# A New Method to Measure the Thermal Response of Superconducting Cable Stacks Cooled by Superfluid Helium to Pulse Heat Loads

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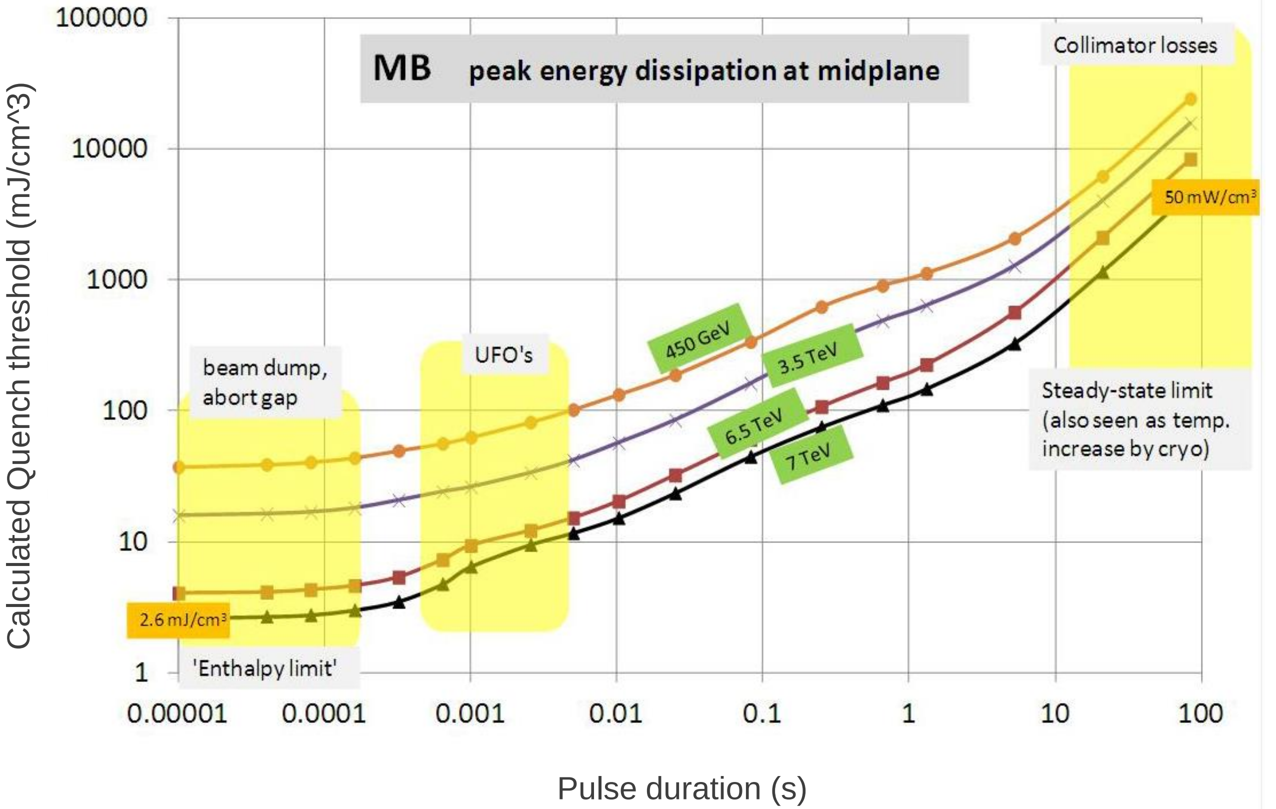
# Motivation

During operation of an accelerator different heat loads occur.

