Core-to-Core Program

MEG II 実験液体キセノン検出器用MPPCに対して低温環境が与える影響の評価

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The University of Tokyo

Mar. 2020

Introduction

- **The motivation of searching $\mu \rightarrow e\gamma$**
- **Overview of MEG II**
- **Liquid xenon photon detector**

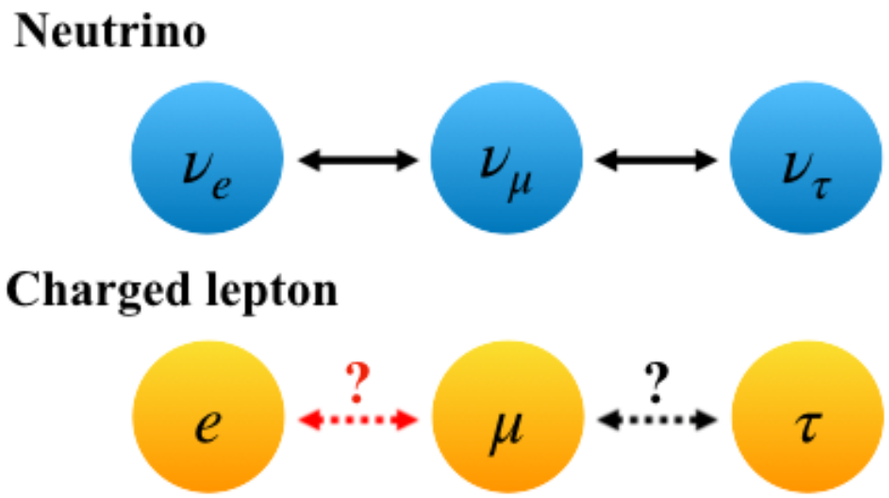
MPPC

- **VUV-sensitive MPPC**
- **The mechanism of VUV detection**
- **MPPC PDE decrease**
- **Surface damage by VUV light**

Measurement of PDE decrease

- **Motivation of the measurement**
- **Setup**
- **Result**
- **Summary**

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

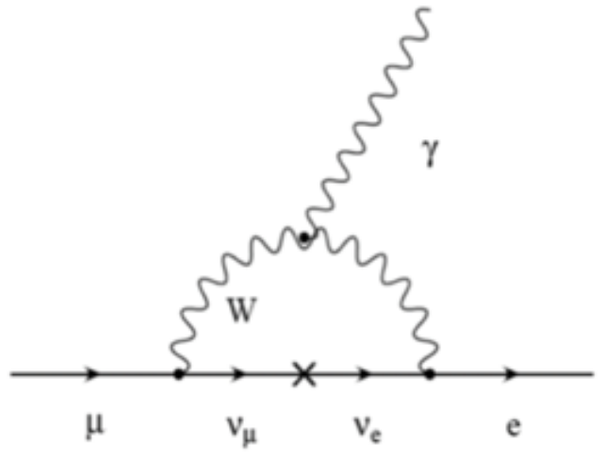


- **Neutrino oscillation was discovered (1998)**
  →Shows that neutrinos have mass and mixing

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

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

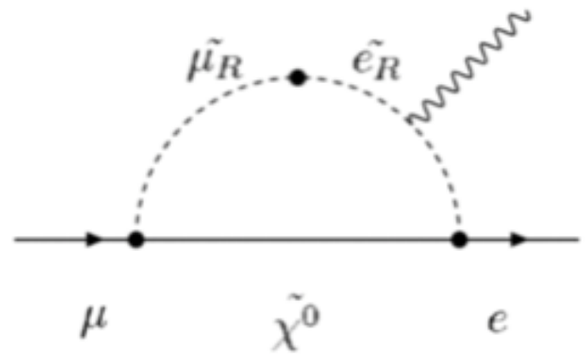
→Cannot be observed



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

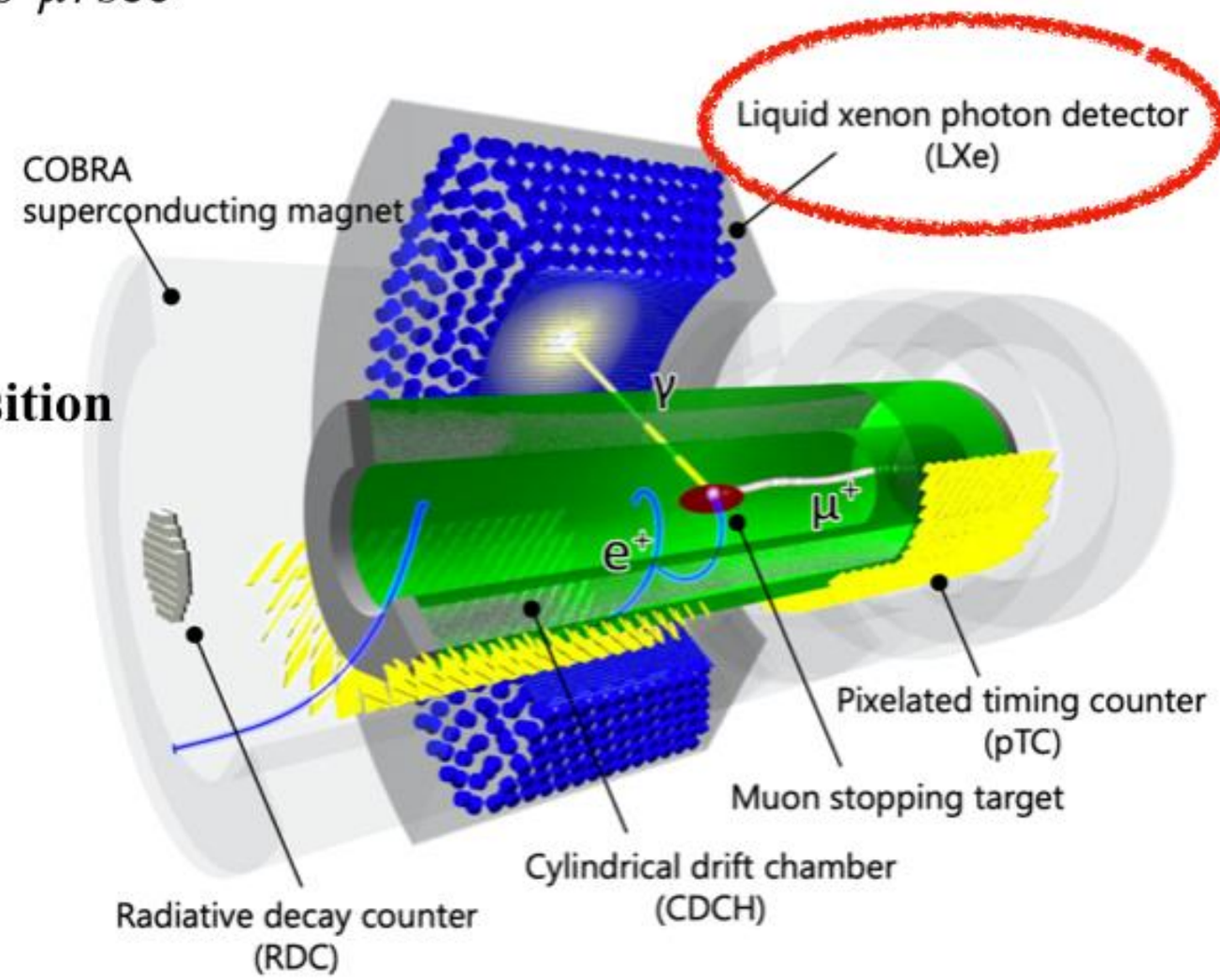
$$Br(\mu \to e\gamma) = \mathcal{O}(10^{-12}) - \mathcal{O}(10^{-14})$$

