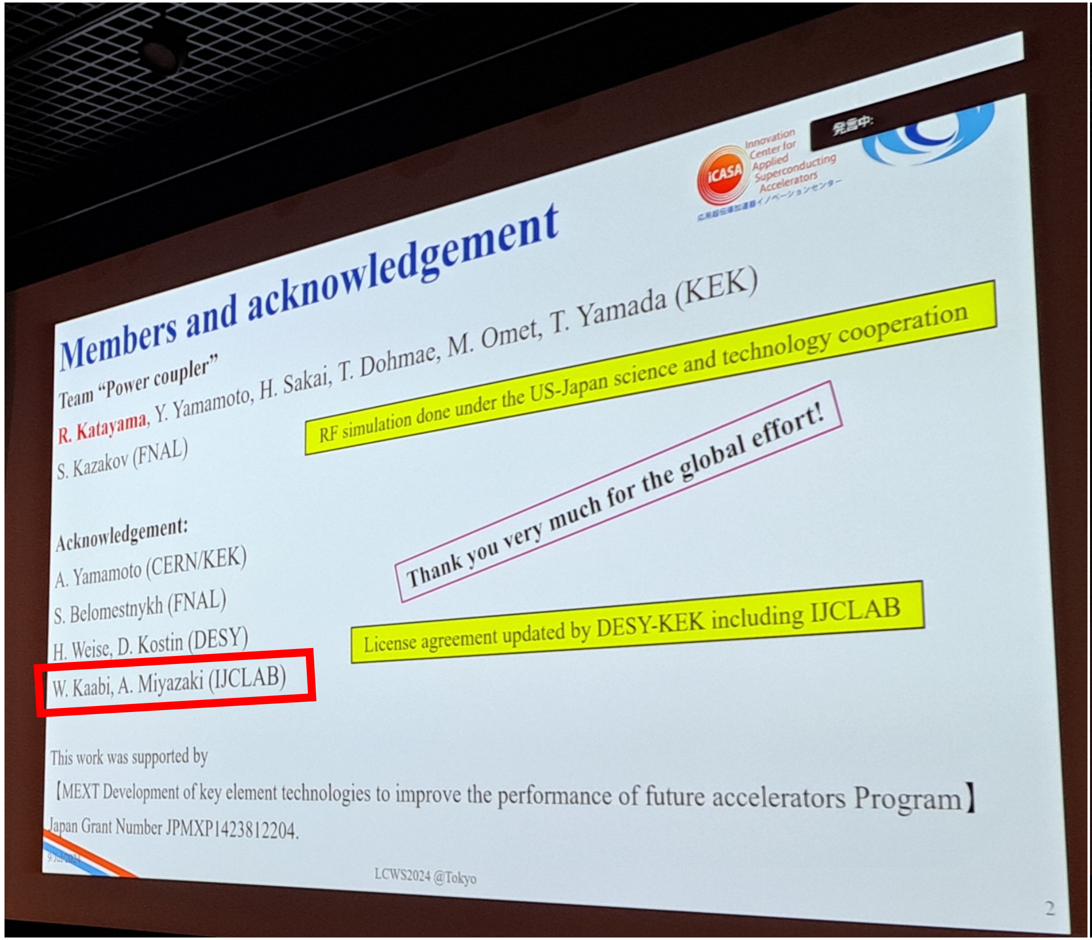
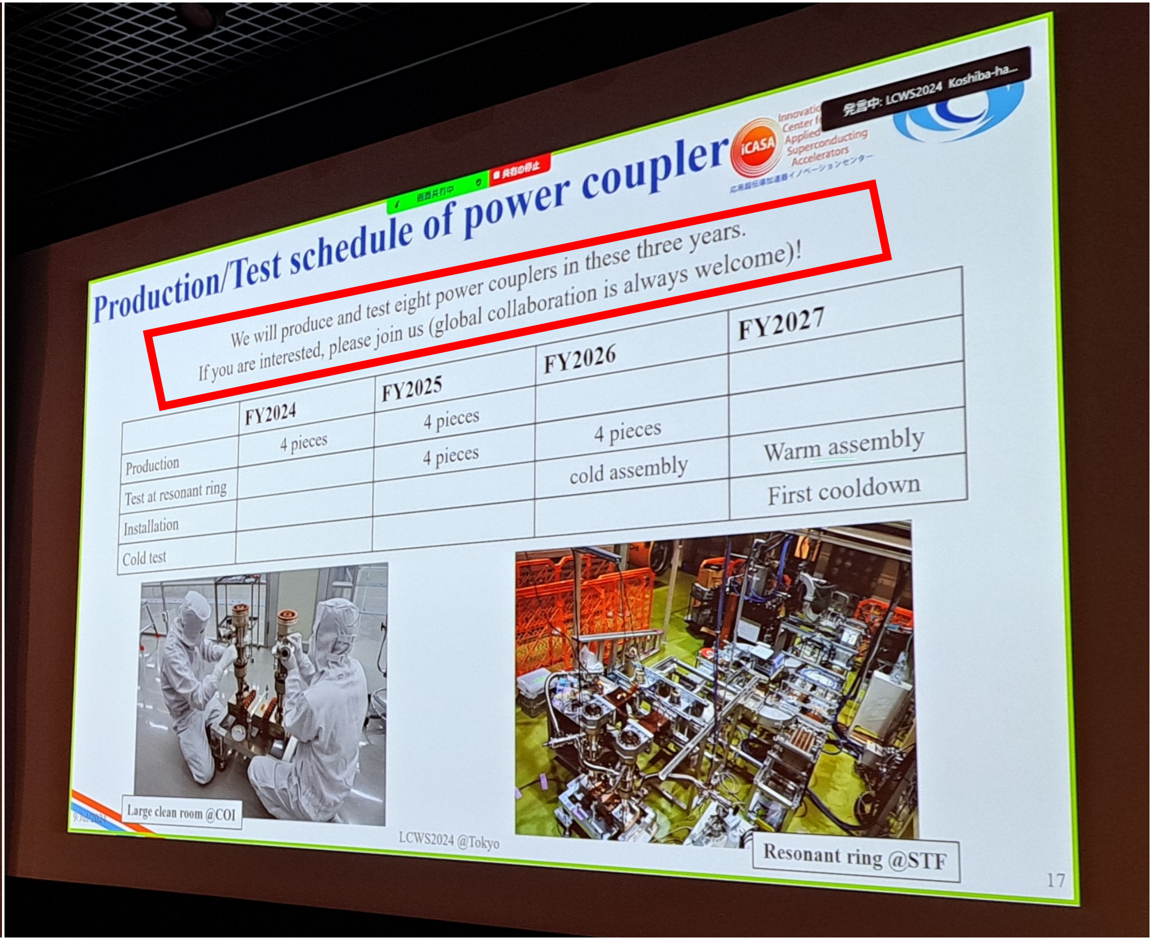
Update on 1.3 GHz cavity activities at IJCLab

