Development of a Low-Noise Front-end ASIC for CdTe Detectors

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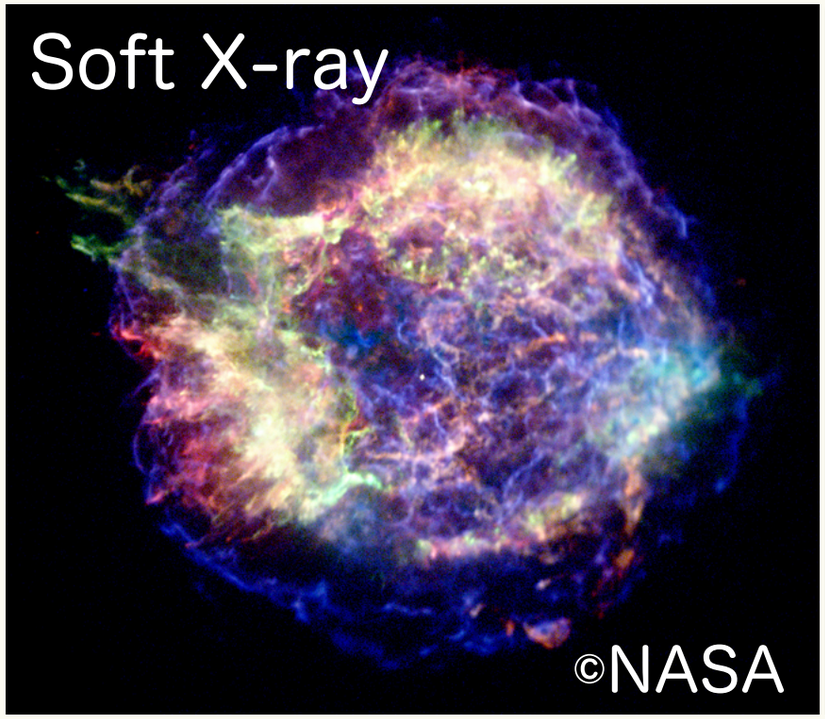
X-ray and Gamma-ray Imaging with Spectroscopy

Astrophysics

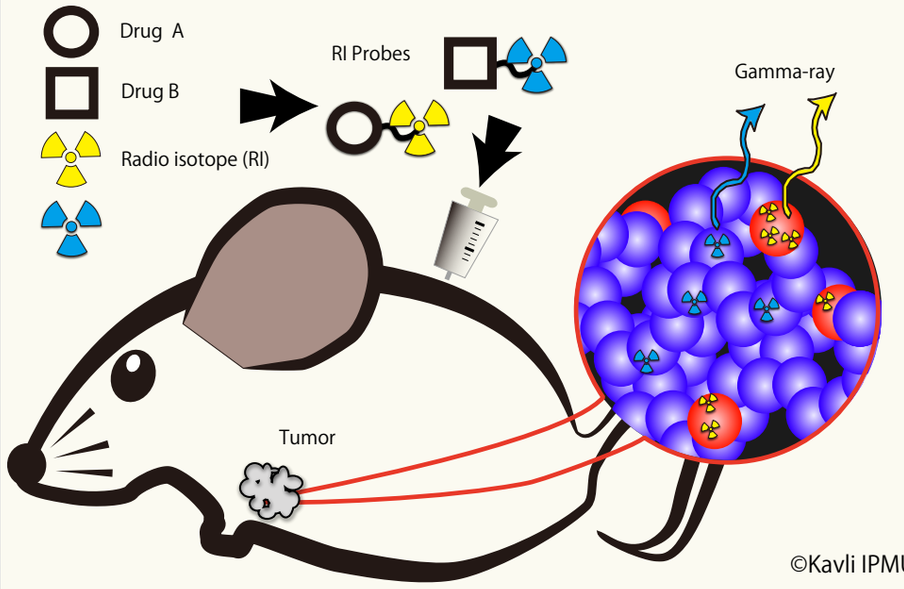


Red: 0.5 keV-1.5 keV
Green: 1.5 keV-2.5 keV
Blue: 4.0 keV-6.0 keV

Red: 15 keV-20 keV
Green: 20 keV-25 keV
Blue: 25 keV-35 keV

Nuclear Medicine

In vivo imaging

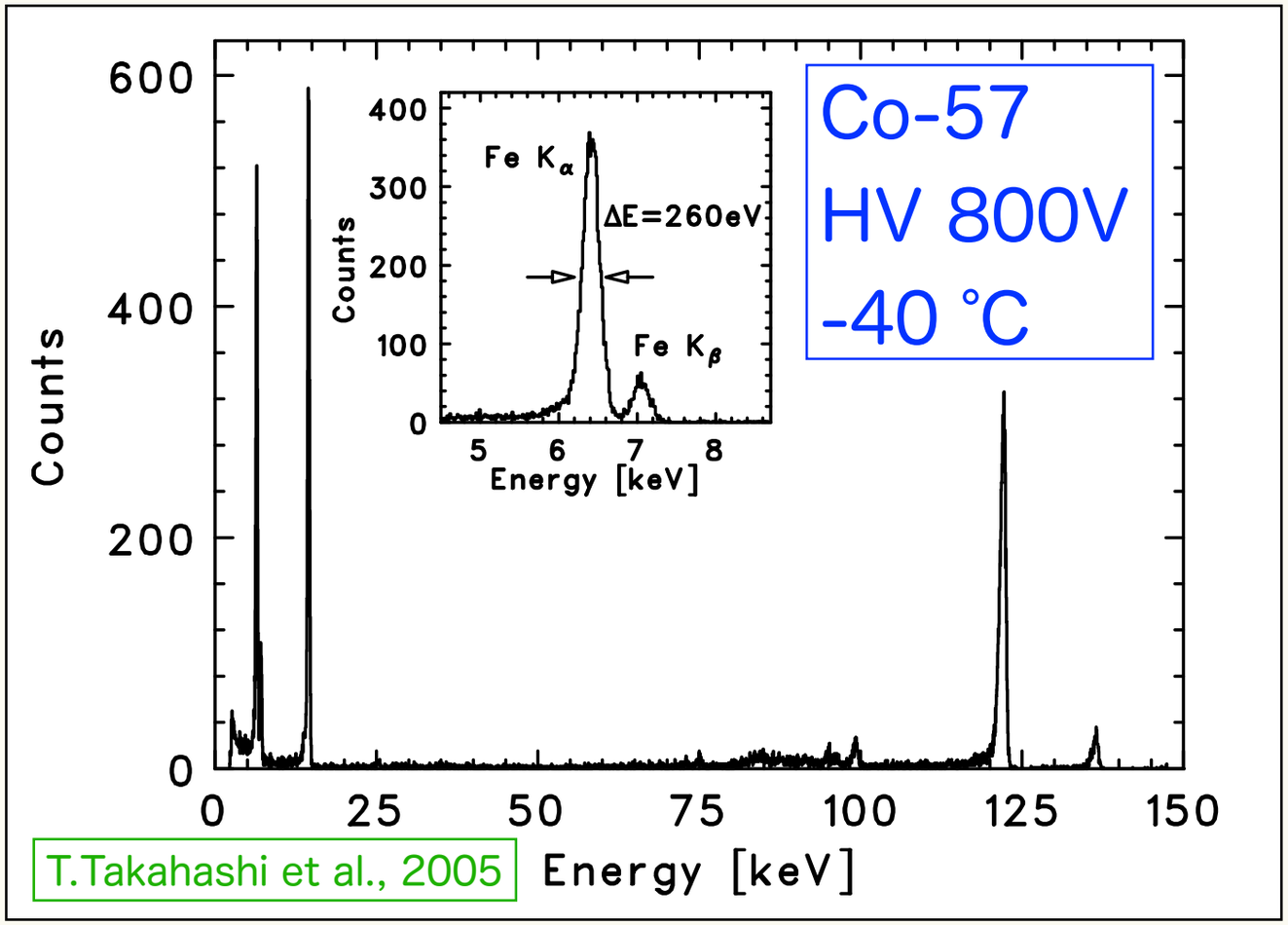


We need to separate spectrum in multi-nuclide.
(^{111}In, ^{125}I, ^{99m}Tc)

Good energy resolution is crucial for hard X-ray and gamma-ray imaging.

For realizing Imaging with good spectroscopy

Our best spectrum with CdTe



- CdTe
  - 3mm x 3mm
  - 1mm thickness
- Front-end ASIC
  - Only one readout chain
  - Only analog circuit (CSA and Shaper)

Our goal is to extend readout channels, keeping high spectroscopic capability:

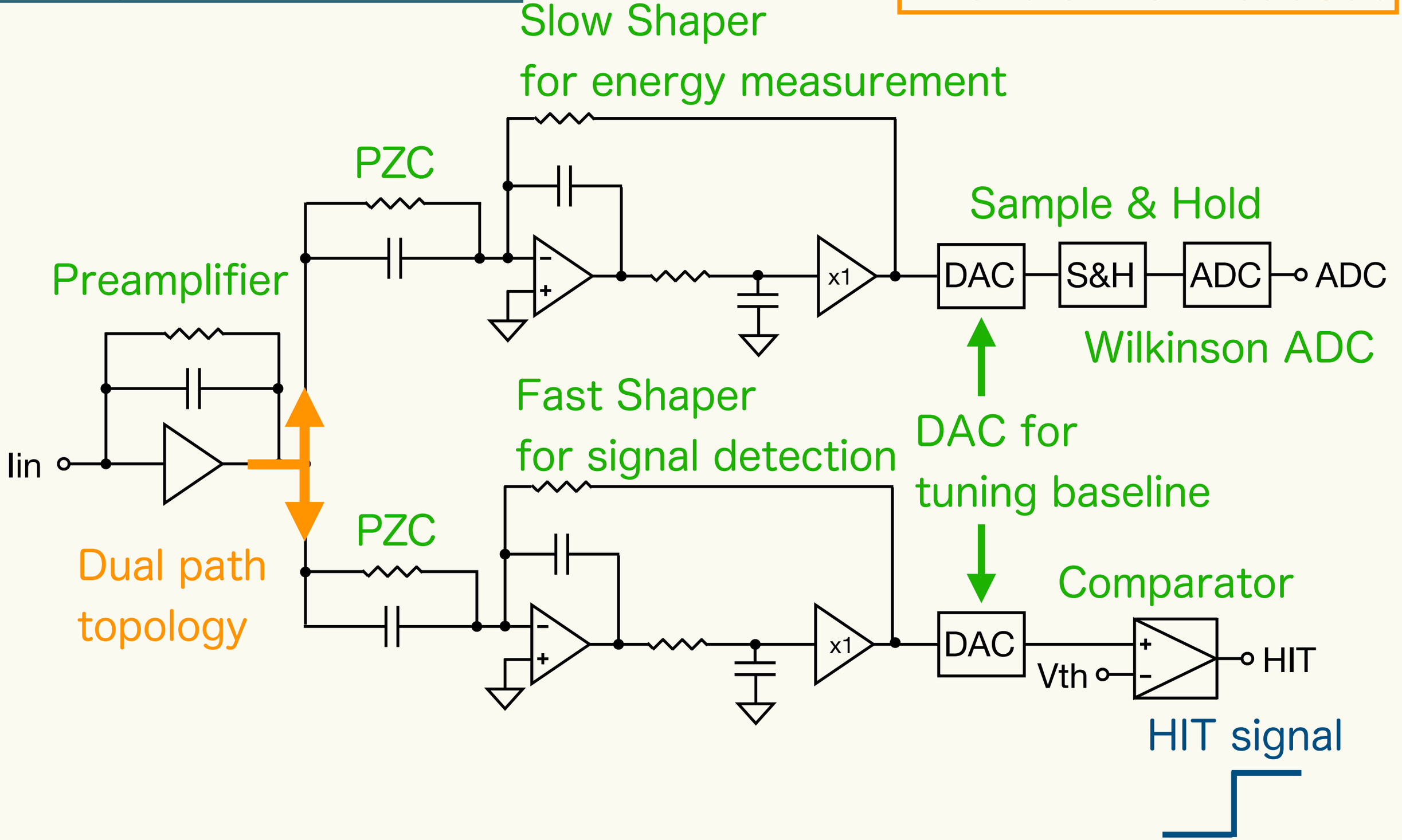
- Resolution ~ 1 keV
- Threshold ~ 5 keV

→ Good ASIC!!

