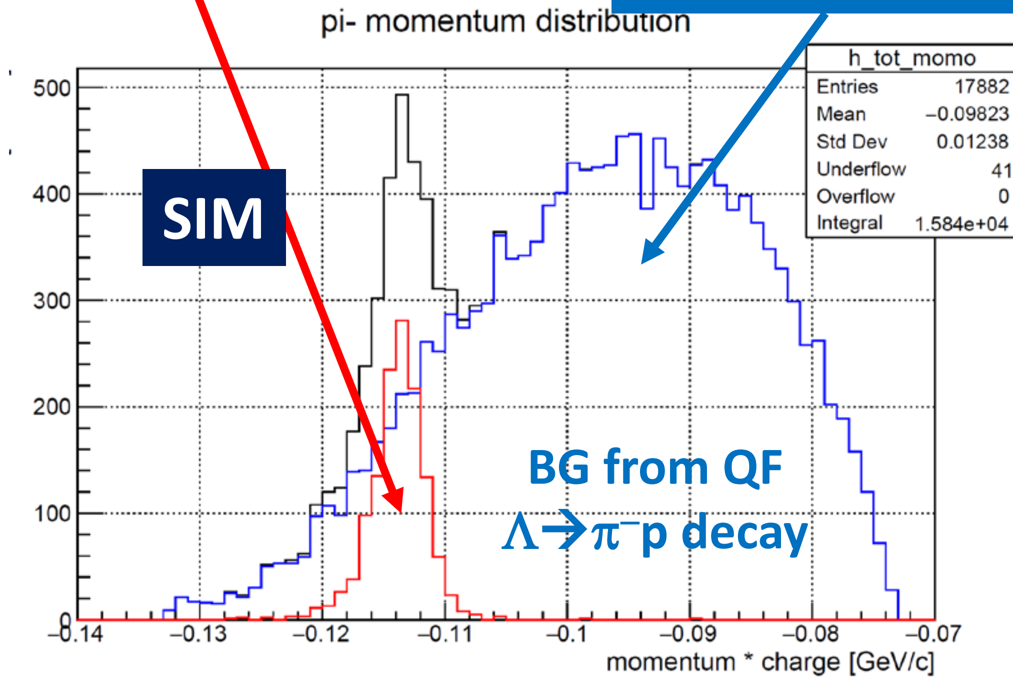
T. Nagae, PLR80(98)1605
T. Harada, PRL81(98)5287

detector acceptance (T_Λ<20MeV)



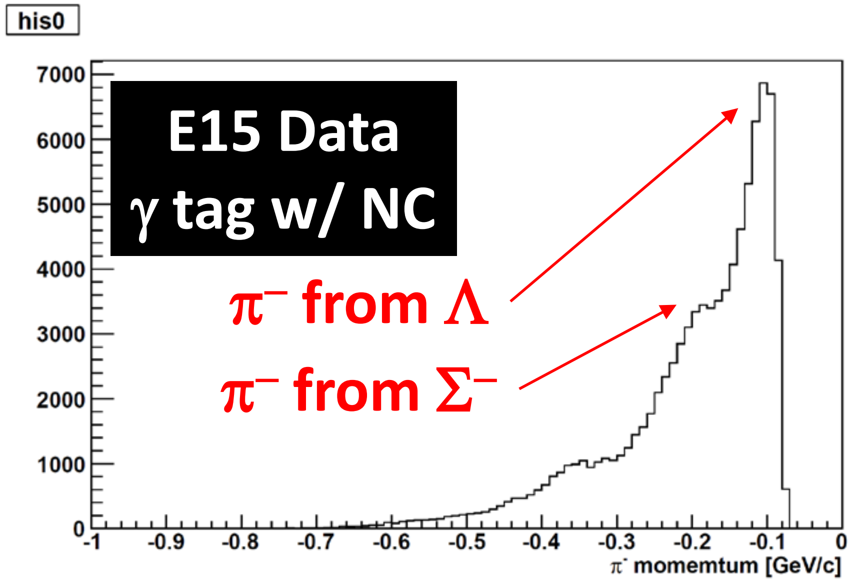
Expected Signal (theoretical CS)

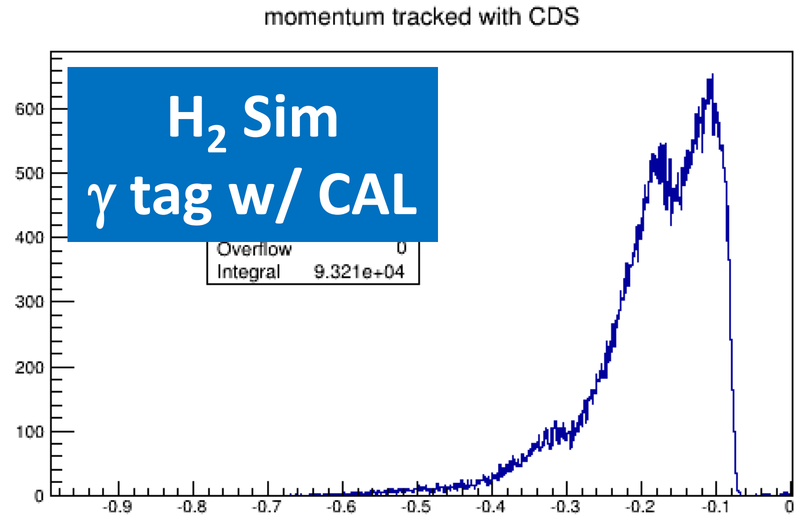
Sim. BG with Geant4 (using Exp. CS)



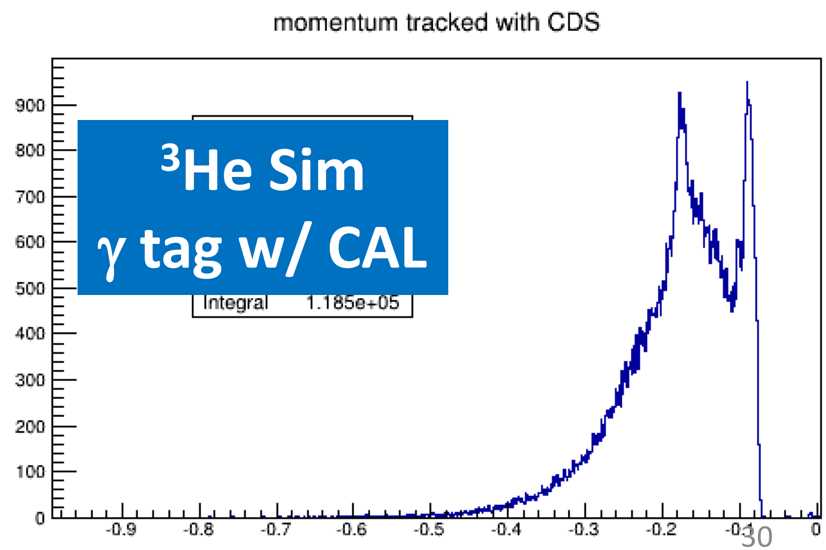
- Expected BG yield is less than that based on "Geant4-CS"
  - S/BG~1/0.5 @ $^4He(K^-,\pi^-)$, 0.6 GeV/c
  - S/BG~1/2 @ $^4He(K^-,\pi^0)$, 1.0 GeV/c
    - mom-transfer 50→100 MeV (x~1/4)
  - **S/BG~1/16 @ $^3He(K^-,\pi^0)$, 1.0 GeV/c**
    - **$\sigma(^3{}_\Lambda H)$ ~ 1/3 x $\sigma(^4{}_\Lambda H)$**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