Akira Miyazaki

LCWS2024 @ UTokyo: IJCLab is recognized

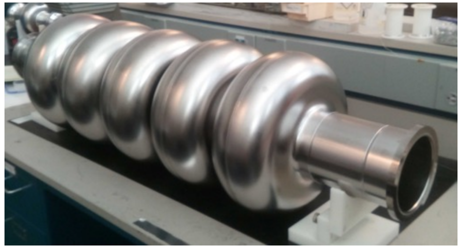




R &D targets

For FCC/PERLE

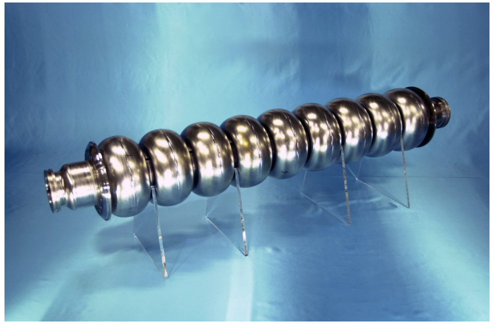
Duty cycle =100%



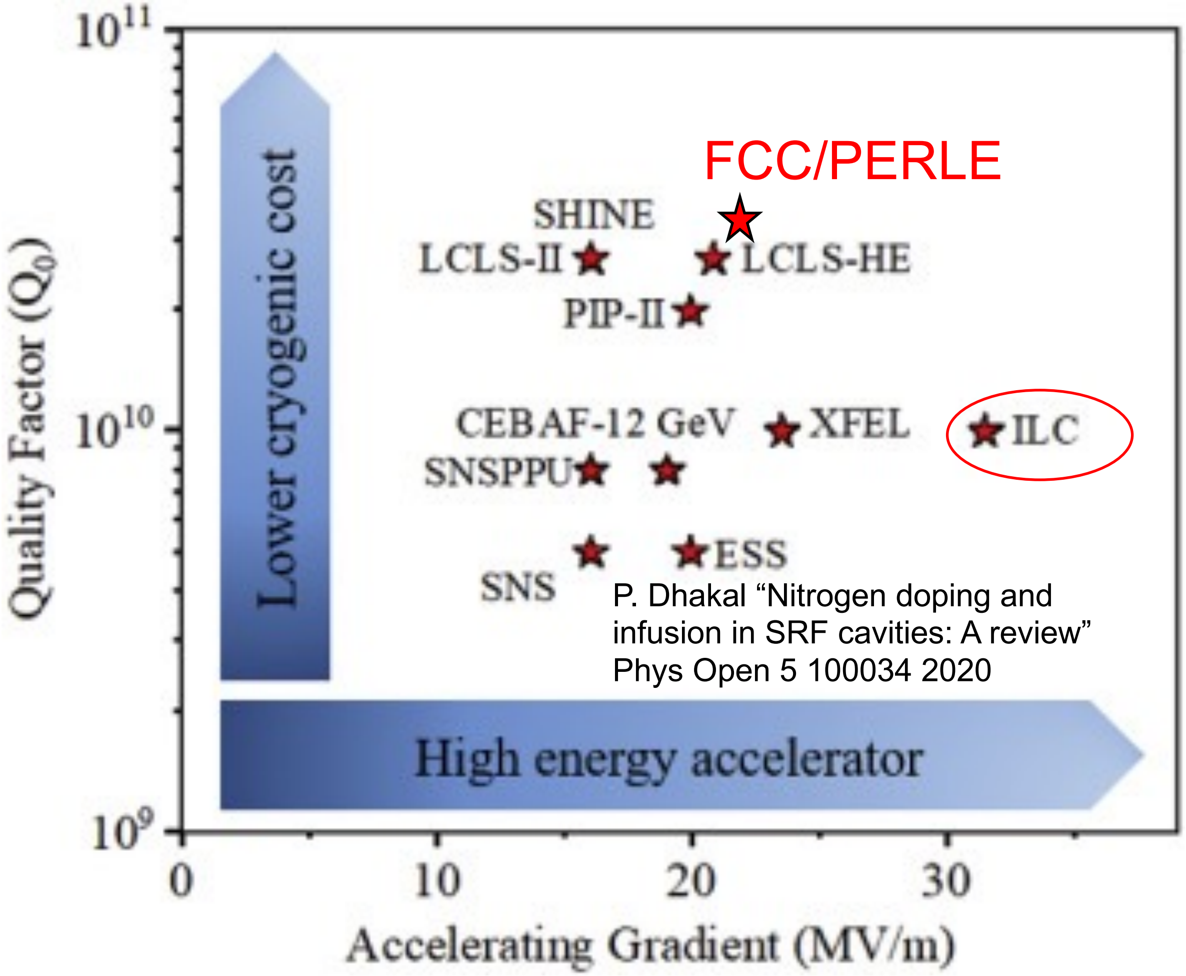
Extremely high-Q at relatively high gradient in large cavities (800 MHz)

For ILC250

Duty cycle <1%



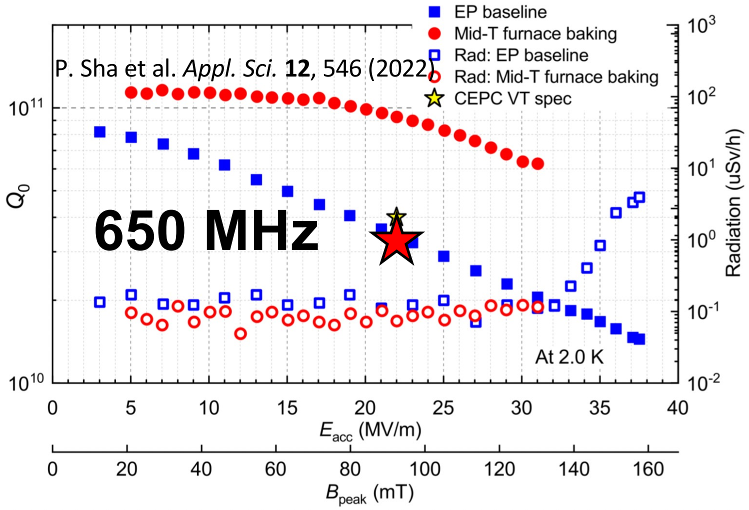
Extremely high gradient with relatively high-Q in a large # of cavities (~8000)



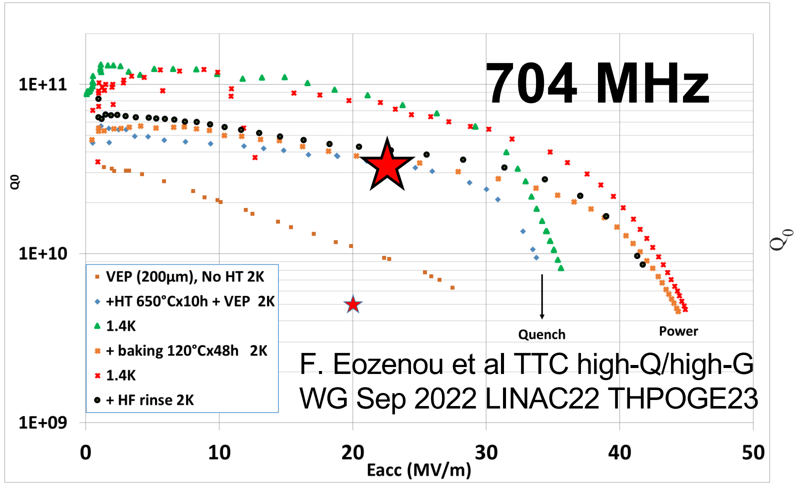
P. Dhakal "Nitrogen doping and infusion in SRF cavities: A review" Phys Open 5 100034 2020

