Thermal transport between and within surface layers of superfluid 3He-B

V. Zavjalov, S. Autti, D. Zmeev

Department of Physics, Lancaster University, Lancaster LA1 4YB, United Kingdom

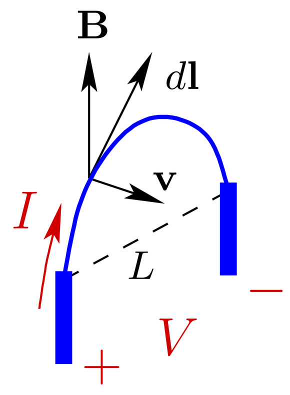
Thermometry in the B phase

Force acting on unit area of a moving object in ^{3}He-B (in a simple 1D scattering model):

$$F(v) = -p_F^2 v_F N(0)\exp\left(-\frac{\Delta}{kT}\right) v_0\,\mathrm{sign}(v)\big(1-\exp(-|v|/v_0)\big),$$

where $v_0 = kT/p_F$.

Vibrating wire with current I and velocity v in magnetic field $\mathbf{B}$: force $F = ILB$, EMF voltage across the wire $V = vLB$.



Velocity responce (bold symbols represent complex parameters):

$$\mathbf{v} = \frac{i\omega\mathbf{F}/m_w}{(\omega_0^2-\omega^2) + i\omega\delta_0\,S(|\mathbf{v}|/v_0)}$$

Non-linearity is determined by function S. For 1D model

$$S(x) = \frac{2}{x}\left(I_1(x) - L_{-1}(x) + \frac{2}{\pi}\right)$$

where $I_n(x)$ and $L_n(x)$ are modified Bessel function of first kind and modified Struve function.

Function S is proportional to real part of wire conductance, one can directly measure it:

$$\delta_0 S(|\mathbf{v}|/v0) = \frac{1}{m_w}\Re\left(\frac{\mathbf{F}}{\mathbf{v}}\right) = \frac{L^2B^2}{m_w}\Re\left(\frac{\mathbf{I}}{\mathbf{V}}\right)$$

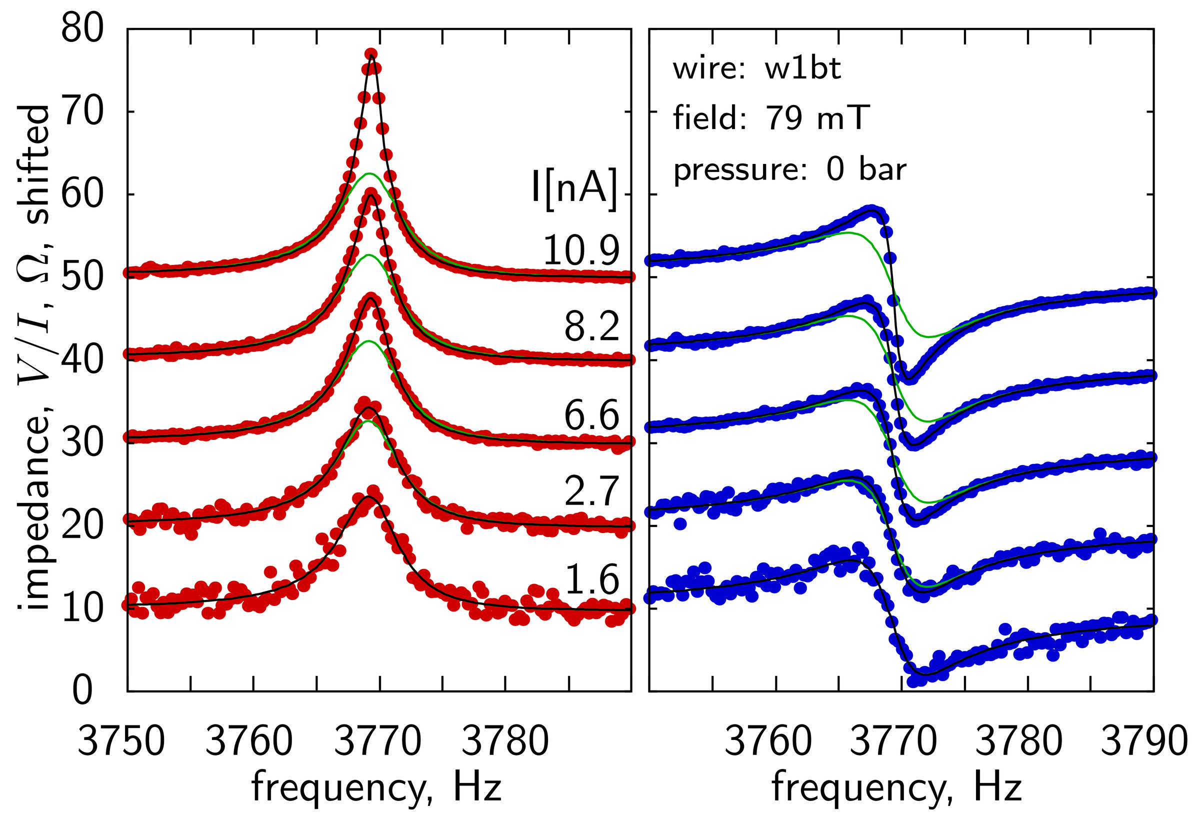
Obtained function S can be used for processing vibrating wire response measured as a function of frequency (picture below), drive, and temperature (picture on the right).

