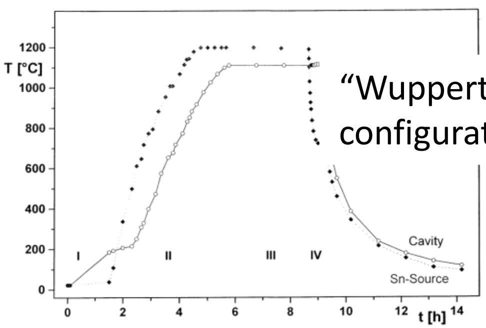
# Progress with multi-cell $Nb_3Sn$ cavity development linked with sample materials characterization

Grigory Eremeev

# Experimental setup

Typical temperature settings to grow $Nb_3Sn$ by vapour diffusion



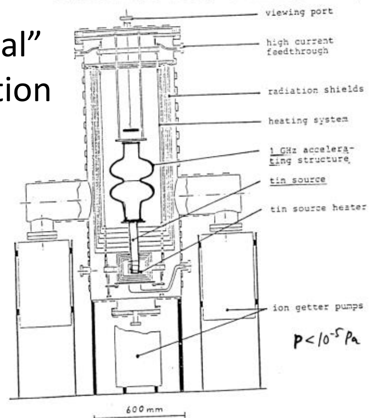

"Wuppertal" configuration

G. Mueller, TESLA 2000-15

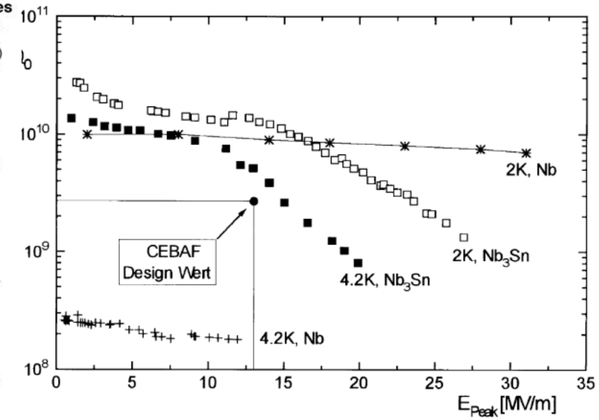
G. Müller, P. Kneisel, D. Mansen, H.Piel, J. Pouryamout, R. W. Röth, EPAC'96

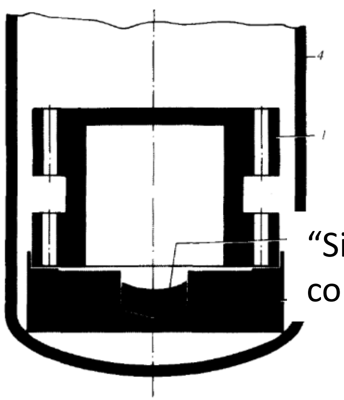
**Fabrication of $Nb_3Sn$ Layers on Bulk Nb Cavities by means of the Vapour Diffusion Technique**

$Nb_3Sn$ coating furnace for accelerator cavities (f≥1Ghz, L≤1m) with seperate heaters for cavity and Sn source (T≤1200°C)




⇒ Improved nucleation of $Nb_3Sn$ especially on high purity Nb by $SnCl_2$ (at T≥200°C) and oversaturated Sn pressure (1Pa)

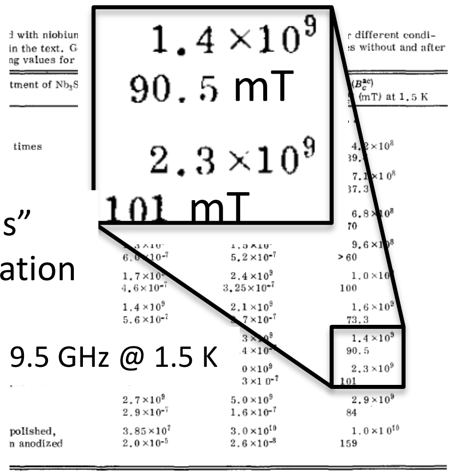


"Siemens" configuration

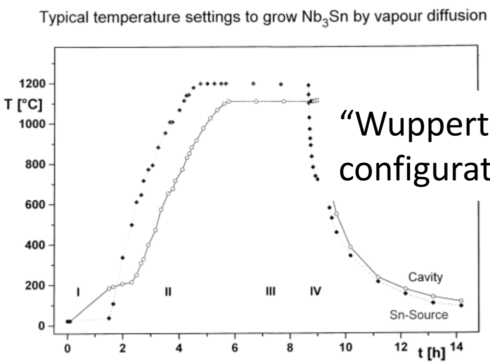
FIG. 1. All-niobium inner reaction room, consisting of the niobium cavity (1) and the niobium bottom plate (2) containing the tin source (3). The lower part of the quartz ampulla (4) is inserted into a resistance furnace.

B. Hillenbrand and H. Martens, J. Appl. Phys. 47, 4151 (1976)




9.5 GHz @ 1.5 K

# Experimental setup




“Wuppertal” configuration

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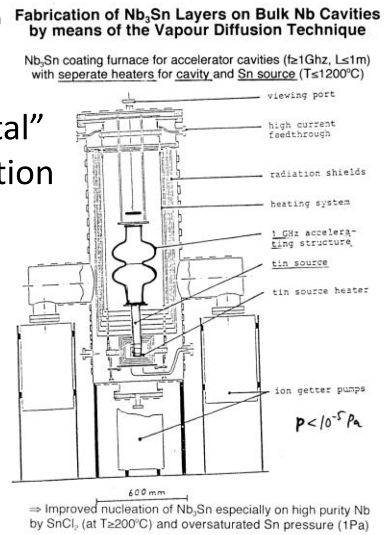
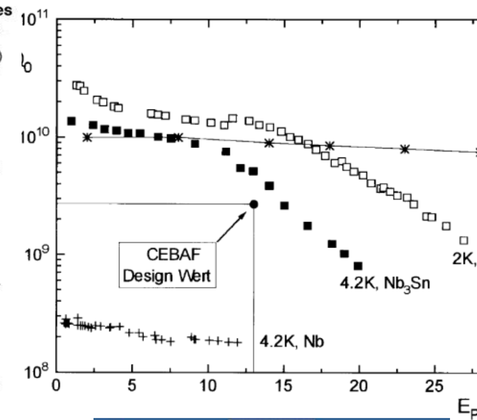
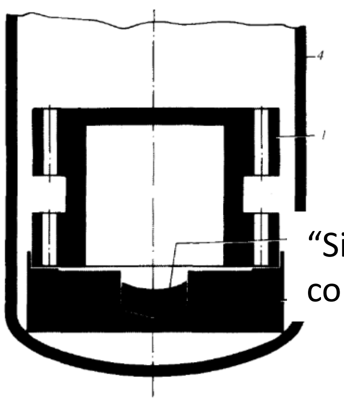



