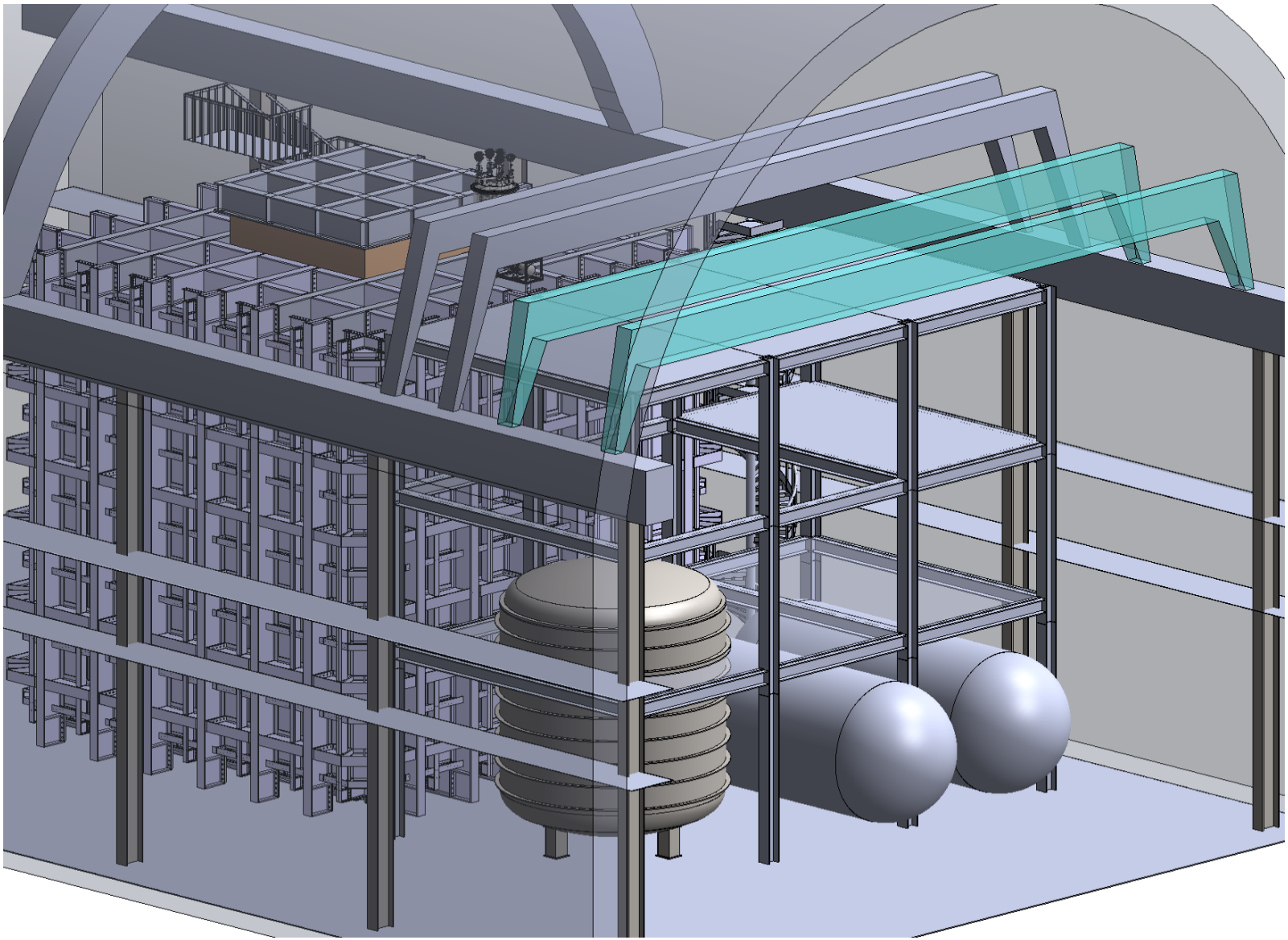
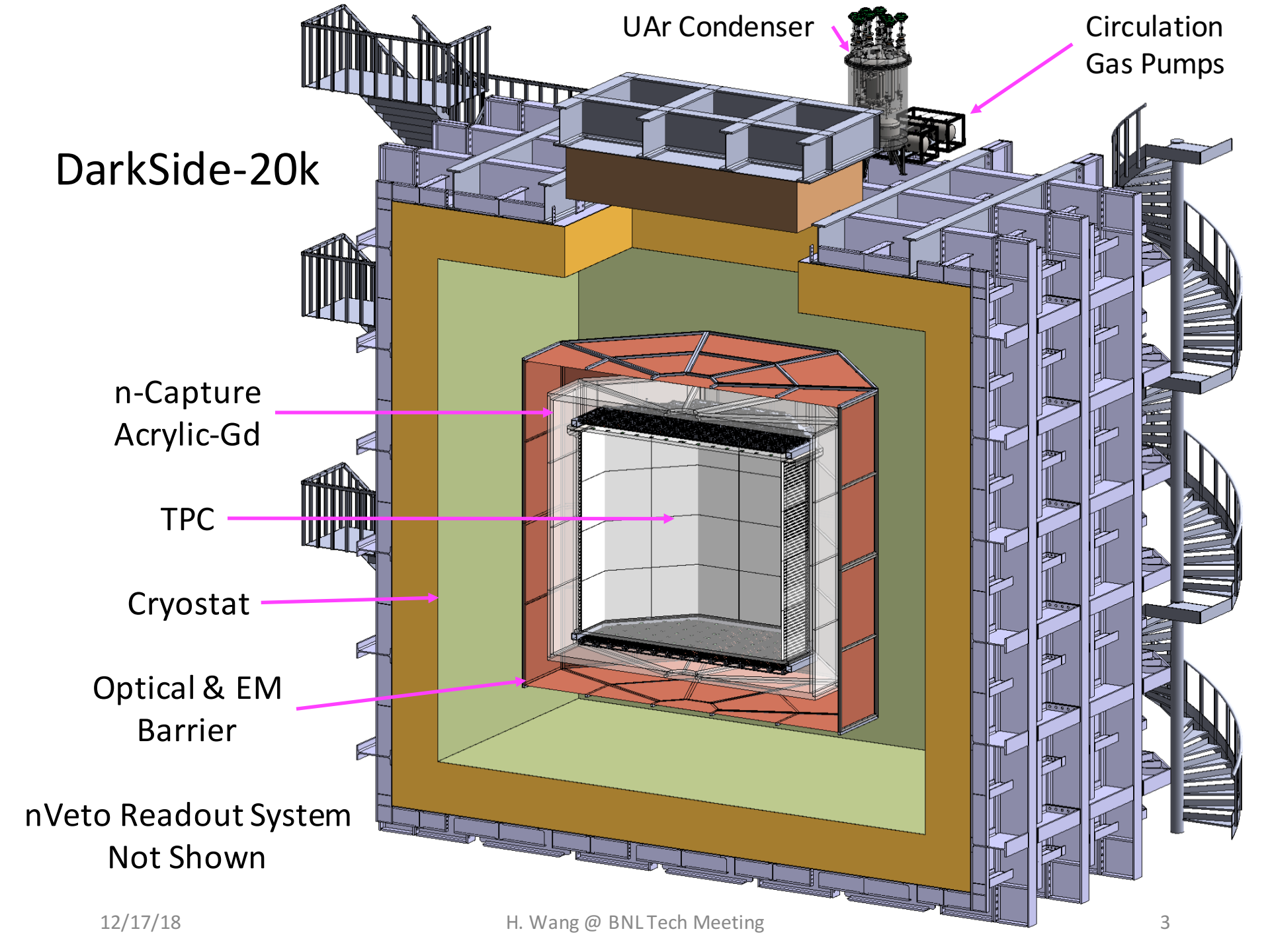
DarkSide-20k TPC & Cryo

Hanguo Wang @ UCLA

DarkSide-20k Detector in Hall-C



DarkSide-20k



TPC

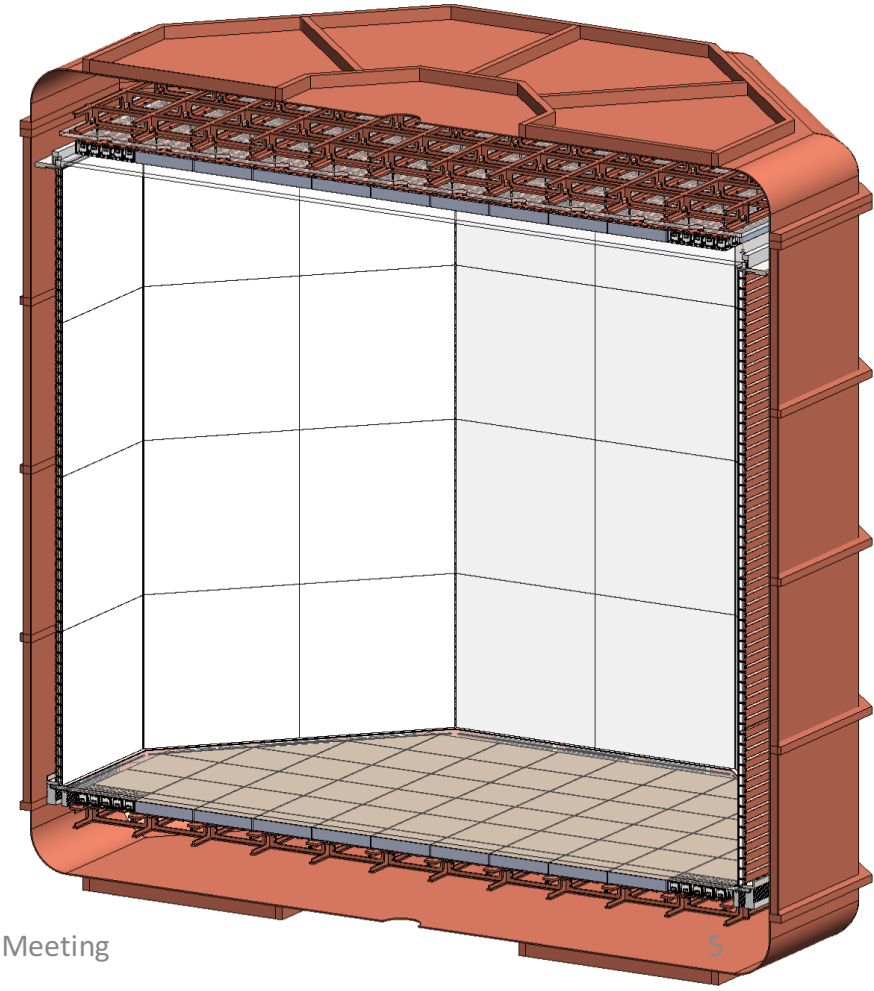
TPC volume Based on 8280 total PDM Channels Octagonal TPC and Copper Vessel

Old baseline design

Natural Size based on PDM Mother board arrangements (4140 top and 4140 bottom):

Total (ton),	active (ton),	Fid(10cm)
~50.8 ,	38.6,	31.8
(8280)	70.0%	64.0%

TPC parts volume displaces ~1.75 ton argon



drift length of TPC 262.8 cm

TPC volume Based on 8280 total PDM Channels
Octagonal TPC and Copper Vessel

Total available argon for DarkSide-20k is 50 tons
with an conservative ? ton reserve for cryogenics system and recovery tank operations

Natural Size based on PDM Mother board arrangements (4140 top and 4140 bottom) and limitation of the top cover clearance:

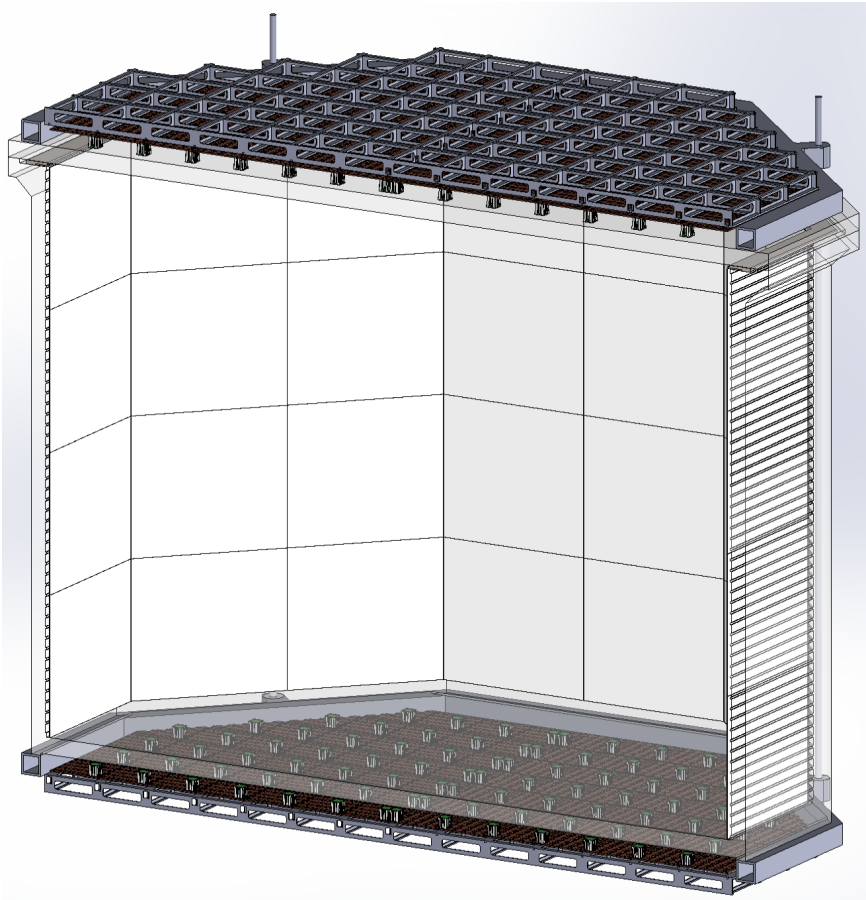
Octagonal face distance: 360 cm

Total Drift Length: 350 cm

Total (ton),	active (ton),	Fid(ton)
51.0	48.2	40.4
	94.5%	79.2 %

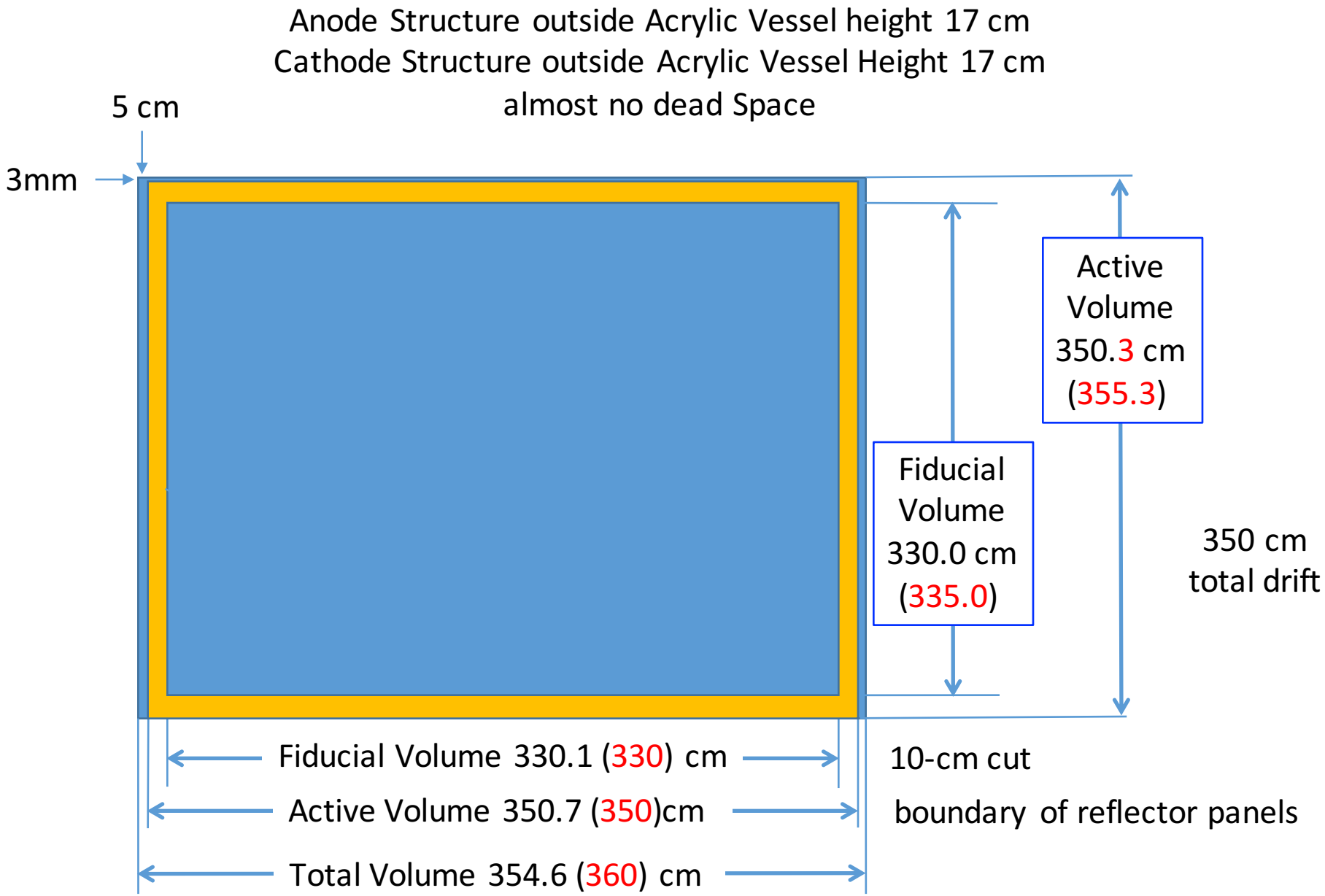
TPC reflector displaces ~100 kg argon

fiducial cut is 10 cm

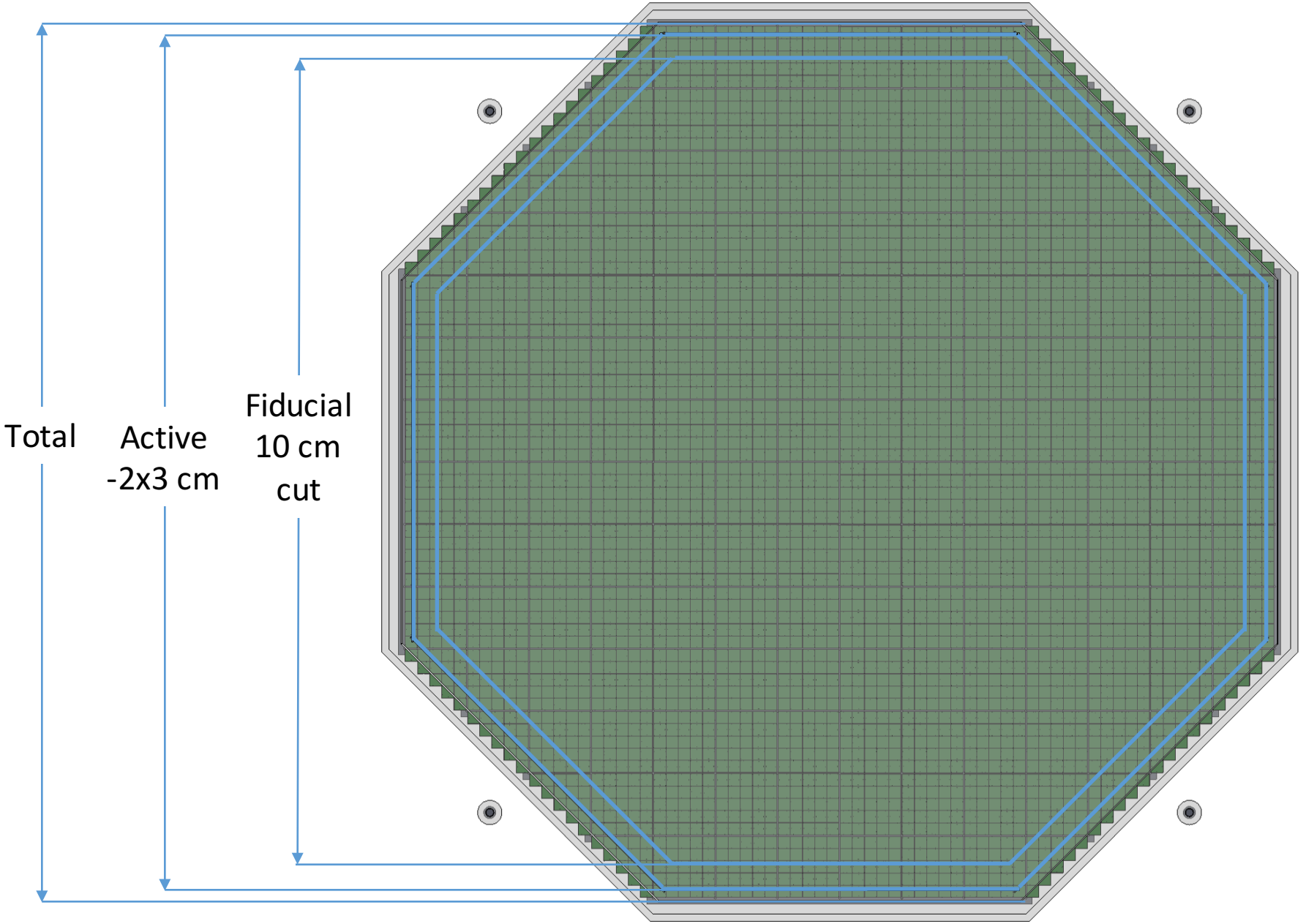


Acrylic Vessel will be designed to conform the volume when cold (assuming 1.5% shrink)

Mechanical dimensions of Acrylic vessel and TPC



DakrSide-20k TPC PDM Coverage and UAr Volume Section Top View (4140 PDMs)



Acrylic vessel TPC

TPC Acrylic:

4.0 + 0.23 ton

PDM and support:

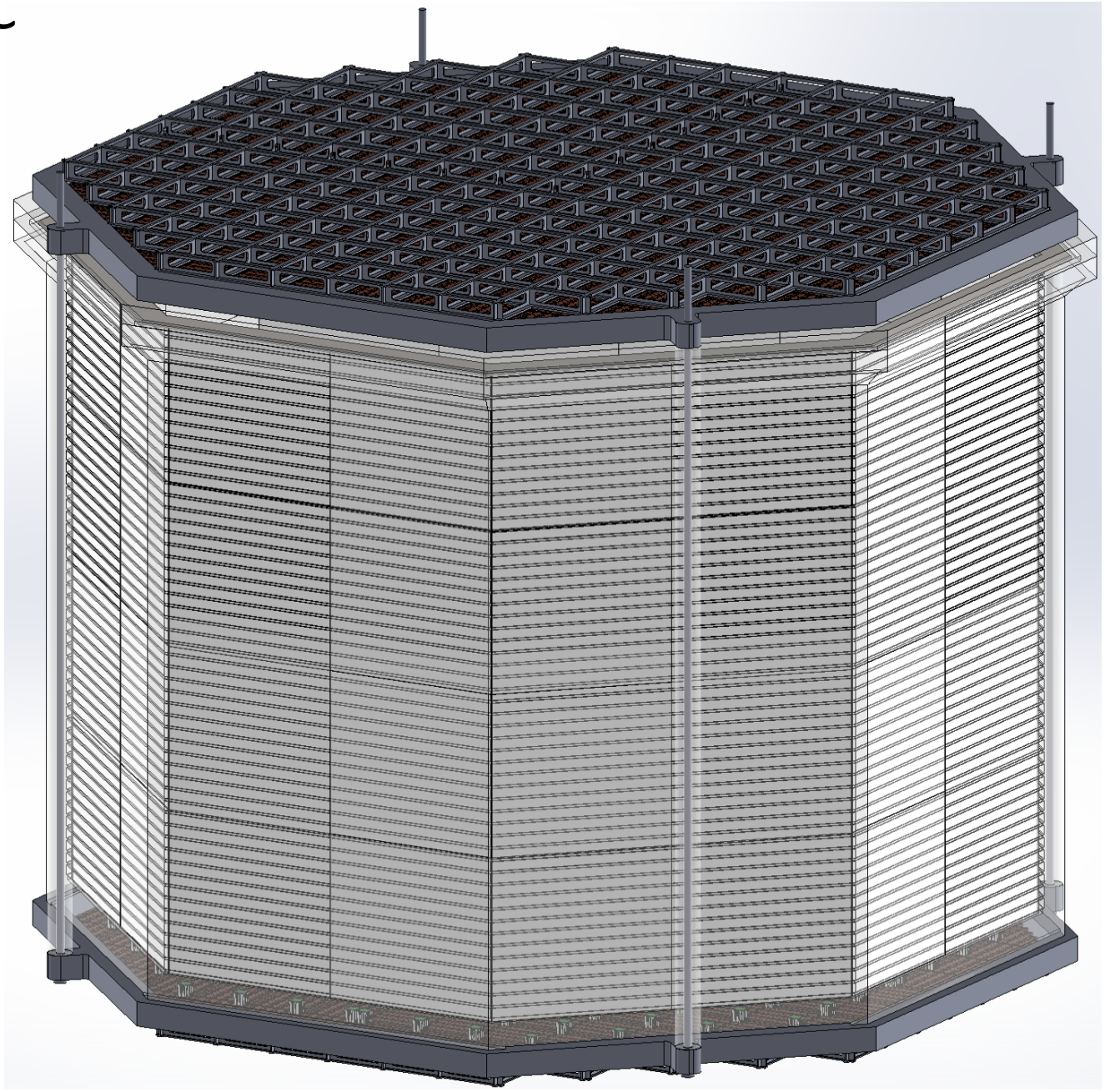
~2 x 1.1 ton

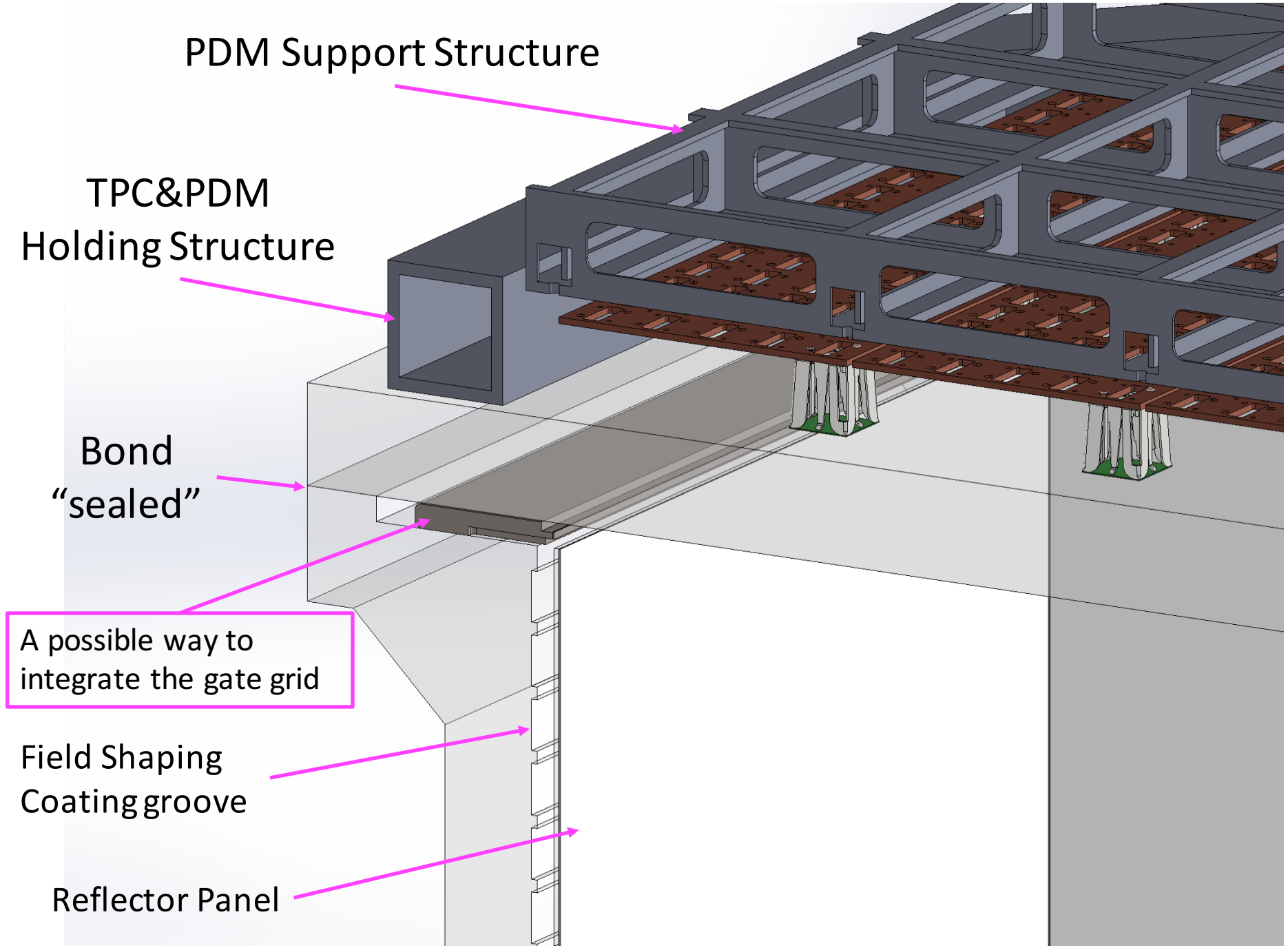
UAr, TPB, Reflectors, Anode and Cathode are Inside the Acrylic Vessel

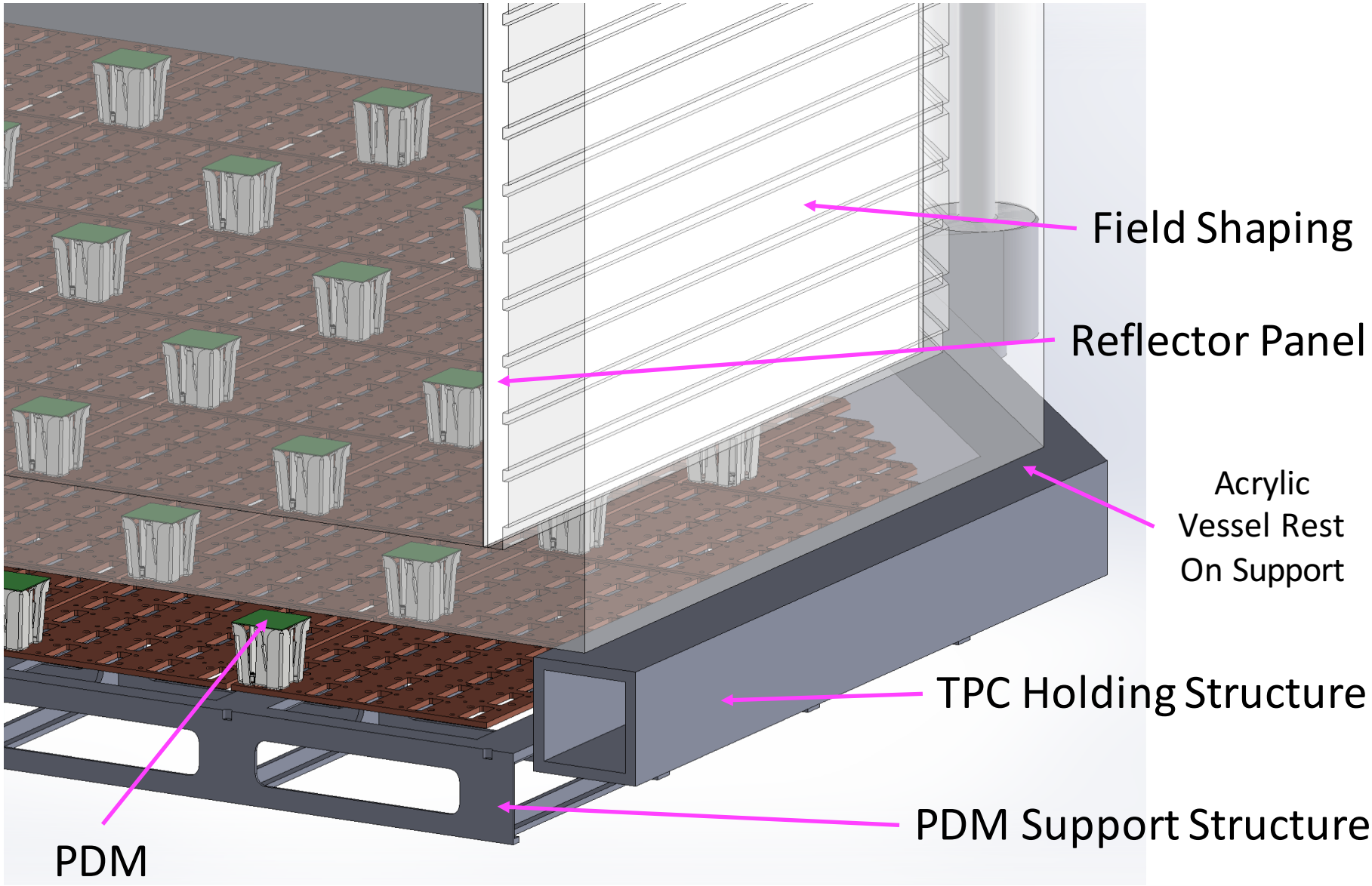
PDMs are Outsize the UAr Volume

Use of Conductive Polymer to Eliminate Copper Field Cage Structure

Use Conductive Polymer to Replace ITO for Anode and Cathode



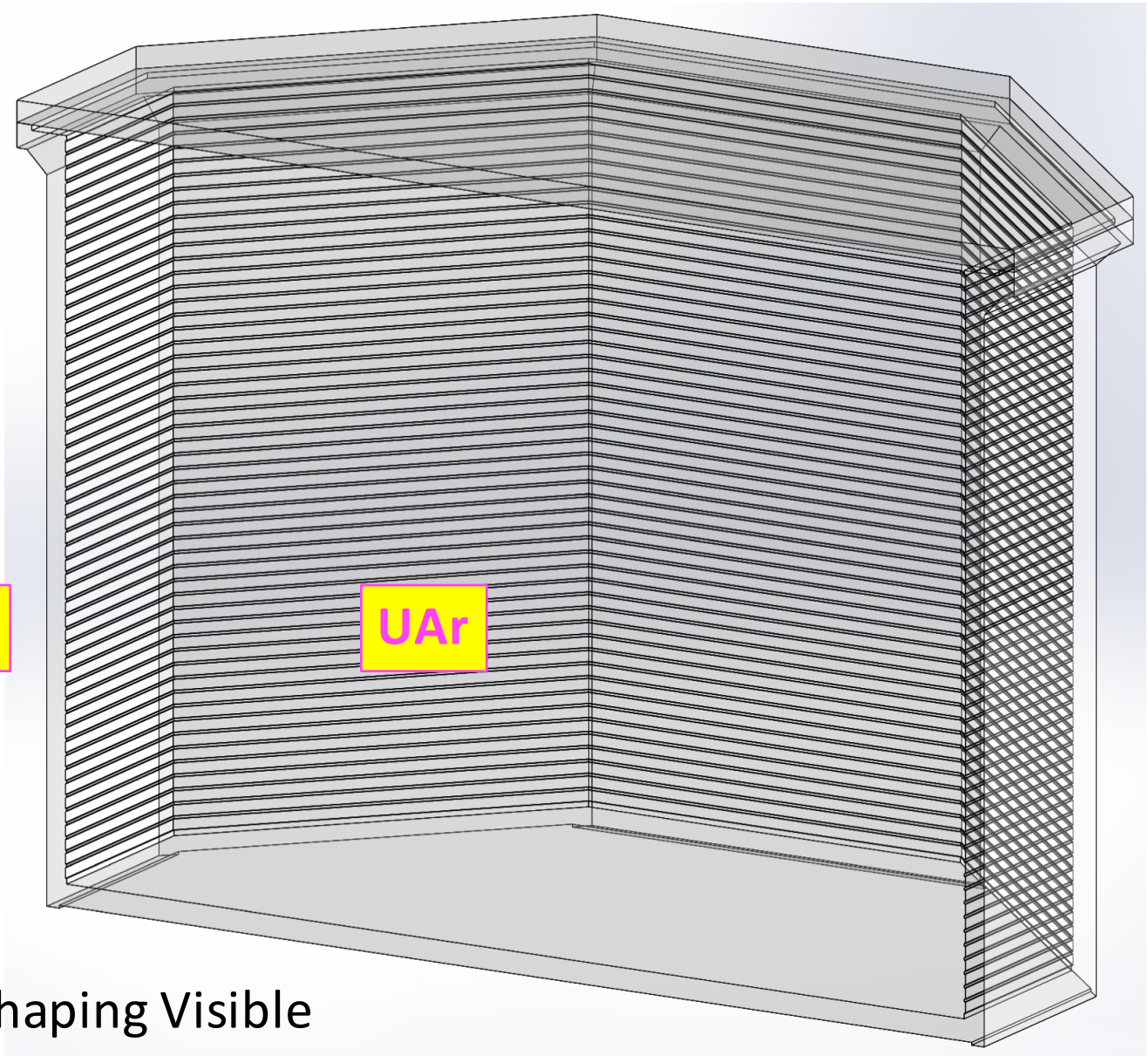

PDM Support Structure
TPC&PDM
Holding Structure
Bond
“sealed”
A possible way to
integrate the gate grid
Field Shaping
Coating groove
Reflector Panel


