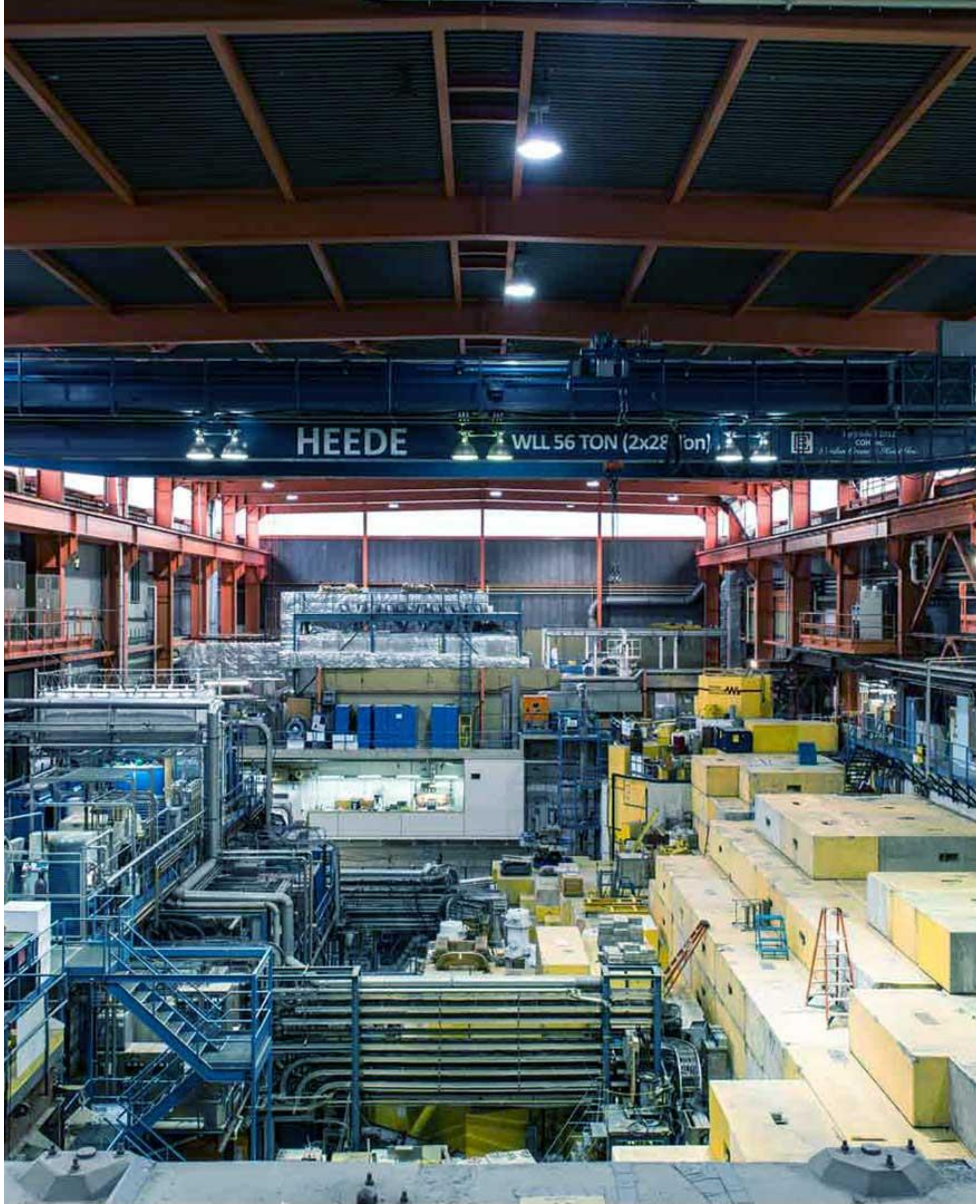
TRIUMF

LD2 System, Tail Assembly, Cryo-Connection Box



Cam Marshall

Engineering Division

2020-01-31

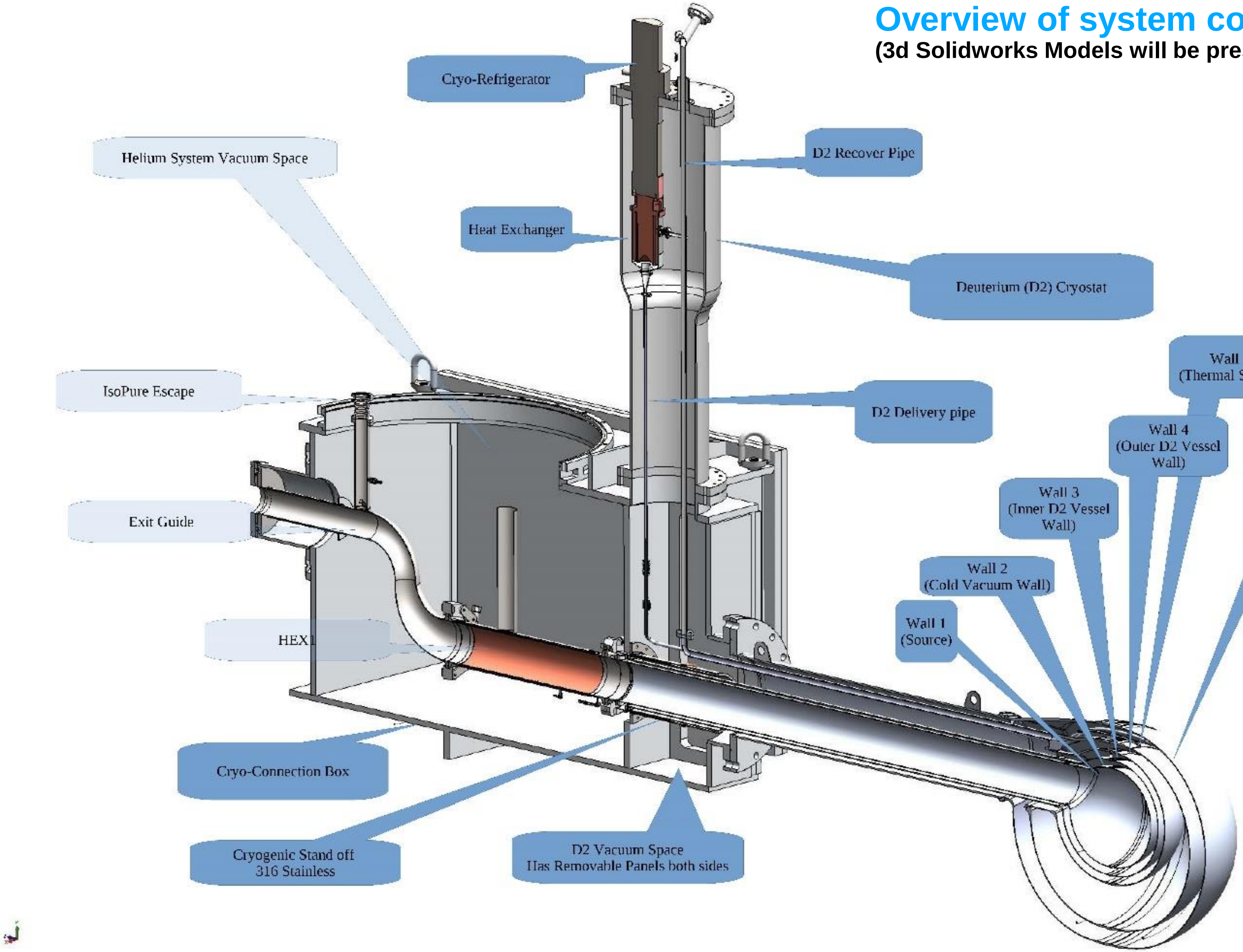
Discovery, accelerated

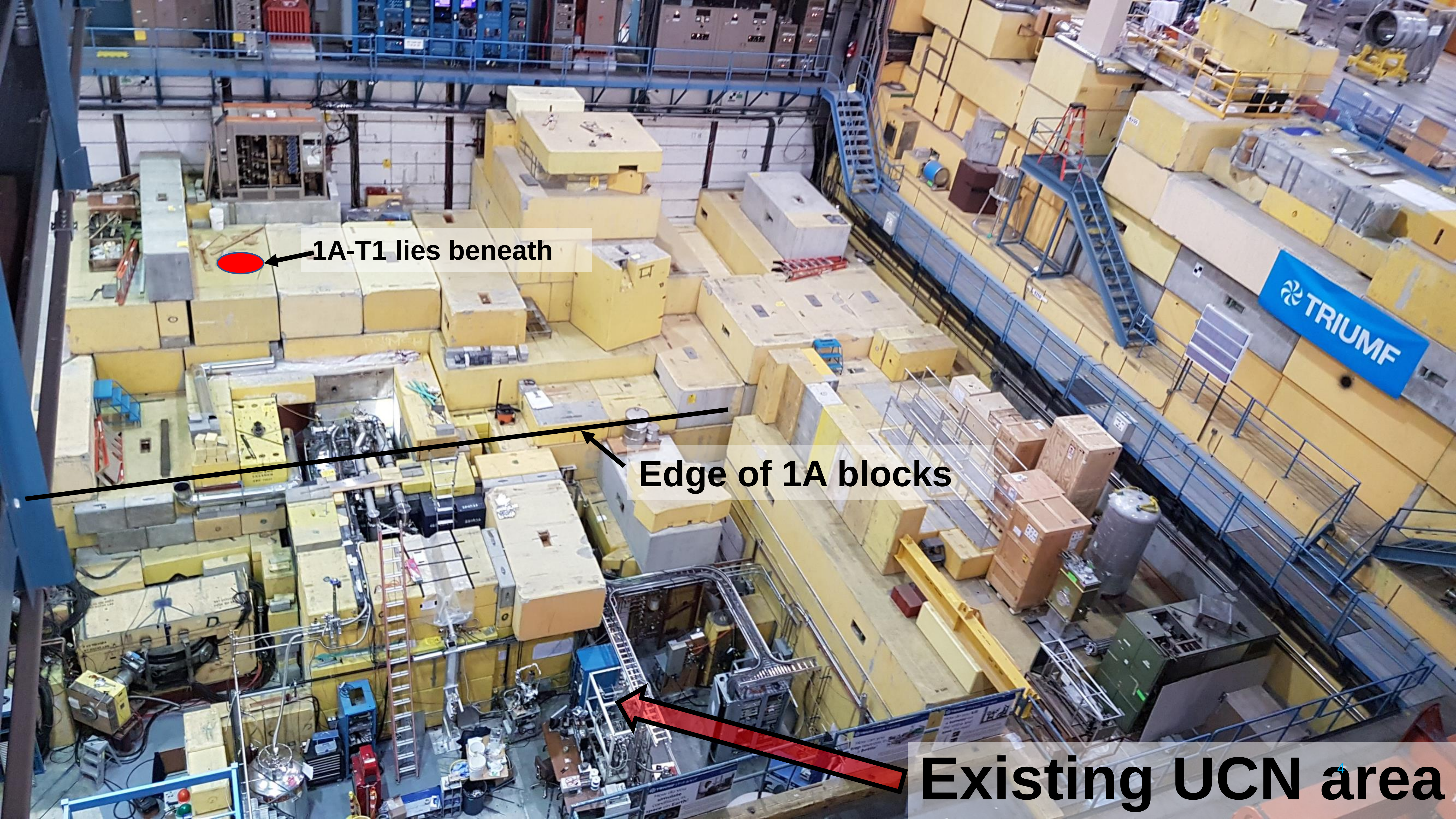
TOPICS

- Overview of components
- Overview of site
- Recap of prior reviews, and present Status
- Challenges
- Upcoming Milestones to meet
- Manpower situation
- Safety

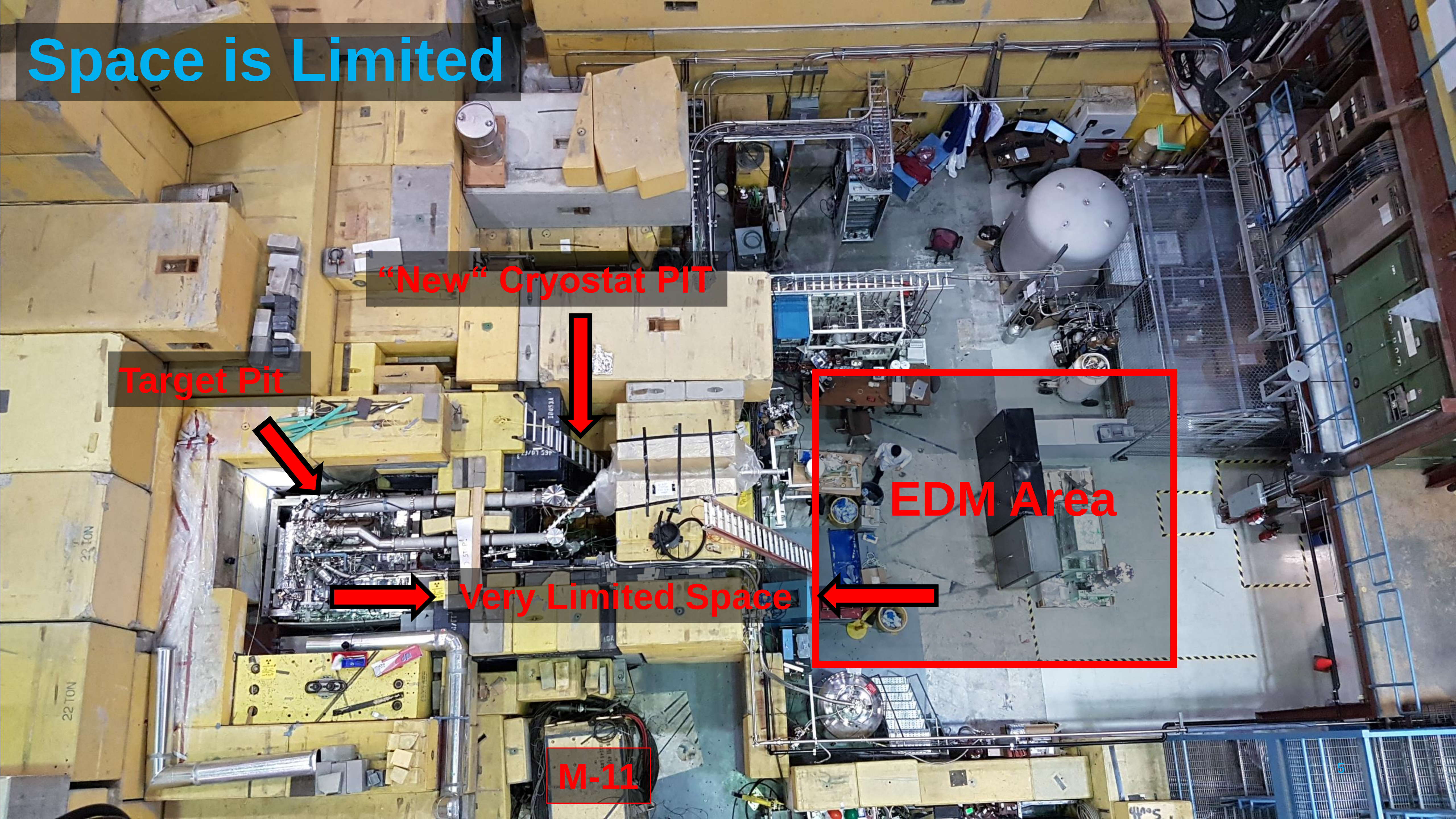
