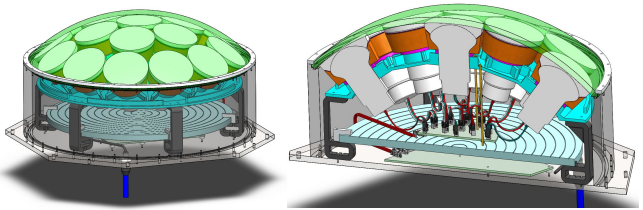
Multi-PMT (mPMT) development for Hyper-K

20th International Workshop on Next generation Nucleon Decay and Neutrino Detectors (NNN19)
7/Nov/2019 @ University of Medellin



Saul Cuen-Rochin
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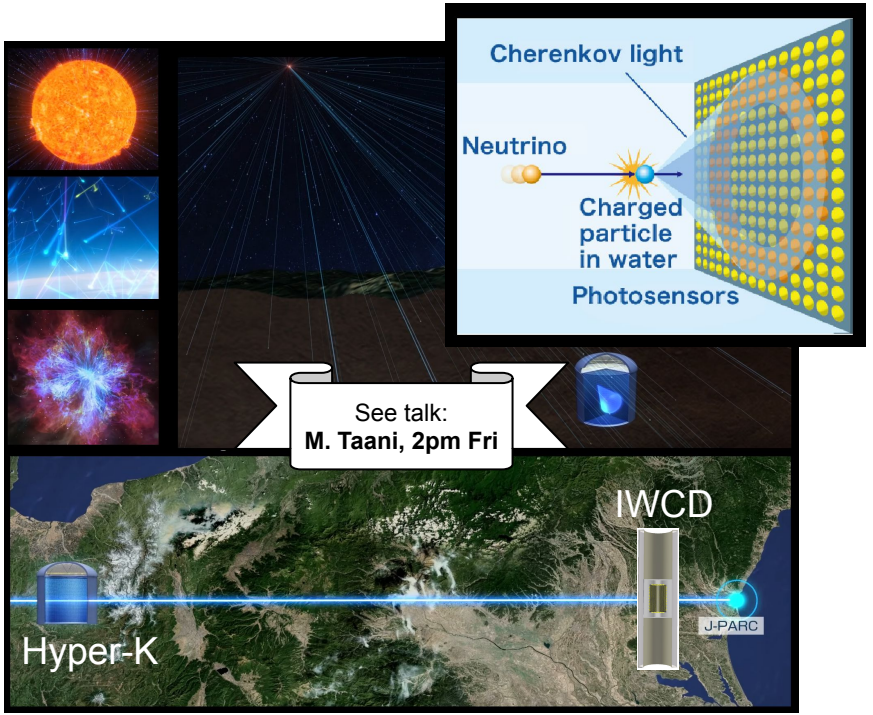
TRIUMF
for the Hyper-K collaboration

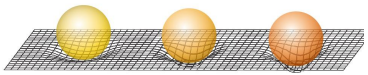
Physics goals

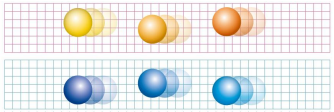
Hyper-K is a next generation, water Cherenkov neutrino far-detector of the ~300 km long-baseline neutrino experiment in Japan with 260k metric tons of ultra-pure water. Hyper-K design report: arXiv:1805.04163

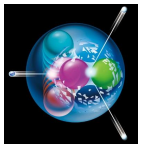
sensitive to: accelerator, solar, cosmic, and atmospheric neutrinos.

goals: discover CP violation in neutrino oscillations, determine the neutrino mass ordering, as well as potentially discover proton decay.









Systematics

To cancel the neutrino flux and cross section uncertainties we are proposing an **Intermediate Water Cherenkov Detector** (IWCD) located at a baseline of ~1 km away from the neutrino source at J-PARC.

Need ~2000 candidates in each oscillation mode in **10y for 3% statistical uncertainty.**

Aiming to reach 1% level in systematics; modeling neutrino production, interactions and detector responses.

