RD Line 4 kick-off Forum meeting

Modelling Tools, Materials Protection and Cryogenics

CERN Virtual Meet

April 18, 2023

Cryogenic developments and thermal characterizations

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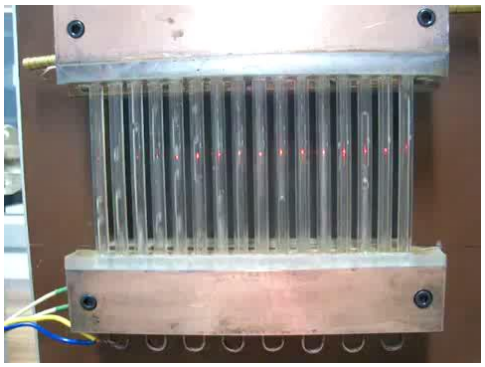
Outline

- Cryogenic PHP development at CEA Paris-Saclay
- HTc SC magnet cooling – PHP as thermal link
- Thermal conductivity measurement

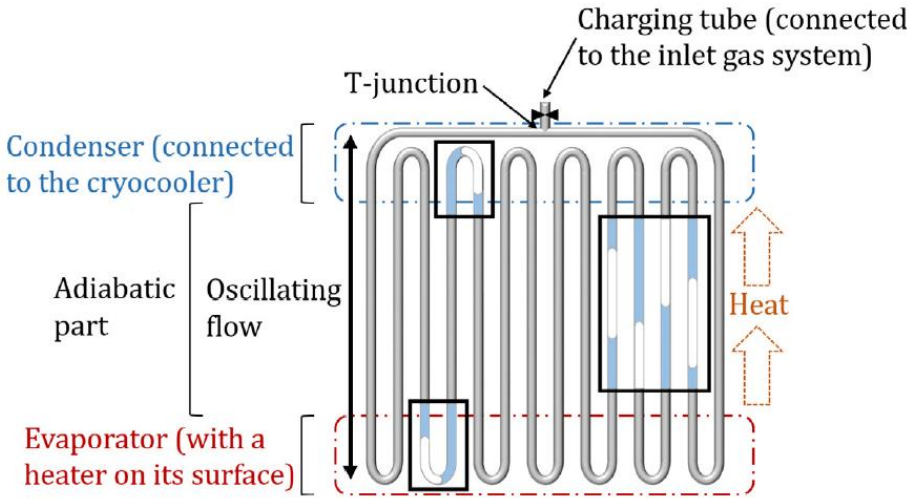
Cryogenic PHP developments

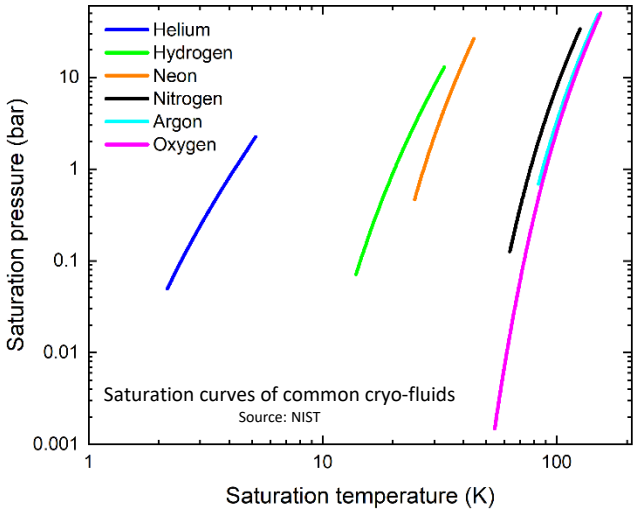
What is a pulsating heat pipe (PHP) / oscillating heat pipe?