Field Shaping
Reflector Panel
Acrylic
Vessel Rest
On Support
TPC Holding Structure
PDM Support Structure
PDM

A possible section view of the finished acrylic vessel

Service penetrations not shown

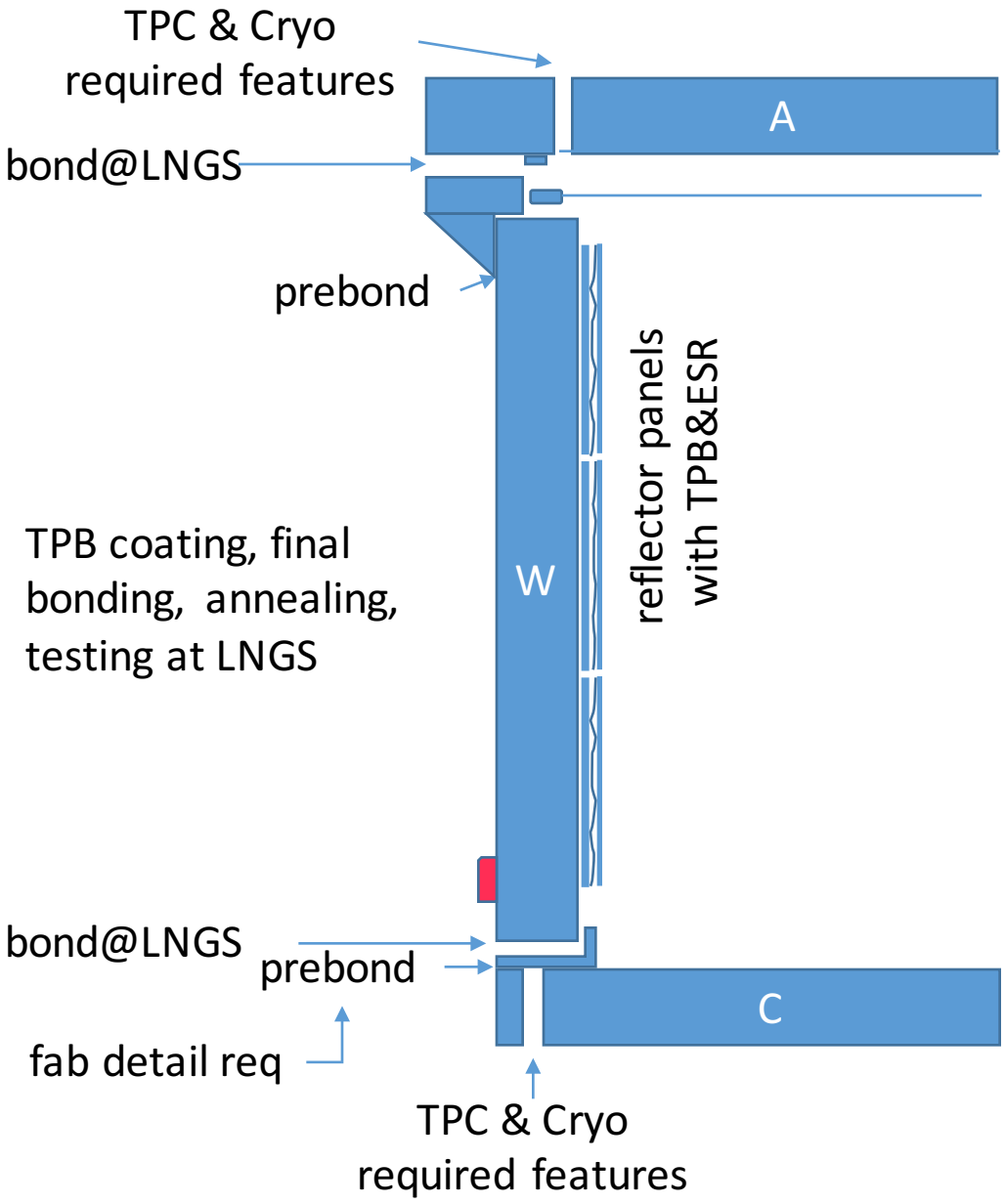
Sealed Vessel



Features for Field Shaping Visible

Three Pieces Prefabricated in Canada A, W, and C

fabrication steps and bonding procedure of Acrylic vessel



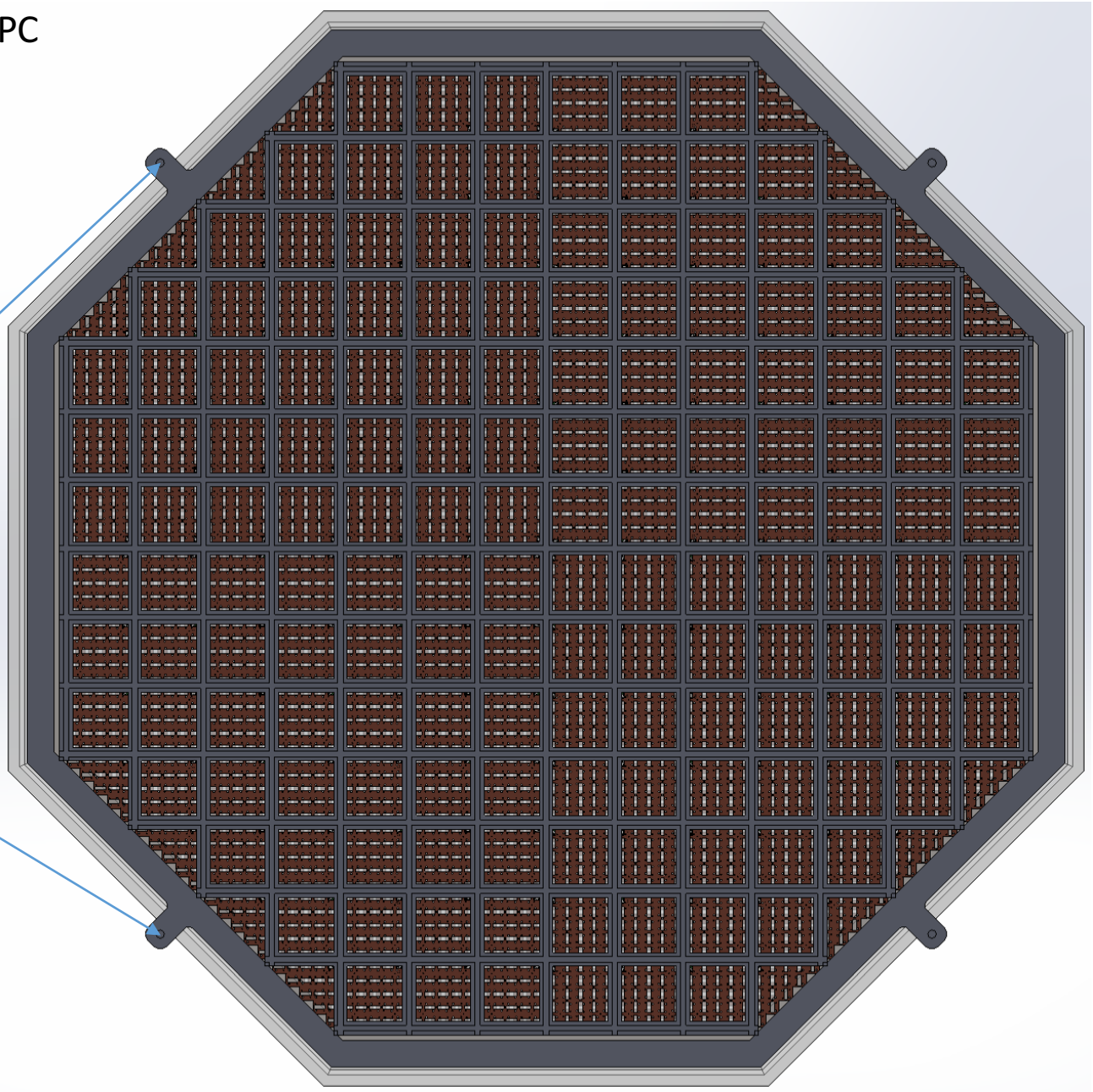
A: top anode plate coated with conductive polymer

W: full Octagonal Wall structure with polymer coated field cage, resistor links, and assembled ESR/TPB panels

C: bottom cathode plate coated with conductive polymer

Result of Discussion
Hanguo & Aksel

Top View of DarkSide-20k TPC



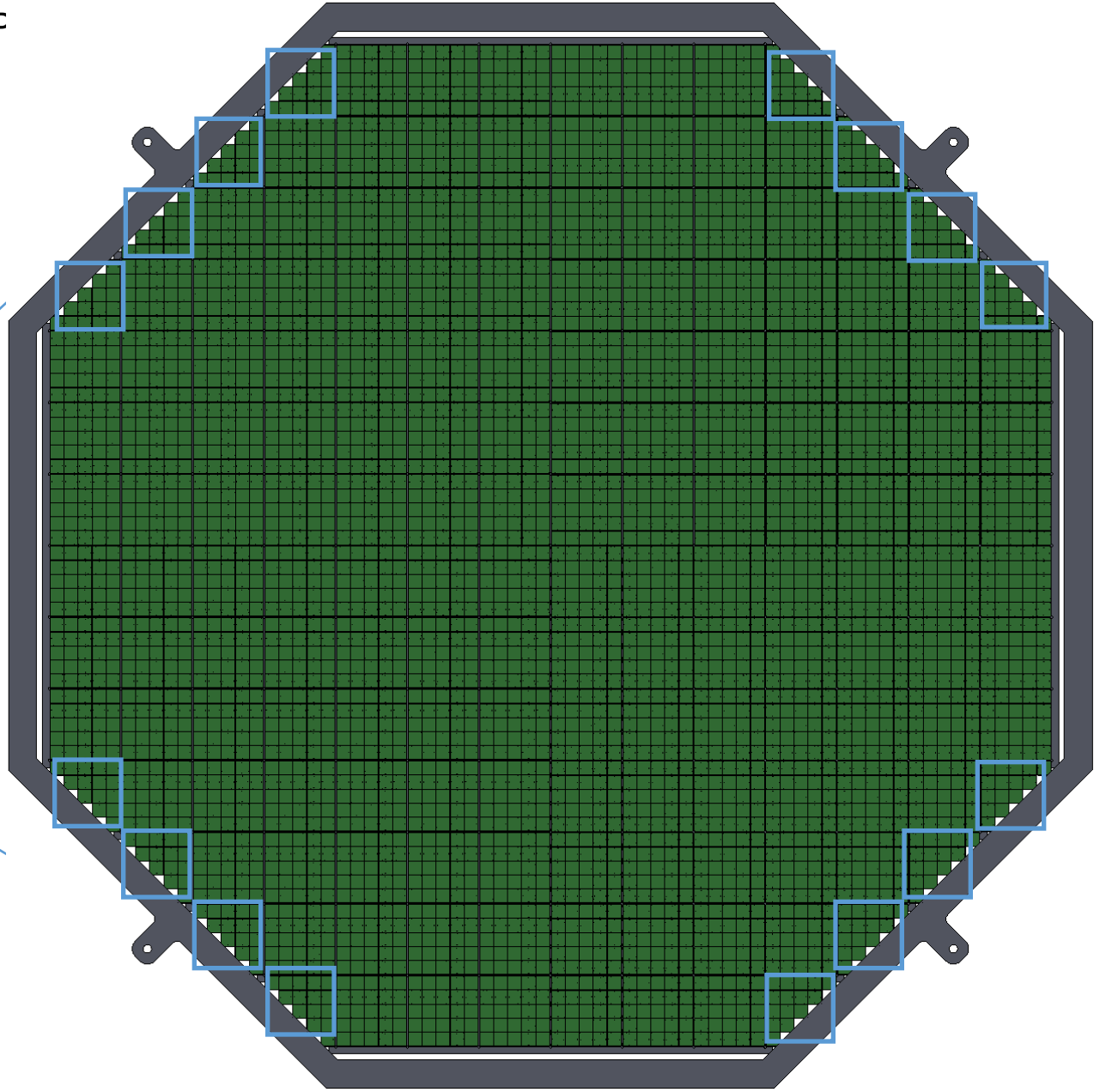
Hanging Structure
For Installation
More to add once
in final location

Top View of DarkSide-20k TP

No Special MotherBoard Required
Use same MotherBoard

Hanging Structure For Installation
More to add once in final location

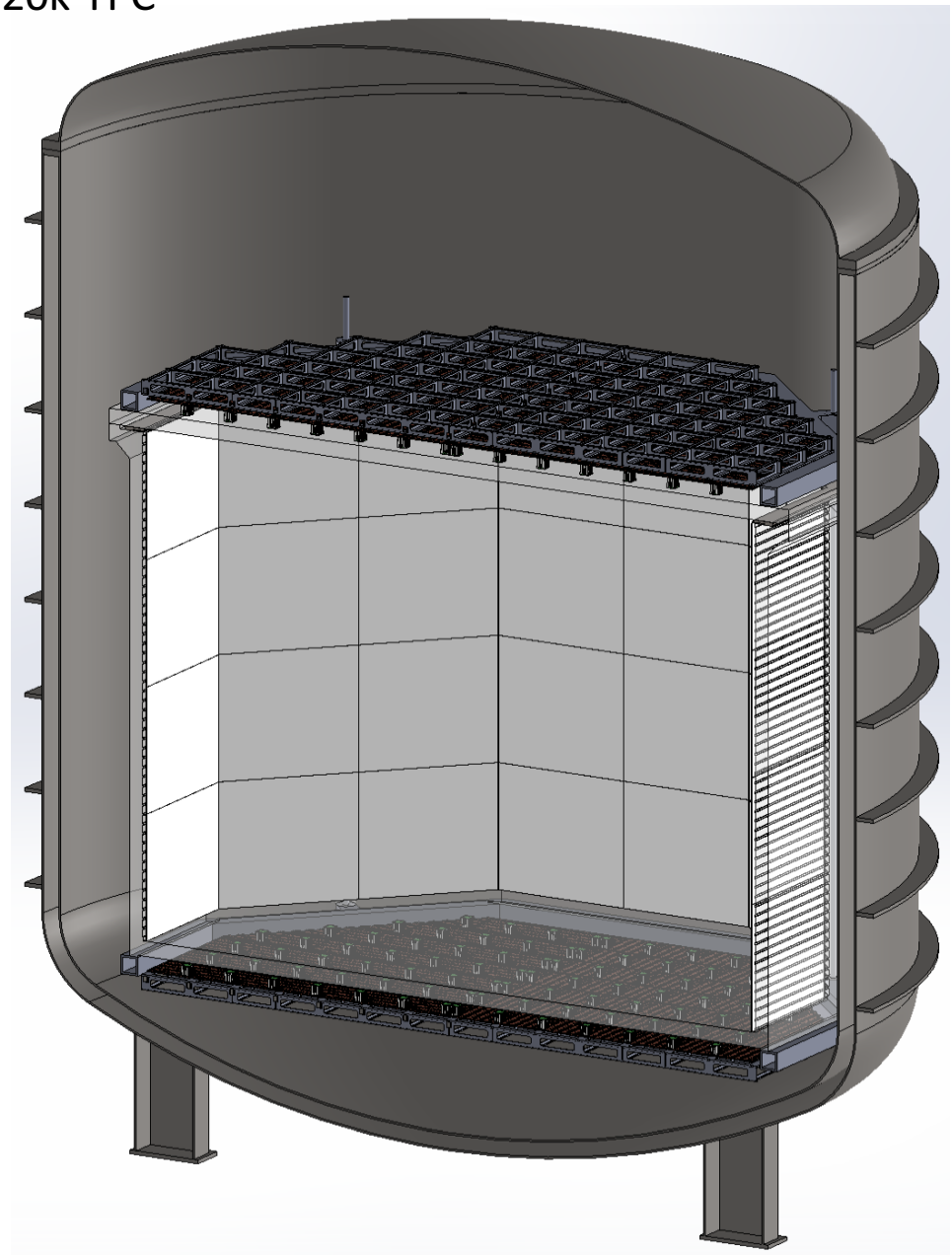
size of each motherboard



A Cryostat to be used to Test the DarkSide-20k TPC

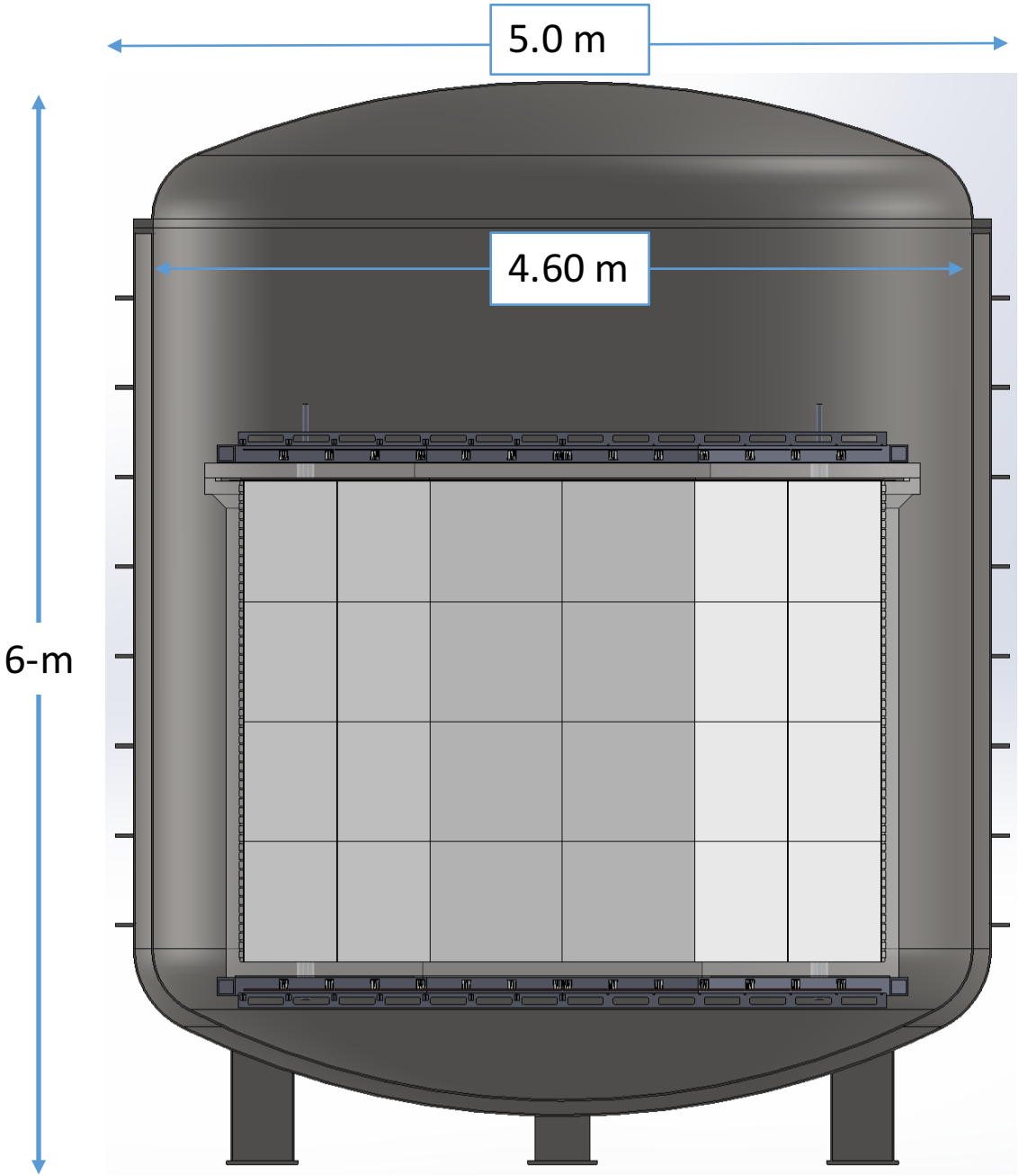
In the process of the TPC fabrication, this cryostat could also be used for:

1. TPC top and bottom TPB coating system
2. Acrylic Vessel leak test
3. annealing after the Acrylic Vessel is bonded.
4. and finally to test run the fully assembled TPC



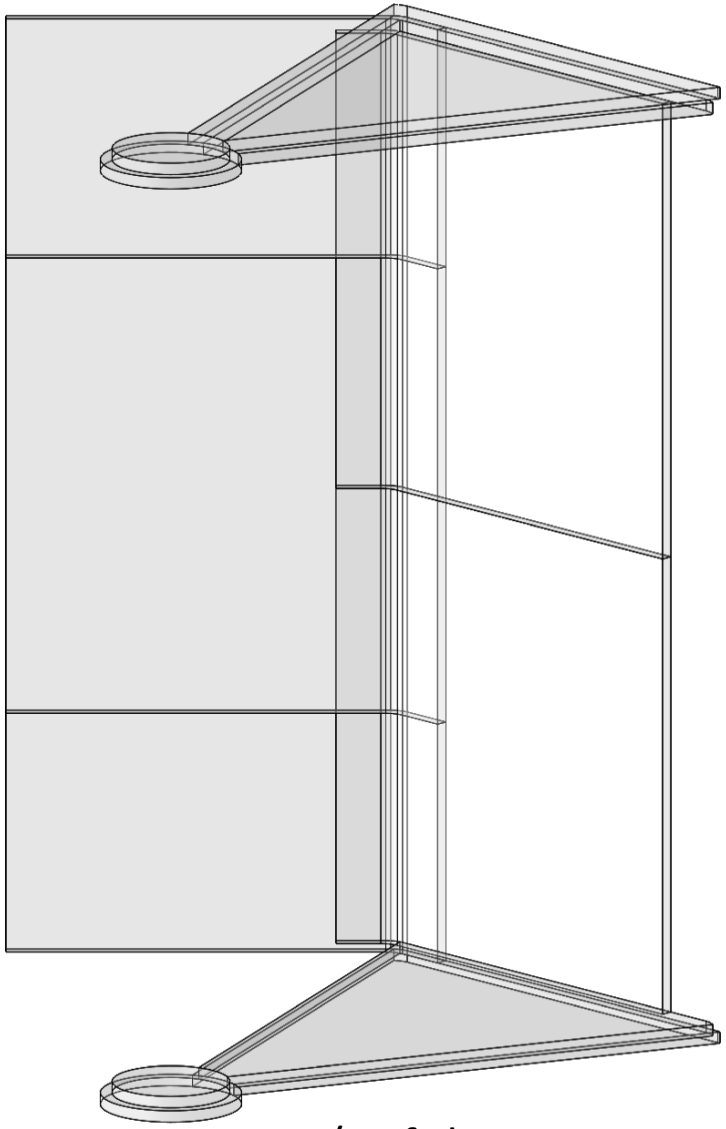
Rough Dimension
for quick Quotation

1. total height: 6 meter
2. ID = 4.6 meters
3. Total OD: 5 meter, this could change depends on the rib width requirement to prevent buckle
4. require a few port on top dome
5. require a bayonet port at bottom for drain.
6. top lid seal can be o-ring with option of indium seal
7. vacuum insulated with super-insulation
8. inner vessel and outvessel can be welded to form on piece.
9. top dome single wall.
10. change bottom dome if required due to large size for buckle prevention.

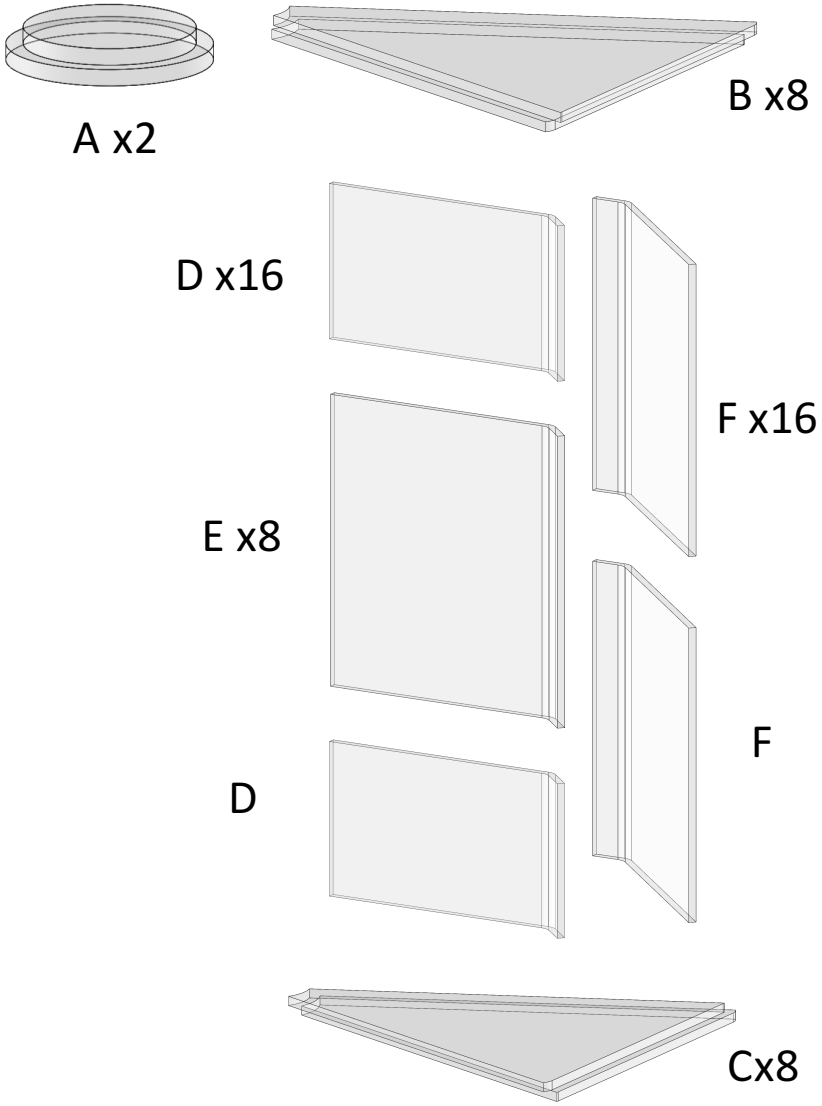


Acrylic-Gd neutron capture shell for the veto

Total of 6 Unique Shapes to Form the DarkSide-20k Veto Acrylic-Gd Shell (all 5 cm thick)



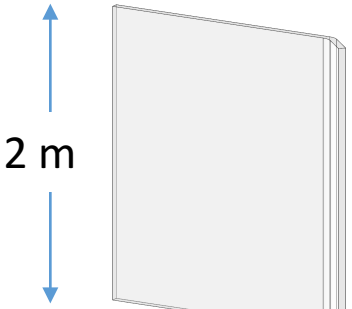
1/8 of the Veto



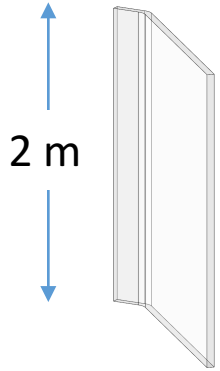
B&C Could be the same shape

Veto n-modulator and absorber Formed with Three Unique Pieces (with single production molding jig) 5 cm thick

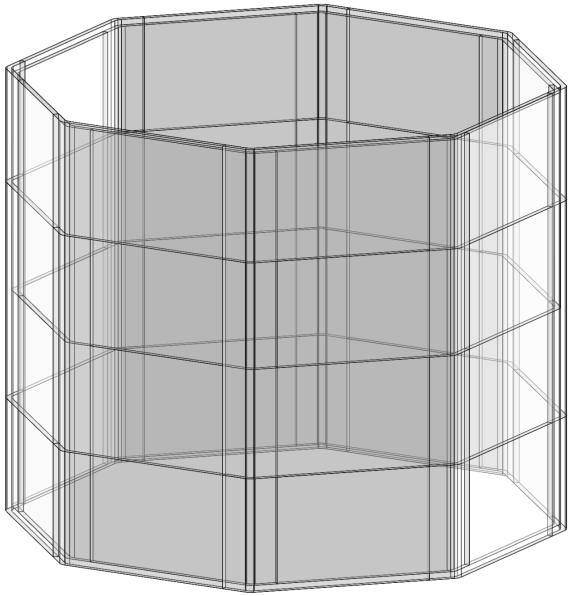
outer top/bottom panel 121 kg X 16



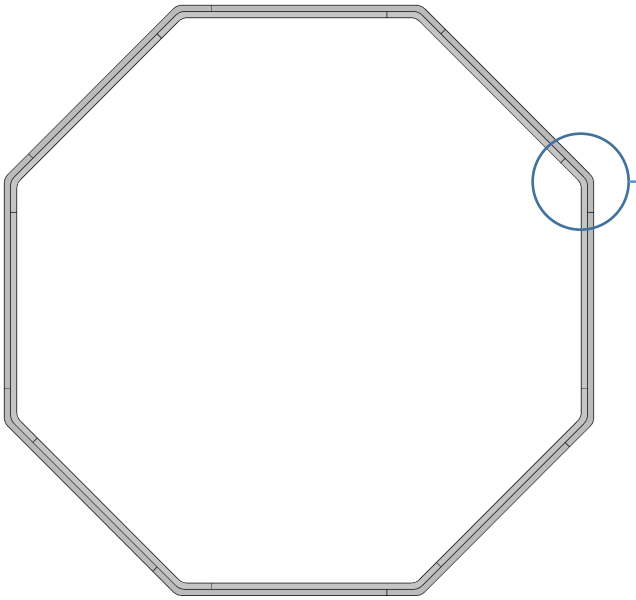
Outer panel 231 kg X 8

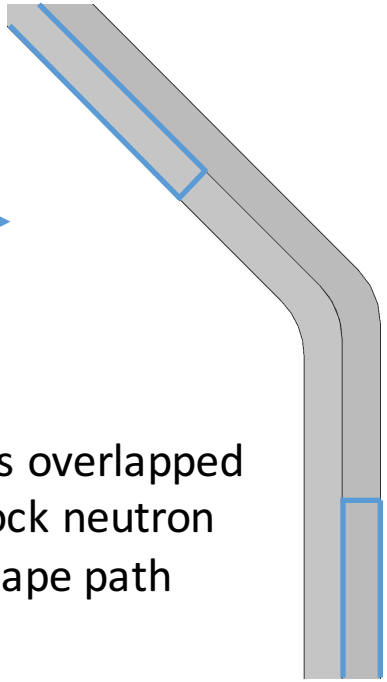


Inner panel 226 kg X 16



7.4 tons (wall only)

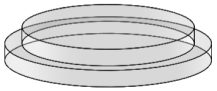


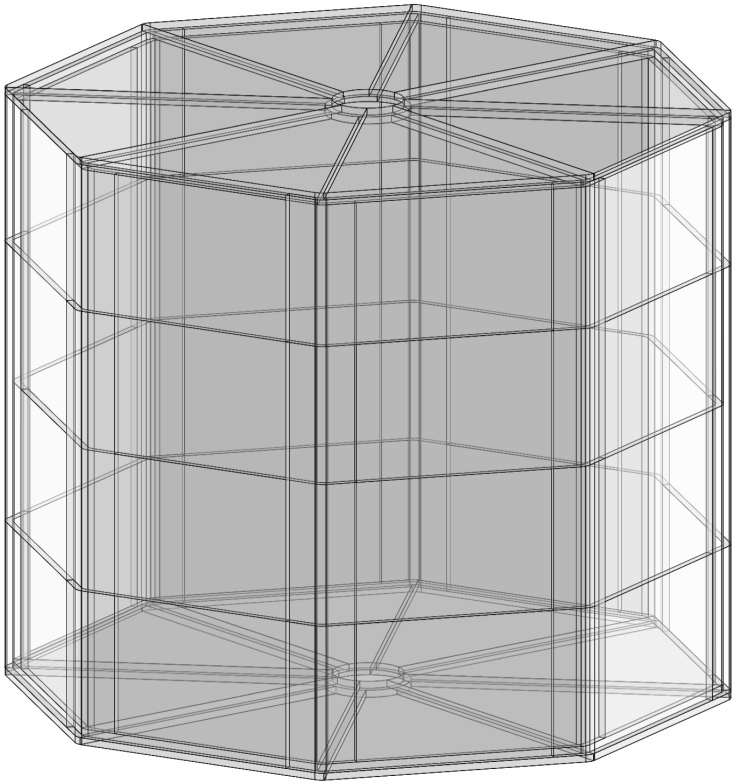


All gaps overlapped to block neutron escape path

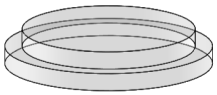
Veto n-modulator and absorber Formed with Three Unique Pieces (with single production molding jig) 5 cm thick

plug 29 kg x 2

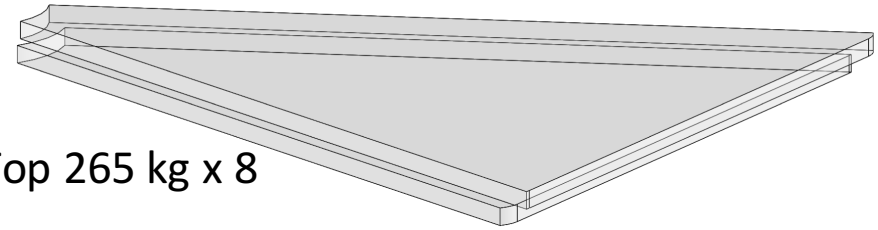


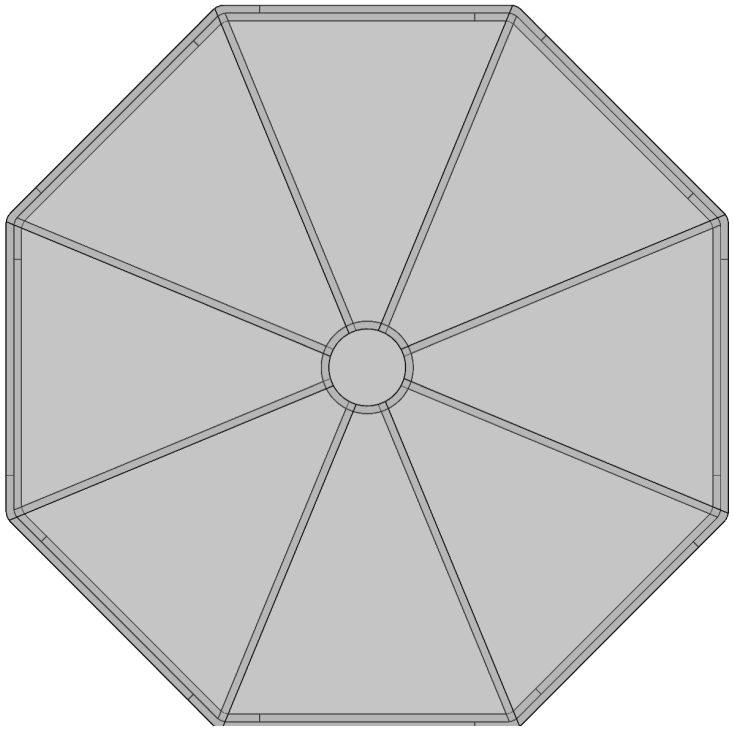


Veto 11.7 ton

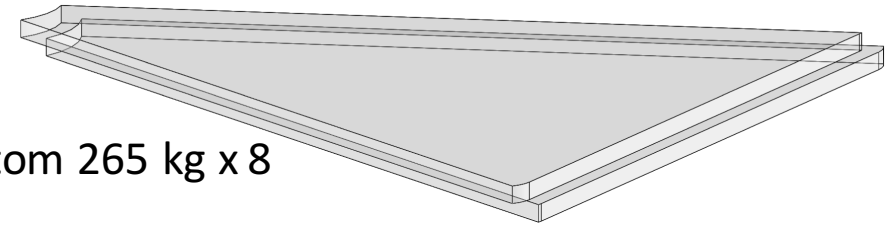


Top 265 kg x 8





Bottom 265 kg x 8

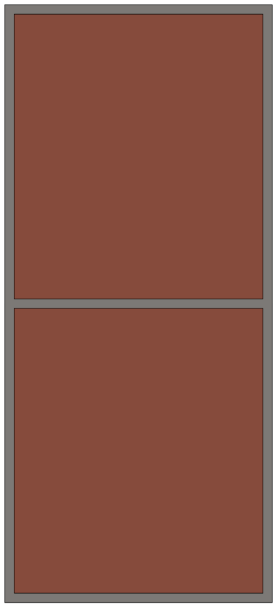


full Faraday cage and light shield

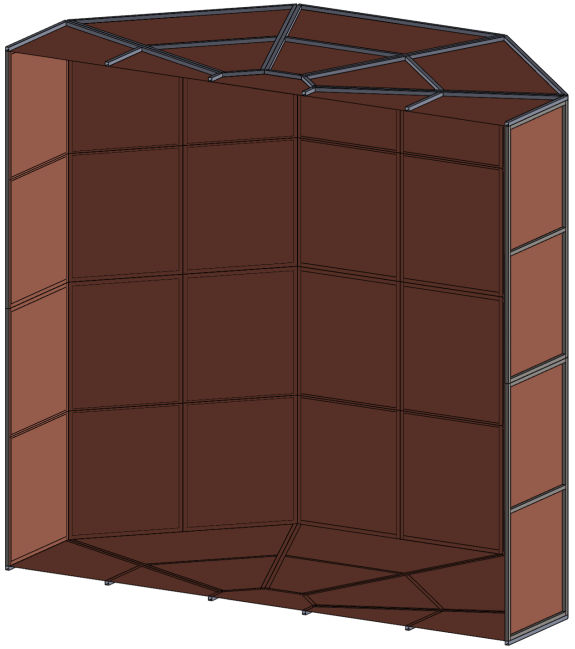
two unique construction panels to form the

