CHATS workshop 2013

Experiment Proposal to quantify the thermal response of superconducting cables to pulse heat loads

Tiemo Winkler
CERN TE-CRG-CI

Rob van Weelderen
CERN TE-CRG-CI

Marcel ter Brake
University Twente

Content

- Motivation: collimator setting are conservative
- Limiting cases between enthalpy and heat transfer limits
- Idea
- Set-up
- Proof of principle: results
- Conclusions

Motivation

- Collimation review this year at CERN revealed that settings for Beam Loss Monitors are conservative
- With increasing beam energies the secondary particle showers will increase in intensity, thus trigger a beam dump earlier
- Heat transfer of magnets to bath limits the beam dump trigger
- Transient state heat transfer has to be determined

Limiting cases

Minimum quench energies (MQE) in steady-state are determined by heat transfer to the bath

-> Heat transfer is fully developed

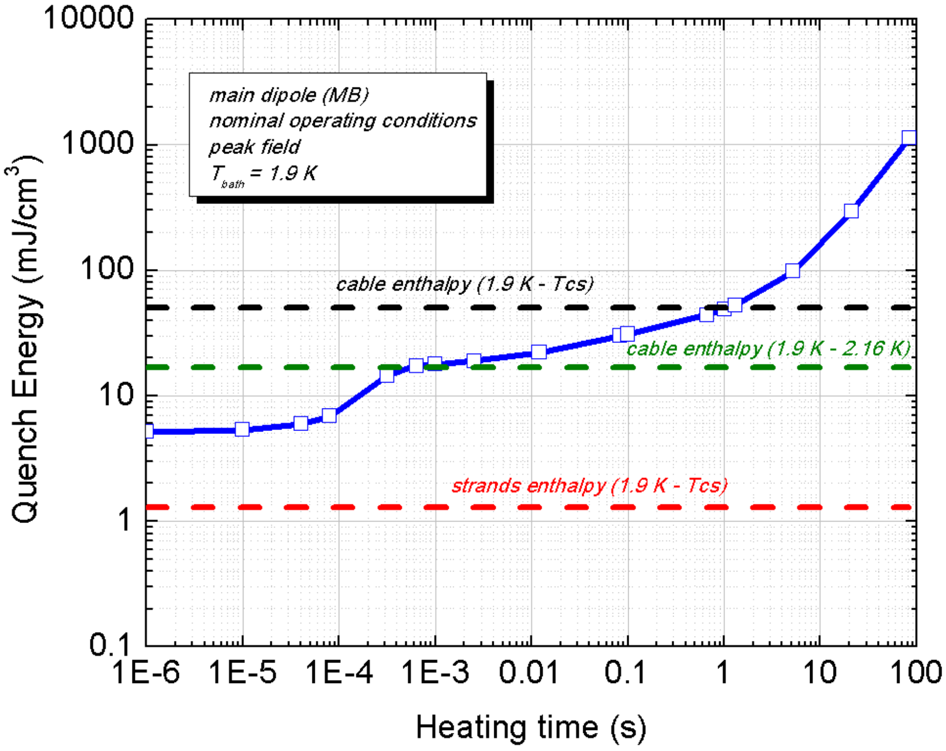
MQE for very short time scales is determined by the specific heat of cable

-> Heat transfer is negligible

Between these two regions:

Heat transfer is not fully established

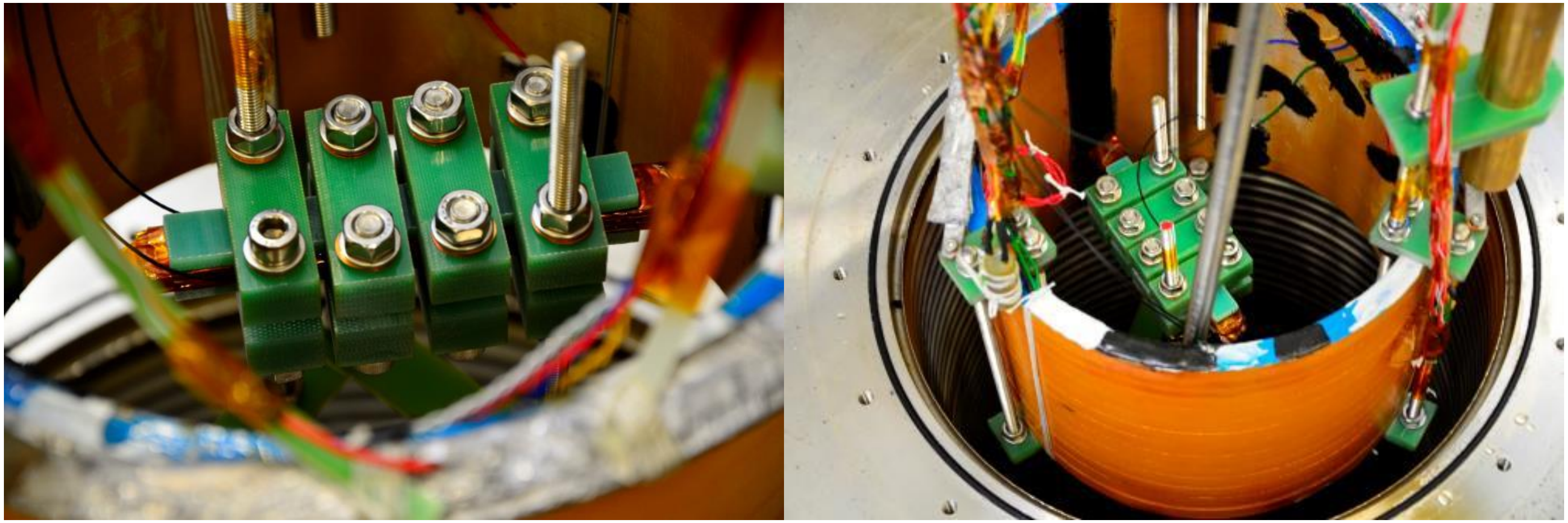
Specific heat plays an important role



Idea

- Use external magnetic field to create AC losses in a sample
- $\dot{Q}_{tc} = \frac{1}{120} * \frac{\dot{B}_t^2}{R_c} * N(N-1) * p\frac{c}{b}$ and $\dot{Q}_{ta} = \frac{1}{6} * \frac{\dot{B}_t^2}{R_c} * p\frac{c}{b}$
- With B_t magnetic field, R_c interstrand resistance, N Number of strands, p,c,b geometrical parameters of the cable

- AC losses are proportional to magnetic field change
- Constant ramping of solenoid => constant losses in superconducting wire
- Magnetic field change proportional to current change



Set-up

- Superconducting solenoid
- 2 bare chip CERNOX in sample
- 1 reference sensor in the bath