→Can be observed



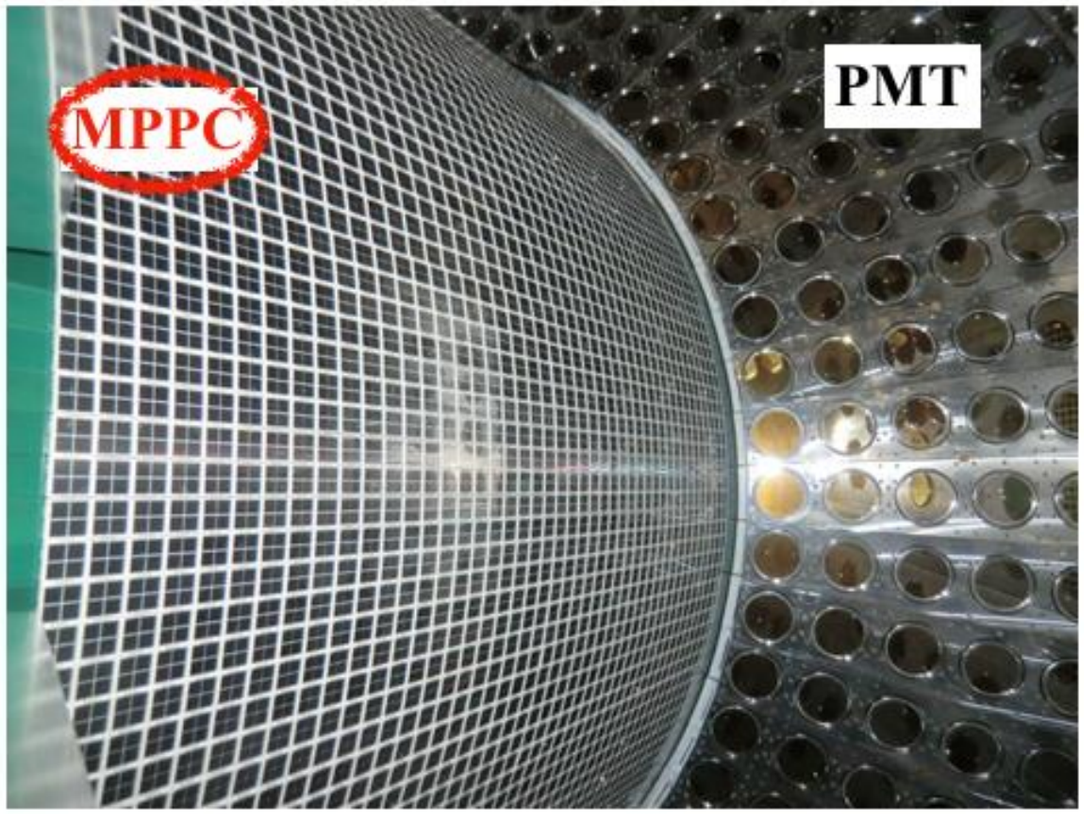
Overview of the MEG II experiment at Paul Scherrer Institut

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

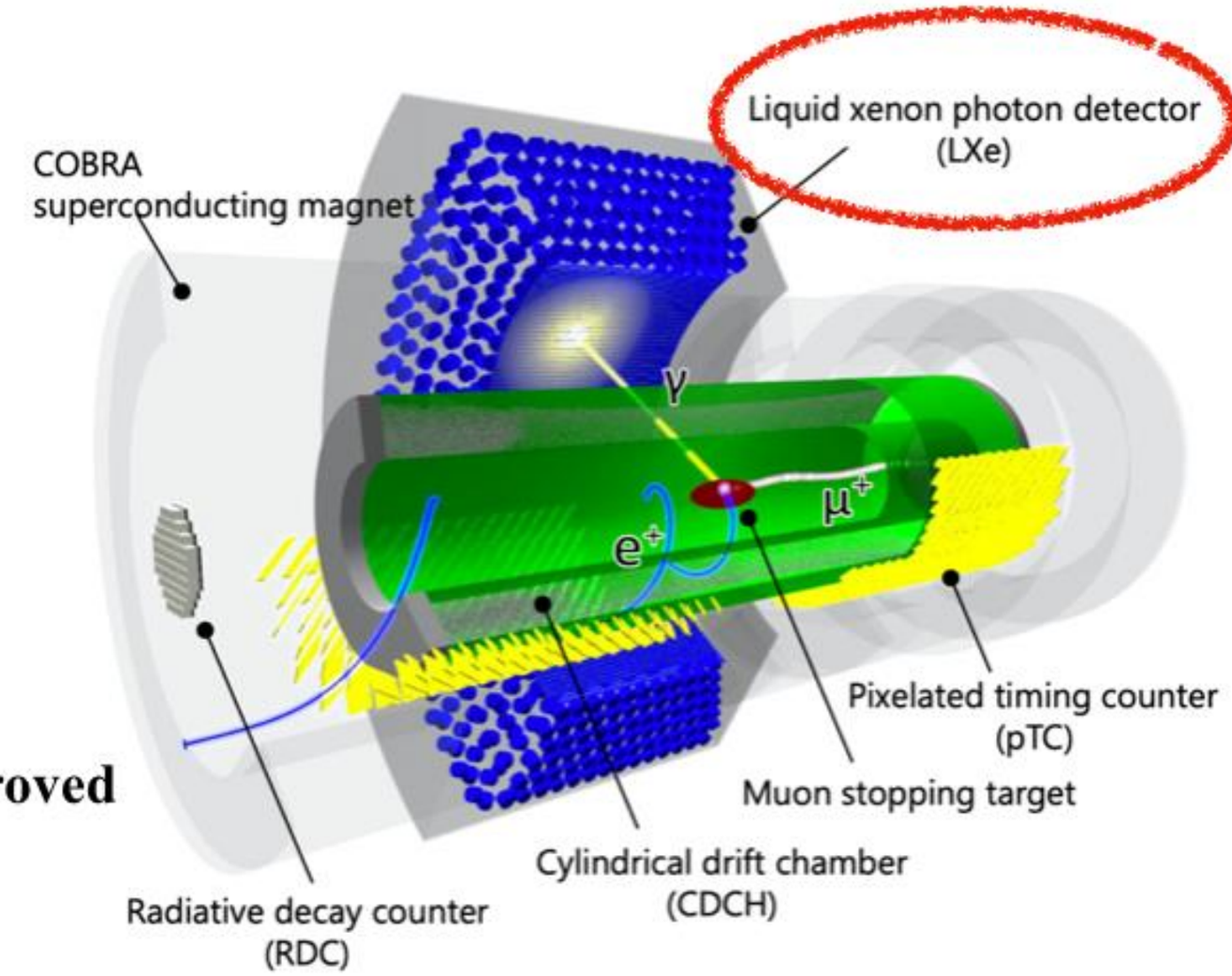


- **The photon energy, interaction point position and time are measured by LXe**

Liquid xenon photon detector (LXe)



