Improved thermal removal from Nb-Ti SC cables

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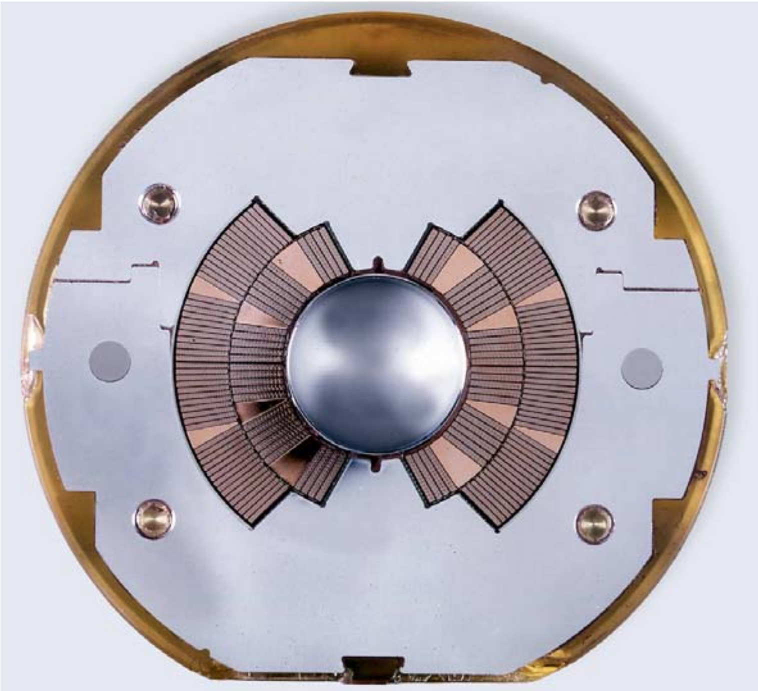
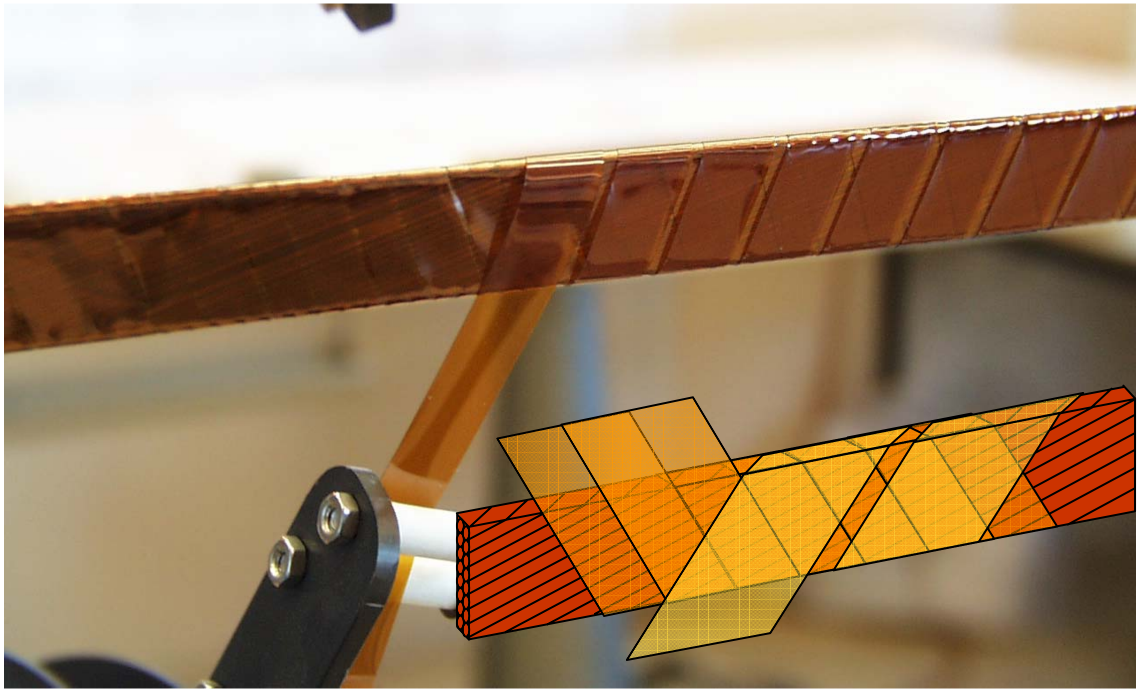
We are modeling *steady-state* heat transfer from SC Rutherford cable to an *isothermal* He II bath.

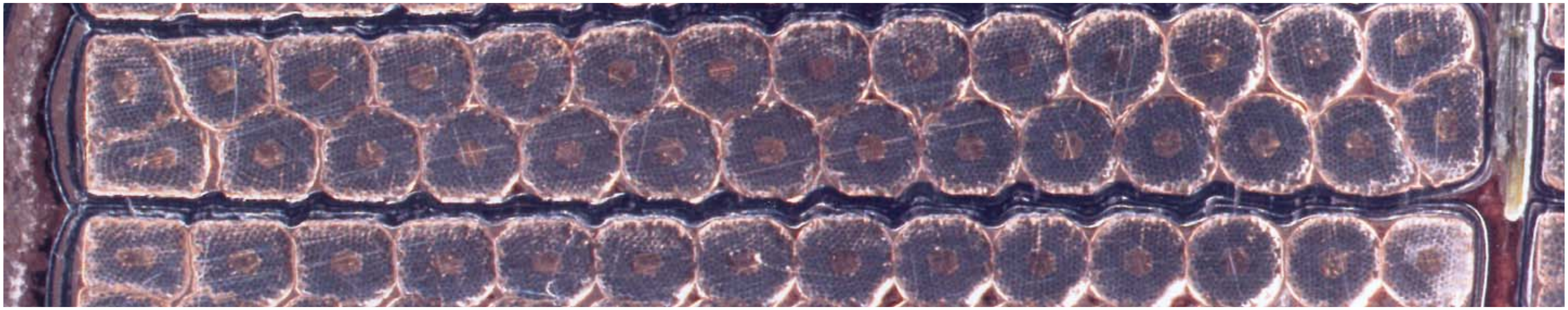
We profit of previous measurements done mostly at CEA-Saclay on different cable insulation schemes.

