MPPC Radiation Resistivity

- Multi Pixel Photon Counter(MPPC)
- Gamma-ray radiation
- Neutron radiation

Mar 3-6 TILC08 at Sendai
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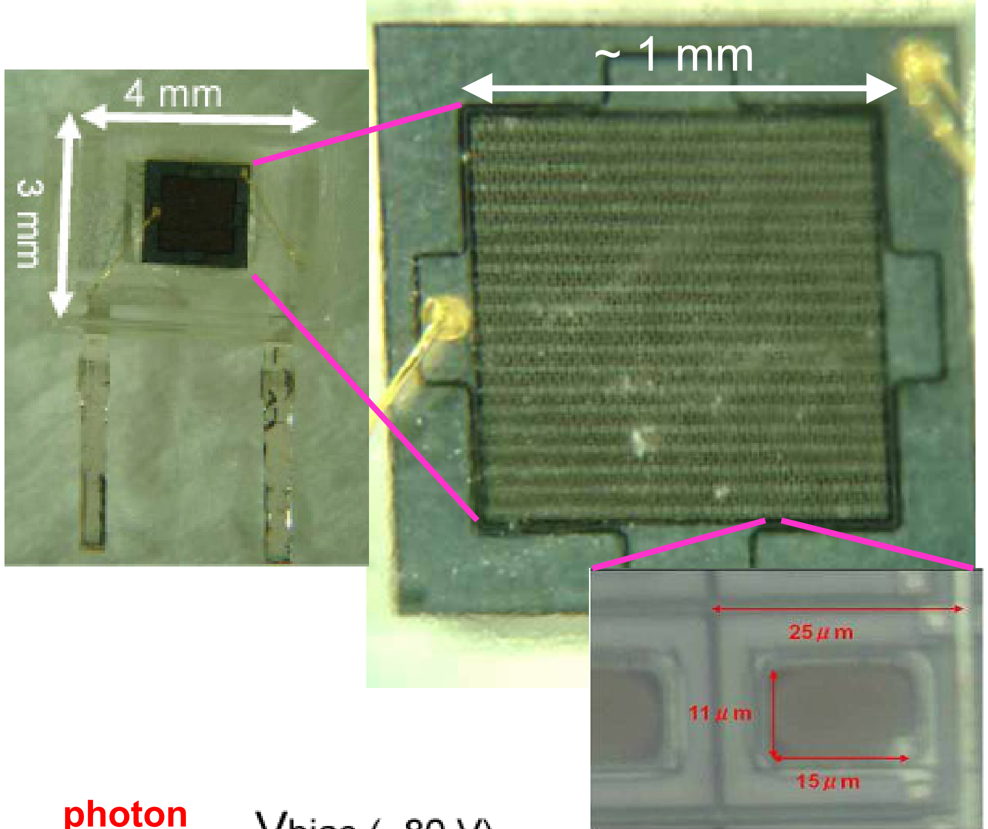
for the ScECAL group

Multi Pixel Photon Counter (MPPC)

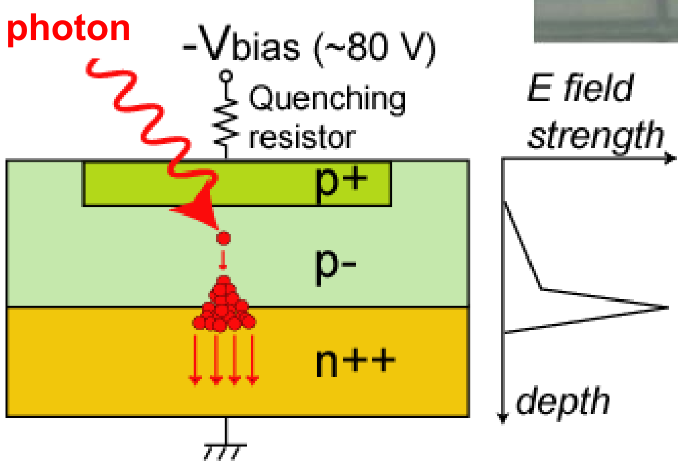
A pixelated photon detector manufactured by Hamamatsu Photonics

- 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



MPPC Radiation Experiments

We are developing and studying the 1600-pixel MPPC with R&D photon-sensor group of KEK and Hamamatsu Photonics for the ScECAL readout.

Knowing radiation resistivity is important to estimate the life time of the calorimeter under the environment at the ILC.
For this far, we have performed radiation tests of MPPC with gamma-ray and neutrons, and measured important properties.

The Measured Properties

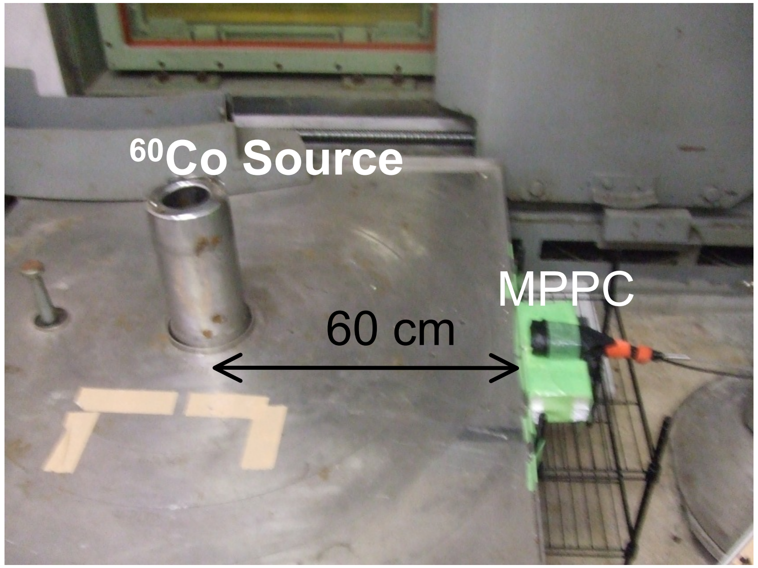
Gain
Leakage Current
Noise Rate
Crosstalk Probability
Hot spots
Response Curve

(The dose at ScECAL is under estimation now.)

Gamma-ray Radiation

Dose amount

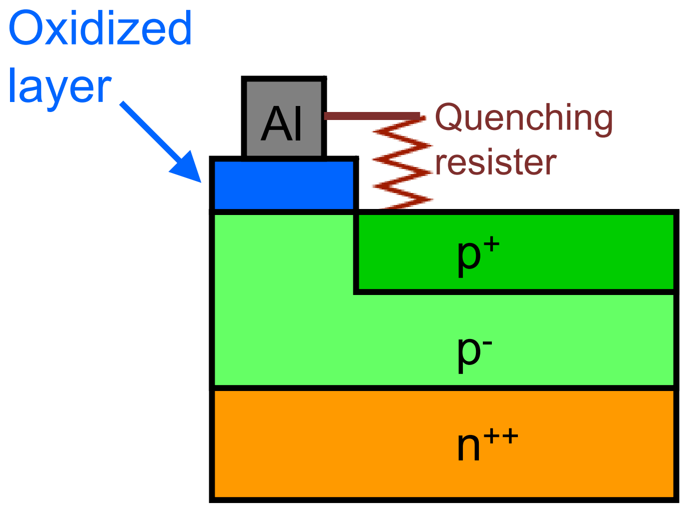
10 Gy/h for 3 hours →30 Gy
10 Gy/h for 6 hours →60 Gy
10 Gy/h for 12 hours →120 Gy
(Gy=100 rad=J/kg)



Radiation source ~15TBq ^{60}Co Source

Prospective damage

Charge accumulation on the oxidized layer.

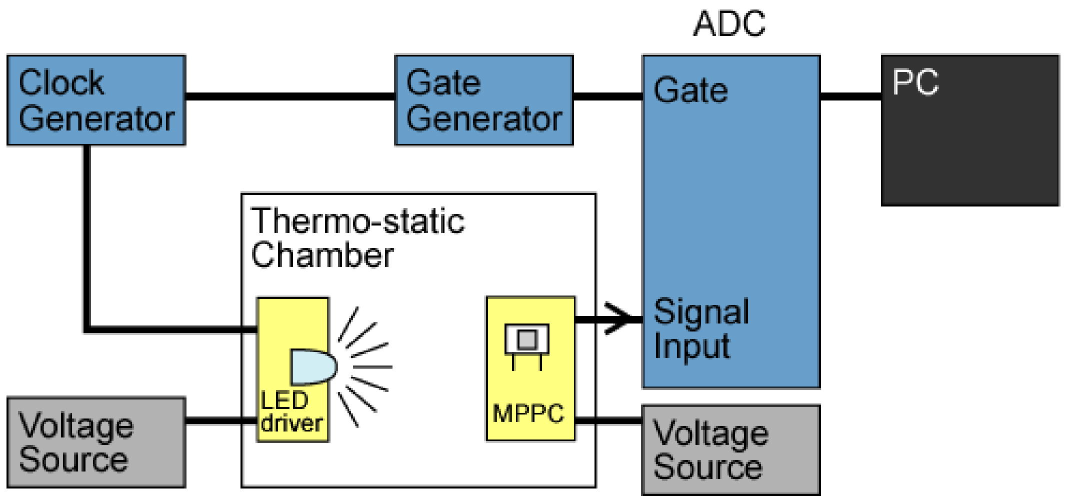


Radiated MPPC Sample

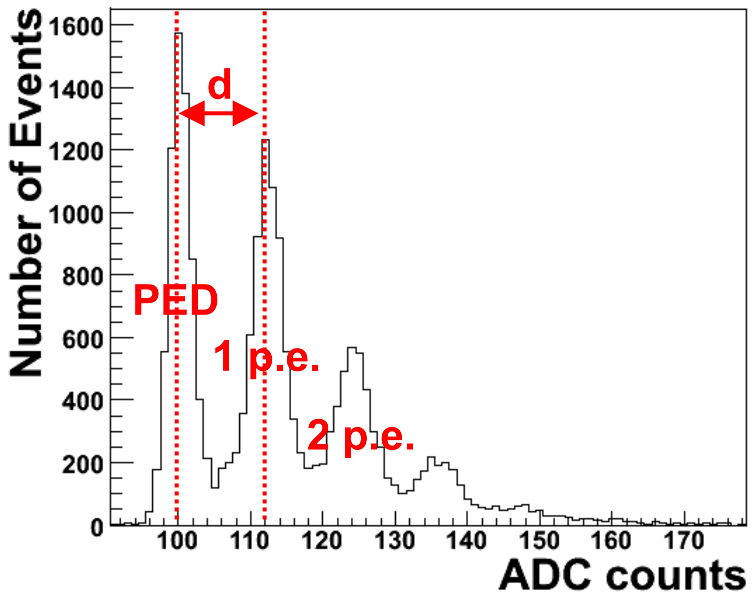
Type : ILC-11-0125M
Size : 1mm × 1mm
1600 pixel (25 μm pitch)

Gain measurement

Set Up (Gain)



