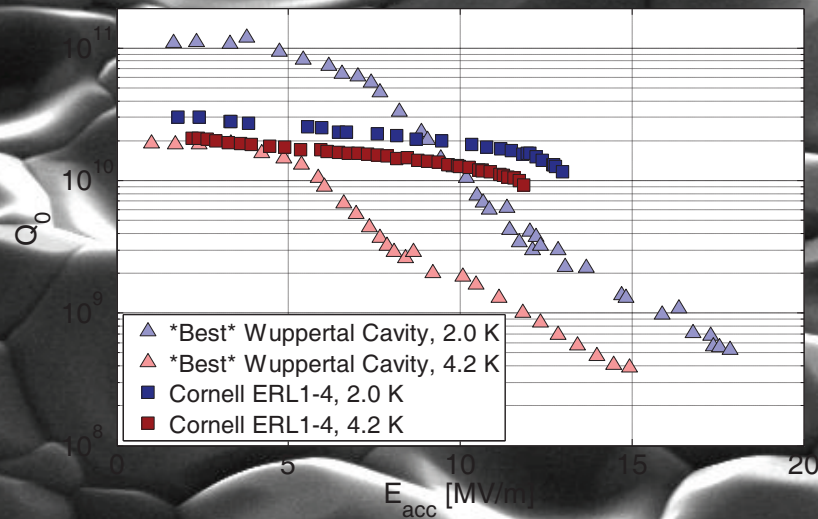


First Cavity Results from the Cornell SRF Group's Nb₃Sn Program

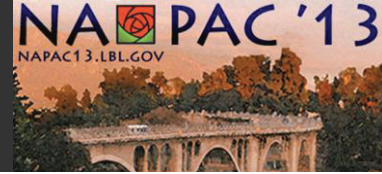


Sam Posen and Matthias Liepe
 Cornell University
 Thursday, Oct 3, 2013
 NA-PAC '13, Pasadena, California





Nb₃Sn For SRF Cavities

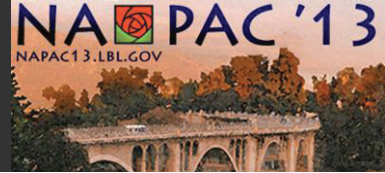


- Nb₃Sn has T_c of ~ 18 K, vs ~ 9 K for Nb: much **lower BCS $R_s(T)$**
- Significant reduction in losses at same temperature
- Possibility to operate at higher temperatures: *LHe at atmospheric pressure? Cold gas?*
- **Smaller cryo plant and less grid power**
 - Application to CW SRF linacs for light sources, small scale accelerators (closed He gas cryogenic system for universities/hospitals), industrial applications (wastewater and flue gas treatment, isotope production)
- **Higher predicted superheating field** ~ 400 mT, nearly twice Nb
 - Application to high energy SRF linacs: **reduce # of cavities**

