Core-to-Core Program

MEG II実験液体キセノン検出器で用いられる光検出器の実機環境における応答の評価

Kohei Shimada
On behalf of MEG II collaboration
The University of Tokyo

Sep. 15th, 2020

Introduction

- **The motivation of searching** $\mu \to e\gamma$
- **Overview of MEG II**

MPPC

- **MPPC PDE decrease**
- **Surface damage by VUV light**

Measurement of PDE decrease

- **Measurement flow**
- **Setup**
- **Result**
- **Summary**

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The motivation of searching $\mu \to e\gamma$

- Neutrino oscillation was discovered (1998)
  - Shows that neutrinos have mixing
  - Indicates charged lepton mixing

- $\mu \to e\gamma$ in the standard model

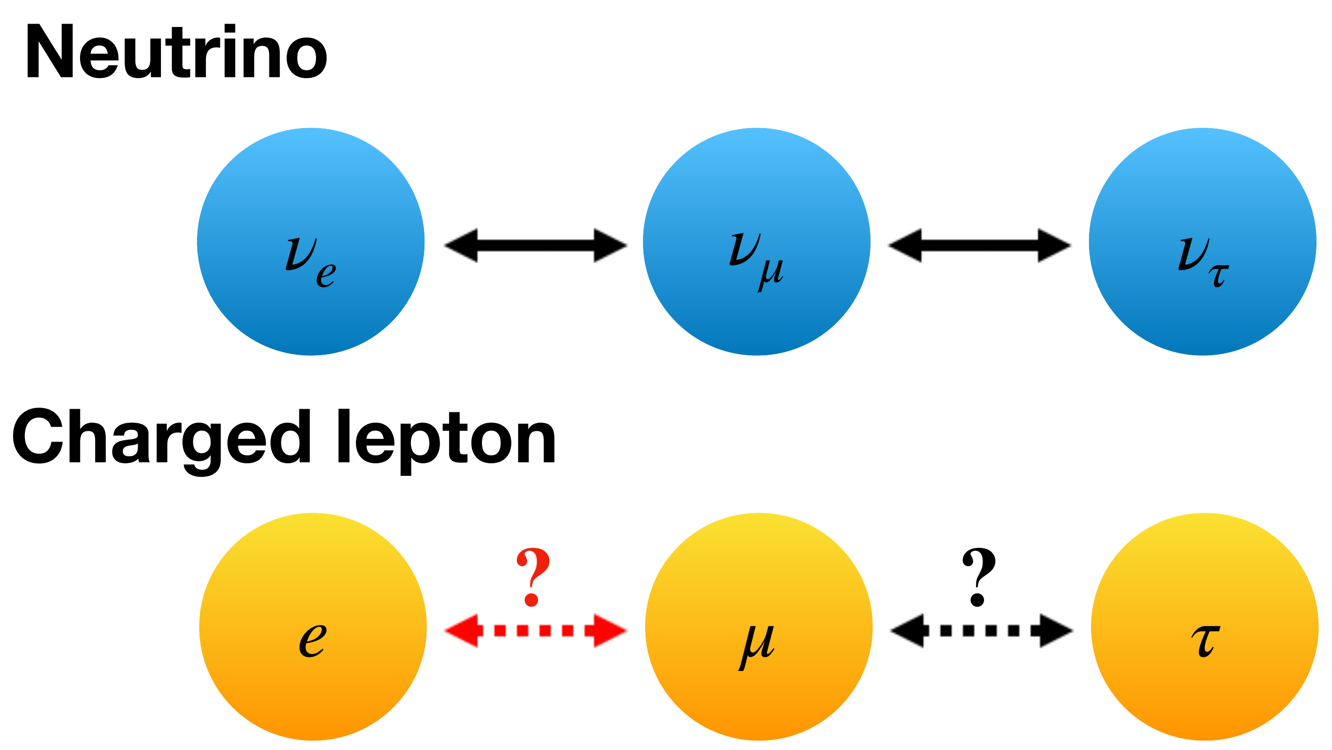
$$Br(\mu \to e\gamma) = \frac{3\alpha}{32\pi}\left|\sum_{i=2,3} U^*_{\mu i}U_{ei}\frac{\Delta m^2_{i1}}{M^2_W}\right|^2 \simeq 10^{-54}$$

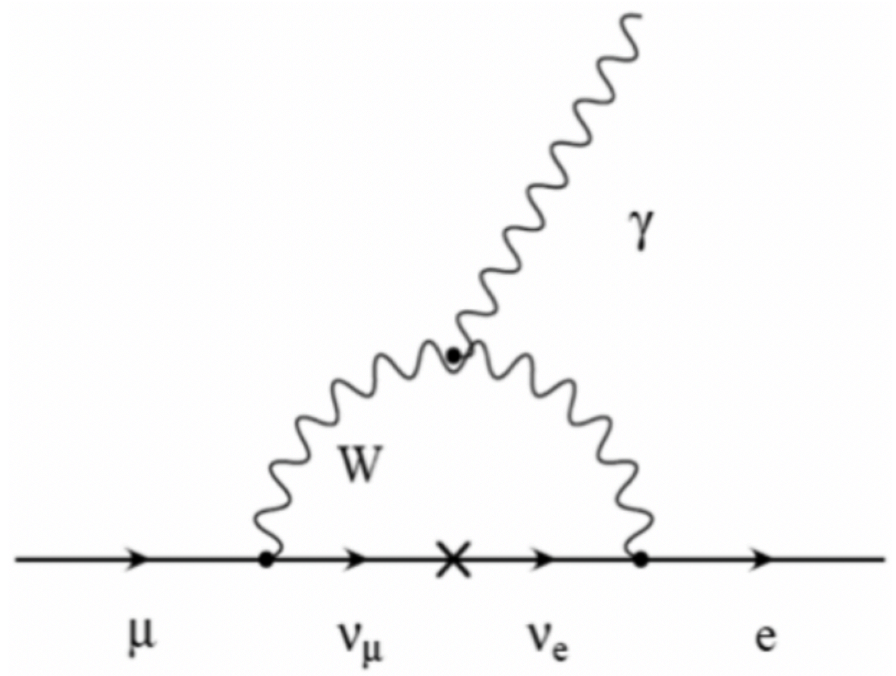
  - Cannot be observed

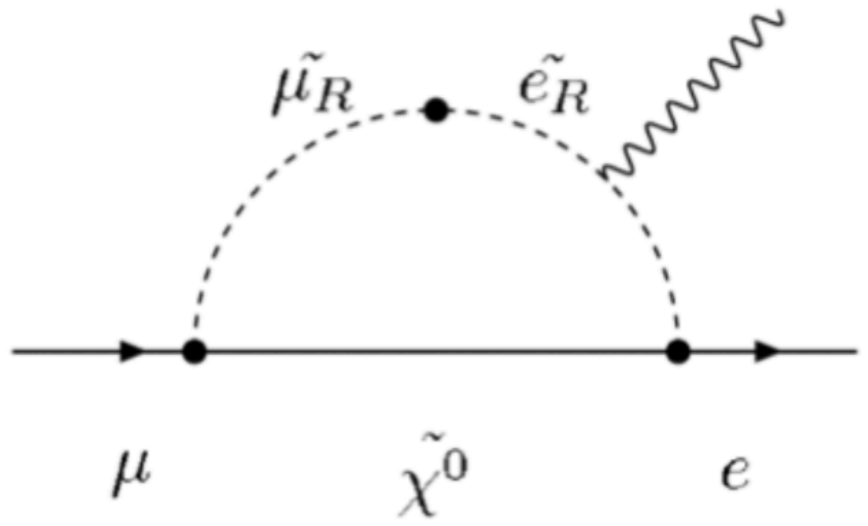
- $\mu \to e\gamma$ in a new physics e.g. SUSY GUT
  - Assume unknown heavy particle

