Overview of Enge Update

The University of Tokyo

Sho Nagao

on behalf of
JLab hypernuclear collaboration

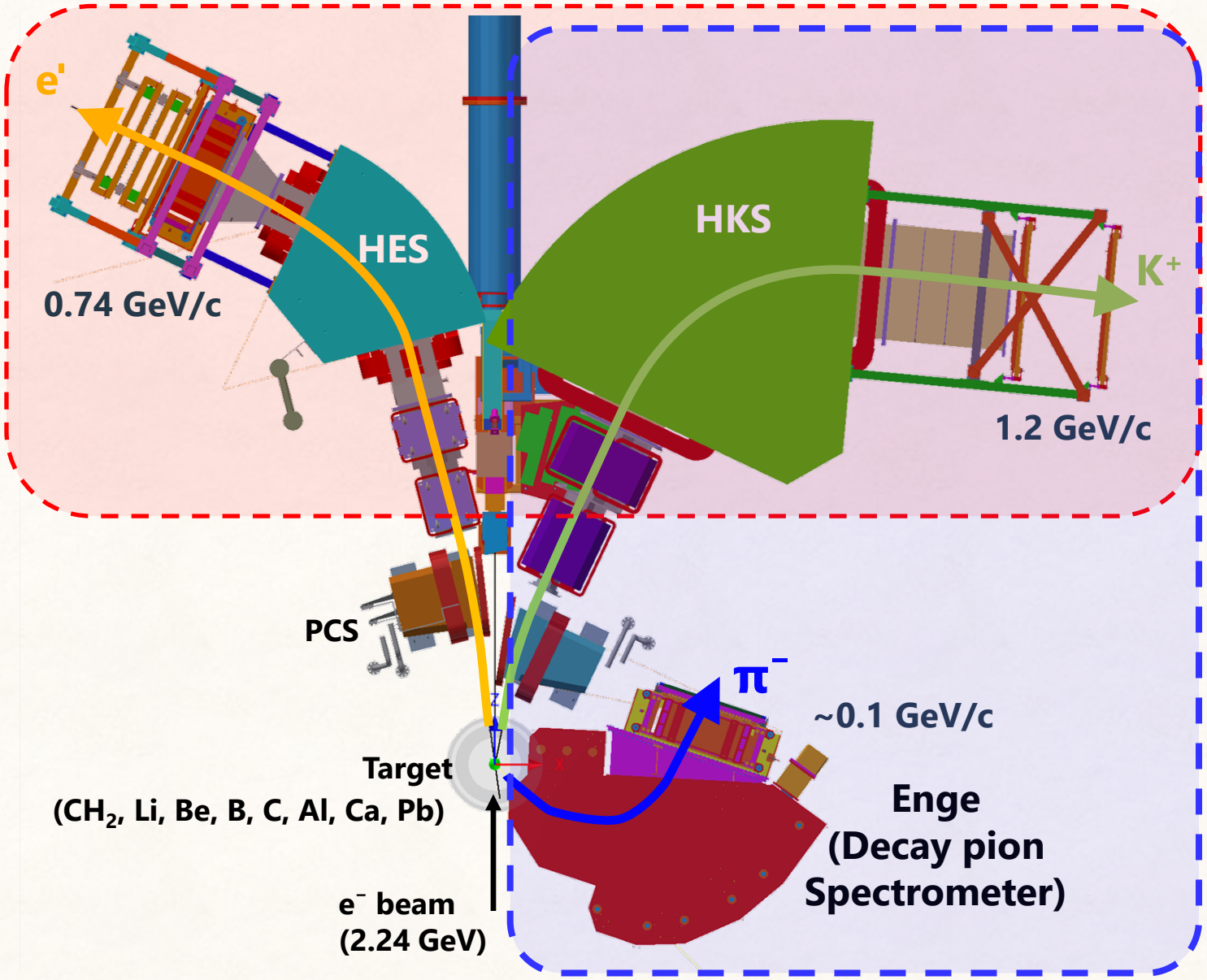
Contents

- Experimental Overview
- Comments from ERR
- Updates

  Drawing, SciFi, Simulation

Hypernuclear Collaboration Meeting 2026

E12-20-013A/E12-15-008A --Decay Pion Spectroscopy--



(e,e'K⁺) Experiments

"e', K⁺" coincidence with HES & HKS

g.s & e.x B_Λ up to A=6 ~ **208**

with **<100 keV accuracy**

Simultaneous data taking

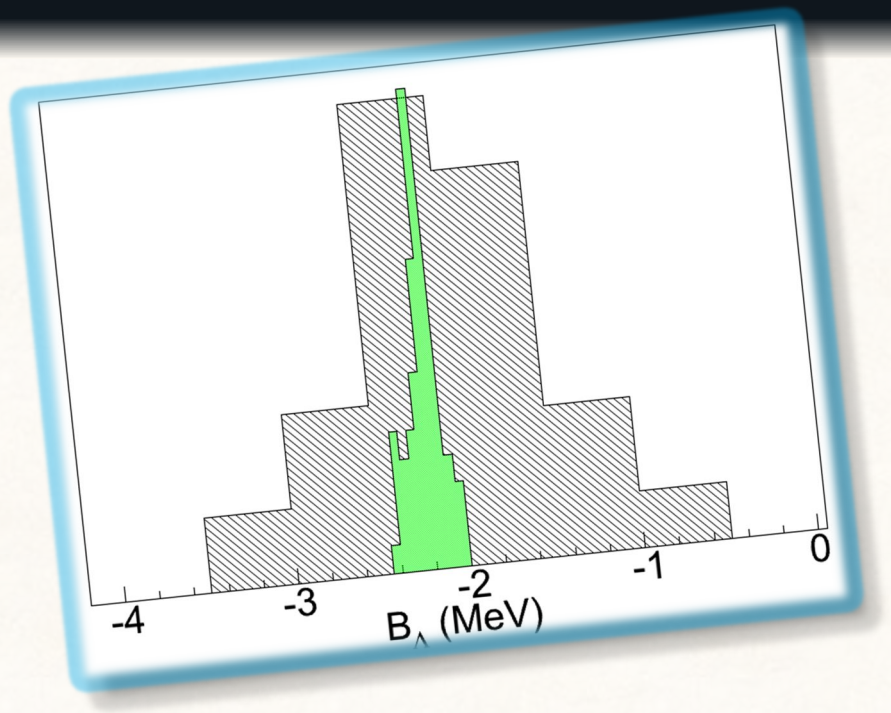
Decay Pion Experiment

"π⁻, K⁺" coincidence with Enge & HKS

g.s B_Λ of **s-**, **p-**, (sd-) **shell**

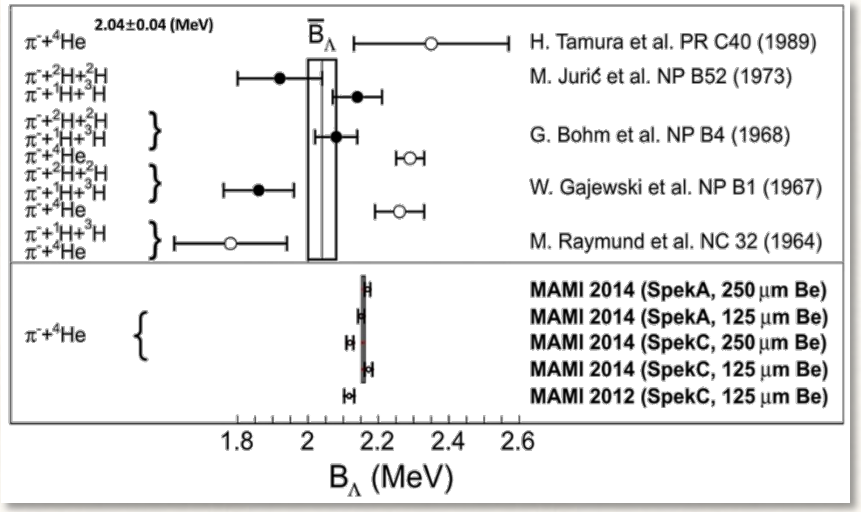
with **a few 10 keV accuracy**

Decay Pion Spectroscopy

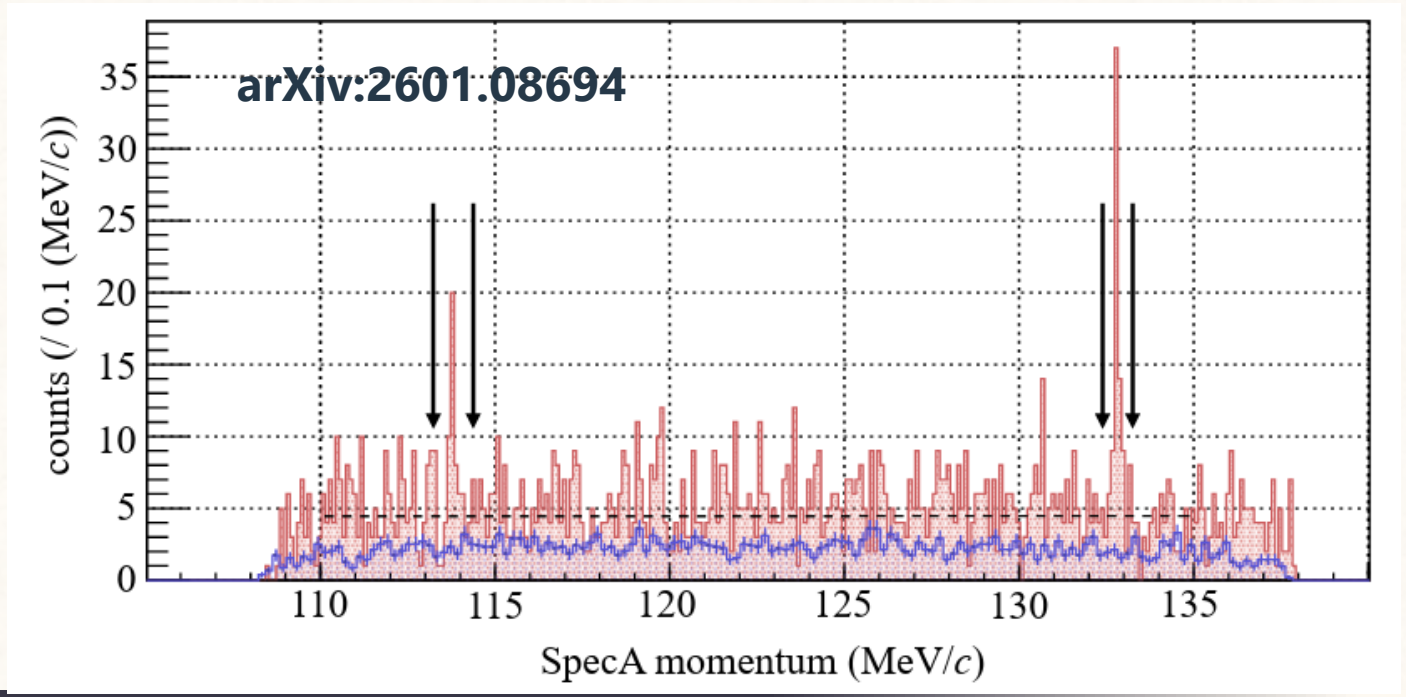


A powerful tool for measuring hypernuclear ground-state energies thanks to excellent resolution

