Insulation Vacuum of SC Cables for Renewable Energy Distribution

Jose Antonio Ferreira Somoza on behalf of TE-VSC-IVO

28 October 2025

CIPEA CERN Innovation Programme on Environmental Applications

Outline

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- **SuperNode collaboration**
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  - Permeability measurements
  - Test rig
- **Summary**

CERN for Climate Action Day

CIPEA 2025 Event

https://indico.cern.ch/e/CIPEA-2025

October 28 @CERN

- **Learn** about the CERN Innovation Programme on Environmental Applications (CIPEA)
- **Meet** CERN experts working on projects for the environment
- **Discover** how you can get involved

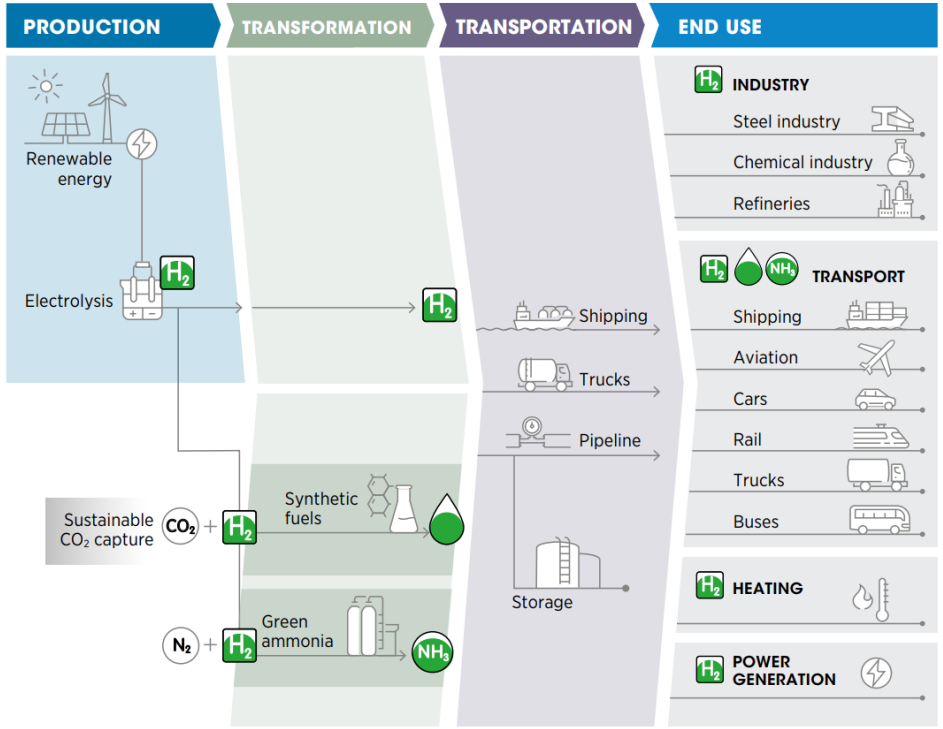
*CIPEA embraces **over 25** projects in the areas of:*

- RENEWABLE AND LOW-CARBON ENERGY
- CLEAN TRANSPORTATION AND FUTURE MOBILITY
- SUSTAINABILITY AND GREEN SCIENCE
- CLIMATE CHANGE AND POLLUTION CONTROL

Knowledge Transfer
Accelerating Innovation

Introduction

- Hydrogen and superconductors are key elements of the energy transition
- Hydrogen transport and storage may require cryogenic conditions (i.e. long-range maritime transport)
- Superconductor applications: power lines for new grids, motors, etc.
- These technologies require cryogenic temperatures => <u>Vacuum for thermal insulation!</u>



Source: IRENA (2020b).
Note: CO_2 = carbon dioxide; N_2 = dinitrogen.

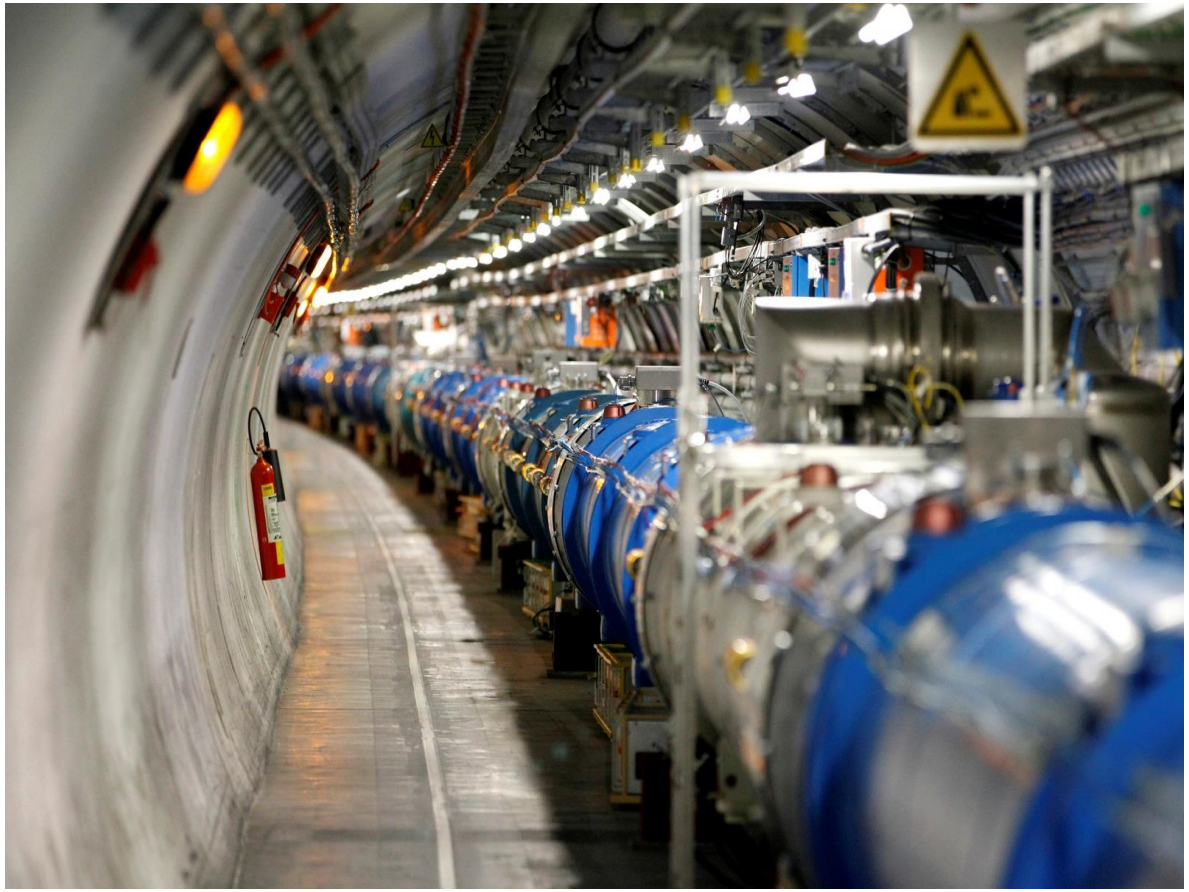
IRENA (2022), Geopolitics of the Energy Transformation: The Hydrogen Factor, International Renewable Energy Agency, Abu Dhabi.