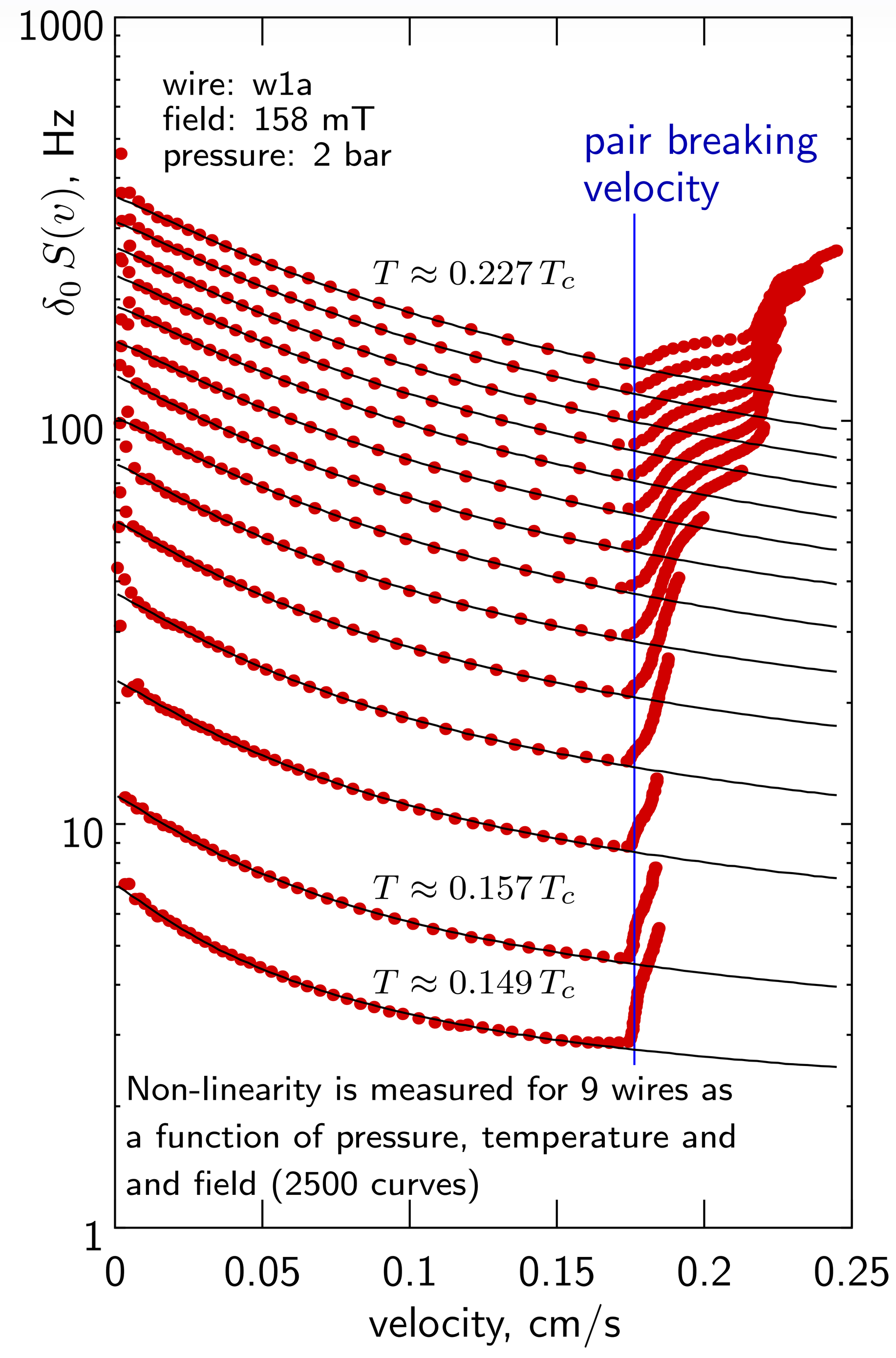
Parameter δ_0 can be found from velocity-dependent damping by extrapolating the function to $v = 0$.

