Wrocław University of Technology

Introduction to Wrocław University of Technology

Dr. Jaroslaw Polinski, Prof. Maciej Chorowski

Faculty of Mechanical and Power Engineering

EuCARD HFM collaboration meeting 24.02.09

Wrocław University of Technology

- **Employees**

  Academicians – 1921

  Administration – 2185 **All: 4106**

- **Students 32800**

- **Degree programmes**

  Bachelor of Sc. – 13, Master of Sc. – 25, PhD - 17

A little bit of history.

- Wrocław University of Technology was founded in 1945. The group of 27 professors from University and Technical University in Lvov arrived to Wrocław and in the destroyed buildings of Technische Hochschule Breslau started Polish academic society. They brought here the academic tradition of Lvov and made sure that the achievements of Lvov University of Technology and Jan Kazimierz University were not lost. Our academic legacy of over 160 years entitles us to invoke the tradition of the European university and our position in the research and teaching field gives us the right to boast the title of the best technical university in Poland.

The first Polish lecture on the 15.XI.45

Wroclaw University of technology - Faculties

Faculty of Architecture

Faculty of Civil Engineering

Faculty of Chemistry

Faculty of Electronics

Faculty of Electrical Engineering

Faculty of Geoengineering, Mining and Geology

Faculty of Environmental Engineering

Faculty of Computer Science and Management

Faculty of Mechanical and Power Engineering

Faculty of Mechanical Engineering

Faculty of Fundamental Problems of Technology

Faculty of Microsystem Electronics and Photonics

FACULTY OF MECHANICAL AND POWER ENGINEERING

The Faculty of Mechanical and Power Engineering (W9) was established 64 years ago, at the same time when Wroclaw University of Technology. Now there are about 1600 students enrolled at the Faculty in 2006 and studying various aspects of mechanical sciences, basic and applied, in power engineering, thermal processes, avionics and refrigeration including cryogenics.

An average number of about 150 students graduates each year, finding employment mostly related to power plants, modern industry and various services.

The faculty staff consists of 25 professors, 55 doctors and 20 assistants. There are 70 doctoral students. All they are aided by 40 research technicians and engineering technicians.

FACULTY OF MECHANICAL AND POWER ENGINEERING - substructure

- Institute of Power Engineering and Fluid Mechanics
- Institute of Aviation, Processing and Power Machines Engineering

Faculty of Mechanical and Power Eng. Research areas:

- Combustion and related fields
  - Combustion of fossil fuels
  - Biomass combustion and gasification
  - Environment protection, reduction of pollutant emission
  - Conversion of energy
  - Numerical simulation of flows and heat processes
  - Explosion capability and fire protection
- Machine building and exploitation
  - Construction and development of steam turbines
  - Construction and development of steam boilers
  - Refrigerators and cryocoolers
  - Clearance and contact seals

Faculty of Mechanical and Power Eng. International cooperation:

- European Organisation for Nuclear Research CERN in Geneva,
- CEA Saclay, France,
- Organisation for Applied Scientific Research, Netherlands,
- Inter University Accelerator Center, Delhi
- Technical University Clausthal, Germany,
- Technical University Munich, Germany,
- Technical University Dresden, Germany,
- Stuttgart University, Germany,
- University of Delft, Netherlands,
- University of Leeds, GB,
- Bristol University, GB,
- The students benefit from European student exchange programs SOCRATES, ERASMUS, LEONARDO.

PWR Cryogenic Group

PWR Cryogenic Group includes scientists from Wroclaw Univerity of Technology who are engaged in a number of activities and research into cryogenics.

Main Members of PWR Cryogenic Group

Prof. Maciej CHOROWSKI - group leader

Dr Jaroslaw FYDRYCH

Dr Artur JEDRUSYNA

Dr Tadeusz WISNIEWSKI

Dr Janusz LICHOTA

Dr Krzysztof TOMCZUK

Dr Slawomir PIETROWICZ

Dr Wojciech GIZICKI

Dr Jaroslaw POLINSKI

Dr Jacek KOSEK

Agnieszka PIOTROWSKA - PhD stud.

Michal STRYCHALSKI - PhD stud.

Main topics of competence

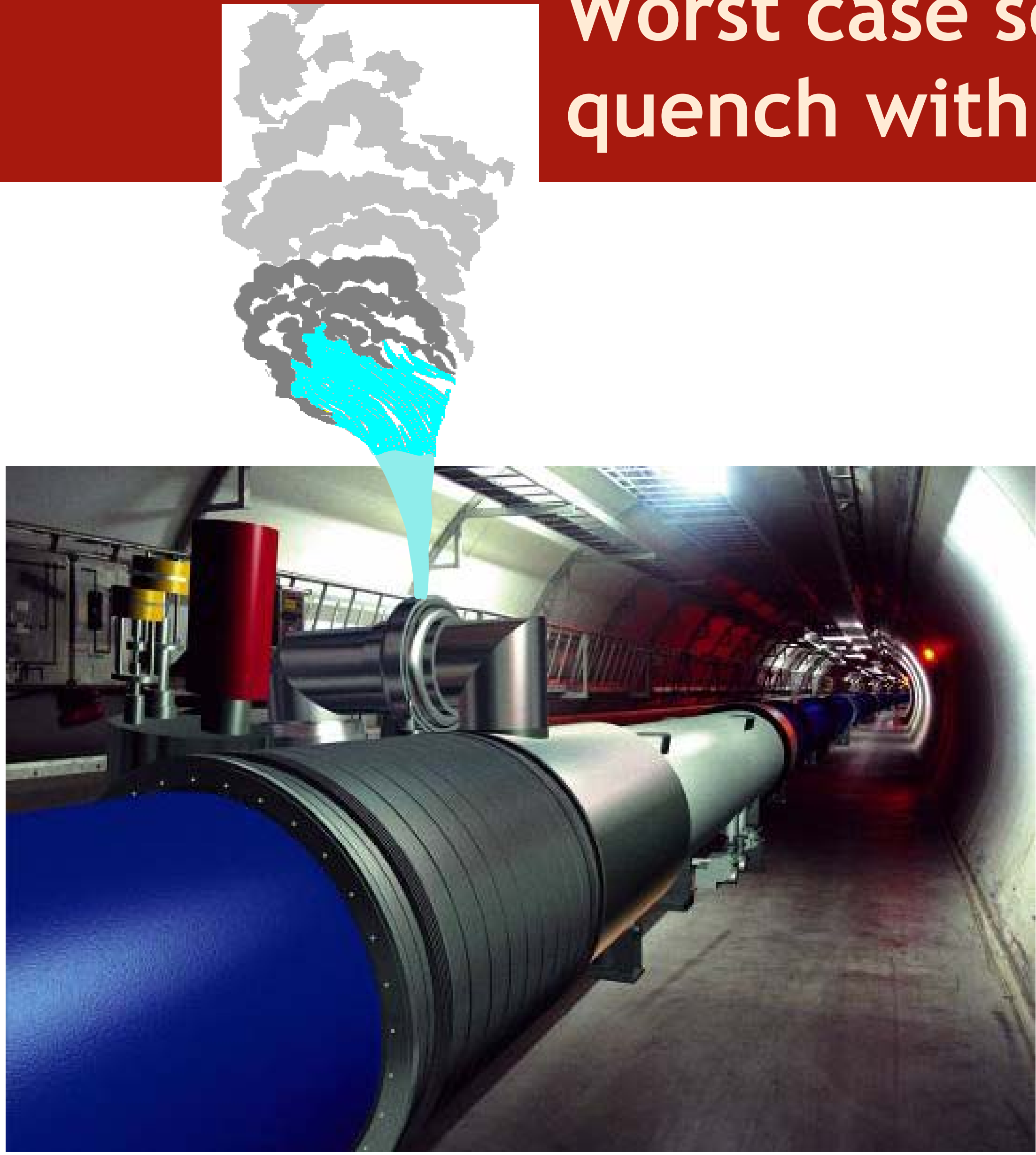
- Design and commissioning of cryogenic installations including gas liquefiers
- Risk and safety analysis of cryogenic systems
- Reception tests of cryogenic installations
- Pressure and helium tightness tests of cryogenic equipments
- Superfluid helium cryostat designs and studies
- Modeling and experimental investigation of cryogenic thermal insulation
- Numerical investigation of cryogenic phenomena
- Thermal and mechanical studies of cryogenic distribution lines
- New materials in cryogenics

Risk and safety analysis of cryogenic systems

Study on cold helium propagation in the LHC tunnel

- PWR-CERN collaboration
- performed in 2001-2003
- aim: to describe teperature and oxygen concentration profiles in the tunnel during an unexpected cold helium discharge into the tunnel

Worst case scenario - quench with helium relieve



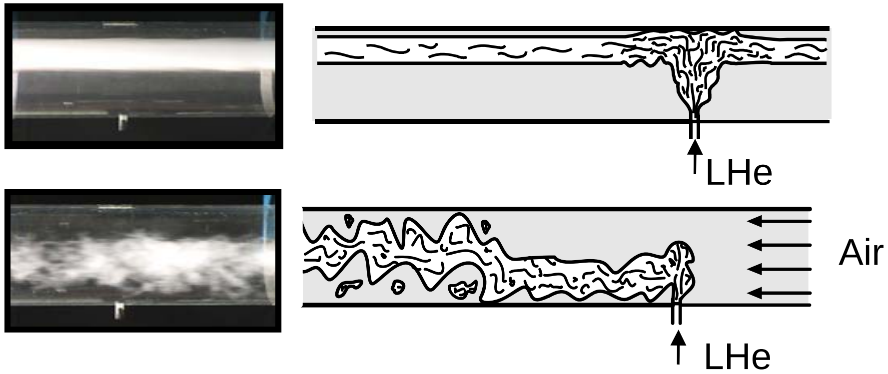
Questions that were to be answered

- Thermohydraulics of magnet resistive transitions
- Pressure evolution in magnet cryostat following quench
- Sector quench and helium relief
- Helium potential flow to the LHC tunnel
- And many others

