



Measurement of Basic Characteristics of Si-pad for ILD ECAL

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On behalf of CALICE collaboration

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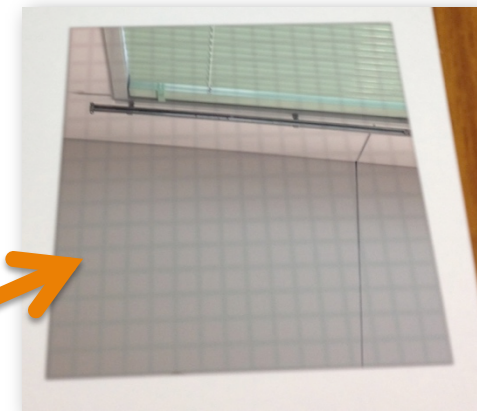
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 - Temperature dependence
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Motivation

- The **Si-pad** (Silicon pixel detector) would be the best for PFA Calorimetry for Linear Collider Experiments.
- We started the Si-pad study.
 - Until now French team has been working.
 - Kyushu University is becoming a new core of the Si-pad study with the strong connection with the French team.
- We are setting up **a test bench** for basic measurements (I-V curve, C-V curve etc.) at Kyushu University.
- The system set up is very important to exam many Si-pad samples uniformly by the same way in future.

Here we show the measured results of a **5mm x 5mm pixel Si-pad** sample with the system.

This is it!





Si-pad & measurement box

reverse side (electrodes)

Si-pad

16x16 pixels

1 pixel size: 5mm x 5mm

Total area: 9cm x 9cm

(Serial number: D4)

Measurement BOX

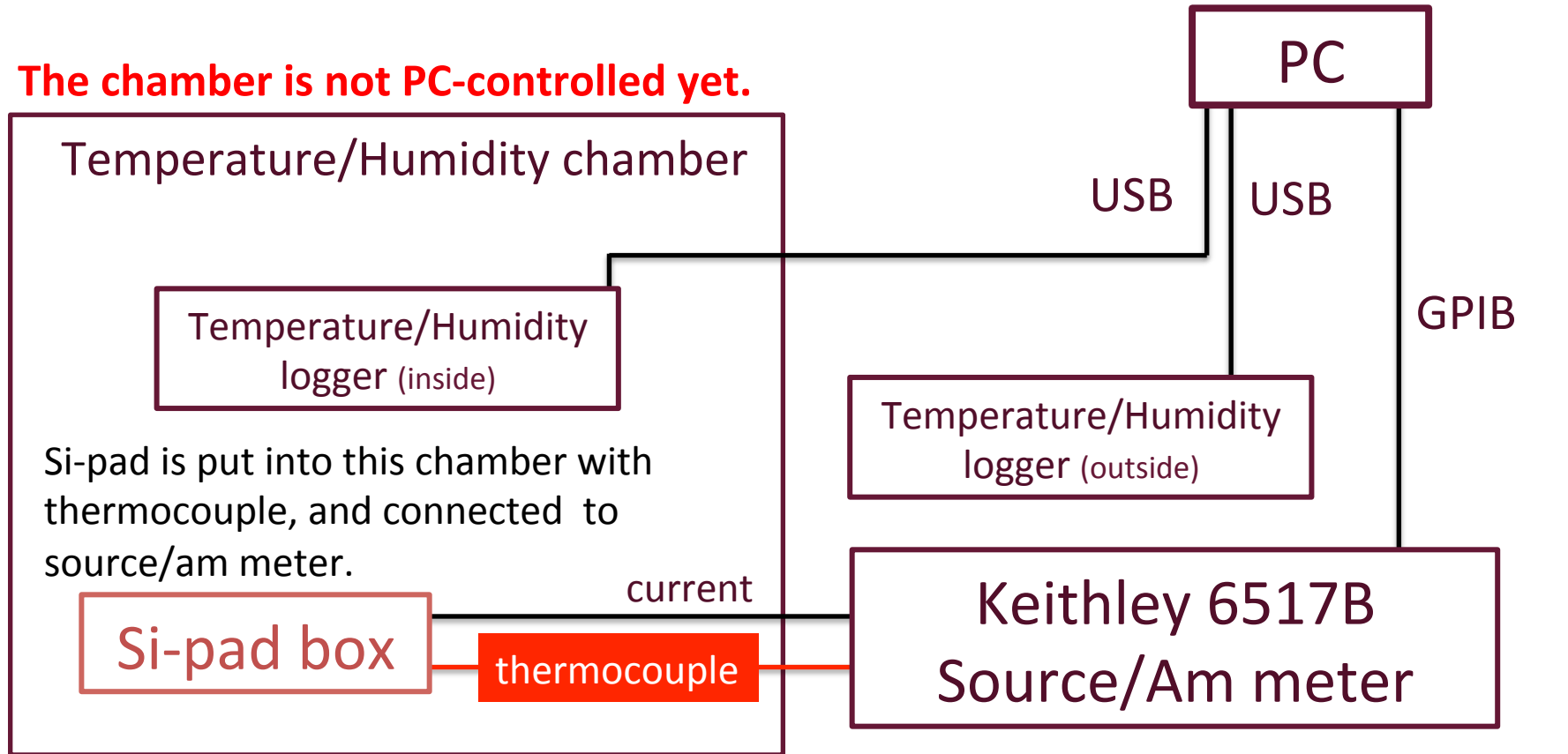
All-pixel currents are ganged
by a copper plate.

Si-pad

Copper plate

I-V measurement setup

The chamber is not PC-controlled yet.



A thermocouple is installed into the box to directly monitor the temperature of Si-pad.

Automatically controlled by LabView

Temperature/Humidity loggers are put into and outside the chamber.

