SC Development Status

06 May 2026

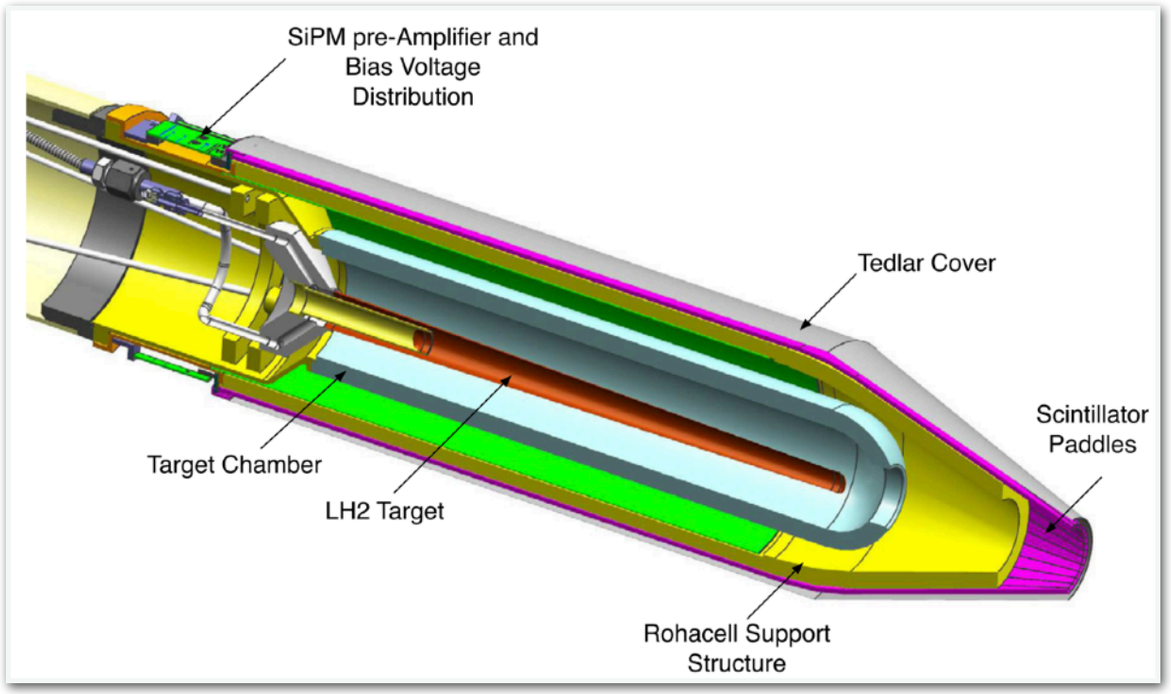
Yoshiki Tanaka (RIKEN)

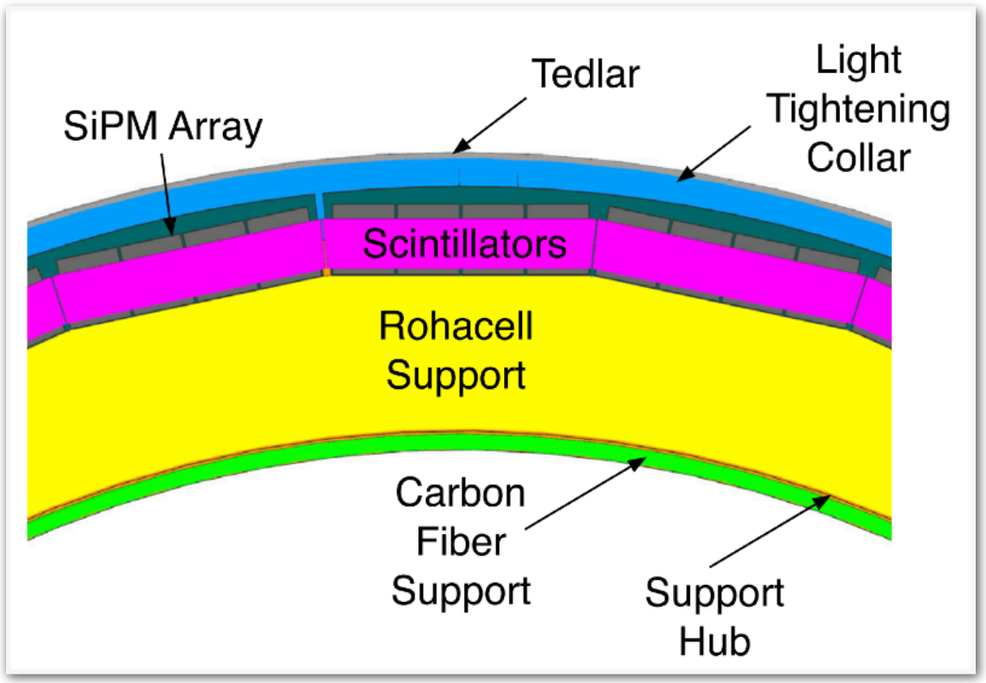
Start Counter

GlueX Start Counter (SC)

- ◇ Innermost detector around LH2 target to define start timing
- ◇ EJ-200 plastic scintillator, 3 mm thickness, 30 segments, bent shape
- ◇ 1 side readout, 4 MPPCs (Hamamatsu, S10931-050P) in series connection.
- ◇ Time resolution was σ ~ 300 ps (sufficient to resolve 4 ns beam bunch)

E. Pooser et al. Nuclear Inst. and Methods in Physics Research, A 927 (2019) 330–342





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- ◇ Time resolution was $\sigma \sim 300$ ps (sufficient to resolve 4 ns beam bunch)

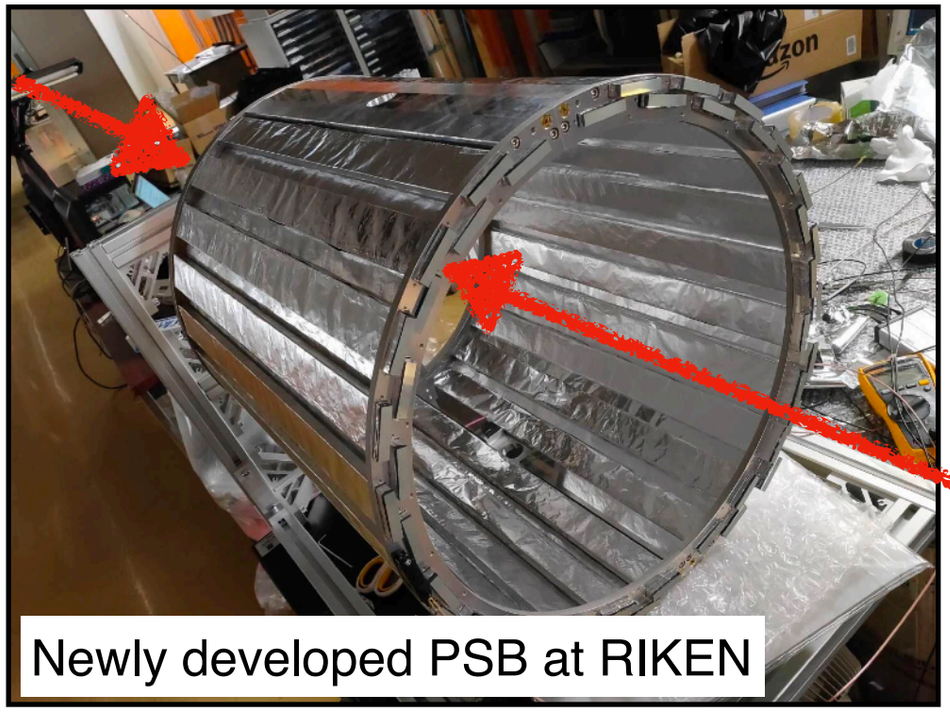
SC counter for KLF experiment

- ◇ Time resolution of SC is important for determination of incident K_L momentum
- ◇ $\sigma \sim 100$–150 ps is required for KLF experiment

