MPPC Radiation Hardness (gamma-ray & neutron)

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for Toshinori Ikuno, Hideki Yamazaki,
and all the ScECAL group

Knowing radiation resistivity is important to estimate the life time of the calorimeter under the environment at the ILC.
In last year we have some chances to have radiation test with gamma-ray and neutrons.

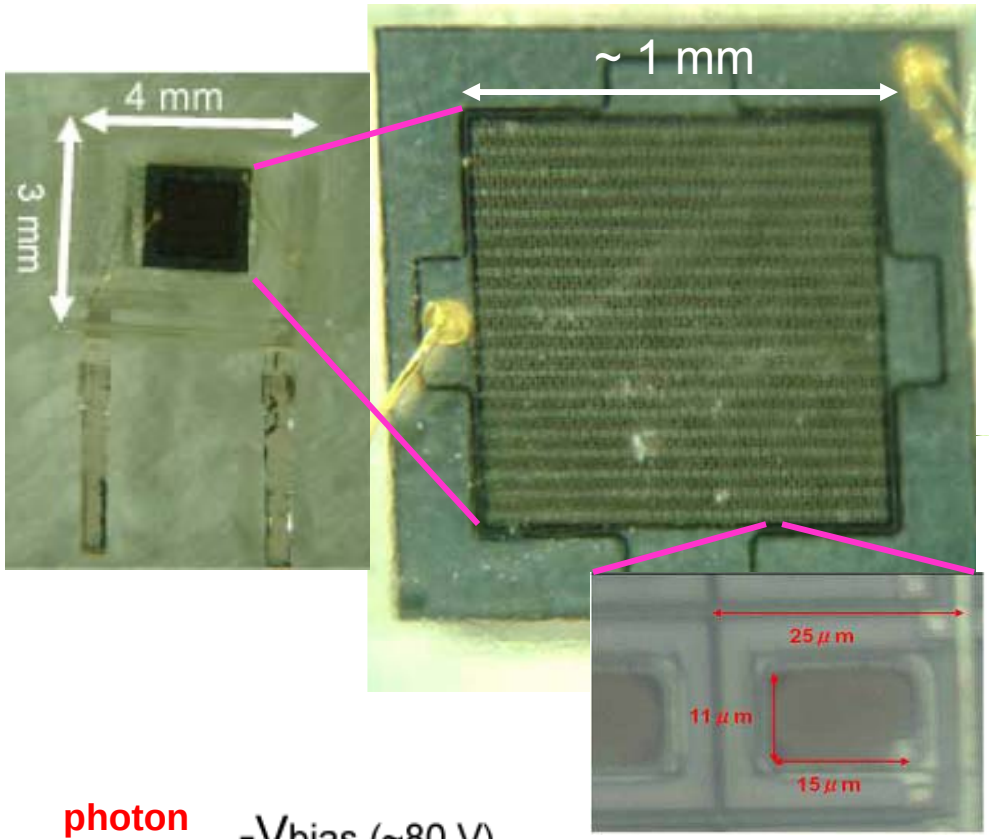
Multi Pixel Photon Counter (MPPC)

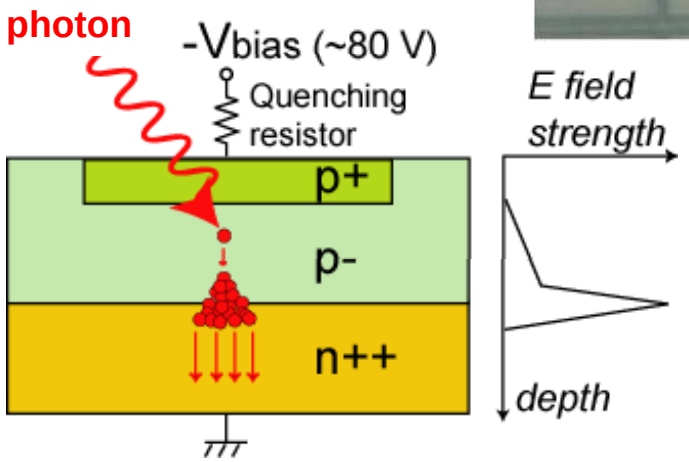
A pixelated photon detector manufactured by Hamamatsu Photonics

- MPPC consists of 2D array of Geiger-mode APD pixels.
- Each pixel can count a photon at same time.
- MPPC outputs signal from all pixels as a summation.

(Properties)

- High Gain (>10^5)
- Good Photon Detection Efficiency (~15% with 1600 pixel)
- Compact (package size ~ a few mm)
- Low Cost
- Insensitive to magnetic field
- Dark count exists (because of thermal electrons)
- Secondary photons from avalanche make crosstalk.
- Input vs output is non-linear





Gamma-ray Radiation

Dose amount

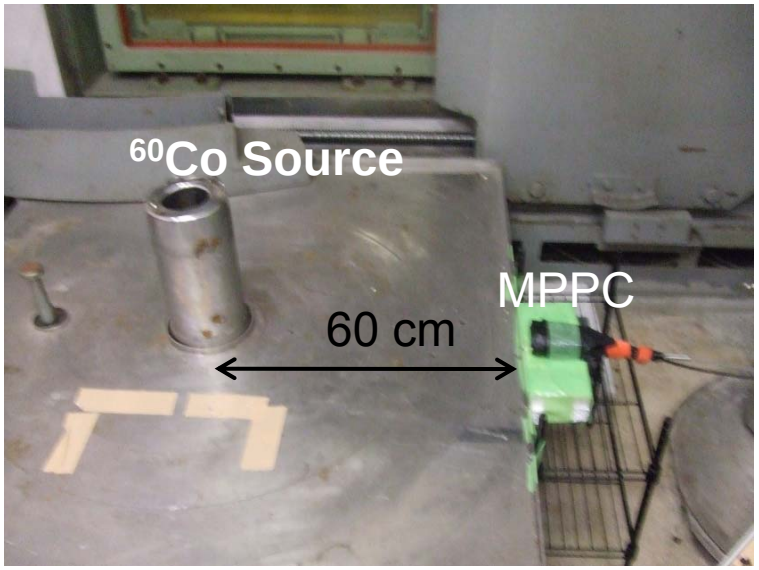
10 Gy/h for 3 hours →30 Gy
10 Gy/h for 6 hours →60 Gy
10 Gy/h for 12 hours →120 Gy
(Gy=100 rad=J/kg)

Prospective damage

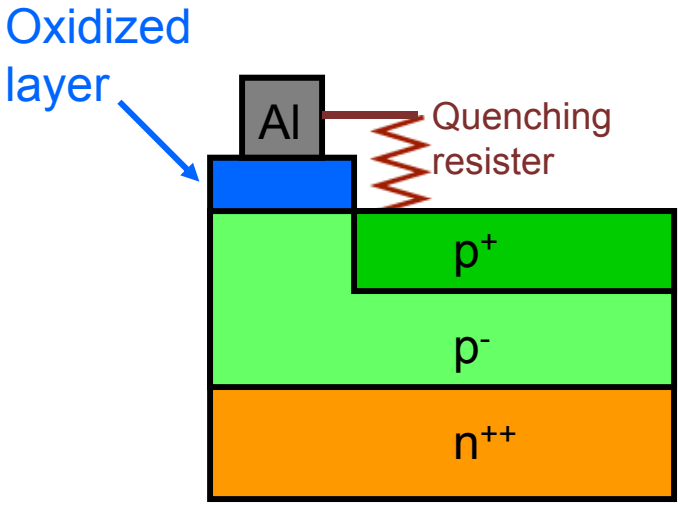
Charge accumulation
on the oxidized layer.

Radiated MPPC Sample

Type : ILC-11-0125M
Size : 1mm×1mm
1600 pixel (25μm pitch)

