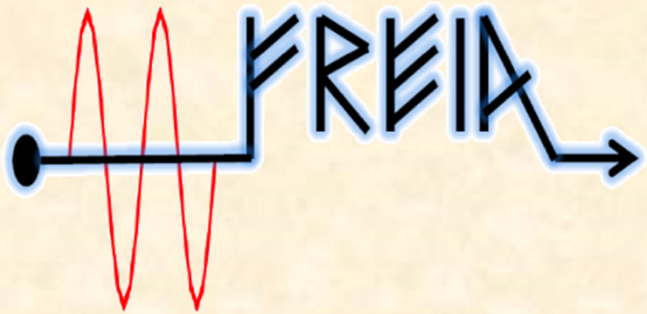




UPPSALA
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Effect of the cavity cooldown on the quality-factor

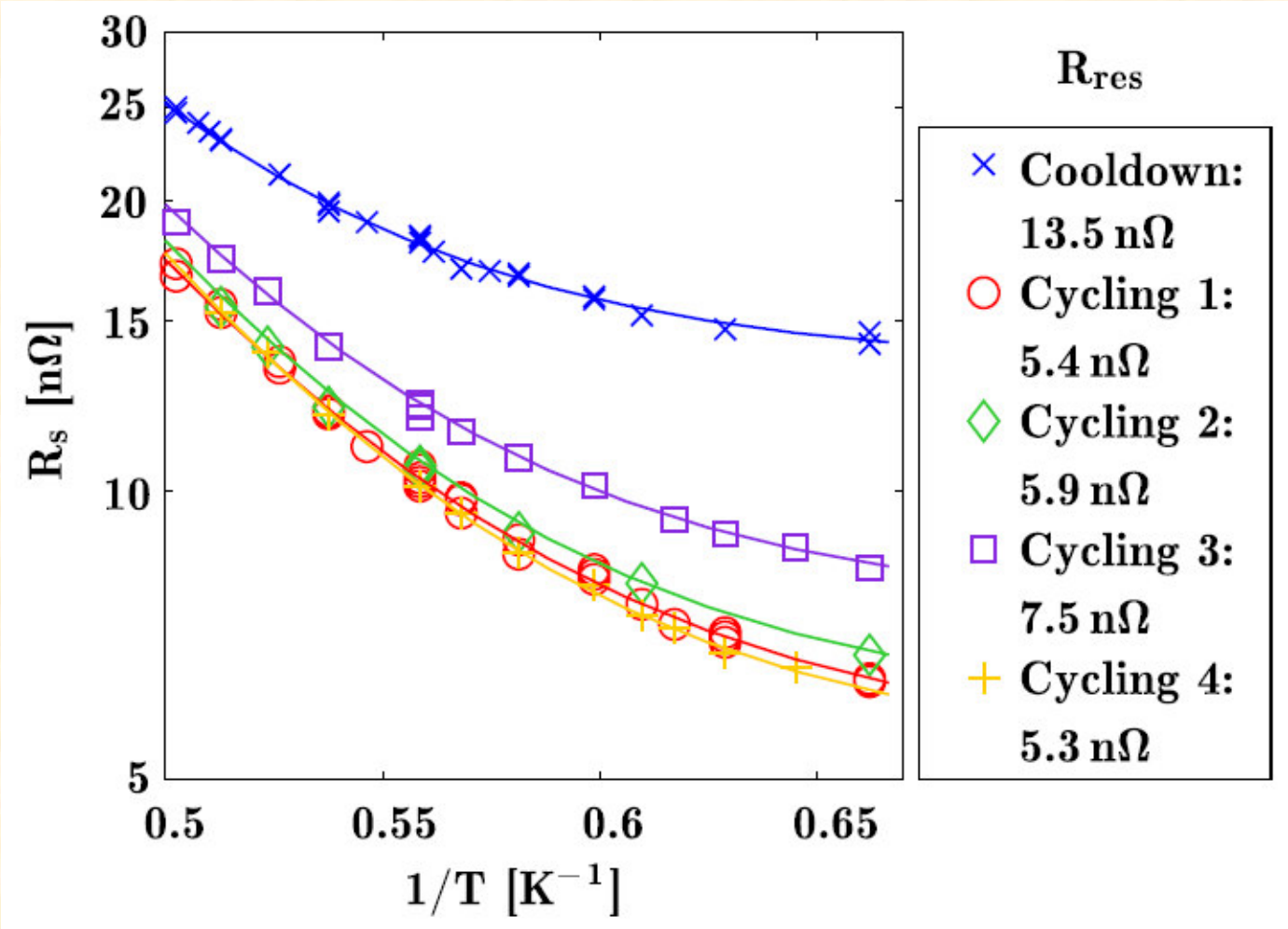
Vitaliy
FREIA, Uppsala
2016-02-08

Paradigm of slow cooling

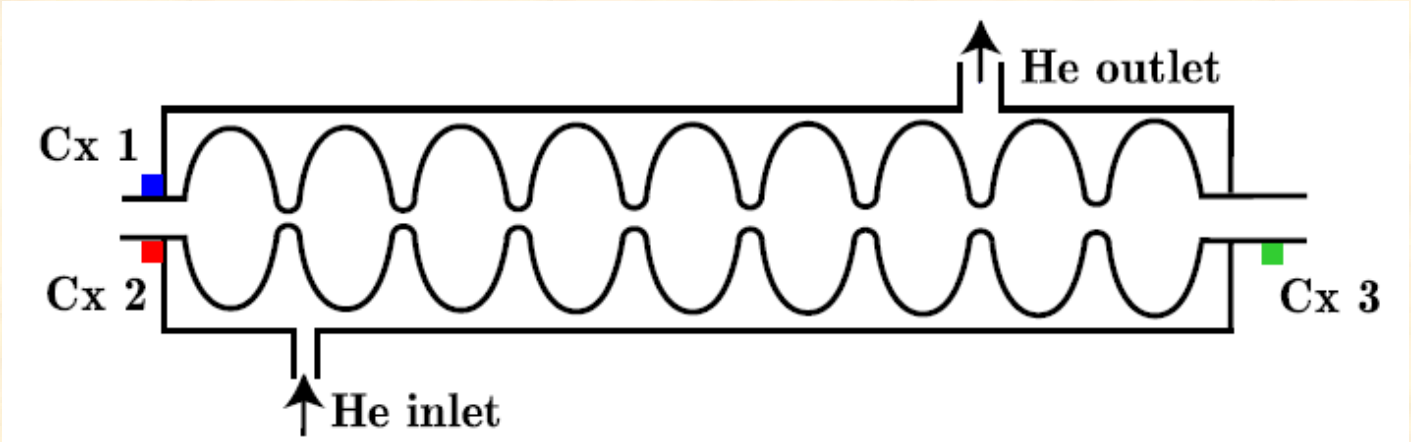
PHYSICAL REVIEW SPECIAL TOPICS - ACCELERATORS AND BEAMS **16**, 102002 (2013)

Impact of cool-down conditions at T_c on the superconducting rf cavity quality factor

