Nb_3Sn Sample Furnace

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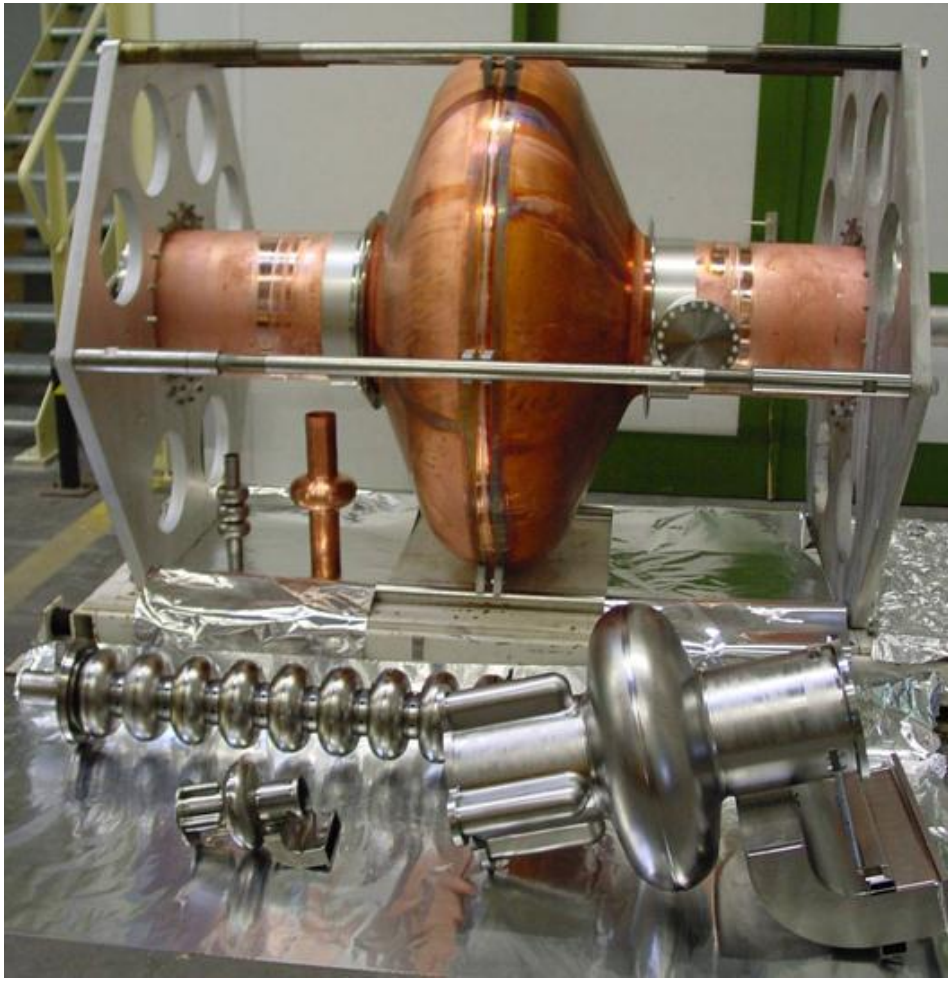
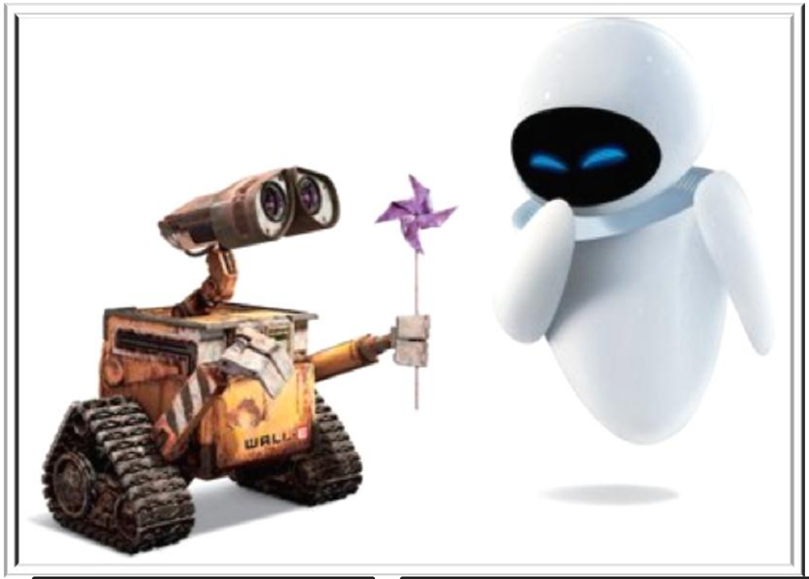
What is an SRF Cavity?

- Superconducting Radio Frequency (SRF)
- A device that accelerates particles to a certain energy using oscillating electric fields and superconducting capabilities.
- Typically made of Niobium with frequency of 1.3 GHz.