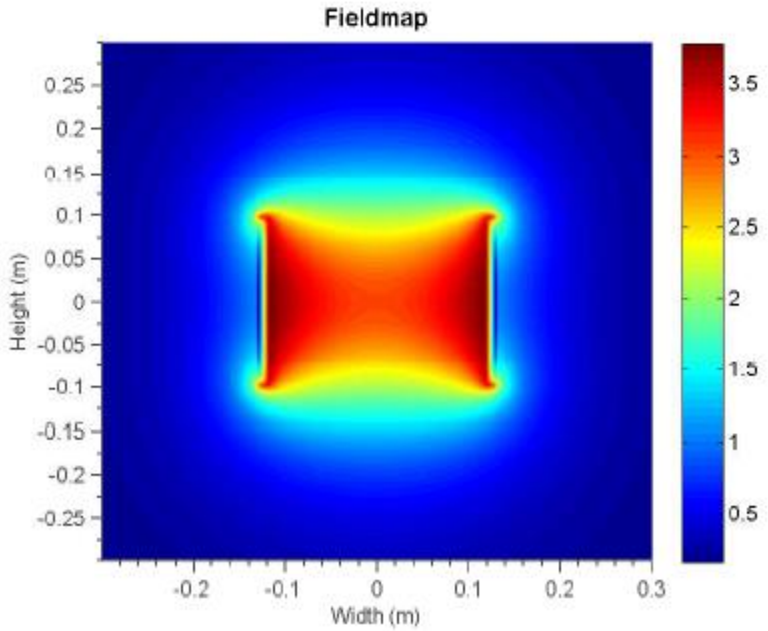
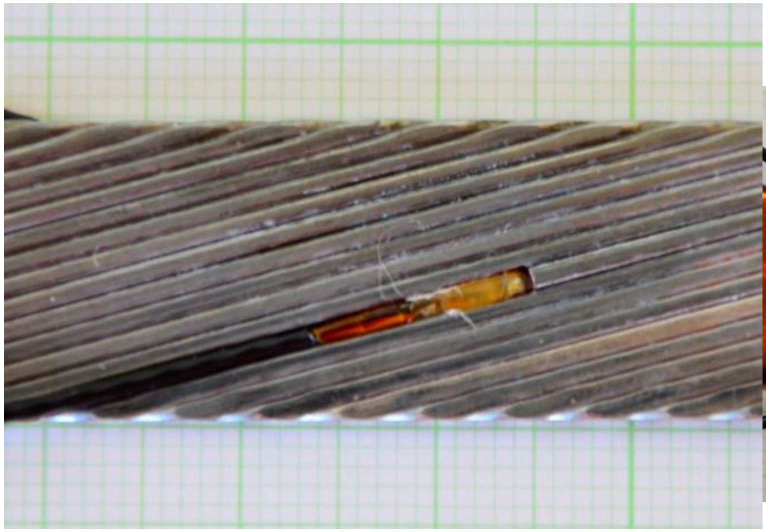
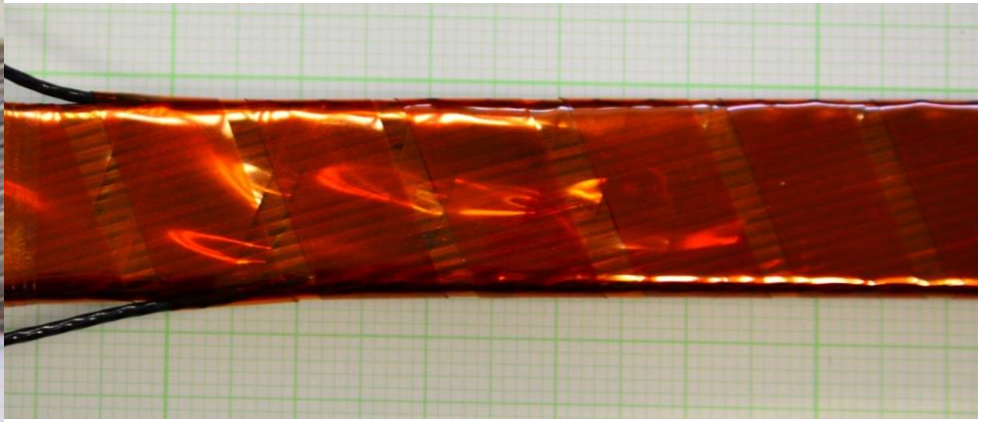
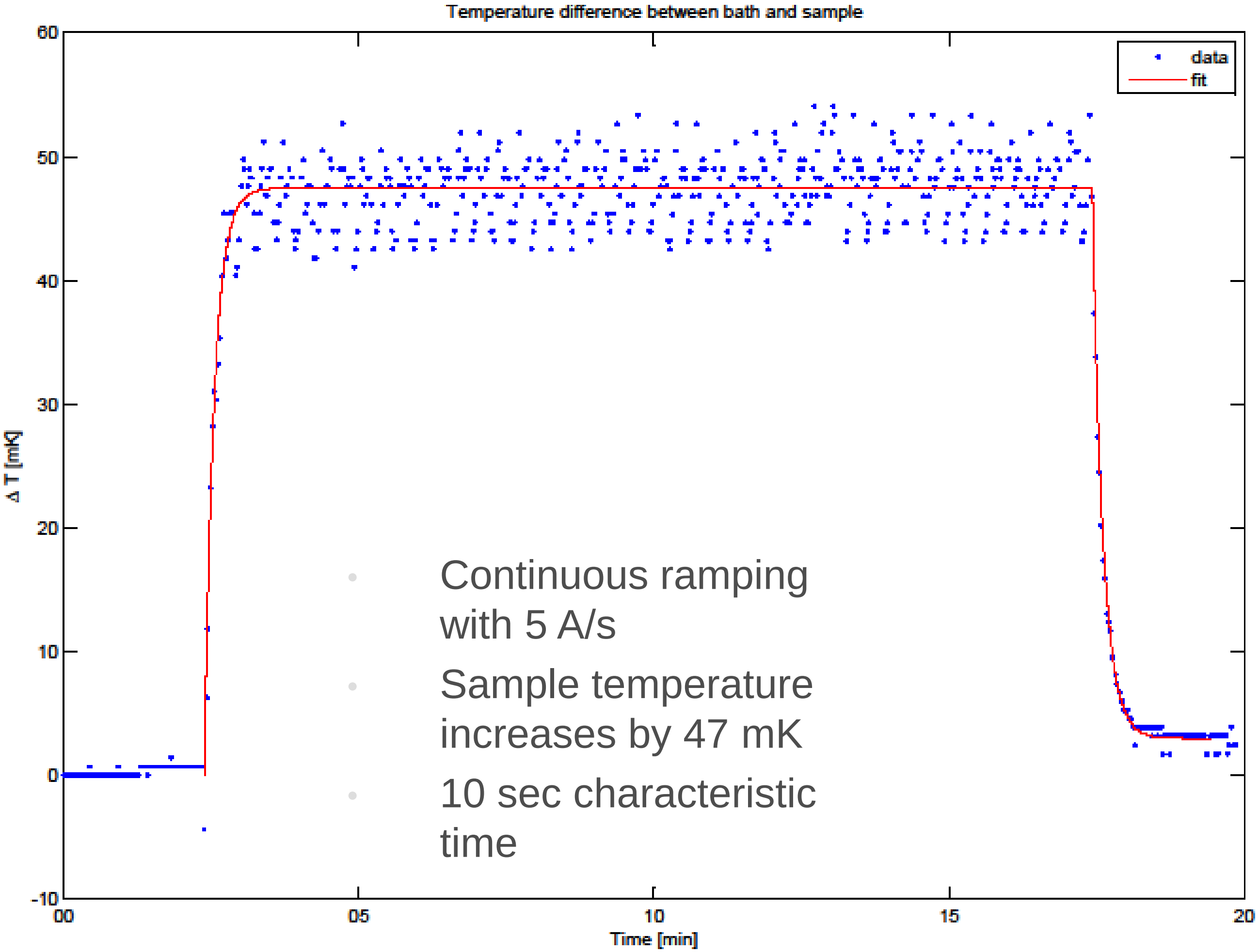


