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# Development of a thermal conductivity test bench at cryogenic temperatures

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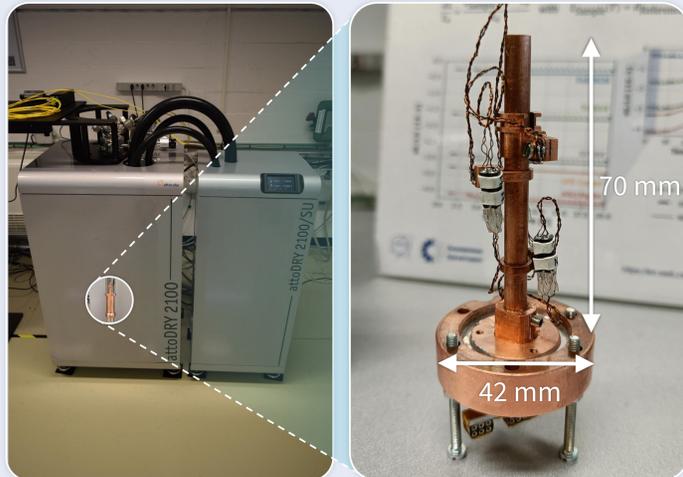


## MOTIVATION

Thermal conductivity is a critical parameter in cryogenics and plays a fundamental role in the design of components operating in cryogenic environments. As cryogenics gain increasing relevance in fields like energy, understanding the low-temperature thermal conductivity of novel materials becomes ever more essential. Meanwhile, the depletion of helium reserves requires the high-energy accelerator community to explore alternatives to liquid helium for cooling accelerator facilities, which will give even more weight to the thermal conductivity of solids.

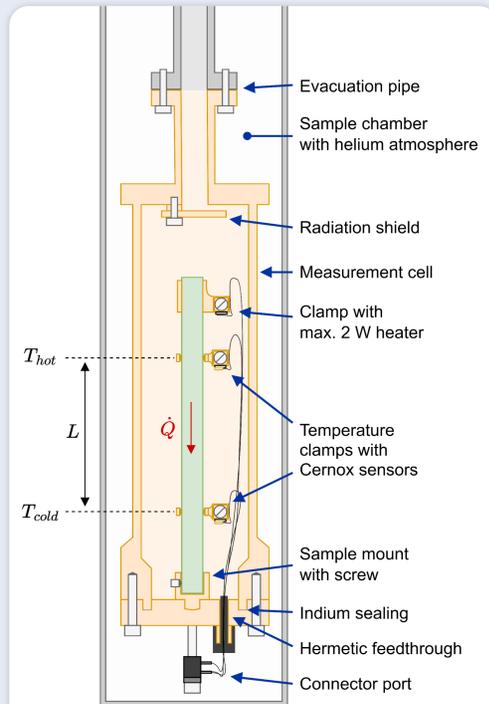
This study presents a thermal conductivity test bench operating from 2 K up to 300 K using a dry cryostat, using a steady-state approach with potential to a dynamic measurement method. The setup can accommodate sufficiently large samples to practically measure composite materials such as low-temperature superconducting cables and high-temperature superconducting tape stacks. By design, the test bench allows analogously the determination of the electrical resistivity, providing a comprehensive platform for thermal and electrical transport characterization.

## EXPERIMENTAL SETUP

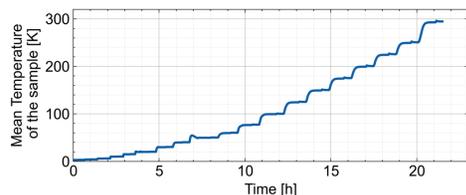


The setup is based on the potentiometric approach, where a known heat is applied to the thermally isolated end of the sample, forcing the heat to traverse through the sample to the thermal sink. By minimizing radiation, convection, and other heat conduction paths, the thermal gradient reveals the sample's thermal conductivity. To meet these requirements, measurements are carried out under vacuum, with the measurement cell temperature kept near the sample temperature.

