Evaluation of a pulse counting type SOI pixel using synchrotron radiation X-rays

KEK IMSS R. Hashimoto, S. Kishimoto, R. Kumai, N. Igarashi

KEK IPNS Y. Arai, T. Miyoshi

IHEP Yunpeng Lu, Yang Zhou, Qun Ouyang

SOKENDAI R. Nishimura

Outline

Introduction

Evaluation of the counting type pixel

- Experimental setup
- Calibration of the discriminator
- 1-dimensional pixel array scan
- 2-dimensional pixel array scan

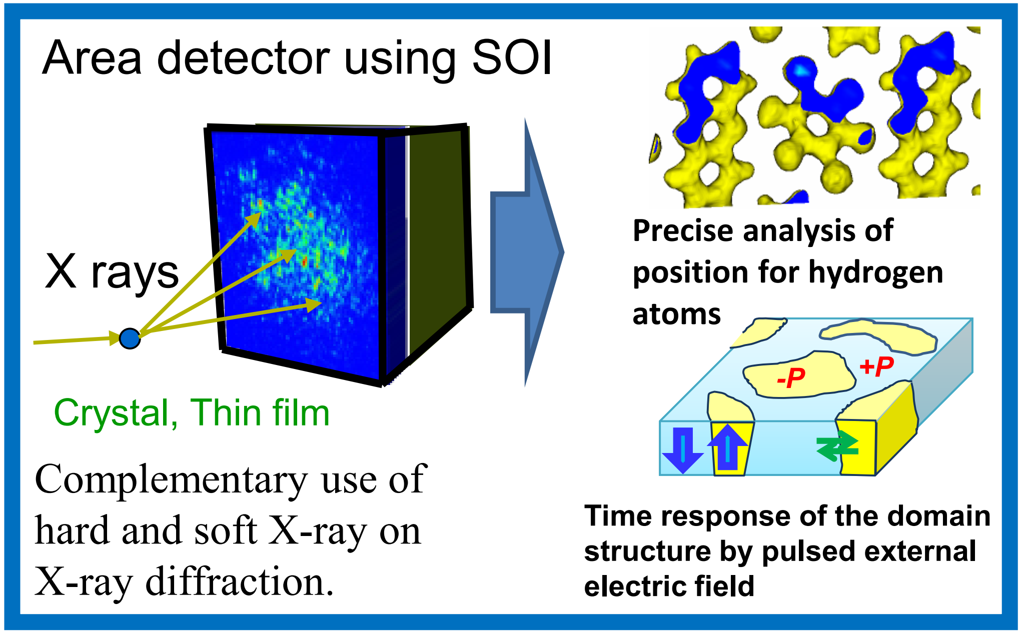
Summary

Introduction

Development of the pulse counting type pixel detector for X-ray structural analysis.

- Small angle X-ray scattering experiment for functional thin films.
- X-ray diffraction experiment for functional materials such as ferroelectrics.

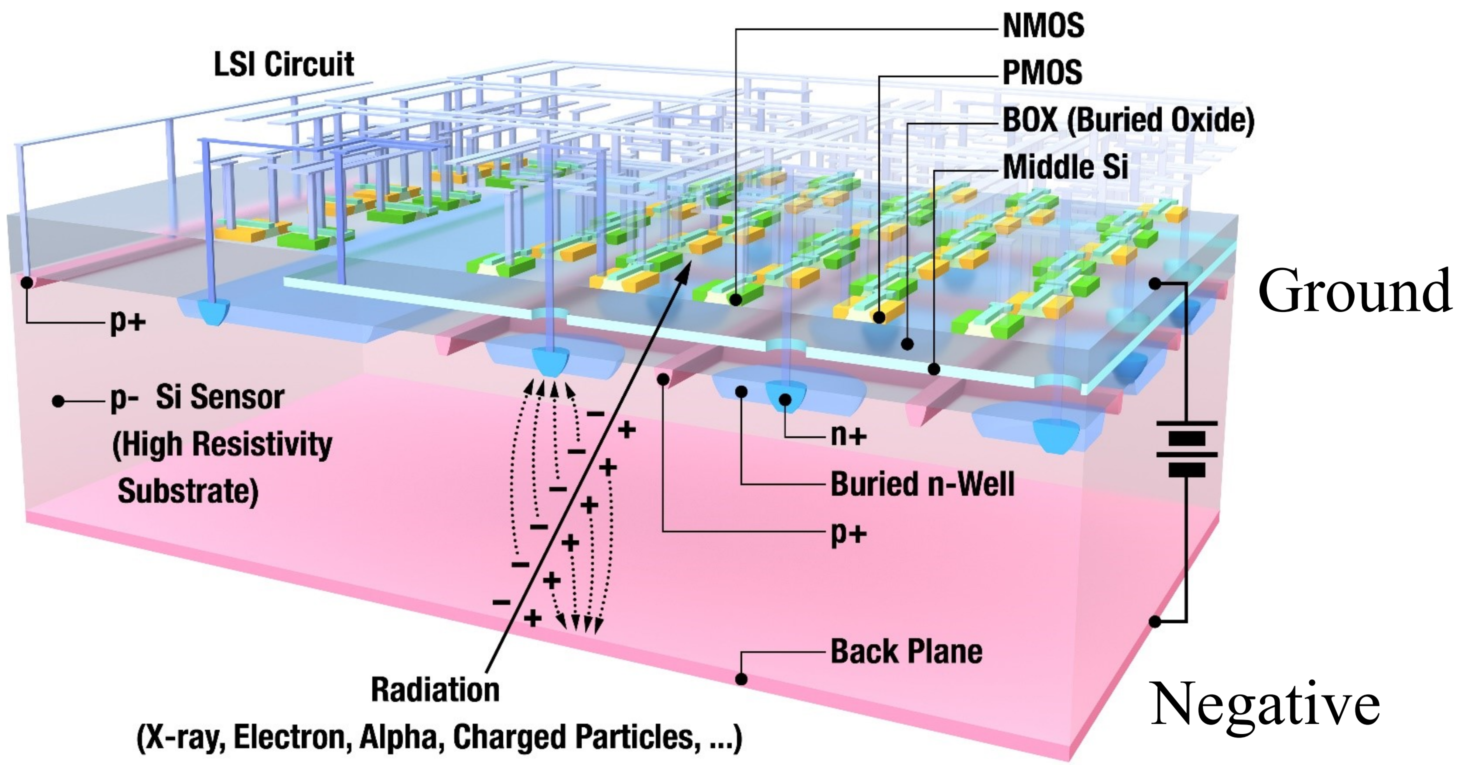
etc…



The Silicon-On-Insulator (SOI) technology plays a very important roll on our detector.