Setup View

Temperature/Humidity chamber

LabView on PC

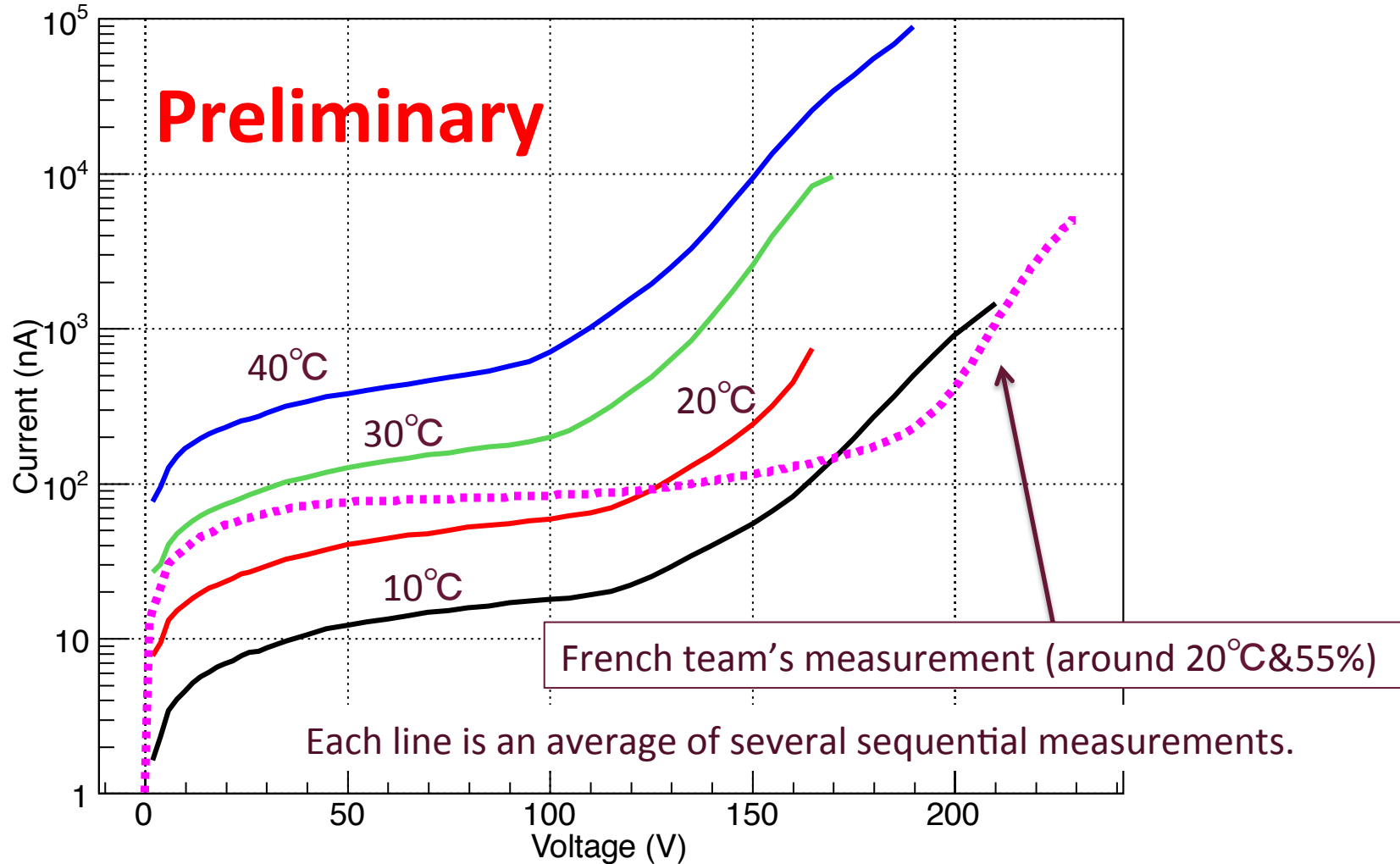
Si-pad box

Temperature/Humidity logger
(inside & outside)

keithley 6517B Source/Am meter

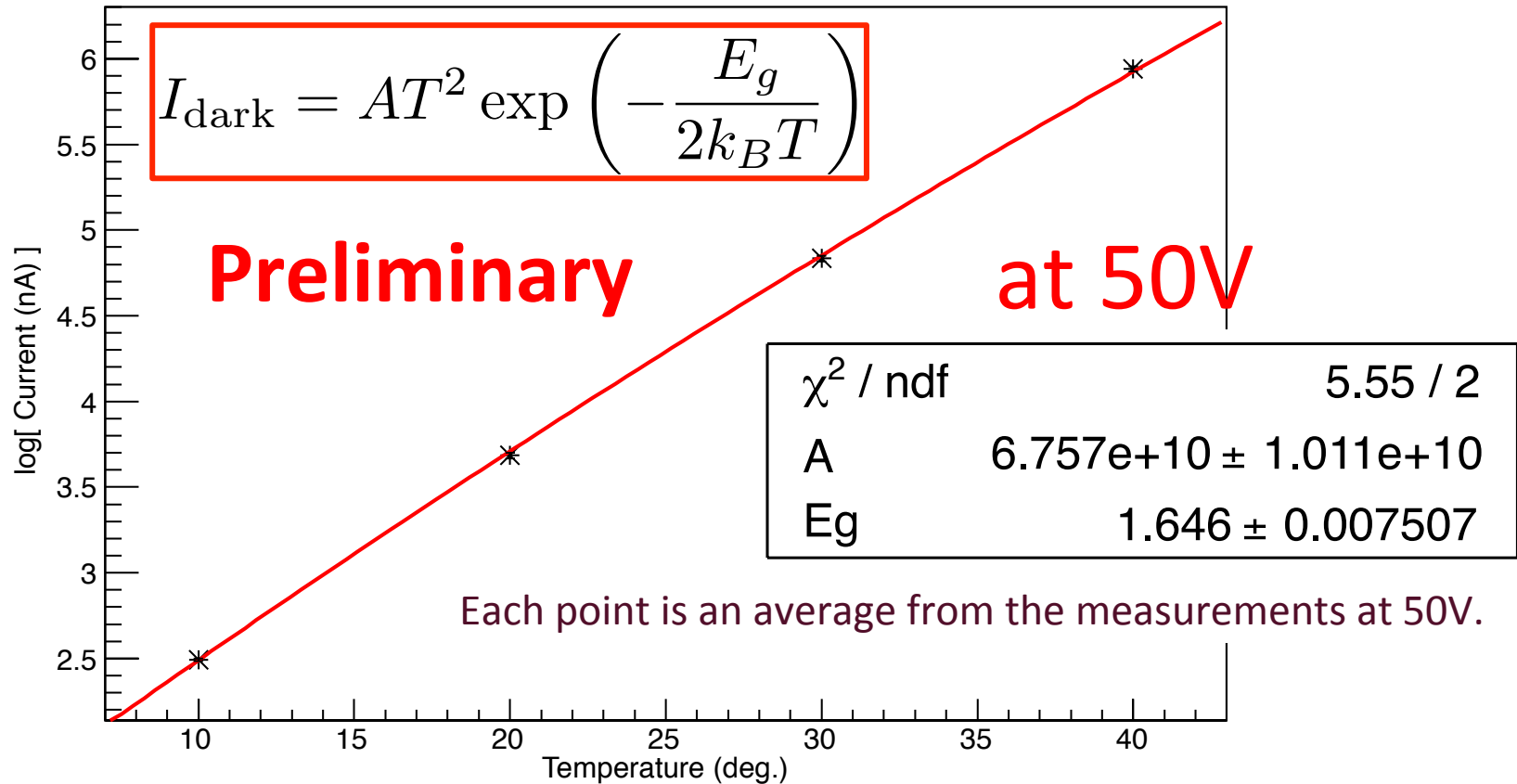
Temperature dependence

Dark current (40%)



The breakdown voltages are smaller than that of French team's measurement, which is around 180V. The flatness is also different.

Temperature dependence

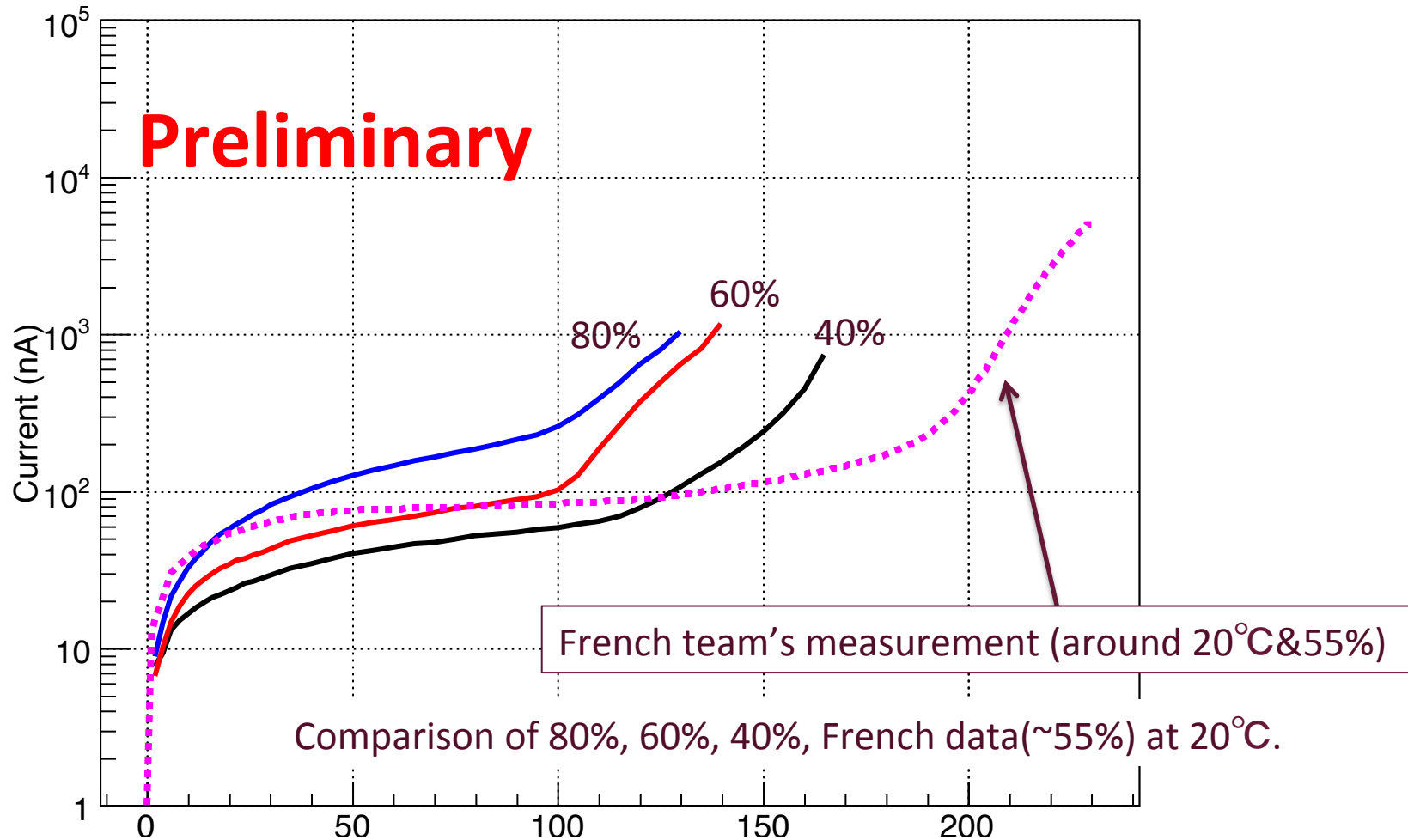


Result of fitting the function to the data

- Can confirm that the measurement system works well.
- The measured Band-gap, E_g , is larger than Si's 1.21 eV (recommended value from ATLAS collaboration). This is under investigation.

