

# The irradiation test of monitor photodiodes at Riken-RANS

4th of July, 2022.

Motoi INABA



# Pretests

The 1st pretest: 12th of January, 2022.

The noise-level test of I-V characteristic in the experiment hall.

➡ No signal because of a large noise with a low-frequency.



The 2nd pretest: 1st of February, 2022.

All signal cables were replaced to the triaxial cables.

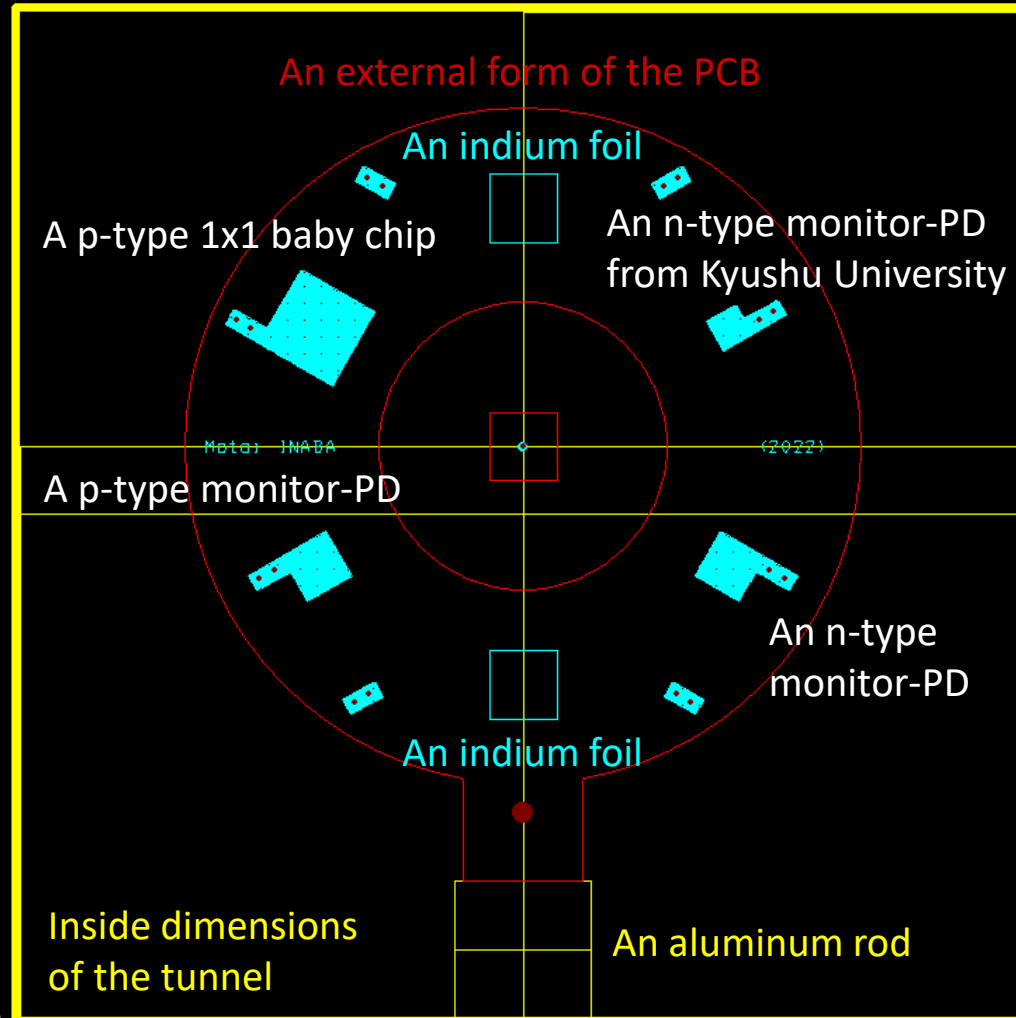
A special black box using a black Delrin.

The I-V measurement (0-to-1000 V).

The C-V measurement (0-to-40 V). --- A new C-meter had arrived.

The beam brought an increase of a leakage current of the sensor.

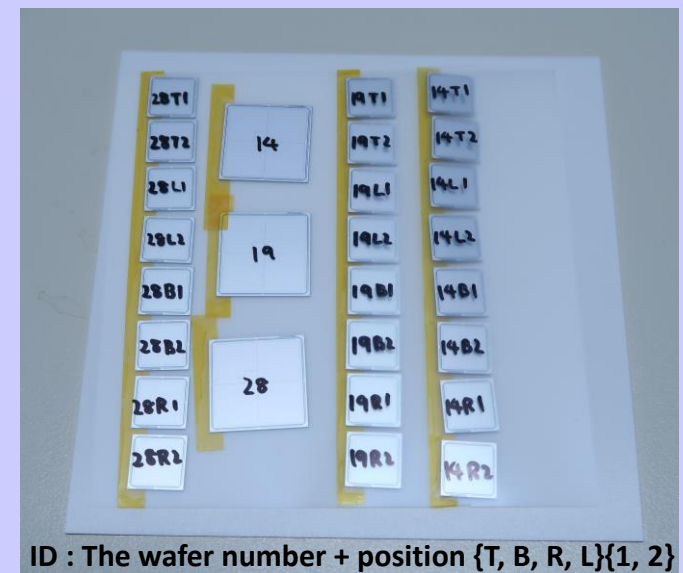
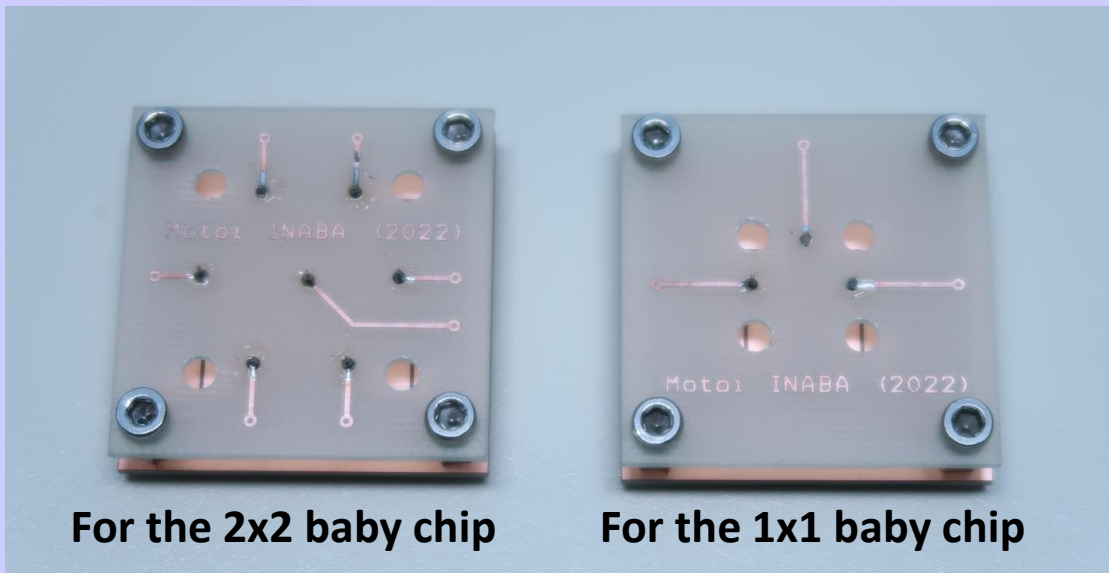
# The PCB prototype for pretests



# Preparation

New PCBs for pretests in a thermostat chamber: 2nd of January.

I made some PCBs boards with probe pins and sent them with new p-type baby chips to Nara women's university for pretests.



The aim of this pretest was to find better p-type baby chips for the irradiation test at Riken-RANS since some chips showed a breakdown below the maximum operation voltage (1000 V).

➡ We selected four 1x1 and three 2x2 baby chips from samples.

# The main test

**Date:** 3rd and 4th of March, 2022.

(敬称略)

**Members:** Yuji Goto, Tatsuya Chujo, Shima Shimizu, Itaru Nakagawa, Ralf Seidl, Park Hanseo (Student), Yuuki Asatani (Student), Koki Sato (UG student) and Motoi Inaba.

**Staffs for Riken-RANS:** Thank you very much !

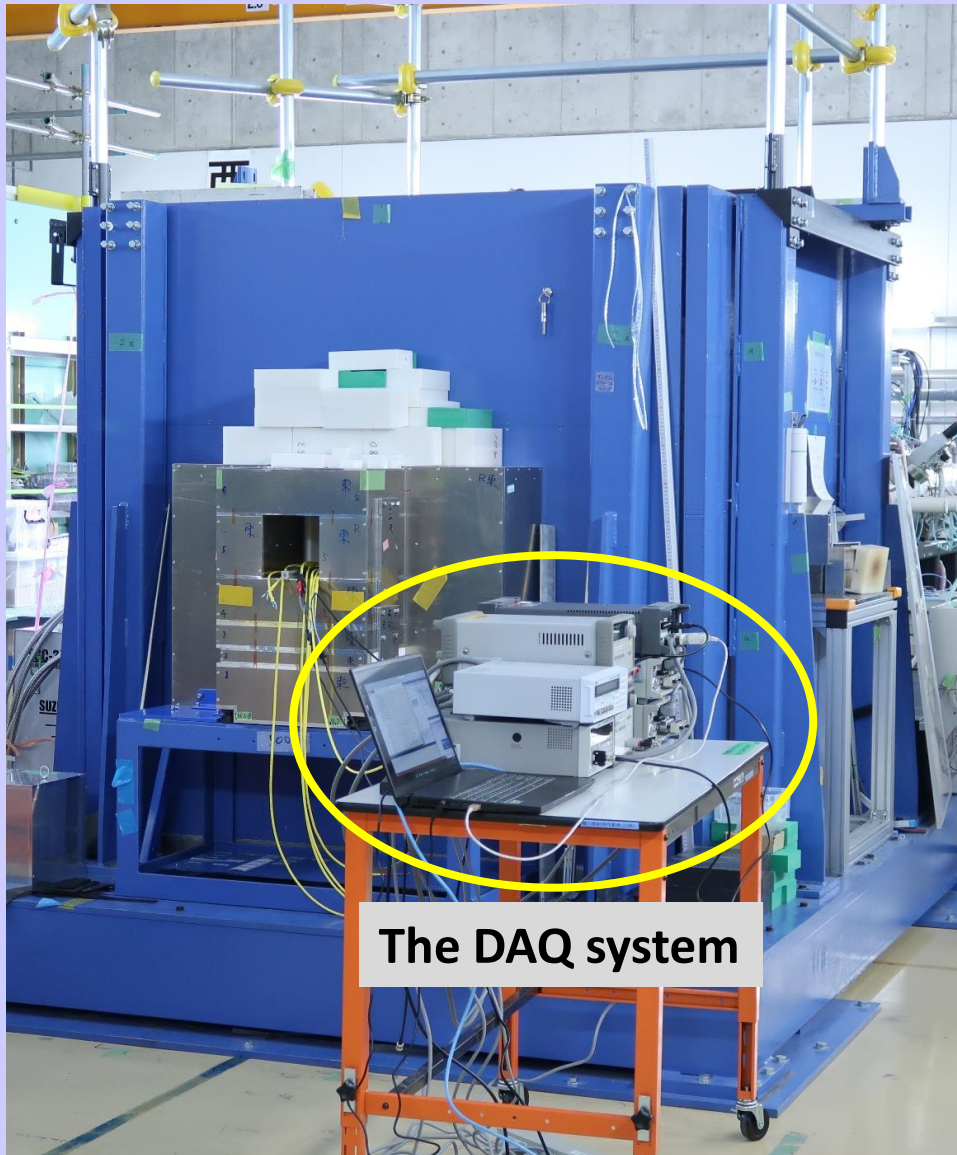
Atsushi Taketani, Makoto Goto and Yasuo Wakabayashi. (敬称略)

**Measured samples:**

[Online] The p-type 1x1 baby chip with G.R., p-type monitor PD, n-type monitor PD and n-type monitor PD from Kyushu Univ.

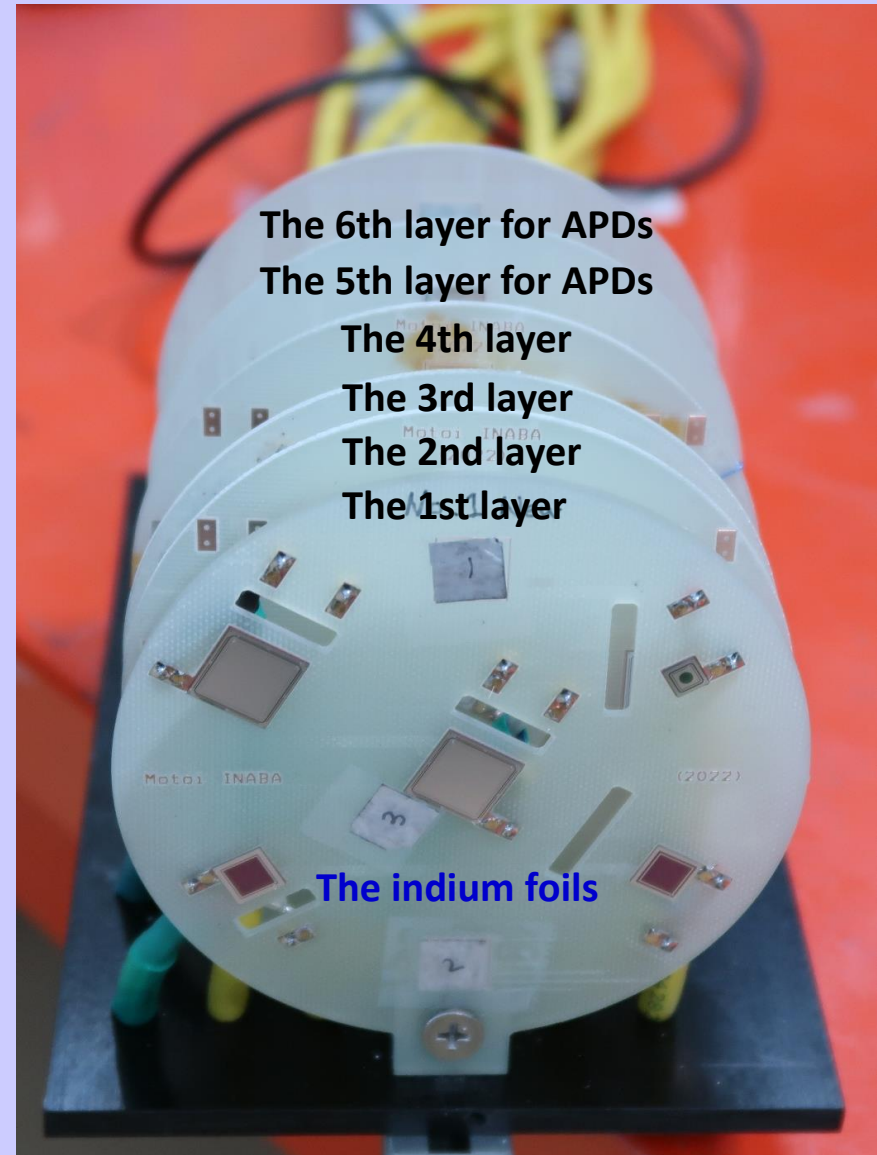
[Offline] The p-type 2x2 baby chip with a calibration cell and G.R. (APDs and a microcable)