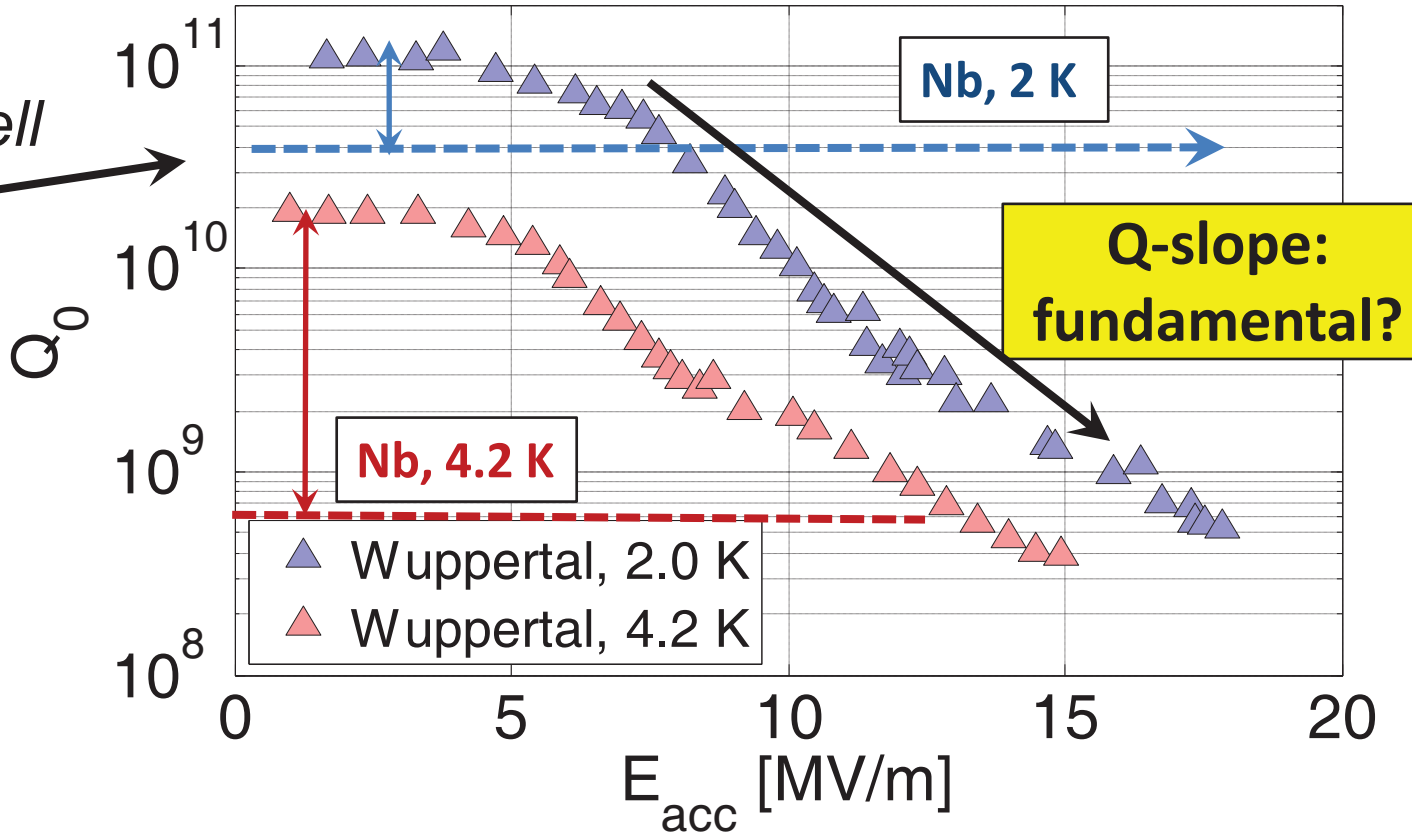




Previous SRF Research with Nb₃Sn



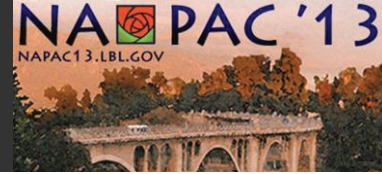
1.5 GHz
single cell
Nb₃Sn
cavity



- Excellent R_s at low fields, but large increase in R_s with field (“Q-slope”) above ~ 5 MV/m
- Various suggested causes: intergrain losses, bad stoichiometry, and **vortex penetration at lower critical field B_{c1}**



Major Test for SRF

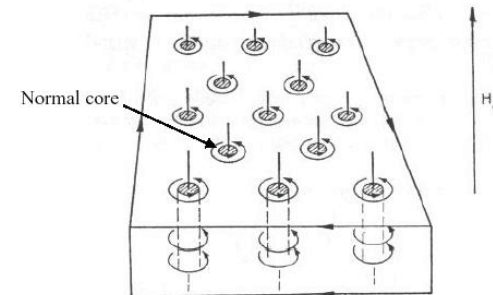


B_{c1} is the onset of metastability. Above B_{c1} , an energy barrier prevents vortex penetration, but surface defects of size $\sim \xi$ lower barrier.

Is ξ of Nb_3Sn so small that B_{c1} is the limit?

ξ of Nb \sim 20-30 nm

ξ of Nb_3Sn , NbN, MgB_2 \sim 3-4 nm

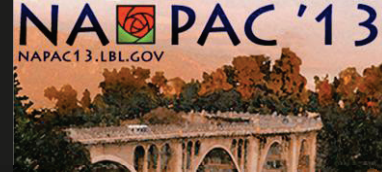


If vortices penetrate at B_{c1} , all alternative SRF materials would be severely limited.