Background Estimation w/o ΔE cut



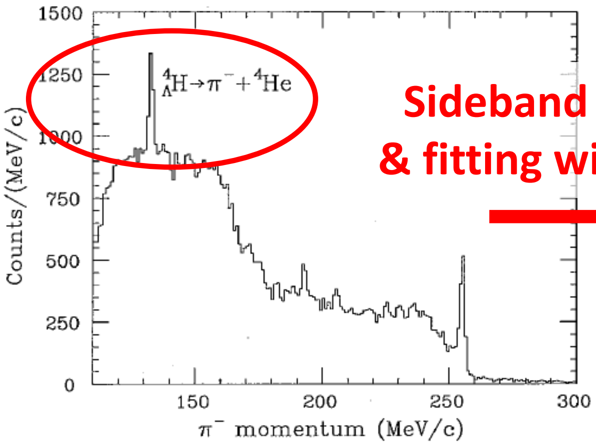


- including low-energy γ (π^0)
  - can be reject with ΔE cut
- **E15 data favors H_2 simulation**
  - **thus we employ H_2 sim.**

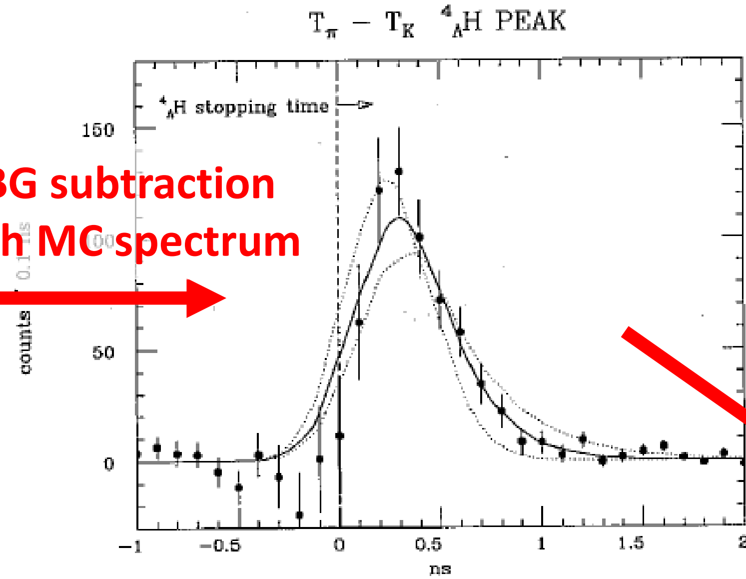


$^{4}{}_{\Lambda}H$ Lifetime @ KEK

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

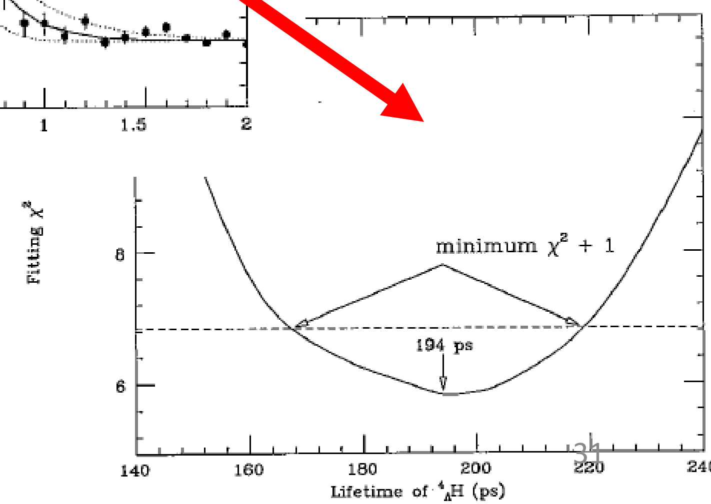


Sideband BG subtraction & fitting with MC spectrum



H. Outa, D-thesis

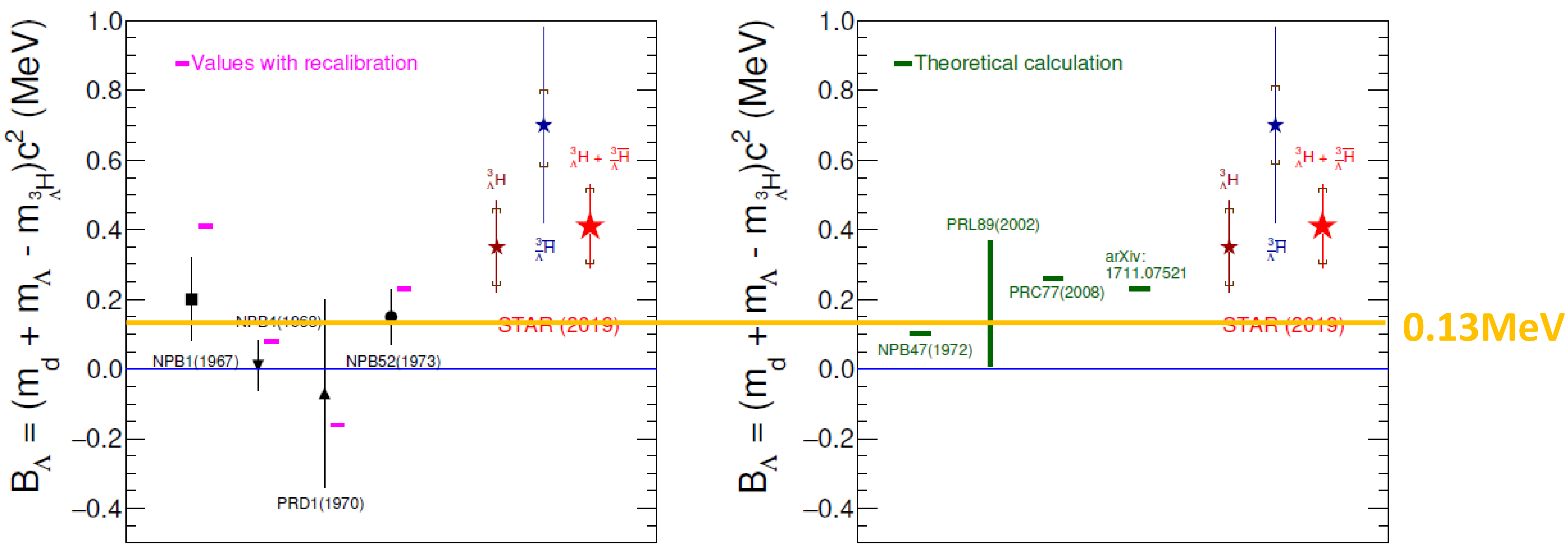
$^{4}{}_{\Lambda}H$ lifetime



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

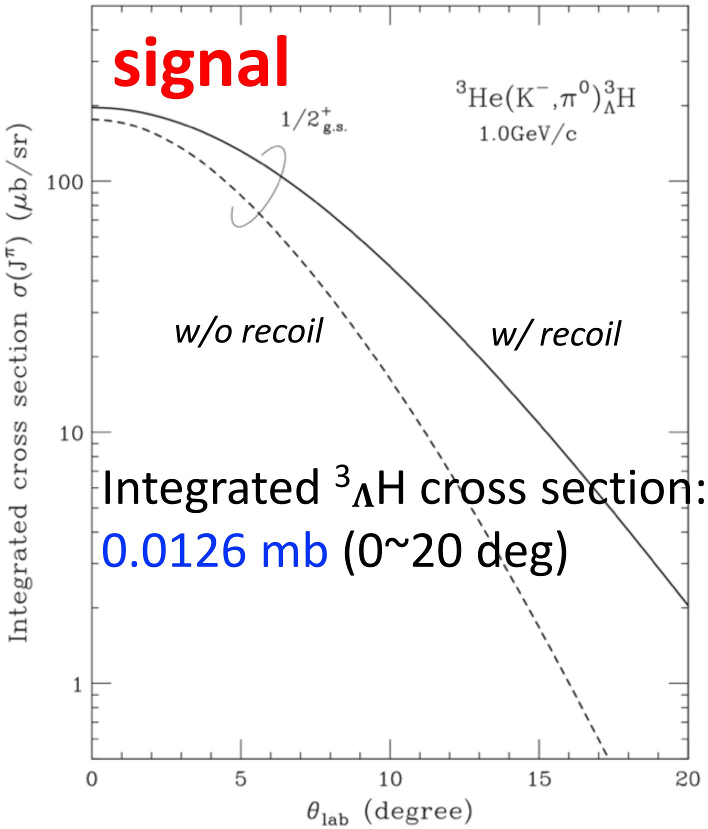