# Photos



The DAQ system

The Riken-RANS equipment

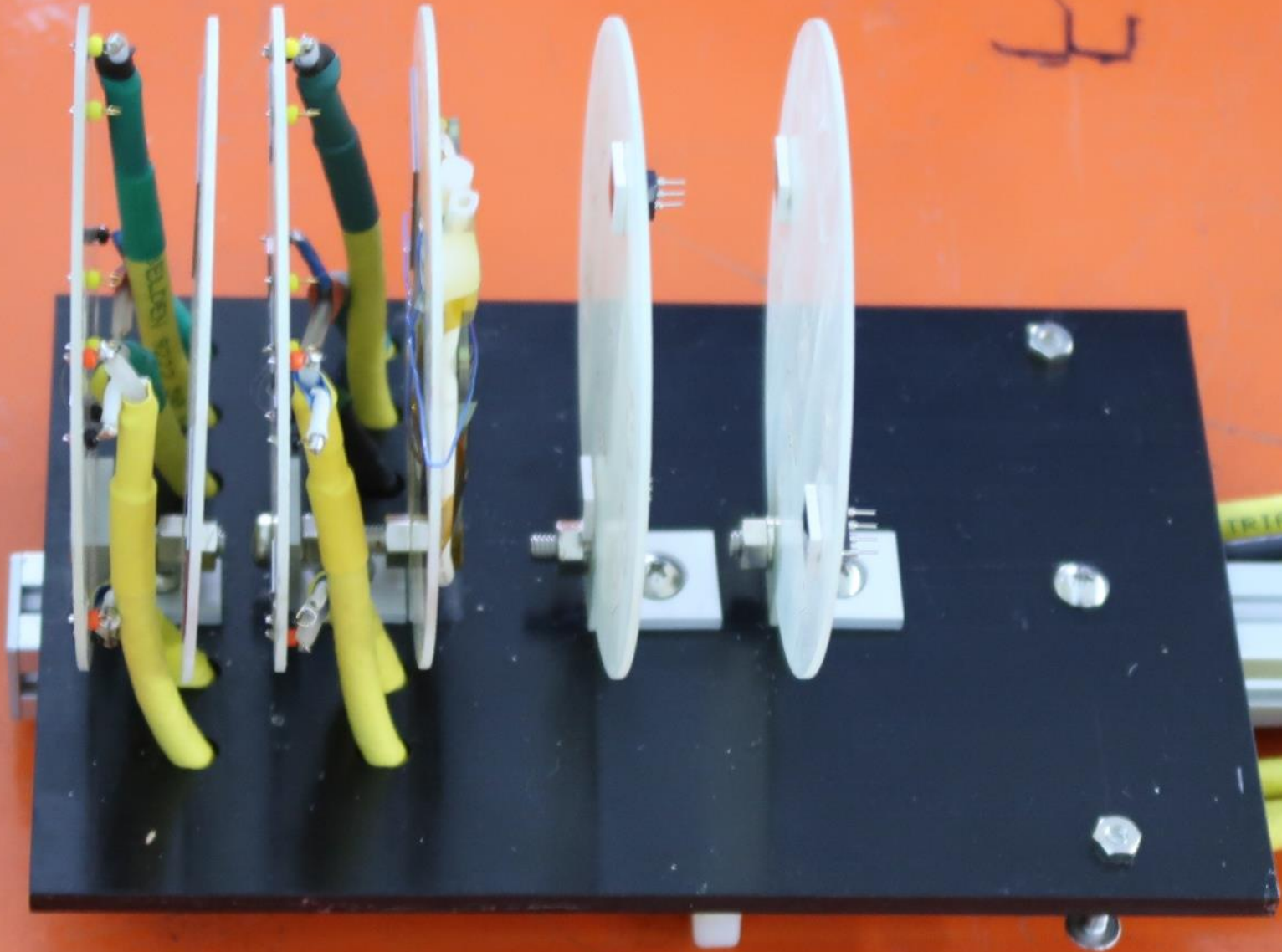


The 6th layer for APDs  
The 5th layer for APDs  
The 4th layer  
The 3rd layer  
The 2nd layer  
The 1st layer