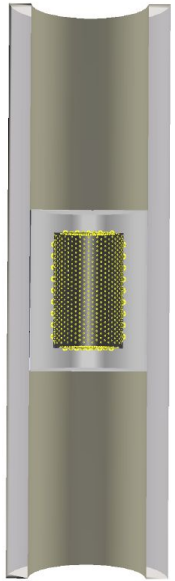


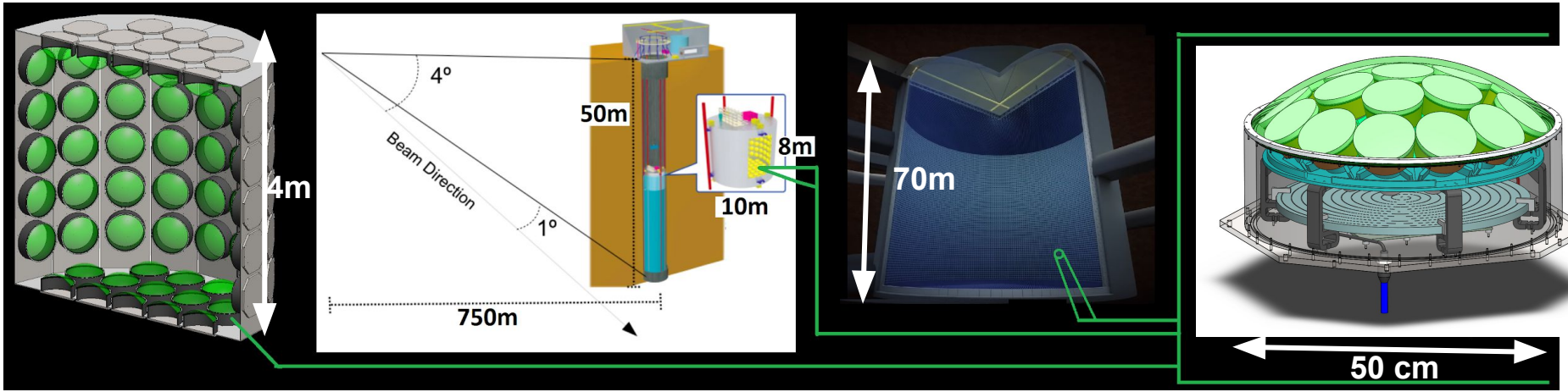
TABLE XXXVIII. Uncertainties for the expected number of events at Hyper-K from the systematic uncertainties assumed in this study.

arXiv:1805.04163

		Flux & ND-constrained cross section	ND-independent cross section	Far detector	Total
ν mode	Appearance	3.0%	0.5%	0.7%	3.2%
	Disappearance	3.3%	0.9%	1.0%	3.6%
$\bar{\nu}$ mode	Appearance	3.2%	1.5%	1.5%	3.9%
	Disappearance	3.3%	0.9%	1.1%	3.6%

See talk:
M. Hartz, 5pm Thu, and 4pm Fri

mPMT for detector suite



WCTE at CERN (~2021) **IWCD** (~2026) **Hyper-K** (~2027)

mPMT module
19 forward looking 7.7-cm PMTs

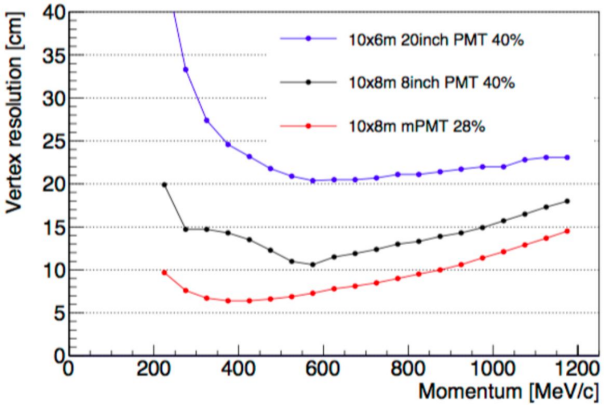
Hyper-K host 40k nominal 50-cm Inner Detector (ID) PMTs.
International contribution ~5k mPMT modules

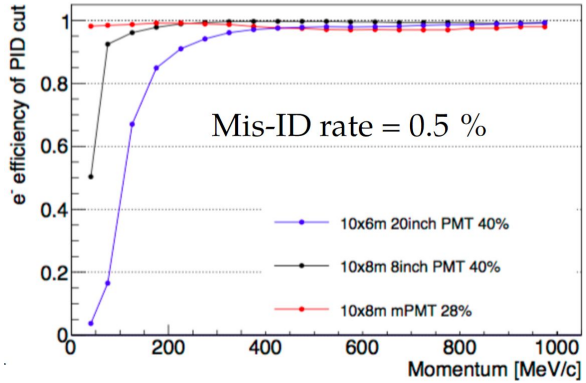
IWCD requires ~500 mPMT
Water Cherenkov Test Experiment (WCTE) at CERN ~120 mPMT
From LOI CERN-SPSC-2019-042 ; SPSC-I-254

Concept from KM3NeT

Why mPMT?

IWCD simulation and reconstruction with mPMTs.





-Improve vertex resolution, Improved PID

-essential for smaller water cherenkov detectors

-Finer granularity, good timing resolution

-each of 19 3'' PMTs have different orientations

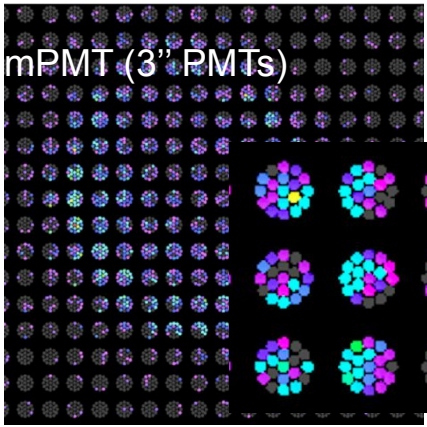
-information on the direction of each detected photon

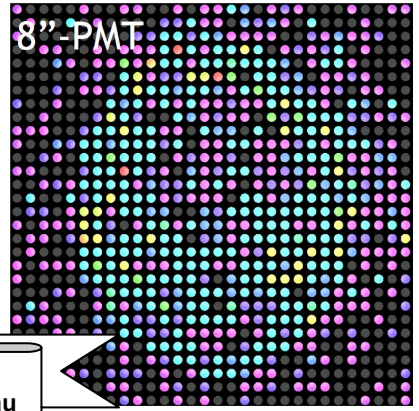
-improve dark hit discrimination and event reconstruction.