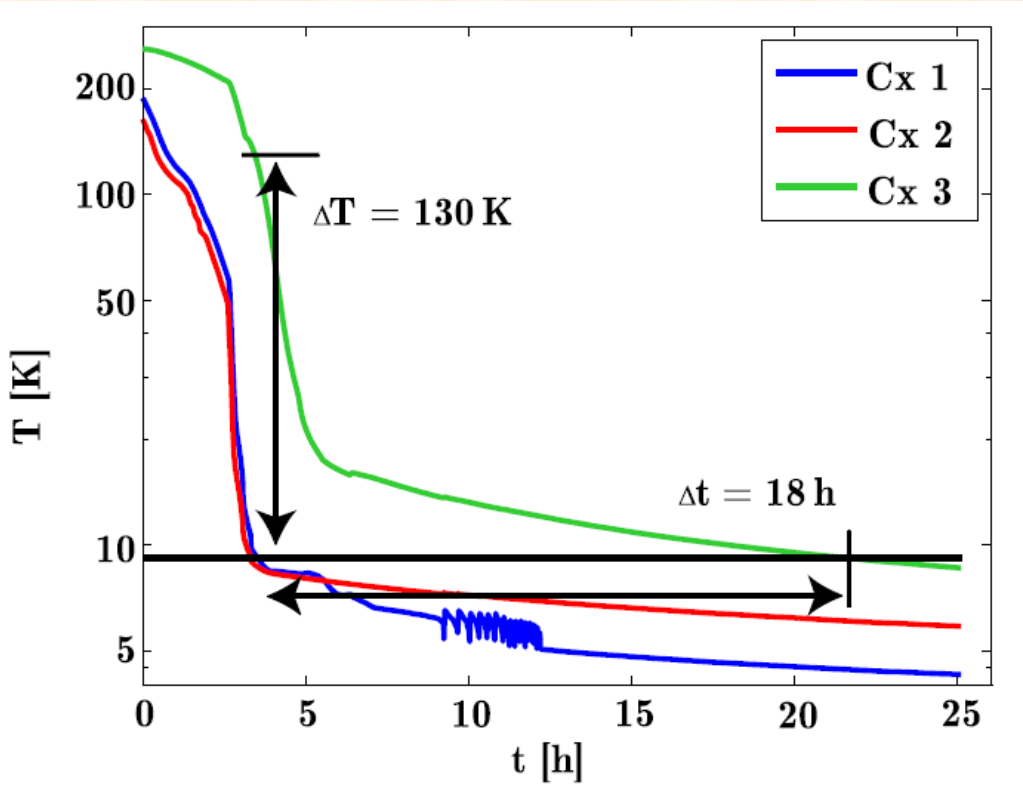
J.-M. Vogt,* O. Kugeler, and J. Knobloch
Helmholtz-Zentrum Berlin, Germany