SuperNode superconducting cable: https://supernode.energy/technology/

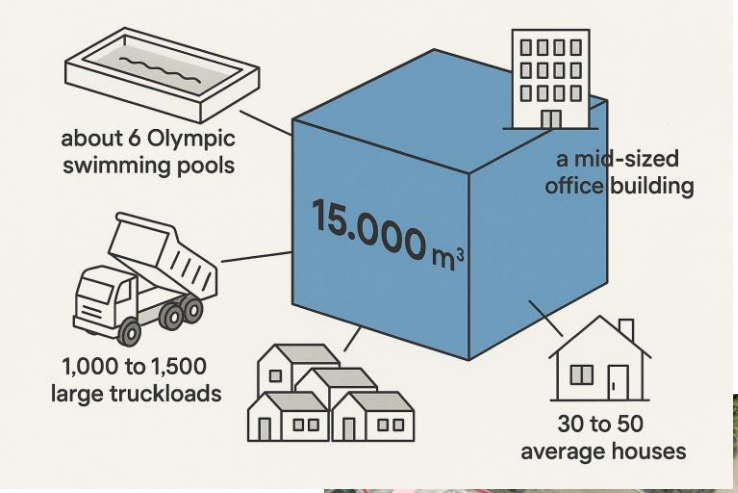
EcoSwing turbine. First HTS 3.6 MW turbine. https://www.theva.com/applications/

CERN capabilities

- **Very large vacuum + cryogenic systems**
- **Combined capabilities in large installations.**
  - Vacuum technology from XHV up to atmospheric
  - Materials and mechanics
  - Cryogenics
- **What TE-VSC can offer from its machine operation experience:**
  - Vacuum system design
  - Operational experience in very large systems
  - Simulations
  - Leak detection strategy and quality control
  - Material qualification
    - Outgassing test
    - Isotherms
    - Permeation
- **But also, surface treatment, coatings, controls, etc.**

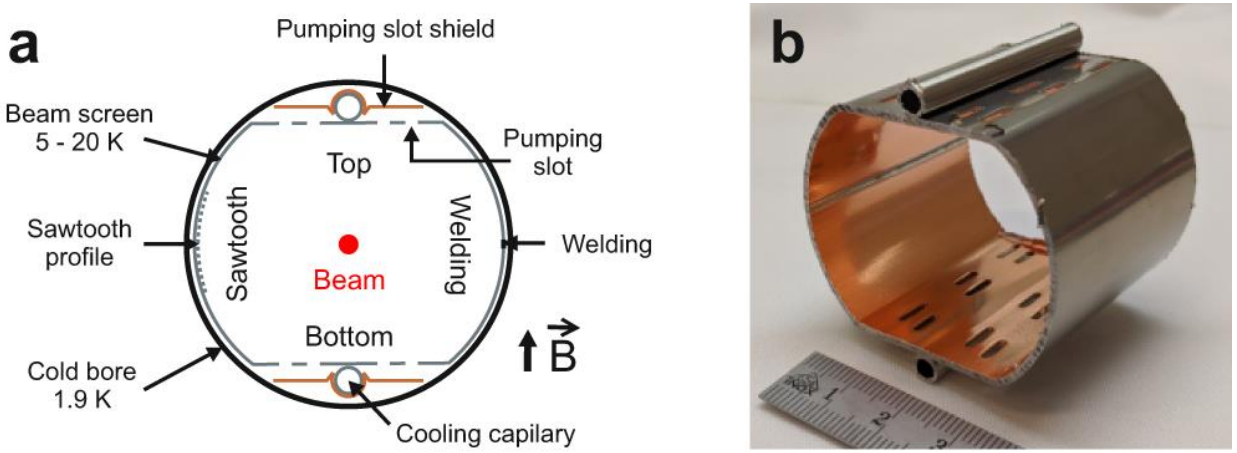


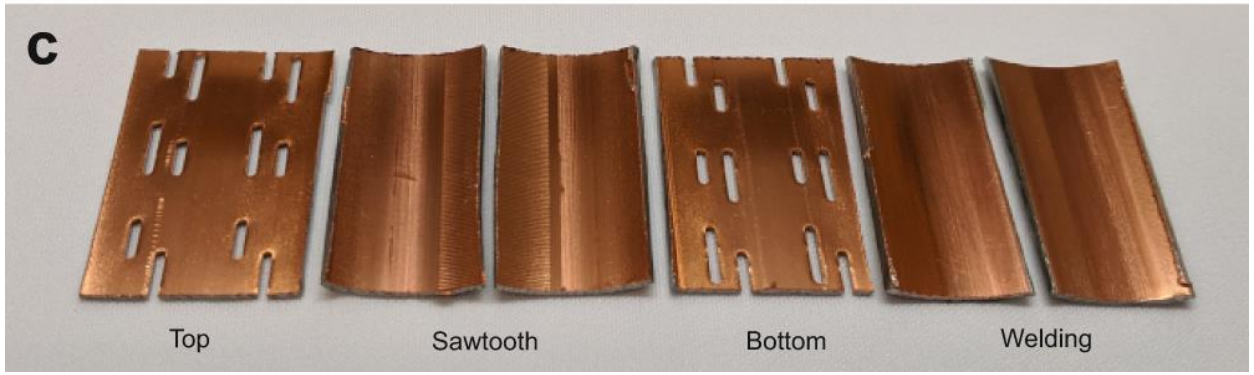
LHC insulation vacuum



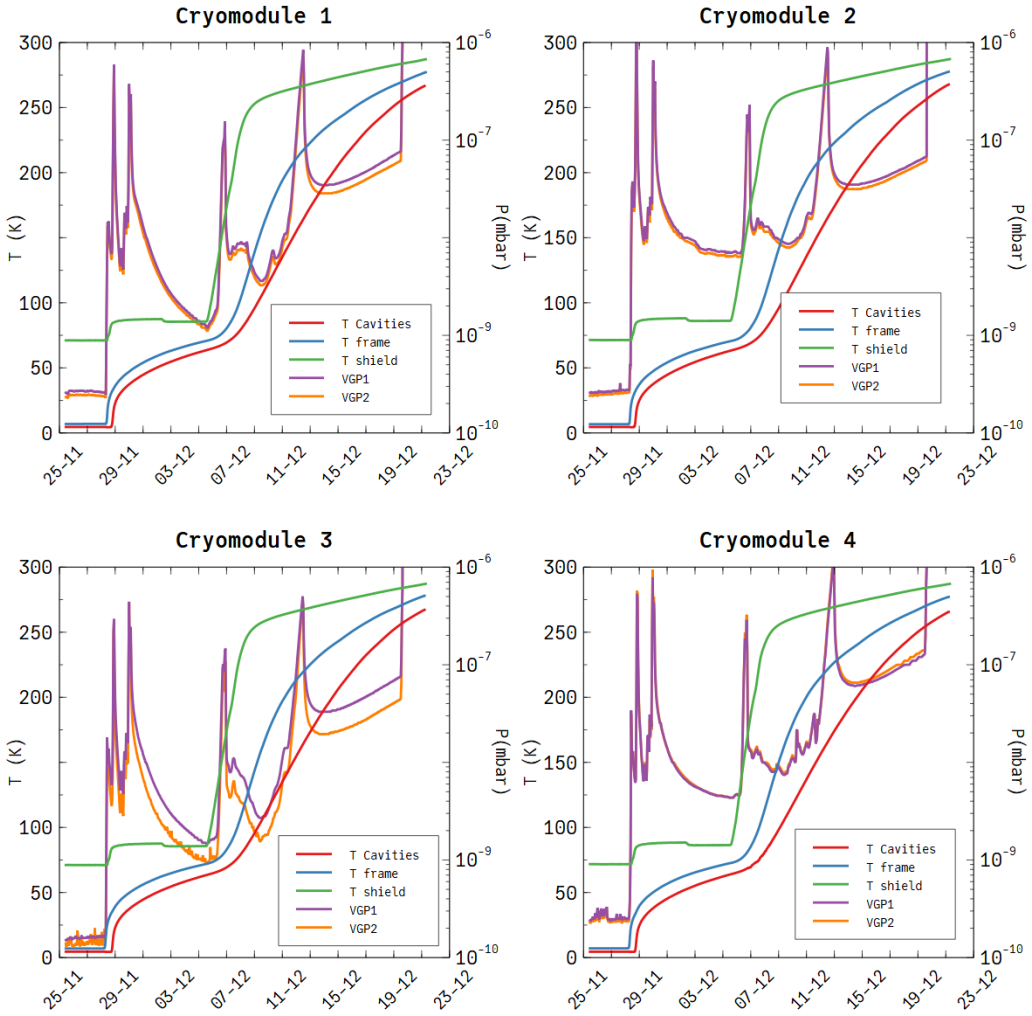
Characteristic	Quantity for LHC machine & distribution line (QRL)
Insulation vacuum system length	22,4 km & 25 km
Welds	~ 250 000 (90 000 in-situ)
Weld length	~ 100 000 m
Elastomer joints	~ 18000
Elastomer joint length	~ 22 000 m
Multi-layer insulation	~ 9 000 000 m^2 or 200 m^2/m of cryostat
Vacuum subsectors	234
Vacuum subsector length	214 m (machine) & 428 m (QRL)
Vacuum subsector volume	~ 80 m^3
Total Volume	> 15000 m^3
Fixed turbo pumps	178
Nominal turbo pumping speed	0,25 l/s/m of cryostat
Fixed vacuum gauges	974
Mobile turbo pumping groups	36
Mobile primary pumping groups	36