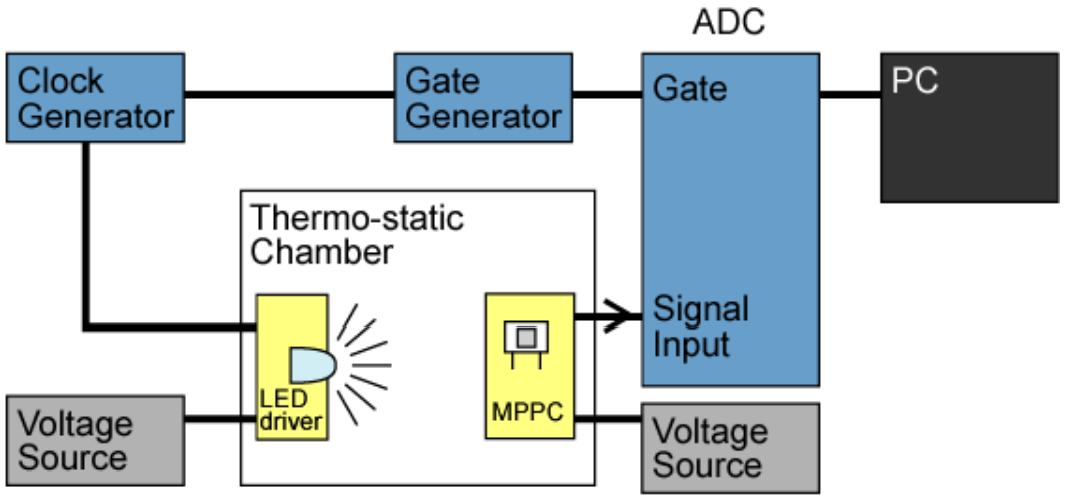


Radiation source ~15TBq ^{60}Co Source

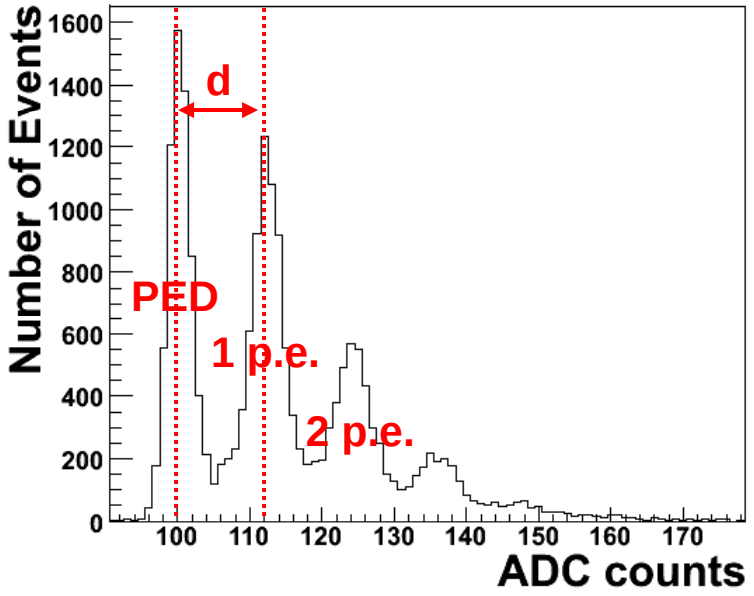


Gain measurement

Set Up (Gain)



An example of ADC distribution

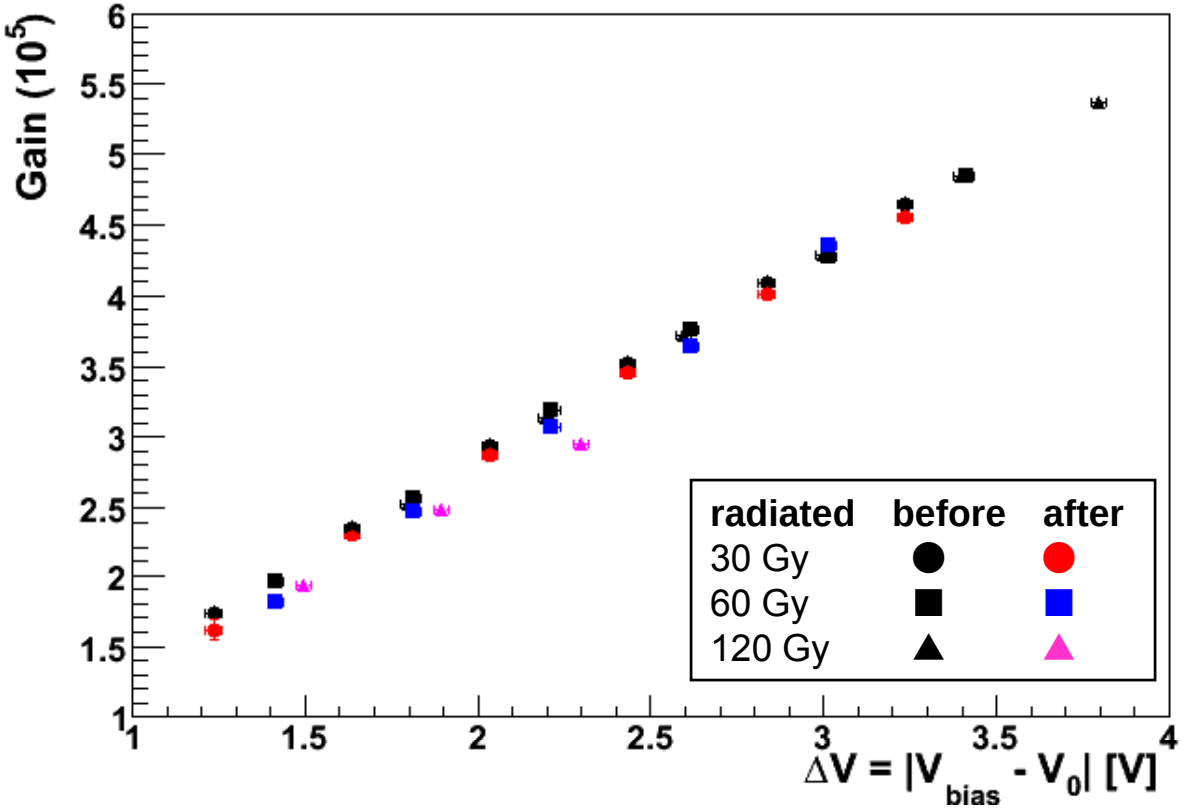


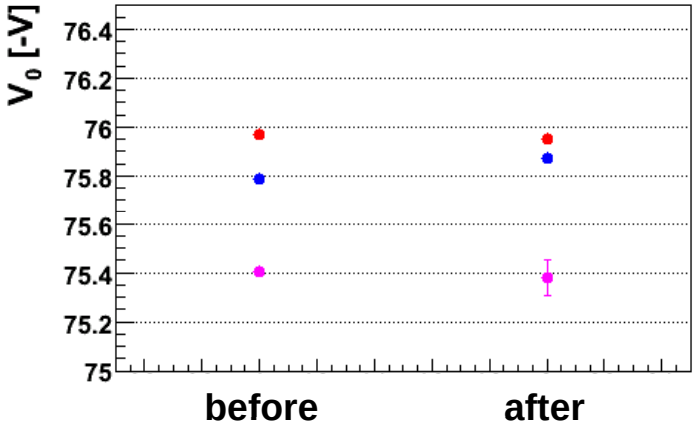
$$Gain = \frac{d \times S}{e} = \frac{Q}{e} = \frac{C}{e}(V_{bias} - V_0)$$

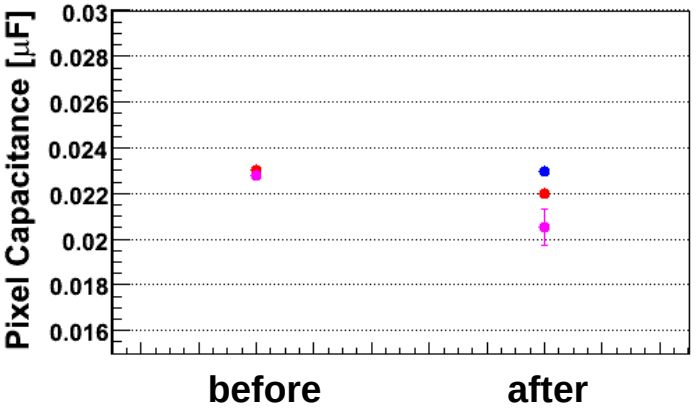
p.e. : photo-electron

S: ADC resolution
Q: charges gained by geiger-mode
e: elementary charge
V_{bias}: Bias Voltage
C: pixel capacitance
V_0: Breakdown Voltage(Threshold of geiger-mode)

Gamma-ray(Gain)