Introduction

SOI detector



Double-SOI wafer (p-type substrate)
Back plane : negative bias
Another Si layer (middle Si) is in BOX layer

Introduction

Requests for detectors from experiments

- high spatial resolution
  → pixel size is less than 50 μm square
- high sensitivity
  → detecting low energy X-ray ～2 keV
- high frame rate
  → more than 1 kHz

⇨ Realizing by counting type pixel

Current status
X-ray test for Test-Element-Group (TEG) chip including pixel TEG.

In this talk, the experimental results of the evaluation for the counting type pixel TEG will be shown.

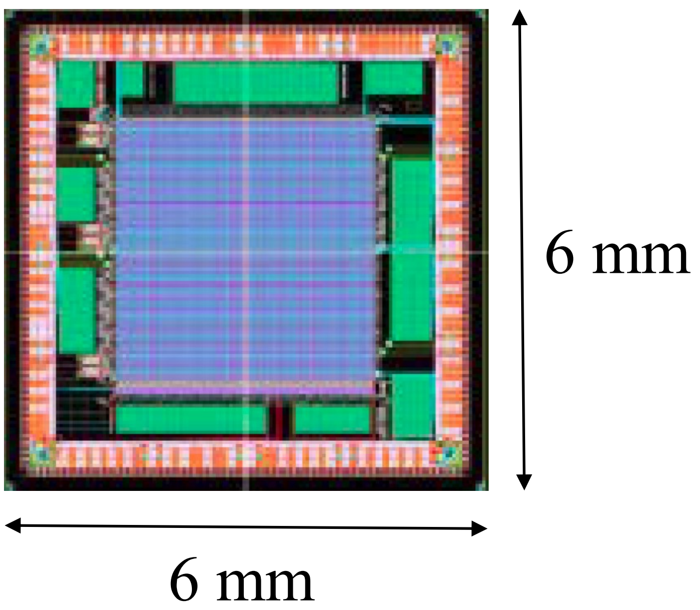
Evaluation of the pulse counting type pixel

Collaborative research between IHEP and KEK.

Development of the pulse-counting-type fine pixelated X-ray detector based on Double-SOI technology.

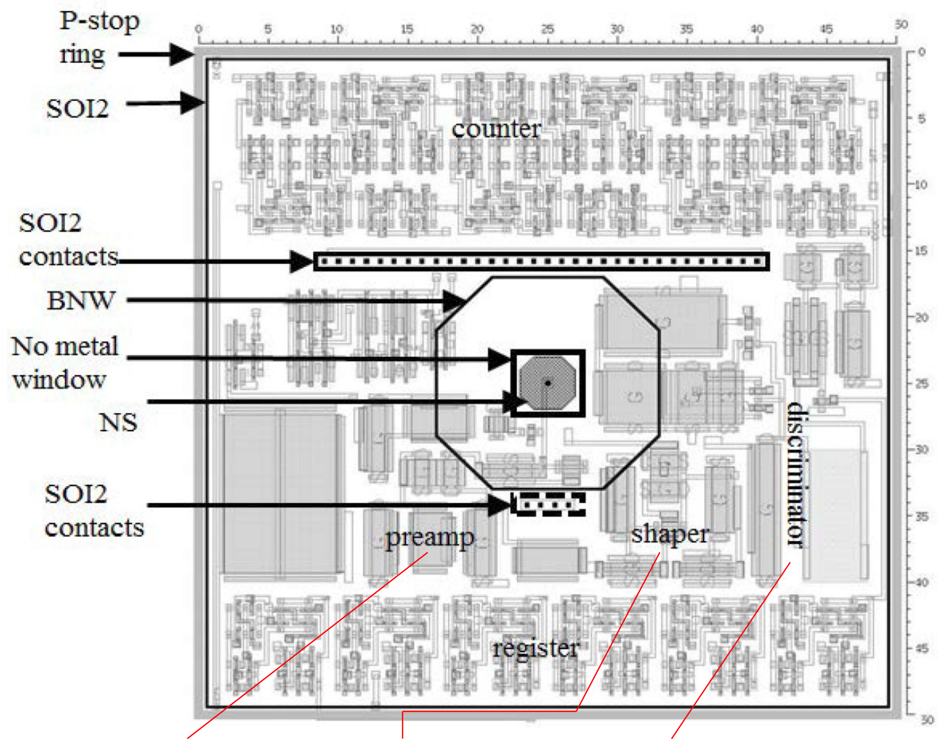
Chip
CPIXTEG3b : 50 μm square pixel
64 × 64 array

