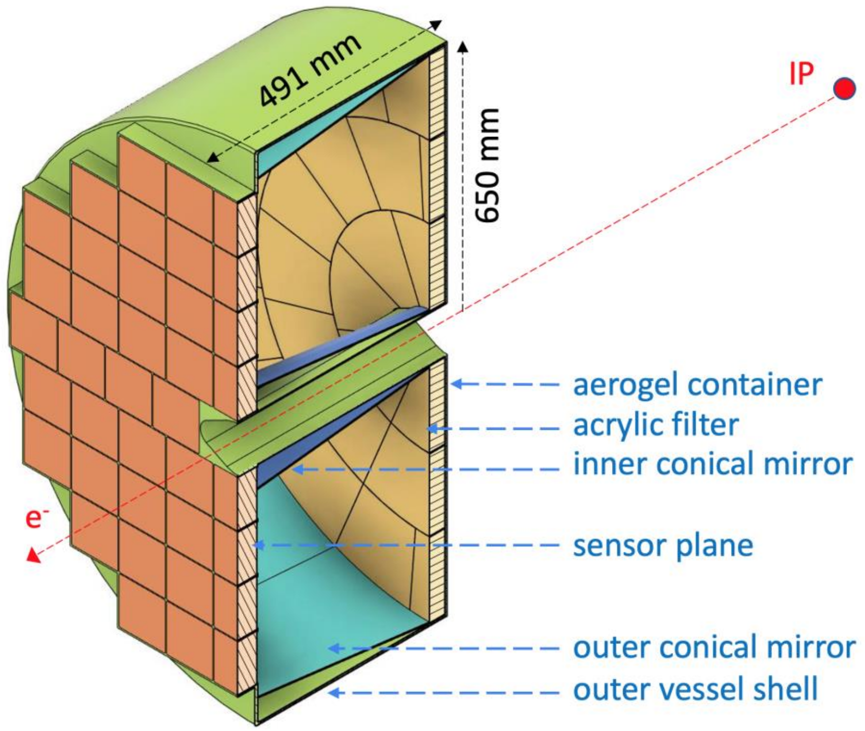
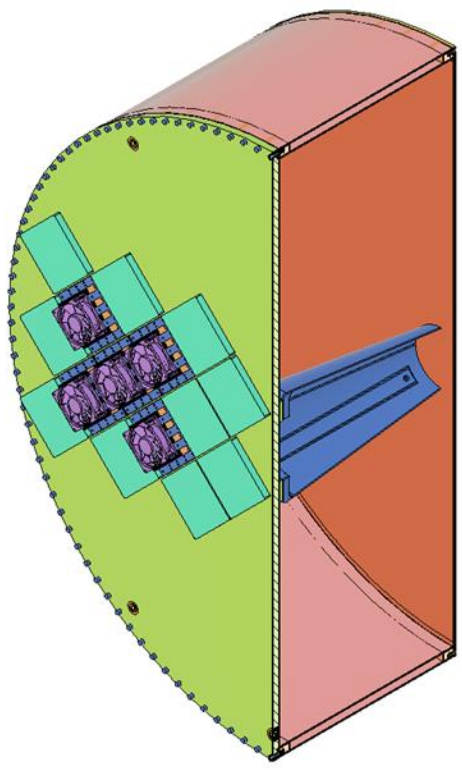
pfRICH Prototype Status



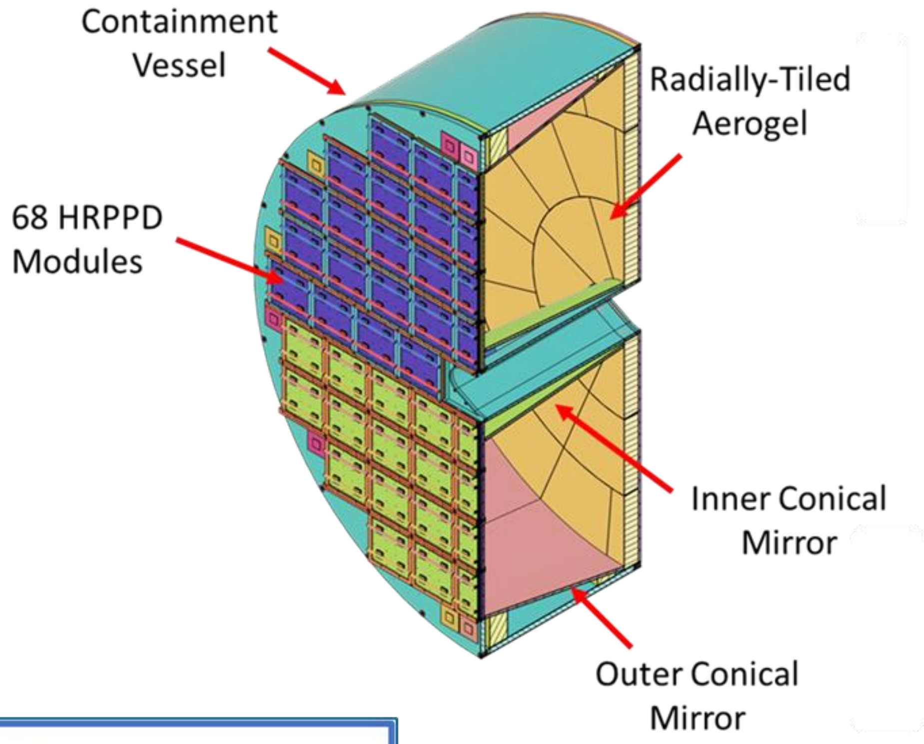
Brian Page
For the pfRICH Team
ePIC TIC Meeting
August 26, 2024

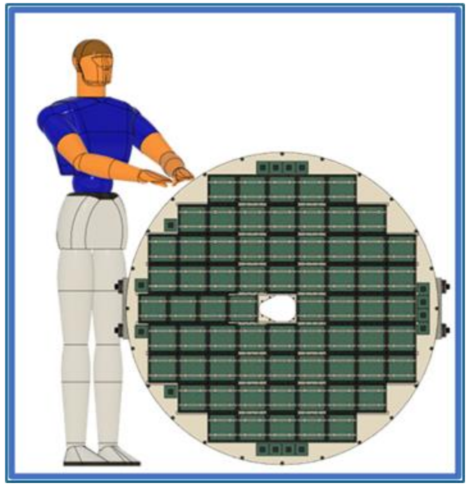


Overview

- ❑ pfRICH Design Reminder
- ❑ Test Beam Design
- ❑ Fabrication Activities
  - ➢ Vessel
  - ➢ End Rings
  - ➢ Sensor Enclosure
  - ➢ Mirrors
- ❑ Other Activities
  - ➢ Laser Monitoring System
  - ➢ HRPPD Evaluations
  - ➢ Aerogel Evaluations

