Designing an AC Magnetic Susceptometer Measurement Technique in Conjunction with High Pressures and Low Temperatures in Neutron Beam Experiments

Presenter: Paul Neves

Mentors: Nicholas Butch & Juscelino Leão

NIST Center for Neutron Research

Summer Undergraduate Research Fellowship

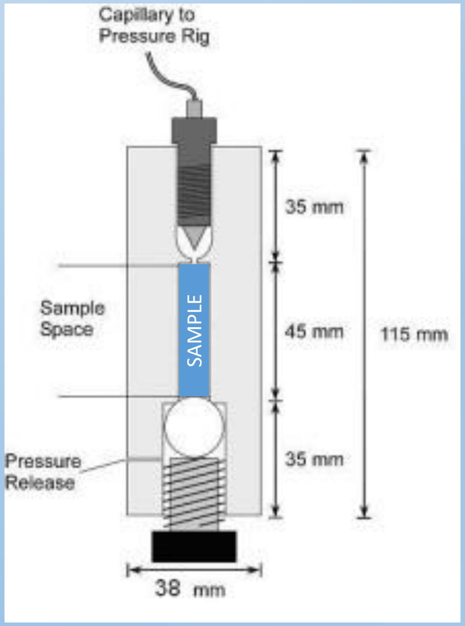
Outline

- Background
- Methodology
- Results

Currently, users can:

- Load their sample in a pressure cell

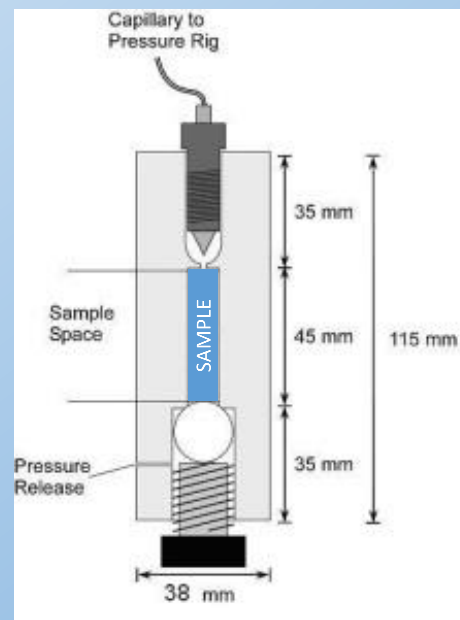
https://www.ncnr.nist.gov/equipment/Pressure.html



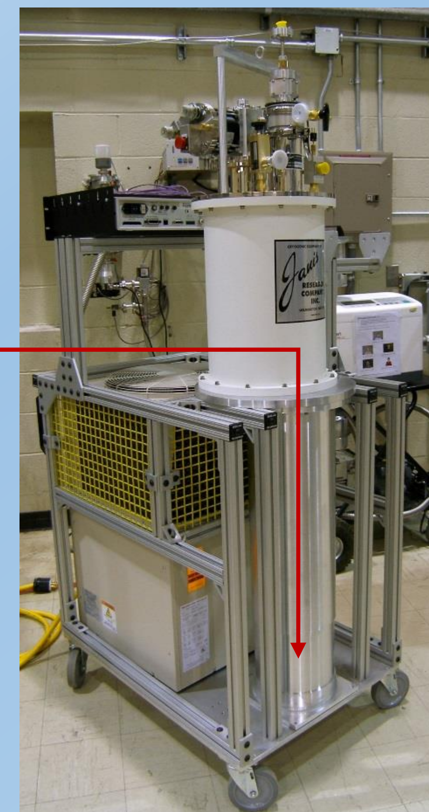
Currently, users can:

- Load their sample in a pressure cell
- Bring that sample to low temperatures in a cryostat

https://www.ncnr.nist.gov/equipment/Pressure.html



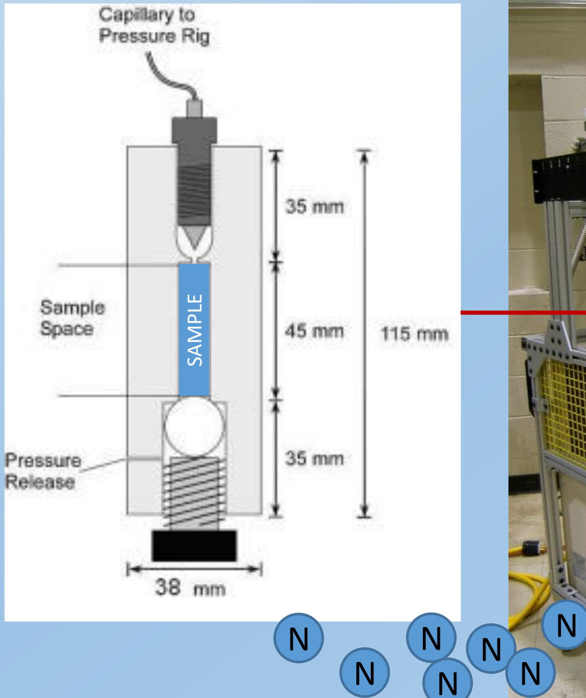
https://www.ncnr.nist.gov/equipment/displex.html



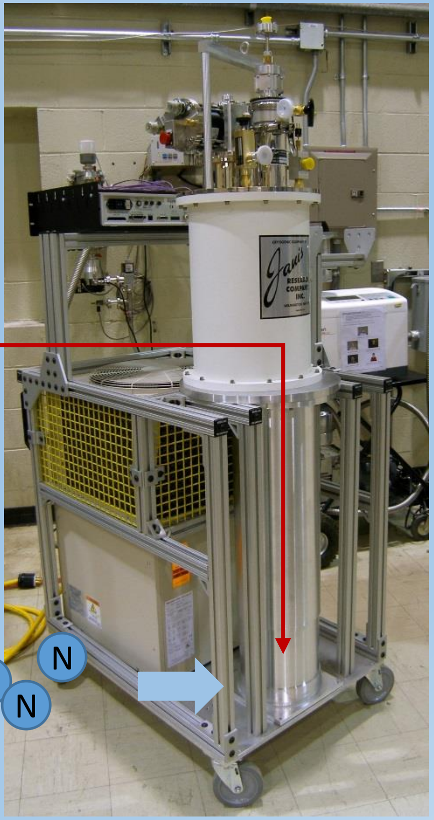
Currently, users can:

- Load their sample in a pressure cell
- Bring that sample to low temperatures in a cryostat
- Then look at it with a beam of neutrons

