# PROGRESS REPORT ON MPPC

## CALICE meeting at Lyon 2009

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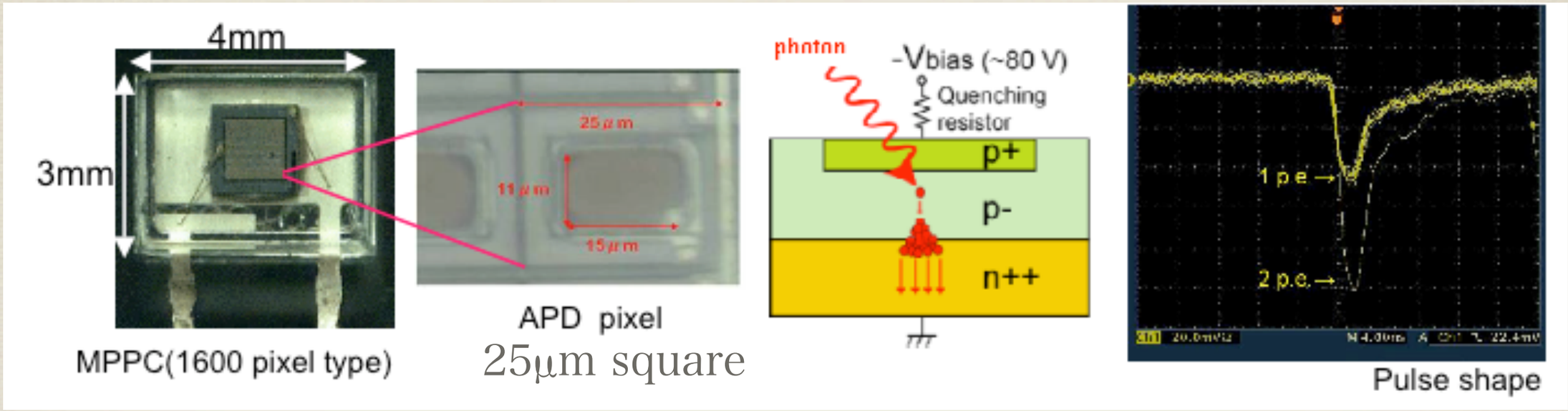
**radiation tolerance**

**long term stability test**

**device simulation**

# MPPC

* multi-pixel Geiger Mode Avalanche photo Diode



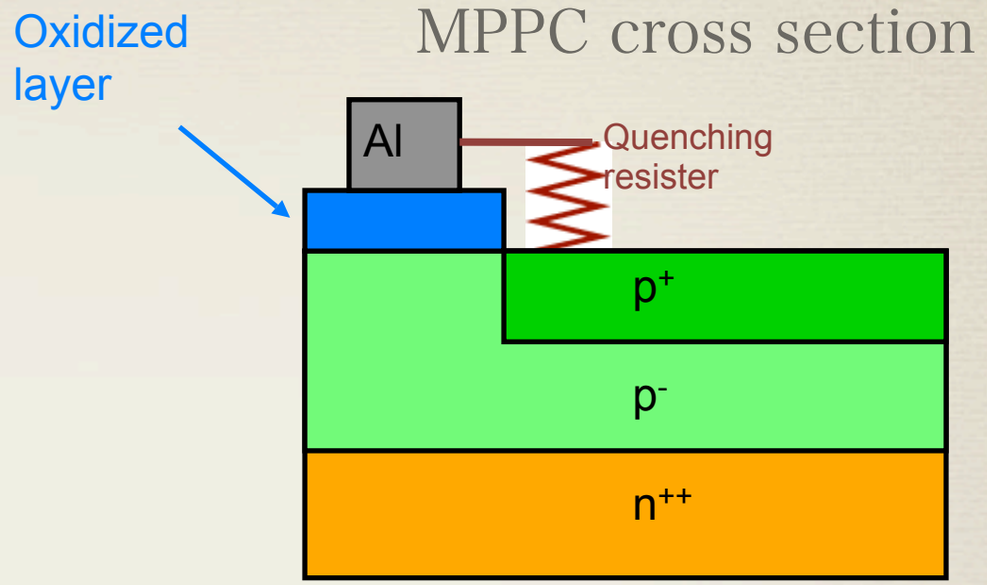

- High Gain (>$10^5$)
- Compact (package size ~a few mm)
- Low Cost
- Insensitive to magnetic field

- Dark count ( thermal electrons)
- Secondary photons from avalanche (X talk)
- Input vs output is non-linear

# Gamma irradiation

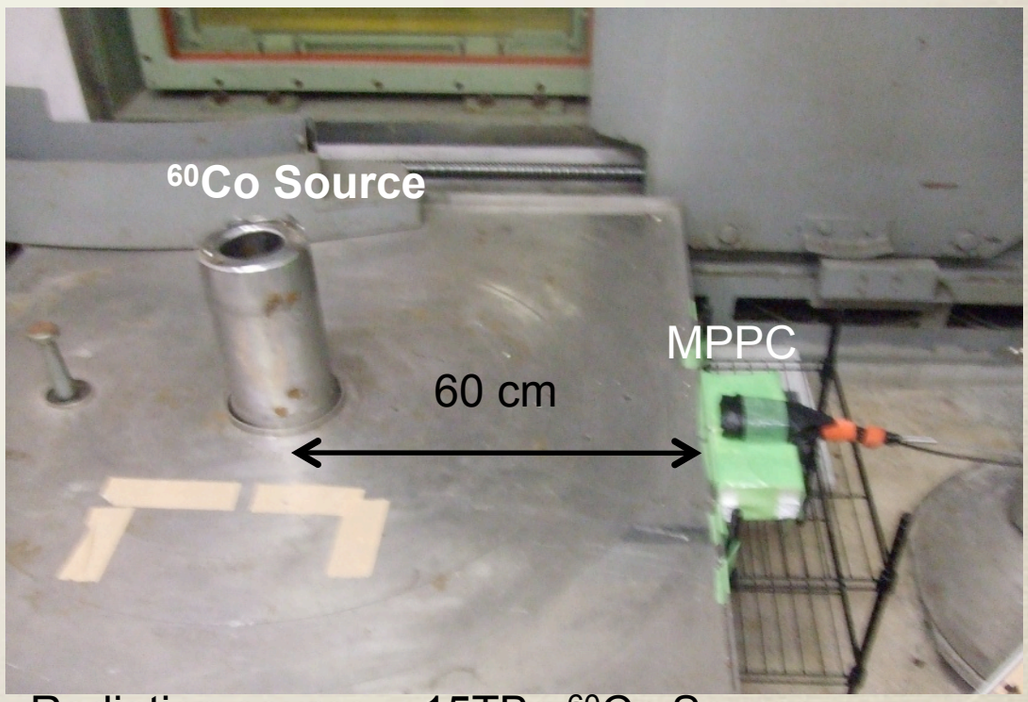
**Prospective damage**

Charge accumulation on the oxidized layer.




**Dose amount**

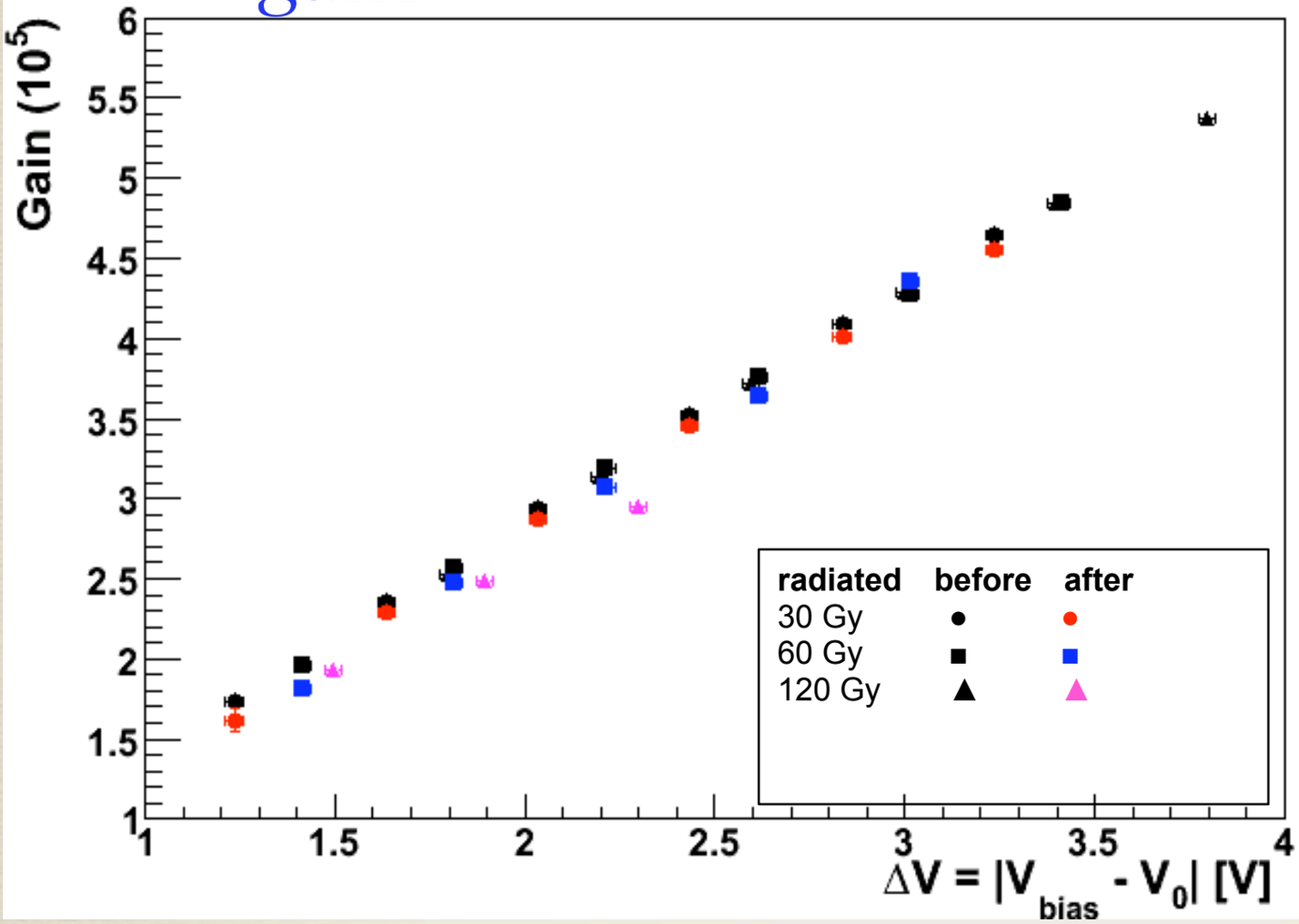
10 Gy/h for 3 hours →30 Gy
10 Gy/h for 6 hours →60 Gy
10 Gy/h for 12 hours →120 Gy

