Probing the Thermal Fluctuations in Bulk YBCO Superconductors

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Overview

- Review of Jargon
- Experimental Objective
- YBCO Structure
- Experimental Setup/Procedure
- Polycrystalline Correction
- Experimental vs Theoretical Results
- Conclusion/Future Work

Jargon

- : Critical Temperature

Experimental Objective

- Investigate thermal fluctuations in a superconductor
  - Manifests in resistivity/conductivity

Goals to achieve Objective

- Measure R(T) in sample
- Convert R into
  - Accounts for indirect current paths and possibly high contact resistance between SC grains
- Compare experimental Δ ( ) with theoretical predictions
- Determine of sample

YBCO Structure

- Yttrium barium copper oxide (YBCO)
  - □ 2 3 7−
- Bulk YBCO is a polycrystal
- SEM imaging of YBCO reveals this polycrystallinity

YBCO Structure

Goal: Measure R(T) in YBCO

- Supply Current – Measure Δ
- Utilize thermocouple to determine T

- Require ~ 10 resolution
  - Due to bulk material + superconductor

- Common technique is the 4-pt probe method
  - Resistance measured is that ONLY of the sample

Review: 4-

Measuring Sample Temperature

- Utilized a Type-T thermocouple (Copper-Constantan)
- V   Δ

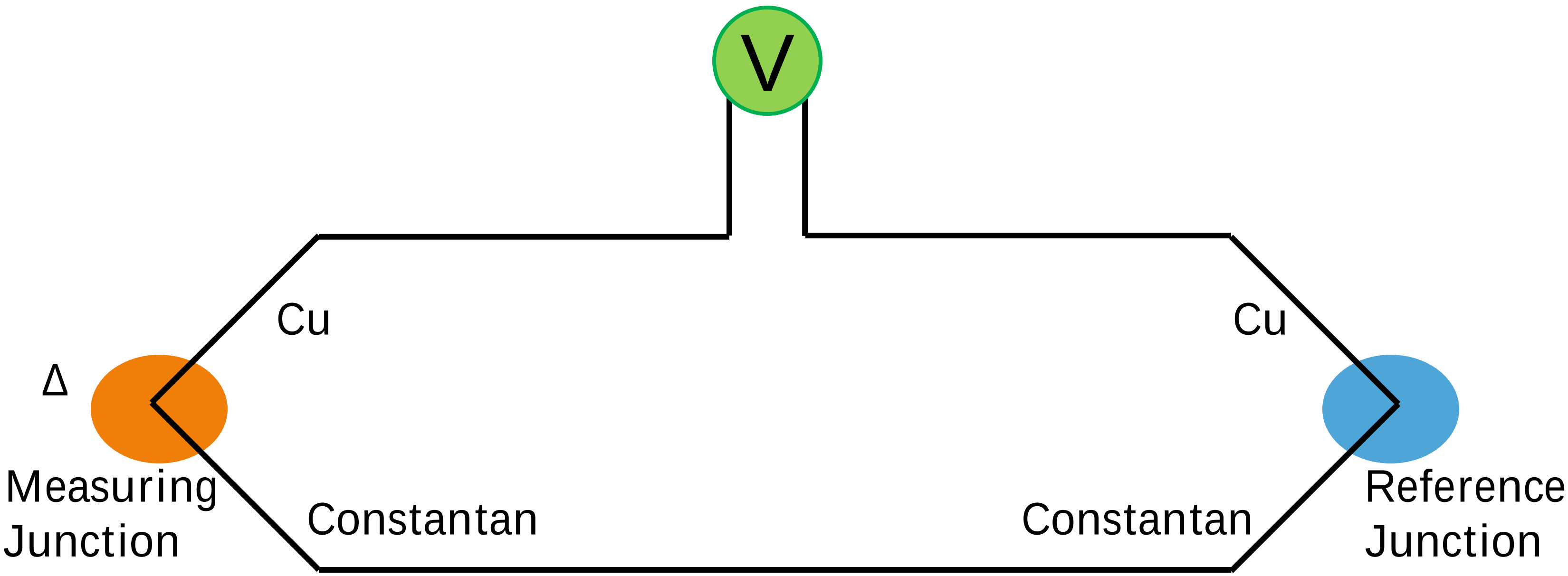


Figure 5. Depiction of a thermocouple used for measuring temperatures.

