0. Abstract

We have developed calibration methods of VUV(Vacuum Ultraviolet)-sensitive MPPCs of MEG II liquid xenon gamma-ray detector. Gain, Excess Charge Factor(ECF) and Photon Detection Efficiency(PDE) have been constantly monitored under high intensity muon beam environment.

1. MEG II Experiment

\[ \mu \rightarrow e\gamma \] decay search at PSI.
• Forbidden in Standard Model
• Observable in BSM(\[Br(\mu \rightarrow e\gamma) \sim 10^{-14}\]).

Kinematics

Key concepts[1]
• High intensity \( \mu \) beam available at PSI.
• \( 7 \times 10^7 \mu/s \)
• High resolution detectors for \( \varepsilon^+ \) and \( \gamma \)

2. Liquid Xenon Gamma-ray Detector

LXe scintillator coupled with VUV-sensitive photosensors.

4760 Photosensors
• 4092 MPPC(Multi-pixel Photon Counter)
• 668 PMT(Photo Multiplier Tube)

In 2018, 640 MPPCs have been operated under high intensity muon beam environment.
• The number of MPPCs is limited due to the limited readout channels.
• Over voltage: 7 V, Temperature: 165 K

Photosensor Calibration

O(1)% precision is essential for detector performance.

\[ N_{\text{photon}} = \text{Charge}/(G \times ECF \times PDE) \]

Gain
Excess Charge Factor
Cross-talk
Photo Detection Efficiency

3. Gain & ECF

Method
Measure subtle blue LED light.
Gain = Charge of 1 photo-electron.

\[ \text{Gain} = Q_{\text{p.e.}}/Q_{\text{p.e.}} \]

Excess Charge Factor(ECF):
Deviation from Poisson distribution

\[ ECF = Q_{\text{observed}}/Q_{\text{Poisson}} \]

\[ Q_{\text{Poisson}} = \text{Gain} \times (-\ln(R_{\text{p.e.}})) \]

Result

Gain & ECF were successfully measured for all MPPCs.
Gain: \( 1.6 \times 10^9/\text{p.e.} \)
ECF: 1~2.5(depending on production lot)
• Relative uncertainty: 3~5%

Stability under muon beam environment has been checked.

4. Photon-detection efficiency(PDE)

Method
Measure \( \alpha \)-ray events from \(^{241}\text{Am}\) sources[2].
• 25 point sources mounted on 5 wires.
• 5.5 MeV \( \alpha \)-ray at \( \sim 100 \) Hz.

The expected number of incident photons is evaluated using MC simulation.

\[ \text{PDE} = N_{\text{phoe,measured}}/N_{\text{phoe,expected}} \]

Result

Measured PDE: 8.6 % (average)
• Relative uncertainty: 4%(channel by channel)
• Lower than the previous measurement(\( \sim 18\%\))\[3\]

\( \sim 30\% \) PDE drop under muon beam (370 hours@\( 7 \times 10^7 \mu/s \)).

Precision meets the requirement.

5. Summary

• VUV-sensitive MPPC has been developed and installed in MEG II liquid xenon gamma-ray detector.
• We have developed calibration methods that realizes O(1)% precision on gain, ECF and PDE.
• Intrinsic response of MPPC has been stable under high intensity muon beam environment.

6. Acknowledgement

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7. Reference