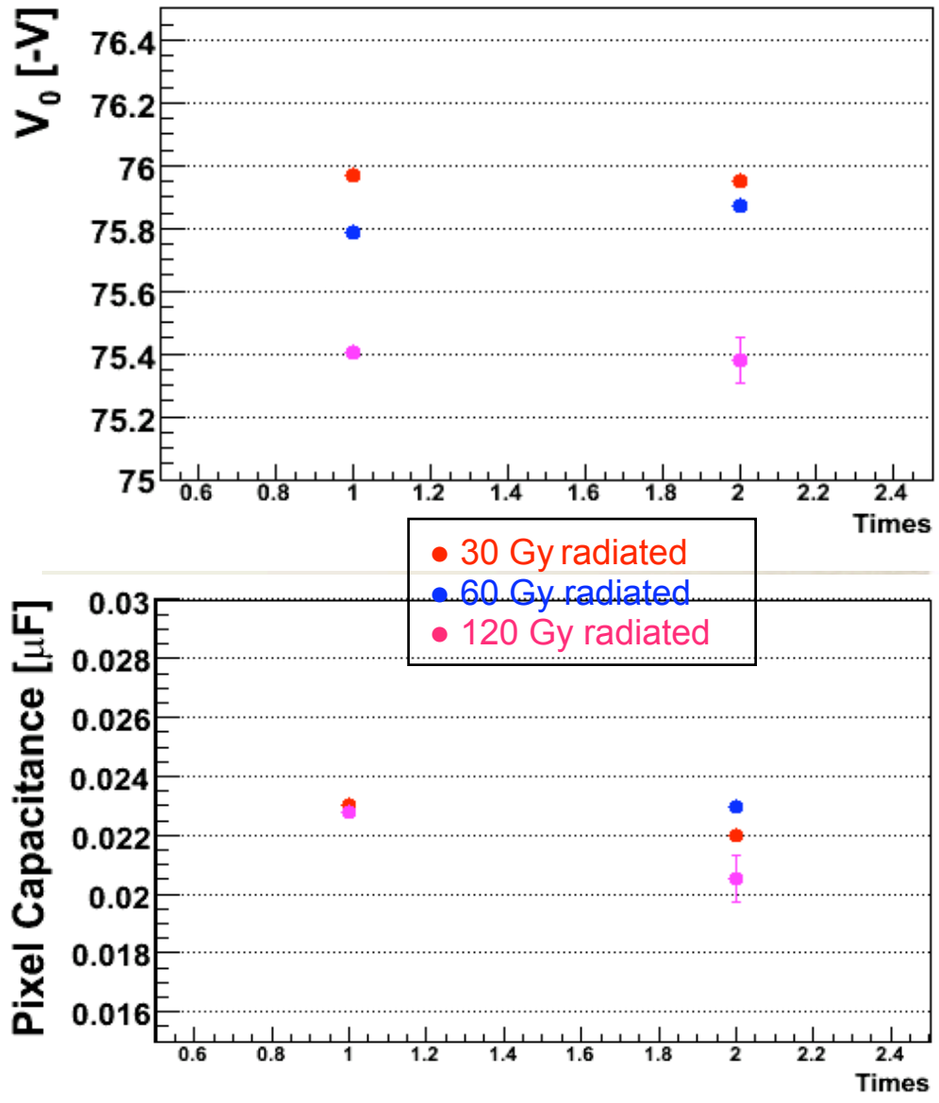



Radiation source ~15TBq $^{60}$Co Source

# Gamma irradiation results

gain



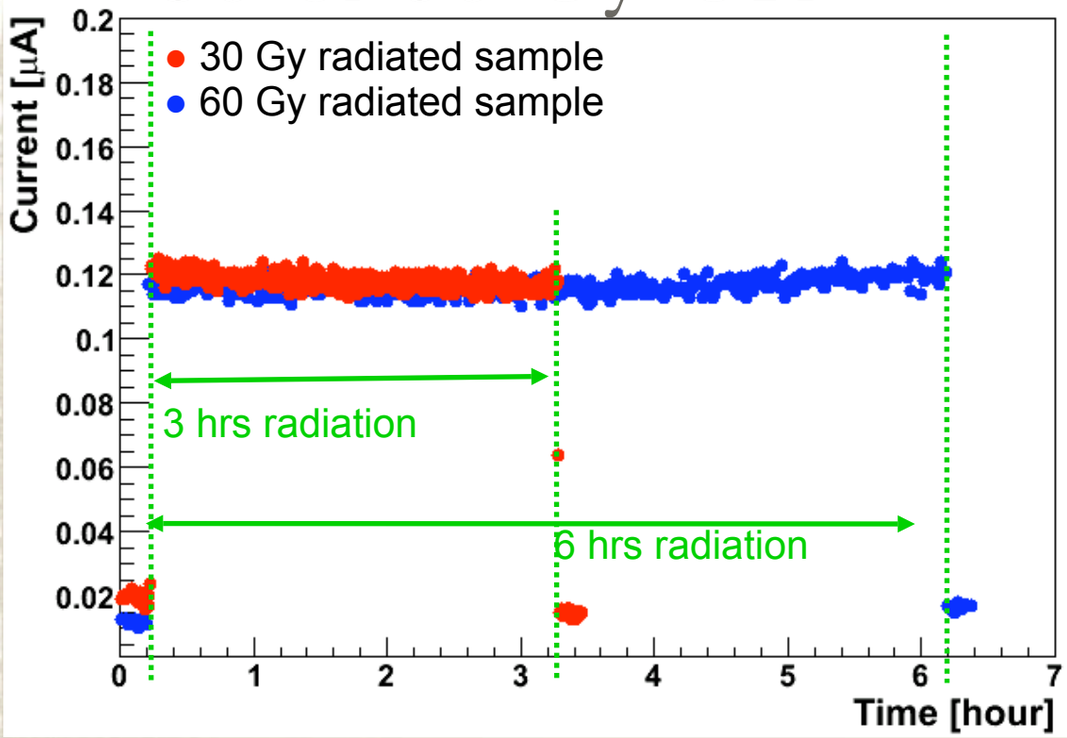




There seem no significant changes on the gain by gamma-ray radiation.

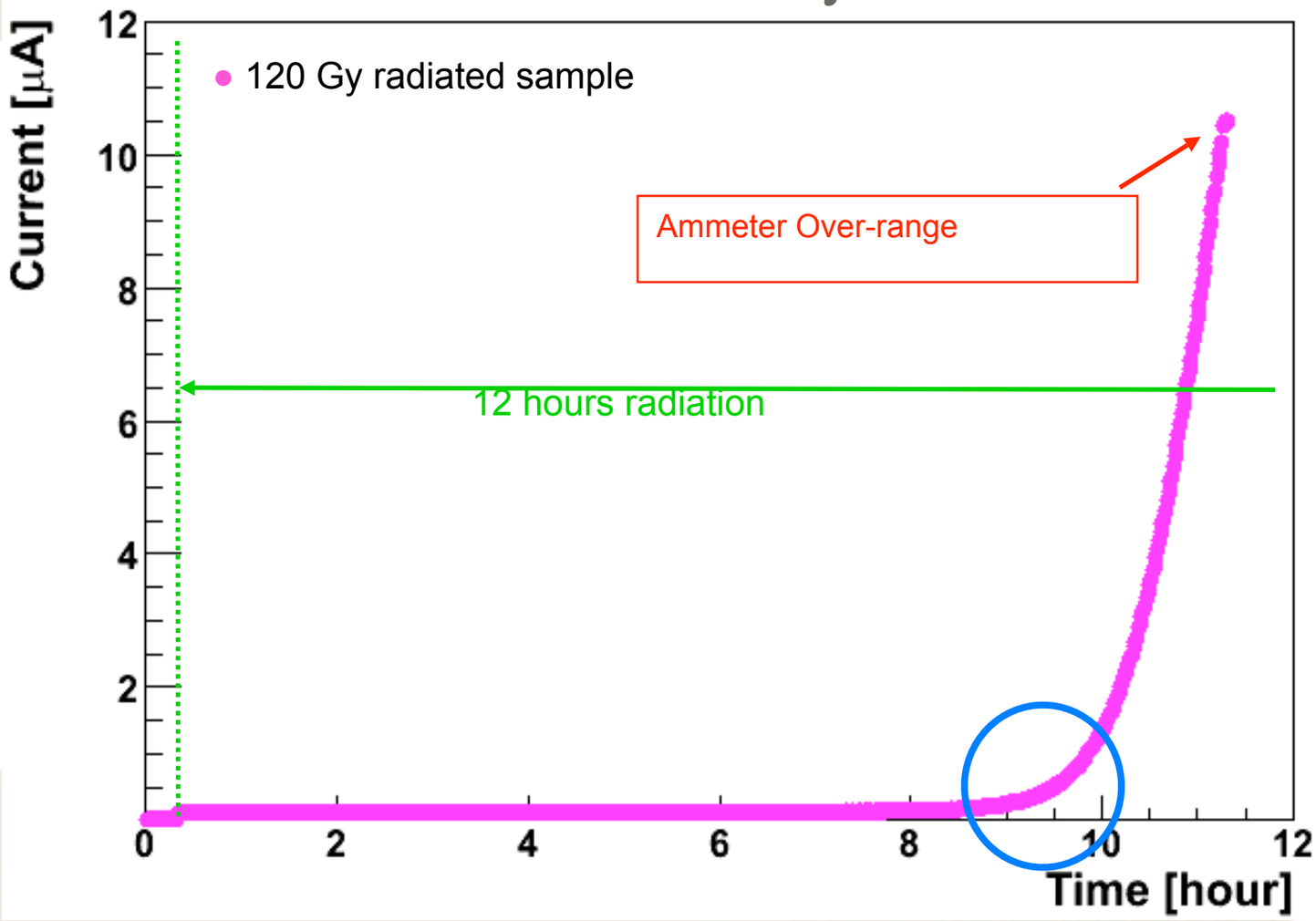
# Gamma irradiation results

* current measured

## 30 & 60 Gy OK



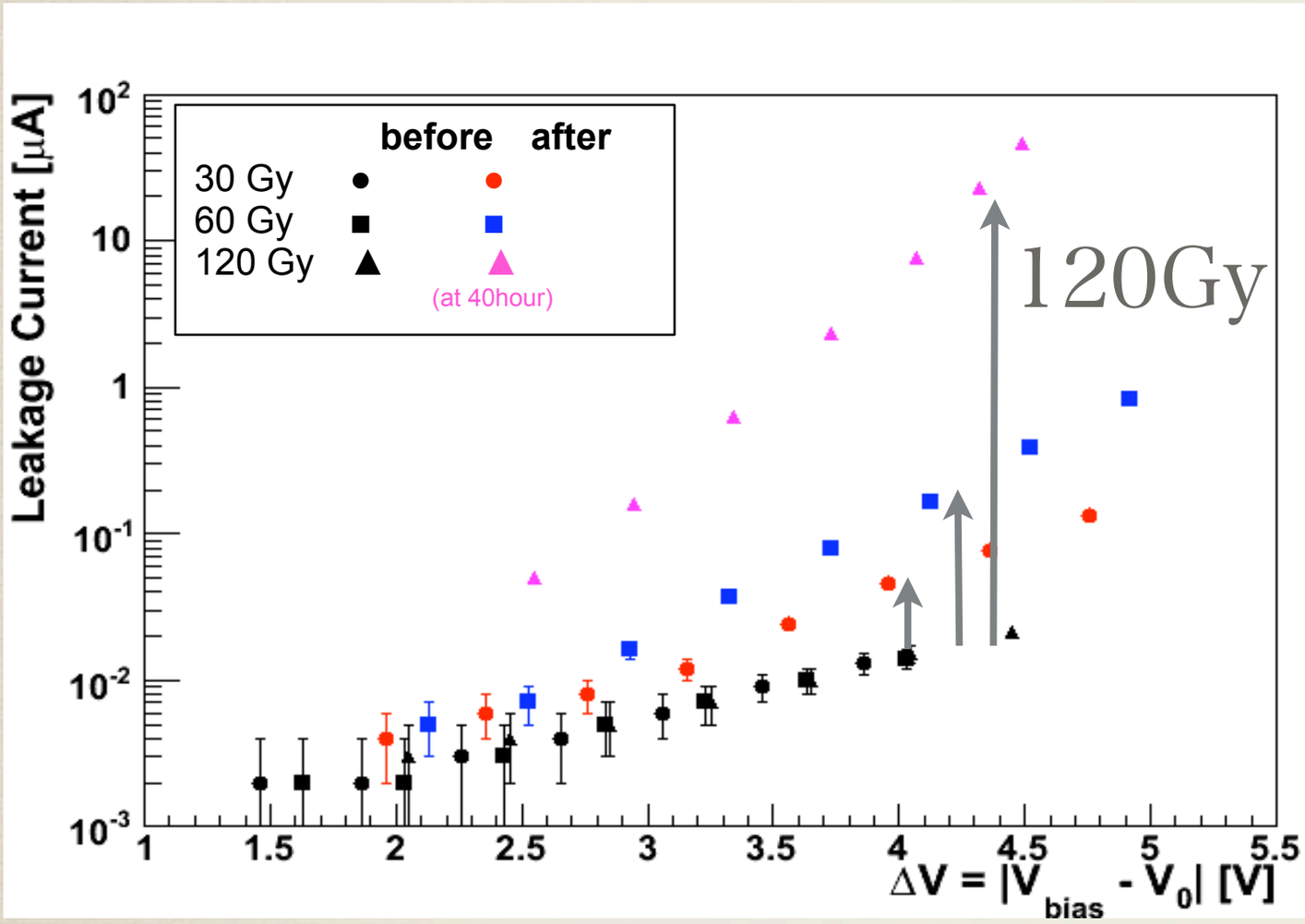

## 120 Gy

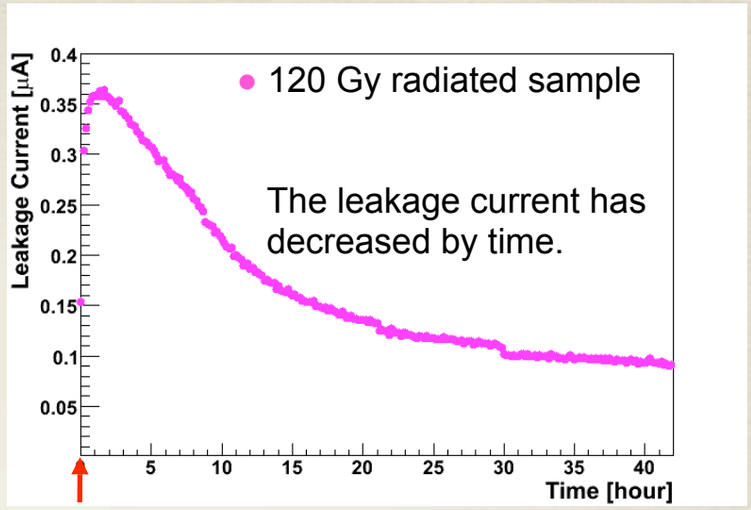



The current has increased drastically.
(about 90 Gy)

