



## MEG II実験 2022年物理ランの現状 (+アニーリング結果)

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PDE decrease and recovery of the LXe detector by annealing

Status and prospect of 2022 run

# PDE decrease and recovery of the LXe detector by annealing

Status and prospect of 2022 run

### Charged Lepton Flavor Violation

- In quark and neutrino (neutral lepton) sector, the flavor violates in SM



- Some theories BSM predict flavor violation in the charged lepton sector
  - In the Standard Model, it is practically prohibited : Br( $\mu \rightarrow e\gamma$ )=10<sup>-54</sup>
  - In BSM,  $Br(\mu \rightarrow e\gamma) \sim O(10^{-14})$  is predicted : large enough to search
- Signal : Gamma-ray and positron with 52.8 MeV (= $m_{\mu}/2$ )



### MEG II experiment

- MEG II experiment aims to search for charged lepton flavor violation :  $\mu^+ \rightarrow e^+\gamma$ 
  - with higher sensitivity by one order of magnitude compared to the MEG
- Consists of LXe detector for  $\gamma\text{-ray},$  drift chamber & timing counter for  $e^+$
- Engineering run and physics run with full number of readout channels were conducted in 2021 : talk by S. Kobayashi (7aA442-1), A. Oya (7aA442-2)



# PDE decrease and recovery of the LXe detector by annealing

Status and prospect of 2022 run

#### Liquid xenon detector : PDE decrease & Annealing

- Photon Detection Efficiency (PDE) decrease was observed in 2021 run (known problem since 2017)
  - Averaged PDE :  $8.4\% \rightarrow 5.6\%$
- It worse the sensitivity if PDE becomes lower than ~4%
- PDE recovery by annealing was conducted before the beam time 2022
  - There are two method
    - Hot water annealing : easy but low temperature (70°C)
    - Joule annealing : established by previous work (but small number)



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#### MPPC PDE vs Irradiation time

#### Annealing with hot water circulation

- Circulating hot water through the cooling pile that surrounds the detector
  - Be able to heat up entire of the detector easily
  - The temperature of hot water is limited up to 45°C because of the limitation from detector component
- Annealing with hot water was conducted for one month
- Recovery of PDE is monitored and estimated with visible LED light
  - Strong correlation with PDE for VUV light

Temperature is monitored by sensors inside the detector (3-0 340 Temperature [K] 335 PMT HV trouble EC Temp 2-0 X<sub>3</sub>-2 XEC Temp 2-3 MPPC face X2-2 Femp 3-0 XEC Temp 3-3 330 XEC Temp 0-4 C Temp 1-1 XEC Temp 1-4 XEC Temp 2-4 X<sub>3</sub>-3 325 EC Temp 3-1 XEC Temp 3-4 XEC Temp 1-2 320 XEC Temp 2-2 315 310 Position with NO MPPCs 305 change A/C setting in the detector hut : 17°C→27°C 300 22 22/03/03 22/03/10 02/17 22/02/24 Date Temperature setting : 45°C (318K)



Temp. are within 3°C range Stable within 0.1°C

#### Annealing with hot water circulation

- Absolute PDE value (for VUV) before/after the hot water annealing
  - Average PDE value of MPPCs used before 2020 : 4.56%  $\rightarrow~$  5.98% (x1.31)
  - Average PDE value of MPPCs used since 2021 :  $6.02\% \rightarrow 7.79\%$  (x1.29)
- Slower than the expected recovery speed : 30 %/month < ~145 %/month(expected)
- Note that the method of evaluation of PDE value is different
  - "Before" value is estimated using VUV light (scintillation of LXe by alpha-ray)
  - "After" PDE value is estimated value using visible LED



### Annealing by Joule heating

- MPPC is annealed by Joule heating using a high current source and LED light
  - Heated with ~1.7W per MPPC
- MPPCs with an interval of 4 are annealed at once
  - Avoid over heating of the detector
  - 240+ $\alpha$  MPPCs are annealed at once
    - $\rightarrow$  17+ $\alpha$  set of annealing is required (30h/set)

#### Power supply with large current : 250 mA/output, 60~80 V



#### Readout electronics on the MPPC face



#### Mass Joule Annealing : Cabling work







#### PDE recovery : Evaluation of the recovery

- PDE value before/after the annealing (Hot water and Joule)
- Calculated using alpha-ray data with liquid xenon filling (VUV-light)