- **Liquid xenon to measure 52.8MeV photon**
- **Detect the scintillation ($\lambda = 175$nm)**
- **4092 MPPCs, 668PMTs at 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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- **The mechanism of VUV detection**
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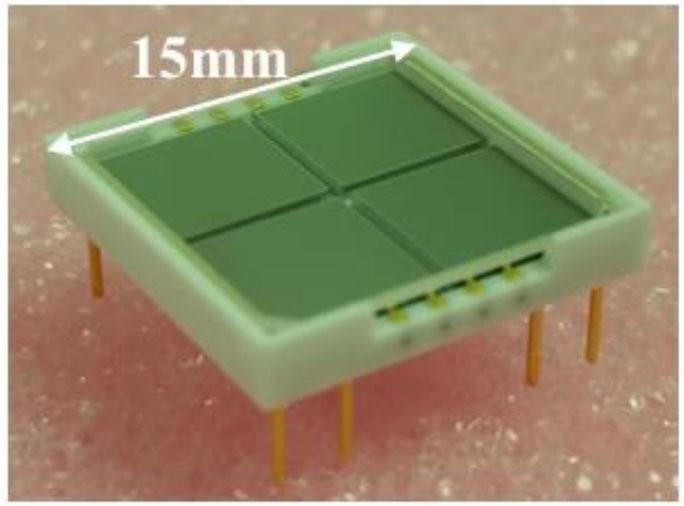
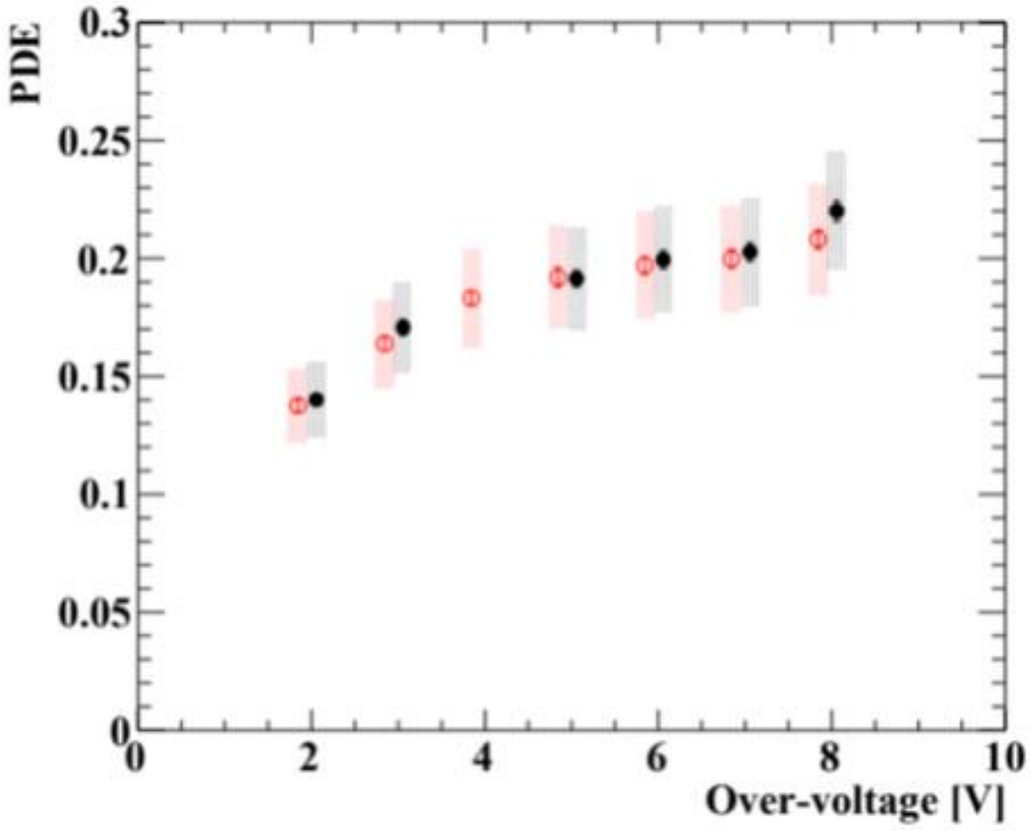
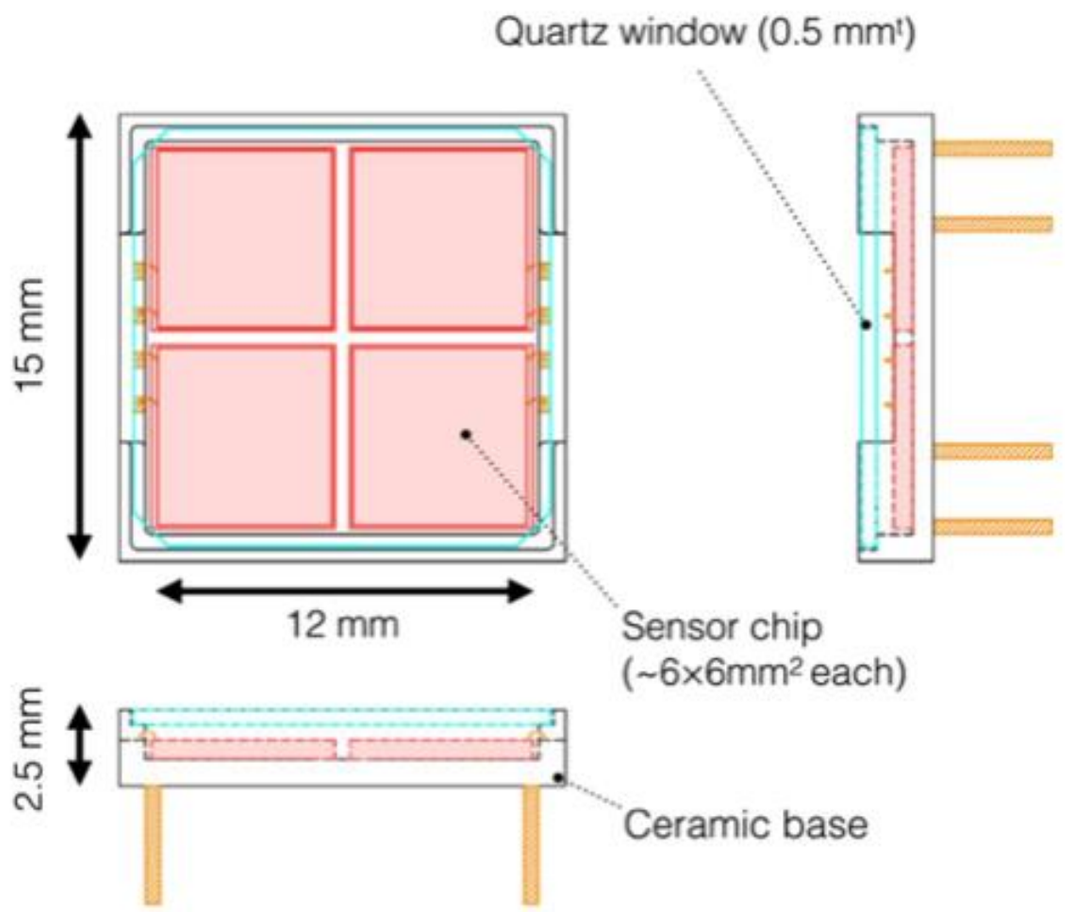
VUV-sensitive MPPC (SiPM)

- **SiPM is a high-performance photon detector**
- **VUV-sensitive MPPC has been newly developed for MEG II**
- **Operational at low temperature (165K)**
- **Photon detection efficiency (PDE) >15% at $\lambda = 175$nm**
- **Large sensitive area** $(12 \times 12\ \mathrm{mm}^2)$







The mechanism of photon detection

- **General SiPM**
  - **Depletion layer : p-n junction**
  - **Incoming photons generate electron-hole pairs**
  - **Reverse voltage is larger than a threshold**

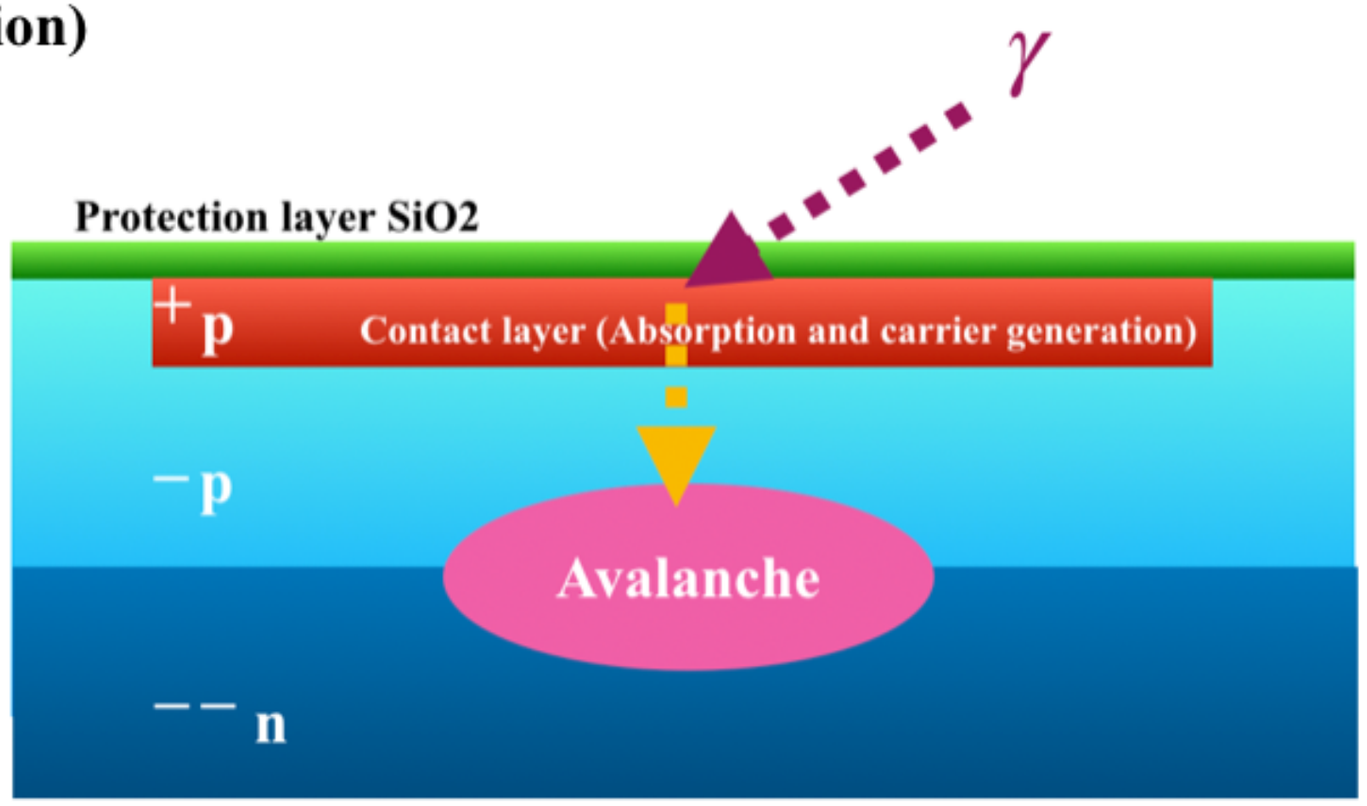
    →"Geiger mode"
  - **In geiger mode, carriers make other carriers**

    →Number of electron-hole pairs increase exponentially (avalanche multiplication) to make a signal
  - **Insensitive to VUV**

    →VUV stops near the surface

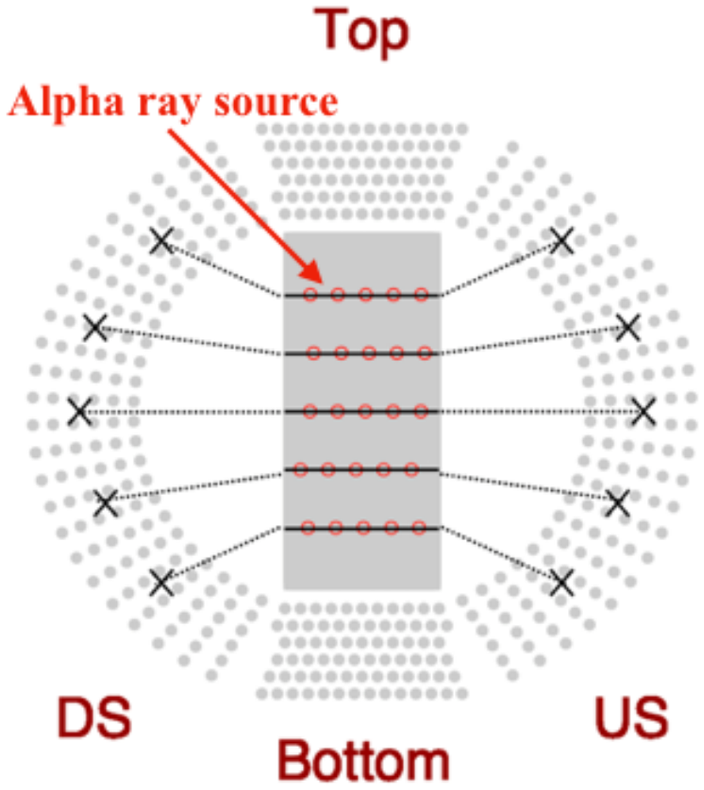
    →Visible light reach the deep part

- **VUV-sensitive MPPC**
  - **Remove the protection coating (epoxy)**
  - **Thin down the contact layer**