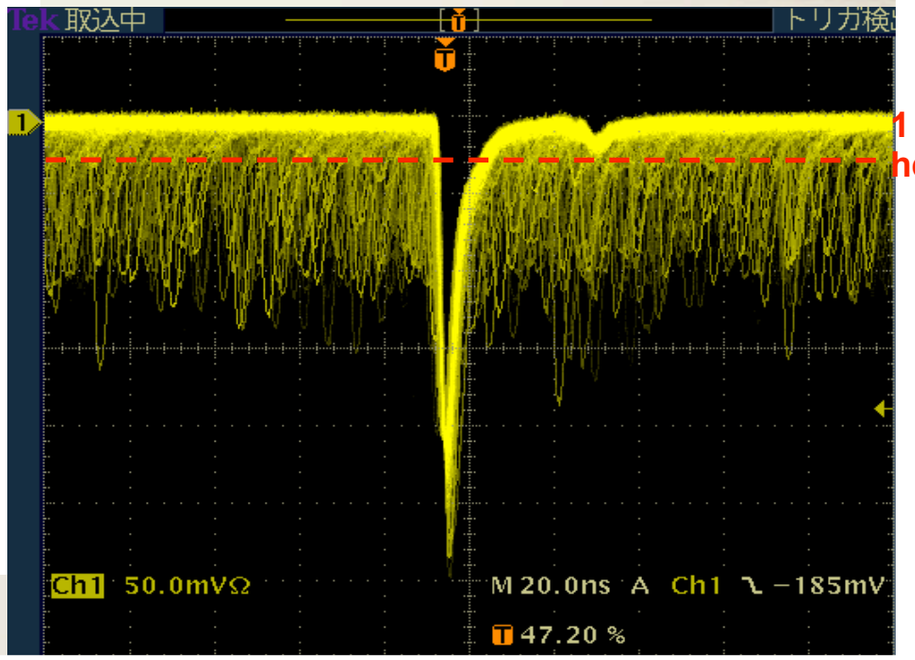
# Gamma irradiation results

## ✳ leakage current vs Vbias




**120 Gy radiated sample**



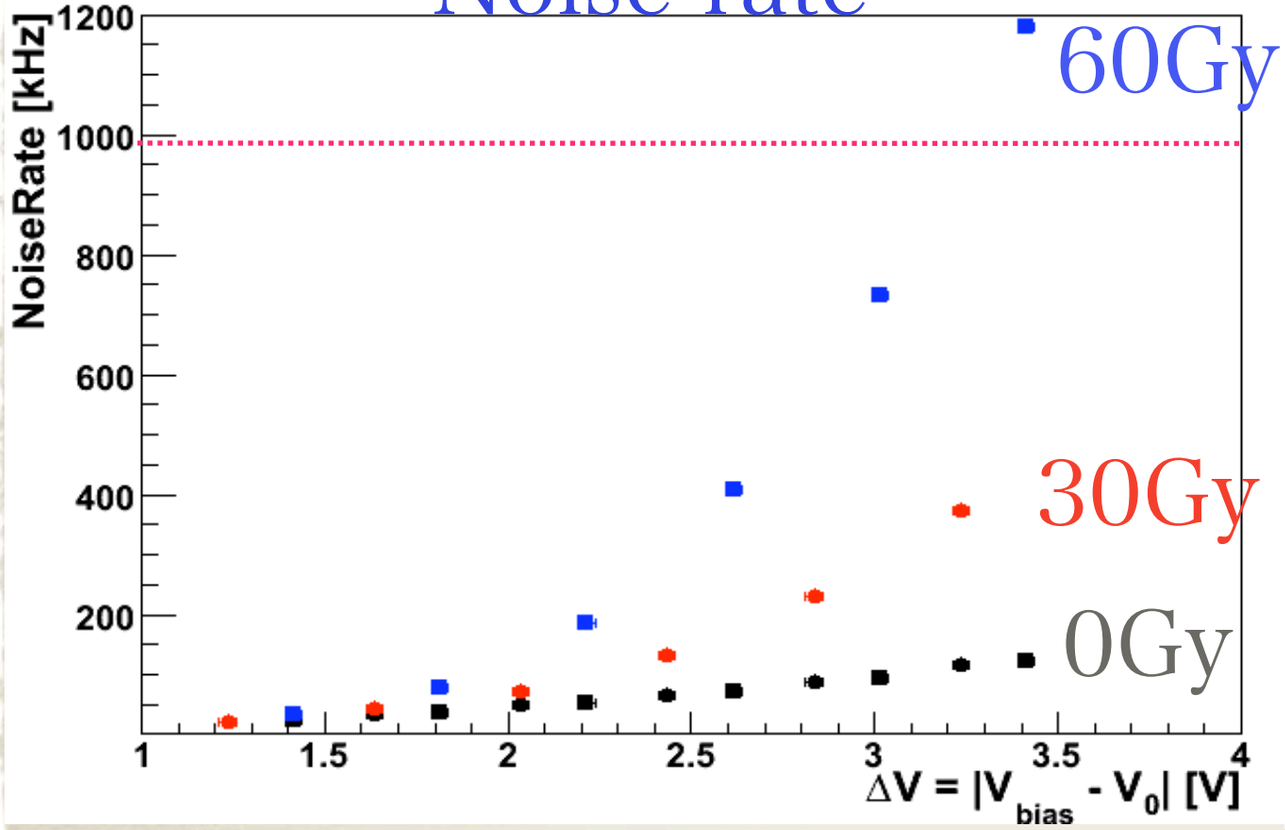

120Gy

The leakage current have increased by gamma-ray radiation.

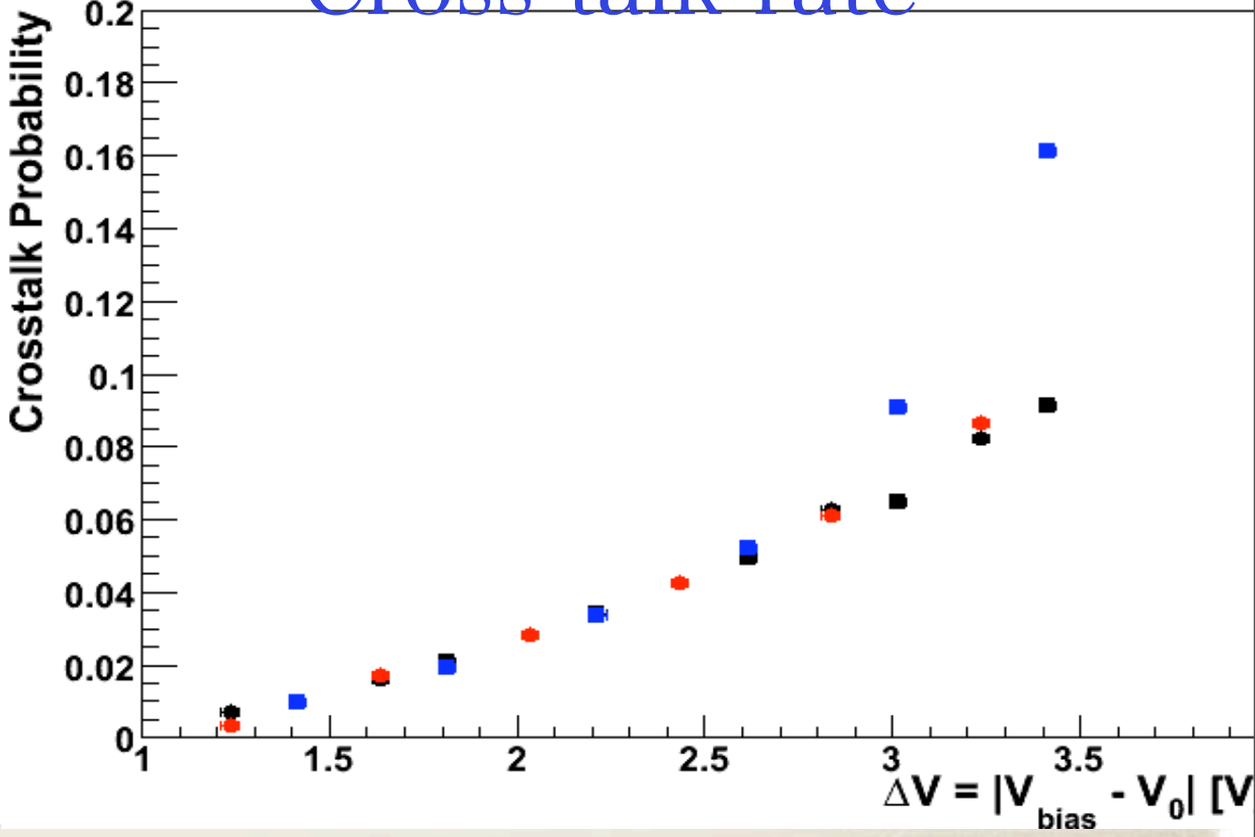
# gamma irrad. results

| radiated | before | after |
|---|---|---|
| 30 Gy | ● | ● |
| 60 Gy | ■ | ■ |

## Noise rate




## Cross talk rate

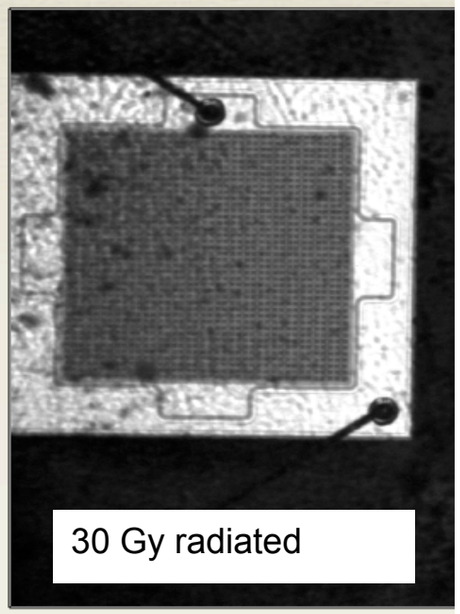


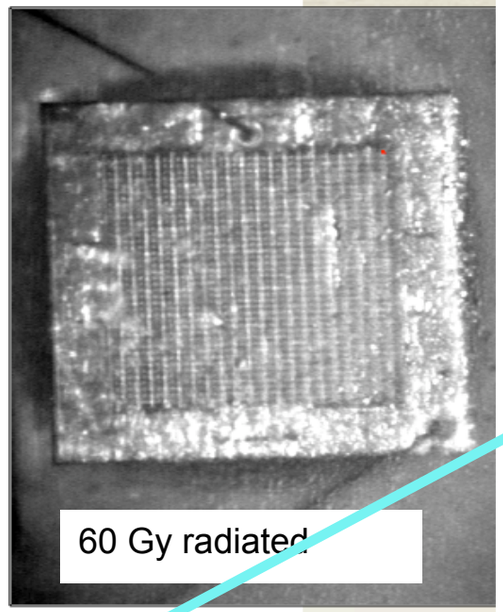

The noise rate have increased by gamma-ray radiation.

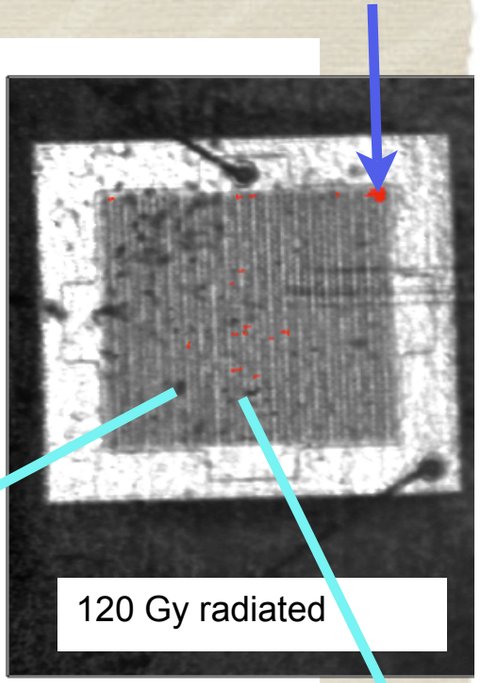
no significant changes on the crosstalk probability by radiation.