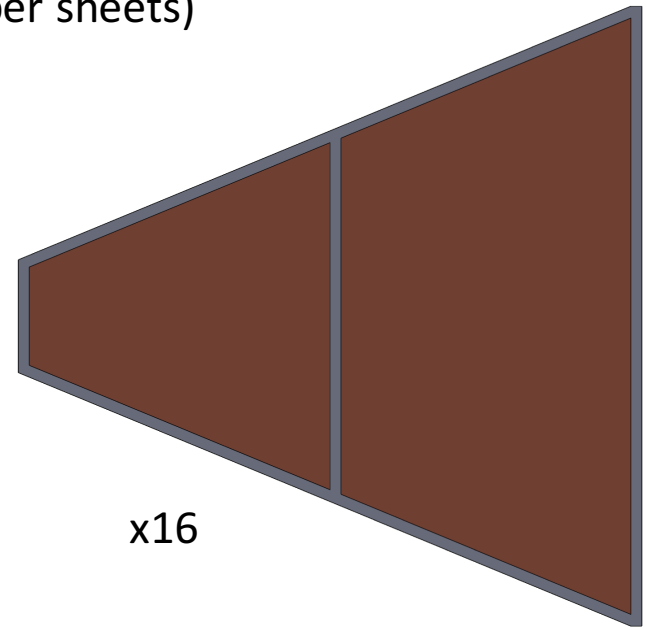
Build with light frame and patched with 0.5 mm copper sheets.
Total weight: 1.32 ton

or 0.81 ton
(with 0.1mm copper sheets)

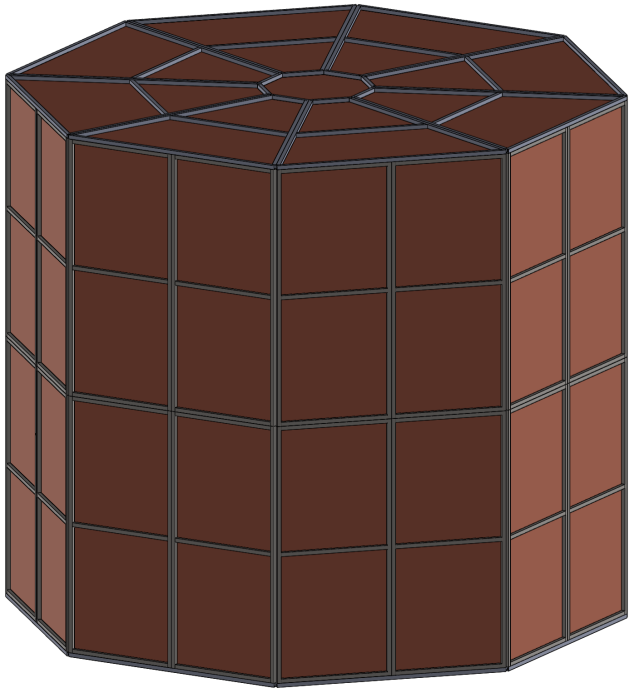


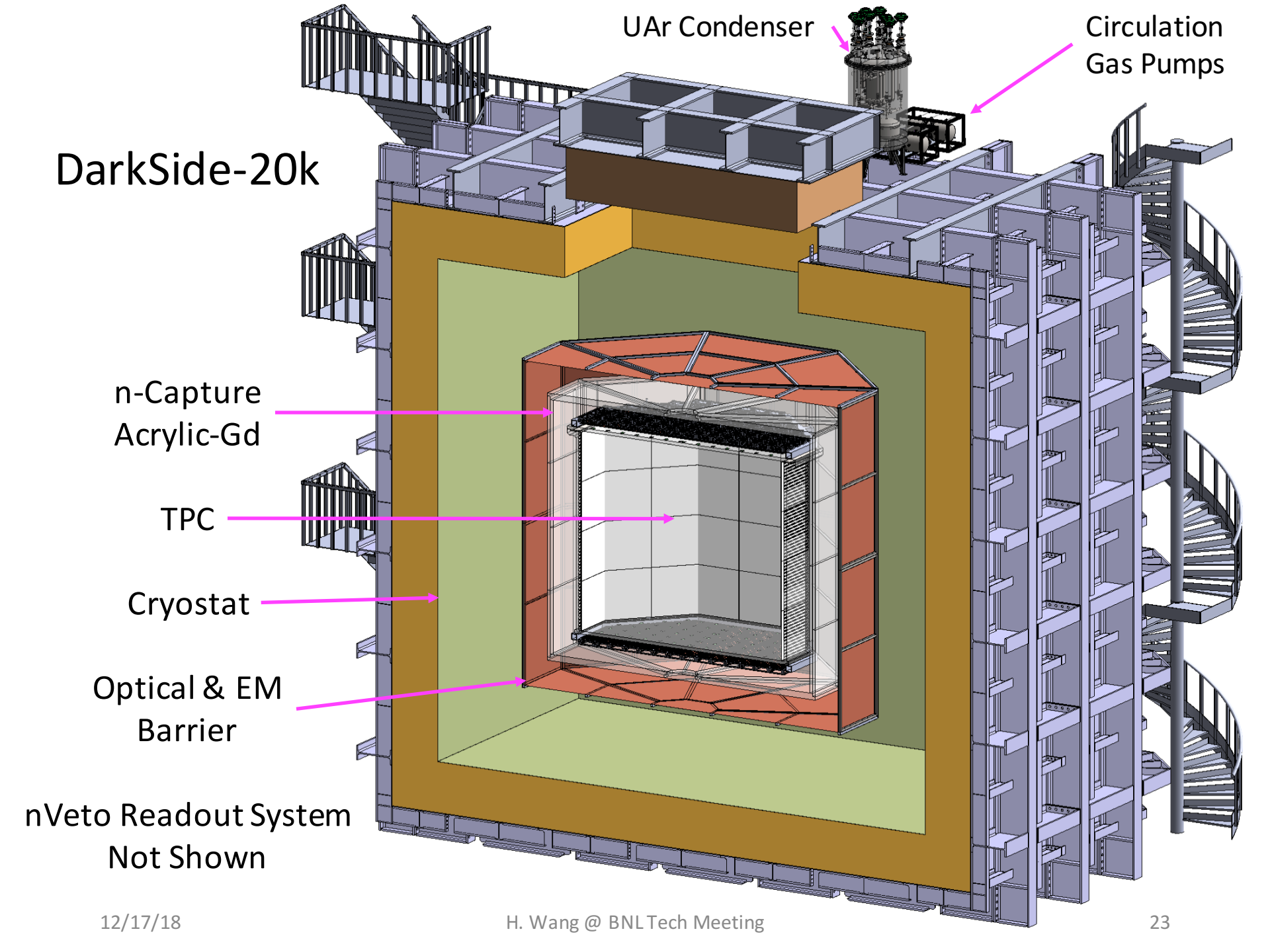
x32

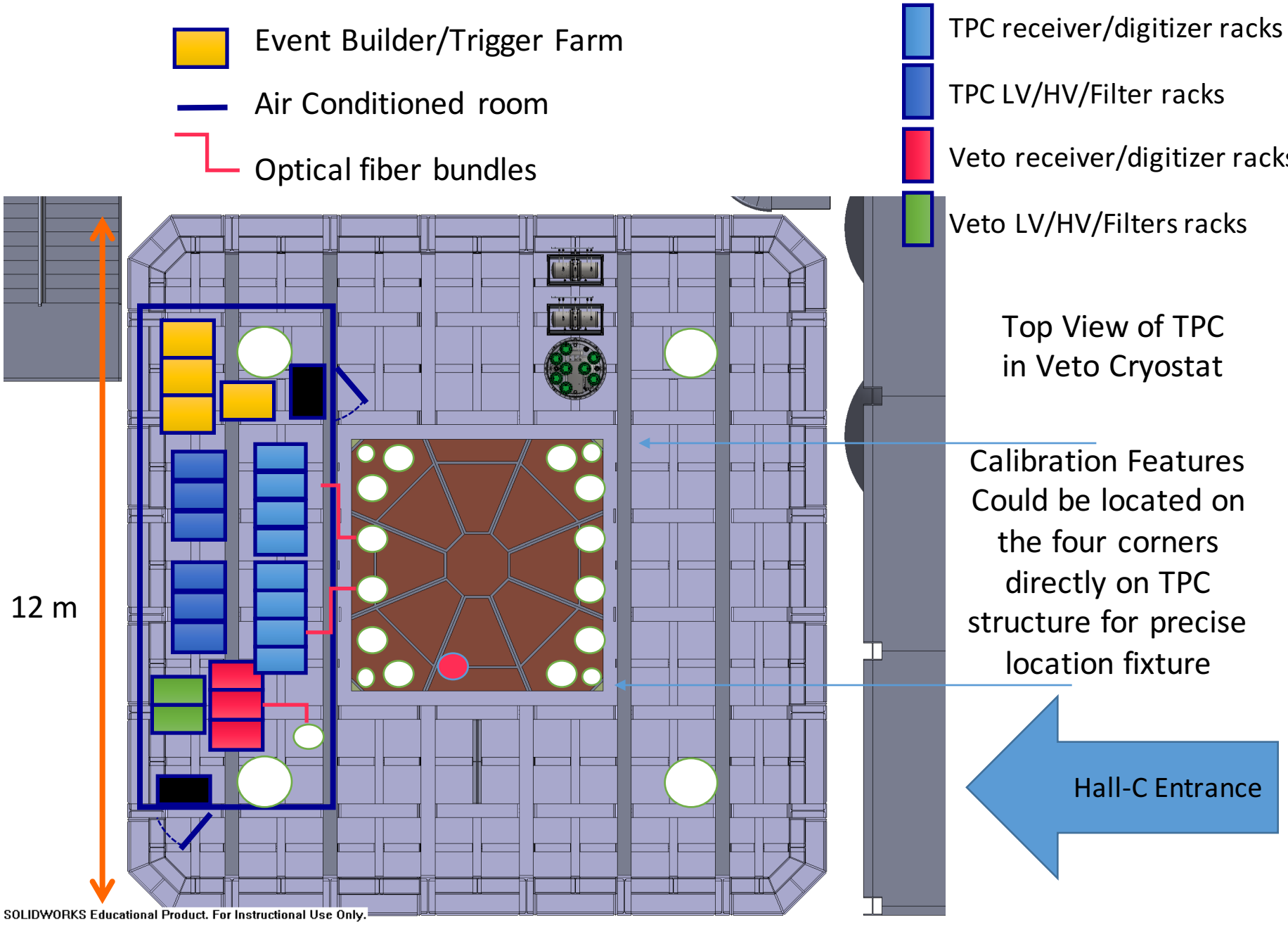




x16



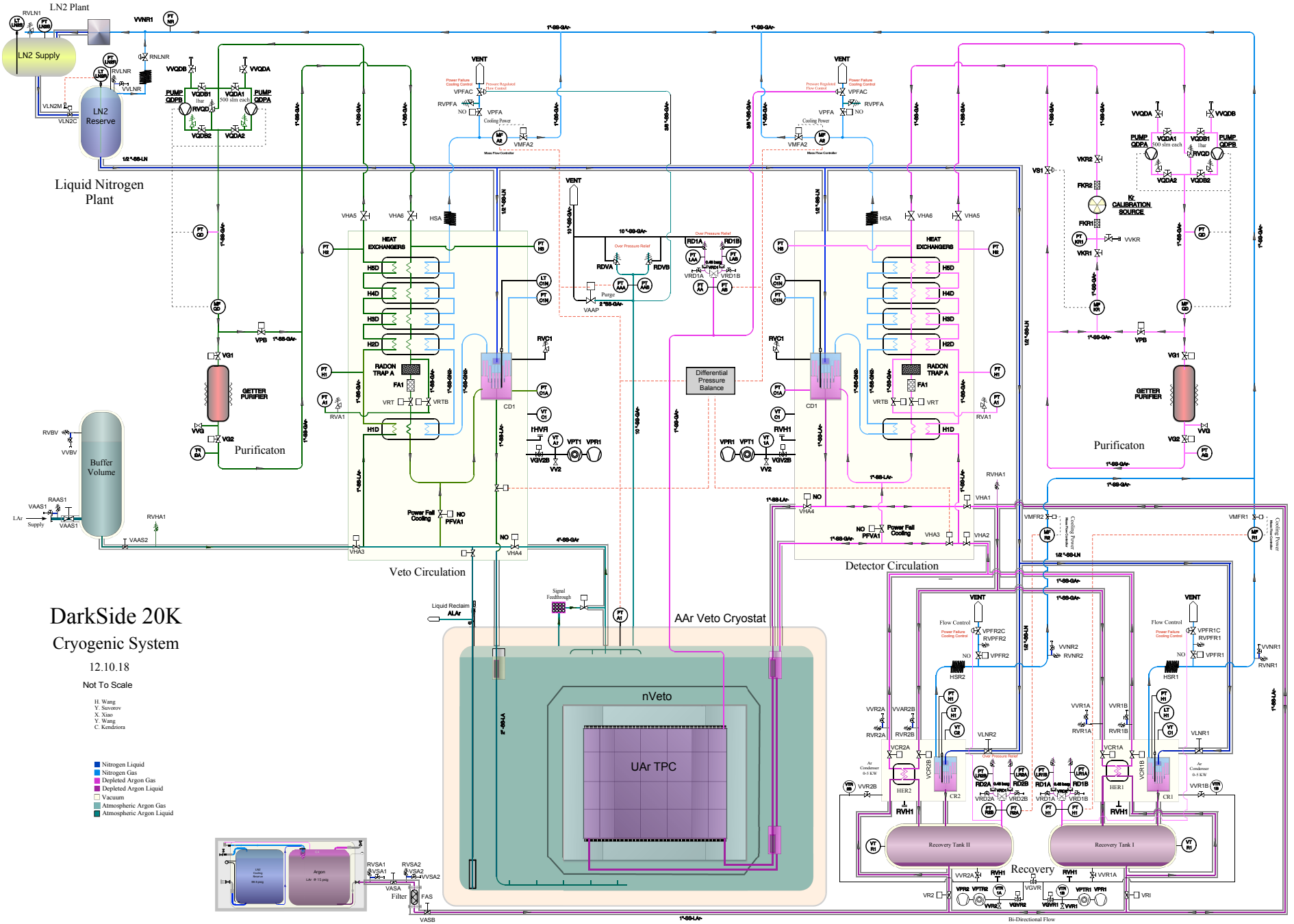

DarkSide-20k
UAr Condenser
Circulation
Gas Pumps
n-Capture
Acrylic-Gd
TPC
Cryostat
Optical & EM
Barrier
nVeto Readout System
Not Shown


Event Builder/Trigger Farm
Air Conditioned room
Optical fiber bundles
TPC receiver/digitizer racks
TPC LV/HV/Filter racks
Veto receiver/digitizer racks
Veto LV/HV/Filters racks
Top View of TPC in Veto Cryostat
Calibration Features Could be located on the four corners directly on TPC structure for precise location fixture
Hall-C Entrance
12 m
SOLIDWORKS Educational Product. For Instructional Use Only.

Cryogenics System

DarkSide 20K Cryogenic System Specifications

- **System is designed to be safe during total power loss**
  - This feature was proven in DarkSide-50 which included a UPS failure
- **Efficient cooling for the entire system**
  - Efficient heat recovery, low total power consumption
- **Continuous argon circulation and purification with Radon Trap**
  - >5ms electron lifetime
  - Purification of argon from both **"liquid"** and **gas** phase simultaneously
  - Radon Suppressed (self cooling feature)
- **Redundant recovery system for emergency and Long Term Storage**
  - Two identical independent recovery systems for redundancy
  - Long term storage in recovery tank
  - Pre-purify argon if needed while UAr is in the recovery system
- **Stable gas pressure in TPC (S2 stability)**
- **Provide Cooling for SiPM PDM and Cold Electronics**
- **LN2/Ar heat Exchanger Condenser (cold source: LN2)**
- **Circulation Driven by "fails safe (UAr)" gas pump**


LN2 Plant
LN2 Supply
LN2 Reserve
Liquid Nitrogen Plant
Purificaton
Buffer Volume
Veto Circulation
Differential Pressure Balance
Detector Circulation
Purificaton
AAr Veto Cryostat
nVeto
UAr TPC
Recovery Tank II
Recovery Tank I
Recovery
Kr CALIBRATION SOURCE
DarkSide 20K
Cryogenic System
12.10.18
Not To Scale
H. Wang
Y. Suvorov
X. Xiao
Y. Wang
C. Kendziora
Nitrogen Liquid
Nitrogen Gas
Depleted Argon Gas
Depleted Argon Liquid
Vacuum
Atmospheric Argon Gas
Atmospheric Argon Liquid
Bi-Directional Flow

