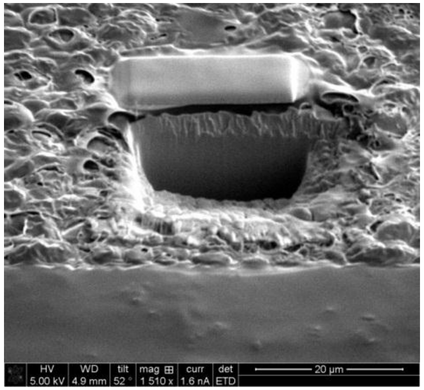

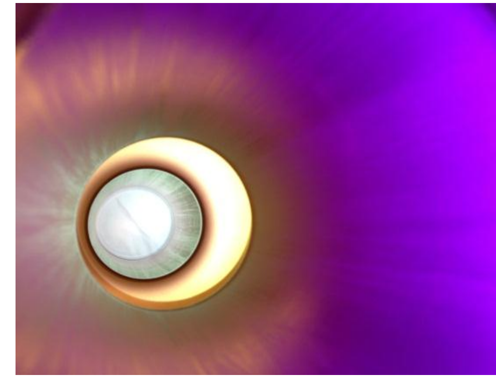

Update on the Development of Coated Cavities

New Results from 1-cell Cavities at Cornell and JLab

Sam Posen, Cornell University
May 28, 2013
Linear Collider 2013

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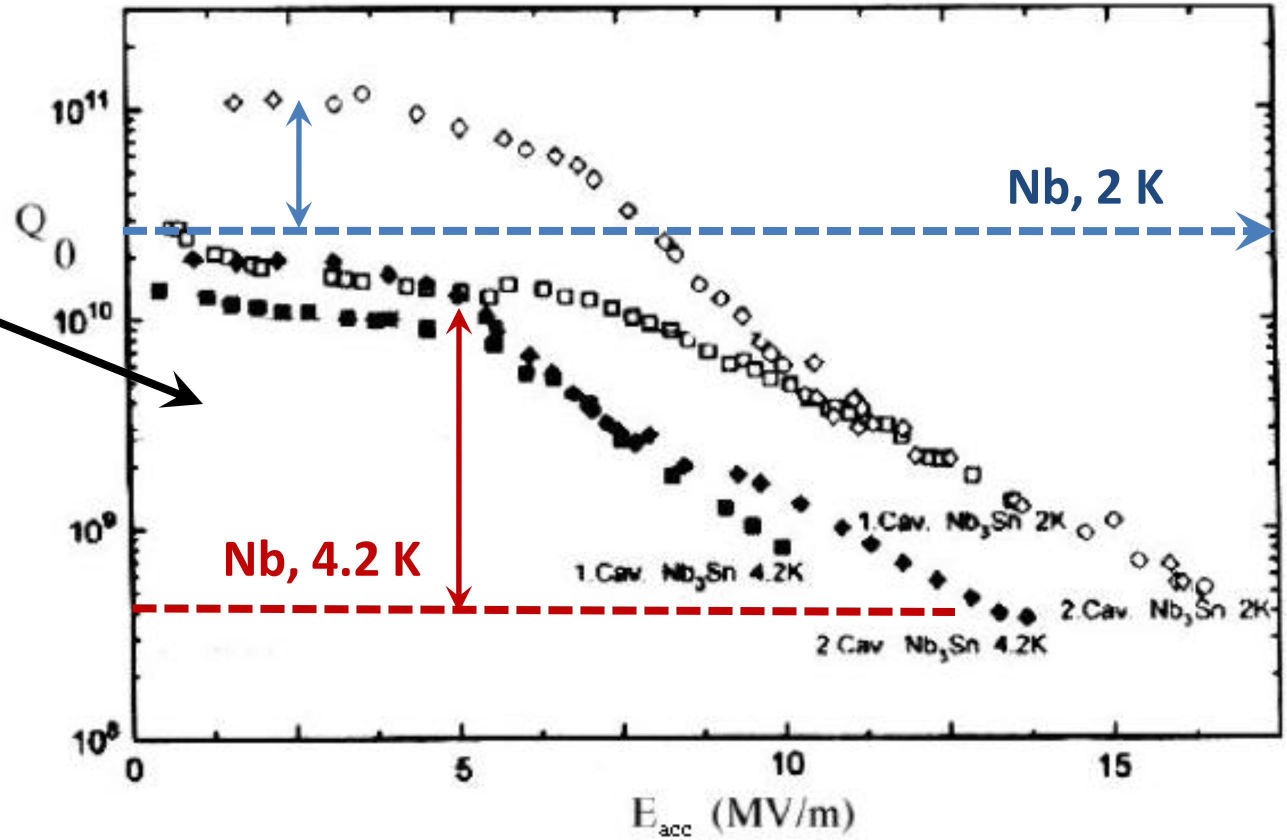
Nb_3Sn For SRF Cavities

LC2013

- Nb_3Sn is an attractive potential alternative material to Nb for SRF cavities, having:
  - A T_c of ~18 K, compared to ~9 K for Nb, giving it a much lower BCS R_s, ideal for CW linacs – huge reduction in cost of cryo plant and grid power
  - A predicted H_{sh} of ~400 mT, nearly twice that of Nb, ideal for high energy linacs – higher accelerating gradient: fewer cavities required
- Cornell has been pioneering new R&D on Nb_3Sn after 10 years of inactivity. Other labs are now starting Nb_3Sn programs as well.