# gamma irrad.

- hot spot pictures
- indicate making noises
- increased number of hot spots (a bit)
- at oxidized layer
- as expected



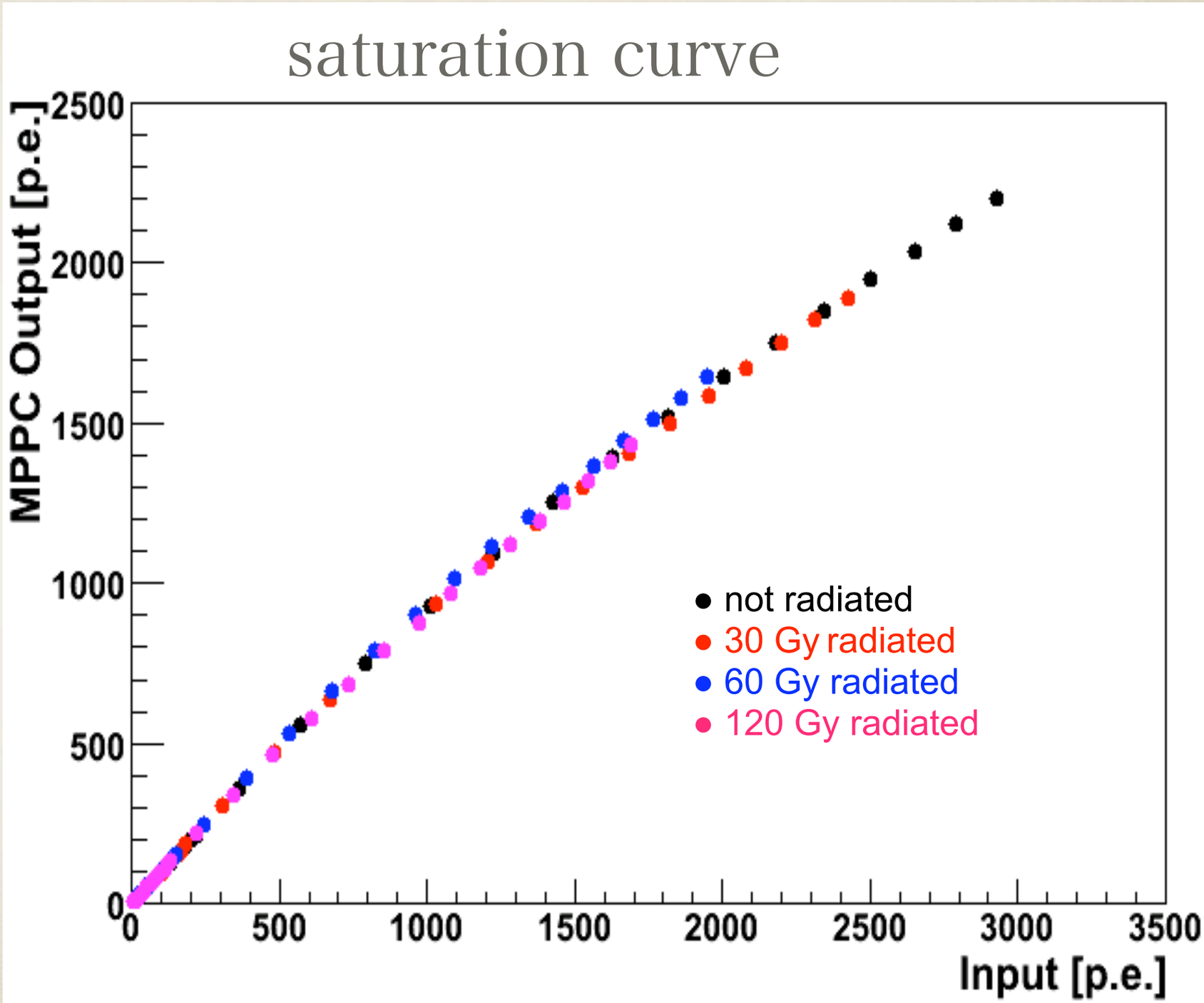




120 Gy radiated (zoomed)

# gamma irrad.

* no significant change in saturation curve



# Neutron irradiation test

* **Prospective damage**

  Increasing lattice defect in silicon bulk

**Flux**

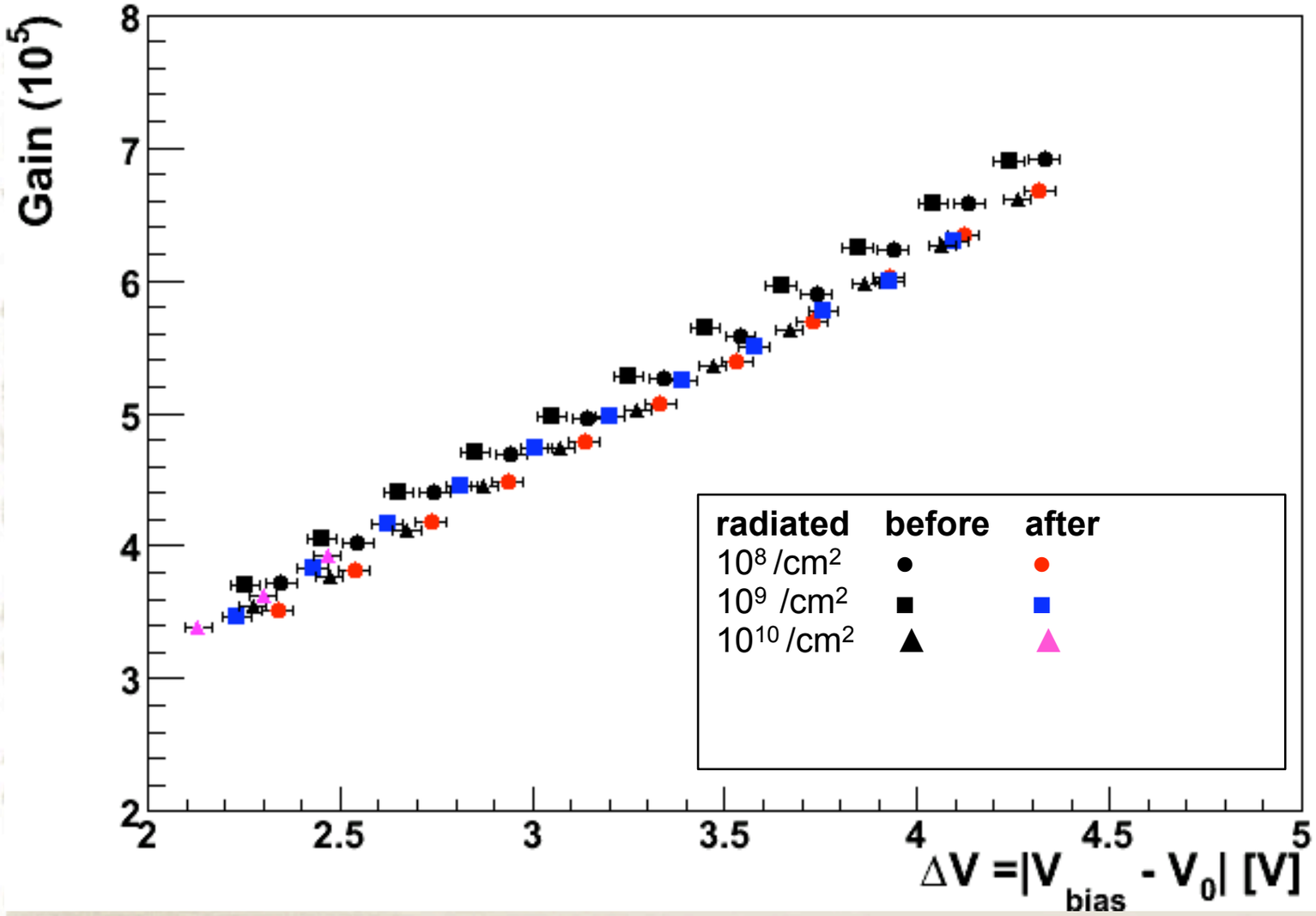
- $3.1\times10^{8}$ neutron/cm$^2$
- $3.1\times10^{9}$ neutron/cm$^2$
- $3.1\times10^{10}$ neutron/cm$^2$
- $3.1\times10^{11}$ neutron/cm$^2$

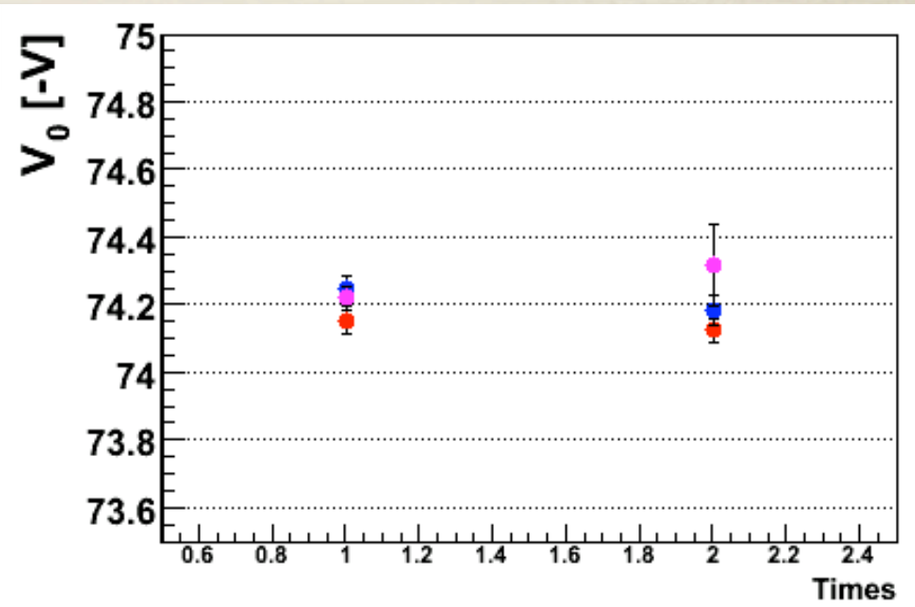
**Radiation test location**

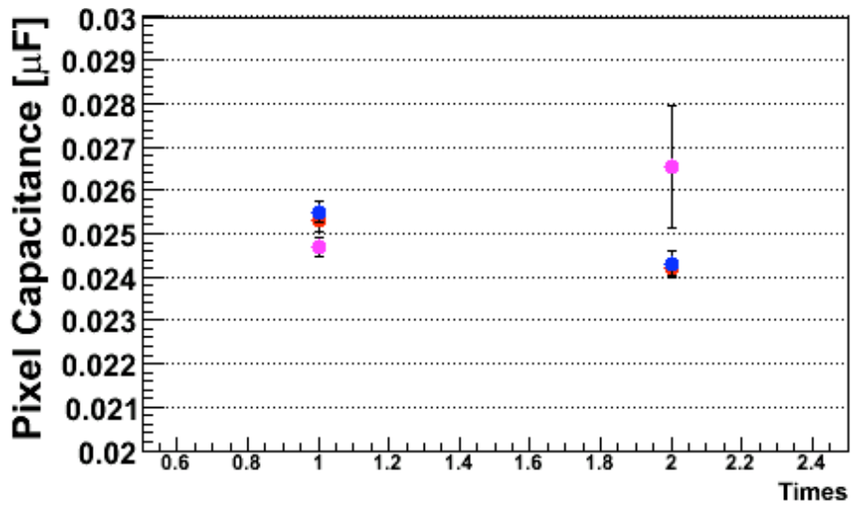
The reactor YAYOI
(Fast neutron source reactor of the University of Tokyo)

# neutron irrad.

* gain vs Vbias



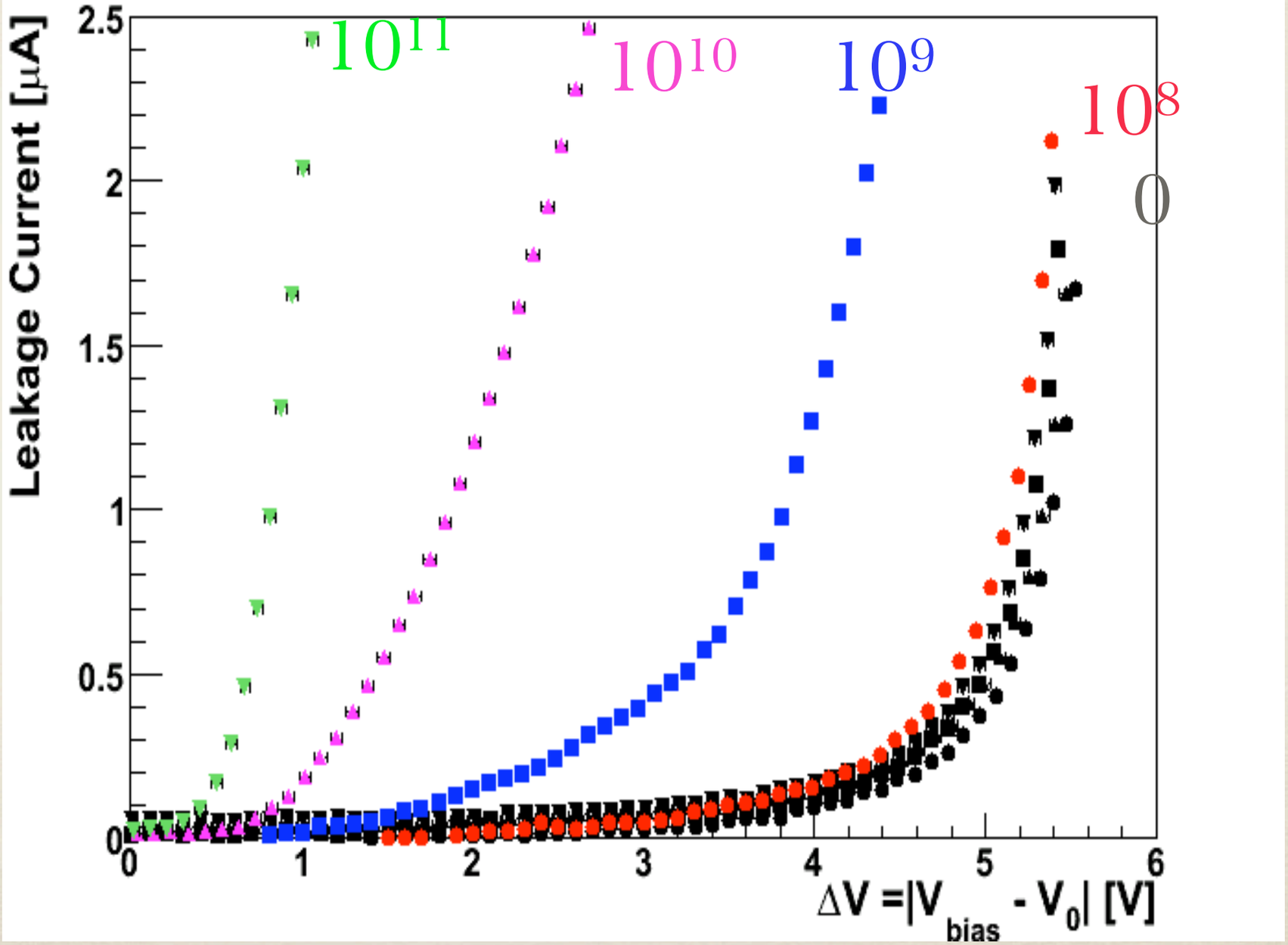

- $10^8$ /cm$^2$ radiated
- $10^9$ /cm$^2$ radiated
- $10^{10}$ /cm$^2$ radiated

no significant changes
on the gain by neutron radiation.