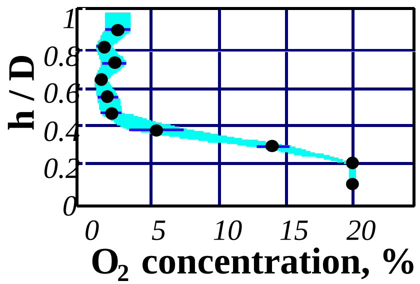
Risk and safety analysis of cryogenic systems

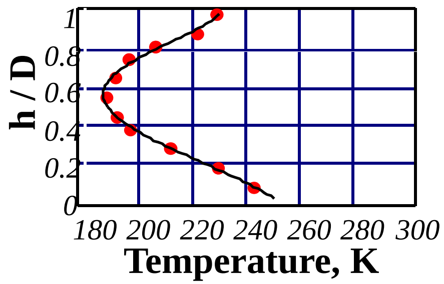
Test set-up
build and operated at PWR

Visualisation results



Measurement results





Risk and safety analysis of cryogenic systems

Cold helium propagation in the LHC tunnel

Large scale experiment at CERN

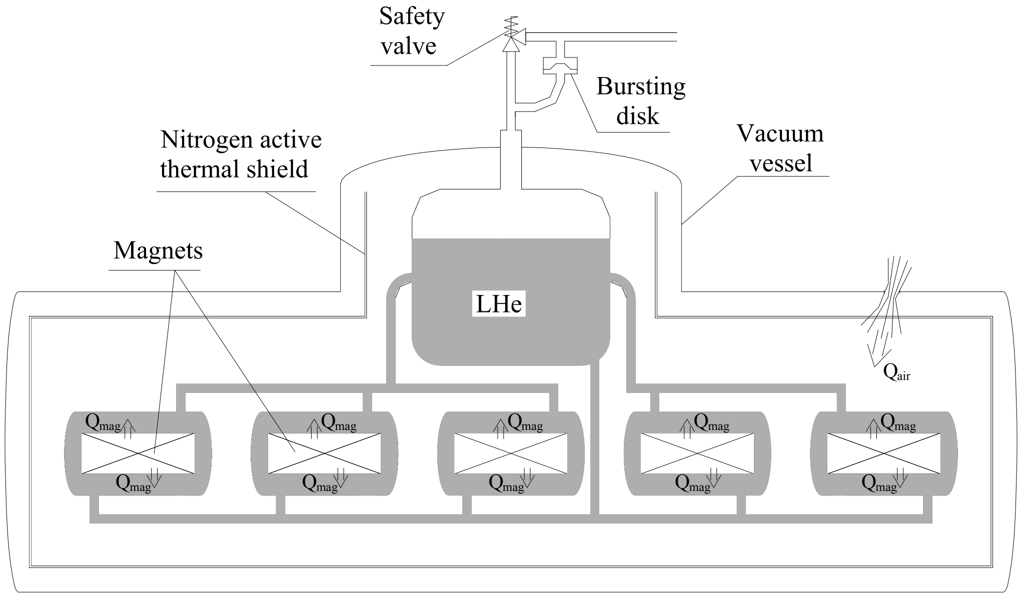
Risk and safety analysis of cryogenic systems

Study on helium safety reliefe system for DPS2-F cryostat of the Karlsruhe Tritium Neutrino Experiment

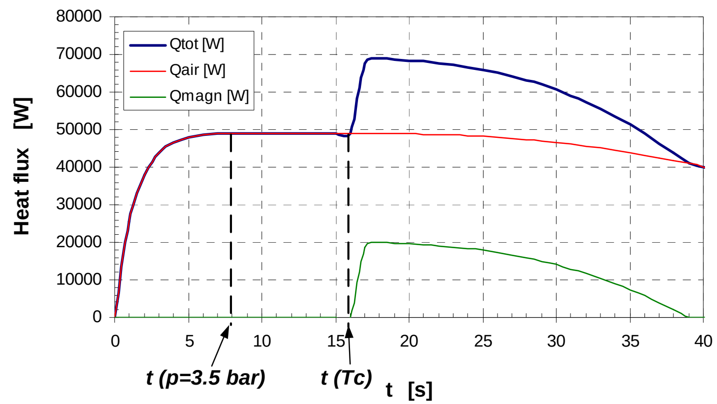
- PWR-Forschungszentrum Karlsruhe collaboration
- performed in 2005
- aims: ● to analyse of some potential scenarios that can lead to the helium relieve from the cryostat to the atmosphere;

  ● to specify potential flow through the bursting disk and safety valve;

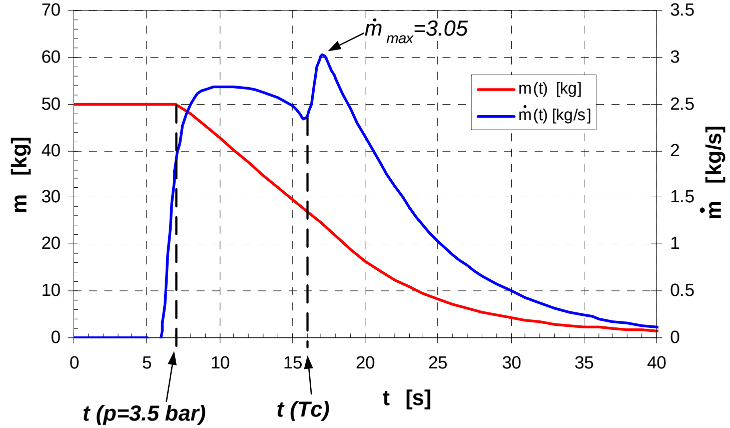
Risk and safety analysis of cryogenic systems



Scheme of the DPS2 cryostat and its safety system



Heat flux to the helium after air venting to the insulation vacuum space



The evolutions of helium mass in the cryostat and helium mass outflow

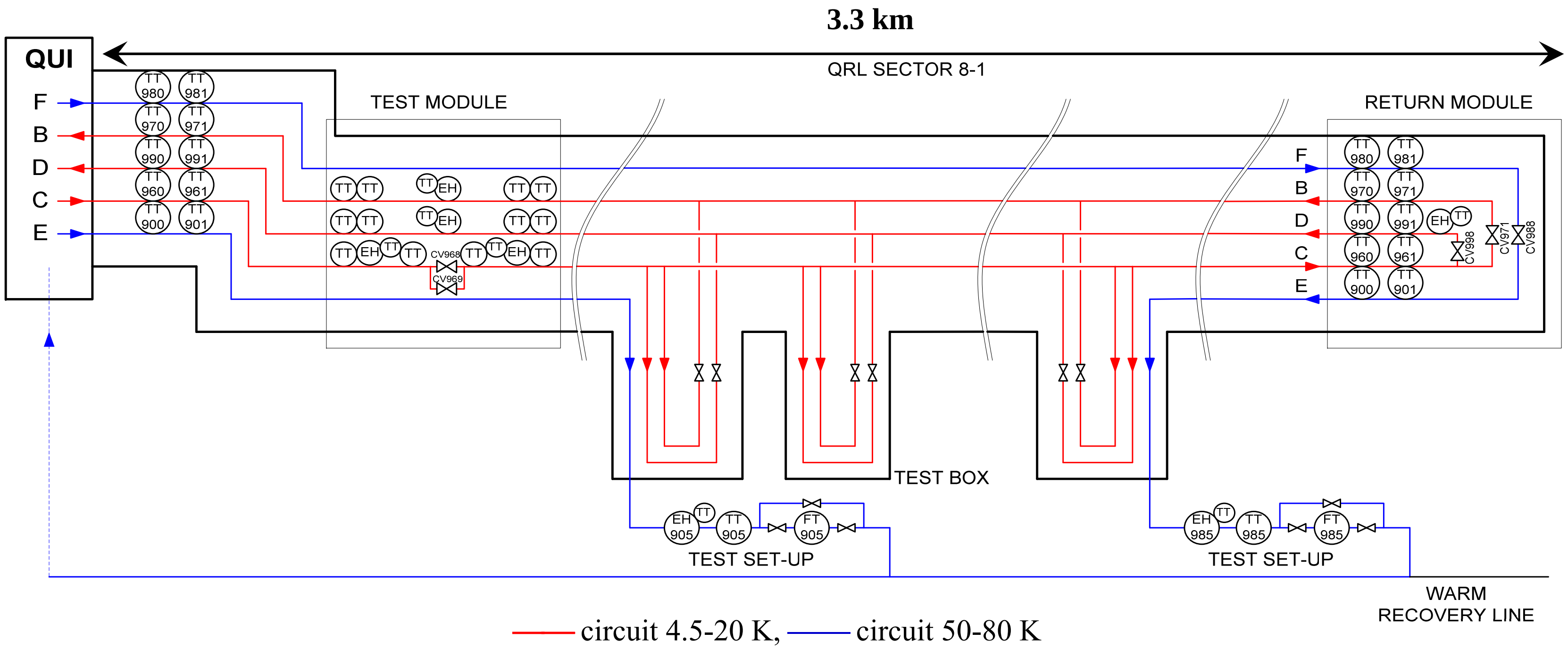
Reception tests of cryogenic systems

Reception test of the LHC Cryogenic Distribution Line in sector 7-8 (sub-sectors A and B)