Previous SRF Research with Nb_3Sn

- Siemens AG
- U Wuppertal
- KfK
- JLab
- Cornell
- And others

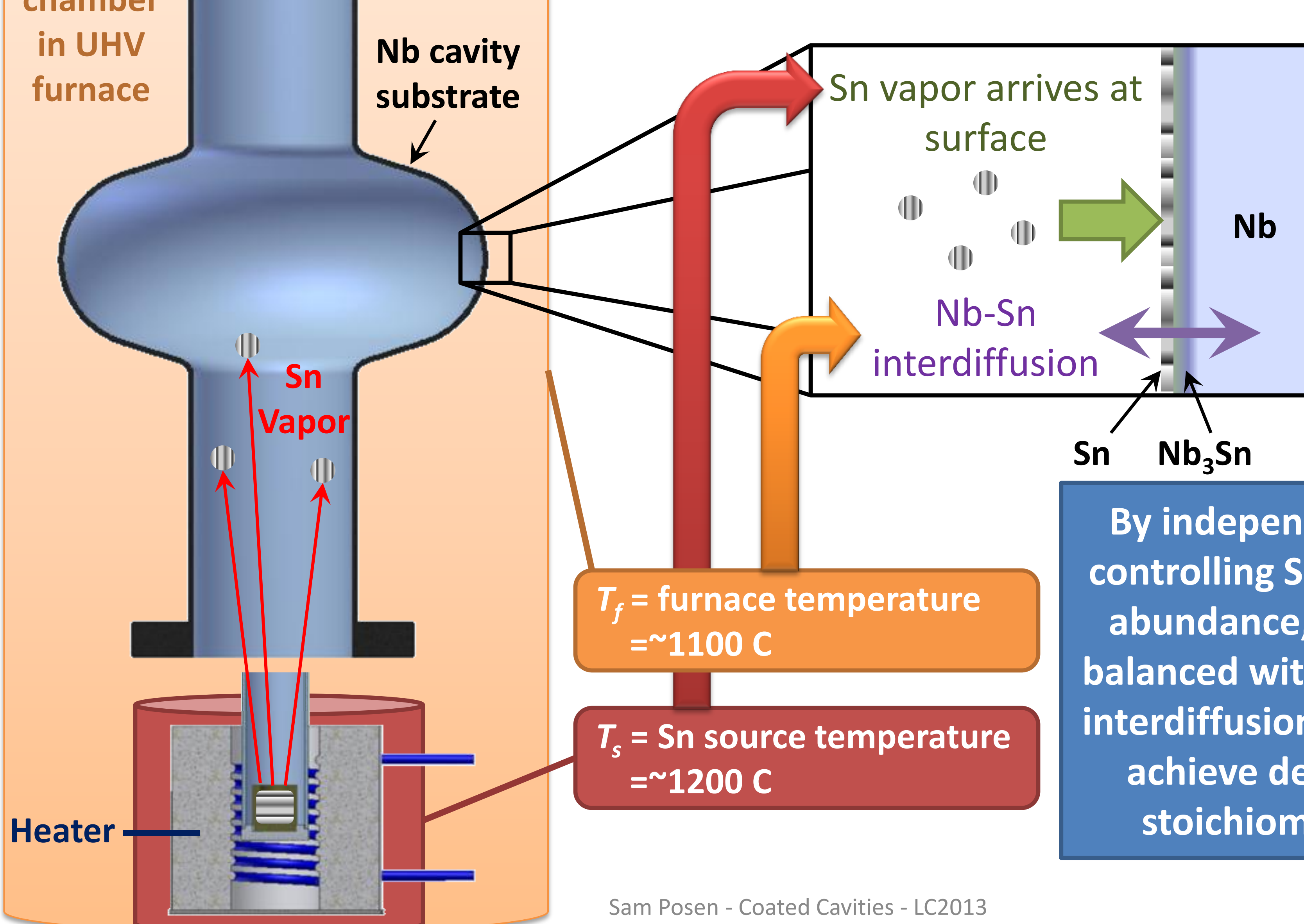


"Determining the origin of these non-linearities and eliminating the possibility that this behavior is not a fundamental property of the films are the next important steps."

–Peter Kneisel, 2012

Coating Mechanism

Vapor Diffusion



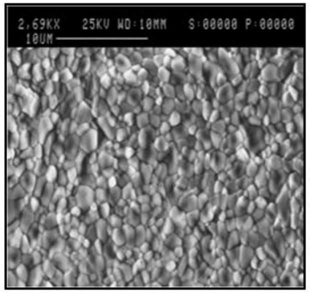
By independently controlling Sn vapor abundance, it can balanced with Nb-Sn interdiffusion rate to achieve desired stoichiometry

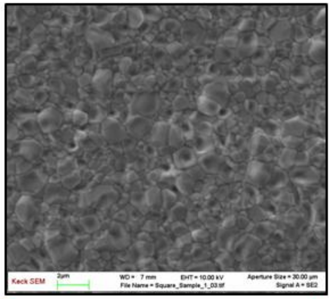
Cornell Sample Results

- Successfully fabricated Nb_3Sn samples with near-ideal stoichiometry
- Uniformity of stoichiometry determined by anodization and EDX
- Appropriate grain size and texture confirmed using SEM

Not anodized

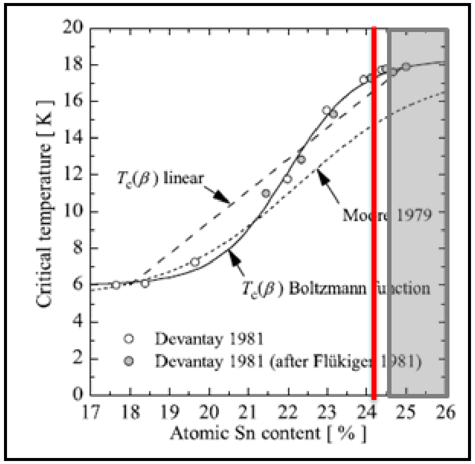
Anodized

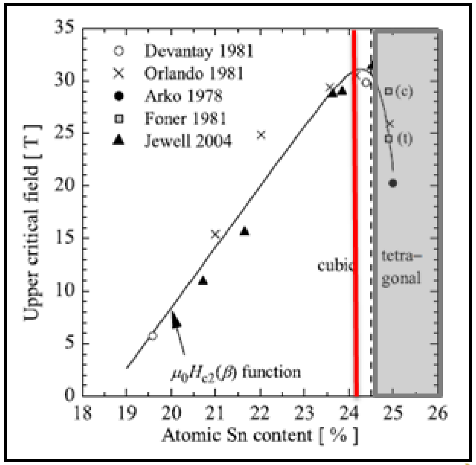




Wuppertal, 1996

Cornell, 2011

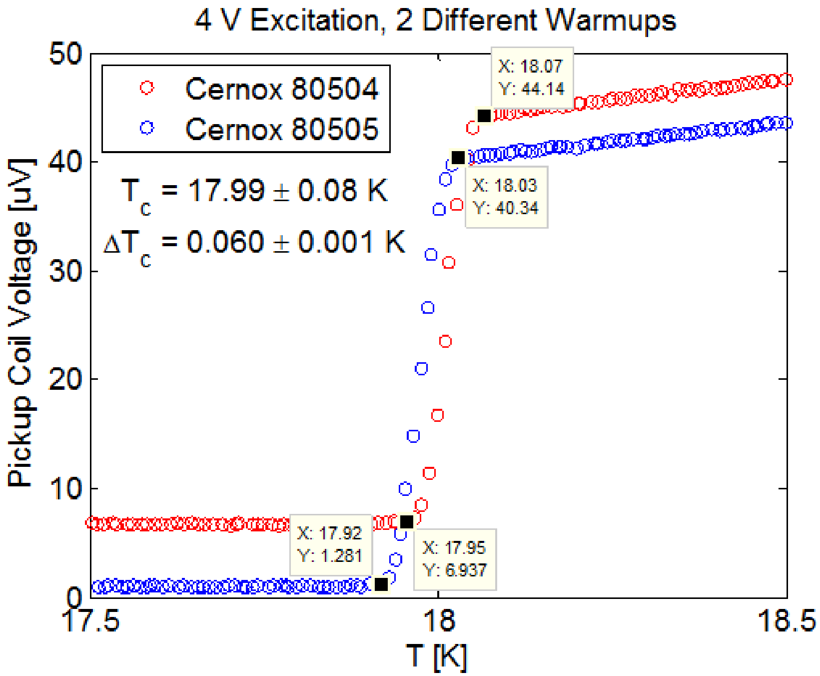


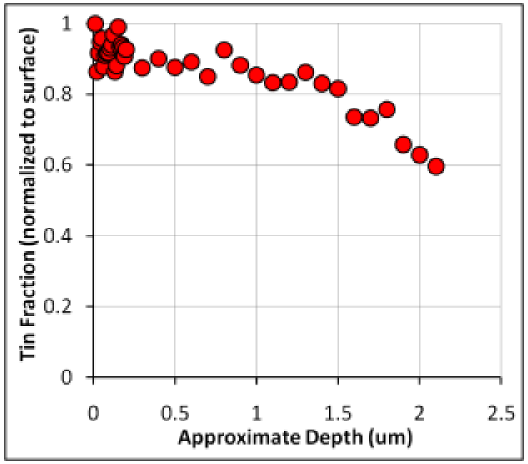


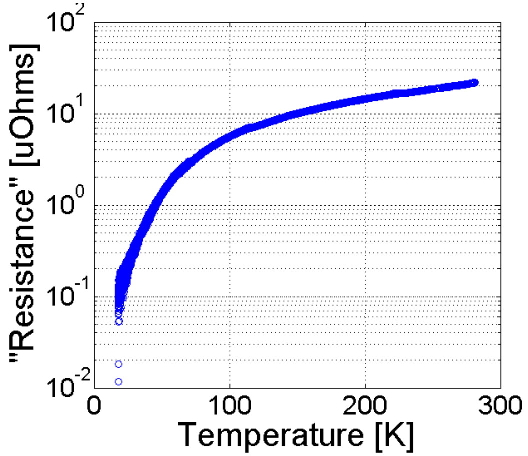
Cornell Sample Results

LC2013

- Appropriate thickness determined through XPS
- T_c = 18.0 ± 0.1 K measured inductively is close to highest literature value
- RRR measured through cryogenic 4-wire probe shows minimal degradation