Overview of system components

(3d Solidworks Models will be presented here)




1A-T1 lies beneath
Edge of 1A blocks
Existing UCN area
TRIUMF

Space is Limited



Recap of Prior Meetings

2017 EAC Tokyo
- Basic LD2 concept was in place, but not presented.
- Timeline for development was presented

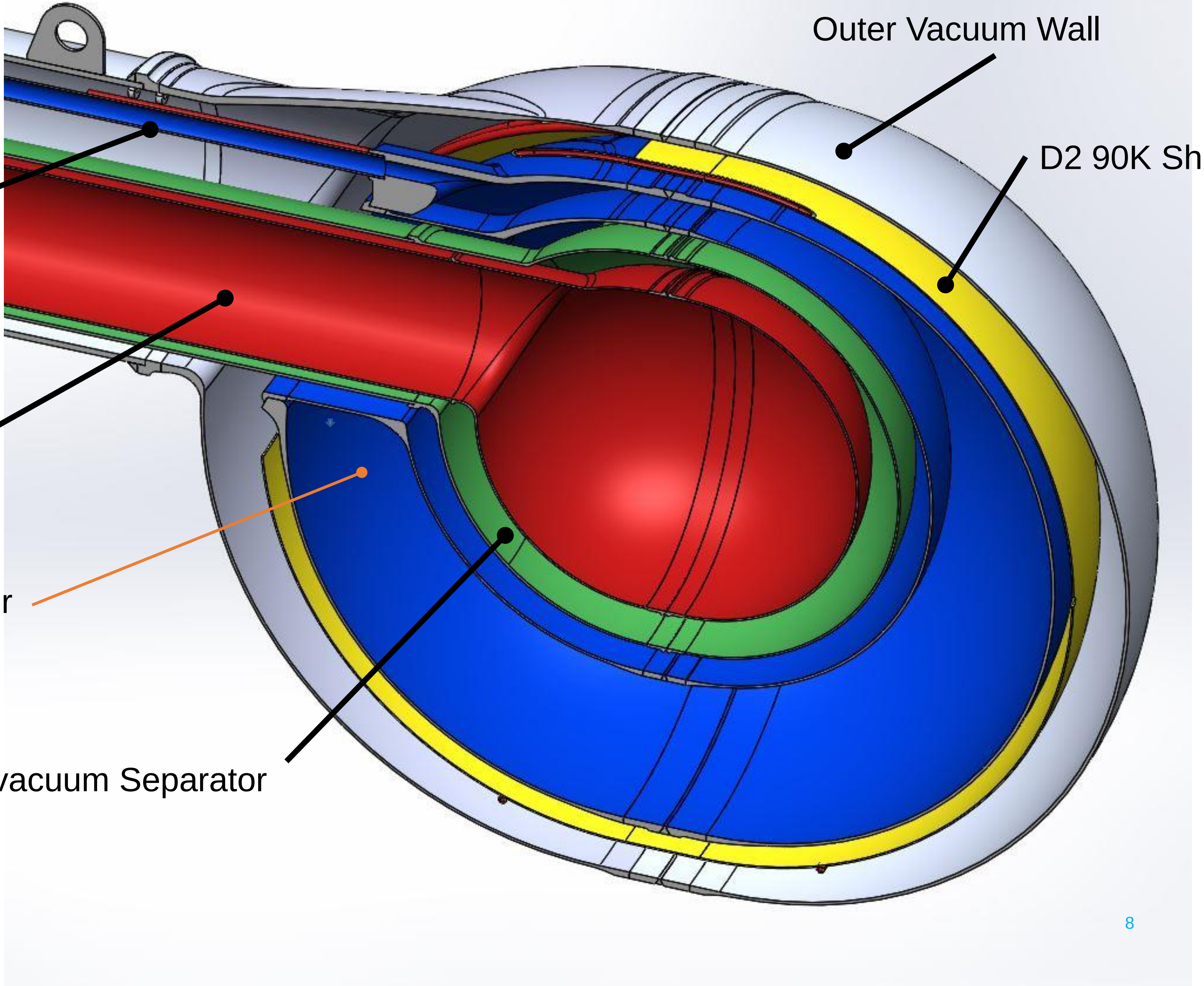
2018 CDR KEK
- LD2 concept presented
- Basic gas schematic, Cooling design, and initial vessel concept presented.