We run “Siemens” configuration

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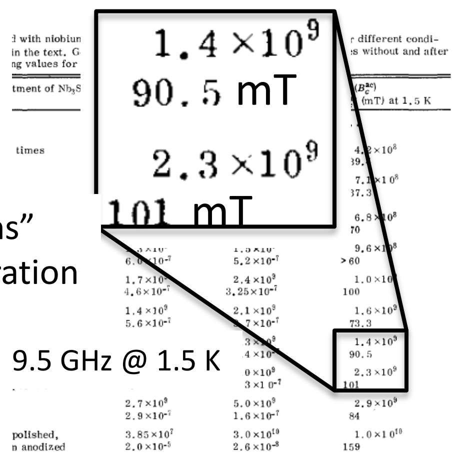
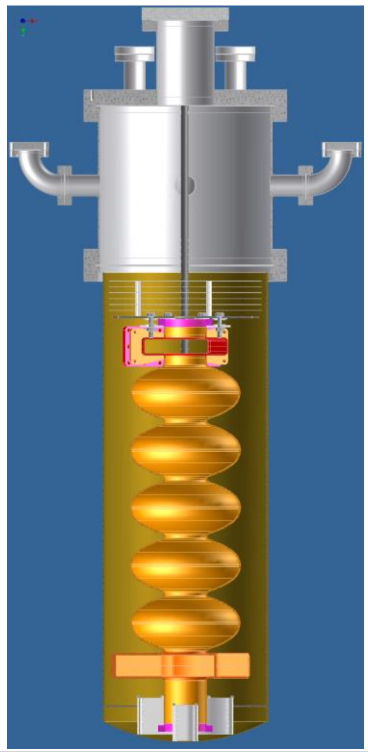
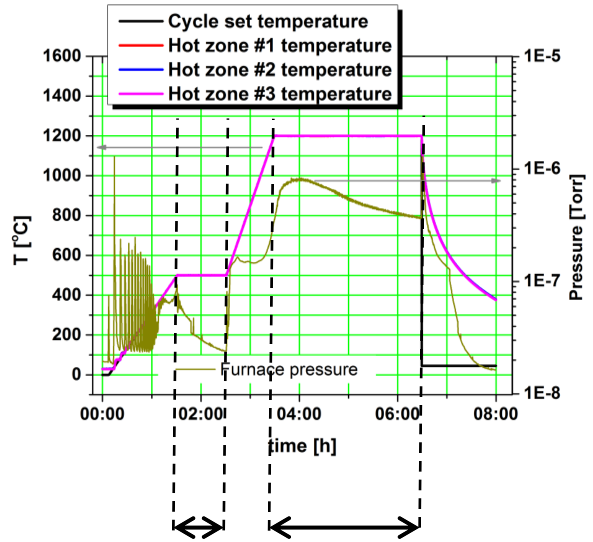



