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Building a Second Harmonic Radio Frequency Cavity for the Booster

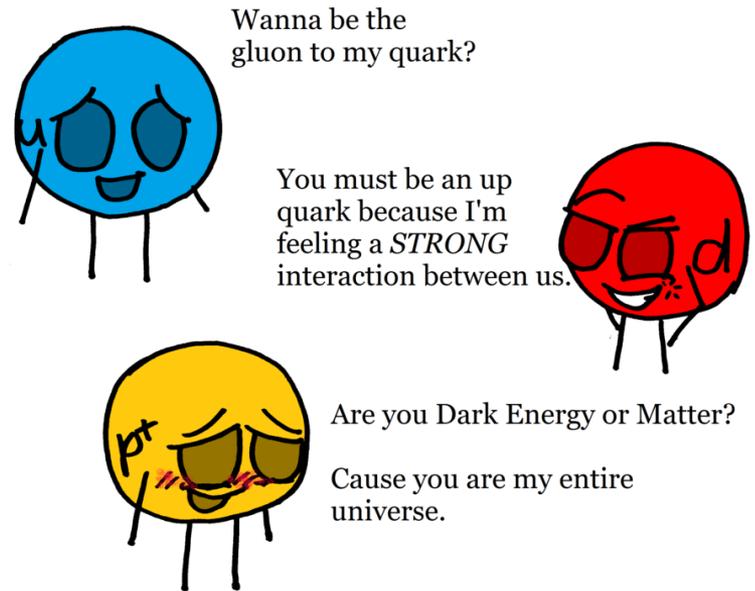
Maggie Lankford
SIST Intern 2015
The College of Wooster
4 August 2015



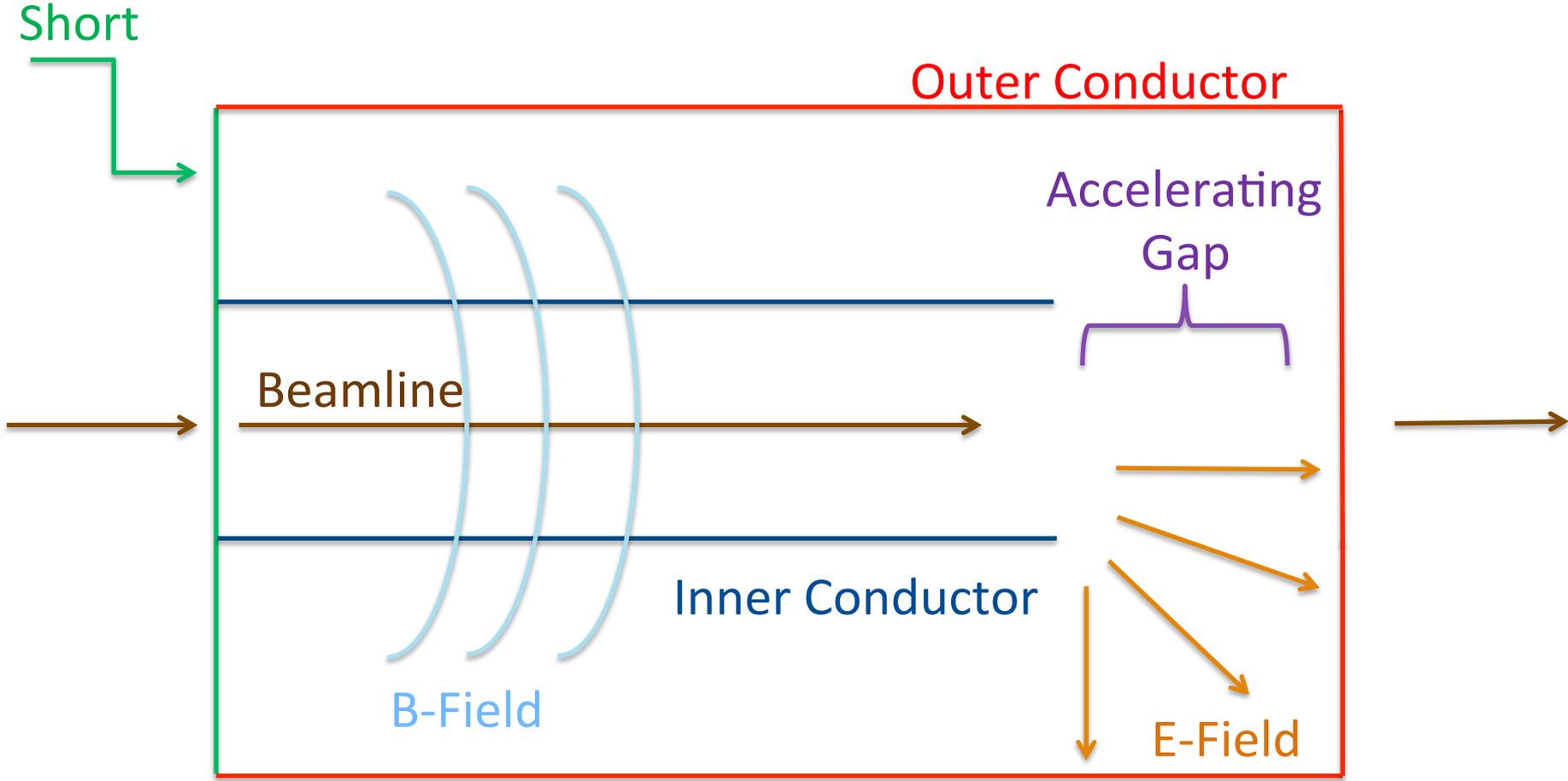
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WOOSTER

Outline

1. Radio Frequency Cavity Basics
2. Perpendicular Cavity Tuning
3. Comparison Between Real and Model Cavity
4. Calculating Permeability
5. Power Amplifier Basics
6. Building a Temperature Probe



Radio Frequency (RF) Basics



Tuning the Cavity

- What do we do when the beam speeds up??

