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64-pixel linear-array Si-APD detector for X-ray time resolved experiments

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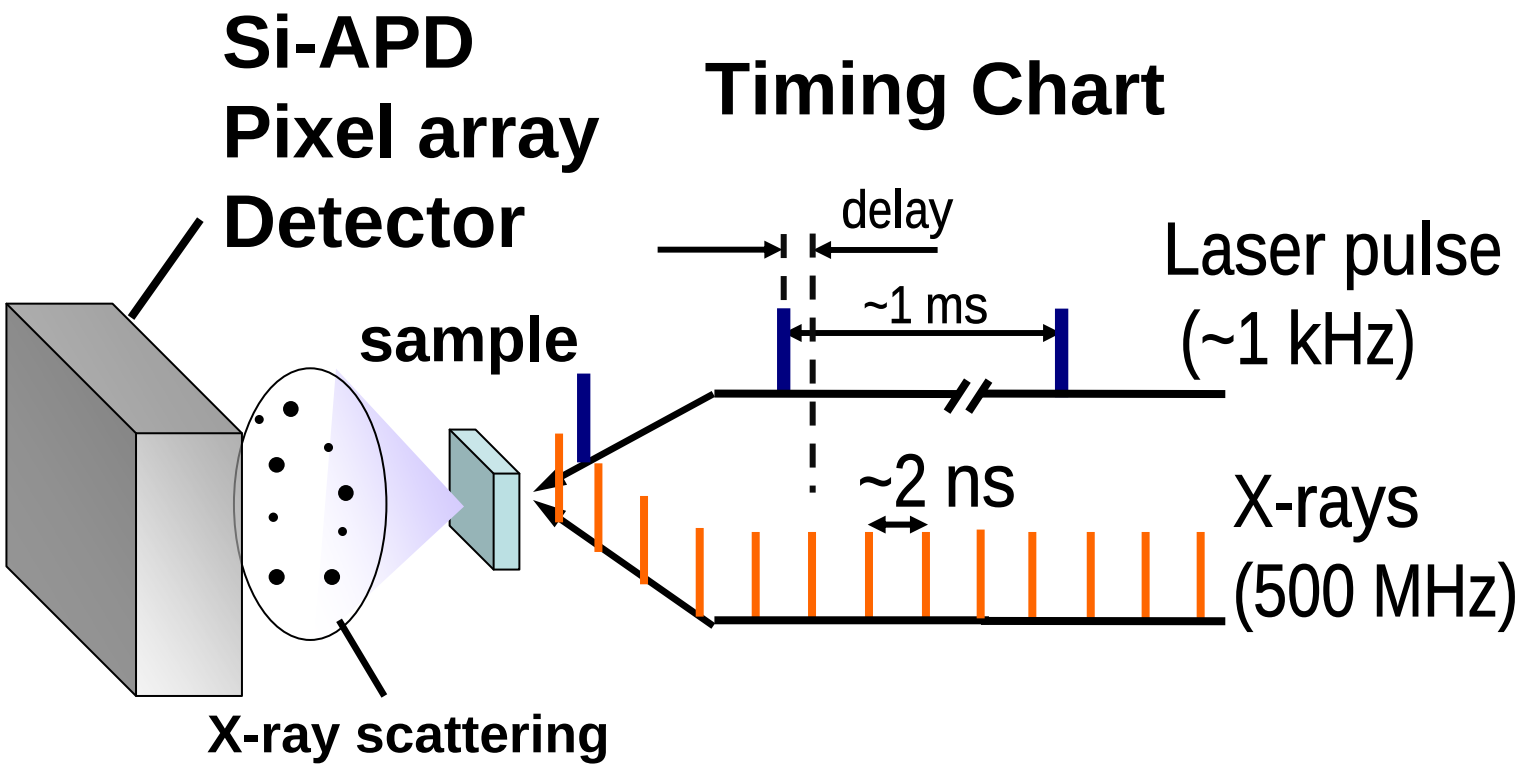
Si-APD pixel array operating in the linear mode :

A high count-rate of > 10^8 s^{-1}/pixel, a sub-nanosecond time resolution and a space resolution (ex.~100 μm)

Nanosecond time-resolved measurements of X-ray diffraction image using 2-ns interval pulses



Difficulties in a Si-APD array

If thick, the gap between pixels increases.

If large, non-uniformity of the gain increases.

64-ch Si-APD linear array:

