New material cavity

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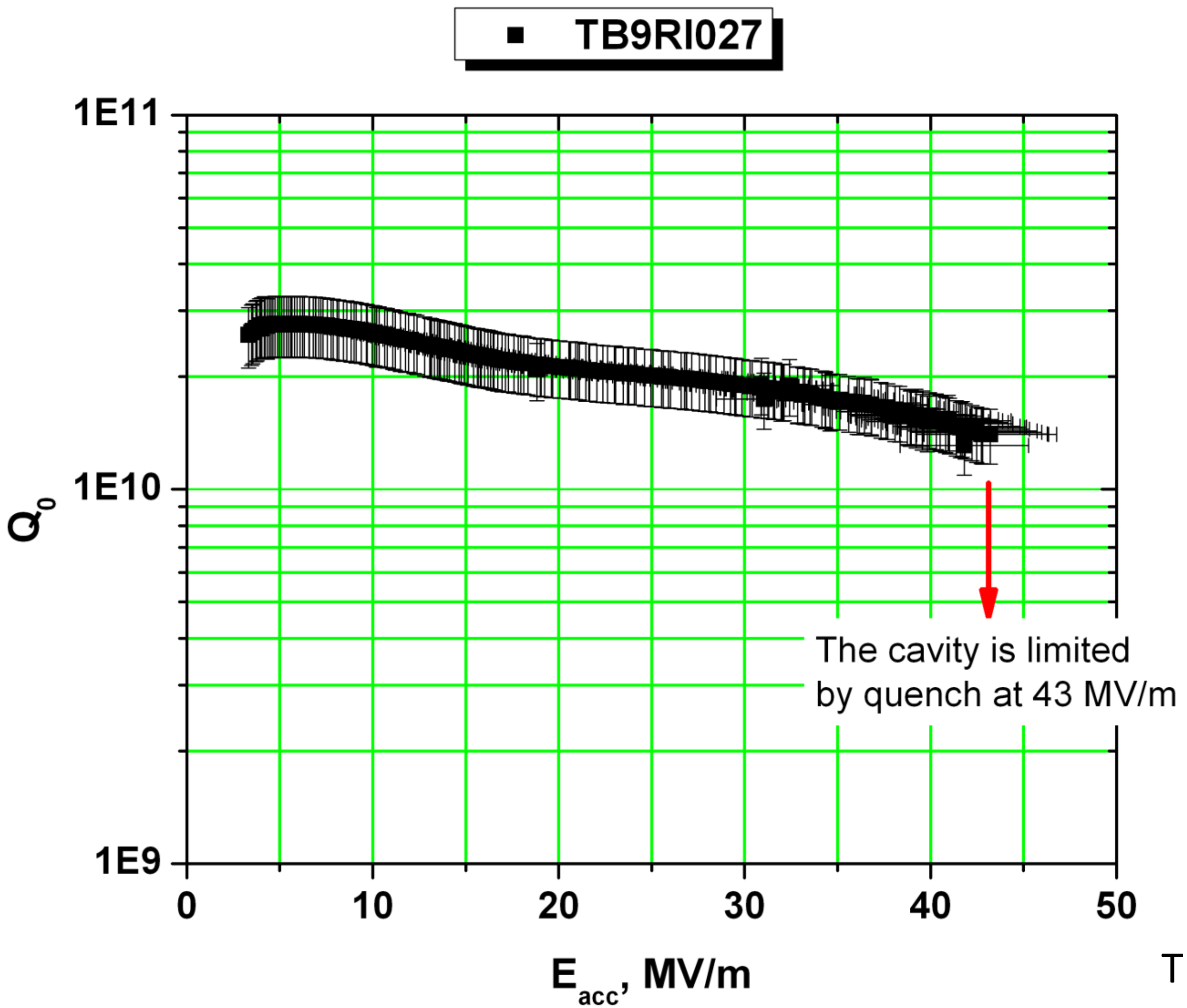
Beyond Niobium Material

- Niobium
  - **35-40 MV/m for TESLA shape cavities**
  - **40-55 MV/m for LL, RE, LSF shape cavities**
    - 60 MV/m seems upper limit w/ further material optimization
- Material beyond niobium
  - **Many candidates on table**
  - **Growing interest**
    - See talks from latest Thin Film Workshop
    - Youtube link http://www.youtube.com/watch?v=vrl9H1Aajql
  - **Need to gap bridge between material fundamental R&D and cavity system development**
  - **Today we will hear two talks**
    - ALD talk by Th. Prolier
    - New material cavity talk by G. Eremeev

