DEMCON | KRYOZ
UNIVERSITY OF TWENTE.
COOLL

Cryogenics Update Workshop

02-06-2025

Einstein Telescope

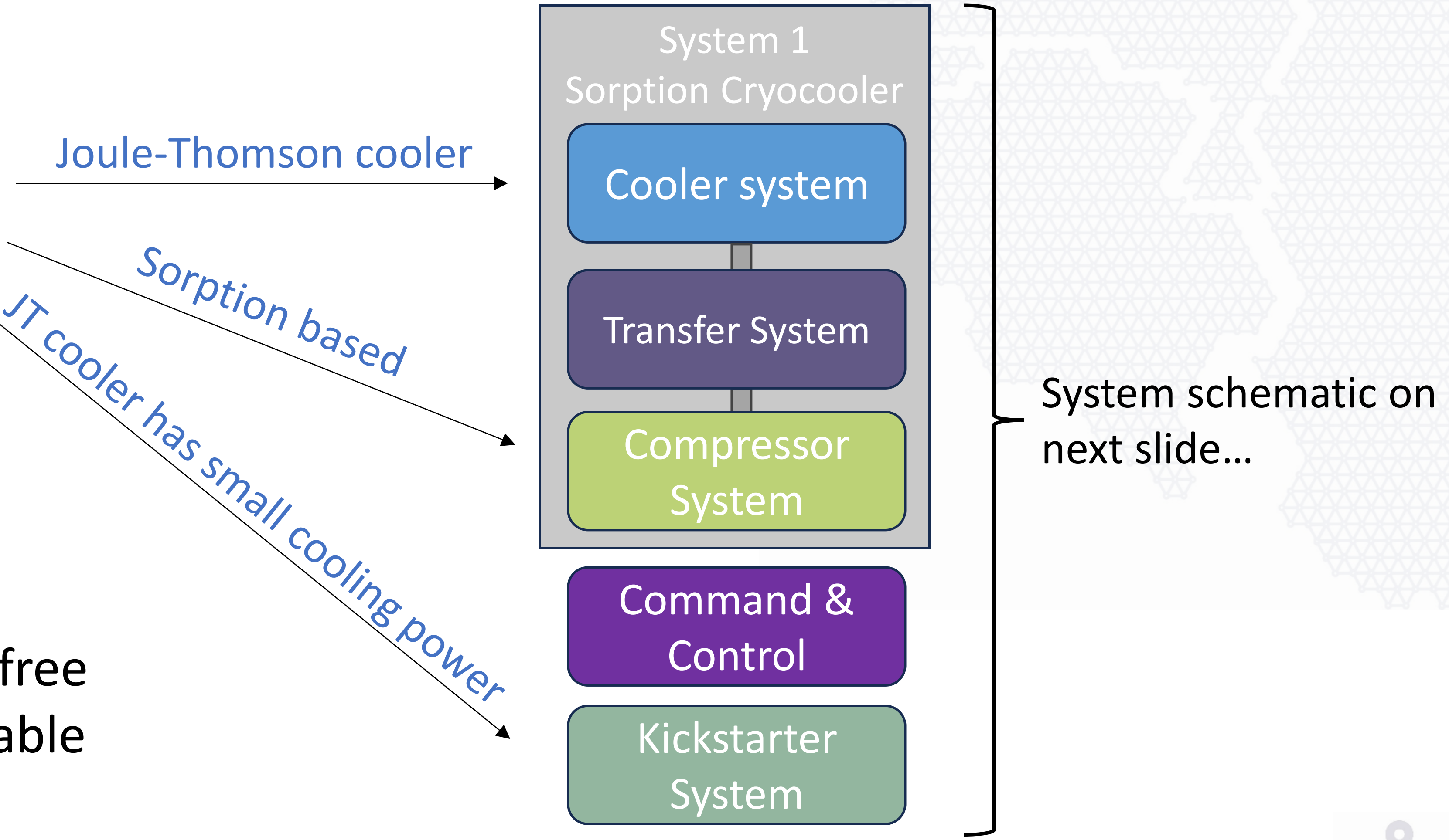
Content

1. Design Overview & System architecture
2. Technical Progress & Milestones
   - Development approach & timeline
   - Achievements since last update
   - Impact 3 key requirements on concept design
   - System assembly
   - Master Test Plan
3. External Interfaces
   - Electrical Interfaces
   - Data Interfaces
4. Safety risks & Mitigations
5. Open points and Q&A

Content

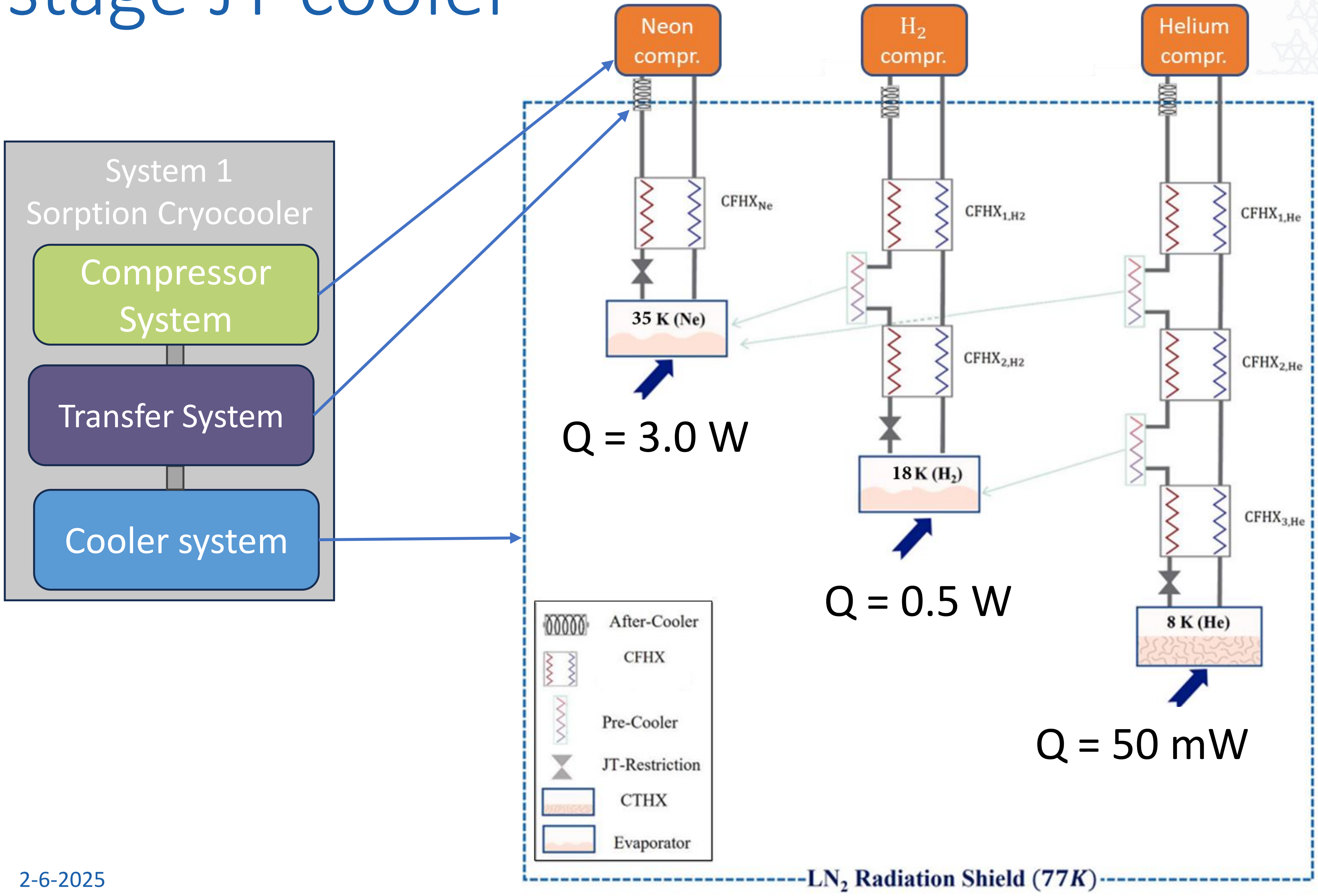
Key requirements

- Requirements:
  - Cooling power: 50 mW @ 8K
  - Vibration level: < 32 nm p2p
  - Cooldown time: < 4 weeks



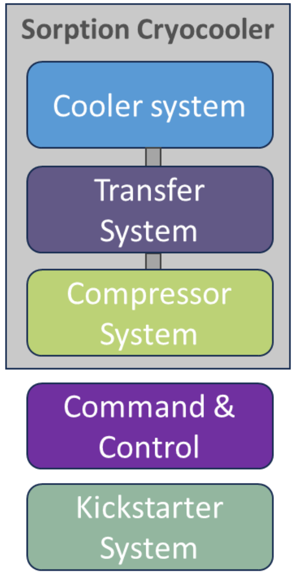
Main challenge: vibration free cryocooling within acceptable cooldown time

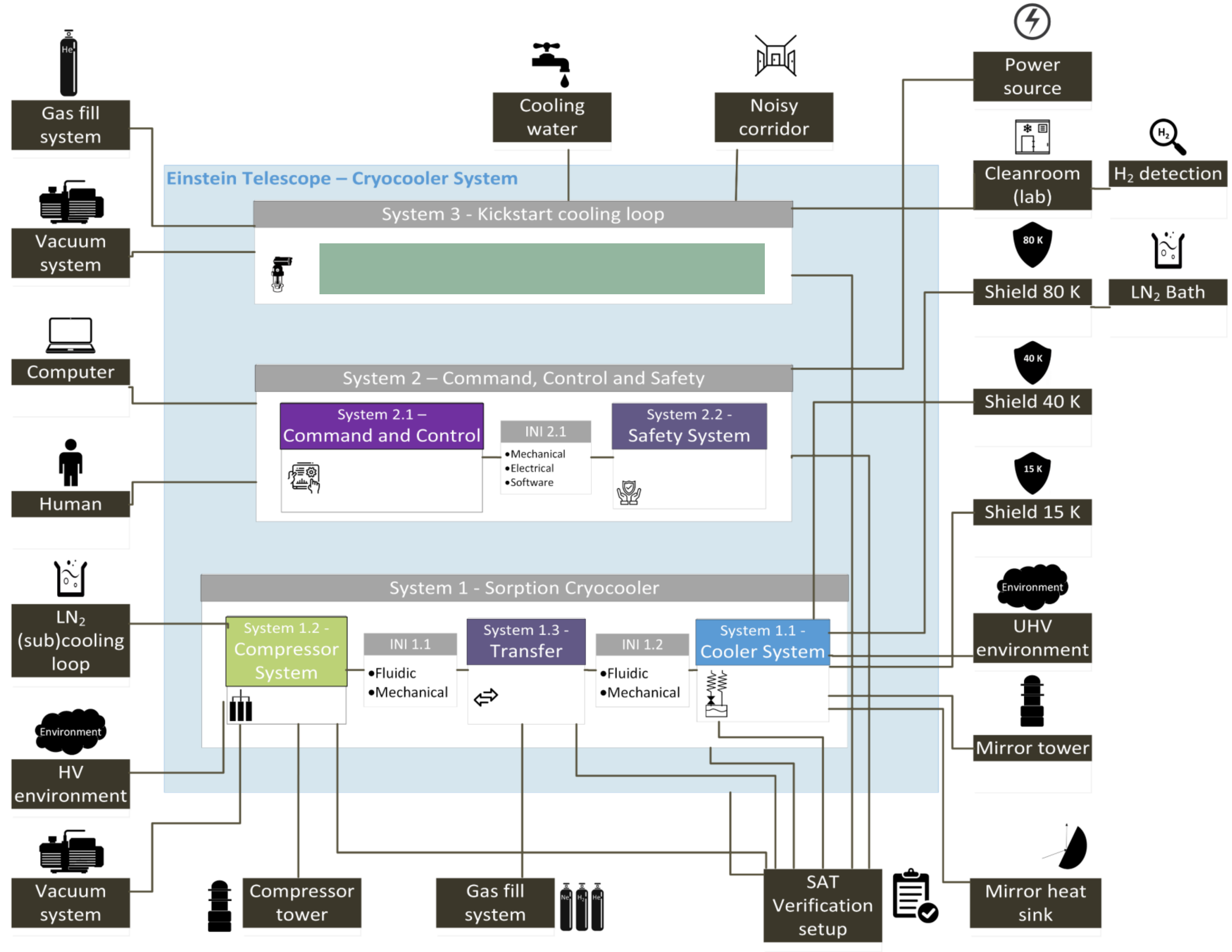
3-stage JT cooler



System Architecture

Einstein Telescope – Cryocooler System
Architecture level 1 version 0.7
RKU 10/2024, TDL 08/2024





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1. Design Overview & System architecture
2. **Technical Progress & Milestones**
   - Development approach & timeline
   - Achievements since last update
   - Impact 3 key requirements on concept design
   - System assembly
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   - Electrical Interfaces
   - Data Interfaces
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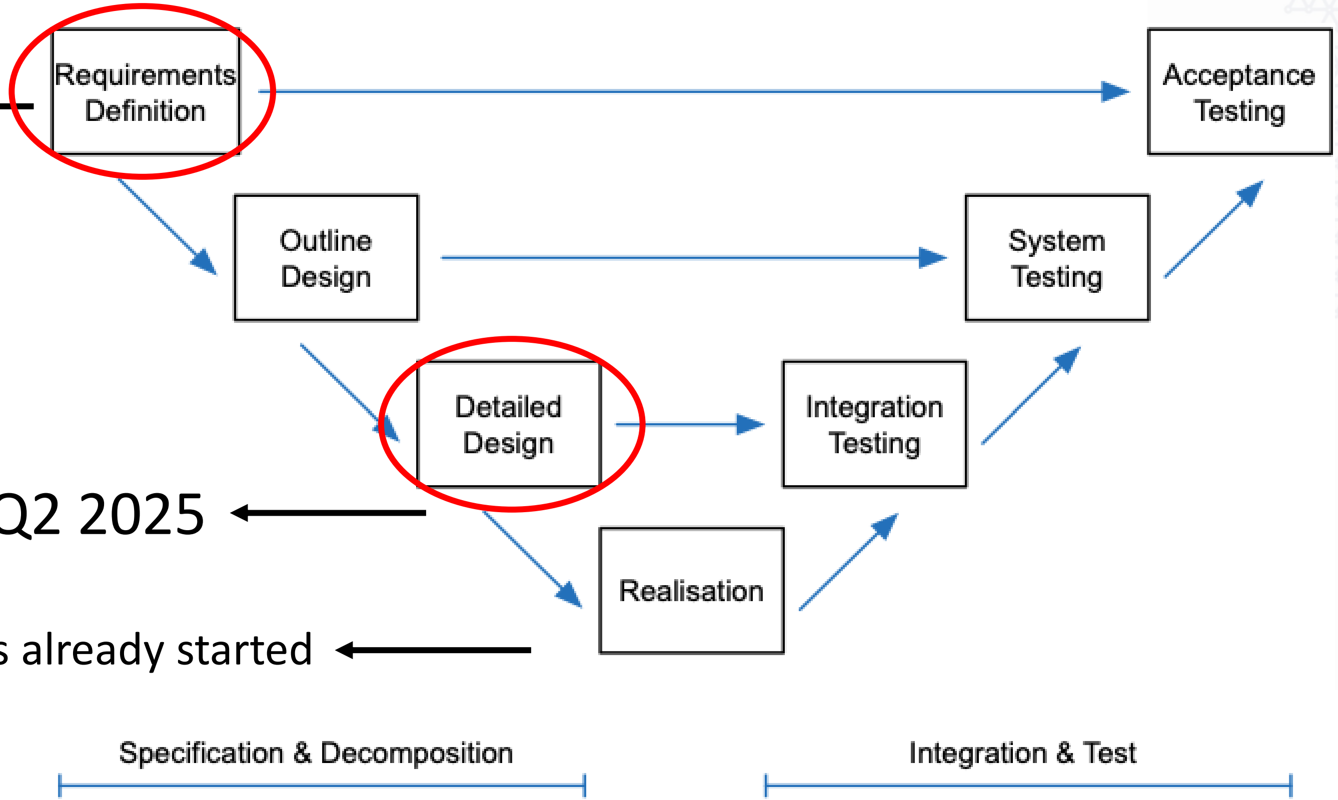
5. Q&A

Development approach & timeline

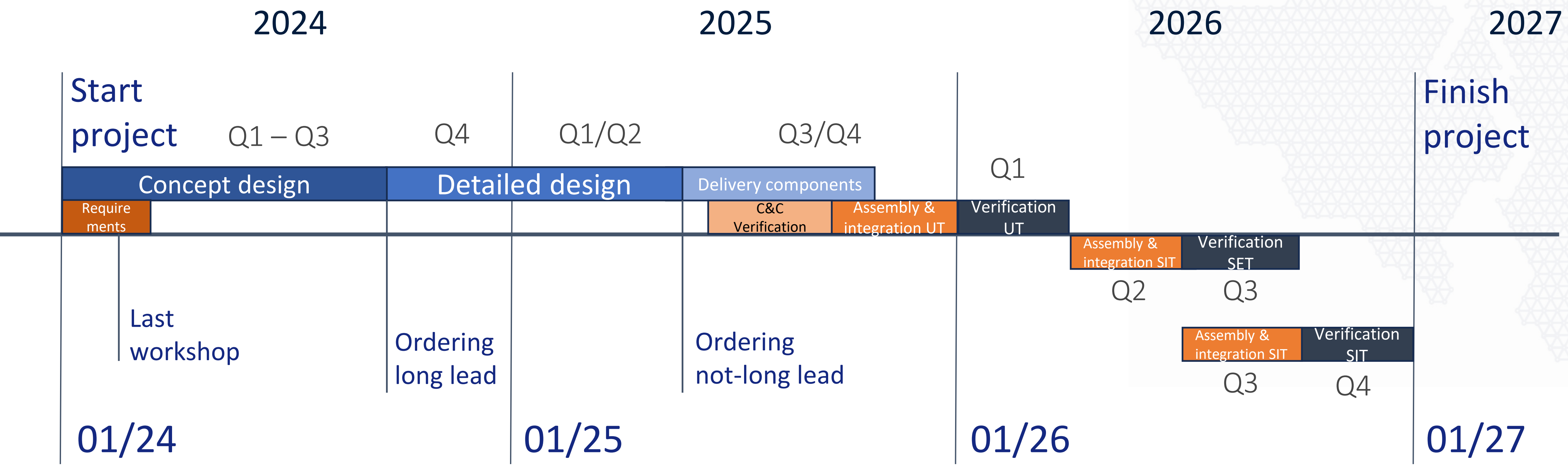
Last workshop



Aim: Q2 2025

Assembly compressor cells already started

Timeline



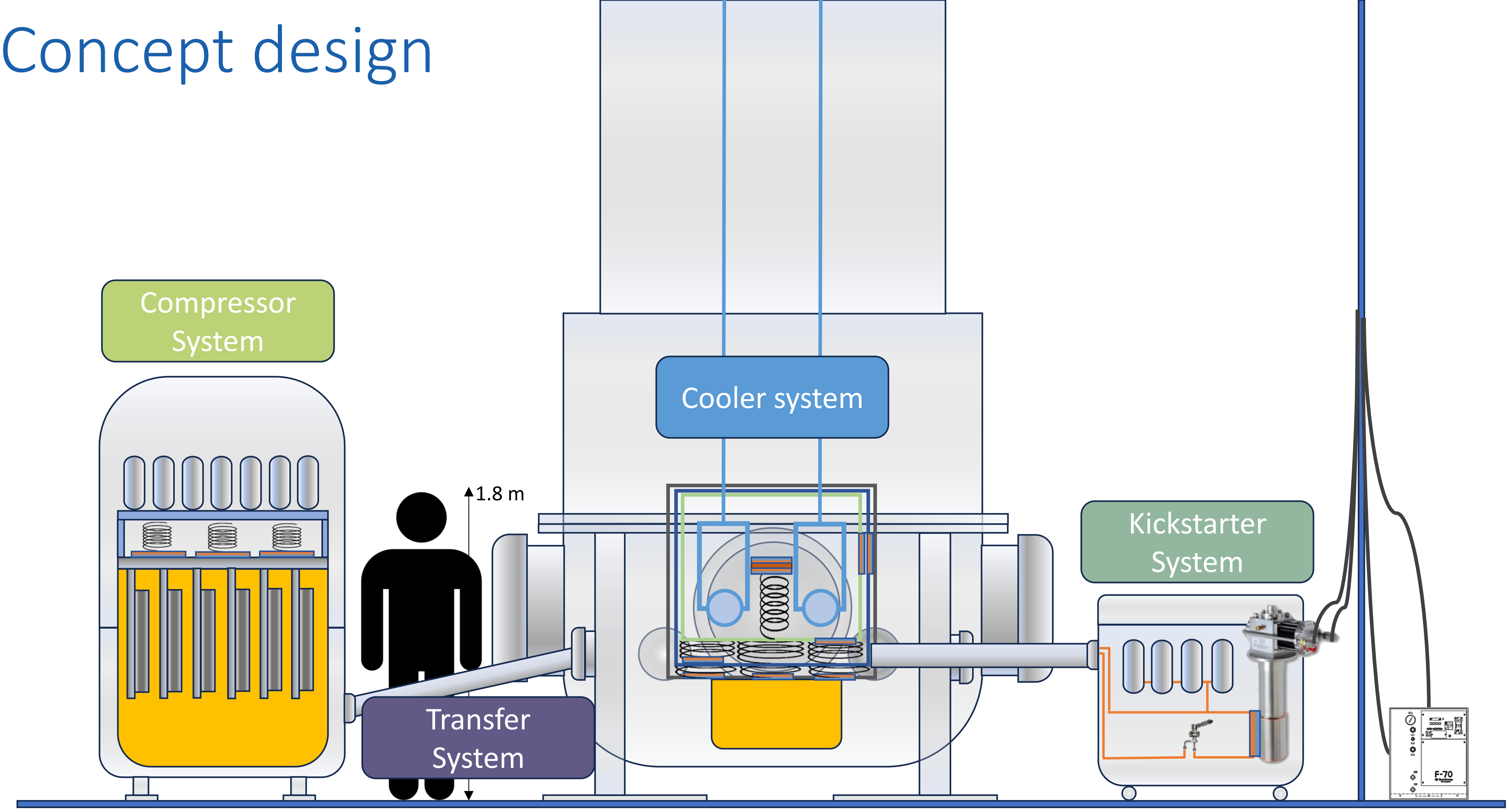
Conclusion: Next week we will start with ordering

Achievements since last workshop

Concept design

- Completed concept design
  - Define system concept
  - Identification of critical components & design choices
  - System engineering (requirements writing, interfacing, etc.)
  - Modelling

Concept design



Achievements since last workshop

Concept design

- Completed concept design
  - Define system concept
  - Identification of critical components & design choices
  - System engineering (requirements writing, interfacing, etc.)
  - Modelling

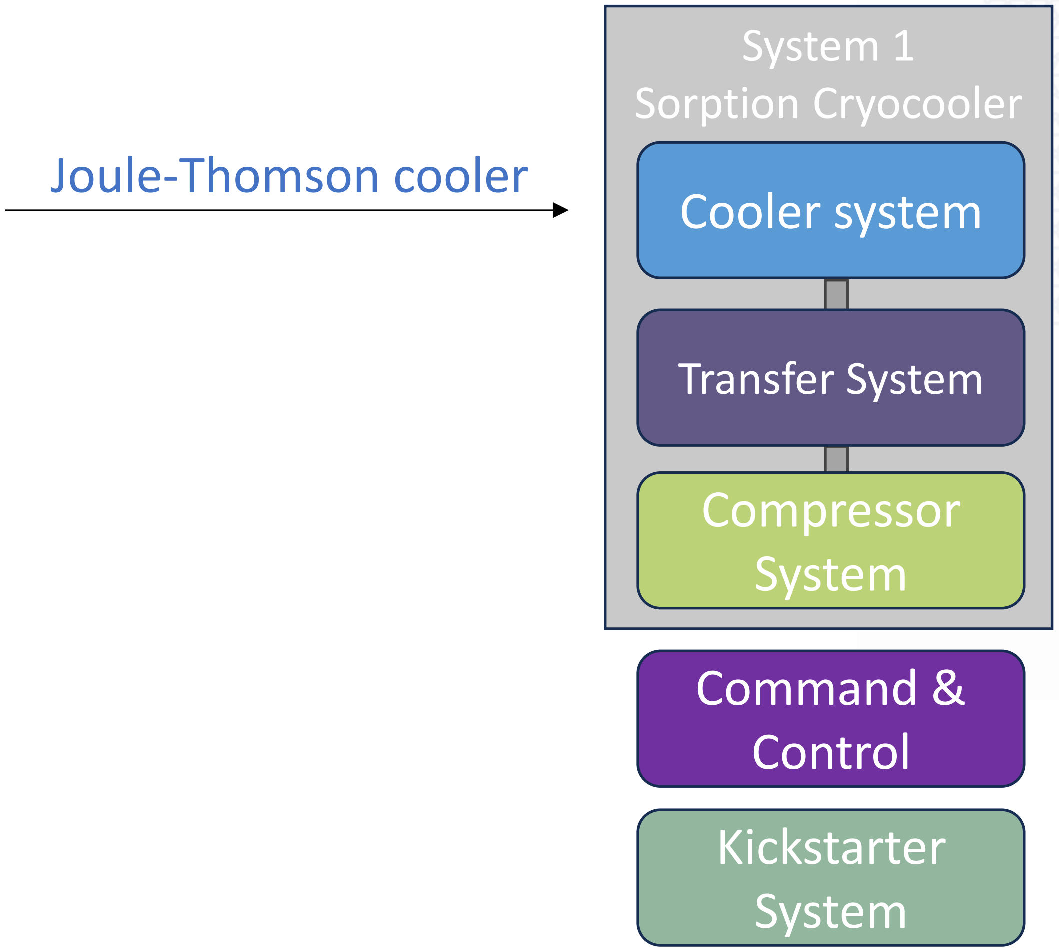
Detailed design

- Almost completed detailed design
  - CAD drawings
  - Component selection
  - Master Test Plan

Next: Concept design explained via the 3 key requirements & detailed design result

Cooling power requirement

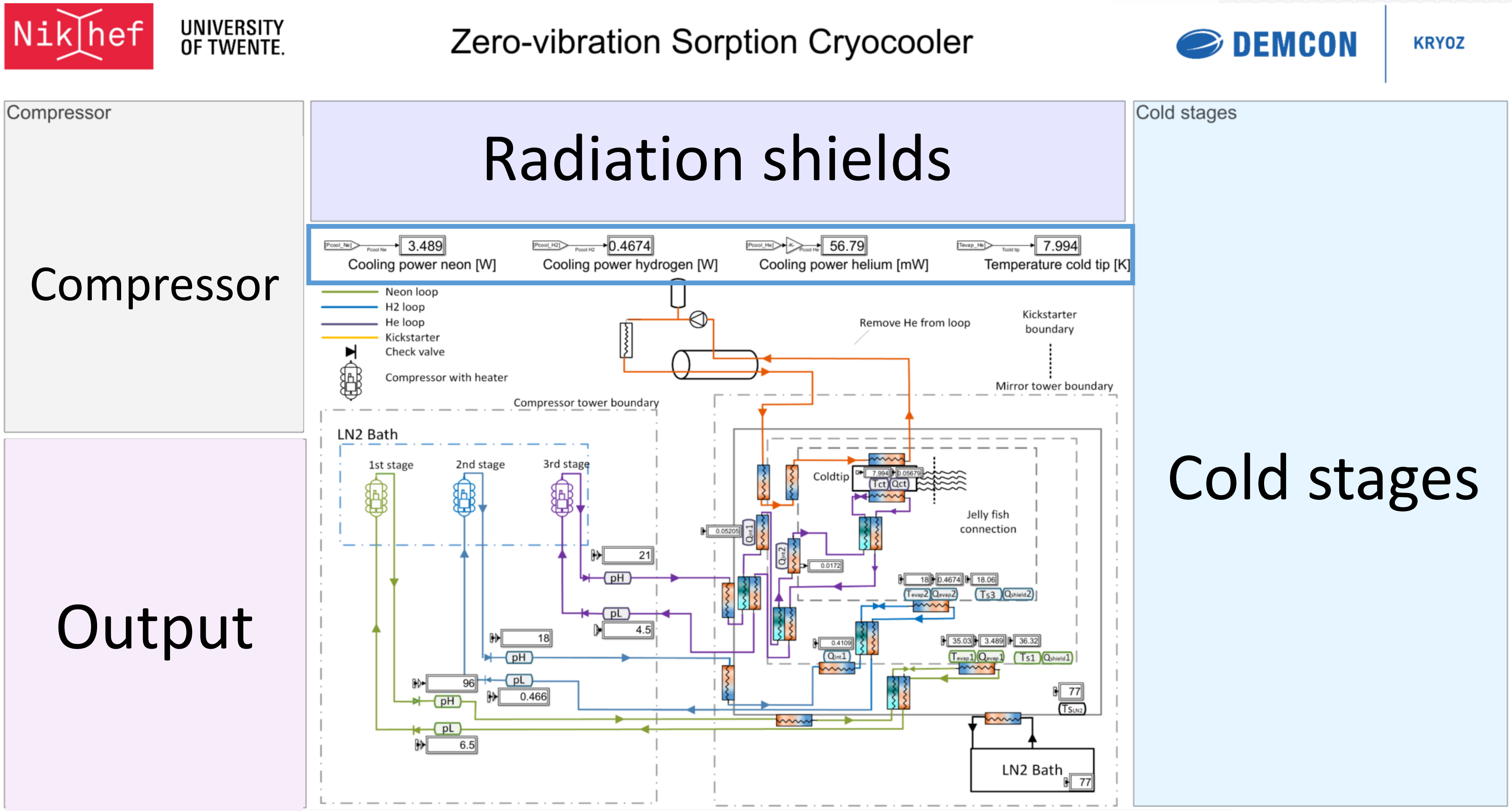
- Requirements:
  - Cooling power: 50 mW @ 8K
  - Vibration level: < 32 nm p2p
  - Cooldown time: < 4 weeks



