High Q_0, High Gradient at JLAB

Research and development efforts continue to focus on fundamental characterization of surface dynamics and structure of impurity-alloyed niobium cavities. The goal is to systematically study the role of impurity diffusion on cavity performance and focus on implementation in new and refurbished CEBAF cavities

Pashupati Dhakal

CAVITIES @ CEBAF ACCELERATOR

- Four cryomodules types are currently operating in CEBAF:
- the original "**C20**" cryomodules with 5-cell cavities fabricated by Interatom, Germany, in the early 1990s.
- the "**C50**" cryomodules which have the same cavities as the C20s but after re-processing with updated SRF cavity processing procedures.
- "**C75**" cryomodules with 5-cell cavities fabricated by Research Instruments, Germany, starting in 2018, with end-groups re-used from **C20** cavities.
- "**C100**" cryomodules with 7-cell cavities fabricated by Accel, Germany, in 2010-2011.

Cavity Type	E_p/E_{acc}	B_p/E_{acc} [mT/MV/m)]	R/Q (Ω)	L_c (m)	E_{acc} (MV/m)	E_g (MV)	Q_0 (×10^9)	P_{RF} (W)	# of CM
C20	2.56	4.56	482.5	0.50	5	20	2.4	43	**24**
C50	2.56	4.56	482.5	0.50	12.5	50	6.8	95	**12**
C75	2.45	4.18	525.4	0.492	19.1	75	8.0	167	**4**
C100	2.17	3.74	868.9	0.70	19.2	108	7.2	206	**12**

Increased heat load due to lower Q_0 is ongoing issue in SRF cryomodules

HIGH Q_0 R&D FOR CEBAF

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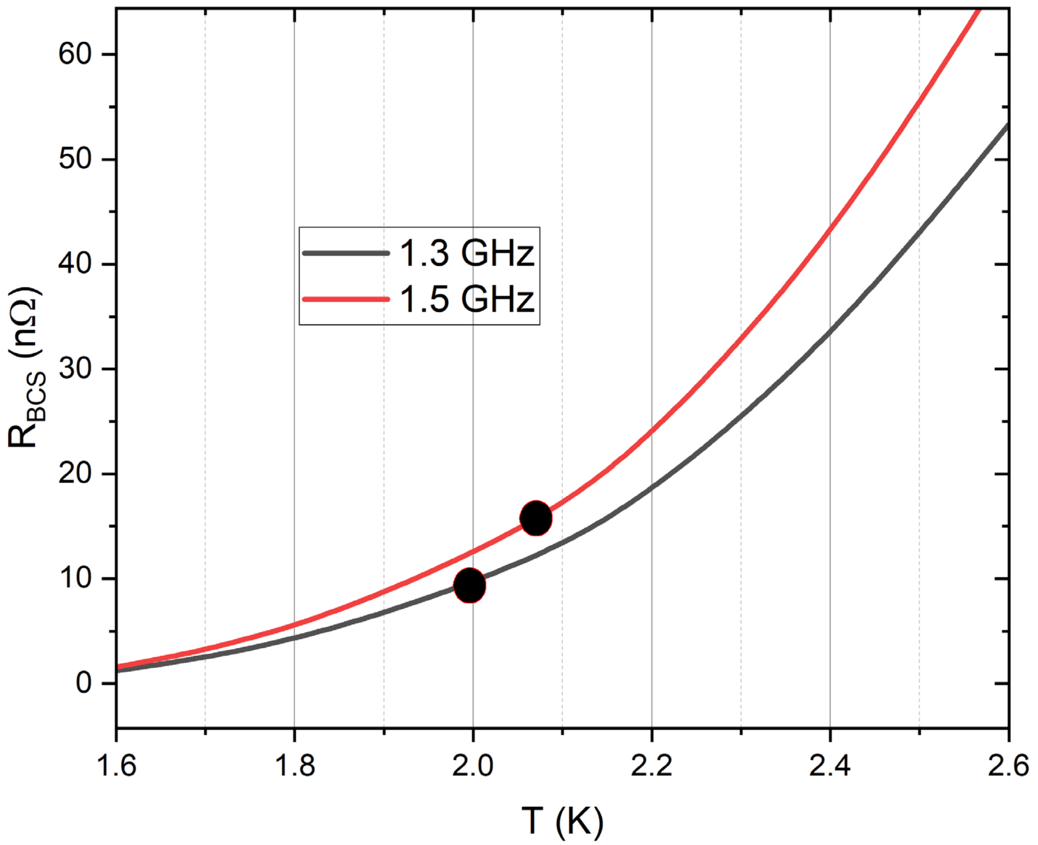
CEBAF is in operation, the only way to implement high Q_0 on existing cavities are during refurbishment and upgrades:

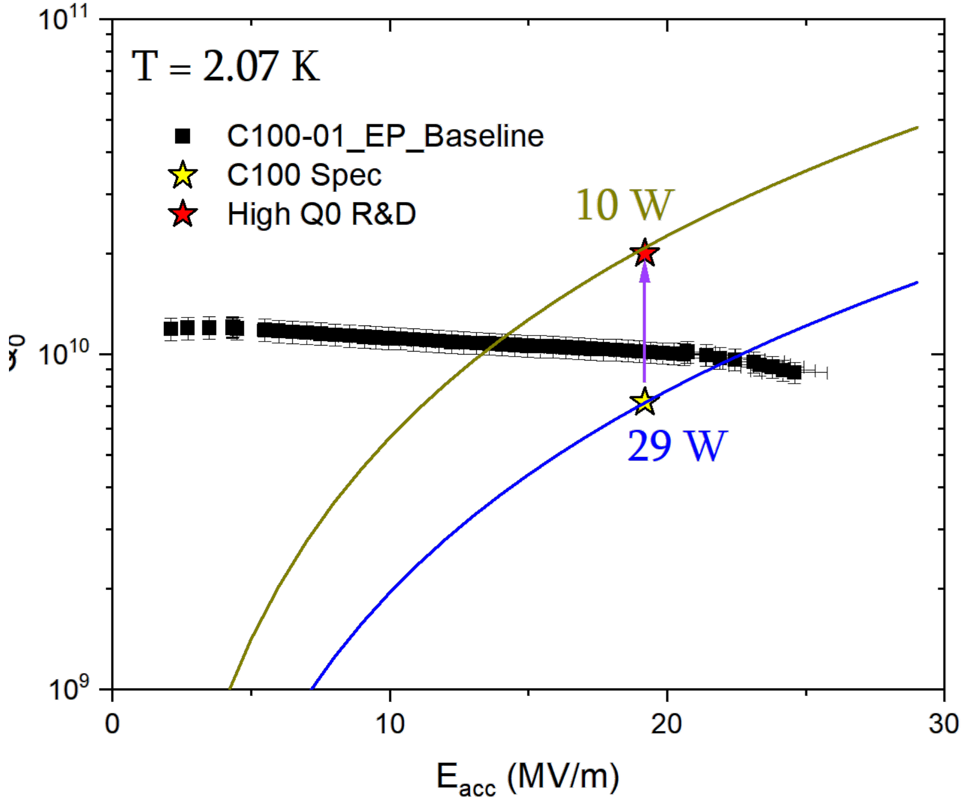
- **Currently older C20 are being replaced with new C75 cavities to increase the over all gradient by ~ 55 MeV per cryomodules**
- **Refurbish underperforming C100 (with light EP and HPR) and reinstallation.**

High-Q recipes: Pros and Cons

	LTB	Nitrogen Alloying	Nitrogen Infusion	O-Alloying
Pros	• Simple processing Steps • Lower flux trapping sensitivity • Potential to maintain higher gradient • Reduced outgassing from cavity-pair	• 2-3 times increase in Quality factor	• 2 times increase in Quality factor • No reduction of E_{max} • Low flux trapping sensitivity • No post chemistry	• 2-3 times increase in Quality factor • No post chemistry
Cons	• No Q-rise with field, limited Q_0-improvement • Risk of leaks when baking a C75 cavity-pair	• High flux trapping sensitivity • Controlled post alloying EP • Q-drop after quench • Reduction of E_{max} 20-30 MV/m over LTB • Furnace contamination could affect the outcome	• Furnace contamination could affect the outcome • No multicell results yet	• Reduction of E_{max} • High flux trapping sensitivity • Furnace contamination could affect the outcome