- Two-phase passive heat transfer device having oscillating train of liquid slugs and vapor bubbles as thermal transport carriers
- Filled partially with working cryo-fluid operating at its saturation condition



Water PHP Credits: Prof. Sameer Khandekar, IIT Kanpur, India

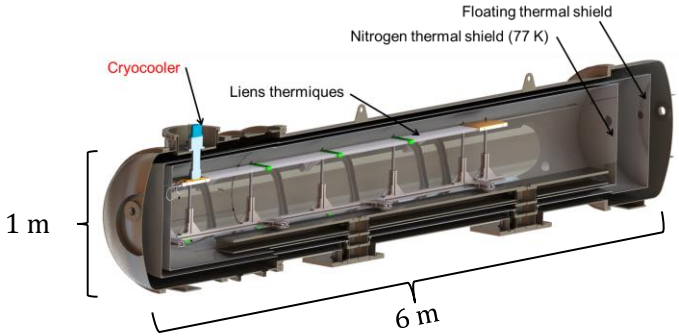




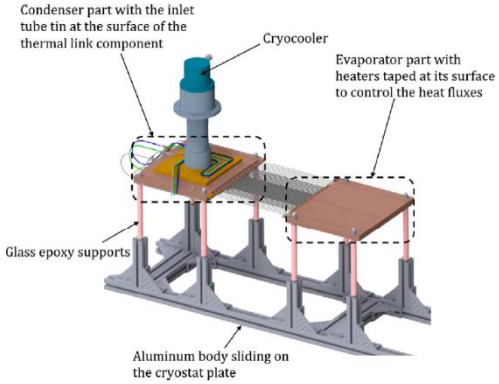
Cryogenic PHP developments

Research on cryogenic PHP at LCSE commenced as part of SR2S European project (led by BB) in 2014

Application: **Cooling thermal shield** between human habitat and superconducting magnet with **nitrogen PHP**



LCSE holds world record for testing the longest horizontal PHP (3.7 m long)



Ref: Barba et al. IOP Conference Series: Mater. Sci. Eng. 278 (2017) 012156

Ref: Maria Asuncion Barba Higueras, Thèse de doctorat, "Study of meter-scale horizontal cryogenic pulsating heat pipes", Université Paris-Saclay, 2019

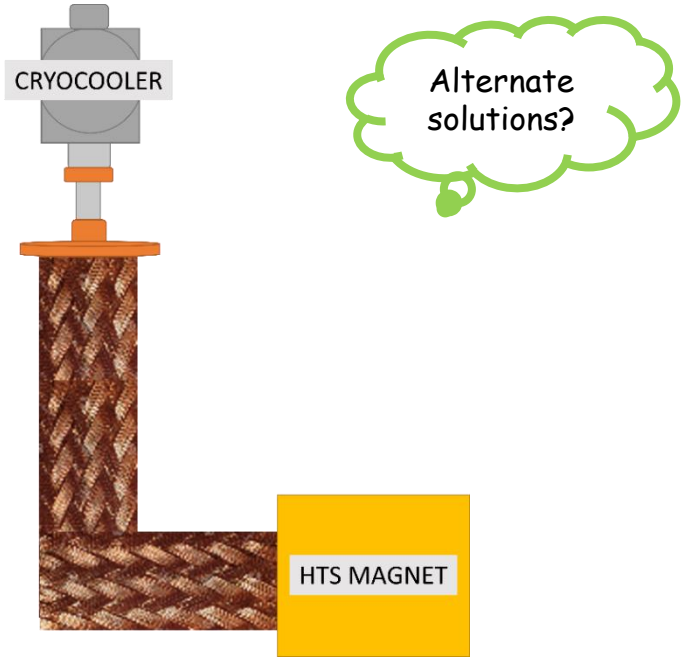
Barba et al. IEEE Transactions on Applied Superconductivity 29 (5) (2019) 0500305.

Barba et al., International Journal of Heat and Mass Transfer 187 (2022) 122458.