From presentation by Rongli Geng here

Motivation



T ~ 1.8 K

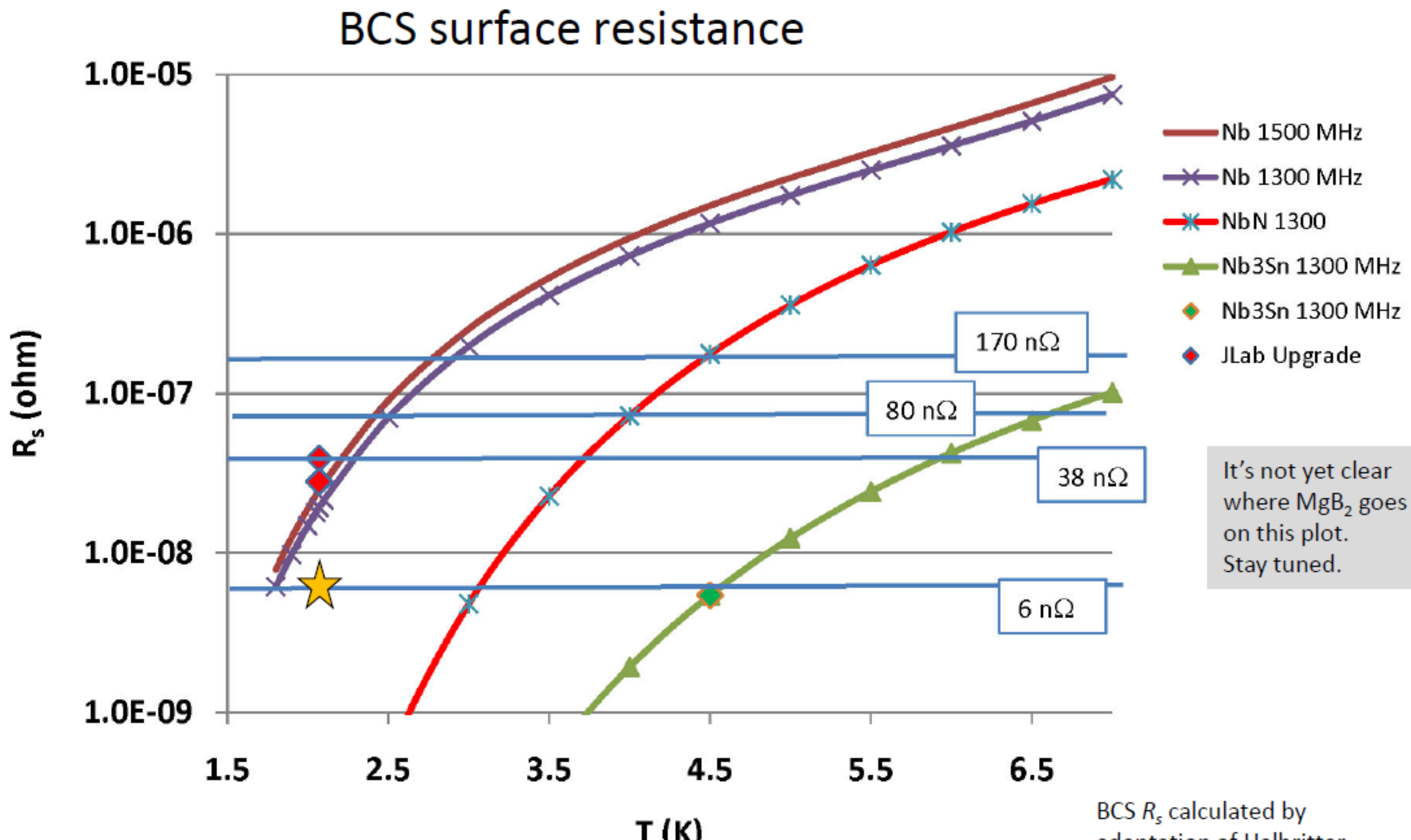
TESLA shaped cavities are reaching close to the fundamental limit of niobium, which should be ~ 50 MV/m. Hence, we have interest in new materials.

Possible Paths to G >> 50 MV/m

- Multilayers Nb/Nb3Sn (NbN) Gurevich
- New high kappa materials
  - Nb3Sn (most experience so far)
  - NbN
    - Best results 500 Oe at 10^{10} Q
  - MgB2 (just starting, samples RF– no cavities)
    - RF measurements show rf losses do not rise until 700 Oe (Tajima/Tantawi)
  - HiTc (YBCO)
    - Very complex, short coherence length
    - Not recommended

