Development of PIXOR Tracking Detector

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Vertex detector

High energy experiment

- recent physics
  - High precision
  - Rare event

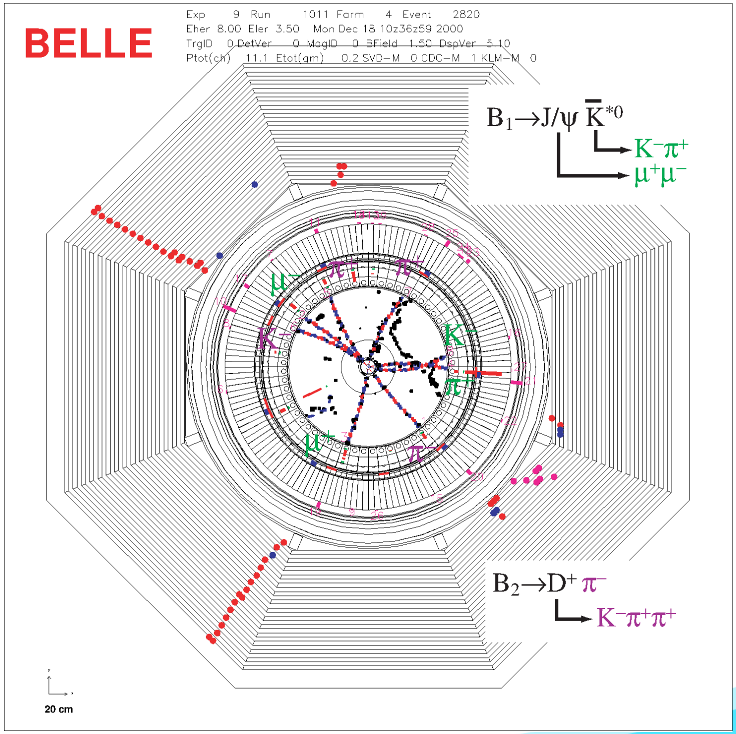
more statistics →

- more frequent collision
- high radiation environment

We must find out effective and rare event from large BGs with many kind detectors.

- Requirements for detectors
  - separate from large BGs
  - high radiation tolerance
  - more frequent DAQ

Event display @Belle

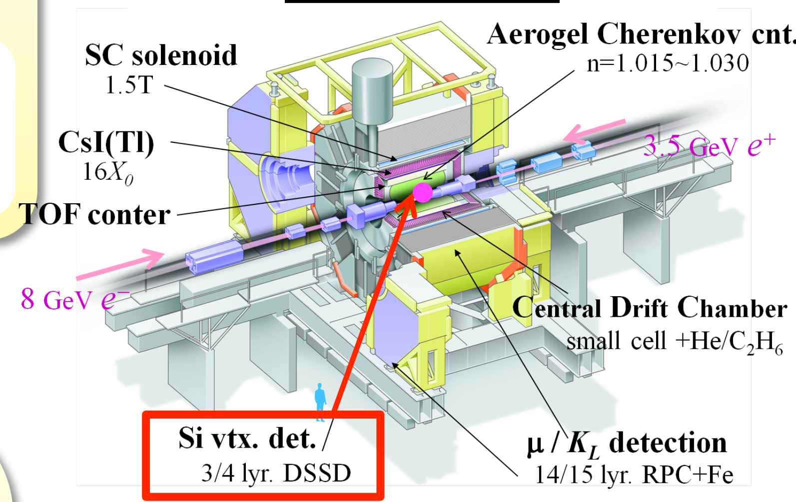


Vertex detector

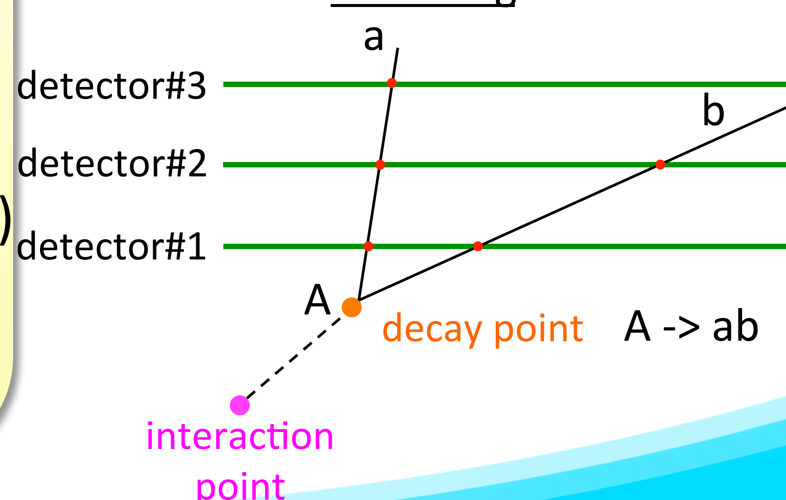
- <u>reconstruct tracks</u>
  - vertex pointing with high precision
  - closest to interaction point

- <u>Requirements for vertex detector</u>
  - fine position resolution (~10um)
  - low occupancy
    - high BG separation power
  - high radiation tolerance(~10Mrad)
  - low material
  - low power consumption

