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TECHNISCHE UNIVERSITÄT DRESDEN

JÜLICH FORSCHUNGSZENTRUM

ESS Cryogenic Moderator System (CMS)

TAC 05.04.2017

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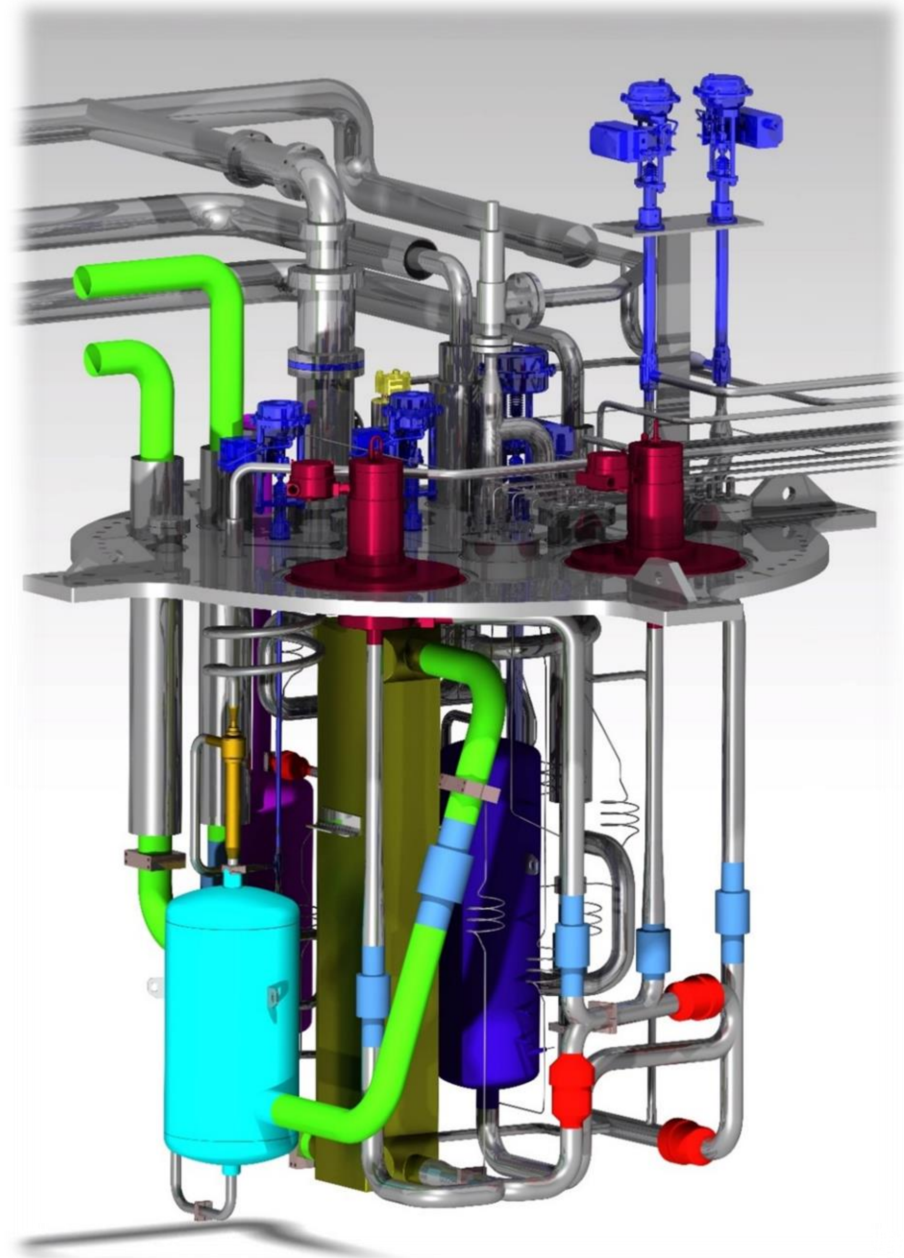
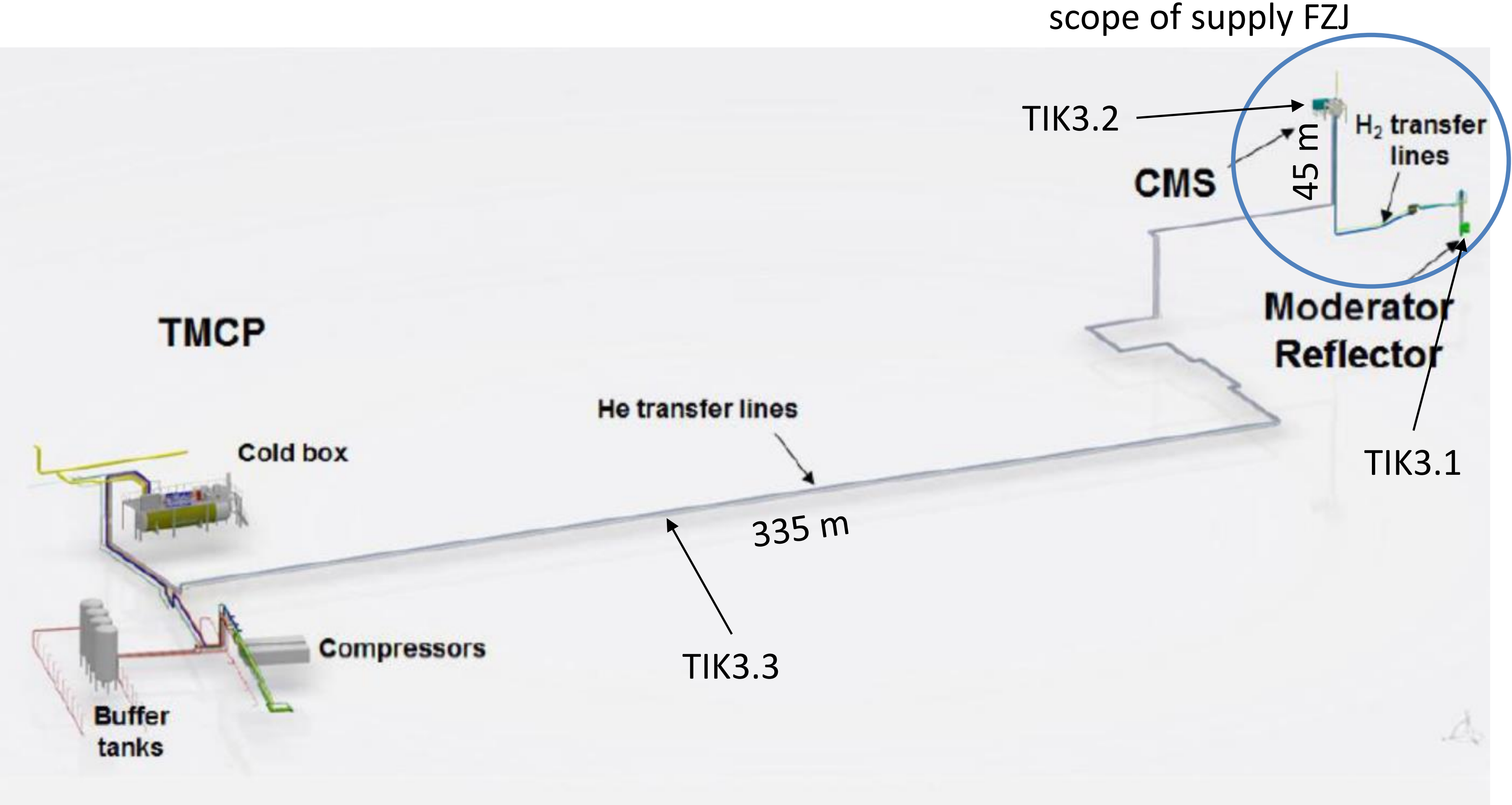
Outline

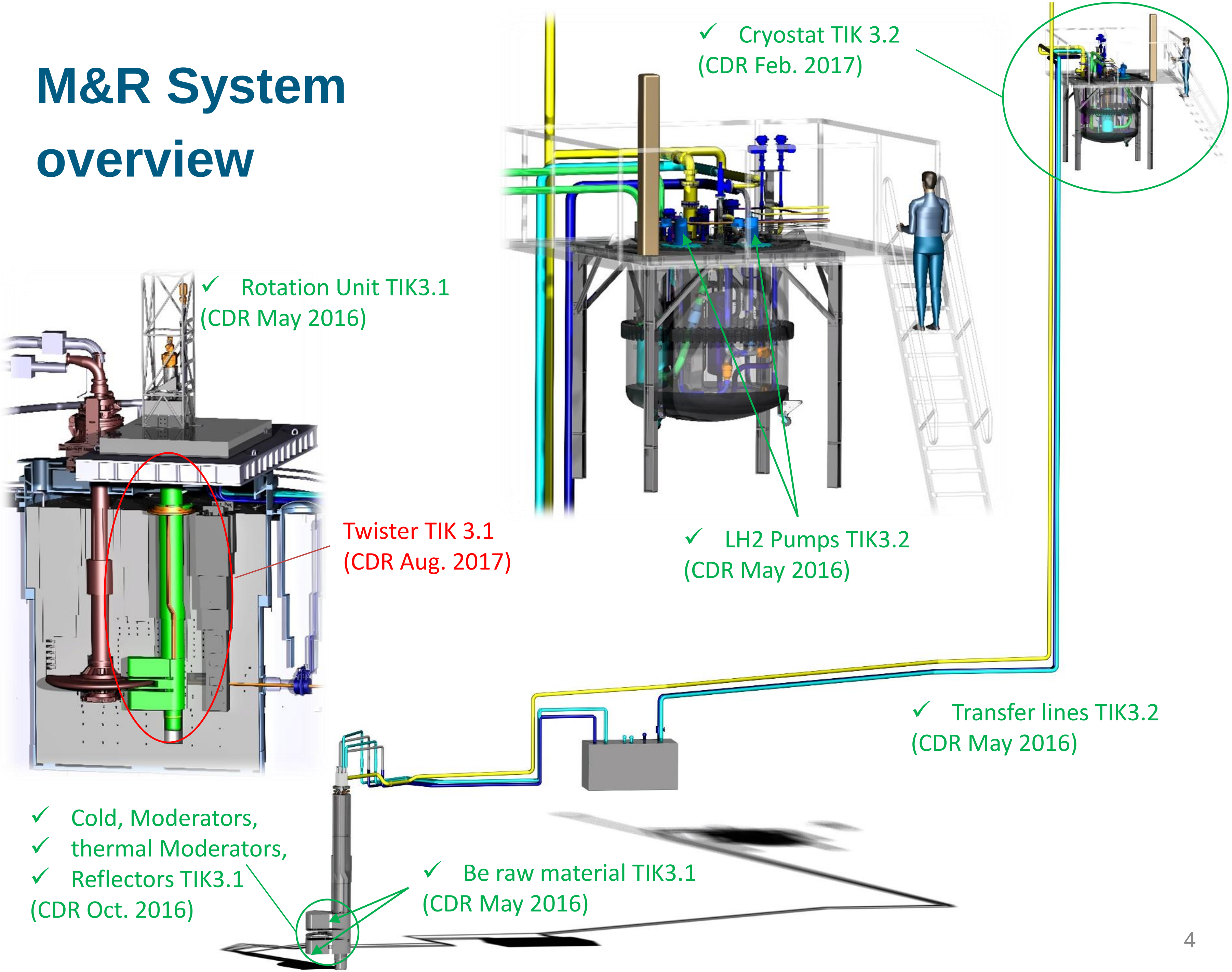
- CMS overview
- M&R System overview
- Cryostat design
- Cryostat calculations
- FAT in Jülich
- Transportation
- Installation on side
- Response to TAC 14 recommendation
- 3D X-Ray of cold Moderator
- 1st and 2nd burst test
- Summery