Conversion to temperature:

$$T/Tc = \frac{\Delta/kT_c}{C - \log(\delta_0)}$$

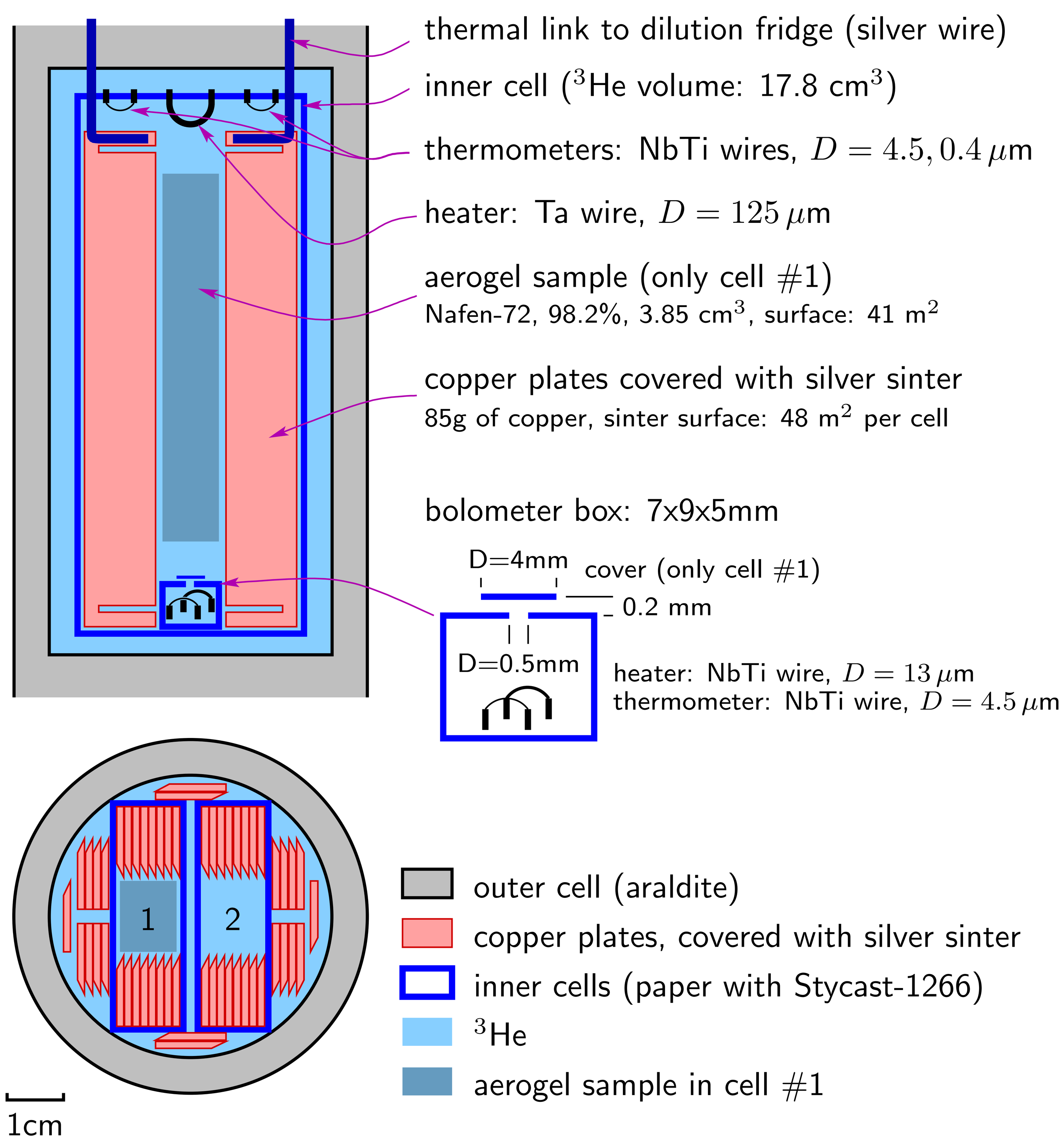
with calibration parameter C.