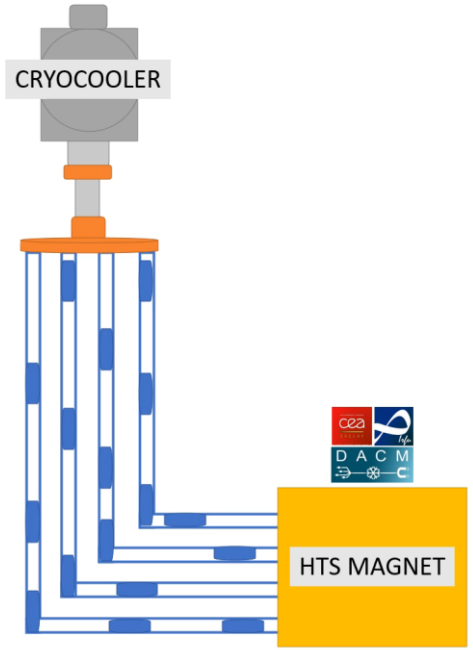
Cryogenic PHP developments

In 2020, development of multi-objective test facility to characterize cryogenic PHPs launched by LCSE

Application: Utilizing cryogenic PHP as thermal link in **cooling** of high-temperature **superconducting magnets**



Alternate solutions?



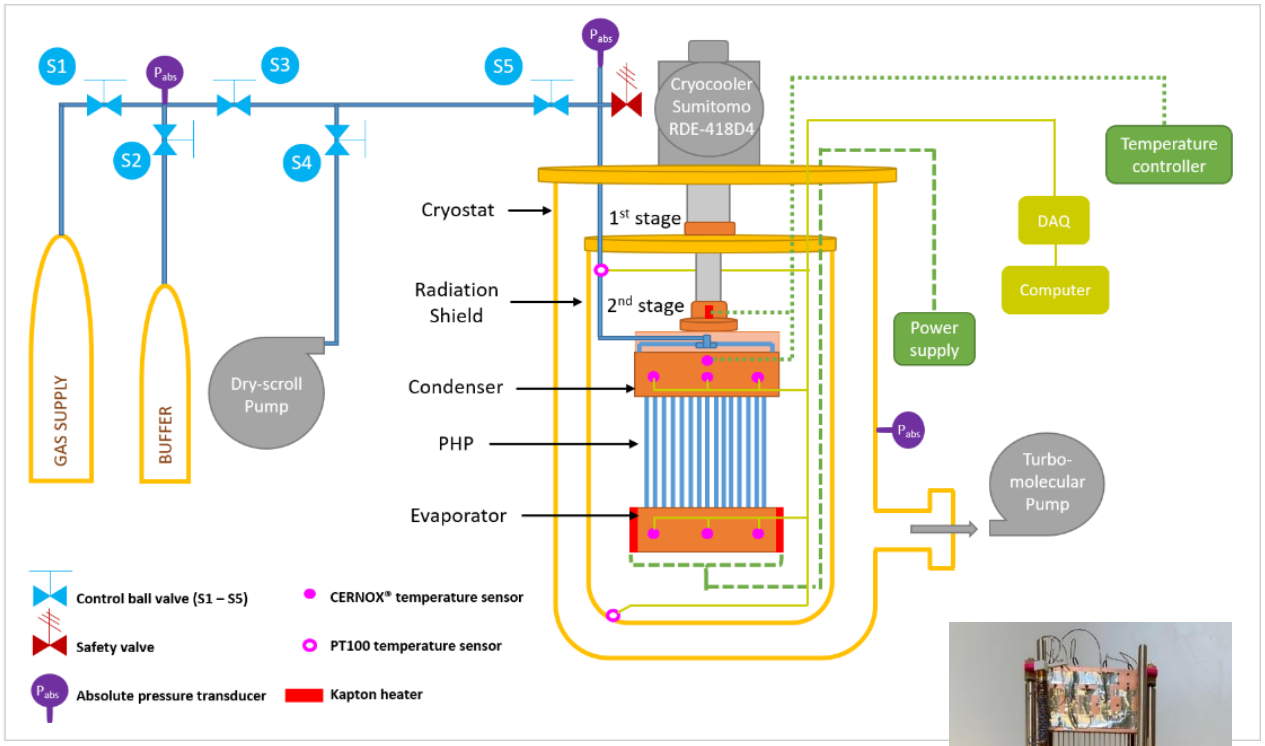
- Slow cooling
- Heavy

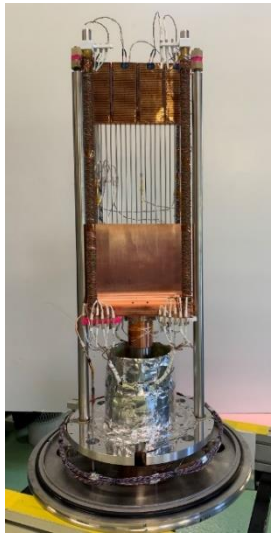
Solid metal thermal links

Pulsating heat pipes

- Light-weight
- Change cryo-fluid for shift in temperature range
- Controllable heat transfer capacity