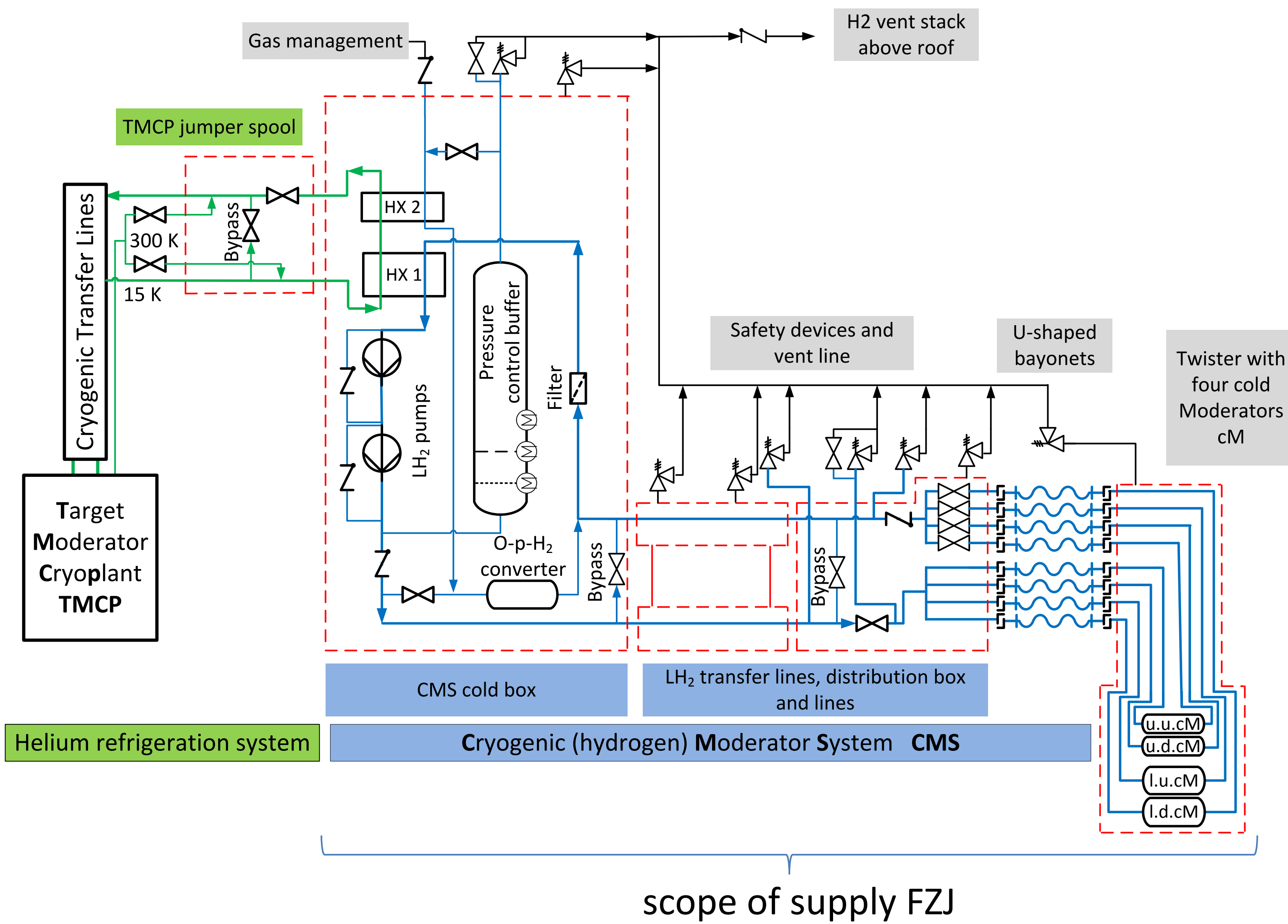
Cryogenic infrastructure overview



M&R System overview



CMS flow chart



Cryostat Design Overview

Weight	2.87 t	(total)
Height	3.1 m	(bottom wheels to upper control valves)
Volume	~ 4500 l	

Components:

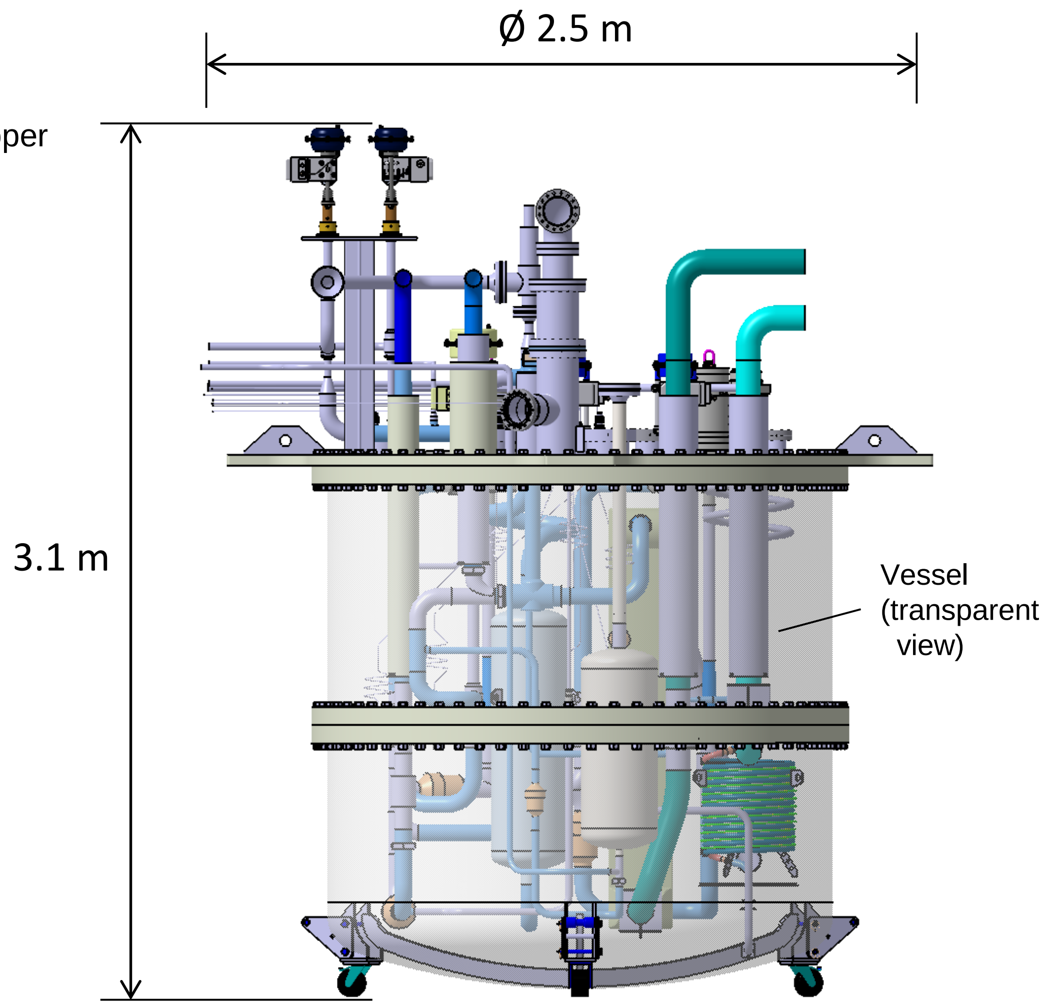
- Vessel (consisting of three parts: top plate, upper cylindrical part, bottom part)

- Hydrogen cycle with Ortho/Para-Converter, Pressure Control Buffer, pumps and filter