The indium foils

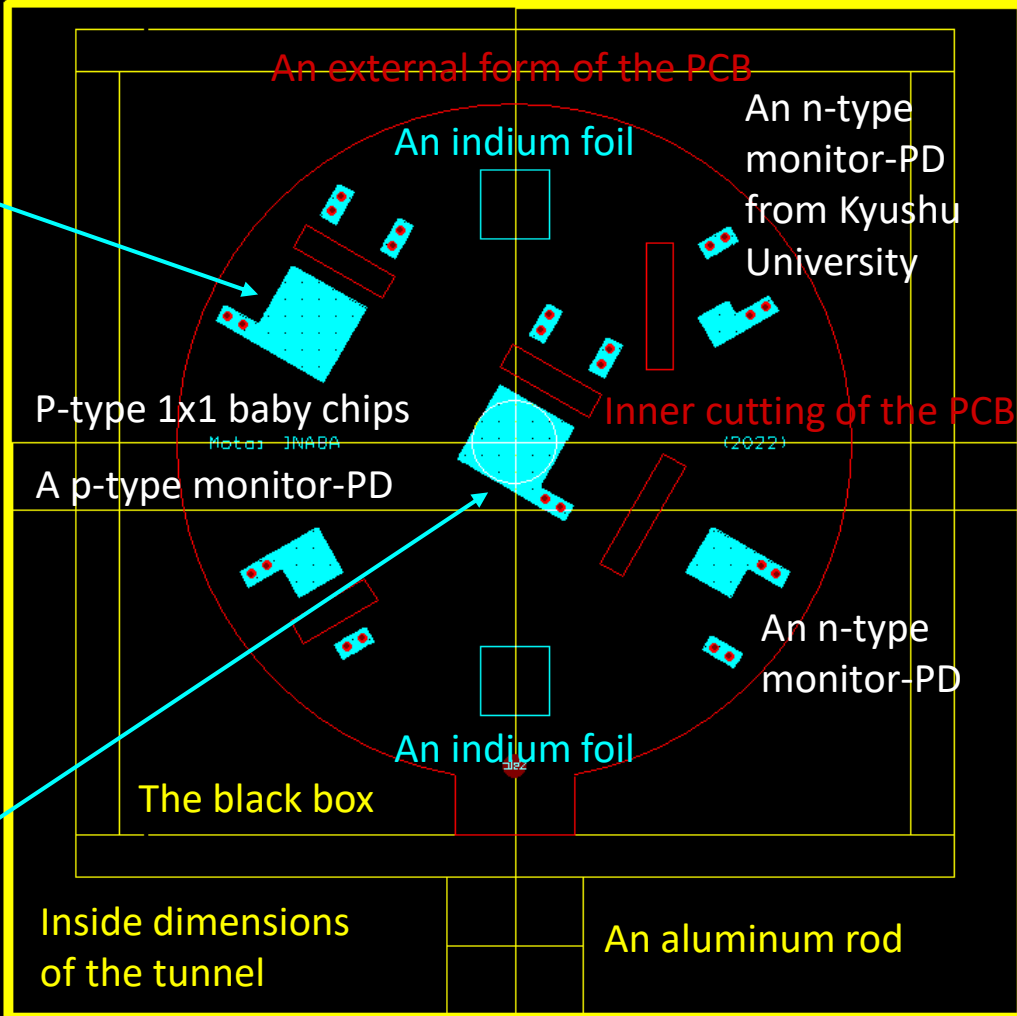
PCBs with the sensors

# Layers



# New PCBs for the main test (1st & 3rd layers)

The sensor ID.  
1st: 14T1  
3rd: 19R1

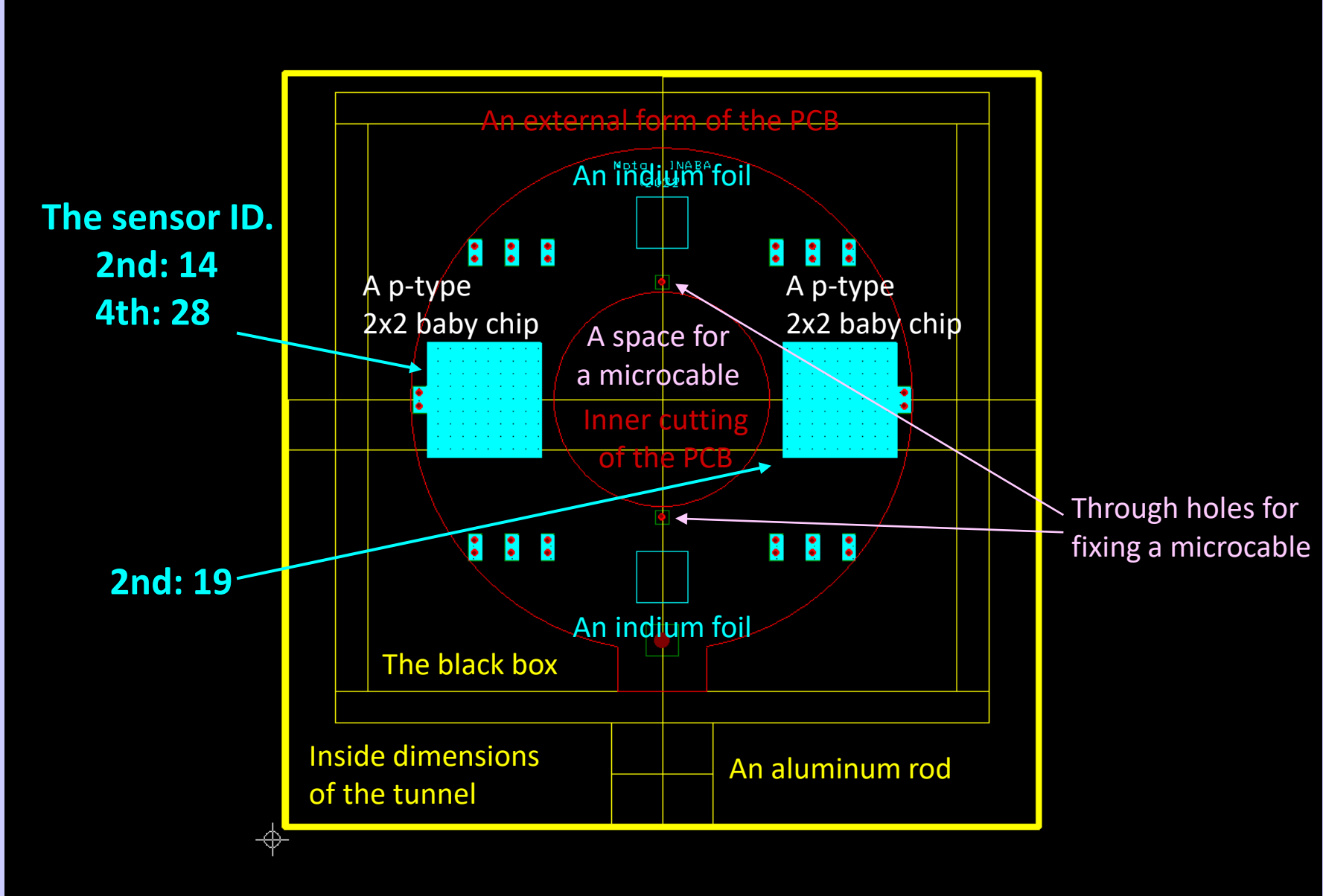


1st: 19B1  
3rd: 28T1

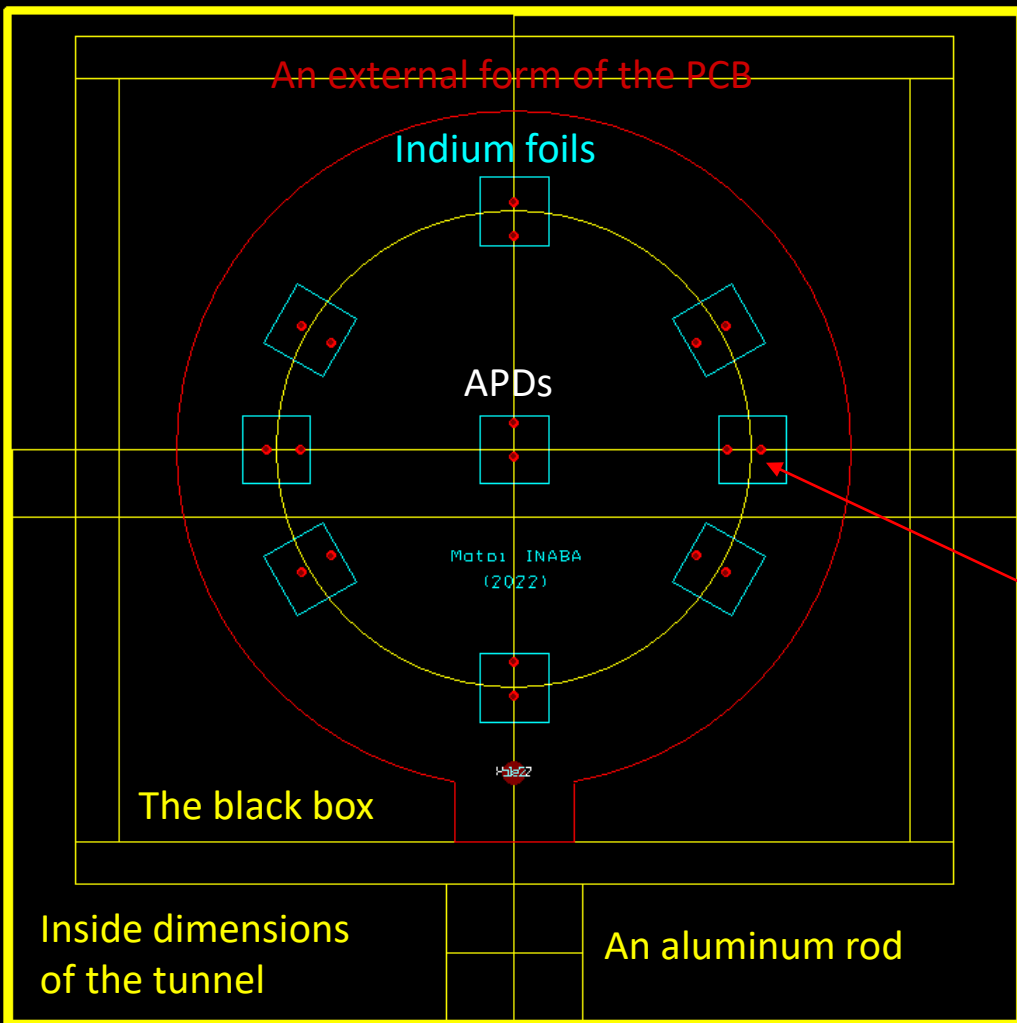




# New PCBs for the main test (2nd & 4th layers)



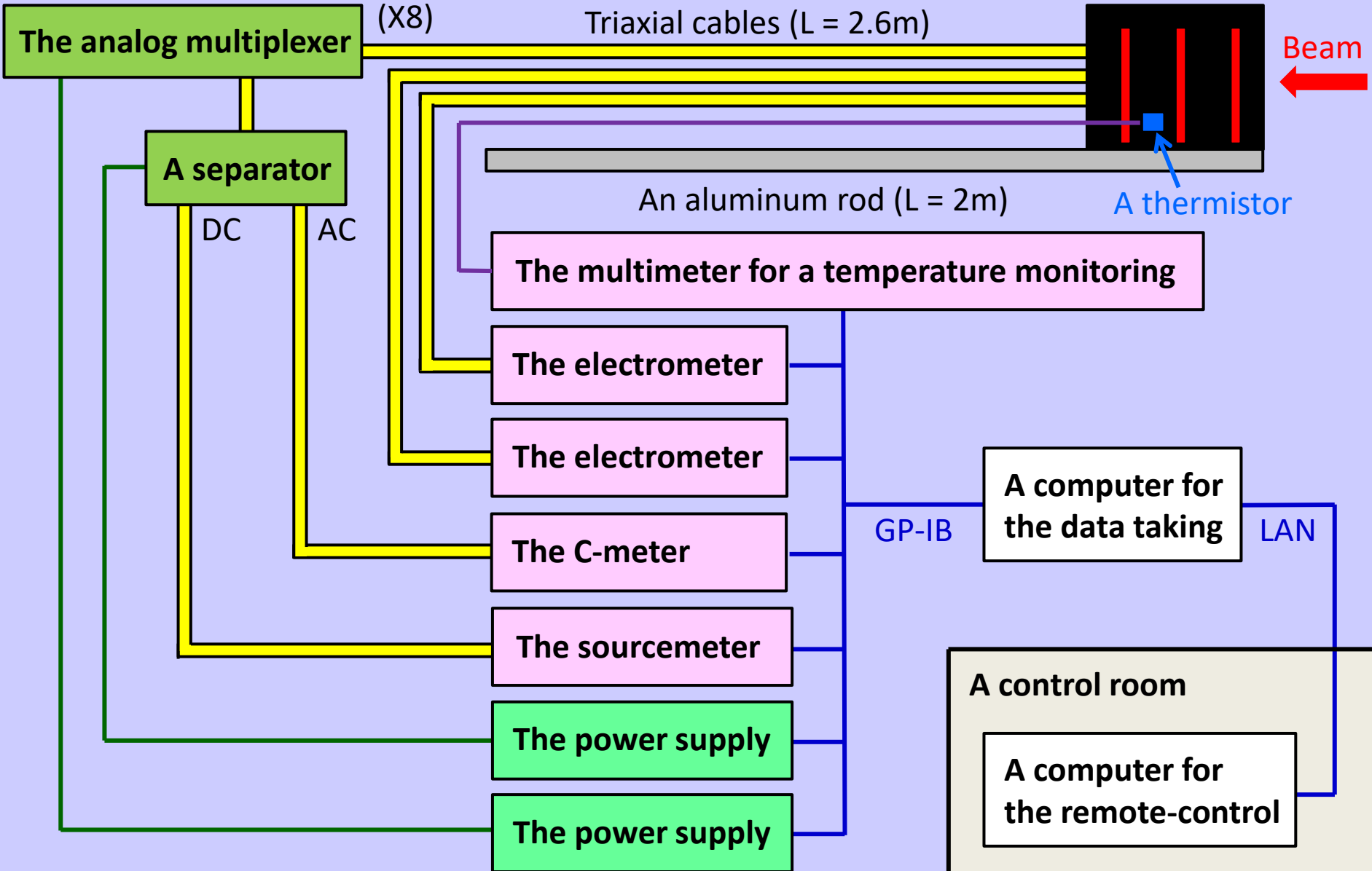
# New PCBs for the main test (5th & 6th layers)



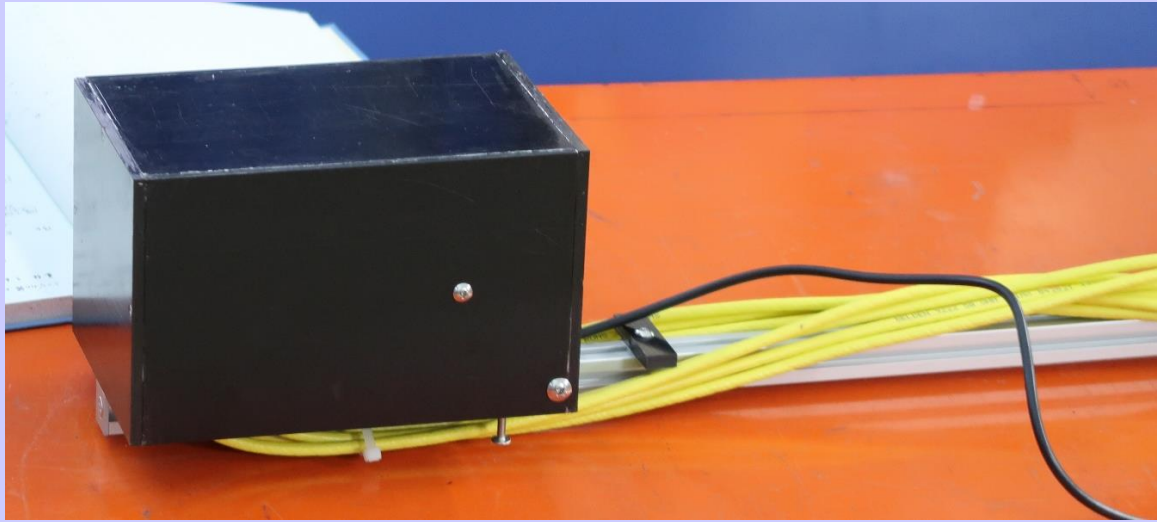
# Setup – Working well at the test bench