high-Q / high-G cavities in the world

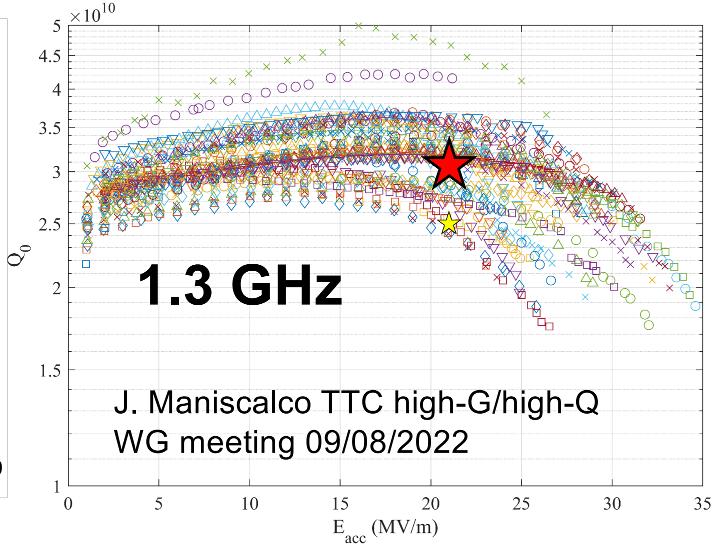
300C baking @ IHEP



120C baking @ CEA-Saclay

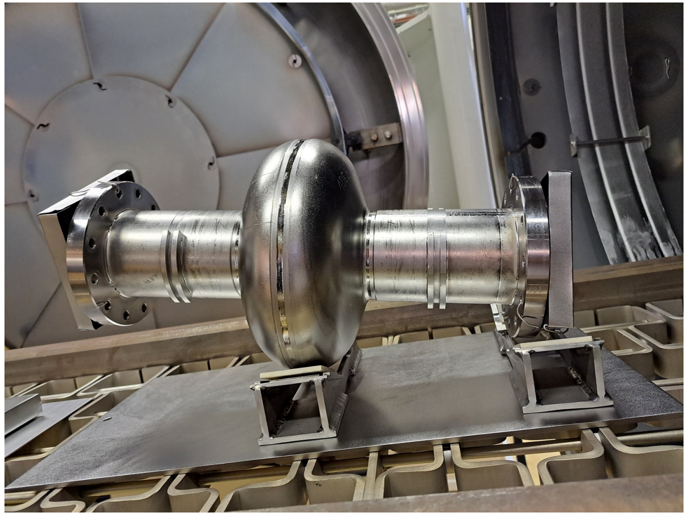


2N0 doping at 800C @ LCLSII



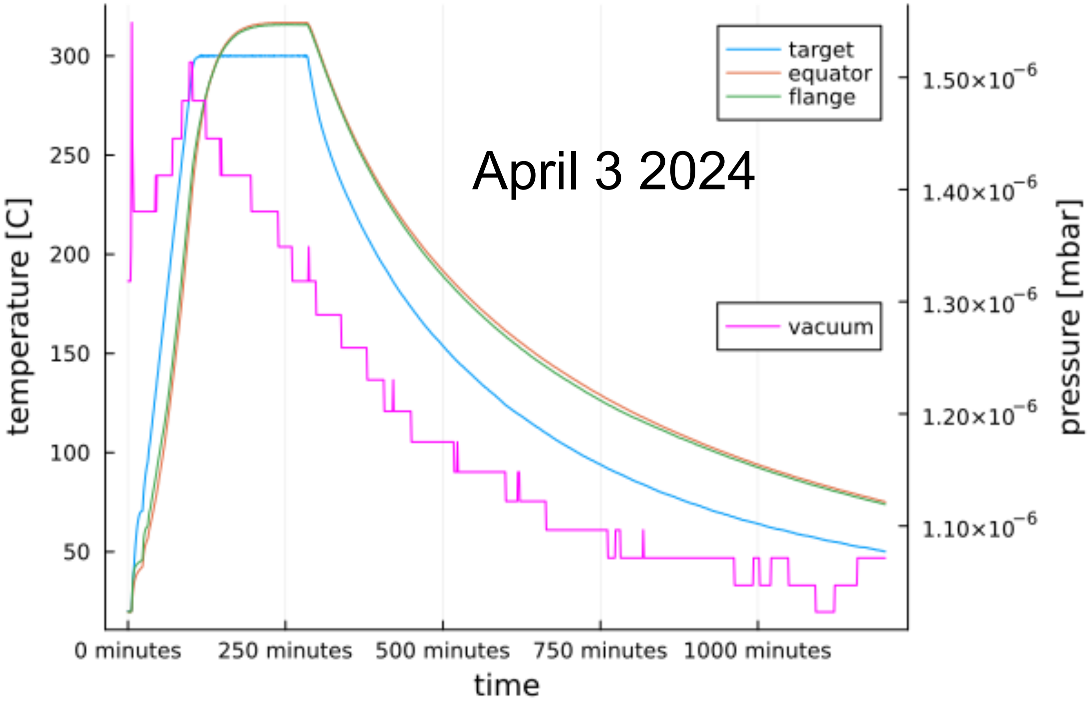
- 300C baking or N-doping seems like the best option for FCC/PERLE
- 120C or 2-step baking for higher gradient → ILC
- **Clean vacuum baking furnace** is key in this research domain

300C (316C in cavity) baking in IN2P3/IJCLab

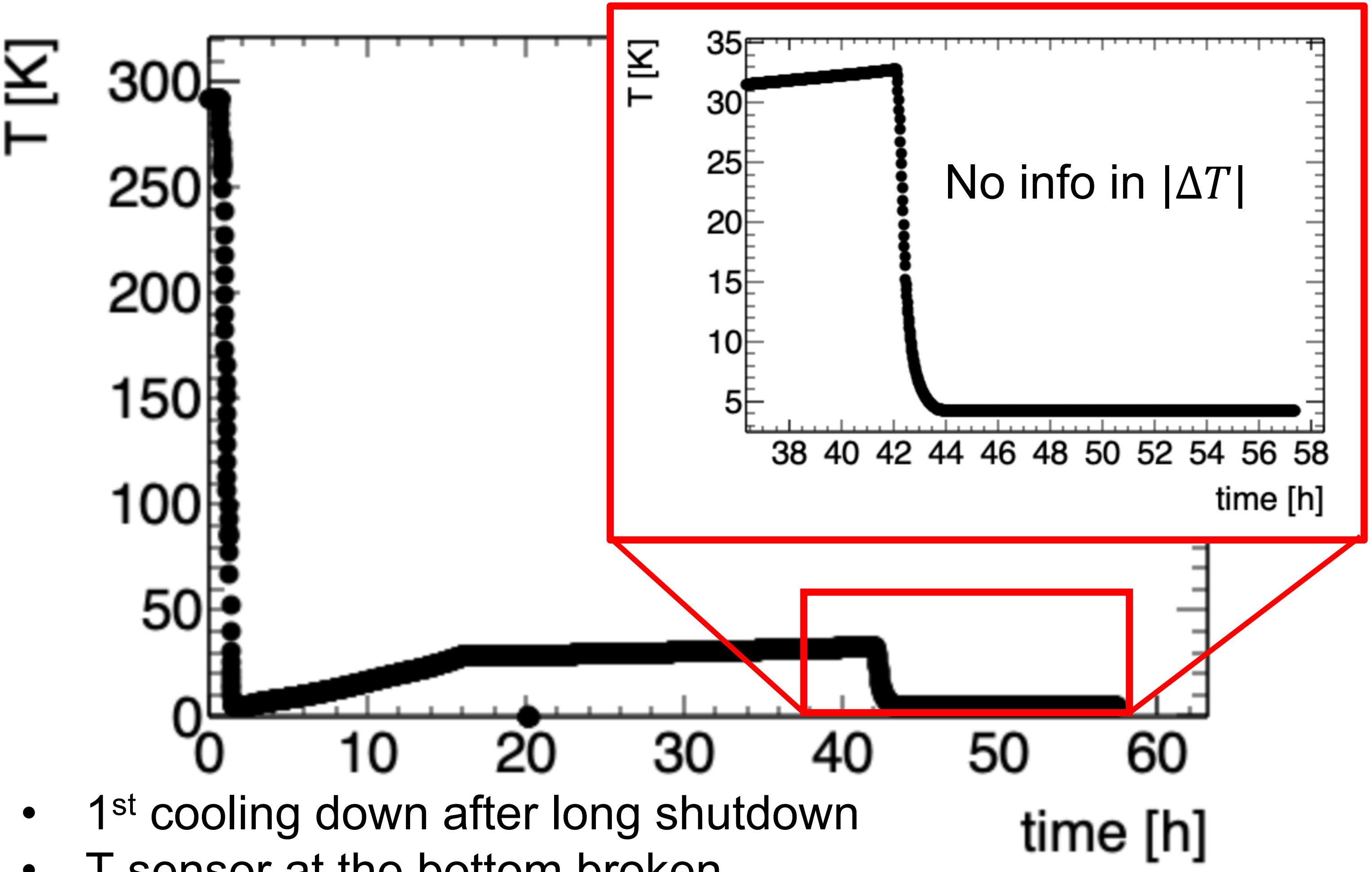


- Vacuum furnace originally used for 600C annealing of ESS spoke cavities
- A cryogenic pump, pure Ar for purging etc
- New R&D with DESY 1.3 GHz cavities