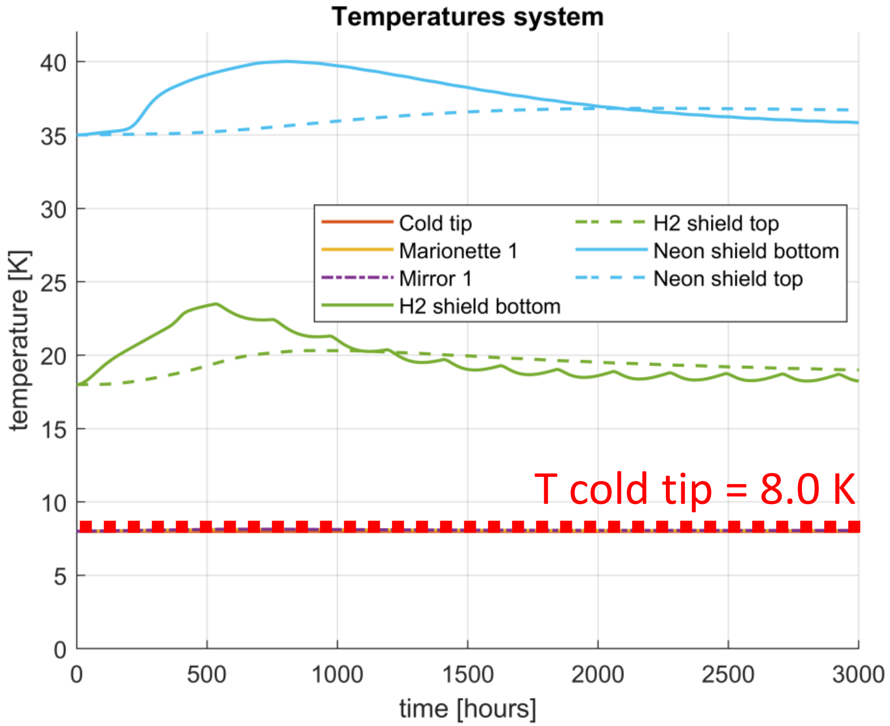
Establish baseline

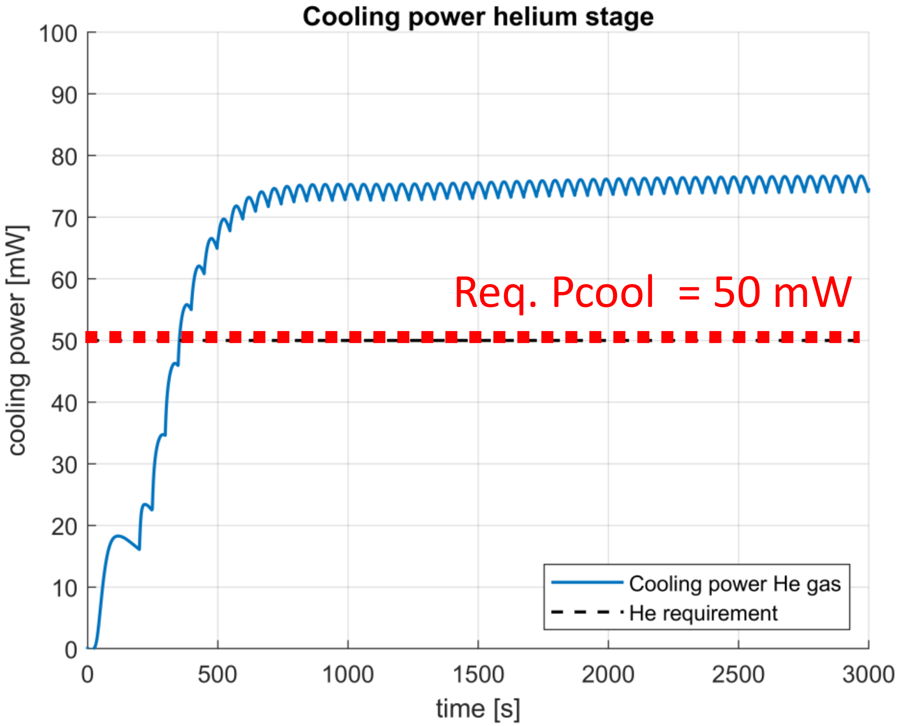
Stage	Working fluid	PH [bar]	PL [bar]	Tmin [K]	Cooling power
1	Neon	96.0	6.5	35.0	3.0 W
2	Hydrogen	18.0	0.47	18.0	0.5 W
3	Helium	21.0	4.5	8.0	50 mW

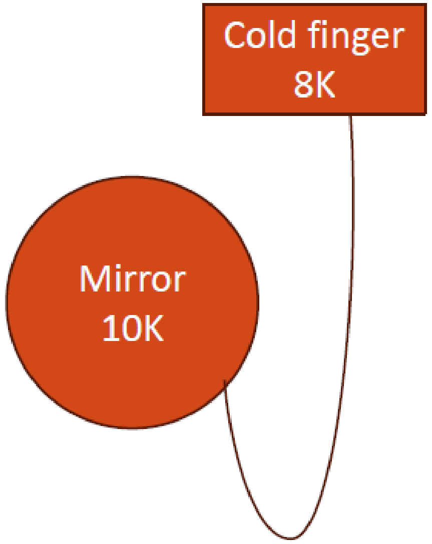
Dynamic LEM model



Temperature requirement







Vibration requirement

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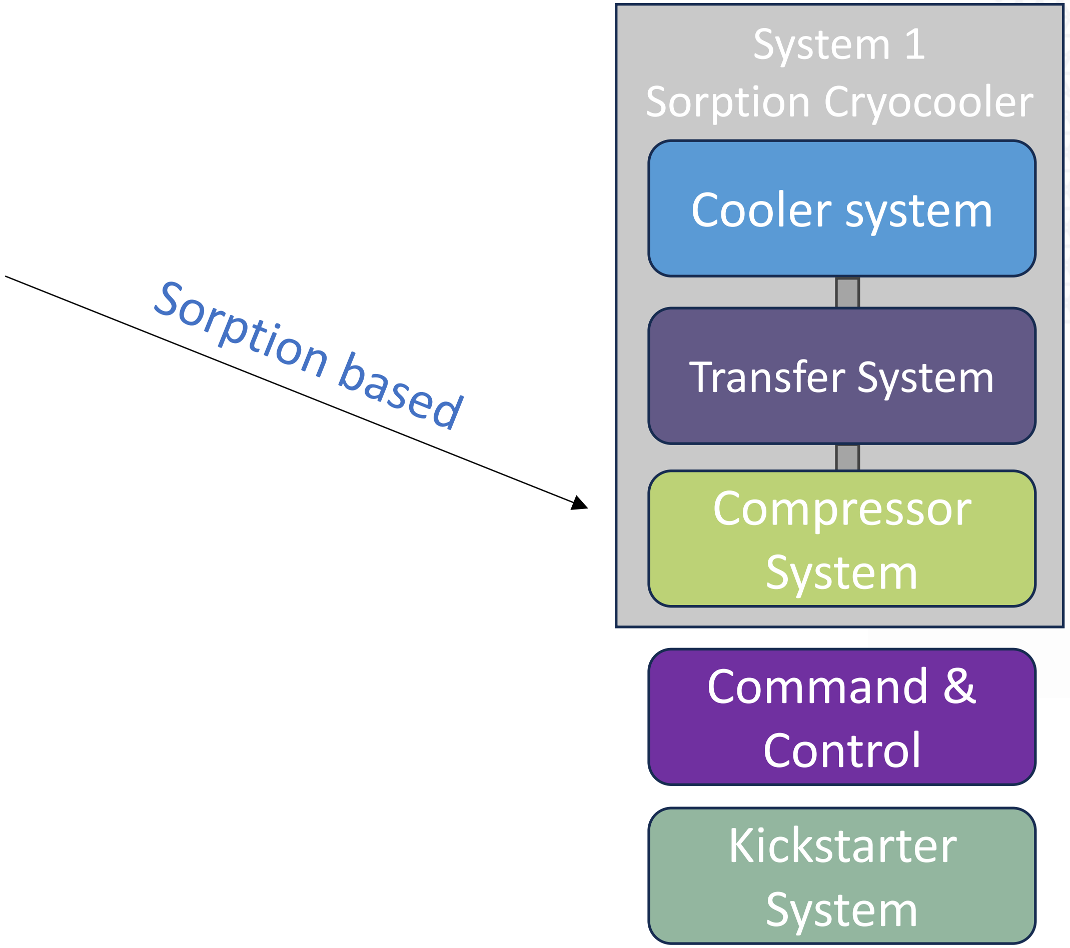
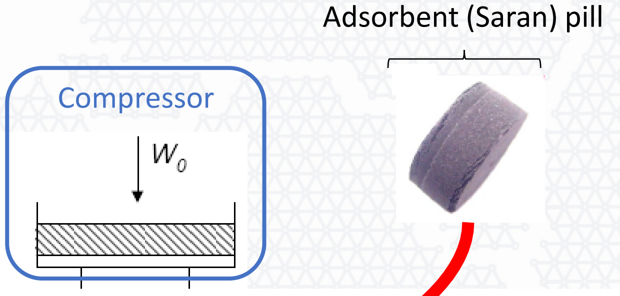
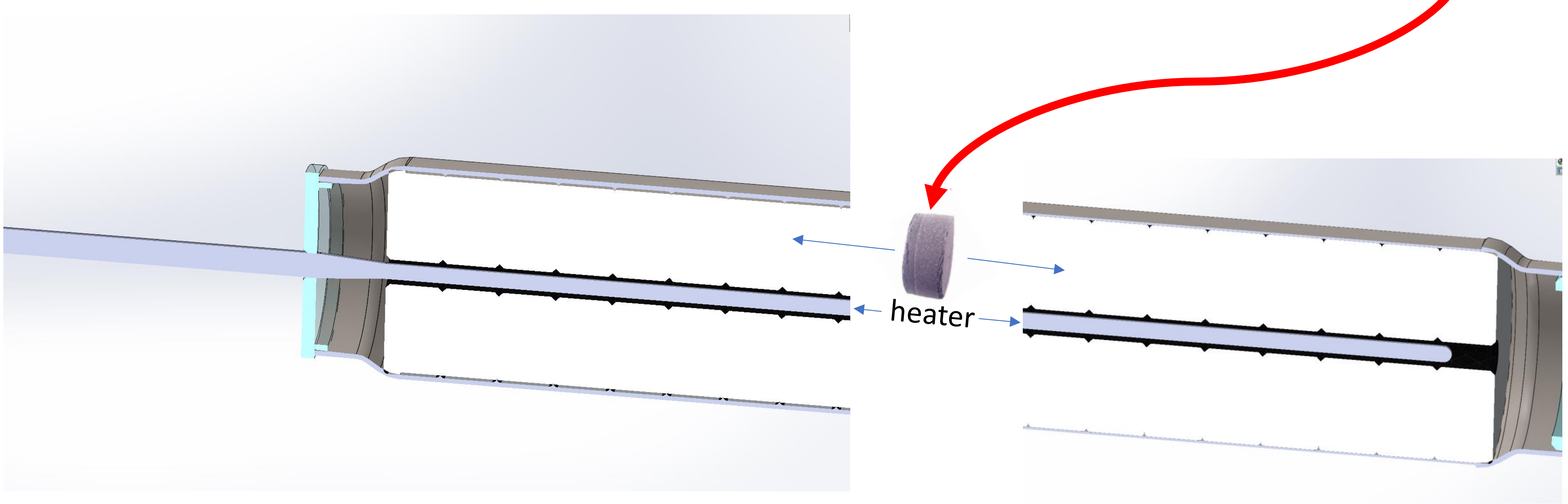


Concept design: vibration suppression

Potential vibration source	Action
Mechanical vibrations compressor	Sorption compressor





→ Performed burst tests and lifetime tests

Concept design: vibration suppression

Potential vibration source	Action
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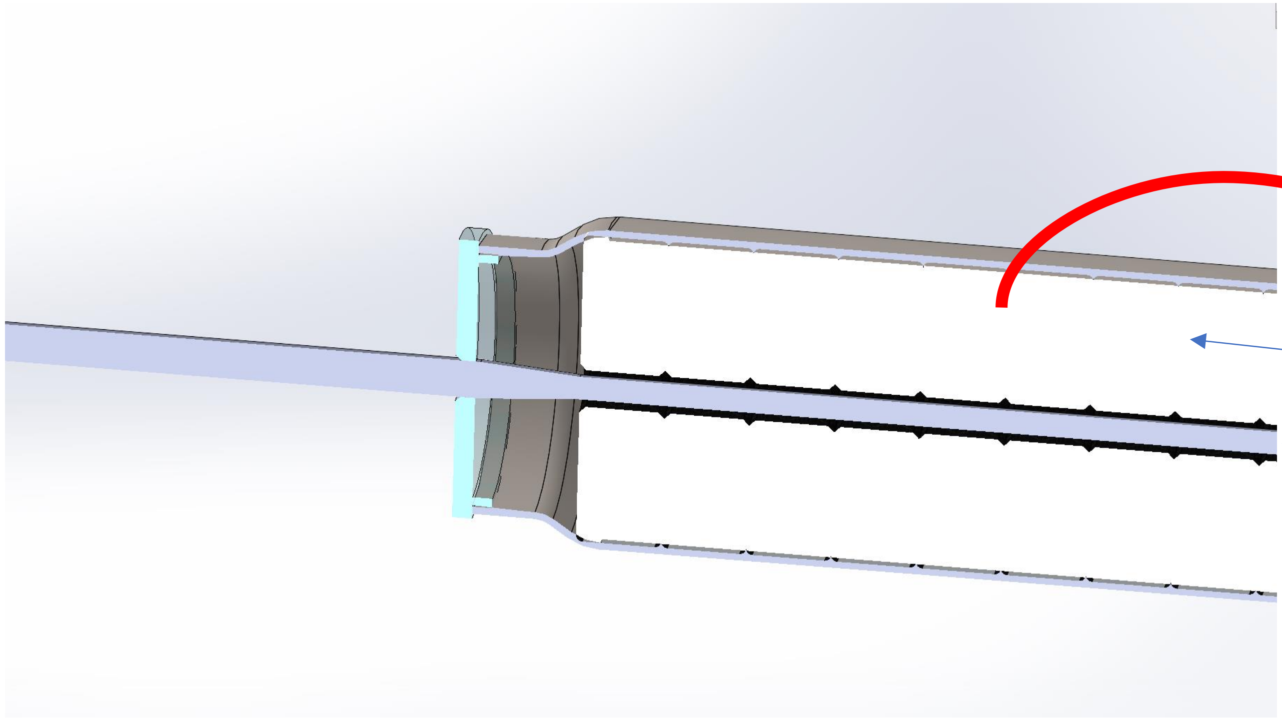
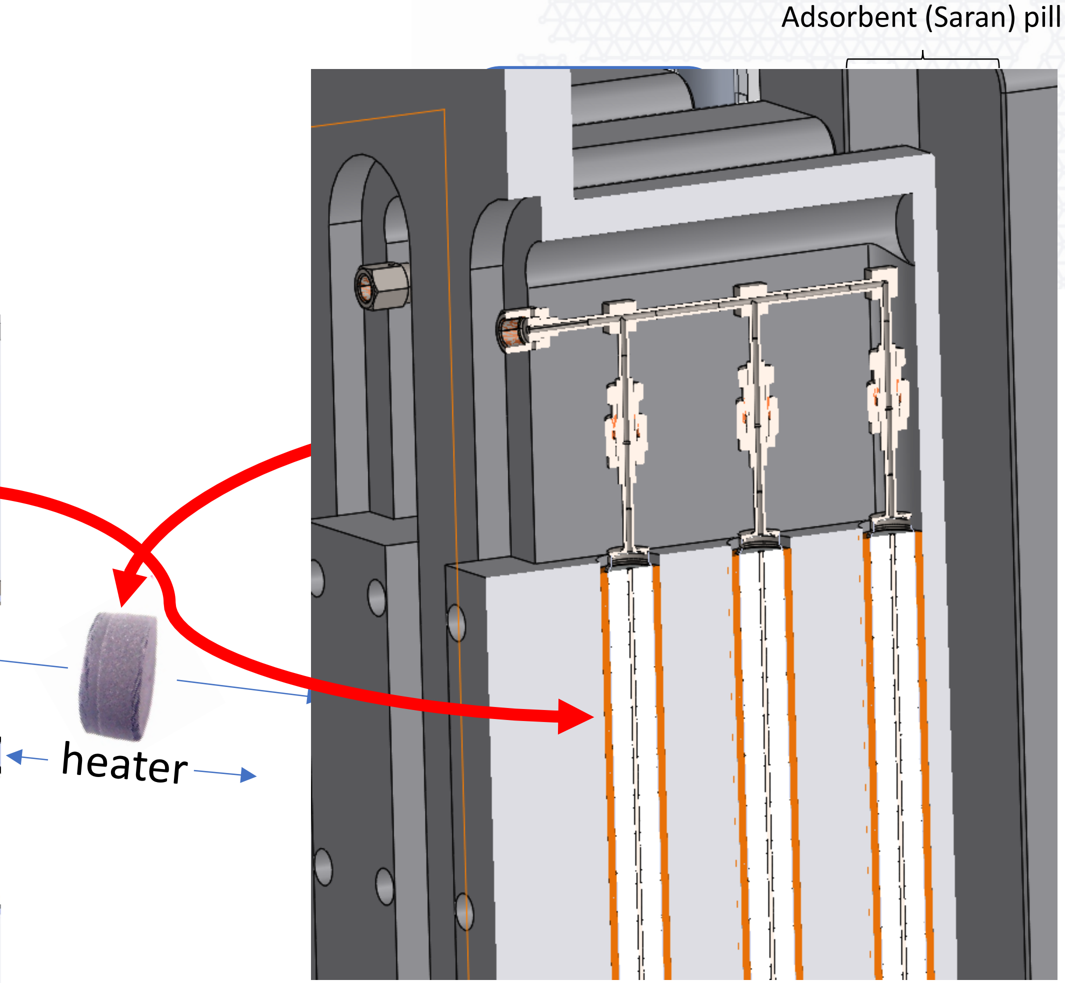

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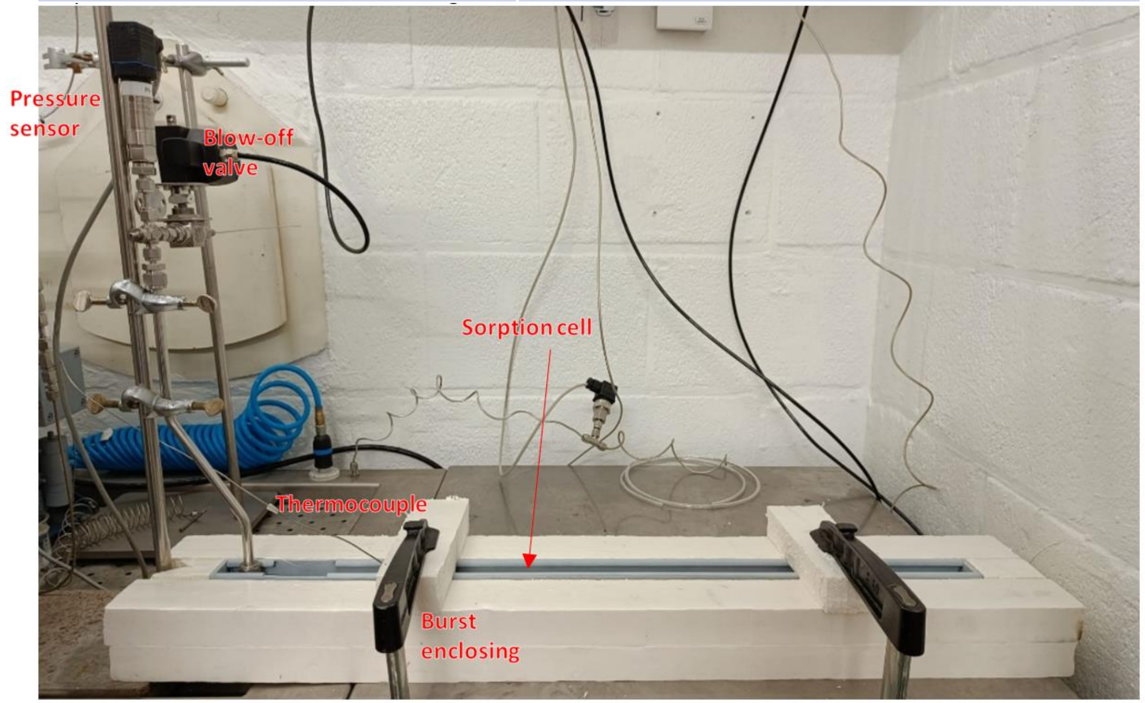

Material	Cycled?	Burst Pressure (bar)	Max Temperature (K)	Remarks
SS-444	No	256	77	-
SS-444	No	247	77	-
SS-444	No	253	77	-
SS-444	Yes	272	77	-
SS-444	Yes	269	77	-
SS-444	Yes	265	77	-
SS-444	Yes	267	77	-
SS-316L	No	No burst	170	P burst > 425 bar
SS-316L	No	230 (deformation @140)	RT	-
SS-316L	No	230 (deformation @130)	RT	-
SS-316L	No	230 (deformation @125)	RT	-
SS-316L	No	No burst	170	P burst > 420 bar
SS-316L	No	No burst	170	P burst > 300 bar
SS-316L	6 M	No burst	170	P burst > 400 bar

Concept design: vibration suppression

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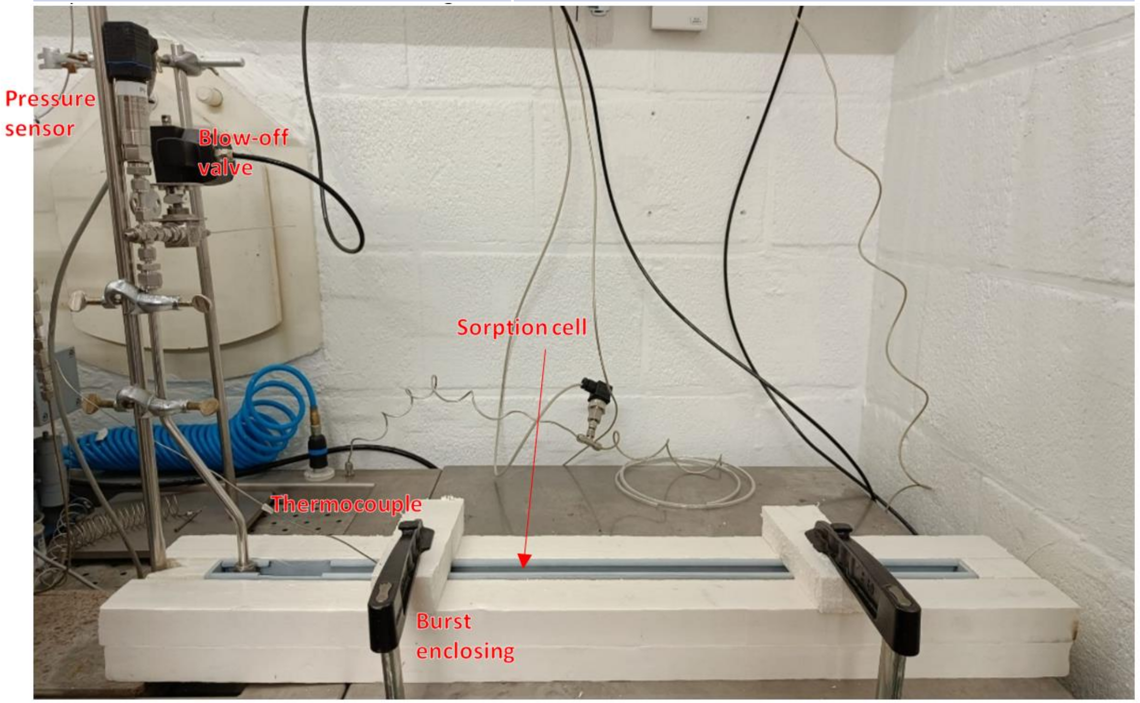
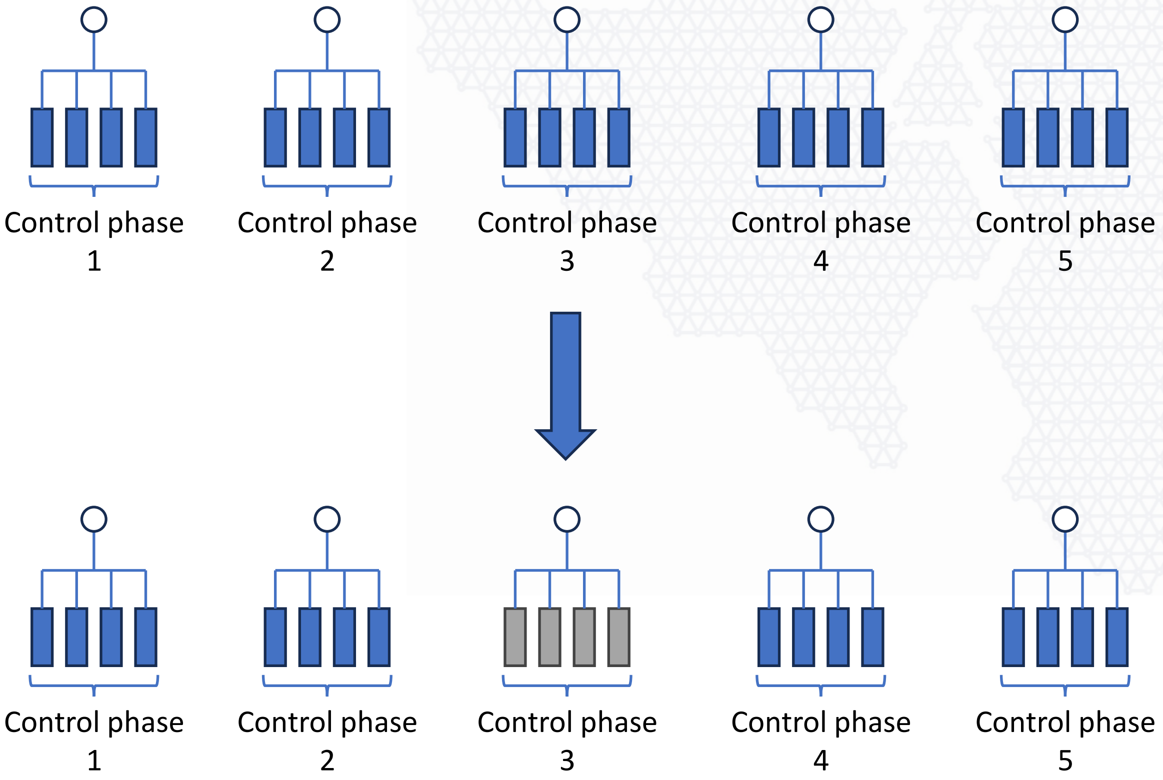
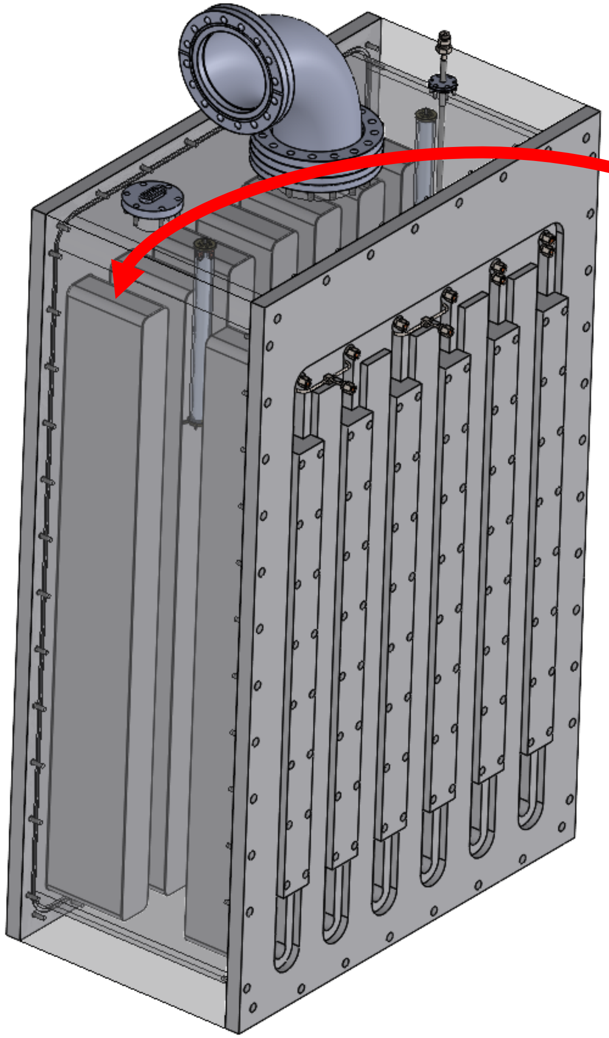