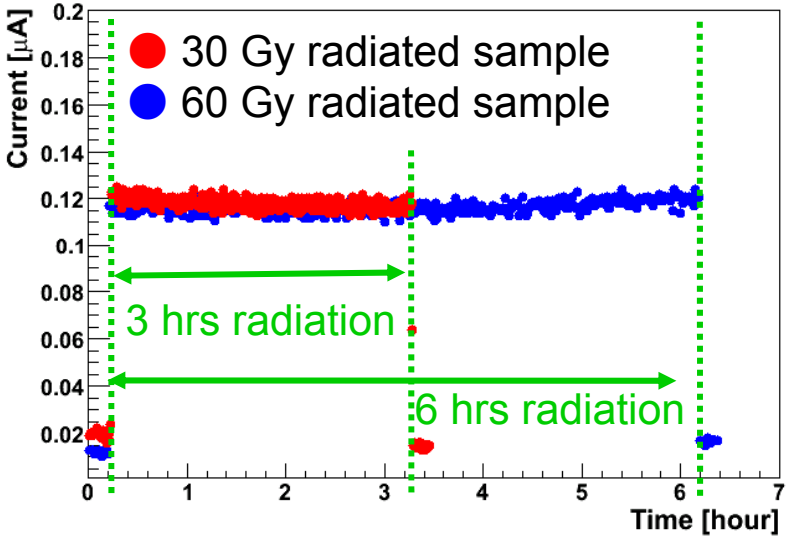


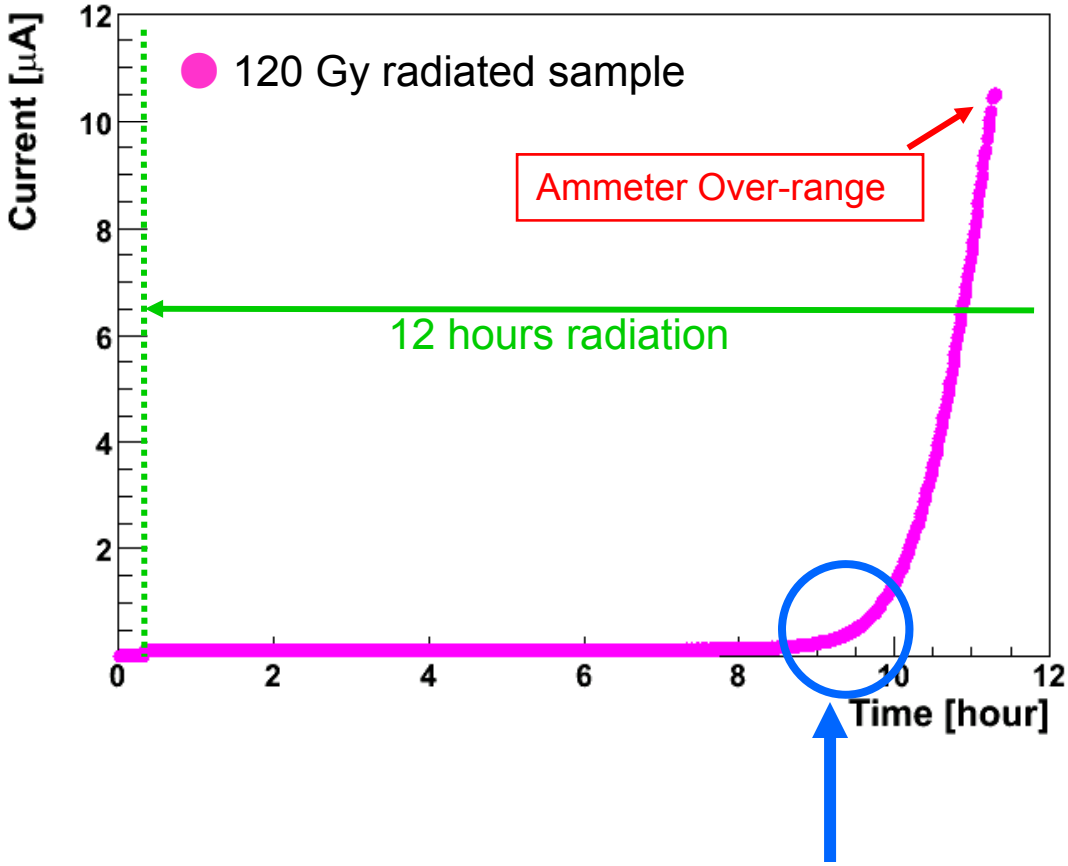
30 Gy radiated
60 Gy radiated
120 Gy radiated

There seem no significant changes on the gain by gamma-ray radiation.

Gamma-ray(current : during radiation)

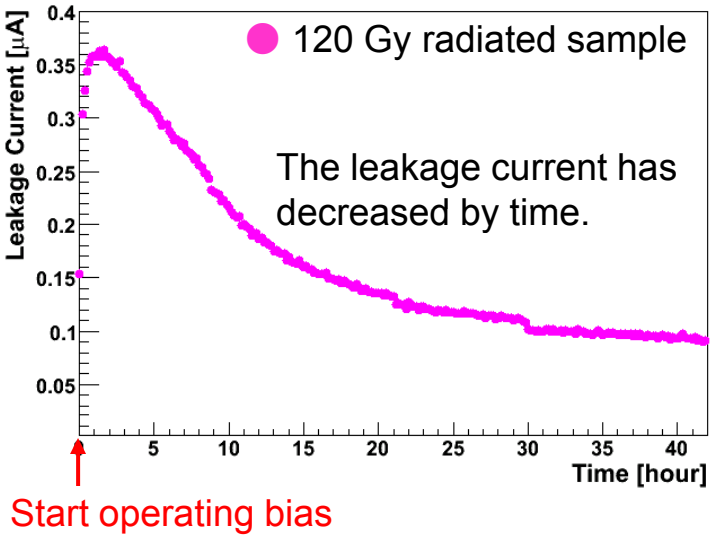
The current was measured by an ammeter.



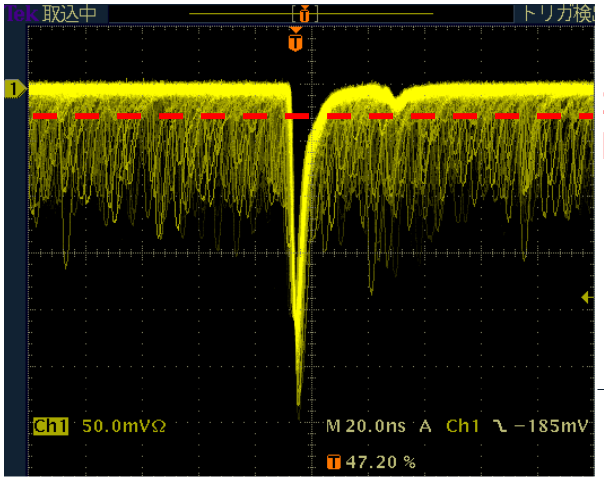


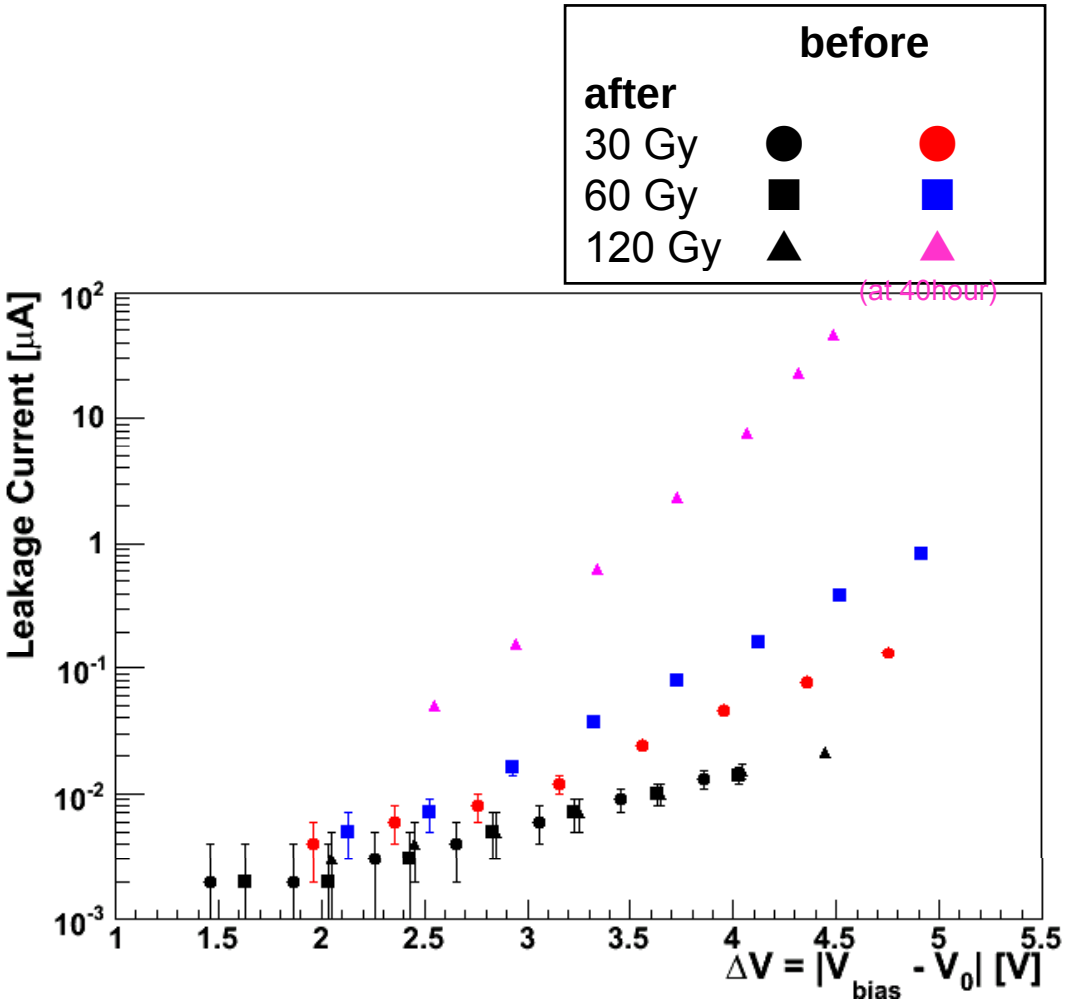
The current has increased drastically.
(about 90 Gy)

Gamma-ray(leakage current : after radiation)