(World-leading resolution & precision for hyper-hydrogen peaks)

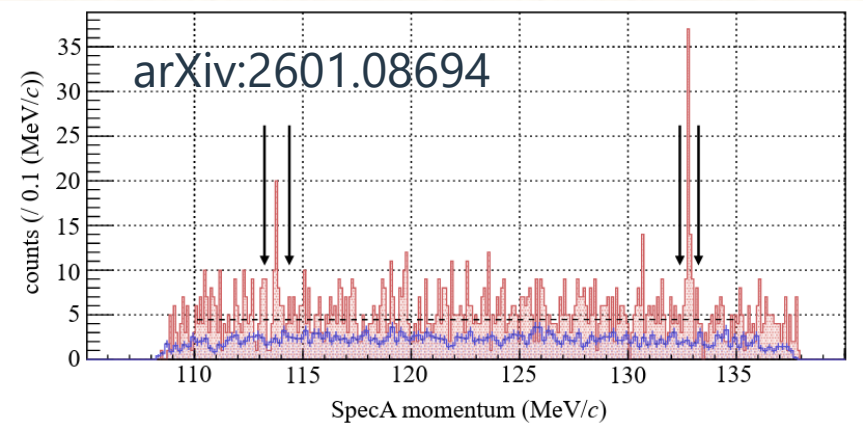


MAMI



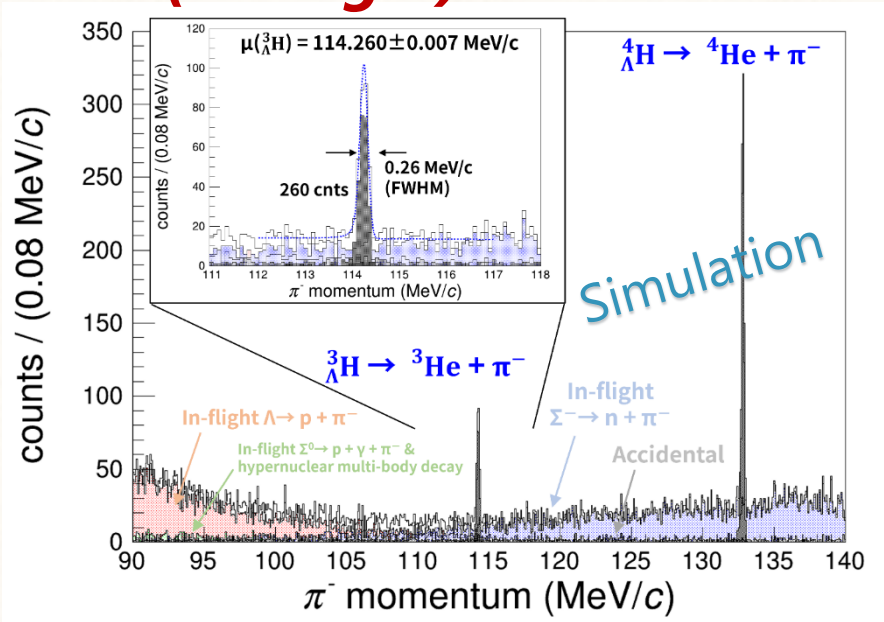
Physics Impact

MAMI

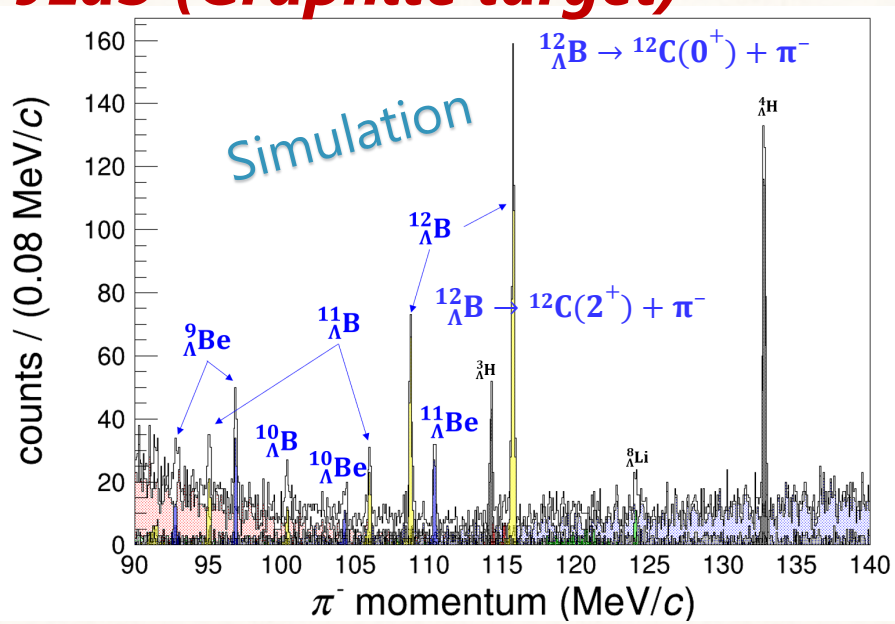


- New determination of B_Λ with **~10 times better accuracy** accuracy has led to further discussion of the ΛN interaction and strange nuclear matter.
- (By-product) Hypernuclear studies via lifetime and spin-parity measurements.

JLab (Li target)

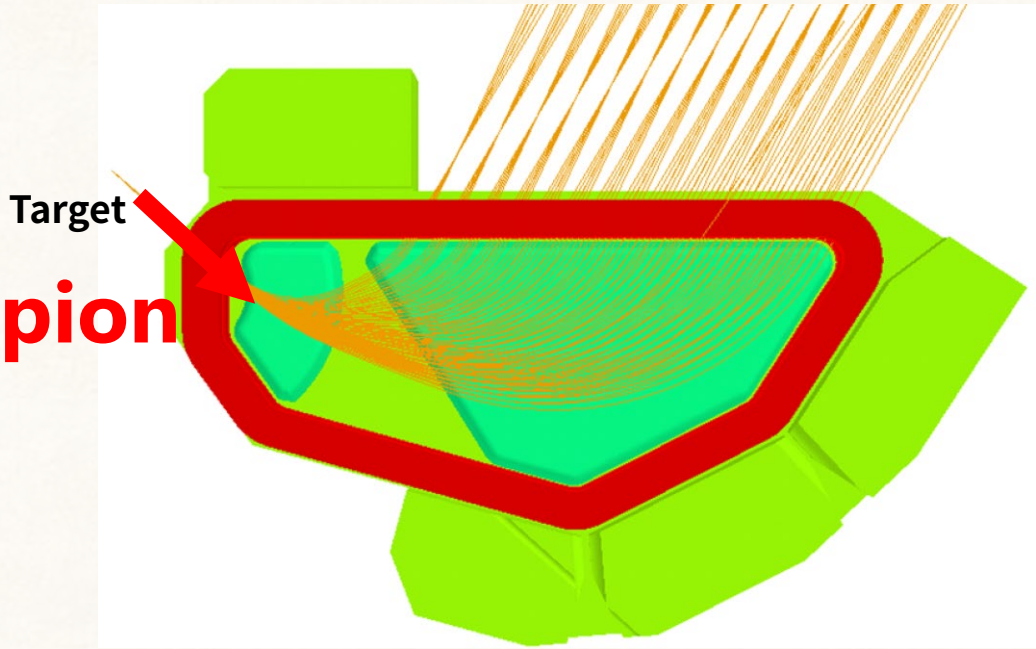


JLab (Graphite target)



Pion Spectrometer --Enge--

Central Momentum	110 MeV/c
Momentum acceptance	78 ~ 140 MeV/c
Dispersion	1.53 cm/(MeV/c)
Momentum Resolution	10^{-3} (FWHM)
Solid Angle	4 msr



$\Delta p/p \sim 10^{-3}$ momentum resolution

- Peak separation, Better S/N
- Momentum from focal-plane position
- Angular information for target reconstruction

A few 10 keV/c momentum calibration

- With alpha-sources (~ 100 MeV/c/q) @target
- Detect α particles with well-known momenta at the focal plane (in vacuum).

Target timing reconstruction: σ ≈ 100 ps

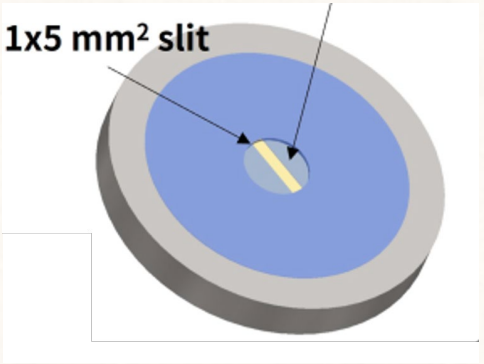
- Suppression of accidental coincidence background
- Particle identification (π / μ / e)
- Lifetime measurement
- → Requires a good start-time counter (σ ≈ 100 ps) and position/angle measurements (σ ≈ 350 μm, 6.7 mrad).

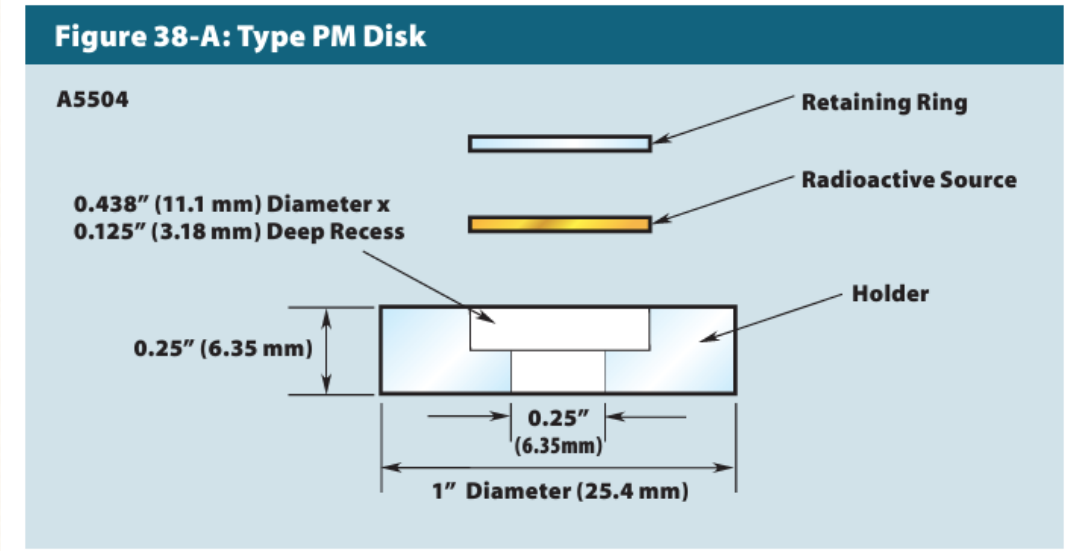
alpha-source

Commercial α sources are available from "Eckert & Ziegler"

