



SOI sensor for ILC vertex detector: SOFIST

IHEP Mini workshop

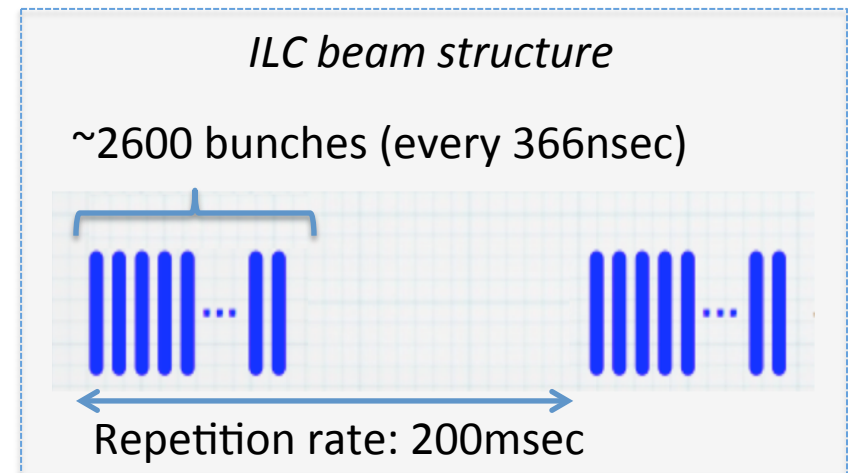
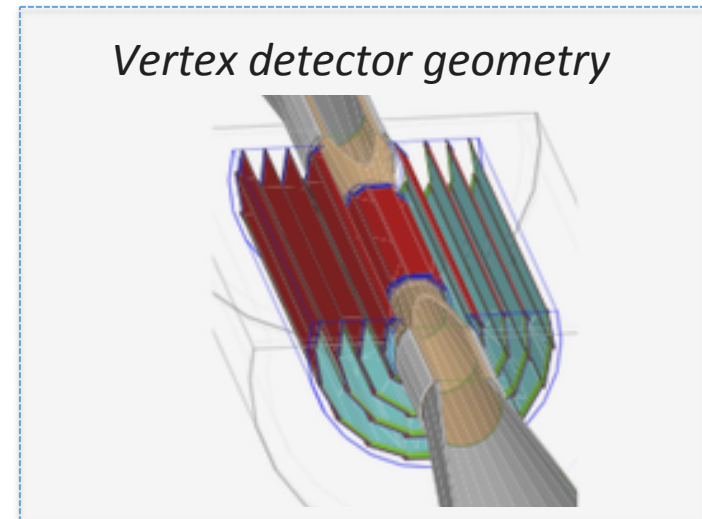
2016/07/15

Shun Ono

(KEK IPNS)

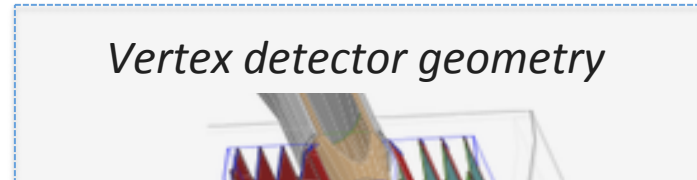
ILC Vertex detector requirements

- Precise determination of particle tracks
 - Better position resolution: $\sim 3\mu\text{m}$
 - Pixel pitch: $\sim 20 \times 20 \mu\text{m}^2$
 - Low material budget: $< 0.1\% X_0/\text{layer}$
 - Sensor thickness: $< 100\mu\text{m Si}$
- Beam bunch-train structure
 - Detector occupancy: $< 2\%$
 - Event separation during bunch collisions
- Radiation damage
 - TID: $\sim 1\text{kGy / year}$



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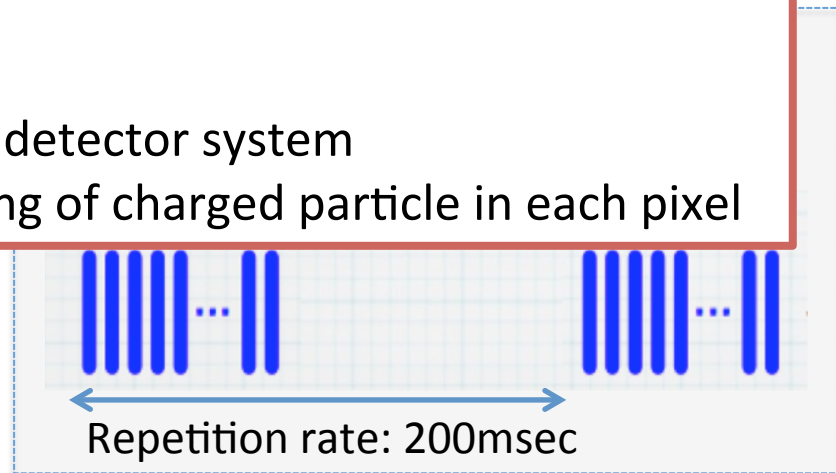
Advantages of SOI pixel sensor

- No mechanical bump bonding: Smaller pixel
- Monolithic detector: Low material budget
- Standard CMOS: Complex functions in pixel circuit
- Double SOI: Tested up to 100kGy



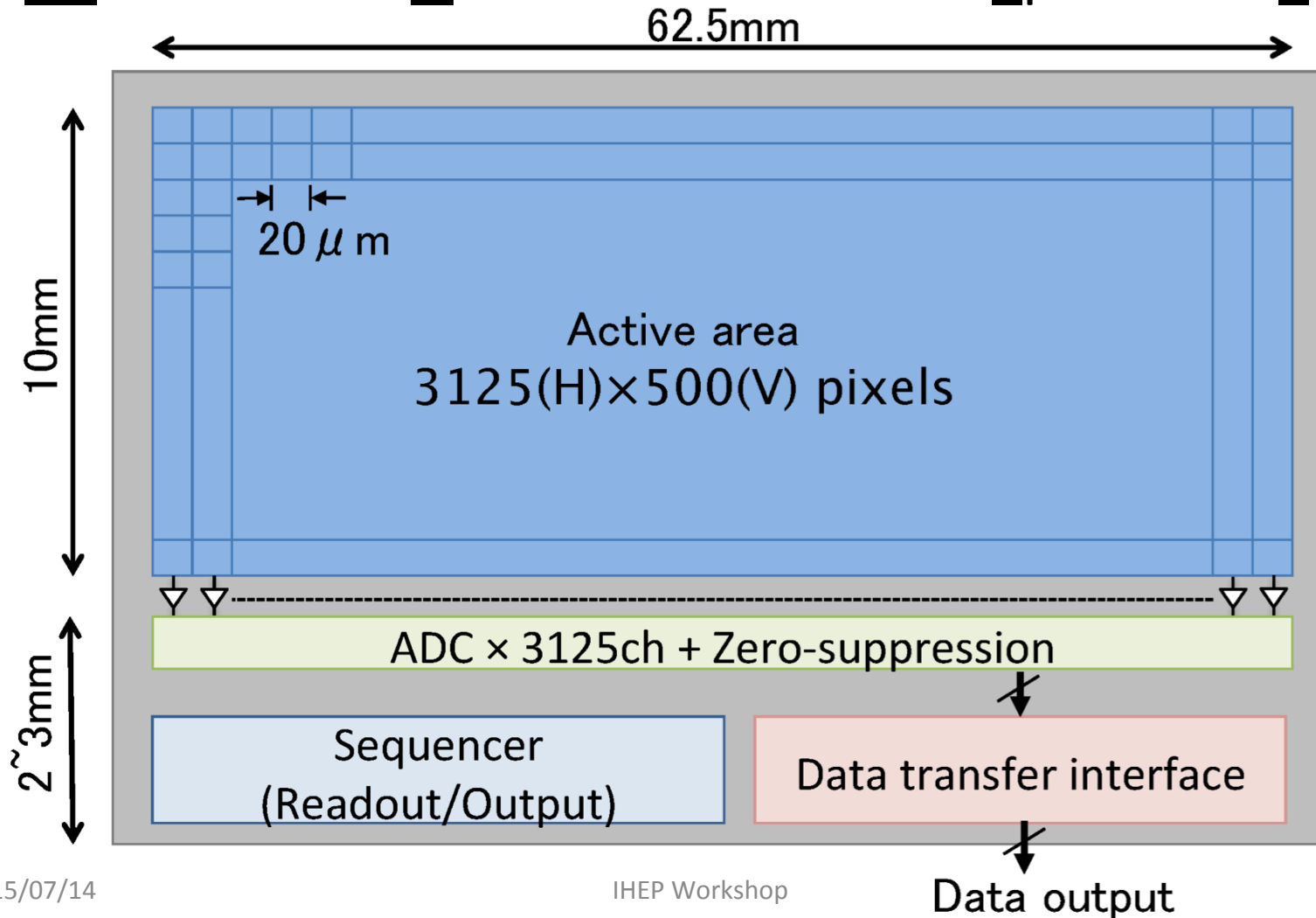
New SOI sensor optimized for ILC Vertex detector system

