Fermilab U.S. DEPARTMENT OF ENERGY Office of Science

# $Nb_3Sn$-coated 1.5 GHz multi-cell cavities and perspectives for beam acceleration tests

Grigory Eremeev

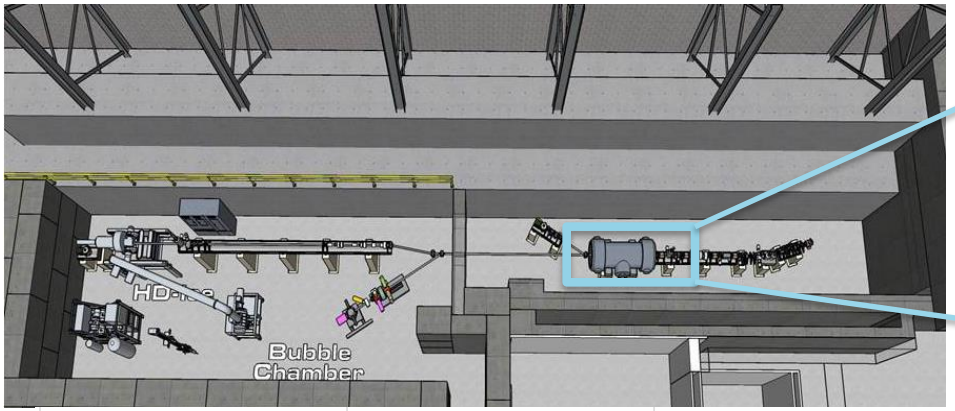
TTC'02022020

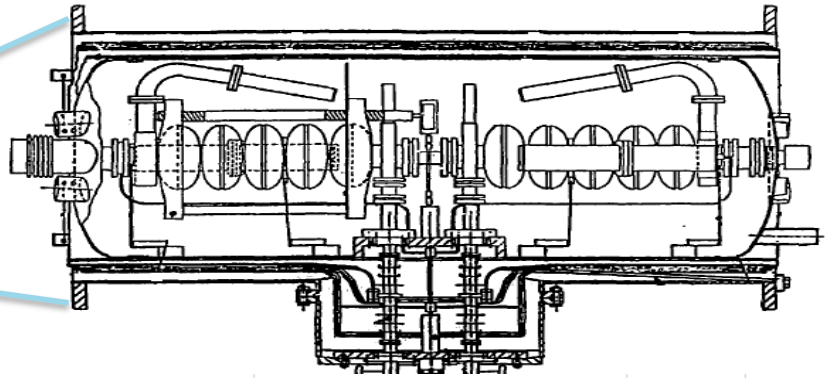
6 February 2020

TESLA Technology Collaboration Meeting

4 - 7th February 2020

# $Nb_3Sn$ cavities for Upgraded Injector Test Facility (UITF) @ Jlab (10 MV x 100 $\mu$A)

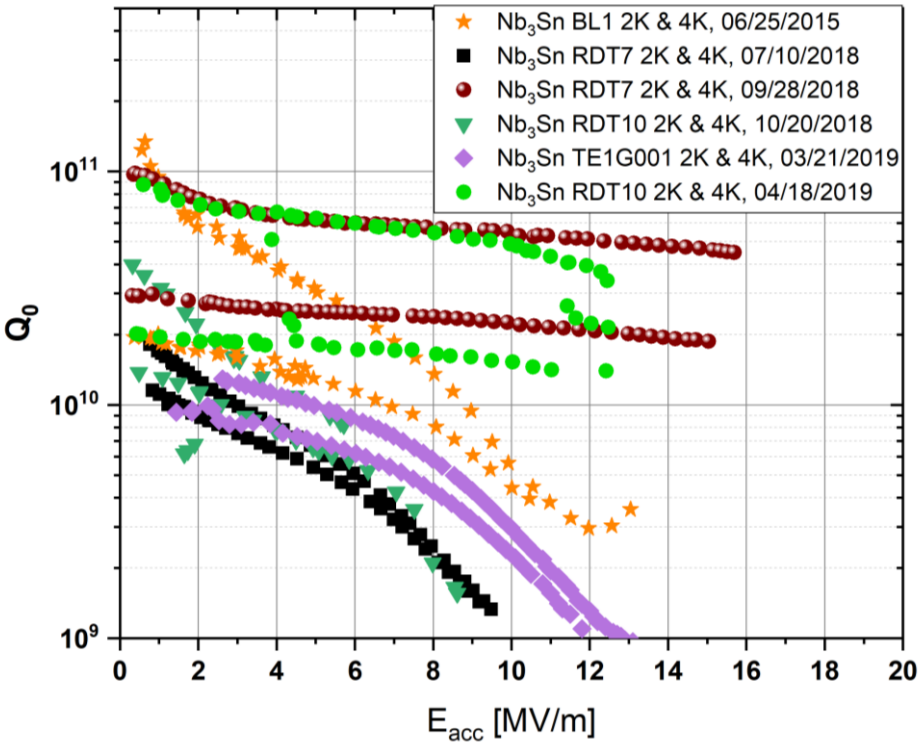


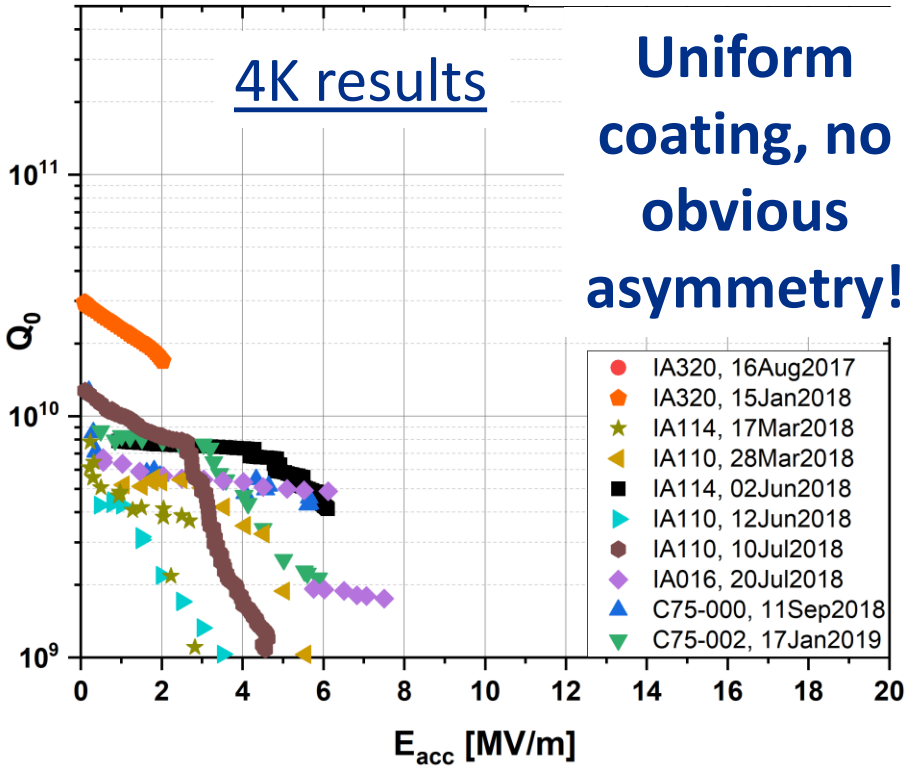



| Application | Beam Energy | Beam Current | Experiment Duration | Notes | Presenter |
|---|---|---|---|---|---|
| Commission QCM for CEBAF | 6 MeV, but prefer up to 10 MeV | up to 100 uA | three or four 1-week long tests | tests complete before long shutdown of 2020, when QCM to be installed at CEBAF | R. Kazimi |
| Commission HDIce for CEBAF | ~ 8 MeV | up to 100 nA for tuning, 0.25 to 5 nA for production | four or five run periods, one-month long each | target provides transverse polarization required for 3 A-rated Hall B experiments | A. Sandorfi |
| Manufacturing polarized targets for CEBAF via DNP | 1 - 10 MeV | 1 to 10 uA | hours, days | likely some R&D to determine optimum polarizing conditions | C. Keith |
| Bubble Chamber astrophysics | 4 - 10 MeV | 0.01 to 100 uA | 3 weeks, as often as possible | UITF better location than CEBAF injector, when CEBAF shutdowns are short | R. Suleiman |
| MeV parity violation experiment | 10 MeV | milliamps preferred, will reduce experiment duration | months to years | requires polarized electron beam, transmission geometry offers advantages | R. Carlini |