Hamamatsu S5343-9158

pixel size: $^{H}100\,\mu m \times {}^{V}200\,\mu m$

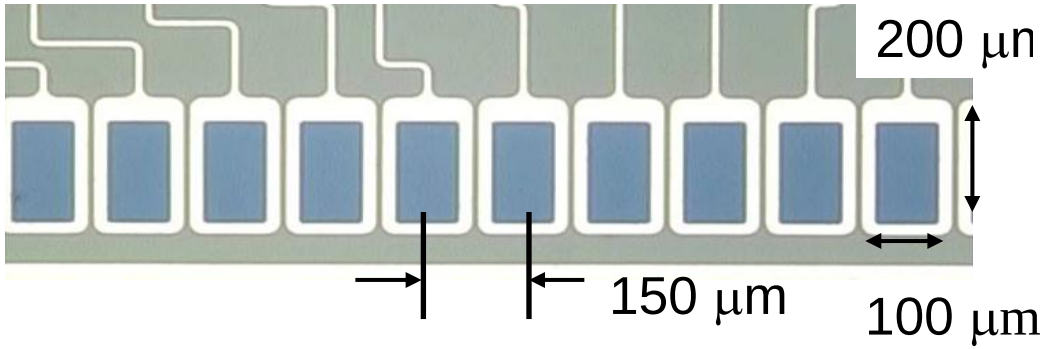
9.6mm long with 0.15-mm pitch

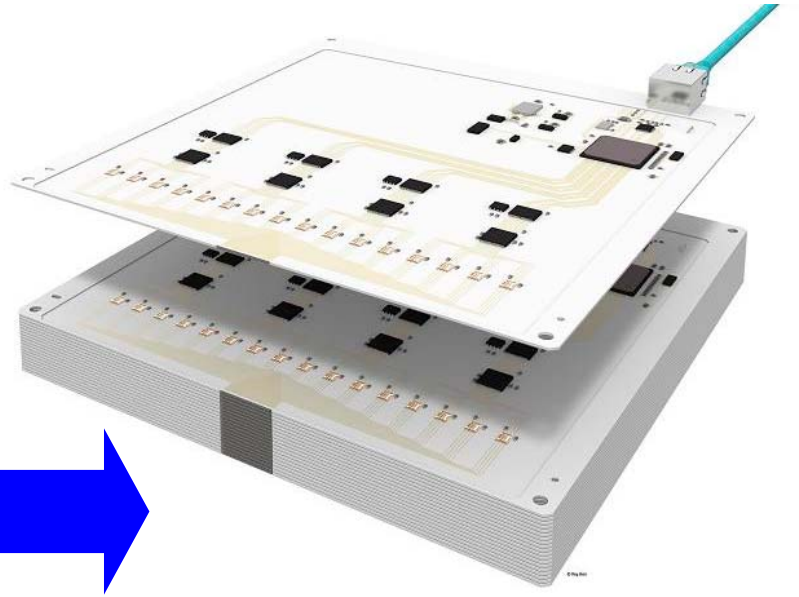
Stack of the linear arrays

≈ Area detector

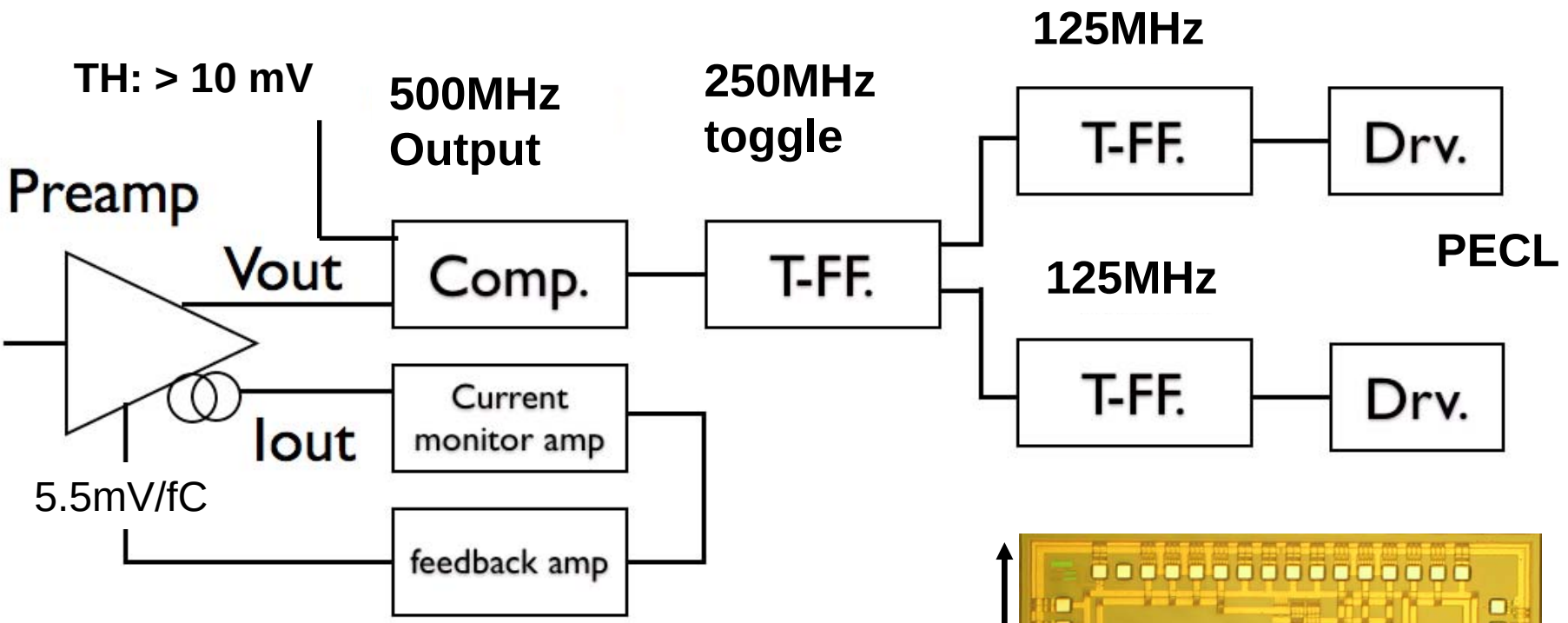
Thickness : 10 μm

→ Time resolution of Si-APD itself : 100 ps



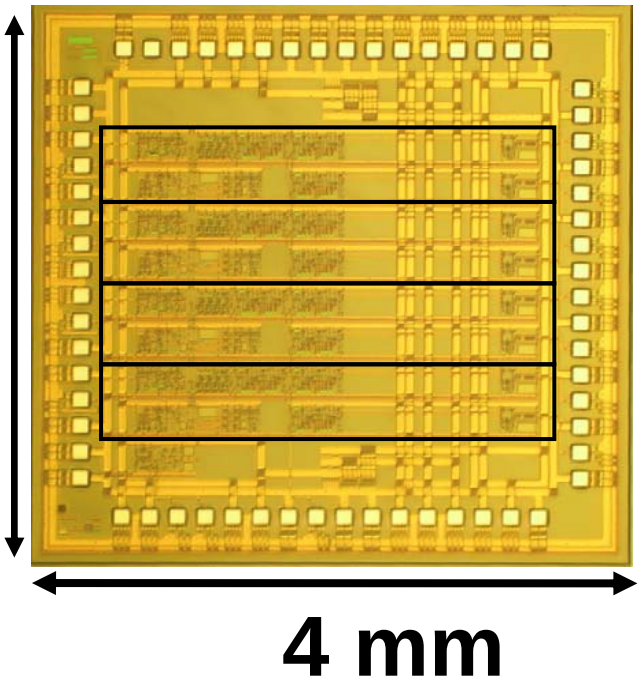


Amp. Shaper Discri. ASIC for Si-APD Ver.1



For baseline restroration

4 mm



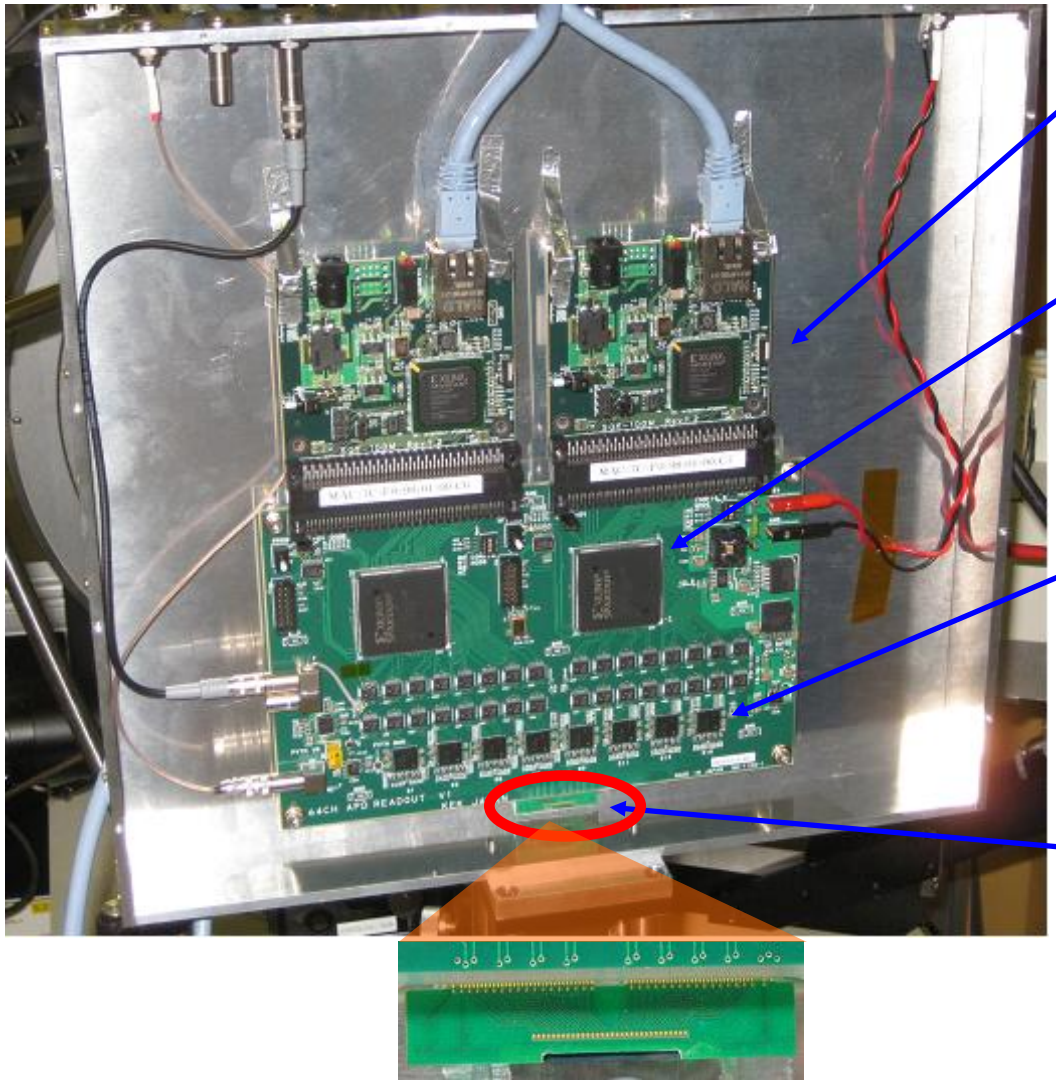
0.8-μm BiCMOS process

4 ch/chip

Counting or Time-resolved counting (→ Multiscaler)

Performance	**Present** **→ Next version**
Count rate	1.25×10^8 s^{-1} × 2 outputs/pixel
Time resolution (Si-APD itself)	100 ps
Pulse-pair resolution Incl. jitters (System)	10 ns (limited by FPGA) → 1 ns
Number of time-course channels (Time range)	256 (ex. 256 × min.10 ns) → 1024 (ex.1024 × min.1 ns)

Test measurements
at BL-14A of the Photon Factory ring



The SiTCP
(a network processor)
board with Ethernet。

FPGA
(XC3S500E-4PQ208C)