Figure 2.2: The magnetic field-map at an operating current of 500A



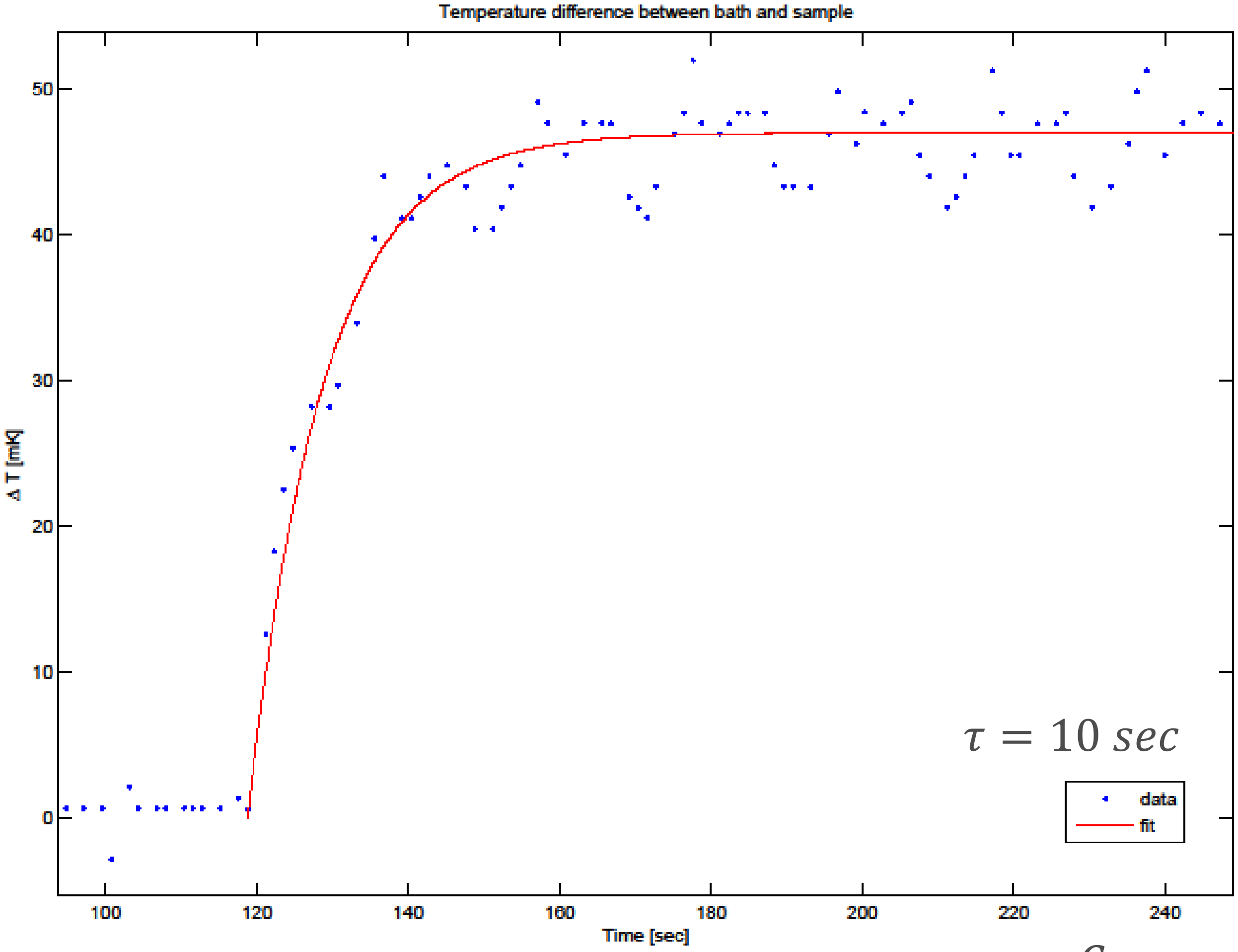


Proof of principle



- Continuous ramping with 5 A/s
- Sample temperature increases by 47 mK
- 10 sec characteristic time

Zoom



$\tau = 10\ sec$

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

With T_0 start temperature,
t time,
tau as characteristic time,
T_eq equilibrium temperature

