MEG II実験液体キセノンガンマ線検出器内のMPPCにおけるPDE減少の放射線源を用いた調査

Research on PDE decrease of MPPC for MEG II liquid xenon photon detector by using radiation source

12pT2-9

Keisuke Yoshida,　on behalf of MEG II collaboration
The University of Tokyo, graduate school of science
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Contents

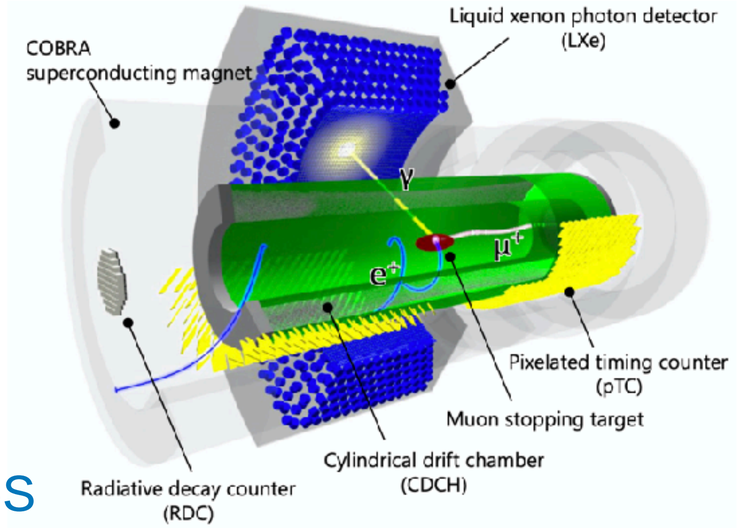
Introduction

MEG II experiment at Paul Scherrer Institute(PSI)

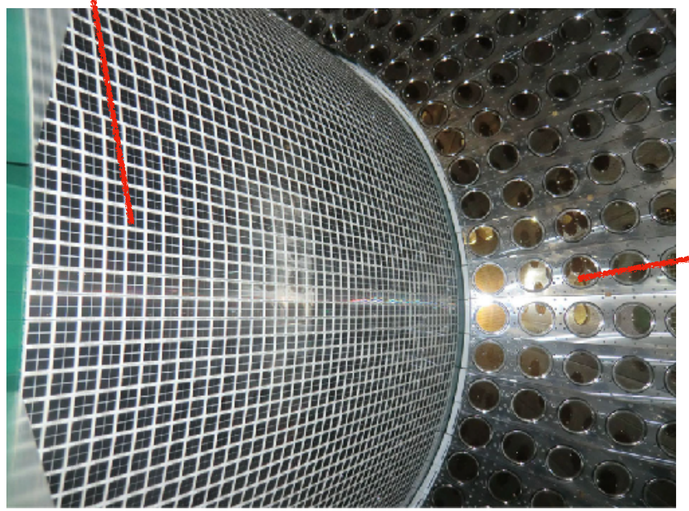
Overview and liquid xenon photon detector(LXe)

- MEG II experiment aims to detect μ→eγ, which is one of charged lepton flavor violation.

- In LXe, energy, interaction position and timing of γ are measured.
- Detect the scintillation light(λ~175nm).
- Use 4092 MPPCs and 668 PMTs.
- Energy and position resolution will be improved comparing to MEG.



MPPCs



PMTs

PDE decrease of VUV-MPPC

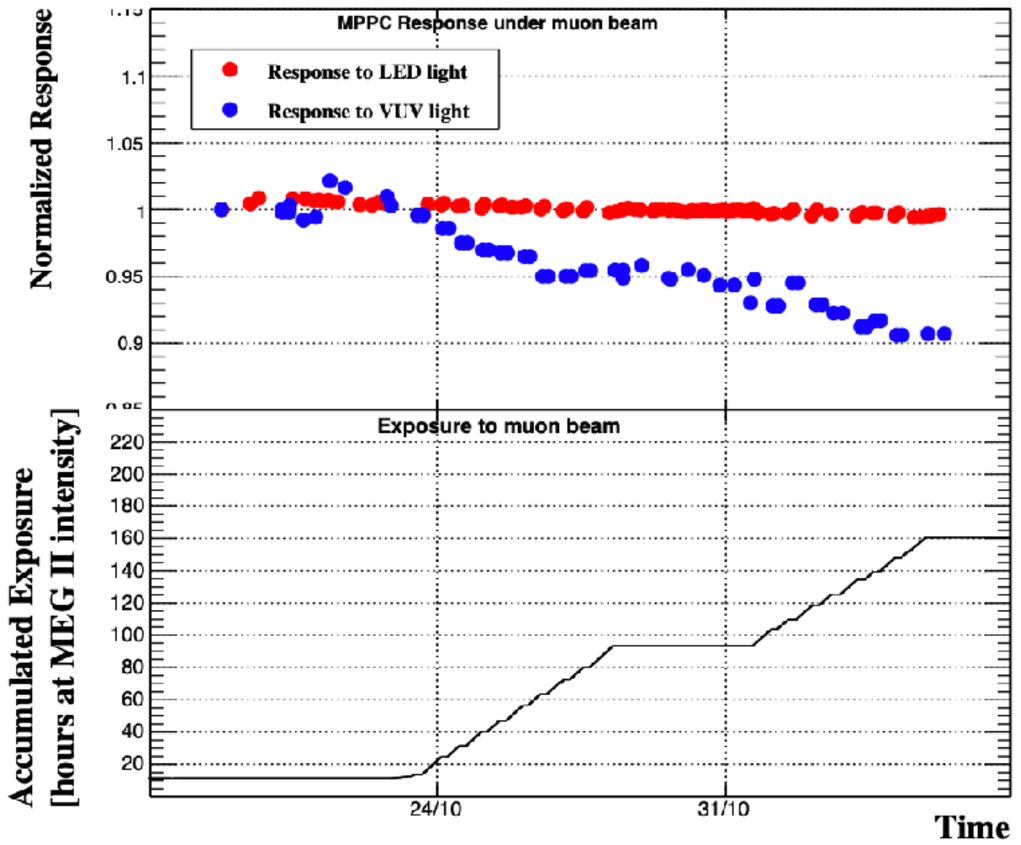
PDE decrease of VUV-sensitive MPPC

cf previous talk 12pT2-8

- PDE(photon detection efficiency) decrease of VUV-MPPC is quite fast(~0.06%/hour in MEG II beam intensity)
- MEG II DAQ time: 120days/year, 3 years

