First Single Cell Cavity Fabricated in Cornell's Nb_3Sn Program

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Cornell University

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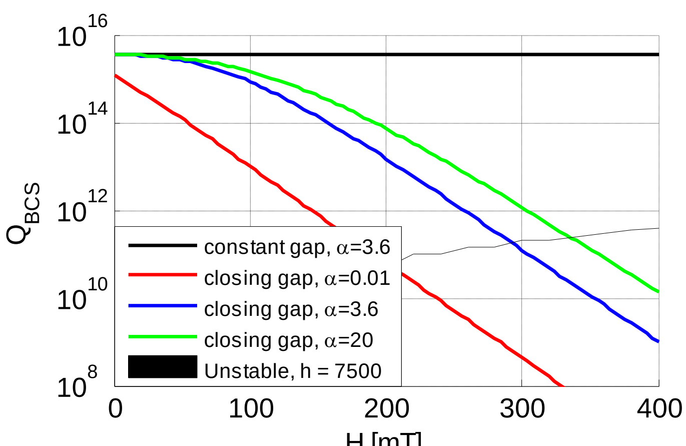
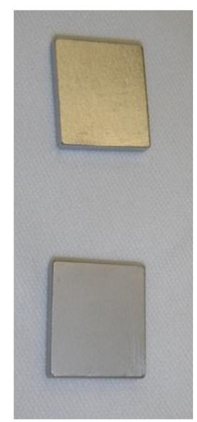
TTC Meeting 2012





Nb_3Sn For SRF Cavities

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- 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 20 years of inactivity. Other labs are now starting Nb_3Sn programs as well.

Previous SRF Research with Nb_3Sn

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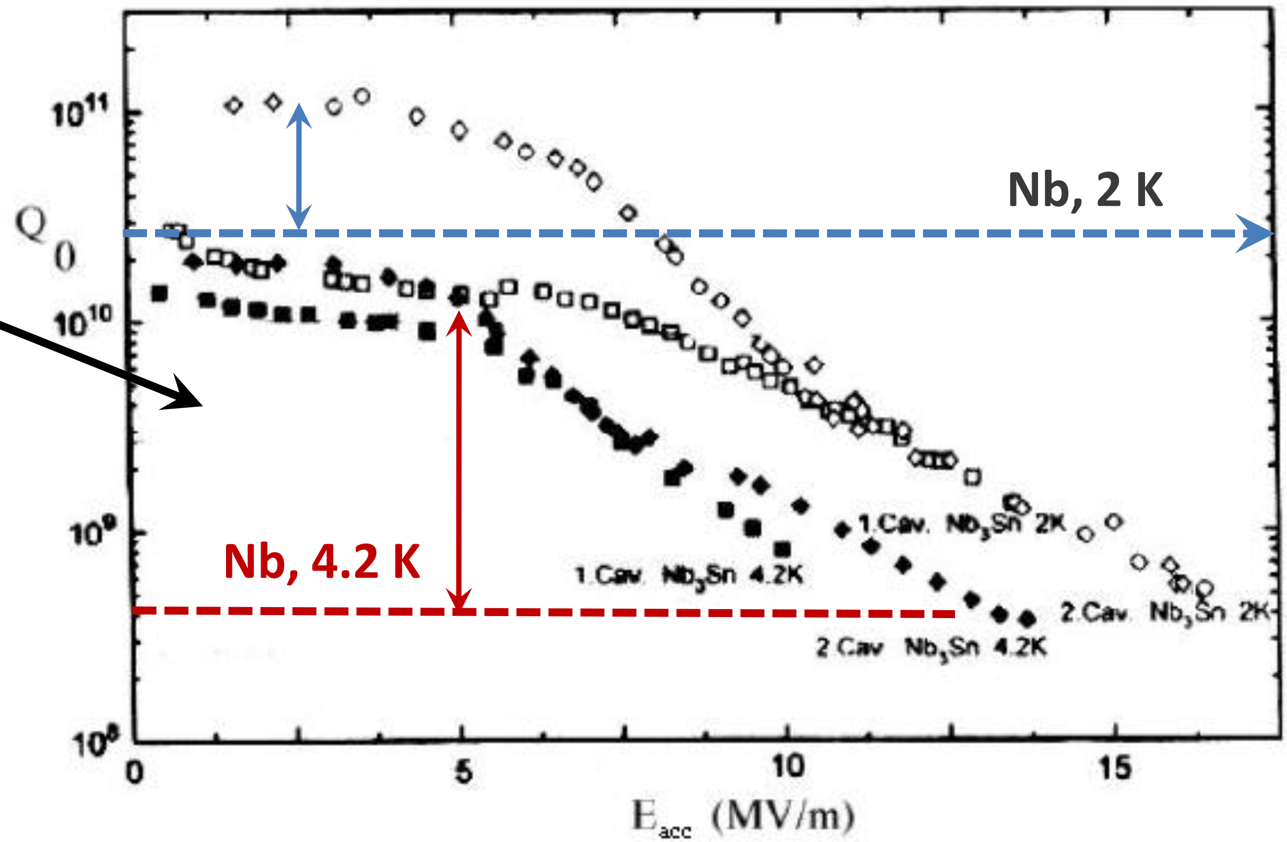
- Siemens AG
- U Wuppertal
- KfK
- JLab
- Cornell
- And others

