Workshop on Beam Induced Quenches Summary of session 4 “Heat Transfer R&D”

Many years of experimental and modeling expertise combined:

Speakers	Topics
Pier Paolo Granieri	Steady-State Heat Transfer in the LHC Superconducting Coils: Status of Experiments and Modeling
Erwin Bielert	Possibilities for Finite Element Modeling for a better understanding of Heat Transfer in Rutherford type Cables.
Marco Breschi	Numerical models for Transient and Steady State Heat Transfer
Bertrand Baudouy	Transient Heat and Mass Transfer to Superfluid Helium in the ms to µs Time Scale
Tiemo Winkler	A New Method to Measure the Thermal Response of Superconducting Cable Stacks Cooled by Superfluid Helium to Pulse Heat Loads
Gerard Willering	Stability measurements Rutherford cables
Daniel Wollmann	Identification of Damage-Levels of SC Magnets for transient beam losses

Quick Summary

Many years of research led to one general conclusion:

We know now better what we don't know.

- Geometry of helium channels

- Heat transfer mechanisms in the micro channels

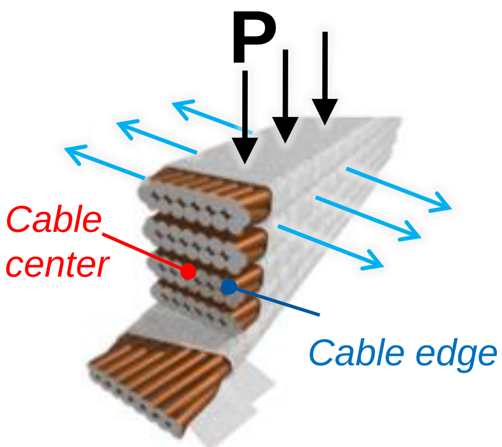
- Interstrand thermal conductivity

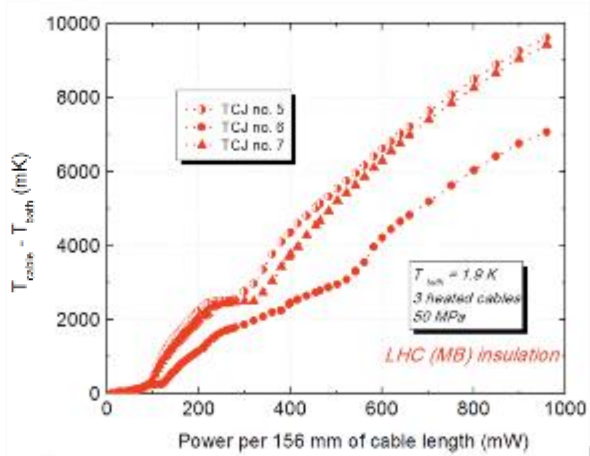
- Interstrand electrical conductivity

In addition:

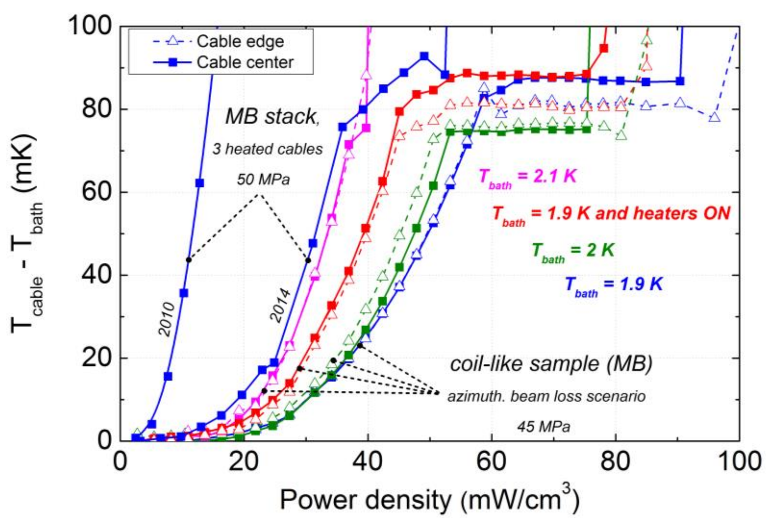
- The variation within a single cable of highly important parameters can be very large.