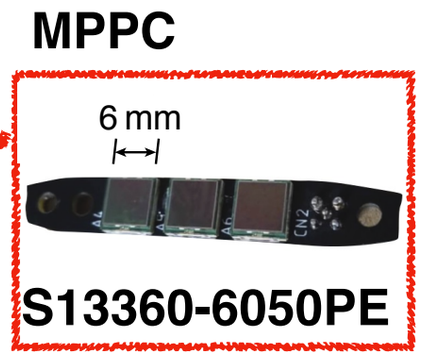
WASA-FRS Plastic Scintillator Barrel

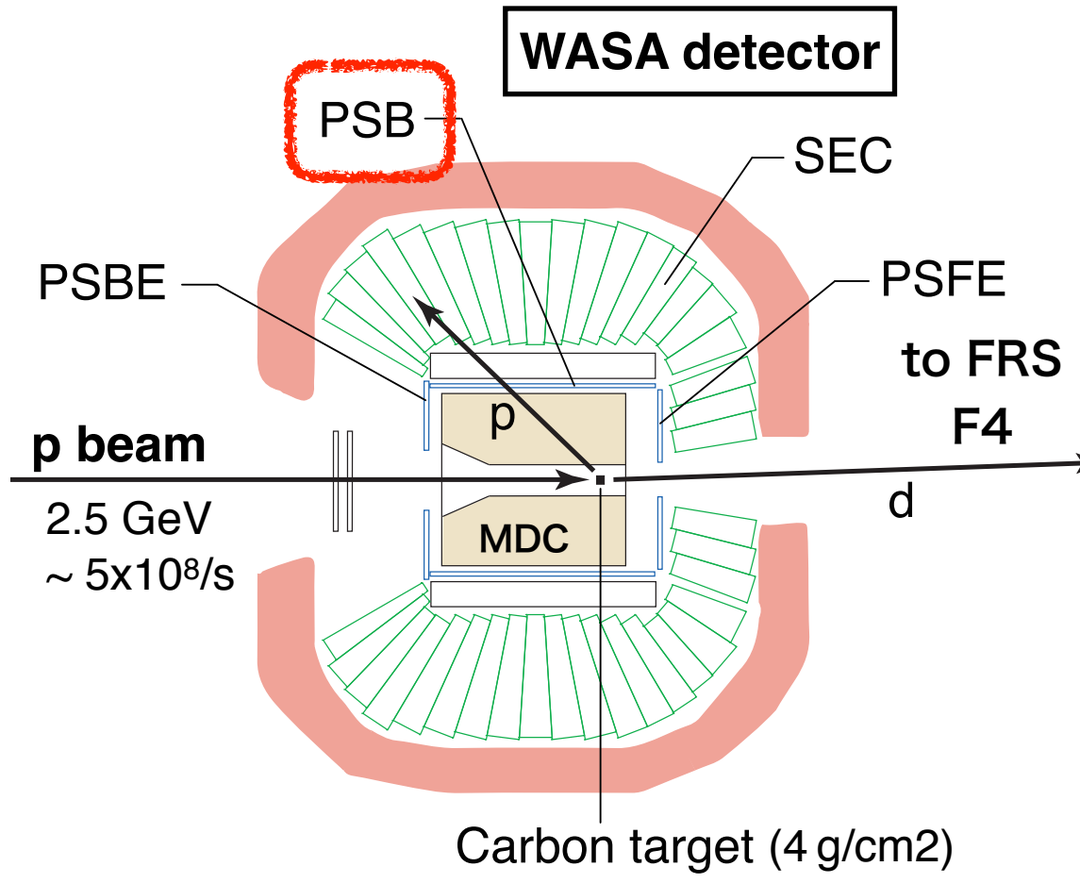
PSB for for WASA-FRS experiments at GSI (2022)

- ◇ Developed for better timing and ΔE resolution and particle reconstruction
- ◇ EJ-230 plastic bar ($550 \times 38 \times 8\ mm^3$)
- ◇ Readout from both side of plastic with 3x MPPCs S13360-6050PE in series connection
- ◇ Waveform data recorded by 2.5 GHz digitizer (CAEN-V1742)



Newly developed PSB at RIKEN





Design and development :
R. Sekiya *et al.,* Nucl. Instr. Meth. A 1034 (2022) 166745

Performance in physics runs :
Y. K. Tanaka *et al.,* Nucl. Instr. Meth. A 1083 (2026) 171065

WASA-FRS Plastic Scintillator Barrel

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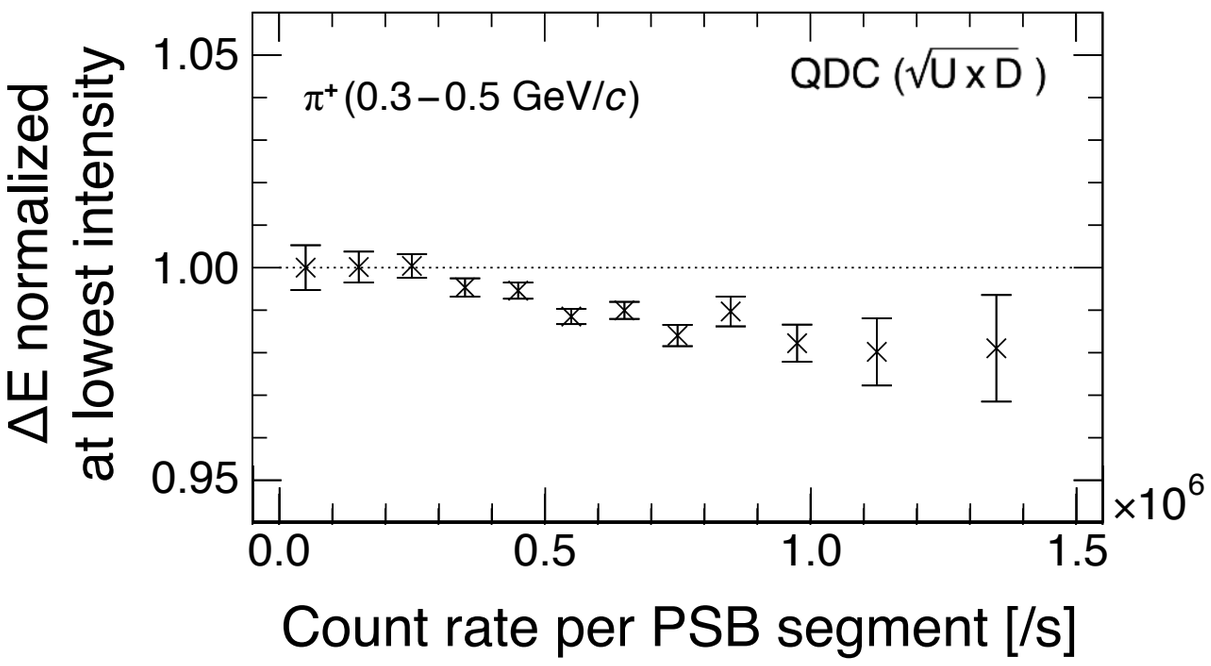
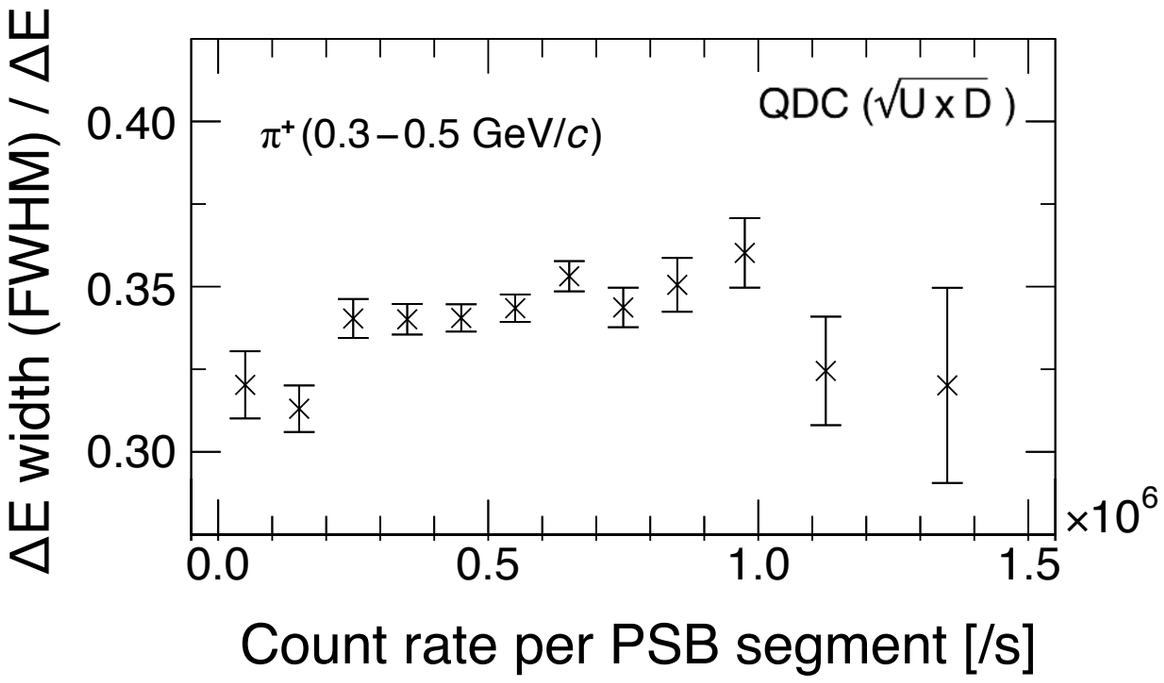
Y. K. Tanaka *et al.,* Nucl. Instr. Meth. A 1083 (2026) 171065