https://www.ncnr.nist.gov/equipment/Pressure.html

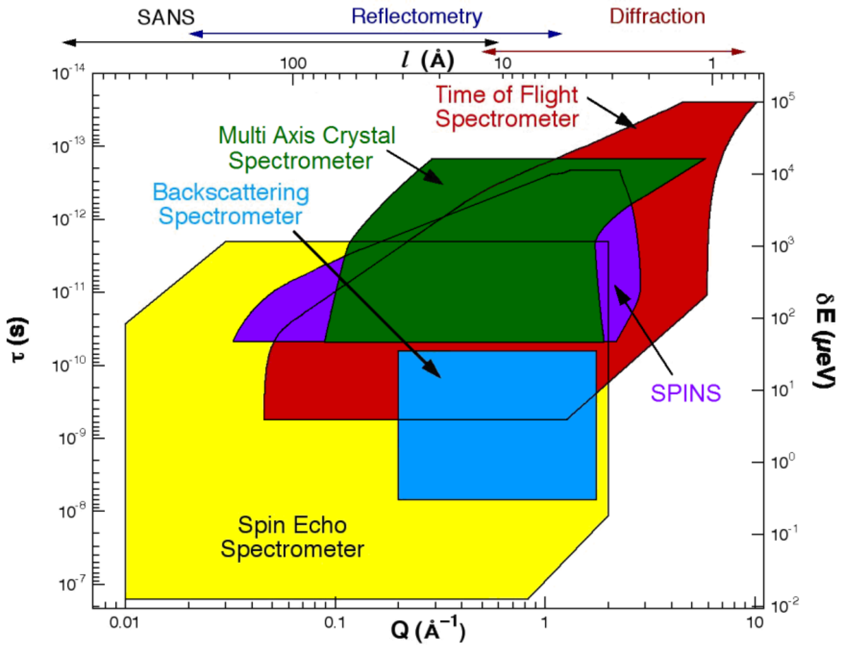


https://www.ncnr.nist.gov/equipment/displex.html



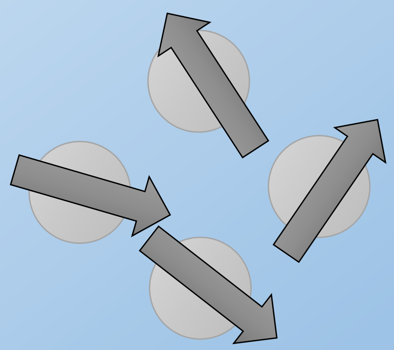
What is an AC Susceptometer and Why Do We Need One Here?

- Measures magnetic susceptibility
- Tells you about the magnetic phase
- In situ with neutrons

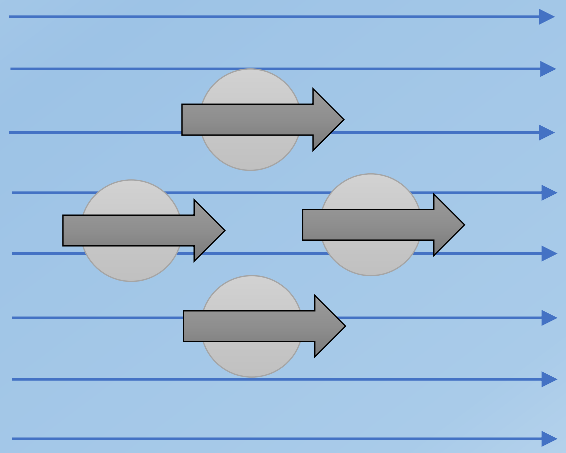


What it Measures

- $M = \chi H$
- Diamagnets, paramagnets, ferromagnets, superconductors, etc



No Field

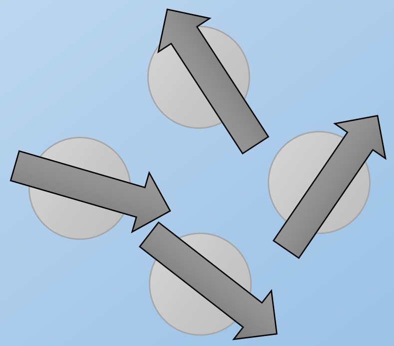


With Field

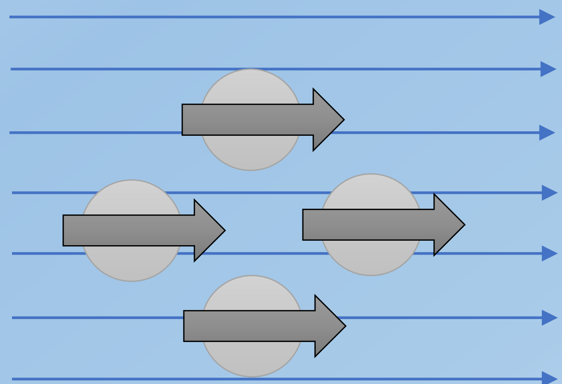
What it Measures

- $M = \chi H$
- Diamagnets, paramagnets, ferromagnets, superconductors, etc

Material:	Response:
Para- or Dia- Magnet	~0
Superconductor	-1
Ferromagnet	Very large



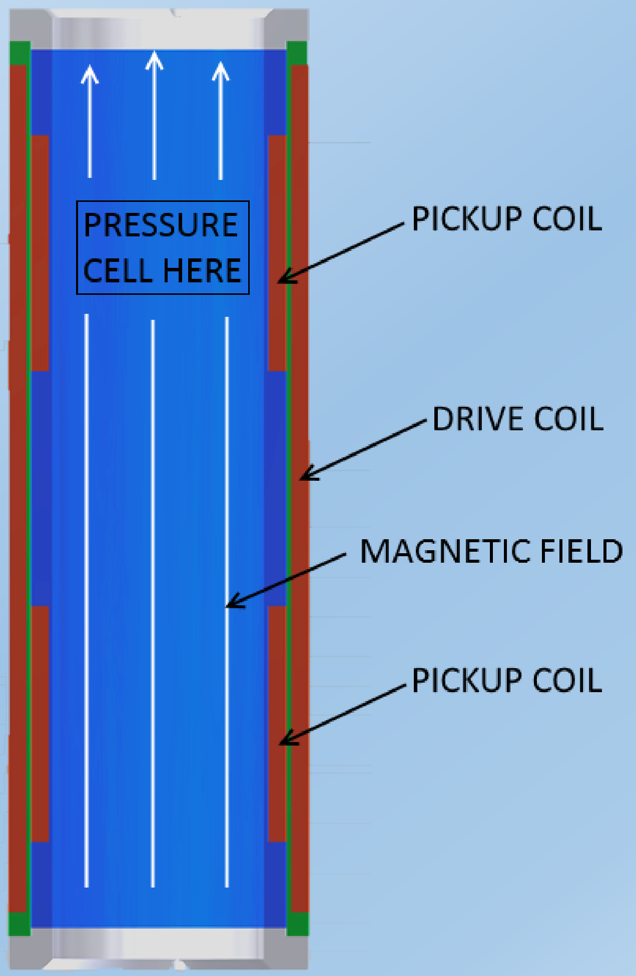
No Field



With Field

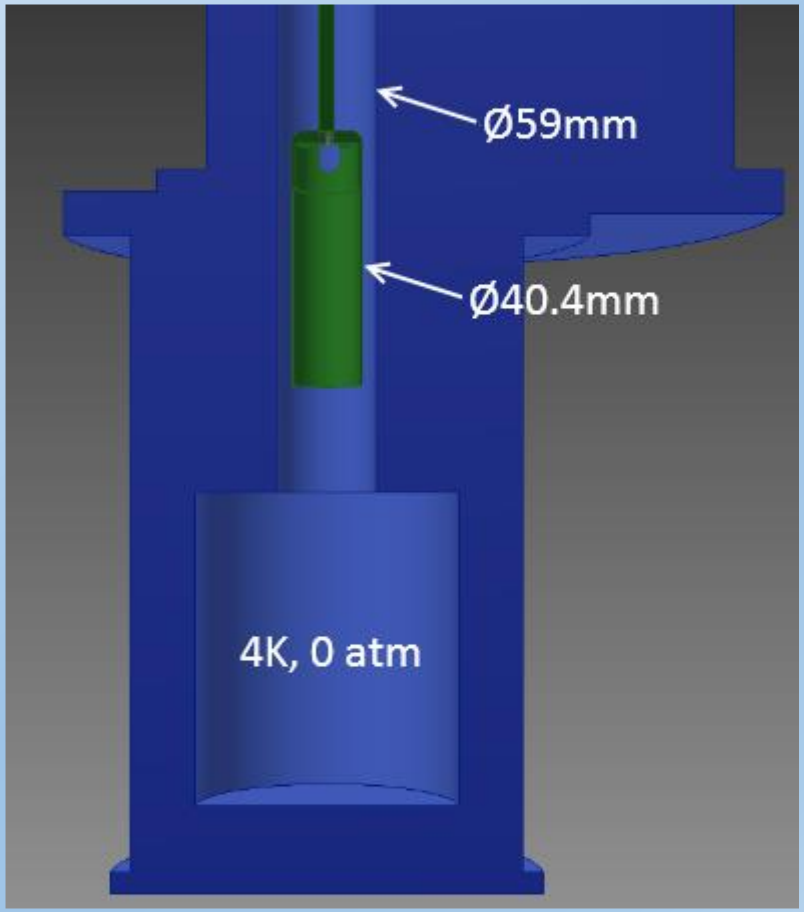
How It Works

- Drive coil makes field
- Pickup coils measure response
- Sample sits in the center



