# THE MEASUREMENT OF RADIATION DAMAGE EFFECTS IN CCD

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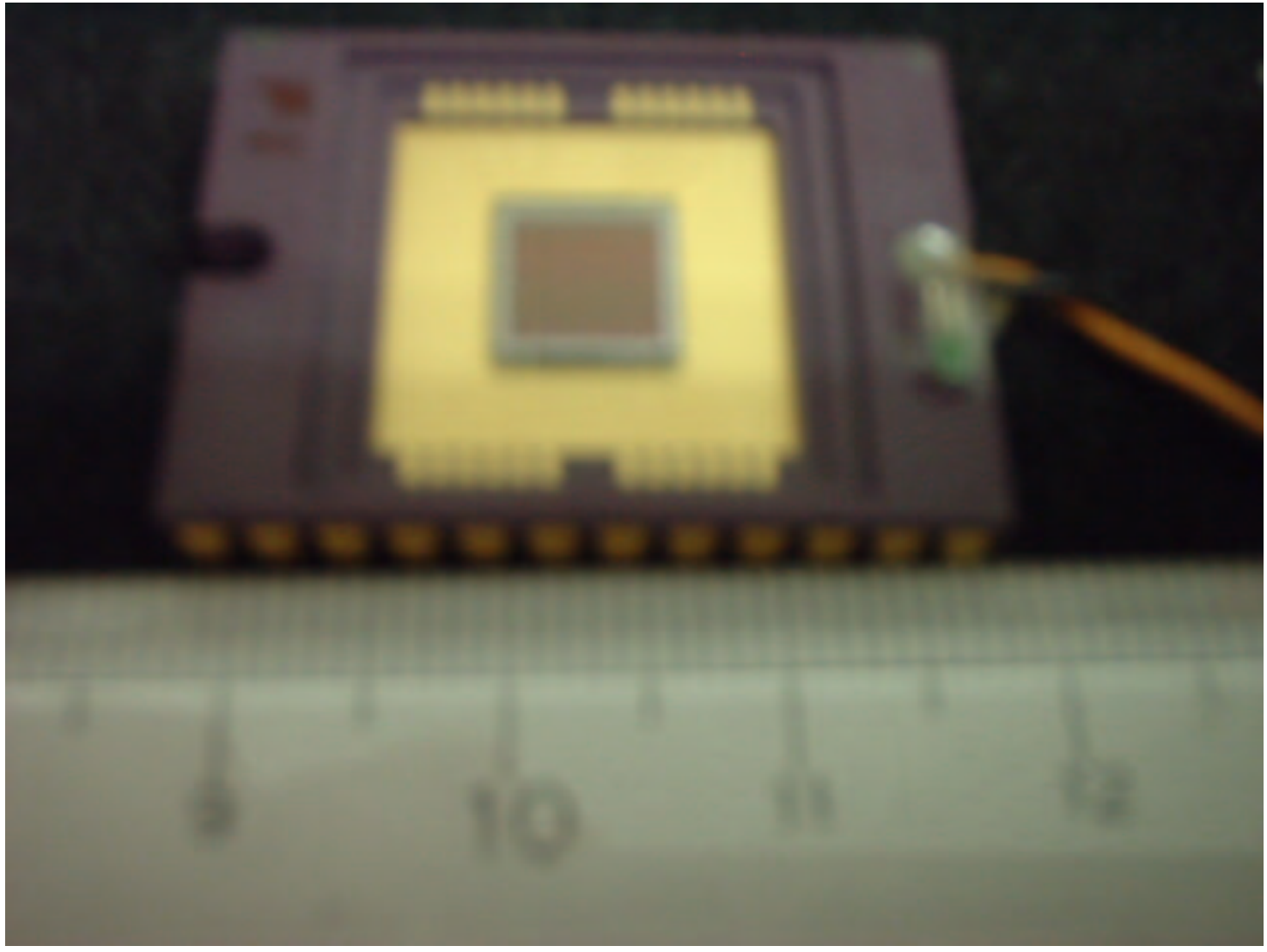
# OUTLINE

- Introduction
- CCD overview
- CCD probrems
- Experiment
- Analysis
- Summary

# INTRODUCTION

- CCD will be use in JLC as vertex detector.
- Requirement from JLC
  - long-range run at $\sim 0°C$
  - radiation hardness, $\sim 4.5 \times 10^{11} e/\mathrm{cm}^2/\mathrm{year}$
  - spacial resolution, $\sim$ several $\mu m$
  - fast readout, $\sim$ several $\times 10$ Mpixel/sec