From presentation by Hasan Padamsee at SRF 2009, Berlin

The Landscape @ 1300 MHz

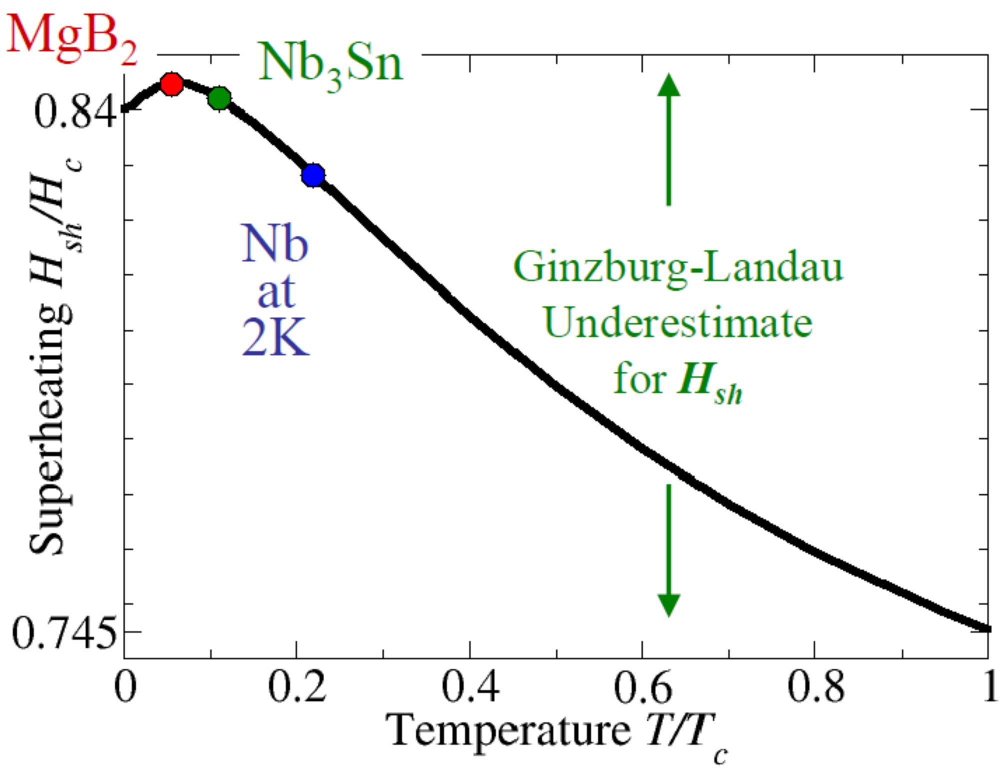


It's not yet clear where MgB_2 goes on this plot. Stay tuned.

BCS R_s calculated by adaptation of Halbritter program my Gigi Ciovati

Sethna: 2007
Eilenberger (Pure BCS) Results !

Superheating field $H_{sh}(T)$ from the Eilenberger Equations
And large κ (so not applicable for Nb)
13% larger ***Hsh*** at low ***T*** than Ginzburg-Landau estimate !



Hrf-critical =
Hsh ~ 0.9 Hc

Which means

G. Catelani and J. Sethna, "Temperature dependence of the superheating field for superconductors in the high-κ London limit," *Phys. Rev. B.*, 78 224509, 2008.

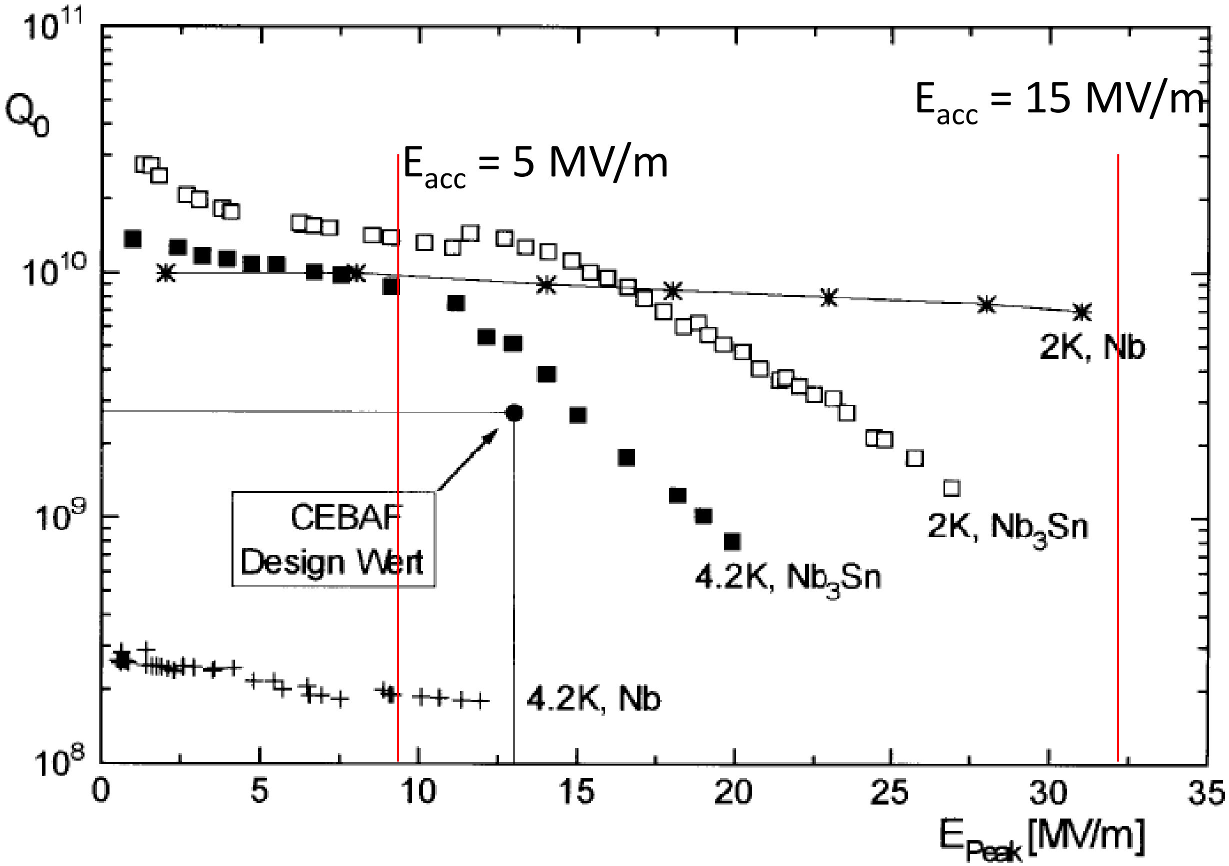
From presentation by Hasan Padamsee at SRF 2009, Berlin

Theory gives hope for 100 – 200 MV/m !