$$v = c / \mu \epsilon$$

v : speed of light in medium

c : speed of light in vacuum

μ : permeability

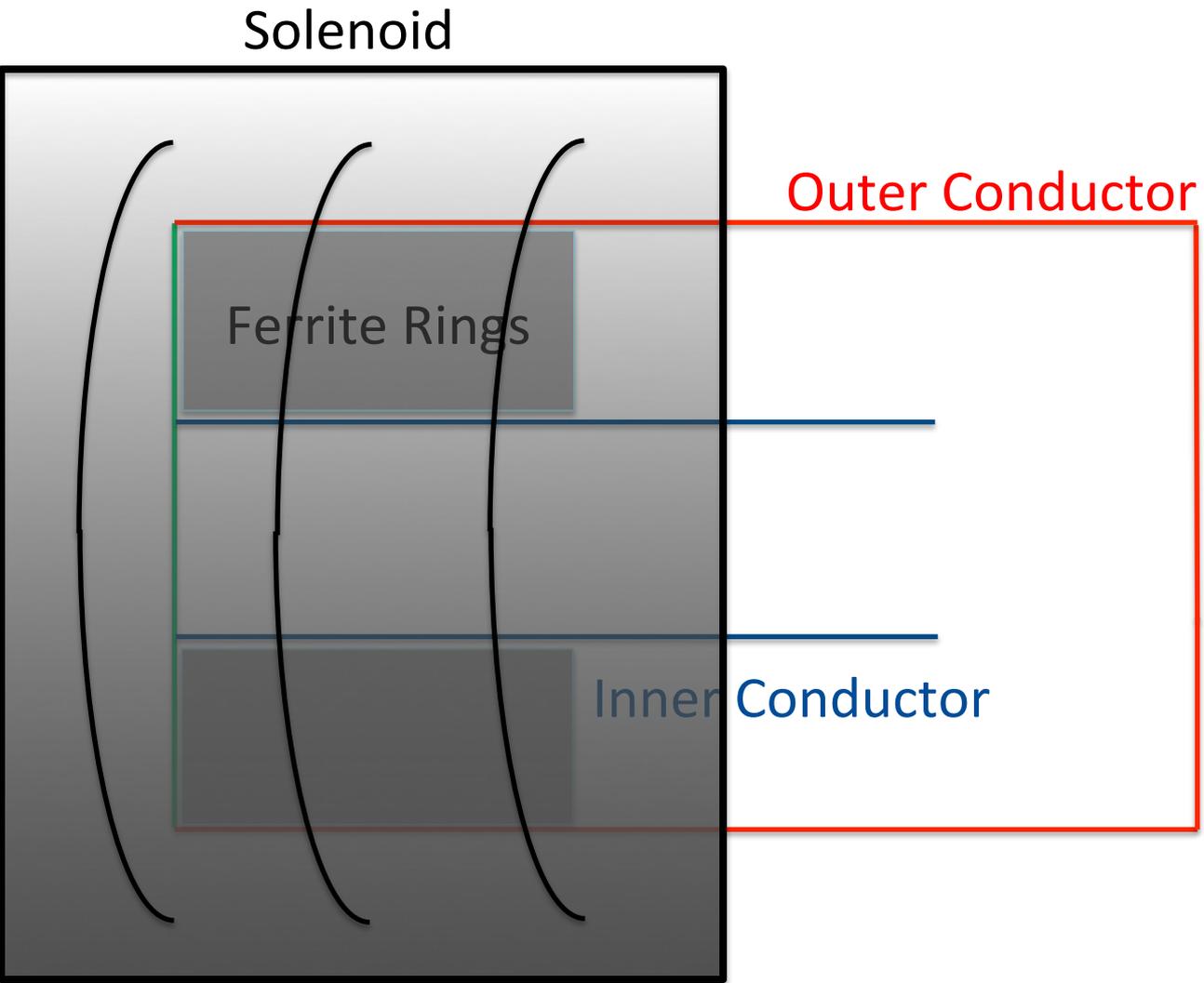
ϵ : permittivity

λ : wavelength

ω : angular frequency

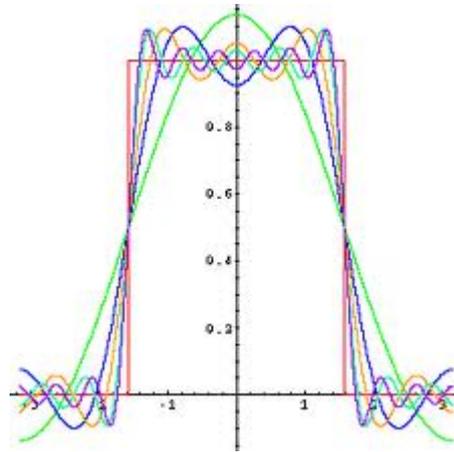
- Changing μ changes the resonant frequency of the cavity!

Perpendicular Biased Tuning

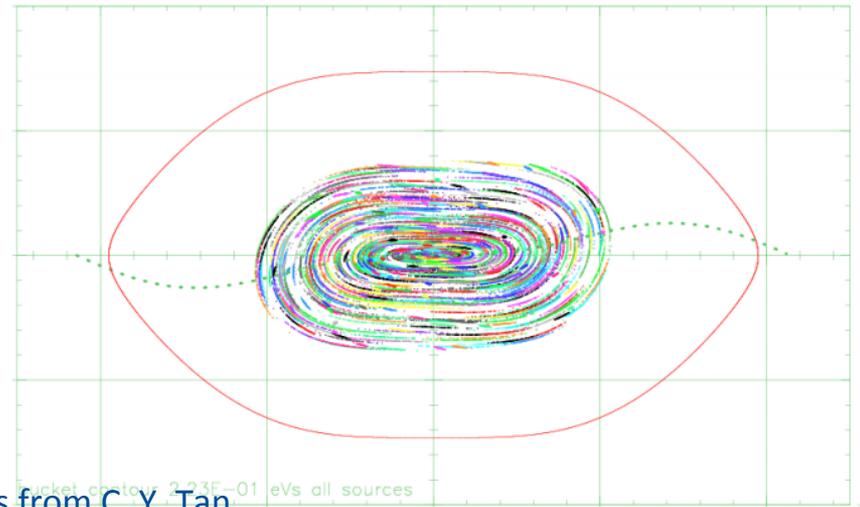
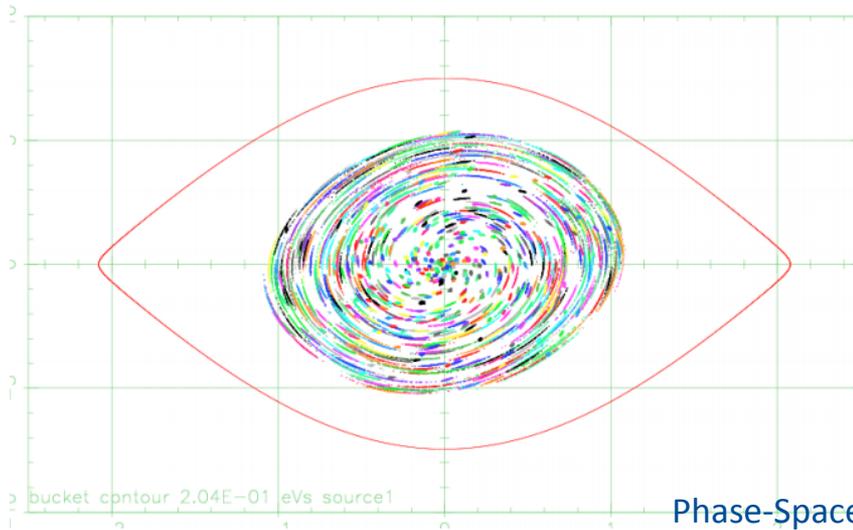