DarkSide UAr Cryogenics System Baseline Concept

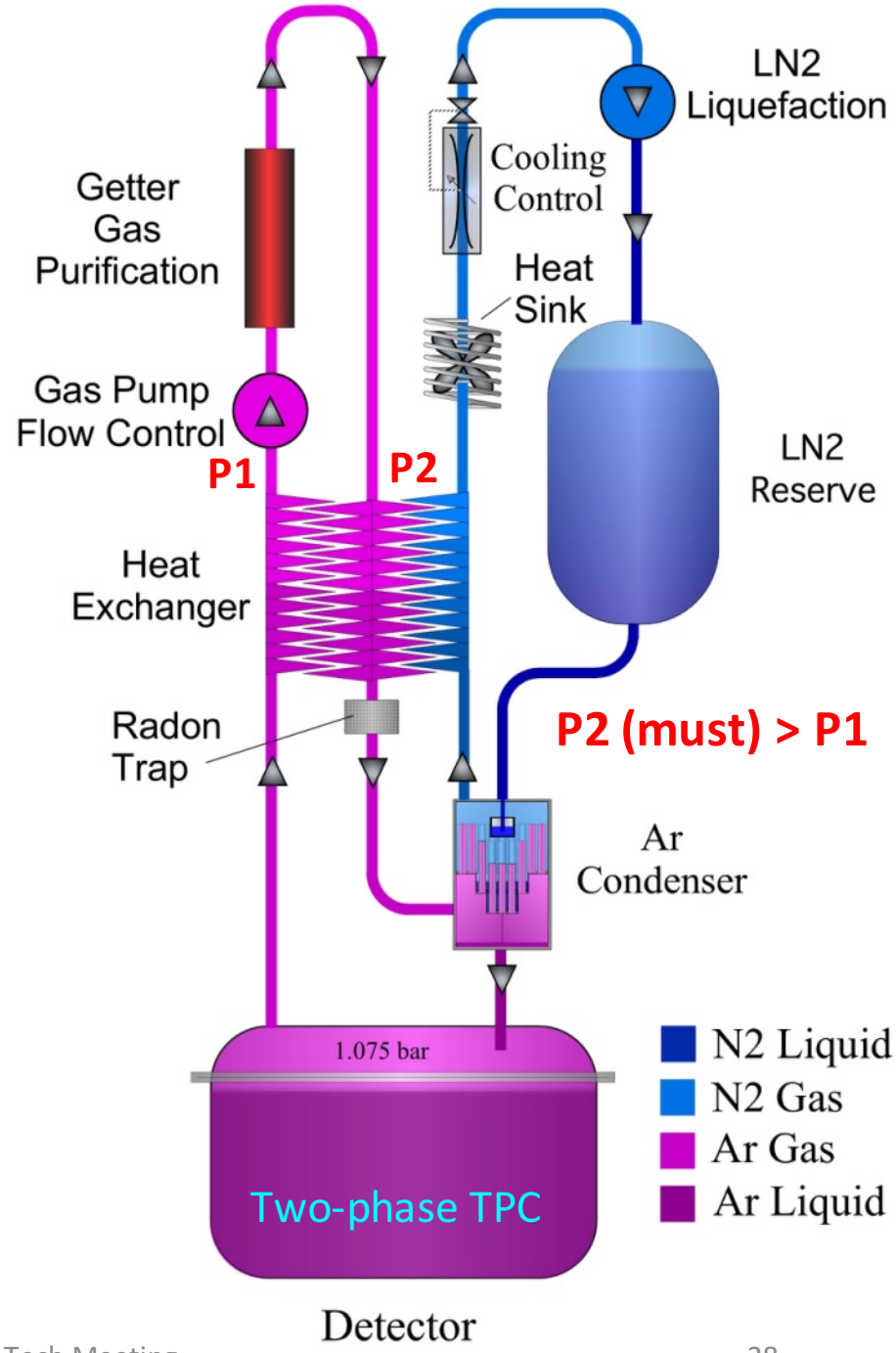
Scale 50kg TPC to 20T TPC

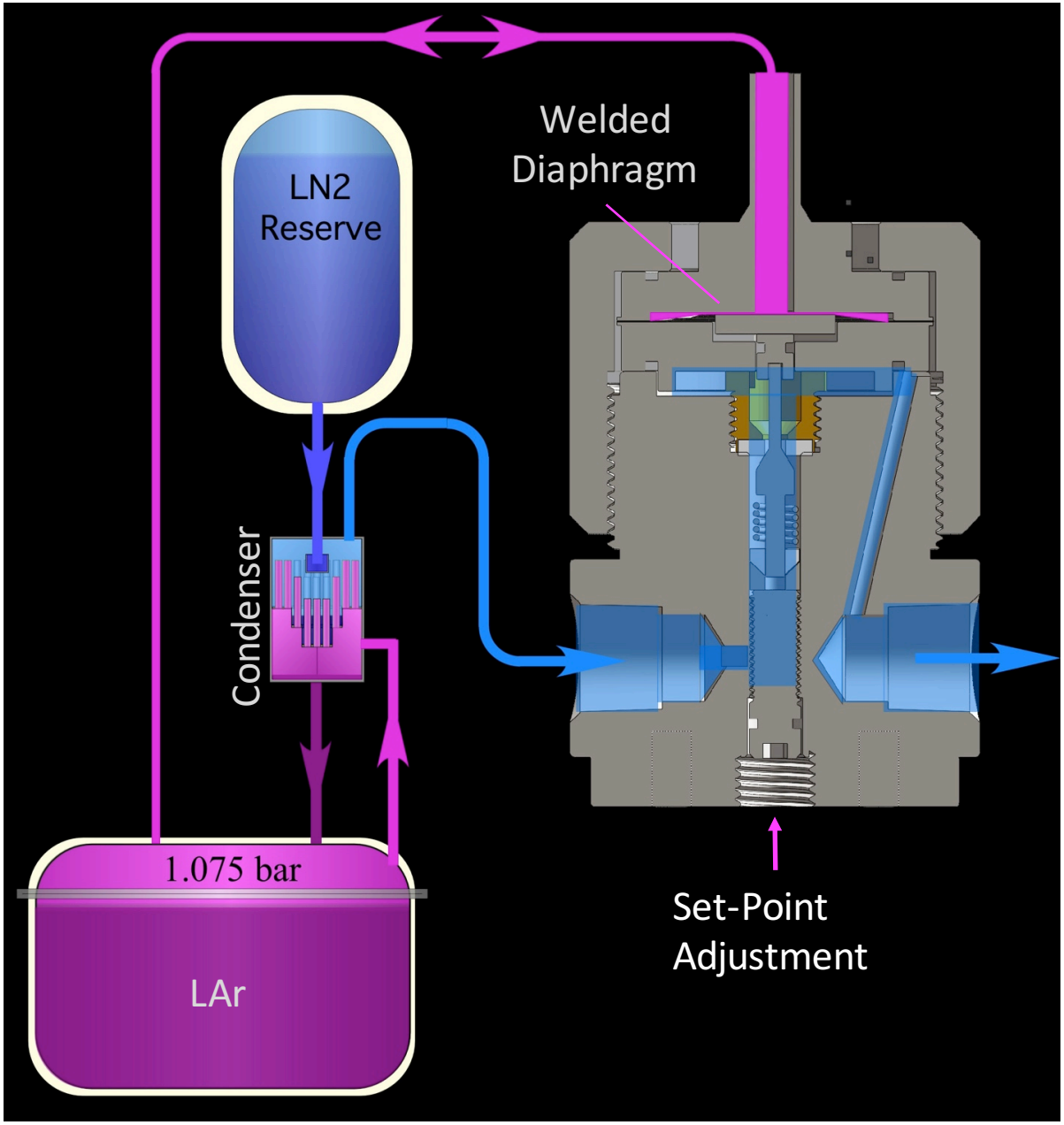
DS-50	30 slm	(77 kg/day)
DS-20k UAr	1000 slm	(2.5 ton/day)
DS-20k AAr	10,000 slm	(25 ton/day)

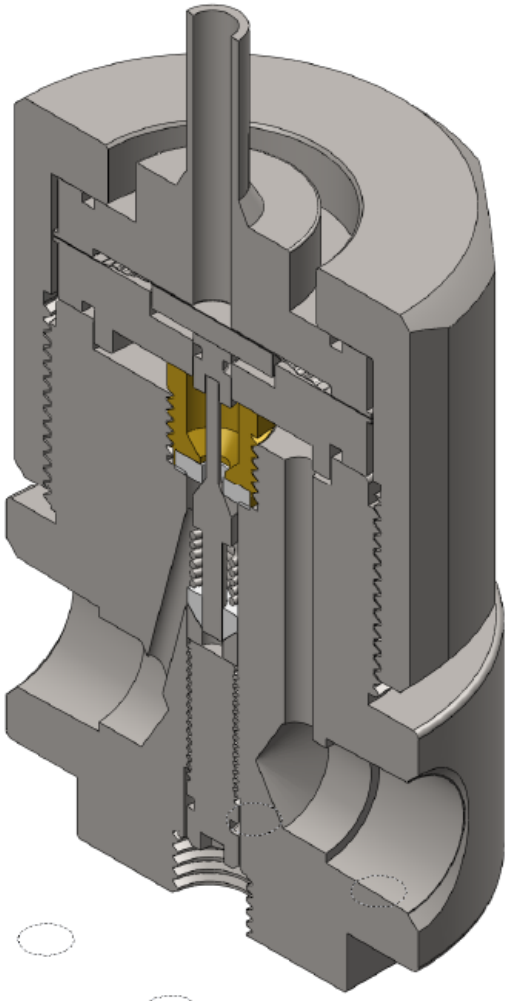
~20 day turnaround

Cryo & Gas Handling System with Major Upgrade compared to DS-50

- LN2 as cooling source (closed loop)
- Ar Purification (closed loop)
- Ar Condenser (LN2 heat-exchange)
- LAr Delivery
- Radon Filter (self cooling trap)
- Full heat recovery
- Remote location (material background)



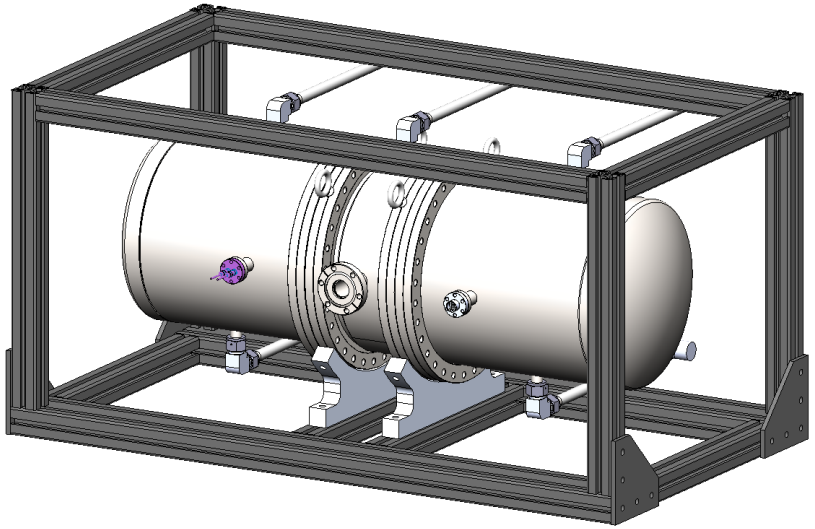




Passive Cooling Power
Control Valve

The first DarkSide-20k Gas Circulation Pump

- First pump main body fabrication completed
- Initial low voltage run tested
- Pump shaped to CERN



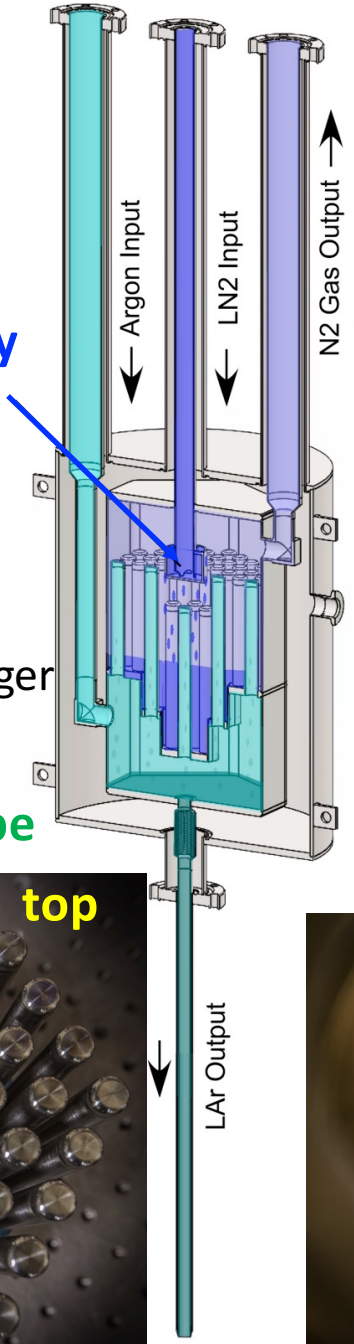
DarkSide-20k Argon Condenser Concept and build

100% Stainless Steel

By design there are:

1. No heater controls,
2. No "temperature" sensors

Chicken Feeder
Auto LN2 Delivery



GN2 vent flow control determines cooling power

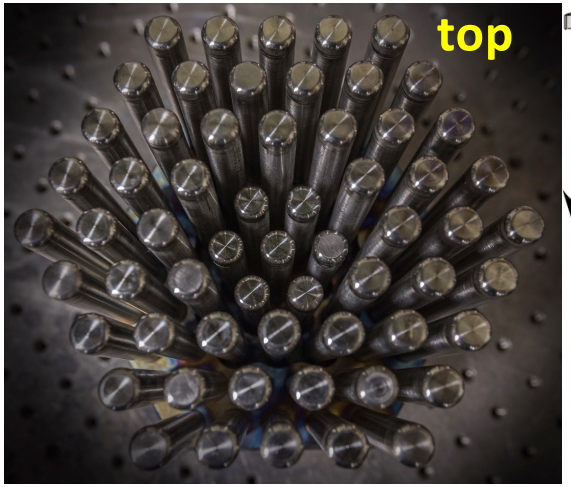
Liquid argon fast drop no freezing above triple point pressure
LN2 level auto balance

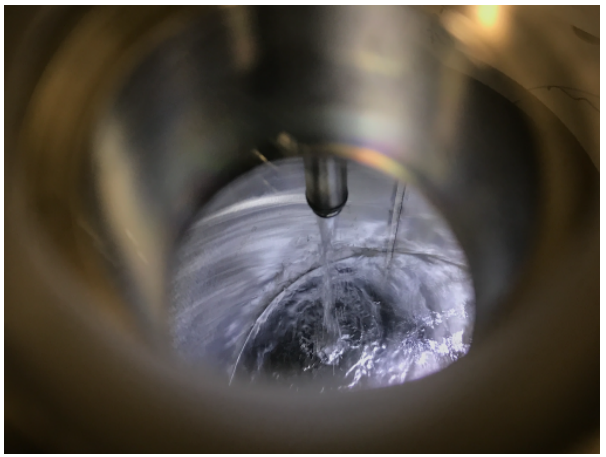
Integrated N2 and Ar pressure sensor ports

2.2 kW latent heat only
4.7 kW with heat exchanger

Argon "inside tube"

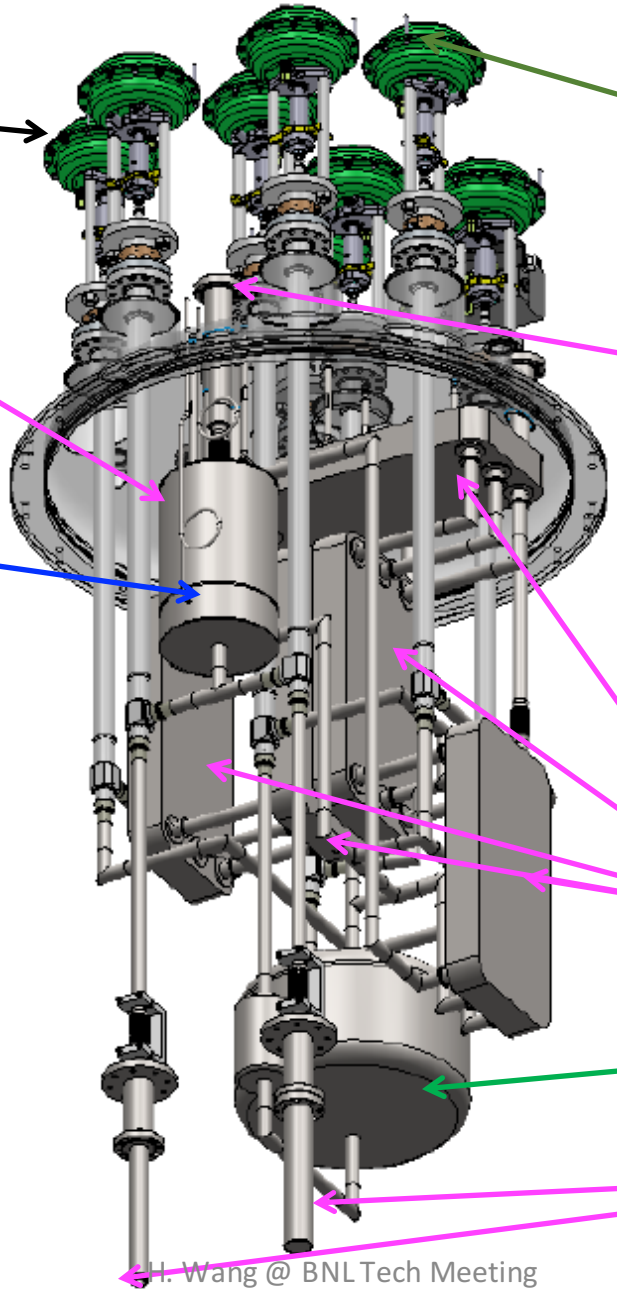
LN2 "out side" tube





https://youtu.be/Be9Uy3UDfsI

DarkSide-20k Condenser Cold Box



Pneumatic Proportional Valve

Pneumatic Control Valves (On/Off)