<u>Belle detector</u>

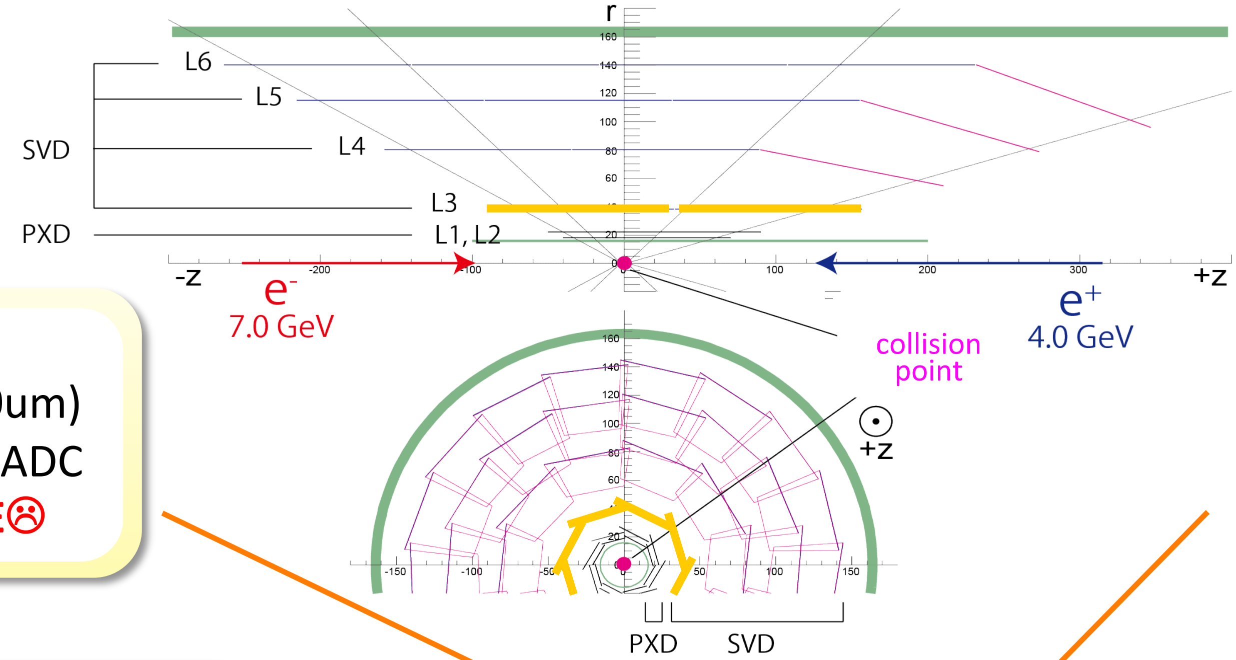


<u>Vertexing</u>



Our target : Belle II vertex

Geometry of Belle II vertex detector



Target : Layer #3

nominal design

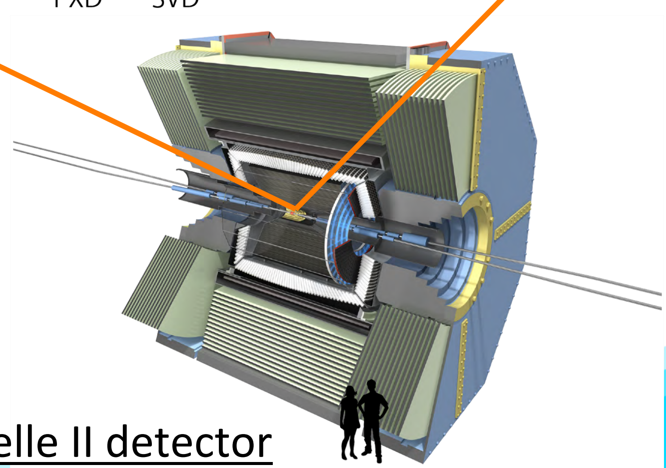
sensor : DSSD (50um*160um)

readout : APV25 + 8~10bit ADC

occupancy ~ 5.5 % ☹LARGE☹

We want to replace ...

