21st July, 2022, WCTE Collaboration Meeting

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MPMT MECHANICAL UPDATE

OUTLINE

- All 19 PMTs are in full contact with the dome (Gel 604 in 96:4 ratio).

  ==> Reproducibility has been reported for both TRIUMF and FORGELABS matrix.

- The gelling procedure with a reflector was performed successfully

  ==> Though essential to control the thickness of gel with small variations.

- The old gel jig design shows an un-even amount of gel around the PMT surface.

  ==> Development and testing of a new gelling jig design is also a scope of discussion in this presentation.

- Report on the pressure test measurement on the mPMT and in-situ gelling update.

  ==> Procedure and development of the setup.

Assembled mPMT

Gel damage during de-moulding - old jig

GEL JIG MODIFICATION

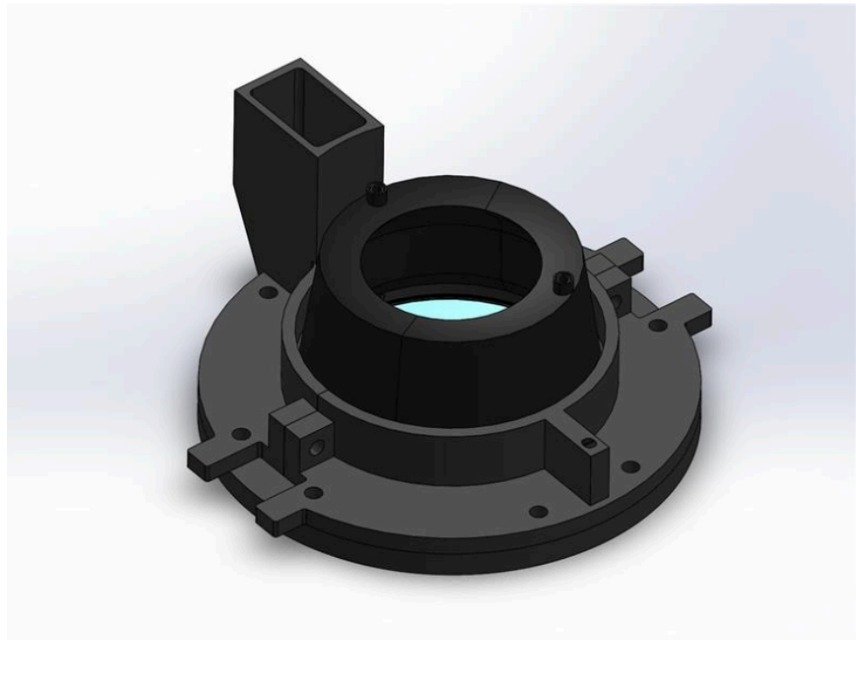
STABILIZING GEL LAYER THICKNESS

- The goals for the modifications in the gelling jig are to ensure the alignment of the PMT cup inside the mould and no excess gel.

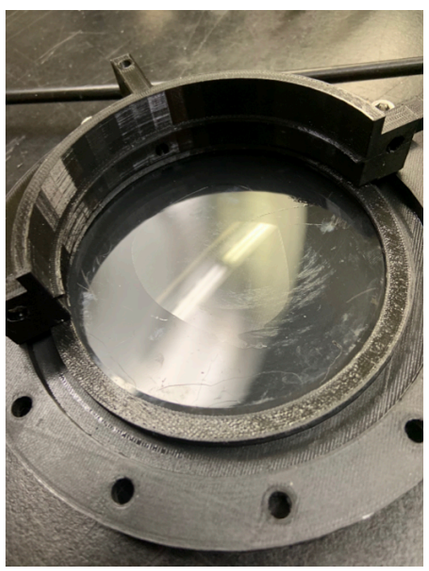
- A rubber gasket has been placed inside the mould to reduce damage to the PMT gel when de-moulding.

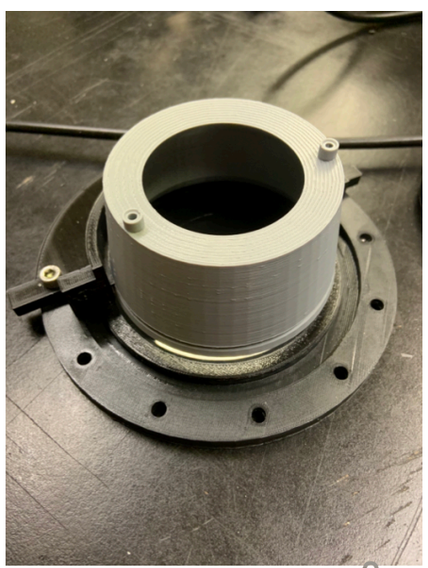
- A new gel jig has been 3D printed and tested for the compression of the rubber gasket and alignment of the PMT cup.

New jig design



3D printed new gel jig





- The jig has been tested for the gel ratio of 9:1.

- Observed tore edge mainly due to the extra gel in mould and rubber material used for gasket was insufficient to prevent gel leakage.

GEL JIG MODIFICATION

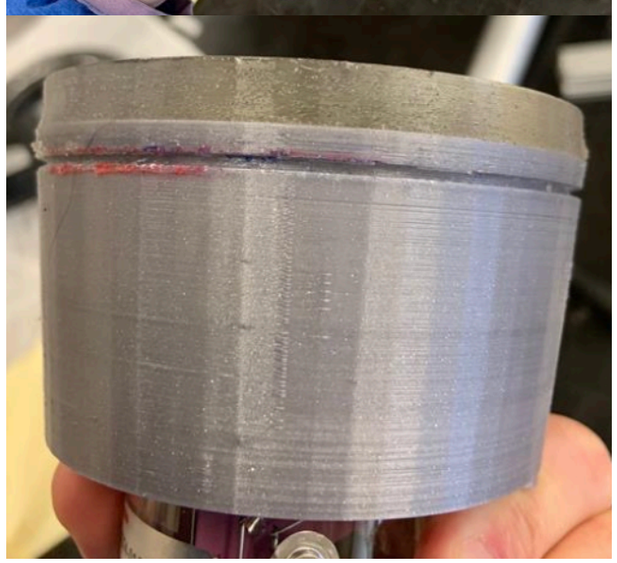
STABILIZING GEL LAYER THICKNESS

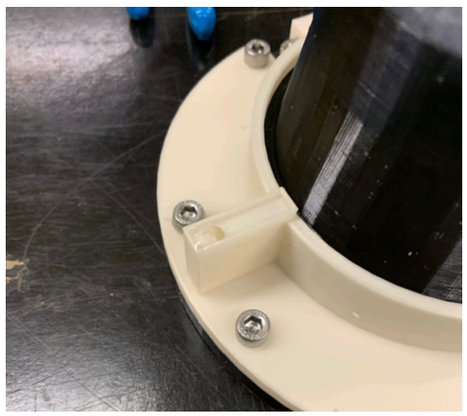
- A gasket has been developed with the sleeve design in order to improve the alignment and no direct contact of the cup with the base plate. Helps in easy de-moulding without tearing gel. Also controls the leakage of the gel.