Why Second Harmonic Cavity?

Use wave physics to create a more square wave for injection



A rectangular bucket has larger area and reduces space charge effects



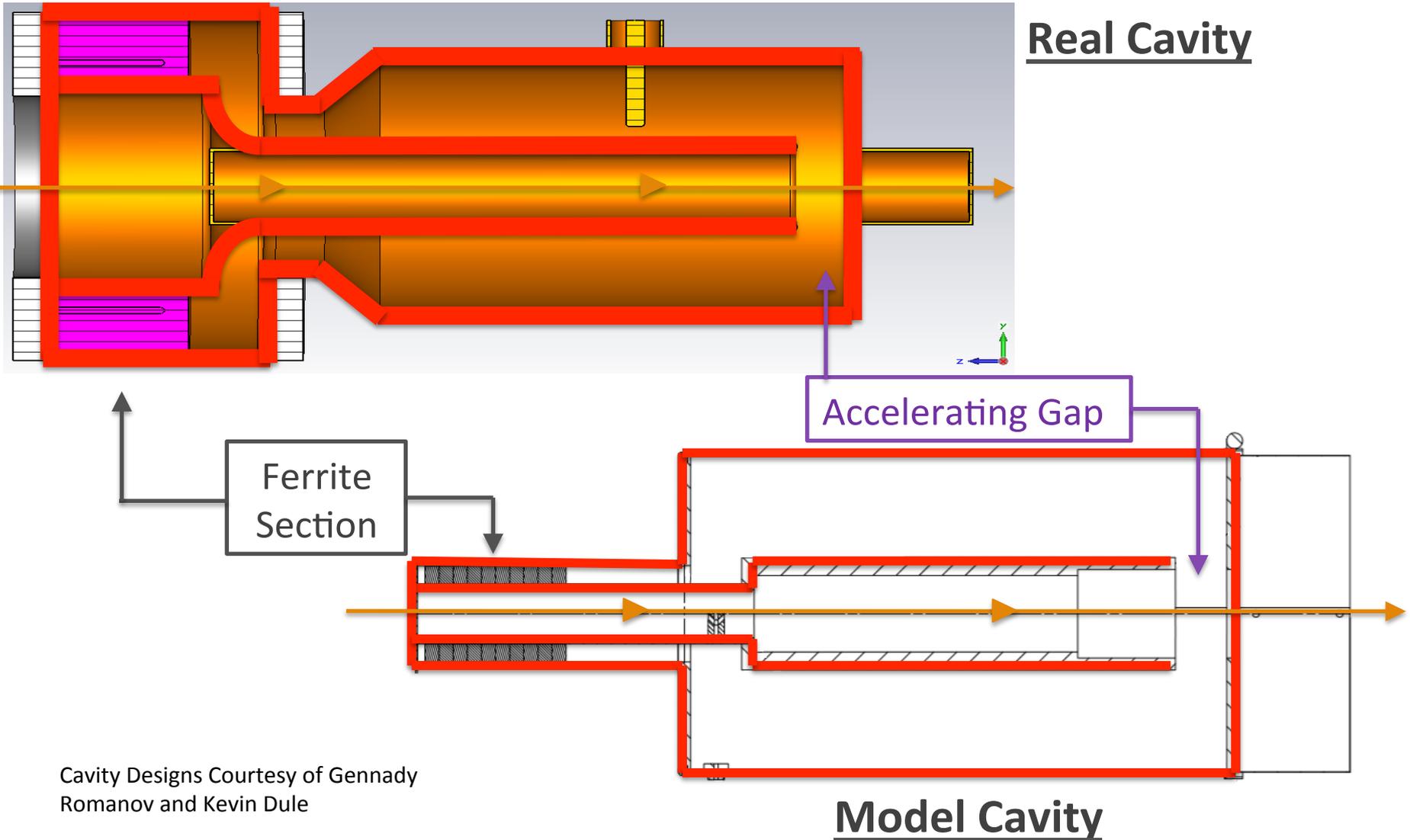
Phase-Space plots from C. Y. Tan

Why We Want a Model

- Designing a new cavity
 - Perpendicular Biased
 - Second Harmonic (76-106 MHz)
- Want to study the cavity
 - Q-Value
 - Shunt Impedance
 - Higher Order Modes
- Small solenoid means **model has different dimensions** in ferrite section