For High Energy Resolution and Low Threshold

Our previous ASIC

Event-driven readout



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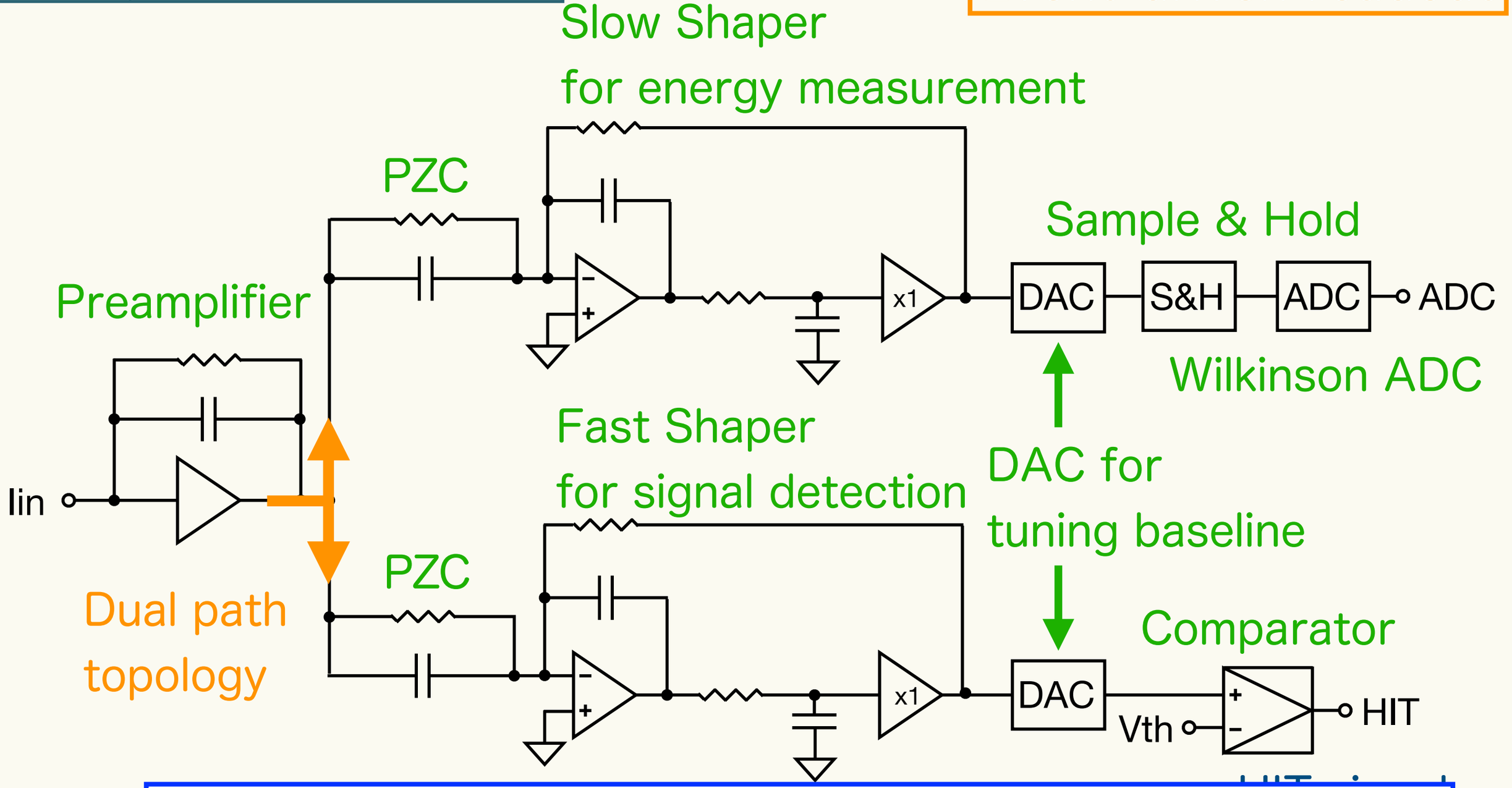

It was hard to investigate the performance of the fast shaper quantitatively.

Circuit Design

Our New ASIC

Event-driven readout

Slow Shaper
for energy measurement

Fast shaper
can be sent to ADC.

PZC

Preamplifier

Iin

Dual path
topology

Fast Shaper
for signal detection

PZC

x1

DAC

DAC for
tuning
baseline

Sample & Hold

S&H

ADC

ADC

Wilkinson ADC

Comparator

Vth1

HIT1

Vth2

HIT2

Additional comparator

Circuit Design

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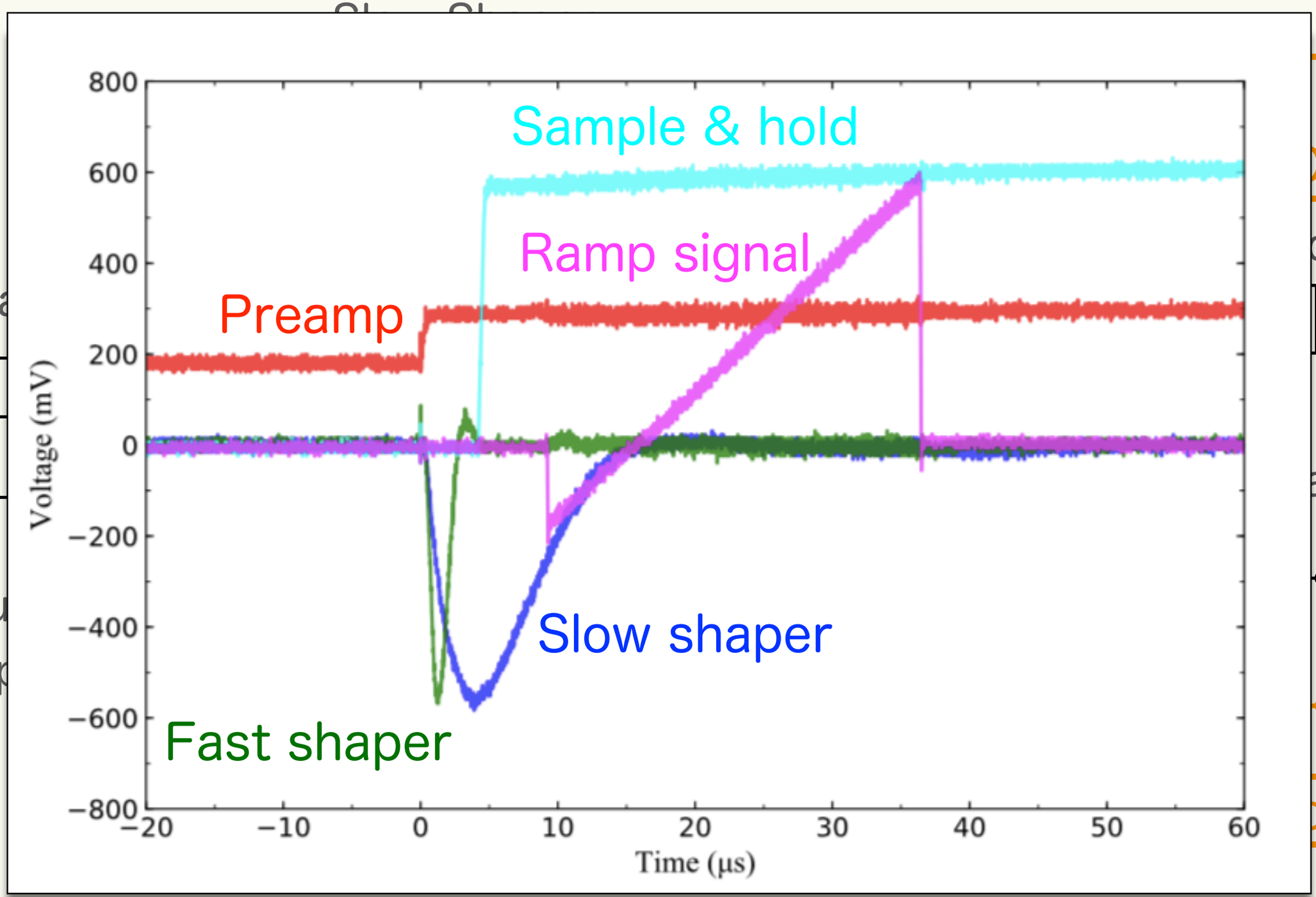
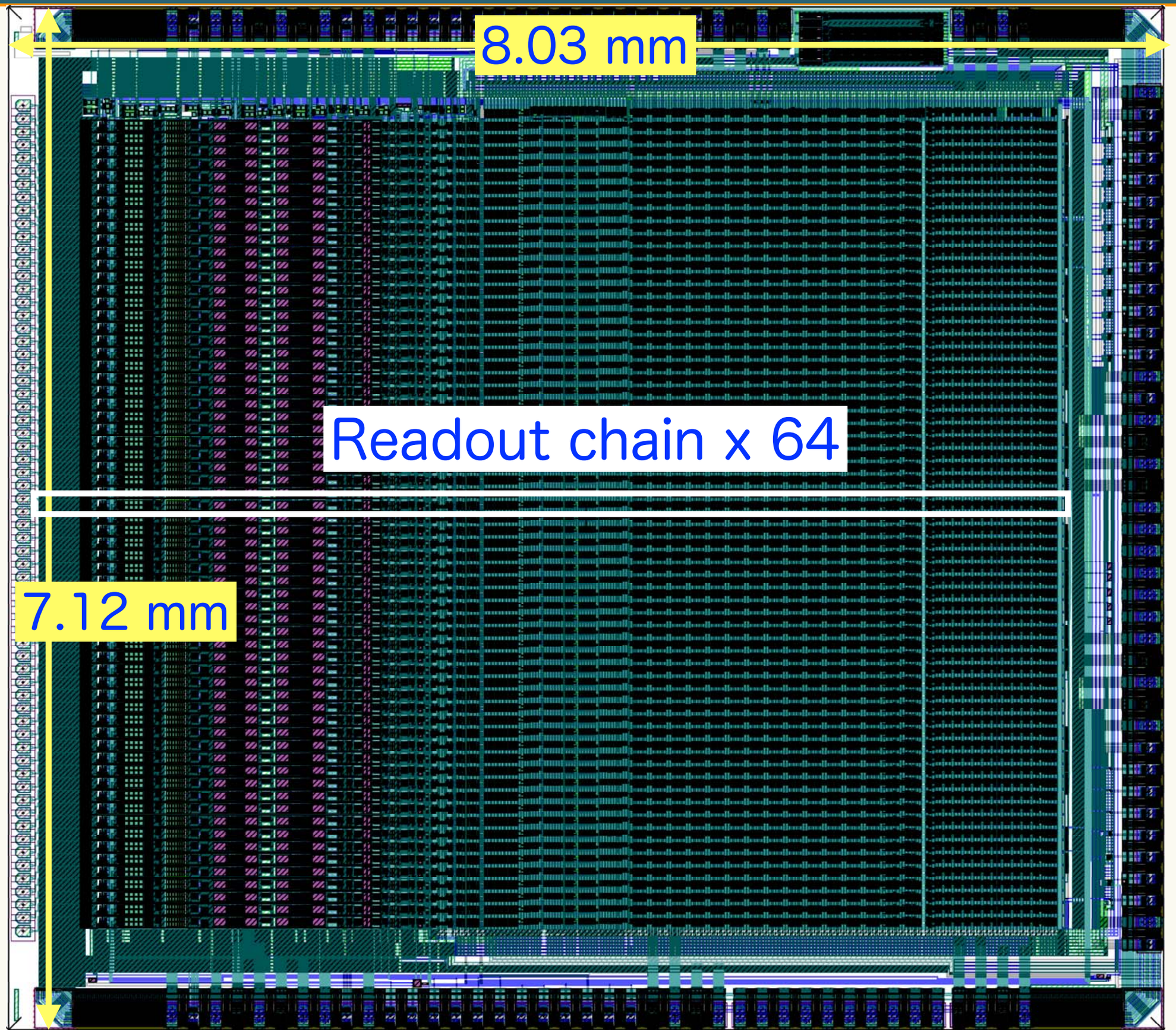
Event-driven readout



