Development of a Fully Depleted Back Illumination Sensor Based on SOI CMOS Technology for Future X-Ray Astronomy Satellites

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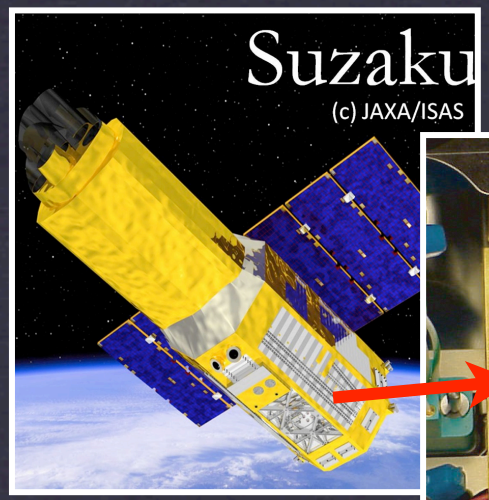
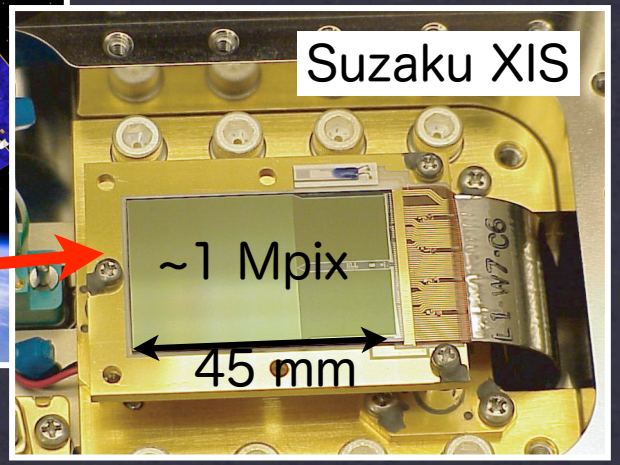
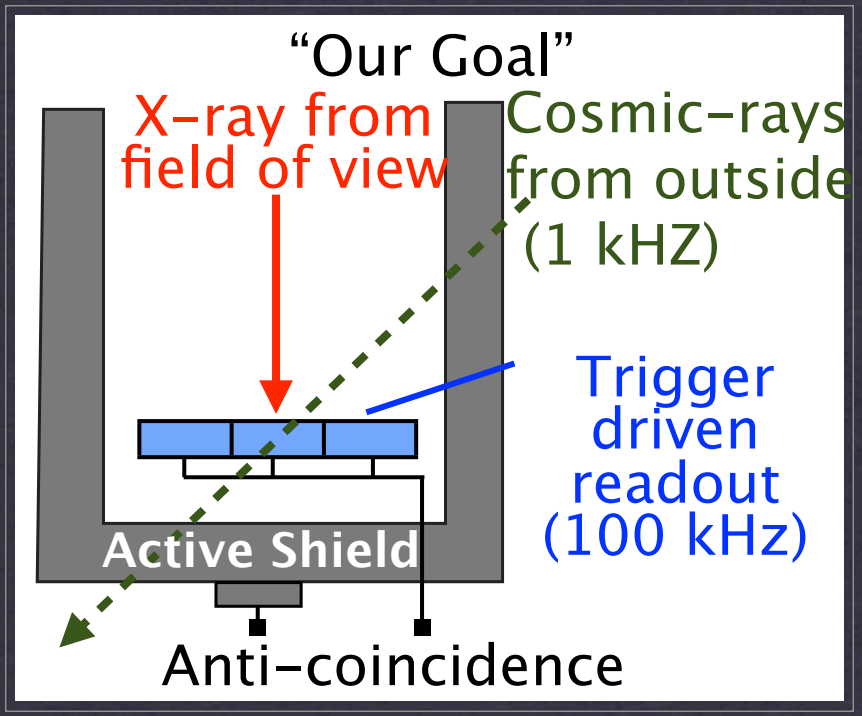
Motivation in X-ray Astronomy