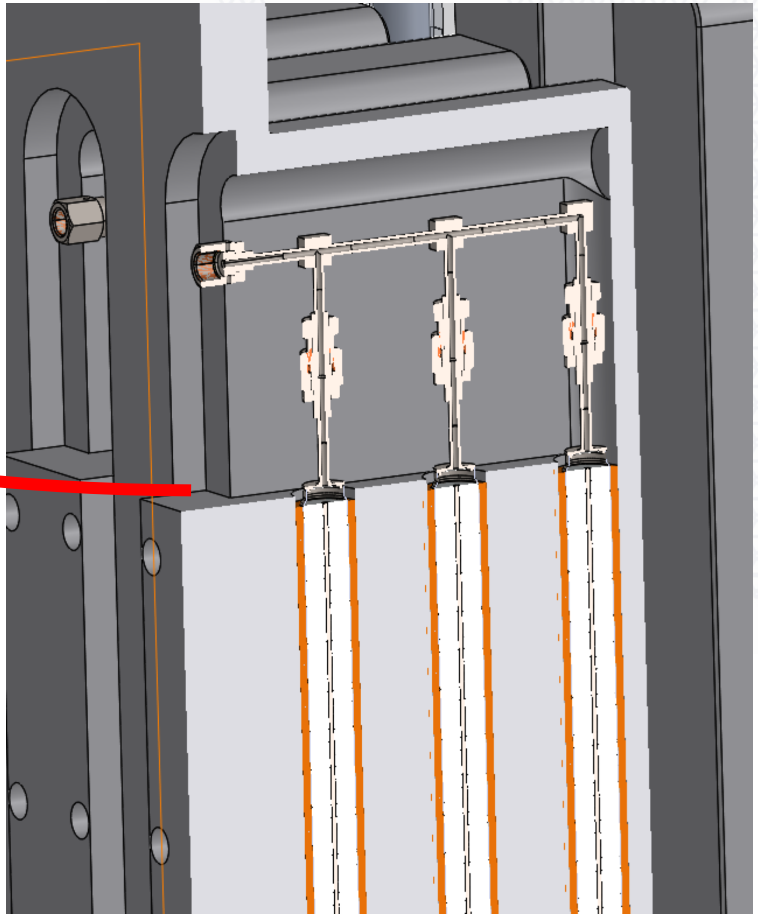


Each stage has 2 redundant branches

Concept design: vibration suppression

Pot	
Me cor	ssor

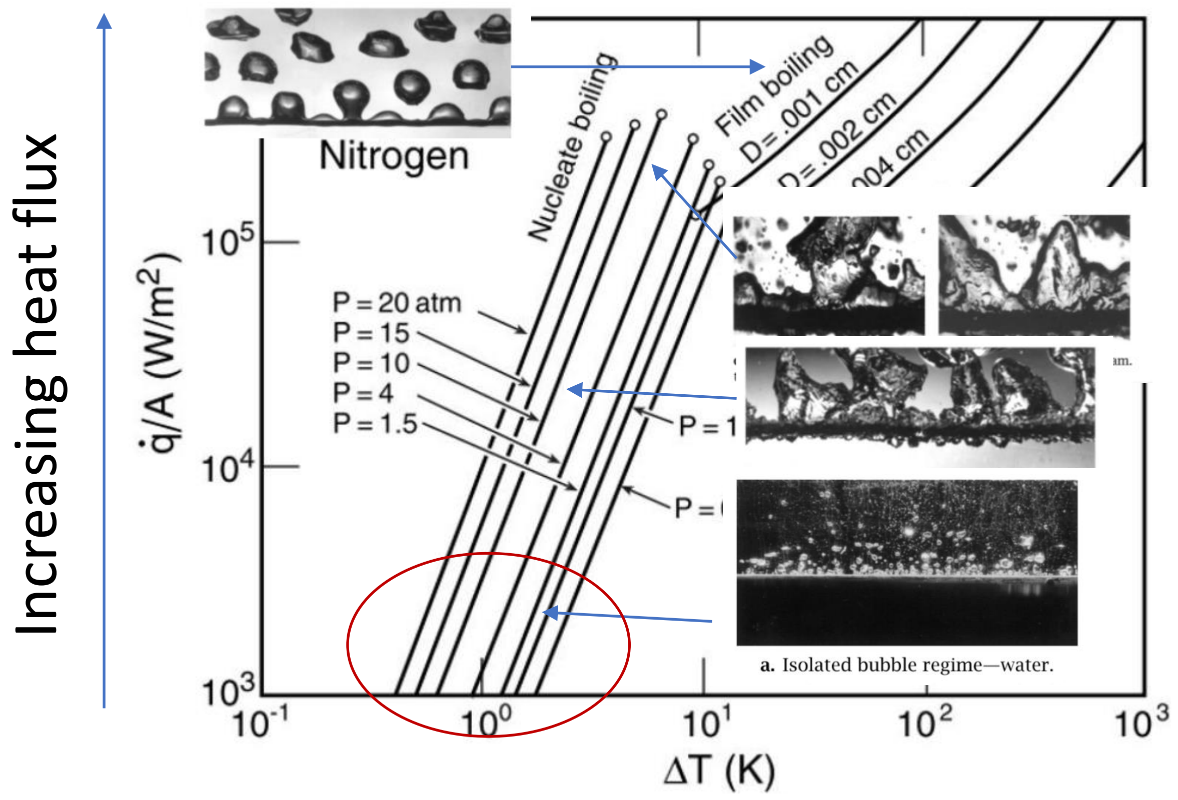




Inside is filled with LN2 for cooling → vibrations caused by LN2 cooling shall also be mitigated

Concept design: vibration suppression

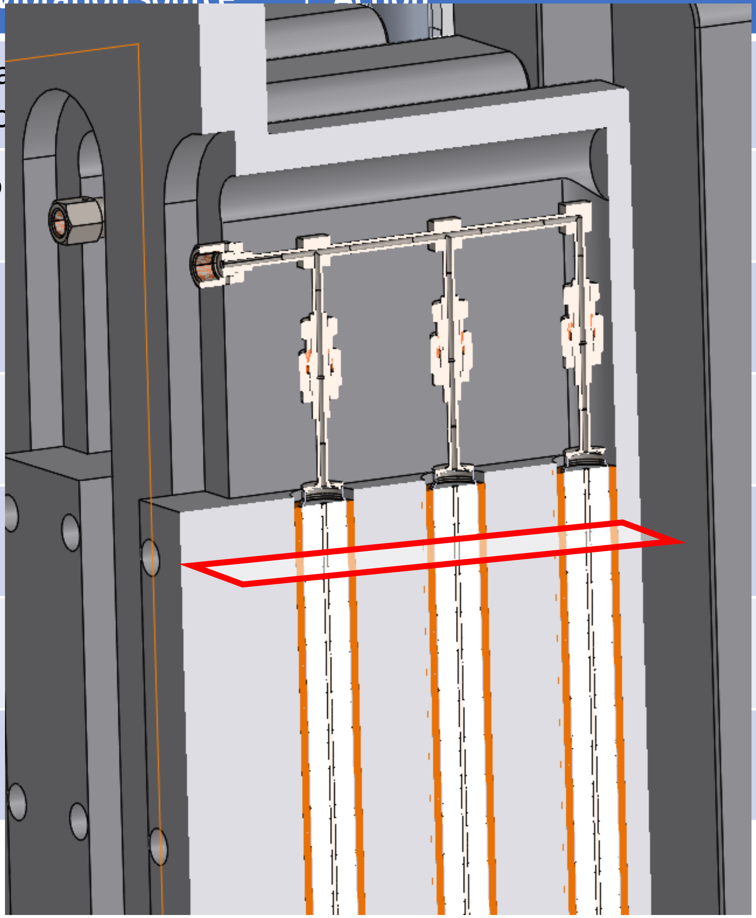
Potential vibration source	Action
Mechanical vibrations compressor	Sorption compressor
Violent boiling at LN2 interfaces	Large surface area h''<3000 W/K/m^2

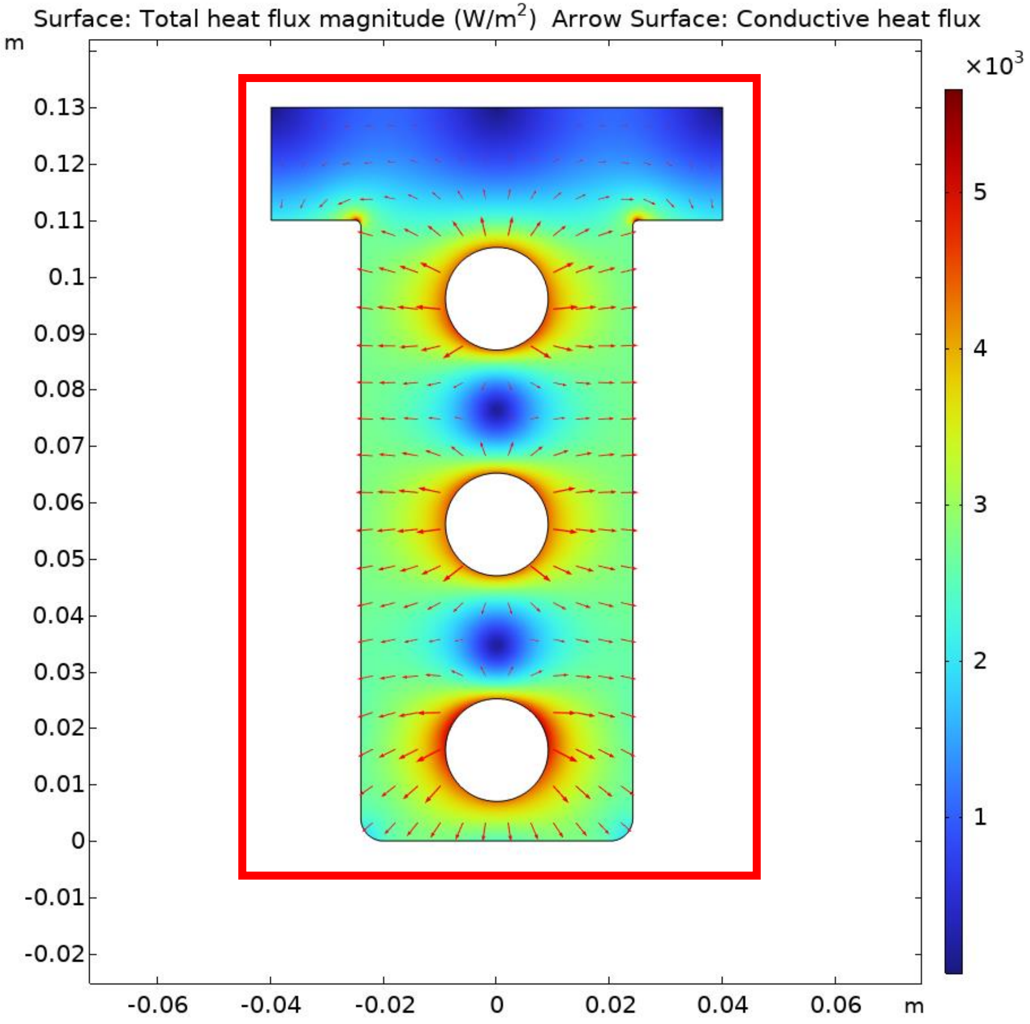


Graph: J.W. Ekin, Experimental techniques in low temperature measurements
Stills: JH Lienhard IV: A heat transfer textbook

Concept design: vibration suppression

Potential vibration source	Action
Mechanica compresso	
Violent bo interfaces	





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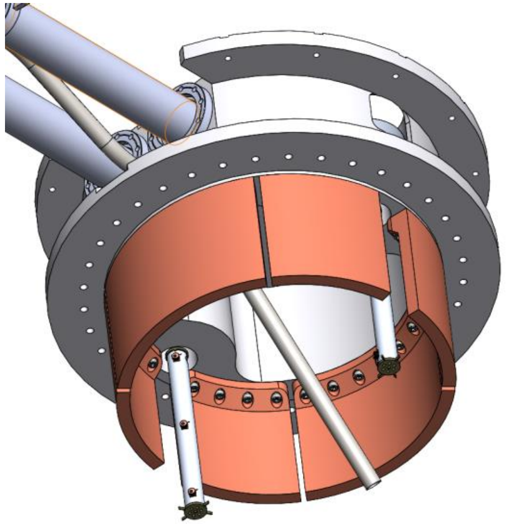

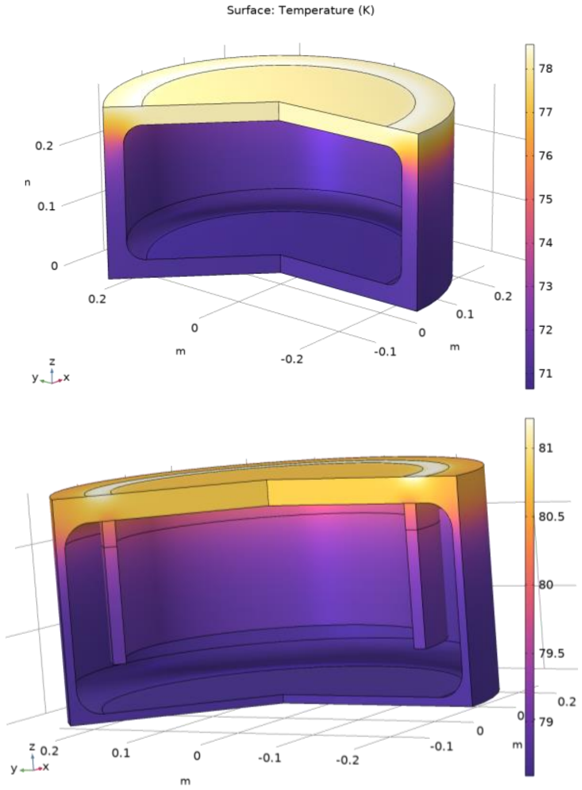

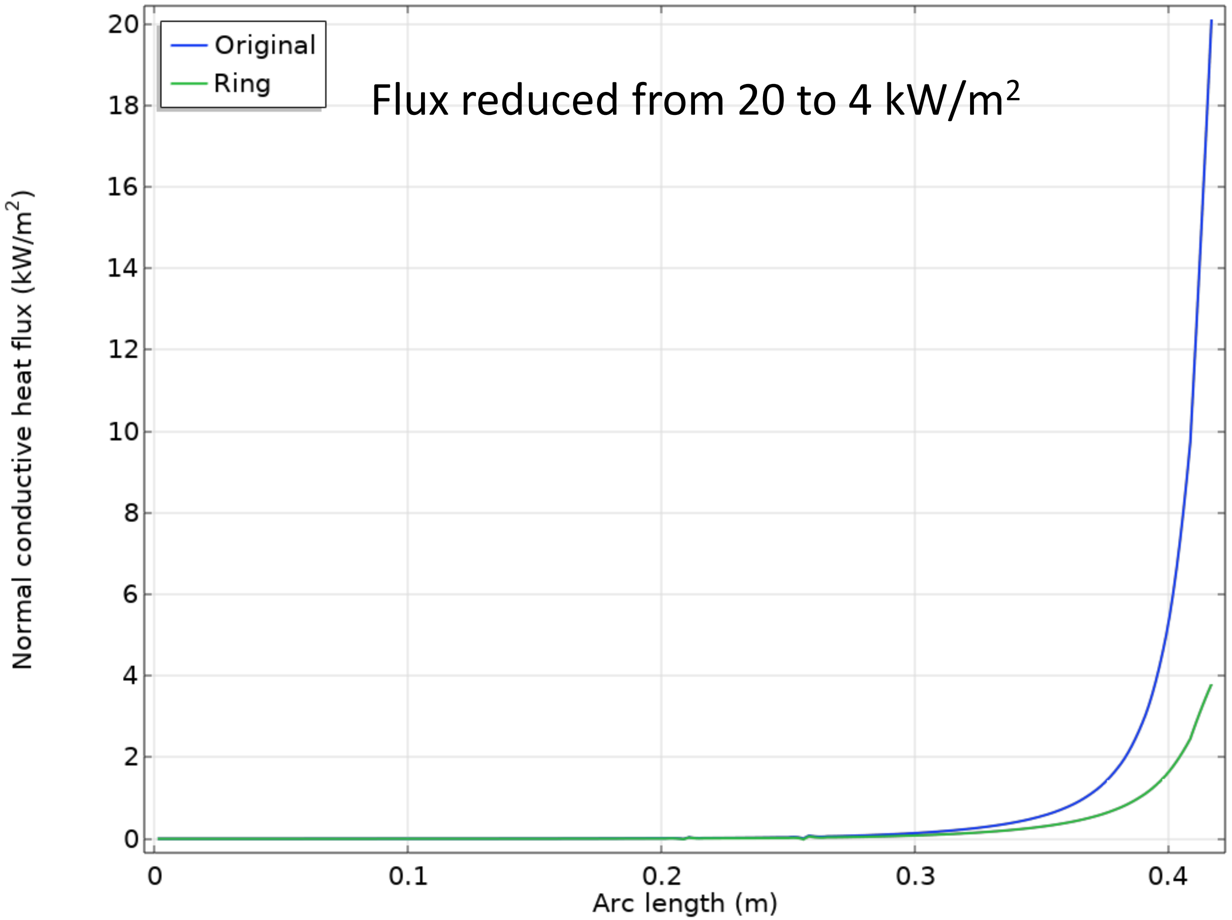

Concept design: vibration suppression

Potential vibration source	Action
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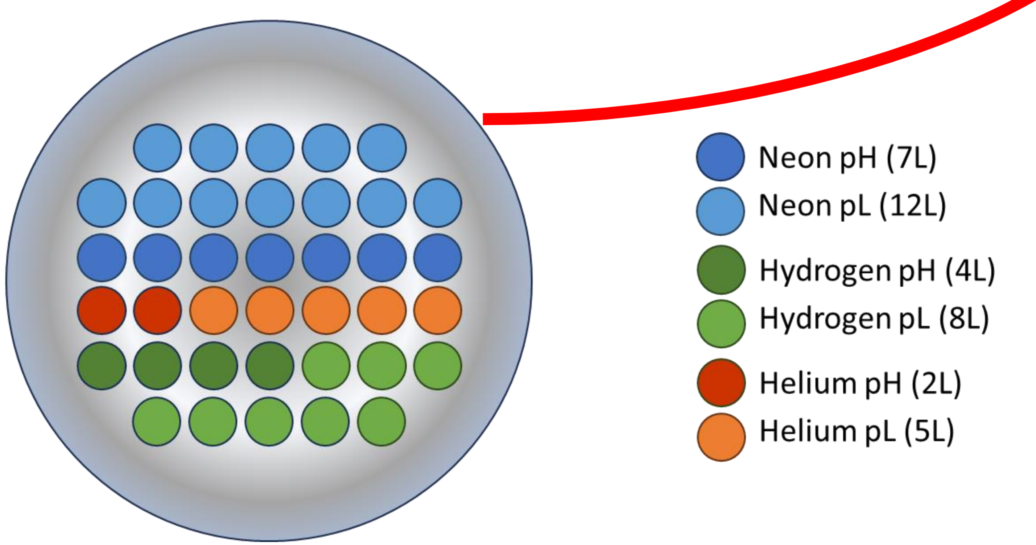
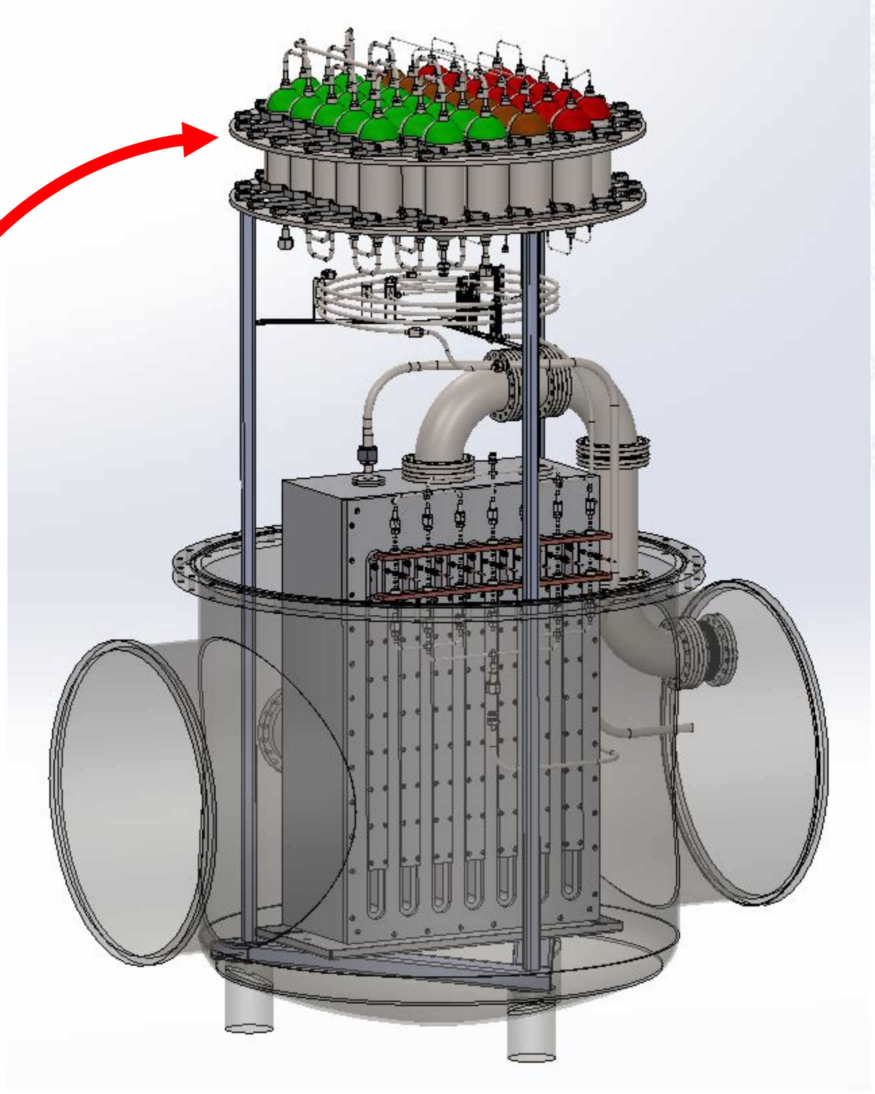
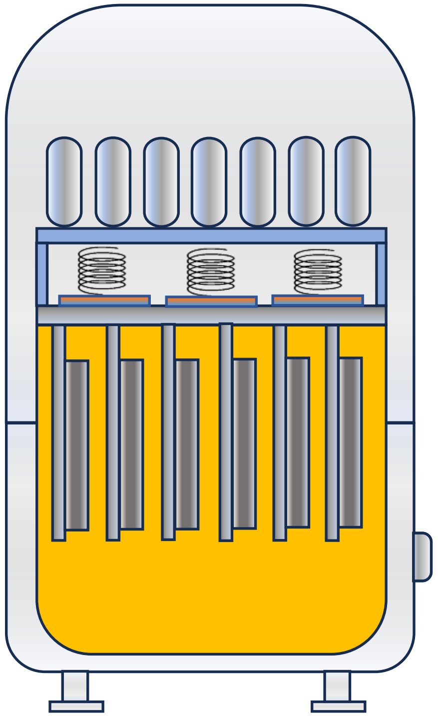
Buffer sizes	Maximize buffers to minimize pressure fluctuations

Proposed configuration

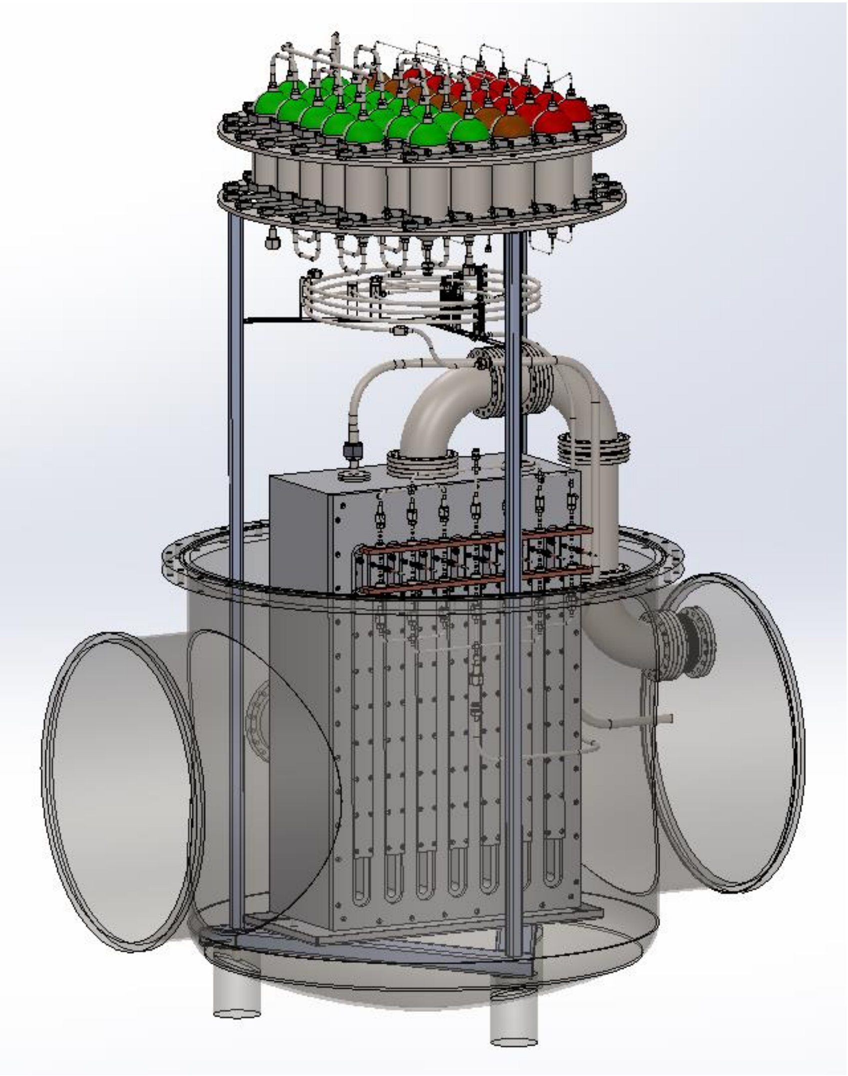




Compressor



Concept design



Detailed design

Concept design: vibration suppression

Potential vibration source	Action
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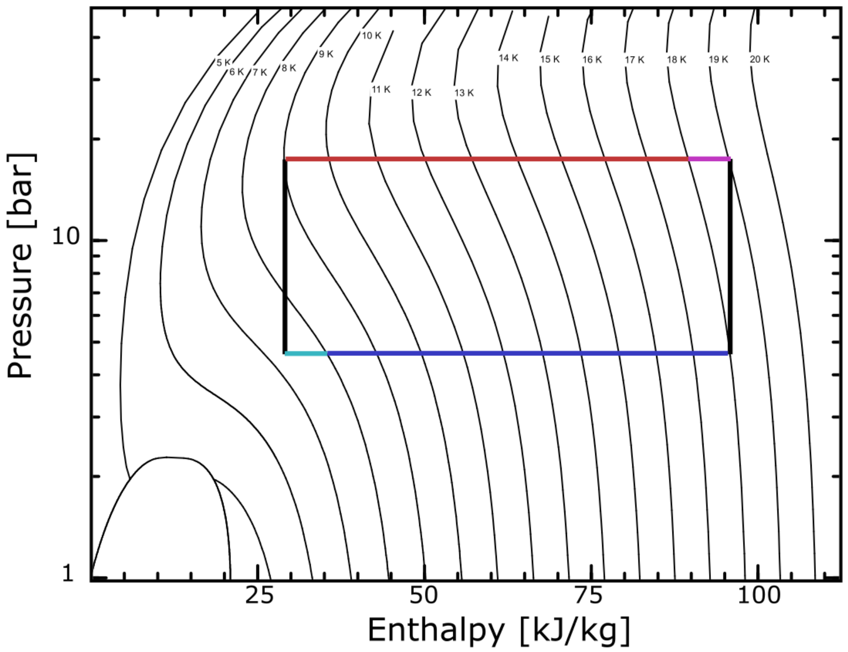
Violent boiling at LN2 interfaces	Large surface area h''<3000 W/K/m^2
Buffer sizes	Maximize buffers to minimize pressure fluctuations (in volume budget)
Turbulent flow	Low mass flow large $\Delta H(p_l, p_h) = \dot{Q}/\dot{m}$

Thermodynamic cycle Helium
(lowest T stage)



https://www.linkedin.com/posts/kyle-may-eit-a44b3615a_computationalfluiddynamics-cfd-fluid-activity-6925803992656617472-oCEc/
A unifying correlation for laminar particle deposition in 90-degree pipe bends - ScienceDirect

Concept design: vibration suppression

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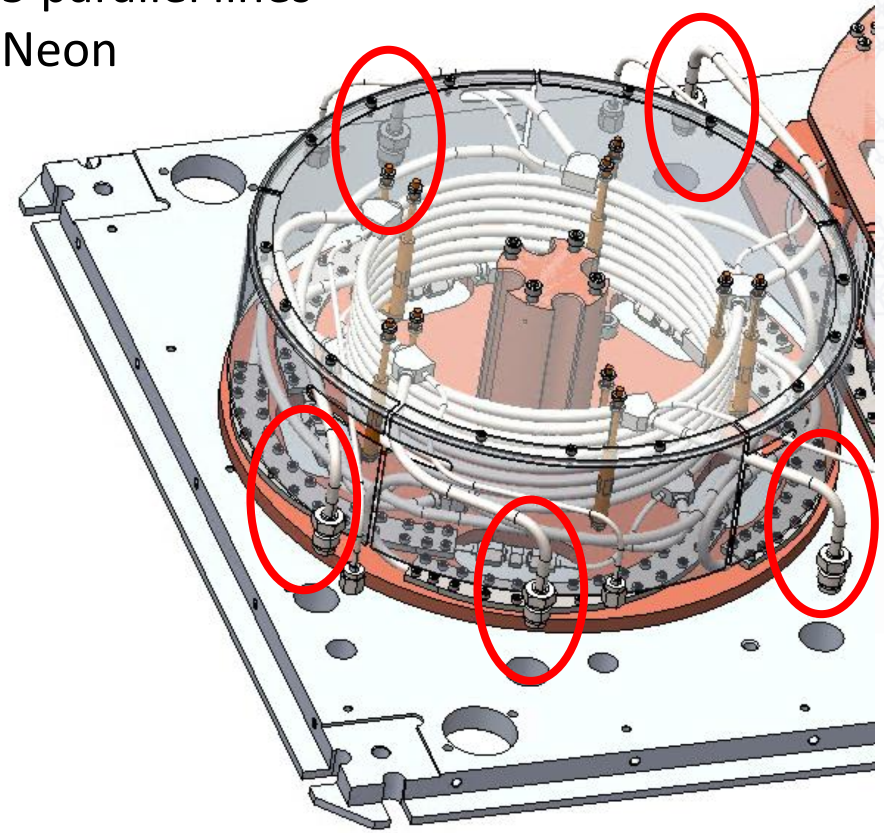
Turbulent flow	Low mass flow large $\Delta H(p_l, p_h) = \dot{Q}/\dot{m}$
Turbulent flow	Stay laminar Reynolds < 2000