Data Acquisition using Logger Pro

- Logger Pro only has millivolt resolution
  - We require microvolt

- To circumvent, we built amplifiers to boost the measured signal
  - With enough gain, able to use Logger Pro for acquisition

Experimental Setup

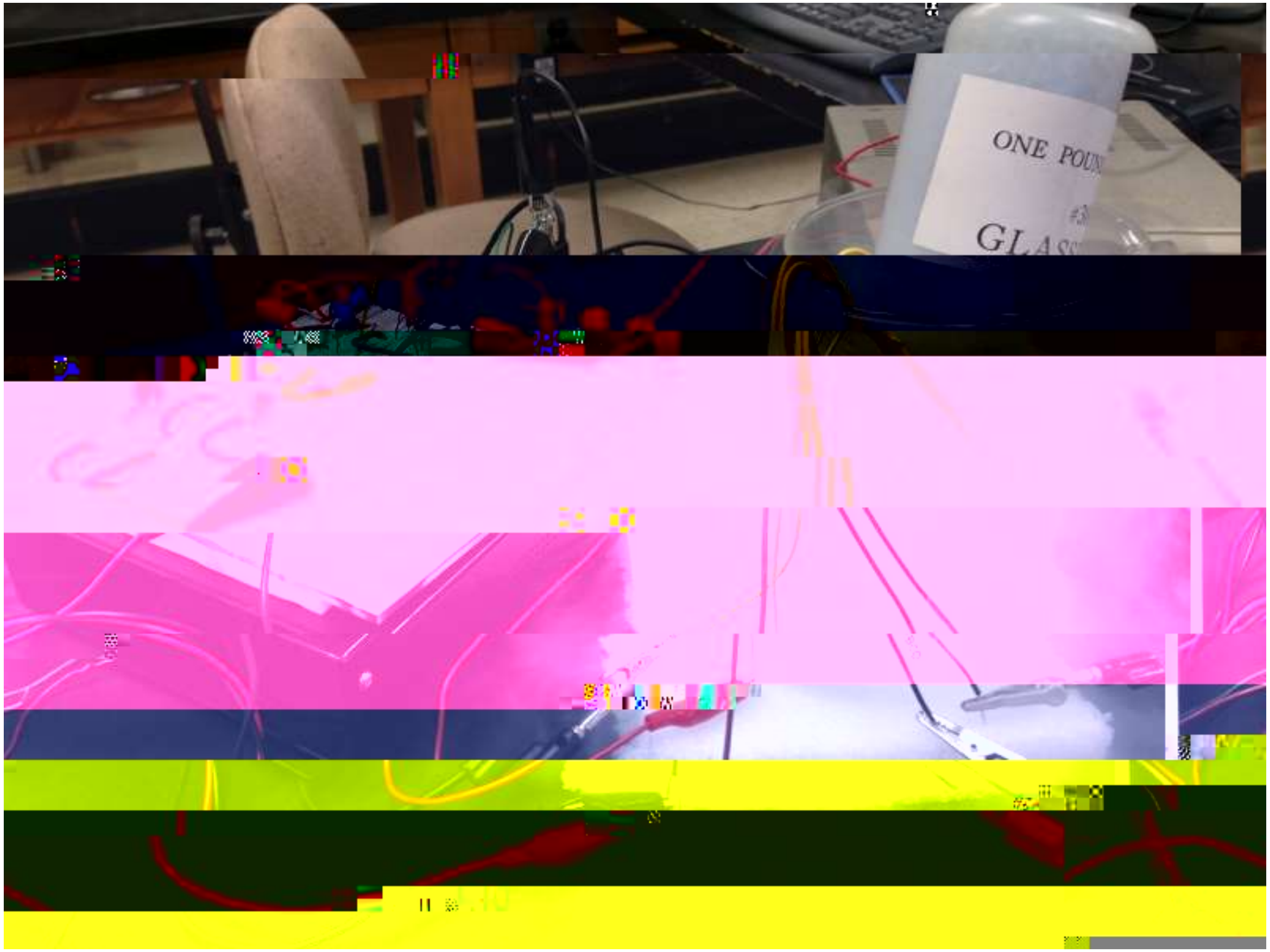


Figure 6. Photograph of the full experimental setup.

Experimental Procedure

- Fix current through sample (dc)
- Cool to LN temperature
- Sample every 2 seconds as sample warms
- =
- , = @77

Determining Temperature

- Used interpolation to “estimate” a functional relationship between measured voltage and what the corresponding temperature should be.