- Eilenberger (BCS) theory predicts
- E_{acc} ~ 120 MV/m for perfect Nb_3Sn
- and 200 MV/m for perfect MgB_2 !!
- This is a strong motivation for materials and cavity push
- But be prepared for a long road to realization..
- Remember how long we took for Nb to reach 30 MV/m..starting in 1965 ! – 45 years
- Can we do it? Where are we now?

From presentation by Hasan Padamsee at SRF 2009, Berlin

The best results with new materials



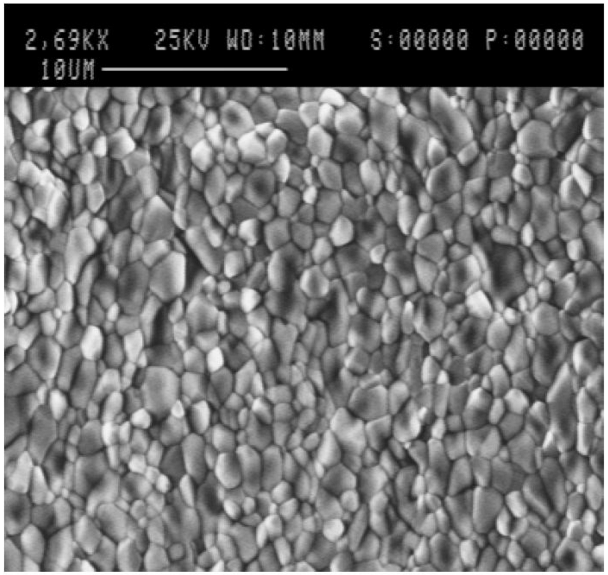


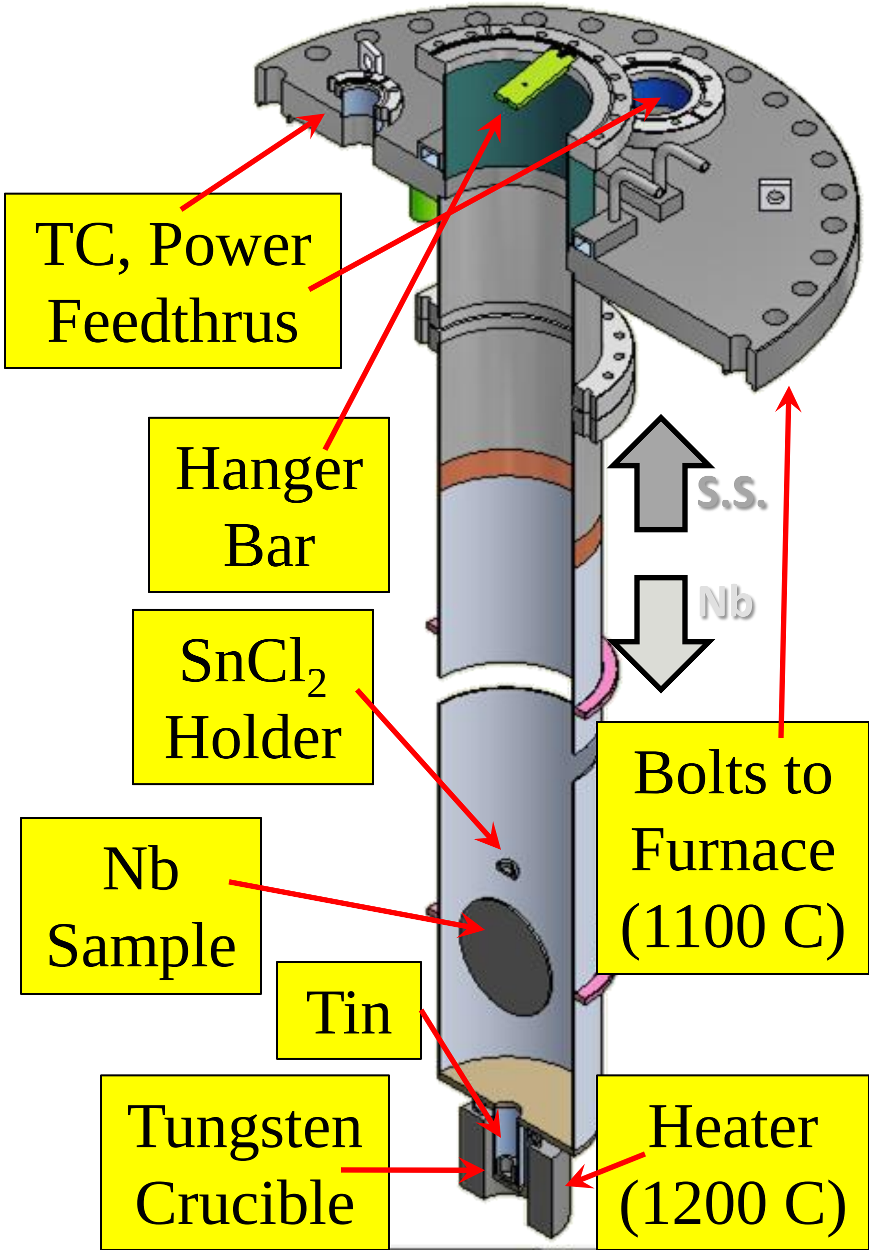
Fig. 2: SEM picture of a typical Nb_3Sn surface as grown for 3h on a high purity Nb sample.