Slides from the 27th PAC

Performance estimation: yield estimation

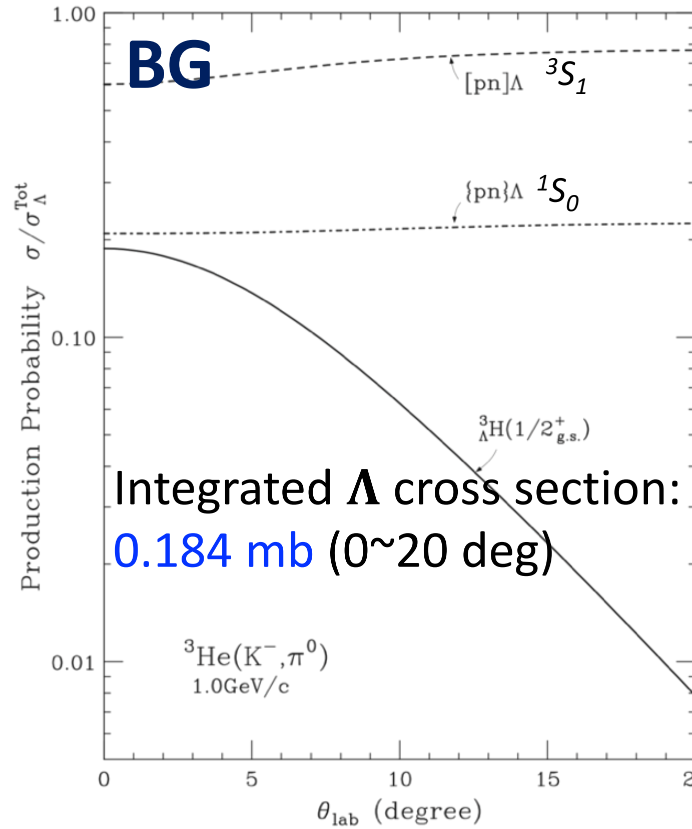
Target: liquid 3He, 10cm	$1.6\times10^{23}/cm^2$
K- intensity @ 1GeV/c	$2\times10^5/5.2s$
σ of $^3{}_\Lambda H$ g.s.	0.0126 mb
Accelerator up time	80%
Beam acceptance	60%
DAQ efficiency	90%
$^3{}_\Lambda H \rightarrow {}^3He+\pi^-$ b.r.	25%
π- & π0 acceptance	6%
$^3{}_\Lambda H$ signal yield	***~1000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



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

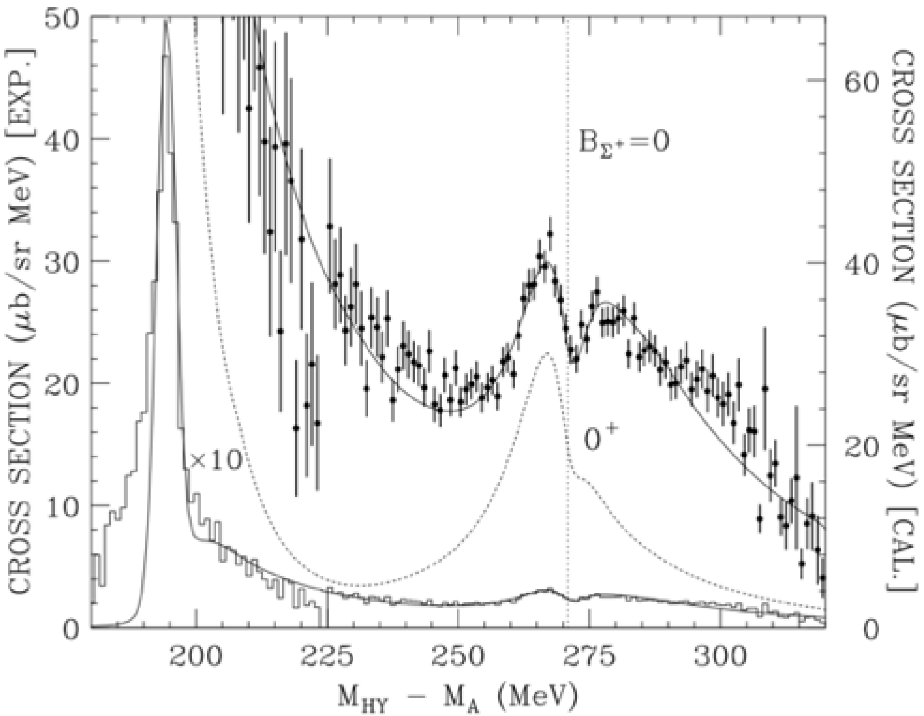


Integrated **Λ** cross section:
0.184 mb (0~20 deg)