VUV-sensitive MPPC PDE decrease

cf. 16pG22-11(Satoru),16pG22-12(Kei),16pG22-13(Shinji)

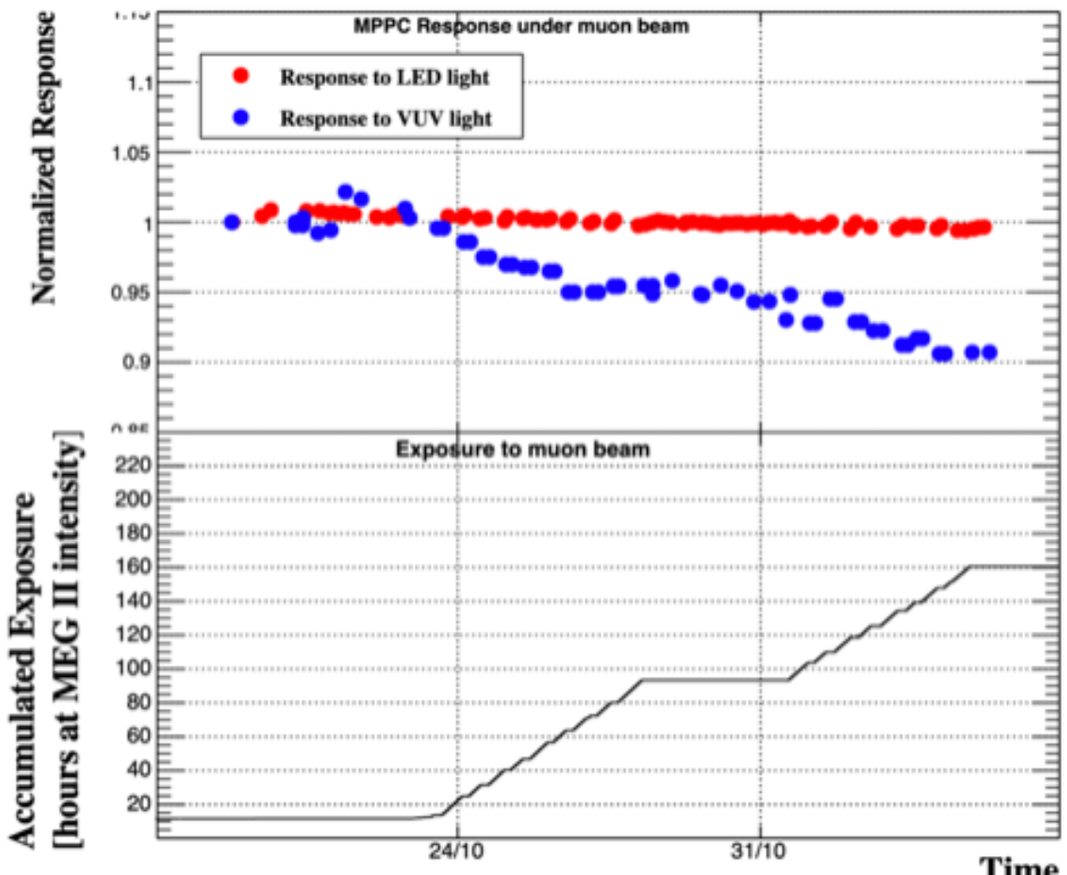


- **Alpha ray sources are in the detector**

  →Produce VUV scintillation light

- $\mathrm{PDE} = \dfrac{\mathrm{N(photon)_{observed}}}{\mathrm{N(photon)_{expected}}} \sim 8\,\%$

  →much lower than that measured in Lab(>15%)



- **Degradation of MPPC VUV-sensitivity**

  →quite fast ~0.05%/hour

  (under MEG II beam intensity $7 \times 10^7 \mu$/sec)

- **MEG II DAQ time (design) : 140 days/year, 3 years**

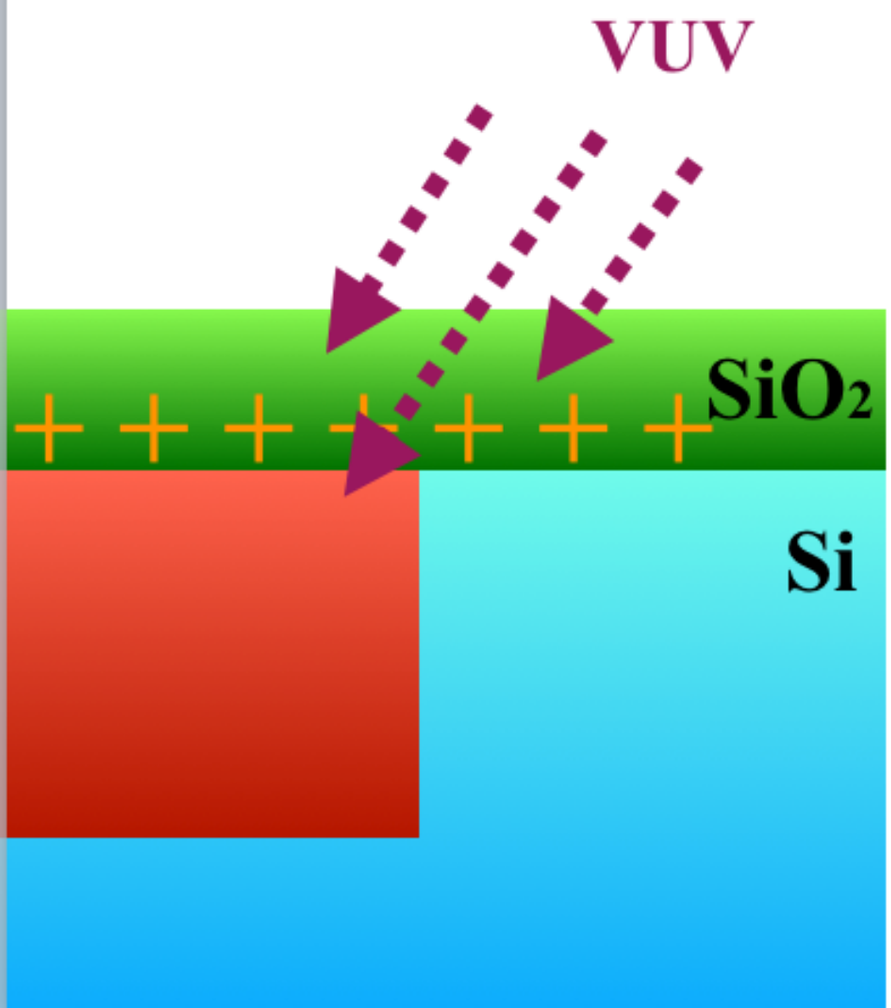
  →This degradation is not negligible

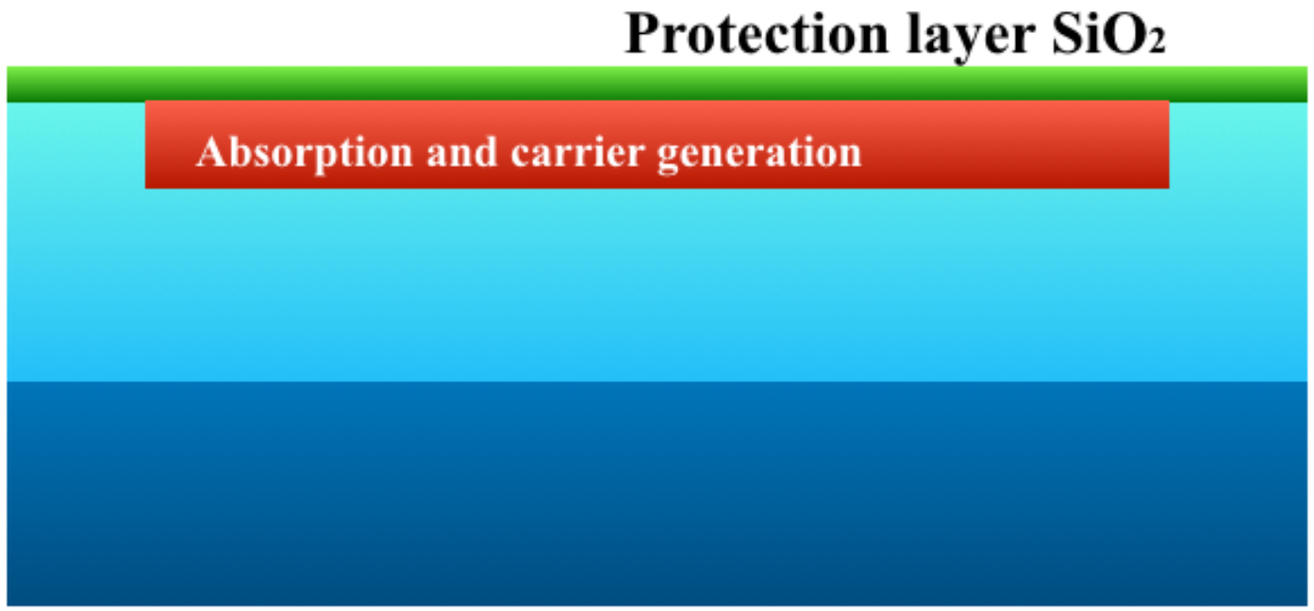
- **A possible cause: Gamma, Neutron irradiation**

