Cornell Laboratory for
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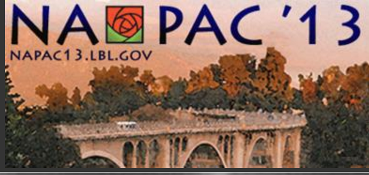
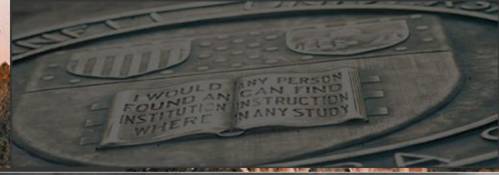
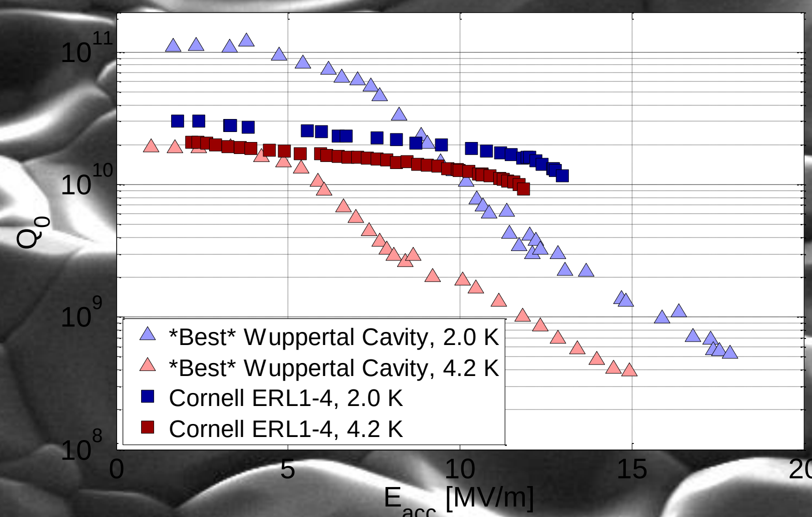




First Cavity Results from the Cornell SRF Group's Nb_3Sn Program



Sam Posen and Matthias Liepe
Cornell University

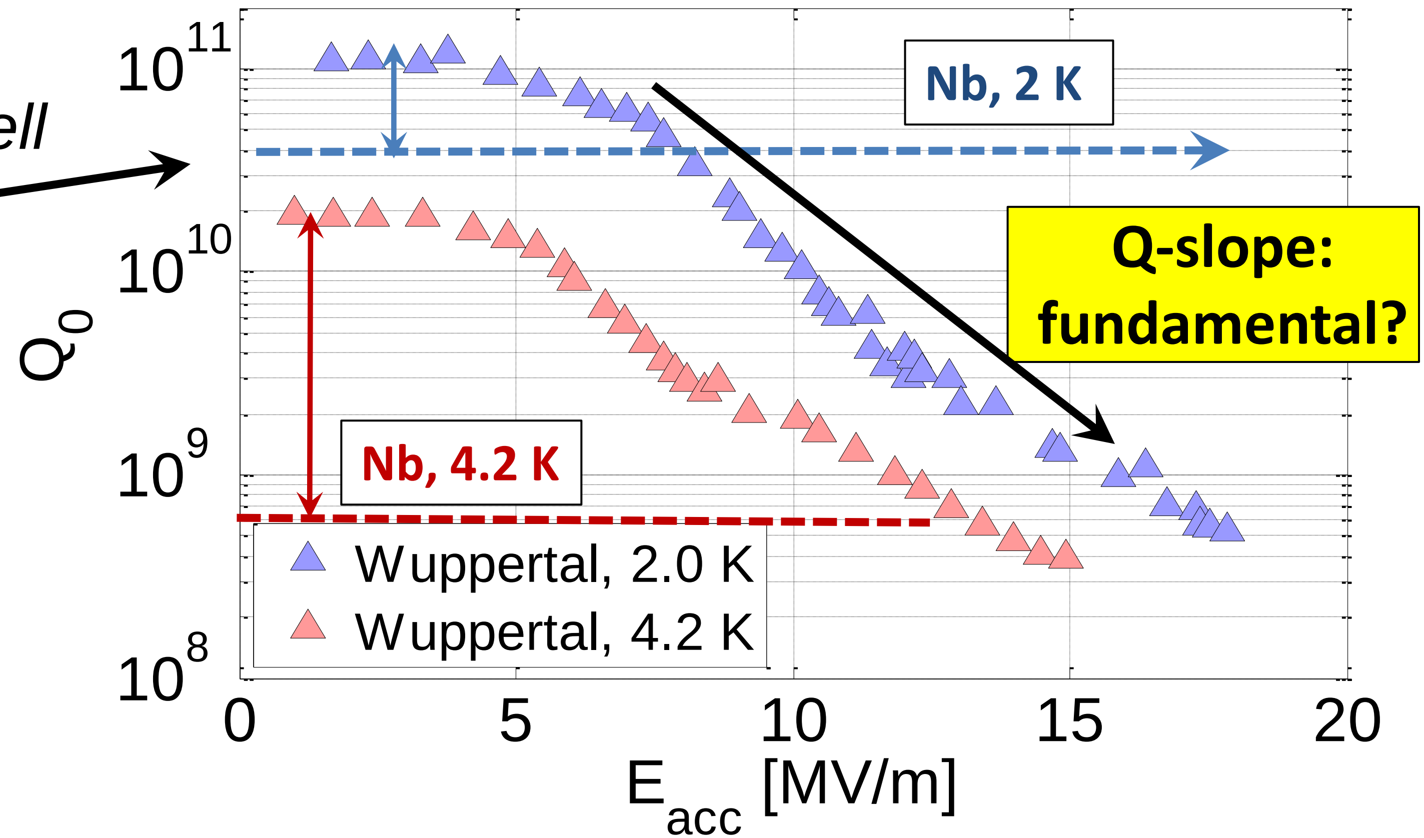
Thursday, Oct 3, 2013
NA-PAC '13, Pasadena, California