HIGH Q_0 R&D FOR CEBAF





HIGH Q_0 R&D FOR CEBAF: NITROGEN INFUSION

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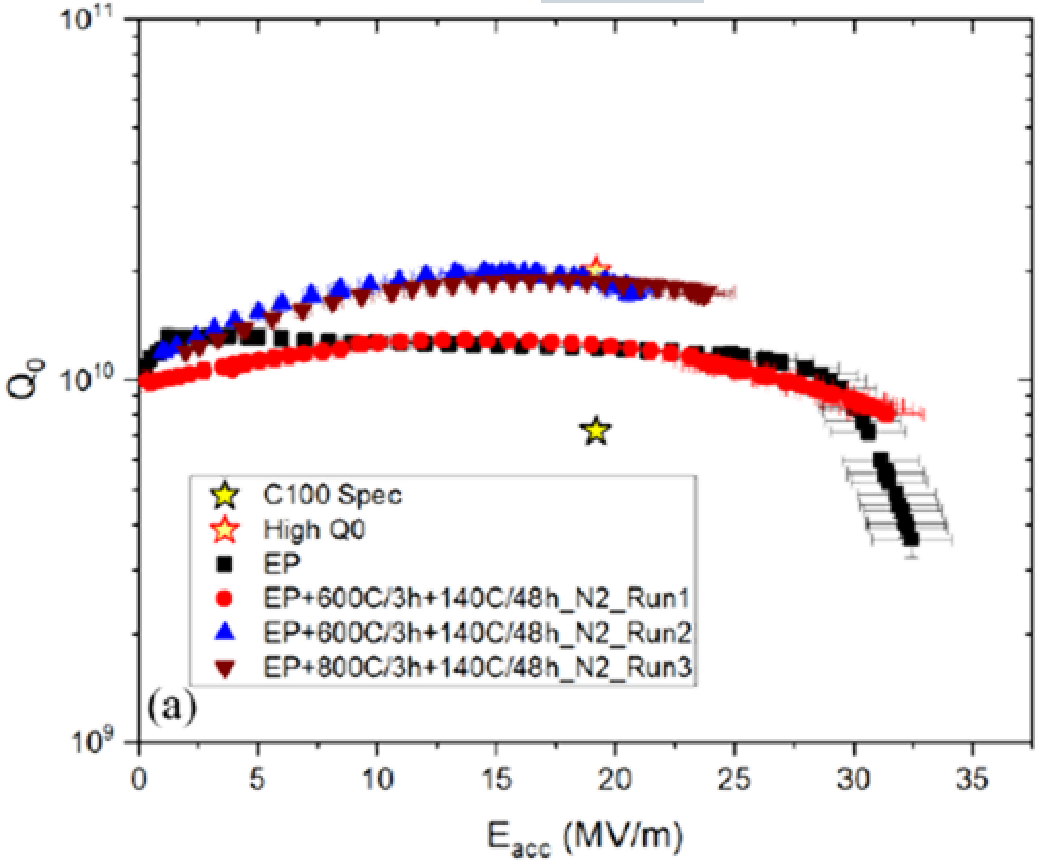
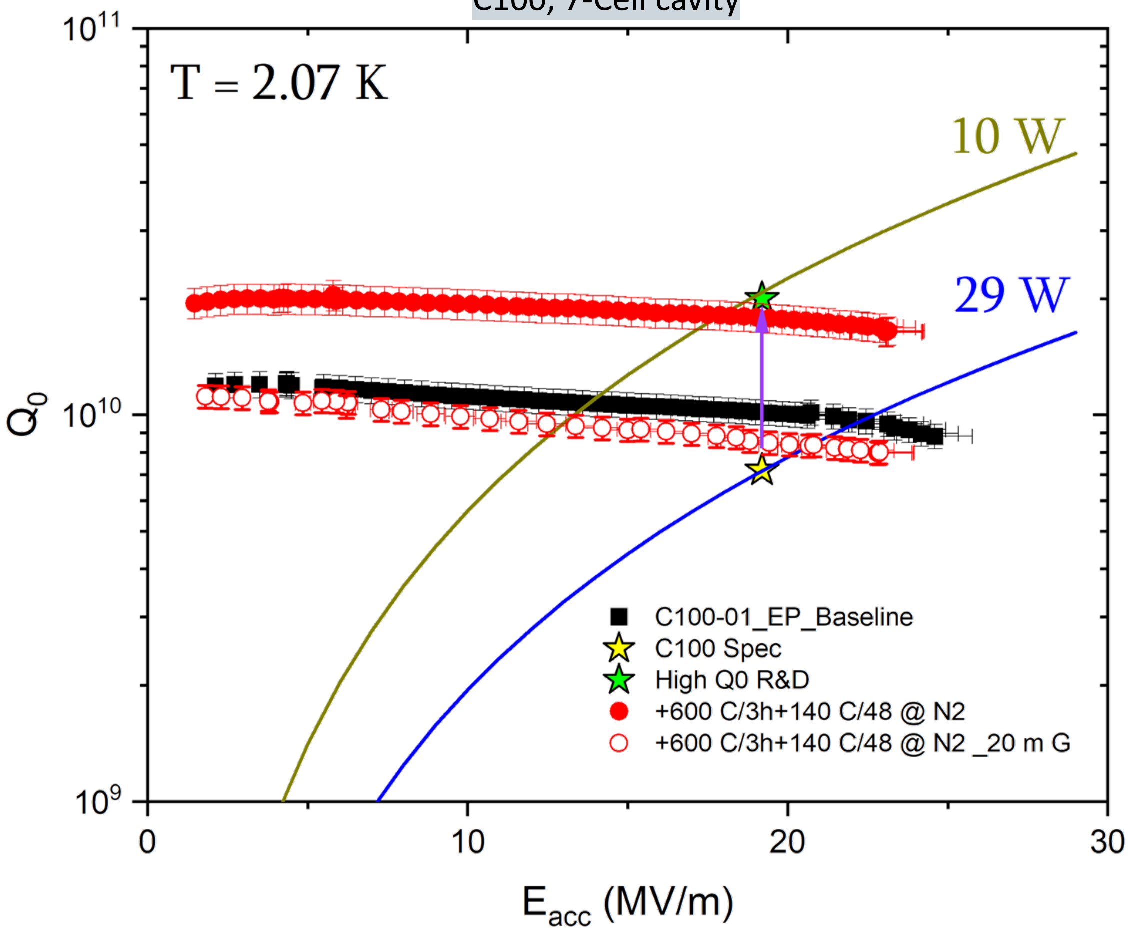
Single Cells