9.5 GHz @ 1.5 K



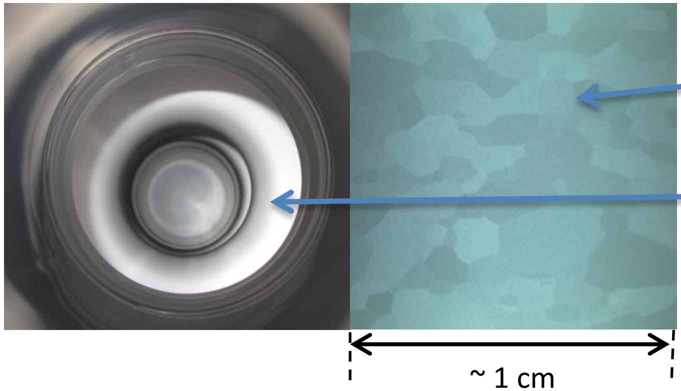



Sn seeding @ 500 °C x 1 hr

$Nb_3Sn$ growth @ 1200 °C x 3 hrs

3 gr of $SnCl_2$ per cavity, 3 gr of Sn per cell

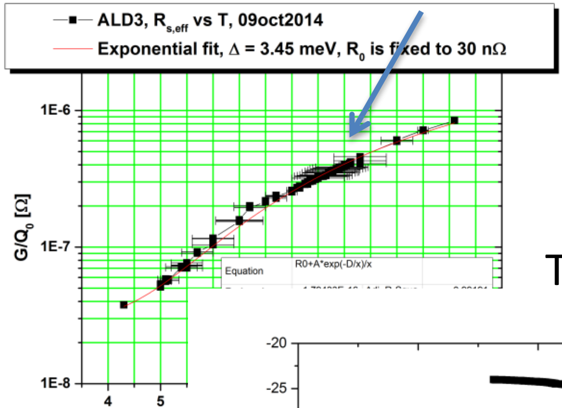
# Cavity experimentation



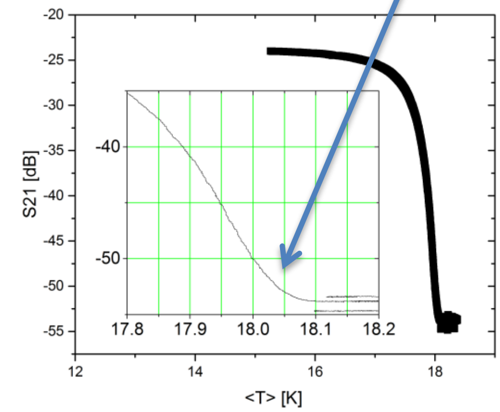

Nb$_3$Sn on Nb grains

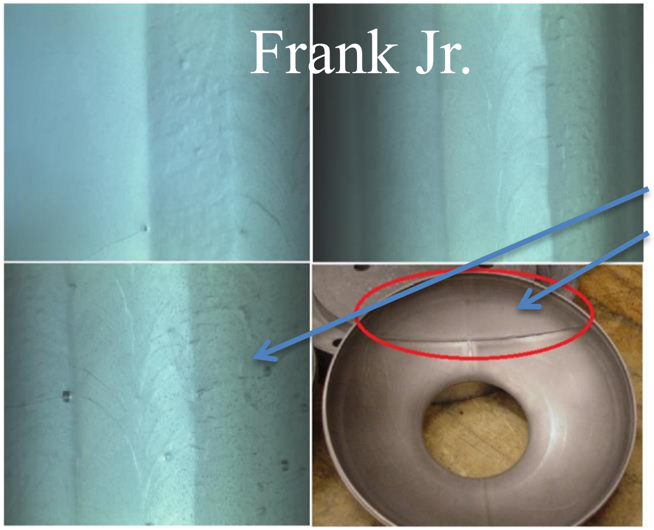
Nb$_3$Sn coated surface

Δ= 3.4 meV, ~2x larger than that of niobium



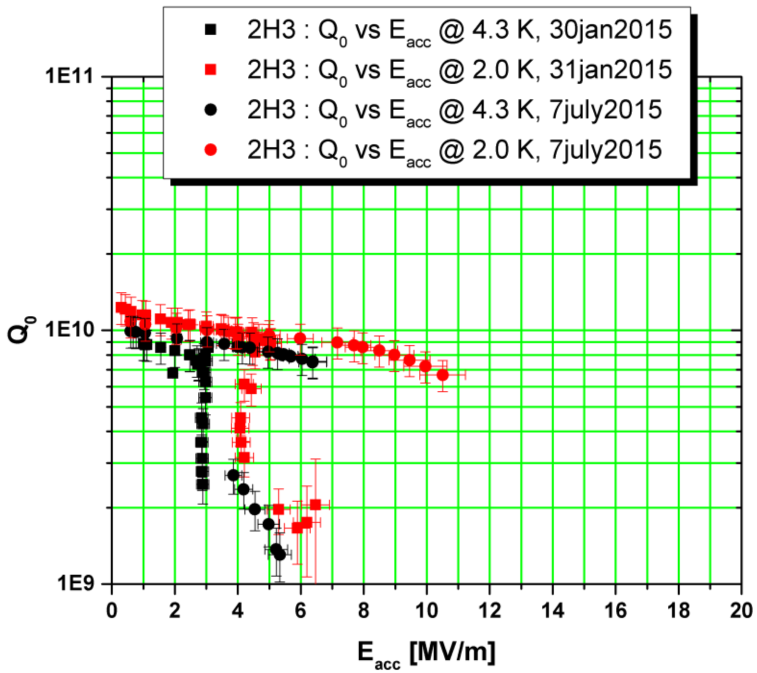

T$_c$ ≅ 18 K



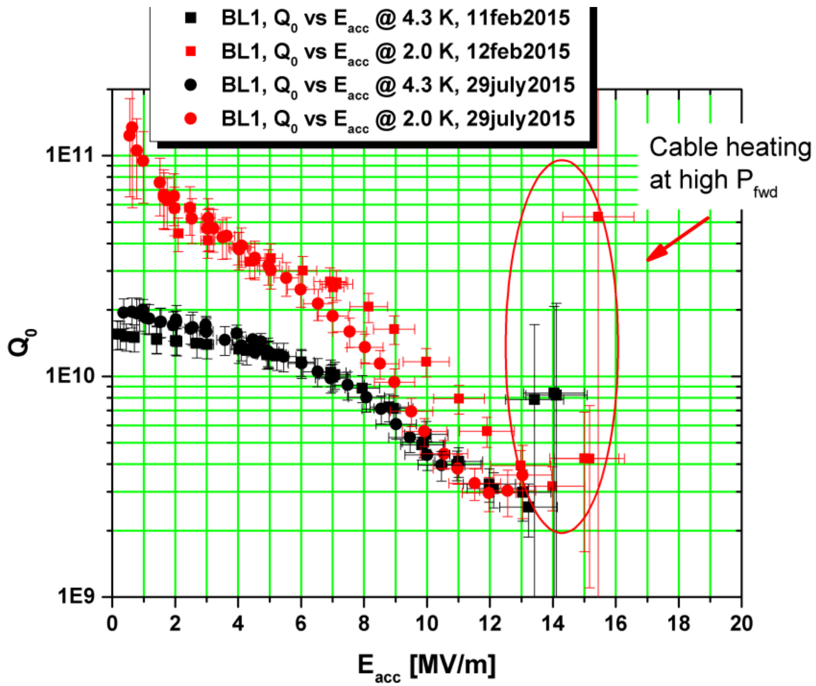




Features were confined to one strip of niobium. The rest of the surface had visually uniform Nb$_3$Sn coating