Nb_3Sn For SRF Cavities

- Nb_3Sn 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 Nb_3Sn

1.5 GHz single cell Nb_3Sn 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}

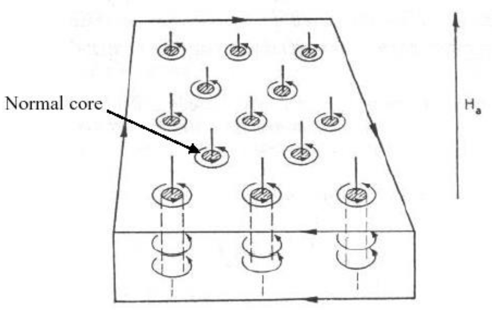
Major Test for SRF

B_{c1} is the onset of metastability. Above B_{c1}, an energy barrier prevents vortex penetration, but surface defects of size ~ξ lower barrier.

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

ξ of Nb ~ 20-30 nm

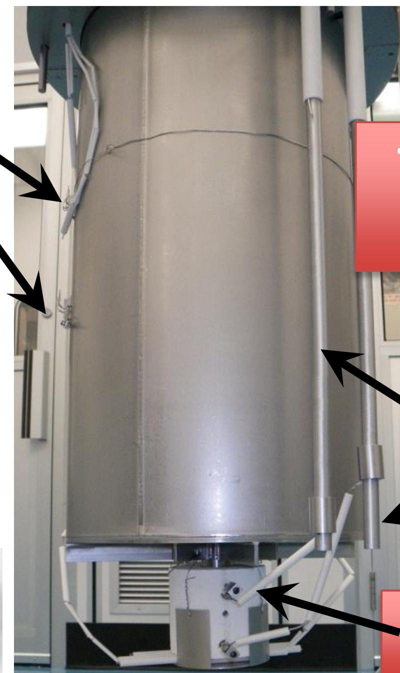
ξ of Nb_3Sn, NbN, MgB_2 ~ 3-4 nm

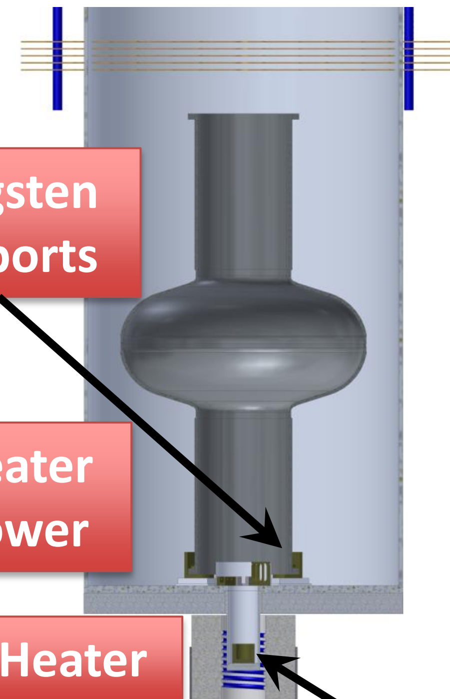


If vortices penetrate at B_{c1}, **all** alternative SRF materials would be severely limited.

Cornell Cavity Coating Chamber

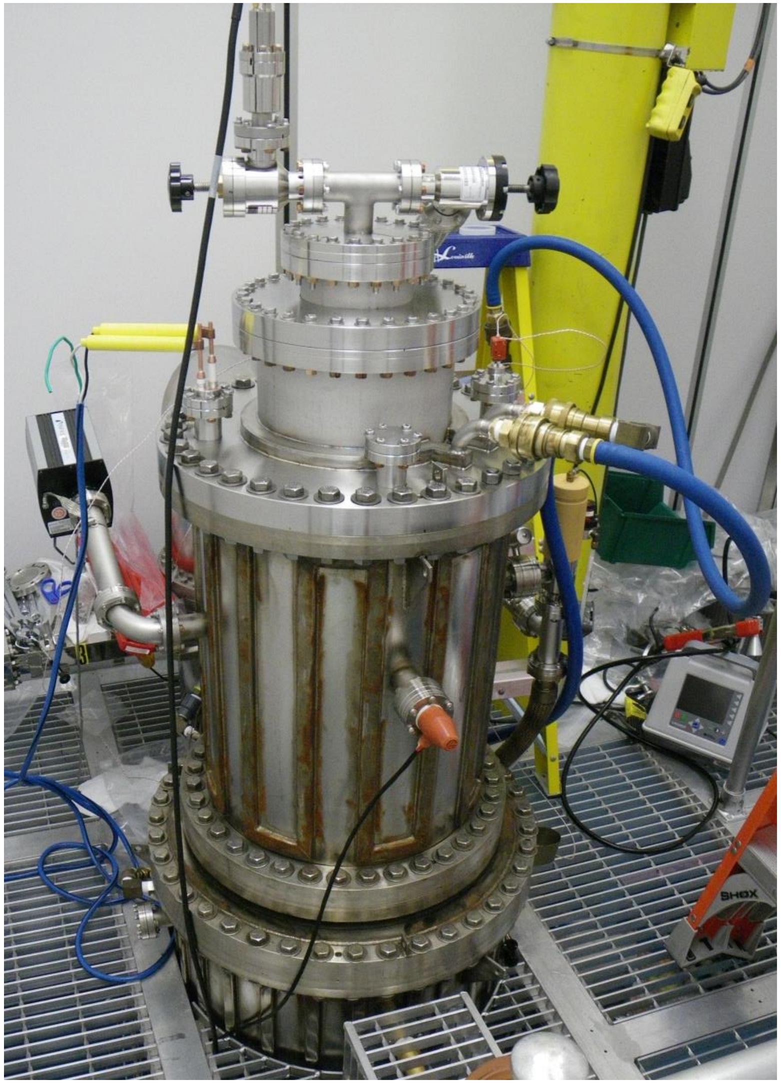
- Degas: 1 day
- Nucleation: 5 hours
- Coating: 3 hours
- Surface diffusion: 0.5 hours

