Nb_3Sn 5-cell cavity qualification for Nb_3Sn cryomodule

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Fermilab

Jefferson Lab

1st International Workshop on Nb_3Sn SRF
Science, Technology, and Applications

U.S. DEPARTMENT OF ENERGY | Office of Science

13 November 2020

Nb3SnSRF'20

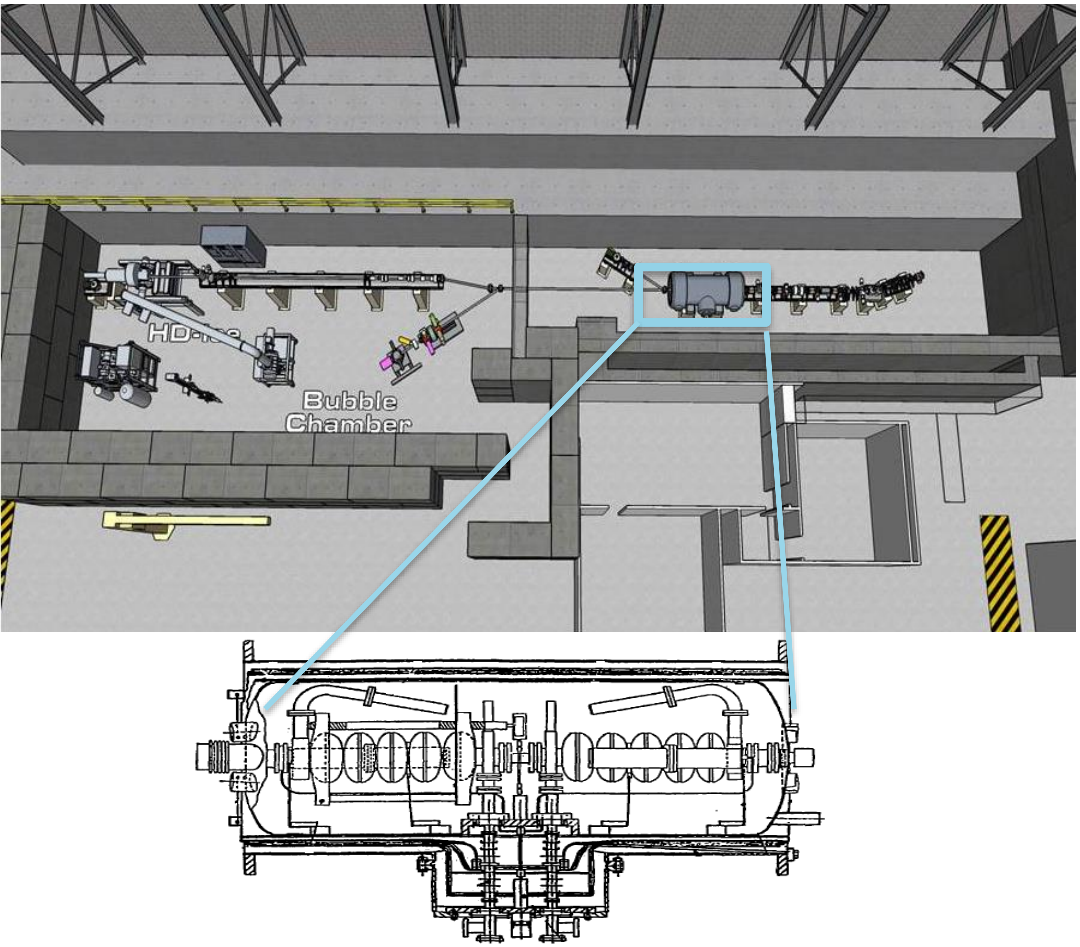
Acknowledgements

- Michael Kelley, Gigi Ciovati, Bob Rimmer, Anne-Marie Valente-Feliciano, Larry Phillips, Peter Kneisel, John Mammosser
- Jlab & FNAL technical staff

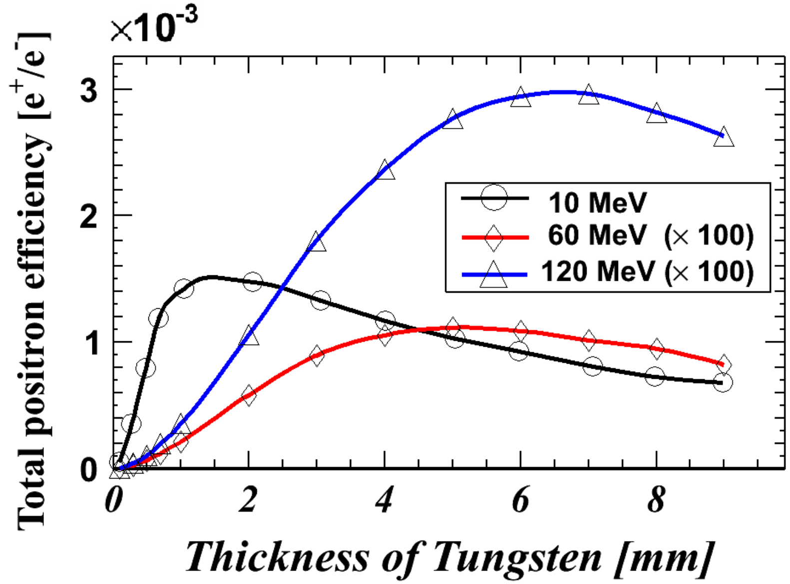
This material is based upon work supported by the U.S. Department of Energy, Office of Science, Office of Nuclear Physics

We are grateful for support from the Office of High Energy Physics, U.S. Department of Energy under grant DE-SC-0014475 to the College of William & Mary.

Nb_3Sn cavities for Upgraded Injector Test Facility (UITF) @ JLab



D. Abbott et al. , Phys. Rev. Lett. 116, 214801
B. DiGiovine et al., Proc. AIP Conf. 1563, 239 (2013)
http://wiki.jlab.org/ciswiki/index.php/Main_Page



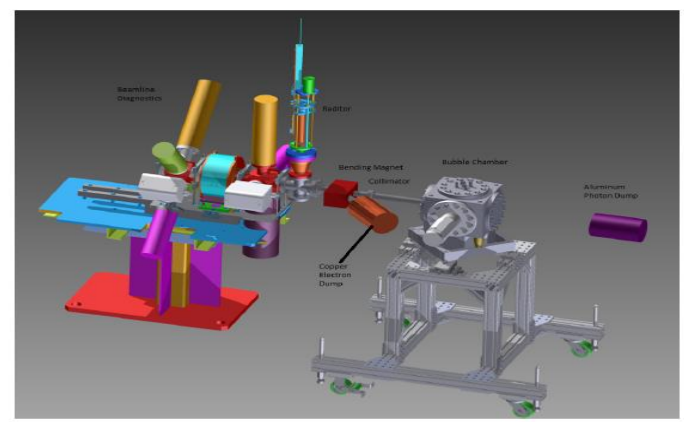


Fig. 12. Schematic of the proposed experiment.