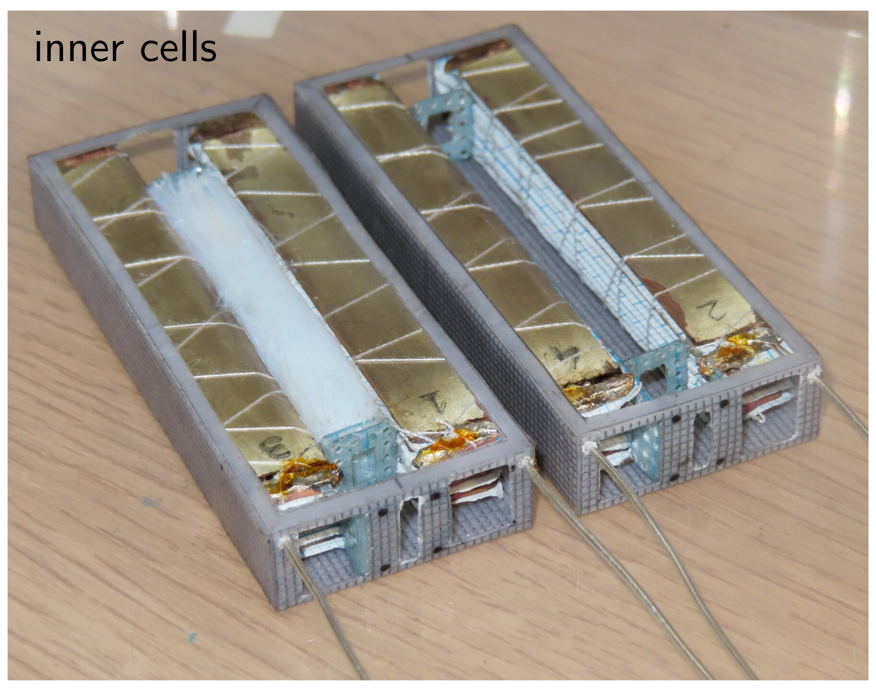


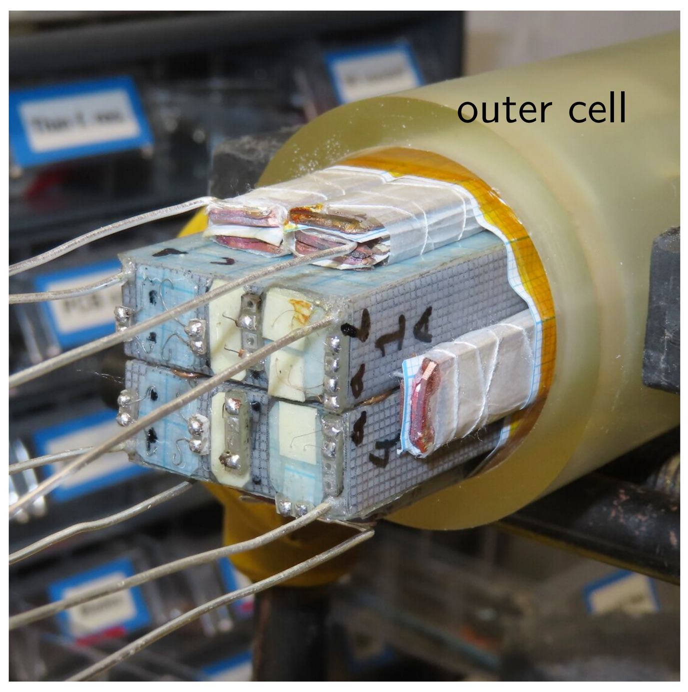