# neutron irrad.

- leakage current
- very much increased

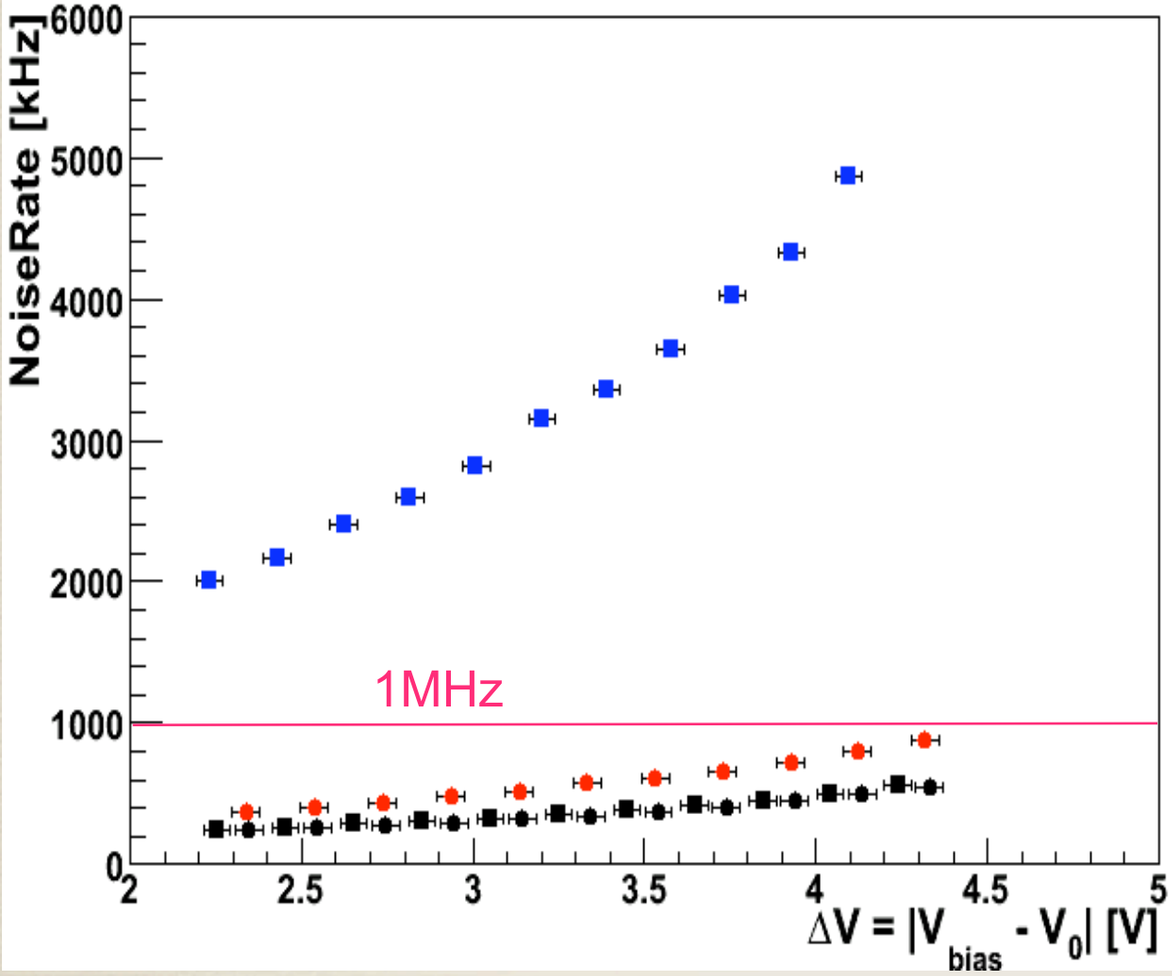
| radiated | before | after |
|---|---|---|
| $10^8$/cm$^2$ | ● | ● |
| $10^9$ /cm$^2$ | ■ | ■ |
| $10^{10}$ /cm$^2$ | ▲ | ▲ |
| $10^{11}$ /cm$^2$ | ▼ | ▼ |

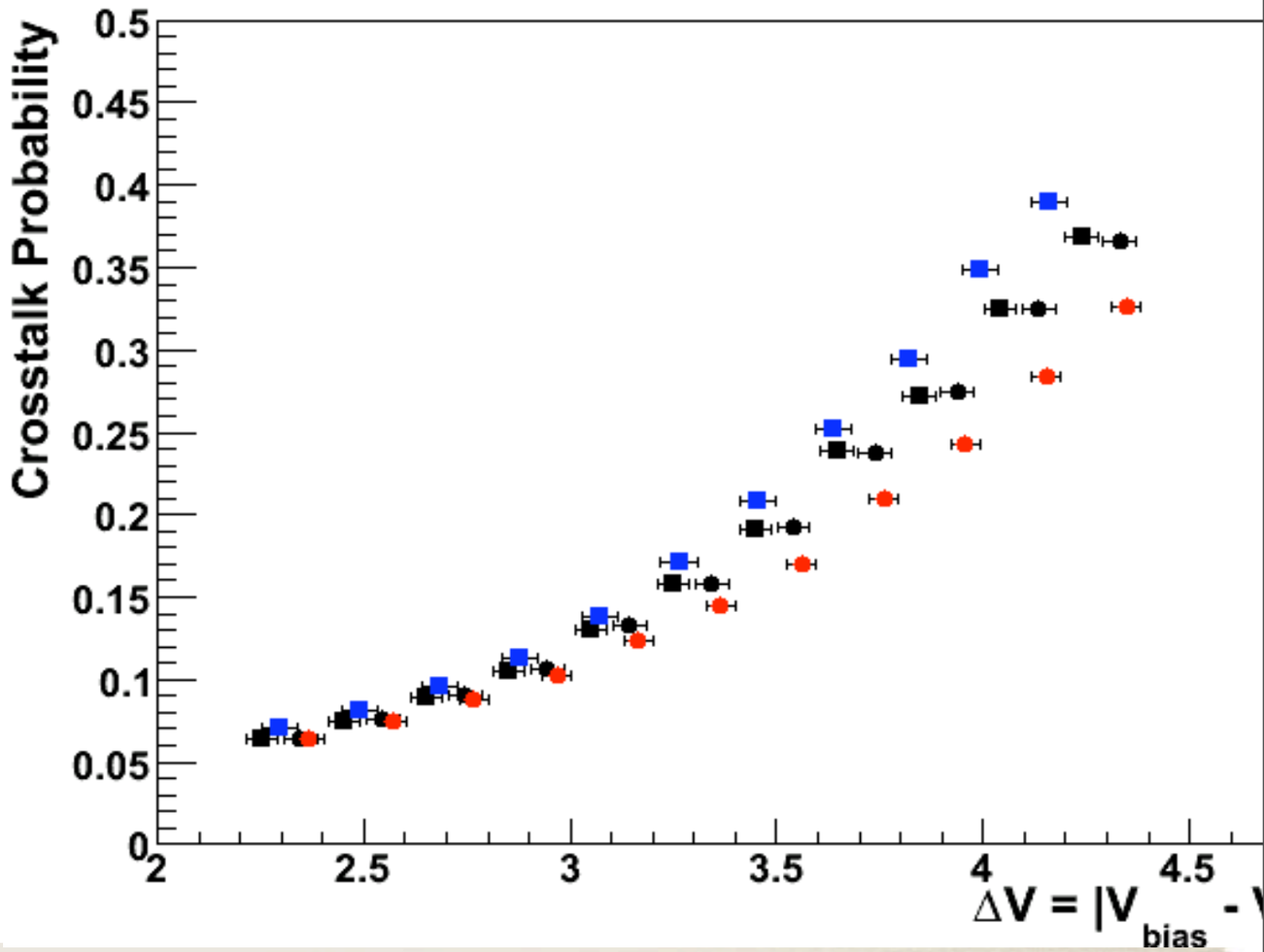


# neutron irrad.

- noise rate & Crosss talk

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



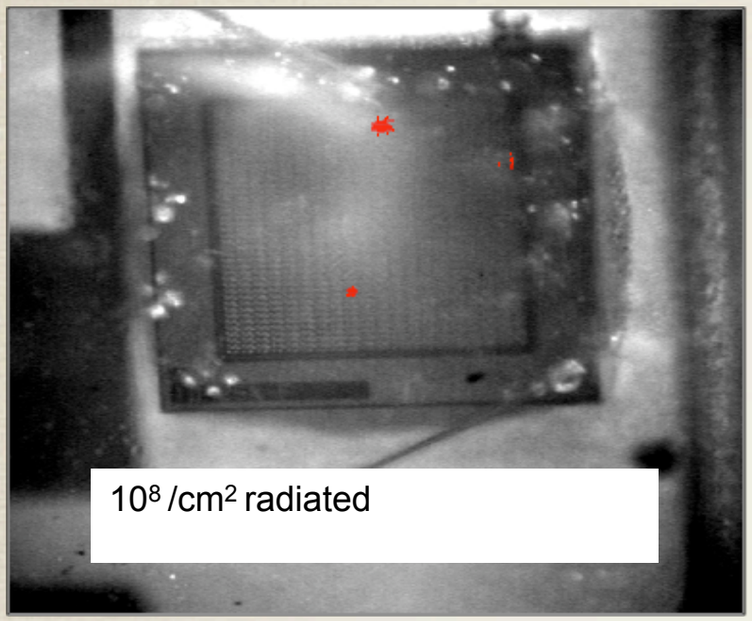



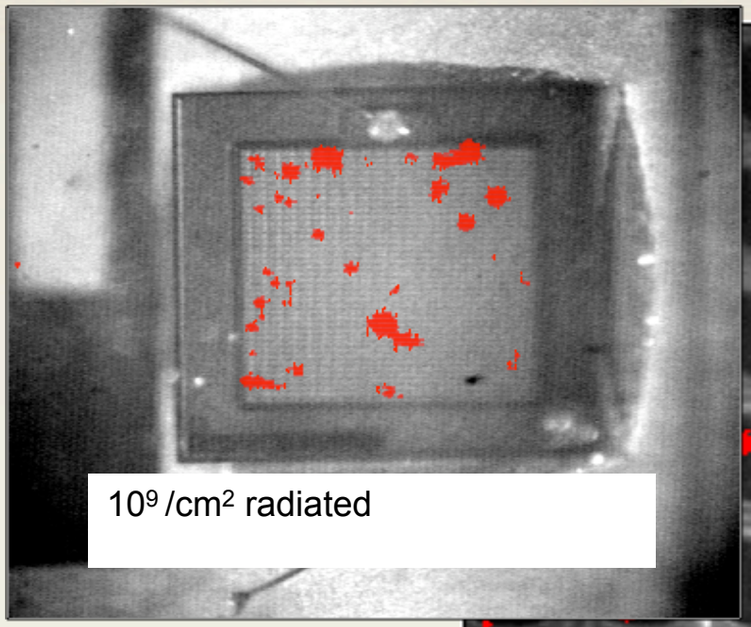

significant changes
on noise rate.

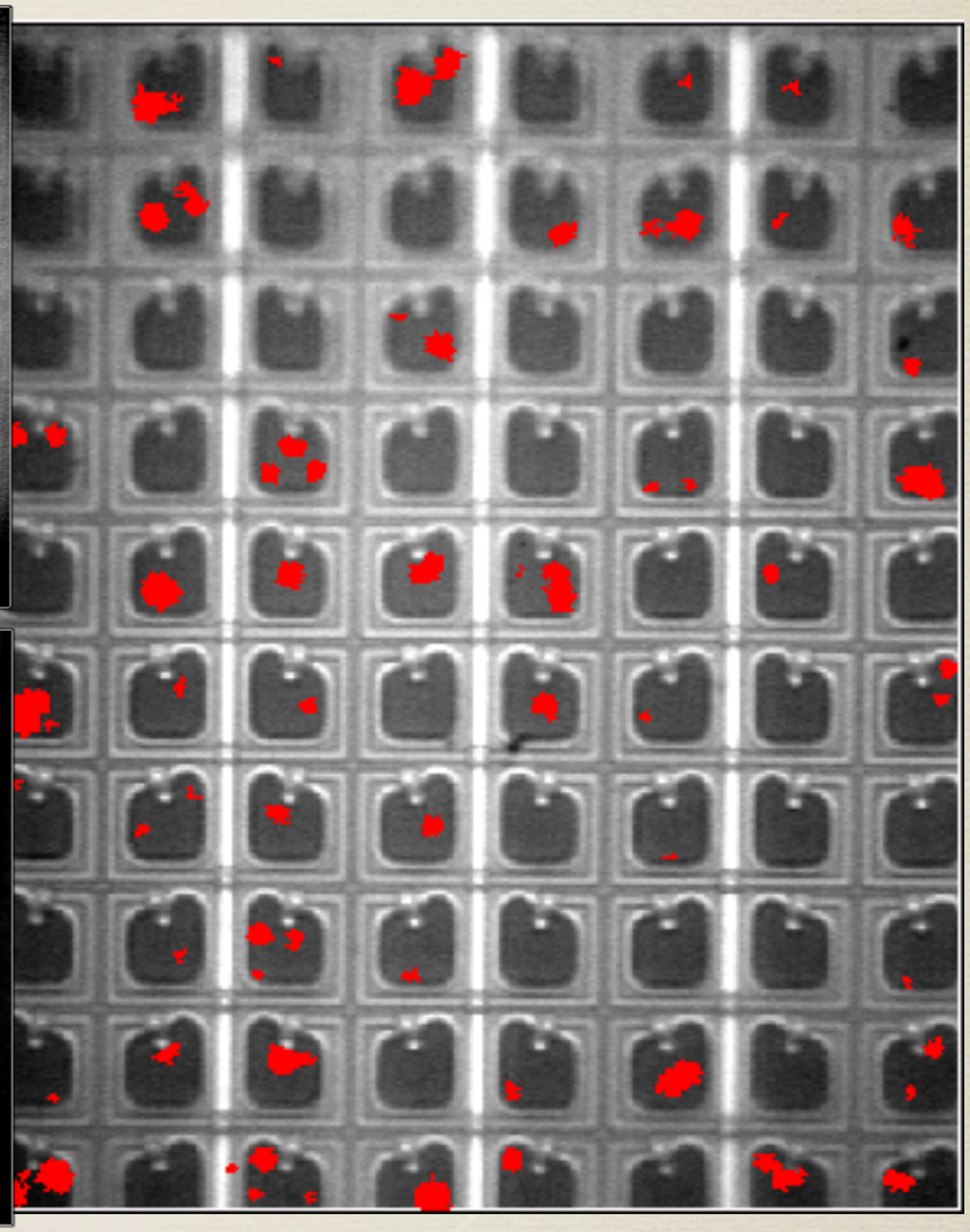
no significant changes
on the crosstalk probability
radiation.