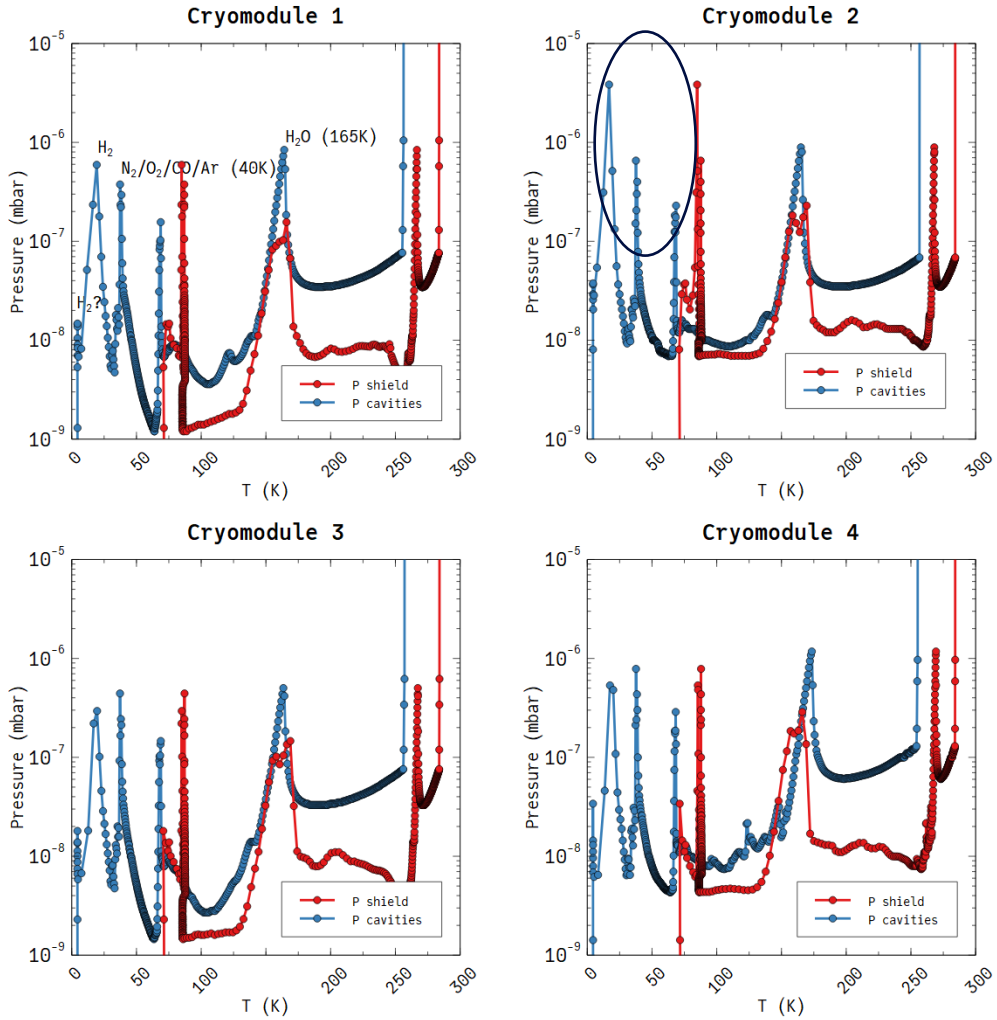
Experience: Design of the vacuum system





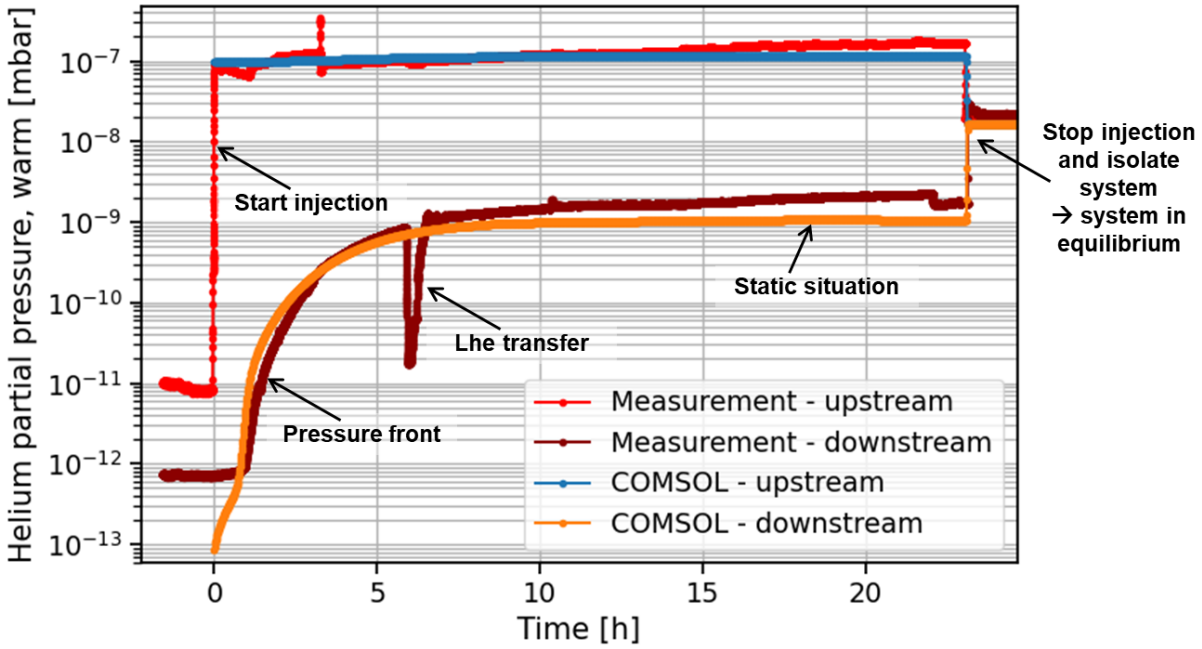
Experience: Operation of large vacuum systems

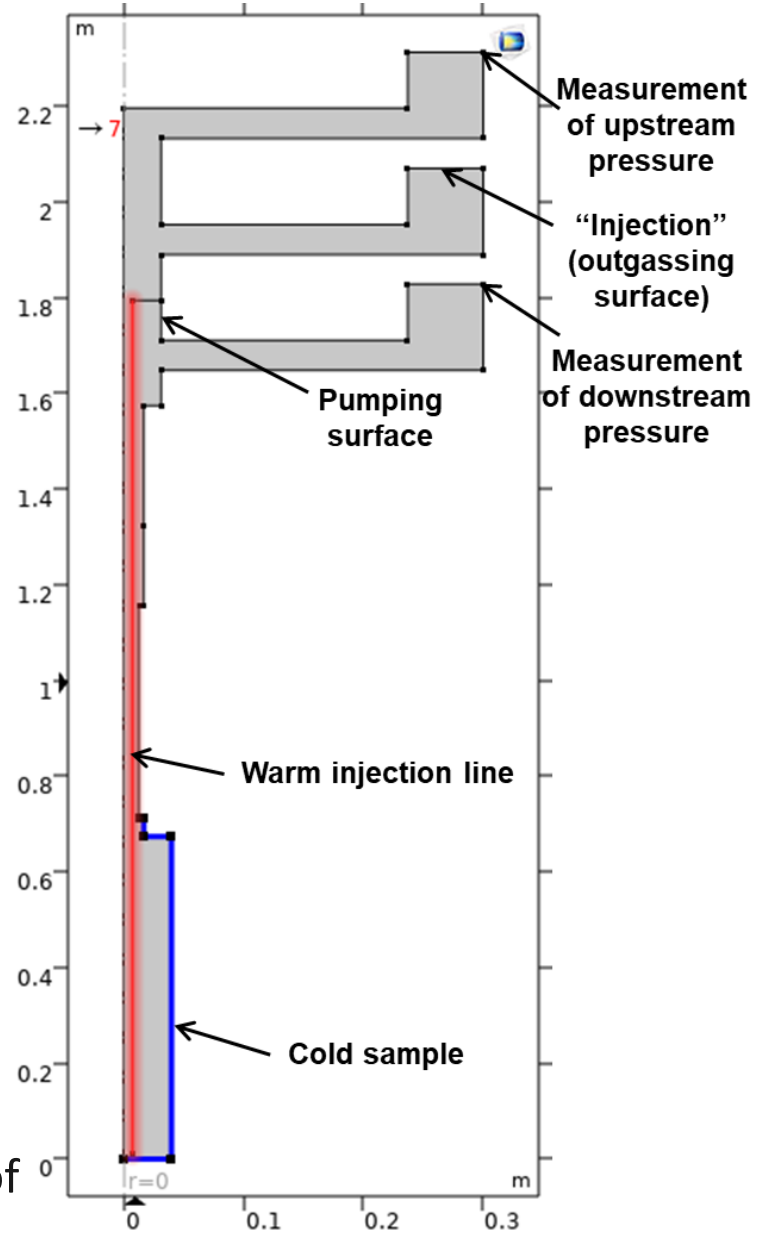




Experience: Simulations

1D to 3D modelling, isotherms, bakeout, slow pumping, etc.