Cornell Cavity Coating Chamber



Flange to UHV furnace

Copper transition weld from stainless to Nb

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

Cavity Temp Thermocouples

Heat Shields

UHV Furnace

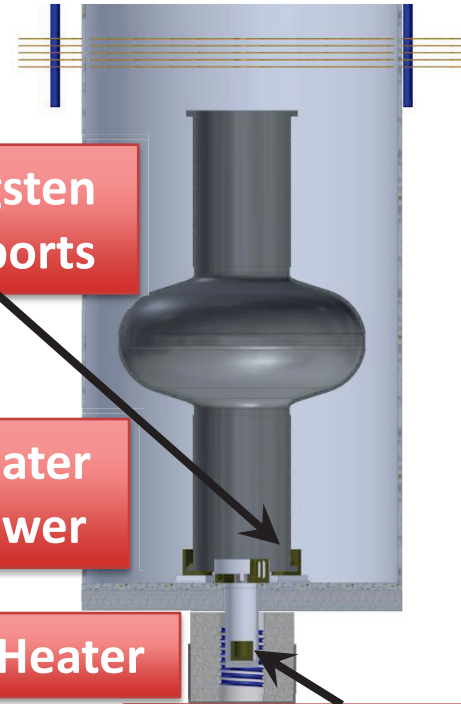
Heater Temp Thermocouples

Tungsten Supports

Heater Power

Tin Heater

Tin Container

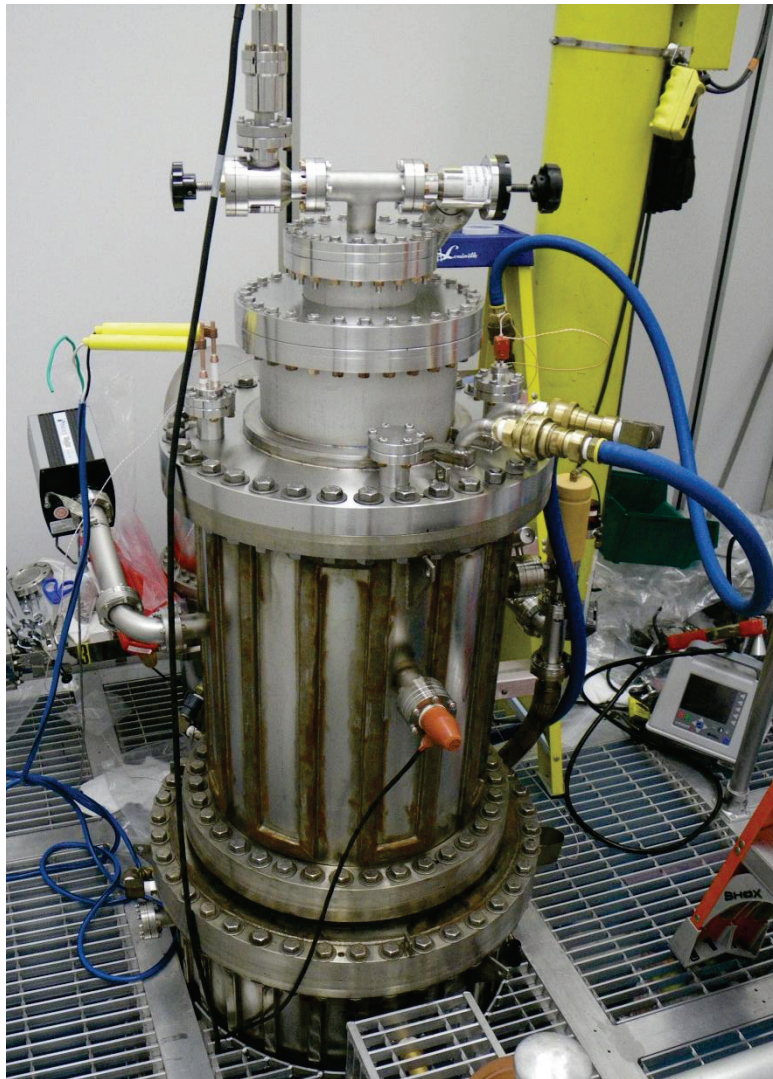
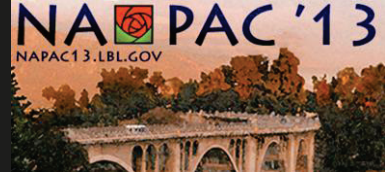


See THPO066, SRF11 for details of coating process and commissioning process using samples.





