Evaluation of Radiation Effects on PDE of VUV-MPPC

東京大学
素粒子物理国際研究センター
International Center for Elementary Particle Physics
The University of Tokyo

Rina Onda, onda@icepp.s.u-tokyo.ac.jp
K. Ieki, T. Iwamoto, S. Kobayashi, T. Mori, S. Ogawa, W. Ootani, K. Toyoda

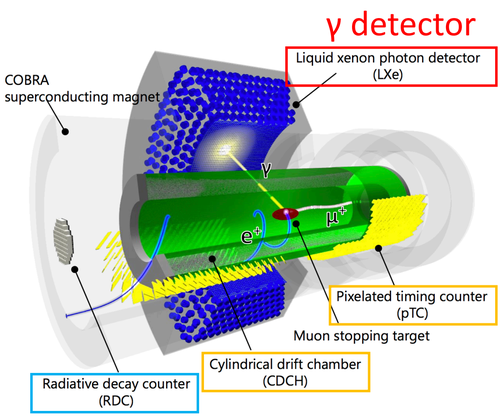
Core-to-Core Program

MEG II Mu - E - Gamma collaboration

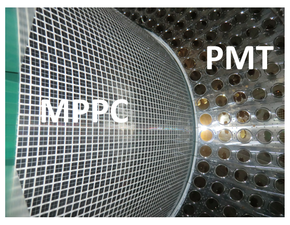
0. Abstract

Large-area Multi-Pixel Photon Counters (MPPC) sensitive to vacuum ultra violet (VUV) light are used to detect scintillation light from liquid xenon in MEG ll experiment. We observed the decrease of light yields detected by the VUV-MPPCs, and thus the degradation of PDE was suspected. As a possible cause, surface damage at Si-SiO_2 interface can be considered. Holes generated by ionizing particle can be accumulated around the interface and reduce the electric field. This can reduce PDE in VUV range. To test the hypothesis, PDE of the VUV-MPPCs irradiated by γ or neutron was measured and compared with that of non-irradiated samples.

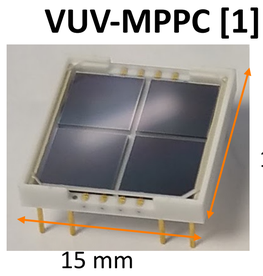
1. MEG II Experiment



Inside LXe



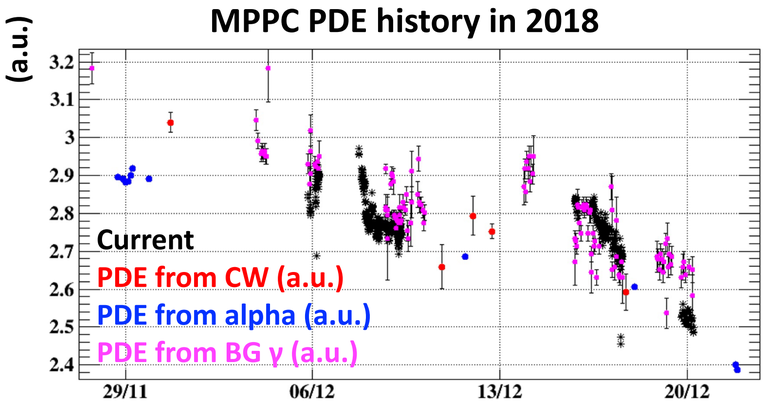
VUV-MPPC [1]



- MEG ll experiment searches μ→ eγ decay, which is one of charged lepton flavor violating decays.
- Liquid xenon photon detector (LXe) detects energy, position and timing of γ.
- Scintillation lights from liquid xenon are detected with PMT and MPPC.