Standard Detector
= X-ray CCDs



new imaging spectrometer
capable of high speed reaout
and low background

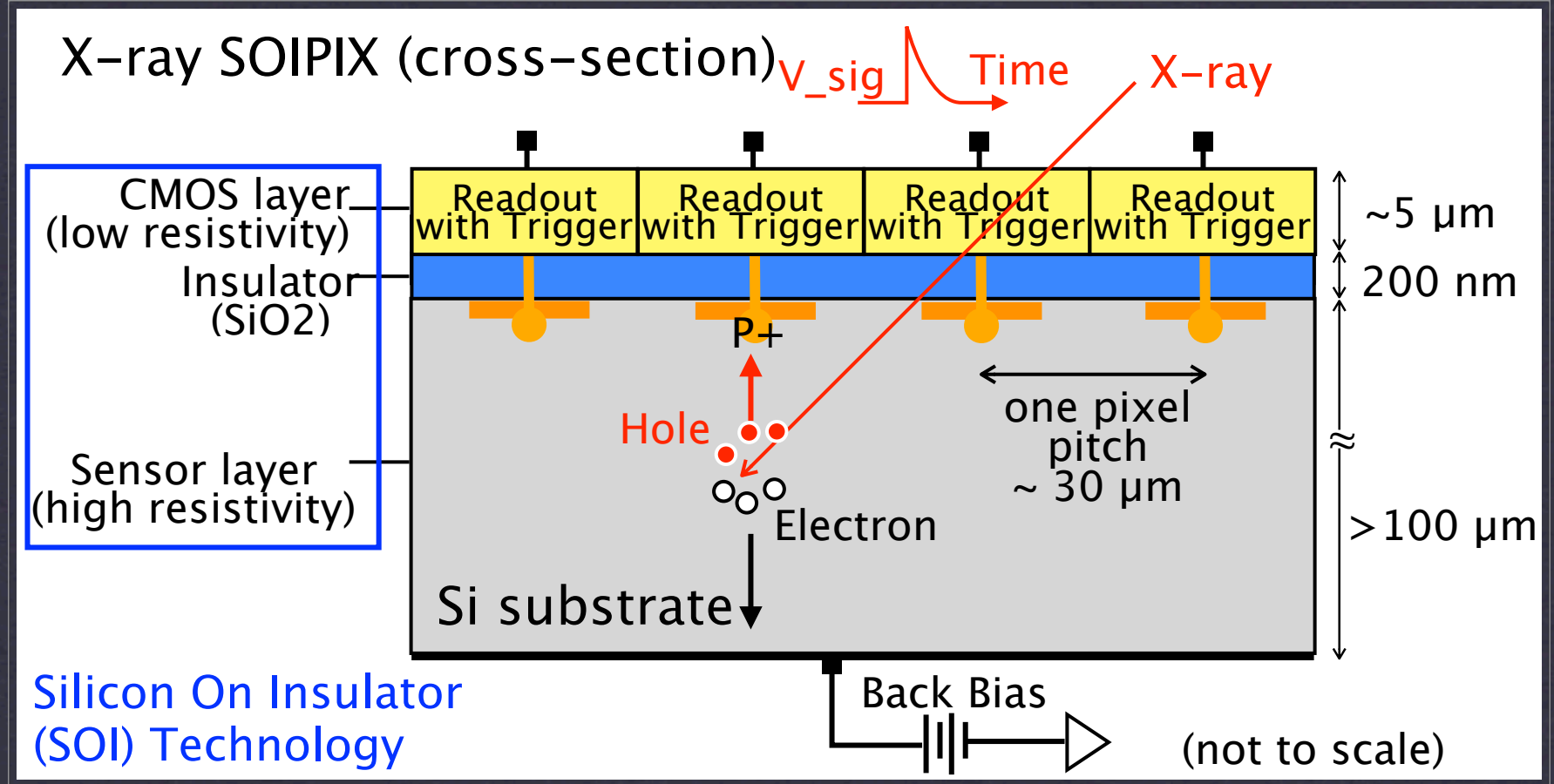


Weak Points

- Poor time resolution of ~ sec
- Non X-ray background above 10 keV
  - due to cosmic rays in satellite orbit

	positional resolution	Energy resolution	Timing resolution	observable energy band
CCD	~ 20 μm	2% FWHM@6 keV	~ sec	0.5 - 10 keV
SOI pixel	< 30 μm	2% FWHM@6 keV	< 10 μsec	0.5 - 40 keV

