Designing and Building a Pair of Scintillating Bubble Chambers for WIMPs and Reactor CEvNS

The Details

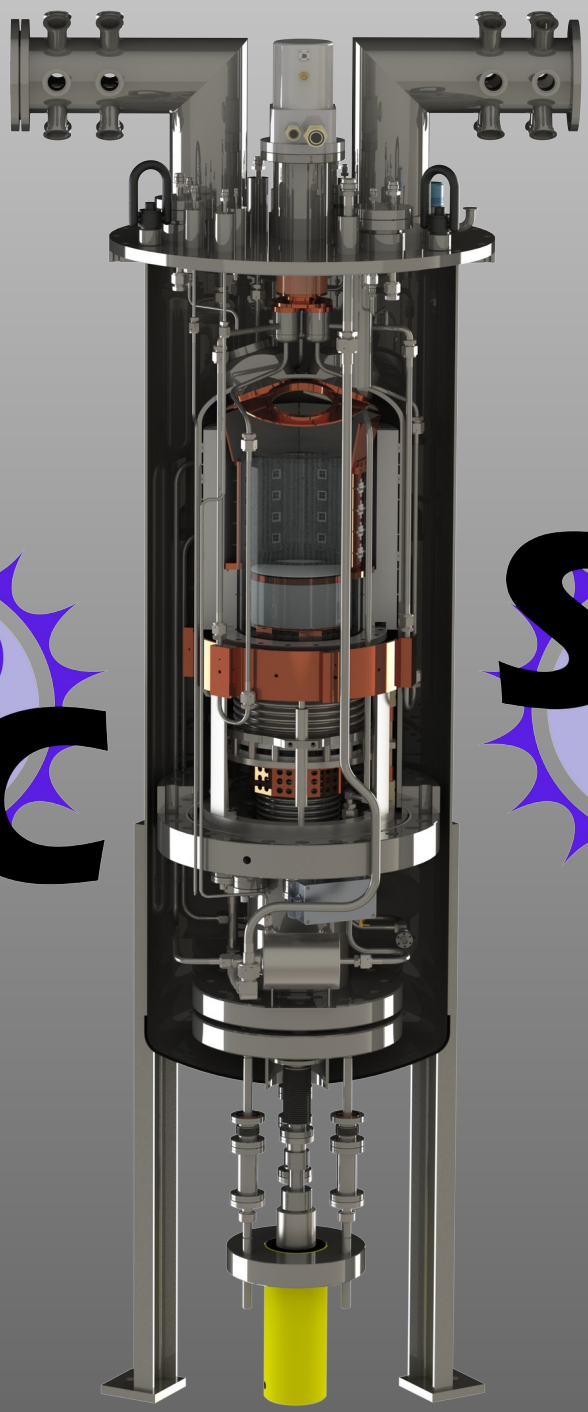
Rocco Coppejans
on behalf of the SBC Collaboration
CPAD, March 2021

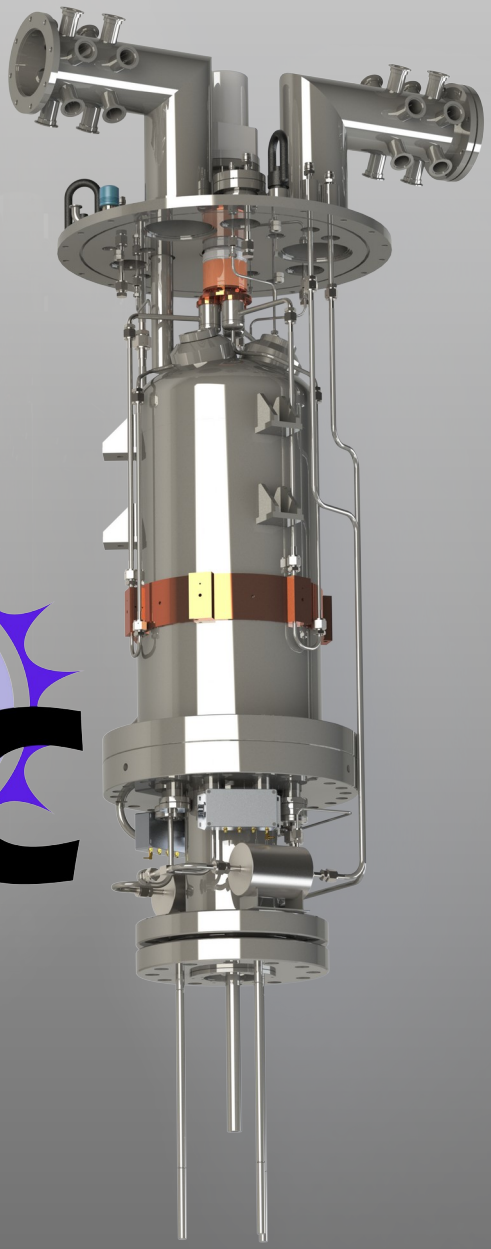
Northwestern
Department of
Physics and Astronomy

COFI
COLEGIO DE FISICA FUNDAMENTAL E INTERDISCIPLINARIA DE LAS AMERICAS

Fermilab

The SBC

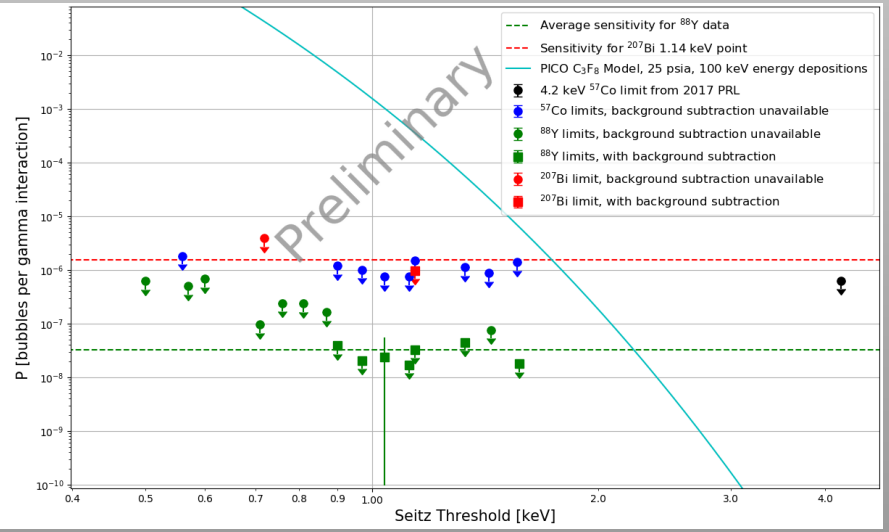




Other SBC Talks

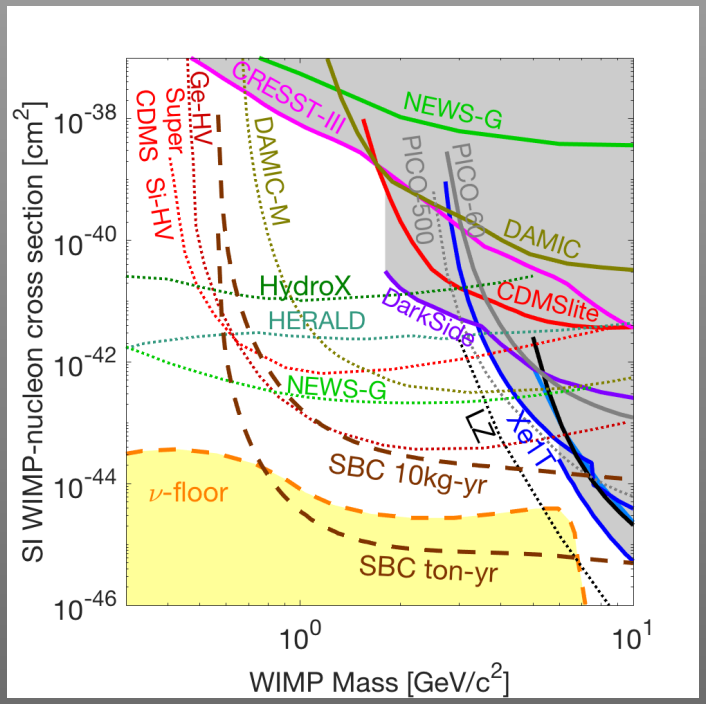
<u>Matt Bressler: Monday 11:05 ET</u>

- SBC calibration strategy



<u>Rocco Coppejans: Monday 12:05 ET</u>

- SBC overview: sensitivity, timelines, objectives ...



The Scintillating Bubble Chamber Collaboration

Northwestern University

- **Eric Dahl**
- Rocco Coppejans
- Zhiheng Sheng
- Aaron Brandon
- David Velasco
- Ari Sloss
- Mahebub Khatri
- Dishen Wang
- Shishir Bandapalli

Queen's University

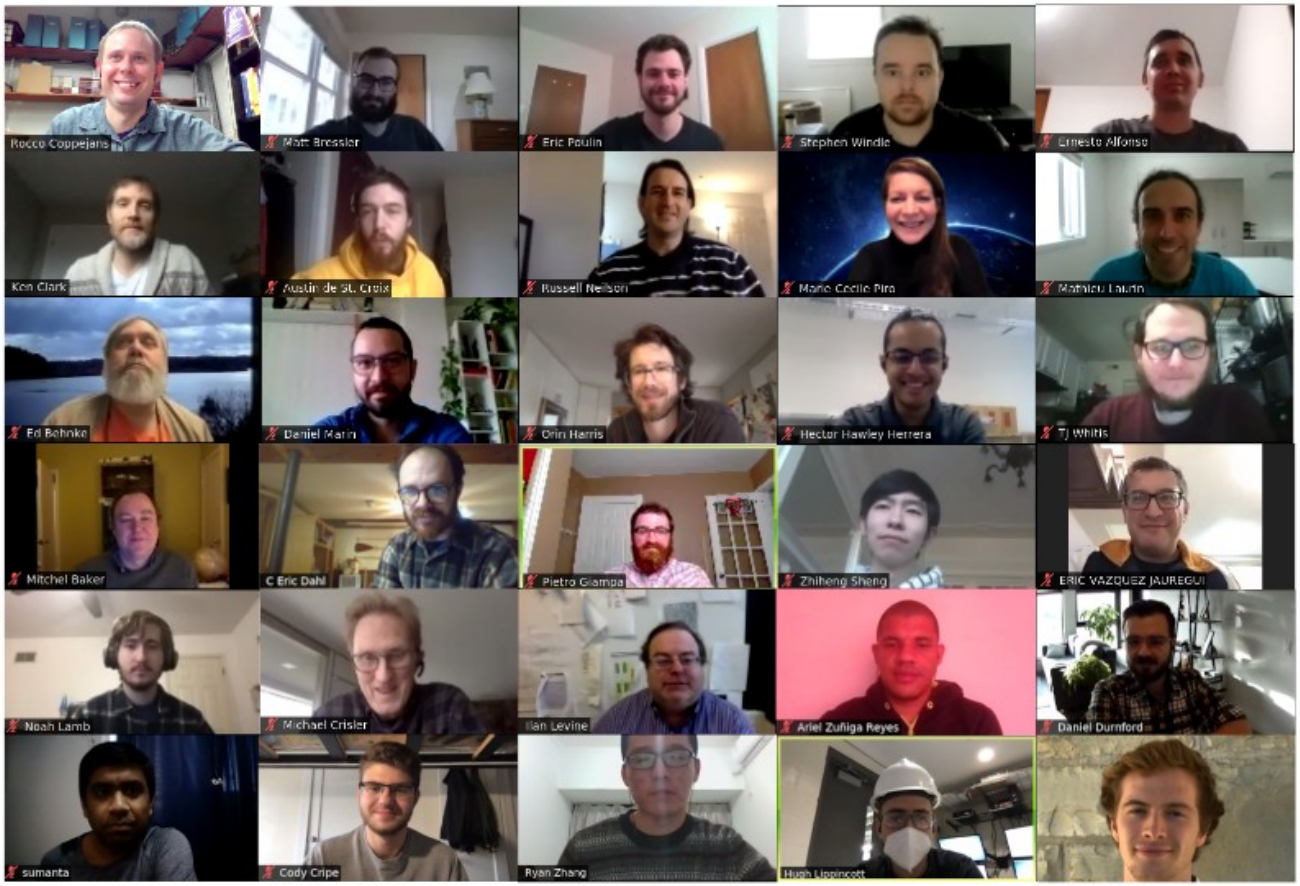
- **Ken Clark**
- Hector Hawley
- Patrick Hatch
- Austin De St Croix

University of Alberta

- Marie-Cécile Piro
- Carsten Krauss
- Daniel Durnford
- Sumanta Pal
- Youngtak Ko
- David Biaré
- Mitchel Baker

SNOLAB

- Pietro Giampa
- Eric Poulin



Université de Montréal

- Mathieu Laurin

Northeastern University

- Orin Harris

Pacific Northwest National Laboratory

- Chris Jackson

Universidad Nacional Autónoma de México

- Eric Vázquez-Jáuregui
- Ernesto Alfonso-Pita
- Ariel Zuniga-Reyes
- Daniel Lámbarri