Cryogenic PHP developments





Chosen PHP parameters

Working fluid = NEON

Material = SS316L_ann

Inner diameter = 1.0 mm

Outer diameter = 2.5 mm

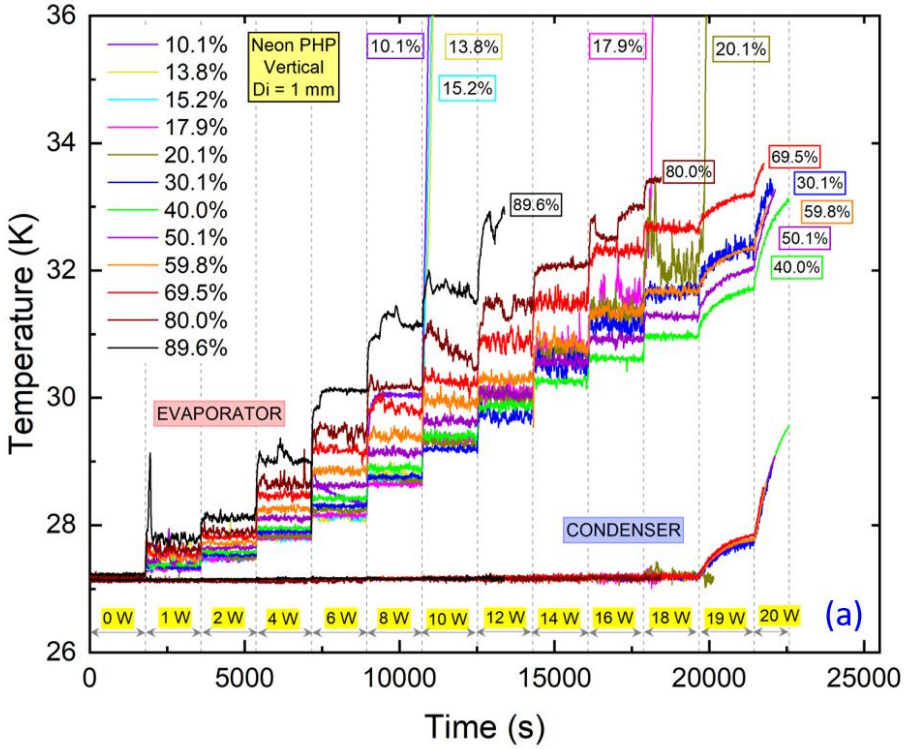
Number of tubes = 20

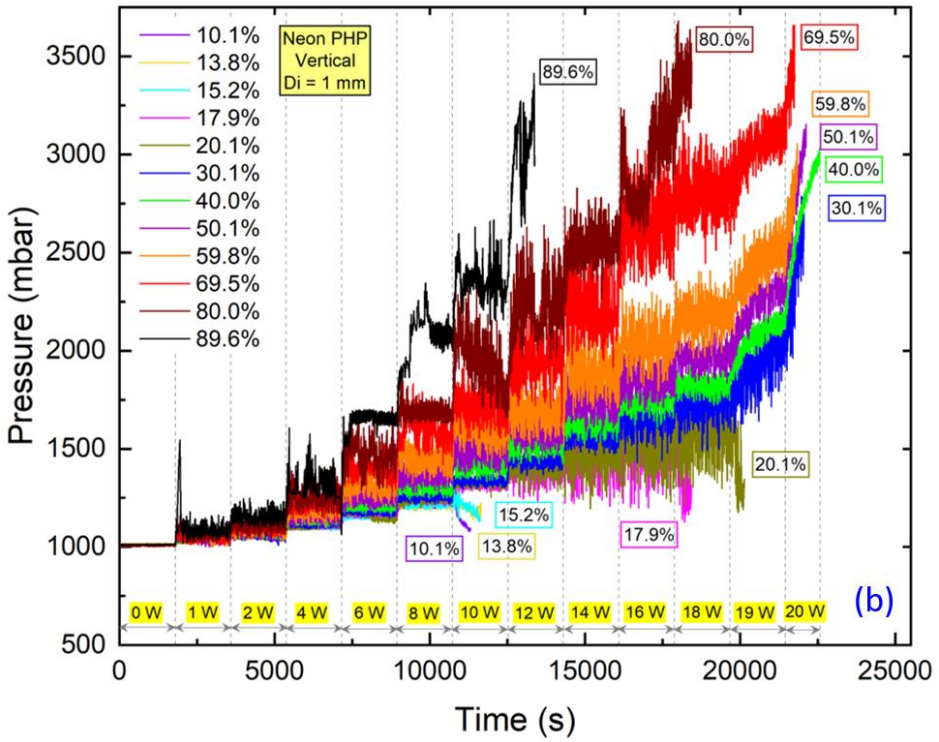
Length = 400 mm