# Summary of cavity results



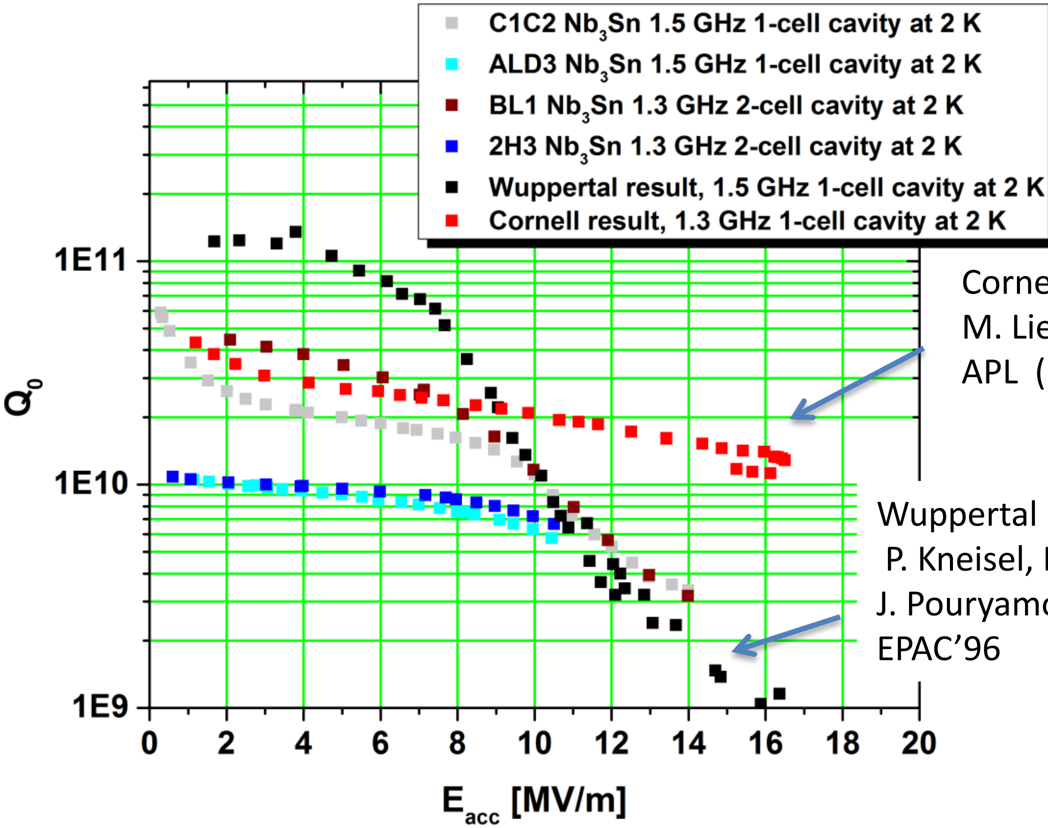

Reproducible $Q_0$ at 4.3 & 2.0 K after re-coating. Quench gradient improved after 5 µm EP before the second coating.




Reproducible $Q_0$ at 4.3 & 2.0 K after re-coating. Variation in the Q-slope probably due to FE.

# Summary of cavity results

The coating results in Q0 ~ 1E10 below 4.3K for *most* cavities. The cavities are limited by $Q_o$ degradation and low field quench. Coatings are reproducible for the same cavity.




Cornell data, S. Posen M. Liepe, and D. L. Hall, APL (2015)

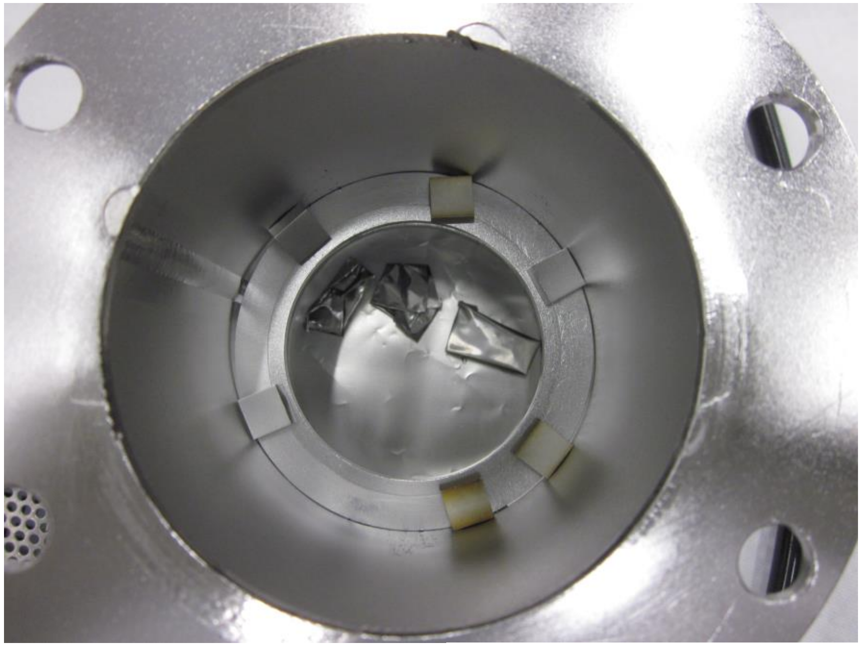
Wuppertal data, G. Müller, P. Kneisel, D. Mansen, H. Piel, J. Pouryamout, and R. W. Roth, EPAC'96

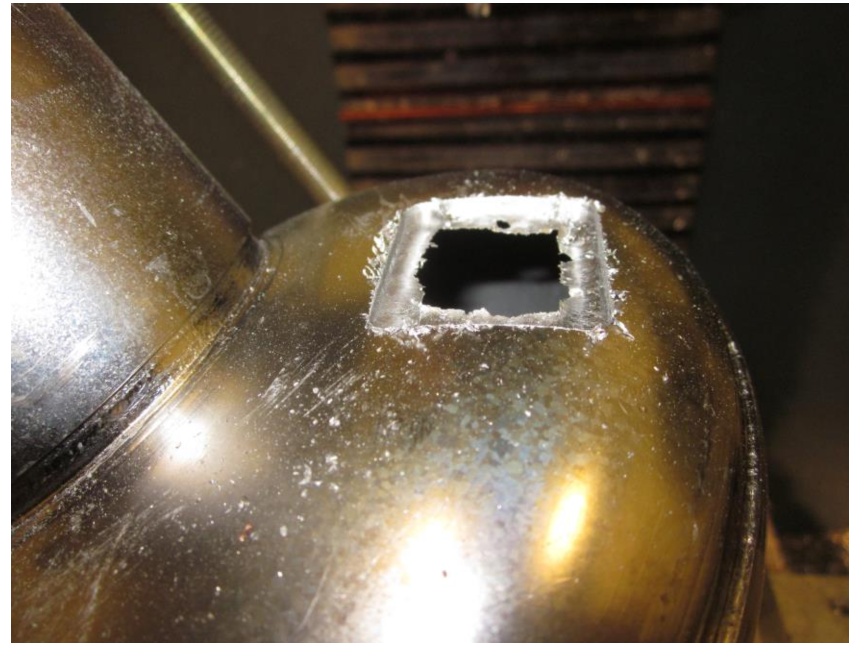
**The potential reasons for $Q_o$ degradation are:**