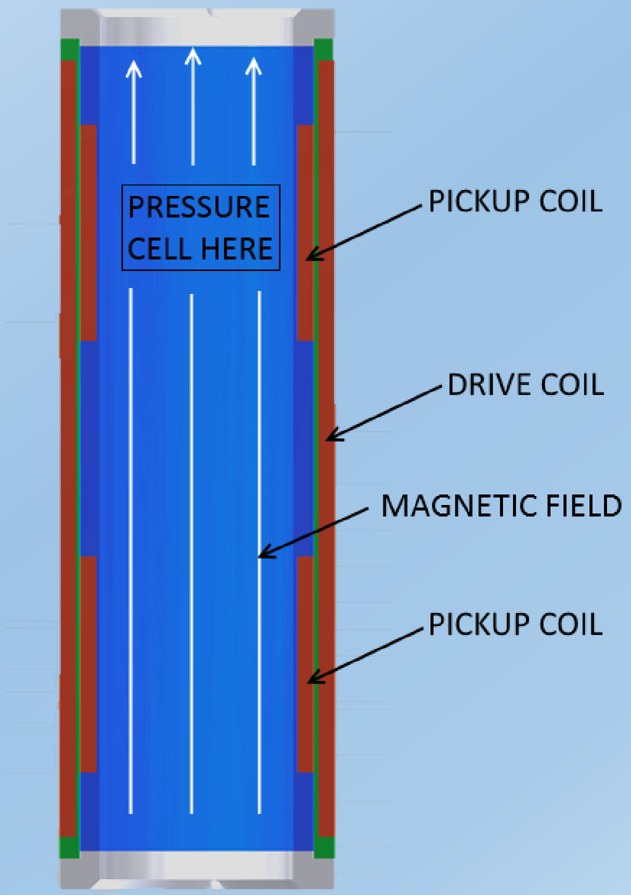
Constraints

- Size
- Low Temperature
- Vacuum Sealed
- Time
- Sensitivity



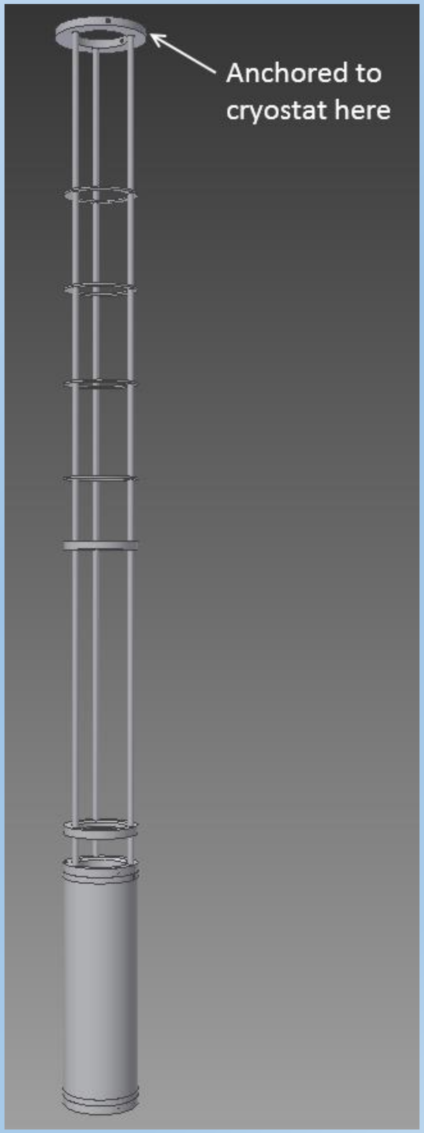
Solutions to Constraints

- Designed thin profile coil



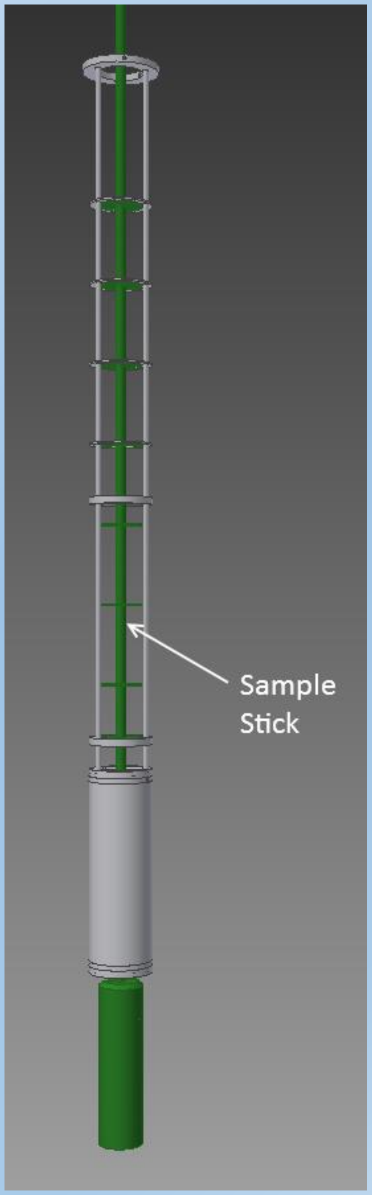
Solutions to Constraints

- Designed thin profile coil
- Which must be supported



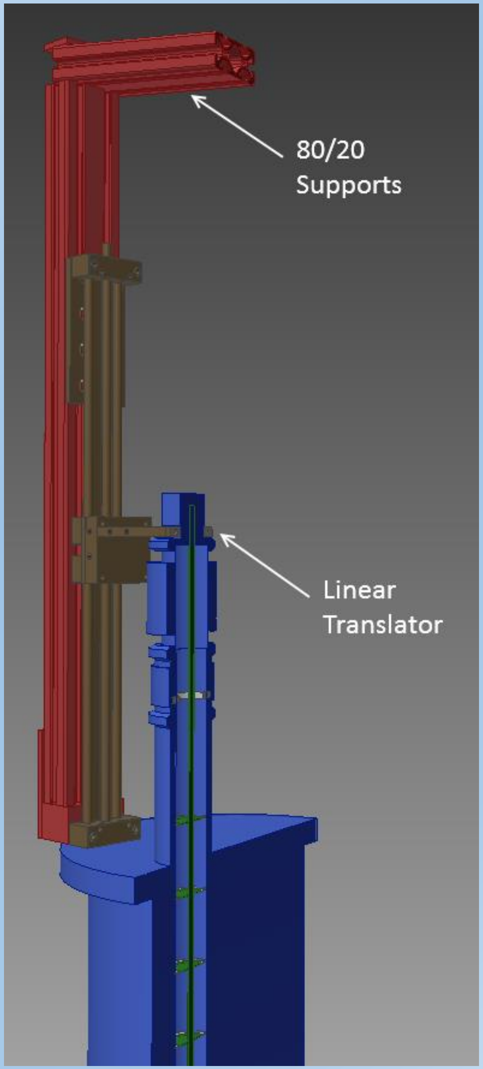
Solutions to Constraints

- Designed thin profile coil
- Which must be supported
- And the sample stick must be modified