Cryogenic PHP developments

Results for 18 W class neon PHP (Tcond = 27.1 K)

Ref: Dixit et al., Cryogenics 132 (2023) 103670, https://doi.org/10.1016/j.cryogenics.2023.103670





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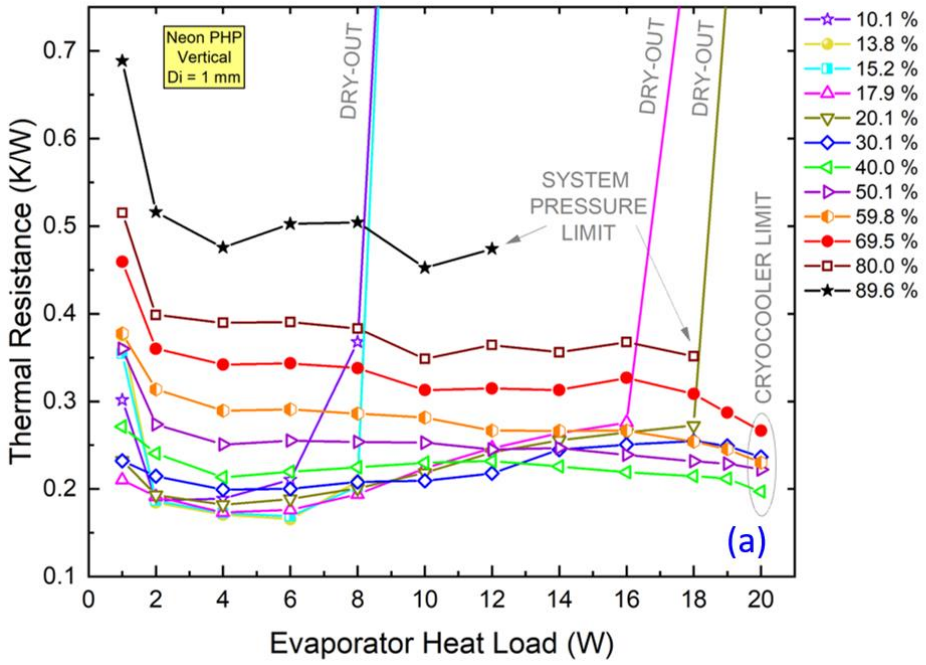