An example of ADC distribution

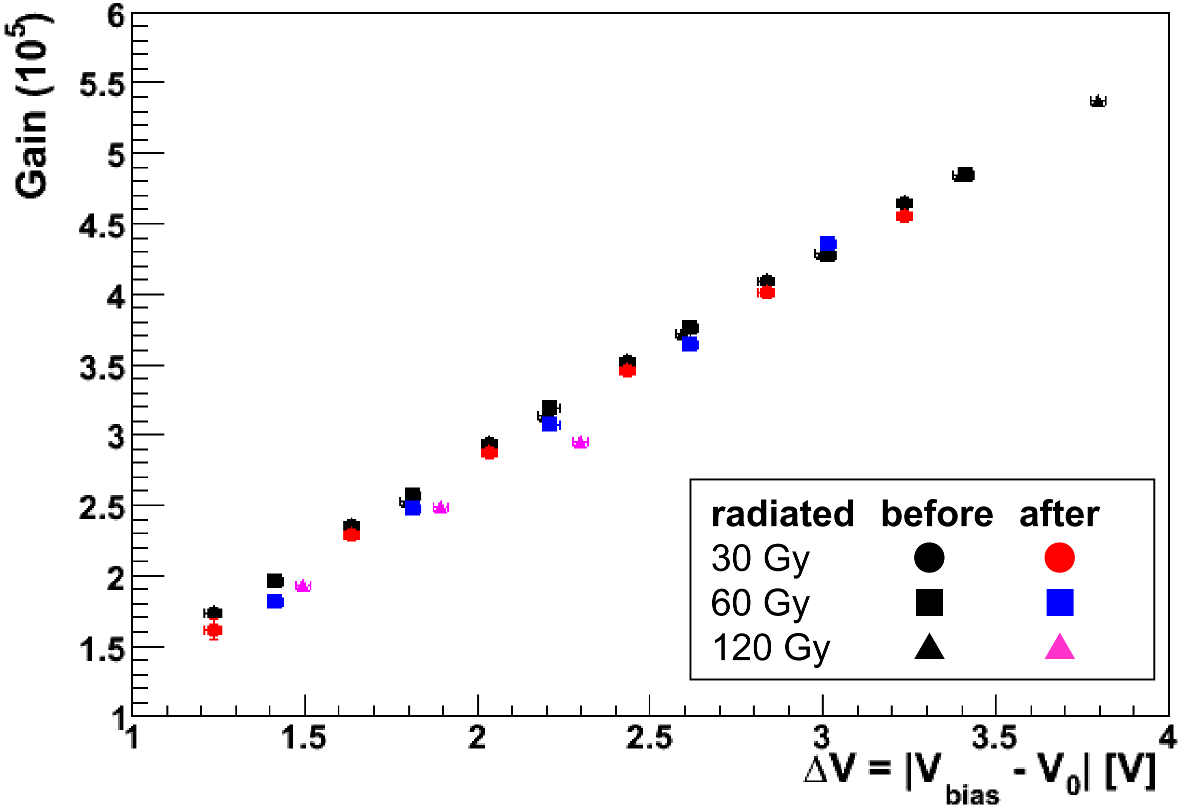


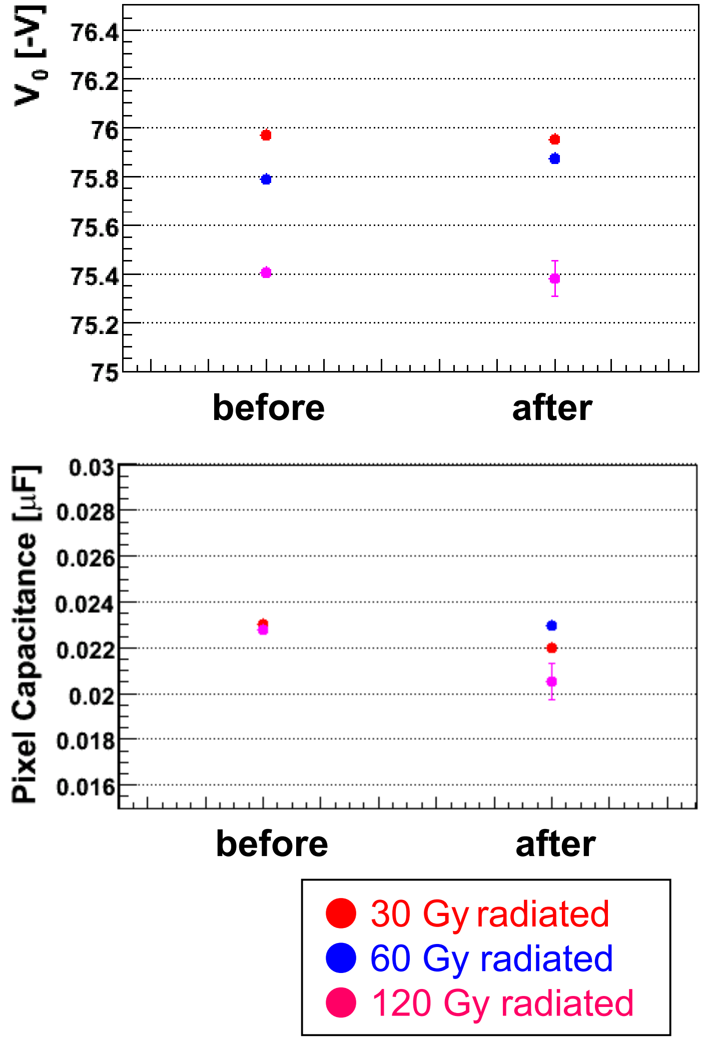
$$Gain = \frac{d \times S}{e} = \frac{Q}{e} = \frac{C}{e}(V_{bias} - V_0)$$

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)

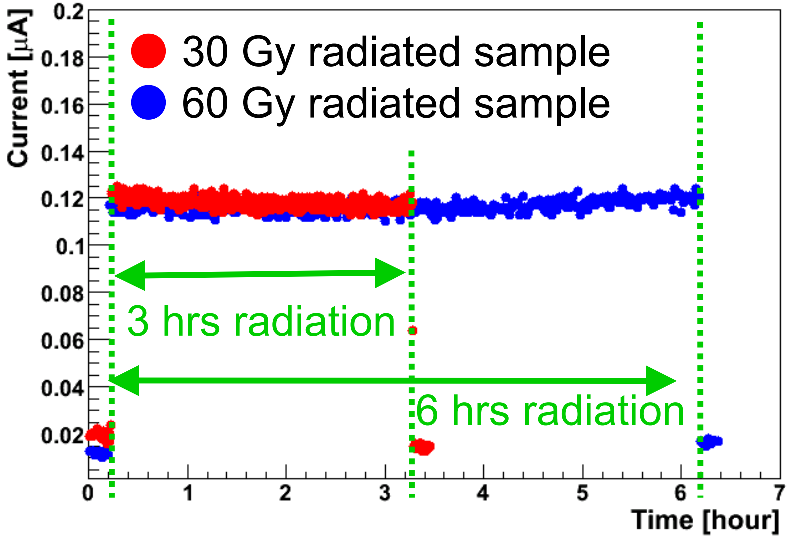


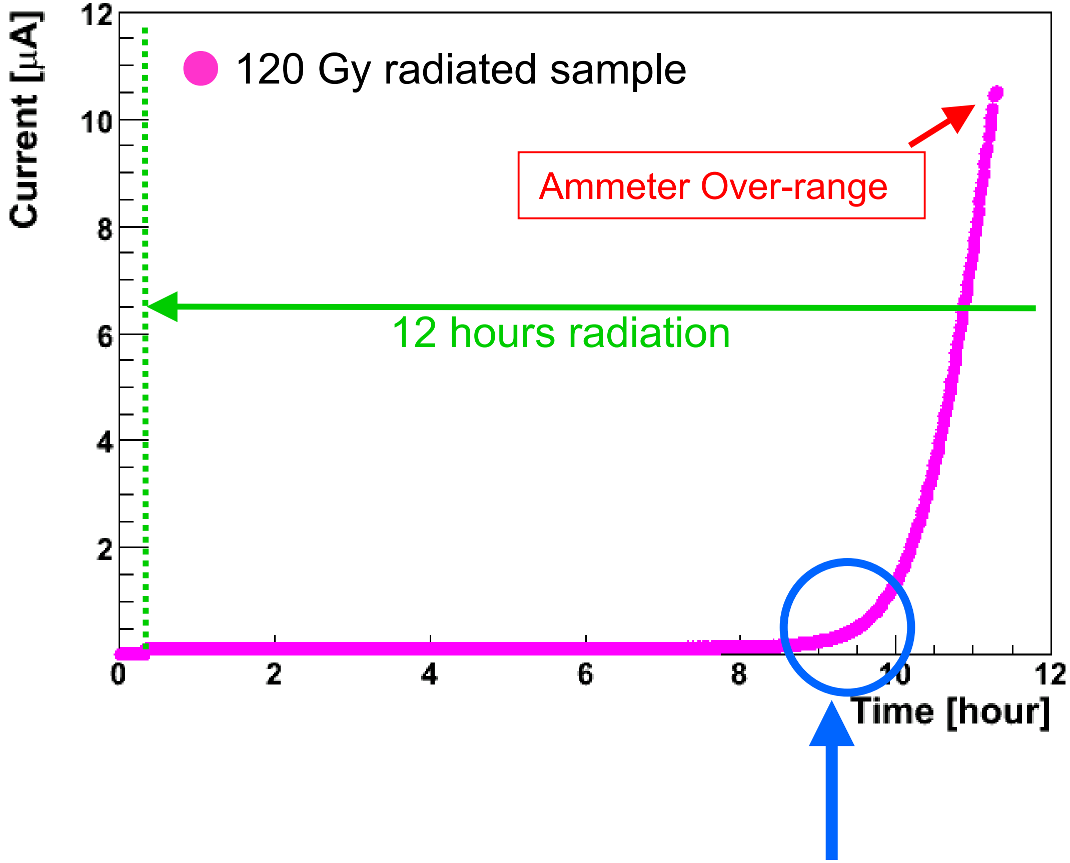


There seem no significant changes on the gain by gamma-ray radiation.

Gamma-ray(current : during radiation)

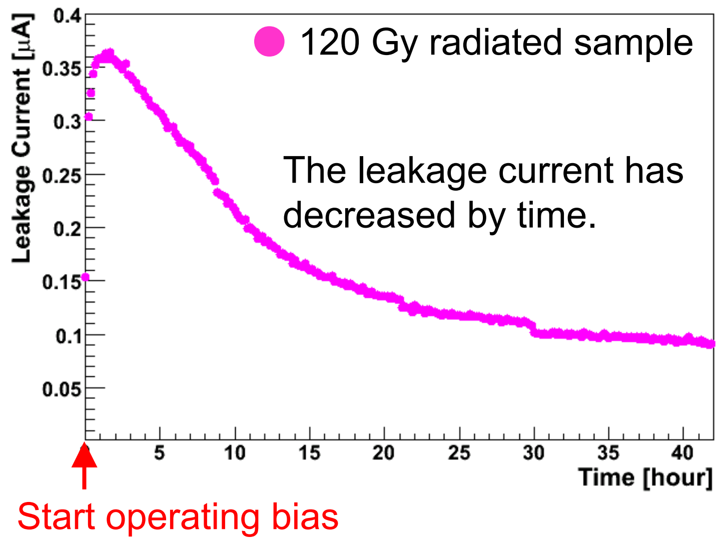
The current was measured by an ammeter.