Concept of X-ray SOIPIX



- Monolithic pixel sensor by Silicon on Insulator (SOI) Tech
- Si sensor + CMOS readout circuit with trigger

Achievements and Scope of This Work

Achievements

- Trigger-driven readout of X-ray signals
- Thick depletion layer (500 μm)
- Readout noise ~ 60 e^-
- Energy resolution 700 eV FWHM at 8 keV

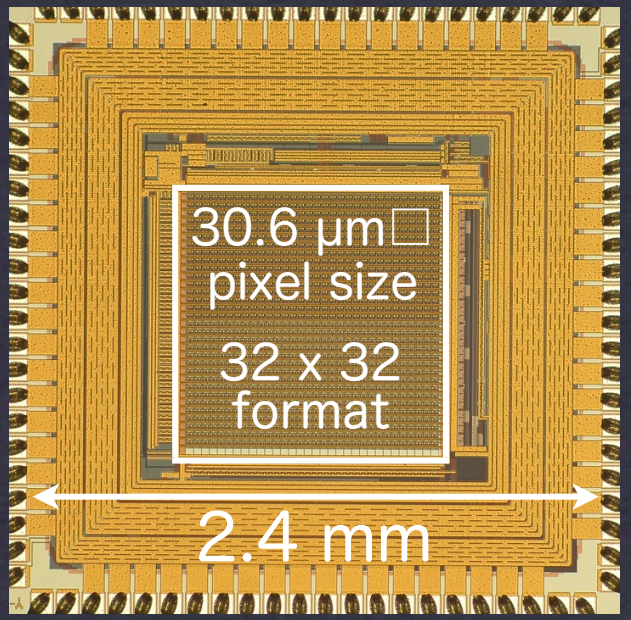
Scope of This Work

- Spectroscopy with back illumination (BI) device
- Investigation of charge collection efficiency

Prototype: XRPIX1b

XRPIX1b-CZ-BI:

- Back illumination sensor
- Sensor layer: 100 μm
- Resistivity: 0.7 kΩcm



XRPIX1b-FZ-FI:

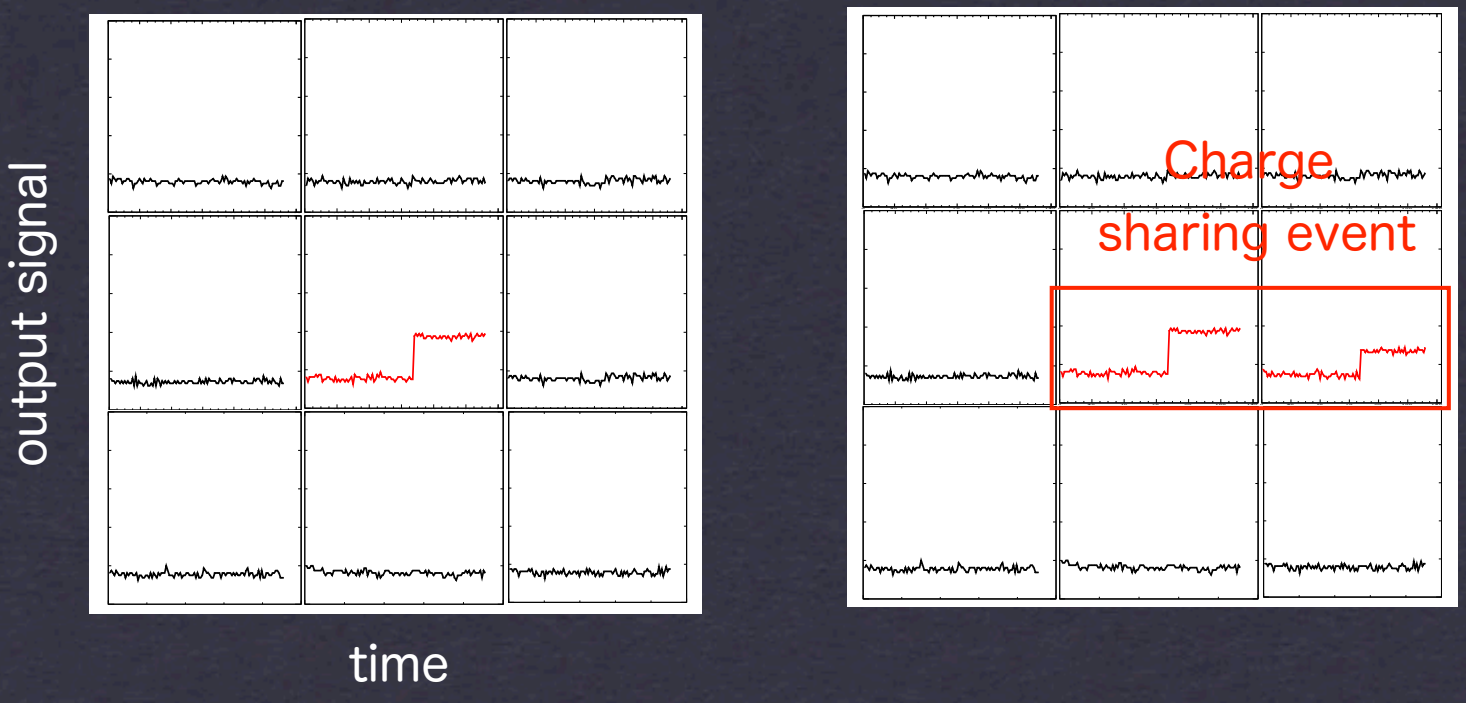
- Front illumination sensor
- Sensor layer: 500 μm
- Resistivity: 7 kΩcm