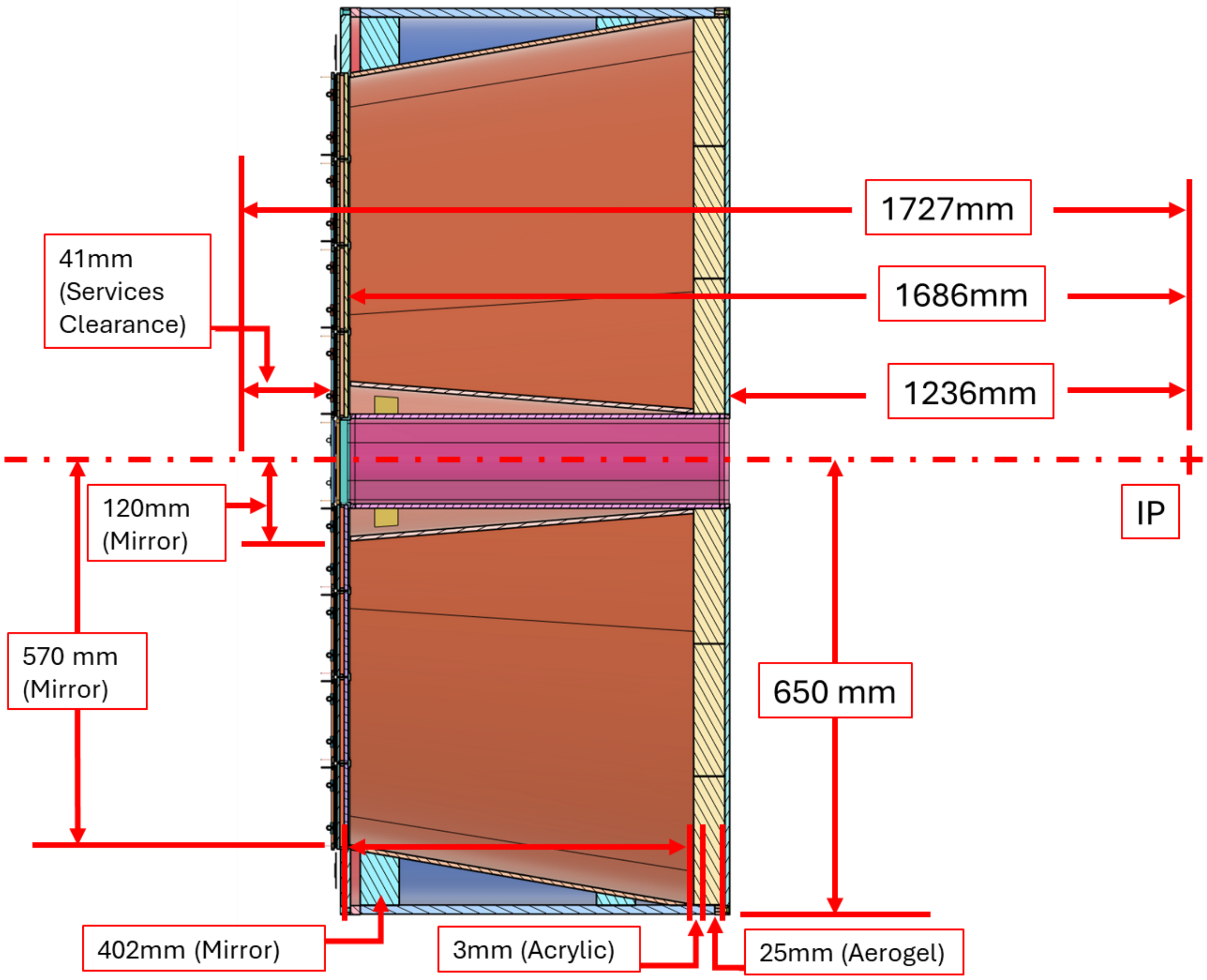
pfRICH Design



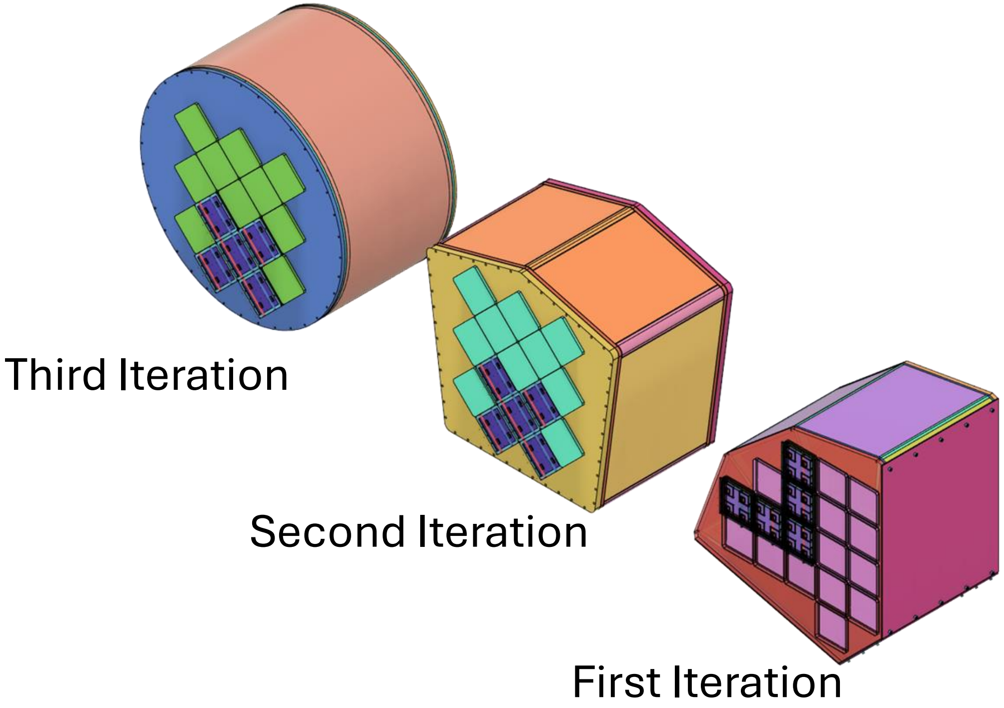


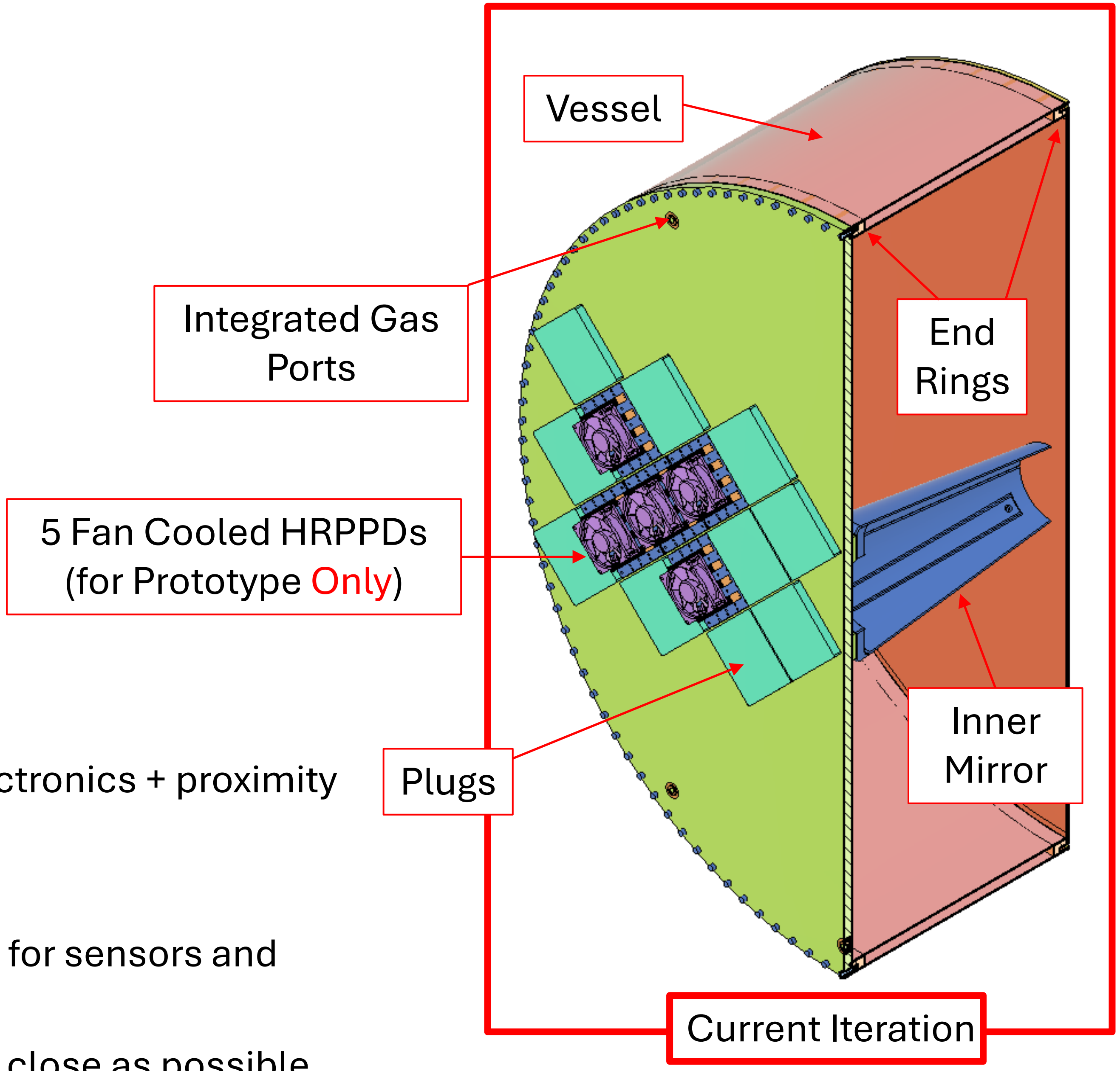
Major Components:

- Vessel
- Sensor Plane
- Mirrors
- Aerogel Wall



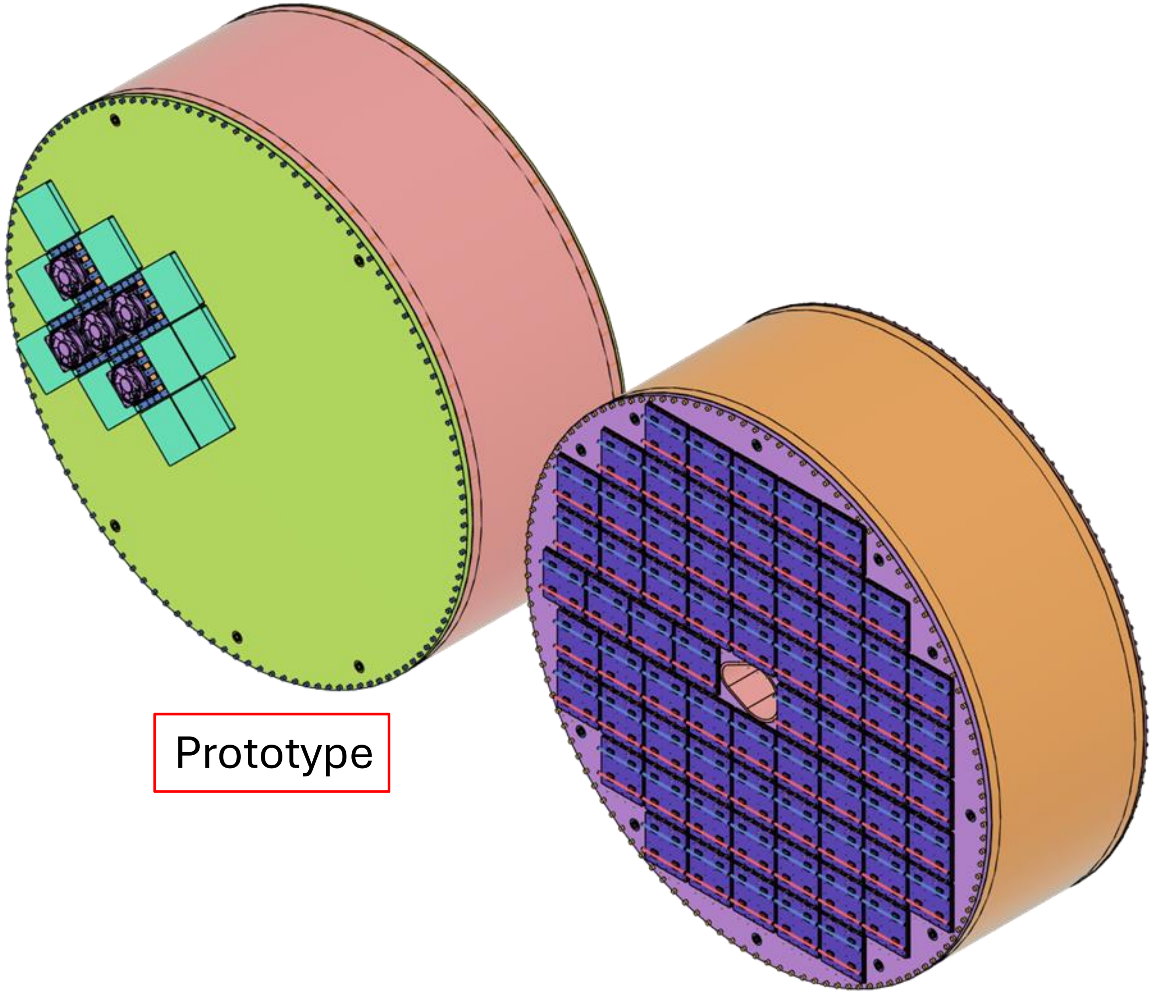
Test Beam Vessel Design

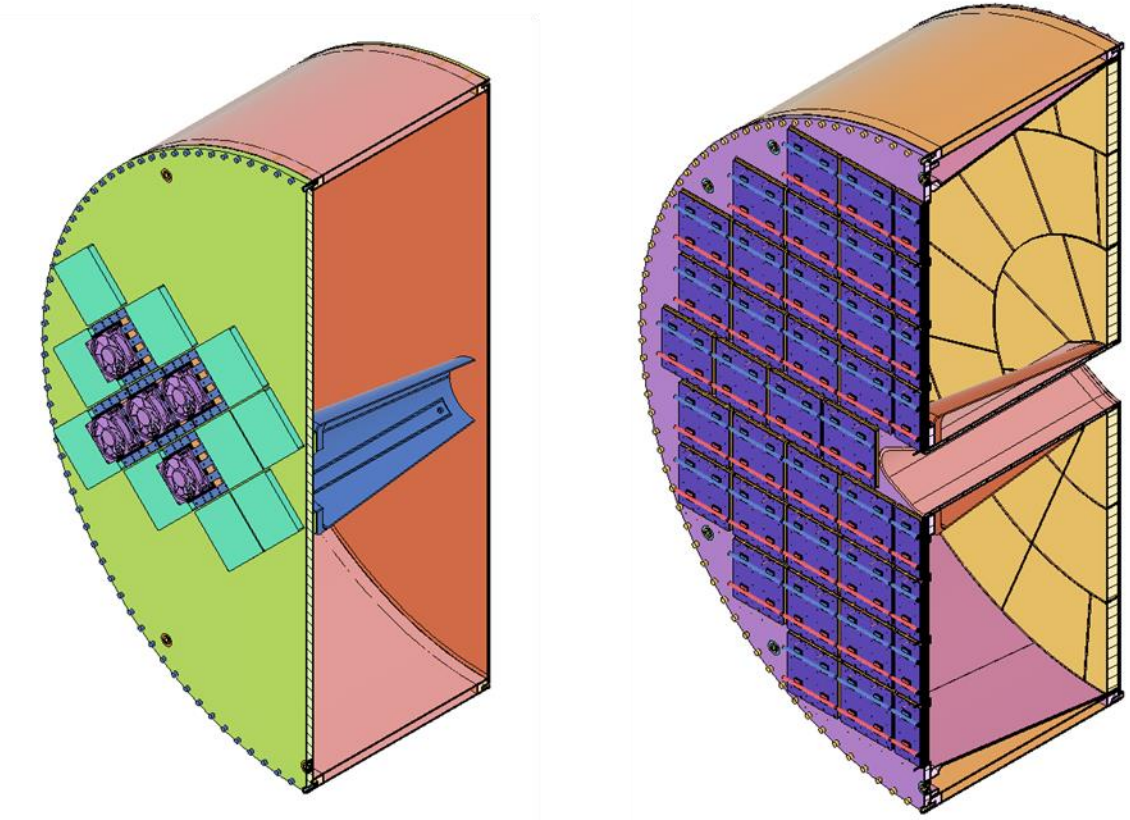




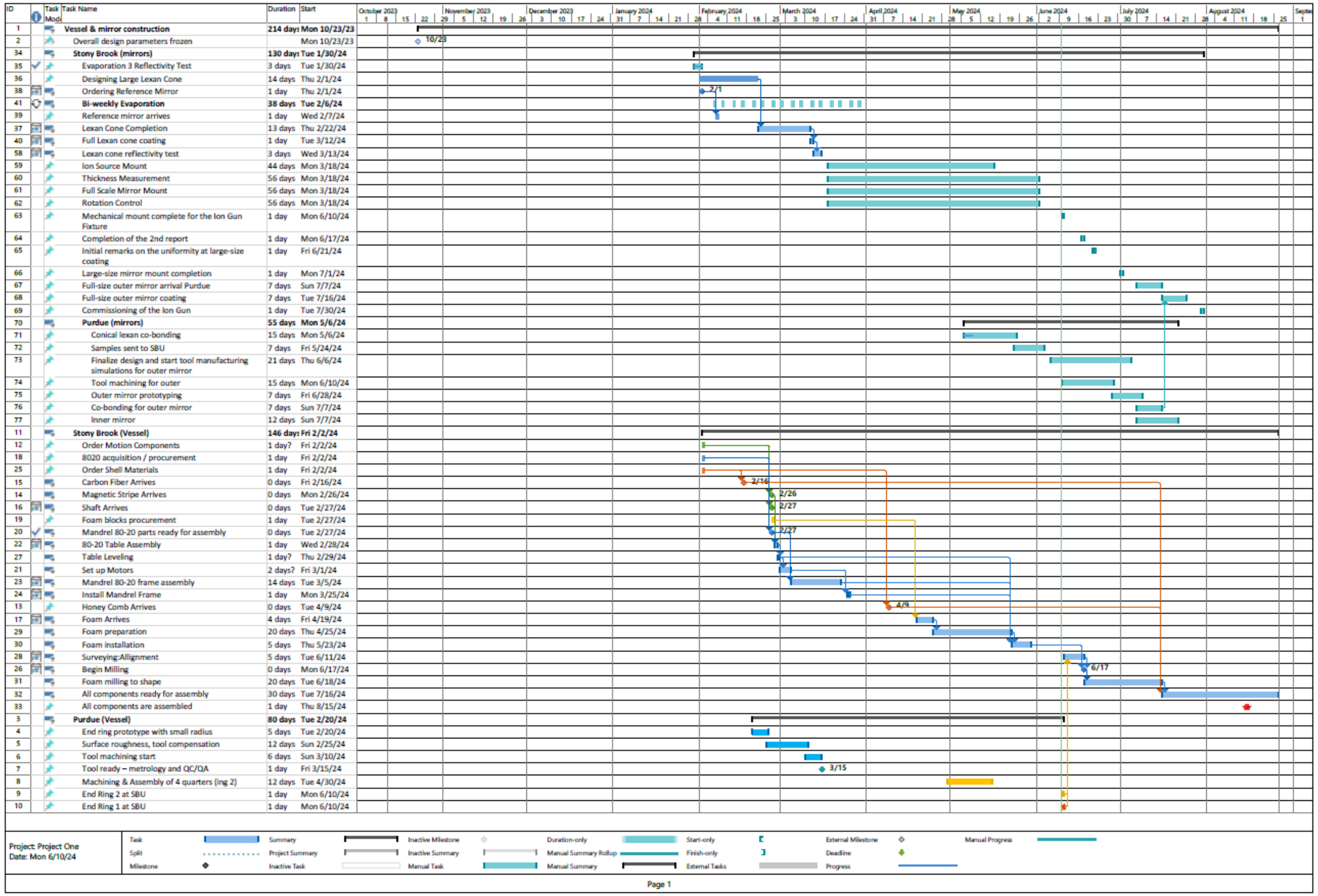
- ❑ Test Beam Goal: evaluate the aerogel + HRPPD & electronics + proximity gap performance (timing + imaging)
- ❑ Also gather data for pi/k separation proof
- ❑ Early vessel concepts were simple light-tight holders for sensors and aerogel
- ❑ Kill 2 birds with one stone: make test beam vessel as close as possible to final design – allow for performance tests (with mirrors) and learn how to build the final detector

