CERN

R&D topics in the CERN Central Cryogenic Laboratory (Cryolab)

Torsten Koettig on behalf of the Cryolab team

The Cryolab team

- 5 Technicians / Techn. Engineer
- 1.5 Staff
- 2 Fellows
- 2 PhD students
- 3 Students
- 1 Trainee
- 1 Internship

Mid. 2015

15.5 colleagues => ~35 projects/year

Content

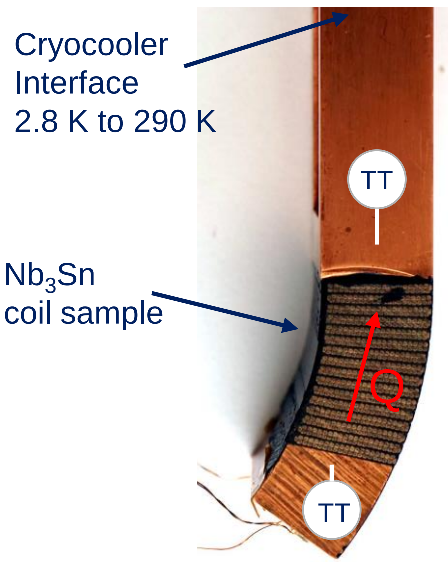
- Material property test stands
- HIE-ISOLDE => RF system thermal runaway mock-up test
- Superconducting RF – Cavity Quench spot localisation
- He II heat transport in confined geometries - Rutherford cable stacks
- “Zero” boil off cryostat for the Antimatter Factory
- Controlled cold He spill in the LHC tunnel

- Heat transfer at metallic dielectric interfaces at ultra low temperatures

Material property test stands

Thermal conductivity

T= 2.8 K to 300 K



- Nb_3Sn coil samples
- Inermet 180 alloy
- Titanium support rod
- RF high power cable
- OFHC copper
- Al 6061 & 5083

Thermal expansion

4.2 K and 78 K

- Inermet 180 alloy
- G10 warp and normal
- Al 6061, Al 5083

RRR and Tc

4.2 K to 300 K

- Nb on sapphire
- Nb on quartz
- Nb on Cu
- Nb Plate
- Cu on SS
- Nb_3Sn

Splice resistance

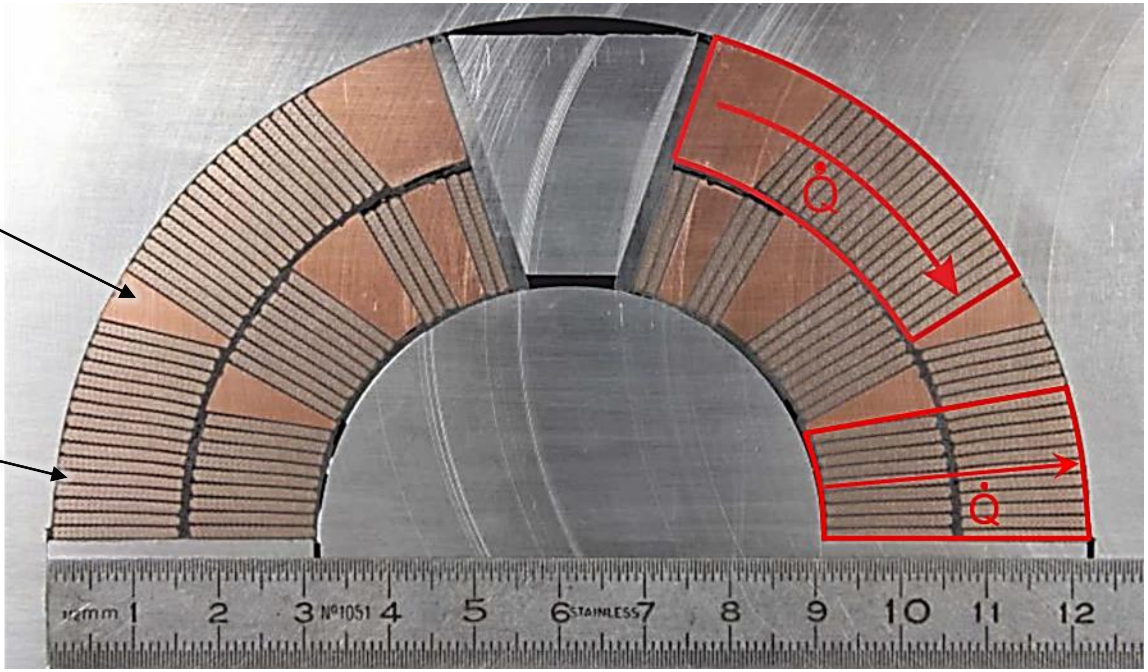
4.2 K

- MgB_2
- Explosion welded interfaces

High Luminosity upgrade of LHC – Nb_3Sn magnets

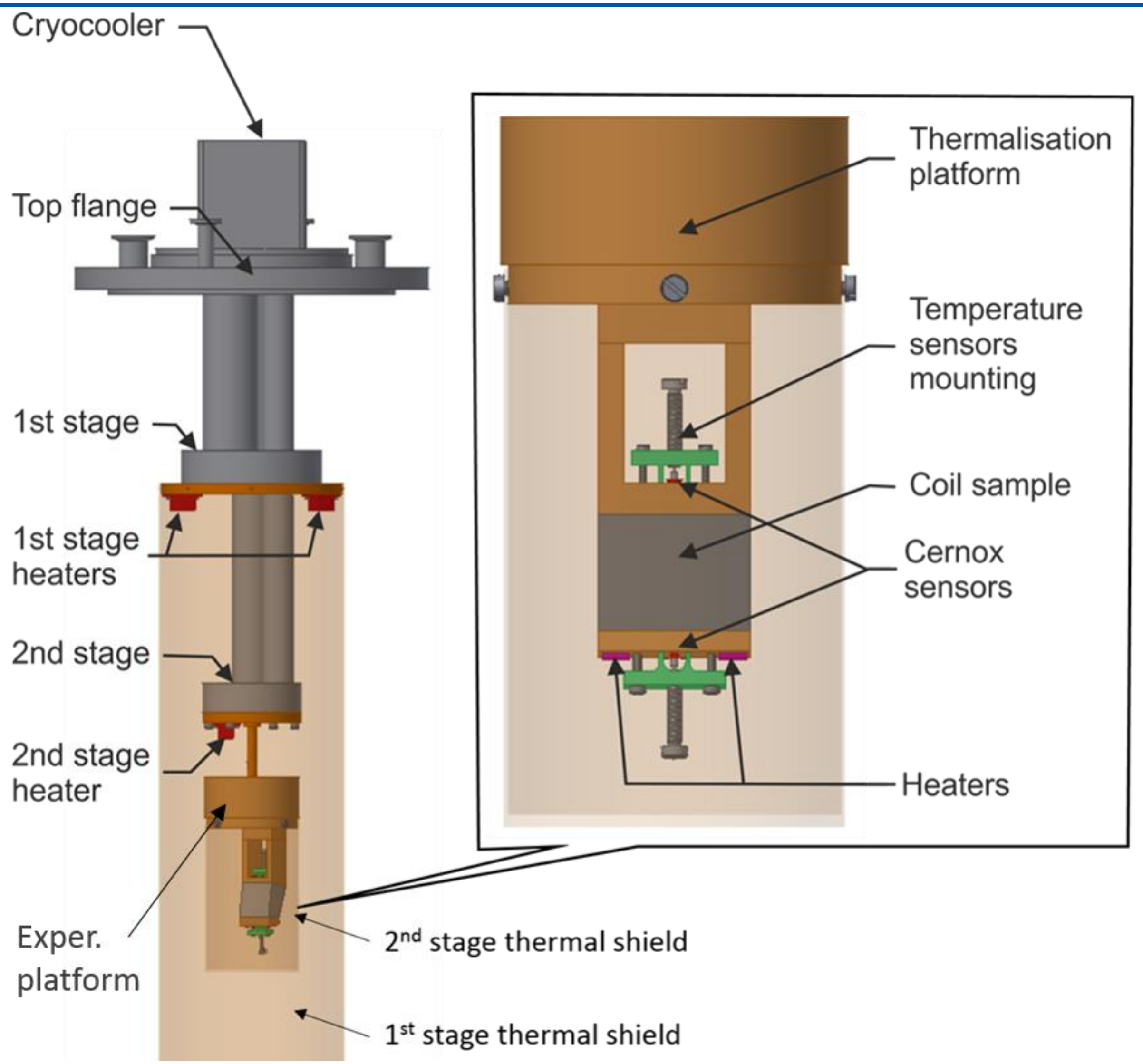
Copper wedges:

Rutherford cable:
40 strands of ø 0.7 mm



- Fully impregnated coils with binder and resin
- Cooling only by superfluid helium at the inner surface
- Thermal conductivity data are essential for quench propagation study

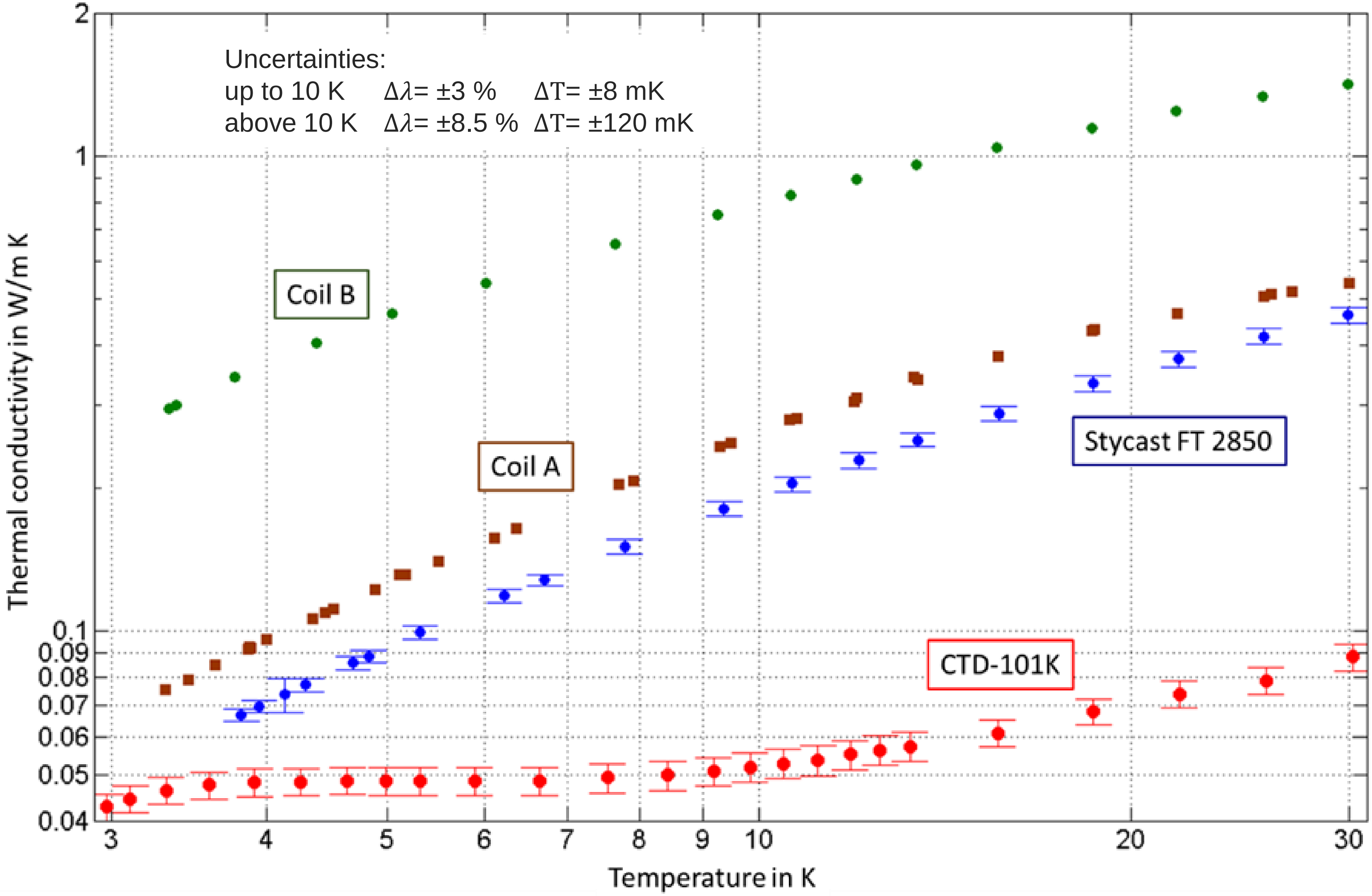
Thermal conductivity test set-up

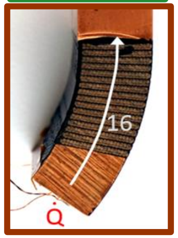


Instrumentation:

- 3 temperature sensors calibrated to each other + offset compensation
- Stepwise change of platform temperature 1-2 K
- ΔT on sample 0.2 to 0.3 K
- Electrical heater chosen to expected therm. conductance
- Wires for current Ø0.1 mm Cu
- T-sensor + voltage taps Ø 0.127 mm Manganin twisted pairs
- Heat intercepts at each stage and at the exp. platform

Measurement results impregnated Nb_3Sn coil smaples

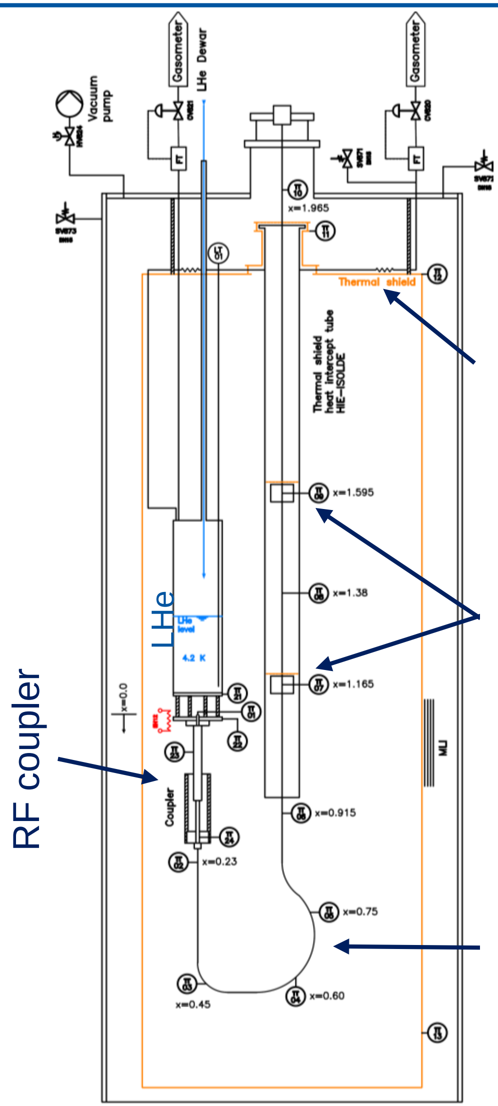


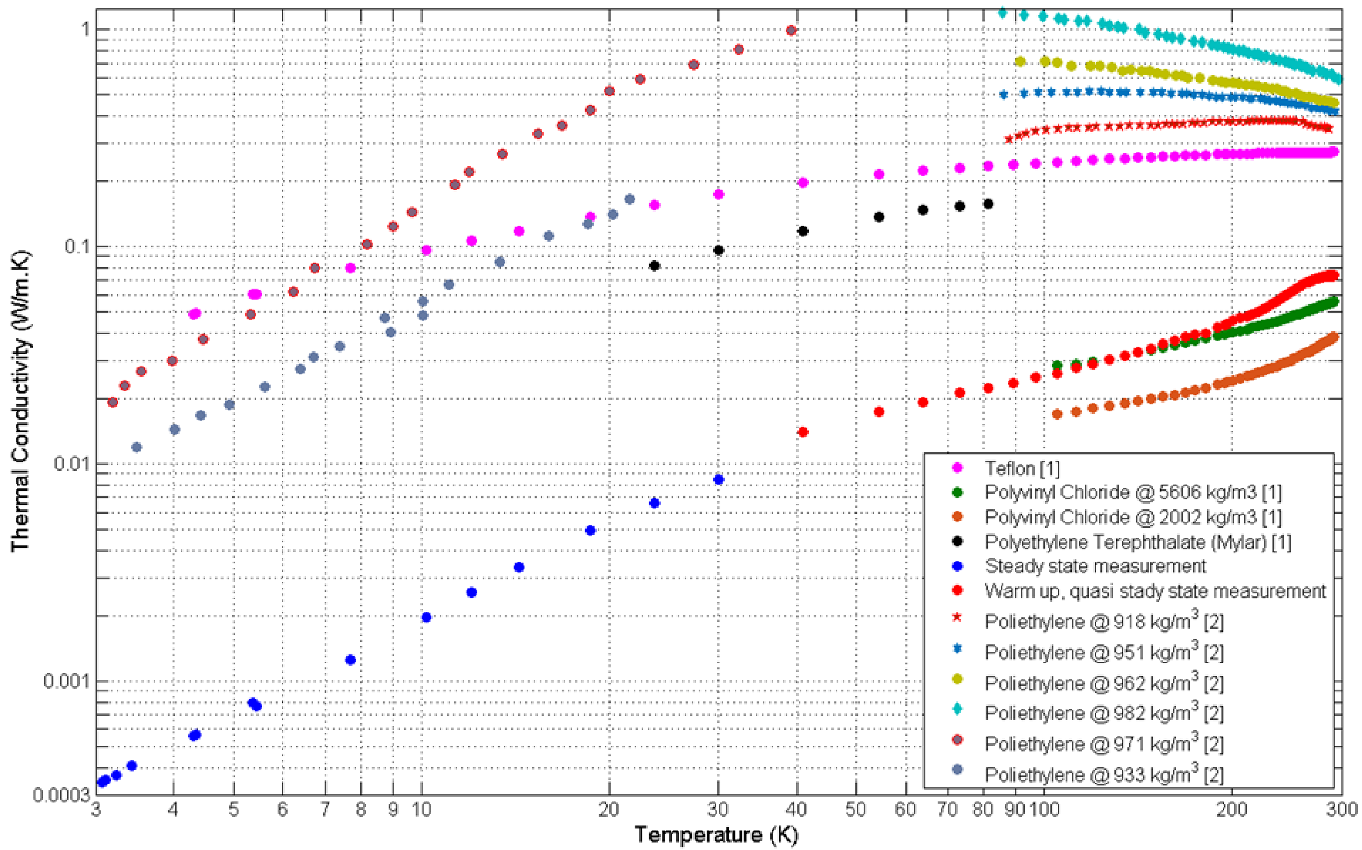


HIE-ISOLDE thermal test of the cryo-RF system

Reproducing thermal conditions of HIE-ISOLDE CM1

Coupler and high power RF cable test set-up in vacuum



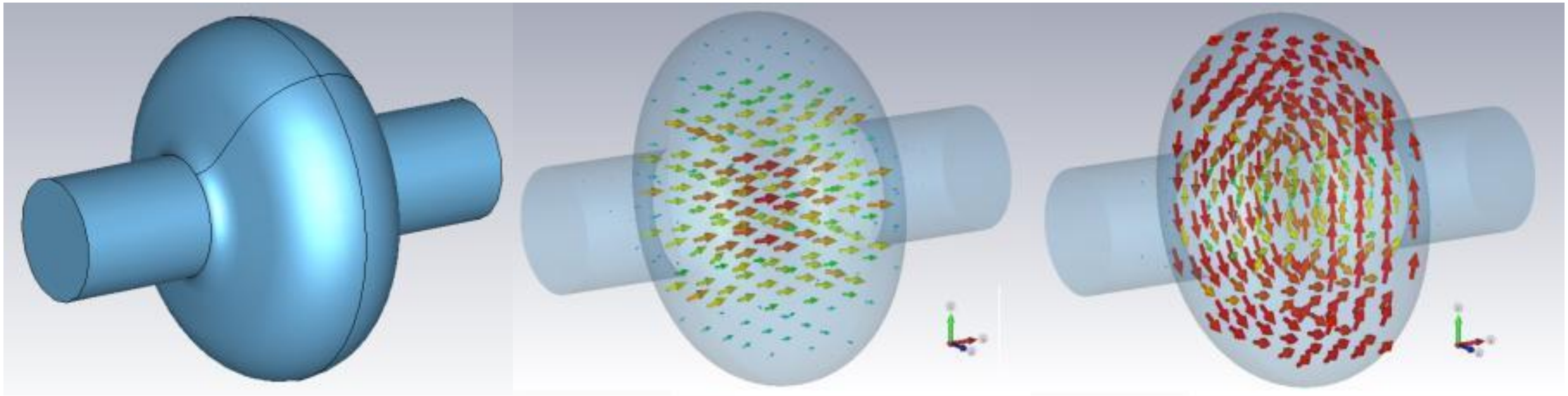


[1] http://cryogenics.nist.gov/MPropsMAY/materialproperties.htm [2] Perepechko, Low temperature Properties of Polymers

Superconducting radio frequency cavities

- Resonators are used to accelerate charged particles in an alternating electric field
- The ac electric field is resulting in an ac magnetic field
- The resonator houses the electro magnetic field by surface currents
- Currents lead to heating of the cavity related to the electric resistance of the resonator
- Electrical resistance is minimized by use of superconductors

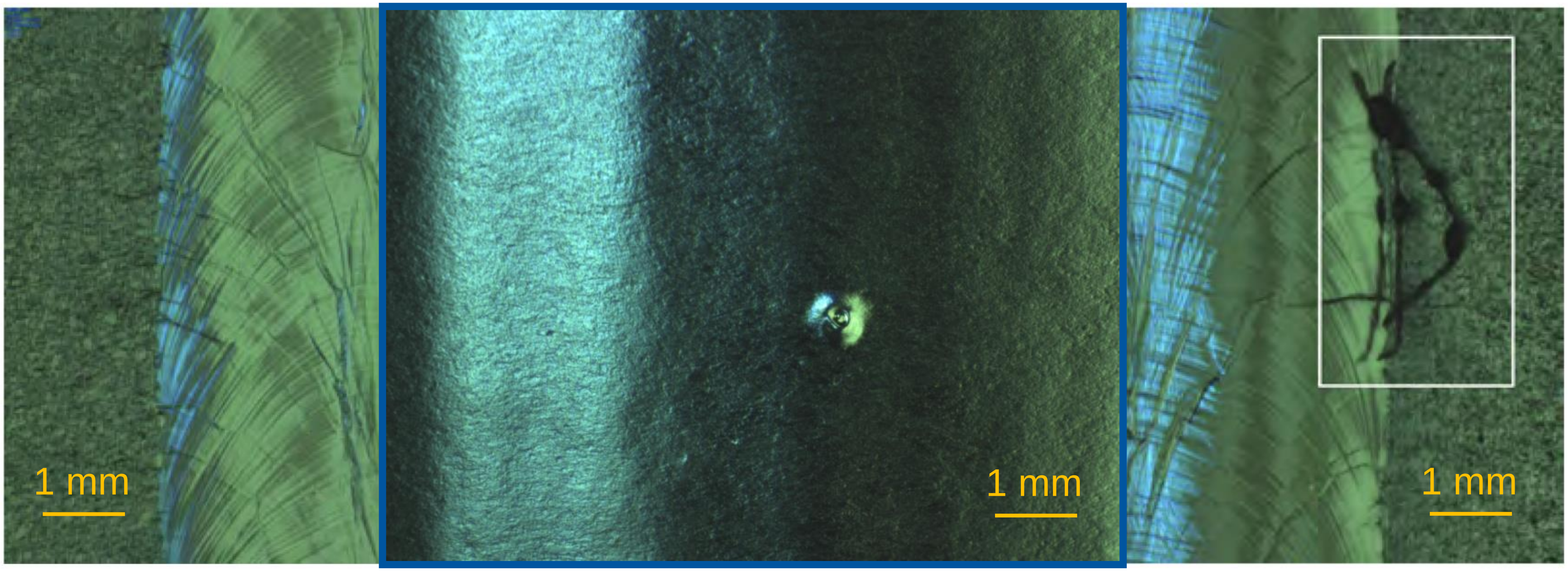
Elliptical cavity, standing wave resonator => electric field distribution magnetic field distribution.