Sleeved gasket

Capable of protecting gel during de-moulding and further reducing gel leakage in the mould design

Gel=96:4



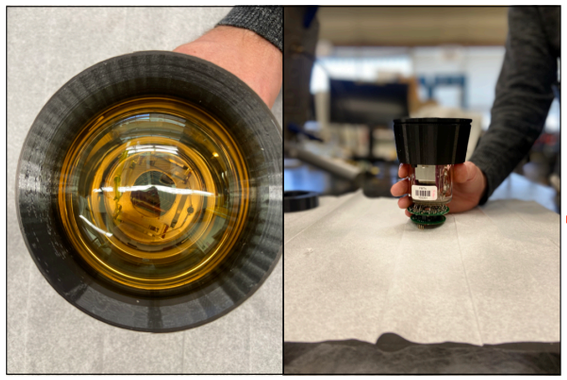


Some relevant modifications in the jig design

1. Moved alignment groove from mould to gasket.
2. Increased the distance of the cup adapter from the base by 0.7mm to maintain the gel thickness of 7.5mm
3. Added overflow trough to outflow spout.
4. Added height indicator to inside of inflow spout

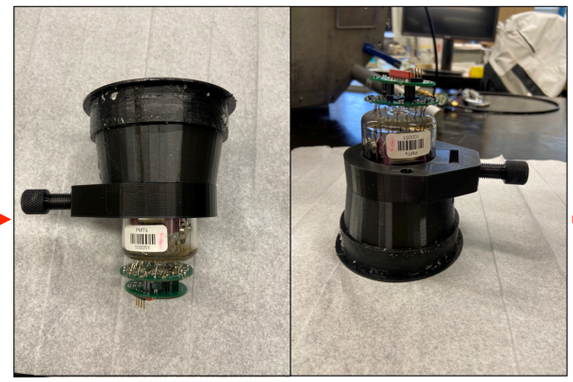
PMT GELLING PROCEDURE

A PMT gelling procedure has been set up in order to achieve the consistent gel thickness on the PMT surface and a defects-free de-moulding procedure.

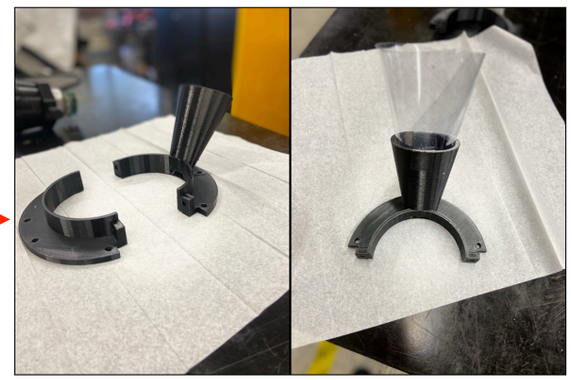


Cup fixation

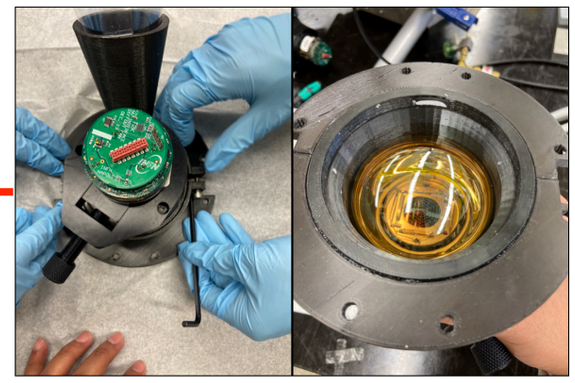
Gasket fixation



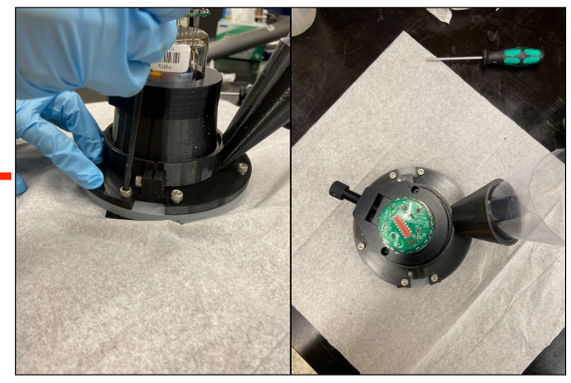
Clamp in place



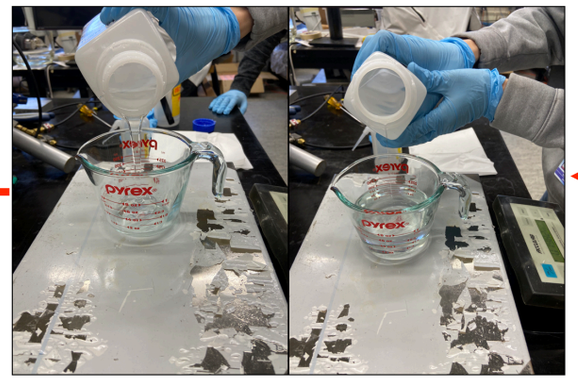
Mould spout prep.



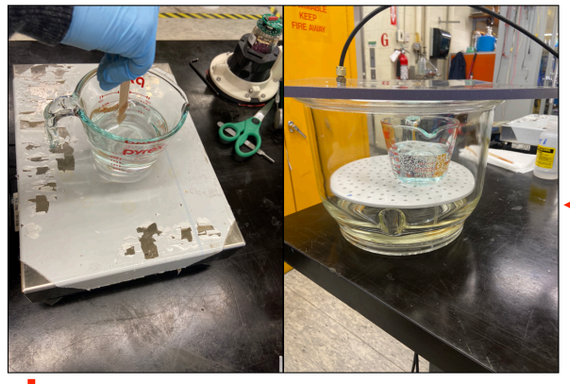
Mould fixation



Base plate fixation



Gel ratio



Mixing gel

Pouring gel

Finally used the conical spout for easy cleaning of the gel residue

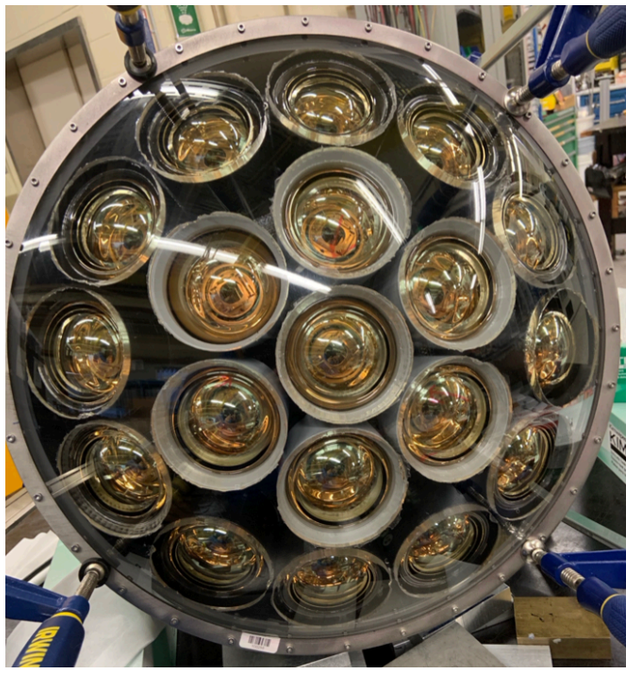
Times of PMT mass production can be cut down if cleaning is limited to areas where PMT gel will make direct contact. Because of the new gasket sleeve design, this leaves three primary areas: the gasket interior face, the acrylic plate, and the inflow/outflow spouts.

Task	Duration in minutes (x4)	Duration (x1 average)
Cleaning molds of gel residue	60	15
Assembling and prepping molds	20	5
Mixing and filling gel	30	7.5
Total	110	27.5

MPMT ASSEMBLY ATTEMPTS

A few mm's of matrix misalignment was present in the prior assemblies. It should be corrected using a 3D-printed alignment jig.

