Tue-Af-Po2.08-F4 ReBCO Wires and Cables

A Stability diagram for YBCO Roebel Cables at 77 K with varying heat pulses and I/Ic

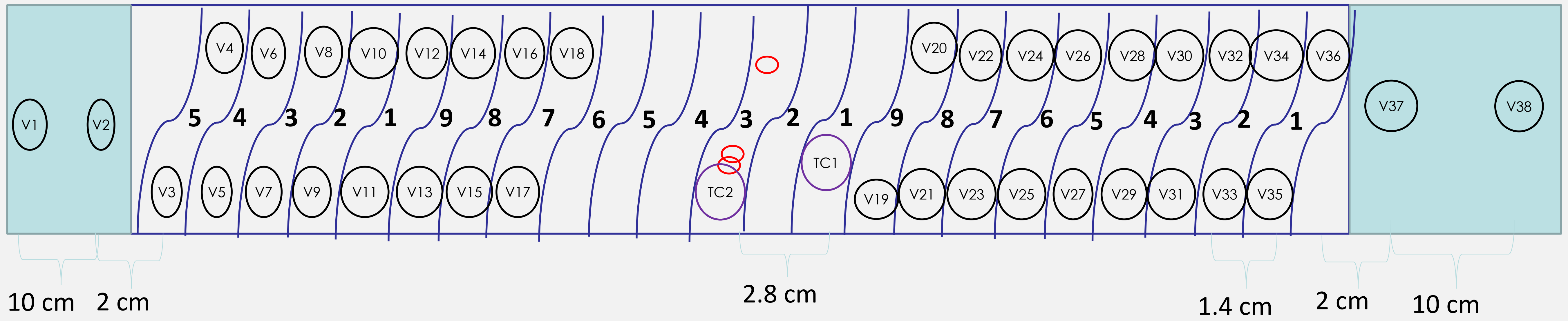
C.J. Kovacs, **M.D. Sumption, M. Majoros**

Center for Superconducting & Magnetic Materials (CSMM), Department of Materials Science & Engineering, The Ohio State University, USA

U-shaped YBCO Roebel Cable

Parameter	Specification
Roebel cable manufacturer	Karlsruhe Institute of Technology
ReBCO tape manufacturer	SuperPower Inc.
Type of Roebel cable	9/5.6
Number of Tapes	9
Tape Width, w_{tape} (mm)	5.6
Cable Width, W_C (mm)	11.8
Insulation	3-layers of kapton over cable (not individual tapes). No epoxy impregnation.
Tape thickness, t_{tape} (mm)	0.1
Pitch Length, L_p (mm)	126
Cross-over angle, φ (degrees)	40
$L_{Inter\text{-}strand\ gap}$ (mm)	0.4
$W_{Cross\text{-}over}$ (mm)	5.6
I_c @ 77 K, sum of tapes (A)	1168

Instrumentation of Sample



Each individual tape was tinned with Wood's Metal and the entire cable was pressed slightly while solder cooled to create 15 cm long solder regions. The length between these solder regions was 350 mm.

- ○ = Voltage Tap
- ○ = Type-E Thermocouple
- ○ = Kapton Heater
- ▢ = Soldered Current Tap