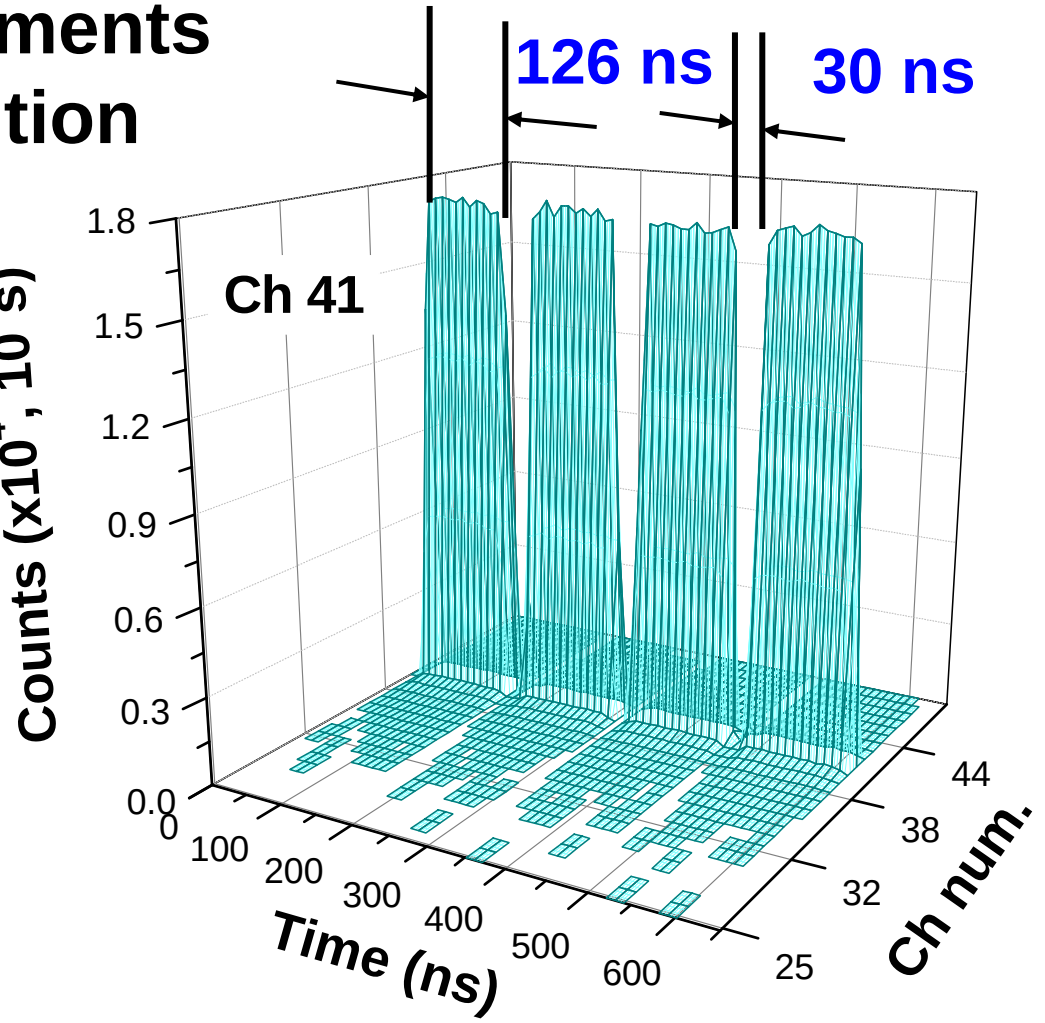
The Frontend Board,
mounting
16 ASD-ASICs

The Si-APD
Linear-array

Time-resolved measurements with a 10-ns time resolution

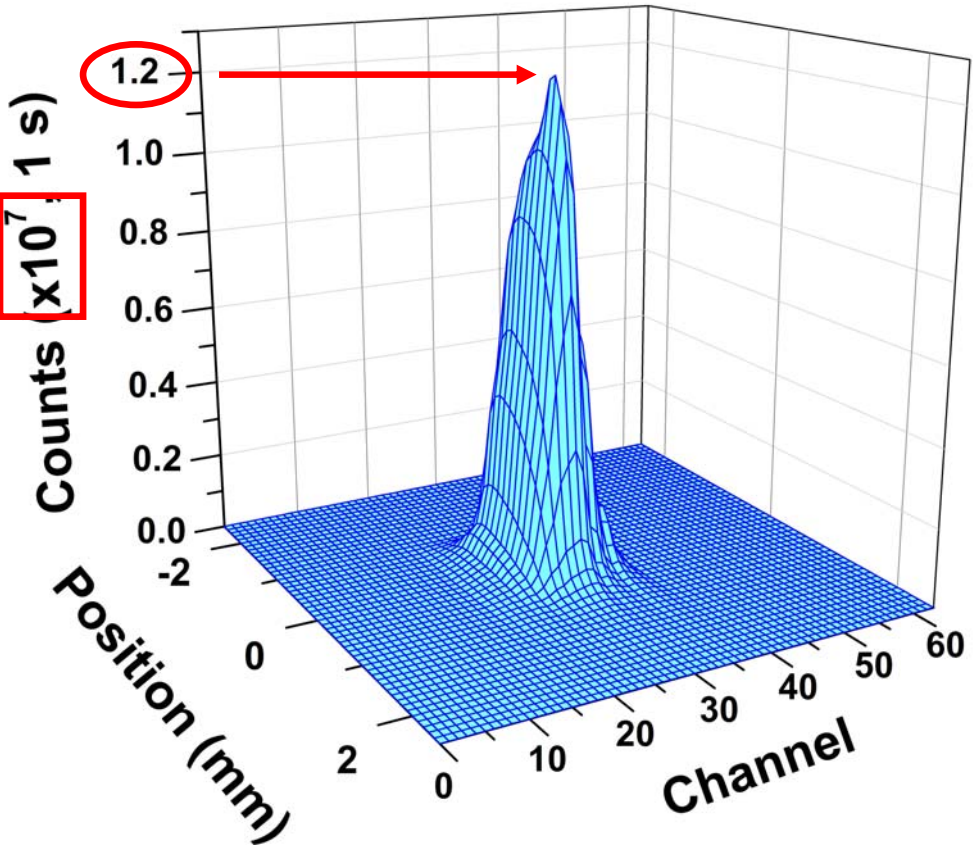
X-ray beam of 10 μm in dia. hit one pixel of Ch 41, using a pinhole.