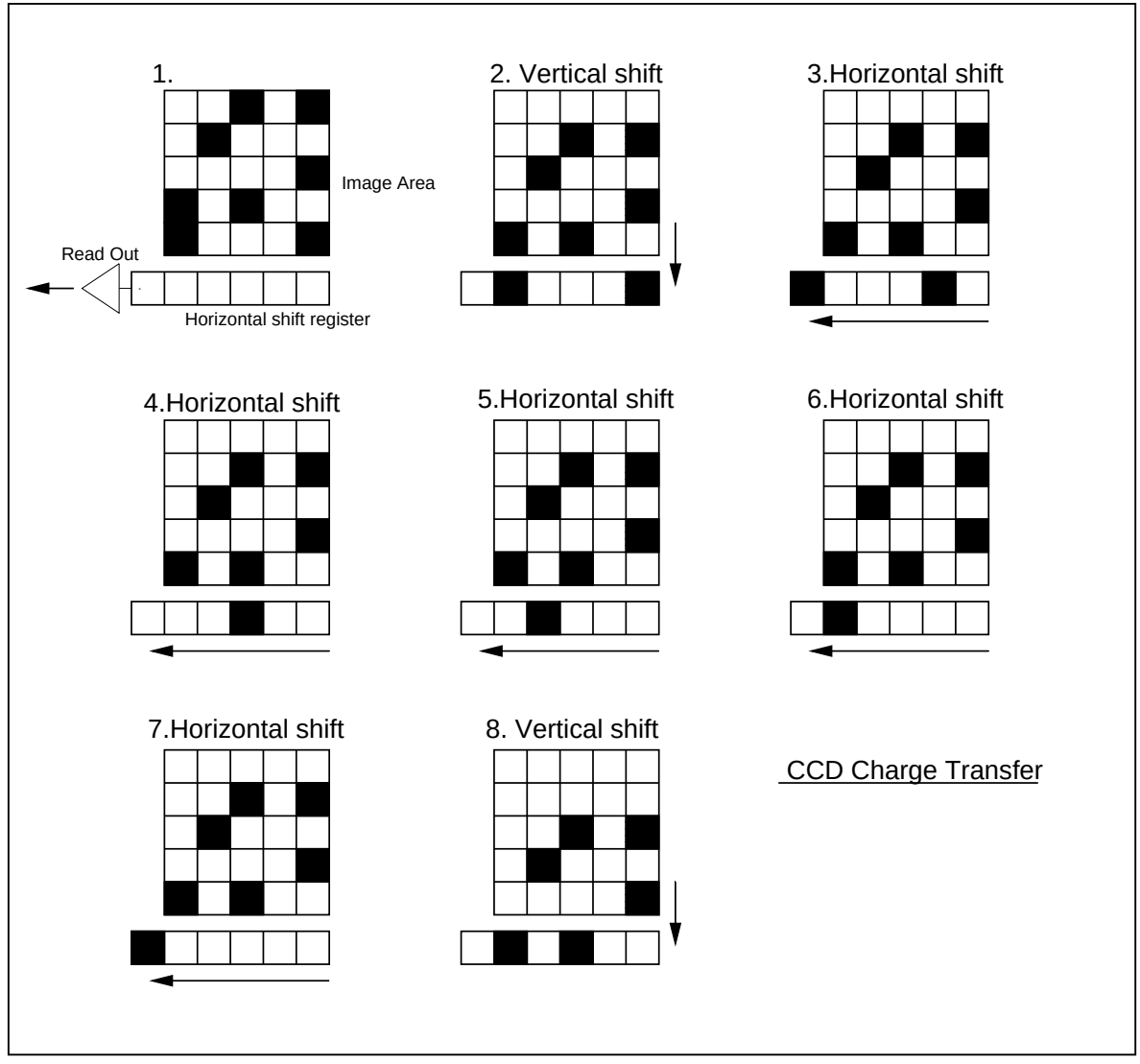
# SPEC I



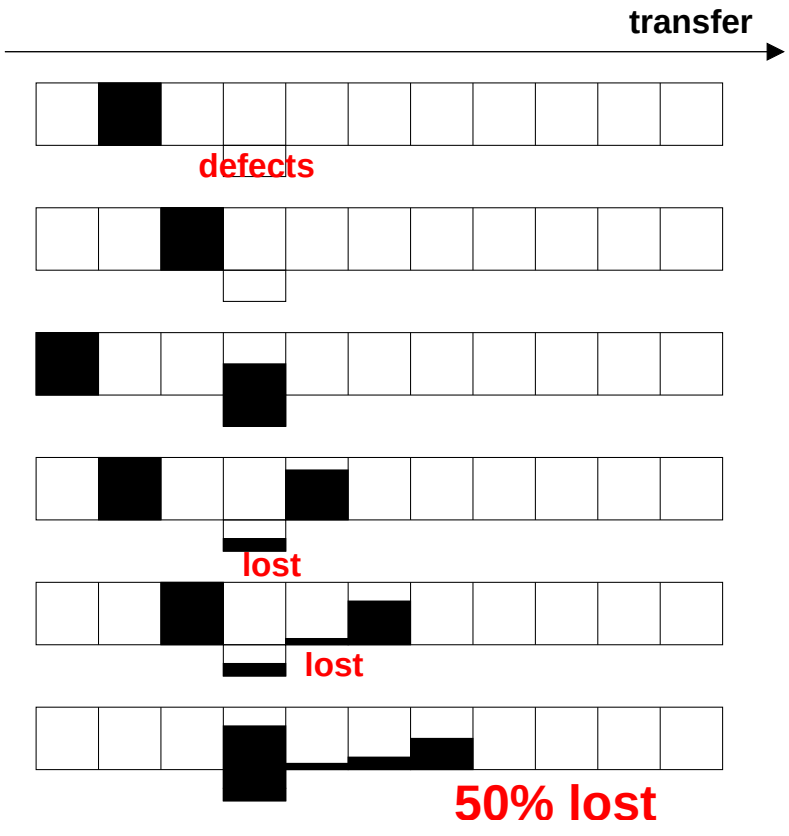
# SPEC II

| | |
|---|---|
| Format | $256(\mathrm{H}) \times 256(\mathrm{V})$ |
| Pixel size | $24\mu m \times 24\mu m$ |
| Thickness | $10\mu m$ |
| Gain | $2\mu V/e$ |