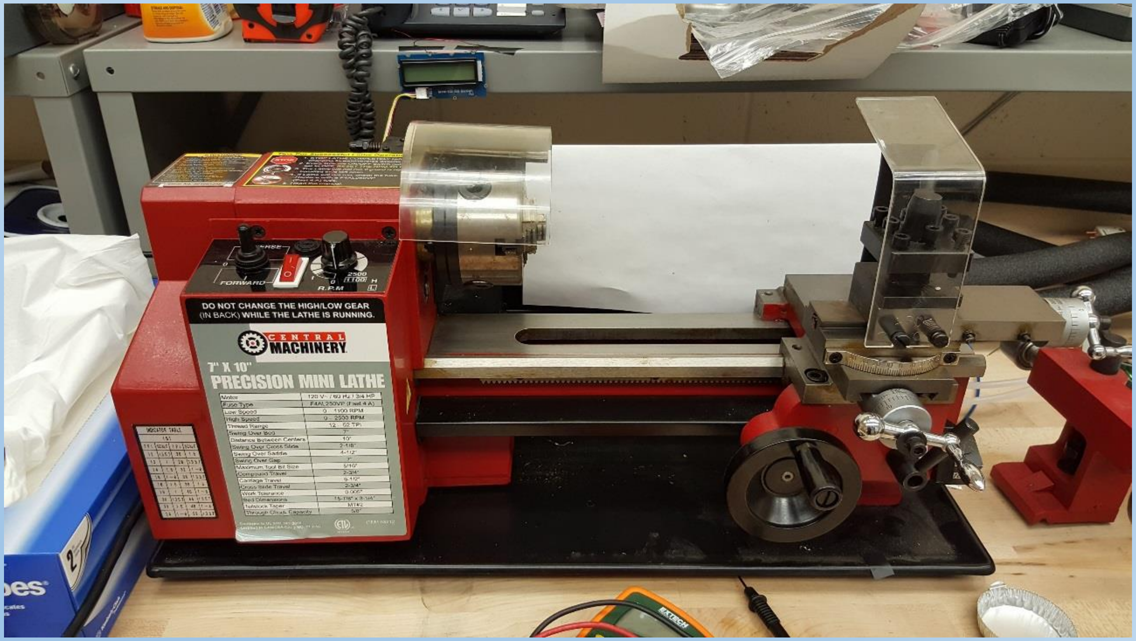
Solutions to Constraints

- Designed thin profile coil
- Which must be supported
- And the sample stick must be modified
- And given motion