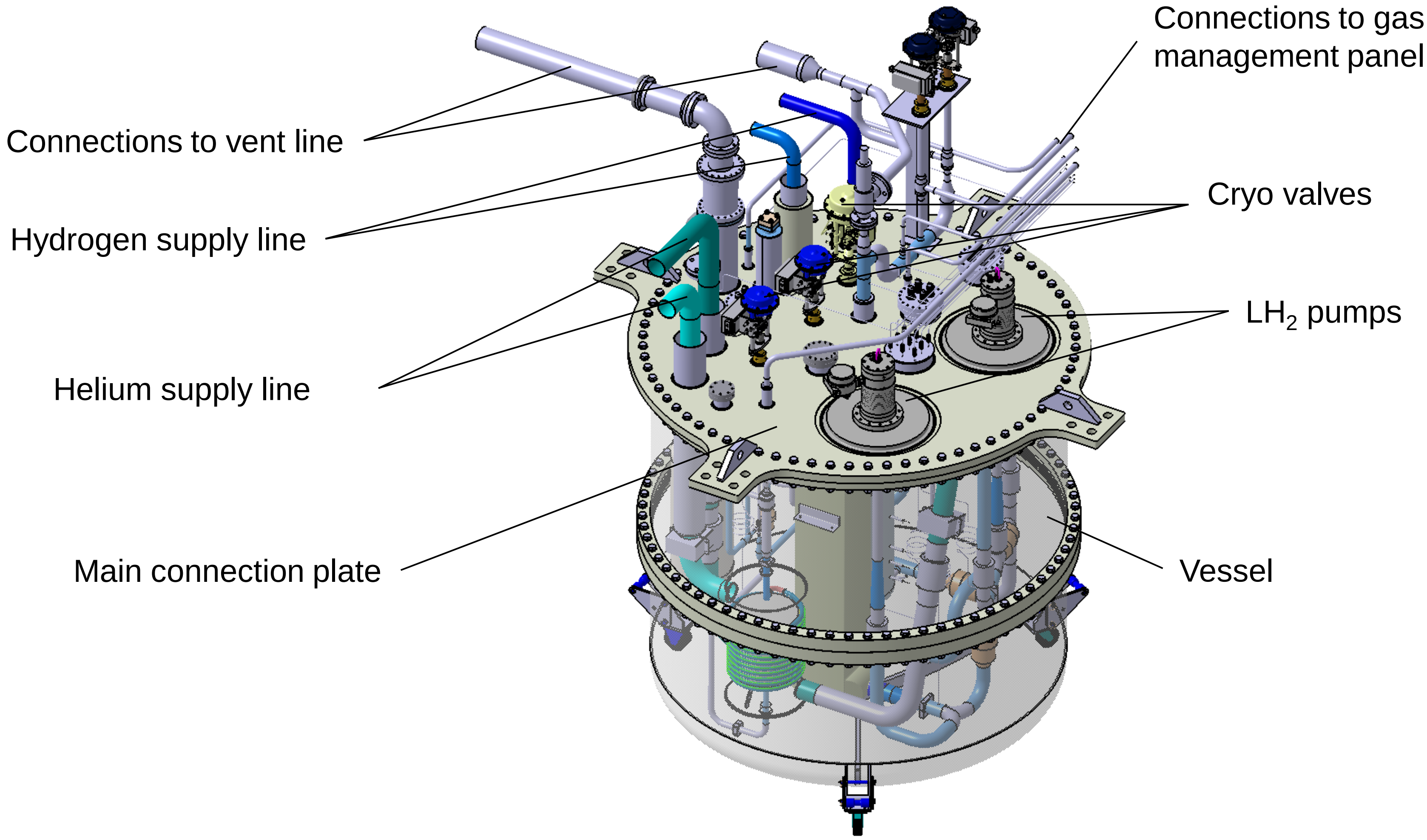
- Helium cycle with heat exchangers

- Control valves and check valves

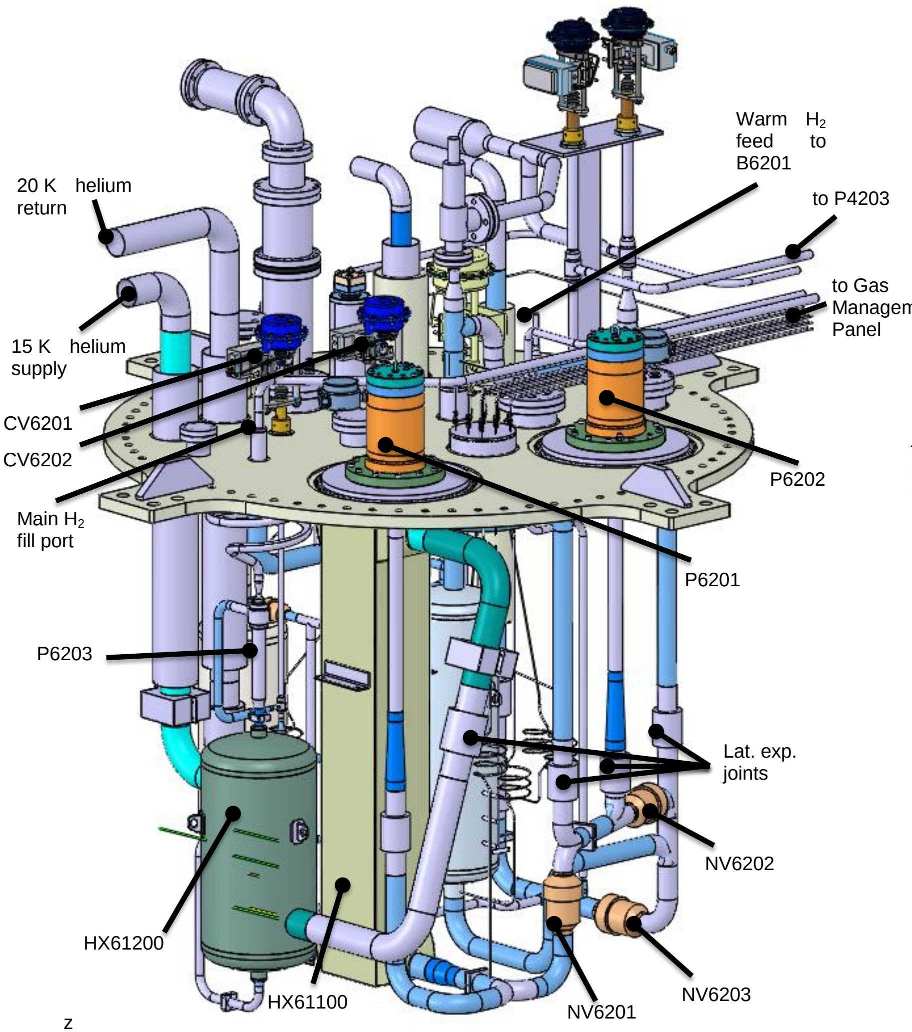
- Instrumentation (pressure and temperature sensors)