Feb

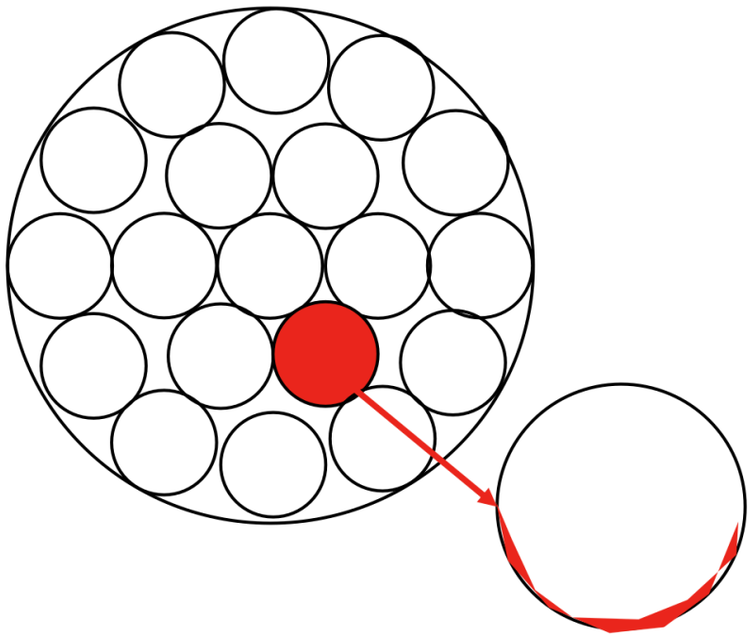


PMTs are arranged in a random fashion compared to the last assembly. Full contact was achieved with some minor imperfections

Remark

Full contact could be achieved by proper alignment of the matrix.

March



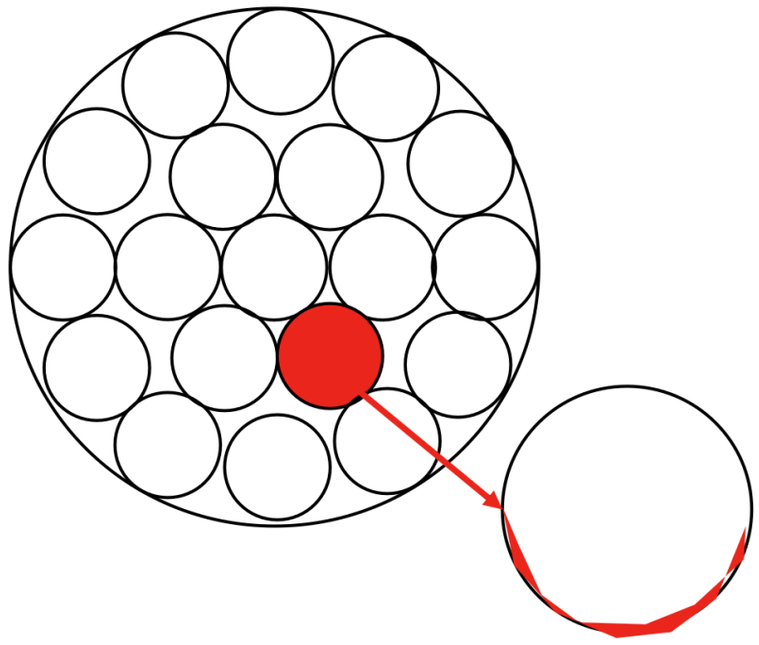
Matrix has been centred, gel ratio of 9:1, increased the poron adapter thickness by 1mm.

Remark

Increasing poron thickness reduces the effects of tolerance in adhesion

Centred matrix worked on 96:4 but not in 9:1

March



Matrix has been centred, gel ratio of 9:1, increased the poron adapter thickness by 1mm, dome rotated 90 degrees clockwise.

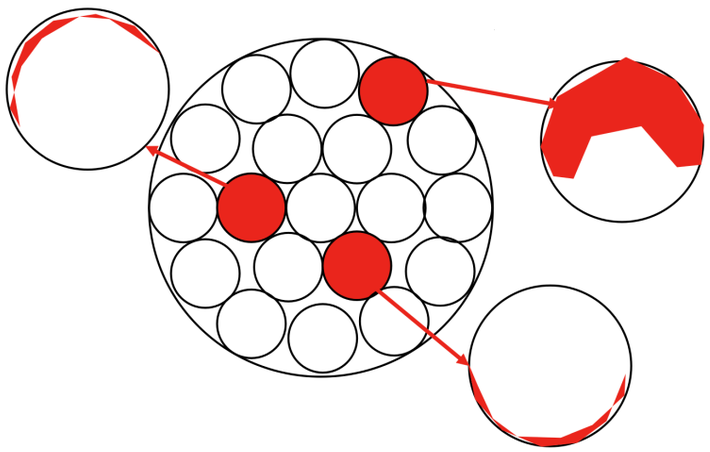
Remark

Dome orientation does not affect the gel delimitation

MPMT ASSEMBLY ATTEMPTS

Newly gelled PMTs required for the full assembly in order to understand the delamination cause.

March

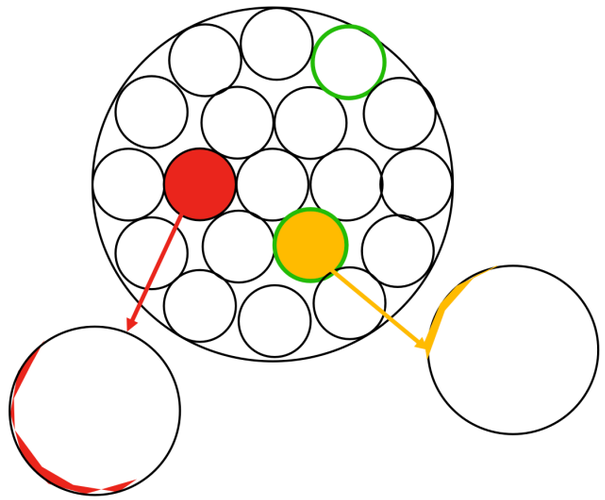


Matrix has been centred, gel ratio of 96:4, standard poron thickness, newly gelled PMTs

Remark

New gelled PMTs are ~0.2mm shorter.
Dimensional error in built-in adapter cup.
Acrylic plate dimensional error.

March



Matrix has been centred, gel ratio of 96:4, standard poron thickness, Replaced green PMTs with older ones

Remark

3rd row PMT failure was due to a mismatched cup design.
2nd row PMT cup failure was fixed after replacing with the old PMT.

April

- The quality of PMTs is the sole reason for the delamination area, however, it was not completely eliminated by them.
- Newly gelled PMTs causing the repetitive failure at the same location in 2nd and 3rd raw.
- A 3D-design alignment jig is a reliable method for re-installing the matrix into the dome.
- A full set of 19 PMTs required to understand this failure.

MPMT ASSEMBLY ATTEMPTS

Full contact is achievable using the newly gelled PMTs.