38 voltage taps, 2 Type-E thermocouples

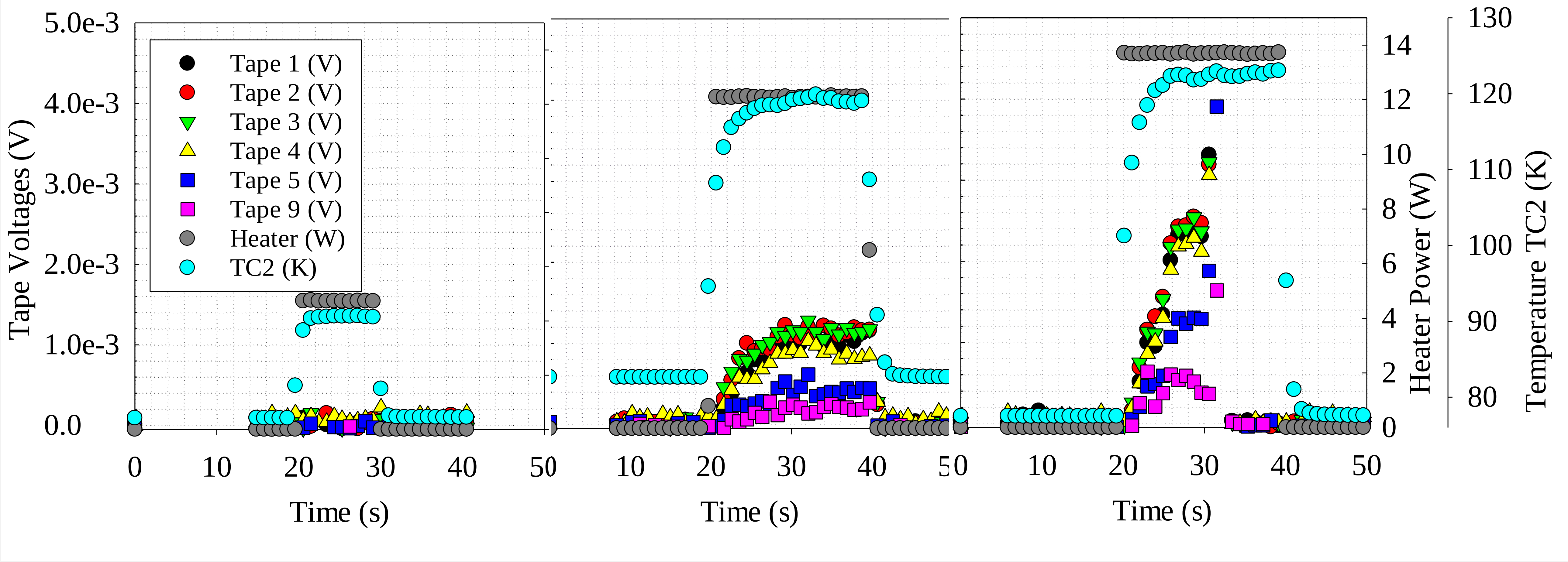