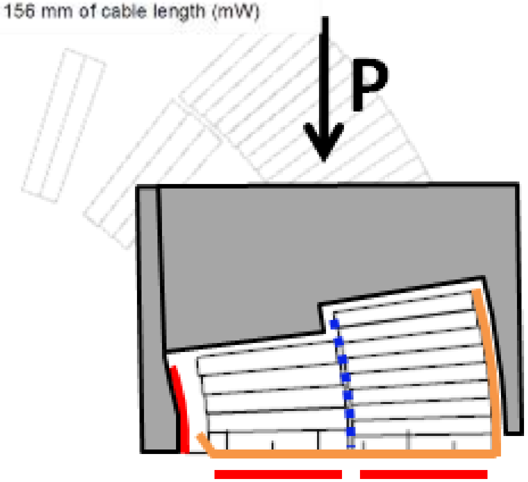
Experiments – Steady state





Consolidated results from cable stack measurements in multiple institutes.

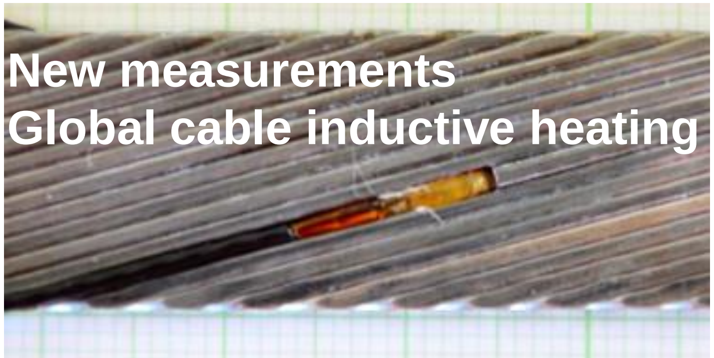


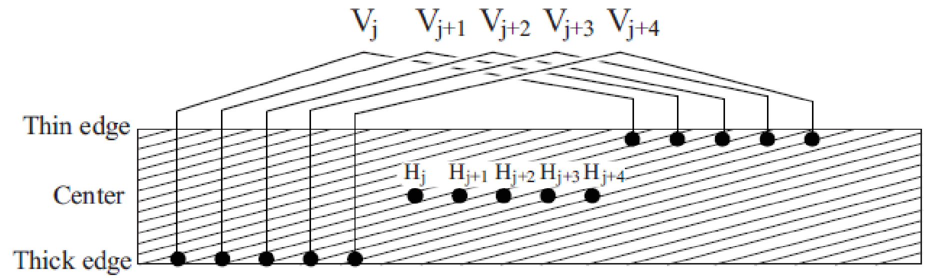


New experiments ongoing including “fish-bone” cooling give unexpected results

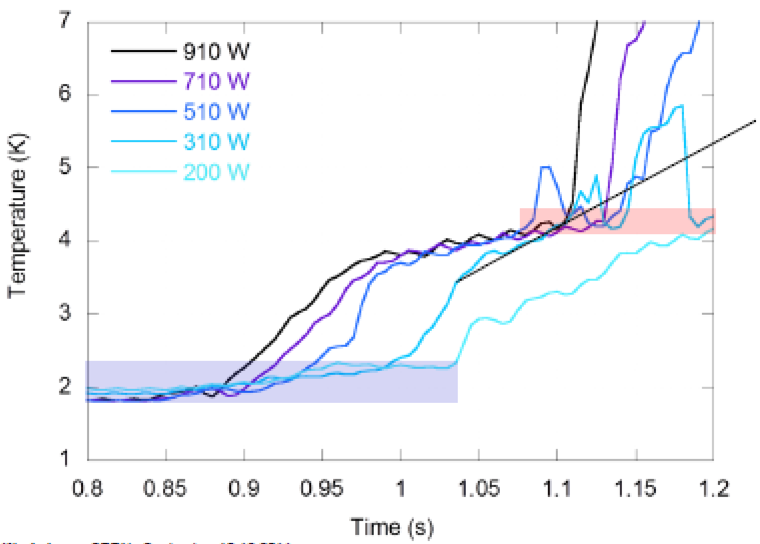
Experiments - Transient

Experiments





Measurements with local pulse heaters
Available for NbTi and Nb_3Sn