They can be distinguished by their duration into:

- Steady state
- Transient
- Intermediate regime

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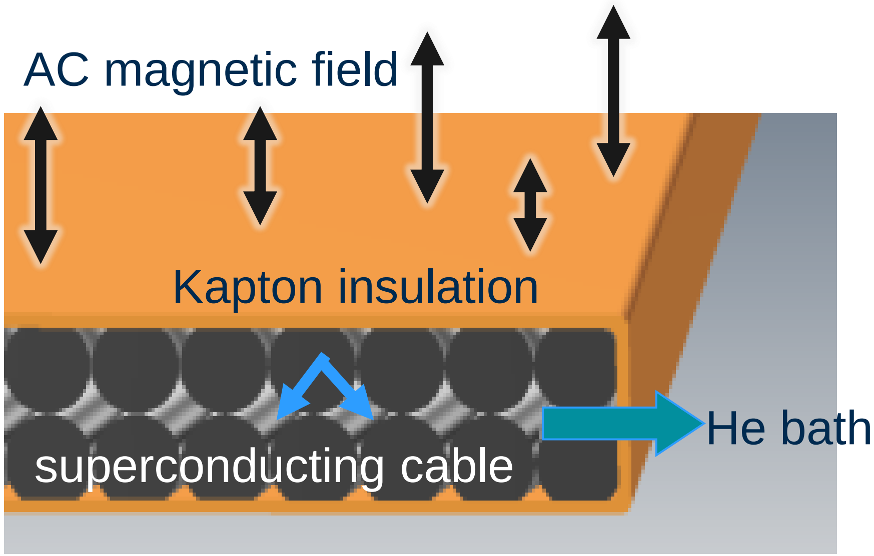
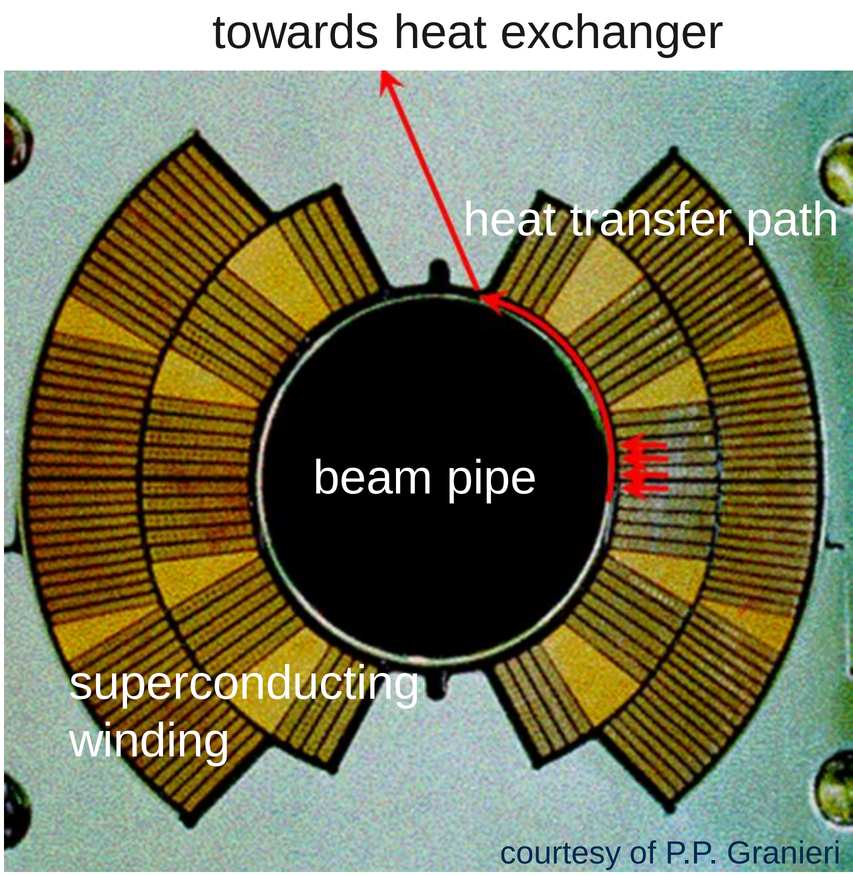
# Motivation – Heat Transfer

