# **Recovery of Photon Detection Efficiency of SiPMs** in the liquid xenon detector by annealing

S. Ban, F. Ikeda, T. Iwamoto, S. Kobayashi, A. Matsushita, T. Mori, W. Ootani, A. Oya, Y. Uchiyama, K. Yamamoto, T. Yonemoto

**The University of Tokyo, ICEPP**, contact : bansei@icepp.s.u-tokyo.ac.jp





#### **VUV-Sensitive MPPC (SiPM)** developed by Hamamatsu



- Hamamatsu Photonics developed SiPM (VUV-MPPC) which sensitives to VUV light ( $\lambda \sim 170$  nm) for the MEG II experiment
- Photon Detection Efficiency (PDE) : >20% (at manufactured)



#### **Decrease of Photon Detection Efficiency (PDE)** in beam environment

- In total, 4092 VUV-MPPC are used In the liquid xenon detector **E0.085** for gamma-ray measurement
- It turned out that PDE of VUV-MPPC decreases in muon beam environment
  - the cause is under investigation (radiation damage?)
- In 2021 run, the averaged PDE decreased from 8.5% to 5.6%
- Low PDE (< 2%) worsen the sensitivity of MEG II experiment



MPPC PDE vs Irradiation time

2021 data

### **Recovery of PDE by annealing**

- Annealing (heating) procedure recovers PDE
  - Joule heating by the current of VUV-MPPC itself can be used to heat up itself
- Strong correlation exists between recovery ratio of PDE for VUV light and visible light
- [Recovery ratio for VUV light] = 10 \* [Recovery ratio for visible light]
- Can be used for monitor of degree of recovery
- Annealing for small number of VUV-MPPC was conducted in 2019 as a test

## Mass annealing

- Annealing for almost all VUV-MPPC in the liquid xenon detector was proceeded during the beam off period in 2022
- ~240 MPPC are annealed at once for one set of annealing, ~36 hours per one set -
- ~1.75 W per channel



making current to VUV-MPPCs by irradiating blue LED light

RpDI



- Because of the temperature limitation of the detector material, detector temperature was monitored by thermo-sensors inside of the detector
- LED data for monitoring were taken during cooling time



### **Result of the annealing**

- PDE was evaluated using alpha-ray data
  - alpha-ray sources are placed inside the detector
- PDE distribution of the MPPC face of the detector
  - Effect of temperature gradient is shown (at the top)



- PDE of each channel before/after the annealing and estimated PDE value by visible LED
  - Match well with the PDE value after the annealing
  - Usefulness of monitor by visible LED is shown



- Averaged PDE :  $5.6\% \rightarrow 15.6\%$





- Decrease of PDE of the VUV-MPPCs were shown in the beam time and it was recovered by mass annealing during the beam off period in 2022
- Averaged PDE of VUV-MPPC : 5.6% (at the last of 2021)  $\rightarrow$  15.6 ± 2%
- Mass annealing method is established, and we can execute "sustainable" experiment by conducting the annealing procedure if needed