Courtesy: P. Zhang simulation tesla style cavity

Superconducting radio frequency cavities - imperfections

- Loss of superconductivity by exceeding critical surface: temperature, current, magnetic field,
- The ac electromagnetic field causes heat dissipation at the normal conducting spot (defect),
  => can lead to a propagating quench.



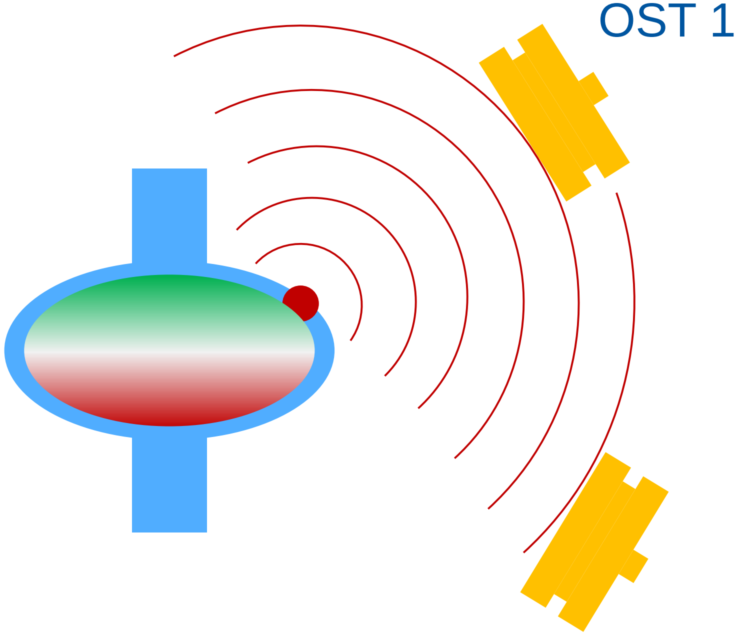
Pictures courtesy of: S. Horvath-Mikulas, CERN BE/RF-SRF

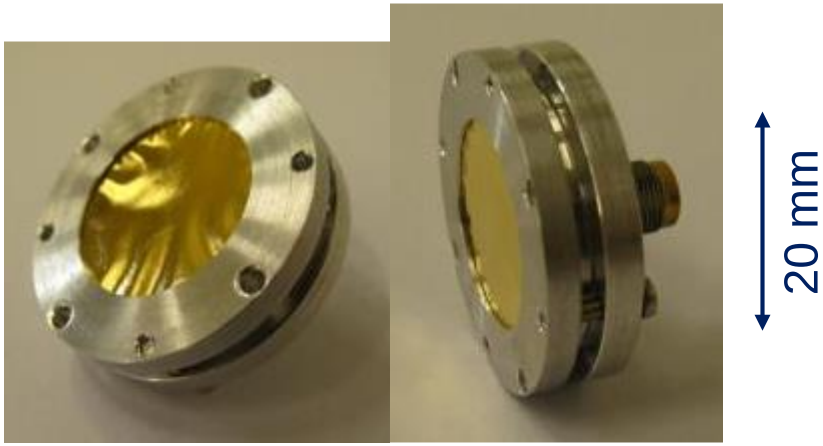
- Stored energy of an acceleration cavity is in the range of **100 J**.
- Duration of a quench is typically in the range of **milliseconds**.
- Typical defects are usually significantly smaller than **1 mm**.

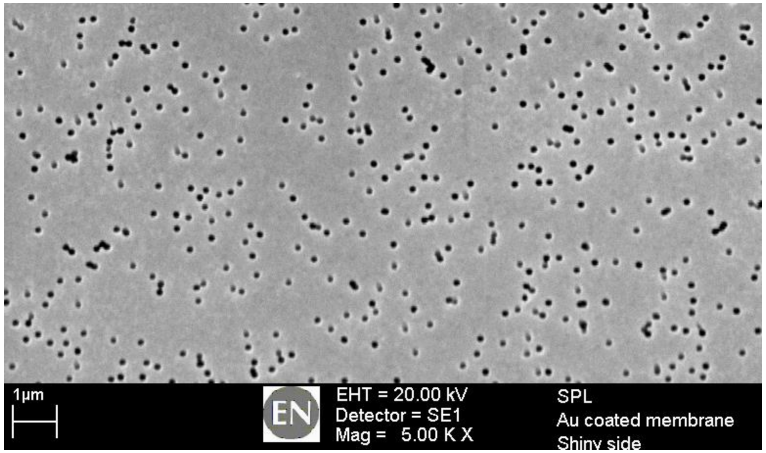
$\left.\right\} \dot{Q} > 10\ \mathrm{kW/cm^2}$

He II – Oscillating Superleak Transducers (OST)

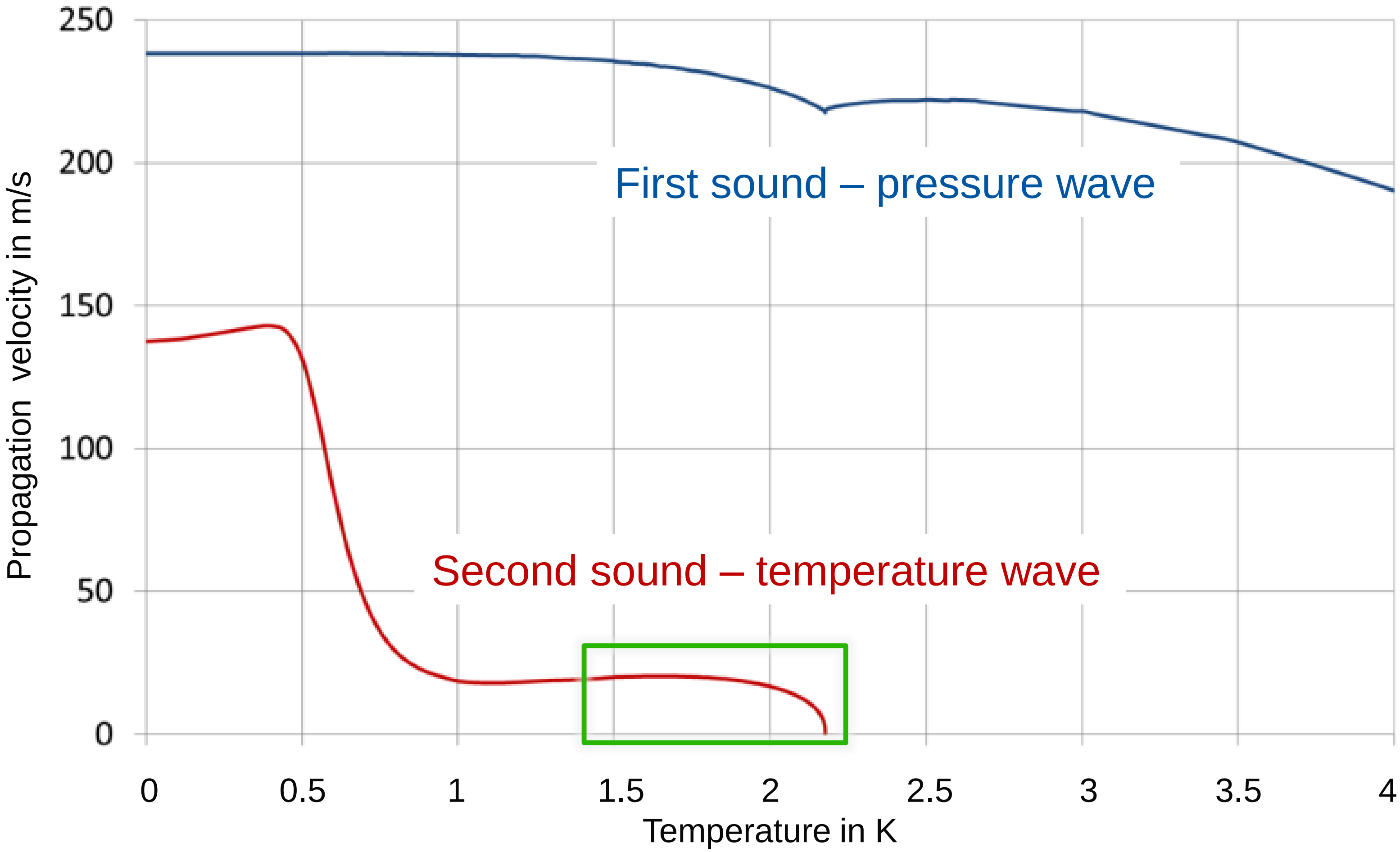
Detection and localization of quench spots on superconducting RF cavities by the measurement of the second sound propagation