2020 Status overview
- 2017 Timeline was not met due to unplanned Engineering input to:
  - He-II source Development
  - Existing beamline (handover to other groups did not occur)
  - Vertical source UCN experiments to verify designs for new source.
- 2020 Status
  - Process Schematic Complete
  - Heat load Calculations 90%
  - Tail vessel Engineering 90%
  - Cryo-Box Engineering 90%
  - Moderator/Graphite Design 80%

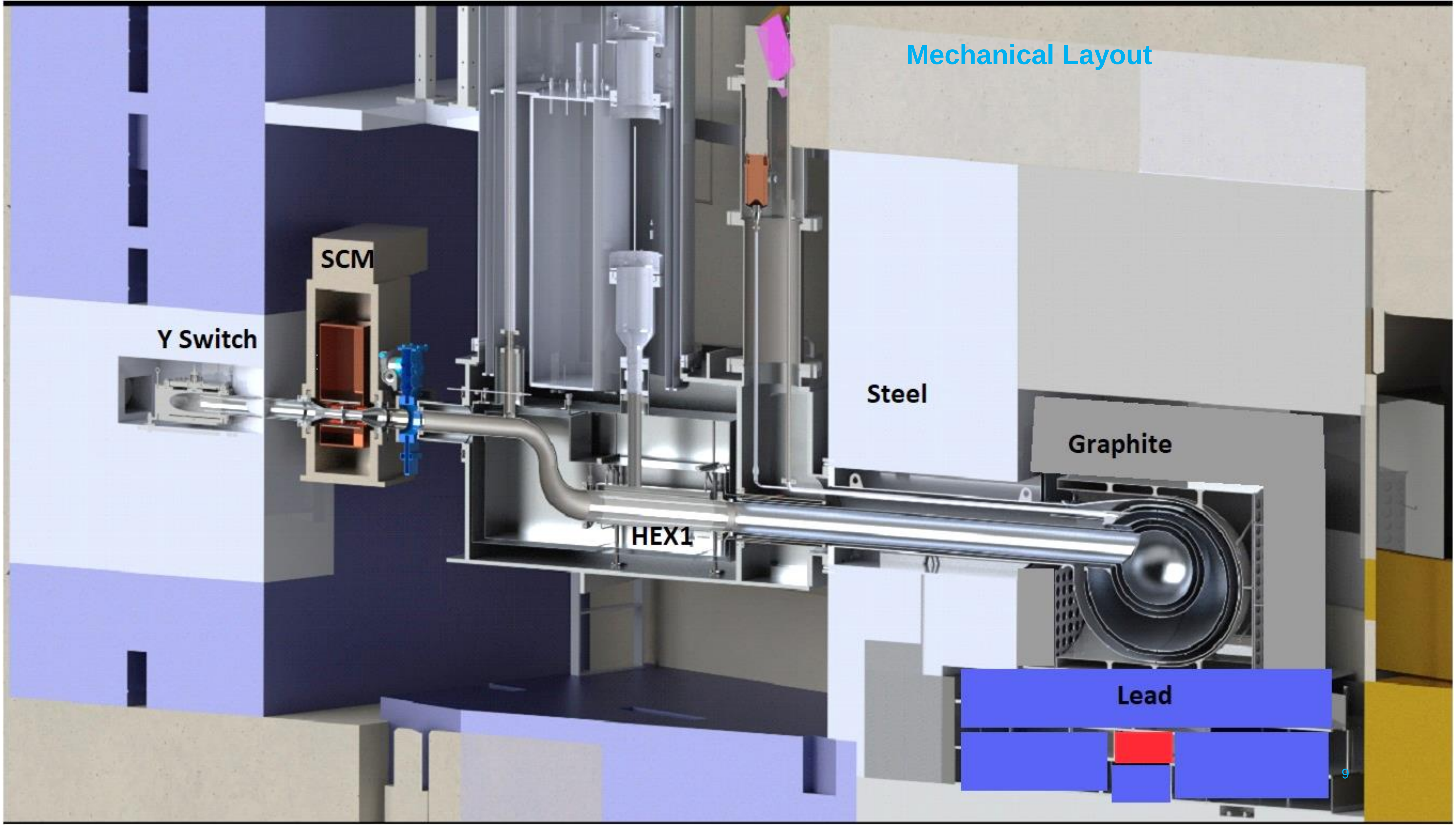
Challenges

- Extremely Complicated "Tail Vessel" assembly.
- High radiation environment
- Achieving High Strength but Low Mass
- UCN compatible surfaces
  - Avoidance of Bends, Gaps, Bellows.
- Minimized length to experiment
- Achieving shielding, but allowing accessibility.

Configuration Details



Mechanical Layout



Engineering Requirements

- Materials to have low Neutron absorption
  - Low loss of UCN neutrons= Higher cold neutron flux in production volume
  - Lower heat input to cryogenics
  - Less activated material = lower dose to personnel
- Requires High strength vs Low mass

Materials Explored> Beryillium, Magnesium, AlBeMet
- All good for physics.
- Avoided due to either welding difficulty, Cost, and or time to develop

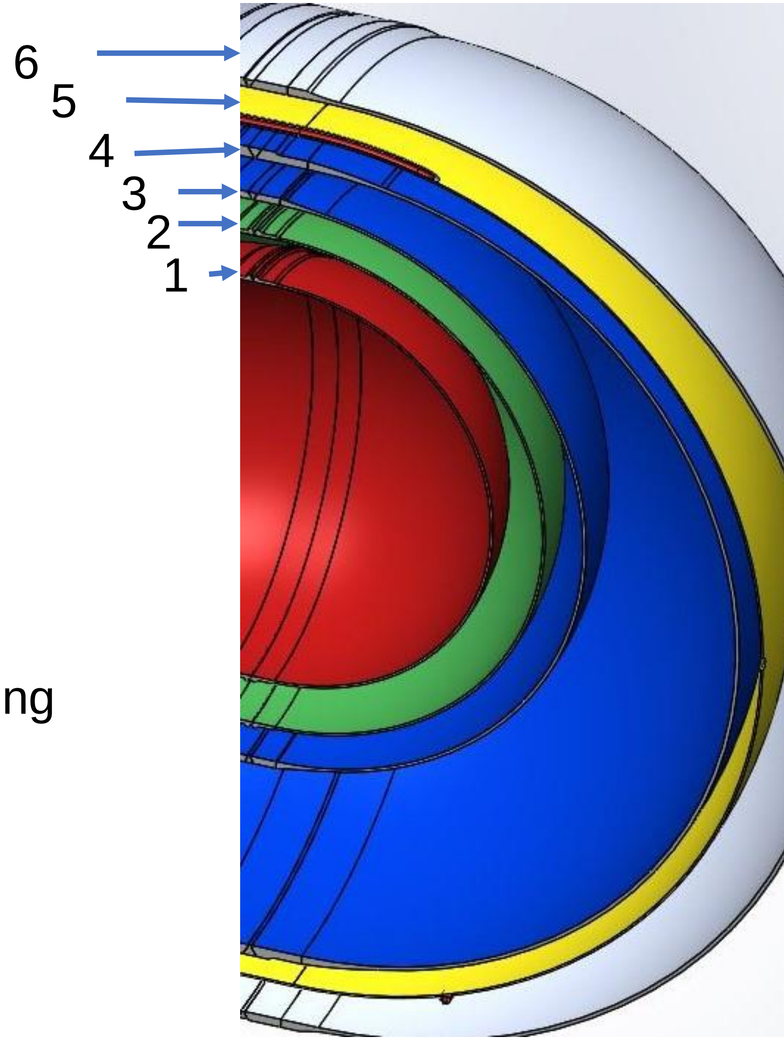
➢ 2219-T6 chosen for vessels for lowest mass and highest post-weld strength
➢ 5083-H16 chosen where mass not as critical (Cryo-Connection box)

- Structures to be analysed for all conditions of operation
  - Temperature & pressure extremes.
  - As installed condition (considering weld tempers)
- Service of high activated parts to be avoided
- Deuterium cavities to be designed for potential explosion pressures
- For ASME pressure vessel code 3:1 safety factor is required

Safety Statements

- Redundancy.
  - Beyond mechanical safety factors, where a failure would risk personnel, three levels of failure are required before a dangerous event takes place
- Design will be compliant with Canadian Codes
  - Fire, Building, Pressure Vessel, Piping, Electrical, Radiological
- Design will be reviewed
  - ASME certified pressure vessel company.
  - Design and installation reviewed by TSBC
  - Offsite Hydrogen handling experts.
  - Triumf Onsite Technical reviews.
- Procedures & Training
  - All work carried out is driven by written & reviewed procedures.
  - Emergency procedures in place
  - Personnel must receive adequate training from a qualified person.