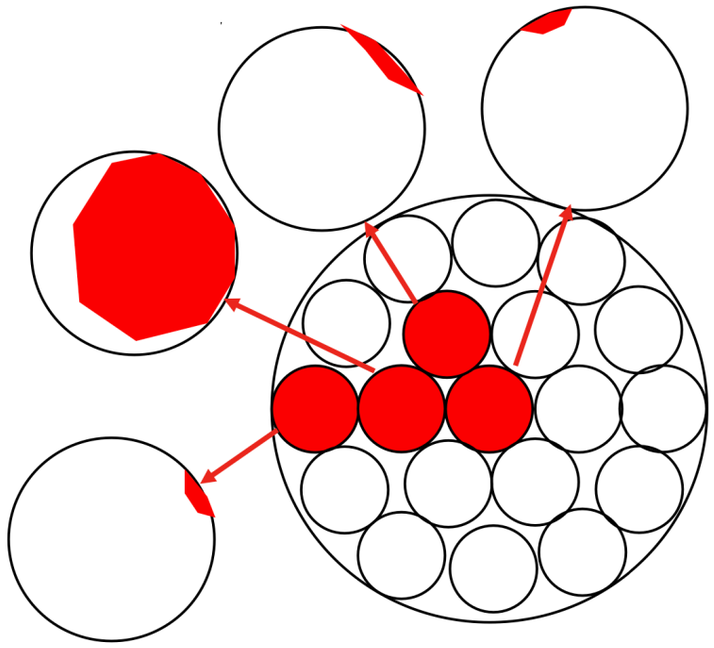
April

Matrix has been centred, gel ratio of 96:4, standard poron thickness, only newly gelled PMTs.

Remark

Full contact has been achieved with the newly gelled PMTs in the isolation.

May



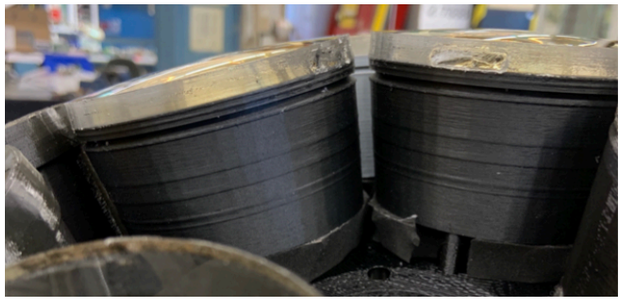
Matrix has been centred, gel ratio of 96:4, standard poron thickness, full newly gelled PMTs.

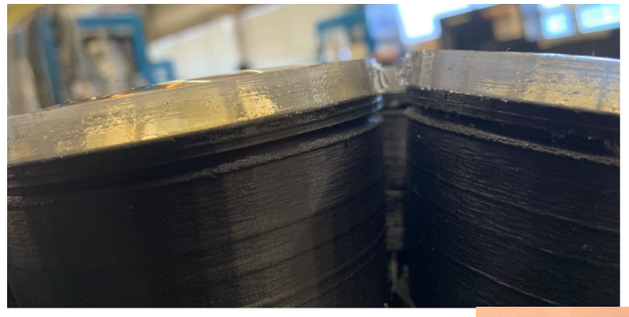
Remark

The contact has been improved significantly with the newly gelled PMTs.

May

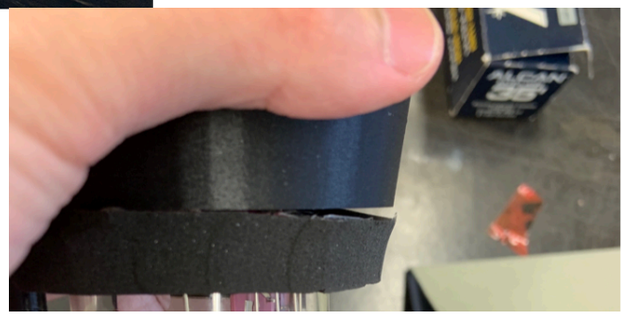
Proper PMT seating





Improper PMT seating

Poron ring warped



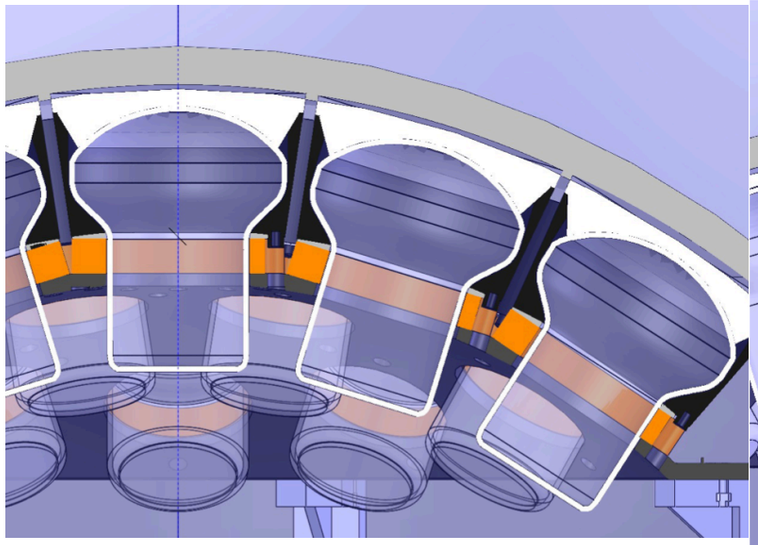
Remark

A large gap between gel and PMT cup results in improper adhesion with dome under vacuum.
Due to PMT tilt edge delamination has been observed

MPMT ASSEMBLY ATTEMPTS

A significant interference should be present between PMTs and dome, as confirmed with the CAD model

May

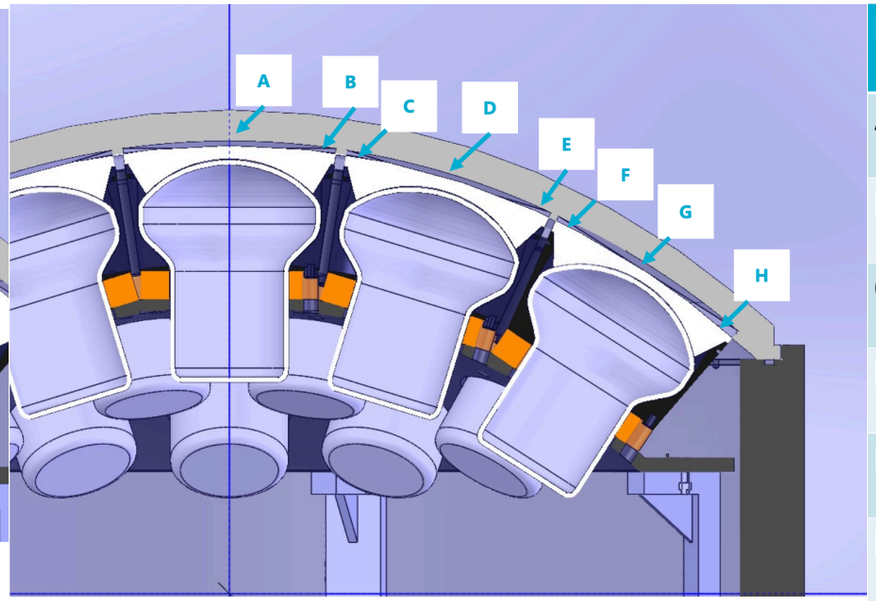


Dome used in the mPMT assemblies so far was 3.5 mm shorter compared to the CAD model, confirmed with the 3D scanner.

Remark

Shorter pillars are required to compensate for this error in dome height.