-vessel houses digitization electronics and calibration sources.

-Finer Granularity also helps reconstruction for Hyper-K

-Currently developing ML analysis



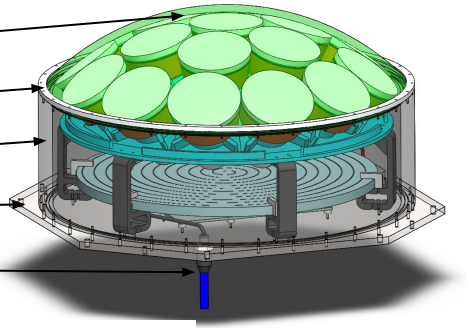


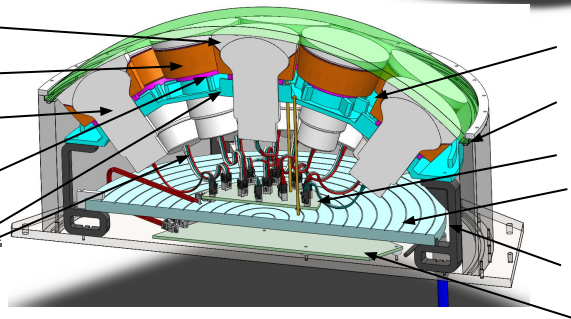
See **ML** talk:
N. Prouse, 2:30pm Thu

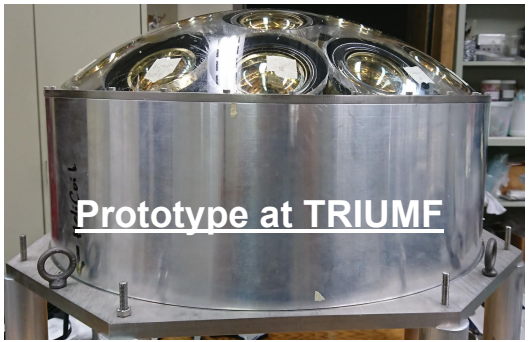
Requirements and components

pressure tolerant to 20m-80m

compatible with ultrapure water





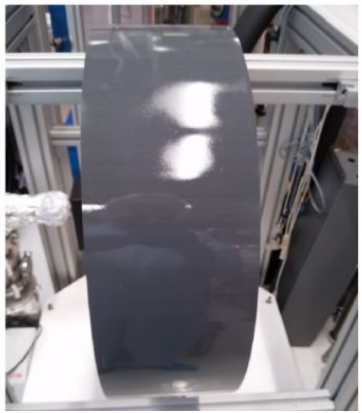


Prototype mechanically ready for IWCD. We are going through an optimization phase of the vessel to have the same design/assembly for both IWCD and Hyper-K.

PVC cylinder

-Prototype with cheap PVC cylinder machined from commercial 20ft tube. Added helicoil insert for screws
-Coated with PMMA for ultra-pura water compatibility.

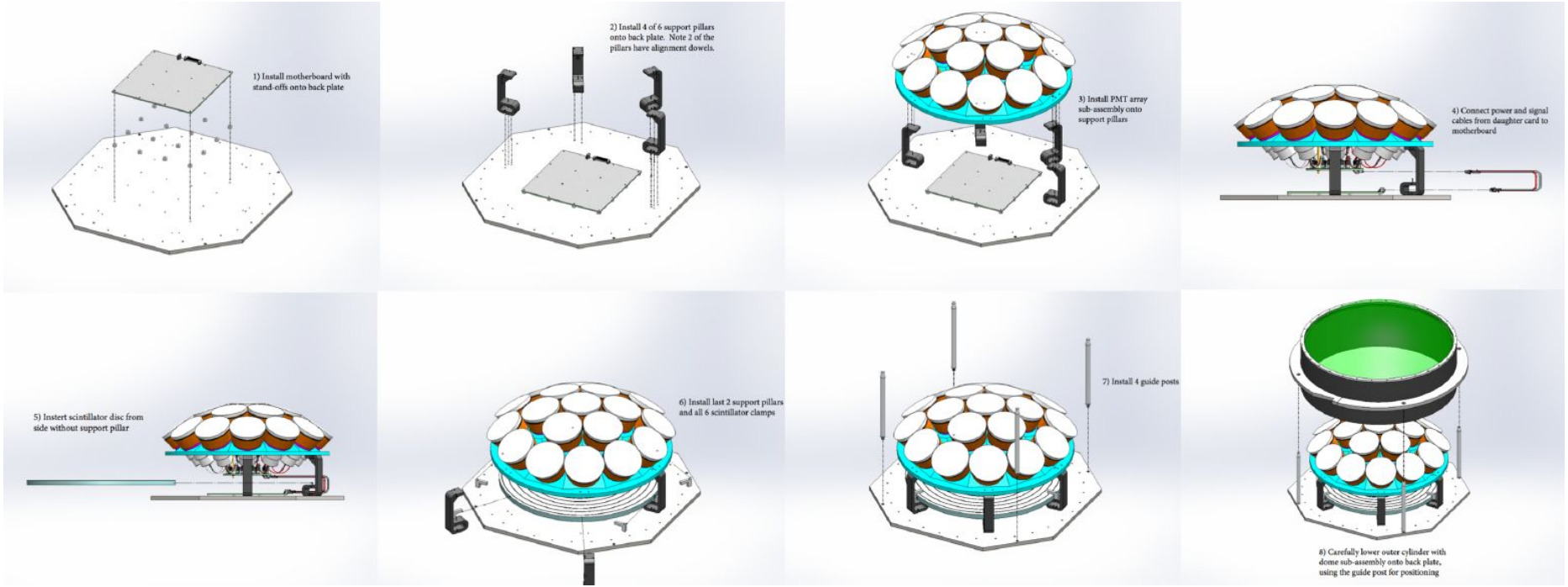
-compatibility test to be done… for different types of pvc with and without coating
-looking for high radon levels and leaching that could affect transparency in water (soaking test)