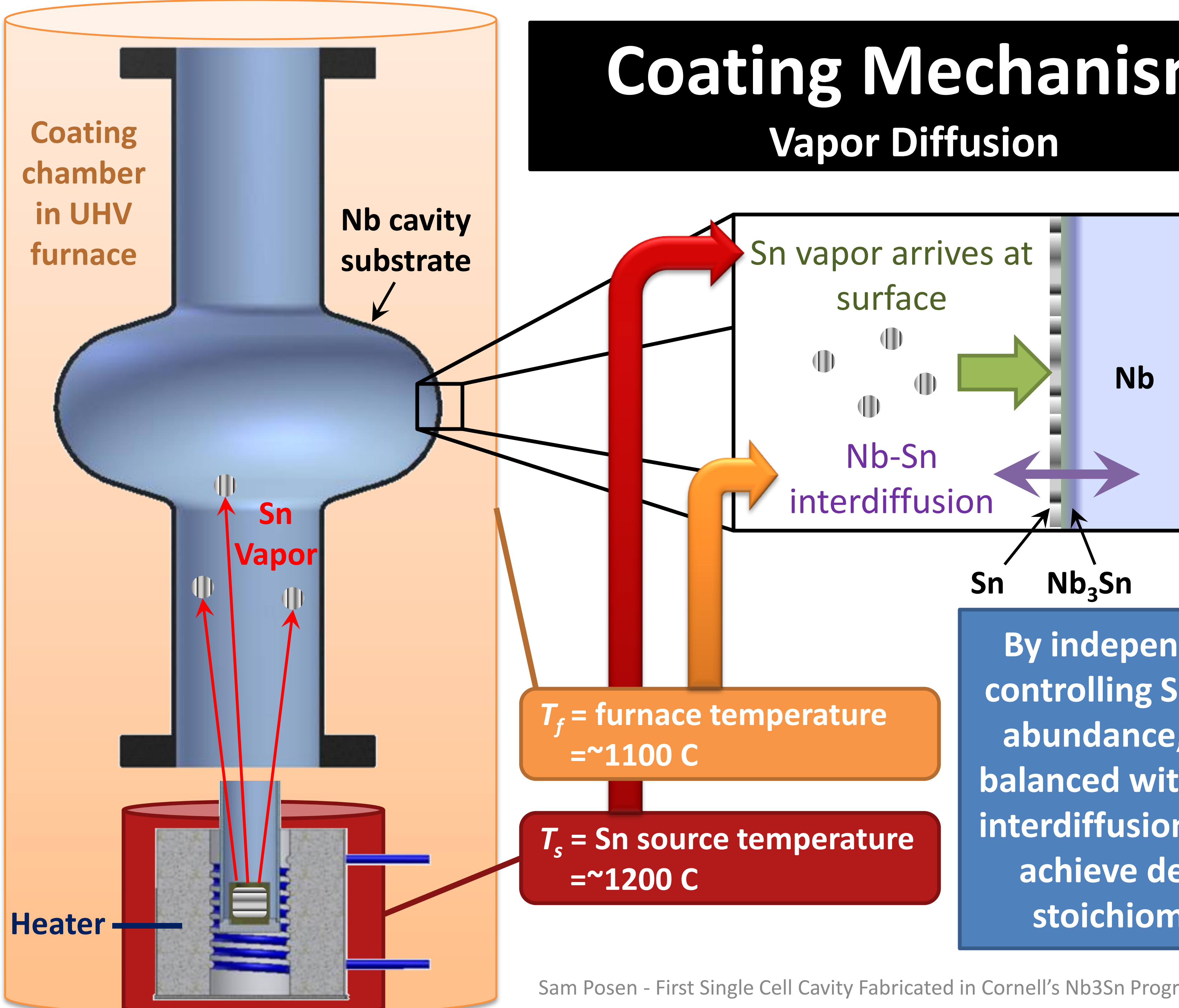


"Determining the origin of these non-linearities and eliminating the possibility that this behavior is not a fundamental property of the films are the next important steps."

