mPMT for HyperKamiokande

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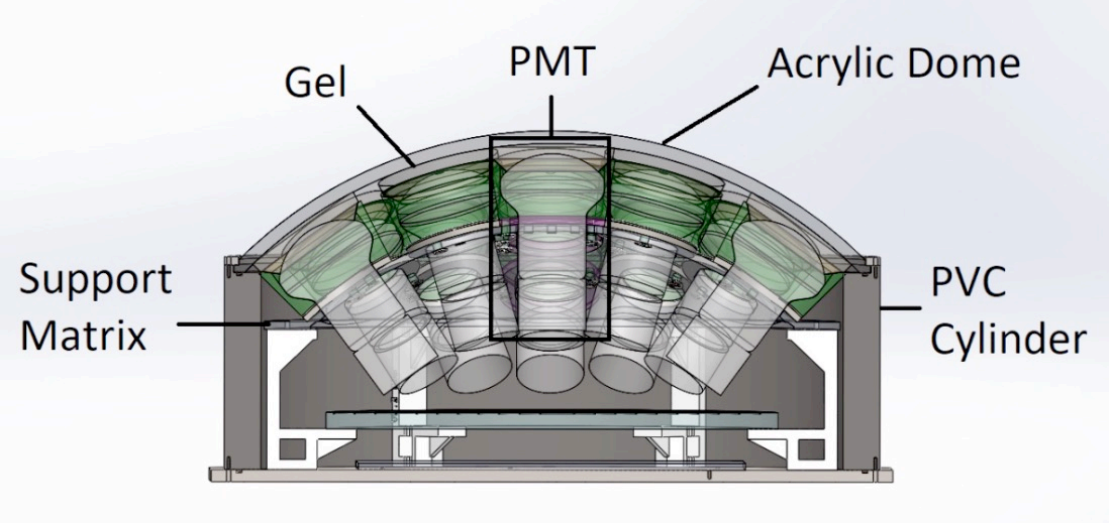
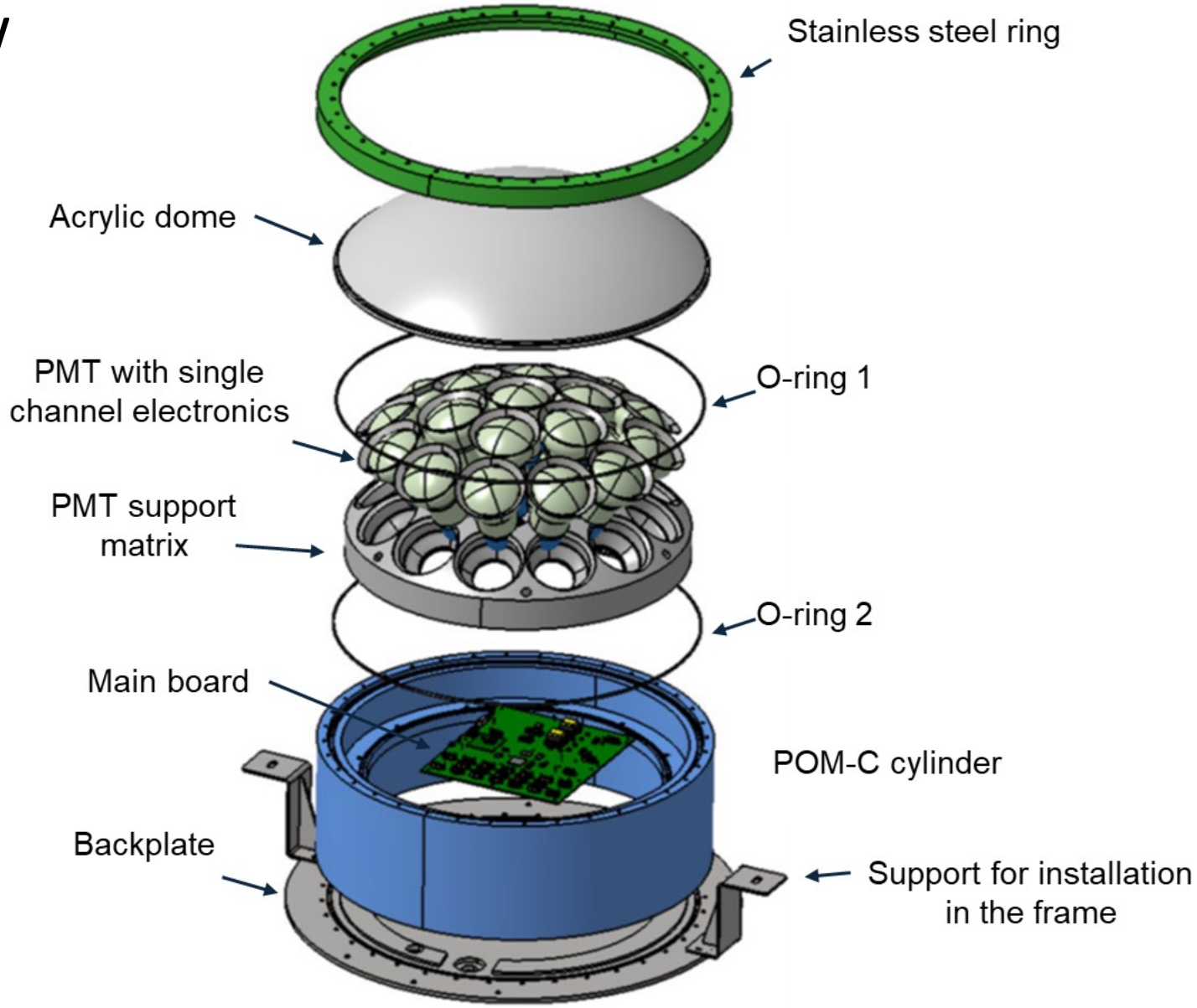
mPMT Overview

Photodetectors and electronics arranged inside pressure resistant vessel

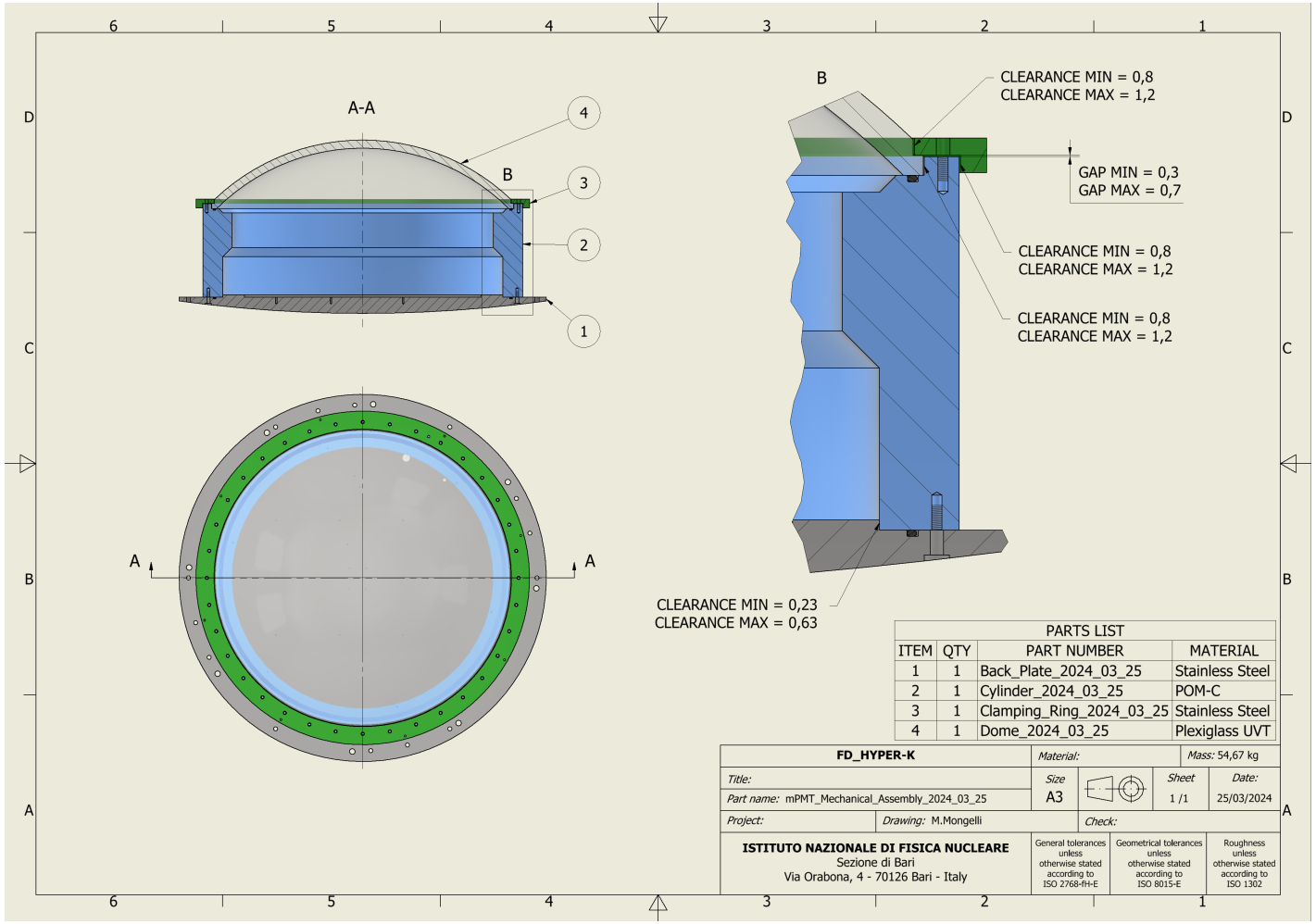
- Directional information of arrival photons, accurate photon counting, excellent timing resolution.
- Overall Plan in HyperKamiokande:
  - 100 mPMTs in Water Cherenkov Test Experiment at CERN in 2024
  - 800 mPMTs in Hyper-K FD to complement 20” PMTs
  - 400 mPMTs to instrument IWCD