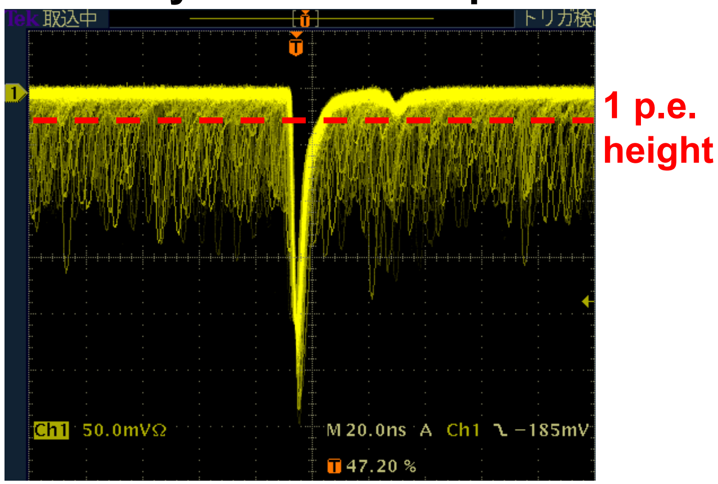


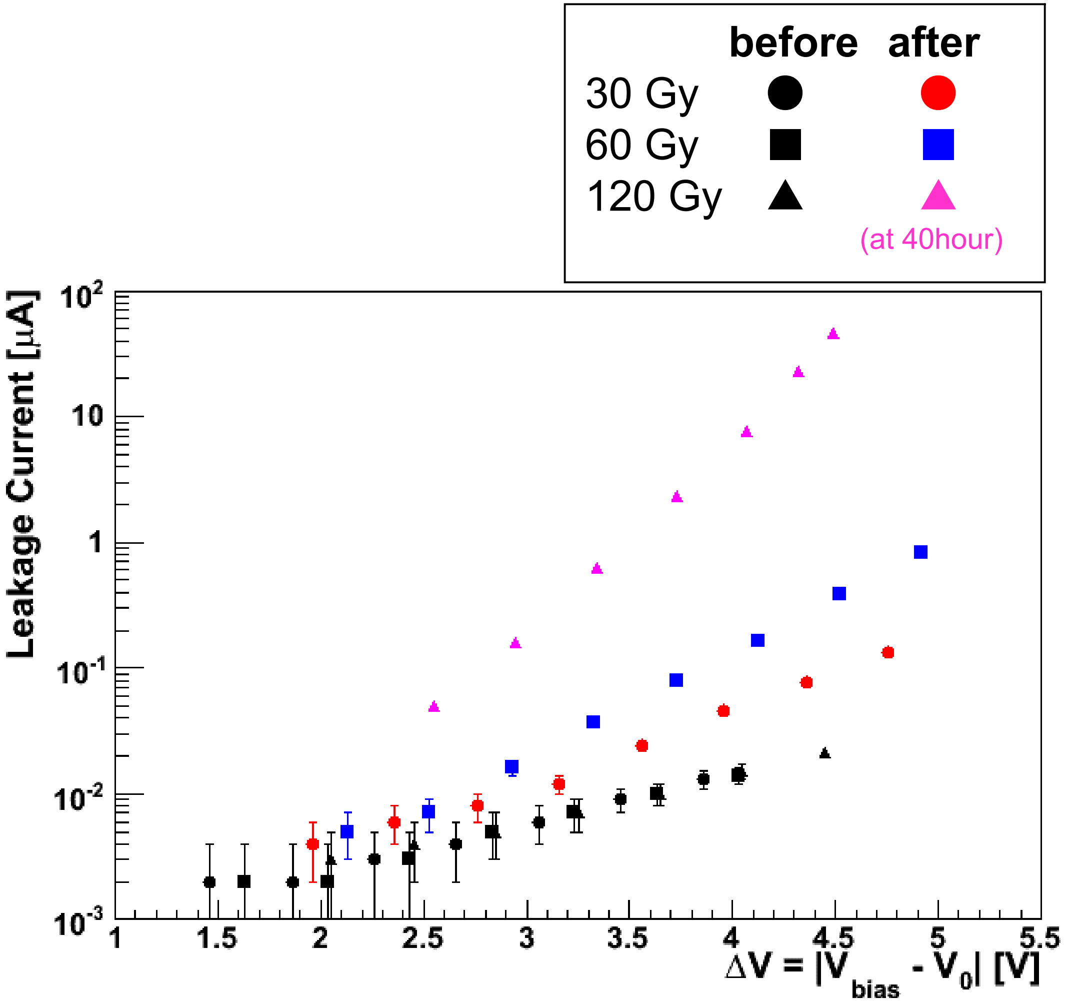
The current has increased drastically.
(about 90 Gy)

Gamma-ray(leakage current : after radiation)



120 Gy radiated sample



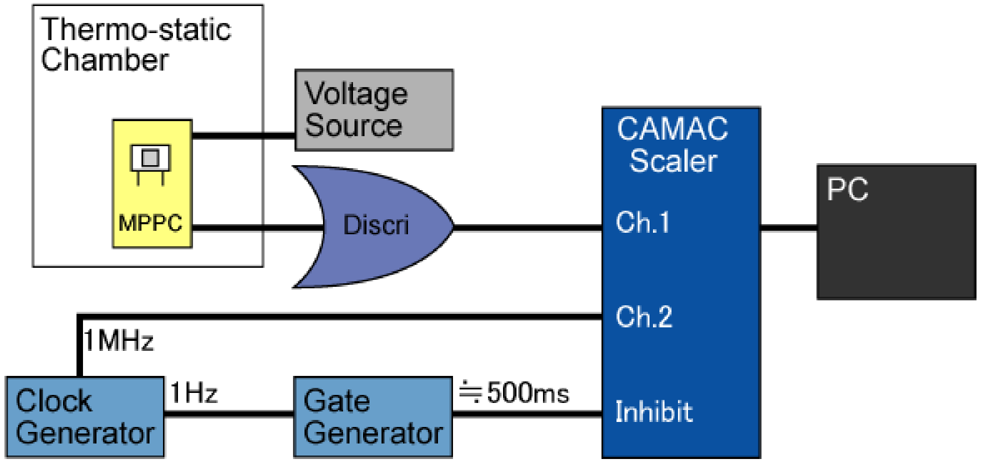


The leakage current have increased by gamma-ray radiation.

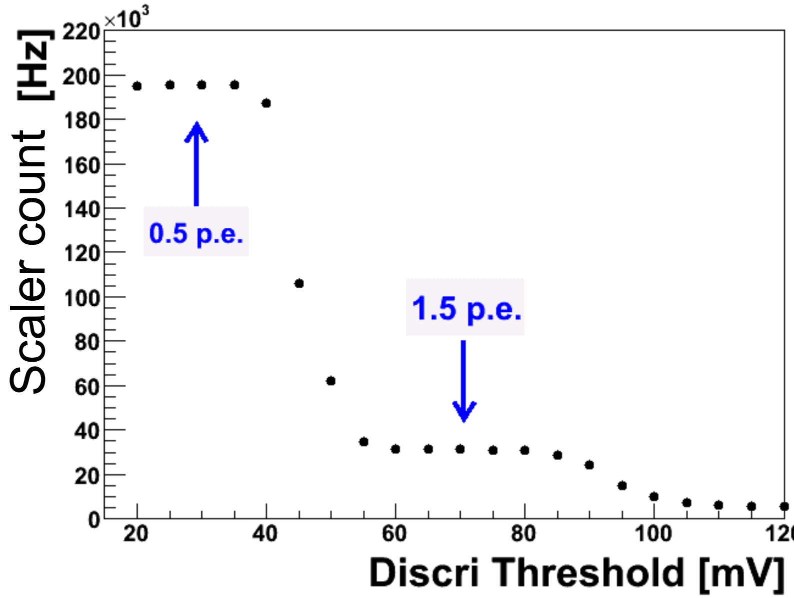
NoiseRate measurement

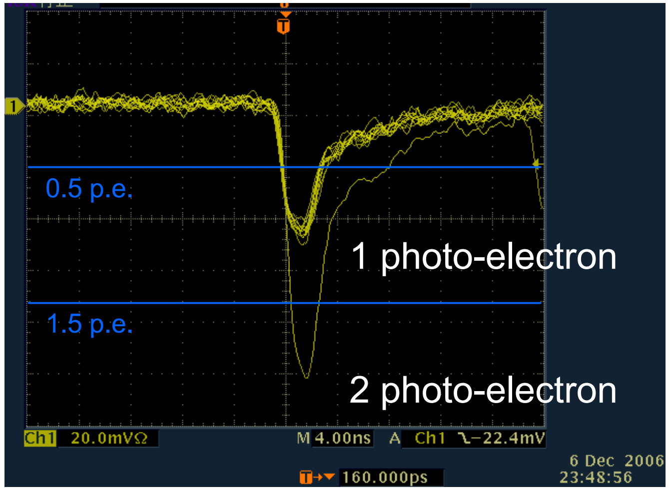
(Crosstalk Probability measurement)

Set Up (Noise Rate/Crosstalk Probability)



An example of Threshold curve

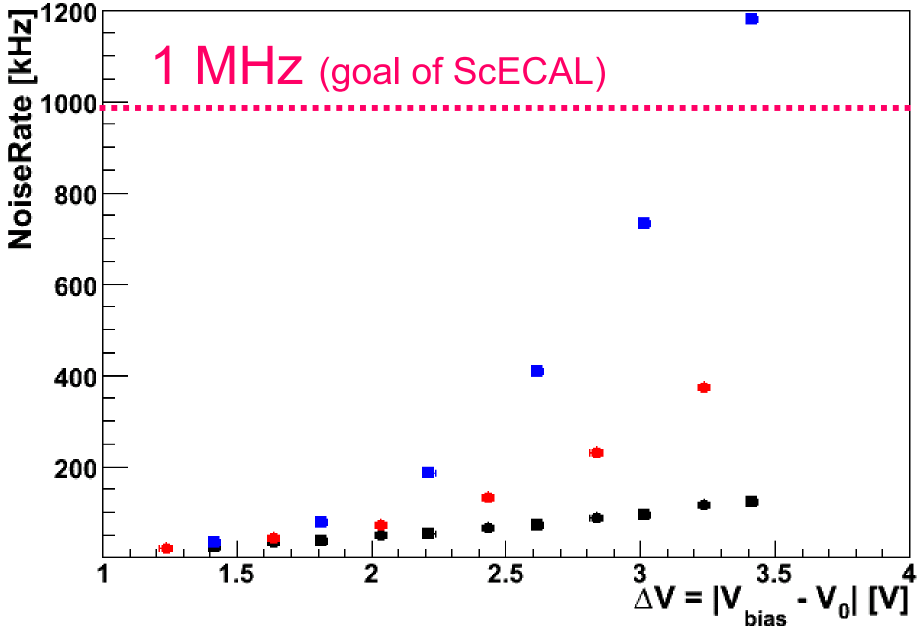




$$NoiseRate\,[Hz] = \frac{Scaler\ count(>0.5\ \ p.e.\ Thr.)}{time\,[s]}$$

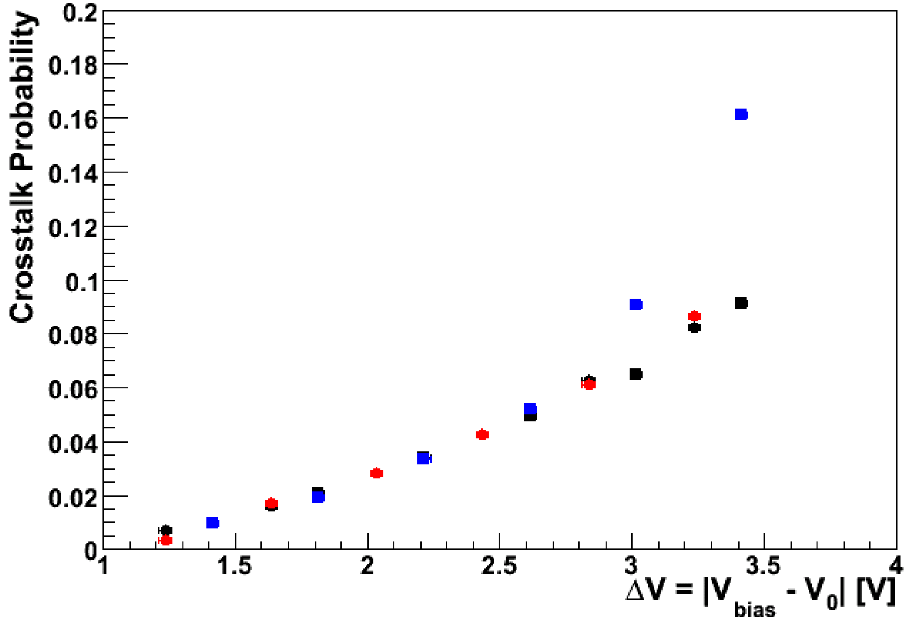
$$Crosstalk\ \ Probability = \frac{Scaler\ count(>1.5\ \ p.e.\ Thr.)}{Scaler\ count(>0.5\ \ p.e.\ Thr.)}$$

Gamma-ray(Noiserate / Crosstalk Probability)



The noiserate have increased by gamma-ray radiation.

radiated	before	after
30 Gy	●	●
60 Gy	■	■

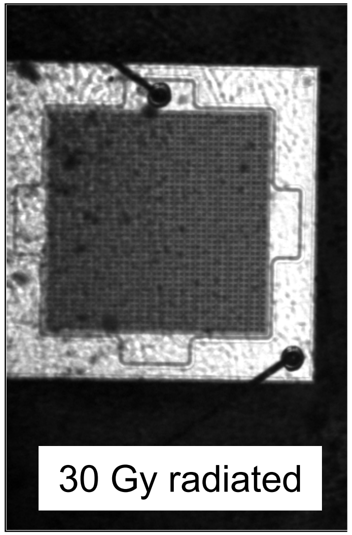


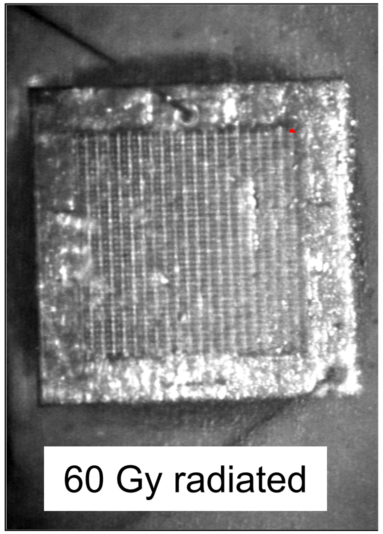
For almost all points, there seem no significant changes on the crosstalk probability by radiation.