A Tale of Two Metals

- Once upon a time (in the 80's) there were two metals being considered for superconducting cavities; Niobium and Niobium 3 Tin (Nb_3Sn)



Nb_3Sn | Nb (Niobium)

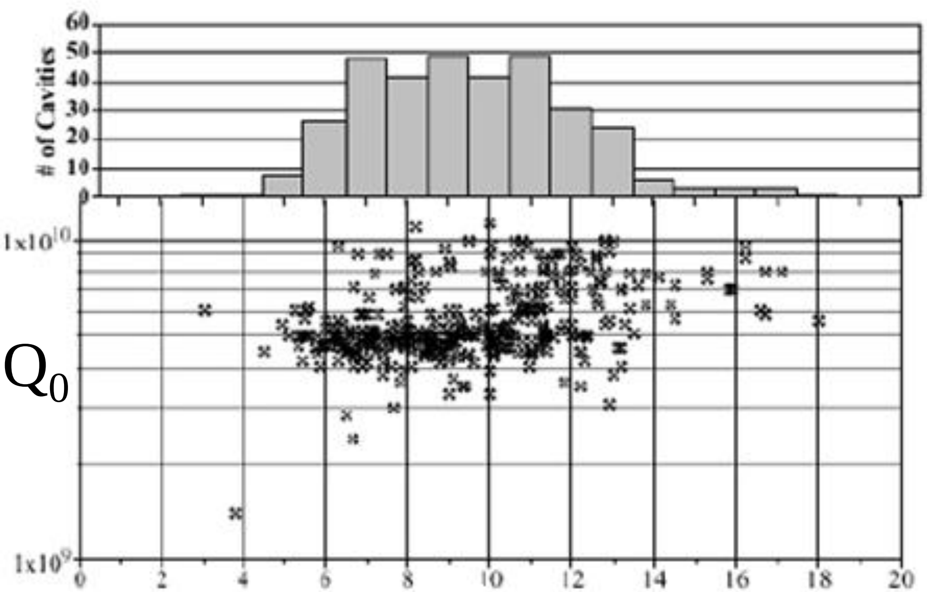
Q_0 vs. E_{acc} Matchup

- Both Metals came up short on the projected allowed gradient (E_{acc}) and quality factor (Q_0) which had been expected.

$$Q_0 = \omega U_{stored} / P_{Dissipated}$$

Q_0 vs. E_{acc} plot for pure niobium

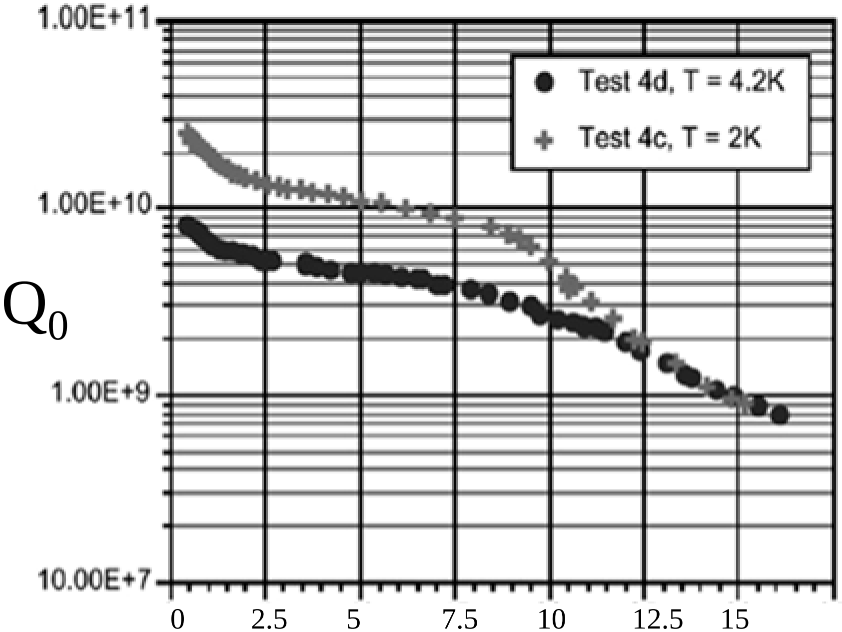
Q_0



E_{acc} (MV/m)

Q_0 vs. E_{acc} plot for Nb_3Sn superconductors

Q_0



E_{acc} (MV/m)

