High Field Q-Slope in Superconducting RF Cavities

Jordan Webster

Advisor: Matthias Liepe

August 7, 2008

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. . . A Tragic Experimental Tale

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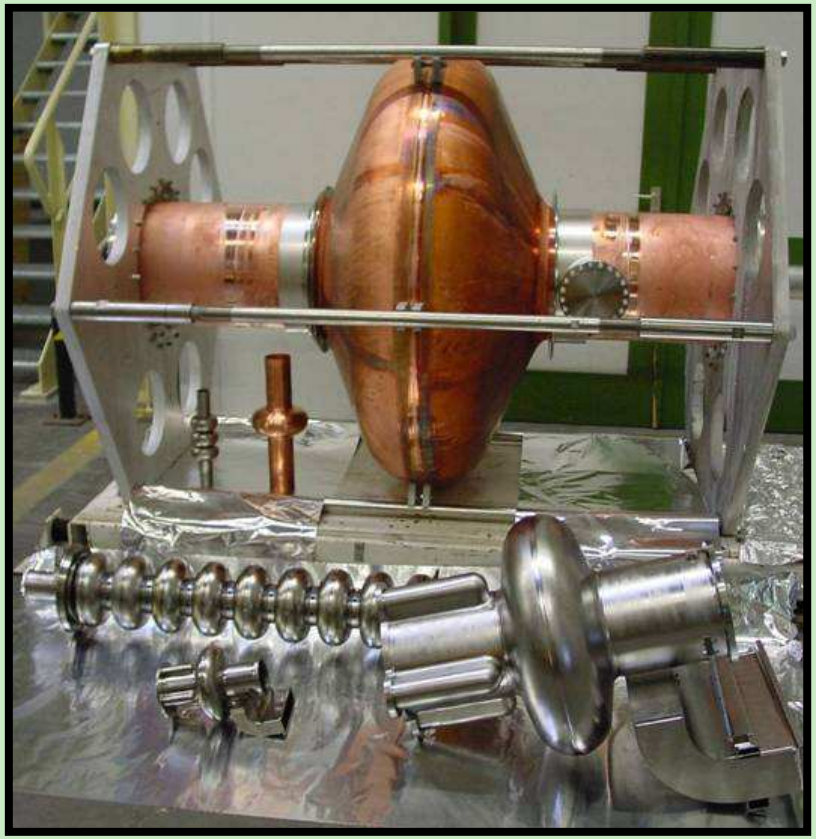
Background
SRF Cavities



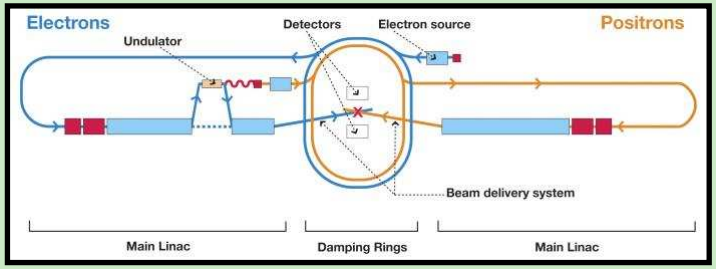
Collection of SRF cavities, taken at Cornell

Used to accelerate bunches through EM waves

normal conducting

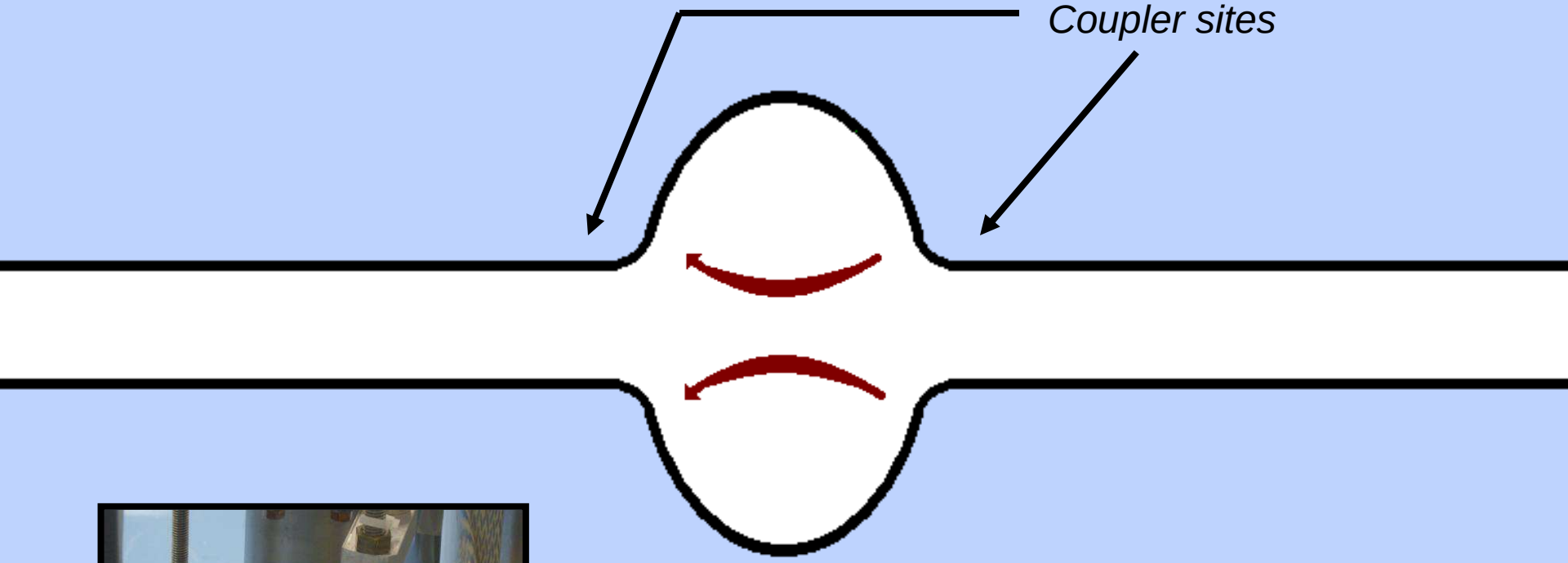
superconducting (1965)