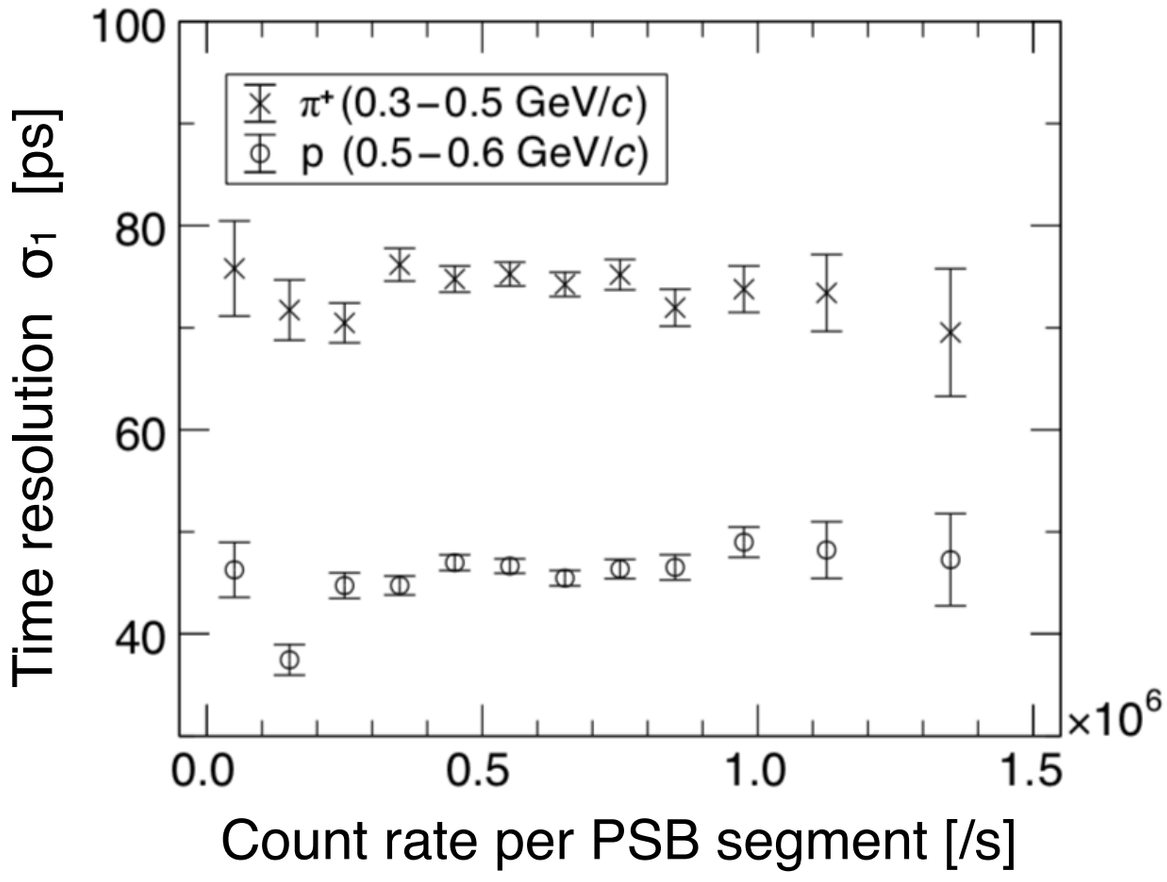


◇ Stable performance was maintained up to 1.35 MHz per PSB segment
- amplitude reduction < 2%
- no visible width broadening

WASA-FRS Plastic Scintillator Barrel

PSB for for WASA-FRS experiments at GSI (2022)

Y. K. Tanaka *et al.,* Nucl. Instr. Meth. A 1083 (2026) 171065



◇ Time resolution σ ~ 75 ps for π^+ (0.3 – 0.5 GeV/*c*) and σ ~ 45 ps for *p* (0.5 – 0.6 GeV/*c*)

◇ Stable performance was maintained up to 1.35 MHz per PSB segment.

Design of New Start Counter

◇ Plastic Material :

- EJ-200 (6 mm thickness) or EJ-212 (3 mm)

PROPERTIES	EJ-200	EJ-204	EJ-208	EJ-212	EJ-228	EJ-230
Light Output (% Anthracene)	64	68	60	65	67	64
Scintillation Efficiency (photons/1 MeV e^-)	10,000	10,400	9,200	10,000	10,200	9,700
Wavelength of Maximum Emission (nm)	425	408	435	423	391	391
Light Attenuation Length (cm)	380	160	400	250	–	120
Rise Time (ns)	0.9	0.7	1.0	0.9	0.5	0.5
Decay Time (ns)	2.1	1.8	3.3	2.4	1.4	1.5
Pulse Width, FWHM (ns)	2.5	2.2	4.2	2.7	1.2	1.3
No. of H Atoms per cm^3 ($x10^{22}$)	5.17	5.15	5.17	5.17	5.15	5.15
No. of C Atoms per cm^3 ($x10^{22}$)	4.69	4.68	4.69	4.69	4.69	4.69
No. of Electrons per cm^3 ($x10^{23}$)	3.33	3.33	3.33	3.33	3.33	3.33
Density (g/cm^3)	1.023	1.023	1.023	1.023	1.023	1.023