The photon yield that hits the bubble chamber is shown in figure 14. Here the electron beam has a kinetic energy of 8.5 MeV and is irradiating the 0.02 mm Cu radiator. Since the $^{16}O(\gamma,\alpha)^{12}C$ cross section is very steep, only photons next to the end point will produce events from this reaction.

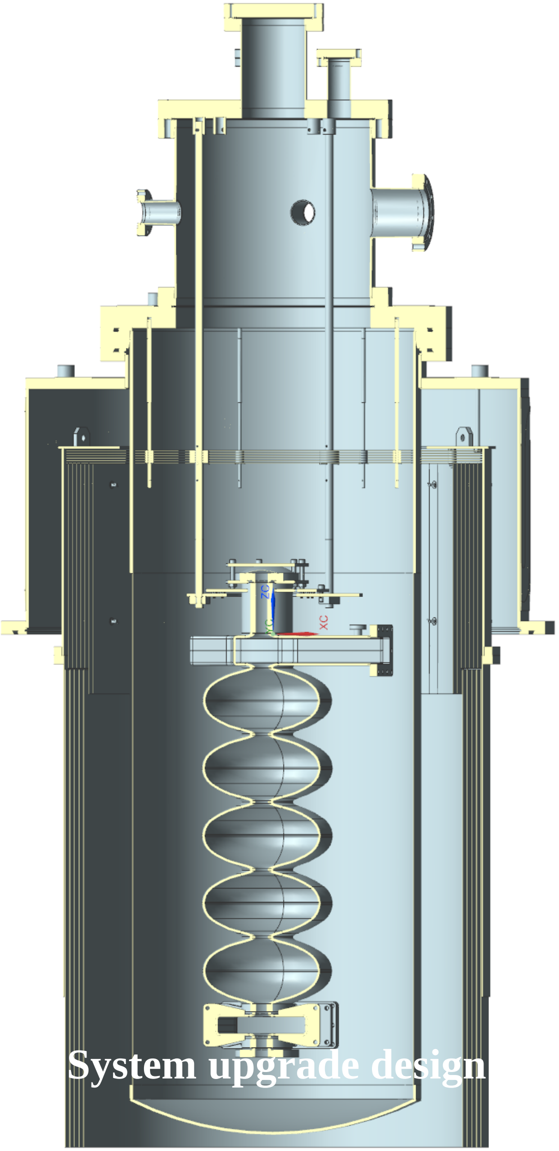
Courtesy of M. Poelker

Nb_3Sn cavities for Upgraded Injector Test Facility (UITF) @ JLab

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	10 to 18 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, ~ 3 runs/year	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 Nb_3Sn-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