Humidity dependence

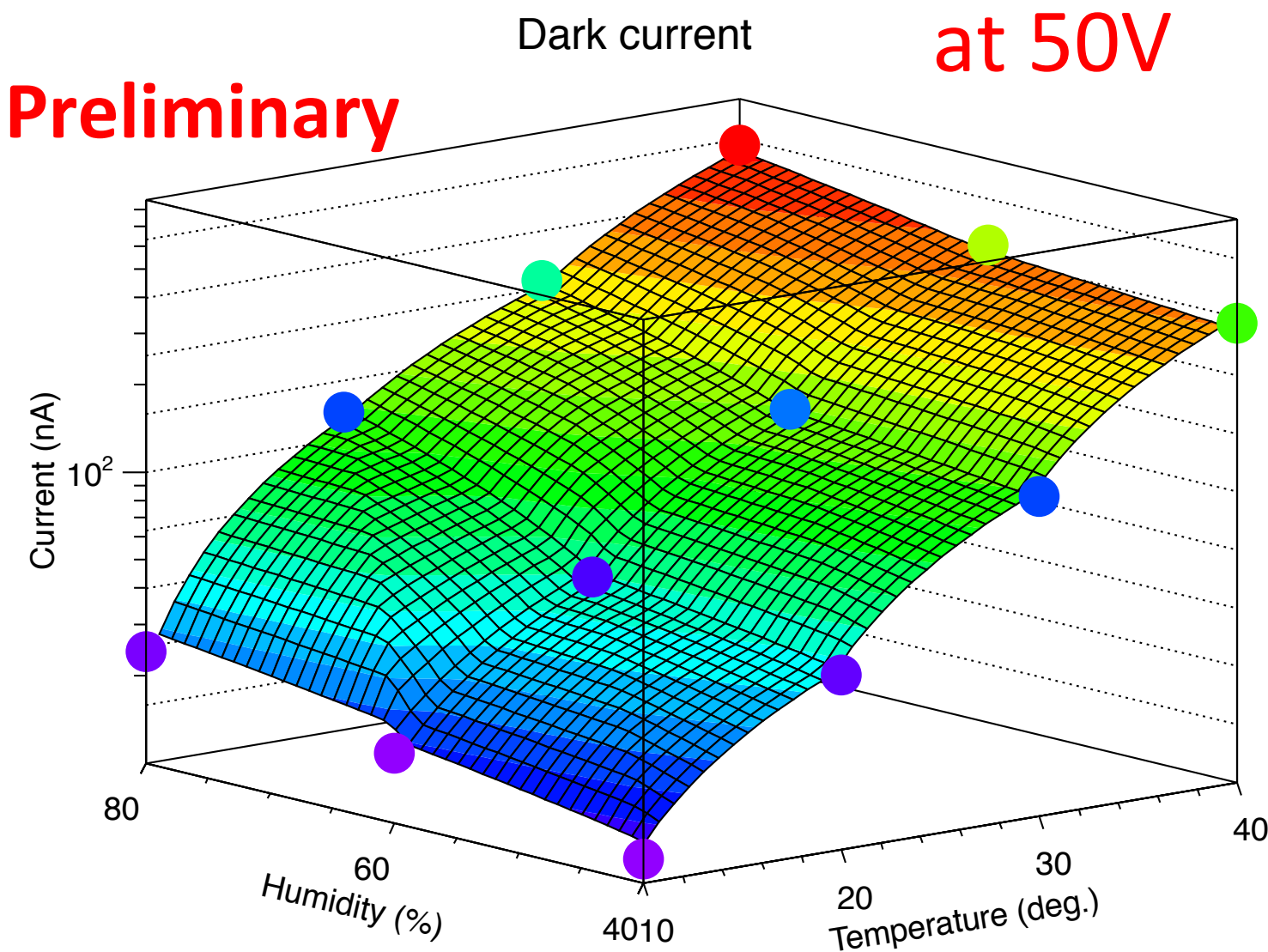
Dark current (20deg.)



A change obviously occurs, the origin is under investigation.



Summary of dependences

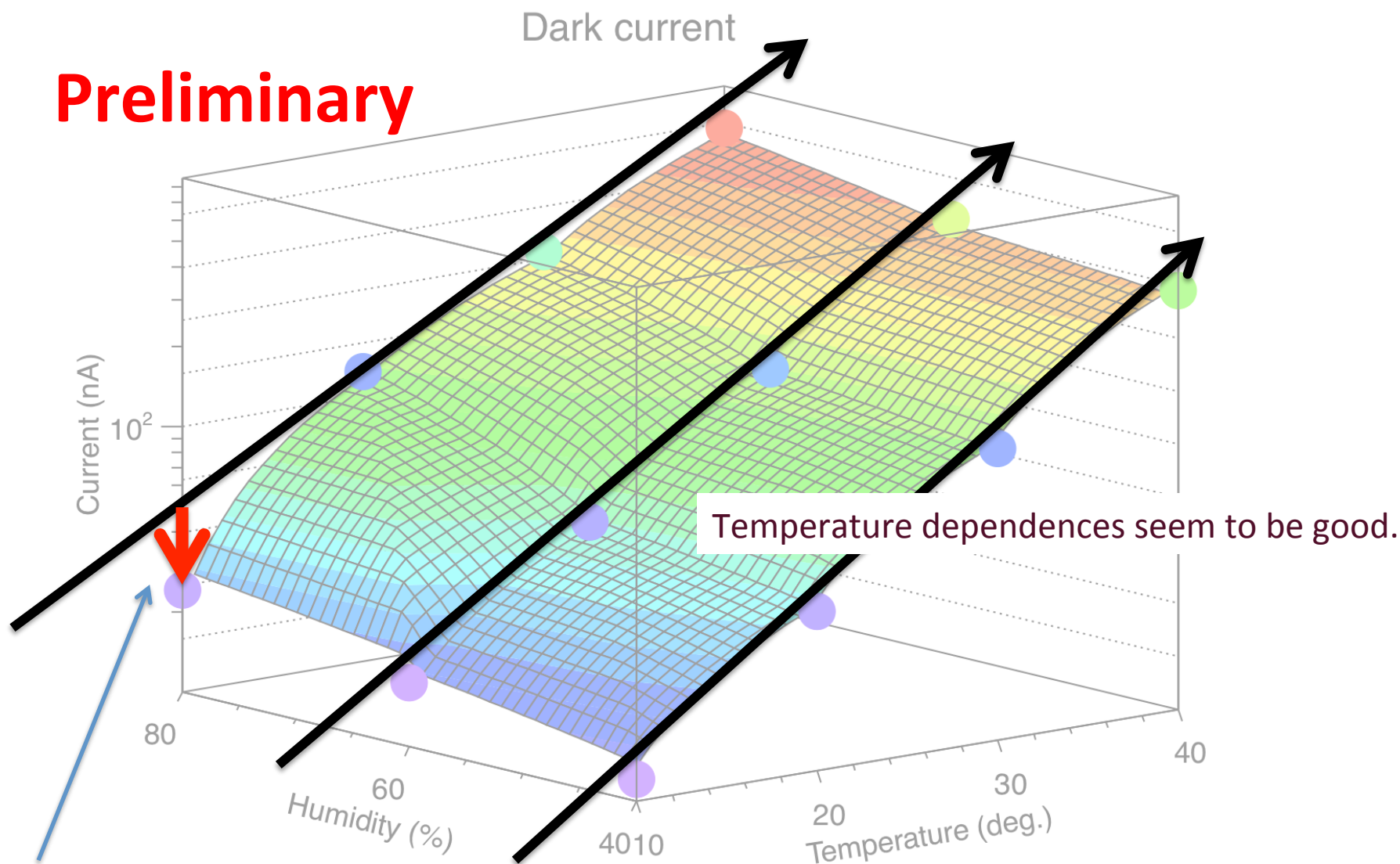


Each point is an average value of several sequential measurements at 50V.