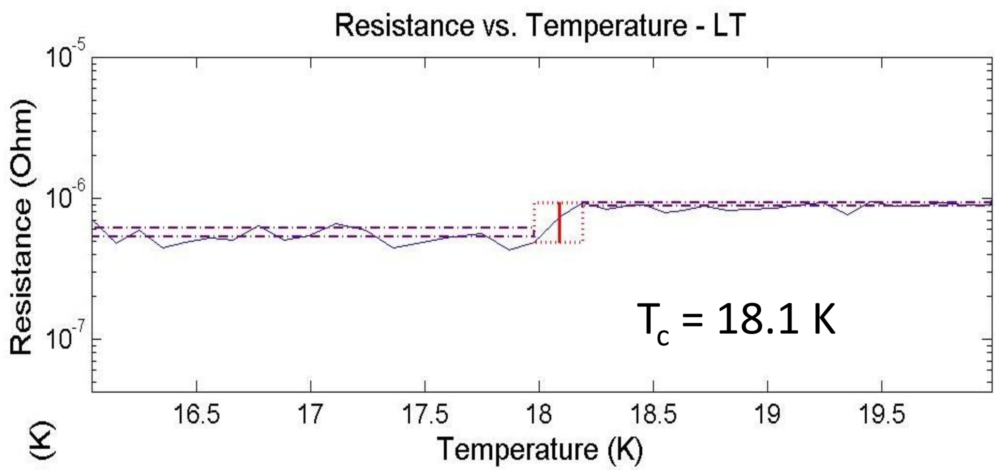
**Diffusion driven process -> Sn gradient -> stoichiometry variation?**