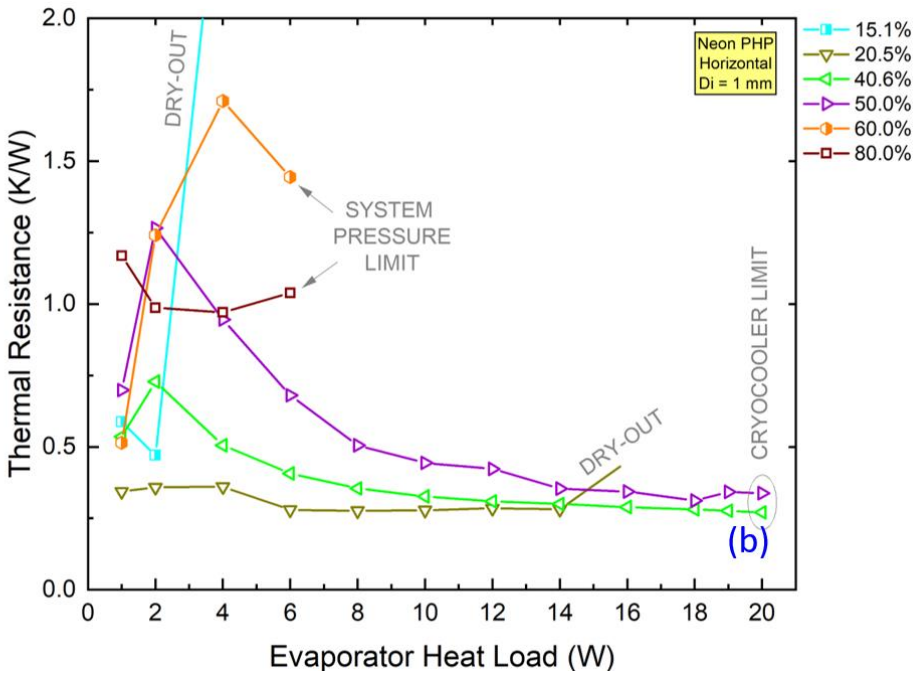

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