^{3}He(K^{-}, π^{0})$^{3}_{\Lambda}$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: $^{4}{}_{\Lambda}H$ cross section



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

No direct calculation available

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

1, for $^{4}He(K^{-}, \pi^{-})^{4}{}_{\Lambda}He$ 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

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

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

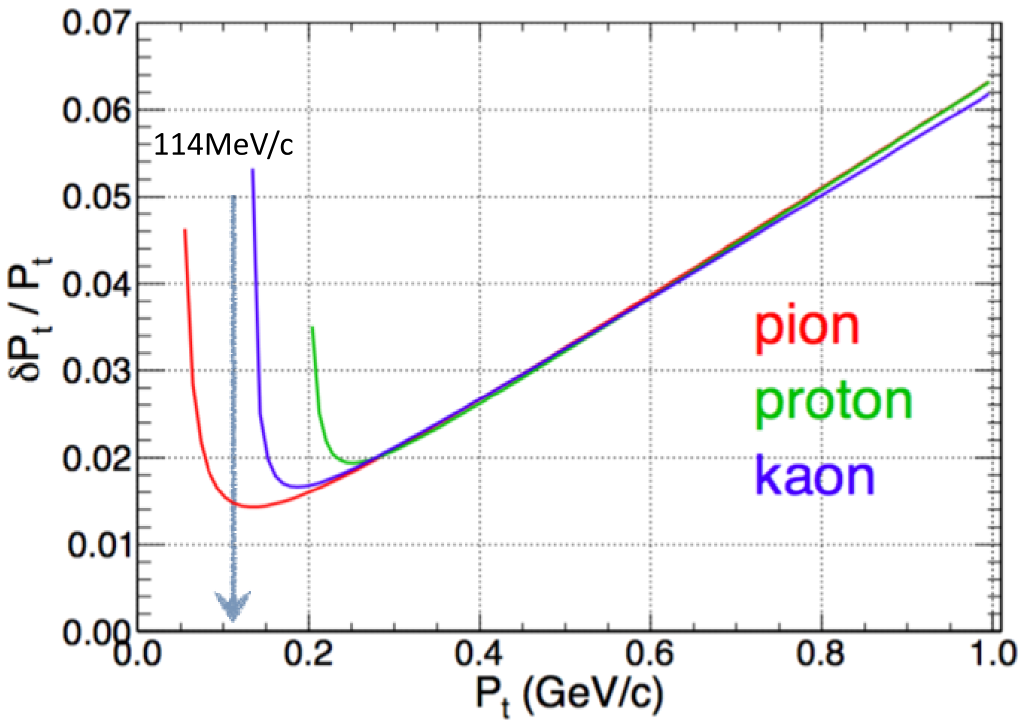
Part I: Performance estimation

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
$K^- \, ^3He \rightarrow \pi^0 \, ^3_\Lambda H \rightarrow$	$\pi^0 \pi^- \, ^3He \rightarrow 2\gamma \pi^- \, ^3He$	delayed π^-	?%	?%
	π^0 p n $n_s \rightarrow 2\gamma$ p n n	delayed p	?%	?%
$K^- \rightarrow$	$\pi^0 \mu^- \bar{\nu}_\mu \rightarrow 2\gamma \mu^- \bar{\nu}_\mu$	prompt μ^-	3.32%	Not included
	$\pi^0 \pi^- \rightarrow 2\gamma \pi^-$	prompt π^-	20.92%	
	$\pi^0 \pi^0 \pi^- \rightarrow 4\gamma \pi^-$	prompt π^-	1.76%	
K^- p $\rightarrow \pi^0 \Lambda \rightarrow$	$\pi^0 \pi^0$ n $\rightarrow 4\gamma$ n	N. A.	35.8%	4.5
	$\pi^0 \pi^-$ p $\rightarrow 2\gamma \pi^-$ p	delayed π^-, p	63.9%	
K^- p $\rightarrow \pi^0 \Sigma^0 \rightarrow \pi^0 \gamma \Lambda \rightarrow$	$\pi^0 \gamma \pi^0$ n $\rightarrow 5\gamma$ n	N. A.	35.8%	0.36 (scaled)
	$\pi^0 \gamma \pi^-$ p $\rightarrow 3\gamma \pi^-$ p	delayed π^-, p	63.9%	
K^- p $\rightarrow \pi^- \Sigma^+ \rightarrow$	$\pi^- \pi^0$ p $\rightarrow 2\gamma \pi^-$ p	prompt π^-, delayed p	51.57%	0.9
	$\pi^- \pi^+$ n	N. A.	48.31%	
K^- p $\rightarrow \pi^+ \Sigma^- \rightarrow \pi^+ \pi^-$ n		N. A.	100%	Not included
K^- n $\rightarrow \pi^- \Lambda \rightarrow$	$\pi^- \pi^0$ n $\rightarrow 2\gamma \pi^-$ n	prompt π^-	35.8%	Not included
	$\pi^- \pi^-$ p $\rightarrow 2\pi^-$ p	N. A.	63.9%	
K^- n $\rightarrow \pi^- \Sigma^0 \rightarrow \pi^- \gamma \Lambda \rightarrow$	$\pi^- \gamma \pi^0$ n $\rightarrow 3\gamma \pi^-$ n	prompt π^-	35.8%	Not included
	$\pi^- \gamma \pi^-$ p $\rightarrow \gamma \, 2\pi^-$ p	N. A.	63.9%	
K^- n $\rightarrow \pi^0 \Sigma^- \rightarrow \pi^0 \pi^-$ n $\rightarrow 2\gamma \pi^-$ n		delayed π^-	100%	0.9 (scaled)