- Our SOI
  - lower occupancy
  - lower material
  - finer position resolution



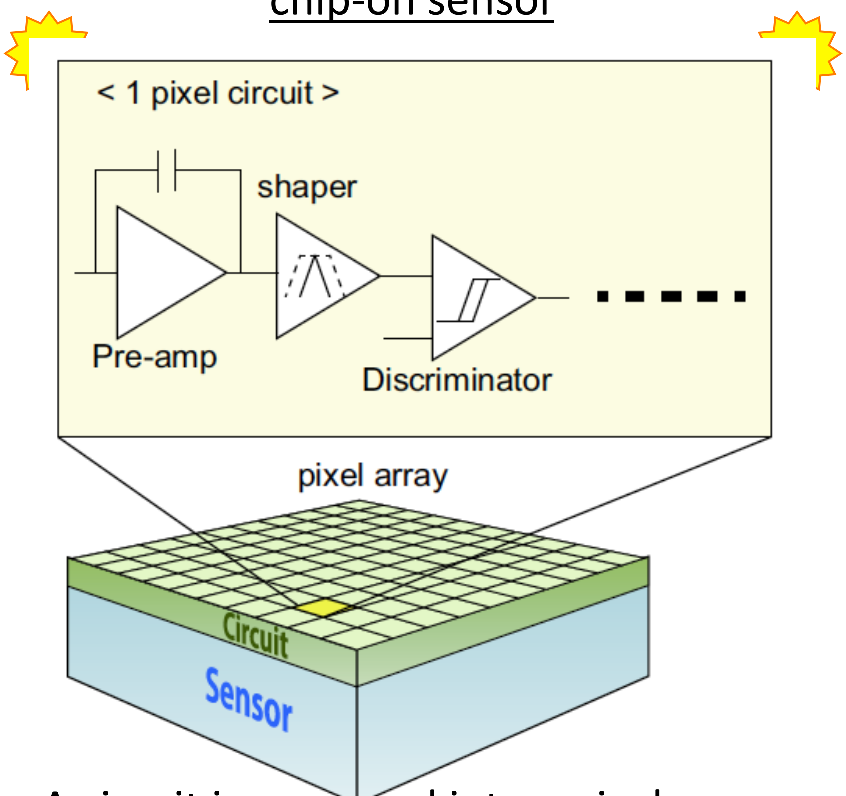
Belle II detector

PIXOR & circuit

Dilemma for readout chip-on sensor

general monolithic/hybrid pixel detector = readout chip-on sensor

chip-on sensor

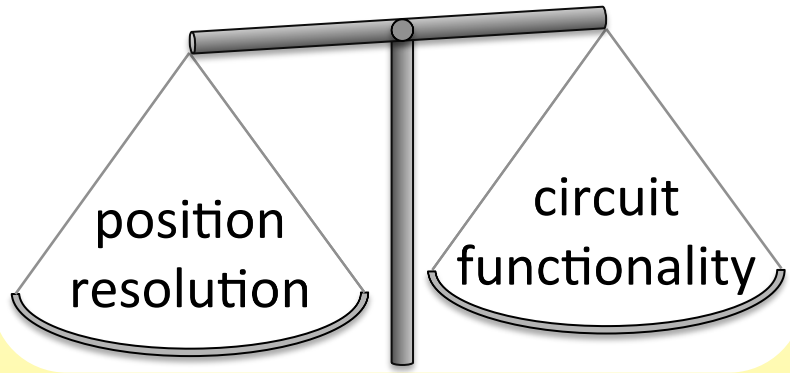


A circuit is crammed into a pixel area.

A pixel has a circuit
for simultaneous process.

pixel size > circuit area

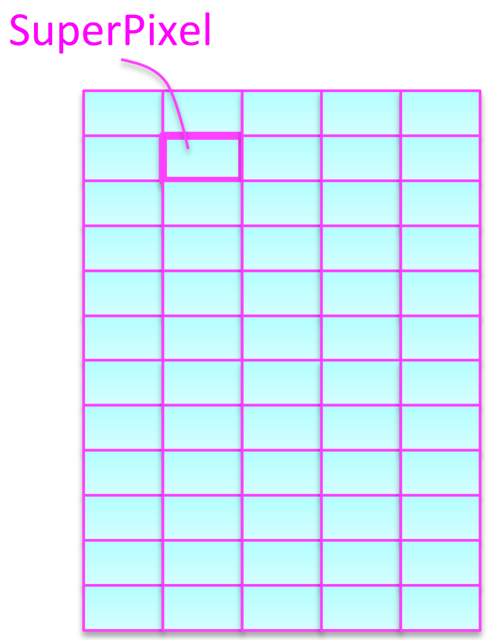
trade-off



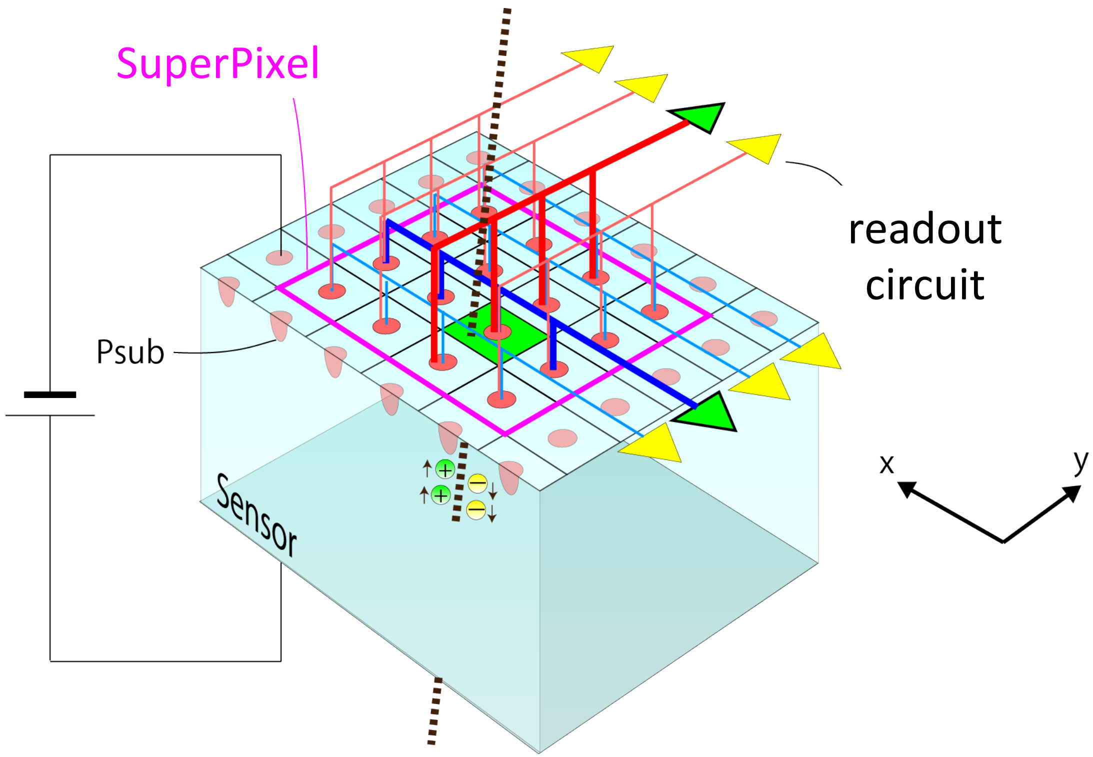
We greedily require both of them.

Pixel OR (PIXOR) scheme

We can solve your dilemma. → PIXOR [piksər]