We show there is a potential for a large margin of improvement of heat removal with respect to present LHC schemes

Cable insulation

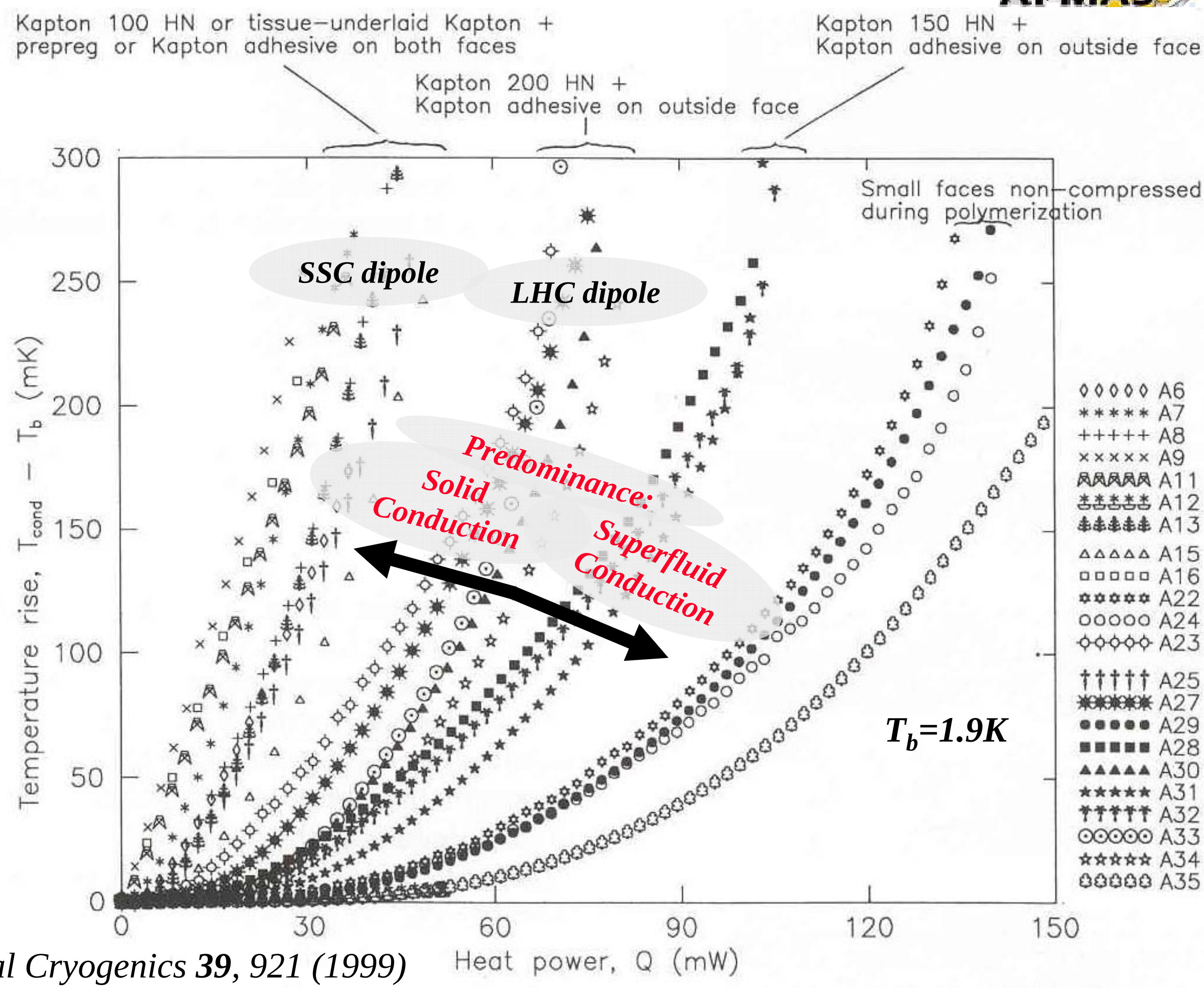






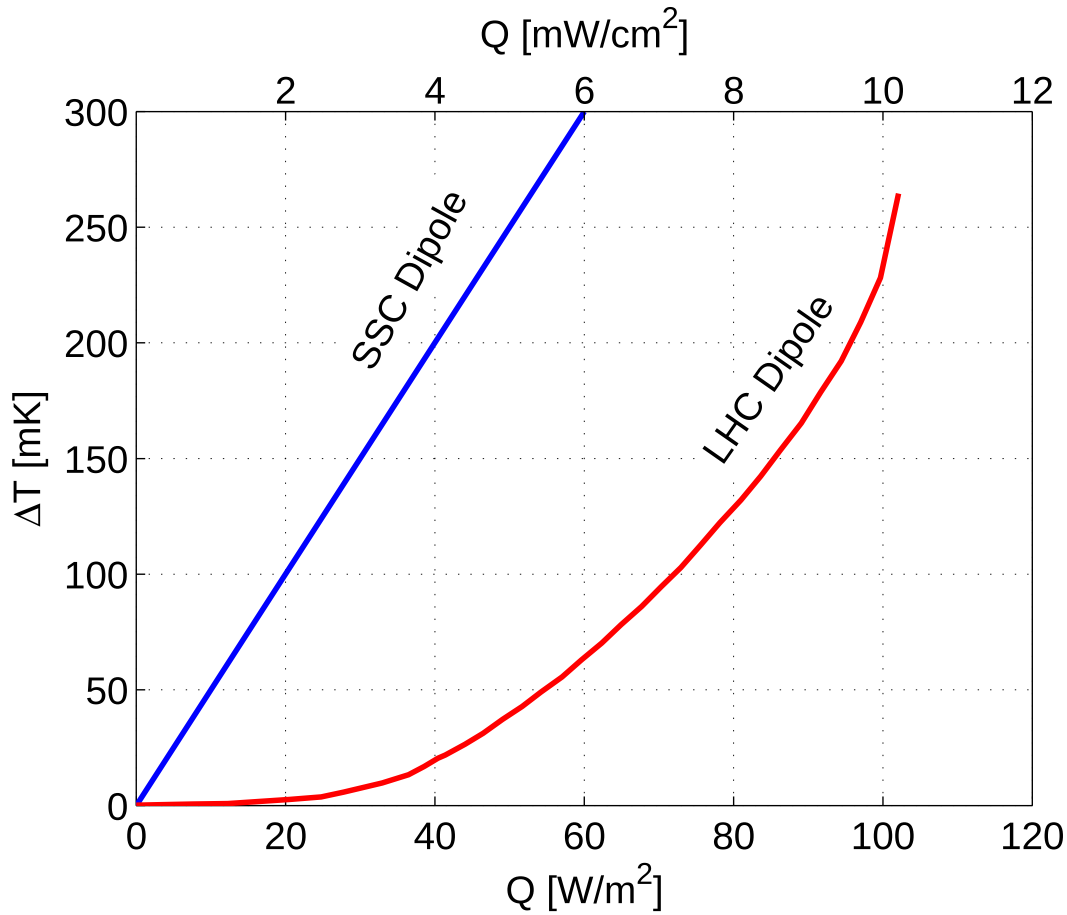
Heat transfer

- Nb-Ti pourous insulations
- Insulations are wrapped around a steel cable mock-up, 150 mm long.
- Conductor is always wet by He II
- He II Channels saturate $T_c = T_\lambda$



From B. Baudouy et al Cryogenics **39**, 921 (1999)

Heat transfer



Elaborated from B. Baudouy et al Cryogenics 39, 921 (1999)

For a LHC main dipole :