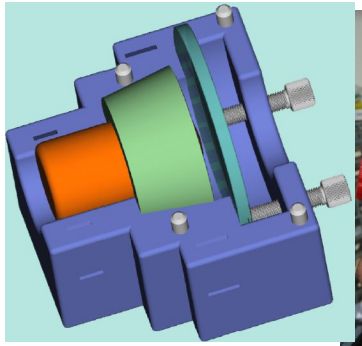
-SuperK uses special PVC that requires NO coating

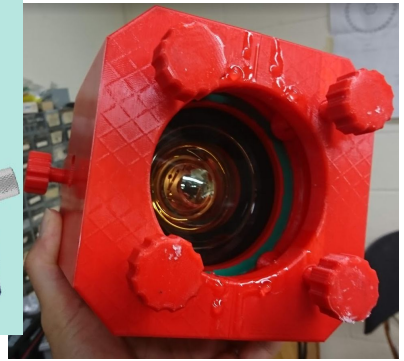
-We contacted supplier and might migrate if necessary...

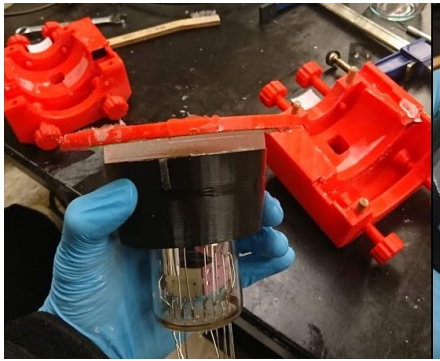
Full mPMT assembly

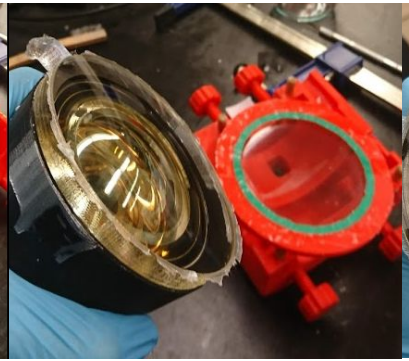


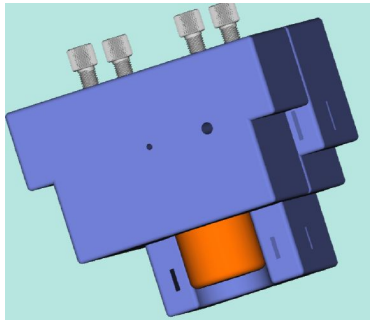
Gel casting system







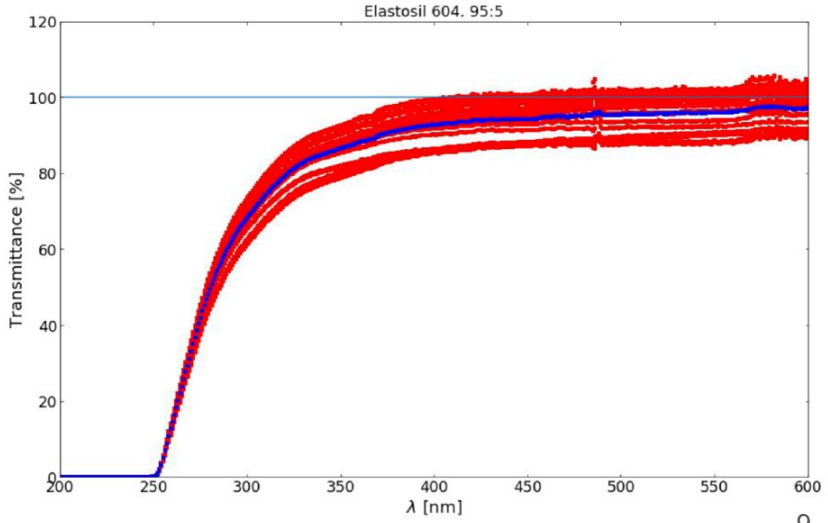




System works!