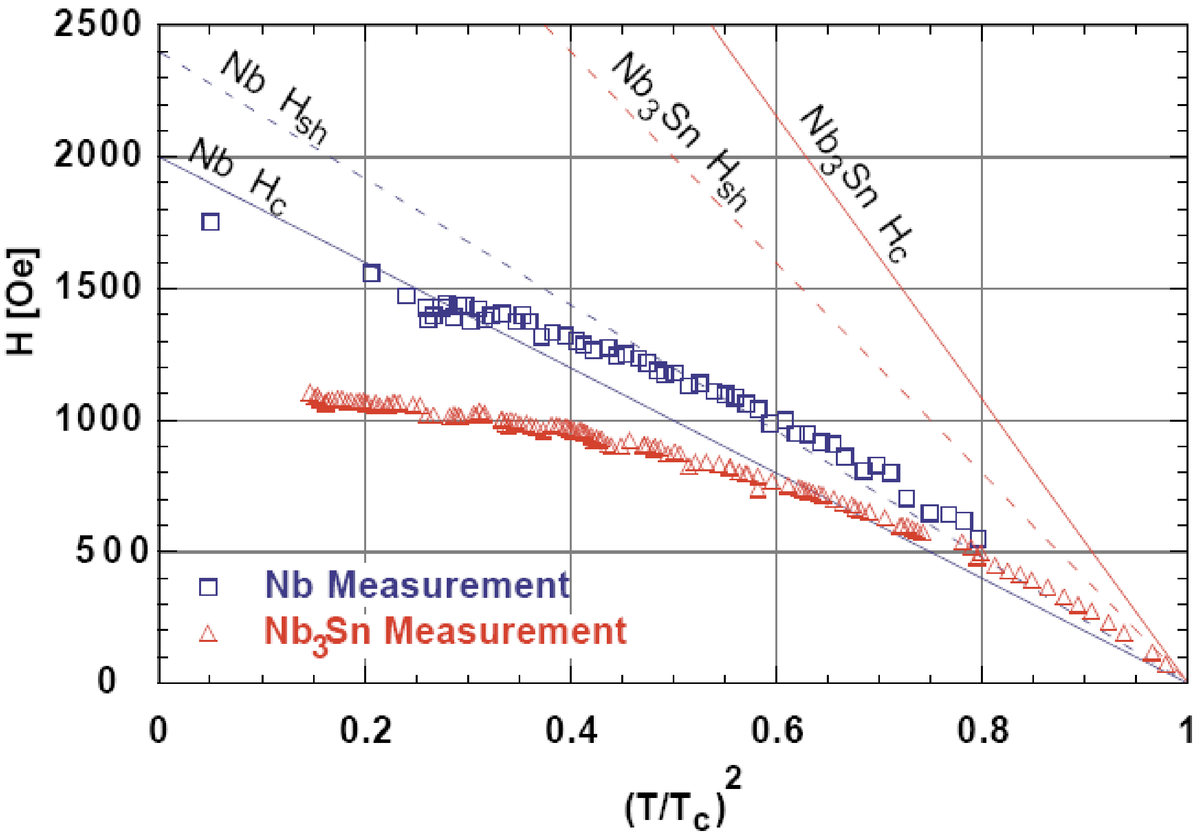
Theoretical Temperature and Maximum Field

- Theorically, Nb_3Sn should have had twice the superheating field (H_{sh}) and critical temperature (T_c) as regular niobium.
- Superheating field (H_{sh}) – analogous to a "supersaturated magnetic field"

Superconductor	T_c (K)	$\mu_0 H_c(0)$ (mT)	$\mu_0 H_{sh}(0)$ (mT)	max E_{acc} (MV m^{-1})
Pb	7.2	80	105	25
Nb	9.2	200	240	57
Nb_3Sn	18.2	540	400	95

Actual Temperature and Field

- Nb_3Sn indeed had a T_c of 18.2 K!
- However, the results showed Nb_3Sn to come up far short of expectations.



The Deciding Factor

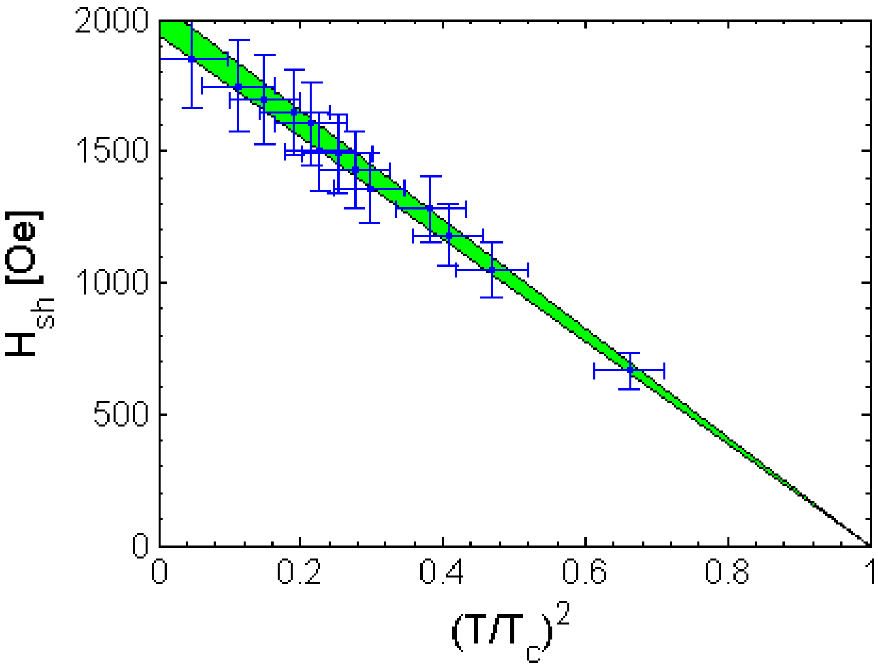
- Niobium was easy to create and form into cavities.