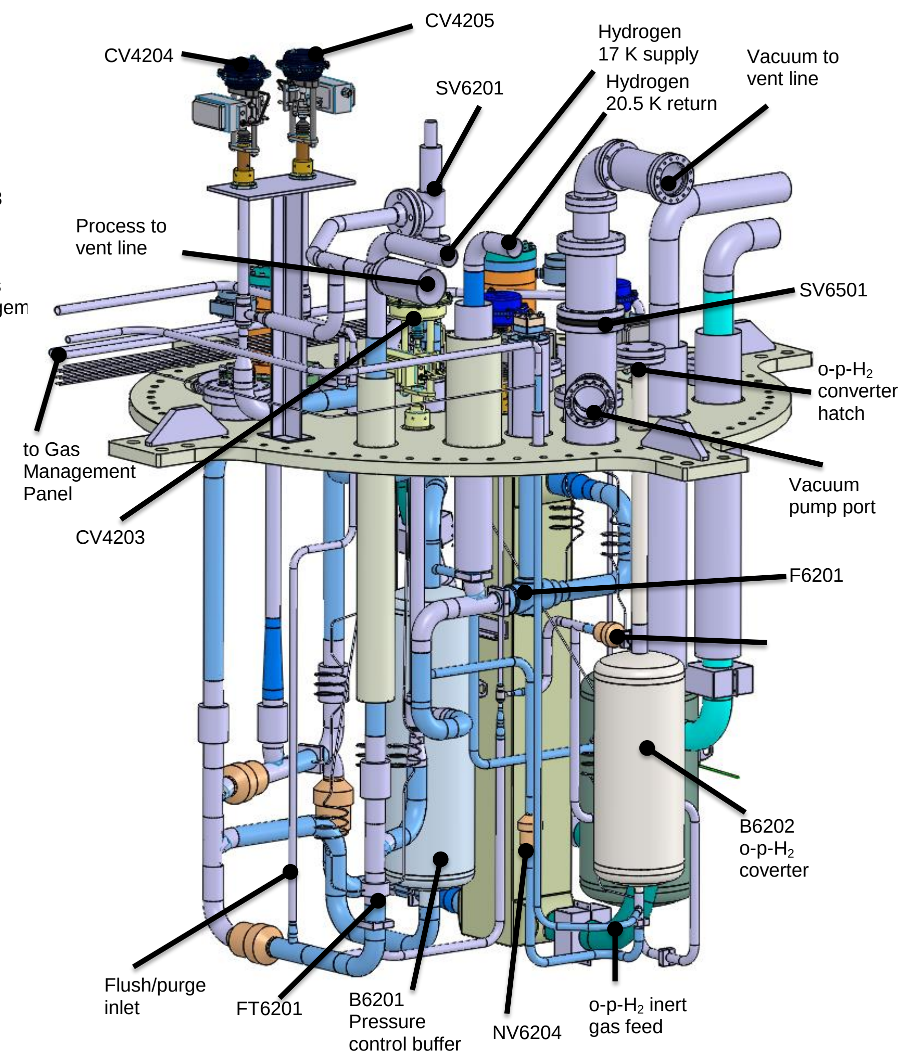


Cryostat Design Overview



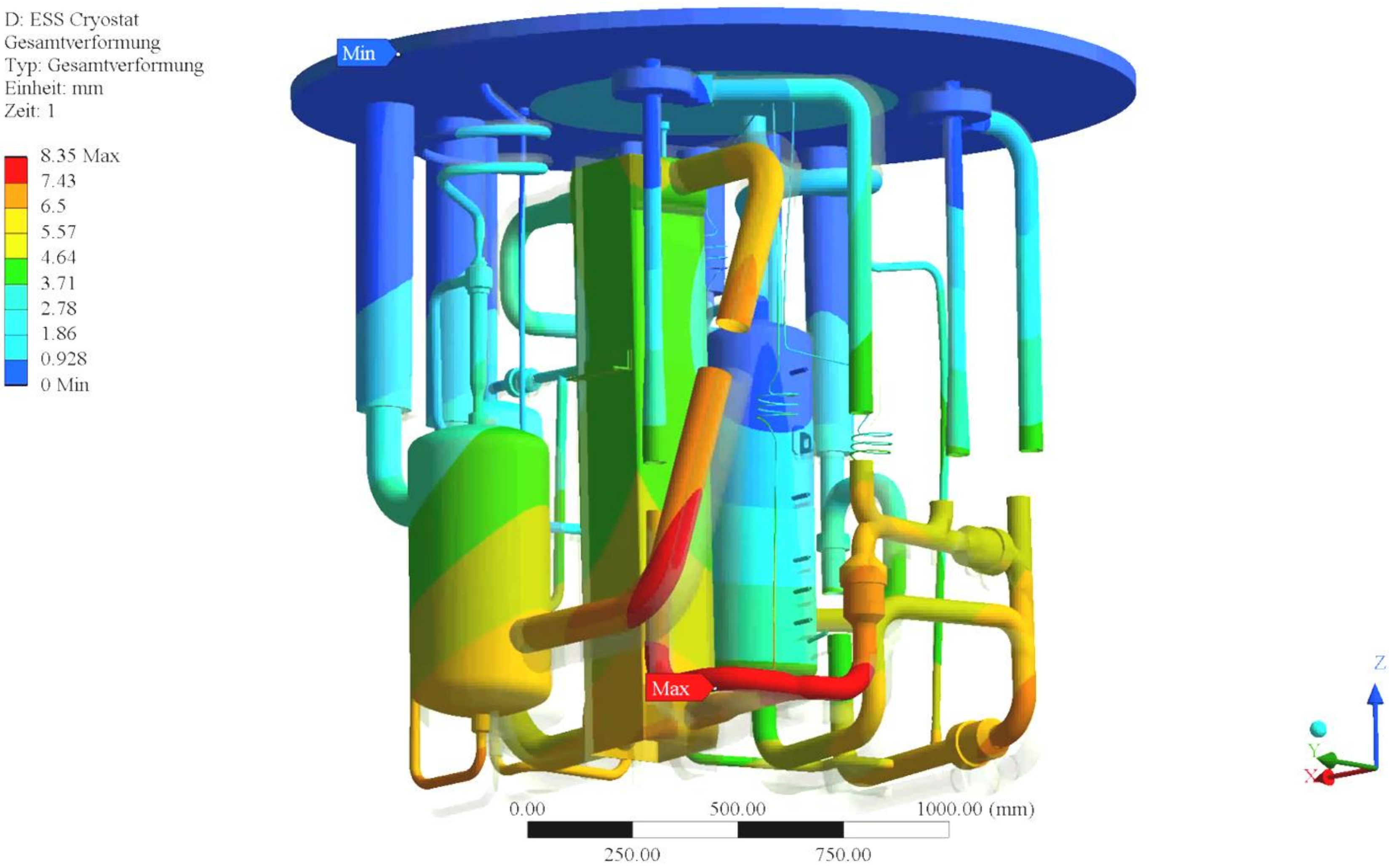
Cryostat Design Overview



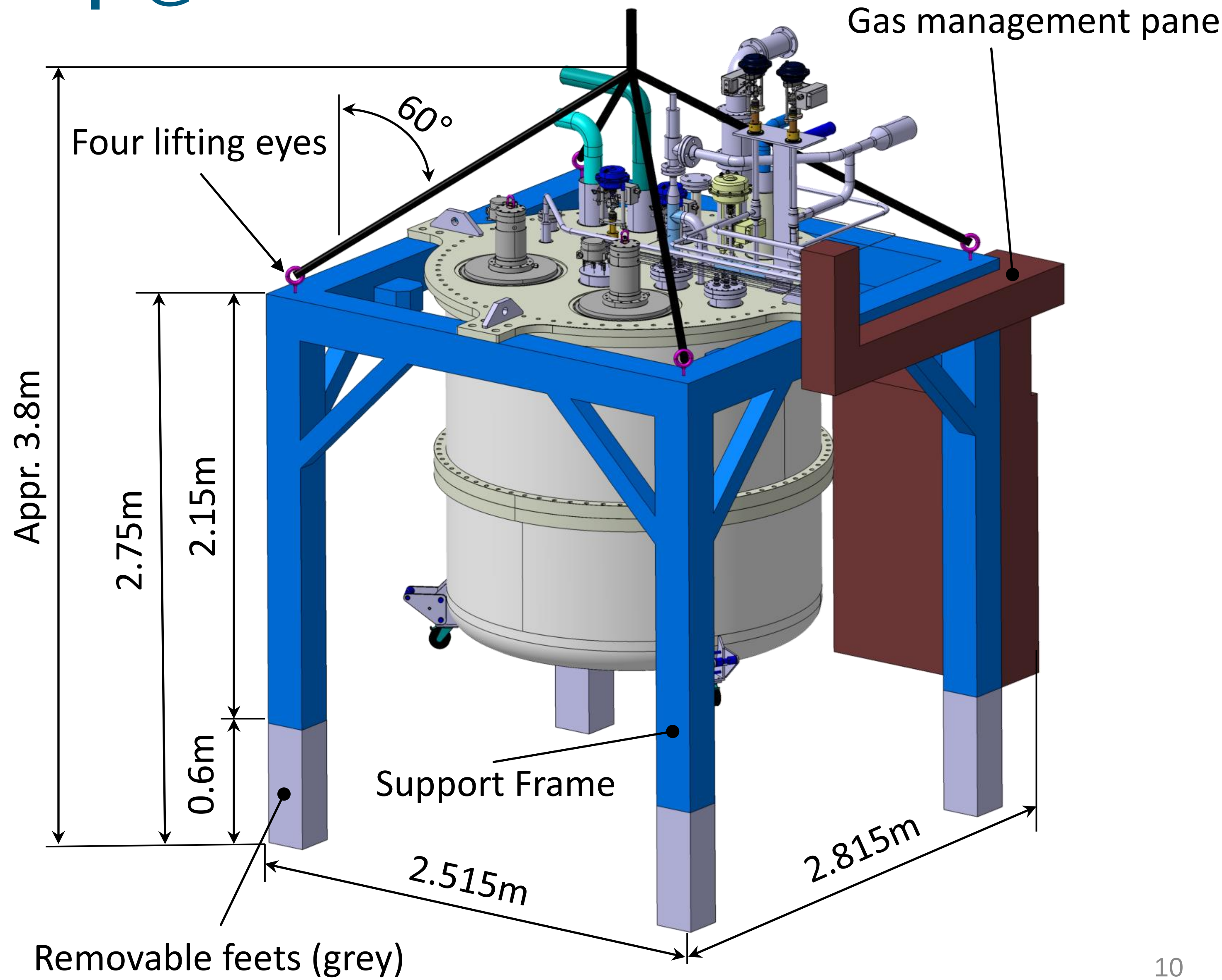


CMS FE calculations

-Simulation results (total deformation)



FAT set up @ FZJ



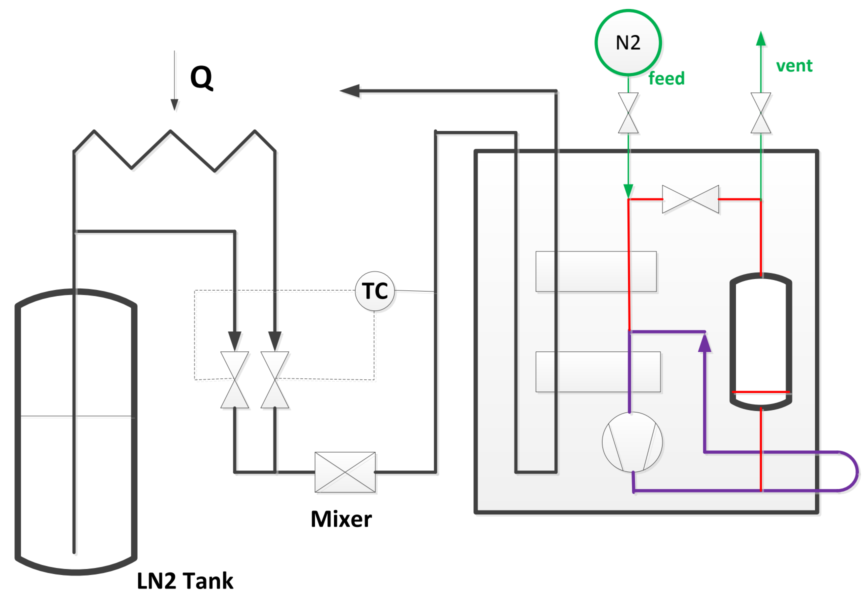
Additional Equipment needed for the FAT

Special testing equipment

- Cooling unit: To make tests at liquid nitrogen temperature a special LN2 cooling unit is needed, which allows the cooldown and the steady state cooling of the loop for a certain time. Since maximum temperature differences on the plate-fin heat exchanger the cooling unit must be able to provide in the beginning gaseous nitrogen at any desired temperature between 300 and 80 K.

- Nitrogen refrigerant feed: A source of gaseous nitrogen with a pressure higher than 15 bar.

- Nitrogen venting system to outside the building: For the venting of the refrigeration nitrogen and for the exhaust of the active and passive safety valves and the box vacuum safety relief.



Test 1: Warm cryostat with removed shell

Inspection of piping and instruments

- Inspection of piping for compliance with PFD and PID
- Inspection of instrument location and tests of wiring to transmitters
- Photographs of all internals

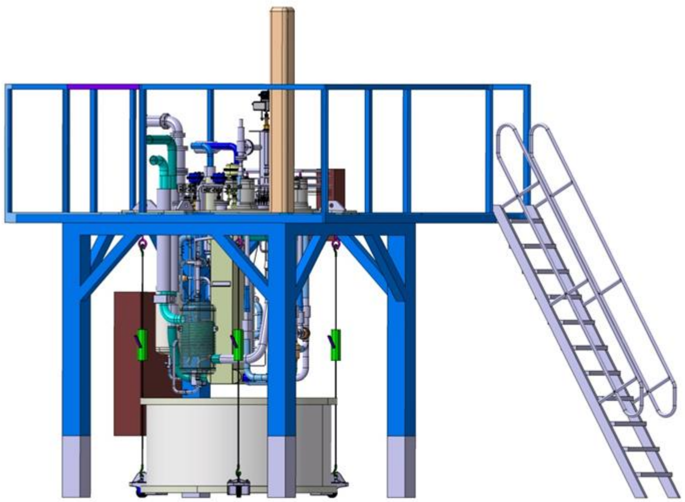
Valve functioning control

- All valves shall be actuated along their full stroke repeatedly. The valves shall move softly within the whole range of mechanical operation, without any visible, audible or otherwise noticeable signs of jerks.