$$Br(\mu \to e\gamma) = \mathcal{O}(10^{-12}) - \mathcal{O}(10^{-14})$$

  - Can be observed



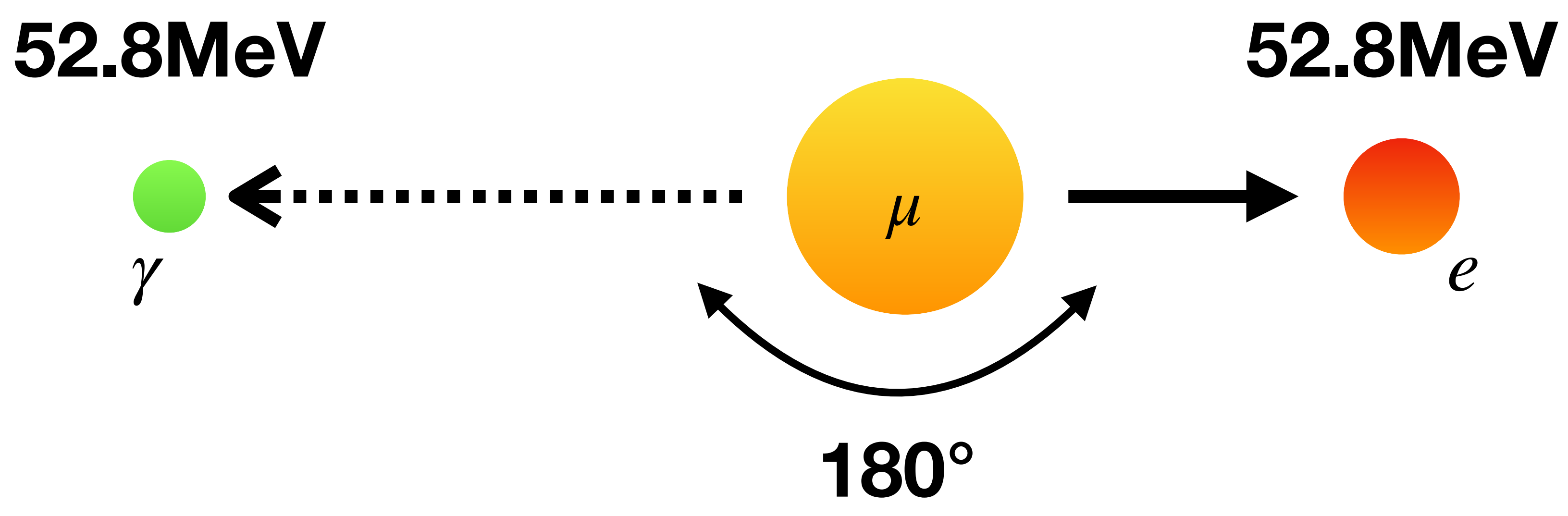


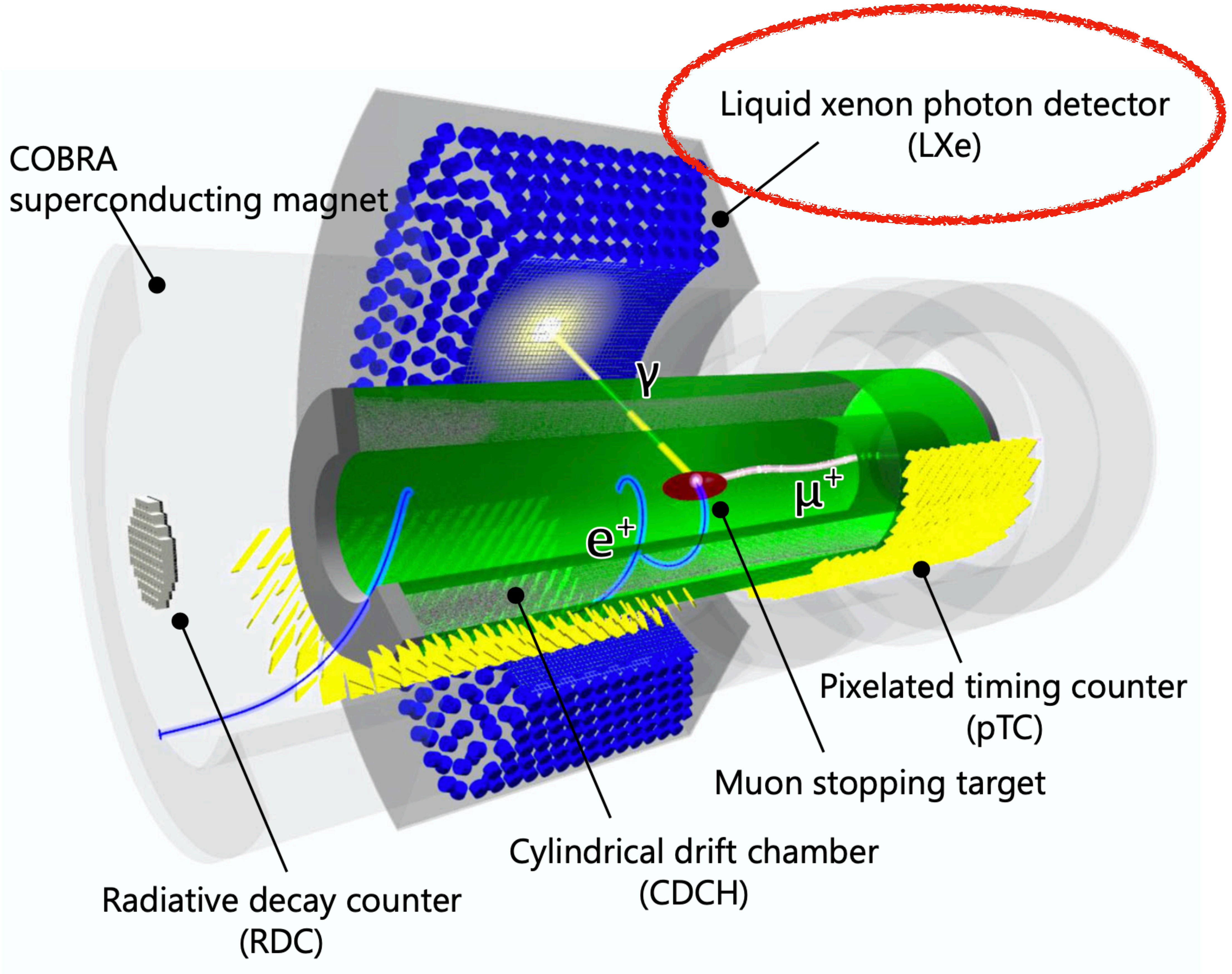


Overview of the MEG II experiment at Paul Scherrer Institut

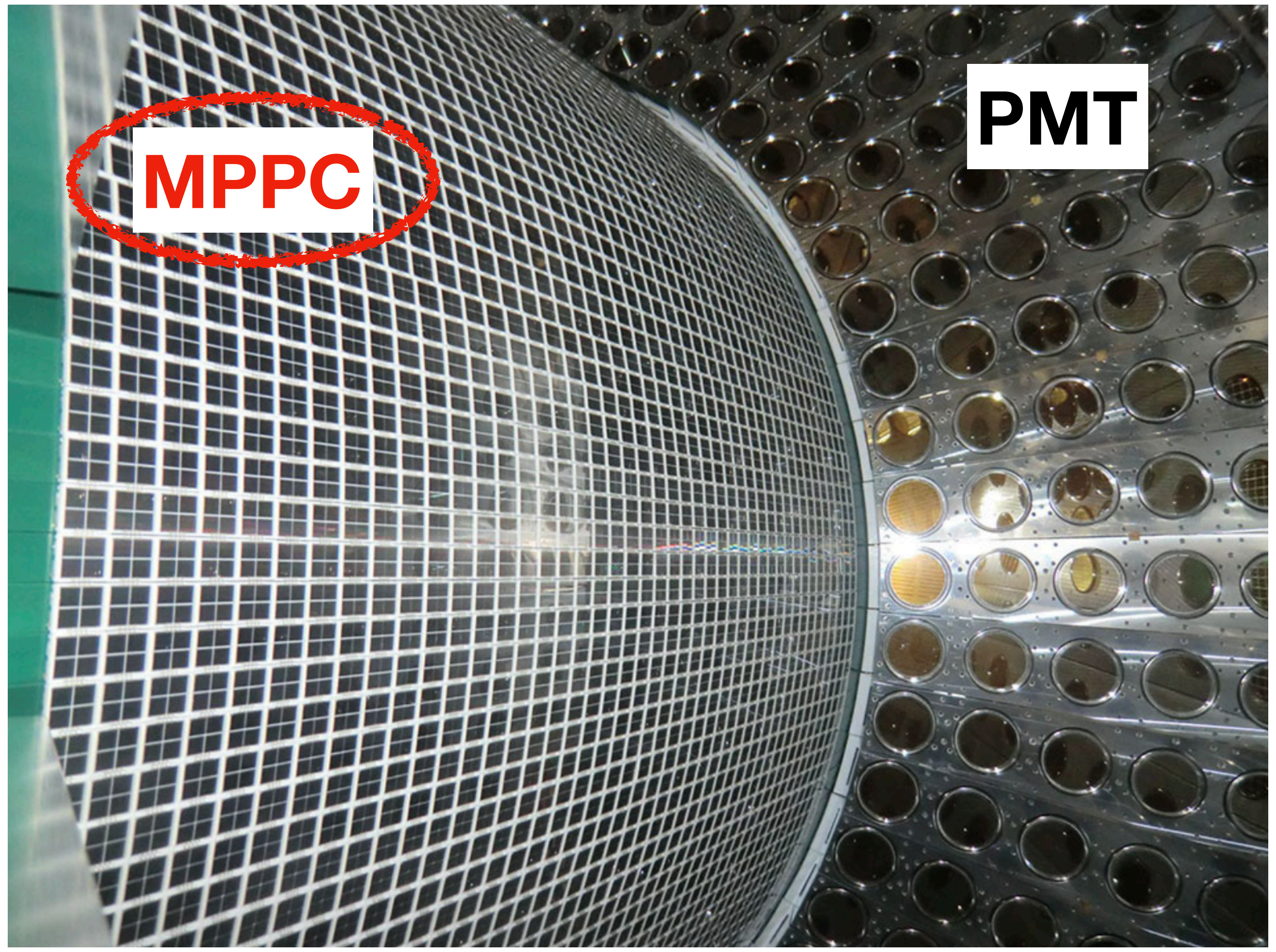
- The world's most intense μ beam $7 \times 10^7 \mu/\mathrm{sec}$
- Muons are stopped at the target
- Two-body decay

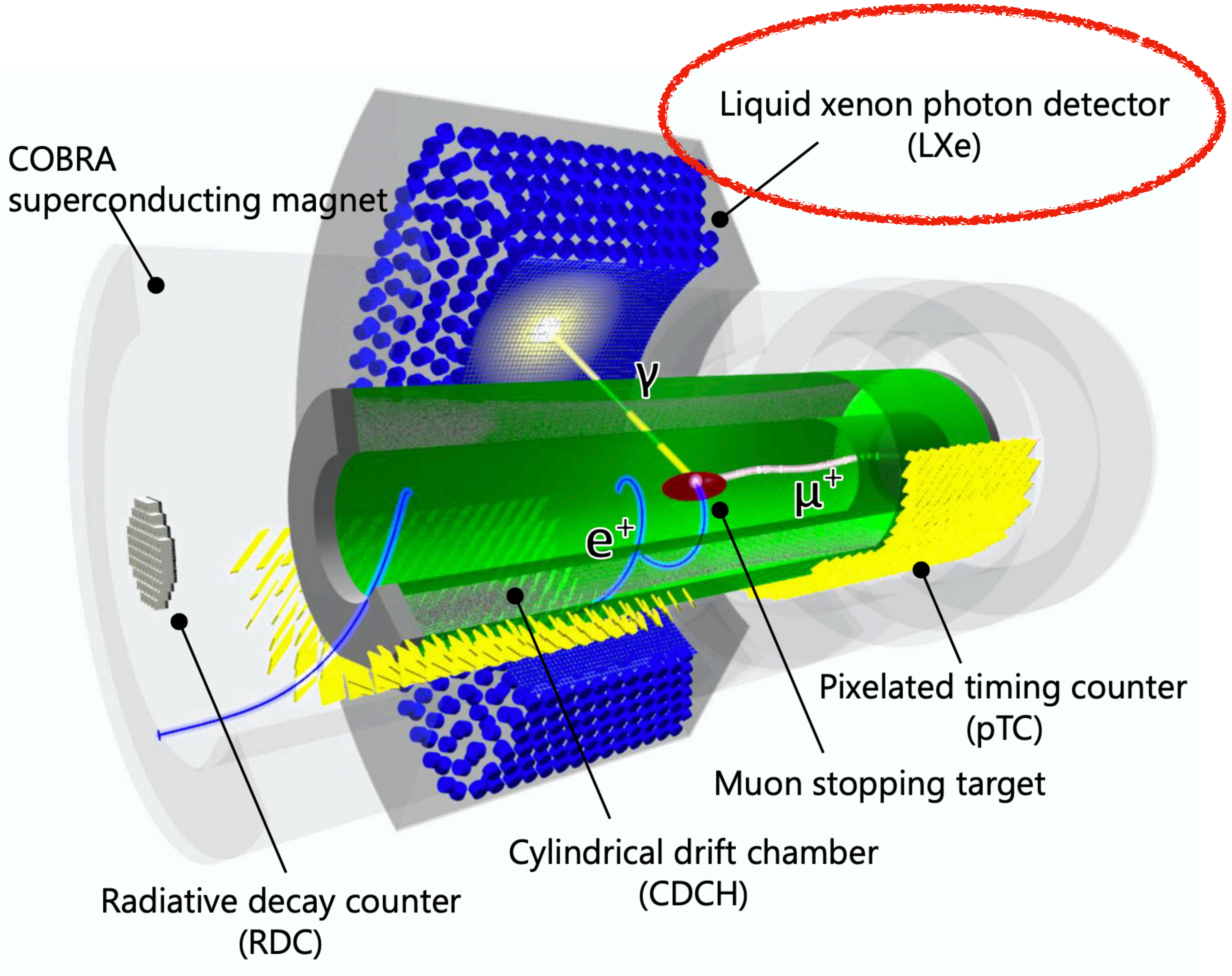
- The photon energy, interaction point position and time are measured by LXe





Overview of the MEG II experiment at Paul Scherrer Institut





- Detect the scintillation ($\lambda = 175\mathrm{nm}$)
- 4092 MPPCs, 668PMTs at 160K~165K
- Energy and position resolutions will be improved as compared with MEG by a factor of two
- Under commissioning since 2017

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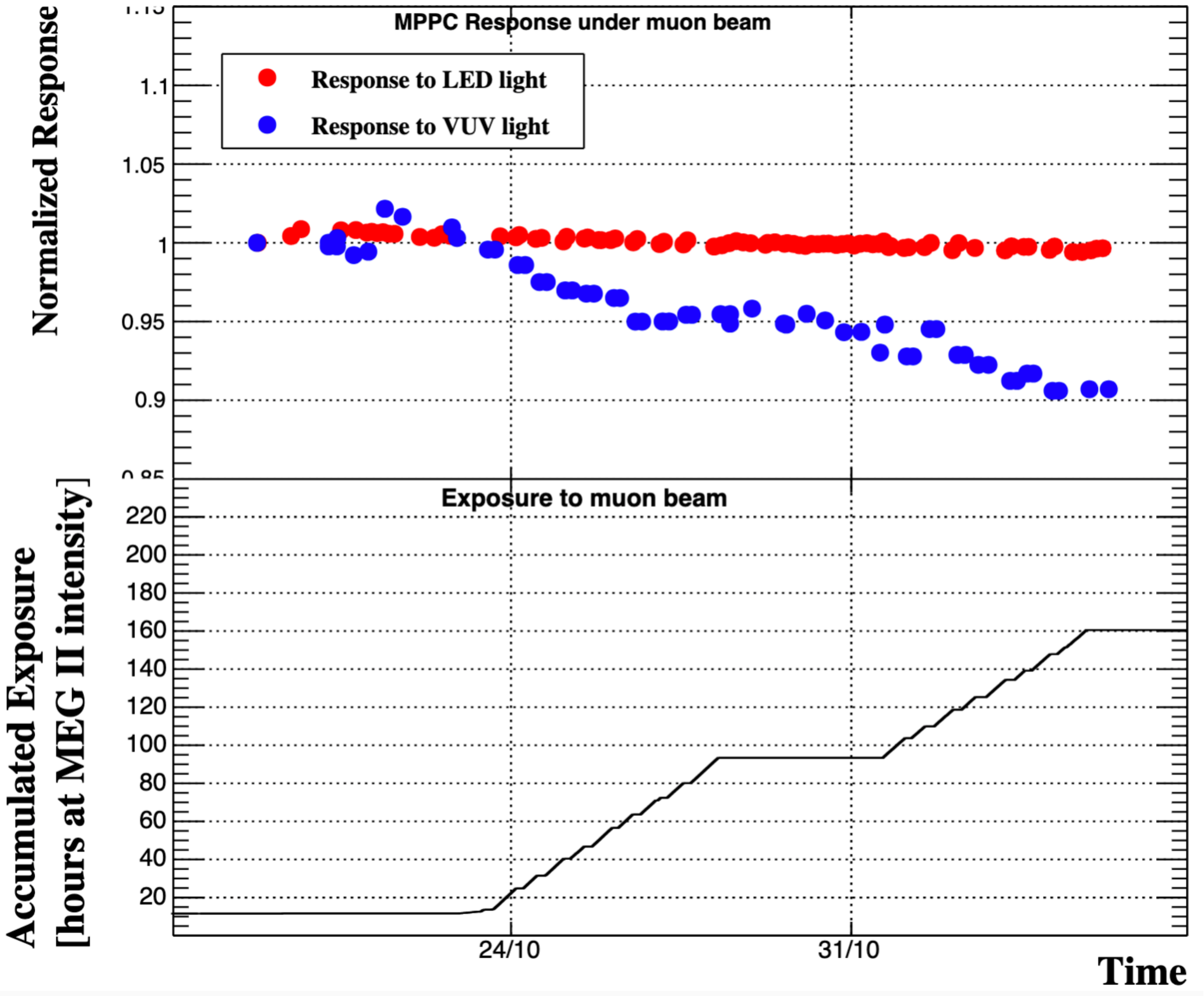
VUV-sensitive MPPC PDE decrease