Reception test of the LHC Cryogenic Distribution Line in sector 8-1

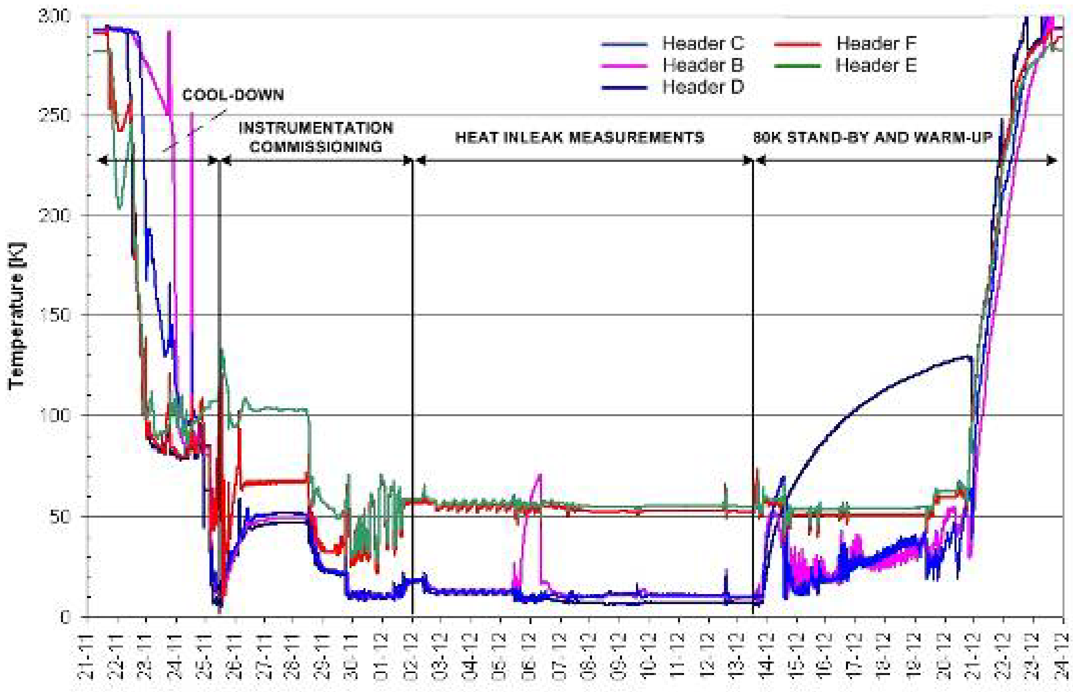
- PWR-CERN collaboration
- performed in 2005-2006
- aims: ● to verify overal behaviour of the line at cryogenic temperatures;
  ● to measure heat inleaks to the circuts 4.5-20K and 50-80K

Reception tests of cryogenic systems



Configuration of the LHC Cryogenic Distribution Line in sector 8-1 for the reception test

Reception tests of cryogenic systems



Temperature evolutions
of the Cryogenic Distribution Line main headers
during the reception test in sector 8-1

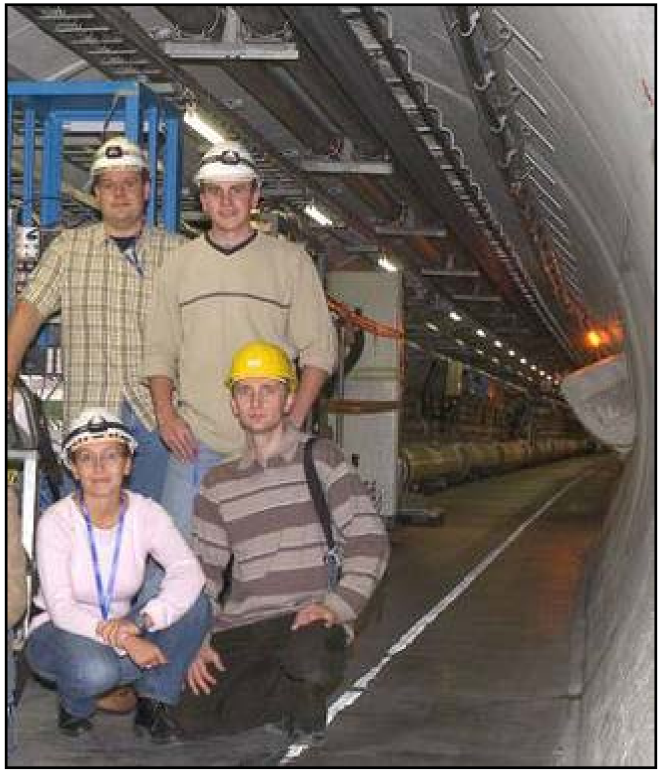
Measured heat inleaks
to circuit 50-80 K

	Heat inleak
11-Dec	8818 W
12-Dec	9007 W
13-Dec	8920 W

Measured heat inleaks
to circuit 4.5-20 K

	Heat inleak	
	with JR	without JR
11-Dec	633.3 W	603.9 W
12-Dec	632.9 W	582.3 W
13-Dec	635.1 W	572.5 W

Reception tests of cryogenic systems



Some members of PWR cryogenic grup in the LHC tunnel

The LHC Cryogenic Distribution Line during the reception tests in sector 8-1

Stability tests of QRL bellows, commissioning of the LHC

Stability tests of some bellows types for Cryognic Distribution Line were performed at PWR in 2006

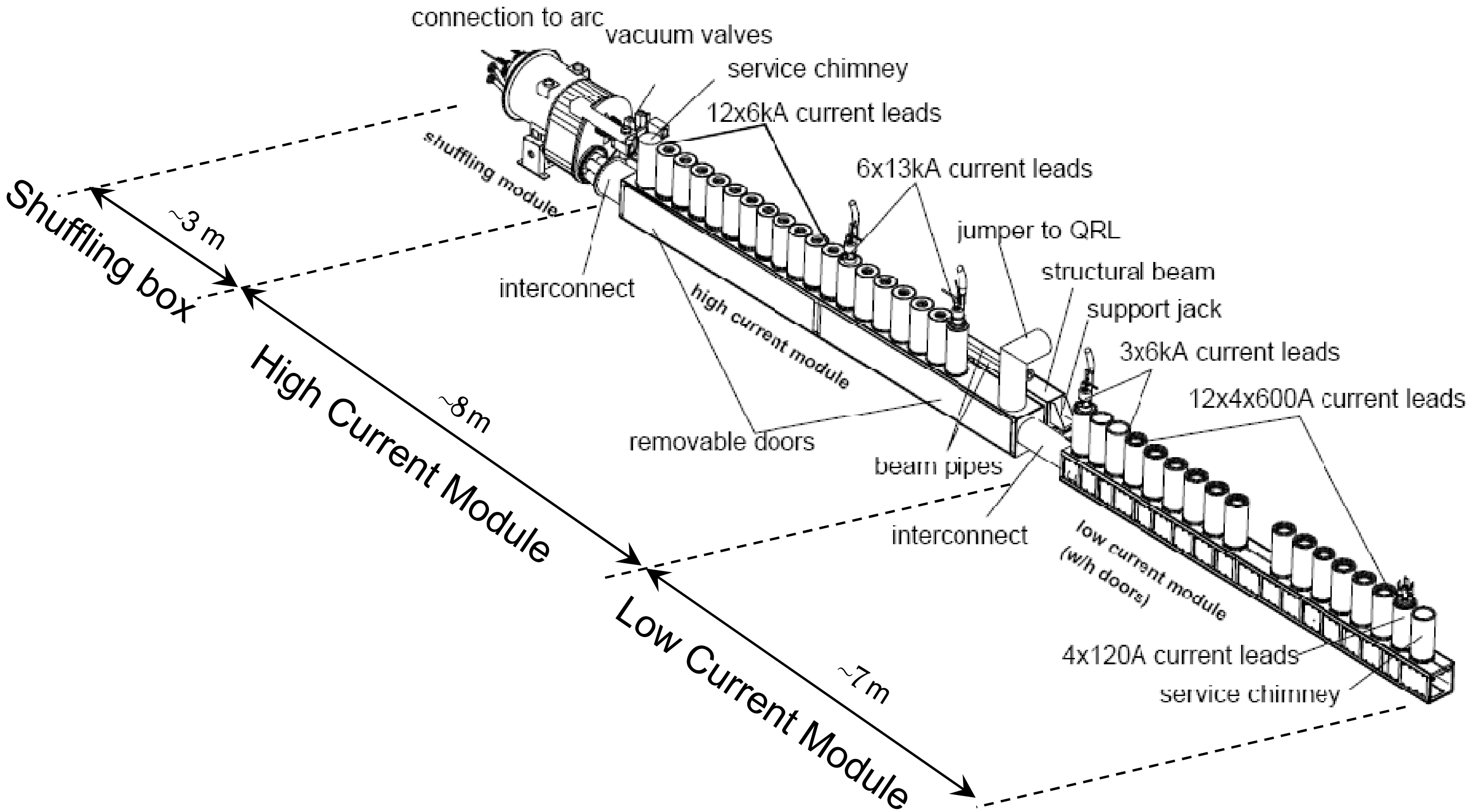
Pressure and leak tightness tests of cryogenic equipments

Pressure and leak tightness tests of the LHC Cryogenic Electrical Feedboxes

- PWR-CERN collaboration
- performed in 2006-2007
- aim: to verify high pressure resistance and leak tightness and to measure residual leaks (at the level below $1{\cdot}10^{-9}$ mbar l/s)

Pressure and leak tightness tests of cryogenic equipments

Cryogenic Electrical Feedboxes for the LHC



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Pressure and leak tightness tests of cryogenic equipments

Low Current Module of Cryogenic Electrical Feedbox under pressure and helium leak tightness test

Pressure and leak tightness tests of cryogenic equipments

High Current Module of the Cryogenic Electrical Feedbox (DFBAC) during preparation for the pressure and helium leak tightness test