Our Latest ASIC: KW04H64



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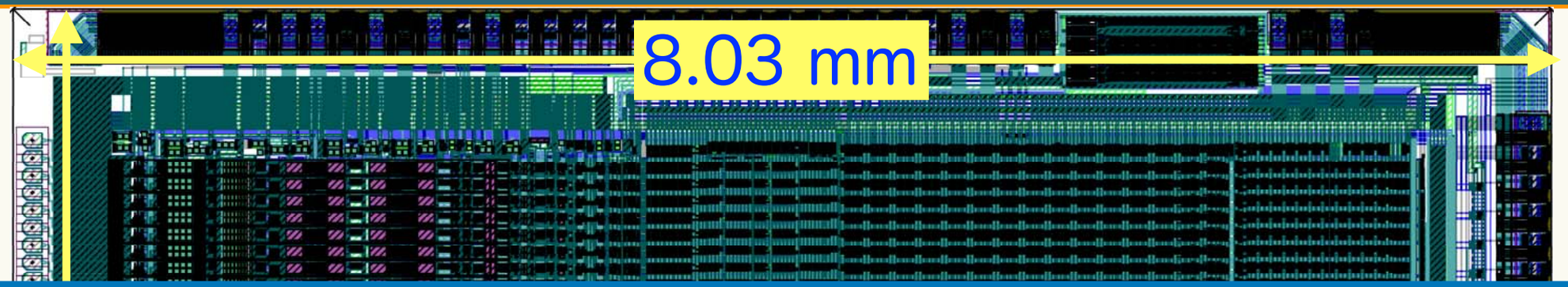
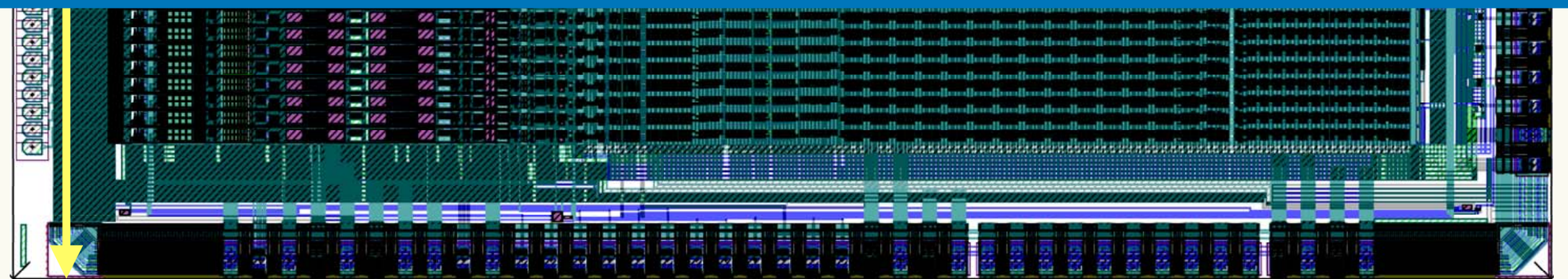


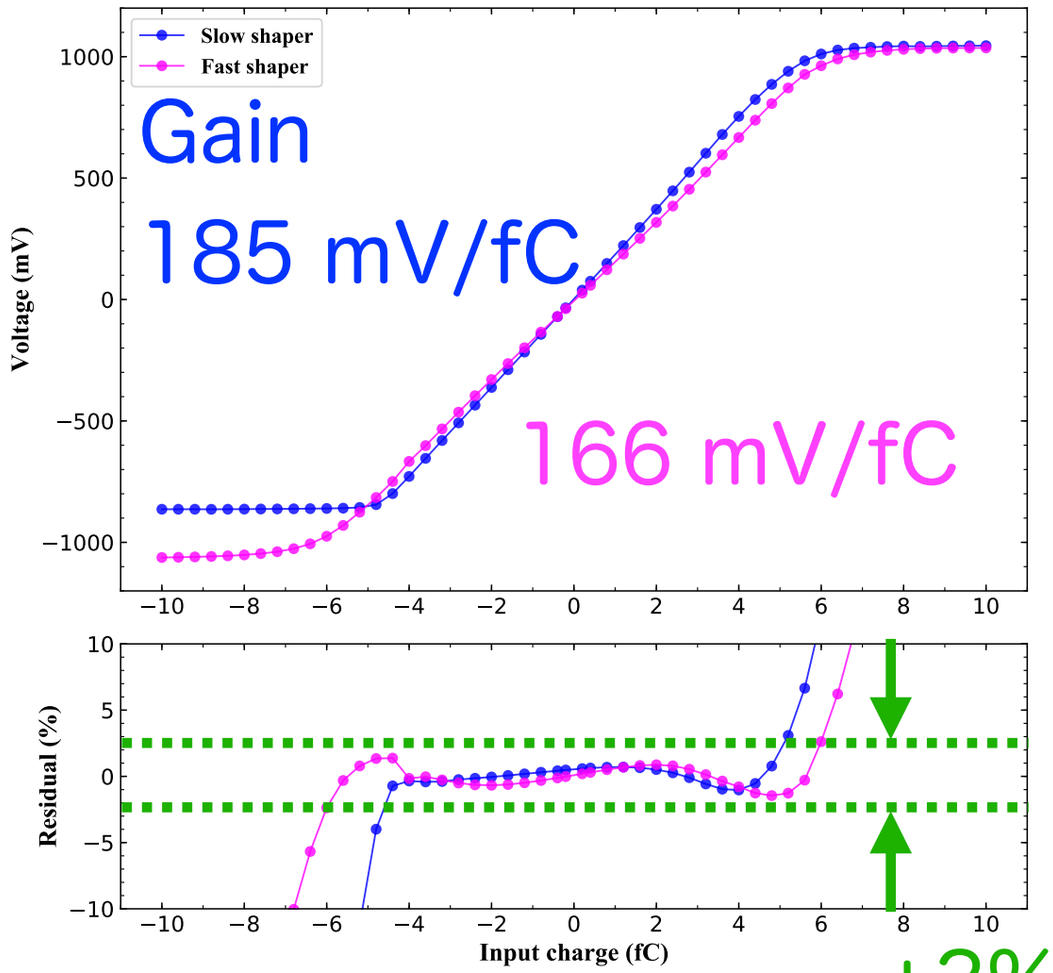
Fabrication process	X-FAB XH035 (CMOS)
Chip size	7.12 mm × 8.03 mm
Number of channels	64
Power rail	±1.65 V
Power consumption	2.1 mW/ch
Peaking time	~1.8 us (from simulation)



ASIC Performance from Simulation

✓ Dynamic range, Linearity

Simulation

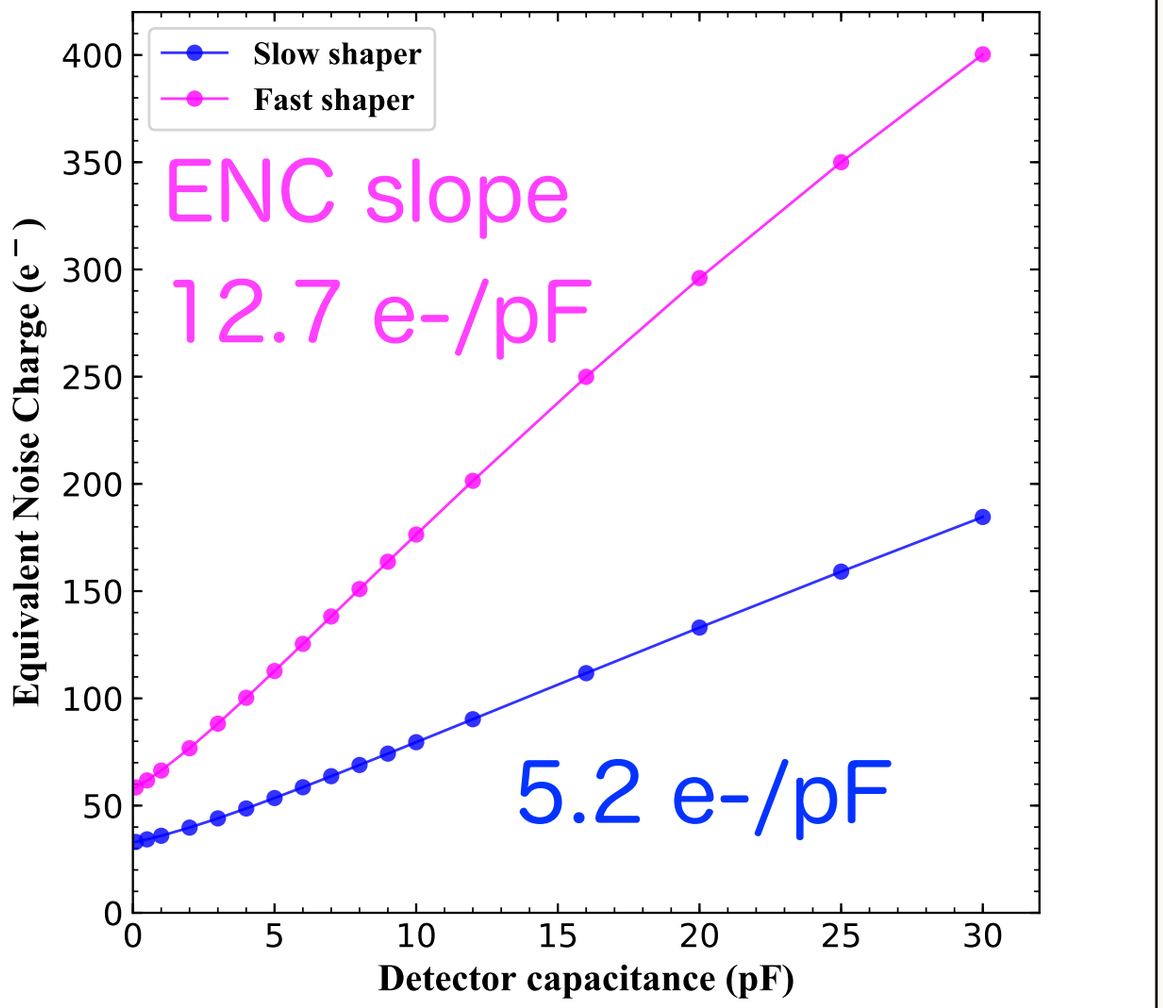


Dynamic range

~32000 e⁻ (for each polarity)

✓ Noise performance

Simulation *Leakage current 1pA



ENC @0 pF load

33.0 e⁻ (Slow shaper)

58.4 e⁻ (Fast shaper)