- Heat transfer knowledge relies heavily on simulations
- Experimental qualification of simulations has been done for steady-state cooling conditions and on mock-up cables
- For transient cooling conditions experiments have been done with resistive cables, or with superconducting cables with spot heating
- Measurements on superconducting cables / stacks in transient conditions in a liquid helium bath need to be done

# Measurement Idea

- Measurement with a superconducting cable stack
- Measurement in transient cooling conditions
- Use an external AC magnetic field to generate losses on the stack cooled by a liquid helium bath



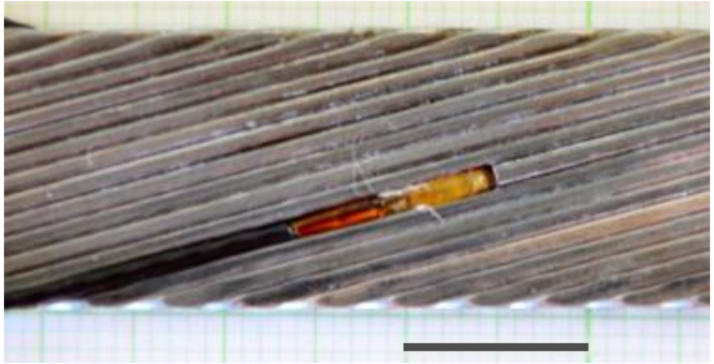



# Experimental Set-up

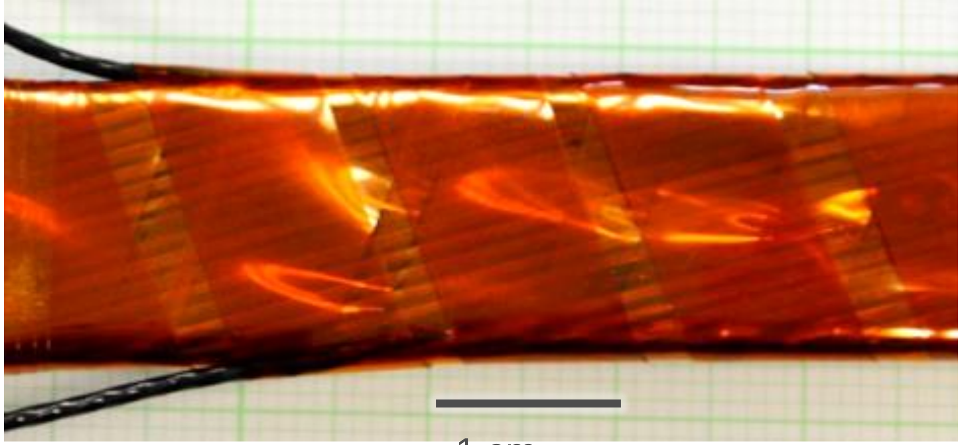
One cable is instrumented with Cernox® temperature sensors