May



May

Position	Interference (mm) 106.11mm pillars	Interference (mm) 107mm pillars
A	1.65	2.52
B	1.98	2.87
C	1.97	2.82
D	1.64	2.48
E	1.99	2.84
F	1.93	2.67
G	1.60	2.34
H	2.01	2.74

Remark

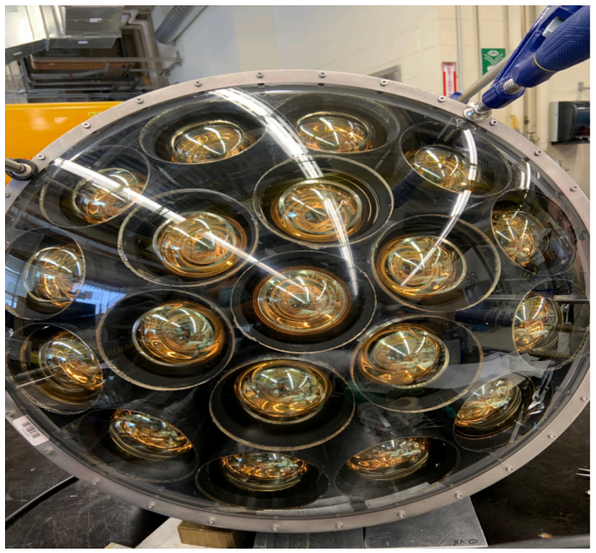
Current measurements indicate that interference is present, but may not be enough to ensure full contact purely from dome compression. i.e. 1mm of interference could be compromised by slight dome deflection, poron deformation, or thinner PMT gel.
An increase in pillar height will provide a sufficient increase in interference across PMTs in the 2nd and 3rd row, to the 2.5mm requirement. Effects of pillar height increase are reduced slightly for outermost PMTs.

MPMT ASSEMBLY ATTEMPTS

Hurrrrraaayyyyyyy!!!

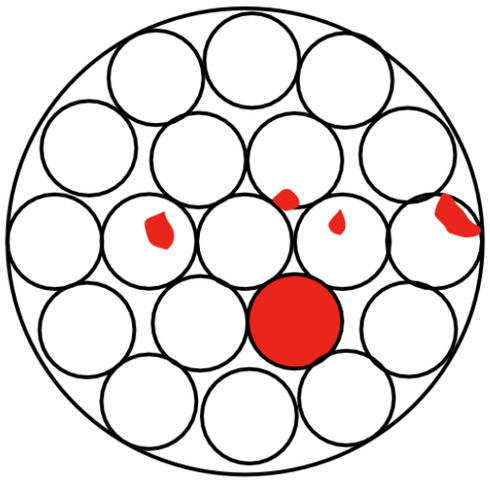
A full contact has been achieved for both the FORGELAB and TRIUMF printed matrix.

June

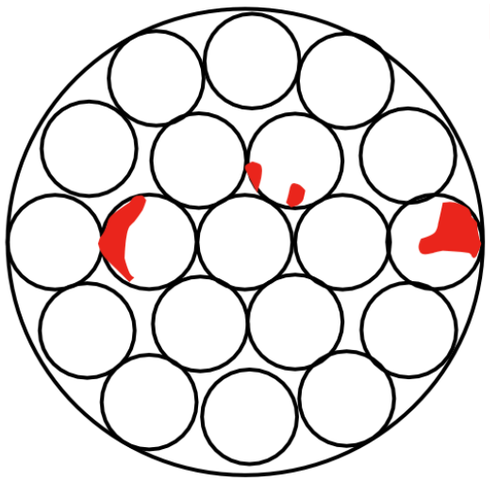


A full contact has been achieved with the increased pillar height in the first attempt.
Prior to vacuum application, the majority of PMTs already achieved close to full contact, with the exception of 3 PMTs in the 3 rd row.

June



Pre-vacuum



Post-vacuum

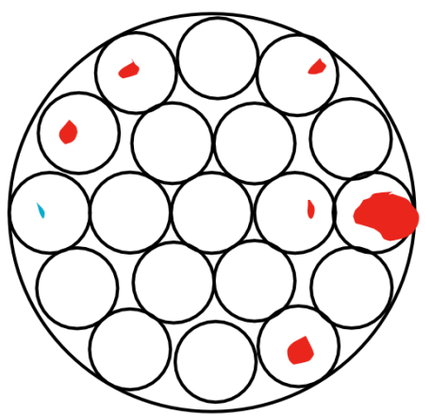
June

- An additional 1mm of height added to matrix pillars was sufficient to improve contact on both the Forgelabs and TRIUMF matrices. Both single-PMT and full assemblies show sufficient contact prior to vacuum application.
- For the TRIUMF matrix pin hole size in the matrix increased from 6.75mm to 7mm to reduce the constraining factor of pins.

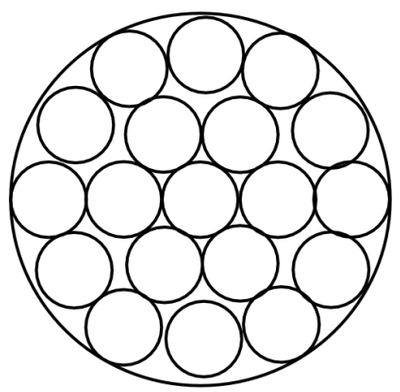
Remark

TRIUMF matrix PMT seating is heavily constrained by pin inaccuracies and could potentially use widening of pin holes for more consistent seating

Pre-vacuum



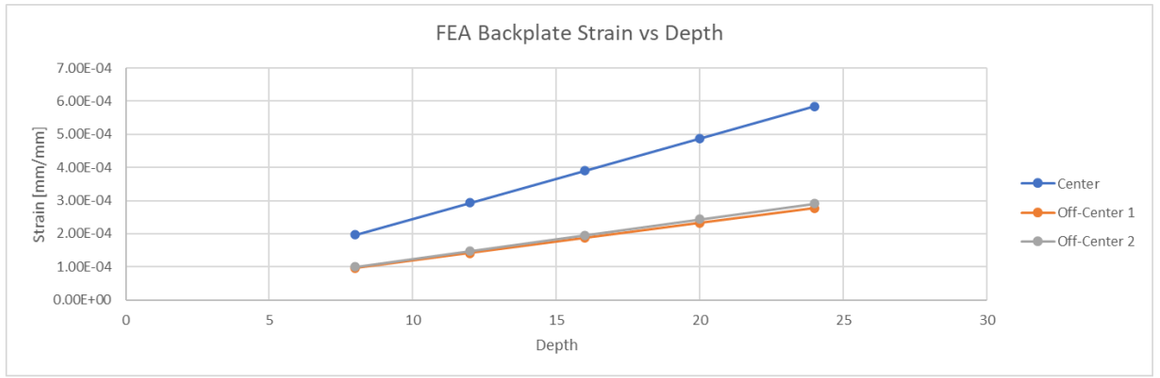
Post-vacuum



PRESSURE TEST

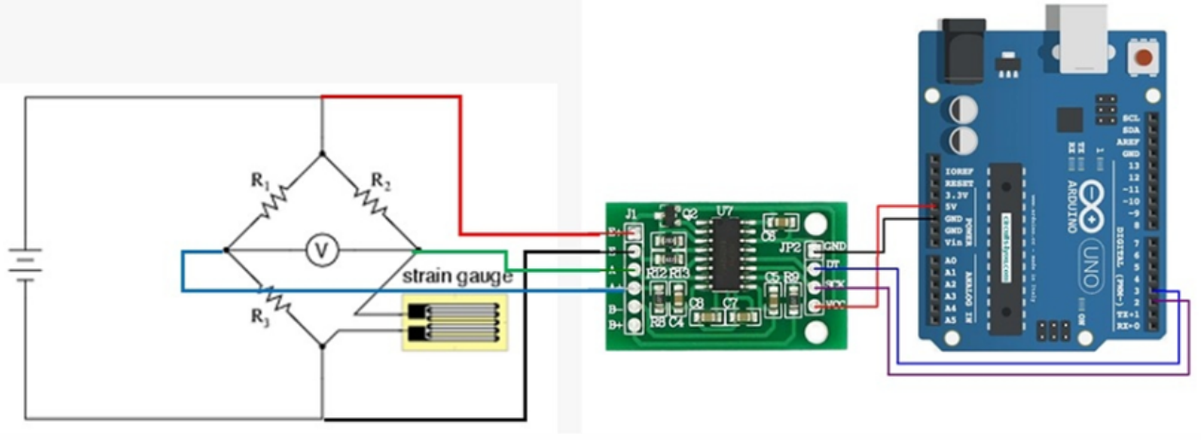
A strain gauge experiment using the Arduino and pressure chamber.