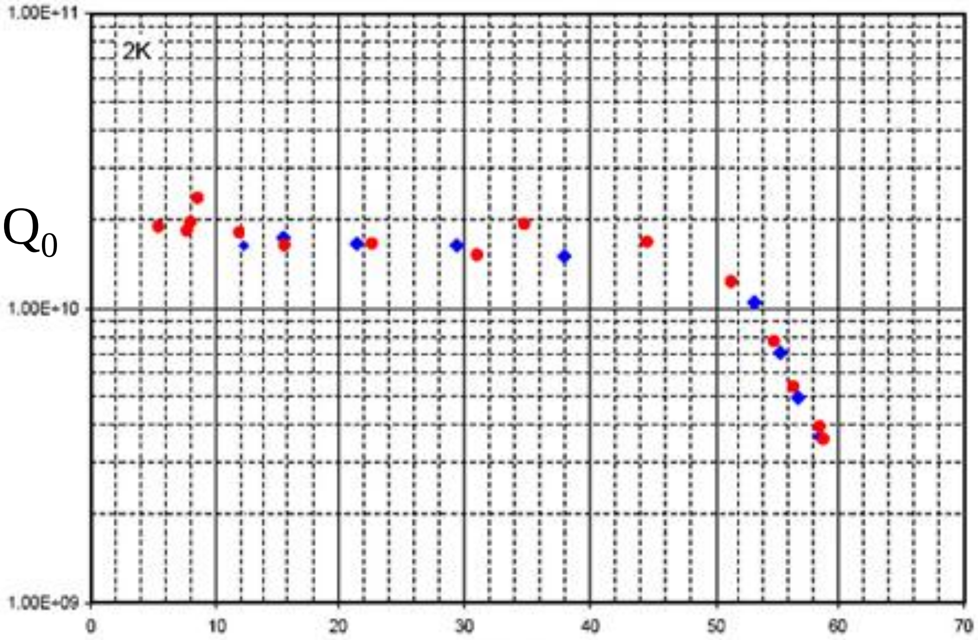
- Nb_3Sn was difficult to produce (as will be seen) and form into cavities.

Regular niobium won!

Roadblocks for Niobium SRF

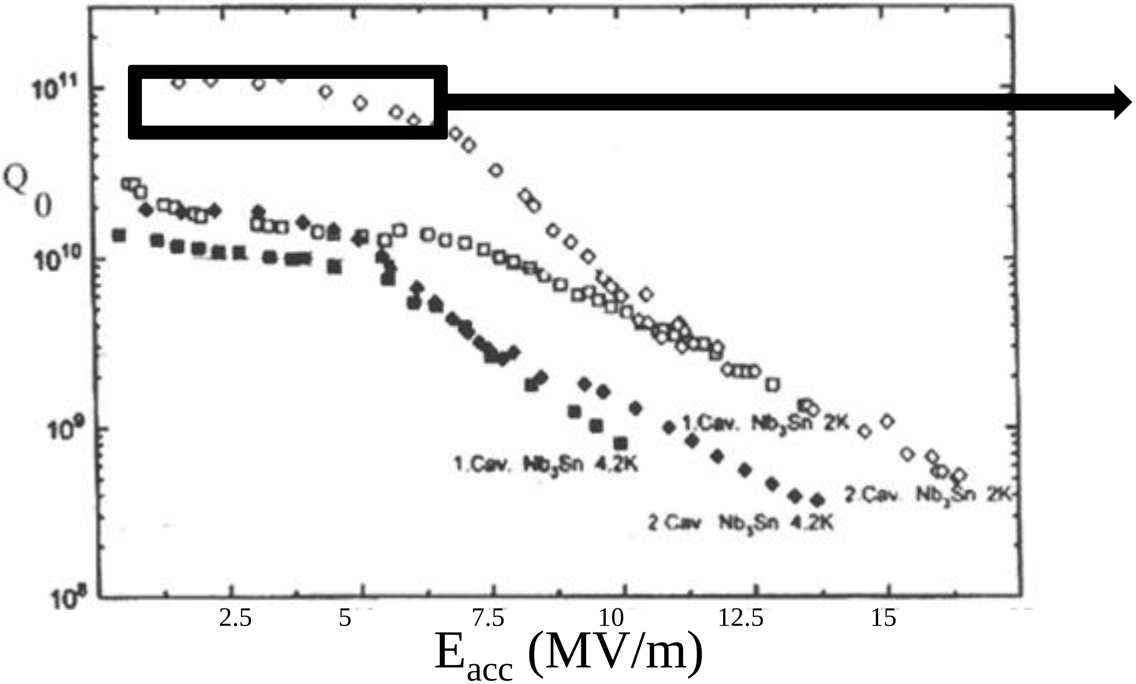
- Finally reached goal of 50 MV/m with Niobium cavities.
- Maximum super heating field limits (Ex: Niobium ~240 mT)
- Niobium quality factor (Q_0) seemed to be leveling out slightly above 5.0×10^{10}.