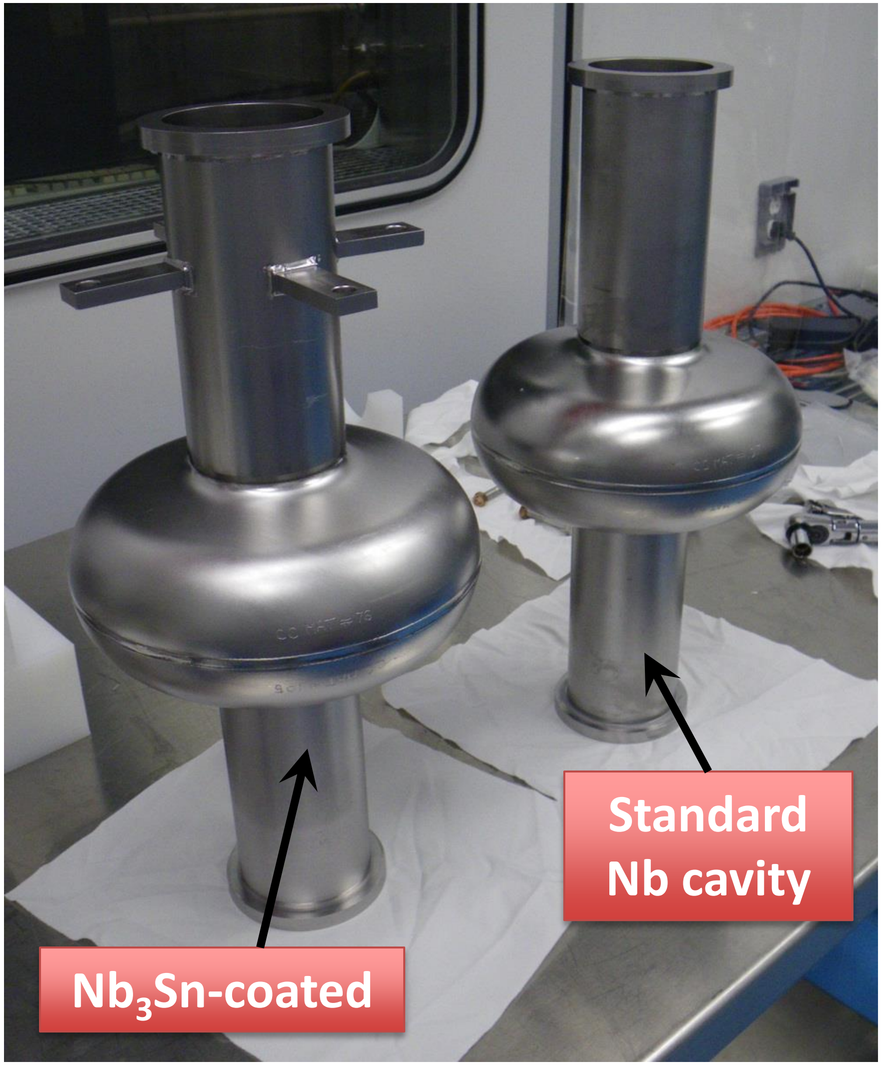


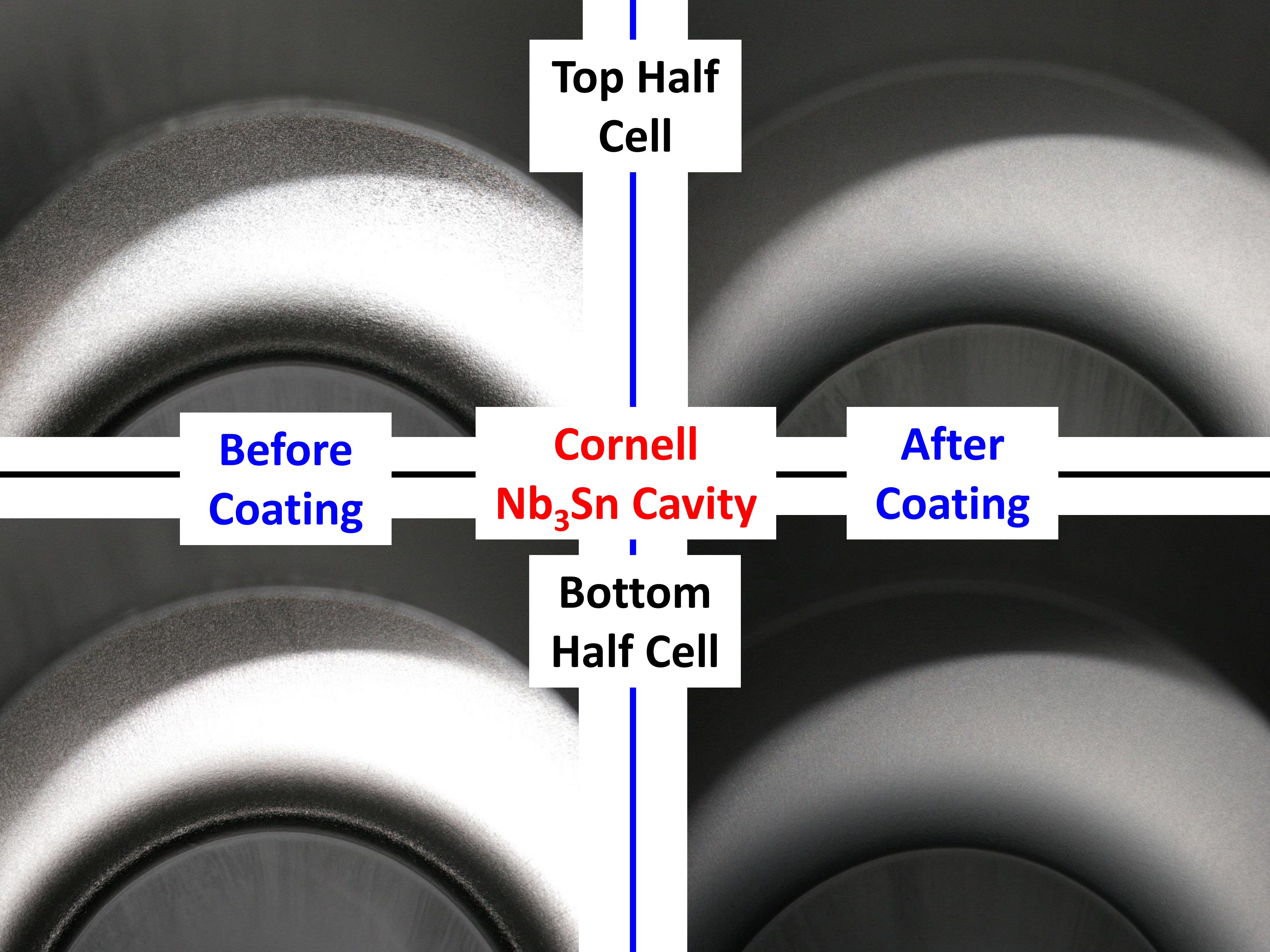


See THPO066, SRF11 for details of coating process and commissioning process using samples.