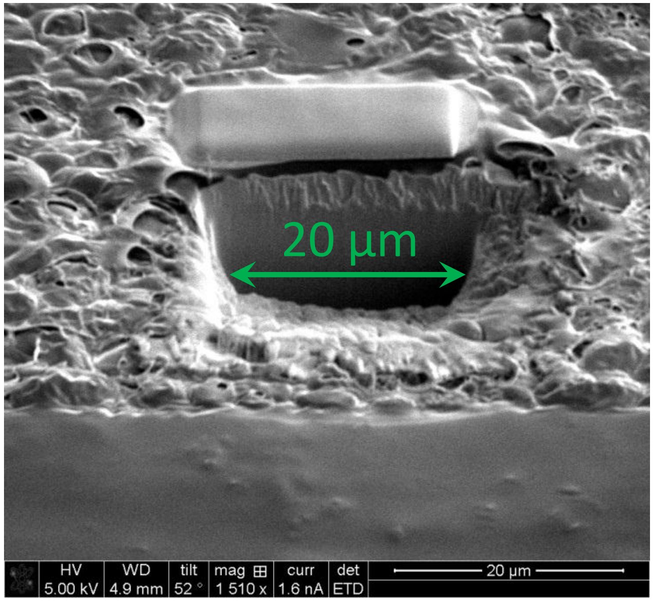


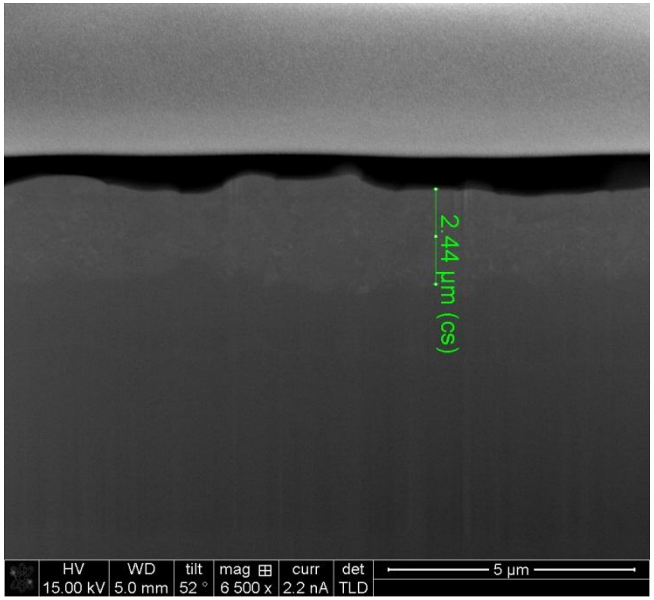


New FIB Results

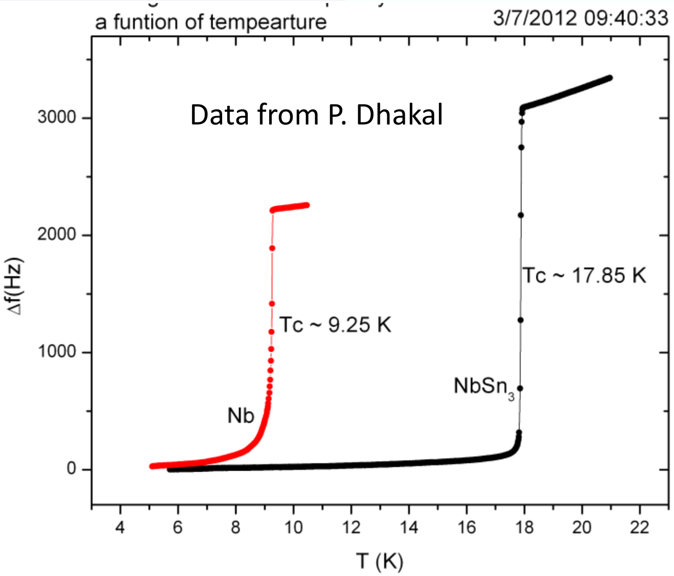
LC2013

- Recently used focused ion beam milling to see cross section of coated sample
- Layer thickness measurement agrees with XPS
- TEM to come…

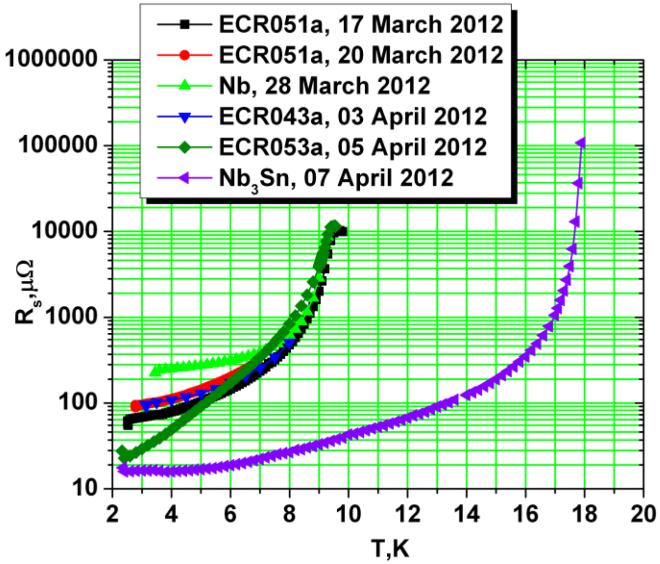




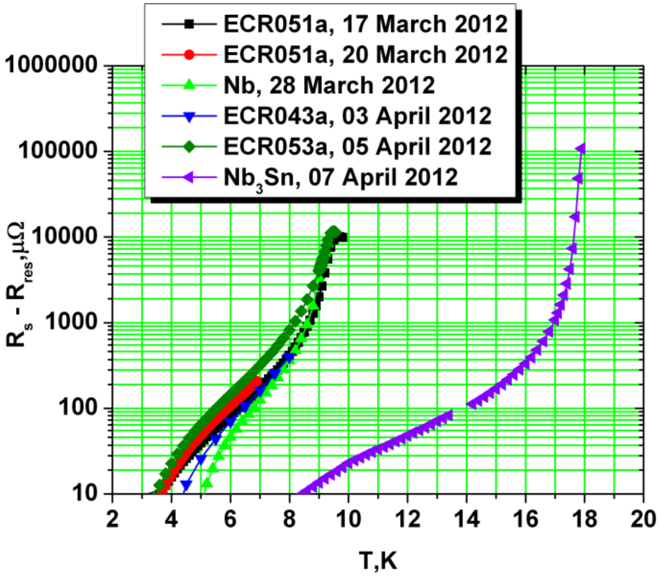
Sample Measurement at JLab



Transition temperature is ~ 17.85 K. The best of three samples shows very smooth surface with no residual tin contamination