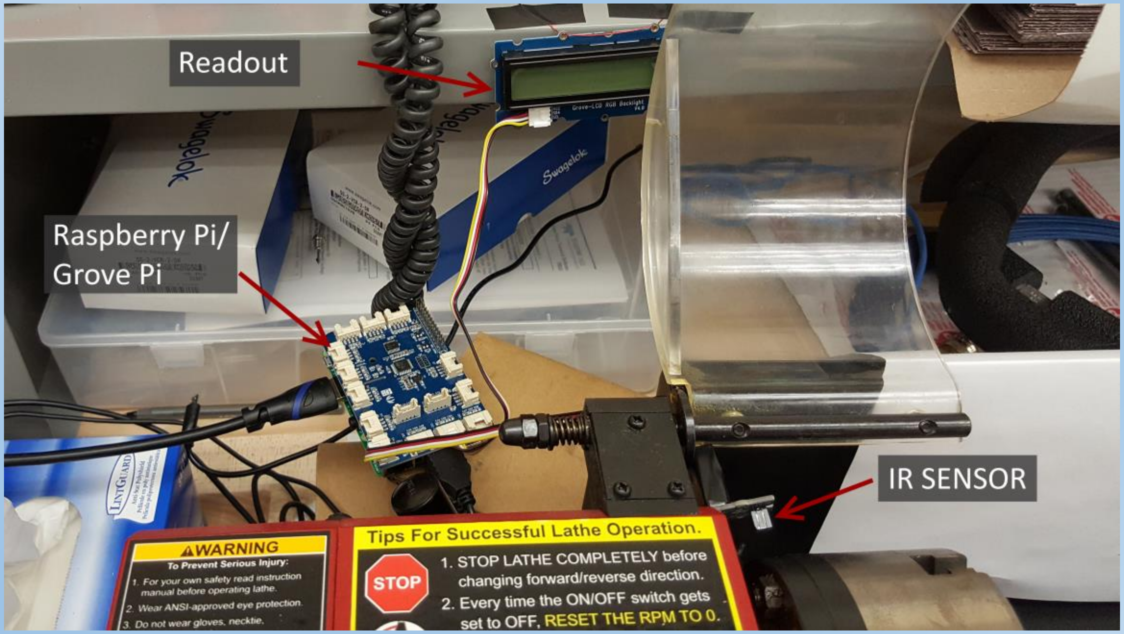
Winding the Coils

- Lathe controls turning



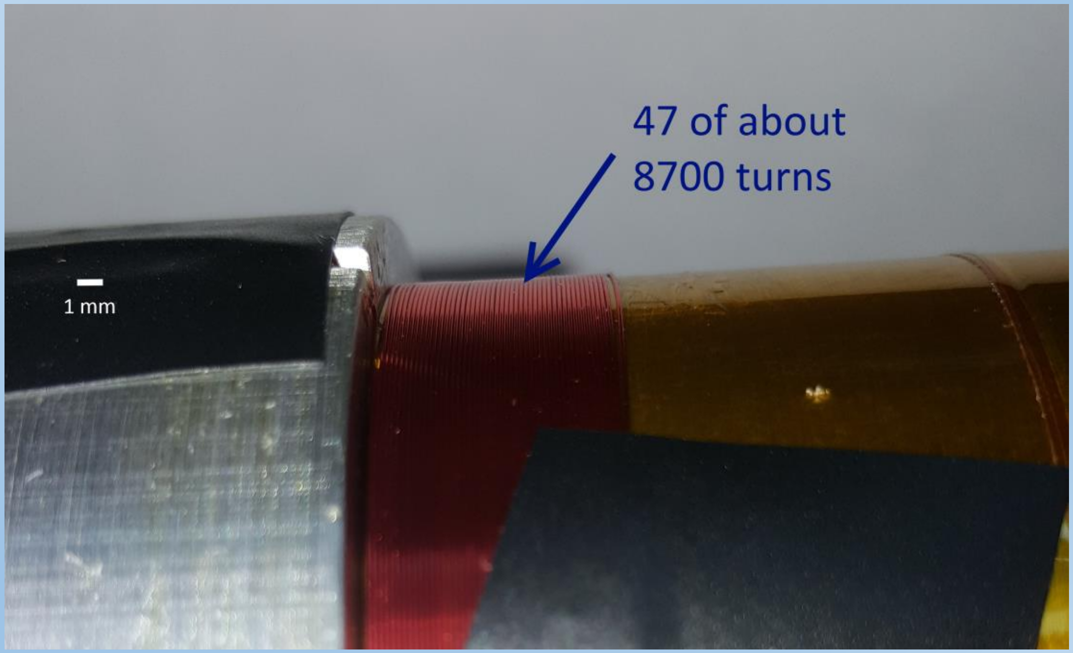
Winding the Coils

- Lathe controls turning
- Raspberry pi counts turns



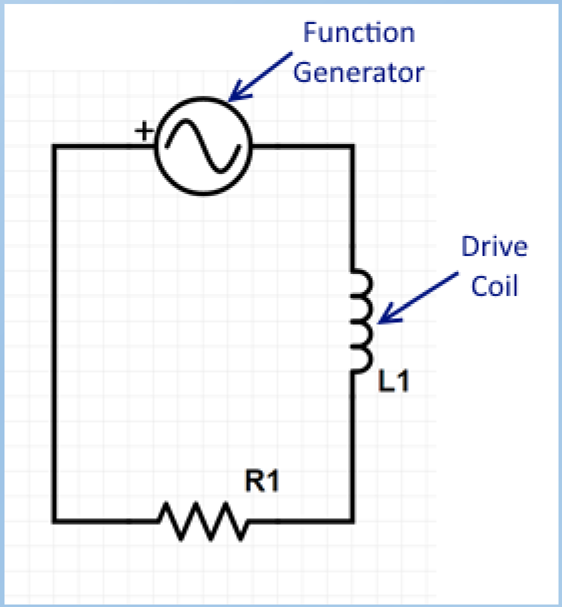
Winding the Coils

- Lathe controls turning
- Raspberry pi counts turns
- A lot of turns…



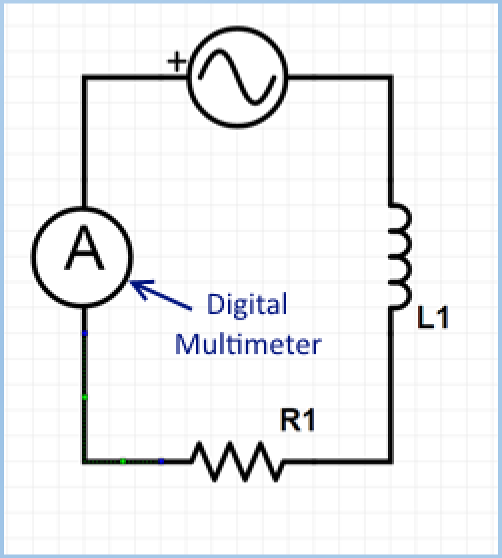
Wiring and Programming

- Function generator controls drive coil



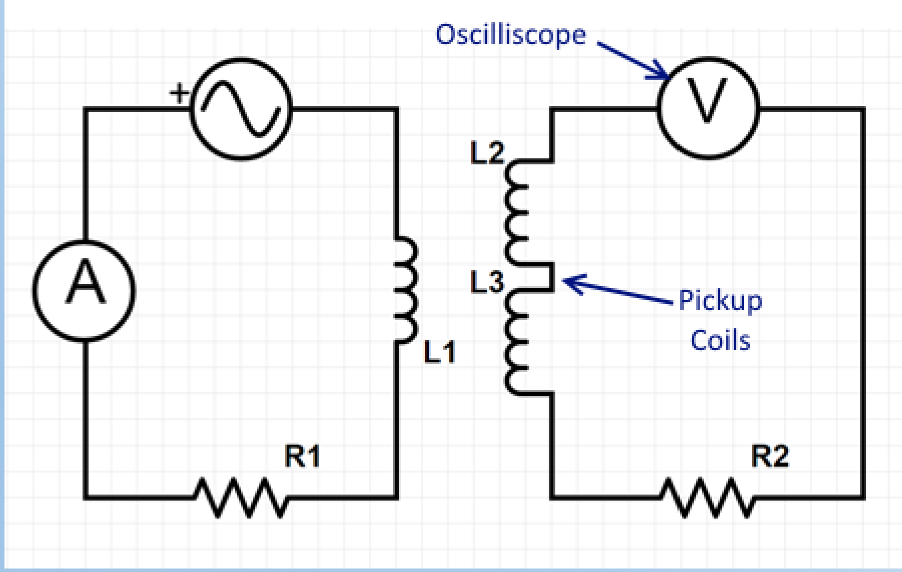
Wiring and Programming

- Function generator controls drive coil
- Multimeter measures drive current



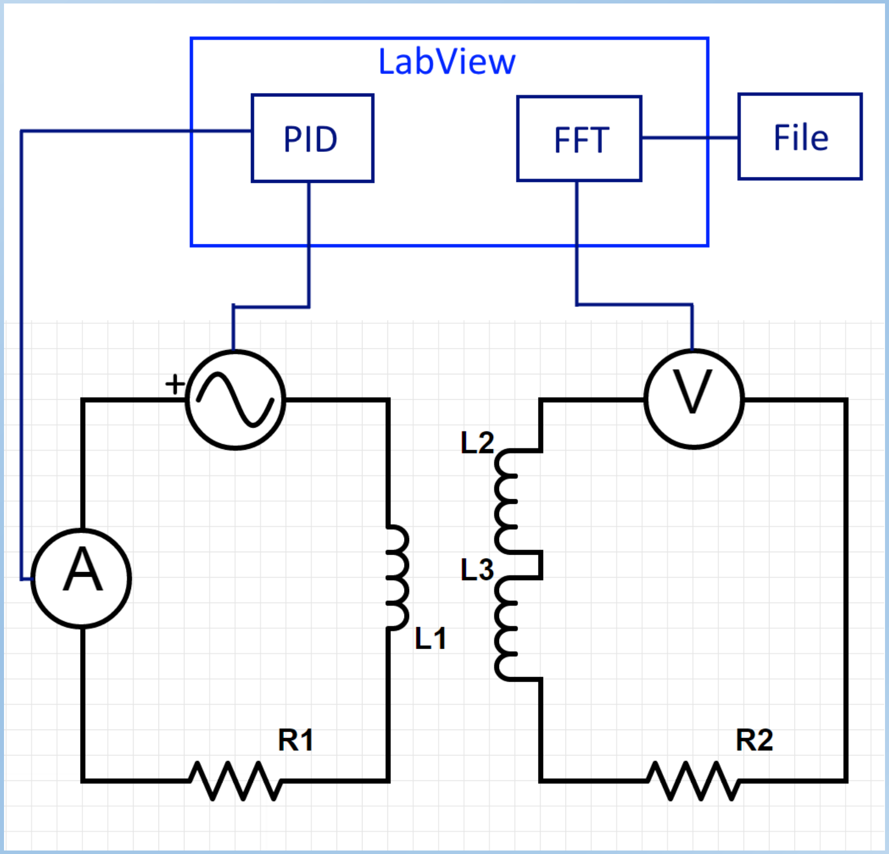
Wiring and Programming

- Function generator controls drive coil
- Multimeter measures drive current
- Oscilliscope measures pickup coil response