Elastosil 604 A:B (95:5 ratio)

- Slighter harder than Silgel 612
- Does not stick to dome
- Longer curing time 12-24 hr but could improve with heat



KM3NET gelling system takes a lot of time to do assembly compared to single pmt gels

mPMT subassembly mass production

Alternative concept for mass production with PBC support developed with Zenzen.

ZEN ZEN
www.zenzengineering.com

1: Cut PMT pins in cutting fixture

2: Solder components in soldering fixture

3: Assembly PMT/PCB/connectors into cup, then reflector on top and poron from bottom.

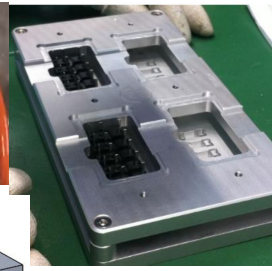
4: Insert into 2-piece positioning fixture

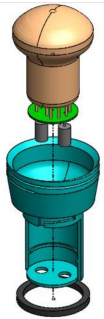
5: Extract positioning fixture and screw cover mold

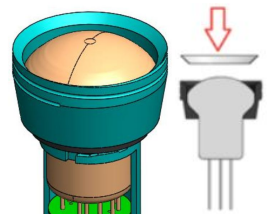
6: Cast gel from hole in the cap, cover hole.

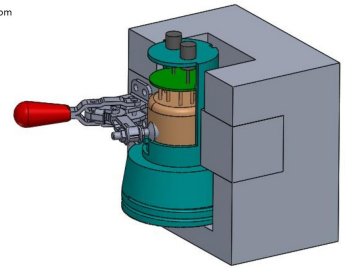
7: Dry and store for 24hr (drying process can be accelerated with heat)

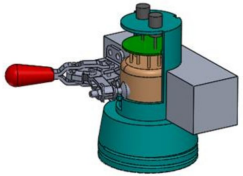
8: Unscrew and liberate fixture

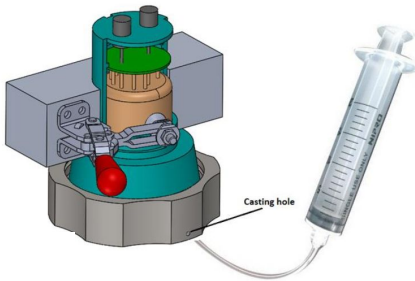




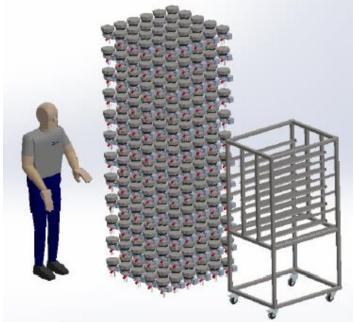


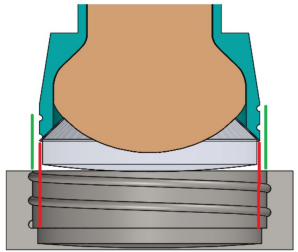


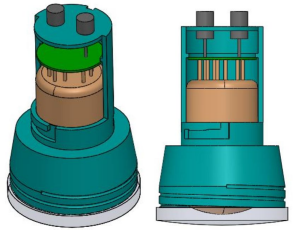




360 subassemblies

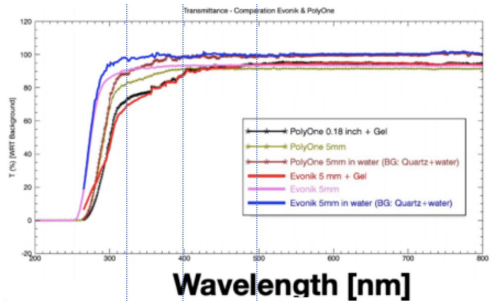


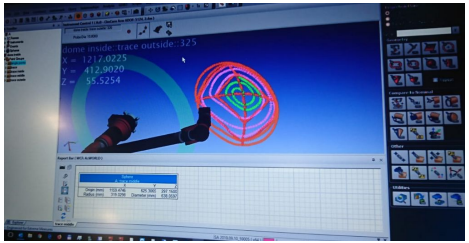


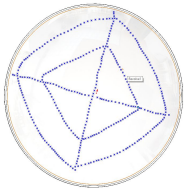


Acrylic dome

- **INFN** worked with supplier for good transmission properties.

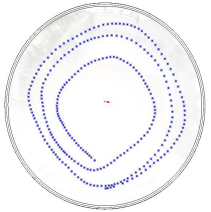


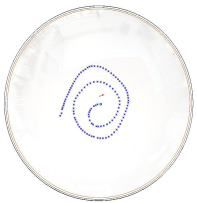




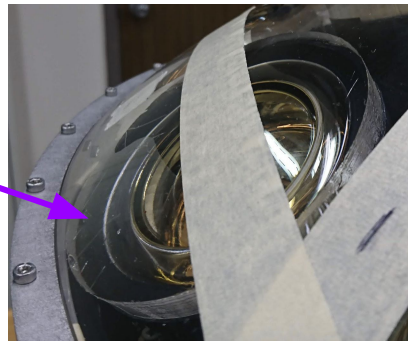
-Liras (Italy) is thermoforming our domes.

