PROCEEDINGS OF SCIENCE

Long-term performance and its stability of Hyper-Kamiokande PMTs in the SK water tank from 2018 to present

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For the Hyper-Kamiokande experiment, A new 50cm Box & Line type PMT (HKPMT) has been developed. 136 HKPMTs have been installed in Super-Kamiokande since 2018. Using this data, long-term measurements of the gain variation of the HKPMTs in the water were performed with PMT dark hit data obtained from cosmic muon events. As a result, we observed a small gain increase of +0.79%/year, which is similar to that of the SKPMTs (+1.42%/year).

38th International Cosmic Ray Conference (ICRC2023)
26 July - 3 August, 2023
Nagoya, Japan

*Speaker

PoS(ICRC2023)1167

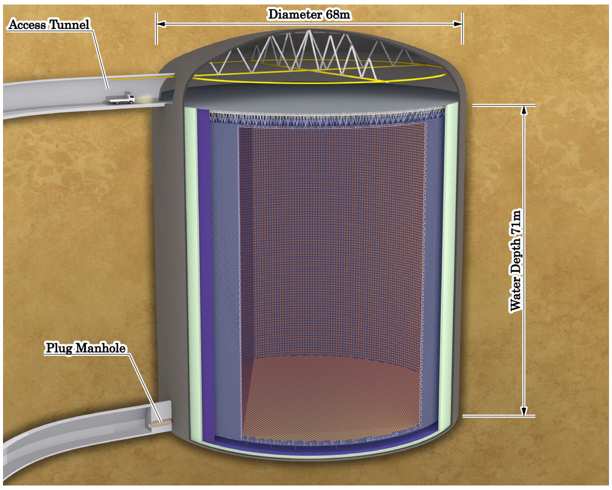

Figure 1: Hyper-Kamiokande detector,Diameter:67m, Height:71m, is filled with 258 kton pure water.

1. Introduction; Hyper-Kamiokande photo-multiplier tubes installed in SK

The Hyper-Kamiokande is a next-generation water Cherenkov detector with a 68-m diameter, 71-m high cylindrical water tank that holds 258 kilotons of pure water [1][2]. The size of the water tank is five times larger than that of the Super-K, and its fiducial volume will eventually be eight times larger. Hyper-K's physics goals are precise measurements of neutrino oscillations using atmospheric and accelerator neutrinos to determine the CP phase, the mass hierarchy and θ_{23} -octant, observations of astrophysical neutrinos, and searches for nucleon decay. Hyper-K observes Cherenkov radiation emitted by charged particles from neutrinos and particle interactions, and reconstructs the events from the time information and light intensity. Detail information for Hyper-K can be found elsewhere[2] For the Hyper-K experiment, a new 50-cm PMT with Box & Line type dynode (HAMAMATSU R12860; HKPMT) was developed (Fig. 2). The developed PMT has improved detection efficiency and resolution compared to the PMT used in Super-K (HAMAMATSU R3600; SKPMT). Compared to the SKPMT, HKPMT achieves 1.5 times higher quantum efficiency and 1.35 times higher collection efficiency, resulting approximately 2 times higher photon detection efficiency[3].

Performance of R12860 has been evaluated in the air for charge resolution, time resolution, dark rate, and detection efficiency. In order to evaluate long-term performance in the water as actual use, 136 HKPMTs were installed in Super-K during Super-K renovation in 2018, and data acquisition started in March 2019. The quantum efficiency and gain variation in the water have already been studied by using Ni-Cf calibration[4] data. In this study, the gain variation of the HKPMTs in the water were performed with PMT dark hit data obtained from off-time window hits in cosmic muon events. Since this method has been originally used for the gain monitor of the SKPMTs, it is adopted for gain monitor of the HKPMTs in the Super-K water tank to measure the long-term gain variation. It allows for automated evaluation with more statistics, continuous data taking, and longer measurement periods than that by Ni-Cf calibration data.

