Wrocław University of Technology

TIARA and Wrocław University of Technology

Prof. Maciej Chorowski

Wrocław University of Technology
Faculty of Mechanical and Power Engineering

Mid-term meeting of the TIARA-PL group, 27-28 Sep. 2012,
Institute of Nuclear Physics Polish Academy of Sciences, Kraków

PWR as TIARA associated intitute

Test Infrastructure and Accelerator Research Area
Preparatory Phase

Intranet

Associated Research Organizations

15	**AGH University of Science and Technology - Krakow**	AGH	**Poland**	http://www.agh.edu.pl
16	**Cracow University of Technology - Krakow**	CUT	**Poland**	http://www.en.pk.edu.pl
17	**Technical University of Lodz - Lodz**	TUL	**Poland**	http://www.p.lodz.pl
18	**Narodowe Centrum Badań Jądrowych - Swierk (formerly Andrzej Soltan Institute)**	NCBJ	**Poland**	http://www.ncbj.gov.pl
19	**Warsaw University of Technology - Warsaw**	WUT	**Poland**	http://eng.pw.edu.pl
20	**Wroclaw University of Technology - Wroclaw**	PWR	**Poland**	http://www.portal.pwr.wroc.pl

Activities and competences related to accelerator technologies

1. Risk analyses for the cryogenic instalation of acelerators
   - 1.1. Methodology of risk analysis developed at WUT
   - 1.2. Risk analyses performed at WUT
   - 1.3. Examples of risk anaylsis results
2. Measurements at cryogenic temperature conditions
   - 2.1. Methodology of measurements
   - 2.2. WUT cryogenic laboratory infrastructure
3. Design and manufacturing of cryogenic devices
   - 3.1. XFEL/AMTF cryogenic transfer line and vertical cryostats
   - 3.2. FAIR local cryodistribution system

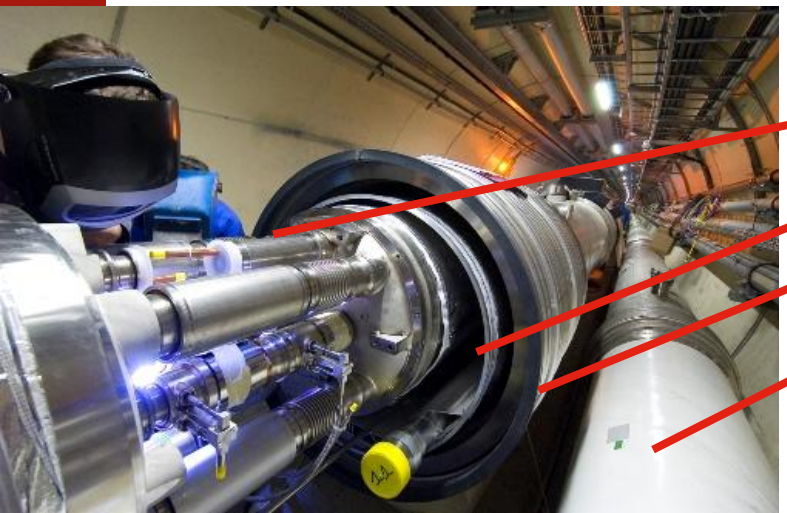
Contents

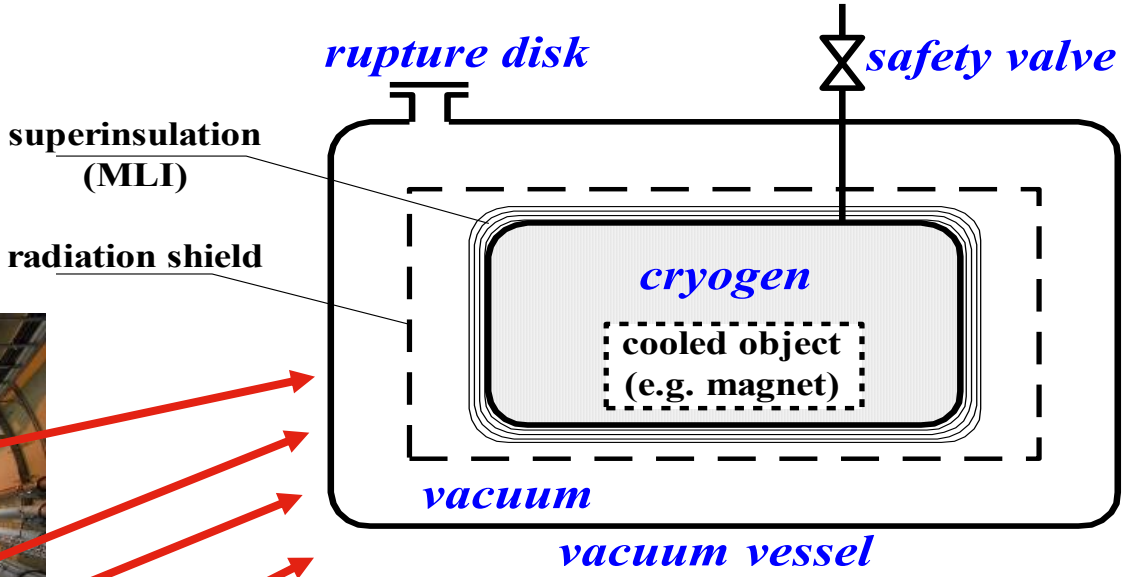
Methodology of crygenic system risk analysis developed at WUT

1. Definition and identification of the cryogenic system nodes.
2. Identification of the locations of the nodes.
3. Analysis of the potential failures and the determination of credible incidents.
4. Identification of credible scenarios for chosen node and the analysis of their potential causes and consequences.
5. Specification of the most credible incident(s) and most credible scenario(s).
6. Investigation into the dynamics of the most potential helium descharge to the vacuum insulation and to the environment (ODH, pressure, temp.).
7. Proposal for the mitigation of the most credible incident consequences.
8. Specification of remedial actions.

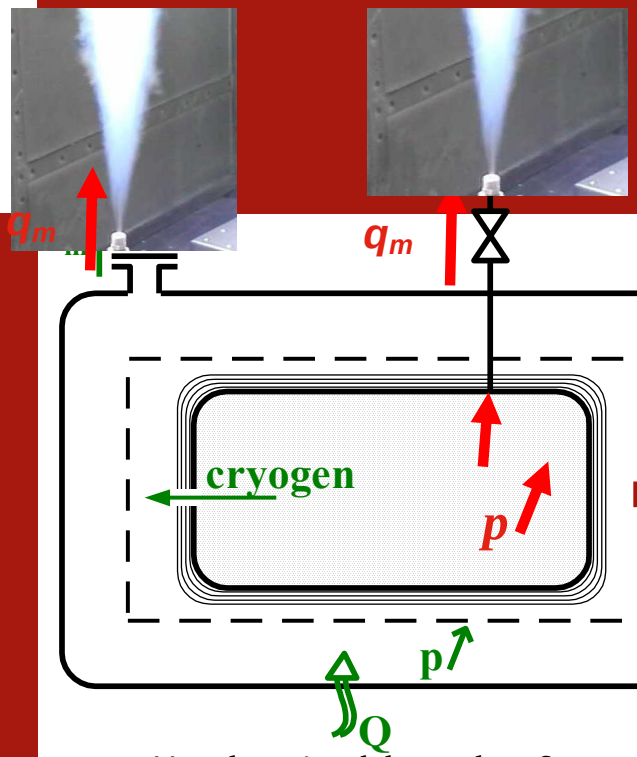
Cryogenic node – simplest element of the cryogenic system – basis for the risk analysis

Each component of the machine like pipe, vessel, heat exchanger, and cryostat can been treated as separate helium enclosure, characterised by the amount and thermodynamic parameters of helium.





Safe operation of cryogenic systems



- Mechanical break of warm vacuum vessel
- Fast degradation of vacuum insulation with air
- Intensive heat flow to the cryogen
- *Magnet quench (optionally)*
- Pressure increase of the cryogen
- Opening of the safety valve
- Cryogen discharge through the safety valve

Underestimation of heat flux to the helium caused serious damage of the LHC accelerator in 2008

Large Hadron Collider accident - faulty electrical joint of two superconductors

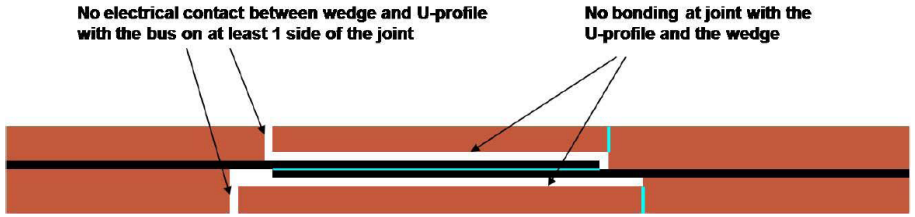
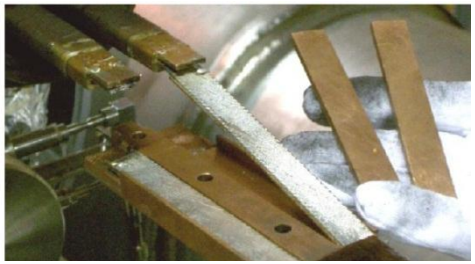
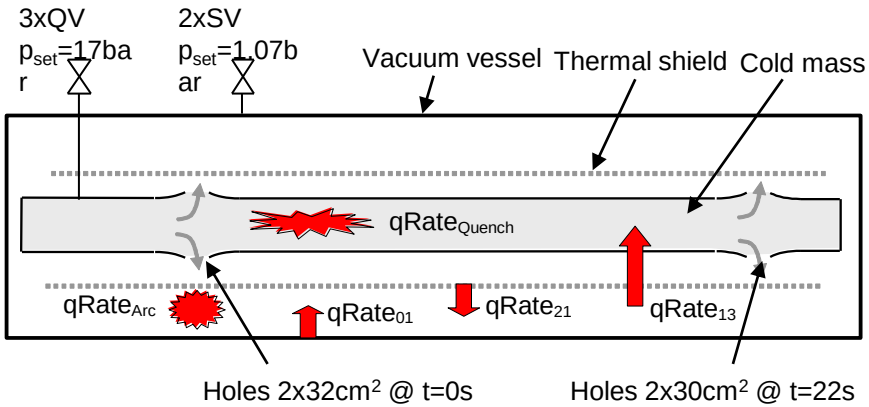
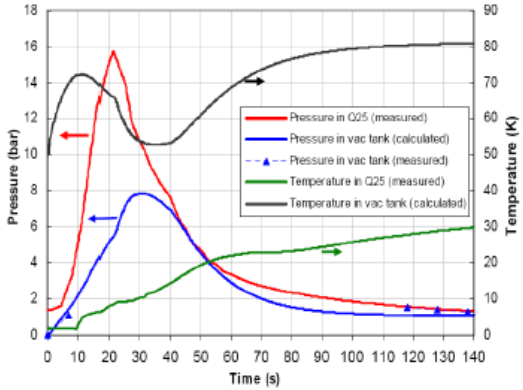


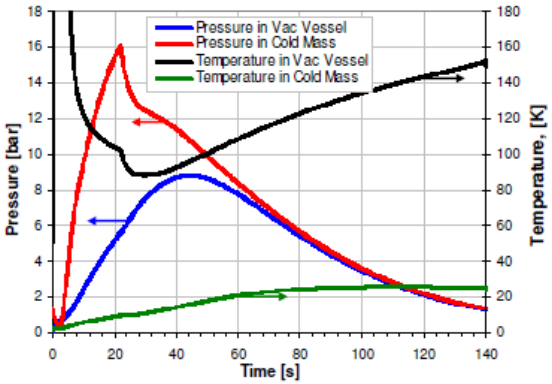
Figure 7: Model of resistive joint in bus bar with bad electrical and thermal contact with the stabilizer



Thermodynamic model



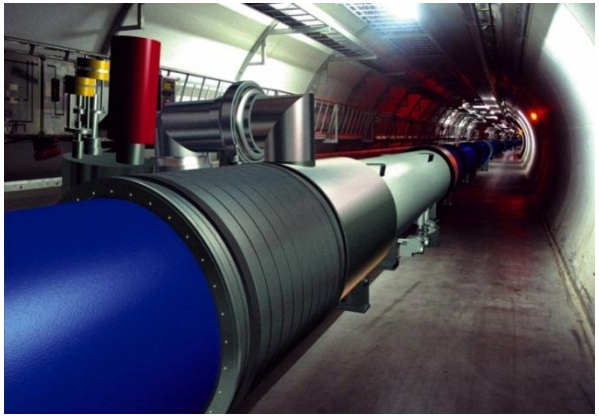


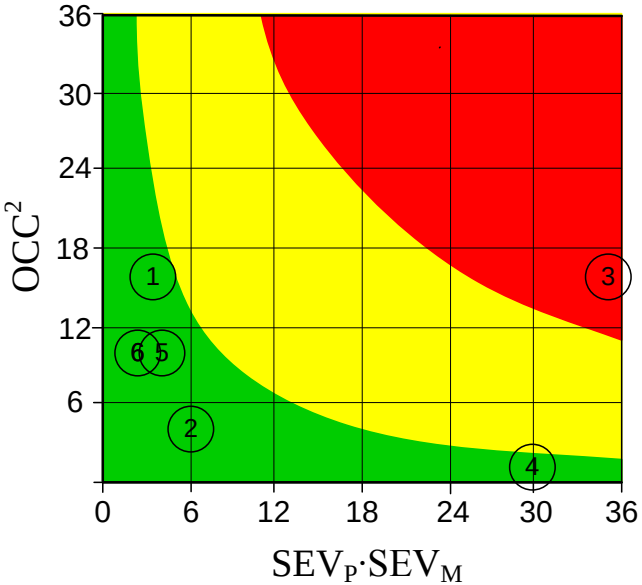


CERN Note 200, 2010

WUT risk analysis of LHC cryogenic system: failures and criticality matrix

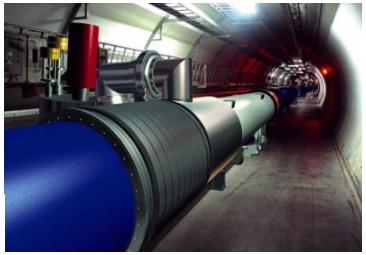
	Failure	Total amount of He relieved	Maximum mass flow rate	Criticality
1	He flow to cryostat insulation vacuum of the cryomagnets	1236 kg	1 kg/s	64
2	Quench line damage following a sector quench	2340 kg	10 kg/s	24
3	LHC cryomagnets energy release due to electrical arc	4731 kg	32 kg/s	576
4	He flow to air, jumper connection break	4536 kg	27 kg/s	30
5	He flow to DFB insulation vacuum	3870 kg	15 kg/s	36
6	Helium Ring Line break	1457 kg	3.1 kg/s	27