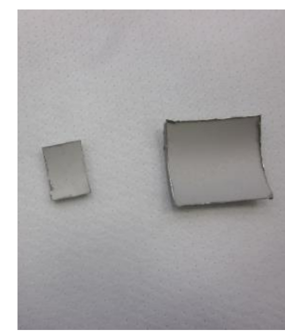
**Cl or Ti contamination?**

# Modelling and analysis approach

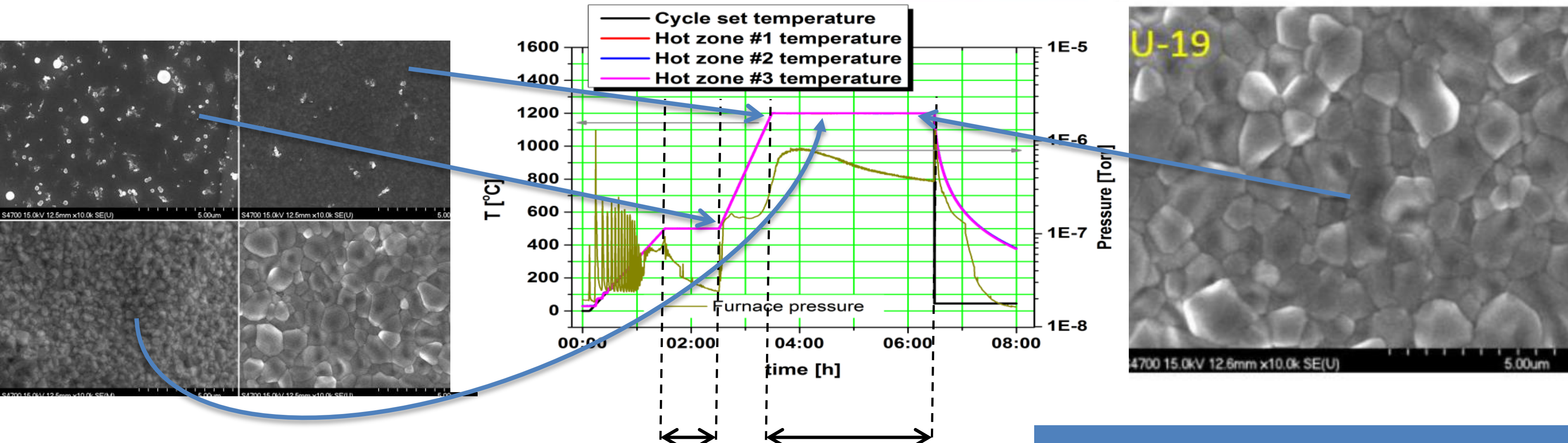






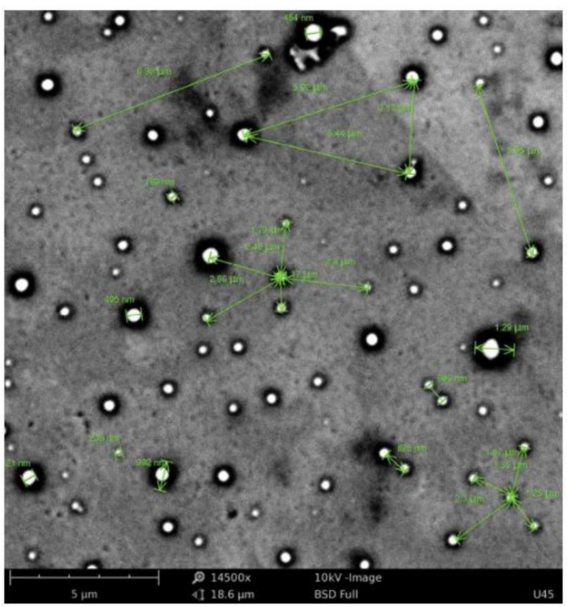



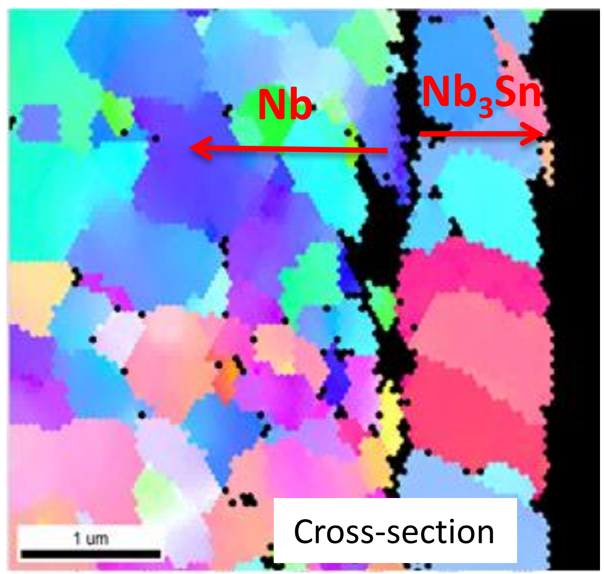
# Sample results




Sn seeding @ 500 °C x 1 hr

$Nb_3Sn$ growth @ 1200 °C x 3 hrs



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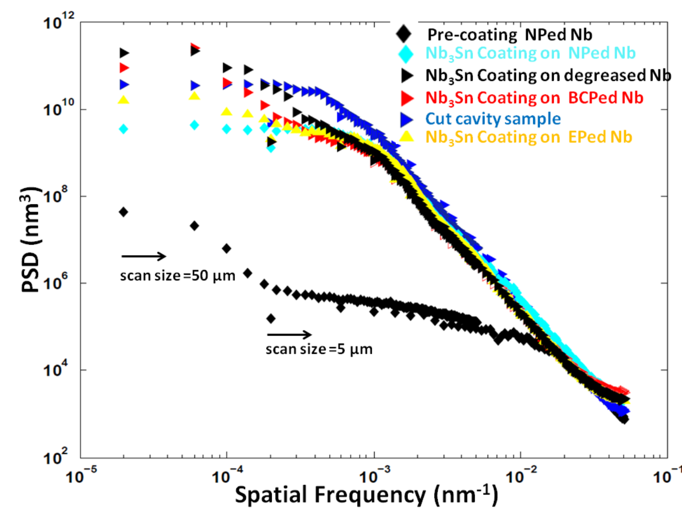
Uttar Pudasaini et al., TUPB054



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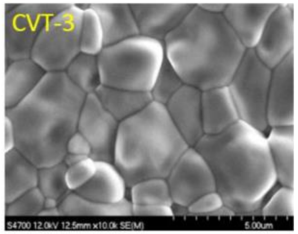
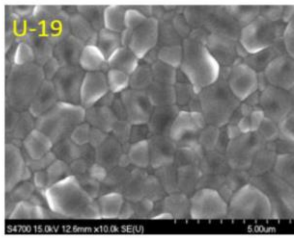
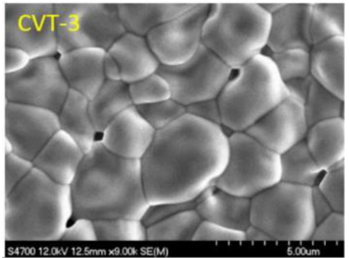
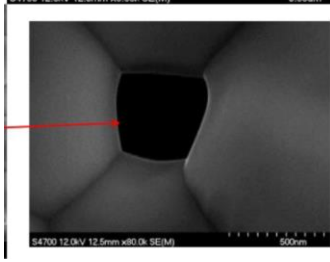
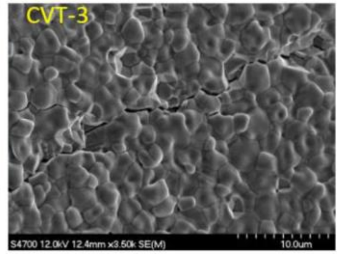
# Cutouts results

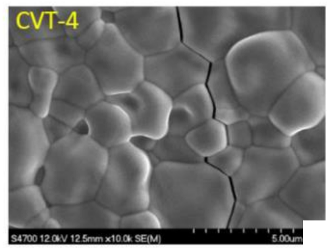


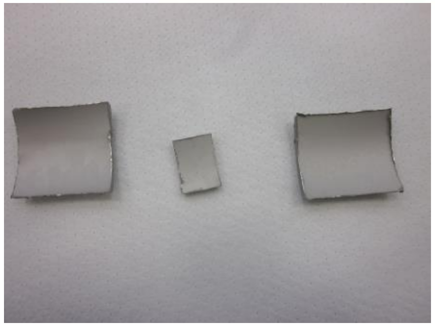



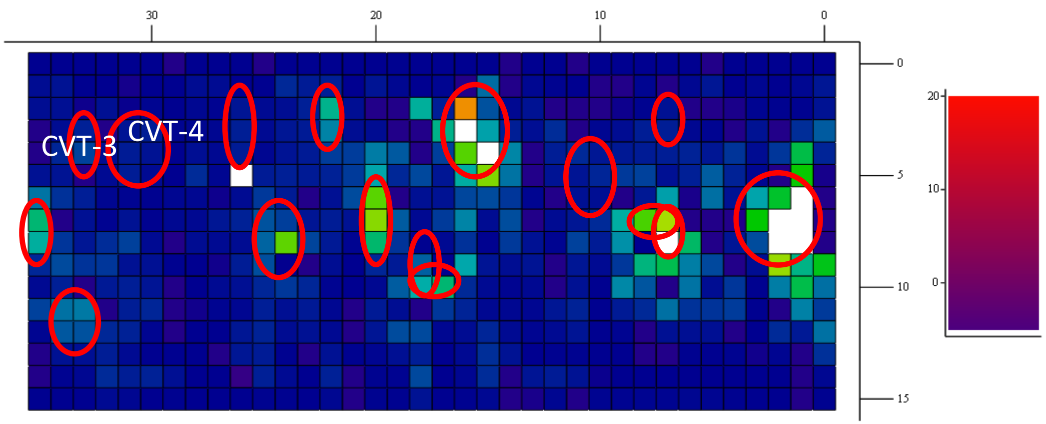



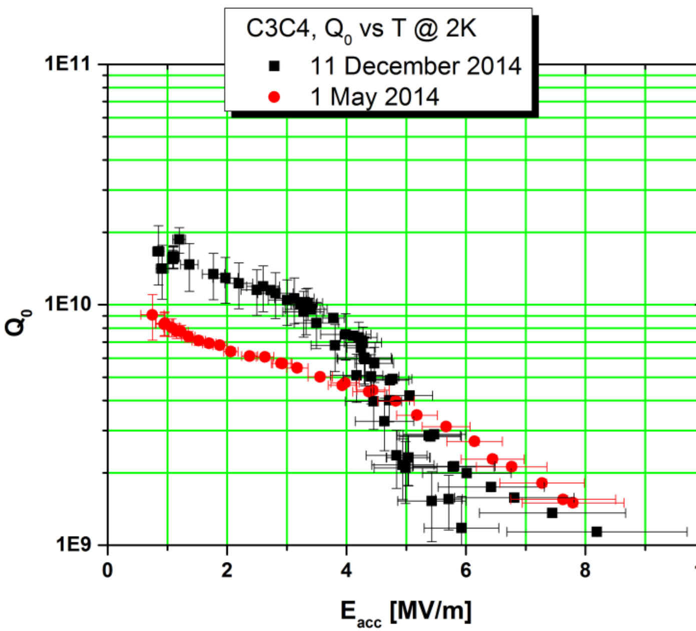


EDS : 24.5 ± 2.0 at. %.