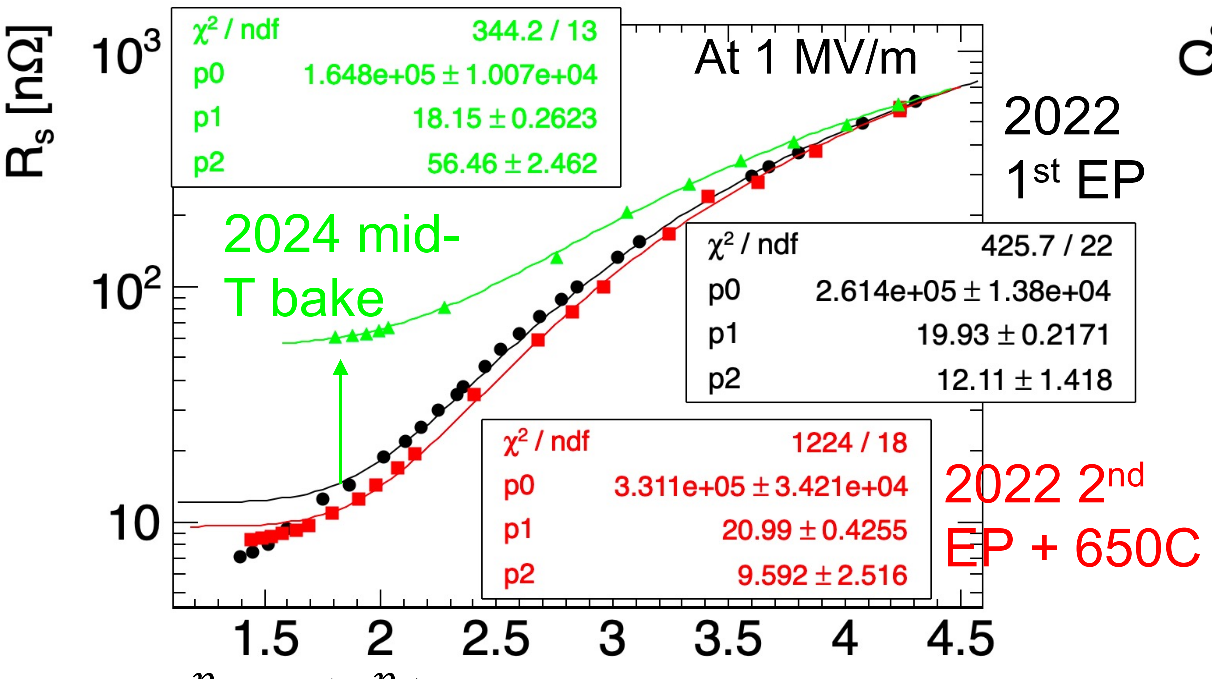
M. Fouaidy et al., IEEE Transactions on Applied Superconductivity, vol. 28, no. 4, pp. 1-6 (2018)



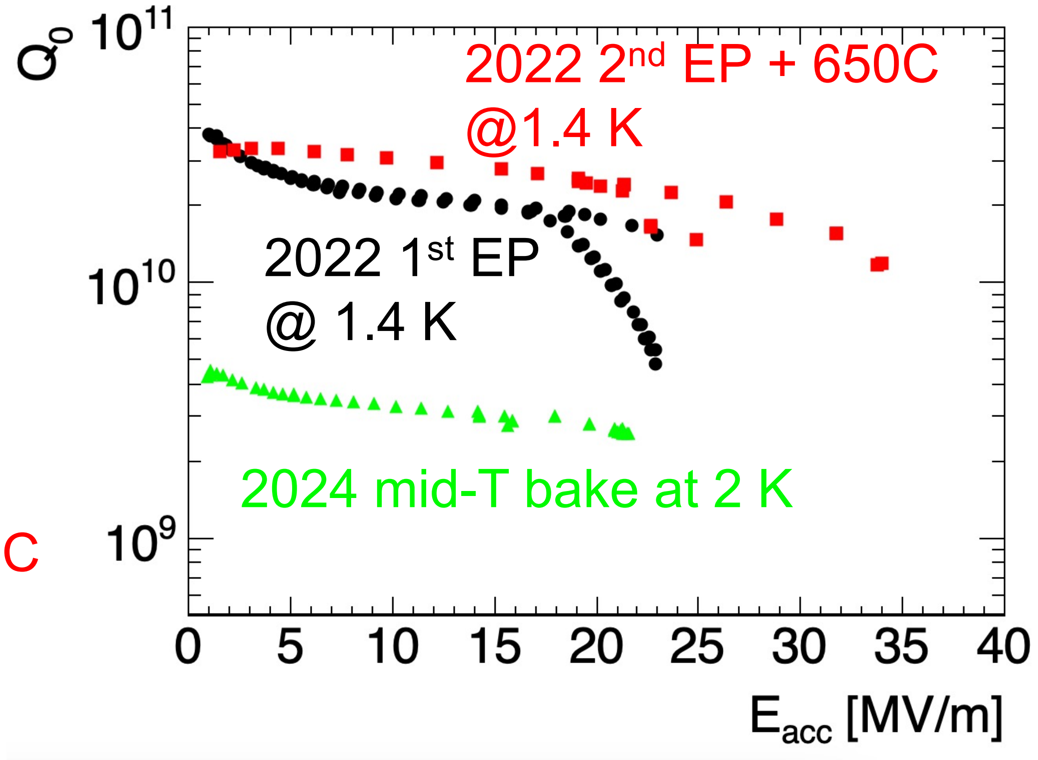
1st test is always far from ideal (CV1 at CEA Saclay on June 18 2024)



- 1st cooling down after long shutdown
- T-sensor at the bottom broken



$$R_s(T) = \frac{p_0}{T}\exp\left(-\frac{p_1}{T}\right) + p_2$$



- The mid-T baked cavity showed significantly high residual resistance $\Delta R_{res} > 46\ n\Omega$