Courtesy of M. Poelker

Accelerator cavity coatings



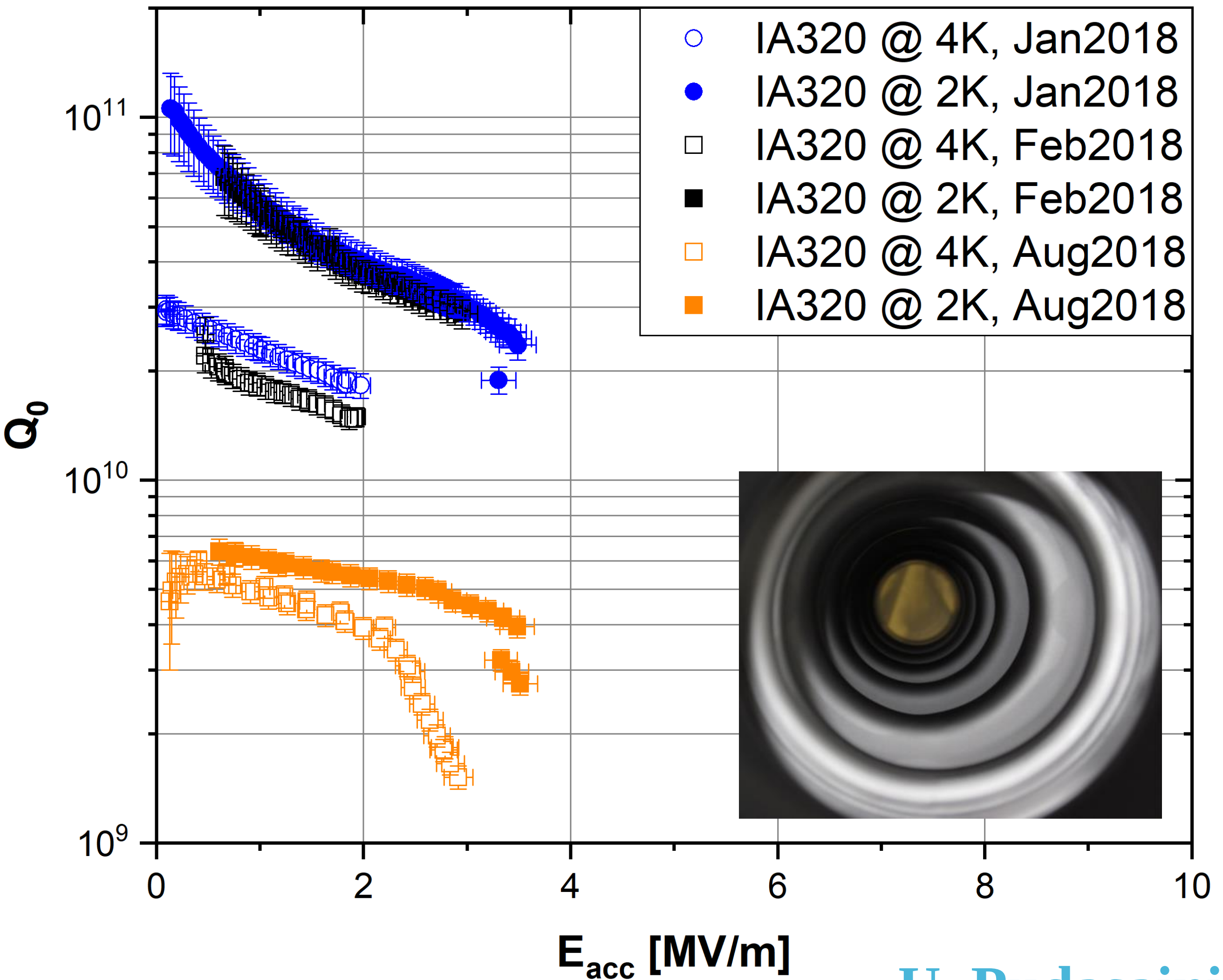
System upgrade design

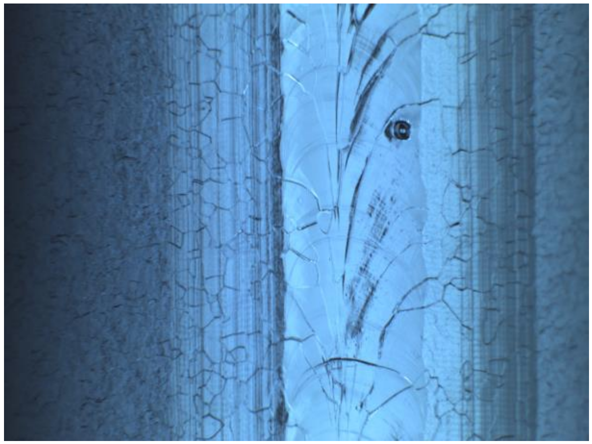
Upgrade commissioning

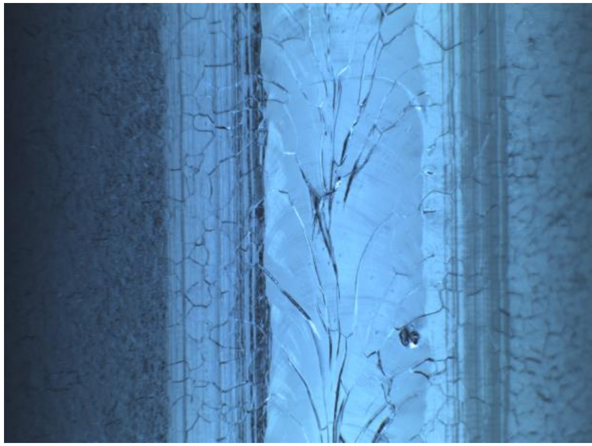
The new coating chamber

IA320 after coating

CEBAF 5-cell cavity coating results

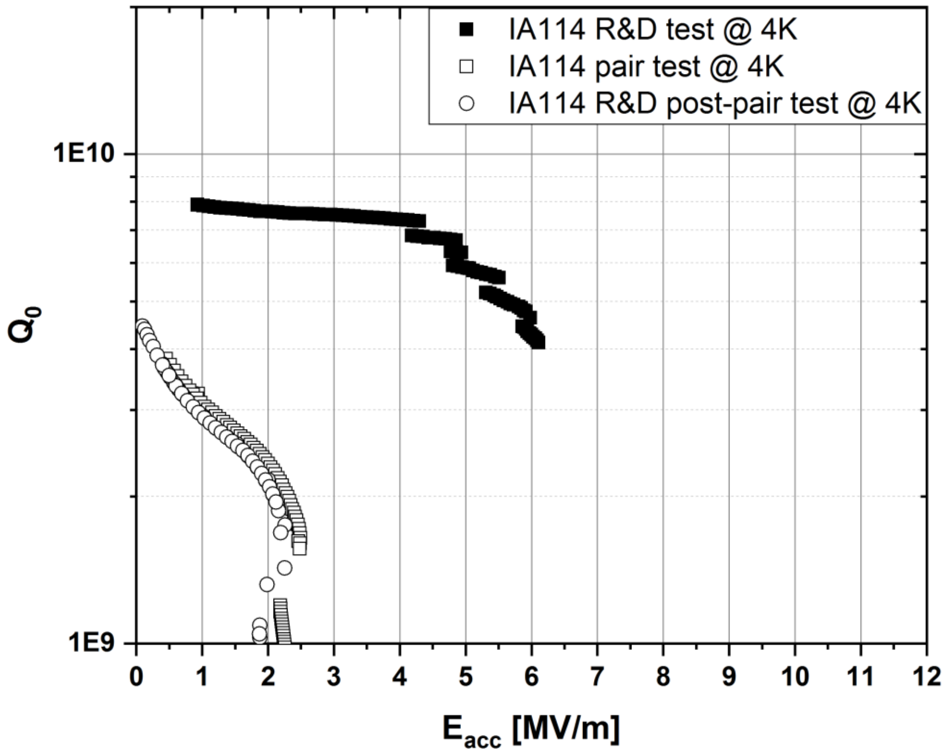