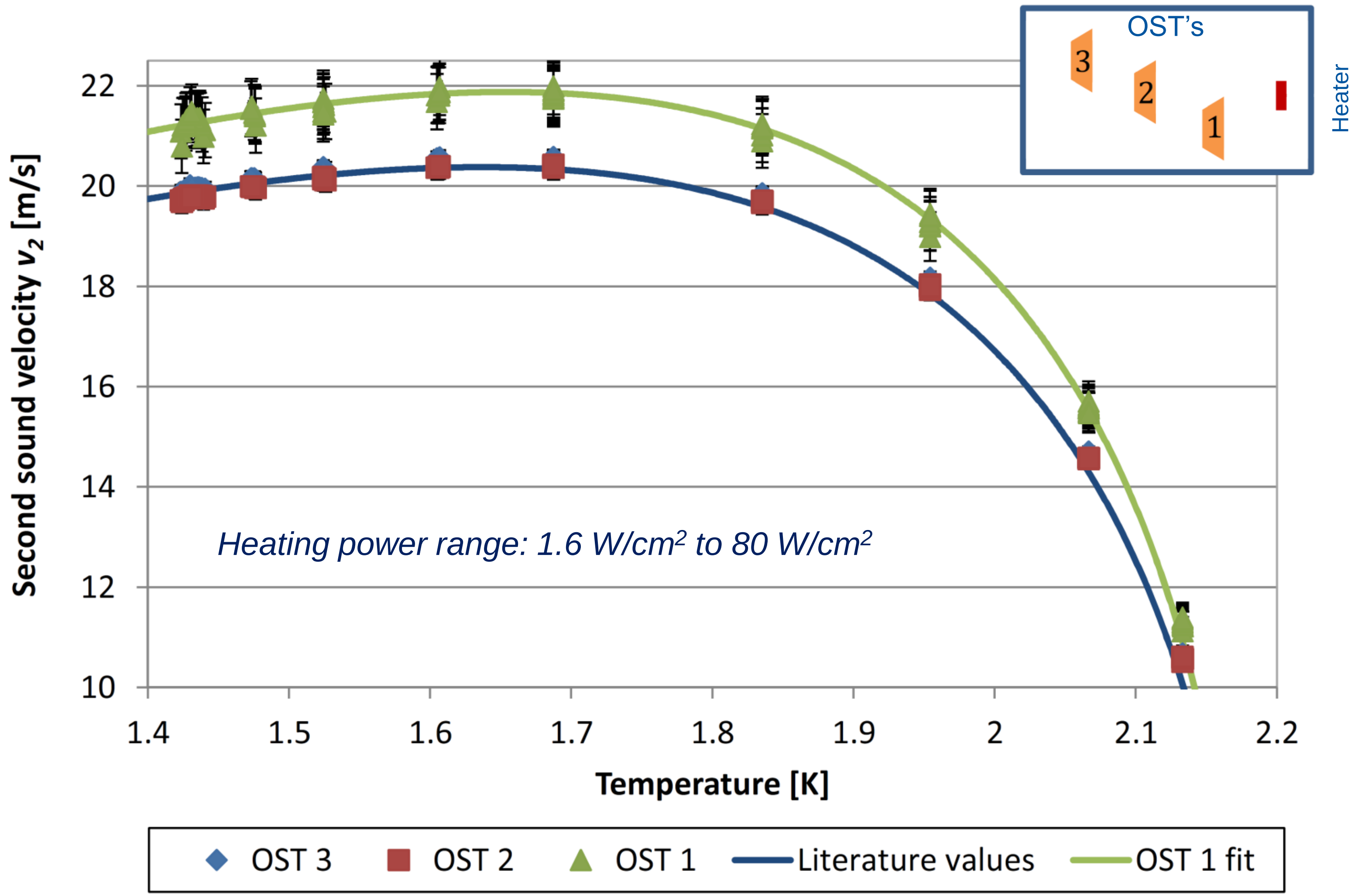


Propagation velocity of second sound in He II

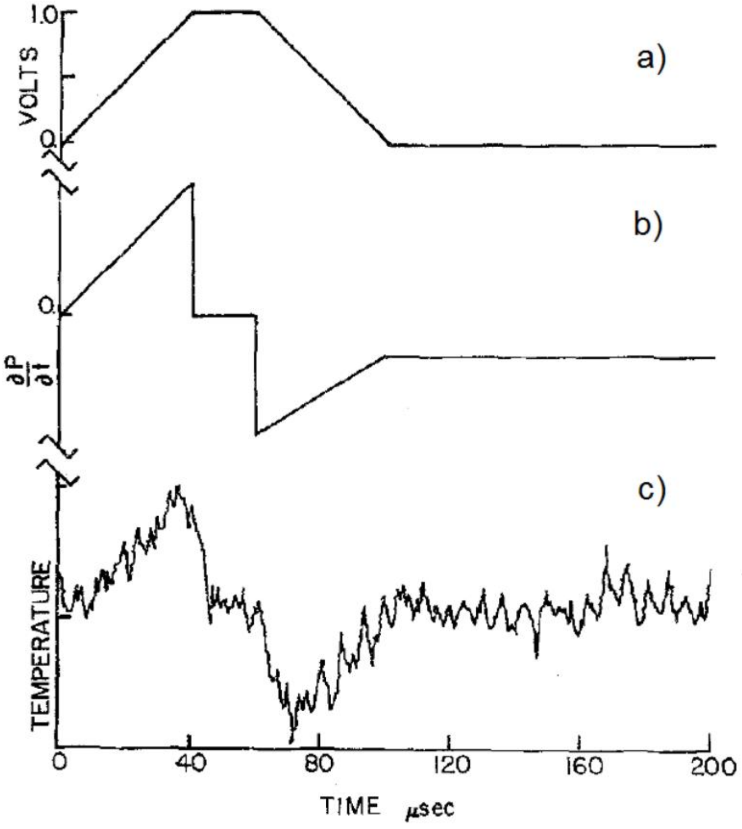


Data from Hepak®

Second sound velocity - heat flux dependency



Second sound – 3d propagation



Pulse shape study

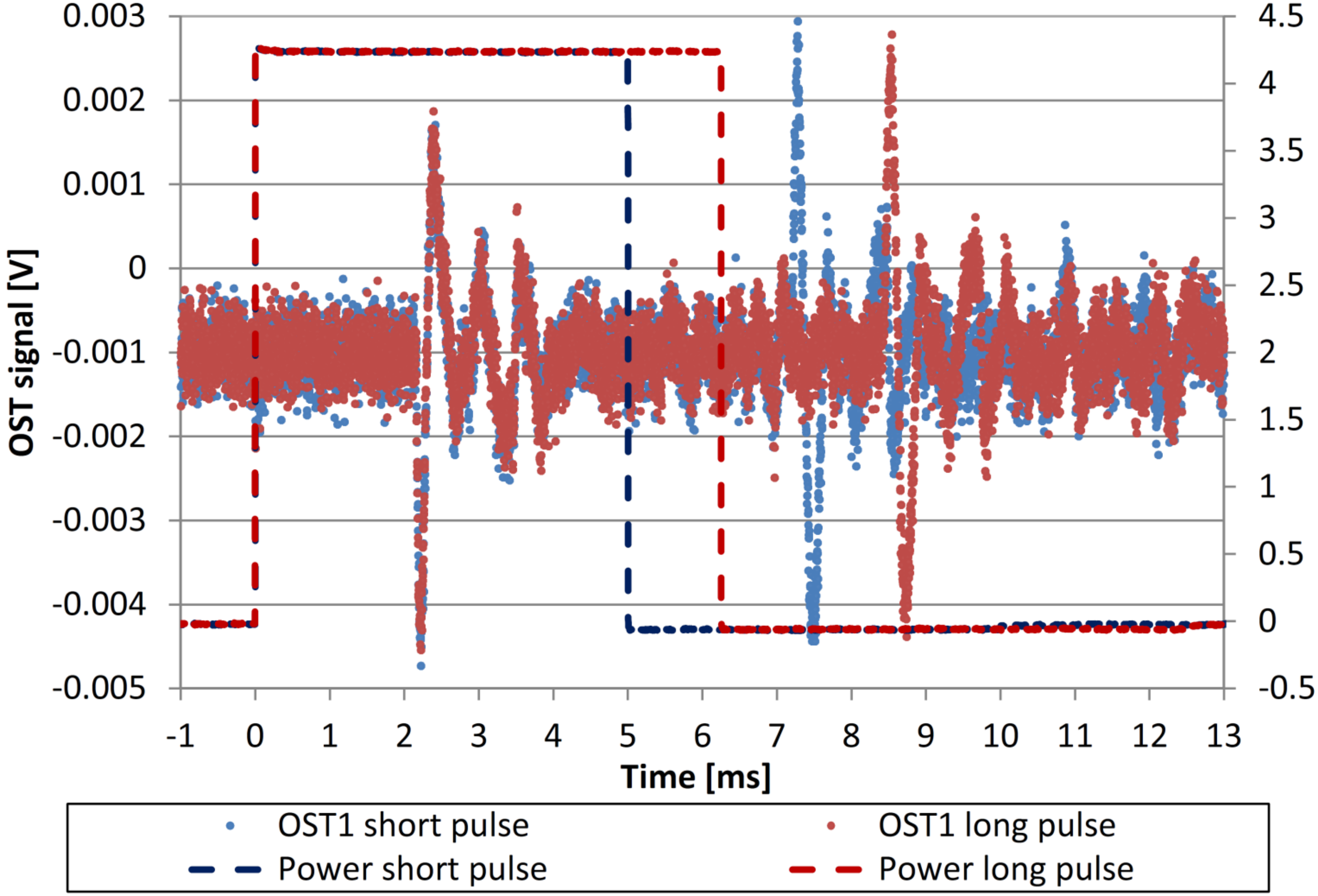
a) The input voltage pulse to create heating with a resistor immerged in He II. One has to consider the heating power is $P = U^2/R$.

b) The time derivative of the input power.

c) The measured second sound pulse at 1.449 K and 10.8 atm. (the signal was already post processed)

T. Worthington, J. Yan and J. U. Trefny, "Shape analysis of pulsed second sound", *Journal of Low Temperature Physics,* Vol. 22, pp. 293-300, 1976.