5 parallel lines

Neon



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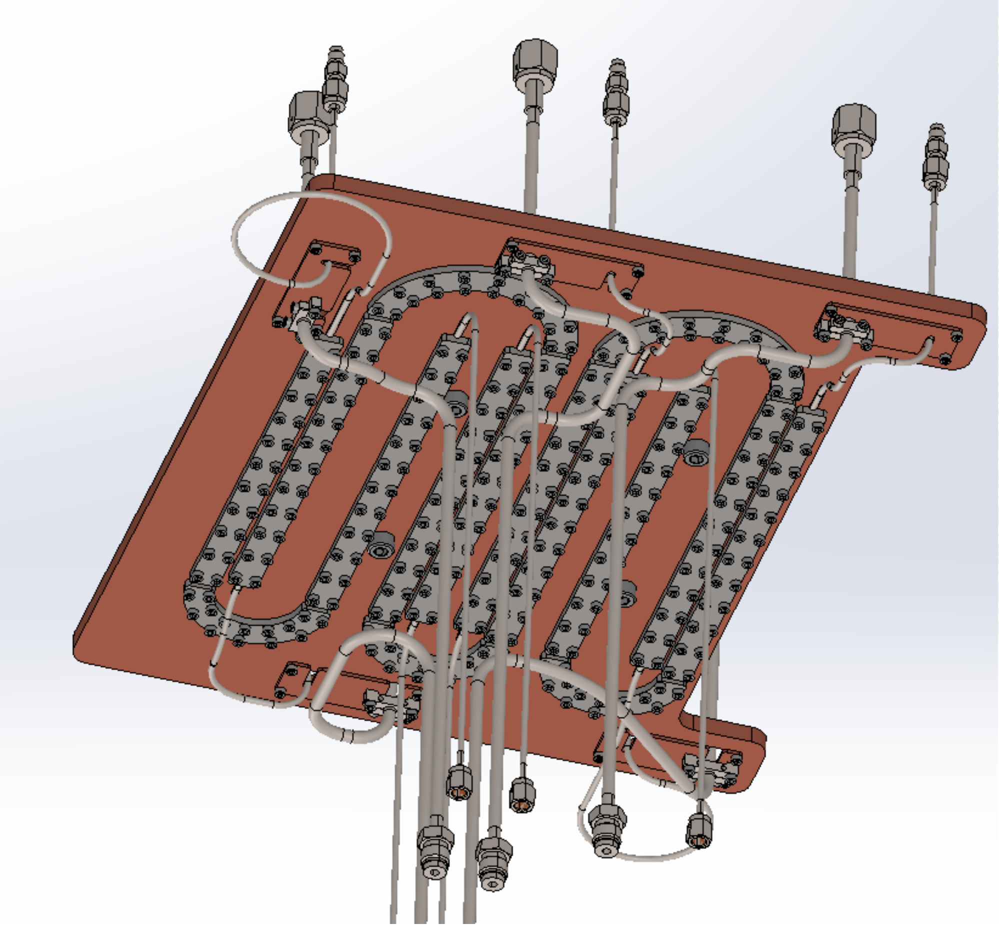
Secondary flow instabilities	No sharp turns in tubes Dean=Re$\sqrt{d/D}$ <60



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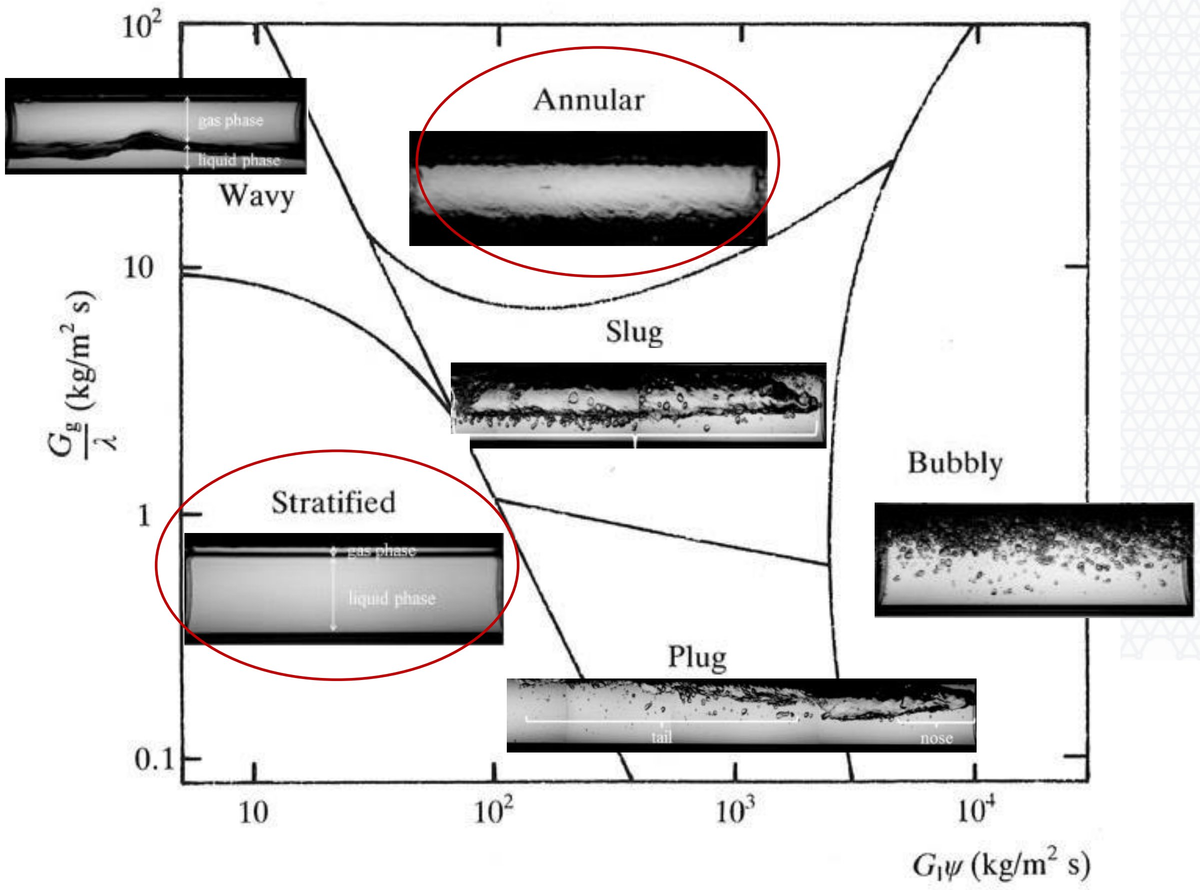
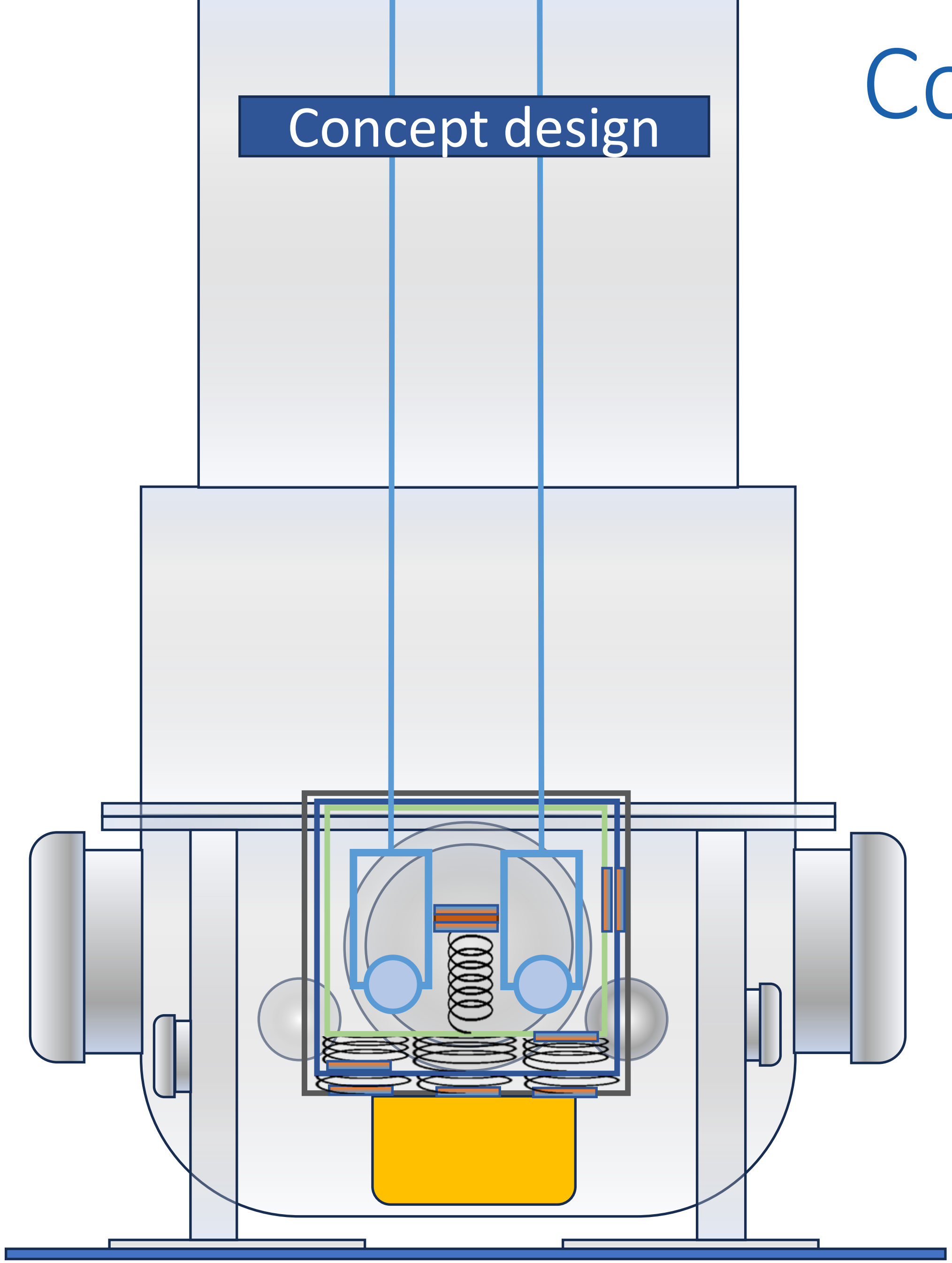
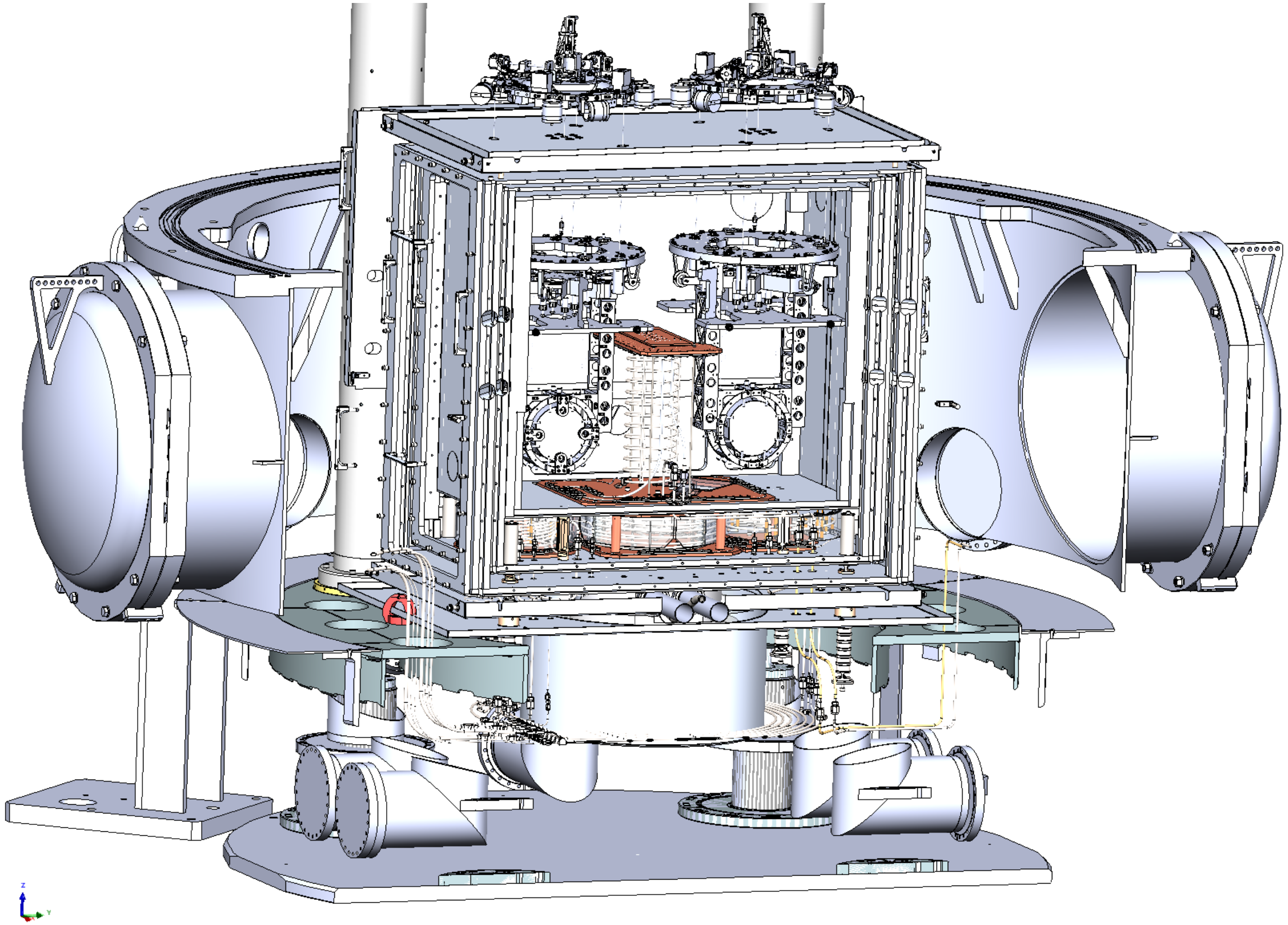
Turbulent flow	Stay laminar Reynolds < 2000
Secondary flow instabilities	No sharp turns in tubes Dean=Re$\sqrt{d/D}$ <60
Boiling in the evaporators	Combine 2 flow regimes



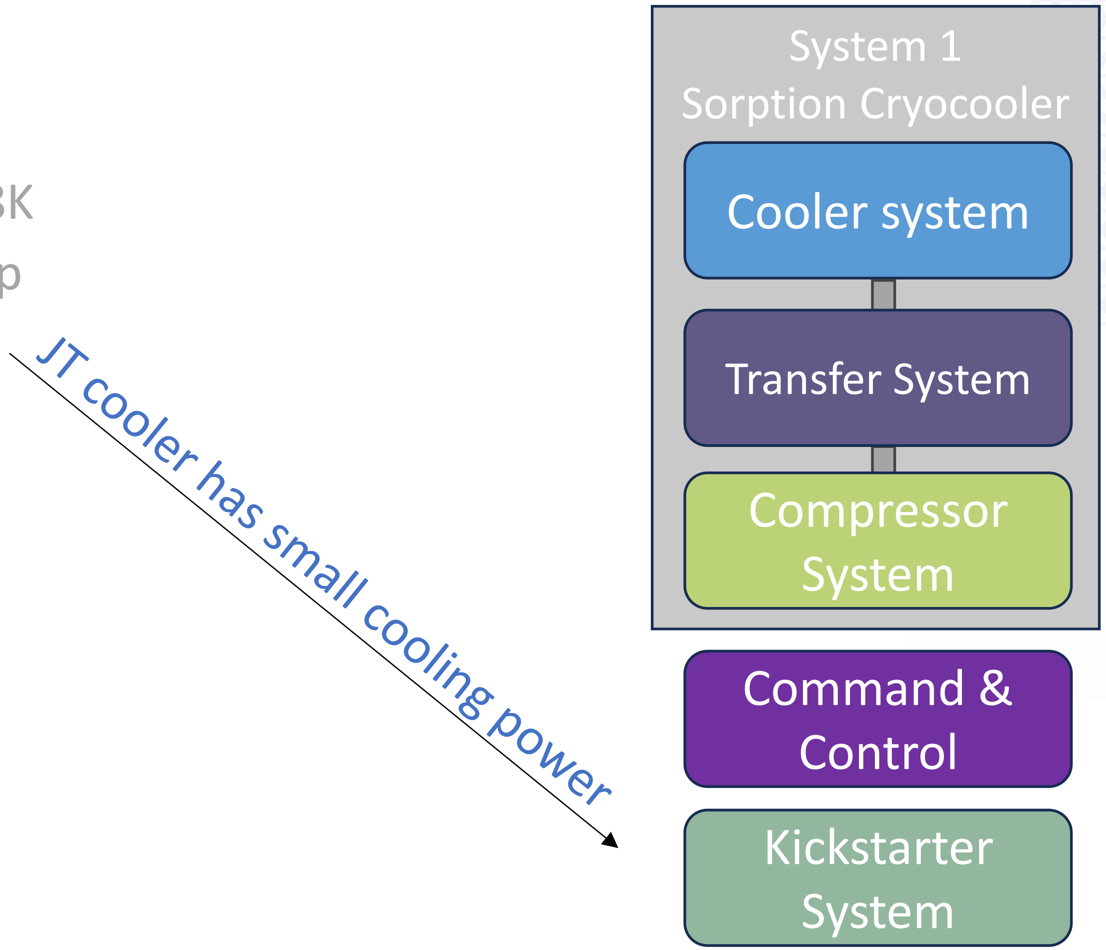
Cooler



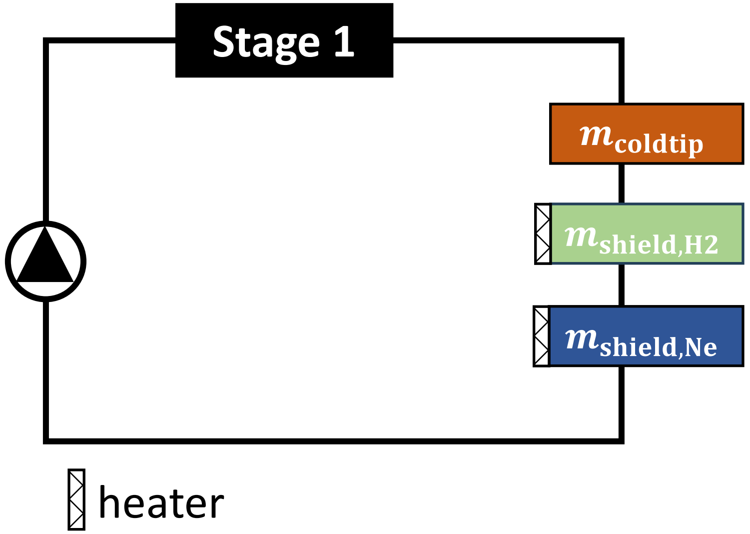


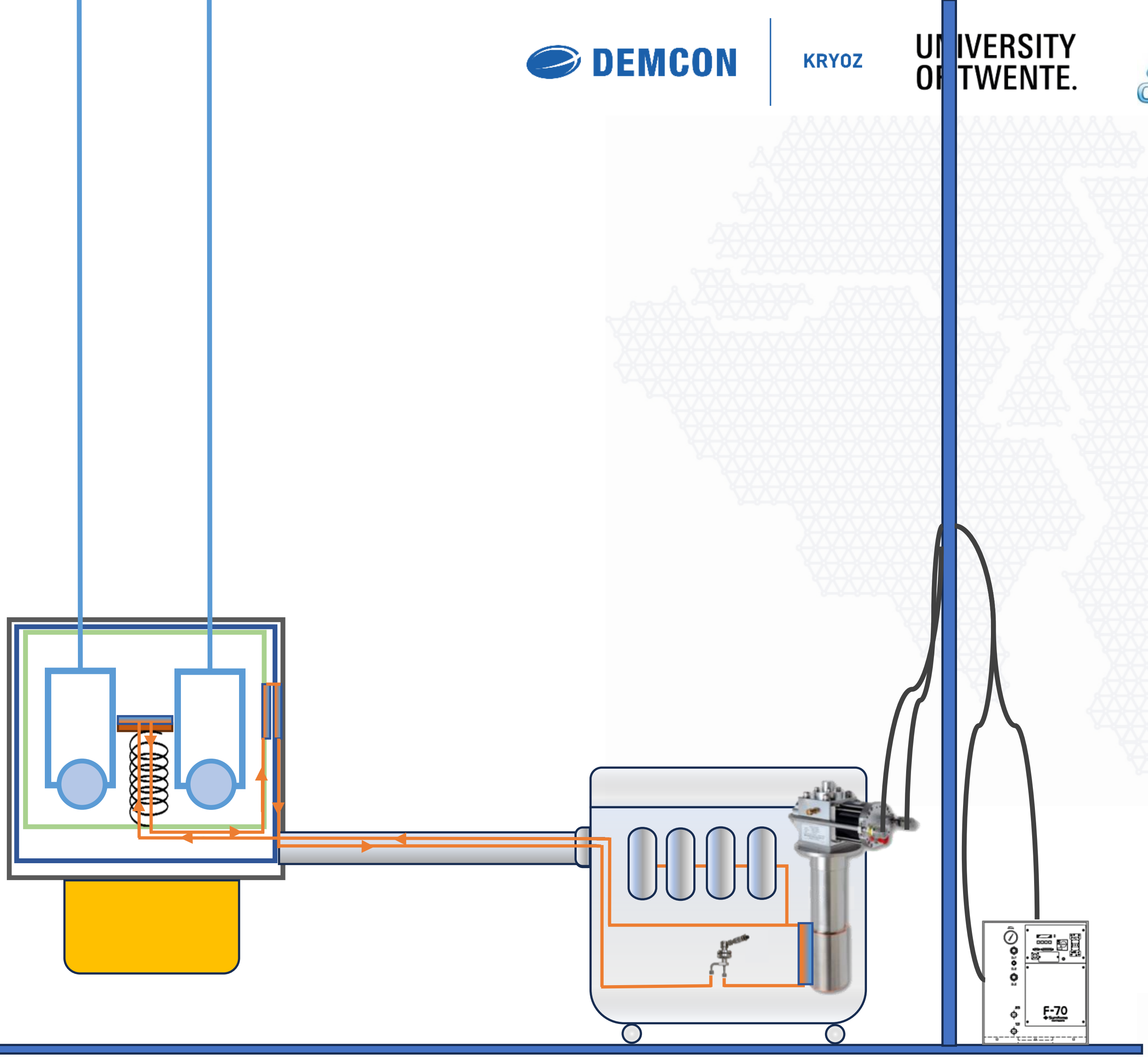
Cooldown requirement

- Requirements:
  - Cooling power: 50 mW @ 8K
  - Vibration level: < 32 nm p2p
  - Cooldown time: < 4 weeks



Kickstarter





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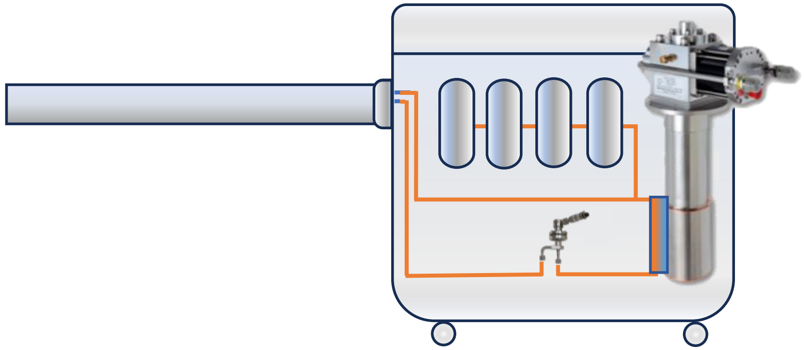
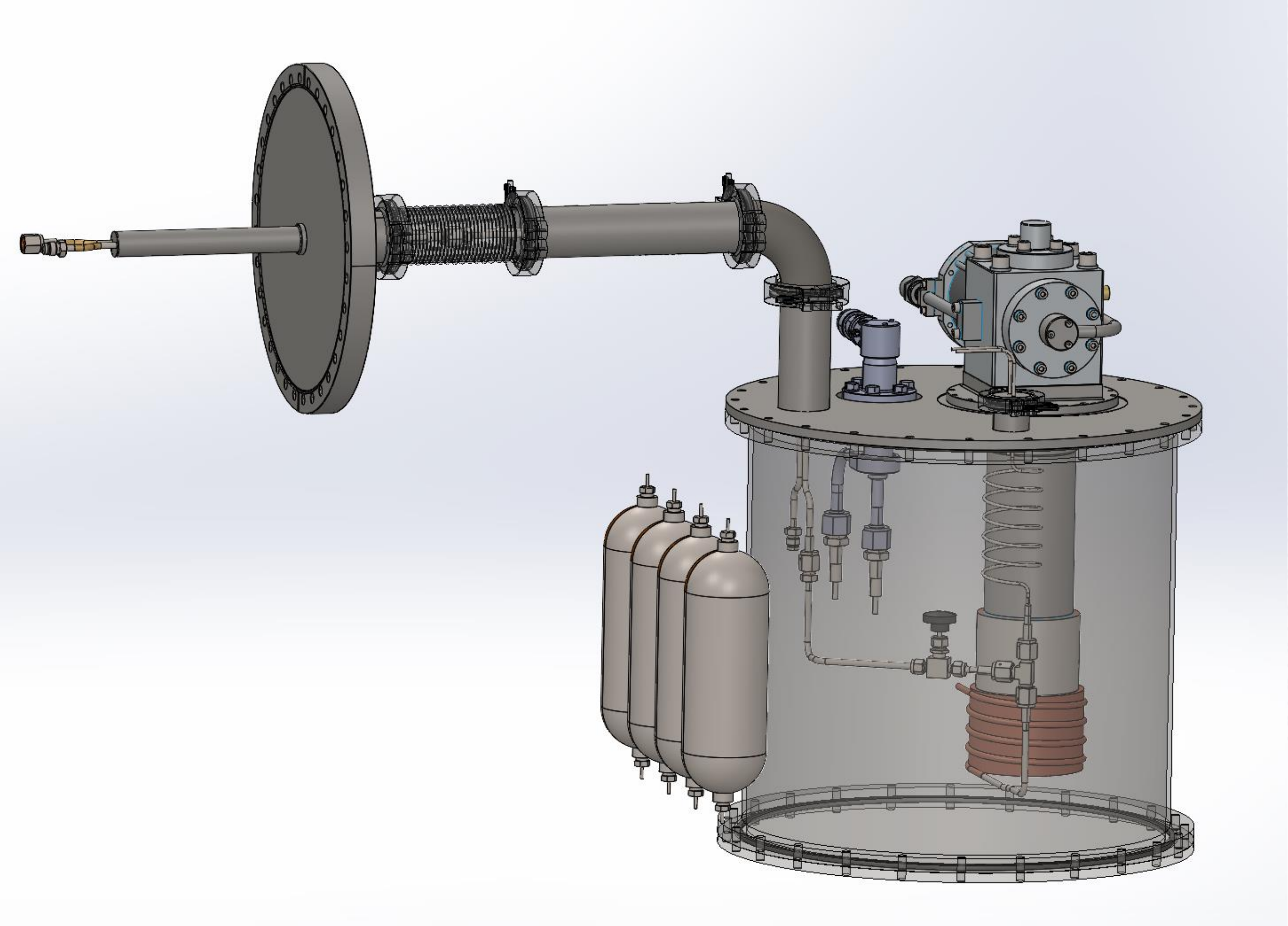
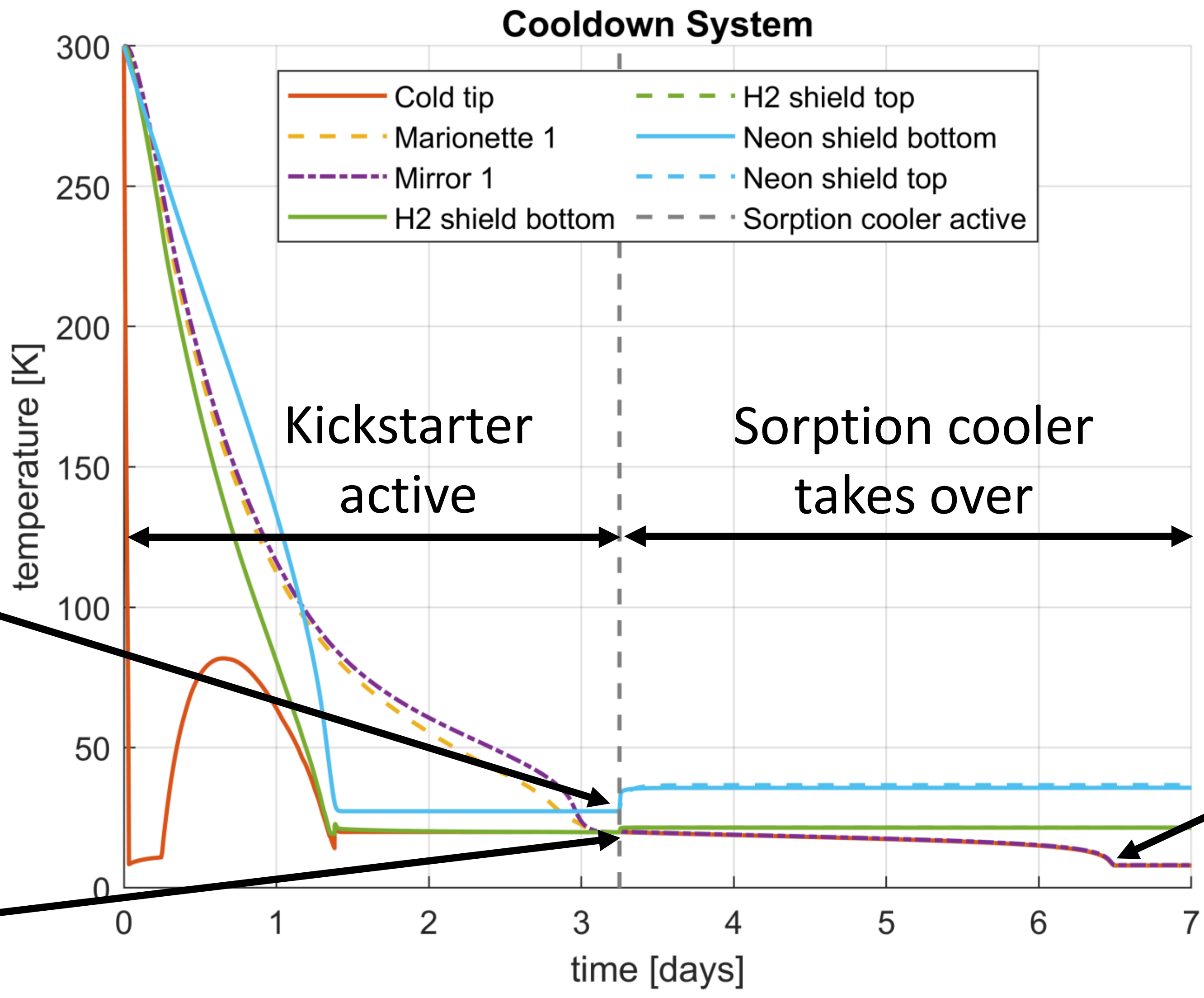