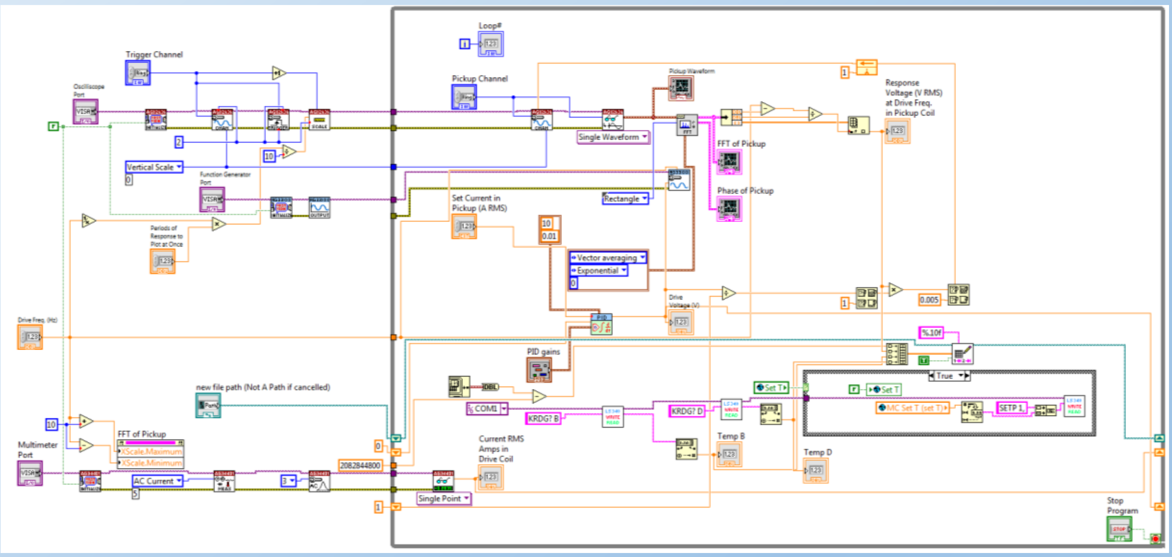


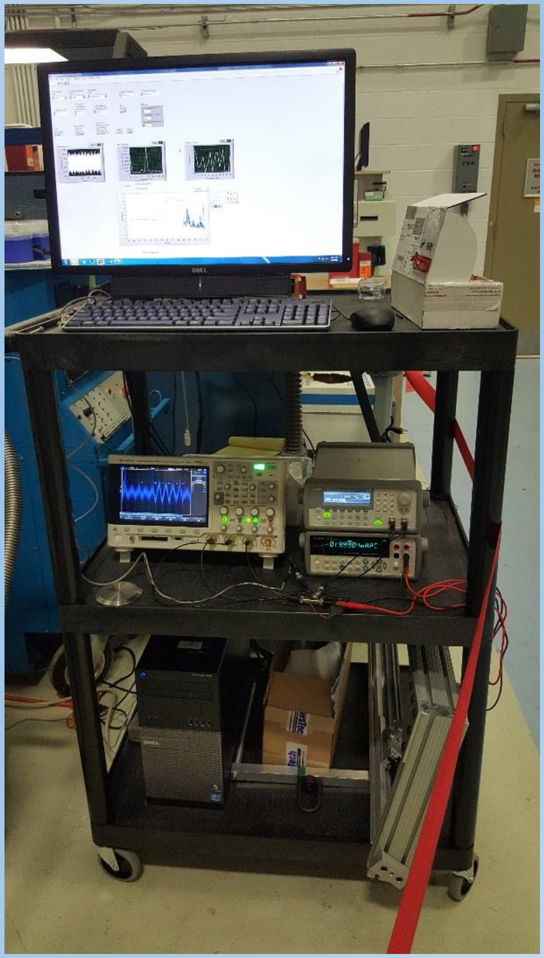
Wiring and Programming

- Function generator controls drive coil
- Multimeter measures drive current
- Oscilliscope measures pickup coil response
- LabView controls all three instruments and records data



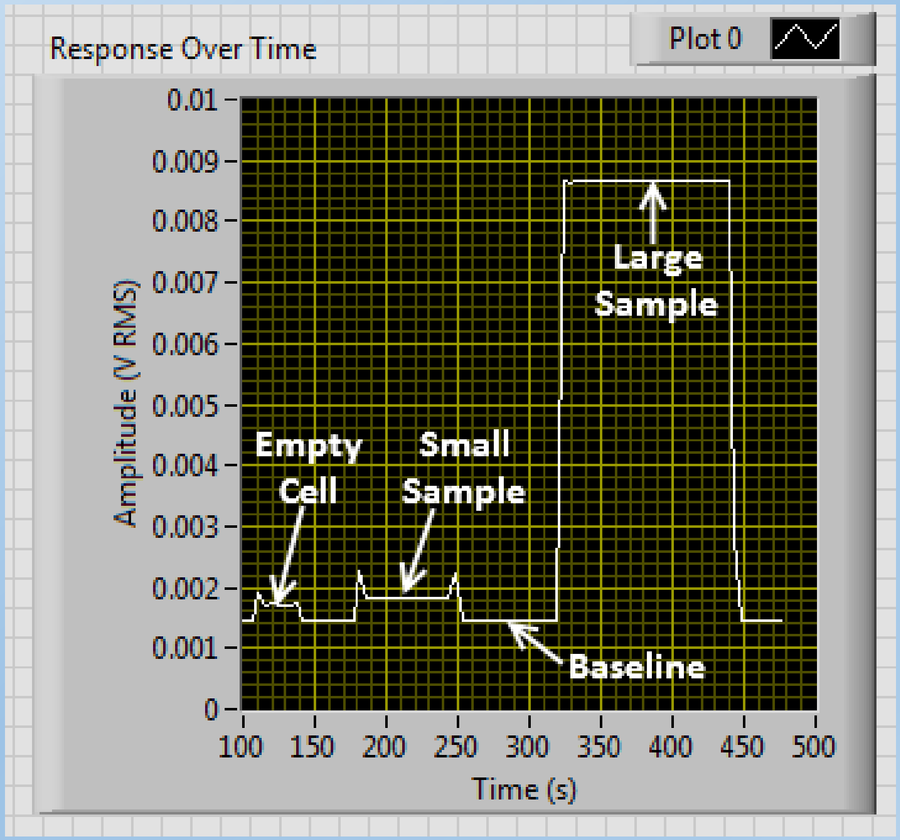
Wiring and Programming





Testing the Coils

- Baseline
- Empty pressure cell
- ~0.5g steel
- ~6g steel



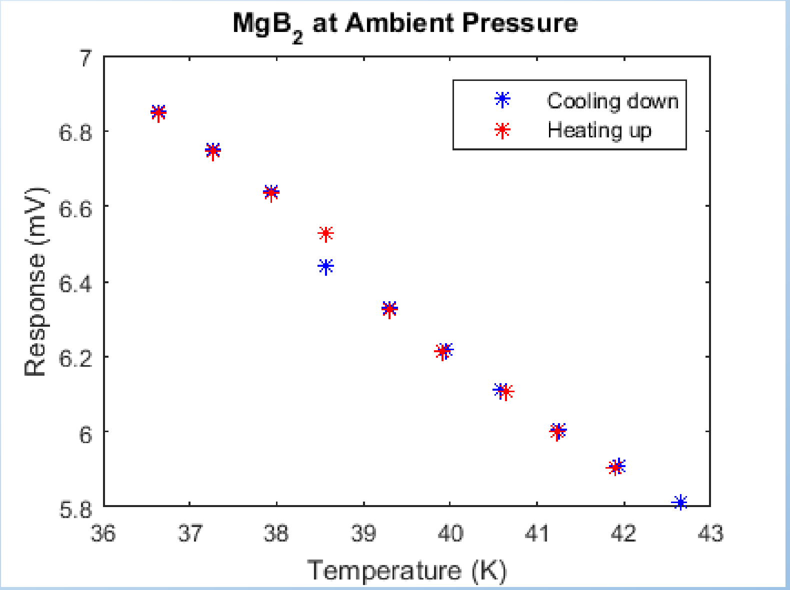
Test Samples

- Empty pressure cell
- MgB_2, a low temperature superconductor (T_C=39K)