- Storing both the hit position and timing of charged particle in each pixel
- Radiation damage
 - TID: $\sim 1\text{kGy} / \text{year}$



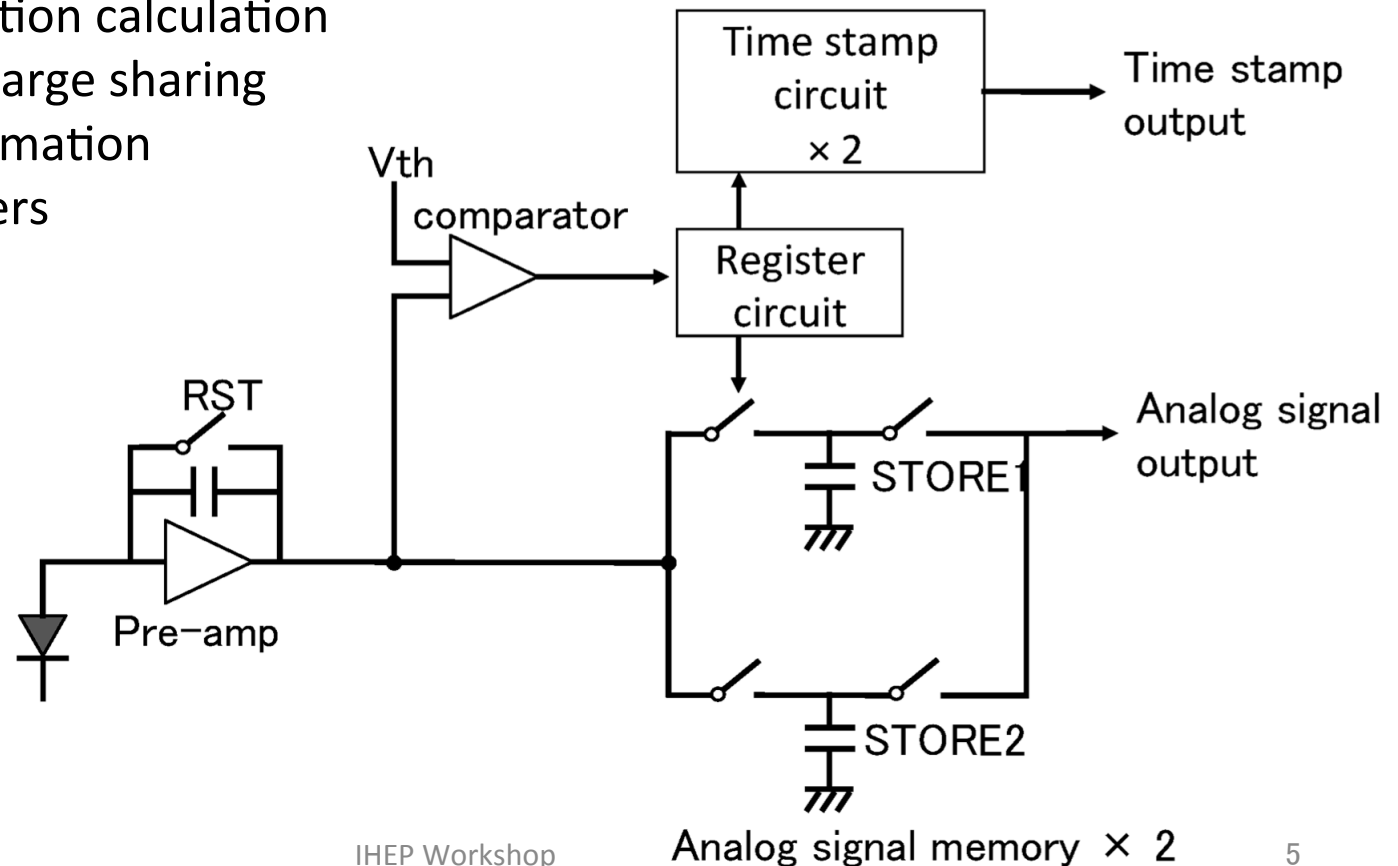
SOI sensor for ILC: SOFIST

- SOI sensor for Fine measurement of Space and Time

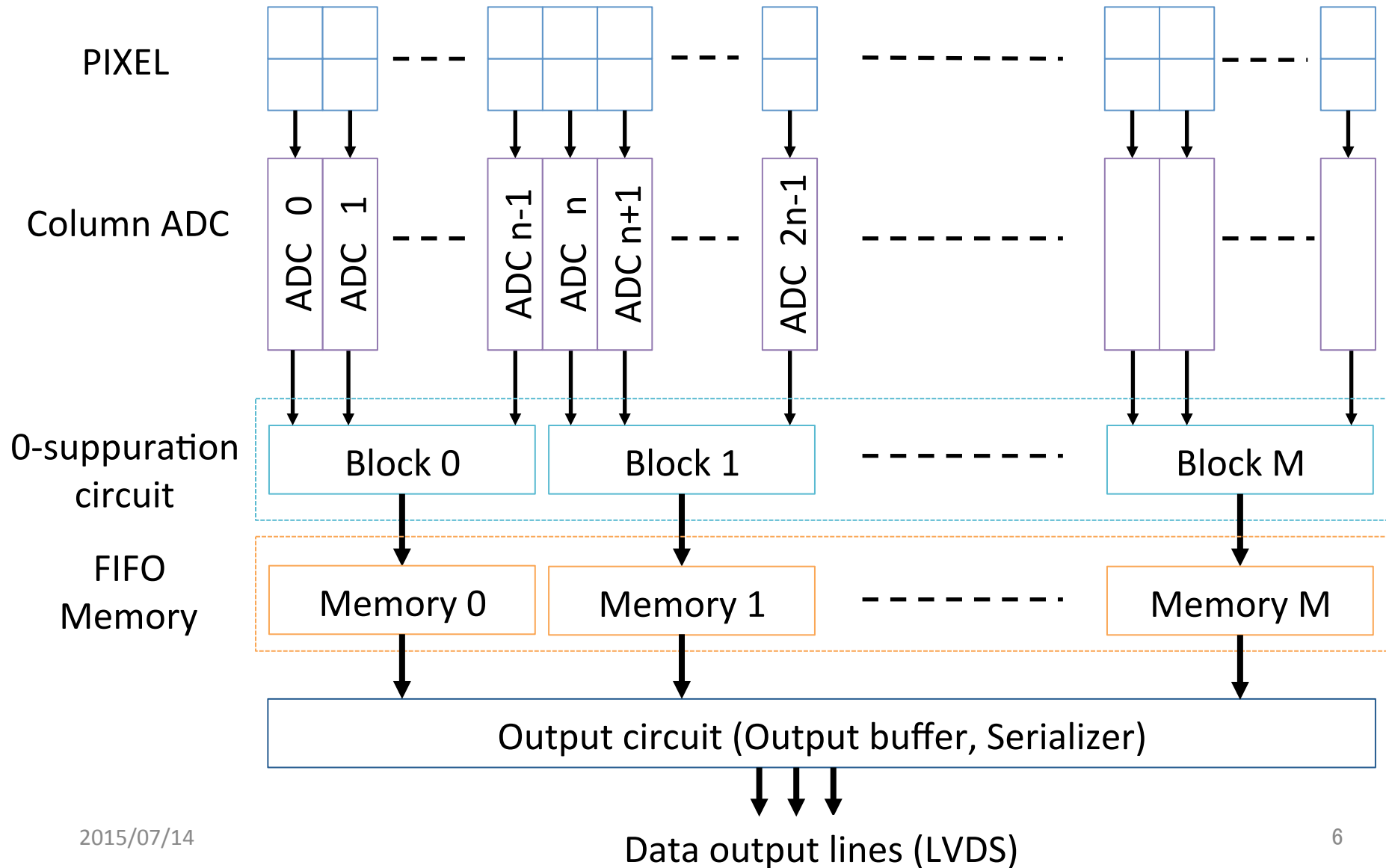


SOFIST pixel architecture

- Implementation area: 20x20 μm^2
- Storage data
 - Charge signal
 - Hit position calculation from charge sharing
 - Timing information
- Multi-store buffers