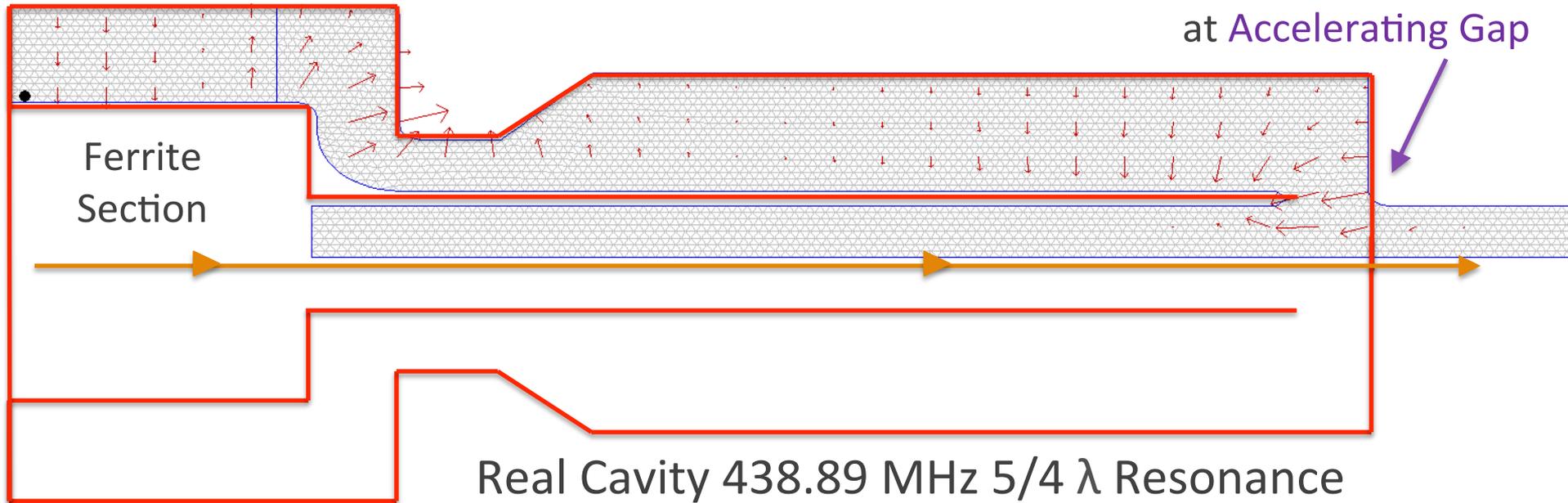


Real and Model Cavity Cross-Section

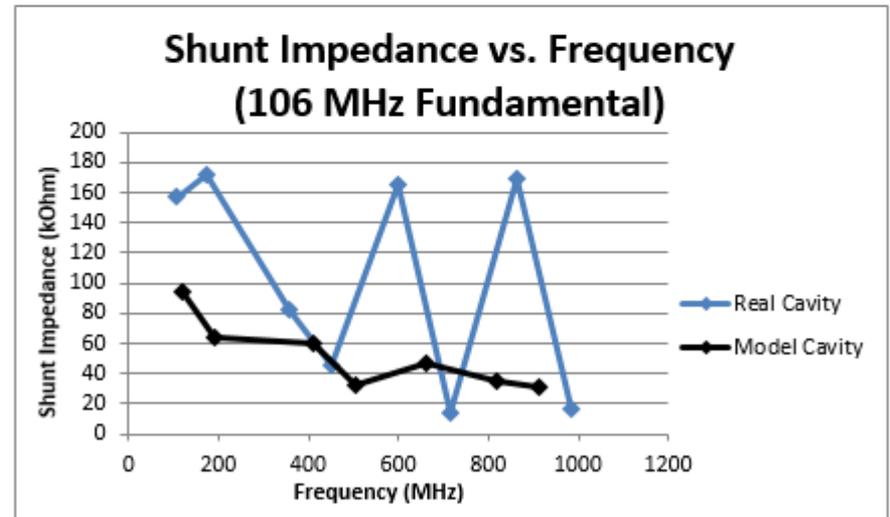
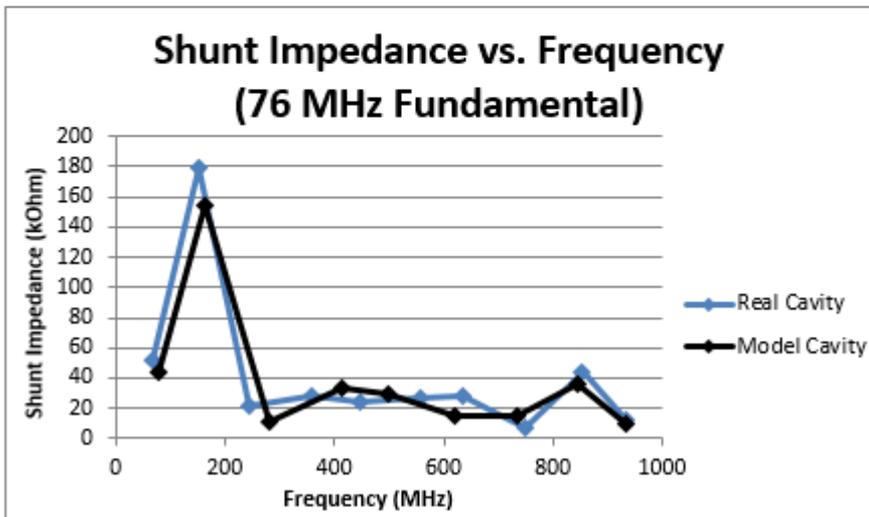
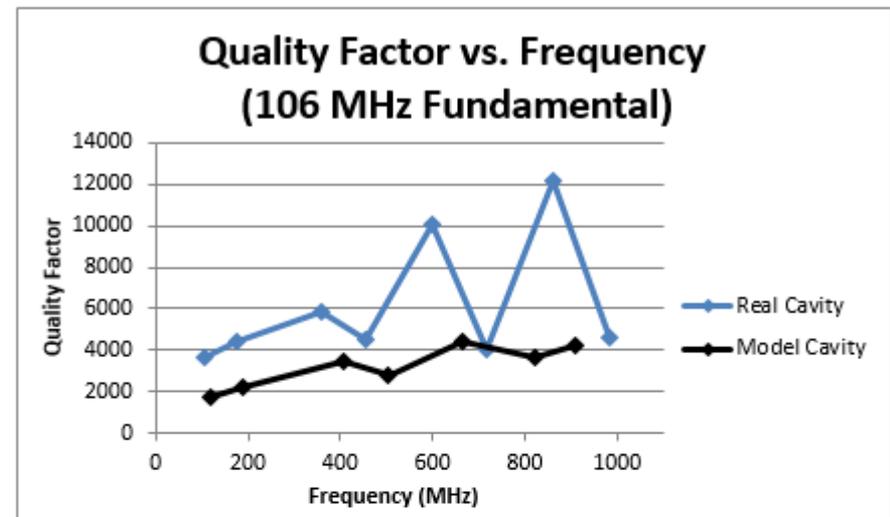
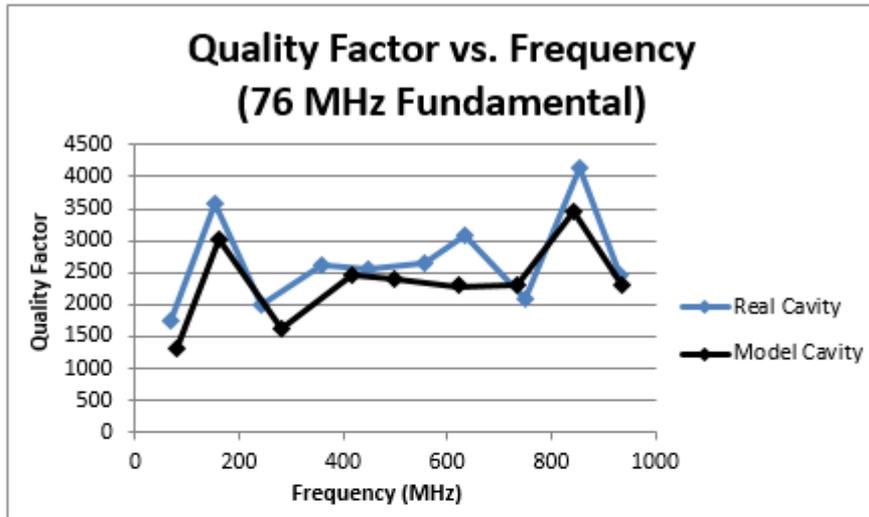


