Stability measurements Rutherford type cables

Small overview of research done from 2005-2009

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With thanks to
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Herman ten Kate

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- How was it measured
- Current redistribution effects
- Influence of interstrand contacts
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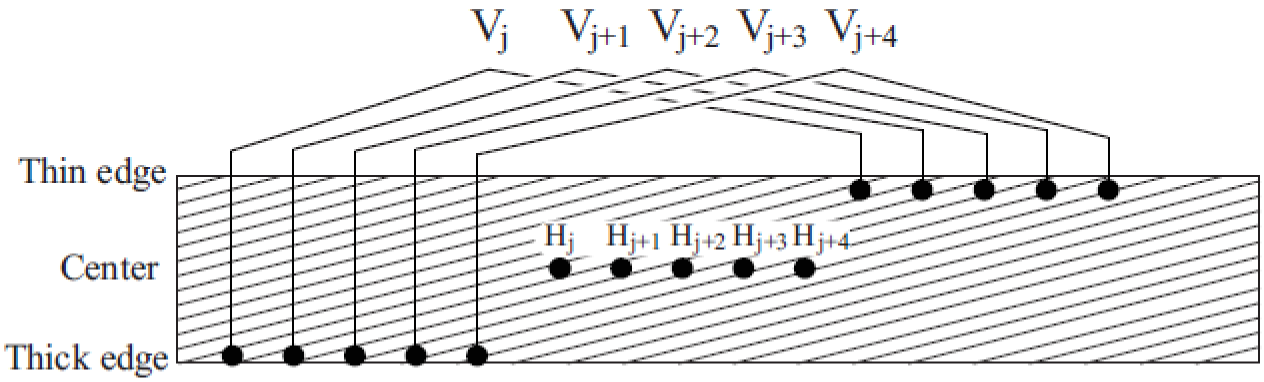
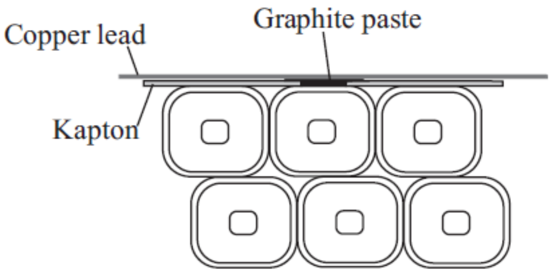
What was measured

Minimum Quench Energy (MQE)

Definition: Minimum energy needed to quench when the energy is deposited in an infinitely small point with a delta pulse.

Real life: Spot heater 0.5 mm diameter, effective pulse duration from 100 µs to 10 ms.

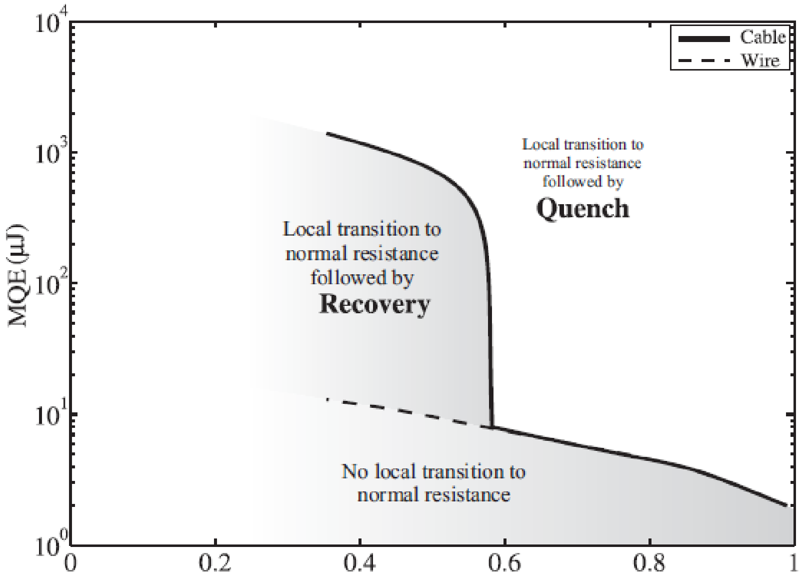




Spot heaters of graphite paste:

- Very good thermal contact with the cable.
- Heating generated very close to the cable.
- Response time of < 100 µs.
- Are used as voltage taps too.