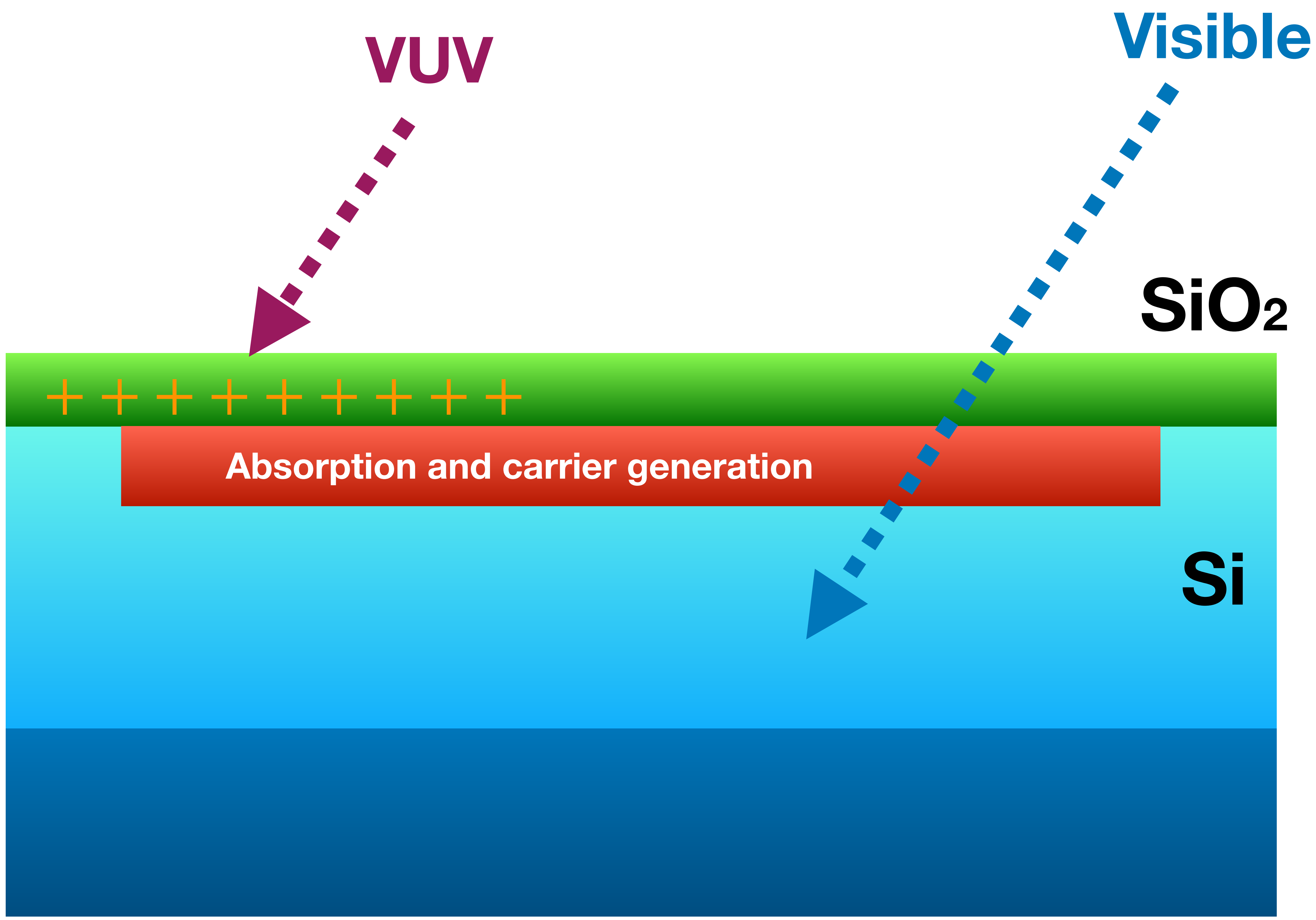


- **Degradation of MPPC VUV-sensitivity**
  →quite fast ~0.05%/hour
  (under MEG II beam intensity $7 \times 10^7 \mu/\mathrm{sec}$ **)**

- **MEG II DAQ time (design) : 140 days/year, 3 years**
  →This degradation is a serious problem

- **A possible cause: Gamma, Neutron irradiation**
  →In lab test, no effect on PDE was observed

Possible cause : surface damage by VUV light



- Electron-holes are generated in SiO2 by VUV light
- Holes are trapped at interface SiO_2-Si
- The electric field near the boundary of the two surfaces will be reduced by the holes
  →Collection efficiency will be reduced
- Degradation may be accelerated at low temperature
  →Holes hardly move
  →Anealing is one of solutions

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Overview of the measurement

- Previous research : Irradiation measurement was done at room temp
    - Degradation speed was much lower than LXe detector
- In this measurement : Approached to actual environment
    - Temperature : Used refrigerator and heater control to keep ~160K
- Irradiation source : Xe-lamp is used
    - To reach the dose level of LXe detector in realistic time

Measurement flow

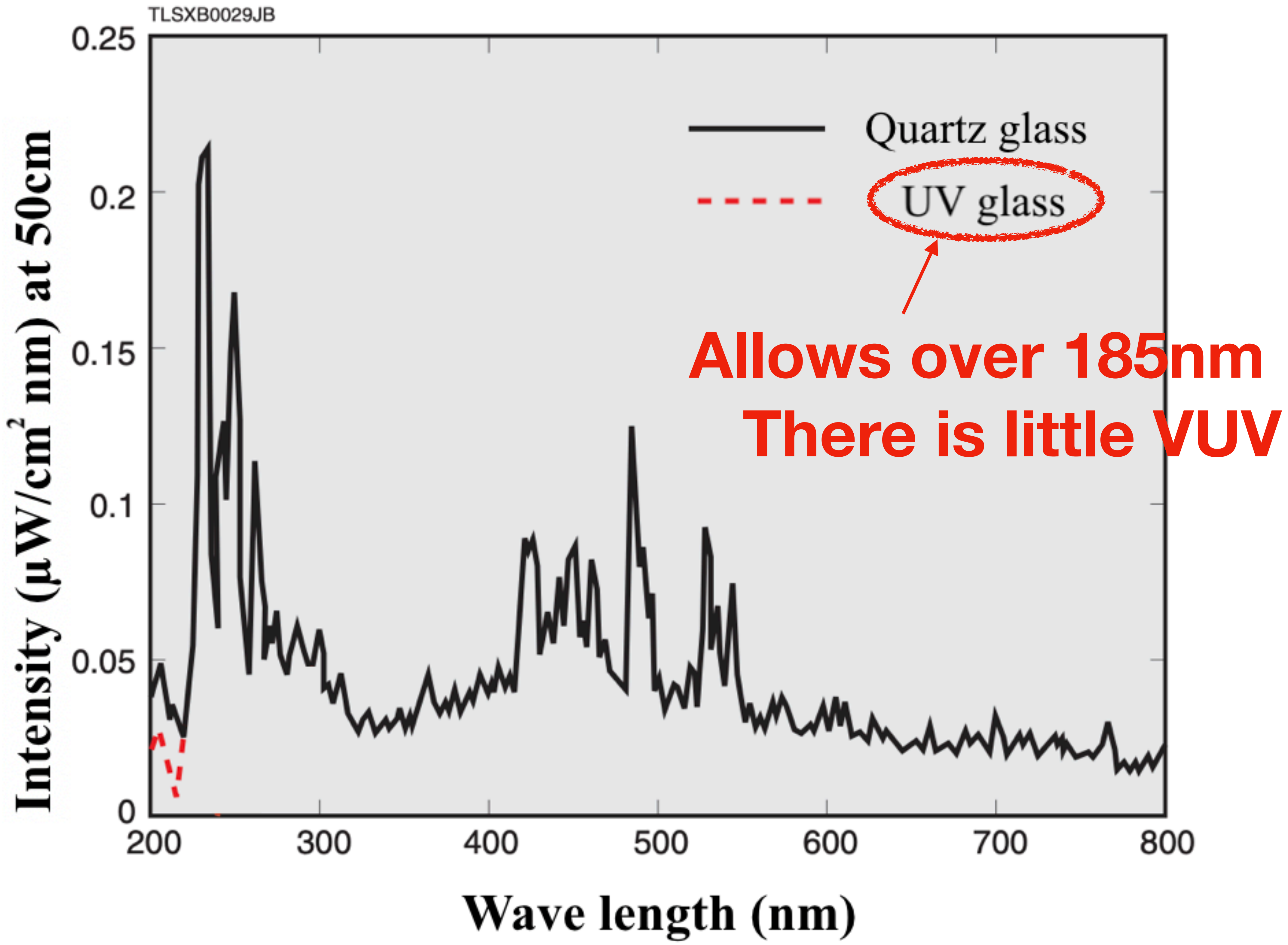
1 : Measure PDE for UV and visible
- To observe difference of PDE b/w UV and visible

2 : Irradiate VUV-MPPC for 24h at room/low temp

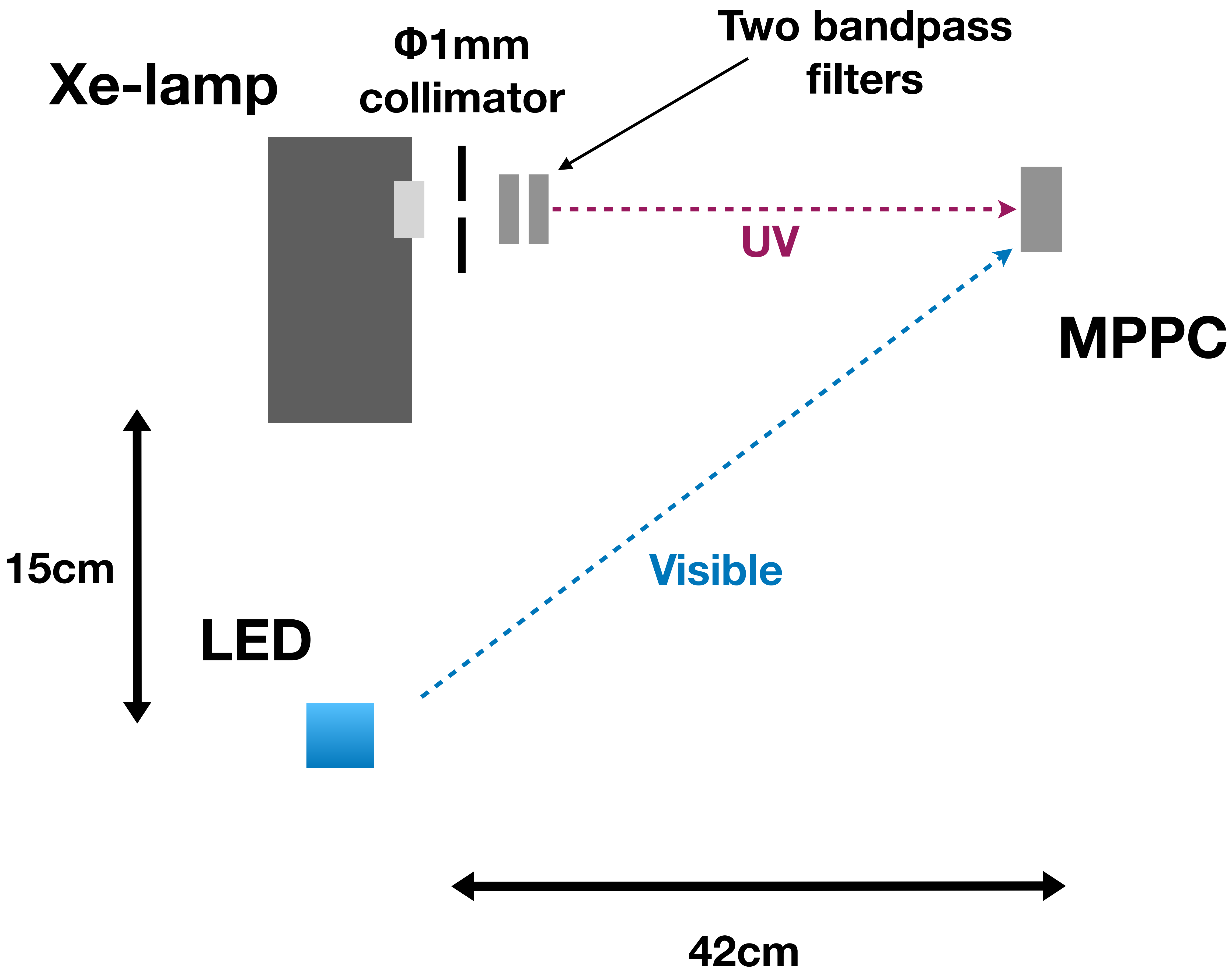
3 : Measure PDE for UV and visible again