G. Müller, P. Kneisel, D. Mansen, H. Piel, J. Puoryamout, and R. W. Röth. Nb_3Sn layers on high-purity Nb cavities with very high quality factors and accelerating gradients. In S. Myers, A. Pacheco, R. Pascual, C. Petit-Jean-Genaz, and J. Poole, editors, *Proceedings of the 1996 European Particle Accelerator Conference*, pp. 2085–2087, Barcelona, Spain, 1996.

Courtesy of Matthias Liepe and Sam Posen, Cornell University

Cornell Nb_3Sn Furnace Insert

- Vapor diffusion coating method from Wuppertal
- Crucible of Sn is heated in an evacuated chamber
- Evaporated tin coats Nb sample in the chamber
- Insert is compatible with existing UHV furnace
- $SnCl_2$ nucleates growth
- Independently control Nb, Sn temperatures

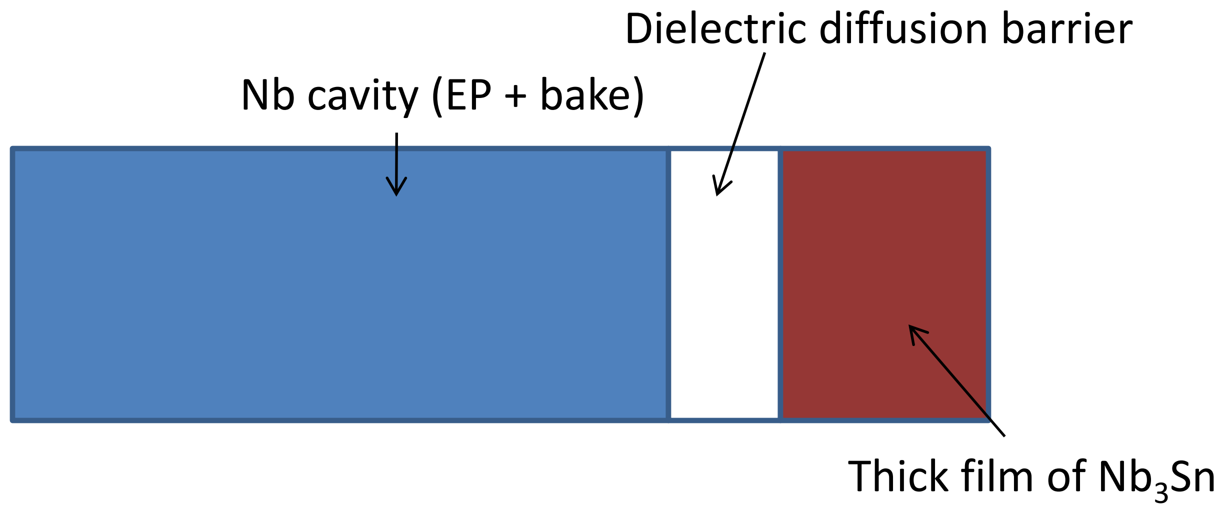


Outlook and Plans

- Characterize Nb_3Sn coatings with surface studies
- Measure RF performance with Cornell TE cavities
- All parts obtained for insert, and machining almost done; hope to start coating mid-November
- Once process parameters optimized, coat cavities
- Use thermometry and Cornell OST quench detection to locate any weak areas in coating during RF tests
- Dissect cavities so that surface studies can be performed on weak areas
- Use this feedback to improve coating technique