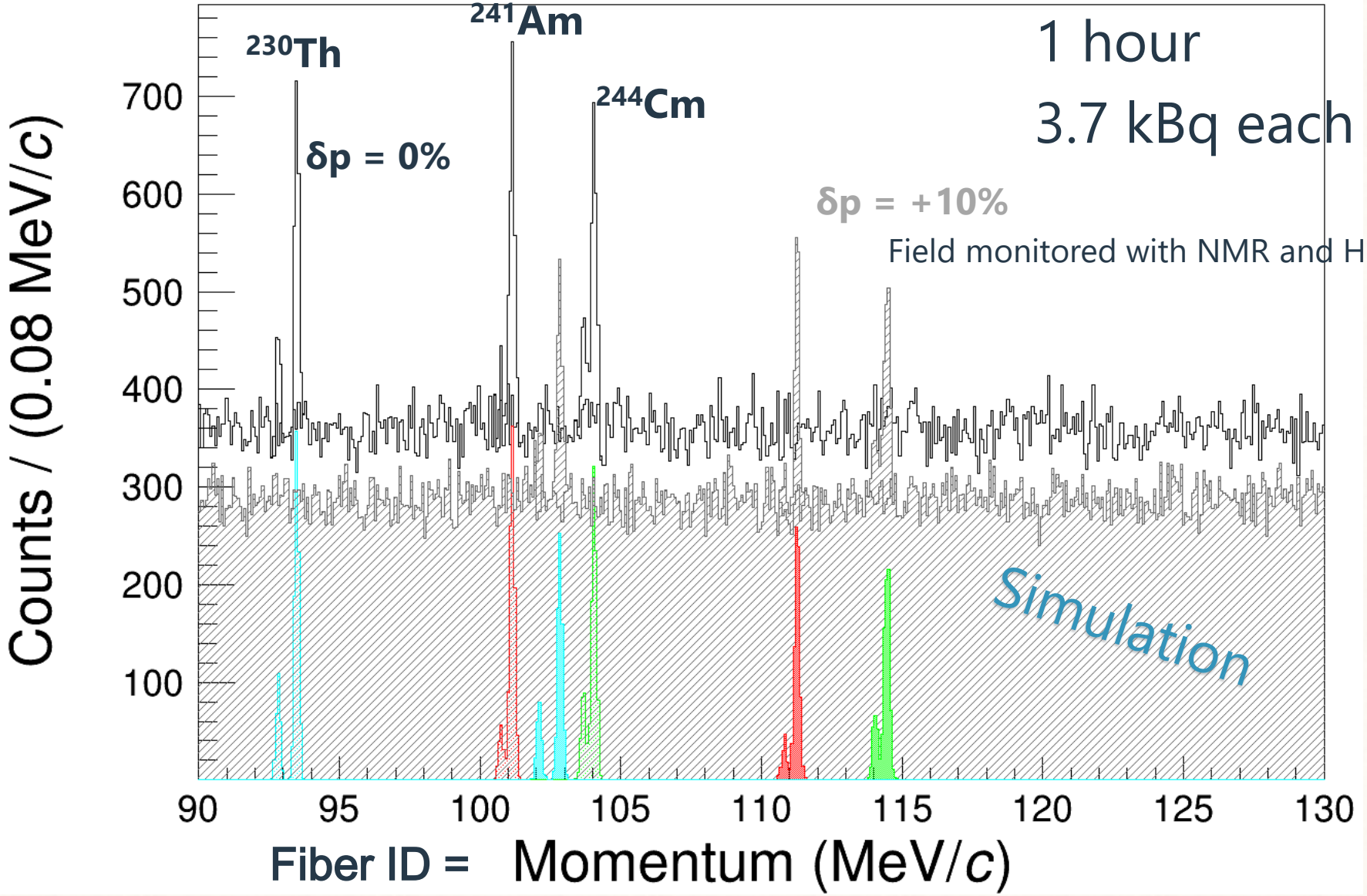
Procure an AF-type mixed 3-nuclide source via RadCon

- **^{230}Th, ^{241}Am, ^{244}Cm (1~5 kBq each)**
- Active diameter: 5 mm (no window)
- <20 keV resolution (FWHM)
- **Removable** package
- $3,610, Lead time: 5–6 weeks
- Make special holder to mount to target ladder and **1x5 mm^2 slit** to make small source point





Expected alpha-source result

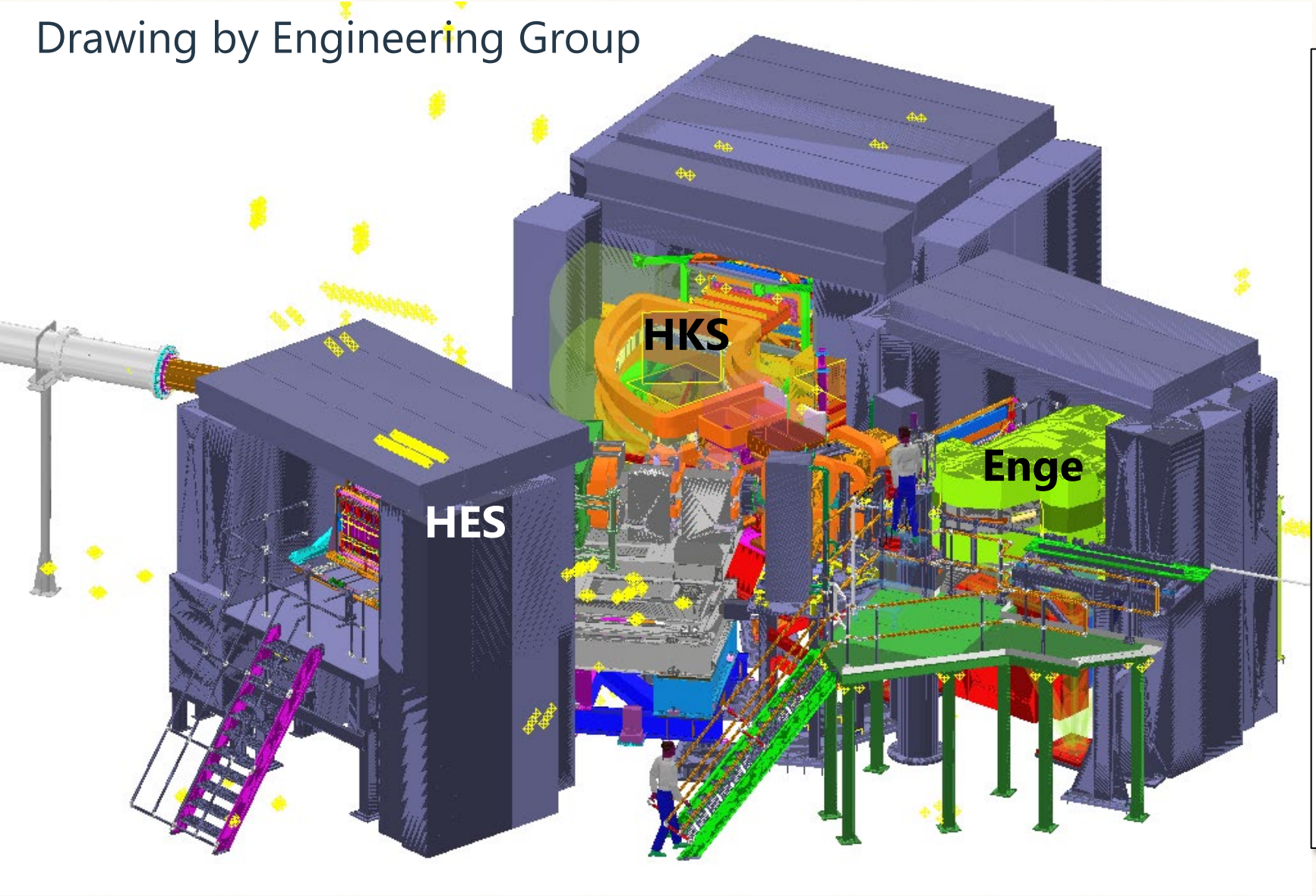


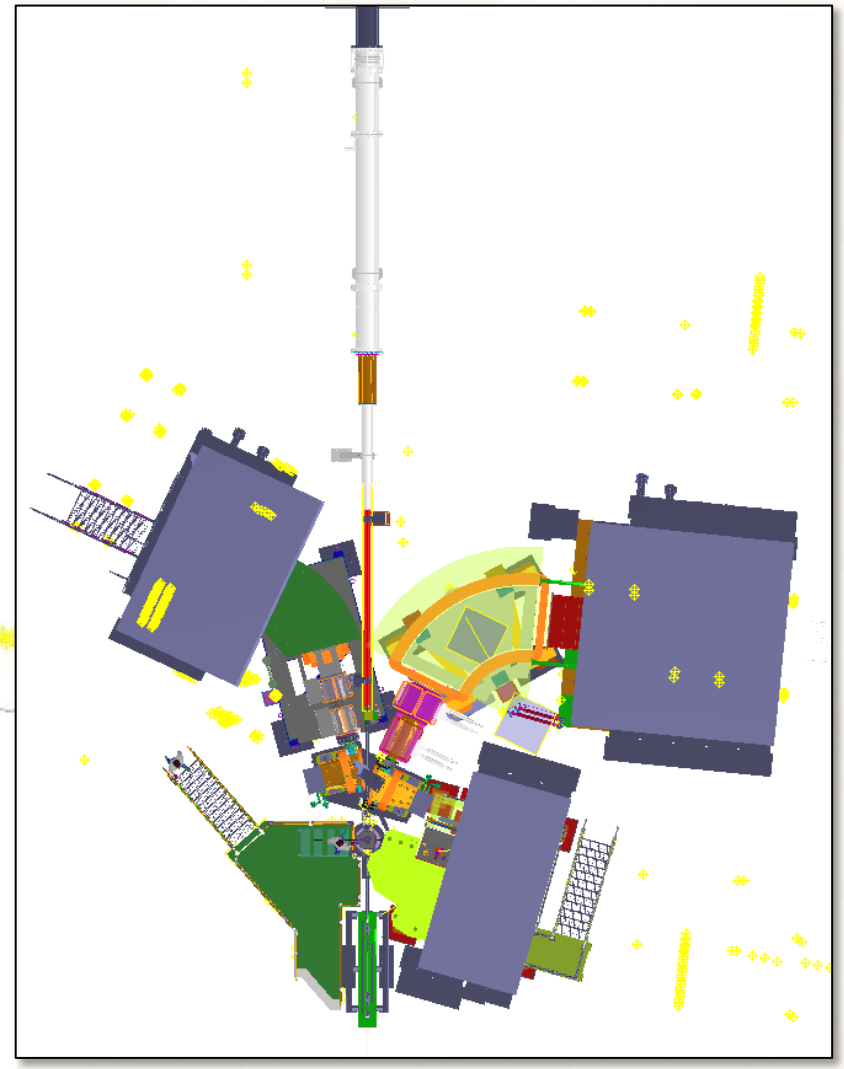
Comments from the previous ERR

- **Finalize the location and shielding configuration** for electronics in the hall.
- Develop a realistic plan for shielding the **SiPMs from radiation damage.**
- **The effect of the PCS magnet's stray field** on the ENGE optics needs to be investigated.
- Alpha-source calibration with PCS magnets ON and OFF should be evaluated. Polarity reversal may change calibration, and possible nonlinear effects on calibration from polarity reversal should be evaluated. **An NMR probe should be installed** to better track the magnetic field.