| Testing Nb3Sn-coated cavities | determining the beam energy of test cavity is point of test | up to 100 uA | as many tests as possible | Nb3Sn cavities require only 4K Helium | G. Eremeev |
| Wastewater treatment | 2- 10 MeV | 100 uA | imagine week-long test durations over three years | together with local partners | G. Ciovati |
| Polarized positron source | 5 - 10 MeV | up to 100 uA | staged tests, likely many required, 1-week long duration | requires polarized electron beam | J. Grames |
| EIC: fast kicker tests | 5 - 10 MeV | up to 100 uA | two 1-week long tests | together with sbir-partner | H. Wang |
| EIC: testing high bunch charge | 5 - 10 MeV | up to 100 uA | two 1-week long tests | requires polarized electron beam | J. Grames and J. Guo |

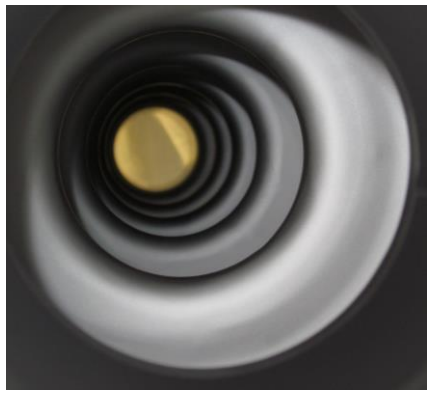
# Recent data after the coating system upgrade

U. Pudasaini




- Consistent $Q_0$ between Q-slope free cavities
- Q-slope limited performance for some coatings was linked to variation in Sn source; studies are ongoing
- RDT7, RDT10 & TE1G001 had NbTi flanges replaced with Nb flanges



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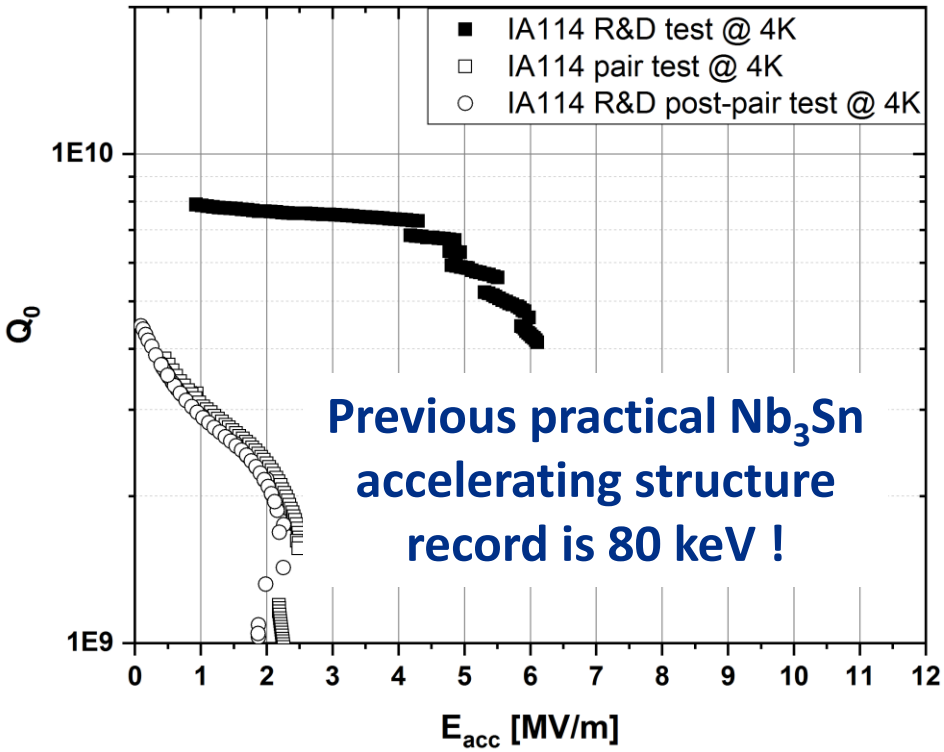
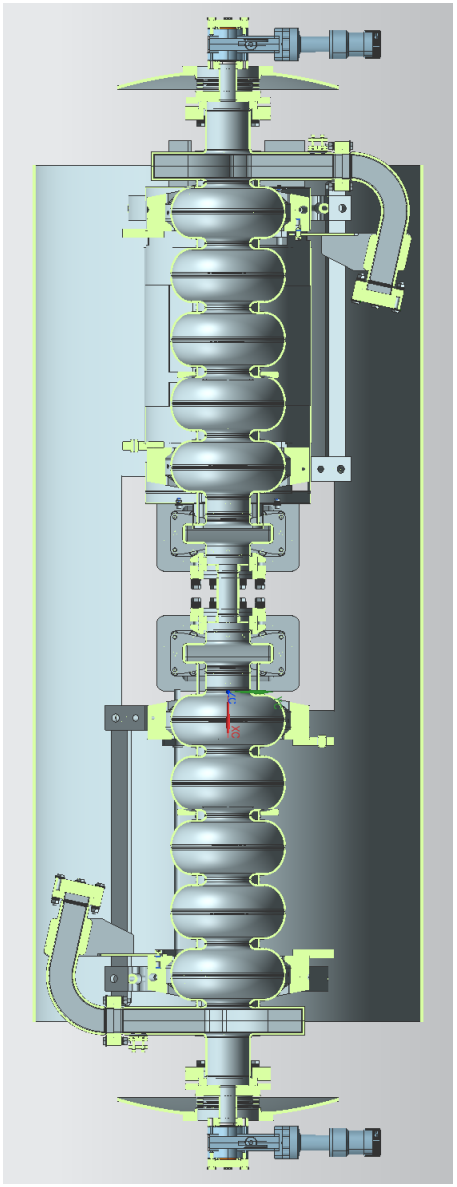
# Pair work and results



Quality factor and quench degraded after the cavity was tuned by about 200 kHz down. Tuning added field-dependent surface resistance, which increase by about 30 nΩ at low fields