Poisson Superfish Simulations (LANL)

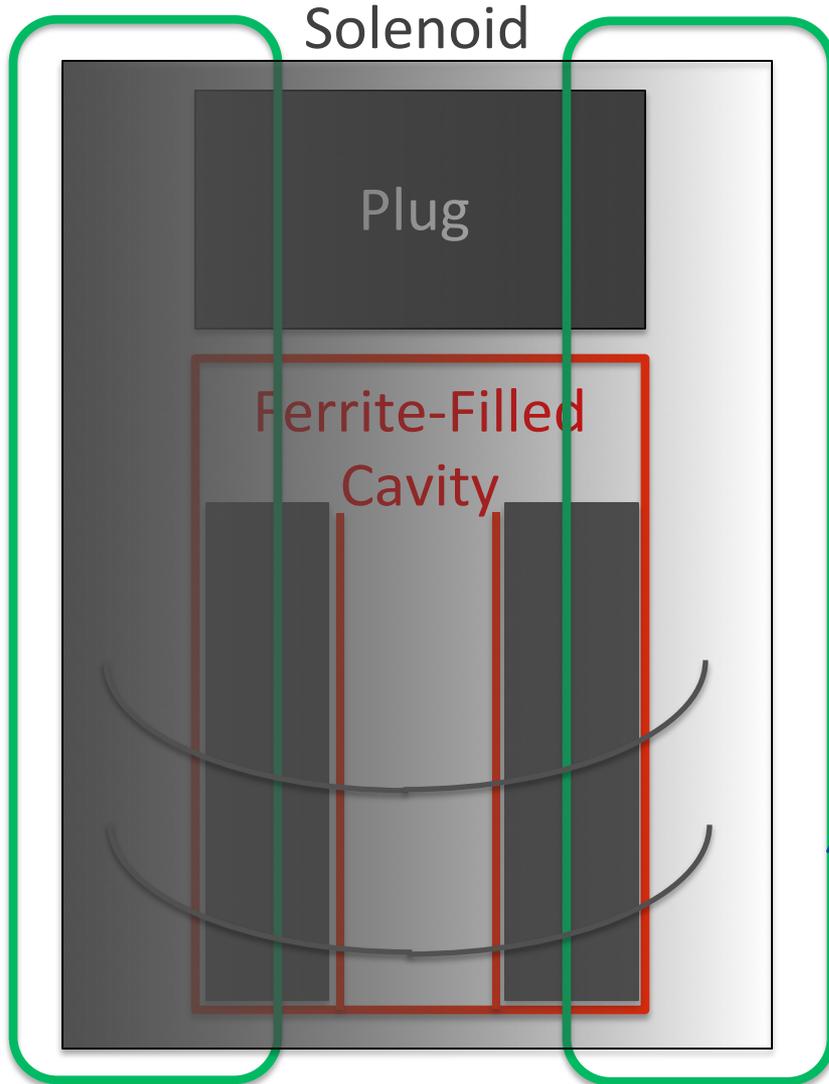
- Investigating
 - Change in dimensions
 - Fundamental frequency
 - Change in μ
 - Difference between Real and Model



Difference between Real and Model cavity



Ferrite Permeability Study



$$\mu = \mu' - i\mu''$$

Tuning parameter μ' Lossy component μ''

