Journal of Physics: Conference Series **1468** (2020) 012162 doi:10.1088/1742-6596/1468/1/012162

Basic studies of 3-inch PMT for multi-PMT development

M. Inomoto[1], M. Ishitsuka[1], M. Kuze[2], Y. Nishimura[3] and B. Quilain[4] for the Hyper-Kamiokande Proto-Collaboration

[1] Faculty of Science and Technology, Tokyo University of Science, Japan
[2] School of Science, Tokyo Institute of Technology, Japan
[3] Faculty of Science and Technology, Keio University, Japan
[4] Kavli IPMU, WPI, The University of Tokyo, Japan

E-mail: 6219507@ed.tus.ac.jp

Abstract. Hyper-Kamiokande is the next generation large-scale water Cherenkov detector. In Hyper-Kamiokade and Intermediate Water Cherenkov Detector for its long baseline project with J-PARC neutrino beam, use of multi-PMT, which is made by combination of 3-inch PMTs, is being considered. As part of multi-PMT development, we measured the characteristics of the 3-inch PMT including the temperature dependence of dark noise rate. The dark noise rate is important characteristic for detection of low energy events including neutron tagging. In addition, since PMT is generally susceptible to the magnetic field, we confirmed the photon detection efficiency in the condition where the magnetic field was applied.

1. Introduction

Hyper-Kamiokande is the next generation large-scale water Cherenkov detector. It is designed to have approximately an order of magnitude larger fiducial volume than its predecessor, Super-Kamiokande. Its physics goals are to reveal neutrino properties such as the CP violation, to investigate astrophysical neutrinos, and discovery of proton decay. In Hyper-Kamiokade and Intermediate Water Cherenkov Detector for its long baseline project with J-PARC neutrino beam, use of multi-PMT is being considered [1]. Multi-PMT is a new device made by combination of multiple 3-inch PMTs. As part of multi-PMT development, we made measurements at a laboratory to understand performance of the 3-inch PMT (Hamamatsu R14374).

2. Measurement of the 3-inch PMT dark rate

One of the purposes for this measurement was to confirm the temperature dependence of dark noise rate (dark rate) around 13 °C, which is the water temperature in Super-Kamiokande. Dark noise is caused by thermal electron or radio-activities. The dark rate is important characteristic especially for detection of low energy events, such as solar neutrinos and neutron tagging. The setup of dark rate measurement is described in Figure 1. Temperature is controlled in an incubator. The result of this measurement is summarized in Figure 2. Dark rate is slightly lower in lower temperature.

Another purpose was to check the effect of HA coating. HA coating decreases the dark noise made by external potential on the side of the bulb especially for negative high voltage (HV). We compared one HA coated PMT and one non-HA coated PMT. We can see from Figure 2 that the former has lower dark rate than the latter. There is no significant difference on dark rate between positive HV and negative HV in the air. We note that the effect of HA coating is expected to be clearer in the water.

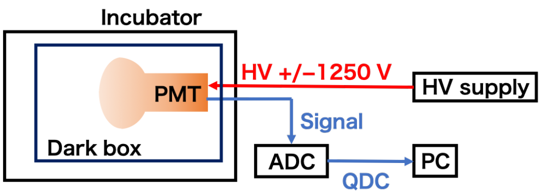


Figure 1. Setup to measure the temperature dependence. Temperature around the 3-inch PMT was stable with the incubator. Integrated charge of the signal from the PMT in dark box was digitized by ADC.

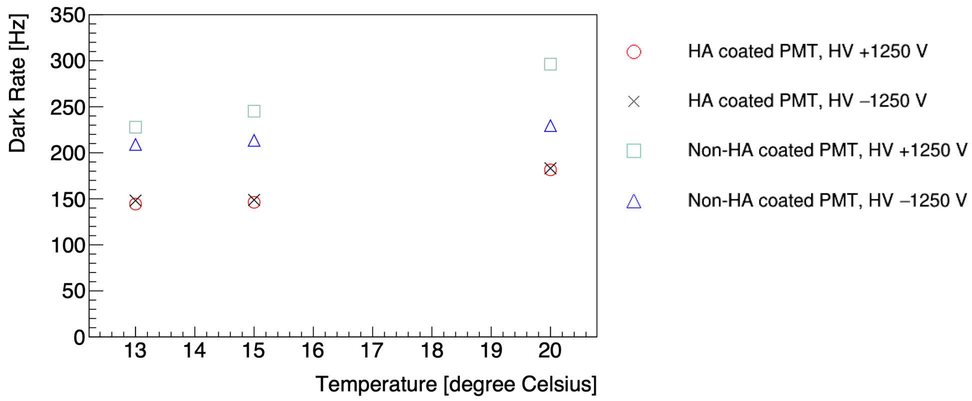


Figure 2. Temperature dependence of dark rate.