Cornell Nb₃Sn Coated Cavity



**Top Half
Cell**

**Before
Coating**

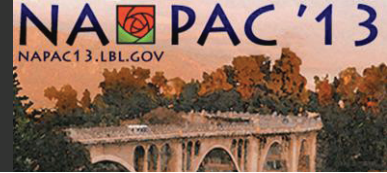
**Cornell
Nb₃Sn Cavity**

**After
Coating**

**Bottom
Half Cell**



Breakthrough Nb₃Sn Cavity

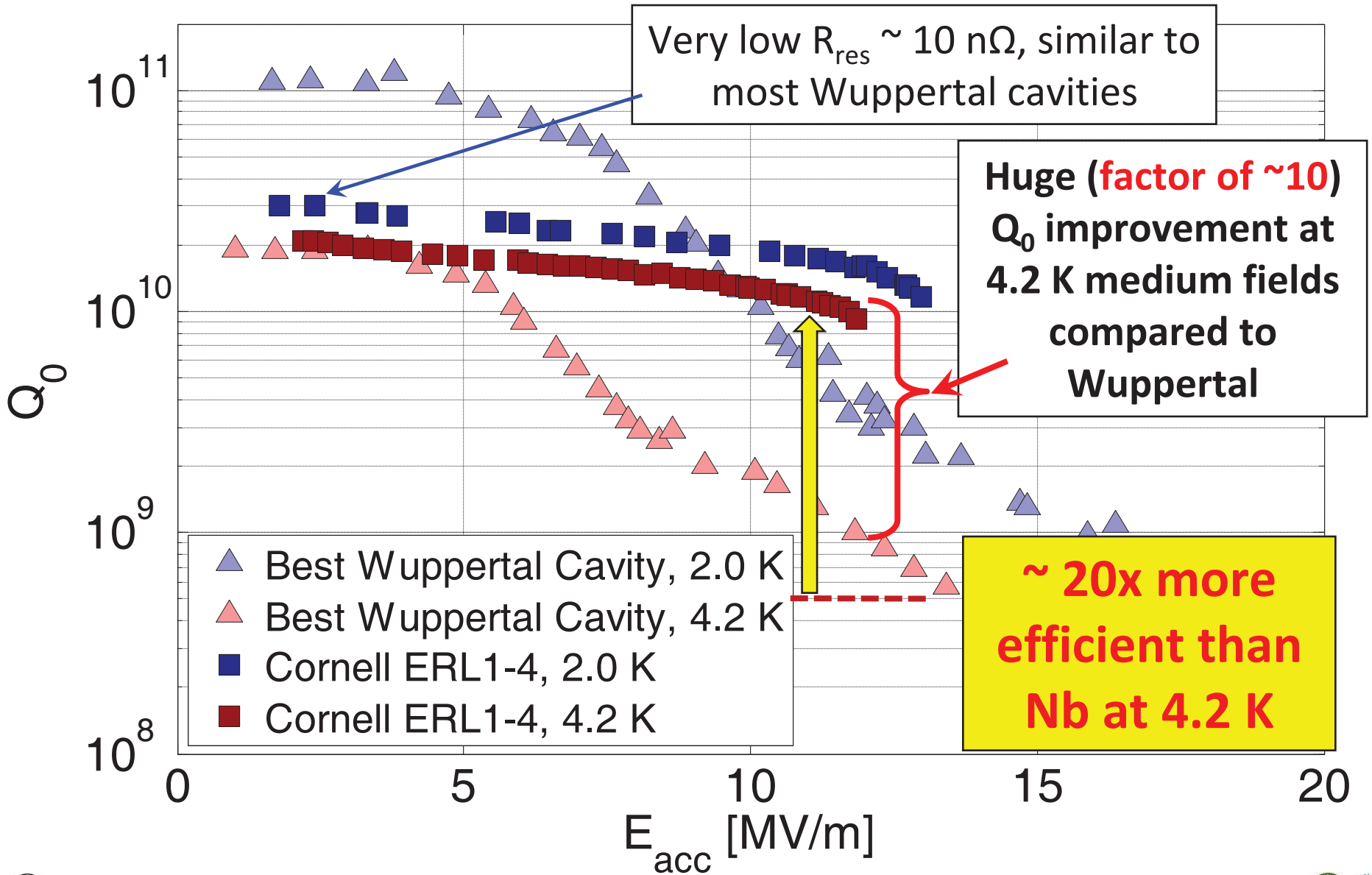
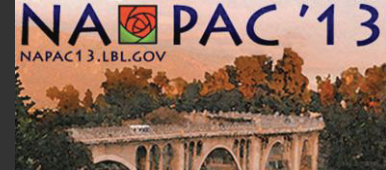


- New Nb₃Sn cavity: ERL shape (similar to TESLA), single cell, 1.3 GHz
- Tested after very slow cool (>~6 min/K)
- Excellent performance, especially at 4.2 K
- **The first accelerator cavity made with an alternative superconductor that far outperforms Nb at usable gradients**