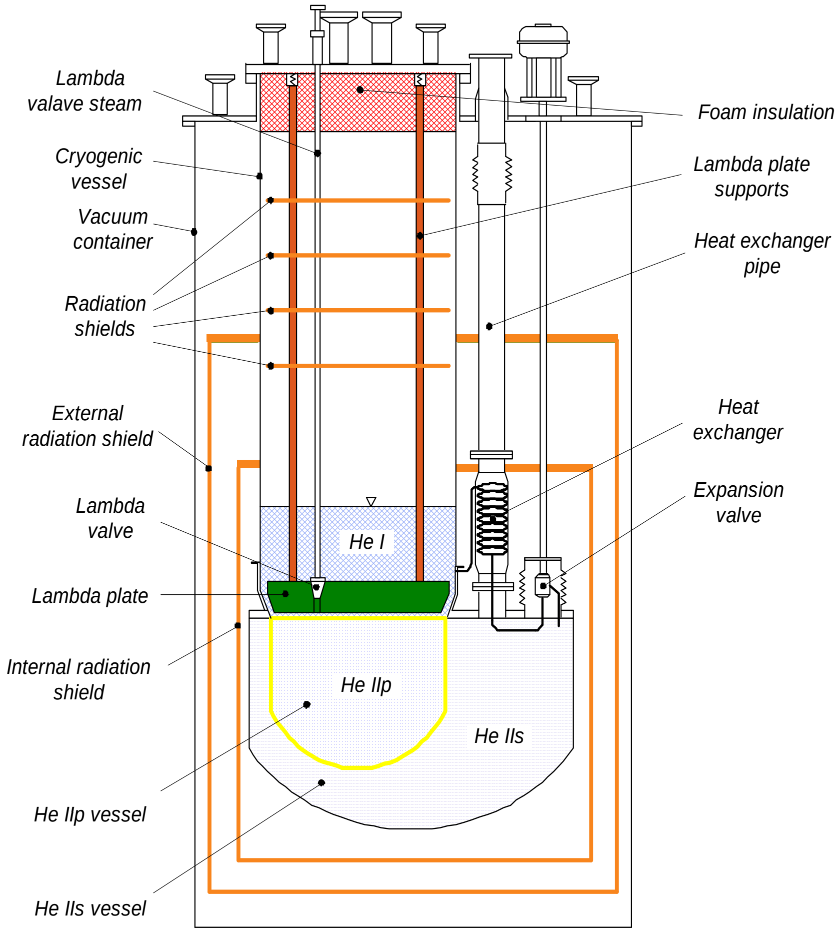
Superfluid helium cryostat designs and studies

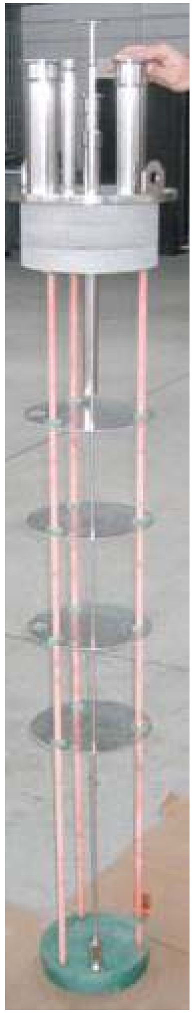
Superfluid helium cryostat for Next European Dipole project

- PWR participation in CARE (FP6 project)
- performed in 2004-2005
- aim: designing, construction and study on the He II cryostat to perform measurements in low temperature conditions

Superfluid helium cryostat designs and studies

Next European Dipol cryostat





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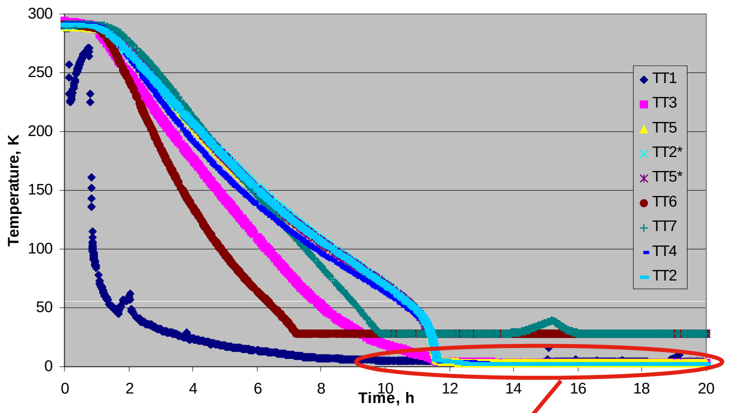
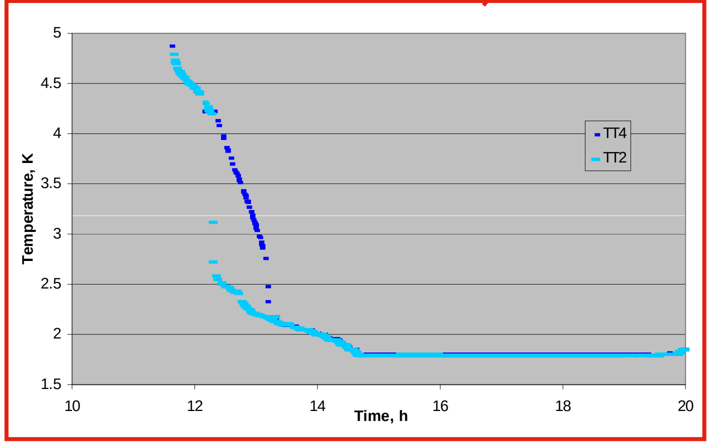
Superfluid helium cryostat designs and studies

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

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



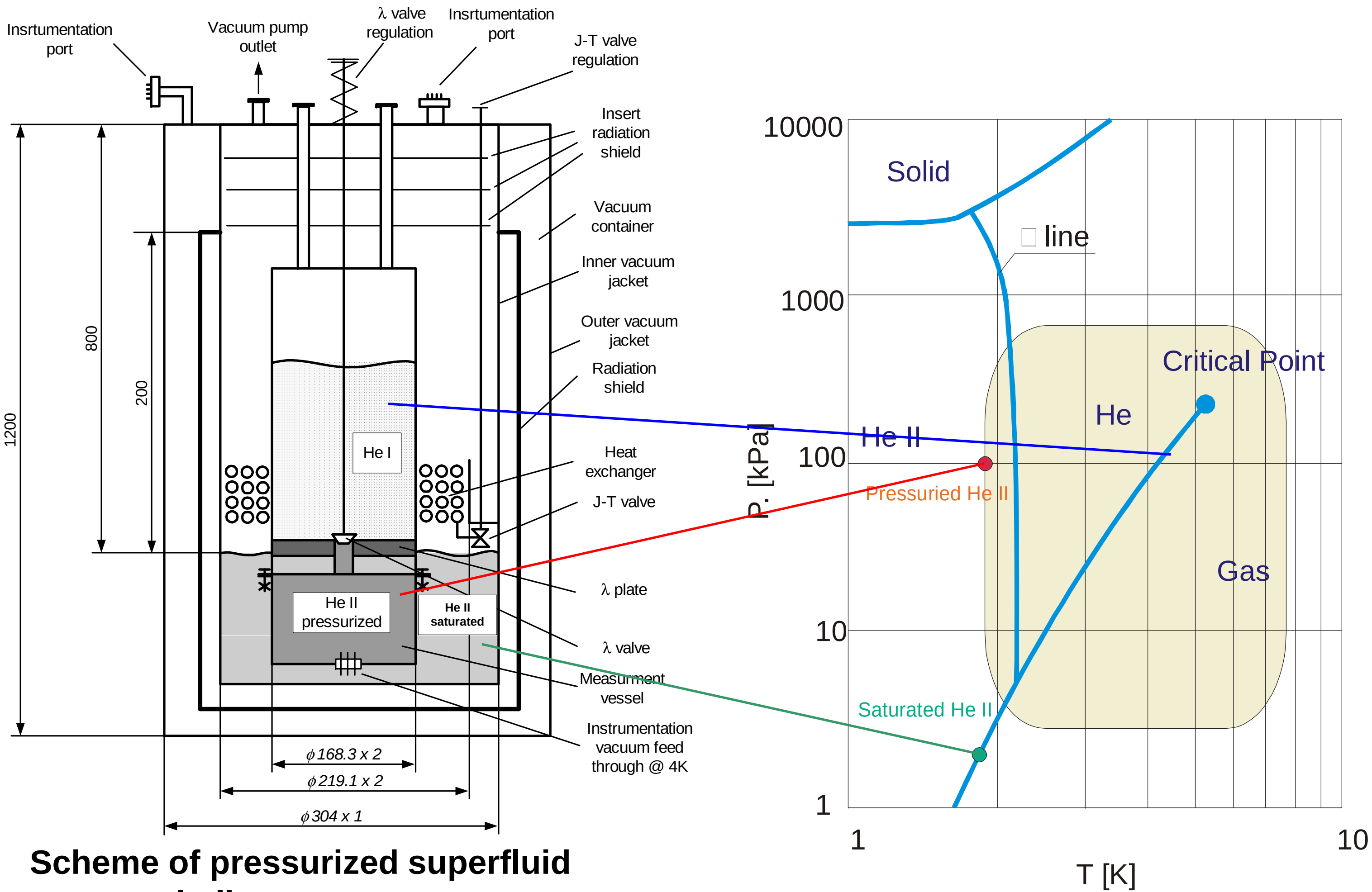


Temperatute evolution during the first cryostat cool-down

Superfluid helium cryostat for the measurement of heat transfer in He II

- PWR-CERN collaboration
- performed in 2005-2007
- aim: to measure and obtain heat transfer coefficients in superfluid, saturated and supercritical helium