# CHARGE TRANSFER



# CHARGE TRANSFER INEFFECIENCY



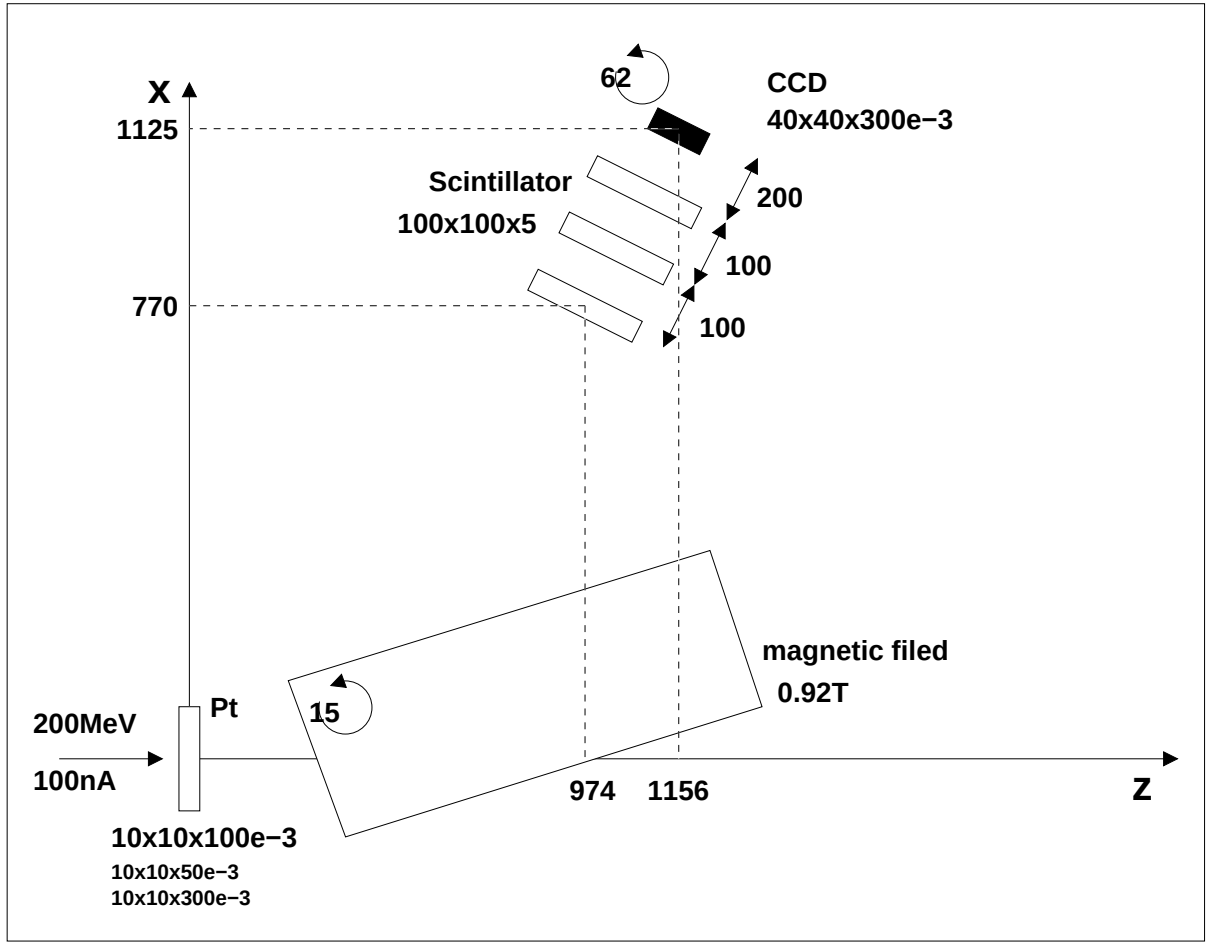

**C**harge **T**ransfer **E**fficiency is efficiency by a transfer.

$$CTI = 1 - CTE$$

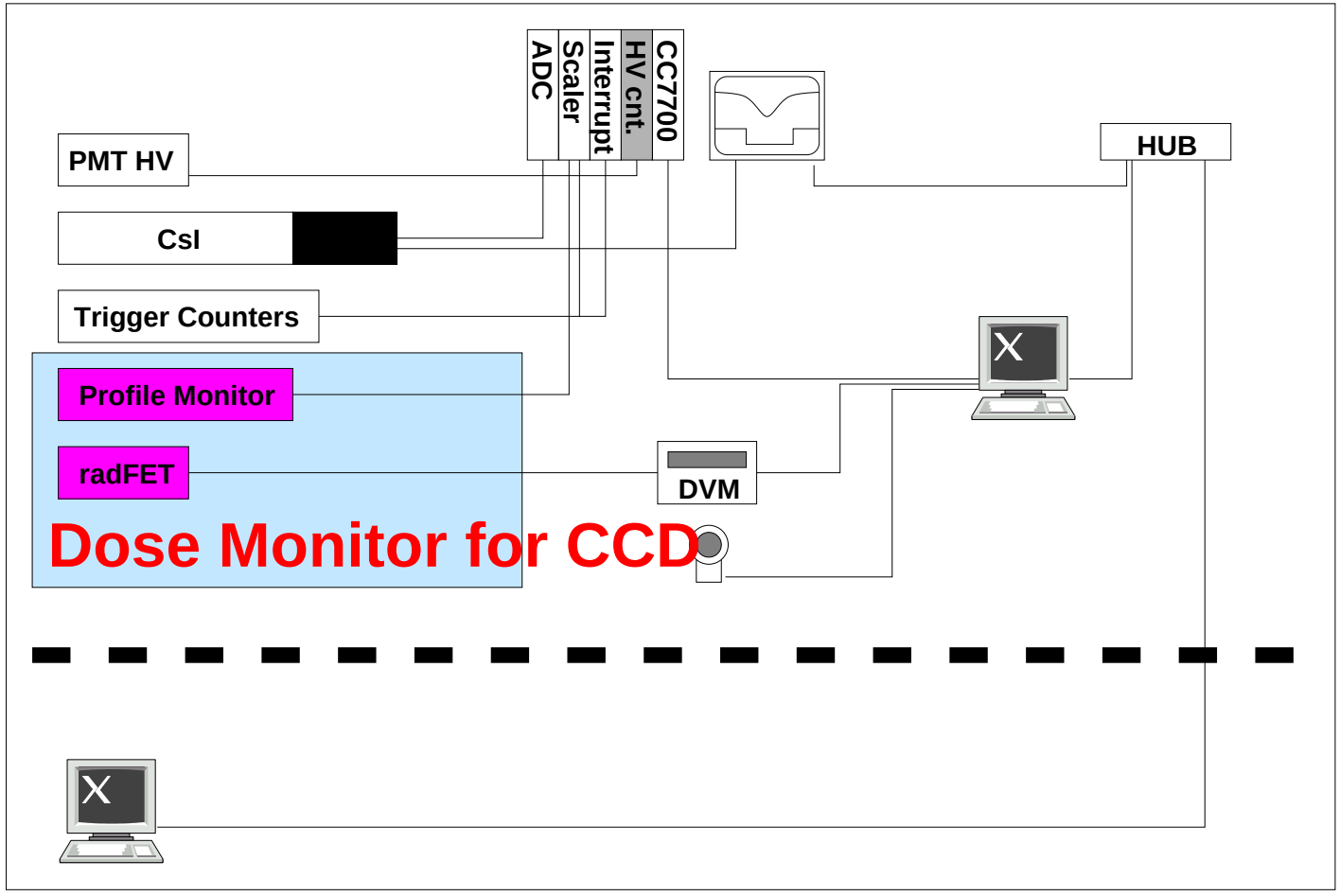
This example, both of CTE and CTI is 0.5.