PIXOR detector



PIXOR scheme

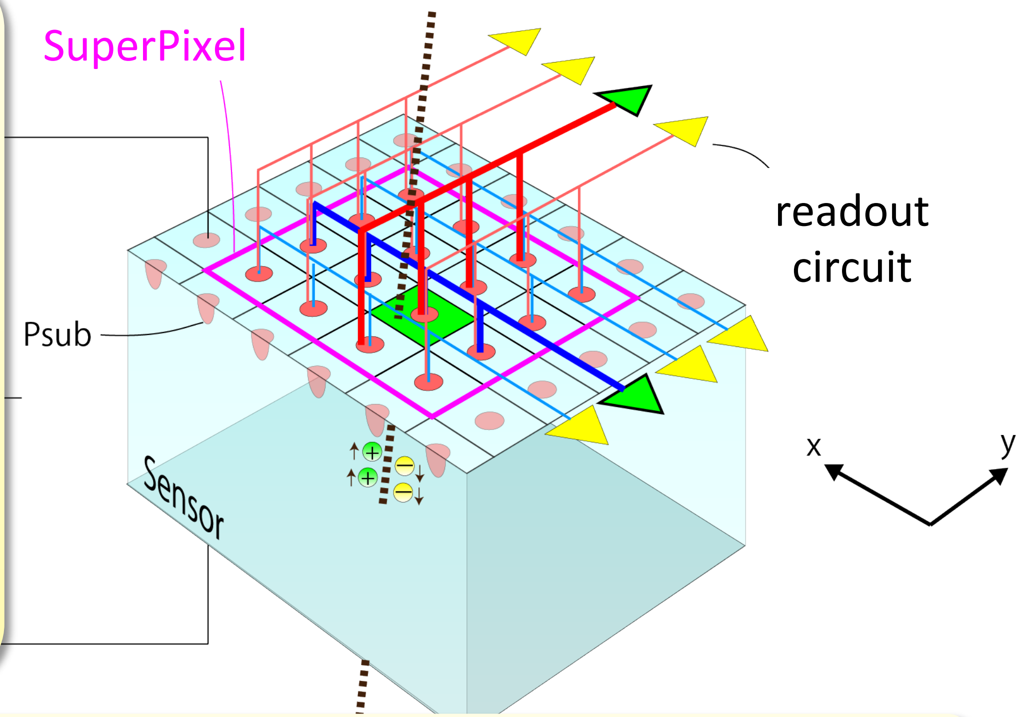
A PIXOR detector consists of the array of SuperPixels.

Pixel OR (PIXOR) scheme

We can solve your dilemma. → PIXOR [piksər]

1. A signal from the pixel-node is divided into two directions (**X**, **Y**)
2. The **X** signal of *n* pixels in that column are analog ORed together, it's same with **Y**.
3. The ORed signal is processed by a readout circuit on its SuperPixel.
4. We get the 2-dimentional hit info.

<u>4 OR PIXOR (16 pixels -> 8 circuits)</u>



The number of circuits on a SuperPixel is reduced n^2 (pixel) → $2n$ (PIXOR)

It's like an intermediate structure between pixels and strips.

Advantage of PIXOR

of circuits is reduced and depends on # of ORed pixels.

We can design a detector as following strategy…

Circuit area increases → Fixed Pixel size (position resolution)

Increased The number of OR

become like strips → occupancy increase

☺ **advantage**
- With keeping the point resolution, complex circuitry can be mounted.

☹ **side-effect**
- ghost appear
- signals become 1/2

Currently, we select 16-pixels OR structure (256 -> 32channels).

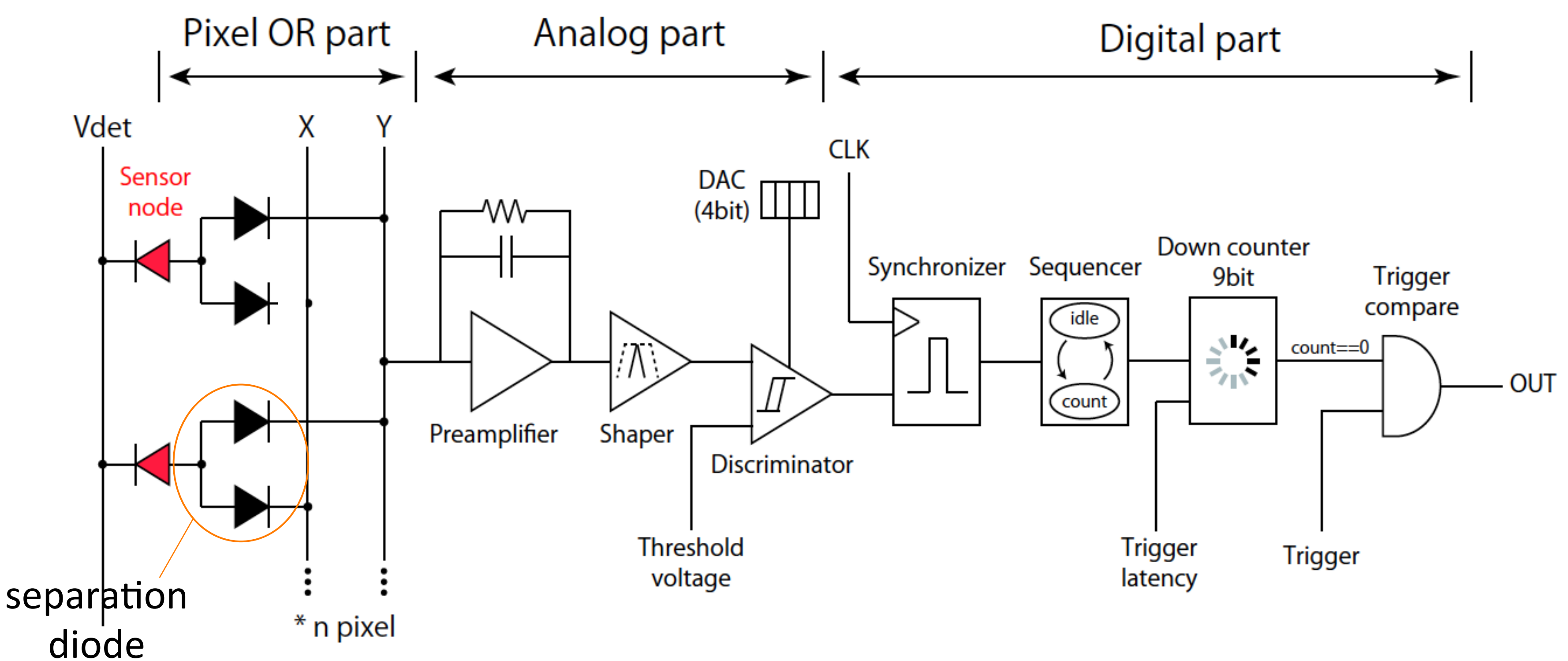
for Belle II DAQ/vertex system

- Trigger DAQ
  - We take the data by a trigger signal when the event shape is worth of our physics.
  - The trigger is sent in 5us later from the real time to judge by the hardware processor, with the max 30kHz rate.