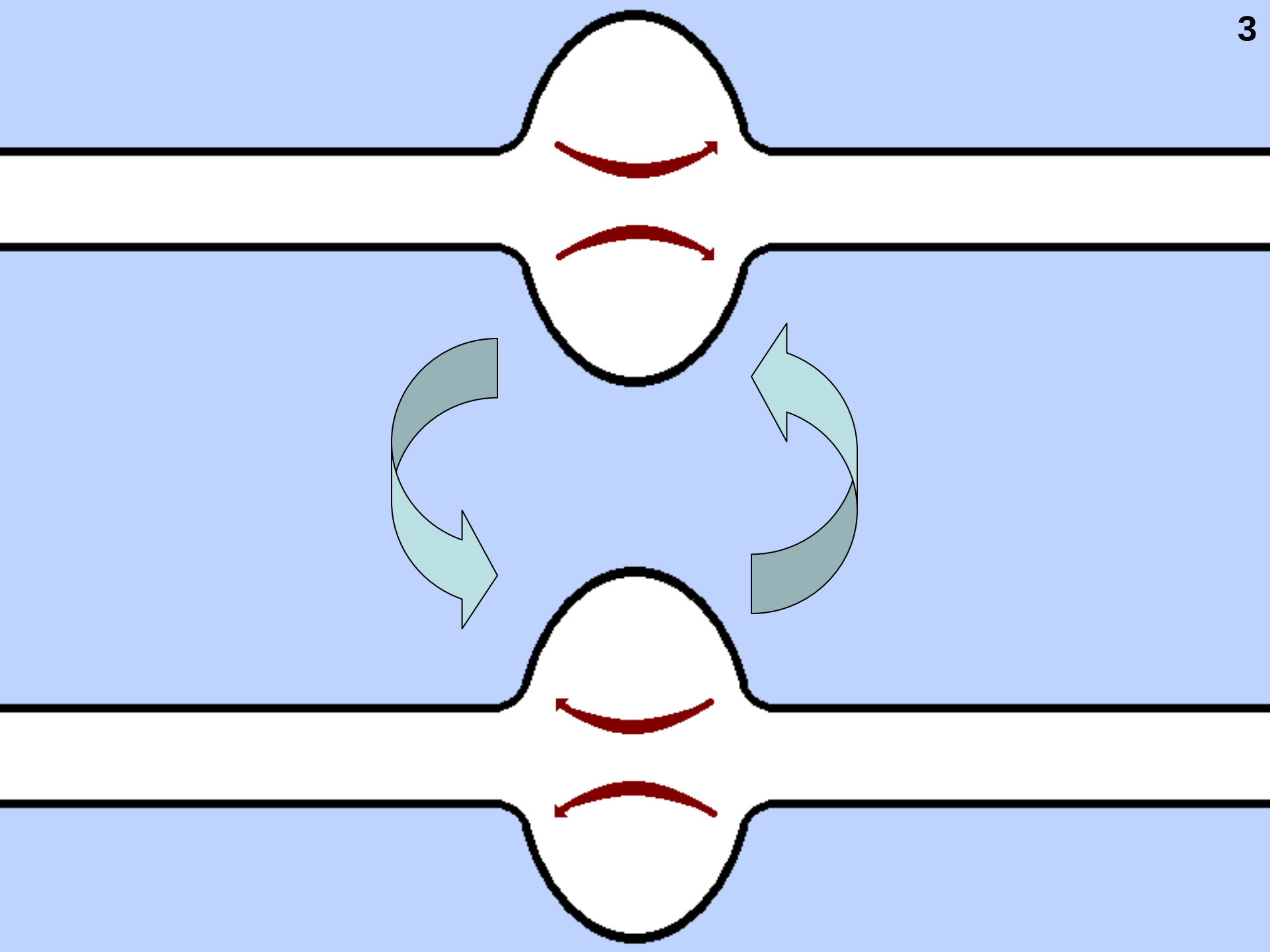
constructed from niobium

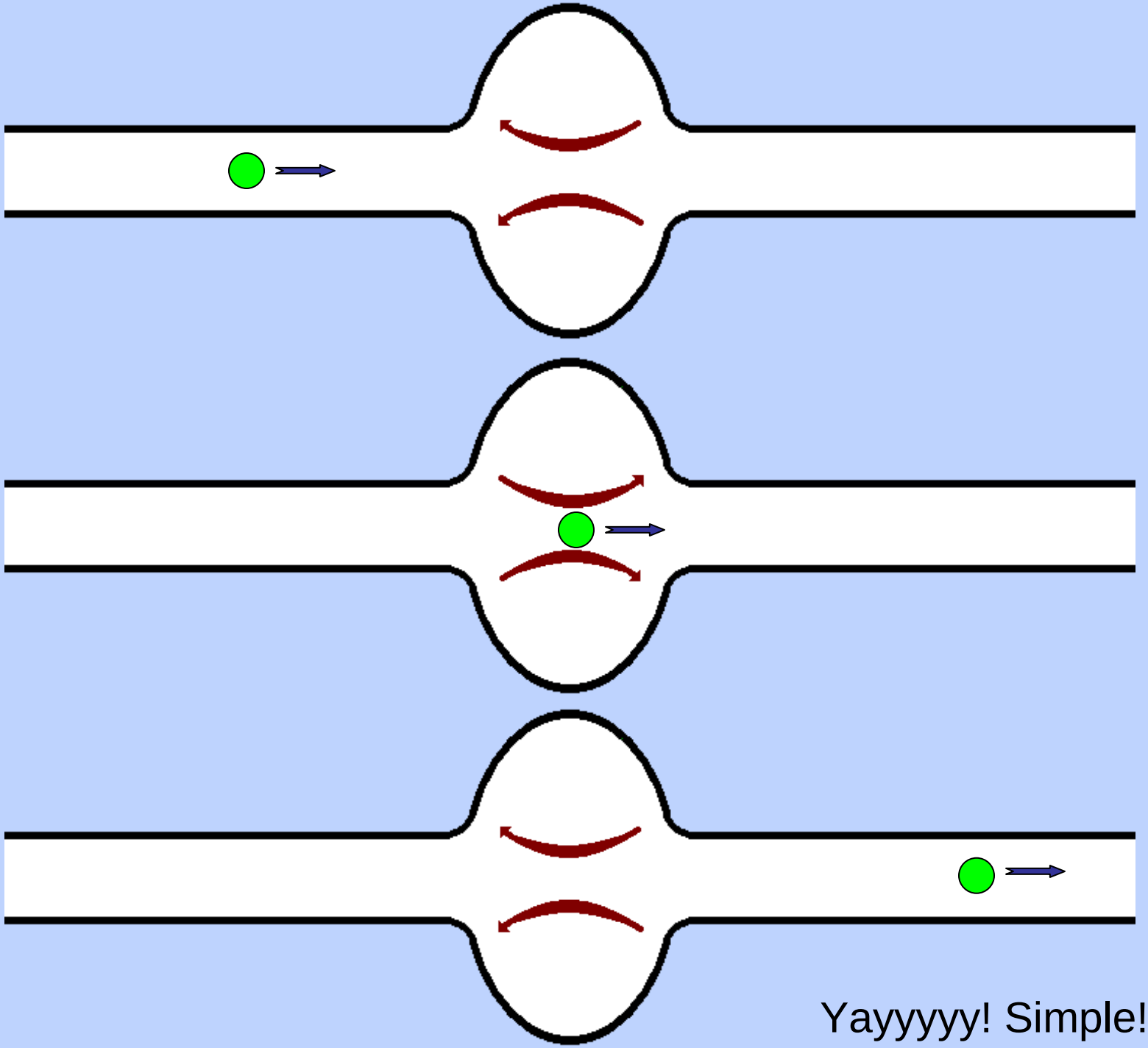


ILC

Single-Cell Cavity

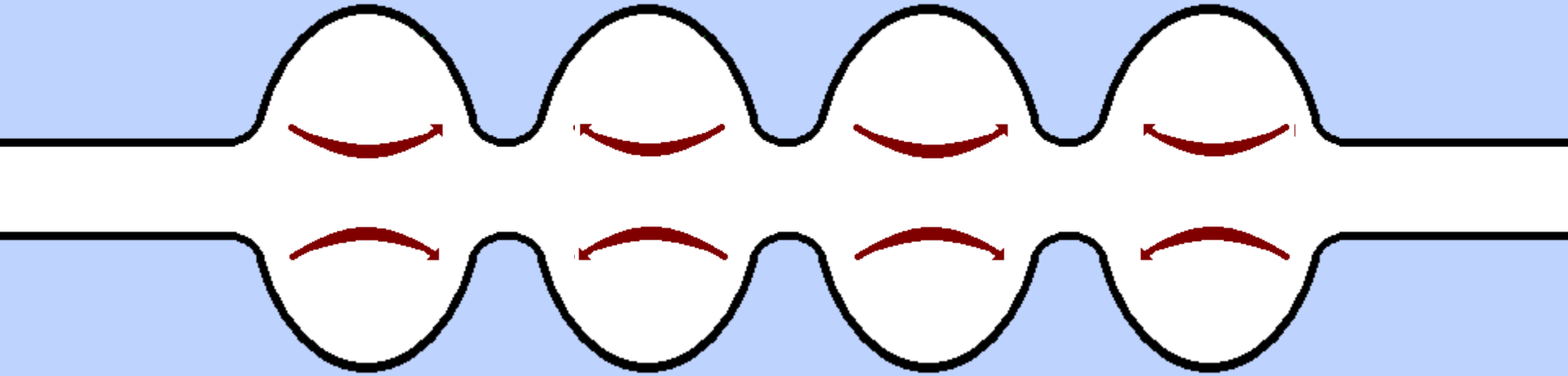