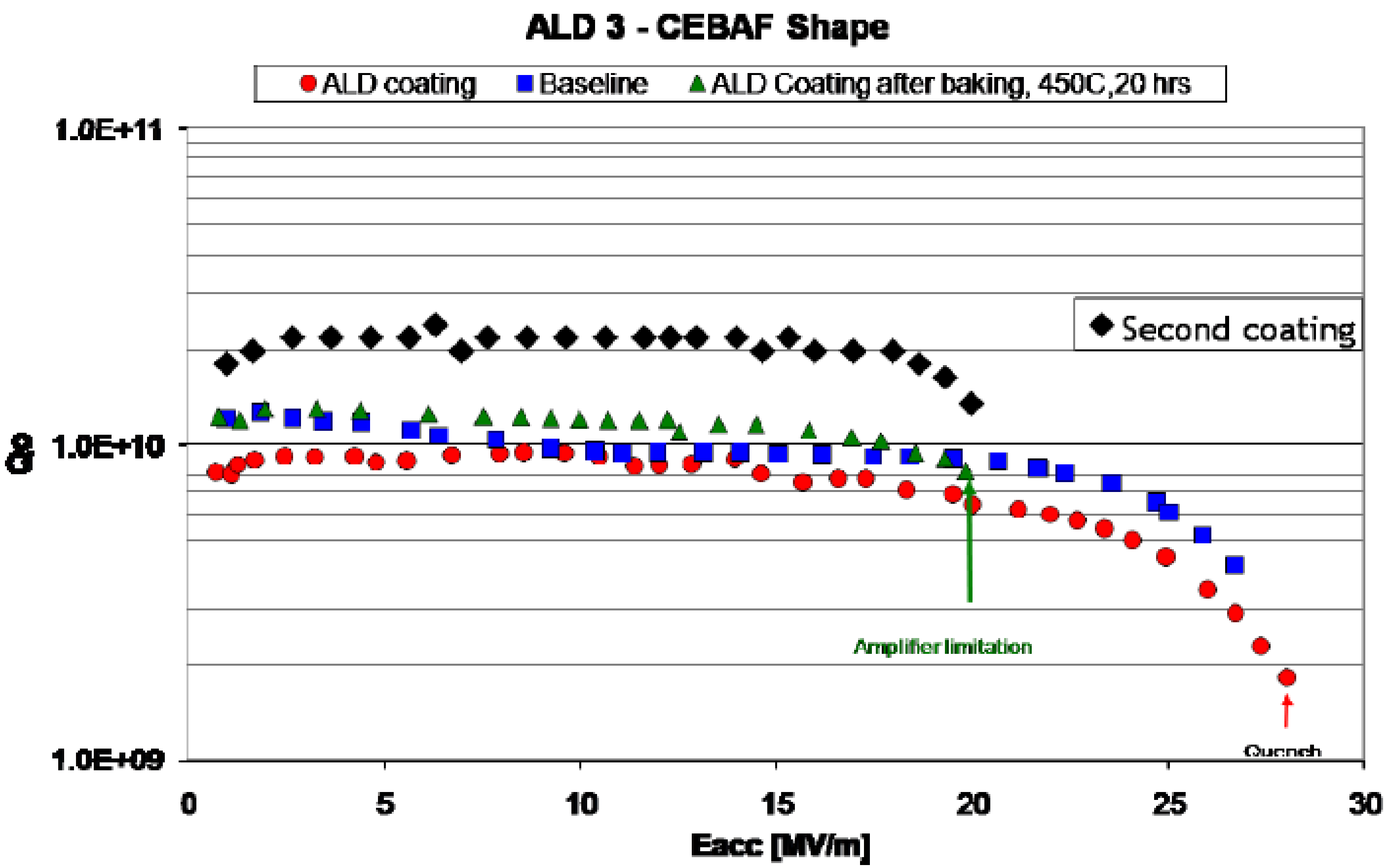
New material cavity at JLab

- We also would like to coat a cavity with Nb_3Sn with good control and flexibility over coating parameters, because superconducting properties depends crucially on stoichiometry: from 18 to 25 at. % Sn, the superconducting transition temperature of Nb_3Sn changes from about 6 K to 18.3 K, and its upper critical field from 6 T to 30 T
- Therefore, the idea is to stabilize the optimal stoichiometry by creating a dielectric diffusion barrier between the niobium substrate and Nb_3Sn film



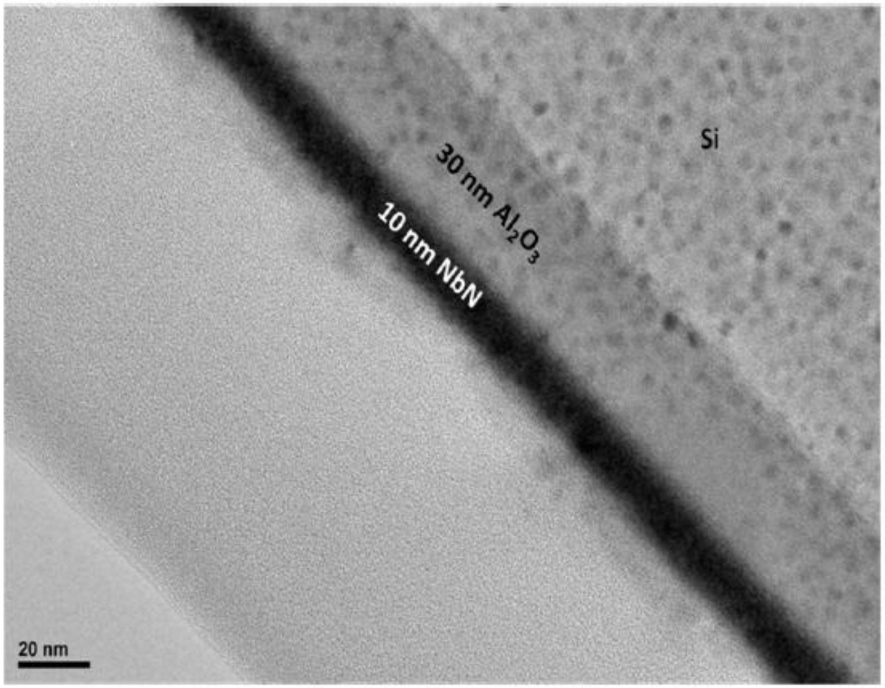
New material cavity at JLab

- Atomic Layer Deposition technique seems to be the best approach to creating a dielectric diffusion barrier



Th. Proslier et al., Proceedings of PAC09, Vancouver, BC, Canada

Cross-sectional TEM Analysis of ALD NbN Film



Cross-sectional TEM image showing a 10 nm ALD NbN thin film deposited on a Si substrate with 30 nm ALD Al_2O_3 film. The ALD NbN film has similar structure as shown in Figure 3 exhibiting NbN crystallites surrounded by amorphous NbN because the film was deposited at 450 °C. Furthermore superconductor-insulator (S-I-S) multilayers were realized by ALD. The TEM micrograph demonstrates that an ALD NbN film was successfully deposited onto ALD Al_2O_3 on Si substrates.