Cornell Nb_3Sn Coated Cavity



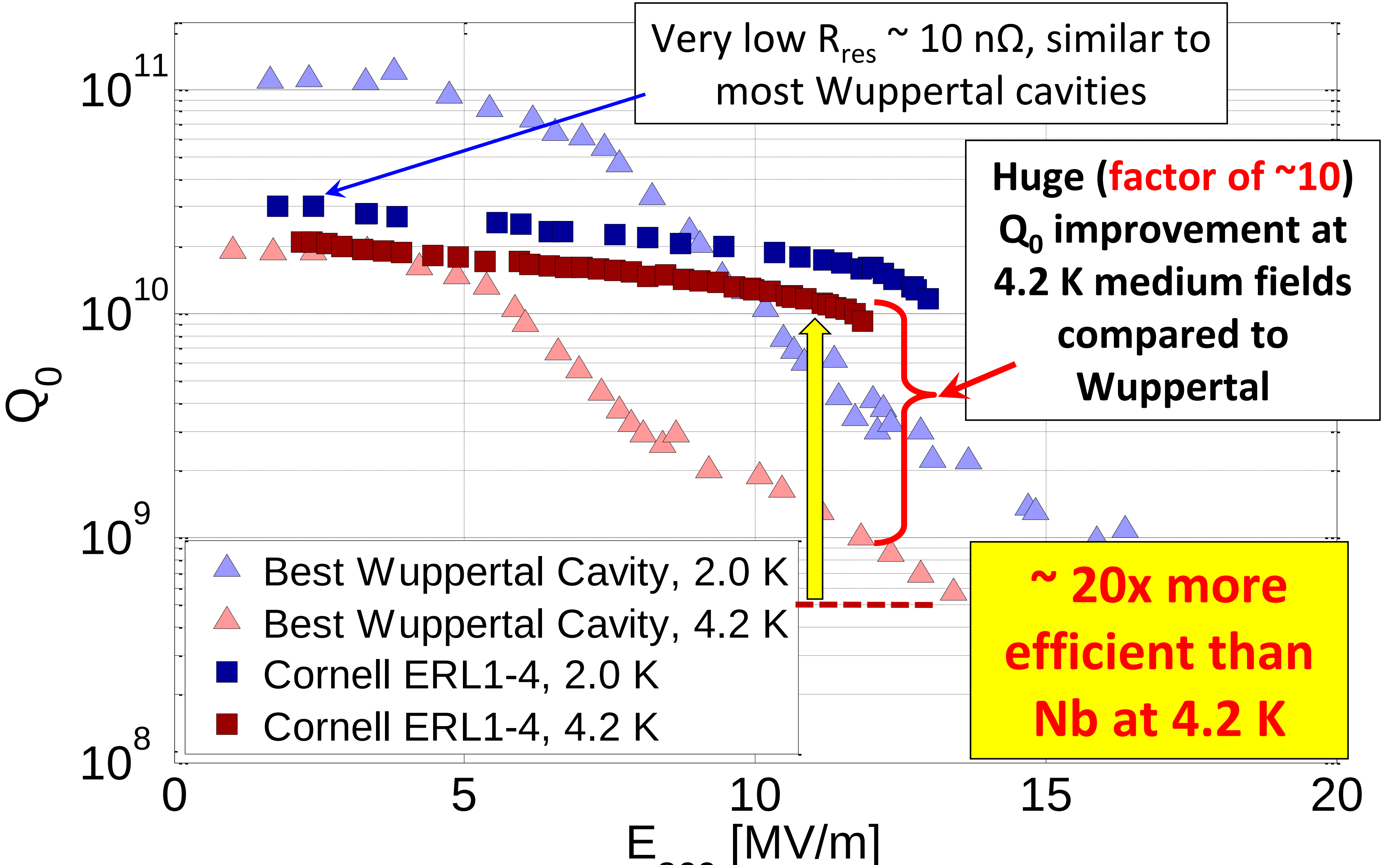



Top Half Cell
Before Coating
Cornell Nb_3Sn Cavity
After Coating
Bottom Half Cell

Breakthrough Nb_3Sn Cavity

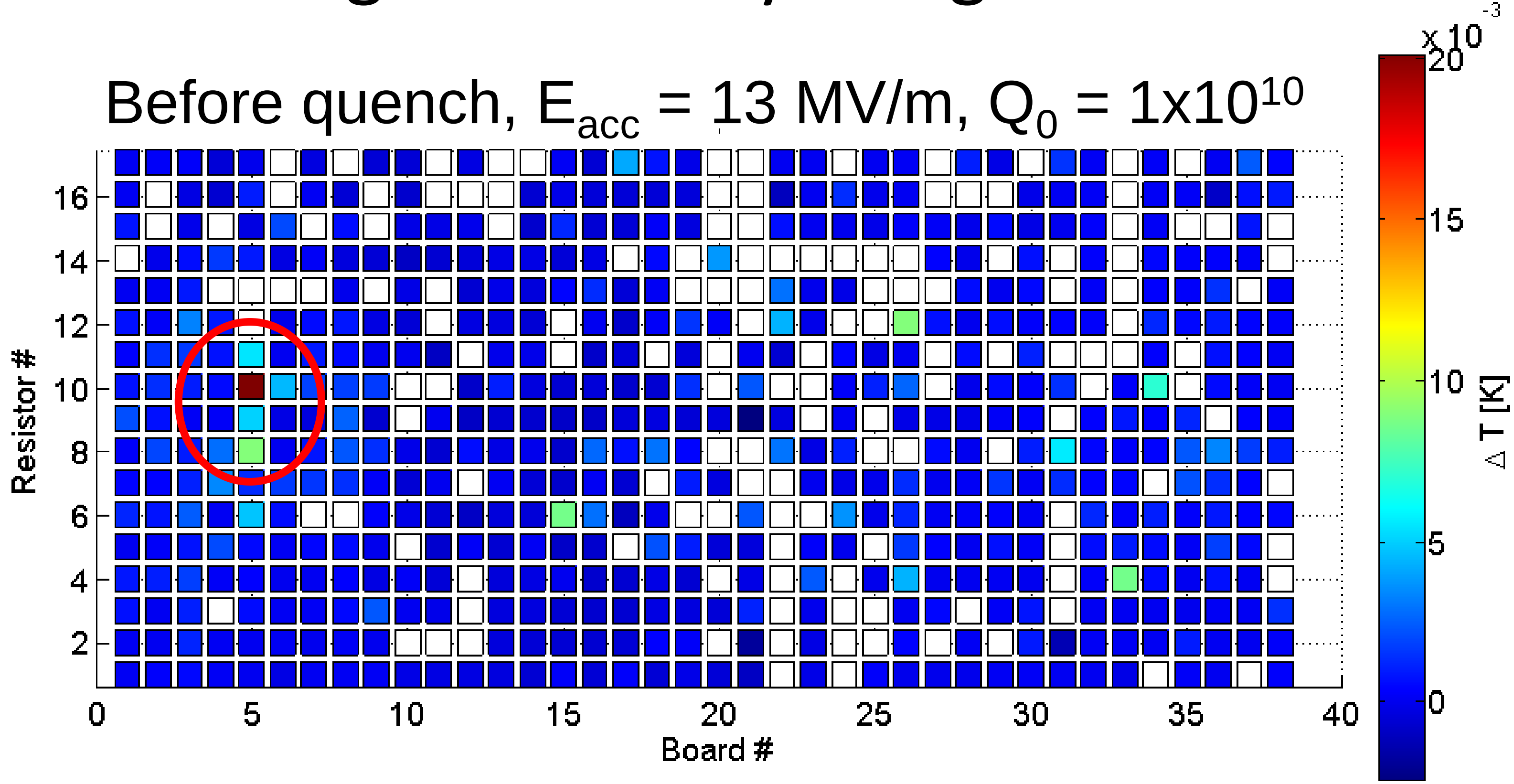
- New Nb_3Sn cavity: ERL shape (similar to TESLA), single cell, 1.3 GHz
- Tested after very slow cool (>~6 min/K)
- Excellent performance, especially at 4.2 K
- **The first accelerator cavity made with an alternative superconductor that far outperforms Nb at usable gradients**