Test Beam Vs ePIC Design





From Here to There: Fabrication Schedule

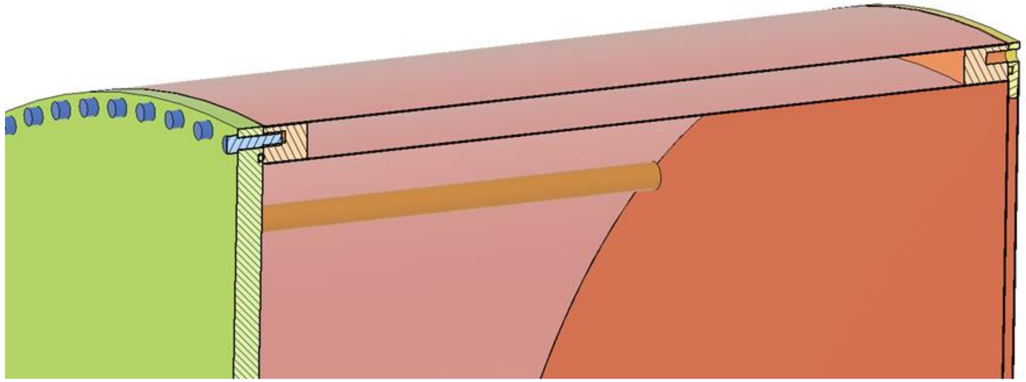


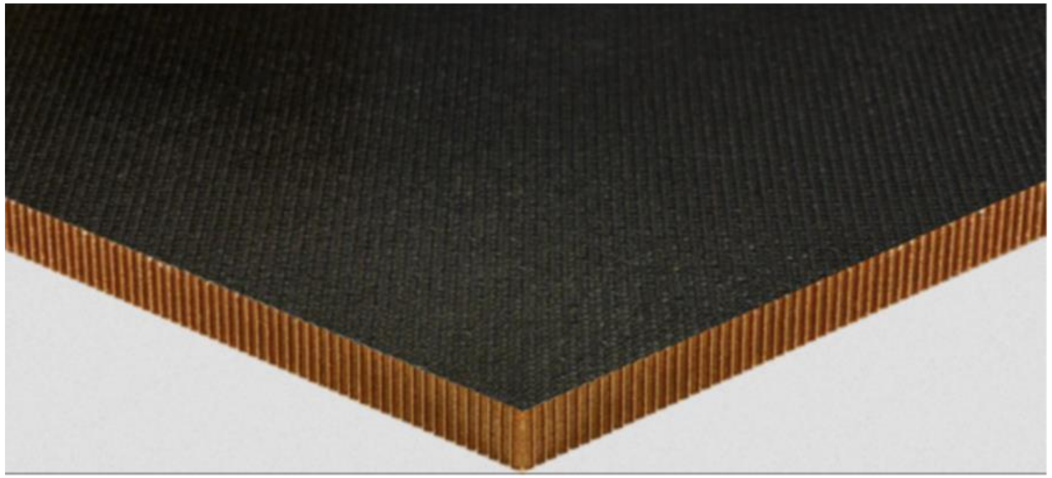
- Current PED work geared toward having a first article ready for test beam studies in the spring

- Scope:
  - Vessel Construction (SBU)
  - End Ring Fabrication (Purdue)
  - Sensor Plane Fabrication (Purdue)
  - Mirror Substrate Fabrication (Purdue)
  - Mirror Coating (SBU)

Vessel Fabrication: Shell

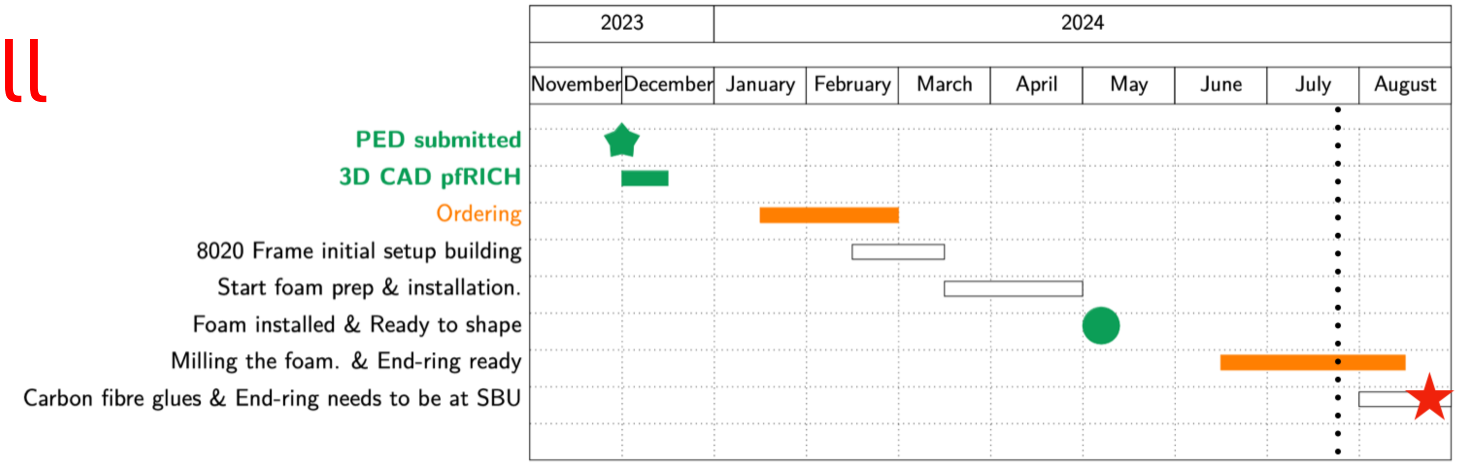
- ❑ SBU tasked with creating the cylindrical shell for the pfRICH vessel
- ❑ Use carbon fiber sandwich design -> light, stiff, gas- and light-tight vessel wall
- ❑ Vessel mandrel mostly done – construction will begin soon