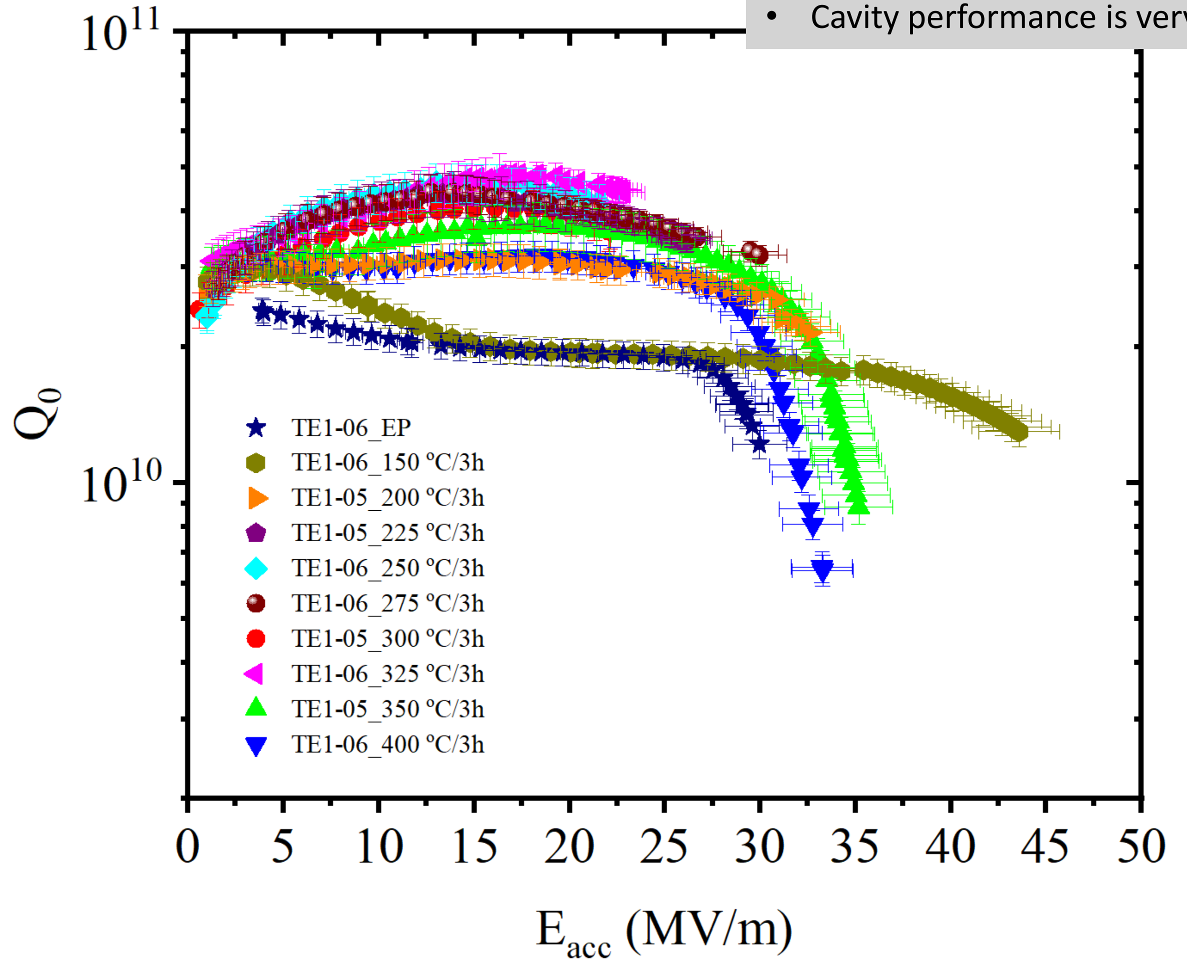


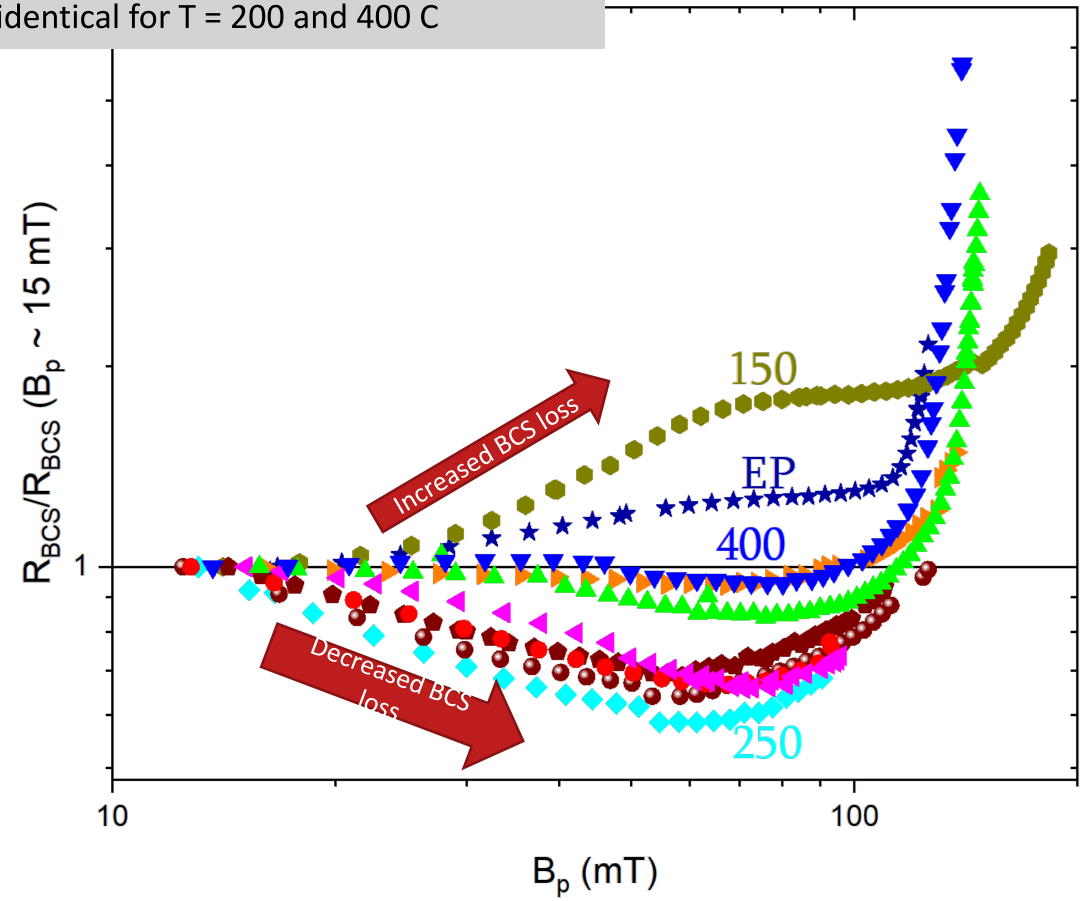
C100, 7-Cell cavity



$Q_0(E_{acc})$ and Field Dependence R_{BCS} (mid-T)