First leak test of internal piping

- Filling of the circuit with helium of about 2 bar. Looking for leaks by sniffing and by overnight pressure stability.

After these tests the cryostat shell will be mounted and the cryostat will be evacuated.



Test 2: Warm cryostat with mounted shell

Leak test of vacuum jacket

– The vessel shall be evacuated to a sufficiently low pressure and then submitted to helium leak tests (ESS Vacuum Handbook Part 4 – Vacuum test manual). During these tests all the welding seams, flanges, feed-throughs, etc. shall be sprayed from outside with helium. The leak detector shall be connected to one of the provisional flanges on the vacuum vessel. Any detected leaks shall comply to the specified values.

Integral process piping pressure and leak test

– The pressure test shall be carried out in accordance with the PED and with EN 13480-4 requirements. The test pressure shall be not less than 1.43 times the maximum allowable pressure (17 bar.a). During the pressure test, the pressure in the assembled parts shall be gradually increased to a value of 50 % of the required test pressure. Thereafter the pressure shall be increased in steps of approximately 10 % of the required test pressure until the test pressure is reached. The pressure shall be then reduced after 10 min to the maximum allowable pressure and held during the inspection of the assembled parts. The helium content in the exhaust of the vacuum pump will be monitored. The vacuum level in the cryostat will be monitored. Outside connections to the process loop will be sniffed with a helium leak detector.

Test 3: First cooldown of cryostat

- *Installation of superinsulation*

First cooldown

– The process pipes will be evacuated and filled with small amounts of nitrogen gas repeatedly. Then the process will be filled with 10 bar nitrogen and the pressure control system will be operated.
– The pumps will be started and will circulate the nitrogen via the bypass valve.
– The cooldown will start with cooling gas from the cooling unit. The initial cooling gas temperature will be about 260 K and will be lowered in accordance with the loop temperature.
– The cooldown will go down to about 150 K. The system will be held at this temperature level for the following tests.
– The performance of the temperature sensors will be monitored.

Check of superinsulation

– Wall sections, which have not been internally insulated sufficiently, will become wet on the outside. The insulation will be improved after the next warm-up.

First inspection of pump operation

– The operation of the pumps will be monitored qualitatively concerning stable running, temperatures on the outside, functioning speed control etc.

Test 4: First warmup of the cryostat

First warmup

- The warmup will be performed with “warming” gas from the cooling unit. The initial warming gas temperature will be about 180 K and will be increased in accordance with the loop temperature.
- The operation of the pumps will assist in the warmup to 300 K.
- The nitrogen pressure in the loop will be lowered to atmospheric pressure.

Opening of the shell

- After the warming up to 300 K the two shells of the cryostat will be removed.

Repair of superinsulation and instrumentation

- All deficiencies detected during the first cooldown will be repaired.

- *All components and pipes of the process – with the exception of the pressure control buffer and holding points for transportation- will be covered with superinsulation.*

Test 5: Second cooldown

Second cooldown

- The process pipes will be evacuated and filled with small amounts of nitrogen gas repeatedly. Then the process will be filled with 10 bar nitrogen and the pressure control system will be operated.

- The pumps will be started and will circulate the nitrogen via the bypass valve CV-6203. The cooldown will start with cooling gas from the cooling unit. The initial cooling gas temperature will be about 260 K and will be lowered in accordance with the loop temperature.

- The cooldown will go down to about 120 K. The pumps will be shut down before the condensation of nitrogen starts.

- From now on the final cooldown and filling with liquid nitrogen will be performed without rotation of the pumps. After the whole loop (except the upper section of the pressure control buffer) is filled with subcooled liquid nitrogen, the pumps will be started again.

Test 6: Buffer performance test

Pressure control buffer cryogenic performance test

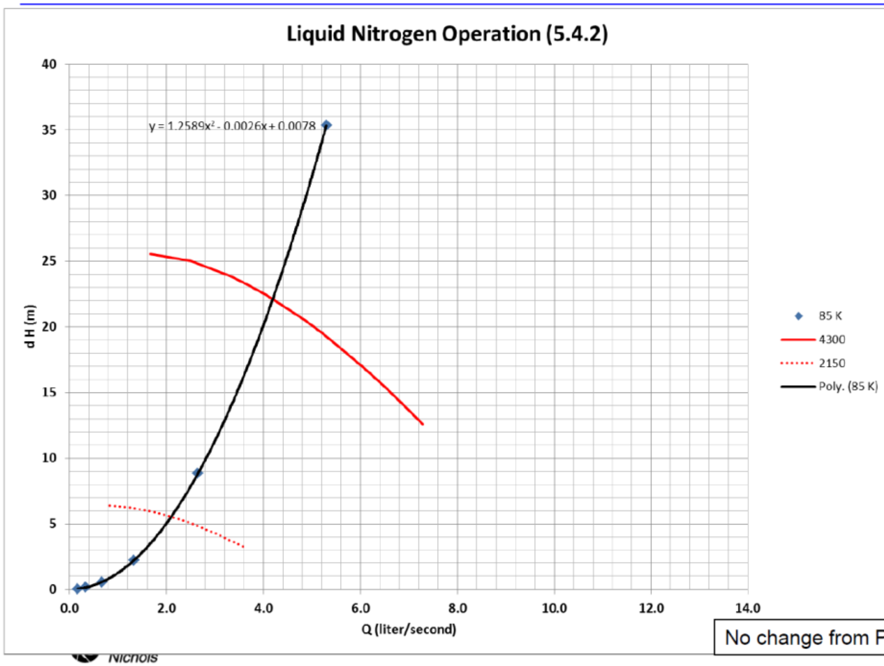
– As soon as the loop is fully filled with liquid nitrogen and the pumps have been started, the functioning of the pressure control system is tested by simply changing the set value of the pressure controller: For an increase of the pressure the vapor release valve at the top will be closed and the electric heating at the bottom will be increased. For a lowering of the pressure the release valve will be opened and the heating at the bottom will be reduced.

Test 7: Pump performance test with subcooled LN2

Turbo pump performance test

– The performance curves of the pumps with liquid nitrogen on a pressure level of e.g. 10 bar will be established by variation of the speed and the bypass valve setting. The subcooled liquid nitrogen is cooled by liquid nitrogen evaporating in HX 1 at e.g. 78 K. Cold operation with impact on the pump geometry and thermal behavior can be verified. Furthermore, the predicted performance of the pump contractor at rated conditions shall be matched with experimental values.

Liquid Nitrogen Operation



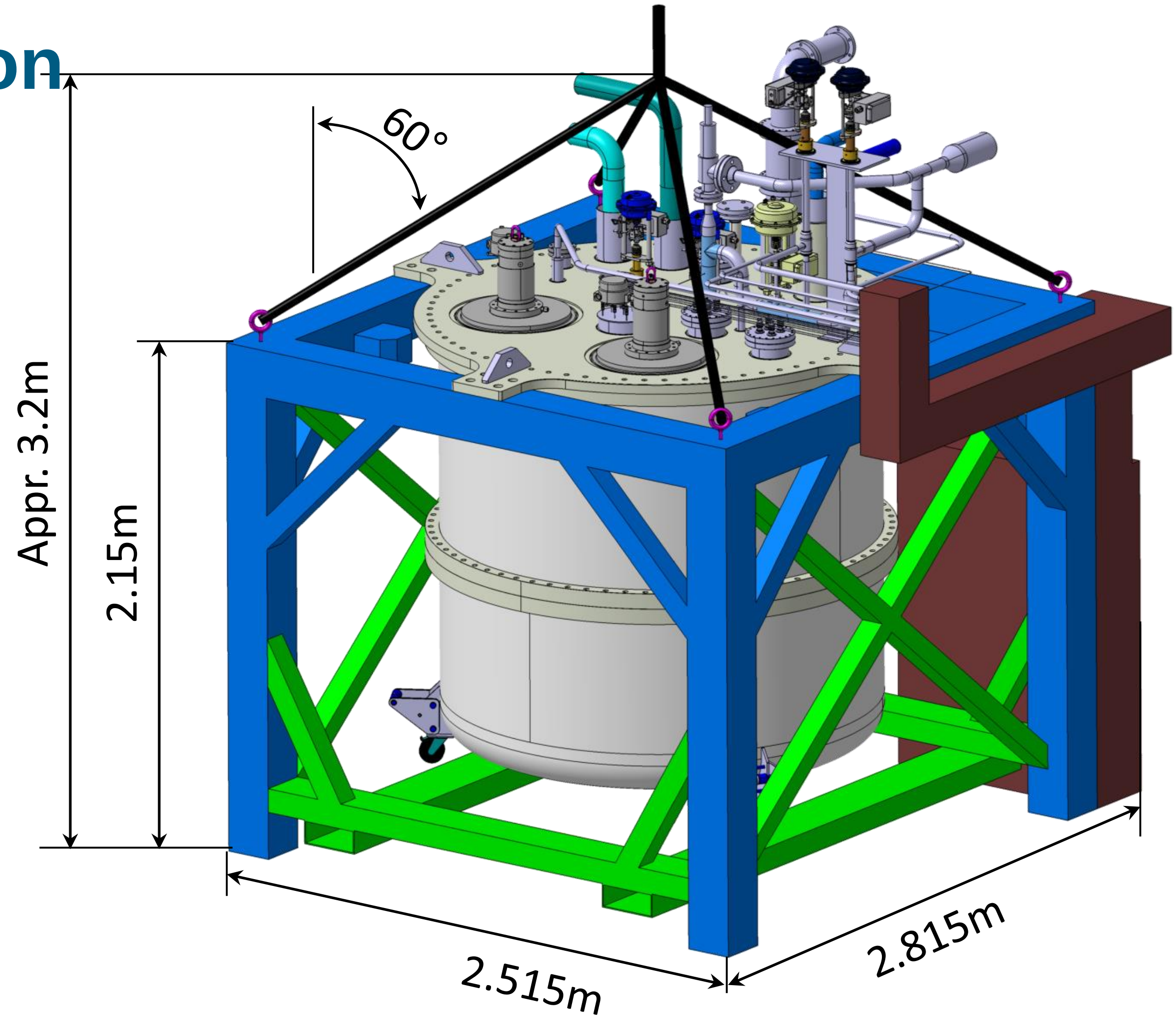
No change from PDR

After this test, the system will be warmed up. It is now ready for packing and shipping to ESS.