4 : Compare the PDE decrease b/w room and low temp

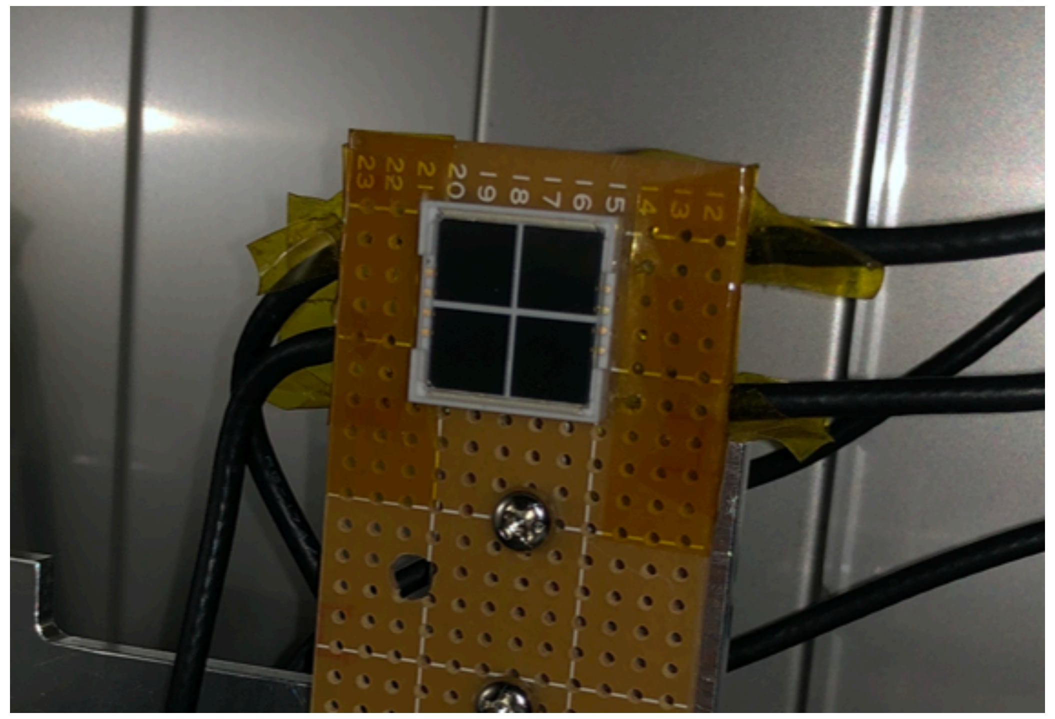
Irradiation source



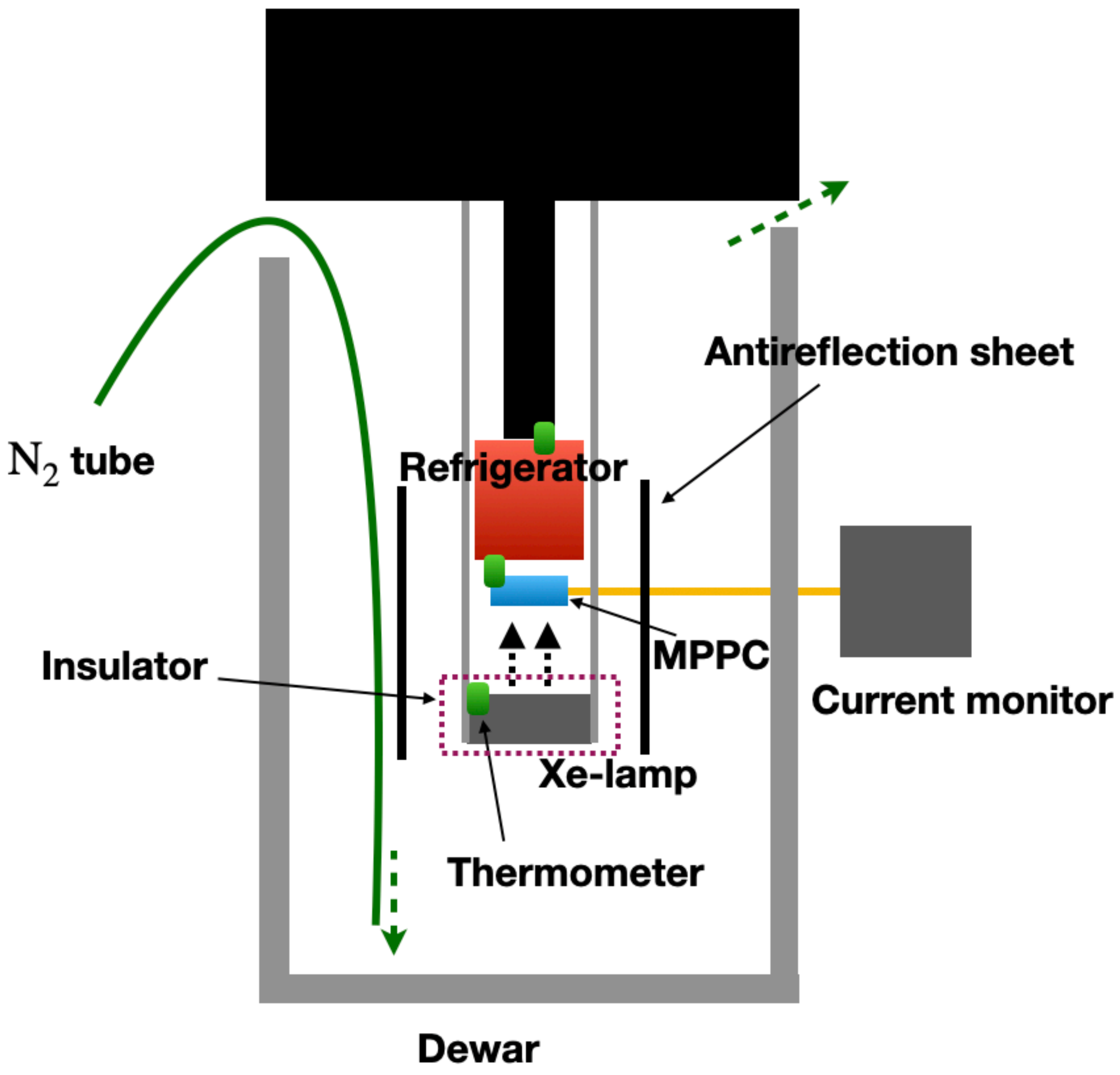
Setup for charge measurement



- Charge was measured by oscilloscope to observe PDE decrease
- Irradiate MPPC by Xe-lamp w/ filter and PDE for UV was observed
  - UV : 185nm~400nm
- Irradiate MPPC by LED w/o filter and PDE for visible was observed
  - visible : ~450nm
- 4 chips of VUV-MPPC was used
  - Two MPPCs are used separately room/low temp
  - Non irradiated MPPC was also used as a reference



Setup for irradiation

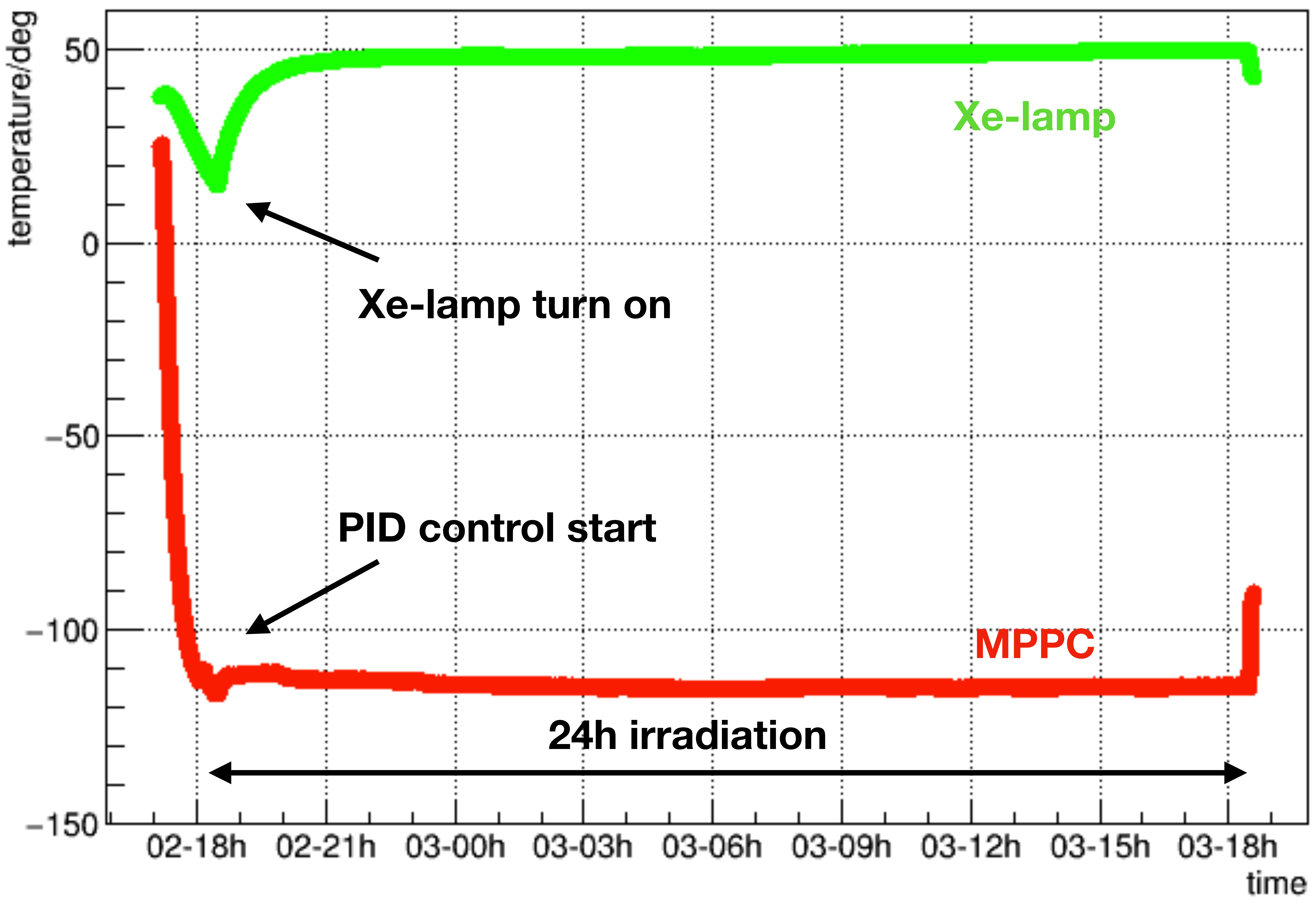


- MPPC is mounted on pulse tube refrigerator
- Xe-lamp is fixed in Dewar
  - Irradiate MPPC directly
  - 3cm away from the lamp window

    →total dose level of UV will reach 2019run in ~10sec
- Make N_2 flow
  - Prevent dew formation
- 2ch current monitor
  - MPPC’s response to irradiation light was monitored w/o HV

※Room temp
- Basically the same as Low temp
- Prevent Xe-lamp temp rising

Temperature control



Refrigerator : Aisin TAC 101J

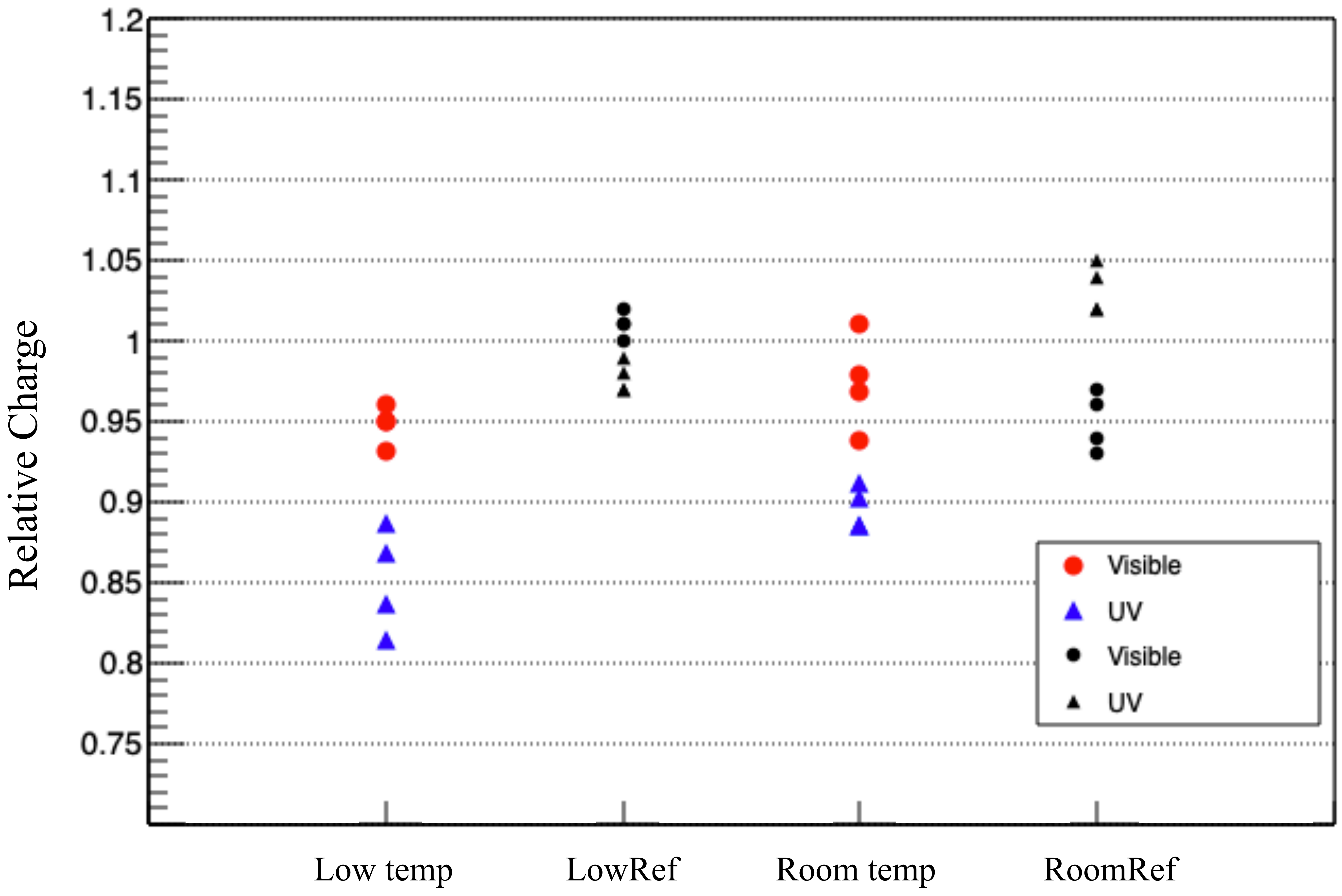
- Pulse-tube type
- Can only cool

To keep temp stable we performed PID control

- Using heater and thermometer

→succeeded at keeping temp of 161K - 162K

Result



- UV PDE decrease at low temp was larger than at room temp
  - Low : 14.8%
  - Room : 10.4%

- At low temp, UV PDE decrease was larger than visible
  - UV : 14.8%
  - Visible : 5.2%