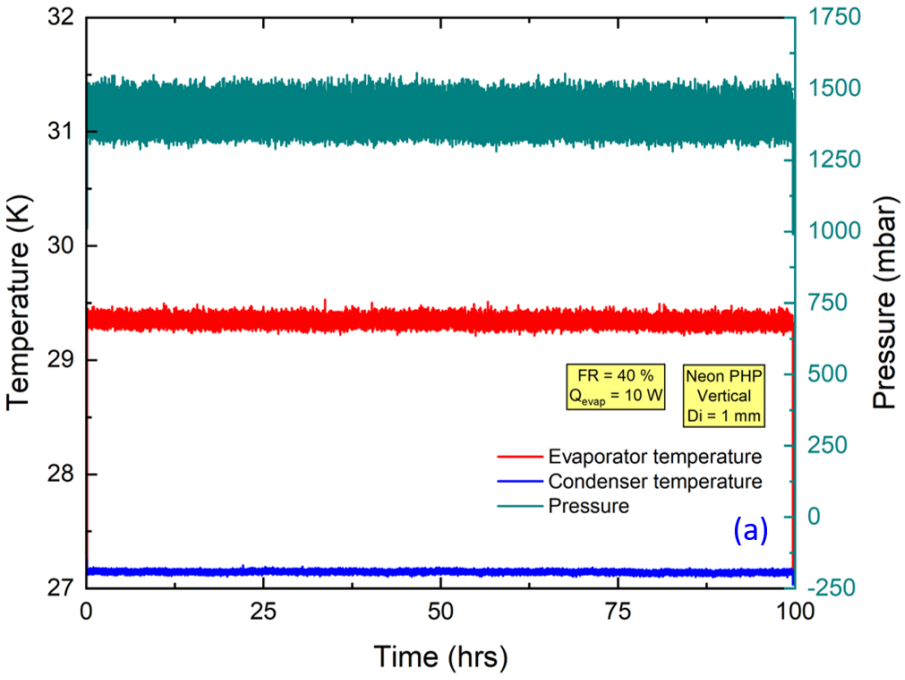
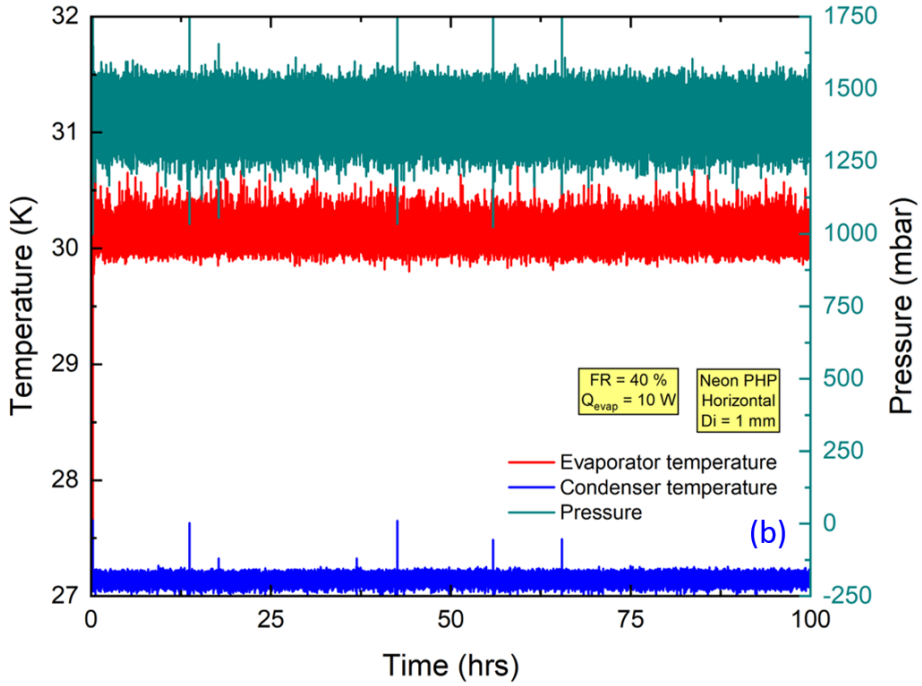
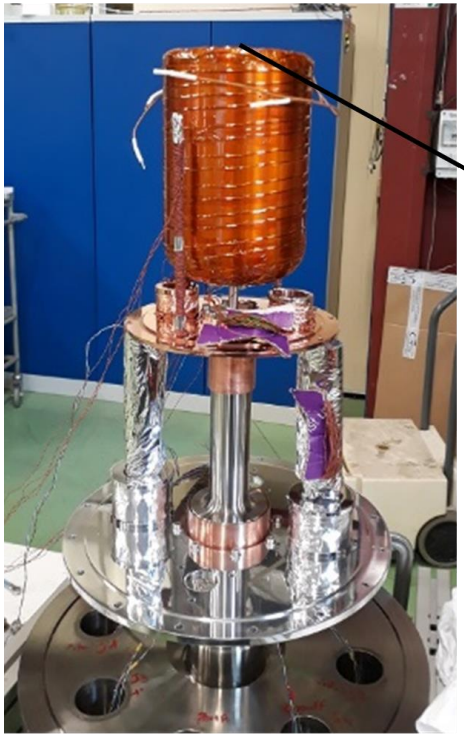