https://www.ncnr.nist.gov/
equipment/Pressure.html

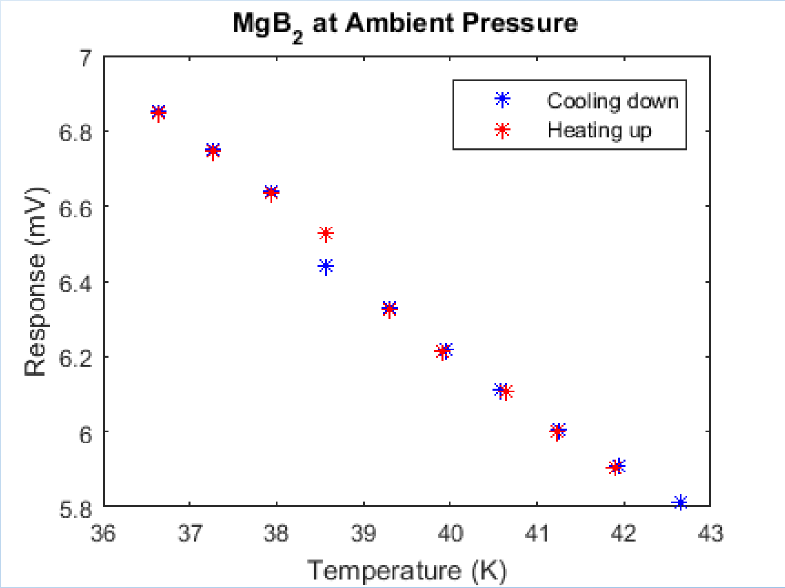
wikipedia

Results

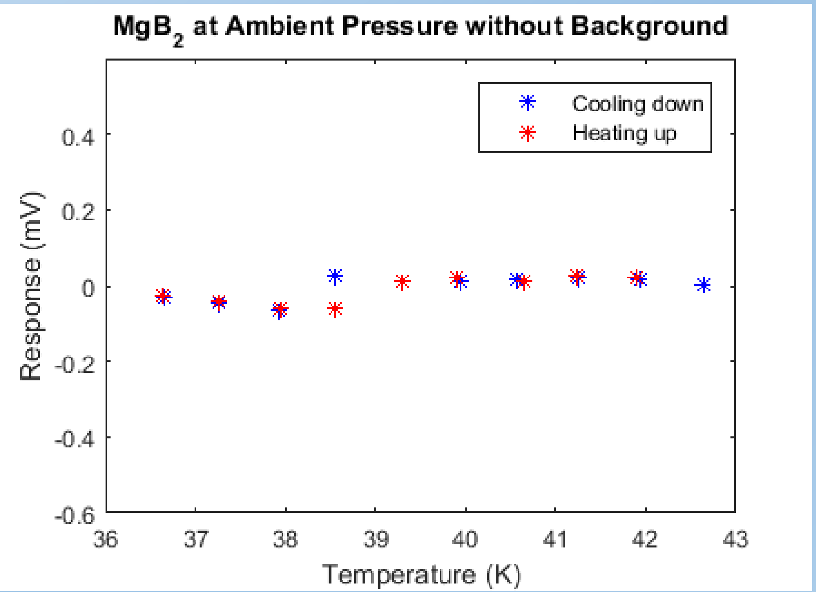


MgB_2 at Ambient Pressure
Response (mV)
7
6.8
6.6
6.4
6.2
6
5.8
36
37
38
39
40
41
42
43
Temperature (K)
Cooling down
Heating up

Results

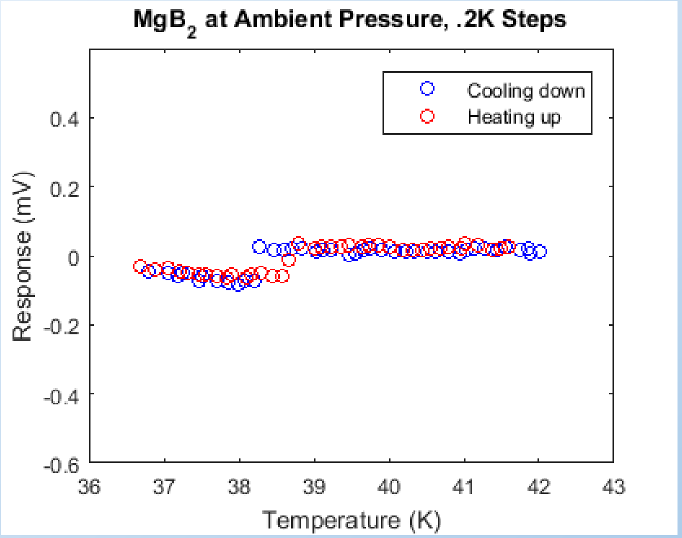


MgB$_2$ at Ambient Pressure
Cooling down
Heating up
Response (mV)
Temperature (K)

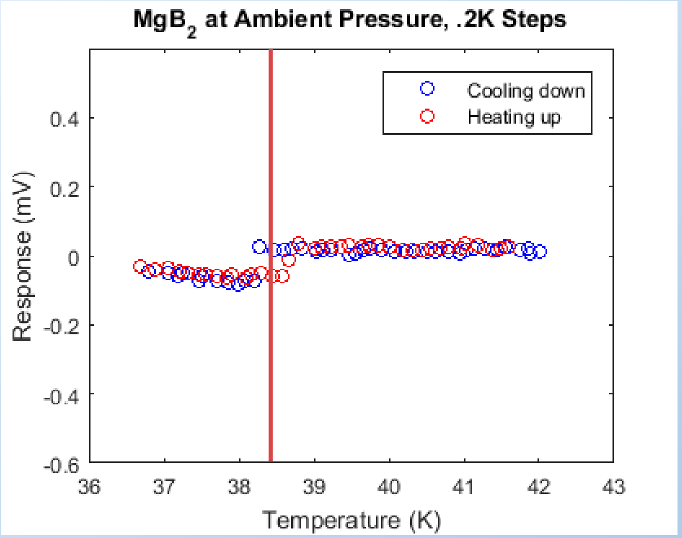


MgB$_2$ at Ambient Pressure without Background
Cooling down
Heating up
Response (mV)
Temperature (K)