3. Measurement of magnetic field dependence

We performed a measurement in the magnetic field to examine whether Earth's magnetic field affects photon detection efficiency. PMT is generally susceptible to the magnetic field. Figure 3 shows the setup to check the magnetic field dependence of the photon detection efficiency. The magnetic field is applied by a coil. Figure 4 shows the results of this measurement. The result in Figure 4(a) shows that Earth's magnetic field, which is about 0.046 mT, has little effect on the efficiency. Efficiency variation is less than 4 % in the range from −0.2 mT to 0.2 mT. The result in Figure 4(b) indicates that the efficiency is stable in the range of Earth's magnetic field but it decreases in the magnitude of more than 0.6 mT. We need more precise measurements in the magnetic field parallel to photocathode.

4. Summary

In conclusion, there is only small temperature dependence of dark rate around 13 °C. The efficiency is stable in the magnitude of Earth's magnetic field (0.046 mT) but its close to the limit. We will make more precise measurements in the magnetic field especially for the direction parallel to the photocathode.

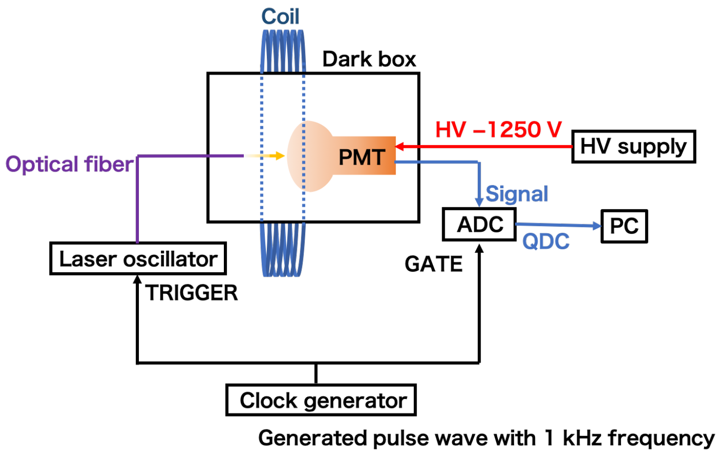
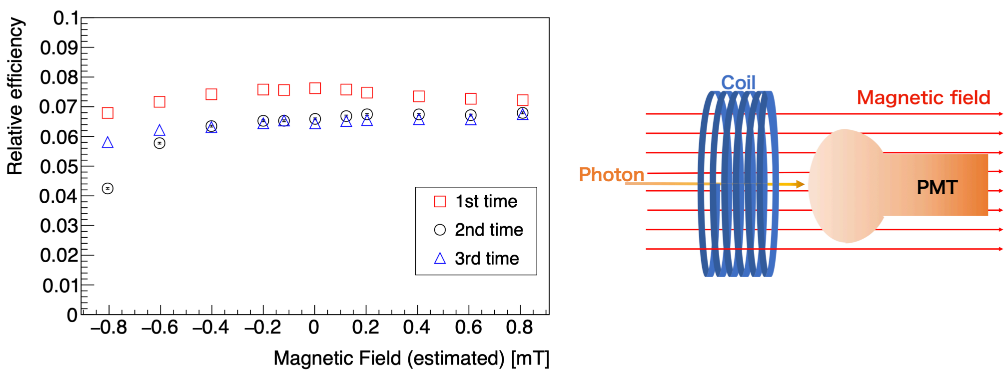
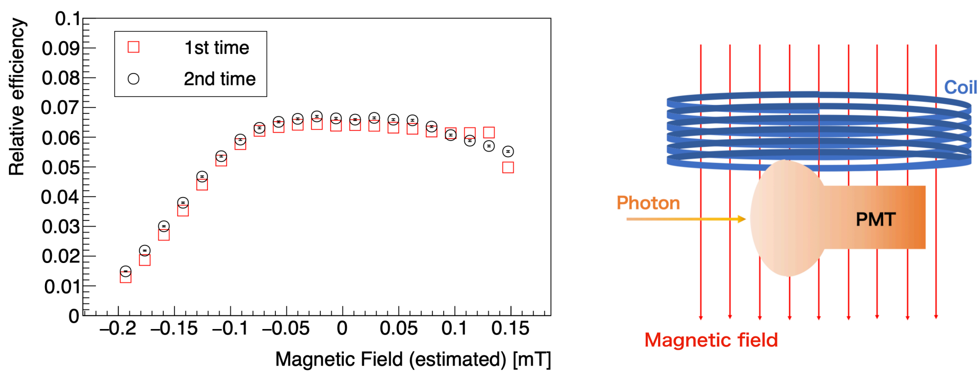


Figure 3. Setup to measure the magnetic field dependence. The 3-inch PMT was set in the magnetic field generated with coil. The center of PMT was illuminated with laser oscillator. The signal from the PMT in dark box was read out with ADC .



(a) Magnetic field perpendicular to photocatode



(b) Magnetic field parallel to photocatode

Figure 4. Magnetic field dependence of photon detection efficiency.

References

[1] K. Abe *et al.* [Hyper-Kamiokande Proto-Collaboration], arXiv:1805.04163 [physics.ins-det].