https://eljentechnology.com/products/plastic-scintillators/

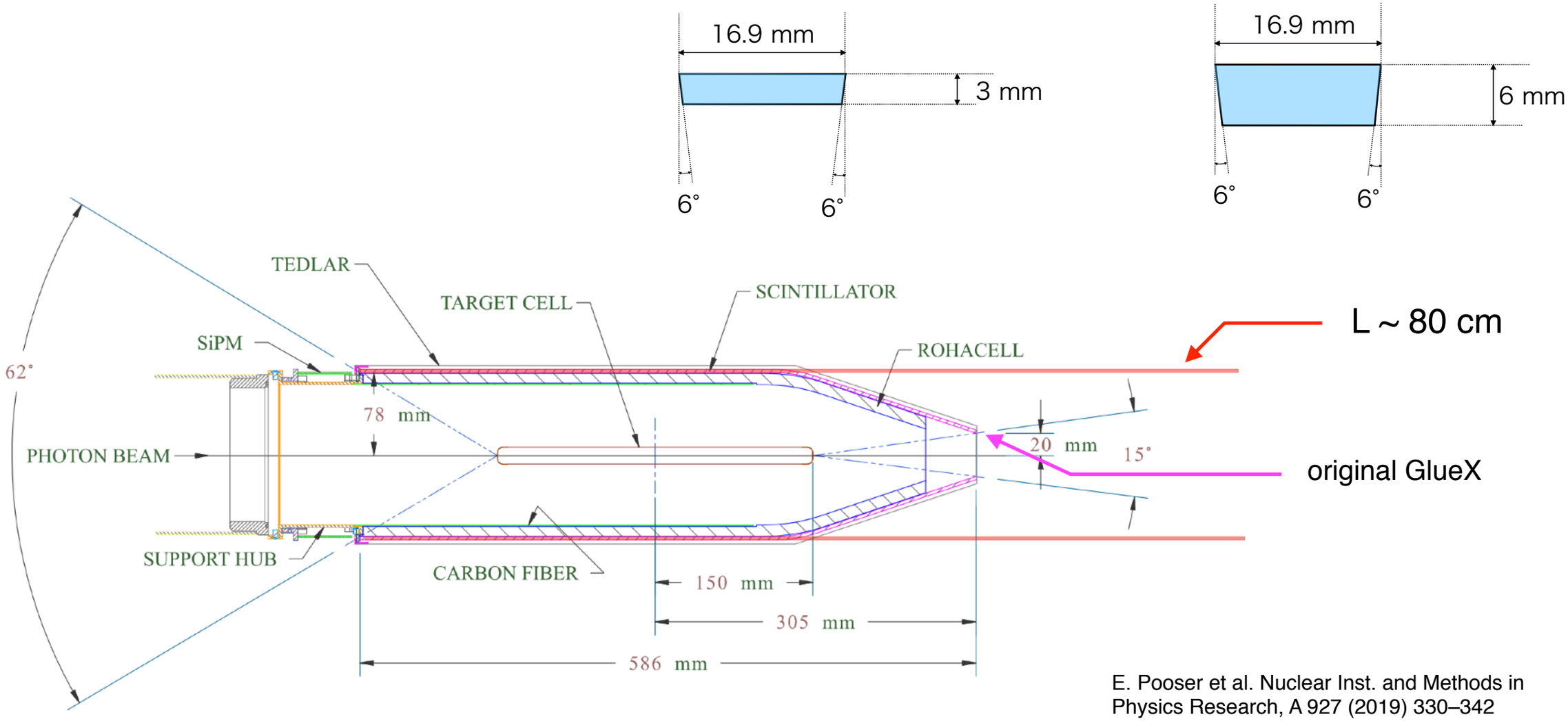
Design of New Start Counter

◇ Plastic Material :

- EJ-200 (6 mm thickness) or EJ-212 (3 mm)

◇ Dimensions:

- 30 segments, trapezoidal cross section
- Longitudinal length ~ 80 cm



E. Pooser et al. Nuclear Inst. and Methods in Physics Research, A 927 (2019) 330–342

Fig. 2. 2-D cross section of the Start Counter.. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

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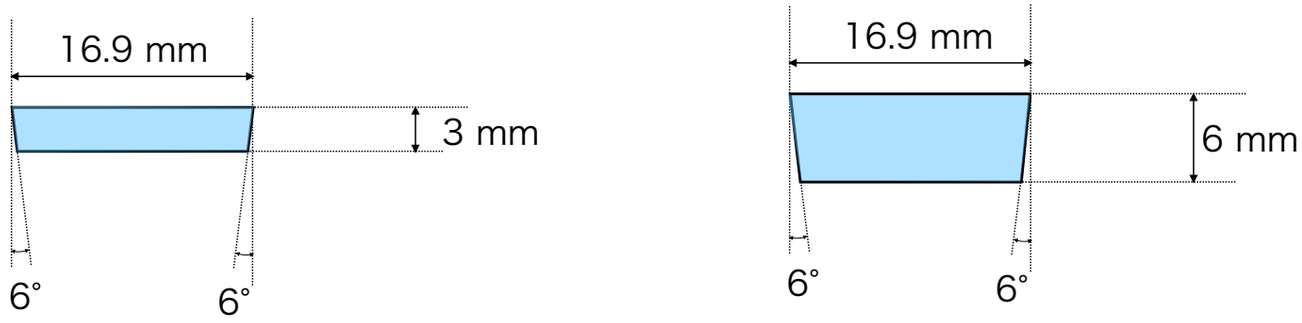
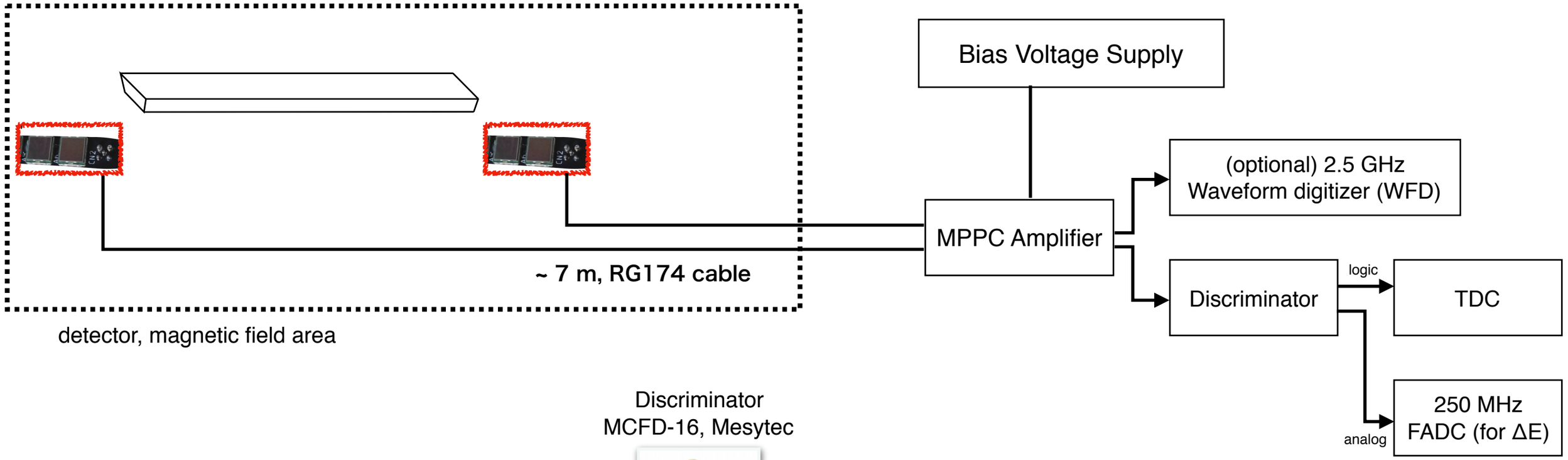