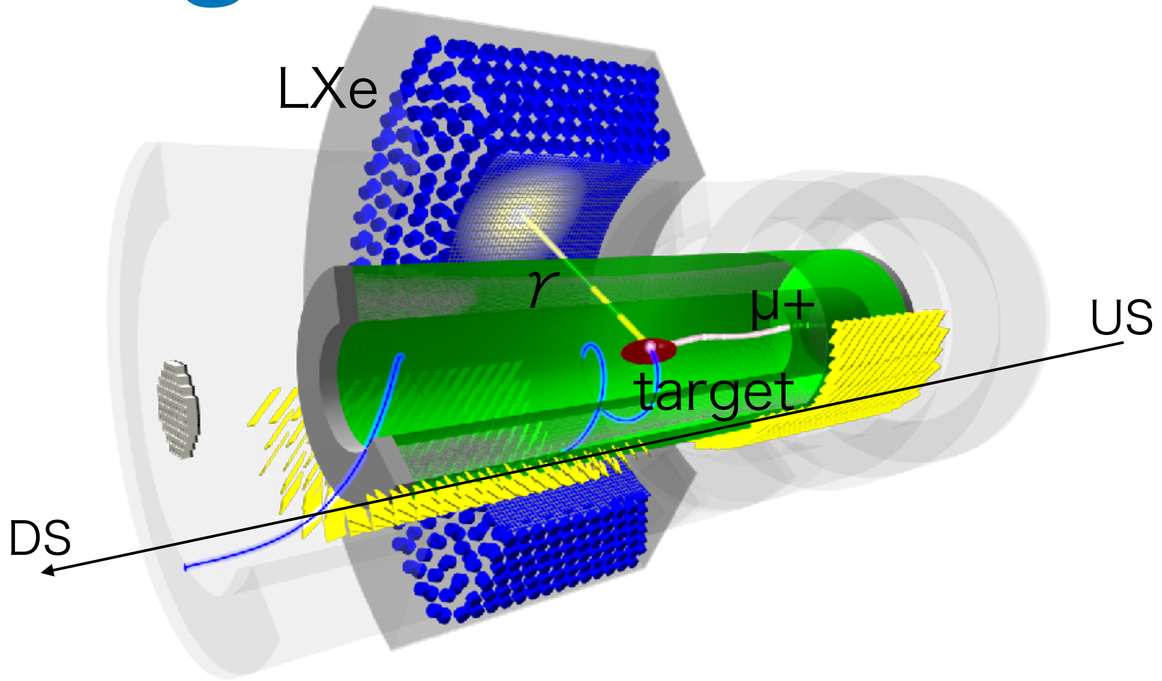
=> PDE decrease is crucial problem.

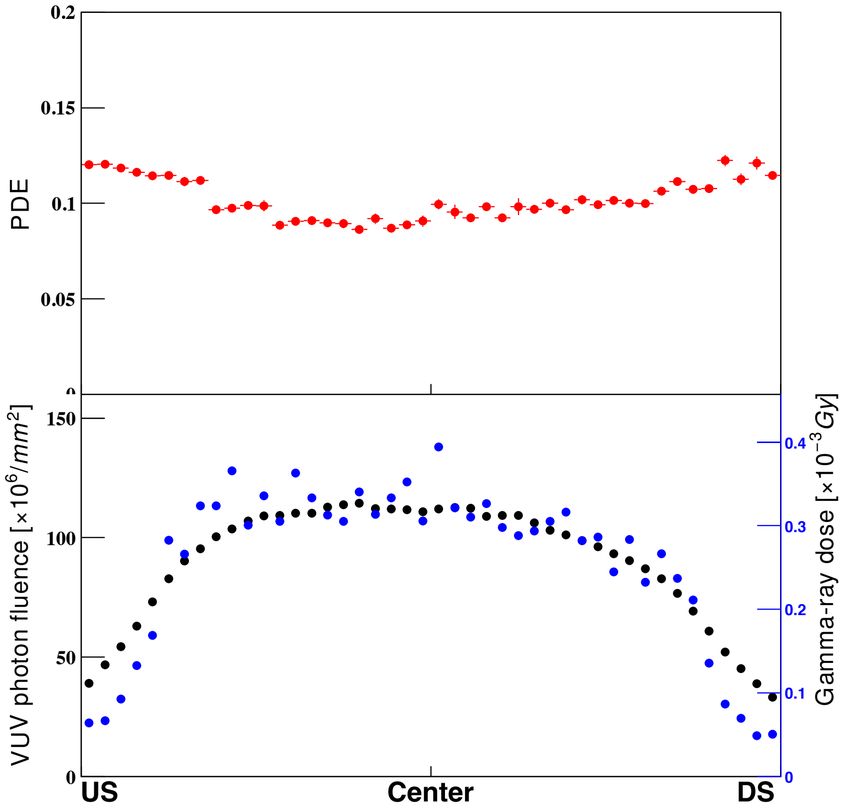
- Possible cause: VUV light, gamma



PDE history in 2019

Suspecting causes





- we suspected VUV light as cause of PDE decrease, but the decrease was not observed(previous talk 12pT2-8).
- PDE decrease have dependence of VUV-MPPCs' position.

=>cause of PDE decrease comes from the target.