Breakthrough Nb₃Sn Cavity

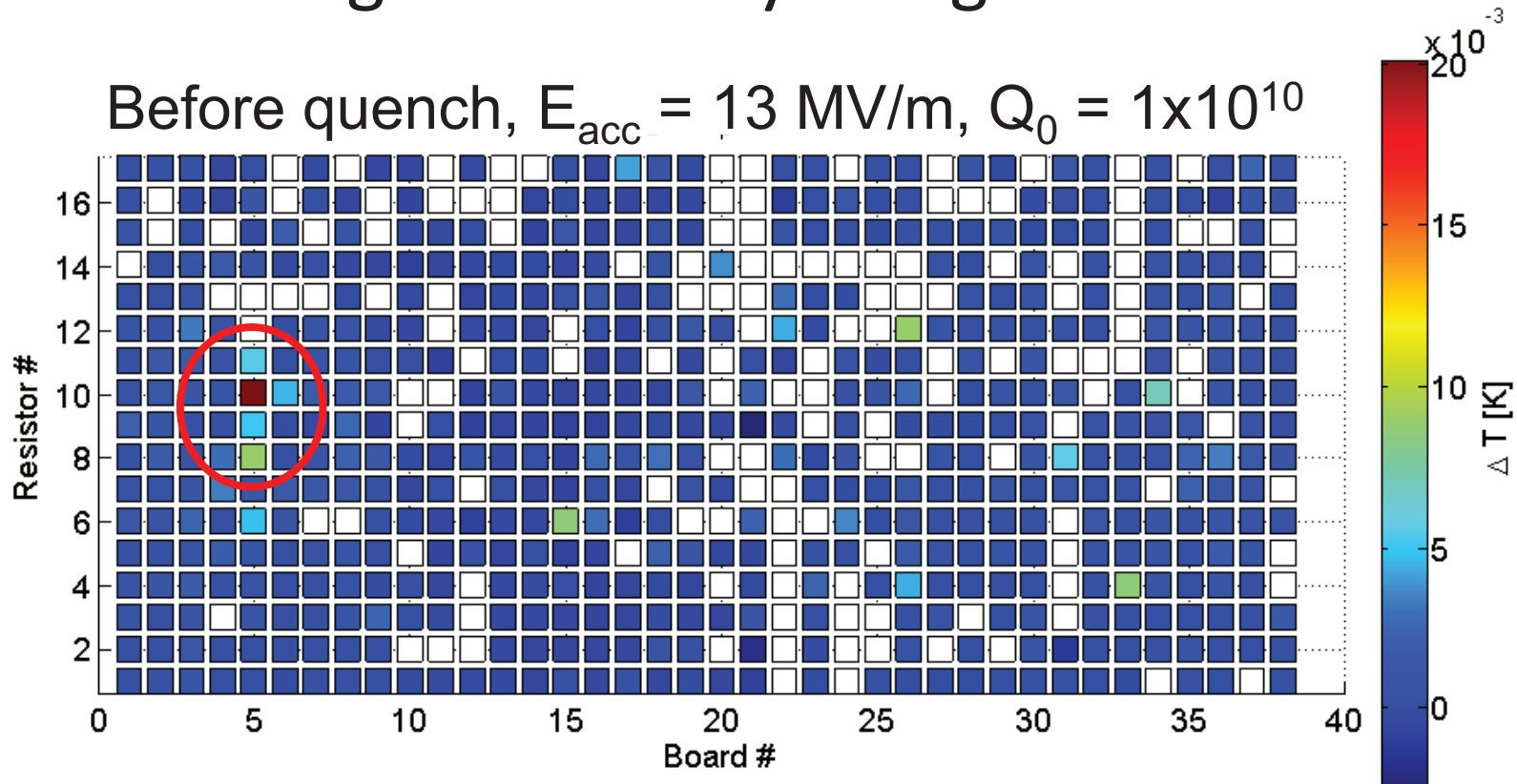




Limiting Defect at 2K

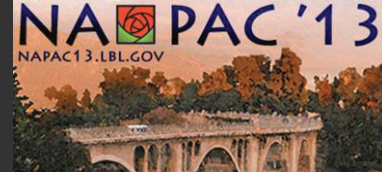


- Localized pre-heating just below first quench
- Defect – not a fundamental limit
- Can reach higher fields by fixing defect