  →In lab test, no effect on PDE was observed (at room-temp)

Surface damage by VUV light

- Electron-holes are generated in SiO_2 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 seems accelerated at low temperature
  →Holes hardly move





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Measurement of PDE decrease

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Motivation of the measurement

cf. 17aG22-7(Rina)

PDE degradation of the MPPC was observed in LXe photon detector

- **PDE decrease by VUV irradiation at room-temp was slower than in LXe photon detector**
- **Gamma, Neutron irradiation has no effect on PDE in previous research at room-temp**
  (Cannot exclude the possibility that the irradiation damage(Gamma, Neutron)
  at low-temp is different from room-temp)

- **To survey the effect of low temperature on the PDE decrease**
  →Compare the PDE decrease at room temperature and low temperature

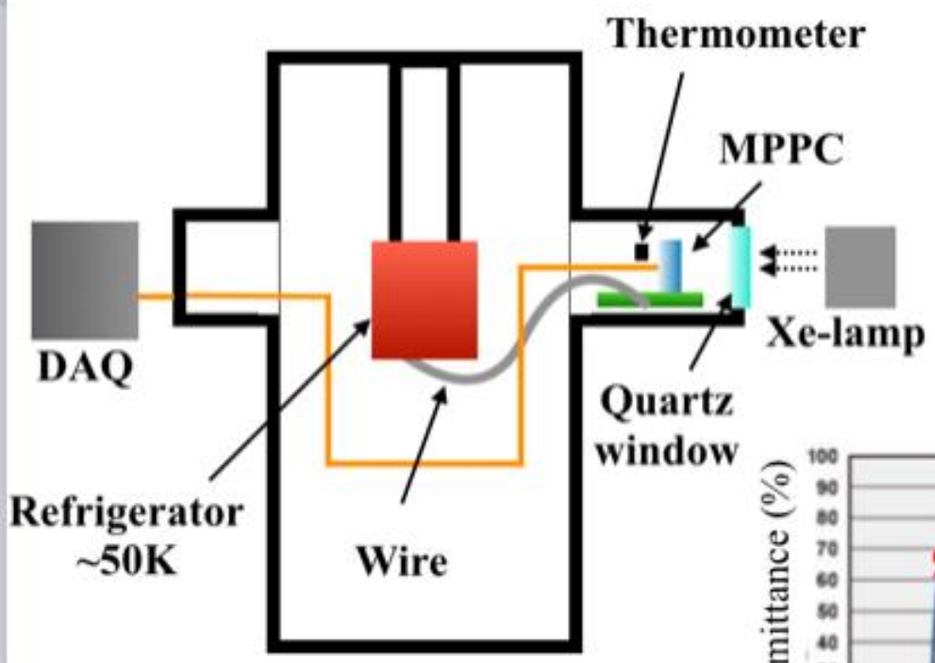
- **To induce and monitor the PDE decrease**
  →Irradiate a MPPC
  →Read current with no bias voltage (Gain 1)
  (in previous research, correlation between current and PDE was observed)

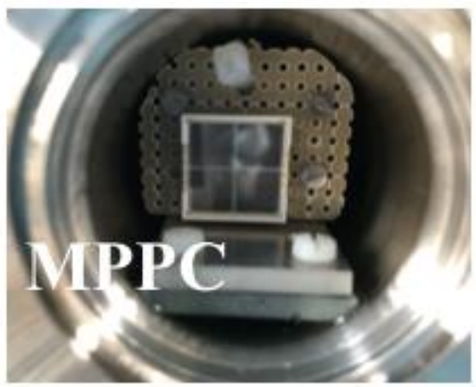
Setup

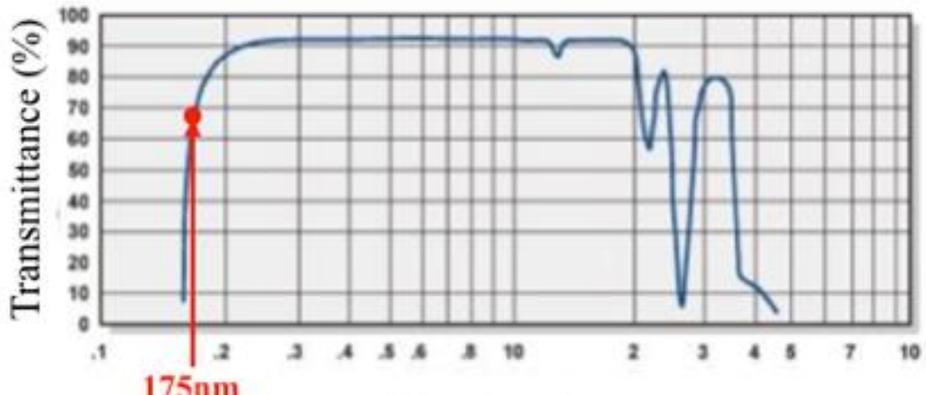
- Make vacuum in the chamber for insulation
- Wire carries low temperature from refrigerator
- ~240K, around the MPPC
  →Could not reach the LXe temp(165K)

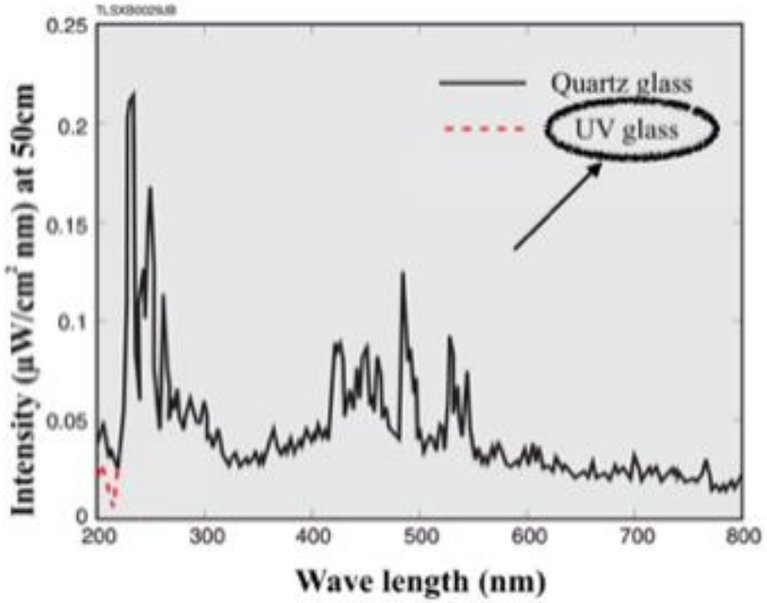
- MPPC is irradiated through quartz window
  →Distance : 5cm
- Read 1chip current (MPPC has 4chip)
  →HV=0V
- Xe flash lamp as a irradiation source
  →To irradiate with short-wavelength light (~175nm)