- 3D scanned (2) domes and we found the inner radius increases towards the the edges about 3 mm.

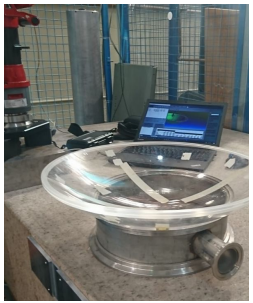


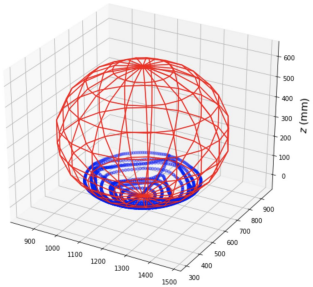


-This explains the non-pressure points between the gels and the dome right at the edges



- A fresh 20 batch order from Liras is on its way, we plan measure all of them.



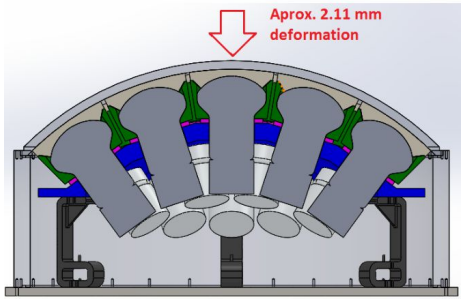


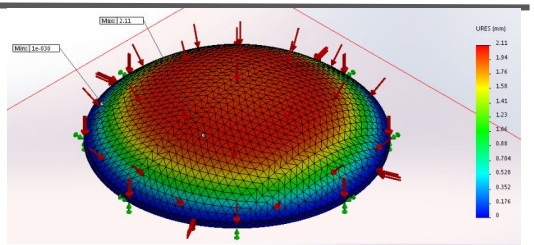
Pressure testing

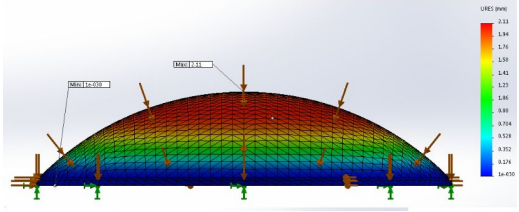
Test in Japan, shows dome depression about 2.5 mm at 0.8Mpa

Simulation (preliminary) at 1.2Mpa shows depresion of about 2.1 mm

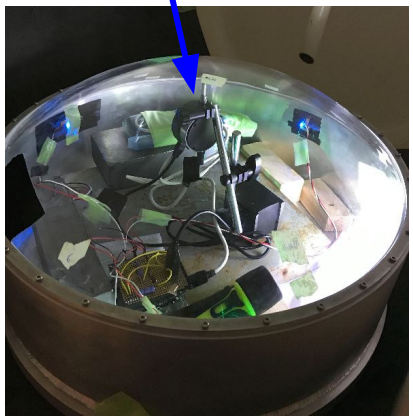
Cellula Robotics (Canada) has a pressure vessel 60 cm wide and 560 cm long. Could accommodate about 10 mPMTs for mass production testing.