Summary of dependences

Preliminary



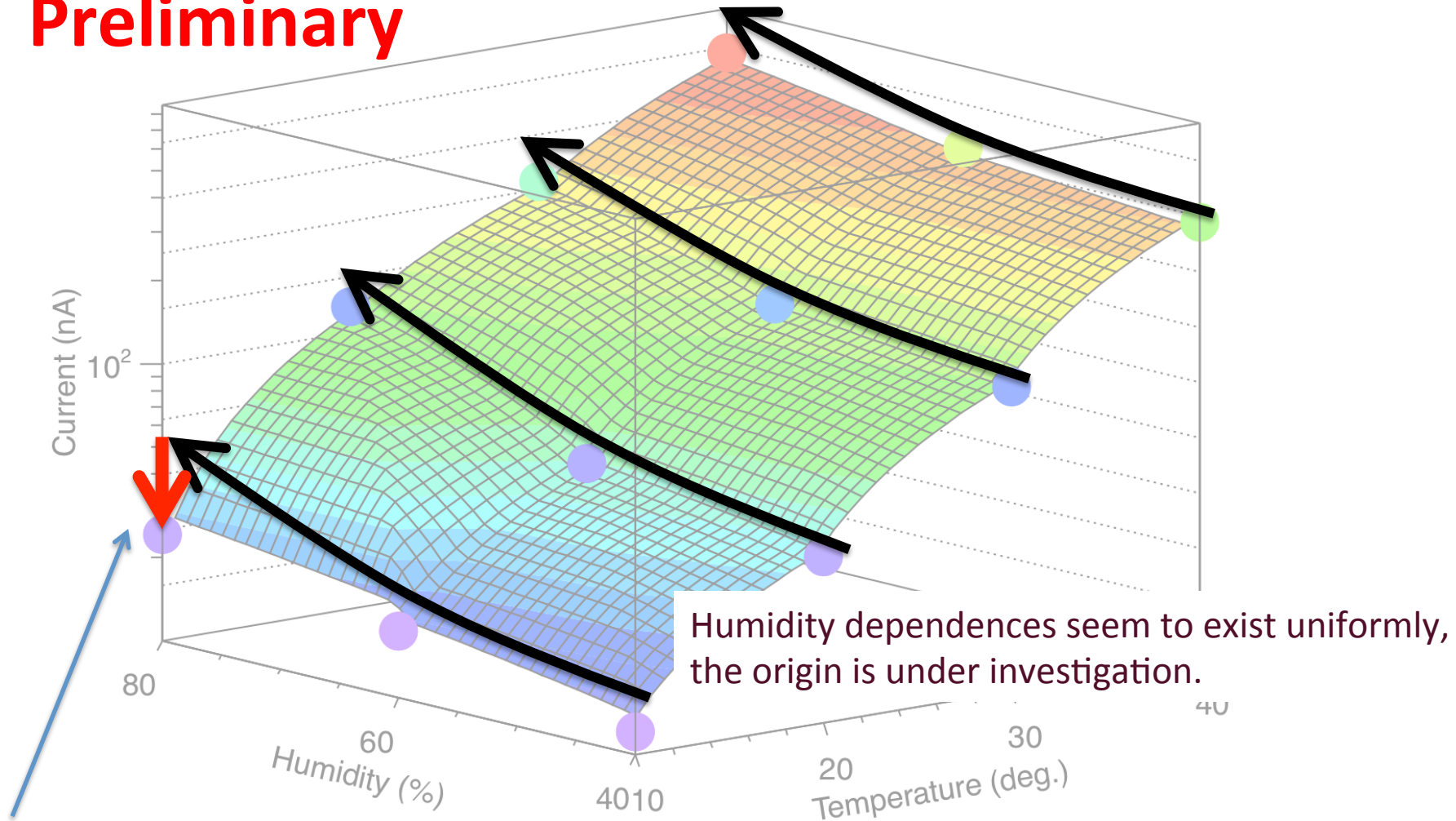
At this condition current is not consistent with extrapolation.



Summary of dependences

Preliminary

Dark current



At this condition current is not consistent with extrapolation.

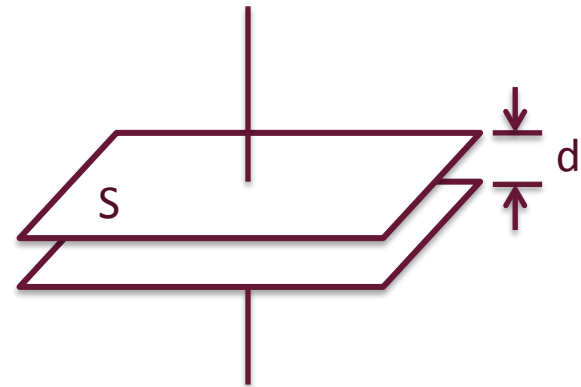
Capacitance Measurement

- We have measured an entire capacitance of 5mm x 5mm pixel Si-pad.
- When a Si-pad is fully depleted, the layer size hopefully should be identical to thickness of the Si-pad, $d \sim 350\mu\text{m}$ (measured for 5mm x 5mm samples).
 - Then Si-pad's entire capacitance reduces to

$$C = \frac{\epsilon_{\text{si}} S}{d} = 2.4 \text{ nF}$$

$$S = 9\text{cm} \times 9\text{cm}$$

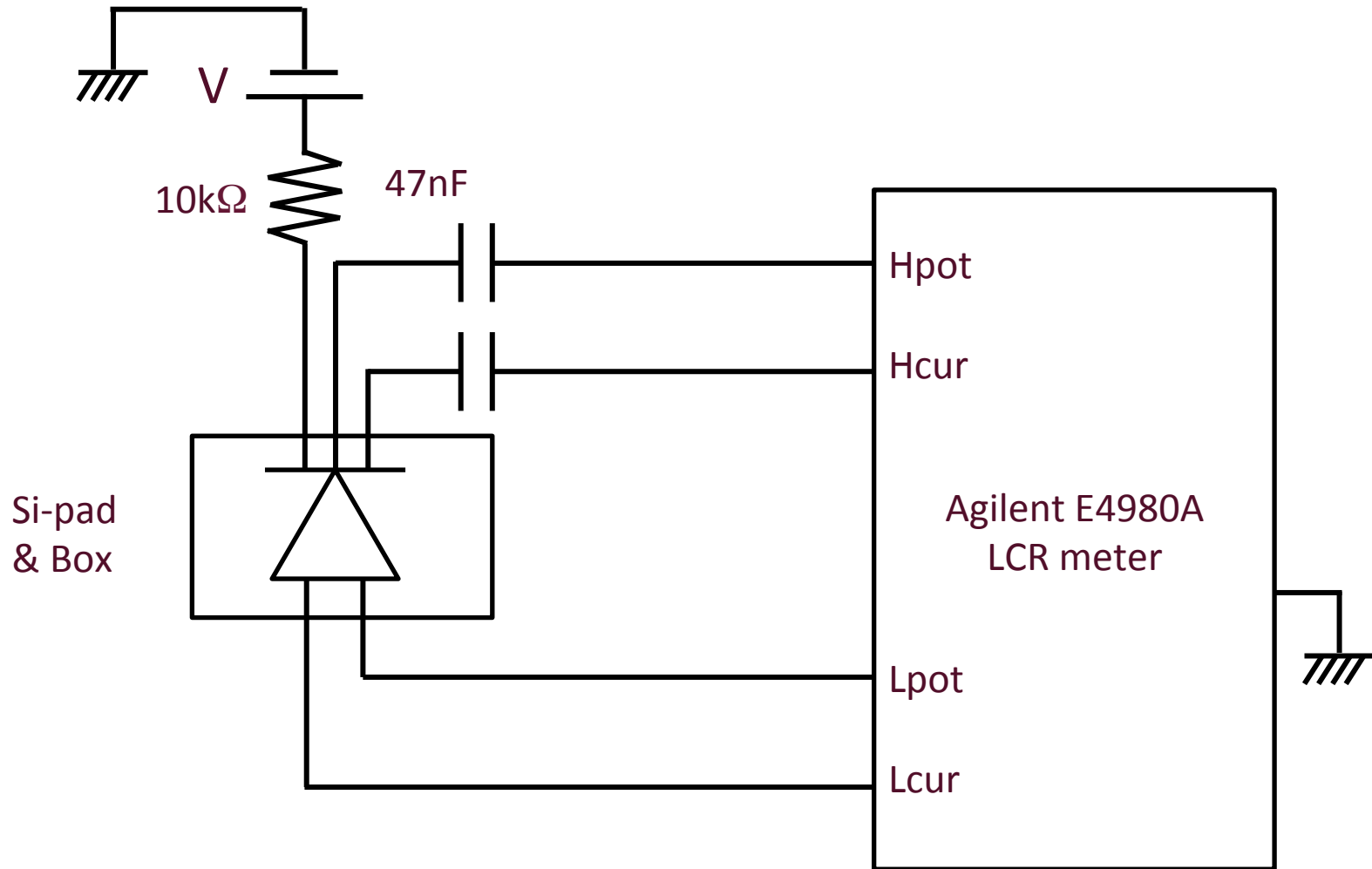
$$\epsilon_{\text{si}} = 1.03 \times 10^{-10}$$