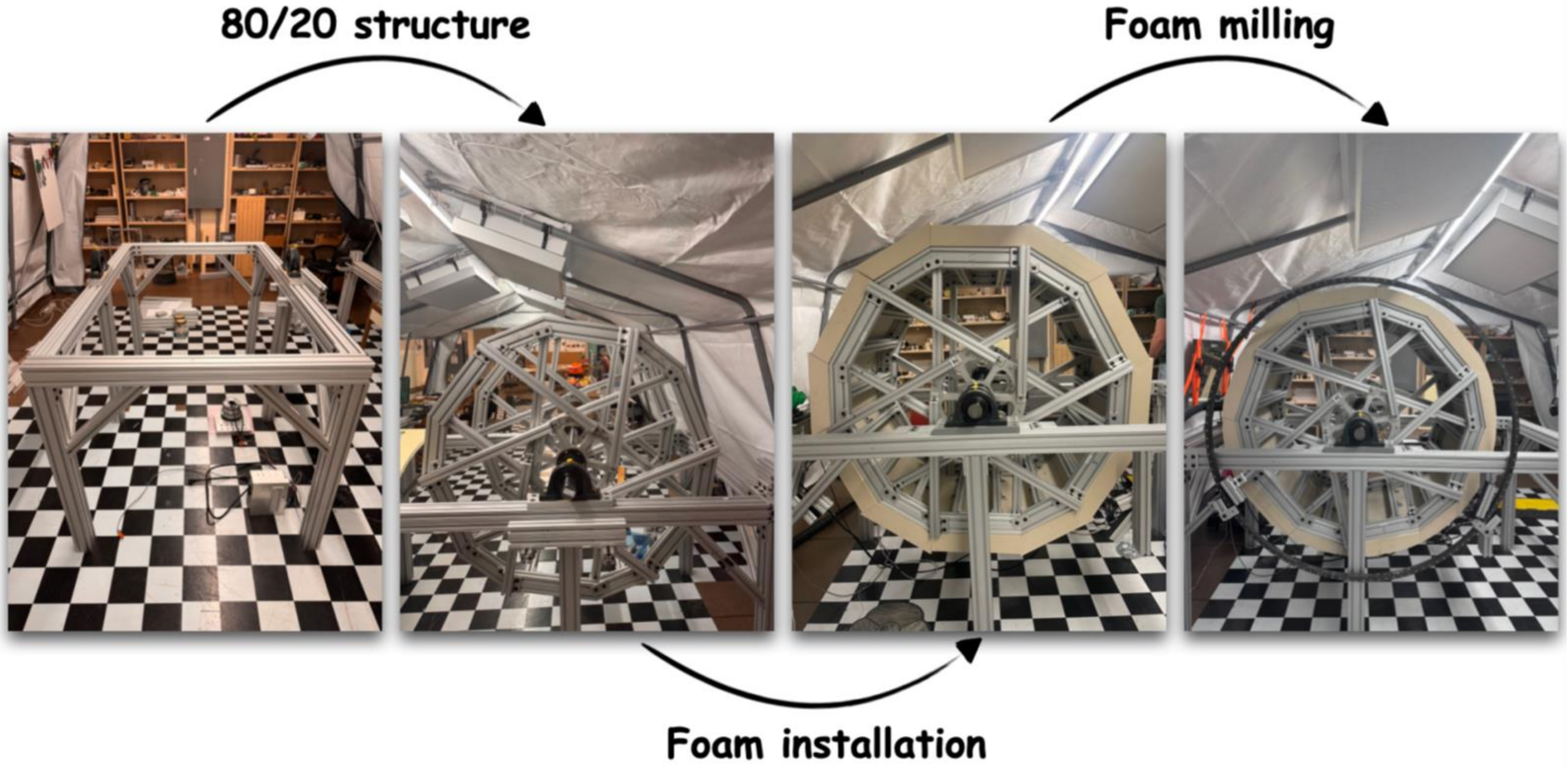




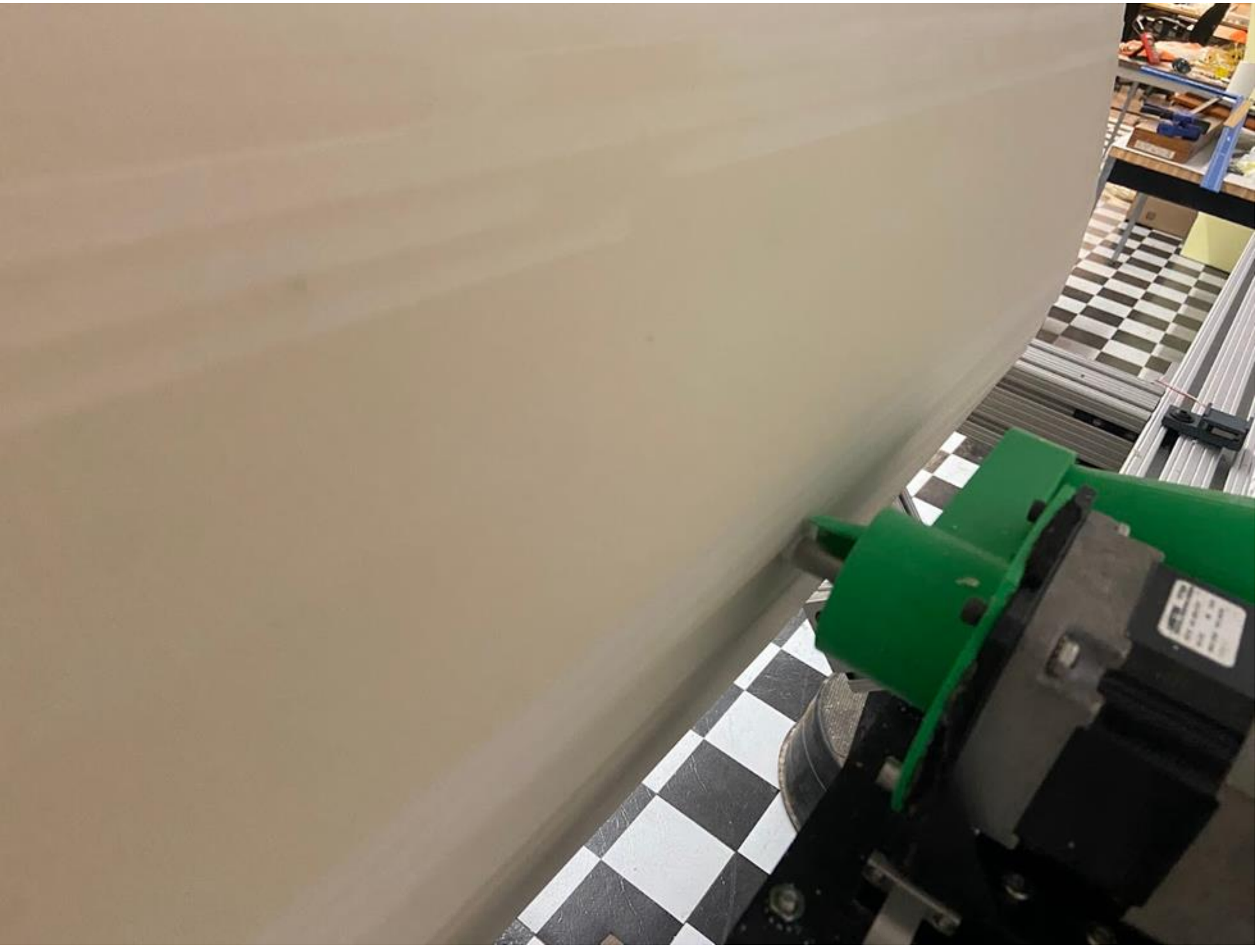
- ➢ Shape: 1/2” thick cylinder (12.7 mm)
- ➢ Outer Diameter: 1300 mm
- ➢ Length: 491 mm
- ➢ Precision: < 1 mm radius and length
- ➢ Technology: Carbon-fiber composite material with nomex honeycomb core

Vessel Fabrication: Shell

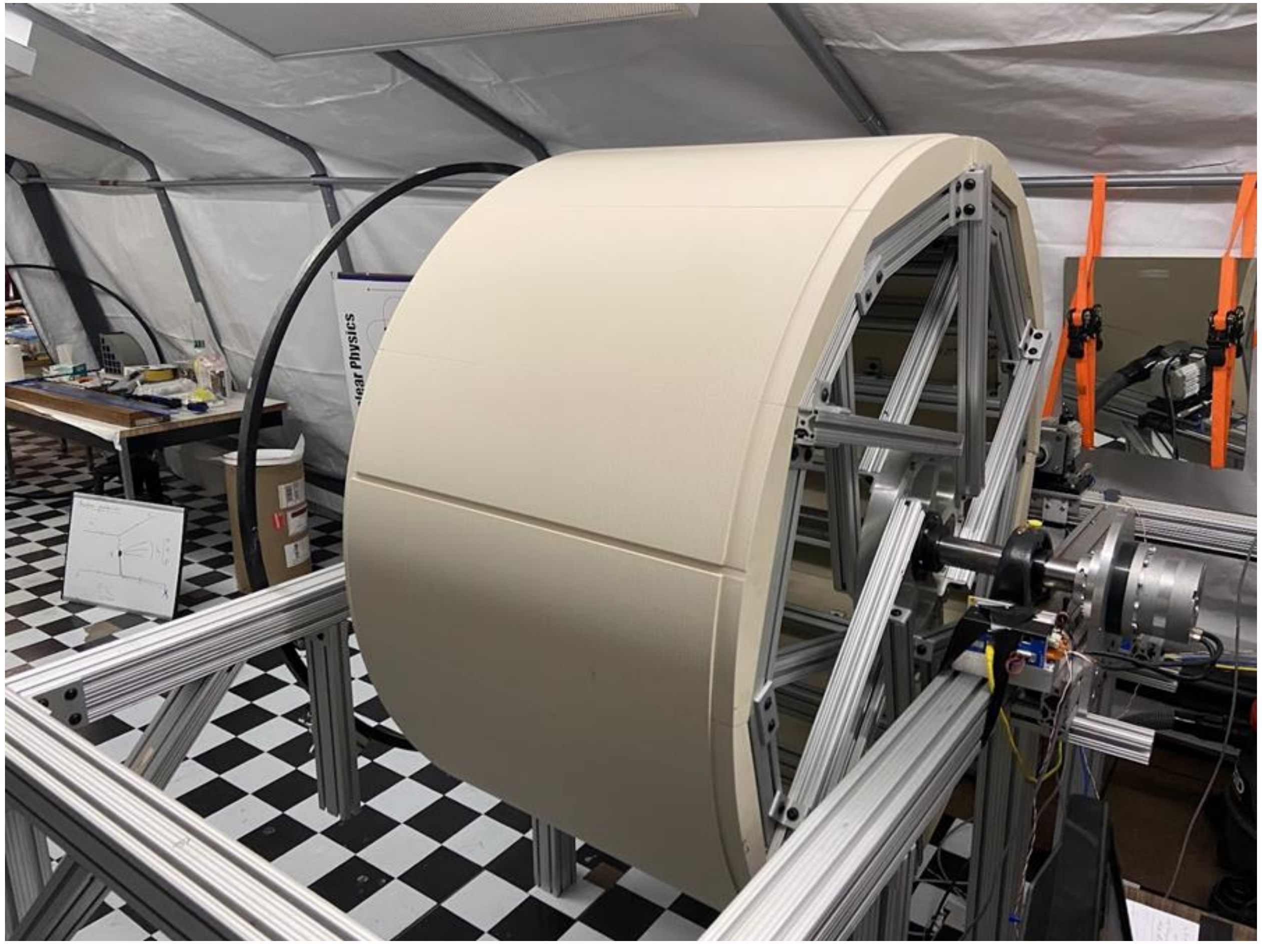




Vessel Fabrication: Shell



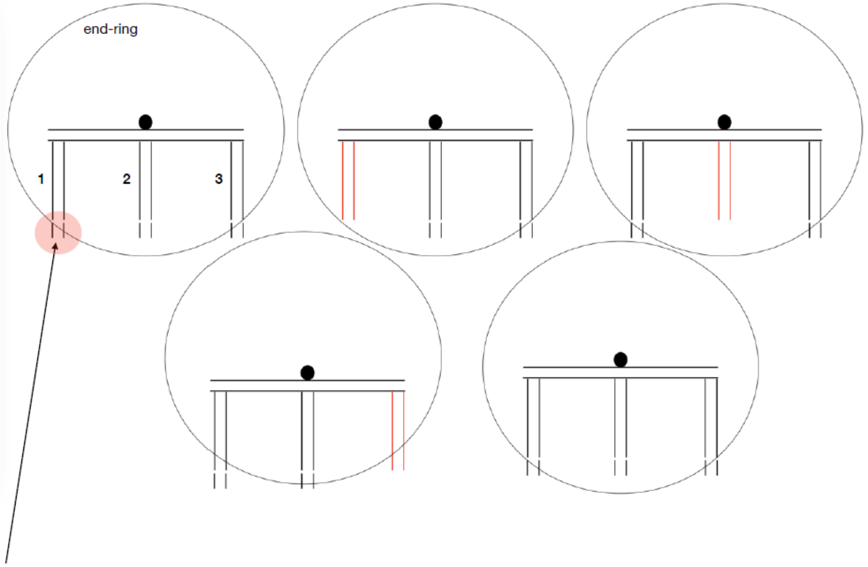
Milling attachment on its linear guide



Milled foam vessel mandrel with end ring test groves

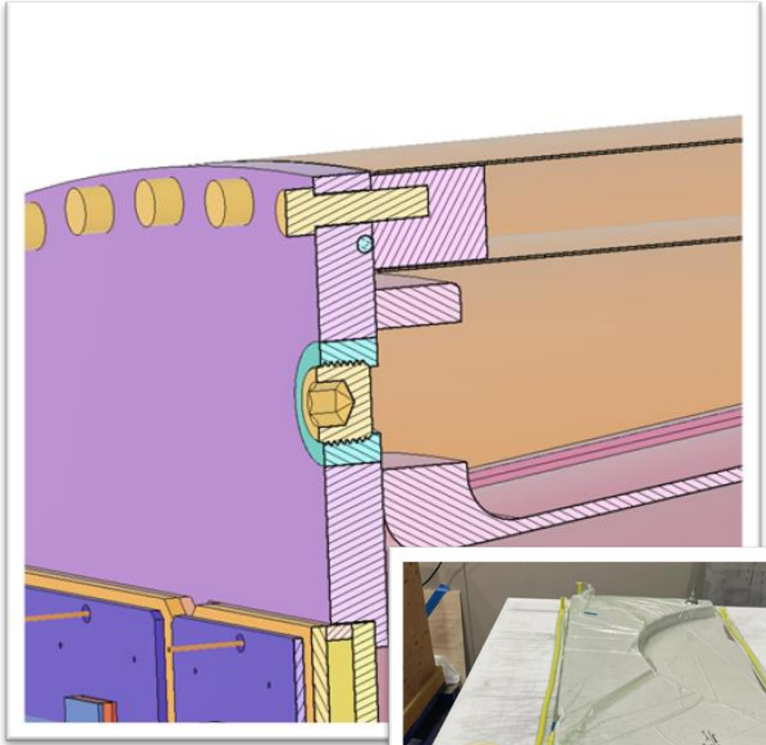
Vessel Fabrication: Shell

- ❑ Need to get end ring through 80/20 frame and onto foam
- ❑ Modify frame with gaps to allow ring through
- ❑ Lower part of legs removed and replaced in sequence to let ring pass



The lower part of each leg can be removed. Combine 1, 2, and 3 for the installation.