Breakthrough Nb_3Sn Cavity



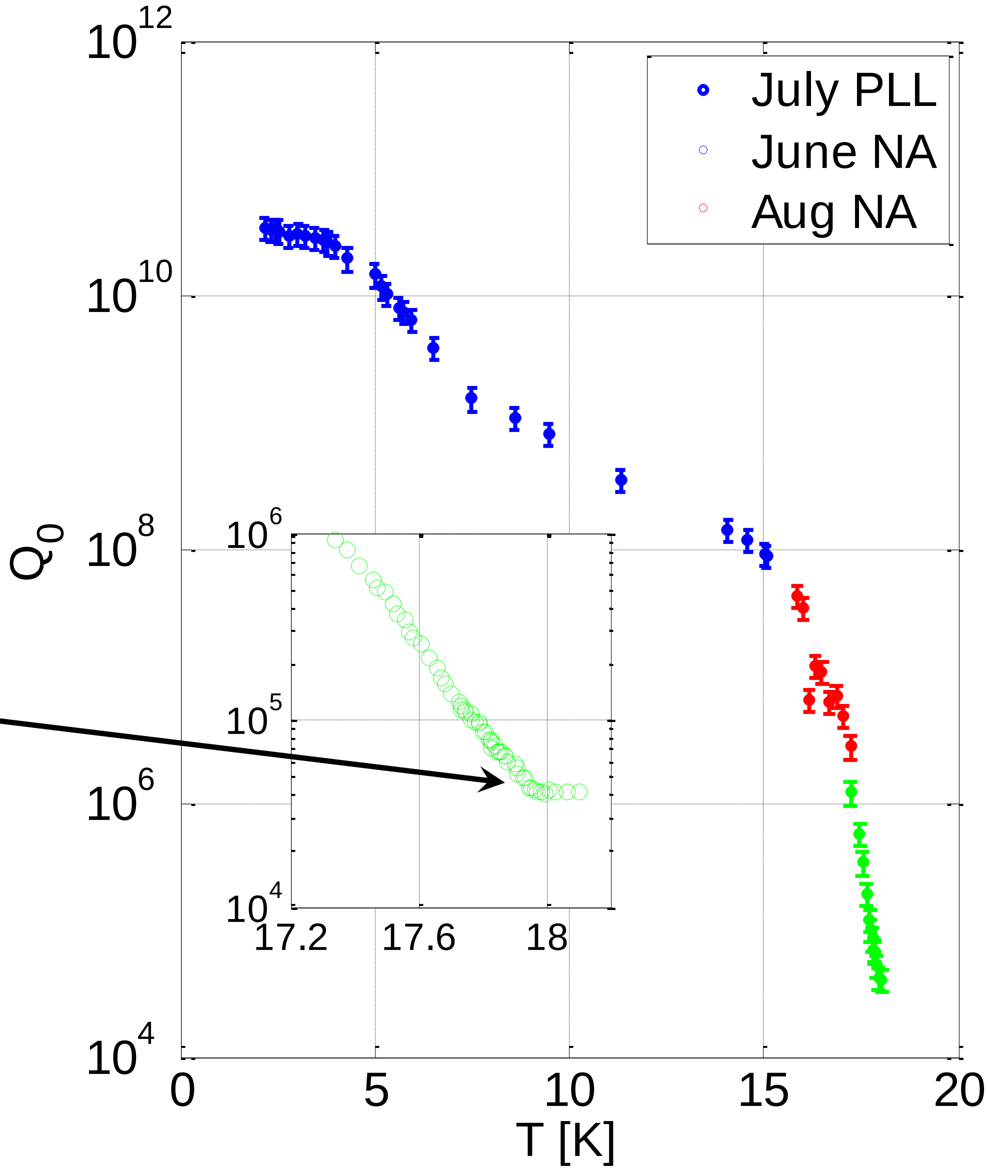
Limiting Defect at 2K

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



Q vs T

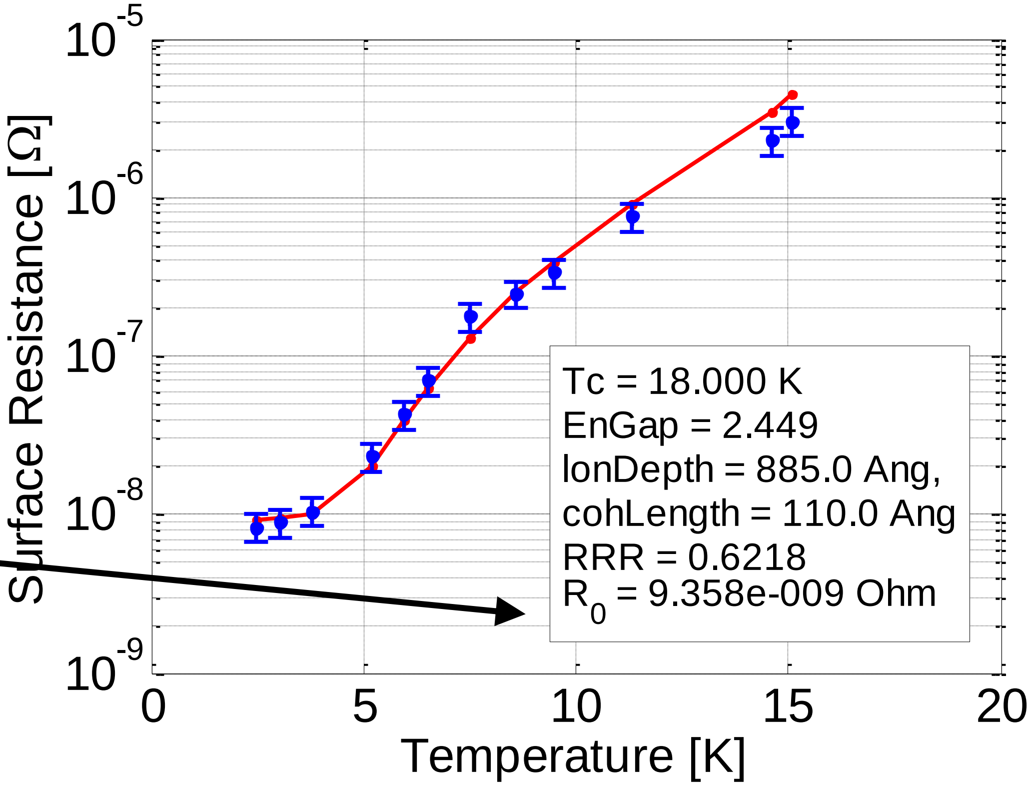
- No sign of Q_0 change near T_c of niobium: excellent Nb_3Sn coverage!
- High T_c of 18.0 K close to maximum literature value
- Extract material parameters from this data



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
Δ/k_BT_c	2.4 ± 0.1
l [nm]	3.7 ± 0.5
R_{res} [nΩ]	9 ± 2
$\lambda_{eff}(0)$ [nm]	(1.5 ± 0.2)x10^2
$\xi_{GL}(0)$ [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