Goals for Nb_3Sn Production

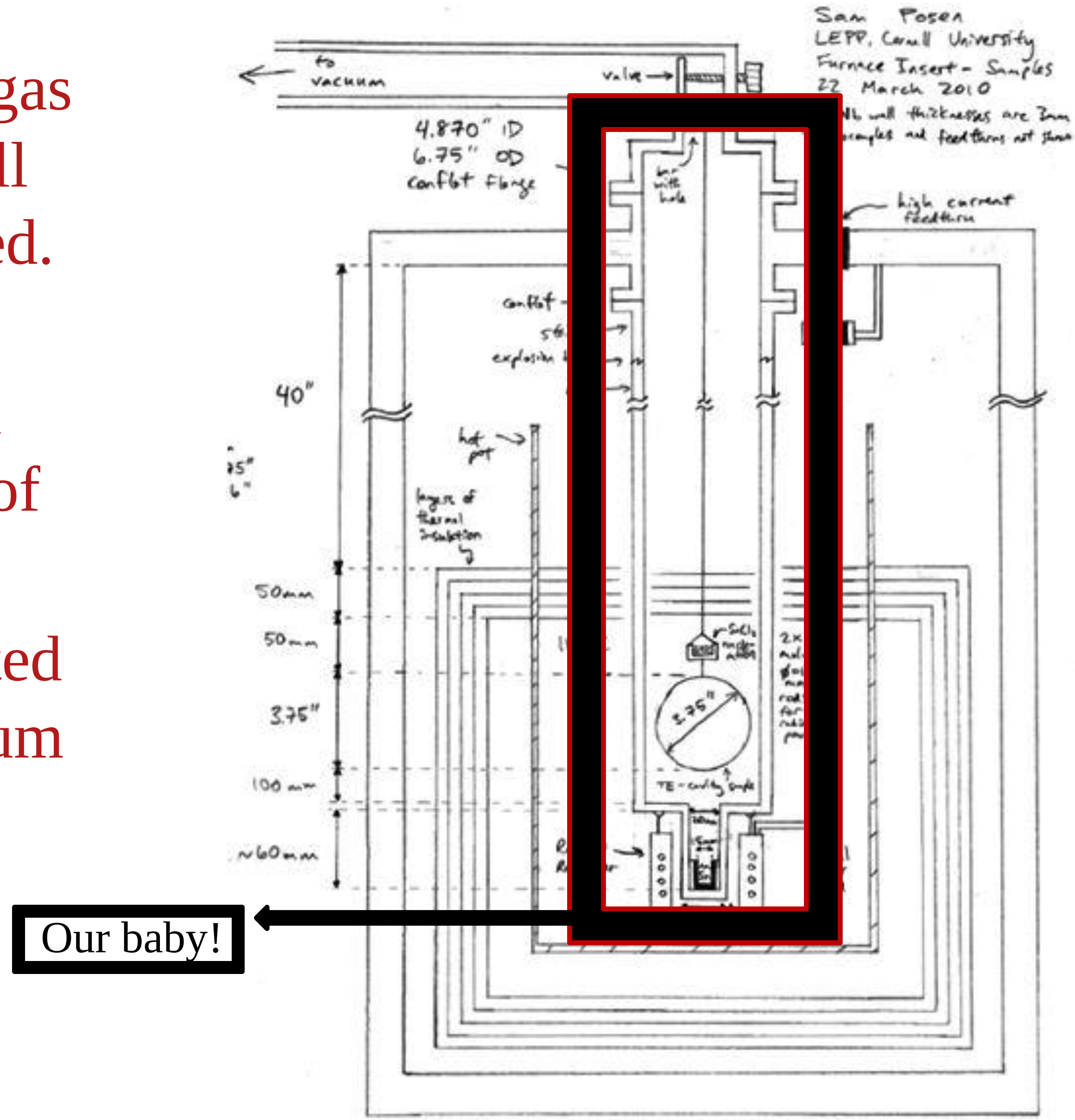
- **This is where Nb_3Sn comes into play!**
- Research of Nb_3Sn sample making processes can lead to more efficient cavities with higher quality factors (Q_0).
- Samples produced can be used to study ***actual*** critical field of Nb_3Sn (this information is not known yet).