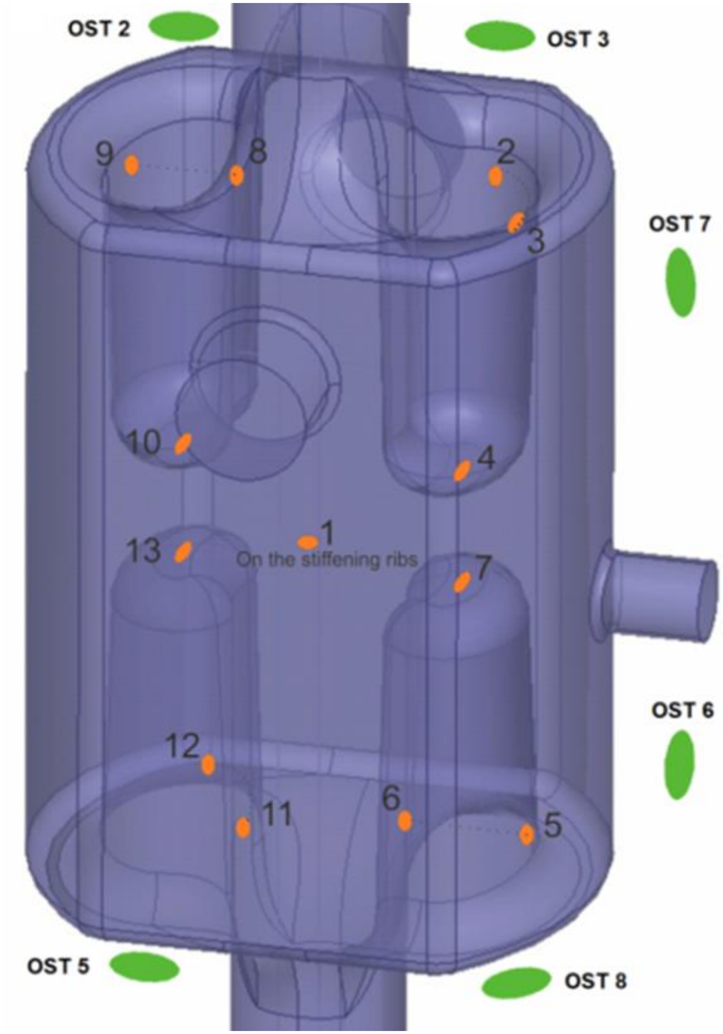
Second sound – 3d propagation

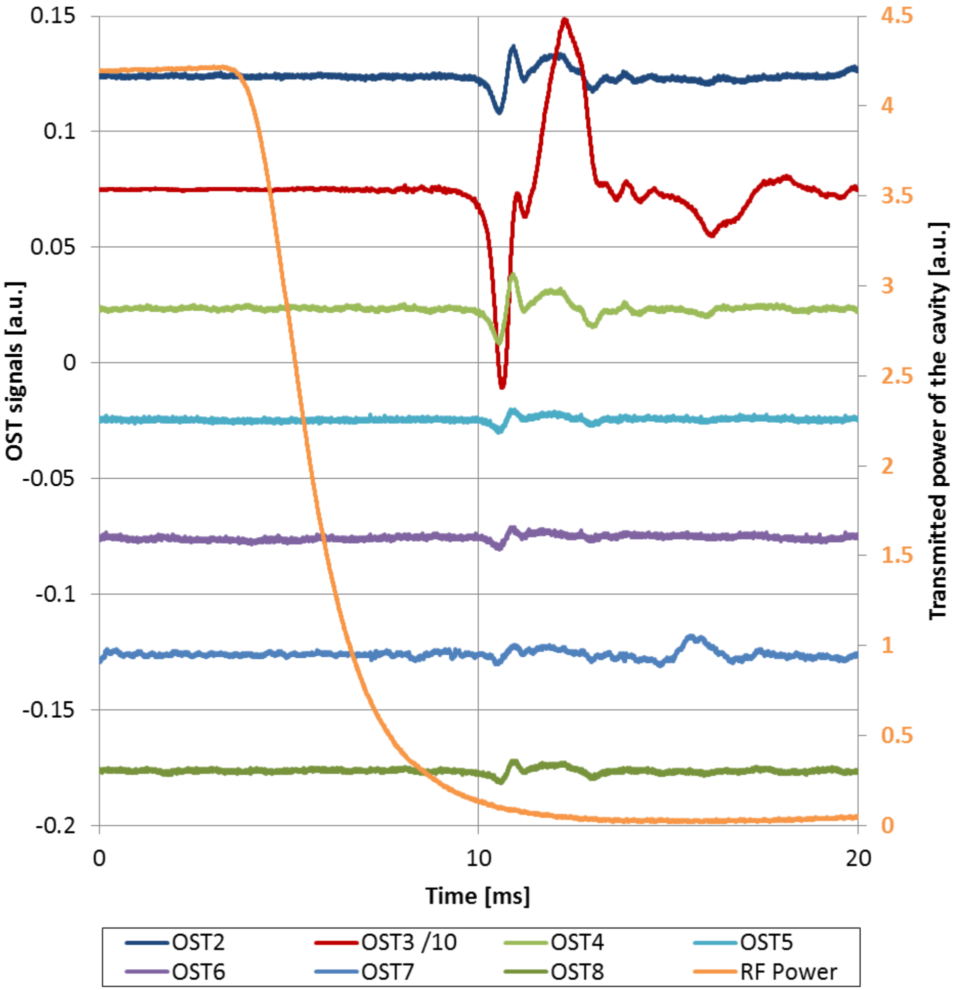


Observed Boiling in He II

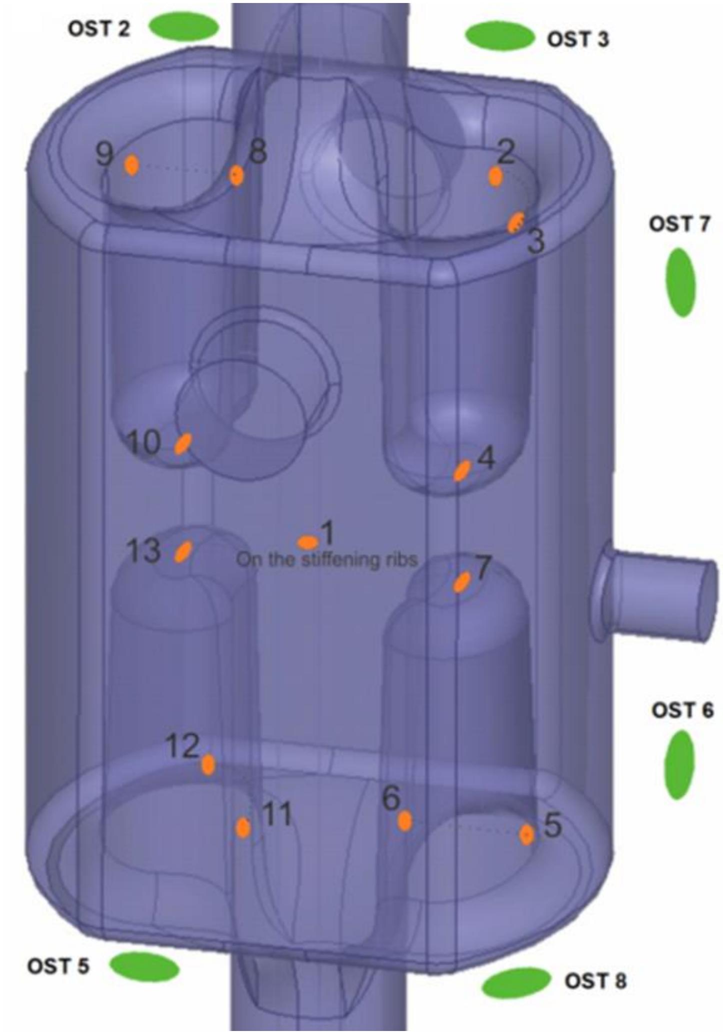
RF heater in He II => 700 W/cm^2 heating pulses

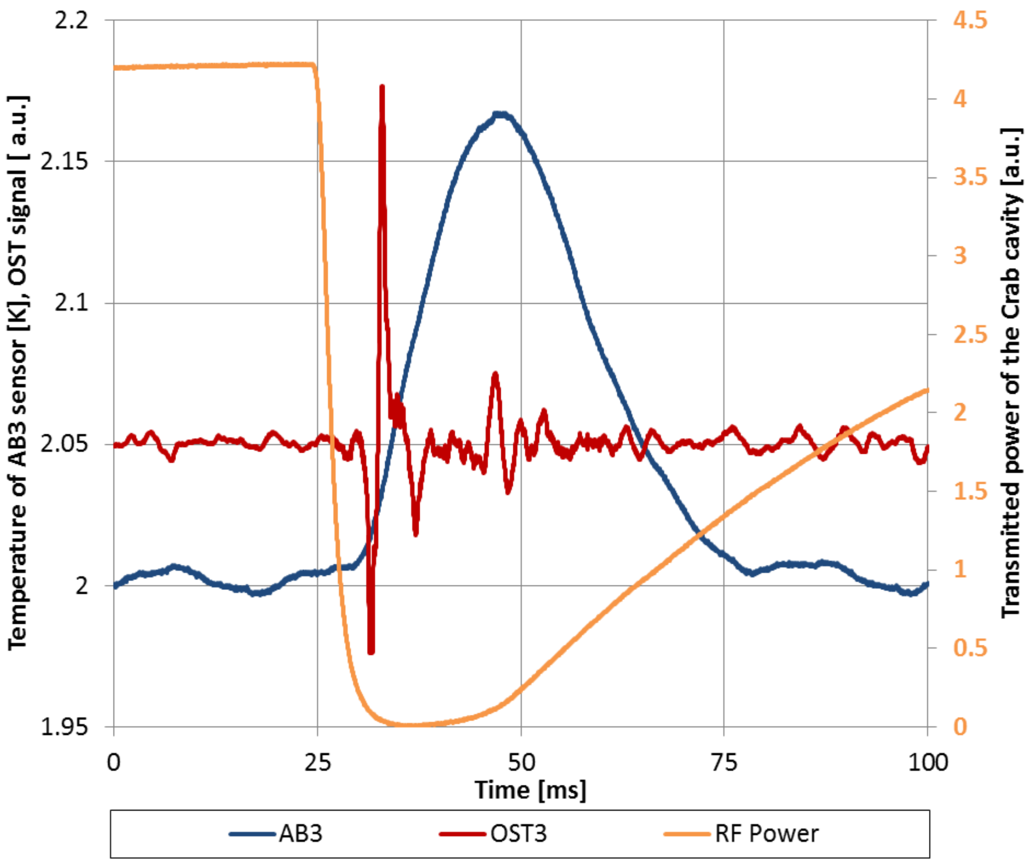
OST Quench localization - CRAB cavity (BE/RF-SRF)



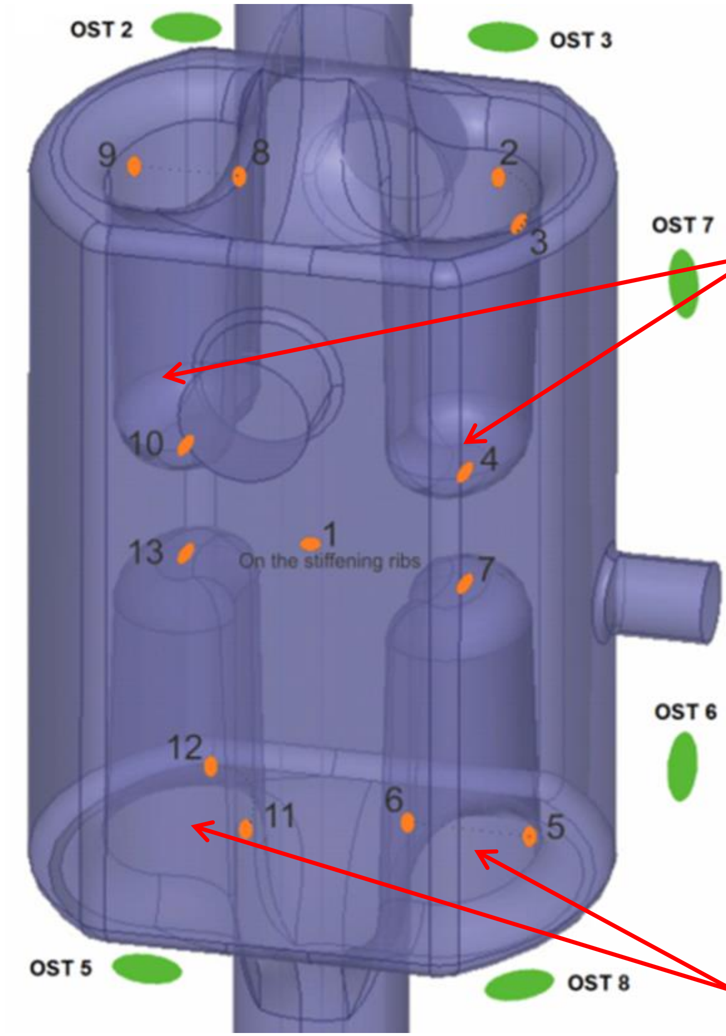


OST Quench localization - CRAB cavity (BE/RF-SRF)





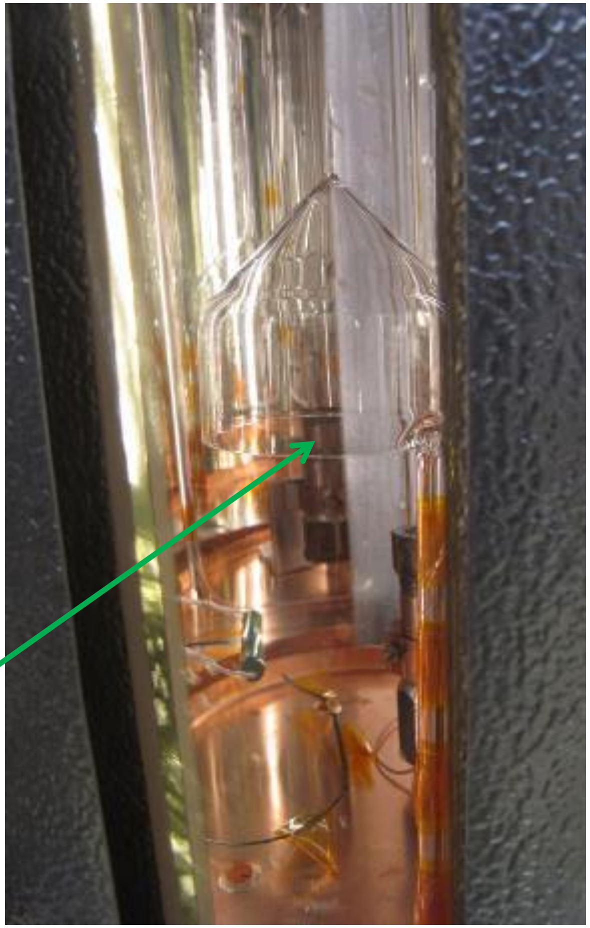
Trapped volume in liquid helium



Two deep-drawn structures from top

Two deep-drawn structures from bottom

Set-up with glass beaker



Upside down installed glass beaker representing the trapped vapor volume

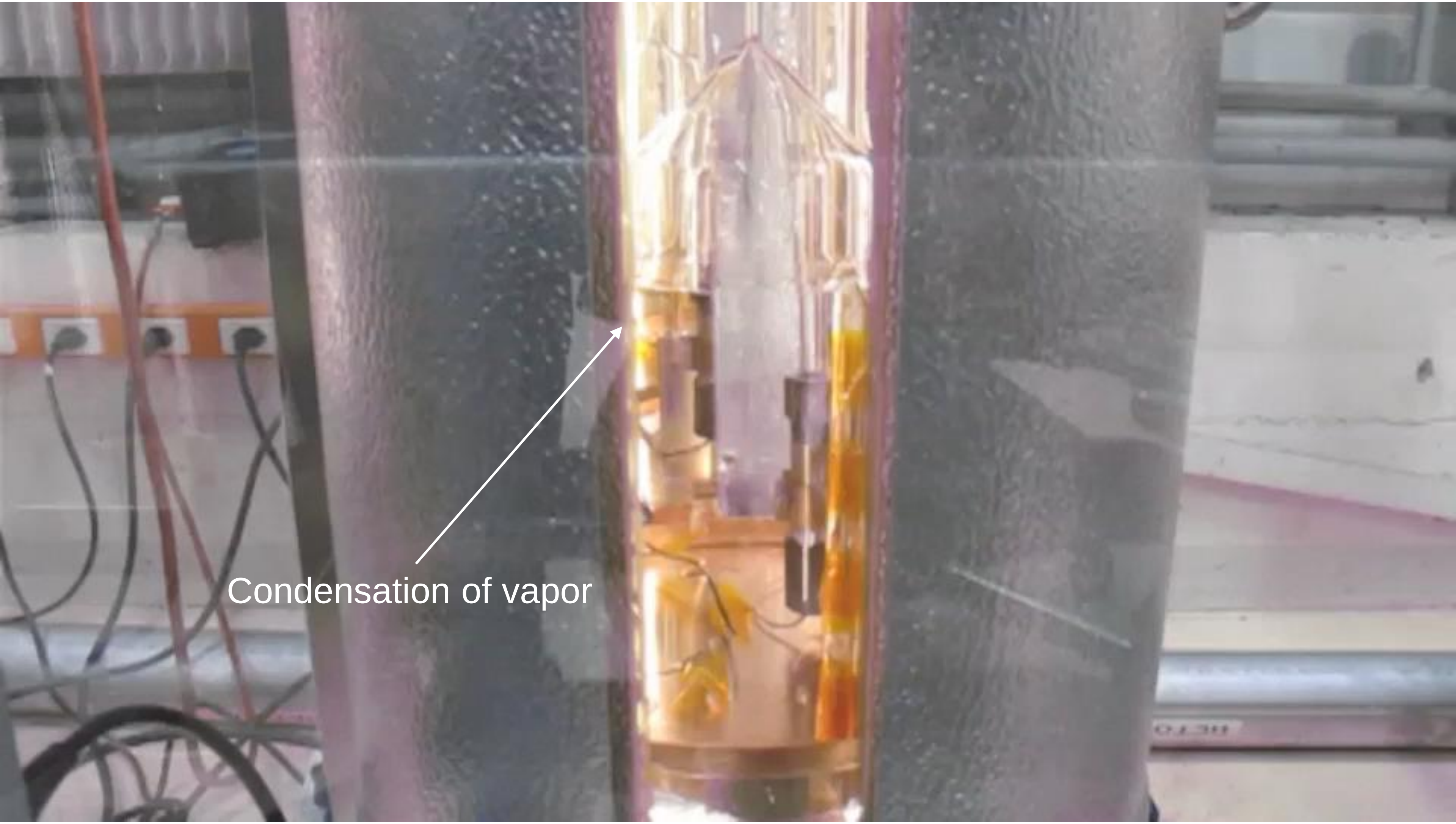
LHe at 4.2 K and saturated vapor pressure