Interpolated T vs V

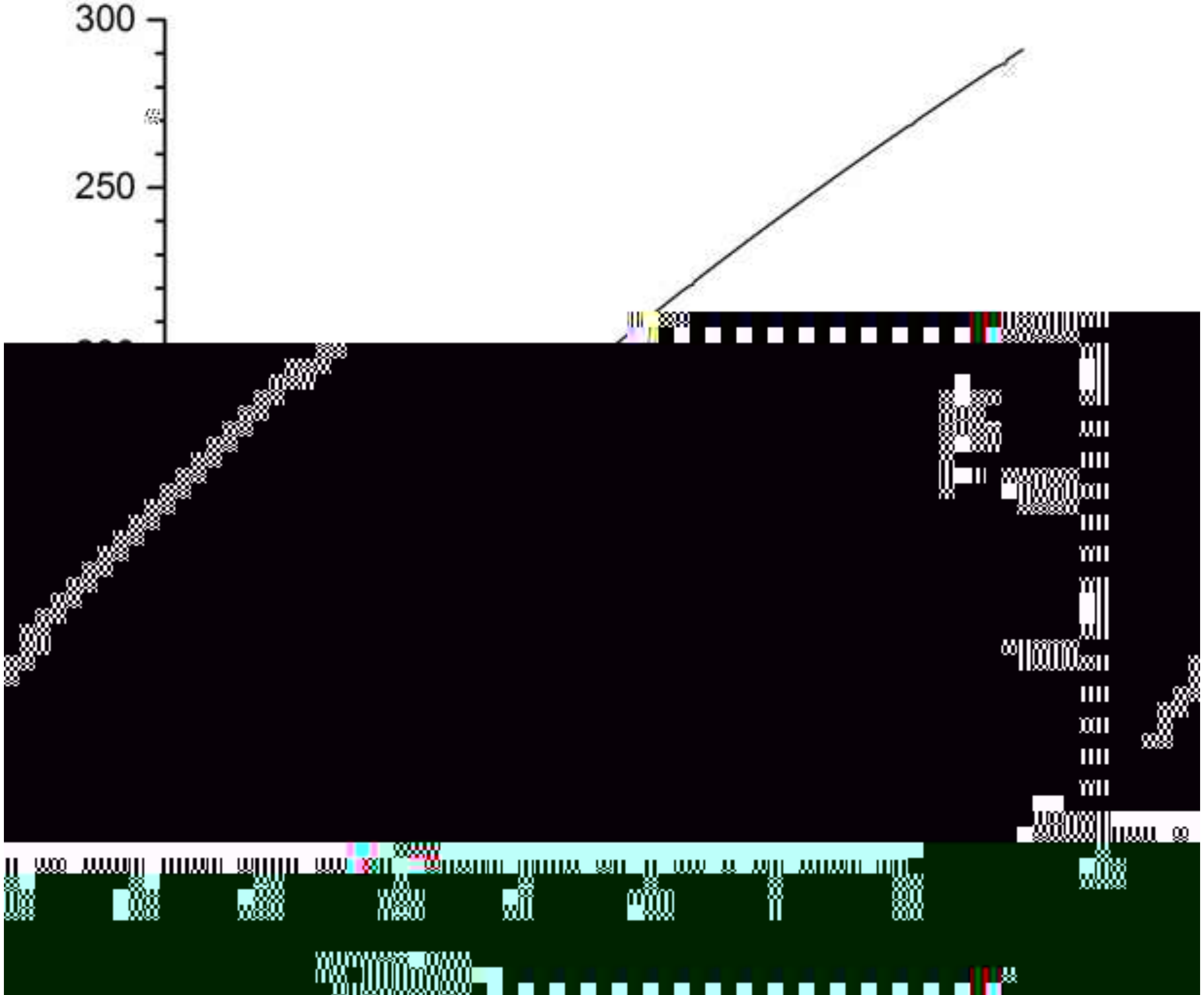


Figure 7. Plot of interpolated T vs

R(T)