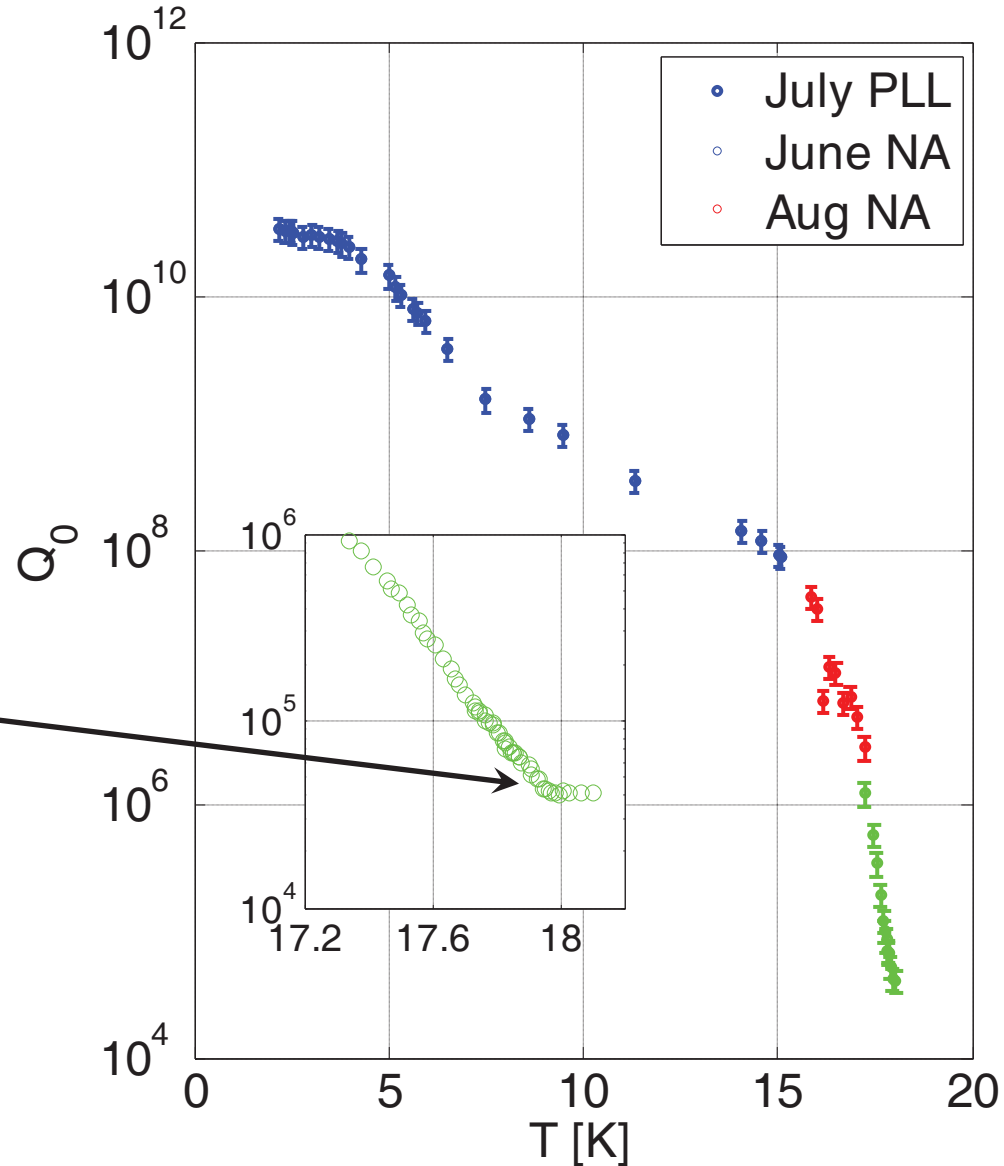




Q vs T

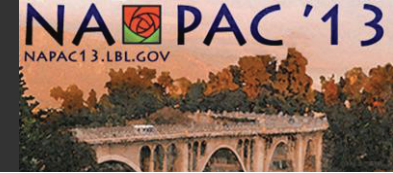


- No sign of Q_0 change near T_c of niobium: excellent Nb_3Sn coverage!
- High T_c of 18.0 K close to maximum literature value
- Extract material parameters from this data



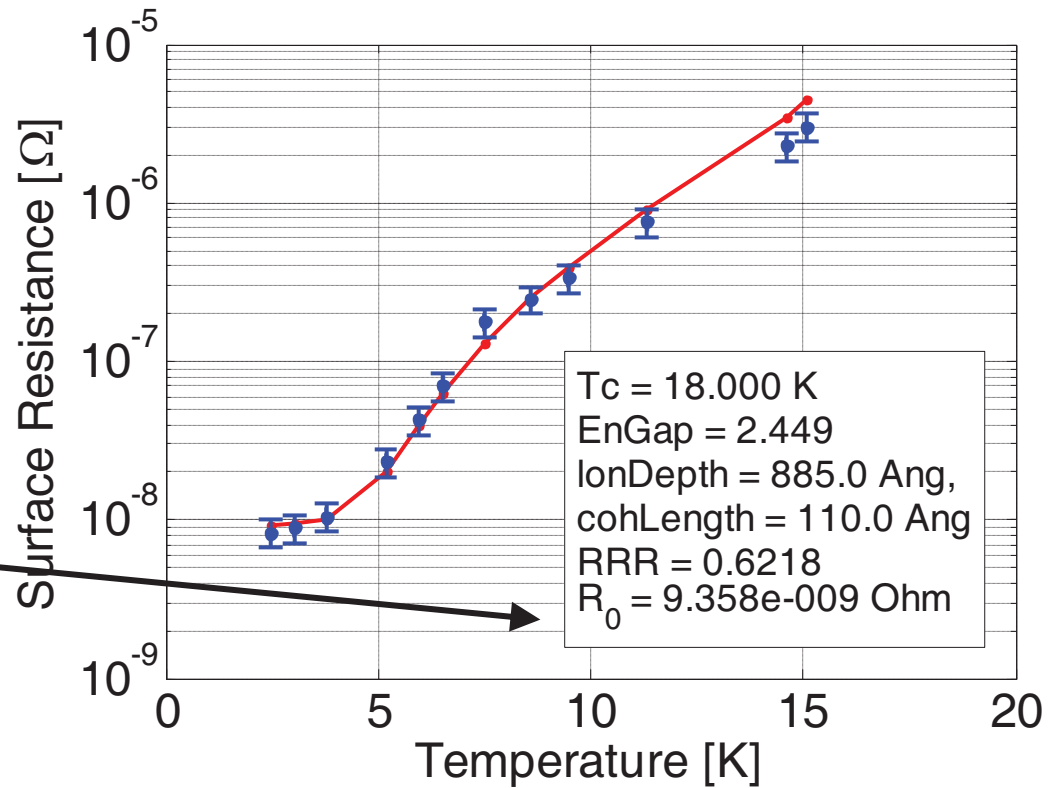


Fits to Material Parameters



Parameter	Value
$\lambda_L(0)$ [nm]	89 ± 9
$\xi_0(0)$ [nm]	7.0 ± 0.7
T_c [K]	18.0 ± 0.1
$\Delta/k_B T_c$	2.4 ± 0.1
l [nm]	3.7 ± 0.5
R_{res} [n Ω]	9 ± 2
$\lambda_{eff}(0)$ [nm]	$(1.5 \pm 0.2) \times 10^2$
$\xi_{GL}(0)$ [nm]	3.2 ± 0.2
κ	47 ± 6
$B_c(0)$ [T]	0.47 ± 0.06
$B_{c1}(0)$ [T]	0.027 ± 0.005
$B_{sh}(0)$ [T]	0.33 ± 0.05