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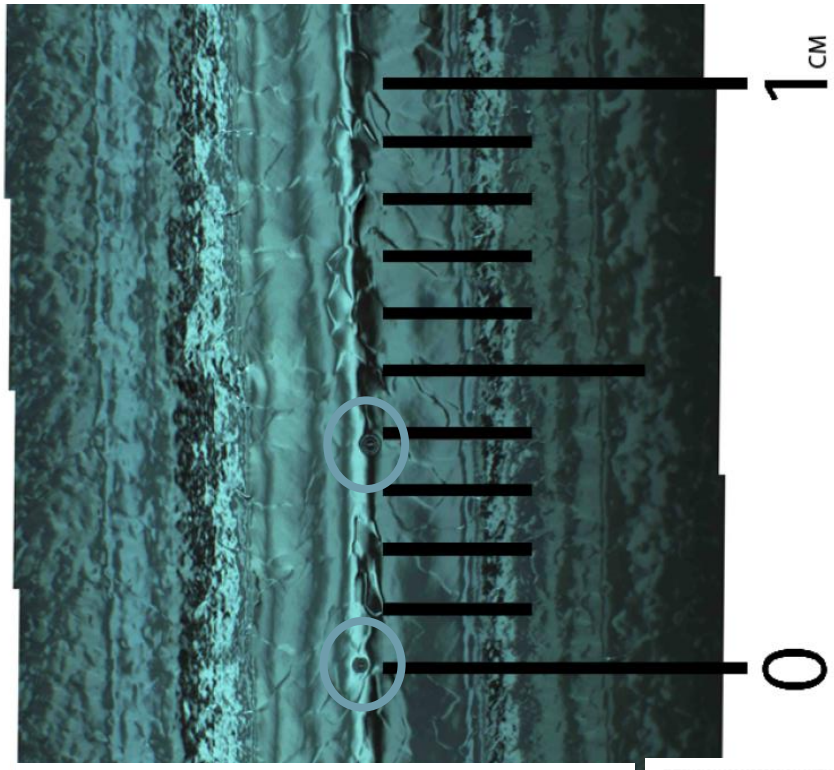
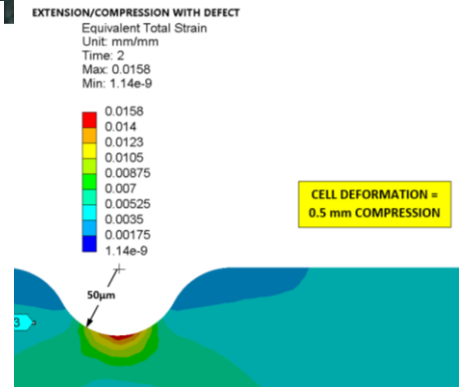
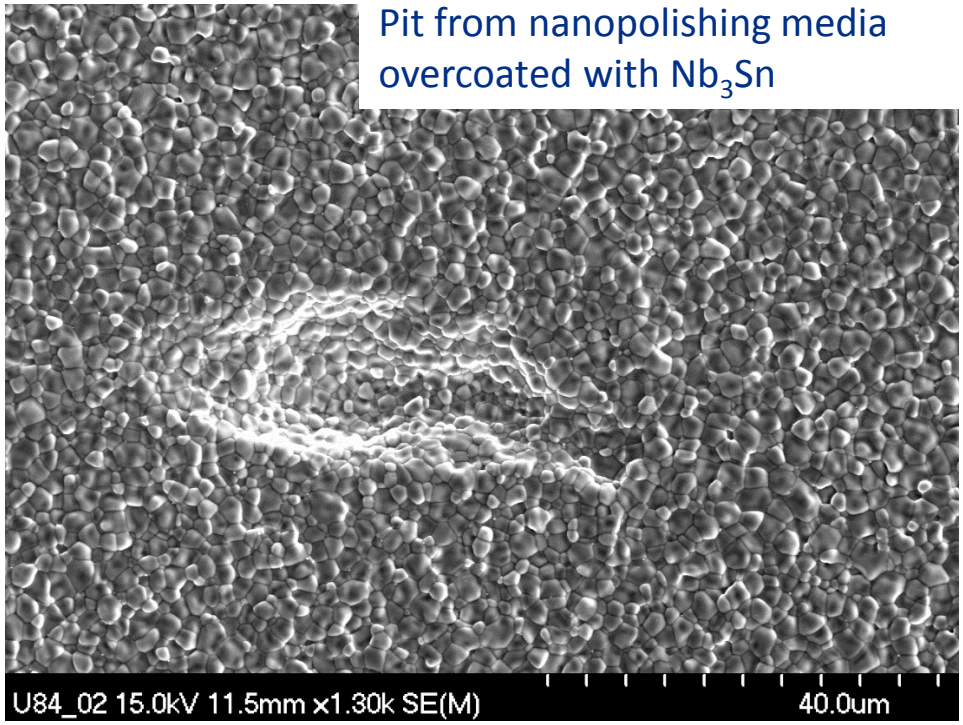
# Weak points?



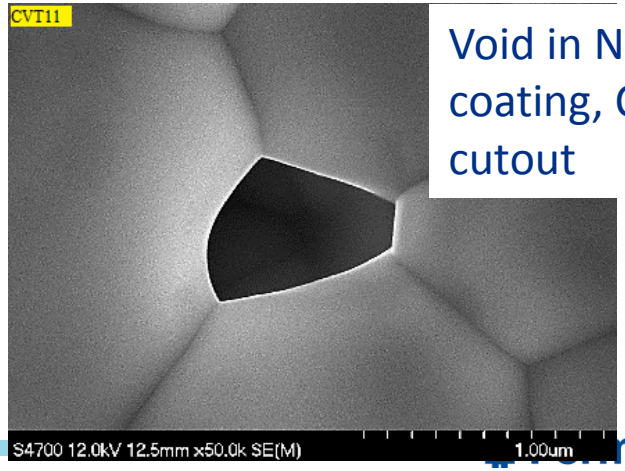

Surface imperfection are likely high stress points, where strain exceeds the average levels and significantly degrades surface resistance → smoothen the surface by centrifugal barrel polish