–Peter Kneisel, 2012

Coating Mechanism

Vapor Diffusion



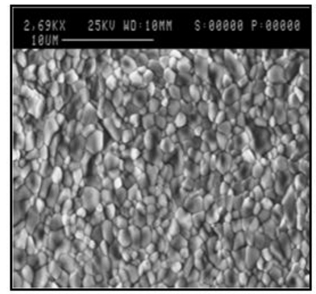
By independently controlling Sn vapor abundance, it can balanced with Nb-Sn interdiffusion rate to achieve desired stoichiometry

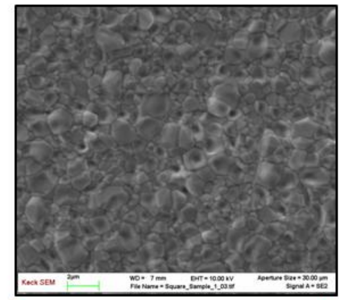
Cornell Sample Results

- 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

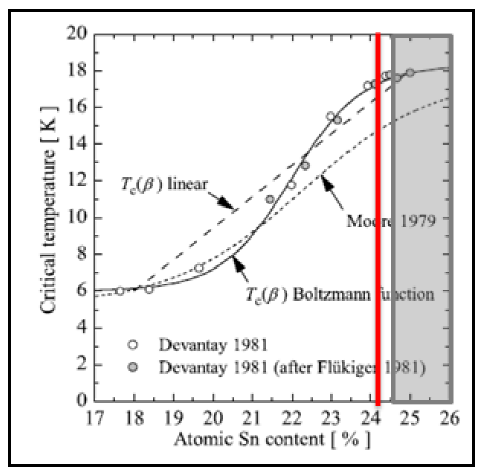
Anodized

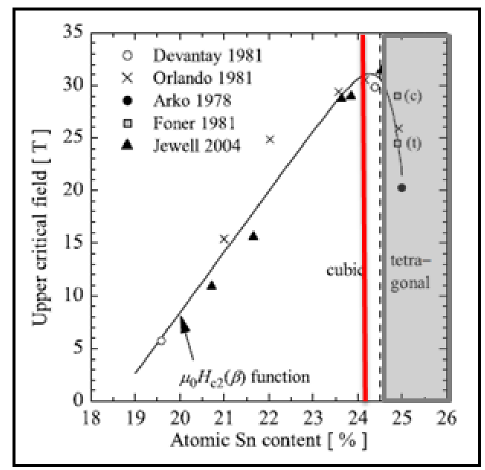




Wuppertal, 1996

Cornell, 2011





Cornell Sample Results

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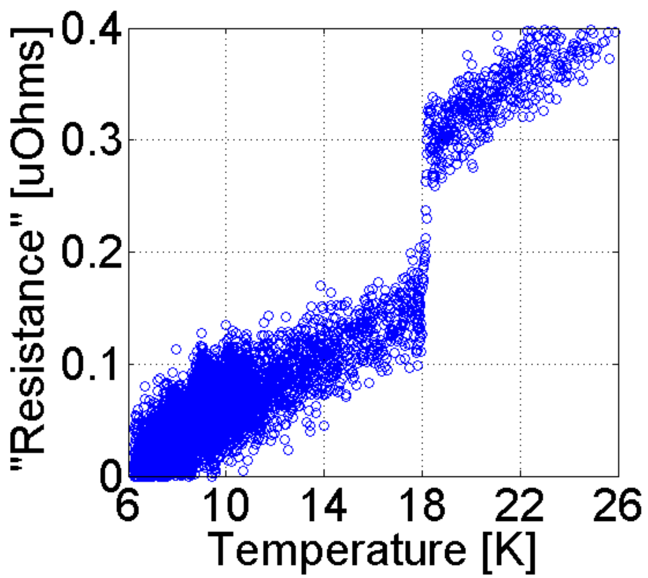
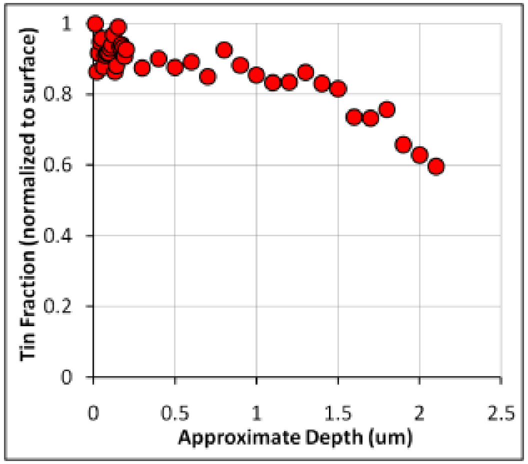
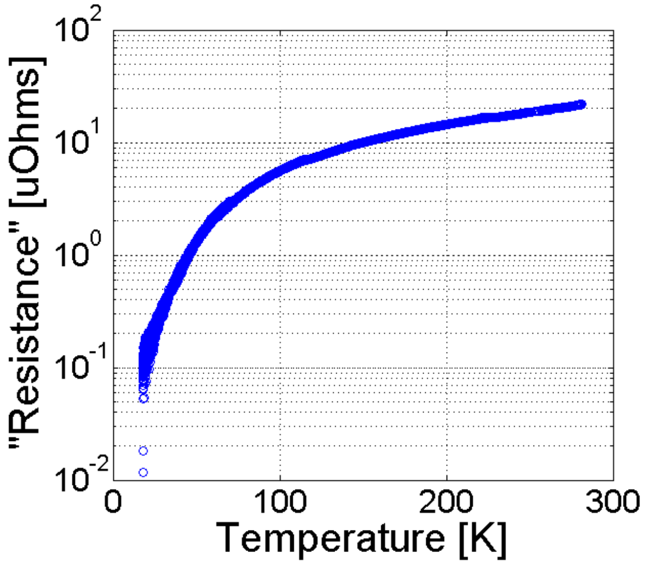
- Appropriate thickness determined through XPS
- T_c and RRR measured through cryogenic 4-wire probe. T_c ~18.1 K near highest literature value. Minimal RRR degradation shown.