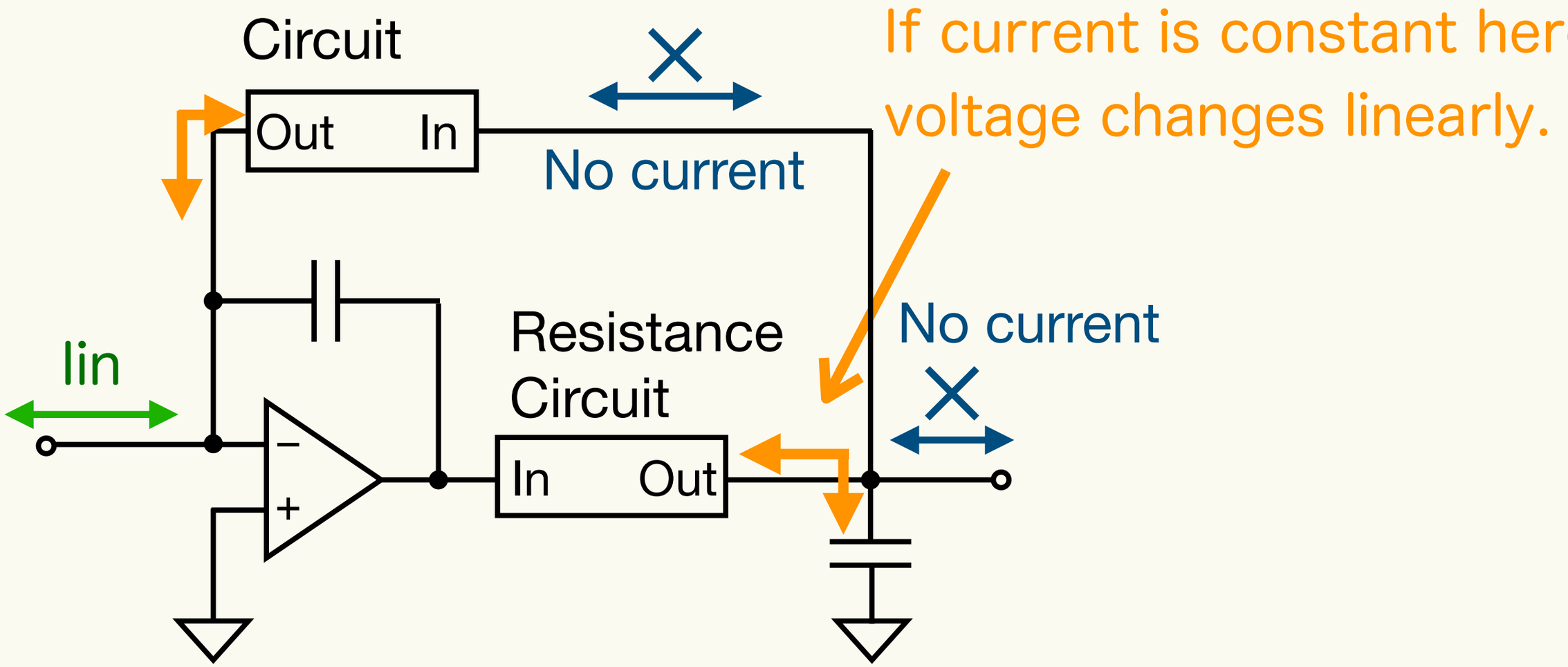
Slew-rate Operation

Required current > Current capable of flowing

↓

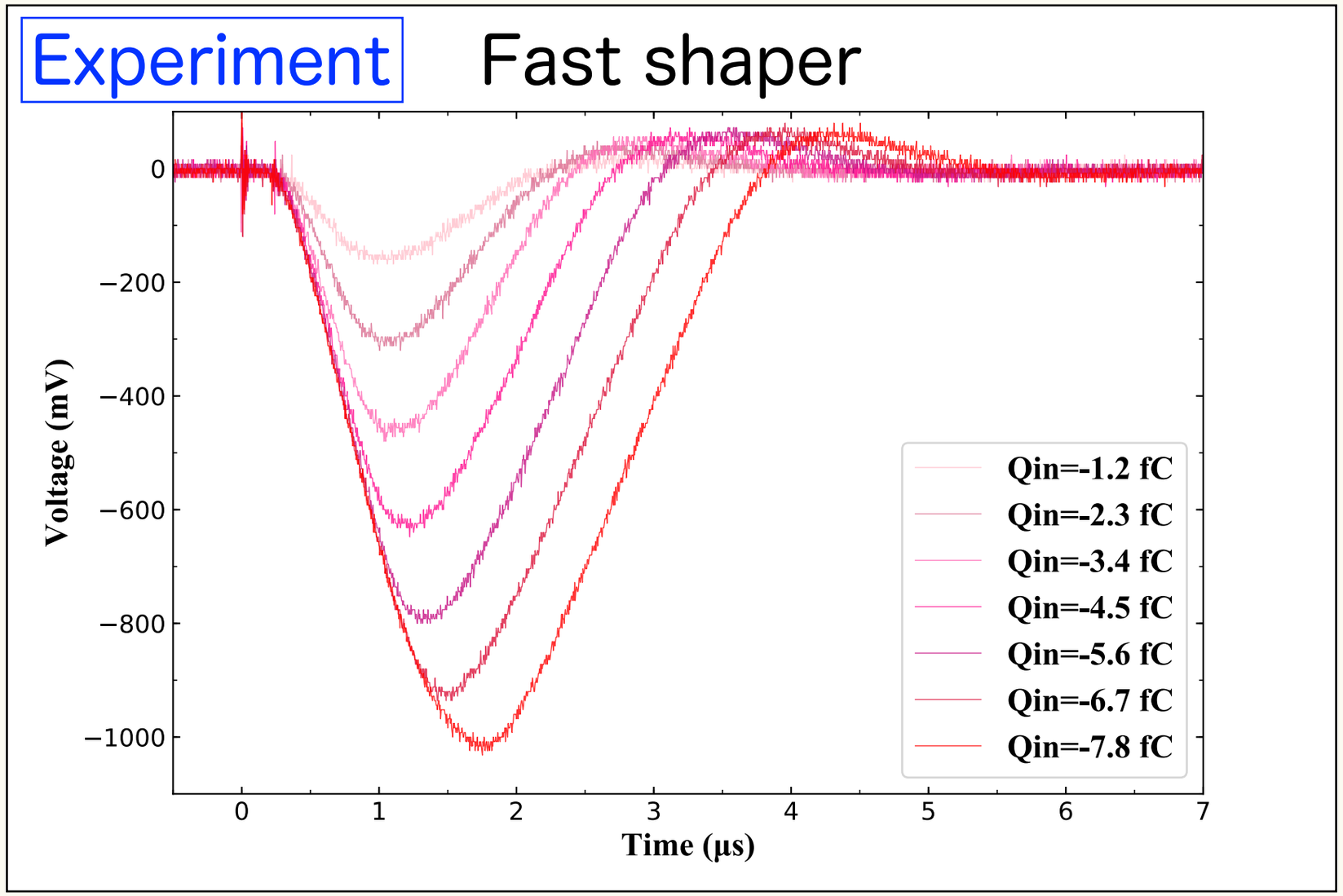
Maximum Current flows.

Shaper



Slew-rate Operation at Fast Shaper

Slew rate operation at fast shaper is essential for insensitivity of trigger timing to input charge.



Accurate timing measurement → Accurate peak capturing

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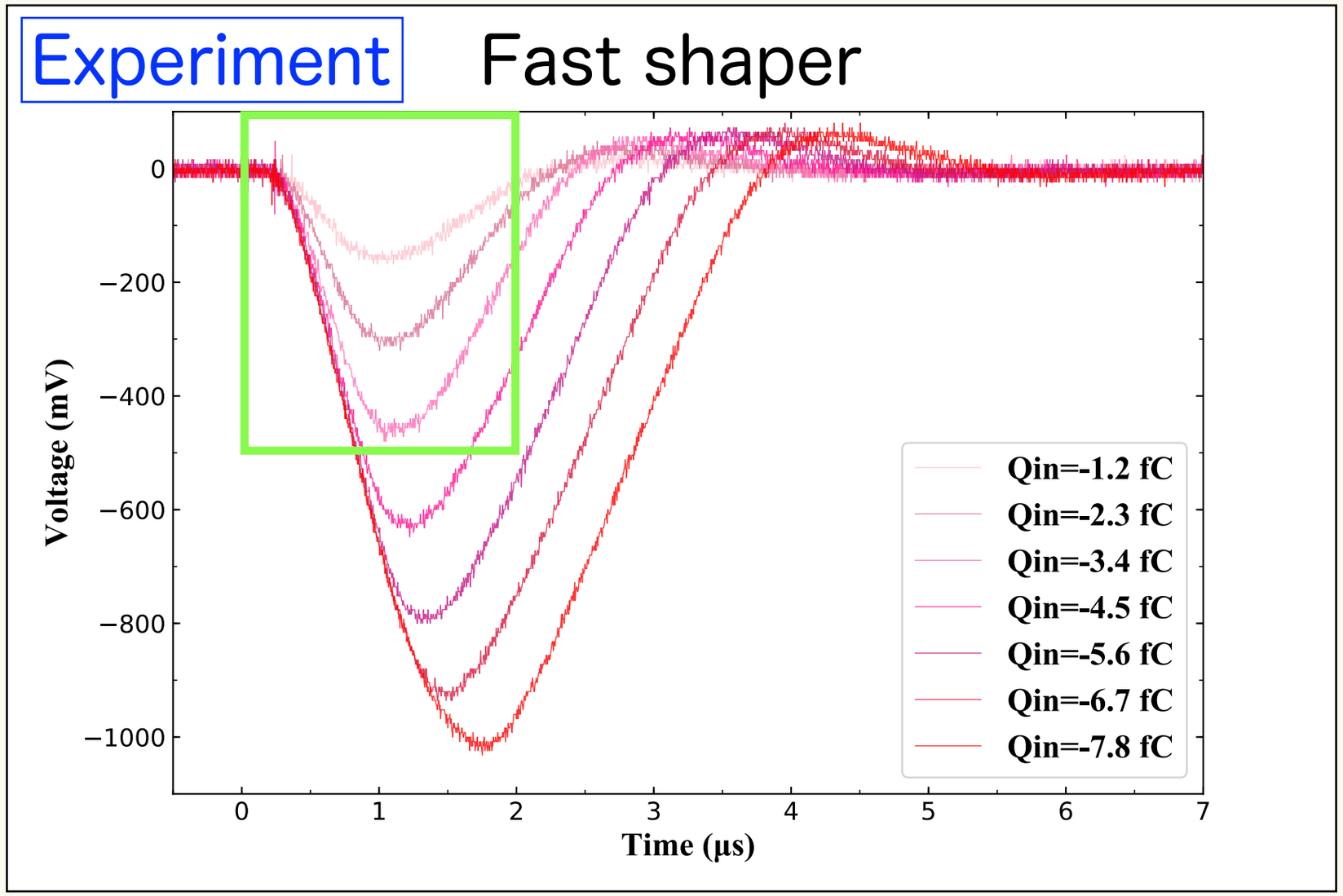