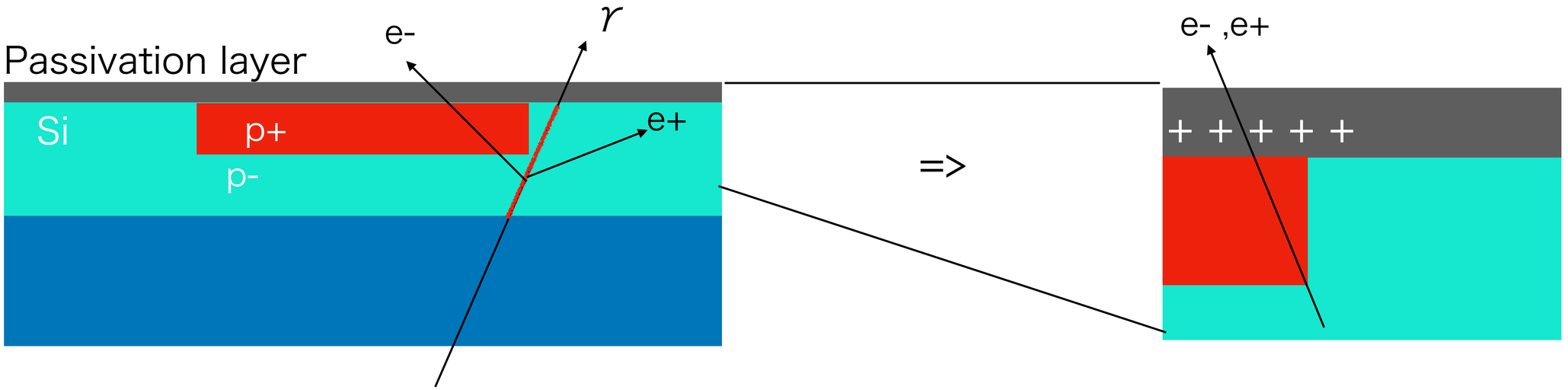
=>we started to suspect γ as the cause.

2019 mass test
horizontal:position of MPPCs(US:upstream of beam)
red:PDE of each MPPCs,
black:VUV photon fluence of those
blue:γ rays dose of those

Suspecting process of PDE decrease

We suspect surface damage.

- γ rays deposit energy in Si and produce e- and e+.
- e- and e+ damage Si-passivation layer interface and holes are made.
- The electric field near the boundary of two surfaces will be reduced and collection efficiency will be reduced.
- Annealing is effective solution of PDE decrease(may remove holes).

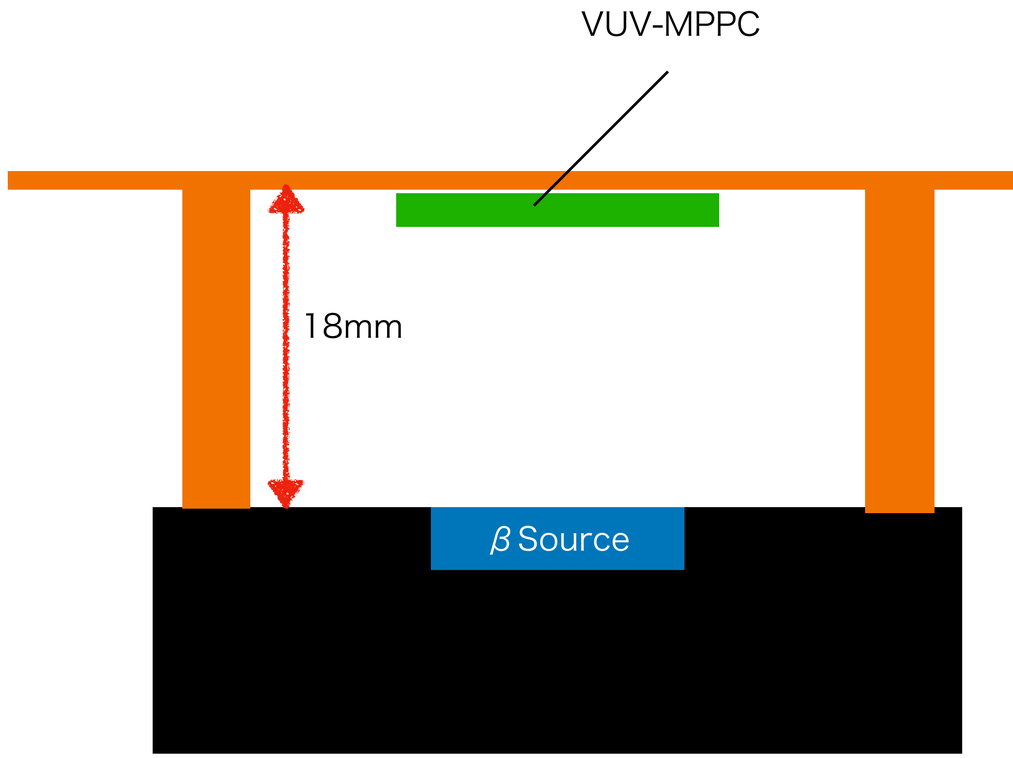


Experiment

Preparation

Setup of Irradiation to VUV-MPPC

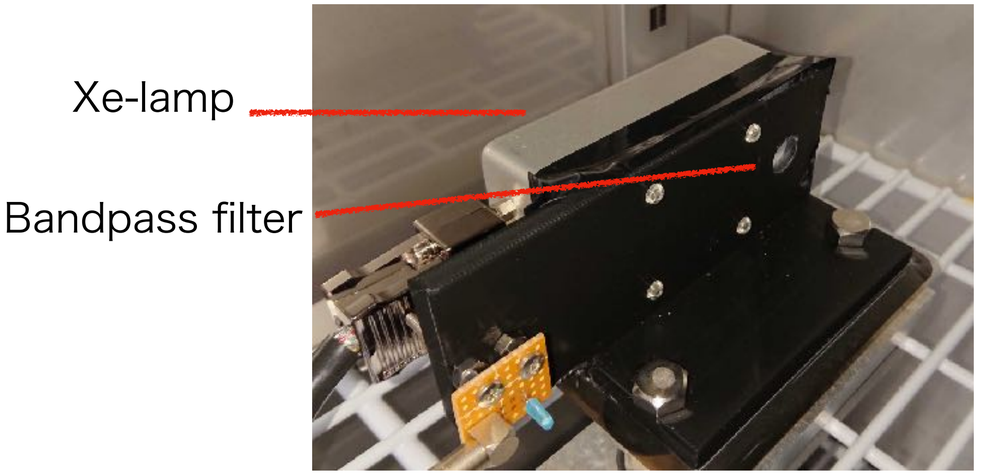
- Used β rays source(Sr90) to reach γ dose in MEG II DAQ in laboratory.
- Irradiation was done in HV=0
- Relative position of β source and VUV-MPPC was fixed by irradiation structure to reduce uncertainty of dose.
- Irradiation structure was put in dark box at room temperature when the irradiation was done.