- Strain gauges are employed to measure the changes in dimension i.e. strain of a structure subject to external loading.
- Measured strain values can then be used to verify the forces acting on the structure—in this case, the empty/full mPMT module.
- Also, a goal is to verify the results obtained from the simulation calculations.

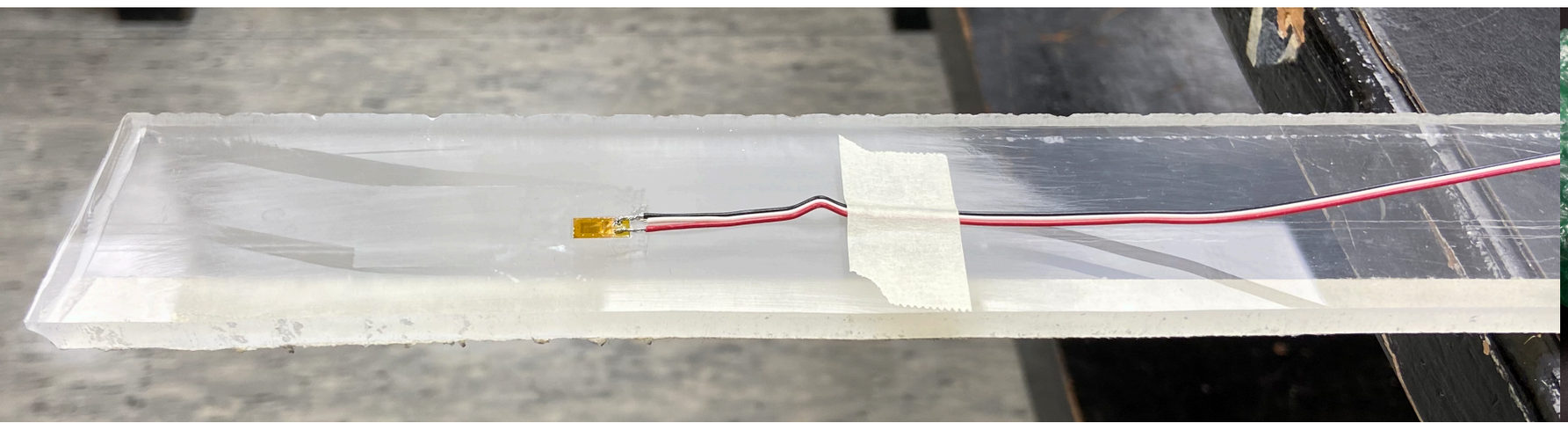


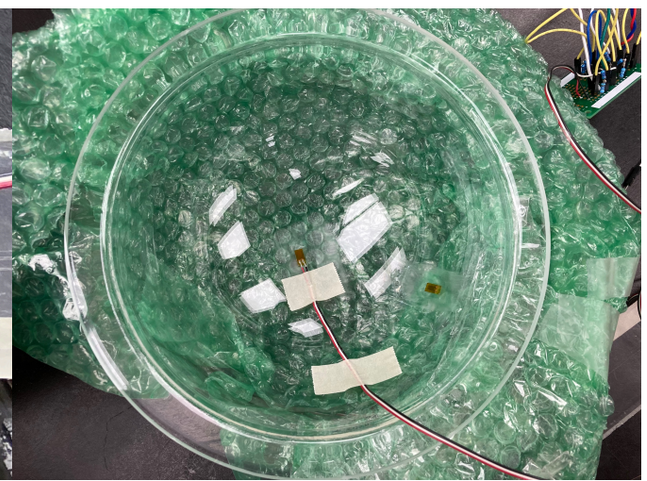
The idea is to measure the change in resistance of the strain gauge, a balanced Wheatstone bridge and calculate the corresponding strain value.

- Installed the strain gauge on the metallic and acrylic surface and did the calculation for the unknown strain by bending the surface.
- Planning a short-term pressure test up to 30m of depth at the company in Burnaby (NV Mechanics Design Ltd.).
- In total will install the 5 strain gauges—2 on the backplate, 2 on Acrylic Dome, and 1 on the PVC cylinder.