Concept design



Detailed design

Cooldown strategy



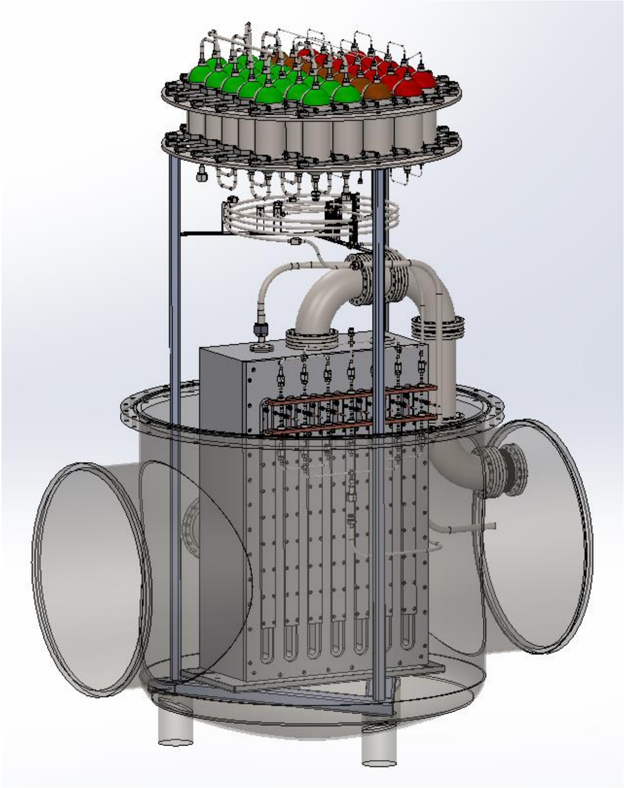
Heater prevents freezing of neon

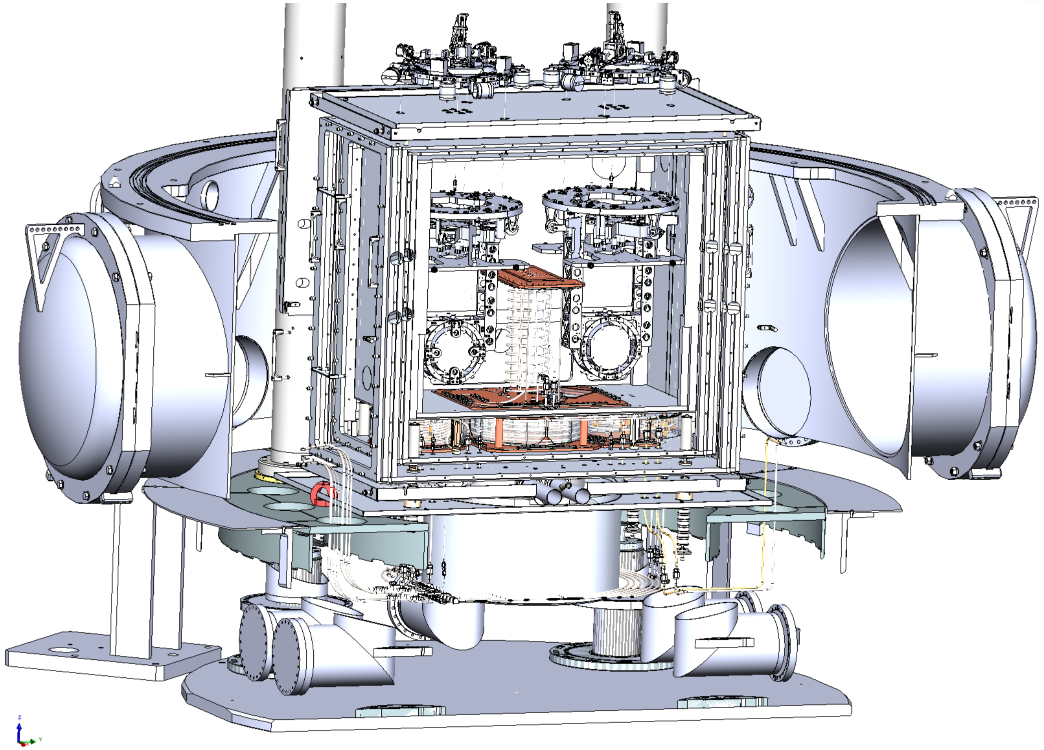
Cold tip reaches 20 K

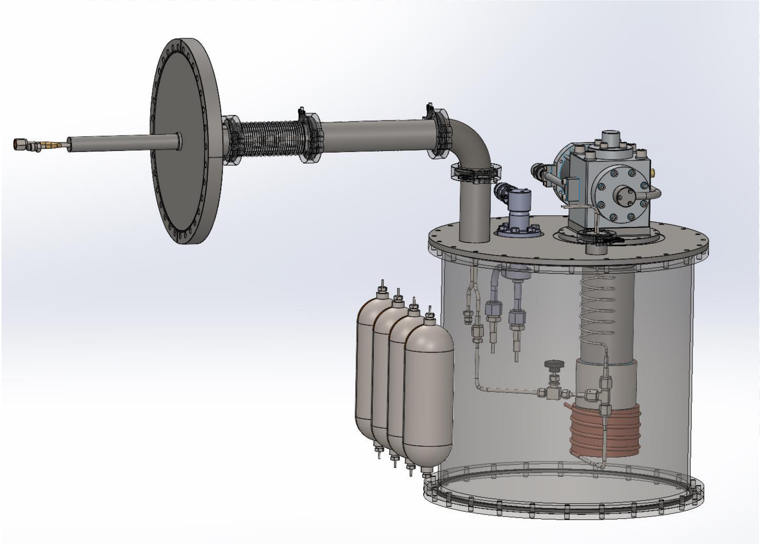
Cold tip reaches 8 K

Total cooldown: 6.5 days
Requirement: 4 weeks

Subsystems detailed design







Next: system assembly

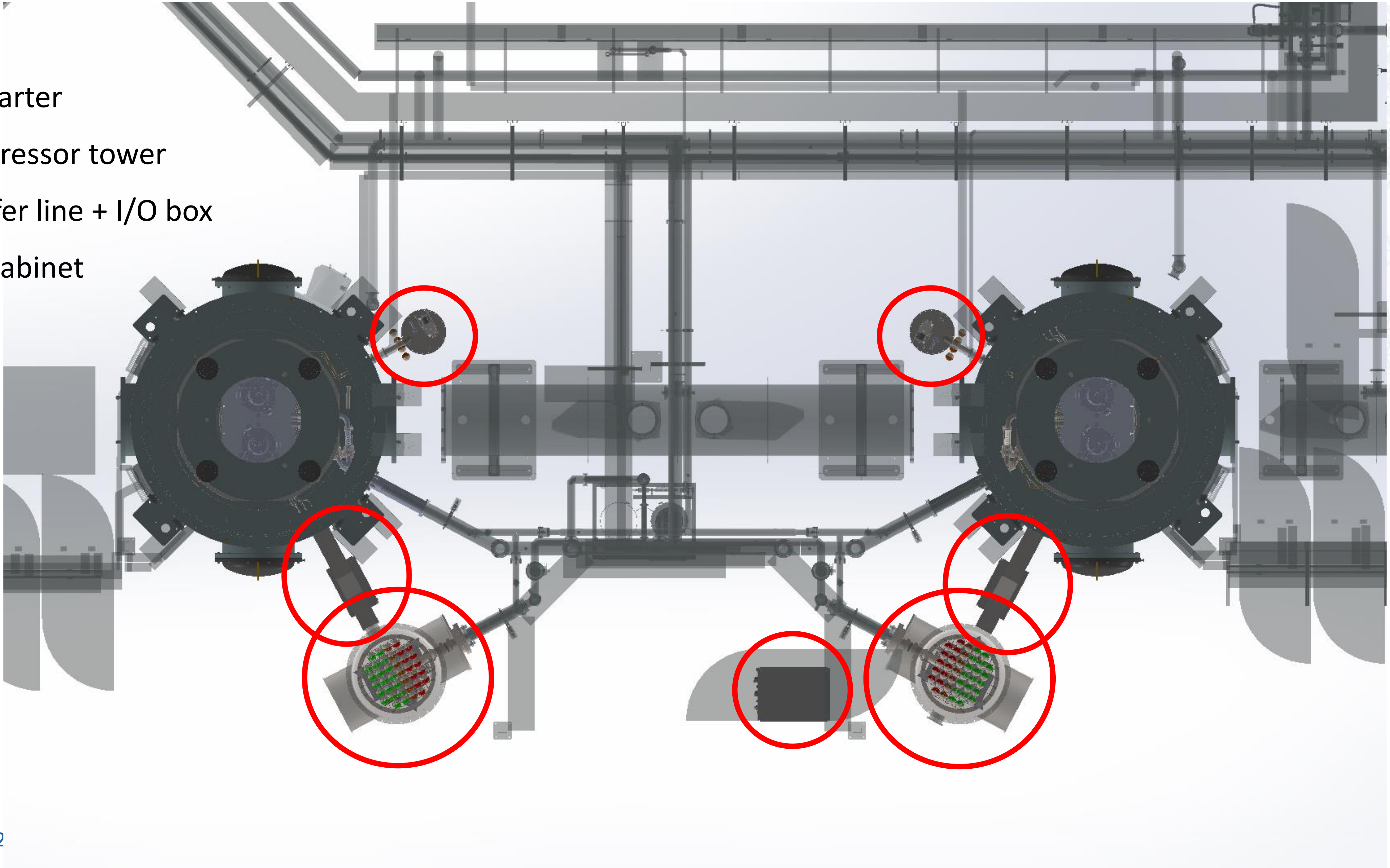
System assembly

Kickstarter

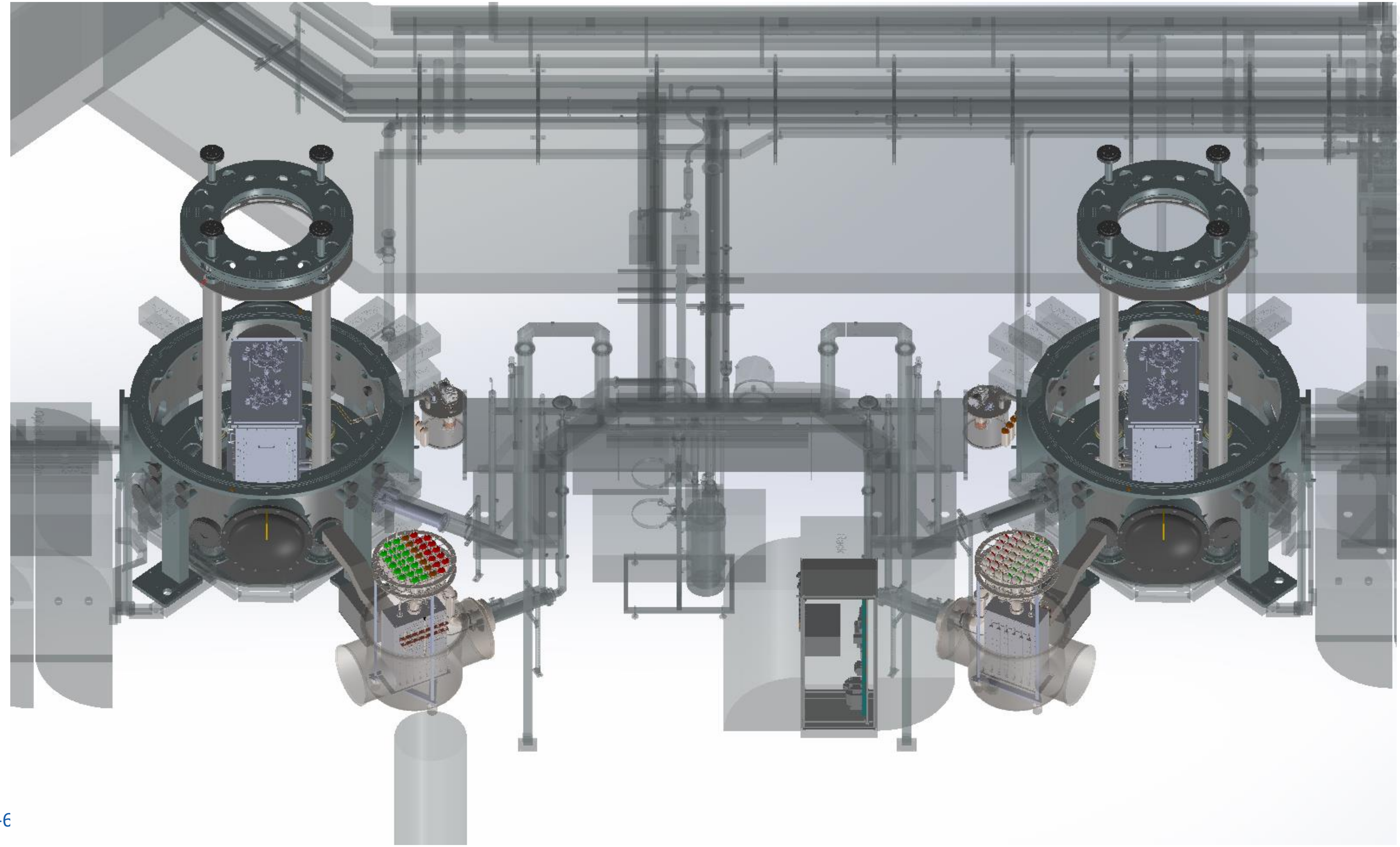
Compressor tower

Transfer line + I/O box

C&C cabinet



System assembly



System assembly

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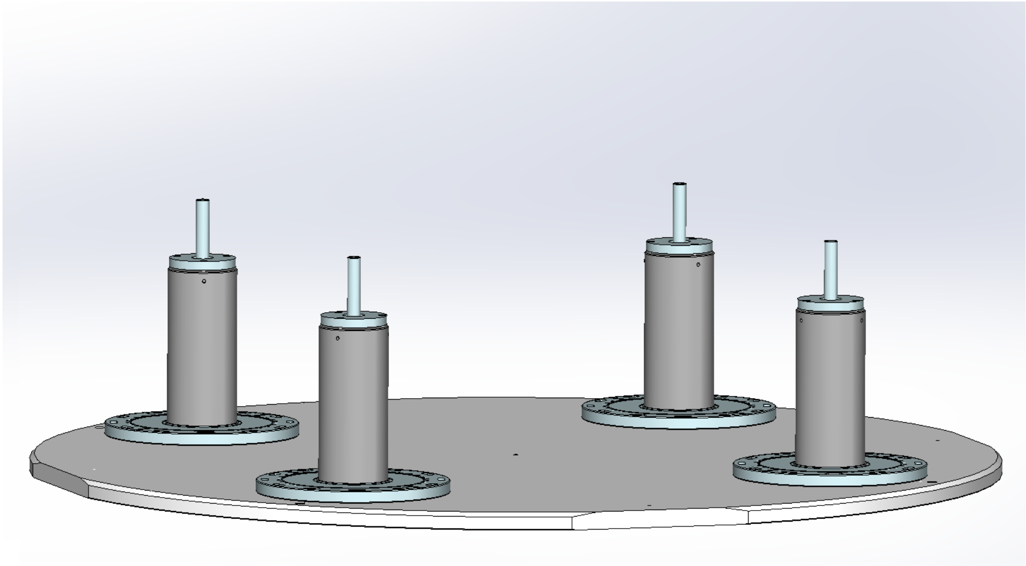
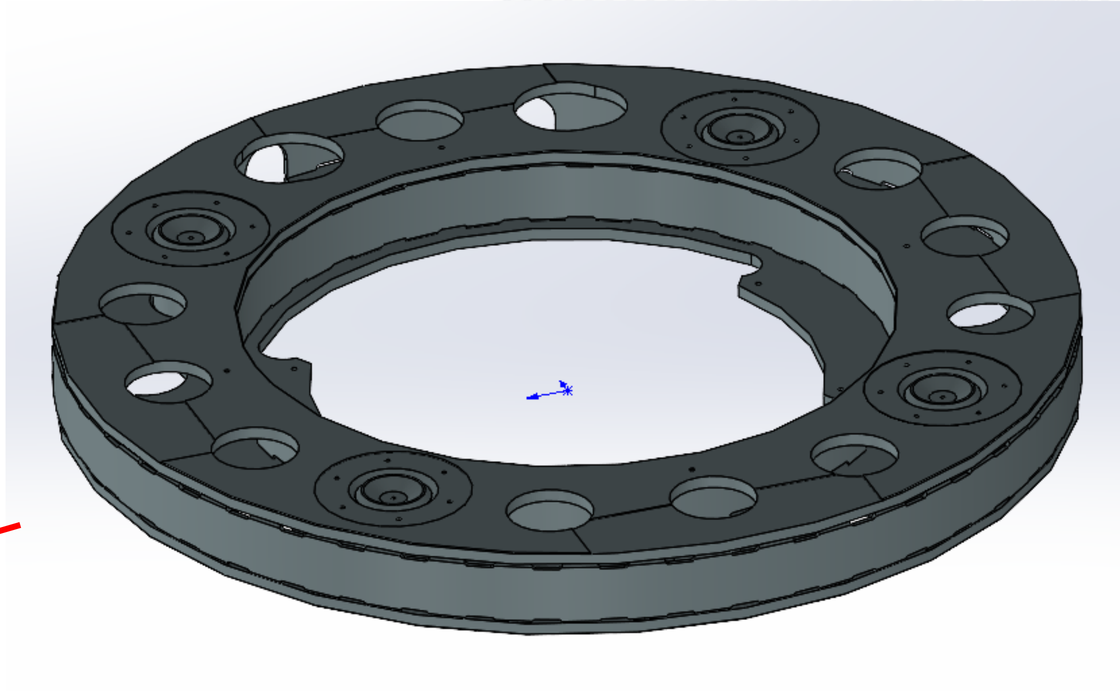
Master test plan
Build-up mirror tower