Summary

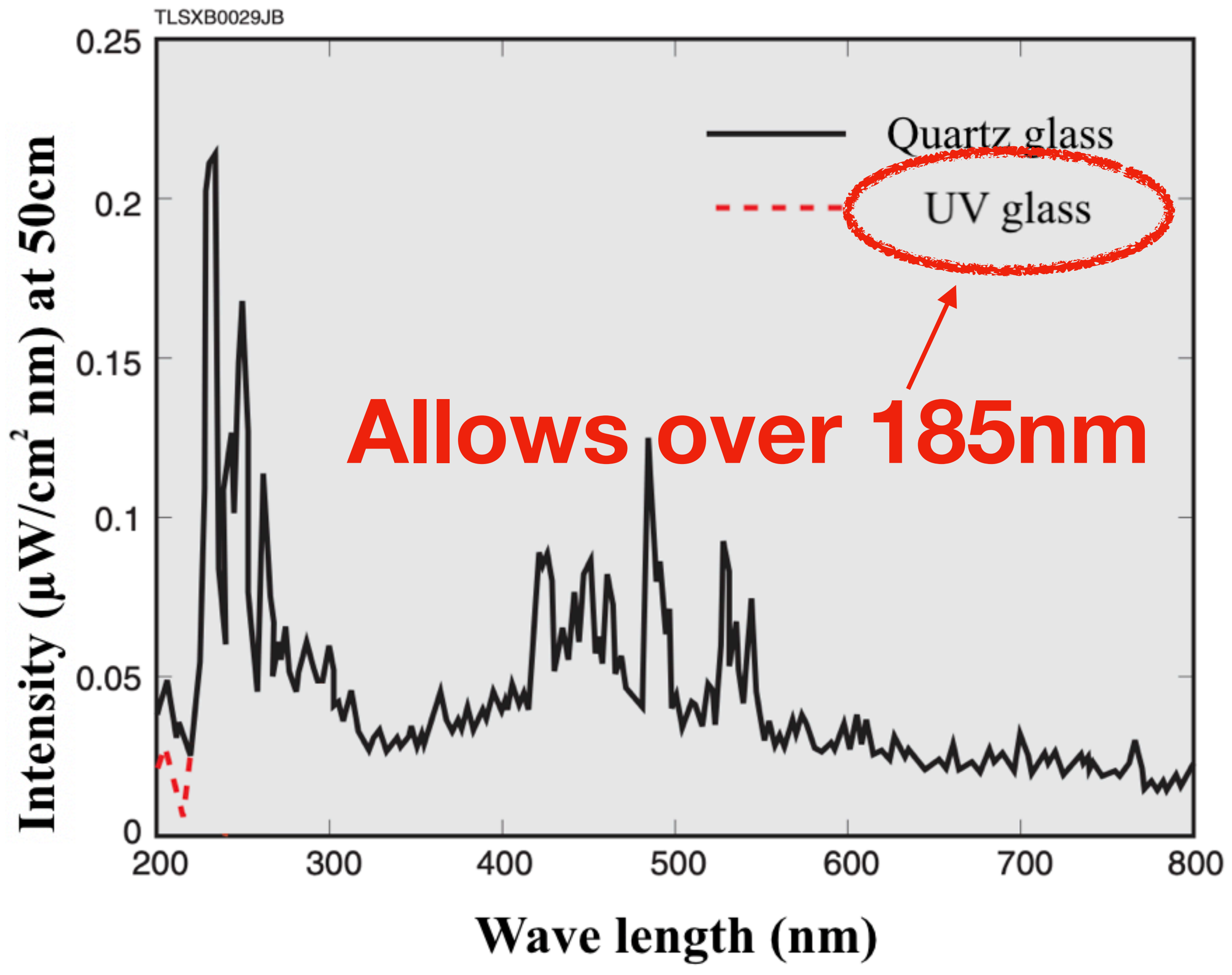
- In MEG II LXe detector, PDE decrease for VUV was observed
  - May be accelerated at low temp

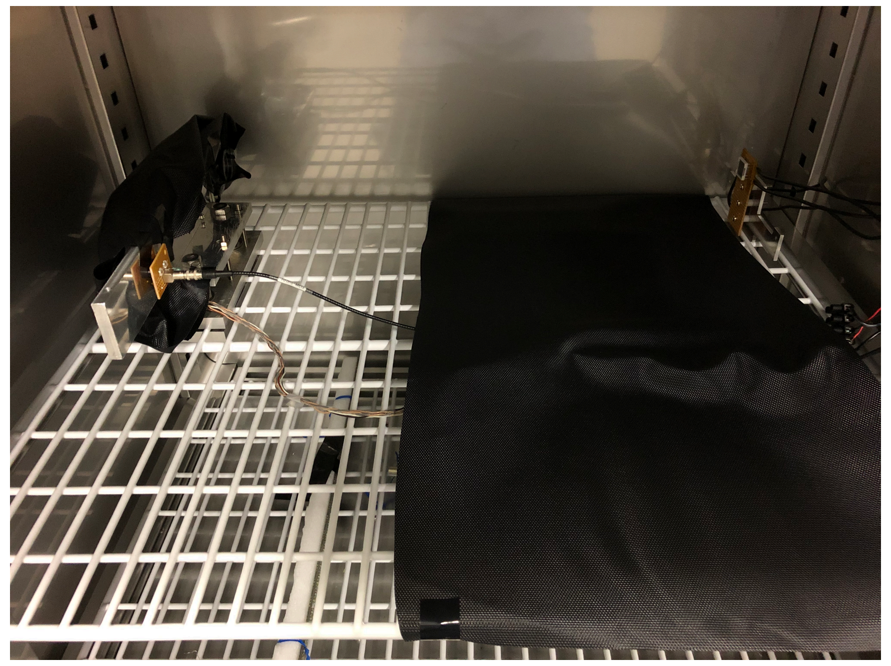
- We performed irradiation by Xe-lamp at room temp and low temp
  - UV PDE decrease at low temp was larger than at room temp
    - Low temp effect was observed
    - But, degradation speed was much lower than LXe detector
    - We need to irradiate with VUV

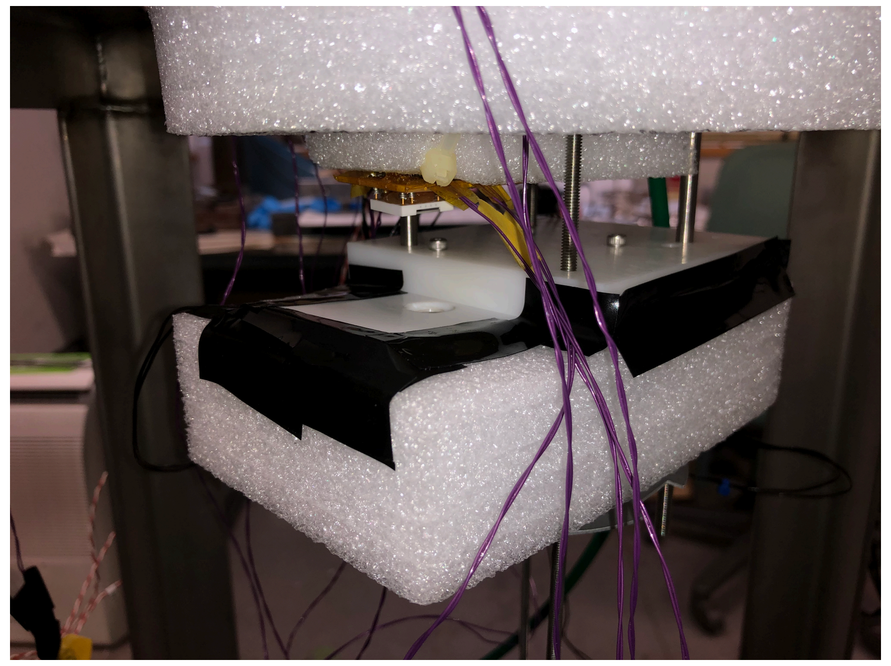
	Xe-lamp	MEG II LXe
Total dose level	4.5e16 photon	4.4e12 photon
PDE decrease	14.8%(UV)	9%(VUV)

Prospect

- Main purpose : Understand the situation of PDE decrease in MEG II LXe detector
  - We don’t know how PDE decrease in a few years
- Xe-lamp window is UV glass
  - Not allow under 185nm photon (LXe scintillation : 175nm)
    →Xe-lamp with quartz window
- Bandpass filters
  - Filters have transmittance peak at ~190nm
  - But 300nm~400nm photons couldn’t be rejected
    →more filters, another light source
- Optical system
  - We need to move Xe-lamp b/w PDE measurement and irradiation
  - There may be changes in optical system and it can cause change of reference PDE
    →use two light sources

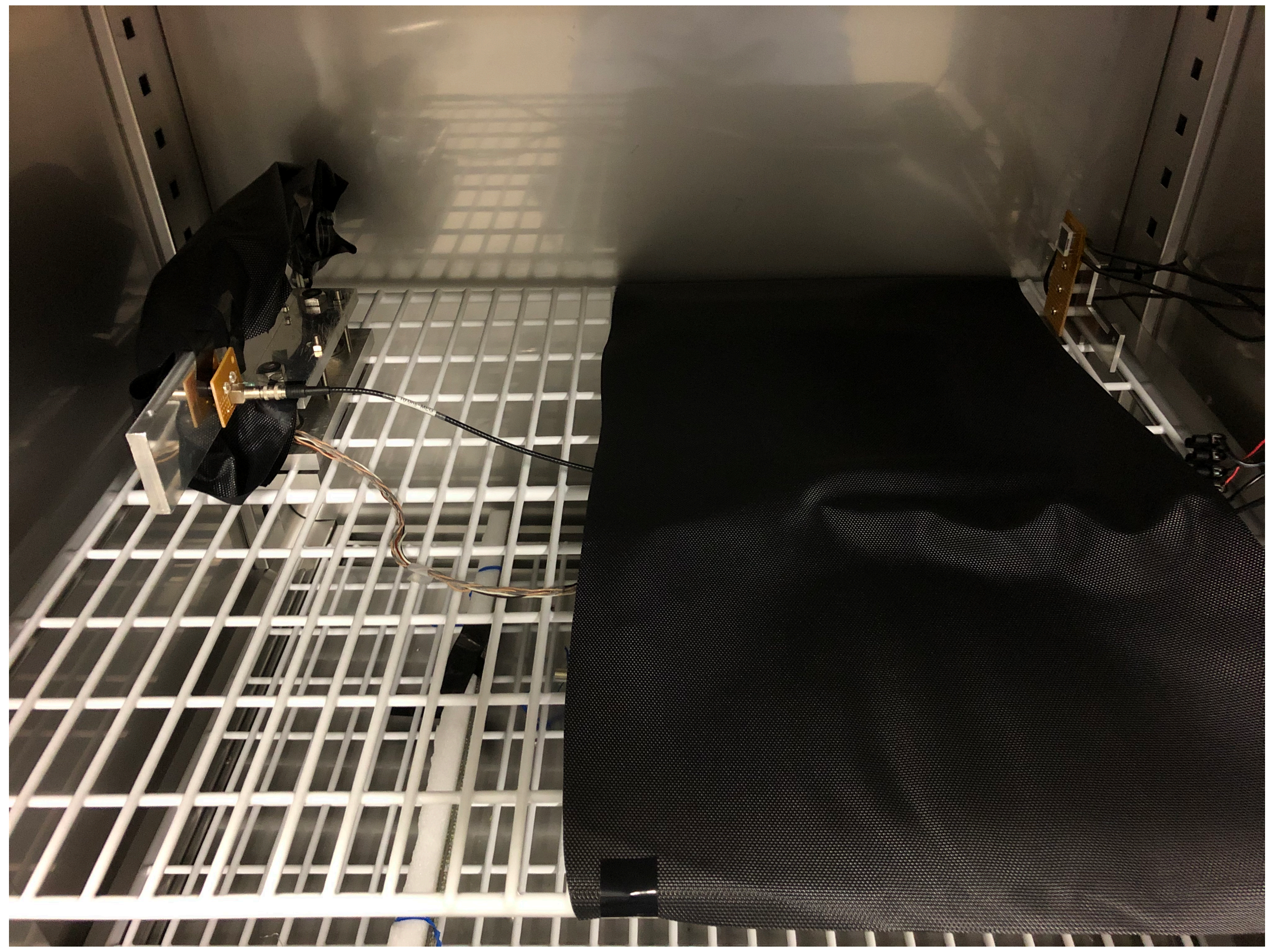






Backup slides

Dose level of Xe-lamp at 45cm w/ bandpass filter 25%*25% and ϕ1mm slit

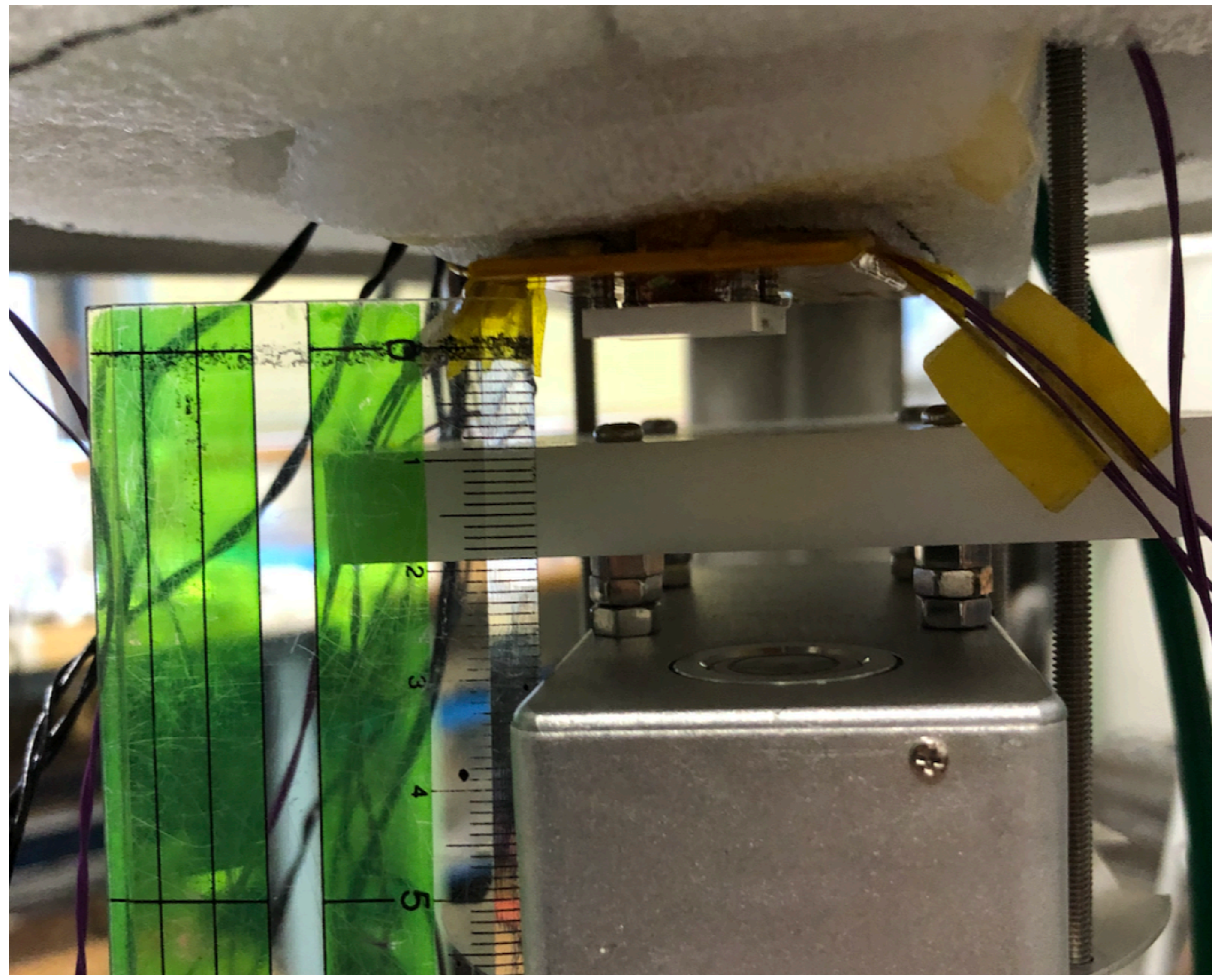


$\cdot\ N_{phe,VUV} = 60\mathrm{p.e./mm^2 \cdot pulse}$

$\rightarrow N_{pho,VUV} = 400\mathrm{photon/mm^2 \cdot pulse}$ if $\mathrm{PDE} = 15\,\%$