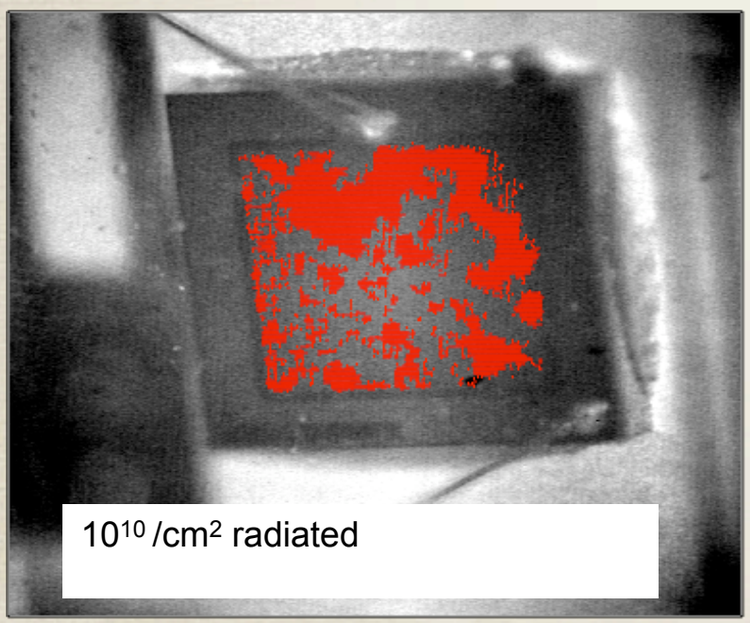
# neutron irrad.