- TC1 on top of two heaters

3 40Ω Kapton heaters

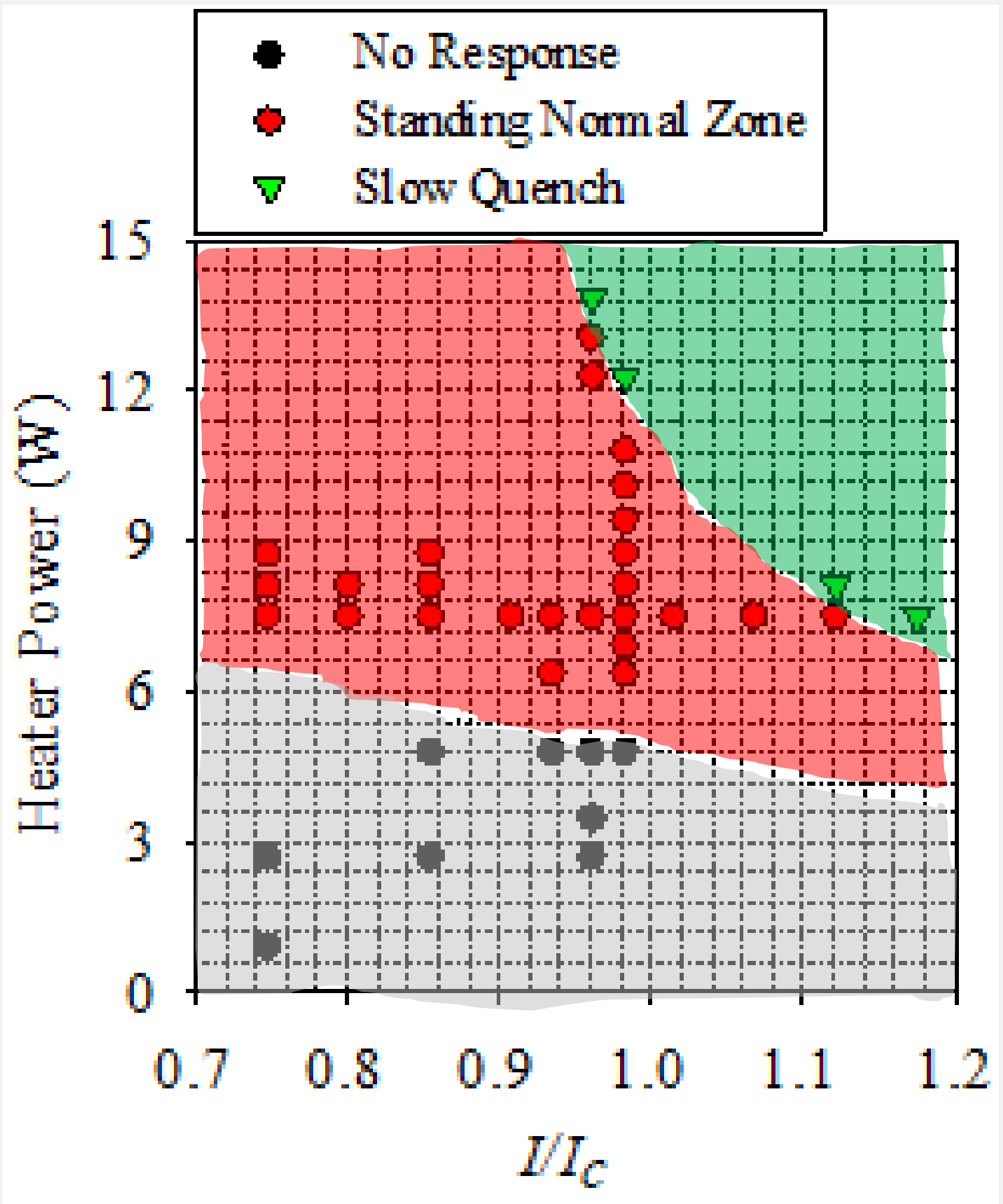
Labview with:

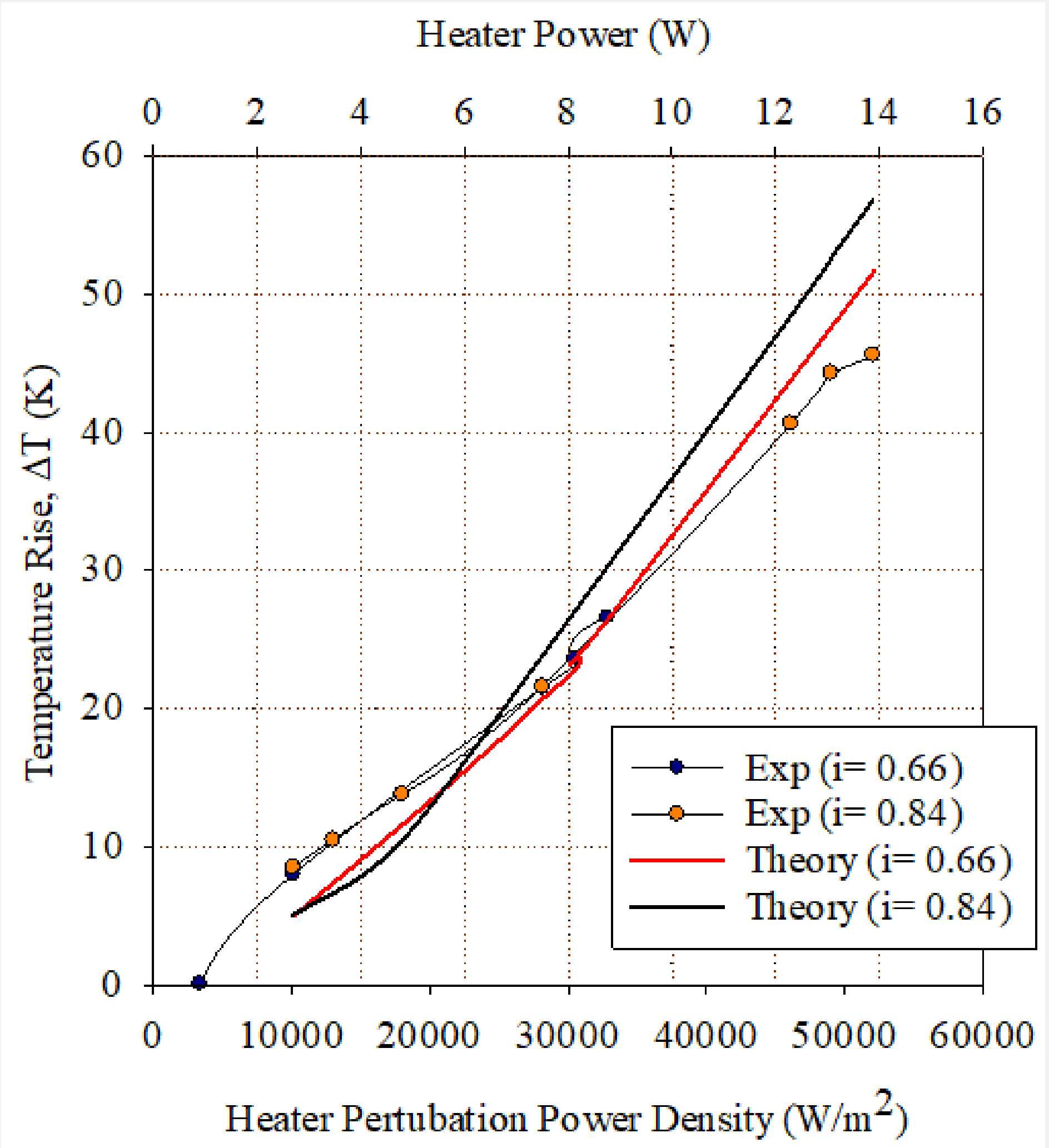
- National Instruments DAQ

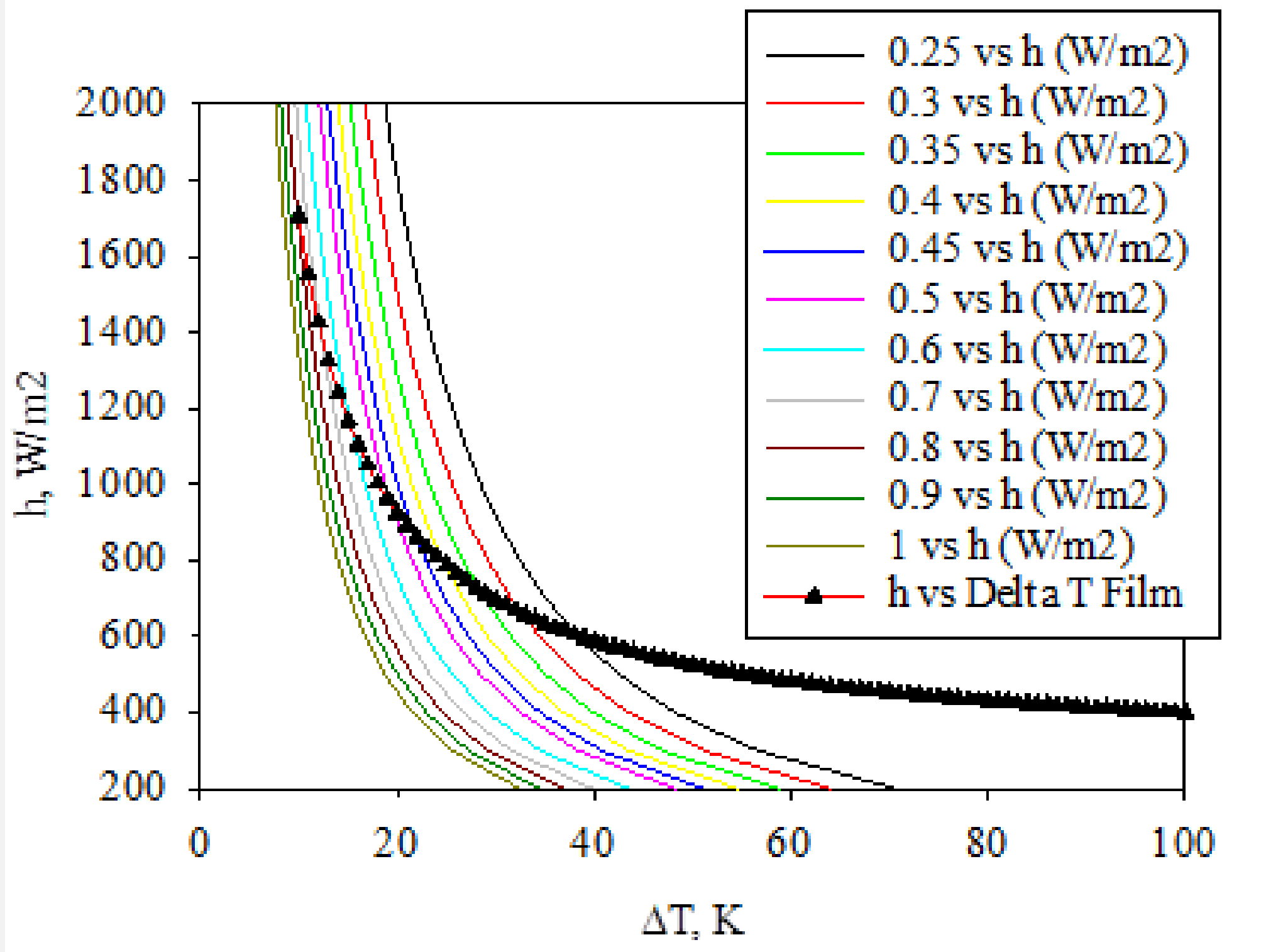
Experimental and Theoretical Data



Three classes of stability response to heat pulses at variable I/I_c: (a) no response: $I/I_c = 0.9348$, $P_{heater} = 4.8$ W, $E_{heater} = 48$ J (b) stationary normal zone: $I/I_c = 0.9615$, $P_{heater} = 12.3$ W, $E_{heater} = 246$ J, (c) slow quench: $I/I_c = 0.9615$, $P_{heater} = 13.9$ W, $E_{heater} = 277$ J.







From Left to Right: (1) Experimental stability response vs heat perturbation. (2) Two experimental data sets (i= 0.66 and 0.84) compared to that as predicted by theory. (3) Determination of Eta, i.e. the % of cable area efficiently utilized for cooling.

Discussion of Results

The large temperature margins of HTS conductors will likely prevent epoxy cracking, friction from sudden mechanical motion, and flux jumps from initiating a quench [1]. Additionally, the large temperature margin will result in relatively long quench decision times on the order of seconds even under adiabatic conditions [2]. For these reasons, it may make more sense to approach HTS stability in terms of Minimum Quench Power (MQP) instead of MQE (Minimum Quench Energy) [3,4].

Using the Stekly criterion:

$$\alpha = \frac{\rho \times I_c^2}{Perimenter \times A_{Cu}} \times \frac{1}{Q_{LN2-NucleateMax}}$$