Mechanical Drawing with Shielding

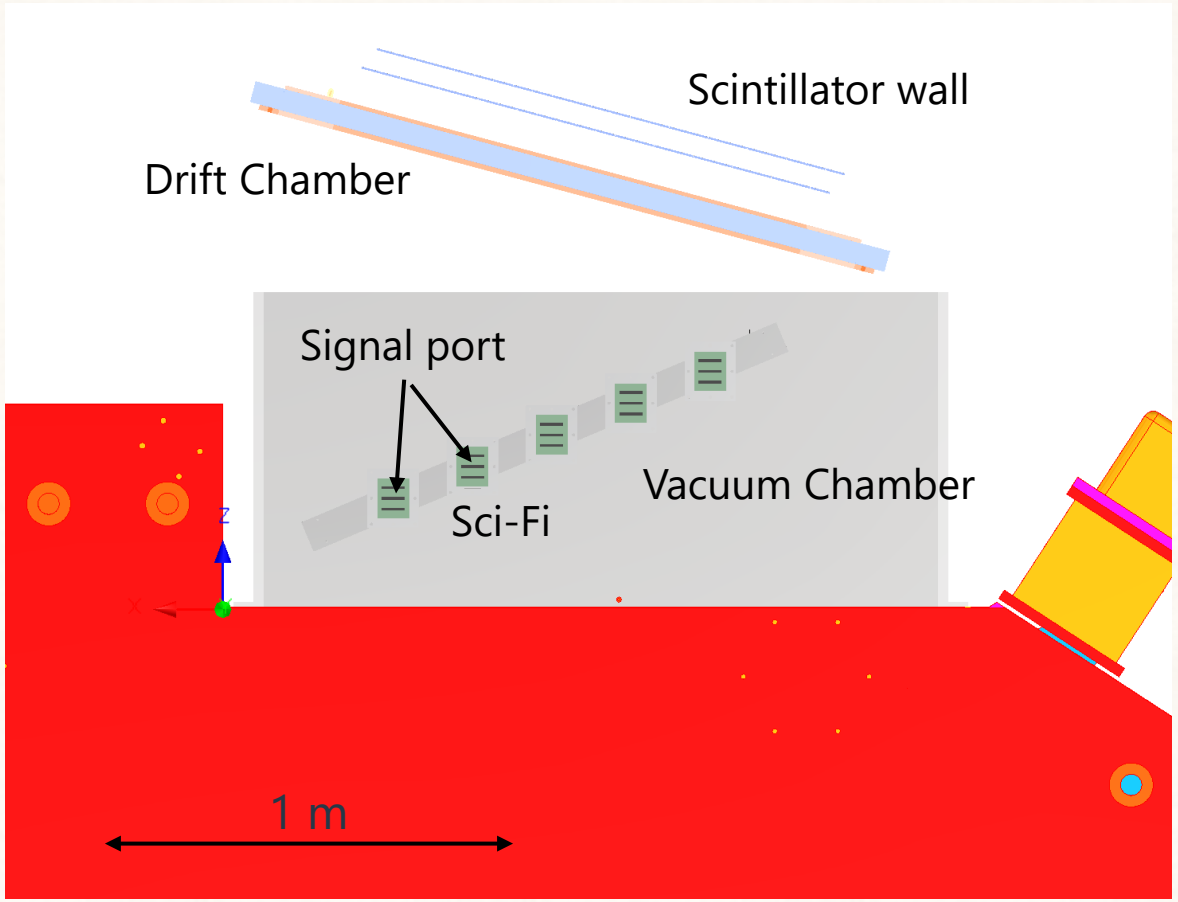
Drawing by Engineering Group



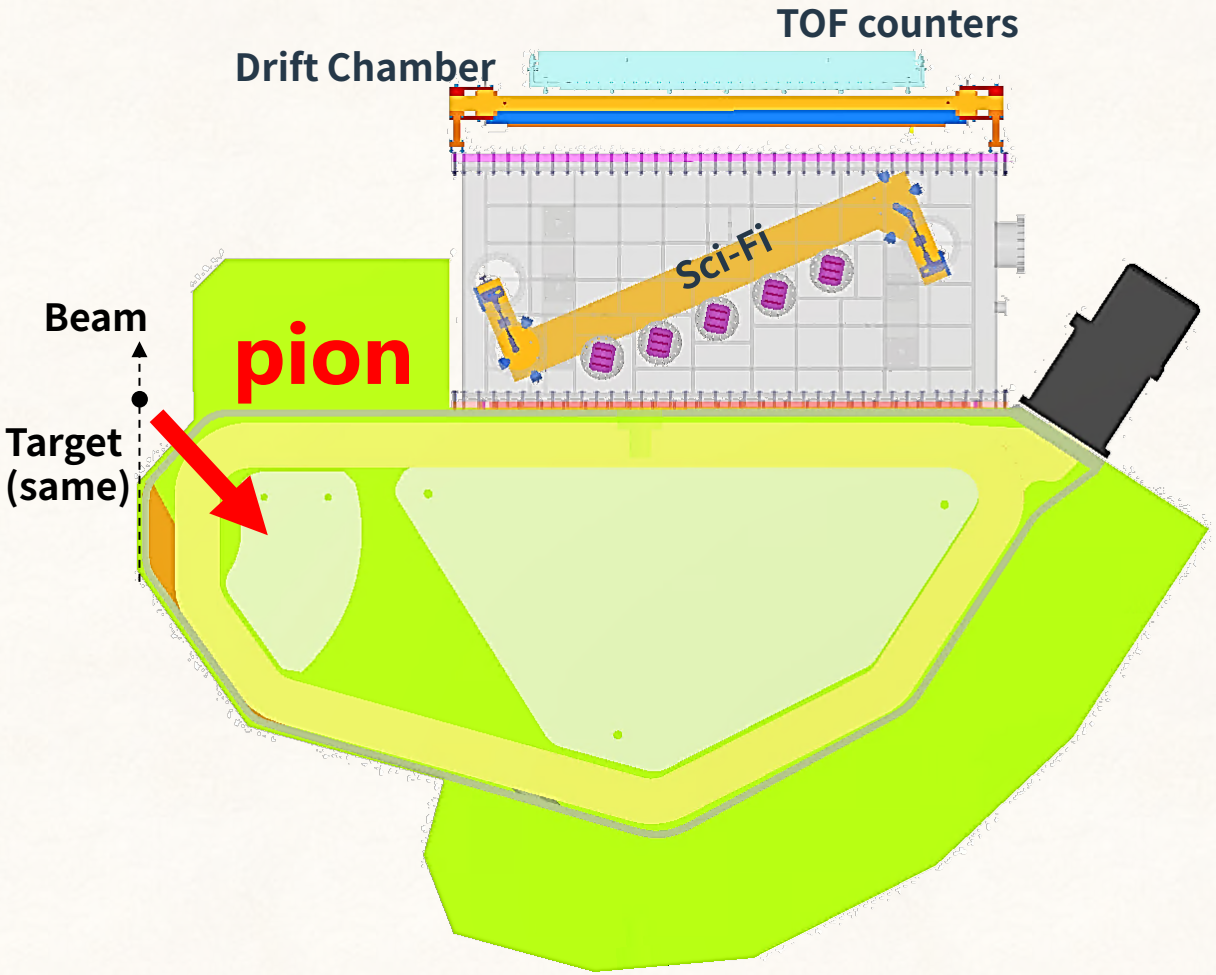


Enge Drawing Update

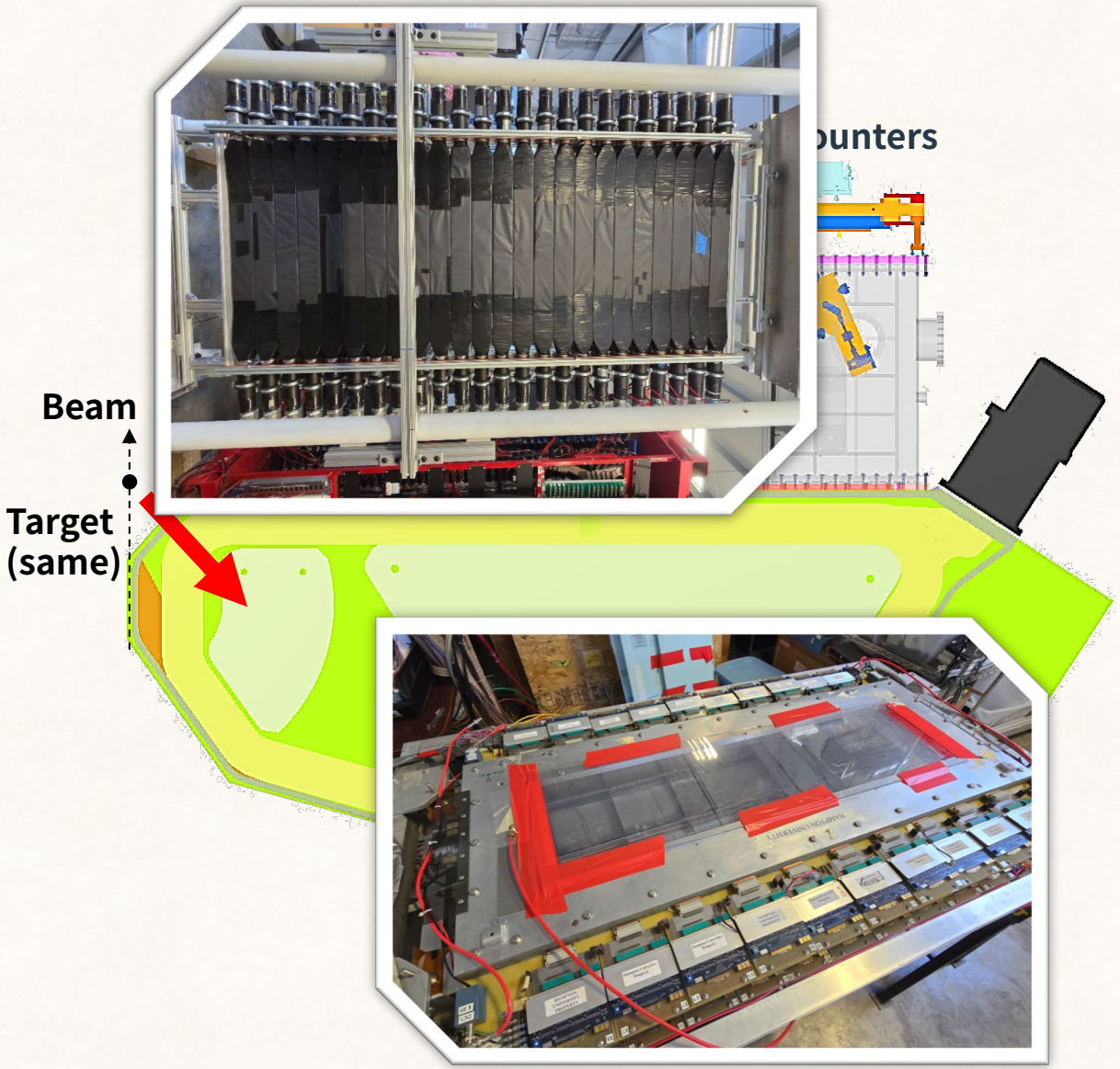
Previous ERR



Latest Version



Enge Detector Setup



TOF counter

Timing measurement & Trigger Timing
Two layers of plastic scintillator paddles
Re-assembling scintillators at ESB
Performance evaluation is ongoing (σ_{TOF} ~200 ps)

by Kotaro

Drift Chamber

Tracking for target reconstruction
Employing HKS Drift Chamber
Evaluation with cosmic-ray data