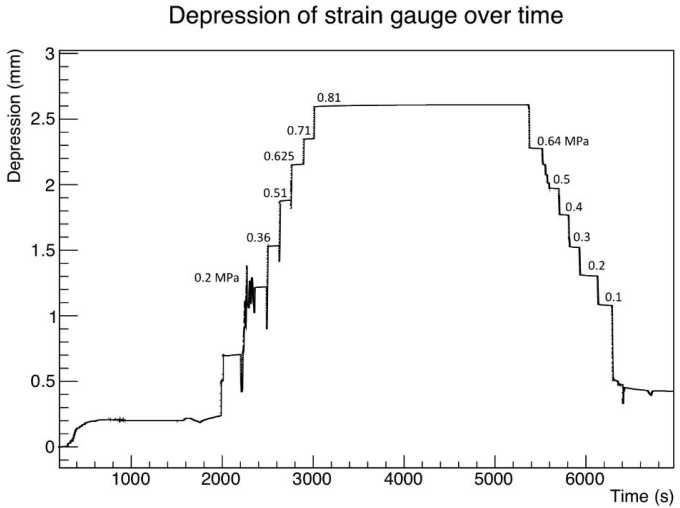






Dial gauge





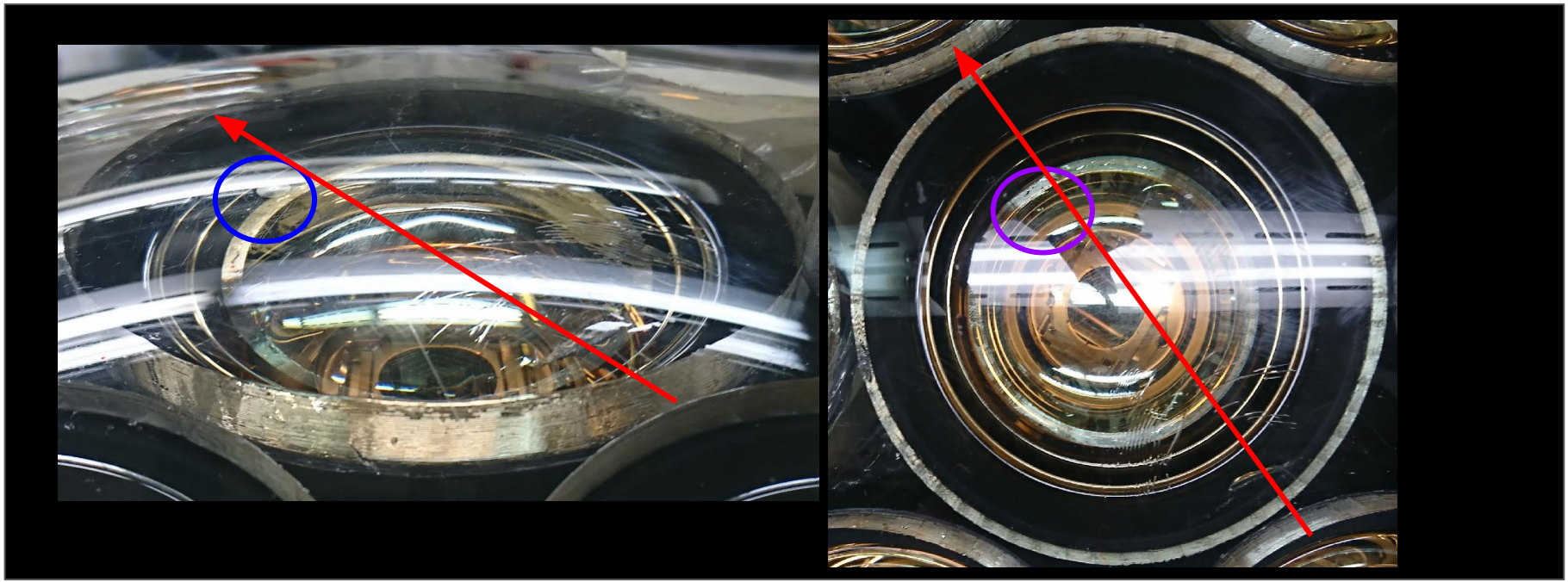
Assembly: dome/gel contact (1)

Air bubbles get trap during assembly…. But go away after a day of the assembly.

Could accelerate the process with a vibration motor.

Assembly: dome/gel contact (2)

Air bubbles get trap during assembly…. But go away after a day of the assembly.



Could accelerate the process with a vibration motor.

(Dis)assembly test [VIDEO]

-**Good contact** between **acrylic dome** and **gels**

mPMT cup and PMT support matrix

Currently 3D printing cups at TRIUMF.

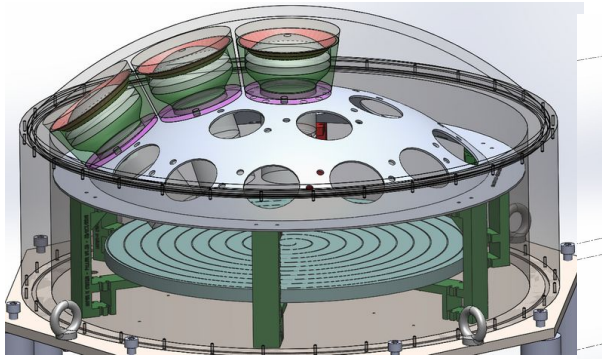
New spherical and thin matrix model with extra holes for orientation with cup with pins.

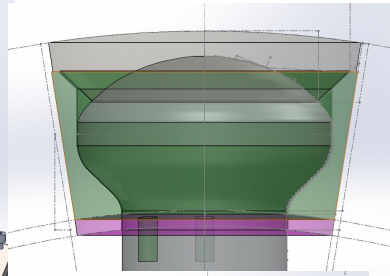
3D printing at ForgeLabs in Canada.
-we are trying to make a version with less material

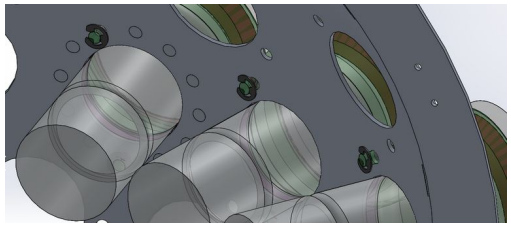
→ looking into mass production options:
Ensinger
-*Reaction mold* (casting) in Europe
-*Thermoforming and 5-axis CNN machining* in USA