Vessel Fabrication: End Rings



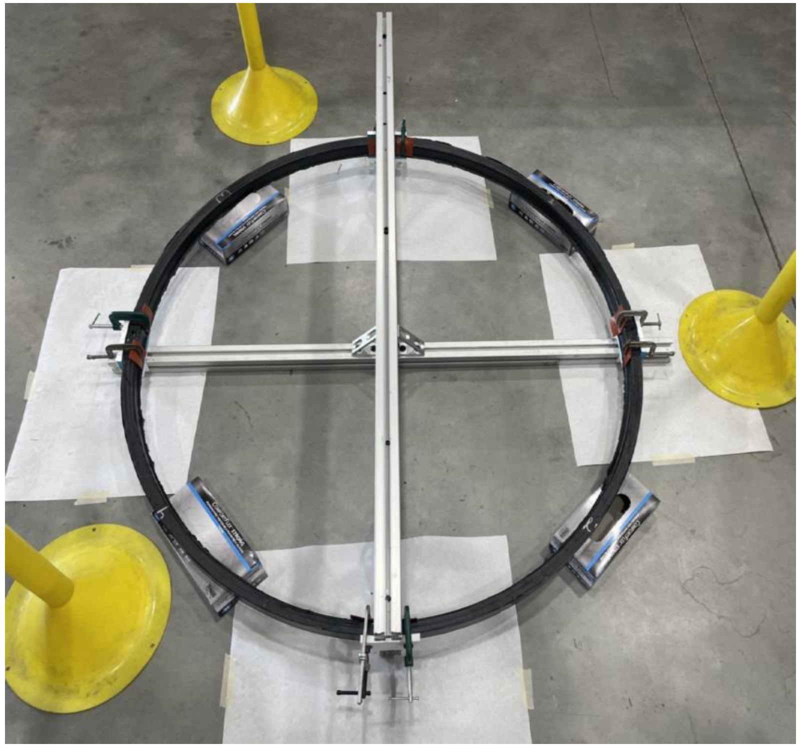
1

2

3

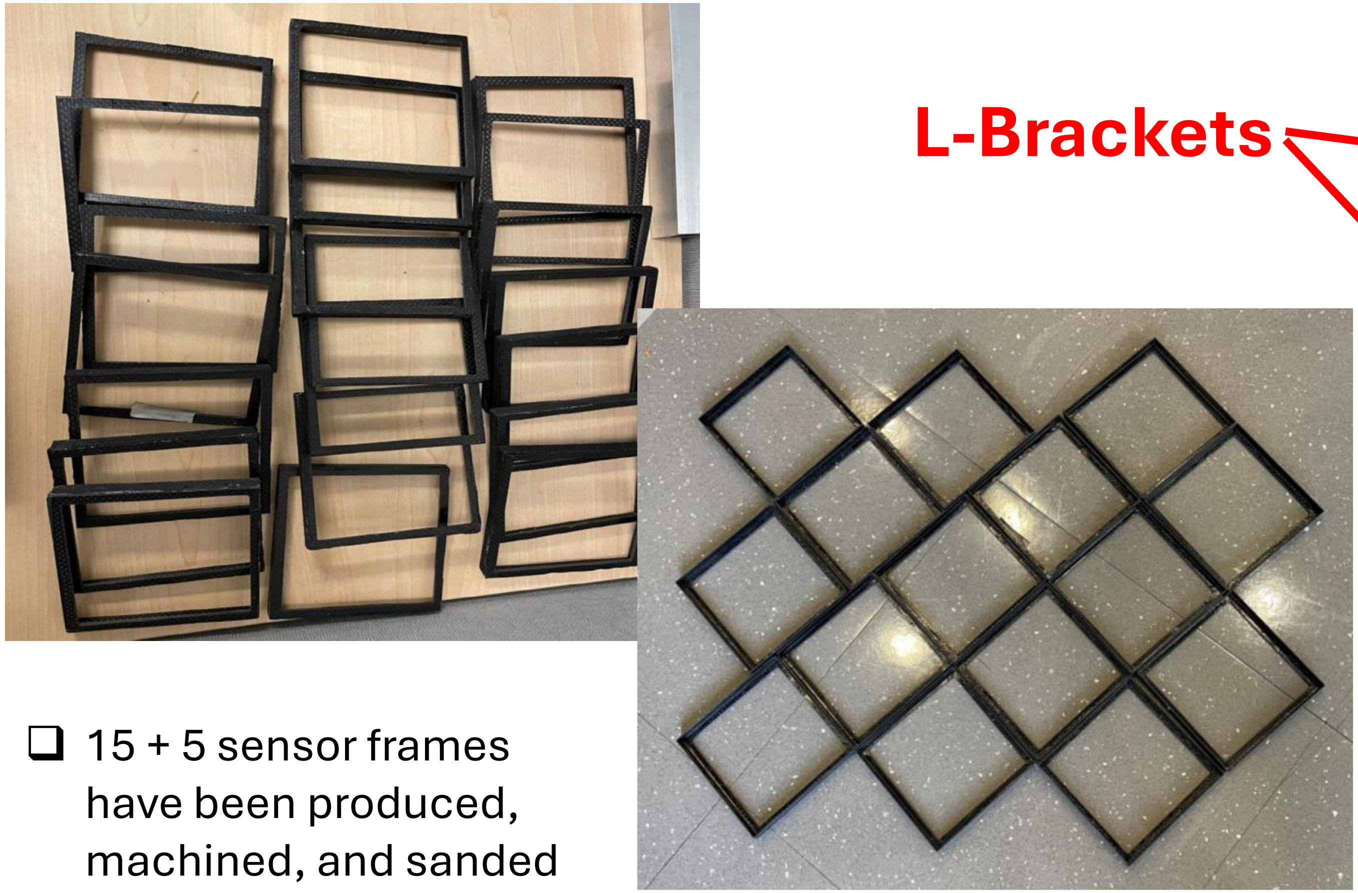
4

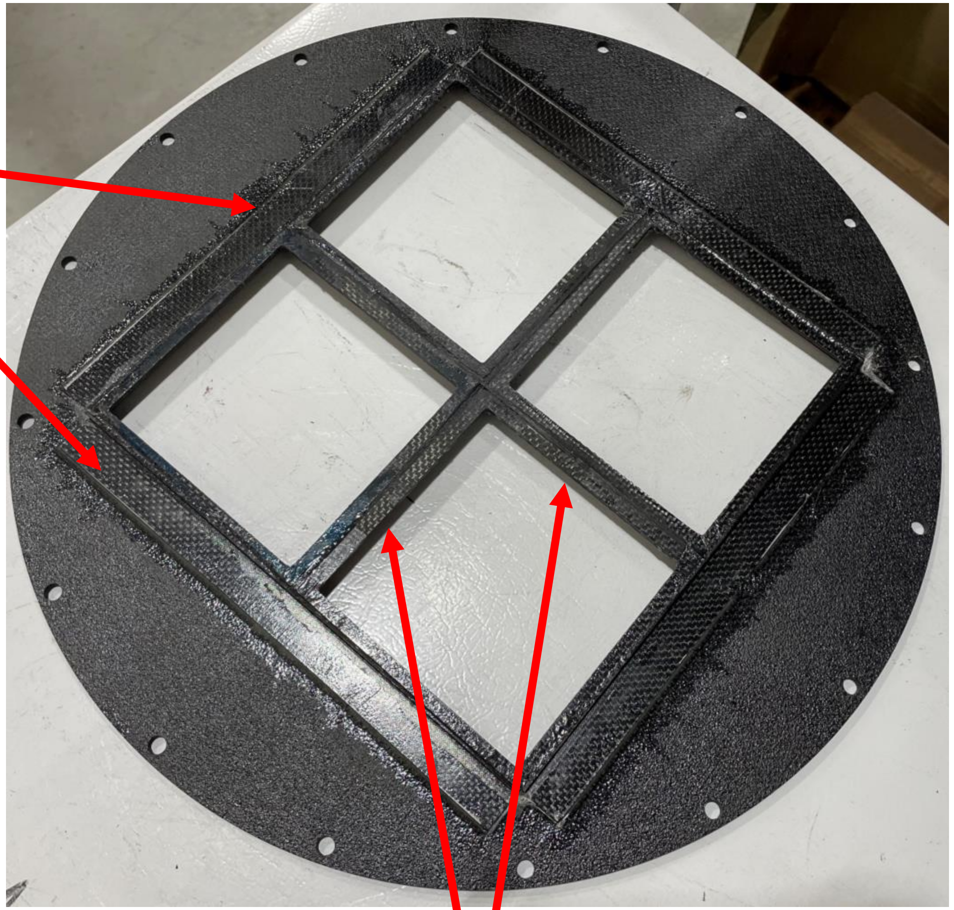
5



1. End ring design
2. Ply cutting and layup
3. Quarter sections
4. Metrology
5. Glue-up jig

Vessel Fabrication: Sensor Enclosures



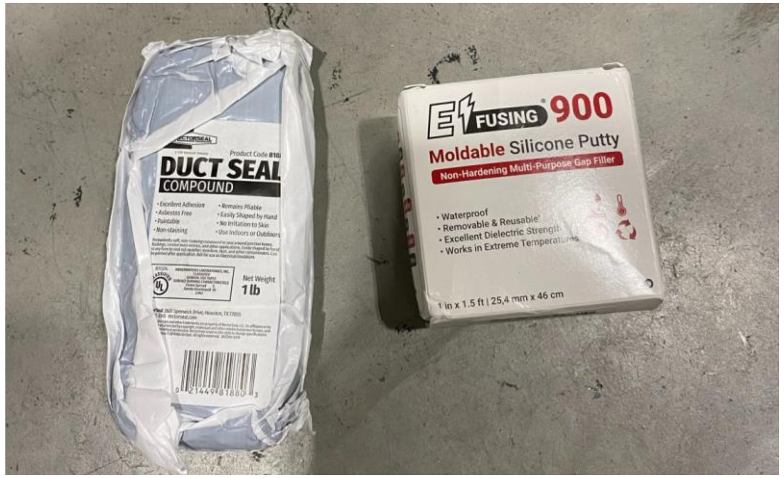


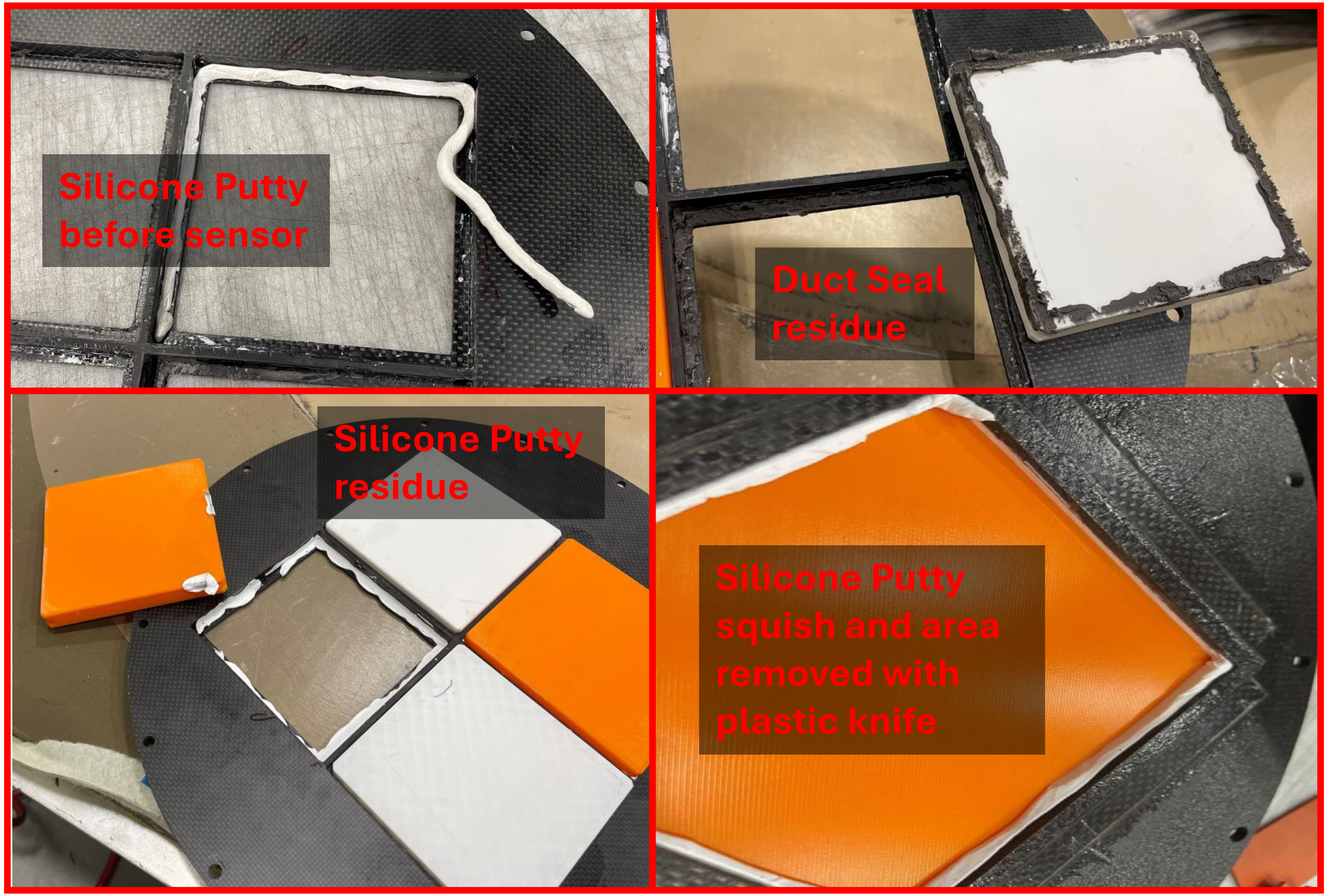
L-Brackets

Interstitial Beams

- 15 + 5 sensor frames have been produced, machined, and sanded
- L-brackets for bonding frames to outer plate have been produced
- Production of interstitial beams to support frames ongoing