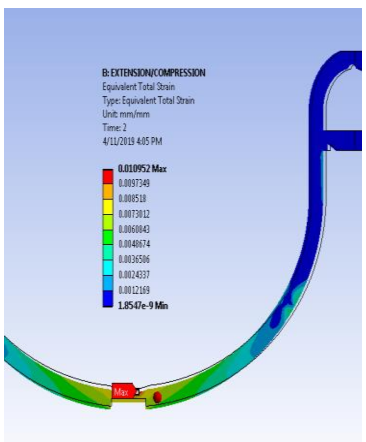


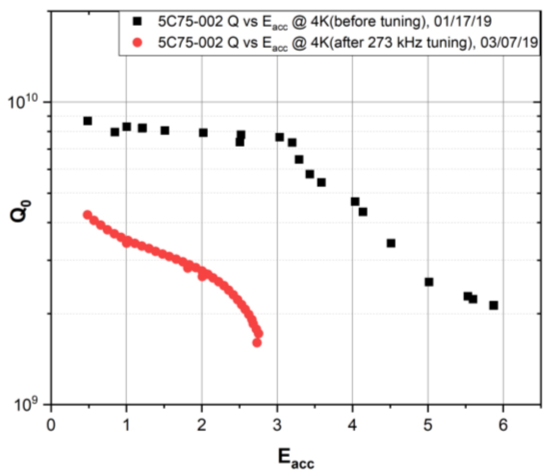


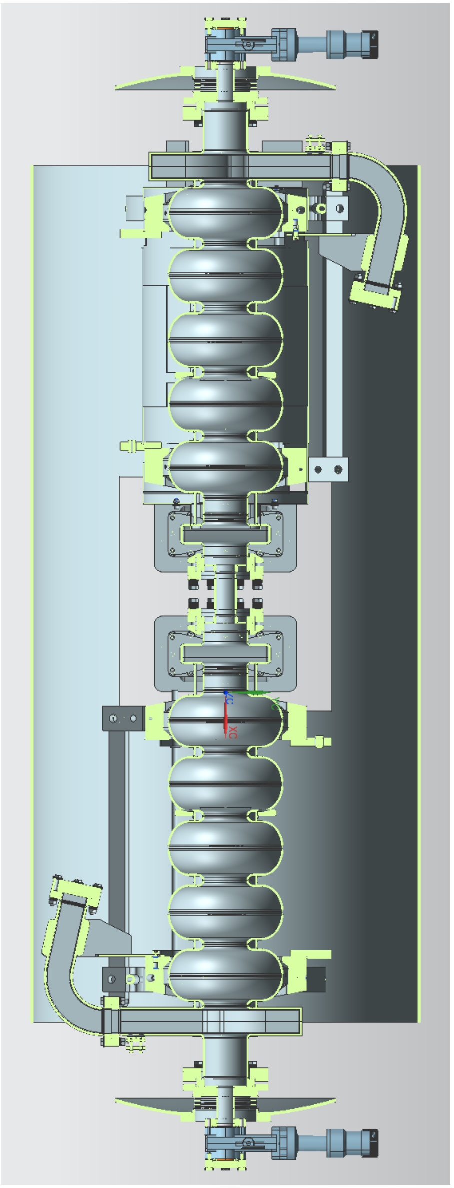
U. Pudasaini

First Nb_3Sn accelerating pair

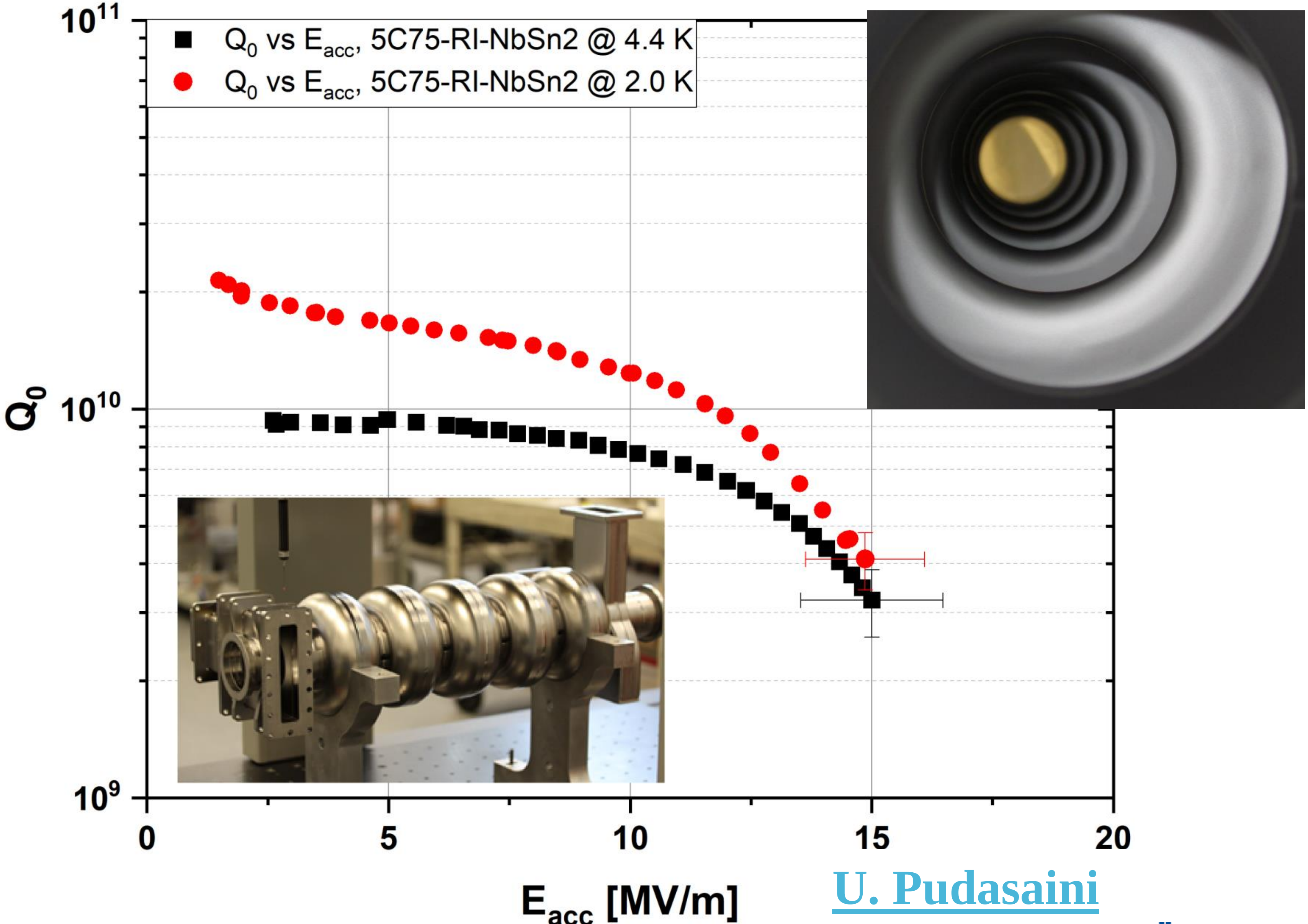






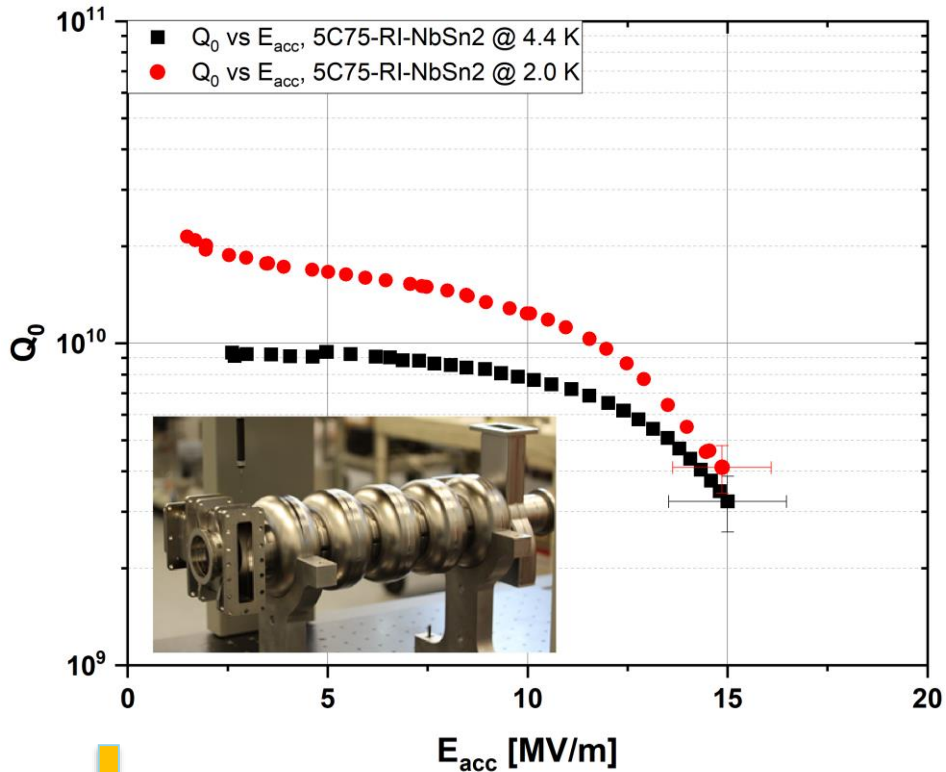


New C75 CEBAF 5-cell cavities coated with Nb_3Sn



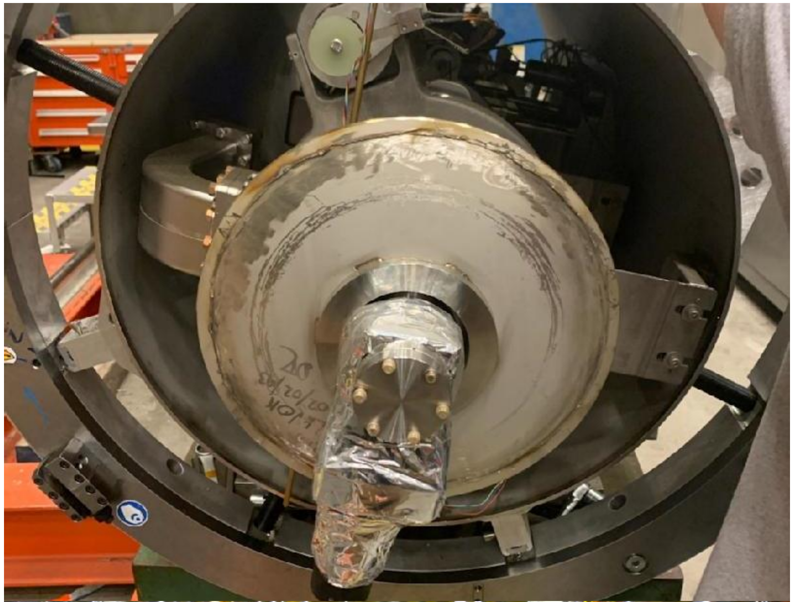
U. Pudasaini