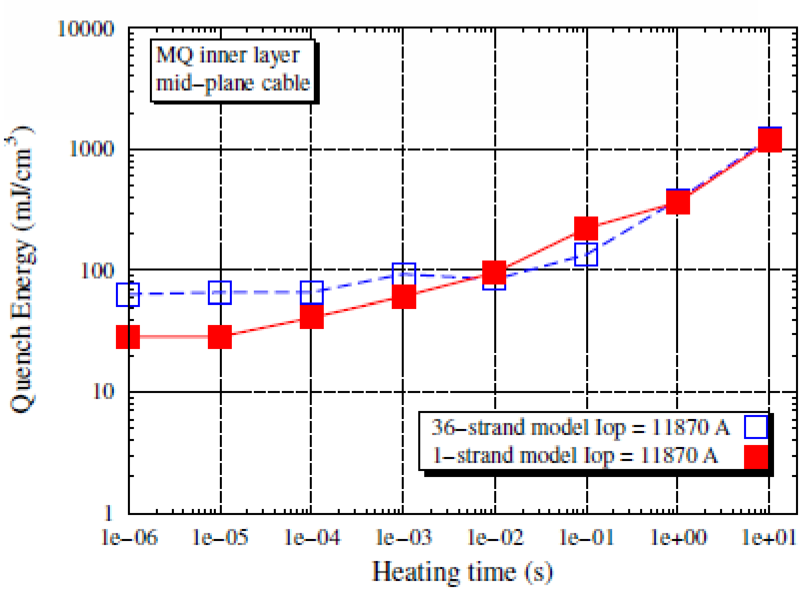


Transient heat transfer measurements in He channels

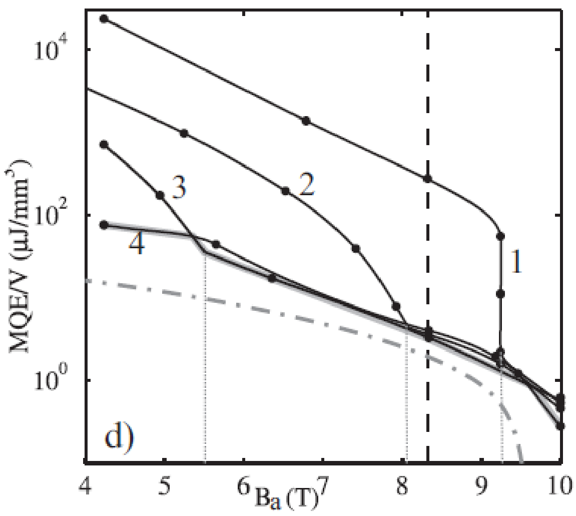
Modeling

"Many models available. With the same input parameters they will give the same results"

Network model (THEA) and lumped model are compared over the whole time range.



CUDI was used to model transient local pulses and quench levels with validated parameters from experiments.



Modeling

Finite element modeling with commercial codes:

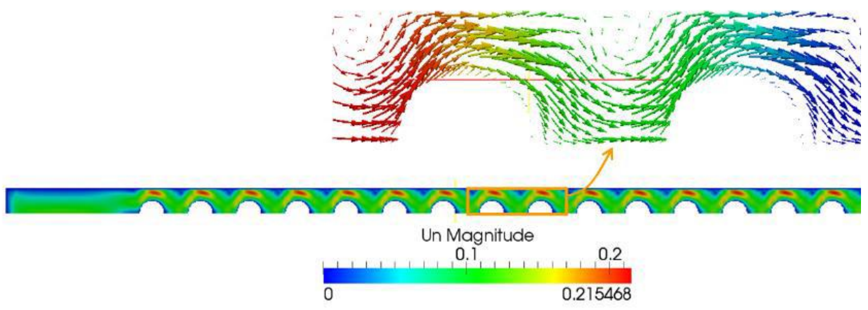
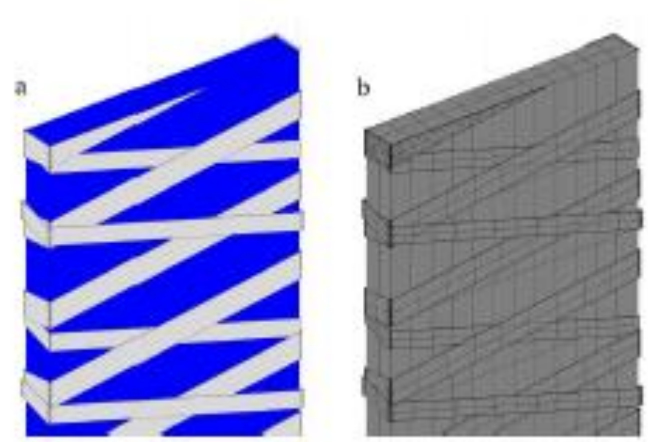


Figure 14: Plot of the normal velocity magnitude and of the normal velocity vectors in two adjacen
clearly notice cyclic flow patterns.



Heat transfer is investigated with

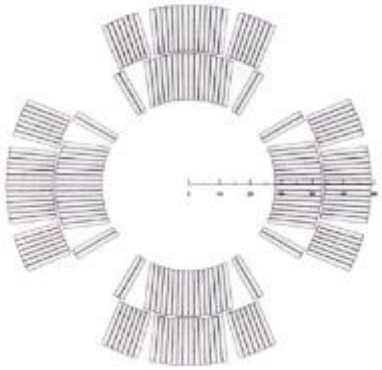
- ANSYS-CFX
- Fluent
- OpenFOAM
- Comsol

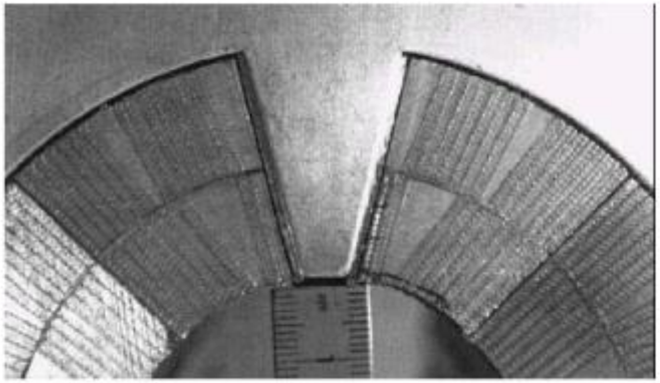
FEM modeling is complimentary to network model approaches.

Experiments – Damage levels

A new campaign started to identify the critical parts of the SC coil.

Investigation is still in the early phase.





Can we compare LHC quench tests to subscale experiments?

LHC Quench tests with real beam may be the most simple:

- Quench or no Quench
- All parameters are realistic!
- Exact beam loss may be unknown

Subscale experiments are more complex

- Detailed knowledge of physics behind the quench levels can be aquired
- But, strand-to-strand variation in parameters can be important
- Helium cooling mechanisms not well known
- Instrumentation not so easy due to small scale, high precision and fast response.
- **Despite difficulties the knowledge of the mechanisms may improve quench levels in future generation magnets**

Conclusions

- Large volume of measurement data is available, but:

  With all the possible variations in parameters the measurements do not cover all possible real cases. Extrapolation with modeling needs to bridge the gap.
- Combining measurements and modeling is essential
- All models give the same result if the input parameters are similar. Knowing **input parameters** is critical.
- Least investigated is the intermediate time scale (10 ms to 1 s)
- There is still a lot to learn and to collaborate on!

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