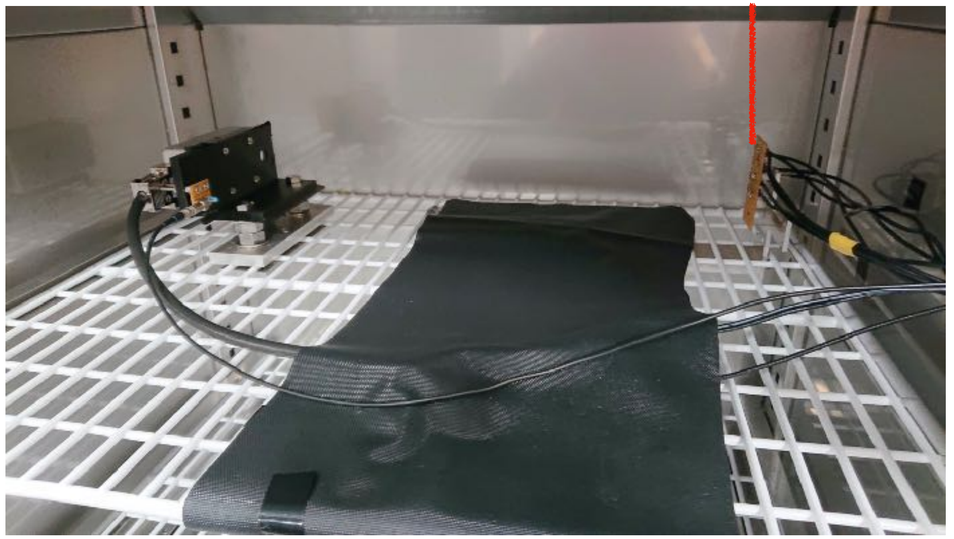


Preparation

Setup of PDE measurement

- PDE was measured by Ultra-Violet light(UV,λ~195nm).
- Xenon lamp(hamamatsu) and Bandpass filter was fixed to support structure for PDE measurement .
- Relative positions of lamp and VUV-MPPC were fixed.
- Temperature at PDE measurement: 15℃
- PDE was measured for irradiated and reference VUV-MPPC.



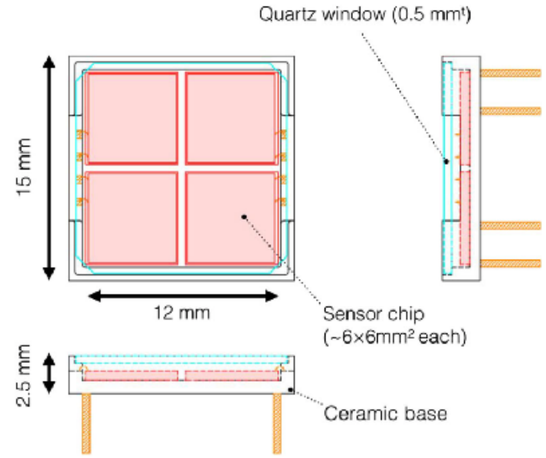


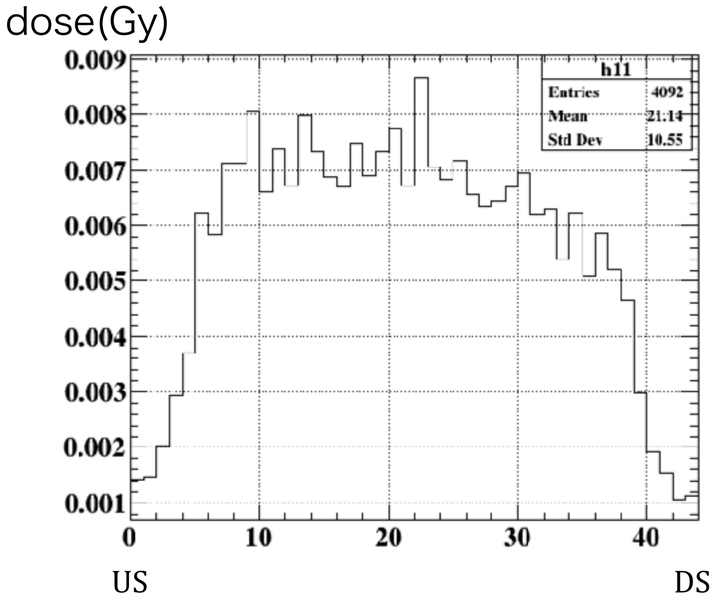
Preparation

calculations for irradiation dose

- Passivation layer:12mm×12mm
- Distance between MPPC and radiation source: 18mm
- dE/dx(min)=1.664MeV*cm^2/g (in case of Si)
- Radiation source: Sr90,1MBq
- In this experiment, I used VUV-MPPC being removed Quartz window to ignore deposit energy in window.

