A multi-PMT photodetector system for future water Čerenkov detectors

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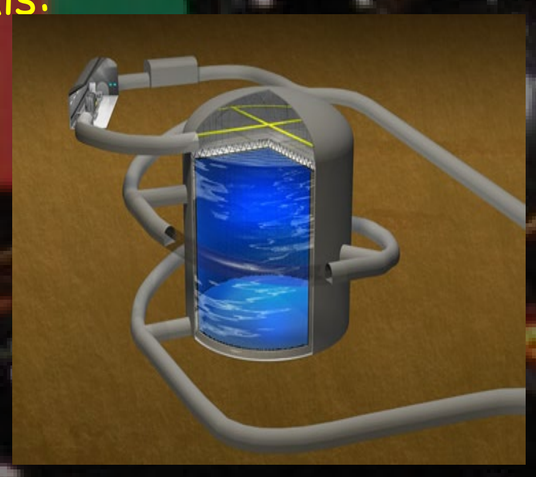
Abstract: Hyper-Kamiokande (Hyper-K, HK) is the next upgrade of the currently operating Super-Kamiokande experiment. HK is a large water Čerenkov detector with a fiducial volume which will be approximately 10 times larger than its precursor. A system of small photomultipliers, as implemented in the KM3NeT experiment and named multi-PMT module (mPMT), is considered as an option to improve the Hyper-K physics capability. The resulting segmentation of the sensitive area features several attractive advantages compared to the conventional single-PMT concept due to a superior photon counting, extension of dynamic range, intrinsic directional sensitivity, while uncorrelated singe-hit noise such as dark rate can be suppressed by using local coincidences among individual PMTs. In this contribution the development of a mPMT module for Hyper-K is discussed.

Hyper-Kamiokande

Hyper-K is a multi-purpose **Water- Čerenkov detector** with a variety of scientific goals:

- ✧Neutrino oscillations;
- ✧Neutrino astrophysics;
- ✧Proton decay;
- ✧Non-standard physics.



Hyper-K Design:
2 tanks with the staging construction.
- ➢ Cylindrical tank: diameter 74 m and height 60 m
- ➢ Total and fiducial volumes (for each tank): 0.26 and 0.19 Mtons, respectively; ~10xSuper-K
- ➢ Baseline design: Photo-cathode coverage: 40%. 40,000 ID 50-cm PMTs and 6700 OD PMTs per tank.

1 kilo-ton scale water Cherenkov detector located ~1 km from the neutrino source (IWCD)

The mPMT concept

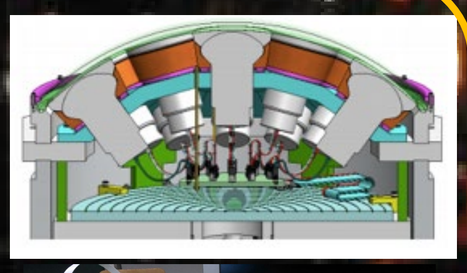
Array of photodetectors and their electronics arranged inside a pressure resistant vessel as implemented in the KM3NeT experiment [1]:
- Superior photon counting
- Improved angular acceptance
- Extension of dynamic range
- Intrinsic directional sensitivity
- Local coincidences

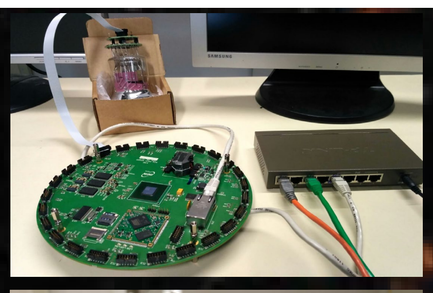
mPMT is considered as an option to improve the HK physics capability. This alternative option involves a combination between 50-cm PMTs and mPMTs

Requirements for HK experiment
- Vessel: radio purity of material.
- Electronics: timing resolution better than PMT TTS:
  - ~300-500 ps timing resolution from electronics for 1 PE
  - Good charge resolution: ~0.05 PE to 25 PE

mPMT Prototypes for Hyper-K

- Demonstrate the effectiveness of a vessel system based on acrylic
- Define a solution for electronics
- Mechanics optimized for HK detectors

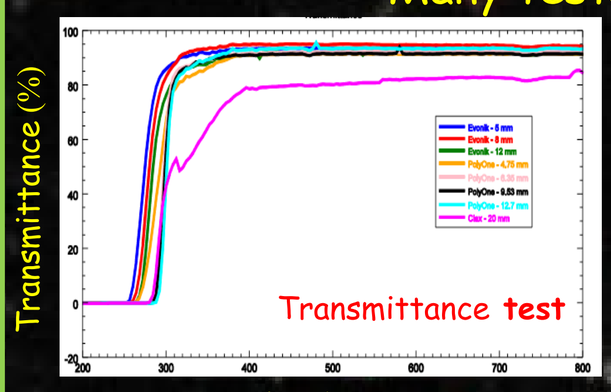




Acrylic vessel

Several acrylics tested: PLEXIGLAS® GS UV Transmitting by Evonik choosen to make the mPMT for Hyper-K.