$$\rightarrow N_{pho,VUV} = \underbrace{400 \times 144}_{\text{4chip}} \div \underbrace{(0.25)^2}_{\text{Filters}} \times \underbrace{500\mathrm{Hz}}_{\text{Lamp freq}} \times \underbrace{\left(\frac{3\mathrm{mm}}{1\mathrm{mm}}\right)^2}_{\text{Window ratio}} \times \underbrace{\left(\frac{42\mathrm{cm}}{3\mathrm{cm}}\right)^2}_{\text{Distance ratio}} \mathrm{photon/ch}$$

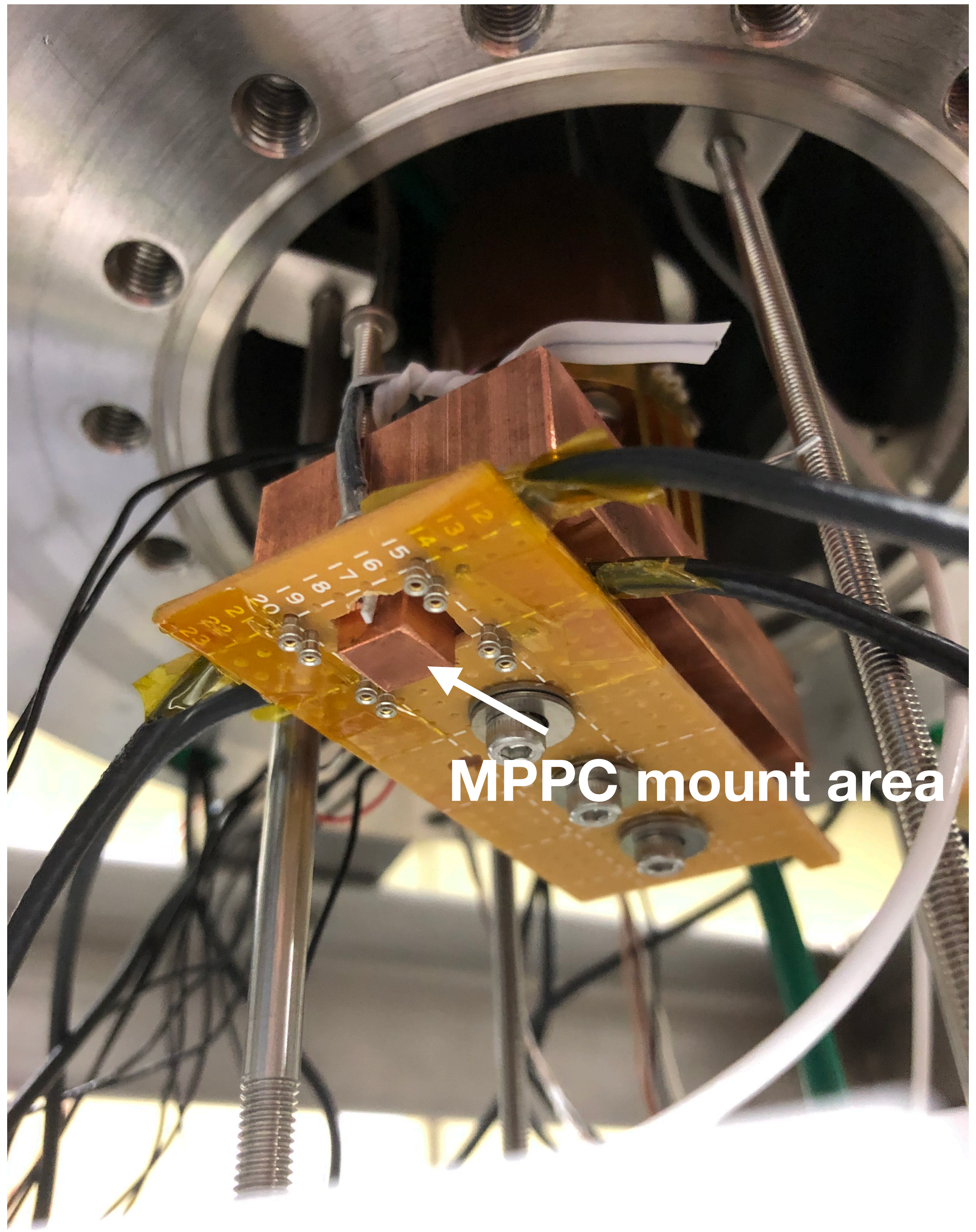
$$= 2.1 \times 10^{12}\mathrm{photon/ch \cdot sec}$$

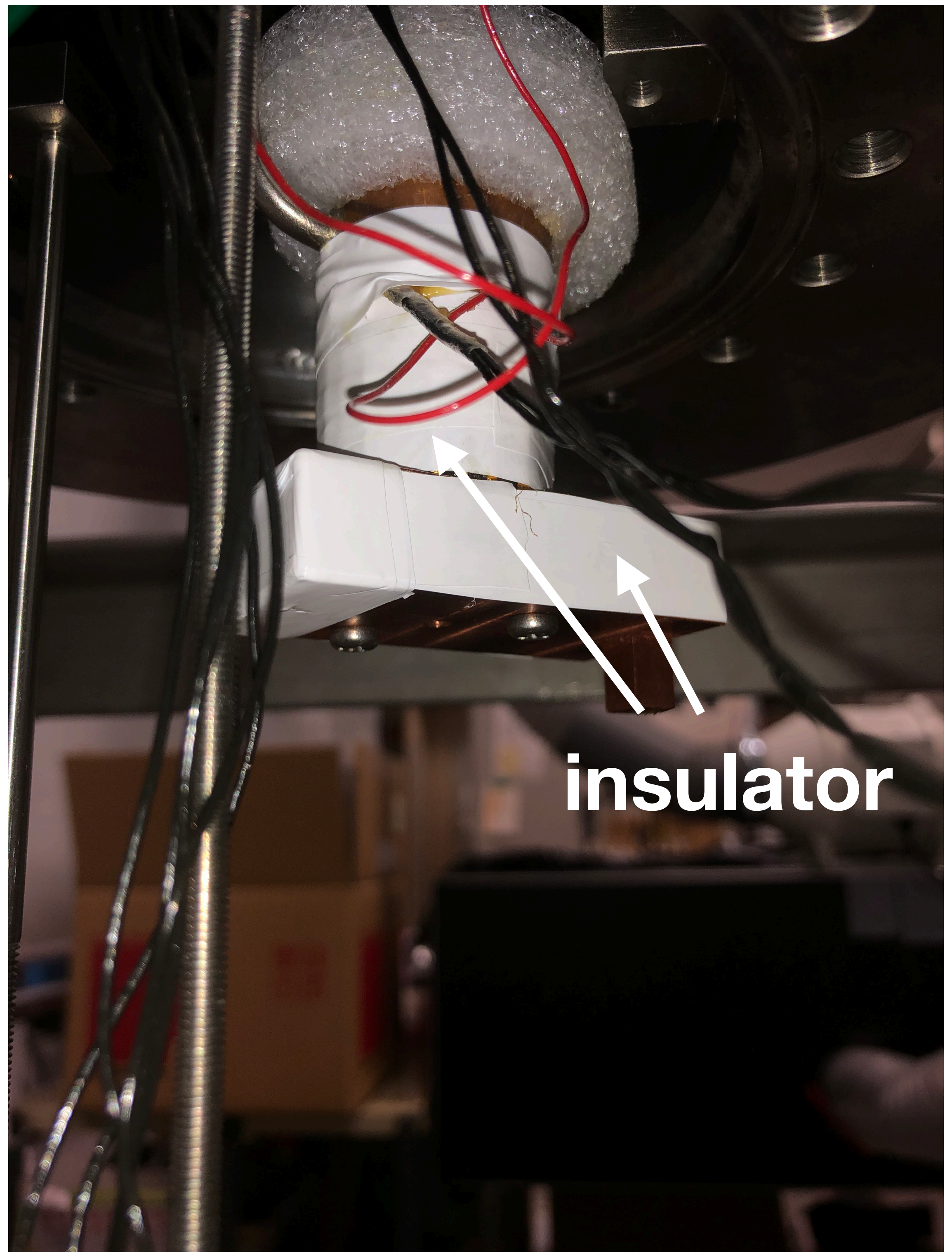


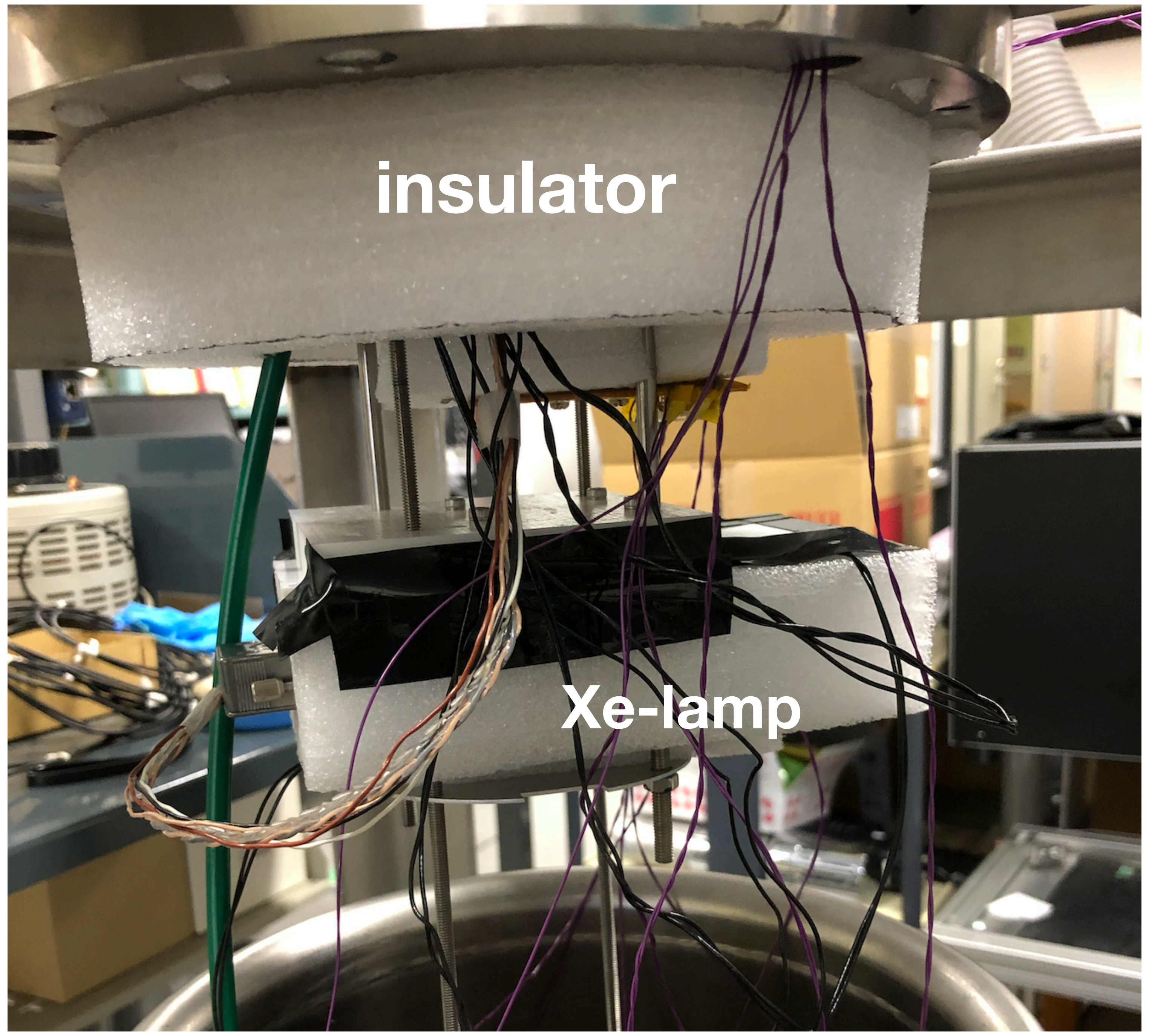
$\cdot\ N_{pho,2019} = 1.0 \times 10^{13} - 2.5 \times 10^{13}\mathrm{photon/ch}$