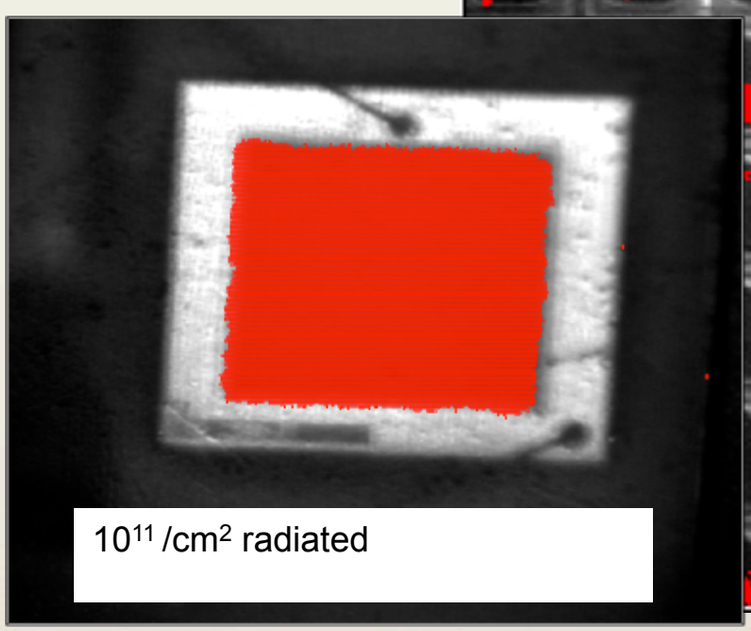
* hot spot pictures



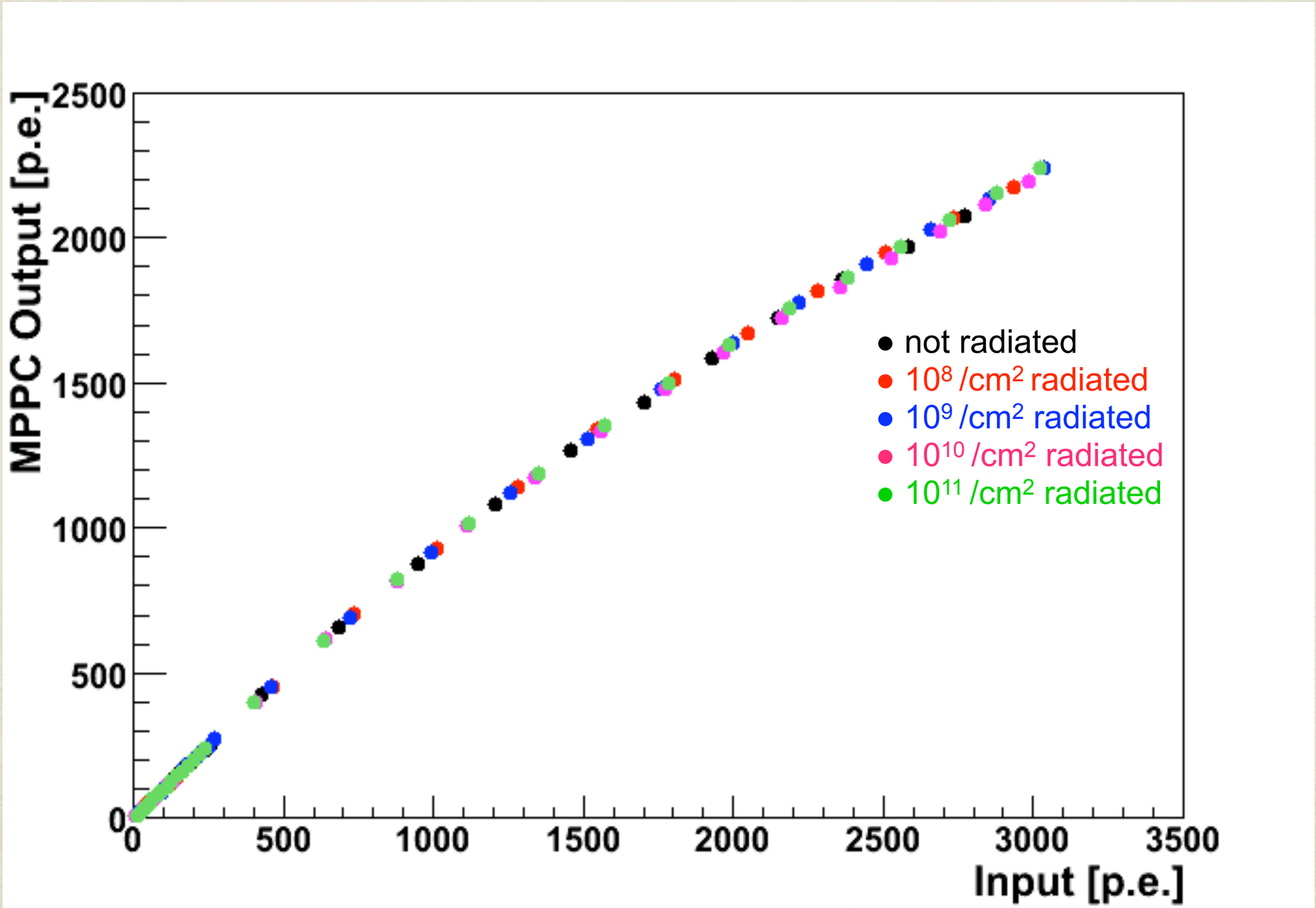




increased number of hot spots > $10^9$ at sensitive area

# neutron irrad.

- saturation curve
- no significant effect

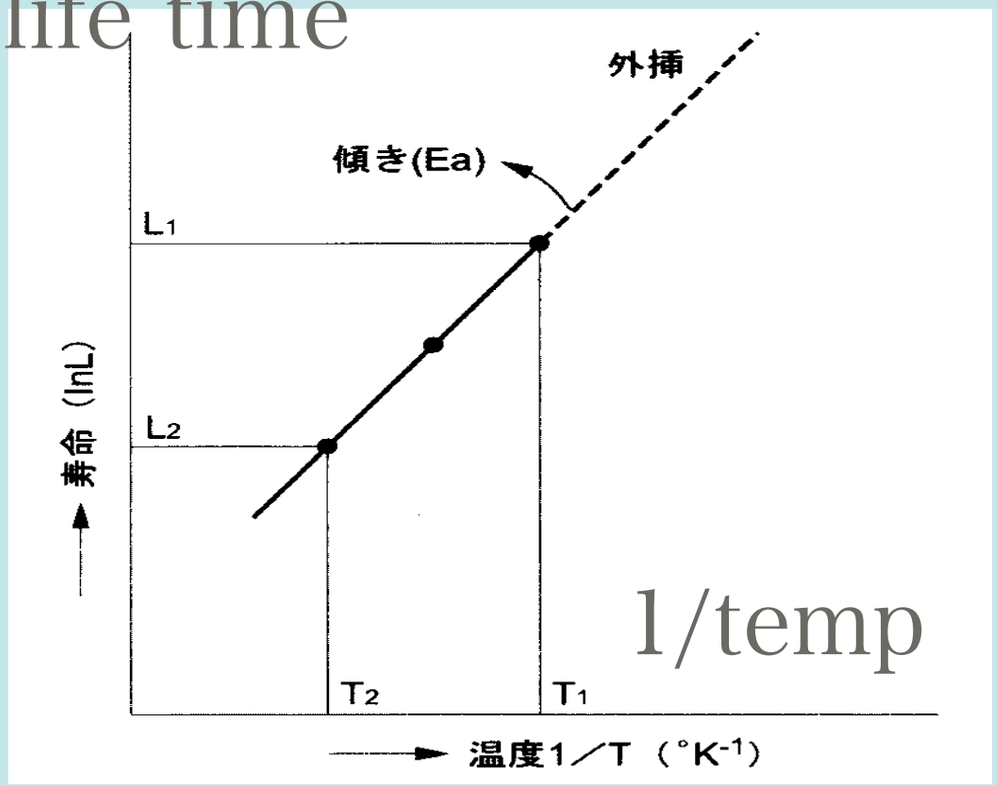


# long term stability

* at high temperature
* accelerate aging

$$L = \Lambda \exp(\frac{Ea}{kT})$$

life time

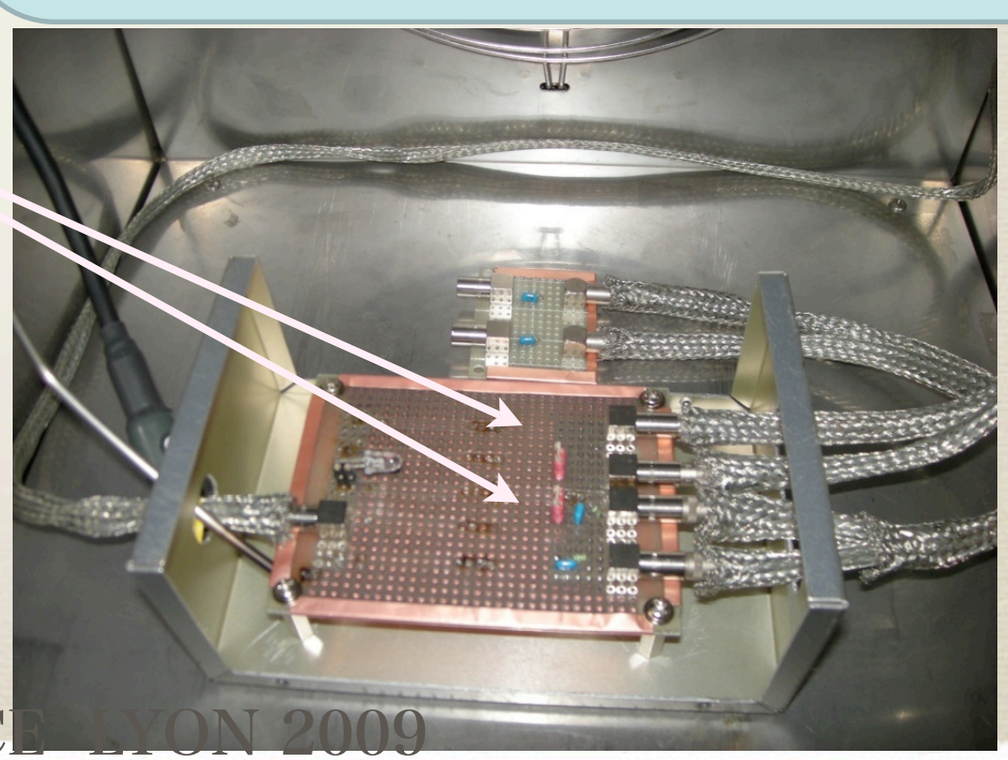



2 MPPCs are tested

at 85C

45 times faster

if Ea=0.58eV

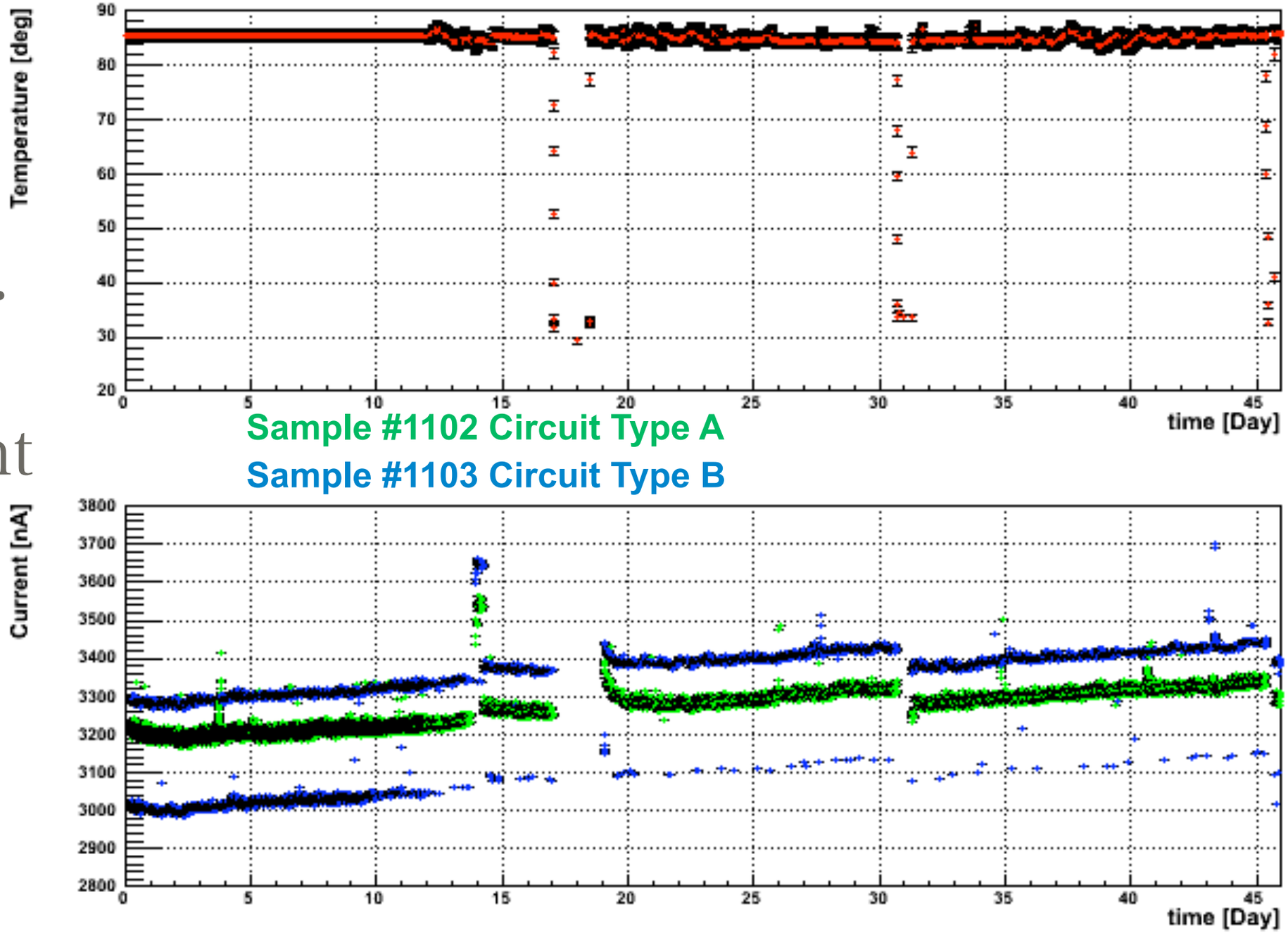


# long term stability

- 45 days ~ 10 years ILC running
- leakage current  monitor : a bit increased

temp.

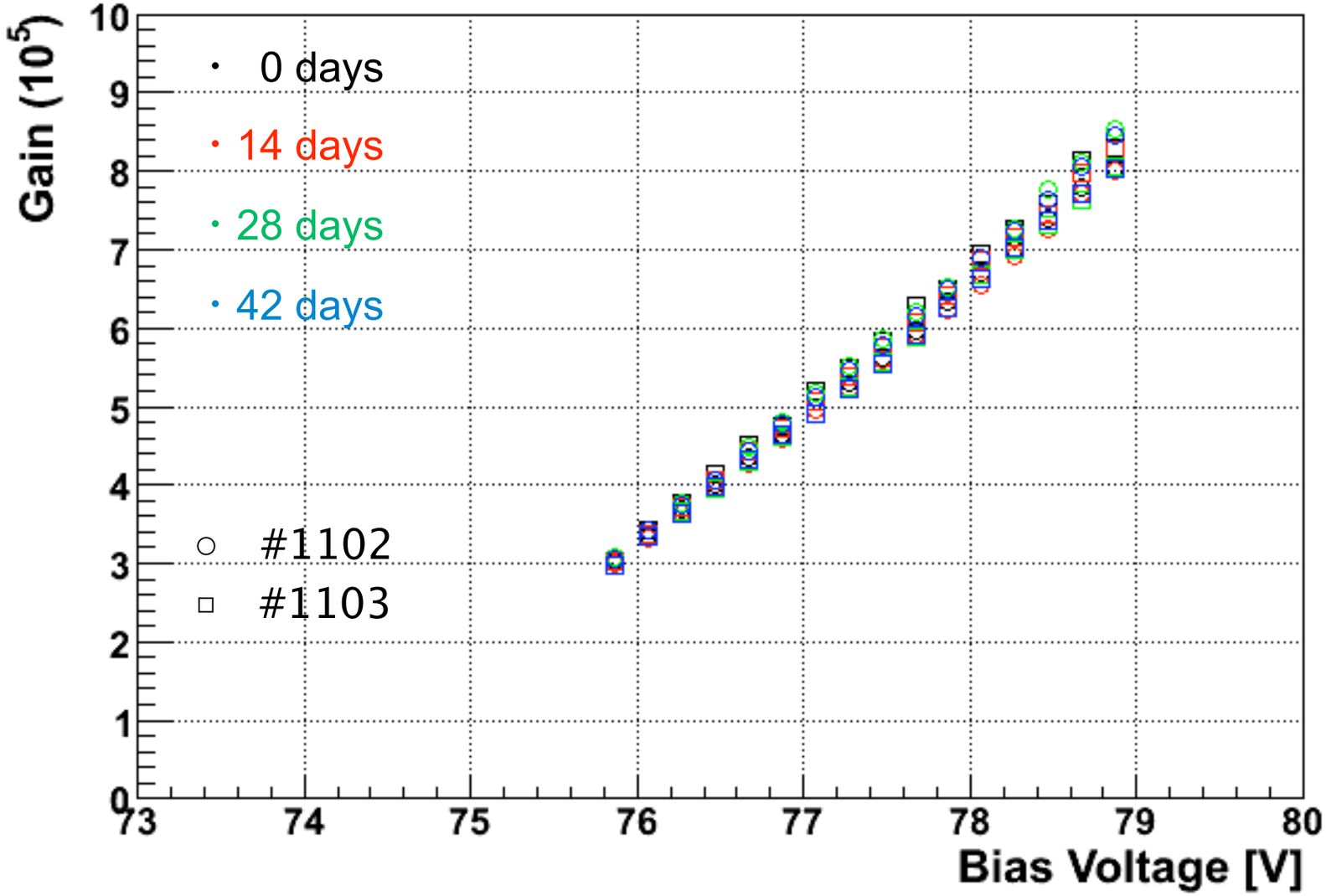
current

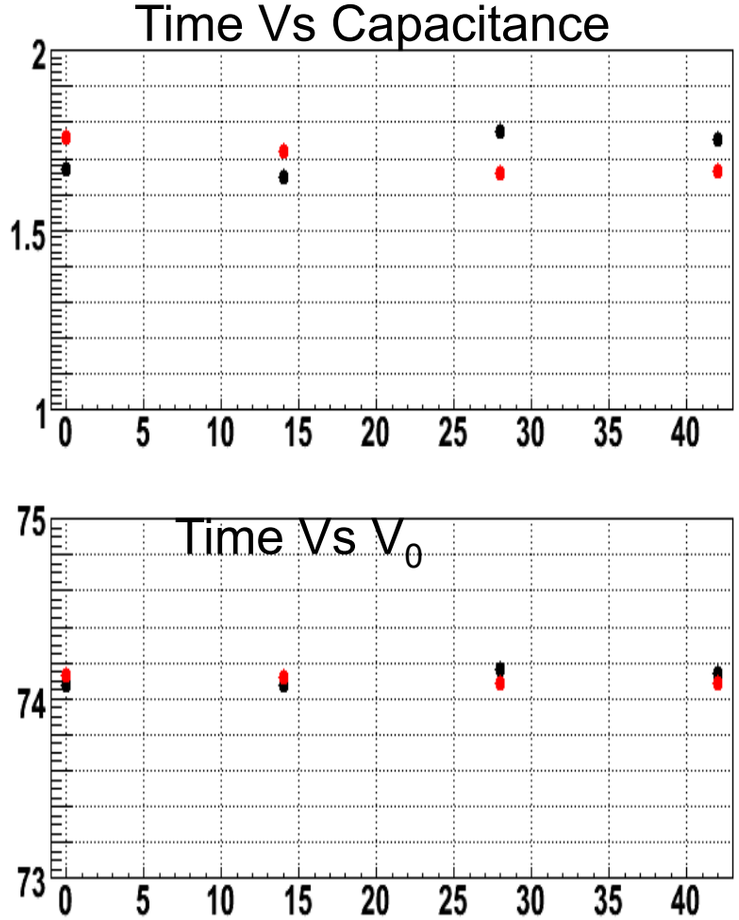


# long term stability test

* gain monitor

quite stable




* NO gain change in 10 years of ILC

# long term stability

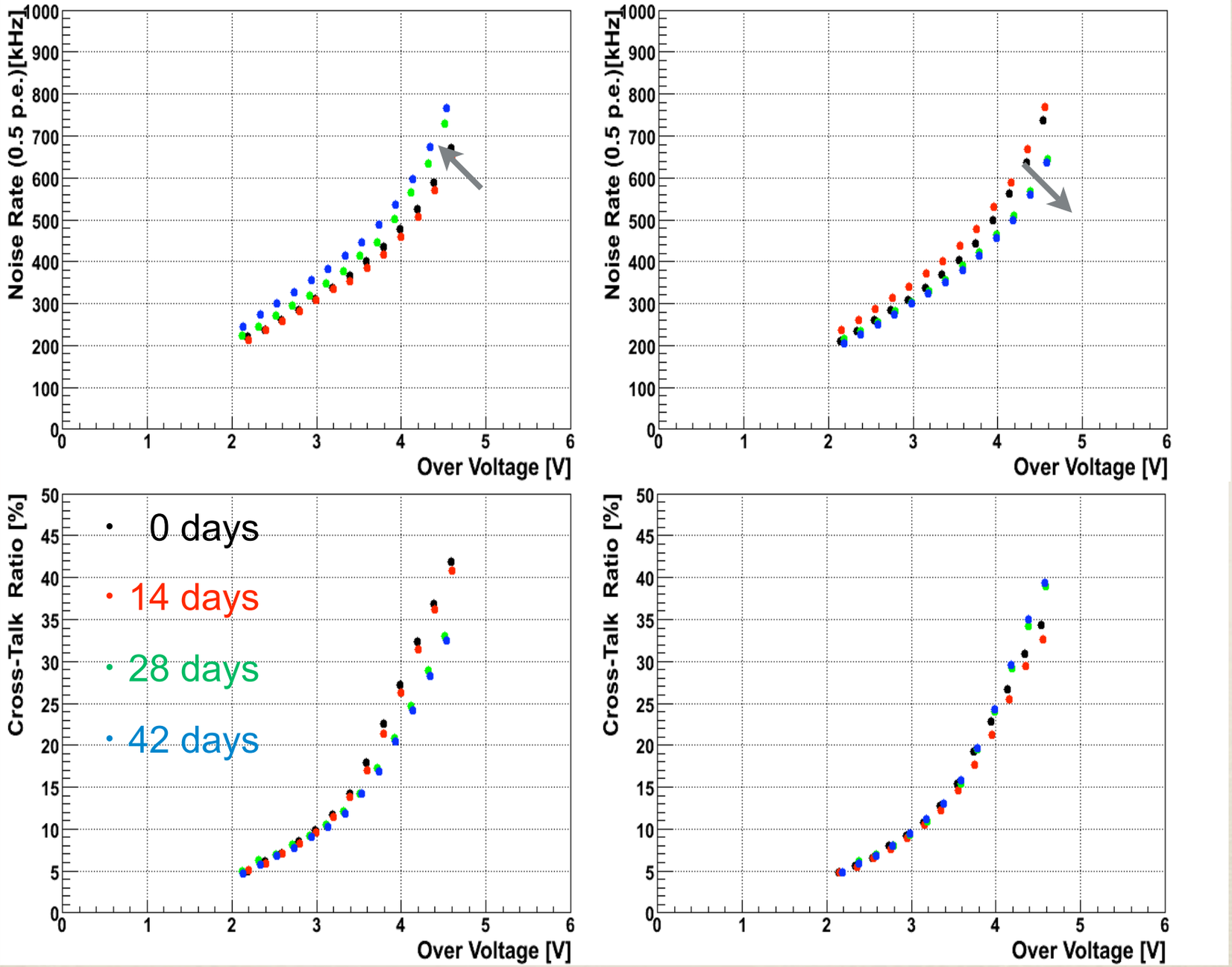
* Noise rate & Cross talk

NoiseRate
(0.5 p.e.)

