Multi-Channel PMT Optical Module

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From single large PMT to multiple small PMTs: multi-PMT

- Developed by the KM3Net collaboration for the Mediterranean km^3 neutrino telescope.
- Under investigation by the IceCube-Gen2 collaboration for neutrino telescope in ice.
- 20'' PMTs not very pressure resistant, although lots of R&D (see talk Y.Nishimura). mPMTs are encased in pressure vessel.
- Natural solution for in-water electronics.

From single large PMT to multiple small PMTs: multi-PMT

- Small PMTs do not need magnetic field shielding.
- Directionality: each single PMT sees a different part of the tank
- Improved granularity should help reconstruction and enlarging fiducial volume.
- Price per photocathode area cheaper then/comparable to 20" PMTs.
- Electronics could be simplified.

Performance of 3inch PMTs

PMTs available

ETEL D792   Hamamatsu R12199   HZC XP53B20

R12199-02 as measured by KM3NeT collaboration (From Proceedings of VLVnT 2013 (AIP Conf. Proc. 1630, 118 (2014)):

TABLE (2) Test results summarized. Minimum, maximum and mean values are listed. All measurements have been performed at a gain of 5x10^6. For each parameter the number of tested PMTs is showed within brackets. Some measurements were excluded because of miscalibrations. The TTS measurements include cross-measured PMTs and so entries are above 203.

| Parameter	Minimum	Maximum	Mean
Photocathode's diameter (1)			76 mm
Nominal Voltage for Gain 5x10^6 (181)	900 V	1450 V	1183 V
QE at 390 nm (158)	25 %	30 %	27 %
QE at 470 nm (158)	18 %	25 %	21 %
TTS (FWHM) (210)	2.8 ns	4.7 ns	3.9 ns
Dark Rate (190)	200 Hz	5000 Hz	916 Hz
Pre-pulses (20)	0.01 %	0.8 %	0.16 %
Delayed pulses (179)	2 %	5 %	3 %
Afterpulses (10 ns - 10 µs) (38)	2%	13%	6.3 %

MultiPMTs: Two example designs
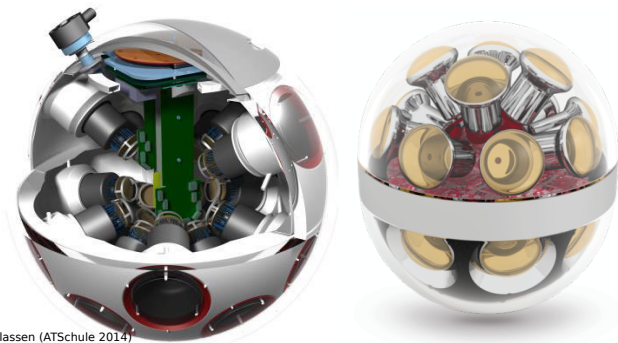
L.Classen (ATSchule 2014)

- KM3Net: 17" sphere with 31 3" PMTs (Top: 12, Bottom: 19). Maximum possible for 17" glass pressure sphere. Being deployed now.
- PINGU and beyond: 14" sphere with 24 3" PMTs (2 x 12). Currently in R&D phase.
- HyperK: in standard perifery geometry need different ID and OD. More flexibility for vessel size, hence filling. Initially replace 20" photocathode area.

Multi-PMTs for Hyper-K

- Benefit from the R&D synergies with KM3NeT and IceCube-Gen2.
- Different requirements for ID and OD: mainly ID 20" PMTs could be replaces by half multi-PMTs, while OD could be integrated in the opposite half.
- 3" PMTs: measured in detail by KM3NeT and ongoing R&D by IceCube-Gen 2 (eg. reducing dark rate). Already qualify for Hyper-K.
- Less strong pressure requirements: explore acrylic pressure vessels.
- Current status: Flexible implementation in WCSim (see E. O'Sullivan) for first performance studies with possibility for optimization.
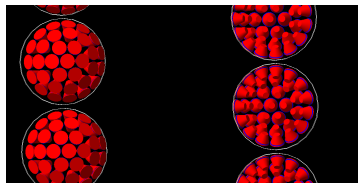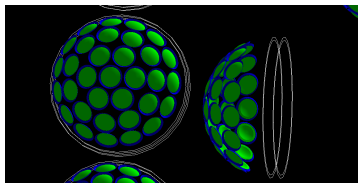
Implementation in WCSim
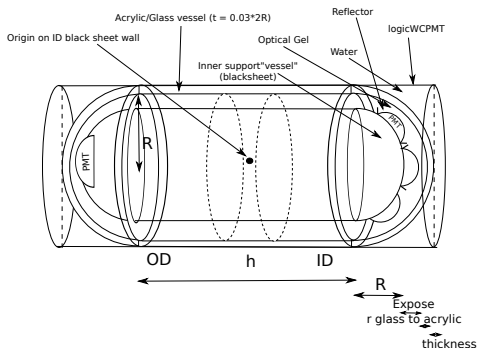

- User options in macro file for simulation:
 - Cylinder height and radius.
  - Orientation of cylinder wrt wall: vertical, horizontal, perpendicular.
  - Material for outer container (glass/acrylic/wavelength shifter/...), absorbing material for support structure.
  - ID and OD PMT type: Same vessel with different ID/OD configuration (in progress)
  - Reflector properties.
  - Free parameters for number of PMTs in mPMT with algorithm giving their optimal orientation.

Implementation in WCSim

- 20" PMT = 33×3" PMT in 16mm thick sphere of R=262mm.
- Implemented 3" R12199-02, except detailed charge and timing properties.
- Implemented reflectors, acrylic, silicon gel.
- Made sure PMTs view above neighbouring mPMT and bases do not touch.
- Flexible fill-PMT-algorithm: run python script with total number of PMTs and minimum tilt angle. Result is config txt file, used by WCSim.

Design drawing for Hyper-K prototype
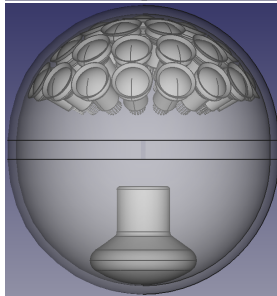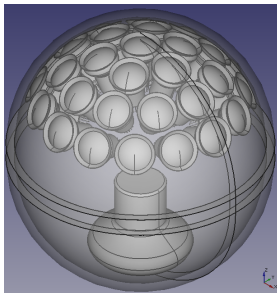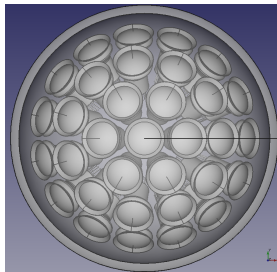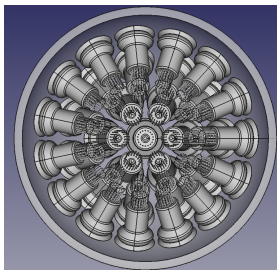
Summary

- mDOM integration ongoing for KM3NeT strings.
- Active R&D ongoing for mDOM as candidate for IceCube-Gen2.
- Flexible implementation of multiPMTs in WCSim ready for performance studies.
- Multi-PMTs are promising candidates for Hyper-K and can benefit from large synergies with KM3NeT and IceCube-Gen2.
- Detailed reconstruction and physics performance studies under way for Hyper-K.