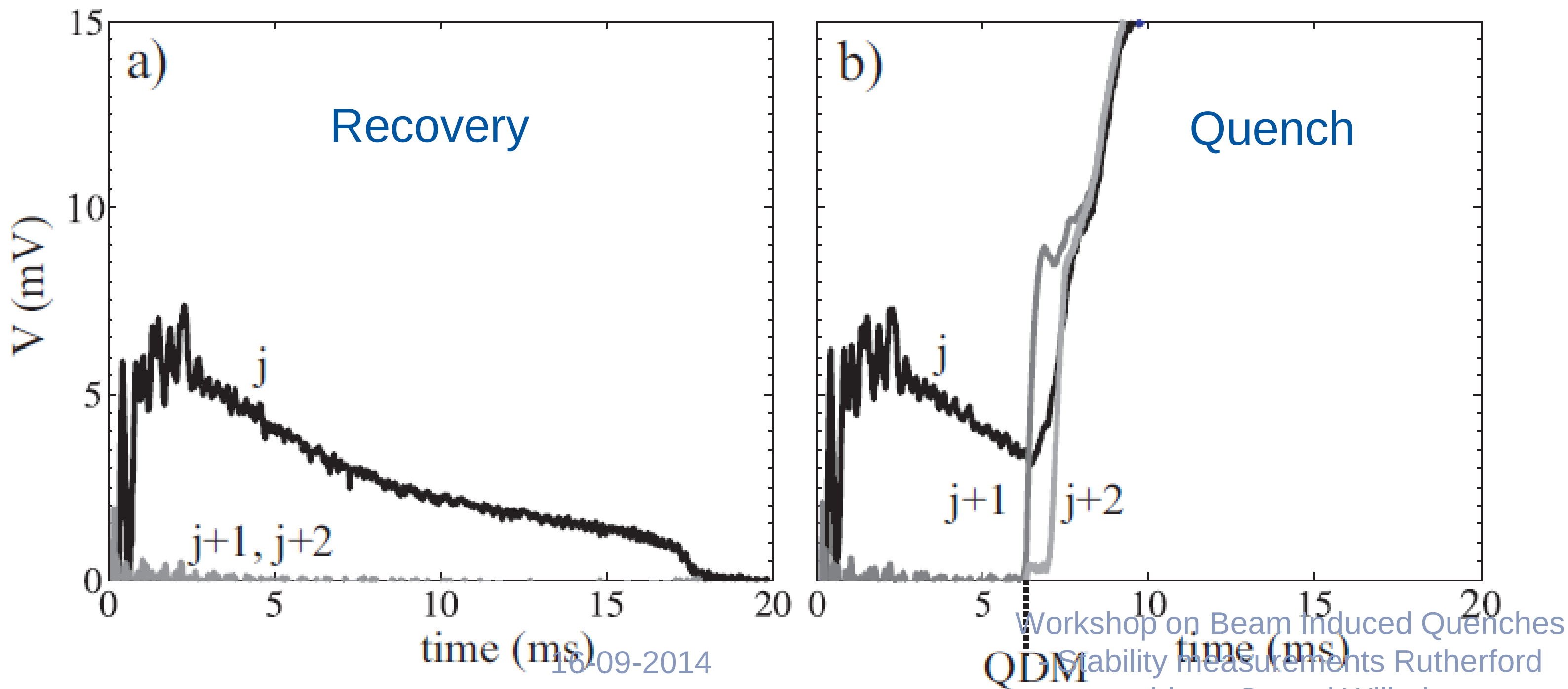
What was measured



Dashed line is similar to single strand data.

The area “Recovery” is the most interesting.