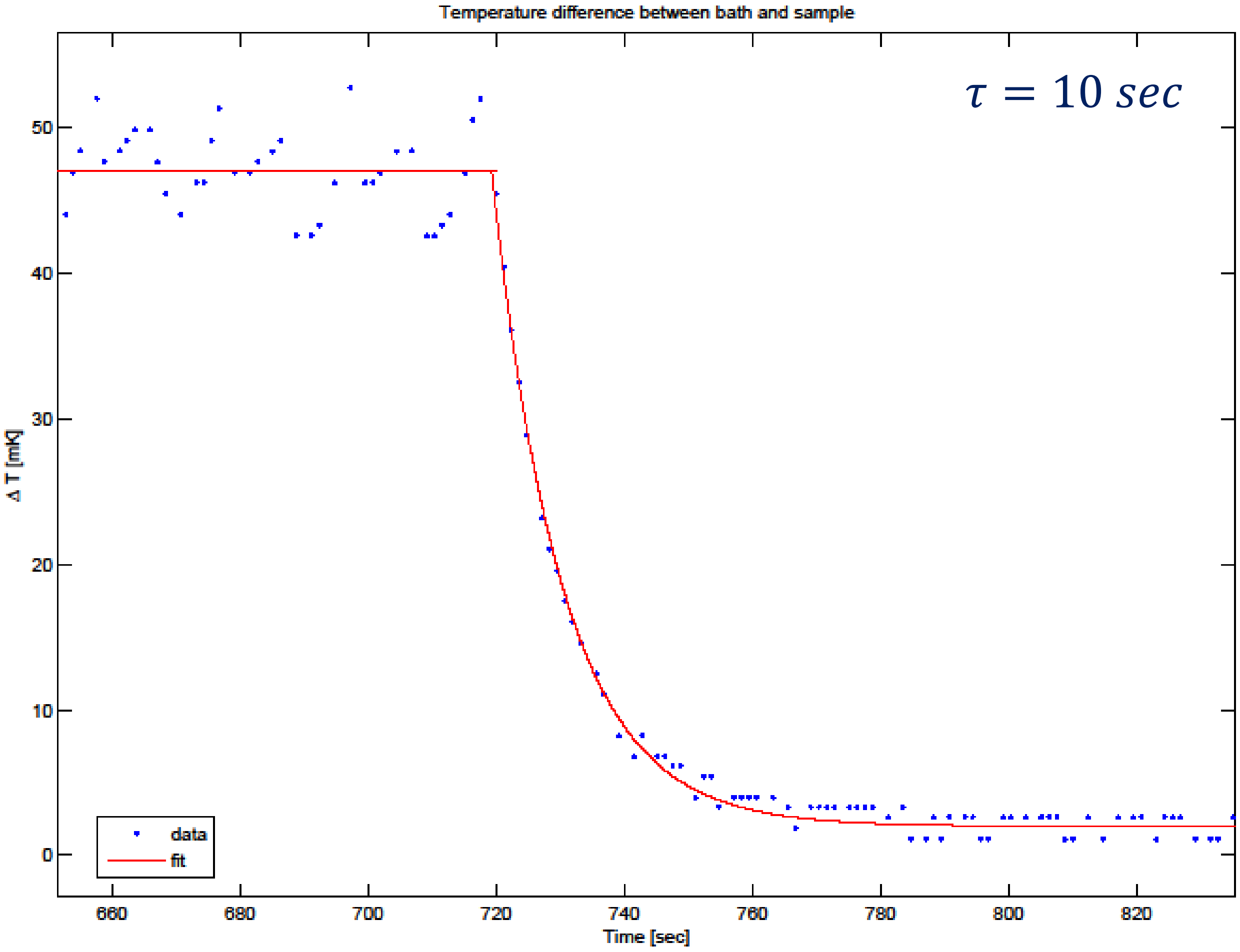
Generated heat

- The generated heat can be roughly estimated.
- Assuming the specific heat of the sample mostly consists of the Helium in the voids of the sample
- Using the characteristic time tau, the specific heat of the Helium voids and the relation between the steady-state temperature

$$\Delta T = Q * \frac{\tau}{C_p}$$

- The generated heat can be calculated to be 0.1 mW/cm3

Zoom



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

With T_0 start temperature,
t time,
tau as characteristic time,
T_eq equilibrium temperature