Chip layout

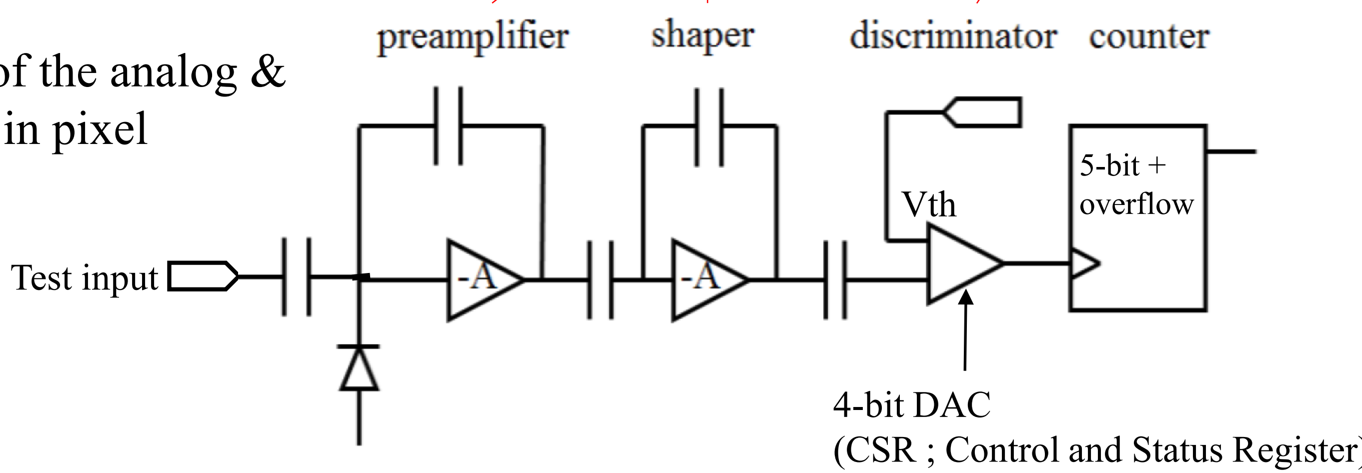


Evaluation of the pulse counting type pixel

Pixel layout

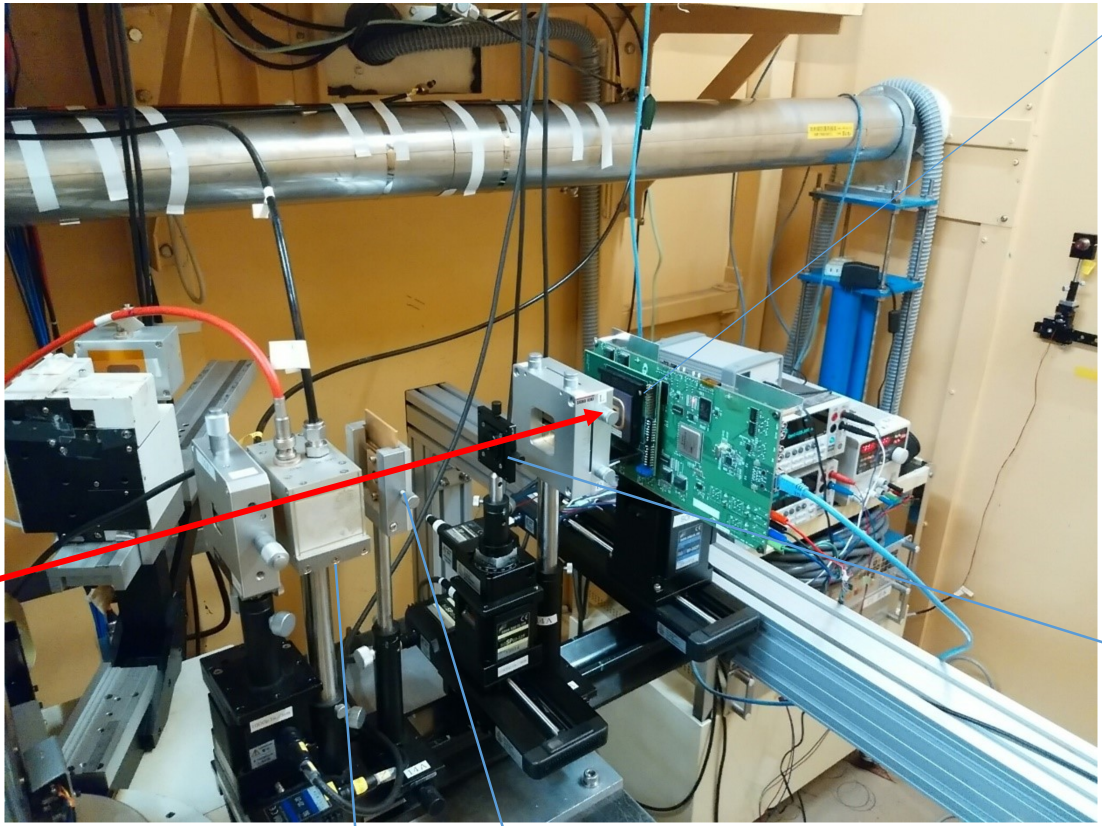


Simple view of the analog & digital circuit in pixel



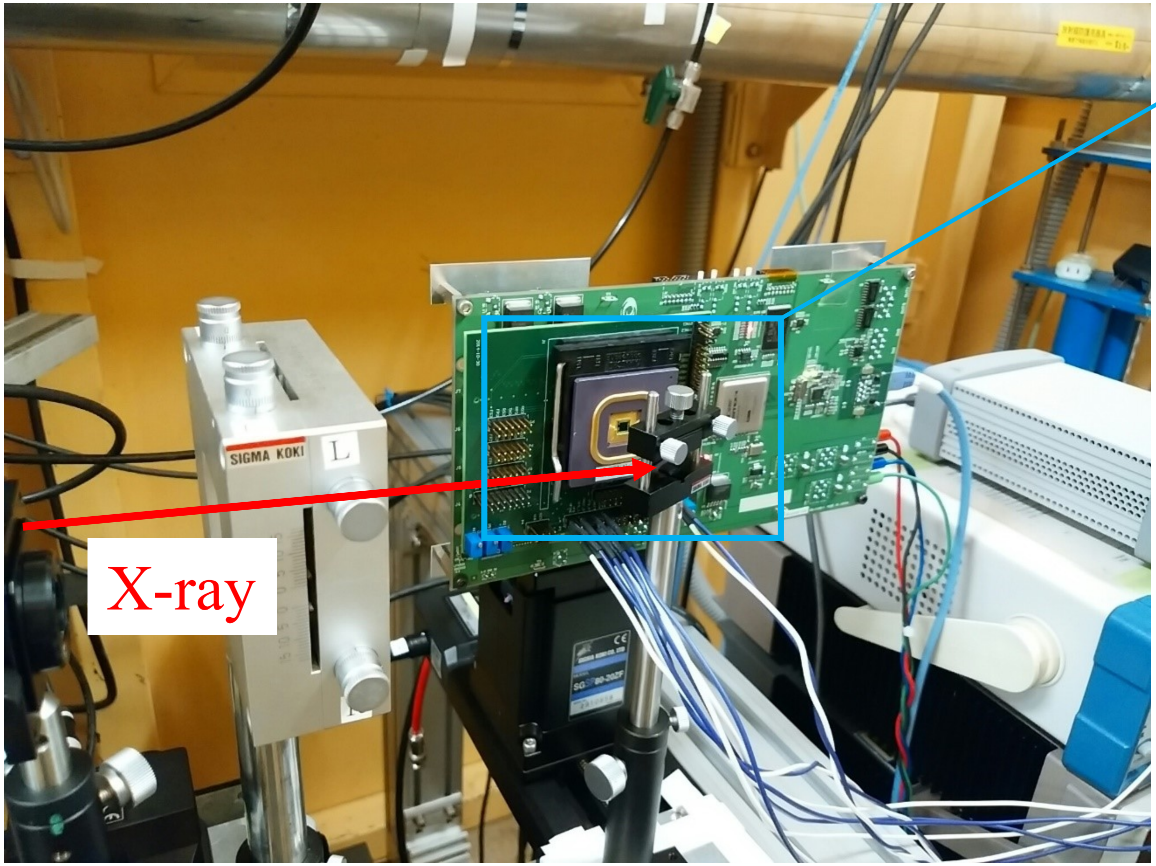
Experimental setup

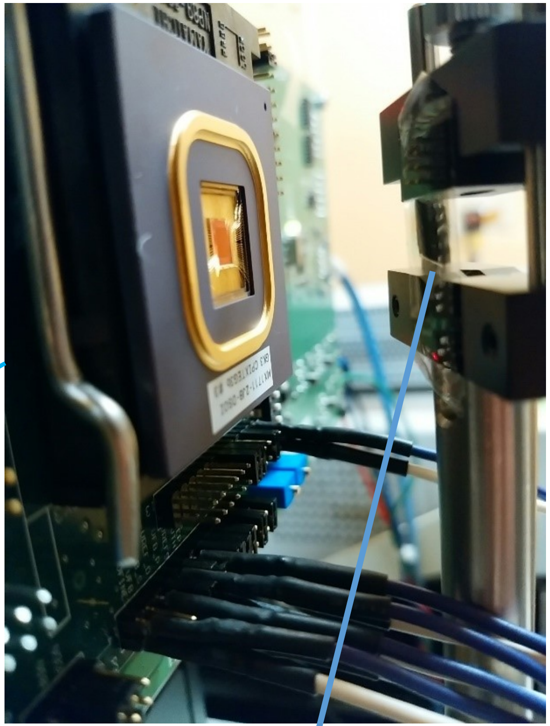