Theoretical Developments

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- Lin and Gurevich predicted exponential increase in R_s with B caused by closing quasiparticle gap for RF superconductors
- Numerical simulations at Cornell show excellent range of operation for Nb_3Sn even with gap closing
- Potential for high Q performance at moderate-to-high fields not compromised by this theory
- Thermal instability taken into account

Nb_3Sn with Closing Gap

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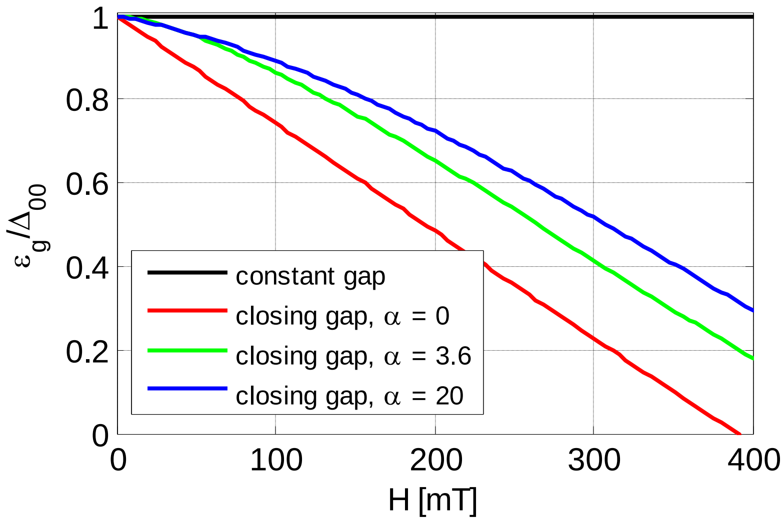
Predicted closing energy gap for Nb_3Sn



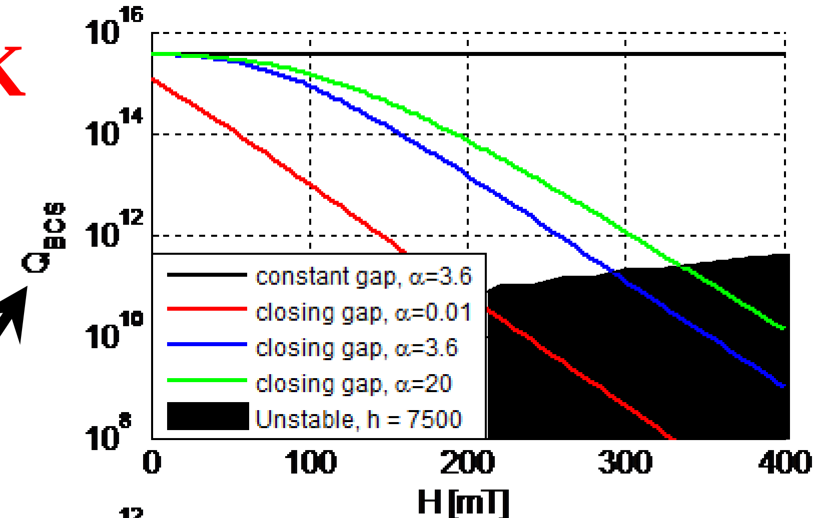
Numerical simulations of $Q_{BCS}(H)$ for a Nb_3Sn-coated ILC Cavity

- At 2 K, max E_{acc}~70 MV/m with Q_{BCS}~$2x10^{11}$
- At 4.2 K, max E_{acc}~40 MV/m with Q_{BCS}~$4x10^{10}$