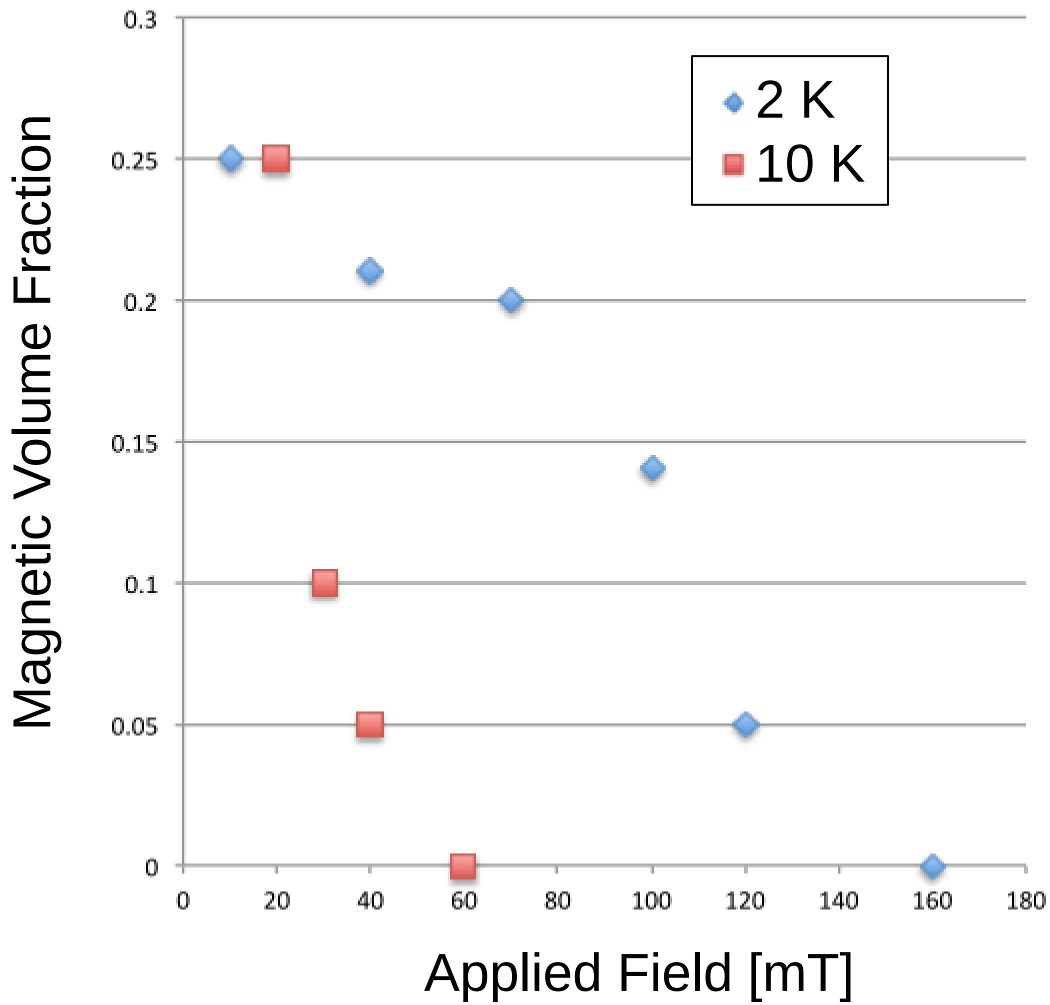
from fit



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

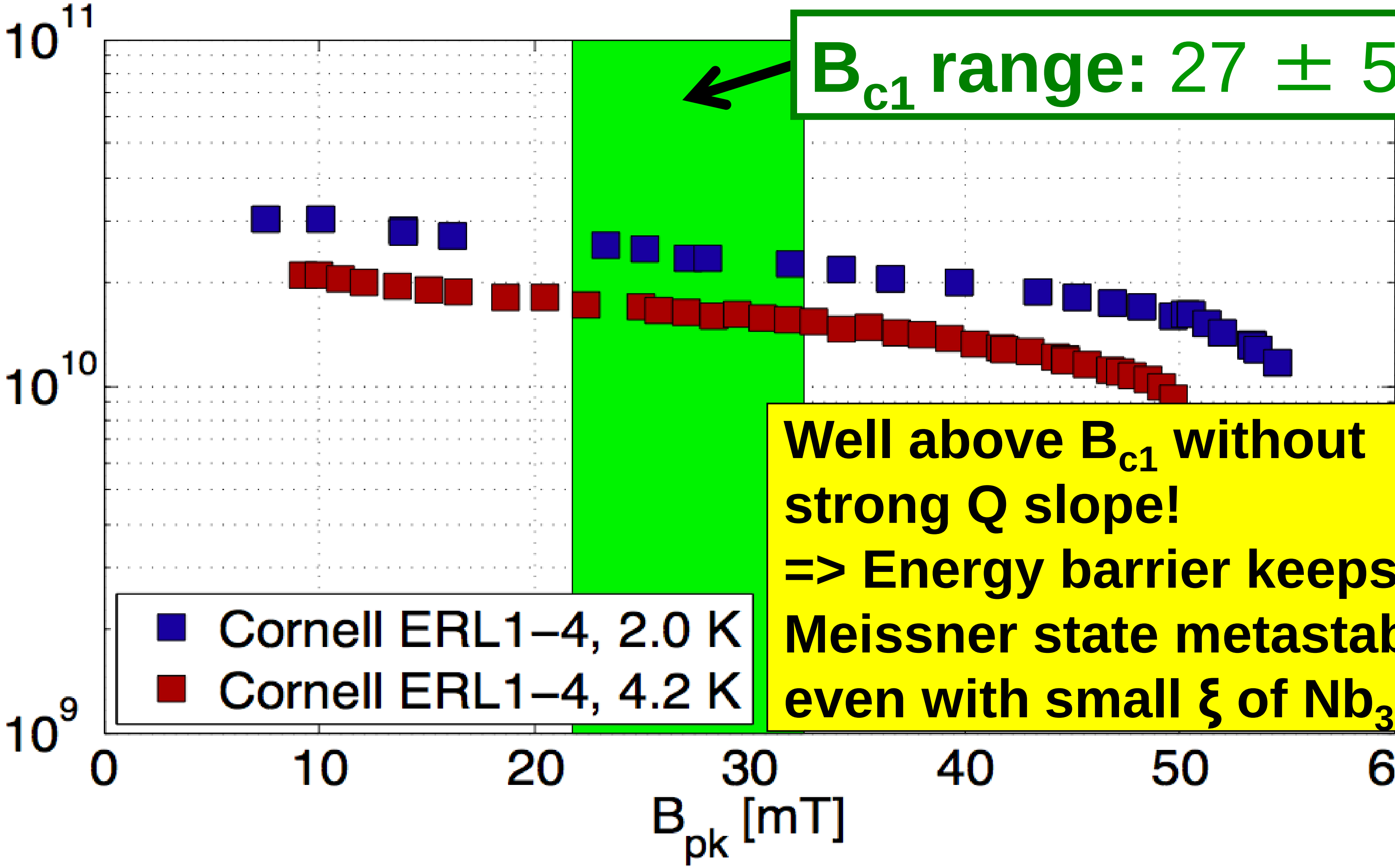
Sample B_{c1} Measurement

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



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

Cornell Nb_3Sn Cavity and B_{c1}



B_{c1} range: 27 ± 5 mT

Well above B_{c1} without strong Q slope!
=> Energy barrier keeps Meissner state metastable, even with small ξ of Nb_3Sn.

B_{c1} is NOT a fundamental limitation!

Conclusions

- *Current status*: Nb_3Sn is **now a promising alternative SRF material** for certain future accelerators: Cornell cavity demonstrated at 4.2 K, usable gradients ~12 MV/m, Q_0 of 10^{10}, 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 Nb_3Sn to push performance (as has been done in Nb over many years)
- *Eventual Hope*: Prevent non-fundamental limitations to reach fields close to ultimitate limit, B_{sh} ~ 400 mT