@KEK/PF BL-14A
10 µmφ beam mode



Experimental setup

@KEK/PF BL-14A
Flat field X-ray mode



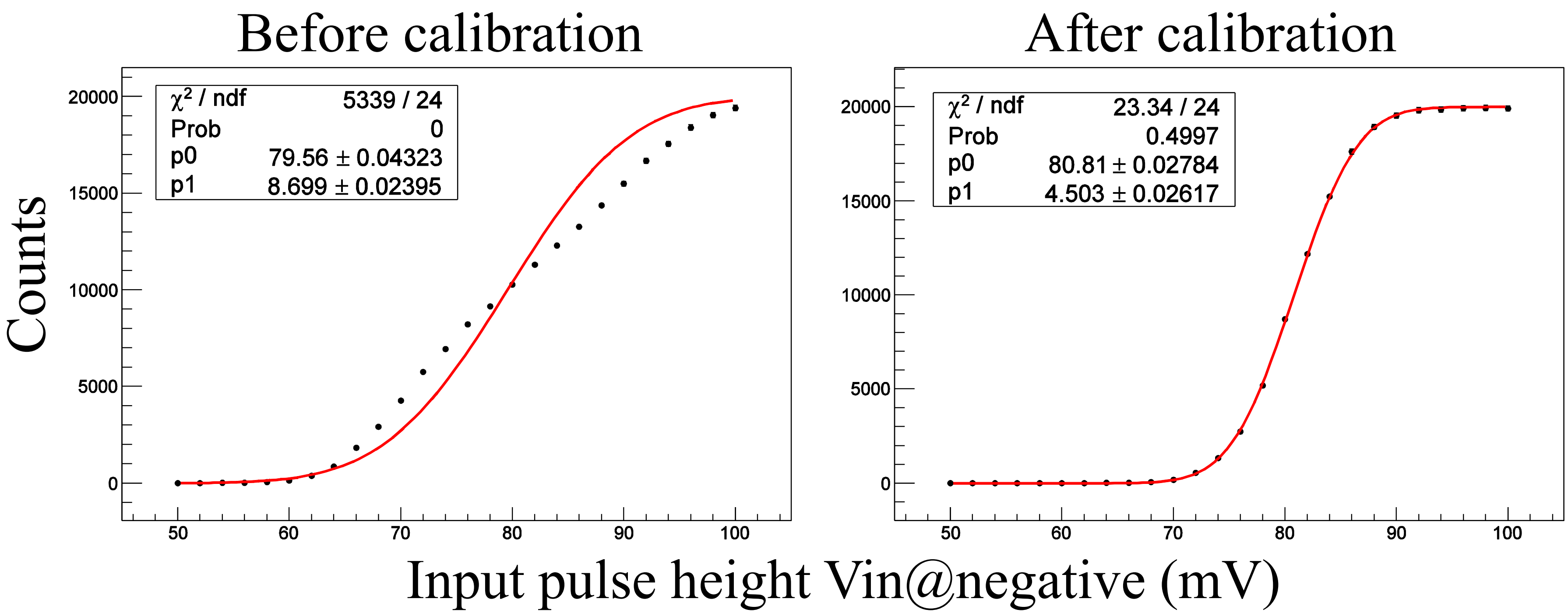


Scattering target
(Glassy carbon)

Calibration of the discriminator

CSR adjustment by test pulse
The discriminator can be calibrated by 4-bit CSR on each pixels.