Conditions:

- Saturated He bath
- 0.2 m static height

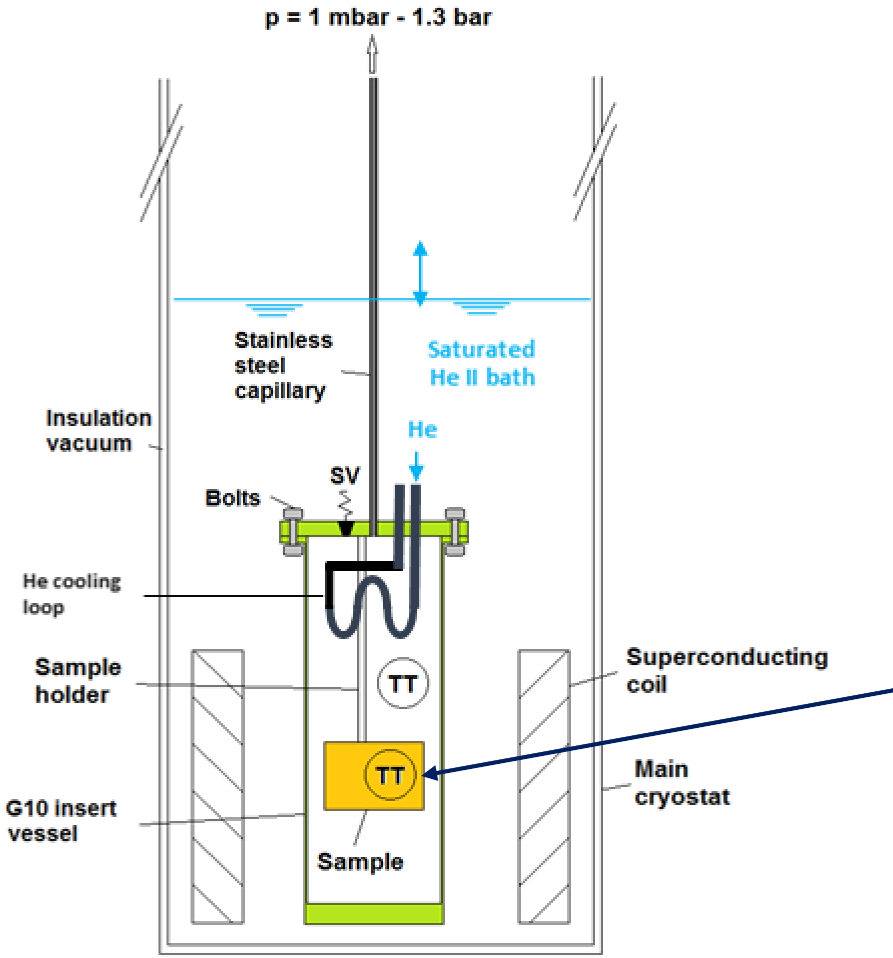
No condensation of vapor during 8 h.

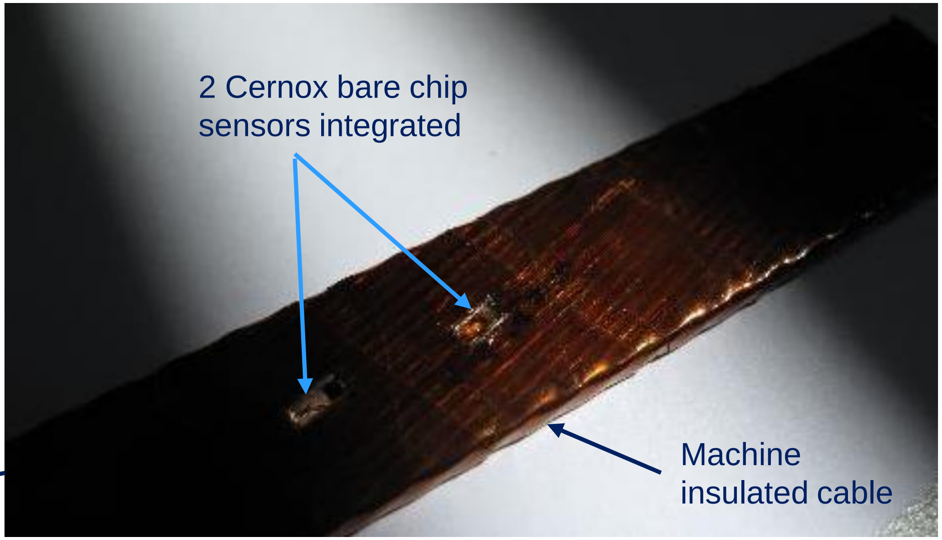
Helium - lambda transition p < 50.4 mbar



He II - Transient heat transport in LHC cable stack

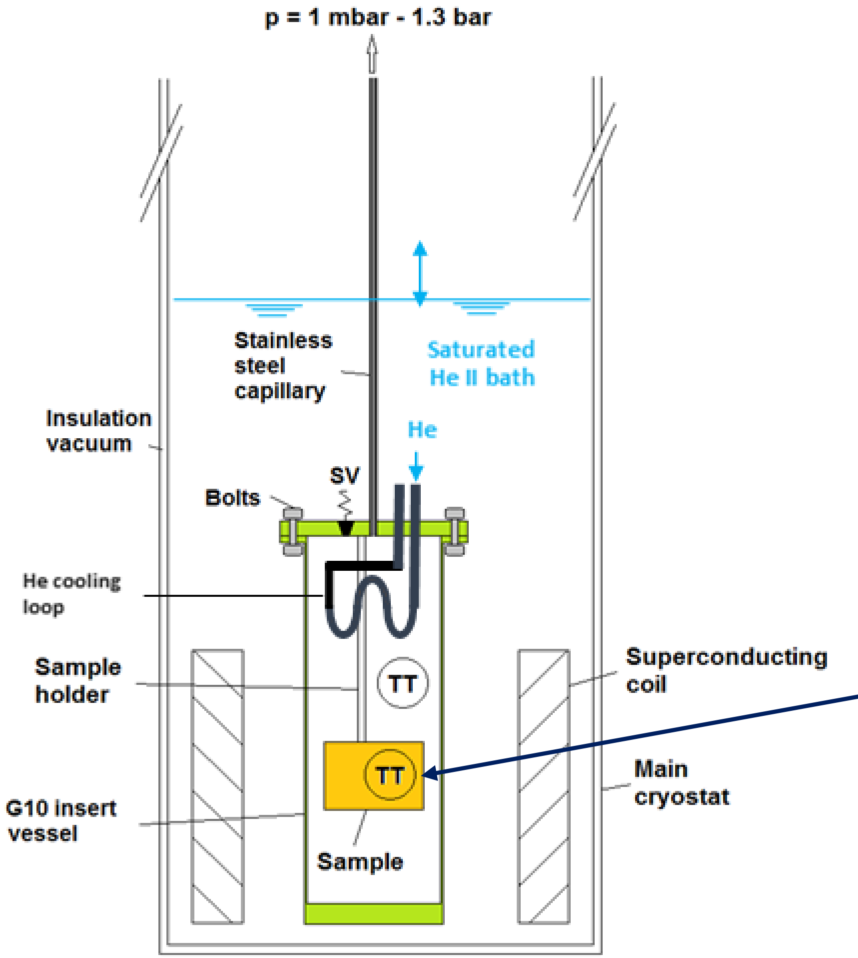
Study on the He II heat transport within the voids of a superconducting Rutherford cable stack.
Use of AC loss mechanisms to generate heat in real superconducting cables.