Individually Kapton® insulated NbTi Rutherford cables are used

The change of the geometry of the cable is only necessary for instrumentation

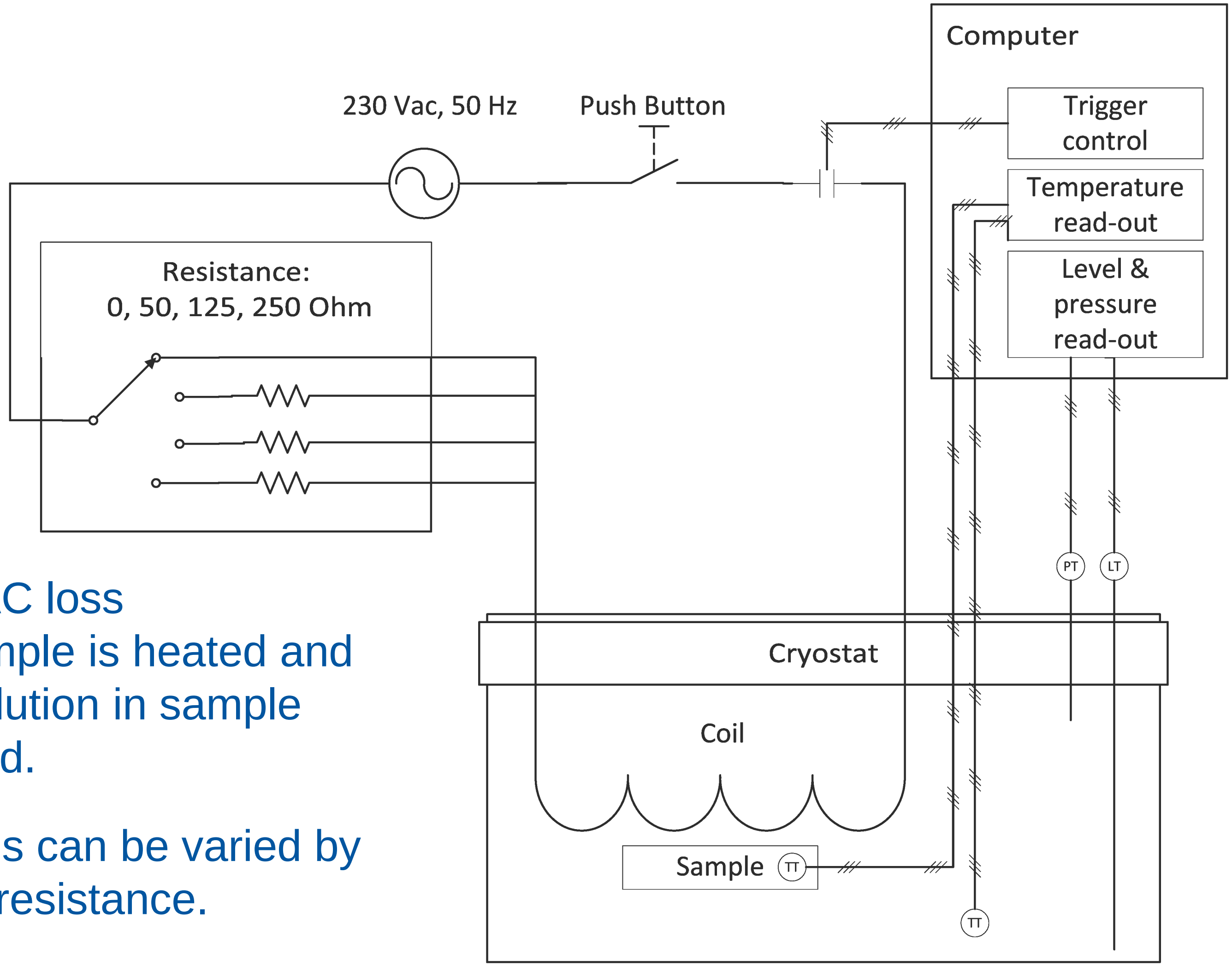


1 cm



1 cm

# How do we measure?

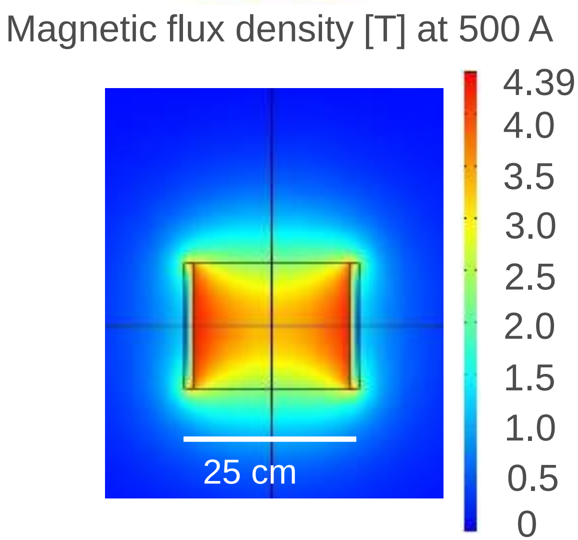


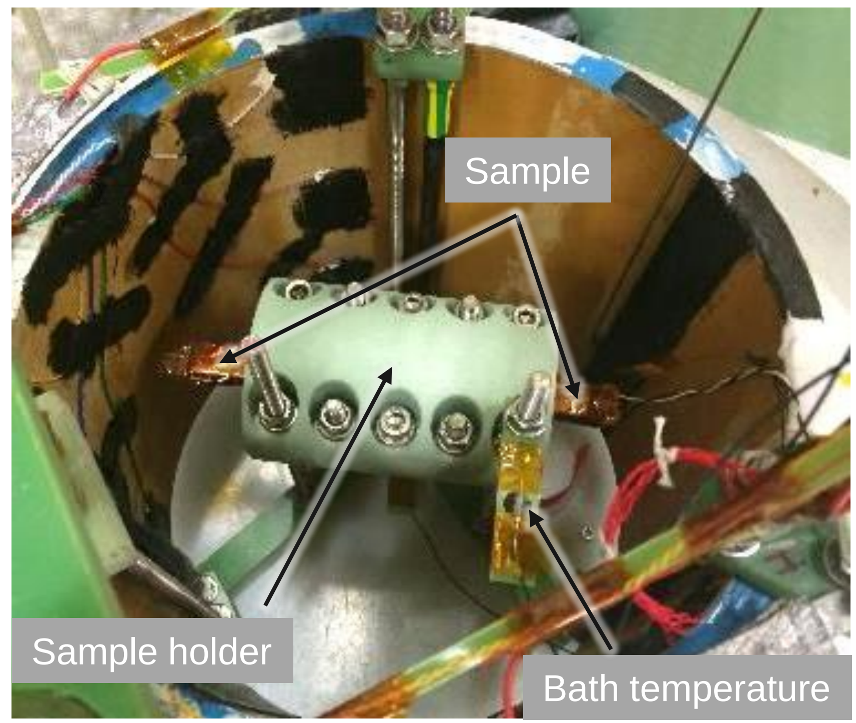

Exploiting different AC loss mechanisms the sample is heated and the temperature evolution in sample and bath is measured.

The generated losses can be varied by changing the series resistance.

# Experimental Set-up 2

- Cable stack is kept under mechanical pressure equivalent to magnet operating conditions
- Use of external AC magnetic field to induce AC losses in superconducting cable stack