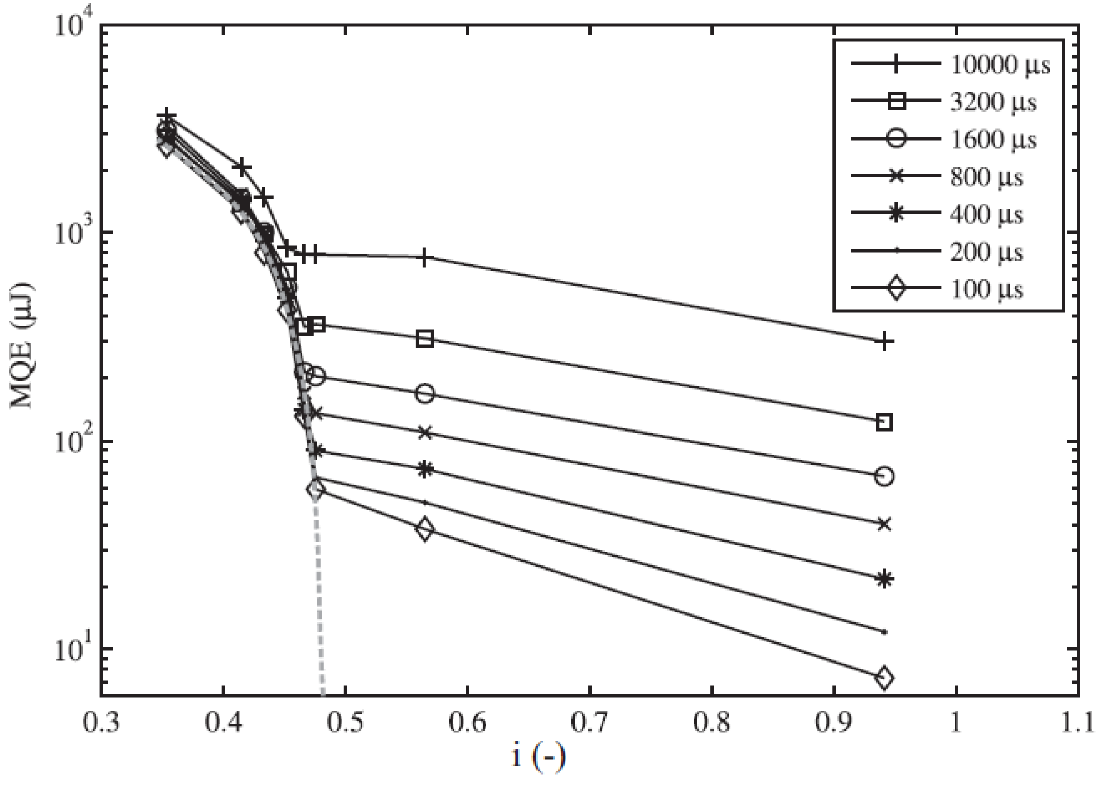
“Quench Decision Moment” (QDM) can be much longer than pulse duration in the cable regime.