Heat Loads (for Tail, Cryo-Box, and Guide)



The most significant loads from Neutron, Gamma, and Beta-Decay

- Wall 1 & contained Helium = 8.1 W @ 1K (cooled by He-II system)
- Wall 2 (Vacuum Separator) = 9.9 W @ 20K (cooled by He-II system)
- Wall 3 & 4 & contained LD2 = 63 W @ 20K (Cooled by GM cooler)
- Wall 5 (Thermal Shield) = 6.6 W @ 90K (Cooled by He-II system)
- Wall 6 (Outer Vacuum Can) = 26 W @ 300K (Cooled by ambient convection)

Static Heat loads

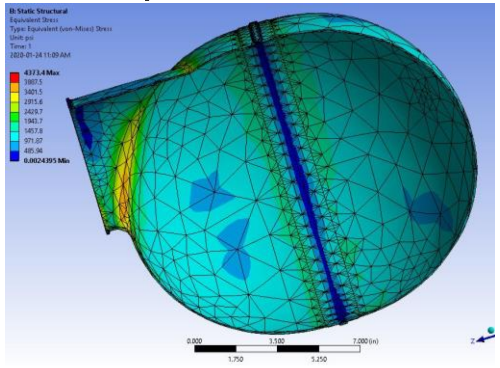
- Surface emissivity dramatically effects the heat load
- Although radiation resistant MLI was planned but questioned for not knowing the end point temperature of the individual layers under high Neutron flux.
- Fall back is to polish the surfaces, and keep under an inert atmosphere.

Static Heat Loads

- Wall 1 & Guide = up to 1 W (Funneling most significant)
- Wall 2 (Vacuum Separator) = 9.9 W @ 20K (cooled by He-II system)
- Wall 3 (outer LD2) = xx W @ 20K (Cooled by GM cooler)
- Wall 4 (Thermal Shield) = 11 W (insulated) 25 W (polished bare), 76W (degraded)(Cooled by He-II system)

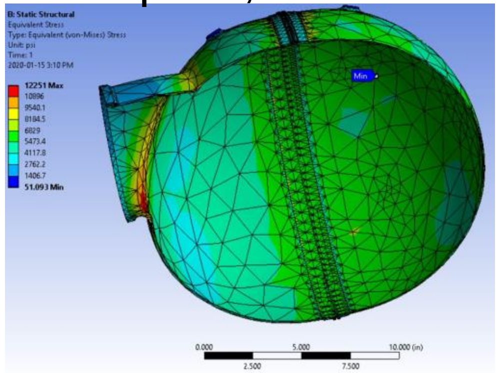
Vessel Engineering (Peak pressure loading Results)

4ksi peak,1ksi ave.



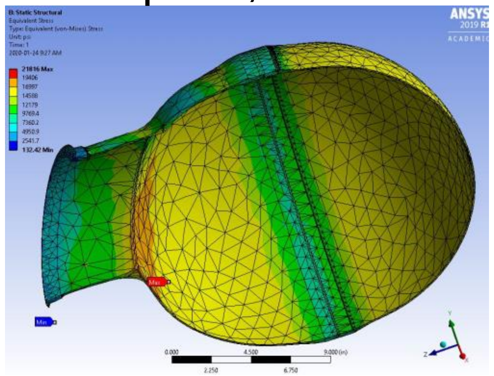
Wall 1

12ksi peak, 6ksi ave.



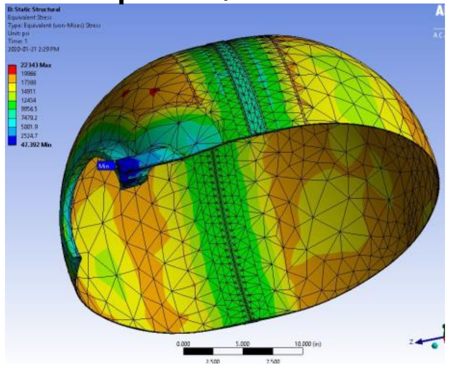
Wall 2

22ksi peak, 15ksi ave



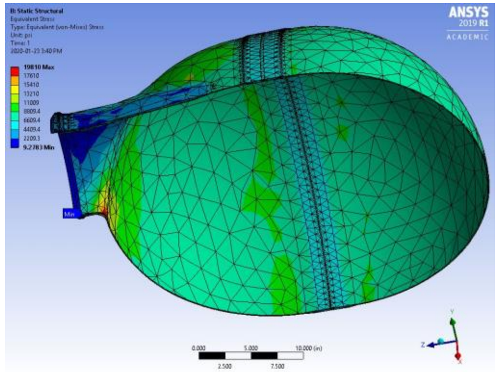
Wall 3

22ksi peak, 18ksi ave.

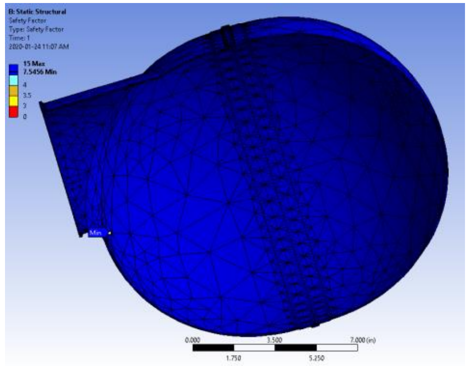


Wall 4

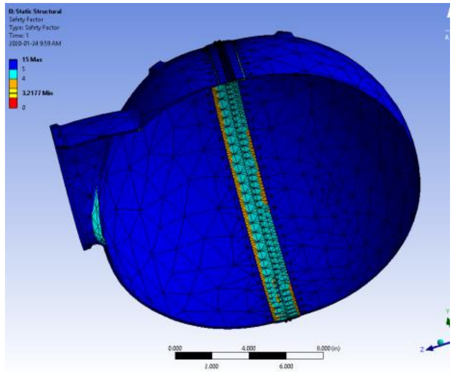
20ksi peak, 9ksi ave.