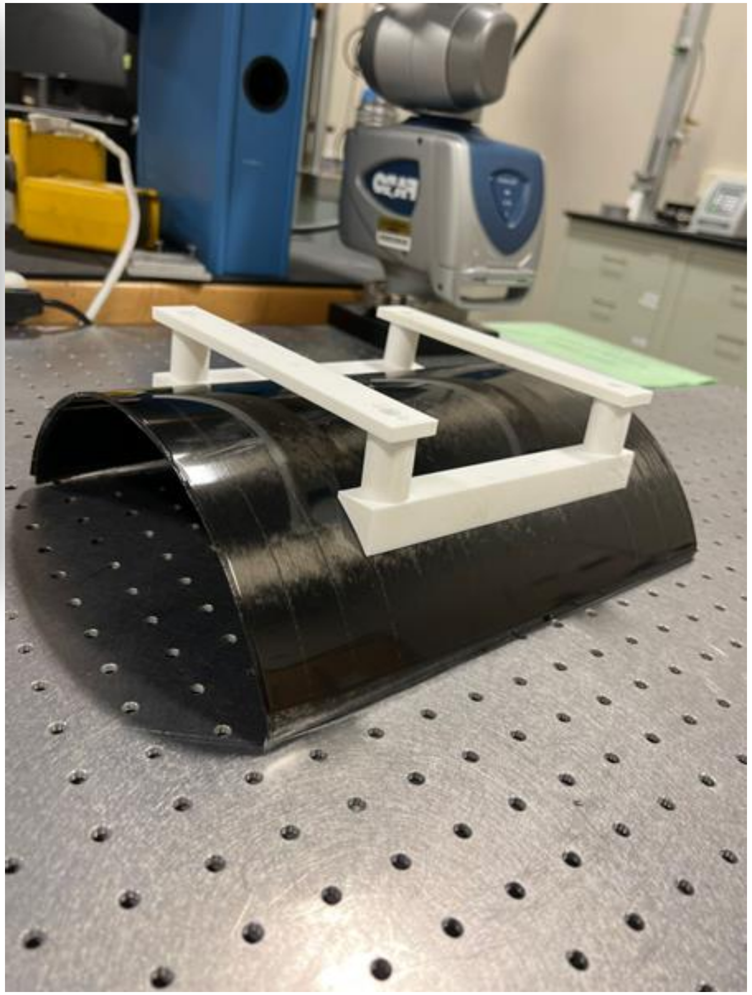
Vessel Fabrication: Sensor Enclosures

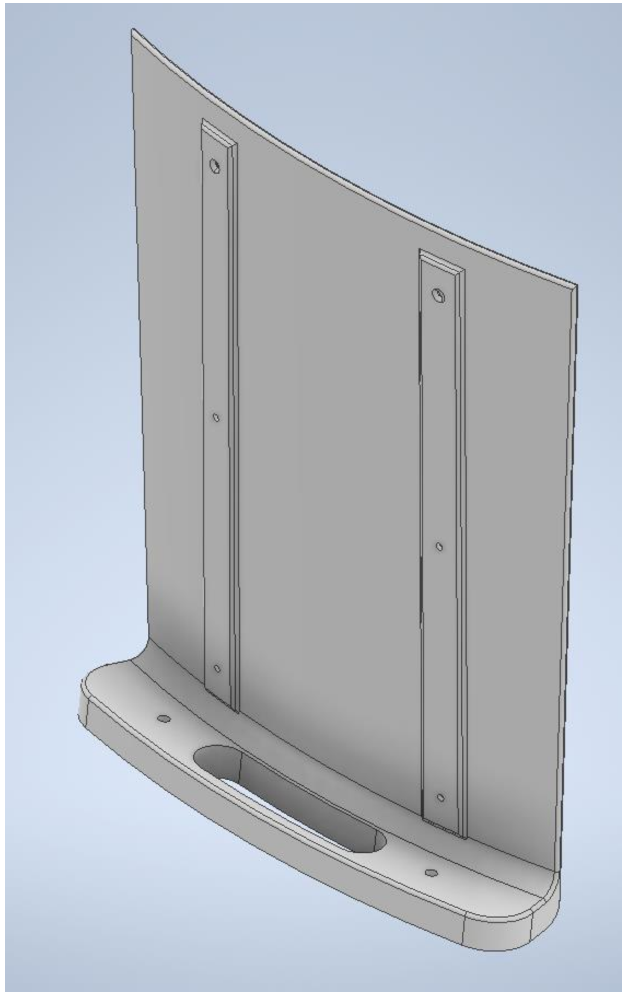




- ❑ Studies of best way to seal sensors in their enclosures ongoing
- ❑ Duct Seal worked but left residue on sensor blanks
- ❑ Silicone putty left little residue and was easily cleaned, best gas seal, easy to work with
- ❑ Putty has a tendency to “squish out” on front face of sensor when pushed into frame
- ❑ Effects of time and radiation on seal not yet explored

Mirror Fabrication: Substrates





- ❑ First full sized curved mirror test substrates produced
- ❑ Lexan co-bonded to carbon fiber back
- ❑ Sent to SBU for mirror coating

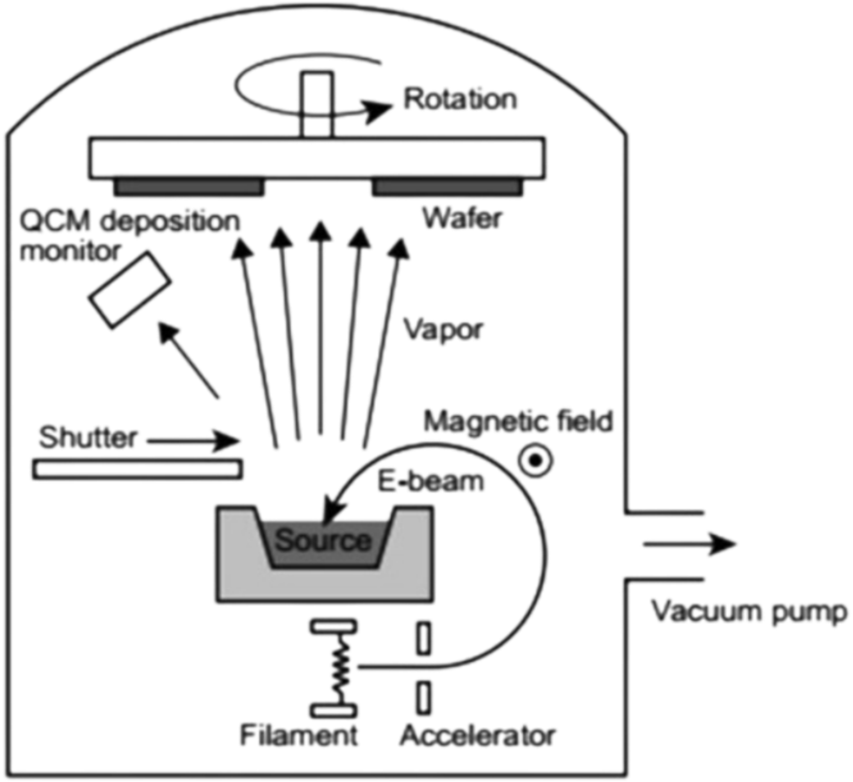
Mirror Fabrication: Coating

Rotating Fixture

Quartz Crystal Microbalance

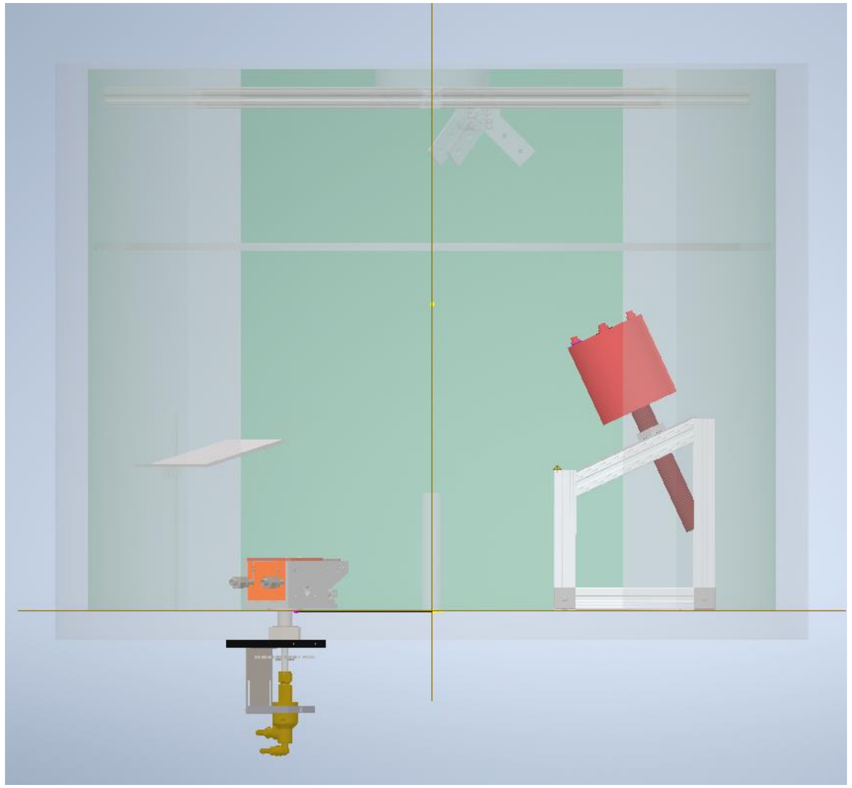
Remote Shutter

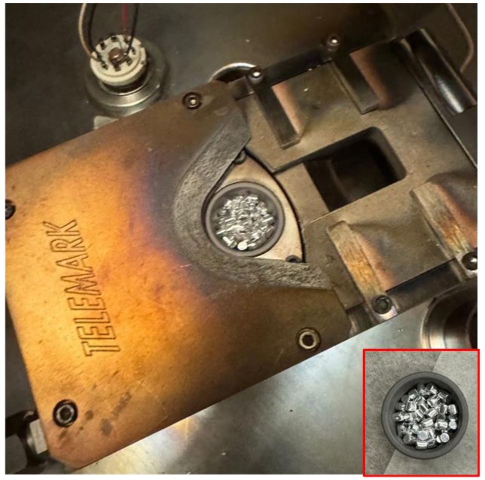
Electron Gun



Mirror Fabrication: Coating

Evaporation Number	Coating Recipe (Values at QCM)	Procedural Changes	Reflectivity
7	Cr: 5.19 KAng Al: 12.03 KAng	Decrease in total deposition amount from previous coatings 70 KAng → 17 KAng	88%
10	Cr: 4.66 KAng Al: 22.24 KAng	Increased Aluminum Coating	86%
11	Cr: 5.08 KAng Al:12.36 KAng	Consistency Check Repeat of #7	89%
12	Cr: 5.17 KAng Al:12.27 KAng	Substrate Waviness Test + Rotation Decrease 60 RPM → 30 RPM	88%
13A	Cr: 0.11 KAng Al: 0.93 KAng	NA62 / COMPASS recipe	20%
13B	Cr: 1.13 KAng Al: 2.578 KAng	Account for QCM to Substrate deposition ratio [rough estimate of distance discrepancy]	74%





- ❑ Many test coatings done to refine Cr/Al recipe and thicknesses
- ❑ Other parameters such as substrate placement, rotation rate, etc also explored
- ❑ Settle on ~90 nm Al and 10 nm Cr -> 90% peak reflectivity between 300-700 nm with uniformity of 1-2%

Future Improvements:

- ➢ Mounts for larger substrates
- ➢ Introduce dielectric coating (SiO_2) to improve resilience of coating
- ➢ Ion gun to smooth coating
- ➢ Better vacuum