Inner cable perimeter ~ 12 cm

For ΔT = 150 mK $\Rightarrow$ Q = 85 W/m^2

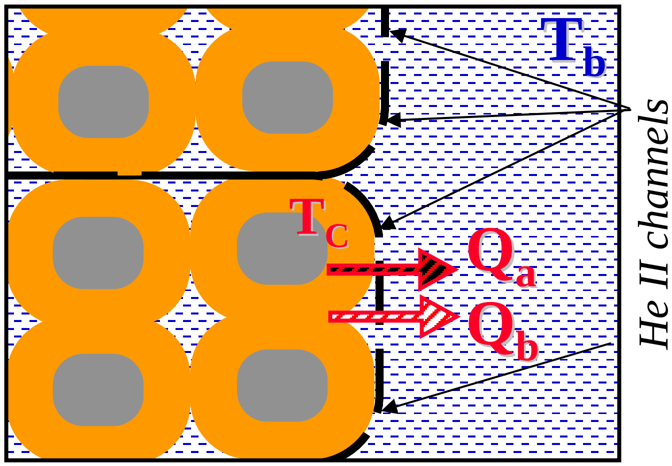
$\Downarrow$

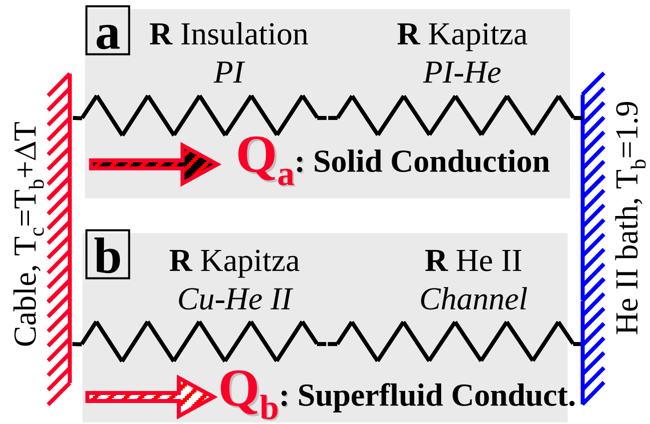
Heat transfer ~ 165 mW/m per turn

IF UNIFORMELY DISTRIBUTED

~10 W/m per aperture