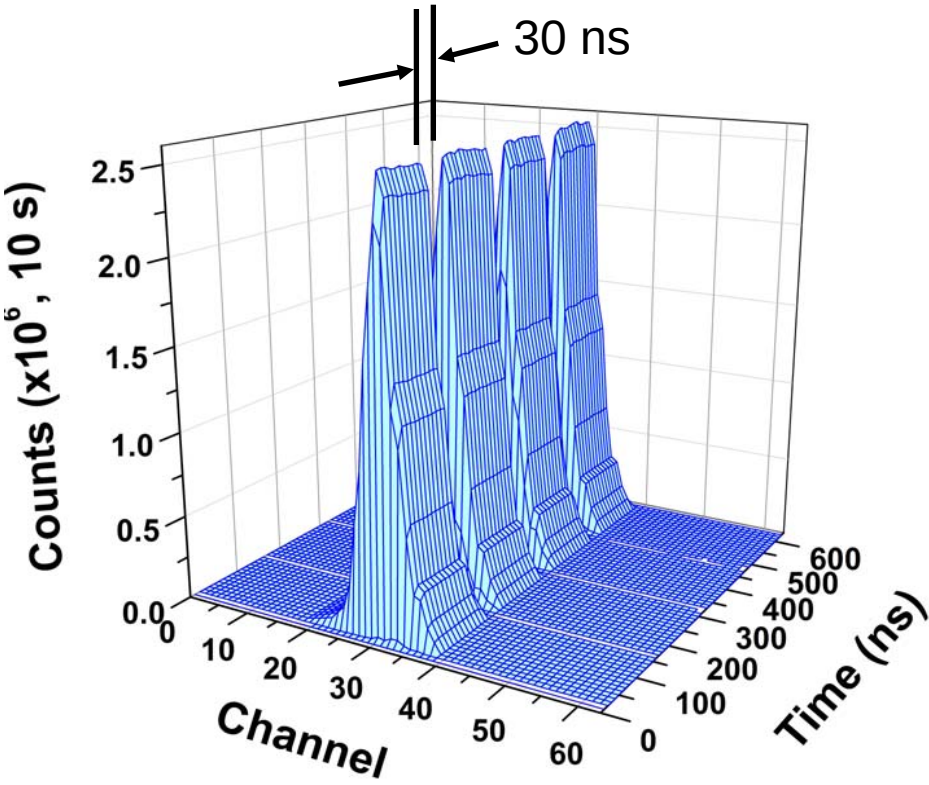
X-ray energy: 8 keV



Time structure of X-ray pulses
from the PF ring ：624 ns in one revolution
= 4x (Multi-bunches:126ns＋**gap**：**30ns**）
with the minimum interval of 2 ns (500.1MHz)

X-ray beam profiles w/o the pinhole





A beam profile of 8-keV X-ray beam, obtained by scanning a position of the 64-ch linear array

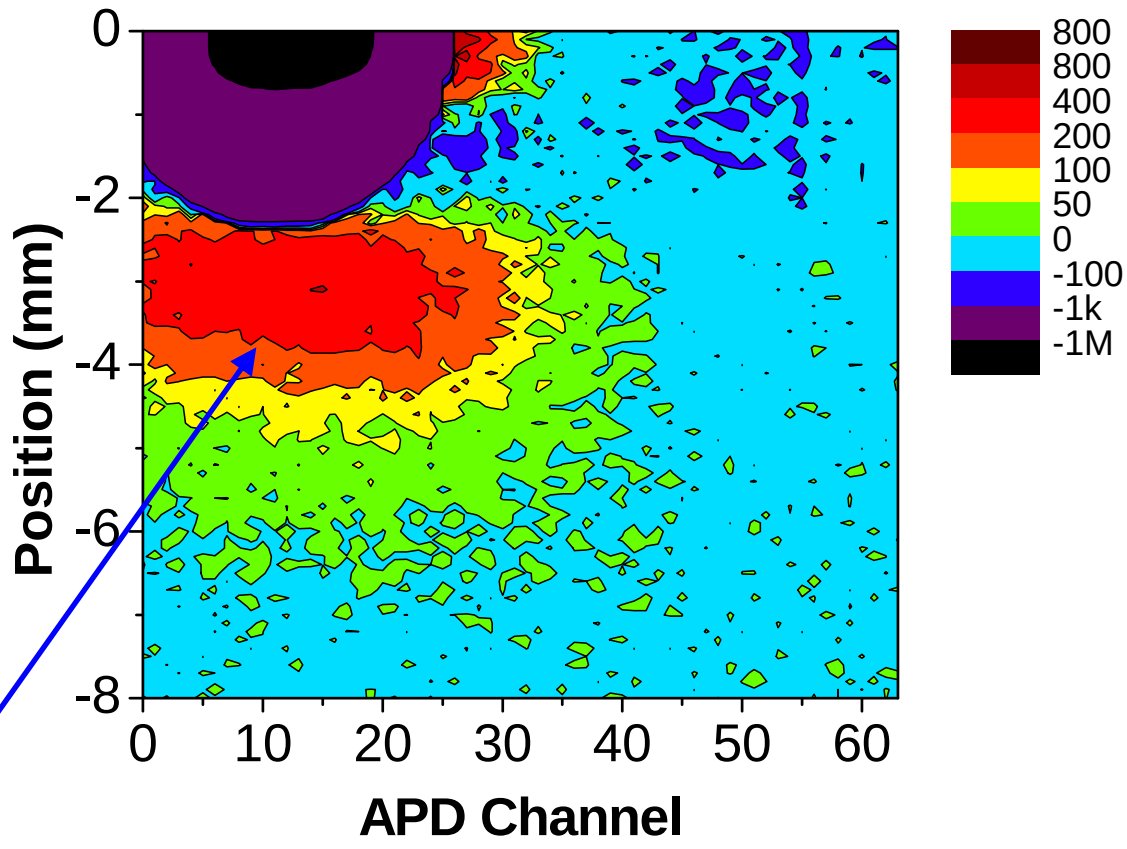
Time-resolved profile with a 10-ns time bin (Int. time: 10 sec at 0 mm)