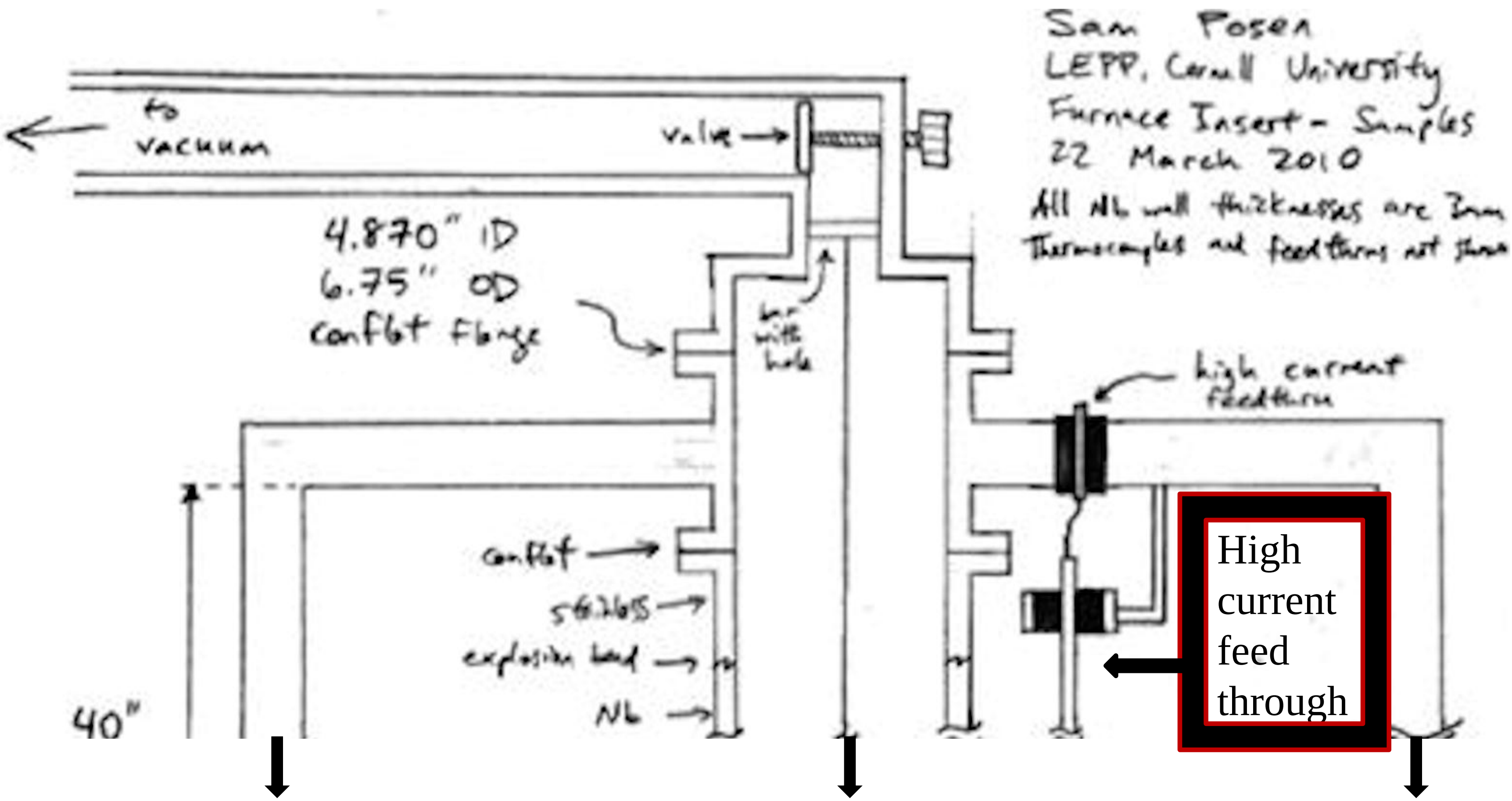
Nb_3Sn has been shown to reach quality factors of 10^{11} MAGNITUDE!

Production of Nb_3Sn

- Vapor diffusion of tin gas onto niobium metal will be the technique utilized.
- Tin will be heated to ~1200 °C in a tungsten crucible at the bottom of the furnace.
- This tin will be deposited on the walls of a niobium sample at ~1100 °C.



The Design Thus Far (top of furnace)



Toward the bottom of the furnace

The Design Thus Far (bottom of furnace)