=>expected dose in laboratory= 0.02Gy (in 1hours)>0.009Gy(maximum dose of some MPPC in MEG II 3years DAQ)

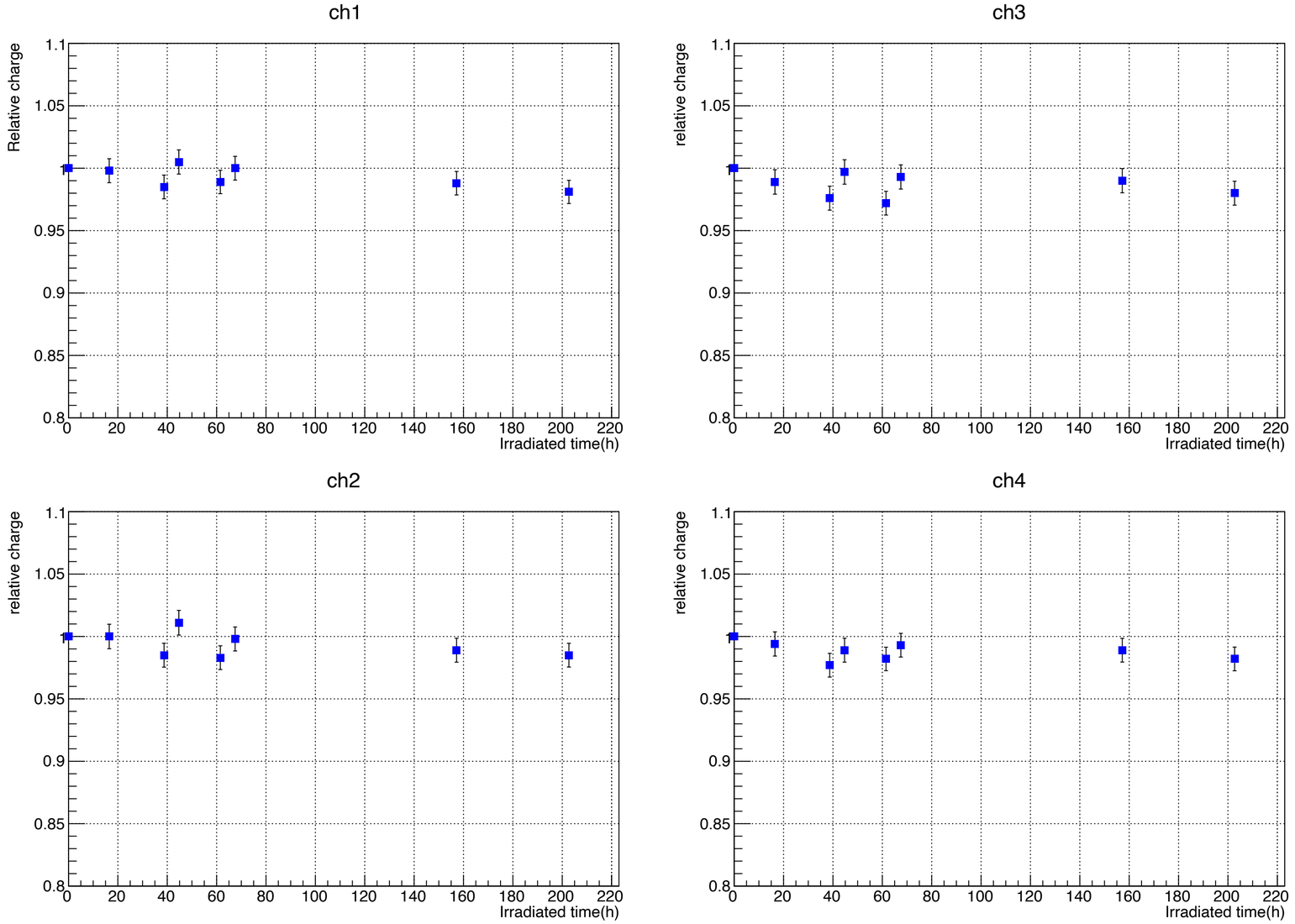




γ dose of each MPPC in 3years

Results

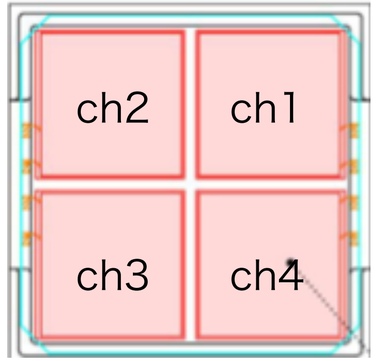
- PDE decrease was not observed in this experiment.



- About 1hours is corresponds to dose in MEG II 3years data time(120days/year)

=>Irradiated 200×γ dose in MEG II 3year DAQ

- Error: considered stability of Xe-lamp



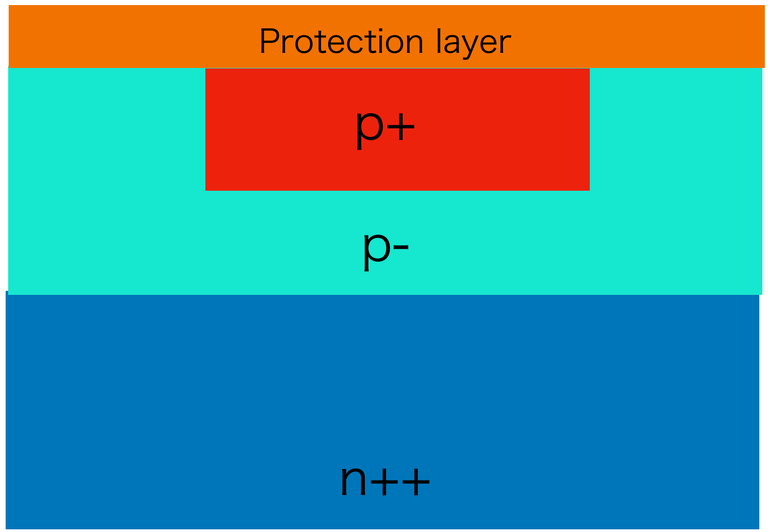
Summary and next

- MEG II experiment aims to detect μ→eγ.
- PDE decrease of VUV-MPPC in LXe is crucial problem.
- we have suspected VUV light and γ ray as cause of it, and I researched about γ ray.
- PDE decrease of VUV-MPPC was not observed in this experiment(at room temperature,293K).
- We plan to irradiate radioactive rays at 165K(temperature of liquid xenon) to inspect whether γ is cause of PDE decrease in our suspecting process.