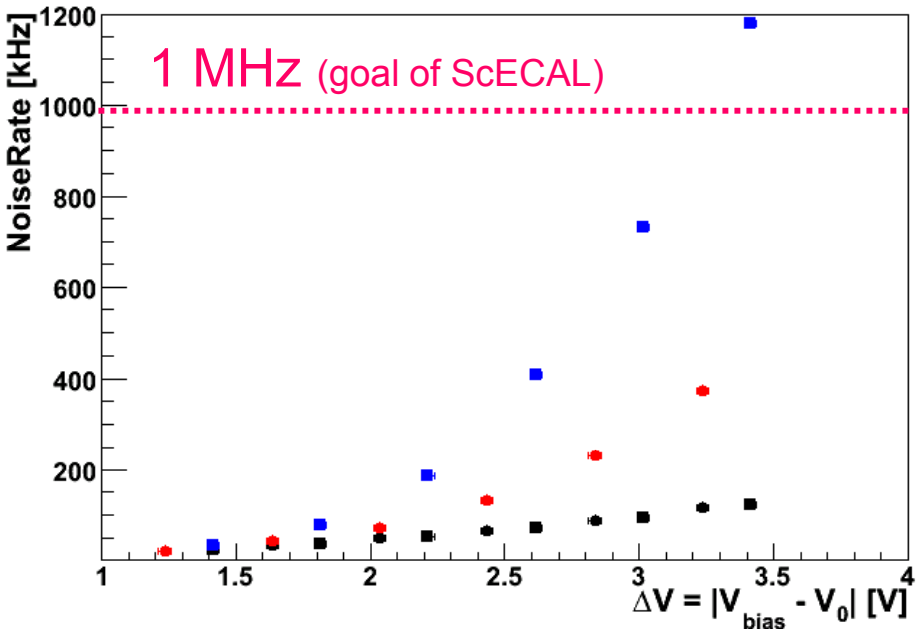
120 Gy radiated sample

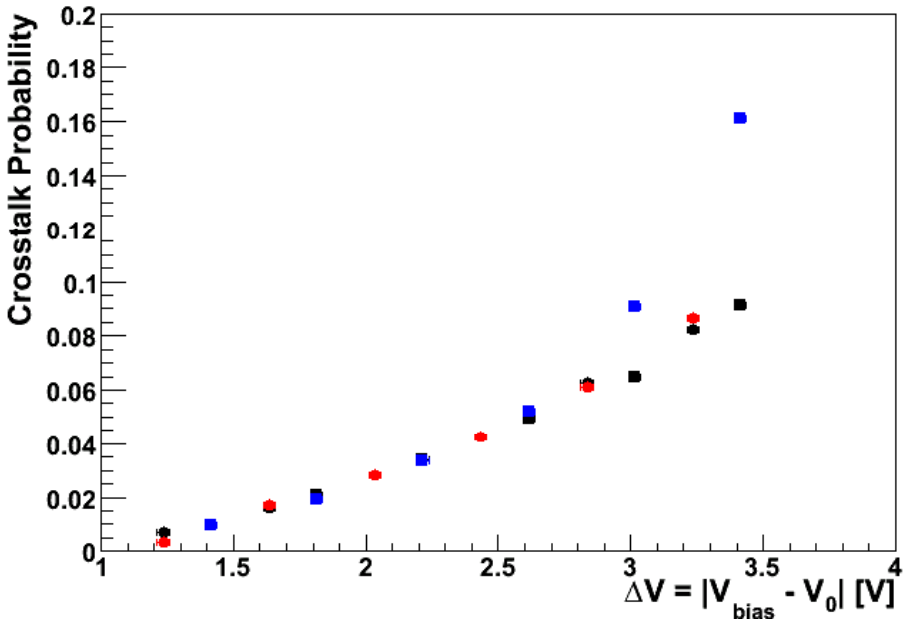




The leakage current have increased by gamma-ray radiation.

Gamma-ray(Noiserate / Crosstalk Probability)





The noiserate have increased by gamma-ray radiation.

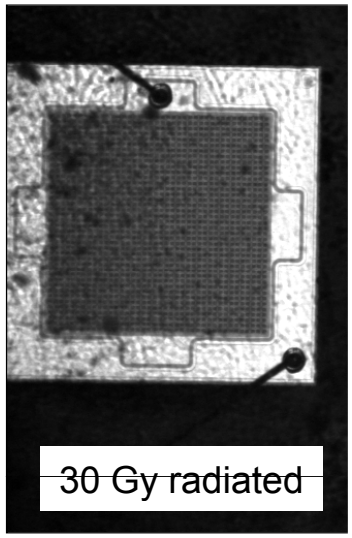
radiated	before	
after		
30 Gy	●	●
60 Gy	■	■

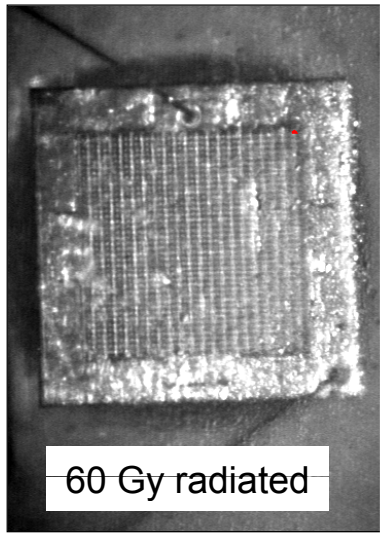
For almost all points, there seem no significant changes on the crosstalk probability by radiation.

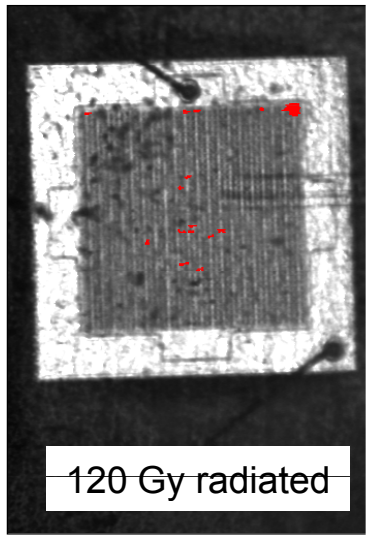
Gamma-ray(Hot spot pictures)

We took infrared pictures to see the hot spots.

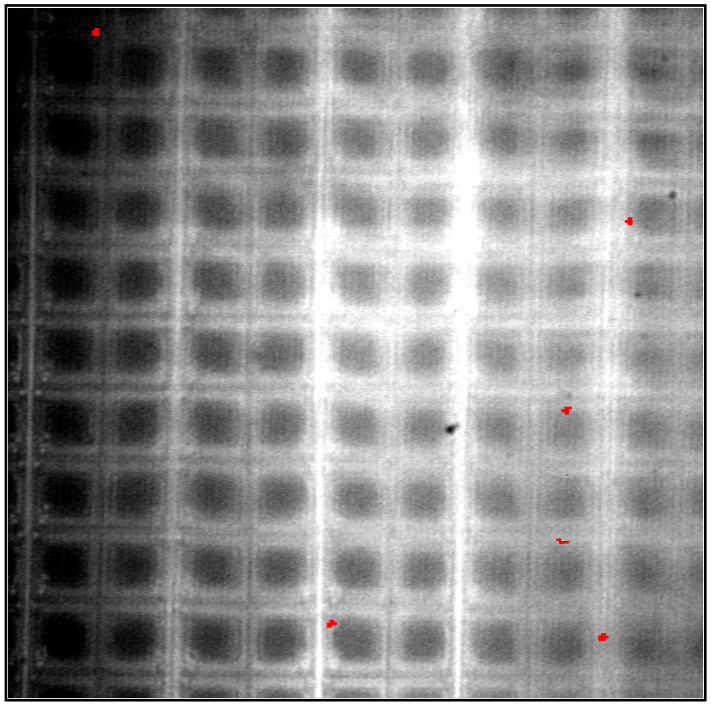
(Hot spot : The spot which always let out noise.)