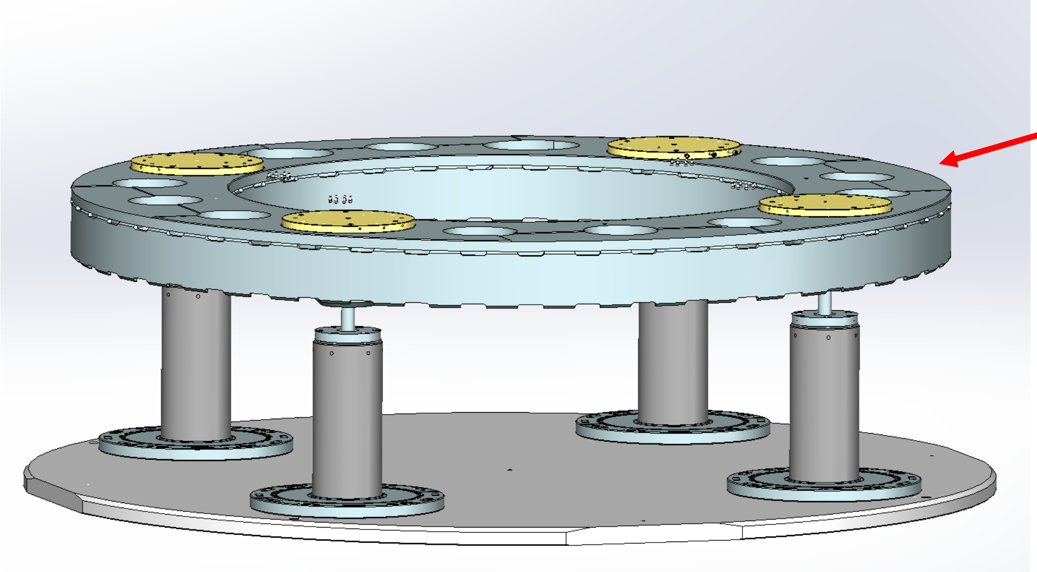
IP feet



Master test plan
Build-up mirror tower

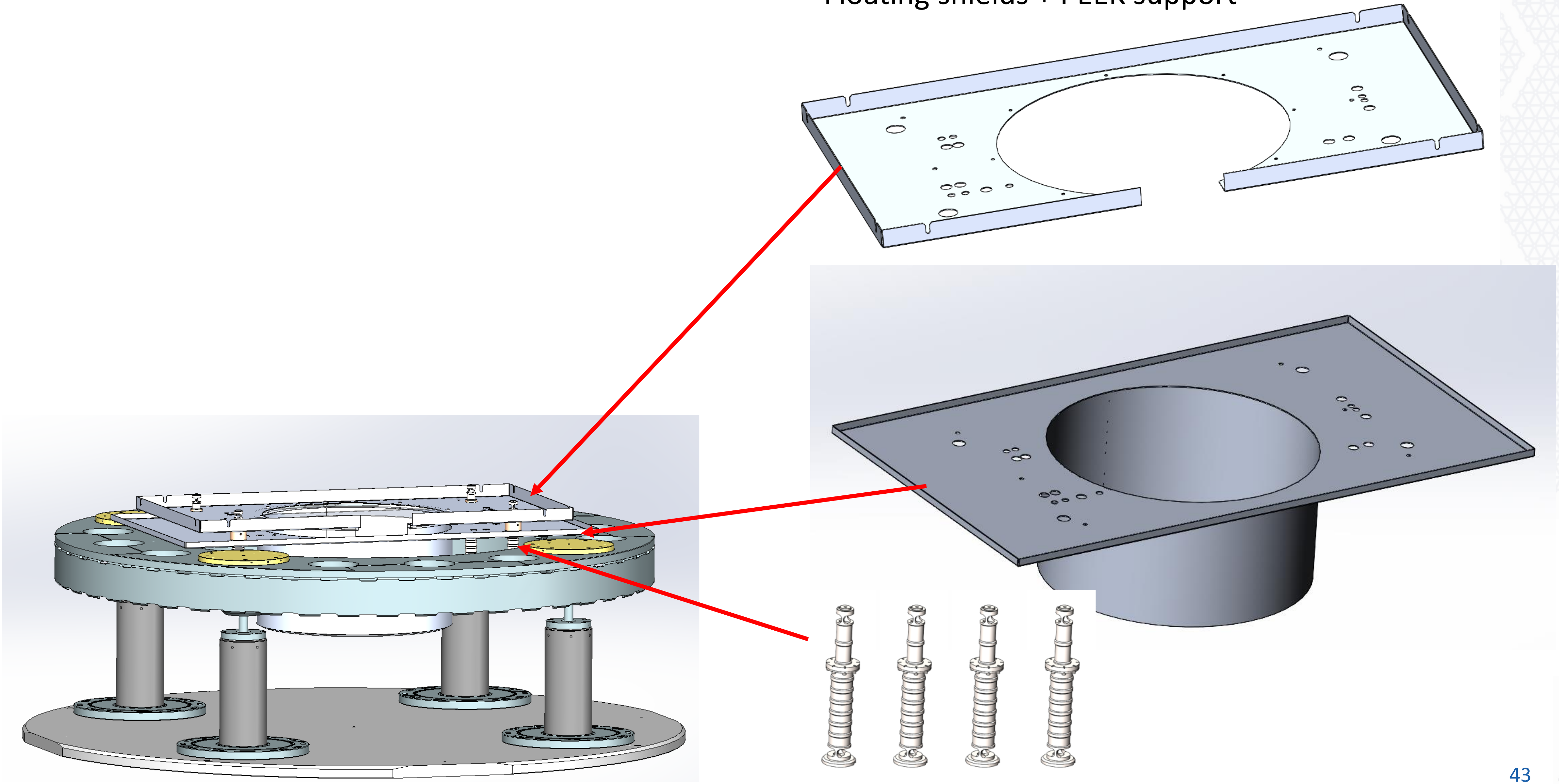
IP ring





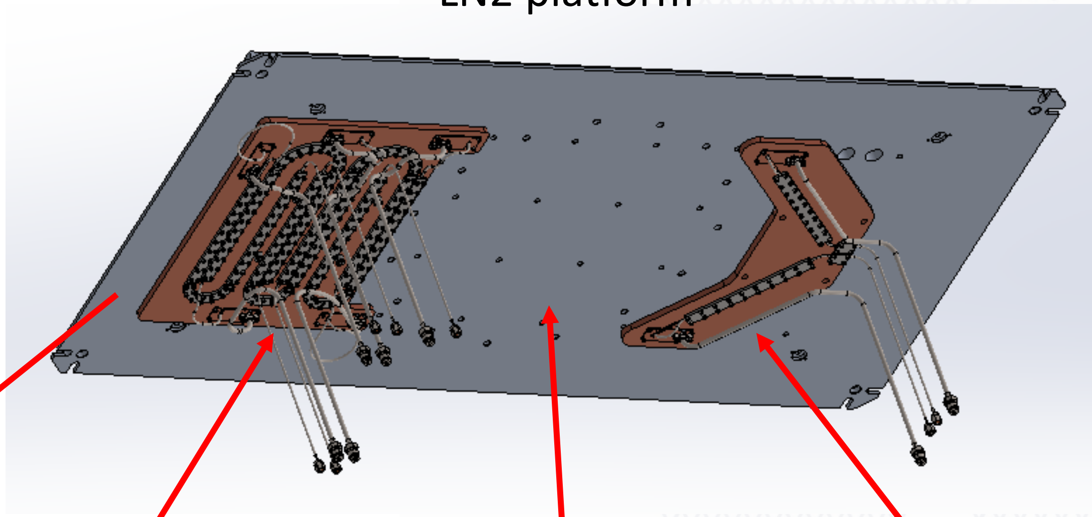
Master test plan
Build-up mirror tower

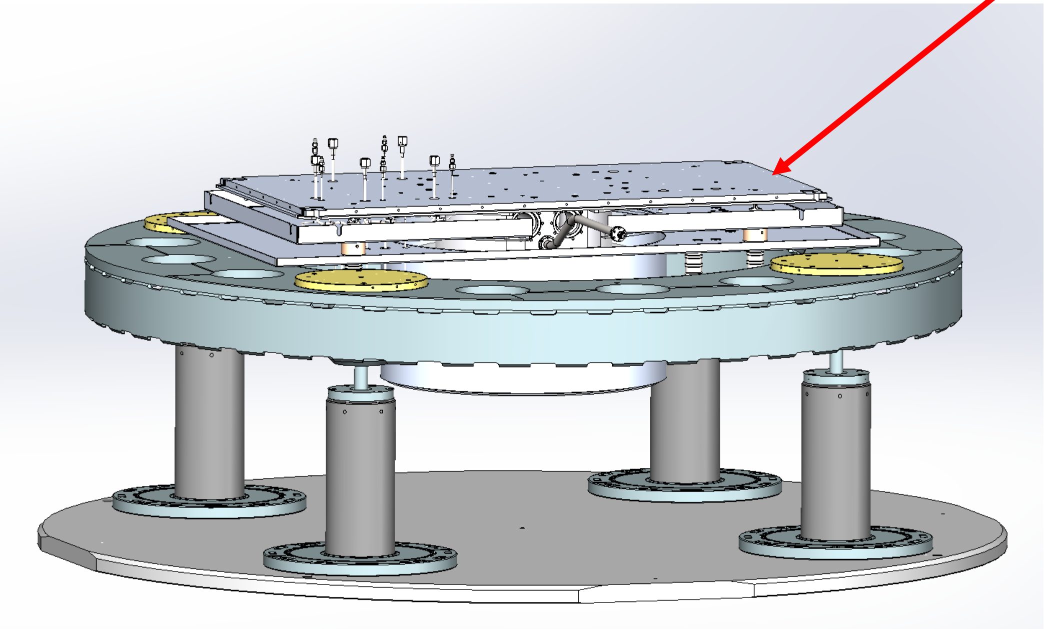
Floating shields + PEEK support



Master test plan
Build-up mirror tower

LN2 platform

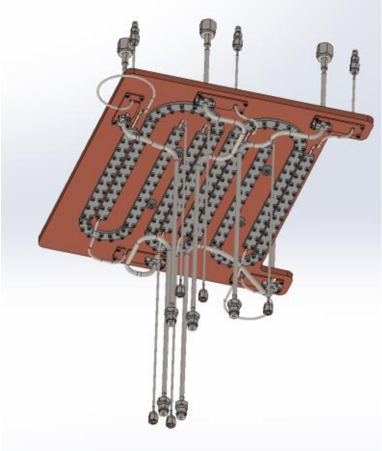


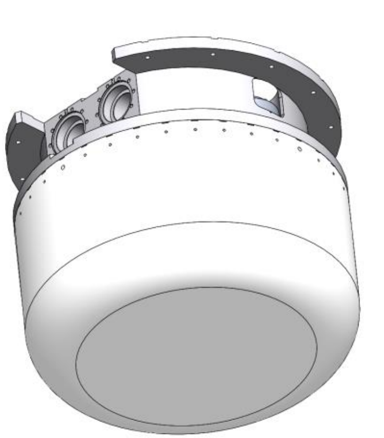


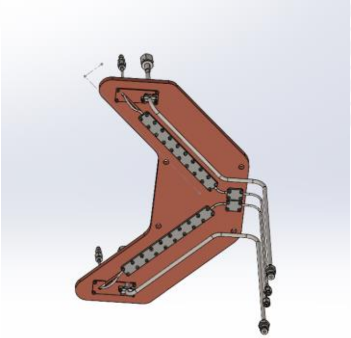
Neon 77 K HX

LN2 Vessel

H2 & He platform





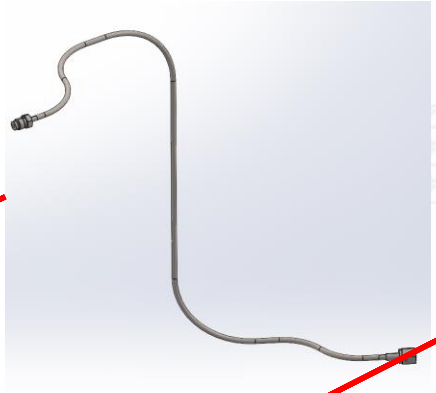


Master test plan
Build-up mirror tower

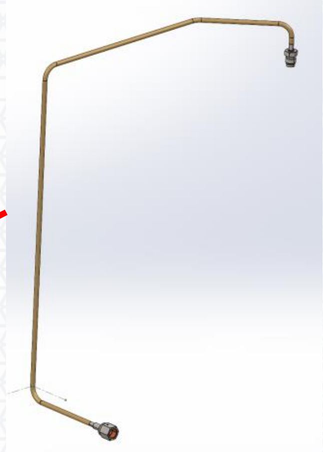
Test required after assembly step

- Leak test
- Flow logics
- Electronics testing

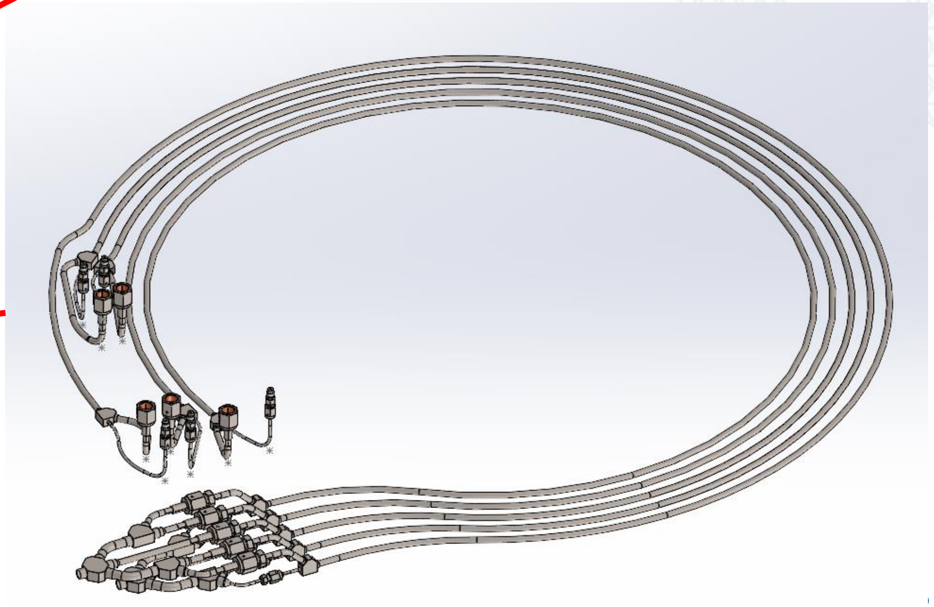
Connecting tubes to 300 K

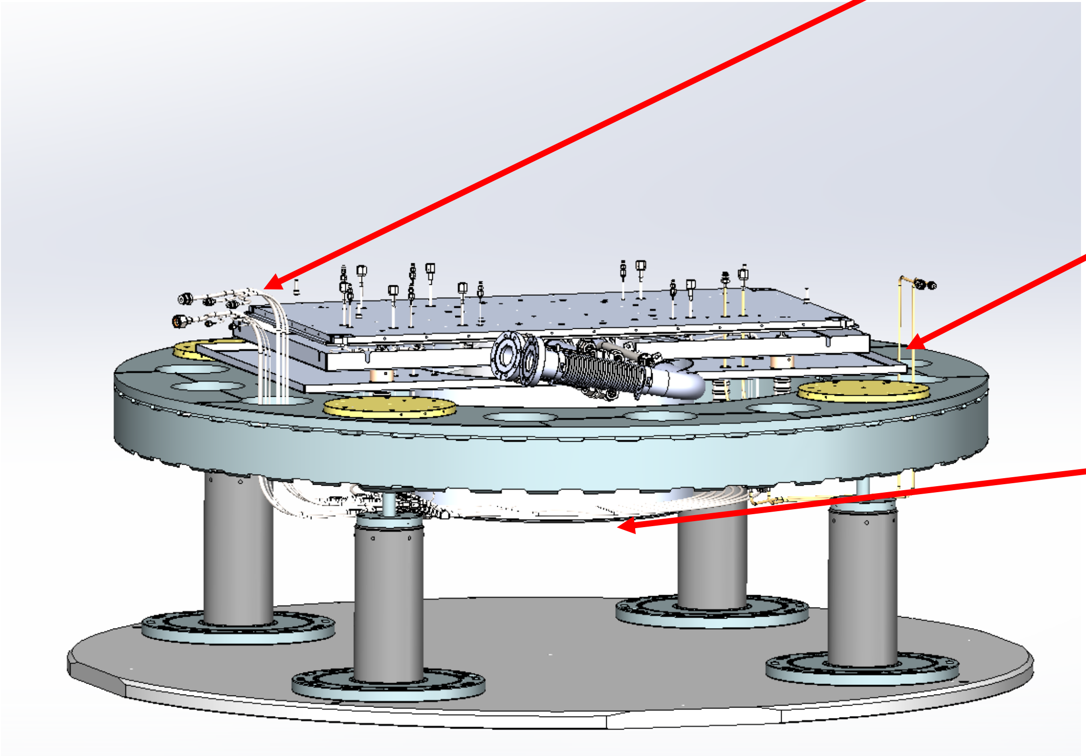


Kickstarter tubes to 300 K



300 K to 77 K CFHX's



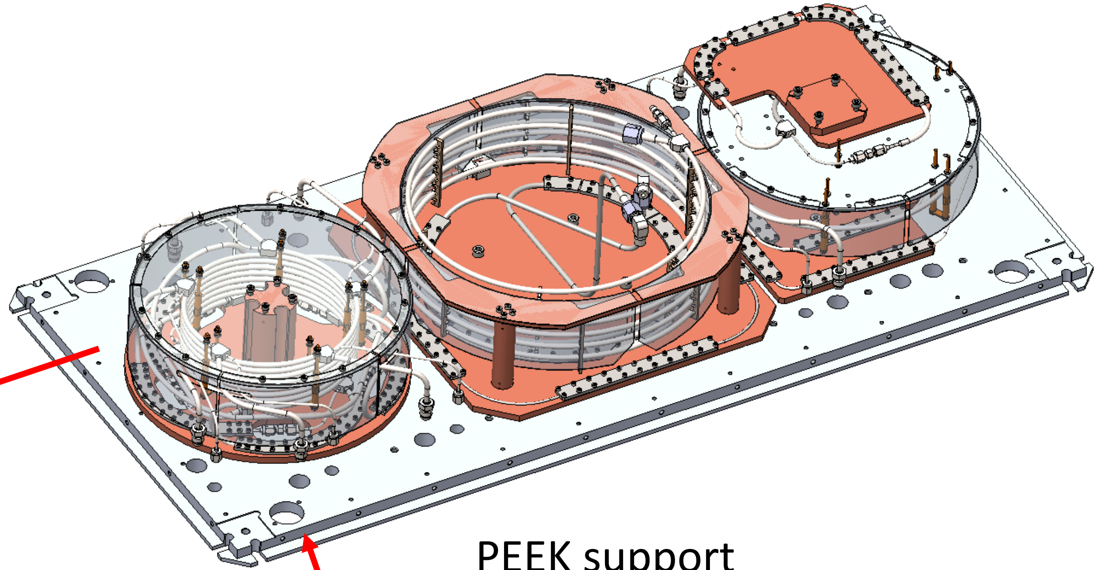


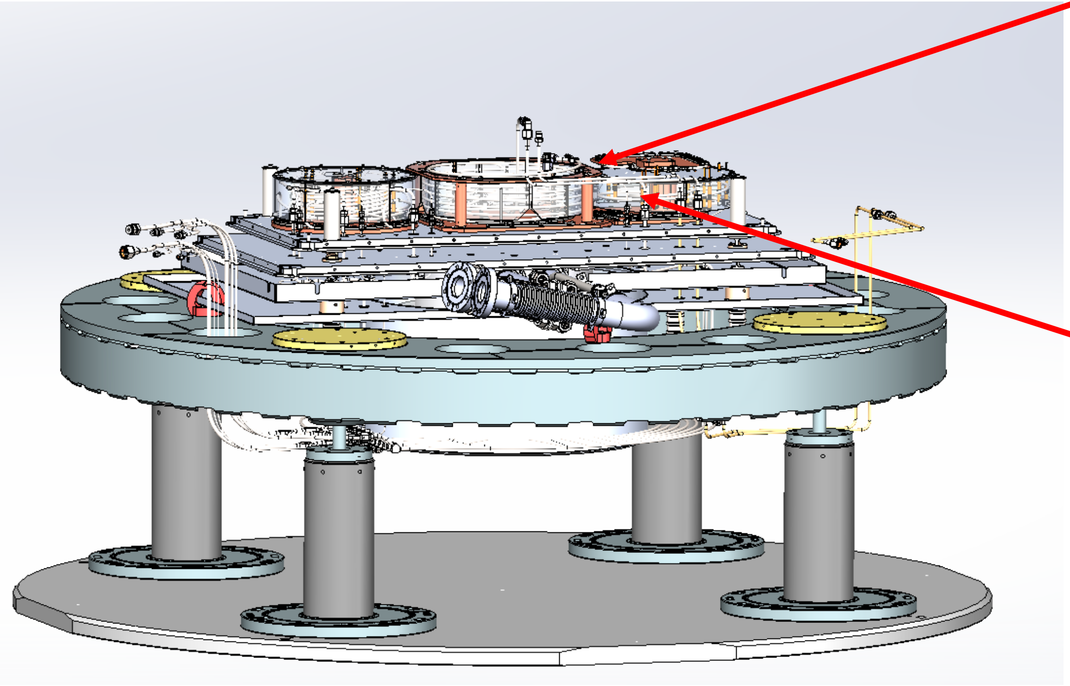
Master test plan
Build-up mirror tower

Test required after assembly step

- Leak test
- Flow logics
- Electronics testing

Neon, Helium and Hydrogen CFHX, HX and Evaporator assembly on top of 40 K platform



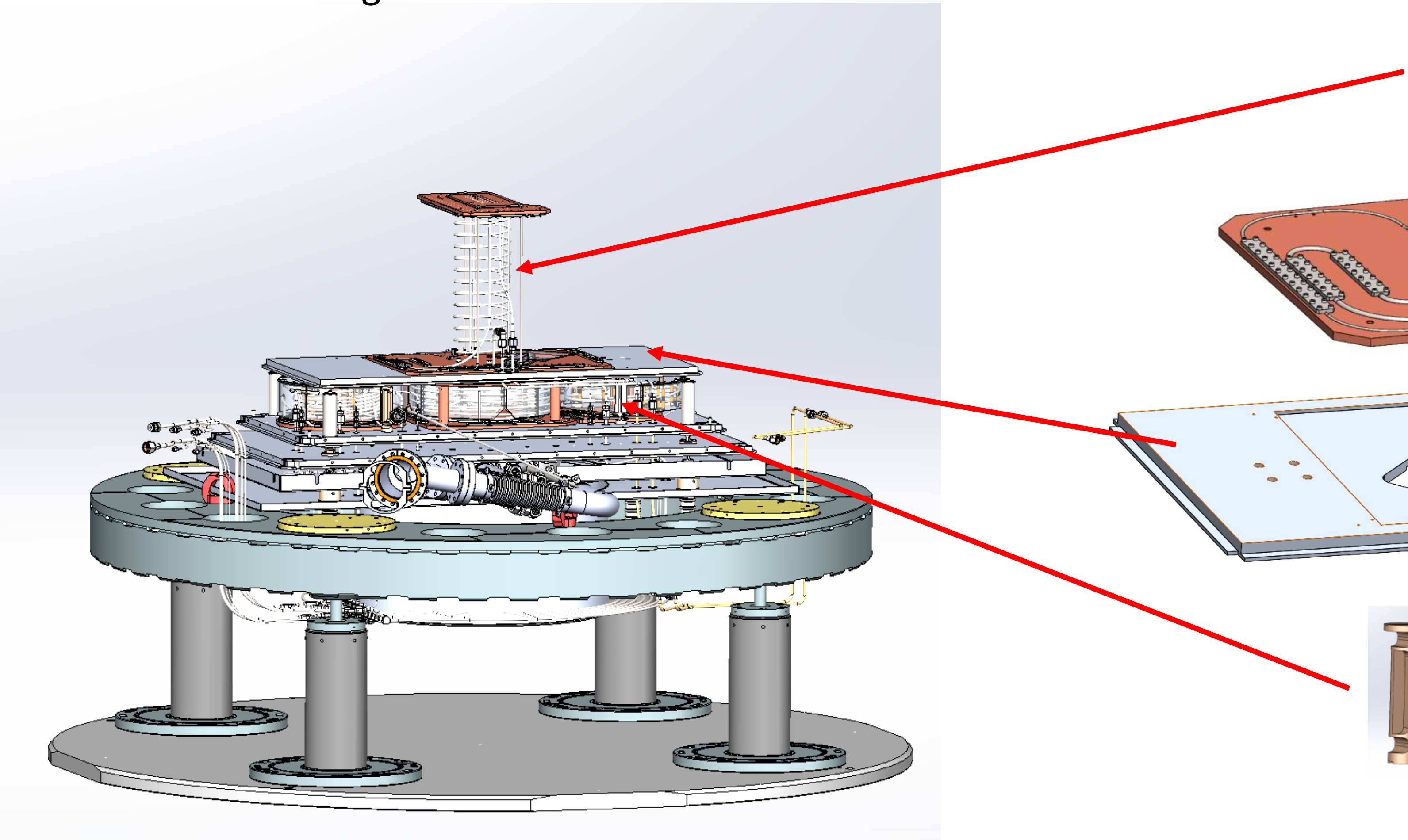


PEEK support

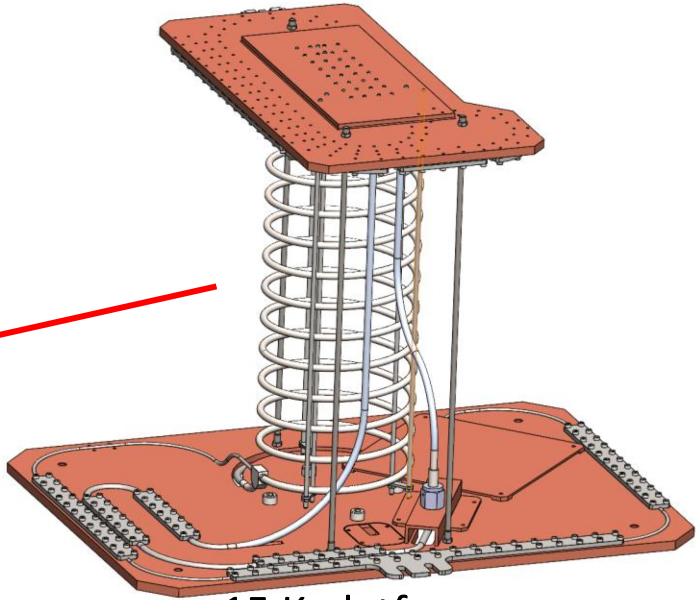
Kickstarter tubing

Master test plan
Build-up mirror tower

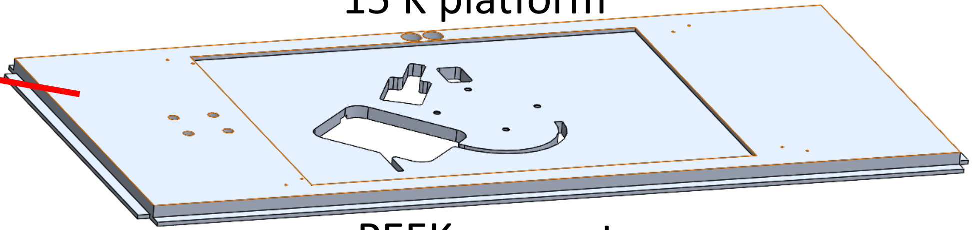
Test required after assembly step
- Leak test
- Flow logics
- Electronics testing



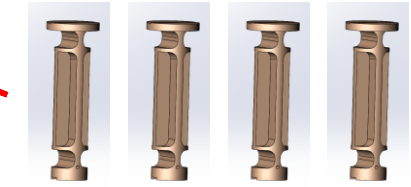
Helium 15 to 8 K assembly on top of 15 K platform