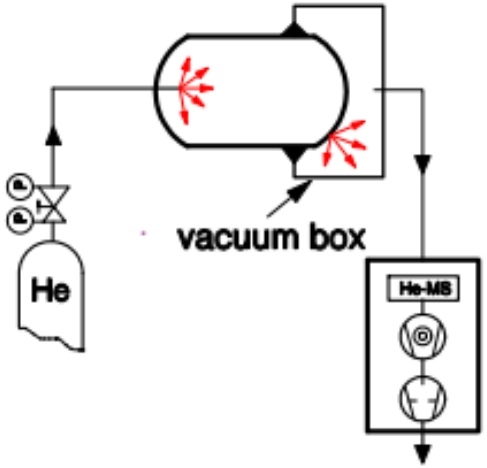


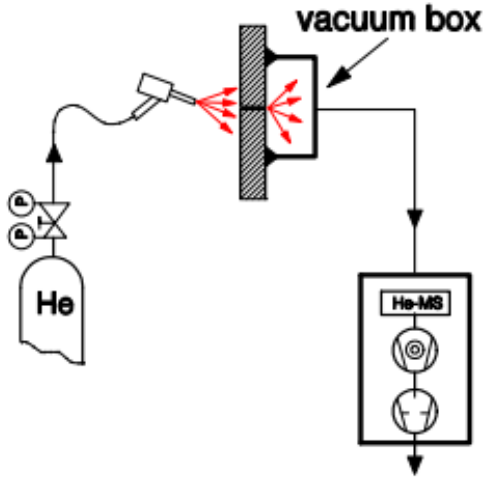


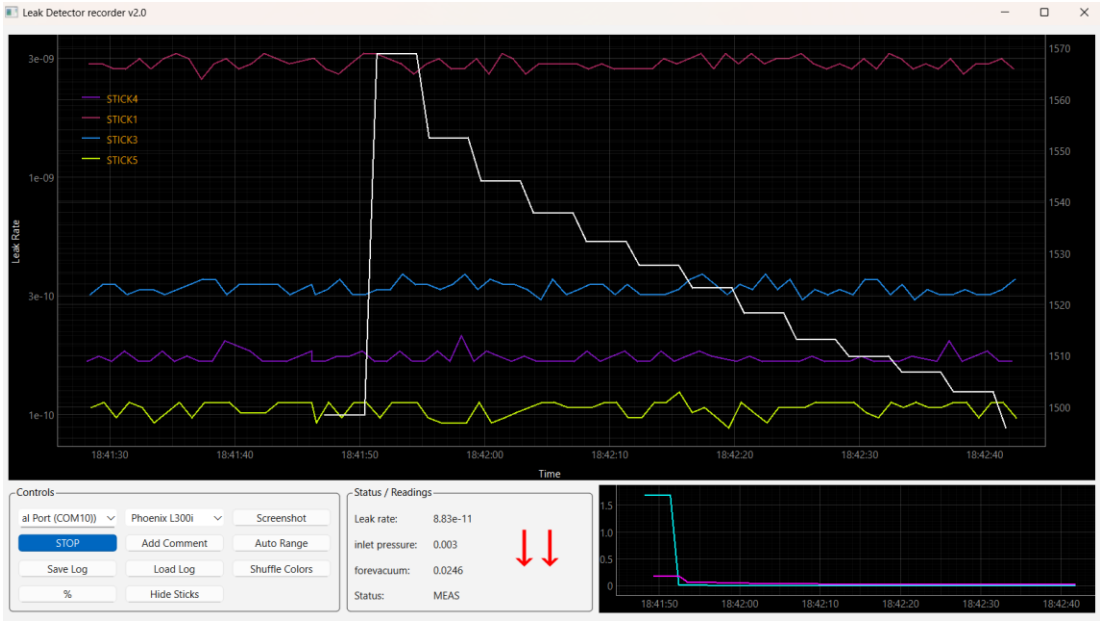
Isotherm fit values from isostere measurements used in COMSOL simulation of the helium propagation measurement

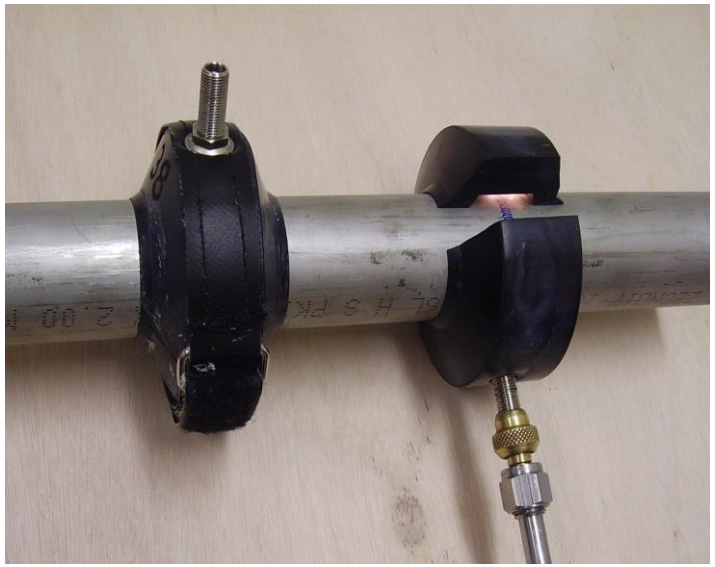
Experience: Leak detection

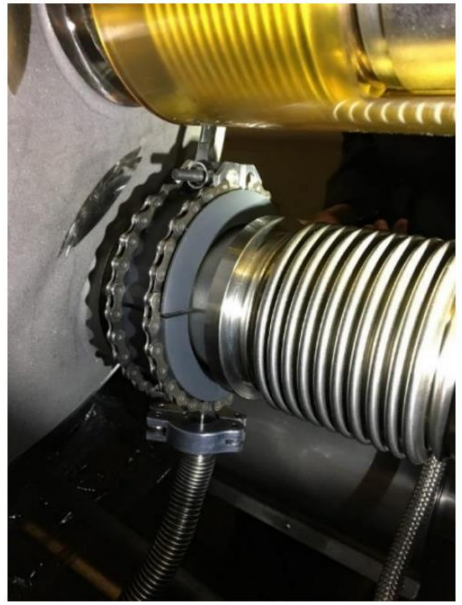
Development of tooling, software, methods etc.