The experiment hall

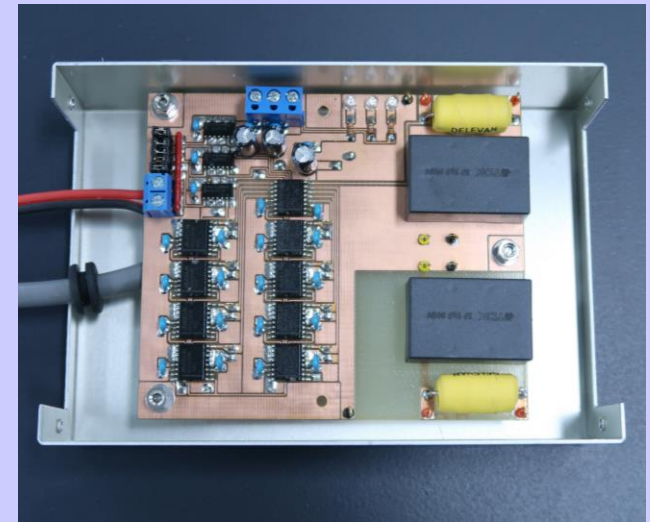
Sensors on PCBs in the black box



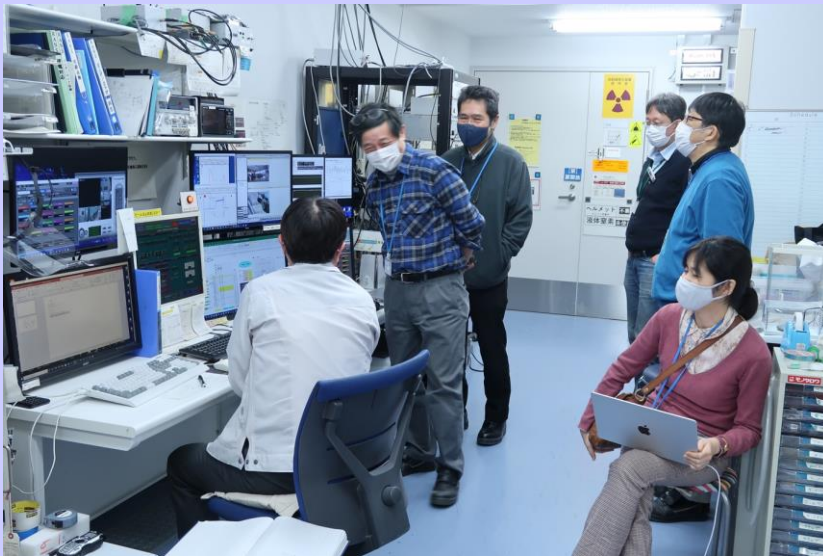
# Photos



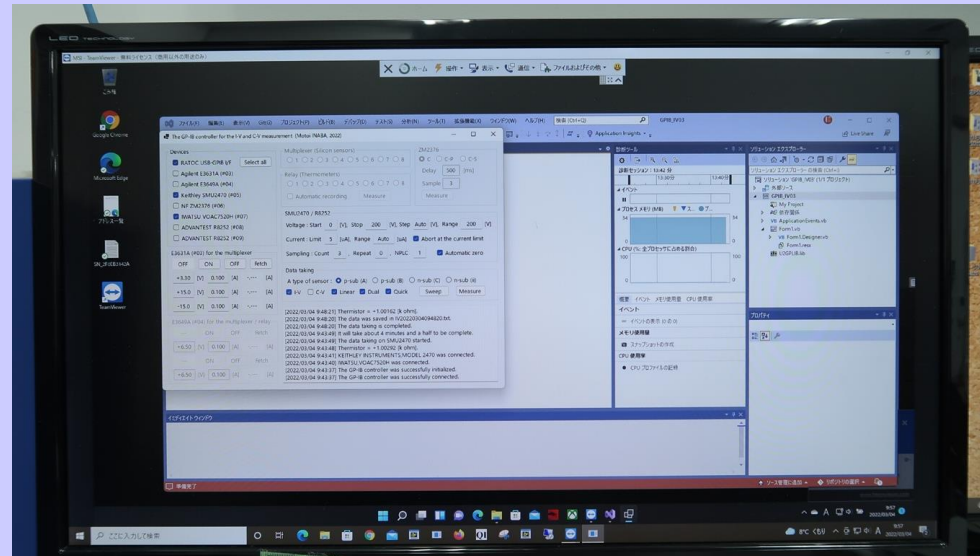
The sensors in a new black box



The analog multiplexer



In the control room

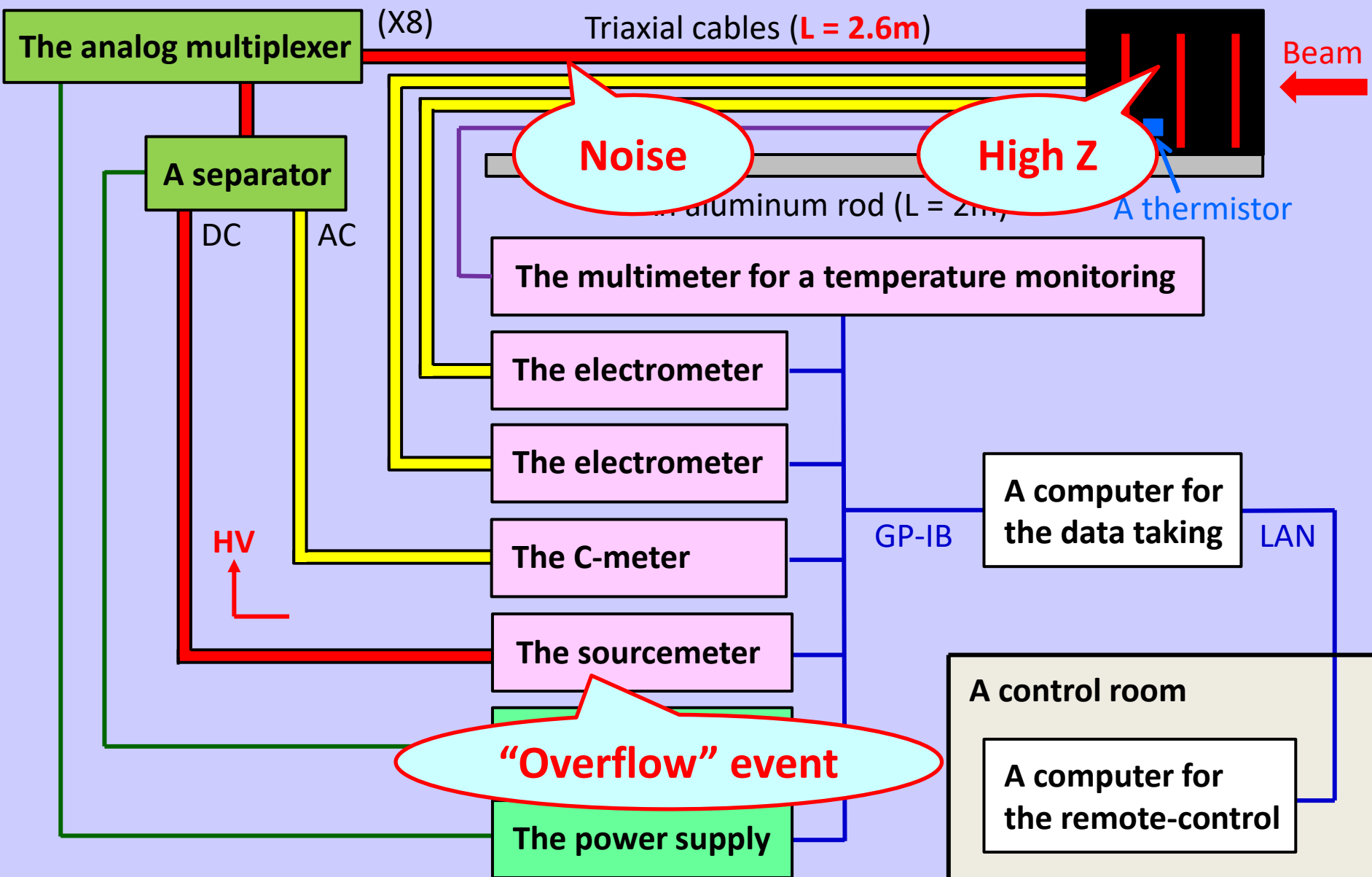


The DAQ program

# A new problem – No bias for C measurement

The experiment hall

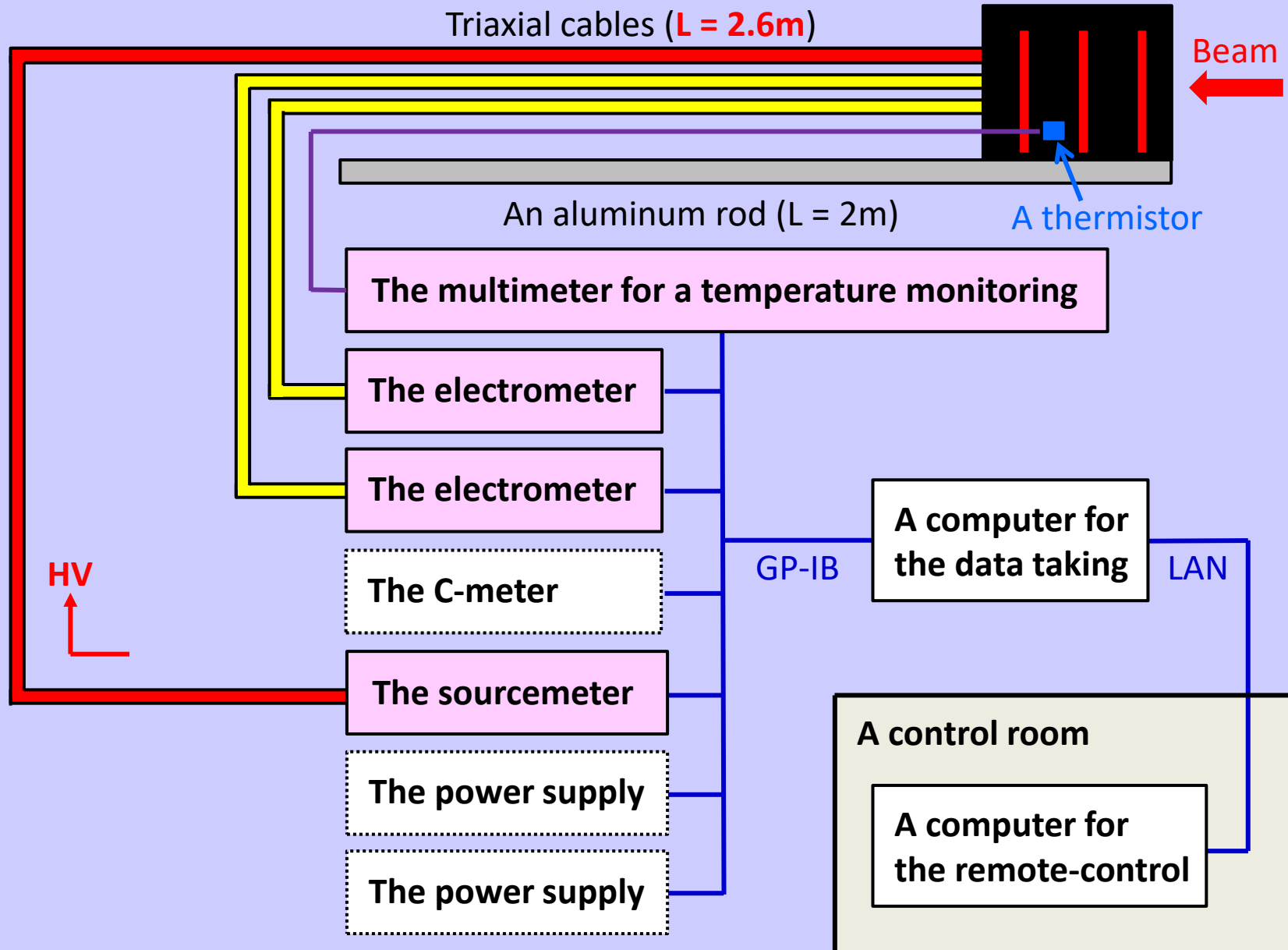
Sensors on PCBs in the black box



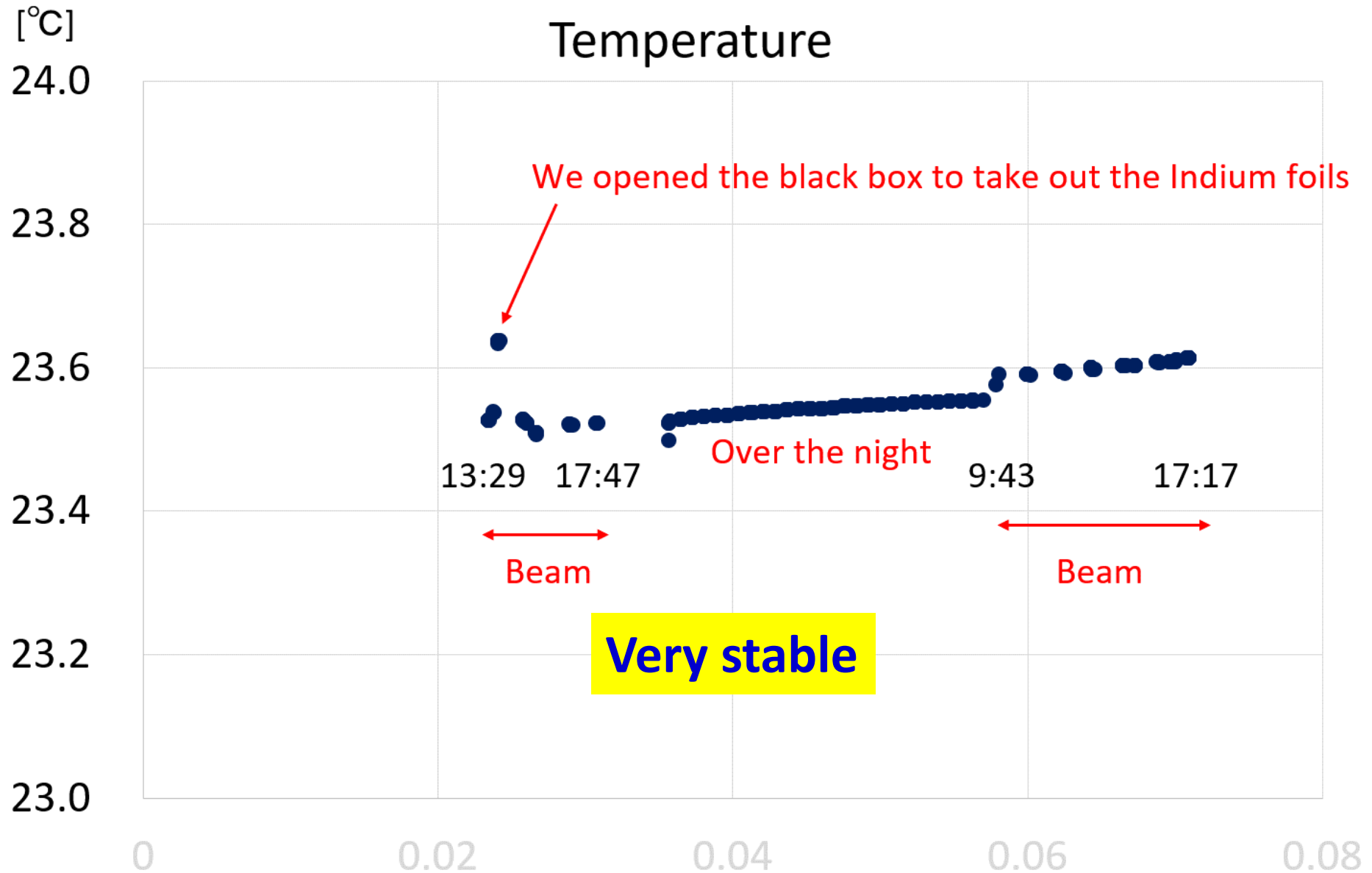
# The final setup (No C meter / No multiplexer)

The experiment hall

Sensors on PCBs in the black box



# Temperature in the experiment equipment



# The n-type monitor PD (Tsukuba)

A leakage current [ $\mu\text{A}$ ]

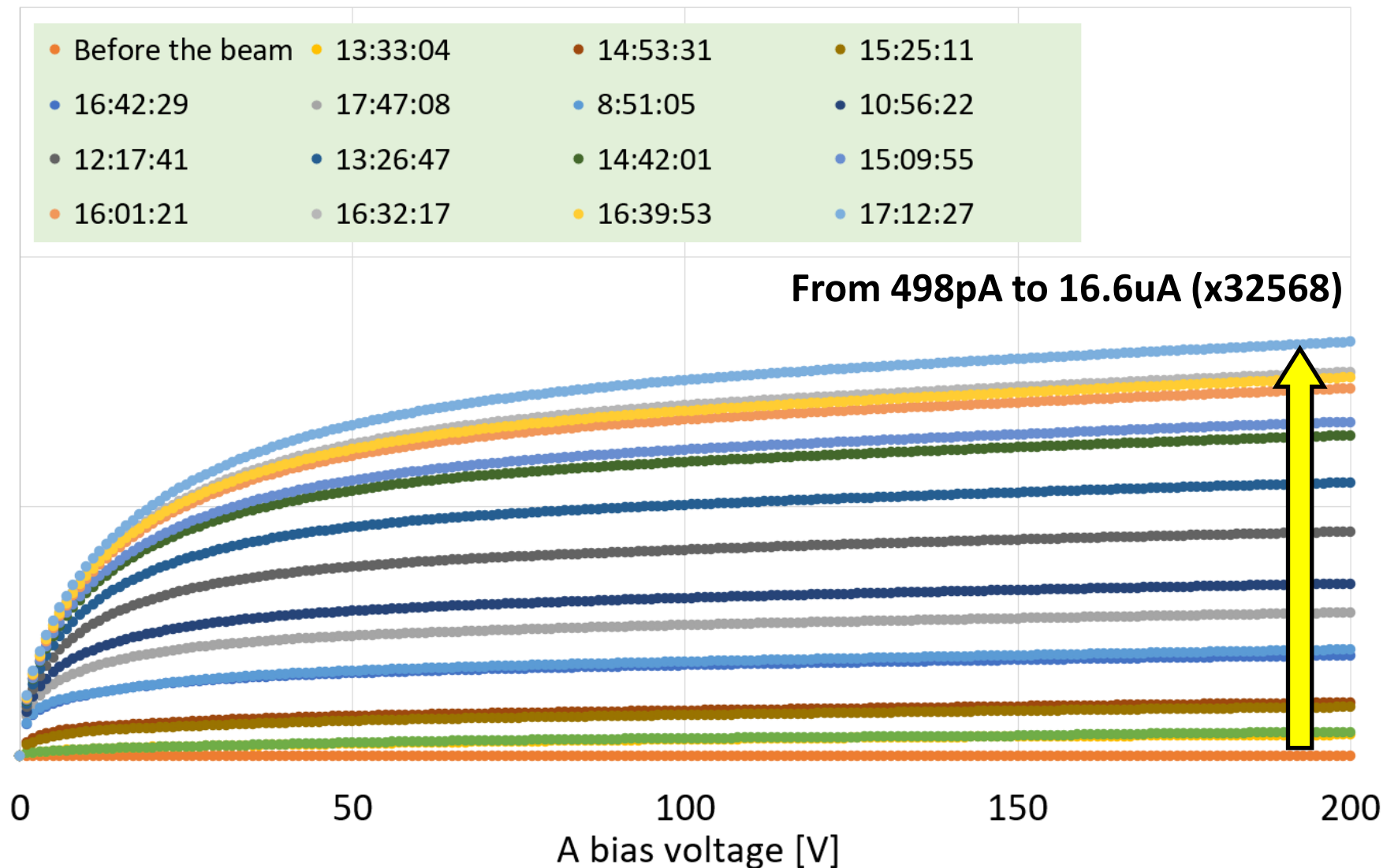
I-V characteristics of the n-type MPD (Tsukuba)