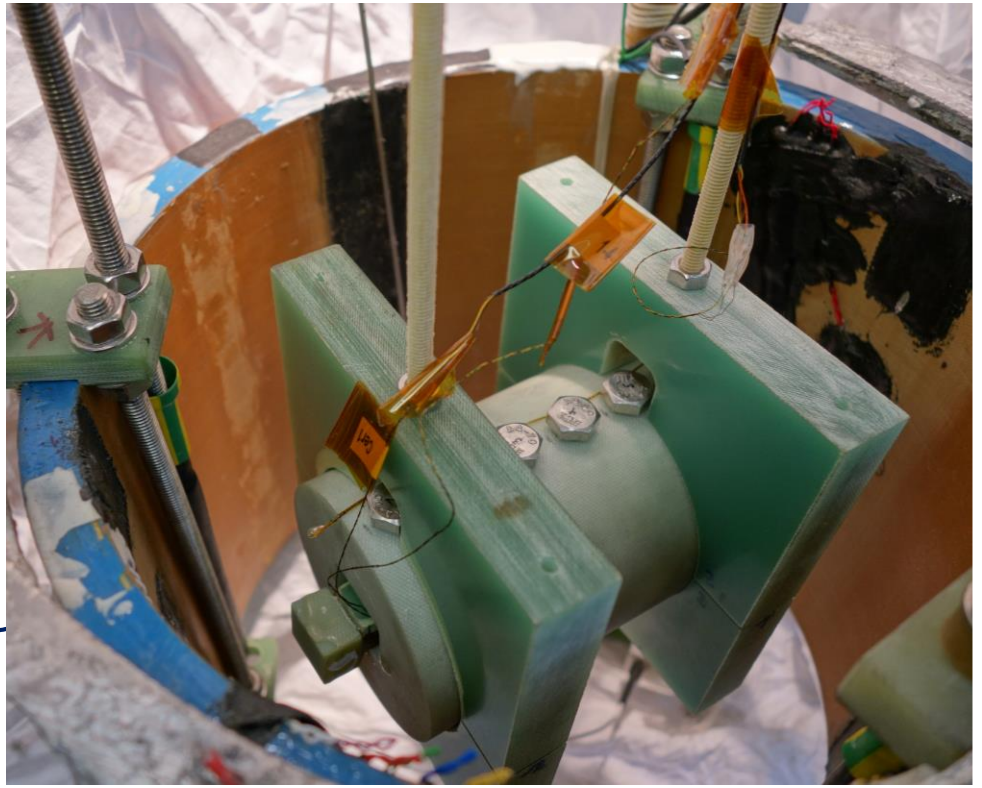




He II - Transient heat transport in LHC cable stack

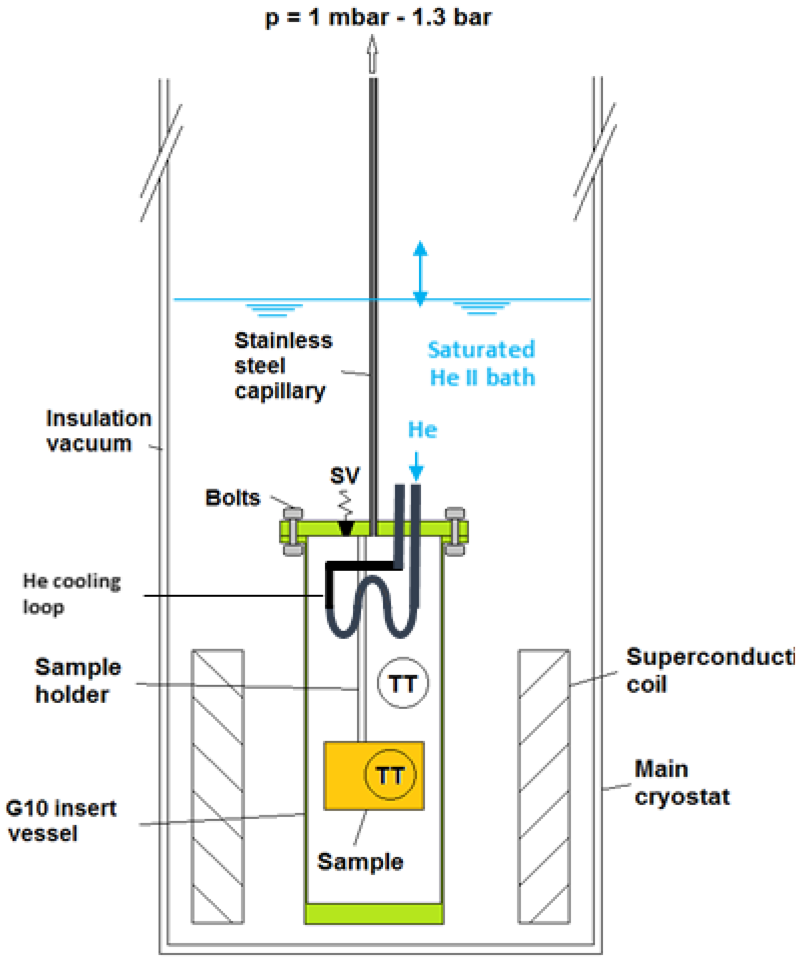
Study on the He II heat transport within the voids of a superconducting Rutherford cable stack.
Use of AC loss mechanisms to generate heat in real superconducting cables.



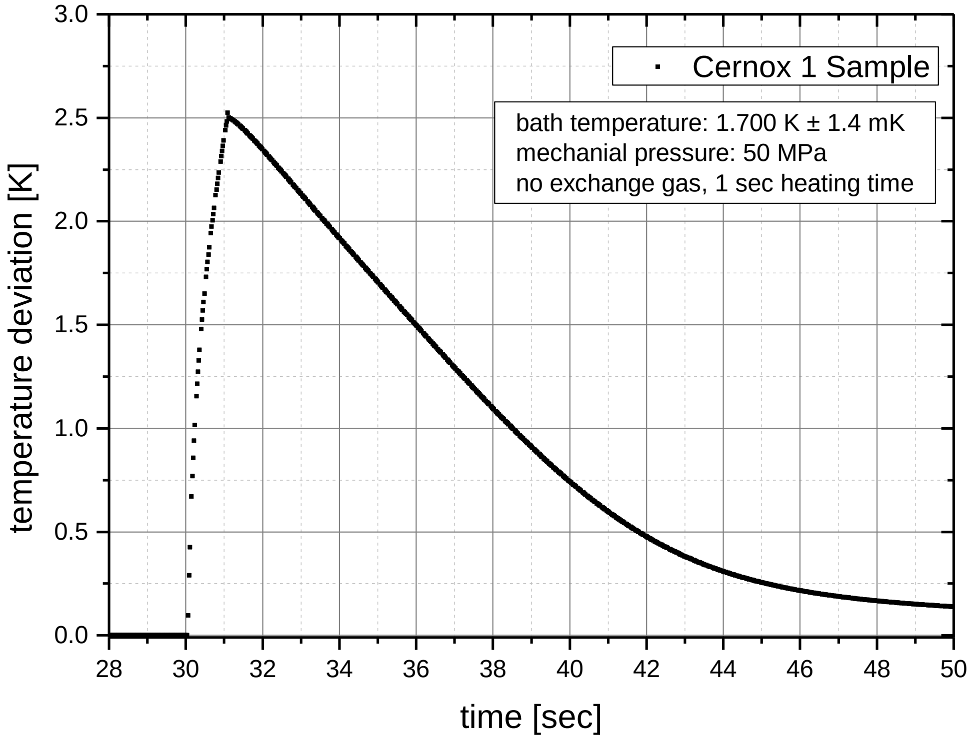


He II - Transient heat transport in LHC cable stack

Study on the He II heat transport within the voids of a superconducting Rutherford cable stack.
Use of AC loss mechanisms to generate heat in real superconducting cables.

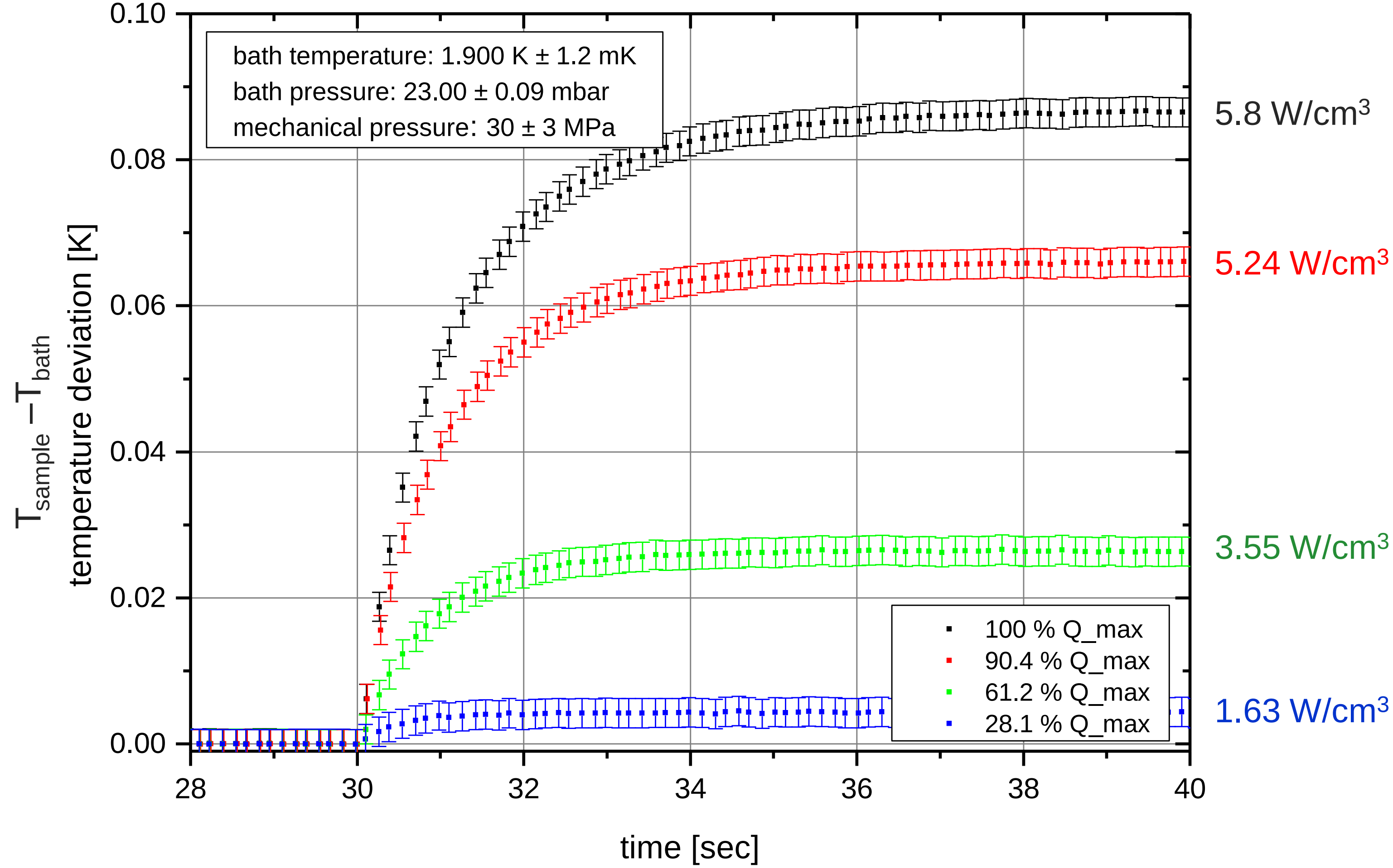


Calorimetry =>
determine generated heat in the sample



He II - Transient heat transport in LHC cable stack

Sample 30 MPa mechanical pressure, saturated He II, different applied heating powers