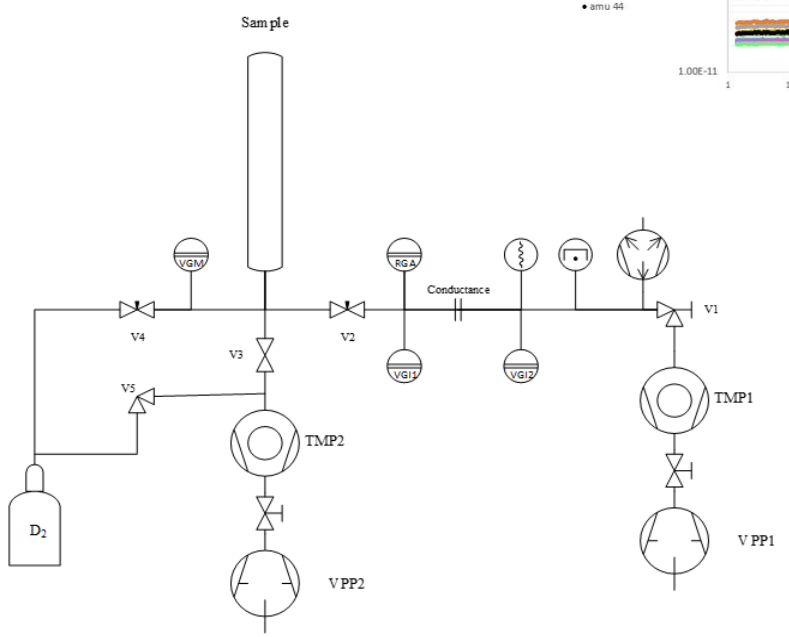


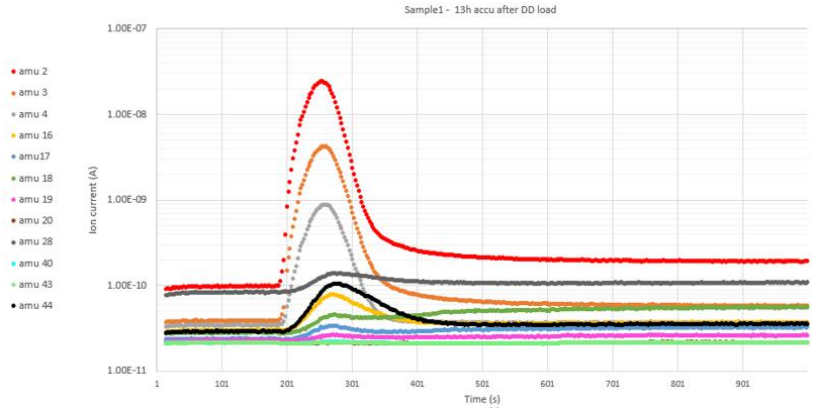


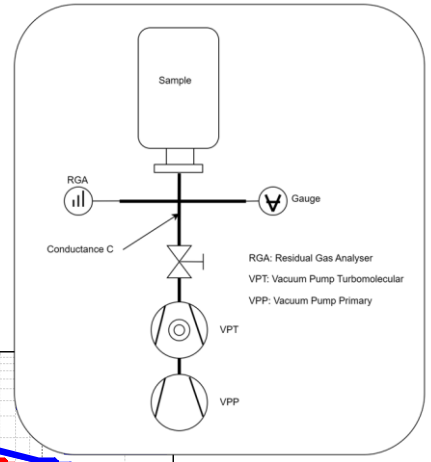


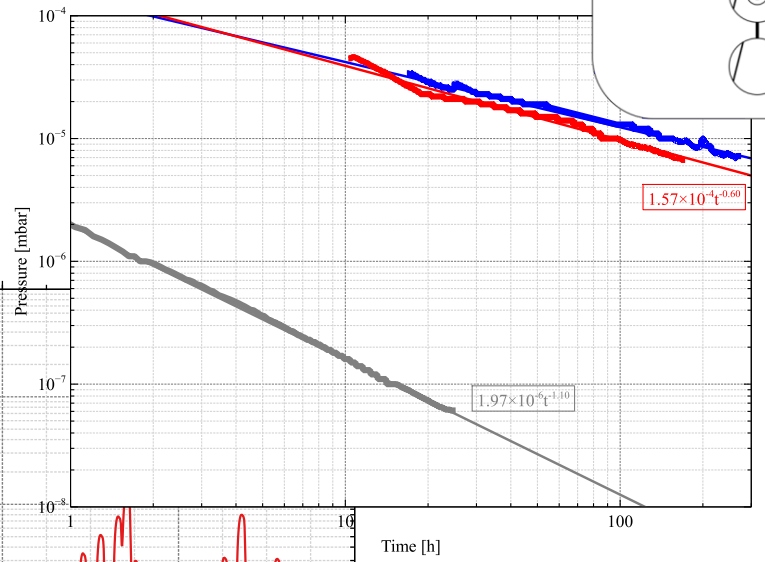
Experience: Material characterization

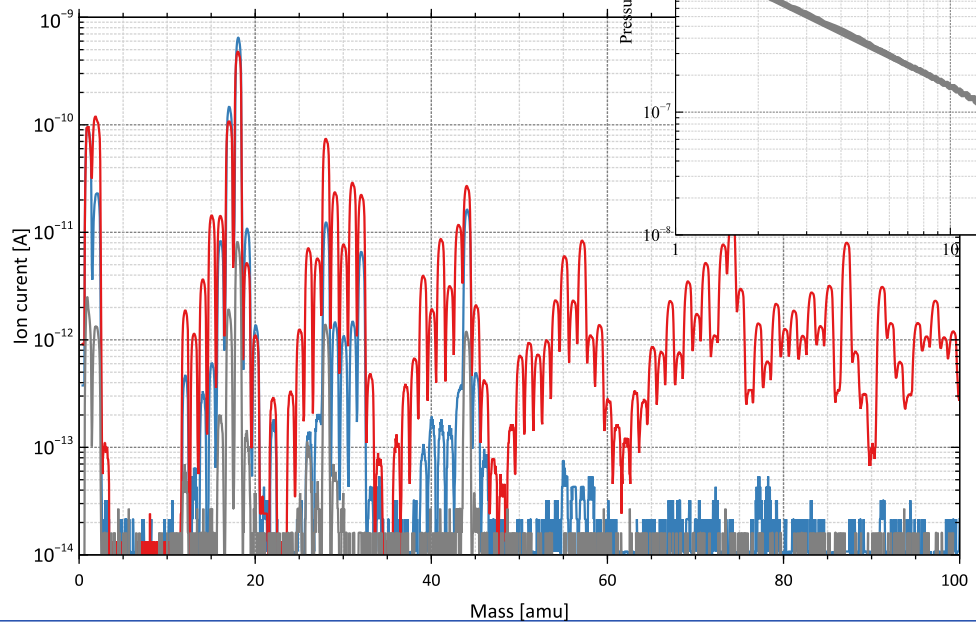
ITER tube testing, OG measurements





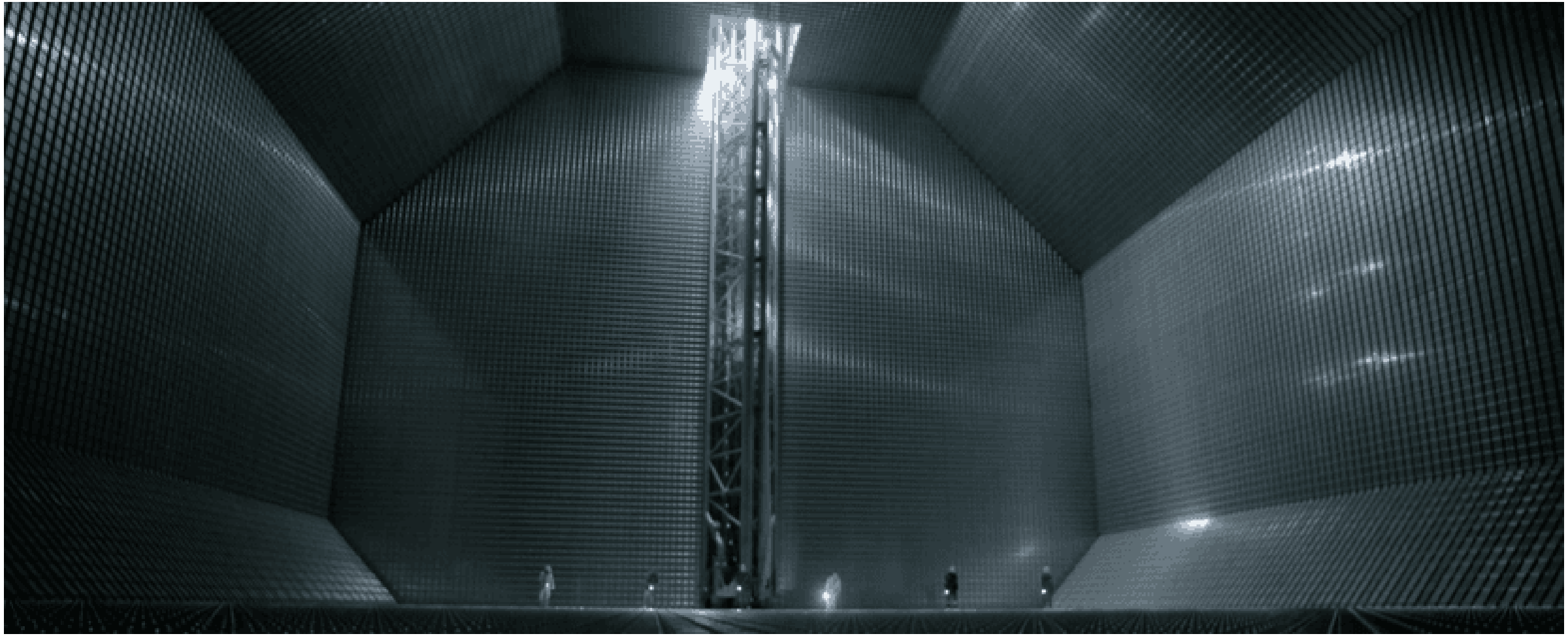






H_2 transport: Material characterization, outgassing measurements

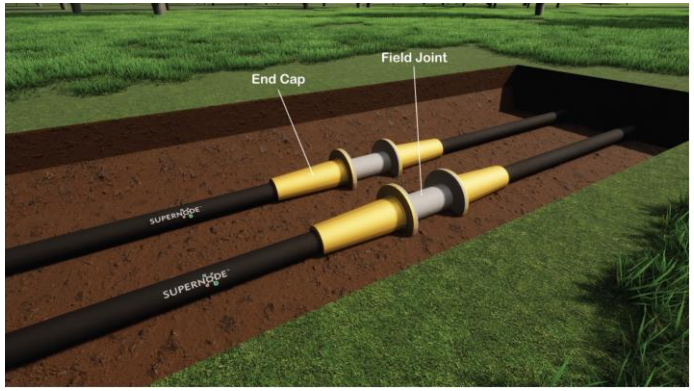
Maritime deal to enable a hydrogen-based economy | CERN

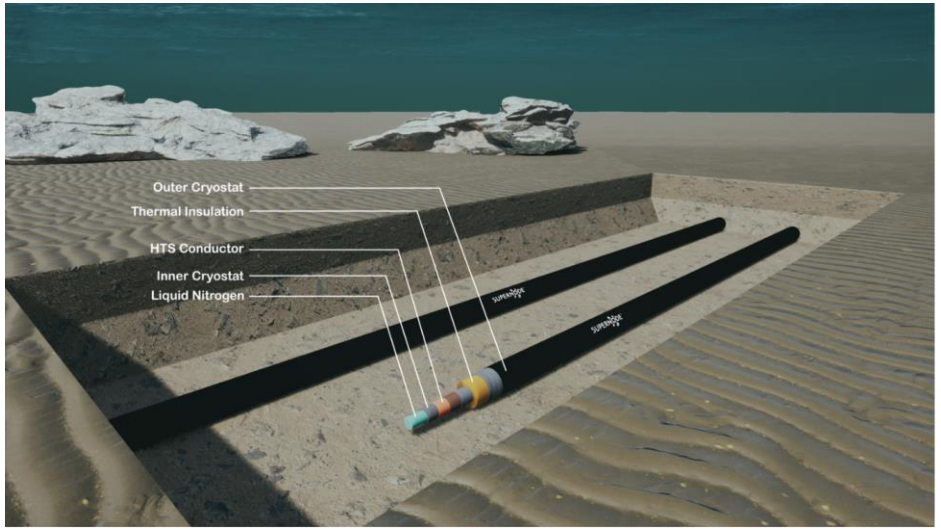


SuperNode collaboration