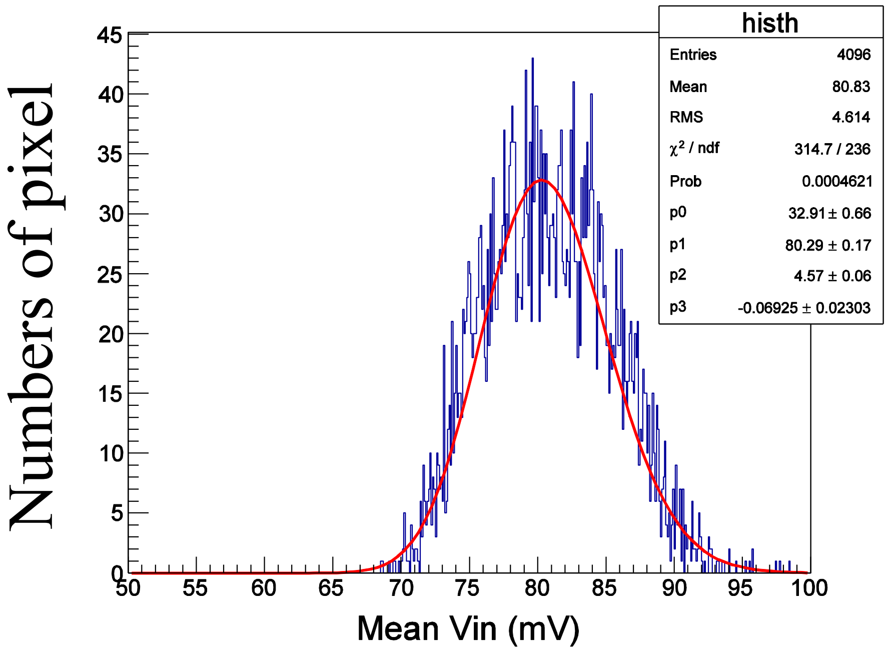
S-curve before/after CSR adjustment



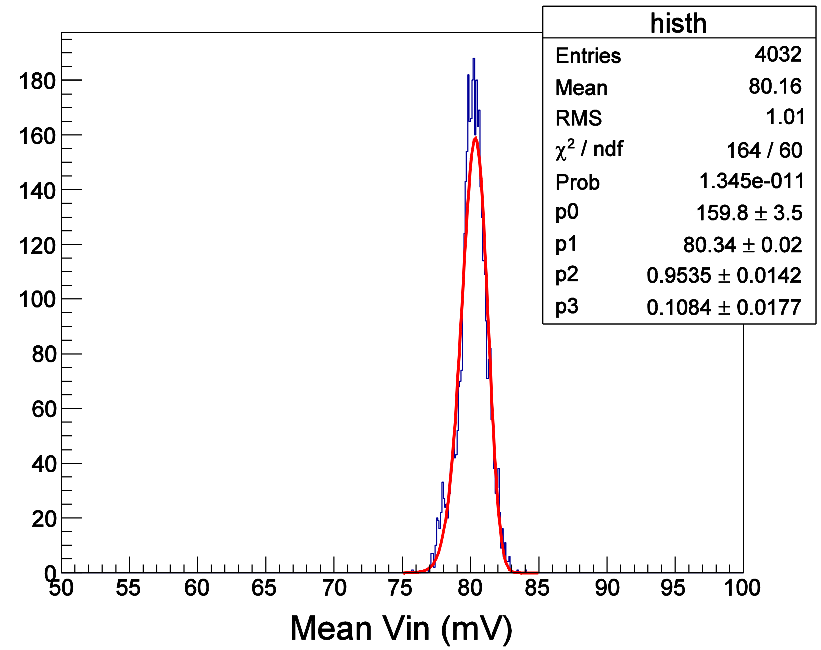
Calibration of the discriminator

Mean distribution of S-curves

Before



After

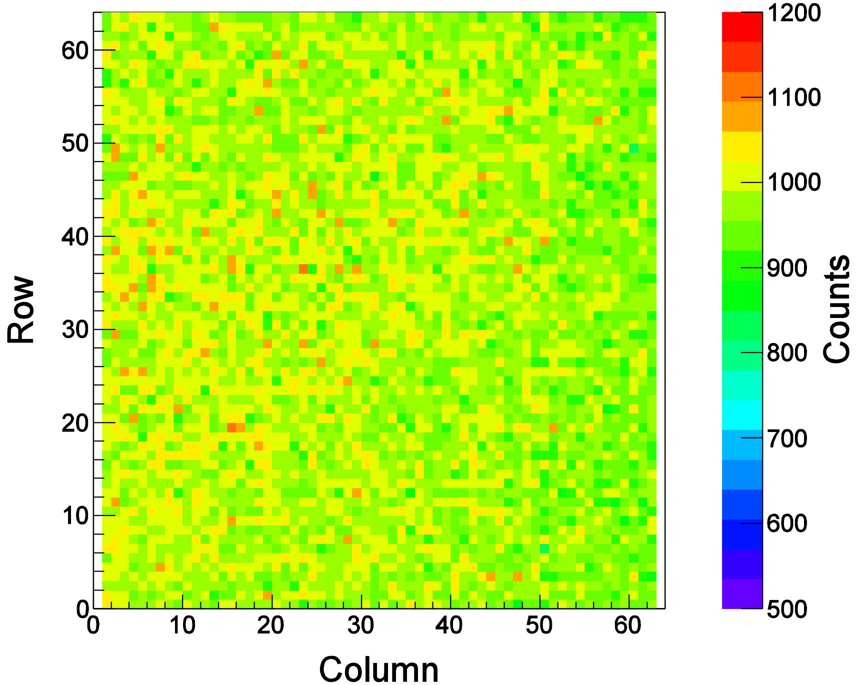


σ value became better to about 5 times.