Transportation

-Removing the removable feet and installing an additional transport safety device (green) with forklift attachment.

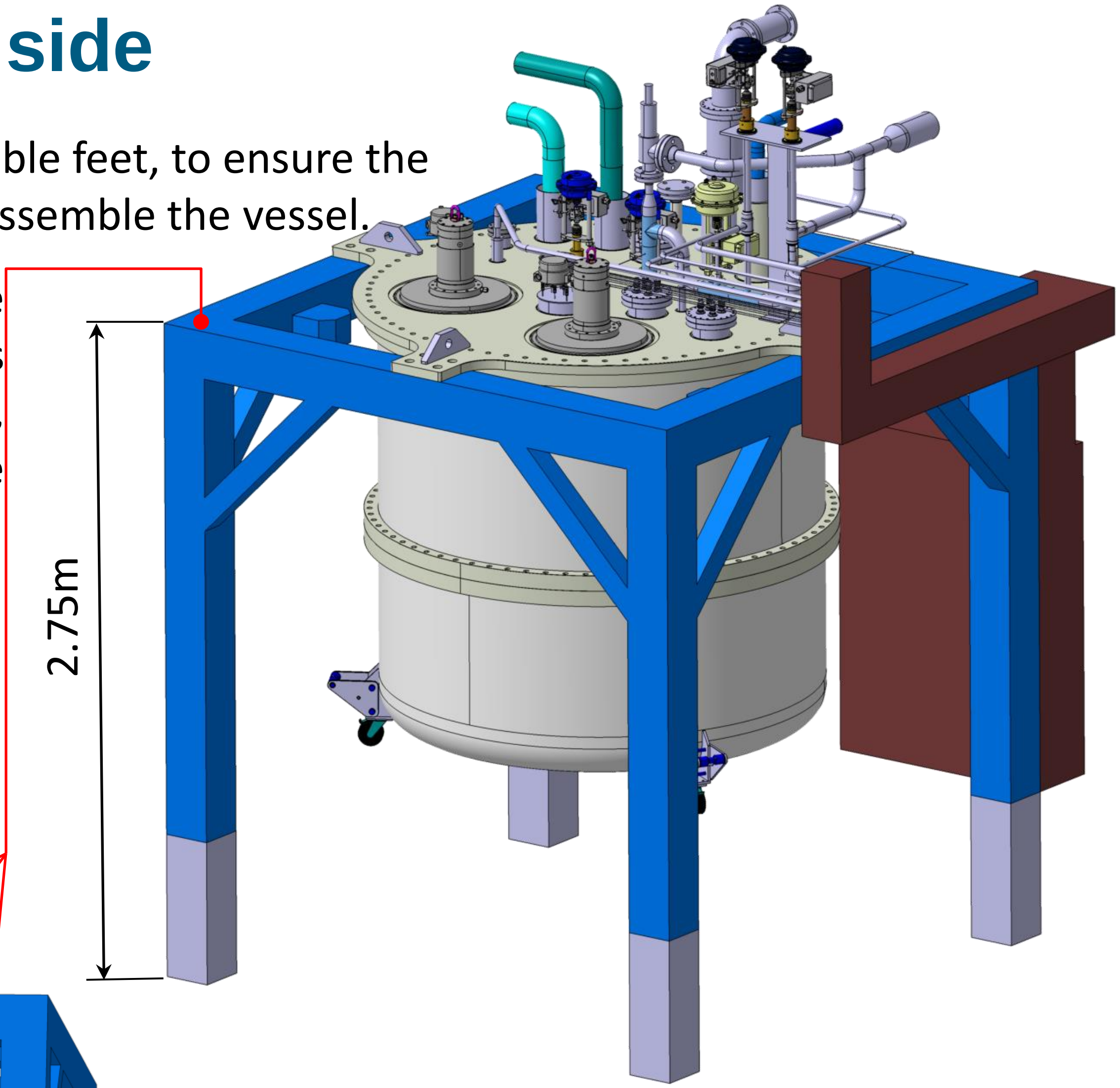
-MLI is on some parts not installed to have space for fixing structure for transportation



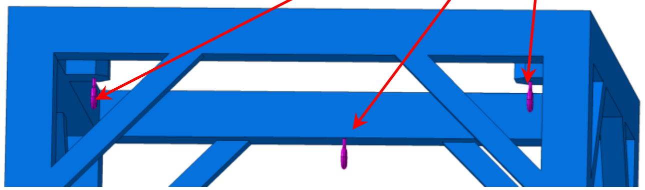
Installation on side

Re mounting of the removable feet, to ensure the necessary clearance to disassemble the vessel.

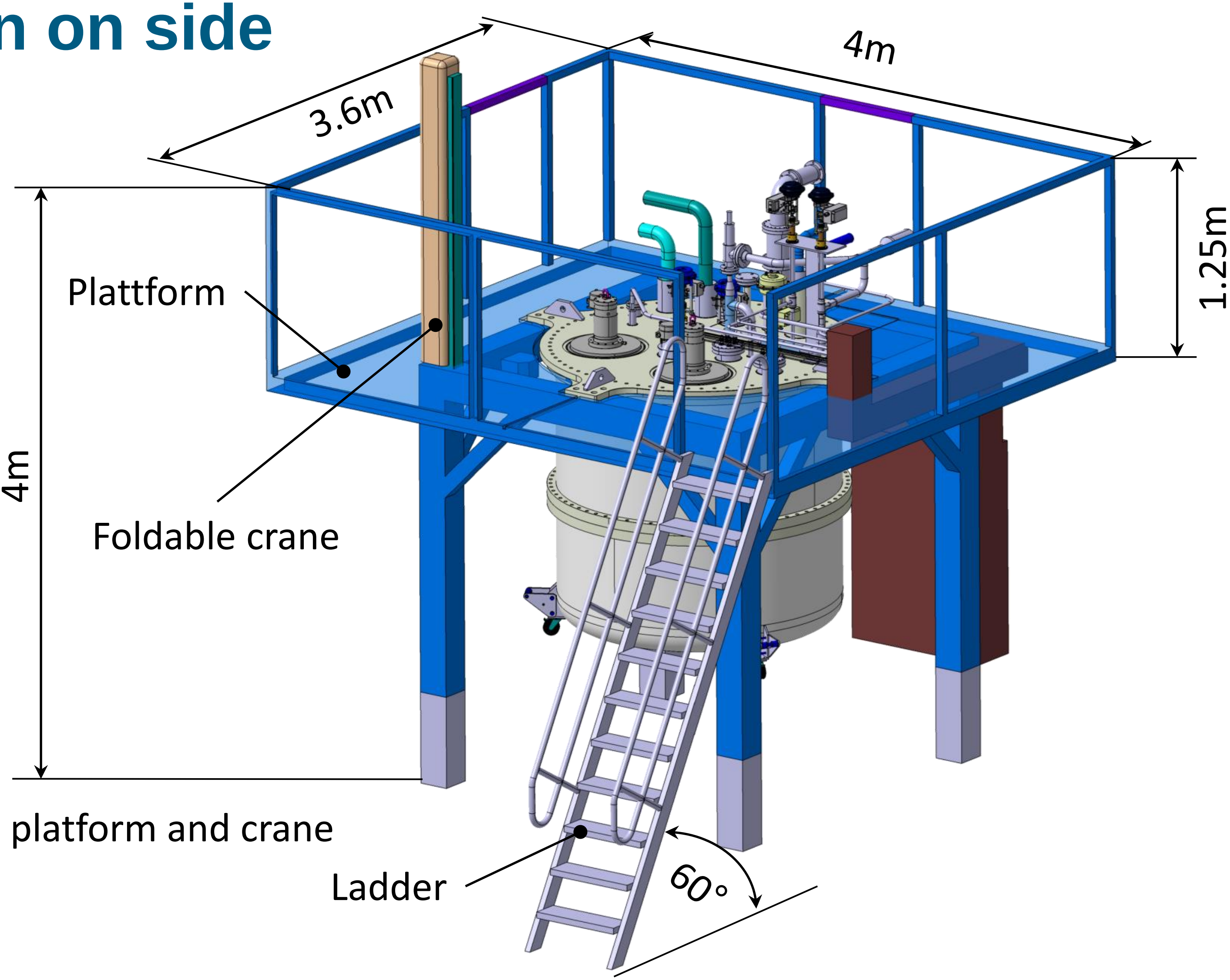
The lowest Point of the cryostat inner components is a meter above ground, the two vessel parts are 970mm.



Three of the lifting eyes will move to the lower attachment points for later use and one in storage Position.