30

20

10

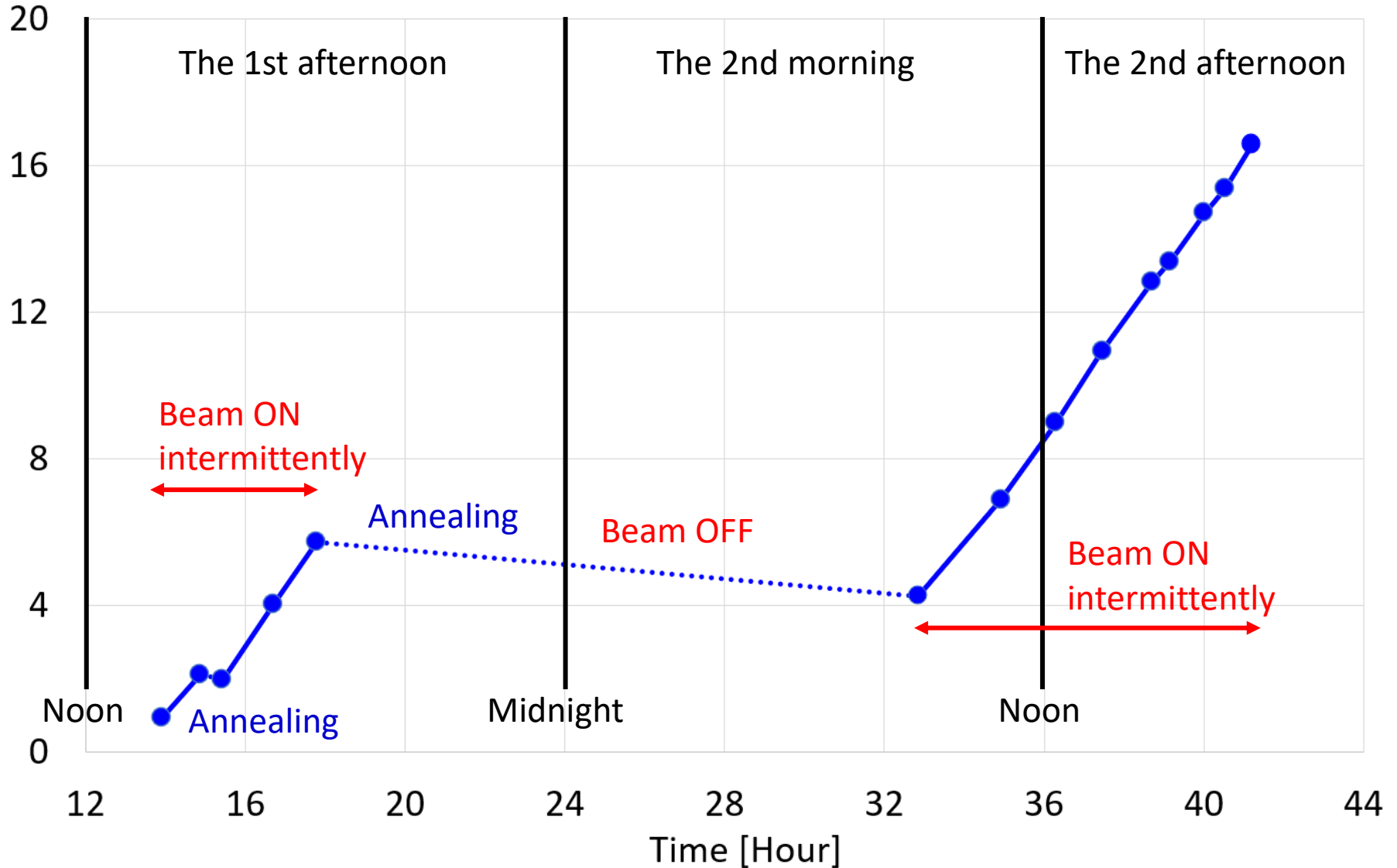
0





# The n-type monitor PD (Tsukuba)

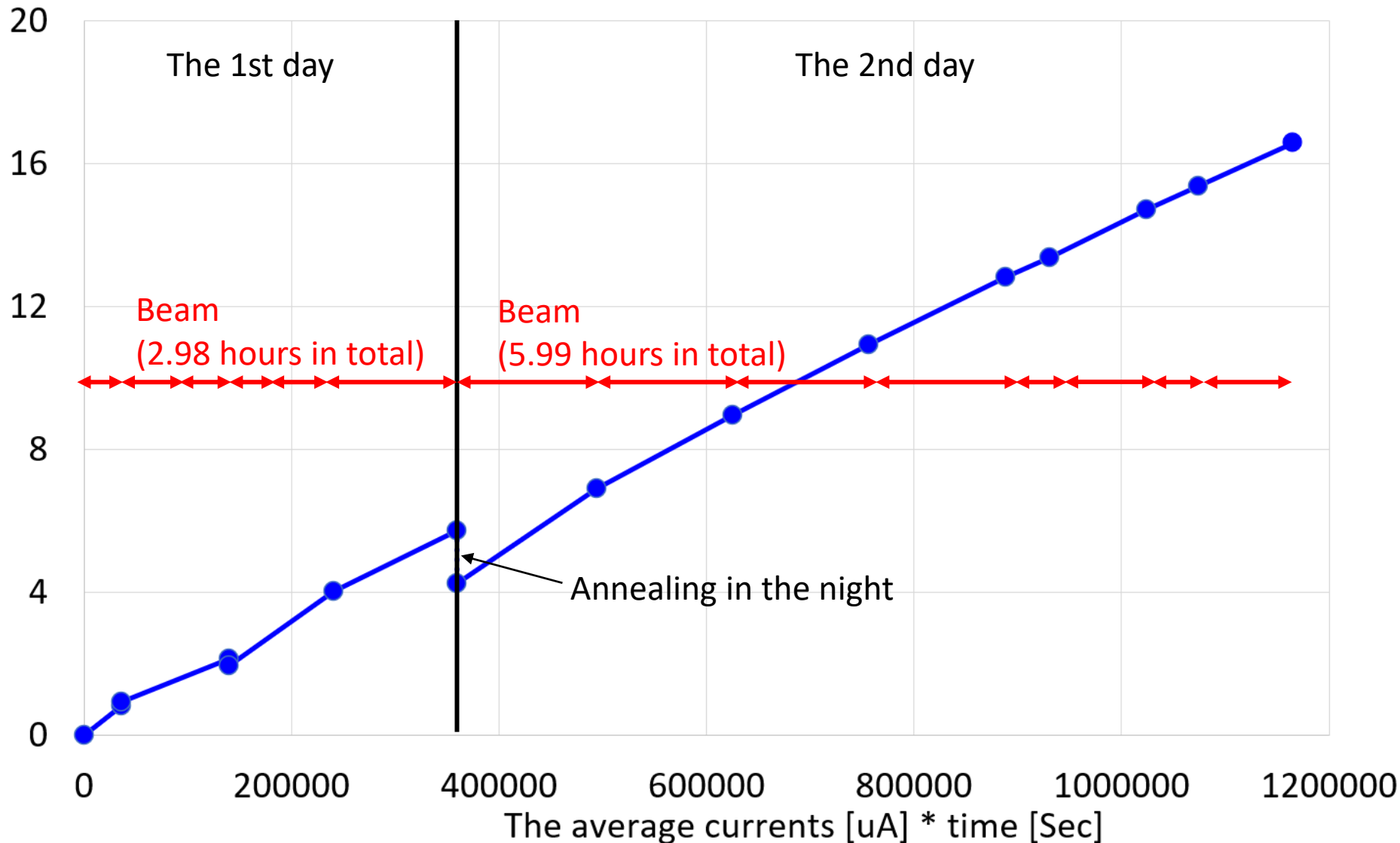
A leakage current [uA] A leakage current vs time (N-type MPD Tsukuba)



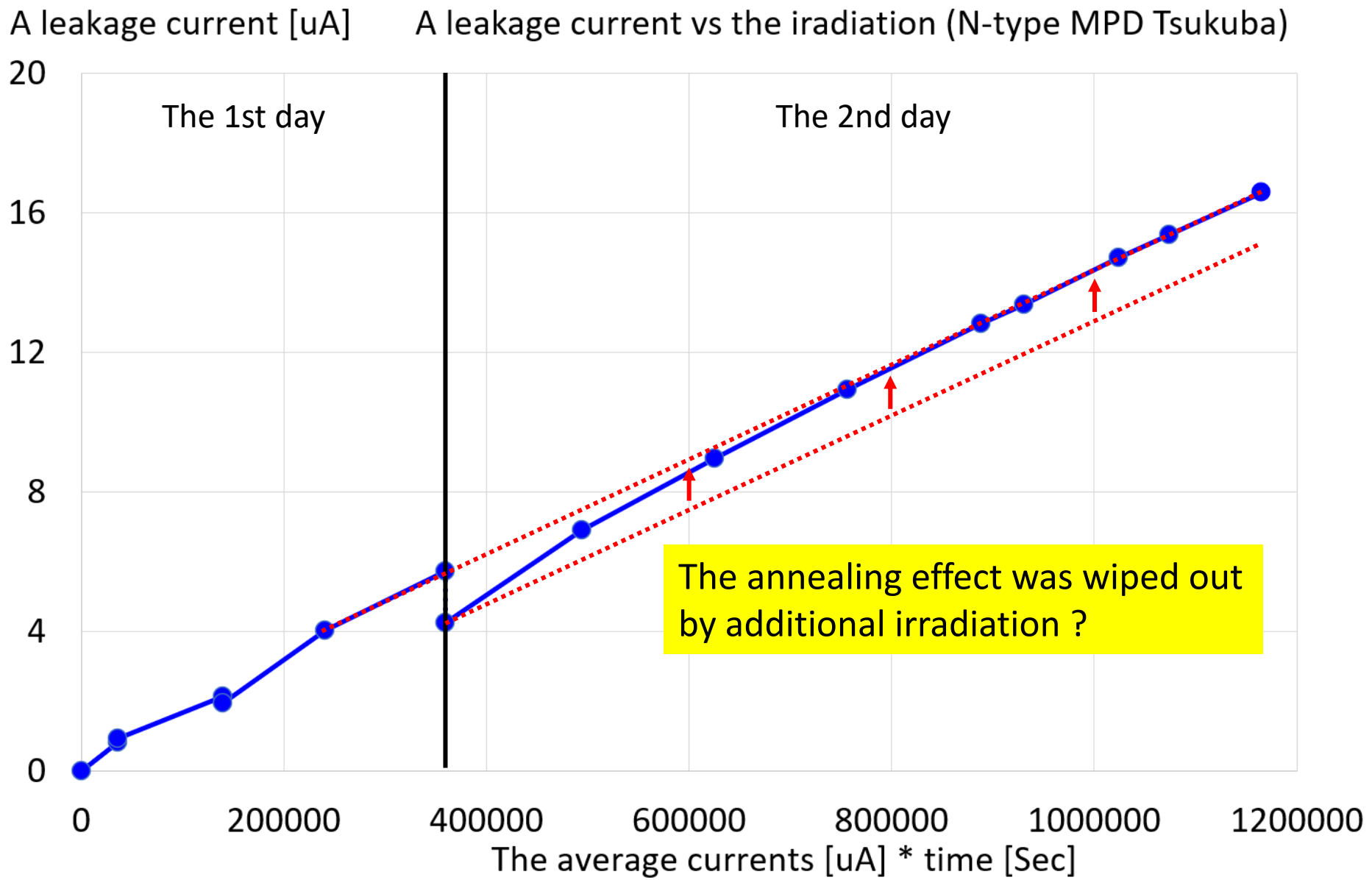
# The n-type monitor PD (Tsukuba)

A leakage current [uA]

A leakage current vs the irradiation (N-type MPD Tsukuba)



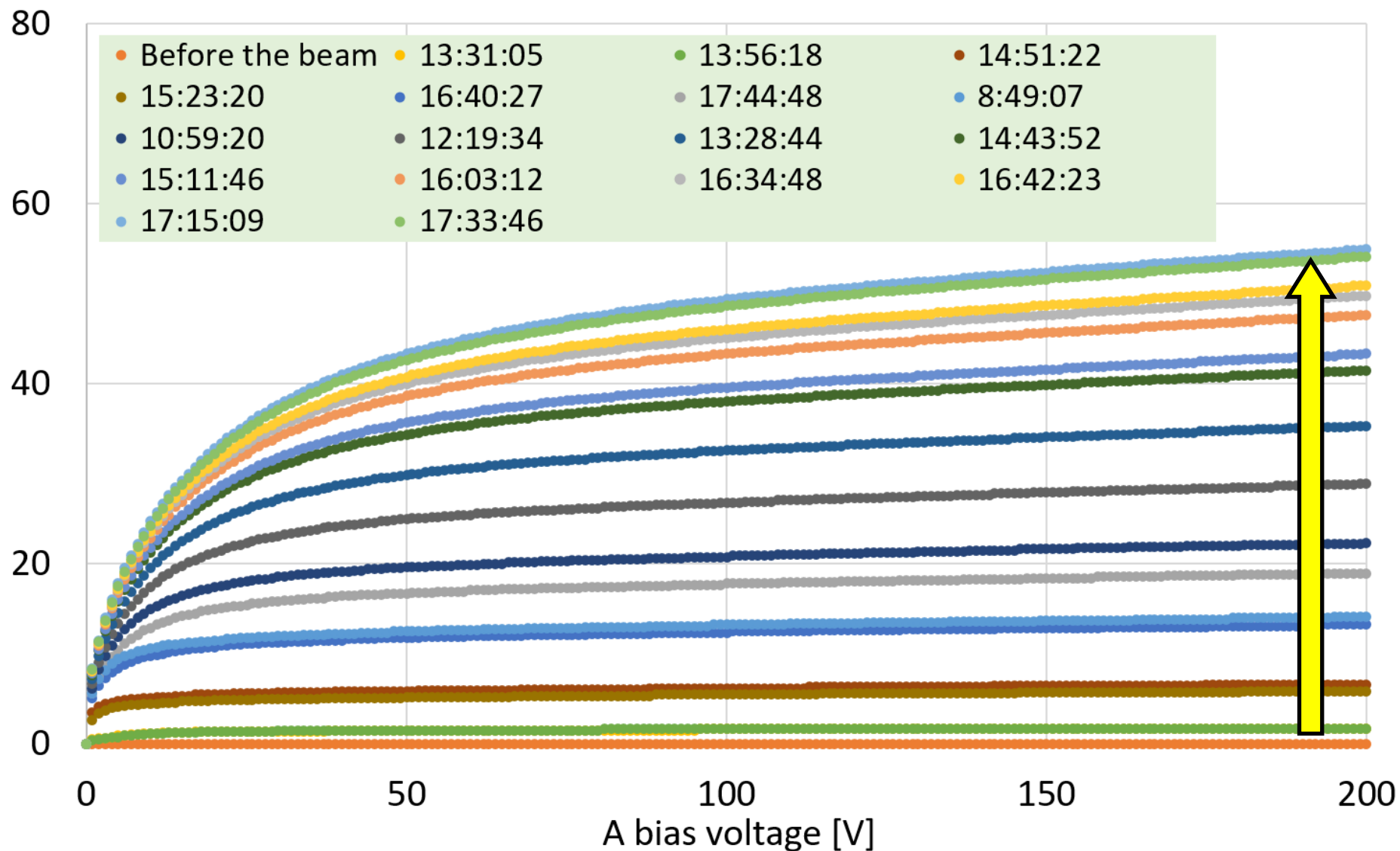
# My consideration



# The n-type monitor PD (Kyushu Univ.)

A leakage current [ $\mu\text{A}$ ]