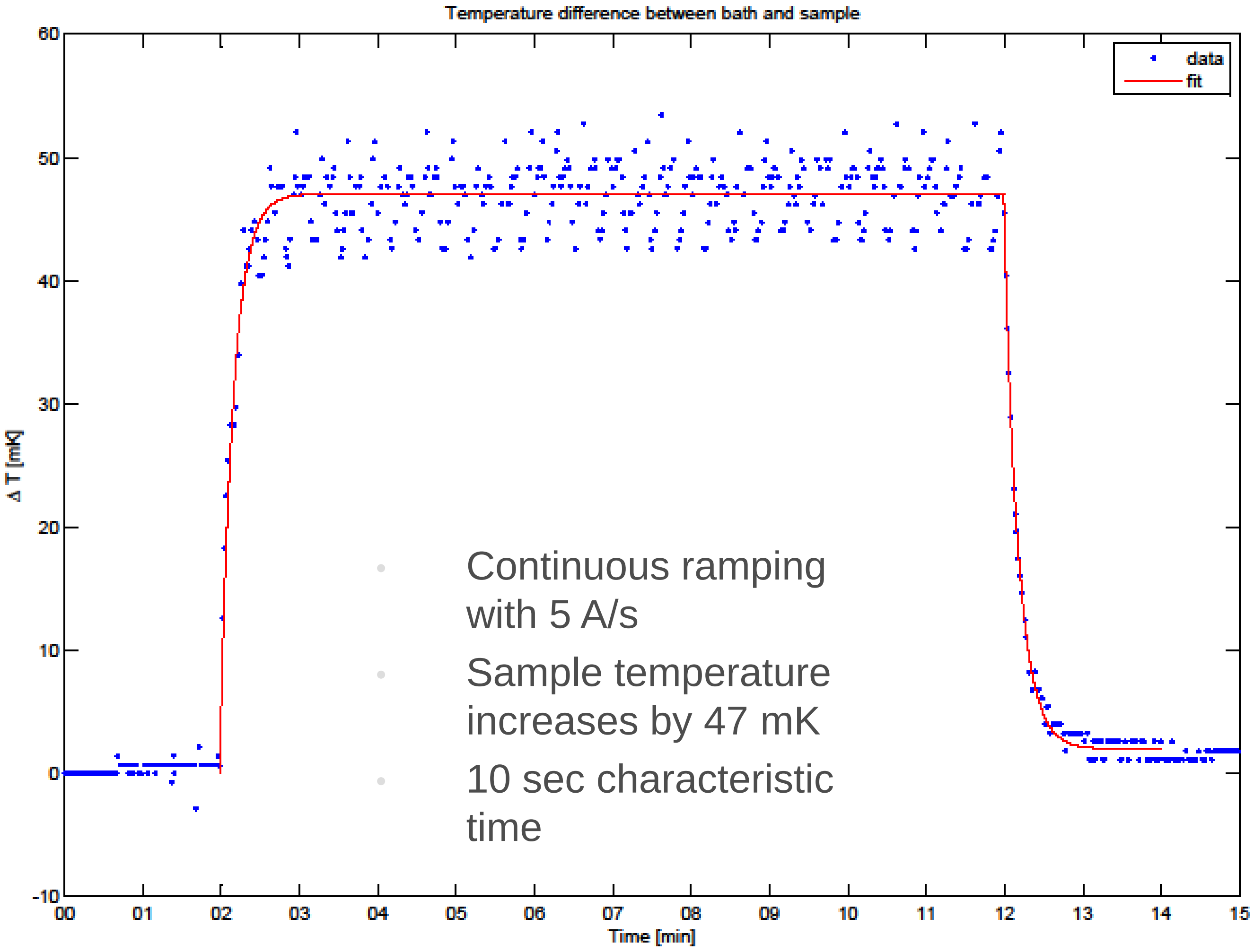
Conclusions

- Use a mass flow meter to determine deposited heat
- Power supply
  - change for a bipolar power supply to enable faster ramp rates
  - Increase maximum output current for longer more homogenous ramps
- Increase sample mass to increase sensitivity
- Include strain gauge in setup to measure sample pressure during cool down