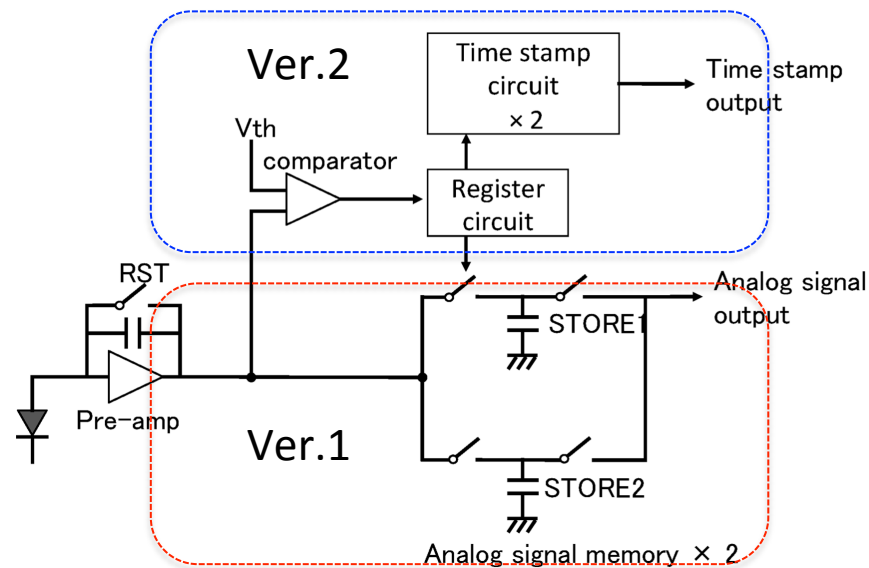


Pixel data output

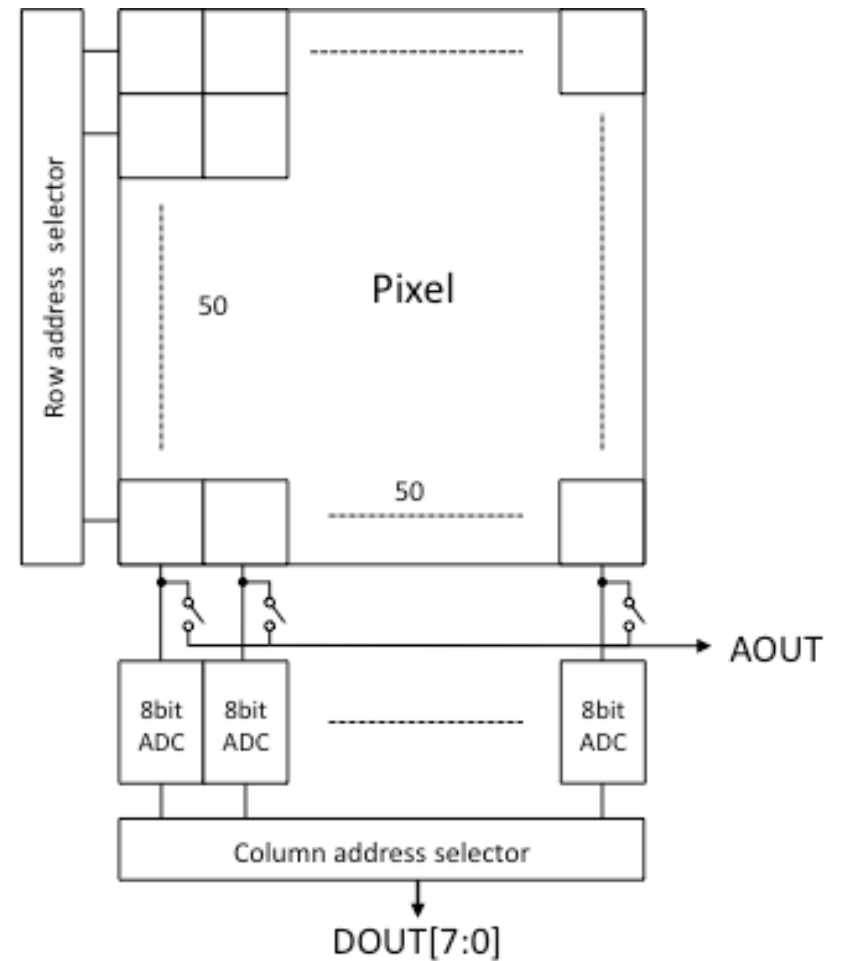
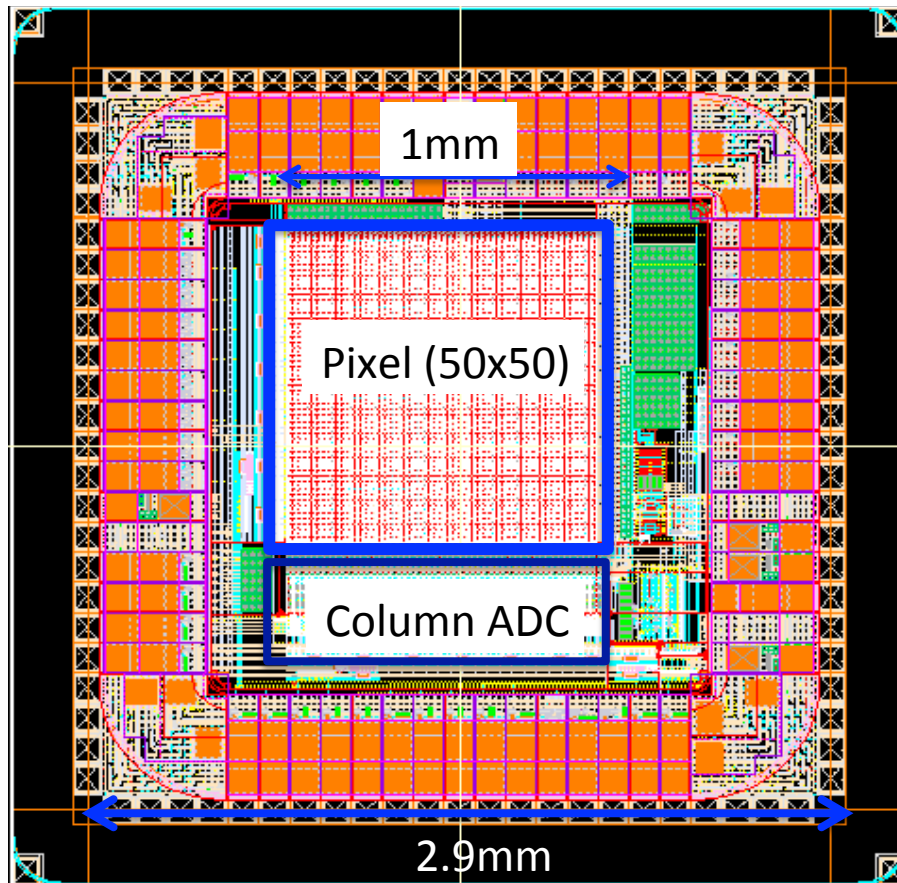


Sensor development

- Development of prototype sensors
 - **Ver.1:** Pixel(Analog signal readout)、Column-ADC
 - Sensor production was done. Evaluation is ongoing
 - **Ver.2:** Pixel(Signal detection, time-stamp) 、Zero suppression
 - Sensor design was finished. (→ Next talk)
 - **Ver.3:** Pixel integrated both analog signal readout and time stamp.