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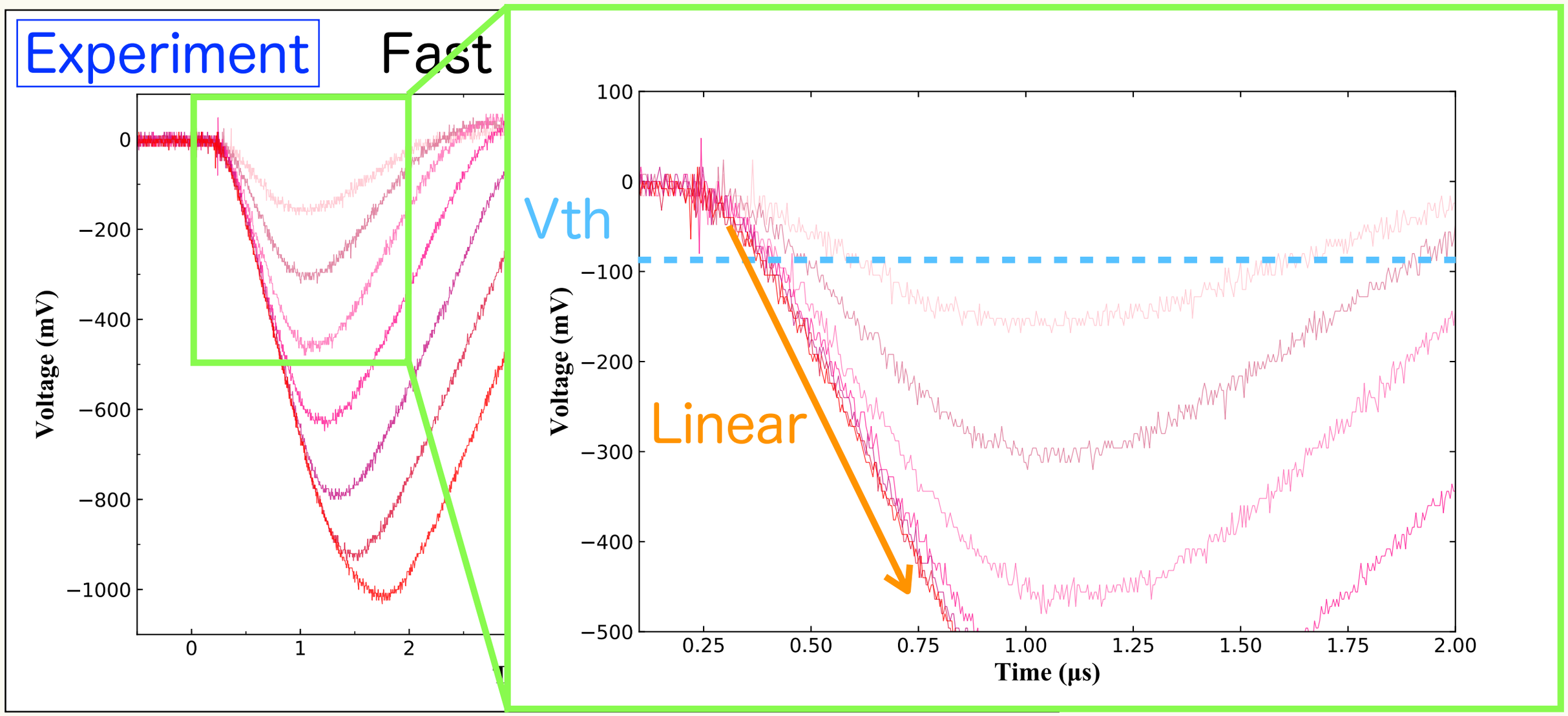
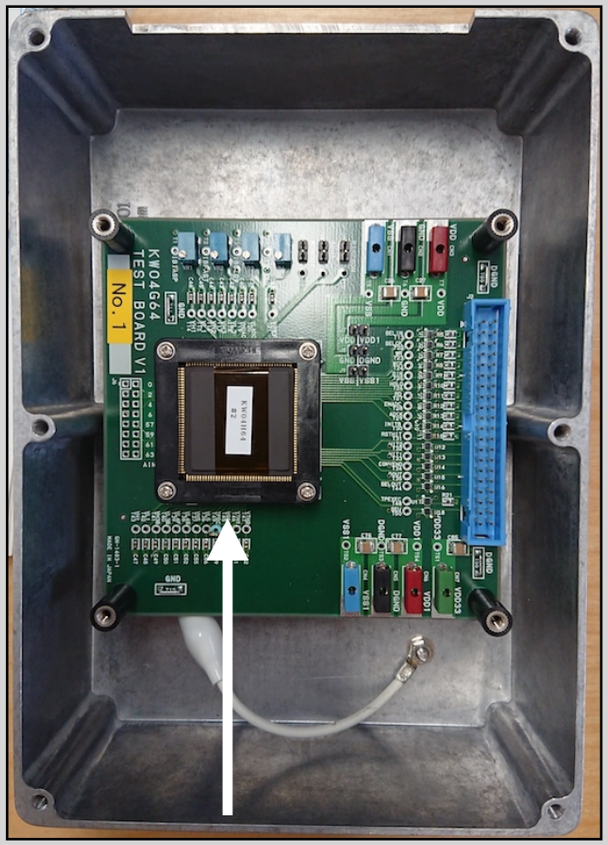


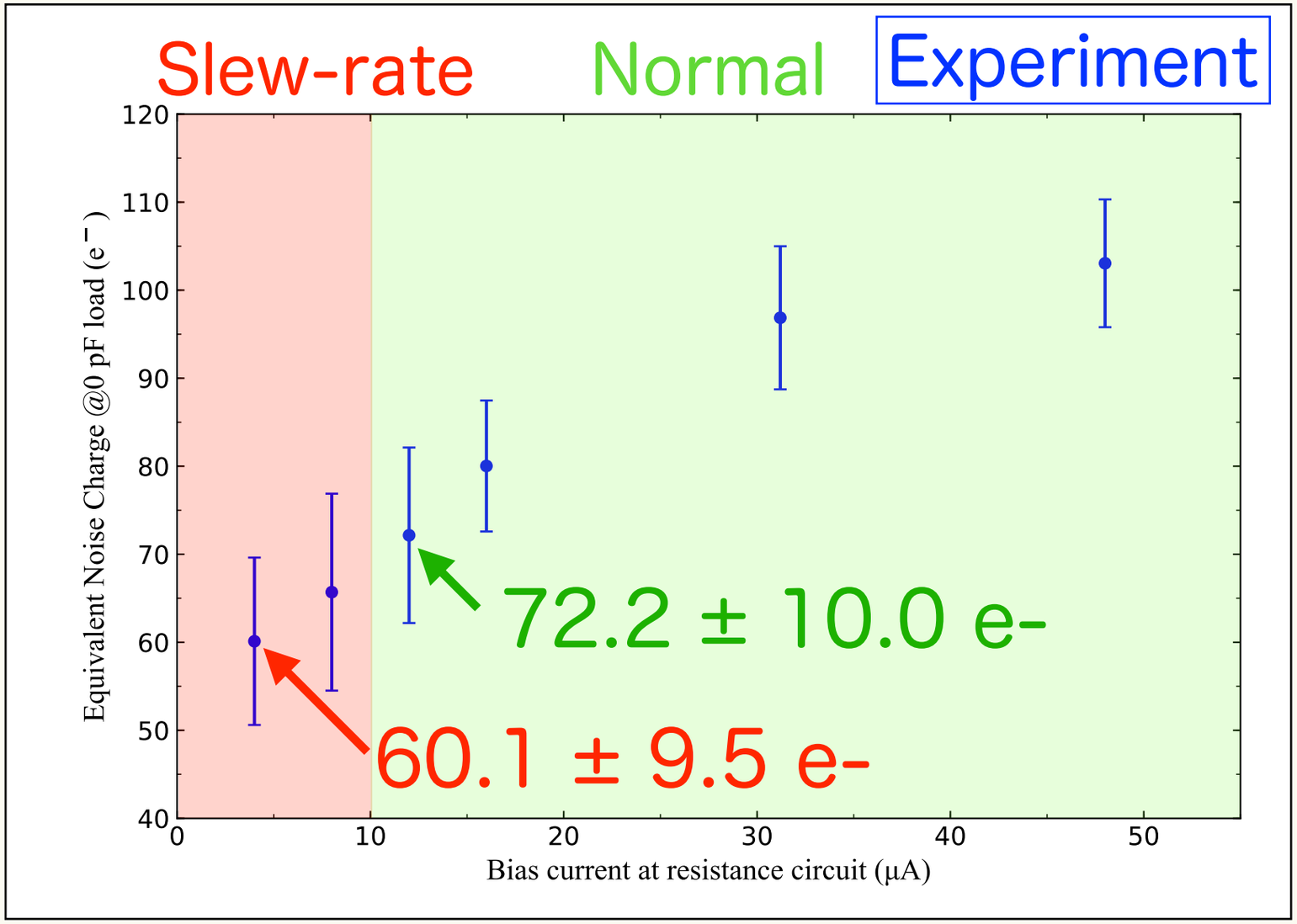
Accurate timing measurement → Accurate peak capturing

Slew-rate Operation at Slow Shaper

In our circuit, it has turned out that slew-rate operation is also effective for better noise performance. G. Sato et al., 2011



Packaged ASIC



Slew-rate operation improved ENC for ~10 e⁻.

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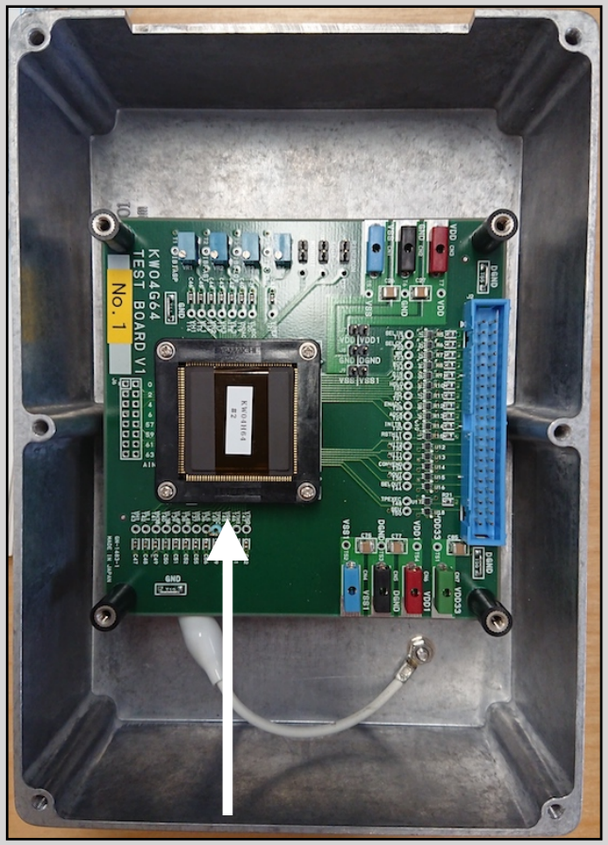