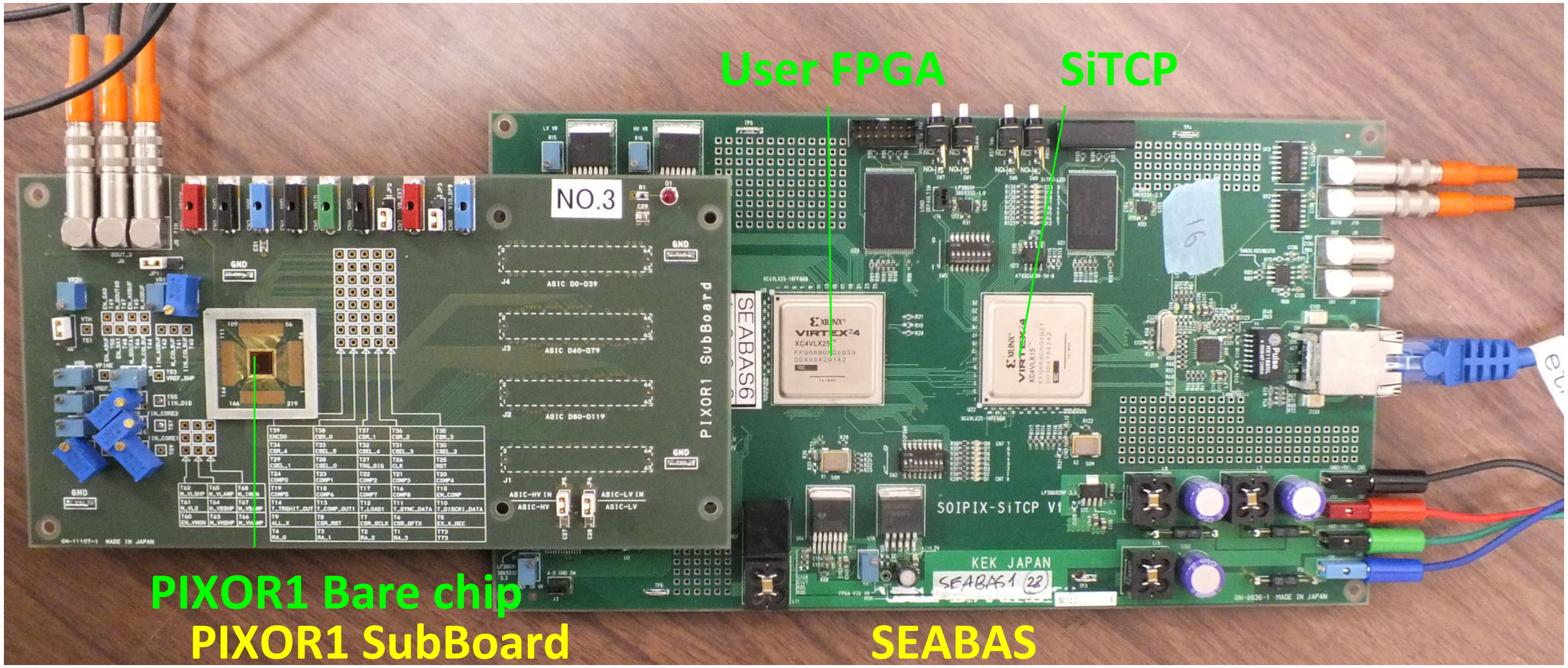
Layer#3 vertex detector	nominal design DSSD + APV25		SOI PIXOR
sensor type	double-sided strip		PIXOR (16 OR)
pitch	ϕ:50um z:160um		35um * 70um
thickness	300um		**50 or 100um ☺**
max trigger latency	5us		12us
system CLK	42.33 MHz		42.33 MHz
analog delimiter	8~10 bit		1 (binary)
estimated occupancy	5.5 %		**0.035 % ☺**

Circuitry

1 channel circuitry



- **A**nalog part : gain ~ 100uV/e- (Preamplifier + Shaper)
- **B**inary readout : Discriminator(external threshold+4bit fine tuning)
- **C** : no candidate here, sorry
- **D**igital part : store hit information during trigger latency



Evaluation

Activity of PIXOR evaluation

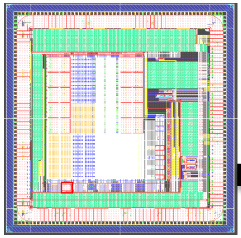
- History

2011

Mar. — PIXOR project start.

Sep. — submit PIXOR1

PIXOR1

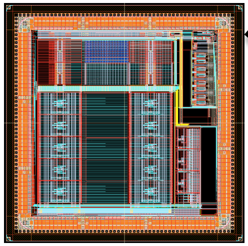


2012

Feb. — evaluate PIXOR1

Jul. — submit PIXOR2

PIXOR2



2013

Feb. — evaluate PIXOR1 (Double SOI ver.)