120 Gy radiated (zoomed)

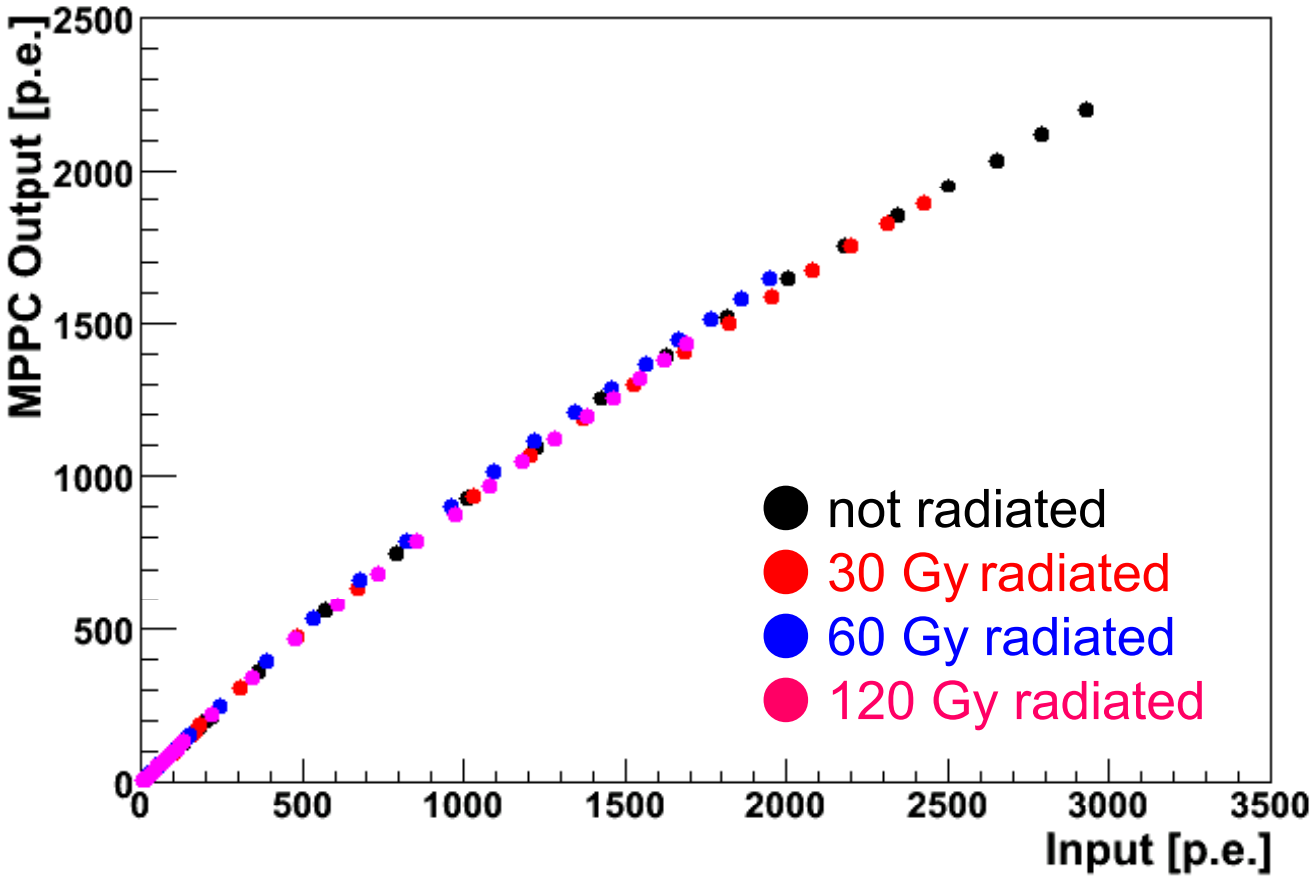


There seem hot spots have increased by gamma-ray radiation,

The black squares are the sensitive areas. The white lines are the oxidized layer with bias lines.

The hot spots only appeared on the oxidized layer.

Gamma-ray(Response Curve)



The response curves have not changed by gamma-ray radiation.

Neutron Radiation

Flux

3.1×10^{8} neutron/cm^2
3.1×10^{9} neutron/cm^2
3.1×10^{10} neutron/cm^2
3.1×10^{11} neutron/cm^2

Prospective damage

Increasing lattice defect in silicon bulk

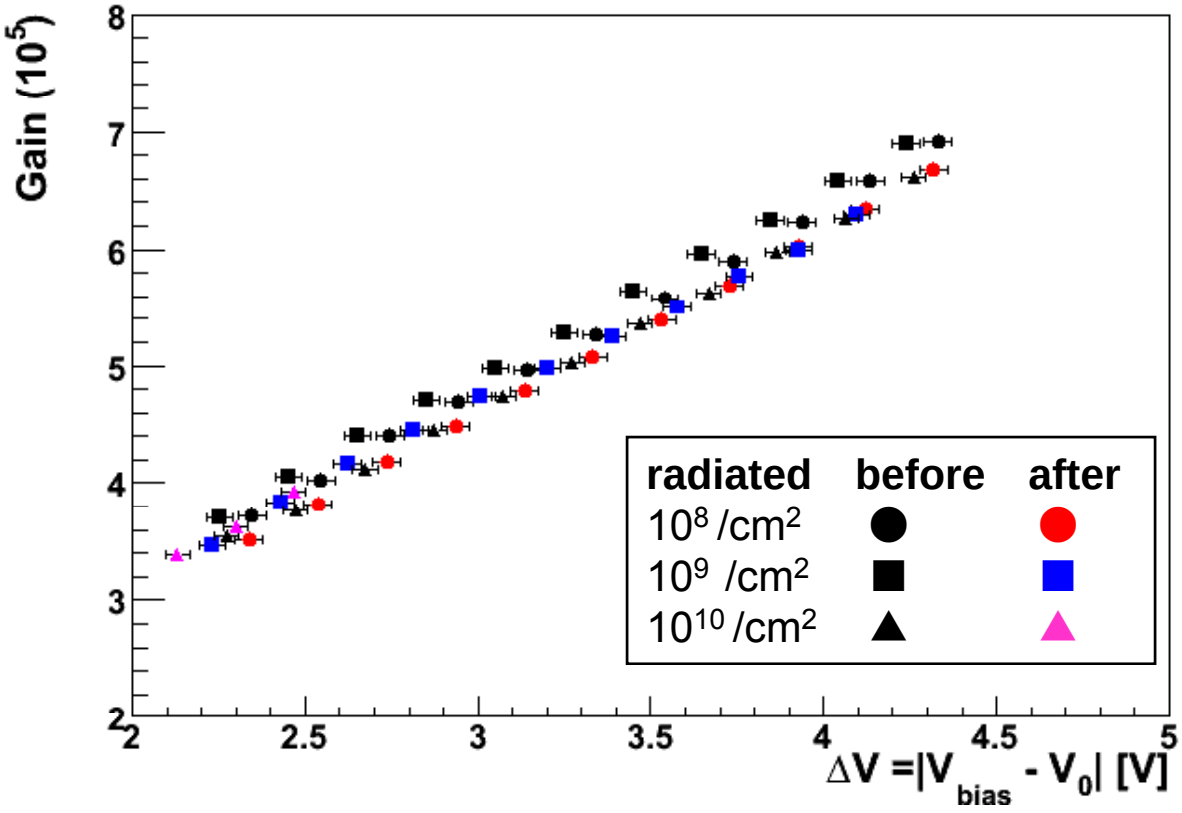
Radiated MPPC Sample

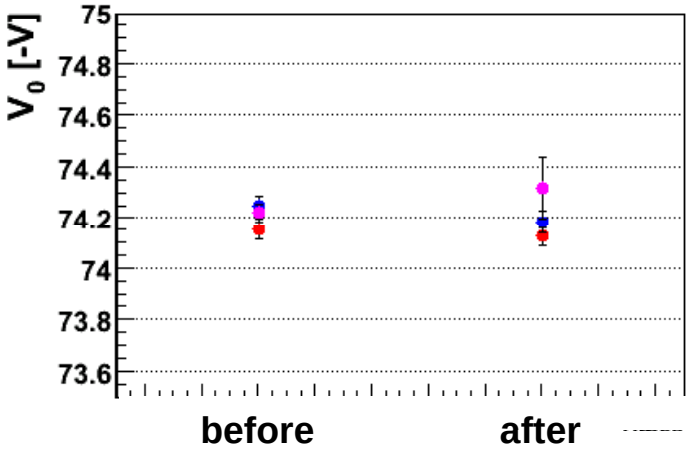
Type : S10362-11-025MK
Size : 1mm×1mm
1600 pixel (25μm pitch)

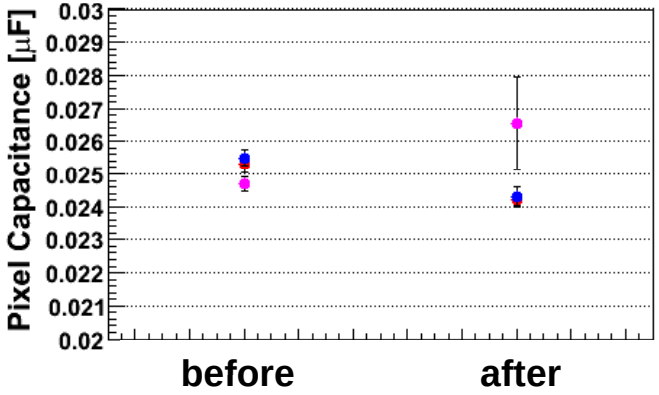
Radiation test location

The reactor YAYOI
(Fast neutron source reactor of the University of Tokyo)

Neutron(Gain)