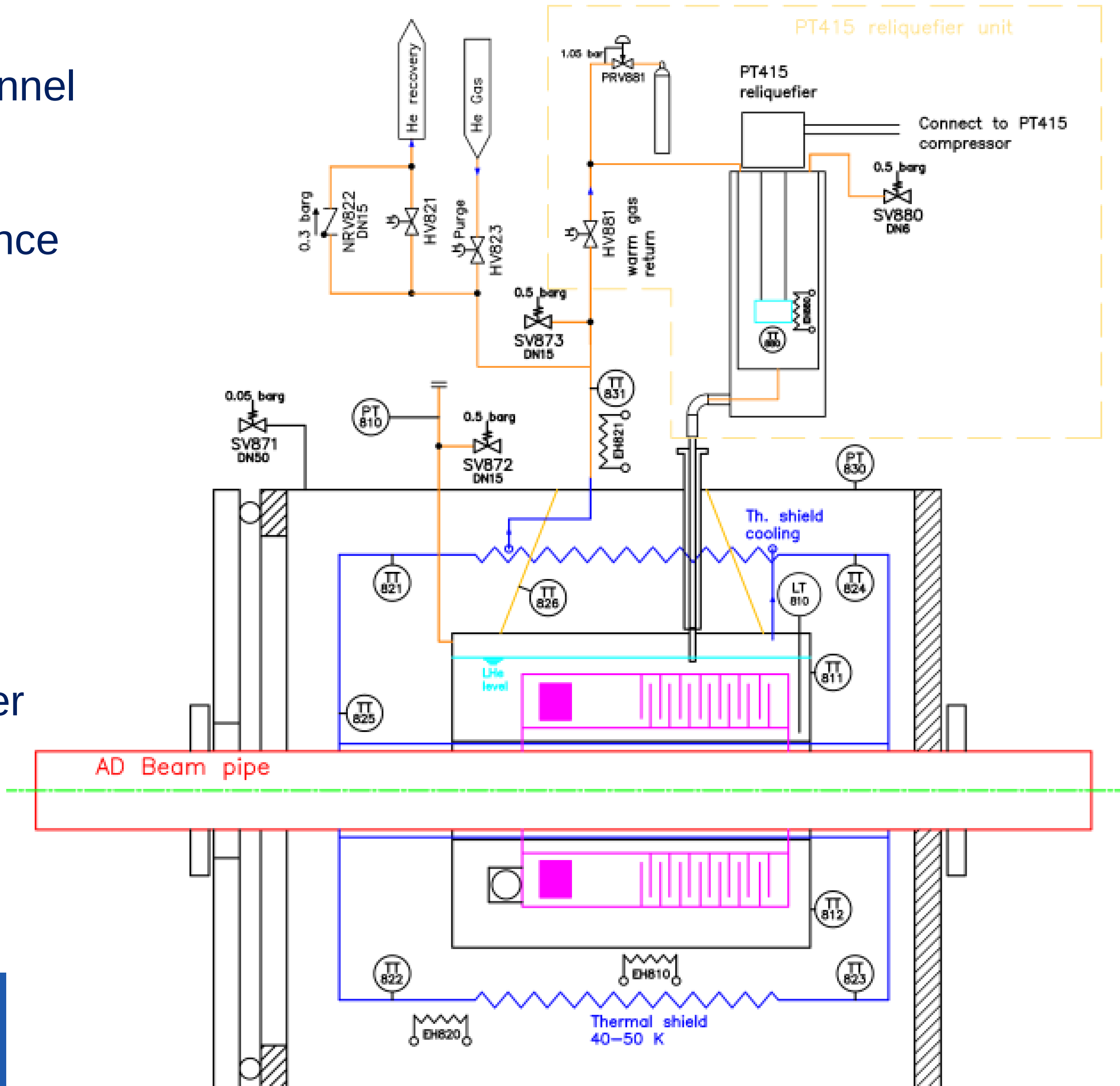


Cryogenic System of the BCCCA - P&ID

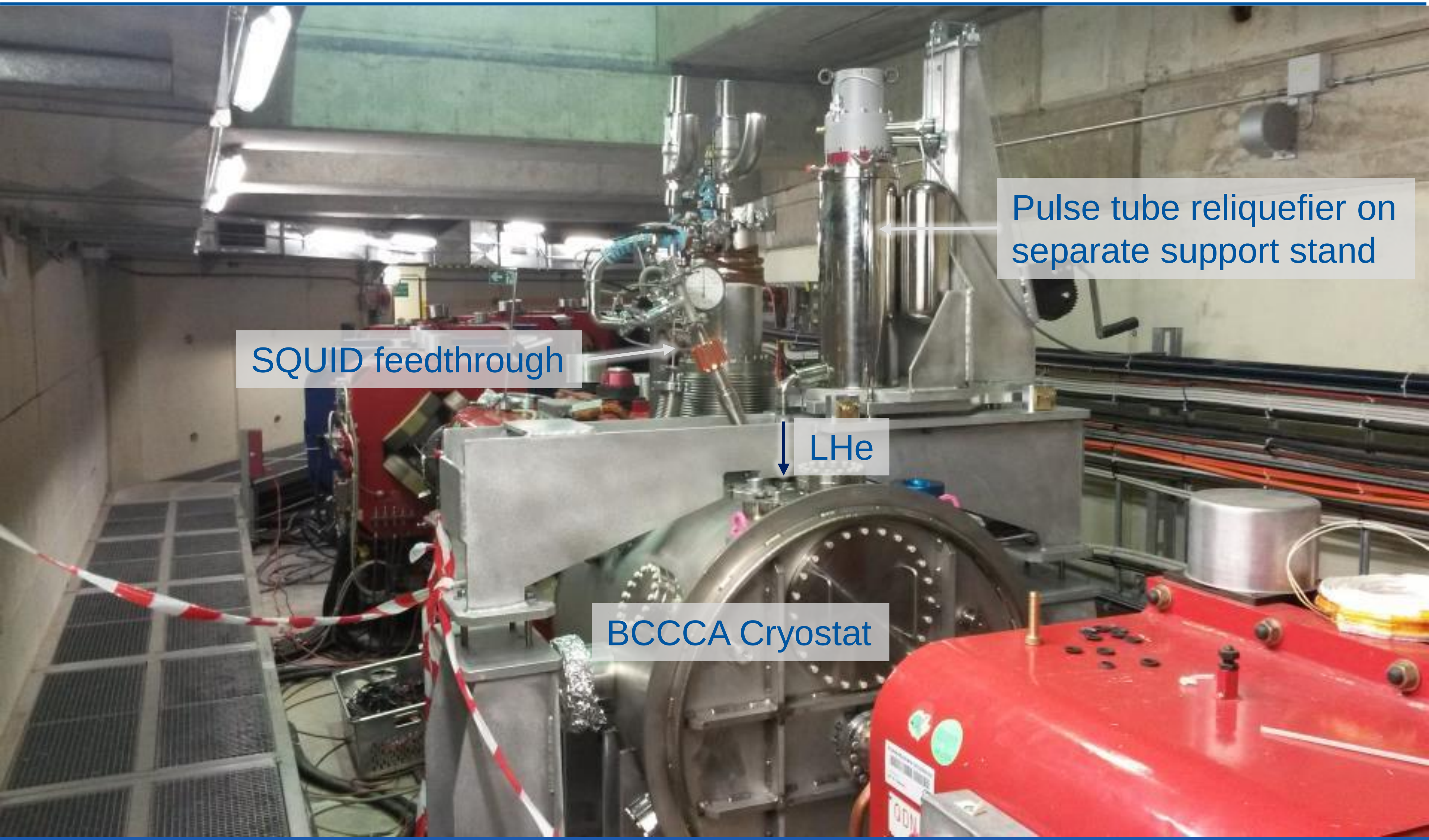
- Access limitation in AD tunnel
- Long term operation
- Low vibration levels
- Electromagnetic interference

"Zero boil off" cryostat using a pulse tube refrigerator as reliquefier unit

Only one commercial supplier
=> Cryomech Inc.
Liquefaction rate 15 L/day
equiv. to 0.43 W @ 4.2 K



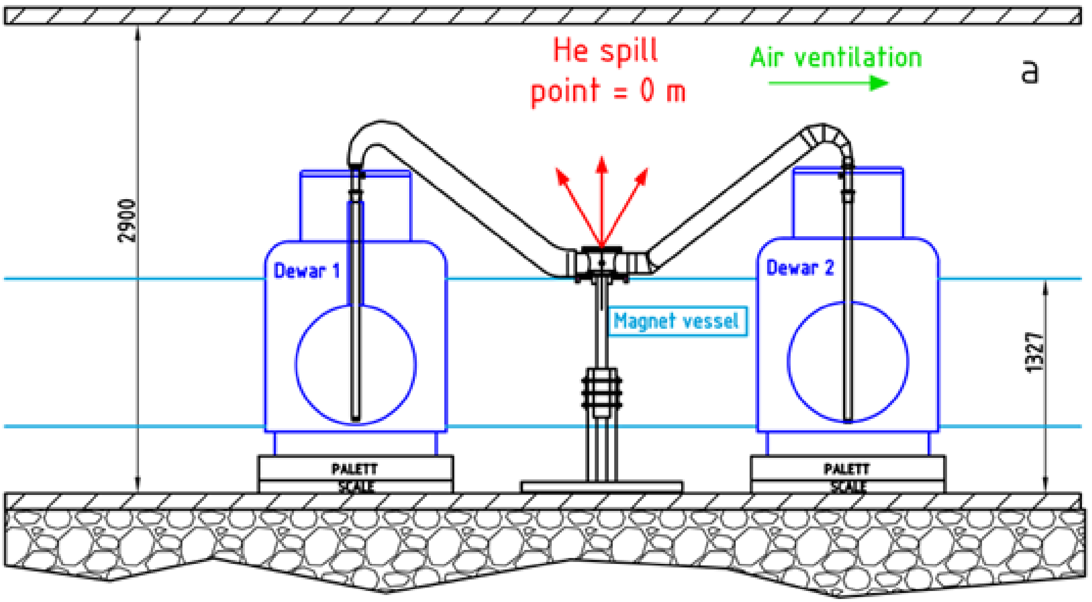
Antiproton Decelerator tunnel - installation



Controlled Cold He Spill in the LHC Tunnel

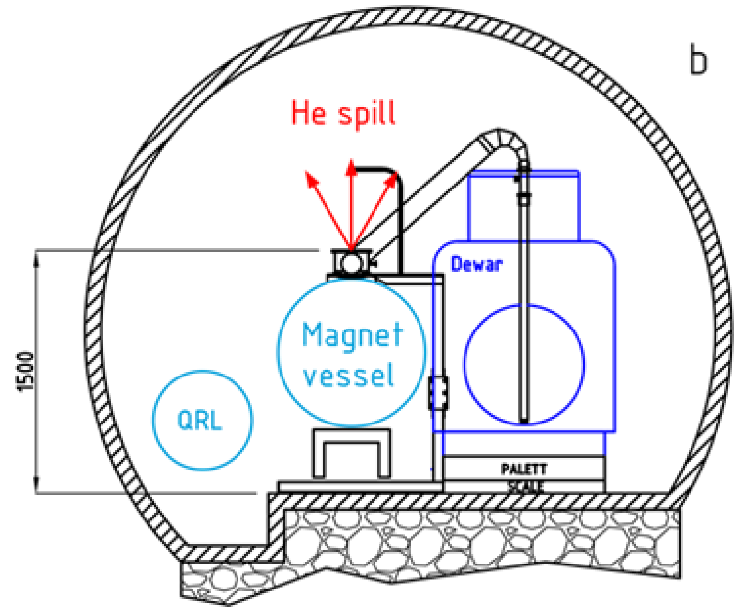
9 tests with He spill of 1 kg/s, 0.3 kg/s and 0.1 kg/s under realistic tunnel conditions

Tunnel side view



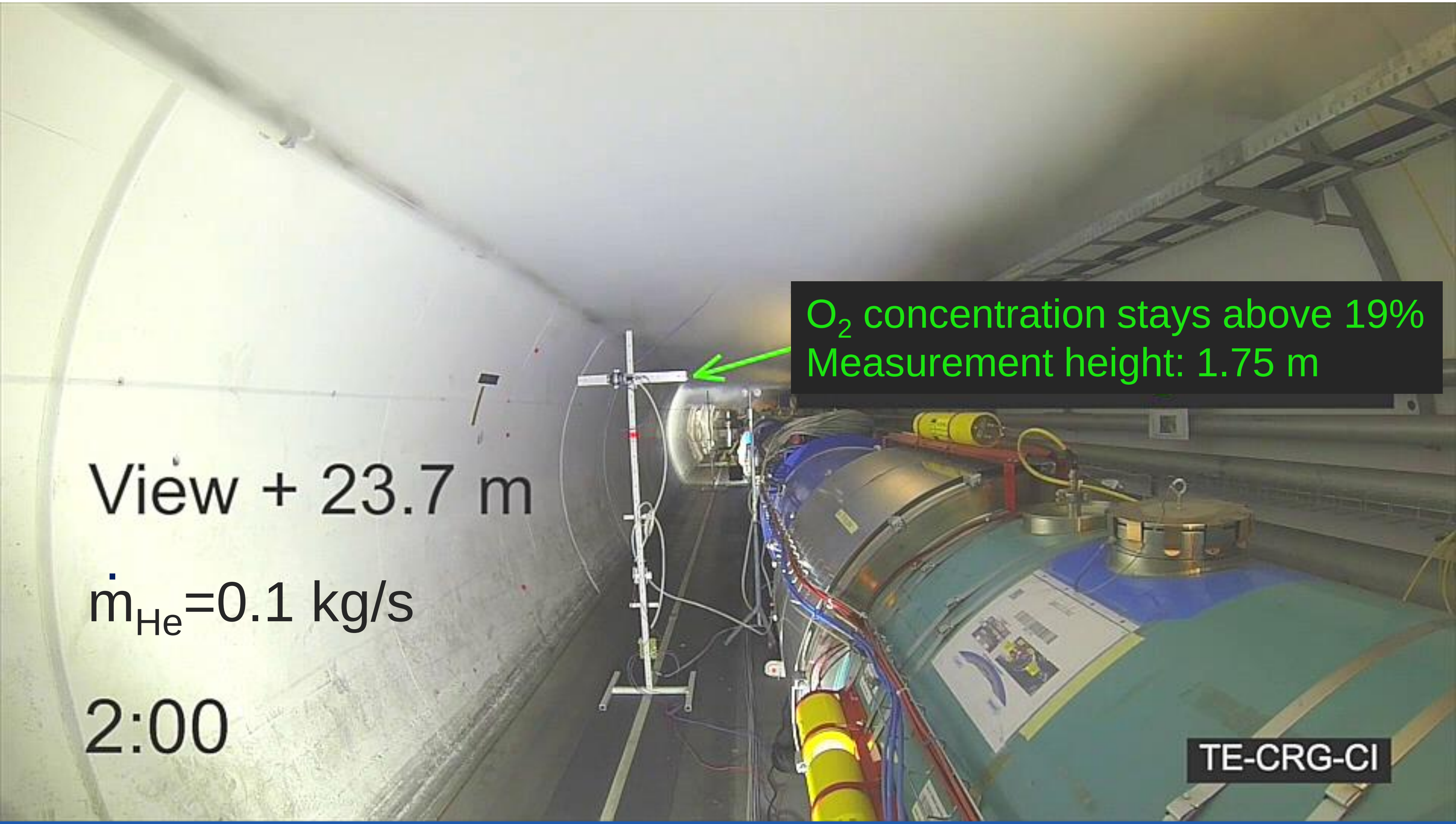
2 x 500 l Dewars with liquid helium
combined extraction system

Tunnel cross section



Dewars placed in the walk way
Release mock-up on top of magnet

Controlled Cold He Spill in the LHC Tunnel



Thank you for your attention.

www.cern.ch