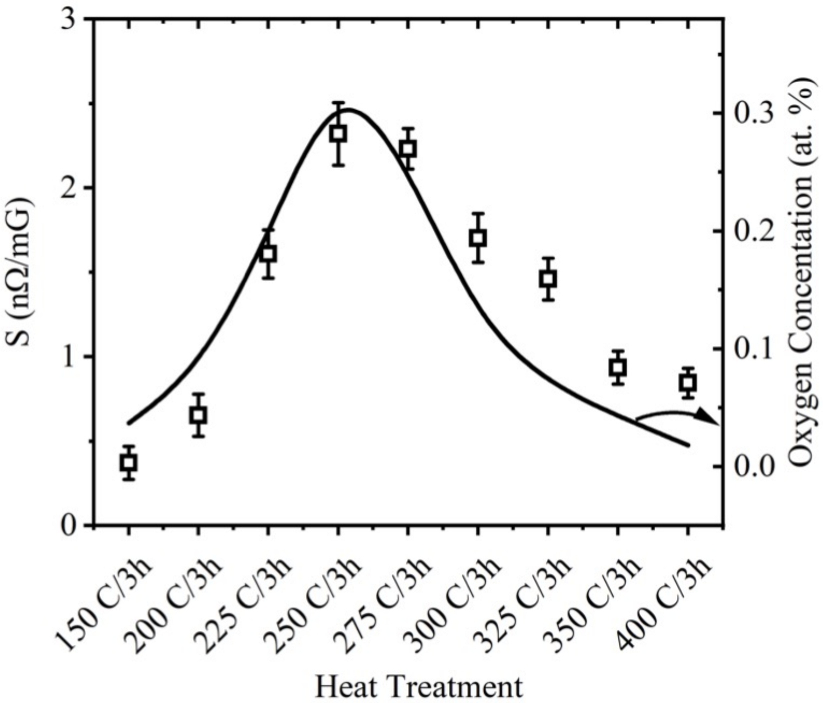
→ Is it due to contamination of furnace/cavity or magnetic field effect?

Magnetic field sensitivity (1.3 GHz cavities)

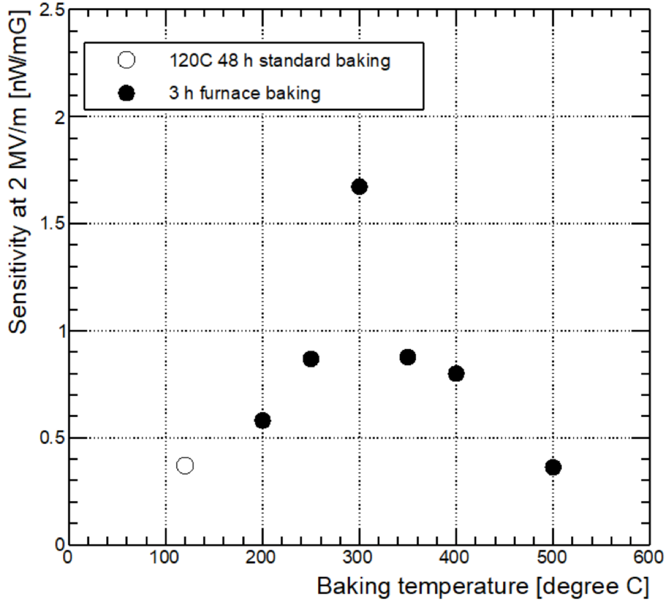
$H_{ext} \sim 25\ \text{mG} = 2.5\ \mu\text{T}$

Not yet optimized

JLab



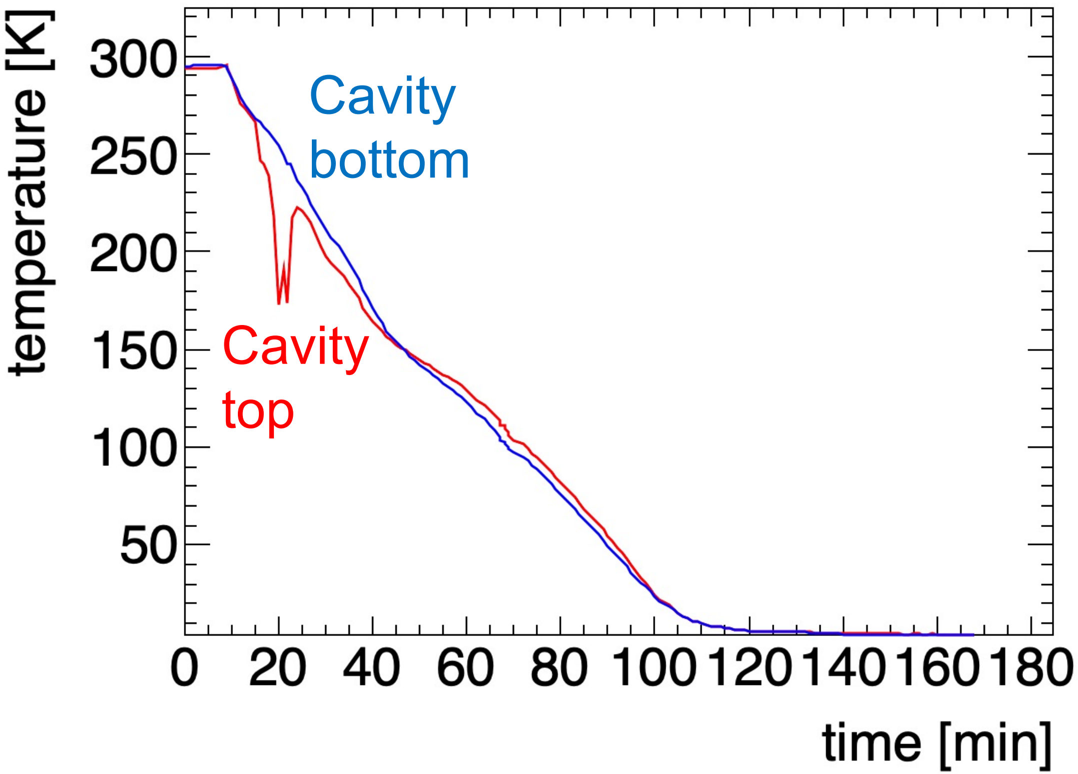
KEK

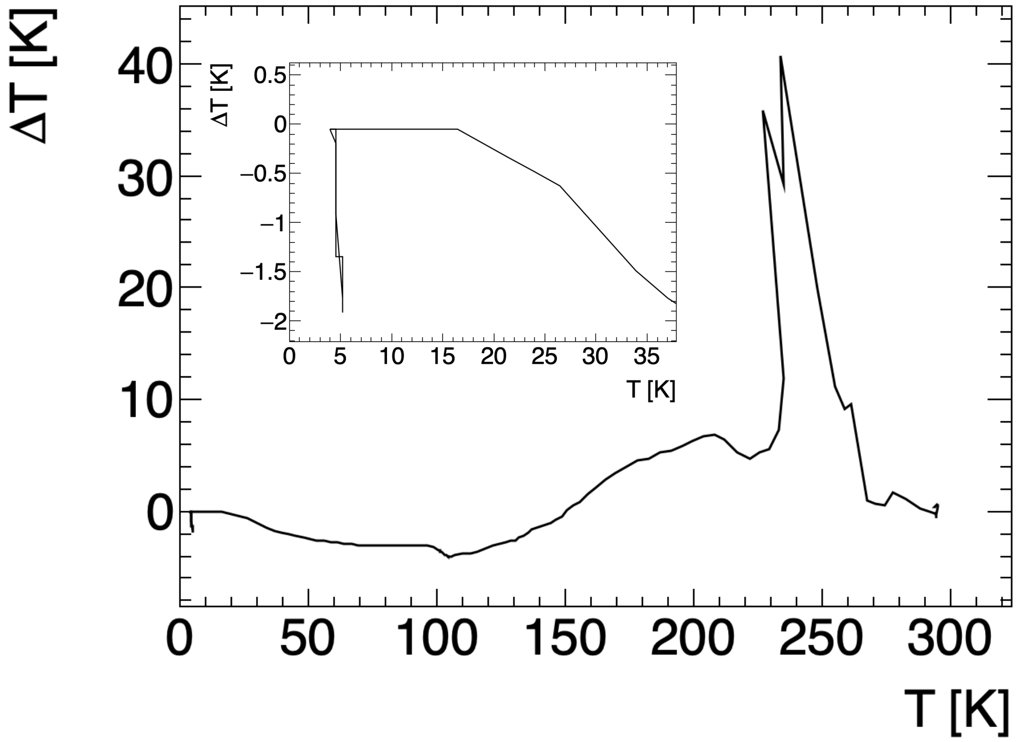


$S \sim 2\ \text{n}\Omega/\text{mG}$

$\rightarrow \Delta R_{res} \sim S H_{ext} = 50\ n\Omega$

2n cooling down: temperature sensors were OK (July 18 2024)