Figure 2: HKPMT; A new Box & Line PMT (HAMAMATSU R12860)

2. Data set and analysis methods

The data period used was Mar./2019 - Sep./2022. The data acquired by the 129 PMTs excluding 7 bad channels were used for the analysis. Figure3 shows the typical hit time distribution of 129 HKPMTs for cosmic muon events. The peak corresponds to the arrival timing of Cherenkov photon emitted from a cosmic muon. Here we defined the off-time window from -3500ns to 500ns as shown in Fig. 3. The dominant part of the hits recorded in this off-time window is the signal due to PMT dark hits.

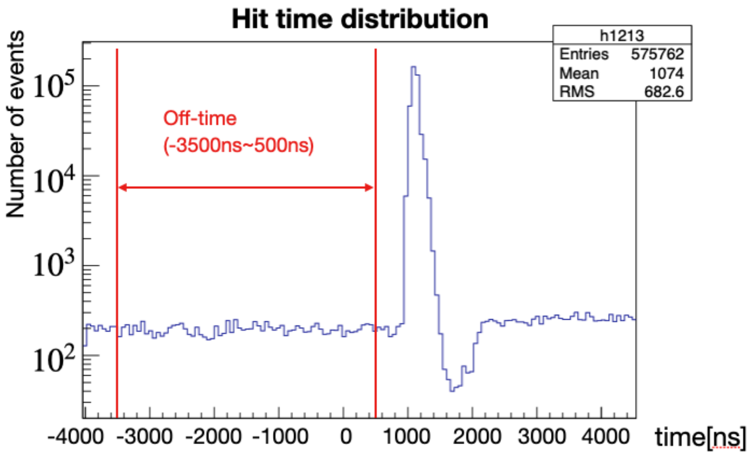

Figure 3: Hit time distribution of PMTs

The charge distribution of the hits for all the 129 PMTs in the off-time window is shown in Figure 4. A Gaussian fit was applied to this charge distribution to cover the peak region in 0.7 p.e - 1.5 p.e. The peak value of the fitted Gaussian function was then plotted as a function of time (date) of data acquisition. A linear function is fitted to the result to quantitatively evaluate the gain variation (increase) by its slope.

3. Results

To confirm the validity of the present analysis method, we compared the gain variation of the HKPMTs installed in Super-K by Ni-Cf calibration data as shown in Figure 5. The present analysis

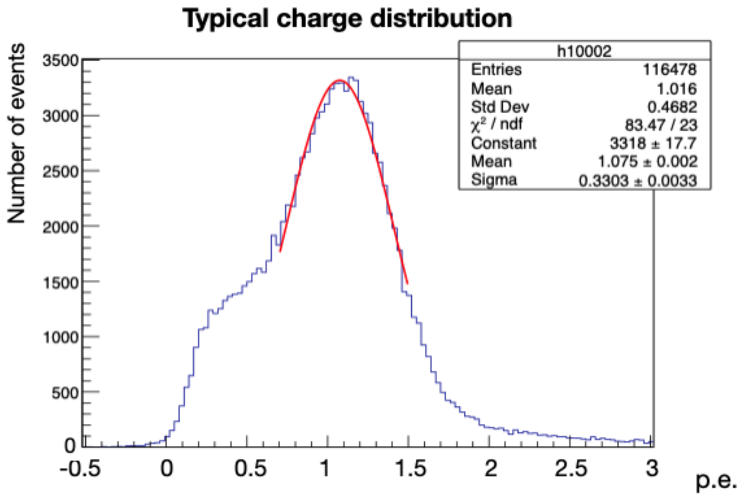

Figure 4: Charge distribution and Gaussian fitting

is consistent with the result by Ni-Cf calibration data, demonstrating even much improved statistical error.

As a result, the gain increase rate of the HKPMTs was +0.79 ± 0.03 %/year as shown in Figure 6. The gain increase was also measured for the SKPMTs using the same method as a comparison (The red points in Figure 7). The rate of increase for the SKPMTs was +1.42 ± 0.01 %/year, showing that HKPMTs and SKPMTs have similar tendency for long-term gain variation in the water.