◇ Readout sensors : MPPC (SiPM) at both ends of the scintillator

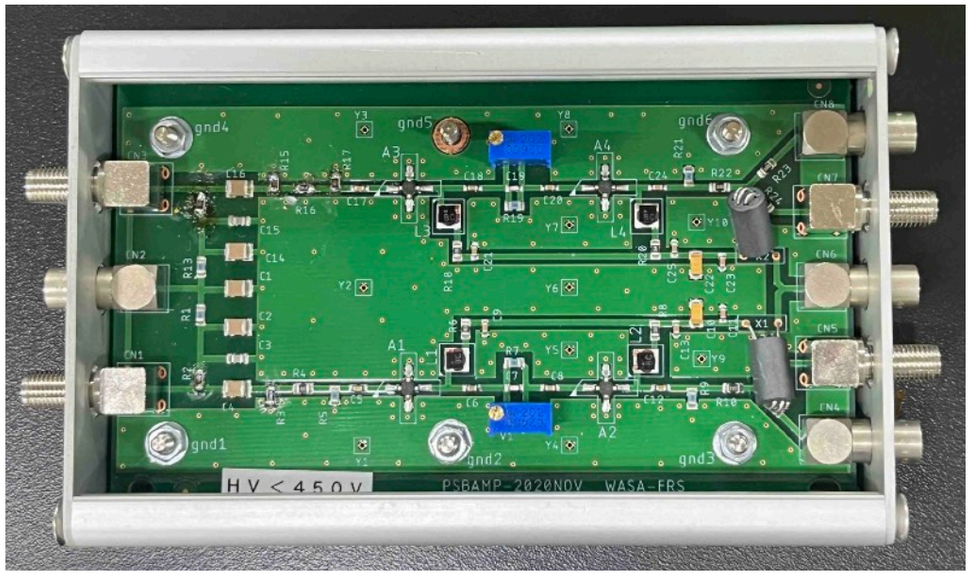
(For 6 mm-thick plastic) series connection of 2 x MPPCs with an area of 6x6 mm^2
Hamamatsu-S13360-6050PE, S13360-6025PE, S14160-6050HS

(For 3 mm-thick plastic) series connection of 4 x MPPCs with area of 3x3 mm^2
Hamamatsu-S13360-3050PE, S13360-3025PE, S14160-3050HS

Readout Electronics



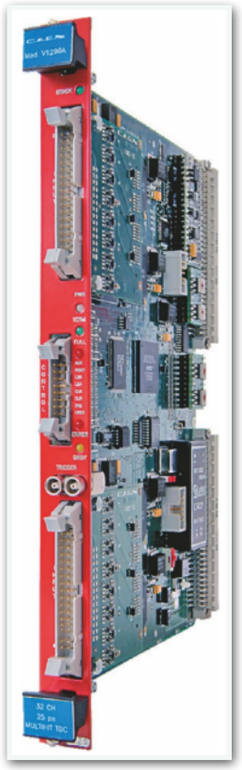
Fast MPPC Amplifier
(based on MEG-II@PSI)



P.W.Cattaneo et al. IEEE Trans. Nucl. Sci. 61,2657(2014).

Discriminator
MCFD-16, Mesytec

CAEN-V1290
(25 ps TDC)



CAEN-V1742
(5 GHz WFD)

Bias Voltage Supply
(Kikusui PMX250-0.25A)

Development Plan

1. Radiation tolerance test of various MPPCs with neutron beams at RANS
   - compare in terms of gain reduction, time resolution, DCR, leak curr. etc. — done

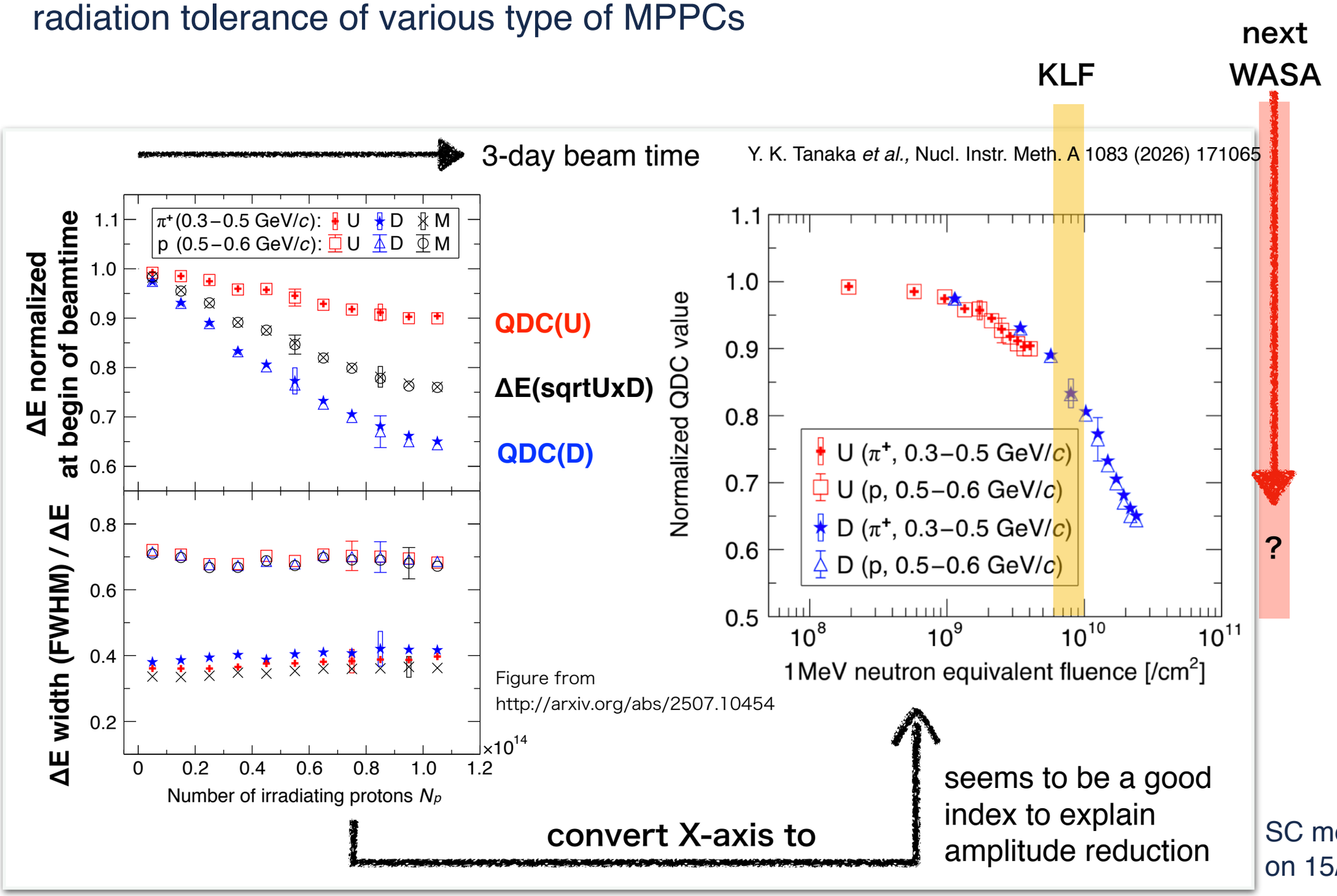
2. Performance test of new SC prototype with β source
   - quick test in a laboratory to check overall system and test time resolution — now
   - compare different MPPCs, Scintillator thickness...