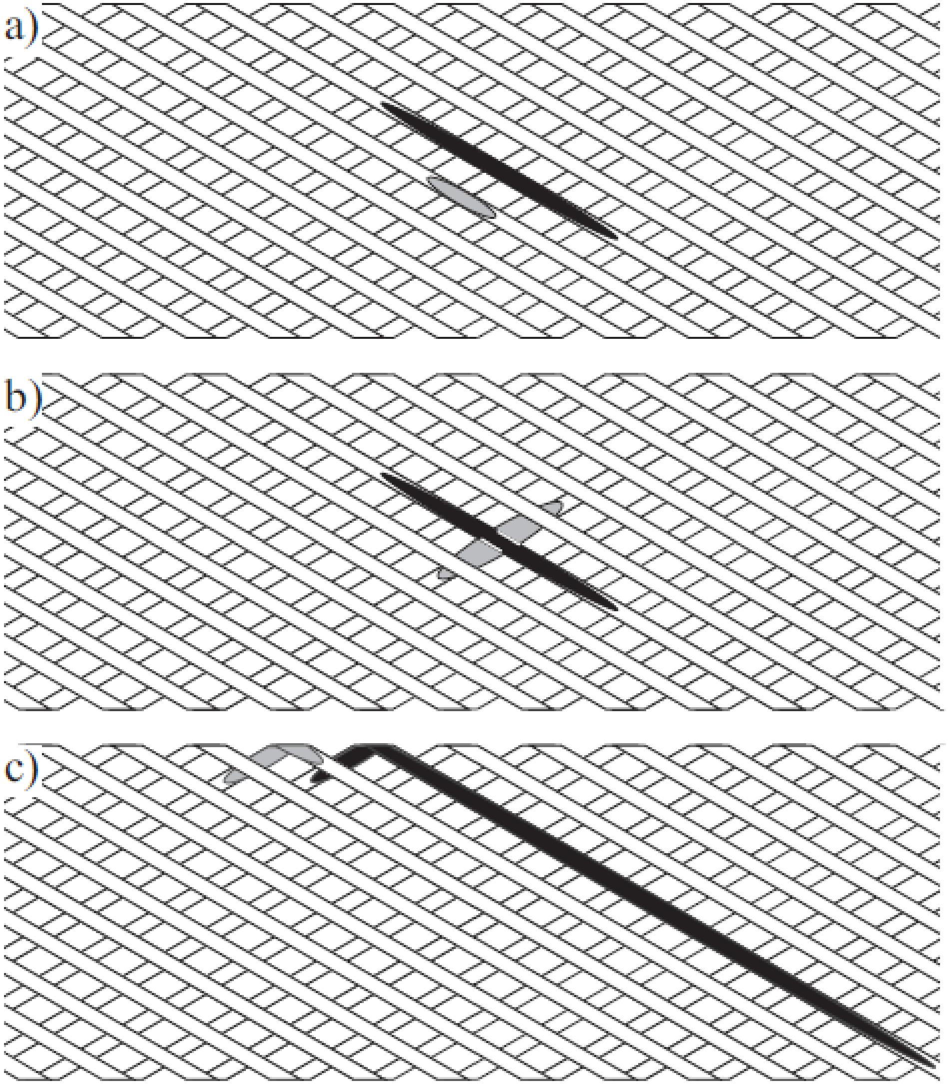
Influence of pulse duration

Measurement range from 100 µs to 10 ms

The “kink” is only slightly depending on the pulse duration, whereas the single strand regime strongly depends on it.