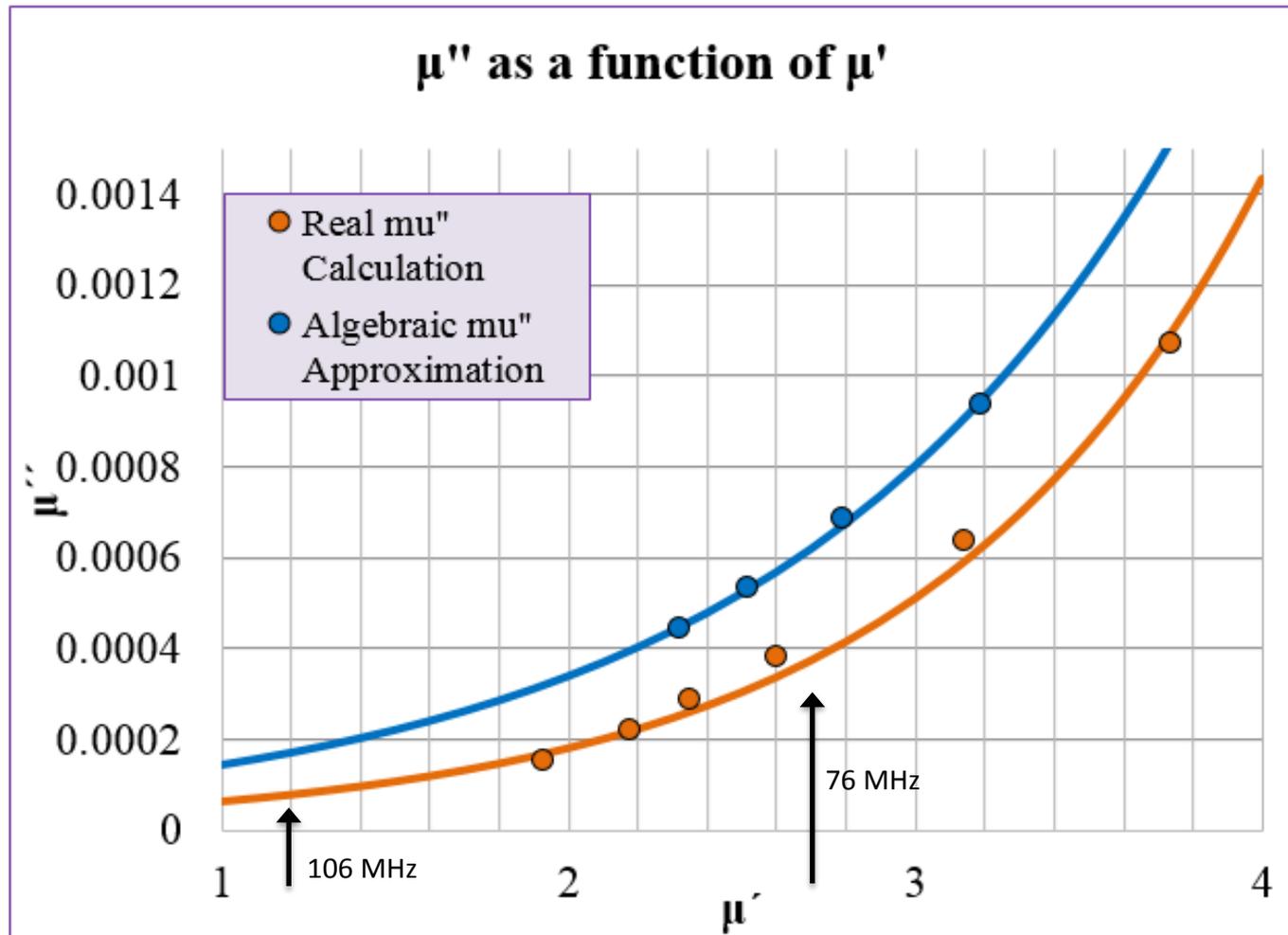
- Measured: Q-value, Resonant Frequency

$$\mu' = 1/\epsilon [c/4lf]^2$$

$$\mu'' = (1/Q - 1 \times 10^{-4})\mu' - F(f, Dim.)$$

Function of frequency and cavity dimensions

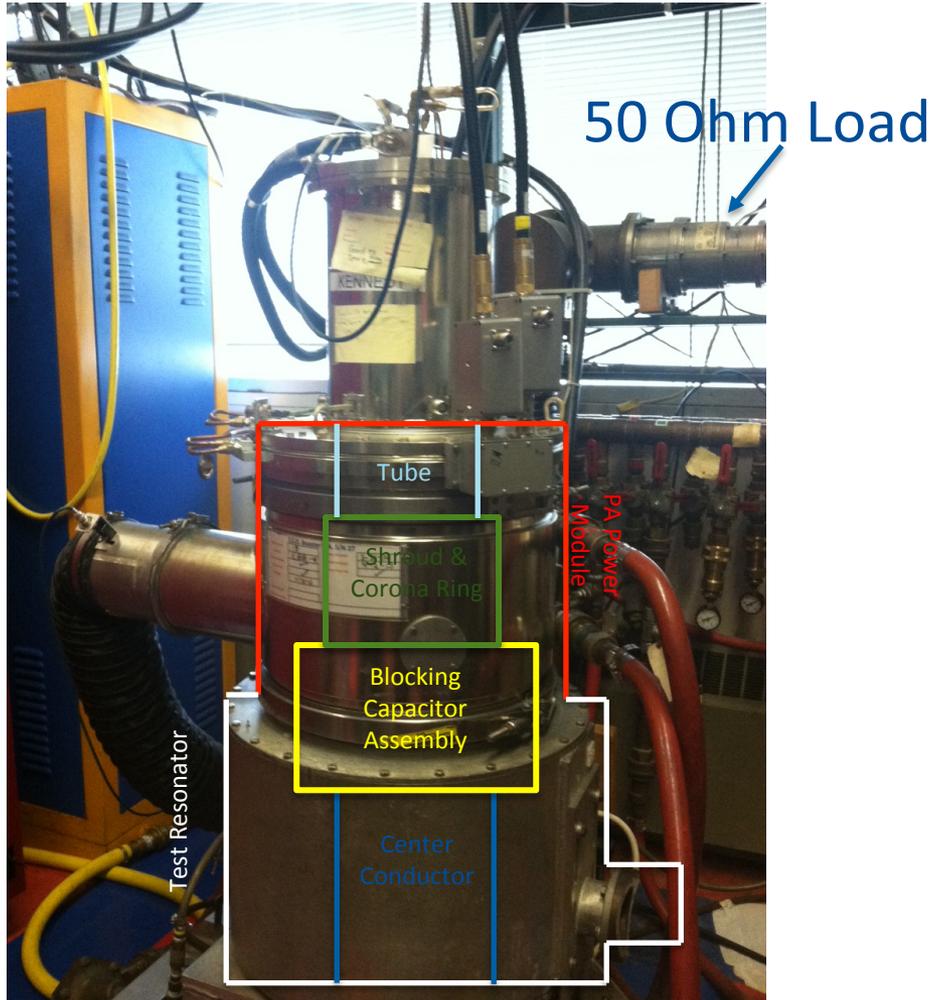
Calculating permeability



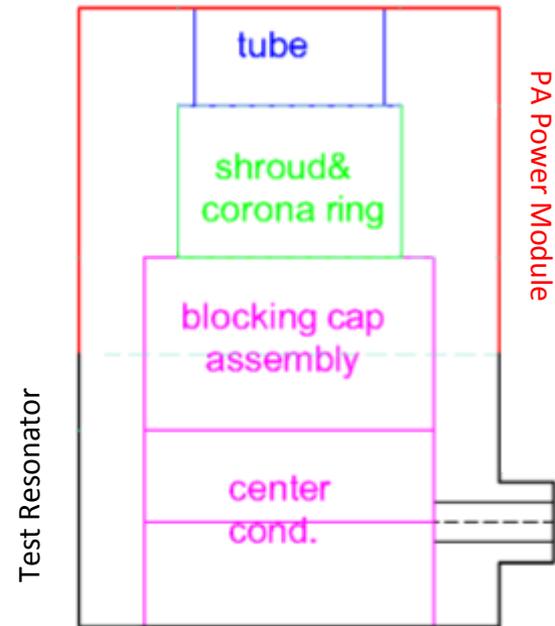
Real μ'' experiment and calculations by Yuri Terechkine and Gennady Romanov