Chamber









Setup

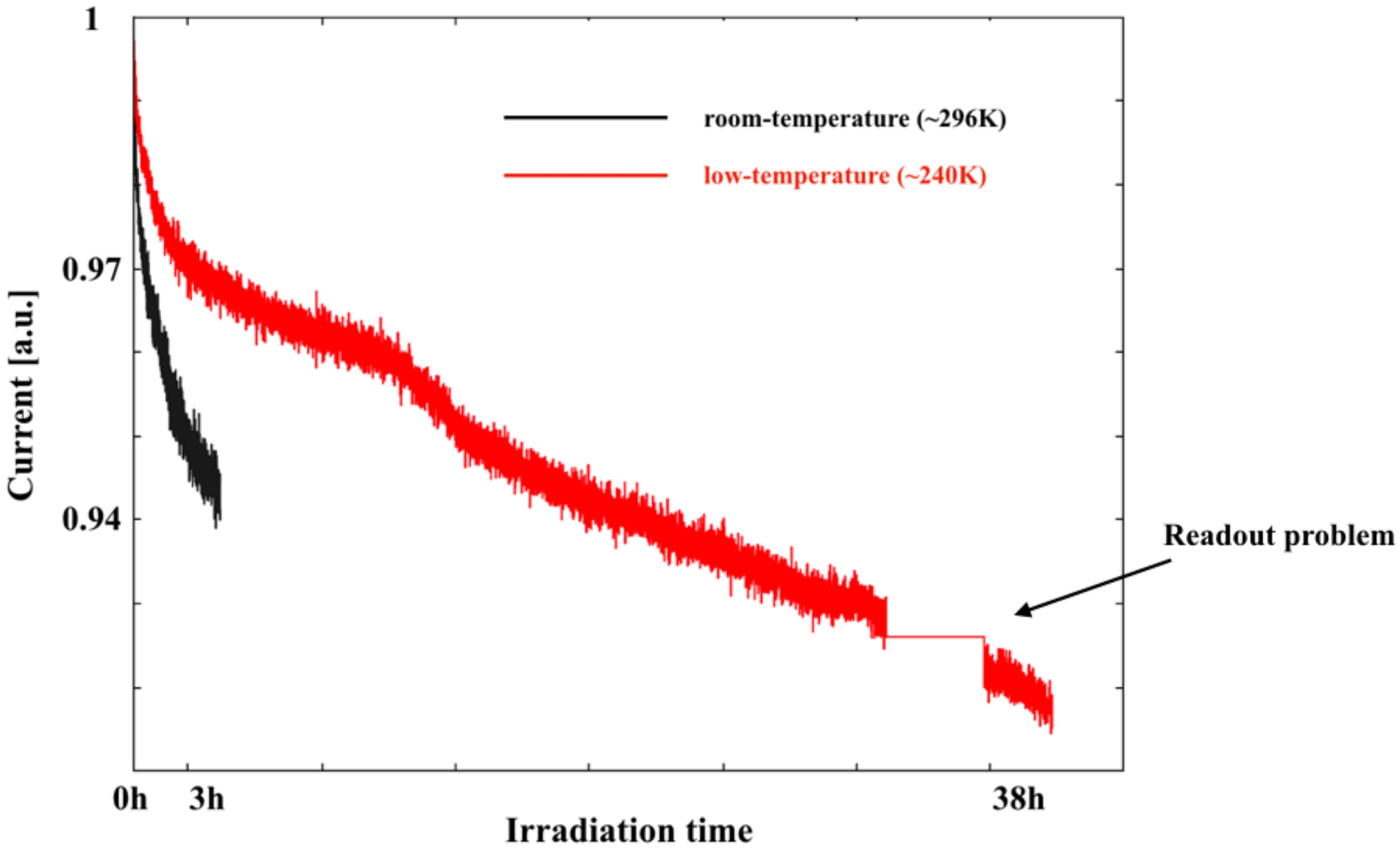
Black sheet
for safety

Trigger for
Xe-lamp

1ch current readout
HV=0V

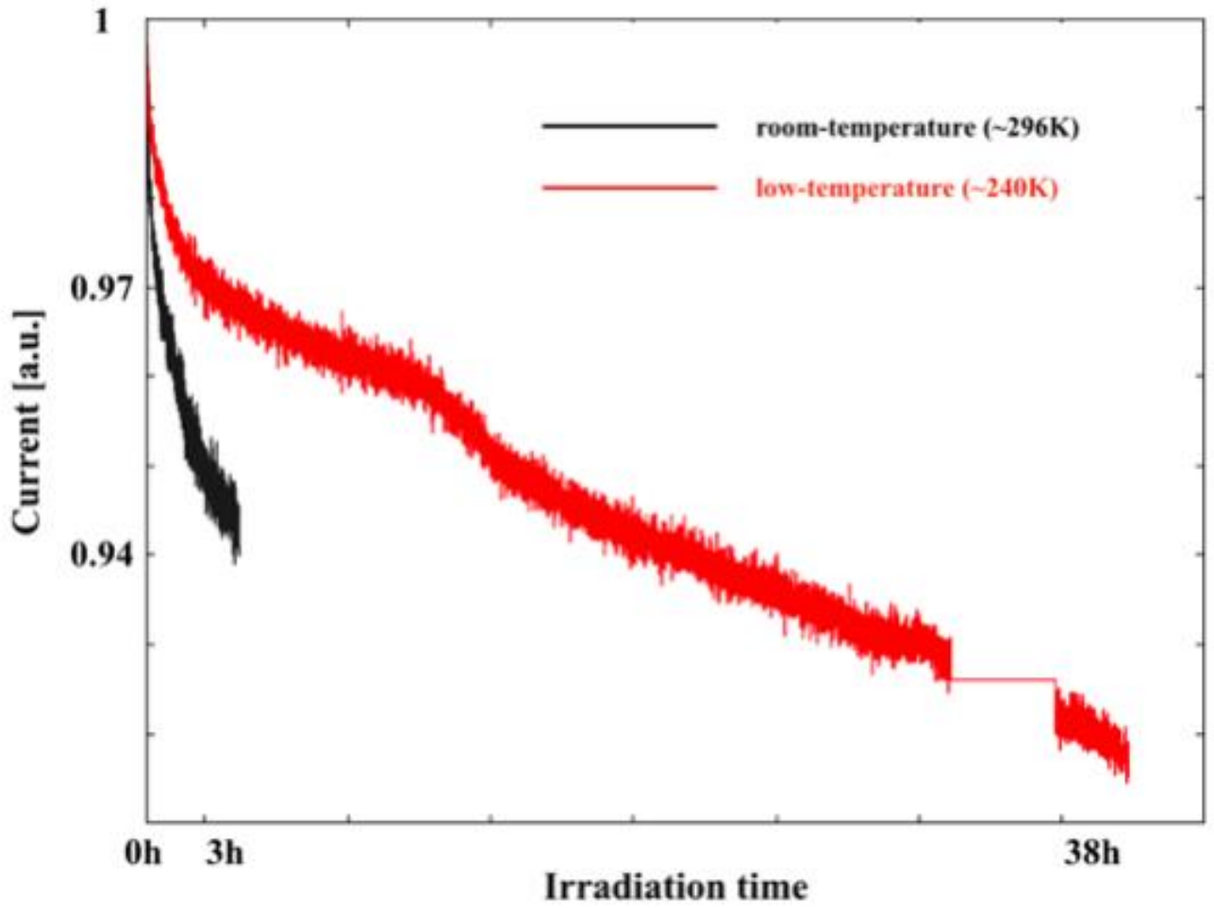
Chamber

Result (HV=0V)



- Irradiated one MPPC (low-temp → room-temp)

Result (HV=0V)



- **Decrease of current was observed both at low-temp and room-temp**
  →This might show PDE decrease
- **The decrease level of low-temperature is smaller than room-temperature**
  →Contrary to expectation
- **The result includes the entire wavelength region**
  →Different from VUV irradiation
- **The temp (~240K) is much higher than LXe temp (165K)**

Summary

Measurement

Room temp(~296K) vs Low temp(~240K)

- **Could not reach the LXe temp(165K)**

  →Improve the setup
  (replace the wire with copper one and improve the insulating performance)