3. Performance test of new SC prototype at KEK PF-AR
   - detailed systematic performance test for nearly MIP particles — 2026 autumn

4. Decide details and produce — 2027

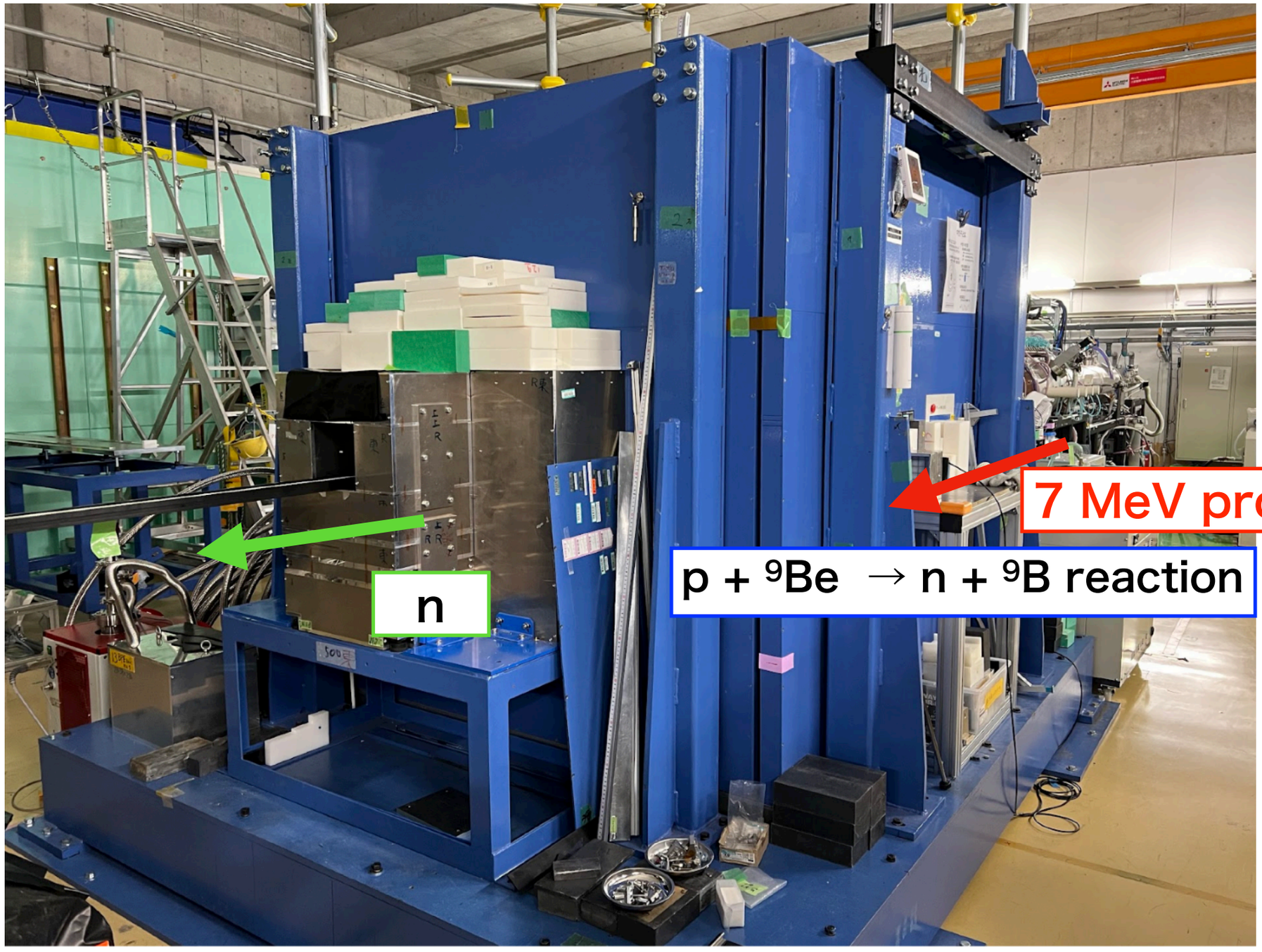
Radiation tolerance of MPPCs

- WASA-PSB performance was satisfactory in a short run of η'-mesic nuclei spectroscopy in 2022
  However, radiation damage effect of MPPCs was significant even in 3 days of production run.
- As a joint effort with WASA-PSB group, we performed irradiation test to evaluate radiation tolerance of various type of MPPCs