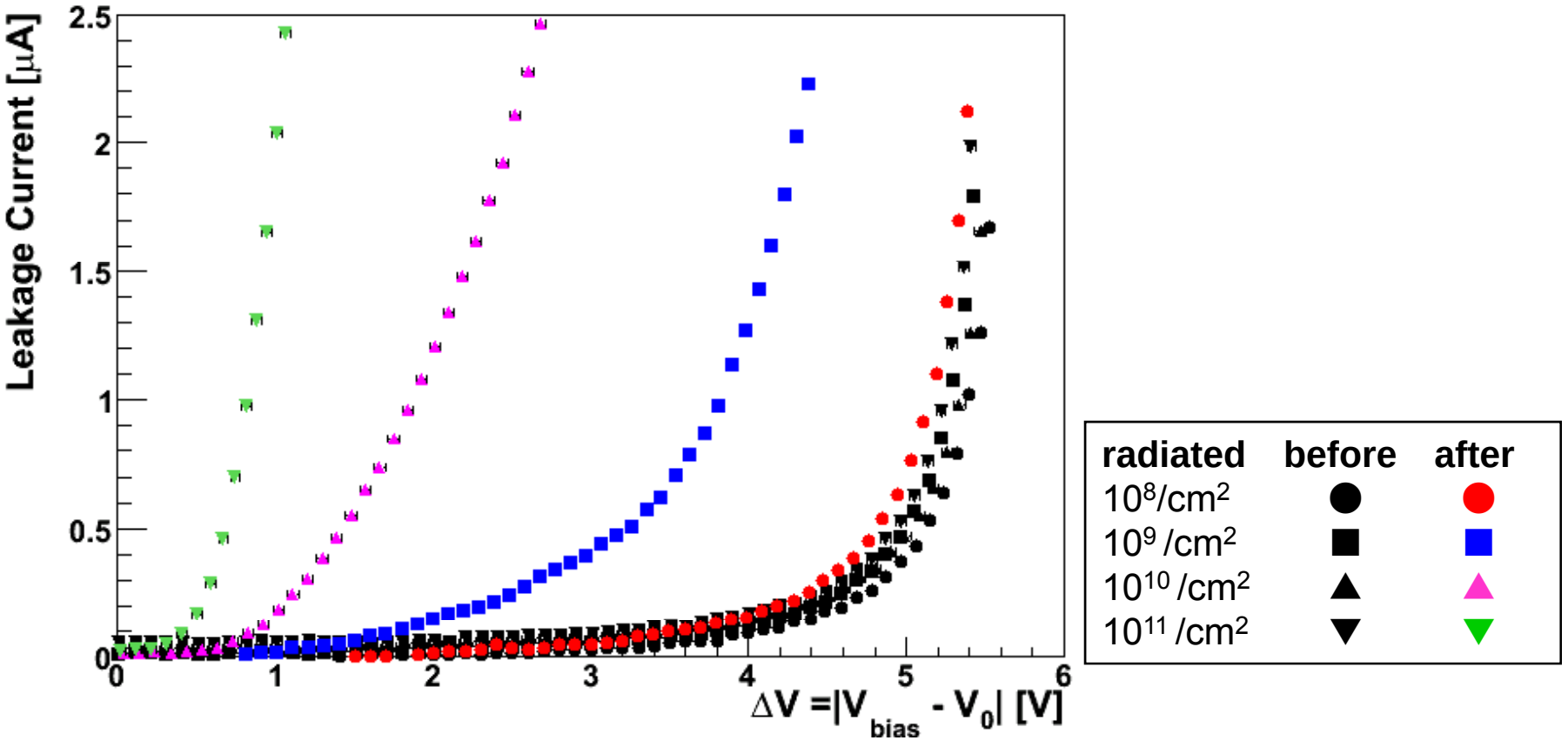




10^8 /cm^2 radiated
10^9 /cm^2 radiated
10^{10} /cm^2 radiated

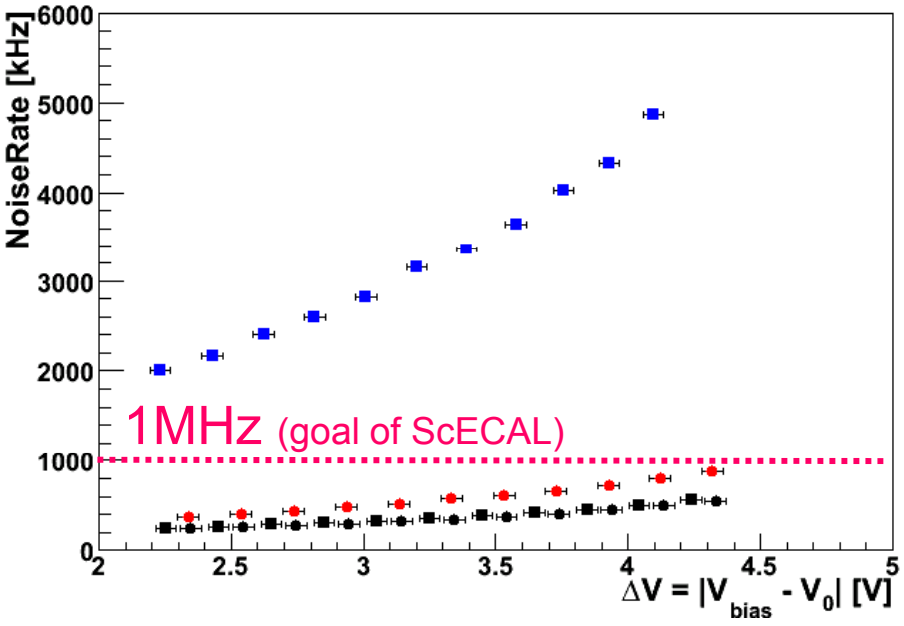
There seem no significant changes on the gain by neutron radiation.

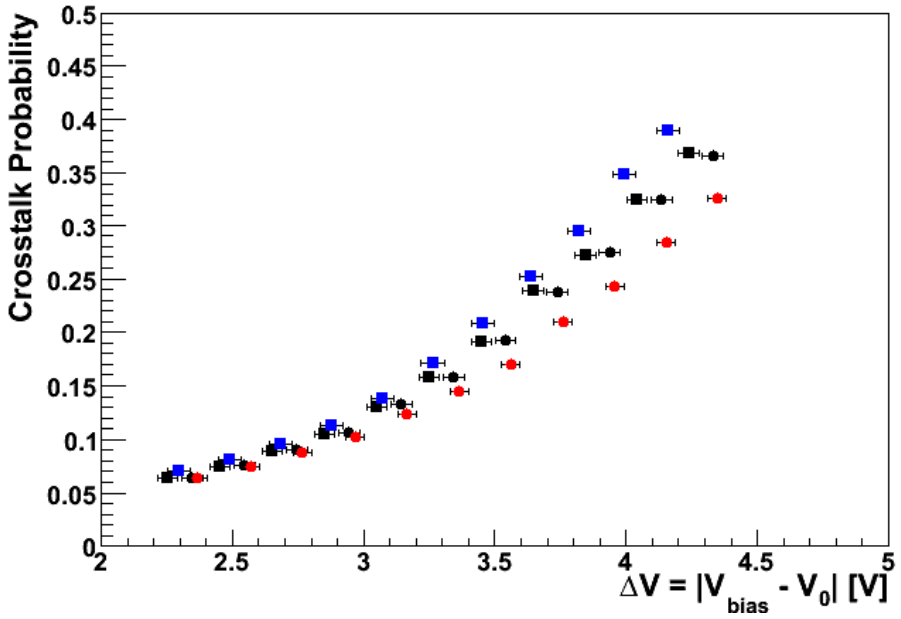
Neutron(Leakage Current)



The leakage current have increased by neutron radiation.

Neutron(Noise Rate / Crosstalk Probability)



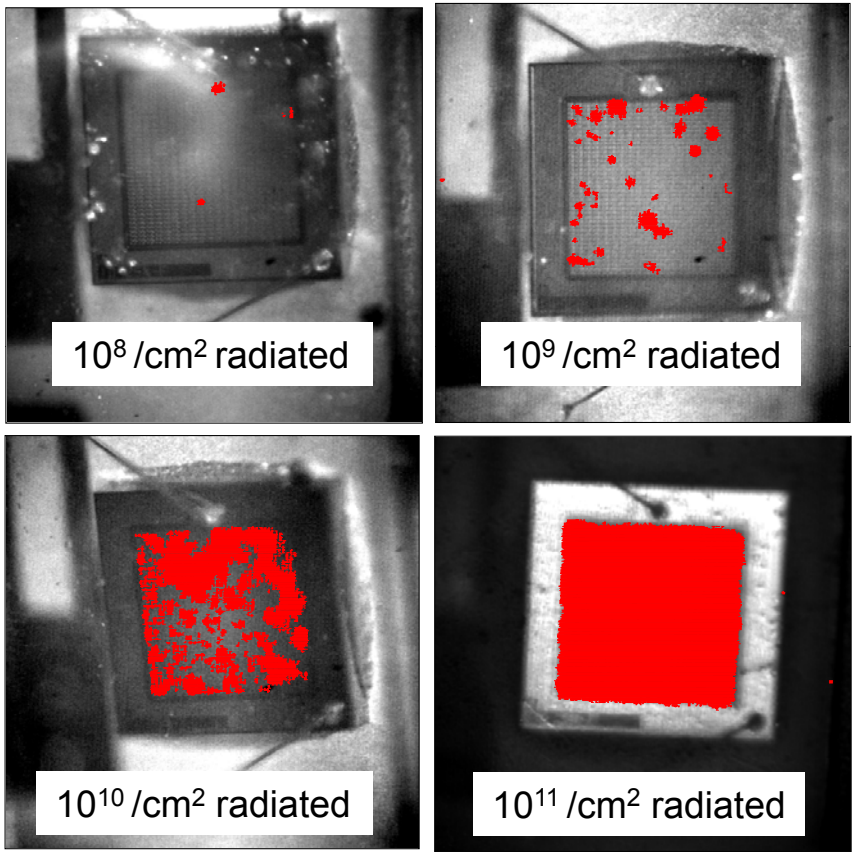


The noiserate have increased by neutron radiation.