- **Contrary to expectations, current decrease at low temp was slower**

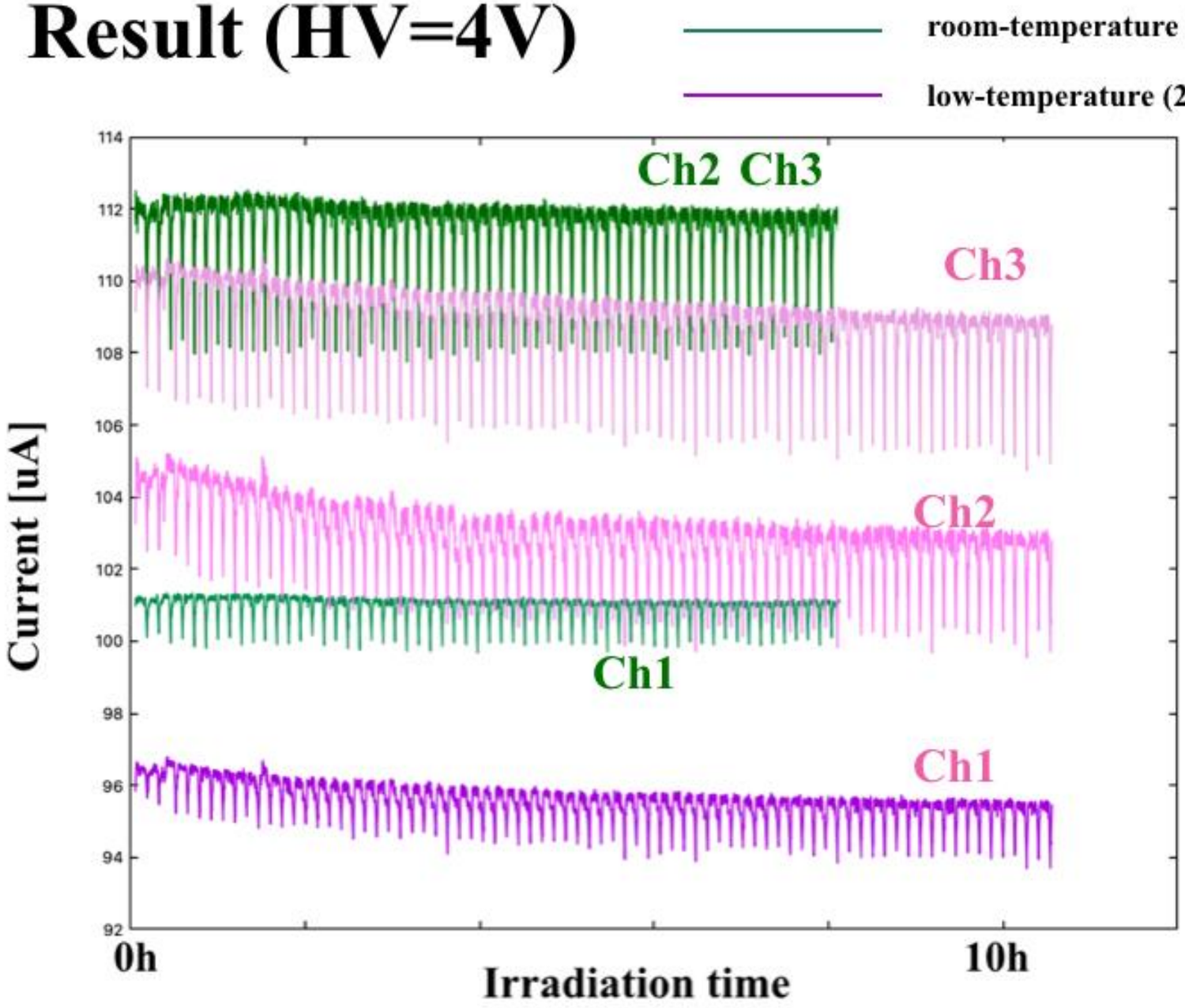
  →We do not know the reason

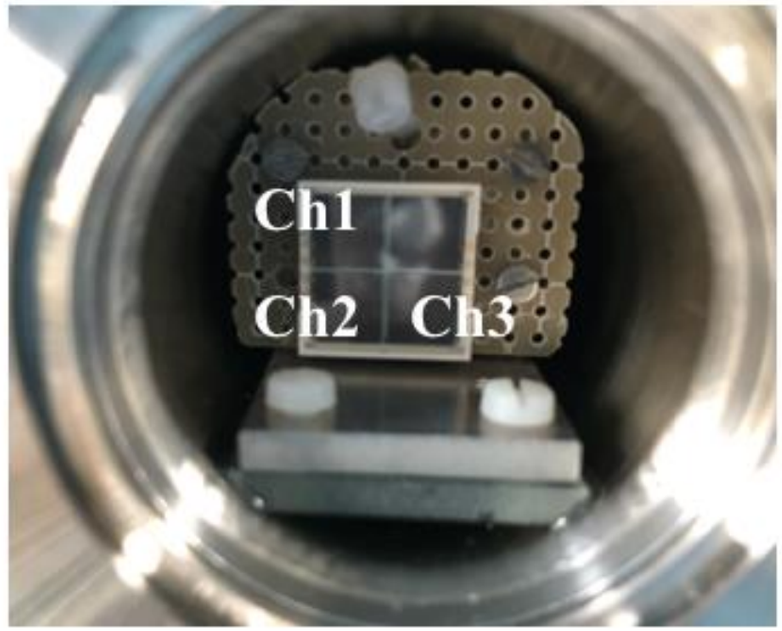
  →The possibility that we did not measure the PDE decrease for VUV light
  (Xe-lamp includes other wave length)

  →We should measure the charge for VUV light using filters

Backup slides

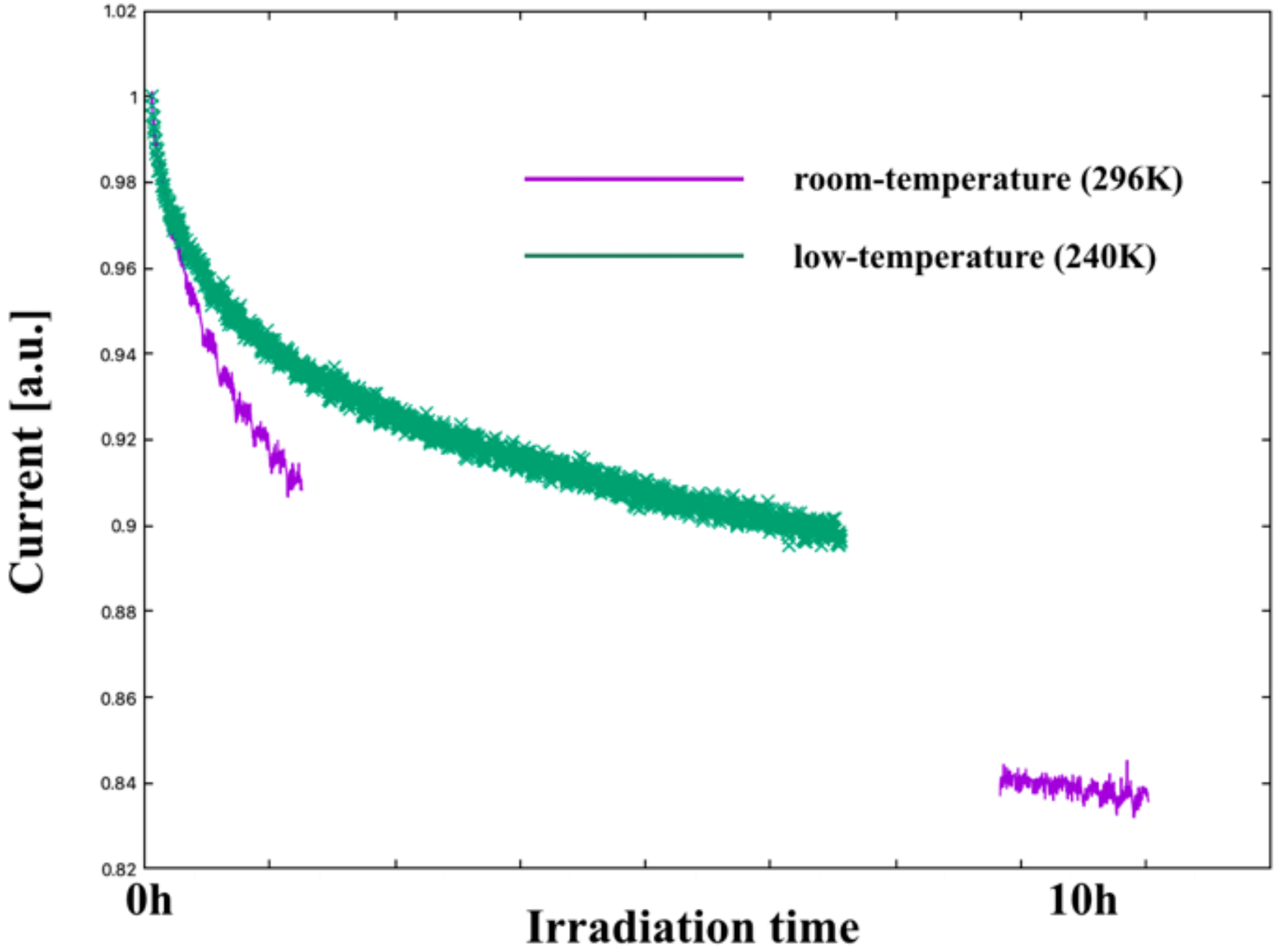
Result (HV=4V)