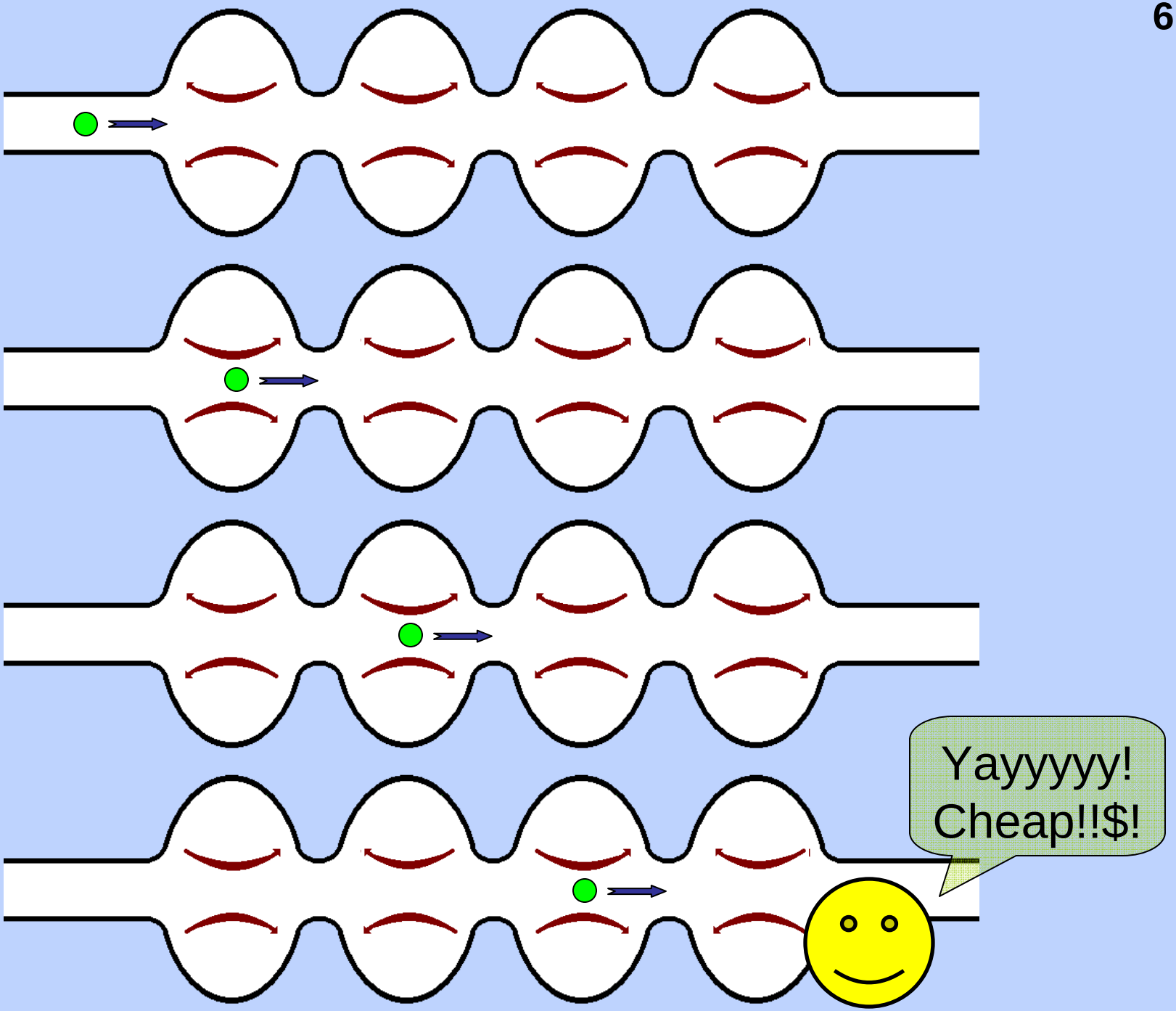




Yayyyyy! Simple!!

Multi-Cell Cavity



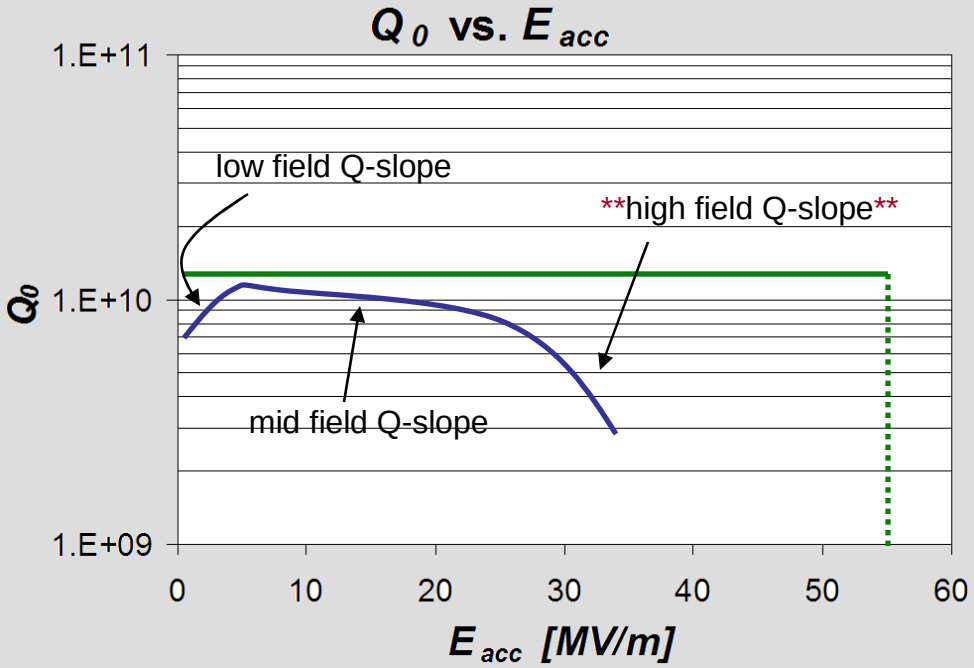

Yayyyyy!
Cheap!!$!