Push towards Nb_3Sn cryomodule



tuning → CMM → tuning → CMM → tuning → CMM

Cryomodule work is in progress!



Measuring the nature of the breakdown by mixing two modes

Passband TM010 modes in multicell cavities

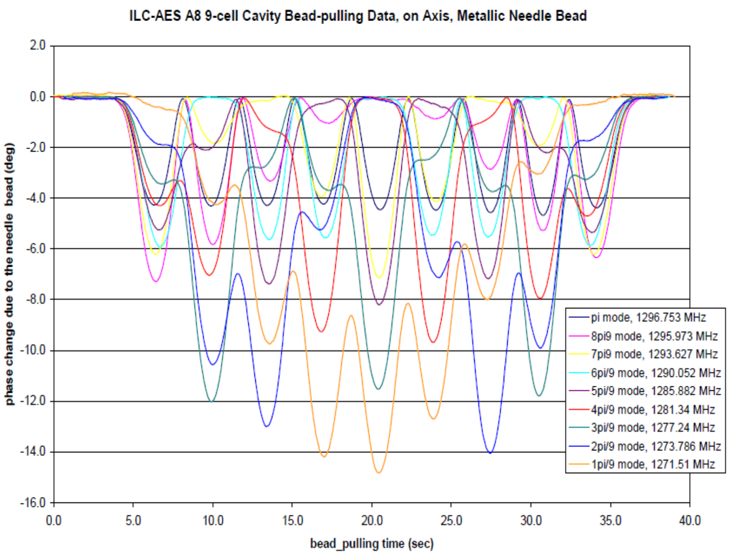
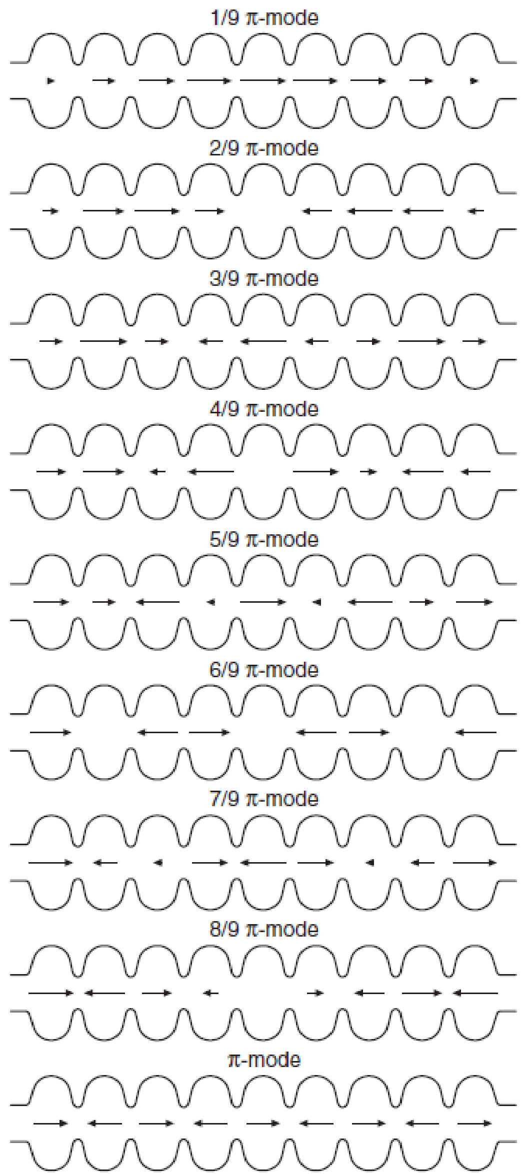


Figure 1: Bead-pulling data obtained from AES A8 cavity after final tuning.