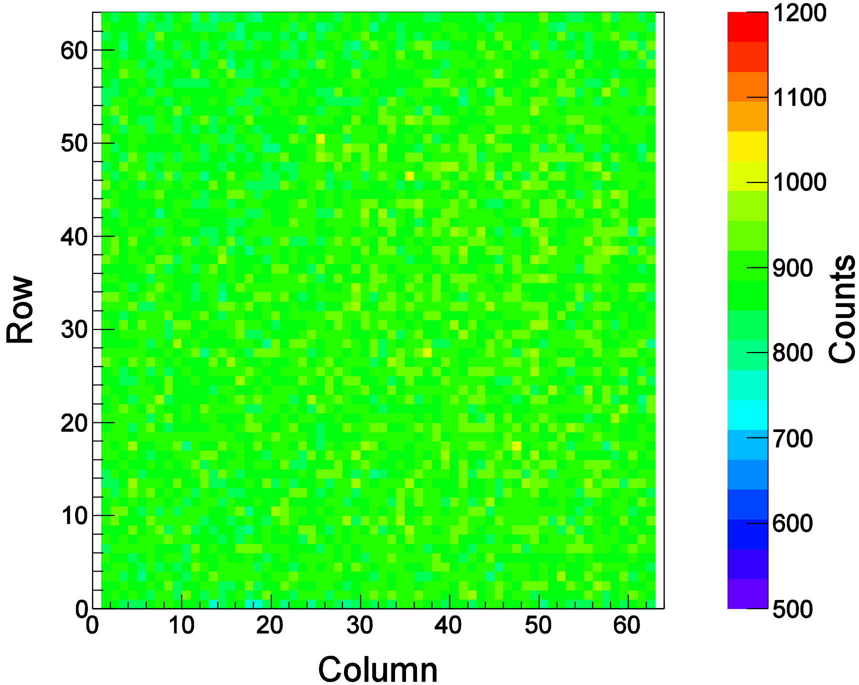
Before : 4.57 mV → After : 0.95 mV @ input pulse height

Calibration of the discriminator

Check by the flat field X-ray

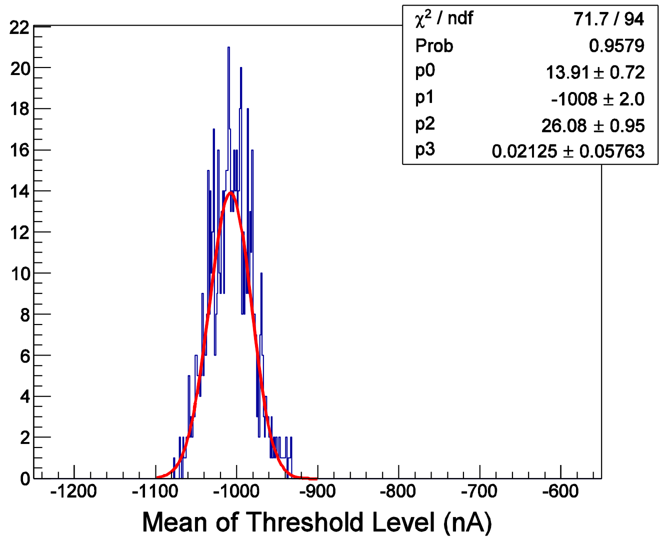


Before

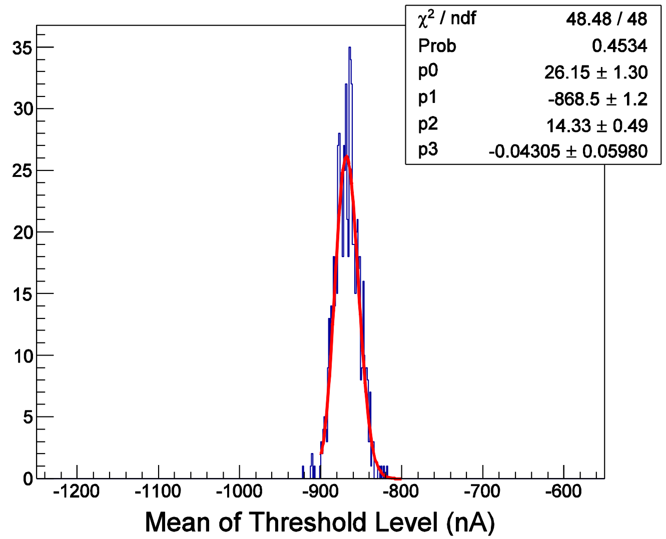


After

Calibration of the discriminator



Before



After

In the test of threshold level scan with flat field X-ray, threshold dispersion became half by CSR adjustment.
Before : 26 nA → After : 14 nA @threshold level