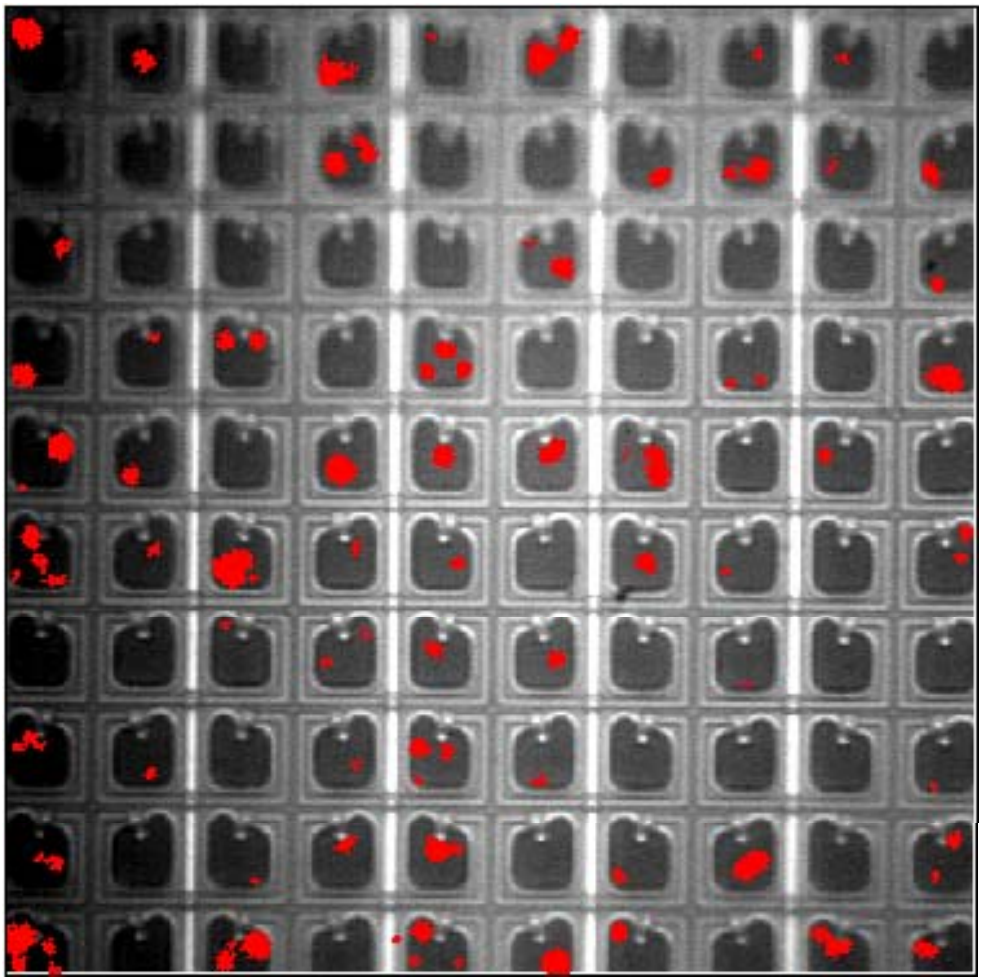
radiated	before	after
$10^8/cm^2$	●	●
$10^9/cm^2$	■	■

There seem no significant changes on the crosstalk probability by radiation.

Neutron(Hot spot pictures)

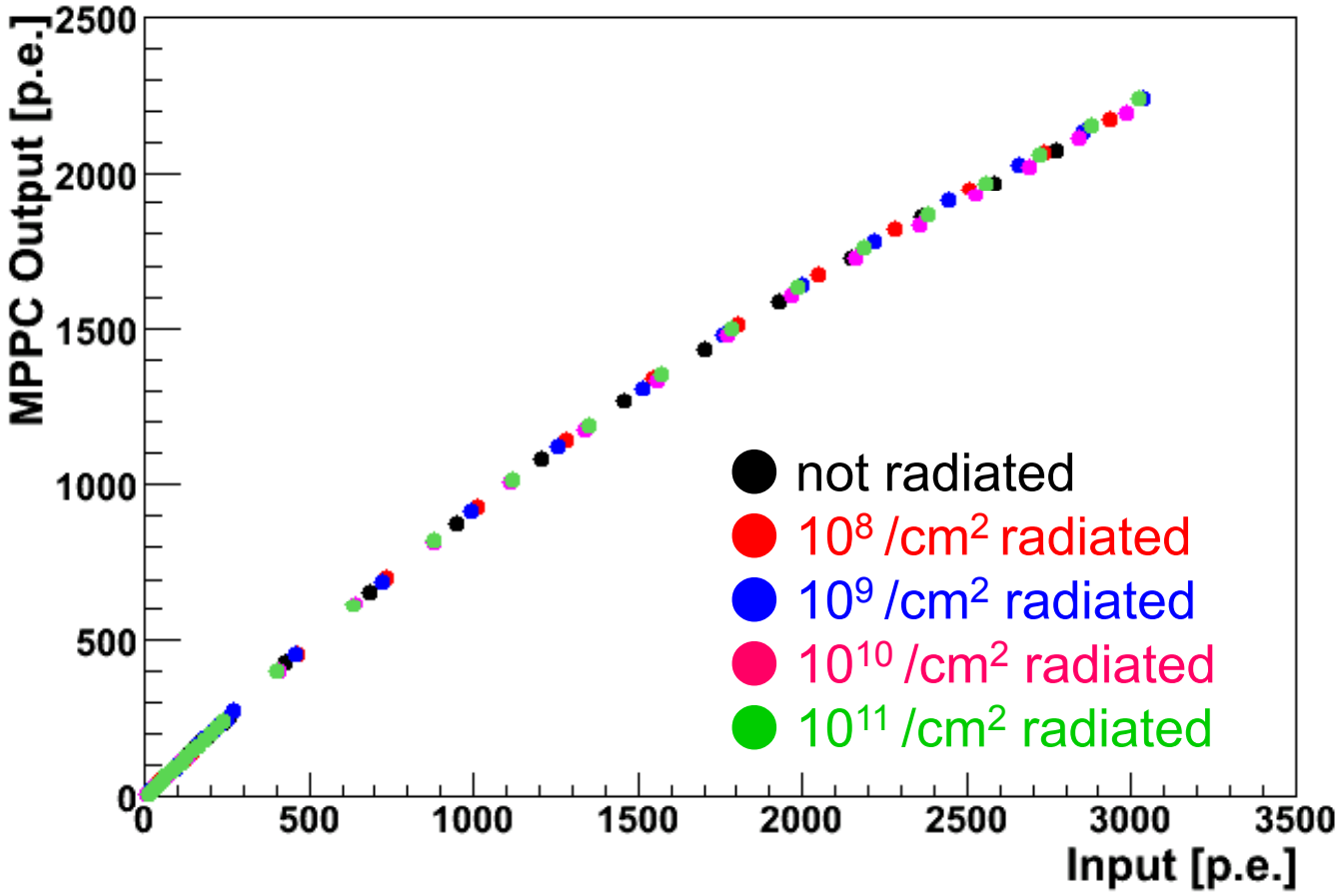


10^{11} /cm^2 radiated (zoomed)



There seem hot spots have increased by neutron radiation.
The hot spots only appeared on the sensitive area.

Neutron(Response Curve)



The response curves have not changed by neutron radiation.

Summary

MPPC Radiation Resistivity Study
(Gamma-ray & Neutron radiation)

- The leakage current and the noise rate are significantly increased.
- There seem no significant changes on the gain and the crosstalk probability.
- The response curves have not changed by radiation.

Even though the dark noise increased by radiation, the MPPC still working as photon-counting device.

Plan

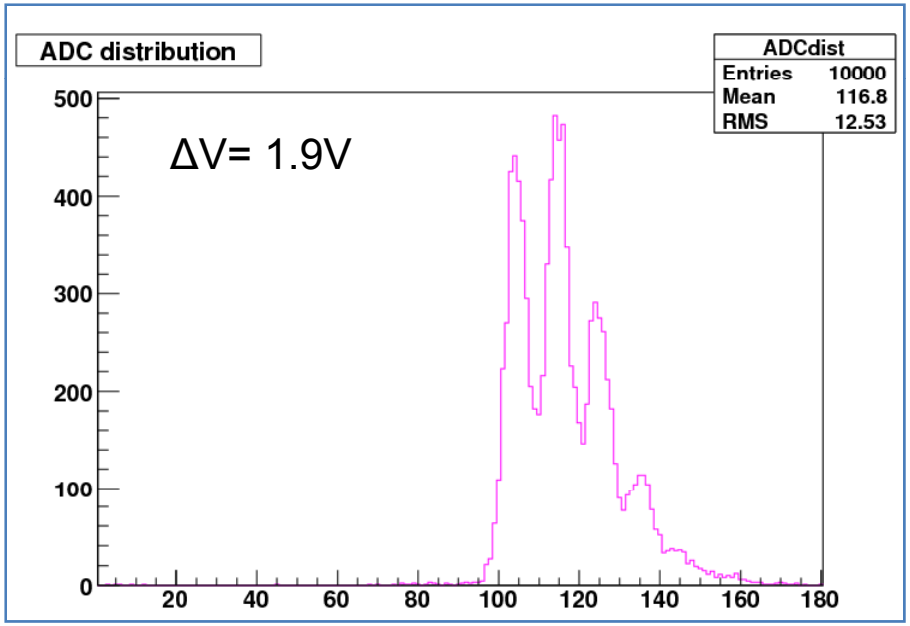
- The estimation of dose at ScECAL (Need simulation tools!).
- More radiation tests with estimated dose.