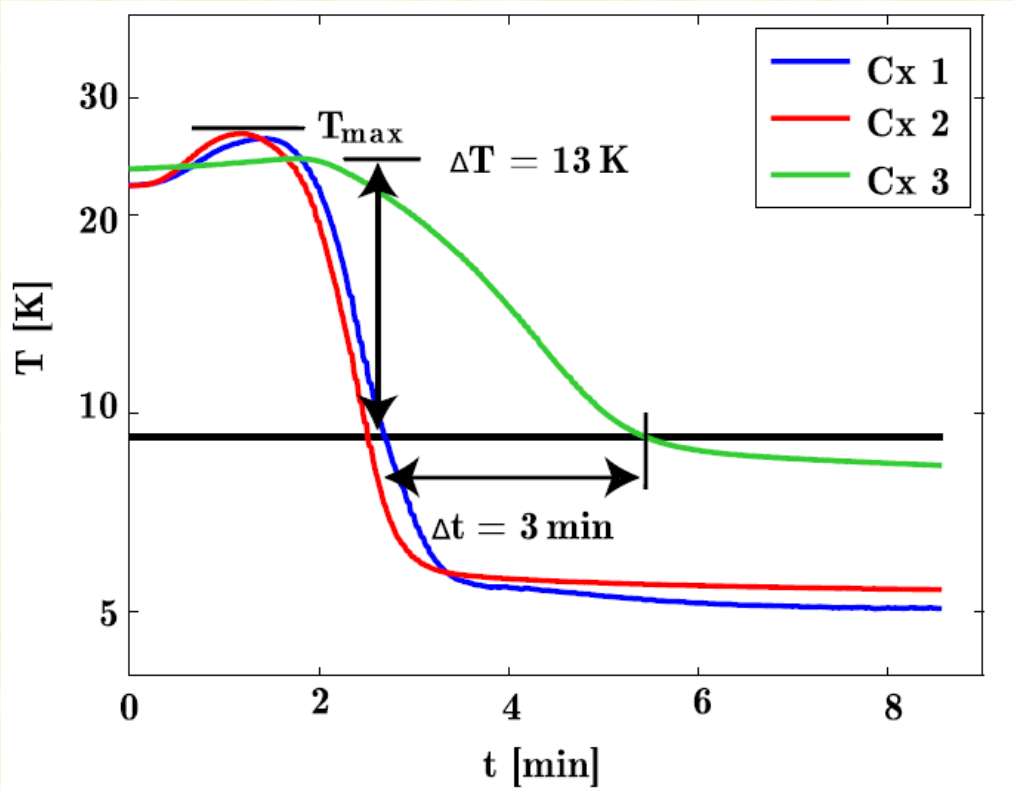
Thermal currents



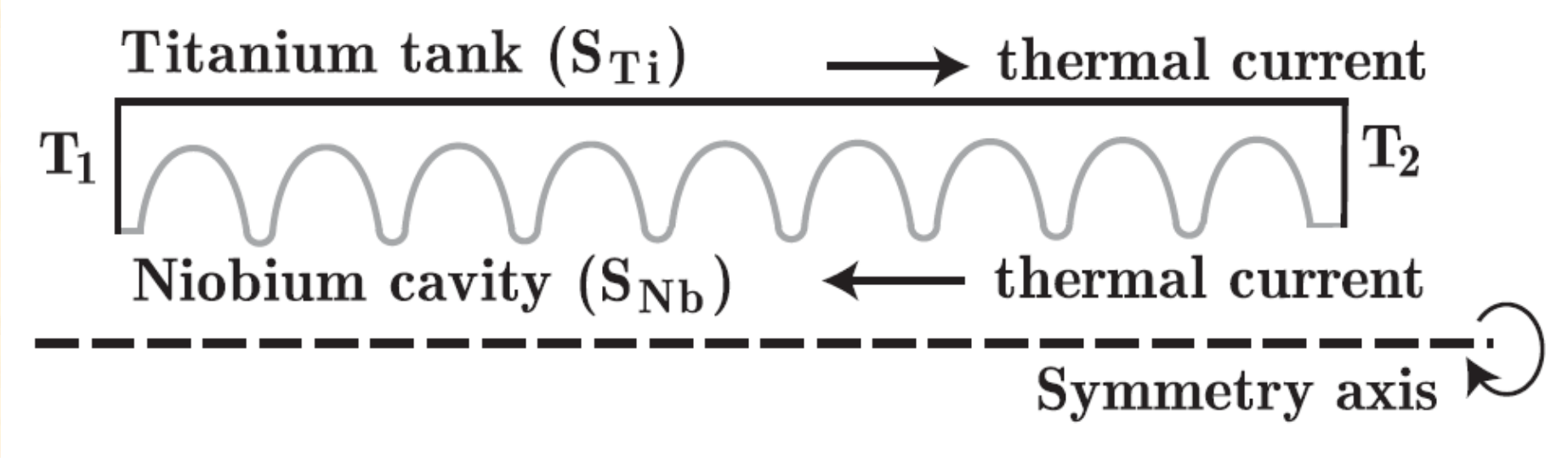
Normal cooldown

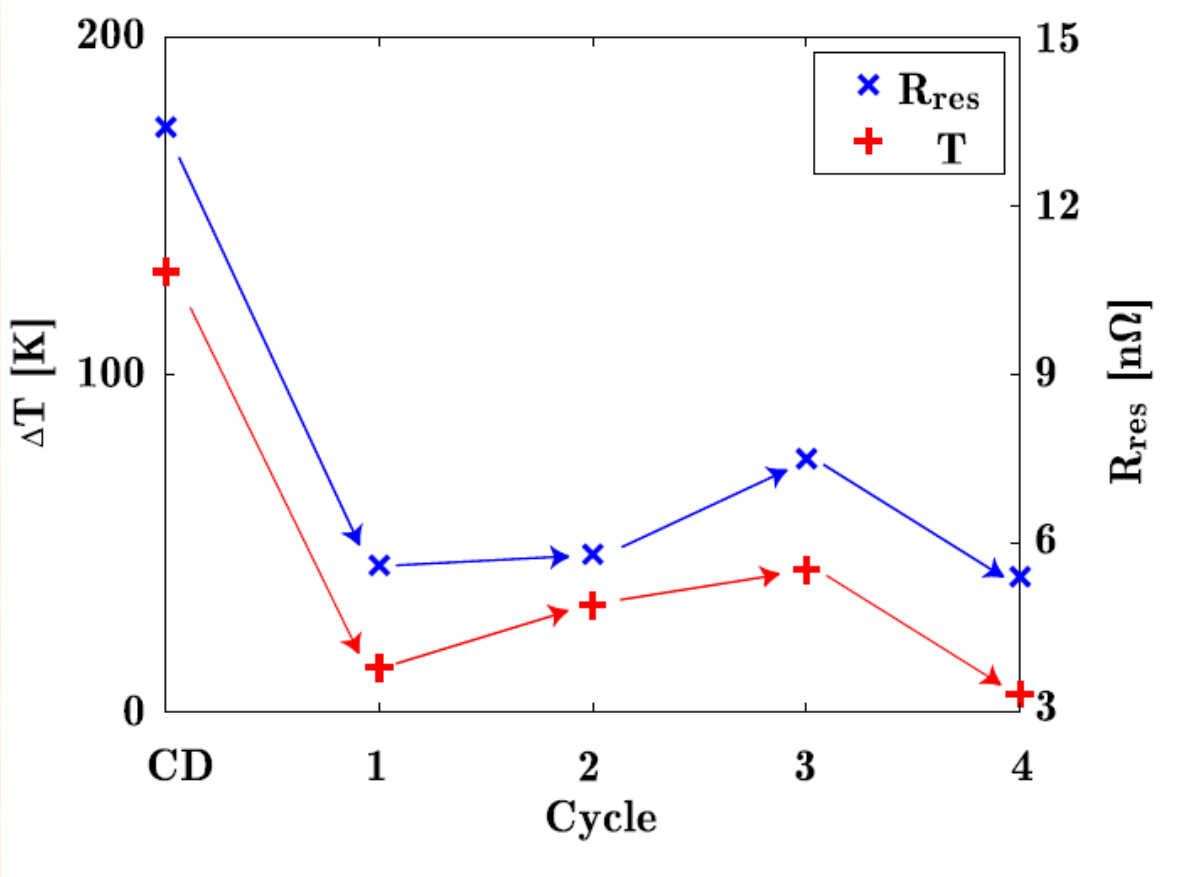


Cycling, slow cooldown



Thermal currents: cont'd





Temperature along the cavity at the onset of the SC phase transition (ΔT) and residual resistance for the cooldown and thermal cycles.

The effect of thermal cycling

TABLE I. Parameters of cooldown and the performed thermal cycles: maximum temperature reached by the cavity T_{max}, temperature difference along the cavity during superconducting phase transition ΔT, duration of the phase transition Δt, and residual resistance after the respective procedure R_{res}.

	R_{res} [nΩ]	T_{max} [K]	ΔT [K]	Δt
Cooldown	13.5	300	130	18 h
Cycling 1	5.4	26	13	3 min
Cycling 2	5.9	42	32	10 min
Cycling 3	7.5	52	42	13 min
Cycling 4	5.3	23	5	1 min

The conclusion of this and similar studies was that the cavity cooldown should be as slow as possible in the vicinity of the transition temperature in order to avoid thermocurrents and associated with them trapping of magnetic fluxes.

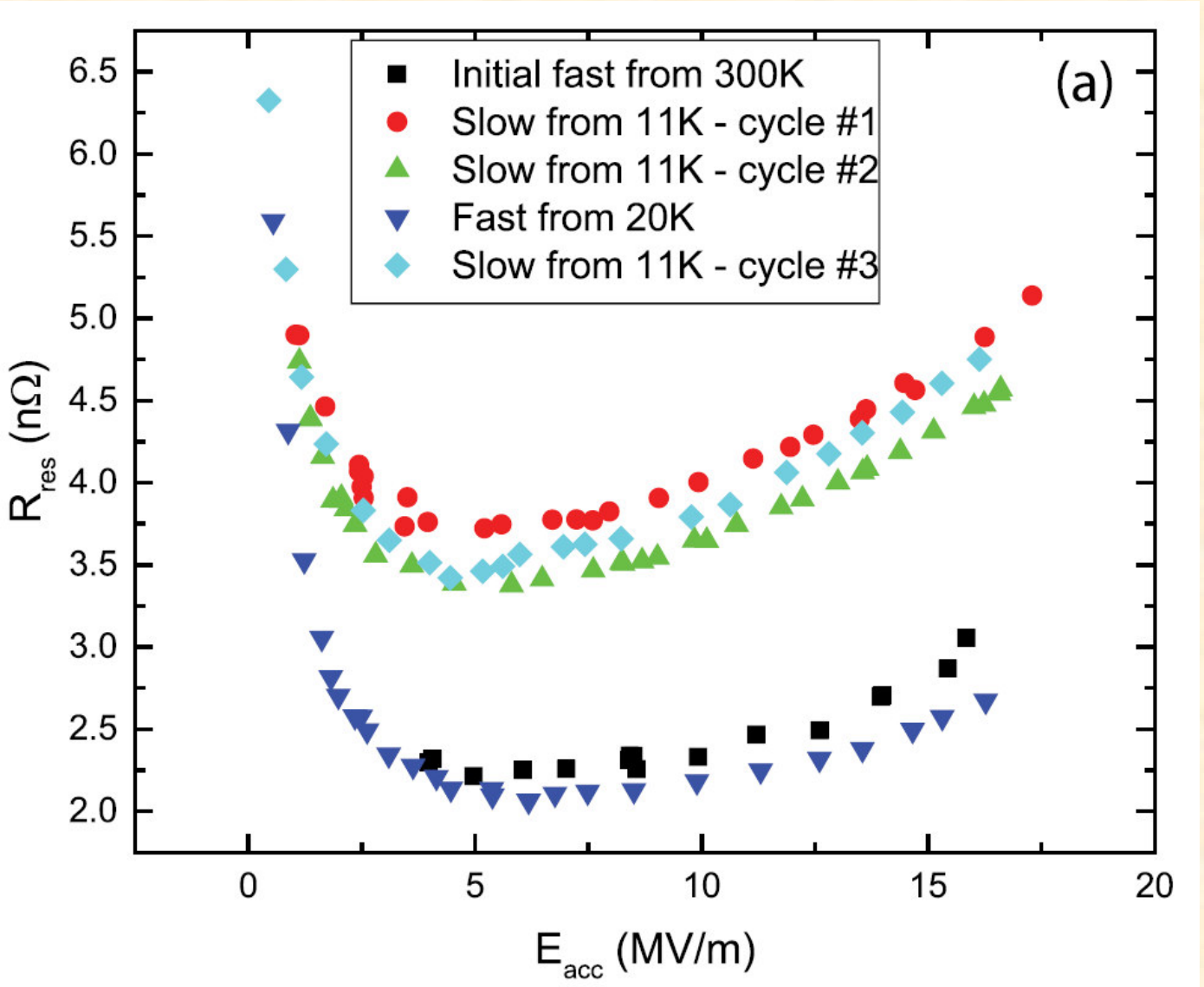
That was also the recommendation of SRF2013.