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Capacitance Measurement

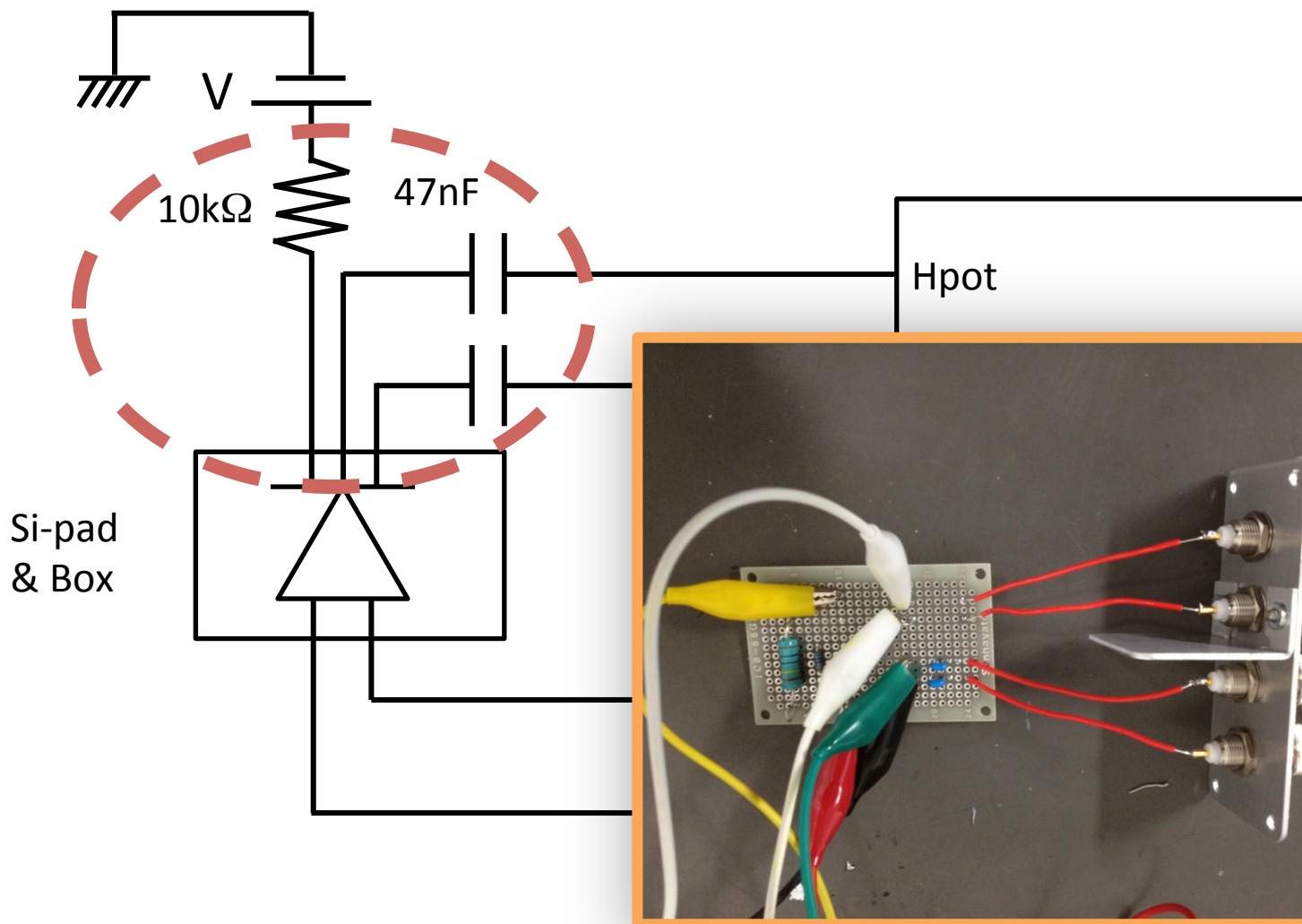


Measurements are done manually. (changing the voltages & the frequencies and monitoring)



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Capacitance Measurement

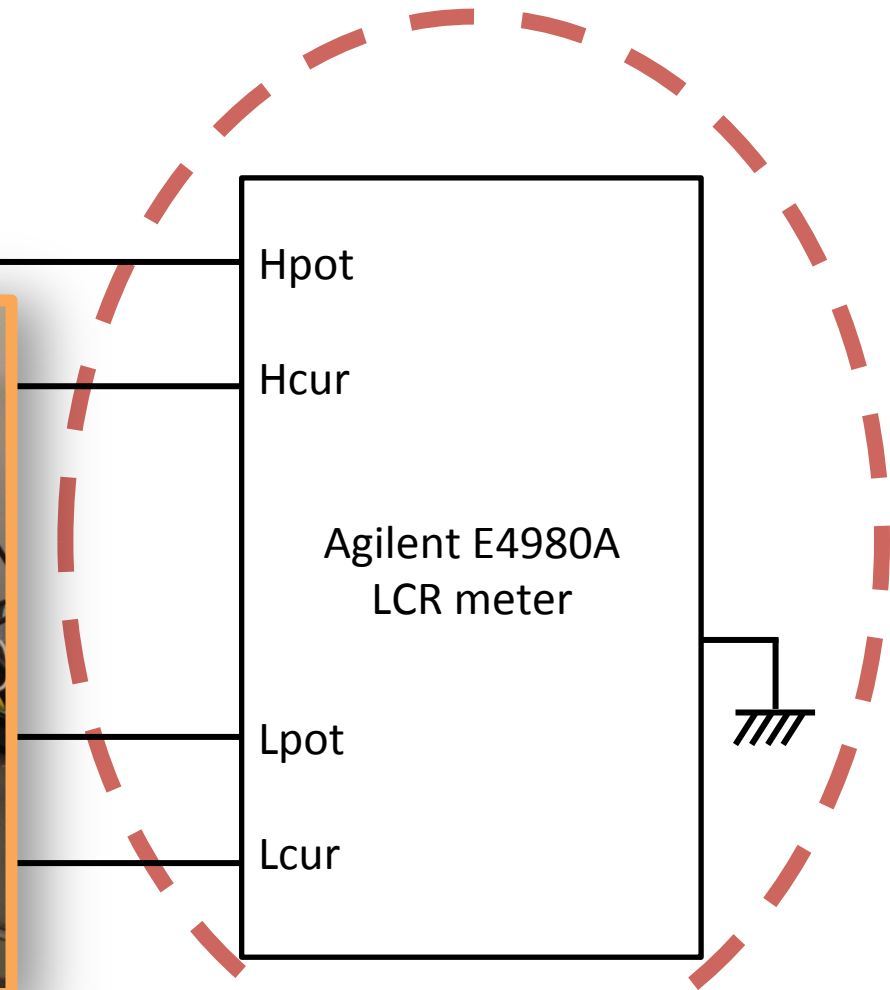
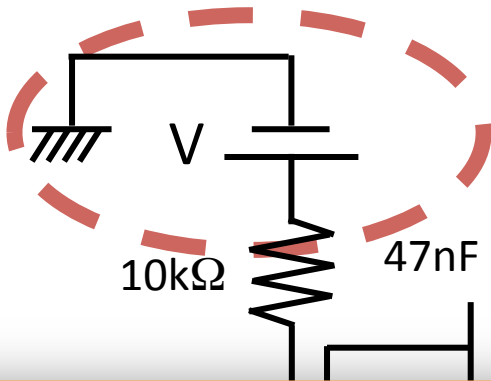