- **Electrification powered by renewables required for decarbonization.**
- **Grids able to distribute the power will balance variability**
- **Offshore wind and solar dominant sources in Europe**
- **Copper underground lines can only transmit a maximum of 1GW**
- **Superconductors:**
  - > 2GW
  - Marine and terrestrial
  - Small footprint, less raw materials
- **Vacuum requirements:**
  - Large separation between pumping stations (conductance!)
  - Low pressure to start cooling
  - Low pressure for thermal insulation

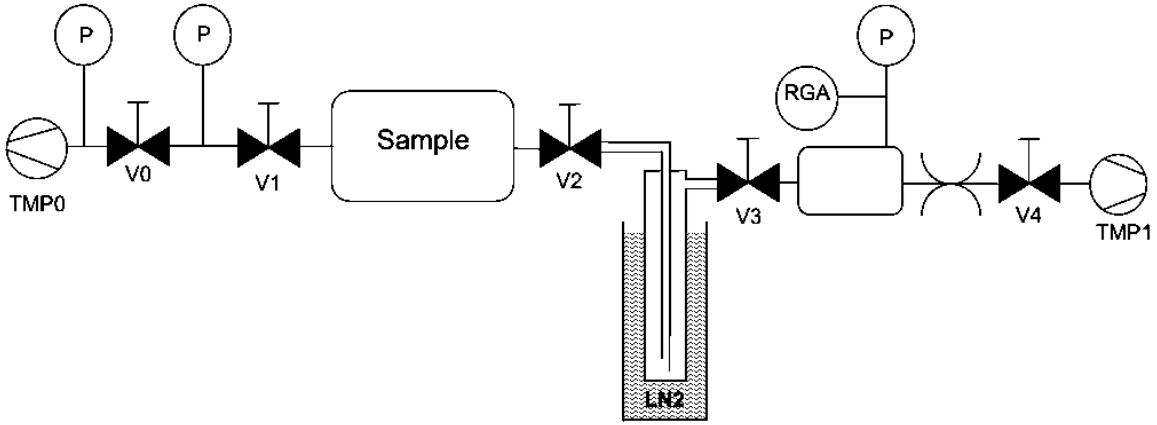
  Gas loads: outgassing, permeation, leaks, etc. are key elements