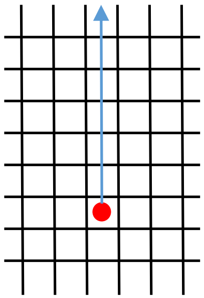
1-dimentional pixel array scan

1-dimensional pixel array scan by 10 μmφ beam

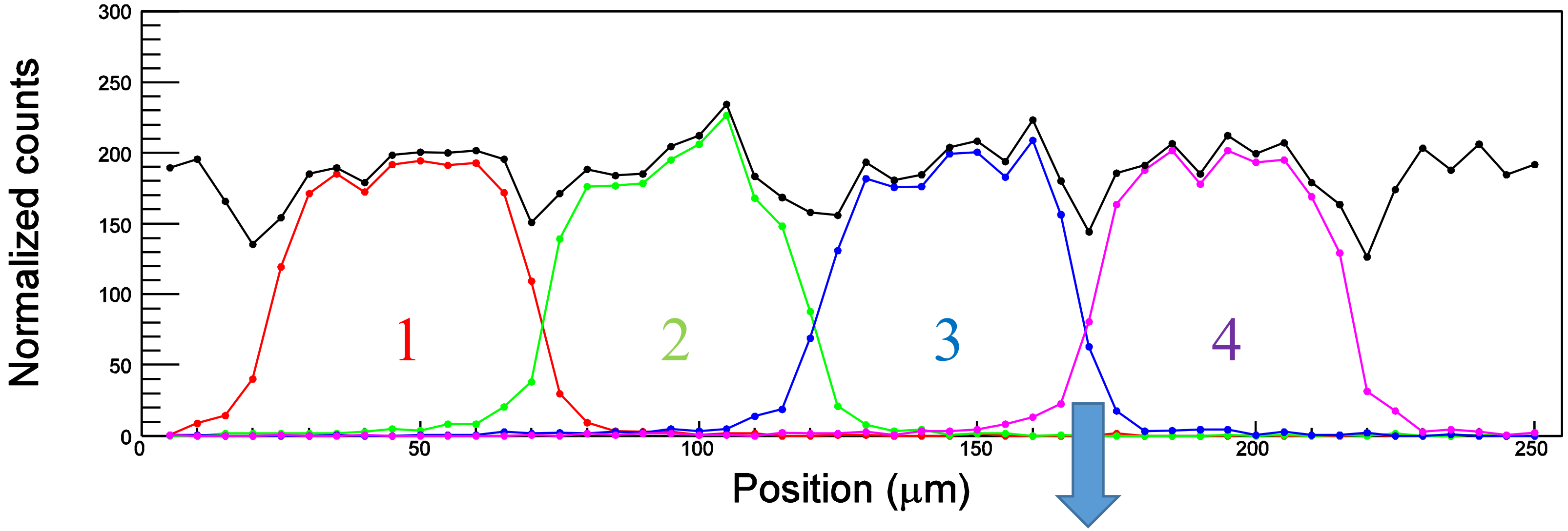
$E_{X\text{-ray}}$ = 16 keV, V_{HV} = -120 V

exposure time = 2 sec / 1point

Threshold = ~1/4 $E_{X\text{-ray}}$



Scan by 5 μm step



▪ : Total counts of all pixels

▪ ▪ ▪ ▪ : Counts of each pixels

Multiple count owing to charge sharing and threshold level.

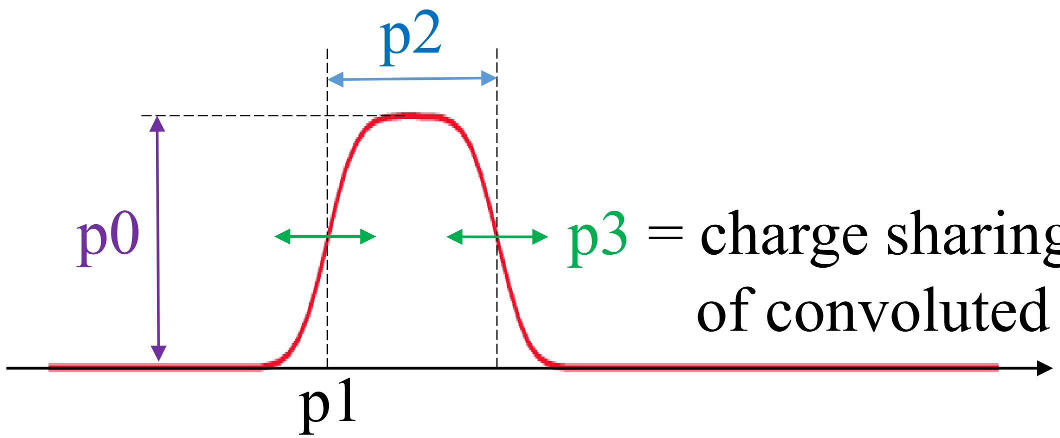
→ For black points, count rate is expected to increase around boundary of pixel but no enhancement (?)

1-dimentional pixel array scan

Evaluation of pixel size and charge sharing effect

Fitting by f(x) as below

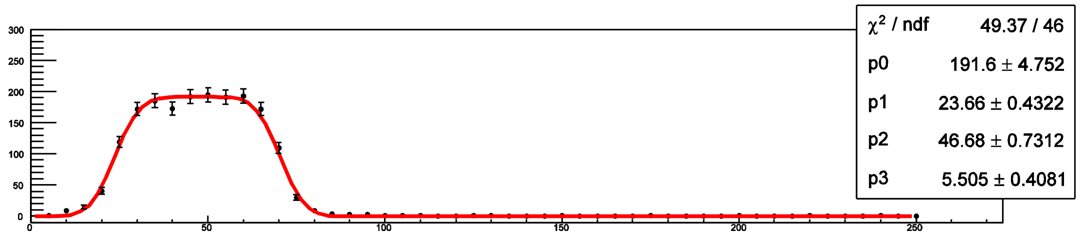
$$f(x) = p0 * \mathrm{Freq}((x-p1)/p3) * (1-\mathrm{Freq}((x-(p1+p2))/p3))$$