Superfluid helium cryostat designs and studies

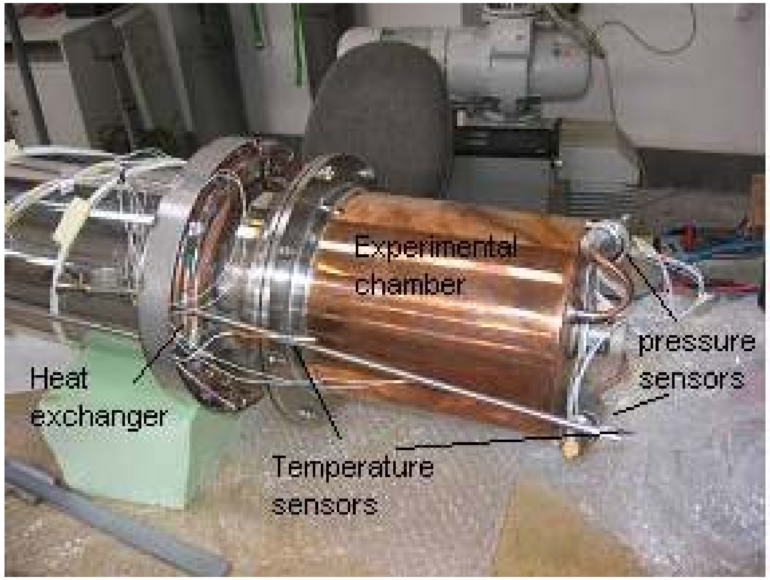


Scheme of pressurized superfluid helium cryostat

Superfluid helium cryostat designs and studies

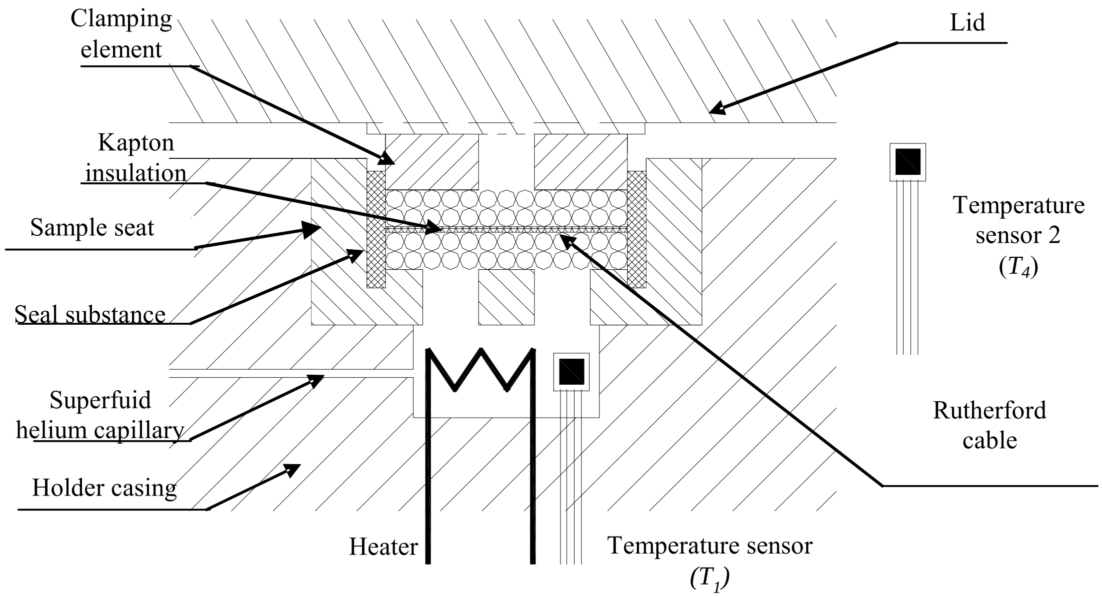
External vacuum jacet during leak test

Radiation screen with MLI



Measurement vessel with instrumentation

Measurements of the heat transfer through SC cable electrical insulation in He IIp



Scheme of the measurement method

Measurement apparatus with instrumentation

Modeling and experimental investigation of cryogenic thermal insulation

- PWR
- performed in 2005-2007
- aims: ● development of some mathematical models of heat transfer through cryogenic insulations;
  ● computer implementation of the model as a tool for cryogenic insulation designing;
  ● experimental determination of the heat flux thought different cryogenic insulations;

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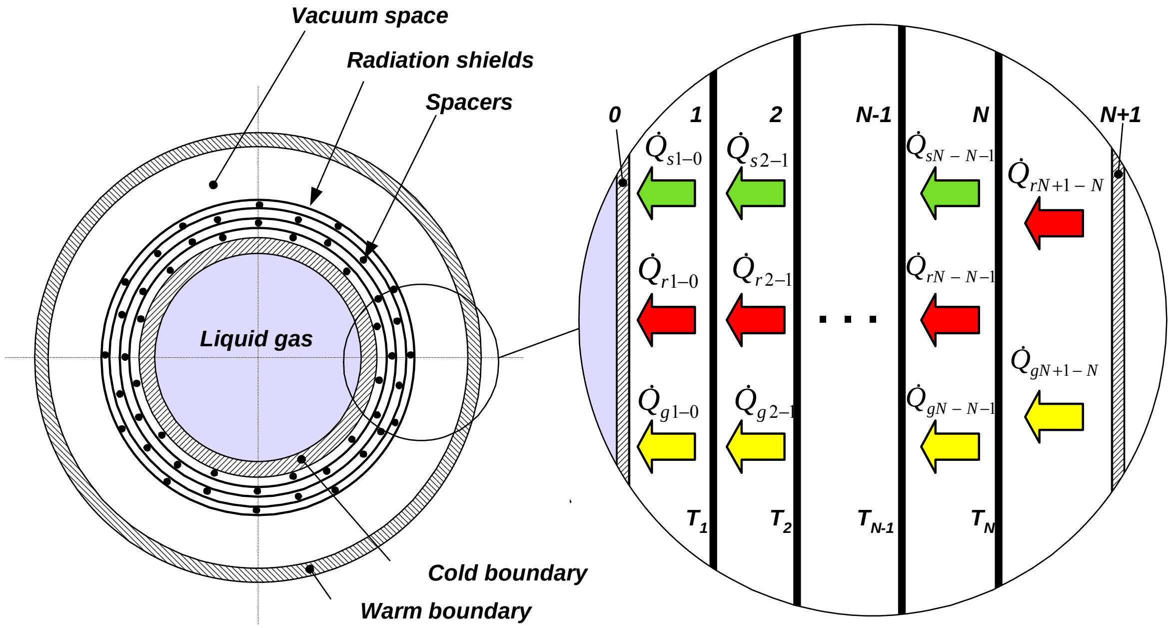
Modeling and experimental investigation of cryogenic thermal insulation

Multilayer Insulation (MLI) heat transfer scheme and mathematical modeling



Set of equations:

$$\begin{cases} \dot{Q} = \dot{Q}_{r\,1-0} + \dot{Q}_{s\,1-0} + \dot{Q}_{g\,1-0} \\ \dot{Q} = \dot{Q}_{r\,2-1} + \dot{Q}_{s\,2-1} + \dot{Q}_{g\,2-1} \\ \dots \\ \dot{Q} = \dot{Q}_{r\,N-N-1} + \dot{Q}_{s\,N-N-1} + \dot{Q}_{g\,N-N-1} \\ \dot{Q} = \dot{Q}_{r\,N+1-N} + \dot{Q}_{g\,N+1-N} \end{cases}$$

Solid heat conduction:

$$\dot{Q}_s = A \cdot \lambda_s \cdot \overline{N} \cdot (T_1 - T_2)$$

Residual gas heat conduction:

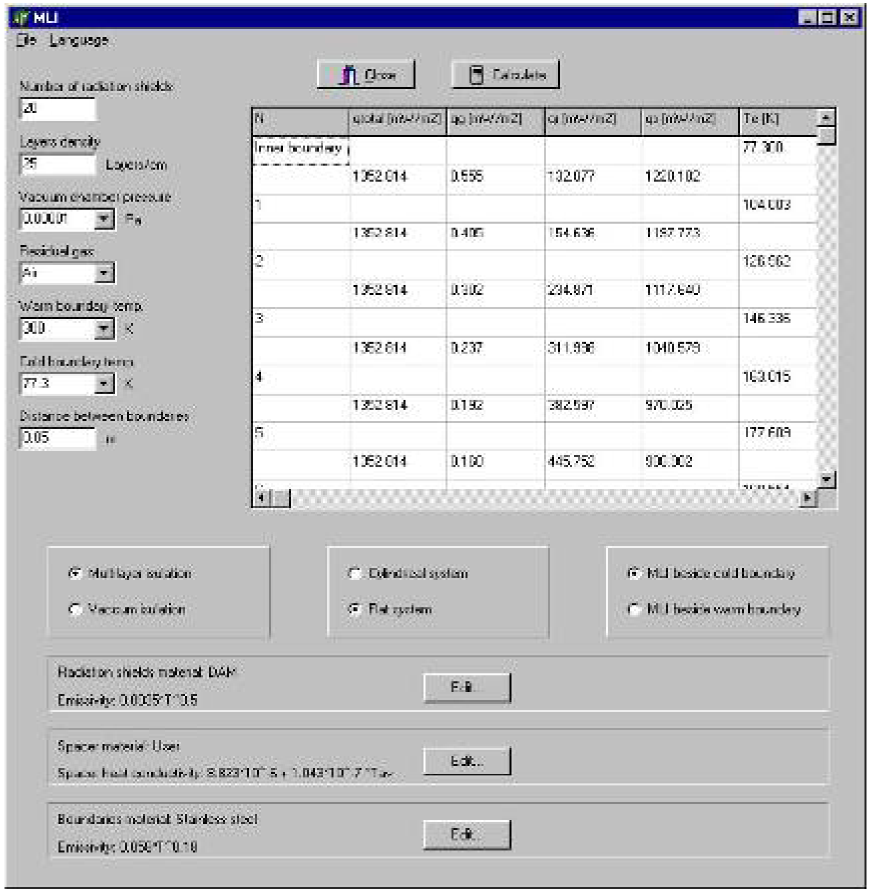
$$\dot{Q}_g = A \cdot \left(\frac{R_u}{8\pi T_0 M_0} \right)^{0,5} \frac{\kappa+1}{\kappa-1} \frac{\alpha}{2-\alpha} p \cdot (T_2 - T_1)$$

Heat radiation:

$$\dot{Q}_r = \sigma \cdot A \cdot \frac{1}{\frac{1}{\varepsilon_1} + \frac{1}{\varepsilon_2} - 1} \cdot (T_1^4 - T_2^4)$$

Modeling and experimental investigation of cryogenic thermal insulation

Computer implementation of MLI mathematical model



Program inputs:

- Number of layers
- Layer density
- Residual gas type (N2/ Air, He, H2)
- Residual gas pressure
- Temperature of the warm and cold boundaries
- Distance between boundaries
- Boundary materials emissivity
- MLI configuration (MLI blanket wound on warm/cold boundary)
- Radiation shield emissivity
- Spacer thermal conductivity coefficient