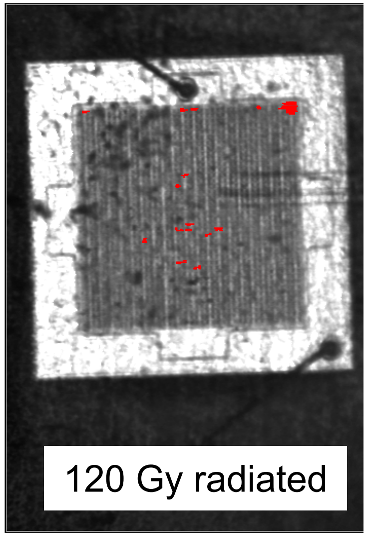
Gamma-ray(Hot spot pictures)

We took infrared pictures to see the hot spots.

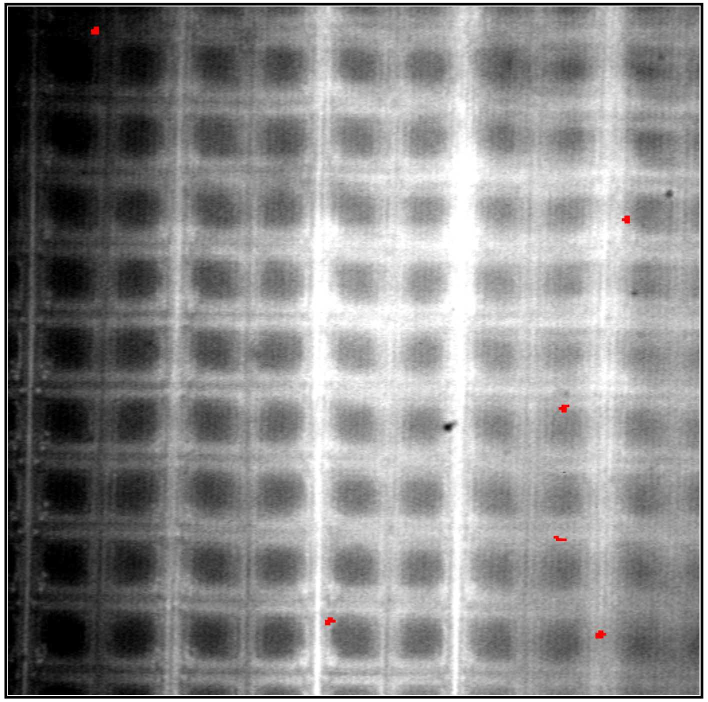
(Hot spot : The spot which always let out noise.)







120 Gy radiated (zoomed)



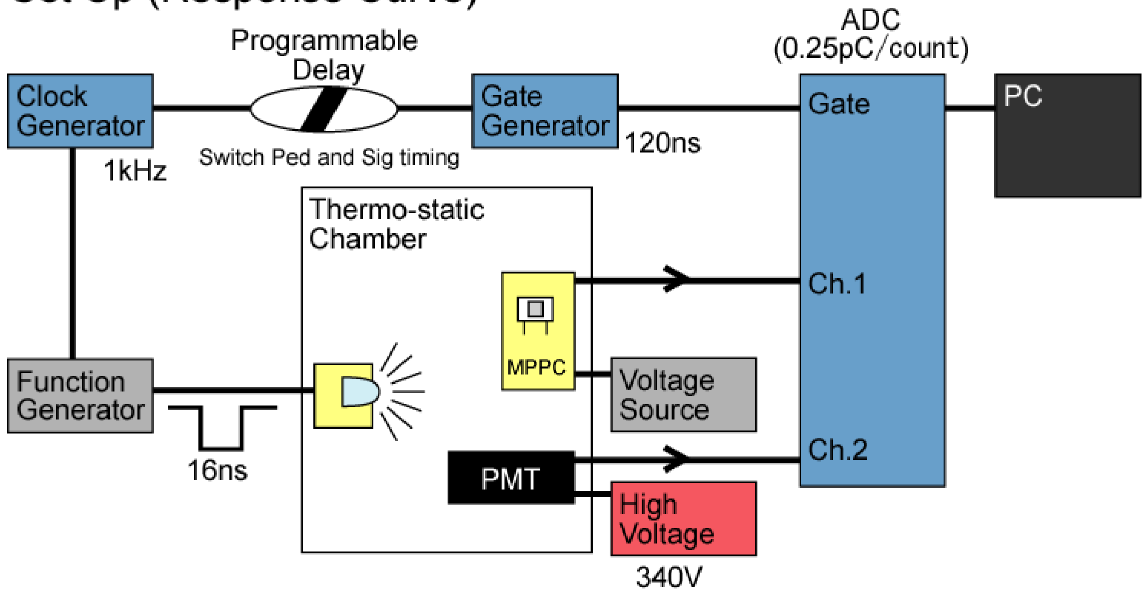
There seem hot spots have increased by gamma-ray radiation,

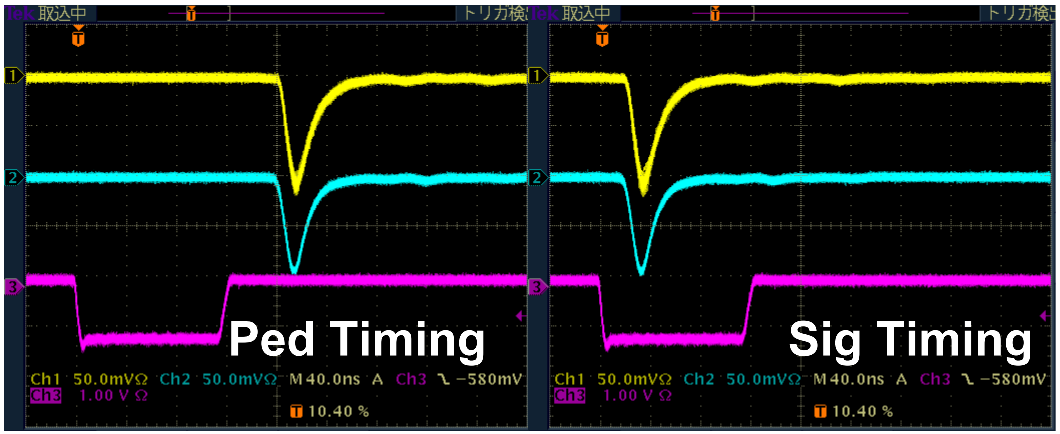
The black squares are the sensitive areas. The white lines are the oxidized layer with bias lines.

The hot spots only appeared on the oxidized layer.

Response Curve measurement

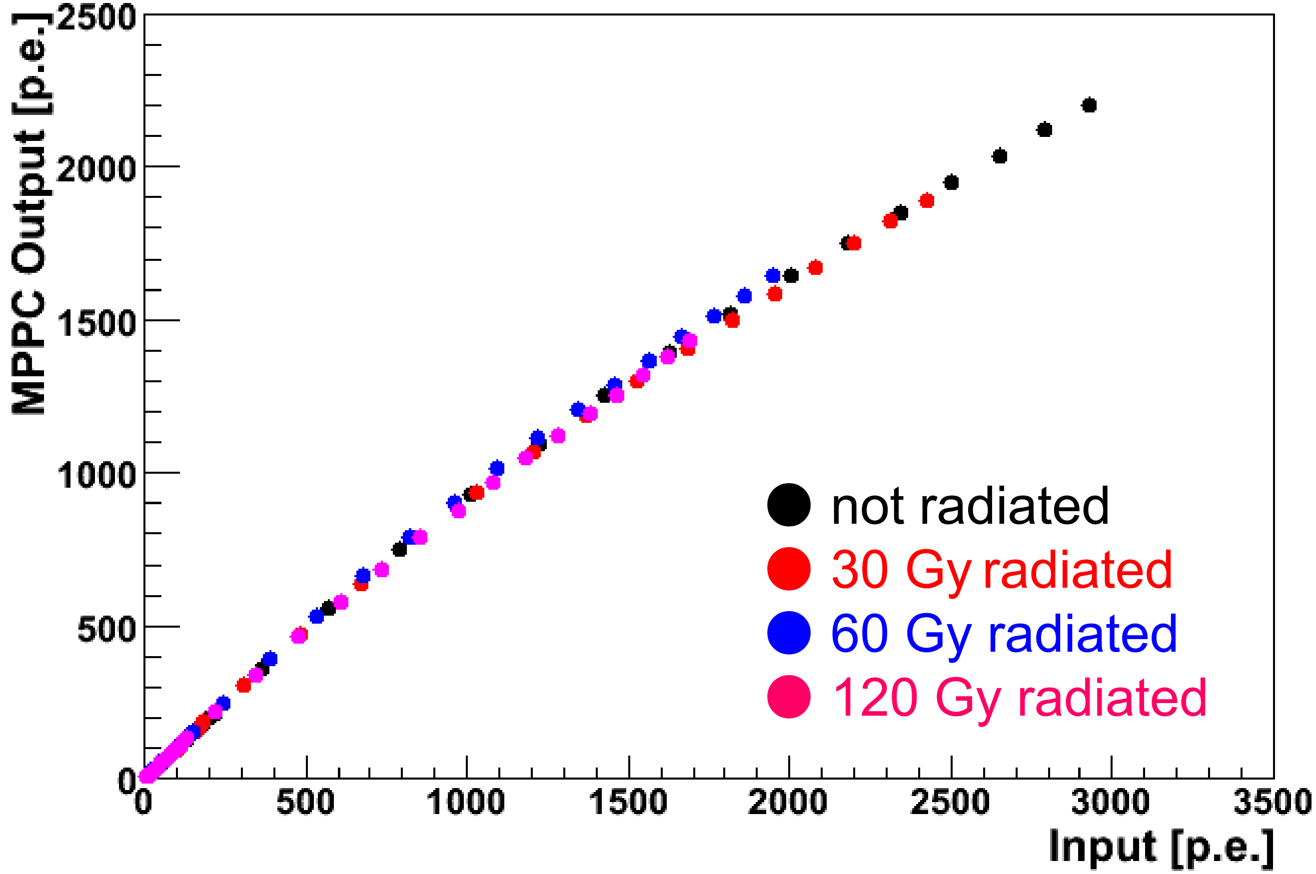
Set Up (Response Curve)