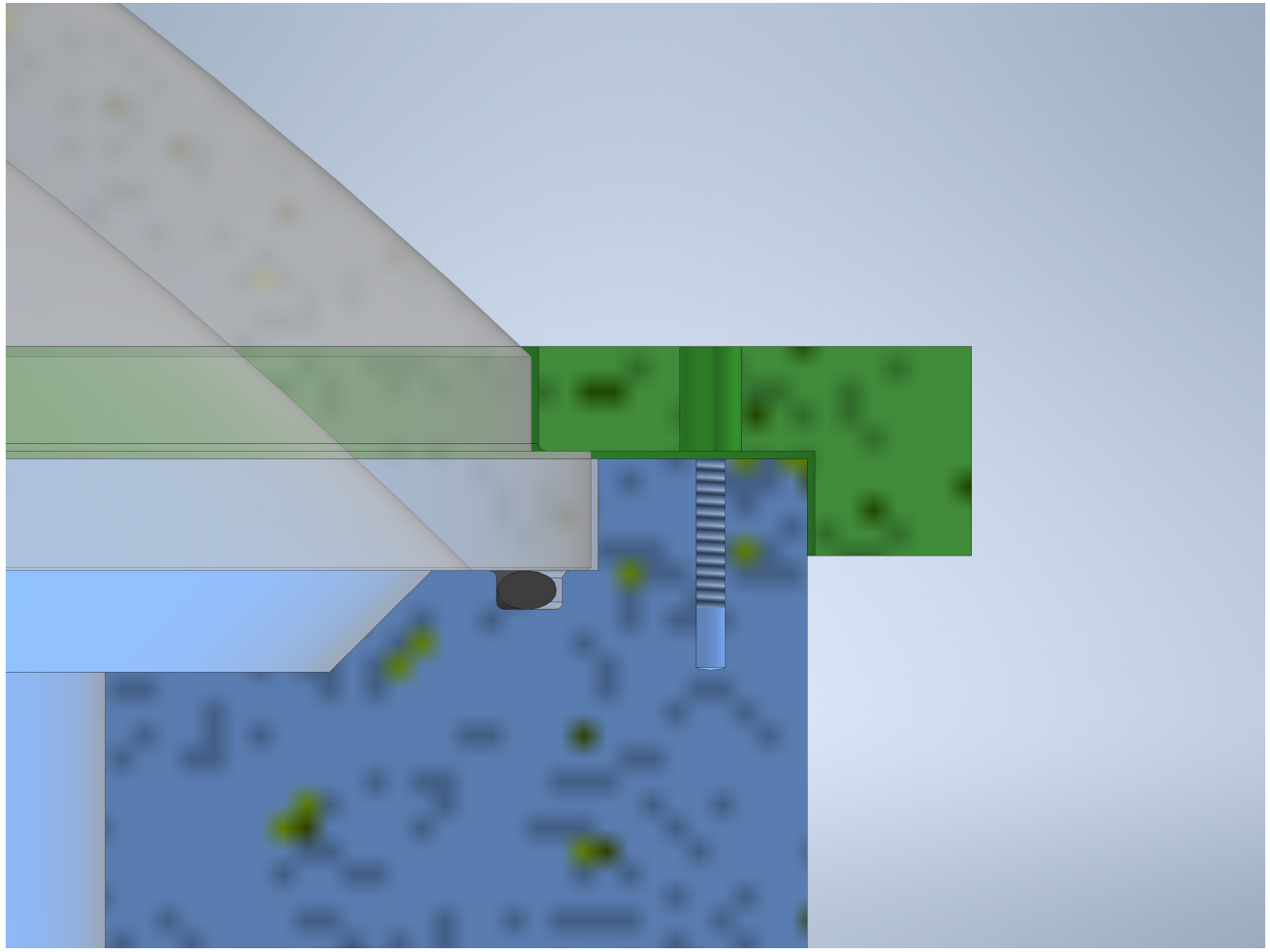
mPMT Overview



mPMT Overview



mPMT Overview



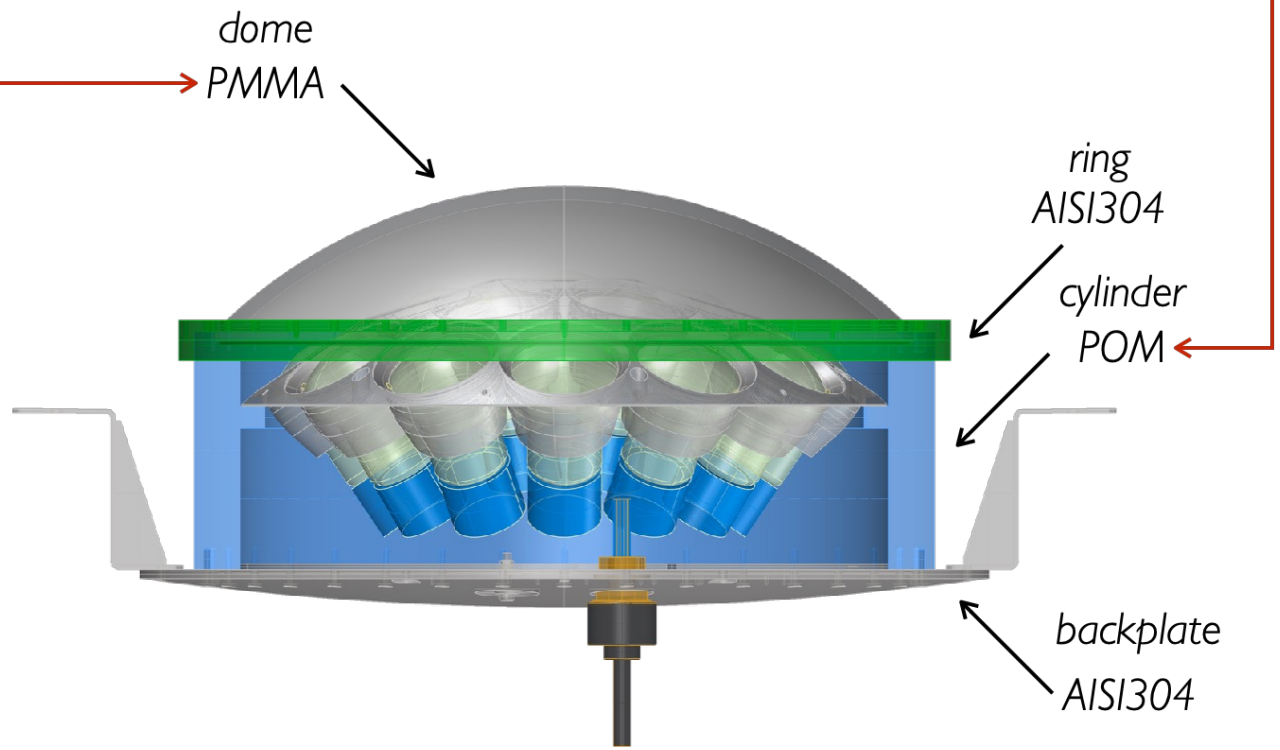
Simulation

PMMA polymethylmethacrylate

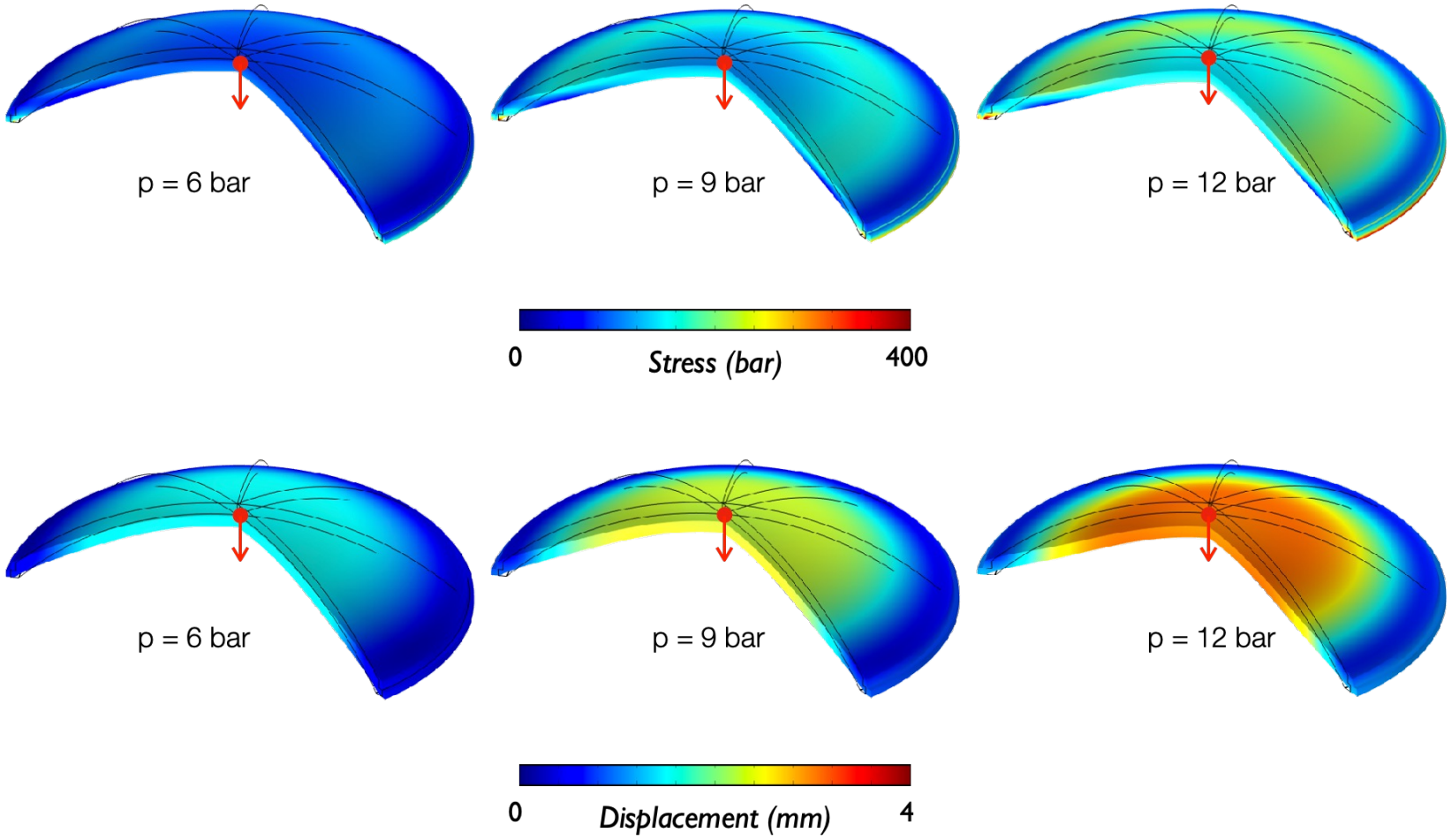
PARAMETER	UNIT	VALUE
Chain conformation	-	double helix 10/1
Entanglement molecular weight	dalton, g/mol, amu	calc.=8,782, 9,200; exp.=9,200
COMMERCIAL POLYMERS		
Some manufacturers	-	Altuglas; Evonic