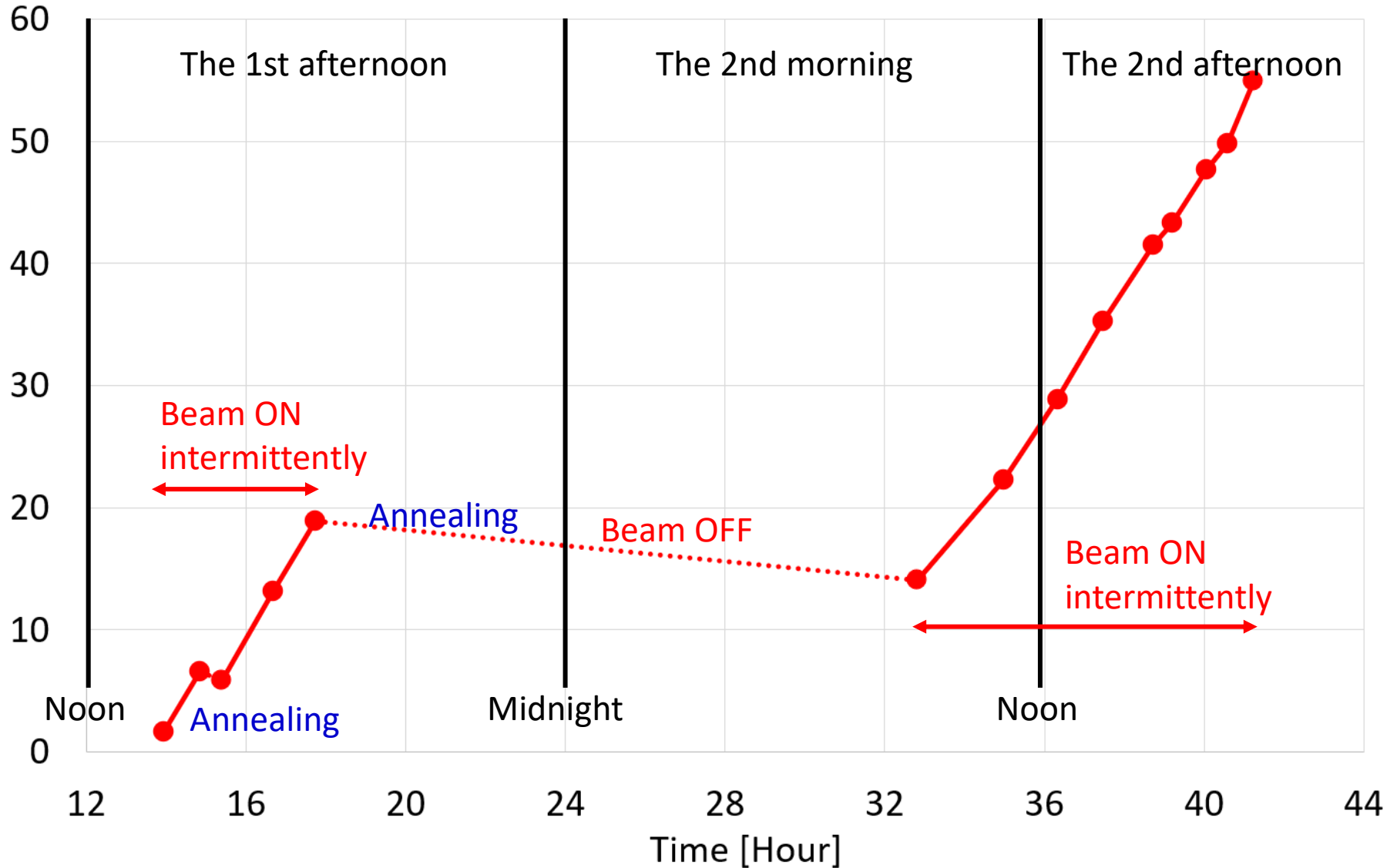
I-V characteristics of the n-type MPD (Kyushu)



# The n-type monitor PD (Kyushu)

A leakage current [ $\mu\text{A}$ ]

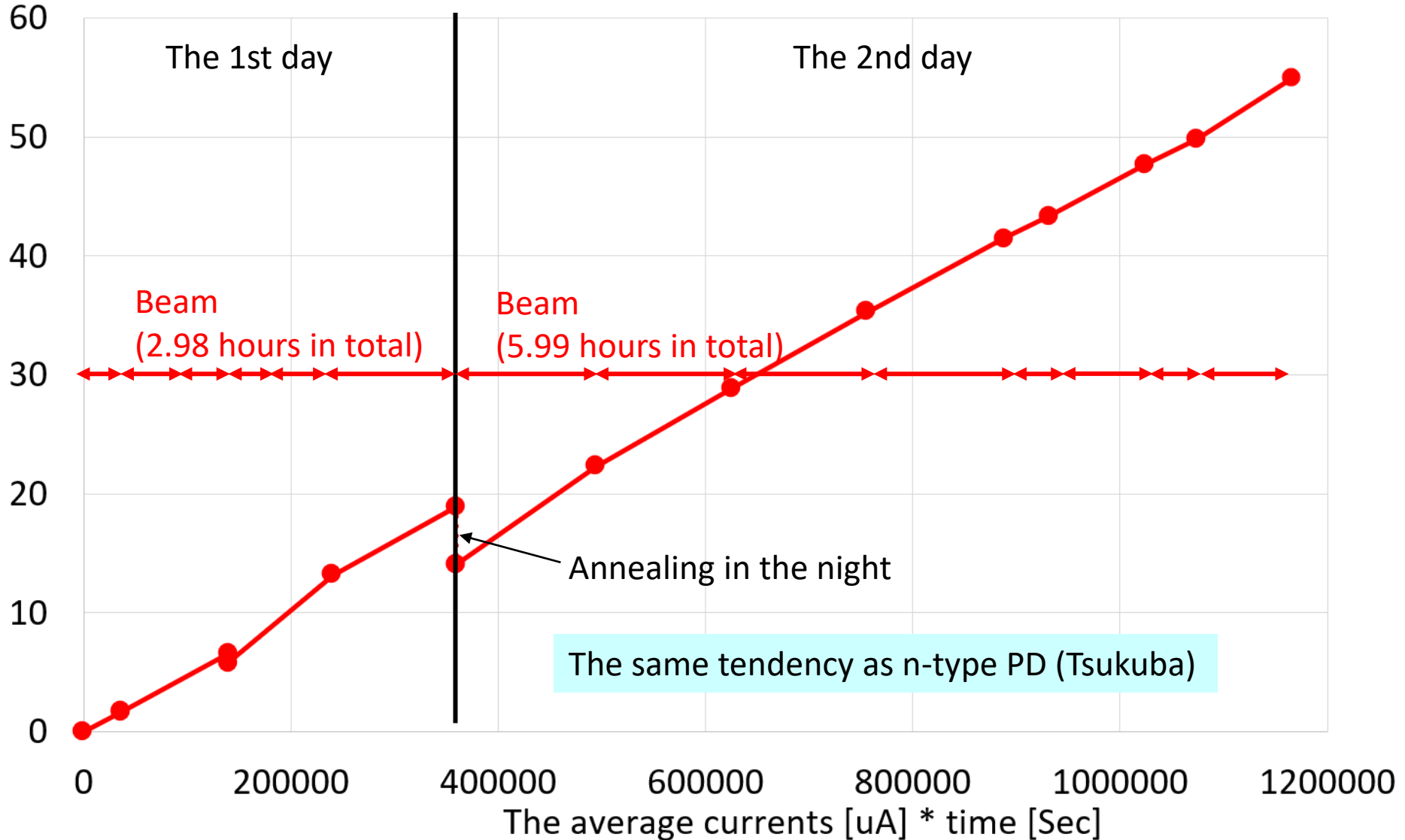
A leakage current vs time (N-type MPD Kyushu)



# The n-type monitor PD (Kyushu)

A leakage current [ $\mu\text{A}$ ]

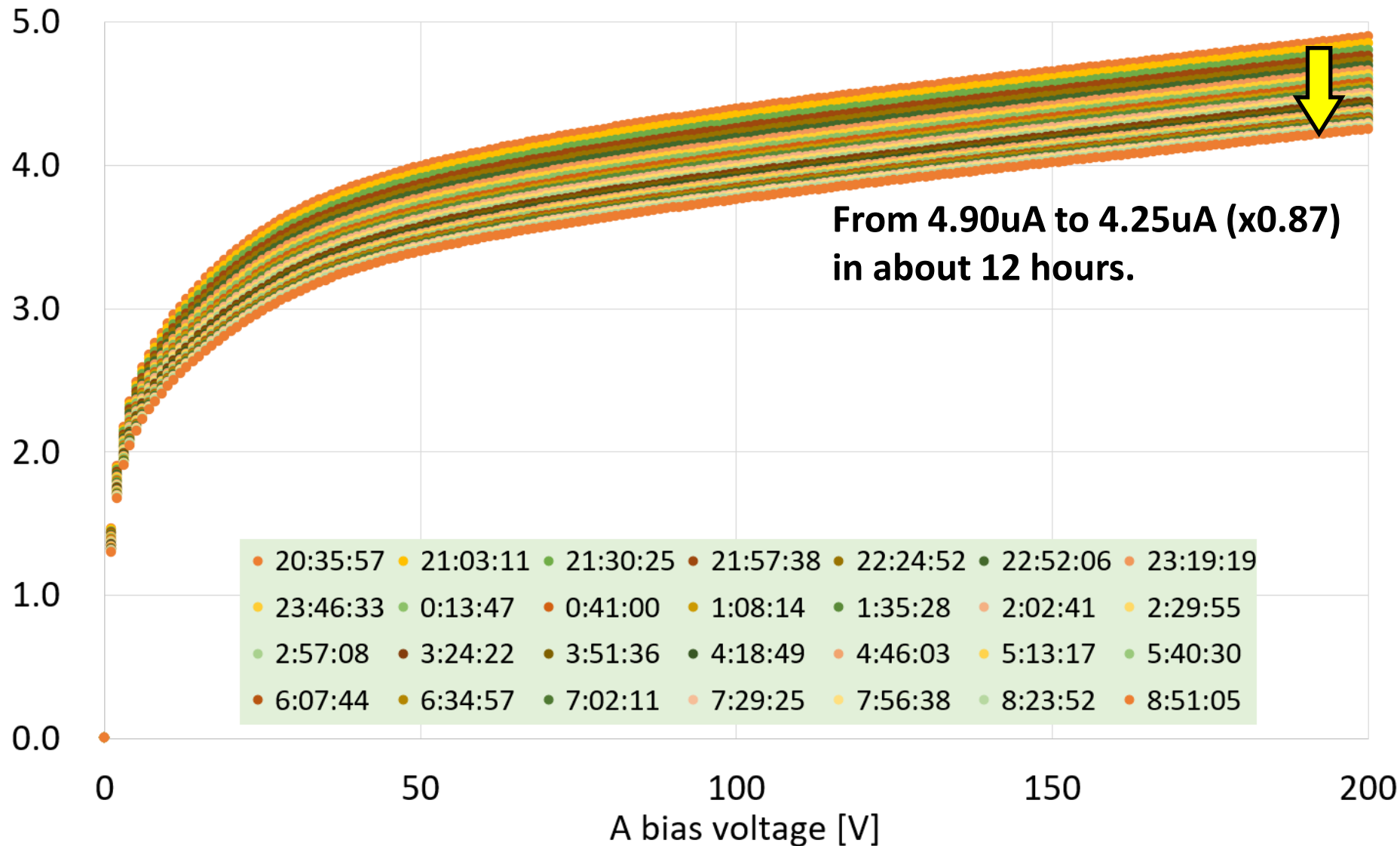
A leakage current vs the irradiation (N-type MPD Kyushu)



# The n-type monitor PD (Tsukuba)

A leakage current [ $\mu\text{A}$ ]

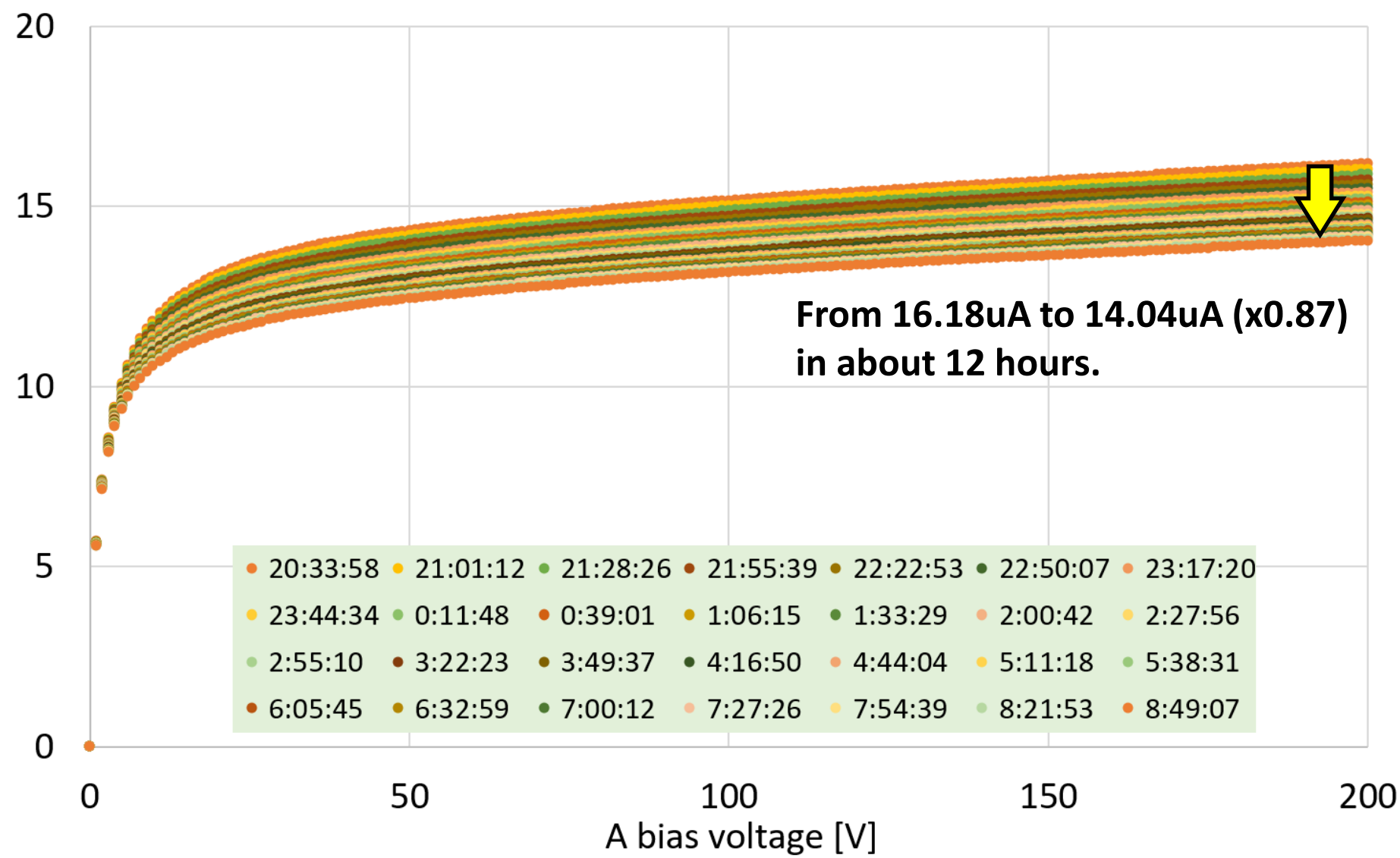
I-V characteristics of the n-type MPD (Tsukuba)