we are here

skip the details

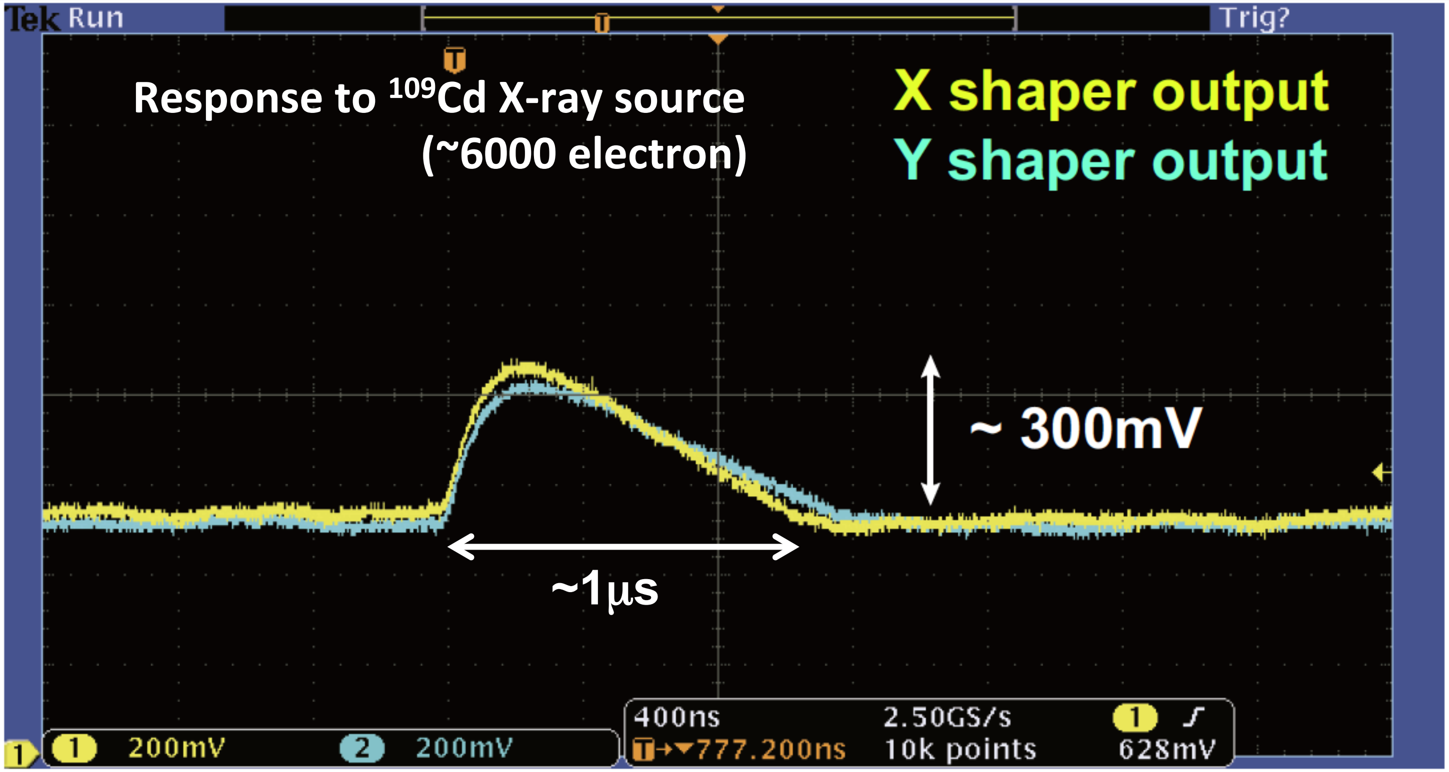
PIXOR1 -> PIXOR2

- mainly digital part
  - counter*2 /ch
  - hit address readout
- pixel pitch change
  - 25um*40um=>35um*70um
  - ∵circuit area enlarge

- Evaluated contents PIXOR1
  - Analog signal division
    - single/double SOI
  - Trigger handling circuit (digital)
  - Discriminator

Analog signal division

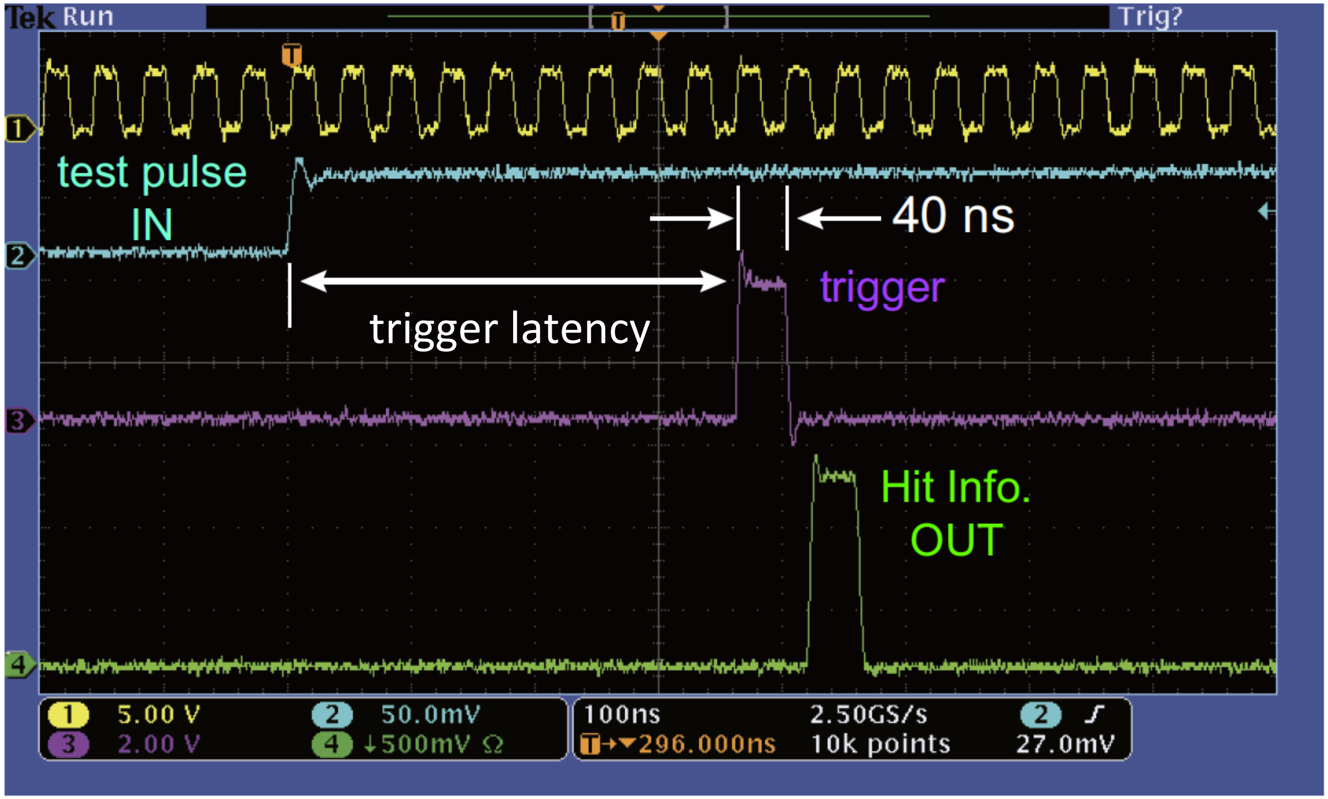
- To get 2-dimensional information,
  - PIXOR must divide an analog signal into the two-directions equally.