3 Warm ports

LN2 Inlet

Upgraded Condenser

Tests planned as soon as build

UAr ColdBox Final Design Pending Collaboration Review Before Final Assembly

Heat Exchangers

Parts Order being placed this week

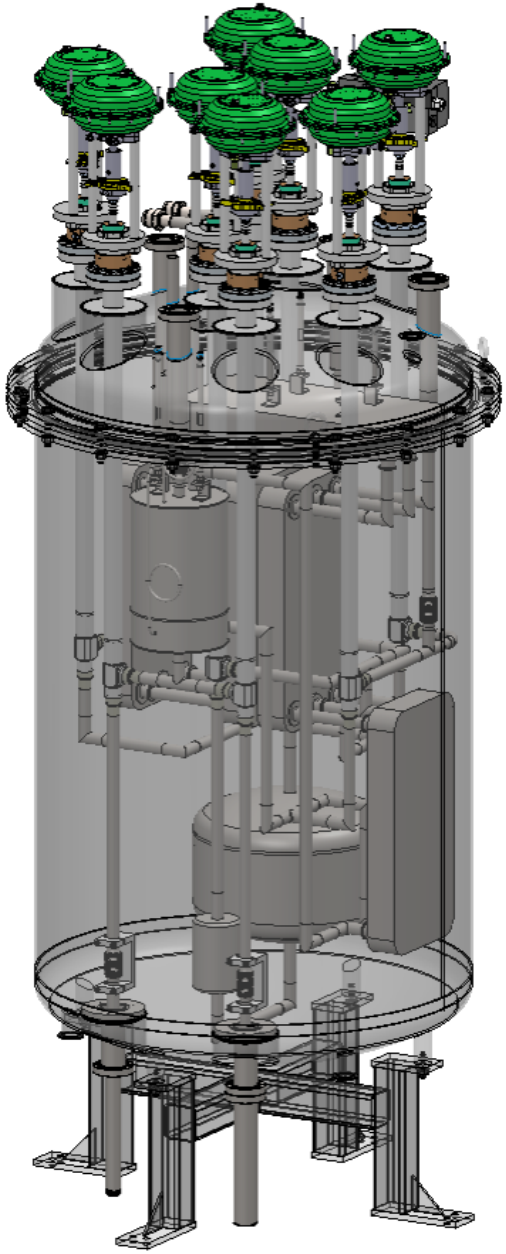
Radon Trap

LAr outlet

Xiang@UCLA

Condenser Cold Box for DarkSide-20k Inner Detector

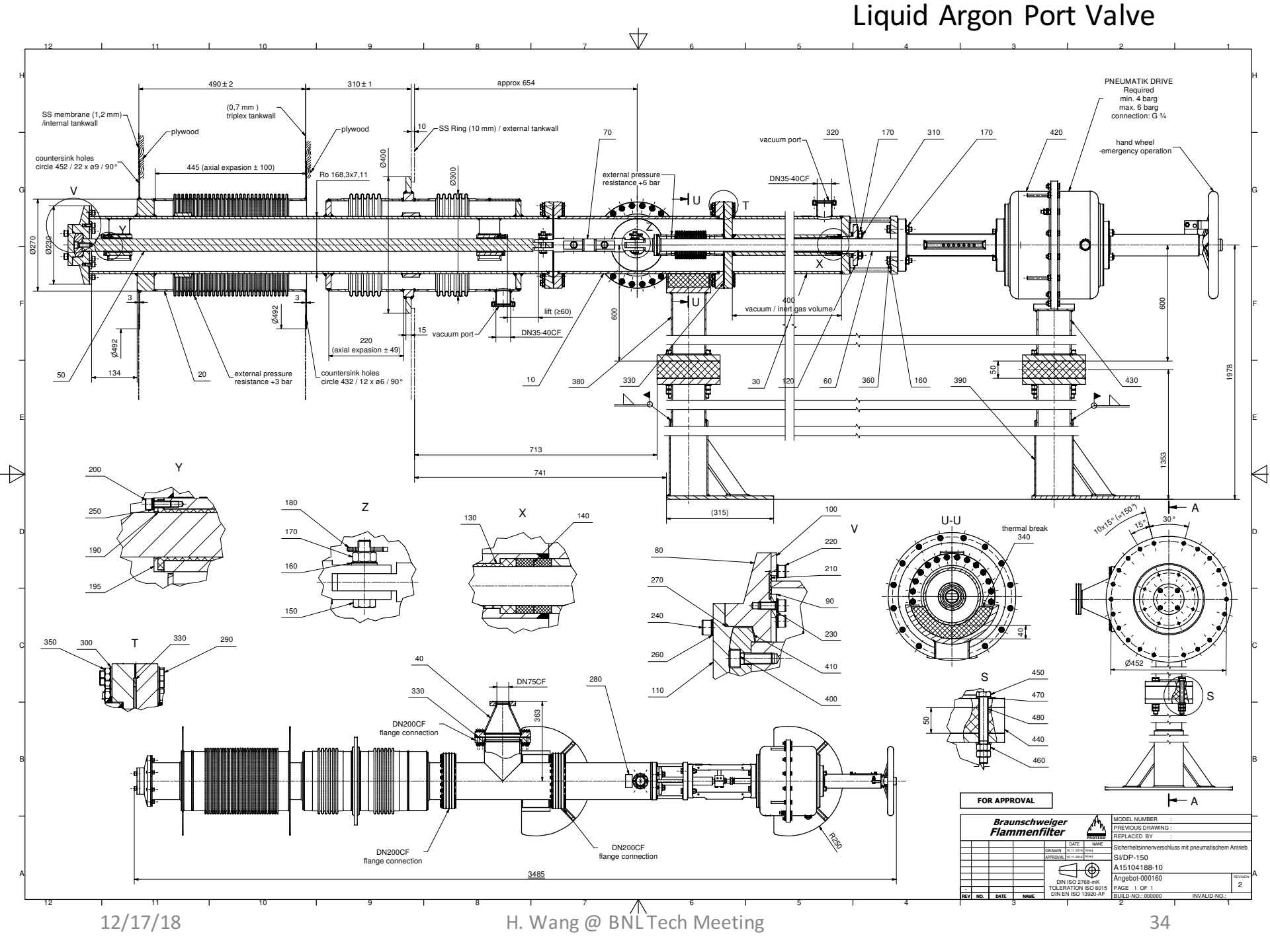
- A modular unit integrates a condenser, a radon trap and a heat exchanger set.
- The total cooling power is 10 kW and the radon trap is passively cooled at ~110 K.
- The cooling power is adjustable from 0 W to full scale capability (~10 kW) by controlling the LN2 vapor gas flow using a MFC operating at room temperature (after the heat-exchanger).
- The cold box engineering details is finalized and parts are at CERN ready for welding.
- With integrated radon trap



102D x 248H (cm)

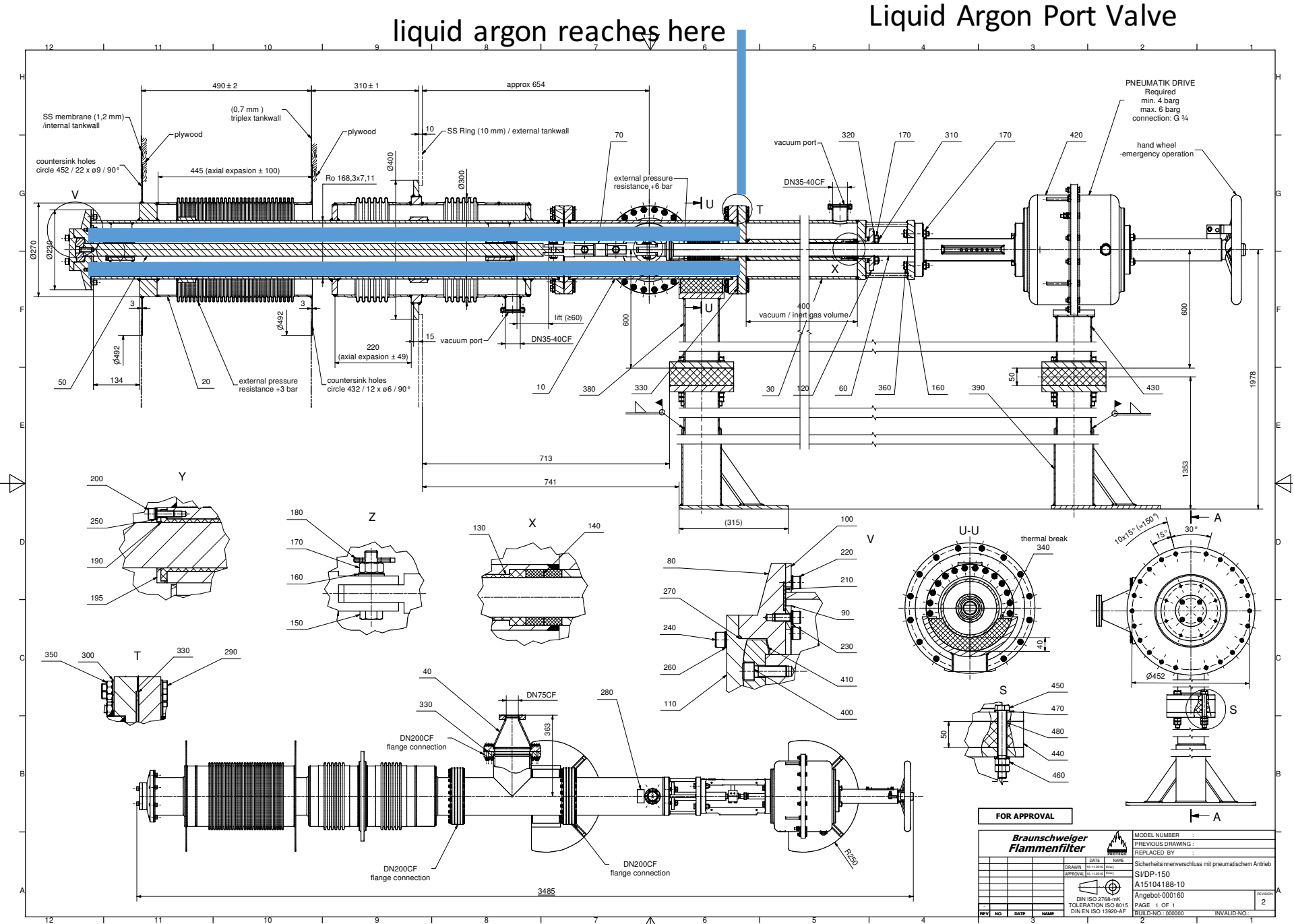
A design report can be found here.
A test report of SS condenser can be found here.