from fit

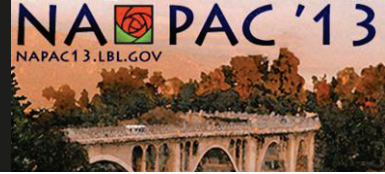


- Good agreement with literature values for ideal Nb_3Sn
- See paper for derivations

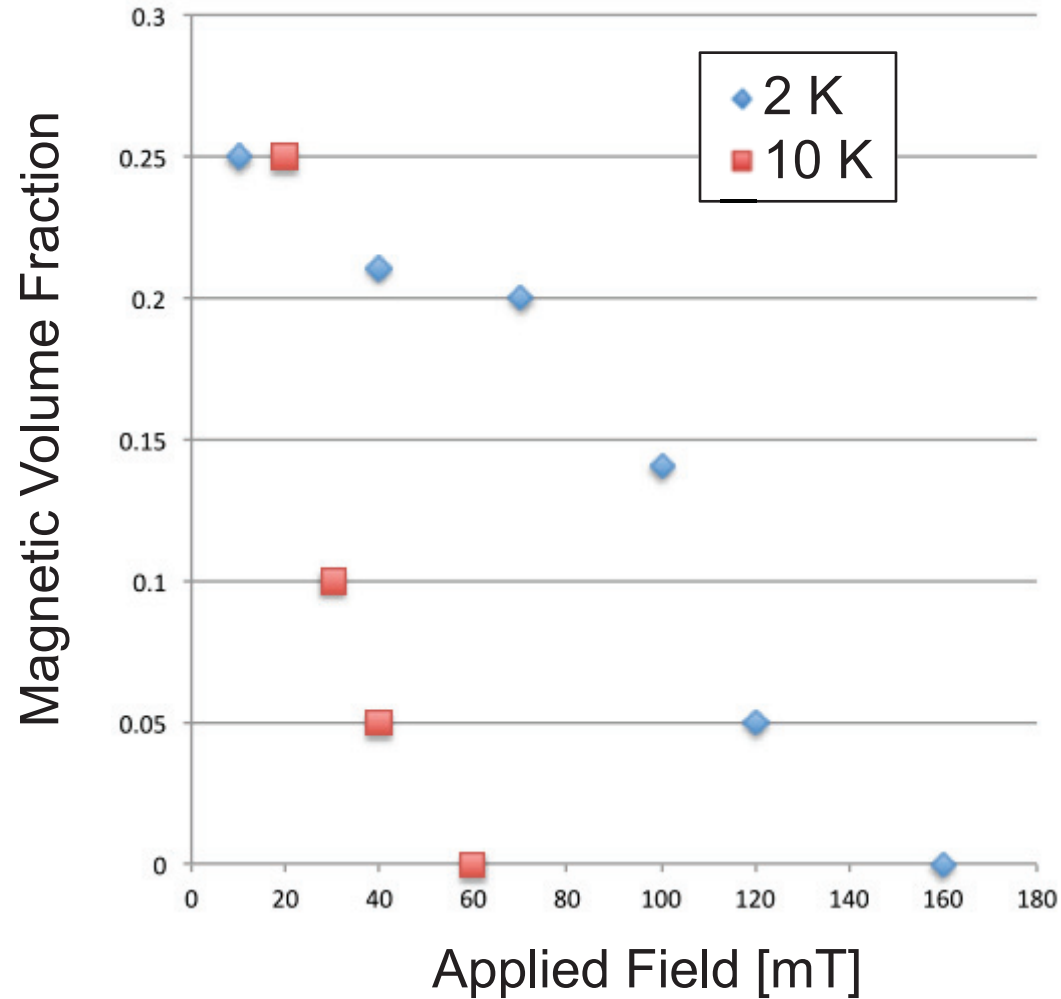




Sample B_{c1} Measurement



- B_{c1} of Nb_3Sn sample measured directly via μ -SR by Anna Grassellino et al.
- $B_{c1} \sim 20\text{-}30\text{ mT}$ agrees with cavity measurement