3 x 3 Pixel Readout Method

- We used special readout method to reduce readout noise
- Charge often spreads over several pixels

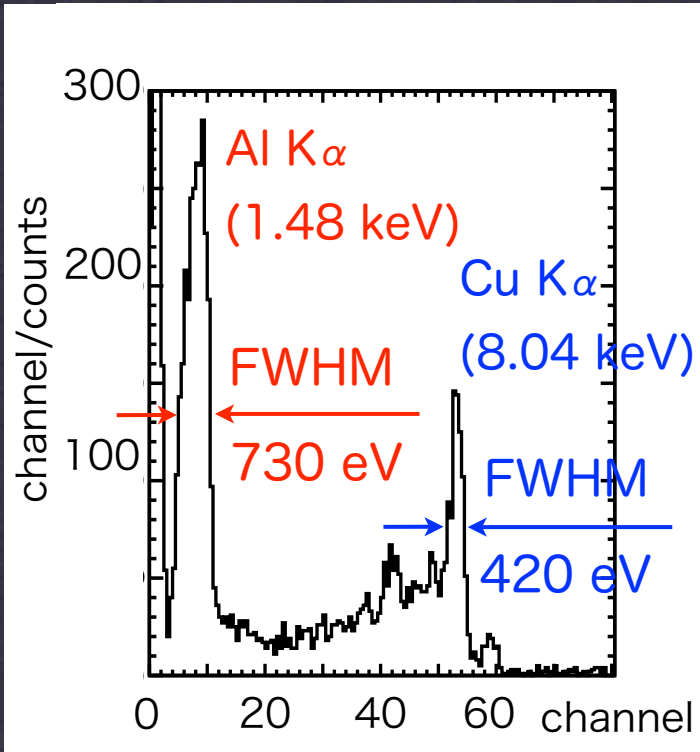
1 pixel event

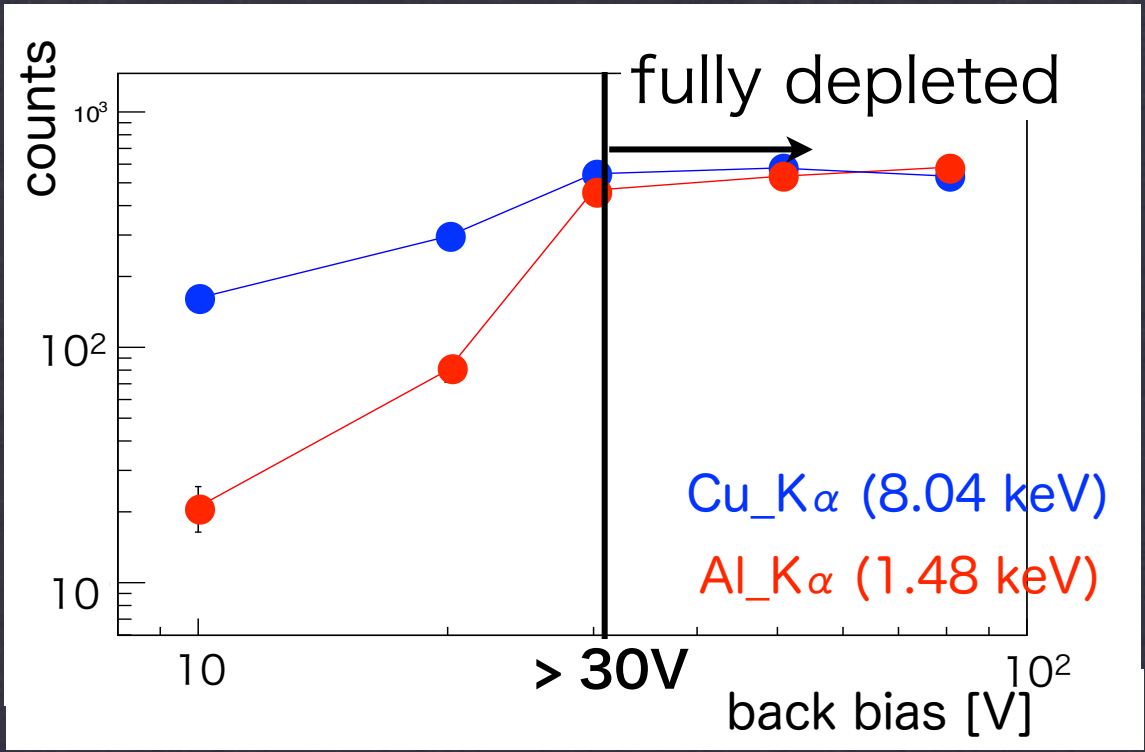
2 pixel event



BI Spectrum

Device: XRPIX1b-CZ-BI





Back Bias: 85 V

Temperature: - 50 ℃

1 hit events spectrum