Drexel University

- Russell Neilson
- Matt Bressler
- Noah Lamb
- Stephen Windle

Indiana University South Bend

- Ilan Levine
- Ed Behnke
- Cody Cripe

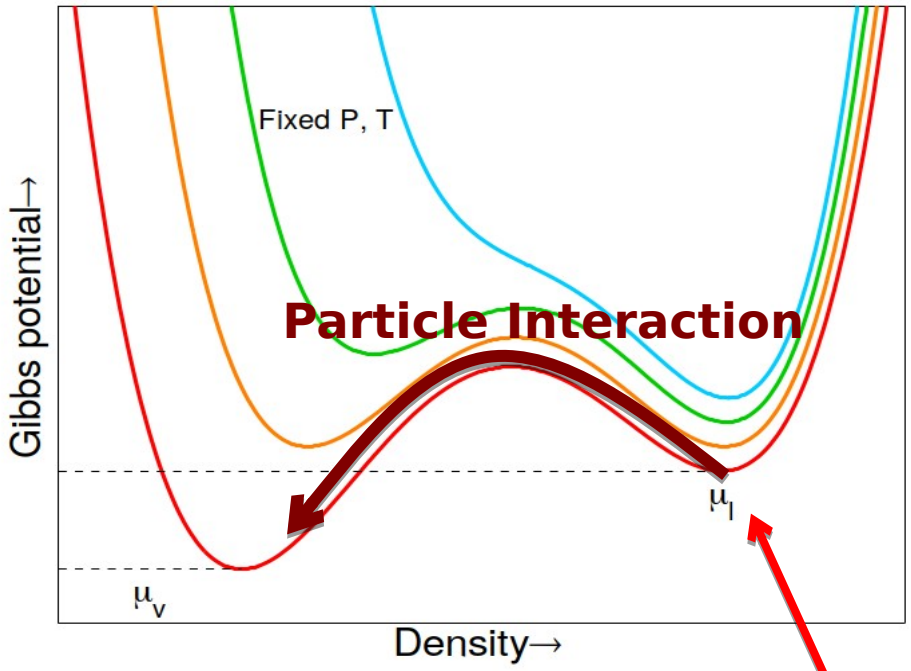
UC Santa Barbara

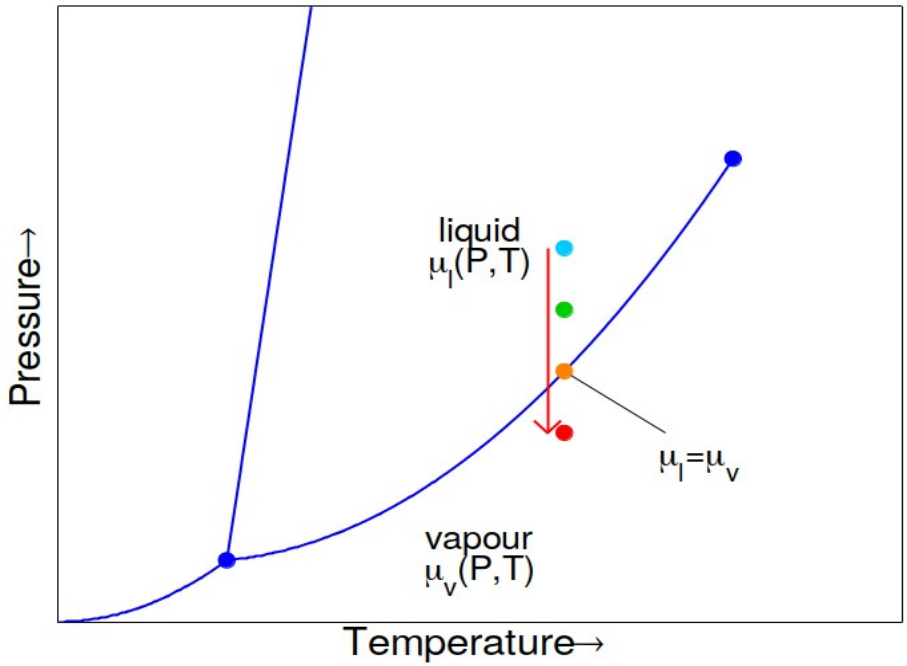
- Hugh Lippincott
- TJ Whitis
- Runze Zhang

Fermilab

- Mike Crisler

How Bubble Chambers Work





Superheated Liquid

What Does an Event Look Like?

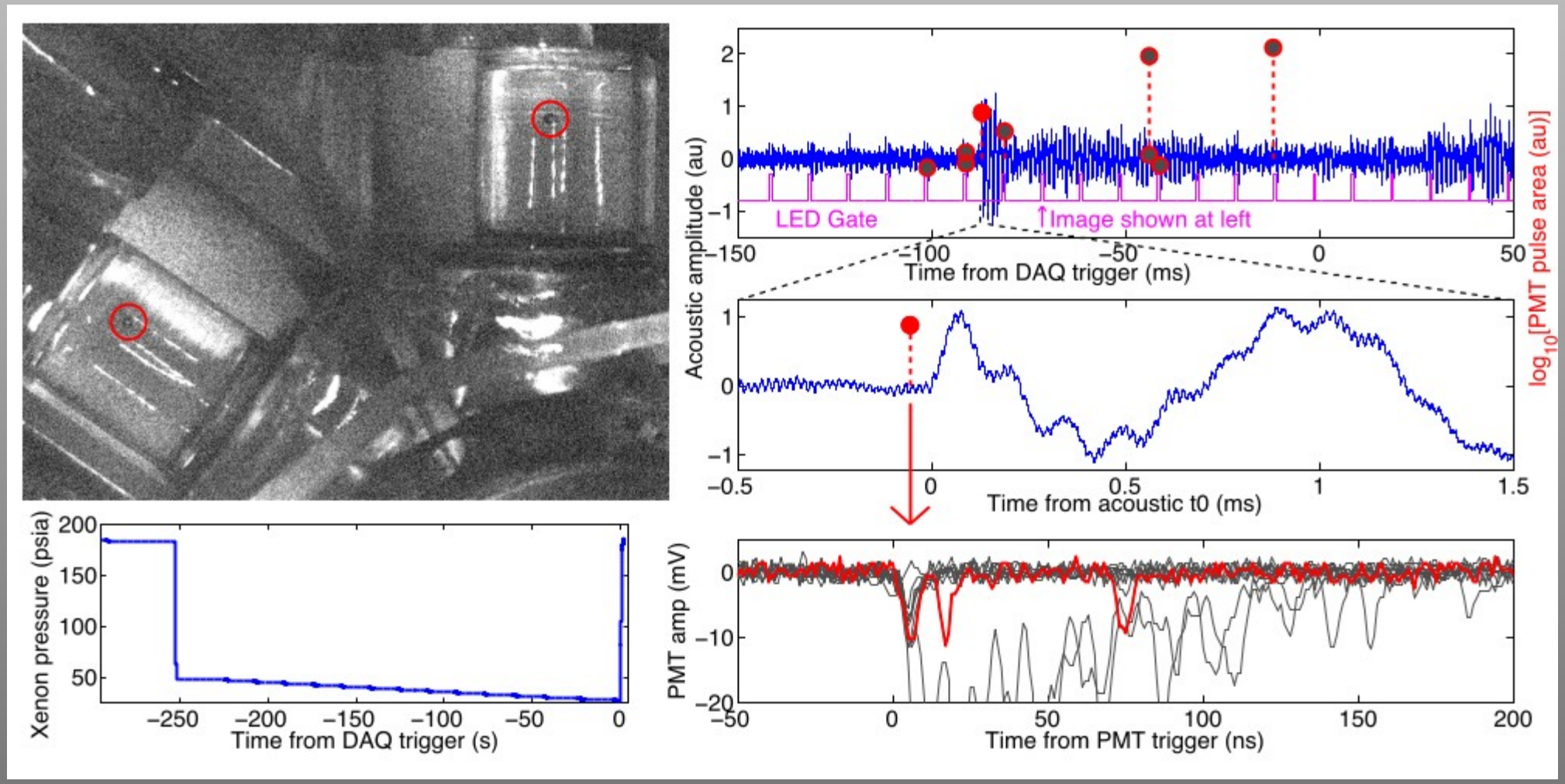
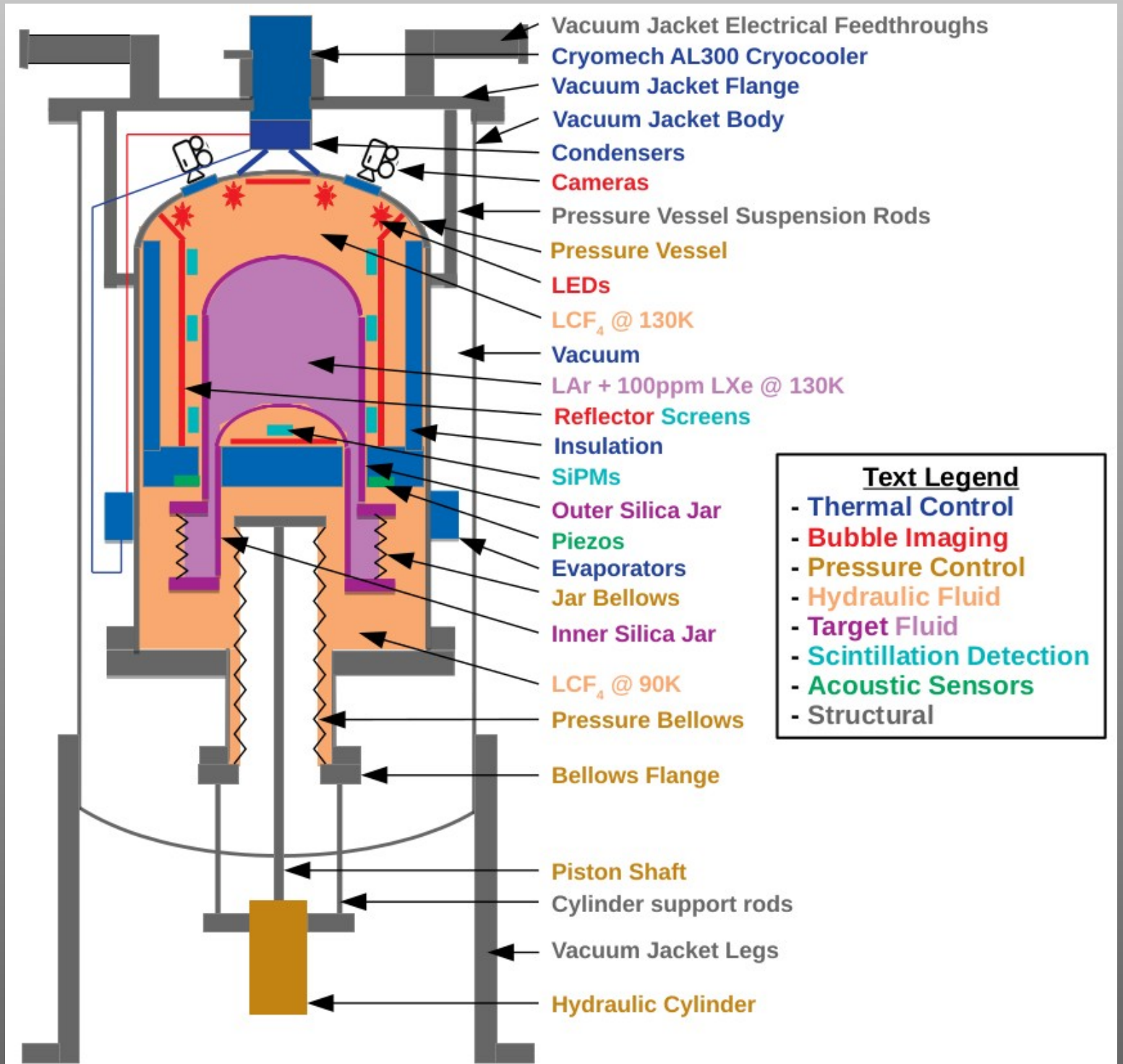


Image from: Baxter D., et al., Phys. Rev. Lett. 118, 231301 (2017)
https://arxiv.org/abs/1702.08861