Trade names	-	Plexiglas; Acrylite

POM polyoxymethylene

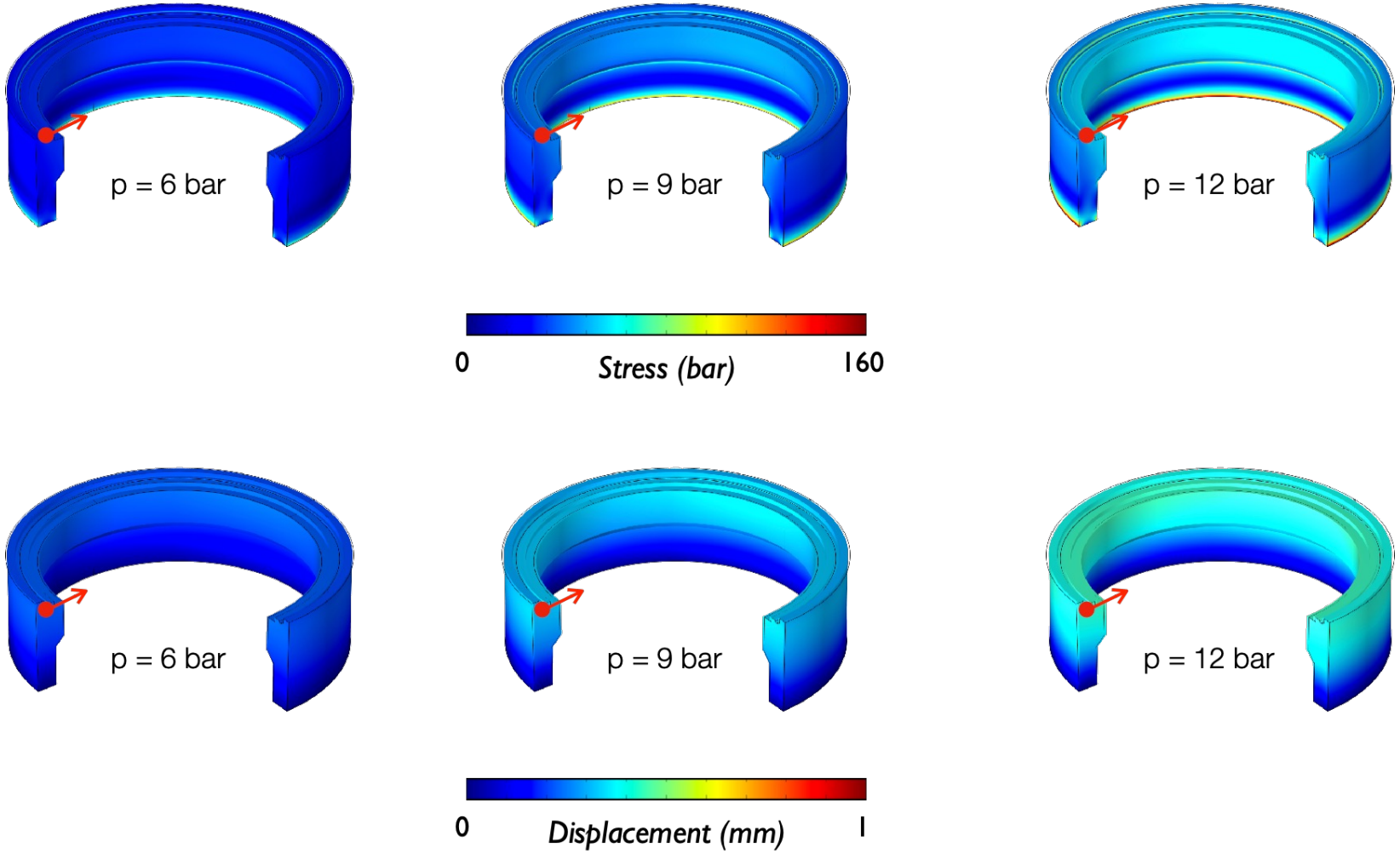
PARAMETER	UNIT	VALUE
GENERAL		
Common name	-	polyoxymethylene, polyacetal
IUPAC name	-	poly(oxymethylene)
CAS name	-	poly(oxymethylene) (9002-81-7); poly(oxymethylene), α-acetyl-ω-(acetyloxy)- (25231-38-3)
Acronym	-	POM
CAS number	-	9002-81-7, 25231-38-3
Formula		$-[CH_2O]_n-$