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

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

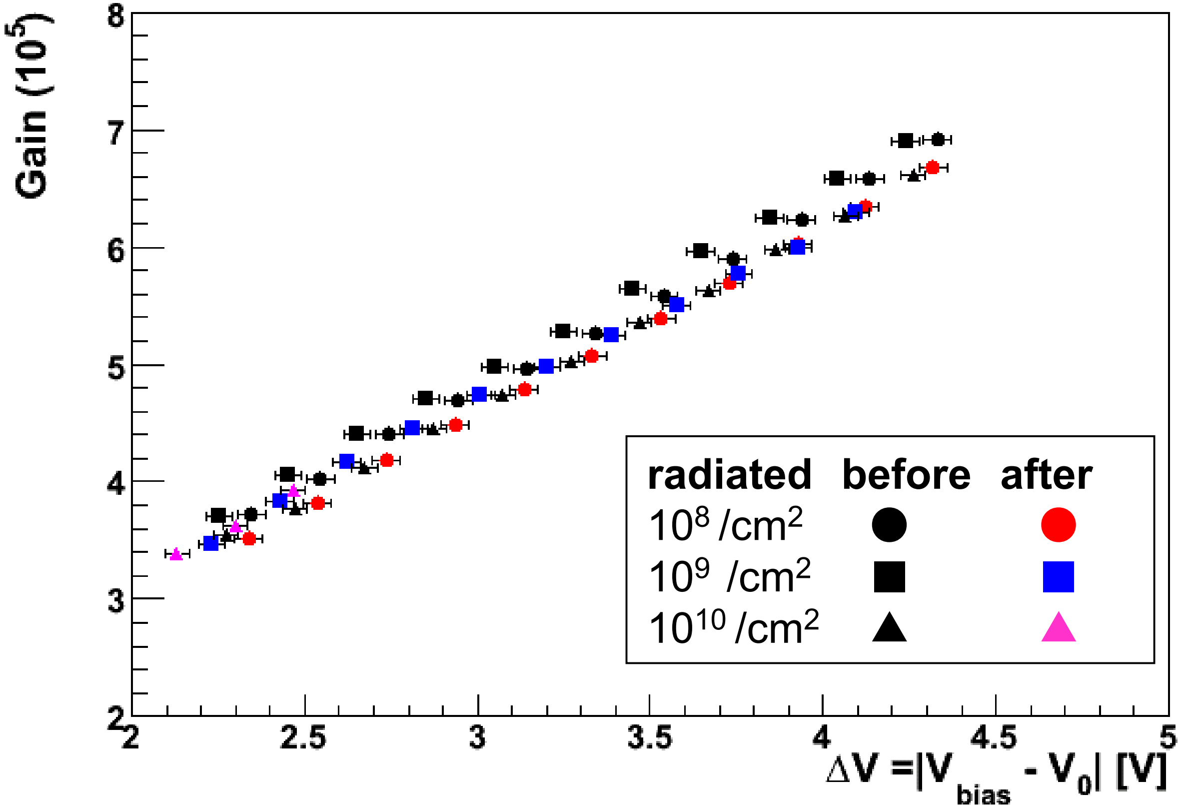
Radiated MPPC Sample

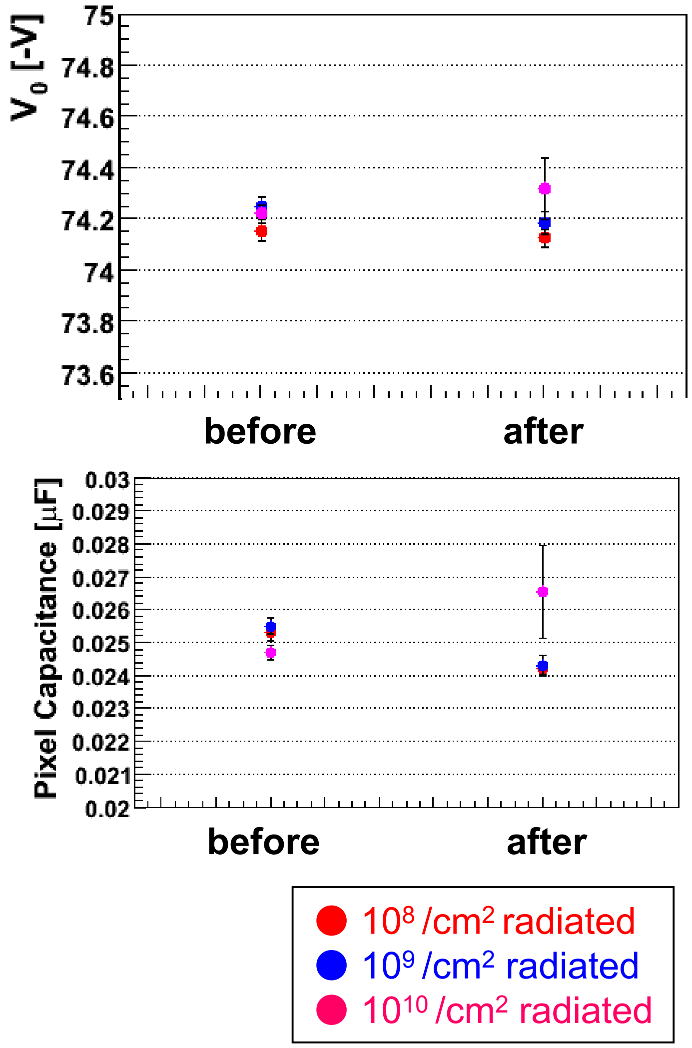
Type : S10362-11-025MK
Size : 1mm×1mm
1600 pixel (25μm pitch)

Radiation test location

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

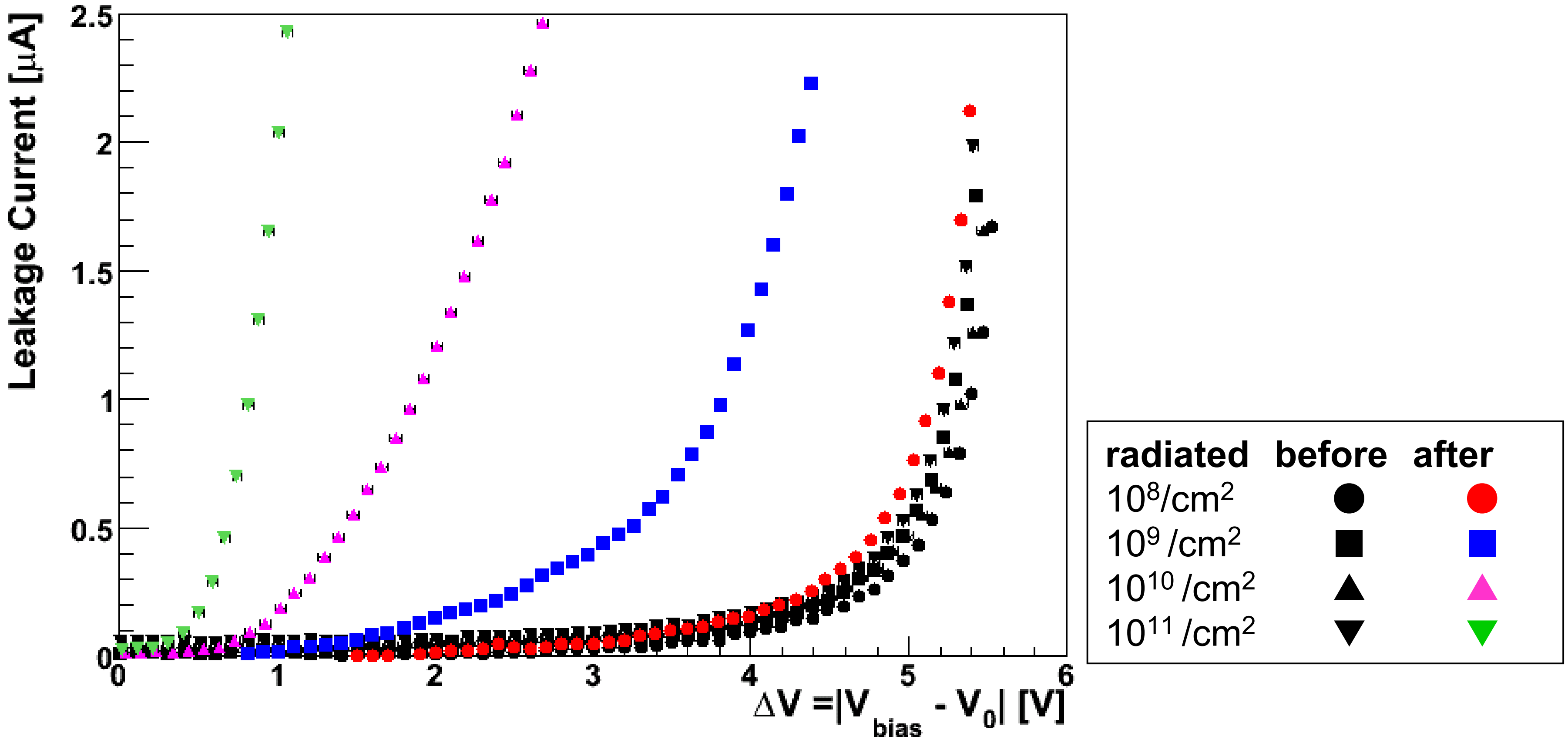
Neutron(Gain)





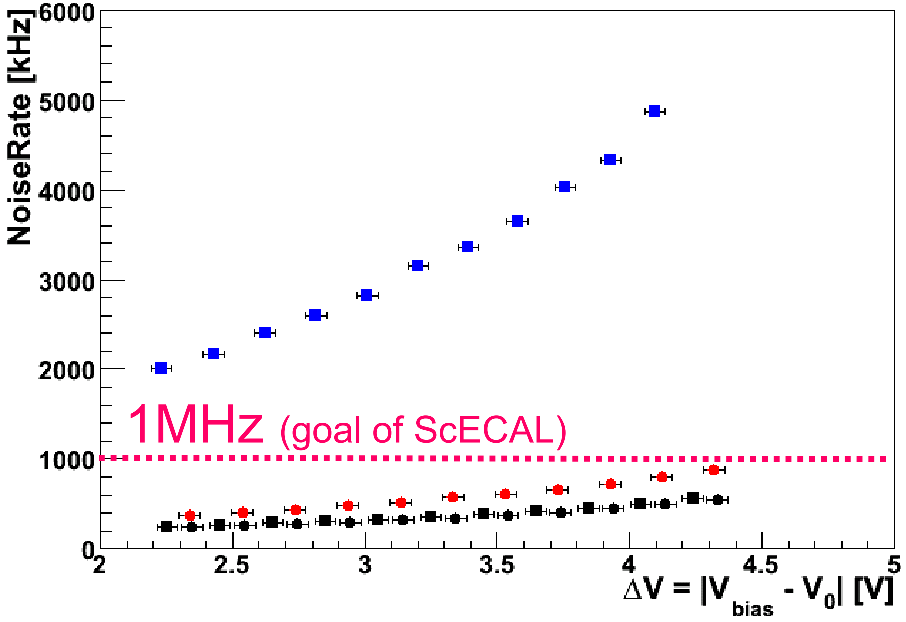
There seem no significant changes on the gain by neutron radiation.

Neutron(Leakage Current)



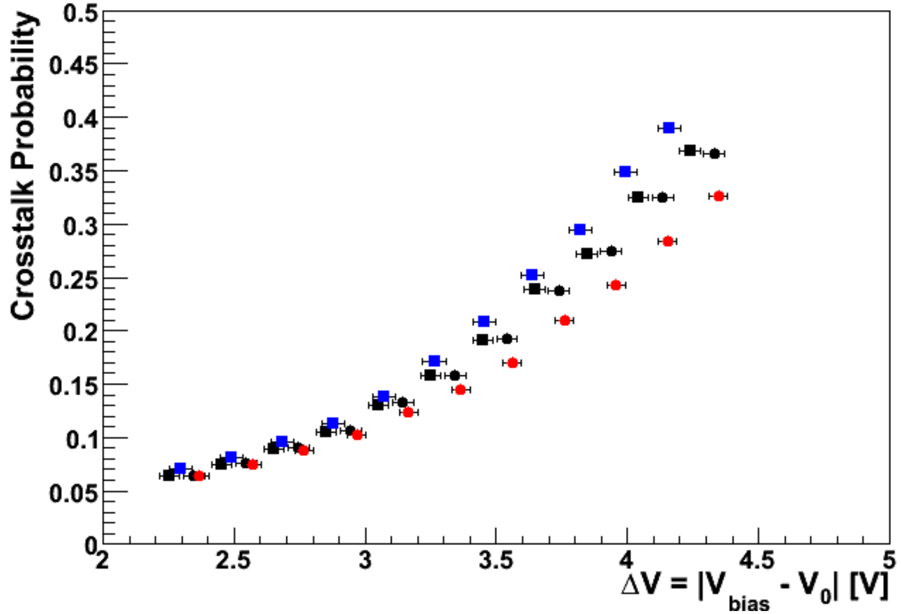
The leakage current have increased by neutron radiation.