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

Performance estimation: pi- resolution



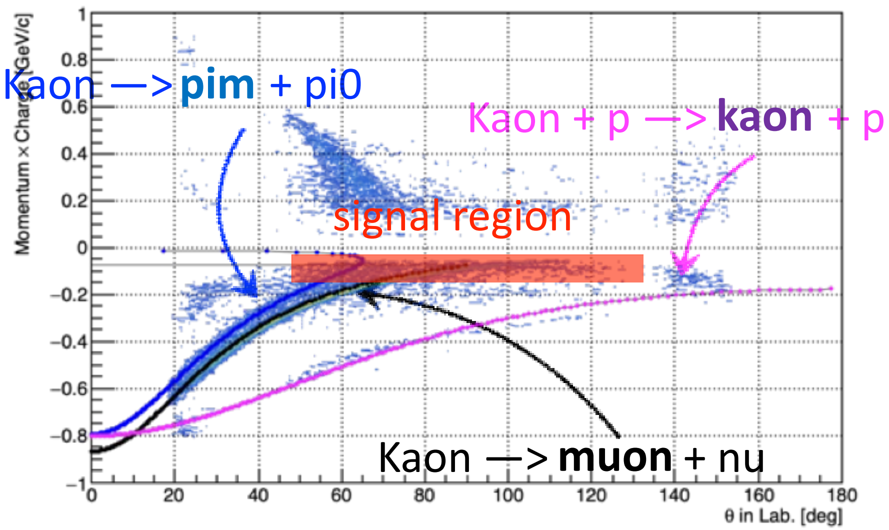
According to GEANT4 simulation,
~2% momentum resolution is achieved for total π^- momentum (pt + pl) after energy loss correction.