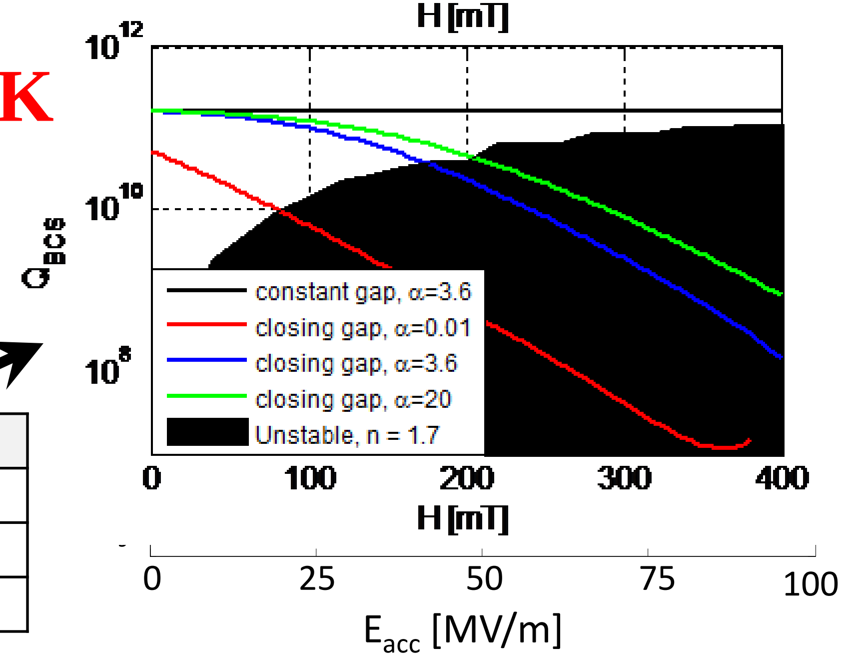
α	Approx RRR
0.01	300
3.6	1
20	0.2

Nb_3Sn-coated ILC cavity with closing gap

2 K

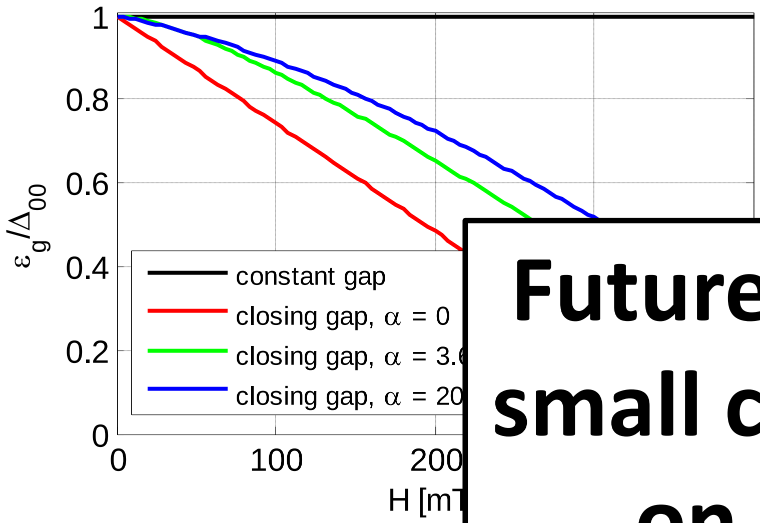


4.2 K

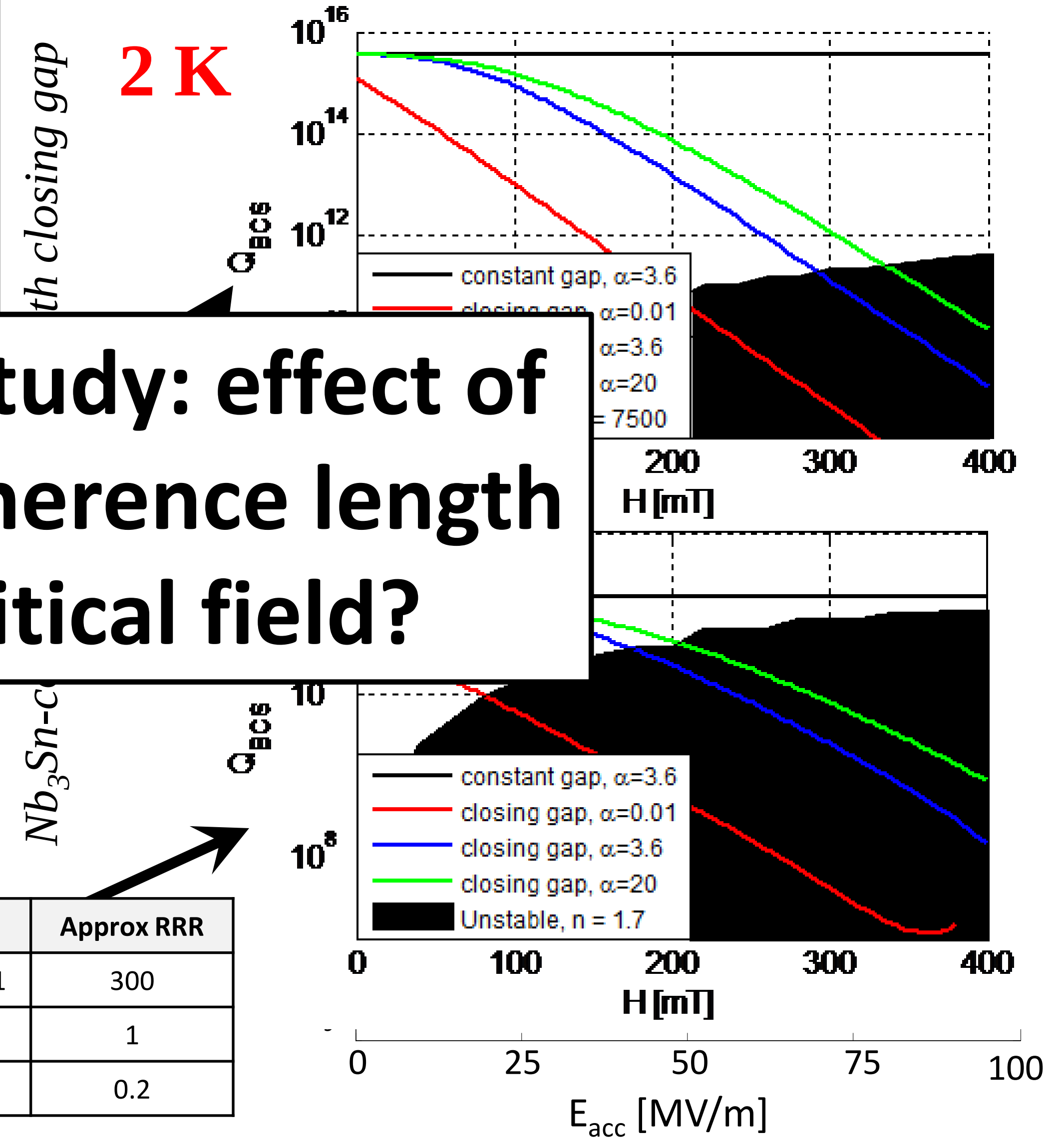


Nb_3Sn with Closing Gap

Predicted closing energy gap for Nb_3Sn



Future study: effect of small coherence length on critical field?



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Single Cell Program