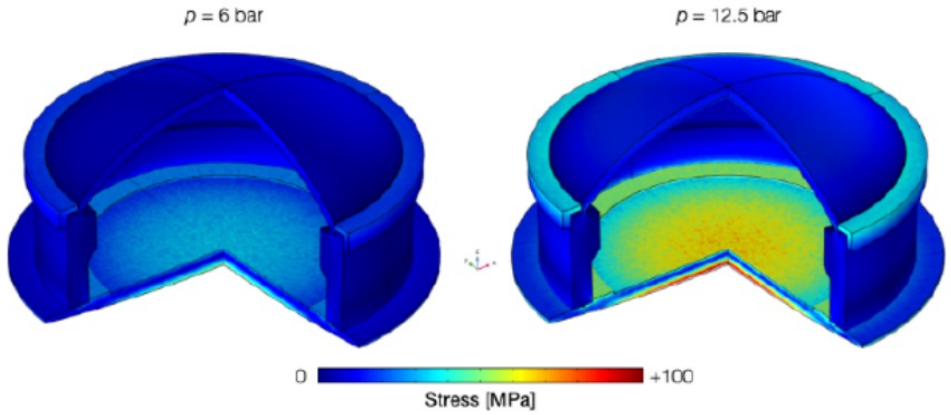
Simulation: dome



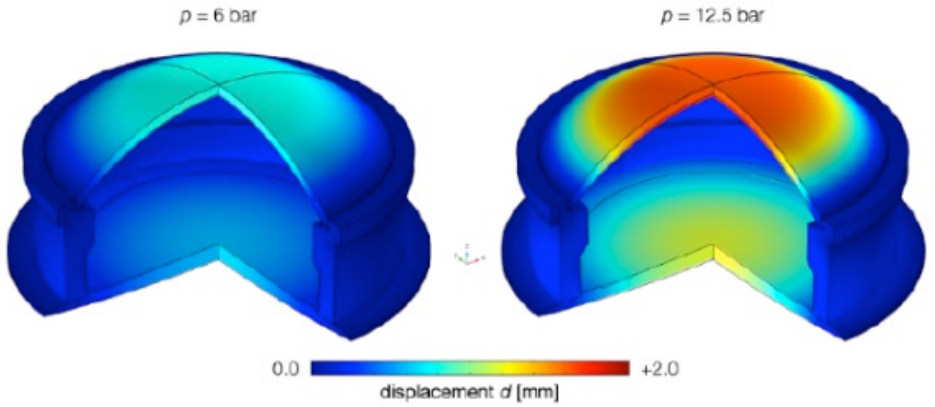
Simulation: cylinder



Simulation: assembly



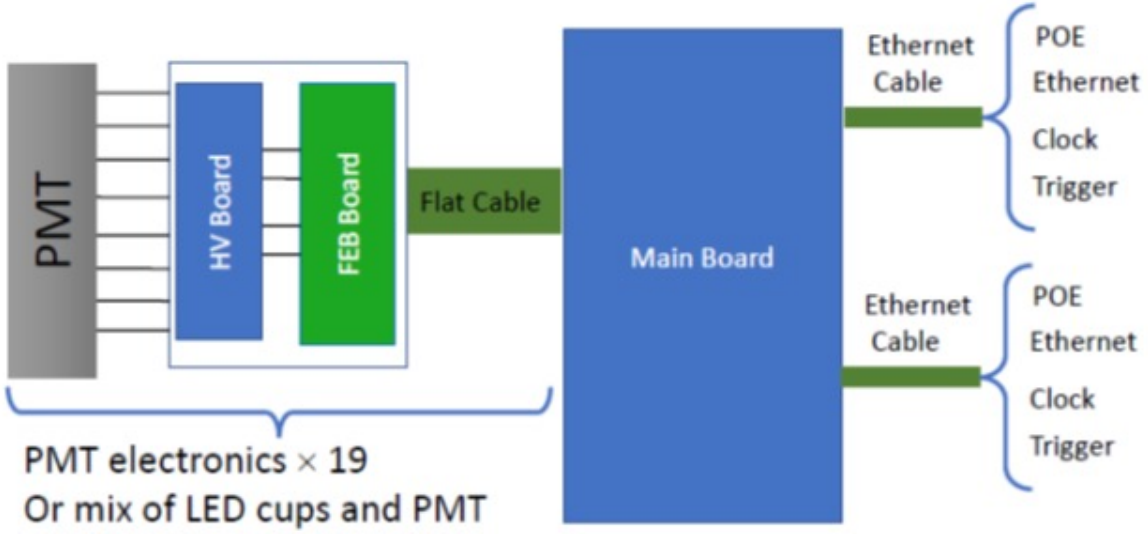
Von Mises Stress

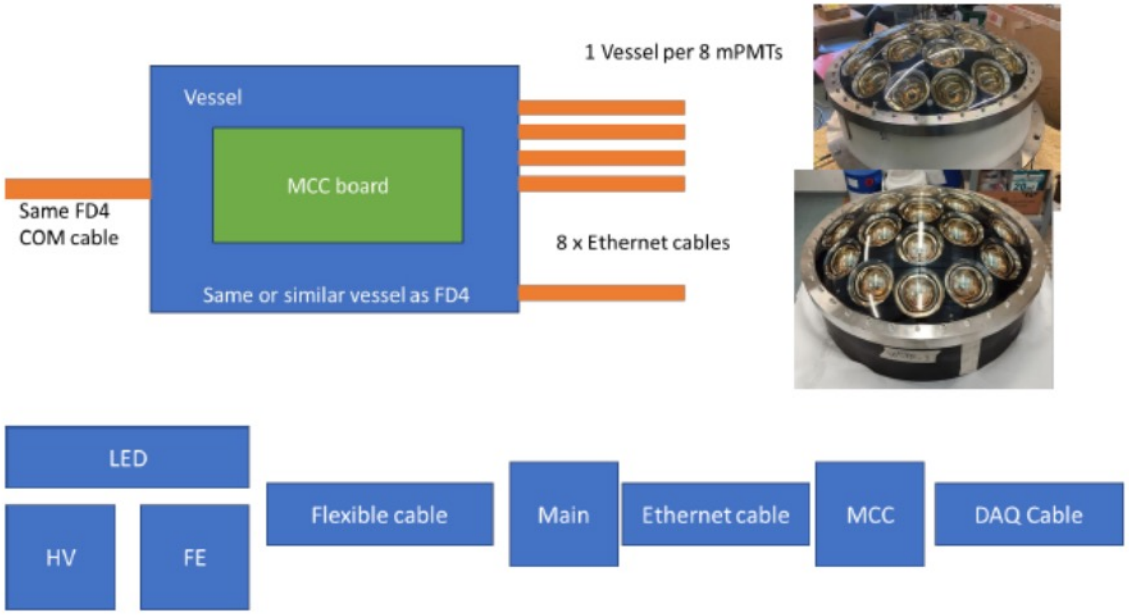


Displacement

Stress was concentrated at the dome's borders, which could lead to high deformation, resulting in cracks and failure of the hydrostatic pressure test.
The clamp ring design avoids shortcomings, constituting the full end plate. The stress was uniformly distributed along and across the dome height, remaining within the elastic limits. The maximum stresses developed on the machinery with a pressure of 12.5 bar were within the specified yield stress limits of 600 bar.