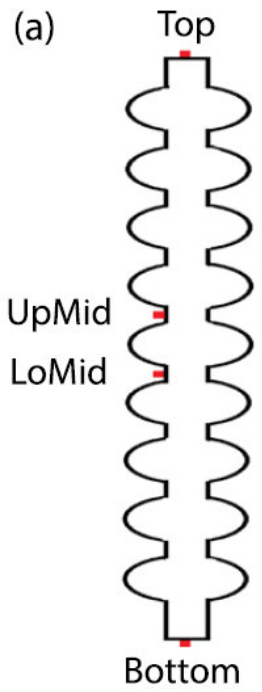
But a year later the Fermilab group made a discovery…

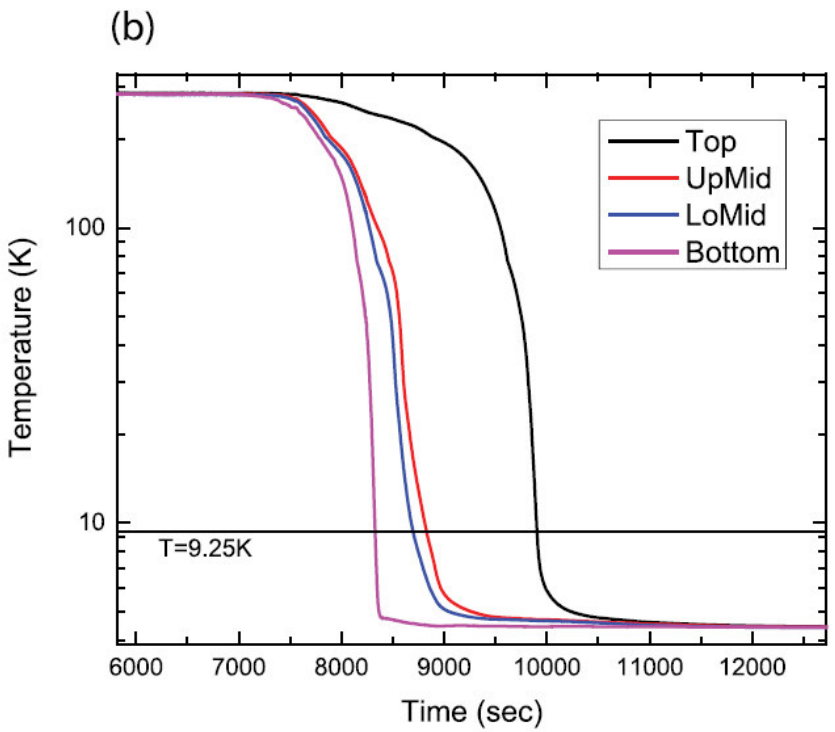
JOURNAL OF APPLIED PHYSICS **115**, 184903 (2014)

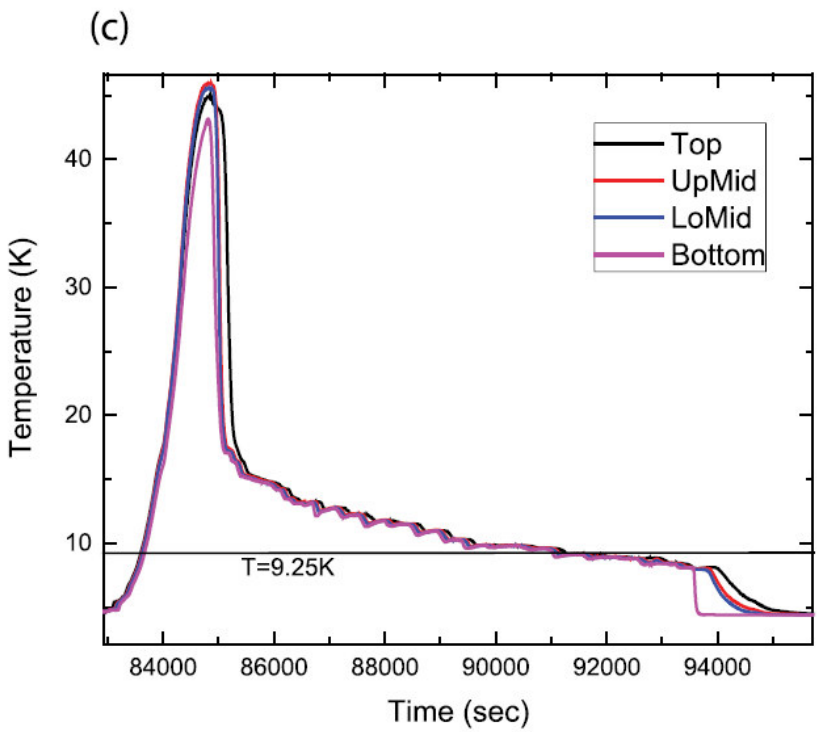
Dependence of the residual surface resistance of superconducting radio frequency cavities on the cooling dynamics around T_c

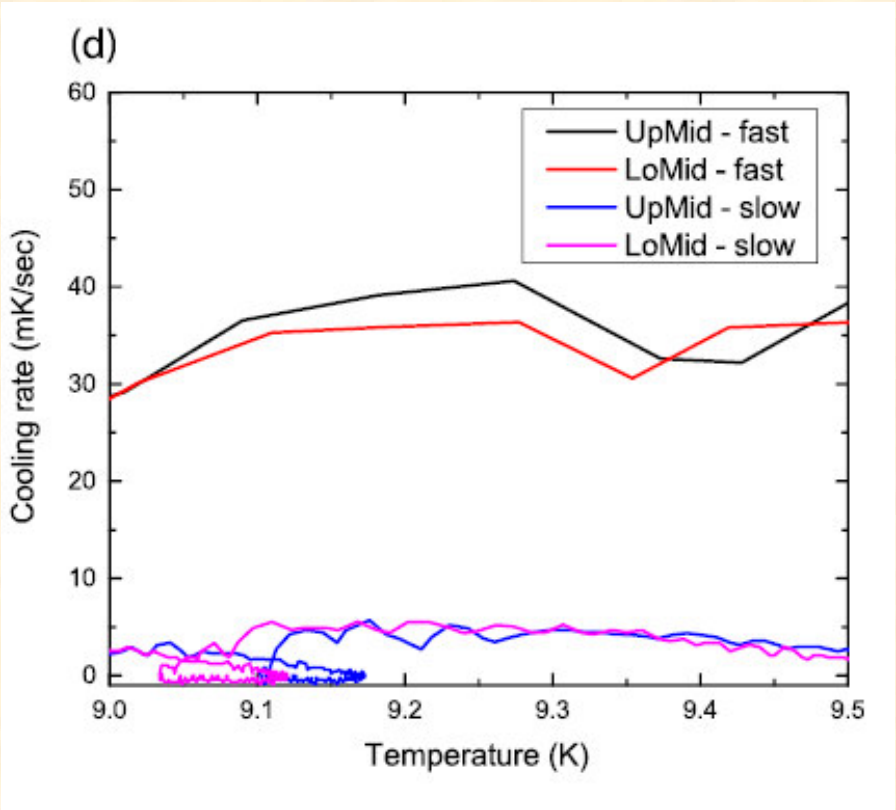
A. Romanenko,[a] A. Grassellino,[b] O. Melnychuk, and D. A. Sergatskov
Fermi National Accelerator Laboratory, Batavia, Illinois 60510, USA