# BEAMTEST I

Dec. 2002, KAKURIKEN, Tohoku Unviersity,

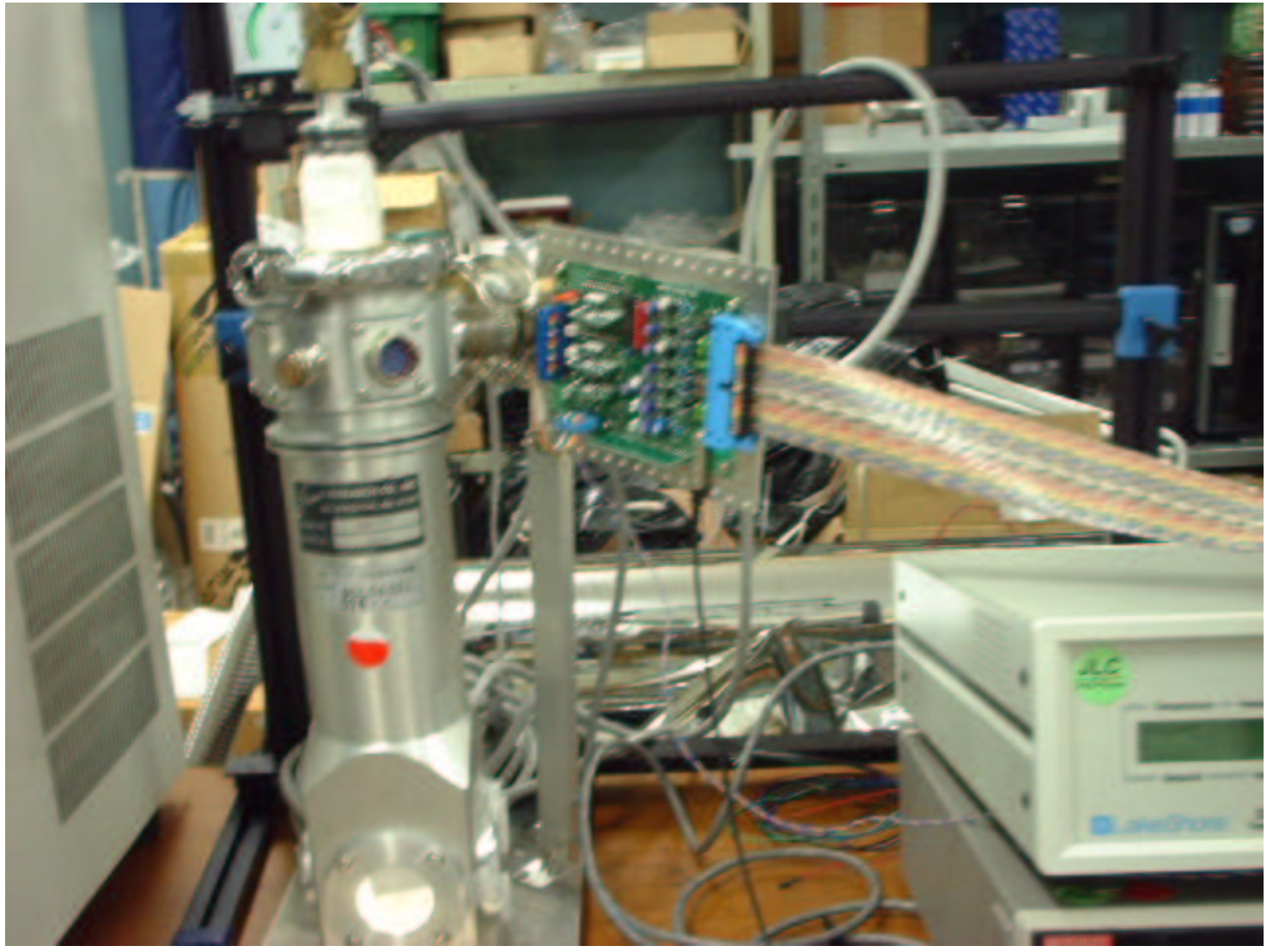


# BEAMTEST II

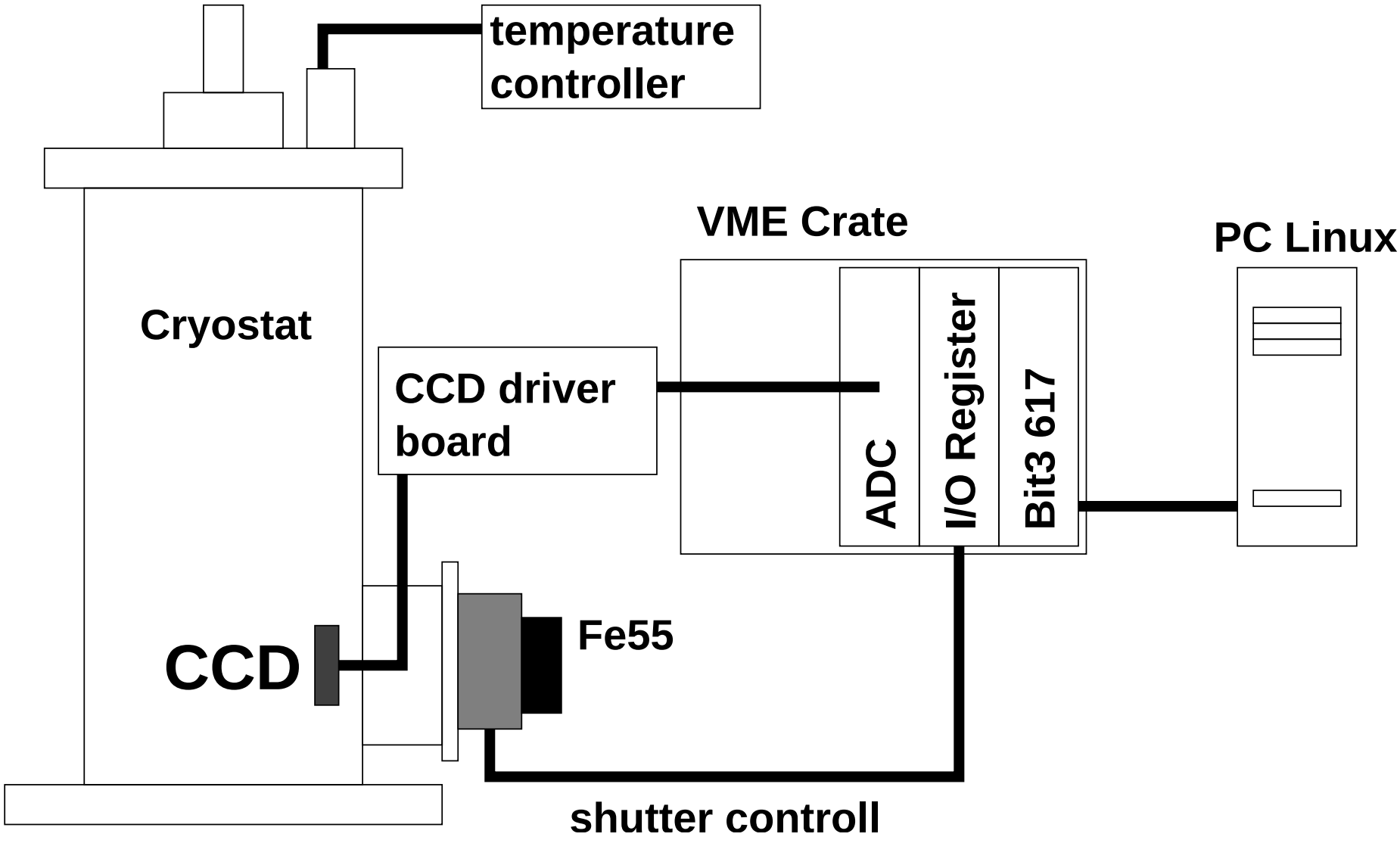



irradiated $\sim 3.6 \times 10^{10} e/\mathrm{cm}^2$ ($\sim 0.95$ krad)