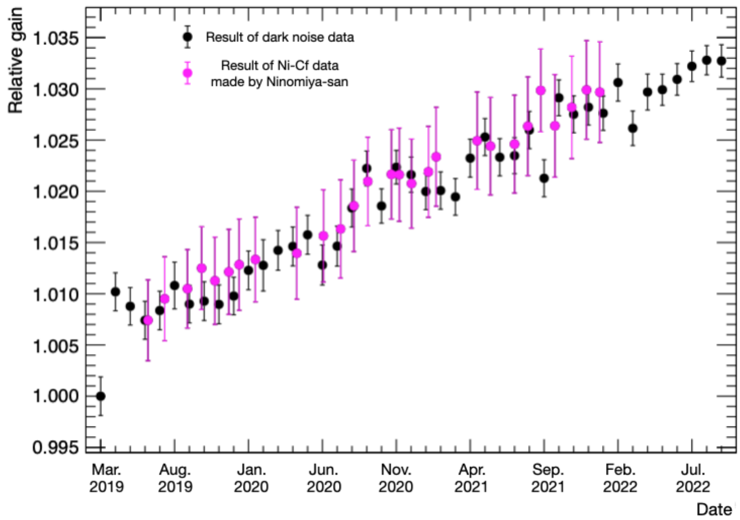

Figure 5: Comparison dark noise data with Ni-Cf calibration data

4. Summary

136 HKPMTs have been installed in Super-Kamiokande since 2018. Long-term measurements of the gain variation of the HKPMTs in the water were performed with PMT dark hit data obtained

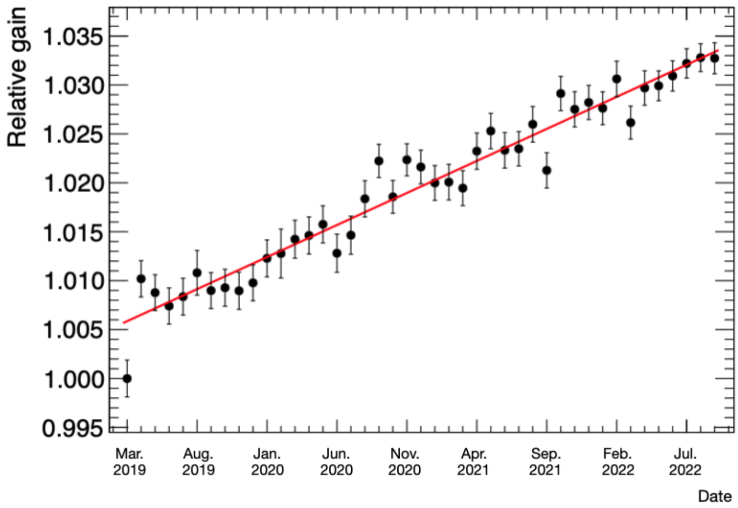

Figure 6: Gain variation of HKPMTs with linear function fitting

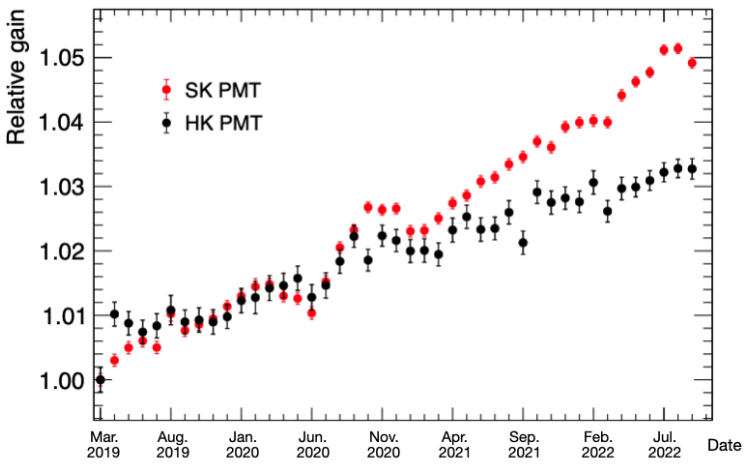

Figure 7: Gain time variation of 129 HKPMTs and all SKPMTs

from cosmic muon events. As a result, we observed a small gain increase of +0.79 %/year, which is similar to that of the SKPMTs (+1.42 %/year).

References

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