Transverse propagation from strand to strand



Different mechanisms

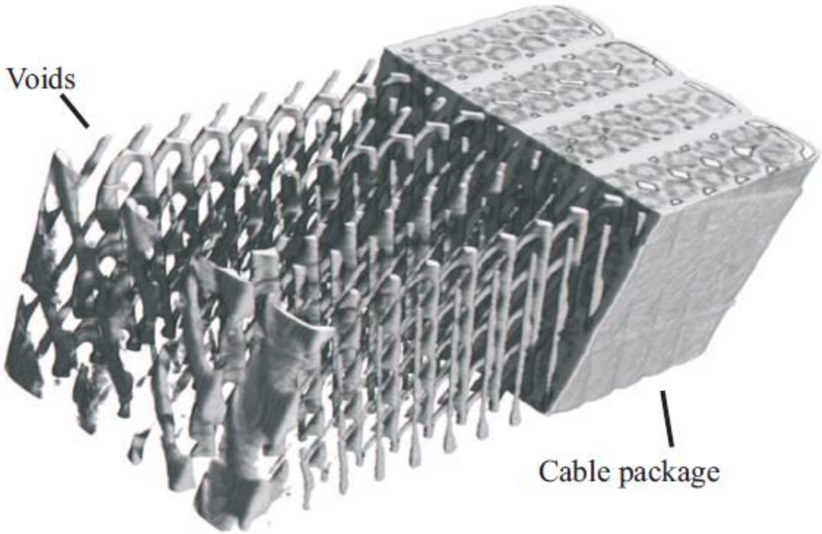
Adjacent propagation

Cross propagation

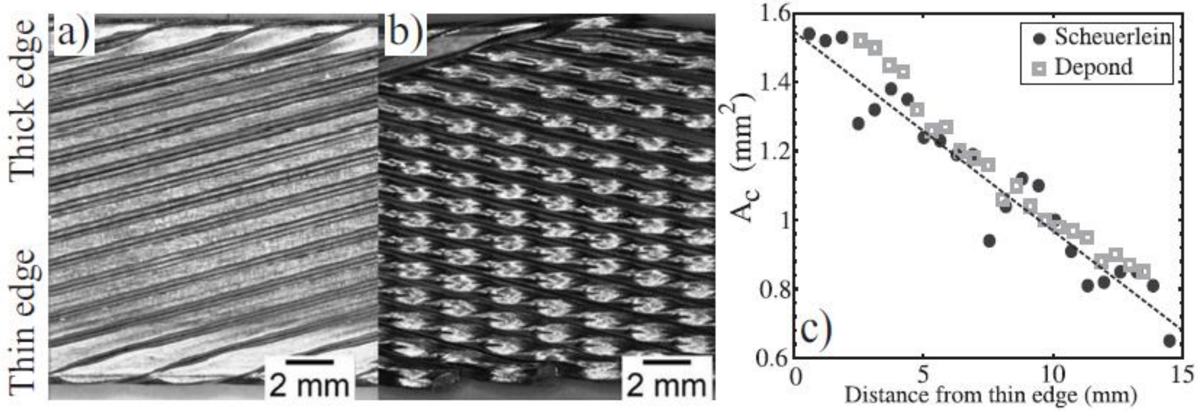
Edge propagation

Geometry parameters

Tomography of a cable stack was done to have correct helium volume and helium contact as function of the cross section of the cable.



Courtesy C. Scheuerlein



Interstrand contact parameters

Different sample prepared, varying the thermal and electrical interstrand contact resistance.

Table 6.1: Properties of the measured samples.

Sample name	Coating	Core	Impregnation	RRR	R_a ($\mu\Omega$)	R_c ($\mu\Omega$)
LHC 01 - A	SnAg	No	No	200	150-200**	15-20**
LHC 01 - B	SnAg	No	No	90	20-300**	2-30**
LHC 01 - C	Al	No	No	250	>1000**	640*
LHC 01 - D	SnAg	No	No	200	150-200**	15-20**
LHC 01 - E	SnAg	No	Yes	200	150-200**	15-20**
LHC 01 - F	Soldered	No	No	300	< 0.1**	< 0.1**
SIS 300 dipole - A	Soldered	Yes	No	346	< 1*	> 20000**
SIS 300 dipole - B	AgSn	Yes	No	89	60-70*	> 20000**
SIS 300 dipole - C	AgSn	Yes	No	245	600-700*	> 20000**
SIS 300 dipole - D	AgSn	Yes	No	272	8000-9000*	> 20000**