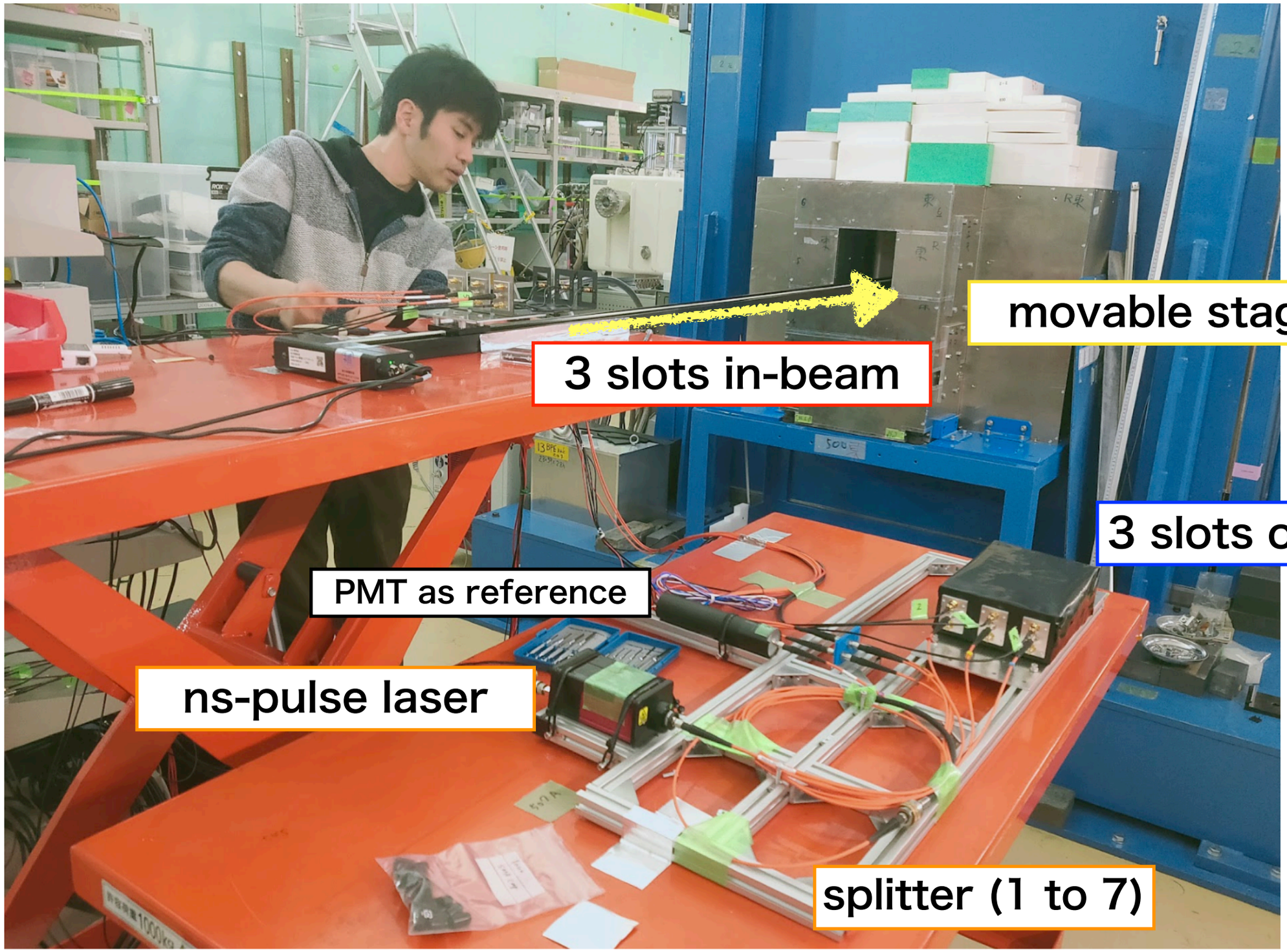


SC meeting report on 15/July/2025

Neutron irradiation test at RIKEN-RANS

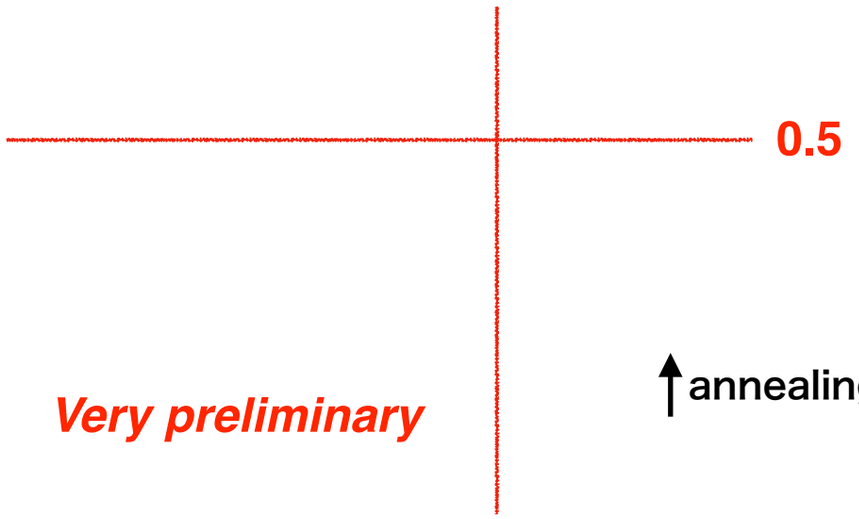


Neutron irradiation test at RIKEN-RANS

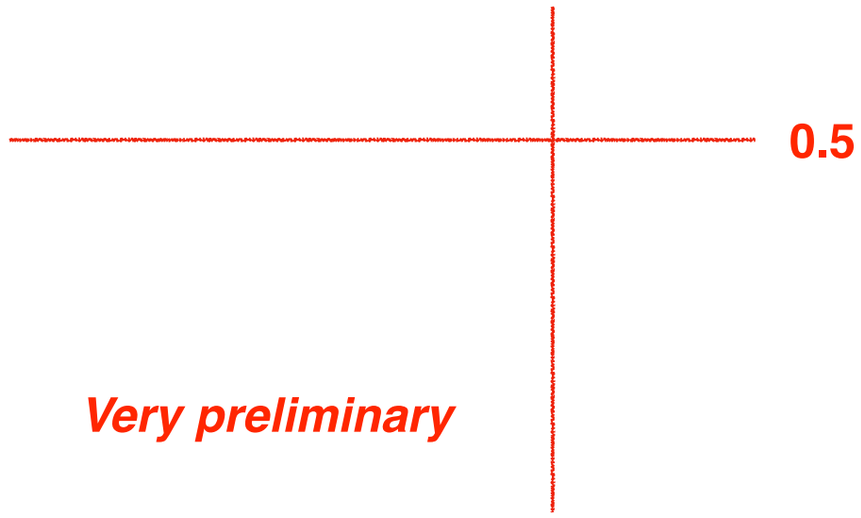


Neutron irradiation test at RIKEN-RANS

50μm pitch



25μm pitch

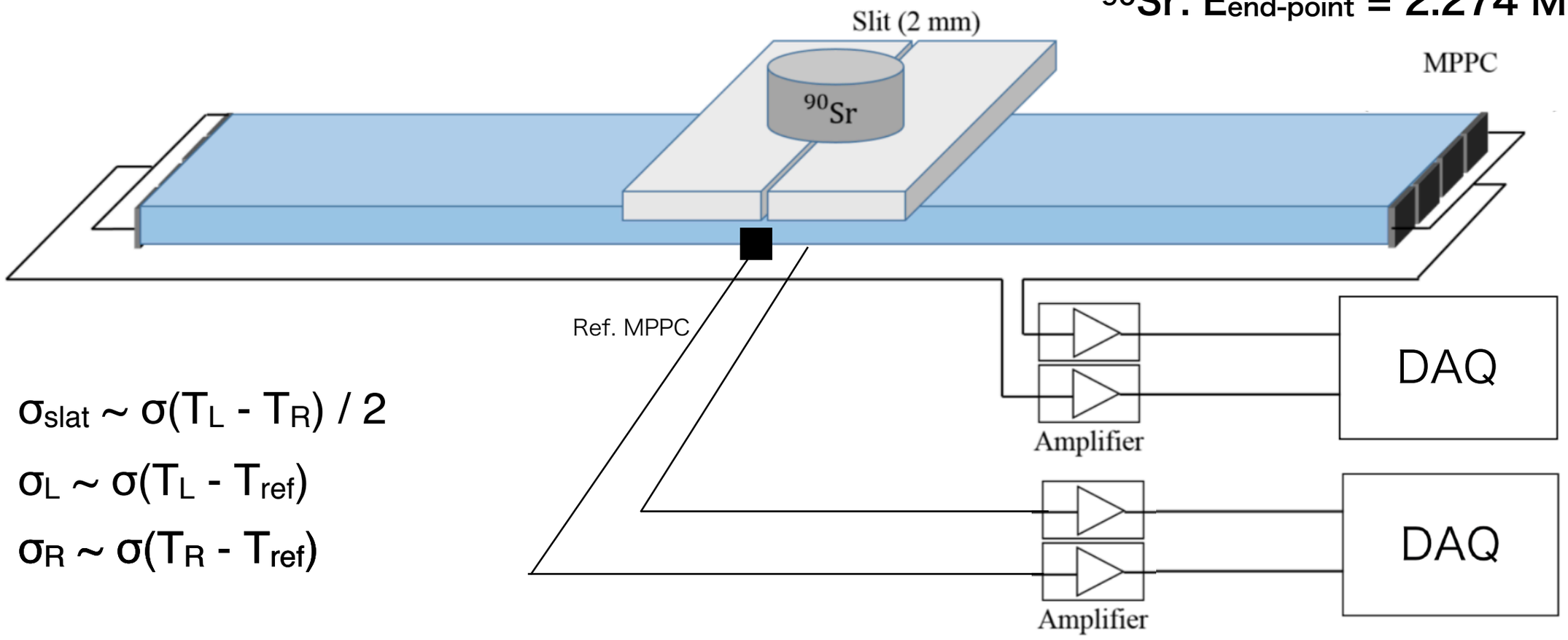


→ confirmed general trend that smaller-pitch MPPC has better tolerance in terms of signal amplitude reduction