Pit from nanopolishing media overcoated with $Nb_3Sn$




Void in $Nb_3Sn$ coating, C3C4 cutout



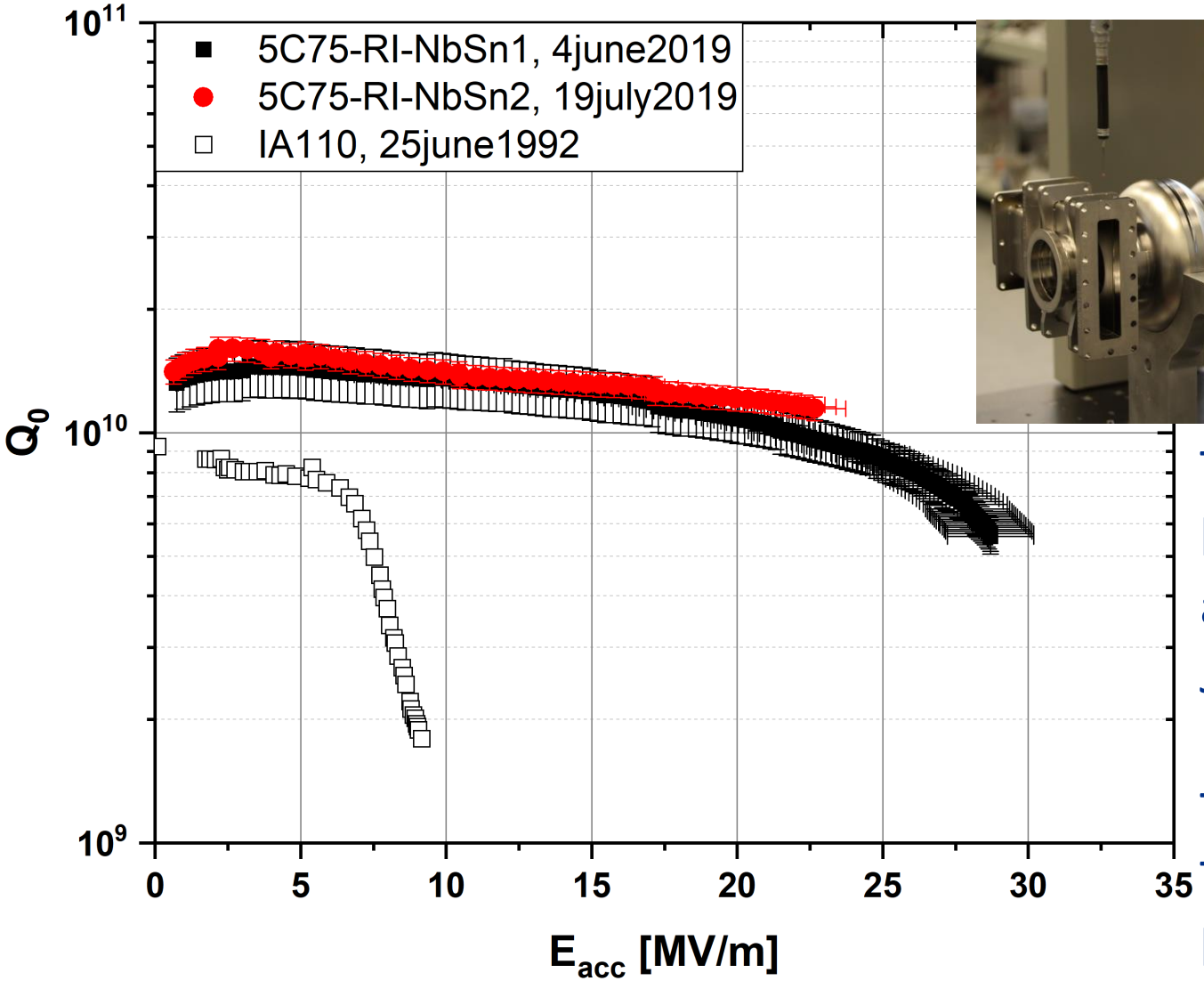
# In lieu of summary

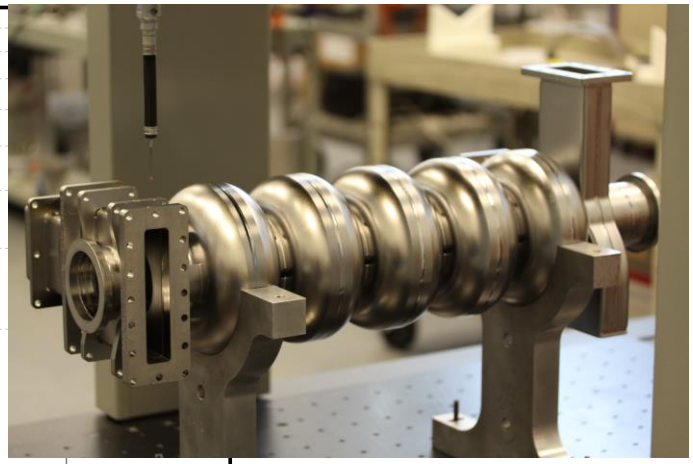
The research in new materials for SRF application is growing…

…but it is important to remember about the quality of the substrate

Eremeev, TTC'18

# Baseline test of the new C75 cavities for $Nb_3Sn$ project



These cavities were built by Interatom/RI and processed at JLab.

There were a few TTC meetings in between …



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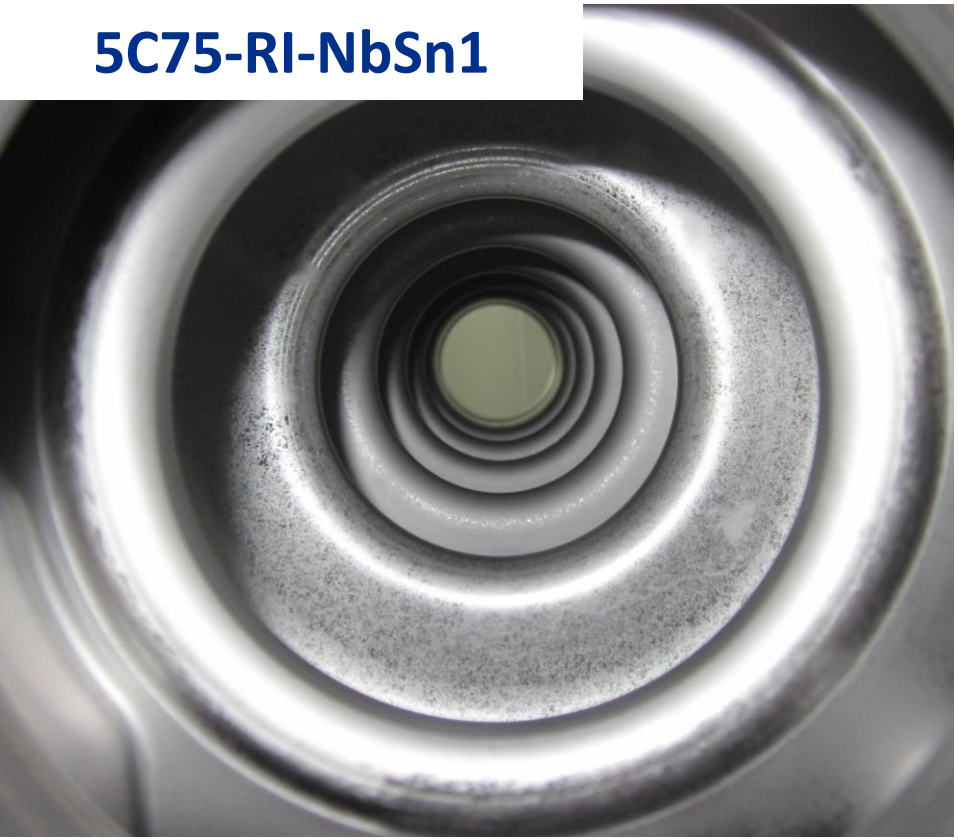
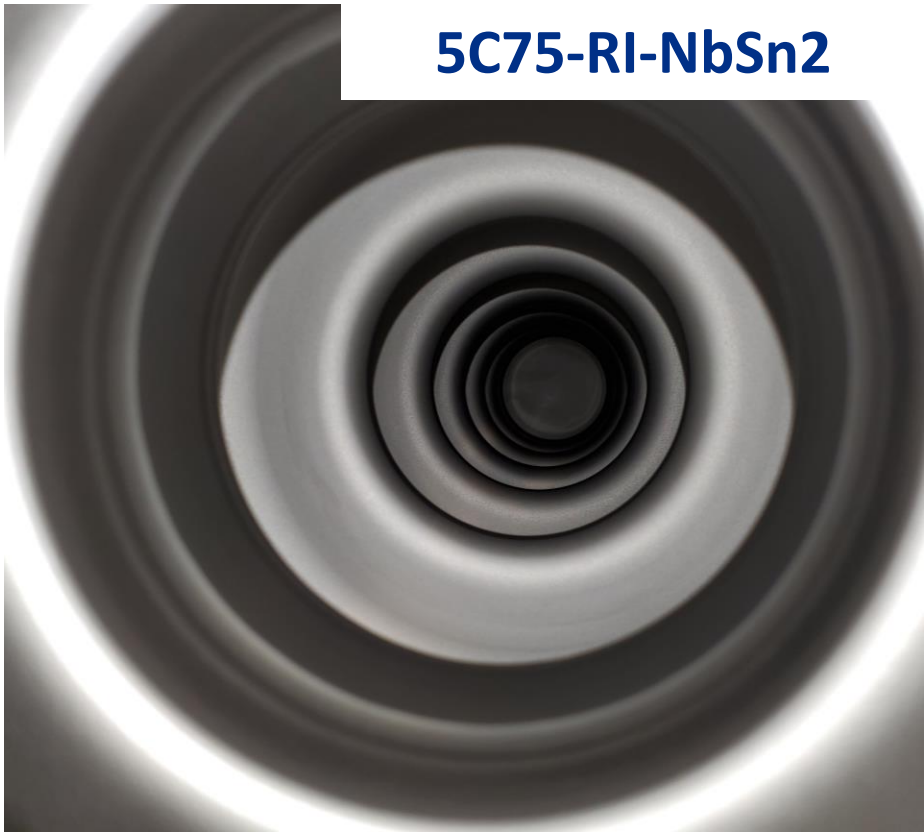
# C75 cavity coating