mPMT Electronics





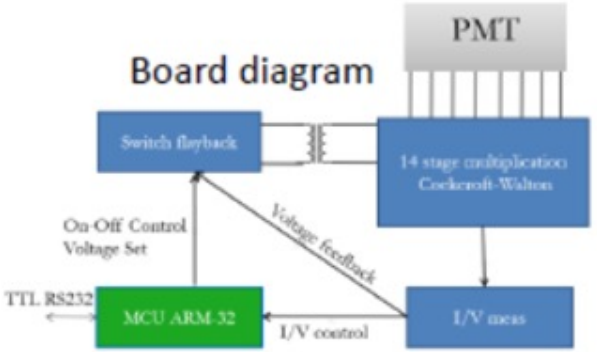
HV Board

CW voltage multiplier

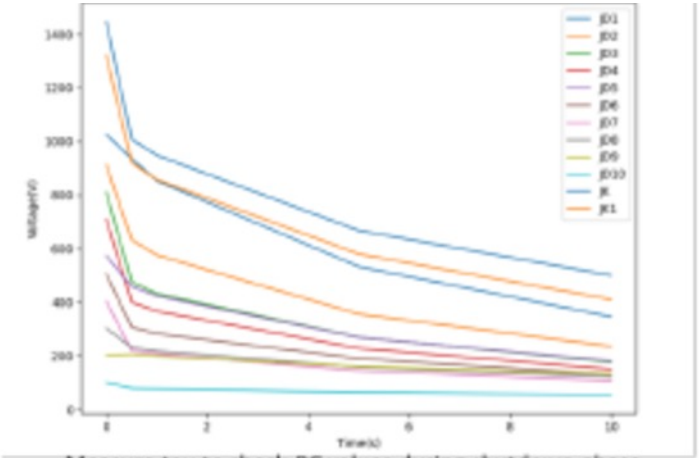
Electrodes	K	Dy1	Dy2	Dy3	Dy4	Dy5	Dy6	Dy7	Dy8	Dy9	Dy
Ratio	3	2	1	1	1	1	1	1	1	1	
Ratio	3	1	1	1	1	1	1	1	1	1	

K: Cathode,
Dy: Dynode,
P: Anode

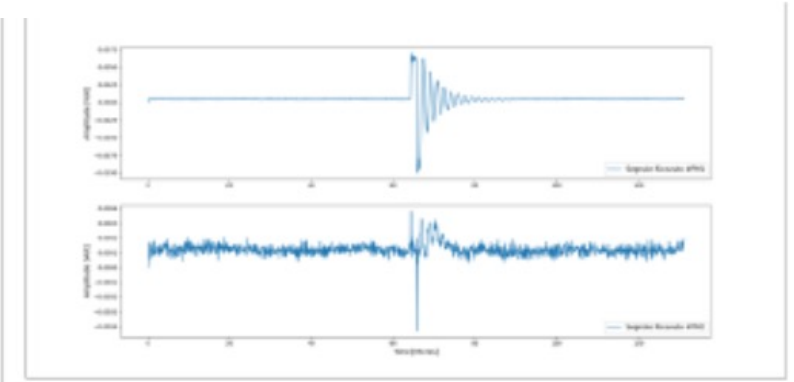
Switching to 3:1:1 ratio also for FD



Tester for HV validation

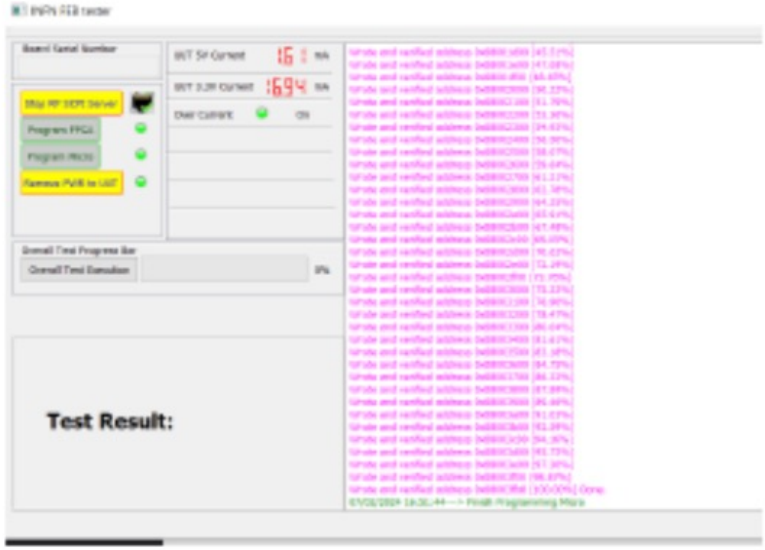


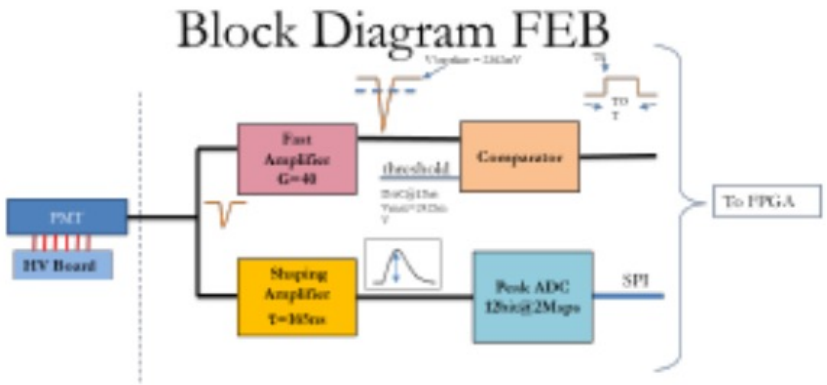
Measure tau to check RC values during shutdown phase



Measure noise induced on signal and also switching signal characteristics, like frequency, tau and maximum voltage