Liquid Argon Port Valve



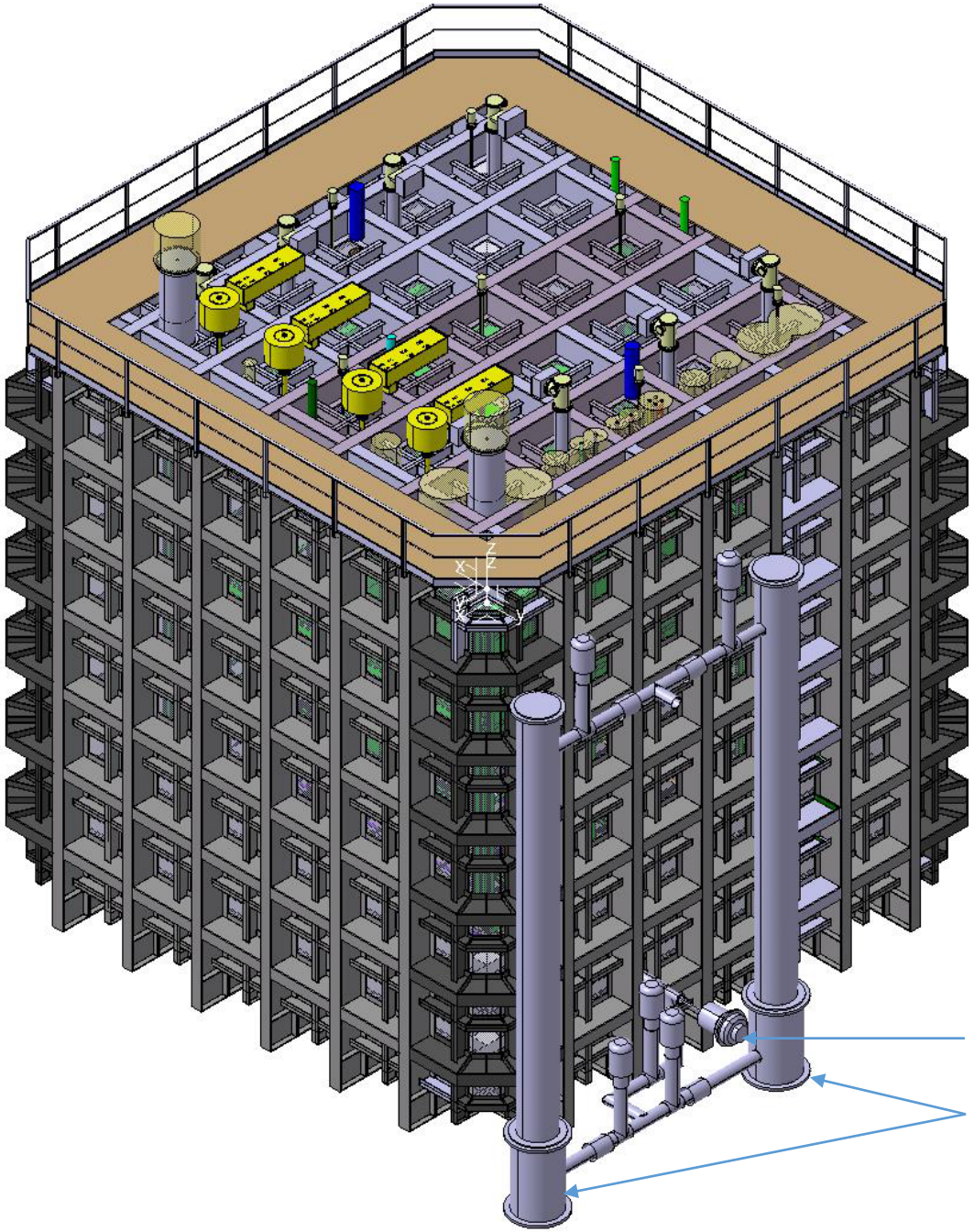
liquid argon reaches here

Liquid Argon Port Valve



Liquid Port Installation before foam was installed

Current Installation at ProtoDUNE

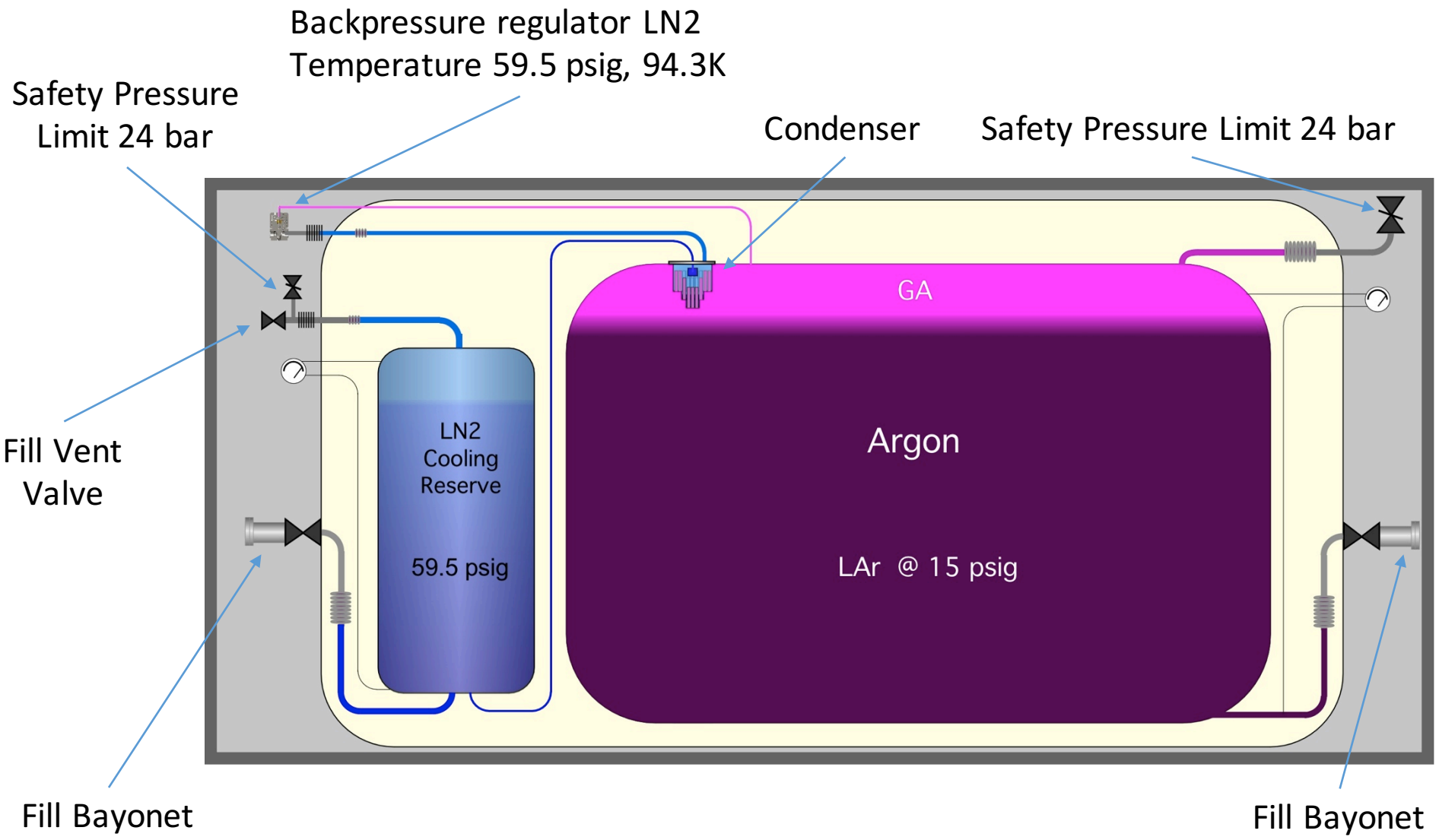


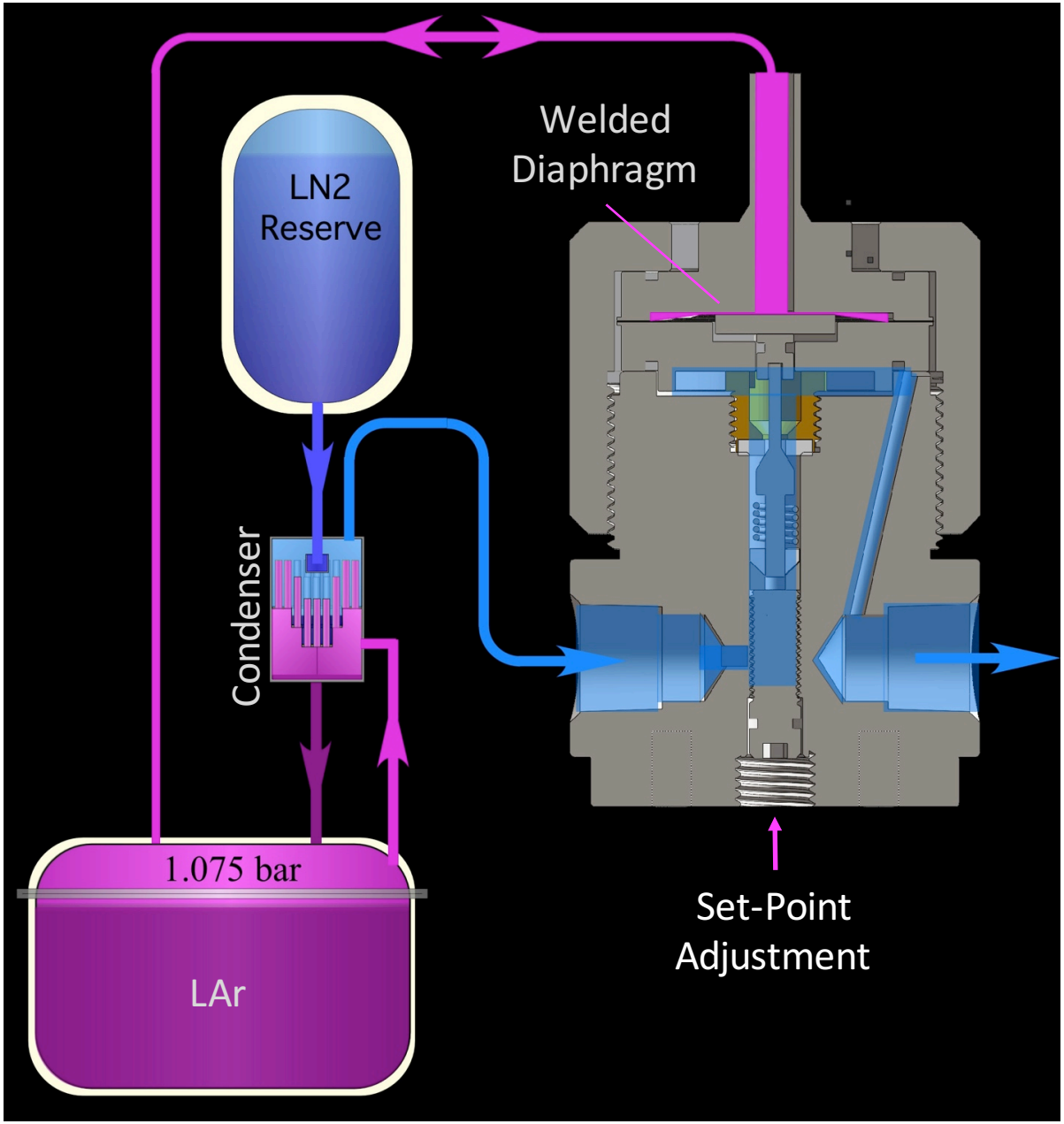
Underground Argon Transportation

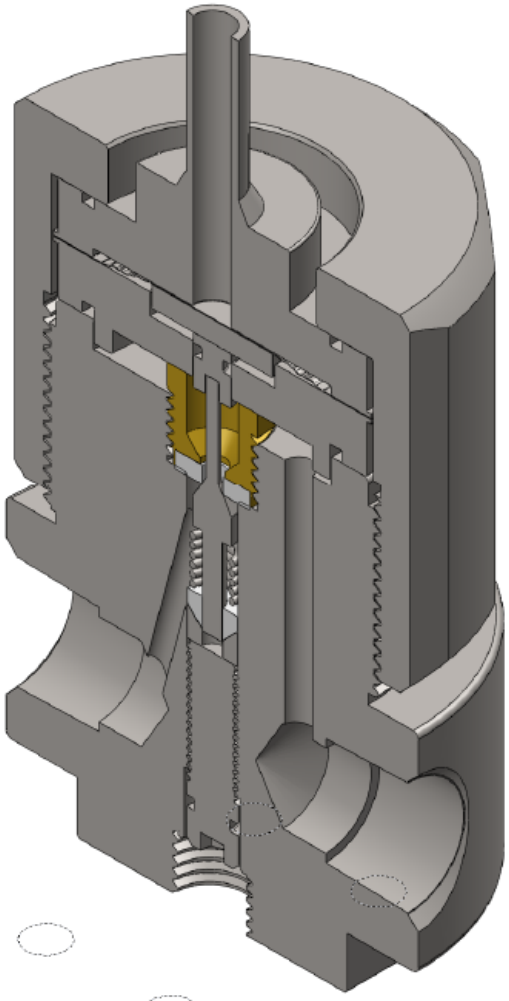
90 day zero loss transportation tank

Cryogenic Shipping Container Concept

Passive Pressure Regulated Safety system



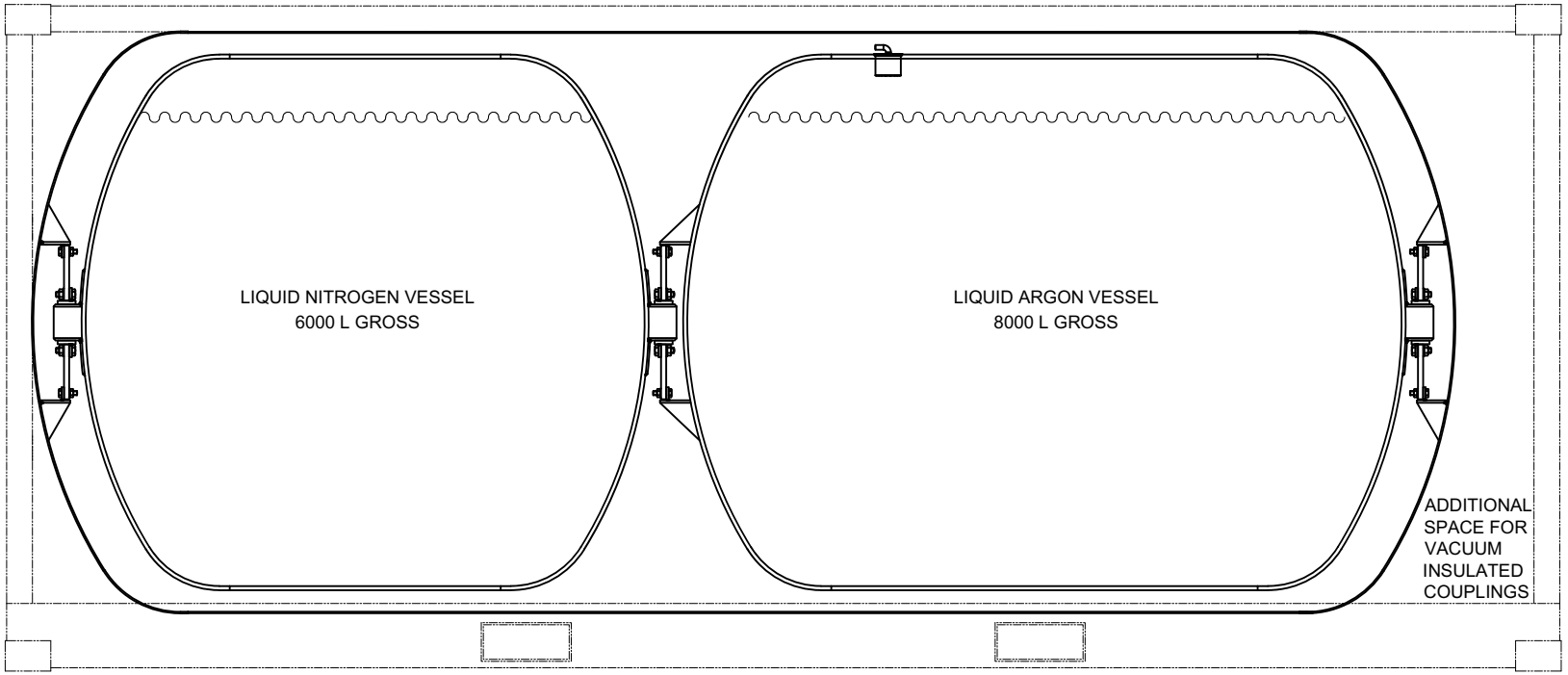




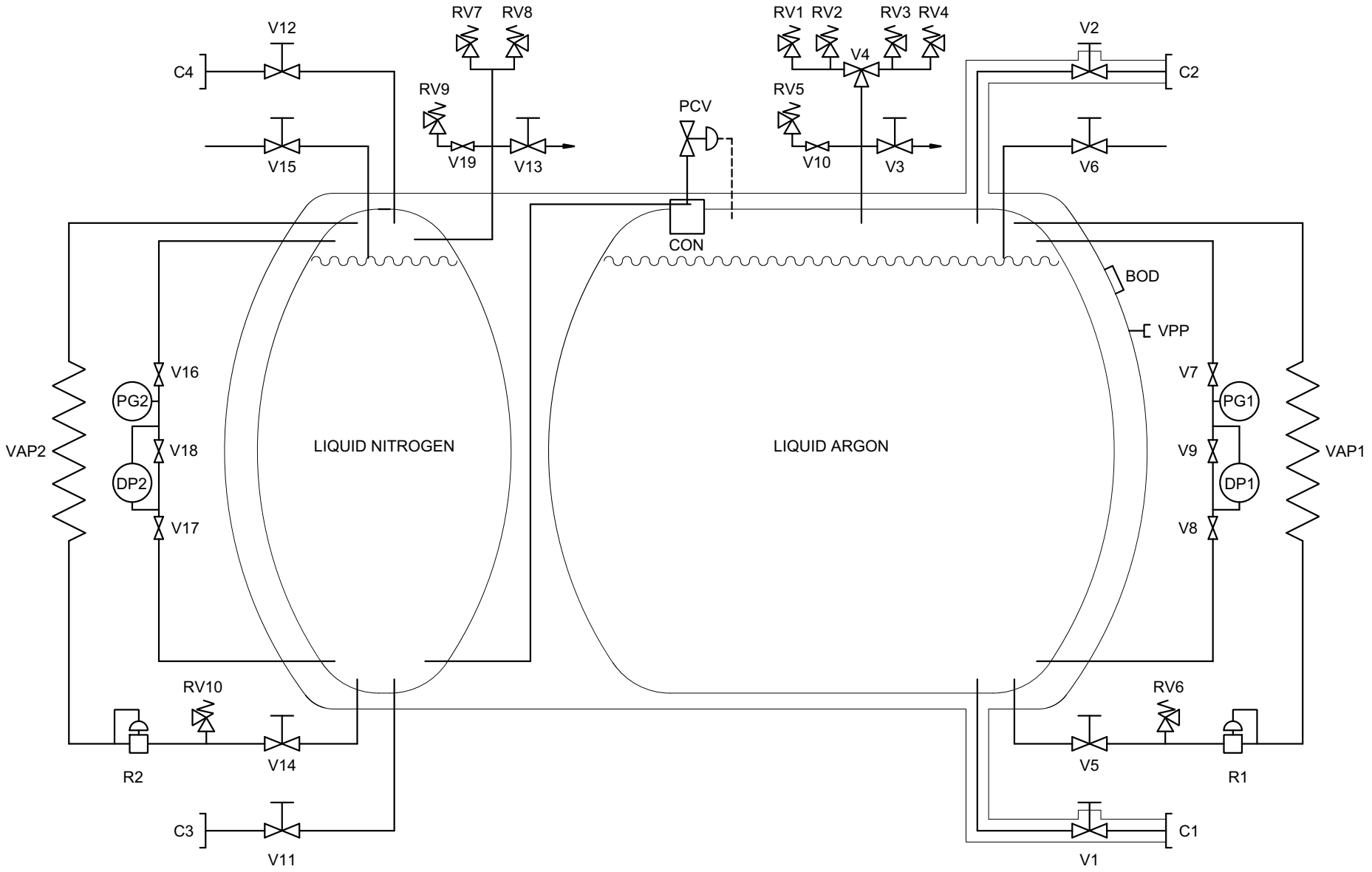
Passive Cooling Power
Control Valve

Custom designed cryogenic shipping vessel (Wessington Cryogenics)
Standard 20 ft ISO shipping format with international land and sea certifications

Zero Boil Off During Transportation (up to ~80 days + xx day before reaching pressure relieve setting)



~10 ton capacity



SCHEMATIC DIAGRAM

Wessington Cryogenics Ltd
Project Dual Tank Argon Heat Load

Calculations By: Paul Charlton
Calculations Date: 28/07/2017

Ambient temperature	**18**	°C
	291	K
Liquid Content	**Argon**	
Liquid Density @ 1 Bar **(kg/m³)**	**1395.40**	kg/m³
Inner Vessel Capacity **(Litres)**	**7895**	Litres
Cold temperature	**-185.85**	°C
	87.30	K
Latent Heat of Vaporisation **(Kj/Kg)**	**161.14**	Kj/Kg

requires 66W cooling

	THERMAL RADIATION	CONDUCTION HEAT LOADS											
	Insulation Inner Vessel	Pipeline A	Pipeline B	Pipeline C	Pipeline D	Pipeline E	Pipeline F	Pipeline G	Pipeline K	Pipeline L	Pipeline M	9070-0000-4-7- Anti Rotation	9070-0000-4-5 End Support
Quantity	1	1	1	1	1	1	1	1	1	1	1	2	1
Insulation condition	Normal Insulation												
Flux Density **(Watts/m²)**	2.037												
Min Temperature **(K)**	87.30	87.30	87.30	87.30	87.30	87.30	87.30	87.30	87.30	87.30	87.30	87.30	87.30
Max Temperature **(K)**	291	291	291	291	291	291	291	291	291	291	291	291	291
Material		STAINLESS STEEL - Average types 303, 304, 316, 347	STAINLESS STEEL - Average types 303, 304, 316, 347	STAINLESS STEEL - Average types 303, 304, 316, 347	STAINLESS STEEL - Average types 303, 304, 316, 347	STAINLESS STEEL - Average types 303, 304, 316, 347	STAINLESS STEEL - Average types 303, 304, 316, 347	STAINLESS STEEL - Average types 303, 304, 316, 347	STAINLESS STEEL - Average types 303, 304, 316, 347	STAINLESS STEEL - Average types 303, 304, 316, 347	STAINLESS STEEL - Average types 303, 304, 316, 347	EFR4	EFR4
Length **(mm)**		500	2000	1000	2000	1000	2000	500	500	1000	2000	10.00	215.00
O/D **(mm)** / Width **(mm)**		48.3	48.3	21.3	60.3	8	8	26.7	48.3	21.3	48.3	70	600
I/D **(mm)**												50	170
Thickness **(mm)**		2.77	2.77	2.11	2.77	1	1	2.11	2.77	2.11	2.77	4	20
Min Intergral **(Watts/cm)**		4.125	4.125	4.125	4.125	4.125	4.125	4.125	4.125	4.125	4.125	0.165	0.165
Min Intergral **(Watts/m)**		412.5285853	412.5285853	412.5285853	412.5285853	412.5285853	412.5285853	412.5285853	412.5285853	412.5285853	412.5285853	16.46366223	16.46366223
Max Intergral **(Watts/cm)**		29.304	29.304	29.304	29.304	29.304	29.304	29.304	29.304	29.304	29.304	0.864	0.864
Max Intergral **(Watts/m)**		2930.4	2930.4	2930.4	2930.4	2930.4	2930.4	2930.4	2930.4	2930.4	2930.4	86.35	86.35
Cross Sectional Area **(mm²)**	19876594.84	396.21	396.21	127.21	500.64	21.99	21.99	163.00	396.21	127.21	396.21	753.98	24190.26
Cross Sectional Area **(m²)**	19.8766	0.0004	0.0004	0.0001	0.0005	0.0000	0.0000	0.0002	0.0004	0.0001	0.0004	0.0008	0.0242
Heat Inleak, Q **(Watts)**	**40.488**	**1.995**	**0.499**	**0.320**	**0.630**	**0.055**	**0.028**	**0.821**	**1.995**	**0.320**	**0.499**	**5.269**	**7.863**
Heat Inleak, Q x Qty **(Watts)**	**40.488**	**1.995**	**0.499**	**0.320**	**0.630**	**0.055**	**0.028**	**0.821**	**1.995**	**0.320**	**0.499**	**10.539**	**7.863**
Proportion	61.30%	3.02%	0.76%	0.48%	0.95%	0.08%	0.04%	1.24%	3.02%	0.48%	0.76%	15.95%	11.90%

Total Heat Inleak

Q - Total **(Watts)**	66.053
1 Watt will Evap approx **(Ltrs/Day)**	0.384
Evaporation Rate **(% Per Day)**	**0.32%**
Evaporation Rate **(Litres Per Day)**	25.38
Evaporation Rate **(cc/min)**	12214.60

Thermal Budget Design Calculation (LAr)
requires 35L-LN2/day to keep it not boiling

Wessington Cryogenics Ltd
Project Dual Tank Nitrogen
Heat Load

Calculations By: Paul Charlton
Calculations Date: 27/07/2017

Ambient temperature	18	°C
	291	K
Liquid Content	Nitrogen	
Liquid Density @ 1 Bar **(kg/m³)**	806.08	kg/m³
Inner Vessel Capacity **(Litres)**	7895	Litres
Cold temperature	-195.80	°C
	77.35	K
Latent Heat of Vaporisation **(Kj/Kg)**	199.18	Kj/Kg

	THERMAL RADIATION	CONDUCTION HEAT LOADS											
	Insulation Inner Vessel	Pipeline A	Pipeline B	Pipeline C	Pipeline D	Pipeline E	Pipeline F	Pipeline G	Pipeline K	Pipeline L	Pipeline M	9070-0000-4-7- Anti Rotation	9070-0000-4-5 End Support
Quantity	1	1	1	1	1	1	1	1	1	1	1	2	1
Insulation condition	Normal Insulation												
Flux Density **(Watts/m²)**	2.136												
Min Temperature **(K)**	77.35	77.35	77.35	77.35	77.35	77.35	77.35	77.35	77.35	77.35	77.35	77.35	77.35
Max Temperature **(K)**	291	291	291	291	291	291	291	291	291	291	291	291	291
Material		STAINLESS STEEL - Average types 303, 304, 316, 347	STAINLESS STEEL - Average types 303, 304, 316, 347	STAINLESS STEEL - Average types 303, 304, 316, 347	STAINLESS STEEL - Average types 303, 304, 316, 347	STAINLESS STEEL - Average types 303, 304, 316, 347	STAINLESS STEEL - Average types 303, 304, 316, 347	STAINLESS STEEL - Average types 303, 304, 316, 347	STAINLESS STEEL - Average types 303, 304, 316, 347	STAINLESS STEEL - Average types 303, 304, 316, 347	STAINLESS STEEL - Average types 303, 304, 316, 347	EFR4	EFR4
Length **(mm)**		500	2000	1000	2000	1000	2000	500	500	1000	2000	10.00	215.00
O/D **(mm)** / Width **(mm)**		48.3	48.3	21.3	60.3	8	8	26.7	48.3	21.3	48.3	70	600
I/D **(mm)**												50	170
Thickness **(mm)**		2.77	2.77	2.11	2.77	1	1	2.11	2.77	2.11	2.77	4	20
Min Intergral **(Watts/cm)**		3.278	3.278	3.278	3.278	3.278	3.278	3.278	3.278	3.278	3.278	0.135	0.135
Min Intergral **(Watts/m)**		327.8399602	327.8399602	327.8399602	327.8399602	327.8399602	327.8399602	327.8399602	327.8399602	327.8399602	327.8399602	13.47262363	13.47262363
Max Intergral **(Watts/cm)**		29.304	29.304	29.304	29.304	29.304	29.304	29.304	29.304	29.304	29.304	0.864	0.864
Max Intergral **(Watts/m)**		2930.4	2930.4	2930.4	2930.4	2930.4	2930.4	2930.4	2930.4	2930.4	2930.4	86.35	86.35
Cross Sectional Area **(mm²)**	19876594.84	396.21	396.21	127.21	500.64	21.99	21.99	163.00	396.21	127.21	396.21	753.98	24190.26
Cross Sectional Area **(m²)**	19.8766	0.0004	0.0004	0.0001	0.0005	0.0000	0.0000	0.0002	0.0004	0.0001	0.0004	0.0008	0.0242
Heat Inleak, Q **(Watts)**	42.465	2.062	0.516	0.331	0.651	0.057	0.029	0.848	2.062	0.331	0.516	5.495	8.200
Heat Inleak, Q x Qty **(Watts)**	42.465	2.062	0.516	0.331	0.651	0.057	0.029	0.848	2.062	0.331	0.516	10.990	8.200
Proportion	61.49%	2.99%	0.75%	0.48%	0.94%	0.08%	0.04%	1.23%	2.99%	0.48%	0.75%	15.91%	11.87%

Total Heat Inleak

Q - Total **(Watts)**	69.058
1 Watt will Evap approx **(Ltrs/Day)**	0.538
Evaporation Rate **(% Per Day)**	0.47%
Evaporation Rate **(Litres Per Day)**	37.16
Evaporation Rate **(cc/min)**	17884.76

Thermal Budget Design Calculation (LN2)
6000L/(37L+35L)=83 days

69W loss + 66W to cool argon