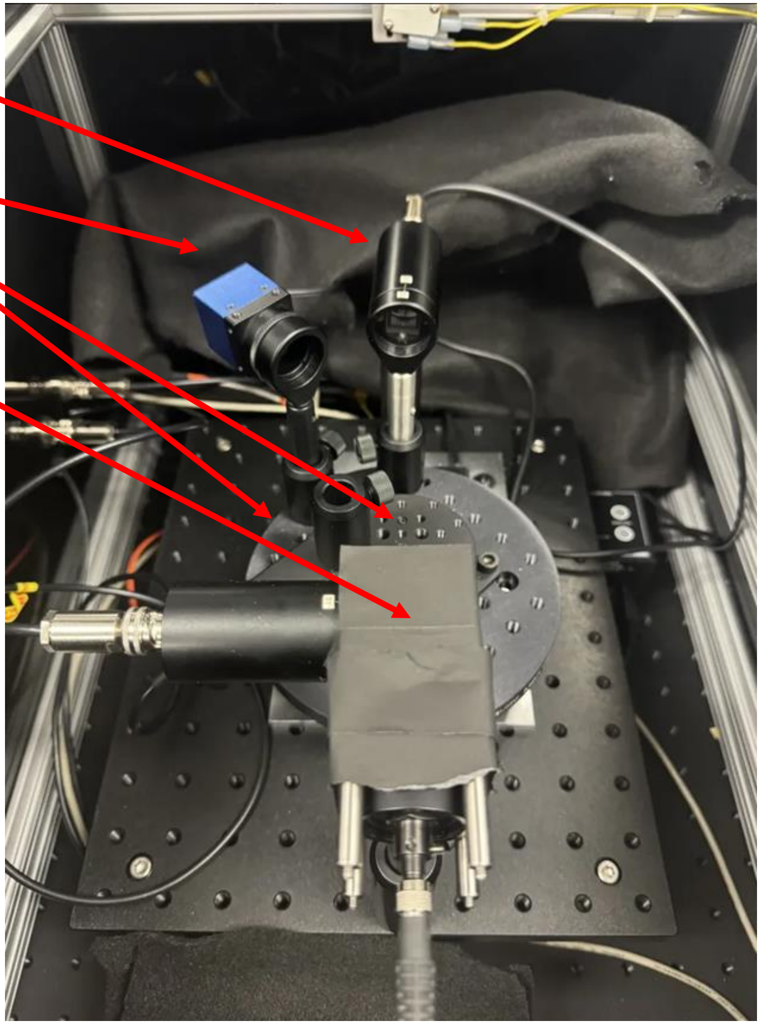
Mirror Fabrication: Reflectivity Tests

Test Photodiode

Camera

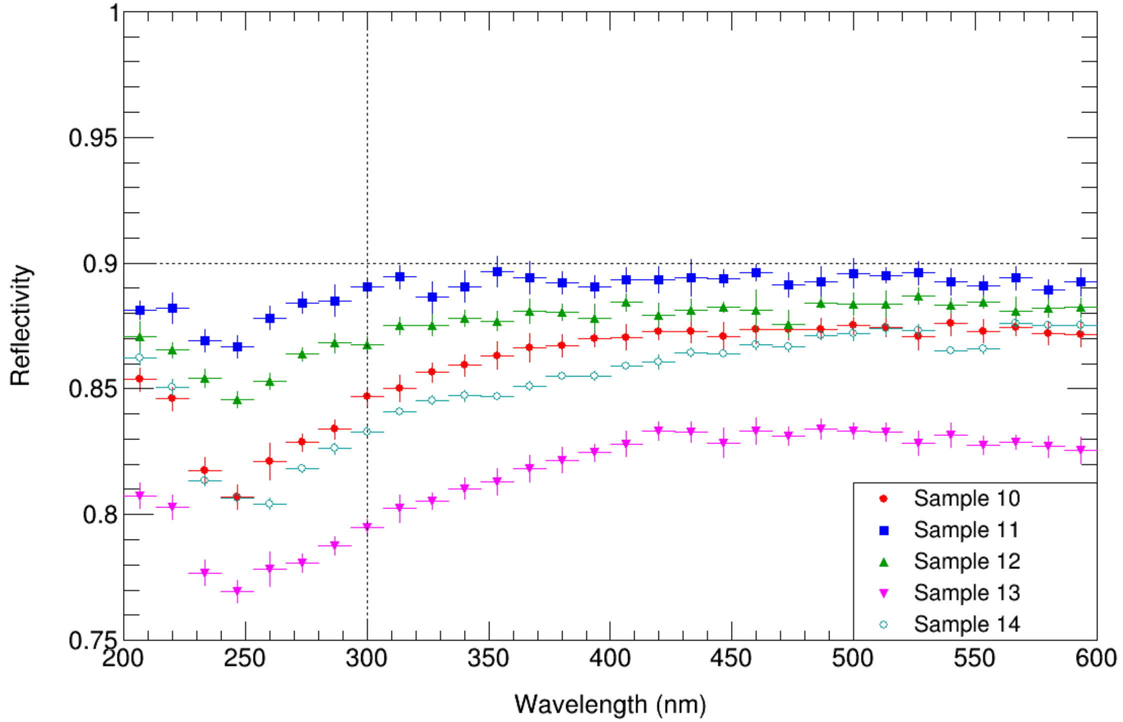
Rotational Stages

Beam Splitter



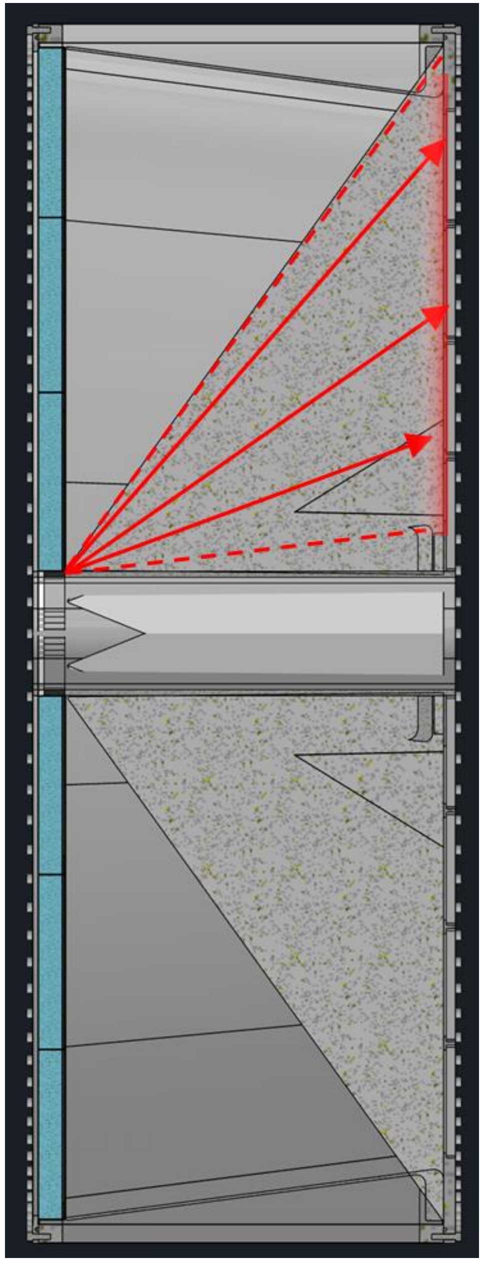
Monochromator:
200 – 600 nm

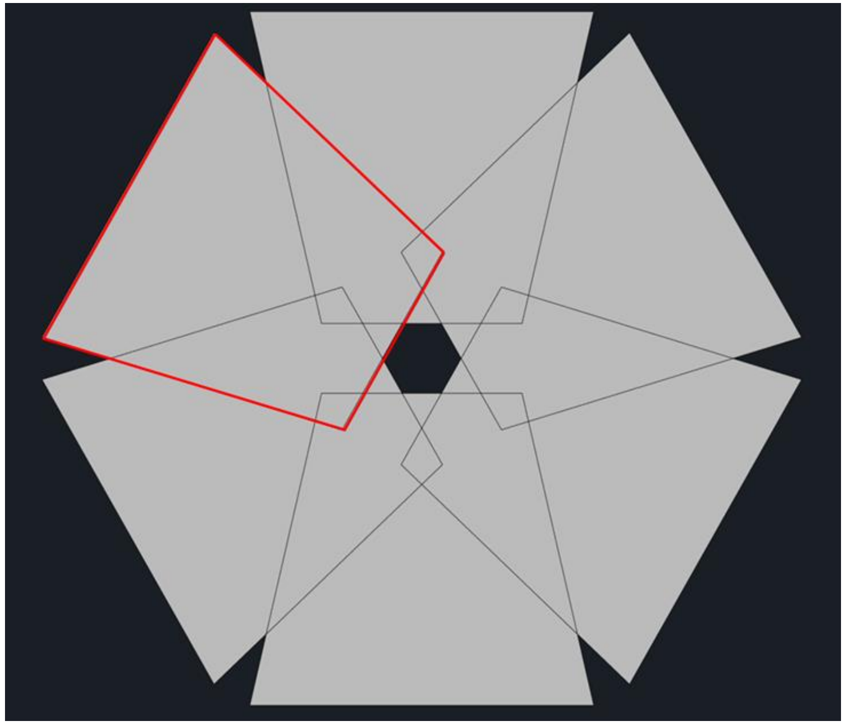
ePIC pfRICH

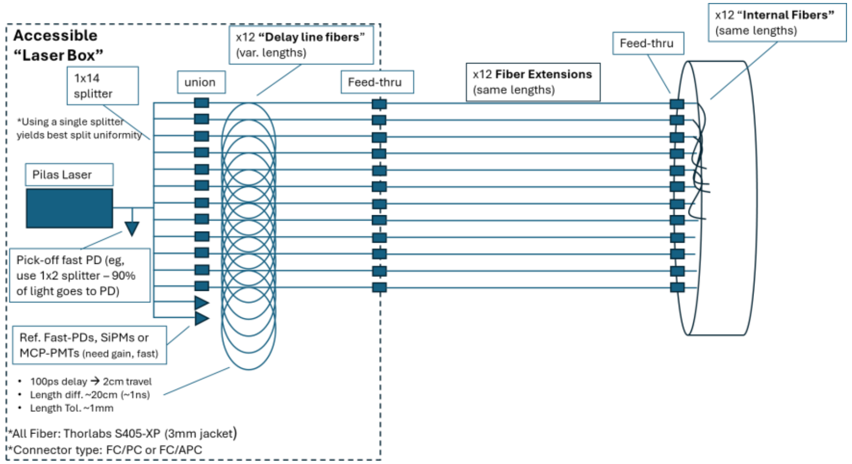


- After coating at SBU, mirror sample reflectivity measured at BNL
- Monochromator light source + dark box with camera/photodiode and sample holder on separate rotational stages
- Reflectivity = reflective/direct light measurements
- Rig calibrated using mirrors with know reflectivity

Other Activities: Laser Monitoring System

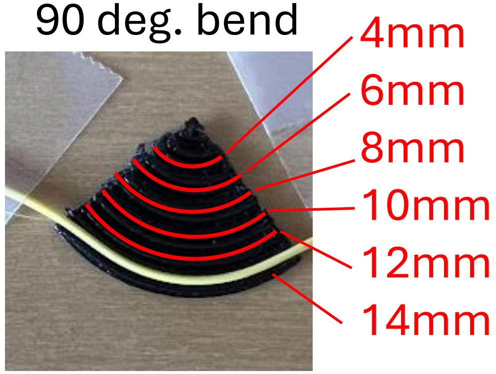


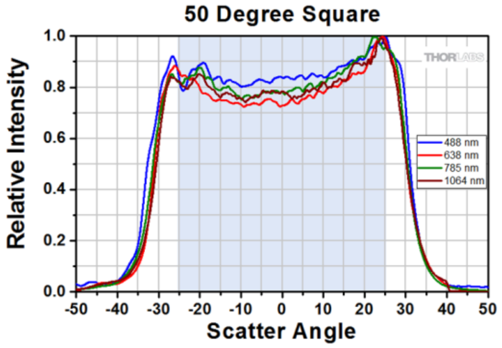




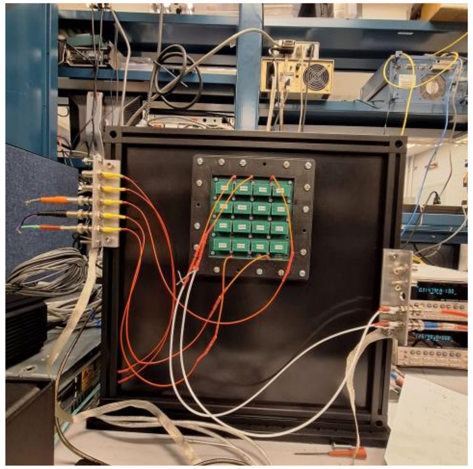
- ❑ Want a way to monitor HRPPD timing performance, signal amplitude, QE, and mirror reflectivity over the lifetime of the experiment
- ❑ Introduce an array of 12 optical fibers from the aerogel side of the vessel: 6 illuminate the photosensors directly and 6 bounce light off mirrors first
- ❑ Distance from fiber to photosensor determines timing and overlapping illumination areas are distinguished by time via fiber delays
- ❑ Appropriate square diffuser identified and fiber bending radius tests need to be performed