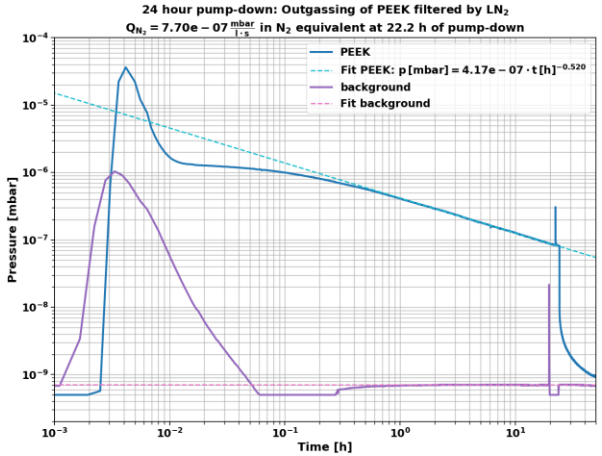


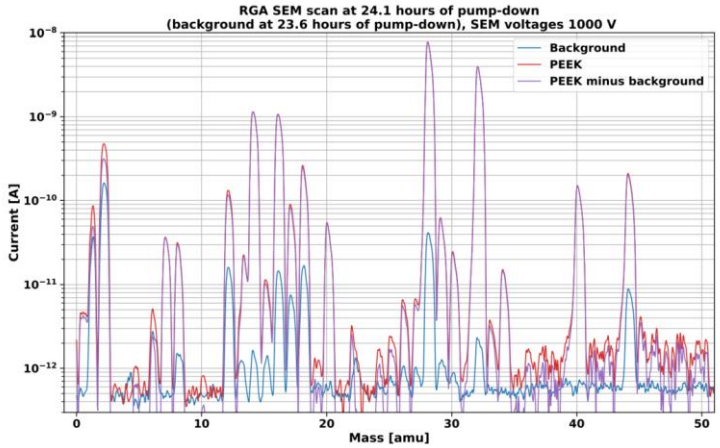


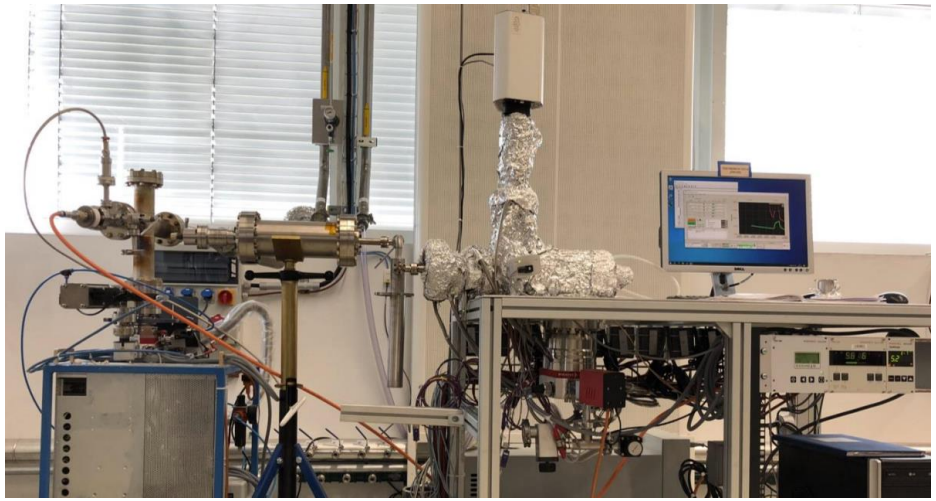
Outgassing measurements

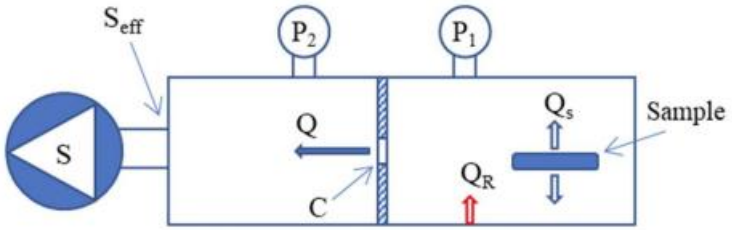
- Full campaign of characterization of different mat
- Validation of thermal treatments
- Development of an ad-hoc test bench to measure outgassing of non condensable gases at 77K