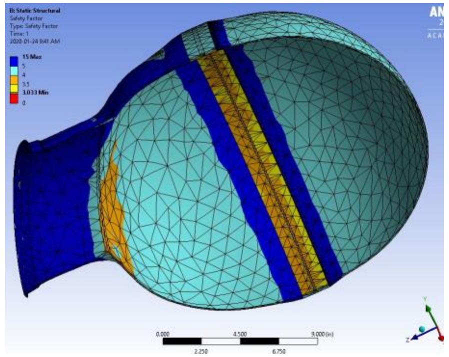
Wall 6



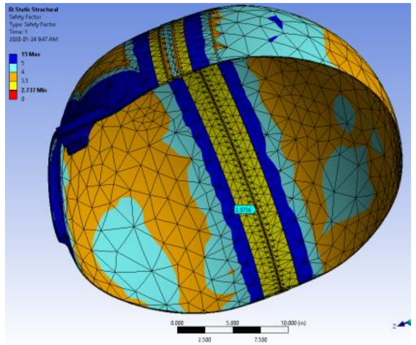
FOS **7.9** :1



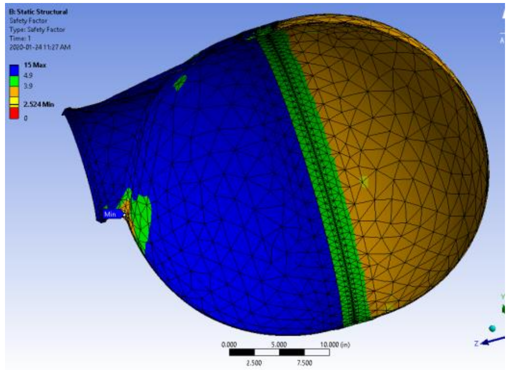
FOS **3.2**:1



3 FOS **3.0** :1



4 FOS **2.7** :1

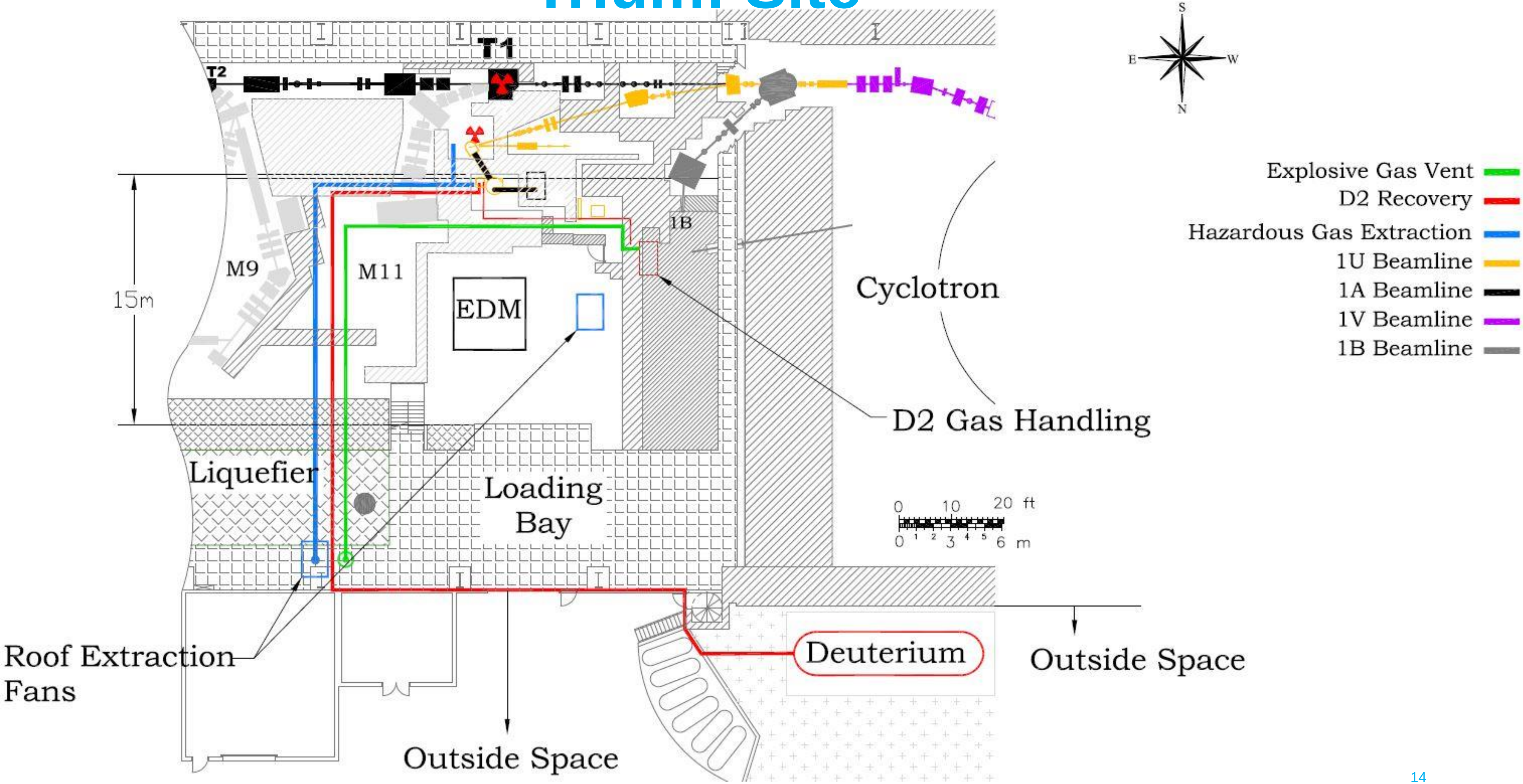


6 FOS-ys **2.5** :1

Red= Limit (3.0), Yellow=Optimal(3-3.5), Orange=(3.5-4), L-Blue= (4-5), Dark Blue (>5) (over- designed)

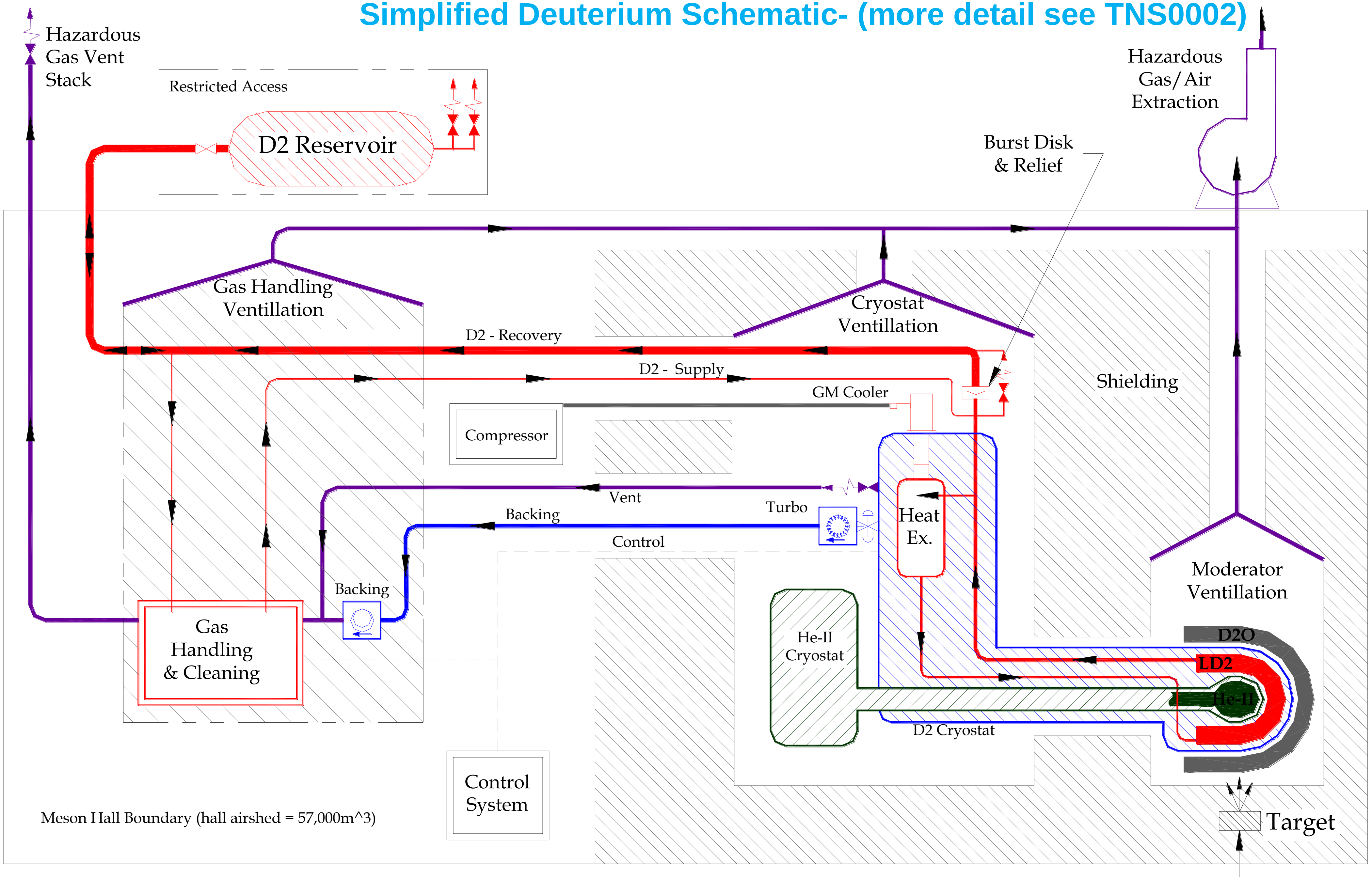
Looking for Yellow or Orange for optimized Vessel