# The n-type monitor PD (Kyushu)

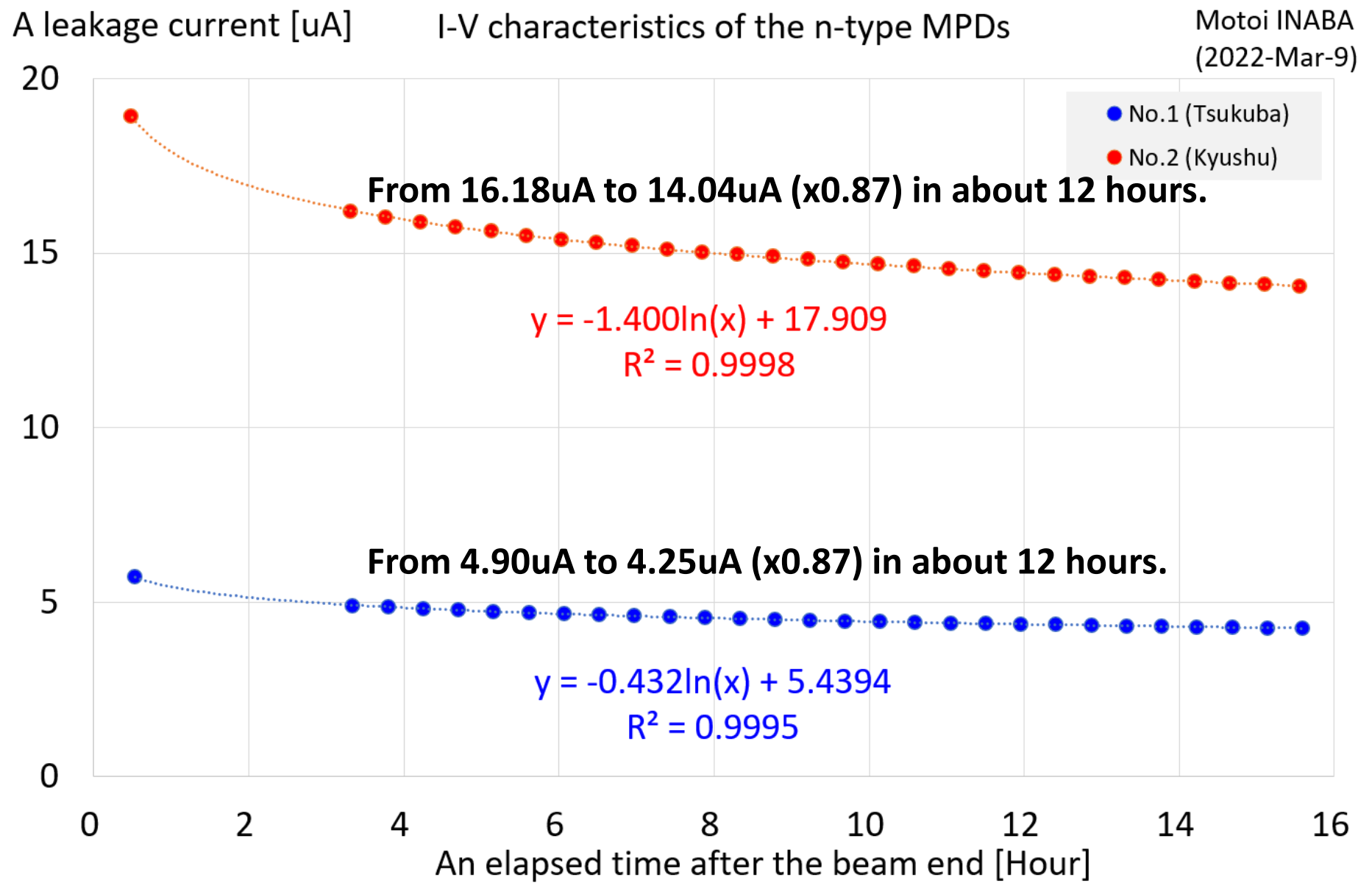
A leakage current [ $\mu\text{A}$ ]

I-V characteristics of the n-type MPD (Kyushu)





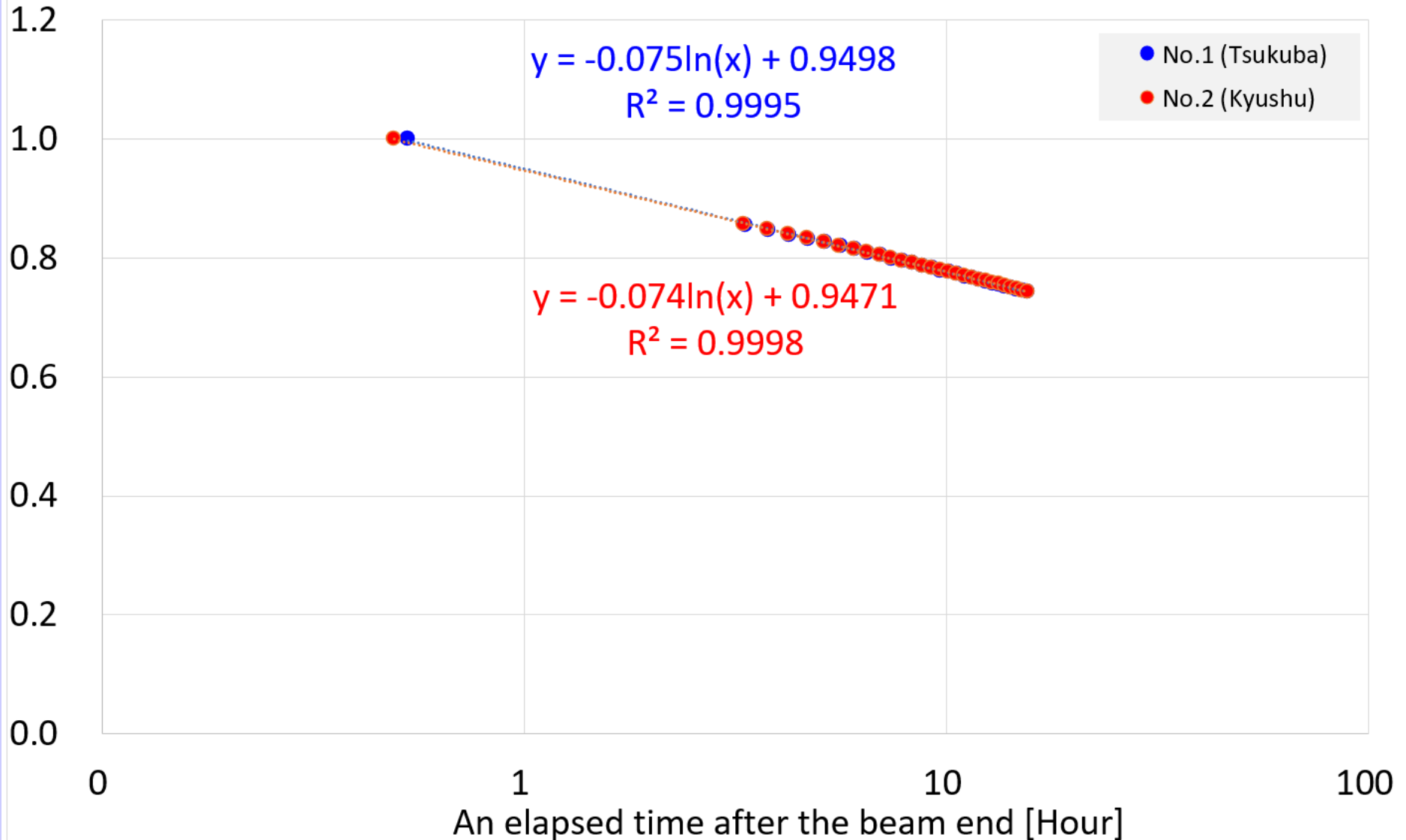
# Annealing in the 1st night



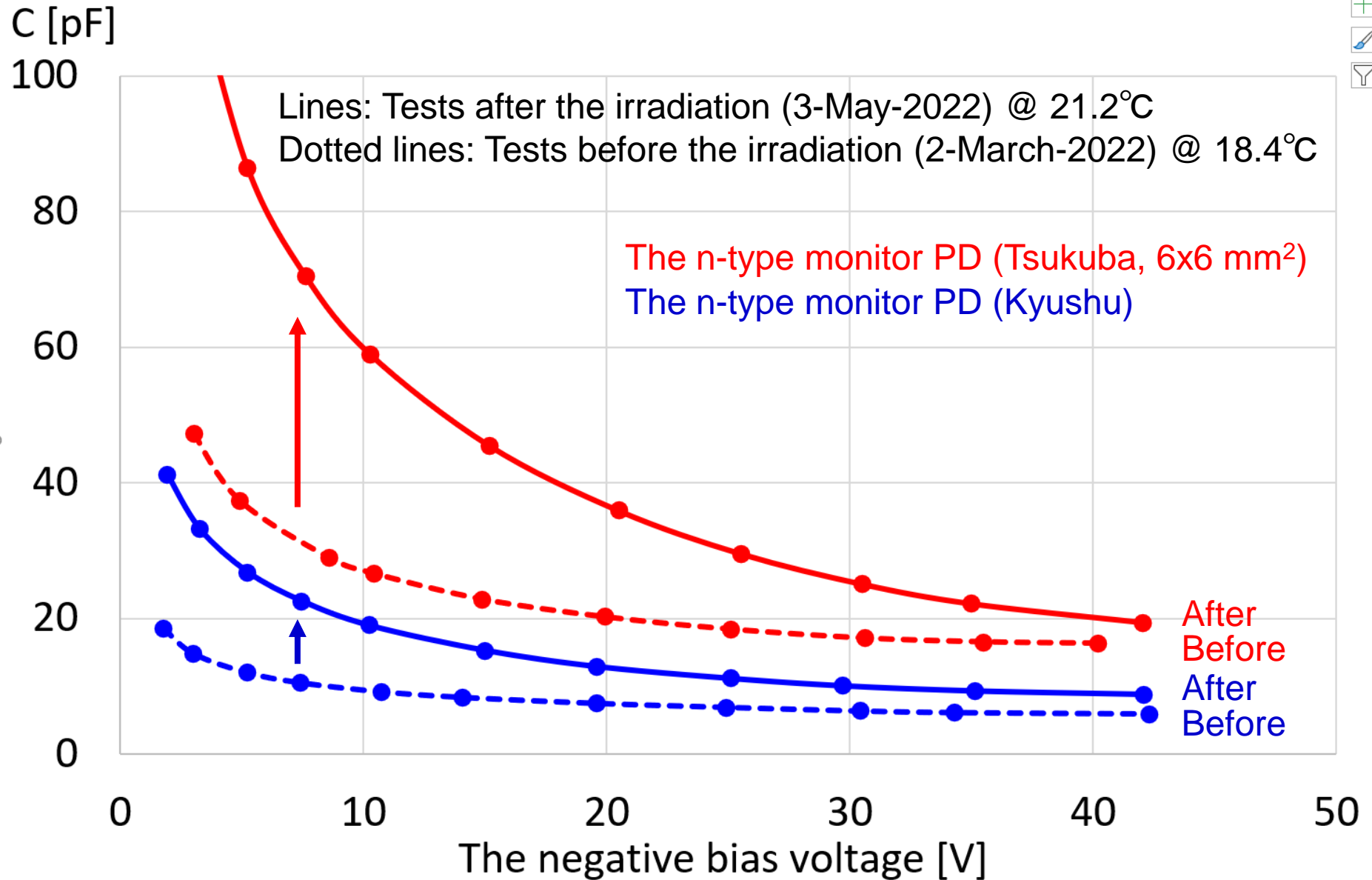
# Annealing in the 1st night

A ratio

A reducing factor of the n-type MPDs



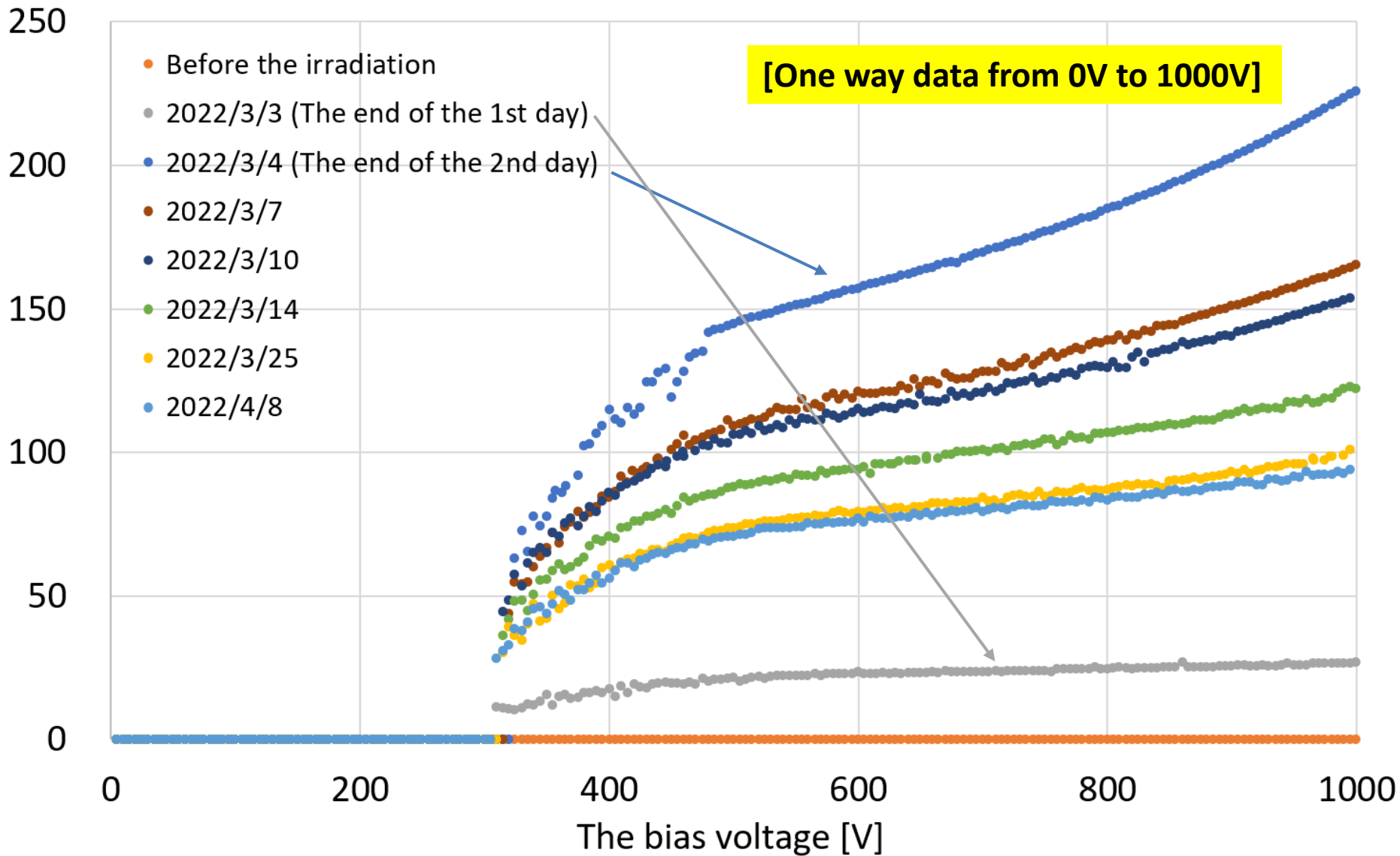
# The C-V characteristics of n-type monitor PDs