above I_c a Roebel Cable in LN_2 should be exceedingly cryostable ($\alpha < 0.027$). The Stekly criterion assumes an internally well-distributed heat perturbation (HP). An applied local HP, a heater in this experimental case, can create a much less stable situation. Below is the situation for when cold-end cooling is taken into account with a local HP.

$$\Delta T = \frac{\dfrac{\rho \times I_c^2}{Perimenter \times A_{Cu}} + \dfrac{P_{HP}}{A_s}}{\eta \times h + \dfrac{\sqrt{2 \times k \times A_{Cu} \times Perimeter \times \eta \times h}}{A_s}}$$

Where:

- ○ A_{Cu}= area of Cu-stabilizer in the cable cross-section
- ○ I_c = Critical Current at 77 K
- ○ Perimeter= the perimeter of all of the tapes in the Roebel cable
- ○ η= the surface area fraction being effectively used for cryogen cooling
- ○ k= thermal conductivity of the cable, h= heat-transfer coefficient to LN_2
- ○ ρ= electrical resistivity of cable in normal-state, $\Delta T = T(t) - T_{LN2}$
- ○ A_s= surface area of all tapes in the HP zone
- ○ P_{HP}= power heat-perturbation

References:

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2. H. Song et al. "Stability and Quench Behavior of $YBa_2Cu_3O_{7-x}$ Coated Conductor at 4.2 K, Self-Field" *IEEE Trans. Appl. Supercond.*, vol. 19, no. 5, pp. 3735-43 (2009)
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