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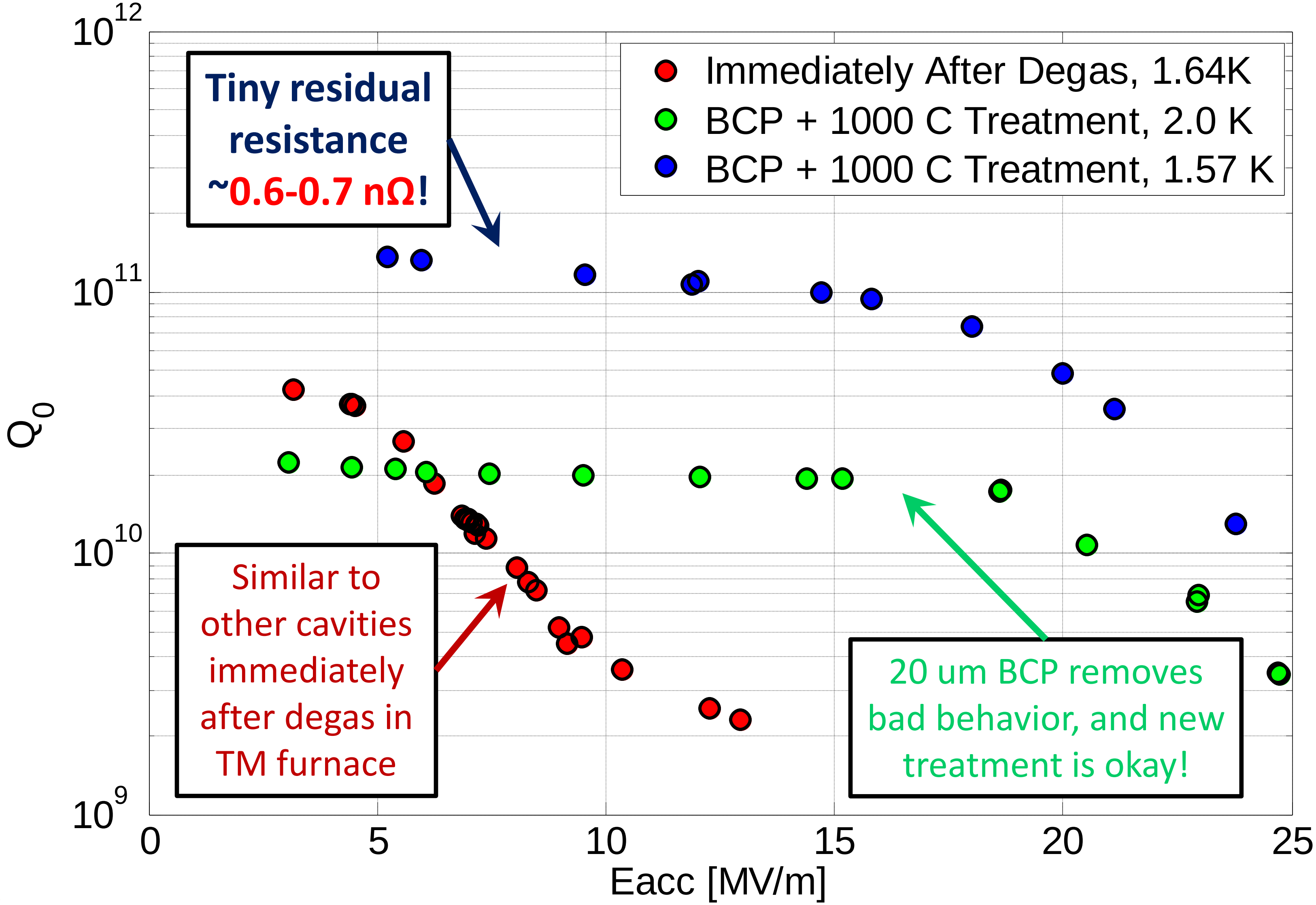
- The first cavity to be coated was given a baseline test **before coating**
- Cornell ERL center cell shape (very close to ILC)
- Preparation
  - Bulk BCP, degas at 650 C for 8 hours -> 1st test
  - 20 um BCP, heat treatment of cavity up to 1000 C in dry run of furnace -> 2nd test