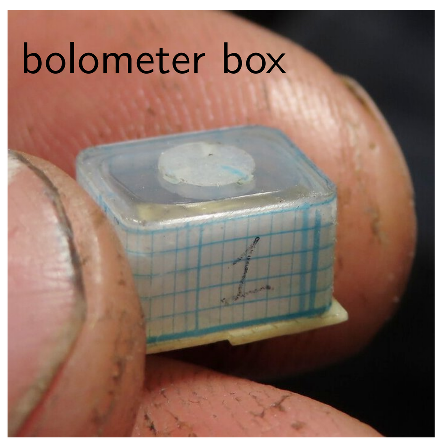
See also: arXiv:2303.01189

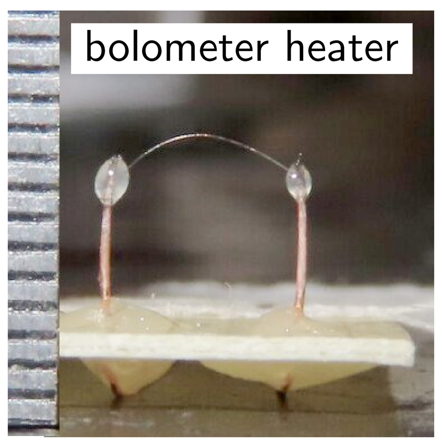