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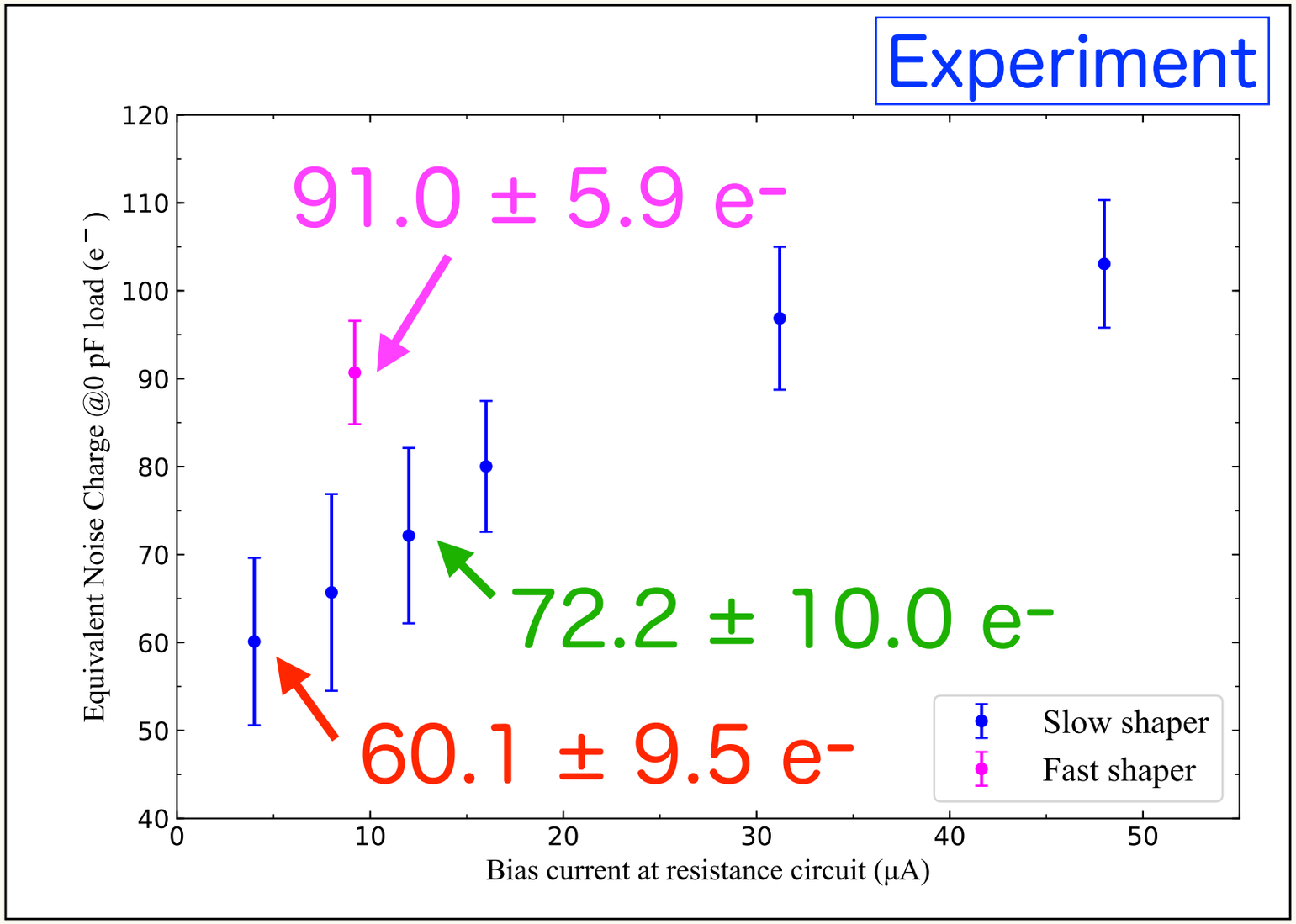

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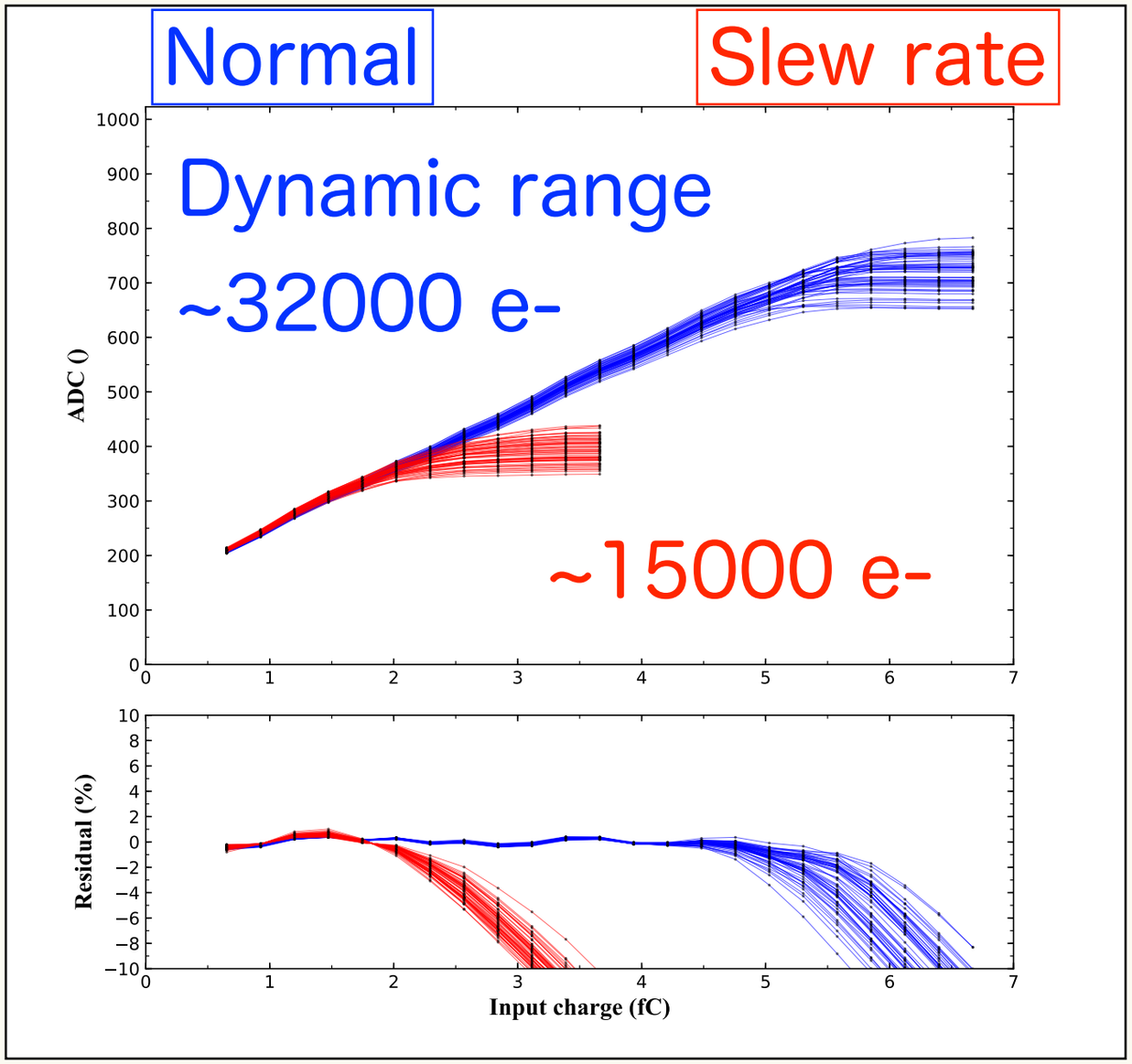
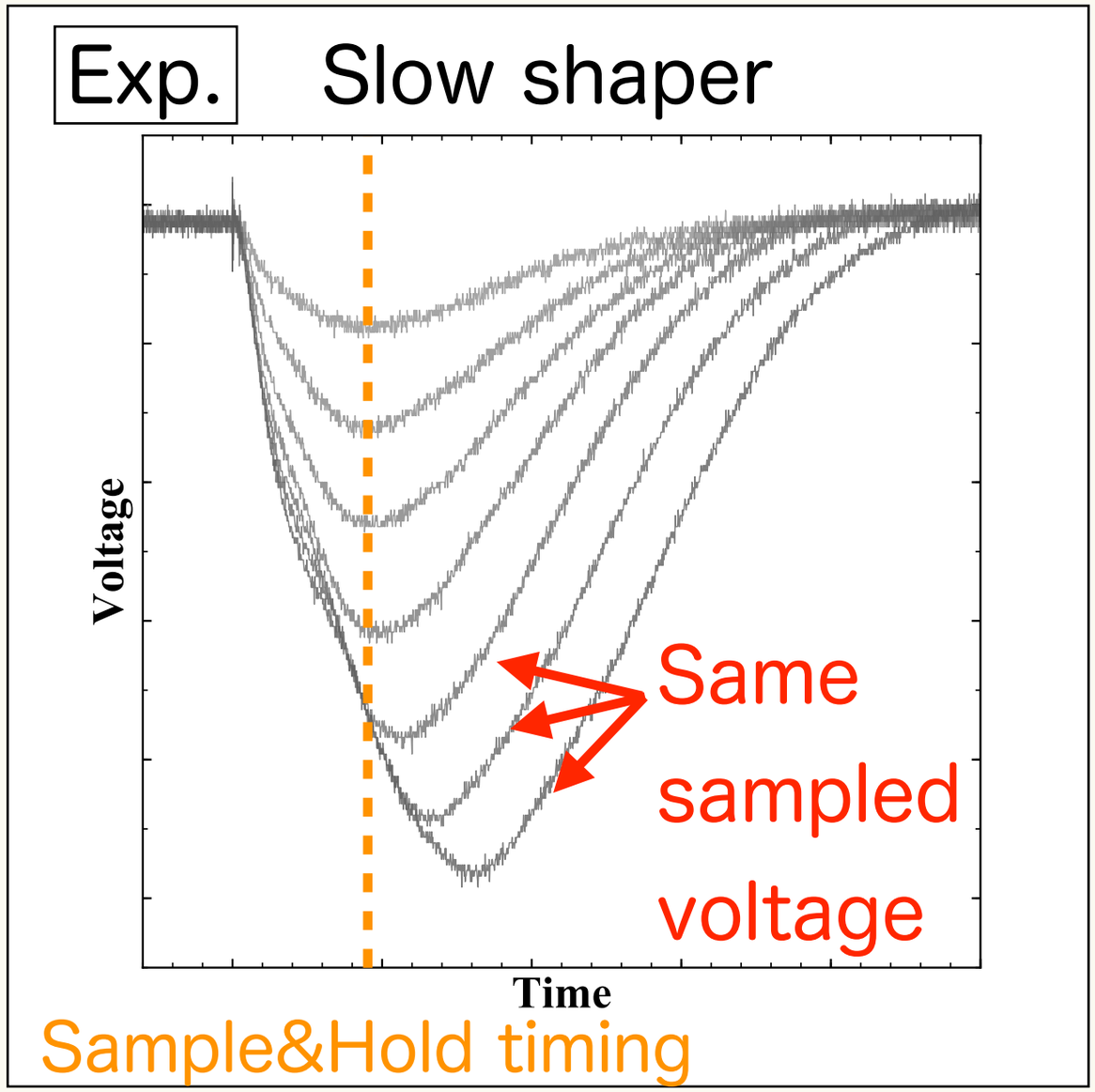
The Problem under Slew-rate Operation

Dynamic range is limited by slew-rate operation as long as sample & hold circuit is employed.