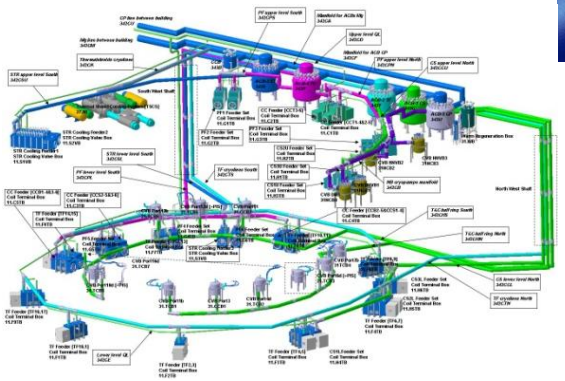


Risk analyses of cryogenic systems performed at WUT

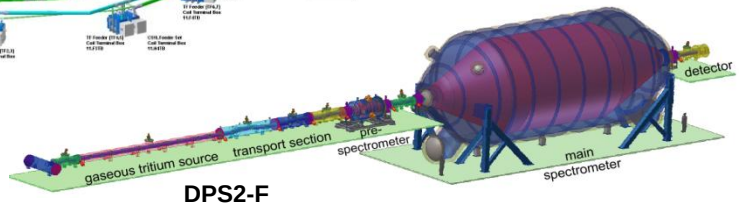
1) Risk analysis of the cryogenic system of Large Hadron Collider



2) Ris analysis of the cryogenic system of International Thermonuclear Experimental Reactor ITER)

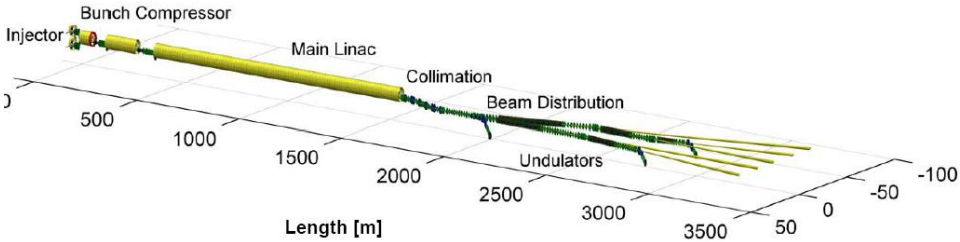


3) Risk analysis of the cryogenic system of KATRIN DPS2-F cryostat

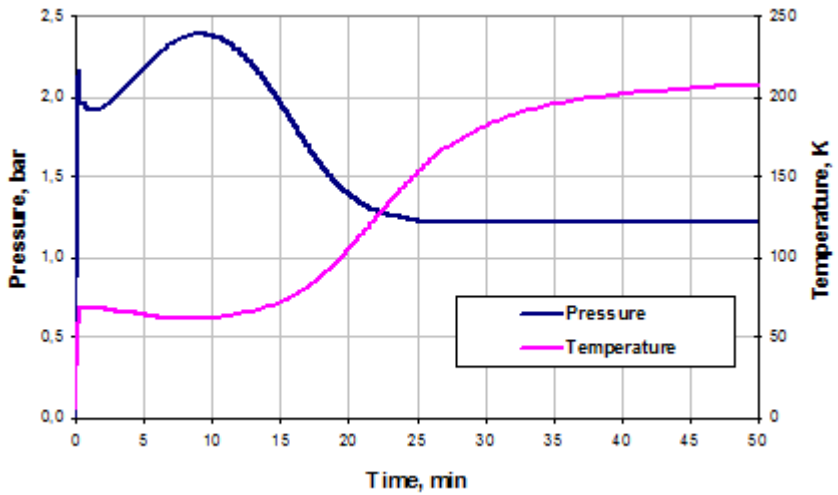


DPS2-F

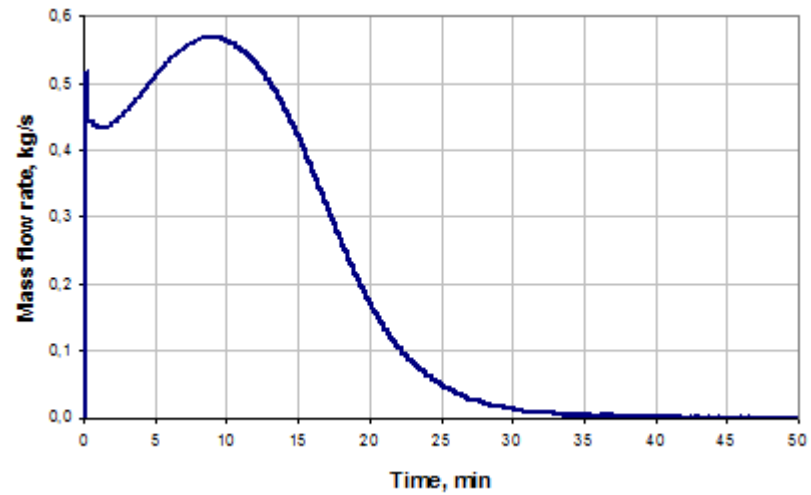
4.) Risk analysis of the XFEL-Linac cryogenic system



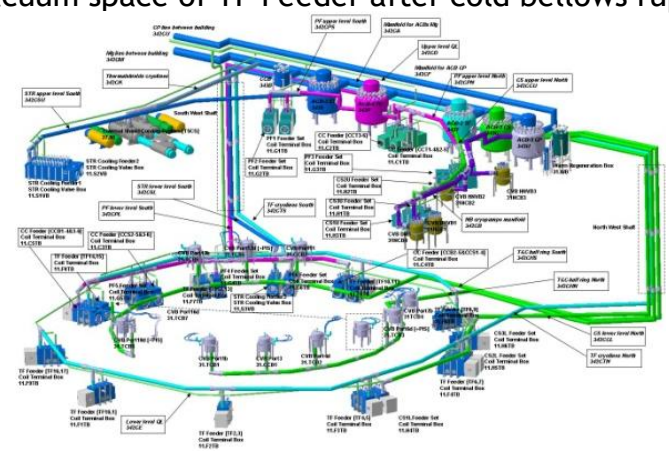
WUT risk analysis of the cryogenic system of ITER: helium leakage modeling

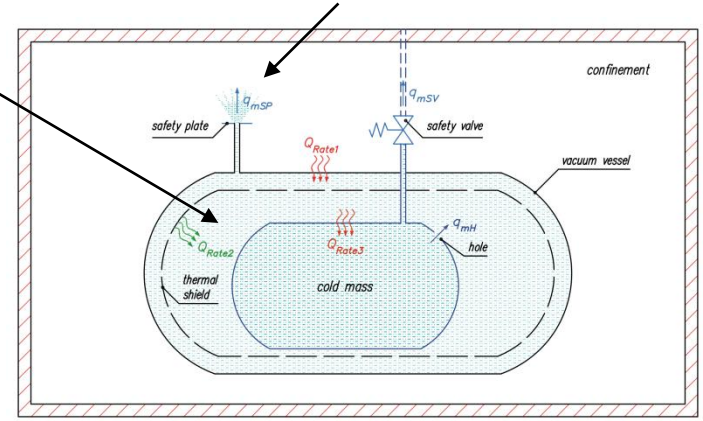


Evolution of the temperature and pressure of the helium in the vacuum space of TF Feeder after cold bellows rupture

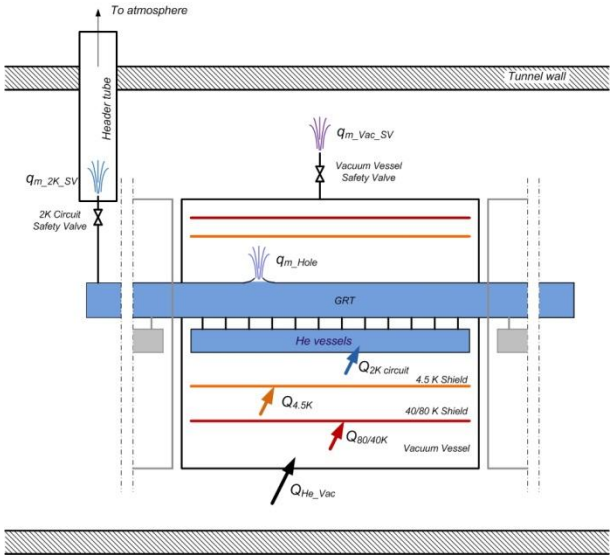


Evolution of the helium mass flow rate through the safety plate of TF Feeder after cold bellows rupture rupture

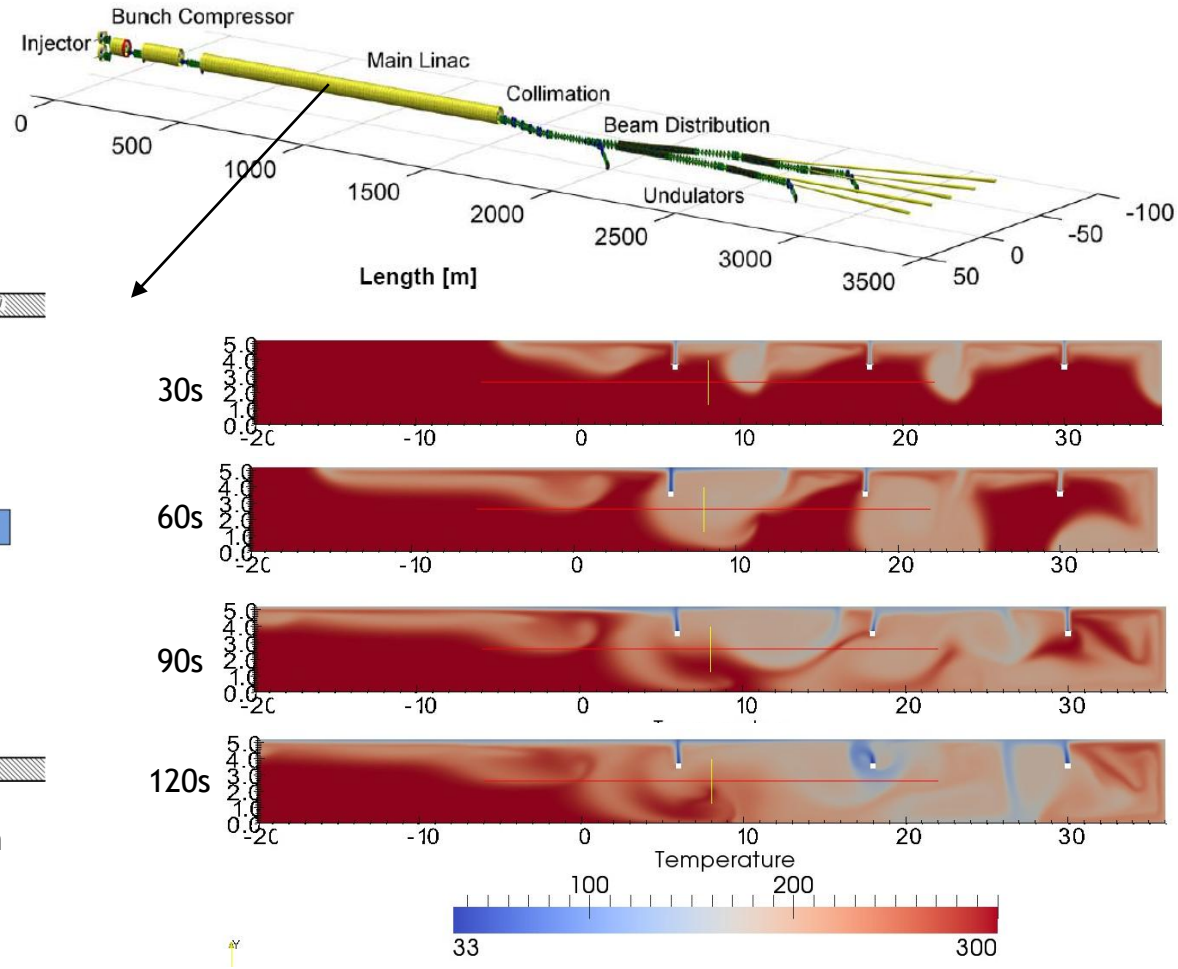




WUT risk analysis of the cryogenic system of XFEL: He propagation in the tunnel



Schematic longitudinal cross section of XFEL Main Linac

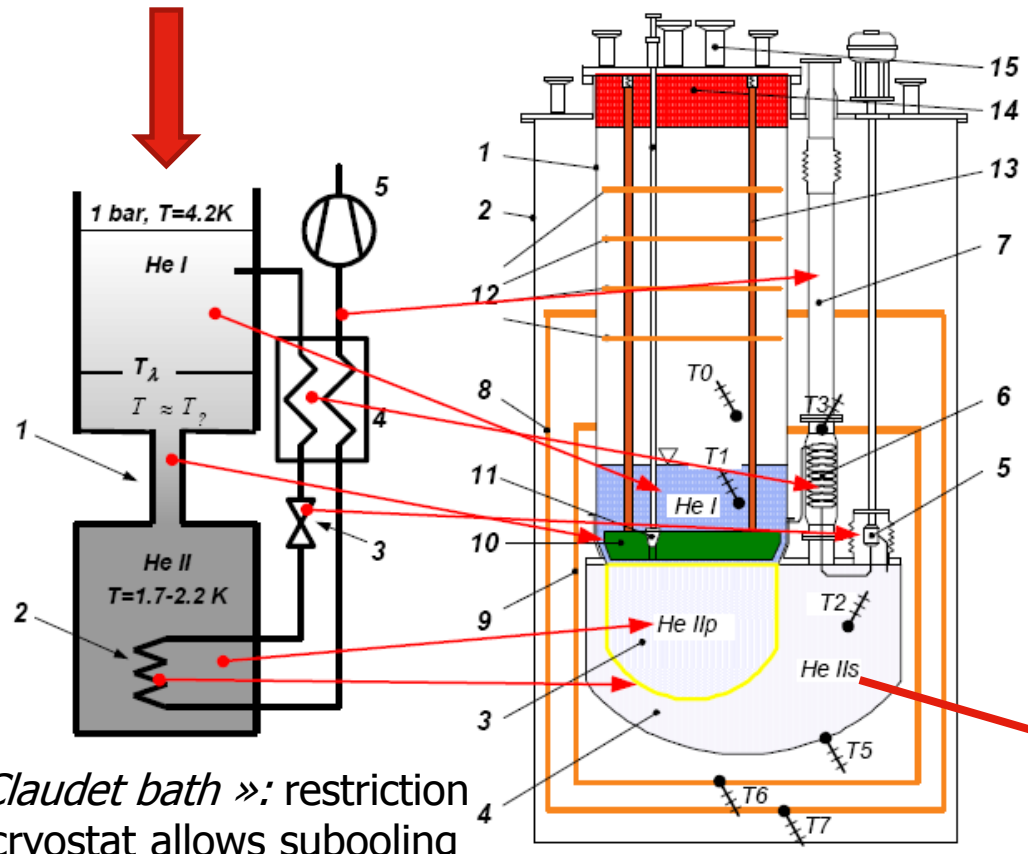


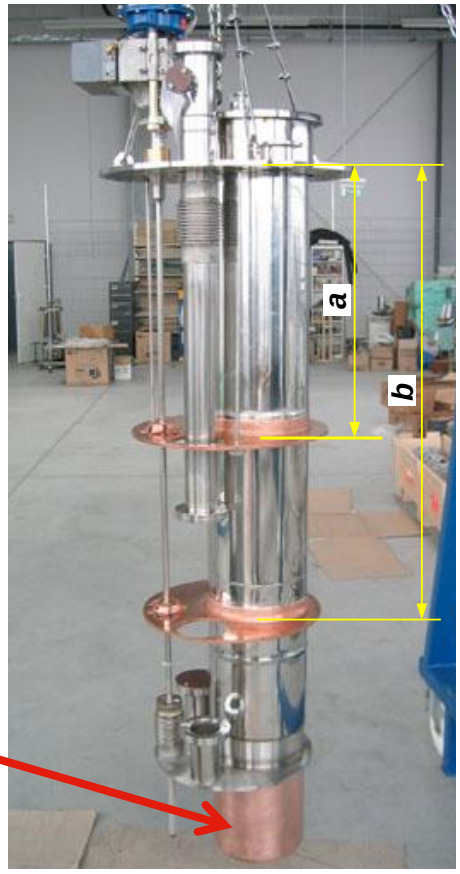
Propagation of the helium-air mixture in the XFEL Main Linac tunnel