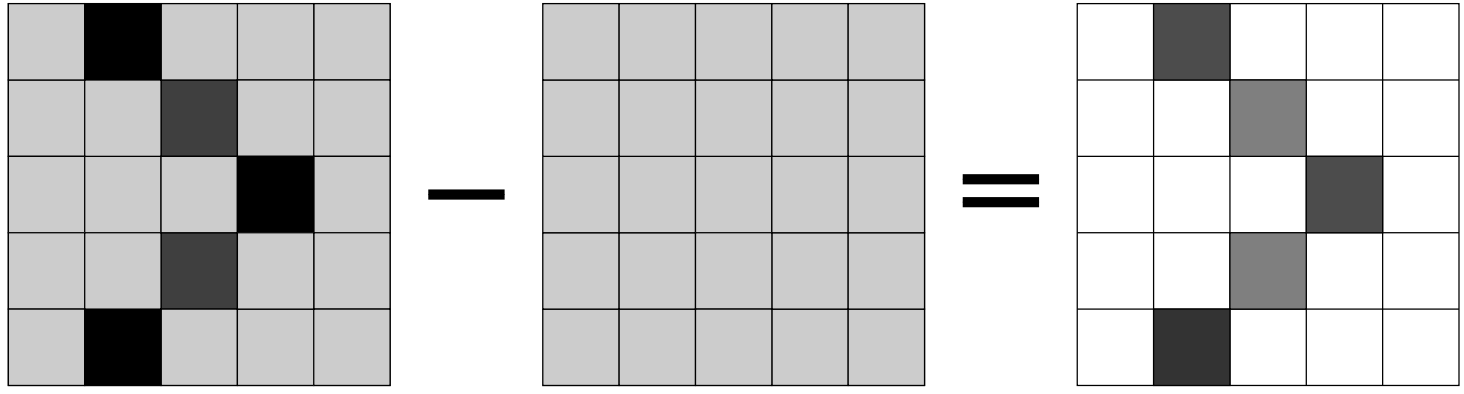
# EXPERIMENTAL SETUP I



# EXPERIMENTAL SETUP II



# SINGLE PIXEL EVENT I



signal frame (include dark current) — dark frame — SIGNAL

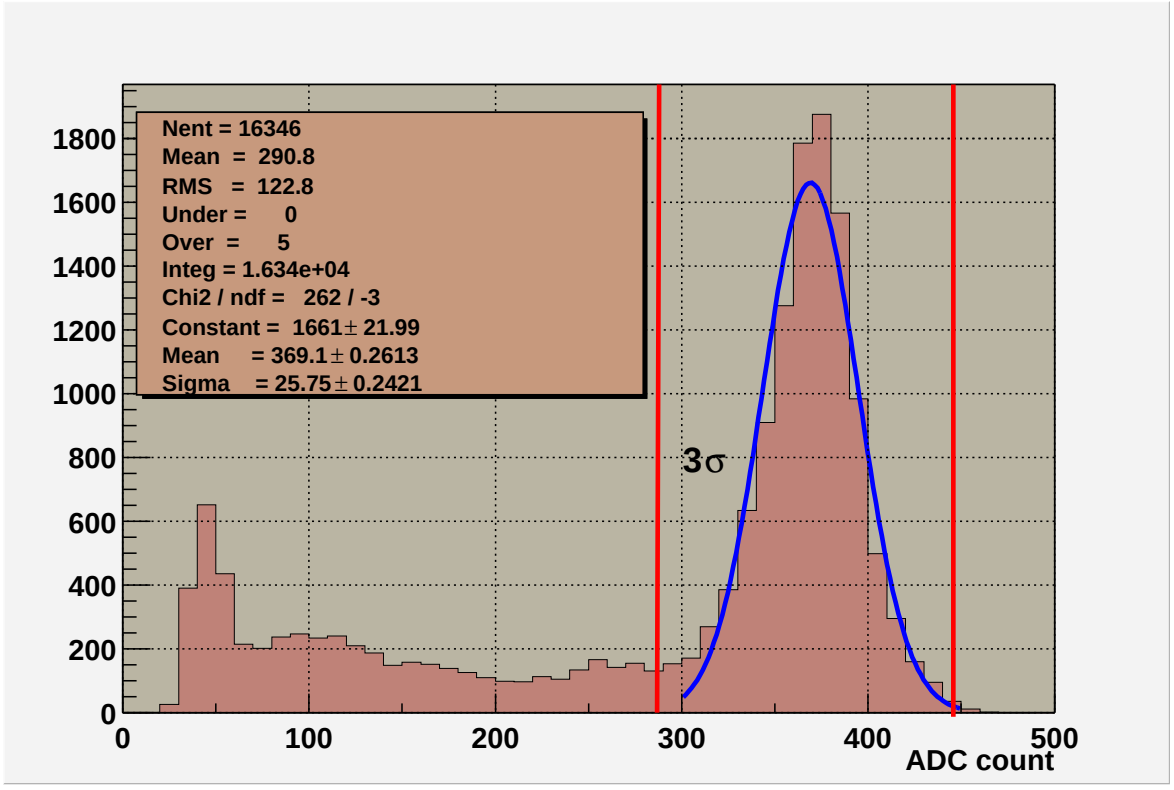
**find out single pixel event from signal exclude dark.**

# SINGLE PIXEL EVENT II

- make a average map of dark current.
- make a RMS map of dark current.
- make a bad channel map.
  - rate of overflow or underflow is more than half.
  - RMS value is more than 20.(this is $\sim 3\sigma$)
- more than average of dark $+6\sigma$.
- no bad channel around.
- not a bad channel.

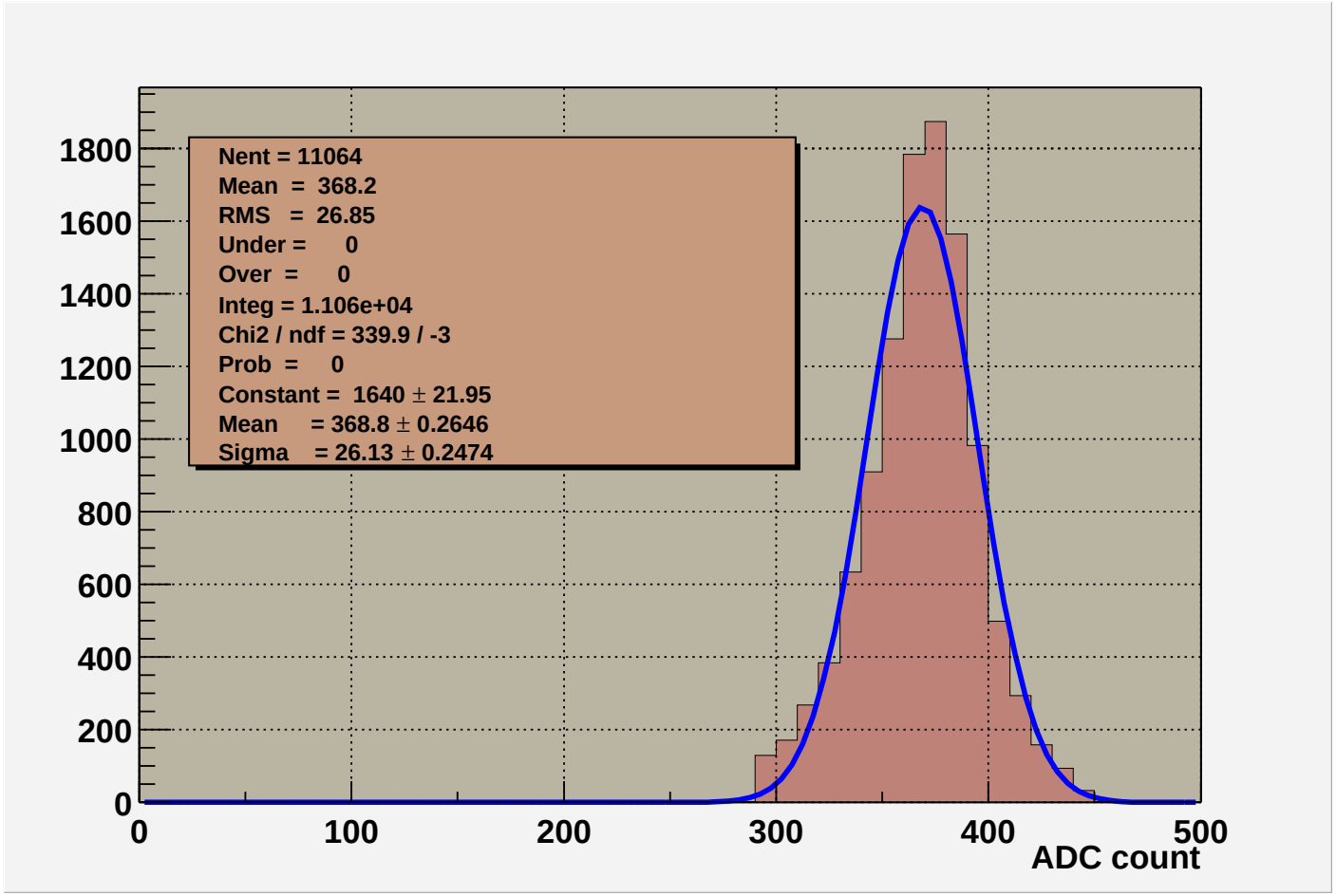
# SINGLE PIXEL EVENT III

ex.) CCD before irradiation(@−80°C)