Measurements are done manually. (changing the voltages & the frequencies and monitoring)



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Capacitance Measurement



Measurements are done manually. (changing the voltages & the frequencies and monitoring)



Measurement of Impedance

Assume Si-pad's impedance is ,

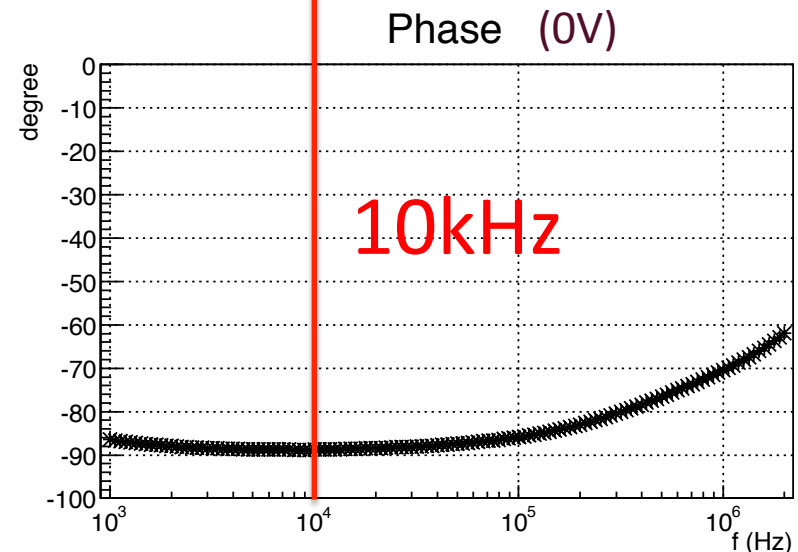
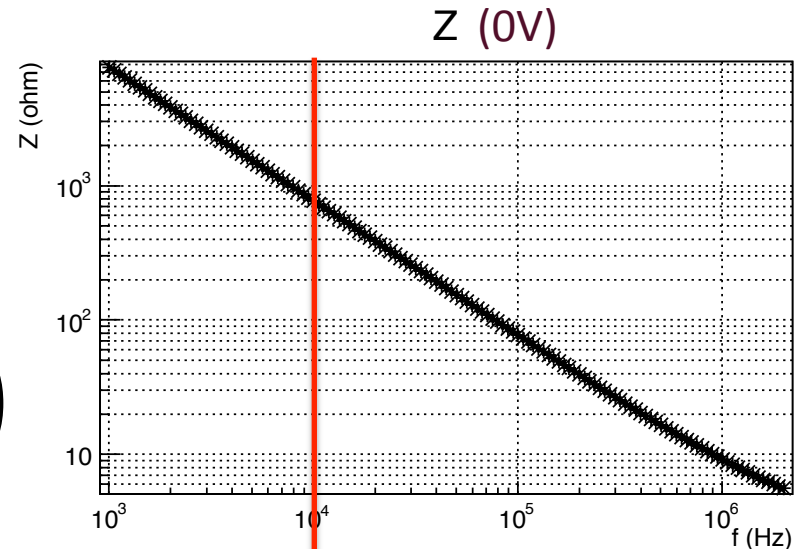
$$Z = |Z|e^{i\theta} = R - i\frac{1}{\omega C}$$

(Serial connection of R & C components)

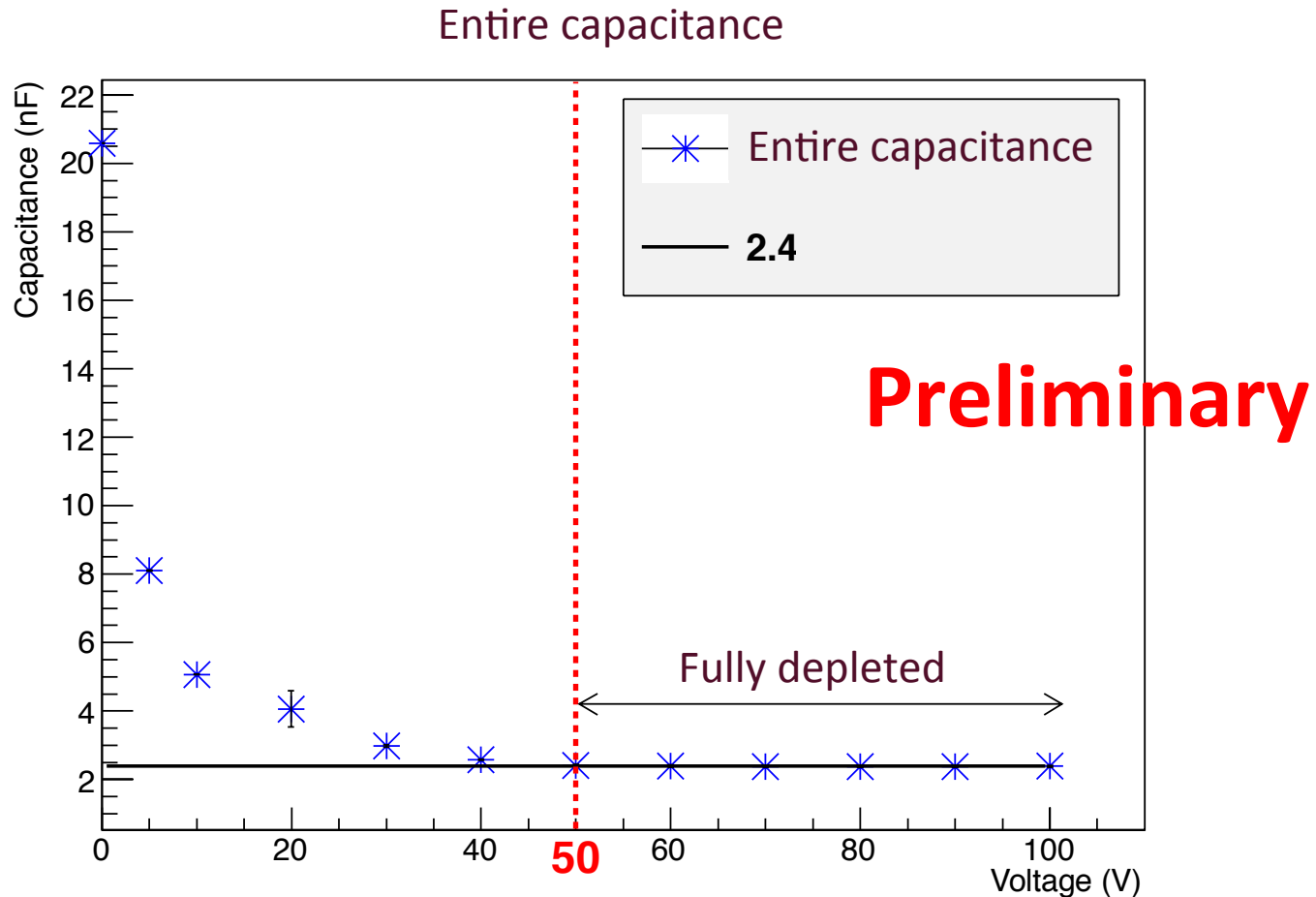
$$|Z| = \sqrt{R^2 + \left(\frac{1}{\omega C}\right)^2} \quad \theta = \tan^{-1} \left(\frac{-1}{\omega RC} \right)$$

The impedance Z and its phase degree are consistent with the assumption.