2. Motivation

MPPC PDE history in 2018



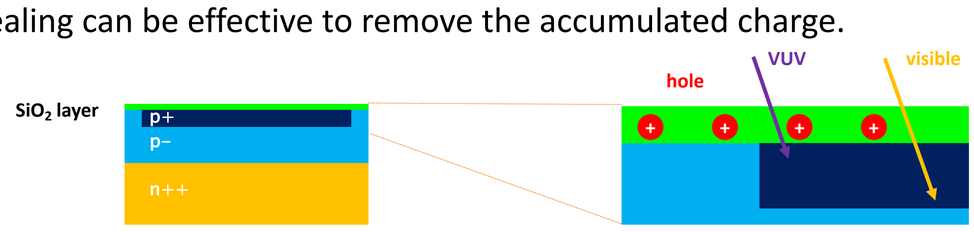
Estimated Radiation in 2018

Irradiation Source	Dose
γ (Gy)	1×10^{-2}
neutron (n/cm²)	2.7×10^{6}
photon (/mm²)	6.9×10^{11}

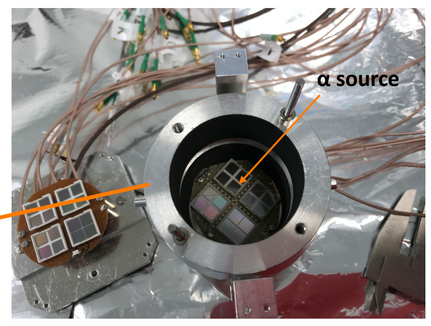
We are **suspecting degradation of MPPC PDE for VUV light** in commissioning with muon beam in 2018.
← Radiation damage??
Radiation effects on PDE of VUV-MPPC were not evaluated because it is known that there is no effect on PDE at other wavelength at the dose level of MEG ll.

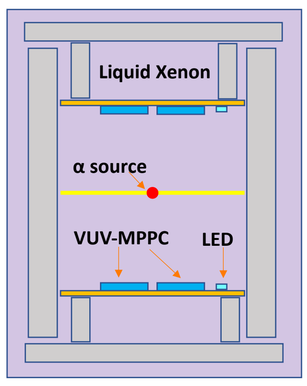
Possible Cause of PDE Degradation

- The issue of the PDE degradation for the VUV-MPPC was discussed with HPK.
- Similar degradation is known for photodiode. QE of photodiode is reduced after strong UV light irradiation [2].
- **Surface damage at Si-SiO_2 interface is most suspicious.**
  - Ionizing particles such as γ, charged particle and VUV light can damage it.
  - The electric field near the interface can be reduced by accumulated holes from the ionization.
  - Only PDE in VUV range can be reduced.
- Annealing can be effective to remove the accumulated charge.



3. Setup for PDE Measurement





- We had γ/neutron irradiated samples.
  γ: $^{60}_{27}\mathrm{Co} \longrightarrow ^{60}_{28}\mathrm{Ni} + e^- + \gamma$ @ Takasaki Advanced Radiation Research Institute in Jan. 2015.
  neutron: ^{9}Be + d$^+$ → ^{10}B + n @ Kobe University tandem accelerator in Jan. 2015.
- MPPCs were installed in a chamber, which was filled with liquid xenon. (two non-irradiated and six irradiated samples)
- α source was fixed in front of MPPCs.
- Signals were amplified with a amplifier and data was taken with a waveform digitizer.

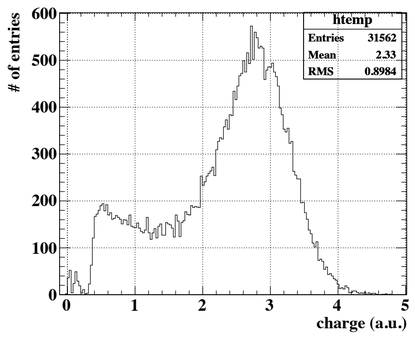
	Dose of Sample	MEG ll Expected
γ (Gy)	1.4×10^3 , 4.1×10^3	0.6
neutron (n/cm²)	4.8×10^9 – 2.0×10^{12}	1.6×10^8

Dose levels of the samples are much larger than expected values of MEG ll

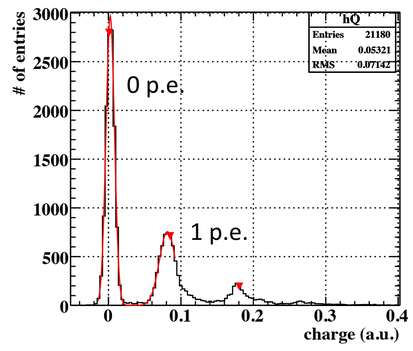
4. Result

Example of Charge Distribution

α source



LED



- PDE can be evaluated by comparing measured and expected number of photons from α source (^{241}Am)

$$PDE = \frac{N_{phe}}{N_{pho}}$$

- The expected number of photons can be calculated considering incident angle.