Contents

Superfluid helium cooling - laboratory cryostat example

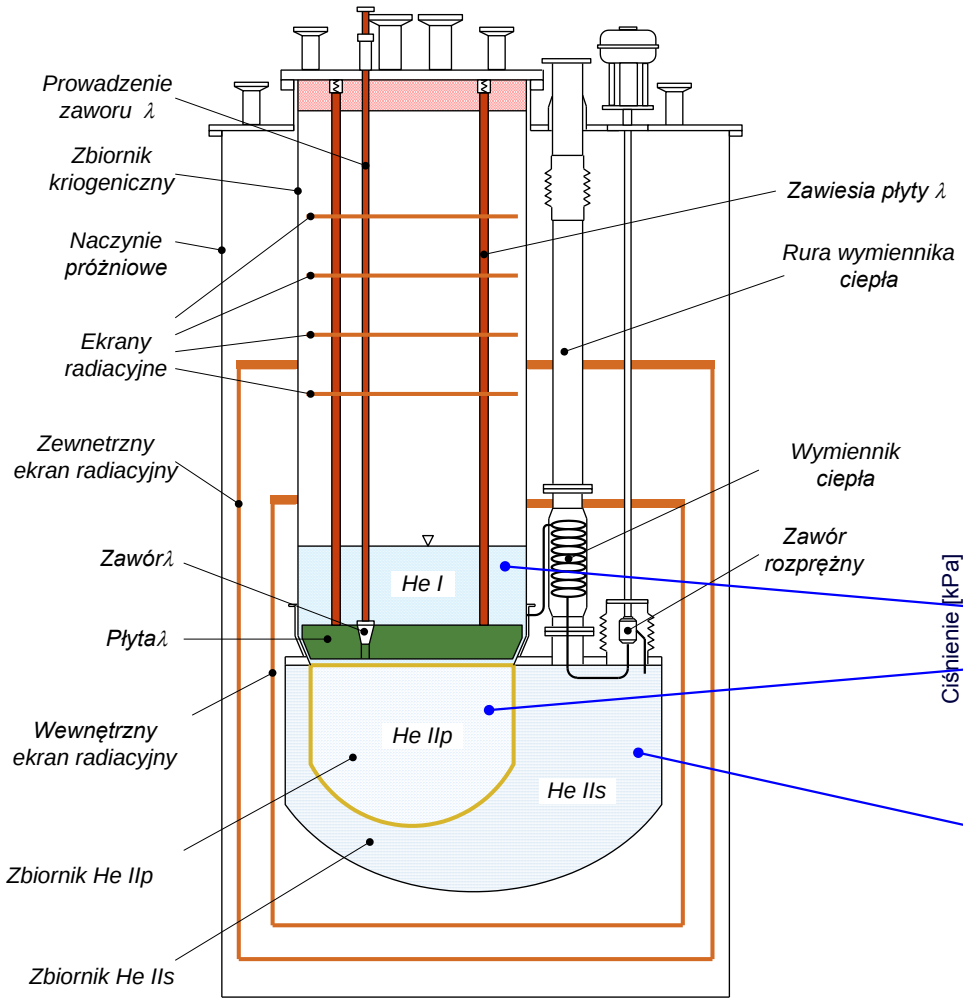
From He liquefier

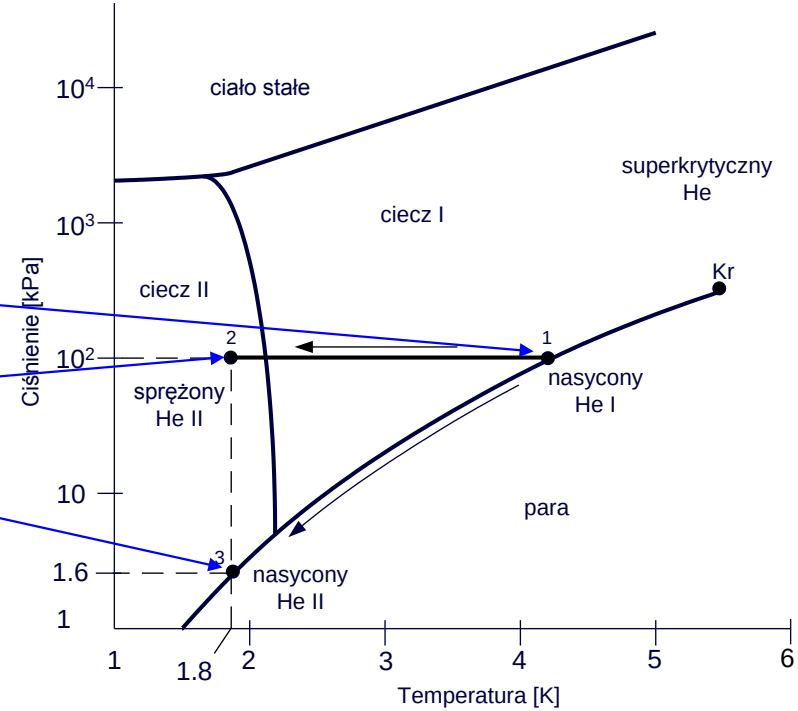




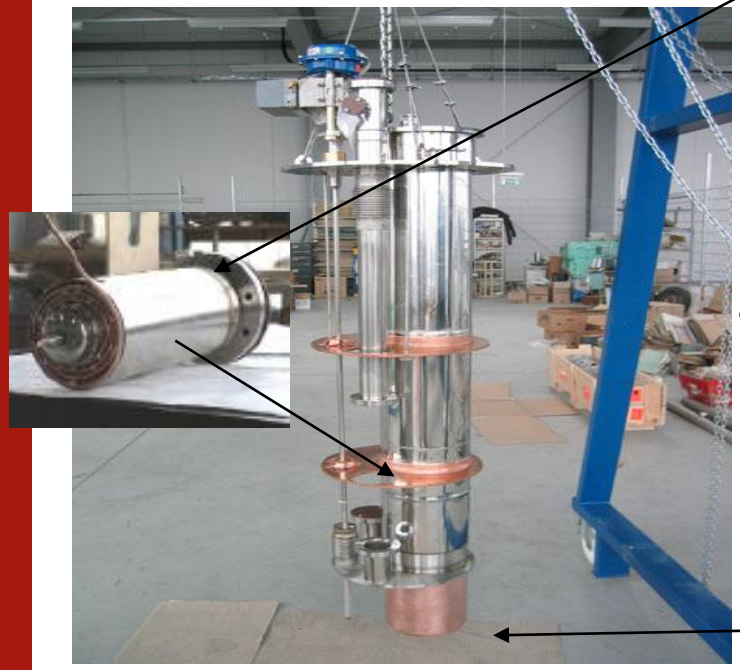
« Claudet bath »: restriction in cryostat allows subooling He II bath to temperatures well below T_λ

WUT manufactured Claudet cryostat depicted on He phase diagram



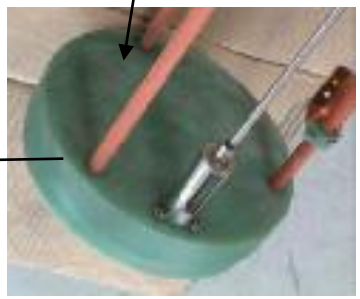


Claudet cryostat – assembly process at industry under WUT supervision



Recuperative heat exchanger

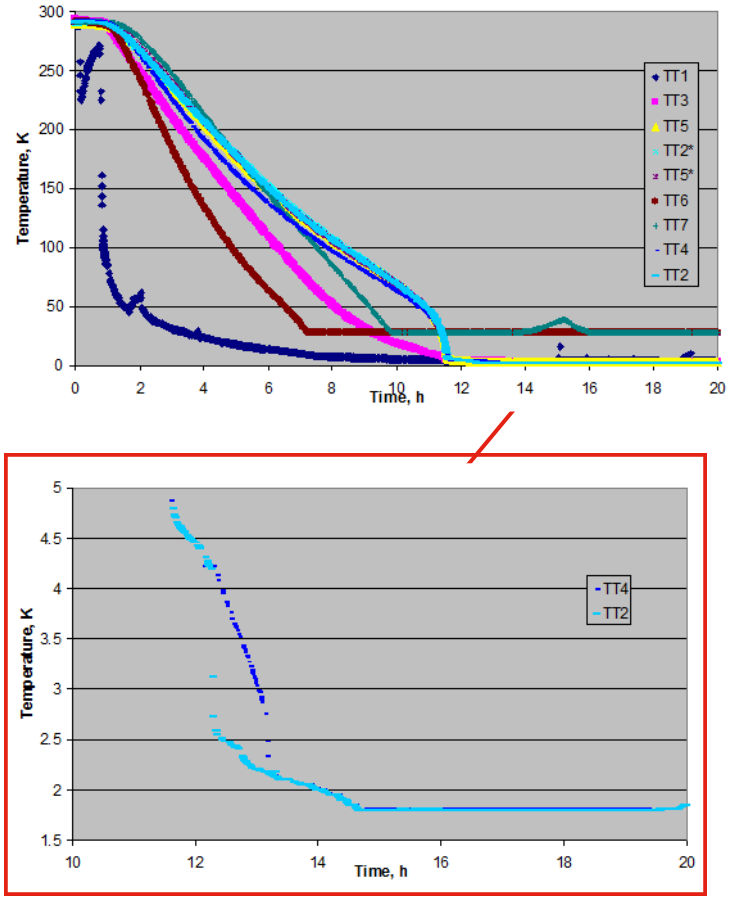
„Lambda plate" boundaring He I (4,2 K) from He II (1,8 K)



Superfluid helium cryostat designs and studies

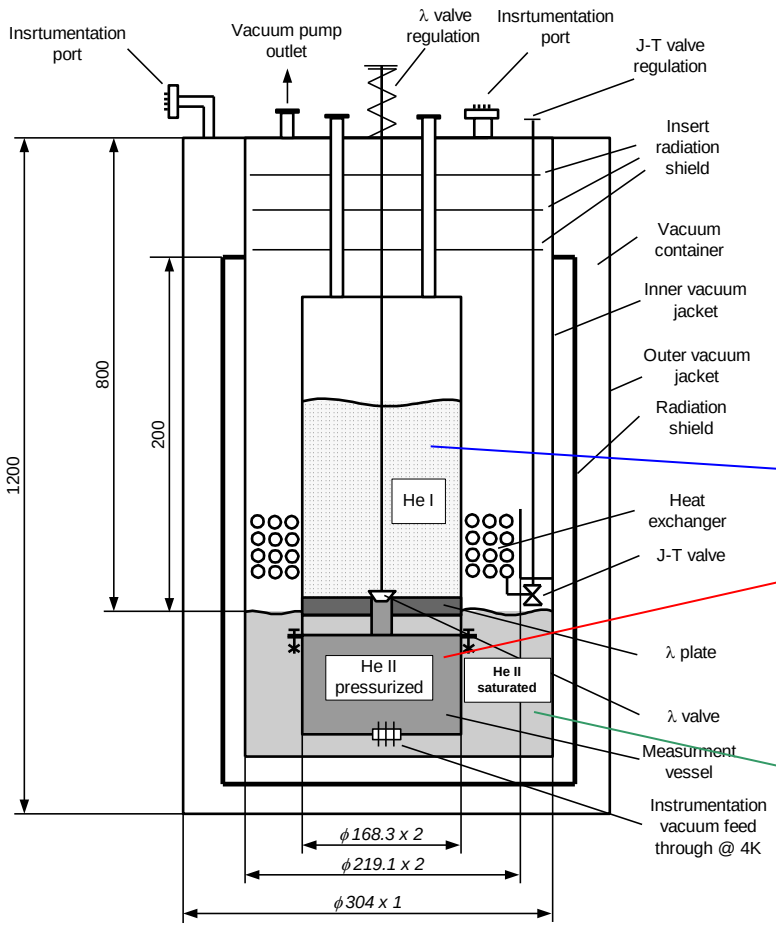
The cryostat in the CARE-NED experimental set-up in CEA Saclay,

1 – Cryostat NED
2 – Cryostat insert
3 – Instrumentation
4 – Pumping and recovery line
5 – Liquid helium dewar