Heat Transfer Model



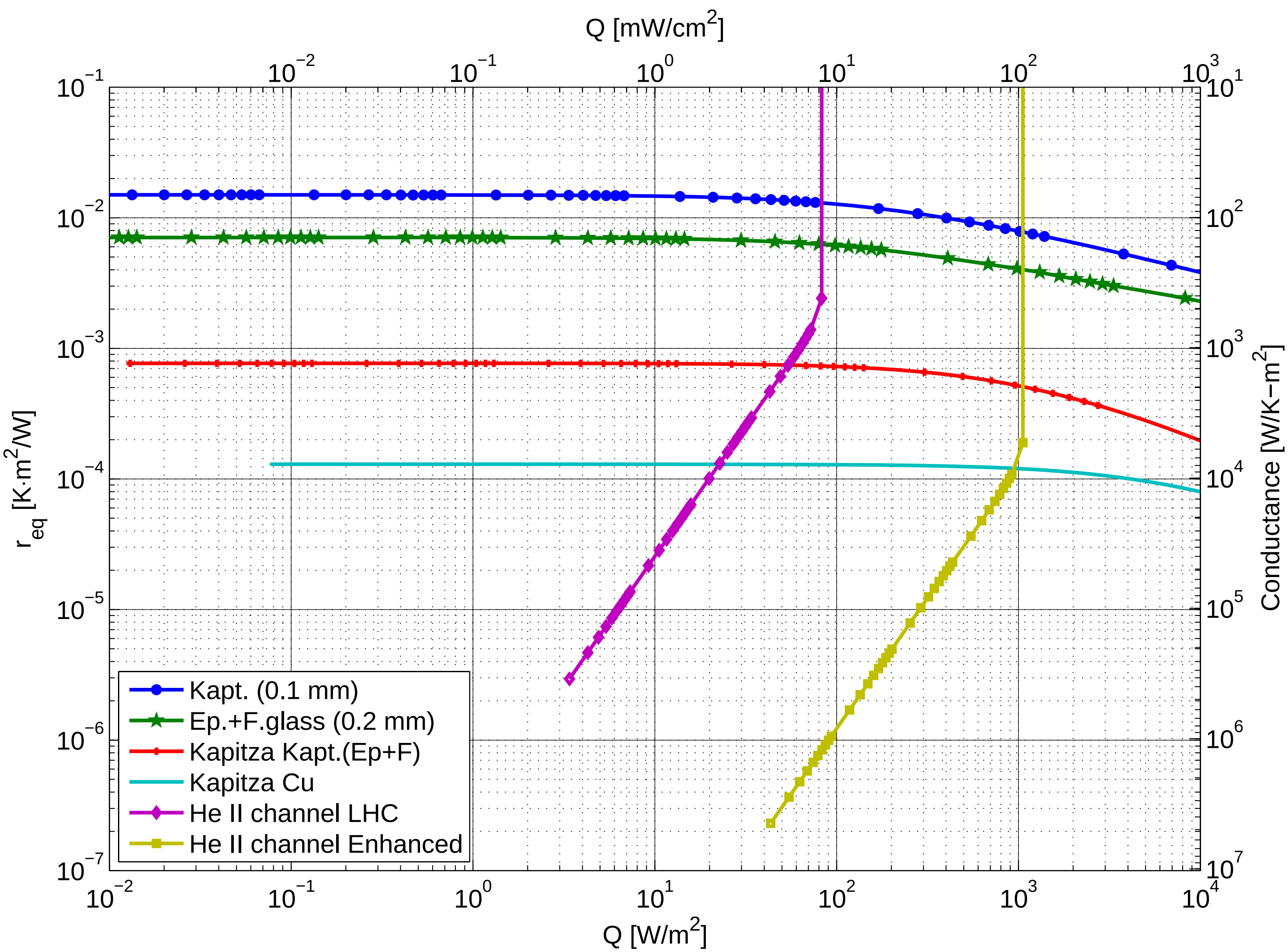


1) ***Q_a* vs *Q_b* depends on insulation porosity**
2) ***Q_a* & *Q_b* are non linear**
3) ***Q_b* has saturation level**

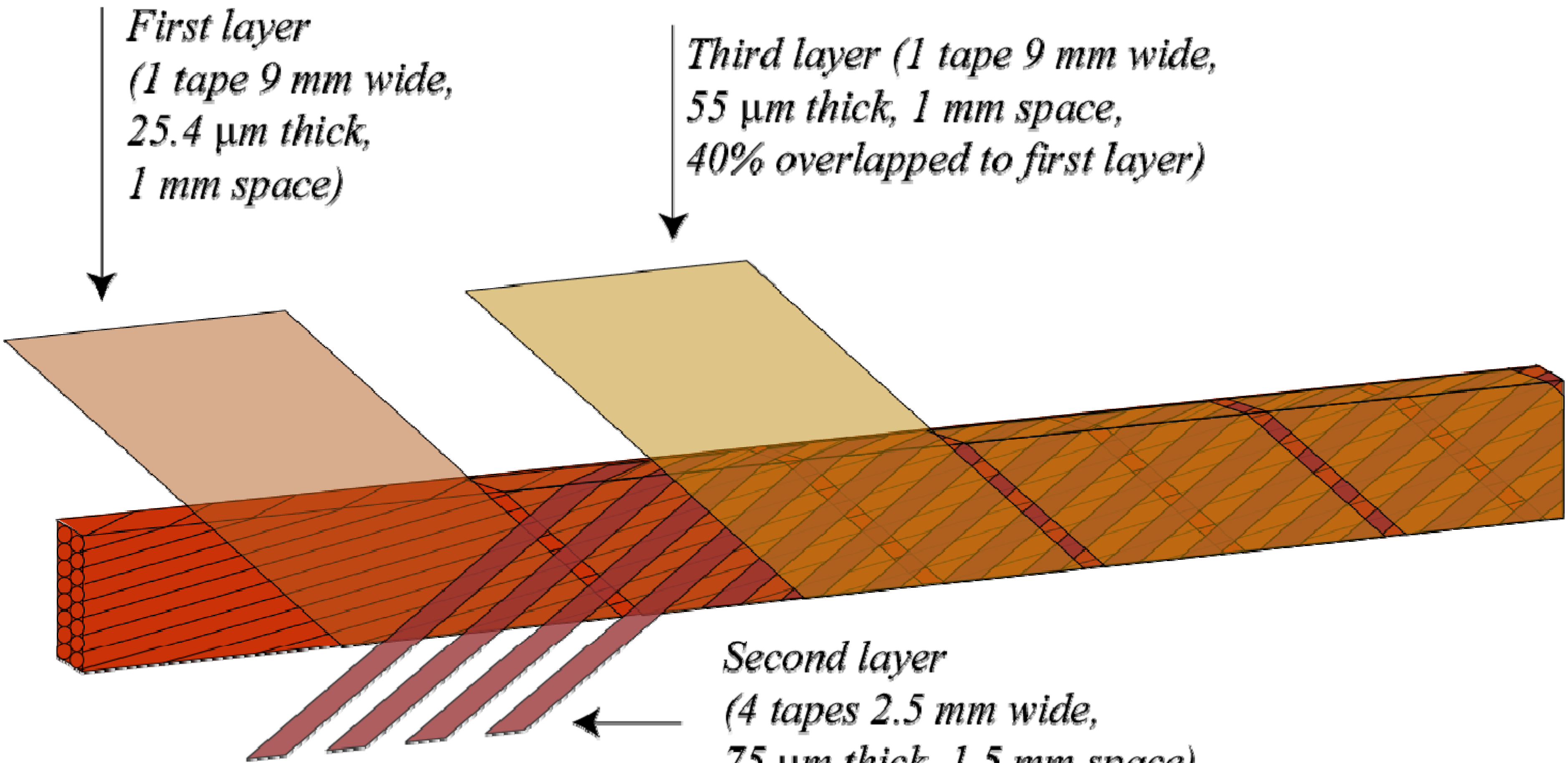
Assumptions:

- Negligible thermal boundary resistance at the strand-insulation interface [3,4]
- Parallel paths are decoupled
- Conductor and He II bath are isothermal
- He II heat transfer regime is Gorter-Mellink [5] (may lead to under-estimate [6]).

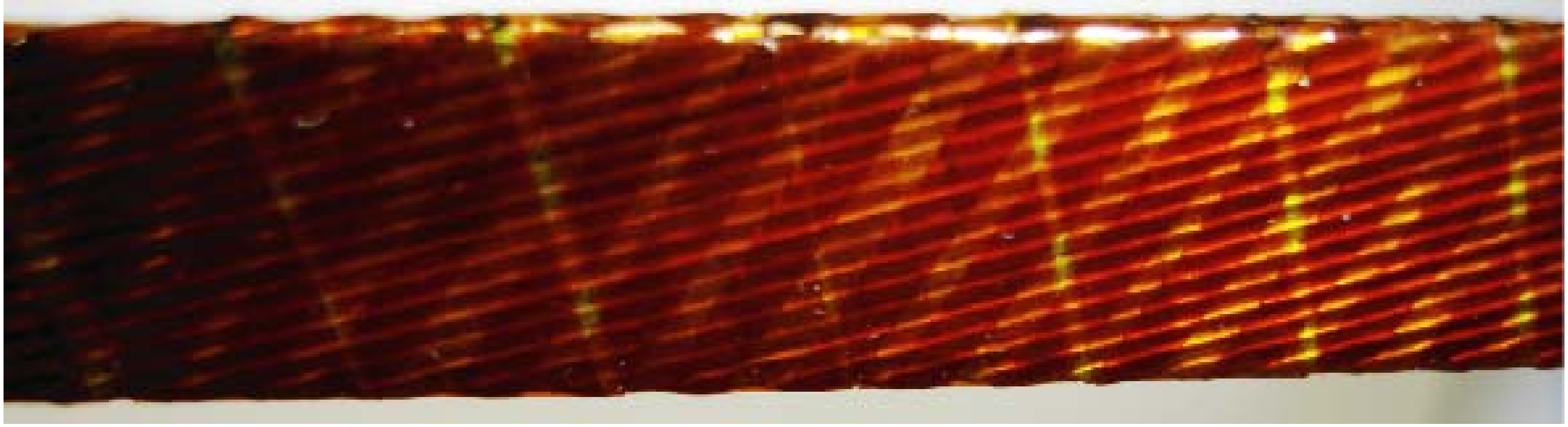
Comparison of Equivalent Thermal Resistances in an Insulated Cable