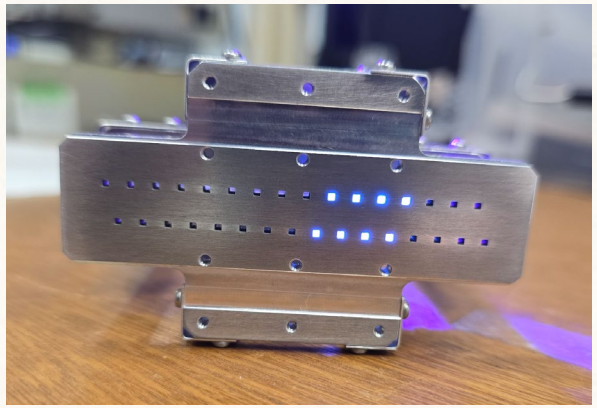
by Ravindu & Ken

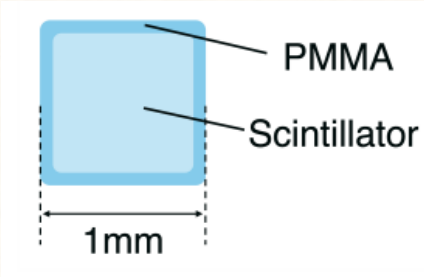
Scintillating Fiber Detector at Focal Plane

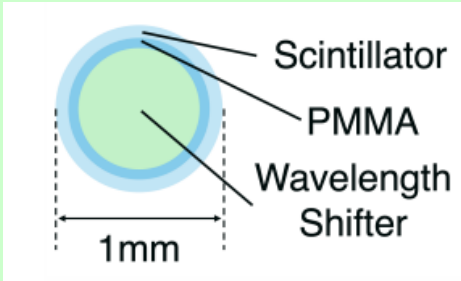
Φ1mm Sci-Fi in vacuum (1000 ch)
Employing Outer-Layer-Scintillating (OSL) Fiber
67 keV/c LSB
Multi-Anode PMT as photon counter
Wide momentum coverage (78 ~ 140 MeV/c)
Fibers & PMT test with β-source $^{90}Sr/^{90}Y$

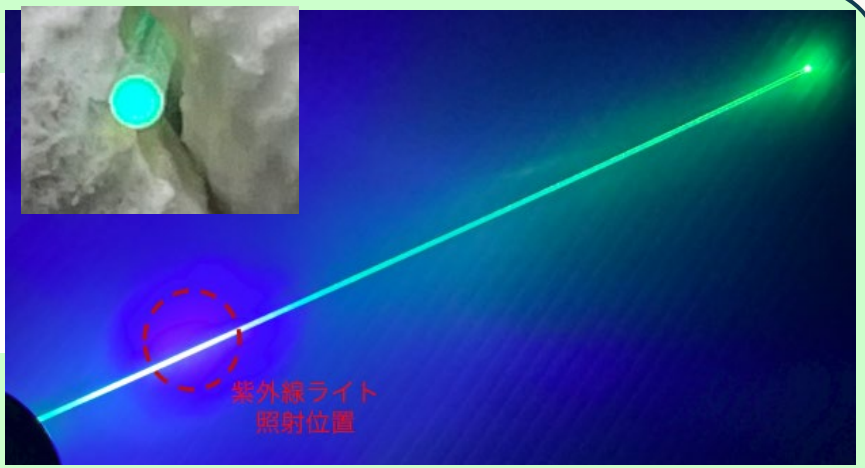
Update for Sci-Fi detector at Focal Plane (New Fiber)

Sci-Fi frame with fibers

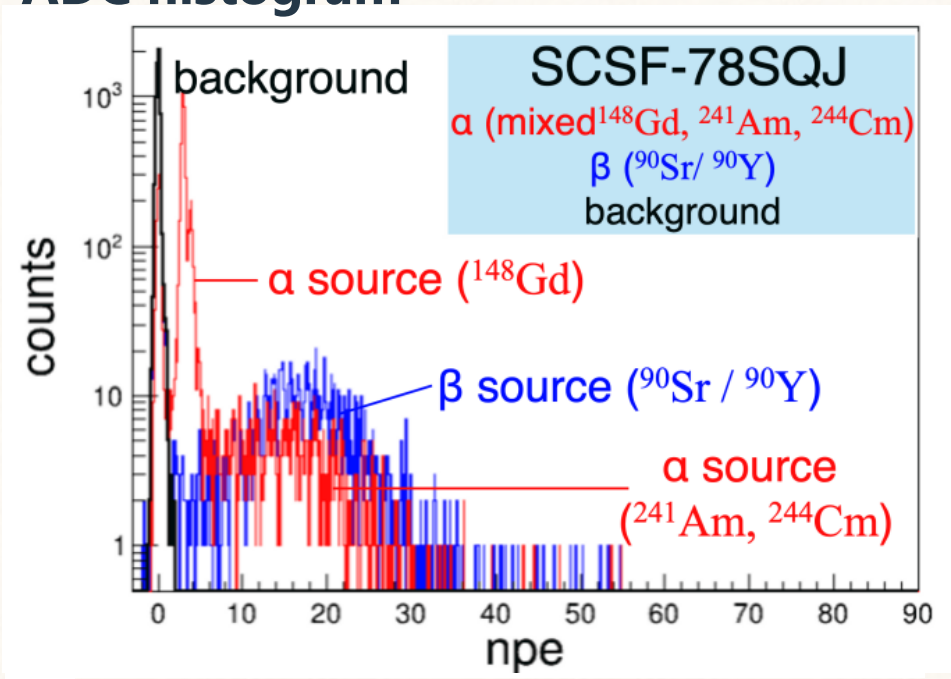


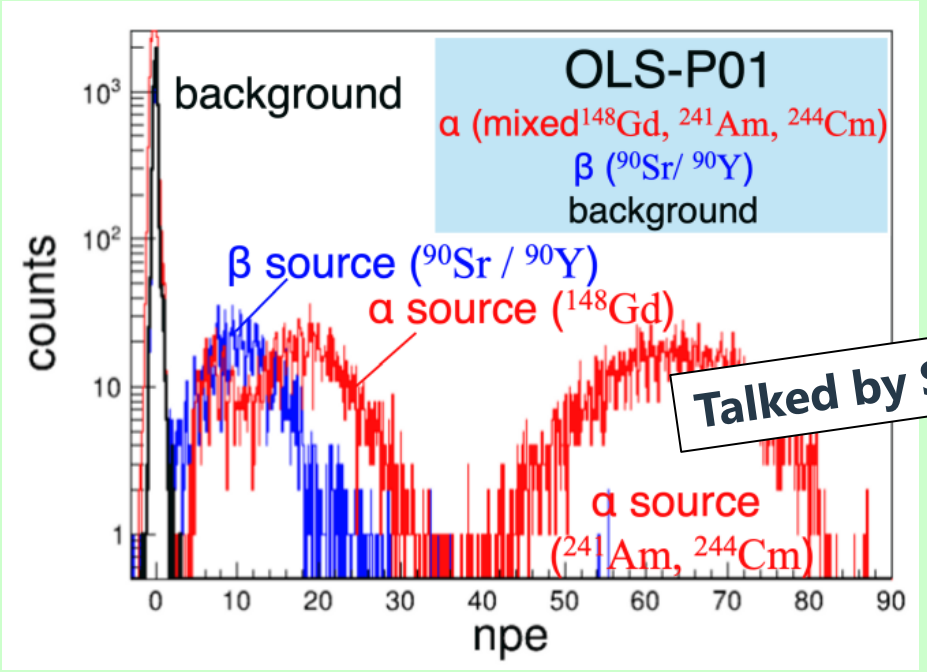






ADC histogram

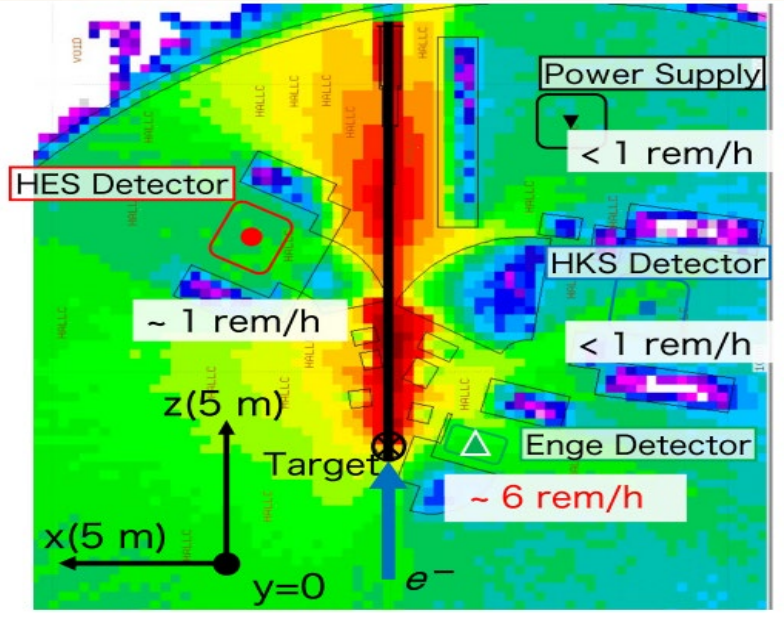




Talked by Shunsuke

Update for Sci-Fi detector at Focal Plane (Radiation Issue)

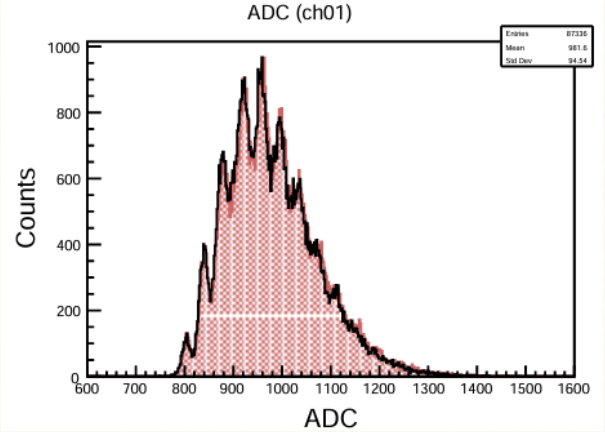
High radiation level at Enge



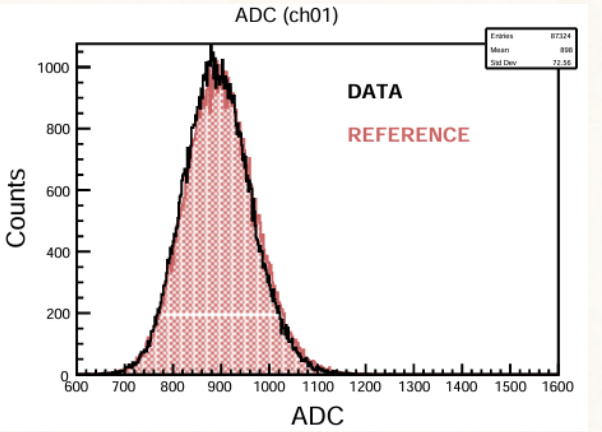
	HES [rem/h]	HKS [rem/h]	Enge [rem/h]	Power Supply [rem/h]
γ	0.080	0.033	0.60	0.048
e±	0.49	0.43	5.6	
n	0.020	0.000014	0.11	0.00020
Total	0.59	0.47	6.3	0.42