FM	Mean eigenfrequency of 116 cavities
π	$f_\pi = (1\,300\,444 \pm 303)$ kHz
$8/9\,\pi$	$f_\pi - (785 \pm 51)$ kHz
$7/9\,\pi$	$f_\pi - (3053 \pm 94)$ kHz
$6/9\,\pi$	$f_\pi - (6501 \pm 157)$ kHz
$5/9\,\pi$	$f_\pi - (10\,694 \pm 243)$ kHz
$4/9\,\pi$	$f_\pi - (15\,122 \pm 347)$ kHz
$3/9\,\pi$	$f_\pi - (19\,237 \pm 430)$ kHz
$2/9\,\pi$	$f_\pi - (22\,594 \pm 503)$ kHz
$1/9\,\pi$	$f_\pi - (24\,773 \pm 543)$ kHz

Elmar Vogel ,“High gain proportional rf control stability at TESLA cavities”,
Haipeng Wang , “TM010 Pass Band Modes of TESLA 9-cell Cavity”

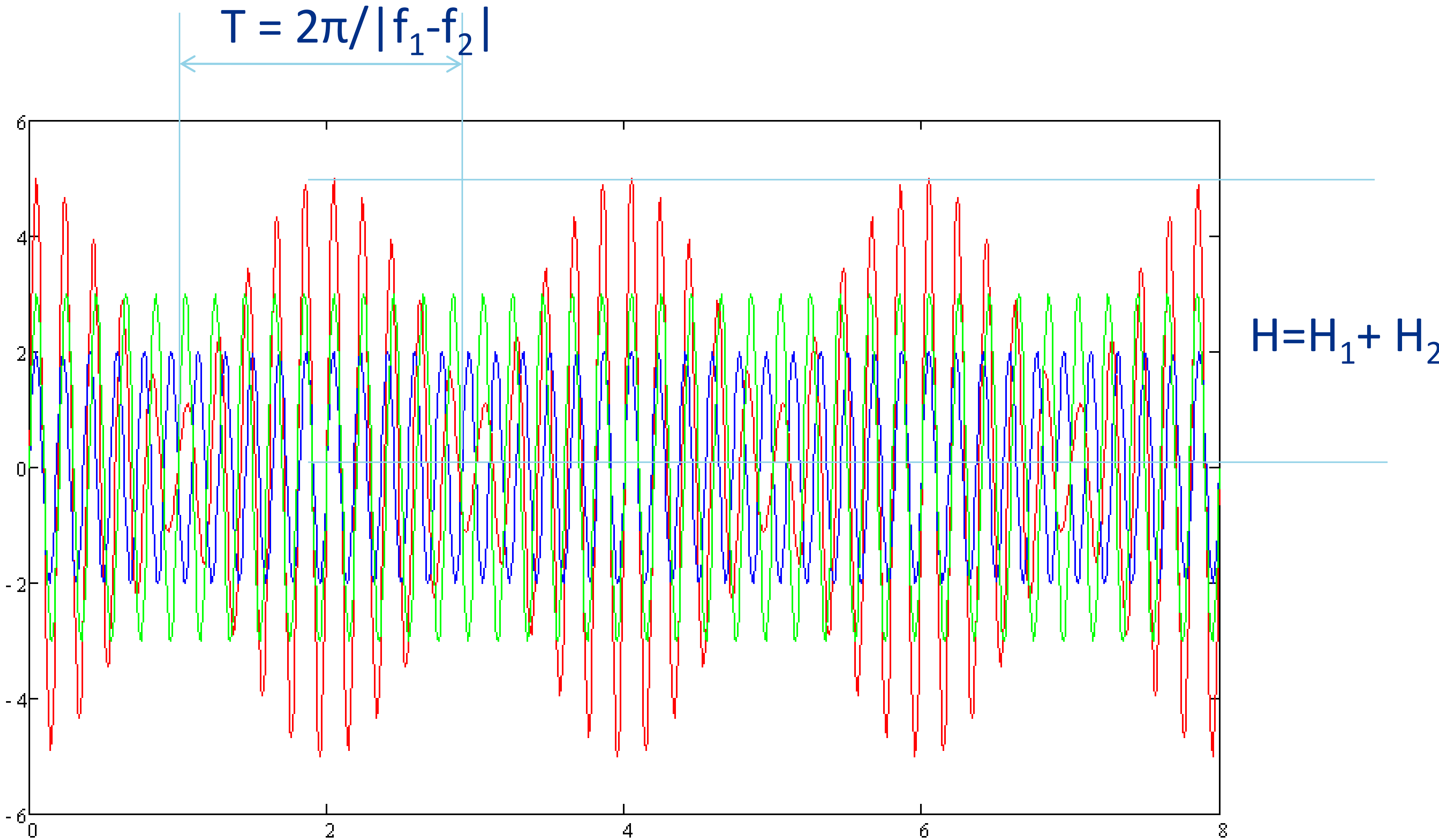


Passband modes in 9-cell

Passband measurements are routinely done on 9-cell cavities to measure limitation in different cells.