Pre-Coating Performance



Cavity Coating Chamber

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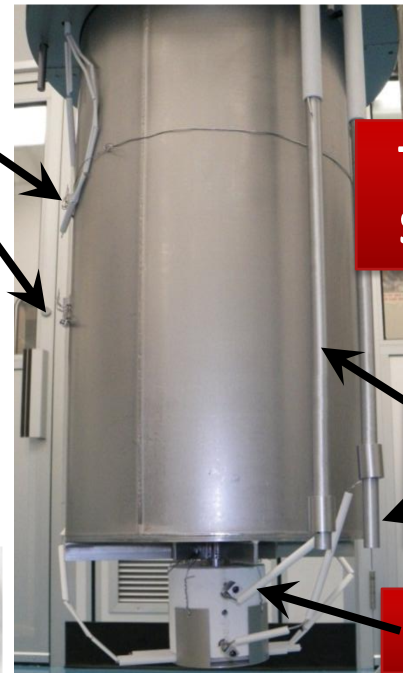
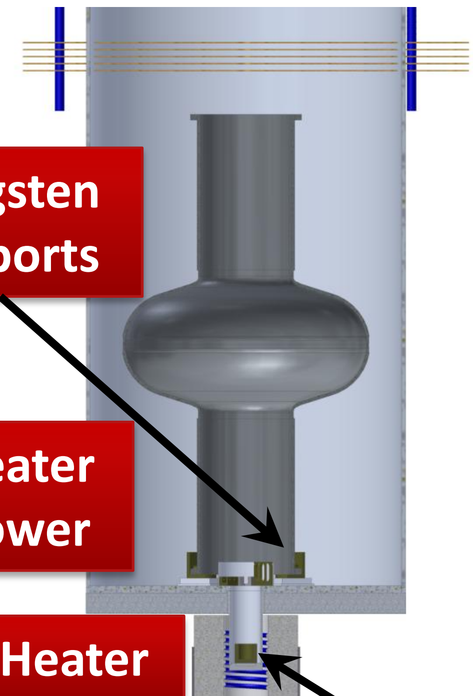
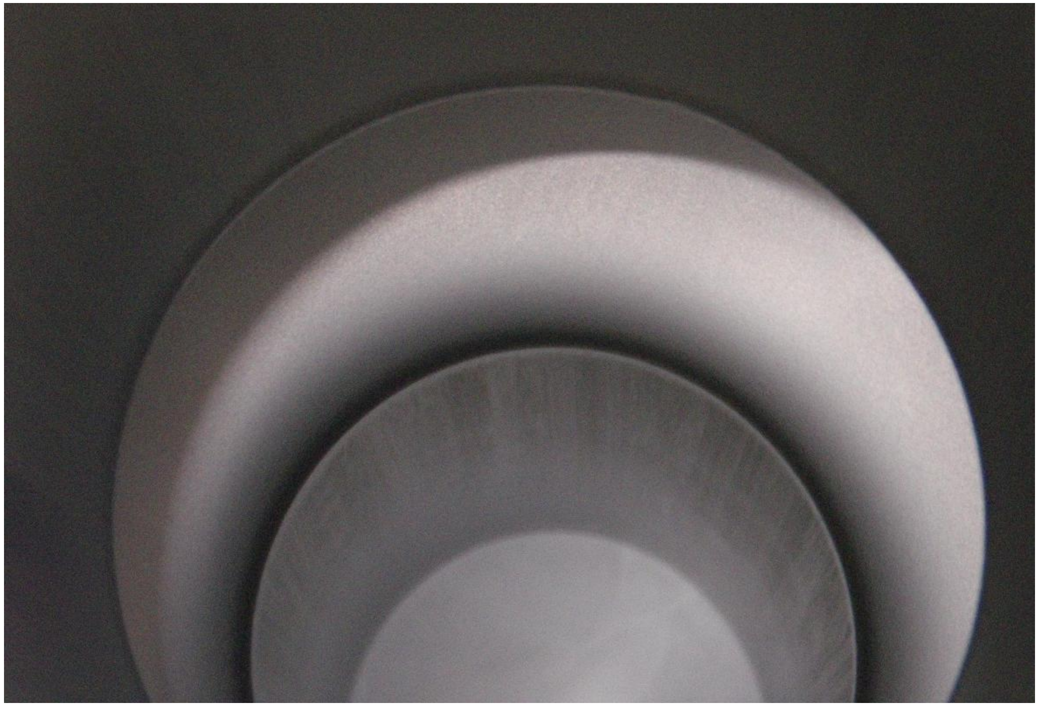
- Degas: 1 day
- Nucleation: 5 hours
- Coating: 3 hours
- Surface diffusion: 0.5 hours