Front End Board

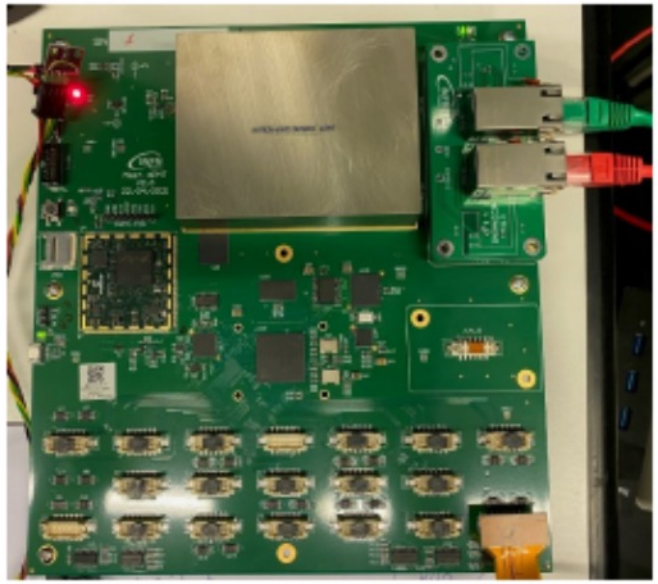


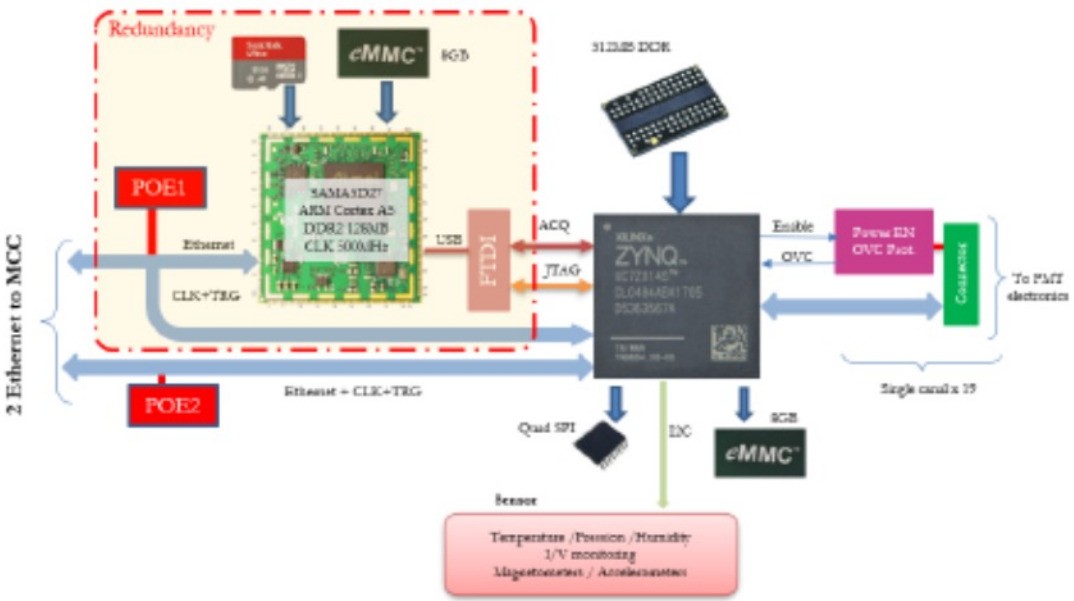


Automatic tester ready for usage in mass production

FE board includes the control circuit for the HV and the acquisition part for the PMT signal.

mPMT Main Board



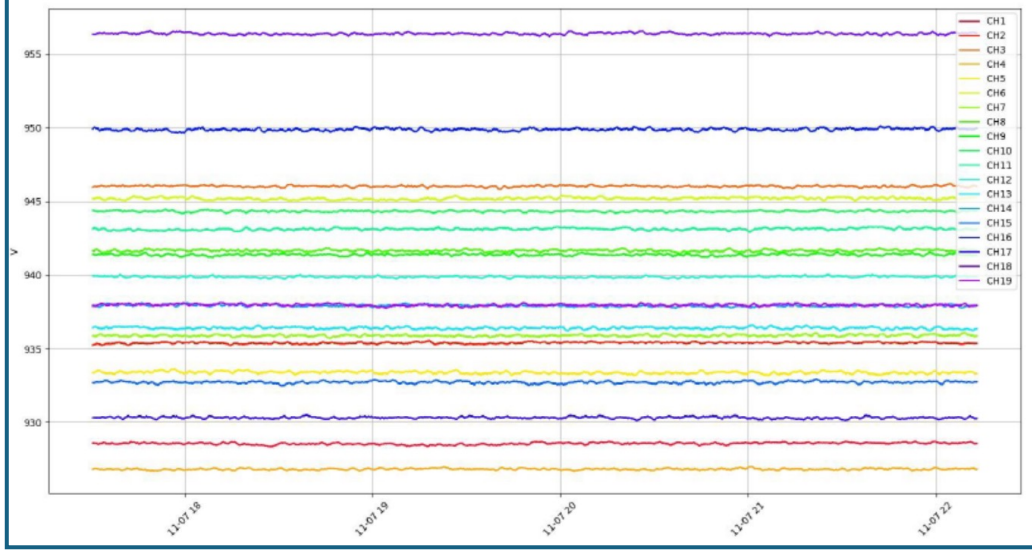


FD mPMT prototypes

Testing ongoing for all mPMTs in dark box
Operative mPMT testing in pressure chamber
Full electronics chain tested:
mPMT+cable+Concentrator