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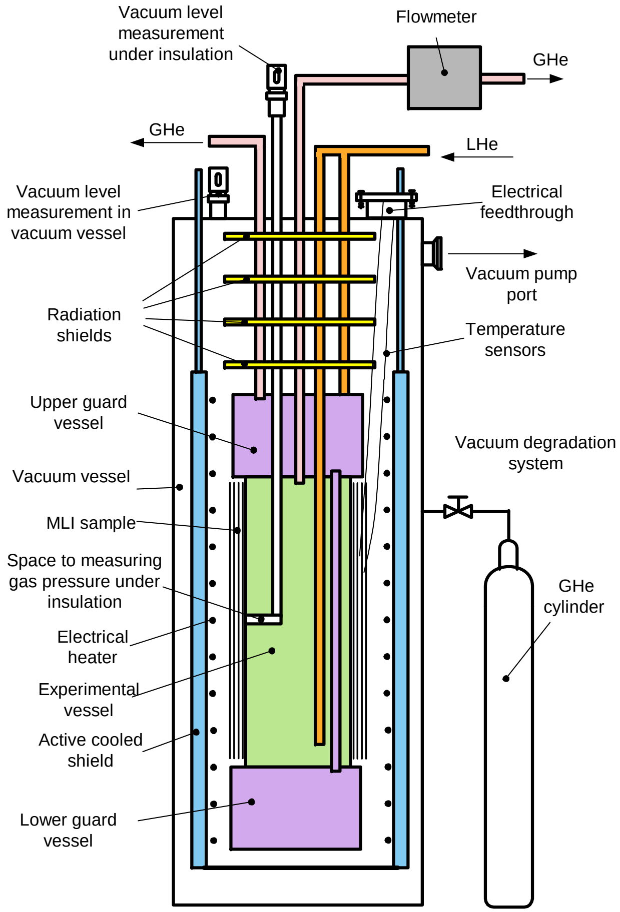
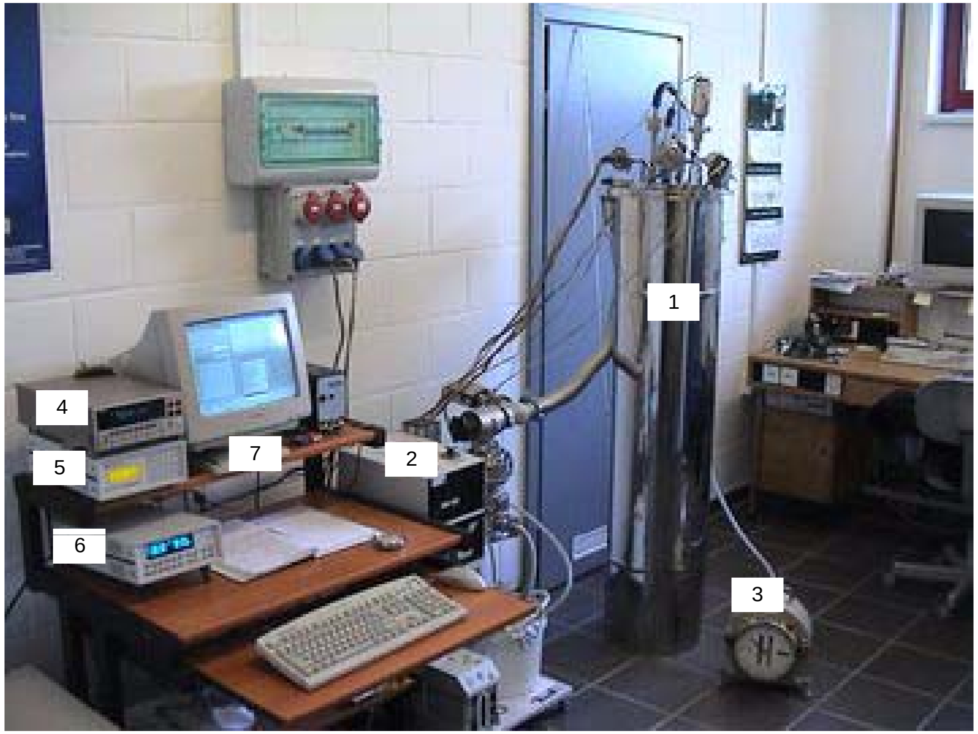
Modeling and experimental investigation of cryogenic thermal insulation

Cryostat to perform tests of heat transfer through cryogenic insulation





Experiment setup: 1 – measurement cryostat; 2 – turbopump; 3 – flow counter; 4 – vacuum pressure monitoring; 5 – temperature monitoring; 6 – active cooled shield temperature regulator; 7 – storage data computer

Numerical investigation of cryogenic phenomena

Numerical modelling of heat transfer between superconduting magnet structure and helium

-PWR-CERN collaboration

- performed in 2006-2007

- aim: to analyse heat transfer and helium flow from the magnet structure to the helium after resistive transition and in ultimate conditions (FEM, ANSYS ICEM and ANSYS CFX software)

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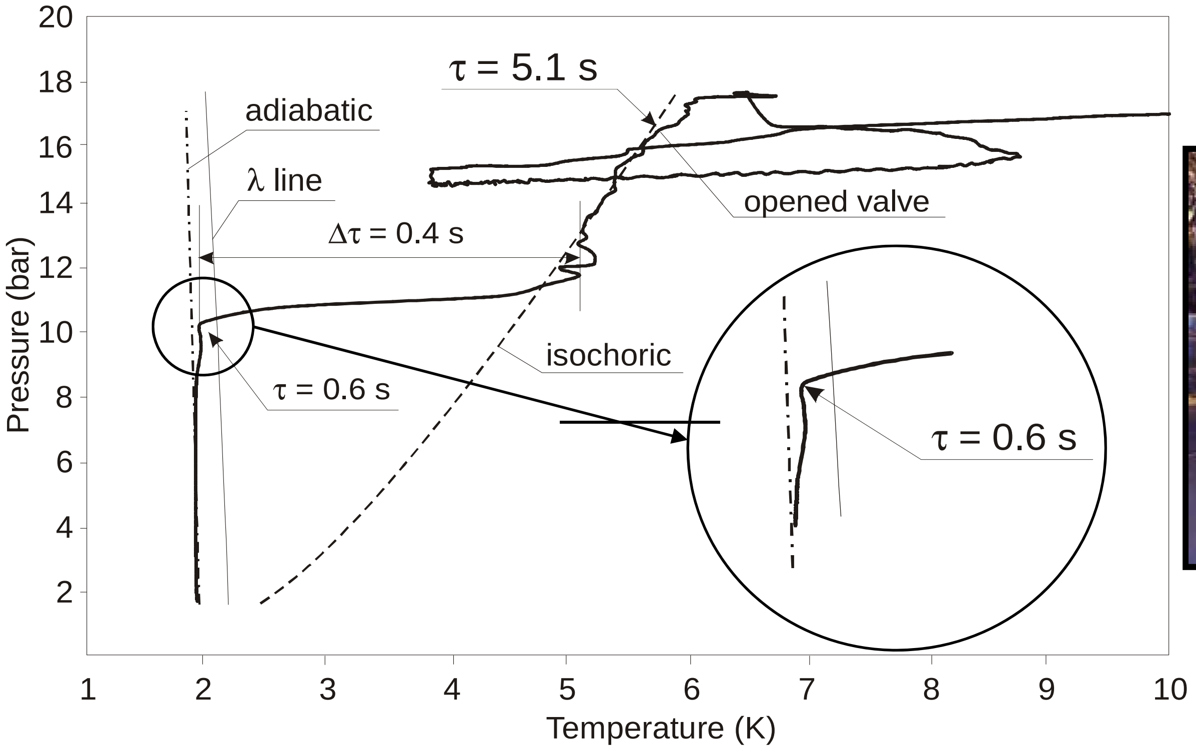
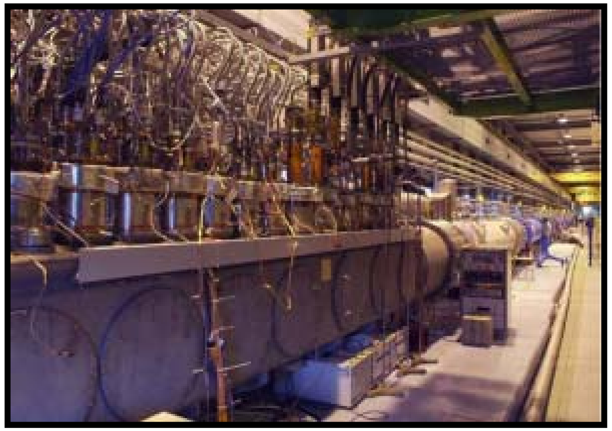
Numerical investigation of cryogenic phenomena