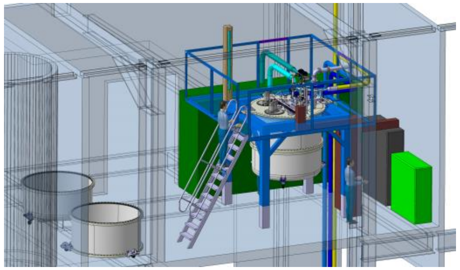


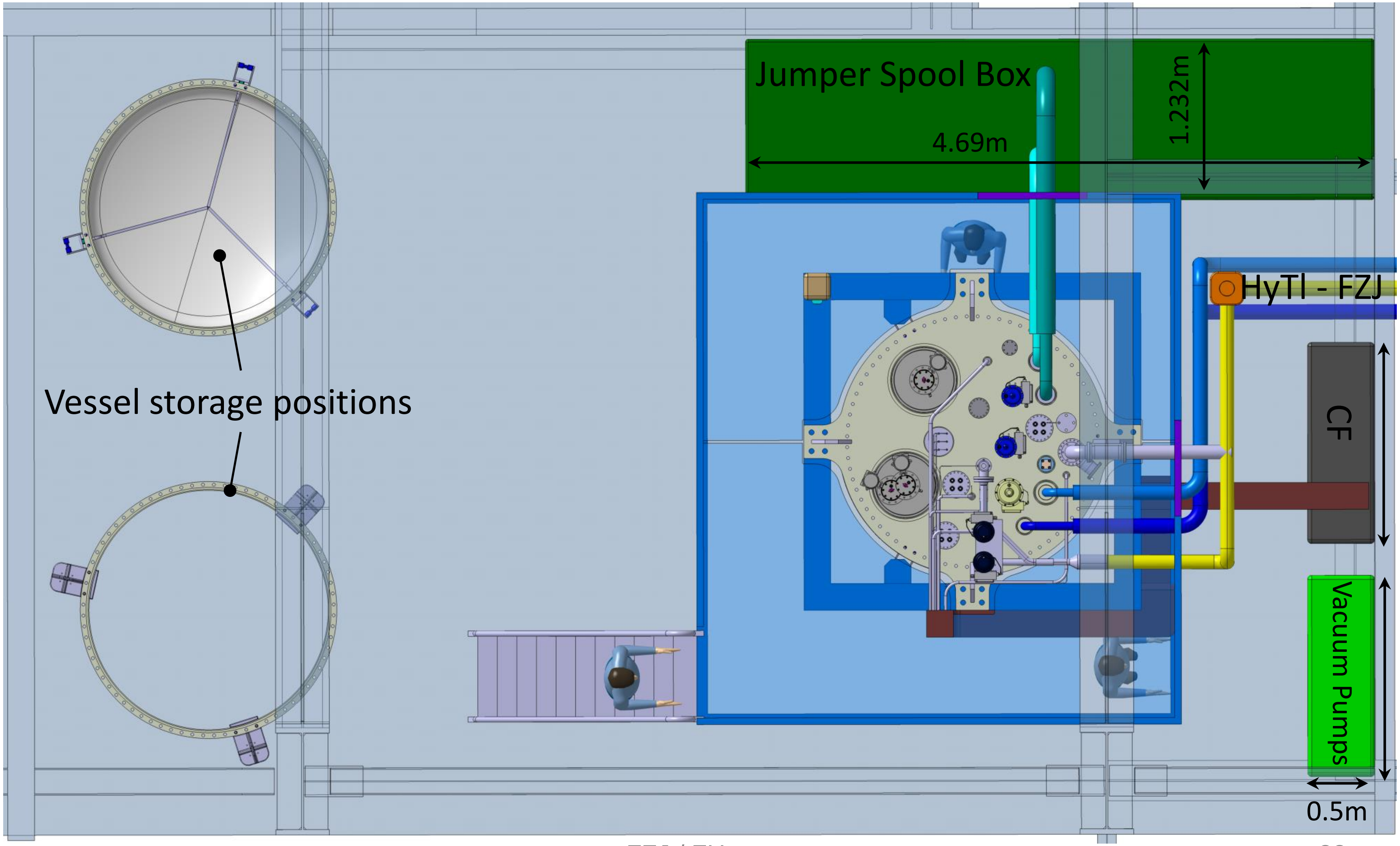
Installation on side



Installation of the platform and crane

Room Layout




Jumper Spool Box
4.69m
1.232m
Vessel storage positions
HyTl - FZJ
CF
1.5m
Vacuum Pumps
1.5m
0.5m

Response to TAC 14 recommendation

o-p-H2 measurement system -Raman Spectroscopy-

LH2 System	Plan to exchange the sapphire window with a blind flange in case of failure to be able to continue operation of the loop.

a) From a vendor, certified for our use, mounted in a CF flange of our choice,
b) Or developed by our in-kind partner/ESS and verified for our use, mounted in a CF flange.
In any case a blind flange will/can be mounted for a safe operation. We also have considered the consequences in case of glass rupture so that the hydrogen will be evacuated in a safe way. Detailed description in the CMS Solution document ESS-0092146.
A replacement of the flange will always lead to a system shutdown.

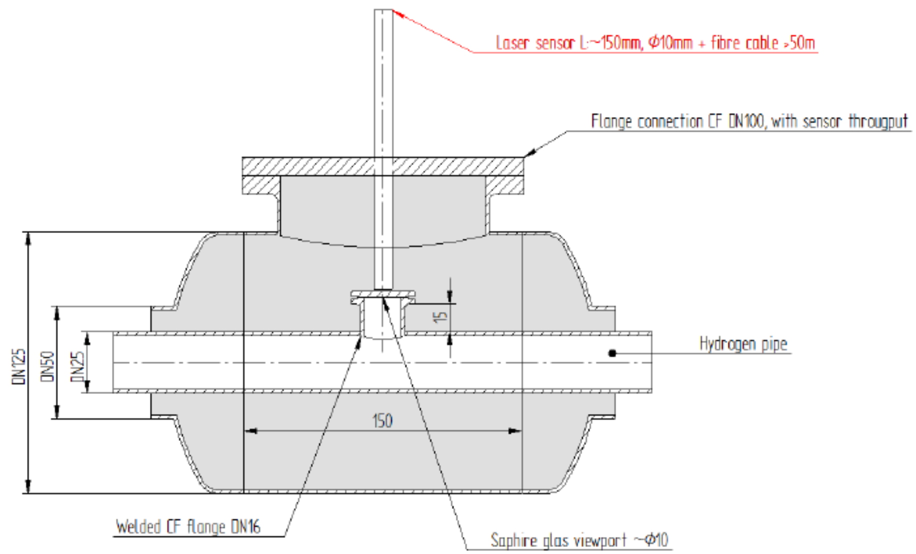
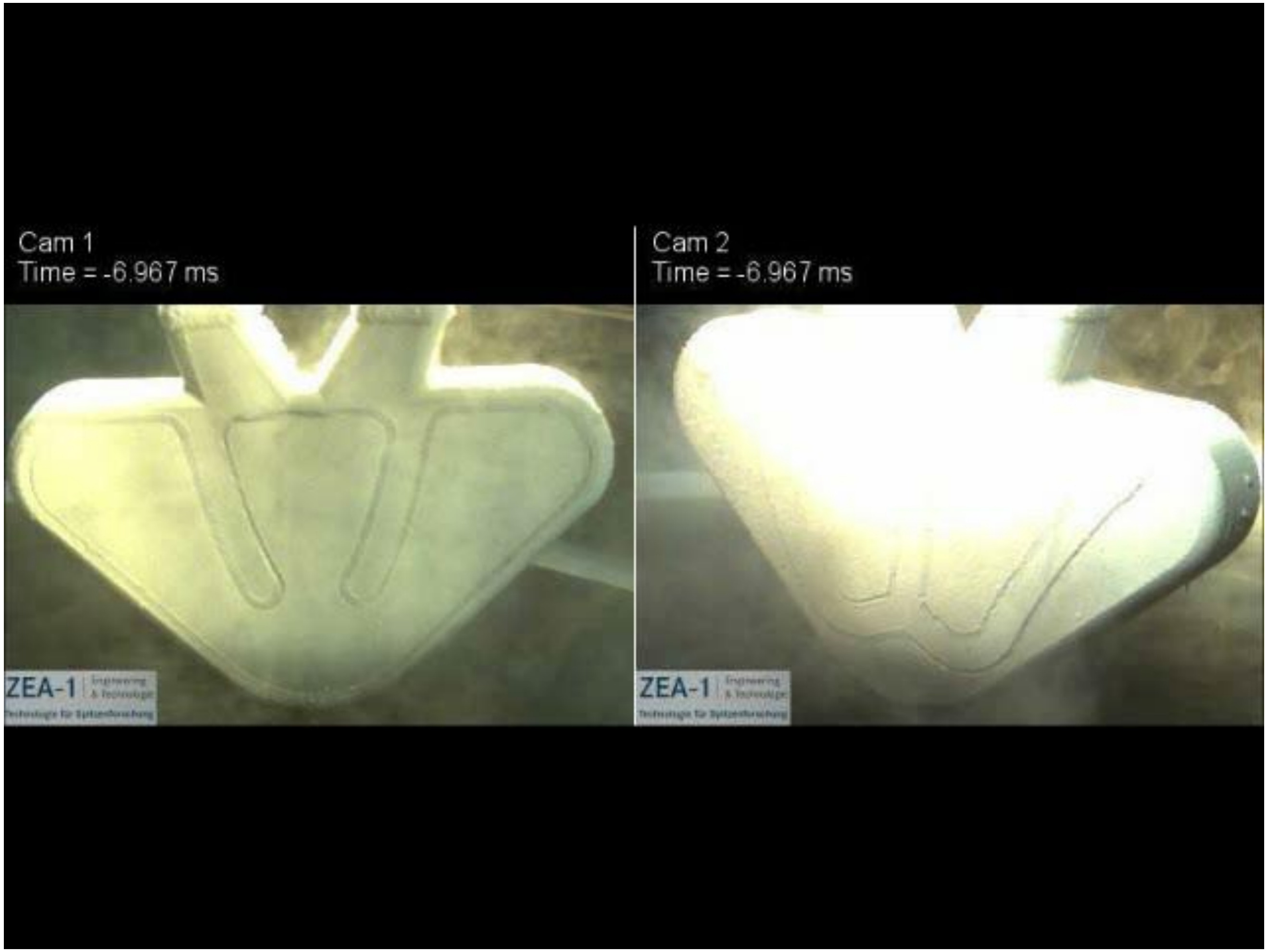


Figure 3: Later installation of sapphire window view ports on the DN16/PN25 flange as example for the distribution return lines.