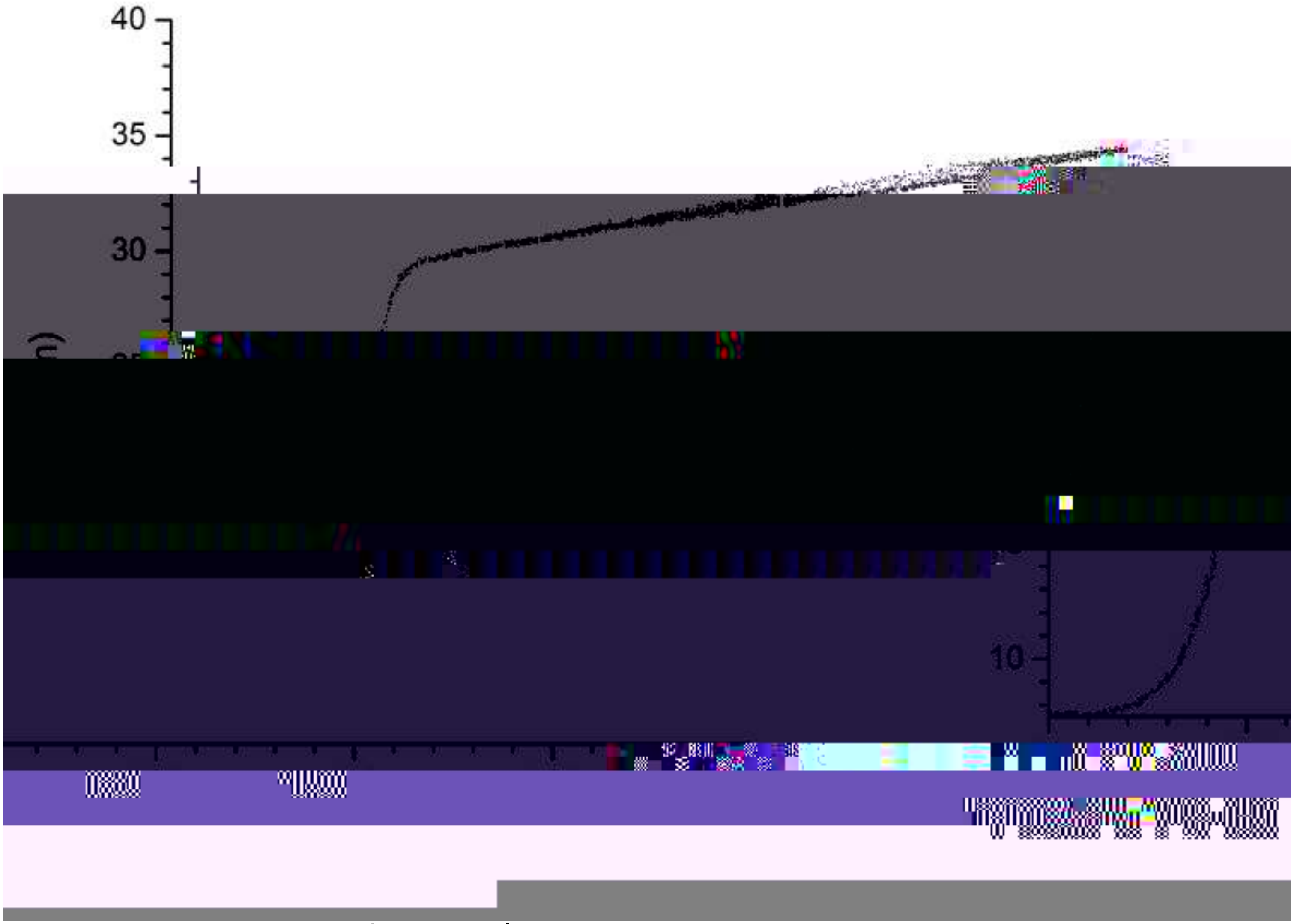


Figure 8. Plot

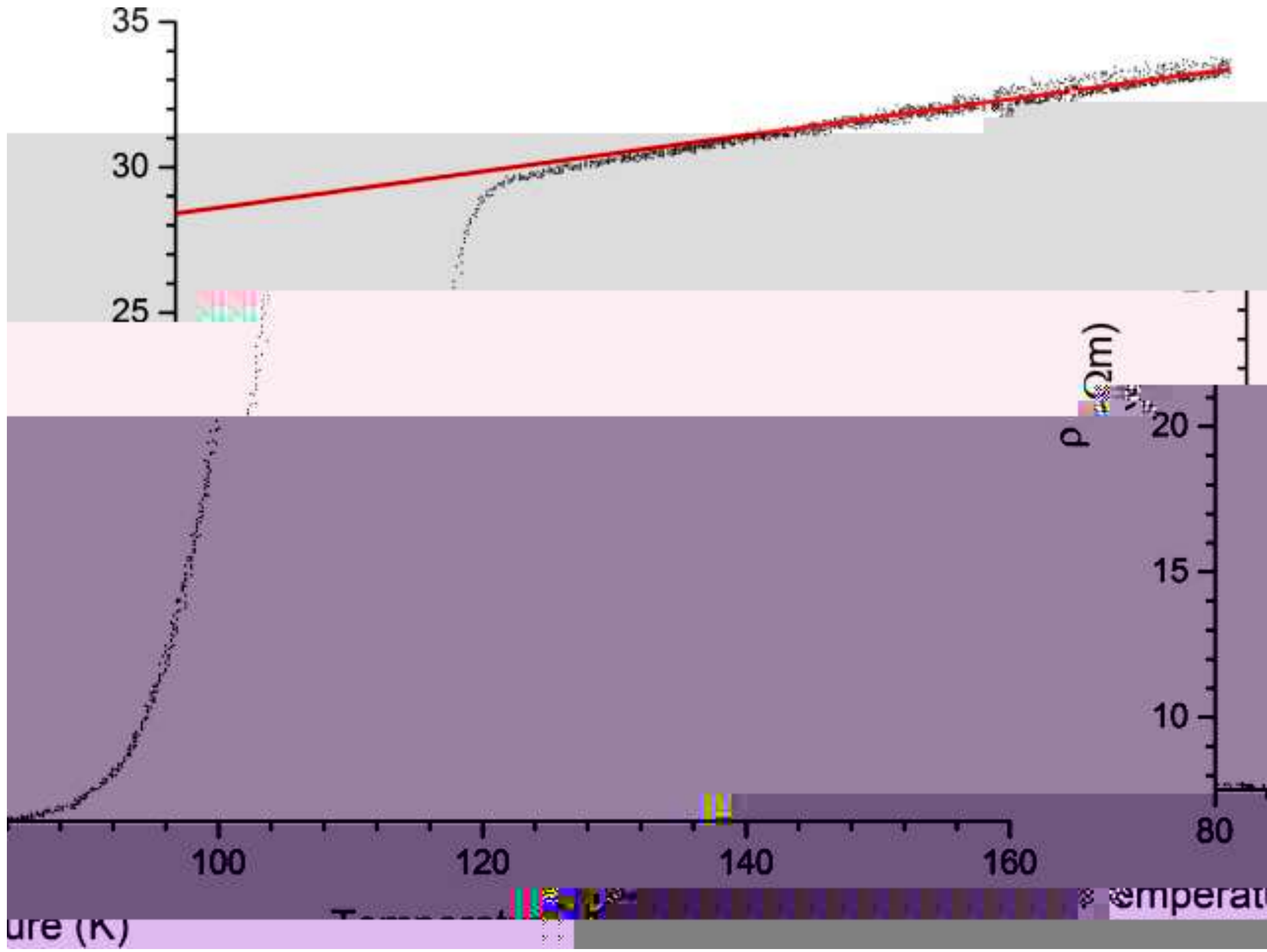
Goal: Convert R into

- Want to extract from the bulk measurement
- $(\quad) = \frac{1}{\quad}(\quad (\quad) + \quad)$
- accounts for c[<0BD40BD5>]TJ 33er6.62 351.07 Tm[( )]TJET

Polycrystalline Correction

- Fit background data of the form:

=

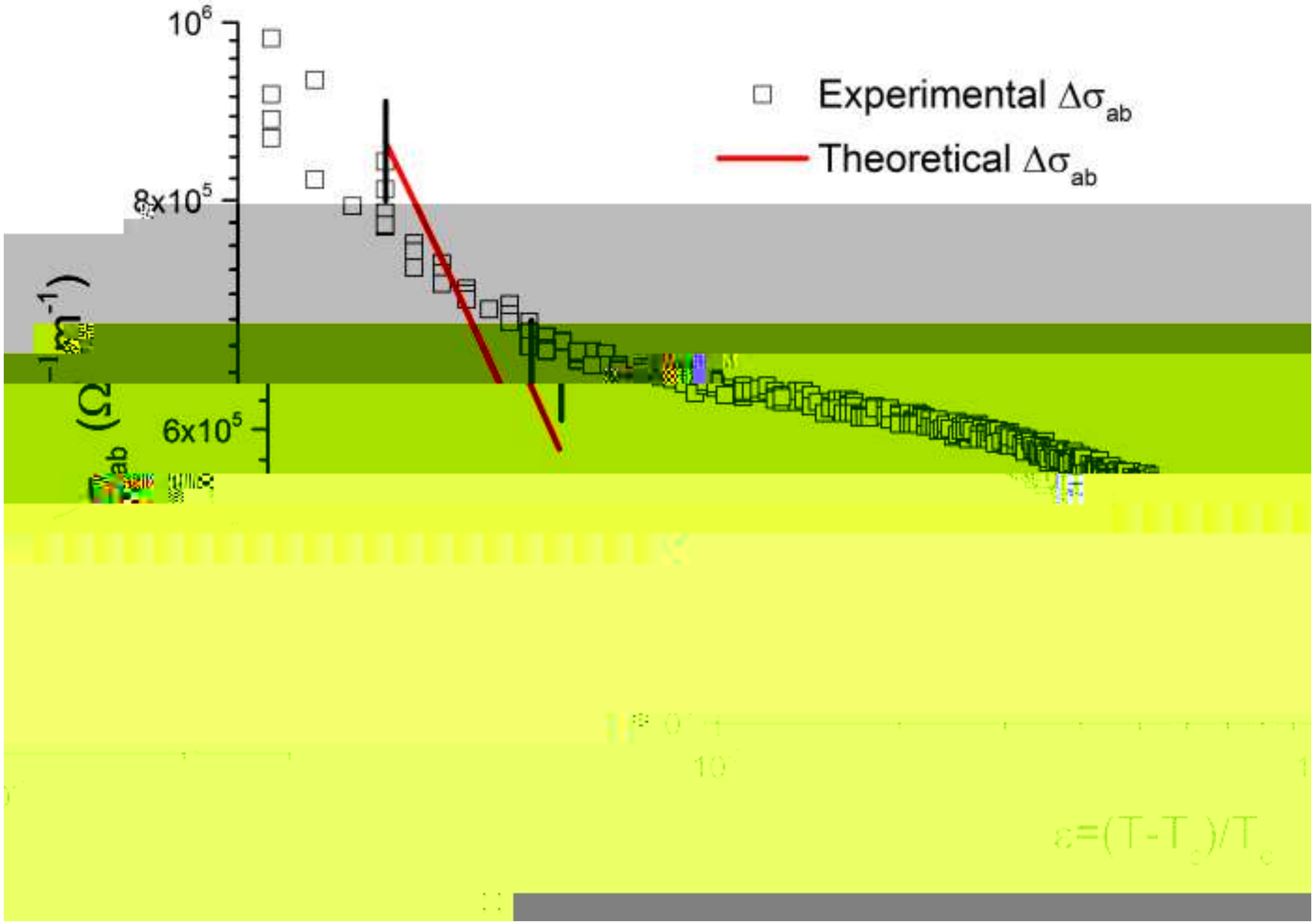


Goal: Determine

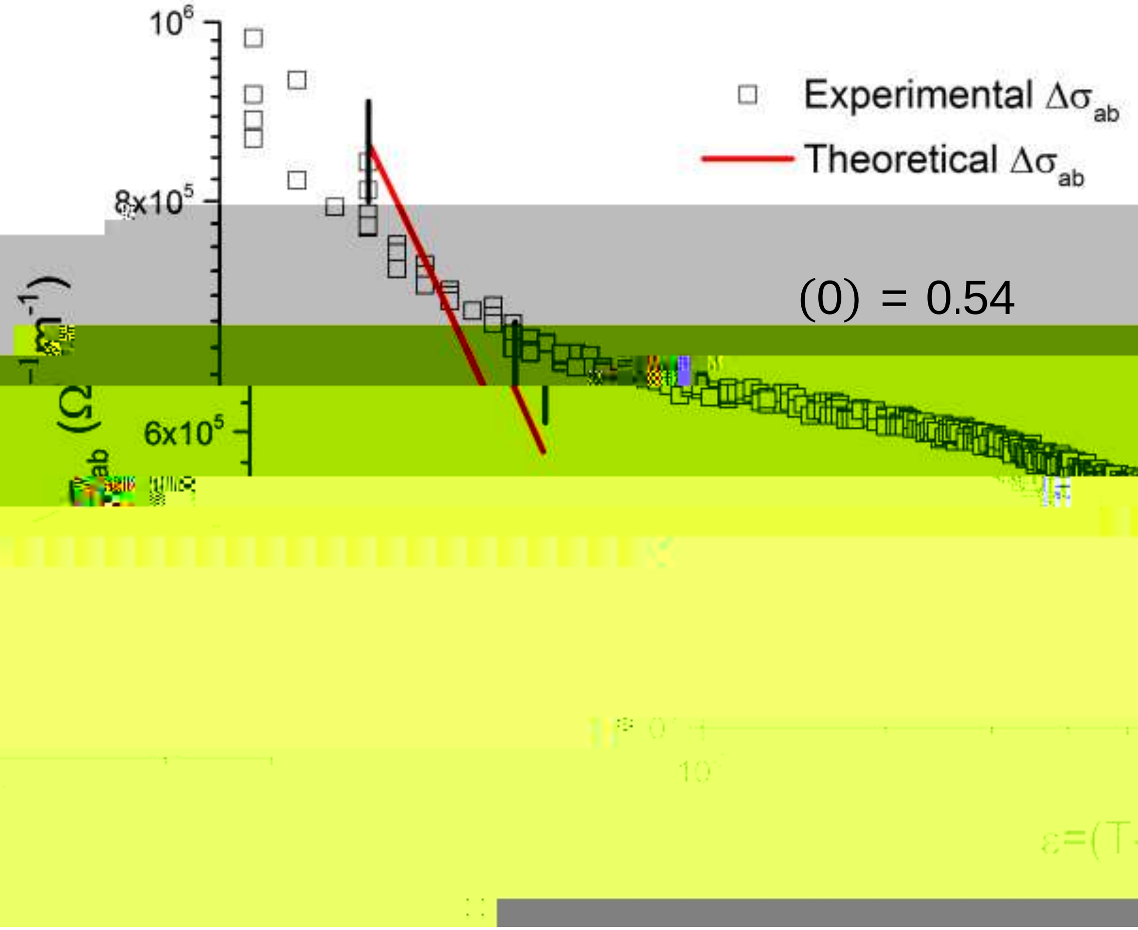
Theoretical Model

- $\Delta \quad (\quad) = \frac{\quad}{\quad}(1 + \frac{\quad}{\quad})^{-\frac{1}{2}}$
- $\quad =$

Goal: Experimental Δ ( ) vs Theoretical Prediction



Results



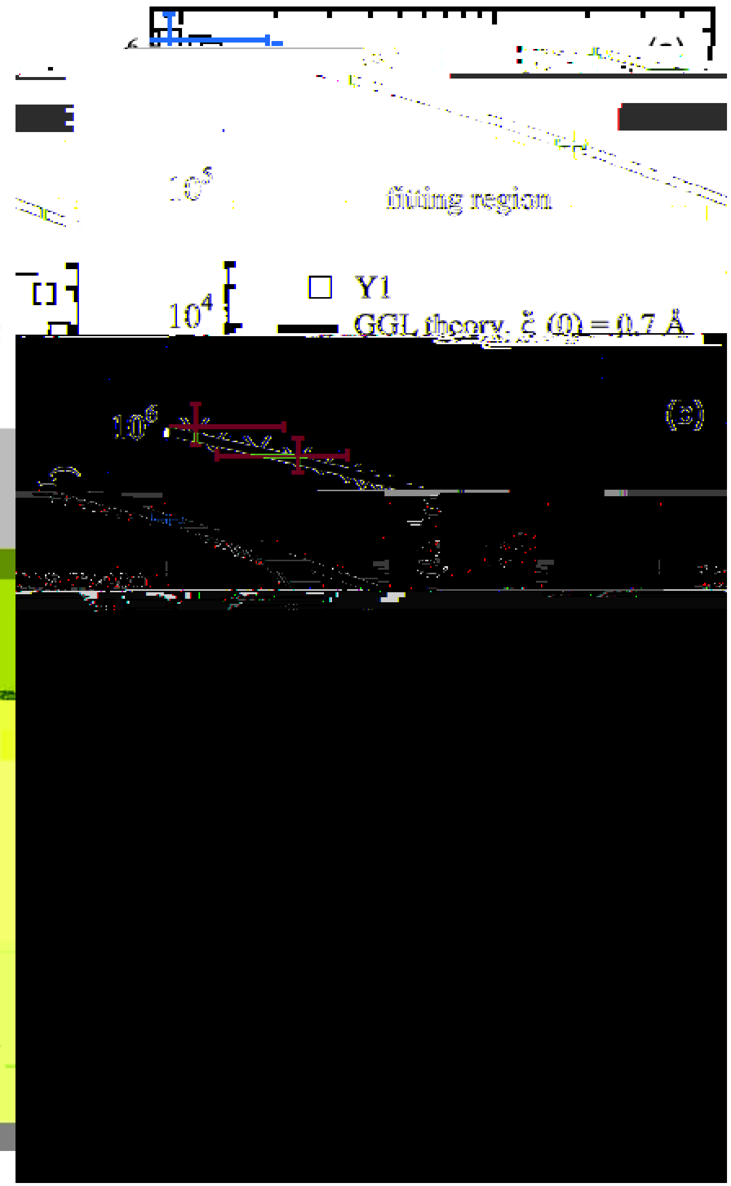


Figure 12. Comparison of our results (left) with Coton et al (right).

Conclusions

- Built a setup capable of measuring R and T of a YBCO sample.
- Able to observe thermal fluctuations via ( ) deviating from linear background/rounded transition.
- Able to determine

References

- Bhattacharya, R.N., High Temperature Superconductors. (Wiley-VCH Weinheim, Germany, 2010). See chapter 1 in particular.
- Kittel, C., Introduction to Solid State Physics, 8th Edition. (John Wiley and Sons, New Jersey, 2005). P. 259-275.
- Annett, James F., Superconductivity, Superfluids and Condensates. (Oxford University Press, New York, 2004) . See Chaps. 3 and 4 in particular.