Talked by Jin

Before



After 20 mrem



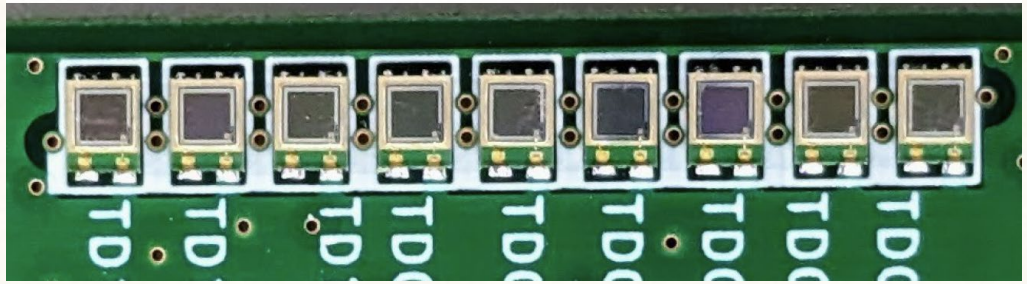
After 20 mrem dose (3 hours for Pb target.),

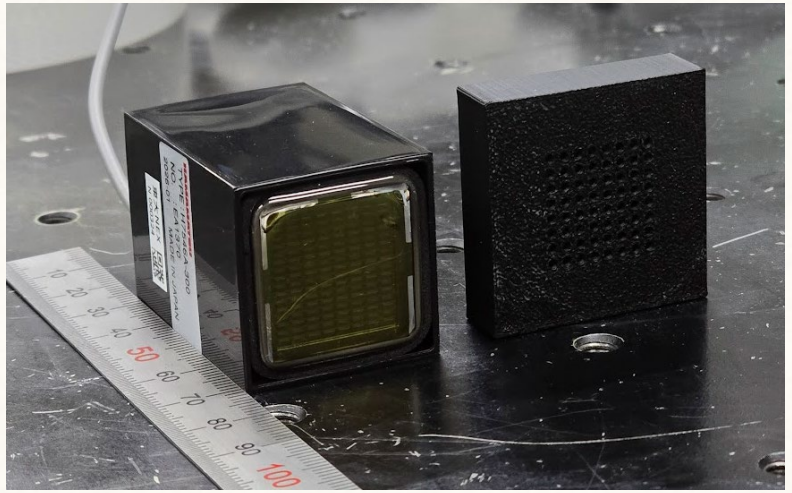
- SiPM degradation is observed

After 320 mrem dose (2 days),

- Leakage current increased to 240 μA (from <10 μA)
- TDC peak efficiency dropped to a few tens of percent
- → Changed plan for stable operation.

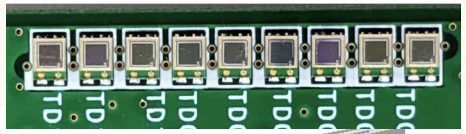
From SiPMs to MA-PMTs





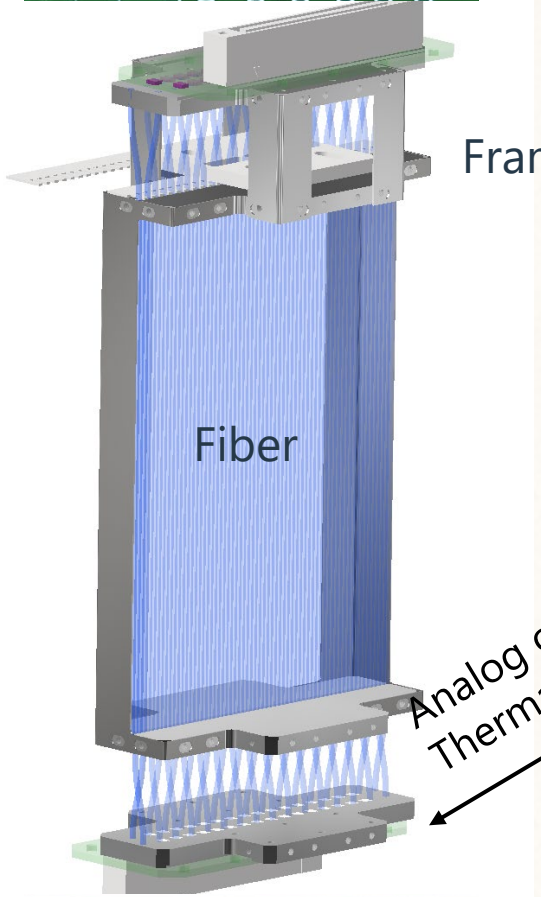
	SiPM (Hamamatsu MPPC)	Multi-Anode PMT (Hamamatsu H7546)
Single Photon Efficiency	~40%	~20%
Dark count rate	>1000 k / sec	20 k / sec
Gain	1.7×10^{6}	5×10^{5}
in Vacuum / in Mag. Field	○ / ○	× / ×
Temperature Depend	×	○
Radiation Damage	×	○

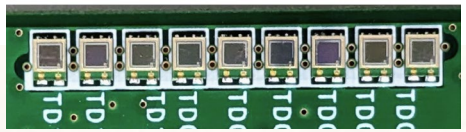
OLD configuration



Frame

Fiber

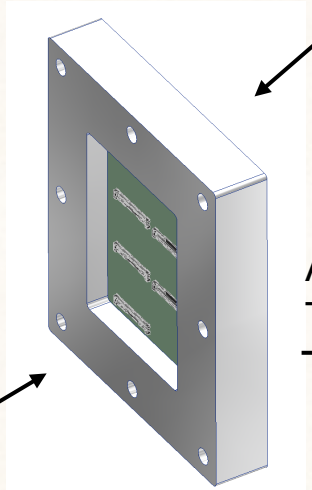




MPPC board

+60 V for Bias (common bias for 64 ch)

Signal port on chamber



Analog out, Thermal, Bias

40pin coaxial

Analog out, Thermal

34pin Flat cable

EASIROC Module on or under the platform

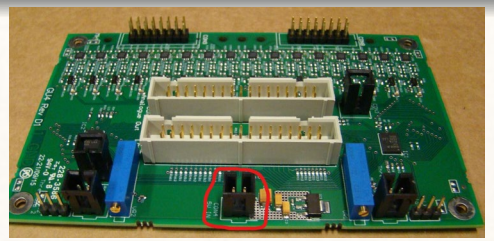
64 ch x 13 modules

LVDS out

34 pin Flat Cable

VETROC LR-TDC @ SHMS

New configuration with MA-PMT



NINO Discriminator Card x 64

100-ft flat cable
LVDS repeater

VETROC TDC @SHMS

Multi-Anode PMT
(Hamamatsu H13700 x 4 or H7546A-300 x 16)

One unit was delivered last month

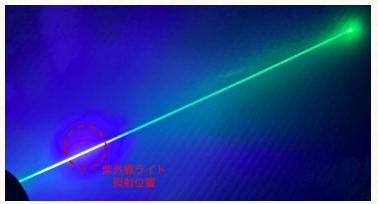
Optical Fiber x 1000
(Kuraray Clear-Fiber)

Vacuum Flange

Cost ~ $10k
Design (by May 2026)
Manufacturing (3 months)

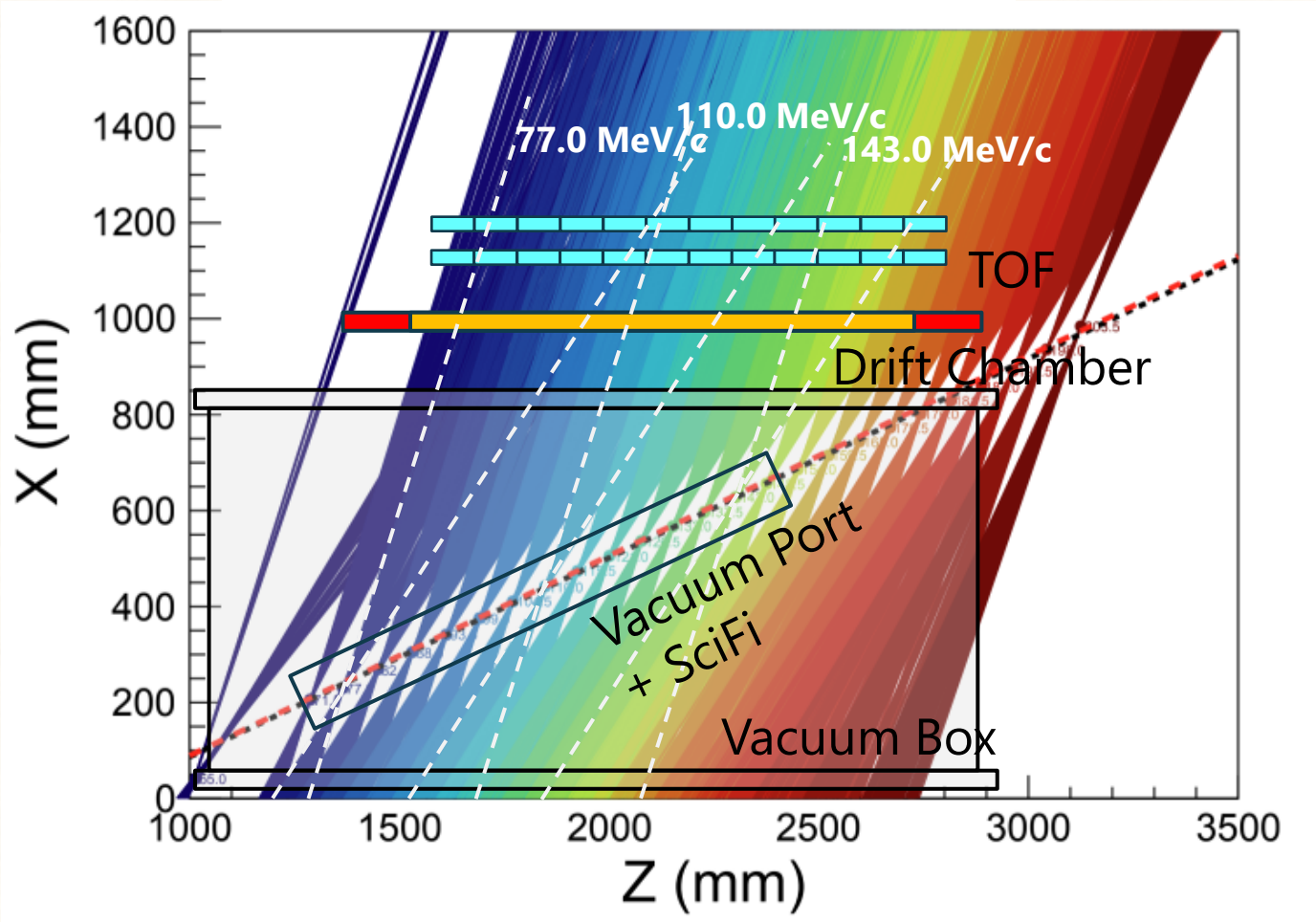
Scintillating Fiber x 1000
(Kuraray OLS-P01 Φ1mm L=100mm)