Boring Math Stuff… & the Q_0 curve

$$V_c = \int_0^d E_{el}\, dz$$ ⇒ (voltage seen by a passing electron bunch)

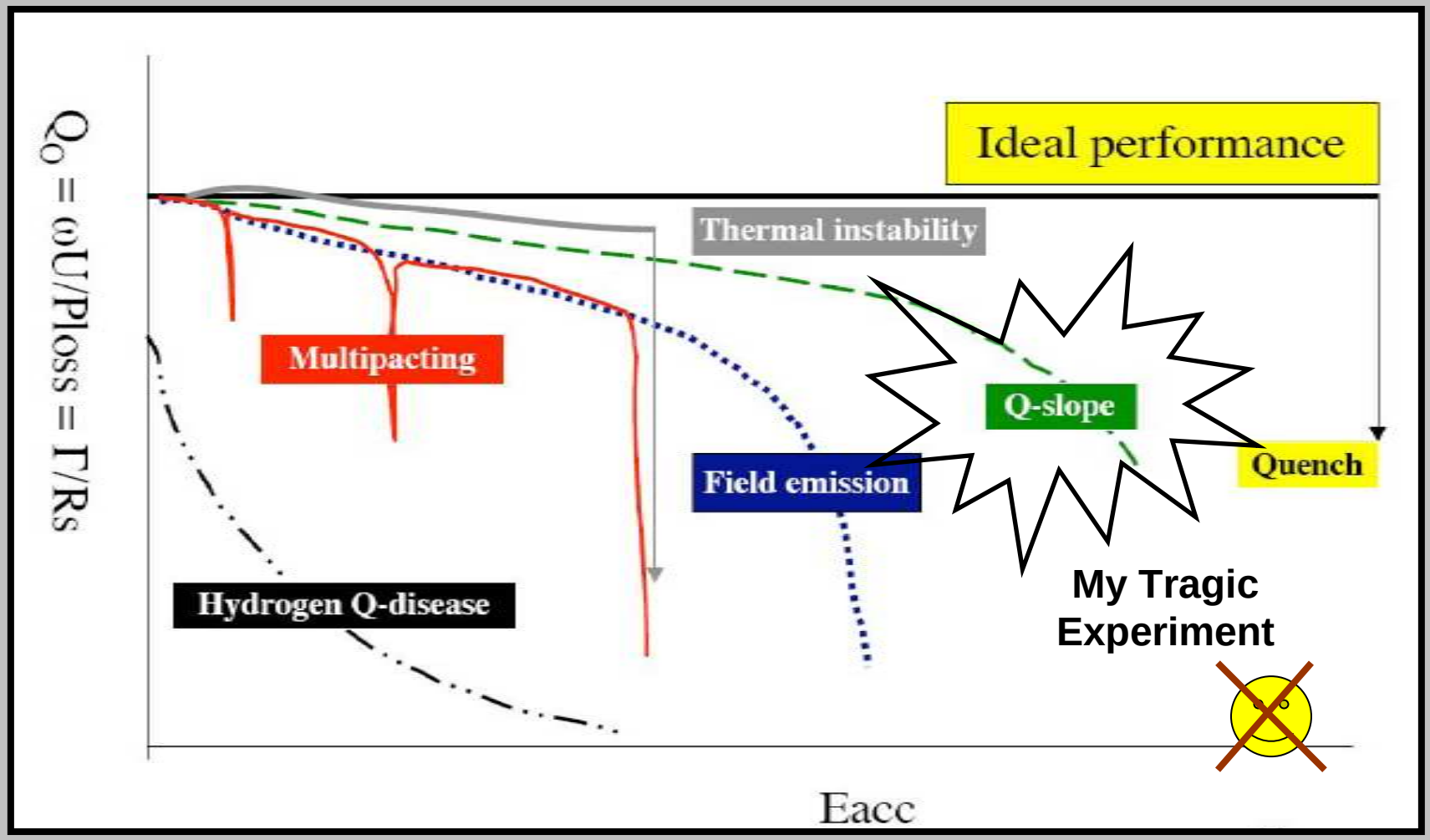
$$E_{acc} = \frac{V_c}{d}$$ ⇒ (average accelerating field seen by a passing electron bunch)

$$Q_0 = \frac{\omega_0 U}{P_C}$$



Quality & Loss Mechanisms

Quality vs. Accelerating Field (Example)



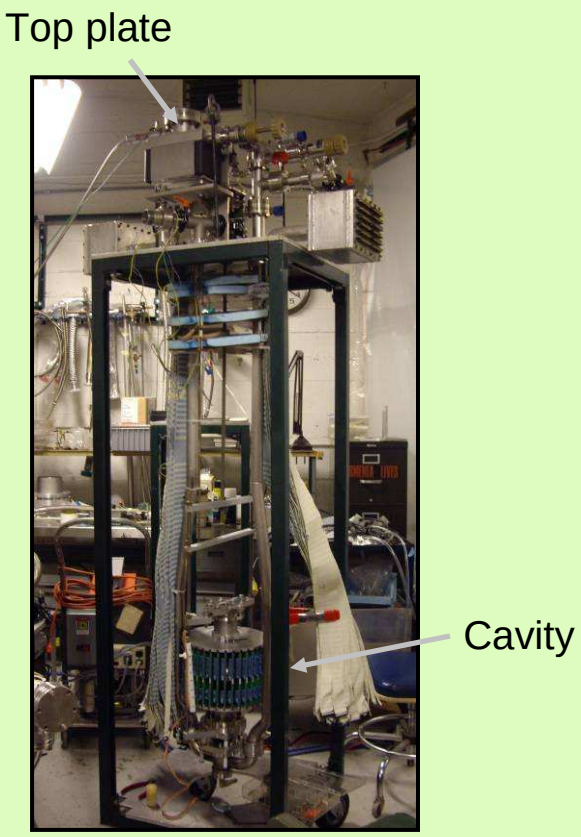
Detlef Reschke (of DESY), tutorial on *Limits in Cavity Performance,* 2007 (2)

Cavity Testing

…finding the Q_0 curve, in 3 easy steps!!!