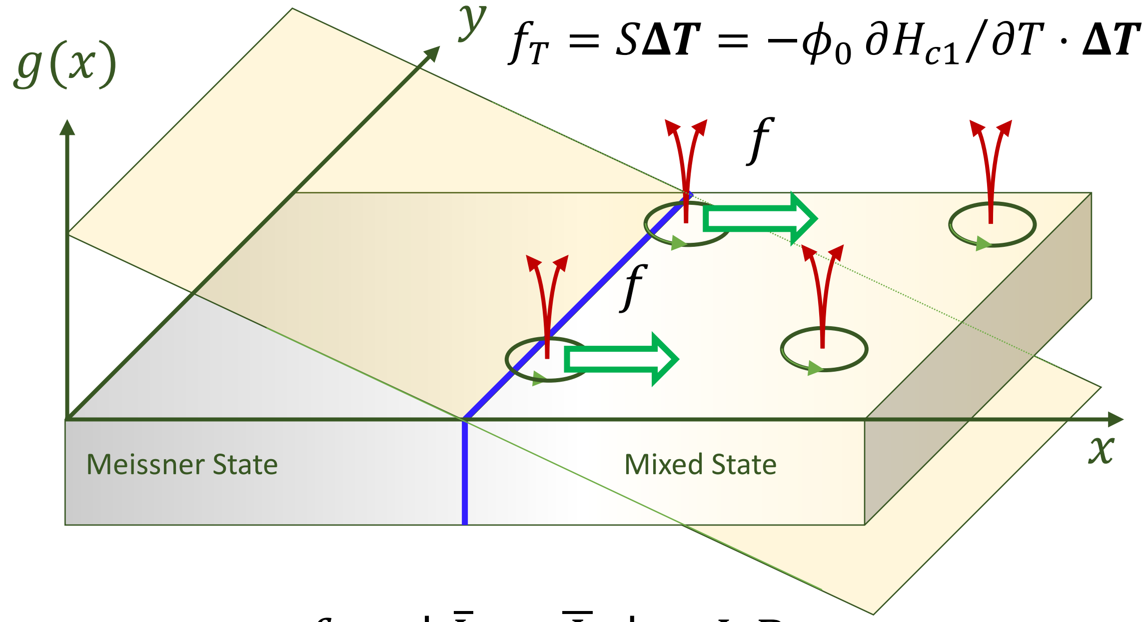




800C & 600C annealed 1.3 GHz cavity with $\Delta T = 0$ at $T_c = 9.25\ K$

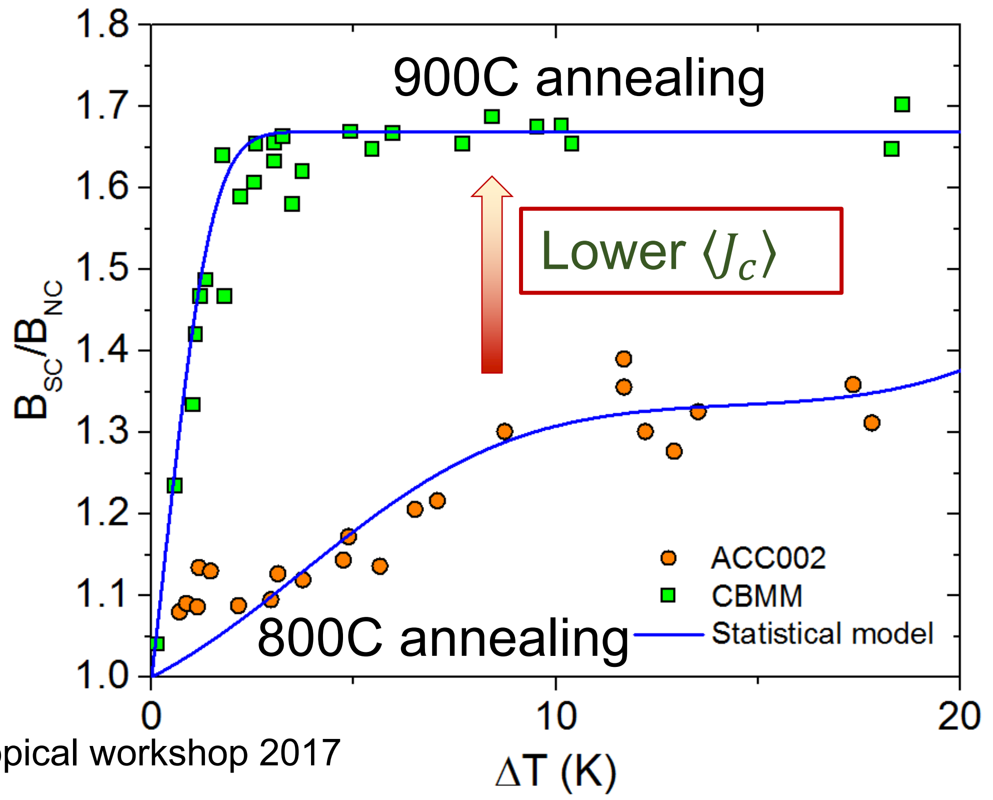
→ No flux expulsion is expected

Flux expulsion is mandatory



$$f_T = S\boldsymbol{\Delta T} = -\phi_0\, \partial H_{c1}/\partial T \cdot \boldsymbol{\Delta T}$$