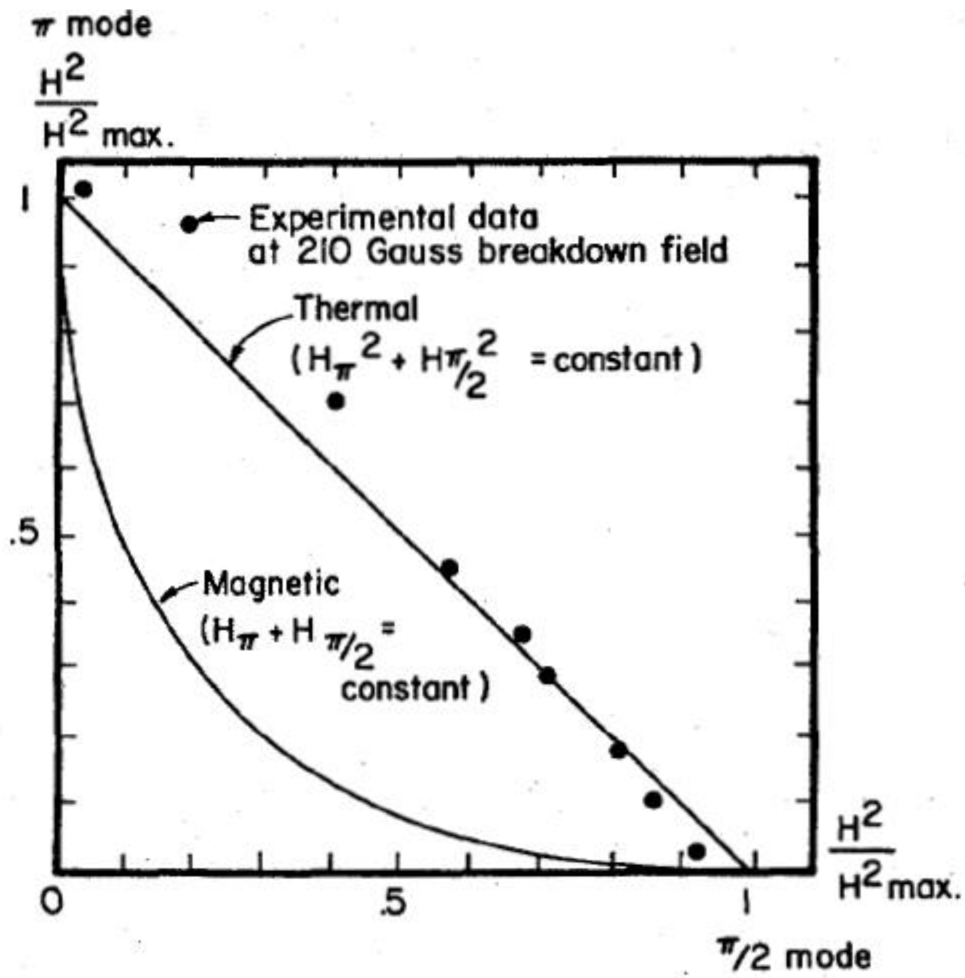
Second sound measurements with oscillating superleak transducers allows to distinguish between different quenches.

"beating" in applied field



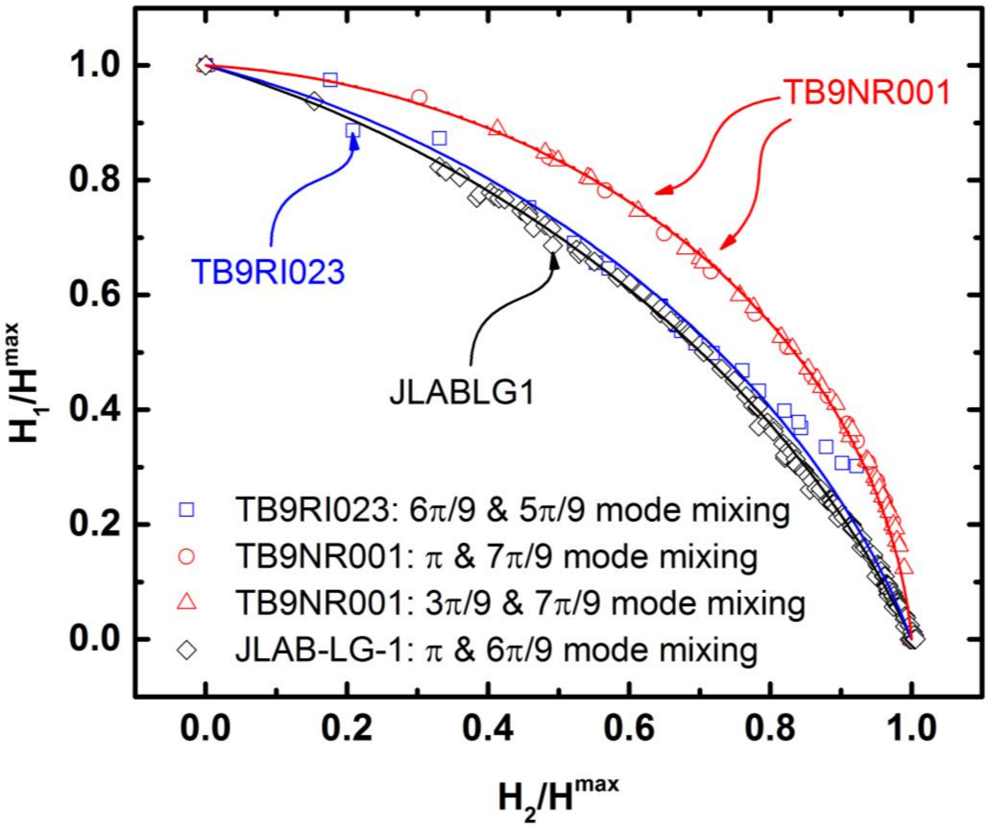
Dissipated heat scales as $H_1^2 + H_2^2$, but the maximum field scales $H_1 + H_2$

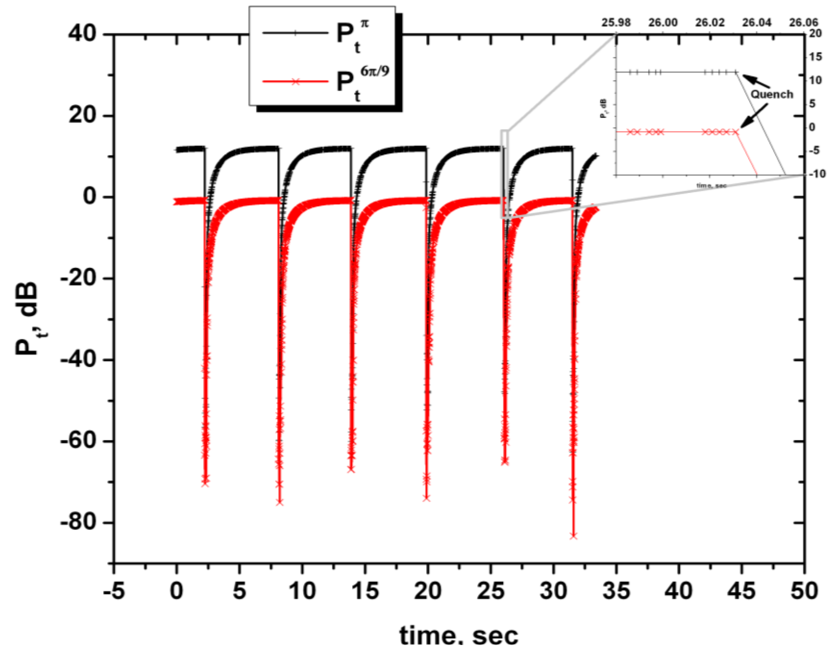
Thermal breakdown limitation in the older niobium cavities