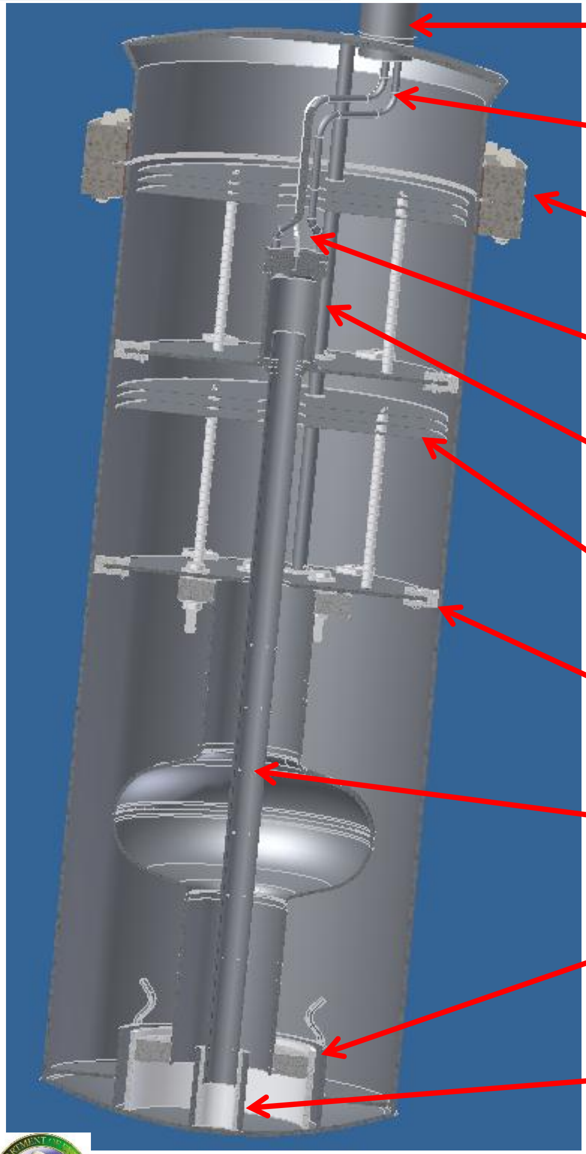


Recent measurements of surface resistance of several ECR films, bulk Nb sample, and Nb_3Sn sample as a function of temperature at 7.4 GHz. The samples exhibit high residual resistance at low temperature, which we believe is related to the measurement system and is extrinsic to the films.

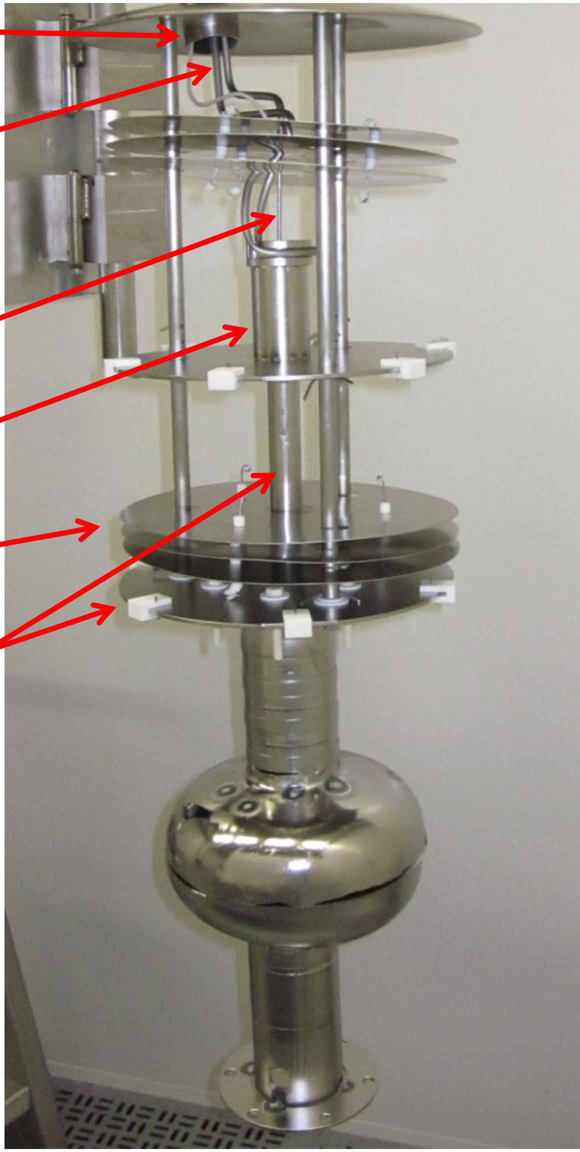


Surface resistance of the films as a function of temperature at 7.4 GHz with the residual resistance subtracted.

Jlab Nb_3Sn Vertical Chamber



- Pump-out line
- He gas cooling line for crucible
- 14'' conflat mating flanges
- Crucible thermocouple
- Sn and $SnCl_2$ crucible
- Nb heat shields
- Nb cavity support plate
- Sn vaporguide
- Cavity flange support cylinder
- Vapor guide support cylinder

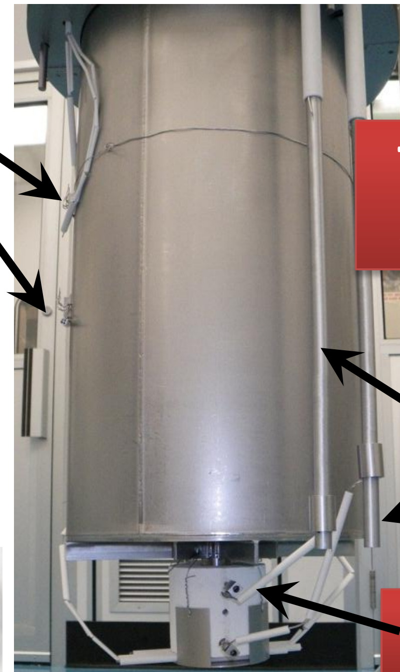


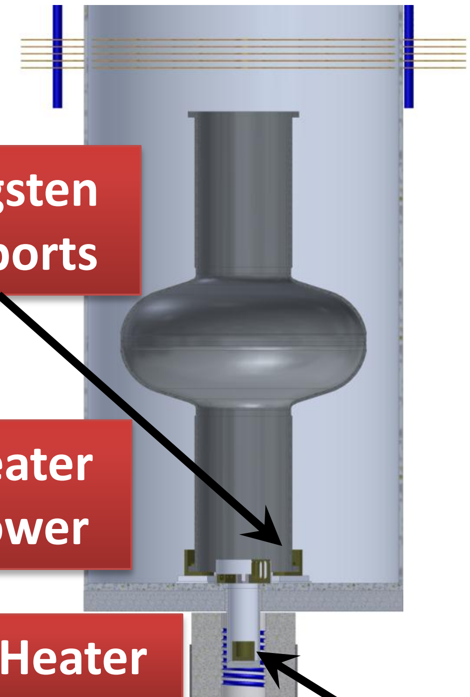
Current Status at JLab

- Preliminary studies with samples have been done.
- The horizontal insert has been built and inserted in the furnace. The first furnace run is being done.
- R&D furnace for Nb_3Sn development has been ordered in October 2012. It is expected to be delivered in August 2013.