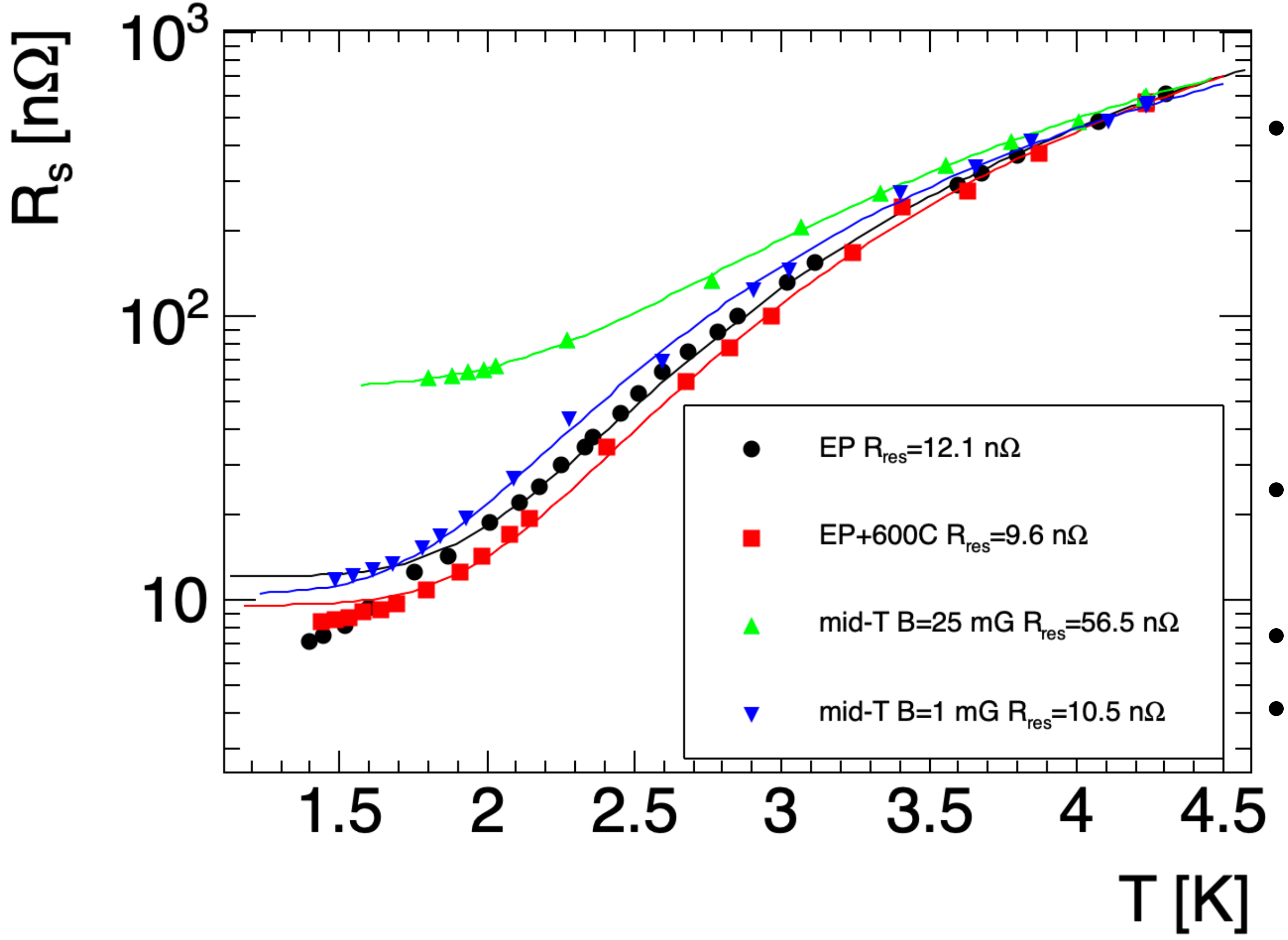
$$f_p = |\bar{J}_c \times n\bar{\Phi}_0| = J_c B$$



M. Checchin TTC topical workshop 2017

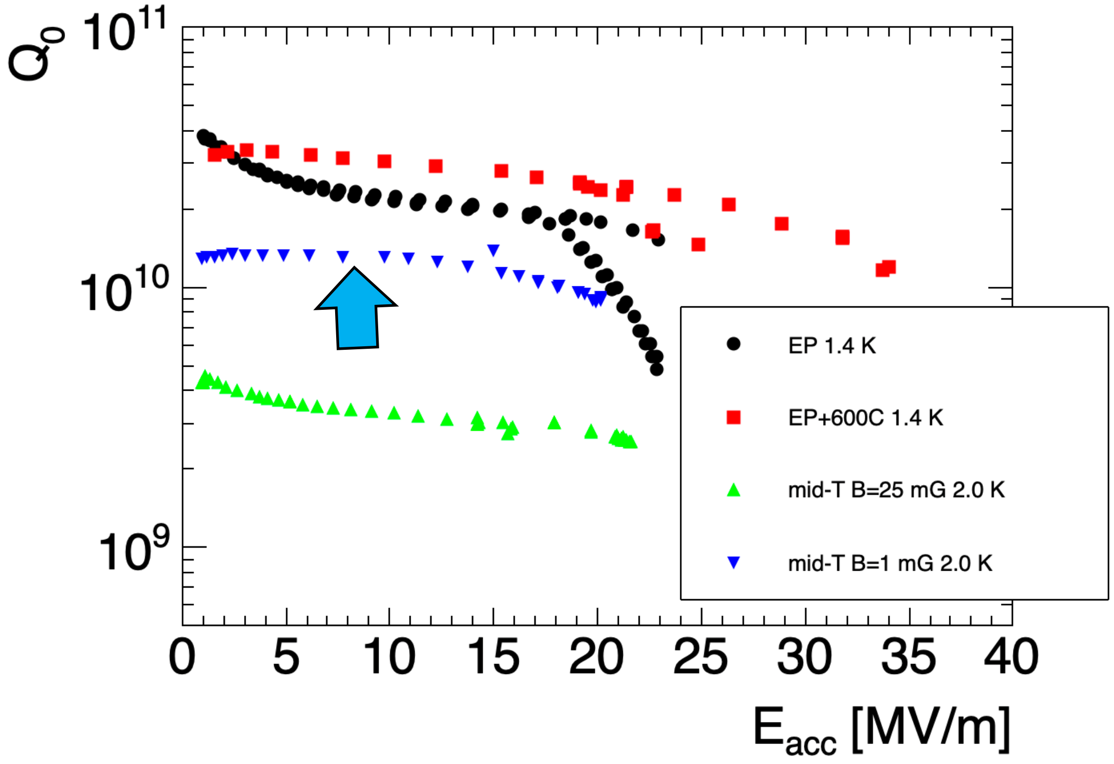
- Balance between thermodynamic force f_T and pinning force f_p in the mixed state
- Higher thermal gradient → higher expulsion efficiency
  → Cooling down with higher thermal gradient is a standard receipt in LCLS-II at SLAC

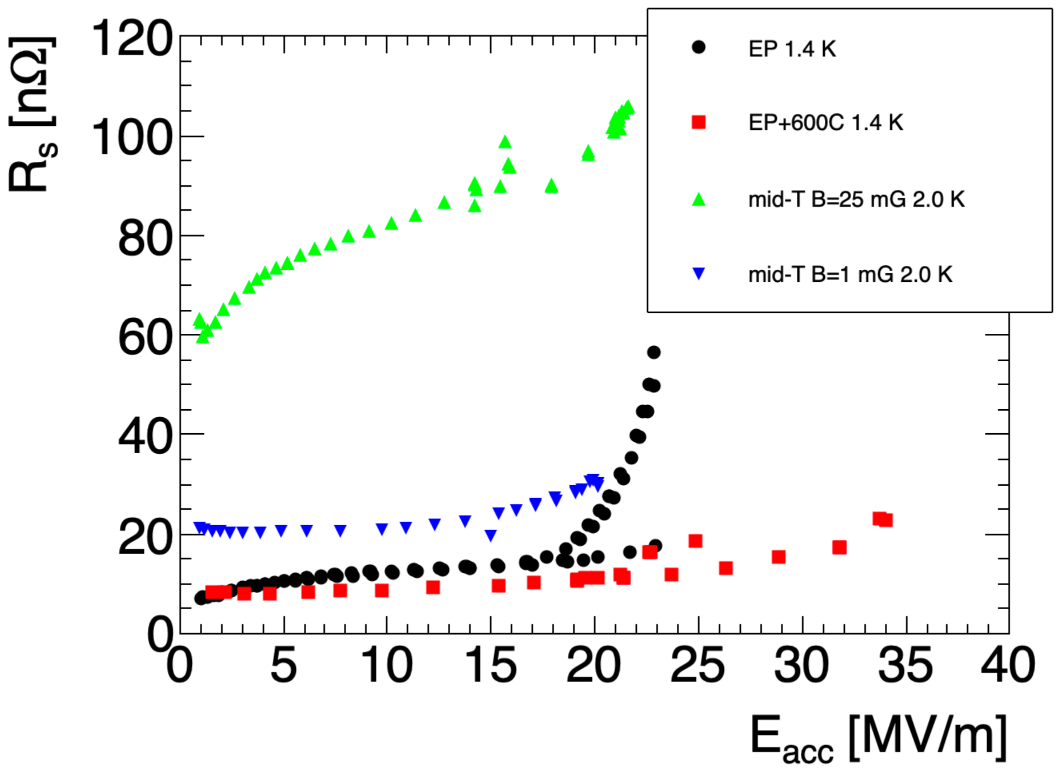
Surface resistance at low field during cooling down