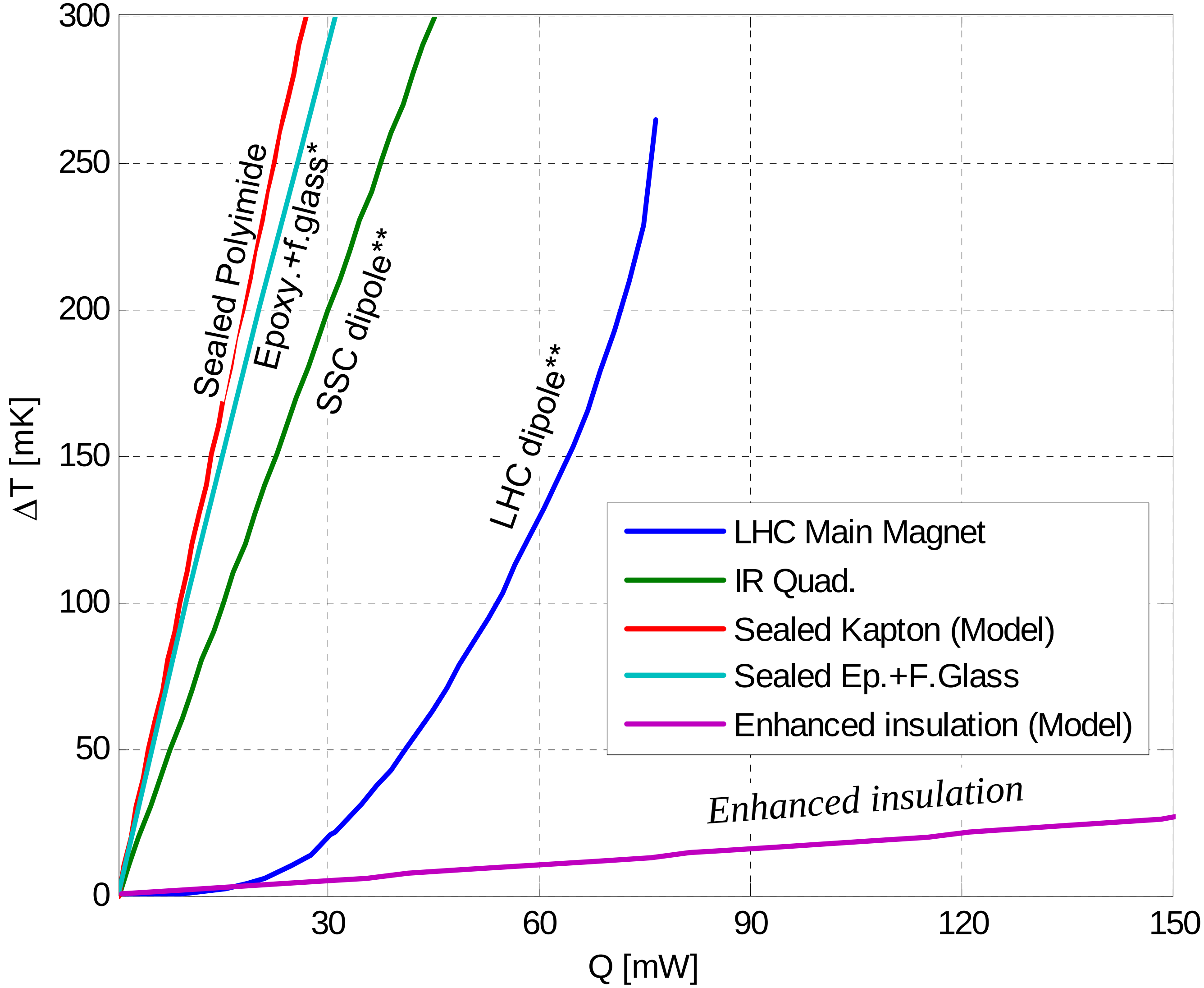
Enhanced Porosity



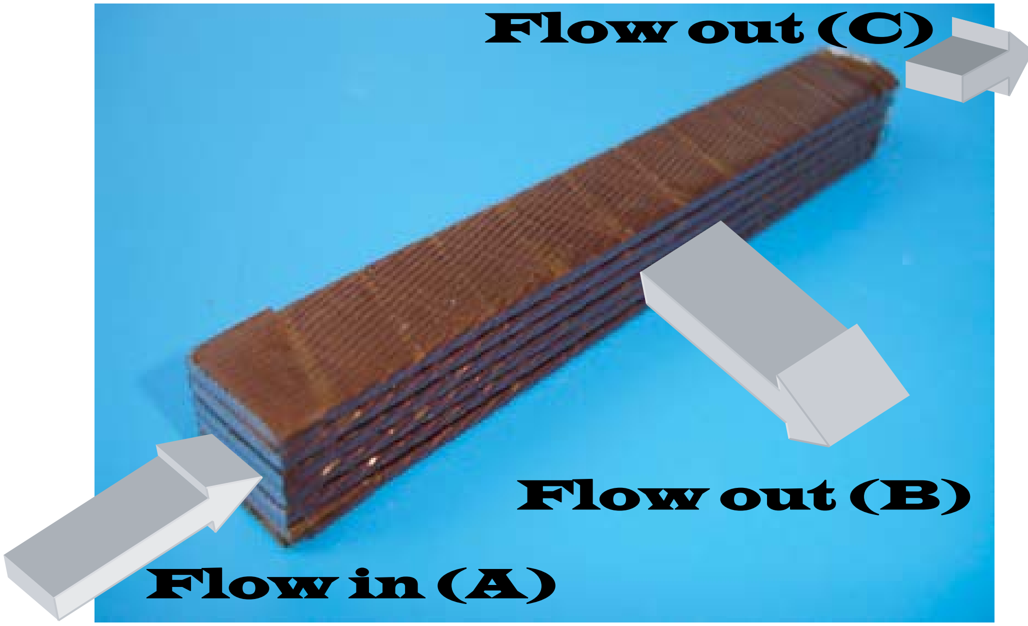
Enhanced Porosity

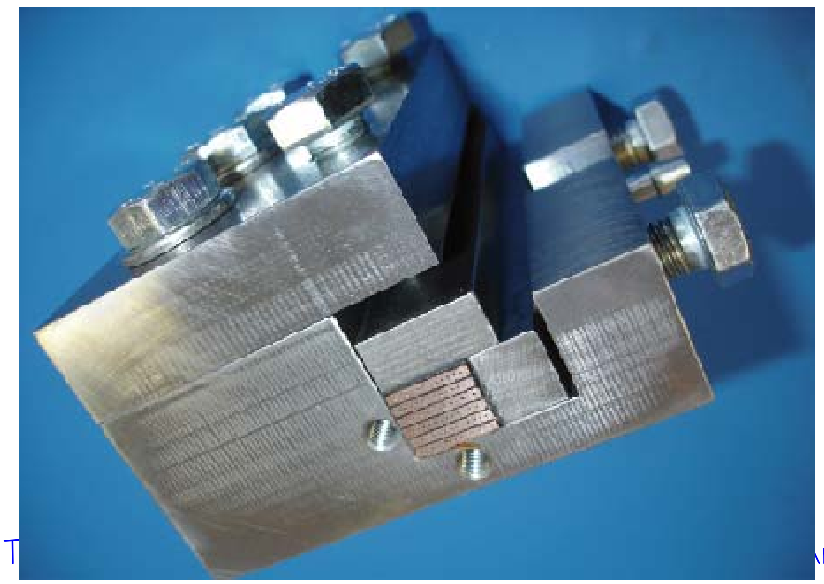


Summary of thermal transfer



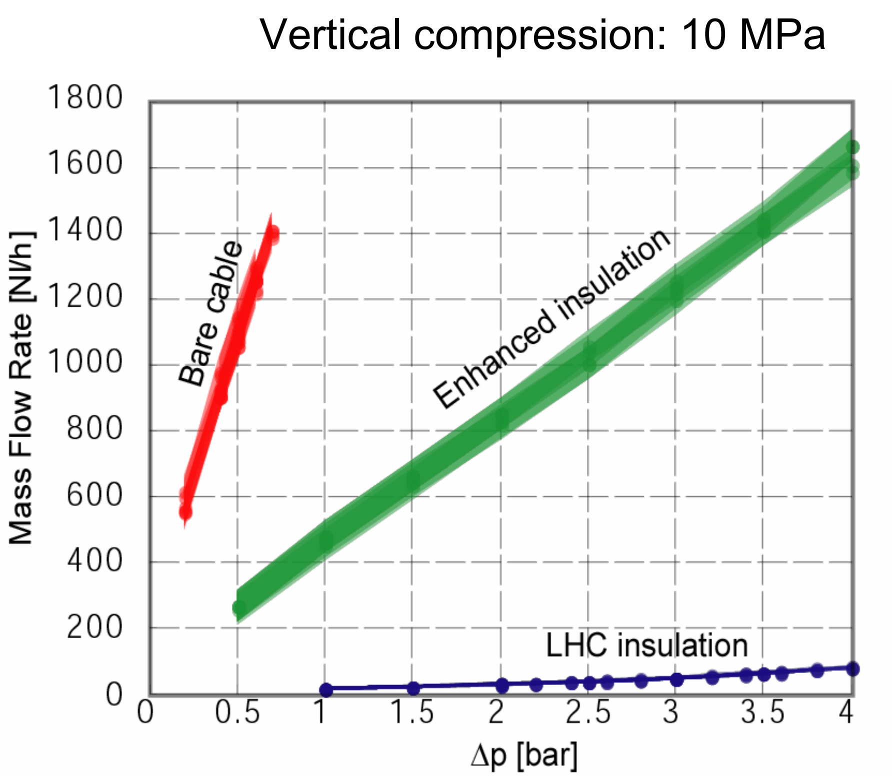
Porosity tests

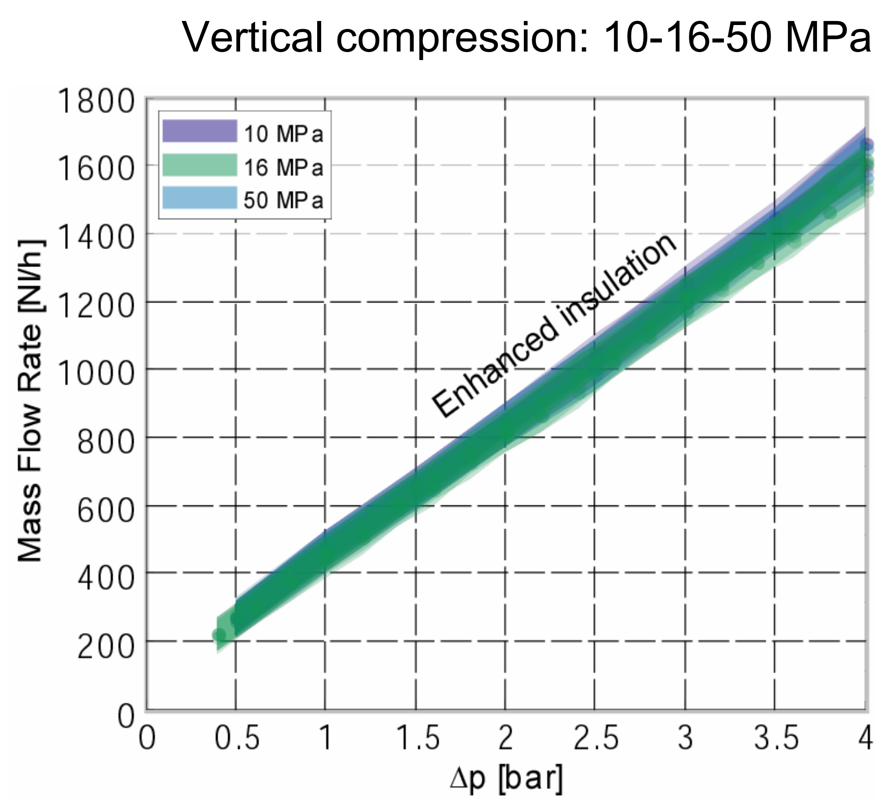




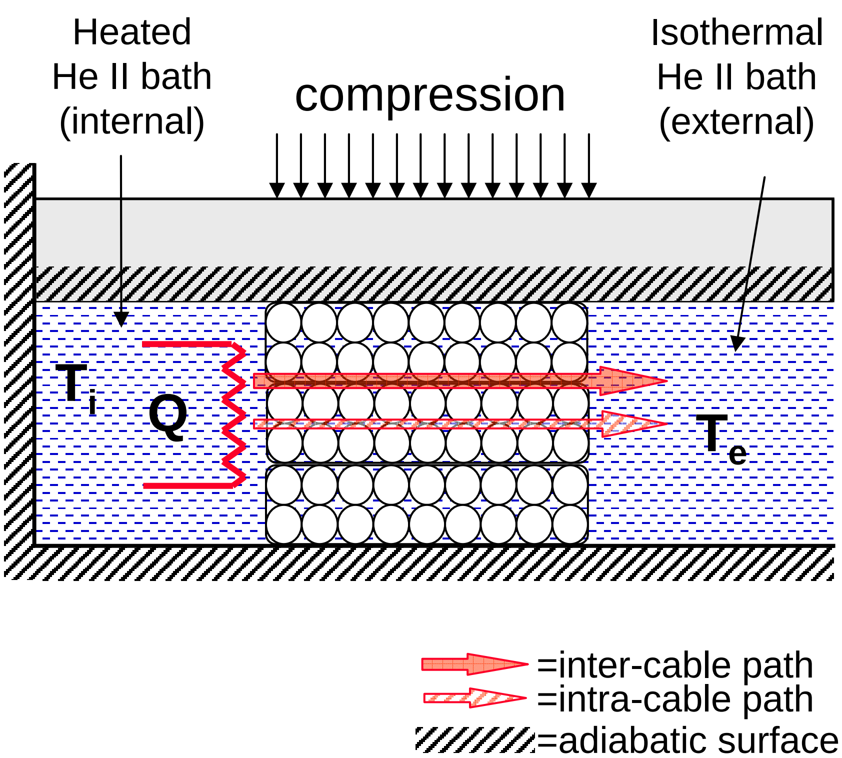
Tests Results: Radial flow

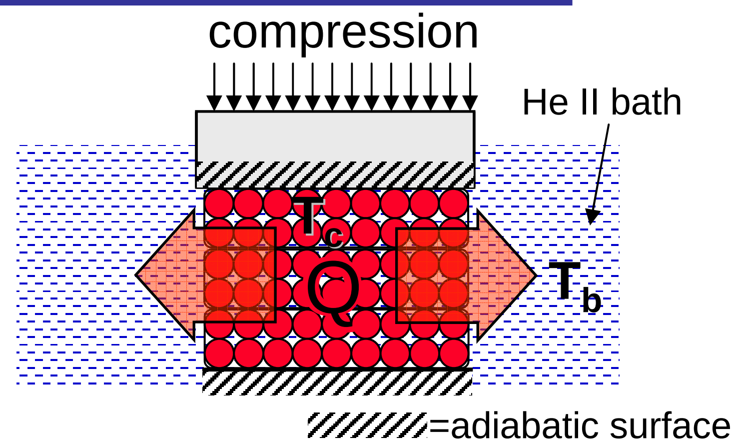
- We show the radial flow rate versus the imposed pressure difference ($\Delta P = P_{inlet} - P_{outlet}$).
- Porosity of enhanced insulation is one order of magnitude larger both at 10 and at 50 MPa vertical compression



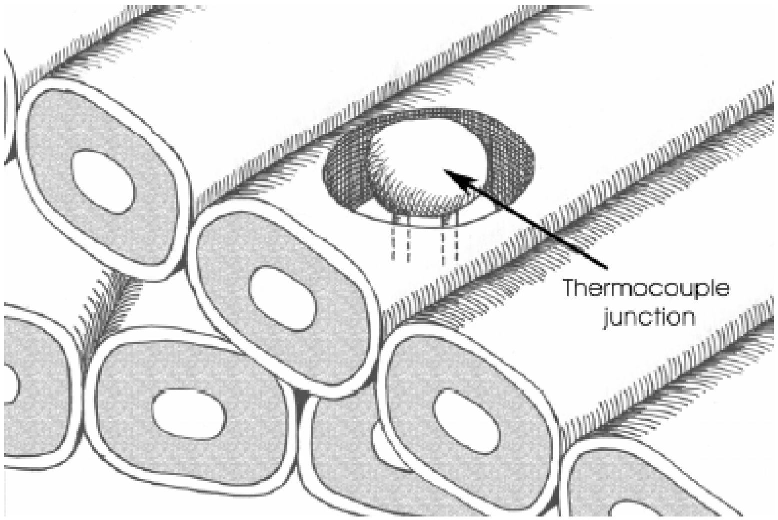


Heat Transfer Tests





Under way : at Cracow University and at CERN



Courtesy of D. Richter (CERN)

Summary

- The present limitation of heat removal from state of the art insulated NbTi Rutherford cables at 1.9 K is about 85 W/m^2 , corresponding to about 165 mW/m for a LHC main dipole turn.

- There is a large potential to increase the dimension of the cooling channels thus moving their saturation at higher heat fluxes