U. Pudasaini

5C75-RI-NbSn1

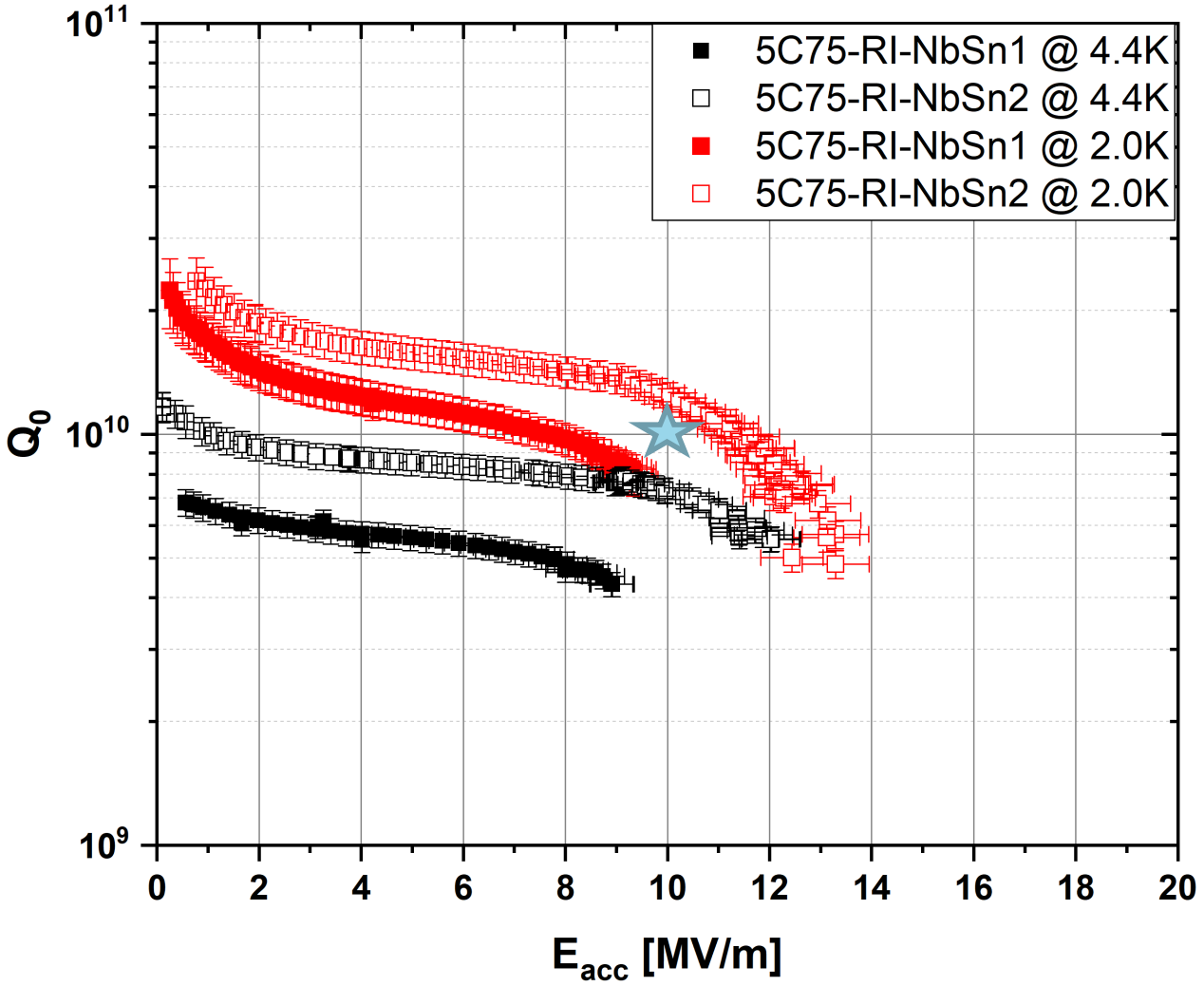


5C75-RI-NbSn2

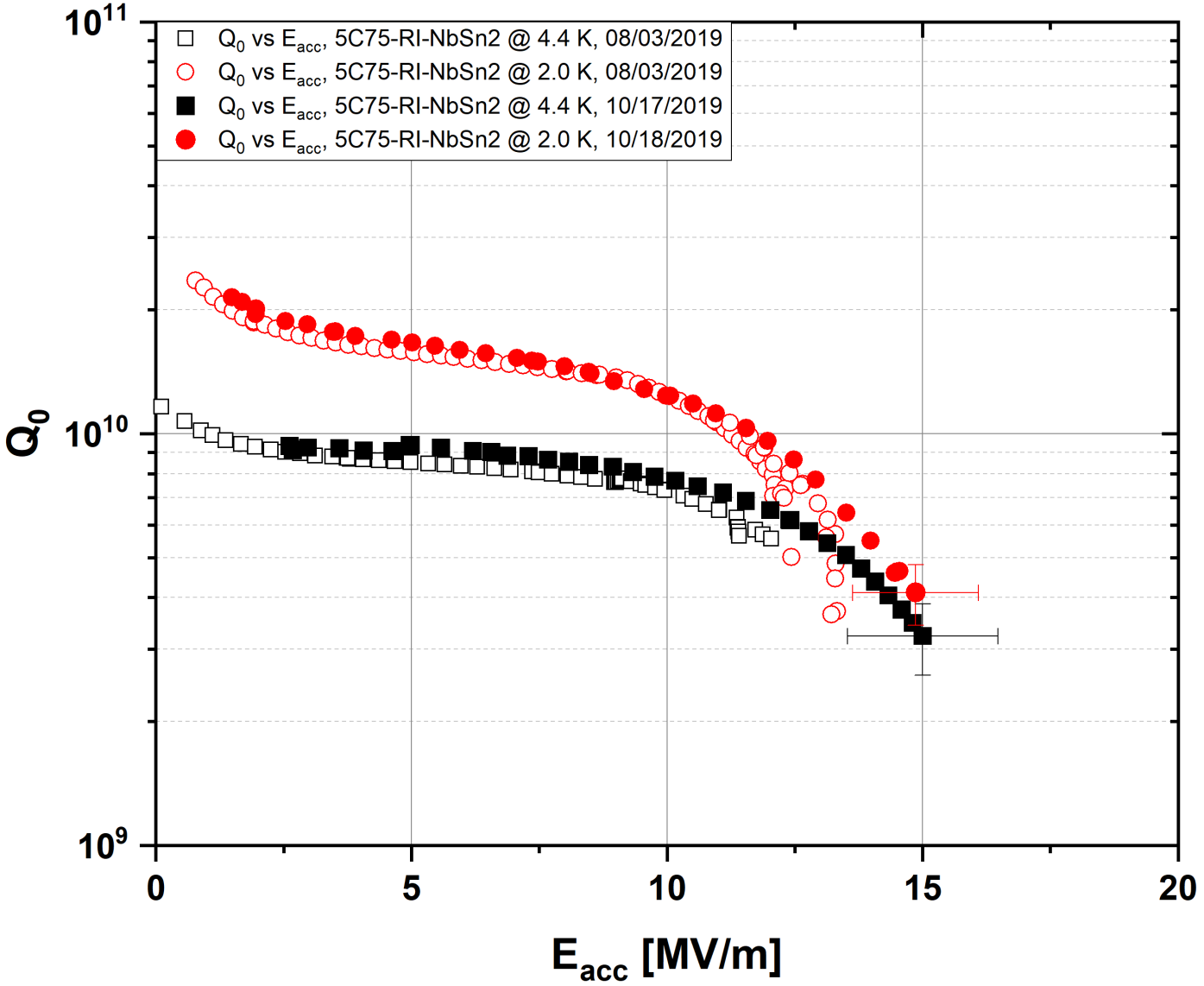


**Uniform coating, no obvious asymmetry… in the second cavity!**

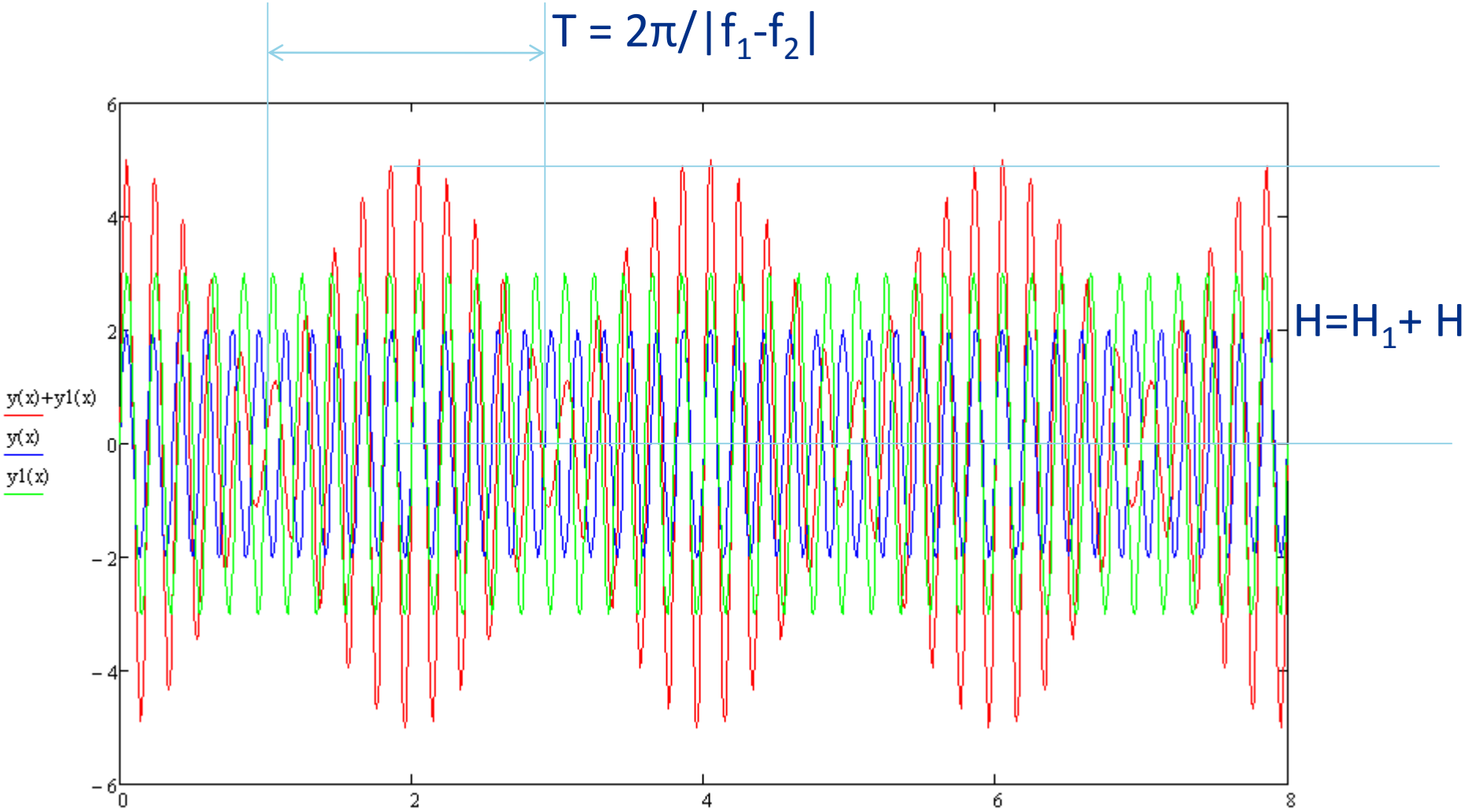
# $Nb_3Sn$-coated C75 cavity test results



# Re-test @ Fermilab



# Two mode intro




Time averaged applied