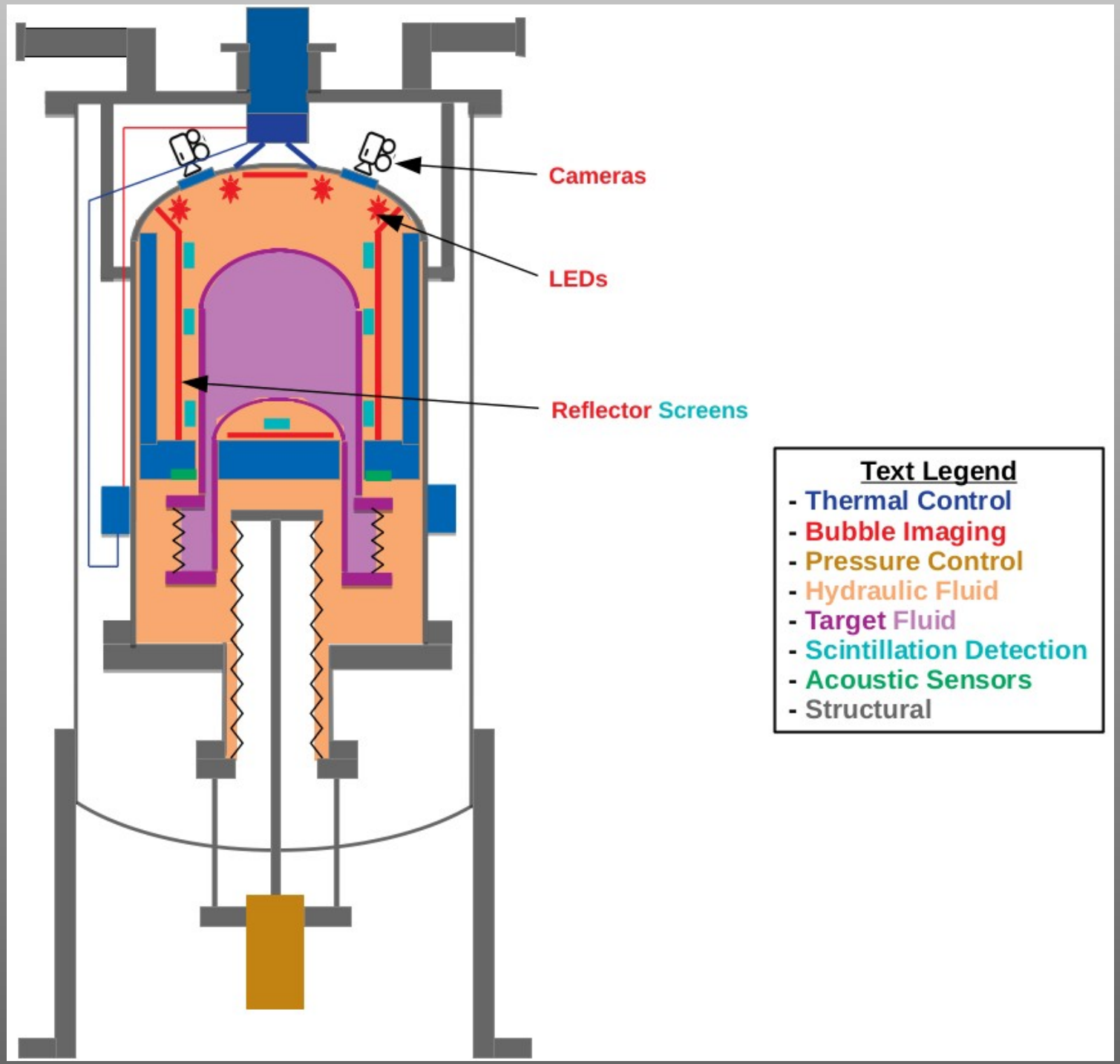
SBC at a Glance

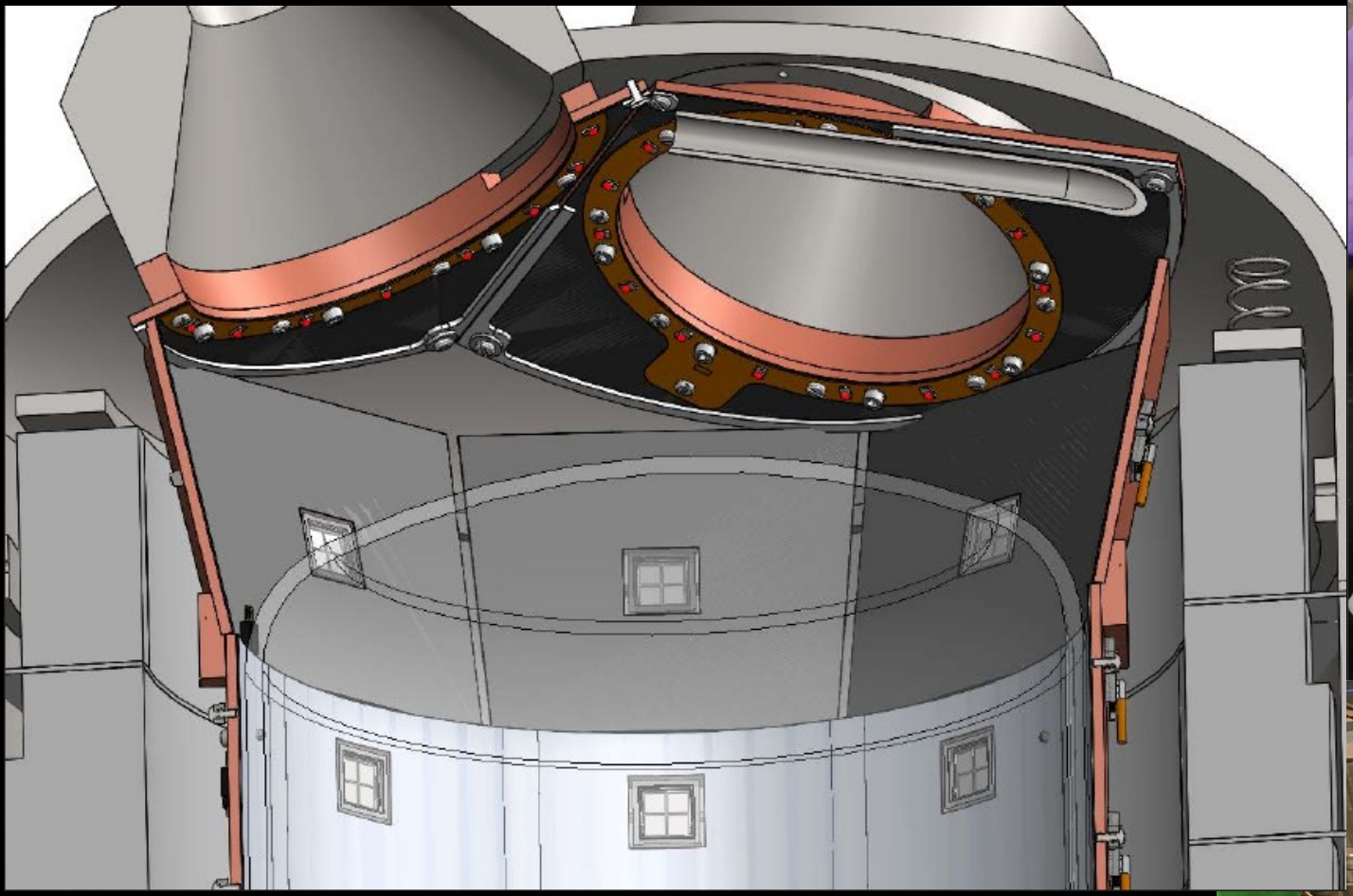
Temperature	Superheated: 130 K Not superheated: 90 K
Pressure	Superheated: 1.4 bara Not superheated: 25 bara
Size	10 x 2.5 x 2.5 feet 3 x 1 x 1 m
Target Fluid	10 Kg LAr + ~100 ppm LXe
Hydraulic Fluid	150 Kg LCF_4 (Tetrafluoromethane)
Instrumentation	Cameras: bubble imaging Piezos: acoustic sensors SiPMs: scintillation detection
Scintillation Light	175 nm
Re-compression Time	1 second

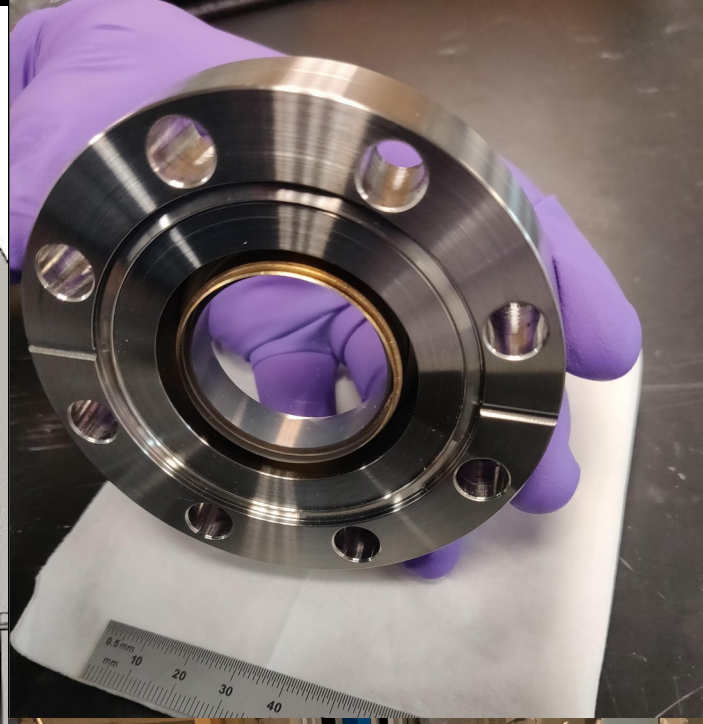
Chamber Schematic

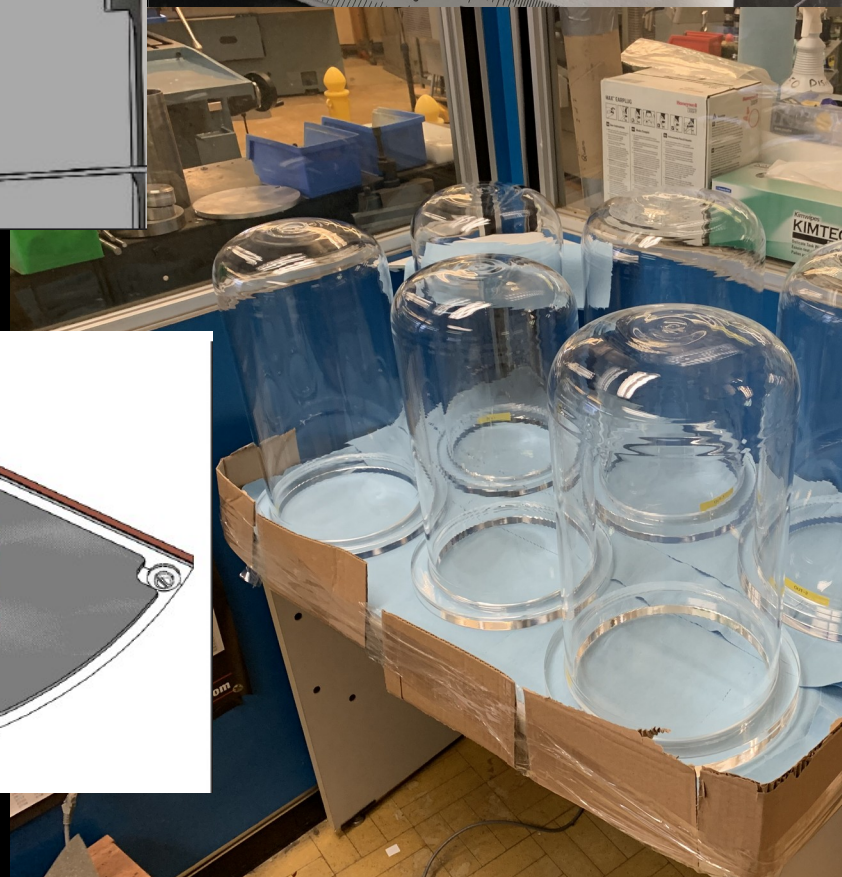


Challenge 1: Bubble Imaging



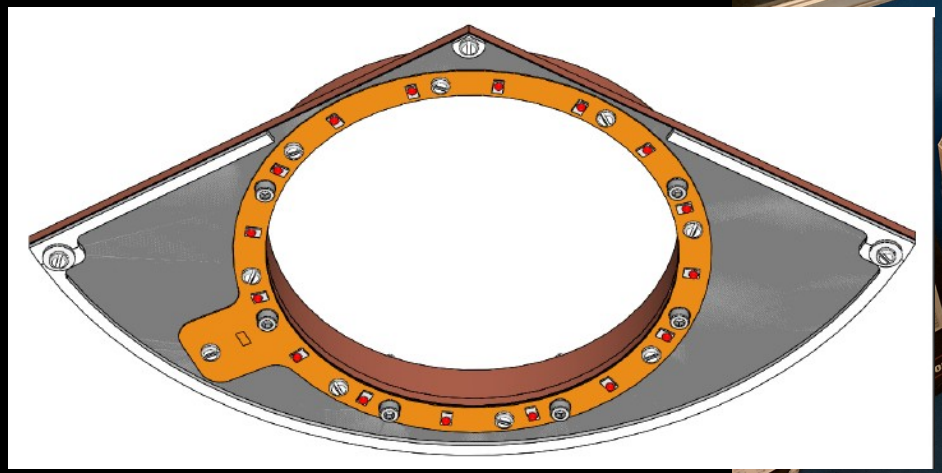


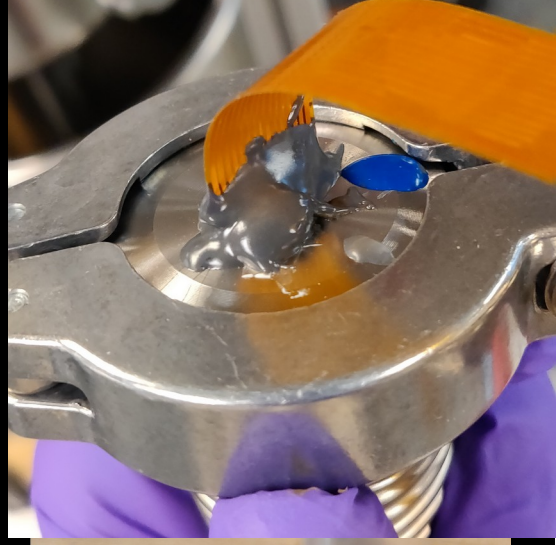


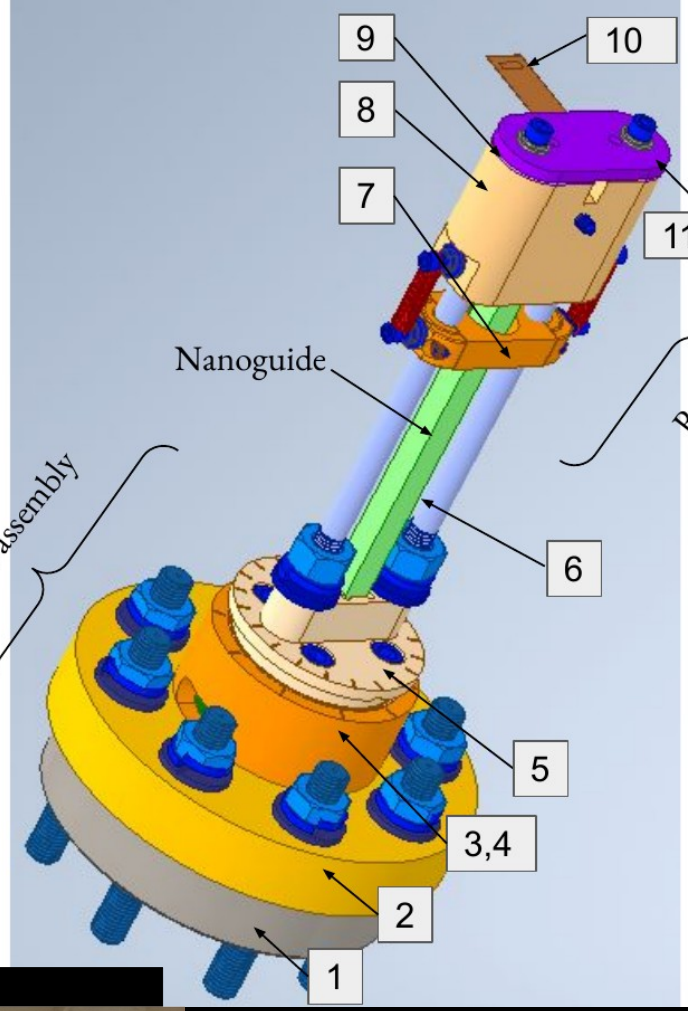


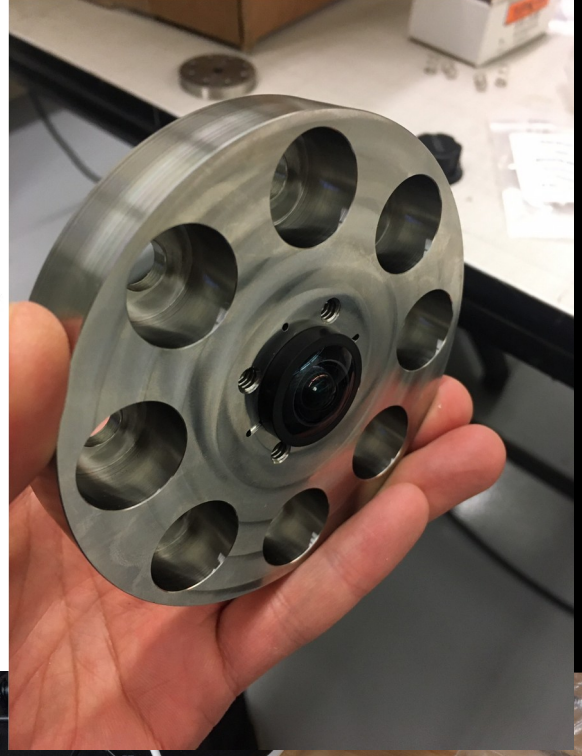
<u>Requirements</u>

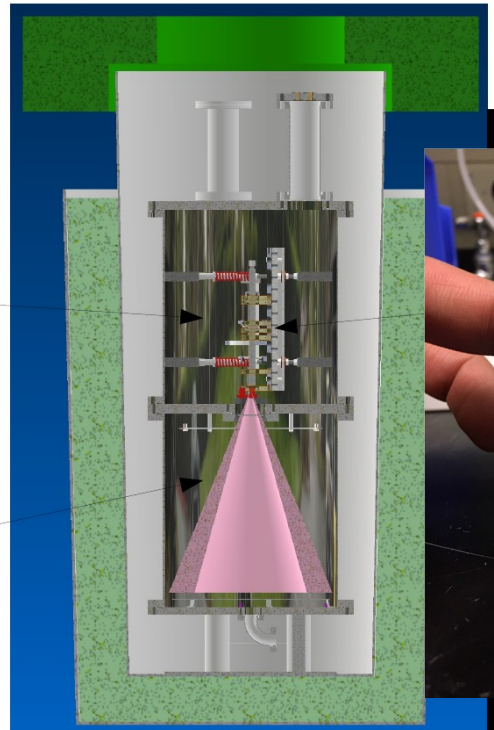
- <0.5mm/pixel
- 100 fps
- 1ms exposure
- Dark field illumination