2D count-distribution of X-ray scattering
from a sample, measured by scanning the linear array

Sample:
Poly (Vinylidene Fluoride) (PVDF)

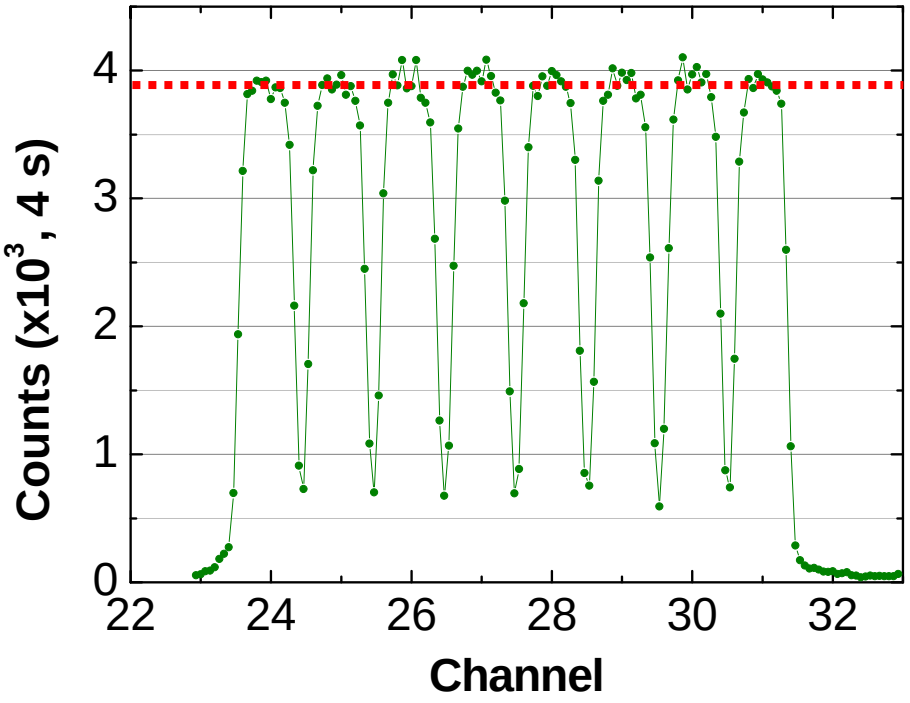
↓

ferroelectric polymer



A small angle scattering at ~0.8 ° was distinguished from the beam tail, using 8-keV X rays.

Switching dynamics in nanosecond time-scale



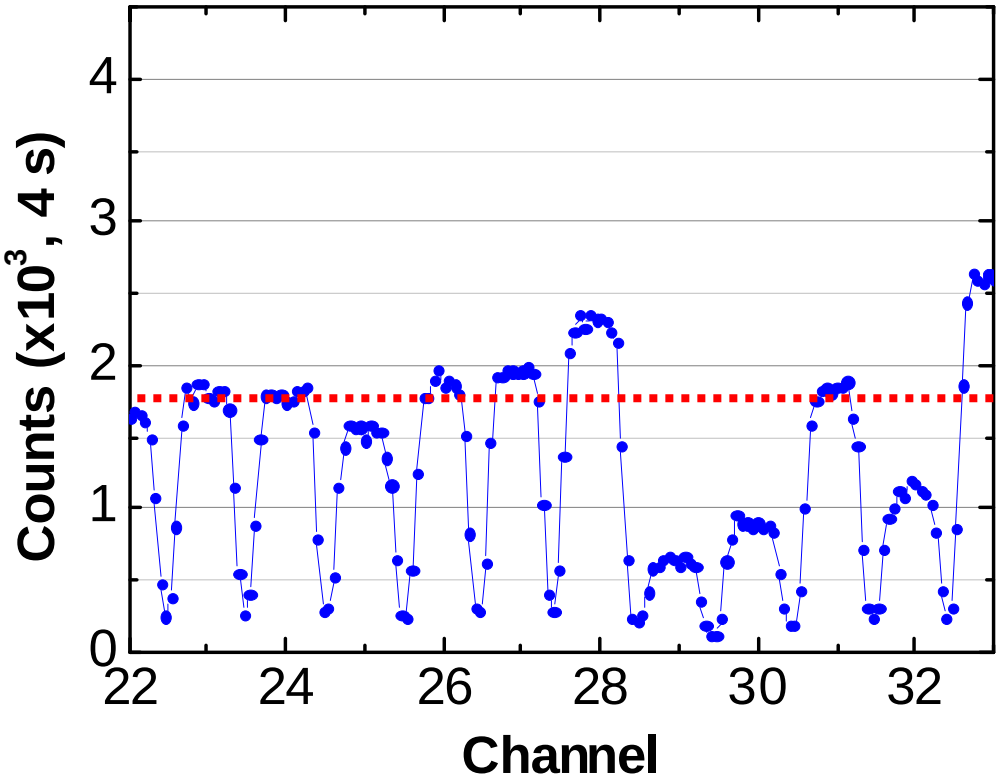
Efficiency

By Charge Amp.:
11% at 8 keV (→ 8 μm thick)

Uniformity: ±2% (in all pixels)

By 64-ch system:
~50% of Charge Amp. (average)

Uniformity:
- 60% ─ +50% (in all pixels)