Cornell Cavity Coating Chamber

- Degas: 1 day
- Nucleation: 5 hours
- Coating: 3 hours
- Surface diffusion: 0.5 hours

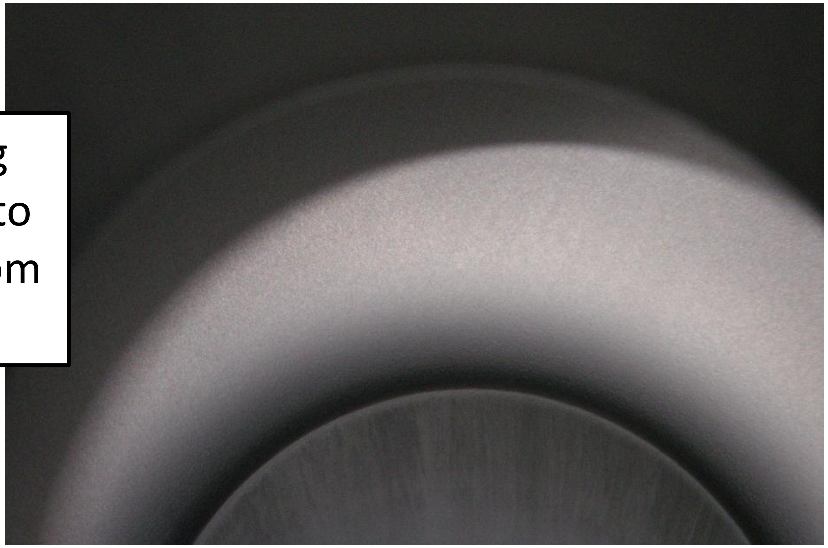




Cornell Cavity Testing

- One cavity has been coated: ERL shape (similar to ILC), single cell, 1.3 GHz
- Tested after very slow cool ($\gtrsim$ 6 min/K) with T-map

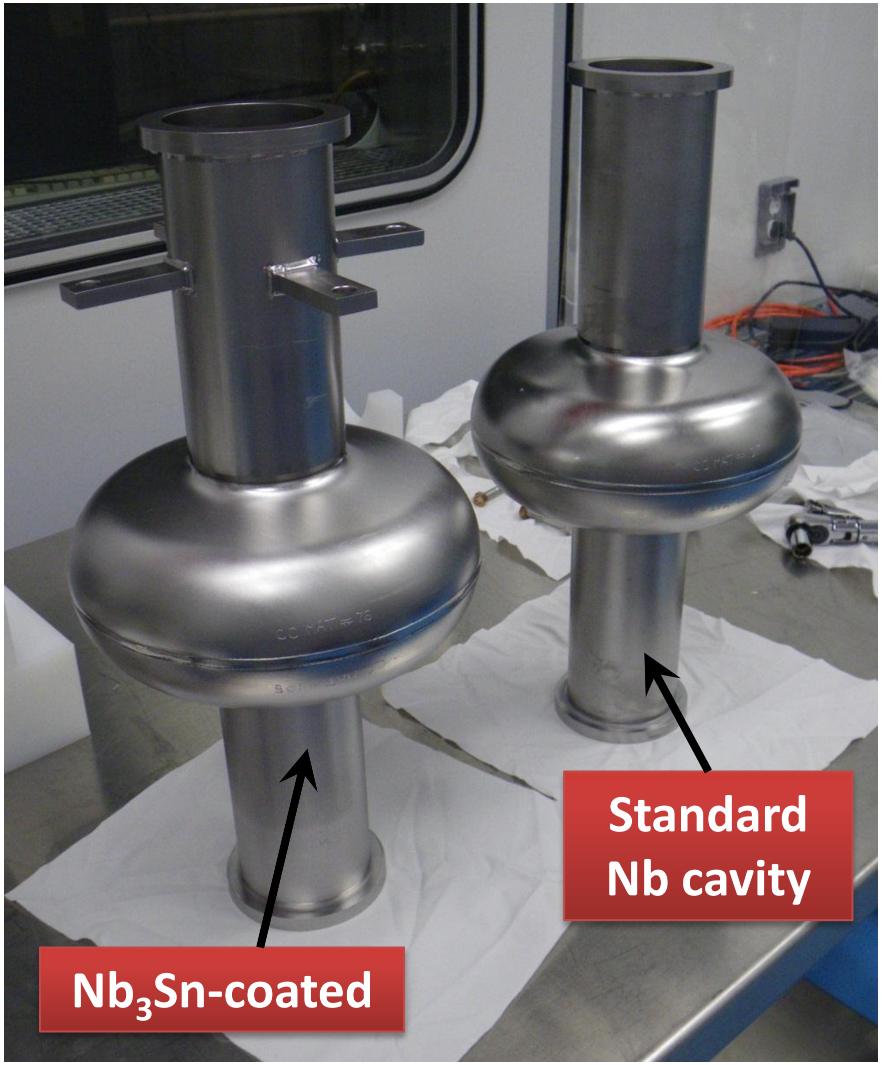
Looking down into cavity from above



Cornell Cavity Testing

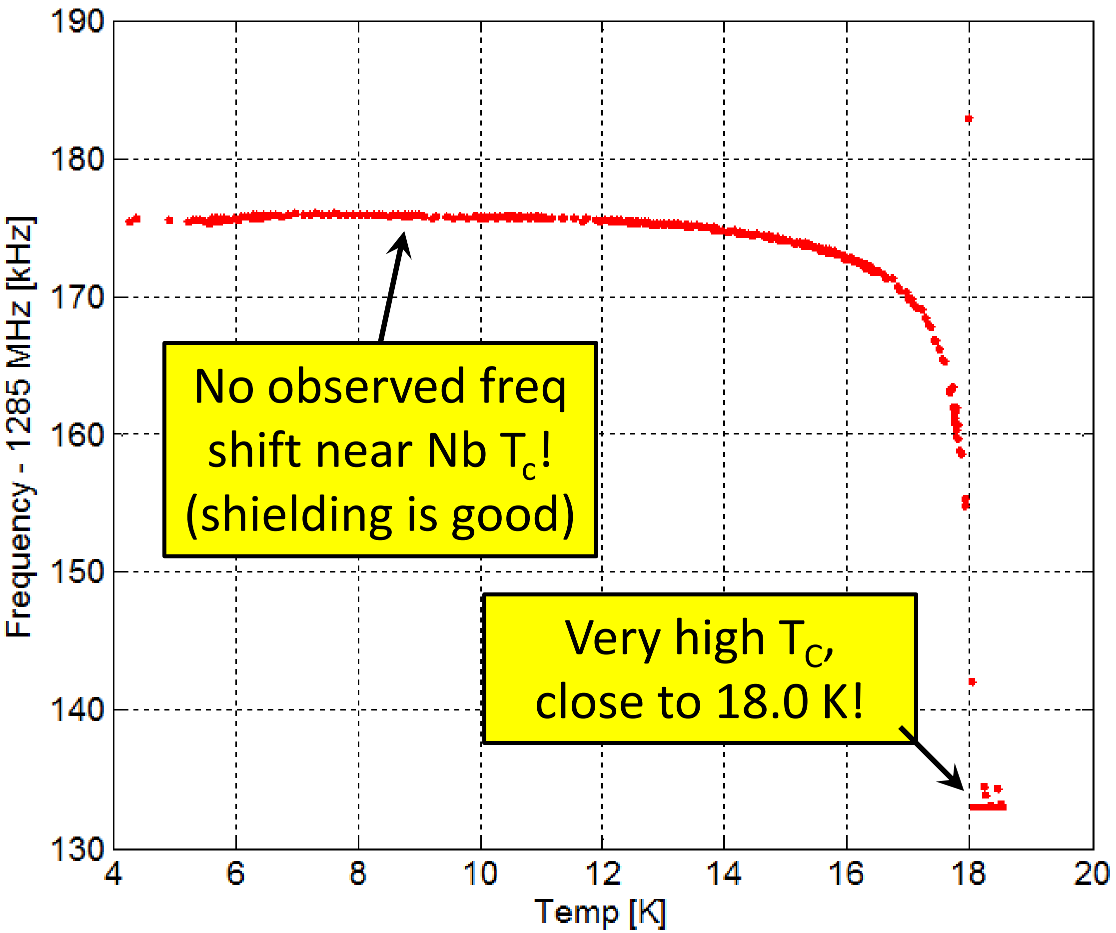
LC2013

- Some very positive results:
  - Very high T_c
  - Reaches mid-field range without quenching
  - 4.2 K Q_0 is much higher than a similar Nb cavity
  - Most of cavity shows little heating in T-map
- Some problems to work on:
  - Residual resistance higher than Wuppertal cavities
  - Some bad spots on T-map