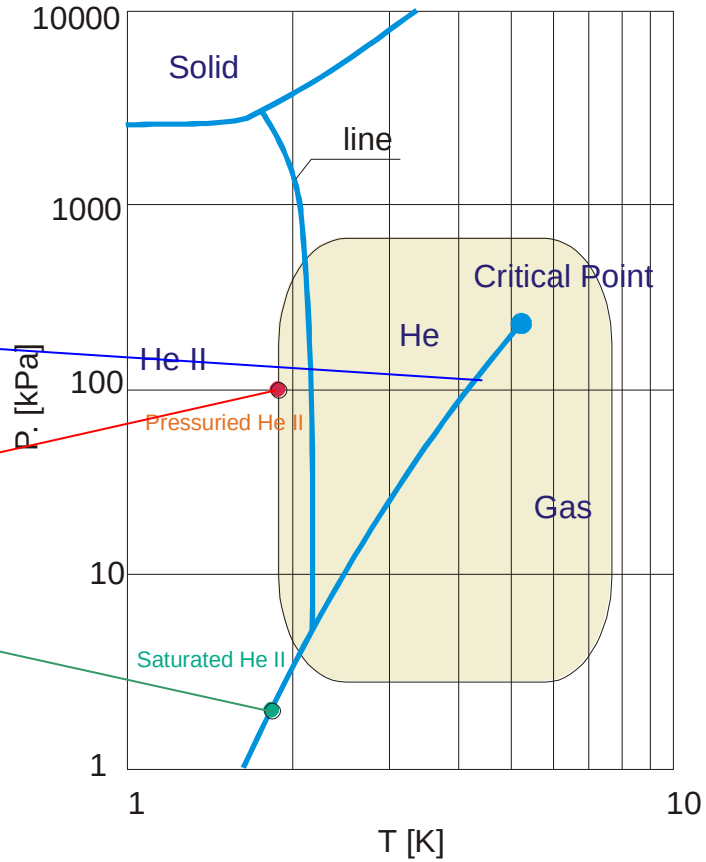


Temperatute evolution during the first cryostat cool-down

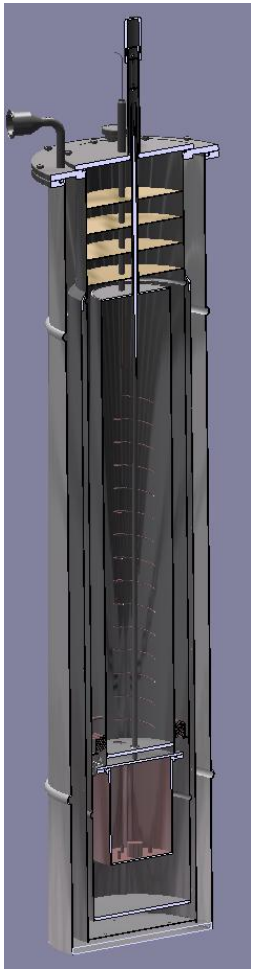
Superfluid helium cryostat for heat transfer measurements at elevated pressures

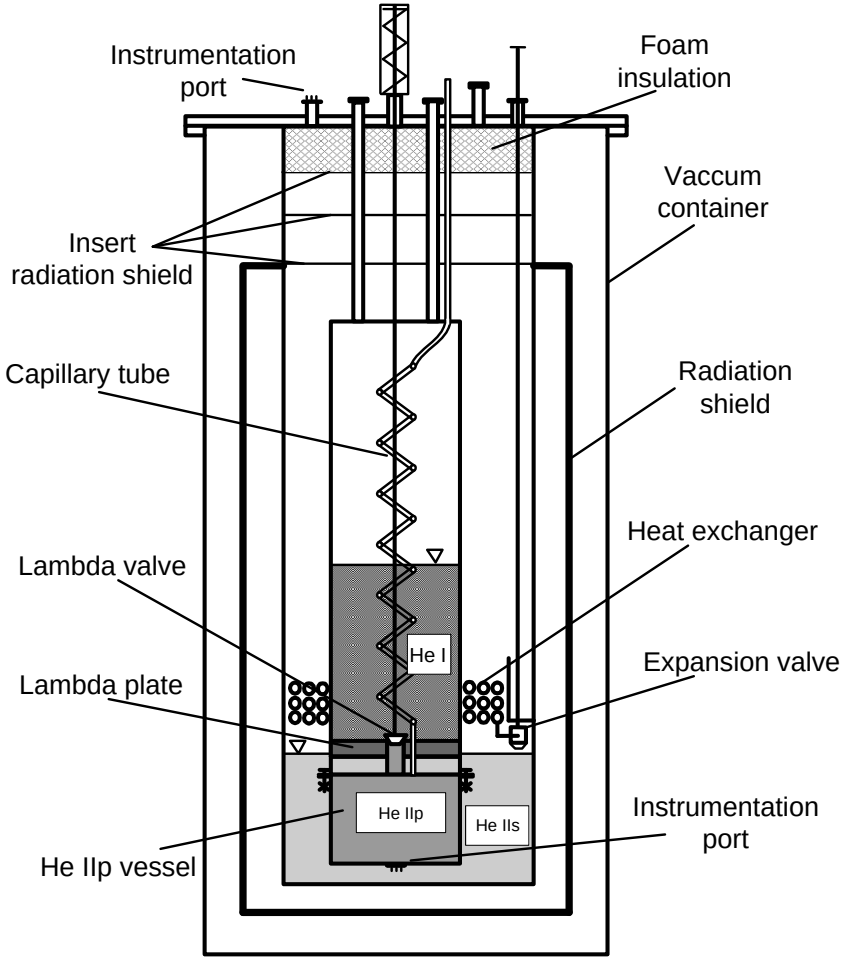


Scheme of pressurized superfluid helium cryostat



Superfluid helium cryostat for heat transfer measurements at elevated pressures

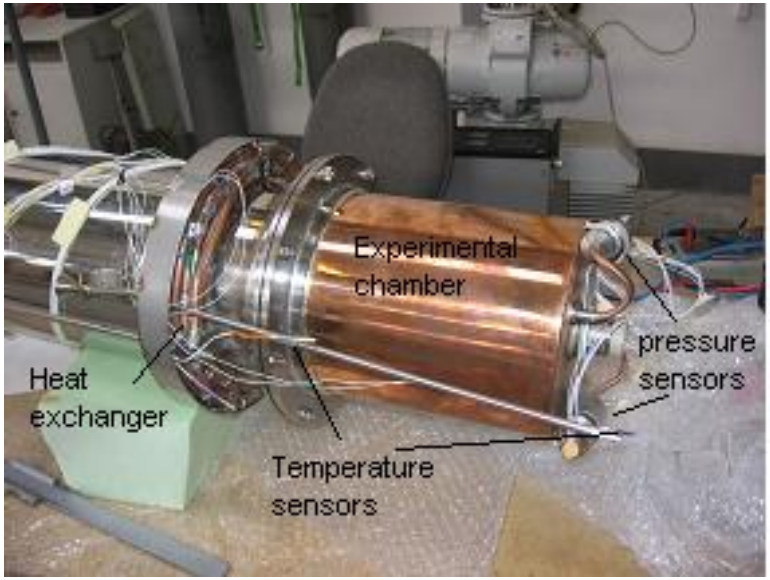




Superfluid helium cryostat for heat transfer measurements at elevated pressures

External vacuum jacet during leak test

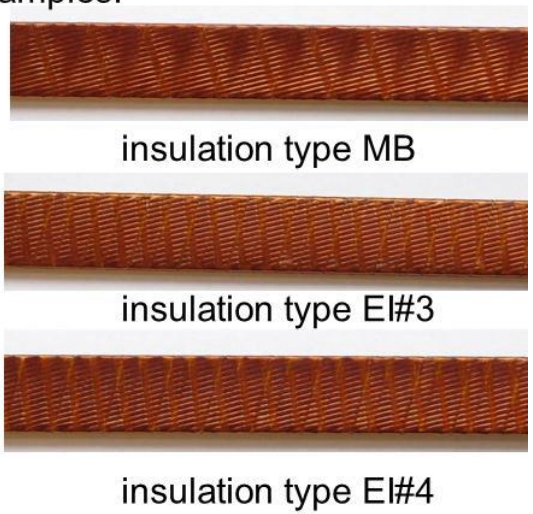
Radiation screen with MLI

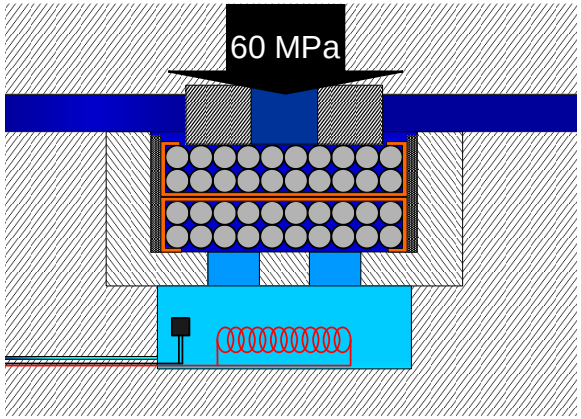


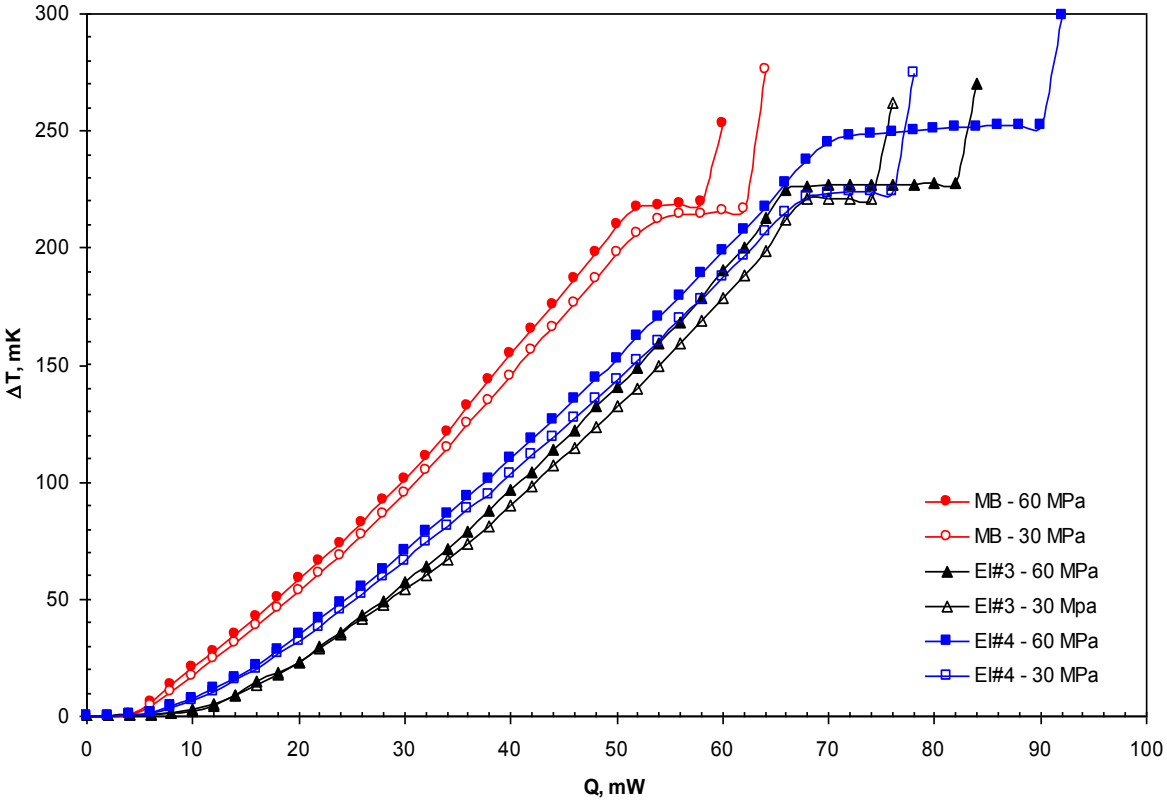
Measurement vessel with instrumentation

Measurements of heat transfer in superfluid helium bath at 1.9 K

Samples:

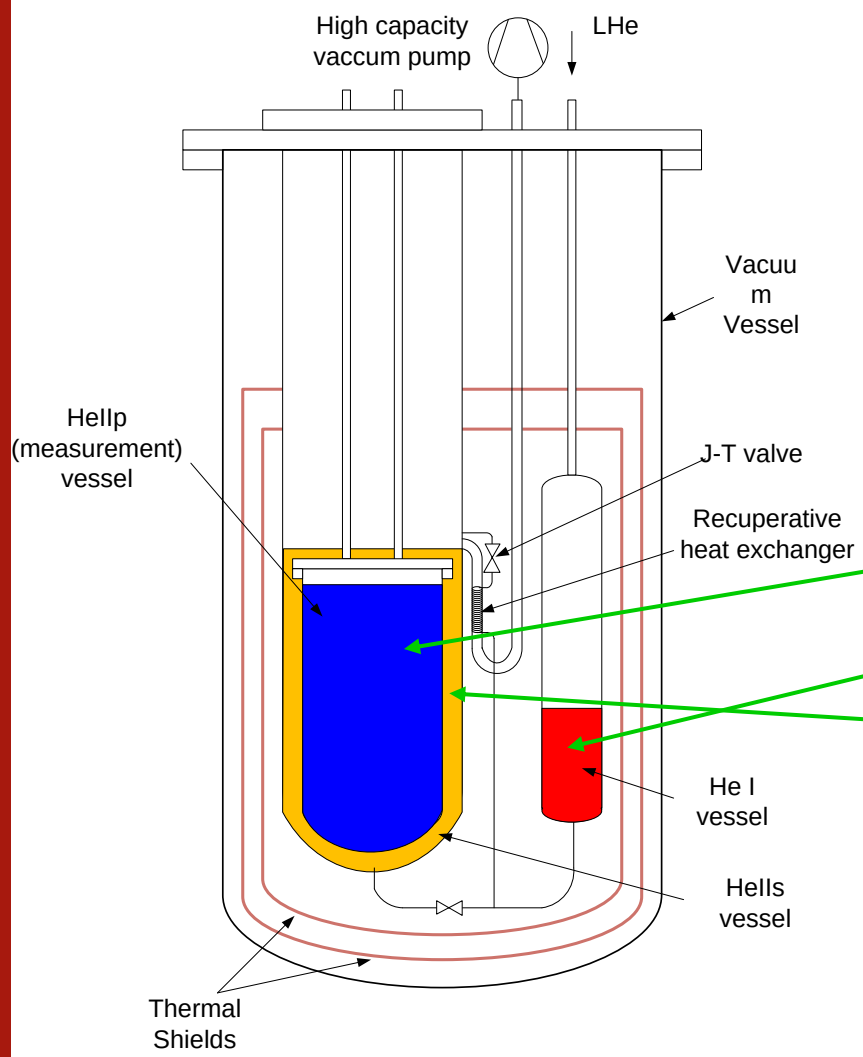


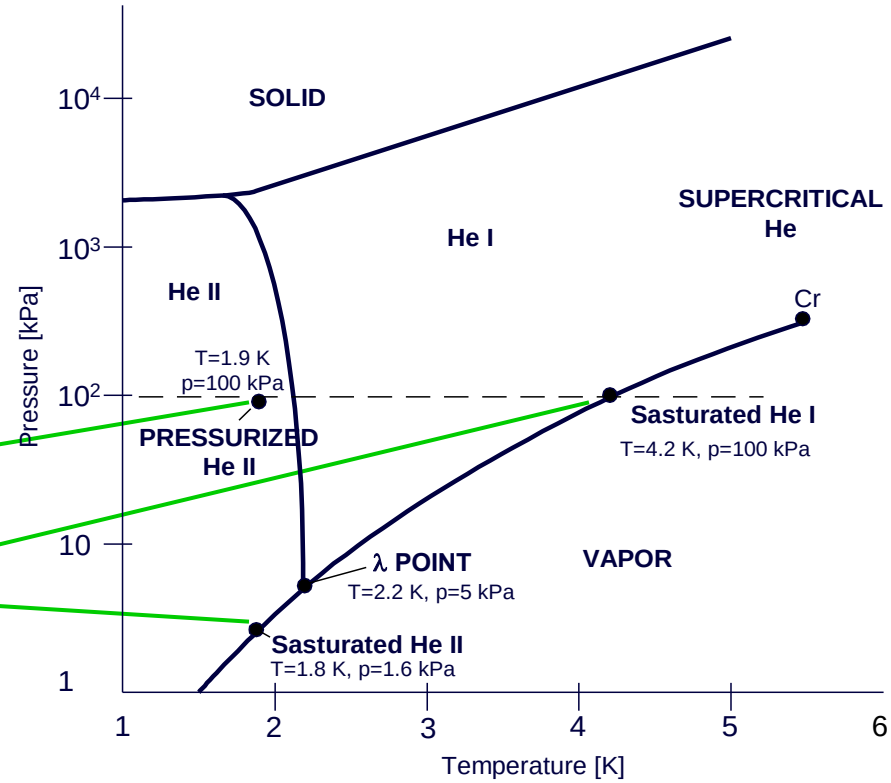




Temperature difference across test samples vs. total heat flux

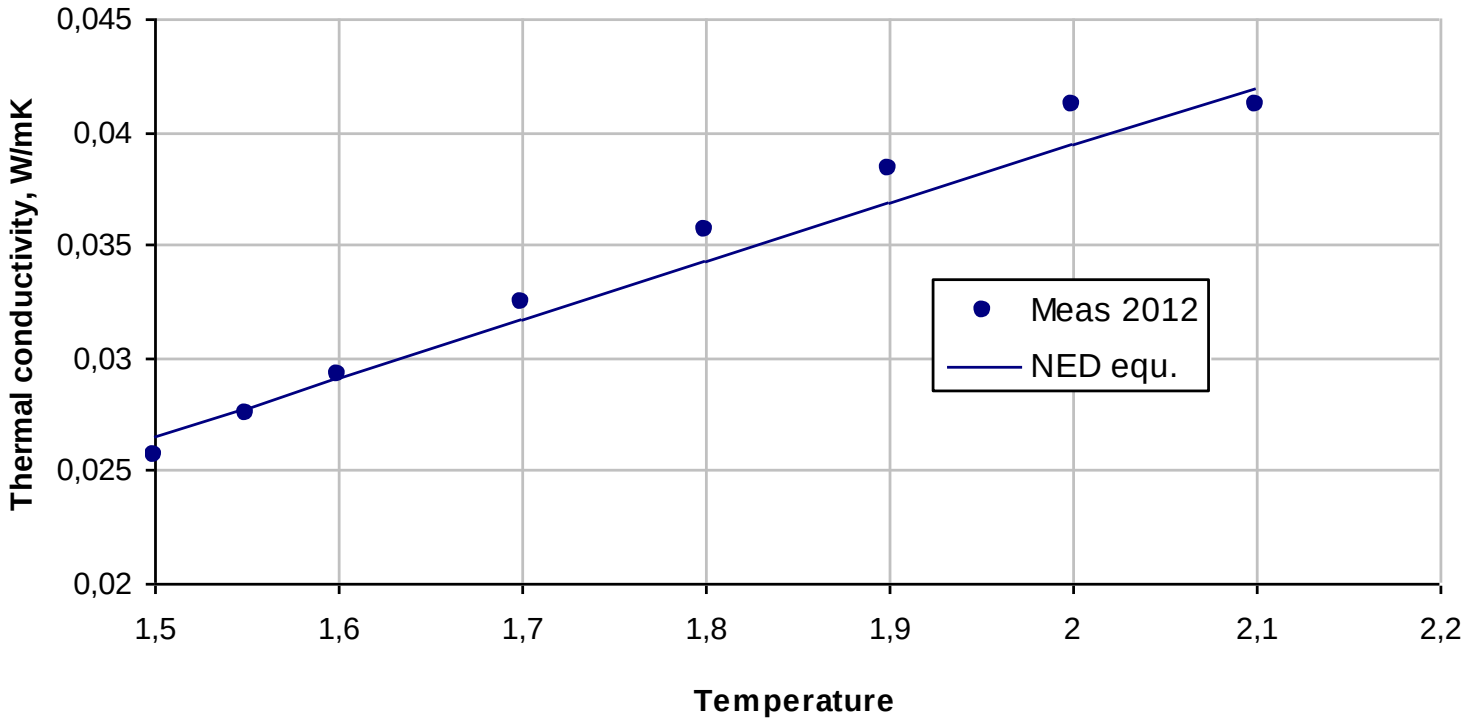
Measurements of heat transfer in superfluid helium bath



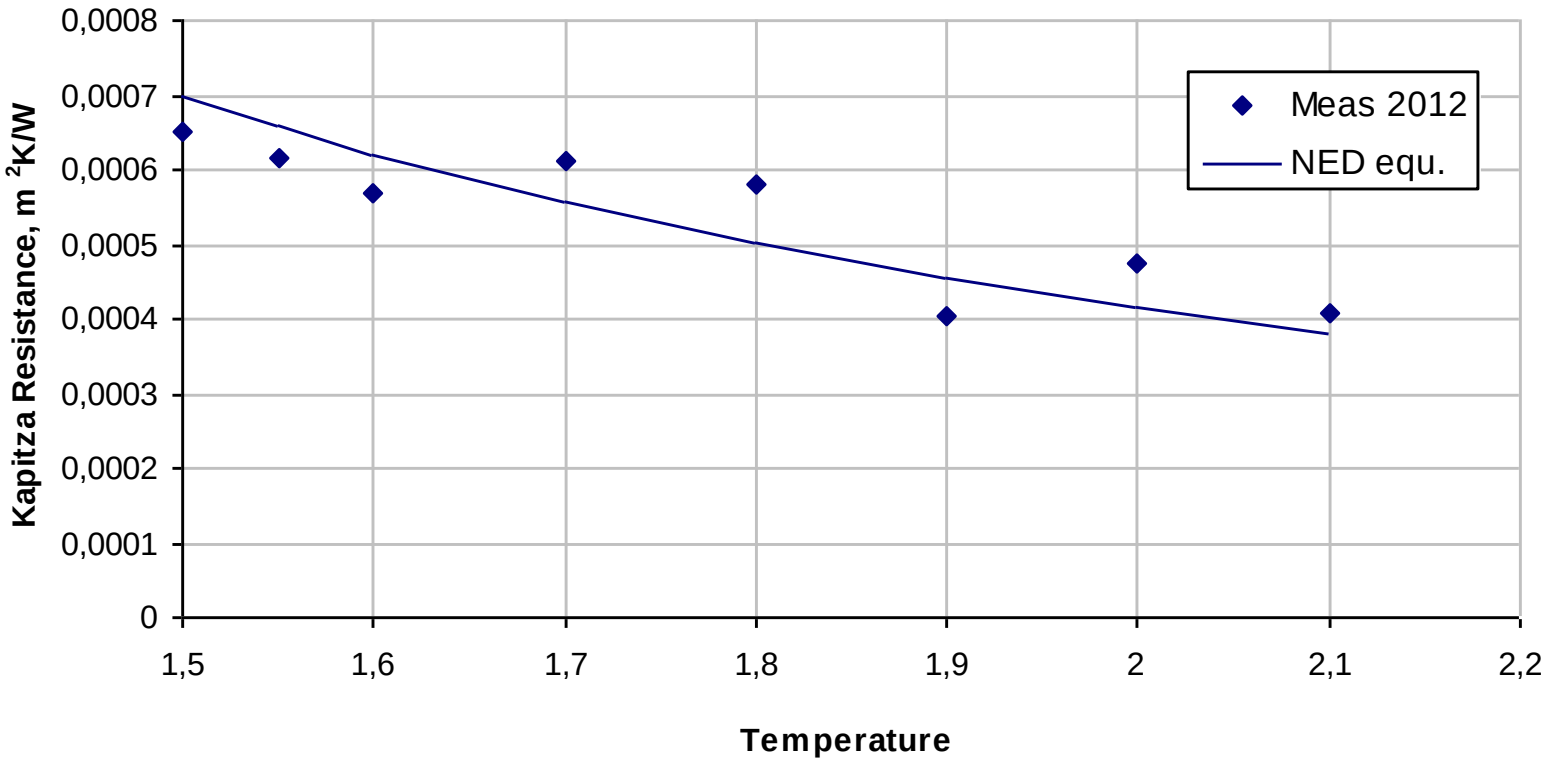


Thermal tests – set-up view

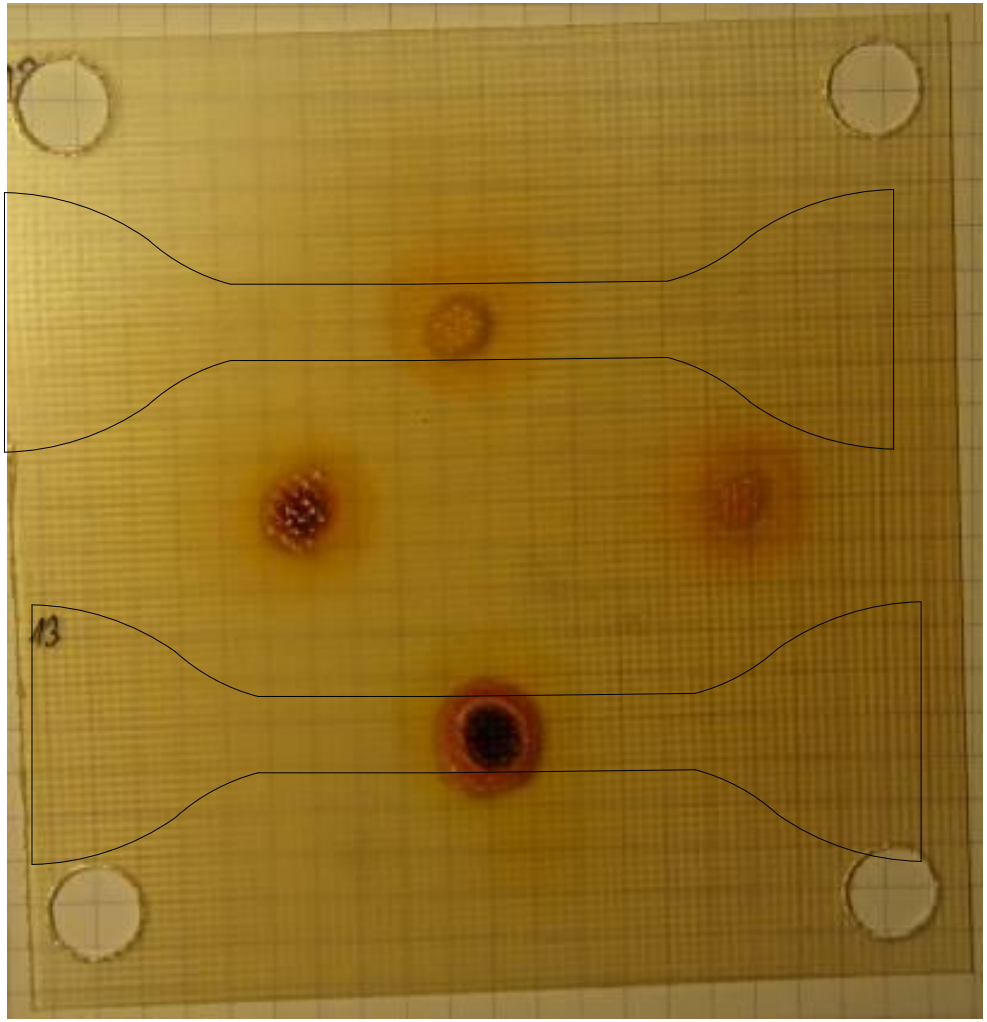
Thermal tests – test results
Thermal conductivity

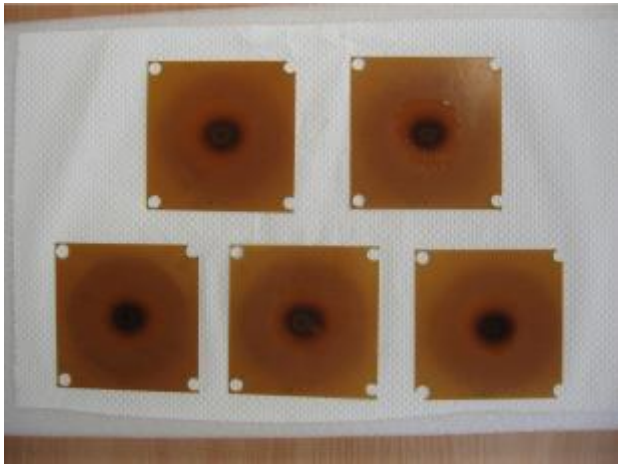


Thermal tests – test results
Kapitza resistance



Irradiation of the samples for themal, mechanical and electrical measurements.

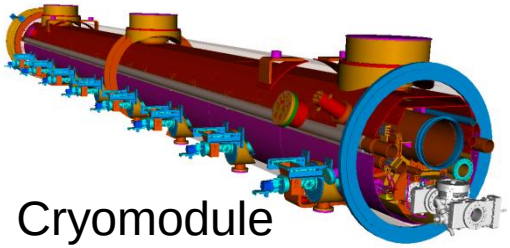




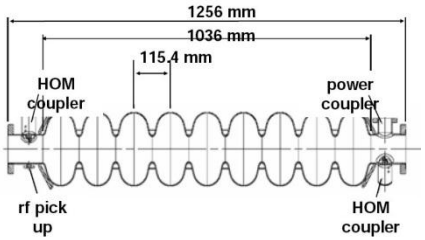
Contents

Polish in-kind contribution to XFEL/AMTF project

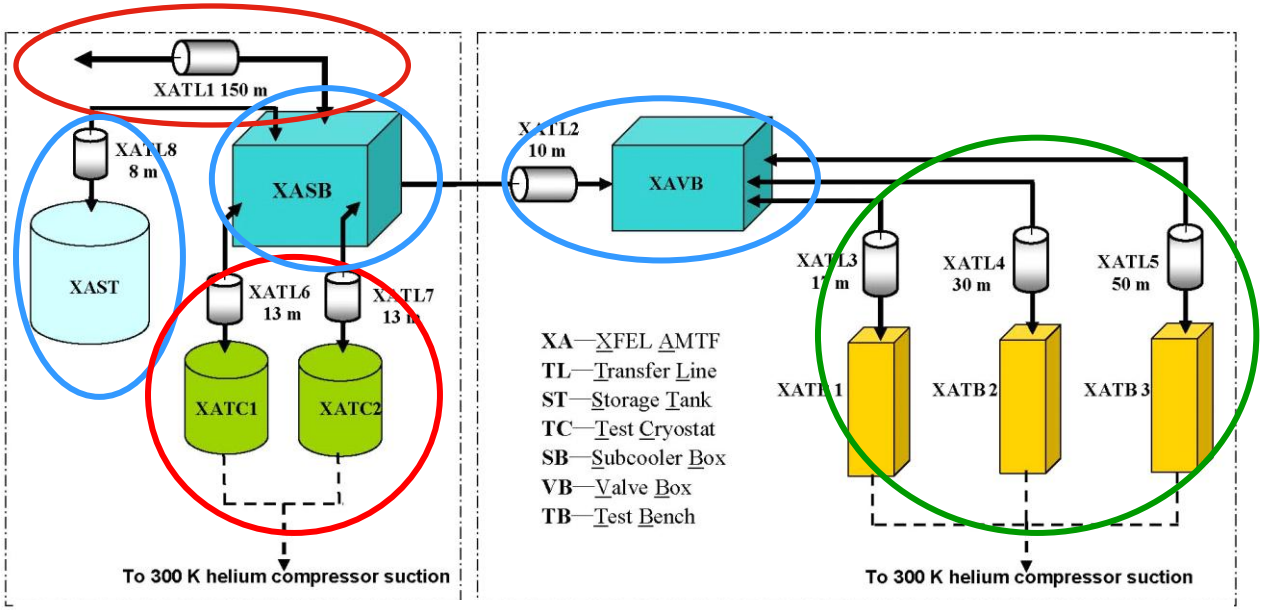
European X-ray Free Electron Laser (**XFEL**) being under construction at DESY in Hamburg will be composed of about 100 cryogenic modules, each holding eight superconducting cavities. The cavities and cryomodules will be tested at their nominal operation conditions in the dedicated **Accelerator Module Test Facility** (**AMTF**).