Quantum Efficiency at 1.48 keV

= 30 %

⇒ dead layer = 9.3 μm

Issues on BI Device

(1) Energy resolution at Al line (1.48 keV)

BI: 730 eV

FI (same device): 300 eV

(2) Thick dead layer

9.3 μm >> our goal ~ 0.1 μm

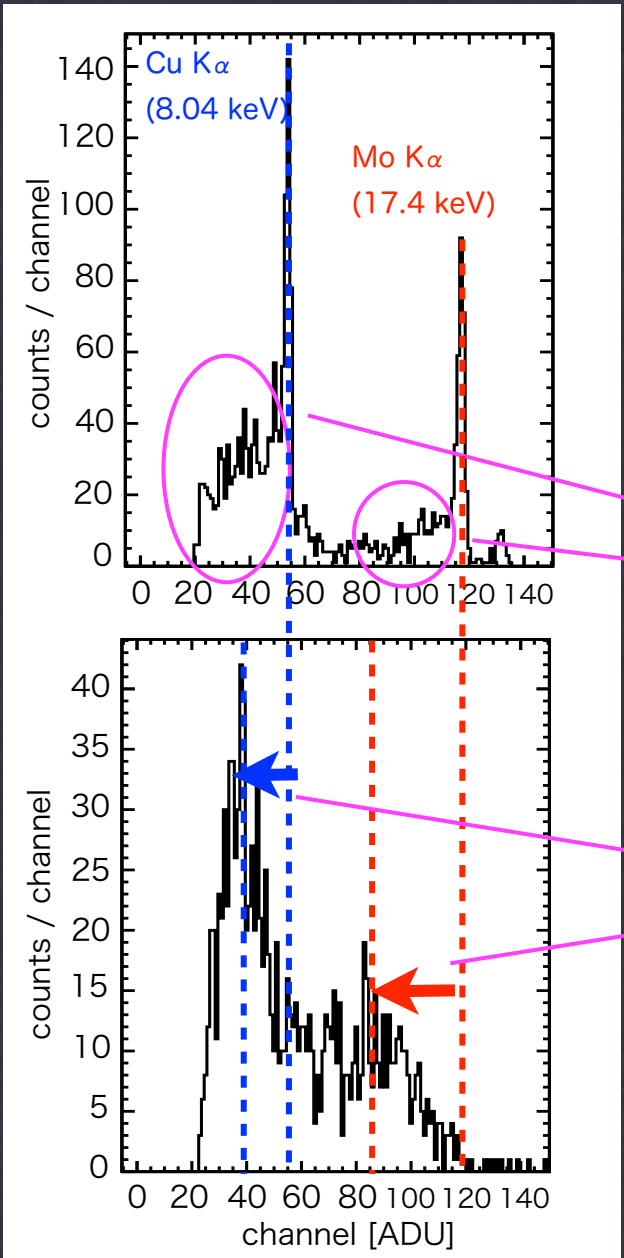
We consider that this degradation is due to imperfection backside process.