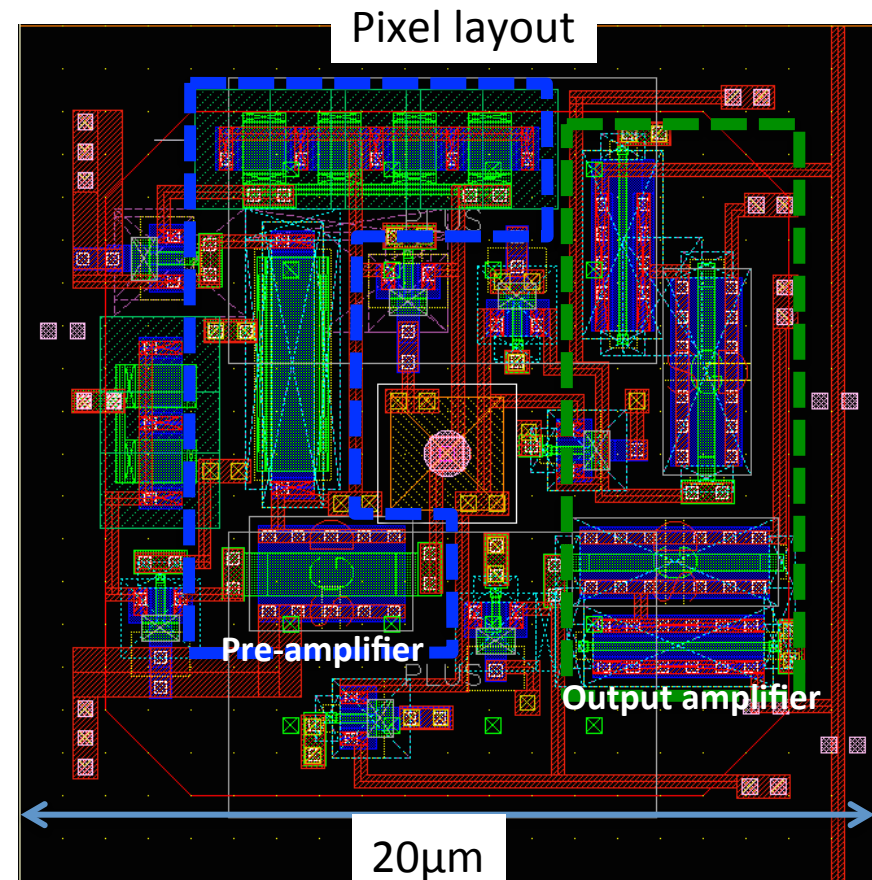
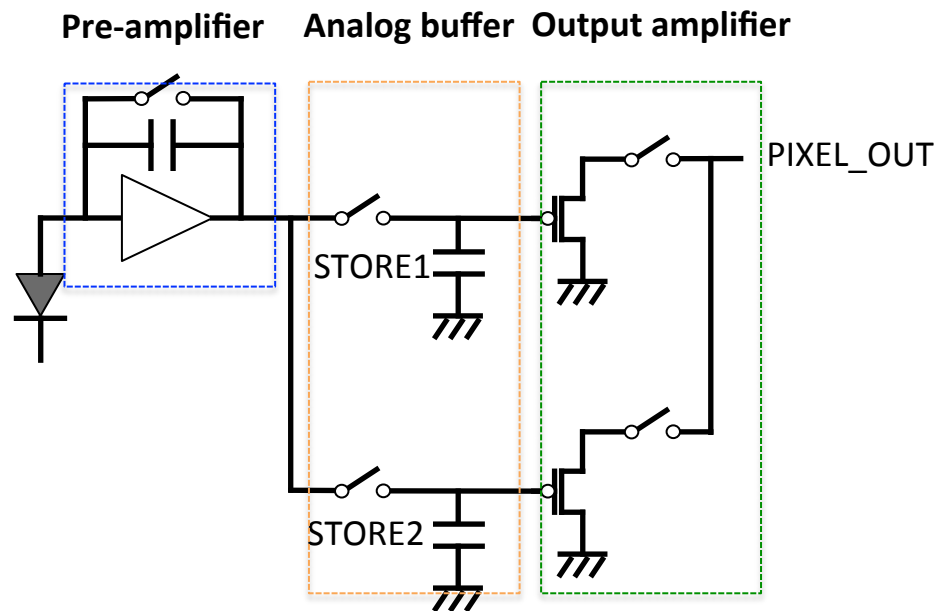


SOFIST Ver.1: Chip, pixel circuit



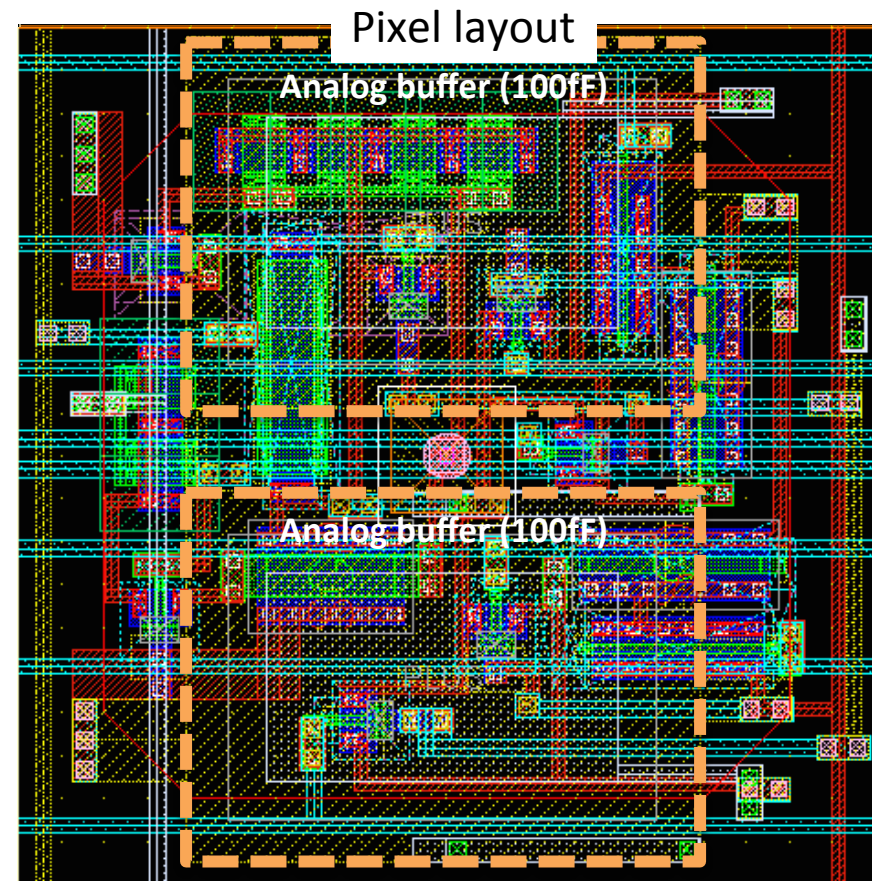
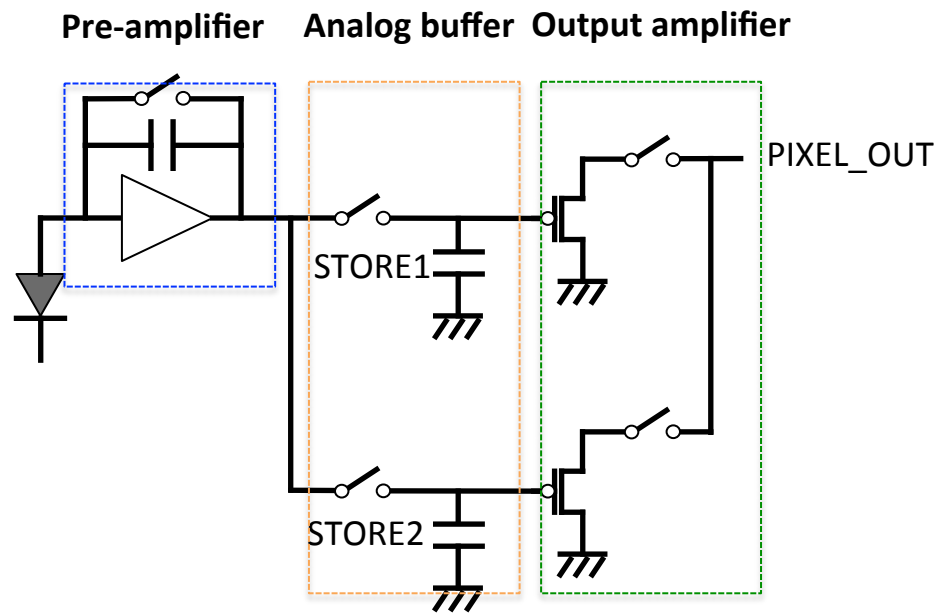
SOFIST Ver.1: Pixel layout

- Pixel circuit schematic and layout
 - Pixel size: 20x20 μm
 - Analog buffer: 2
 - Conversion Gain:
 - 32 $\mu\text{V}/\text{e}$ (= 0.12V/MIP @50 μm)
 - 8 $\mu\text{V}/\text{e}$ (= 0.17V/MIP @300 μm)