Experimental cell



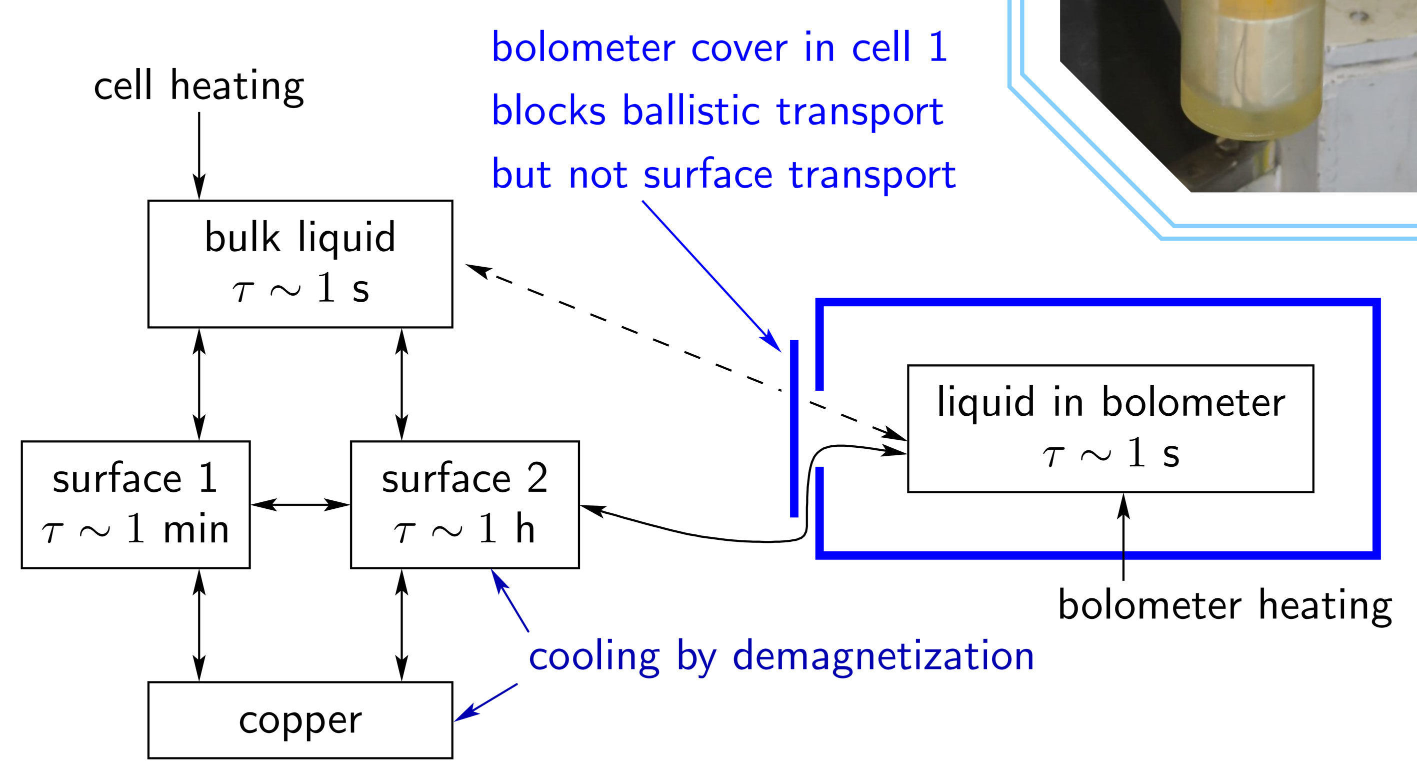






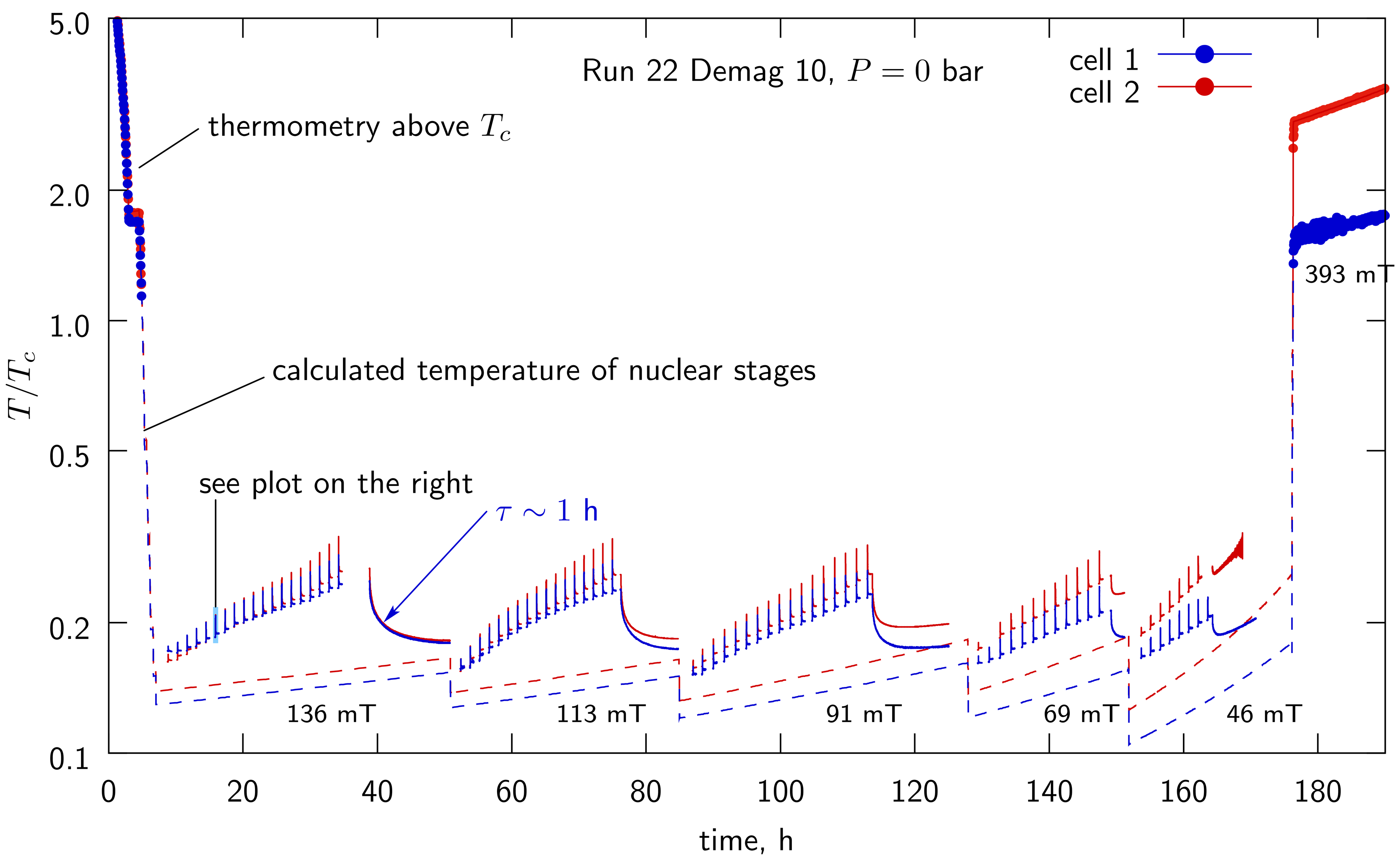