# Experimental Set-up 3

The magnet has an inductance of $0.5\ \mathrm{H}$ and is powered with

$$230\ \mathrm{V_{eff}}, 50\ \mathrm{Hz}$$

resulting in

$$I_{max} = 2.1\ \mathrm{A}$$

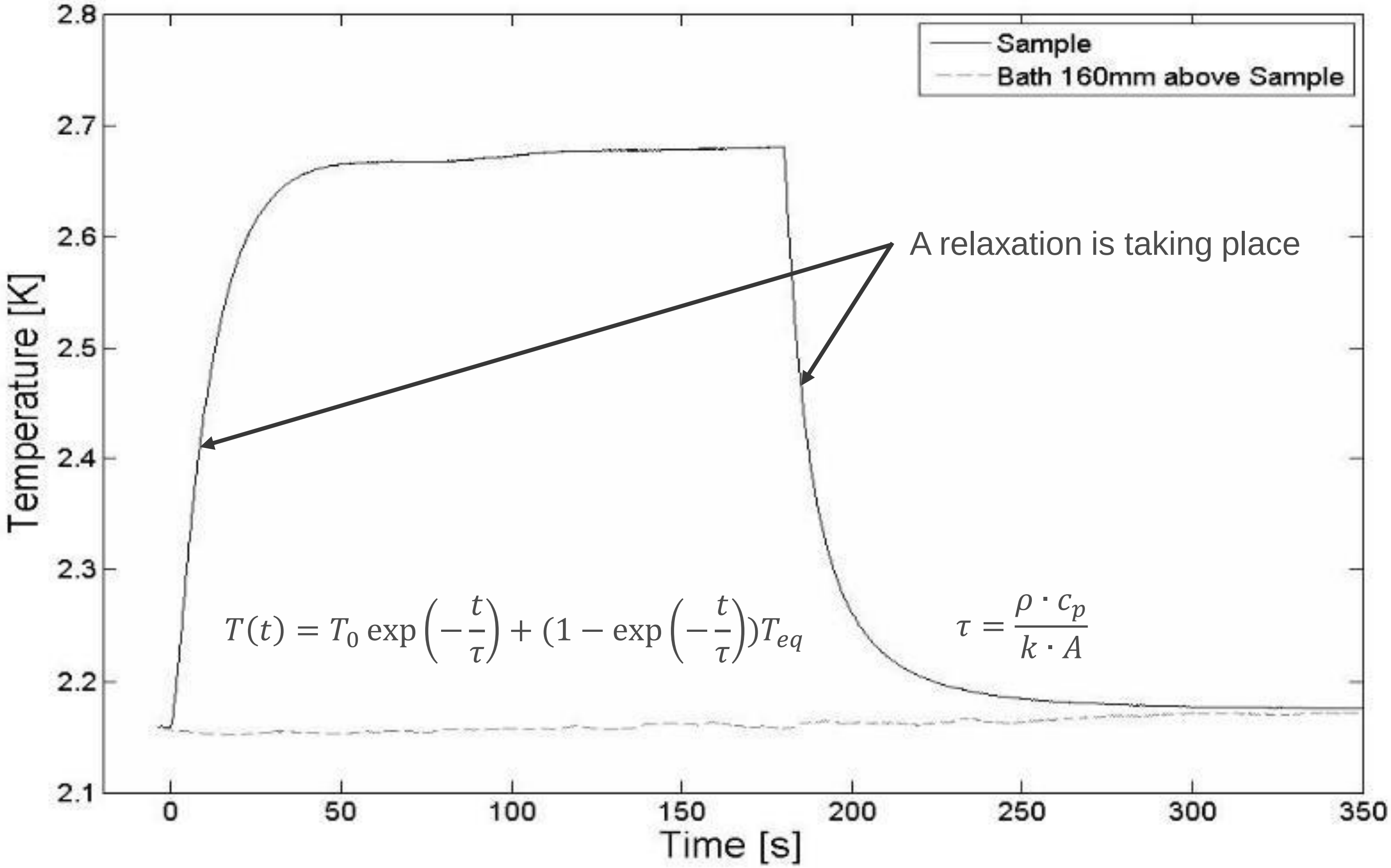
This gives a peak to peak current change of

$$\frac{dI}{dt} = 1300\ \mathrm{A}/s$$

And results in a peak to peak magnetic field change of

$$\frac{dB}{dt} = 8\ \mathrm{T}/s$$

# Measurement Result




$$T(t) = T_0 \exp\left(-\frac{t}{\tau}\right) + (1 - \exp\left(-\frac{t}{\tau}\right))T_{eq}$$

$$\tau = \frac{\rho \cdot c_p}{k \cdot A}$$

# Measurement Result 2

Using the aforementioned function and $\tau$ as fitting parameter one finds values for $\tau$ between

$$9.7 \text{ sec } \pm 0.3 \text{ sec }.$$

From the steady-state temperature difference the heating power $Q$ can be deduced with the equation