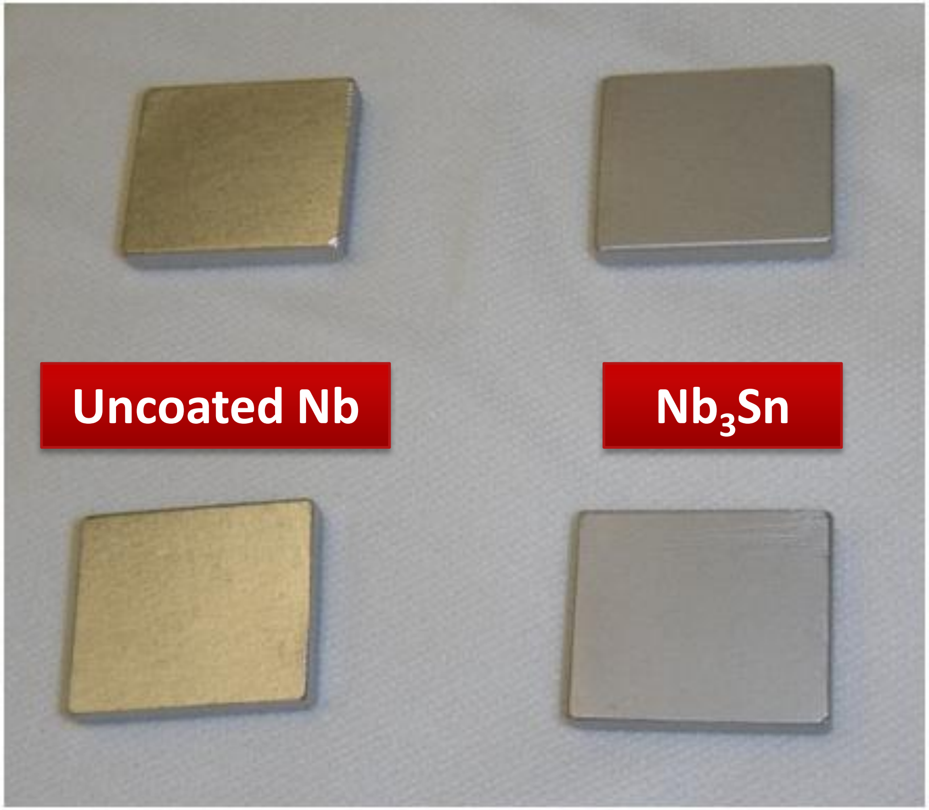
First Coated Cavity!

- No visible tin droplets
- Pictures from Friday – test soon



Before and After Coating

- Witness samples coated with cavity are more matte than uncoated control samples
- Studies to be done on samples
  - Anodization
  - SEM
  - EDX



Summary and Outlook

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- Cornell has proven capability of manufacturing high quality Nb_3Sn on small samples
- First cavity has been coated and will be tested in the coming weeks
- RF performance, T-maps, studies of witness samples will be used to feedback on coating parameters
- This cavity can be etched and recoated or can move on to our second cavity
- After optimization of parameters: EP? 120 C bake? CBP? Multicell?

Acknowledgements

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- Special thanks to J. Sethna for very helpful theoretical discussions
- Special thanks to J. Halbritter for development of SRIMP code and N. Valles for adapting it to Matlab