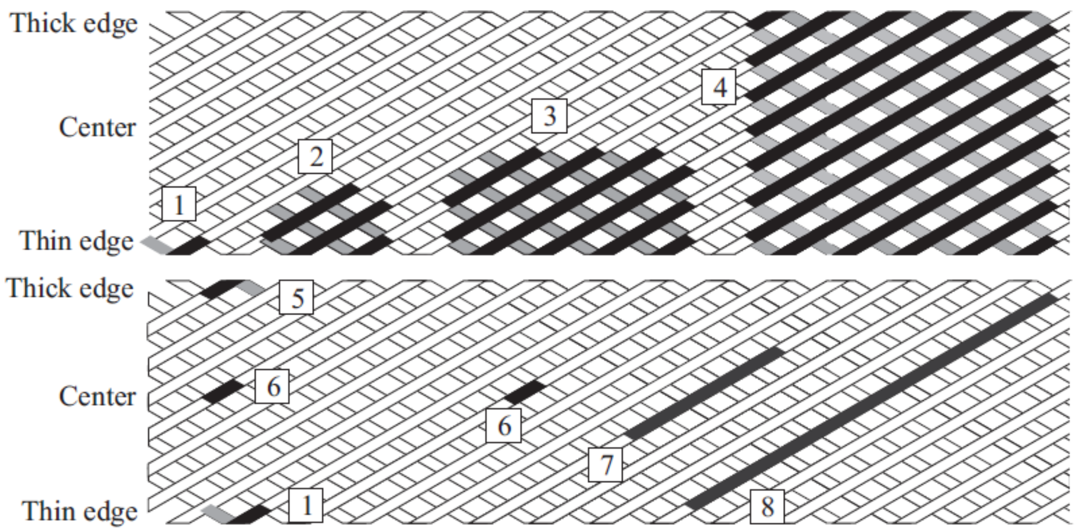
*Measured

**Data determined from literature values.

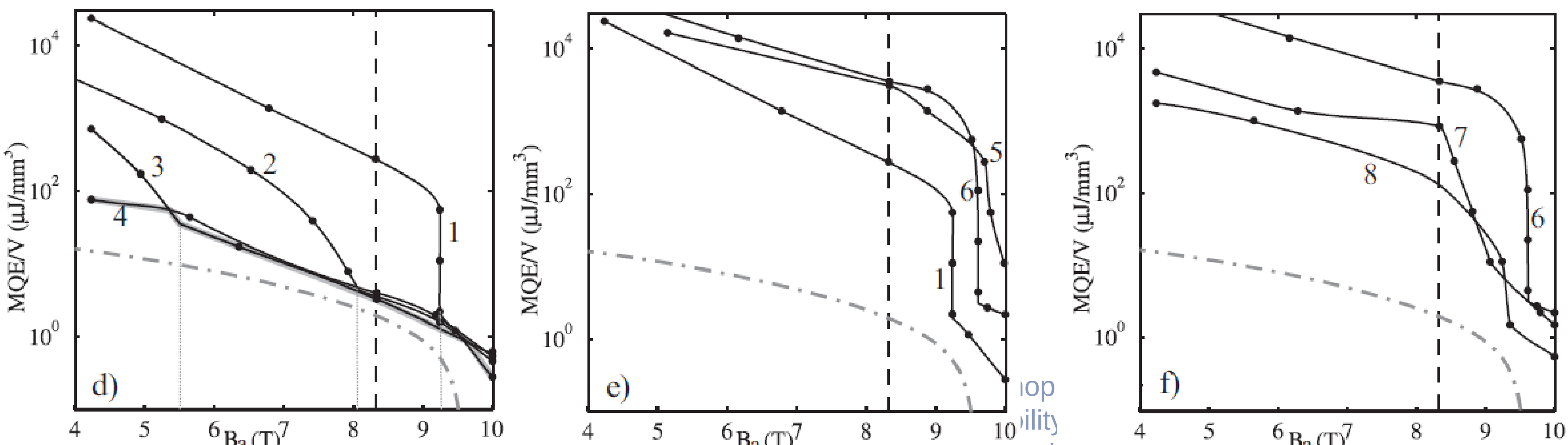
The whole parameter space has been evaluated either by specific measurements or literature research.

How does this translate to LHC magnets

Using CUDI and having validated all parameters by the experiments and using the field as in the LHC magnet. Varying pulse size, pulse duration 10 µs, LHC dipole, turn 40.



Most interesting for Beam loss:
Pulse size 1, 2, 3 and 4



Summary

- A large set of measurement data is available in the 100 µs to 10 ms range on LHC type cable and can be used for model validation.

  (some 10 cables measured, various conditions and preparations, some 8000 heat pulses)

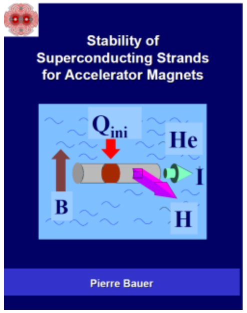
- Many parameters of the cable have been investigated, either directly or through literature.

  (like geometry, helium volume and contact surface, interstrand electrical and thermal resistance).

- Some calculated curves readily available for the LHC main dipole magnets.

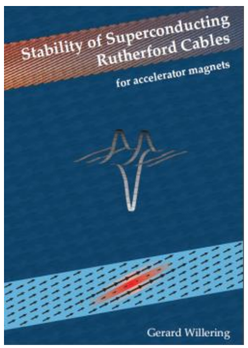
- Most extensive experimental dataset available on LHC type NbTi cables, and a comprehensive set of characteristics of all the parameters that serve as input for calculations.

Further reading



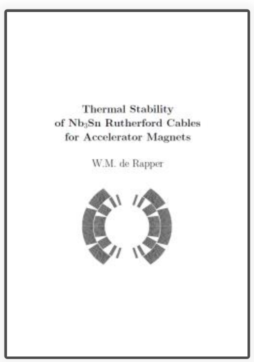
Thesis “Stability of Superconducting Strands for Accelerator Magnets”, P. Bauer, 1996

- http://cds.cern.ch/record/492626/files/Thesis-1996-Bauer.pdf



Thesis “Stability of Superconducting Rutherford Cables for Accelerator Magnets”, G. Willering, 2009

- http://doc.utwente.nl/61331/1/thesis_G_Willering.pdf



Thesis “Thermal Stability of Nb_3Sn Rutherford Cables for Accelerator Magnets”, W.M. de Rapper, 2014

- http://doc.utwente.nl/90653/1/thesis_W_de_Rapper.pdf

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