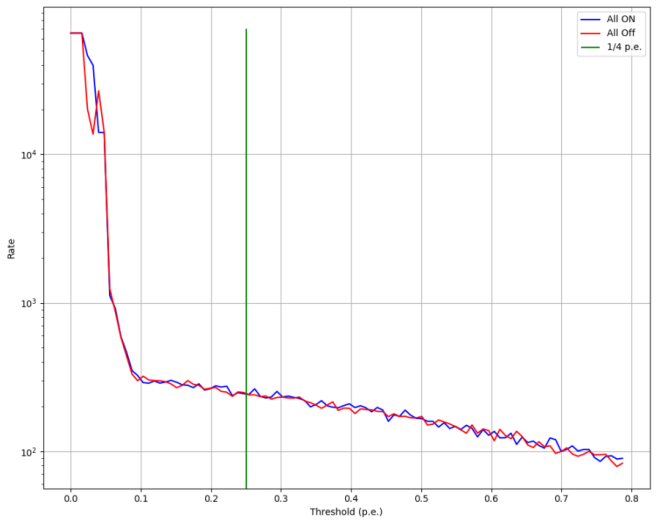
→ passed all the tests so far

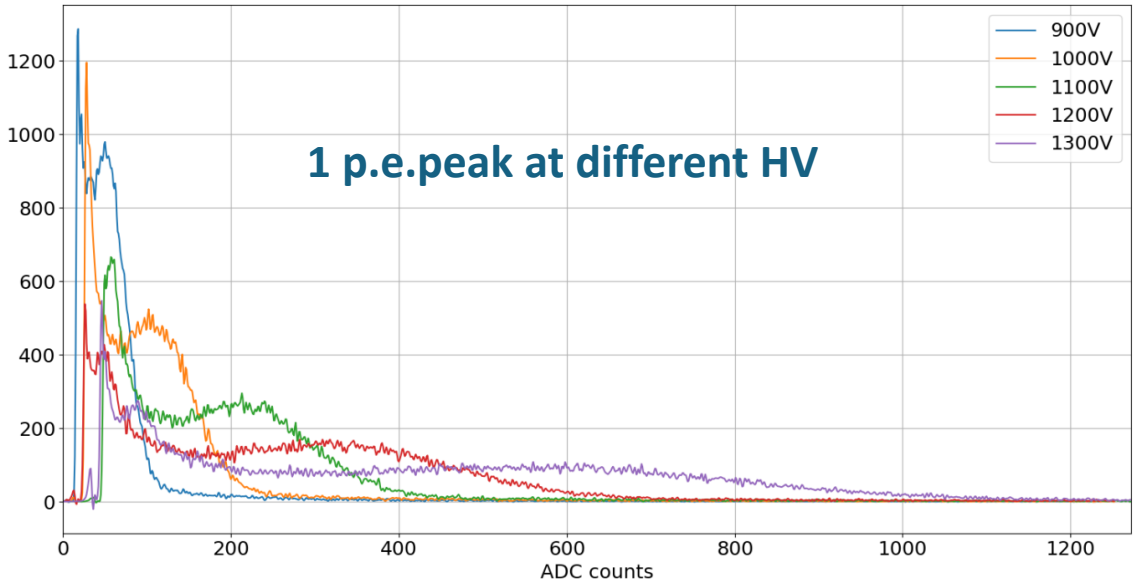
HV stability



HV set to 950 V for all PMTs

Threshold scan

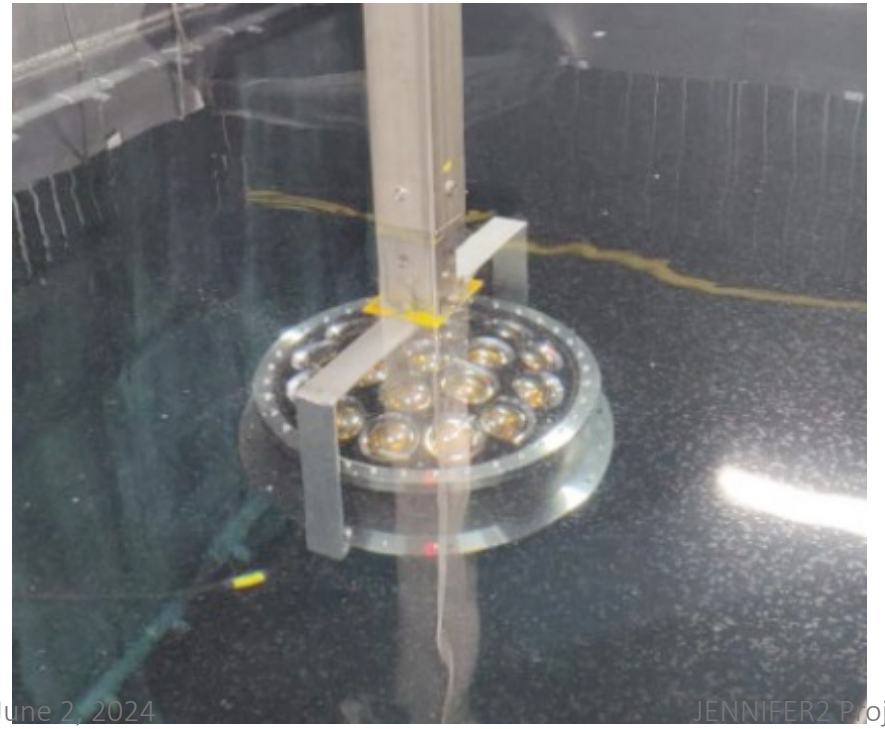


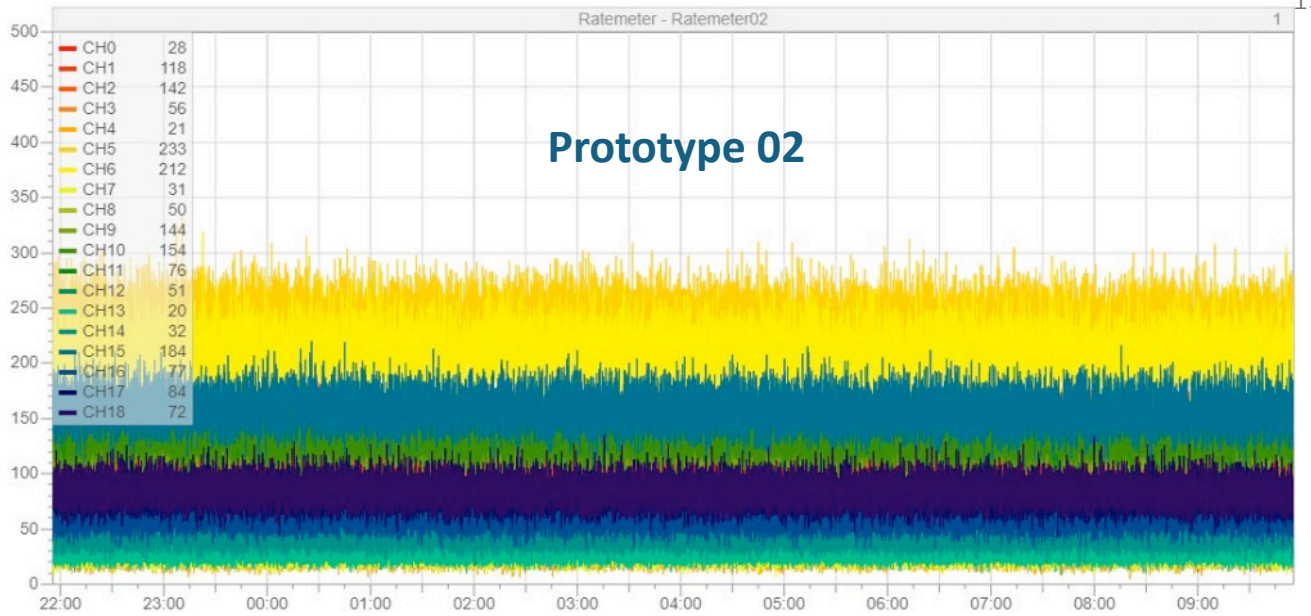


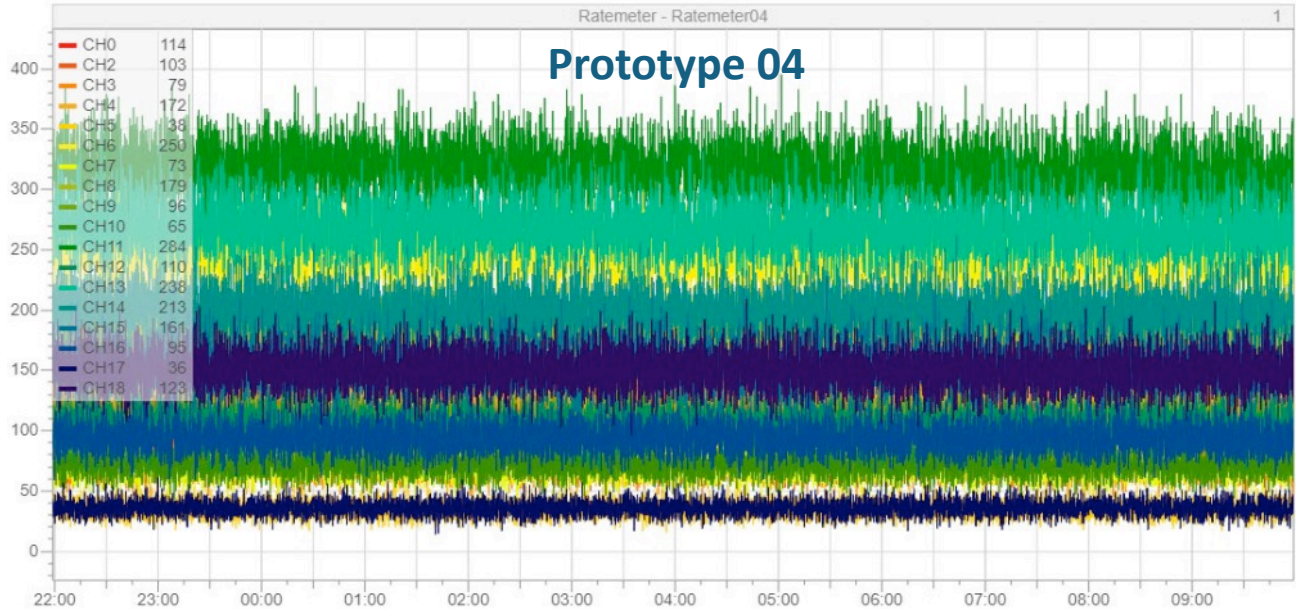
FD mPMT prototypes

Darkrate counts
After 12h in dark the mPMT dark counts are stabilized

Currently under monitoring and test using MIDAS DAQ system
One of the FD mPMT tested in water in KM3Net facility for 20 days