Cross-Talk

Sample #1102

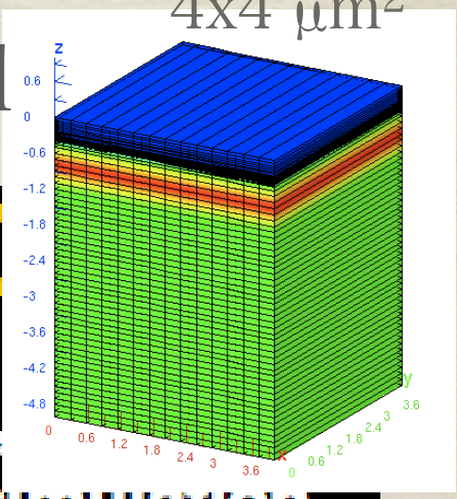
Sample#1103




different read out circuit

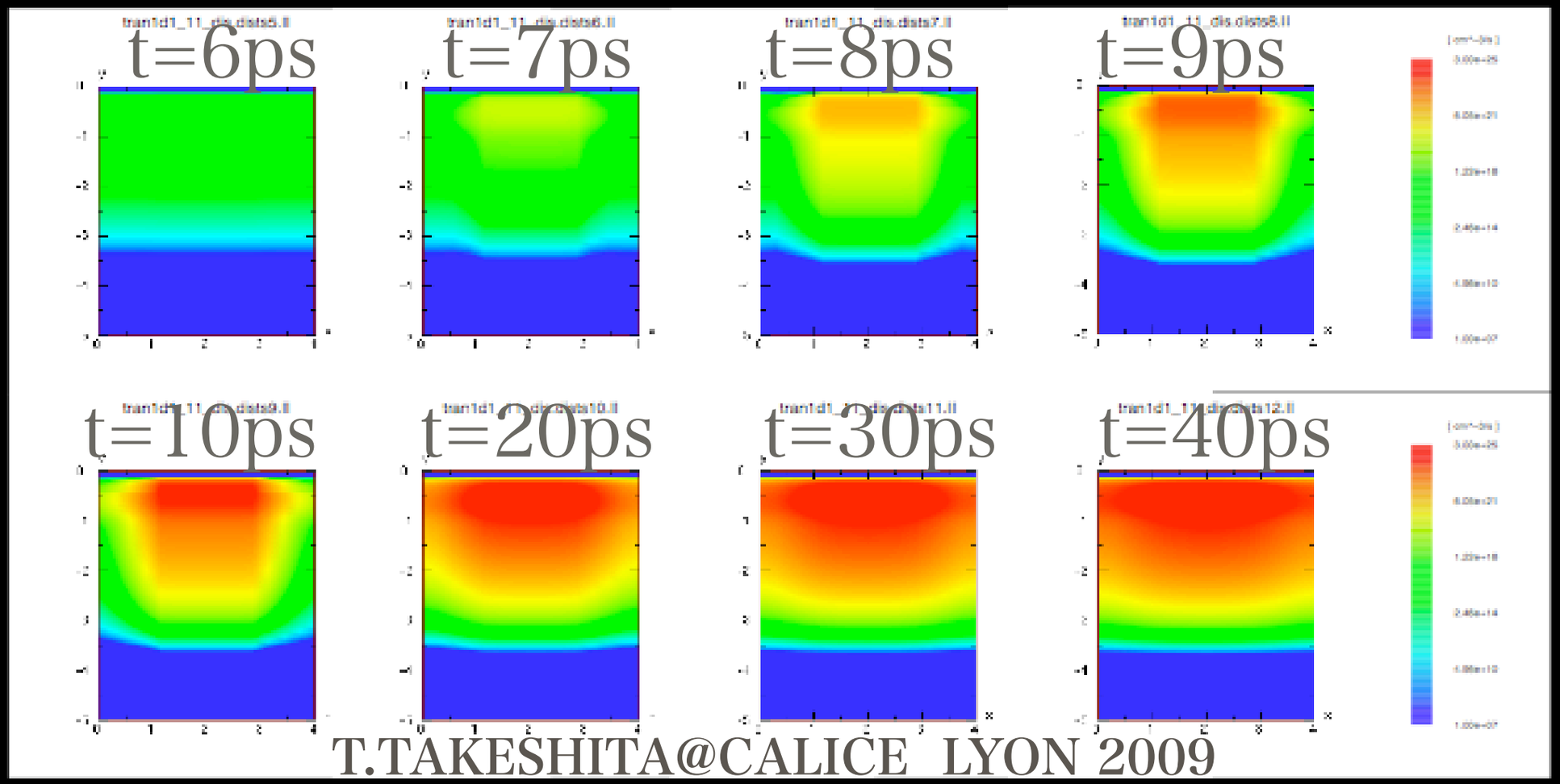
# understanding of MPPC

* simulation of avalanche inside a MPPC pixel




## Avalanche Multiplication (1D

**We show the impact ionization at different times (t = 6, 7, 8, 30, 40 [ps] ). The avalanche effect is clearly visible in this simulation.**



# summary & outlook

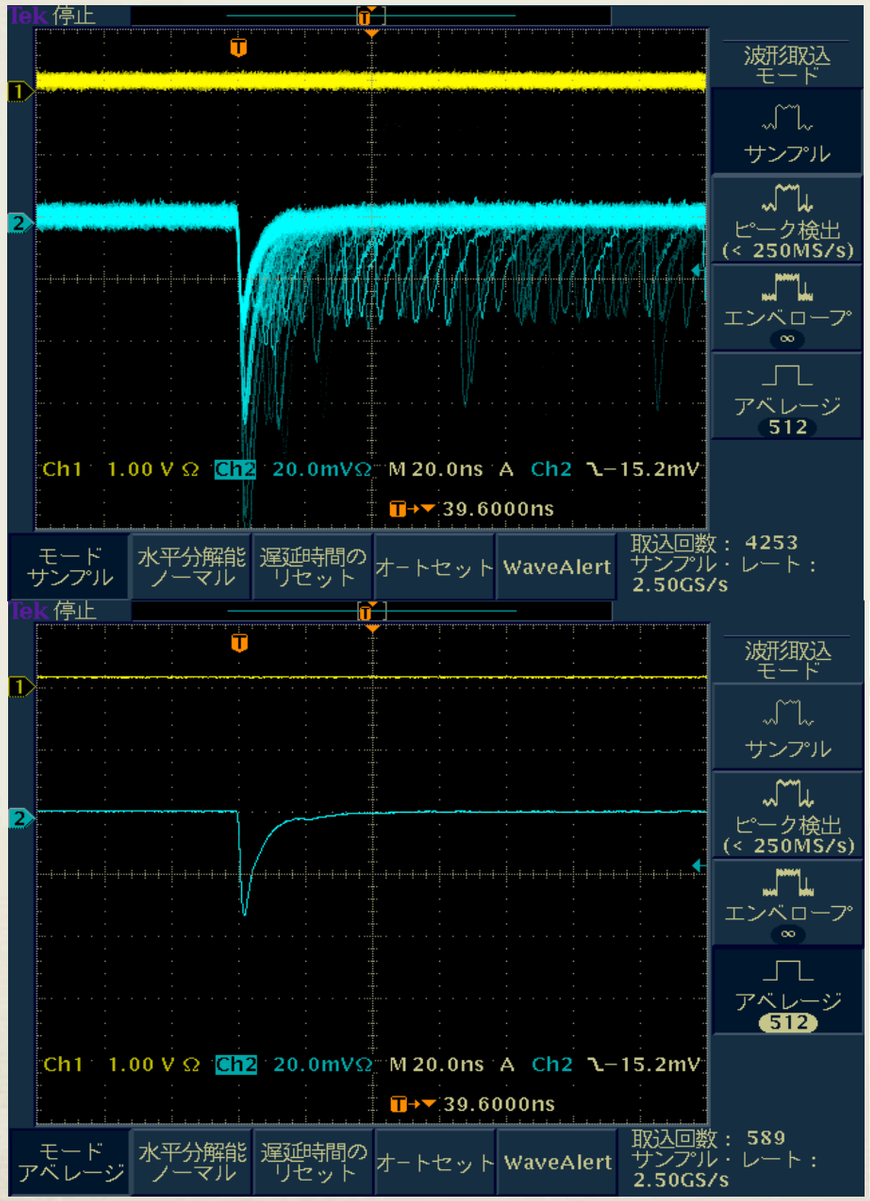
- gamma irradiation
  - 60Gy seems OK (ILC 10 years ~ 10Gy)
- neutron irradiation
  - $10^8$ n/cm$^2$ seems to be OK
  - increase leakage current
- long term stability
  - stable enough for 45 days (~10 year of ILC)si
- simulation understudy to improve  MPPC

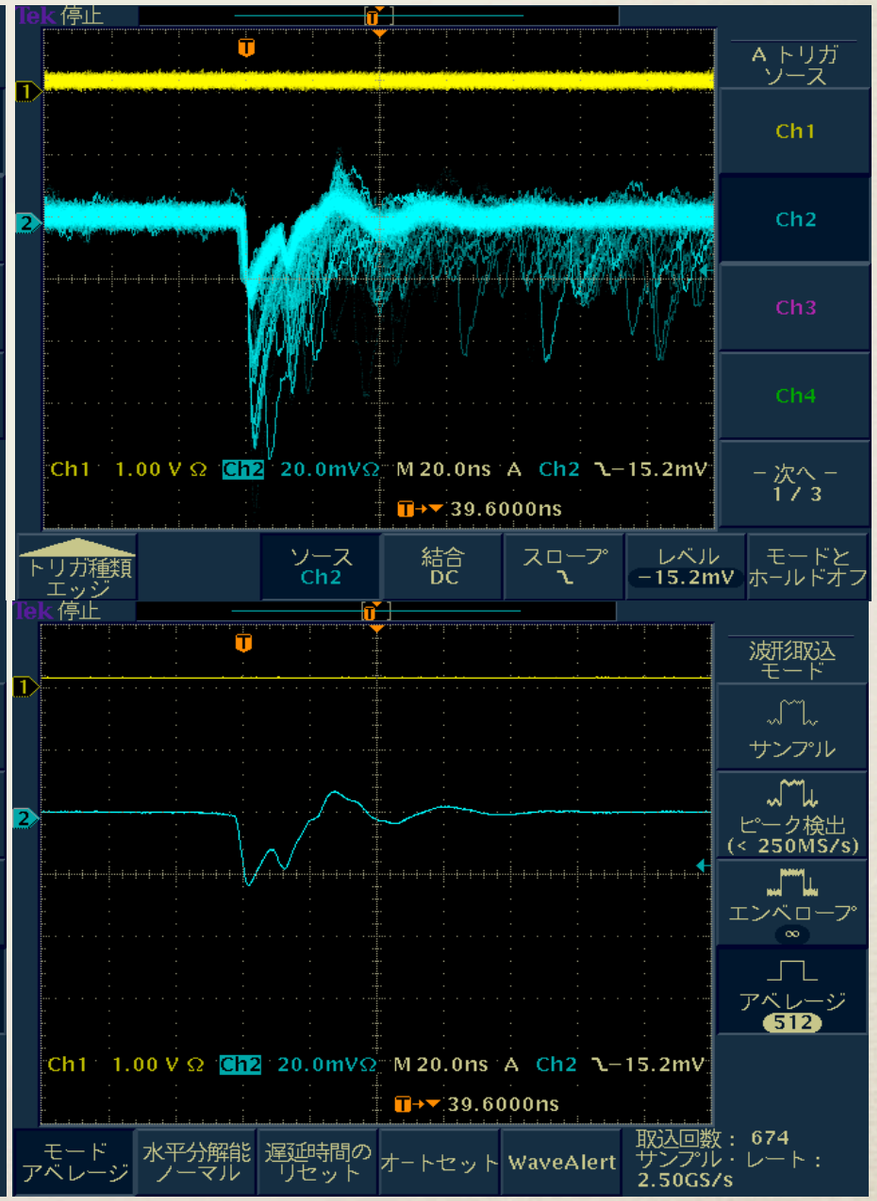
# * different readout circuit

Type A

Type B

MPPC Pulse shape




average