Cryomodule



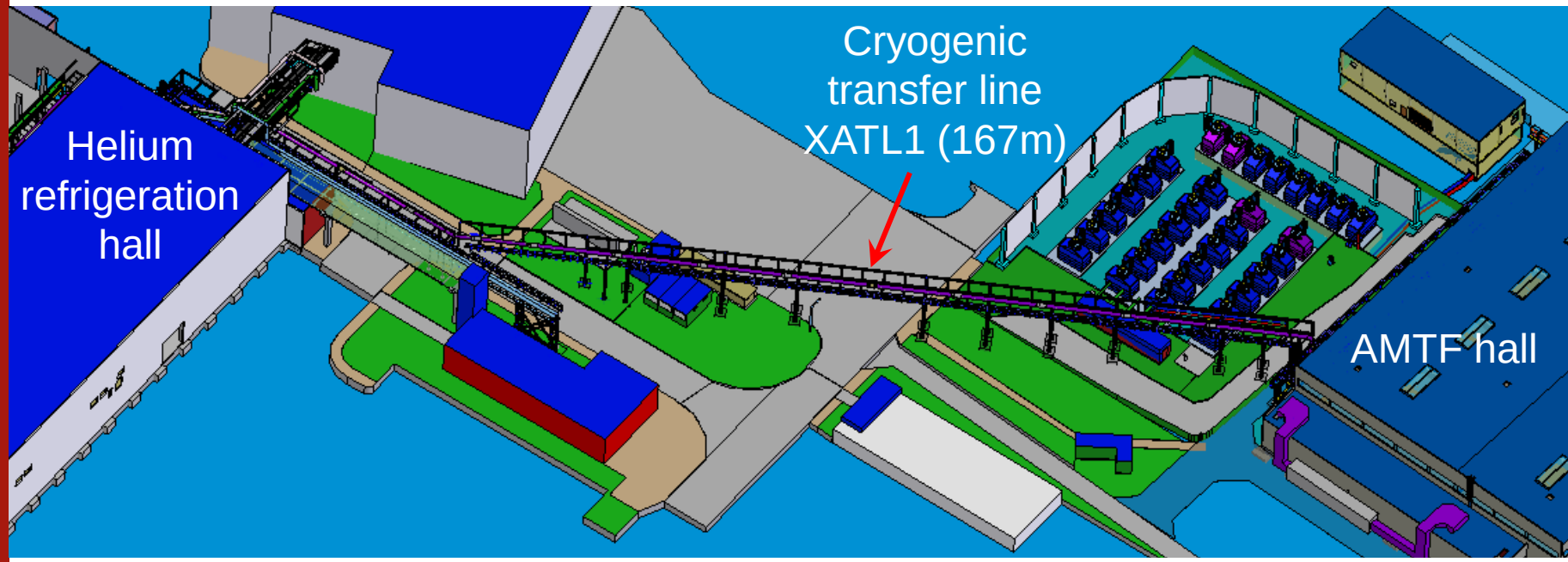
Superconducting cavity

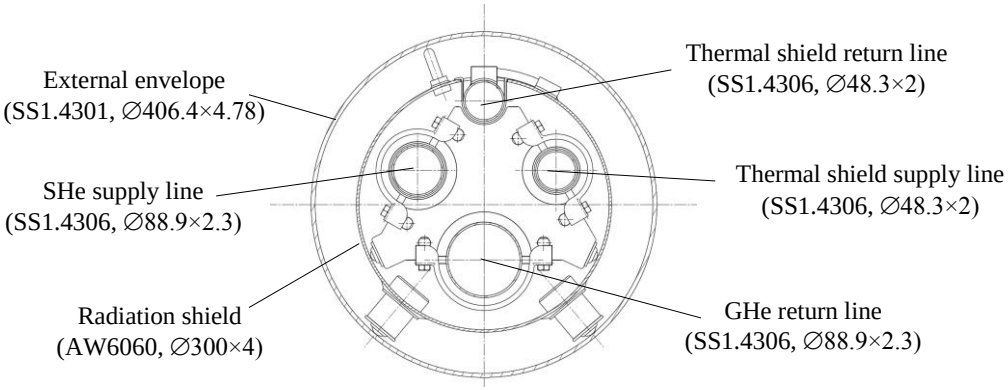


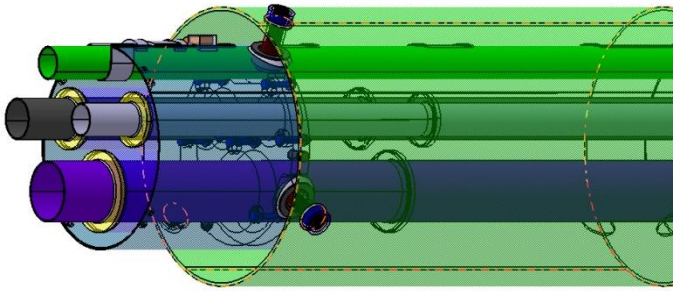
Scheme of the Accelerator Module Test Facility

Red= WUT **Blue = IHEP** **Green= BINP**

XFEL/AMTF cryogenic transfer line (XATL1)



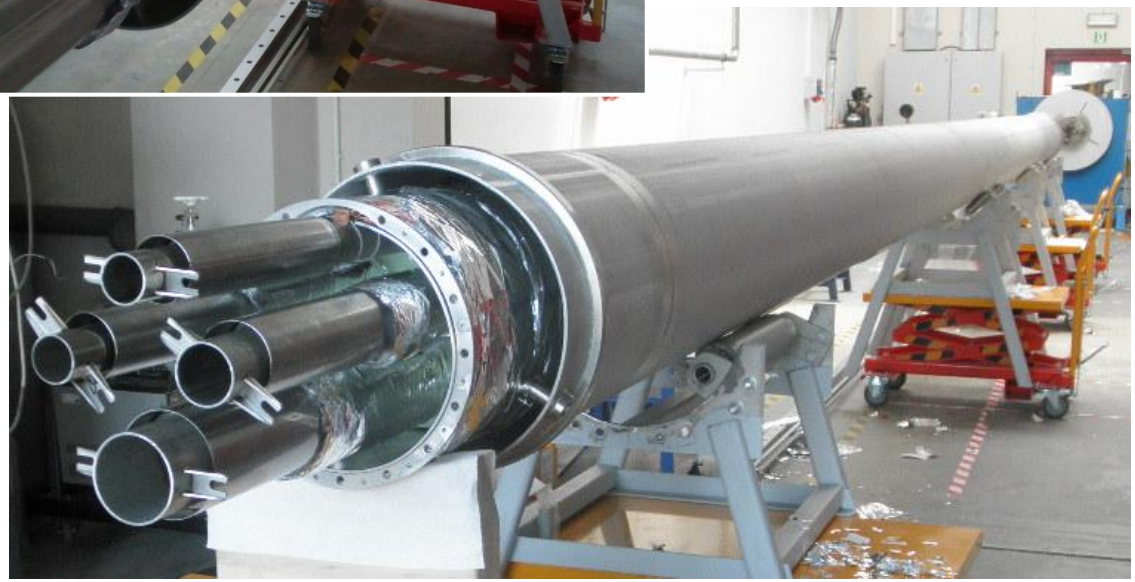




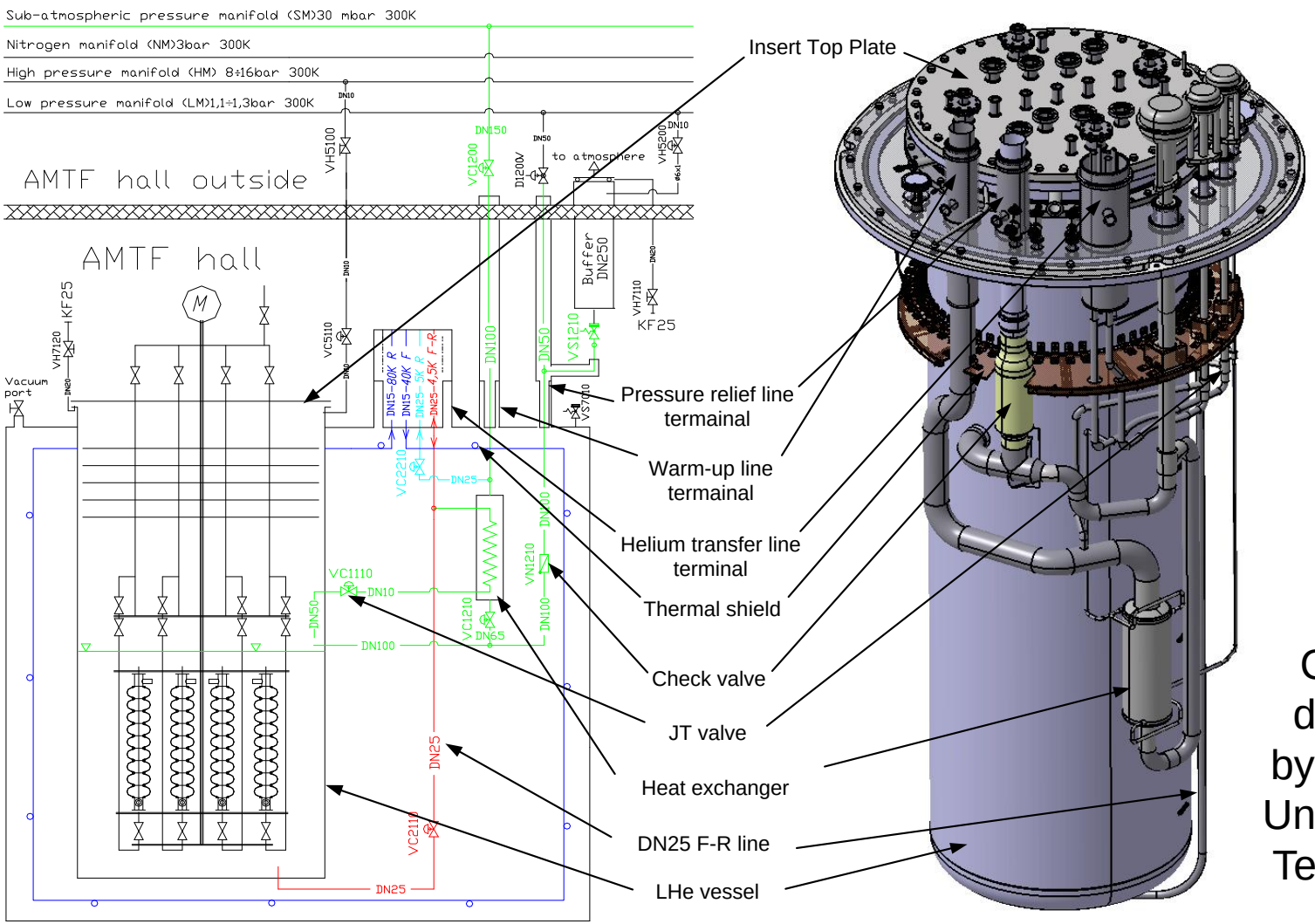
Cryoline XATL1 designed by Wroclaw University of Technology

XFEL/AMTF cryogenic transfer line (XATL1)

Production of the cryogenic transfer line modules at Wroclaw Technology Park (courtesy Kriosystem)



XFEL/AMTF vertical cryostats (XATC1/2)



Cryostat designed by Wroclaw University of Technology

XFEL/AMTF vertical cryostats (XATC1/2)

Production of the cryostats
at Wroclaw Technology Park
(courtesy Kriosystem)

Superfluid helium
vessel (V = 2 m^3)

WUT expression of interest for the FAIR in-kind contribution

Expression of Interest No **15**

WP-Number: 2.5.12 / 2.8.12

Description (PSP structure):
Super-FRS / *Local Cryo*
SIS100 / *Local Cryo*

From (Company):
Wroclaw University of Technology

Address:
Wybrzeże Wyspanskiego 27
50-370 Wroclaw

Country: PL

Received at: 2007-12-07
Corrected for 'no CR Local Cryo' by IKAB secretary, 2008-02-20

Signed by: Maciej Chorowsi
(Dean of Faculty of Mechanical and Power Eng.)