CERN

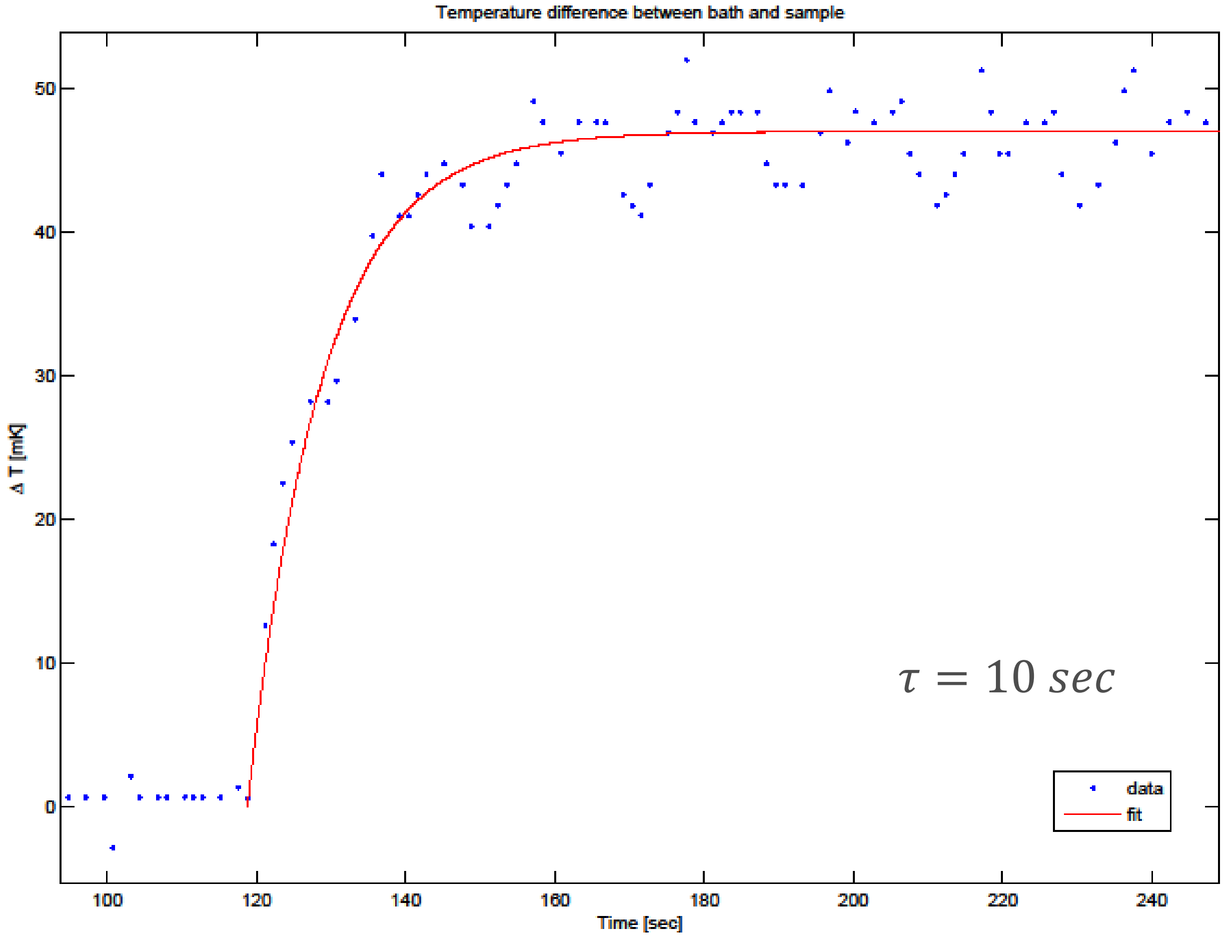
www.cern.ch

First results



- Continuous ramping with 5 A/s
- Sample temperature increases by 47 mK
- 10 sec characteristic time

