Development of Front-End Electronics for Hyper-Kamiokande : Performance Evaluation of Digitizers

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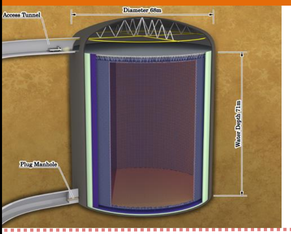
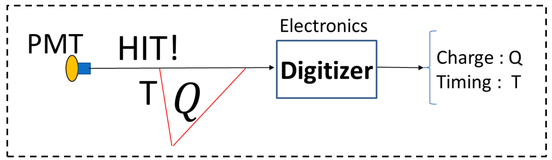


1. Hyper-Kamiokande

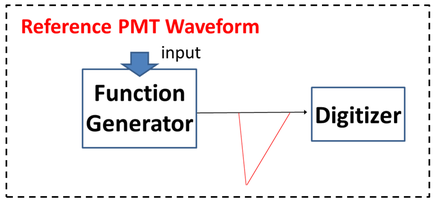
- Hyper-Kamiokande (HK) is a next generation water cherenkov detector.
- HK will be the world's leading detector with its huge volume (SK ×8) and highly sensitive light sensors (Box & Line PMT).
- HK aims to explore proton decay in GUT beyond the Standard Model and study properties of neutrino (CP violation, mass hierarchy).

2. Hyper-K Electronics



- Digitizer converts PMT signal to digital data
- 3 candidate digitizer R&Ds running worldwide
- To select one digitizer, we have to compare under the same condition of digitizers.

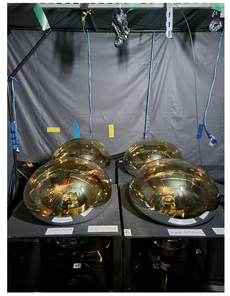
Evaluation Method



Necessary ;
Reference PMT waveforms for various light intensity

3. Box & Line PMT Measurement

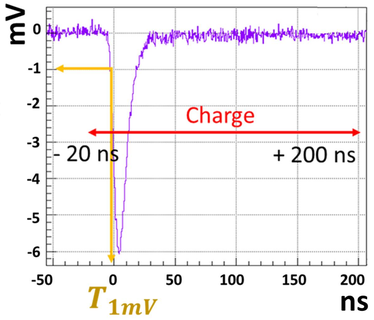
- Recorded PMT (R12860) waveforms with oscilloscope
- Dark room in the Kamioka mine
- Light source (laser diode (λ = 405.6nm)) + diffuser ball
- 3D geomagnetic field compensation coil
- Light intensity and supply HV scanning



4. Waveform Analysis

4.1 Waveform Averaging

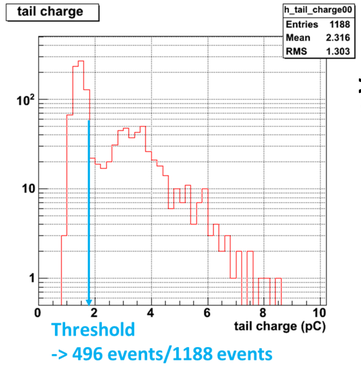
1. Define T_{1mV} as timing of 1mV DAQ threshold
2. Define charge as $\int V\,[T_{1mV} - 20\ \text{ns}, T_{1mV} + 200\ \text{ns}]dt$
3. Select events whose charge is within ±10% of target value
4. Align waveforms at T_{1mV}
5. Average the waveforms

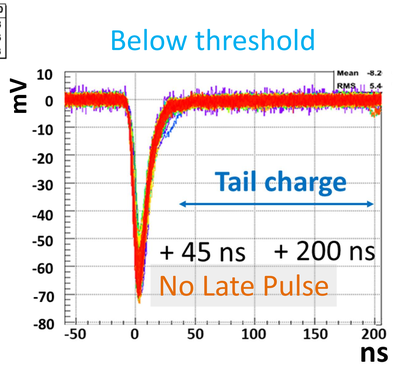


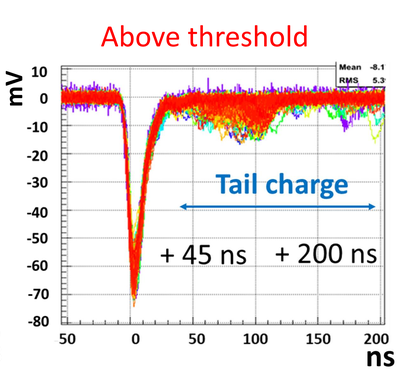
4.2 Late Pulse Elimination

- In PMT waveform, a pulse called "late pulse" is generated ~100 nsec after the main pulse.
- Until the light intensity reaches several tens of p.e., late pulse is generated probabilistically
- Therefore, we decided to eliminate it when creating standard waveforms for this time.

1. Define tail charge as $\int V\,[T_{1mV} + 45\ \text{ns}, T_{1mV} + 200\ \text{ns}]dt$
2. From Tail charge distribution, determine threshold and eliminate events above the threshold.



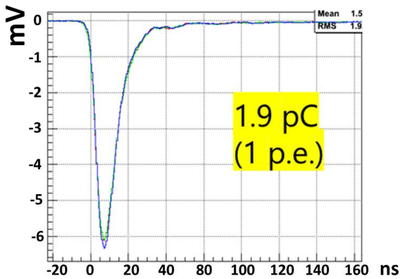




5. Reference Waveforms

- Made reference waveforms with selecting charges in dynamic range of digitizer : 1 p.e. ~ 1,250 p.e.
  (Range for which digitizer linearity is required)

✓These waveforms have been distributed to each digitizer R&D group



6. Digitizer R&D Prospects

1. Now I'm testing output of reference waveforms on function generator.
2. Evaluate whether Japanese digitizer meets requirements.
3. Complete designing in FY2021, move on the next prototype in FY2022.
4. Build a full-assessment system for mass-produced products

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