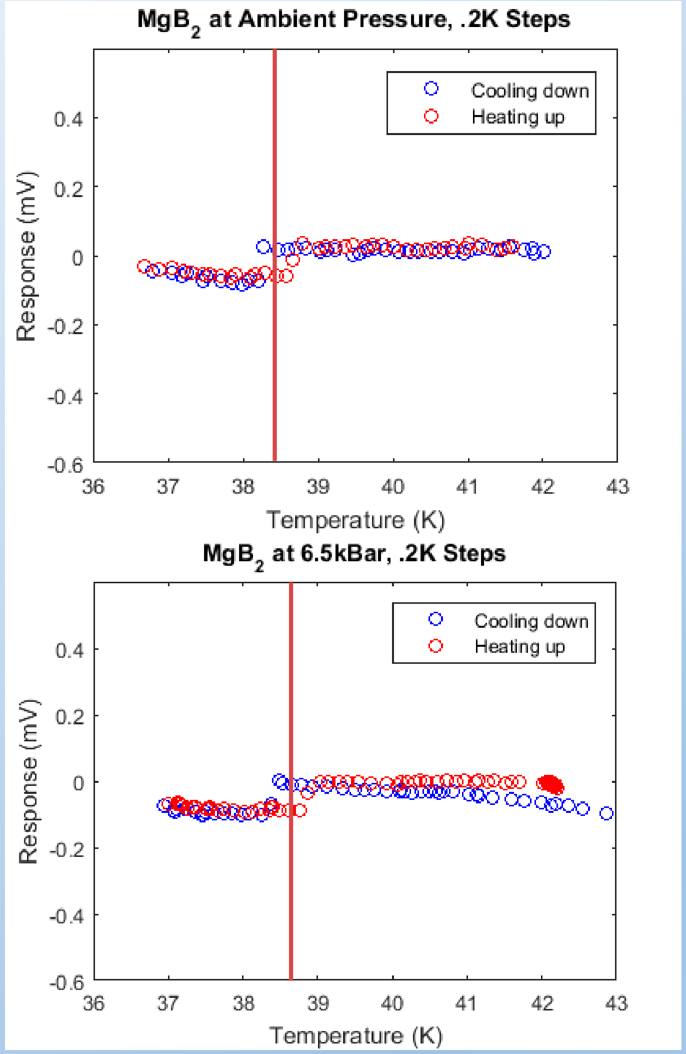
Results, Continued



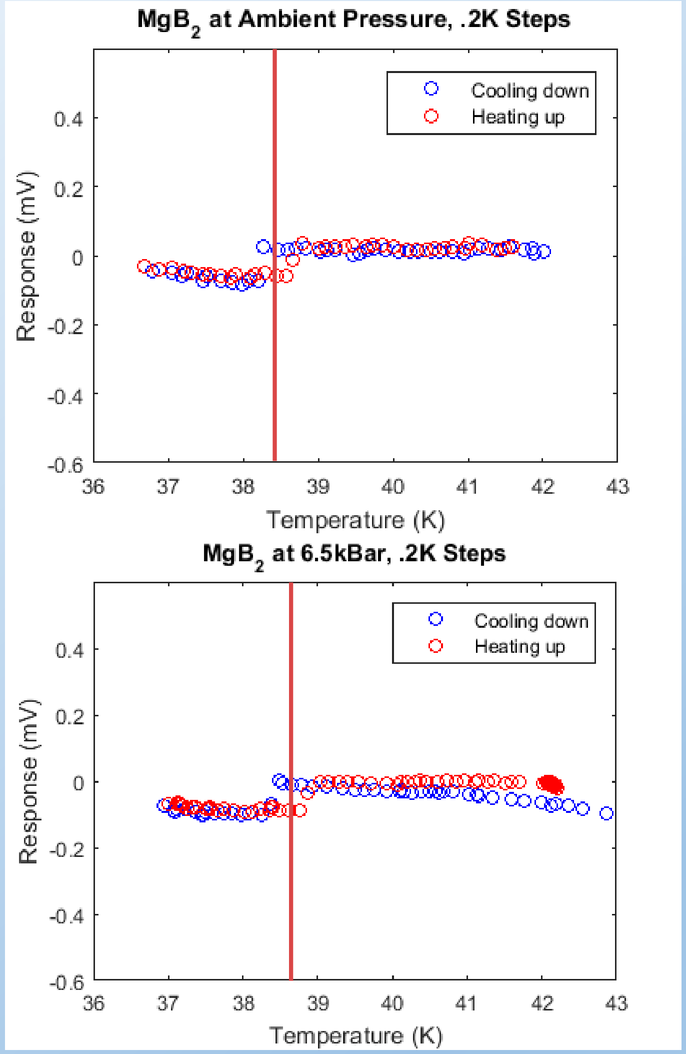
Results, Continued



Results, Continued

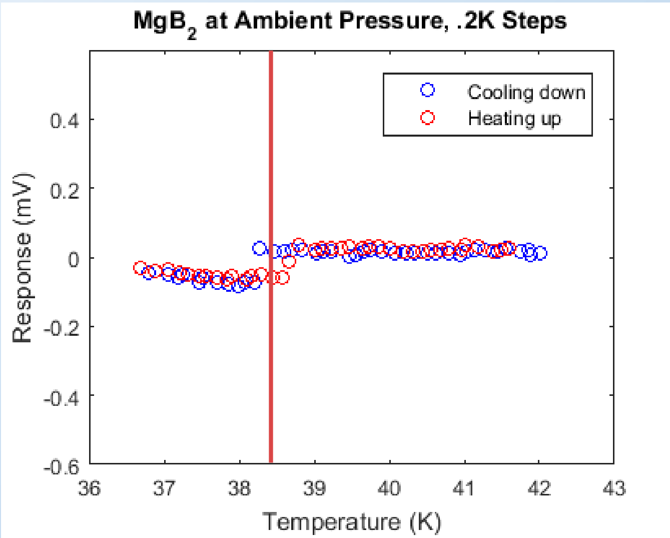


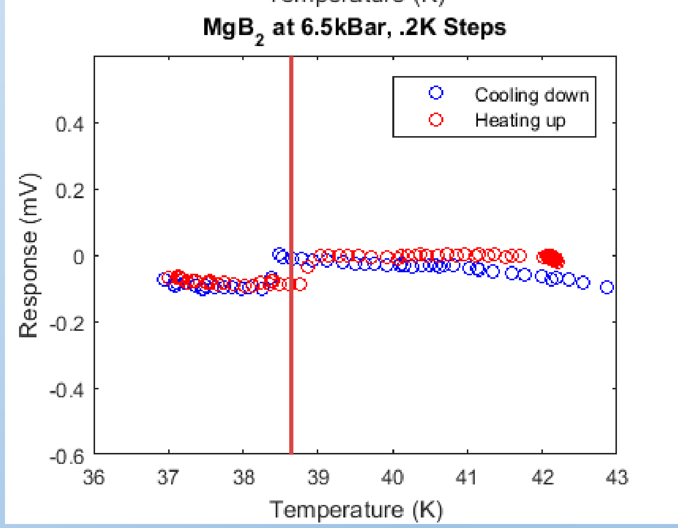
Results, Continued



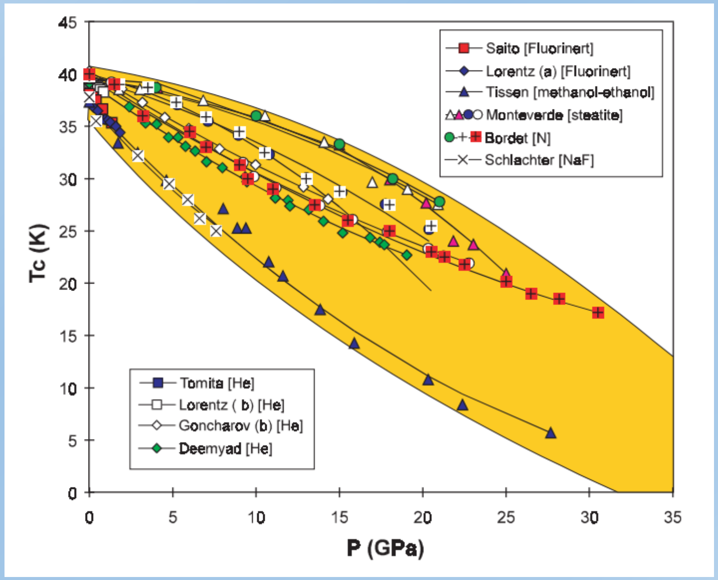
Pressure:	Tc (K):
Ambient	~38.4
0.65 GPa	~38.6

Results, Continued





Pressure:	Tc (K):
Ambient	~38.4
0.65 GPa	~38.6



Buzea, Cristina, and Tsutomu Yamashita. "Review of the superconducting properties of MgB2." *Superconductor Science and Technology* 14.11 (2001): R115.

Summary

- Many constraints
- Useful capability
- It works!

Acknowledgements

- Nick Butch and Juscelino Leão
- NIST and the SURF program
- The NCNR and CHRNS
- Julie Borchers and Joe Dura
- Dan Neumann
- Doug Johnson, Patrick Connelly, Scott Slifer, Colin Wrenn, Andrew Malone
- Markus Bleuel, Alan Ye, Shannon Watson

References

- Feynman, Richard P., Robert B. Leighton, and Matthew Sands. *The Feynman Lectures on Physics, Desktop Edition Volume I*. Vol. 1. Basic books, 2013.
- Nikolo, Martin. "Superconductivity: A guide to alternating current susceptibility measurements and alternating current susceptometer design."*American Journal of Physics* 63.1 (1995): 57-65.