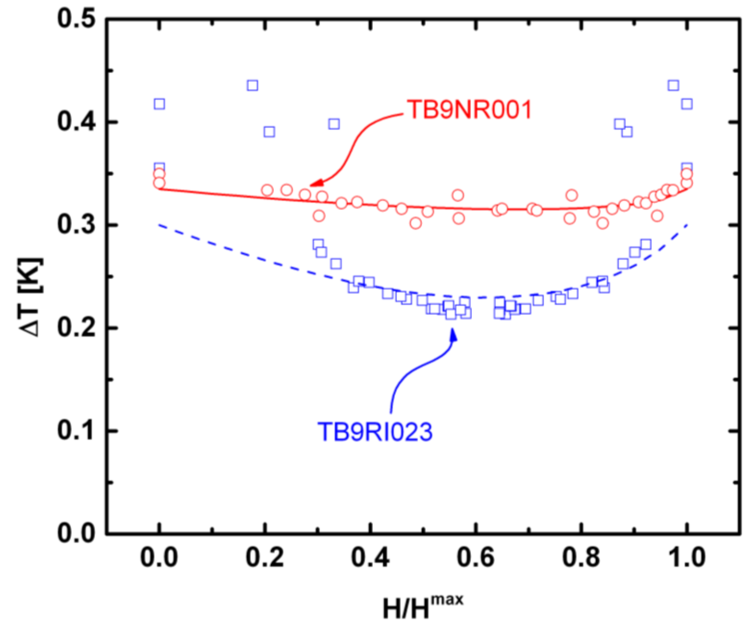


It was done in 1980 by D. Proch on 2-cell cavities:
H. Padamsee, D. Proch, P. Kneisel, and J. Mioduszewski, IEEE Trans. Magn. **17**, 947 (1981).
The conclusion was -- "The data unambiguously supports the thermal model."

Recent mode-mixing measurements







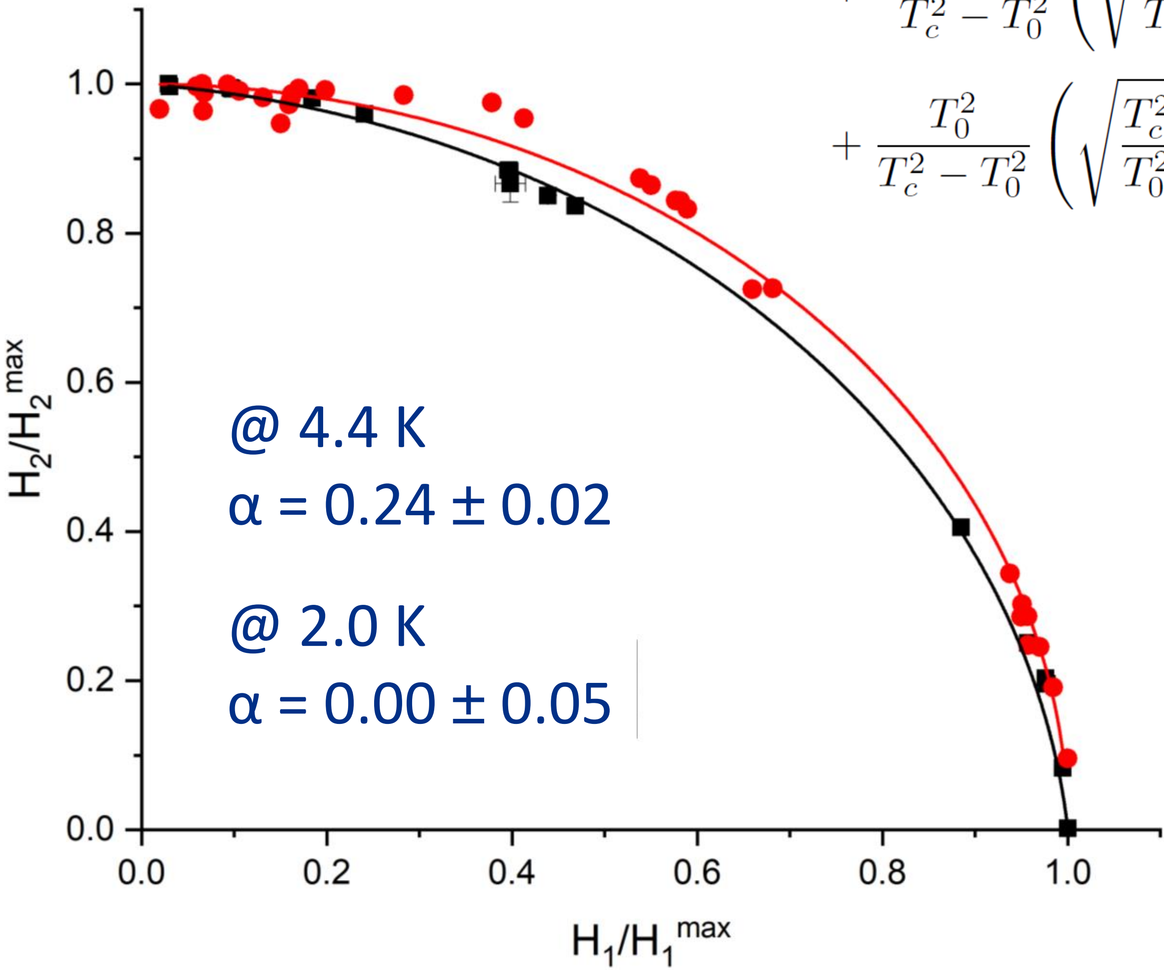
TB9NR001 limited to about 70 mT

TB9RI023 limited to about 140 mT

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

Thermal breakdown in Nb_3Sn cavities

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



@ 4.4 K
α = 0.24 ± 0.02

@ 2.0 K
α = 0.00 ± 0.05

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

"H_c" ≅ 280 mT

Conclusions

- 5-cell accelerating cavities were qualified. Work is in progress to built an accelerating cryomodule with Nb_3Sn cavities

- Tuning sensitivity of Nb_3Sn cavities is the major concern

- “The data unambiguously supports the thermal model”

Backup slides

Backup slides