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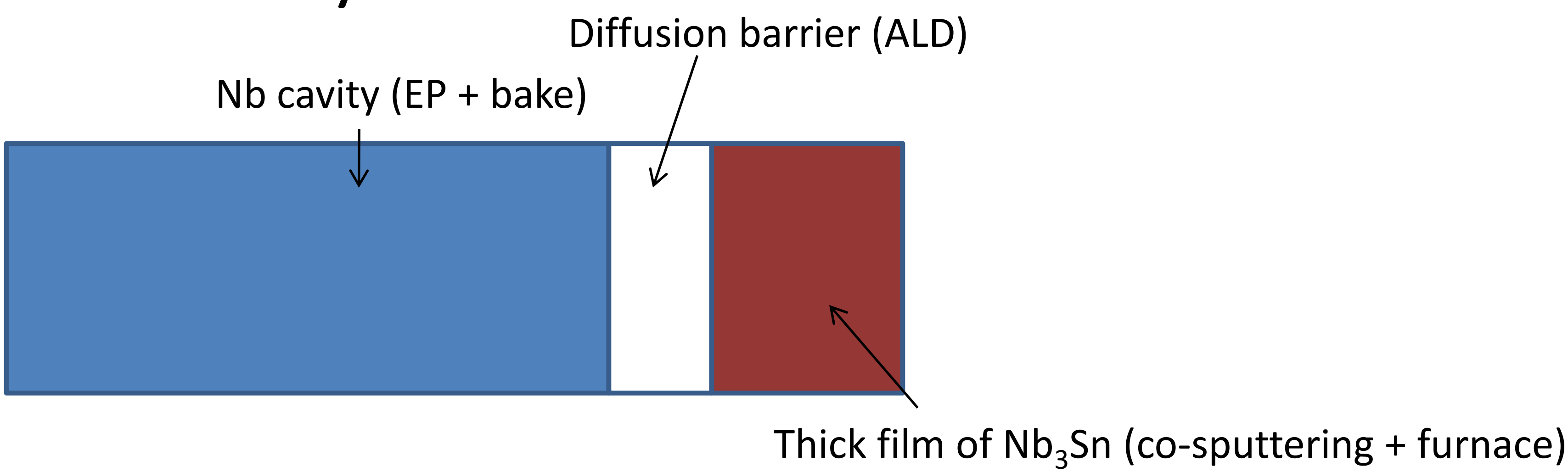
New material cavity at JLab

- Sputtering seems to be the best approach to deposit Nb and Sn on SRF cavity surface
- After sputtering, apply annealing in order to achieve the desirable phase

New material cavity at JLab

- Ideally, we would like to built a system specifically design for 1.3 ILC cavity ALD and sputtering coating. This will allow control and flexibility.



Timeline

1st year	Identify critical parameters for ALD and sputtering systems, and design ALD and sputtering systems around those parameters to coat SRF cavity
2st year	Build ALD and sputtering systems
3st year	Commissioning and studies of coated samples with RF and surface studies techniques
4st year	Studies of coated samples with RF and surface studies techniques, studies of coated cavities with RF and thermometry, cavity dissections studies
5st year	Studies of coated cavities with RF and thermometry, cavity dissections studies