f vs T

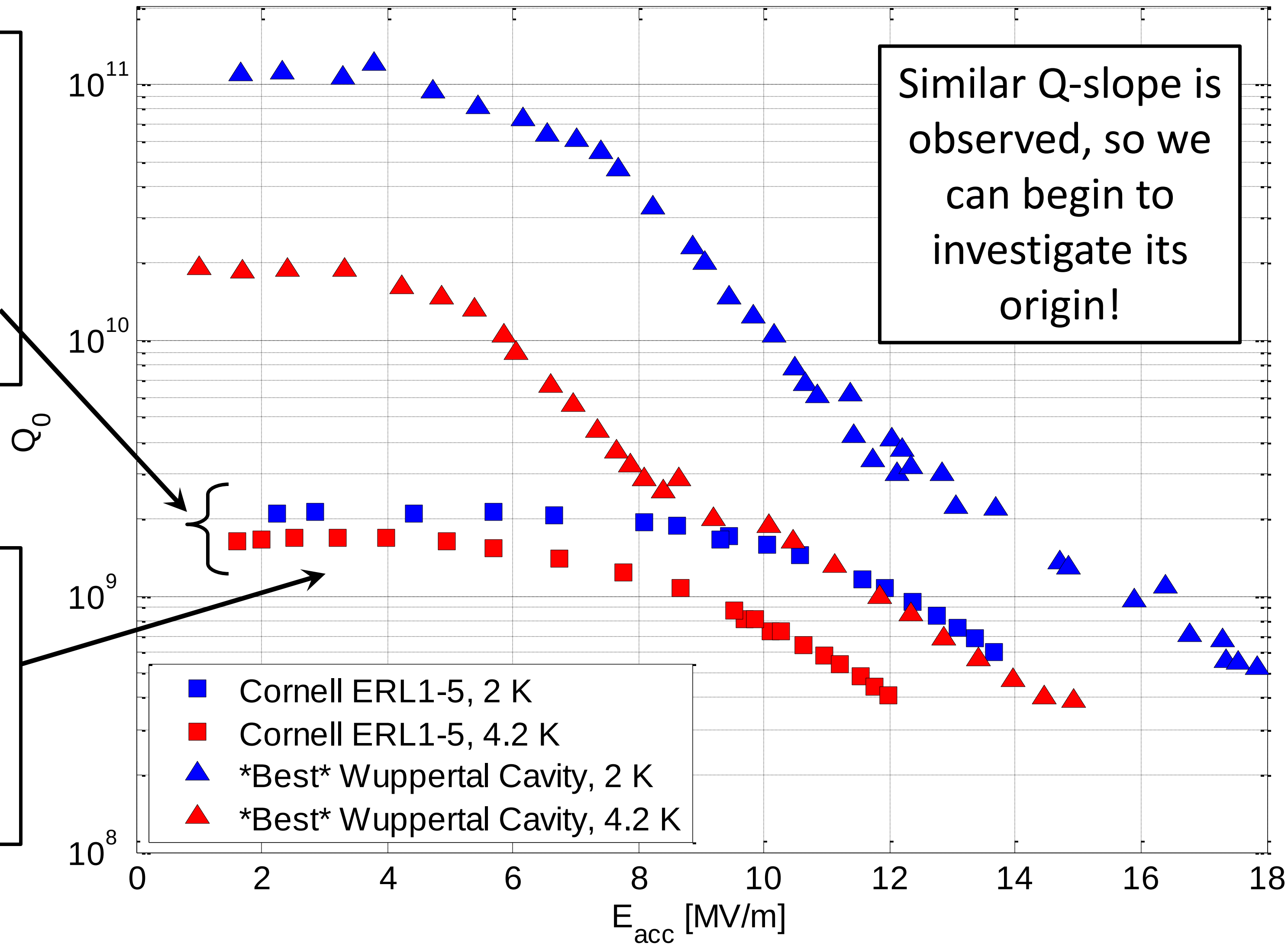
- Network analyzer used to follow resonance during cooldown
- Temperature given by 3 cernox sensors over cavity surface (close agreement between sensors)



Q vs E

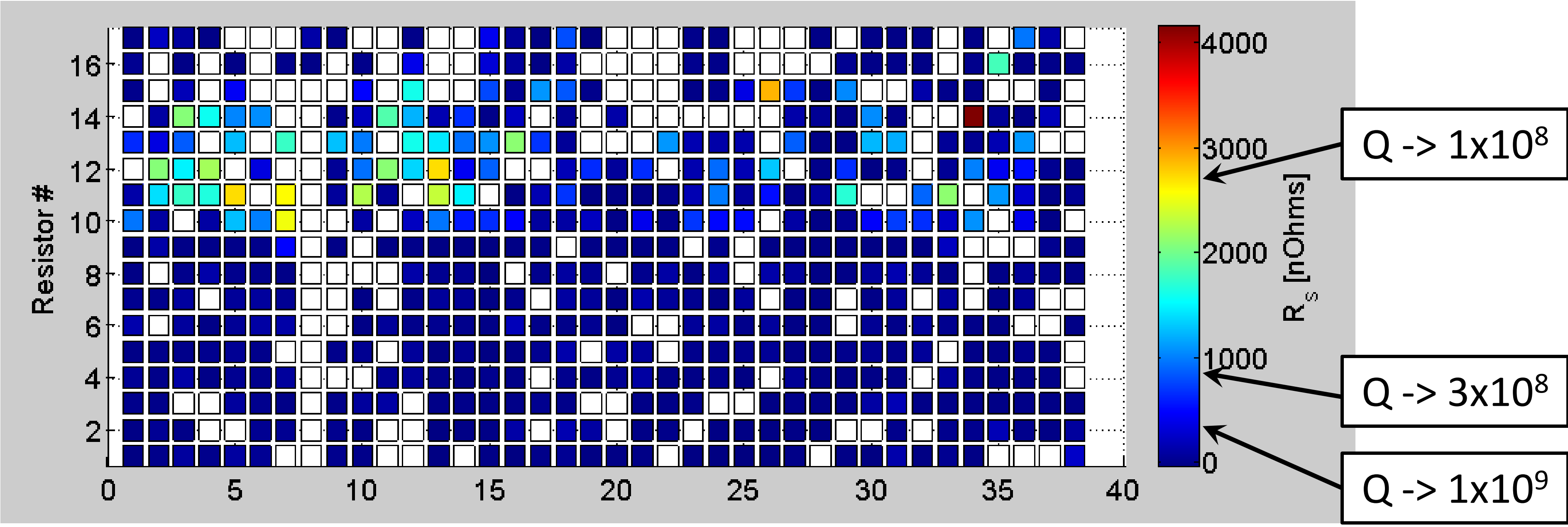
Indication of residual resistance: T-maps on next slide show heating pattern

Strong improvement compared to Nb in 4.2 K Q_0 (Nb ~3-5x10^8)