(a)
Top
UpMid
LoMid
Bottom


(b)
Temperature (K)
100
10
T=9.25K
6000
7000
8000
9000
10000
11000
12000
Time (sec)
Top
UpMid
LoMid
Bottom


(c)
Temperature (K)
40
30
20
10
T=9.25K
84000
86000
88000
90000
92000
94000
Time (sec)
Top
UpMid
LoMid
Bottom

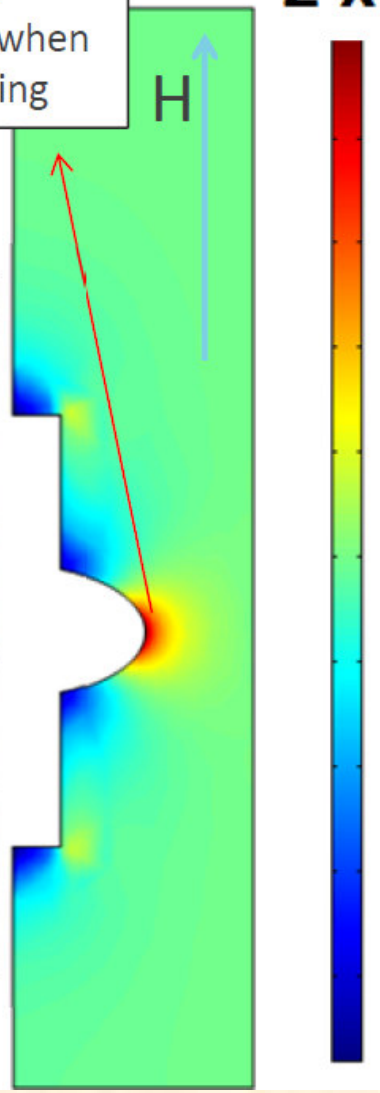

(d)
Cooling rate (mK/sec)
60
50
40
30
20
10
0
9.0
9.1
9.2
9.3
9.4
9.5
Temperature (K)
UpMid - fast
LoMid - fast
UpMid - slow
LoMid - slow

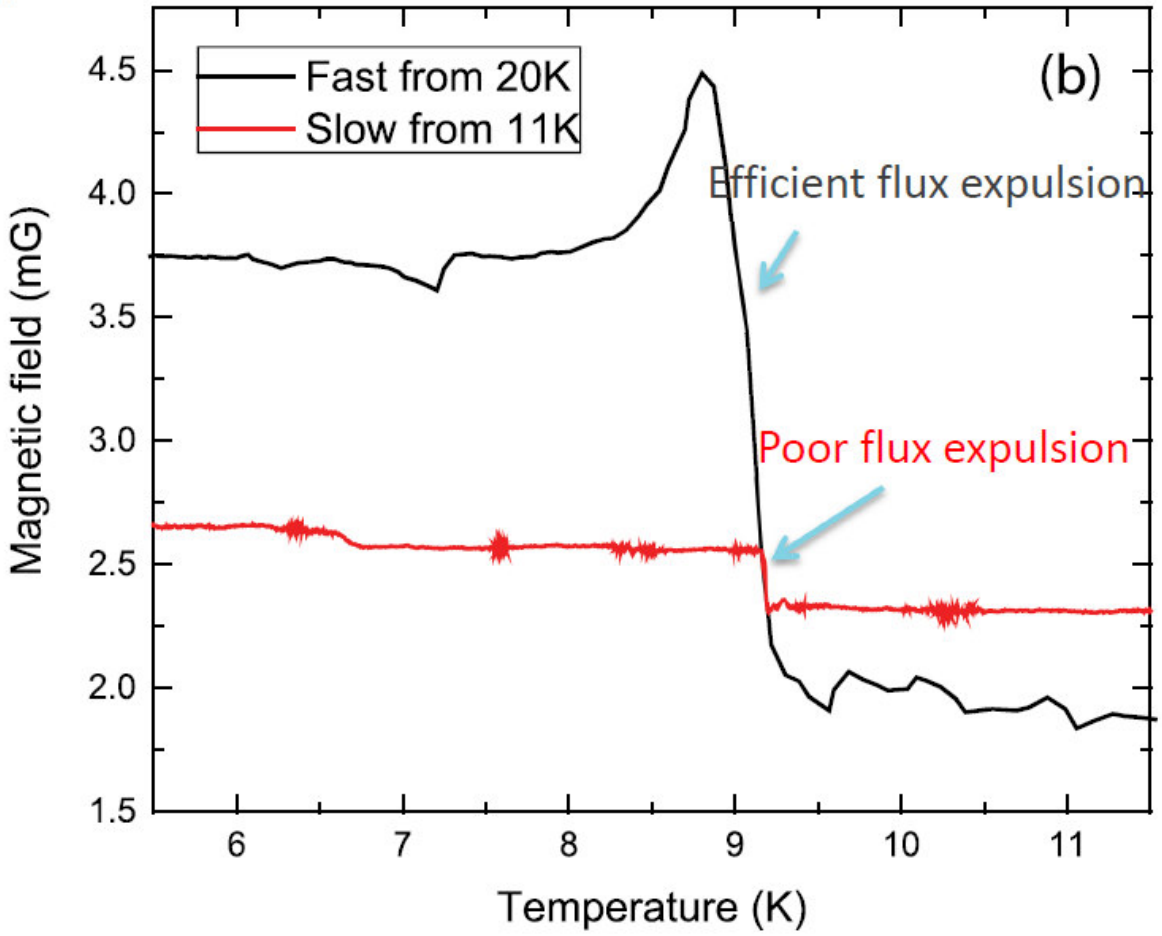
Expulsion effect

Full expulsion of the magnetic field should increase the field at equator ~1.8 times when going superconducting