It will take ~10sec to reach 2019 run at low-temp

Reached LXe temp

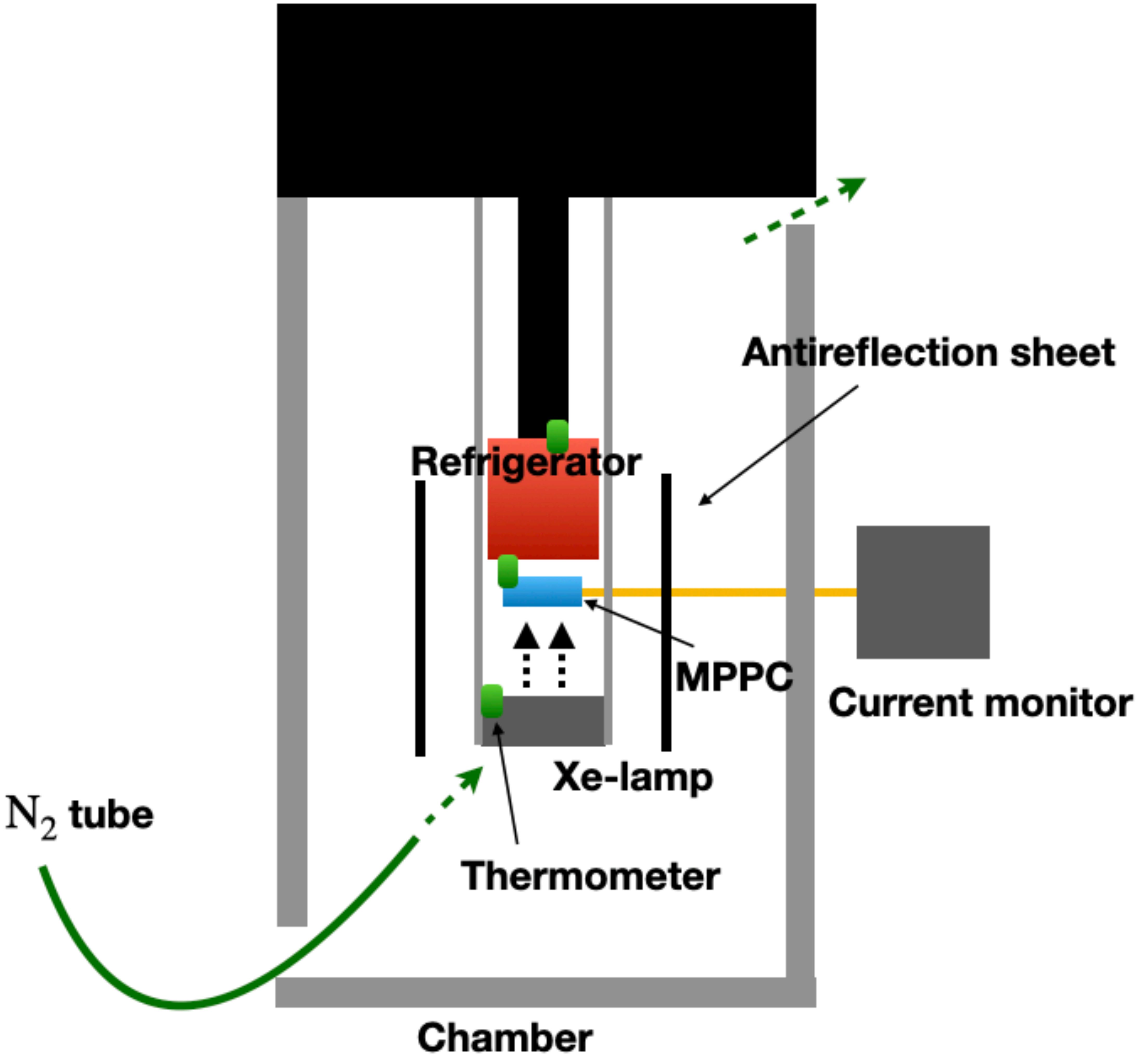






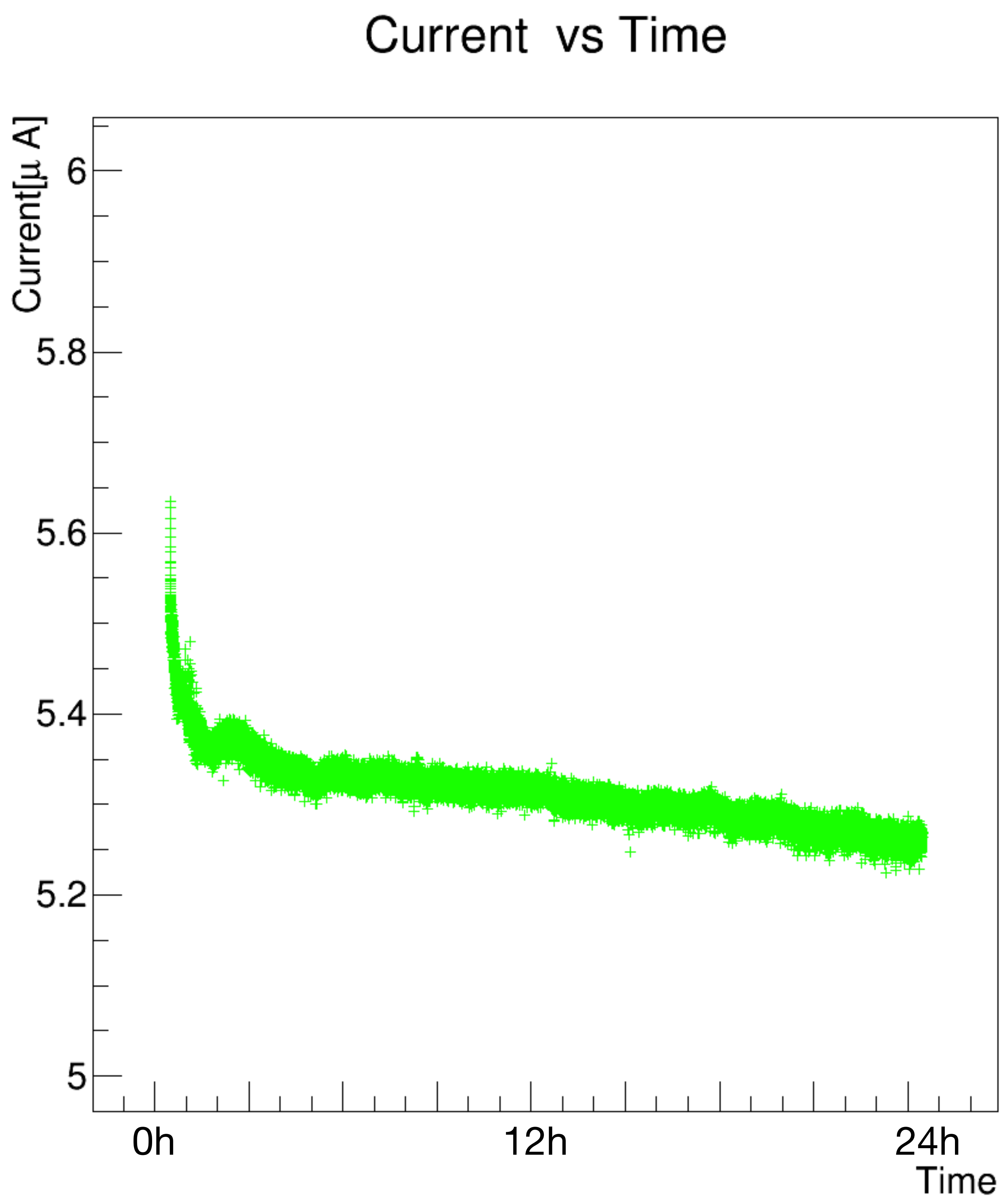
- Apply grease b/w connecting part
  - Efficiently transfer low temp from refrigerator to MPPC
- Cover Xe-lamp and refrigerator with insulator
  - Prevent low temp from being taken by N_2 gas

Setup for irradiation at room temp

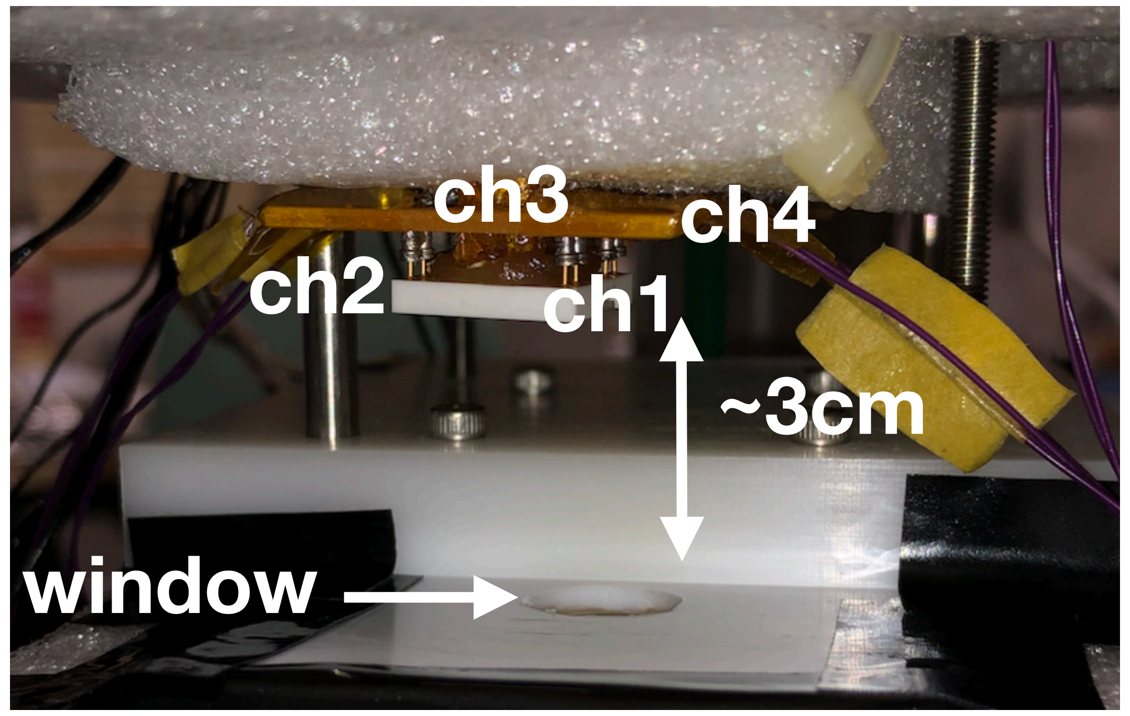


- MPPC is mounted on refrigerator
  - refrigerator not running
- Make N_2 flow
  - make the same condition as at low temp
- 2ch current monitor
- N_2 gas hit Xe-lamp directly
- Dewar → Chamber
  - prevent temperature of Xe-lamp increase

Result at low temp



- Current decrease was observed during 24h irradiation
  - Probably represents the PDE decrease
- Temp (~160K) is stable
- PDE decrease for UV is larger than visible
- PDE decrease of the channels in front of Xe-lamp window (ch1,4) are larger than other two channels(ch2,3)
- Charge measurement results are as written below

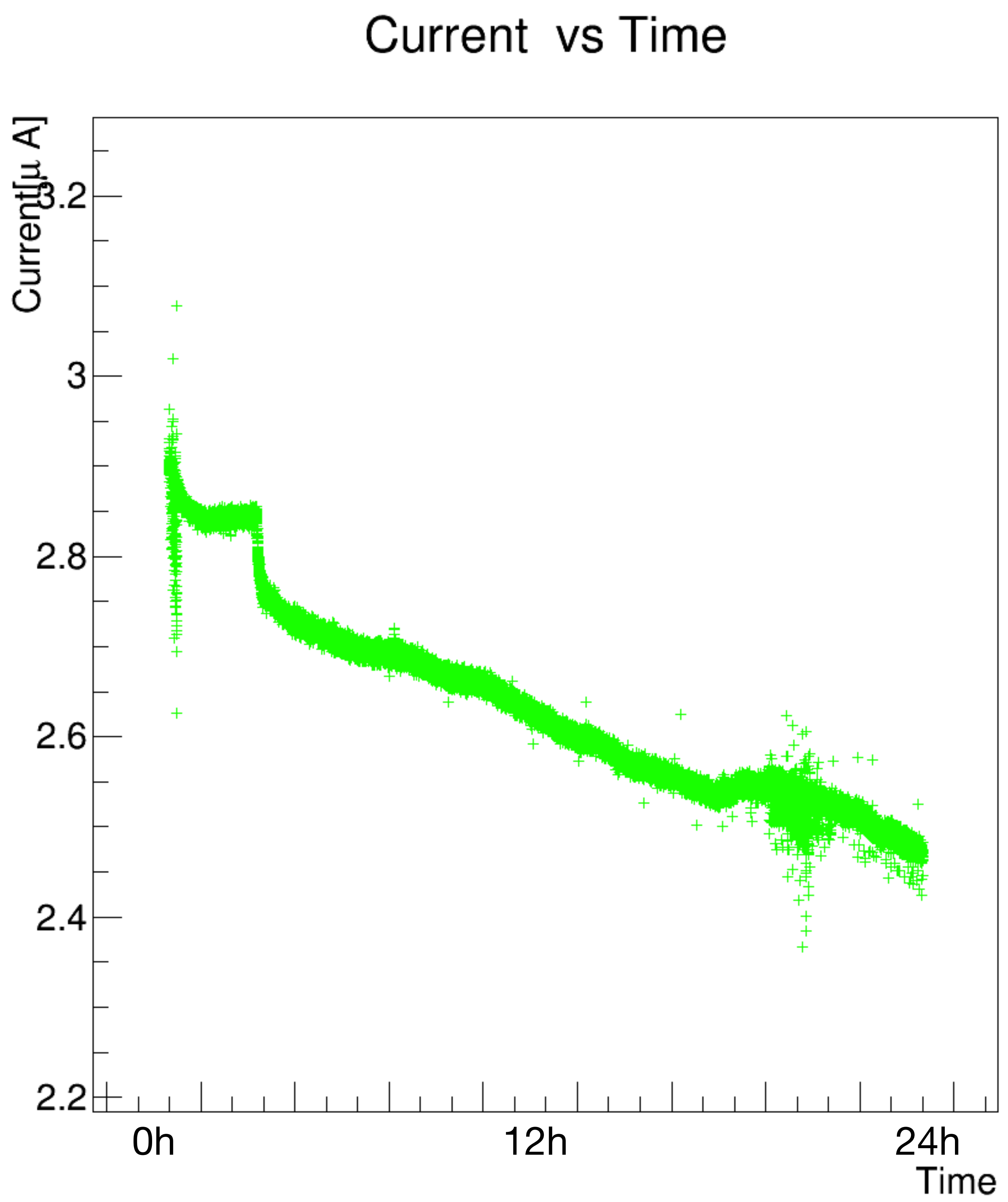


(Normalized with charge before irradiation)

irradiated	Visible	UV
ch1	0.95	0.79
ch2	0.97	0.86
ch3	0.95	0.86
ch4	0.96	0.82

non-irradiated	Visible	UV
ch1	1.02	0.97
ch2	1.01	0.99
ch3	1.00	0.97
ch4	1.01	0.98