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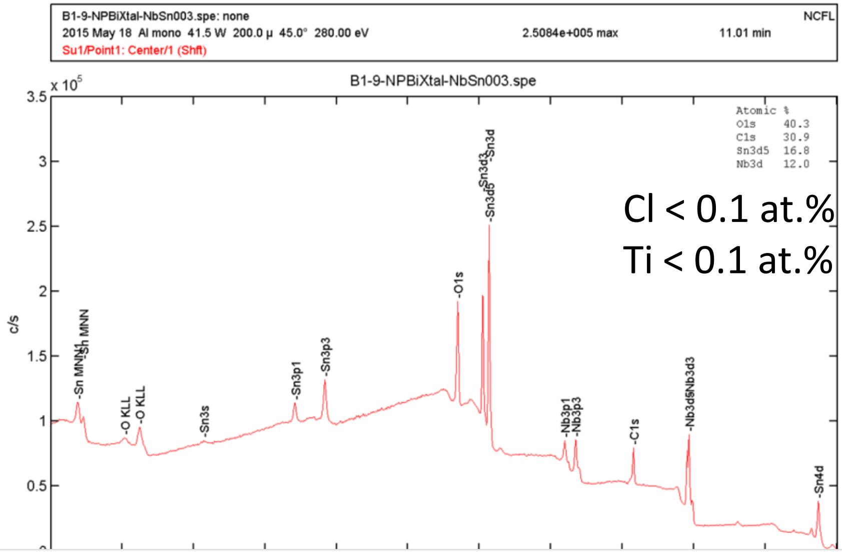
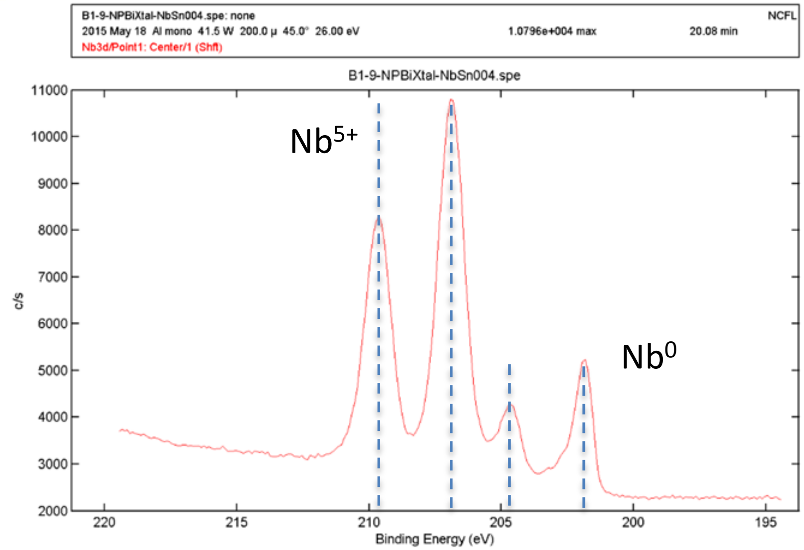
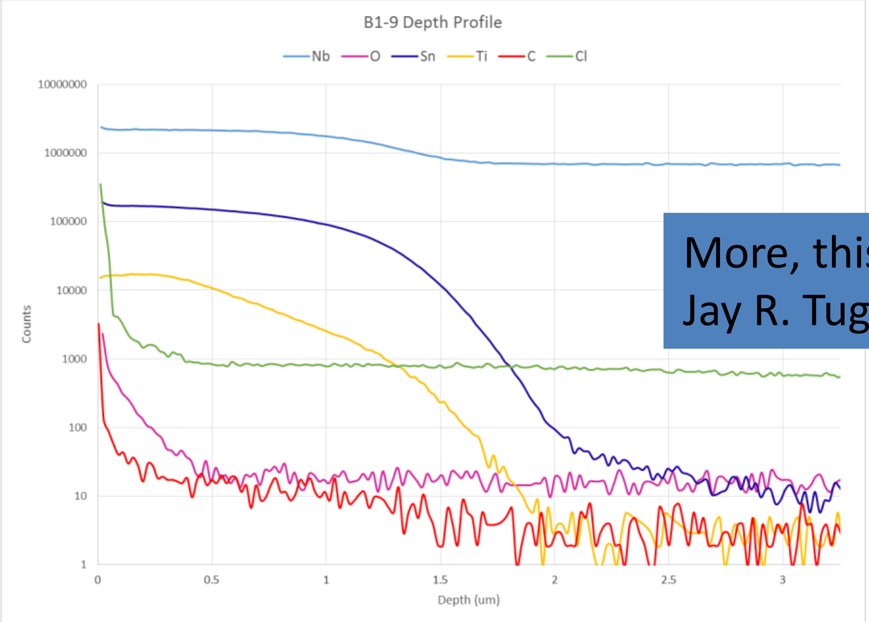
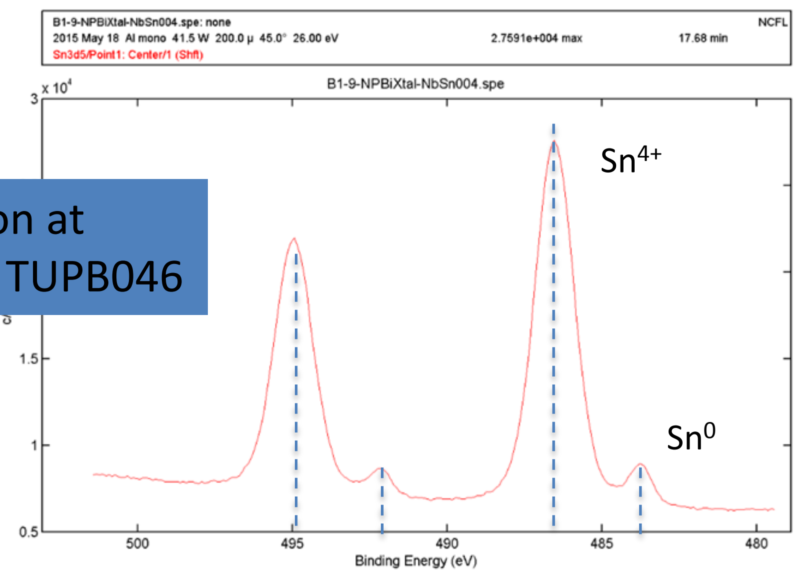
# Surface analysis summary