#### PDE recovery : Evaluation of the recovery

- PDE value before/after the annealing (Hot water and Joule)
- In average, PDE recovered from 5.6% to 11.5%
  - According to the decrease speed in 2021 (0.13%/day with 7e+7 beam)
    - 9% PDE value is necessary for 3e+7 beam (120days) : 🔽
    - 11% PDE value is necessary for 4e+7 beam (120days) : ✓
    - 14% PDE value is necessary for 5e+7 beam (120days)



(to keep PDE>2%)

#### PDE recovery : Evaluation of the recovery

- PDE value before/after the annealing (Hot water and Joule)
- Calculated using alpha-ray data with liquid xenon filling (VUV-light)
- Estimation with visible LED seems not bad
  - Effective way to estimate degree of PDE recovery during annealing period



# PDE decrease and recovery of the LXe detector by annealing

Status and prospect of 2022 run

### Prospect for 2022 run

- Beam time assignment for MEG II : 6th Jun. 11th Dec.
- Beam intensity : 3e+7 muon/sec  $\rightarrow$  will be increased depending on the situation
  - monitoring of the MPPC PDE is important : next talk (A. Matsushita, 7aA442-4)
- Charge Exchange (CEX) run is planned on Nov.
  - Energy, Timing calibration for the liquid xenon detector
- Beam test for upstream RDC (RPC) is planned at the end of the beam time

#### November April May June July August September October December 15 16 17 18 19 20 21 25 27 42 43 22 23 24 26 29 30 31 32 33 34 35 39 40 44 47 48 14 28 36 37 38 41 45 46 49 50 51 7 3 3 7 6 7 3 7 6 7 7 7 6 4 4 7 7 з 7 7 7 3 7 7 7 0 0 6 7 6 6 6 3 0 May/30/22 Aug/15/22 Aug/22/22 Sep/26/22 Apr/18/22 May/16/22 May/23/22 Jun/13/22 Aug/28/22 Sep/12/22 Sep/19/22 Sep/25/22 Oct/31/22 Odf/10/22 Nov/14/22 Nov/28/22 Dec/12/22 Apr/25/22 May/2/22 Nov/21/22 Dec/19/22 May/9/22 Oct/24/22 Apr/11/22 Jun/20/22 Jun/27/22 Jul/25/22 Sep/5/22 Odt/17/22 Jul/18/22 Aug/1/22 Aug/8/22 Oct/3/22 Jun/6/22 Jul/11/22 Nov/7/22 Nov/13/22 Dec/5/22 Apr/4/22 Apr/10/22 Ju14/22 May/22/22 May/15/22 May/29/2/ Aug/21/22 Sep/18/22 Nov/20/22 Nov/27/22 Aug/28/22 Dec/18/22 Jun/19/22 Sep/11/22 Dec/11/22 Apr/17/22 Jun/26/2 Aug/14/22 Jun/12/22 Apr/24/22 May/1/22 Oct/30/22 May/8/22 Jul/10/2: Aug/7/22 Sep/4/22 Oct/16/22 Nov/6/22 Jul/17/23 0d/2/2; Jul/31/22 Jun/5/22 Jul/24/22 Od/9/2: 4/22 MEG II assigned Detector Physics run CEX commissioning done Beam test for RPC

#### MEG II beam time in 2022

### Prospect for 2022 run

- Physics data taking is ongoing since 14th Jul.
  - Stable DAQ without some minor troubles
- Calibration data for the liquid xenon detector and the timing counter are taken
  - Once per day for the liquid xenon detector : ~ 1 or 2.5 h/1set
  - Three times per week for the timing counter : ~20 min/1set
- Estimated sensitivity of the branching ratio:
  - 2021+2022 (assuming 3e+7 beam) : 1.8×10-13
  - can be improved by reducing calibration time or analysis improvement



# PDE decrease and recovery of the LXe detector by annealing

Status and prospect of 2022 run

- MEG II experiment searches for charged lepton flavor violation :  $\mu^+ \rightarrow e^+ \gamma$
- PDE recovery of the MPPCs in the liquid xenon detector was conducted
  - by hot water annealing : slightly recovered but too late
  - by mass Joule annealing : the PDE recovered  $5.6\% \rightarrow 11.5\%$  in average
  - can be tolerable for 4e+7 muon/sec beam in 2022 run
- Physics run is on going with 3e+7 muon/sec beam
  - DAQ is stable
- Estimated sensitivity of the branching ratio (2021+2022) : 1.8×10<sup>-13</sup>