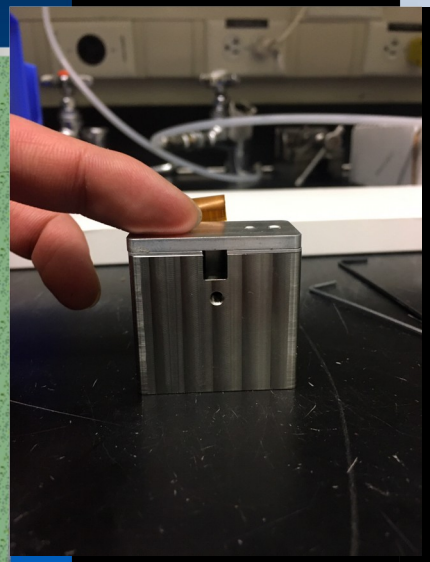




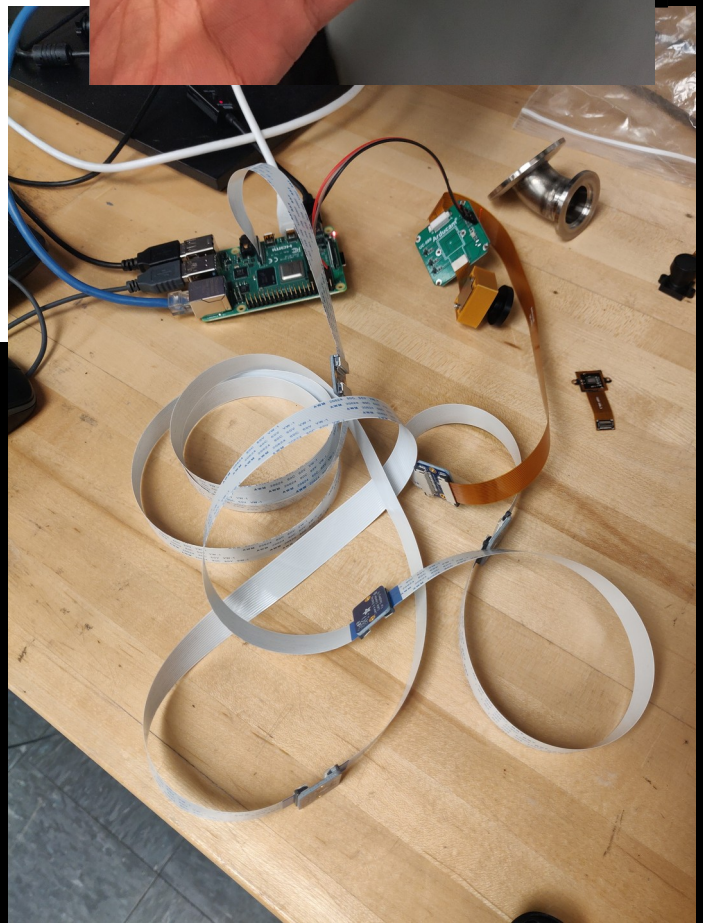




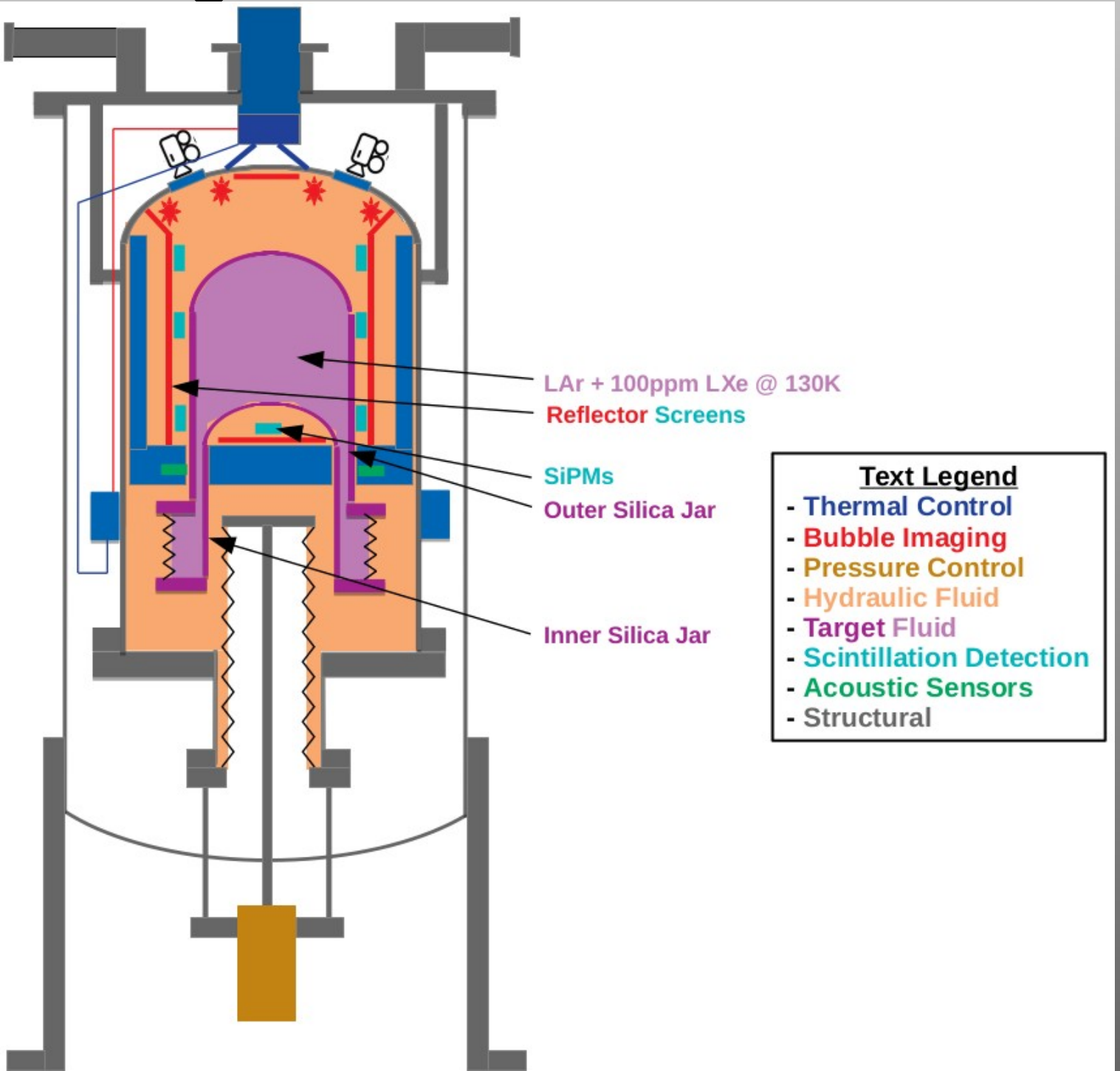


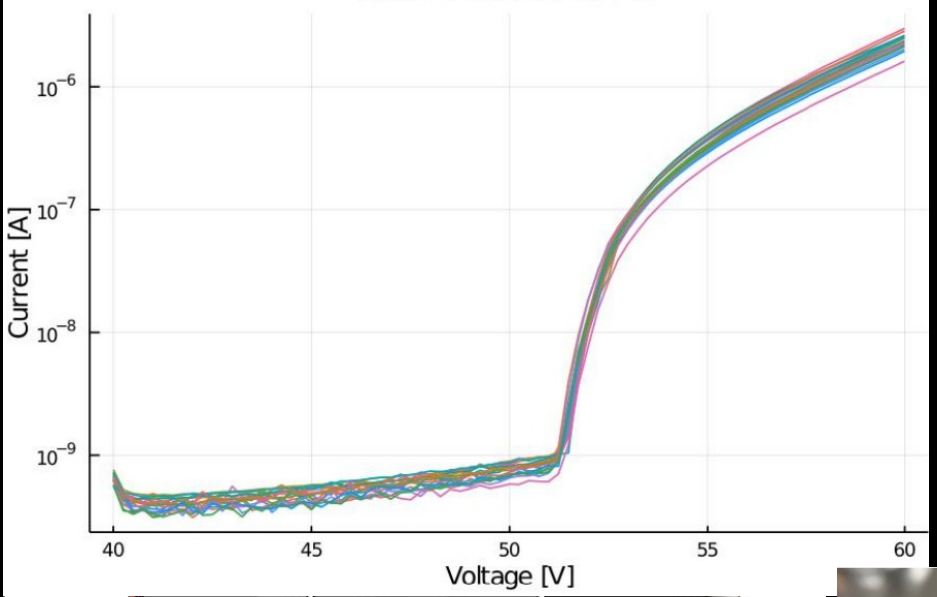


- 1MP OV9281 Omni Vision camera
- Raspberry Pi

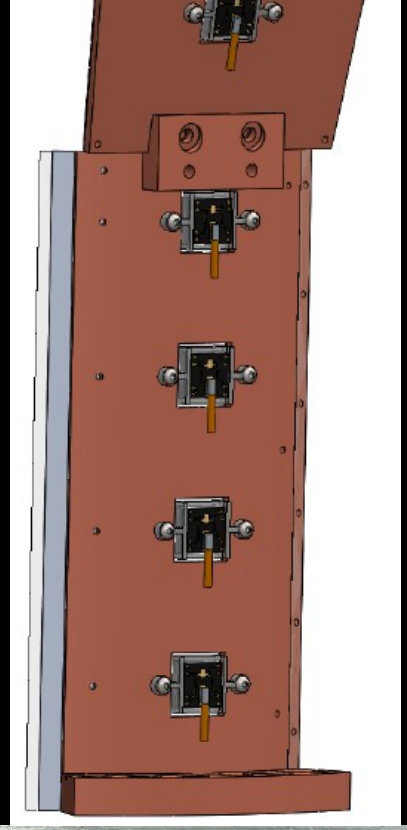


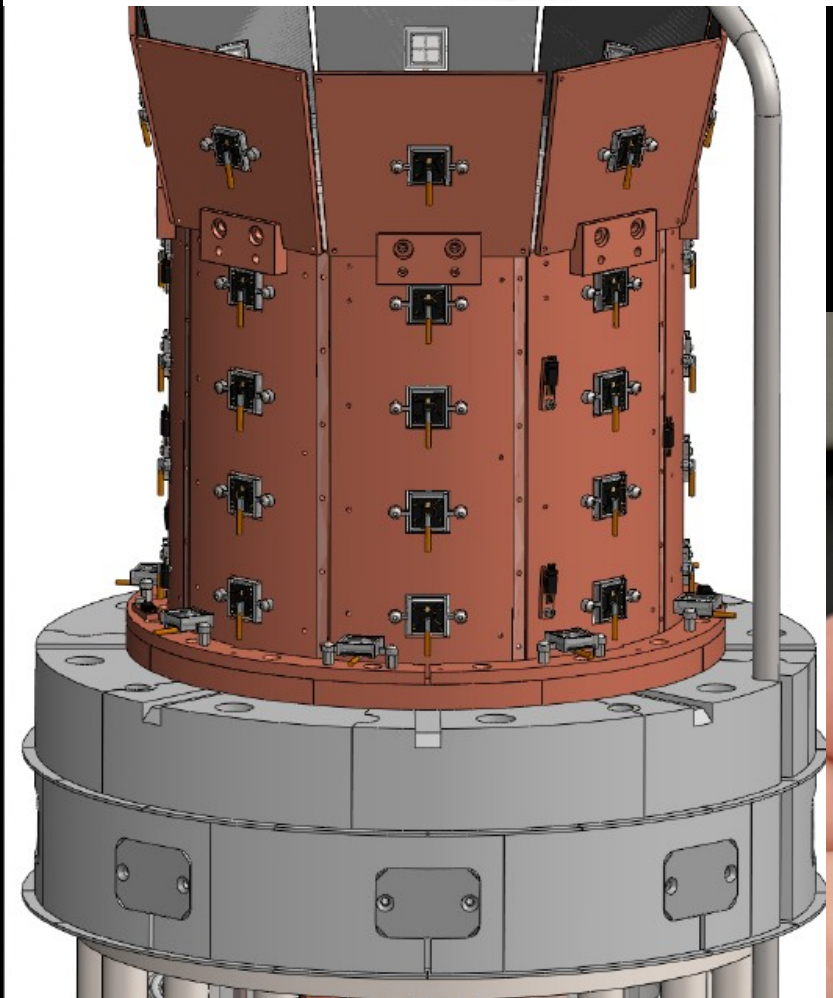
Challenge 2: Scintillation Detection

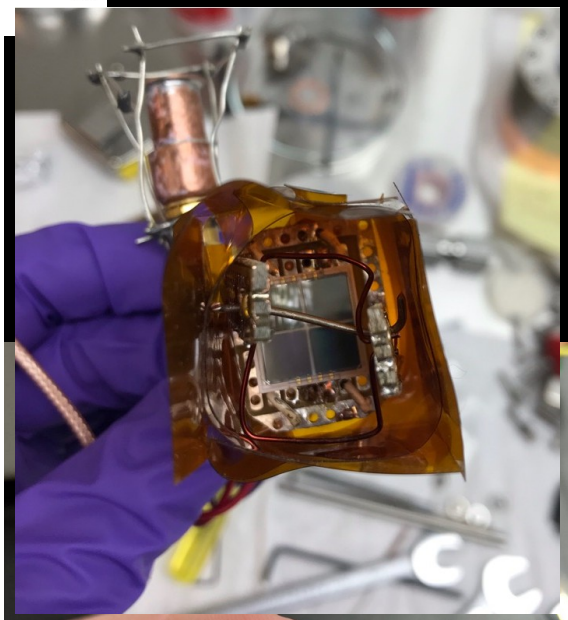


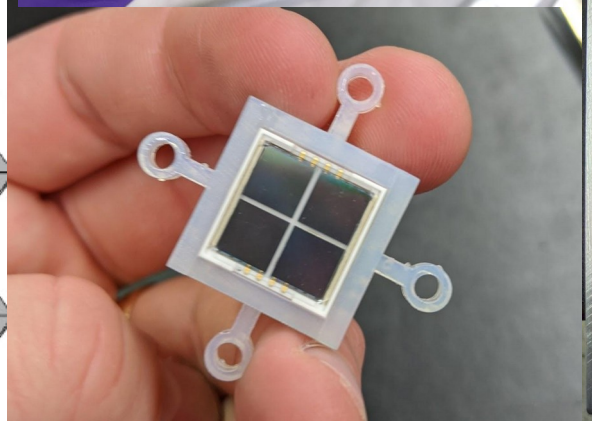


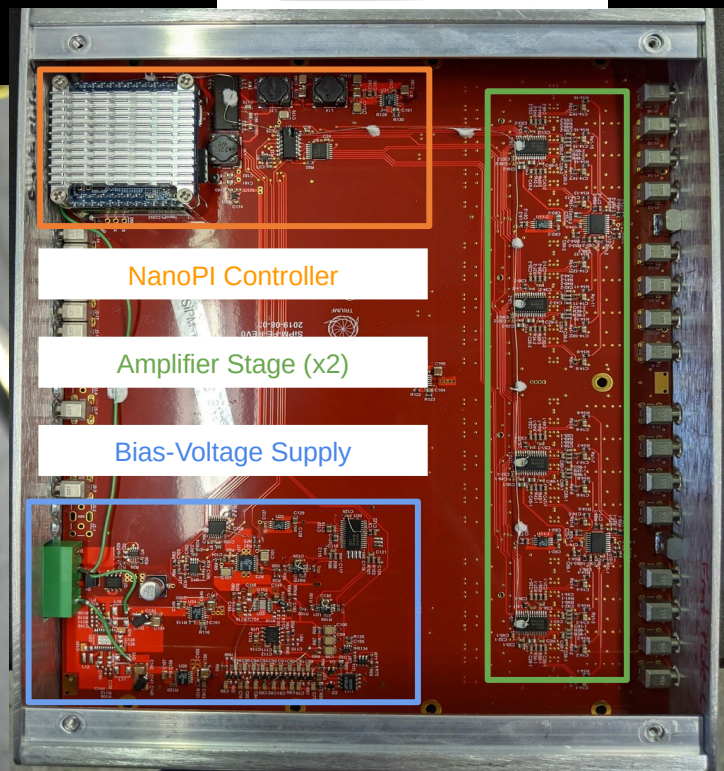
- 32 Hamamatsu VUV4 SiPMs
- 0.002” Teflon reflective screen
- ~100ppm Xe
- 175nm scintillation