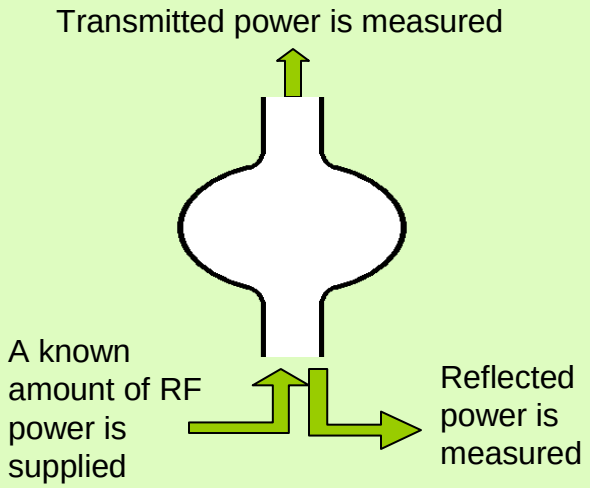
1. Prepare test stand

Cavity is pumped down below 10^{-7}torr, given a leak check, and wired up



2. Place test stand into test pit

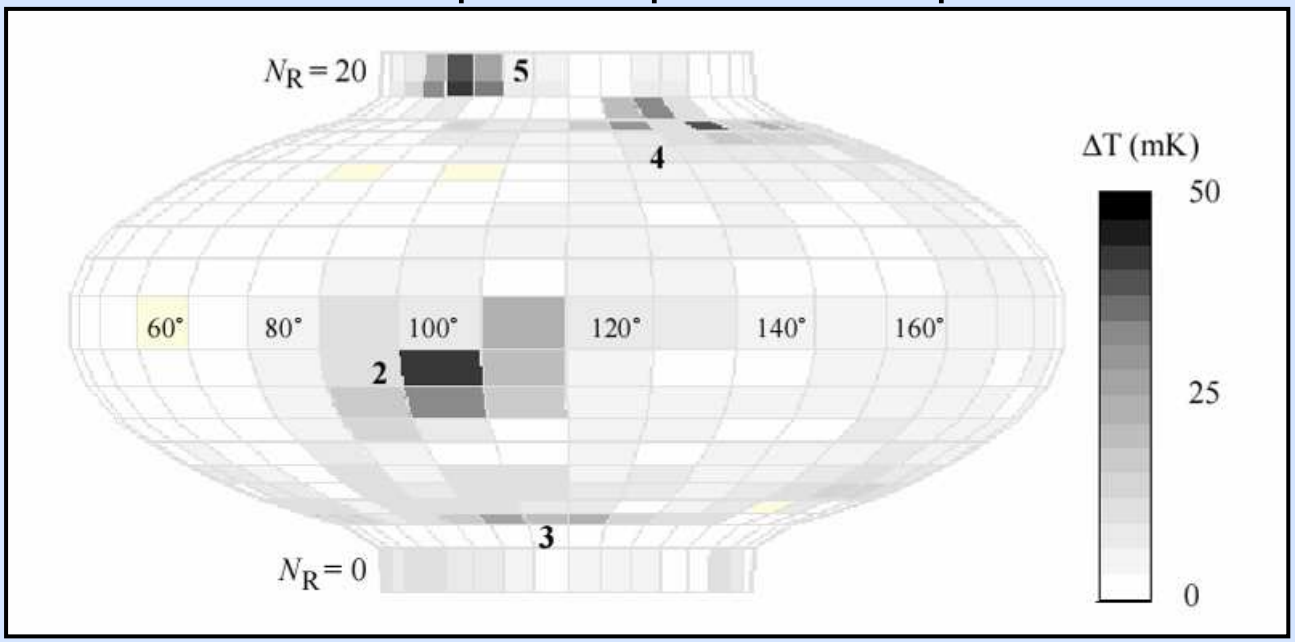
3. Wire up, cool down, and power up!!



Thermometry

Another testing technique…

Example Temperature Map



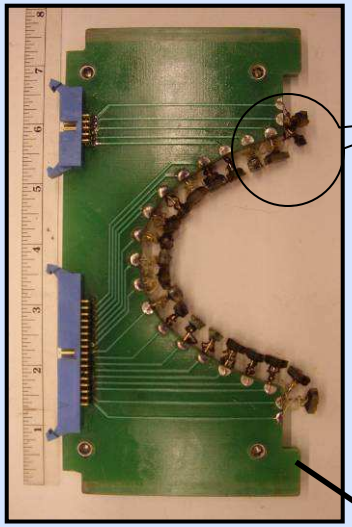
J. Knobloch, “Advanced Thermometry Studies of Superconducting RF Cavities”, 1997, 67

Different loss mechanisms cause cavity walls to heat up in unique ways.

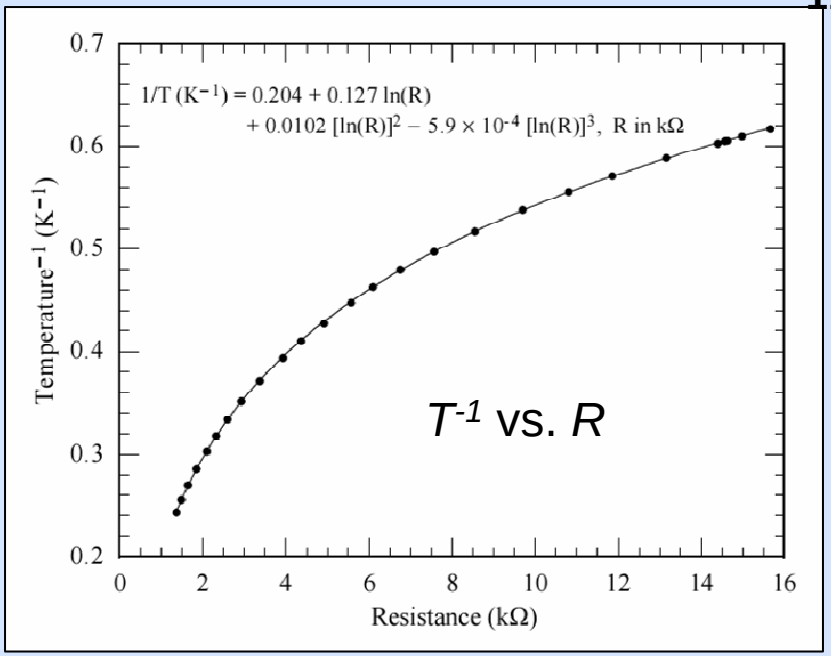
The cavity wall can be monitored and mapped out using lots and lots and lots of thermometers