3D X-RAY of cold Moderator test vessel

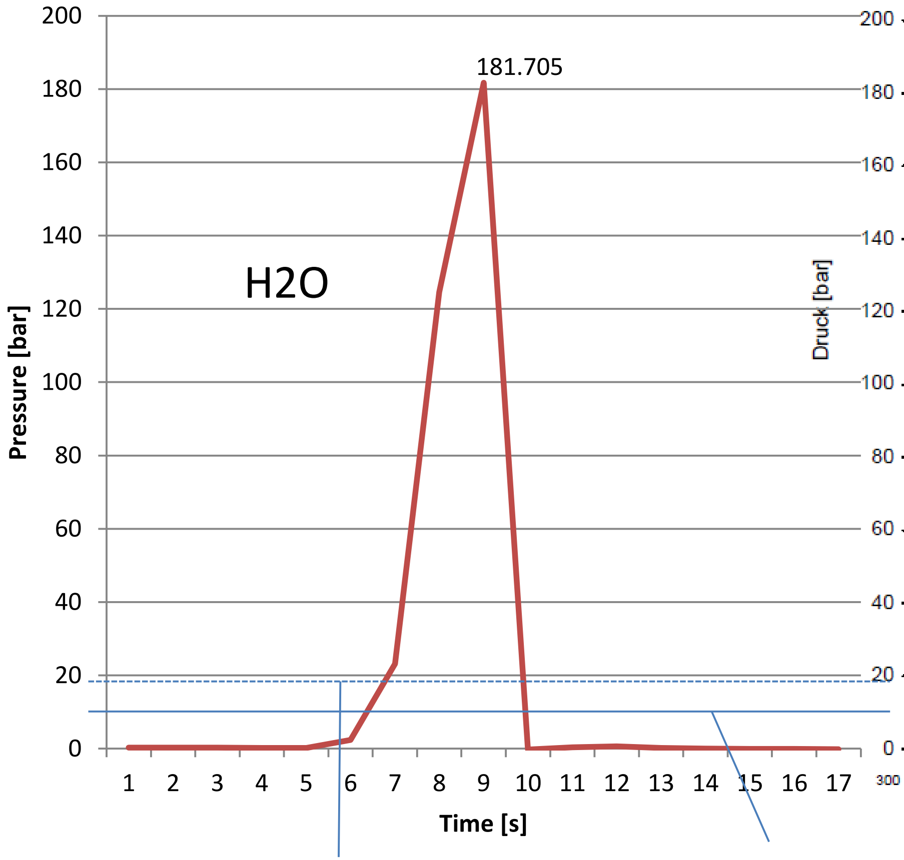
1^{st} Burst test cold Moderator (water)

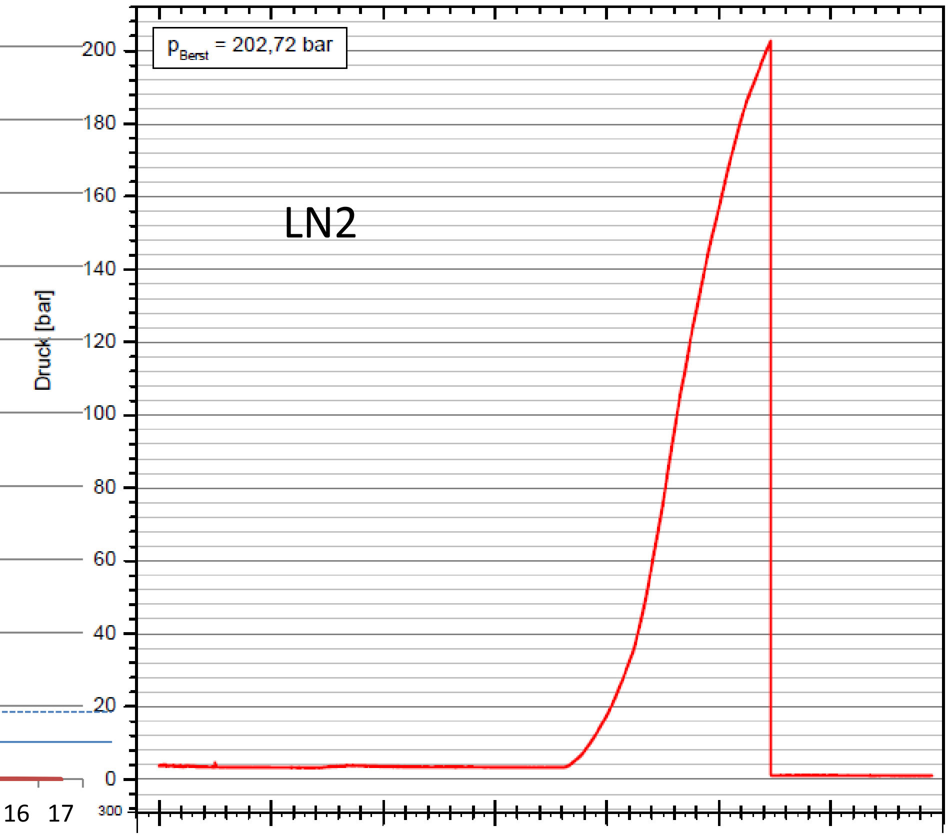
2nd Burst test cold Moderator (LN2)



≈10 m/s

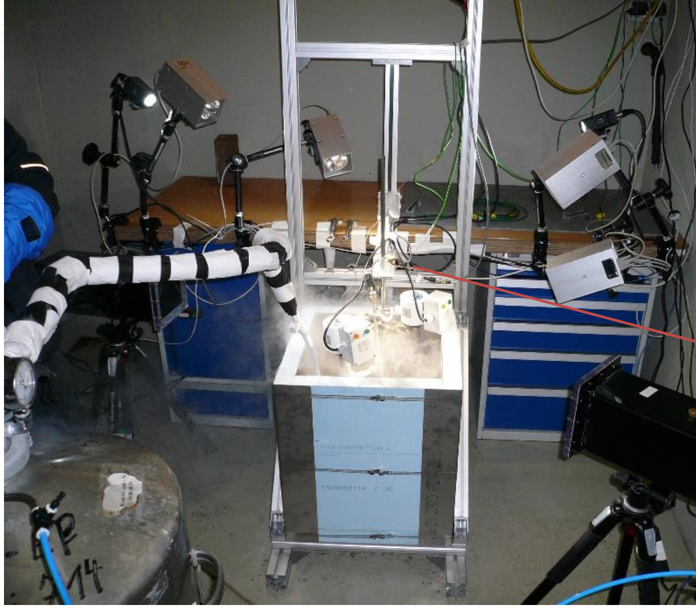
Burst test summery

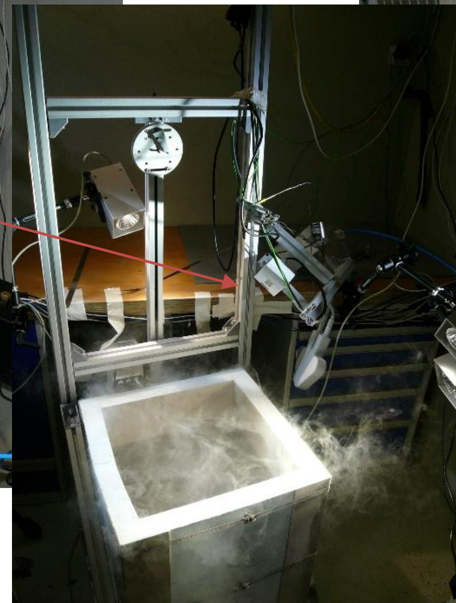


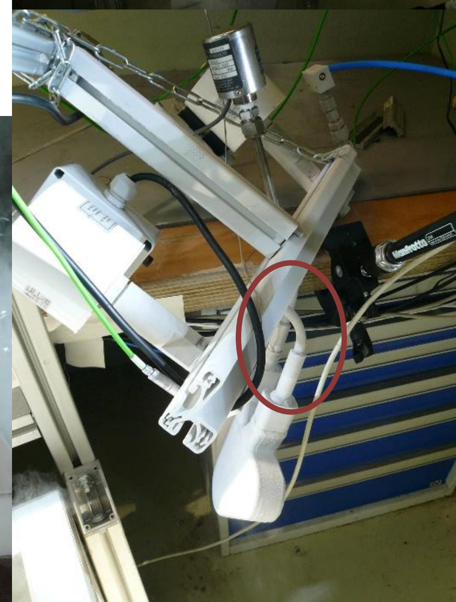


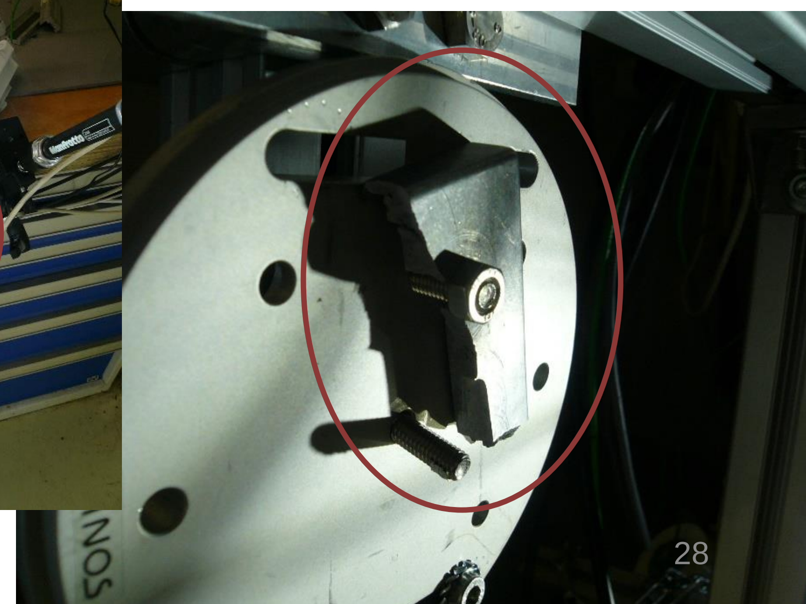
Design pressure
17 bar

Operation pressure
10 bar









Summary

- The final design phase has been successfully completed with a delay of ≈2 months
- Procurement phase is ongoing
- Manufacturing will start soon
- Contract with TÜV is in place (welding inspection according PED)
- We currently prepare our laboratory for the FAT test
- Subsystem test will start in summer 2017
- System shall be ready for transportation in May 2018…

T H A N K S !