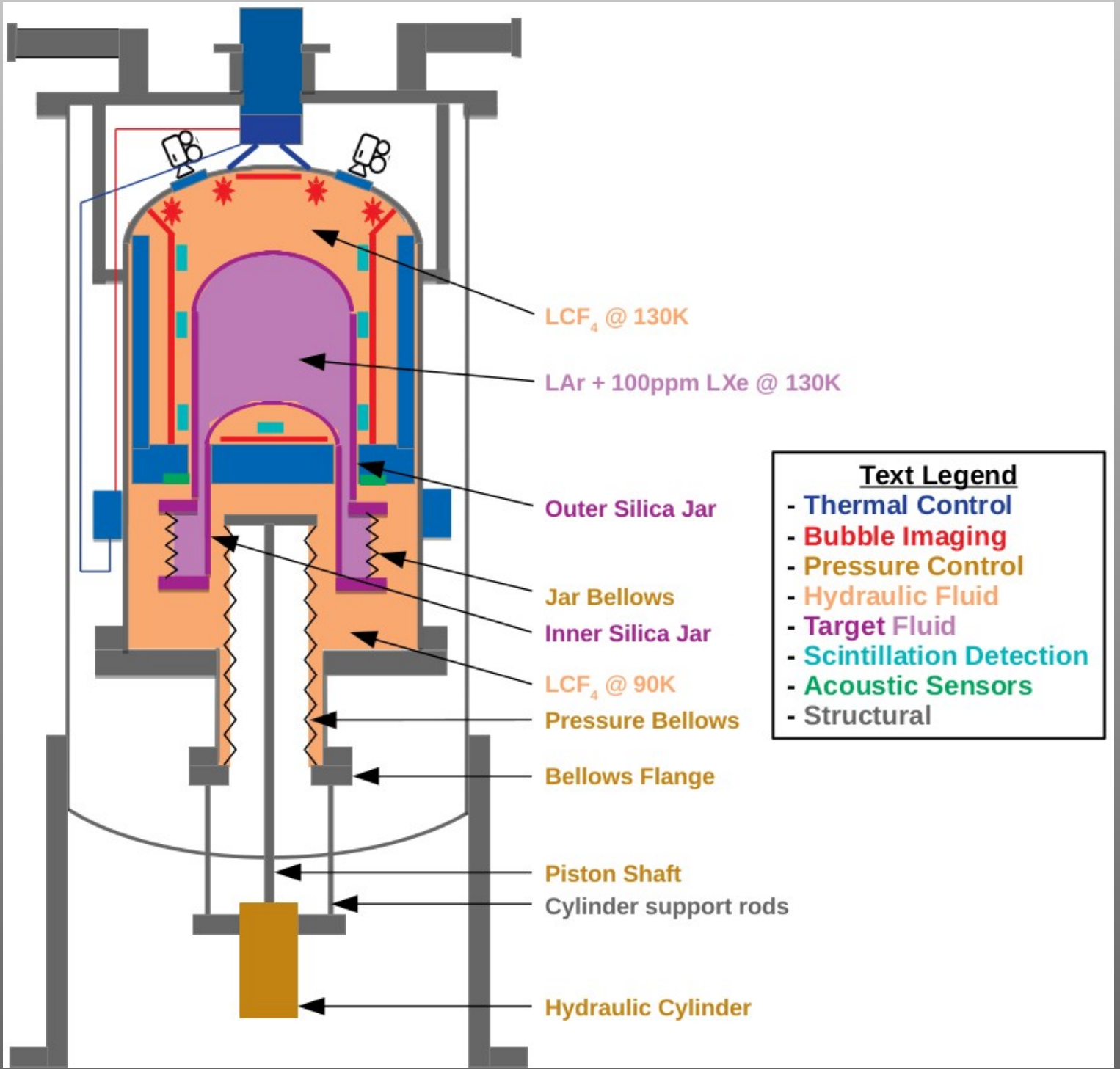


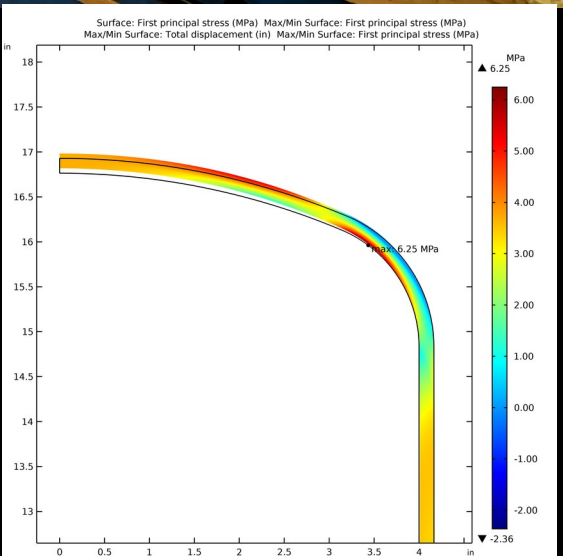


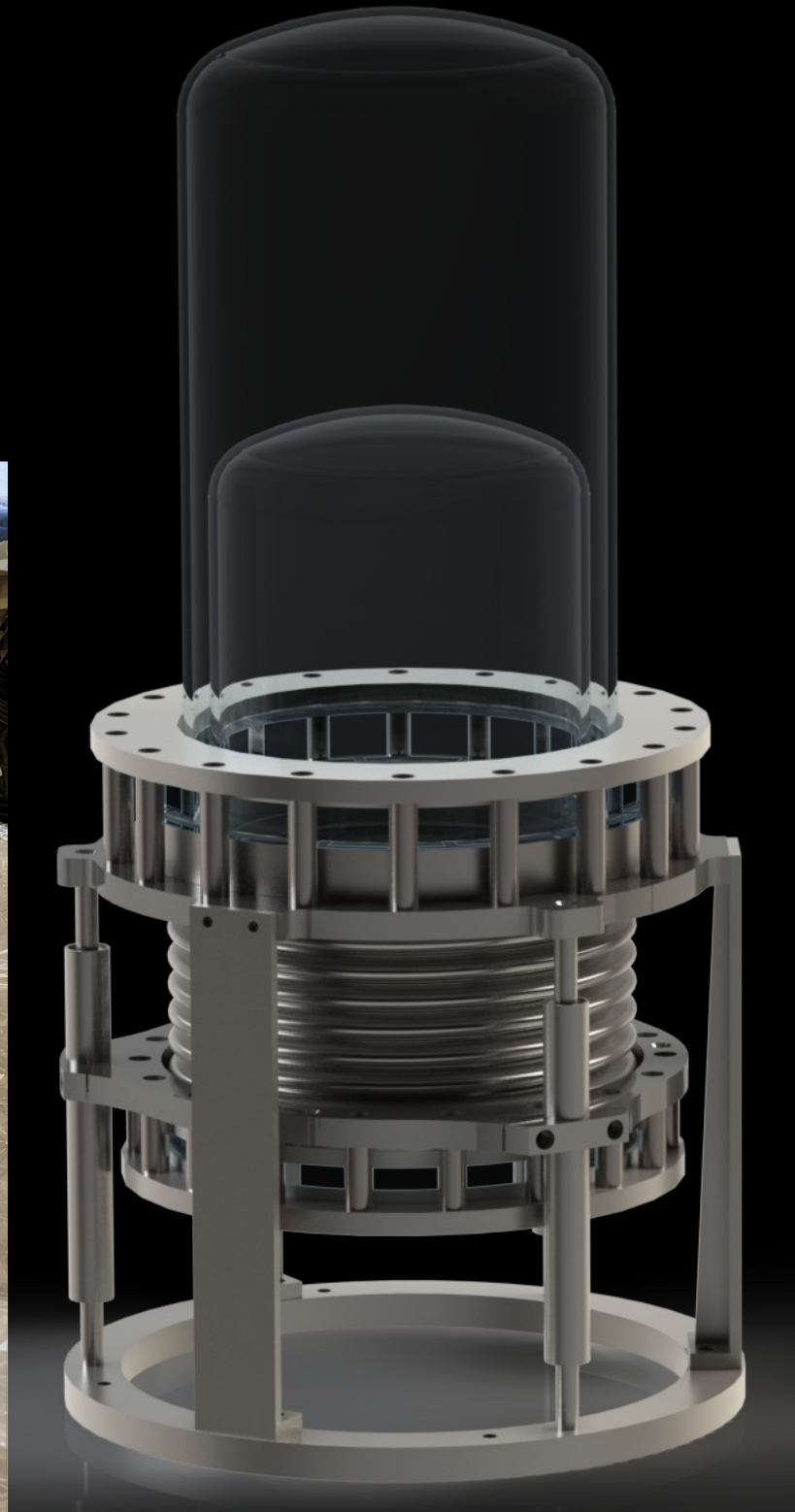


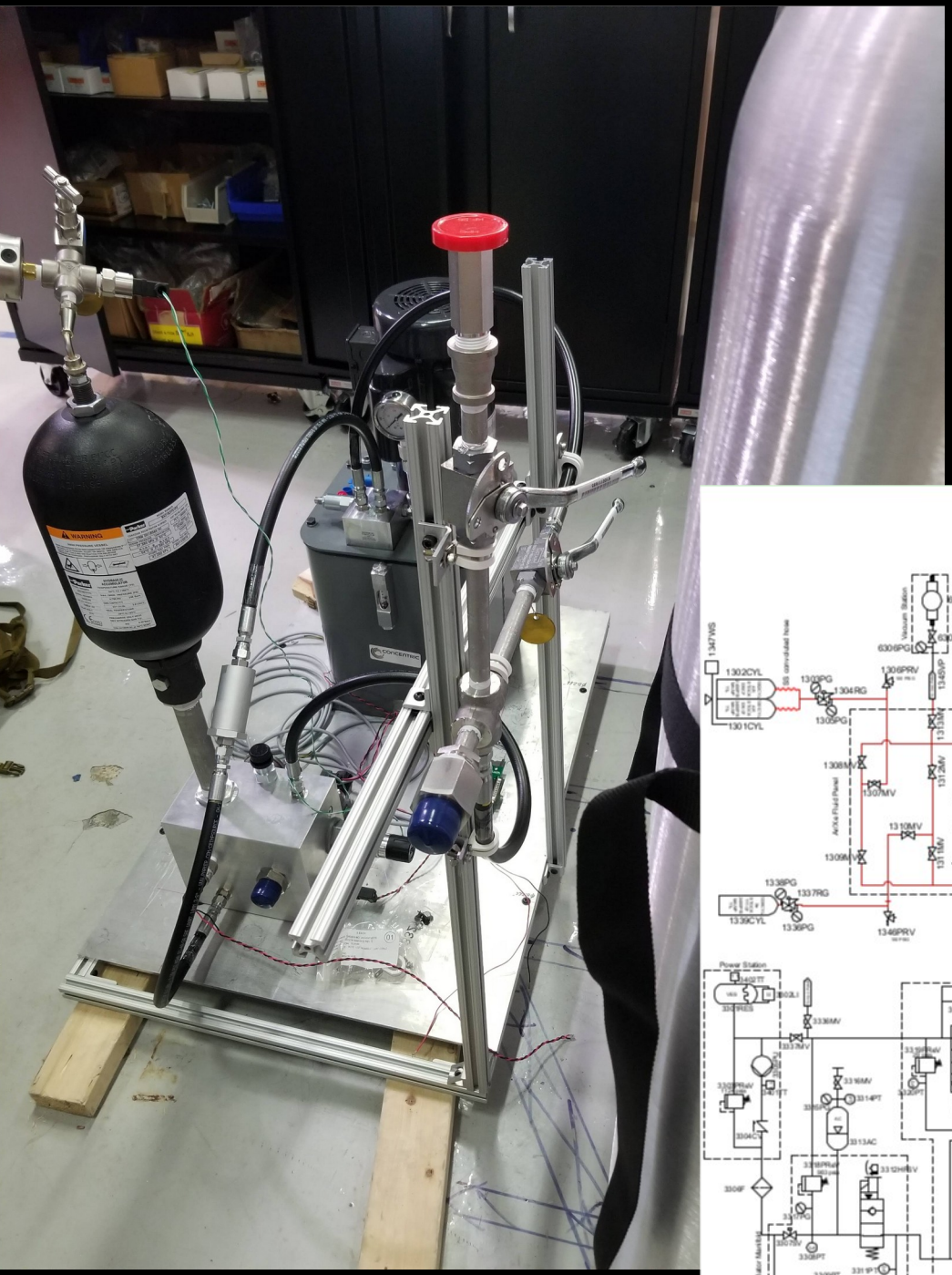


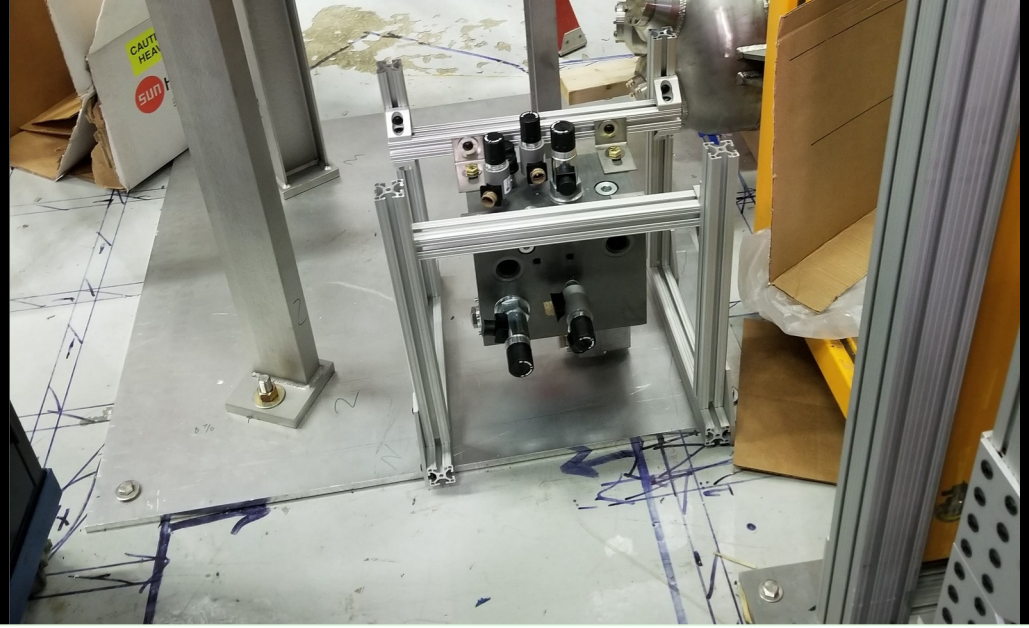
Challenge 3: Pressure Control

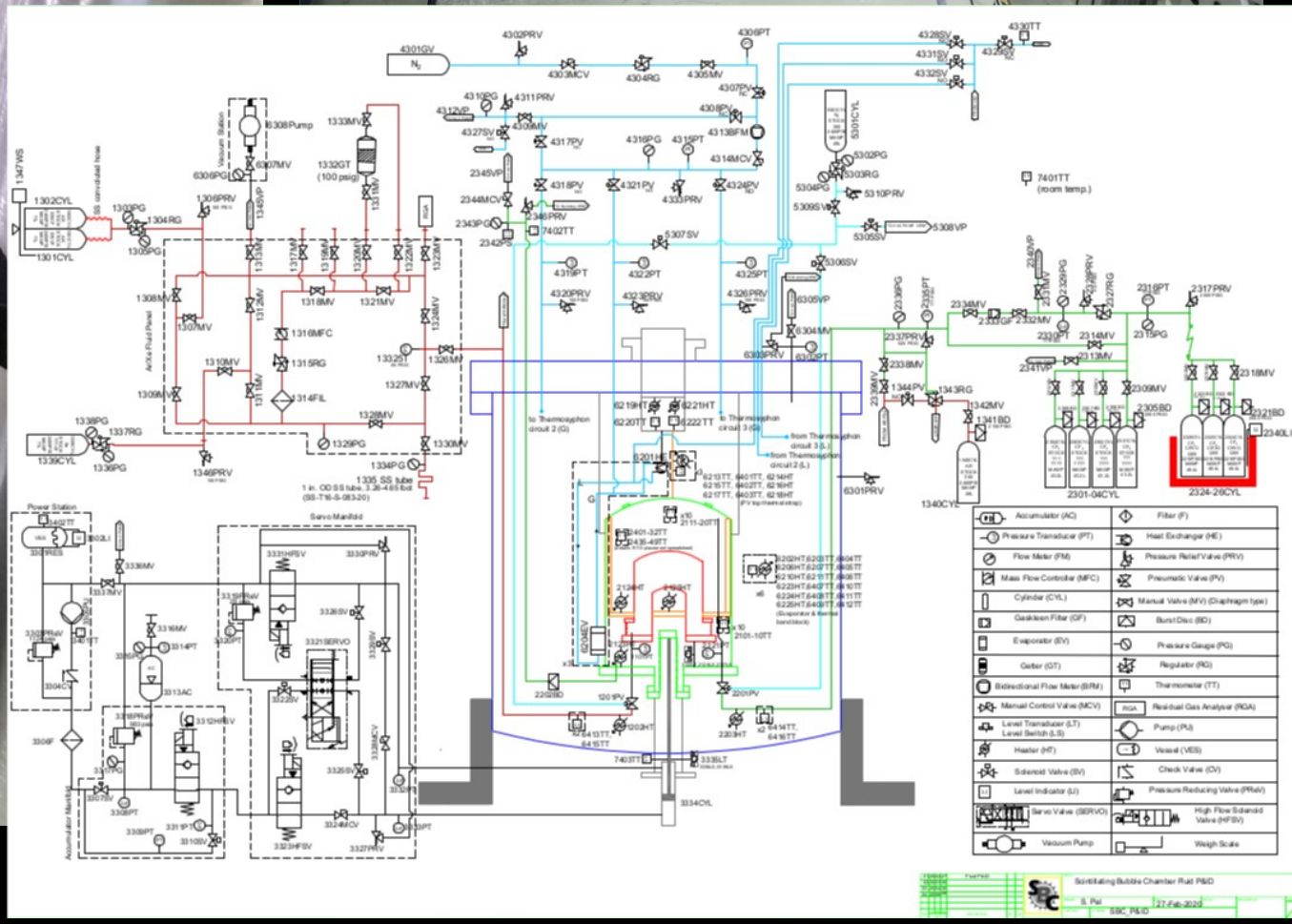



Surface: First principal stress (MPa) Max/Min Surface: First principal stress (MPa)
Max/Min Surface: Total displacement (in) Max/Min Surface: First principal stress (MPa)
in
18
17.5
17
16.5
16
15.5
15
14.5
14
13.5
13
0
0.5
1
1.5
2
2.5
3
3.5
4
in
MPa
▲ 6.25
6.00
5.00
4.00
3.00
2.00
1.00
0.00
-1.00
-2.00
▼ -2.36
fmax: 6.25 MPa








Scintillating Bubble Chamber Rud P&ID
S. Pal
27-Feb-2020
SBC_P&ID
Accumulator (AC)
Pressure Transducer (PT)
Flow Meter (FM)
Mass Flow Controller (MFC)
Cylinder (CYL)
Gasketen Filter (GF)
Evaporator (EV)
Getter (GT)
Bidirectional Flow Meter (BFM)
Manual Control Valve (MCV)
Level Transducer (LT)
Level Switch (LS)
Heater (HT)
Solenoid Valve (SV)
Level Indicator (LI)
Servo Valve (SERVO)
Vacuum Pump
Filter (F)
Heat Exchanger (HE)
Pressure Relief Valve (PRV)
Pneumatic Valve (PV)
Manual Valve (MV) (Diaphragm type)
Burst Disc (BD)
Pressure Gauge (PG)
Regulator (RG)
Thermometer (TT)
Residual Gas Analyser (RGA)
Pump (PU)
Vessel (VES)
Check Valve (CV)
Pressure Reducing Valve (PReV)
High Flow Solenoid Valve (HFSV)
Weigh Scale
Servo Manifold
Power Station
Vacuum Station
Air/Ice Fluid Panel
Accumulator Manifold
1 in. OD SS tube, 3.36-4.65 bd (SS-T16-S-083-20)
1/4 in. OD SS tubing
1/4 in. OD SS tubing (SS-T4-S-035-20)
1/4 in. OD SS tubing (SS-T4-S-035-20) (Evaporator & thermal bandblocks)
to Thermosiphon circuit 2 (G)
to Thermosiphon circuit 3 (G)