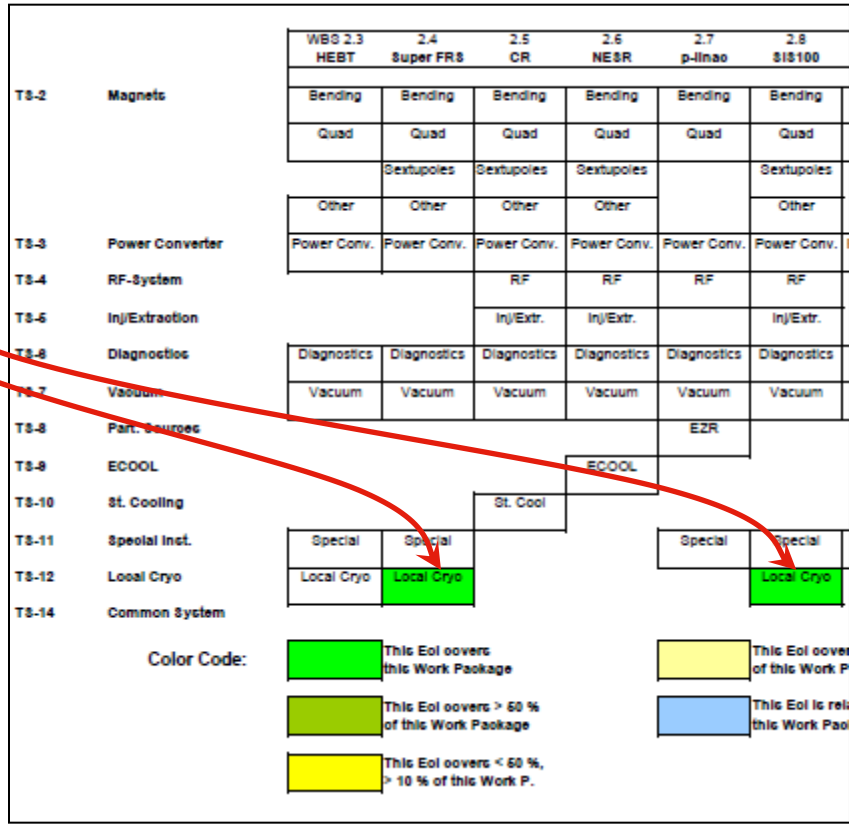
Contact: Maciej Chorowski
maciej.chorowski@pwr.wroc.pl

Planned to produce in own workshops: *not specified*

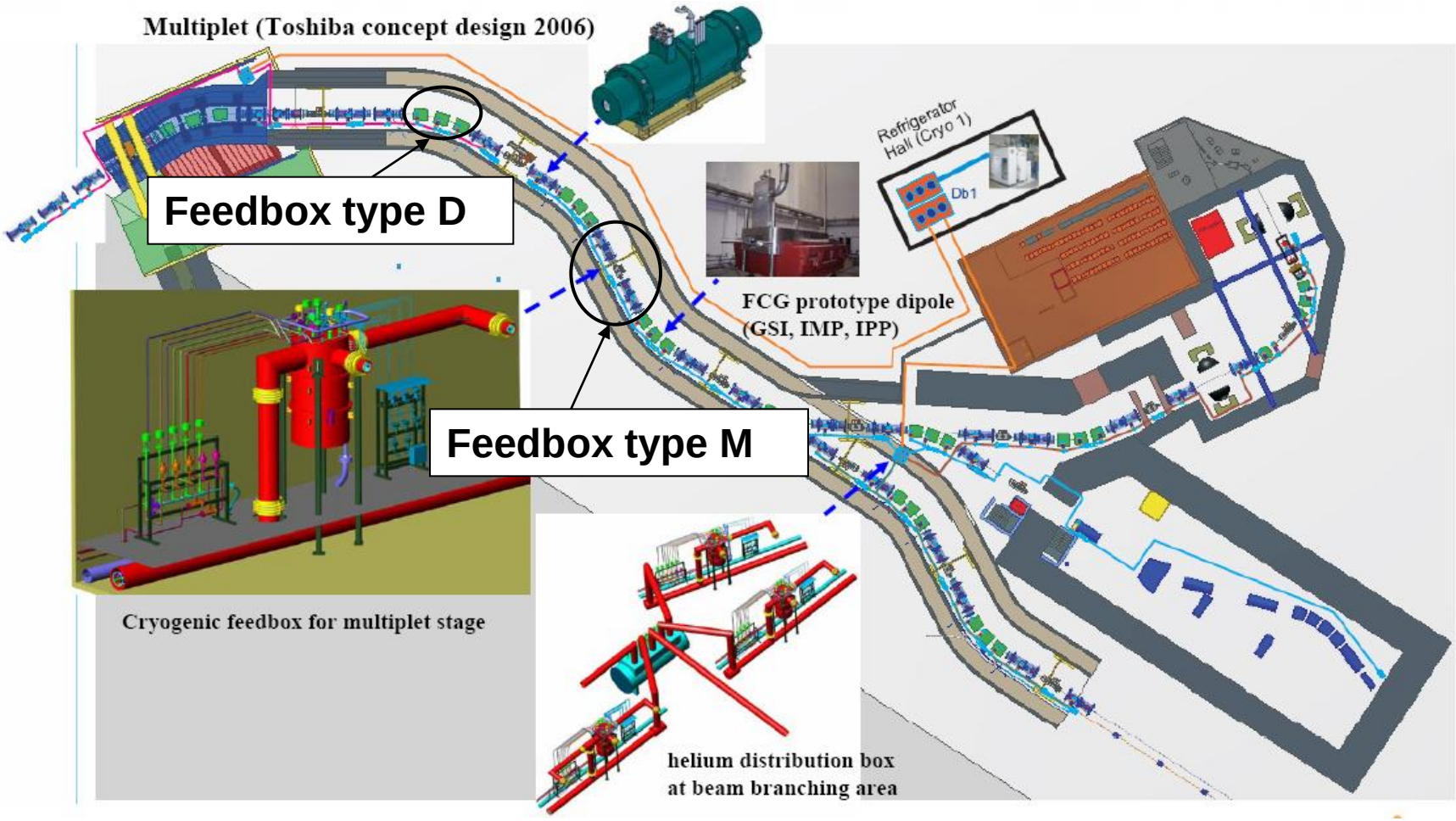
Human res. / size of inst. workshops: 20 persons, incl designers

Planned to procure together with ext. industry: YES
Planned industrial partners: Kriosystem Ltd, ZEC Service