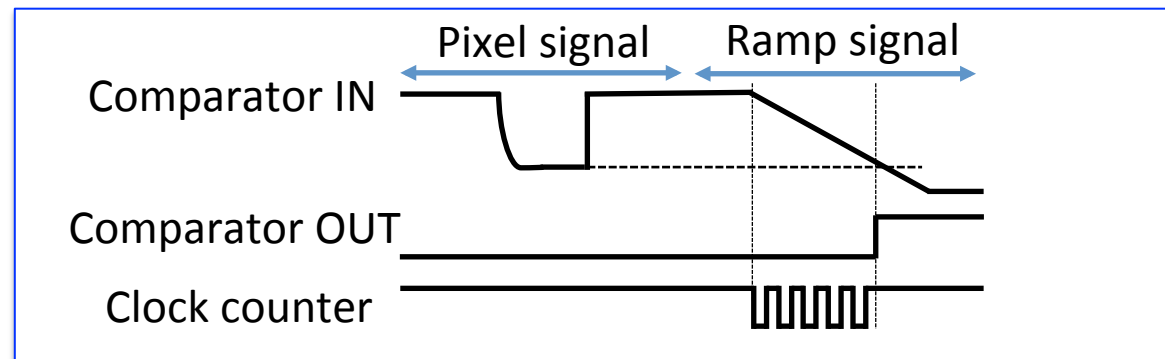
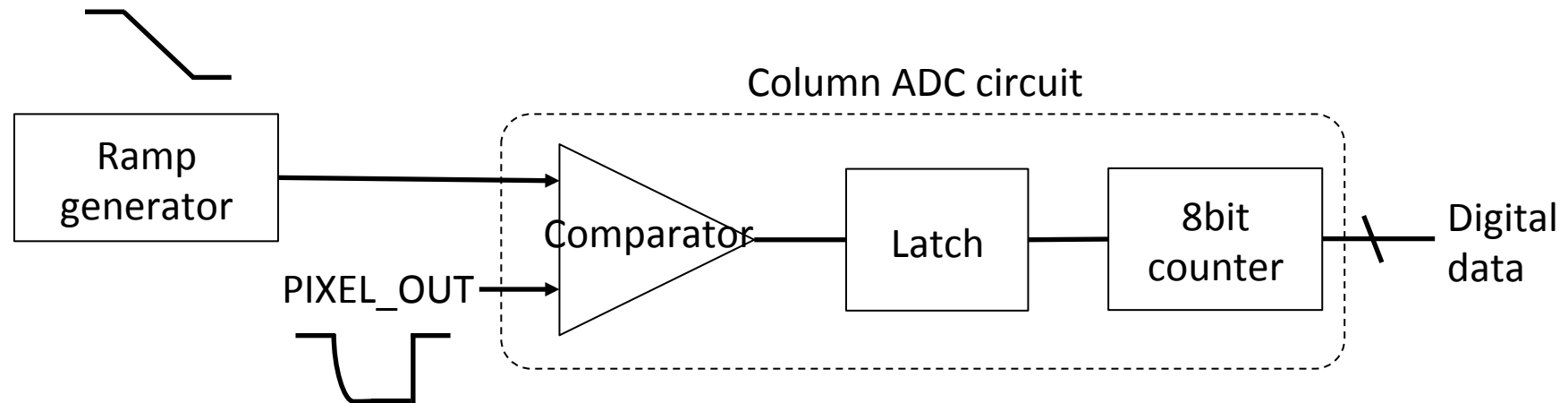


SOFIST Ver.1: Pixel layout

- Pixel circuit schematic and layout
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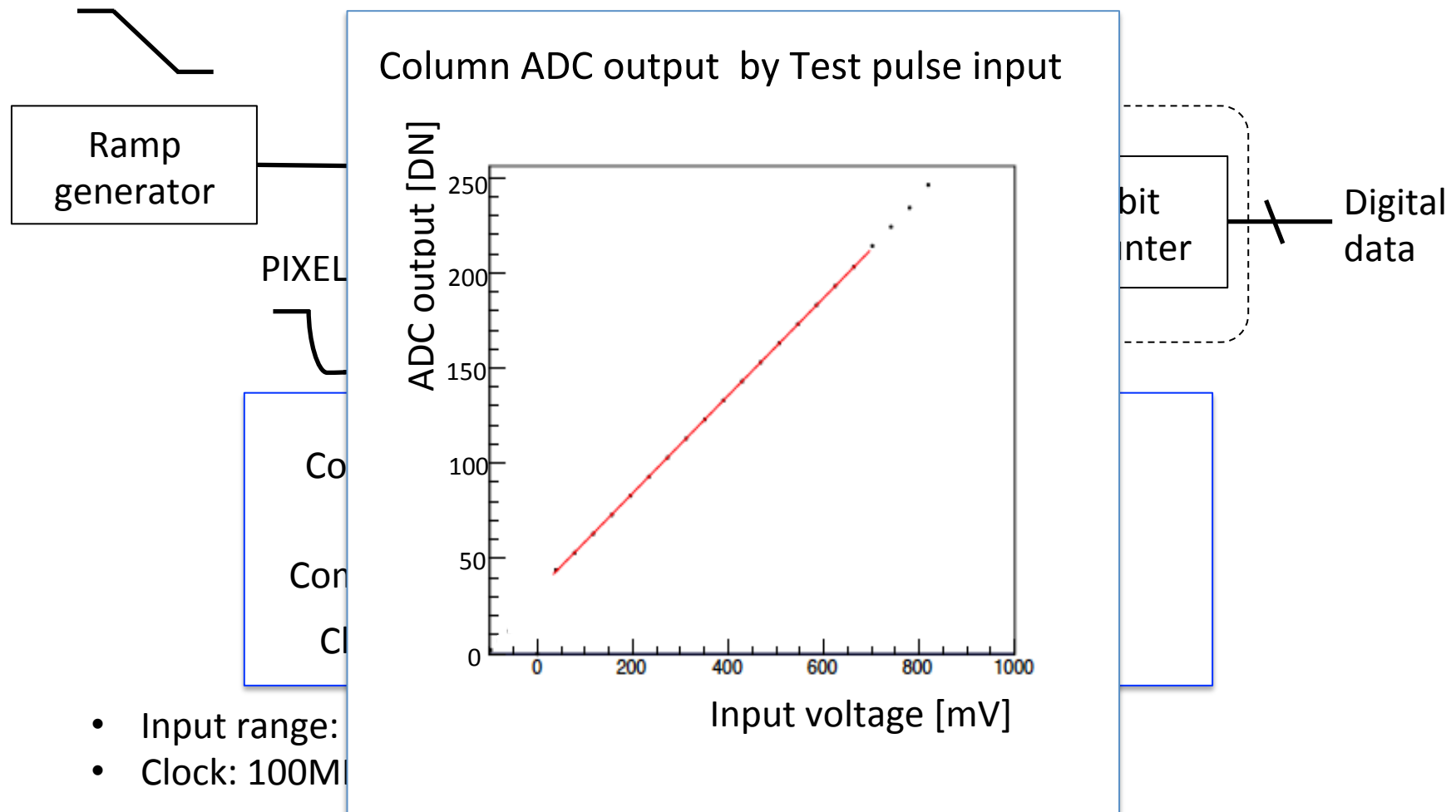