from Thermosiphon circuit 3 (L)
from Thermosiphon circuit 2 (L)
(room temp.)
2301-04CYL
2324-26CYL
1301CYL
1302CYL
1339CYL
1340CYL
3334CYL
1347WS
1347RS
1333MV
1332GT (100 psig)
6308Pump
6307MV
6306PG
1306PRV
1345VP
1303PG
1304RG
1305PG
1308MV
1307MV
1309MV
1310MV
1316MFC
1315RG
1314FIL
1318MV
1321MV
1328MV
1329PG
1330MV
1334PG
1338PG
1337RG
1336PG
1346PRV
1325T
1326MV
1327MV
1324MV
1322MV
1323MV
1335 SS tube
4301GV
N_2
4302PRV
4303MCV
4304RG
4305MV
4306PT
4307PV
4308PV
4309MV
4310PG
4311PRV
4312VP
4327SV
4317PV
4316PG
4315PT
4138FM
4314MCV
4318PV
4321PV
4333PRV
4324PV
2345VP
2344MCV
2343PG
2342PG
4346PRV
7402TT
5307SV
4319PT
4322PT
4325PT
4320PRV
4323PRV
4326PRV
4328SV
4331SV
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5303RG
5304PG
5310PRV
5309SV
5305SV
5308VP
7401TT
6306SV
6305VP
6304MV
6303PRV
6302PT
6301PRV
2339PG
2335PT
2334MV
2332GF
2332MV
2330PG
2329PRV
2327RG
2316PT
2317PRV
2337PRV
2338MV
2336MV
2339PT
2314MV
2315PG
2313MV
2241VP
2318MV
2309MV
2305BD
2321BD
2340LI
1344PV
1343RG
1342MV
1341BD
6219HT
6221HT
6220TT
6222TT
6201HT
6211-20TT
6401-32TT
6435-49TT
2134HT
2136HT
2101-10TT
2202BD
2201PV
2203HT
6254TT
6416TT
6414TT,
6416TT
7403TT
3335LT
3332HS
3302PRV
3303MV
3304GF
3305PG
3306PRV
3307MV
3308F
3309PRV
3310PT
3311PT
3312HFSV
3313AC
3314PT
3316MV
3315PRV
3319PT
3318PT
3320PT
3321SERVO
3322SV
3326SV
3325SV
3324MCV
3323HFSV
3327PRV
3328PT
3329PRV
3330PRV
3331HFSV
3336MV
3337MV
3338MV
3339PRV
3340PRV
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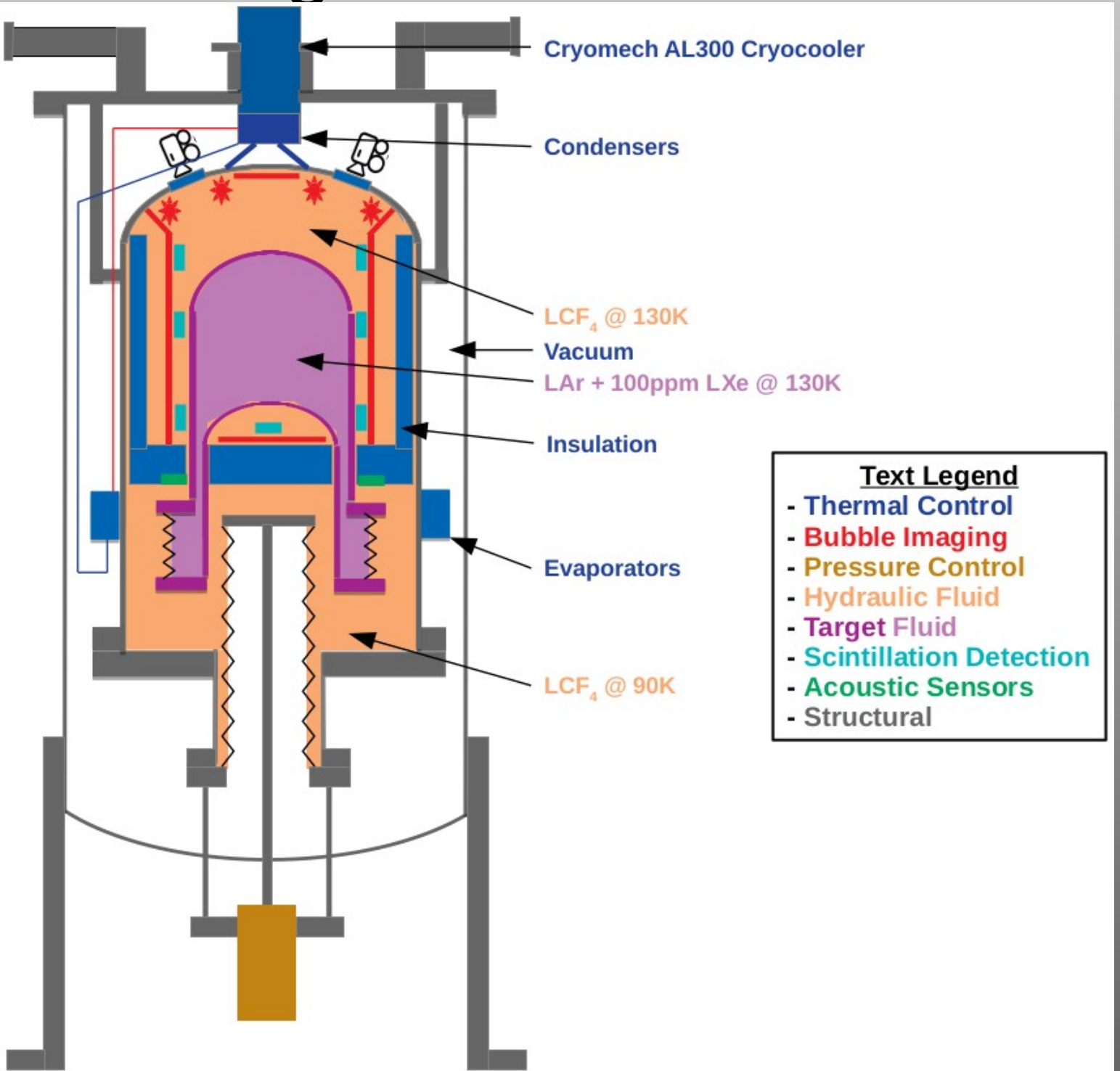
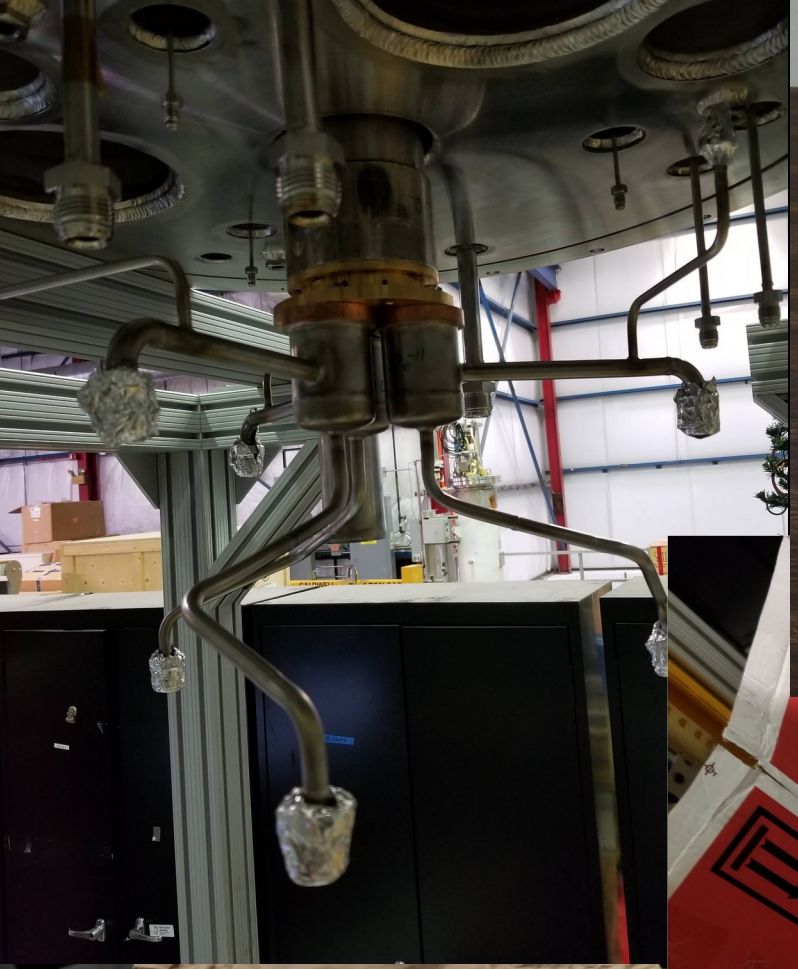
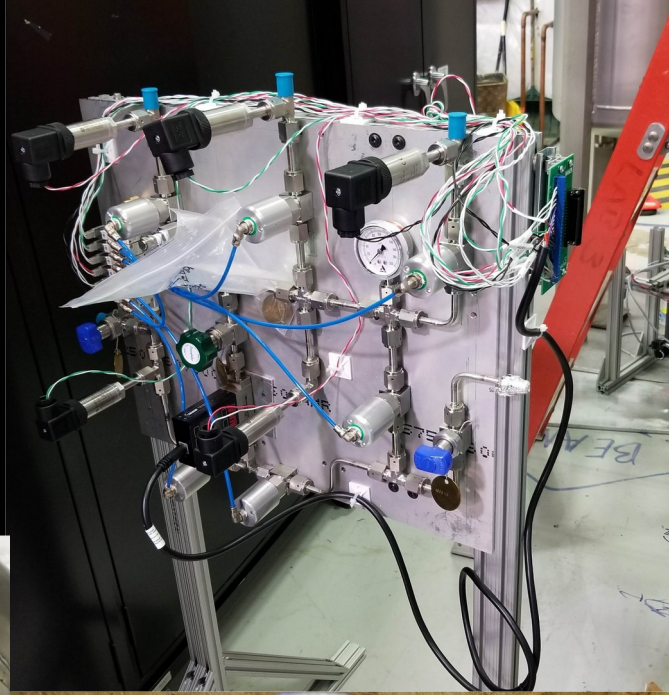
Challenge 4: Thermal Control