Ginzburg-Landau Theory

- Characterizes SC transition based on macroscopic properties
- Introduces
- Developed a spatially varying
  - Phenomenological parameters (function of T)
  - Density of Cooper-Pairs
- Results in dissipation less current flow
- Concept of a coherence length

YBCO Structure

- The cryq ặ ă

Amplifier for the Superconductor

- Non-inverting amplifier to measure
- Opted for a G = 1000
- 3dB = 10 Hz

Figure 9. Schematic of the non-inverting amplifier used to measure sample resistance.

Why G = 1000?

- Want to avoid heating the sample, so we fix current
- fixed, sample resistance fixes
- An appropriate voltage gain chosen to yield full range of Logger Pro's ADC
  - Voltages represented as a 12 bit binary number (0-4096)
  - Want variations in signal to cover this full range

Thermocouple Amplifier

- Difference amplifier to measure
- No electrical isolation of components required
- Opted for a G = 750
-

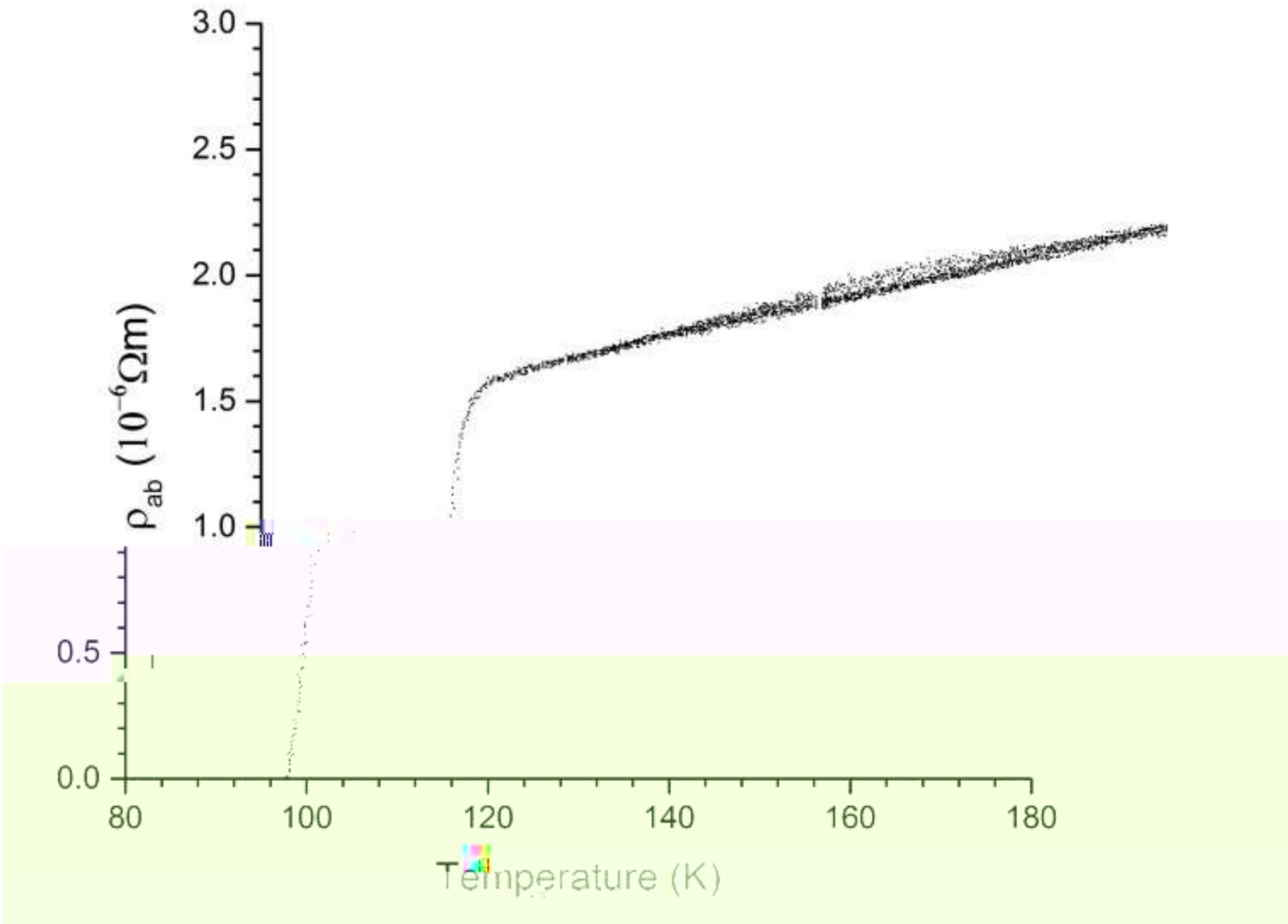


Figure 10. Plot of the in-plane resistivity vs Temperature.