Triumf Site

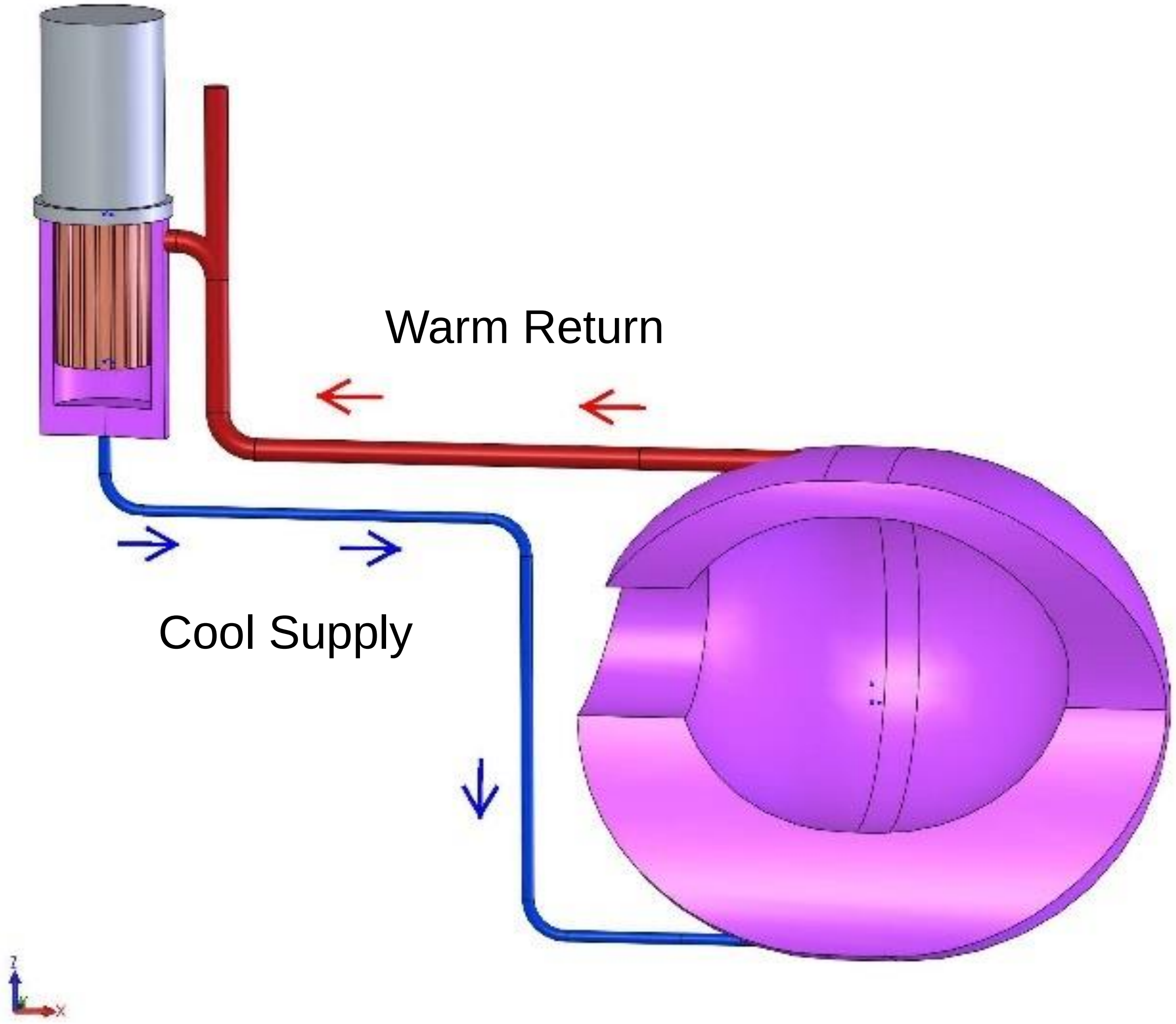


T1
T2
M9
M11
EDM
1B
15m
Cyclotron
D2 Gas Handling
Liquefier
Loading Bay
Roof Extraction Fans
Outside Space
Deuterium
Outside Space
S
E
W
N
Explosive Gas Vent
D2 Recovery
Hazardous Gas Extraction
1U Beamline
1A Beamline
1V Beamline
1B Beamline
0 10 20 ft
0 1 2 3 4 5 6 m

Simplified Deuterium Schematic- (more detail see TNS0002)

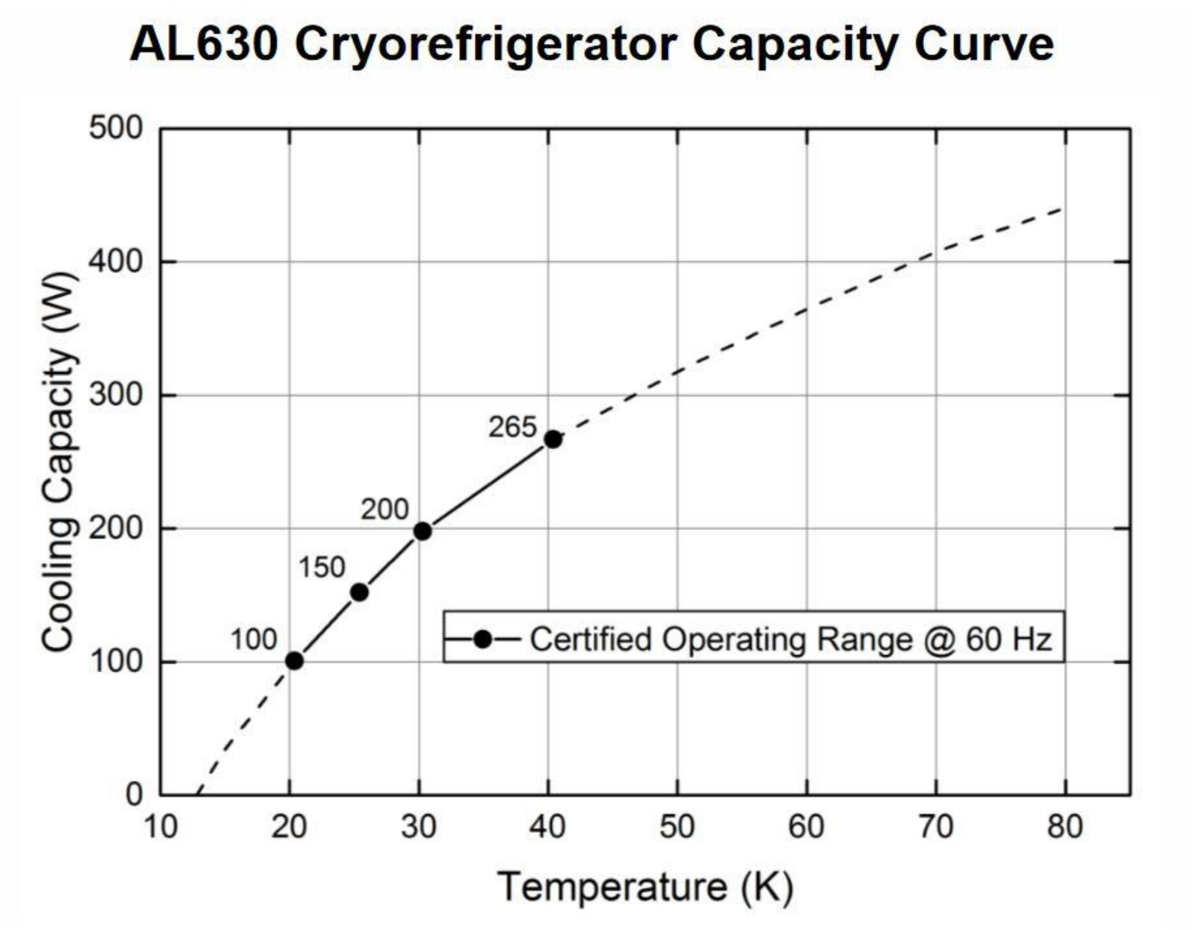


Thermo-Syphon cooling system



Cooling System

Cryo-Mech AL630 GM Cooler (Capacity = 100W @ 20K
UCN Predicted load = 66 Watts(Peak) @ 20K



Upcoming Milestones

1) Design Registration with TSBC – Mid March?

2) Local Technical reviews
- Remote handling Design for target pit – Mid Feb?

3) Expert Technical Review – Mid to end of March?
   ASME Vessel design – Currently under review by external company

4) Material & Process Strength Verification - By end of March?
   - Material alloy & strength as received
   - Welding procedure development
   - Weld quality (Porosity & leaks)
   - Post weld strength achieved.

5) Start Tail Vessel Machining - end of April?

6) Start Tail Vessel welding – May 1 ?

7) Start Cryo-box welding – September?
8) LD2 Cryostat manufacture – November?

Manpower

- Engineering
  - C. Marshall (Cryo and Stress Design, Source/LD2/Cryo-box)
  - PVEng (Contract ASME code verification)
  - D. Rompen (Manipulator Rail design, Cryo-Pit access, and Jigs)
  - S. Horn detail drafting
  - M. Lenkowski (Graphite & D2O assembly design, later Cryo warmup panel)
  - S. Lan (Co-op, Stress analysis)
  - M. Good (hope to utilize for some design work, and later Tech work)
  - B.Richert (hope to use for extraction fans, and ducting)
- Manufacture
  - KALTECH (offsite contract)
  - N. Theim (Triumf Welding, and leak checks)
  - T.B.D. (Assembly/Thermal cycling/leak checking)