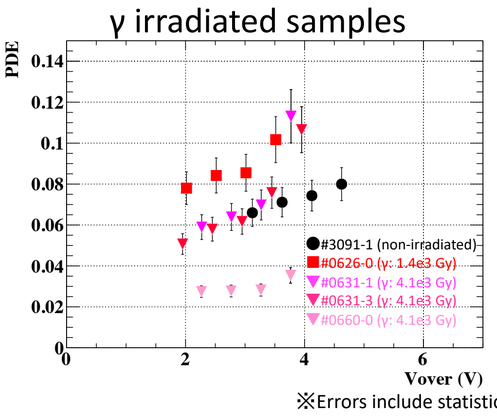
$$N_{npho} = \frac{E_\alpha}{19.6\,\mathrm{eV}} \times \frac{\Omega}{4\pi}$$ E$_\alpha$: 4.78 MeV, $\frac{\Omega}{4\pi}$: ~0.4%

- The measured number of photons can be calculated from a peak of a charge distribution using calibration factors.
  - Calibration factors, Gain and Excess Charge Factor, were obtained by photo-electron peaks from data taken using LED (λ=390 nm, OSA Opto Light GmbH, OCU-400, UE390).

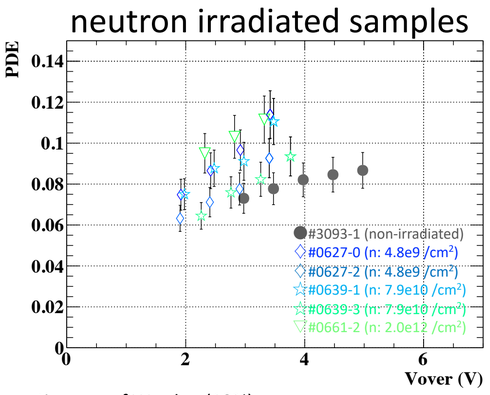
$$N_{\mathrm{pho}} = \frac{Q_\alpha}{(\mathrm{Gain}) \times (\mathrm{Excess\ Charge\ Factor})}$$

PDE for VUV Light

γ irradiated samples



neutron irradiated samples



※Errors include statistic errors and a systematic error of W value (10%)

- **PDE degradation was not observed for all irradiated samples by comparing PDE of irradiated samples with those of non-irradiated samples.**
- Overall PDE were lower than those of the previous measurements (14-20%)
  ← Purity of xenon might be worse.
- Only PDE of #0660-0 was lower though other samples with the same dose level were not.
  ← PDE of #0660-0 for visible light was measured to be roughly same as others.
  There might be a certain damage in the surface except for radiation damage.

5. Summary and Prospect

- PDE of γ/neutron irradiated samples were measured.
  - Dose levels were much higher than expectation of MEG ll experiment.
  - **No radiation effect on PDE for VUV light was observed**.
    ← The result does not support the hypothesis.
- Measurement for PDE of VUV light irradiated samples is on going.
- Effect of annealing will be investigated.
  - Some VUV-MPPCs in LXe were annealed.
  - PDE of the annealed VUV-MPPCs will compared with those measured last year.
  - PDE is supposed to recover after annealing.
- Data taking with fixed environments is planned this year.
  - The beam data in 2018 was taken under unstable environments:
    beam intensity, B-field, firmware update, TRG condition……
  - Calibration data was not taken so frequently.

References

[1] K. Ieki, et al, "Large-area MPPC with enhanced VUV sensitivity for liquid xenon scintillation detector", Nucl. Instrum. Methods A, 925 (2019), Pages 148-155
[2] https://www.hamamatsu.com/resources/pdf/ssd/s12698_series_kspd1084j.pdf