Thermometry Exposed

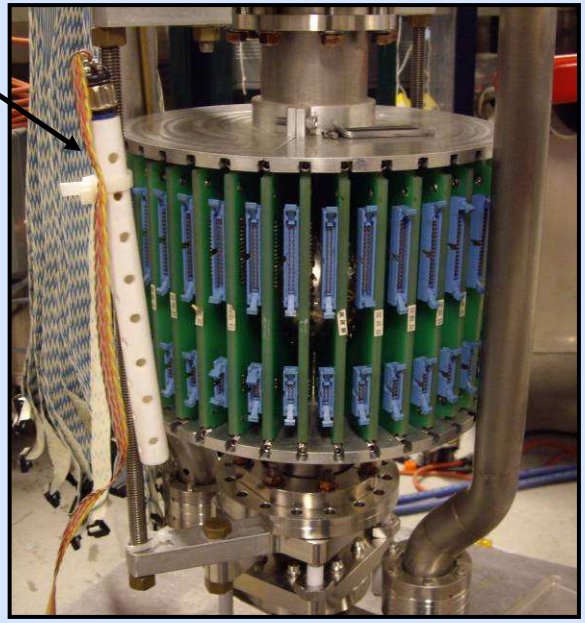
Thermometer board



756 Allen Bradley copper resisters are used to obtain temperature map (~1 resister per square cm)



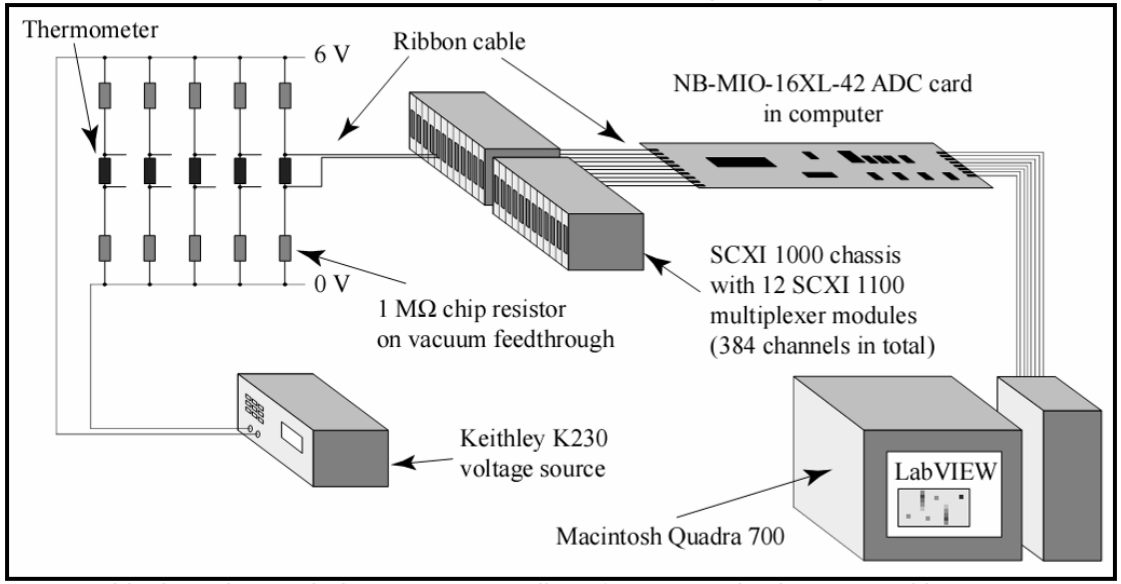
J. Knobloch, “Advanced Thermometry Studies of Superconducting RF Cavities”, 1997, 65



Thermometry More Exposed

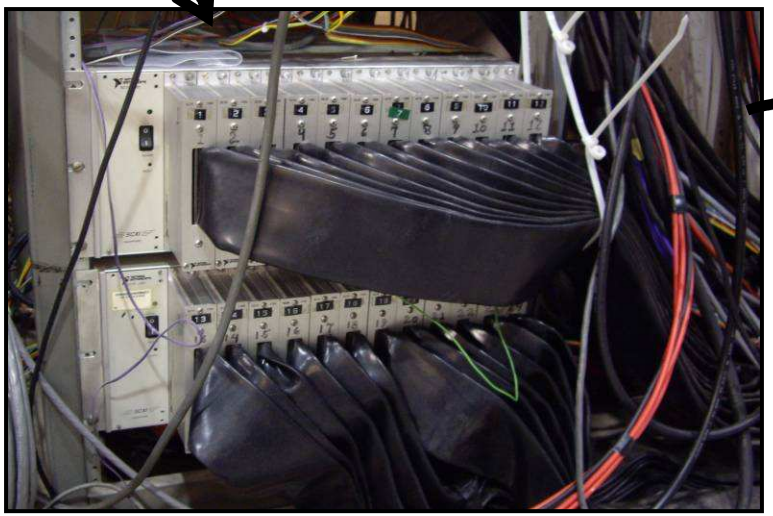
top plate of test stand

schematic of thermometry setup



J. Knobloch, “Advanced Thermometry Studies of Superconducting RF Cavities”, 1997, 63

cavity (in pit)



SCXI multiplexing system

Computer

(w/ Labview)

My Goals:

Improve our understanding of high field Q-drop

Initial Setup: cavity was chemically etched by a BCP, and placed in a class 10 clean room

Here's the plan…

- high pressure rinse
- mount cavity and thermometry system
- test cavity, look for Q-drop
- **HF rinse (removes oxide on surface)**
- high pressure rinse
- test, look for Q-drop