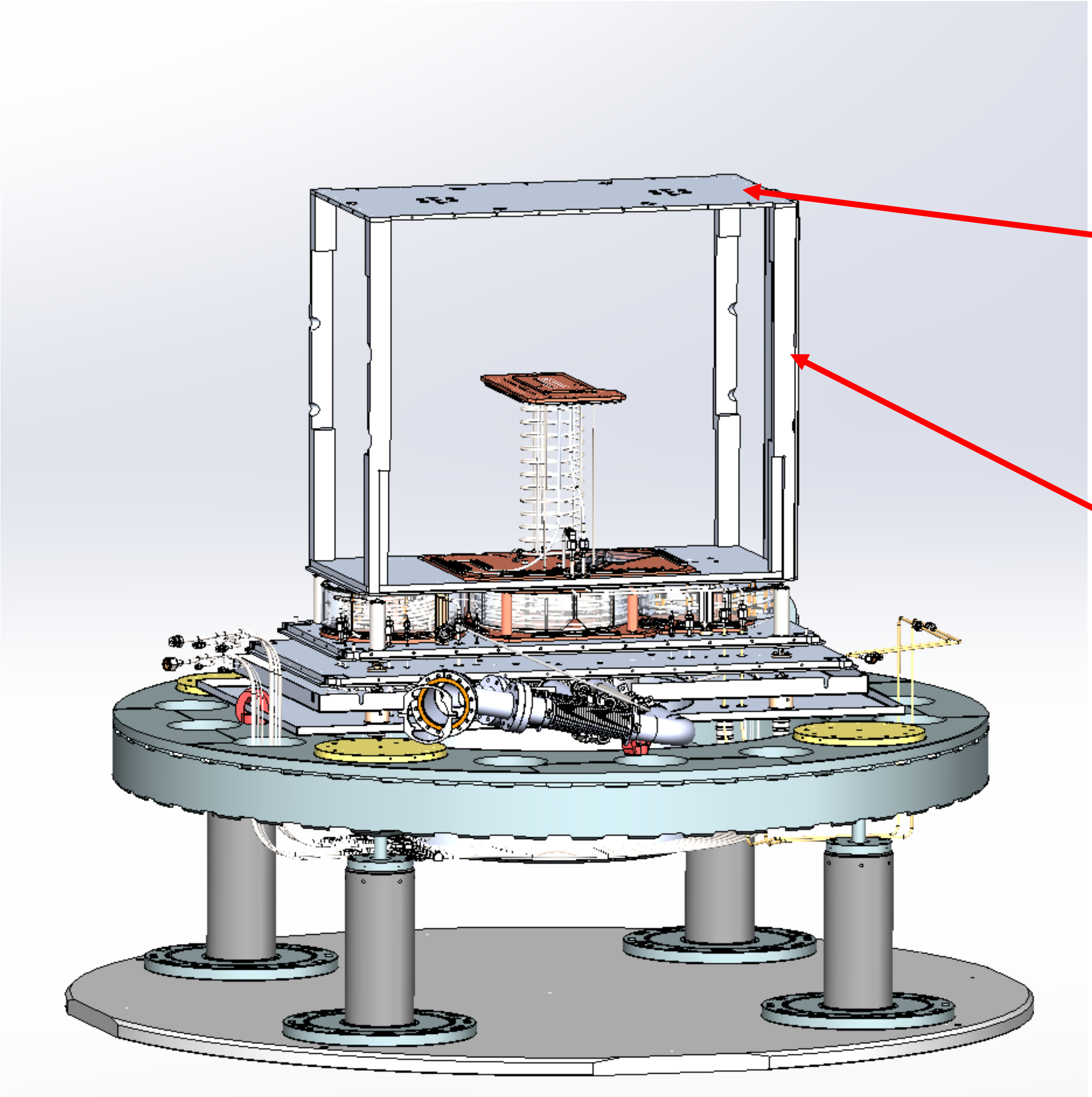
15 K platform



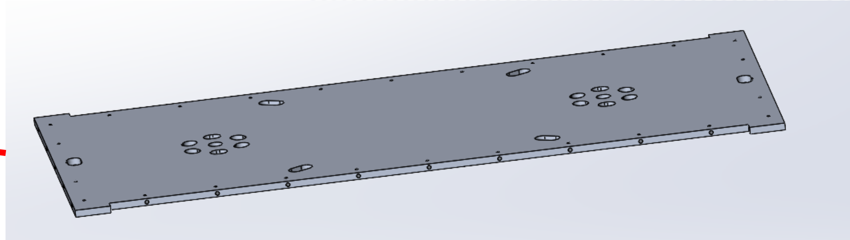
PEEK support

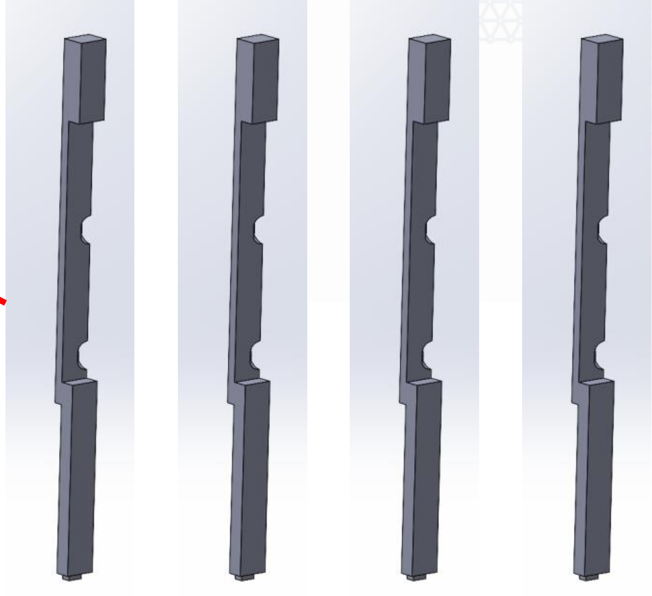


Master test plan
Build-up mirror tower

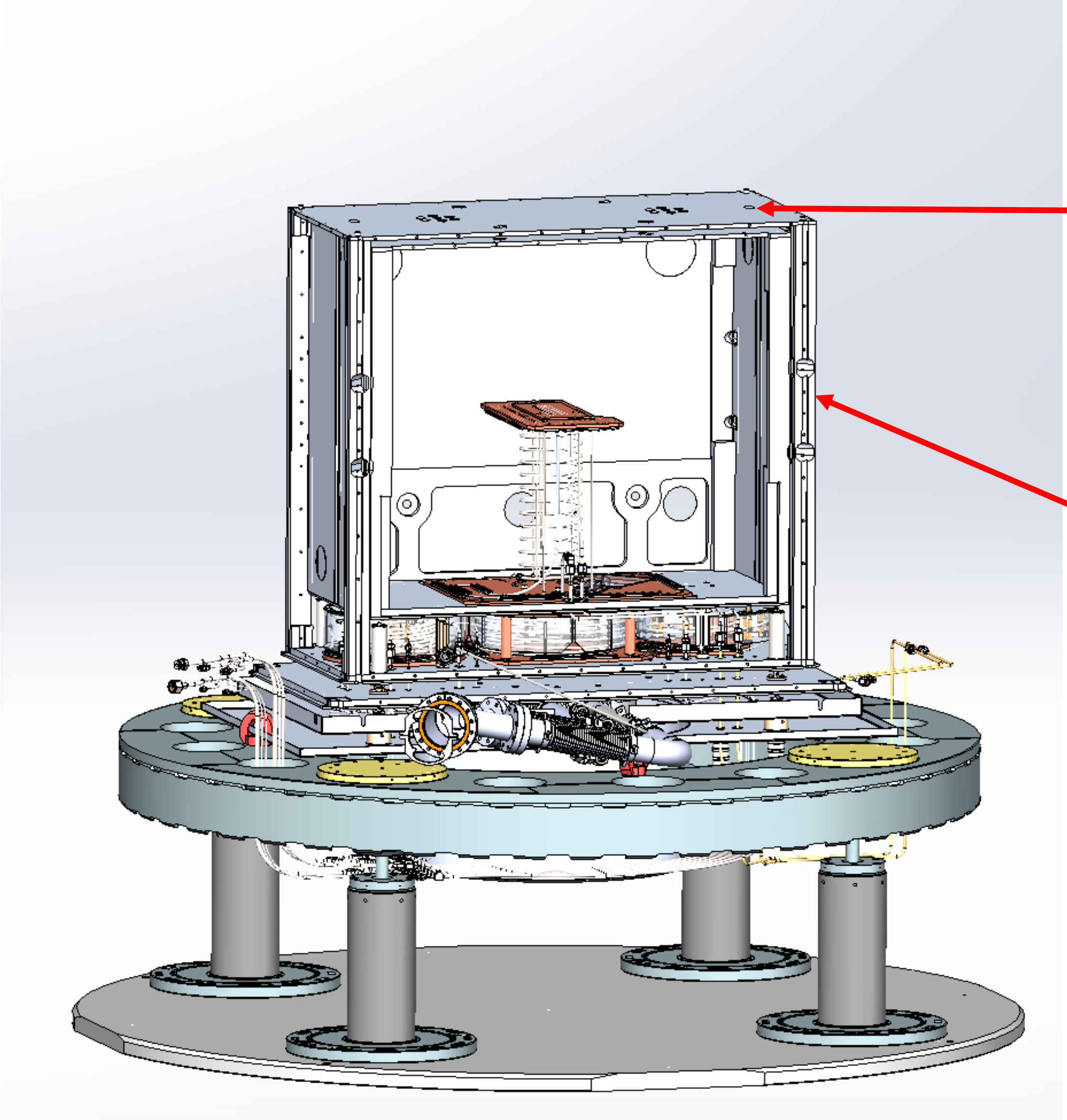


15 K frame

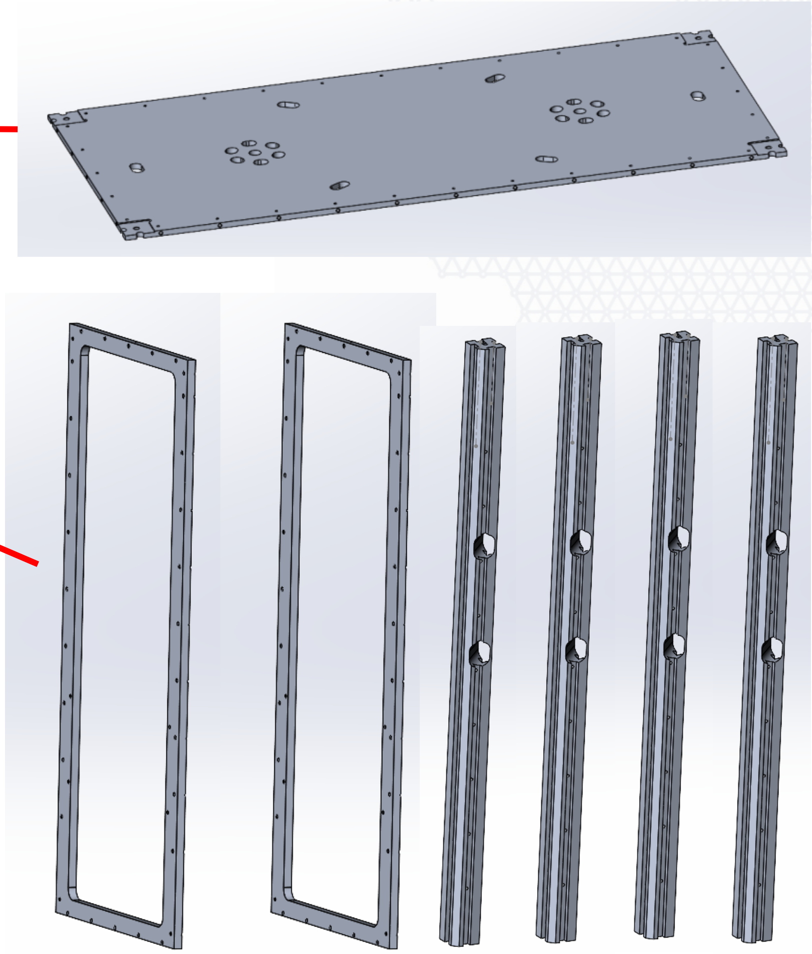




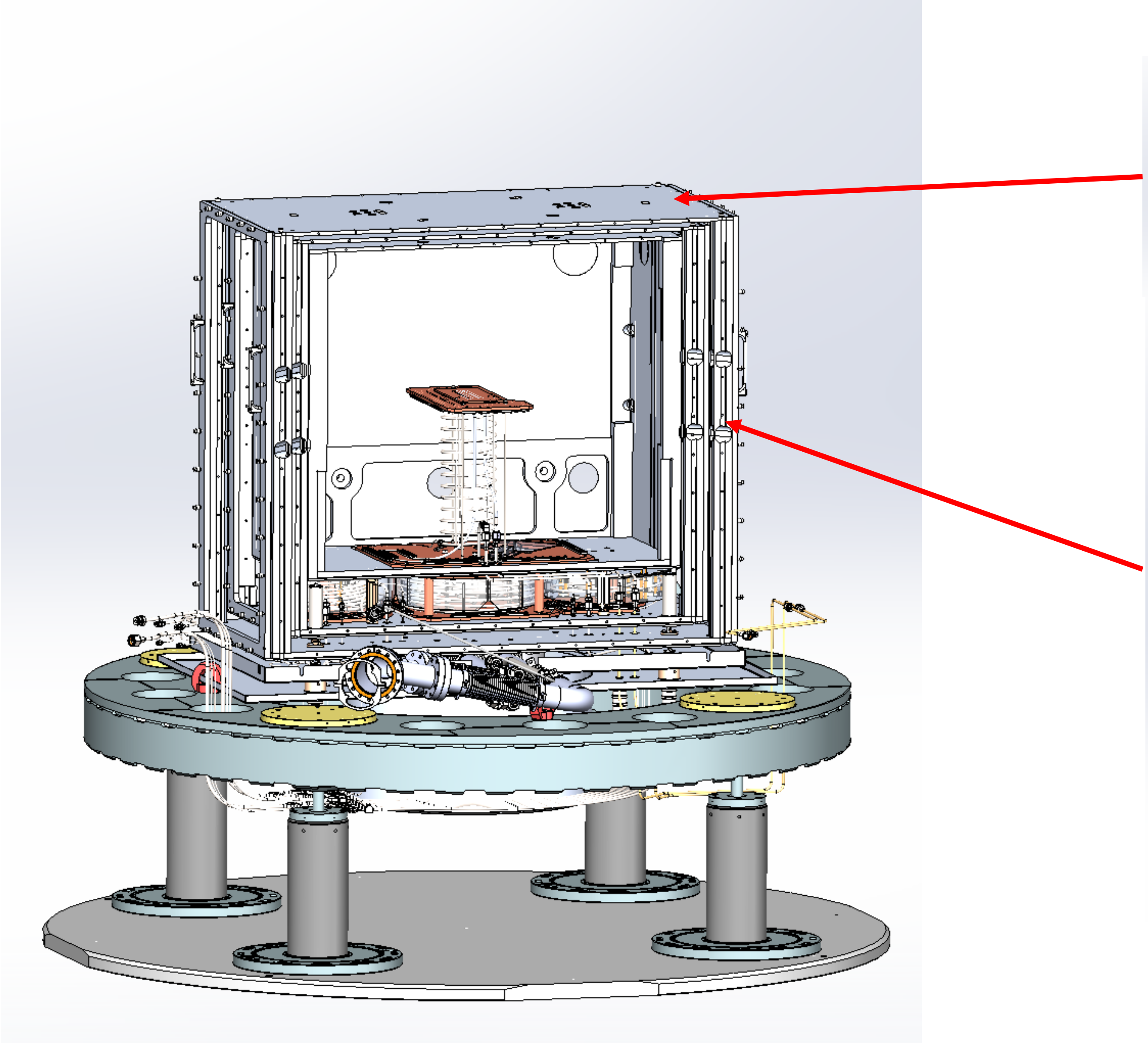
Master test plan
Build-up mirror tower



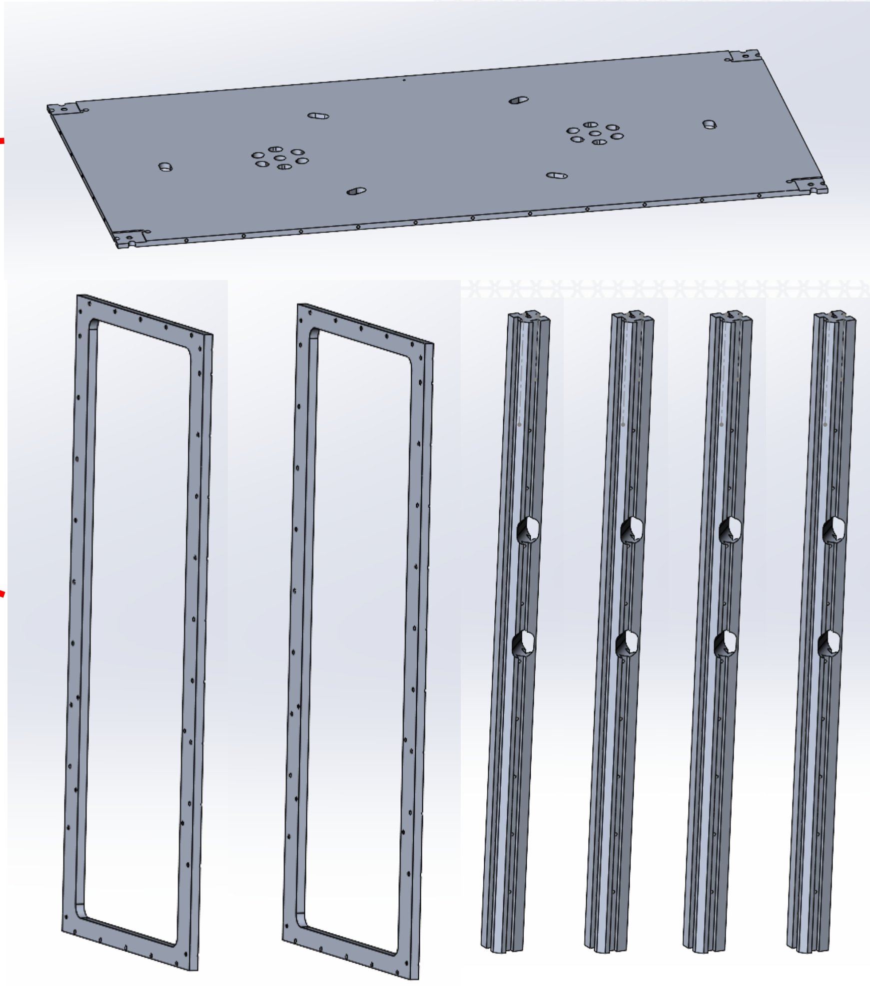
40 K frame



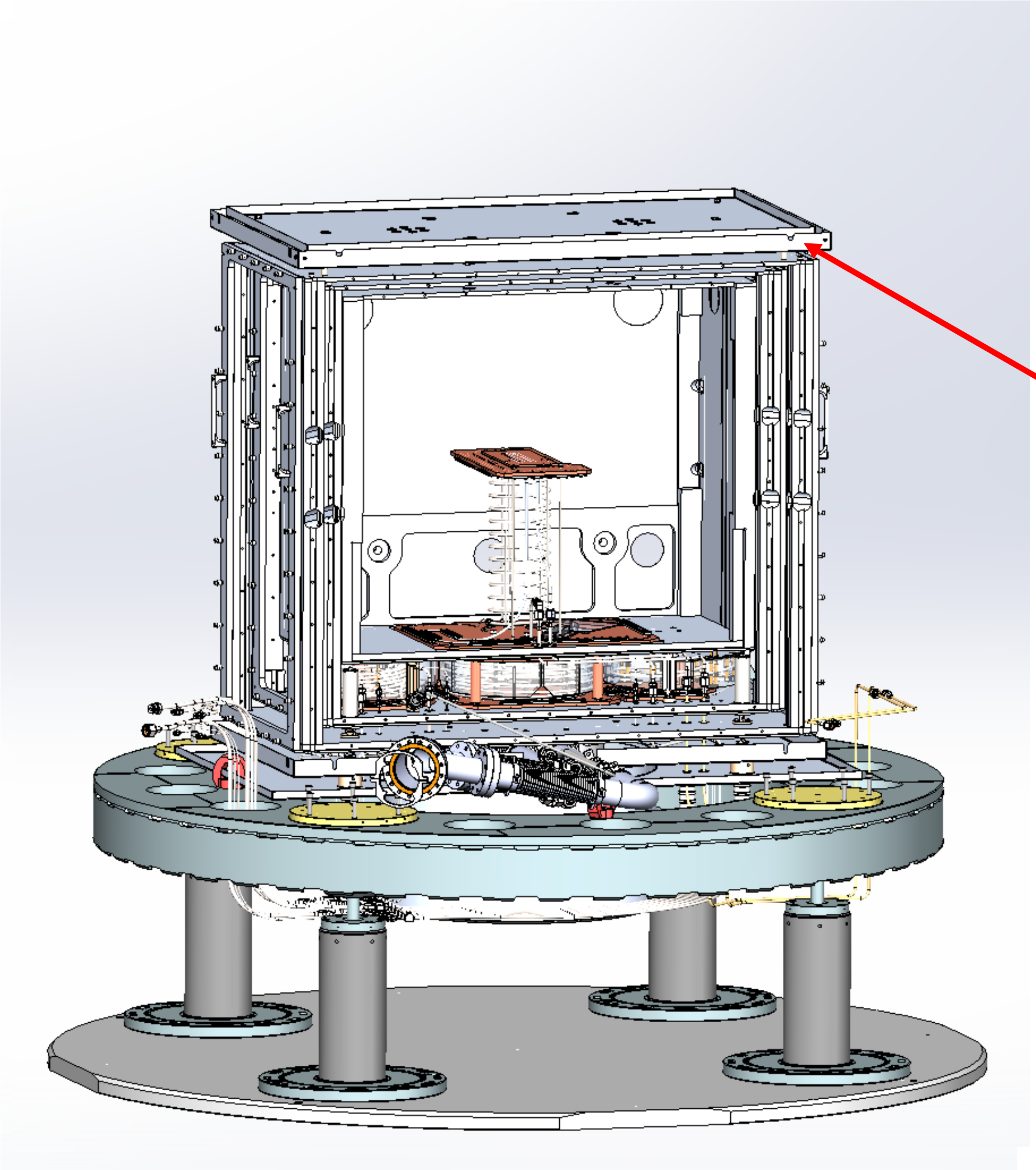
Master test plan
Build-up mirror tower



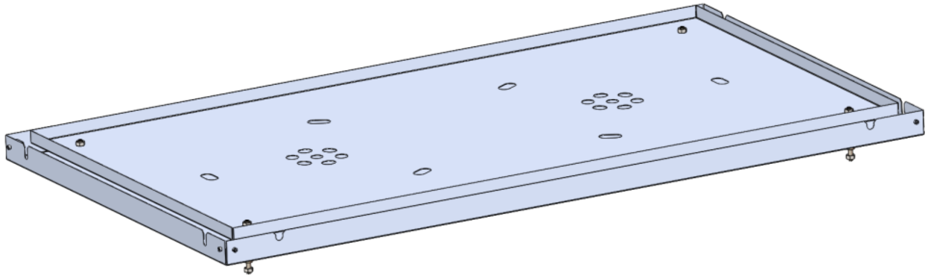
77 K frame



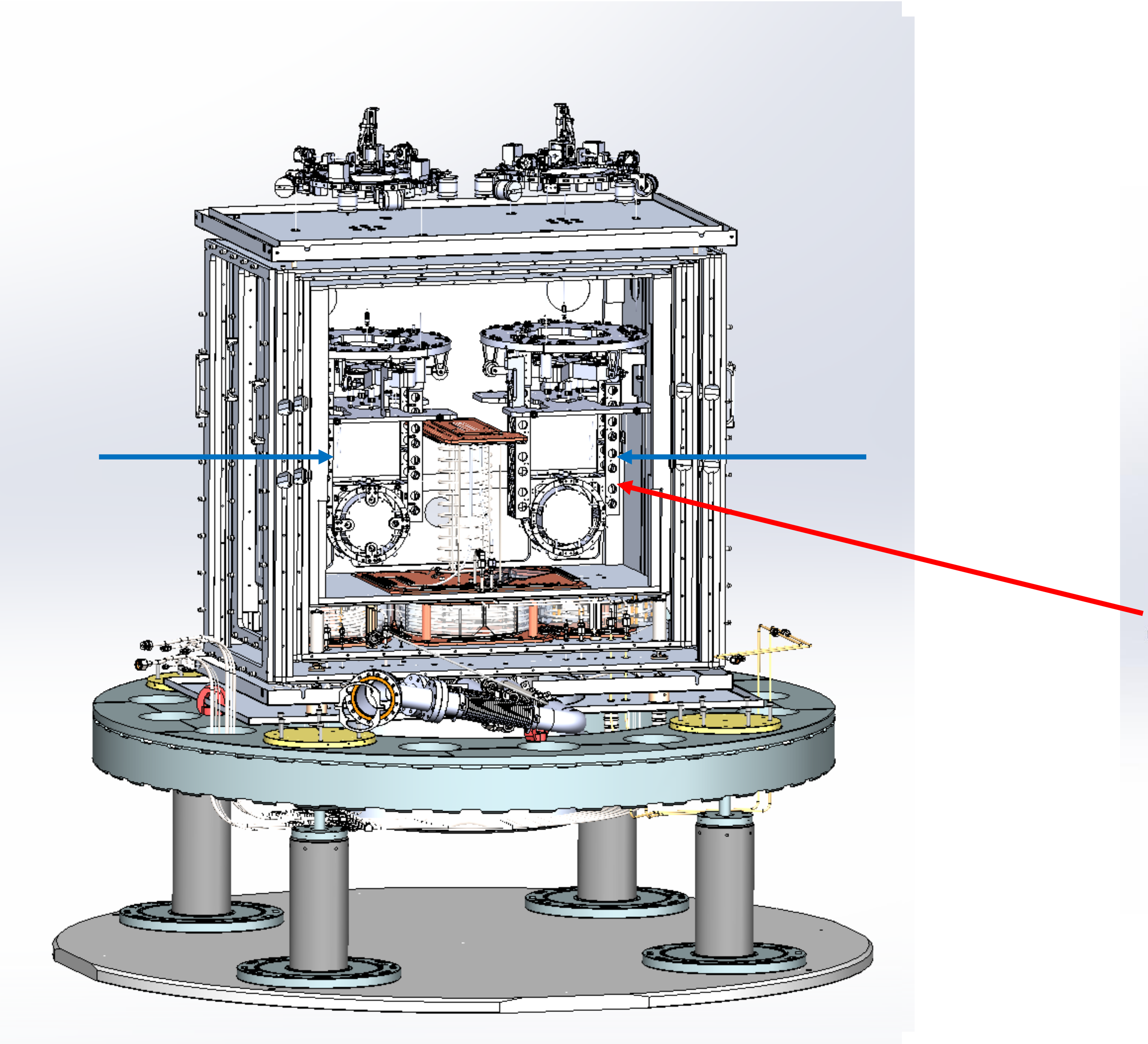
Master test plan
Build-up mirror tower



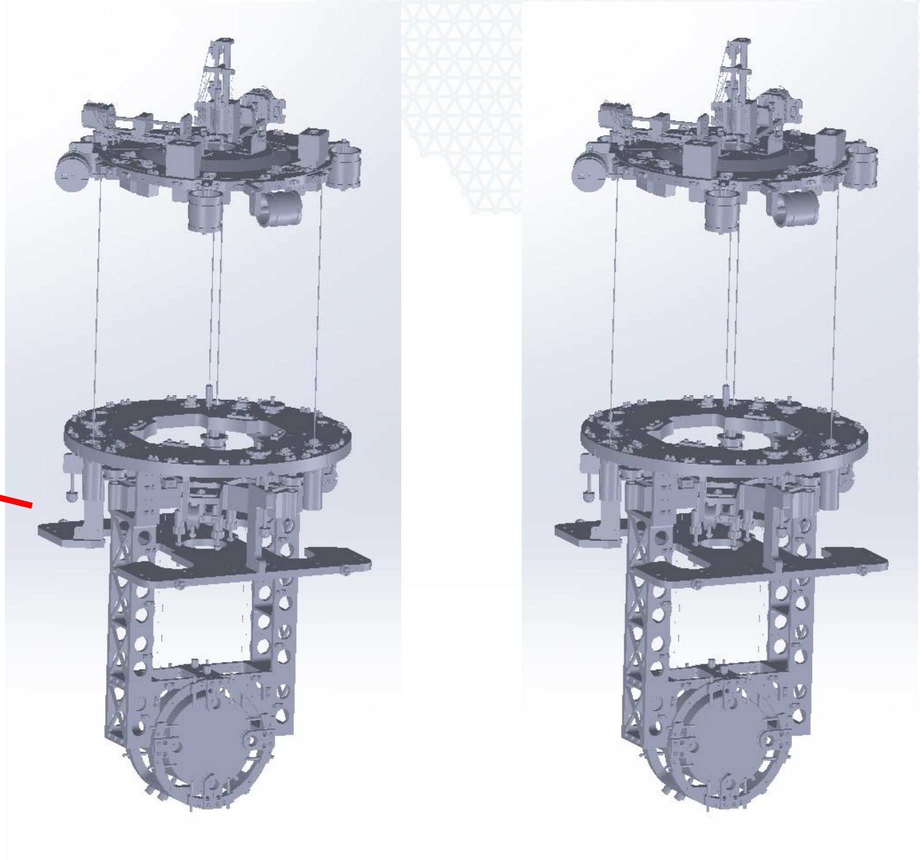
Top floating shields



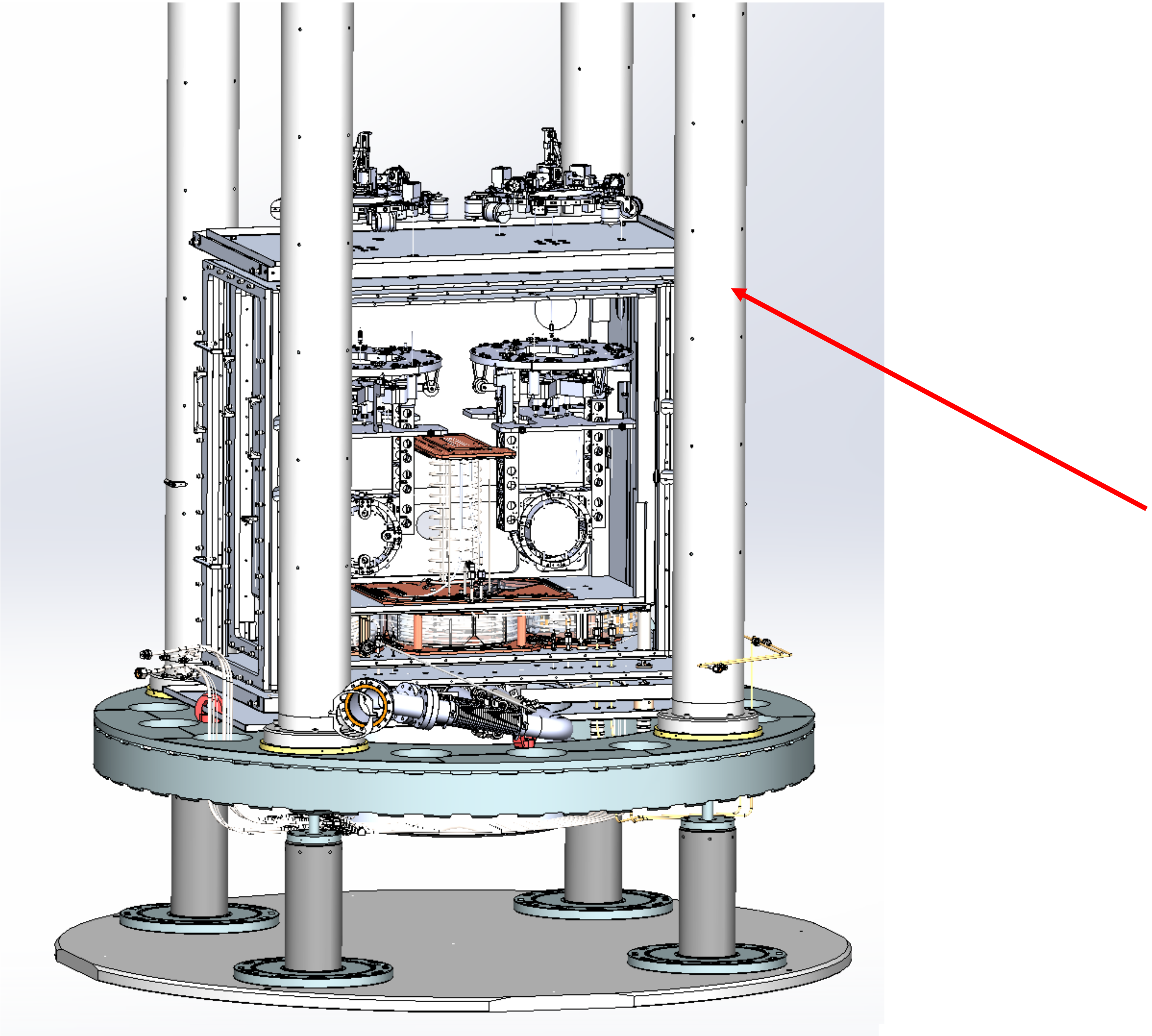
Master test plan
Build-up mirror tower



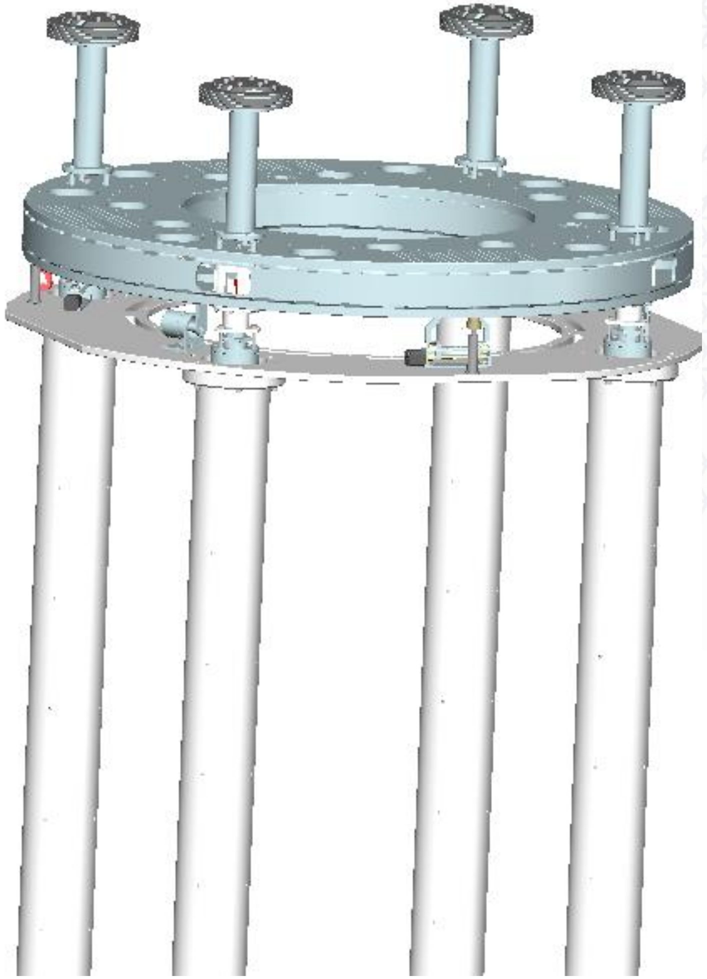
Marionetta



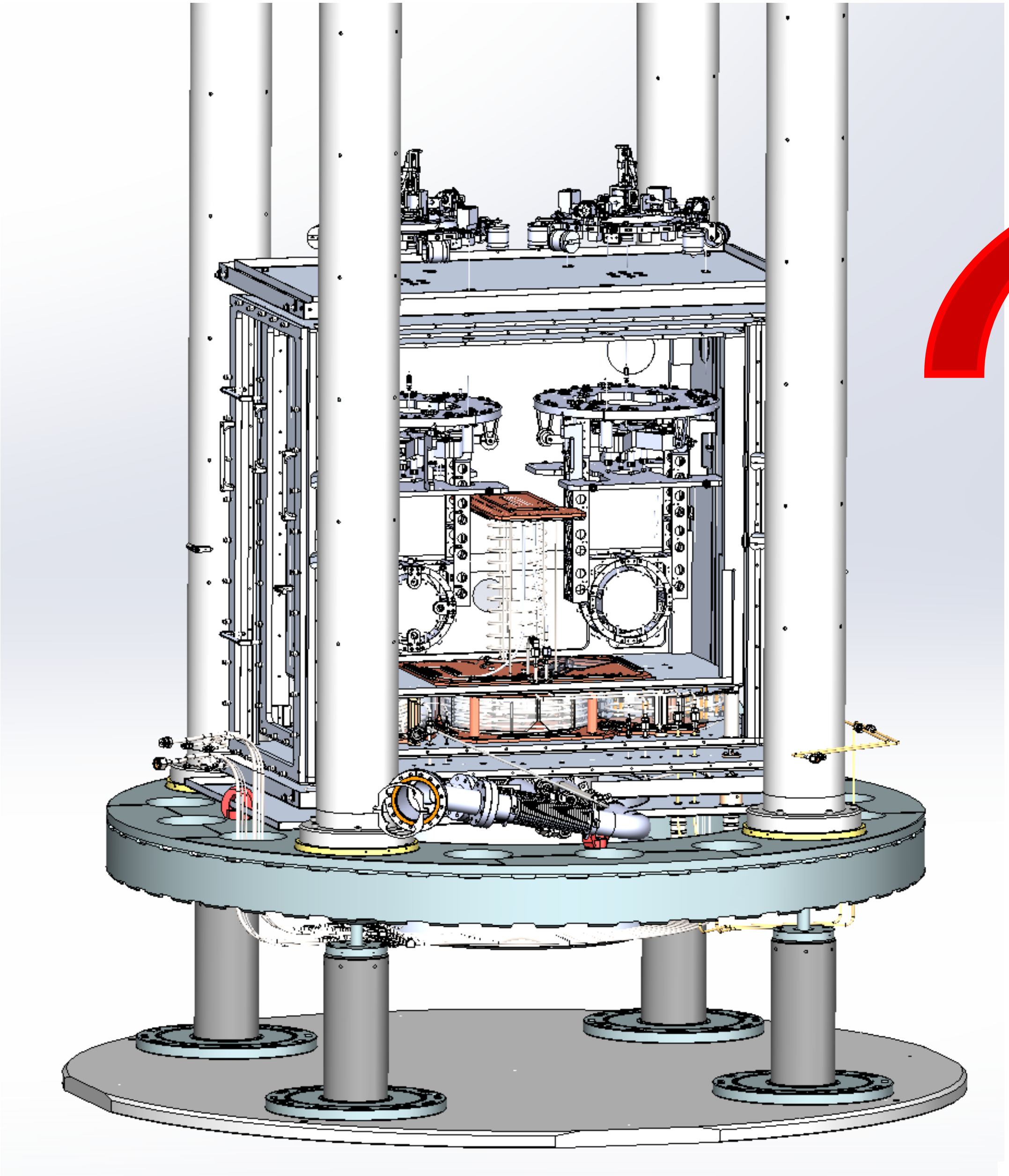
Master test plan
Build-up mirror tower



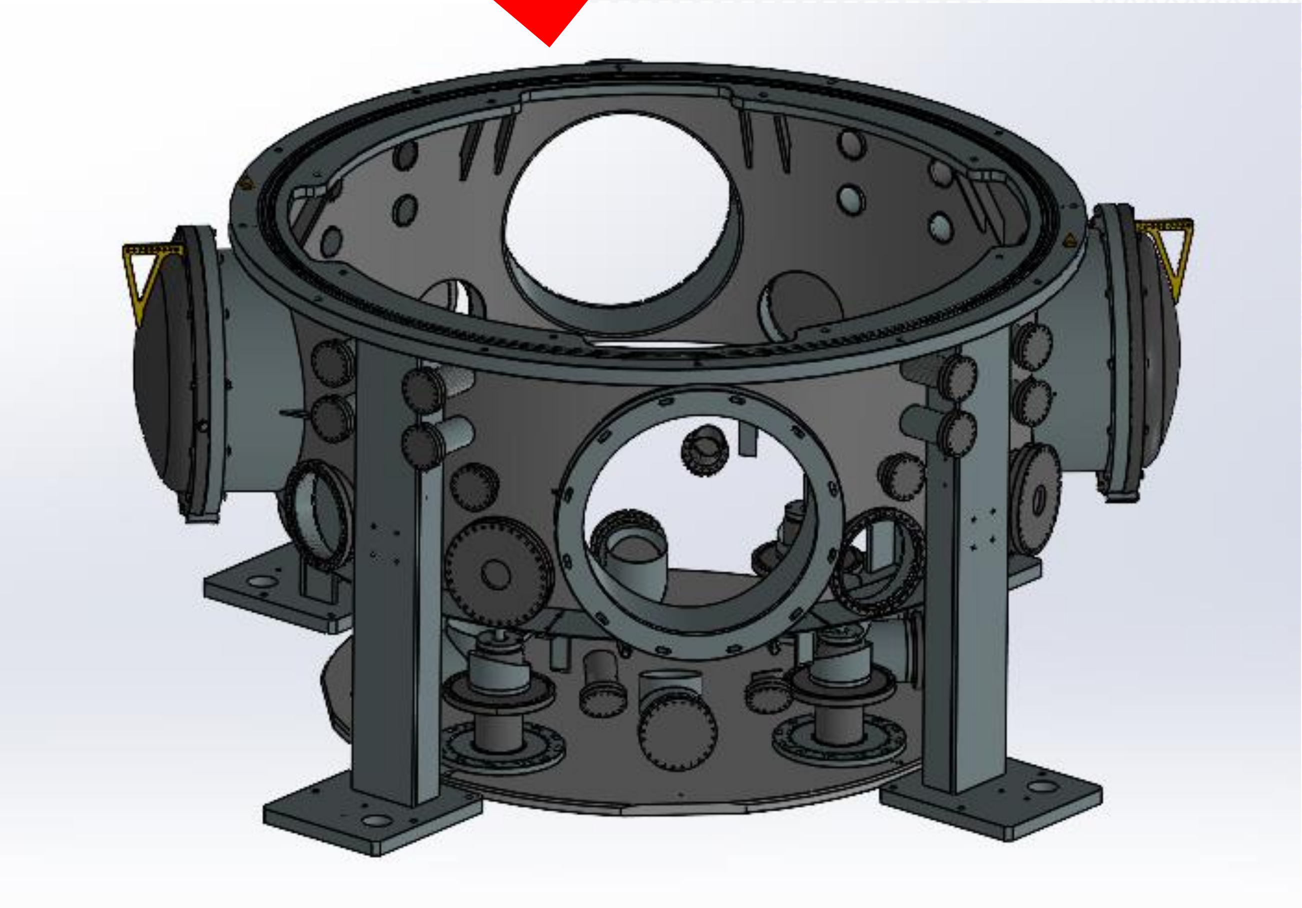
Nikhef assembly: Suspension, GAS filter, etc. can continue