Column parallel ADC



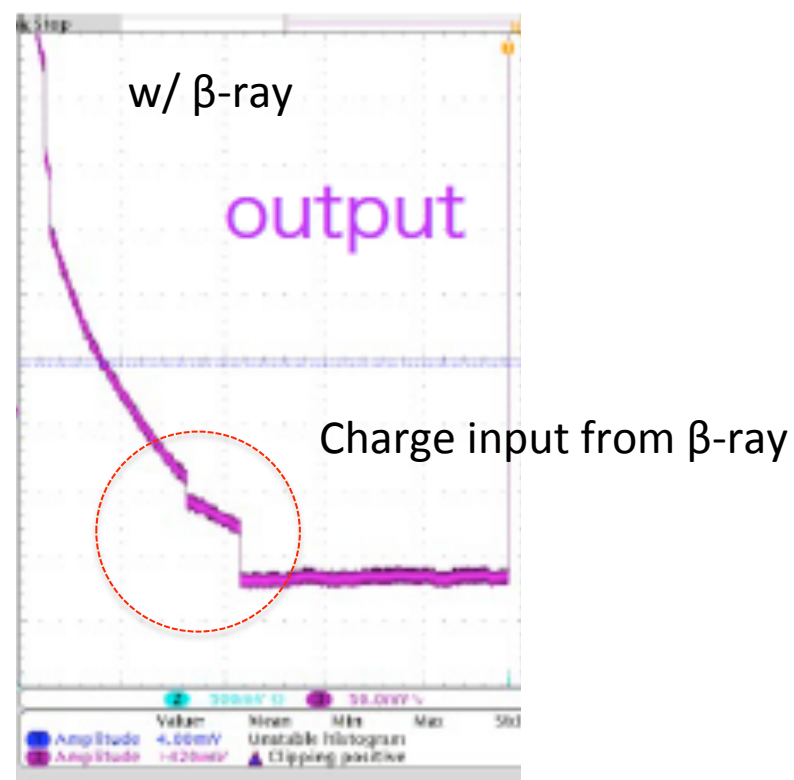
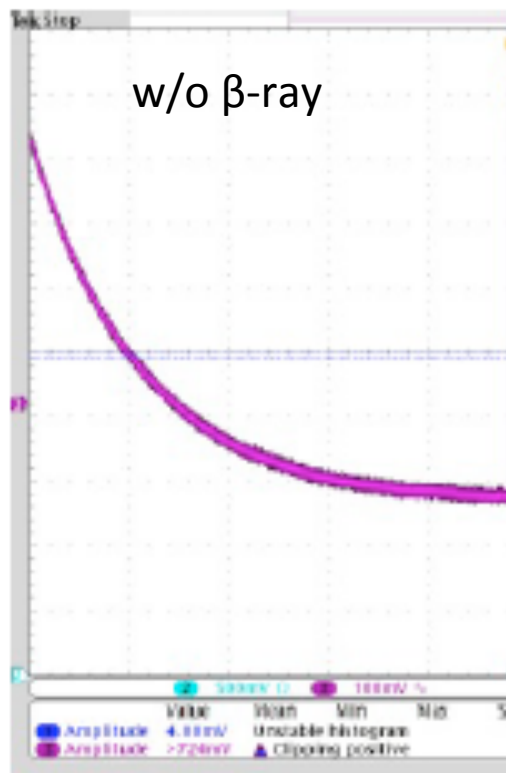
- Input range: 1V, Output: 8bit, Resolution: 1LSB=3.9mV
- Clock: 100MHz

Column parallel ADC



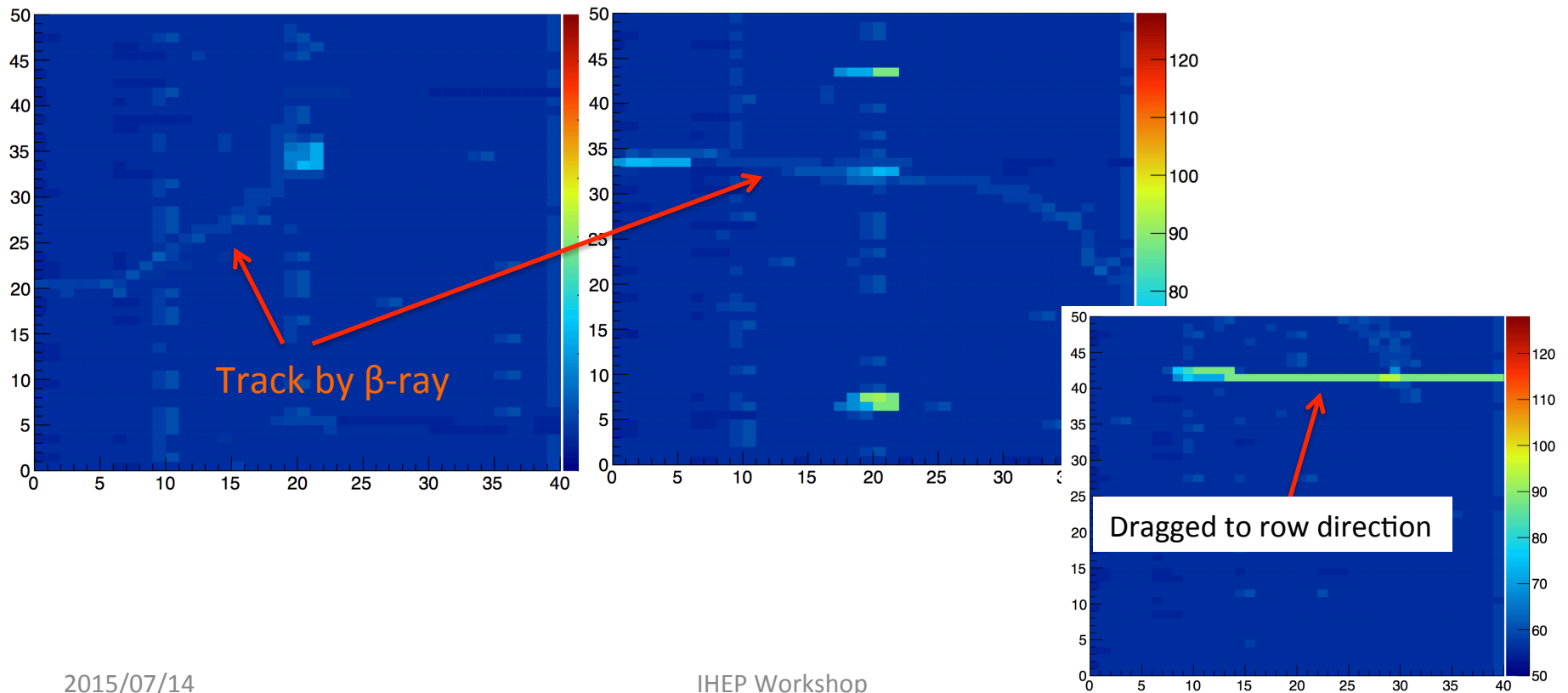
Pixel circuit: Output response

- Measurement of pixel output response
 - Checking source: Sr-90 (β -ray)



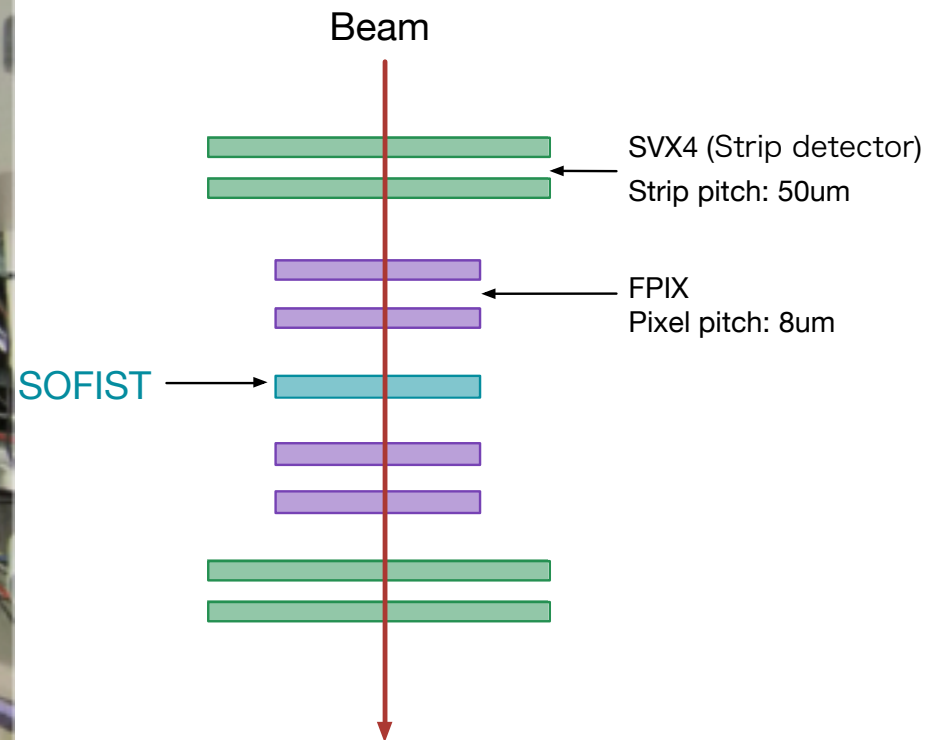
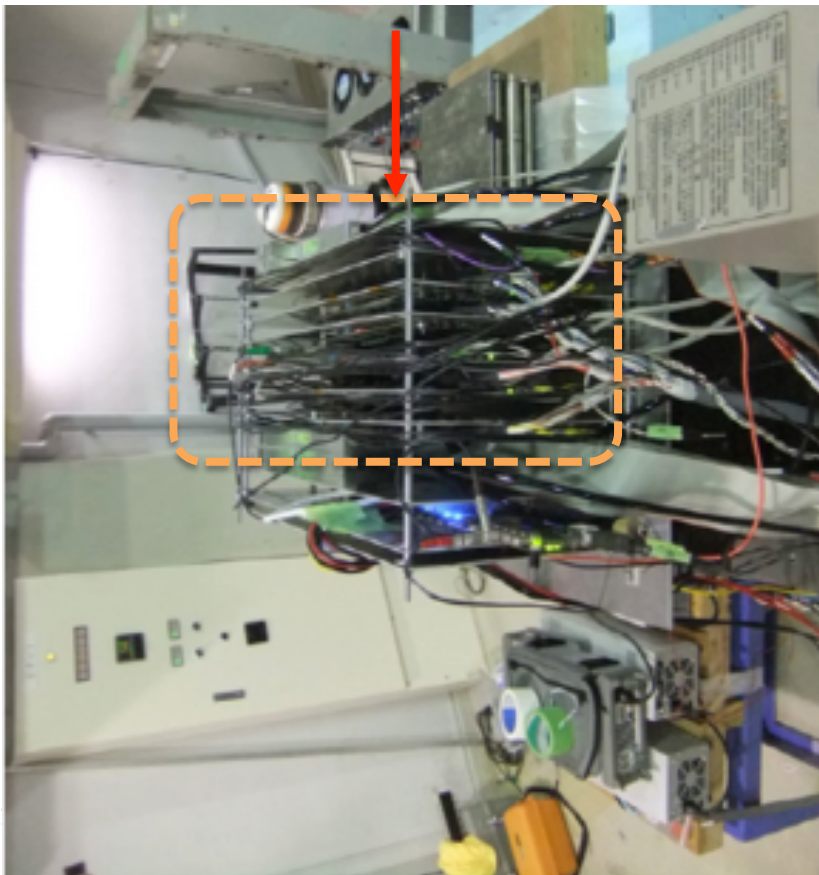
SOFIST Ver.1: Image