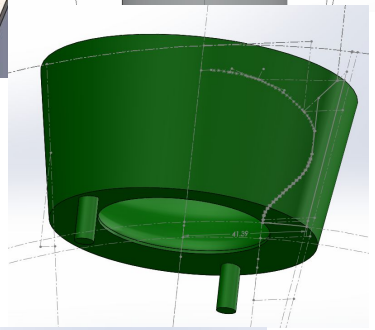
ZenZen: *injection molding* in Mexico

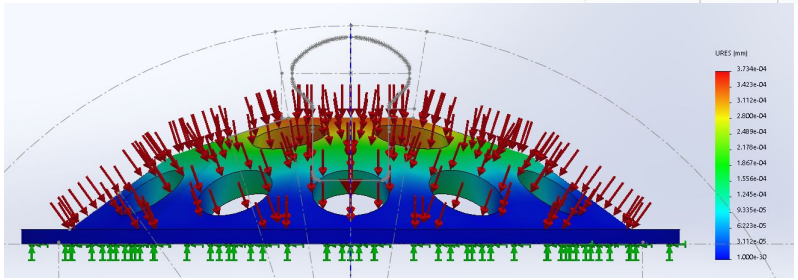
Deformation, Strain, Stress, and FOS simulations in SolidWorks and ANSYS



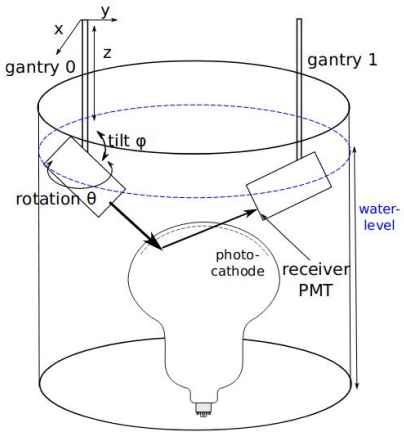




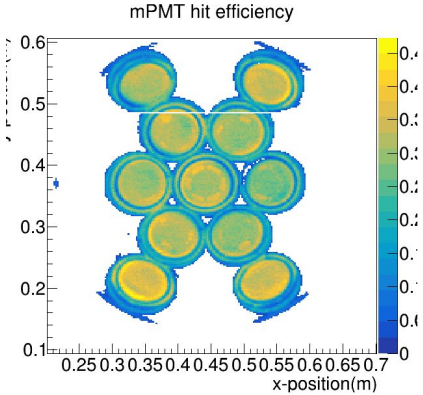


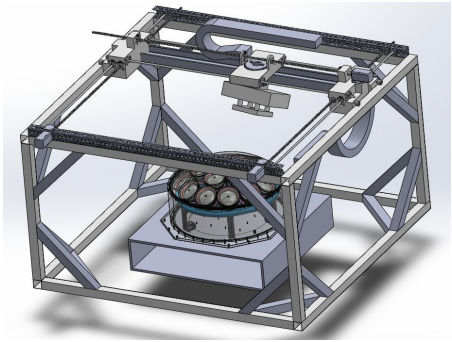


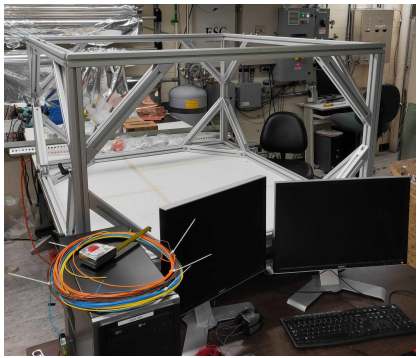
Test stand

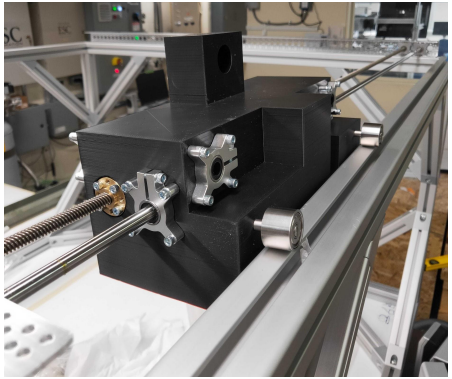


- Used [Photosensor Testing Facility (PTF)] at TRIUMF to get hit efficiency from old mPMT prototype.
- Developing a **NEW mPMT test stand** as a simplified PTF version for mass production testing.
  - shoot photons (laser) at different wavelengths (325, 400, and 500 nm) from all angles.



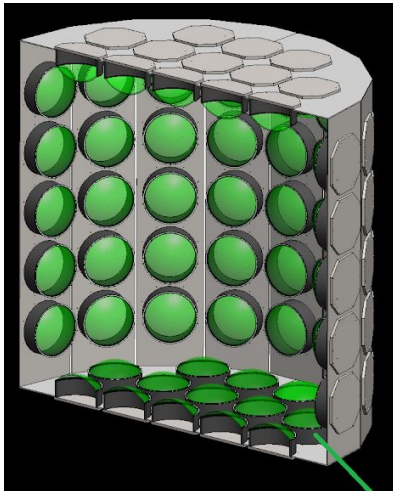






Plan and summary

- mPMT prototype is mechanical ready for IWCD, just fix or accomodate-to dome's curvature.
- Keep design optimization going to further reduced costs of mass production and to reach Hyper-K requirements as well.
- Build and test 4 prototypes within next 6 months.
- Full integration with electronics in 2020
- Production and test of 30 mPMTs in 2020-21 for the **Water Cherenkov Test Experiment (WCTE)** at CERN



Thanks! questions?