Improvement of backside treatment is ongoing.

Spectral Shape

1 pixel event

2 pixel event



Device: XRPIX1b-FZ-FI

Back Bias: 30 V

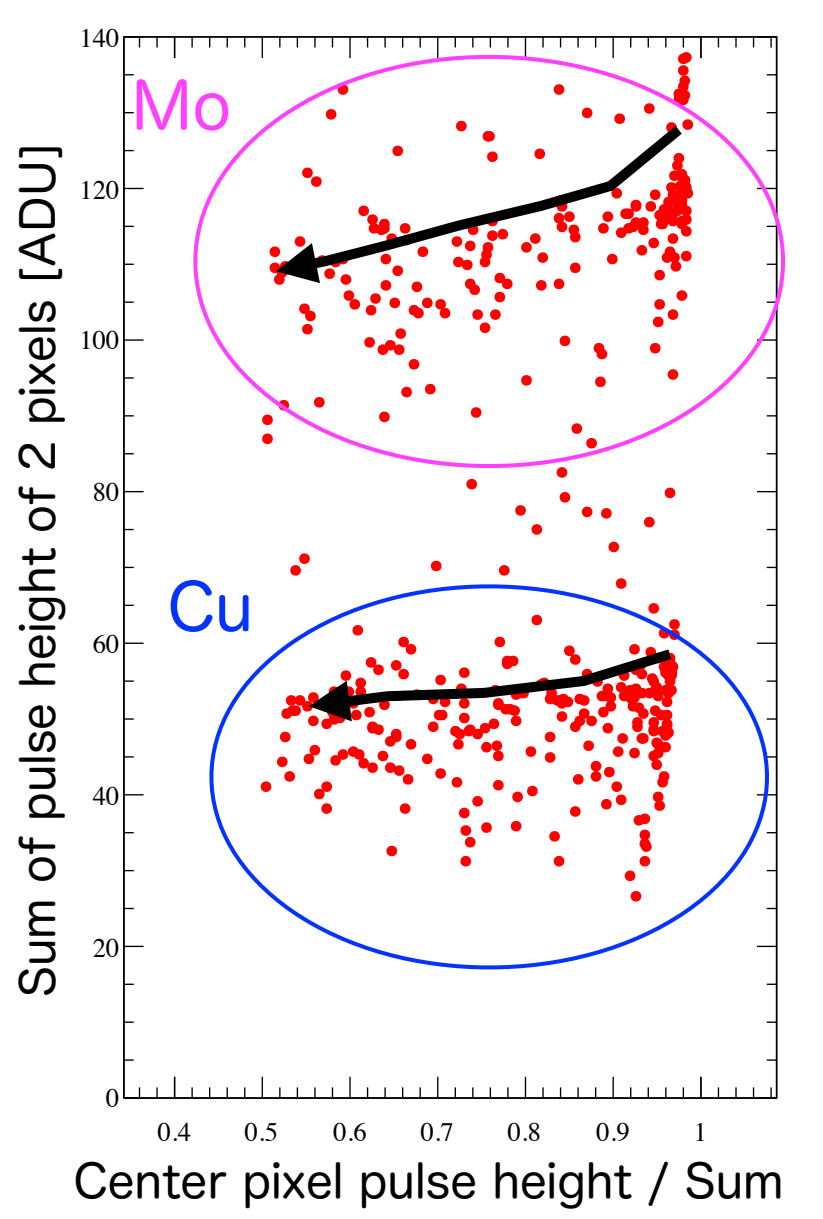
Temperature: - 50 ℃

1 pixel and 2 pixel events spectrum

Large tail components

Peak shift

Spectral Shape



Comparison with Previous Device

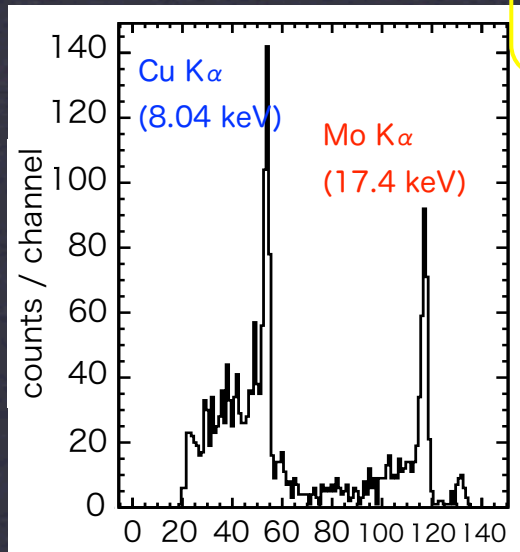
Current Device
XRPIX1b-FZ-FI

BPW size small

