A multi-PMT photodetector system for the Hyper-Kamiokande experiment

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Hyper-Kamiokande

Hyper-Kamiokande (HK) is the next generation Water-Cherenkov detector with multi-purpose scientific goals:
- Investigation on CP-violation in leptonic sector;
- Neutrino oscillations (atmospheric, accelerator and solar);
- Determination of the neutrino mass ordering;
- Proton Decay;
- Observation of astrophysical neutrinos.

Hyper-Kamiokande Far Detector (HK-FD)

Cylindrical tank: $\Phi = 68$ m and $H = 71$ m;
Depth: 650 m;
Fiducial volume: 187 ktons of ultra-pure water;
Baseline design: 20% photo-coverage with 20,000 20'' B&L PMTs and multi-PMT.

The multi-PMT: design

The multi-PMT (mPMT) was first designed for the KM3NeT experiment [1]. A new design, optimized for HK requirements, has been realized. The main features are:
- 19 3'' PMTs inside a pressure vessel;
- Each PMT has a unique orientation;
- The effective area of PMTs is enhanced through a reflector ring installed around each respective photocathode;
- A UV-transparent acrylic dome serves as cover for the mPMT vessel;
- An optical gel fills the gap between the PMTs and the dome, serving as light guide and avoiding light distortion;
- A full electronics system is included in the vessel.

Advantages of mPMTs over single 20'' PMTs:
- Increased granularity;
- Overall lower dark rate;
- Better vertex resolution;
- Superior photon counting;
- Improved angular acceptance;
- Extension of dynamic range;
- Intrinsic directional sensitivity;
- Local coincidences.

Acrylic dome

One of the requirement for the mPMT for HK-FD is the radio purity of materials. In HK, low radioactive UV-transmitting acrylic is used for dome.
Tests to select the best material for the HK project included:
- Radioactive contamination;
- Radon emanation;
- Optical and mechanical performances;
- Pressure resistance.

Results from tests with acrylic materials from different providers show radioactivity contamination levels lower than HK requirements.

mPMT prototypes

Several prototypes have been realized. The tests’ purposes so far have been to:
I. Demonstrate the effectiveness of a vessel system with an acrylic dome;
II. Establish the best design for the installation of the electronics system in the vessel;
III. Optimize the mechanical design of the mPMT vessel;
IV. Test and optimize the mPMT assembly strategy.

Conclusions

- Measurements in HK will be enhanced with mPMT modules.
- mPMT R&D is almost completed.
- mPMT construction for HK FD will start in 2024.