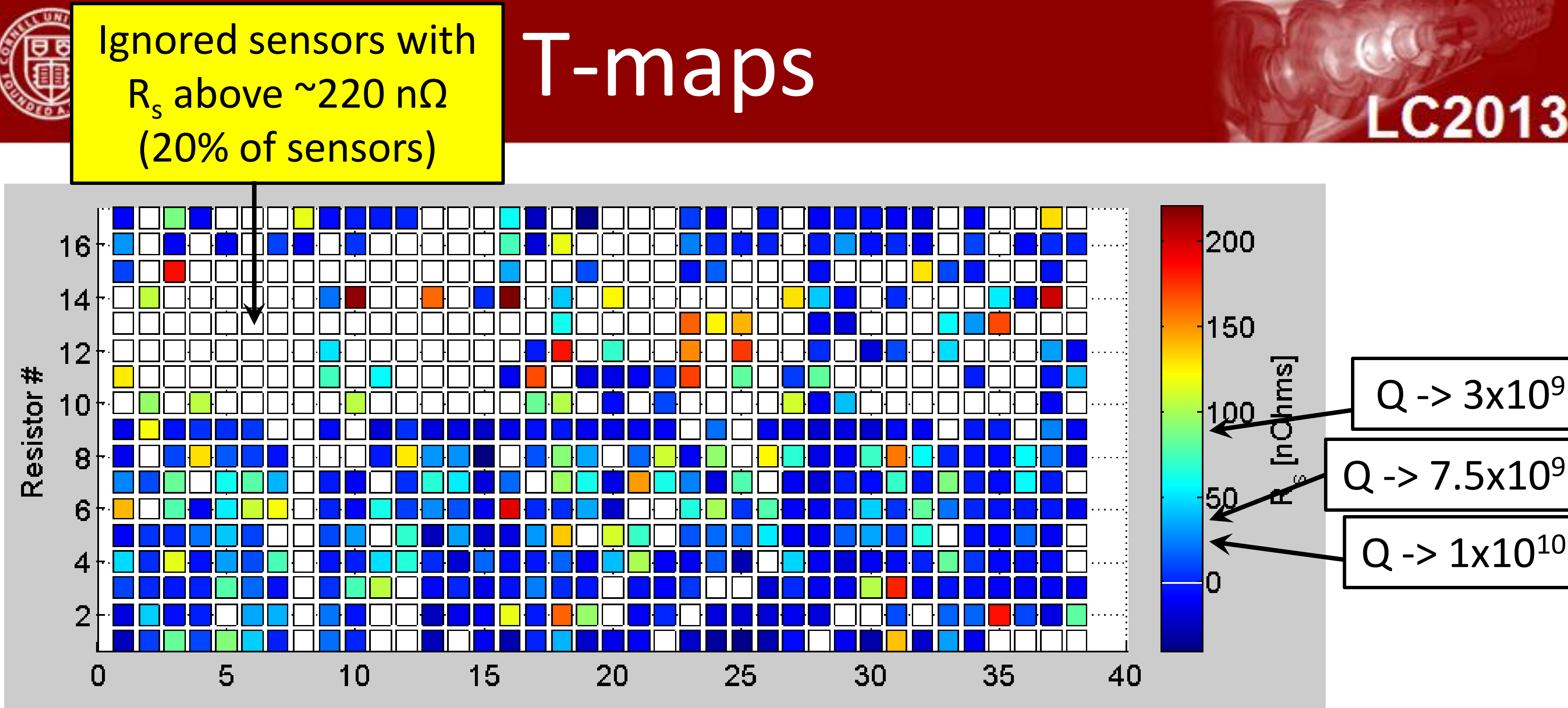
Similar Q-slope is observed, so we can begin to investigate its origin!

T-maps



- Cavity at 2.0 K, 9 MV/m, Q = 1.4×10^9
- White indicates bad channel or R_s very close to 0
- Tmap indicates bad spots with very large R_s

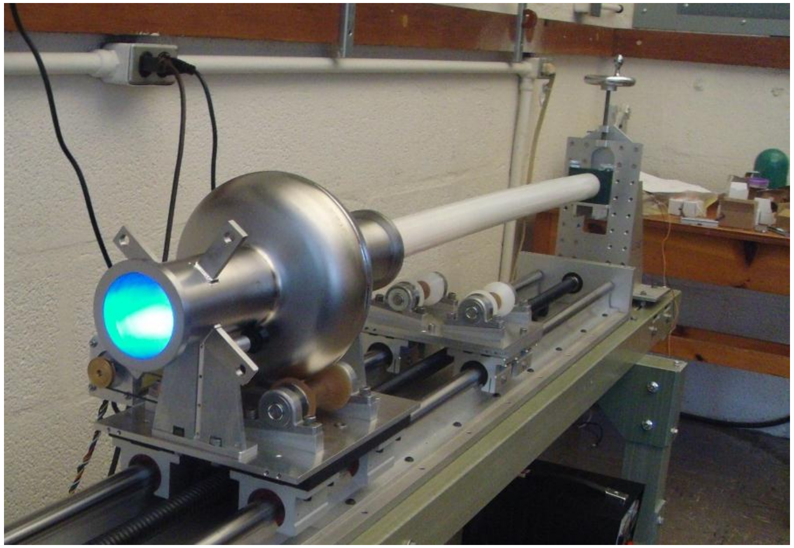
T-maps

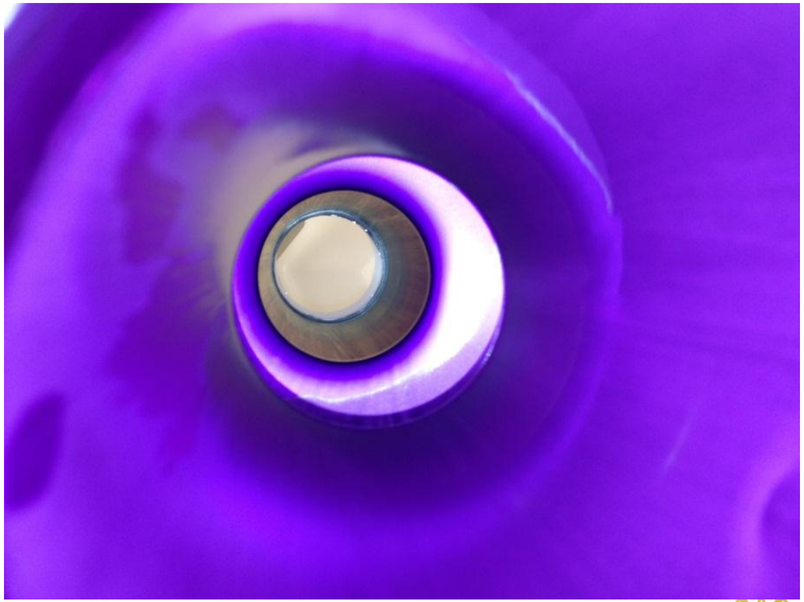


- **Subsection**: 80% of resistors with the lowest R_s
- G/Mean(|R_s|)=$7.5x10^9$
- Conclusion: Most of cavity (including an entire half cell!) has very small R_s: Q $\gtrsim 7.5x10^9$, with measurement limited by noise