Many tests on this material…

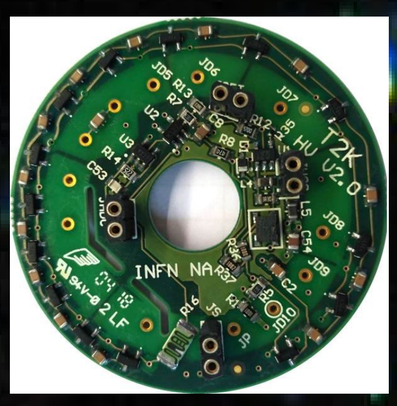


15mm-thick vessel resisted to 1.8 MPa (Constrain: 1.26 MPa)

✓ Radioactivity measurements: contamination lower than requirements

mPMT electronics

High voltage:
Basic Cockcroft-Walton voltage multiplier circuit



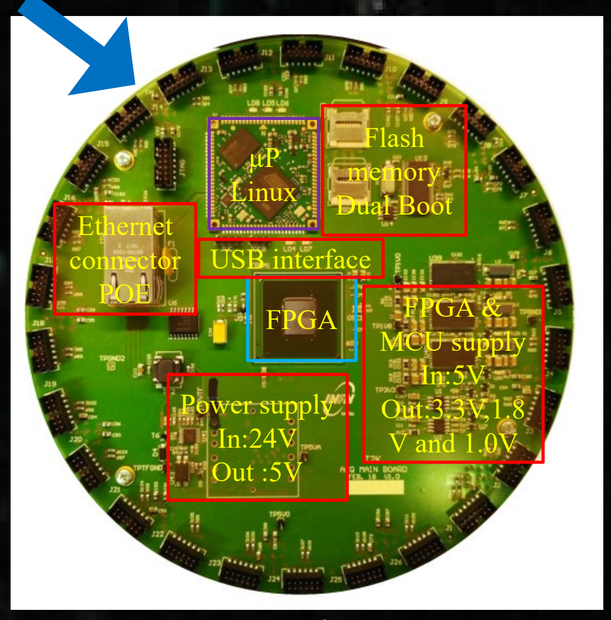
✓ Power consumption: 237.5 mW for 19 channel

✓ Stable HV

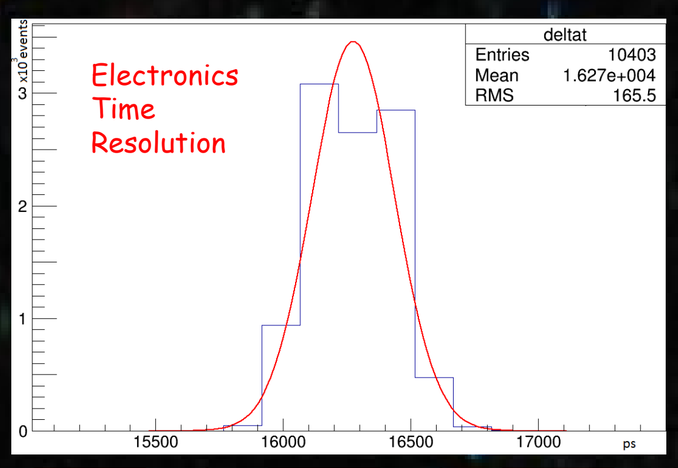
Front-end board and main board

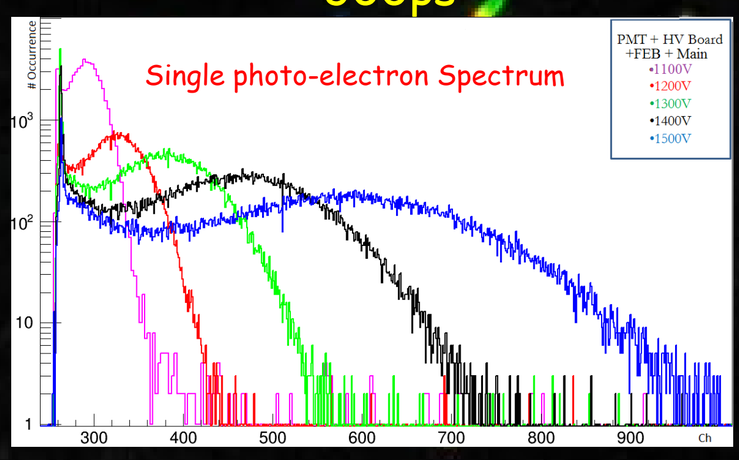
✓ Energy resolution: FWHM/ch 0.1%

✓ Time resolution: 300ps



✓ Total Power consumption: ~4.1 W for 19 channel





References: [1] S. Adrian-Martinez, et al. (KM3NeT Collaboration), Deep sea tests of a prototype of the KM3NeT digital optical module, Eur. Phys. J. C74 (9) (2014) 3056, Preprint arXiv:1405.0839