Thermal conductivity measurements

Thermal measurement facility

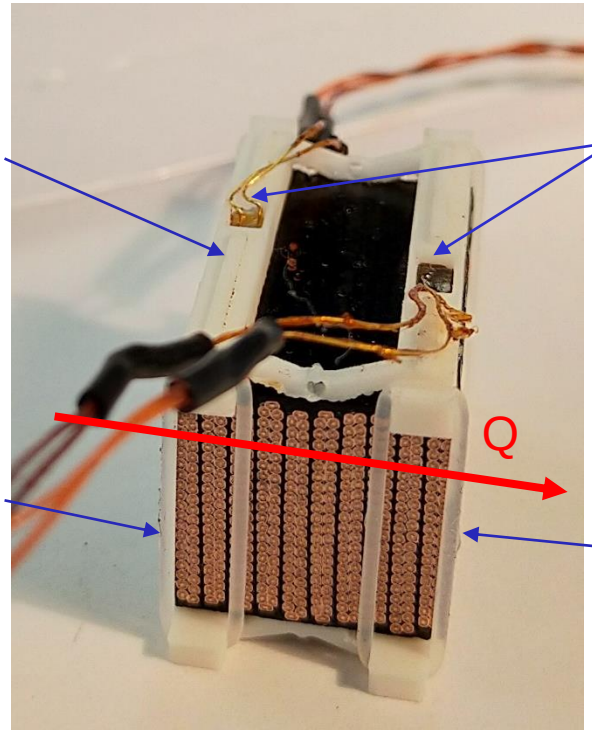
- Isoperibolic cell (ΔT within the cell and the sample less than 50 mk)
- Qualification of the entire facility with instrumentation completed
  - Cell is isoperibolic within 50 mK over the entire temperature range (4 K to 50 K)
  - Calibration with a reference Cu sample (RRR 50)

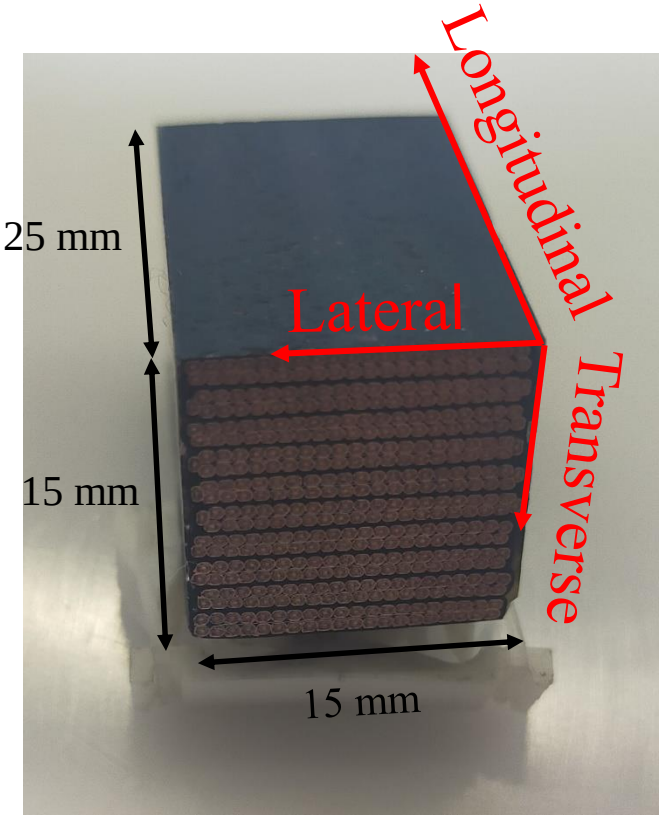


Thermal conductivity measurements

Measurement of the thermal conductivity on impregnated stacks of cables

- Only 11T thermal samples tested
- 3D printed polymer sample holders
- Thermal contact between the sensors and the sample ensured by vacuum grease mixed with copper powder (50 µm) and compression with elastic polymer wire
- Lateral and transverse heat flux configurations; Two lengths tested 25 mm and 50 mm





Thank you for your attention

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