Master test plan
Build-up mirror tower

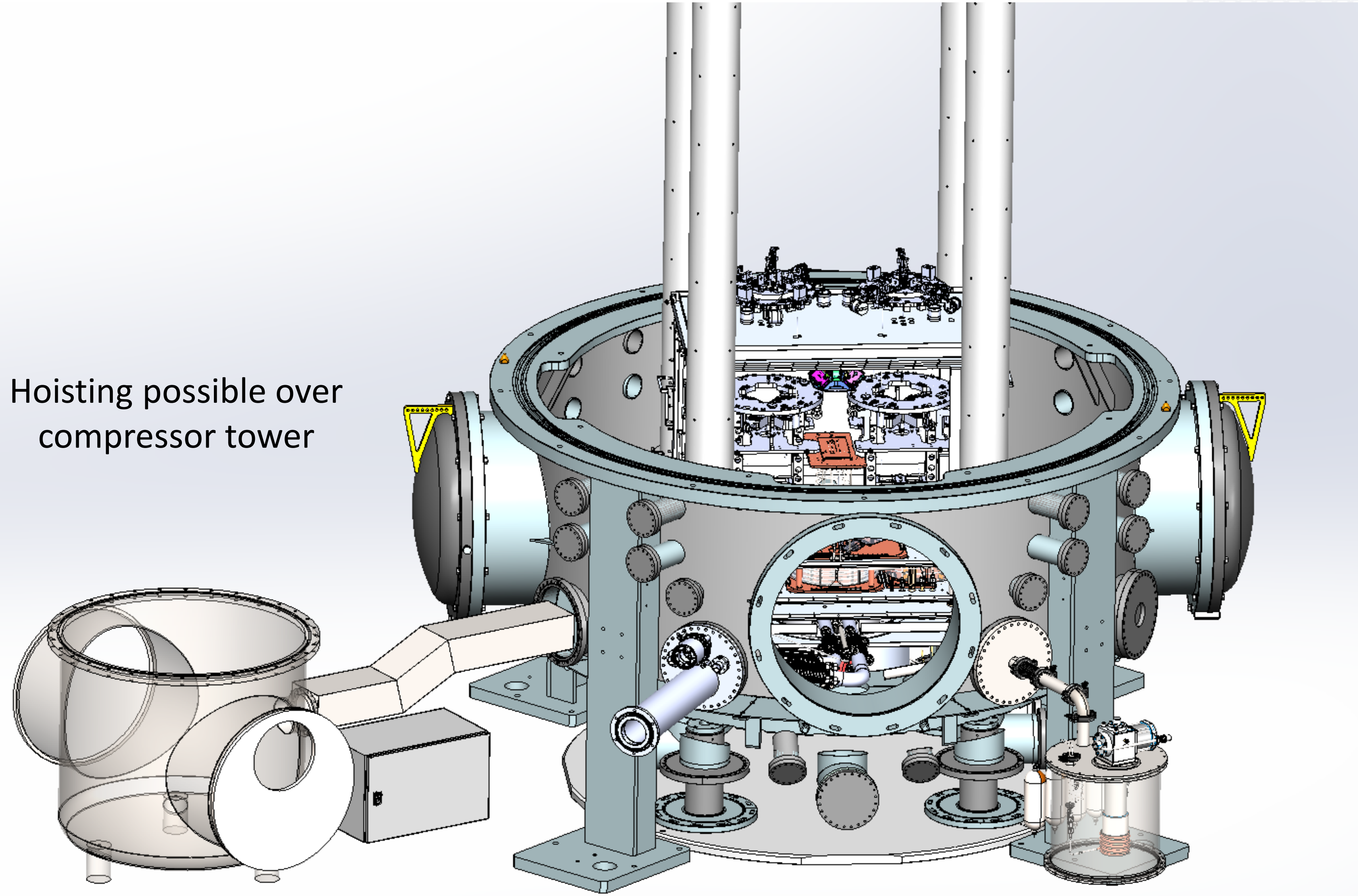


Hoisting assembly in



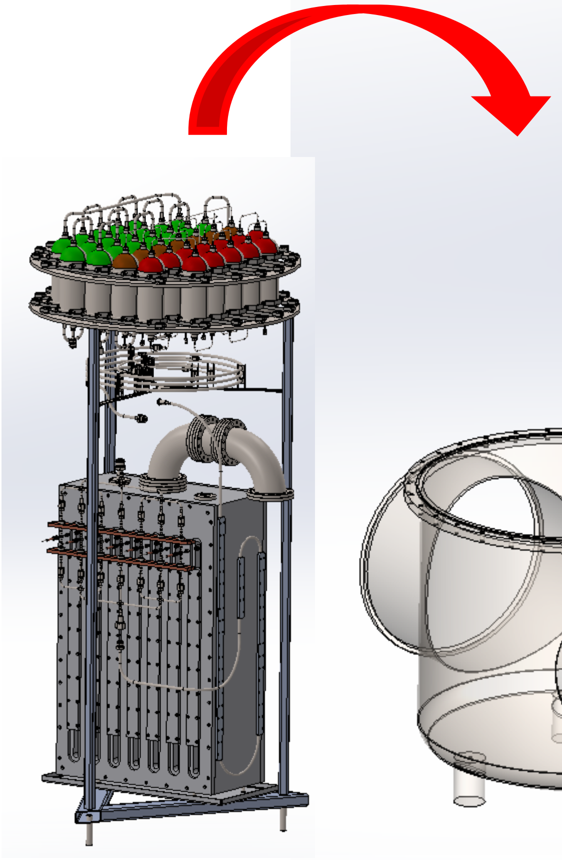
Master test plan
Build-up mirror tower

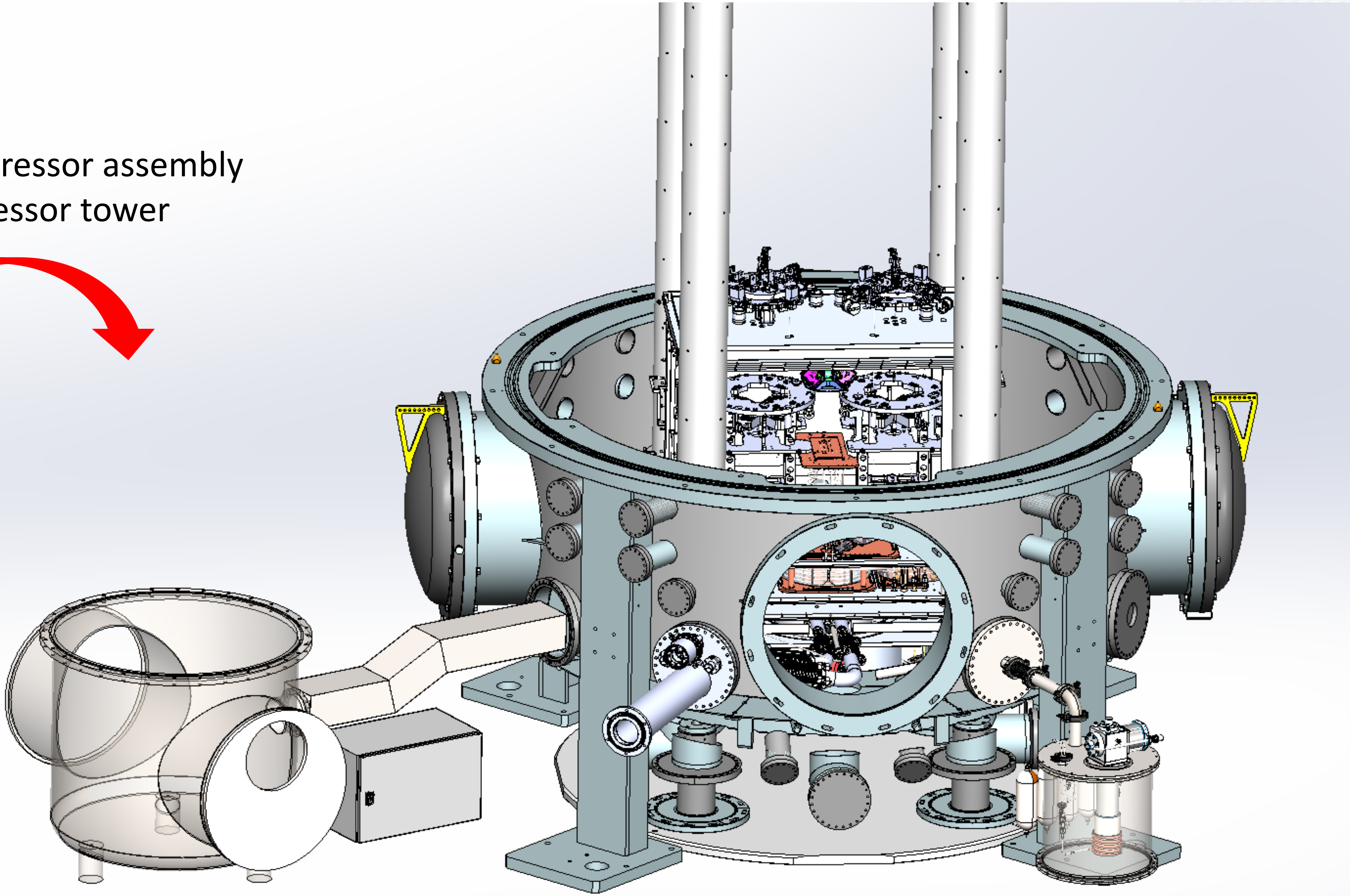
Hoisting possible over compressor tower



Master test plan
Build-up mirror tower

Hoisting compressor assembly
in compressor tower





Master test plan
Build-up mirror tower

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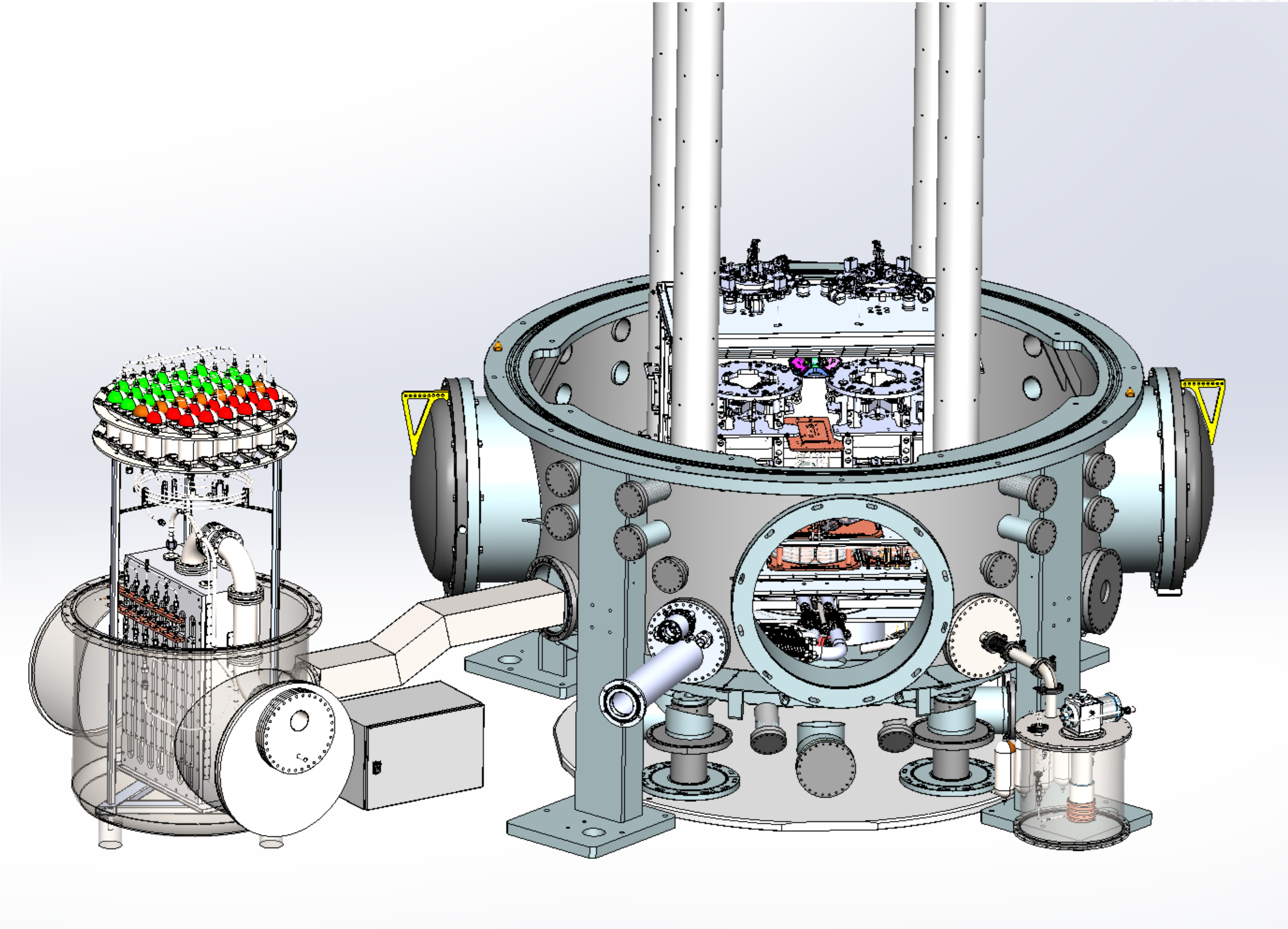


Einstein Telescope

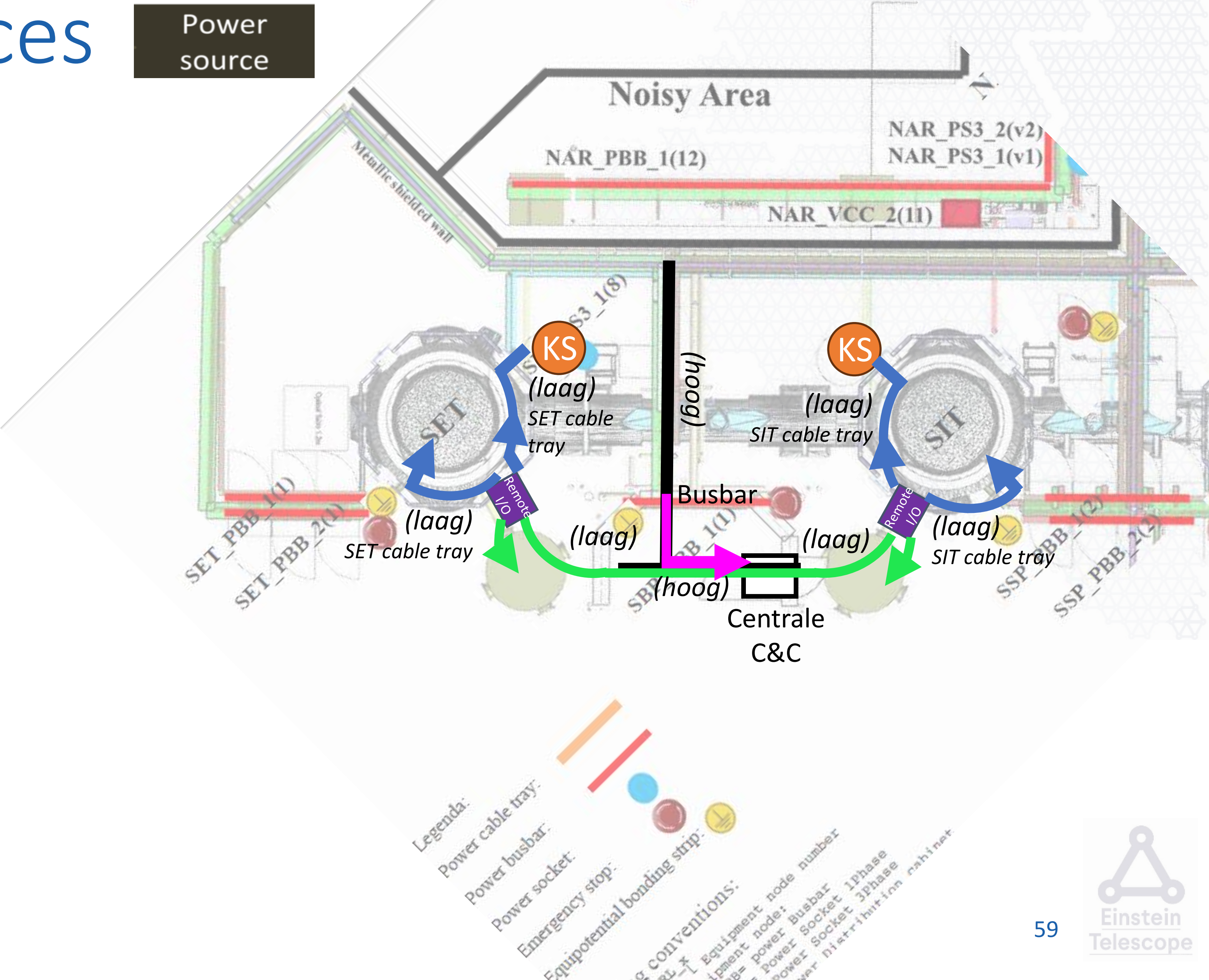
Content

1. Design Overview & System architecture
2. Technical Progress & Milestones
    - Development approach & timeline
    - Achievements since last update
    - Impact 3 key requirements on concept design
    - System assembly
    - Master Test Plan
3. **External Interfaces**
    - Electrical Interfaces
    - Data Interfaces
4. Safety risks & Mitigations
5. Open points and Q&A

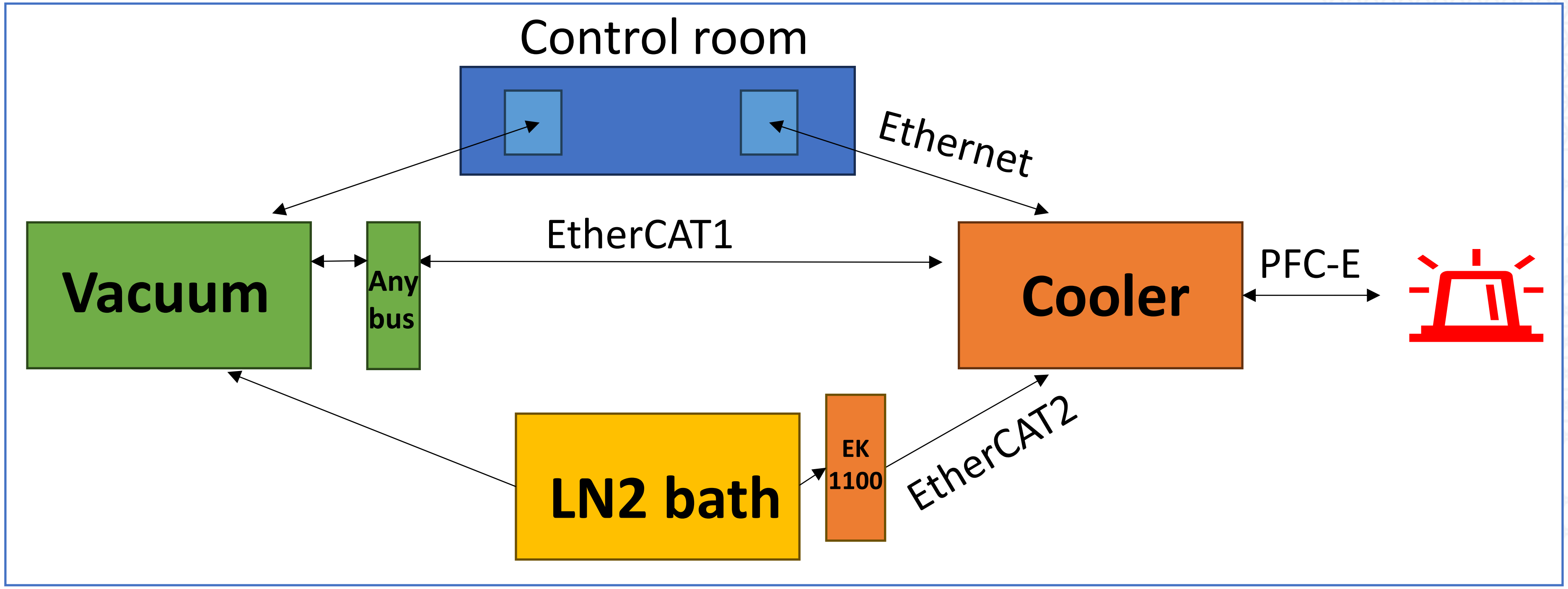
Electrical interfaces

Power source

24V DC
110V AC
400V AC
Kickstarter tower KS
Remote I/O



Data interfaces



Minutes (22-10-2024)

#	SUBJECT	DECISION
1	Exchanged signals cooler -> vacuum	• Lowest temperature • Status (options: ‘non-operational mode’, ‘precooling mode’, ‘start up mode’, ‘active cooling mode’, ‘cooling down mode’) • Heart beat signal
2	Exchanged signals vacuum -> cooler	• Lowest vacuum level • Status (for example also ‘operational mode’, ‘vented’, ‘evacuated’, etc.) • Heart beat signal
3	Communicator	The communication is to be established using Profibus, e.g. with the HMS Anybus communicato It is decided on that the module will be placed in a vacuum subsystem cabinet. Demcon will interface with EtherCAT to the communicator.

Content

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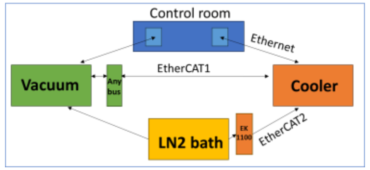
Software safety

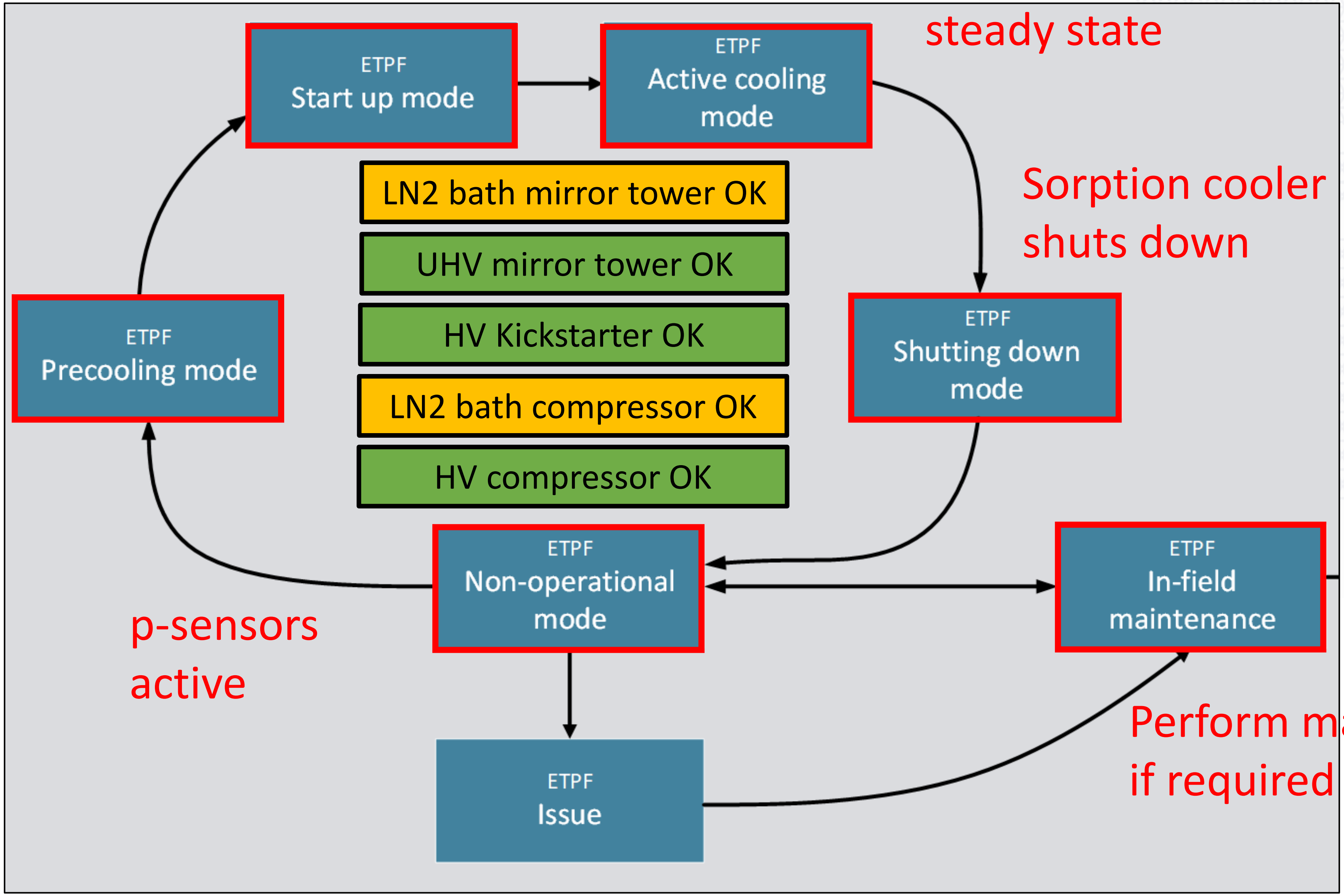


Kickstarter actively cooling down

Sorption cooler takes over

Sorption cooler reaches steady state

Sorption cooler shuts down



p-sensors active

Perform maintenance if required

Gas safety

System baseline

Normal volume H2: 107.07L
Clean room volume: 4000m3
Gas changed 5x / hour
Ratio: **0.0027%**

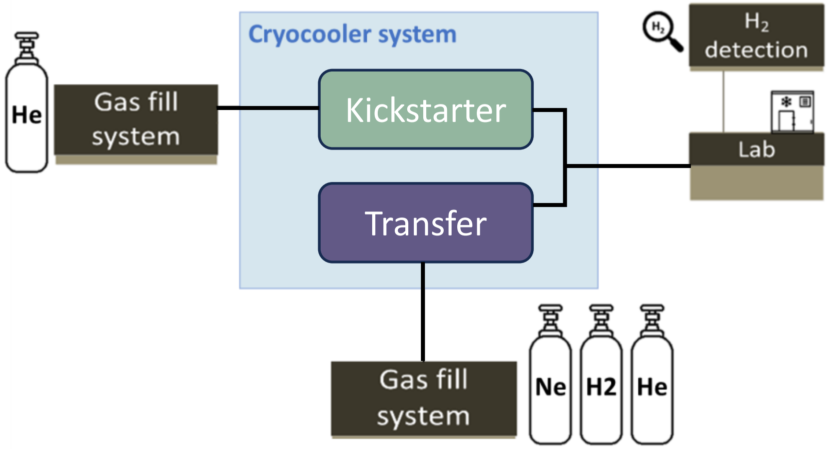
Ignition limit < 4%

Change w.r.t. RMA of 22-10-2024:
Less hydrogen: 8.86 g instead of 10.4 g

Subsystem	Stage	Working fluid	pH [bar]	pL [bar]	Tmax [K]	Tmin [K]	V total [L]	m total [g]	m total [mol]	V normal [L]	pfill [bar]	Ncells
Sorption cryocooler	1	Neon	96.0	6.5	293*	35	20.11	587.62	31.00	755.0	56.9	21
	2	Hydrogen	18.0	0.47	293*	18	12.25	8.86	4.40	107.07	13.6	4
	3	Helium	21.0	4.5	293*	8	7.75	46.66	11.66	283.99	13.1	12
											Total:	37
Kickstarter		Helium	20.0	-	293*	10	4.5	55.7	13.9	347.1	77.3	-
LN2 bath compressor		Nitrogen	1.5	-	-	70	70.0	58.5 kg	2088.5	47437	-	-

* Maximum temperature is the clean room temperature: setpoint is 19°C, lower limit 18.5 °C and upper limit 20°C

Gas safety discussed in RMA



C&C CDR: UPS bypass switch included in case UPS must be bypassed →

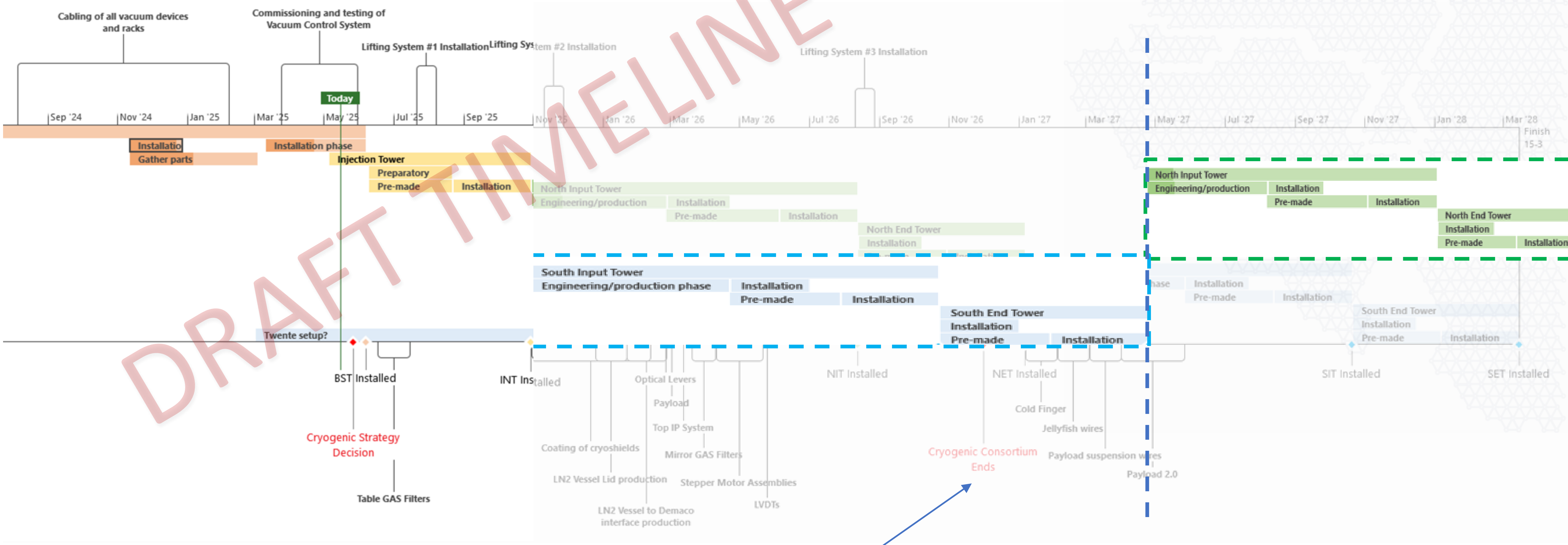
Content

Open points and Q&A

- LN2 vessel
  - **Showstopper**, needs to be produced before September
- Production 15K shield
  - **Showstopper**, needs to be arranged this month
- Sorption compressor tower flanges (+ modification)
  - **Showstopper**, needs to be produced before October
- Mirror heat sinking
  - Need input on interface
- Maximum weight PEEK supports shields
  - Only requires a check
- Shield heaters
  - Requires RGA testing
- Cooling water noisy corridor
  - Needs to be arranged for 2026
- Vacuum pump(s) compressor + kickstarter
  - Needs to be arranged before installation in clean room
- Sorption compressor tower installation
  - Needs to be arranged before installation in clean room
- 123 K test (Science goal)
  - Coating shields (requires RGA testing) & marionetta

Break out session

Planning if we go for strategy A



At end of 2026:

- 0 North towers
- 1 South towers

We may be able to speed up a bit by assembling the subassemblies for both towers simultaneously, but maybe that's wishful thinking with such a complex system.

Mitigation

- Second base plate such that at least both cooler systems for Maastricht can be assembled
  - Worst case: 1 of the 2 cooler systems cannot be verified within 2026

Build-up mirror tower