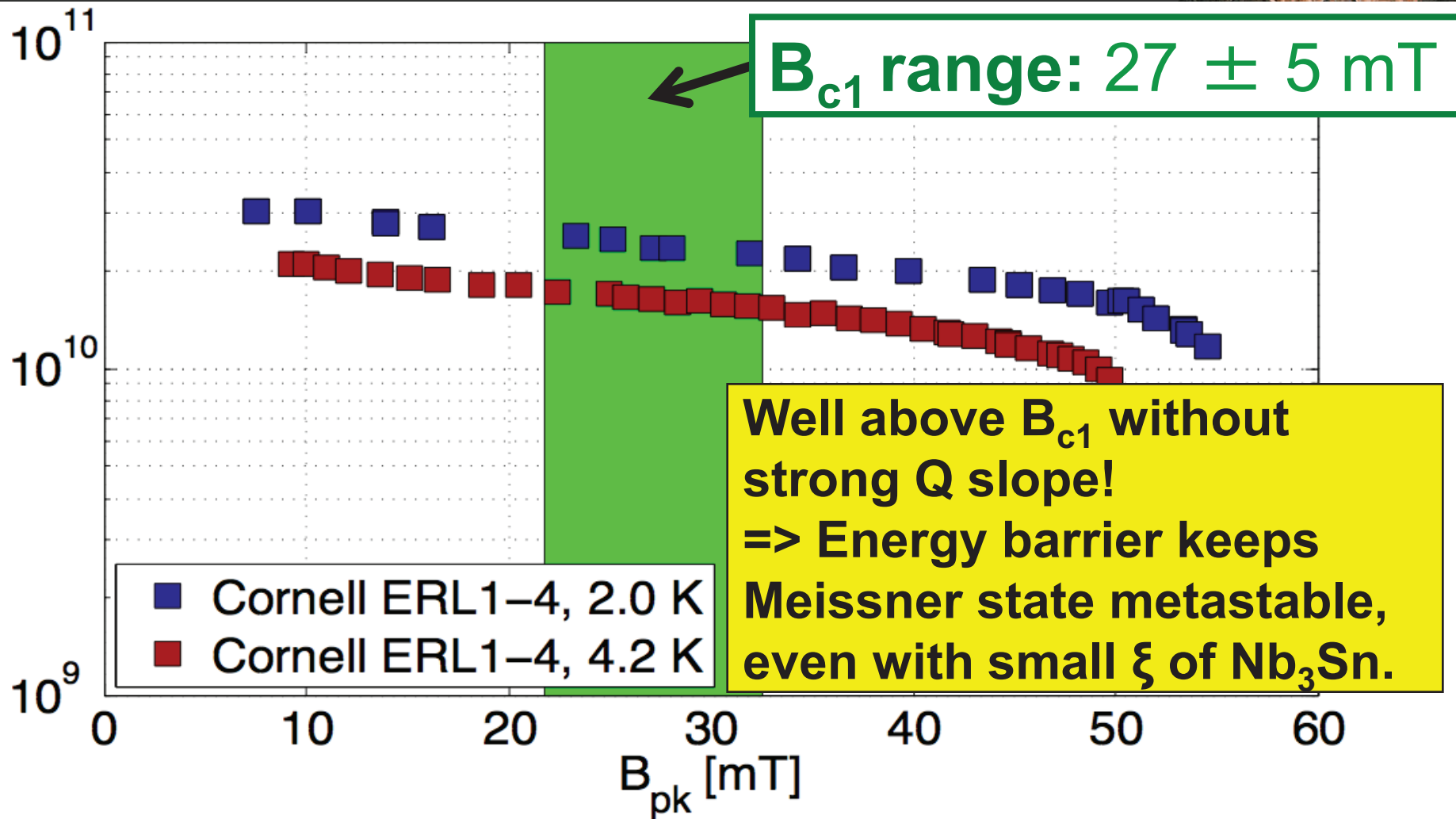
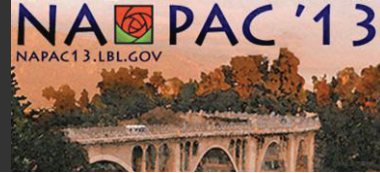


A. Grassellino et al. , TUP029 (Presented at the SRF Conference, Paris, France, 2013).





Cornell Nb₃Sn Cavity and B_{c1}

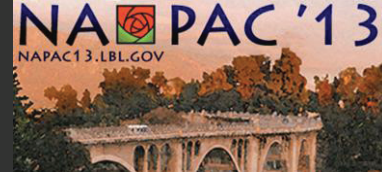


B_{c1} is NOT a fundamental limitation!





Conclusions



- *Current status*: Nb₃Sn is **now a promising alternative SRF material** for certain future accelerators: Cornell cavity demonstrated at 4.2 K, usable gradients ~12 MV/m, **Q₀ of 10¹⁰, 20 times higher than Nb**
 - **Q-slope** seen in previous cavities **not a fundamental problem**
- *Near future*: fix high performing but **defect limited** cavity, or coat new one—expect even higher gradients
- *Longer Term R&D Plan*: Develop **surface preparation methods** for Nb₃Sn to push performance (as has been done in Nb over many years)
- *Eventual Hope*: Prevent non-fundamental limitations to reach fields close to **ultimate limit, B_{sh} ~ 400 mT**