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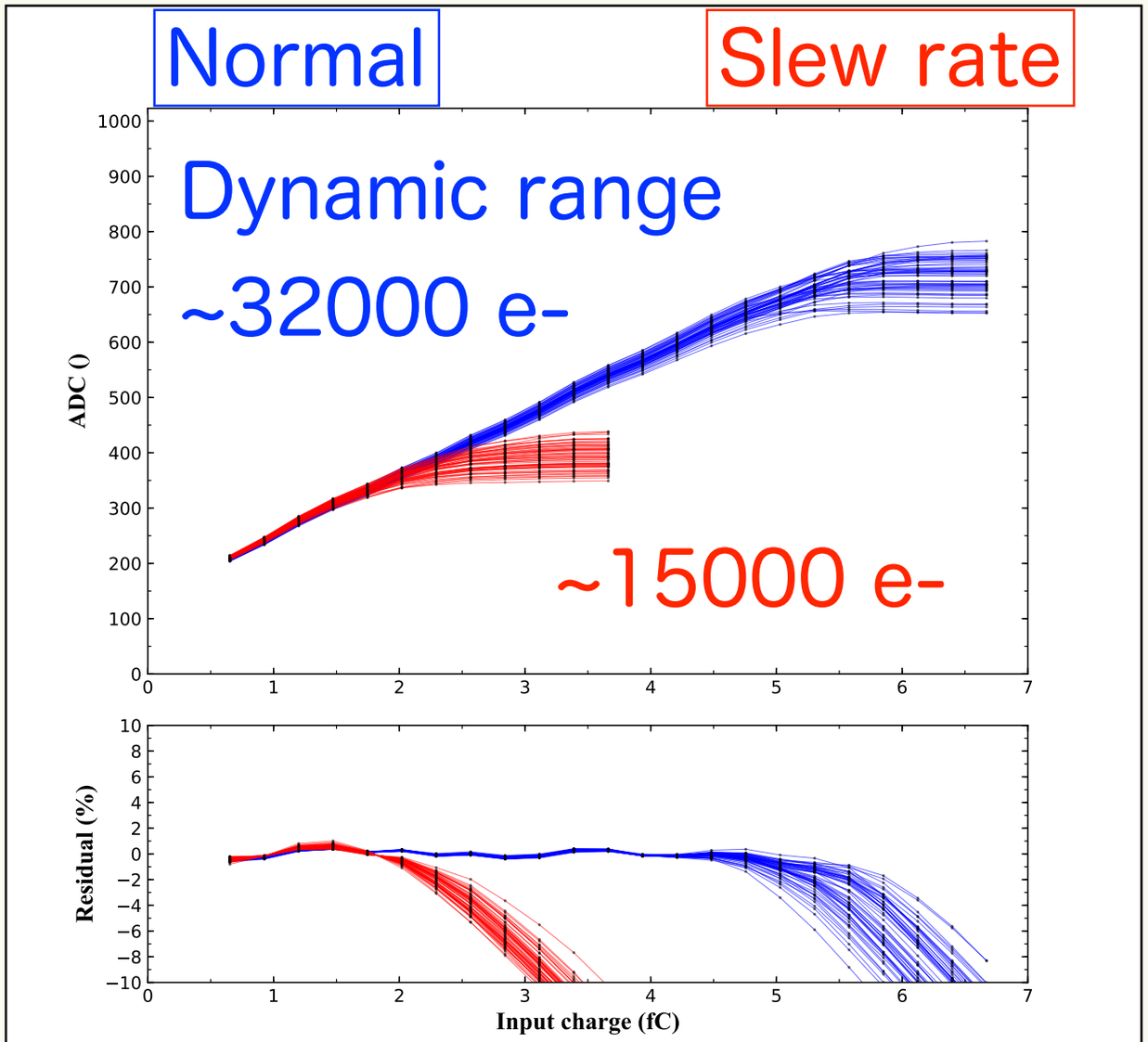
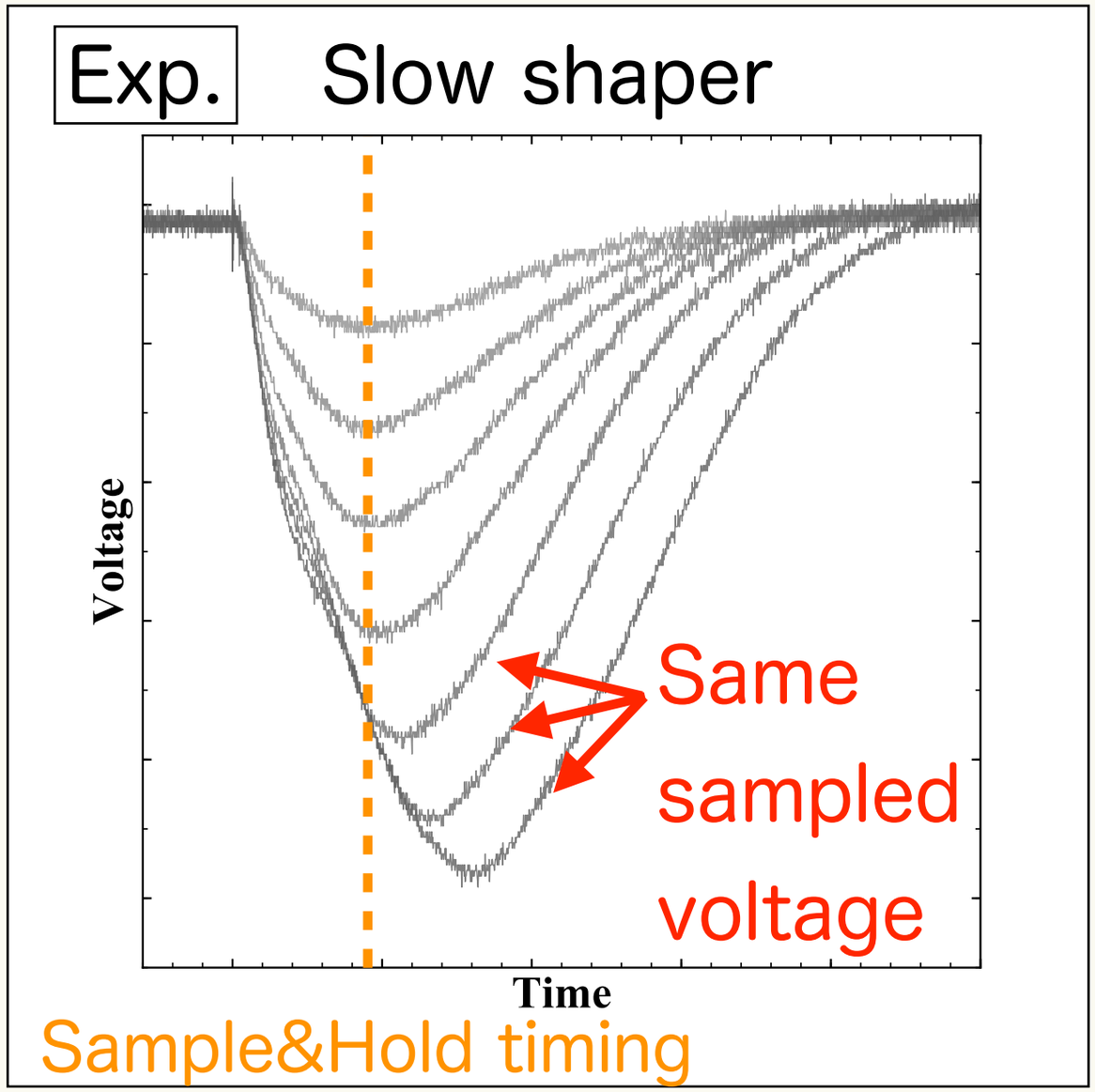
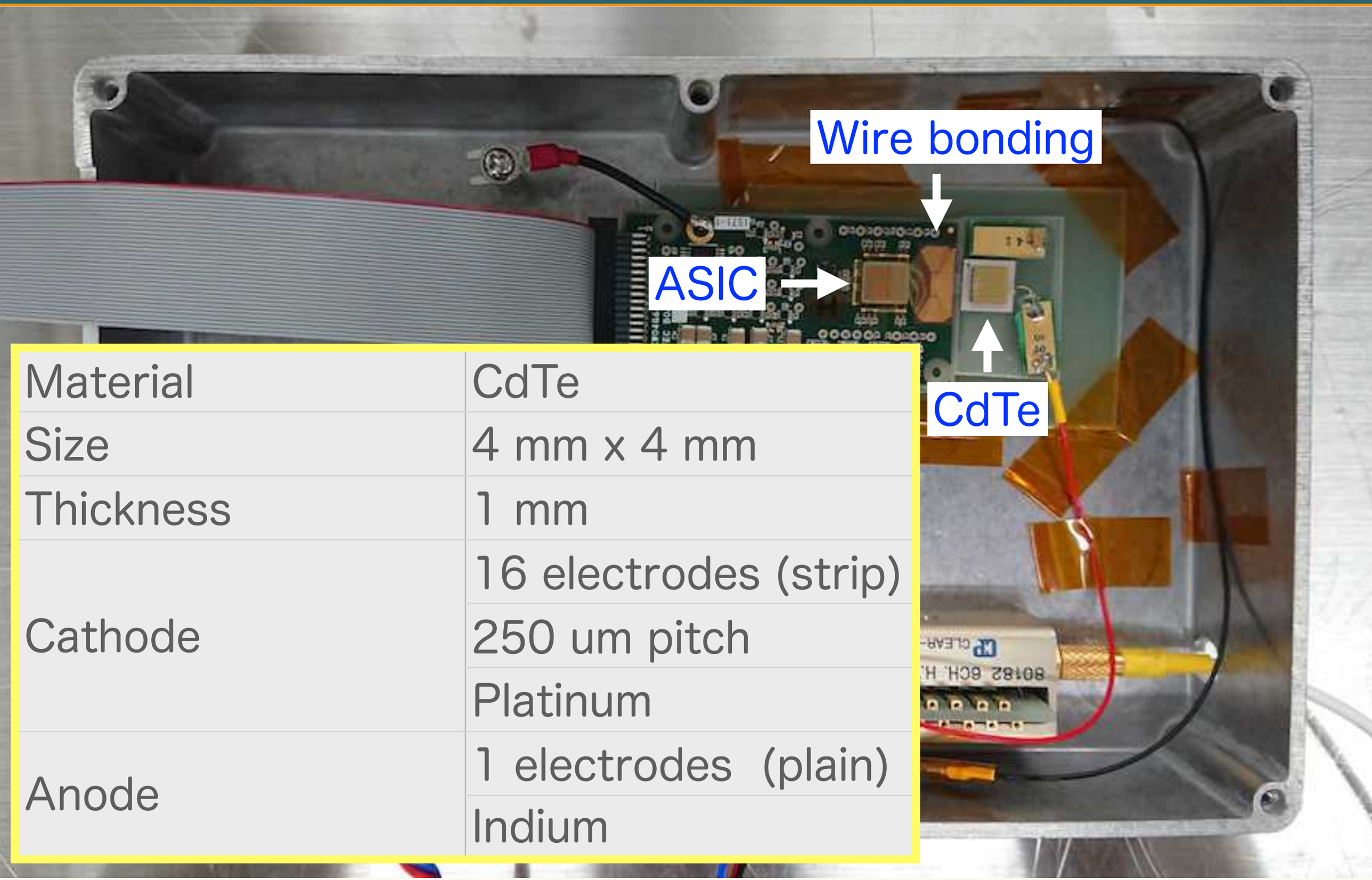




Peak hold circuit is preferred
for wider dynamic range under slew-rate operation.