- This opens new opportunities for using NbTi rutherford cables in costeta structures operating at 1.9 K in presence of heat loads

Coming soon

THERMOMAG-07

A CARE-HHH Workshop on

Heat Generation & Transfer in Superconducting Magnets

Paris, 19-20 November 2007

- Workshop leaflet
- Timetable
- Registration
- Information for authors
- List of participants
- List of hotels
- How to get there

LPNHE – Université Pierre & Marie Curie (Paris VI)
4, Place Jussieu – 75006 Paris
Tour 33 – Amphithéâtre Bernard Grossetête

Minimizing and evacuating heat is one of the main challenges of the next generation of superconducting magnets for high intensity particle accelerators, such as the IR magnet for the LHC luminosity upgrade and the fast cycled magnets for FAIR and for the LHC injector chain upgrade.

This workshop aims at reviewing the present knowledge on heat transfer in superconducting magnets, and at identifying common thermal design bases.

Expected outputs are:

- Identify the state of the art on
    - Cooling techniques (fluids and regimes)
    - Heat transfer mechanisms
    - Modeling of heat transfer from coils to cooling system
    - Heat transfer experiments
- Identify a common set of thermal design criteria

Organizing Committee : B. Baudouy, D. Tommasini, B. Piccirelli
Scientific secretary : H. Allain, M. La China

Thermal Resistances Review

- Thermal boundary resistance at interfaces between different materials (Kapitza):

  We use empirical fits q [W/m^2] ,T [K],

  - Cu-He II: $q = 460(T_{Cu}^{3.46} - T_{He}^{3.46})$, [7]
  - Kapton-He II: $q = 47.43(T_{Kap}^{4} - T_{He}^{4})$, [8] verified for small ΔT, we use it also for epoxy
  - Cu-epoxy: $q = 1300_{2K} \div 3600_{6K}(T_{Cu} - T_{Ep})$, [2] consistent with [3]

- Conduction in solids:

  - Kapton: K=4.638e-3*T.^0.5678 [8] verified for 0.5<T<5K
  - Epoxy+fiberglass: $K = 0.6{*}K_{Ep} + 0.4{*}K_{G10}$, ($K_{Ep}$ & K_{G10} from [9] consistent with [3] and [10])

- He II thermal conductivity

  We consider a fully developed Gorter-Mellink regime [4] (conservative hypotheses [5])

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