- **Cleanly divided !!** => PIXOR scheme works well.
- calculated gain = 130 uV/e

Trigger handling circuit

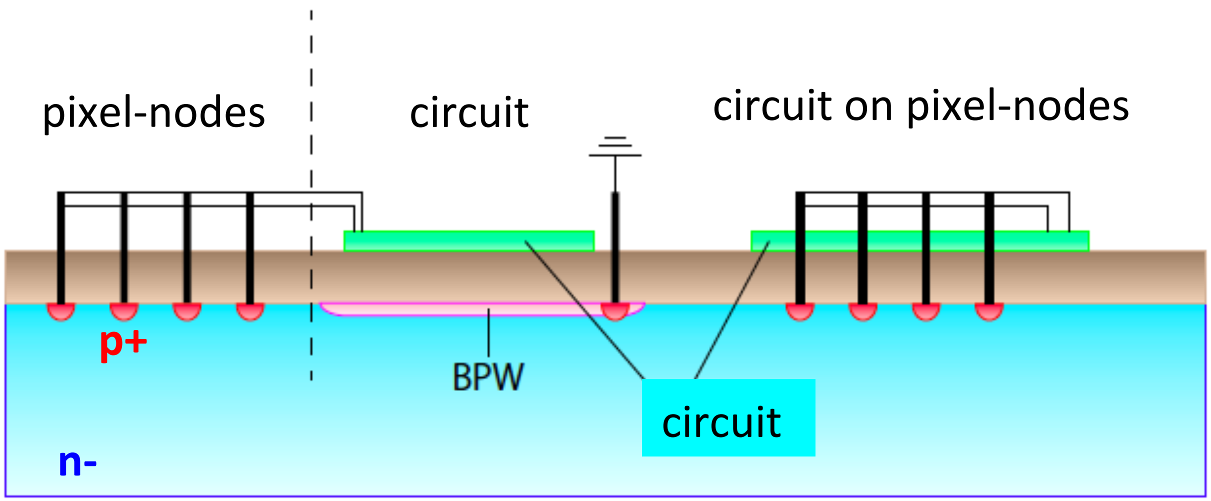
- To suit the trigger DAQ system,
  - PIXOR must store the hit information during the trigger latency.



- **Exactly stored !!** => The digital circuit works well.
- We have confirmed good operation with 25 and 50 MHz clock.

Double SOI :

- Up to here, the results are **OFF-sensor's**.
  - Because we'd like to avoid the crosstalk between sensor and circuit.