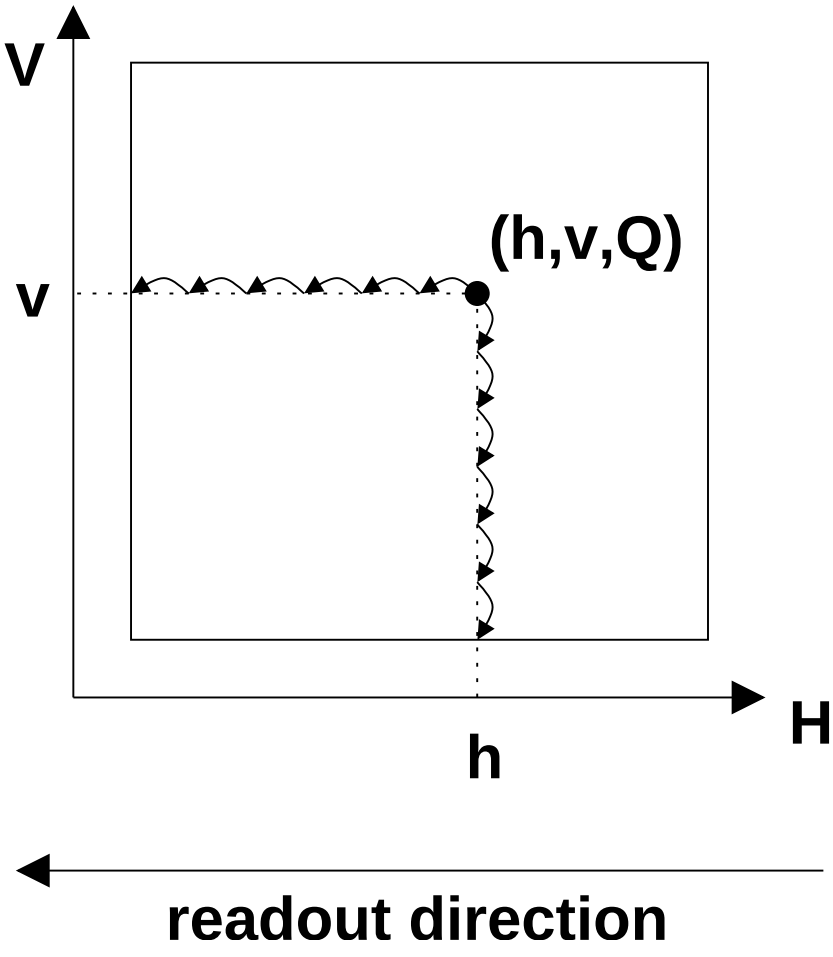

cut off outside of $3\sigma$.

# SINGLE PIXEL EVENT IV




I regard these event as single pixel event, use in analysis.

# ANALYSIS METHOD I

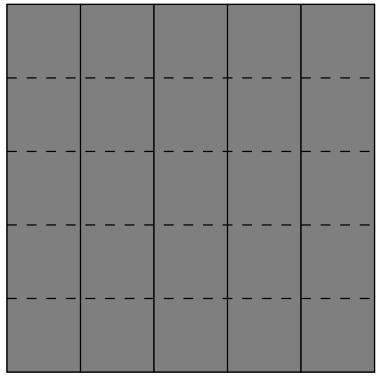



two method:

- using the least-squares method to dataset(h,v,Q).
- divide CCD frame in five region.(talk about later)

# ANALYSIS METHOD II

**CCD frame**



**neglect HCTI effects in each region**

$$Q = Q_0 \epsilon^V (\epsilon : \text{VCTE})$$
$$Q = \ln\epsilon V + \ln Q_0$$

plot dataset(v,lnQ), and fit.

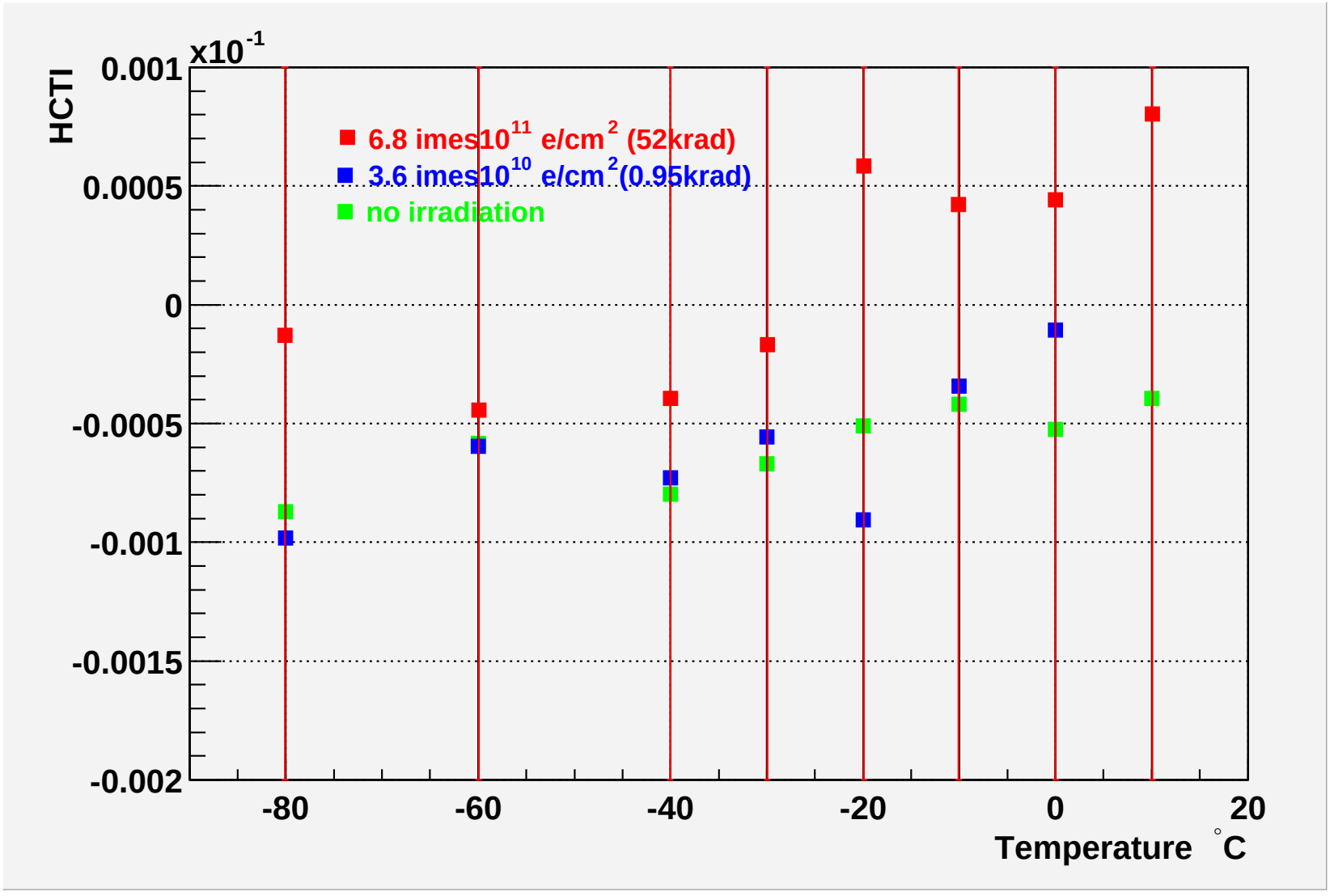
$$y = p_1 x + p_0$$
$$\ln\epsilon = p_1$$