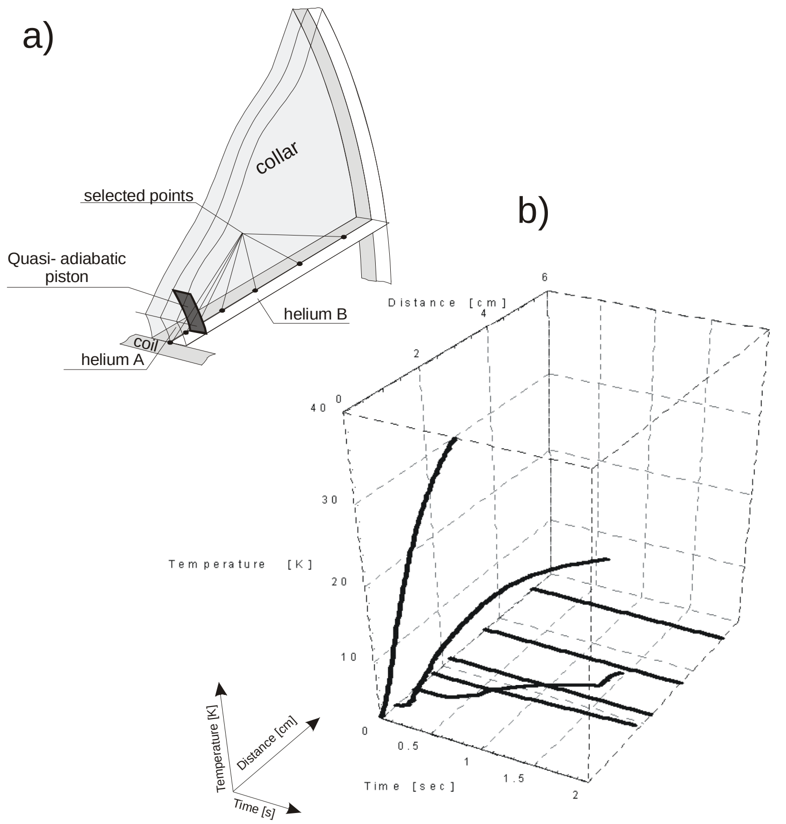


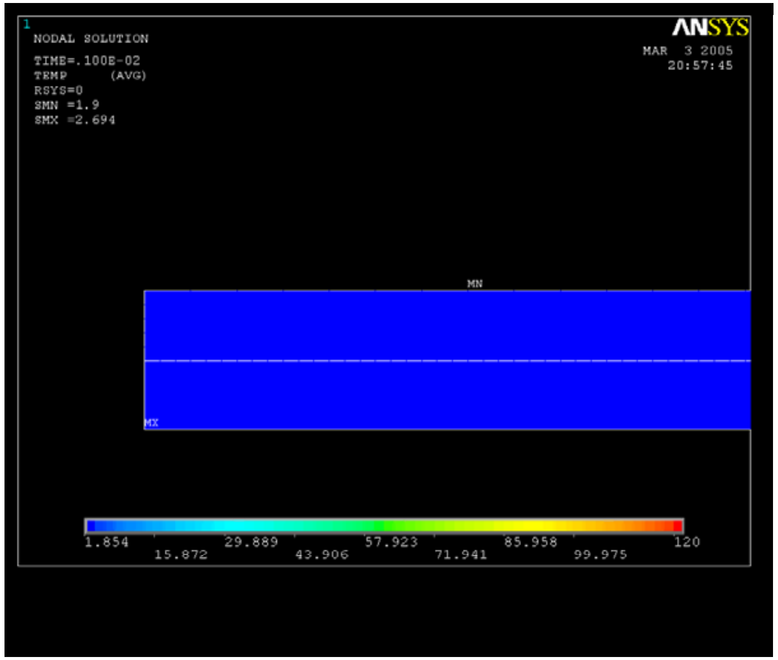


Test banch of the STRING 2 experiment

Bulk helium parameter evolutions after the simultaneous resistive transition of the STRING 2 magnets

Example of numerical calculation





Animation of evolution of temperature in the fin

a). Pictorial view of simplified geometry of numerical calculations with the selected points of the collar

b) Evolution of the temperature in the fin

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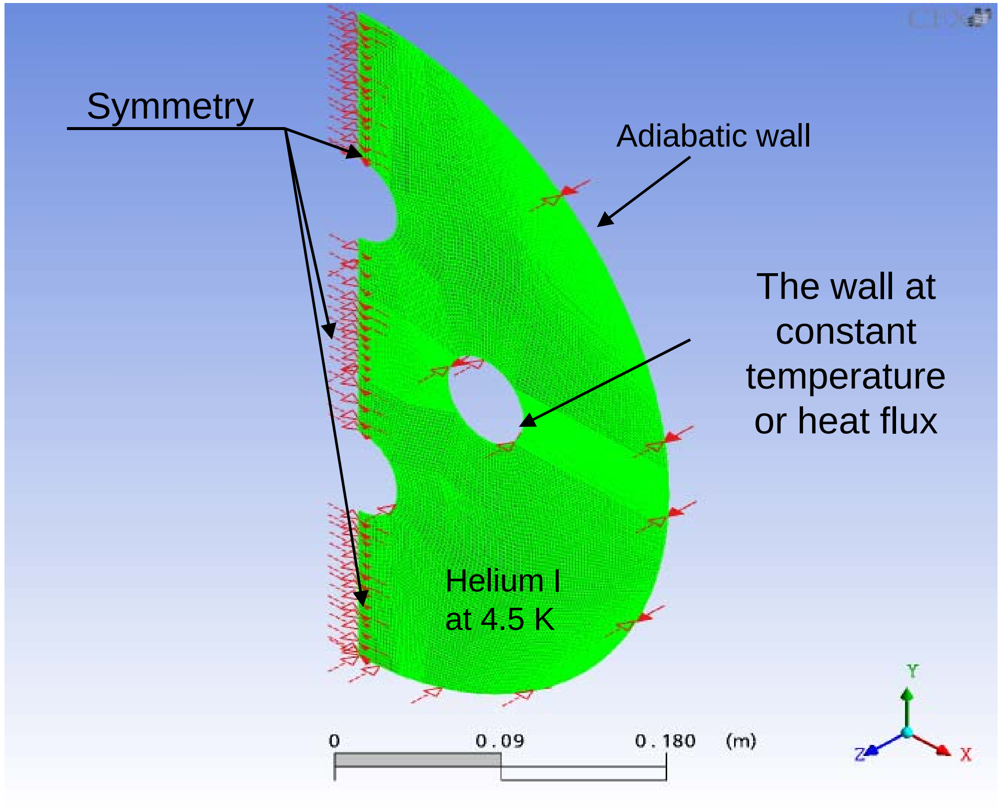
Numerical investigation of cryogenic phenomena



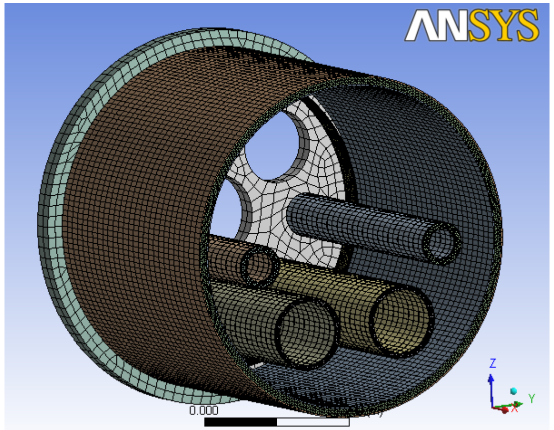
Geometry, boundary conditions and mesh for numerical calculation of the MQY magnet

Thermal and mechanical studies of cryogenic distribution lines

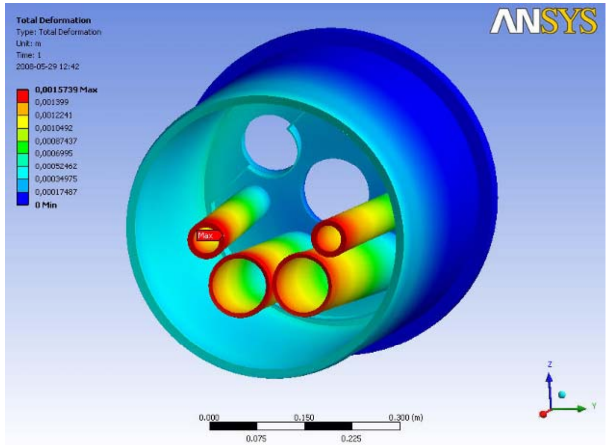
Thermal and mechanical studies of cryogenic distribution lines

- PWR- ITER collaboration
- performed in 2008
- aim: thermal and mechanical analysis of the sections of cryogenic lines for torus and cryostat cryopumps of ITER

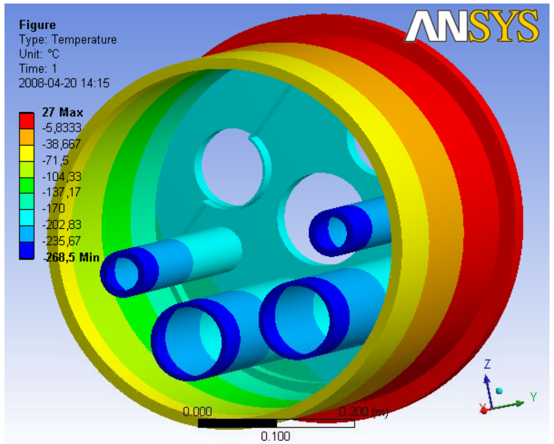
Thermal and mechanical studies of cryogenic distribution lines