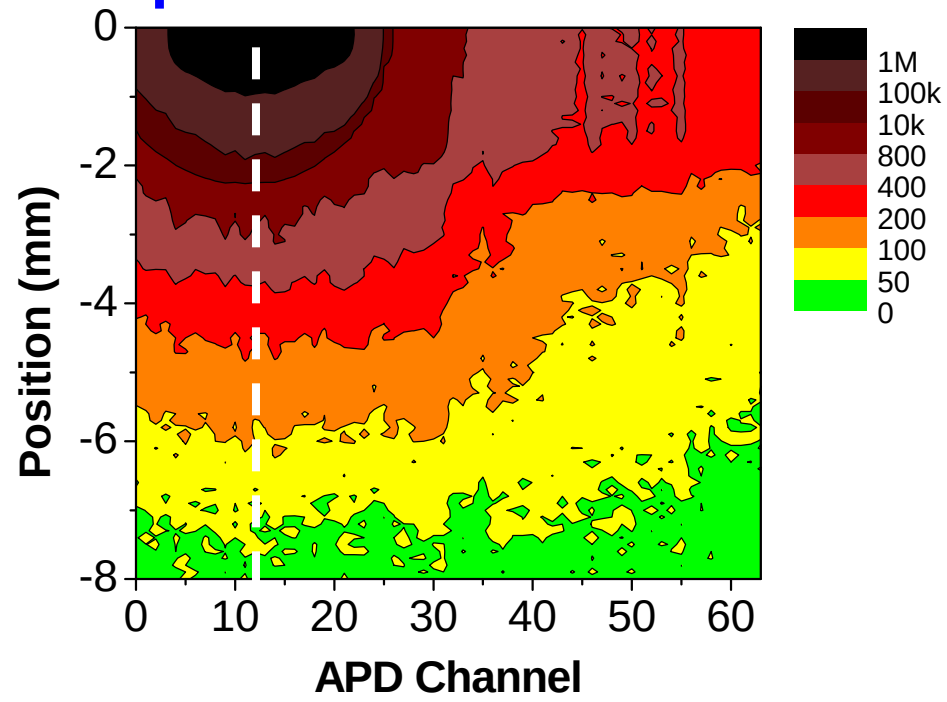


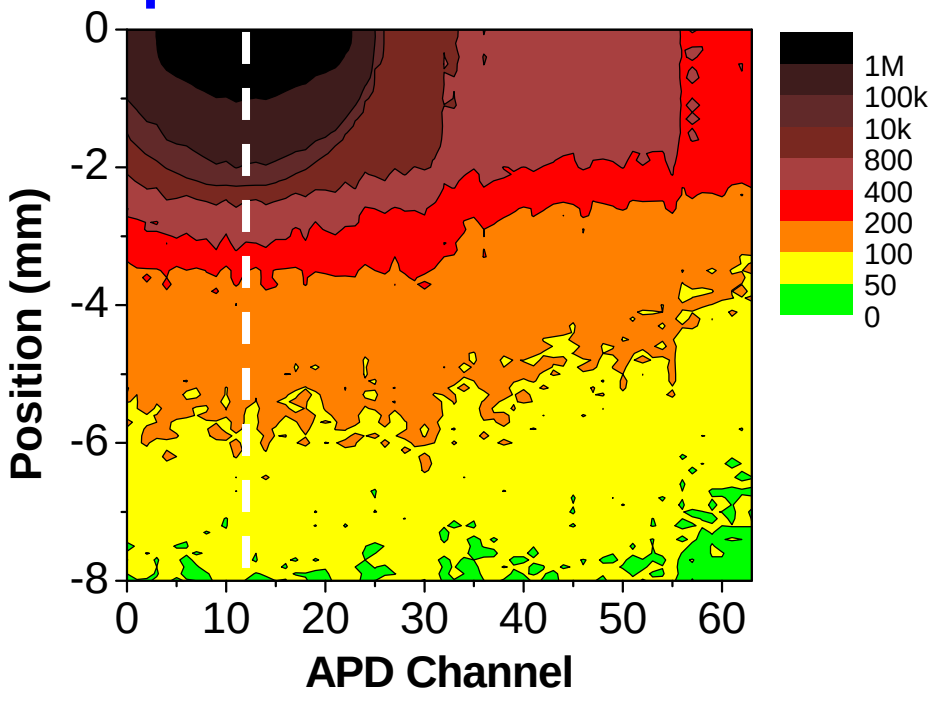
Conclusions

1. ***A Si-APD linear array detector was designed for time-resolved measurements using pulsed SR X-rays of 2-ns interval.***

2. ***The prototype show us a 10-ns time resolution and >10^7 s^{-1}/ch of high count-rate property. By scanning the linear array, we could record a time-resolved image.***

3. ***Problems: low efficiency and non-uniformity in the ASIC system. An improved frontend ASIC and a new digital board are prepared for the next stage. 1-ns time-resolution and better uniformity of efficiency will be available in the second version.***