Power Amplifier Basics

Existing 53 MHz Power Amplifier



76 MHz Power Amplifier Design



Difference is in load position and resonator shape

Power Dissipation to Temperature

Specific Heat Equation

$$\Delta T = Q/mc$$

T: Temperature

Q: Heat Added

m: Mass

c: Specific Heat

- Using the rate of water flow in the cooling solve for mc
- Power is the rate of change of energy
 dQ/dt

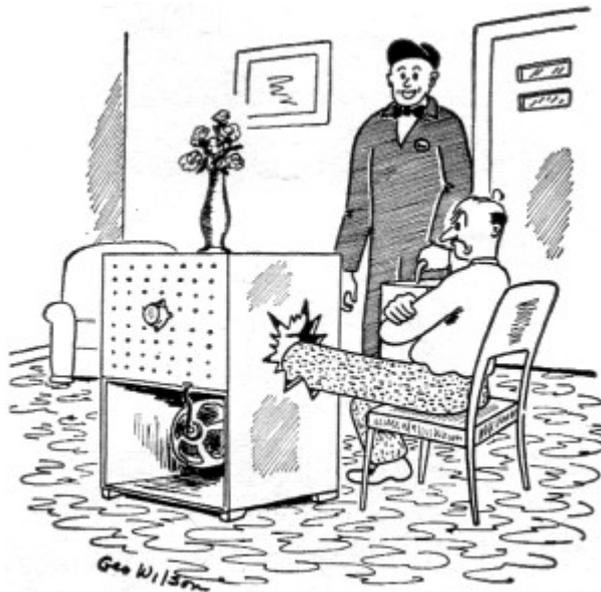


OHM NEVER FORGOT HIS DYING UNCLE'S ADVICE.