# The p-type monitor PD (Tsukuba)

The leakage current [ $\mu\text{A}$ ]

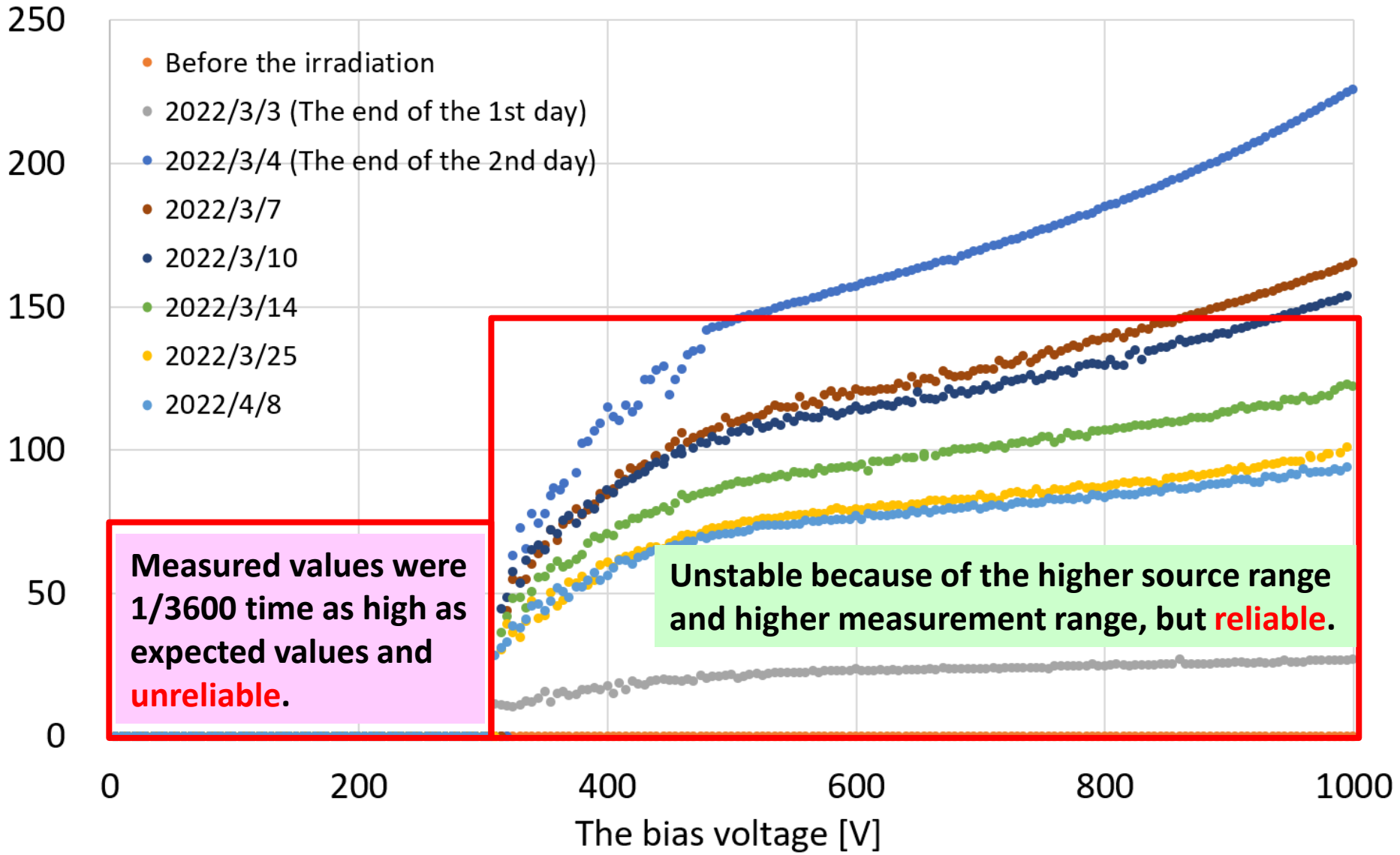
The I-V characteristics of the p-type MPD



# Properties of the sourcemeter

The leakage current [ $\mu\text{A}$ ]

The I-V characteristics of the p-type MPD



# The I-V measurement using the sourcemeter

A strong point of the sourcemeter is the high-voltage source (1000V max) and large current measurement (1A max). On the other hand, it is unstable in the range of 150uA or less.

(An electrometer is suitable for a lower current range, but it is not strong and the maximum output voltage is 200V.)

[Auto range] It was easy to exceed the current limit in each range and lost the data.

[Manual range] It was unstable and unreliable sometimes because it had a very big difference between the measured currents @0V and 1000V. ➡ It needs a slow-control program instead of the sweep function.

P-type MPD (Tsukuba): (x5648)

(0.04uA) -(Irradiation)-> 225.9uA -(Annealing)-> 93.9uA @ 1000V

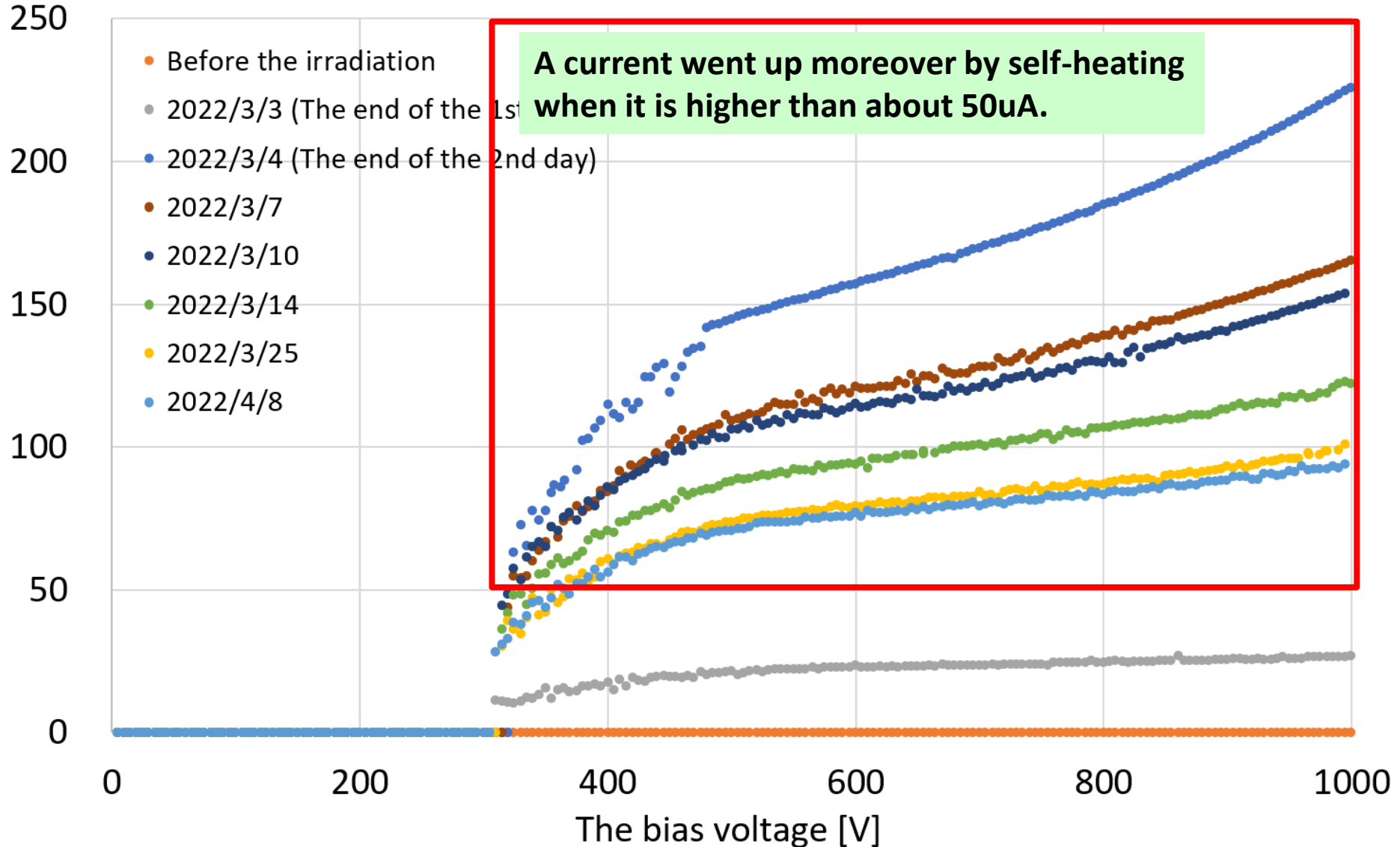


The noisy data because of the measurement range of SMU.

# Self-heating

The leakage current [ $\mu\text{A}$ ]

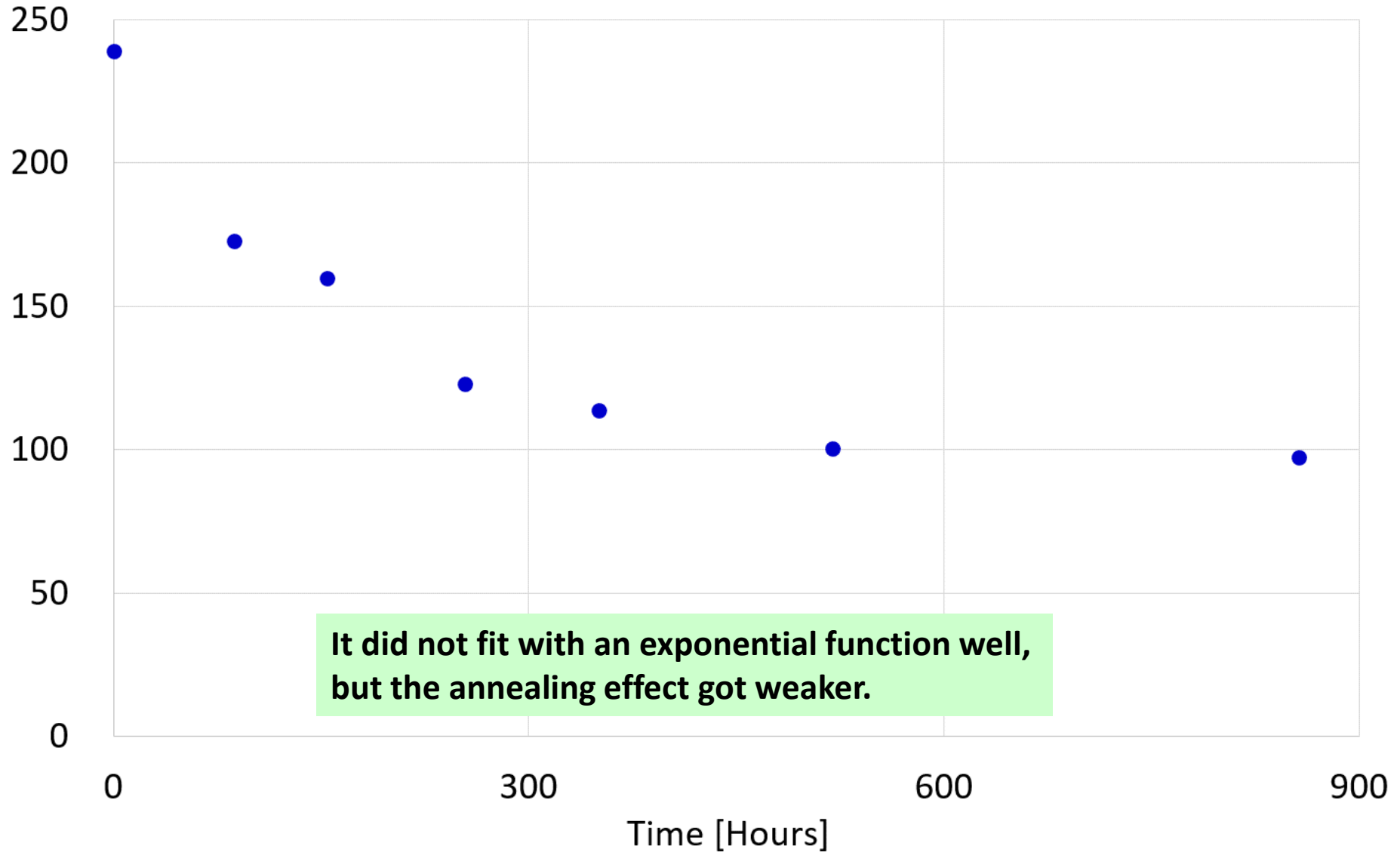
The I-V characteristics of the p-type MPD



# Annealing over one month

The leakage current [ $\mu\text{A}$ ]

The I-V characteristics of the p-type MPD



**It did not fit with an exponential function well,  
but the annealing effect got weaker.**



# Summary of the data so far

We observed that a leakage current went up according to the irradiation and went down by an effect of the annealing.

The sourcemeter sometimes had the high-voltage trip and lost the data because of the interlock. Next time, I will make a new program with a slow control.

The radiation that remained on PCBs with the sensors were higher than we expected. We have to make the better setup next time. For it, a study of better materials is important.

I would like to give a presentation at JPS next spring and so on. Do you have an idea of authors list ? (In case of the ALICE FoCal, it will be [one person] + [for the ALICE collaboration].)