Back Up

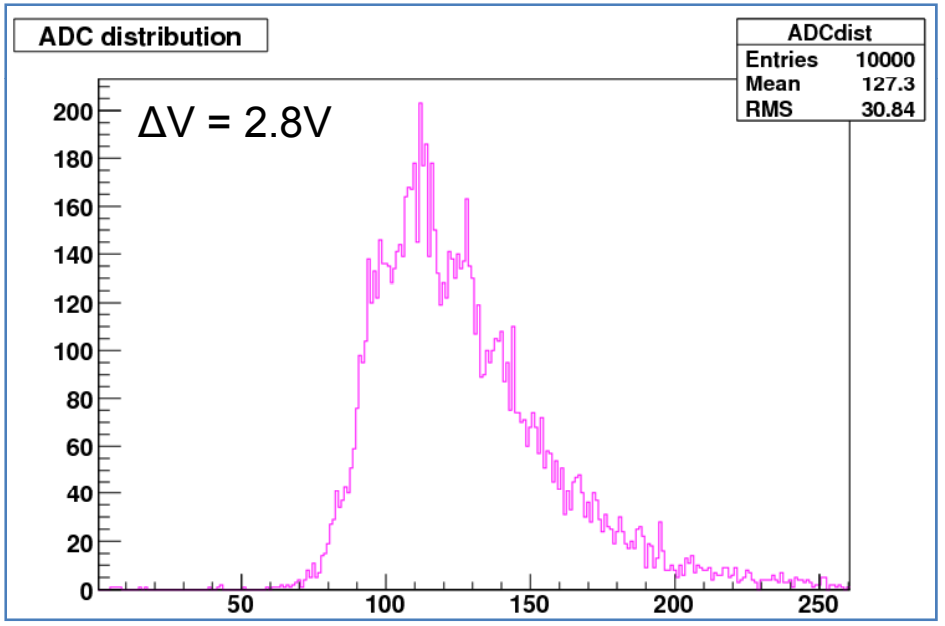
ADC distribution

Some ADC distributions of radiated samples are too noisy to evaluate the gain.

Ex.) The ADC distributions of gamma-ray 120 Gy radiated sample

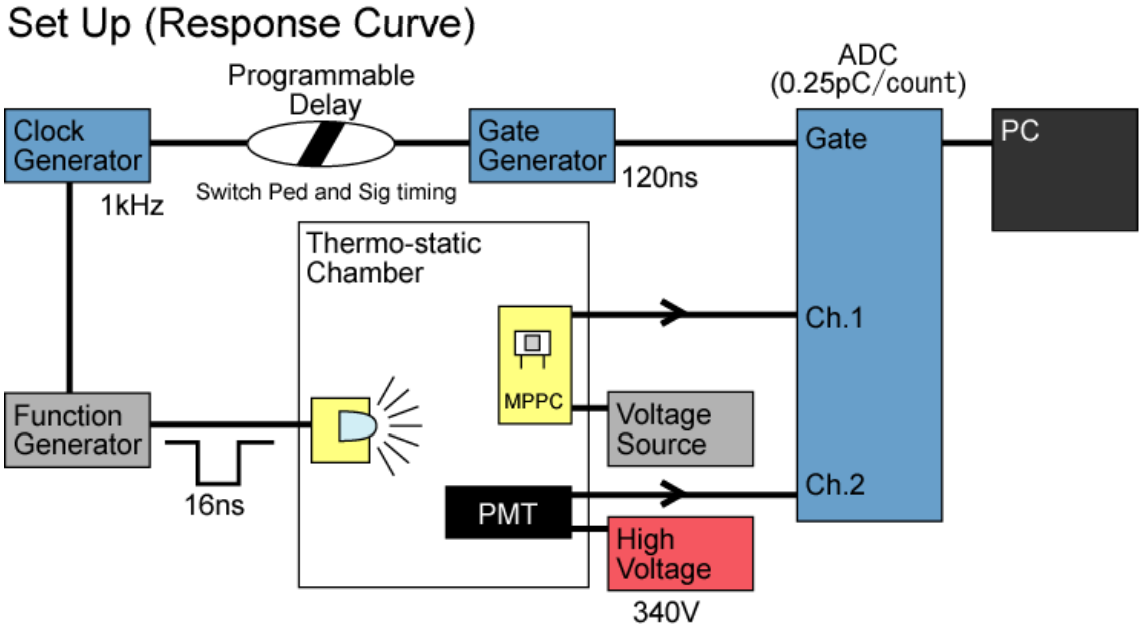


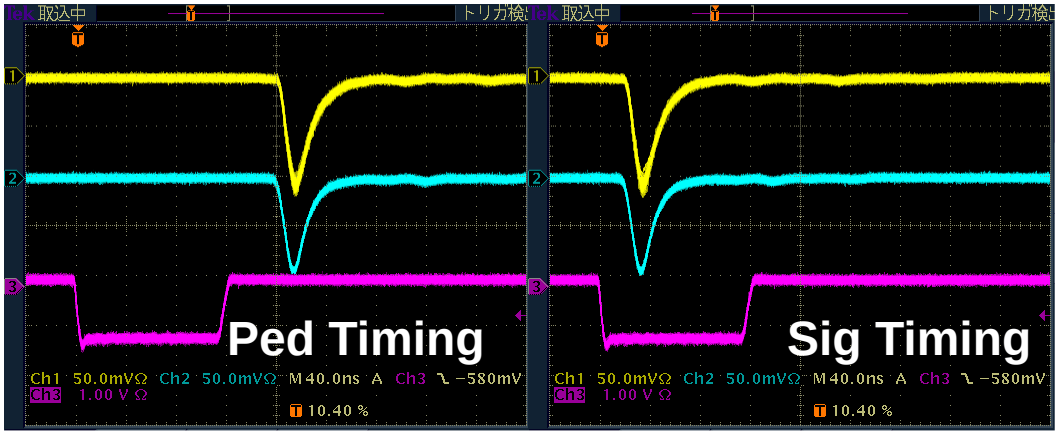
O.K.



N.G.

Response Curve measurement



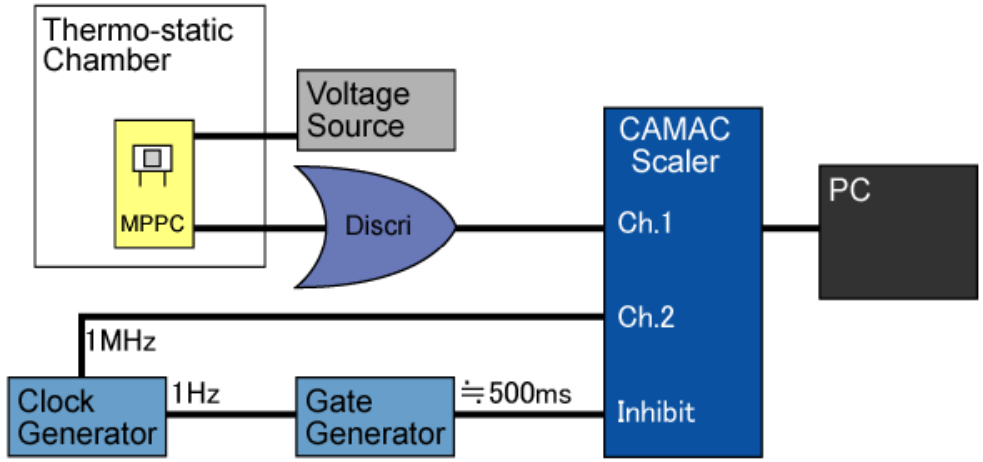


$$Output = ADCmean_{SIG} - ADCmean_{PED}$$

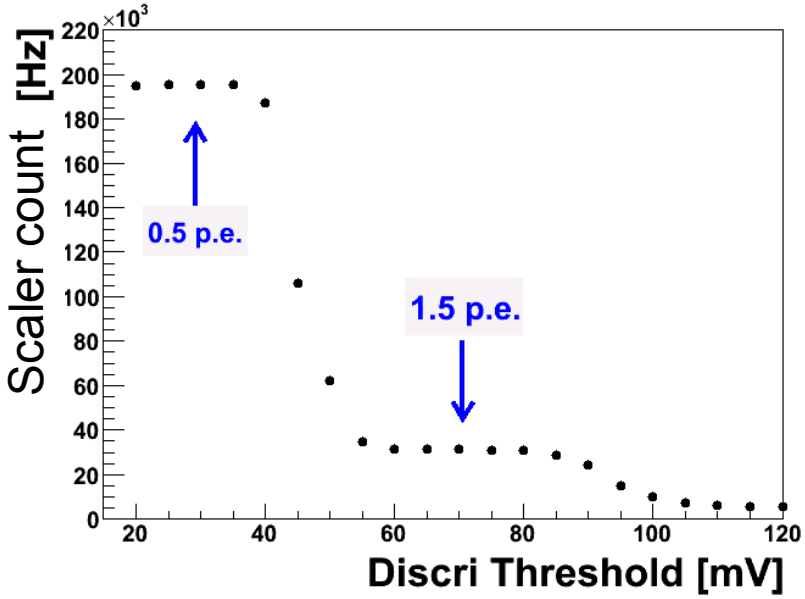
NoiseRate measurement

(Crosstalk Probability measurement)

Set Up (Noise Rate/Crosstalk Probability)



An example of Threshold curve



$$NoiseRate\ [Hz] = \frac{Scaler\ \ count(>0.5\ \ p.e.\ Thr.)}{time\ [s]}$$

$$Crosstalk\ \ Probability = \frac{Scaler\ \ count(>1.5\ \ p.e.\ Thr.)}{Scaler\ \ count(>0.5\ \ p.e.\ Thr.)}$$