T. Hashimoto PhD thesis, University of Tokyo, 2013

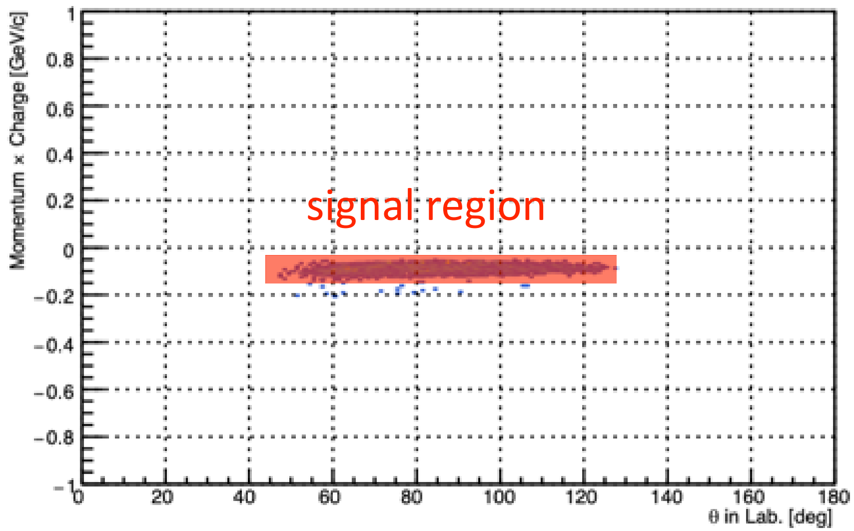
Kaon in-flight decay background

- 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

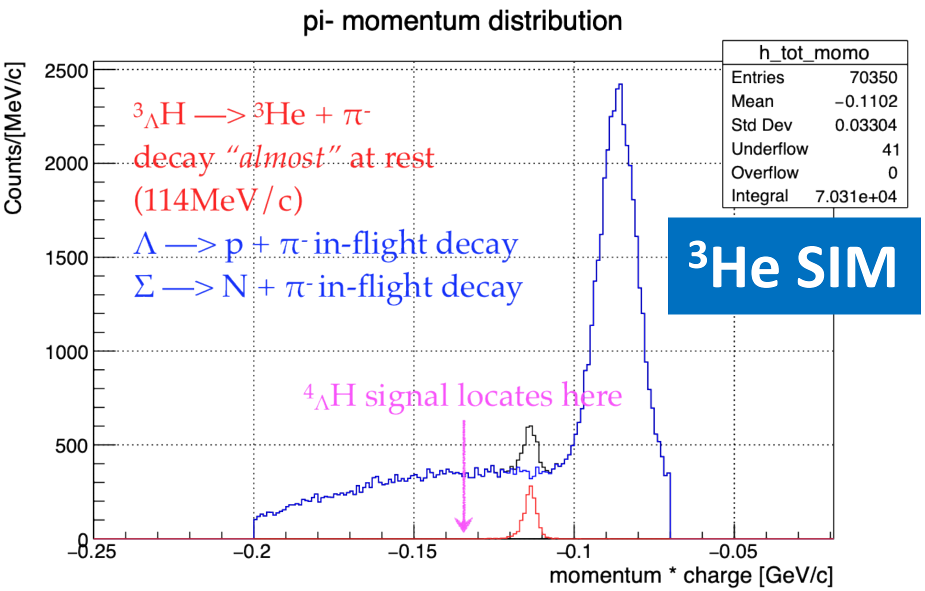


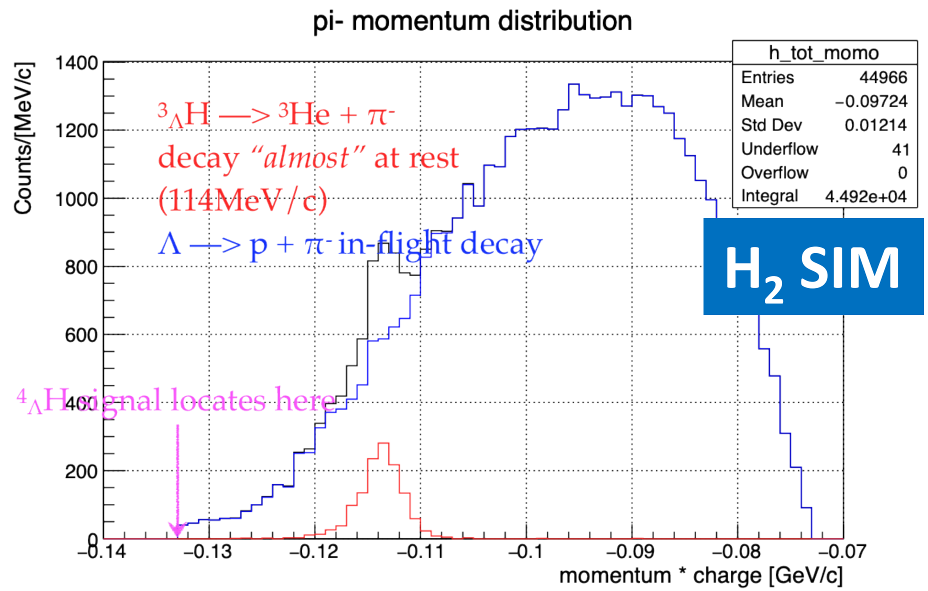
Before event selection



After event selection

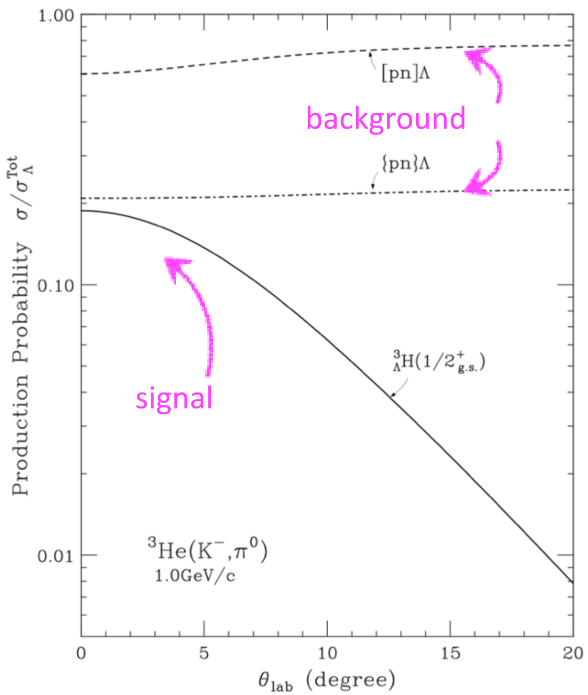
Reaction induced background

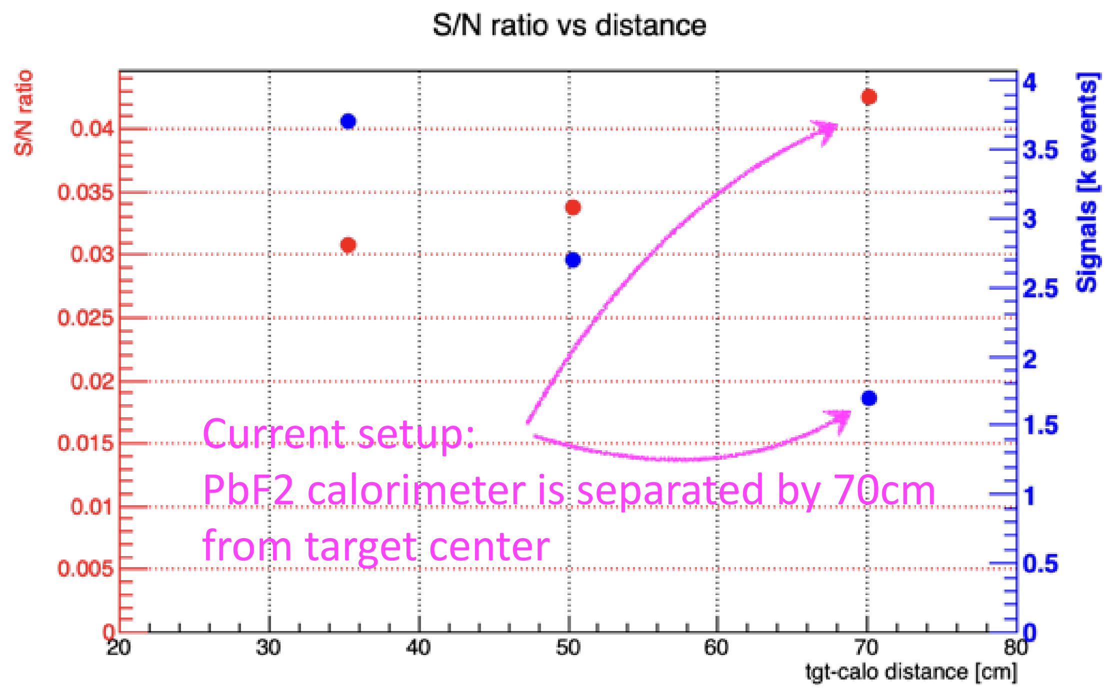




- True background shape may be somewhere in between these two cases ***(an open question)***
- Even for the high background case(Hydrogen), we still can identify the signal region
- ${}^{4}{}_{\Lambda}H$ signal locates ~130MeV/c, which will have better S/N ratio for both cases: ***one week beam time(50kW)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

Setup optimization

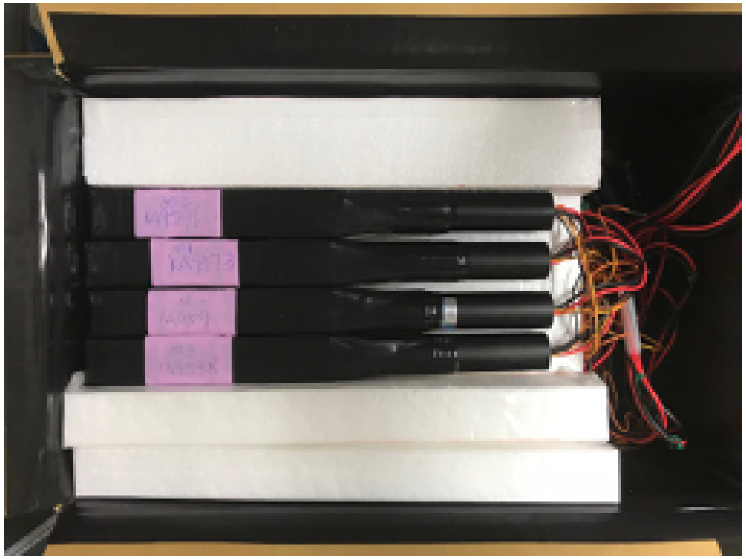




- A balance between S/N and statistical error
- Leave PbF2 calorimeter away from CDS spectrometer to avoid contamination and magnetic field effect on PMT