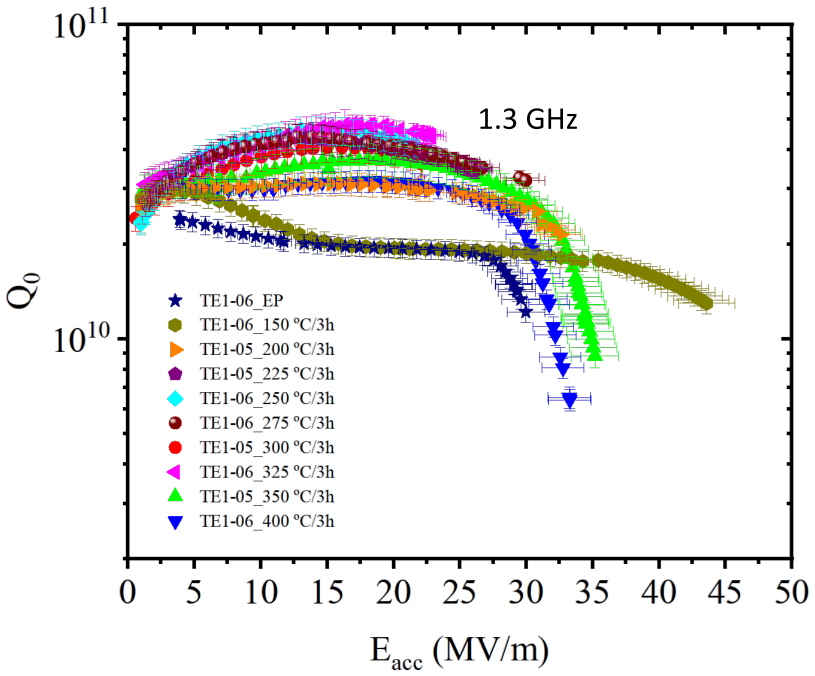
- Normalized BCS slope is positive (T< 200)
- Negative slope increase for (200 <T<250)
- Negative slope decrease for (T > 250 C)
- Cavity performance is very identical for T = 200 and 400 C