Backups

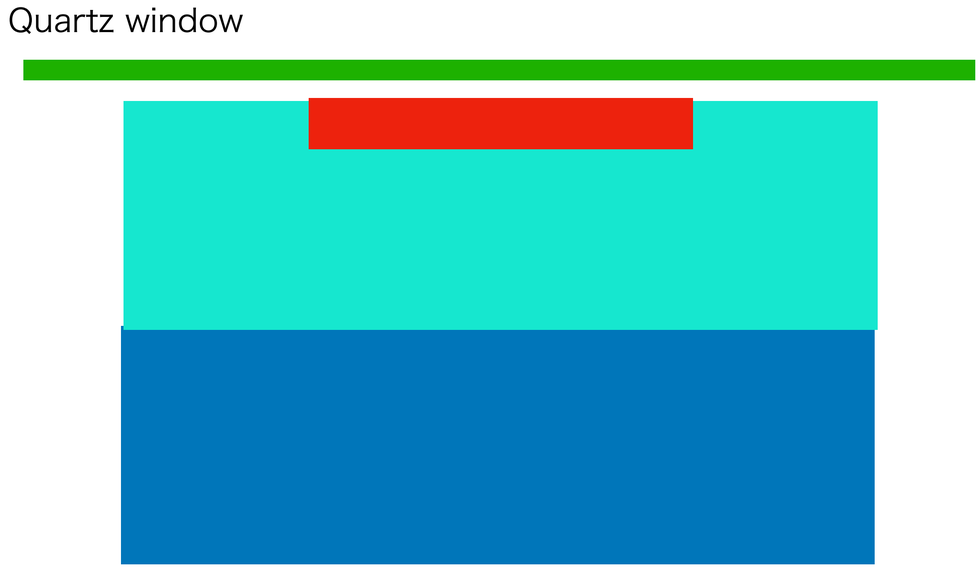
VUV-MPPC

Normal SiPM



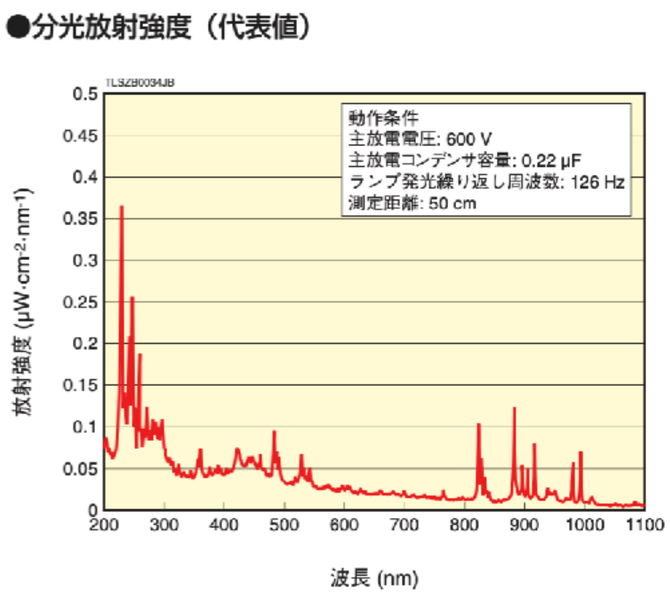
- insensitive to VUV lights because the protection layer and thick p+ layer absorb VUV lights before they reach p- layer

VUV-MPPC

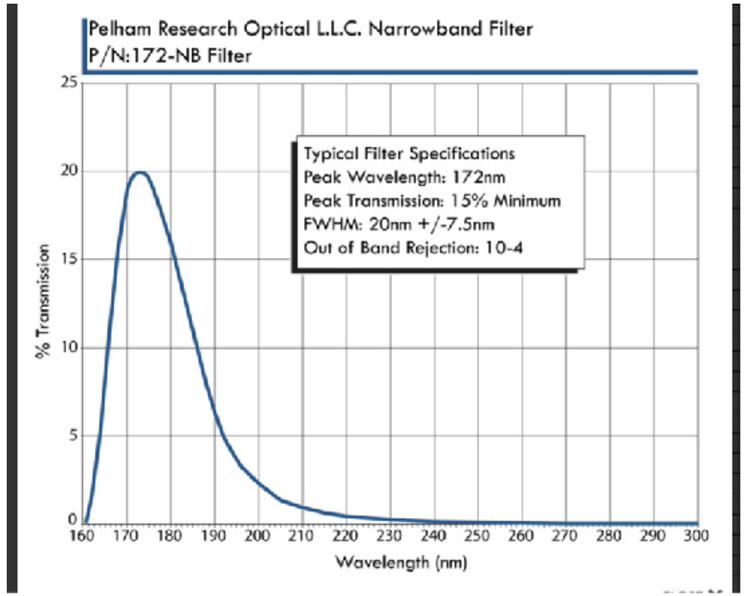


- quartz window to protect its surface instead of the protection layer
- thinner p+ layer

Xe-lamp, Bandpass filter, and β source



Hamamatsu 5W Xe-lamp(L9456-01)
window material: UV glass
wave length:185nm~2500nm



eSource Optics VUV Bandpass filter(25172FNB)

β source(1MBq)

Rate of source

- Used trigger scintillator(5mm×5mm and MPPC),distance between this and radiation source: 13mm＝＞solid angle=0.143