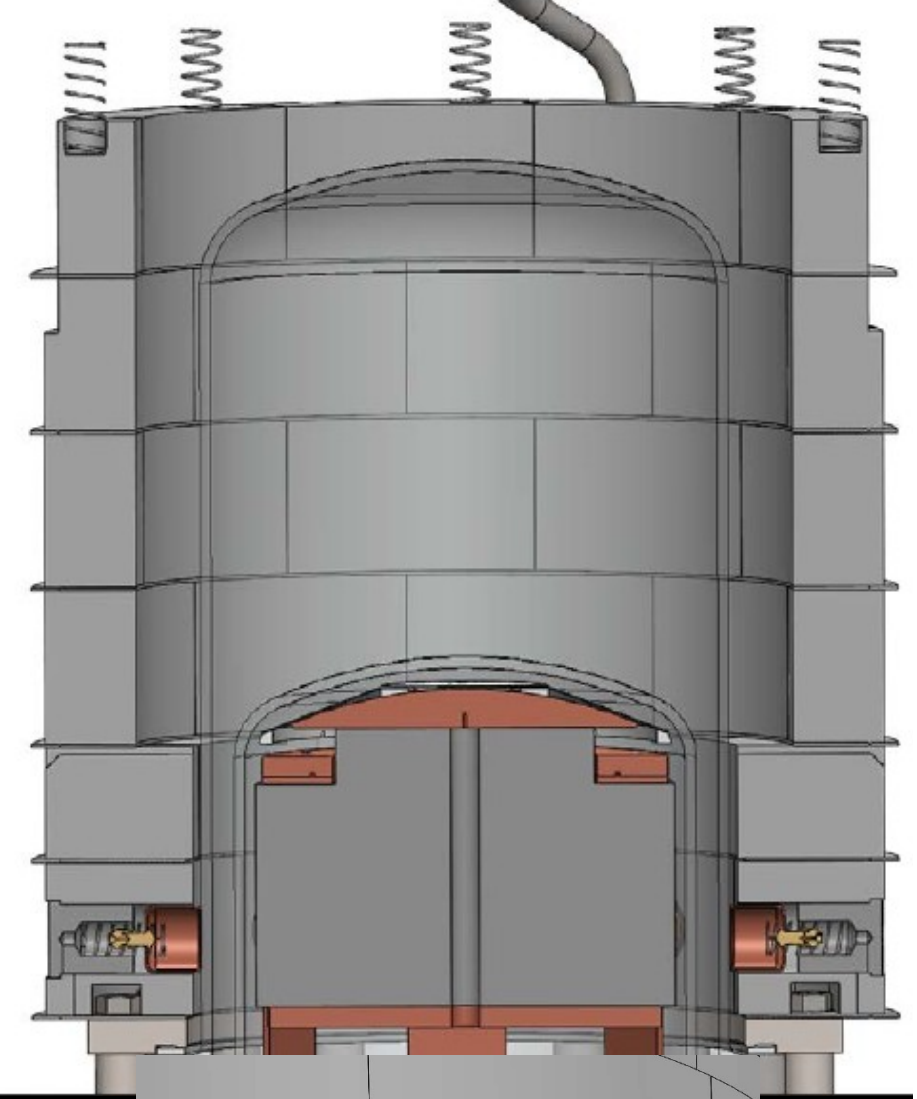


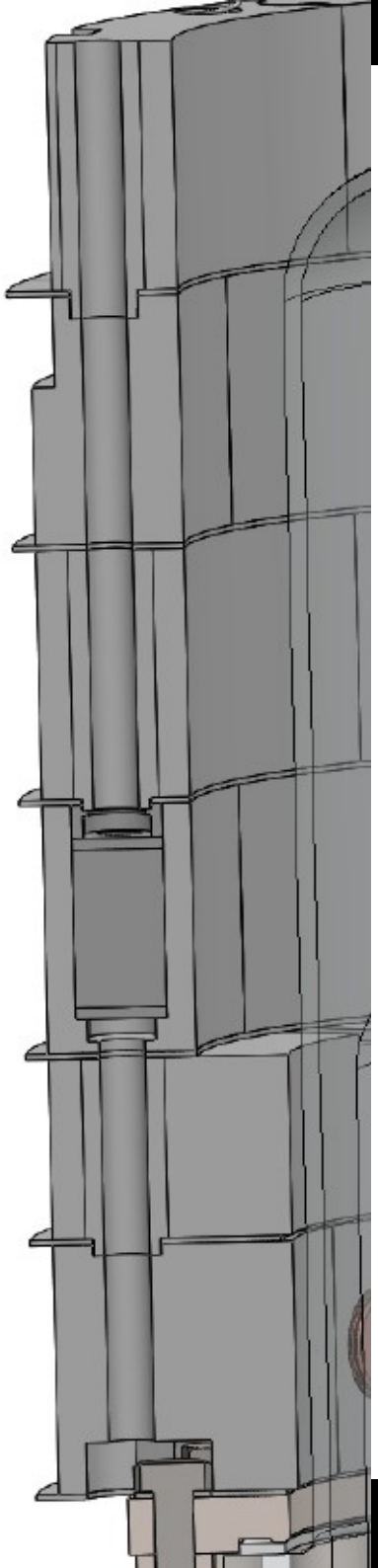
#1
Composite Assembly

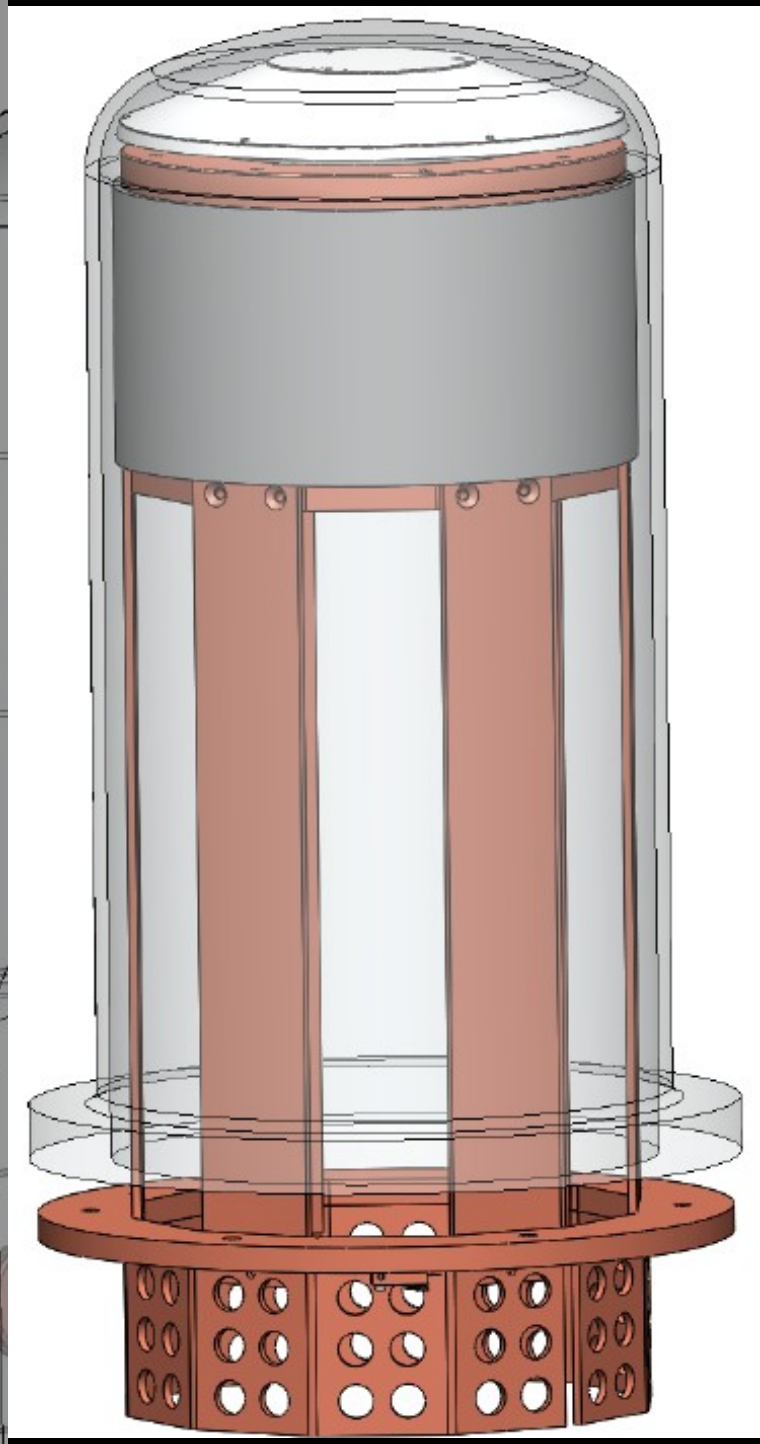


A
A
B
B

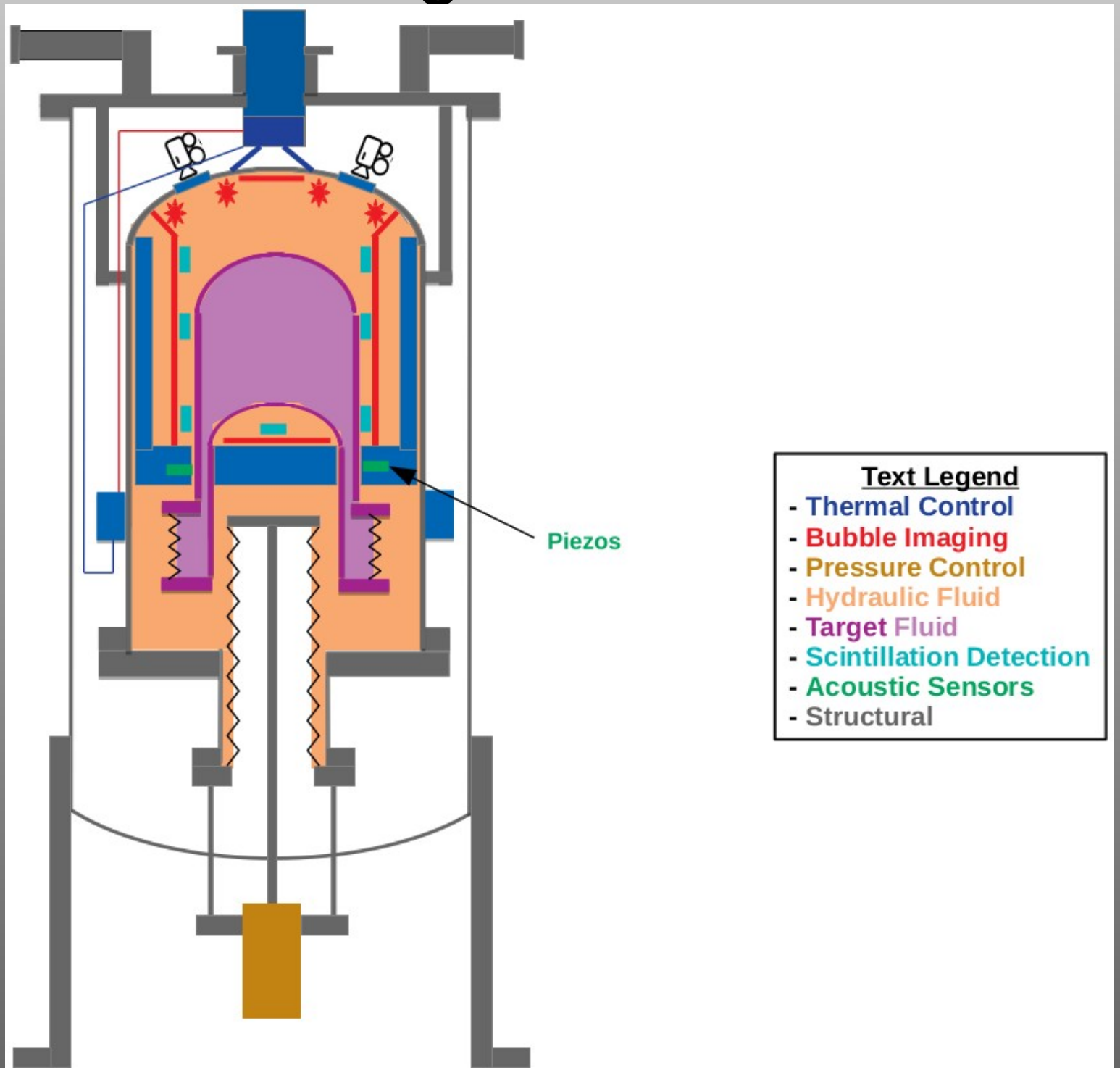
CRYOMECH
MODEL NO
S/N
AMPS
VOLTS

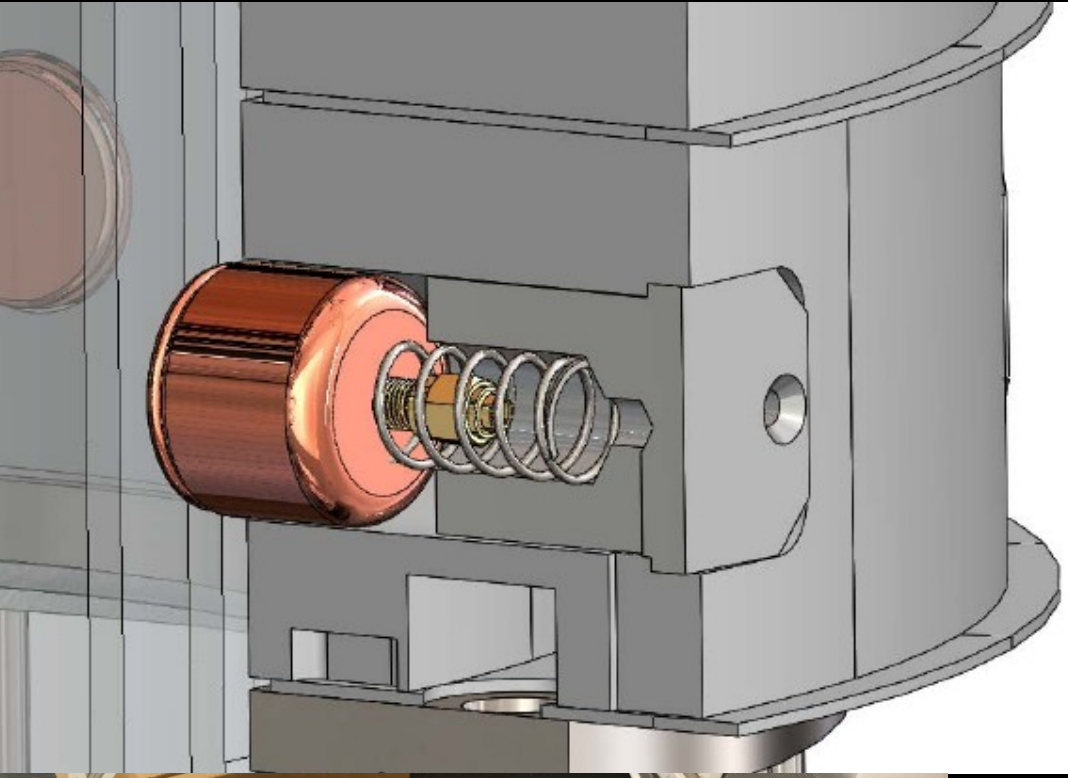


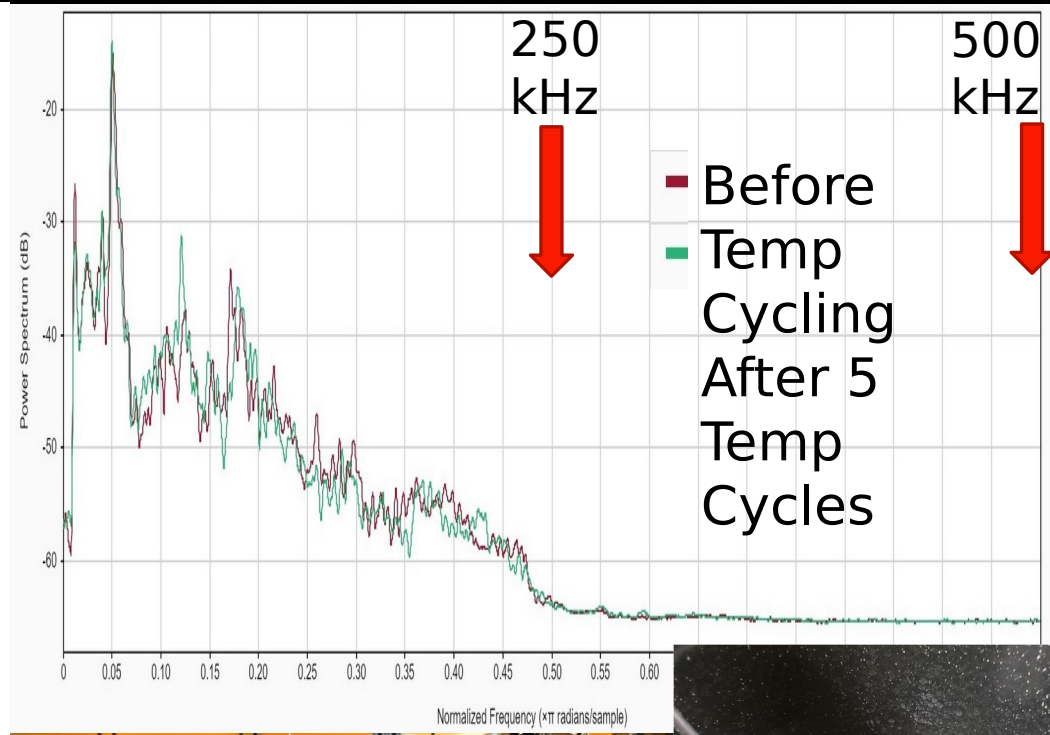


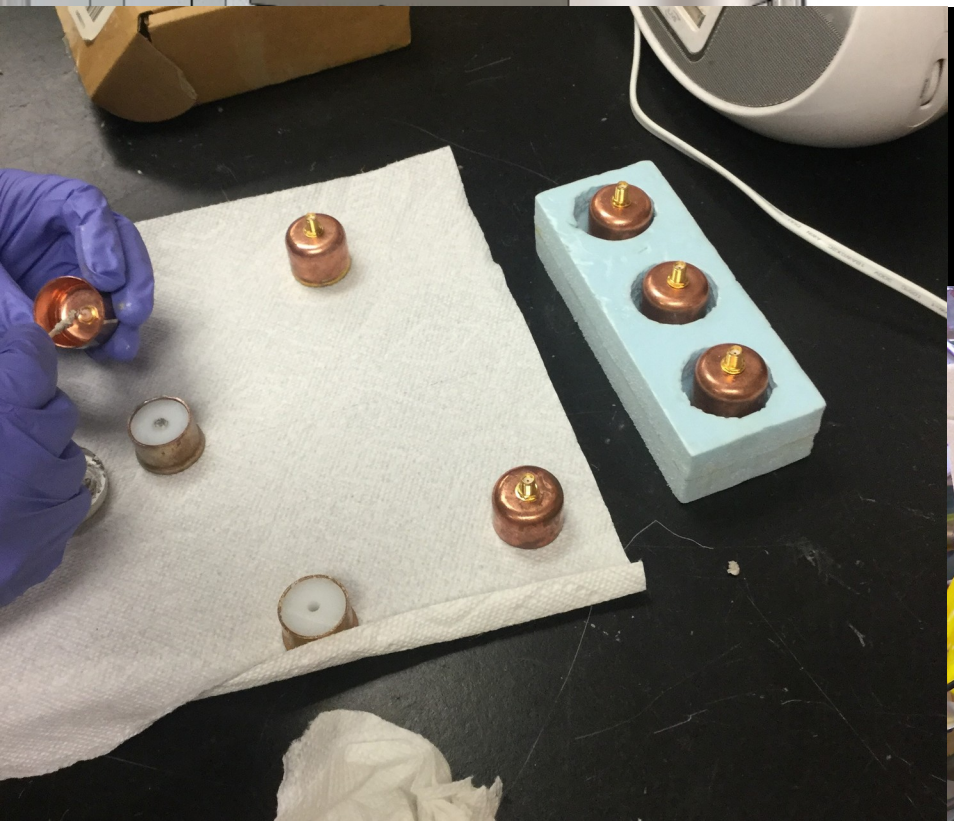