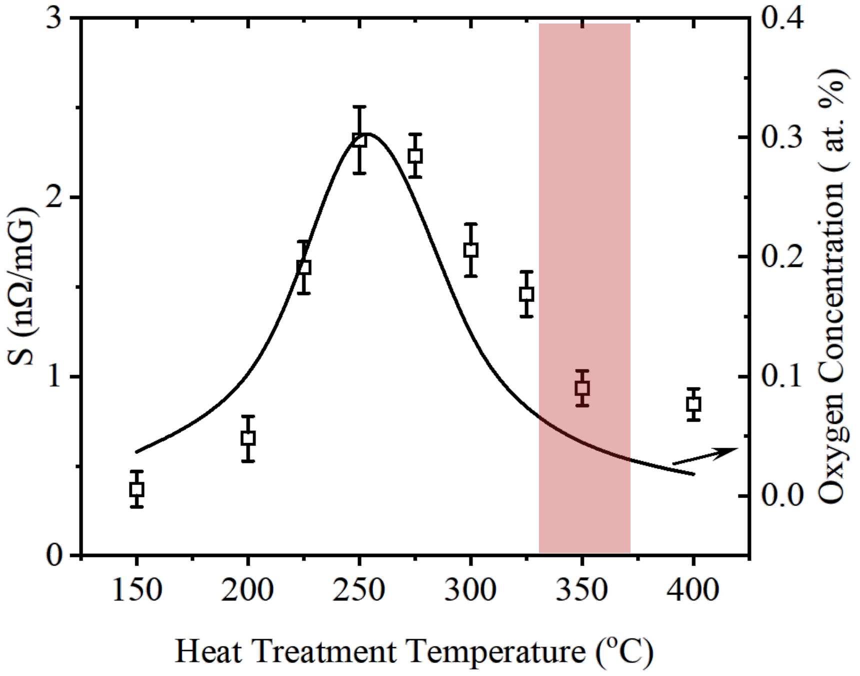




Mid-T bake

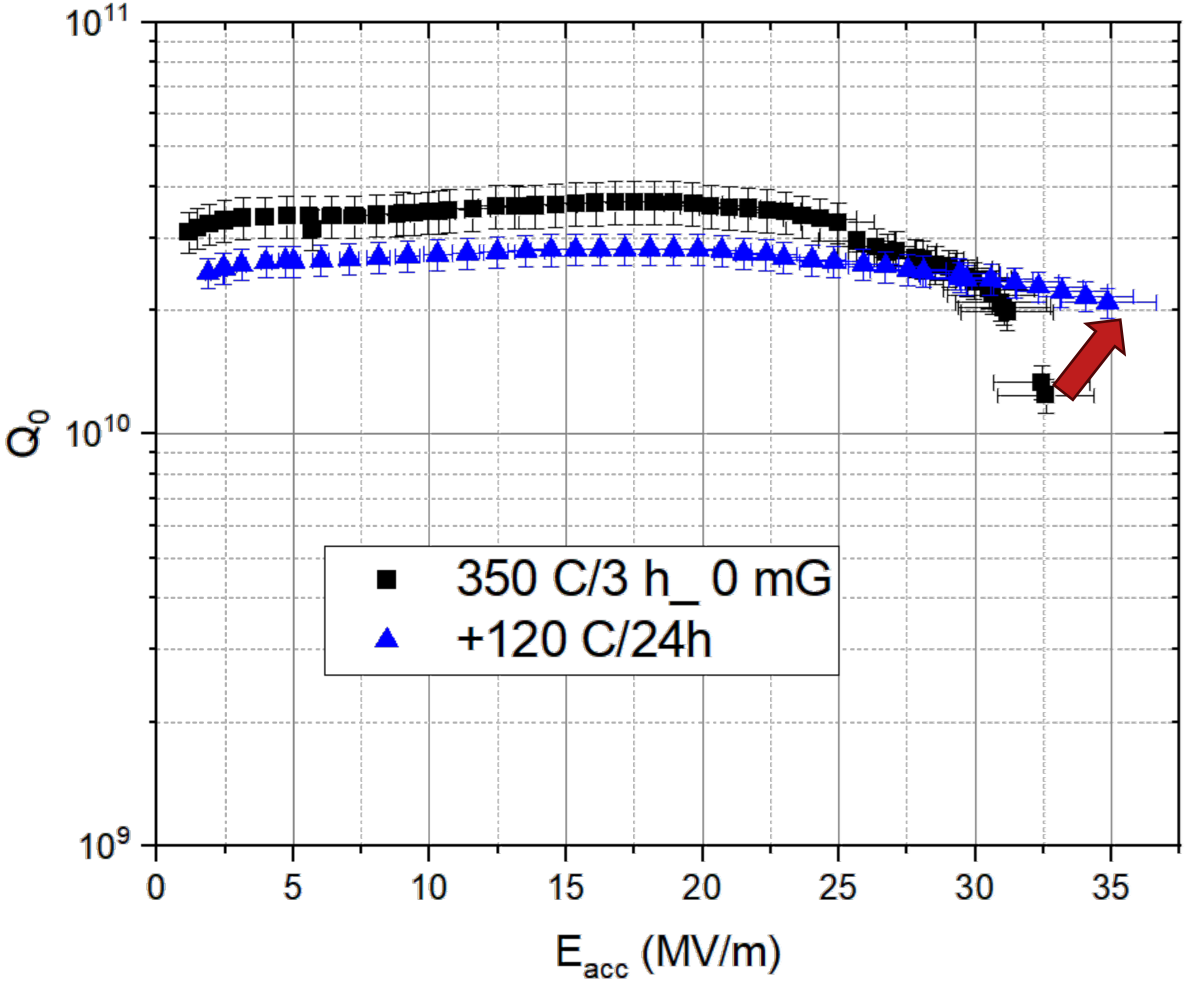
IPAC 24

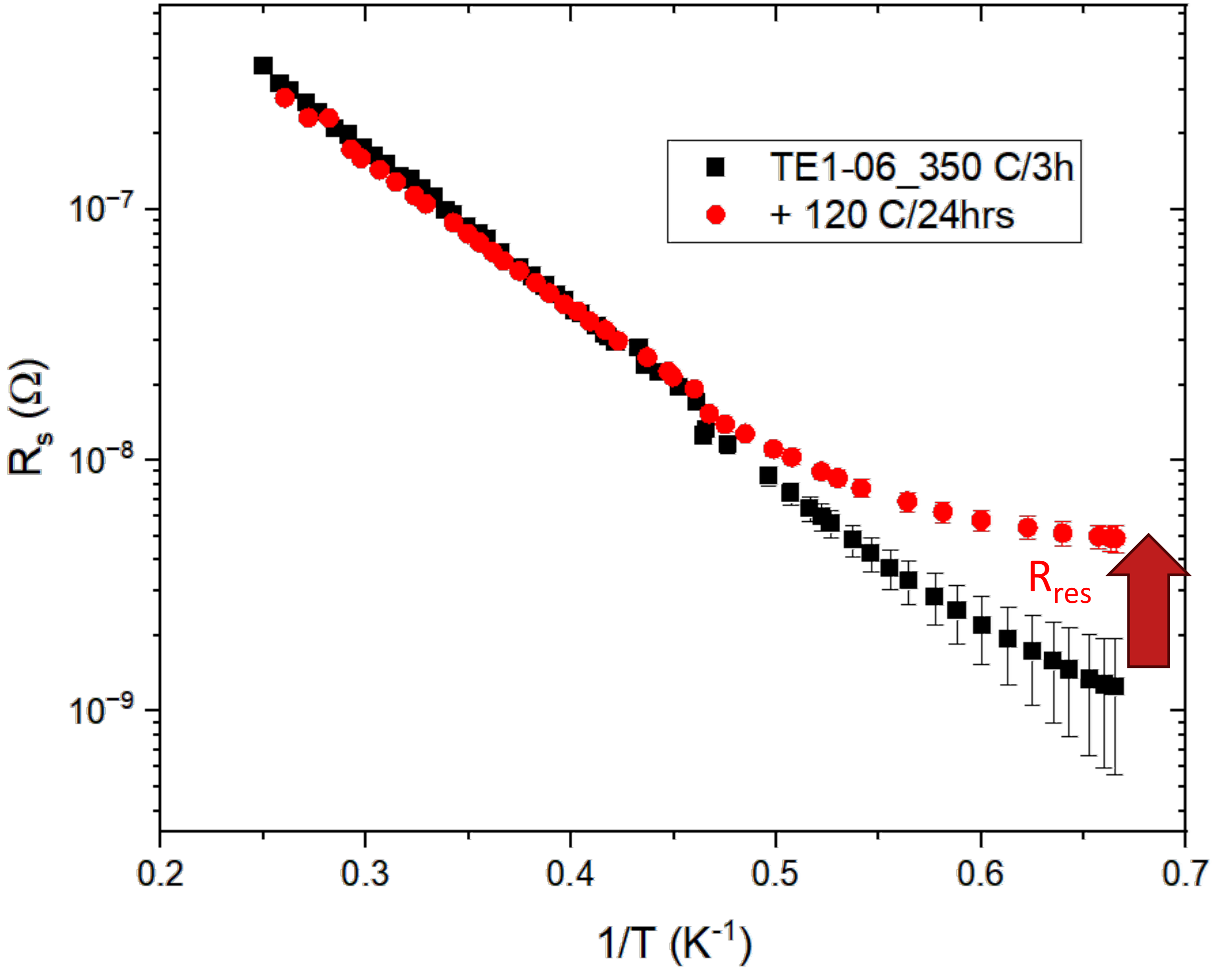




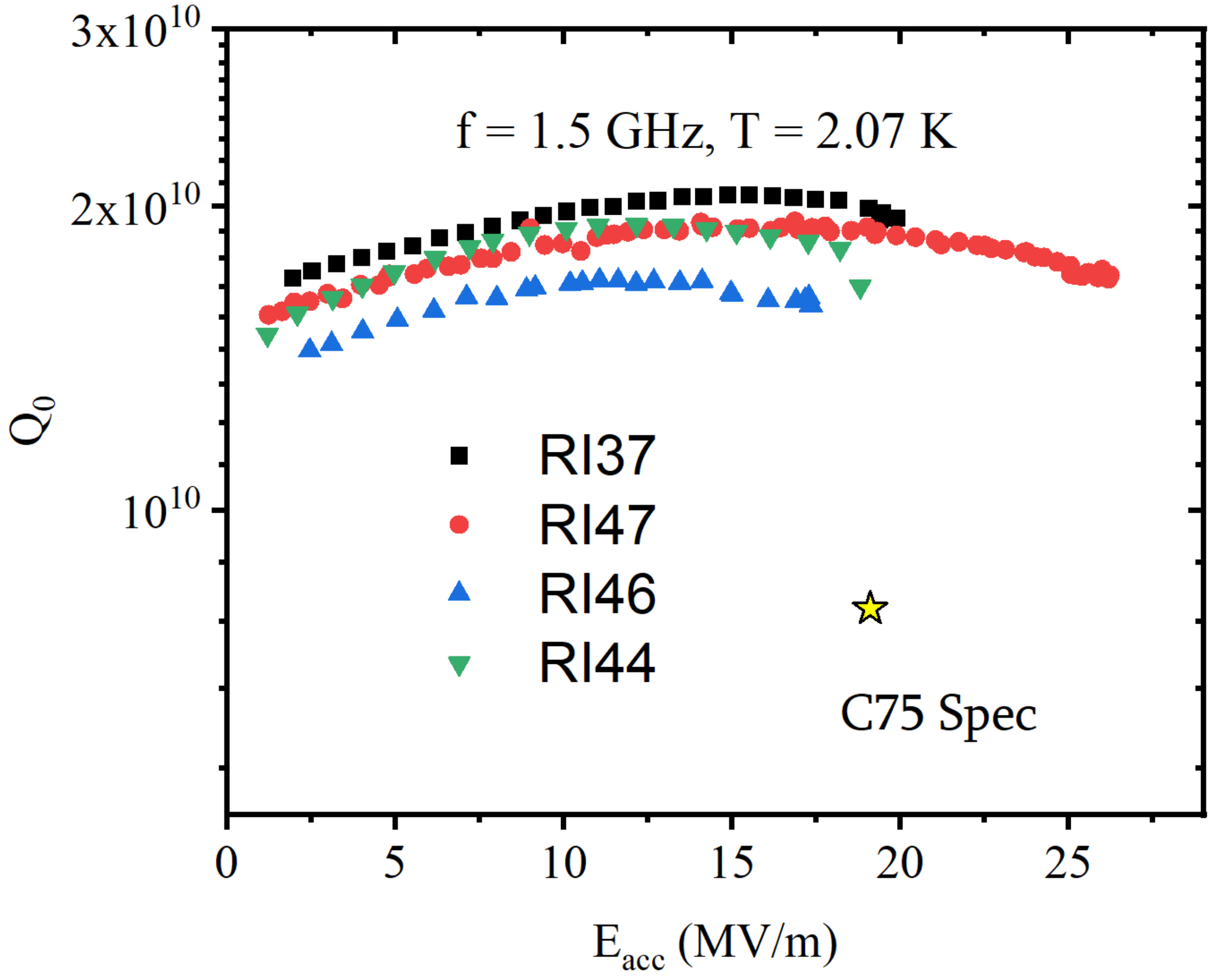
- The enhancement of the quality factor through Q-rise is evident following heat treatments within the temperature range of 200 to 400 °C for a duration of 3 hours
- Cavities treated within the temperature range of 250 to 325 °C/3h exhibit a tendency to quench at lower gradients (20 - 25 MV/m) compared to cavities treated outside of this temperature range.
- The sensitivity to flux trapping increases with rising heat treatment temperatures within the range of (200 - 325 °C/3h) and the sensitivity to flux trapping gradually diminishes with increasing heat treatment temperatures. The bell-shaped flux trapping sensitivity follows the average oxygen concentration within 100 nm.
- The reappearance of high field Q-slope when heat treatment temperature higher than 350 °C, still need further investigation.