More, this afternoon at
Jay R. Tuggle et al., TUPB046

# Summary and Outlook

## Summary:

- Diffusion-based $Nb_3Sn$ coating have been applied to 1-cell 1.5 GHz welded and 2-cell 1.3 GHz seamless cavities.
- The cavities reached up to $E_{acc}$ = 16 MV/m limited by strong Q-slope ("Wuppertal" slope) and early quenches.
- The coated $Nb_3Sn$ has the energy gap of about 3.4 meV and the transition temperature of about 18 K consistent with the high quality $Nb_3Sn$.
- The coating is reproducible for the same cavity, but varies significantly between cavities.
- Surface studies indicate(24.5 ± 2) % Sn content consistent with high quality $Nb_3Sn$.
- XPS data indicates no gross TI or Cl contamination; a thin layer of $Nb_2O_5/SnO_2$ on the surface

## Outlook:

Coating non-uniformity
Low field quenches
Q-slope
Cryomodule demonstration

# Acknowledgements

- Jlab technical staff for assistance with cavity preparation
- Peter Kneisel for the cavities
- Josh Spradlin for sample $T_c$ measurements
- Bill Clemens, Kurt Macha, HyeKyoung Park, Scott Williams, Anne-Marie Valente-Feliciano, and Larry Phillips for valuable suggestions
- Cornell and Fermilab colleagues for useful discussions
- Bob Rimmer for continued support

# Co-authors

- Uttar Pudasaini , Jay Tuggle, Michael Kelley, Charlie Reece

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TUPB046 & TUPB054

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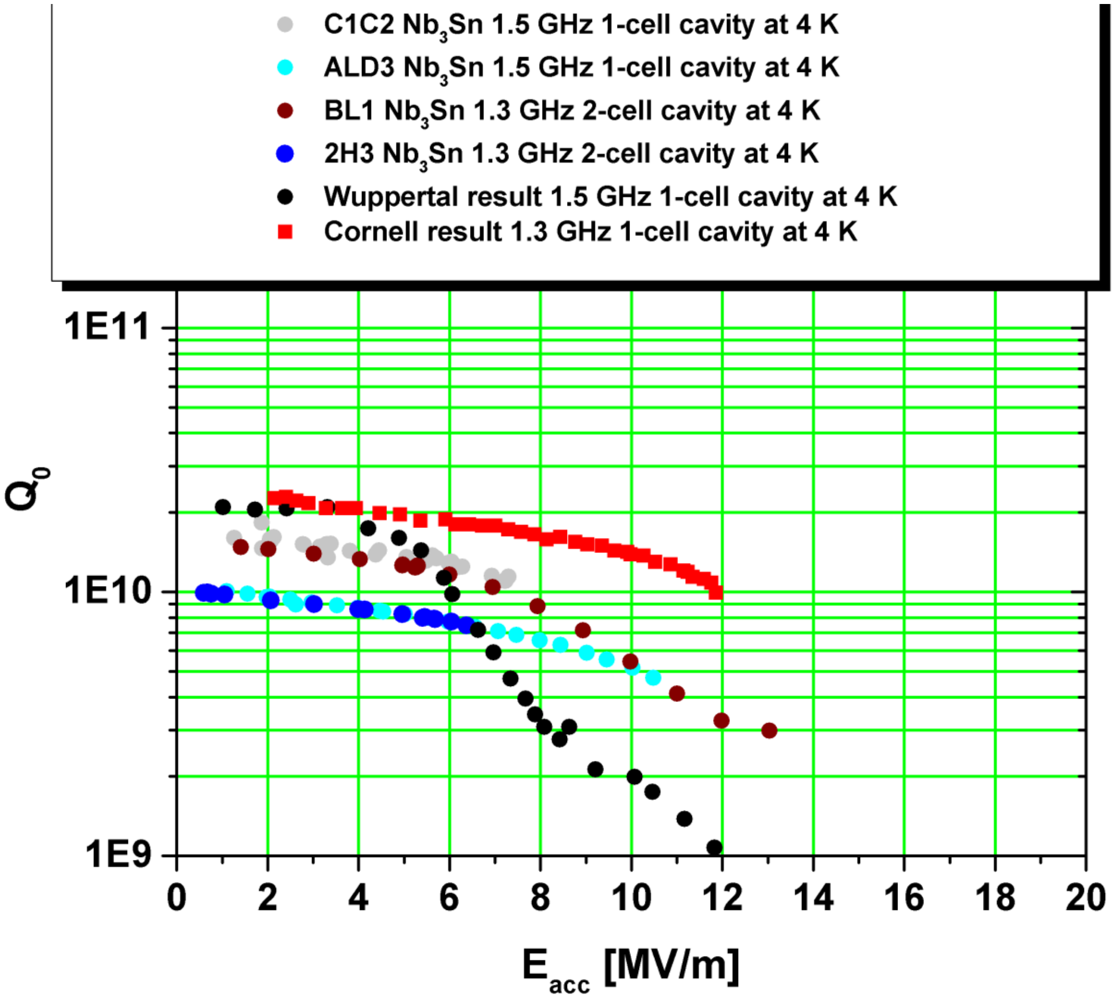
C1C2 Nb3Sn 1.5 GHz 1-cell cavity at 4 K
ALD3 Nb3Sn 1.5 GHz 1-cell cavity at 4 K
BL1 Nb3Sn 1.3 GHz 2-cell cavity at 4 K
2H3 Nb3Sn 1.3 GHz 2-cell cavity at 4 K
Wuppertal result 1.5 GHz 1-cell cavity at 4 K
Cornell result 1.3 GHz 1-cell cavity at 4 K
1E11
1E10
1E9
Q0
0
2
4
6
8
10
12
14
16
18
20
Eacc [MV/m]