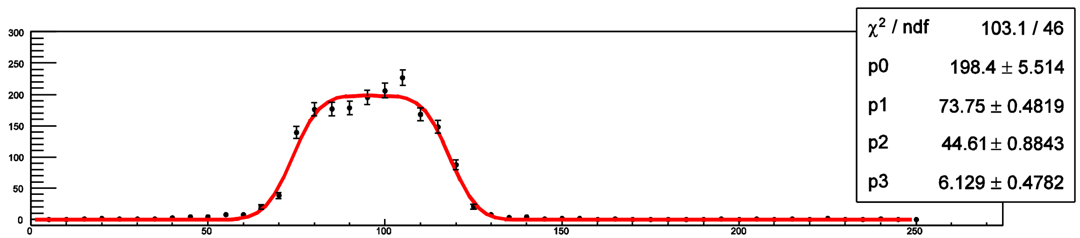


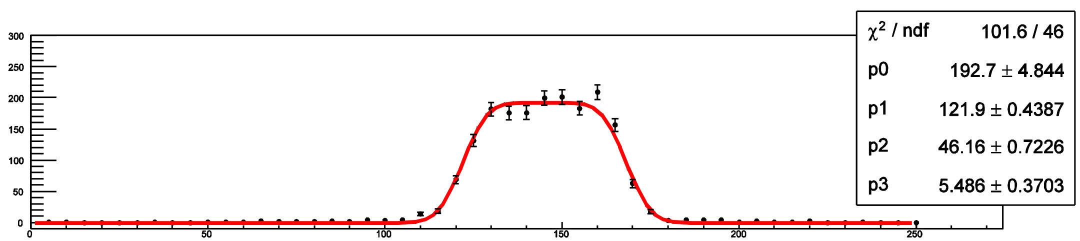
p3 = charge sharing effect declared by σ of convoluted Gaussian

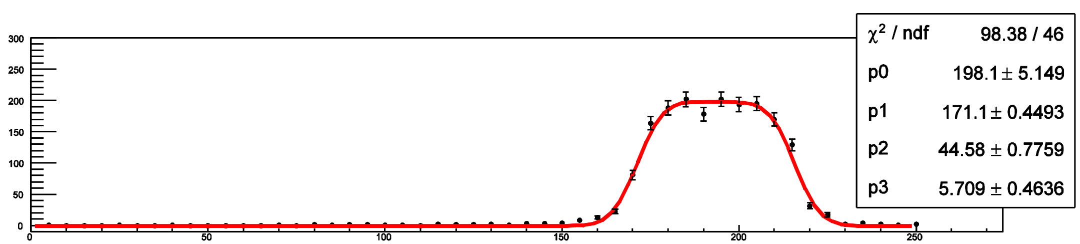
Beam size effect is not clearly contained in f(x).
(implicitly included in p3)

1-dimentional pixel array scan









p2 : size of a pixel (μm)
～ 45 μm
→ 5 μm smaller
due to low detection efficiency in peripheral area of the pixel.

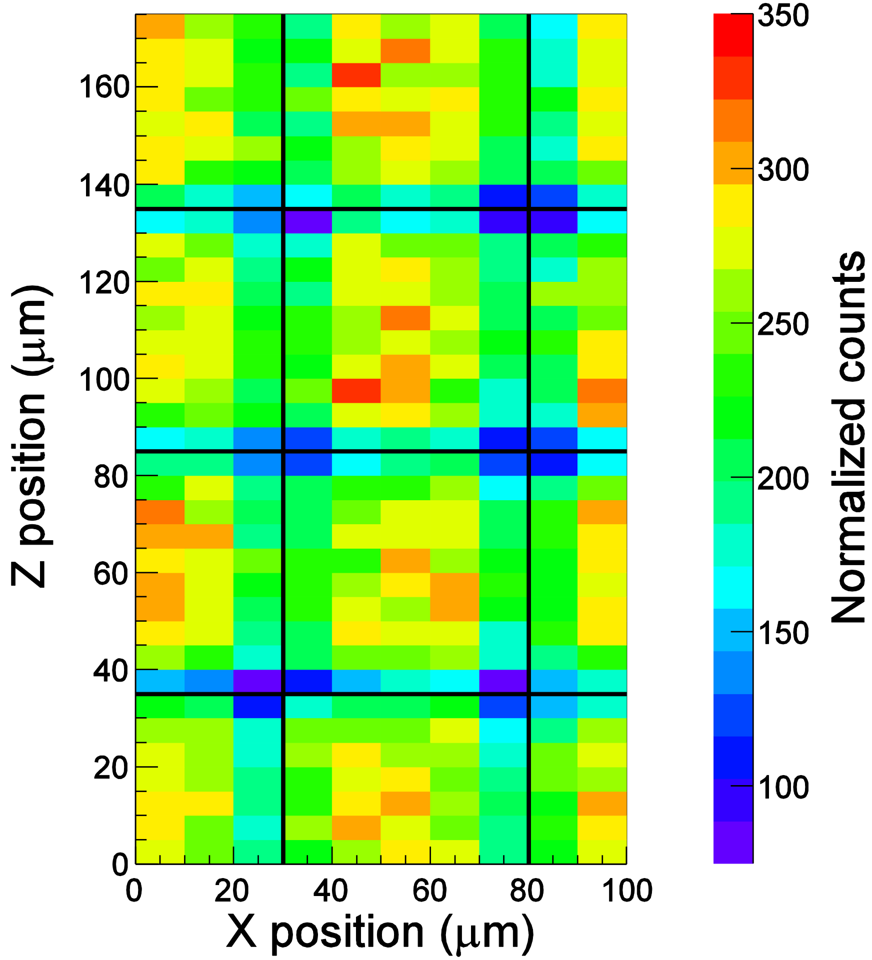
? shortage of the charge collection efficiency

? thickness of the depletion layer is thinner in pixel edge

p3 : degree of the charge sharing effect @σ (μm)
～ 6 μm

2-dimentional pixel array scan

2-dimensional pixel array scan by 10 μmφ beam



Black line : boundary of the pixel

Very low sensitivity in corners of a pixel. Charge was shared in 4 pixels.

Summary

X-ray tests for evaluating the pulse counting type pixel were done in KEK/PF BL-14A.

- Improving the degree of threshold dispersion was succeeded by discriminator calibration.

- The peripheral part of the pixel had low sensitivity.
  Especially in the corners of the pixel, sensitivity was very low because of the effect of charge sharing among 4 pixels.
    about 1/4 counts compared with the center area.

Outlook

The next pixel is designed to resolve charge sharing effect.
It is equipped with a new charge comparing circuit which can determine a true hit pixel in multi-pixel-hit event.

Thank you for your attention !