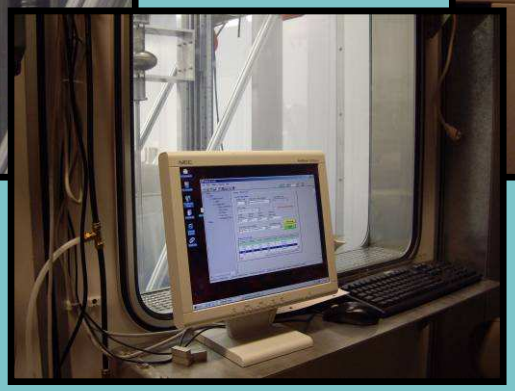
→ effects of oxide layer

- 400℃ bake
- test, look for Q-drop
- **vent cavity with N_2 gas**
- test

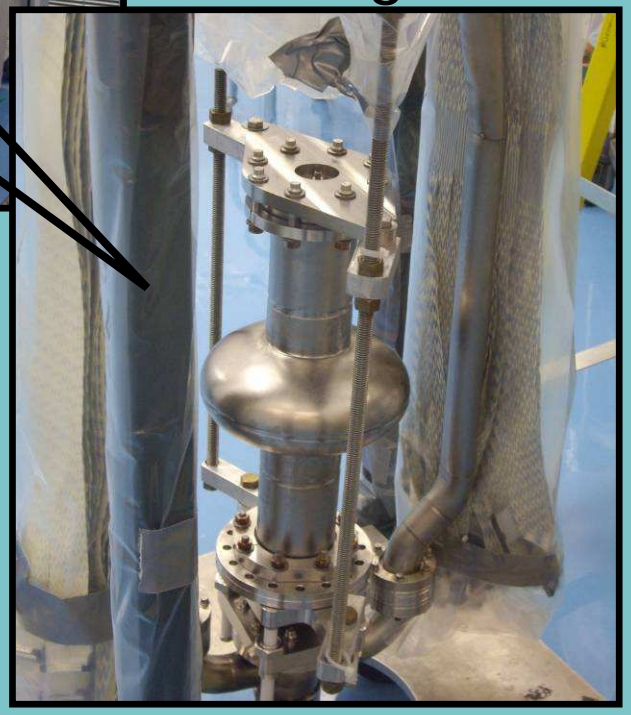
→ effects of N_2 impurities

- more venting…

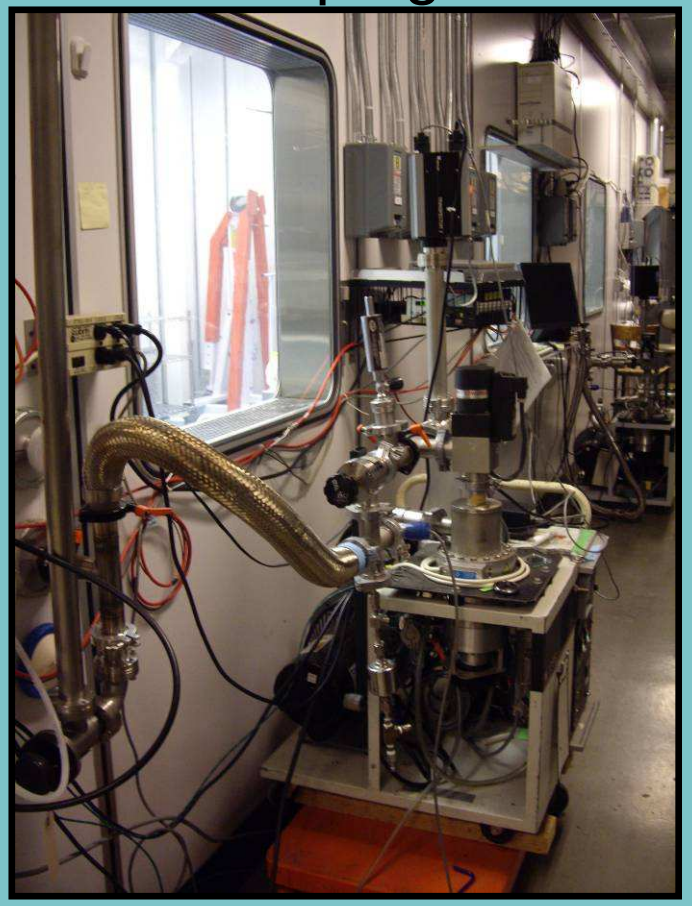
High Pressure Rinse



Mounting

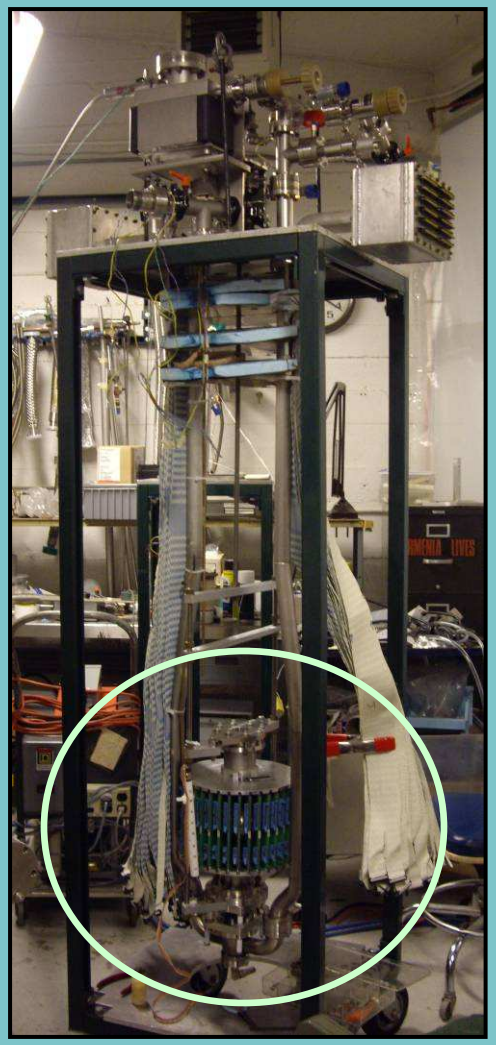


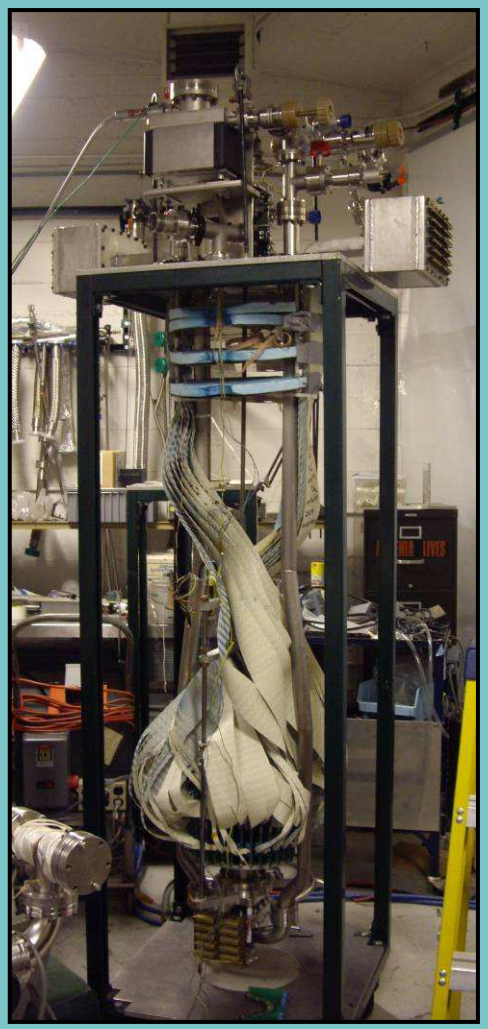
Pumping



& Leak Check

Thermometry System Mounted



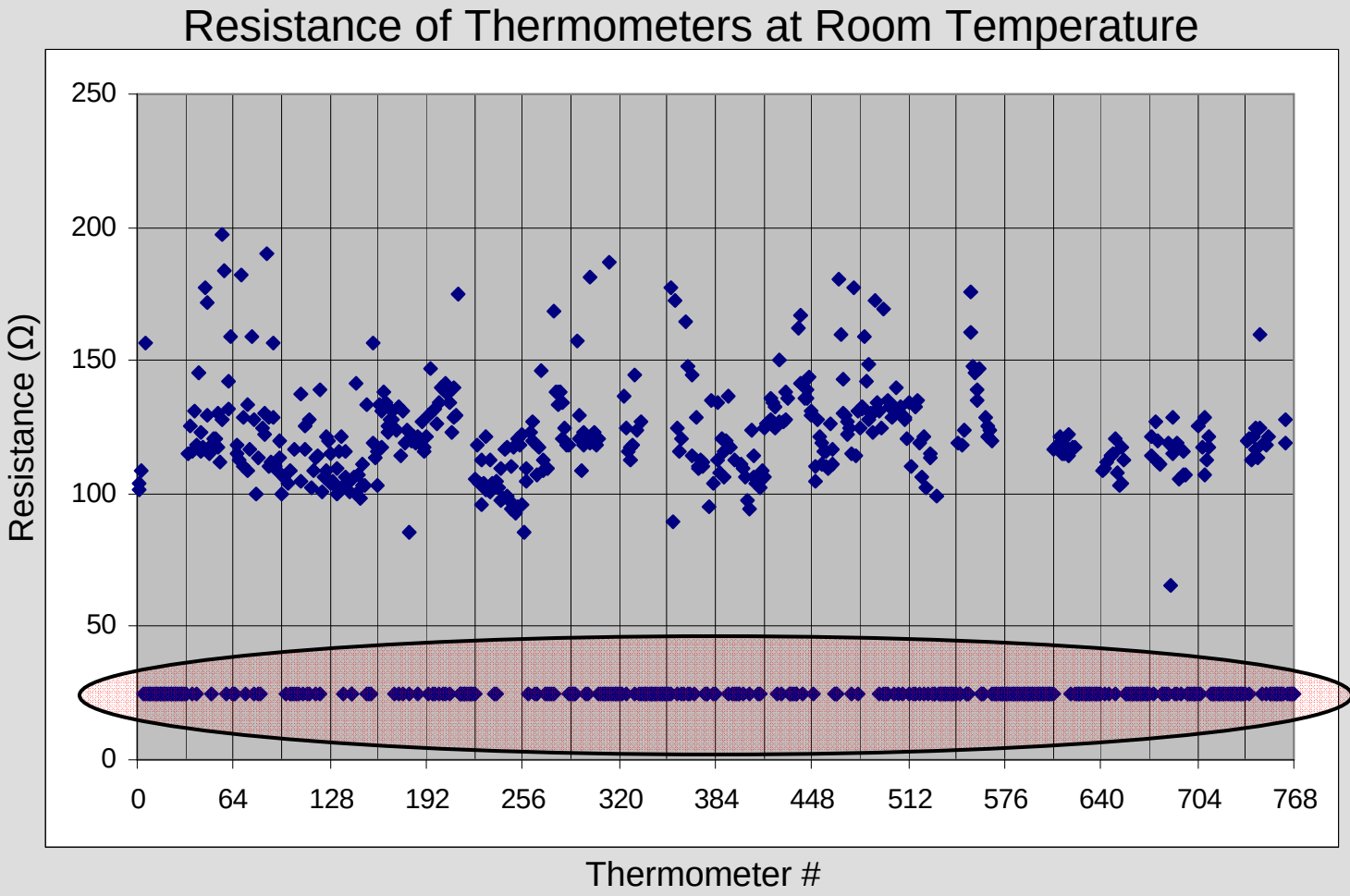


Progress Check List:

- high pressure rinse
- mount cavity and thermometry system
- test cavity, look for Q-drop
- **HF rinse (removes oxide on surface)**
- high pressure rinse
- test, look for Q-drop
- 400℃ bake
- test, look for Q-drop
- **vent cavity with N_2 gas**
- test
- more venting…

Thermometry Trouble!

At room temperature, each thermometer should have a resistance of ~120Ω



All thermometers with resistances outside of the threshold from 50Ω-200Ω were reset to 25Ω on this plot

Broken thermometers

The Culprits

1. Terminal boxes were not plugged in tightly enough to SCXI system (~100 thermometers)

2. Cross-talk caused by broken thermometers with excessively high resistances

3. Some thermometers lacked a thin layer of varnish, shorted to cavity surface

4. Lots of thermometers that were simply broken & needed replacement

3 Weeks Later…

Progress Check List:

- ✓ high pressure rinse
- ✓ mount cavity and thermometry system
- test cavity, look for Q-drop
- **HF rinse (removes oxide on surface)**
- high pressure rinse
- test, look for Q-drop
- 400℃ bake
- ~~test, look for Q-drop~~
- ~~**vent cavity with N_2 gas**~~
- ~~test~~
- ~~more venting…~~

It’s ok though,

just test and move on…

But then…