- measured : 12kHz

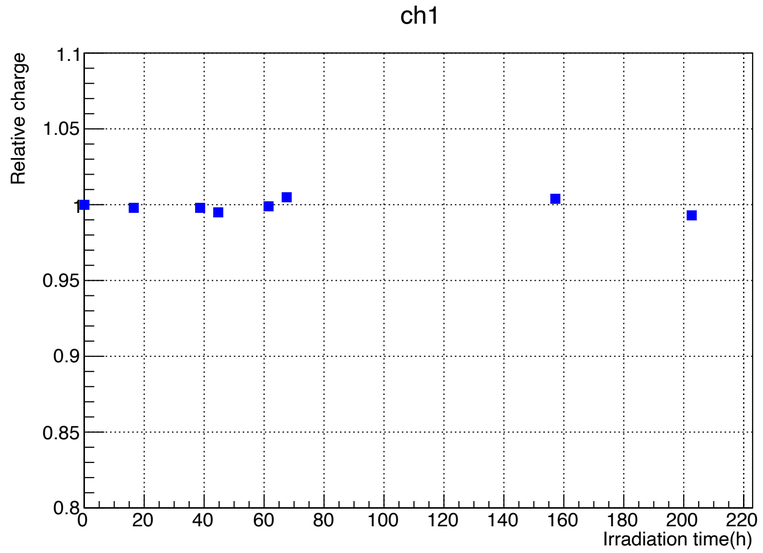
Solid angle of VUV-MPPC

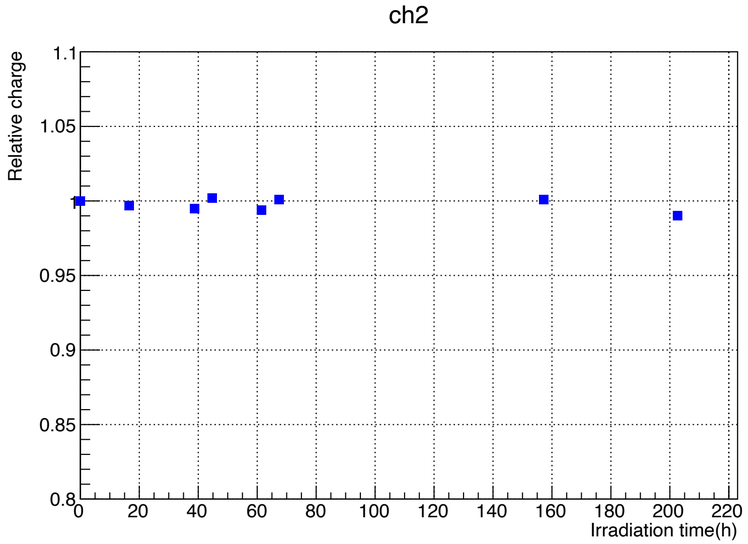
=>rate to VUV-MPPC=12000Hz*(0.4/0.143)=31000Hz

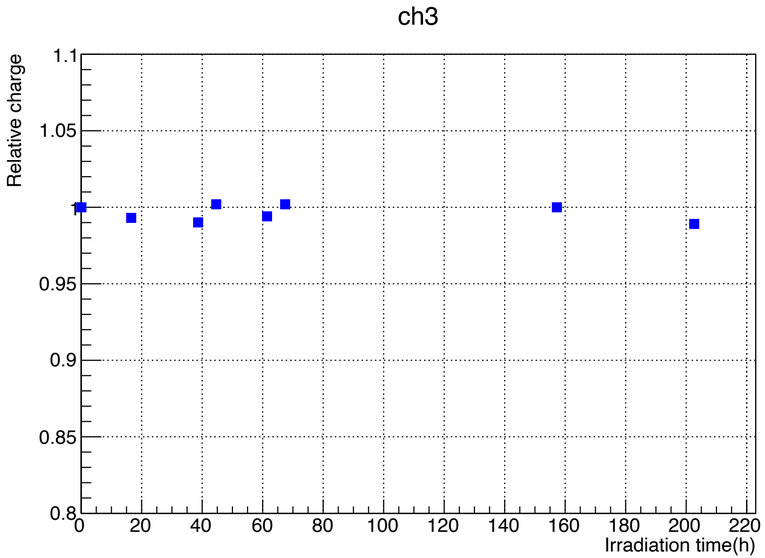
It seems that estimation of source rate is not different largely.

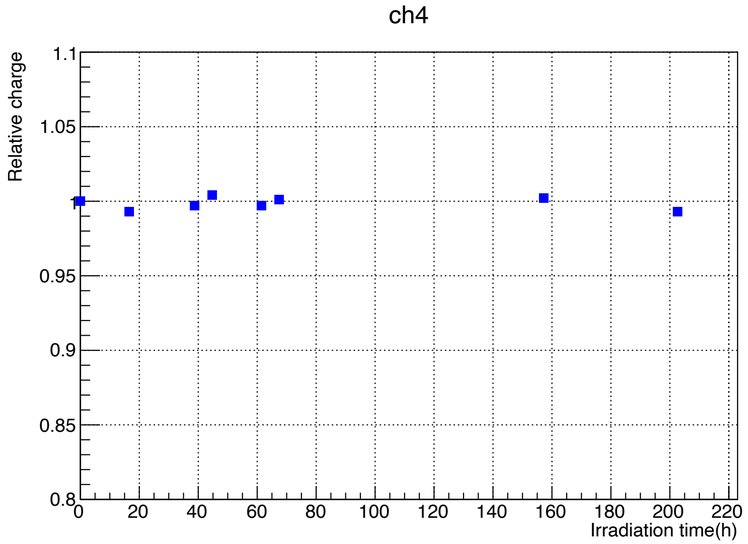
PDE (LED)