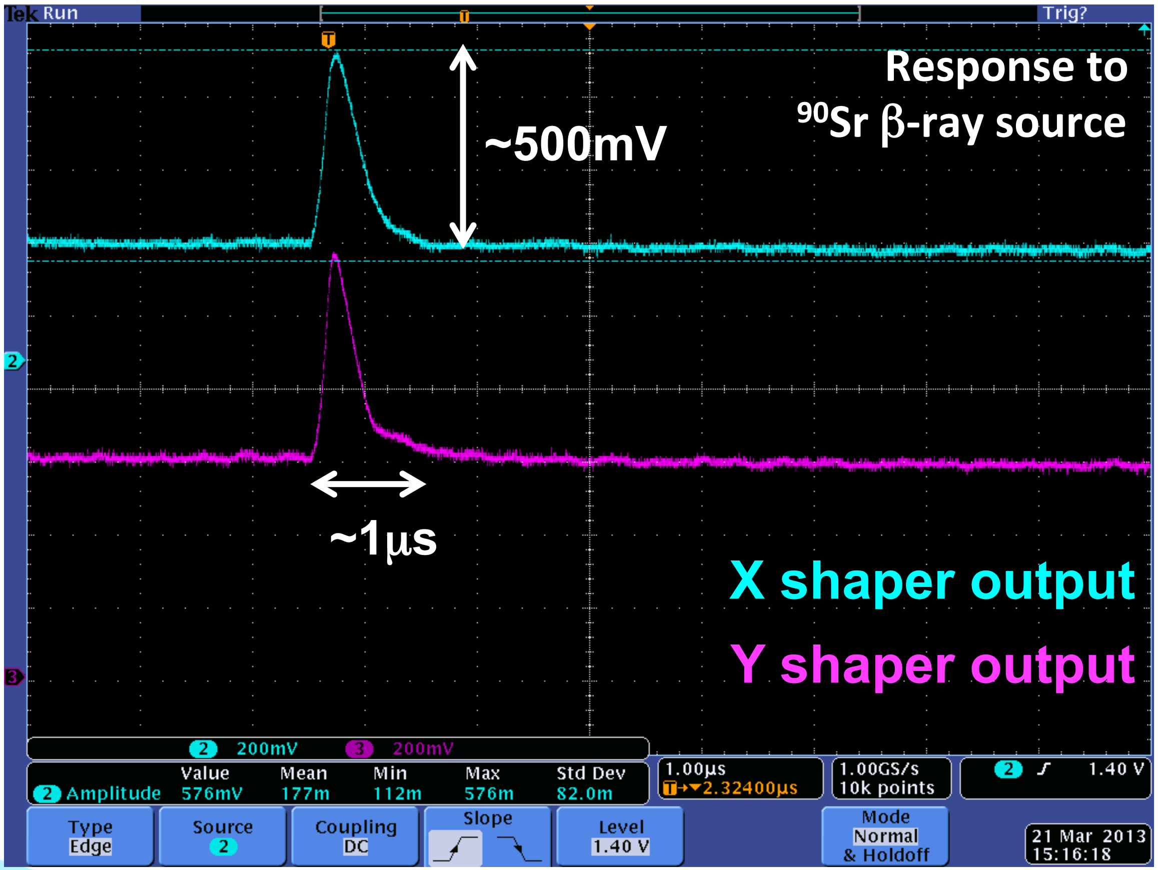


OFF-sensor ON-sensor

The double SOI wafer may solve this problem …

Double SOI : β-ray signal found!!

With **double SOI** wafer in **ON**-sensor region



- **Signals found !!**
- Double SOI can suppress the crosstalk.
- First discovery !?
  - CNTPIX type
  - ON-sensor
  - SOIPIX

Summary

- We are developing SOI PIXOR detector for high energy experiments.
- PIXOR is a new readout scheme which solves the trade-off between the point resolution and circuit functionality.
- We fabricated two prototypes called PIXOR1 and PIXOR2. Then the PIXOR1 is still being evaluated.
- The results of the PIXOR1 are summarized as this table.

contents	status
Analog signal division	☺**Succeeded**
Trigger handling circuit	☺**Succeeded**
ON-sensor's signal with double SOI	☺**Succeeded**

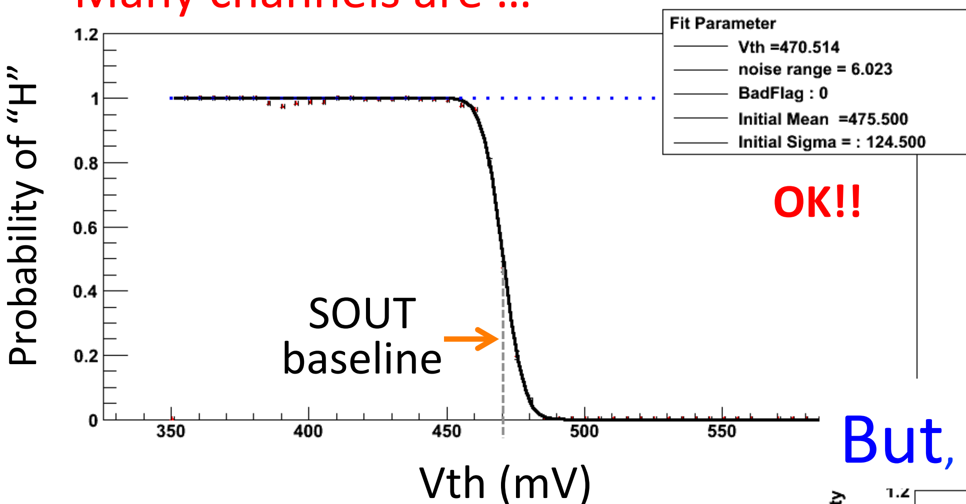
Analog signal division	☺Succeeded
Trigger handling circuit	☺Succeeded
Discriminator trimming	☹Under investigation
ON-sensor's signal with double SOI	☺Succeeded

Appendix

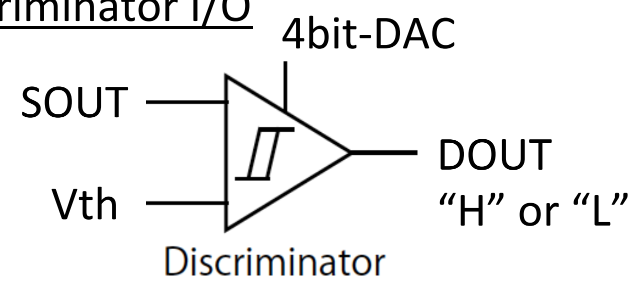
Discriminator

- To set the thresholds uniformly by adjusting 4bit-DAC on each channel,
  - we must measure individual characters of the discriminators.

Many channels are …



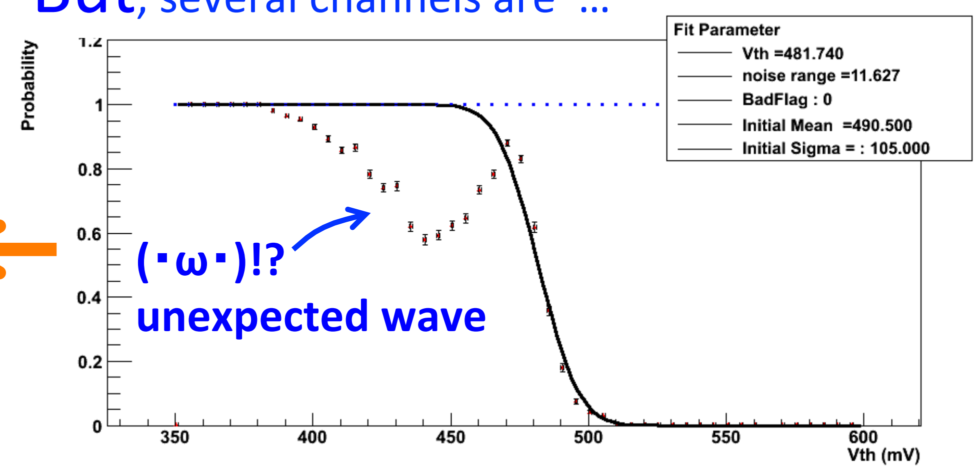
Discriminator I/O



SOUT : shaper output

Vth : threshold voltage

But, several channels are …



Several channels response one with the unexpected wave.

☹under investigation