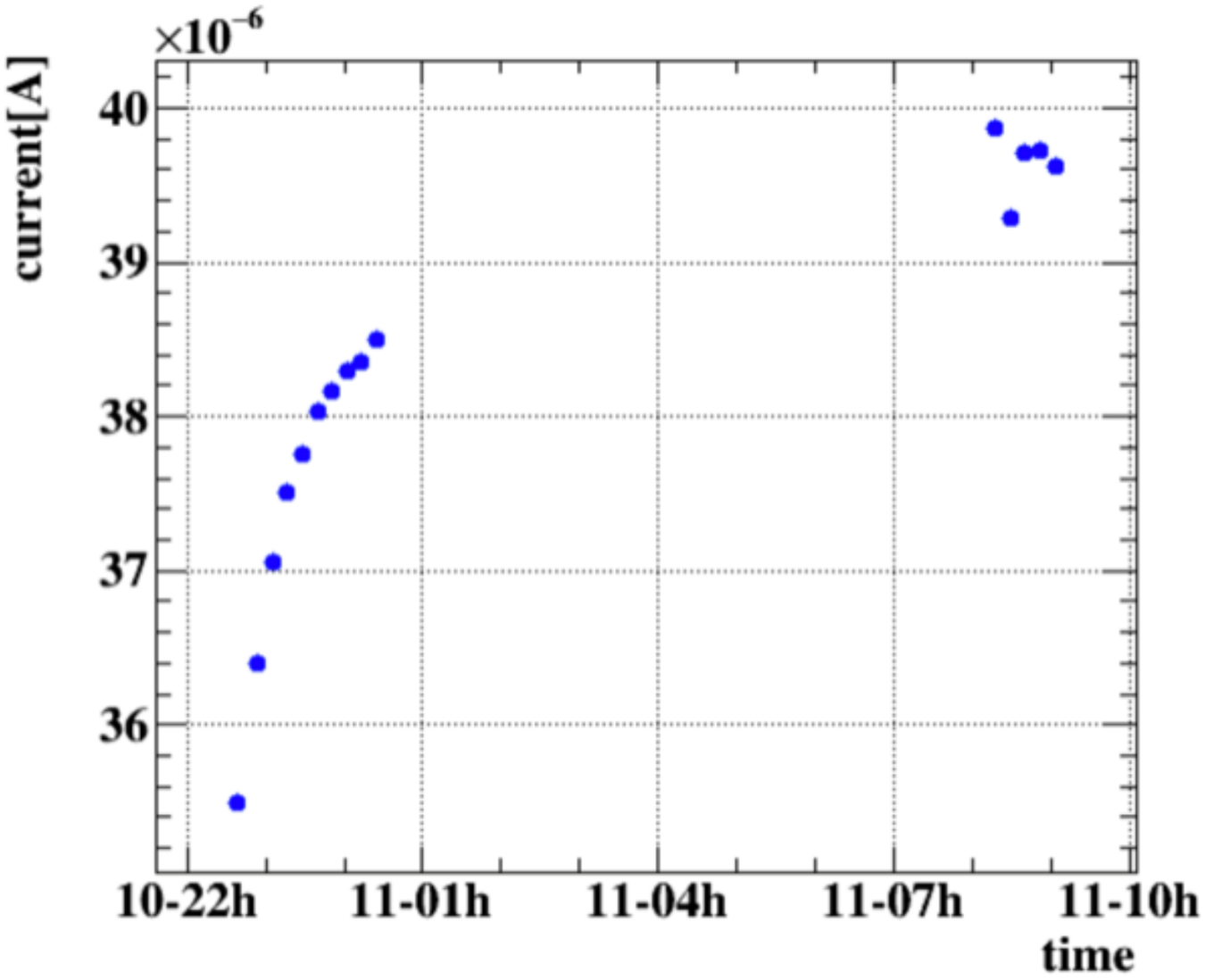
- Total irradiation time : ~10h
- When bias voltage are supplied, low-temperature current seems to decrease
- The result is opposite to that w/o HV

Result (HV=0V)



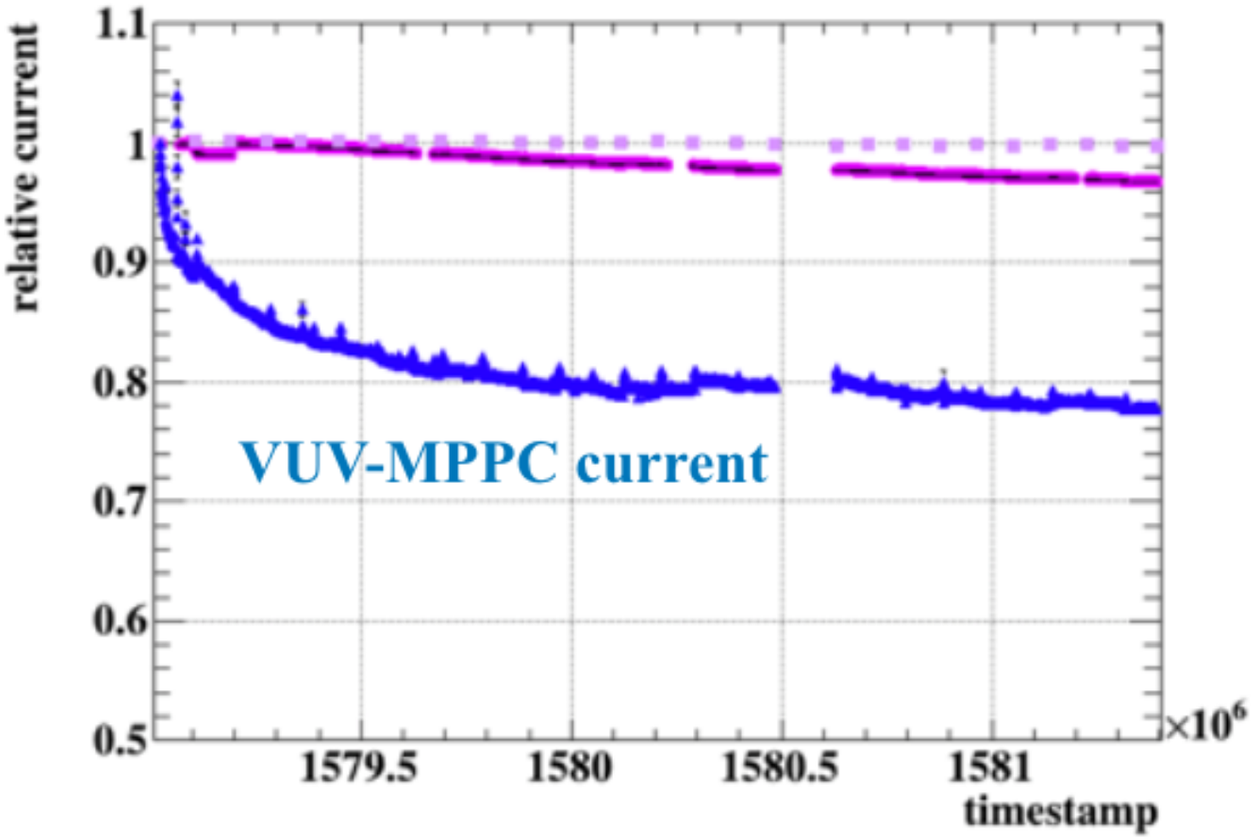
- Irradiated two MPPCs
- Consistent with the result using one MPPC

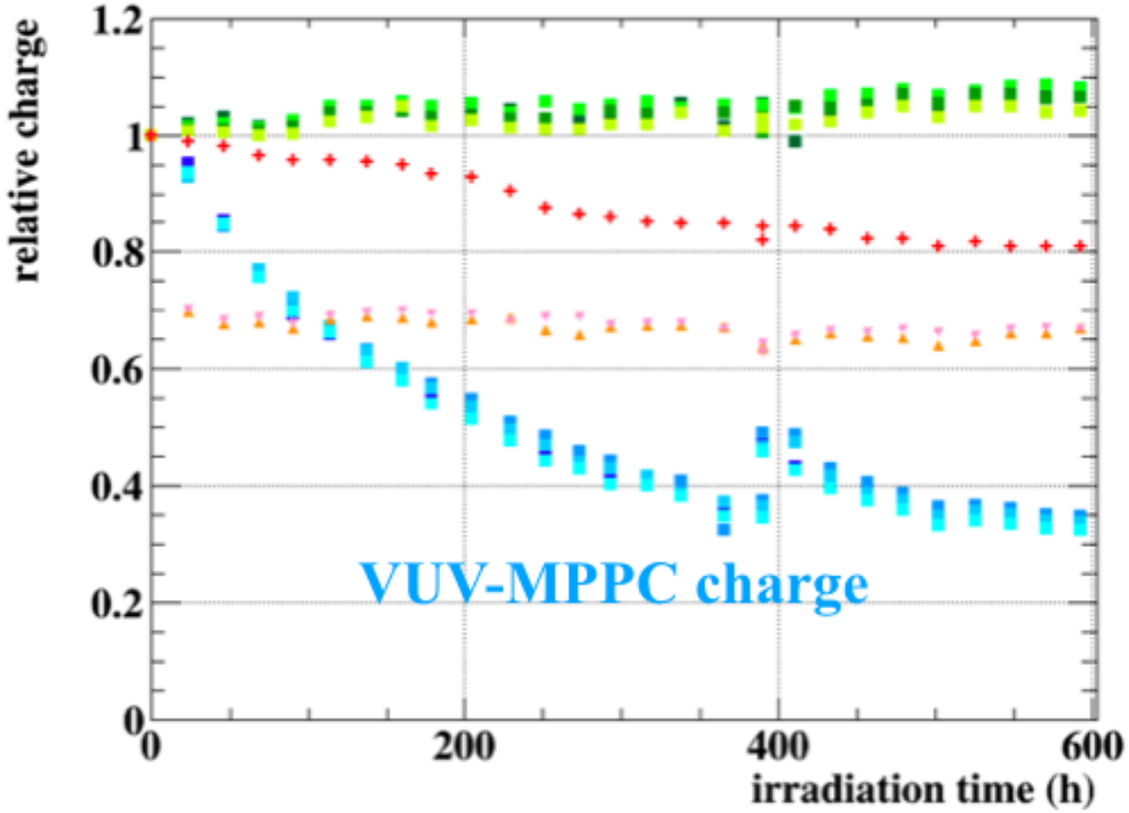
LED response



- MPPC Vover~6V
- Xe lamp off
- current(LEDon) - current(LEDoff)
  to remove the dark current

- Increase of the response to the LED was observed
- Possibly, there happened to be UV cleaning





- **Correlation between current decrease and charge decrease was observed in previous measurement**