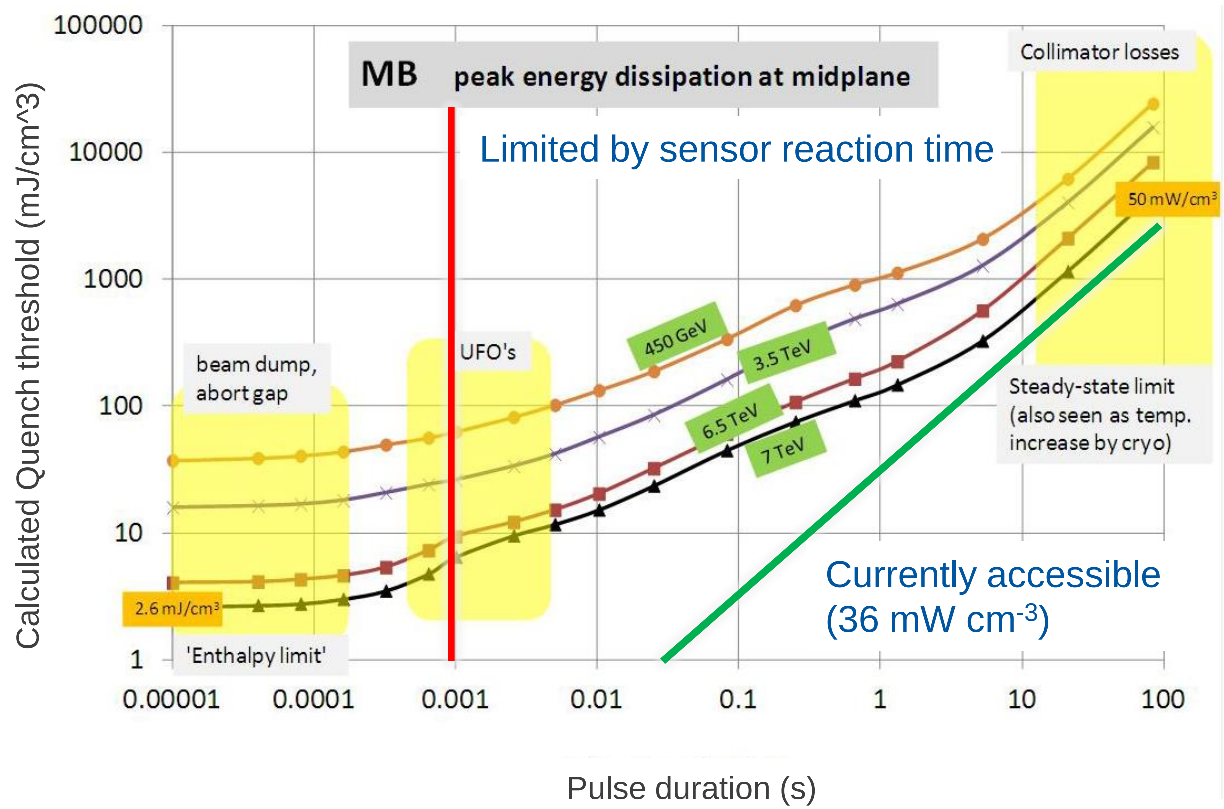
$$Q = (T_{eq} - T_0) \cdot (\rho \cdot c_p) \cdot \tau.$$

A heating power of $\mathbf{36\ mW \cdot cm^{-3}}$ is found.

# Conclusion

With the presented method it is possible to do heat transfer measurements on superconducting cables without needing to implement a heater.

With the current set-up a heat deposit of $\mathbf{36\ mW \cdot cm^{-3}}$ is possible.

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# Outlook

- On bringing the sample in accordance with the insulation as build in the magnets
- Measurements at different temperatures to distinguish between the influence of the thermal link and the specific heat
- A comparison of measurements with an impregnated cable and a non-impregnated cable will give further information about the temperature gradient between the strand and the helium in the cable voids.
- A double bath cryostat will enable measurements in a pressurized liquid helium bath
- A higher excitation frequency to do faster measurements and also increases the amount of generated heat.

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