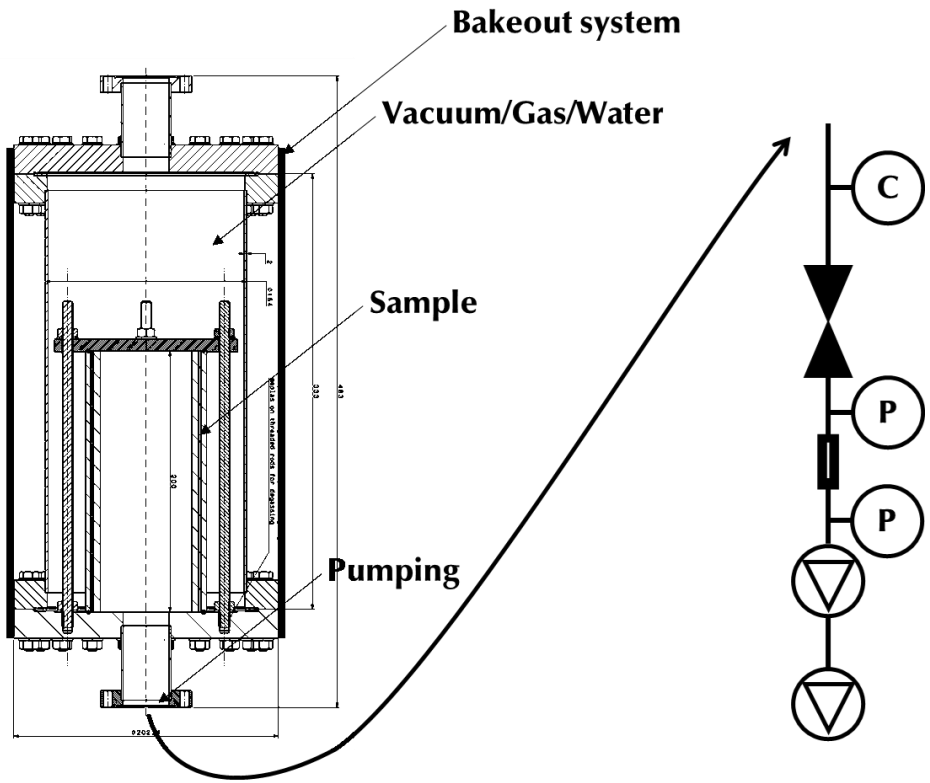


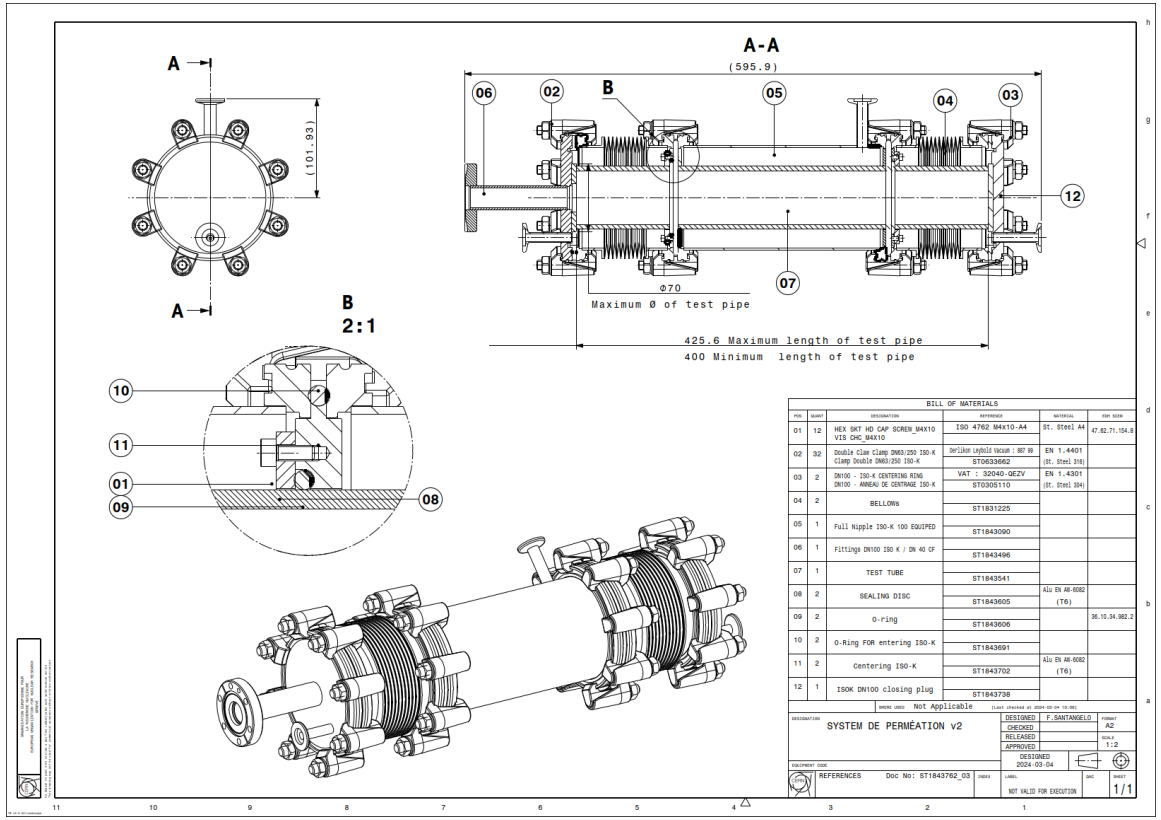




Permeation measurements

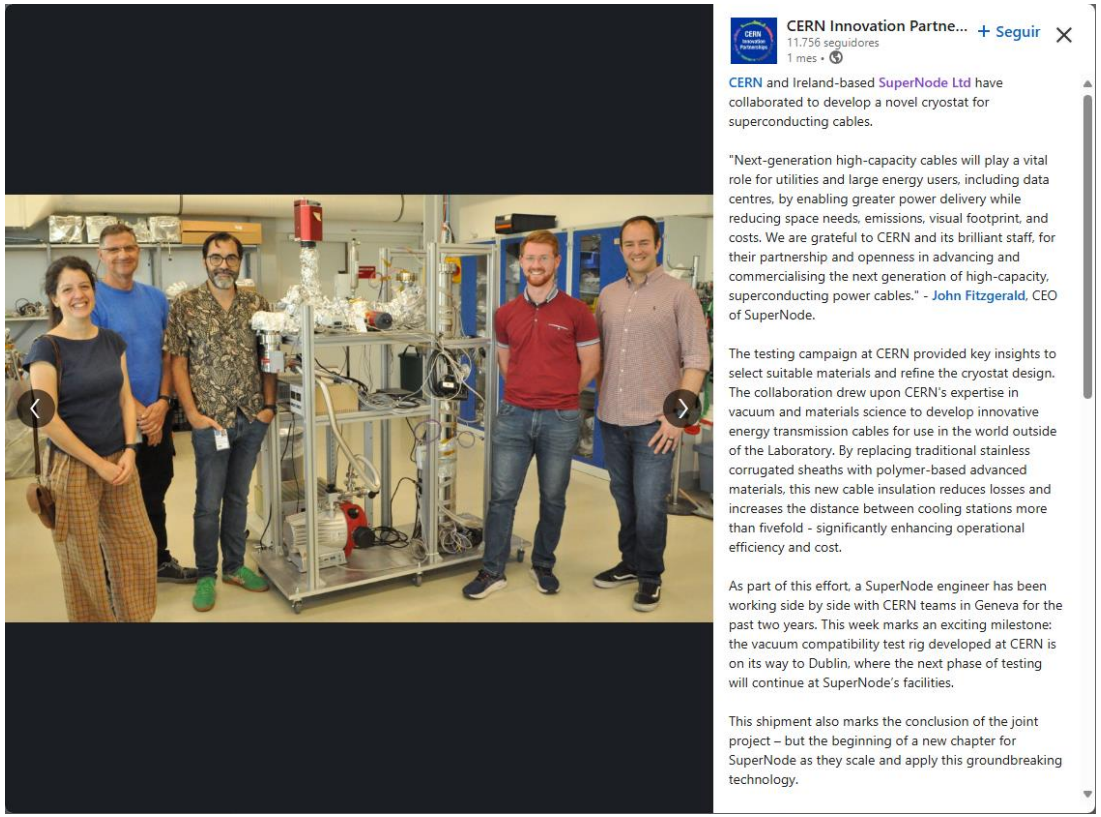
- Several permeation setups to evaluate the permeability of different tube samples
- The evolution allowed to increase the sensitivity and avoid the effect of the pipe ending





Test rig

- A setup that allows full validation of tube samples.
- Combine permeation, outgassing, cooling down, etc.
- Possible further uses, measure pumping speed, degrade insulation vacuum, etc.



CERN Innovation Partne... + Seguir
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CERN and Ireland-based SuperNode Ltd have collaborated to develop a novel cryostat for superconducting cables.

"Next-generation high-capacity cables will play a vital role for utilities and large energy users, including data centres, by enabling greater power delivery while reducing space needs, emissions, visual footprint, and costs. We are grateful to CERN and its brilliant staff, for their partnership and openness in advancing and commercialising the next generation of high-capacity, superconducting power cables." - John Fitzgerald, CEO of SuperNode.

The testing campaign at CERN provided key insights to select suitable materials and refine the cryostat design. The collaboration drew upon CERN's expertise in vacuum and materials science to develop innovative energy transmission cables for use in the world outside of the Laboratory. By replacing traditional stainless corrugated sheaths with polymer-based advanced materials, this new cable insulation reduces losses and increases the distance between cooling stations more than fivefold - significantly enhancing operational efficiency and cost.

As part of this effort, a SuperNode engineer has been working side by side with CERN teams in Geneva for the past two years. This week marks an exciting milestone: the vacuum compatibility test rig developed at CERN is on its way to Dublin, where the next phase of testing will continue at SuperNode's facilities.

This shipment also marks the conclusion of the joint project – but the beginning of a new chapter for SuperNode as they scale and apply this groundbreaking technology.

SuperNode and CERN collaborate on new solutions for renewable energy transmission

The result of this collaboration on superconductivity could greatly improve energy transmission and accelerate the transition to renewable energy

22 APRIL, 2023

CERN and SuperNode have launched a collaboration to develop a novel type of insulation for superconducting cables, in an effort to improve energy transmission and accelerate the transition to renewable energy. (Image: SuperNode)

SuperNode, an Irish company developing cutting-edge energy transmission technology based on superconductivity, and CERN, the European Laboratory for Particle Physics, have launched a collaboration to develop a novel type of insulation for superconducting cables, in an effort to improve energy transmission and accelerate the transition to renewable energy.

"We are thrilled to announce our partnership with such an esteemed and innovative organisation as CERN and are confident that it will help us to better develop our superconducting transmission cables," said John Fitzgerald, CEO of SuperNode. "To meet increasing electricity demands, future transmission grids will have to

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CERN – SuperNode collaboration delivers milestone in cryostat technology for superconducting cables

1st September 2025 by Supernode Energy

This week marks an exciting milestone in SuperNode's testing campaign at CERN – the intergovernmental organization that operates the largest particle physics laboratory in the world. SuperNode and CERN have collaborated to develop a novel cryostat for superconducting cables. Now, the vacuum compatibility test rig, developed at CERN by the two partners, is on its way to Dublin. Here the next phase of testing will commence at SuperNode's facility, the European Cryogenic Centre for Superconductors.

As part of the SuperNode-CERN cooperation, a SuperNode engineer has been working side by side with CERN teams in Geneva for the past two years, allowing SuperNode key insights to select suitable materials and refinement of its cryostat design.

The collaboration drew upon CERN's expertise in vacuum and materials science to develop innovative energy transmission cables for use in the world outside of the Laboratory. By replacing traditional stainless corrugated sheaths with polymer-based advanced materials, new cable insulation reduces losses and increases the distance between cooling stations more than fivefold – significantly enhancing operational efficiency and cost.

"It has been great to collaborate with the SuperNode team over these years, and we look forward to seeing them further develop and apply the technology." – José Ferreira, Head of the Injectors & Insulation Vacuum Operation Section at CERN.

"We are grateful to CERN and its brilliant staff, for their partnership and openness in advancing and commercialising the next generation of high-capacity, superconducting power cables. Next-generation high-capacity cables will play a vital role for utilities and large energy users, including data centres, by enabling greater power delivery while reducing space needs, emissions, visual footprint, and costs. " – John Fitzgerald, CEO of SuperNode.

Summary 1/3

- Running a large facility like LHC demands technologies and expertise beyond what is available in the industry

- H_2 as energy vector and superconductors will play a key role in the energy transition => Large cryogenic systems => Require large insulation vacuum systems

- Requirements often very specific to the application (i.e. weight constraints for H_2 powered planes, pumping speed available, temperature cycles, vibrations, etc.)

Summary 2/3

- **SuperNode contribution**
  - Developing superconducting cables to transport high power over long distances
    - Cost effective
    - Compact footprint
    - Enables the construction of new grids

- **Challenge:**
  - Combine the construction of affordable cables and maintaining the required vacuum level

    => Keep the pumping stations as distant as possible

Summary 3/3

- **Material selection**
  - Management of gas loads is crucial

    => Requires material characterization (outgassing, composition, permeability, etc.)

- **Project outcome**
  - Develop new capabilities

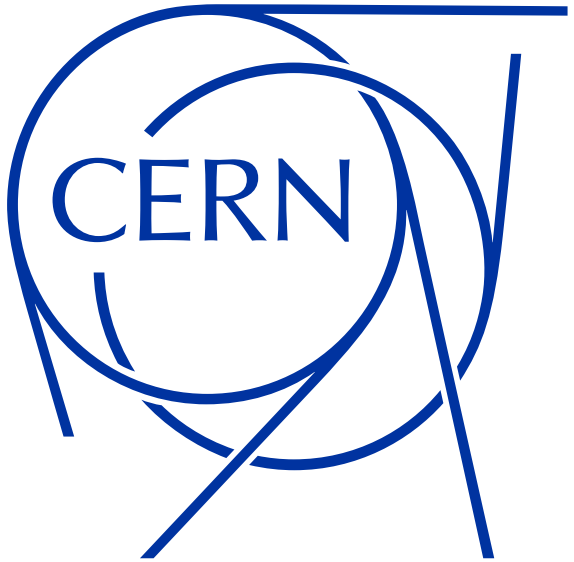
    => Measuring outgassing of non-condensable gases (not initially foreseen, but included later)

    => Permeability measurement of tube samples

- **SuperNode has been an excellent partner throughout the project.**

- **While this collaboration is concluding, a strong and mutually beneficial relationship has been established.**

Thank you!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