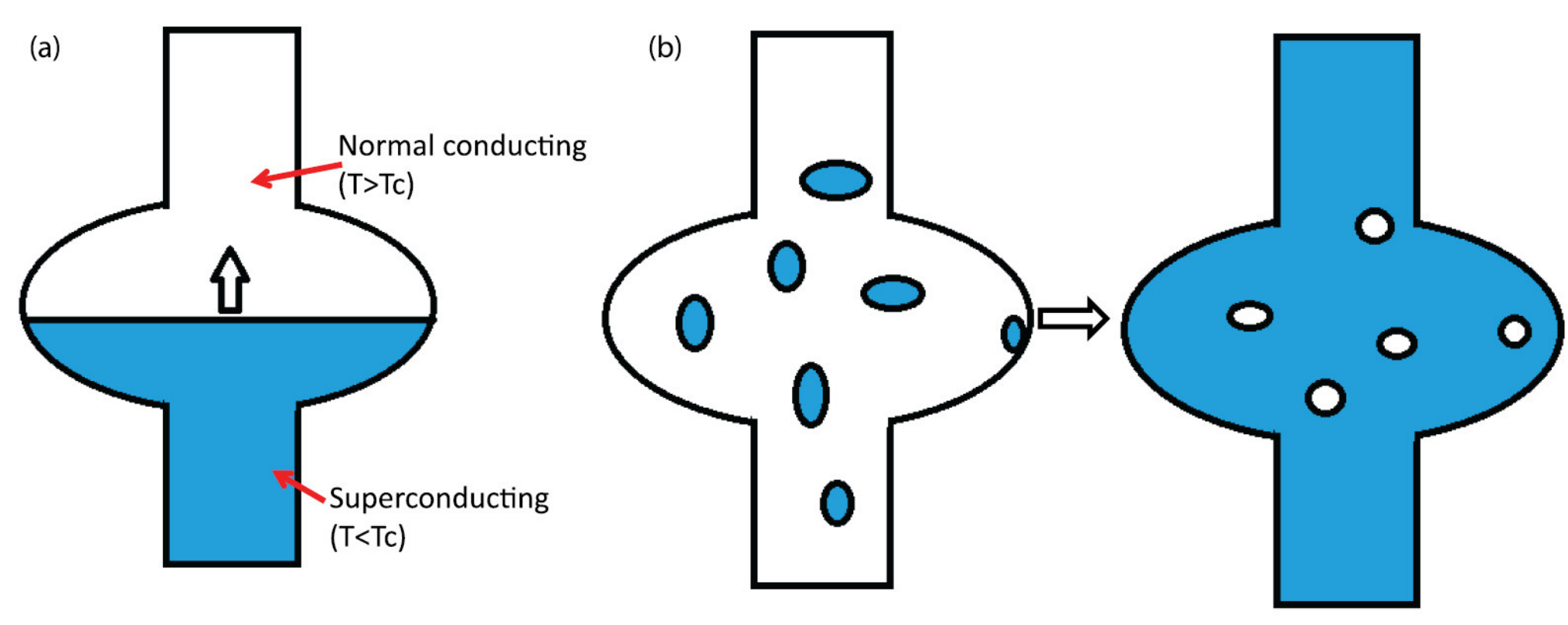


Fluxgate magnetometers





Nucleation of SC phase



The propagating phase boundary sweeps out the magnetic flux.

Temperature gradient for a one-cell cavity

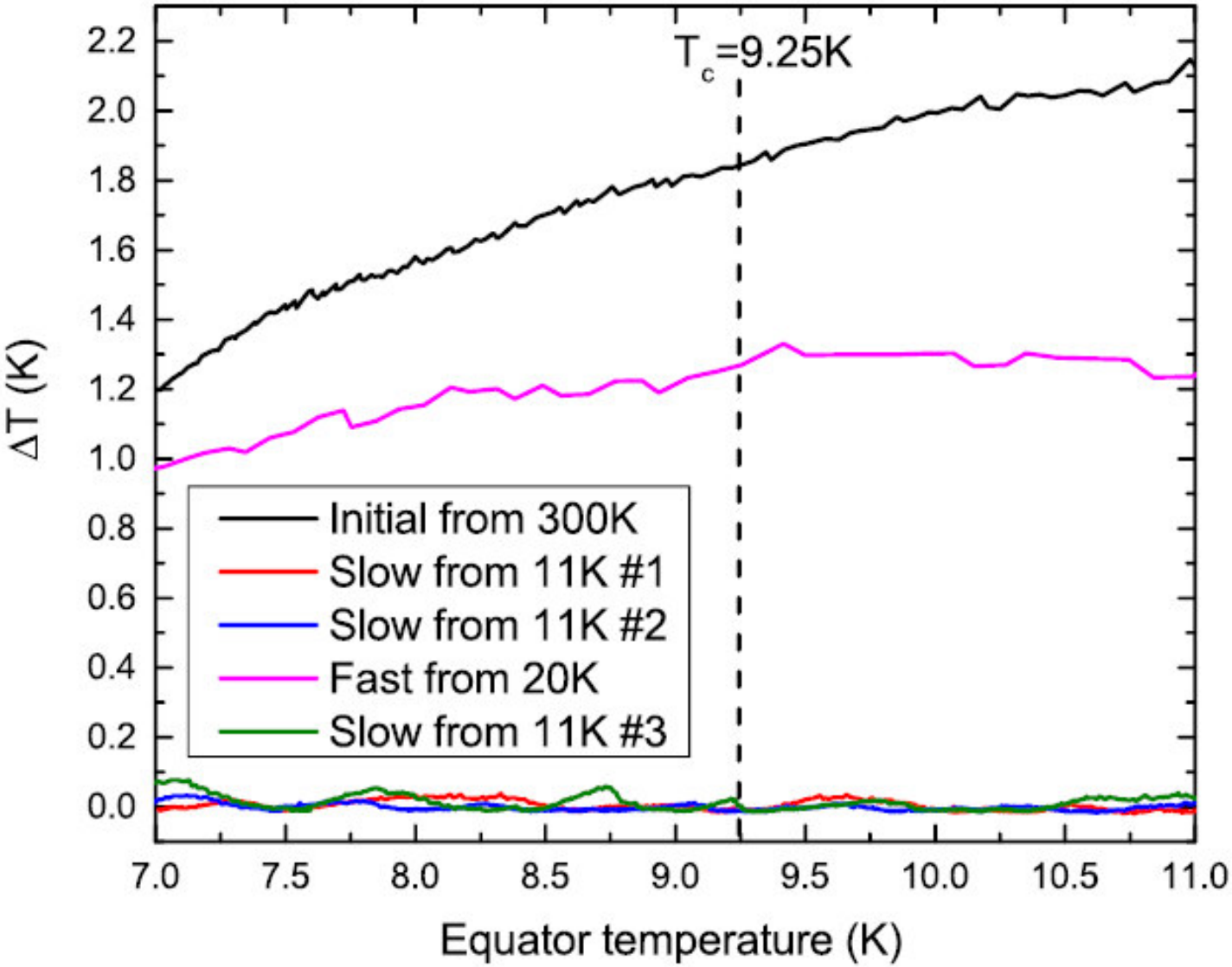
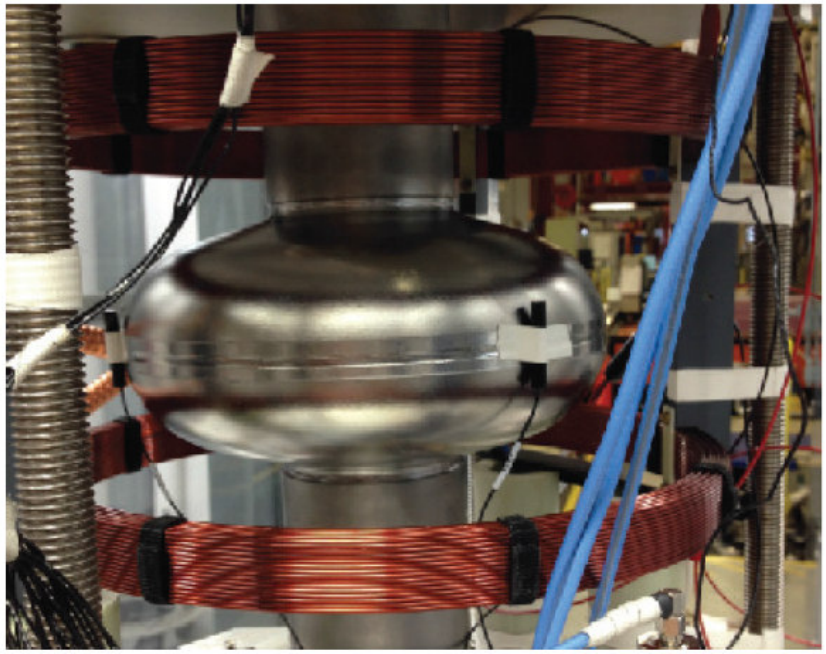