<https://xkcd.com/643/>

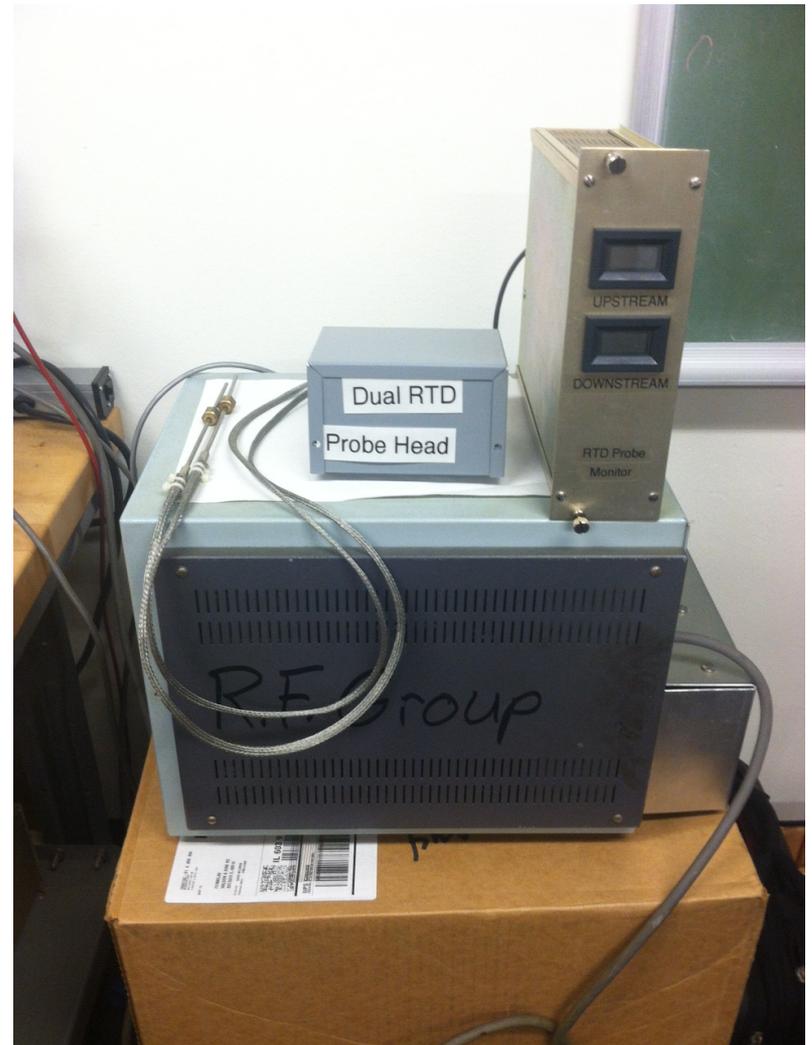
Current State of Electronics

- RTD probe readout electronics complete
- Troubleshooting complete



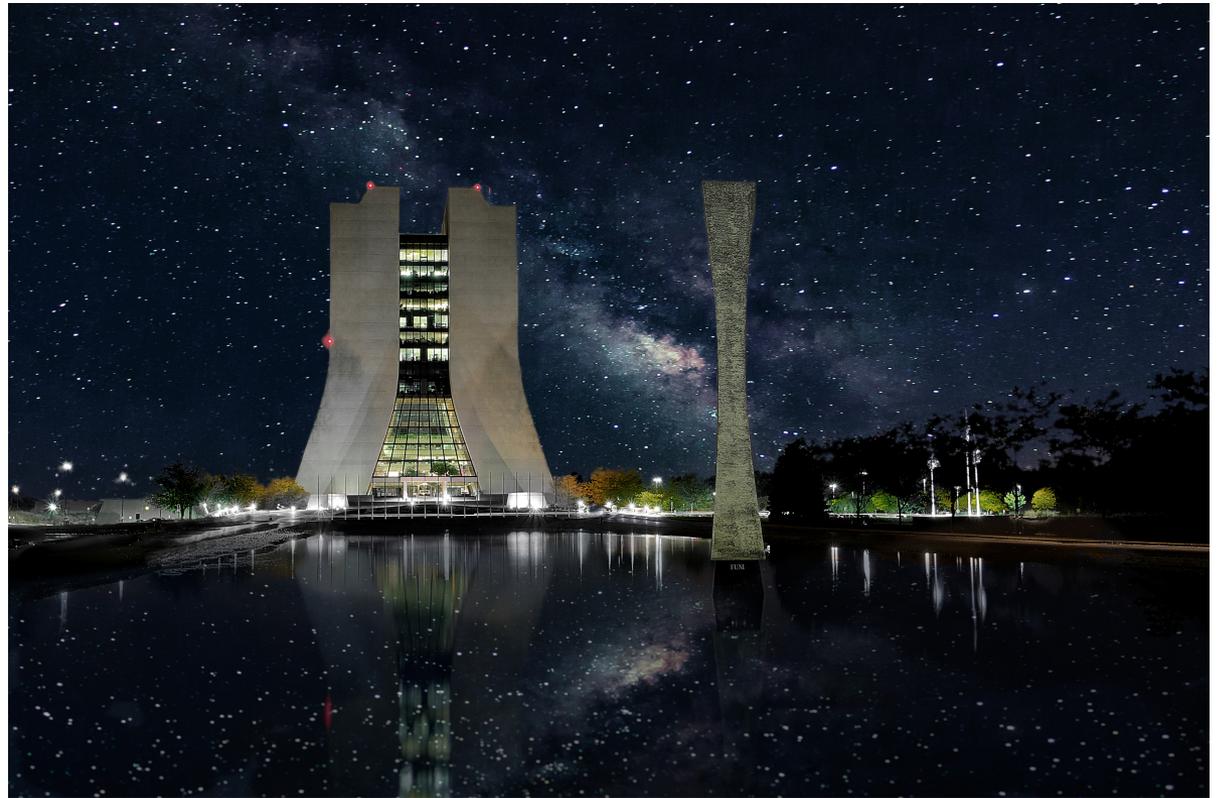
"Didn't work this time, did it?"

<http://www.rfcafe.com/references/radio-electronics/comics-january-1958-radio-electronics.htm>



Conclusions

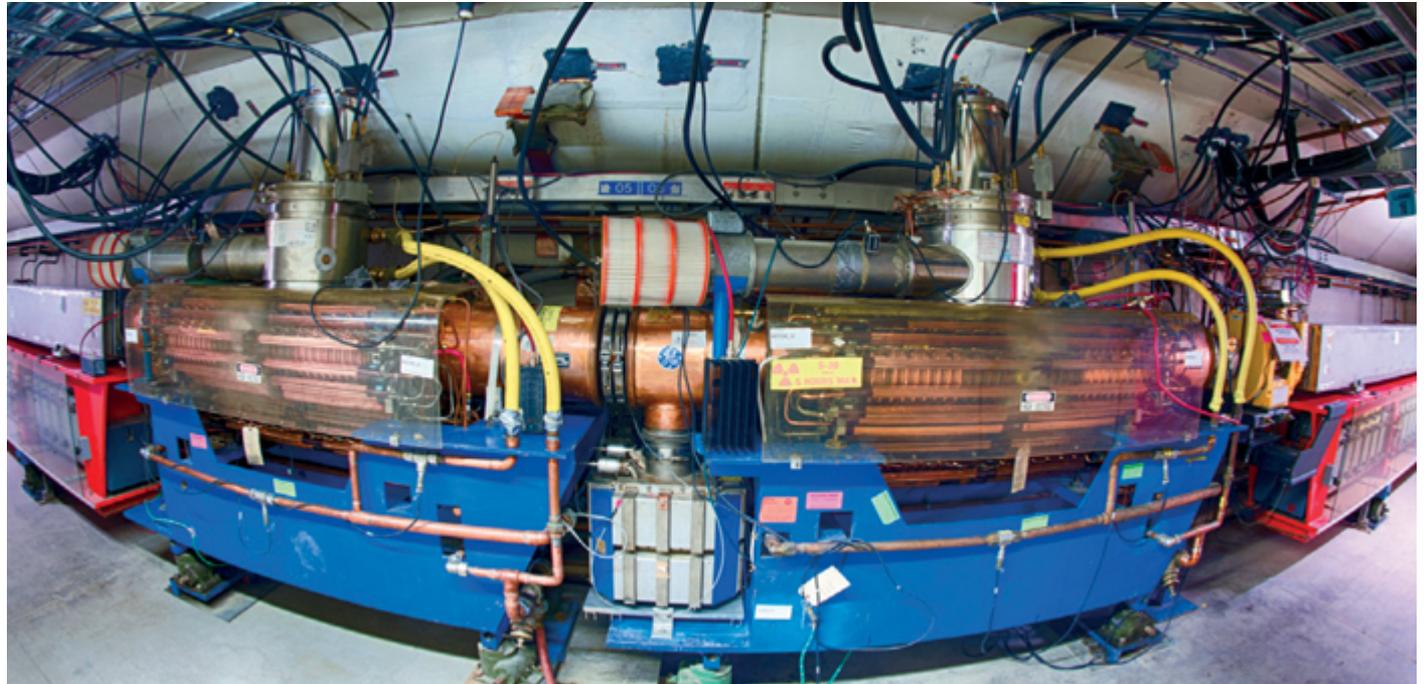
- Comparison study of real and model cavity with Superfish
- Permeability study of the ferrite
- Power Amplifier
RTD electronics
complete



http://www.fnal.gov/pub/today/archive/archive_2014/today14-07-31.html

Future Work

- Assembly of physical model cavity
- 76 MHz Power Amplifier testing
- Study higher order modes in the model cavity



<http://cerncourier.com/cws/article/cern/55333>

Acknowledgments

- Robyn Madrak Plant for her endless help and mentoring
- C. Y. Tan for giving project motivation and background
- The RF Group for their help with the PA electronics
- Dave Peterson for his feedback on the presentation
- The SIST committee for the opportunity to intern at Fermilab



<https://rootsrated.com/chicago-il/cycling/fermilab-cycling>