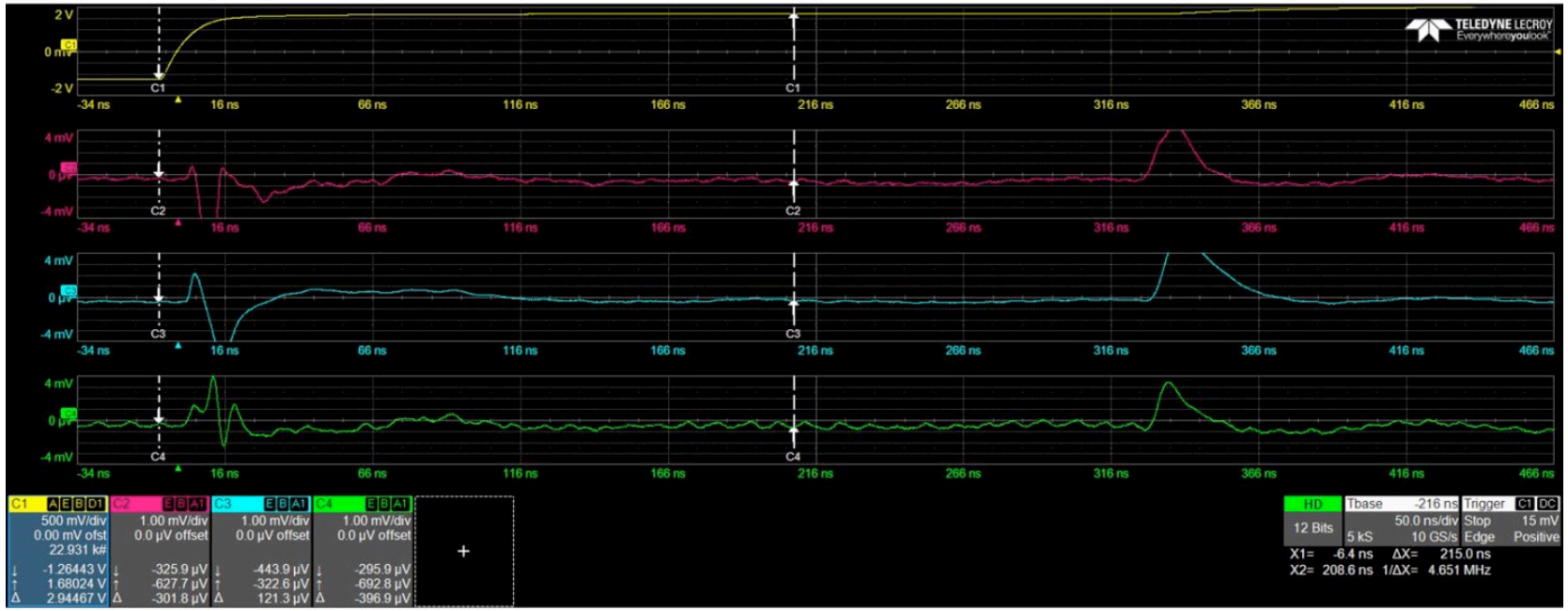


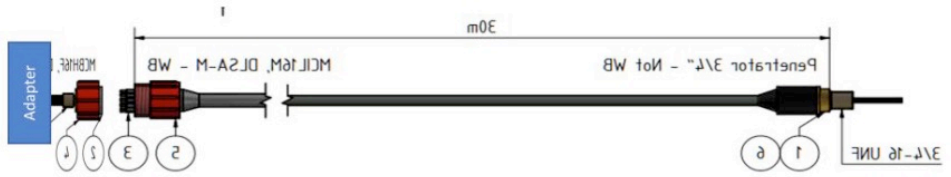


mPMT-MCC cable

Custom cable in collaboration with MacArtney
First prototype fully tested

RI contamination and Rn emanation measured and within HyperK requirements

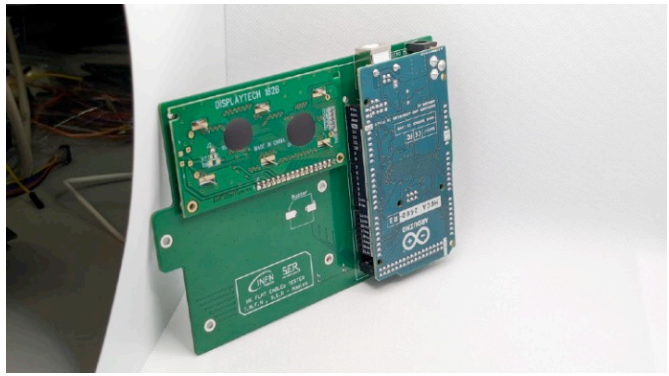


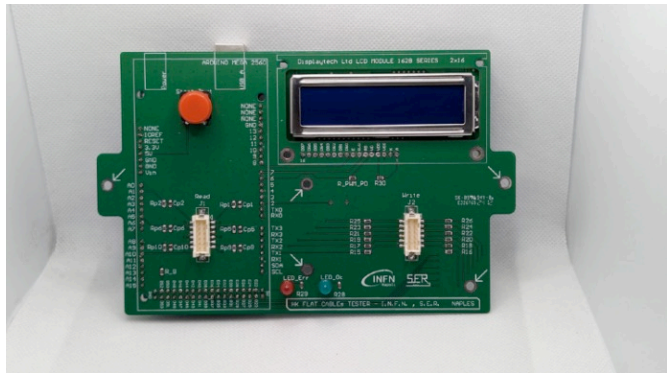


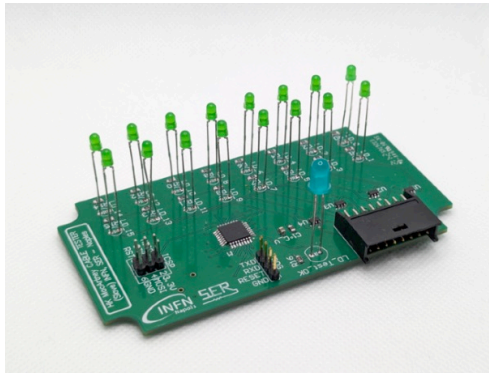
New cable: cleaner, much less noise induced

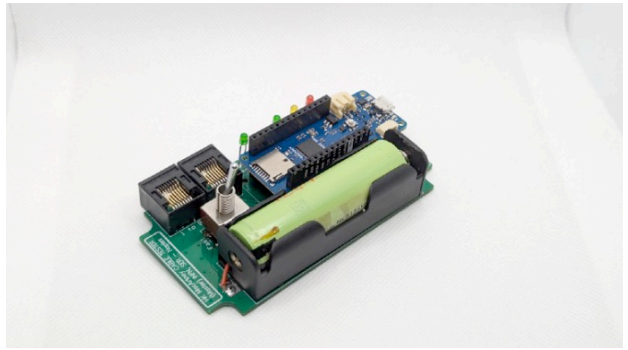
FD mPMT Electronics and cables testing

- Electronics Accelerated Test completed
  - More than one month at 70°C - no failure
- Test systems for internal cables ready
- Test system for MCC-mPMT cable ready



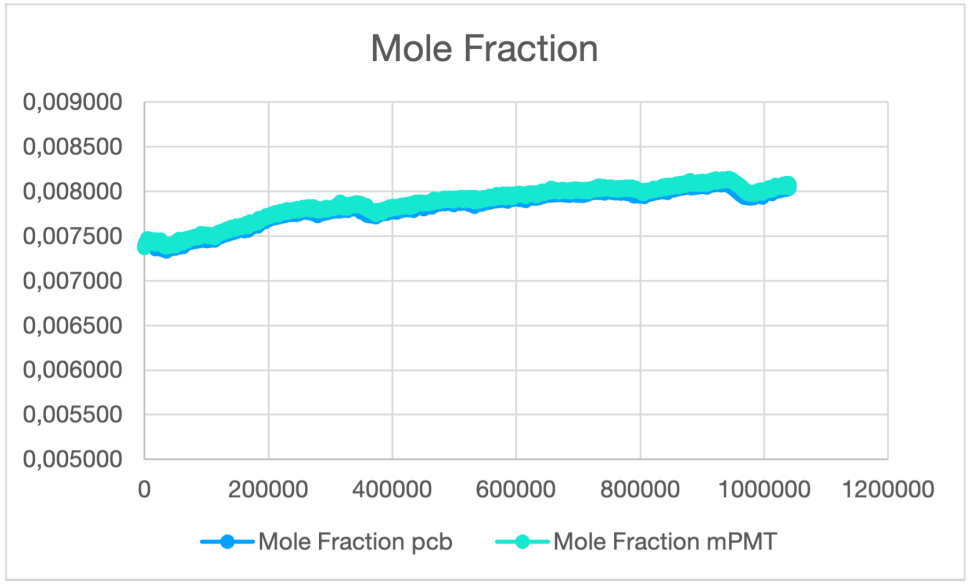






Humidity

The mole fraction ranges from 0.0073 to 0.0081:



Relative humidity

$$R.H. = 100\frac{p}{p_{ws}}$$

$$x = \frac{p}{p_{mPMT}}$$ assuming we have n=2.25 moles.

$$x = \frac{n_{water}}{n_{tot}} \longrightarrow n_{water} = x n_{tot} = \begin{cases} 0.016 \\ 0.018 \end{cases}$$

$$N_{water} = N_A n_{water} = \begin{cases} 0.099\ x\ 10^{23} \\ 0.108\ x\ 10^{23} \end{cases}$$

$$W_{water} = W_{mole} n_{water} = \begin{cases} 1.783\ g \\ 1.945\ g \end{cases}$$

Rate=8.65x10^{14} molecules per second = 0.156x10^{-6} g/s.

That is 49.2 g or water in 10 years.

One single Silicagel packet is able to absorb about 48 g of water.

Conclusions

mPMT project is on track, though on a slightly delayed schedule.

All tests were passed, currently doing more under water tests.