Upcoming bottlenecks

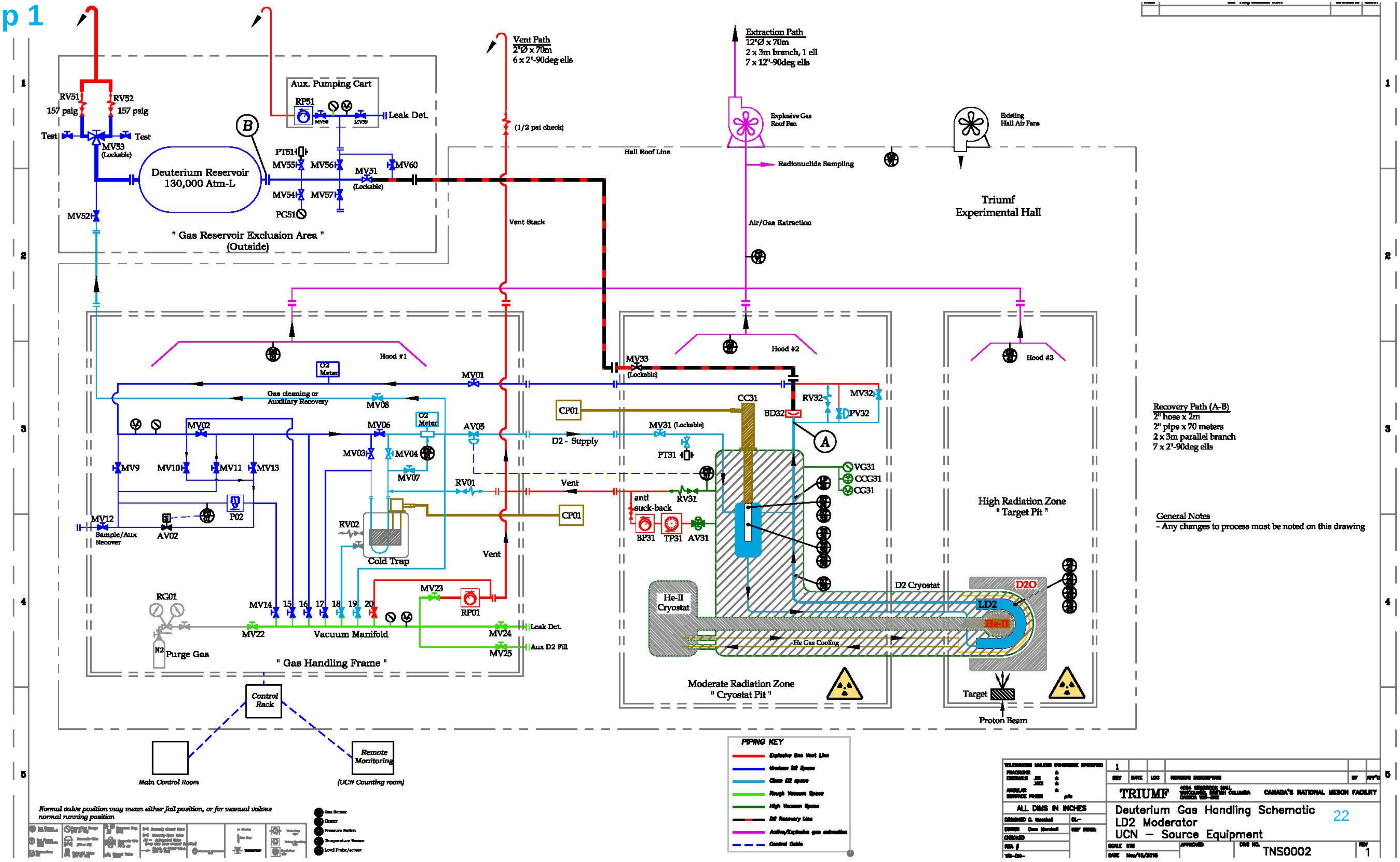
- Designer/Drafting – One needed now, plus one more in a month
- Mechanical Tech
  - Assembly (Tail Build up) – May 2020
  - Disassembly (Area & Vert. Source) - starting Nov 2020
  - Assembly Jan 2021 – Two Mechanical Techs min.

Commissioning

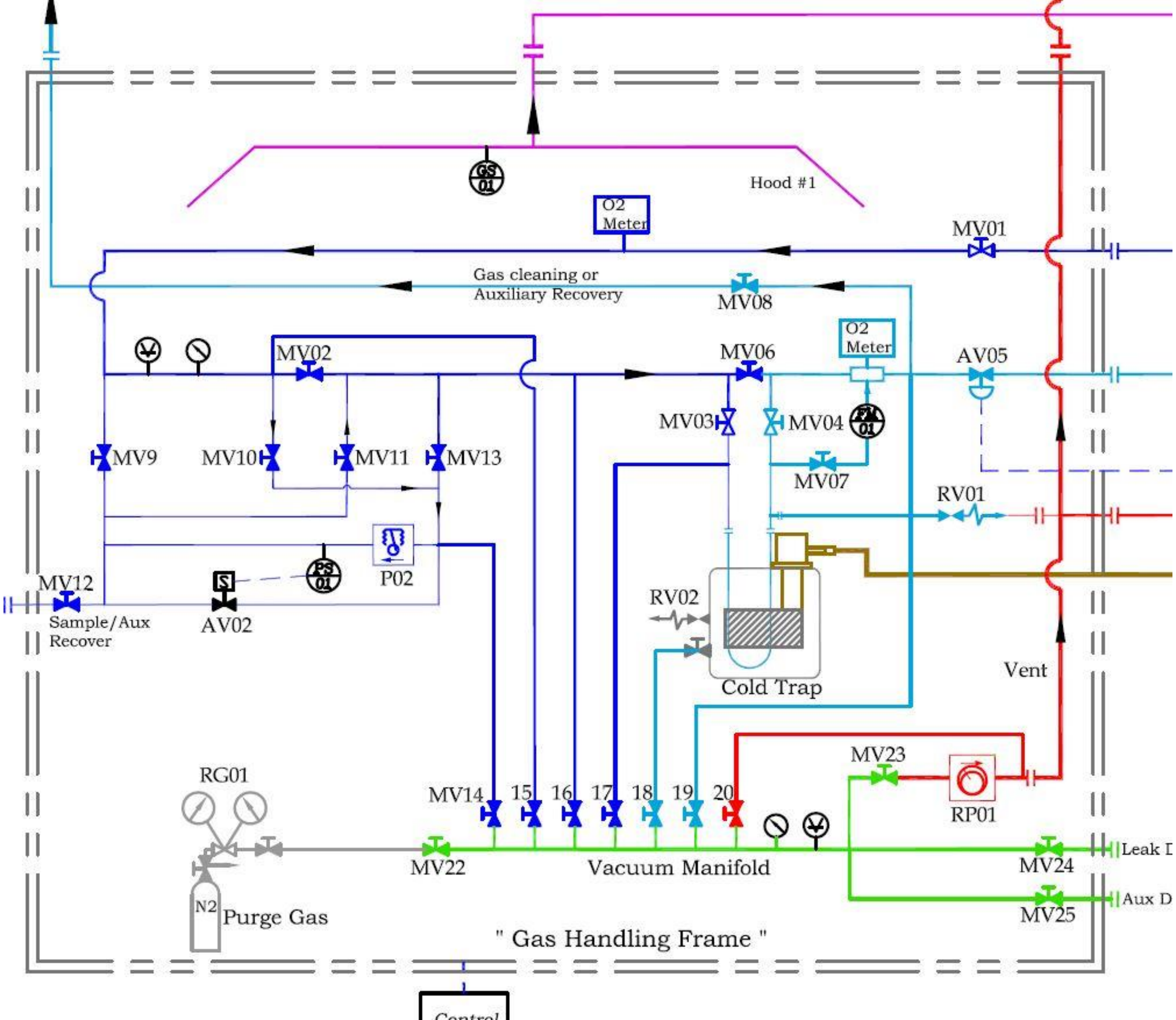
- Thermal cycling, Leak checks and radiograph testing prior to commission
- Full cryogenic test with heater simulation of beam load
- Operating and Emergency procedures in place
- Preliminary operator training complete
- All controls operational
- All system faults repaired
- He-II system tested and fault free before proceeding to beam run.