Neutron(Noise Rate / Crosstalk Probability)



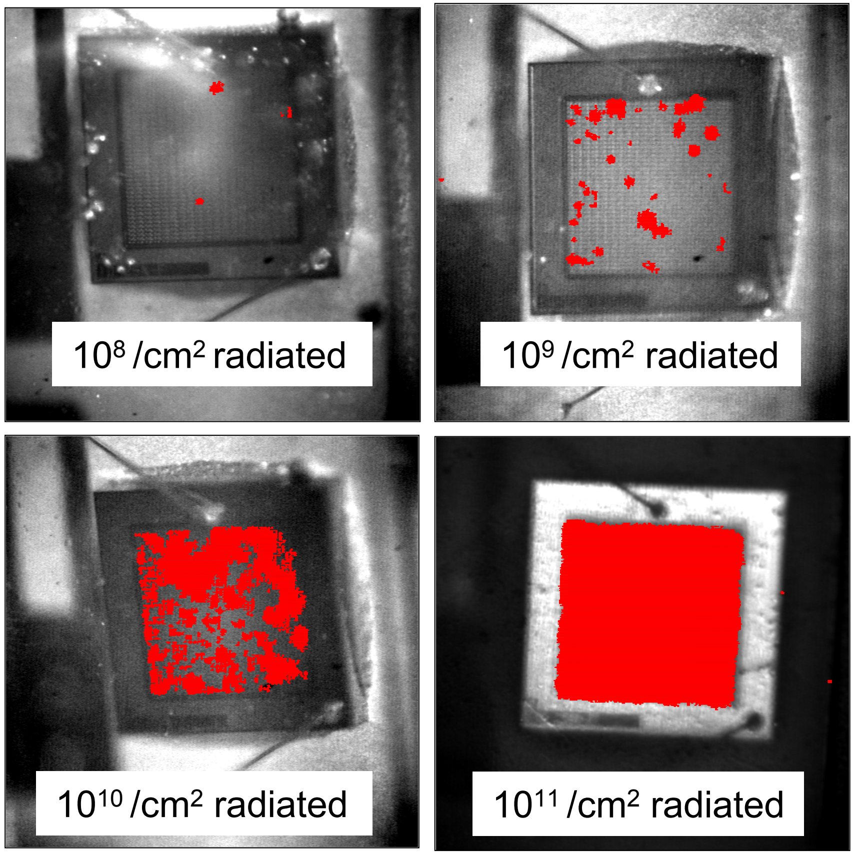
The noiserate have increased by neutron radiation.

radiated	before	after
$10^8/cm^2$	●	● (red)
$10^9/cm^2$	■	■ (blue)

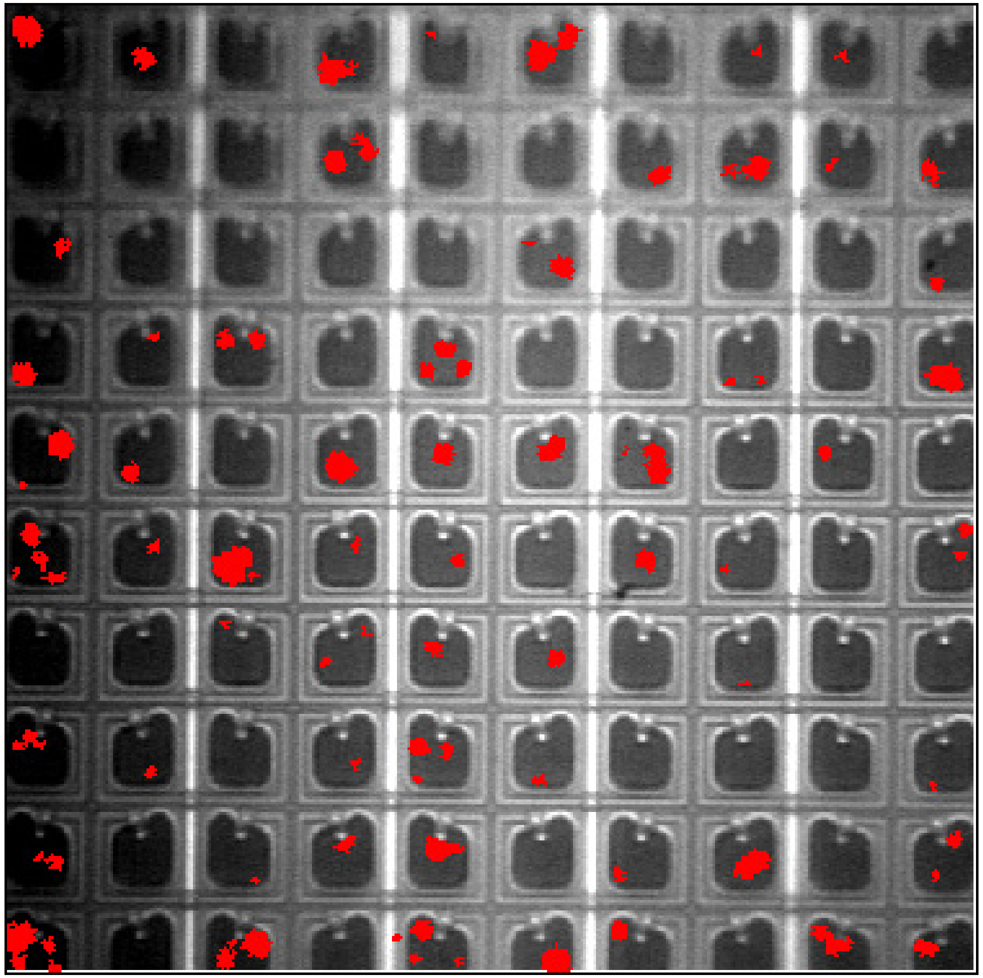


There seem no significant changes on the crosstalk probability by radiation.

Neutron(Hot spot pictures)

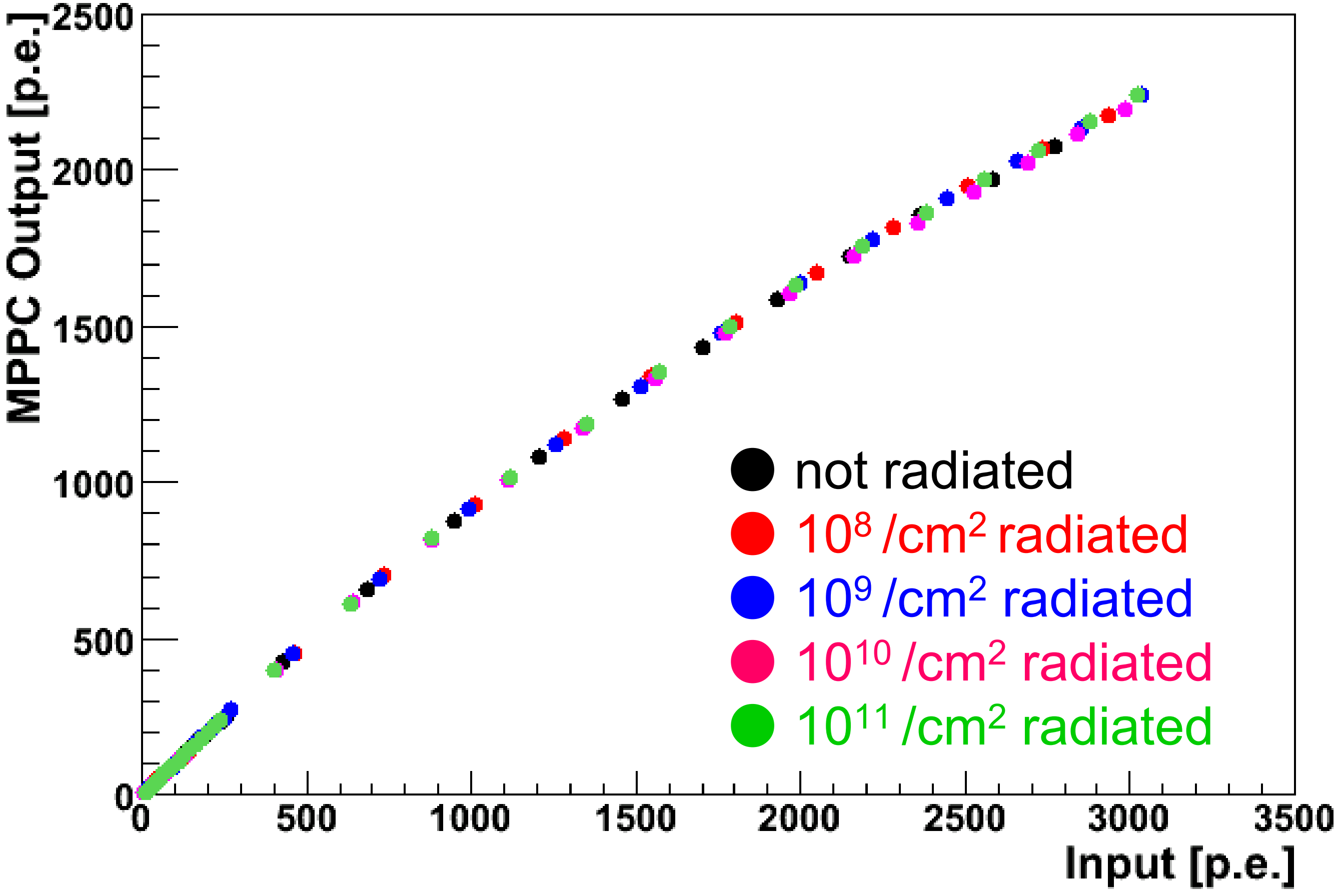


10^{11} /cm^2 radiated (zoomed)



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 noiserate are increased.
(For the gamma-ray radiation, the threshold may be 90Gy.)
・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

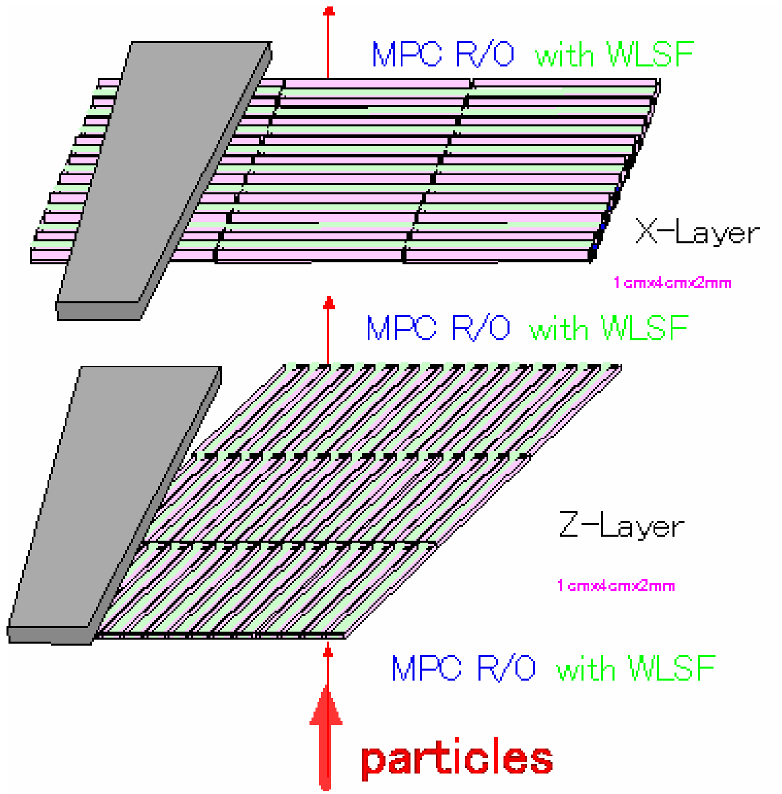
・The estimation of dose at ScECAL.
・More radiation tests with estimated dose.