- PDE decrease was not observed

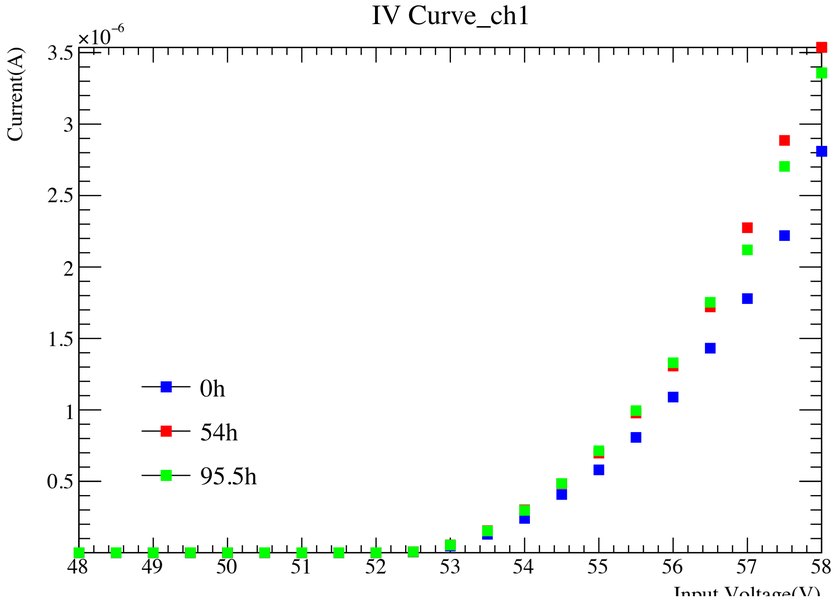


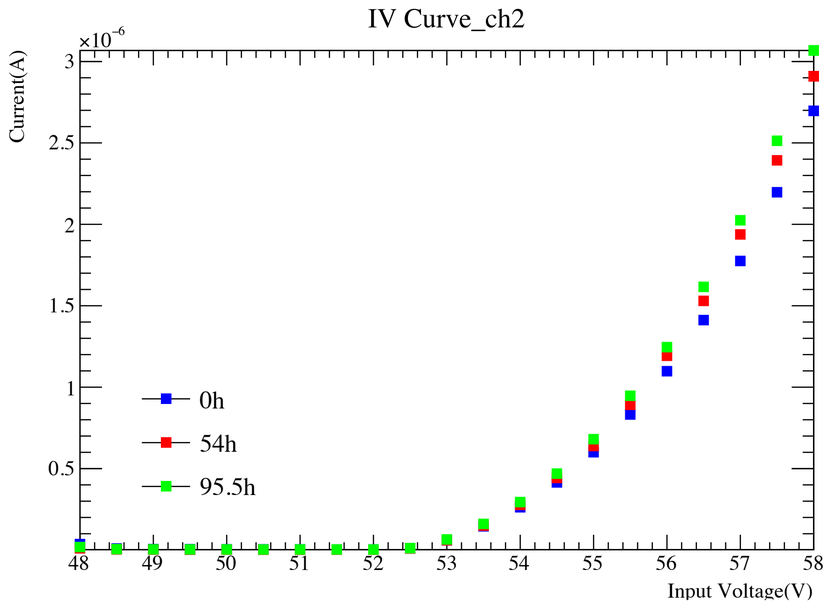


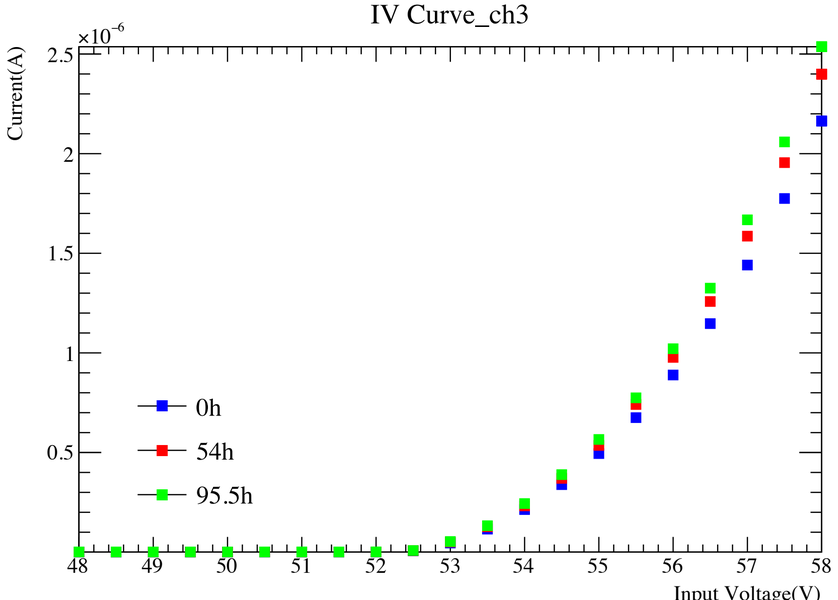


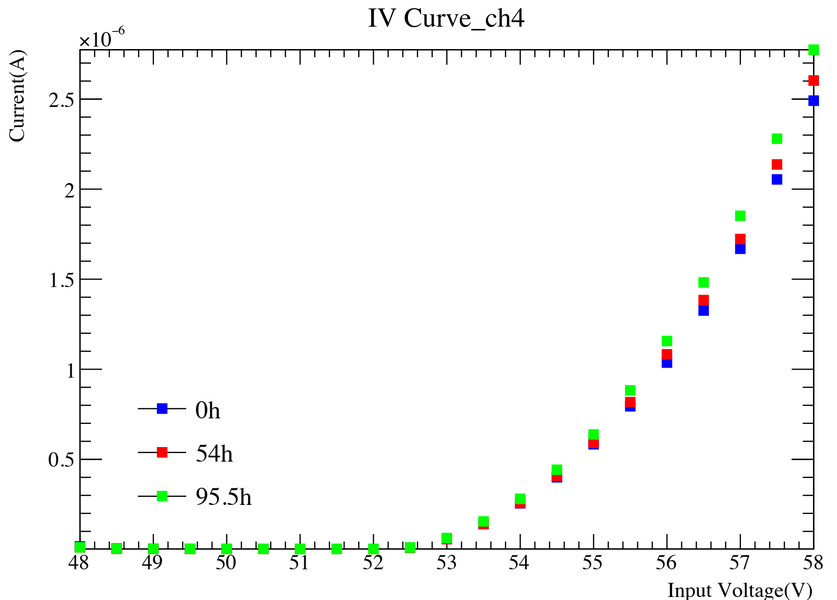


I-V curve


IV Curve_ch1
Current(A)
×10⁻⁶
Input Voltage(V)
0h
54h
95.5h


IV Curve_ch2
Current(A)
×10⁻⁶
Input Voltage(V)
0h
54h
95.5h


IV Curve_ch3
Current(A)
×10⁻⁶
Input Voltage(V)
0h
54h
95.5h


IV Curve_ch4
Current(A)
×10⁻⁶
Input Voltage(V)
0h
54h
95.5h