Result



- Current decrease was observed during 24h irradiation
  - Rate of decrease is lager than at low temp
- N_2 flow rate change affected current decrease rate
  - temperature changed
- There was no significant difference b/w PDE decrease for UV and visible

(Normalized with charge before irradiation)

irradiated	Visible	UV
ch1	0.91	0.93
ch2	0.92	0.92
ch3	0.94	0.93
ch4	0.93	0.92

non-irradiated	Visible	UV
ch1	0.97	1.02
ch2	0.94	1.04
ch3	0.93	1.05
ch4	0.96	1.02

Possible cause : surface damage by VUV light

- Electron-holes are generated in SiO2 by VUV light
- Holes are trapped at interface SiO_2-Si
- The electric field near the boundary of the two surfaces will be reduced by the holes
  →Collection efficiency will be reduced
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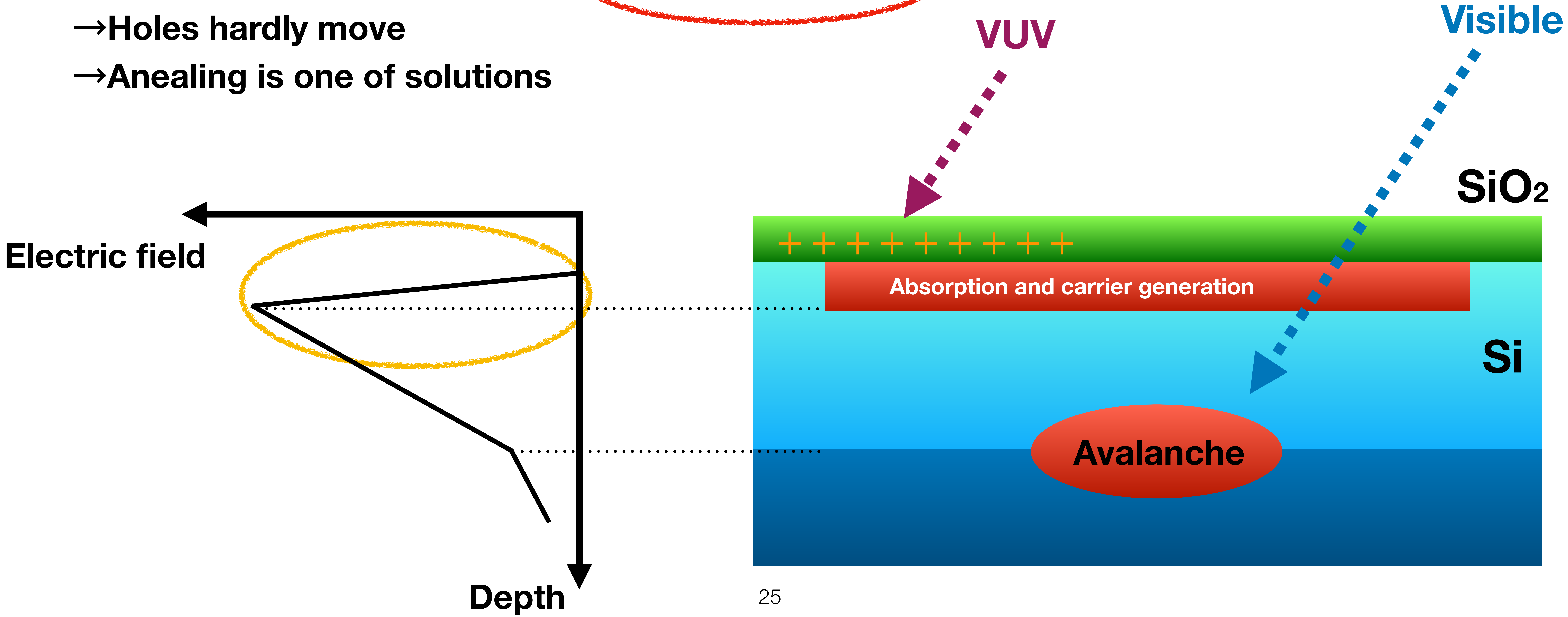

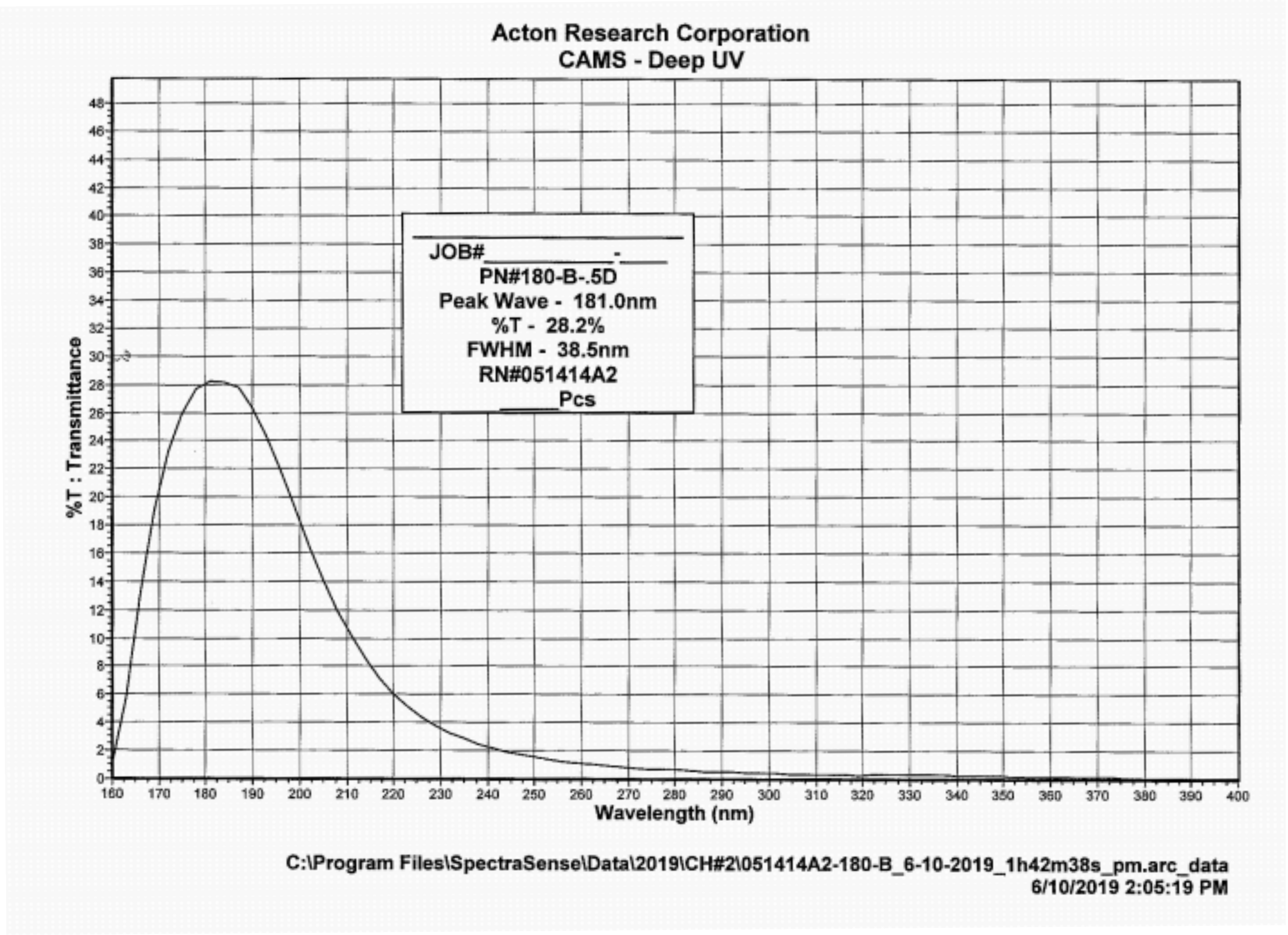
Acton Research Corporation
CAMS - Deep UV
%T : Transmittance
Wavelength (nm)
JOB#_____________-____
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Peak Wave - 181.0nm
%T - 28.2%
FWHM - 38.5nm
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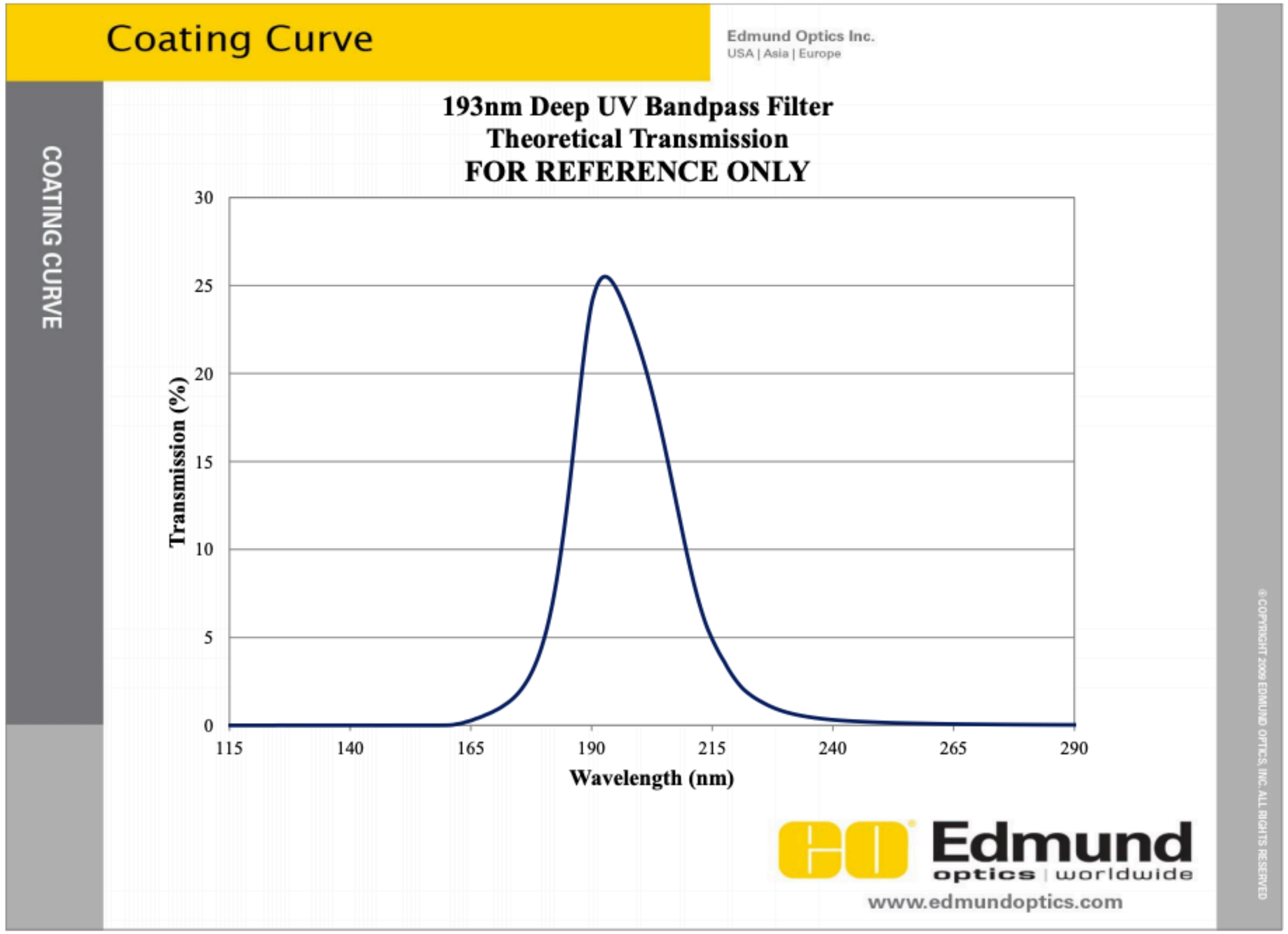
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