- The very high residual resistance of the last measurement after mid-T bake was due to the bad ambient magnetic field
- The magnetic field expulsion is still not perfect
- KEK cryostat for final check
- FJPPN “ERL collaboration”

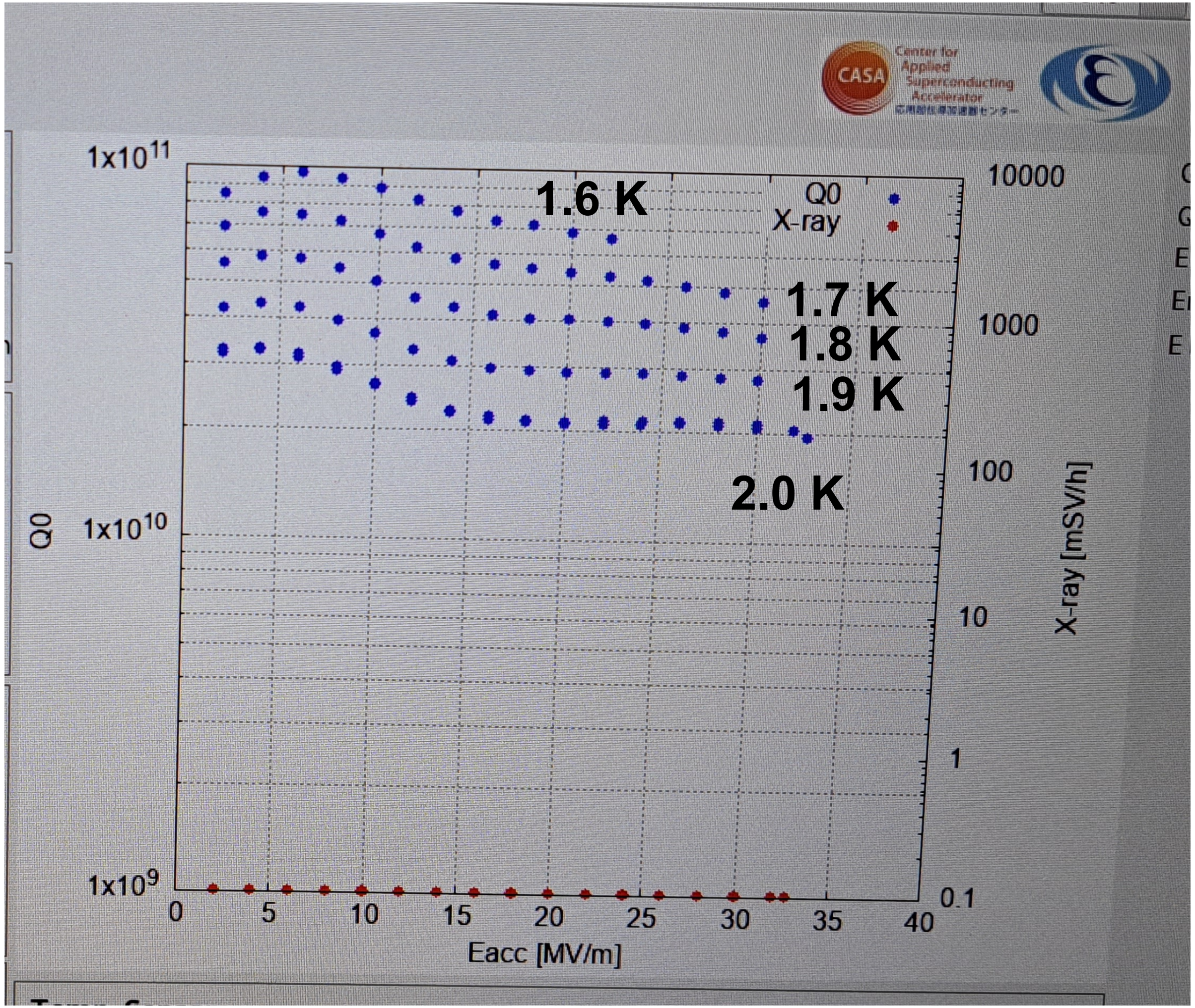
Q vs E and Rs vs E



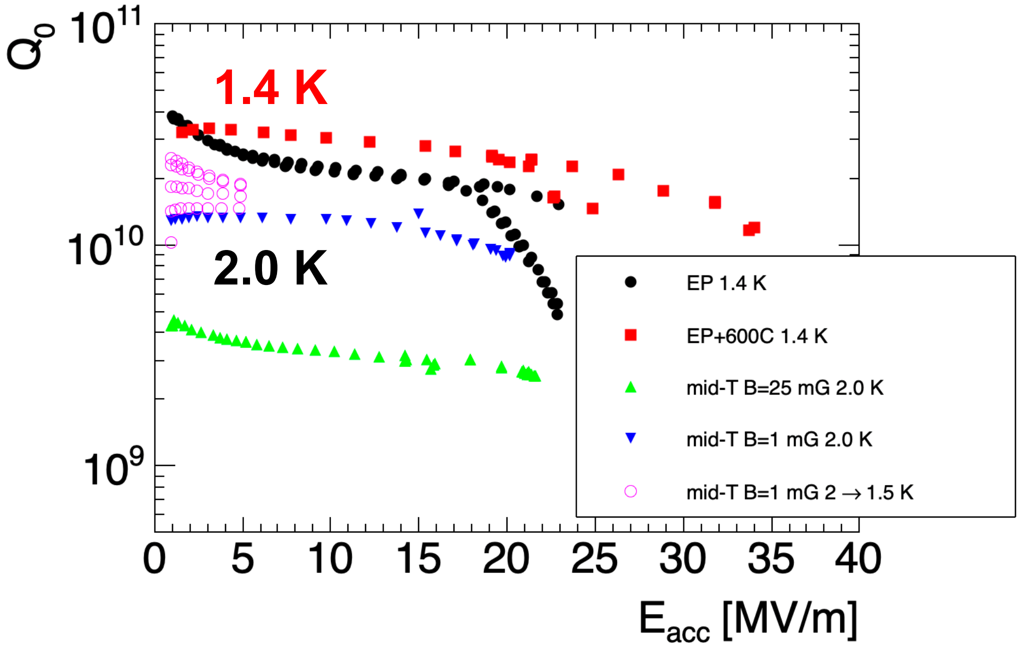


- 20 MV/m seems like a quench limit after the mid-T bake at 316C
- Maybe a small anti-Q-slope was observed
- Before mid-T bake data was taken at 1.4 K

Reference results at KEK (250C baking on medium grain niobium)



Our result: 316C baking, no perfect magnetic field



→ Extremely interesting to test this cavity at KEK

Conclusion

- IJCLab is recognized for ILC-ITN with respect to the coupler business
- New R&D for very high-Q cavities (mainly for PERLE/FCC)
  - 1st heat treatment at IJCLab with the clean vacuum furnace
  - 1st measurement at CEA Saclay → magnetic field problem
  - 2nd measurement at CEA Saclay → much improved but still not in the ideal condition (flux explusion)
  - 3rd test at KEK → compare to their cavities
- How to be invoved in ILC-ITN for cavities?
  - Furnace treatment at 600-900C for CEA's cavities?
  - CEA will do "2-step baking (75C + 120C)" for extremely high gradient, not for Q, which does not need IJCLab's furnace
  - IJCLab is in the loop but not easy to be fully involved in ILC-oriented R&D