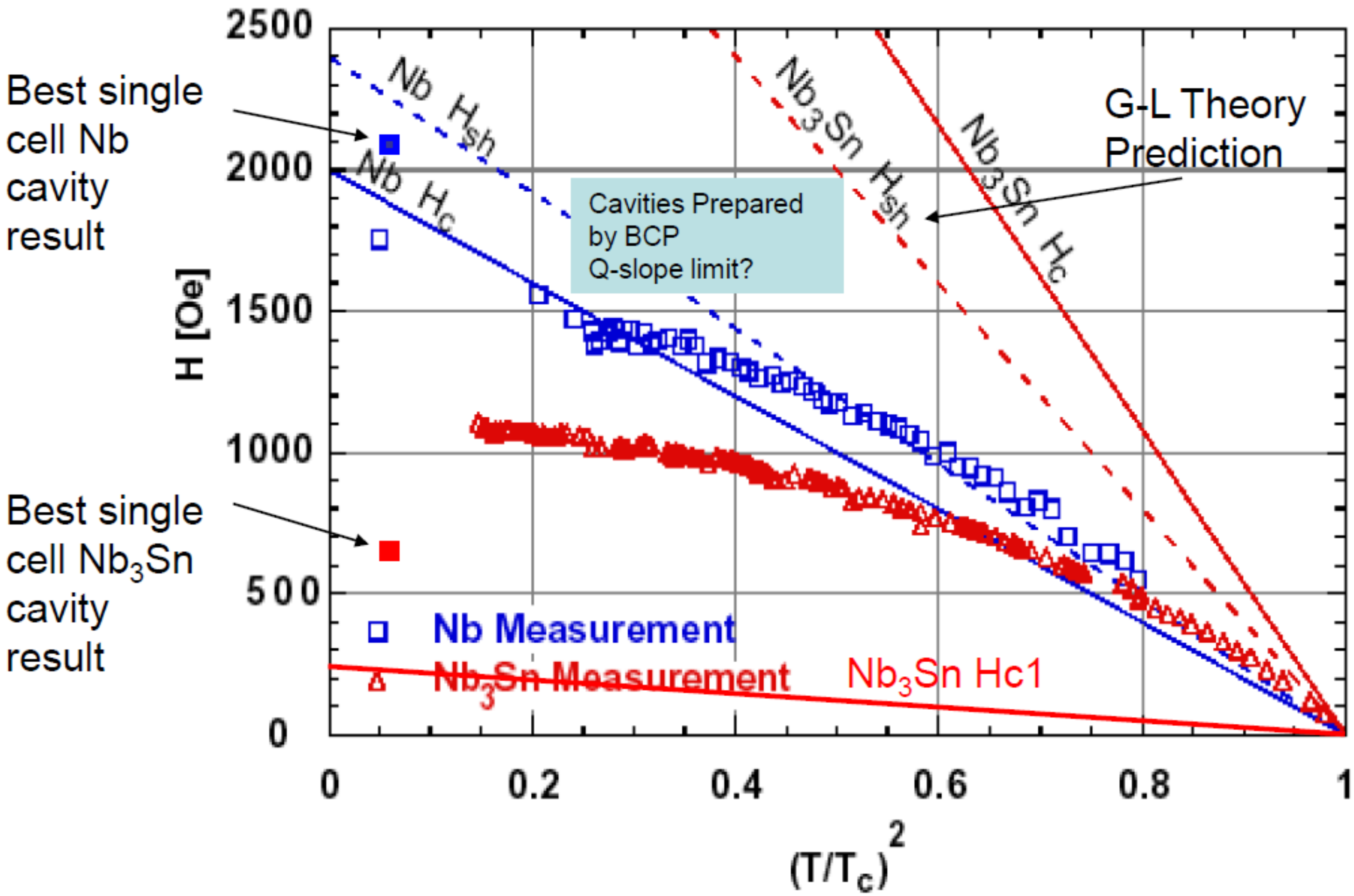
Closing remarks

- New materials is a high risk, but also high reward approach to gradients above 50 MV/m
- Nb_3Sn is the best studied new materials, but we still need a systematic study of this compound in SRF cavities
- It is essential to perform such a study on real SRF cavities in order to get values of interest: residual resistance, field dependence of RF resistance, and limiting fields!!

THANK YOU!

Pulsed Measurements Encouraging
Measured RF Critical Field for : Nb_3Sn Using High Pulse Power
(Calibrated results with Nb)

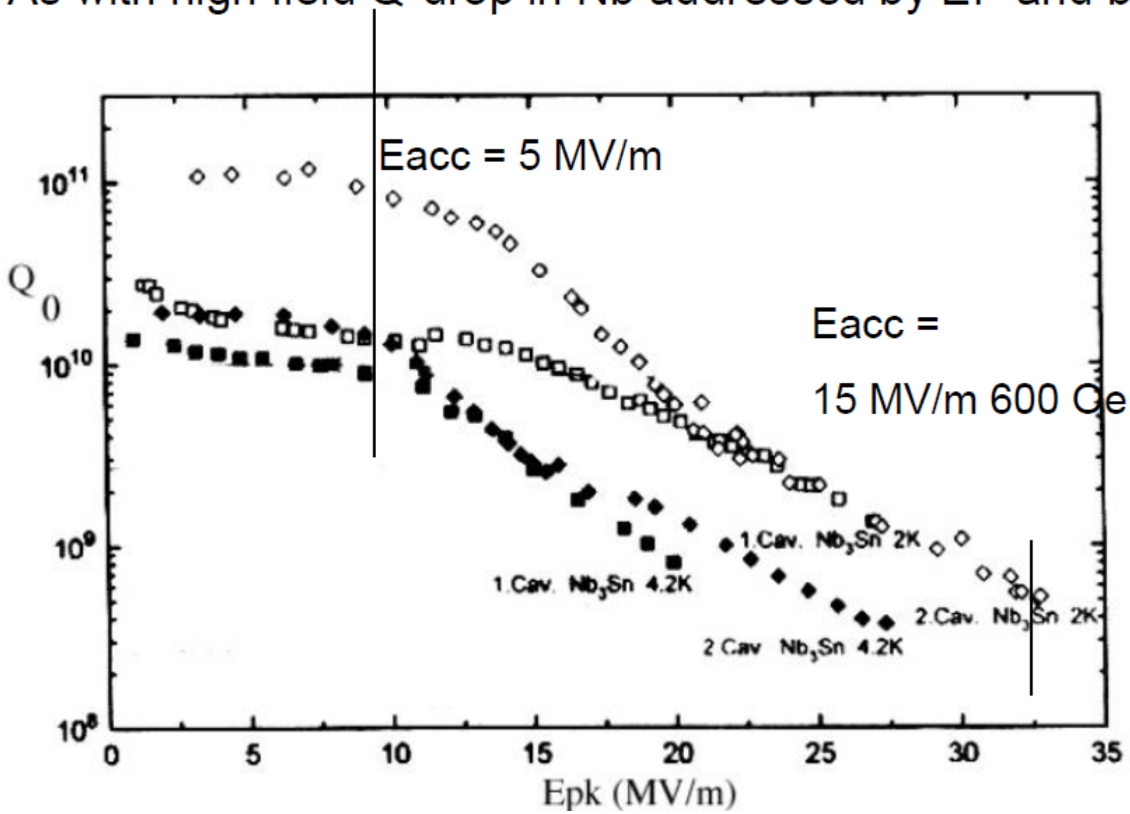
Important: Hrf-crit for Nb3Sn > Hc1..



From presentation by Hasan Padamsee at SRF 2009, Berlin

Best CW Result for Single Cell Nb3Sn Cavity 1300 MHz (Mueller and Kneisel)

- Q-slope observed in CW measurements may be addressed by improved material preparation
- As with high field Q-drop in Nb addressed by EP and baking.



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