- Image data of the Ver.1 chip output. (taken by Column-ADC)
 - Accumulation: 100usec
 - Checking source: Sr-90 (β -ray)



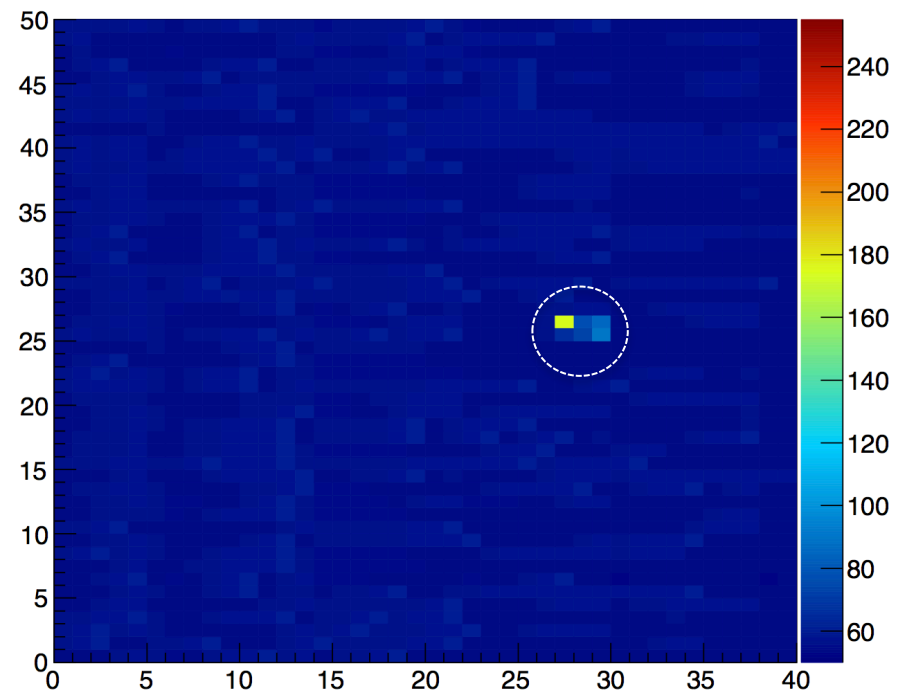
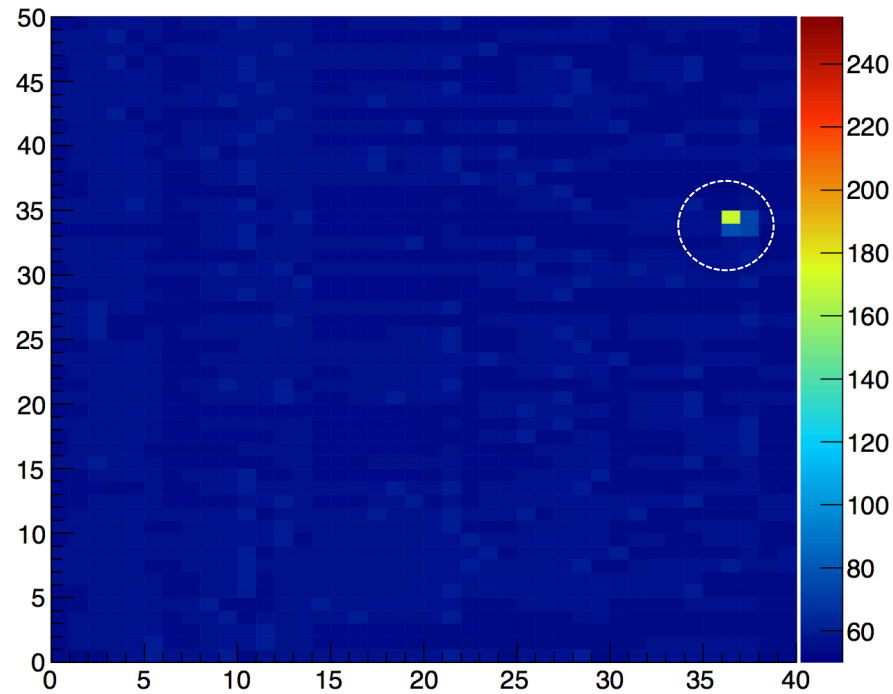
SOFIST Ver.1: Beam test

- Charged particle tracking by beam test
 - 2016/06/22,23 : Tohoku university (ELPH)
 - 2016/12 : FermiLab