Back Up

R&D Status of the 1600 pixel MPPC

	Performance	status
Gain	$10^5 \sim 10^6$	OK
Photon Detection Eff.	~0.2 for 1600 pix. MPPC	OK
Dark Noise Rate	~ 100 kHz	OK
Photon counting	Great	OK
Bias voltage	~ 70 V	OK
Size	Compact	OK
Dynamic range	**Determined by # of pixels and recovery time**	underway
Cost	Expected to be < $10	Negotiating
Long-term Stability	Unknown	Not checked
Robustness	Unknown, presumably good	underway
B field	Expected to be Insensitive	Not checked
Timing resolution	Expected to be 0.1~1 ns	Not chekced

The Scintillator-Tungsten ECAL



Scintillator strip
(4.5 x 1 x 0.3 cm)

- A PFA calorimeter designed for the GLD detector.
- Sandwich structure with Scintillator(2mm)-Tungsten(3mm) layers.
- Adopt well-understood plastic scintillator technique.
- Scintillator stirp structure (1 x 4.5 cm)
  - Aiming to reduce number of readout channels while keeping granularity of 1 x 1 cm.
  - Utilize extruded scintillator production technique.
  - Strip clustering is a key issue.
- Full MPPC (Multi-Pixel Photon Counter) readout.
- Number of readout ~ 10 M channels

Radiation exeperiment location

Gamma-ray

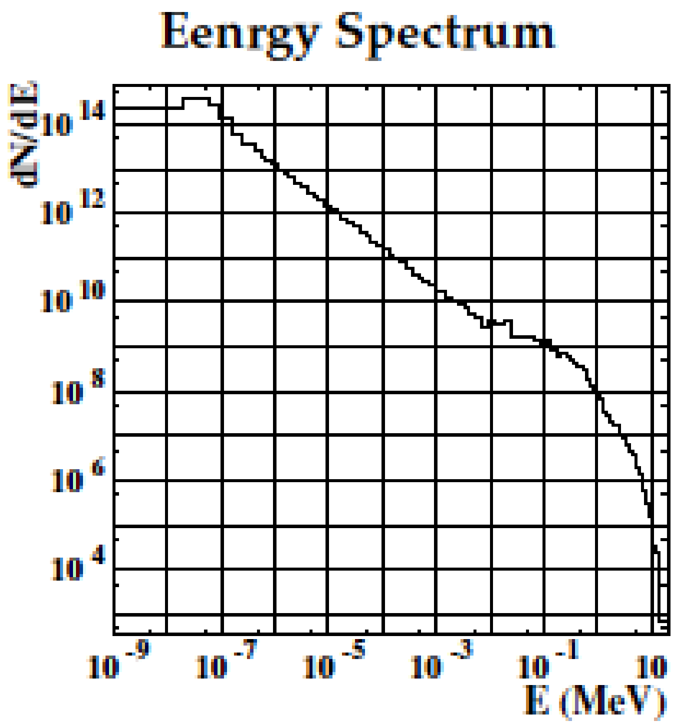
Research Laboratory for Nuclear Reactors
(Tokyo Institute of Technology)

Neutron

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

Flux (for 1MeV conversion)

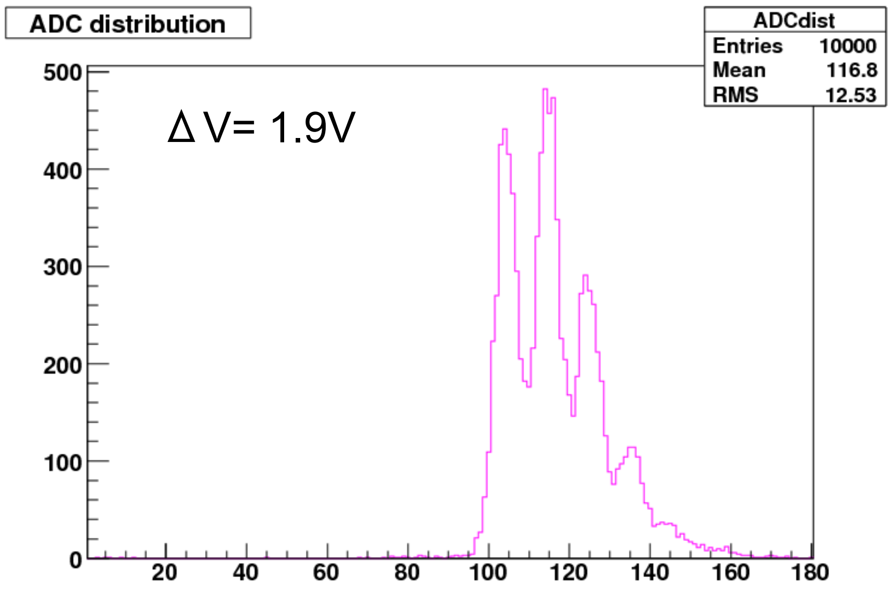
1.2×10^8 1MeV-neutrons/cm^2
1.2×10^9 1MeV -neutrons /cm^2
1.2×10^{10} 1MeV -neutrons /cm^2
1.2×10^{11} 1MeV -neutrons /cm^2



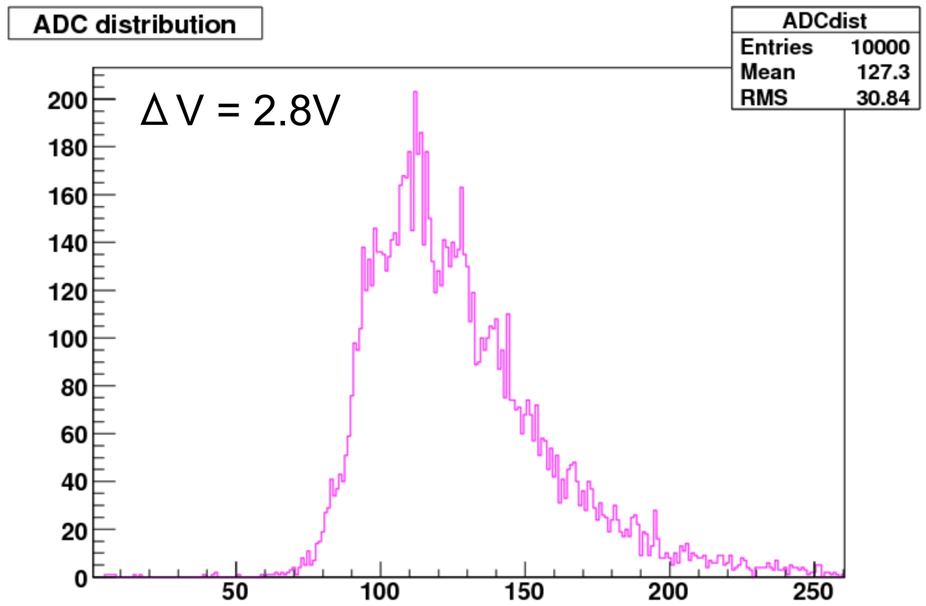
ADC distribution

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.

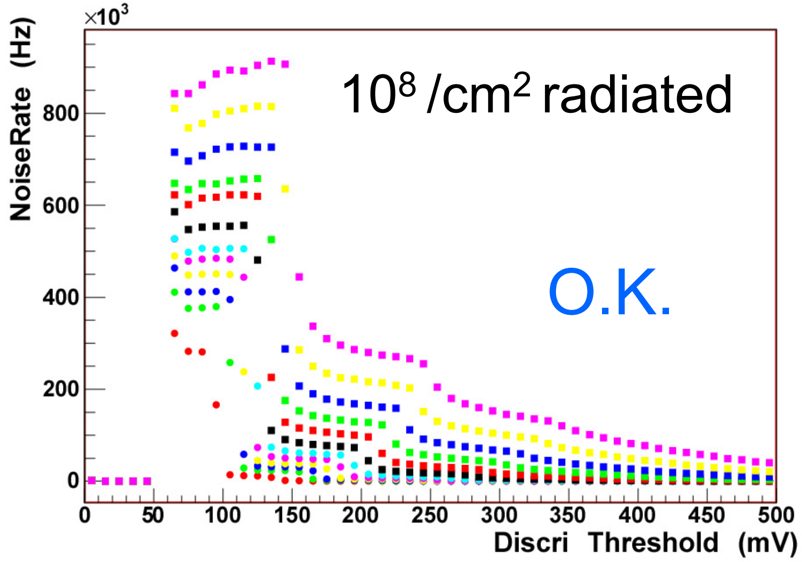


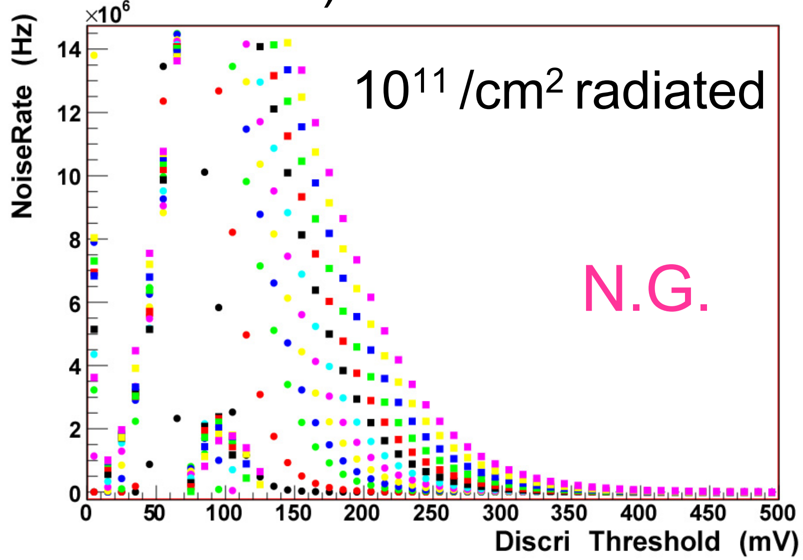
N.G.

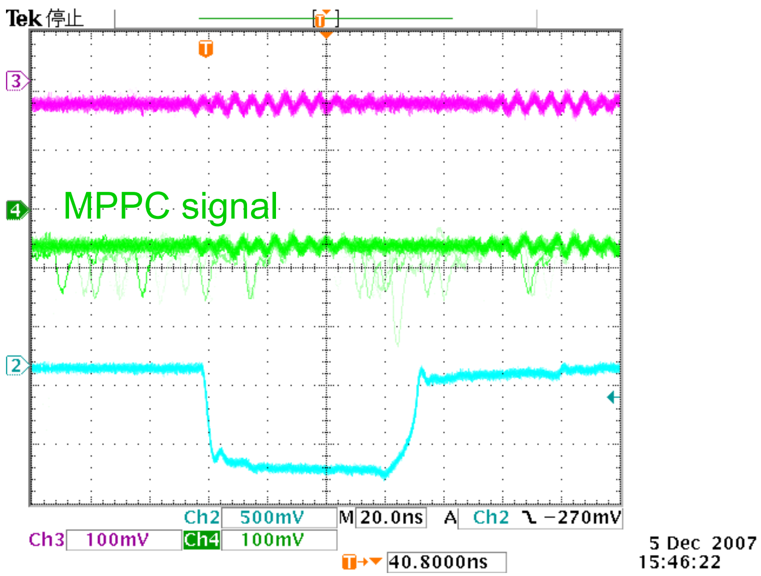
Threshold Curve

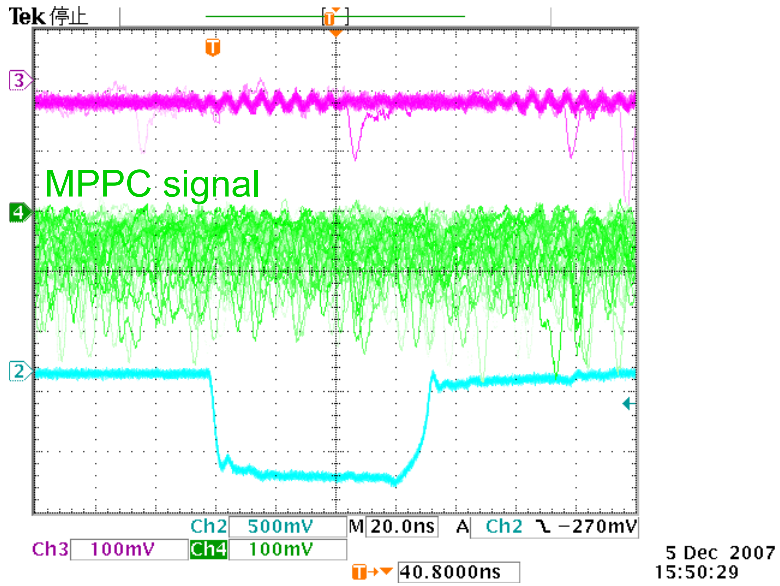
Some threshold curves of radiated samples are too noisy to evaluate the noiserate.