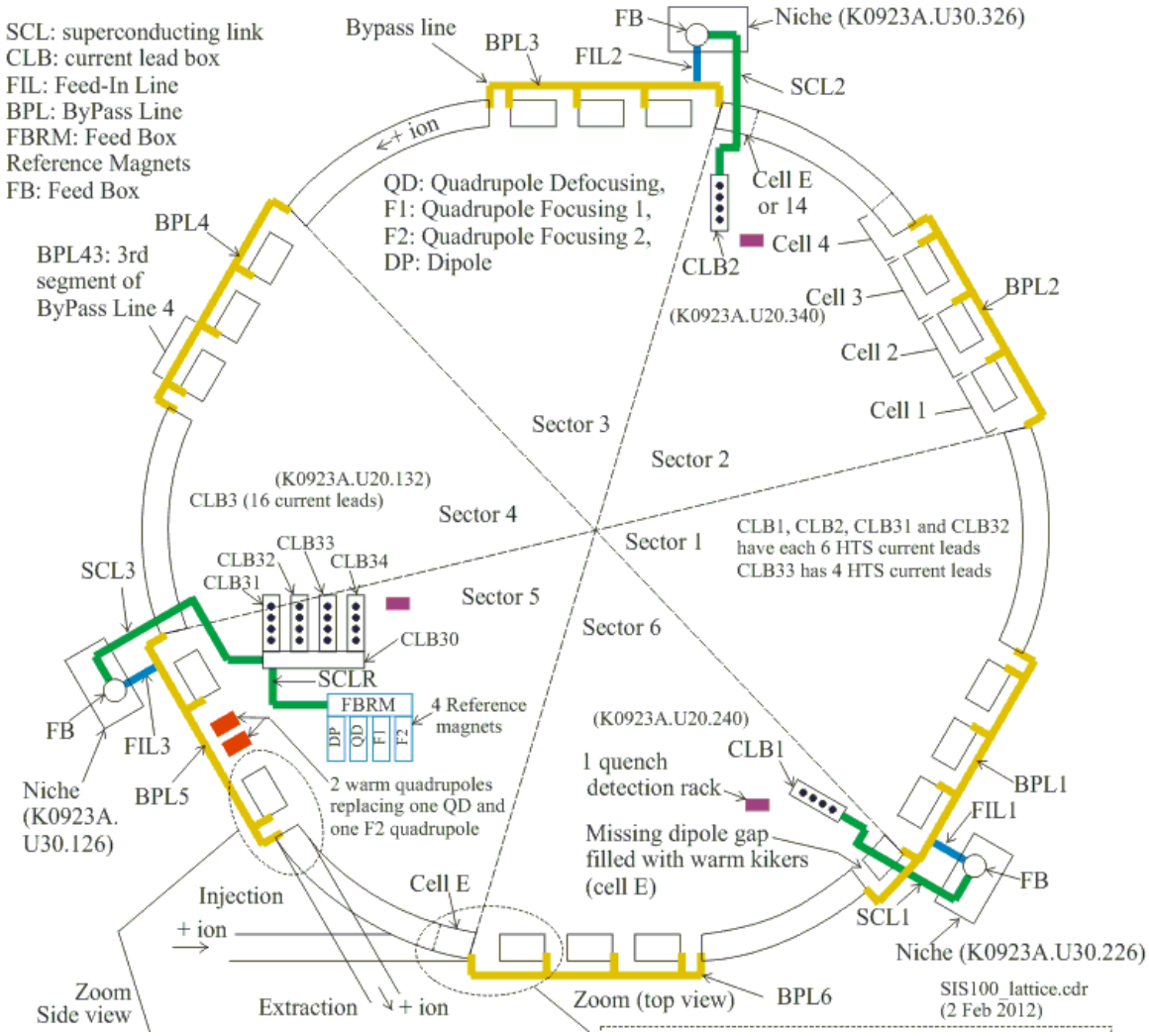
Funding agency: MNiSW
is informed ? YES



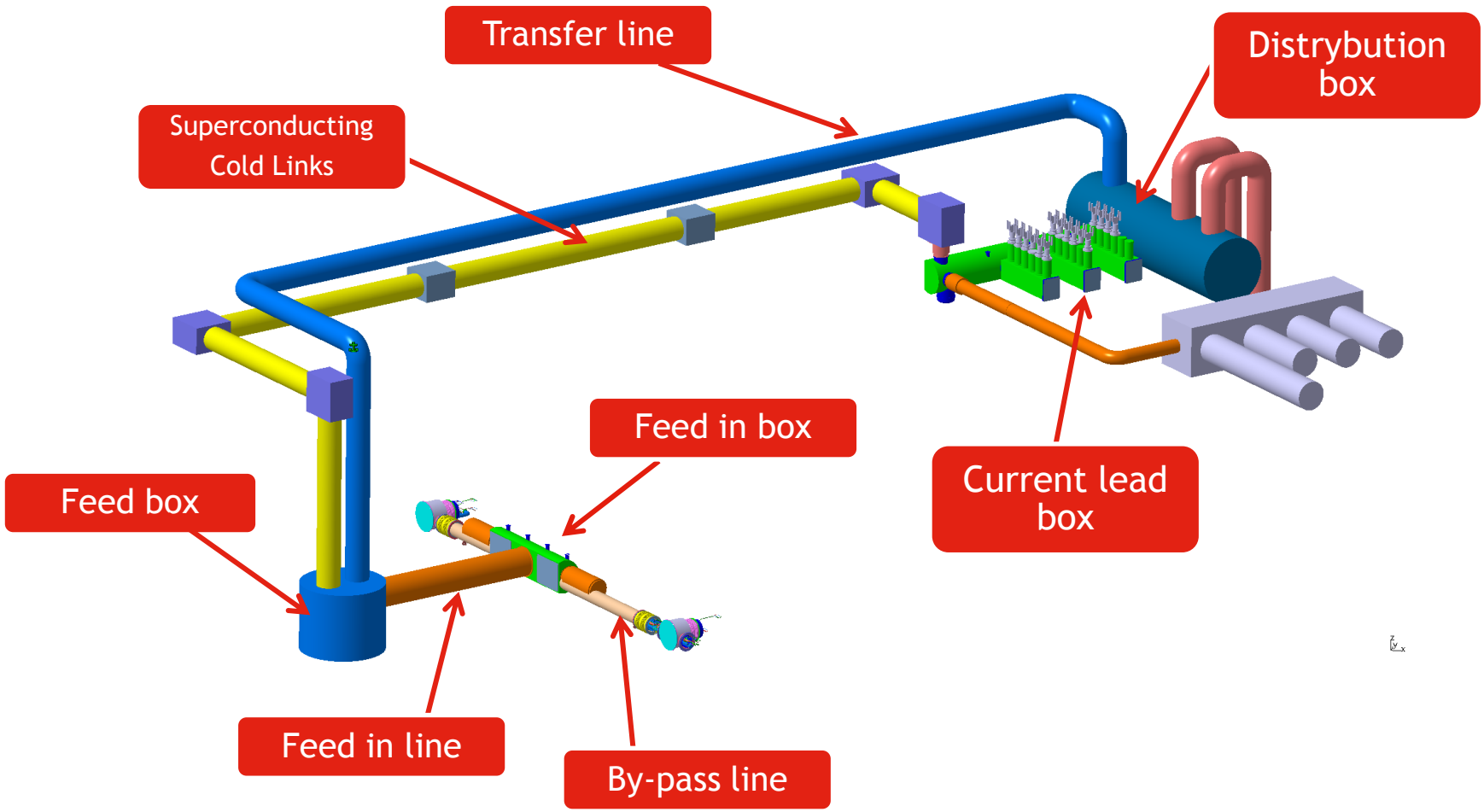
Local cryogenic system of Super FRS



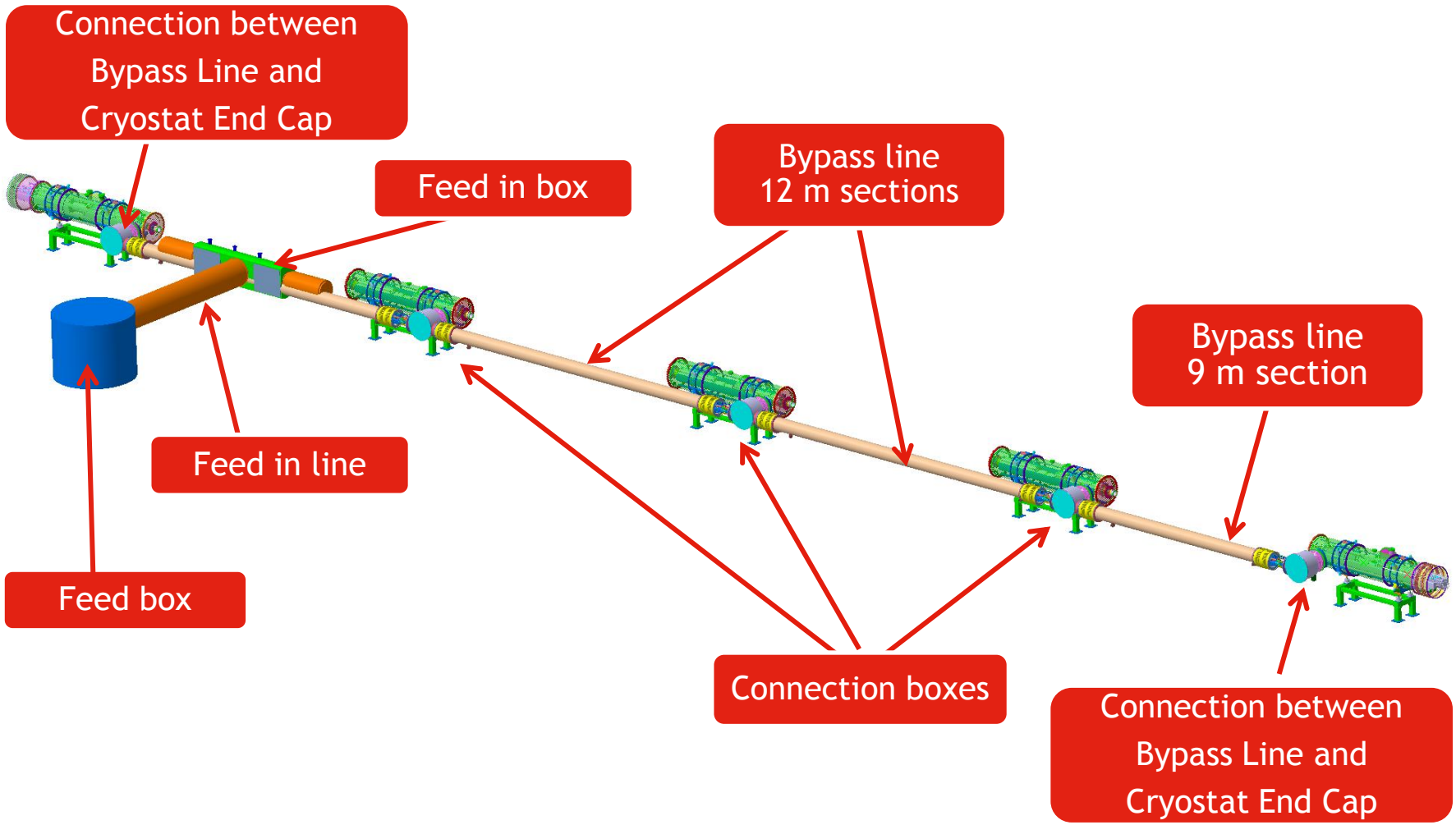
Local cryogenic system of SIS100



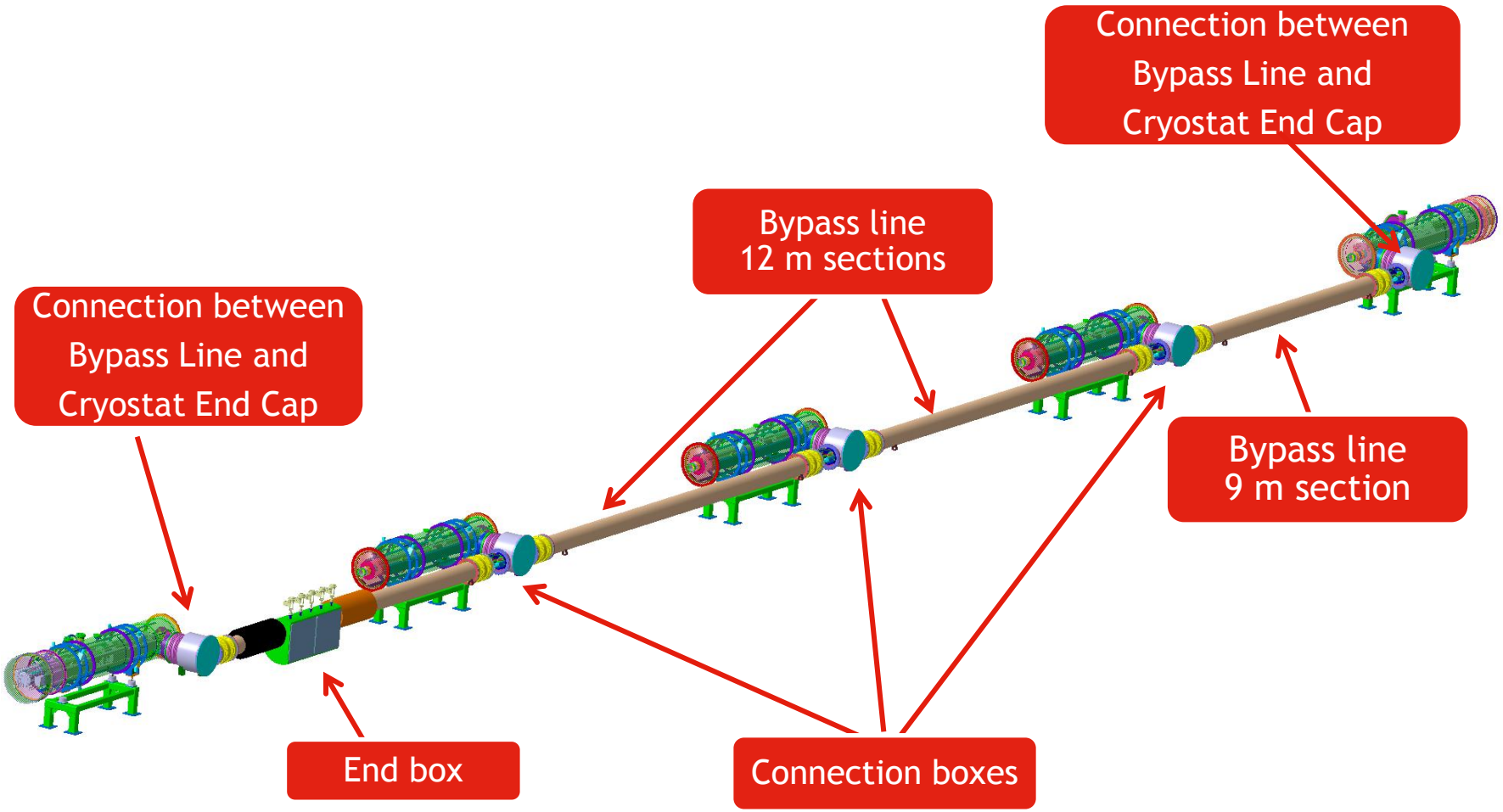
SIS100 / Local Cryo - items at the niche in Sect. 5



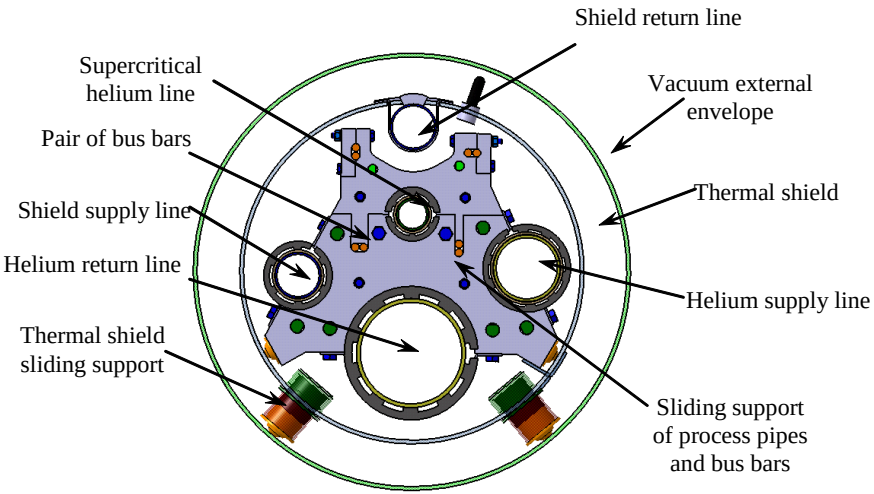
SIS100 / Local Cryo - items in the tunnel in Sects. 1,3 and 5

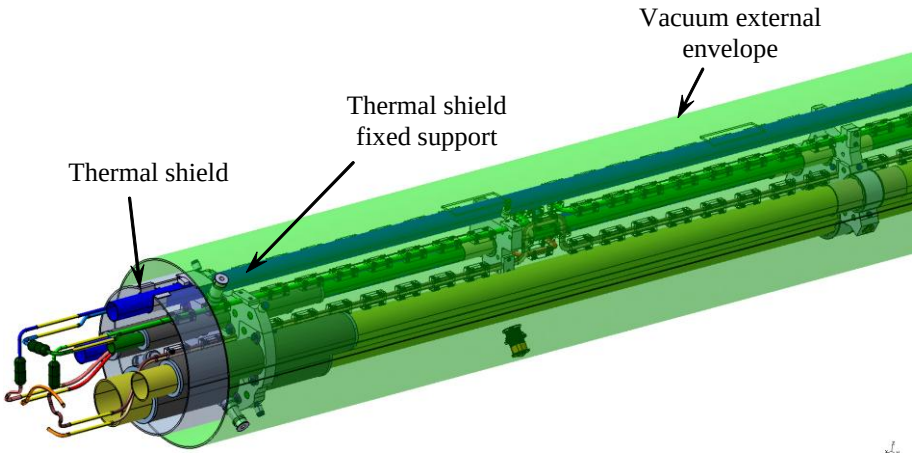


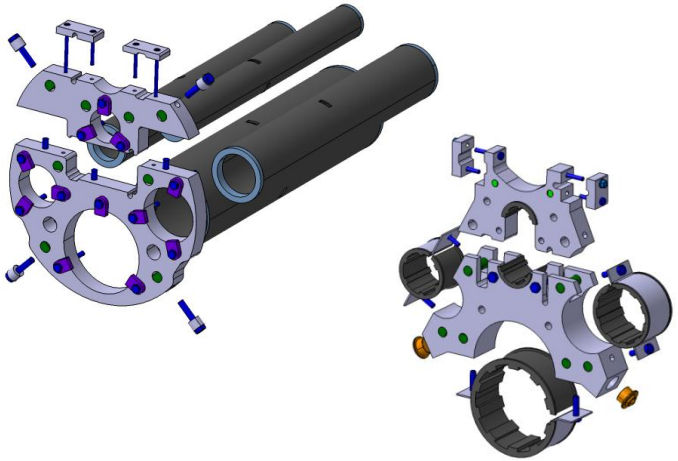
SIS100 / Local Cryo - items in the tunnel in Sects. 2,4 and 6

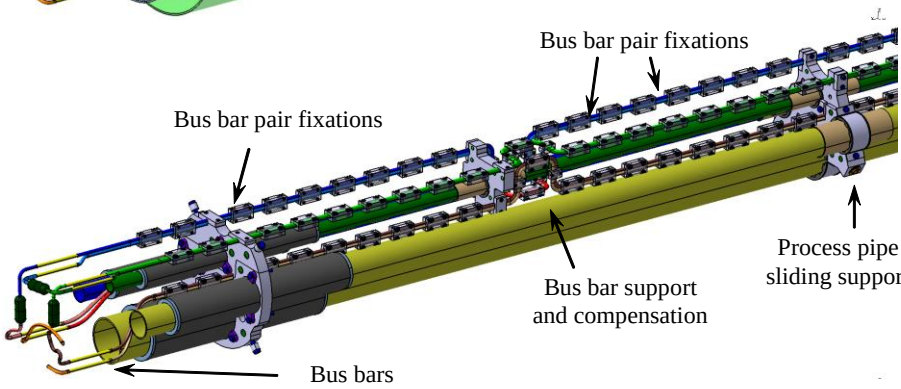


SIS100 / Local Cryo Bypass Line designed at WUT

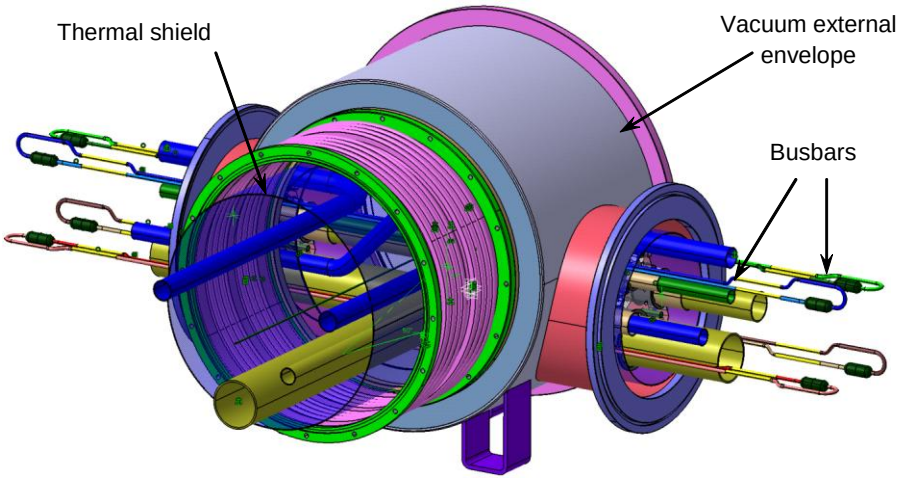


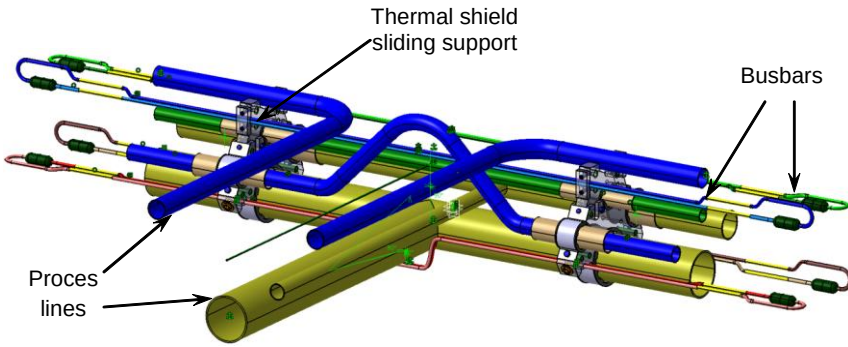


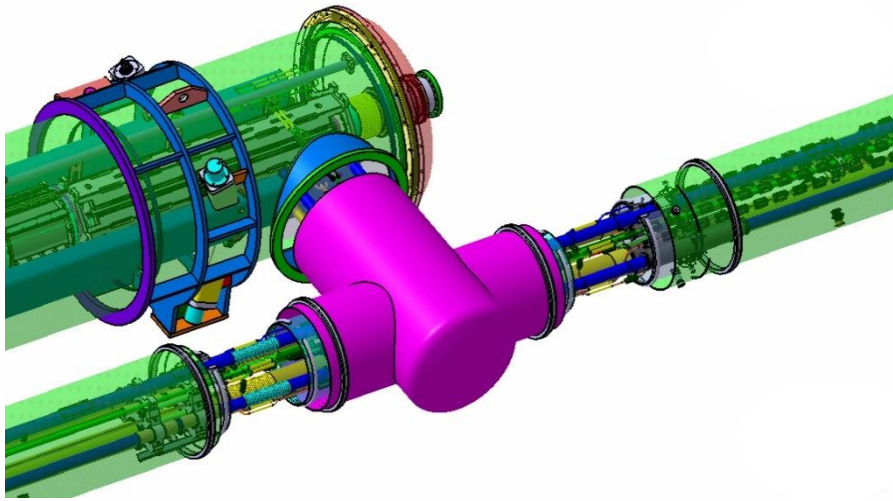




SIS100 / Local Cryo Connection Box designed at WUT







Conclusions - competences relevant to TIARA

1. Complex R&D of cryogenic system, including risk analysys and safety aspects (ODH).
2. Superluid helium He II cryostats and measurements.
3. Thermal (HeII), mechanical (LN2) and electrical measurements of irradiated materials.
4. Modelling, functional and technical design, manufacturing and commissioning of cryogenic components – transfer lines, cryostats, valve boxes.
    - Design and manufacturing according to AD2000
    - Colaboration with UDT and TUV
    - Industrialization of prototypes