Experimental Setup

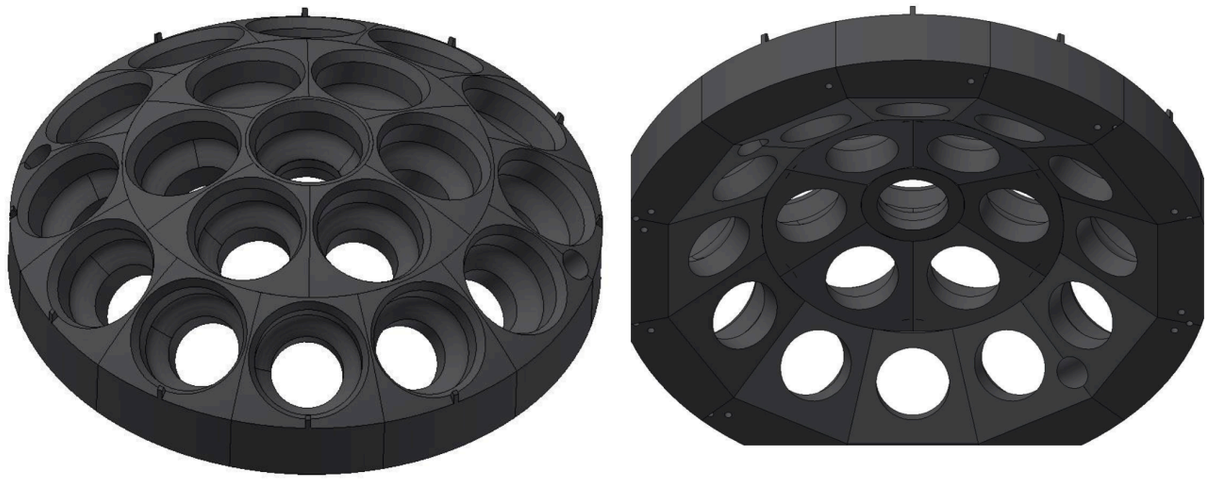




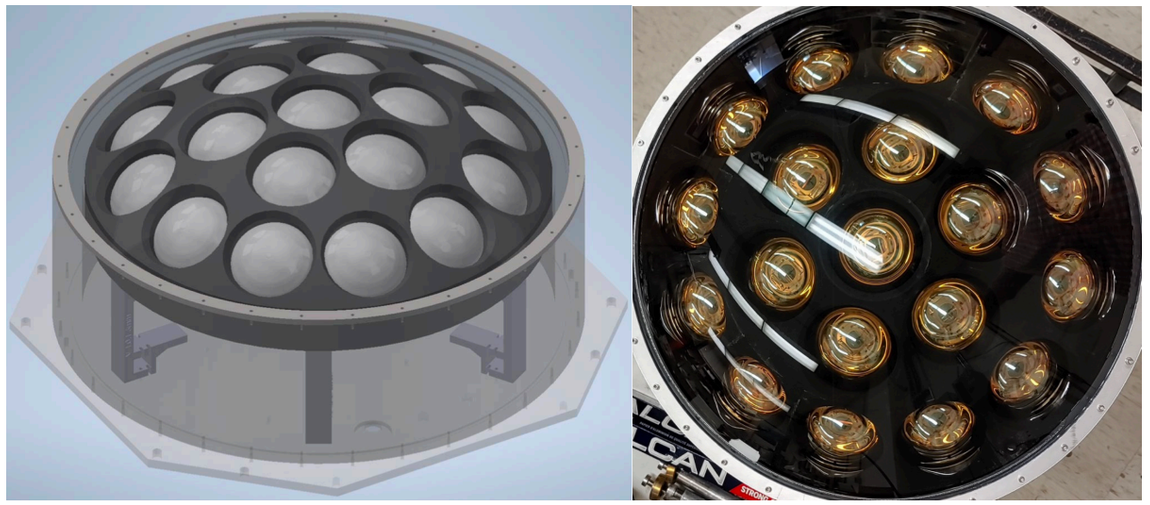
IN-SITU GELLING

Designated as the baseline option, it is based on in-situ gel pouring (following the KM3Net approach)

- The main objective is to have a sturdy, lightweight and low-cost inner support matrix.



- The amount of optical gel required is significantly reduced

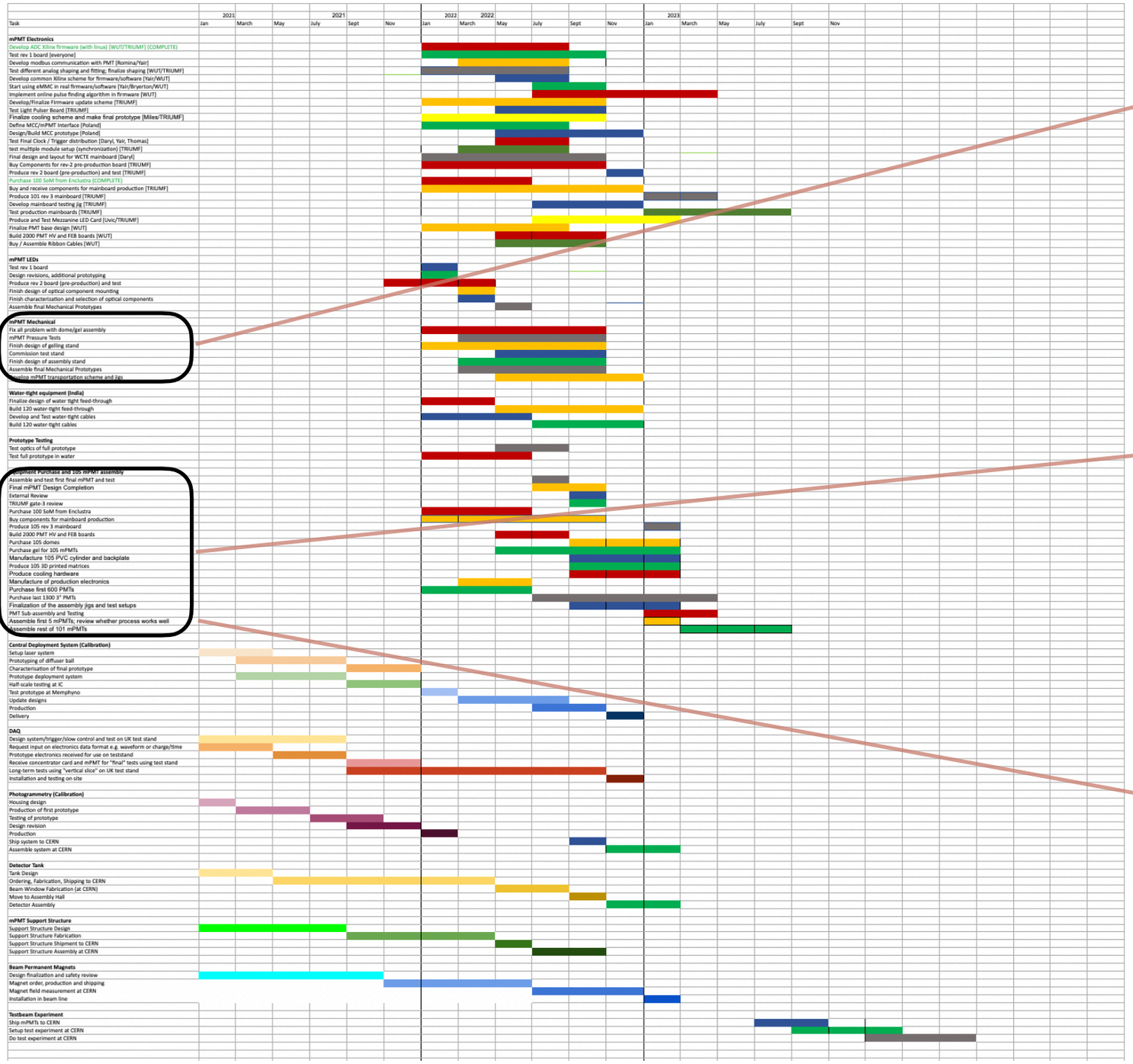


- Used the 612 gel prepared with the hardest manufacturer-recommended ratio A/B of 3/2
  ->Encountered some technical difficulties during the vacuum degassing step leading to delay and then losing part of the gel because it became too viscous
  ->We estimate to have used about 2.5 kg
  -> We have used removable silicone to pad the PMTs to set those which were loose

In general, the test resulted in a very good gelling but few imperfections are present
  ->Systematic air pocket at the exterior edge of each PMT hole in the 2nd ring
  ->One similar air pocket for a single PMT from the first ring
->These issues seem systematic and we do have options to fix such air trapping
  ->Suspect this issue has been artificially generated by excessive application of silicone

MILESTONES

WCTE mPMT production schedule



The mechanical design should be finalized by Sep./Oct. 2022. So that the mass production of the components could be started.

In order to understand the technology and possible hurdles. Assembly of first 5-15 detectors from Jan.-Sep. 2023.

Mass production of rest WCTE mPMT modules in Vancouver and Warsaw from April-August 2023.

SUMMARY

A long way to go!!!

- In February achieved the full contact using the faceted matrix, and the reproducibility of the procedure has been confirmed.

- A huge amount of R&D was performed in order to understand the technical faults in the preparation of the components and final assembly of the mPMT.

- Finally, achieved a well-working procedure for the gelling of the PMTs, producing a controlled amount of gel thickness.

- Full contact of PMTs with the dome is reproducible with a given setup and increased interference. In future, care must be made to maintain proper vertical dimensioning of all components and PMT seating.

- A document has been prepared for the component preparation and assembly of the working mPMT detectors, which could be used in future for the mass production.