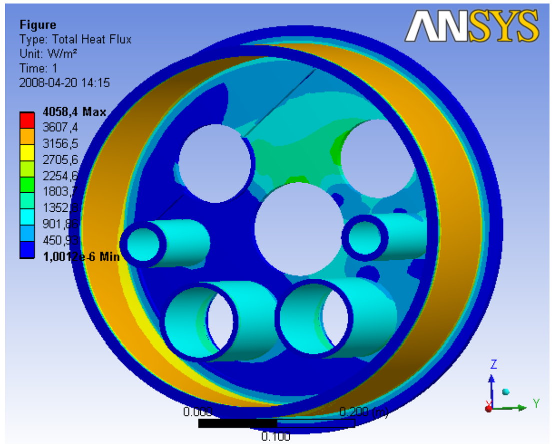
Mesh



Deformation – weight, pressure and thermal loads

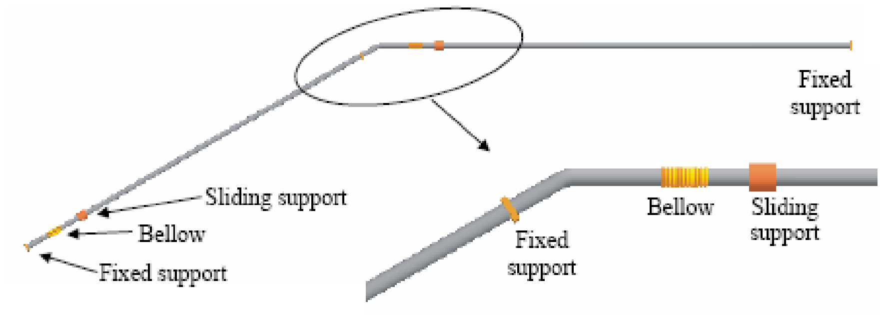


Temperature distribution

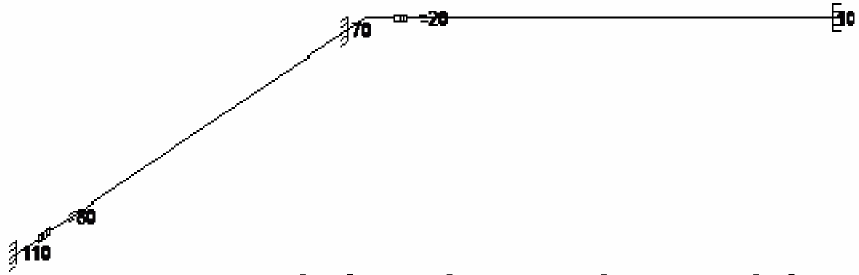


Heat flux distribution

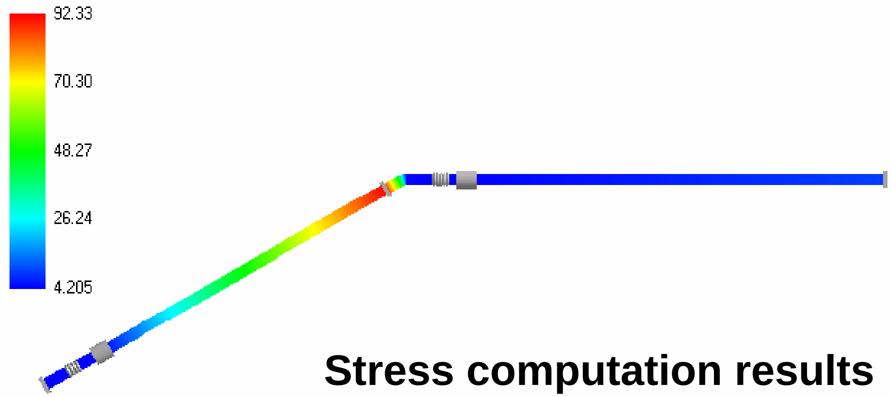
Thermal and mechanical studies of cryogenic distribution lines



Pipe model



Node location on the model



Stress computation results

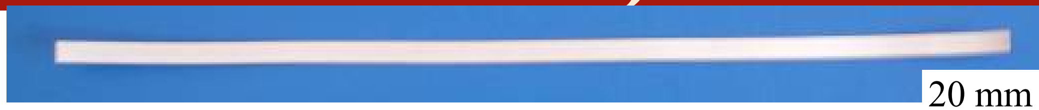
Development of Ag alloys for BSCCO tape sheaths

- PWR
- performed in 2005-2007
- aims: development of the new silver alloys for BSCCO tape with improved diffusion coefficient and with respect of mechanical and thermal properties;

Development of Ag alloys for BSCCO tape sheaths

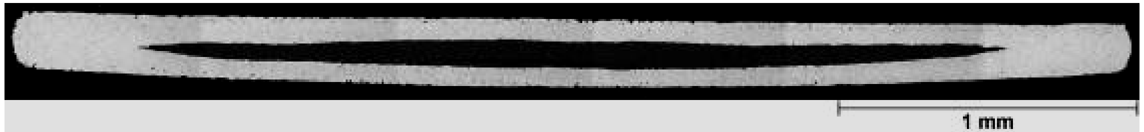
	Material	Equilibrium structure
1	**Ag-Mg**	Solid solution α (Mg in Ag)
2	**Ag-Sn**	Solid solution α (Sn in Ag)
3	**Ag-Sb**	Solid solution α (Sb w Ag)
4	**Ag-Mn**	Solid solution α (Mn in Ag) and precipitates of solid solution β (Ag in Mn)
5	**Ag-Cu-Zr**	Solid solution α (Cu in Ag) and precipitates of phase/phases rich in Cu and Zr
6	**Ag-Cu-Ni**	Solid solution α (Cu in Ag) and precipitates of phase/phases rich in Cu and Ni

BSCCO tapes manufacturing (IFW Dresden)

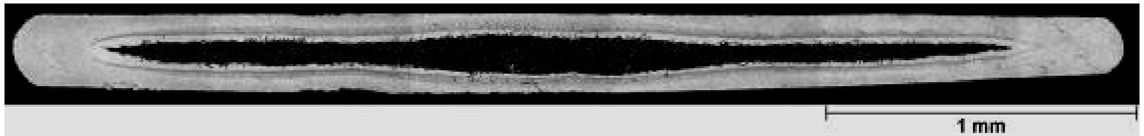


BSCCO/Ag/Ag

BSCCO/Ag/Ag-Mg

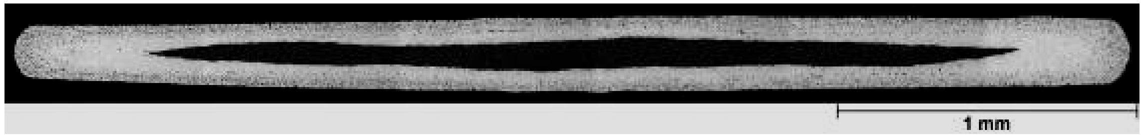


BSCCO/Ag/Ag-Sn

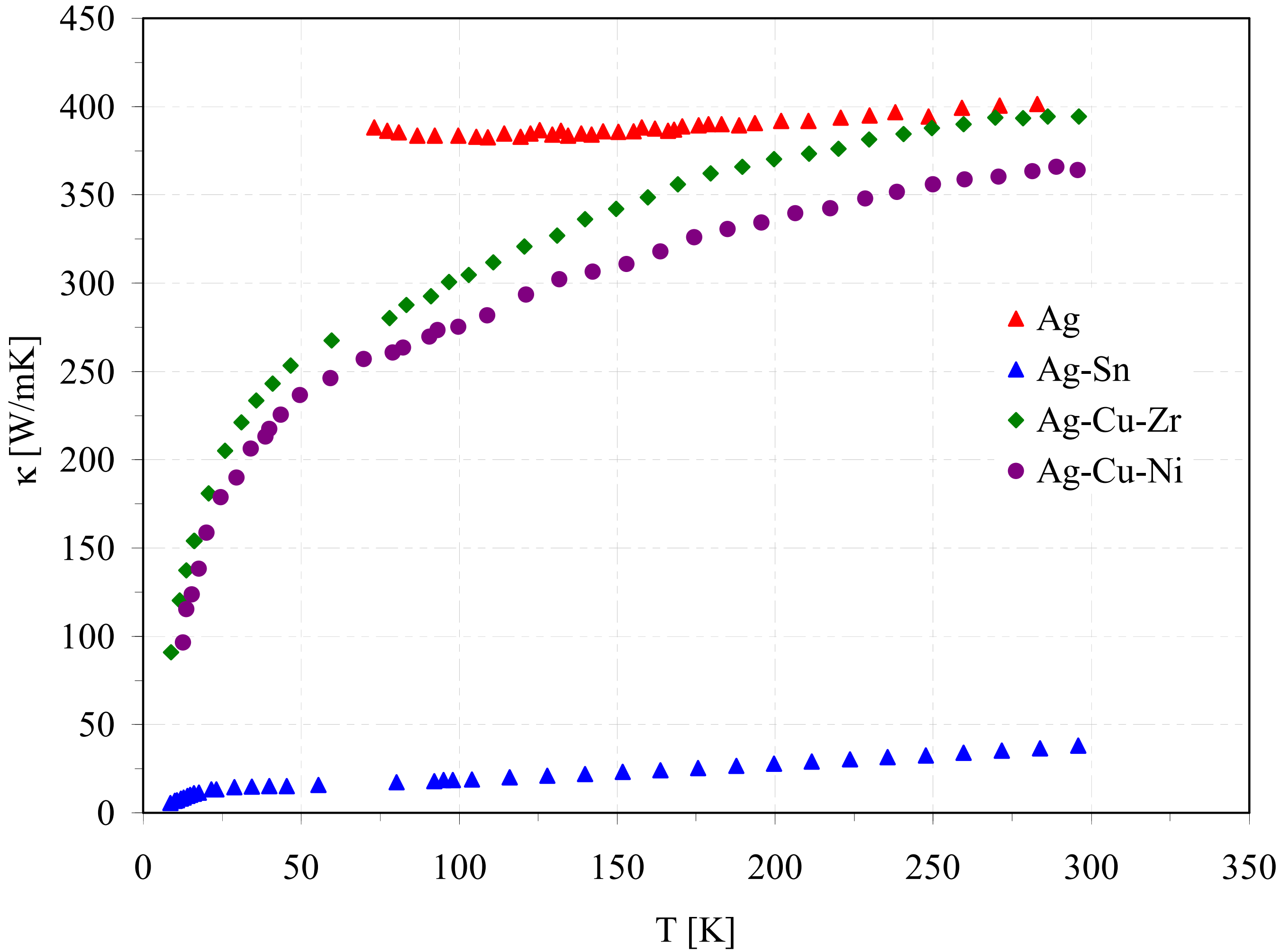


BSCCO/Ag/Ag-Cu-Zr

BSCCO/Ag/Ag-Cu-Ni



Thermal conductivity of sheath material – state after oxidation at 830°C/30h



Connections with Industry

PWR Cryogenic Group has well established relationship with Polish industry, including small and big companies

(for example: Rafako, Kriosystem, Wroclaw Technological Park, etc.)

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Example of RAFAKO cryo-products

Section of the STRING 1 and 2 test-rig

Example of KRIOSYSTEM products

Liquid nitrogen and liquid helium transfer lines

Example of KRIOSYSTEM products

Helium II cryostats

Summary

- PWR – University with over 160 years of tradition, 12 technical faculties, 2000 scientific stuff, more then 30.000 students
- The Faculty of Mechanical and Power Engineering (W9) – 64 years of tradition, 25 professors, 55 doctors , 20 assistants and 70 PhD students; Main subjects: basic and applied mechanical sciences in power engineering, thermal processes, avionics and refrigeration including cryogenics
- PWR Cryogenic Group – some ☺ years of tradition, 12 scientific stuff, strong experience in thermal and mechanical modeling, cryogenic devices designing, safety of the cryogenic systems analysis, process control and electronics, cooperation with international scientific centers and Polish industry