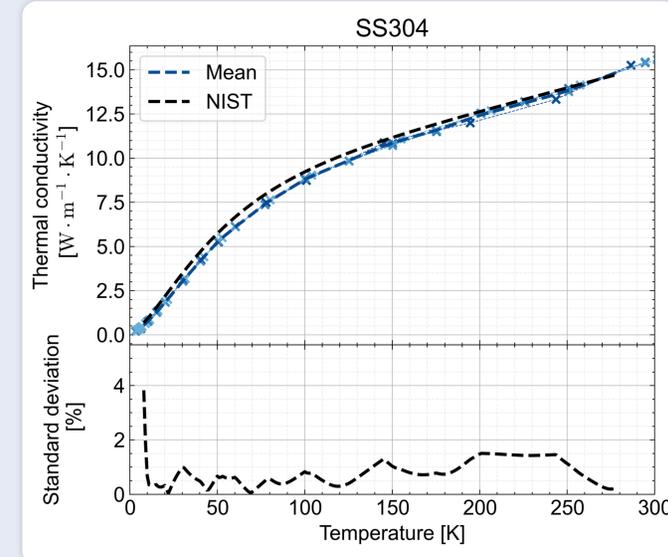
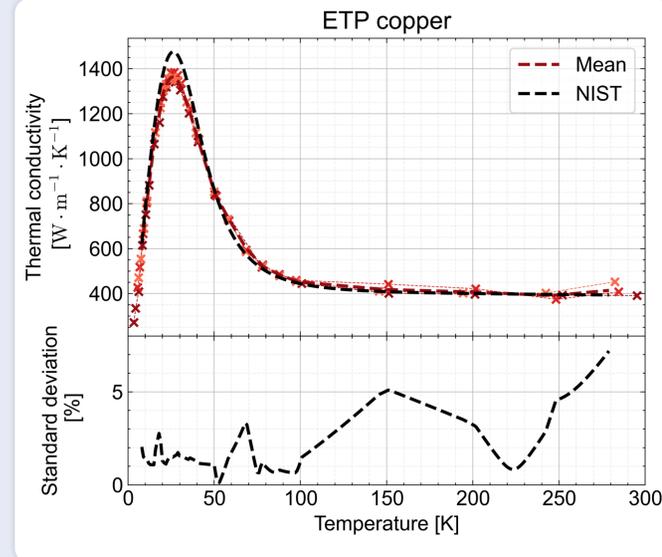
The cell is housed in the sample chamber of a closed-cycle cryostat, allowing a fast and accurate temperature control of the helium atmosphere in sample space from 2 K up to 300 K, in dynamic and steady-state conditions. Depending on the material, a measurement with several measurement steps can thus be completed in less than a day despite the use of a steady-state technique.



$$\lambda \left( \frac{T_{hot} + T_{cold}}{2} \right) = \frac{\dot{Q}_{Heater} \cdot L_{Sensors}}{A_{Cross} \cdot (T_{hot} - T_{cold})}$$

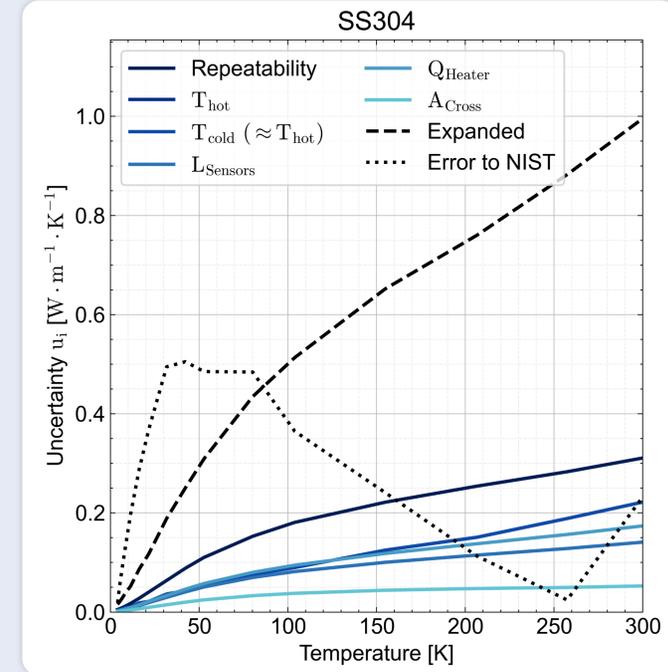
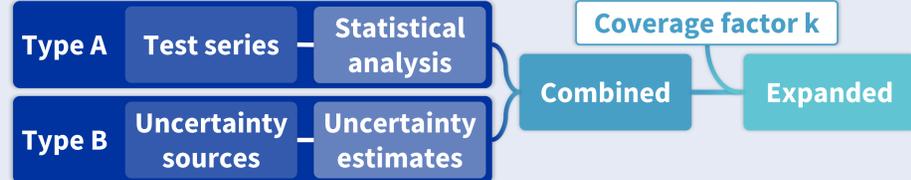


## RESULTS



## UNCERTAINTY

The strong dependence of thermal conductivity on material purity and history, especially at low temperatures, makes it challenging to define a reliable reference material. Thus, direct comparisons with existing reference data can result in misleading conclusions when assessing measurement uncertainty. Therefore, we focus our uncertainty evaluation on the methodology outlined in the *Guide to the Expression of Uncertainty in Measurement* (GUM). In here, key sources of uncertainty of this test setup include temperature measurement, sample cross-section, gauge length between temperature sensors, and heat flow, where the latter also accounts for losses due to radiation and parasitic conduction. The outcomes are summarized in the graph on the right. In general, the expanded uncertainty (k=2) was estimated to approximately 6-7 %.



## CONCLUSION

The uncertainty study and initial results on copper as well as SS304 demonstrate a promising performance of the setup and its potential for characterizing various materials, namely LTS cables and HTS tape stacks. With a typical measurement rate of one sample per day, the setup achieves a well-balanced trade-off between versatility, accuracy, and measurement time. Next steps include tests on additional reference materials such as of polymers, to better quantify radiation-induced errors. In parallel, a dynamic testing approach based on the pulse power method is under development; it is compatible with the current setup and is expected to offer higher throughput. Finally, electric transport measurements are planned as a future extension, requiring both hardware and software integration.