field is $H_1^2 + H_2^2$, but maximum field is equal to $H_1 + H_2$ with $f \sim |f_1 - f_2|$

H. Padamsee, D. Proch, P. Kneisel, and J. Mioduszewski, IEEE Trans. Magn. **17**, 947 (1981).



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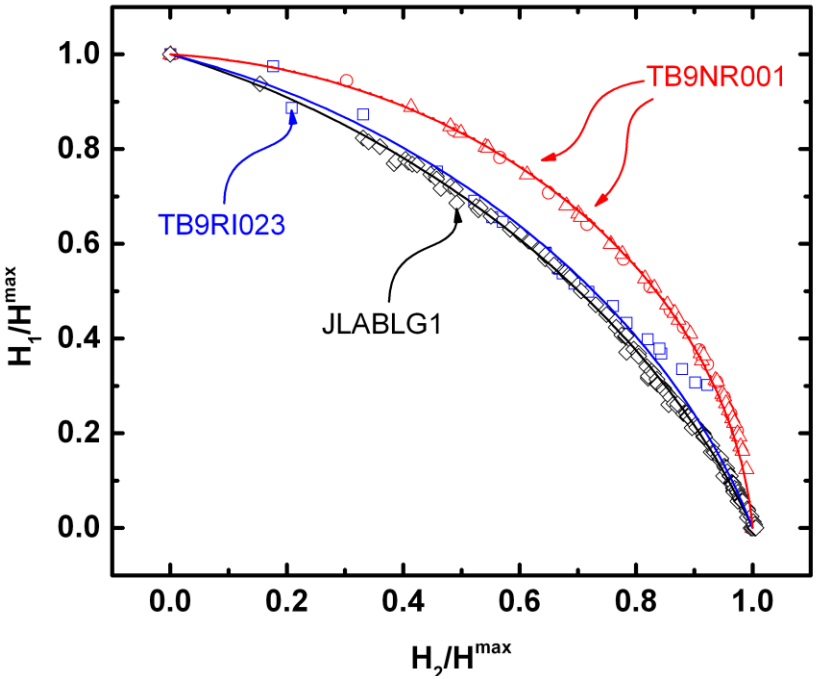
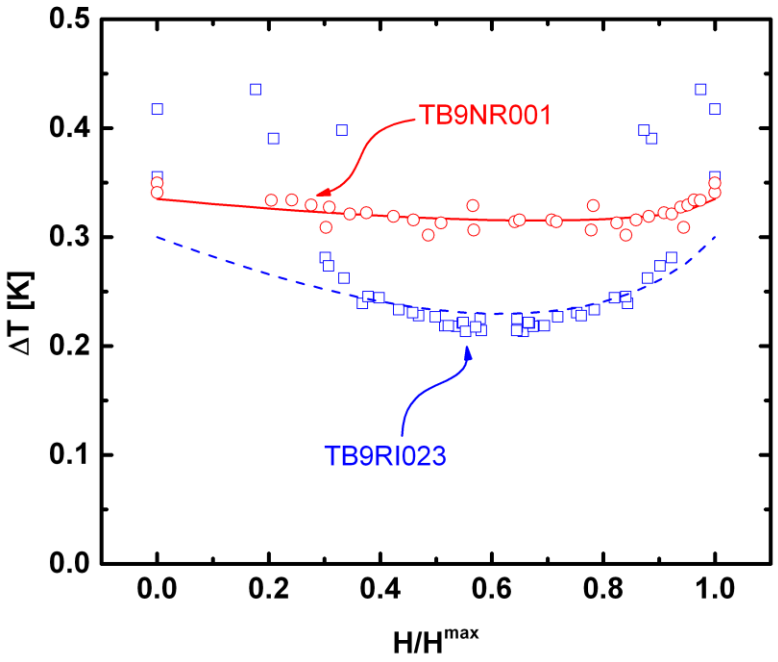
# Two mode intro