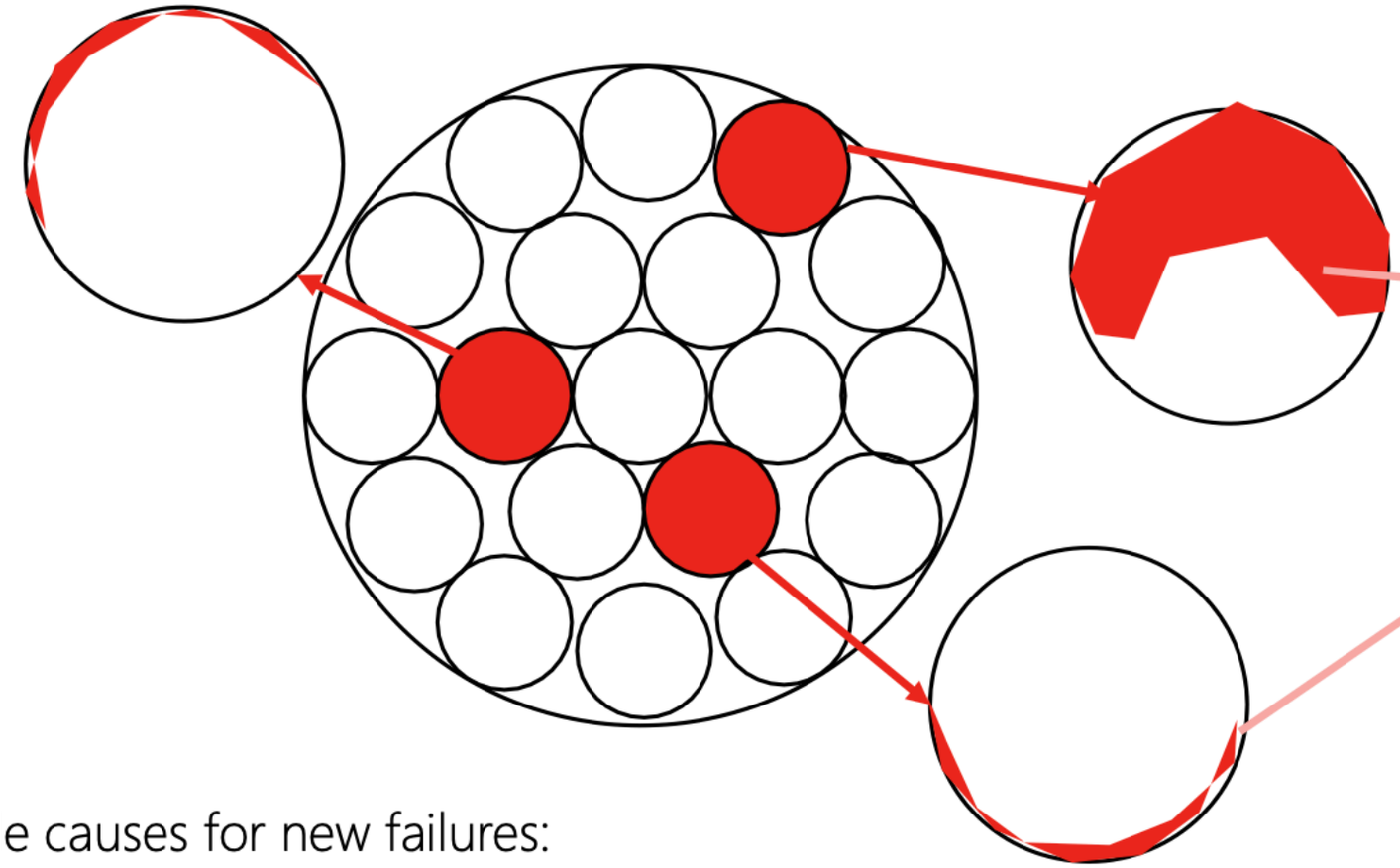
- In near future, planning for a pressure test on the mPMT detector, either with the module only or with the fully assembled mPMT.

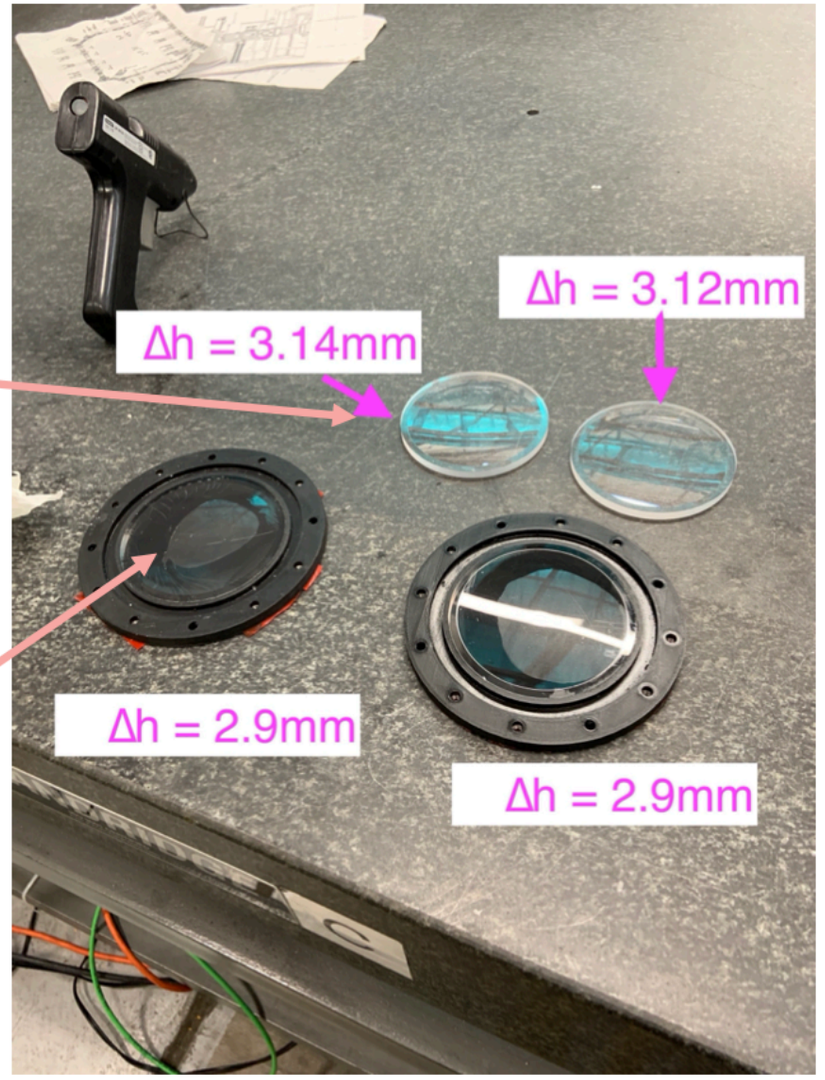
- The schedule is very tight for this fall, as the mechanical design has to be finalized to start the production of the components and pre-production early next year.

Thanks!!!

BACKUP

ANALYSIS





Possible causes for new failures:

- Acrylic plate has the wrong dimensions (in 3rd row PMT)
- New built-in adapter cup may have incorrect dimensions (3rd row)
- New PMTs are controlled at 7.5mm. This may be too thin for full contact, will consider increasing thickness on future iterations
- Underlying matrix deformities exacerbated by thin gel

PREVIOUS INTERFERENCE MEASUREMENTS

Part		CAD		Actual 1	Actual 2	Actual 3	Average		Assembly measurement
Pillar		109.61		109.5	109.5	109.5	109.5		
Cup		45.75		45.9	46.03	45.86	45.93		
Poron		12.6		12.53	12.64	12.72	12.63		
Gel		10.13		10.5	10.6	10.4	10.5		
Matrix Centre		75.94		75.9	76	76	75.96667		
Adjuster		1		1.01	0.98	0.99	0.993333		
Total		**255.03**					**255.52**		**256.12**
Cylinder		161.77		161.5	161.6	161.5	161.5333		
Dome		91							
Total		**252.77**							**250**
Difference		**2.26**							**6.12**

Interference is ideally 2.5mm. Measurements shown are for center PMT only.

6mm interference shown here prompted 3.5mm decrease in pillar height