$$\text{VCTI} = 1 - e^{p_1}$$

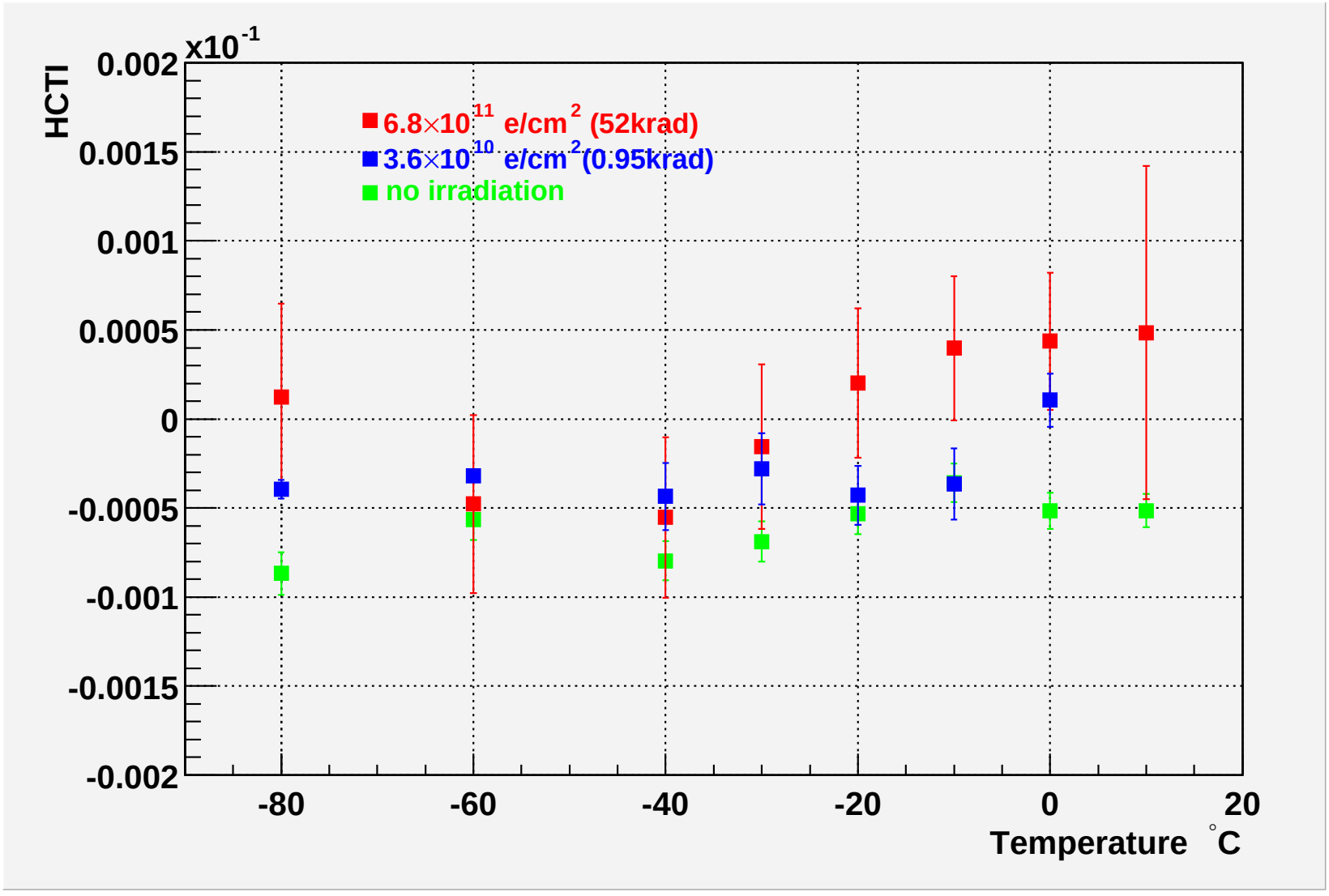
# MEASURING POINT

- no irradiated CCD for reference
- irradiated CCD by $^{90}$Sr
  $6.8 \times 10^{11} e/\mathrm{cm}^2$ (52 krad)
- irradiated CCD by $e^-$ BEAM($\sim$ 100MeV)
  $3.6 \times 10^{10} e/\mathrm{cm}^2$ (0.95 krad)
- $-80°\mathrm{C}$, $-60°\mathrm{C}$, $-40°\mathrm{C}$, $-30°\mathrm{C}$, $-20°\mathrm{C}$, $-10°\mathrm{C}$, $0°\mathrm{C}$, $10°\mathrm{C}$
  8 points every CCDs.