$$\alpha(\tilde{H}_1+\tilde{H}_2)+ \\ +2\frac{T_0^2}{T_c^2-T_0^2}\left(\sqrt{\frac{T_c^2}{T_0^2}(1-\alpha)+\alpha}-1\right)(\tilde{H}_1^2+\tilde{H}_2^2)+ \\ +\frac{T_0^2}{T_c^2-T_0^2}\left(\sqrt{\frac{T_c^2}{T_0^2}(1-\alpha)+\alpha}-1\right)^2(\tilde{H}_1^2+\tilde{H}_2^2)^2=1 \quad (9)$$

$$\alpha=\frac{H_{\max}}{H_c\left(1-\left(\frac{T_0}{T_C}\right)^2\right)}$$

G. Eremeev and A. D. Palczewski, JAP **115**, 023901 (2014)



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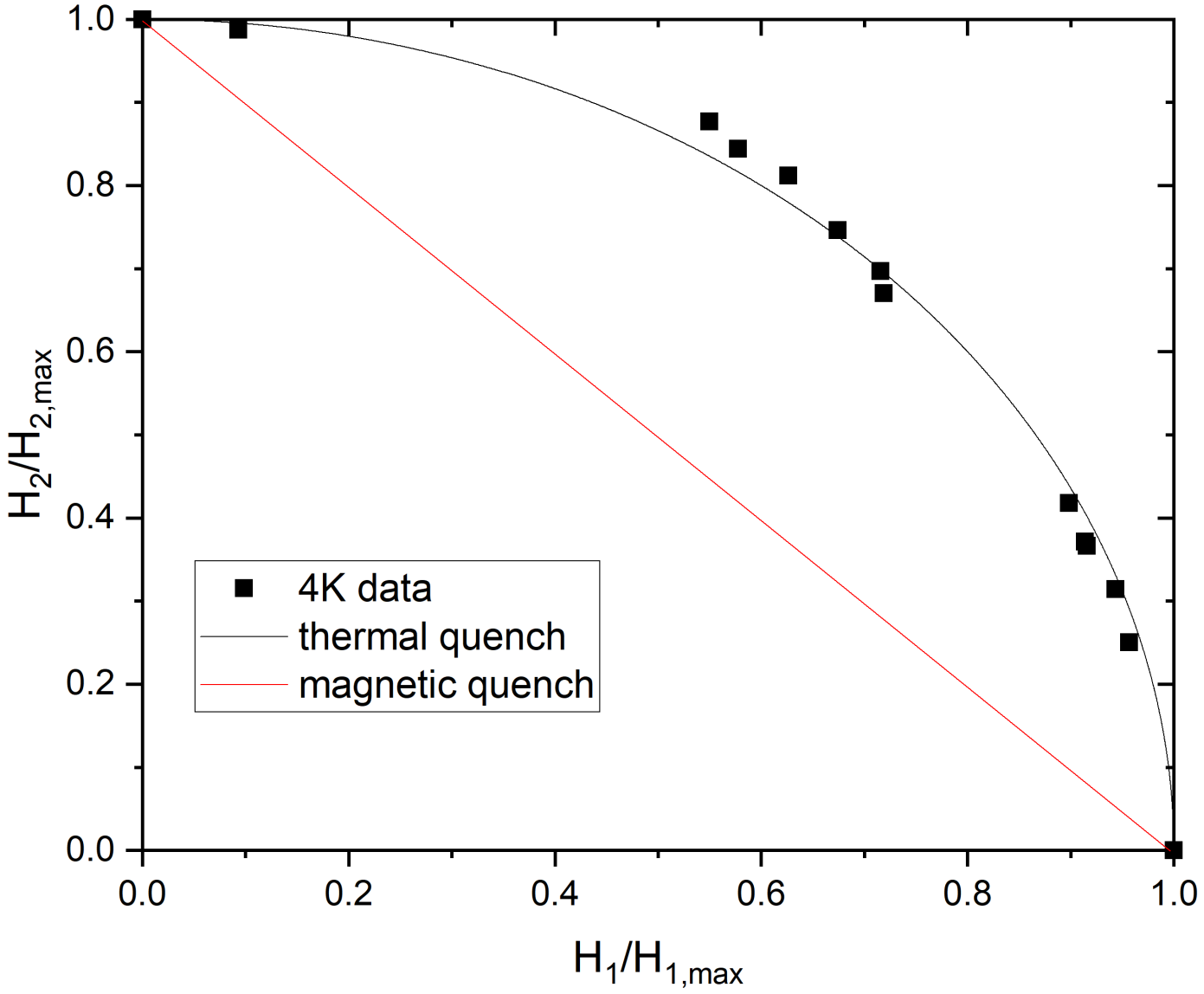
# Two mode results with $Nb_3Sn$-coated 5C75-RI-NbSn2