Thank you

Backup 1

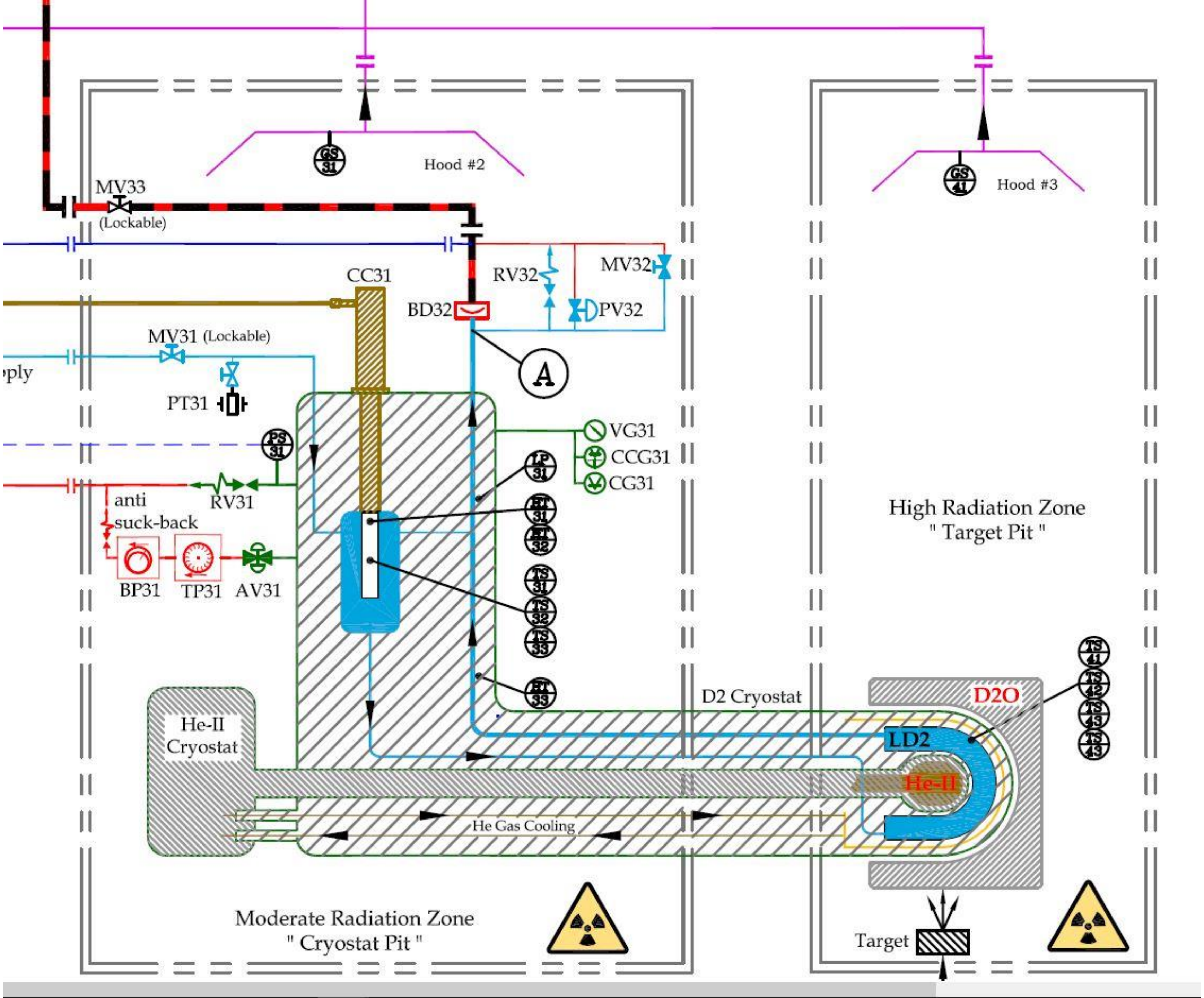

Vent Path
2"Ø x 70m
6 x 2"-90deg ells
Extraction Path
12"Ø x 70m
2 x 3m branch, 1 ell
7 x 12"-90deg ells
RV51
RV52
157 psig
157 psig
Test
Test
MV53
(Lockable)
Aux. Pumping Cart
RP51
Leak Det.
Explosive Gas Roof Fan
Existing Hall Air Fans
(1/2 psi check)
Hall Roof Line
Radionuclide Sampling
PT51
MV55
MV56
MV60
MV51
(Lockable)
MV54
MV57
PG51
Deuterium Reservoir
130,000 Atm-L
MV52
" Gas Reservoir Exclusion Area "
(Outside)
Vent Stack
Air/Gas Extraction
Triumf
Experimental Hall
Hood #1
Hood #2
Hood #3
O2 Meter
MV01
MV33
(Lockable)
Gas cleaning or Auxiliary Recovery
MV08
MV02
MV06
O2 Meter
AV05
D2 - Supply
MV31 (Lockable)
PT31
CP01
CC31
BD32
RV32
MV32
PV32
Recovery Path (A-B)
2" hose x 2m
2" pipe x 70 meters
2 x 3m parallel branch
7 x 2"-90deg ells
MV9
MV10
MV11
MV13
MV03
MV04
MV07
RV01
Vent
VG31
CCG31
CG31
anti suck-back
RV31
MV12
Sample/Aux Recover
AV02
P02
RV02
Cold Trap
CP01
BP31
TP31
AV31
High Radiation Zone
" Target Pit "
General Notes
- Any changes to process must be noted on this drawing
Vent
RG01
MV14
15
16
17
18
19
20
MV23
RP01
He-II Cryostat
D2 Cryostat
D2O
LD2
He-II
He Gas Cooling
MV22
Vacuum Manifold
MV24
Leak Det.
MV25
Aux D2 Fill
N2
Purge Gas
" Gas Handling Frame "
Moderate Radiation Zone
" Cryostat Pit "
Target
Proton Beam
Control Rack
Main Control Room
Remote Monitoring
(UCN Counting room)
Normal valve position may mean either fail position, or for manual valves normal running position
PIPING KEY
ALL DIMS IN INCHES
TRIUMF
CANADA'S NATIONAL MESON FACILITY
Deuterium Gas Handling Schematic
LD2 Moderator
UCN – Source Equipment
TNS0002

Backup 2

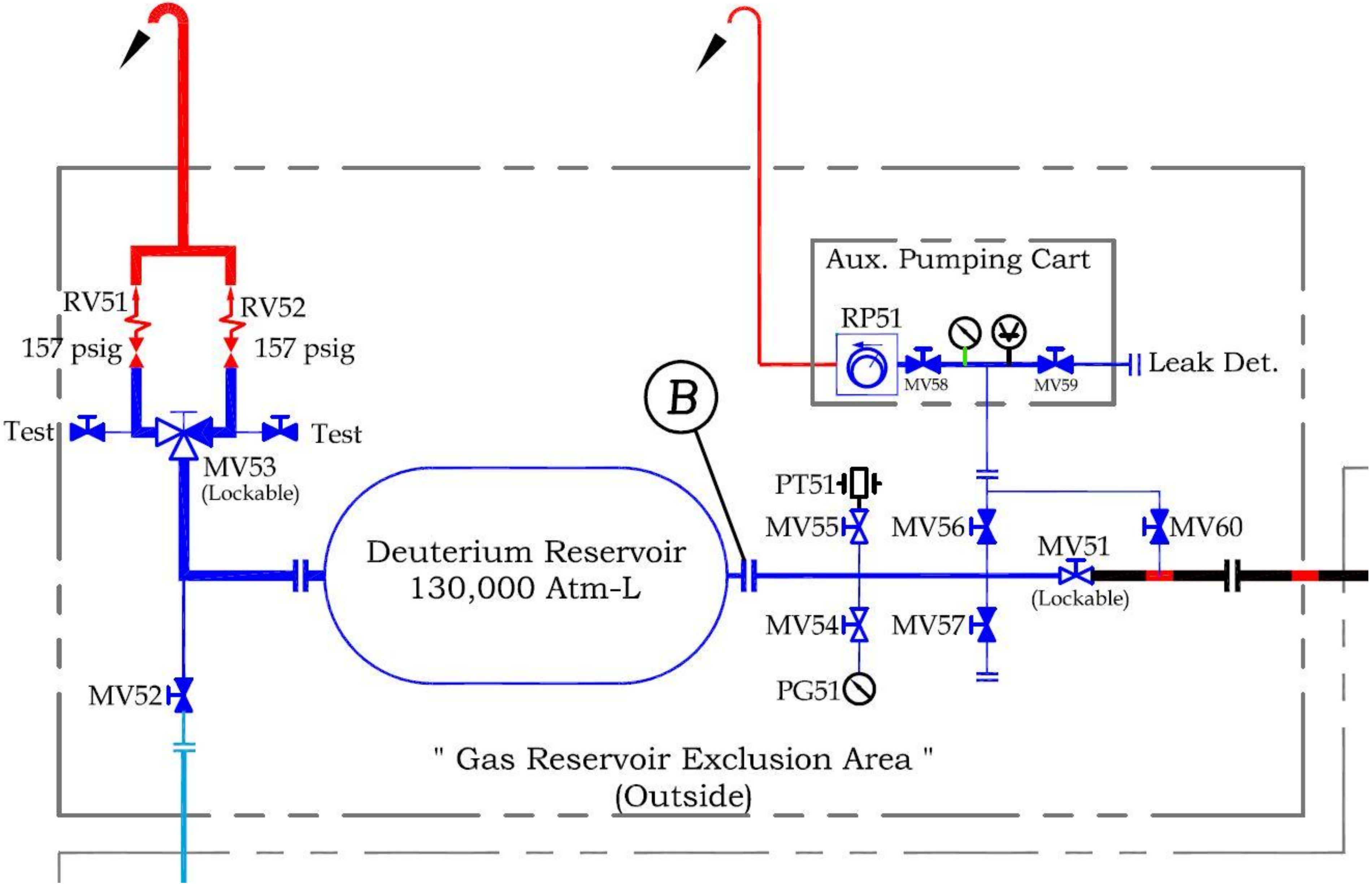


GS 01
Hood #1
O2 Meter
MV01
Gas cleaning or Auxiliary Recovery
MV08
MV02
MV06
O2 Meter
AV05
MV03
MV04
FM 01
MV9
MV10
MV11
MV13
MV07
RV01
P02
PS 01
MV12
Sample/Aux Recover
AV02
RV02
Cold Trap
Vent
MV23
RG01
MV14
15
16
17
18
19
20
RP01
MV22
Vacuum Manifold
MV24
Leak D
Aux D
MV25
N2
Purge Gas
" Gas Handling Frame "

Backup 3


Hood #2
Hood #3
MV33
(Lockable)
CC31
RV32
MV32
BD32
PV32
MV31 (Lockable)
A
PT31
VG31
CCG31
CG31
anti
suck-back
RV31
BP31
TP31
AV31
High Radiation Zone
" Target Pit "
D2 Cryostat
D2O
LD2
He-II
He-II
Cryostat
He Gas Cooling
Moderate Radiation Zone
" Cryostat Pit "
Target

Backup 4



RV51
157 psig
RV52
157 psig
Test
Test
MV53
(Lockable)
Aux. Pumping Cart
RP51
MV58
MV59
Leak Det.
B
PT51
MV55
MV56
MV60
MV51
(Lockable)
Deuterium Reservoir
130,000 Atm-L
MV54
MV57
PG51
MV52
" Gas Reservoir Exclusion Area "
(Outside)