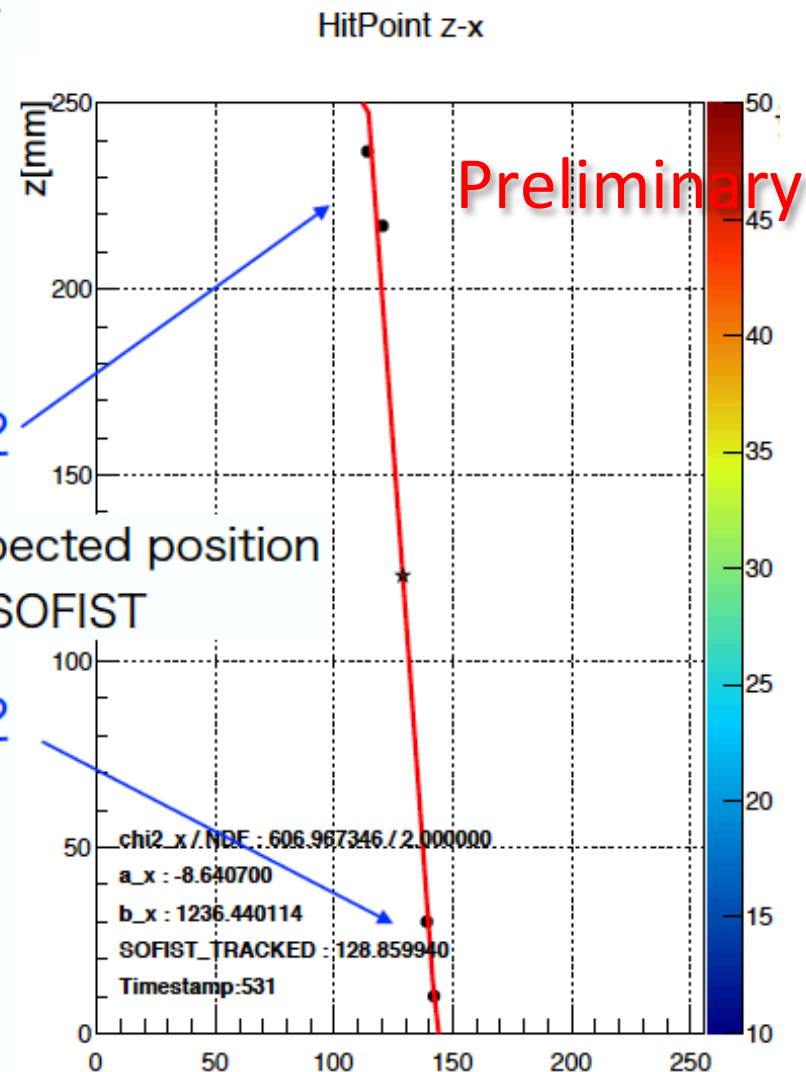
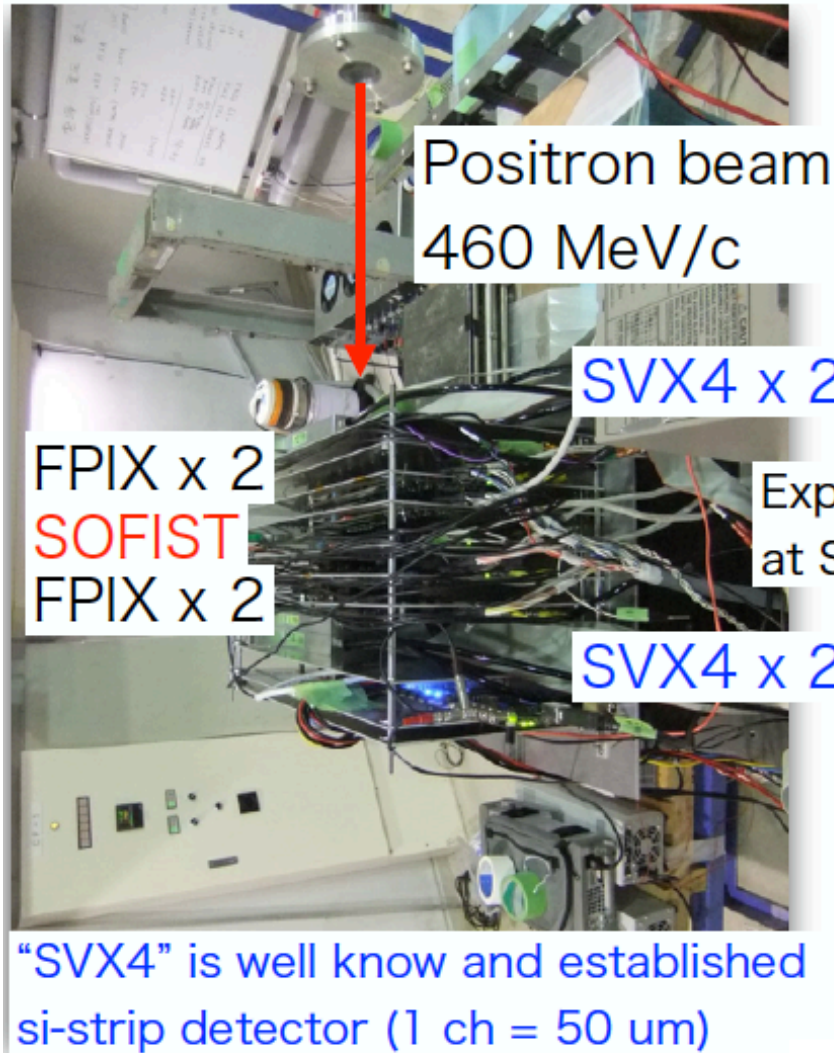
SOFIST Ver.1: Beam test

- Hit detection of positron beam (460MeV/C)



SOFIST Ver.1: Beam test (Tracking)

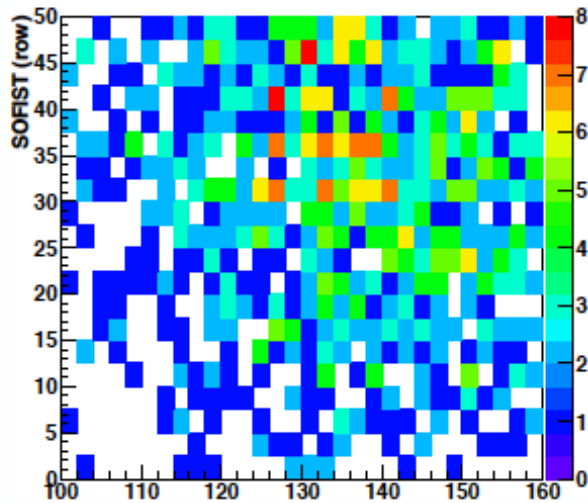
Very rough tracking by SVX4



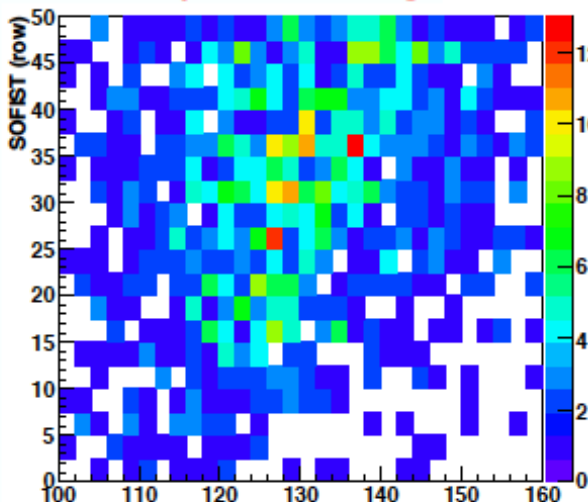
Analyzed by D.Yamamoto, Y.Sawada (Osaka Univ.)

SOFIST Ver.1: Beam test (Tracking)

w/o timestamp matching

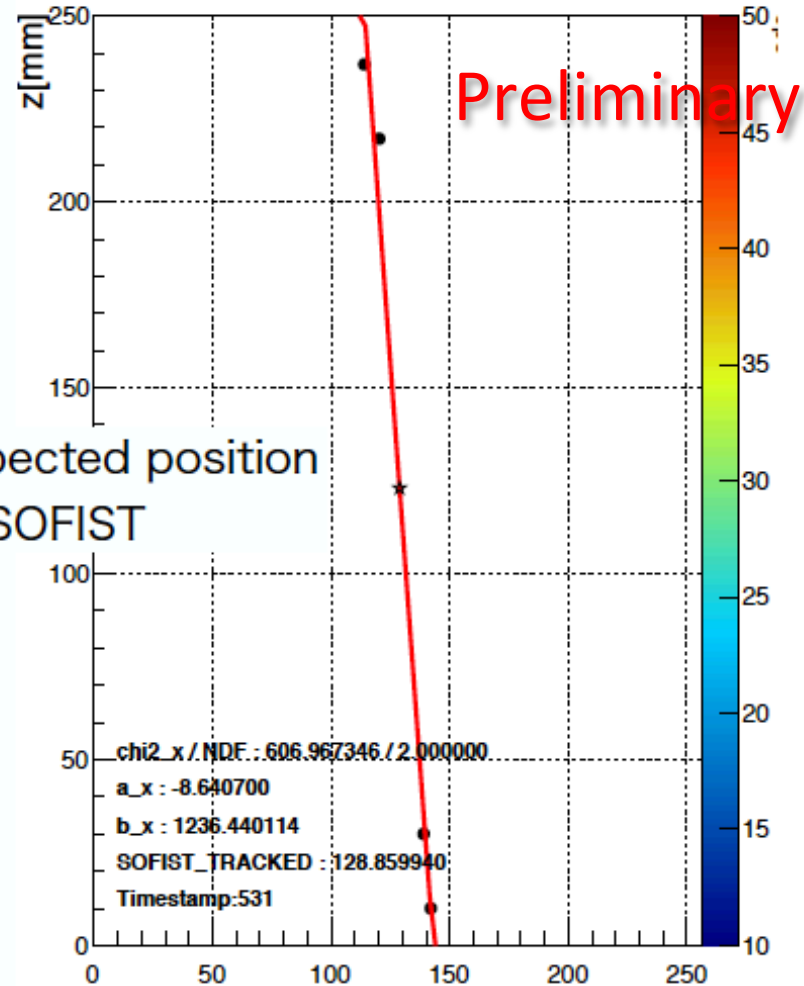


Expected position by SVX4 tracking (ch)
w/ timestamp matching



Expected position by SVX4 tracking (ch)

HitPoint z-x



Analyzed by D.Yamamoto, Y.Sawada (Osaka Univ.)

Summary

- SOFIST: SOI sensor optimized for ILC vertex detector
 - SOFIST stores both position and timing in 20x20um pixel.
- Development of SOFIST Ver.1 chip
 - Pixel with analog signal readout, Column-ADC.
 - Charged particle tracking by beam test.
- SOFSIT1 evaluation is ongoing.
 - Sensor performance: Pixel gain, noise
 - Beam test at Fermilab: Particle tracking, Position resolution