This time we measured the capacitance at 10kHz.



Capacitance Measurement



From this result, a full depletion is thought to occur around 50V.
And the capacitance is equal to the calculated value, 2.4 nF.

Summary

- Construction of the automatic measurement system is important.
 - We are constructing.
 - I-V curve measurement system: constructed.
 - C-V curve measurement system: now being constructed.
- We measured 5mm x 5mm pixel Si-pad's basic characteristics.
 - I-V curve
 - Temperature dependence
 - **GOOD** (the band-gap, E_g , is larger than expected value 1.21eV.)
 - Humidity dependence
 - seems to exist? (still under investigation..)
 - C-V curve
 - Entire Capacitance
 - It has been confirmed that **a full depletion of Si-pads occurred around 50V.**

Prospects (to do)

- I-V curve
 - ✓ Investigation of each dependences
- Capacitance
 - ✓ 1pixel capacitance measurements
- System upgrade
 - ✓ Connection between the chamber and PC
 - ✓ Automatic C-V measurement system
- Radiation hardness study
 - ✓ using γ -ray from ^{60}Co source and p-beam at Kyushu U.
- Laser system set up
- Efficiency study using cosmic ray

Acknowledges

- The French team!!
- My Bosses!!
- Lab mates!!



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Dinner ☺ @ Paris

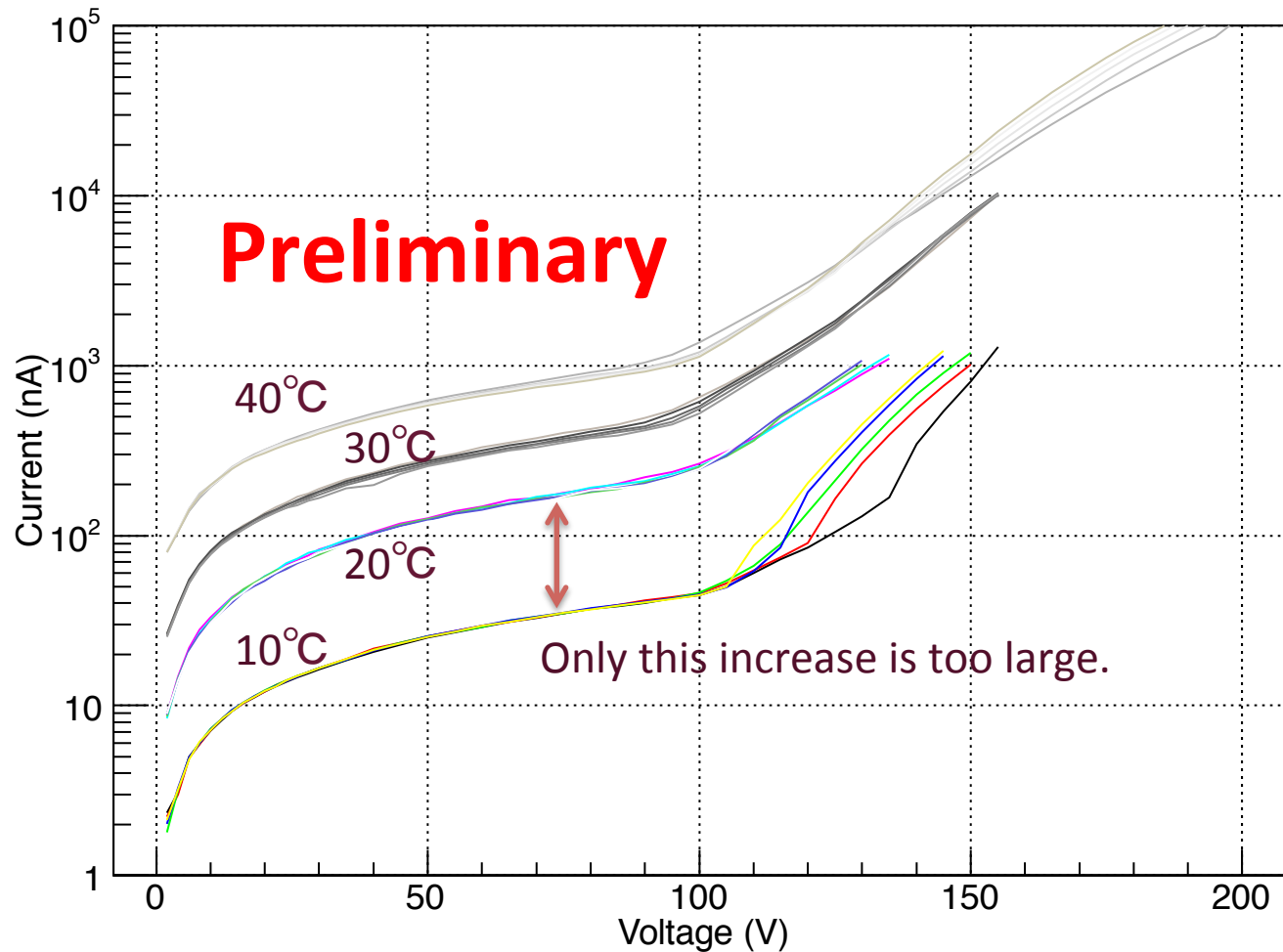


Lunch ☺ @ Daegu

Backups

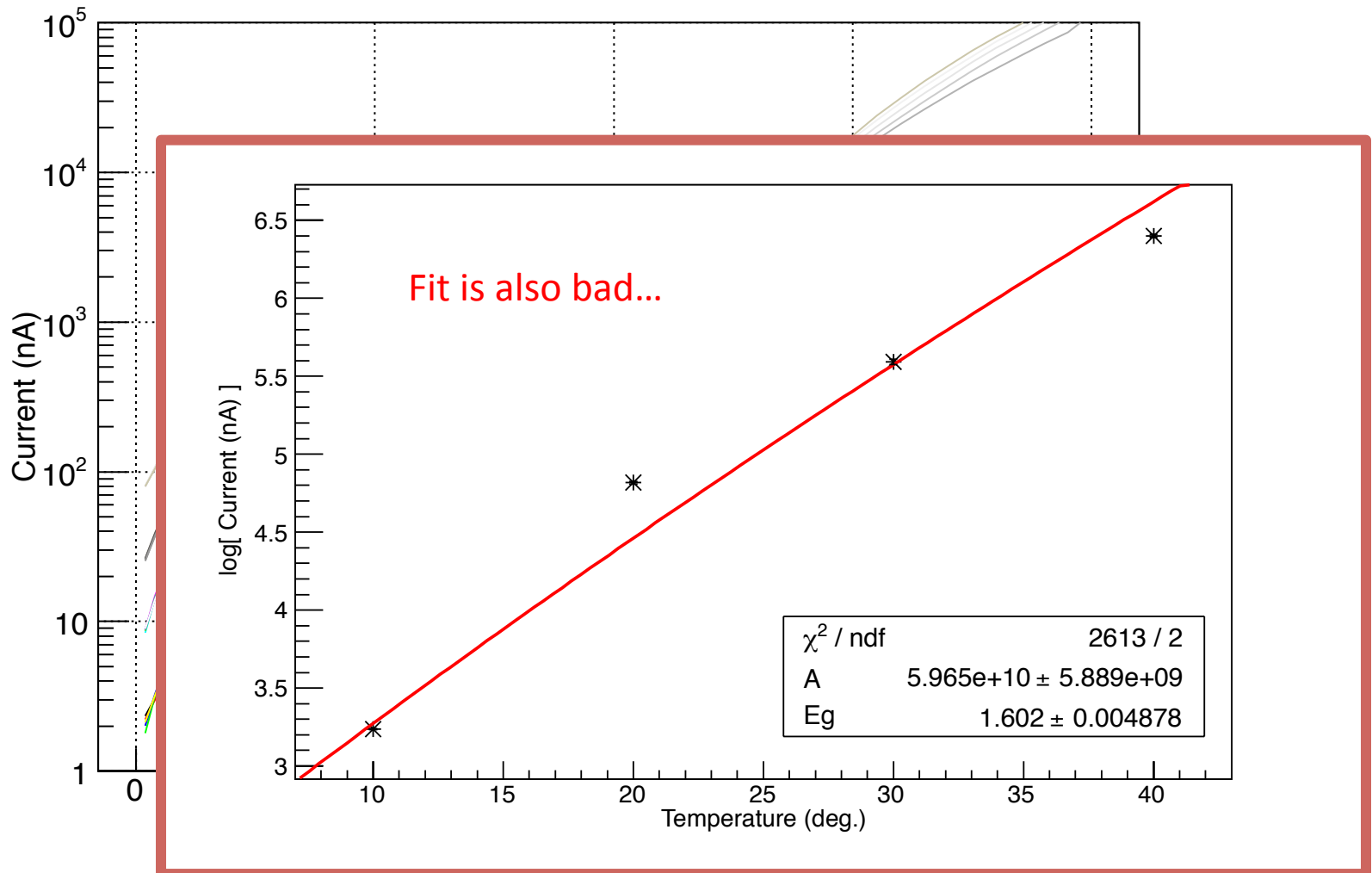
Temperature dependence at 80%

Dark current of D4 (80%)