Prototype test with β source in laboratory

Time resolution evaluation with β source + slit

^{90}Sr: $E_{end\text{-}point}$ = 2.274 MeV

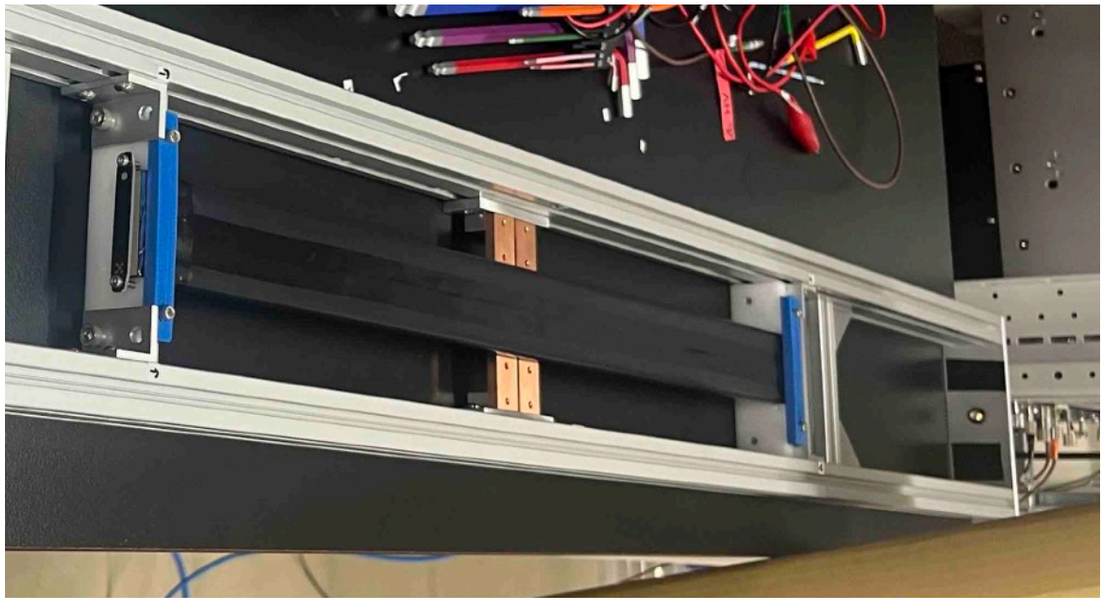


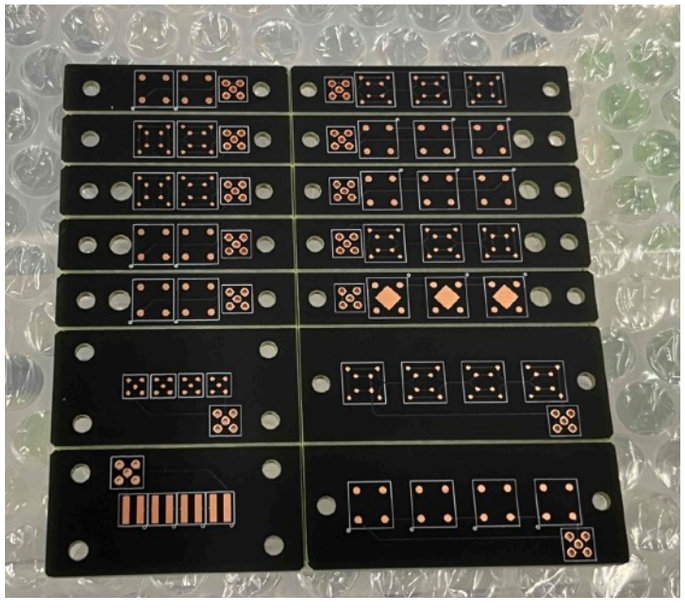
$\sigma_{slat} \sim \sigma(T_L - T_R) / 2$

$\sigma_L \sim \sigma(T_L - T_{ref})$

$\sigma_R \sim \sigma(T_R - T_{ref})$

All components
have been delivered.
→ start measurement
in May 2026

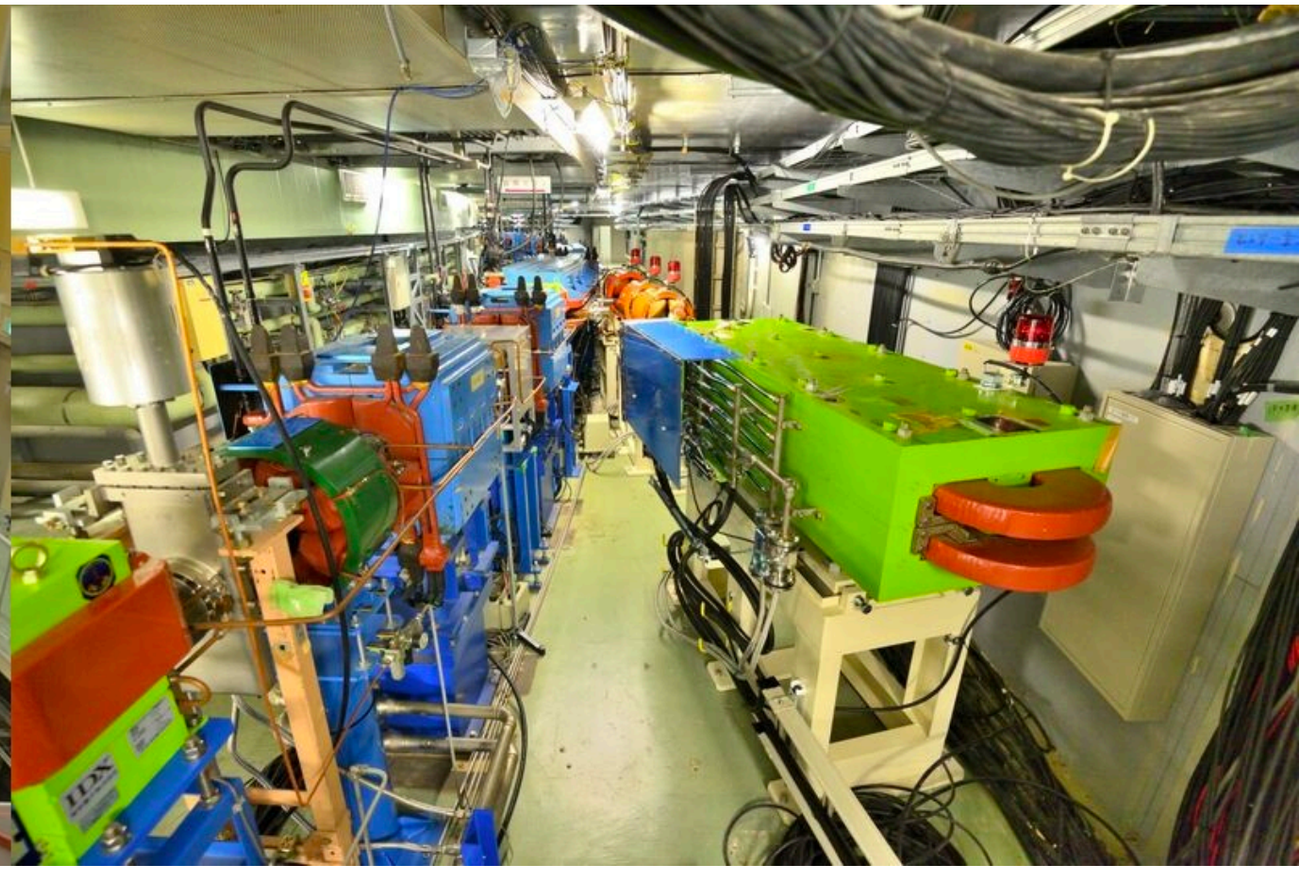




Prototype test with e-/e+ beam at KEK

AR Test Beam Line at KEK-PF/AR

https://wiki.kek.jp/spaces/artbl/pages/124944464/AR+Test+Beam+Line+Home



6.5 GeV KEK-PF/AR

Test beam line with GeV electron (or positron) produced via interaction of halo of the e-beam in the KEK-PF/AR ring and an inserted wire target

Available for detector test experiment

Prototype test with e-/e+ beam at KEK

We aim at perform detailed systematic studies of time resolutions for

- 3 mm or 6 mm plastic thickness
- different MPPCs
- position dependence (→ estimate time resolution with different lengths)
- bias voltage dependence
- incident angle dependence

... etc.

We will apply for the test beam time in the next call for 2026 autumn

Summary

◇ We are developing a new SC counter for the KLF experiment,
aiming to achieve a better time resolution of σ ~ 100 ps,
in a joint effort with the WASA-FRS PSB group.

◇ The basic design of the detector has been reported. Further details
will be determined based on the results of upcoming prototype tests,
as well as the requirements derived from simulation studies.

◇ Neutron irradiation test of various MPPCs has been performed
at RIKEN-RANS in 2026 March.

◇ We have constructed prototype SC detectors.
We will evaluate their time resolutions with β-source in a laboratory first,
and then with e-/e+ test beams at KEK-PF/AR.
→ finalize details of the design, and construct the full barrel in 2027