Ex.) neutron radiated sample



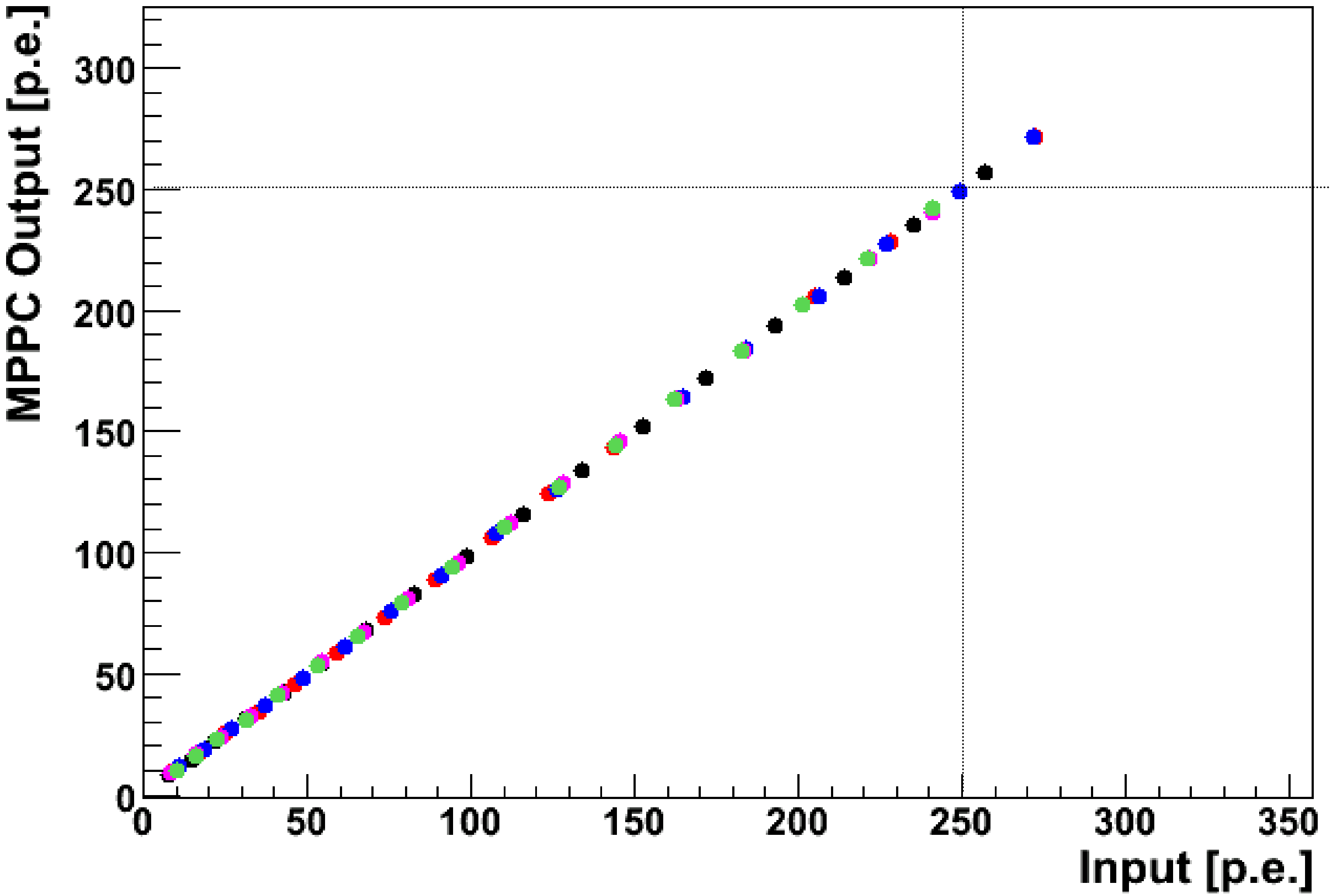






Linearity(neutron)

Response curve (zoomed)



The linearity seems to be up to over 250 p.e.

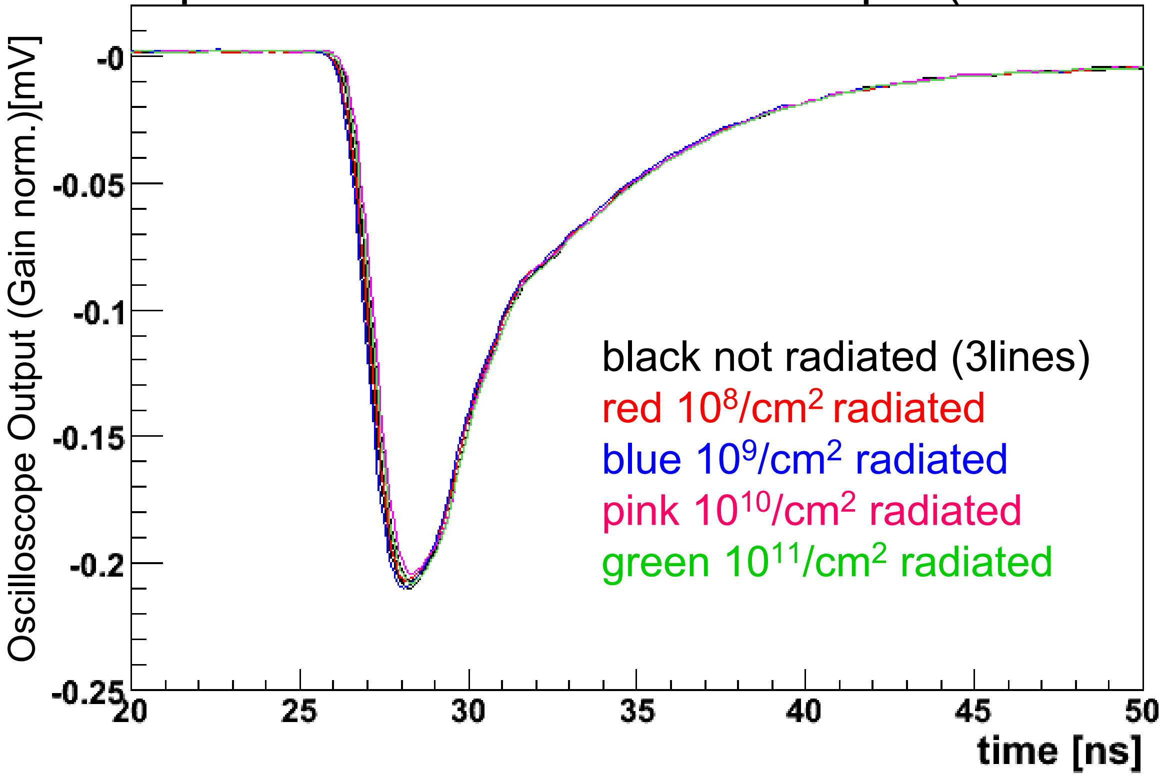
AfterPulse(neutron)

PRELIMINARY

AfterPulse

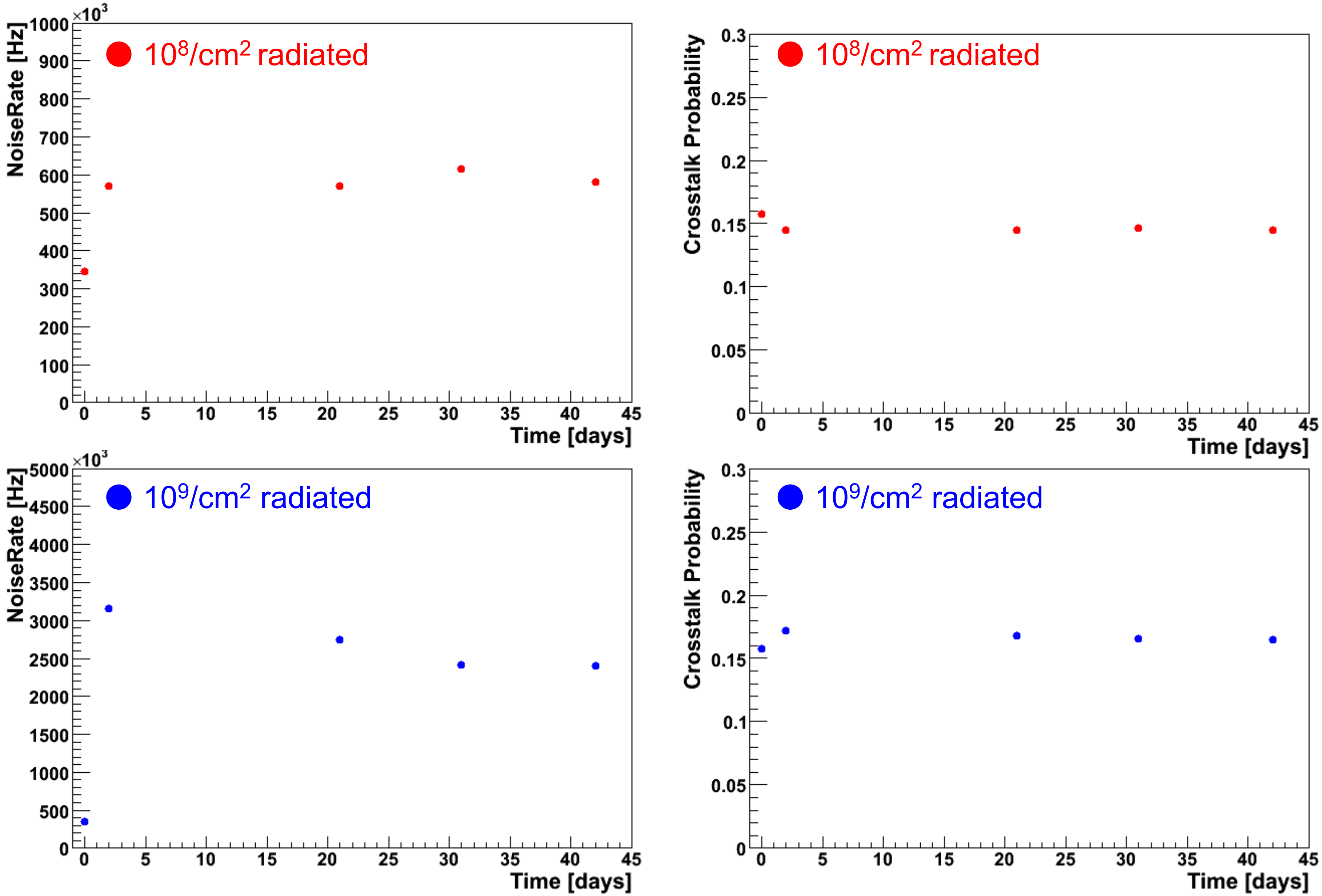
Caused by trapped avalanching electrons at lattice defect.

Pulse shape of MPPC when fired 1600pix (with laser)



There seem no after-pulse increase by neutron radiation

Additonal Meaurement



Additonal Meaurement