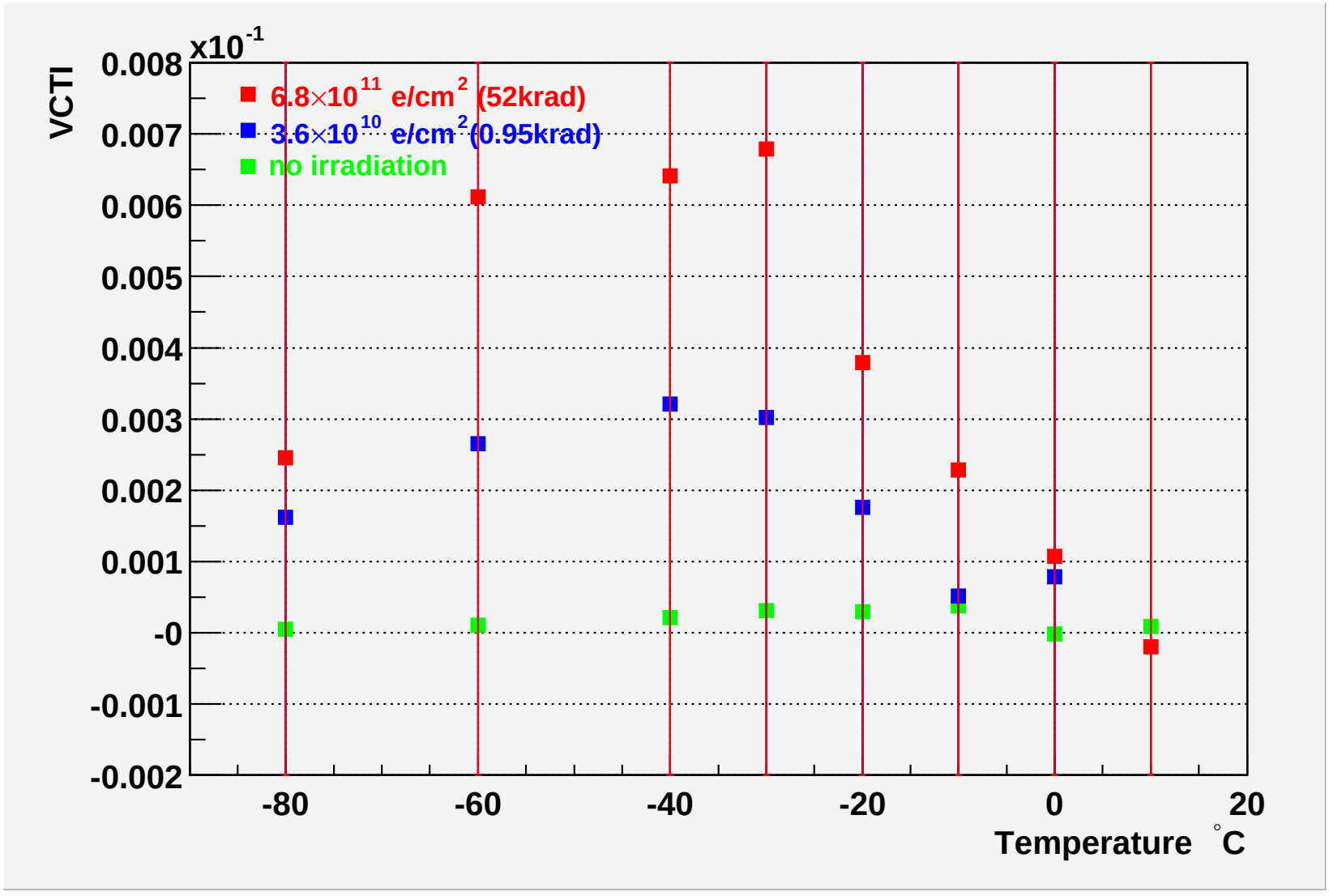
# RESULT I


x10^-1
HCTI
0.001
0.0005
0
-0.0005
-0.001
-0.0015
-0.002
6.8 imes10^11 e/cm^2 (52krad)
3.6 imes10^10 e/cm^2(0.95krad)
no irradiation
-80
-60
-40
-20
0
20
Temperature °C

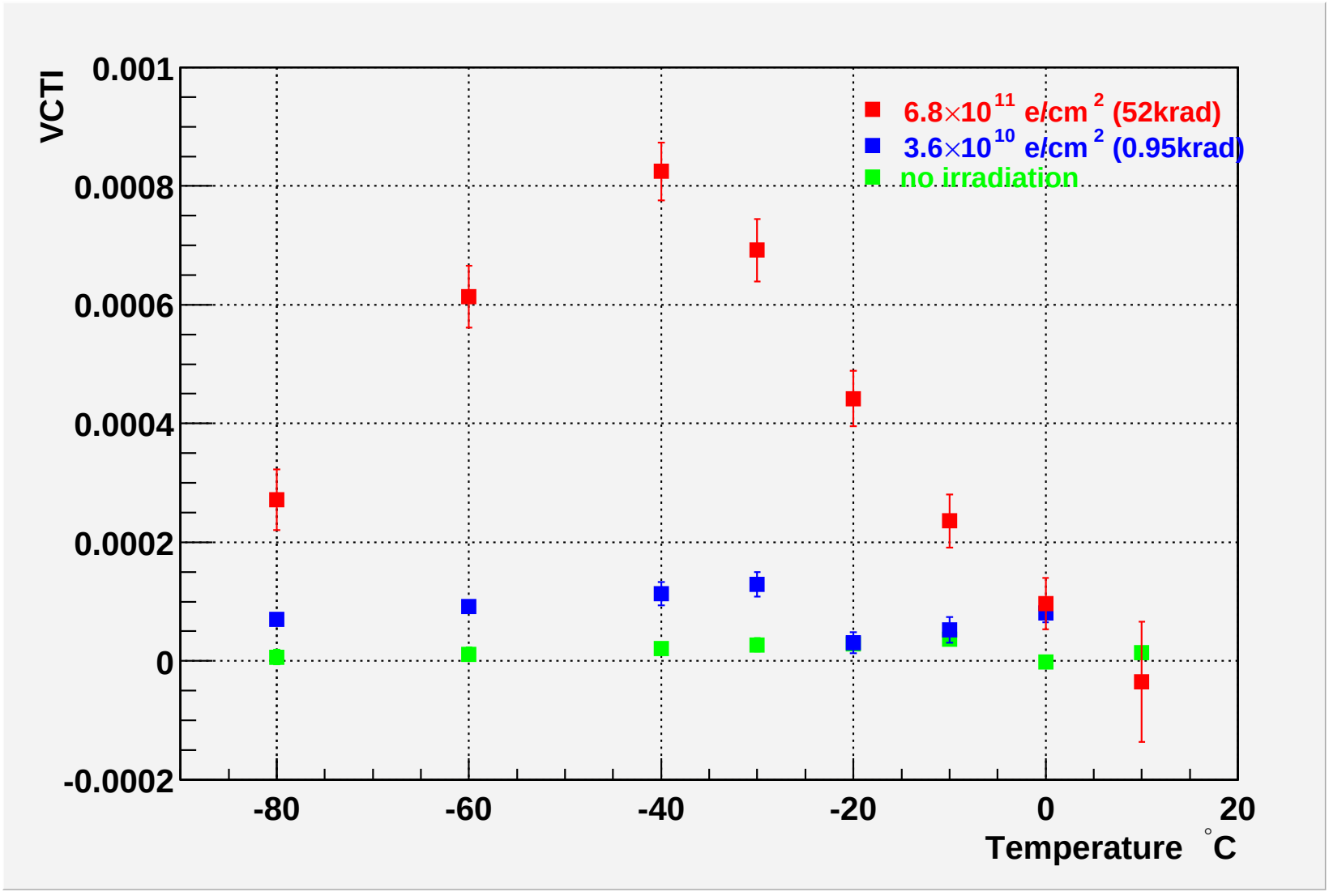
# RESULT II


x10^-1
HCTI
0.002
0.0015
0.001
0.0005
0
-0.0005
-0.001
-0.0015
-0.002
6.8×10^11 e/cm^2 (52krad)
3.6×10^10 e/cm^2 (0.95krad)
no irradiation
-80
-60
-40
-20
0
20
Temperature °C

# RESULT III


x10^-1
VCTI
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
-0
-0.001
-0.002
6.8×10^11 e/cm^2 (52krad)
3.6×10^10 e/cm^2 (0.95krad)
no irradiation
-80
-60
-40
-20
0
20
Temperature °C

# RESULT IV


VCTI
0.001
0.0008
0.0006
0.0004
0.0002
0
-0.0002
-80
-60
-40
-20
0
20
Temperature °C
6.8×10^11 e/cm^2 (52krad)
3.6×10^10 e/cm^2 (0.95krad)
no irradiation

# SUMMARY

**HCTI is very small.**

0°C, VCTI $> 1.0 \times 10^{-3}$:
On the supposition that 1000(H) $\times$ 200(V) pixel model chip, CTE is 0.67 even if worst happens.

| | Method I | Method II |
|---|---|---|
| High energy $e^-$ | $\sim 10^{12} e/\mathrm{cm}^2$ | $\sim 10^{12} e/\mathrm{cm}^2$ |
| Low energy $e^-$ | $\sim 10^{12} e/\mathrm{cm}^2$ | $\sim 10^{12} e/\mathrm{cm}^2$ |

**contains 1 year at JLC beam background.**