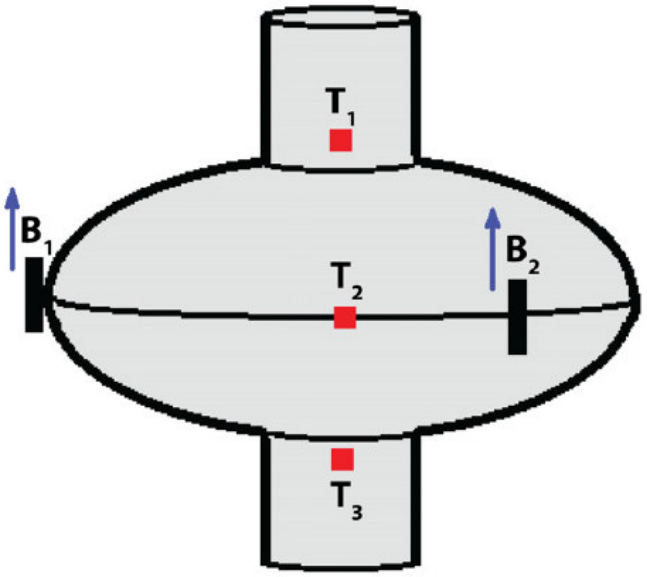
FIG. 11. Temperature difference between the equator and lower iris of the 1-cell cavity during different cooling procedures.

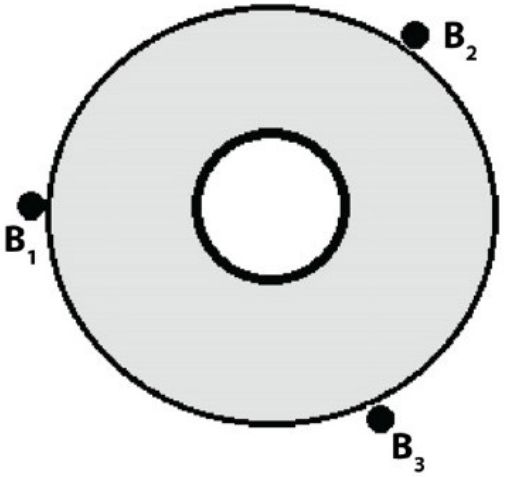
APPLIED PHYSICS LETTERS **105**, 234103 (2014)

Ultra-high quality factors in superconducting niobium cavities in ambient magnetic fields up to 190 mG

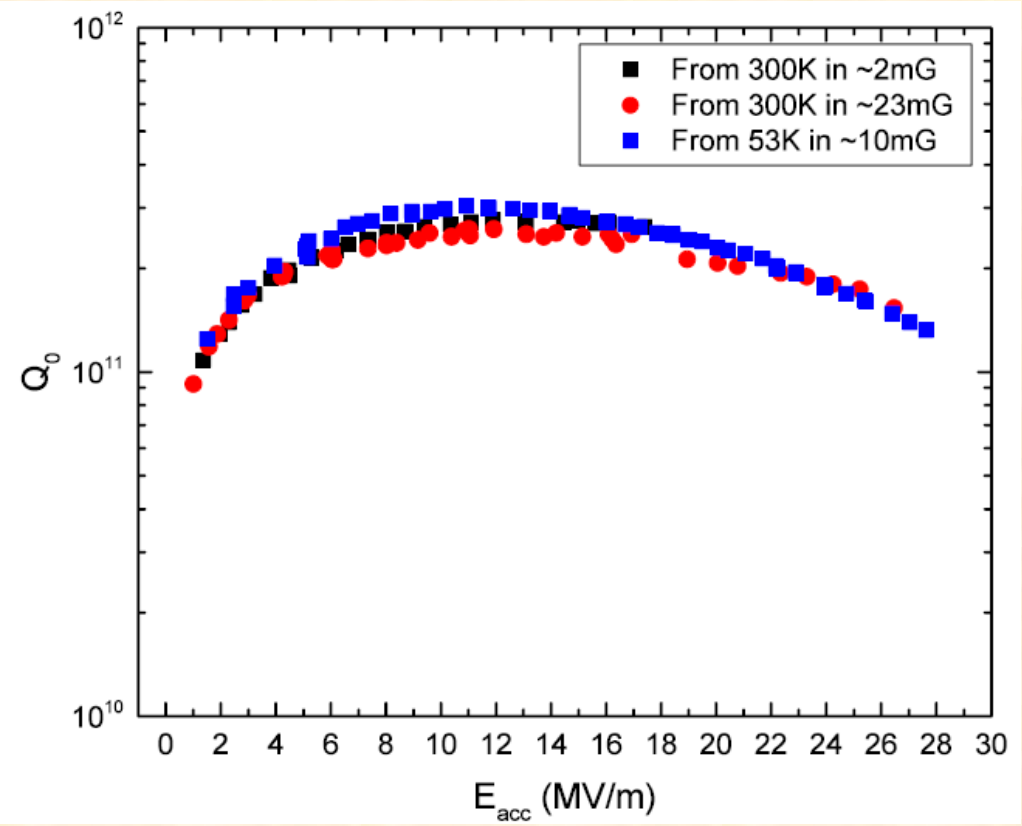
A. Romanenko,[a)] A. Grassellino, A. C. Crawford, D. A. Sergatskov, and O. Melnychuk
Fermi National Accelerator Laboratory, Batavia, Illinois 60510, USA