Will be delivered Late March



Vacuum Chamber Box

Enge Detector Setup with Particle Trajectories



Dependence on production position (Geant4 + TOSCA field map)

	X	Z
Resolution Deterioration (keV/mm)	~2	<1
Dispersion Changes (%/mm)	0.02	0.01
Focusing Position Shift (keV/mm)	**40**	**13**

Shifts in the production point have a non-negligible impact

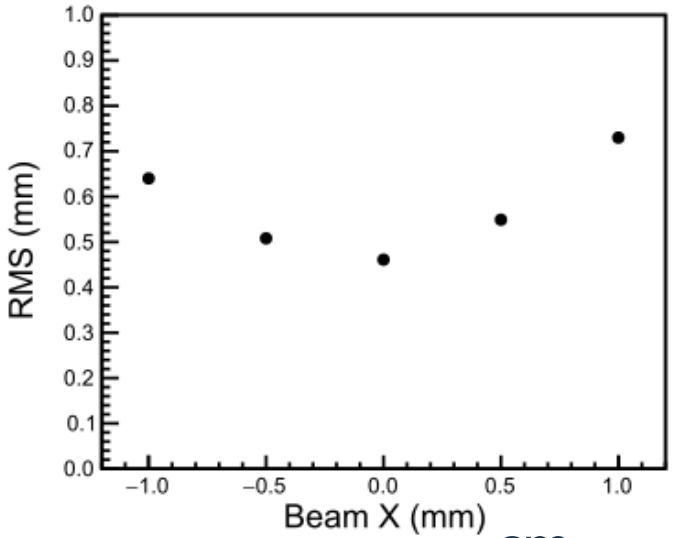
- **Beam position monitor with σ ~ 100 μm**
- **Beam–α-source relative position is known to within 100 μm**

PCS stray field has ~0.08% effect.
→ Non-negligible effect (90 keV/c shifts)

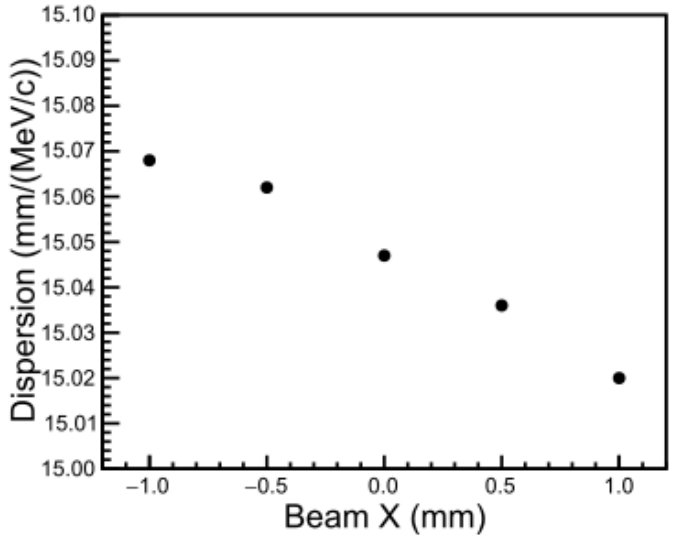
Summary

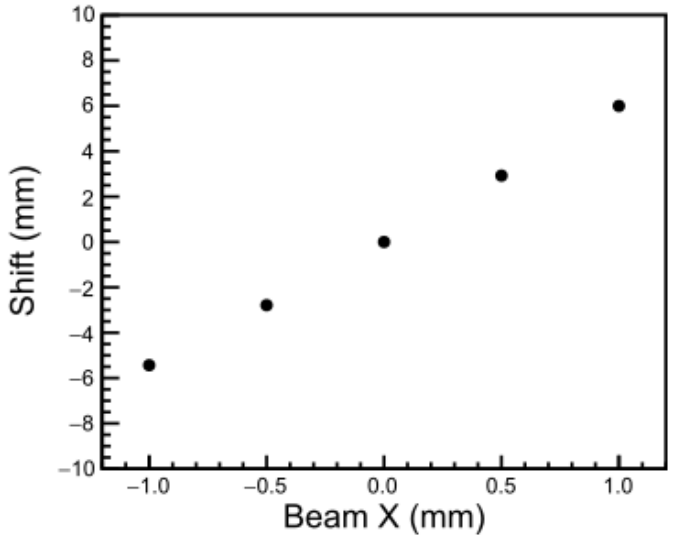
- Run-group experiment "Decay pion spectroscopy" with HKS-Enge simultaneous experiment with (e,e'K^+)
- **Comments on the previous ERR**
  - Finalize the location and shielding configuration for electronics in the hall.
    → Updating detector & shielding configuration
  - Develop a realistic plan for shielding the SiPMs from radiation damage.
    → MA-PMTs instead of SiPMs
  - The effect of the PCS magnet's stray field on the ENGE optics needs to be investigated.
    → Alpha-source calibration with PCS magnets ON/OFF is necessary. PCS magnet 10% deviation is acceptable for Enge calibration.
- **Other Status**
  - TOF counter & Drift Chamber Tests are ongoing with cosmic rays at ESB (by May 2026)
  - Checked new Sci-Fi detector performance with β- and α-sources
  - Detailed design of vacuum port (by May 2026)
  - Sci-Fi small version with MA-PMT & NINO board (by May 2026)

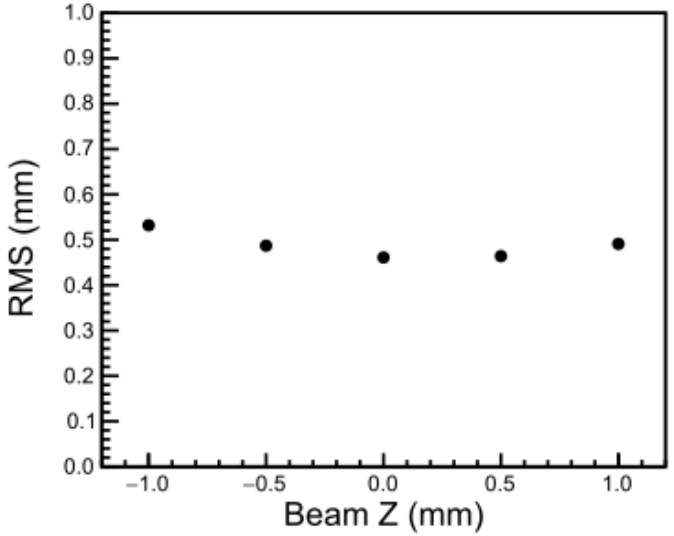
Beam Position Shift Evaluation (by G4)