PbF2 calorimeter

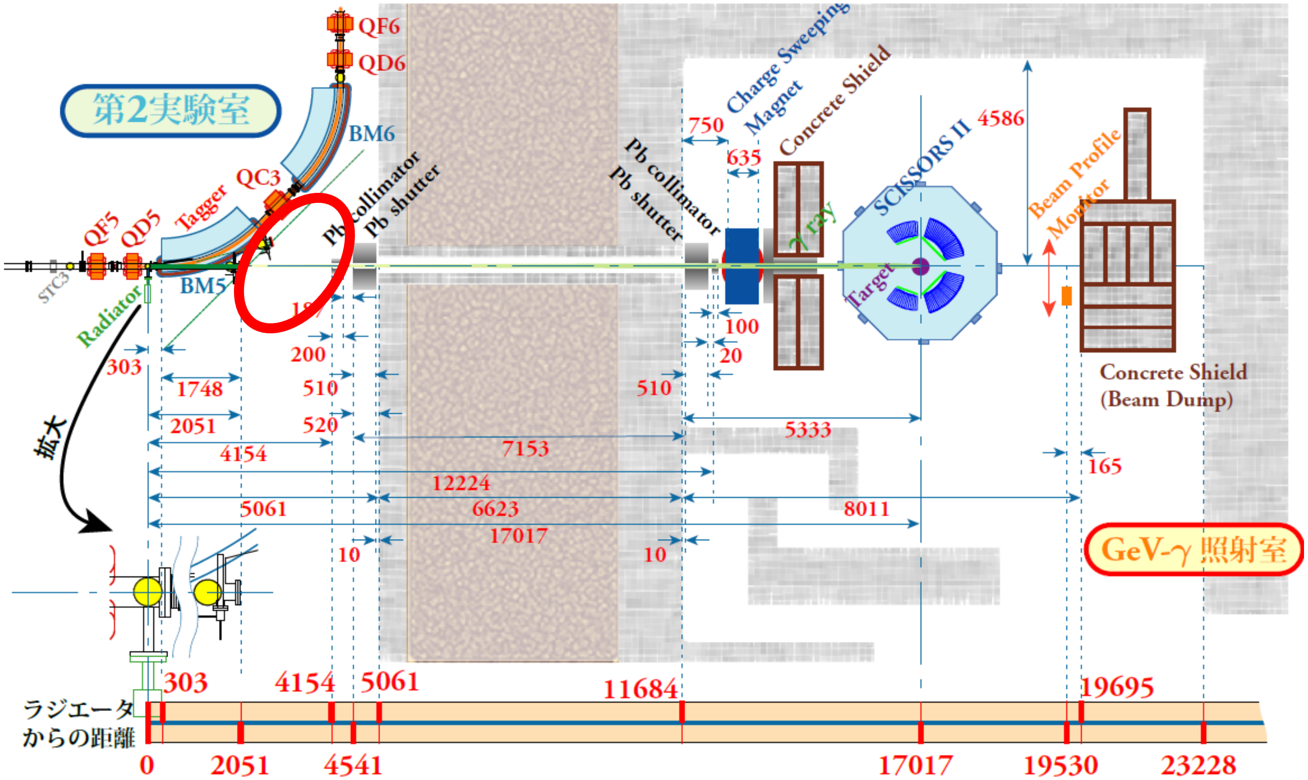
Crystal size: 2.5cm x 2.5cm x 13cm
In total: 36 segments, 6x6
--- 40 pieces in stock
PMT: H6612 (¾ inch PMT)
--- 40 pieces in stock



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

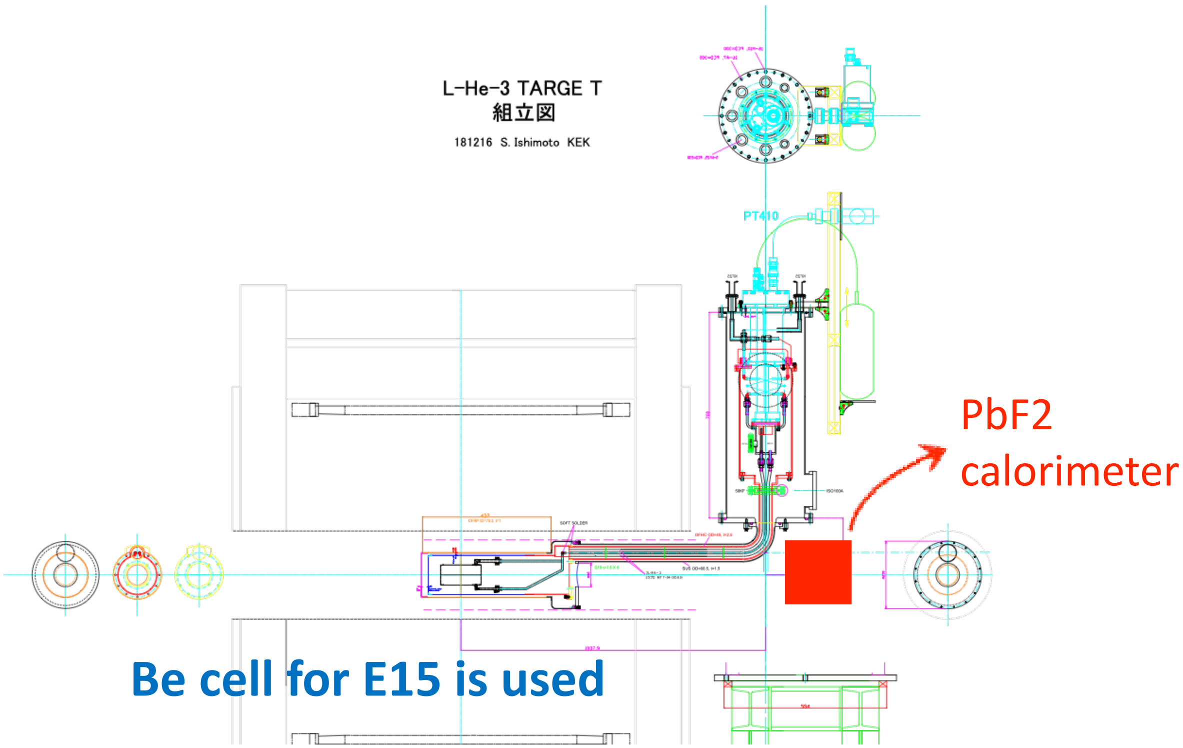
PbF2 calorimeter test @ ELPH

the 2nd experimental room in ELPH



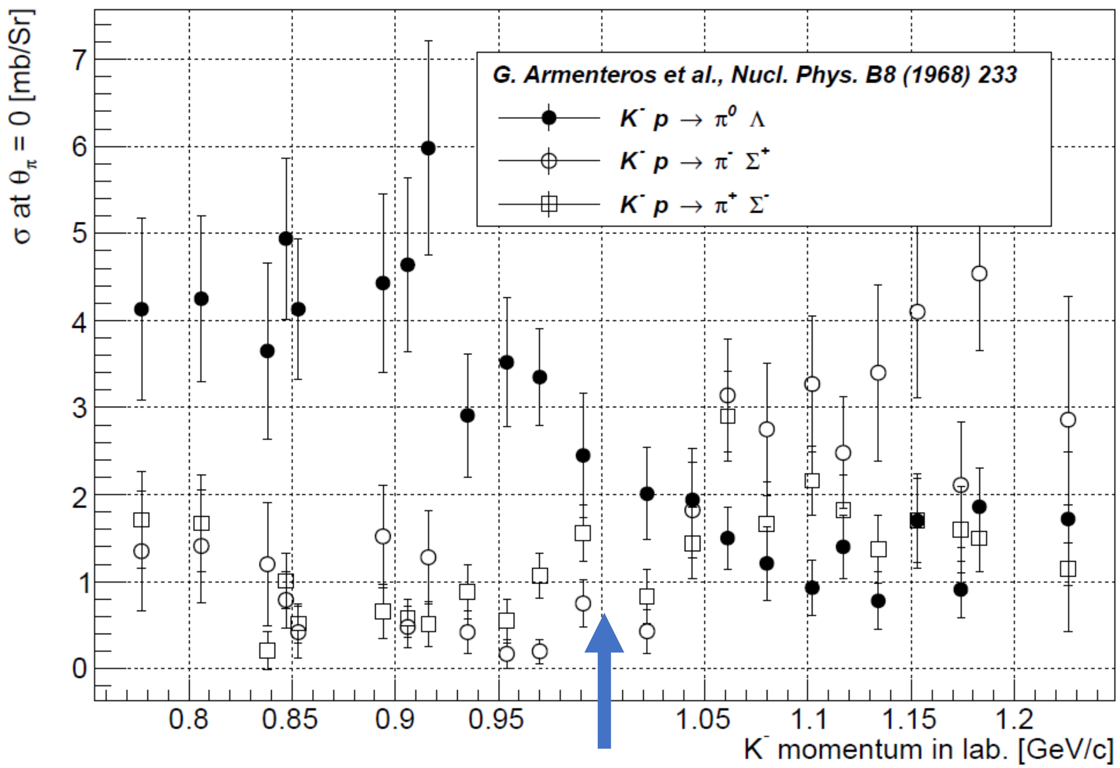
- We are planning to conduct calorimeter test using ~ GeV γ or positron at ELPH, Tohoku-U **in the end of this year (2019)**
  - Gain-uniformity/Position-dependence/Energy-dependence/…