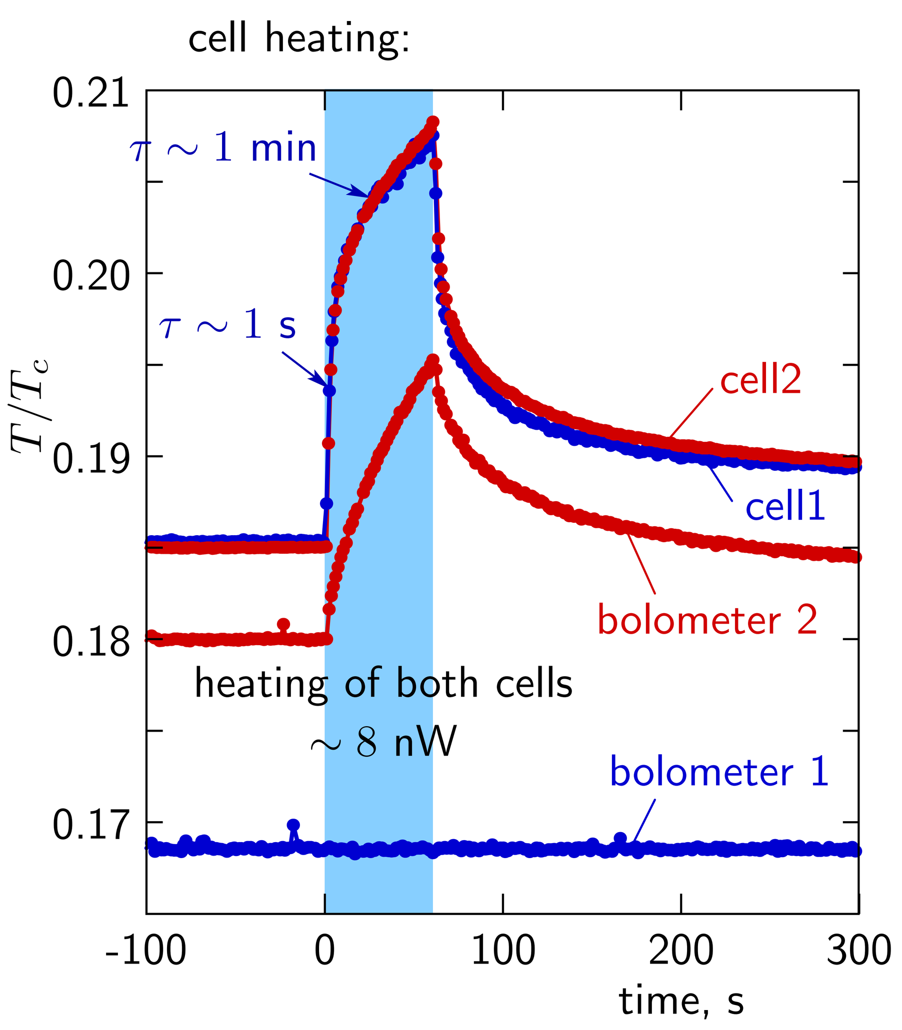
Possible thermal model of cell and bolometer:

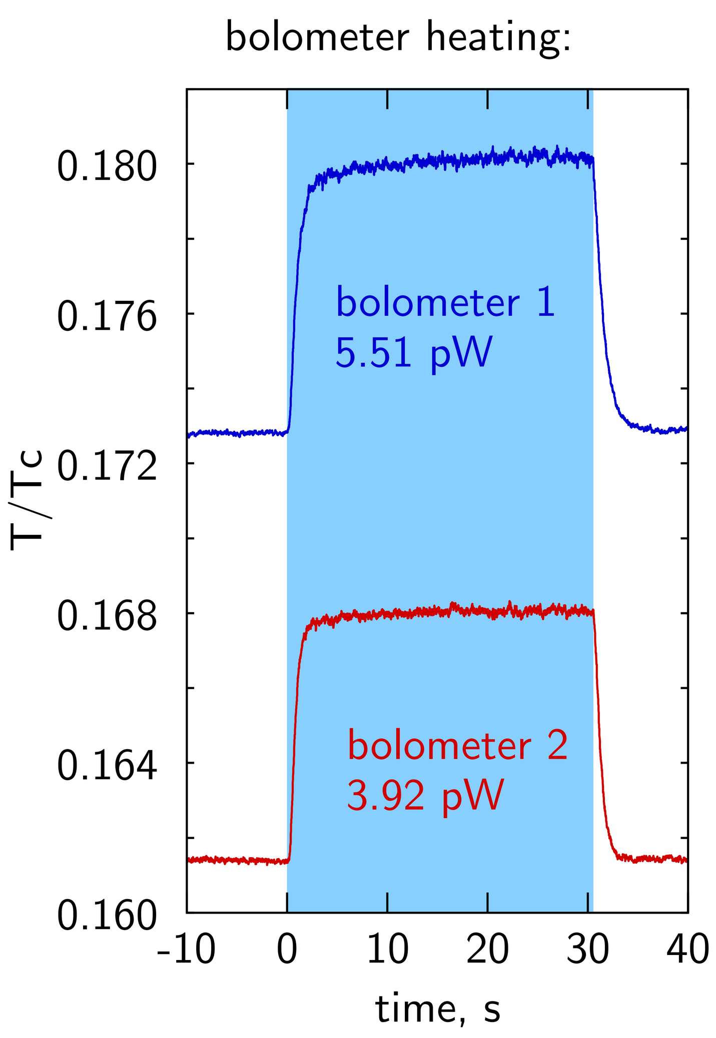


Measurements

Temperature of inner cells during a typical measurement:







Results

Data processing is in progress, we hope to get some quantitative results soon.