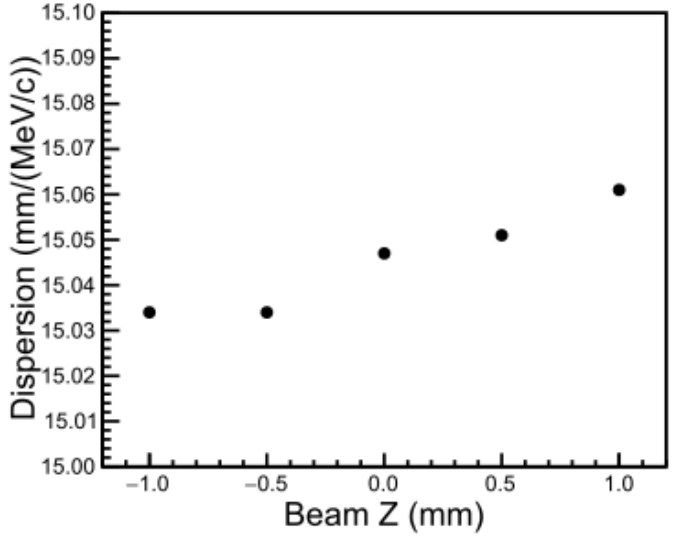


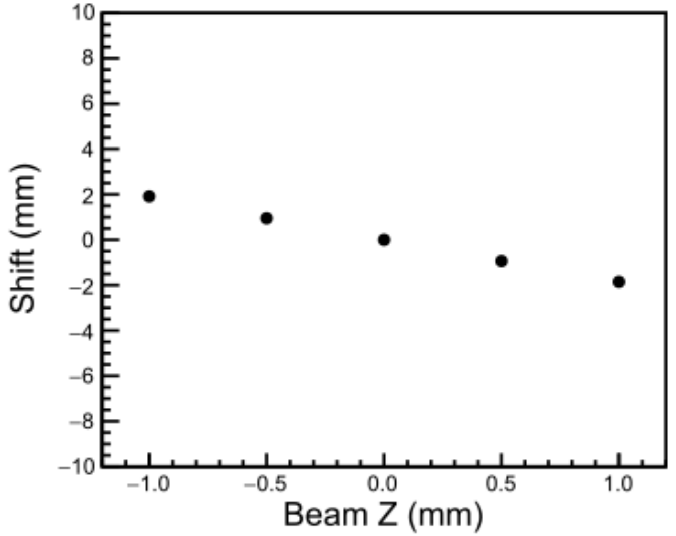
→ cm



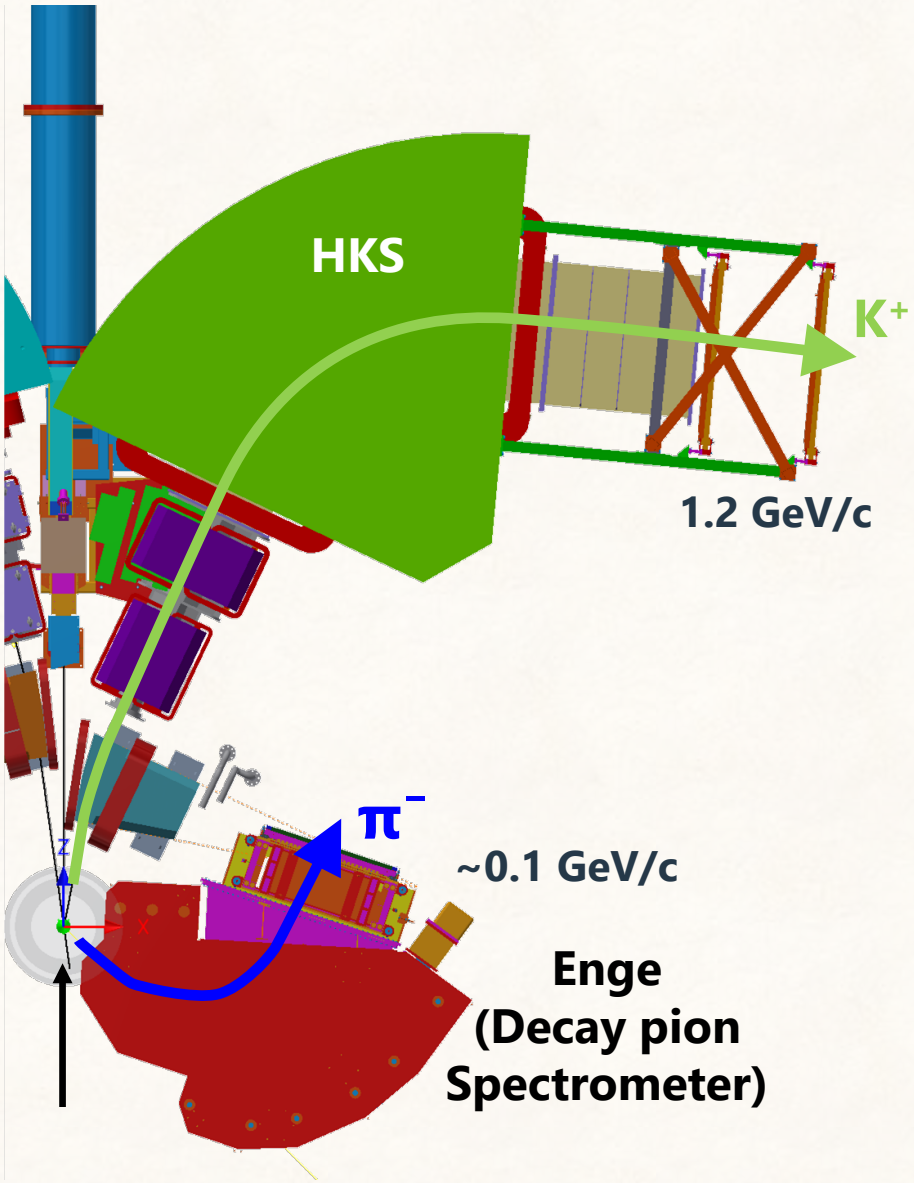


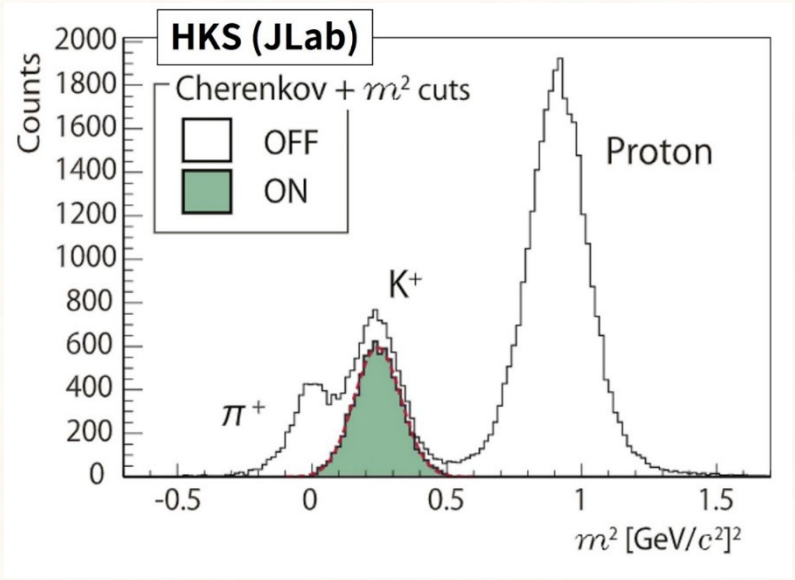


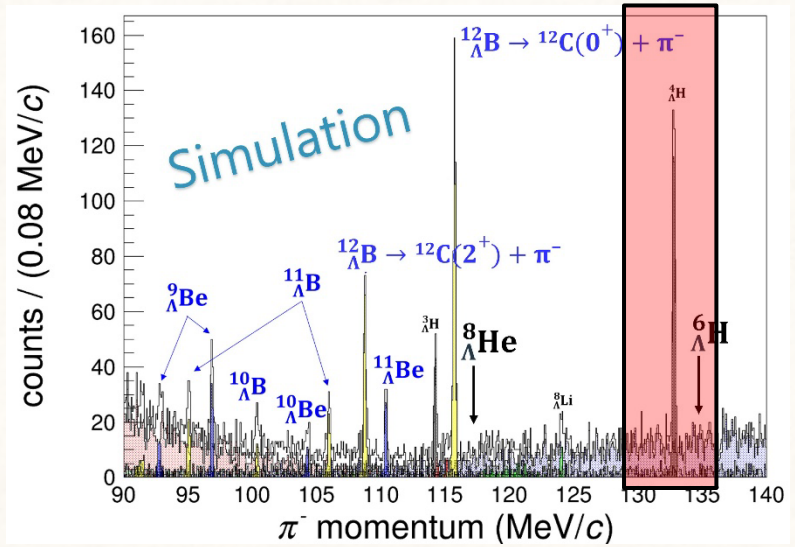




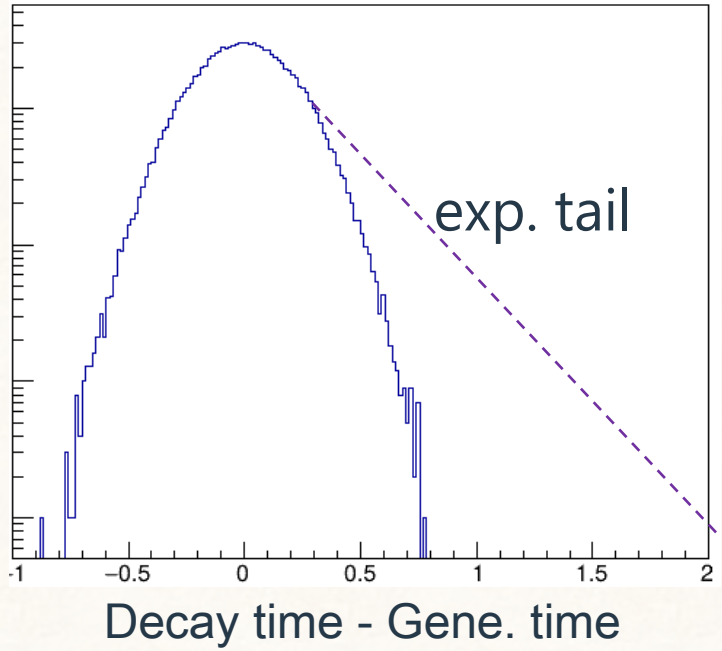
Lifetime measurement (by product)





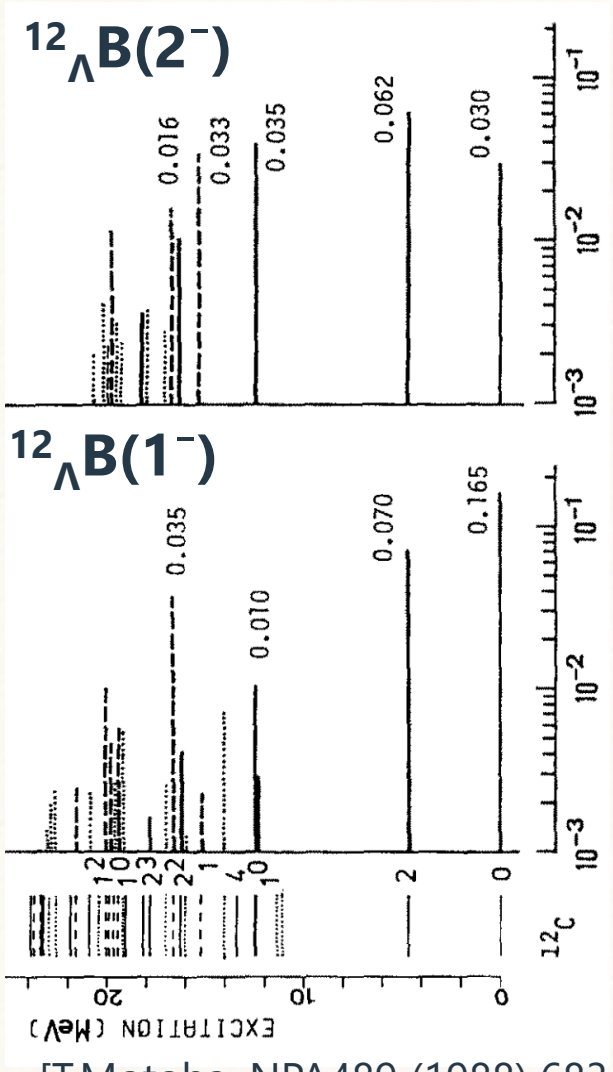


K^+ time = Generate time

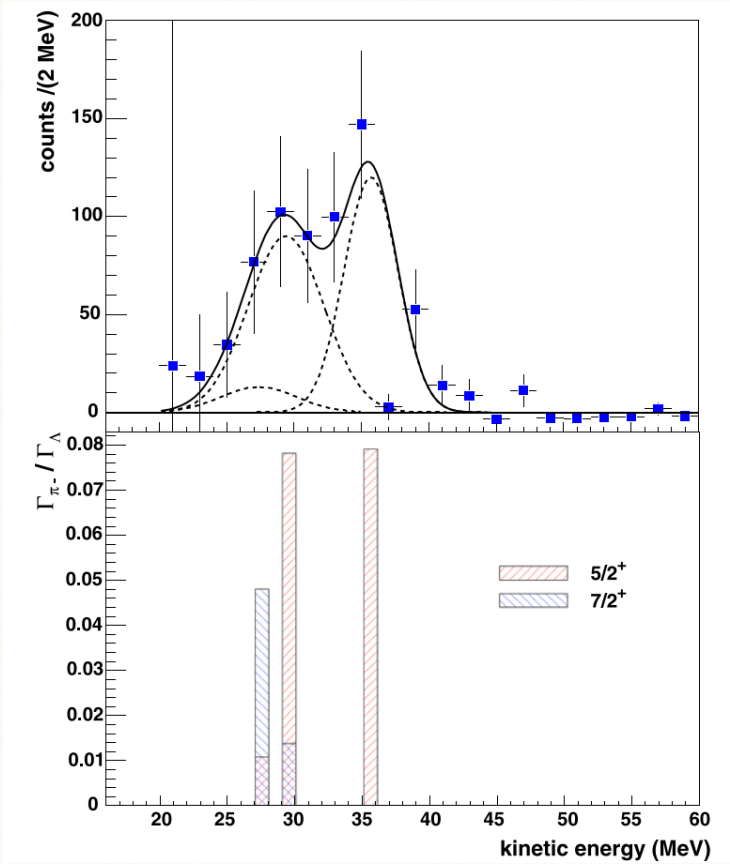


π^- time = Decay time

Possibility of Spin Assignment



[T.Motoba, NPA489 (1988) 683.]



[FINUDA, PLB681 (2009) 139.]

Spin-Parity assignment only for several hypernuclear ground-state

Possibility of spin inversion of the ground state in neutron-rich hypernuclei

Weak-decay branching-ratio depending on the spin-parity relationship of parent hypernucleus and daughter nucleus

→ spin-parity determination from weak decay branching-ratio

FINUDA exp. has determined spin-parity for several hypernuclei

[FINUDA, PLB681 (2009) 139]
[FINUDA, NPA881 (2012) 322]