90 deg. bend



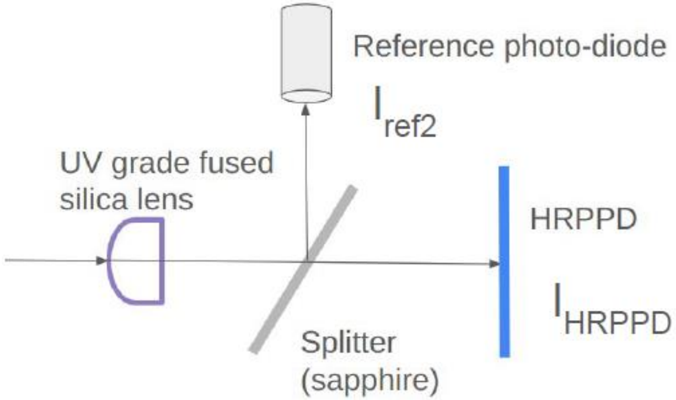


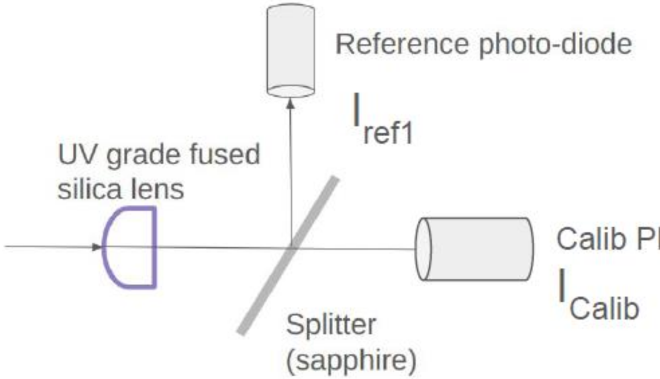
Other Activities: HRPPD QE Scans



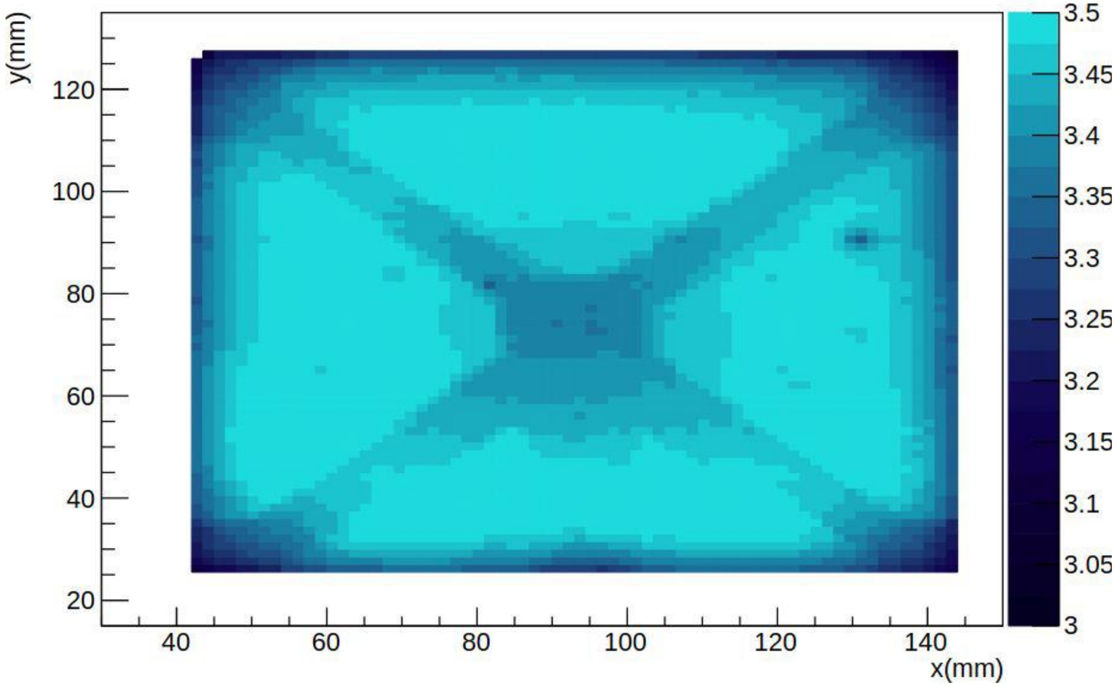
$$(QE)_{theo.} = \frac{N_{el}^{ejected}}{N_{ph}^{incident}}$$

$$(QE)_{mes.} = (QE)_{calib} \cdot \frac{I_{calib}^{pc} - I_{calib}^{dark}}{I_{HRPPD}^{pc} - I_{HRPPD}^{dark}} \cdot \frac{I_{ref2}^{pc} - I_{ref2}^{dark}}{I_{ref1}^{pc} - I_{ref1}^{dark}}$$



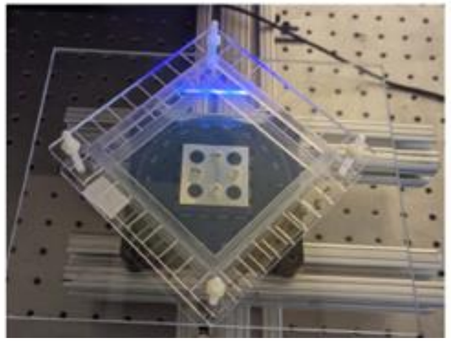


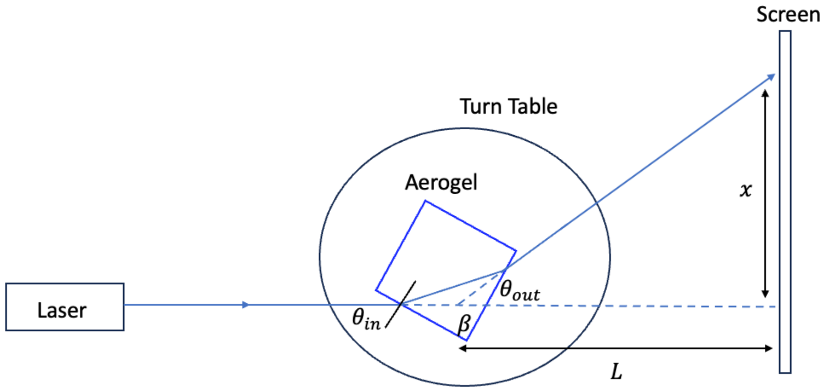
HRPPD 16



- Scans of HRPPD QE recently carried out at BNL (similar studies in preparation at Jlab)
- Reference to HRPPD photocurrent ratio measured – results consistent with Incom (HRPPD 23 also scanned)
- Photocathode voltage and wavelength scans also done and reference measurement with calibrated PD carried out

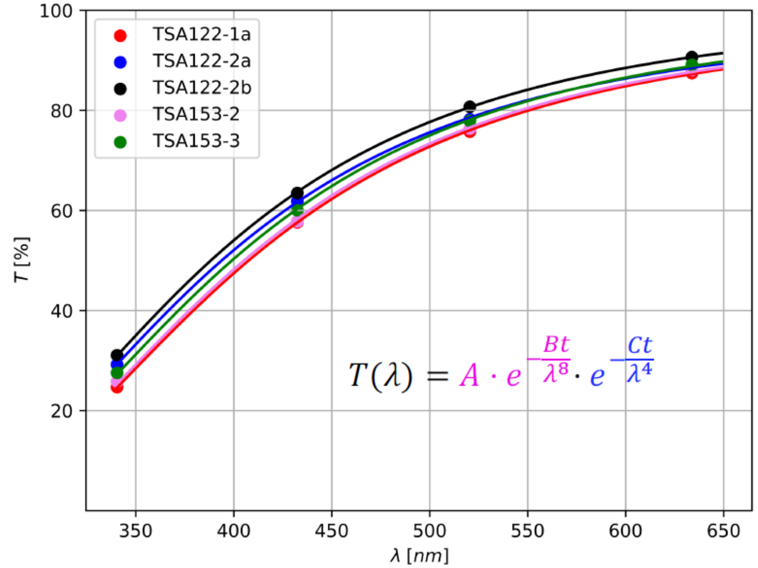
Other Activities: Aerogel Evaluation





- Aerogel tile QA being carried out at Temple University (Matt P.)
- Index of refraction measurements carried out and results consistent with values reported by aerogel factory
- Transmittance also measured and in good agreement with factory values
- New index of refraction method needed as edges of aerogel will be water-jet cut – loss of optical quality

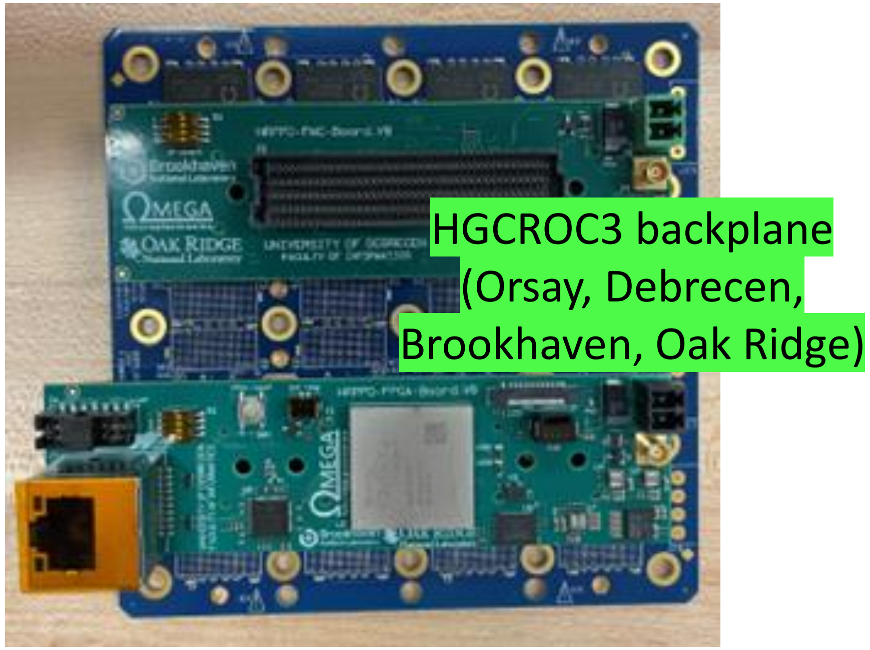
Tile	Measurement Source	LED λ $[nm]$	n	(AF – TU)/AF [%]
TSA122-1a	Aerogel Factory	405	1.0215	
	Temple	**403**	**1.0216 +/- 0.0026**	**0.013**
TSA122-2a	Aerogel Factory	405	1.0215	
	Temple	**403**	**1.0215 +/- 0.0026**	**0.002**
TSA122-2b	Aerogel Factory	405	1.0215	
	Temple	**403**	**1.0215 +/- 0.0026**	**0.002**
TSA153-2	Aerogel Factory	405	1.0215	
	Temple	**403**	**1.0219 +/- 0.0026**	**0.048**
TSA153-3	Aerogel Factory	405	1.0223	
	Temple	**403**	**1.0229 +/- 0.0026**	**0.060**

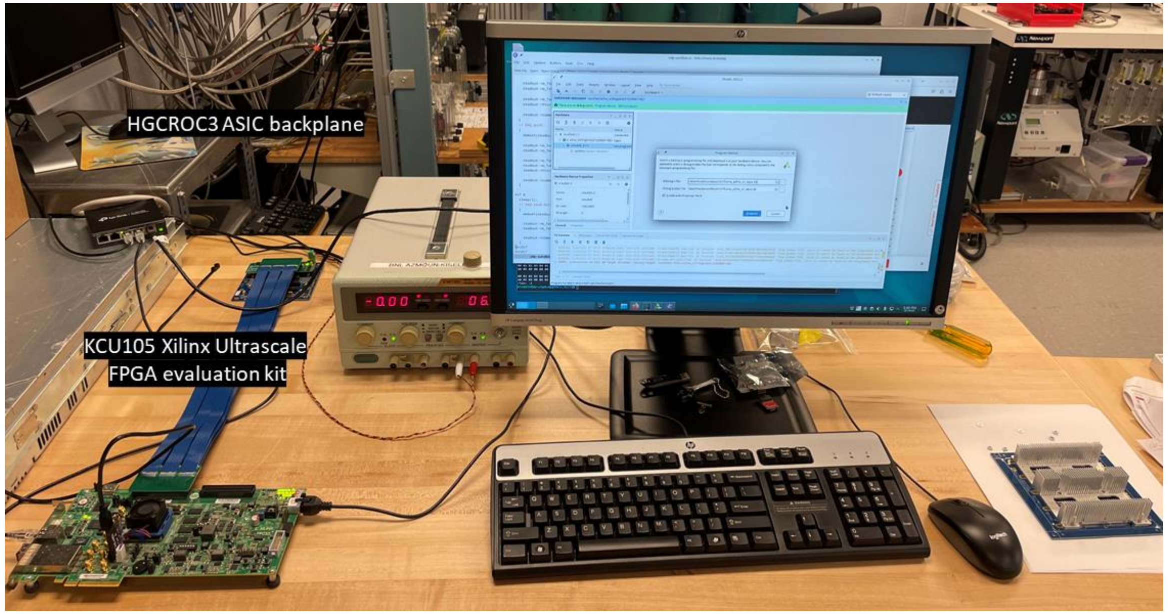


Other Activities

The pfRICH team is busy with a number of tasks related to test beam and final design realization

- HDCROC backplane development
- Further HRPPD sensor characterizations (timing)
- HRPPD aging studies
- HRPPD B-field tests
- Ongoing refinement of manufacturing techniques
- Software
- ...





Summary

- Concept and design of both the final pfRICH subsystem and test beam at an advanced stage
- Good progress toward completing components necessary for Spring 2025 beam test – vessel, end rings, sensor plan, mirrors
- Strong collaboration between various institutes working on pfRICH
- Active and engaged workforce pursuing many different projects needed for realization of the pfRICH

Big thanks to Alex, Charles, Sushrut, Preet, Kong and others for figures, pictures, and slides!

Purdue Team

PURDUE UNIVERSITY

Composites Manufacturing & Simulation Center

Thank You!

Andreas Jung & Sushrut Karmarkar

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Graduate Student: Pau Simpson-Crusafon

SBU Team

- Vessel Production Team (Thank You!):
  - C-J. (“Charles) Naim
  - Julian Driebeek (Graduate Student)
  - Emmett Gebb (Undergraduate Student)