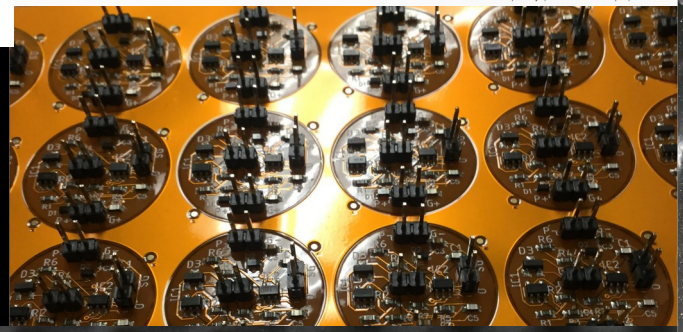
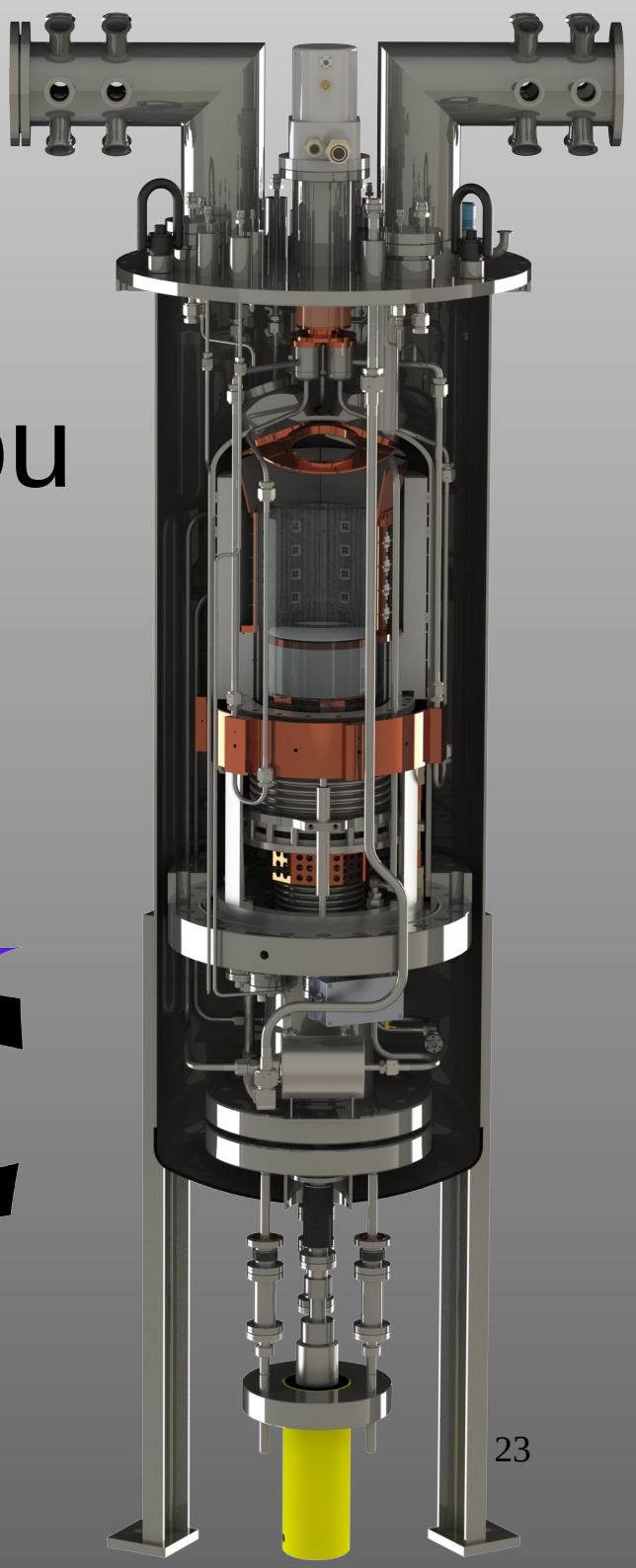
Challenge 5: Acoustics






250 kHz
500 kHz
Before
Temp Cycling After 5 Temp Cycles
Power Spectrum (dB)
-20
-30
-40
-50
-60
0
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
0.50
0.55
0.60
Normalized Frequency (×π radians/sample)





Thank You