# Two mode results

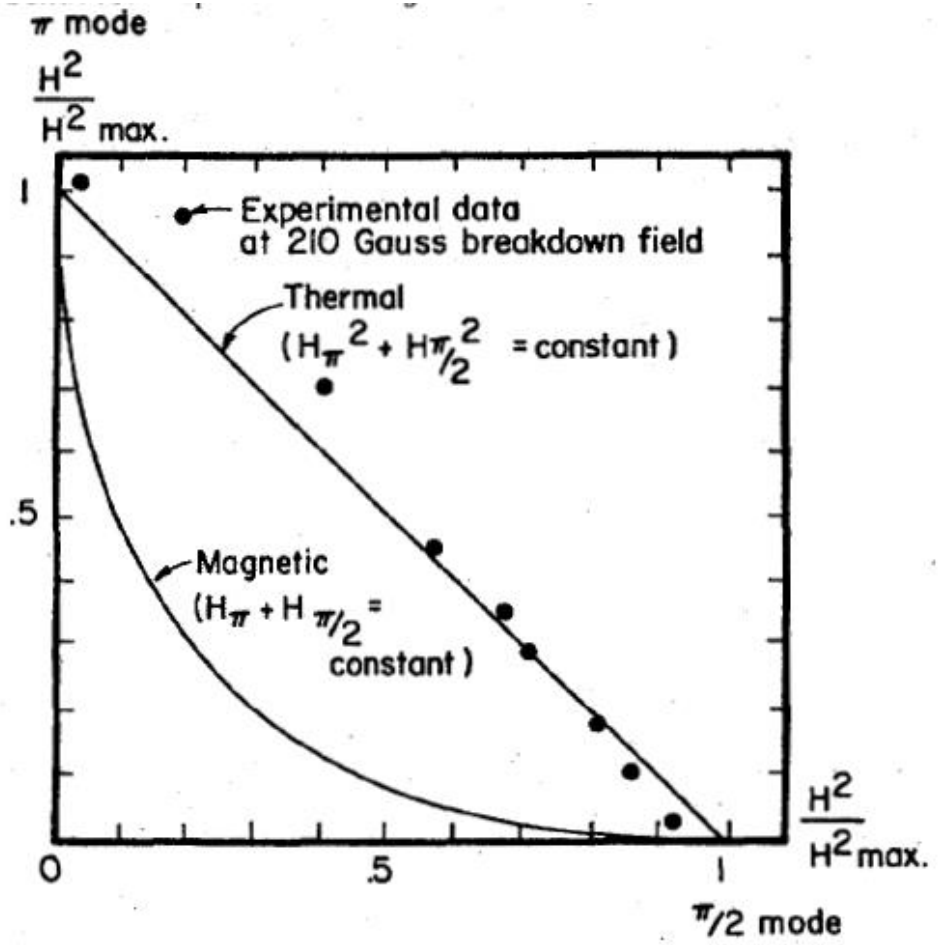
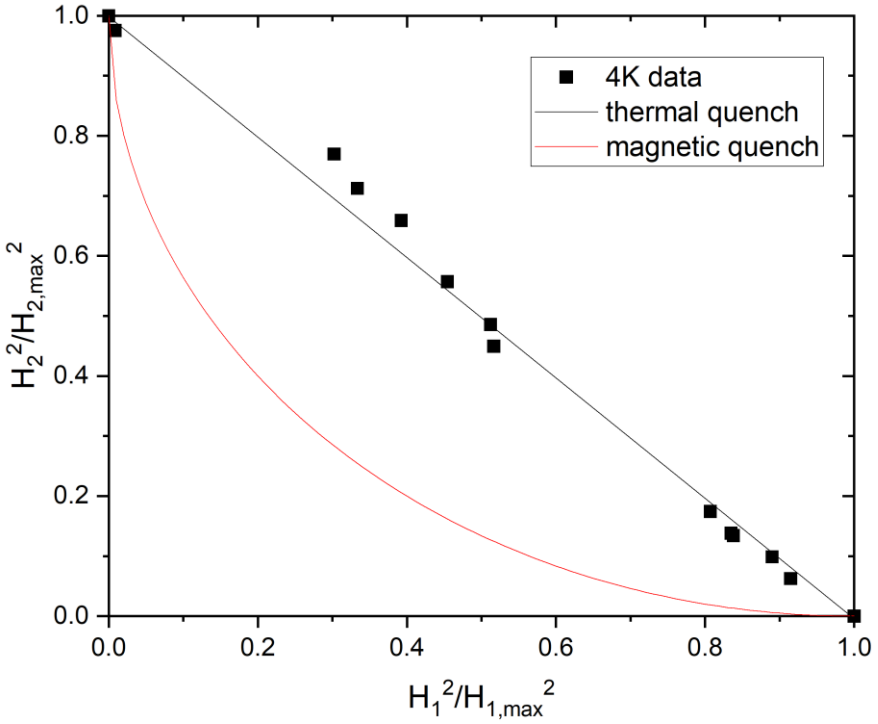



Fig. 4: Mode mixing experimental data to distinguish between thermal and magnetic breakdown.




H. Padamsee, D. Proch, P. Kneisel, and J. Mioduszewski, IEEE Trans. Magn. **17**, 947 (1981).
The conclusion was -- "The data unambiguously supports the thermal model."



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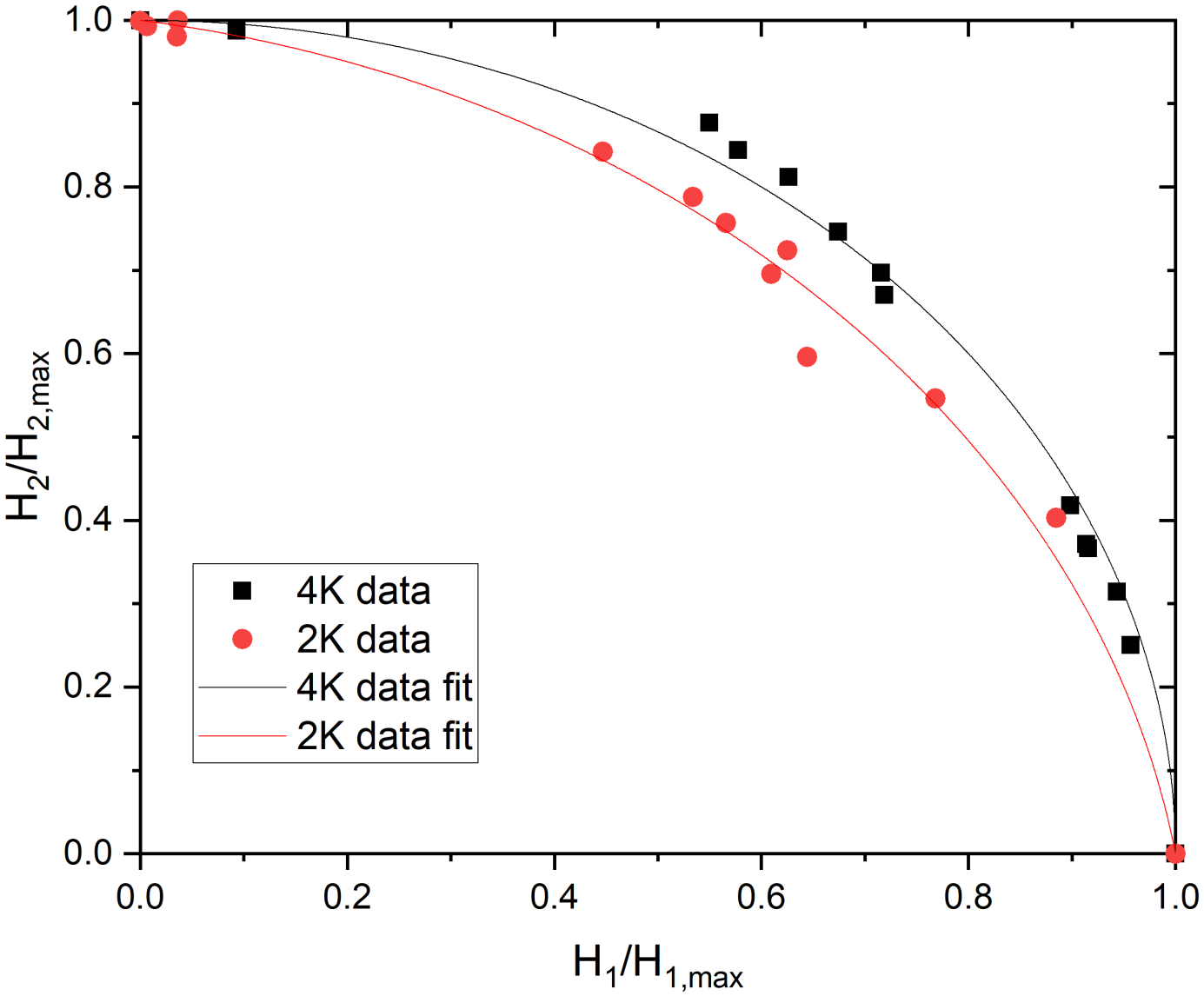
# Two mode results



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# Conclusions

- Two $Nb_3Sn$-coated 5-cell cavities qualified for assembly into a quarter cryomodule for the UITF @ JLab.
- Tin control, avoid titanium, and … tuning or straightening $Nb_3Sn$-coated cavities
- "The data unambiguously supports the thermal model."
  $\Longrightarrow$ the path to higher gradients with $Nb_3Sn$-coated cavities is in the reduction of thermal impedance

## Acknowledgements


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- Gigi Ciovati, Charlie Reece, Bob Rimmer, Anne-Marie Valente-Feliciano, Larry Phillips, Peter Kneisel, John Mammosser
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- ✓ Damon Bice, Roman Pilipenko, Alex Romanenko, Anna Grassellino
- ✓ JLab & Fermilab technical staff

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# Thank you for your attention!