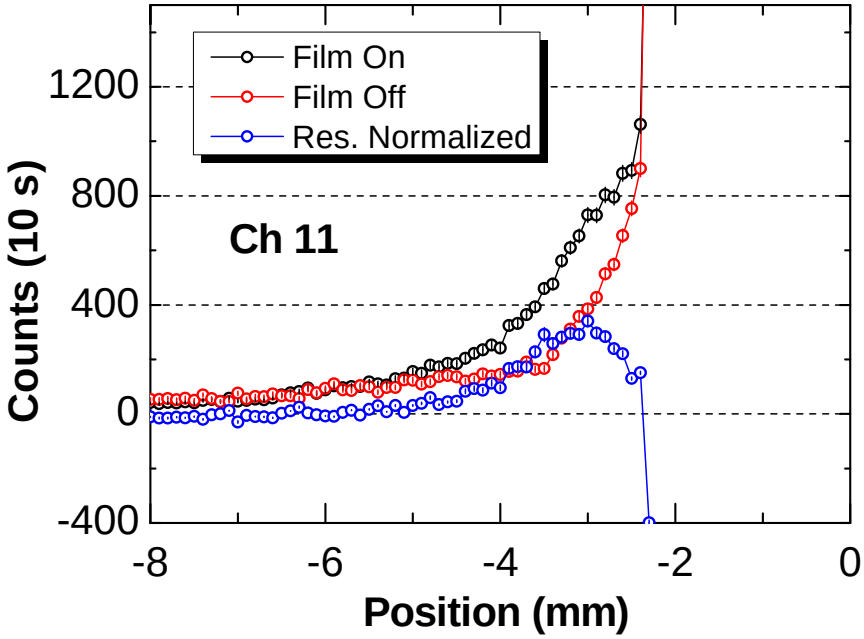


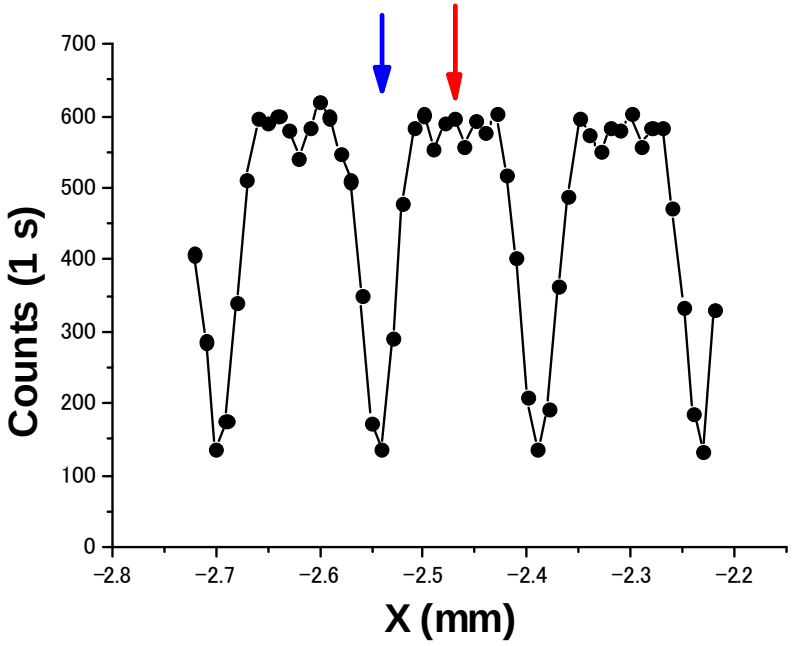


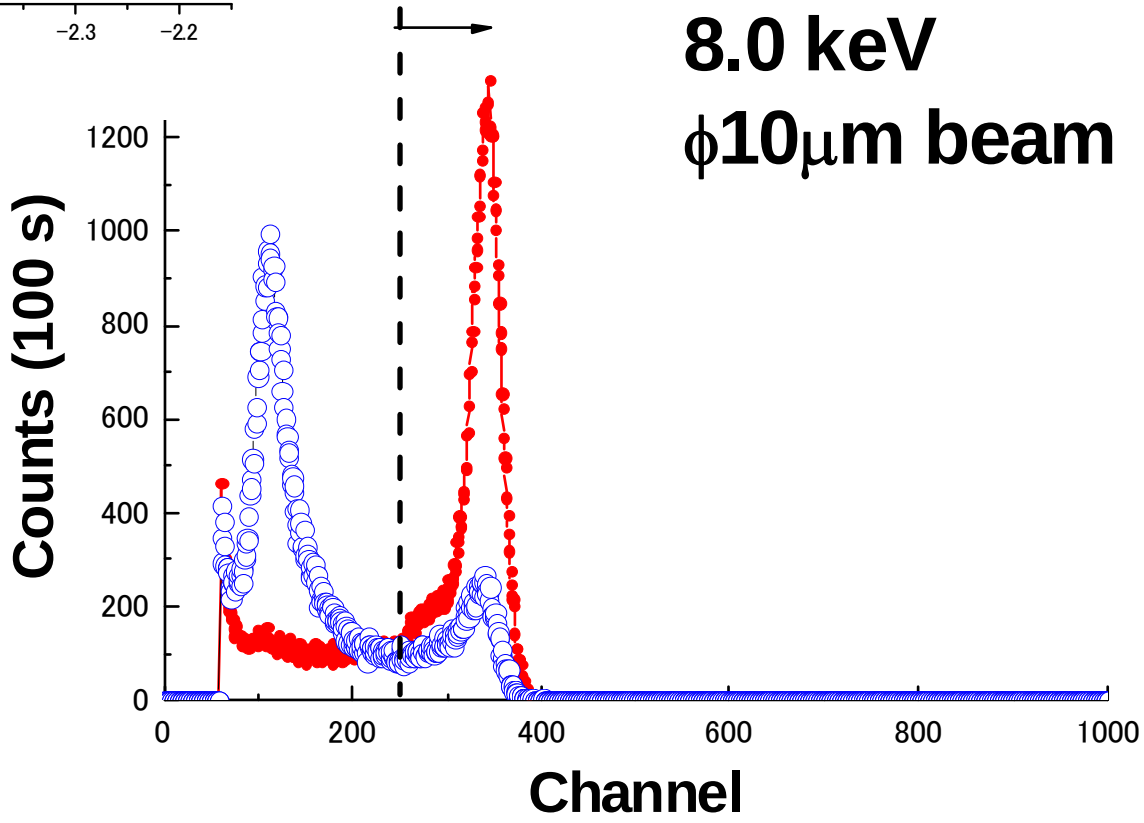
(Film On) – (Film Off)$_{Norm}$

At Ch 11

Film thickness: 110 μm
Trans. : 80% at 8 keV







8.0 keV

ϕ10μm beam