Experimental Setup (Spectroscopy)



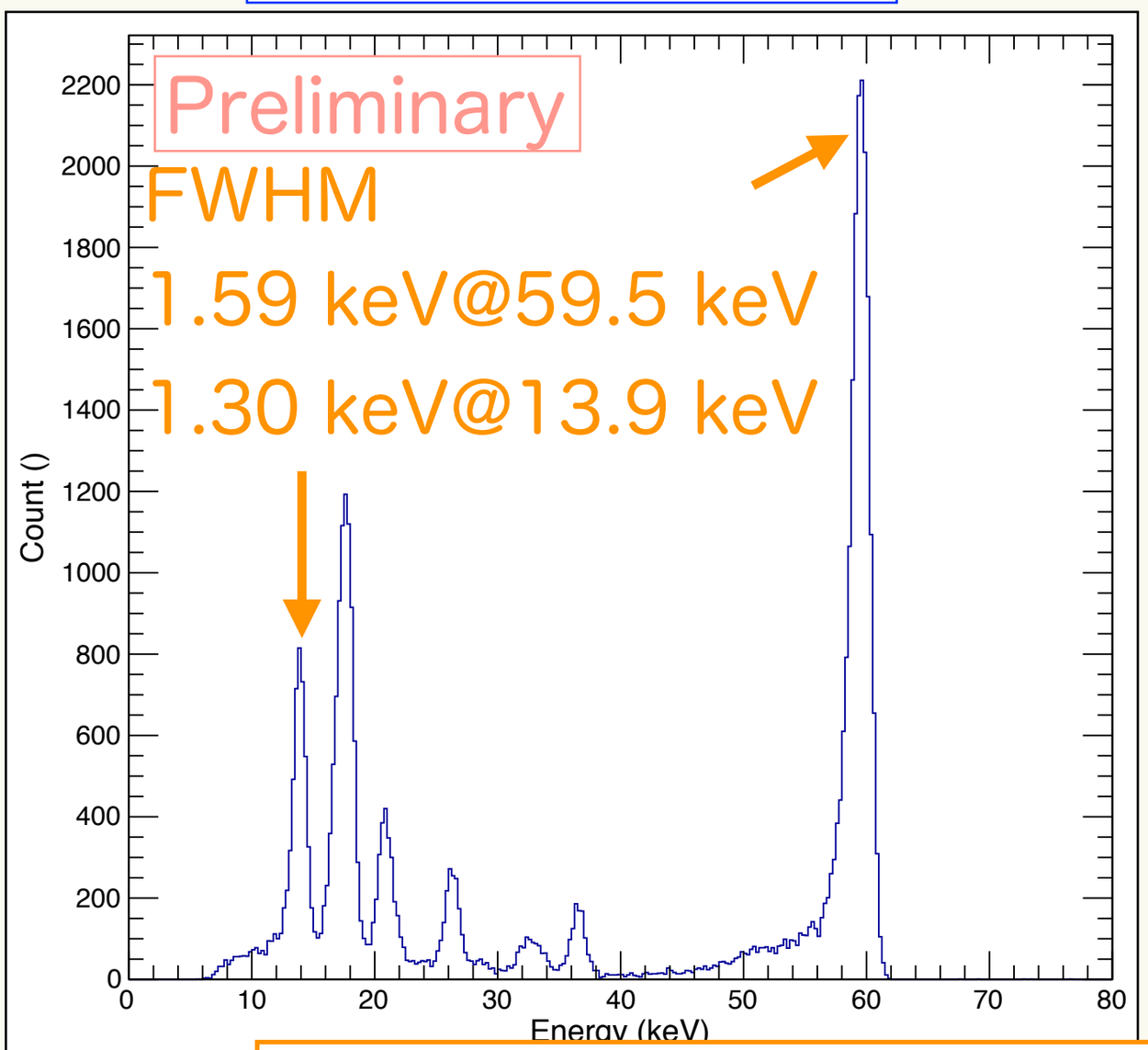
Material	CdTe
Size	4 mm x 4 mm
Thickness	1 mm
Cathode	16 electrodes (strip)
	250 um pitch
	Platinum
Anode	1 electrodes (plain)
	Indium

Spectrum Measured by Slow Shaper

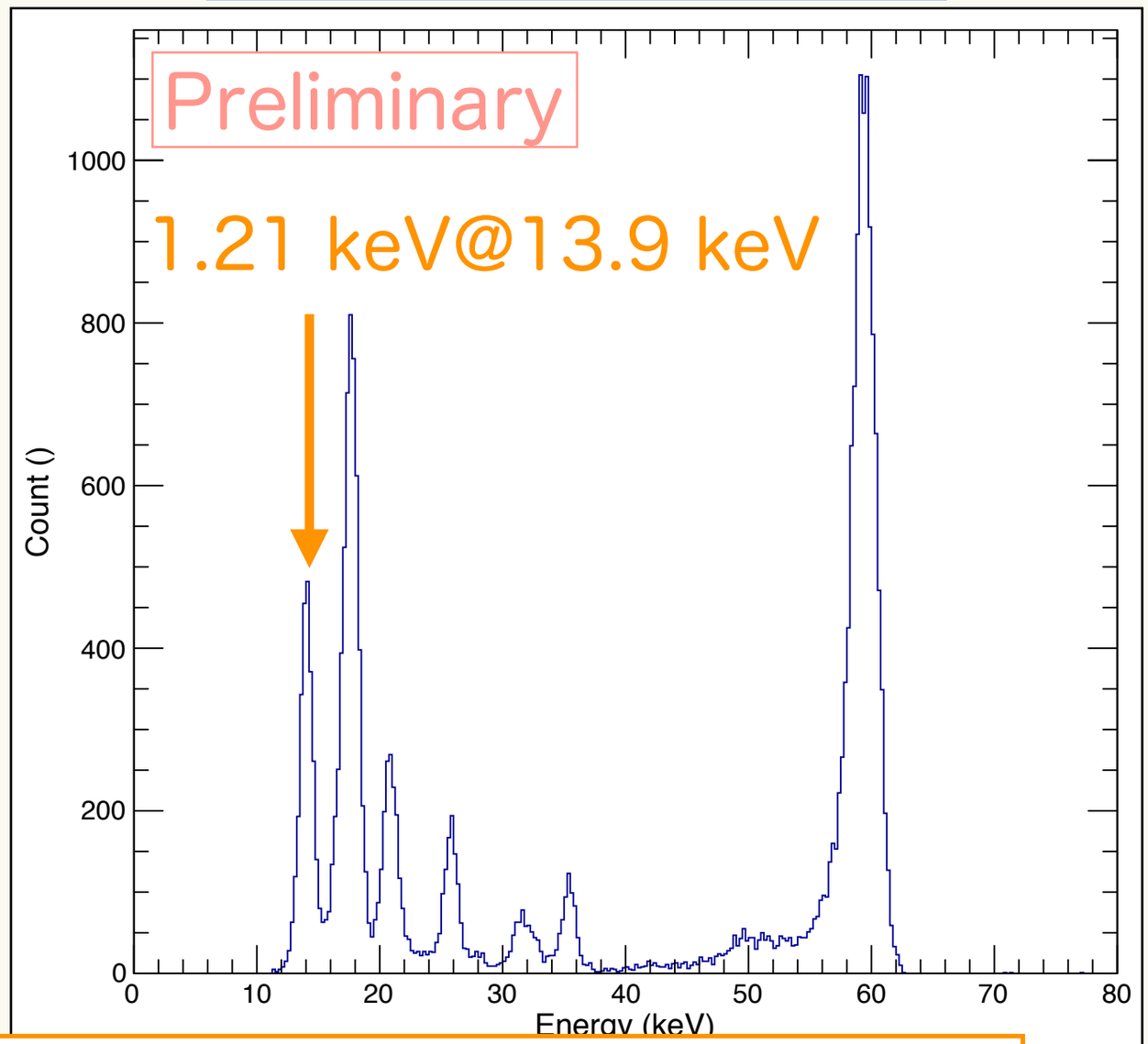
- Only single hit events were extracted.
- Results of one channel are shown.

• Am-241 • Temp. -20 ℃
• HV 1000V • Cathode

Normal operation



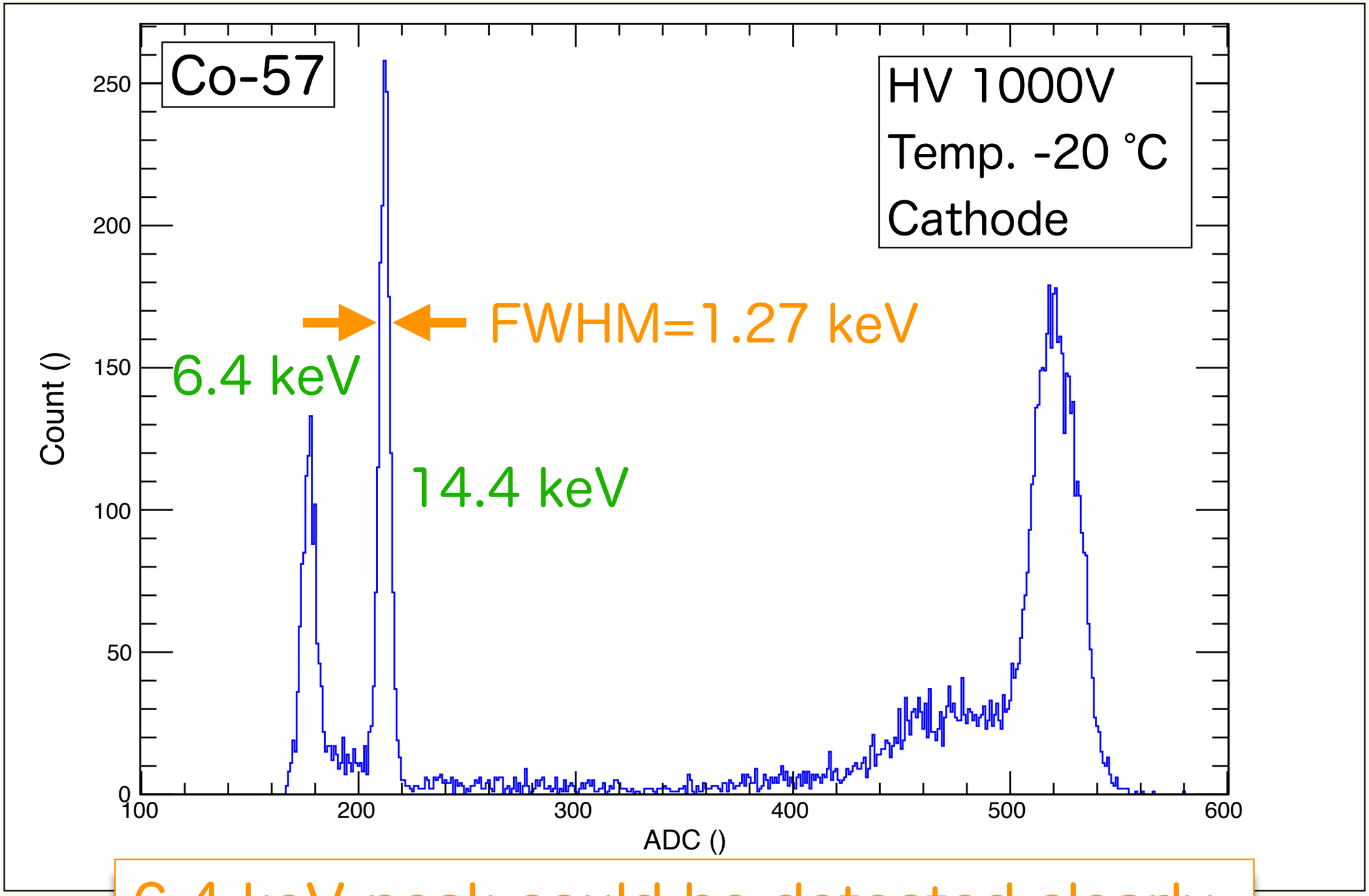
Slew-rate operation



better energy resolution under slew-rate operation.

Spectrum Measured by Fast Shaper

Only single hit events/Result of one channel



6.4 keV peak could be detected clearly.

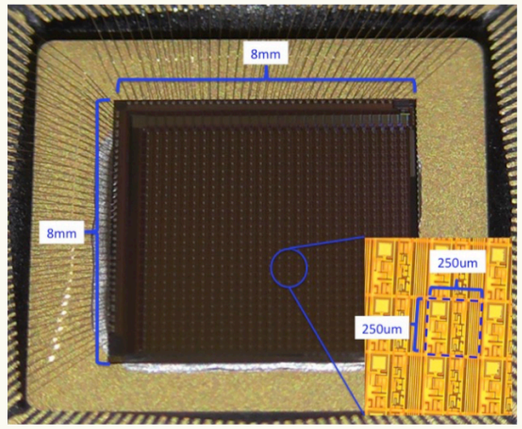
Summary

We have studied readout architectures for hard X-ray and gamma-ray imaging with high spectroscopic capability.

- Slew rate operation ⟶ Better noise performance (~16%)
- Peak hold circuit enables wide dynamic range under slew-rate operation.
- We have succeeded in noise evaluation at the fast shaper.

✓ POSTER
@B1F Meeting rooms #5-6

“Development of CdTe Hybrid Pixel ASIC for Hard X-ray Imaging”



- TSMC 0.35 um
- 28 x 28 ch
- 250 um pitch
- ENC=50 e-