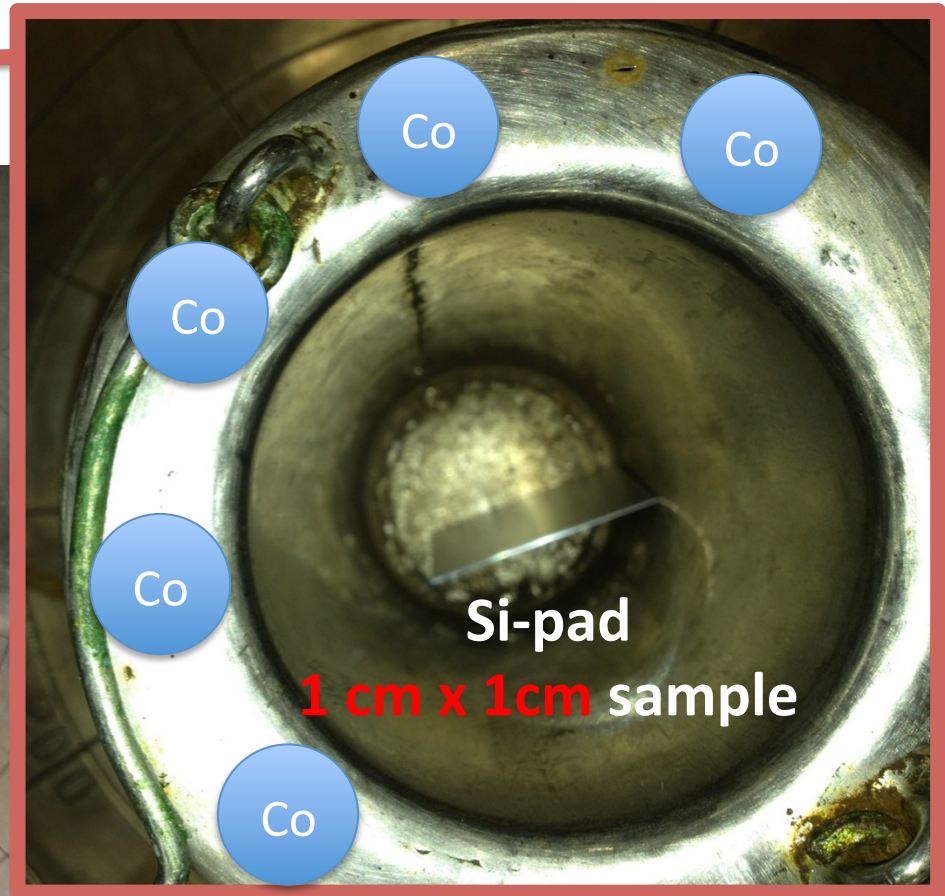
Temperature dependence at 80%

Dark current of D4 (80%)



The origin of these changes is under investigation.

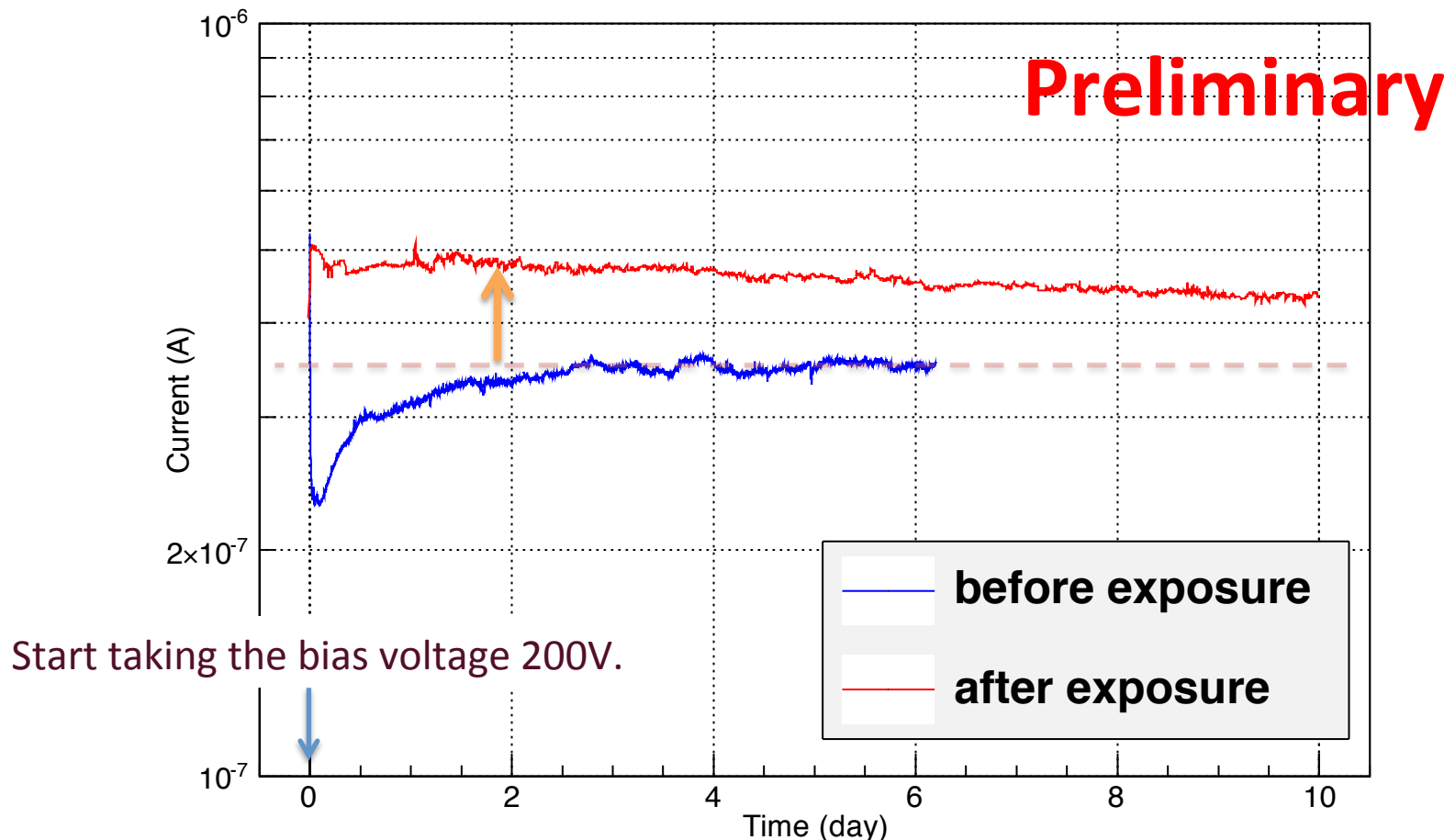
Study of radiation hardness



Exposed Si-pad to 100Gy γ -ray radiation from ^{60}Co (1.17, 1.33MeV)

Result

Dark current of T323 (200V, 20deg)



- 100Gy corresponds to more than ~million years for ILC operation.
- The effect is small ($\sim \times 1.5$). -> GOOD hardness?
- But the effect to the signals should be investigated.