liquid $^{3,4}He$ target



- Liquefaction system is changed from "syphon type with L^4He 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



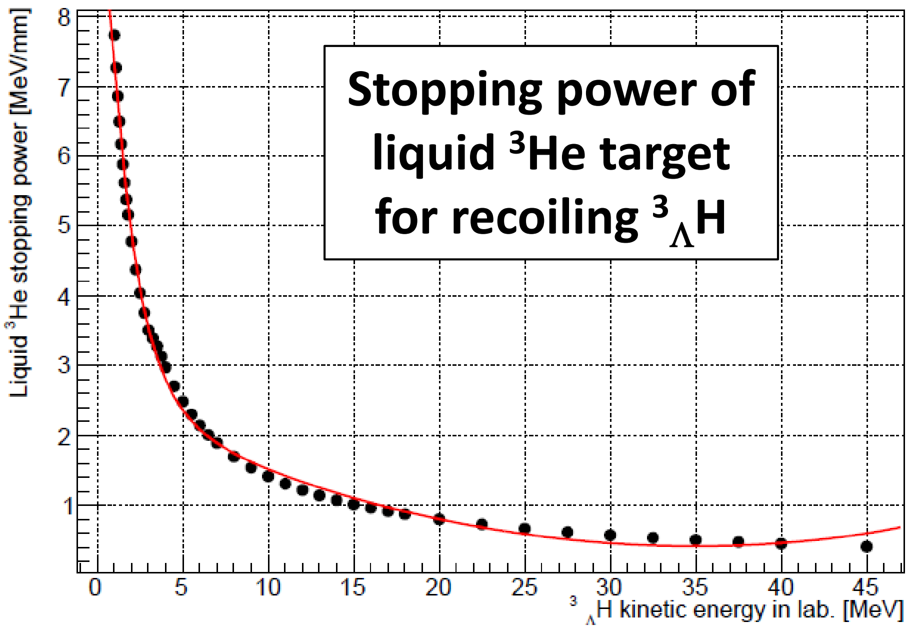
$K^-p \rightarrow \pi^0\Lambda$: ~ 2.5 mb/Sr @ 1.0 Gev/c, θ_π = 0 degree

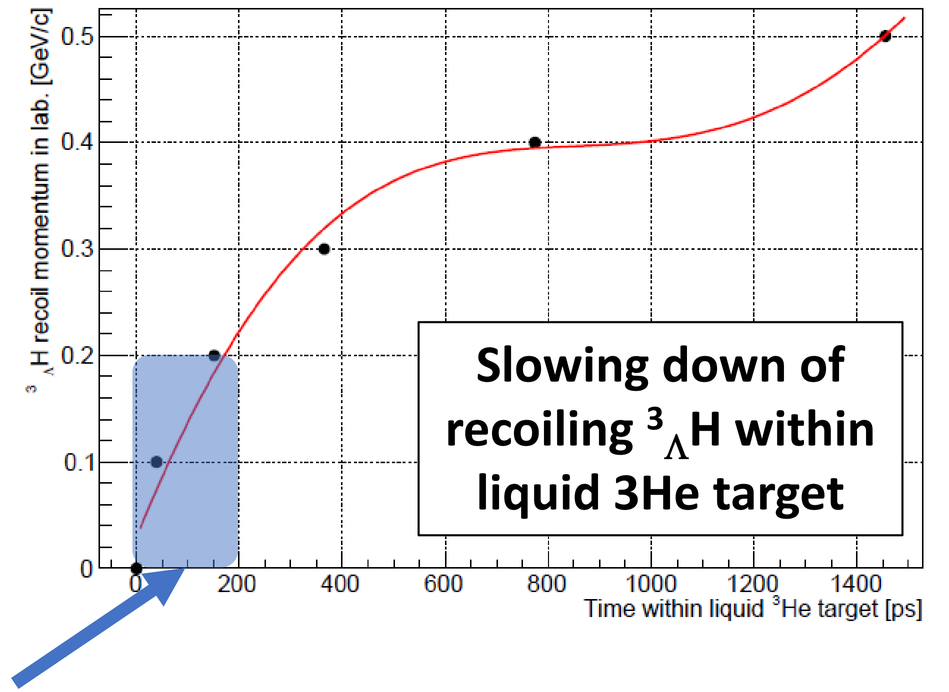
Figure 4: Production cross section for p(K^-, π)Λ,Σ reaction[10].

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

Recoil of $^3_\Lambda H$

calculated with the SRIM package





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

Backup Slides (2)

(K^-,π^0), (π^-,K^0), and (K^-,π^-) at K1.8BR

	(K^-,π^0)	(π^-,K^0)	(K^-,π^-)
Target	L^{3}He	L^{3}He	^{7}Li
Detector based on CDS	γ calorimeter	Ushiwaka + forward $\pi^+\pi^-$ spectrometer	Ushiwaka + forward π^- spectrometer
Beam	$2x10^5$ K^-	$\sim10^7$ π^-	$2x10^5$ K^-
Remark	P73	**Present BL cannot accept 10^7 beam**	Trigger study is needed

Human Resource

for preparation and analysis at K1.8BR over the next few years

	RIKEN	JAEA	KEK (target)	Osaka-U	In total
Staff	5	1	2	2	**10**
Student	1+x	0+x	0	1+x	**2+x**
In total	**6+x**	**1+x**	**2**	**3+x**	**12+x**