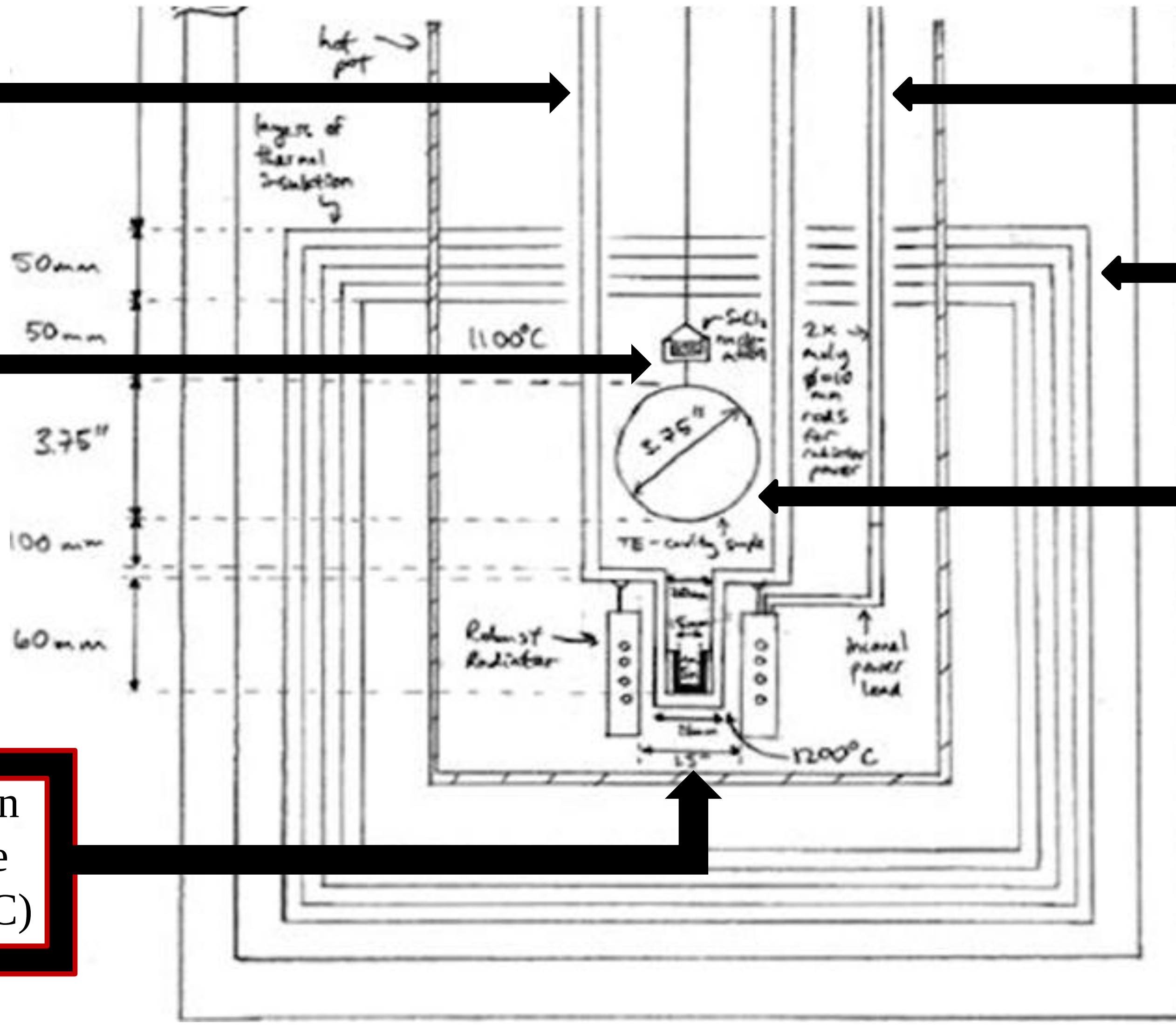
Niobium reaction chamber

Molybdenum conducting wire

Radiation Shielding

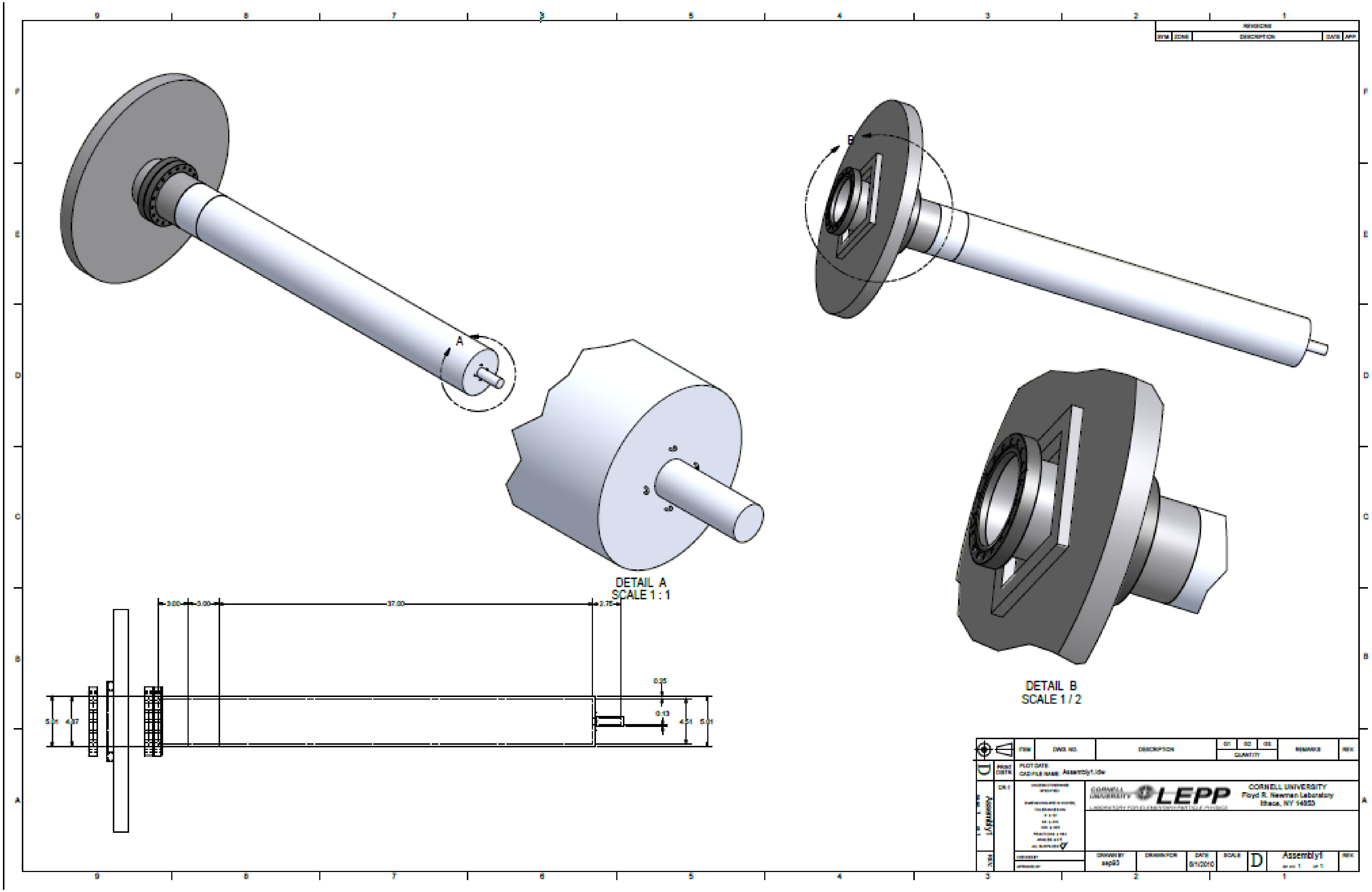
$SnCl_2$ container

Niobium sample plate



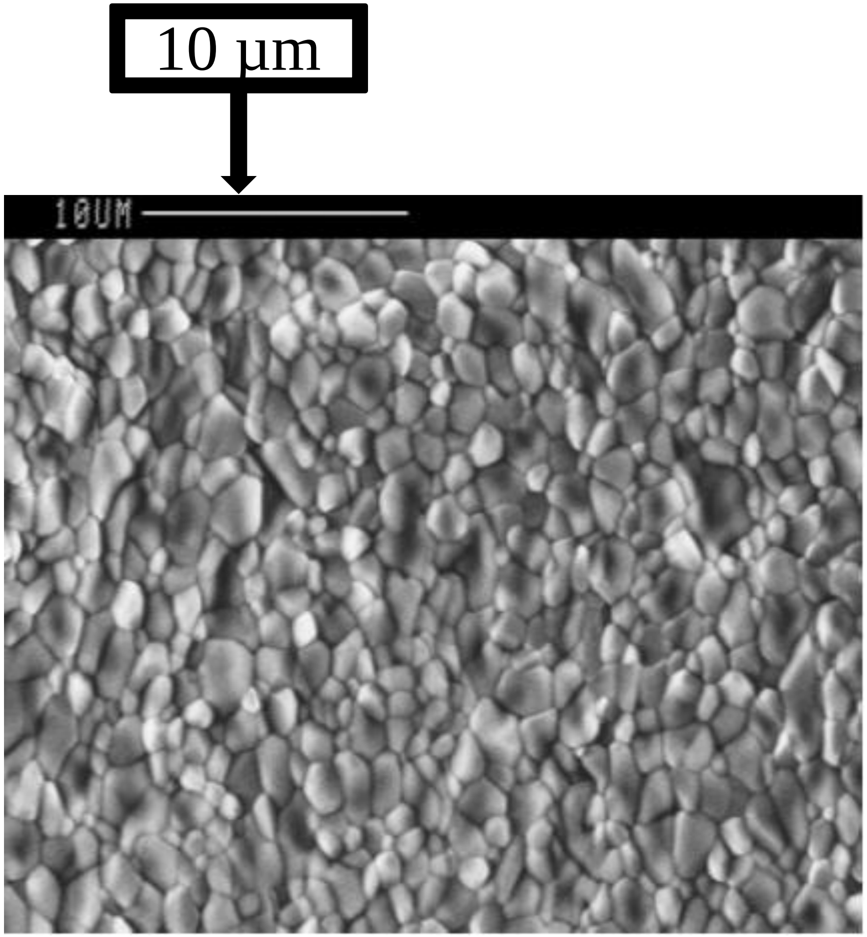
Tungsten Crucible (1200° C)

The Actual Cavity



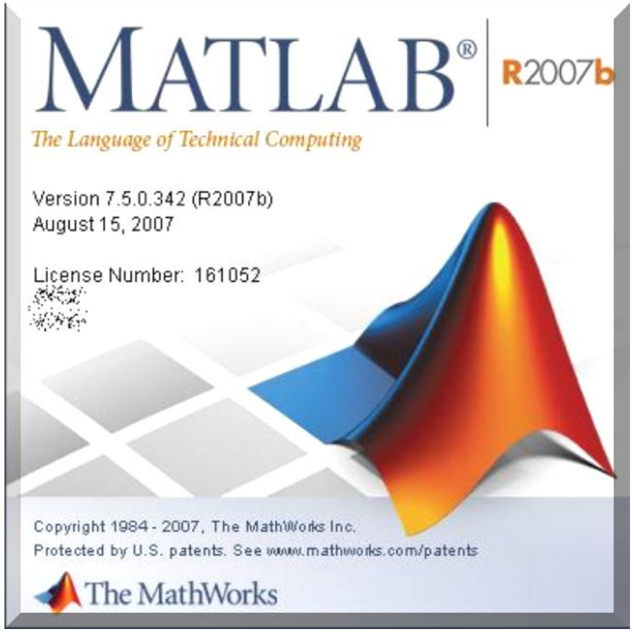
Challenges

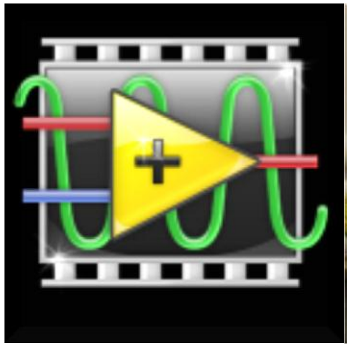
- Equipment needs to be temperature resistant for over 1200 °C.
- Radiation shielding must be adequate to significantly reduce radiation leaving furnace.
- Reaction of tin and Niobium must consistently produce Nb_3Sn.
- Need a good vacuum during reaction!



Tools and Skill Set

- Matlab R2007b – to analyze and collect data from Thermocouple.
- LabVIEW – further data acquisition.
- Clean room training
  - Clean room holds furnace
  - furnace needs to be extremely clean





Any Questions?