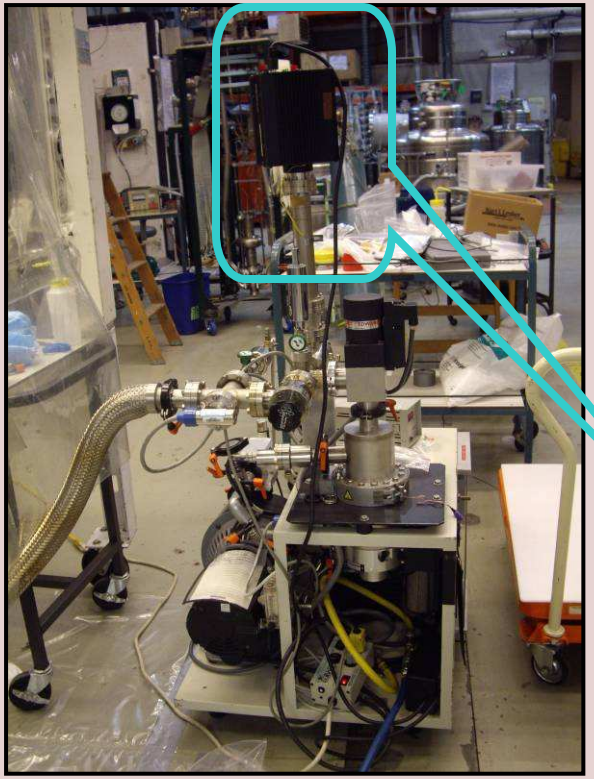
Before data can be taken,

leaks open in vacuum system!@#!

Progress Check List:

- high pressure rinse
- mount cavity and thermometry system
- test cavity, look for Q-drop
- **HF rinse (removes oxide on surface)**
- high pressure rinse
- ~~test, look for Q-drop~~
- ~~400℃ bake~~
- ~~test, look for Q-drop~~
- ~~**vent cavity with N_2 gas**~~
- ~~test~~
- ~~more venting…~~

So, Leak Checking…



Vacuum pump used for pumping cavity pressure down to 10^{-7}torr

Residual Gas Analyzer (RGA): detects amount of helium gas being pumped out of cavity

Helium gas is sprayed around seals while RGA output is monitored to check for leaks

Fun New Leak Checking Techniques:

• “in-pit” leak checking can be used to search for leaks anywhere beneath the top plate of the test stand.

• bagging

• nitrogen purging

Several more weeks pass…

Progress Check List:

- ~~• high pressure rinse~~
- ~~• mount cavity and thermometry system~~
- ~~• test cavity, look for Q-drop~~
- ~~• **HF rinse (removes oxide on surface)**~~
- ~~• high pressure rinse~~
- ~~• test, look for Q-drop~~
- ~~• 400°C bake~~
- ~~• test, look for Q-drop~~
- ~~• **vent cavity with N_2 gas**~~
- ~~• test~~
- ~~• more venting…~~

Current Status:

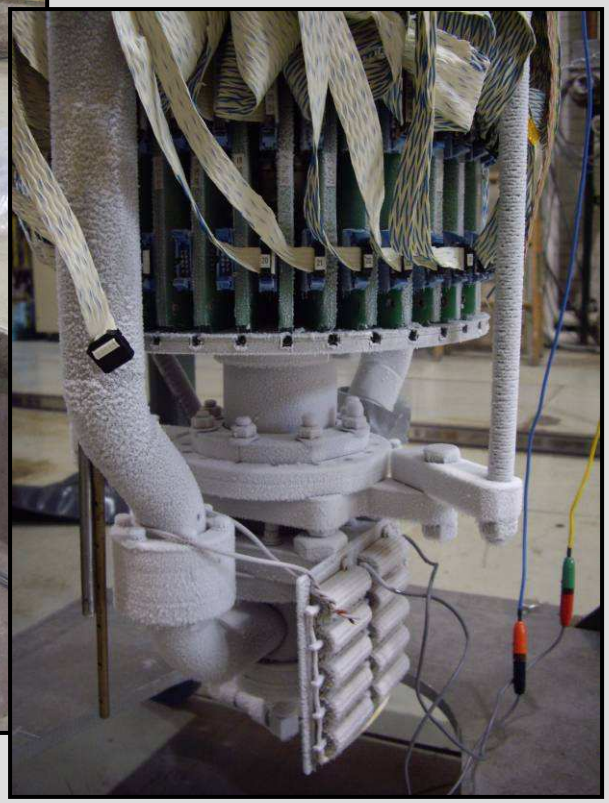
Leaks presumably still exist.

Test stand will be moved to clean room, cavity will be removed, given a HPR, and then reattached to test stand with fresh indium seals.

Some work will have to be done in order to catch up to where we were at the start of the summer…

But much was learned, so all is not lossed!

The End



Thanks to those involved…

- Matthias Liepe
- Dave Meidlinger
- SRF group members
- Rich Galik