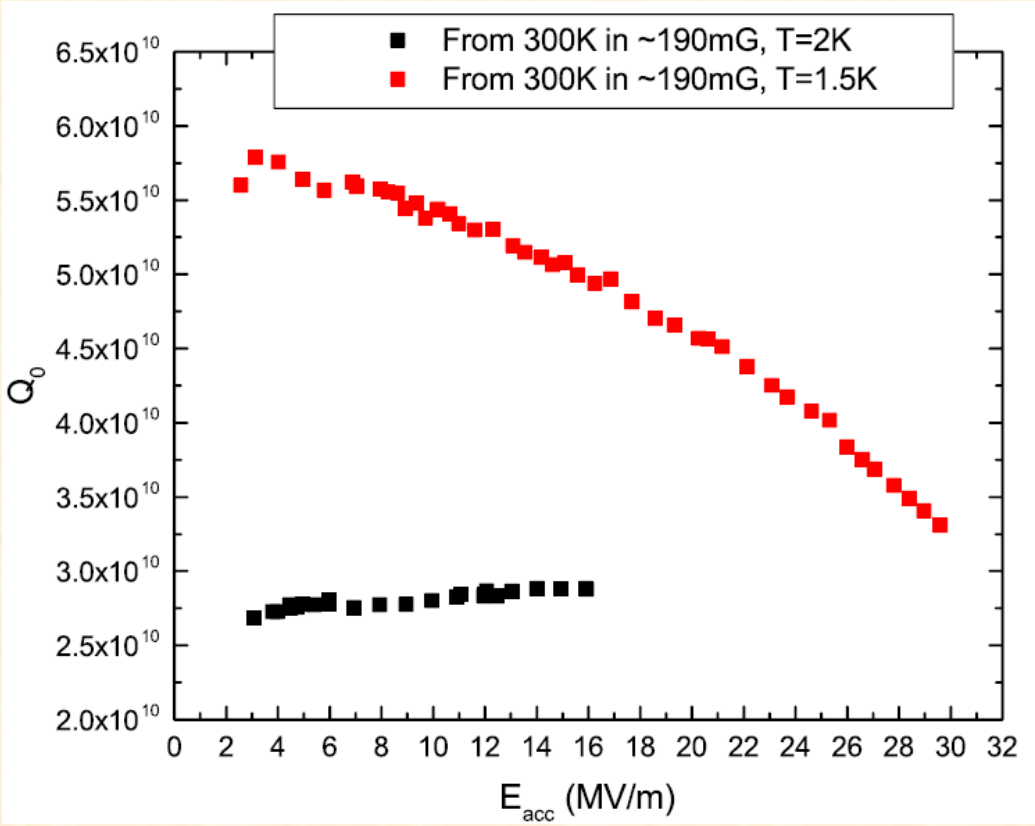




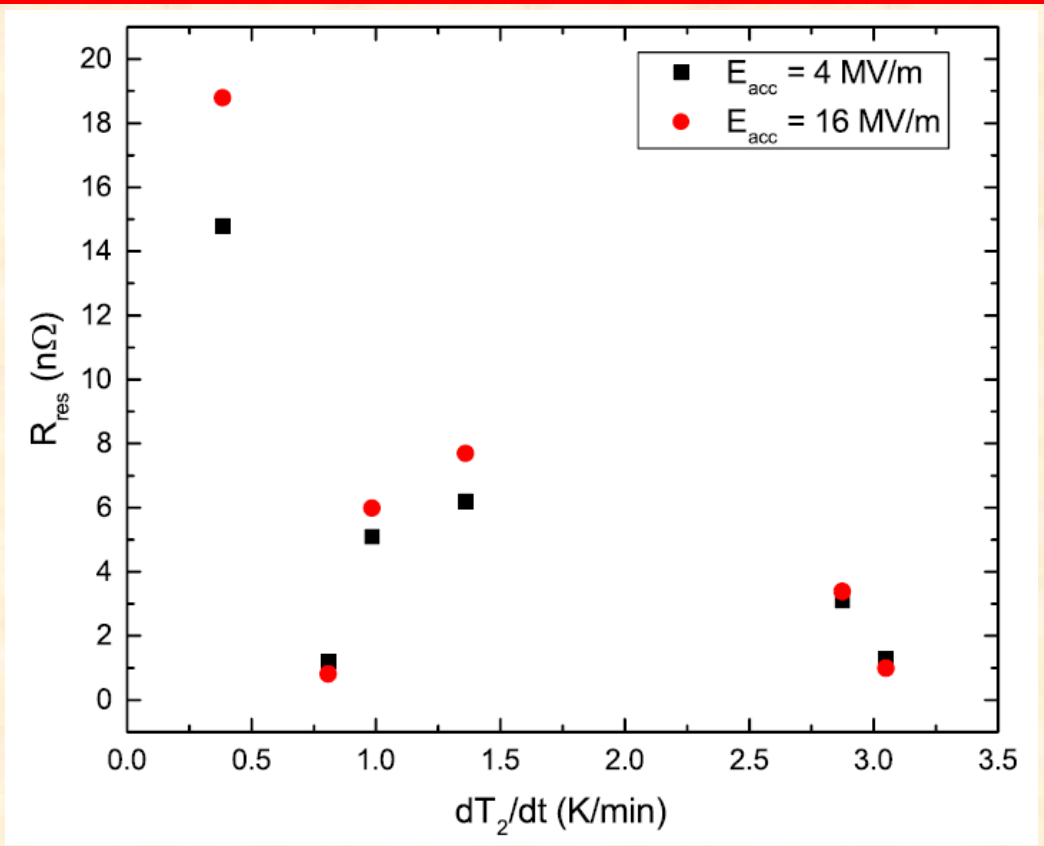


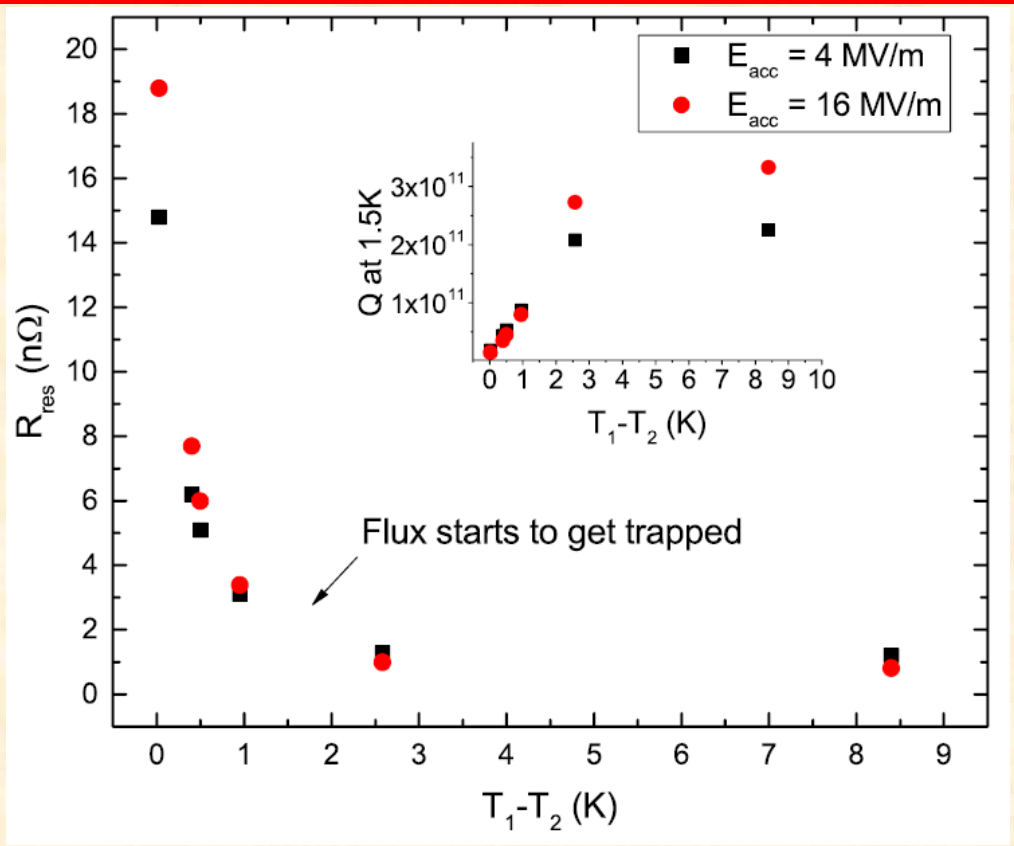
Cooling in the presence of a strong magnetic field





Cooling rate and thermal gradient





The cooldown rate is not the key parameter

The temperature difference at the phase front is the main factor.

The gradient along the cavity surface must be more than 0.1 K/cm.

Summary

Discovery at Fermilab

- Magnetic flux can be expelled from cavity walls by fast/high thermal gradient cooldown
- Allows achieving record low residual resistances
  - Examples:
    - $Q = 2.7 \times 10^{11}$ in 27 mG ambient field;
    - $Q > 5.5 \times 10^{10}$ in 190 mG ambient field

There is still a lot of room in this field of research and it might be of interest for us to look into this effect.