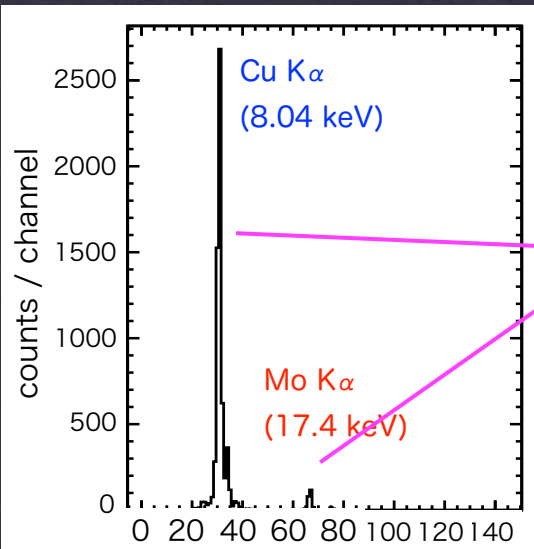
Previous Device
XRPIX1-FZ-FI

BPW size large

1 pixel event

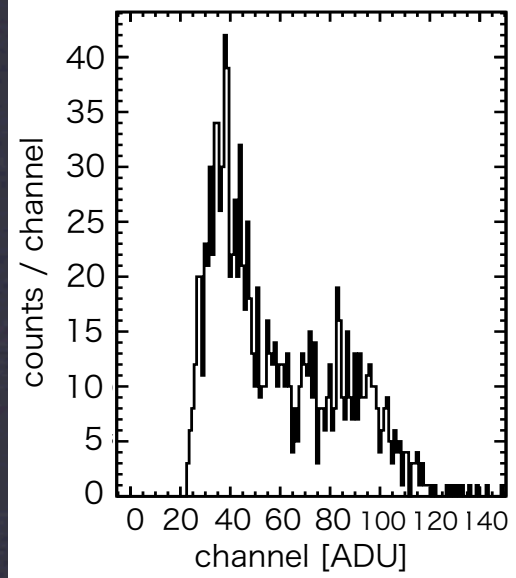


1 pixel event

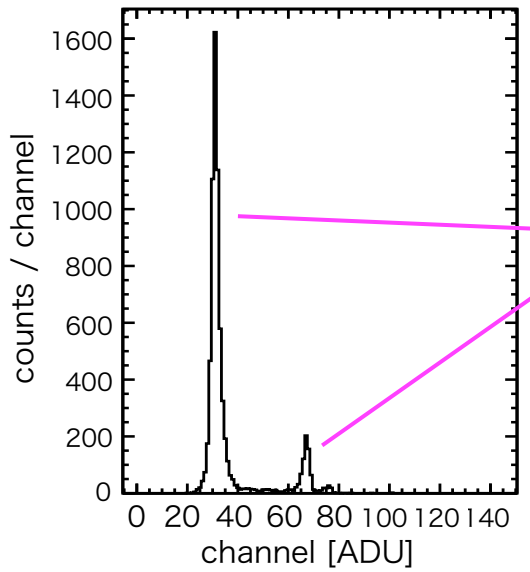


No tail

2 pixel event



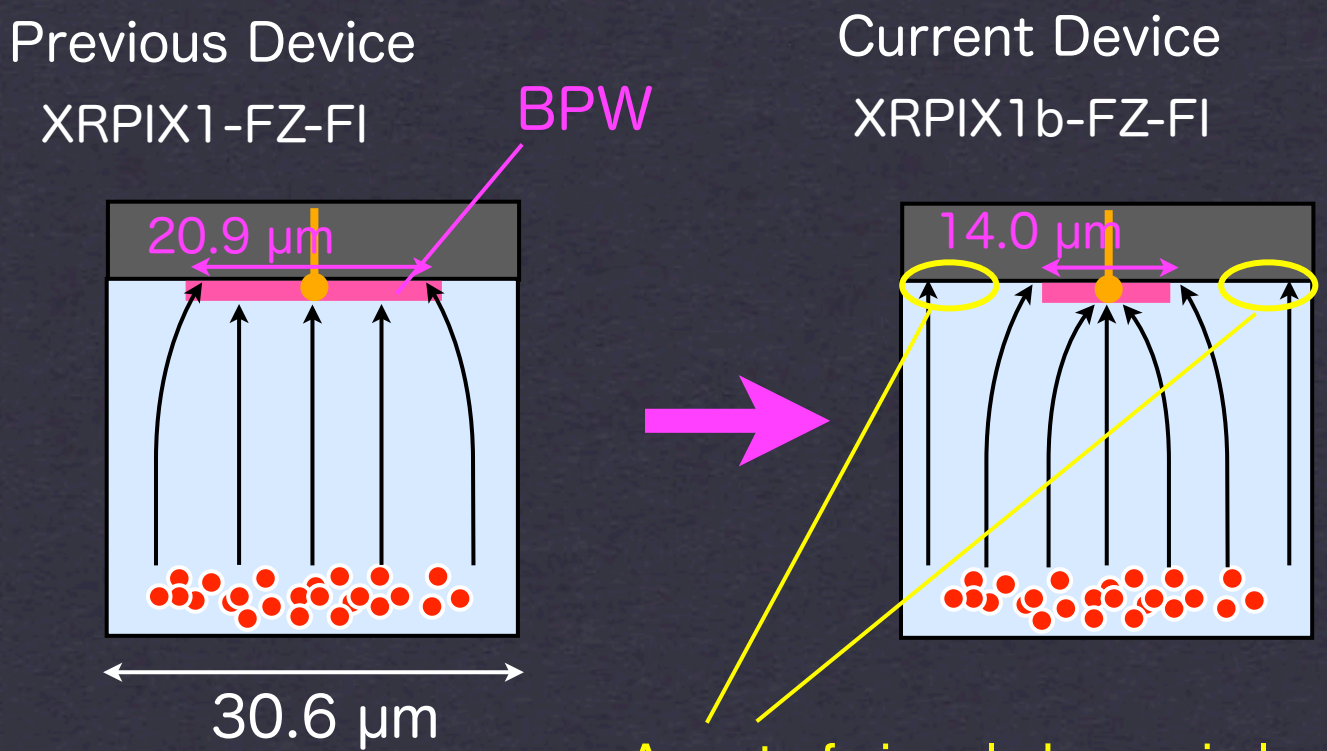
2 pixel event



No peak shift

Our Hypothesis of Charge Loss

Buried P-Well (BPW): Suppression of backgate effect



⇒ We plan to test the hypothesis by irradiating the device with a pencil X-ray beam

Summary

- We successfully obtained spectrum of Al lines using Back Illumination SOIPIX for the first time.
- Energy resolution is 730 eV for Al line (1.48 keV).
- We think that a part of signal charge is lost at the interface region between the insulator and the sensor layer.
- We can test our hypothesis with a pencil beam experiment.

Thank You