Zoom

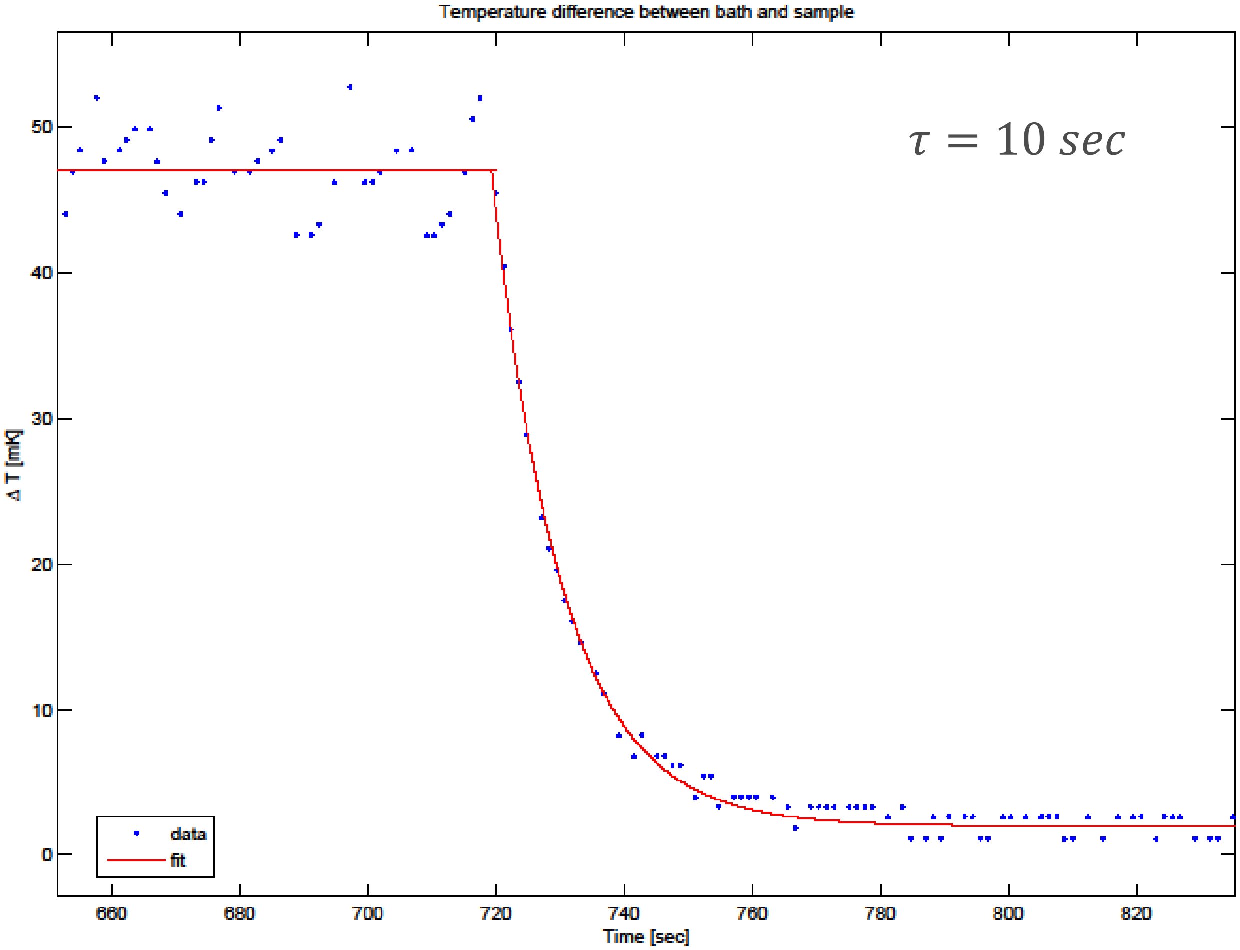


$\tau = 10\ sec$

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

With T_0 start temperature,
t time,
tau as characteristic time,
T_eq equilibrium temperature

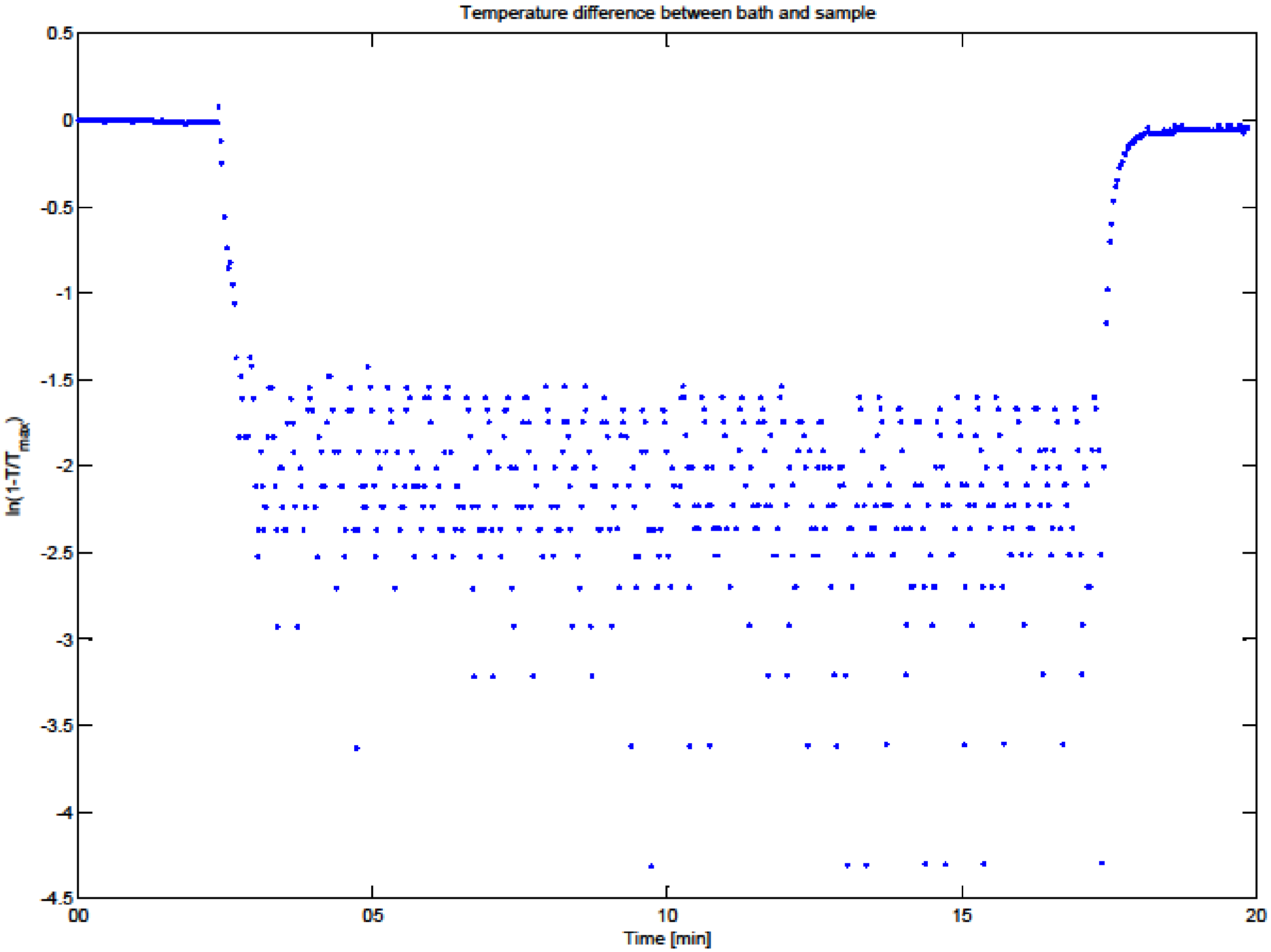
Zoom



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

With T_0 start temperature,
t time,
tau as characteristic time,
T_eq equilibrium temperature

Logarithmic plot



Logarithmic plot