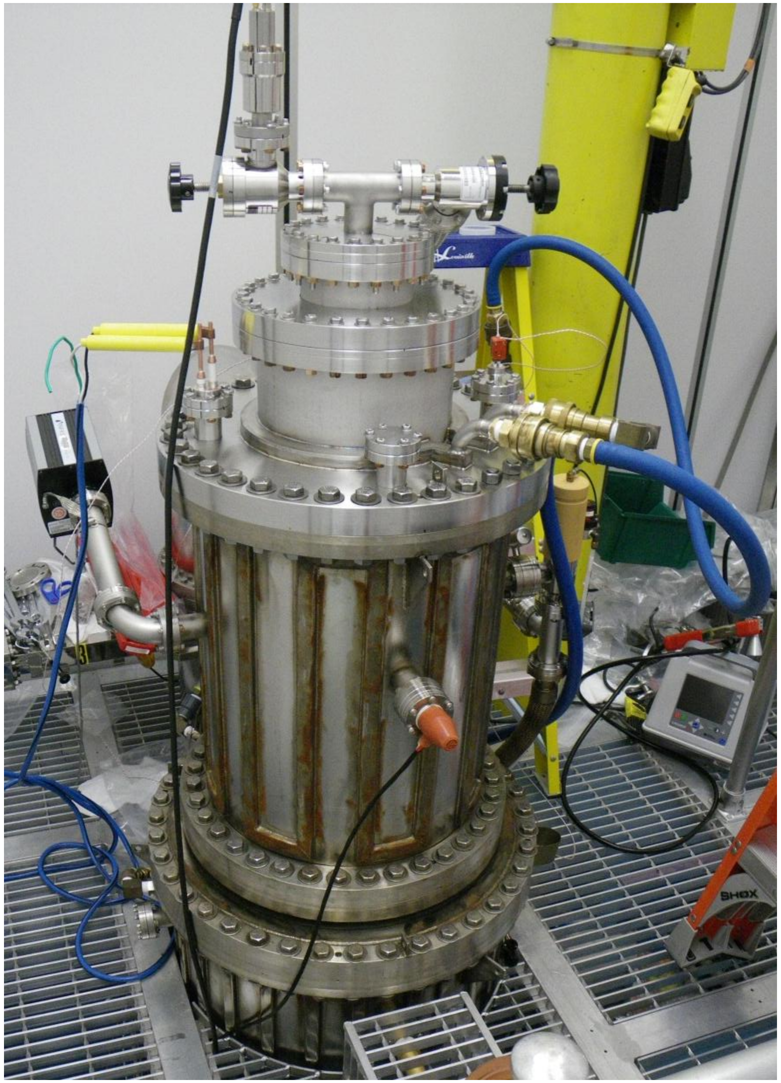
Bad Spots

- Performed a series of vertical tests:
  - Orientation during cooling does not seem to affect location of bad spots
  - 2x HF rinse does not affect Q significantly, 2x oxipolishing reduces Q significantly, bad area remains bad





Bad Spots



- Performed a second coating cycle (following BCP to reset surface):
  - Orientation during coating does not seem to affect the half cell in which bad spots appear
- Overall indication: problem with Nb substrate surface?

Summary and Outlook

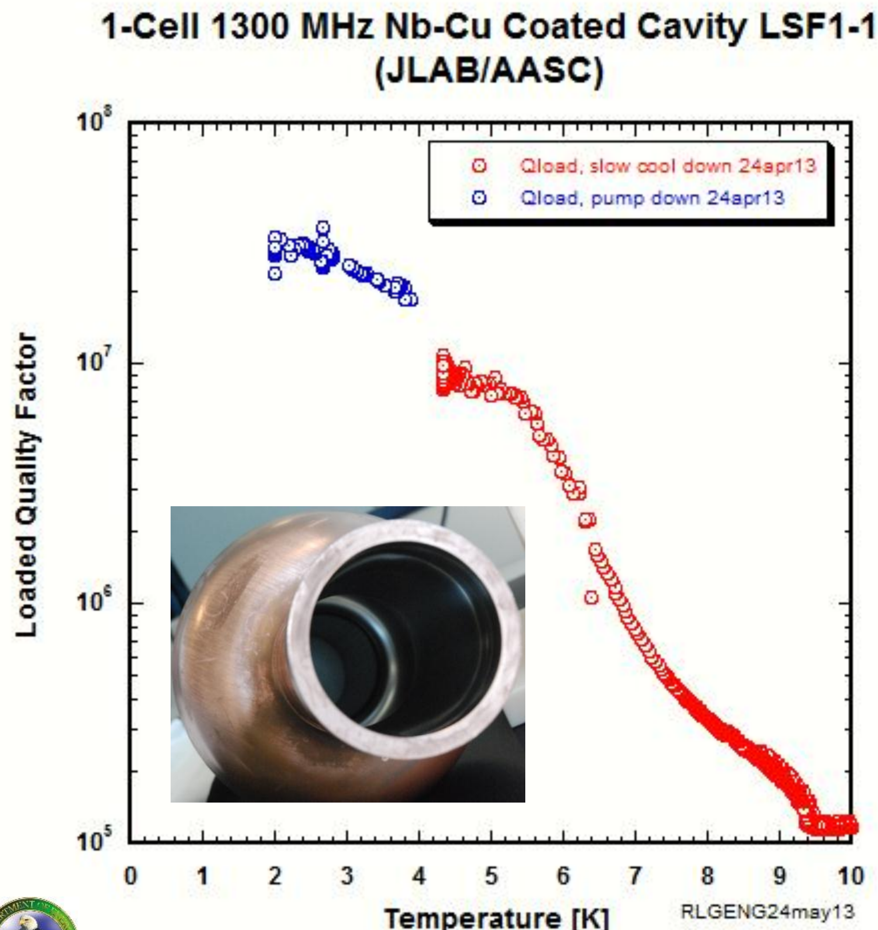
LC2013

- Coating cavities with Nb_3Sn may allow for higher gradients, and therefore shorter linacs
- Cornell has developed repeatable fabrication of high quality Nb_3Sn surfaces on samples
- Great promise in results of first coated cavity
- Already with our first cavity we have an opportunity to study the origin of the Q-slope associated with Nb_3Sn cavities!
- High residual resistance in bad spots may be result of problems with Nb cavity substrate
- Next: Study Q-slope in first cavity, coat a second cavity

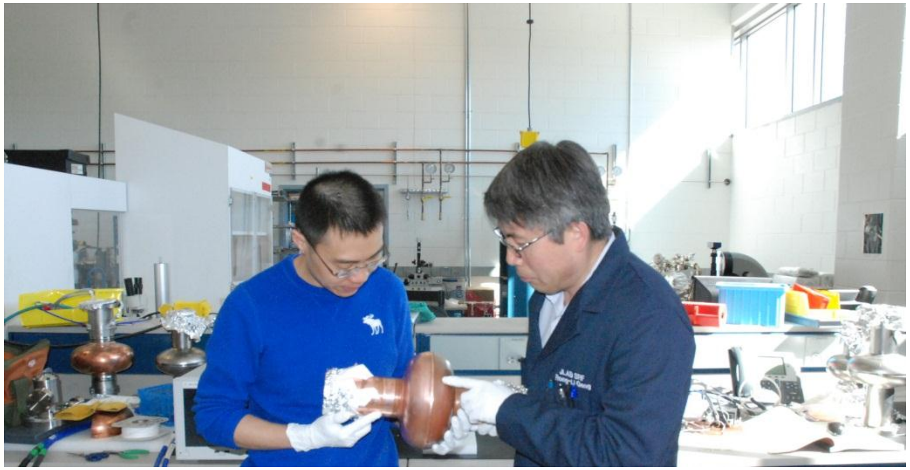
Coated Nb-Cu Cavity Development at JLab

LC2013

Motivation: Ultimately coated cavity. Near term applications to end groups for cost saving



- **Cu cavity fabrication at Jlab**
  - LSF shape
  - Mirror-finish surface
- **Coating at AASC**
  - Energetic condensation via CED
- **Processing and cryogenic RF testing at Jlab**
  - 1st result excellent SC transition
  - But high R_{res} – source being studied



Acknowledgements

- Special thanks to:
  - Grigory Eremeev and Rongli Geng, for slides on JLab progress
  - Mick Thomas, for SEM and FIB
  - Dan Gonnella, for T-map development and assistance with cavity preparation
  - Nick Valles, for Matlab development and development of Q vs T technique
  - The organizing committee, for inviting me
- Thanks for listening!