Mid-T + 120 C Bake



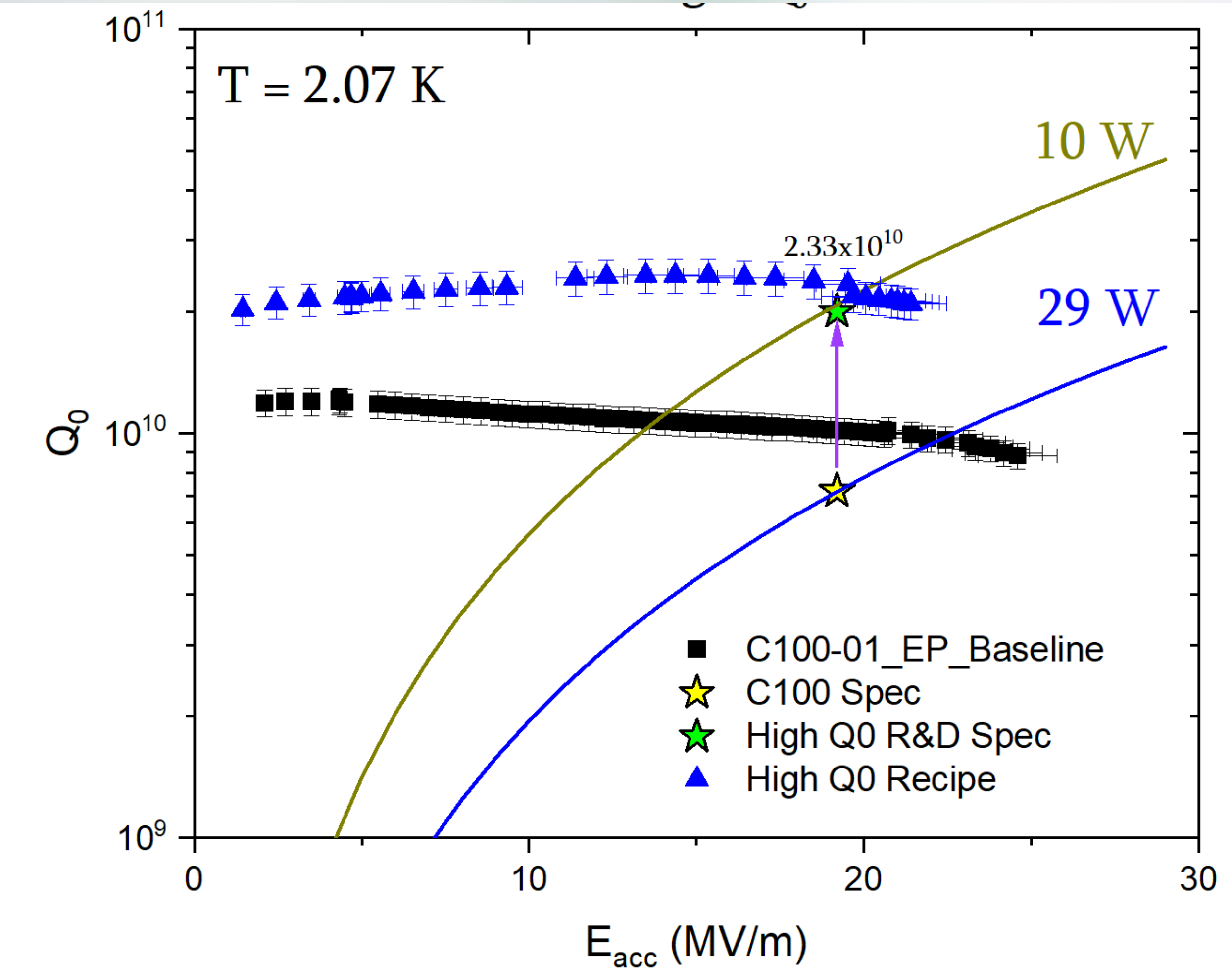


Mid-T in 5 Cell Large grain CEBAF cavities

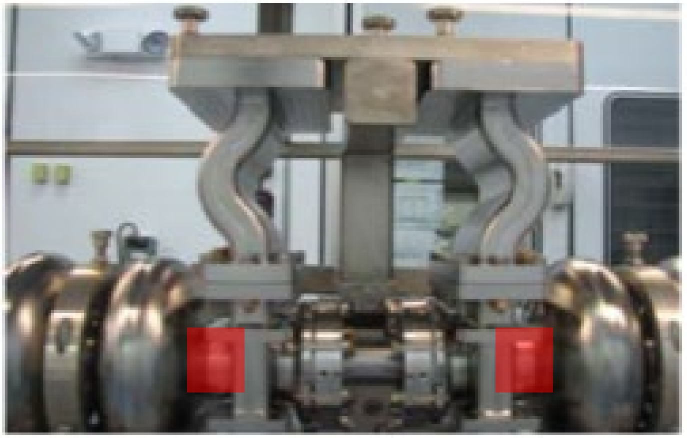


Installation in cryomodules in progress

HIGH Q_0 R&D FOR CEBAF: 7 Cell



Challenges for using high-Q cavities in C75 CM

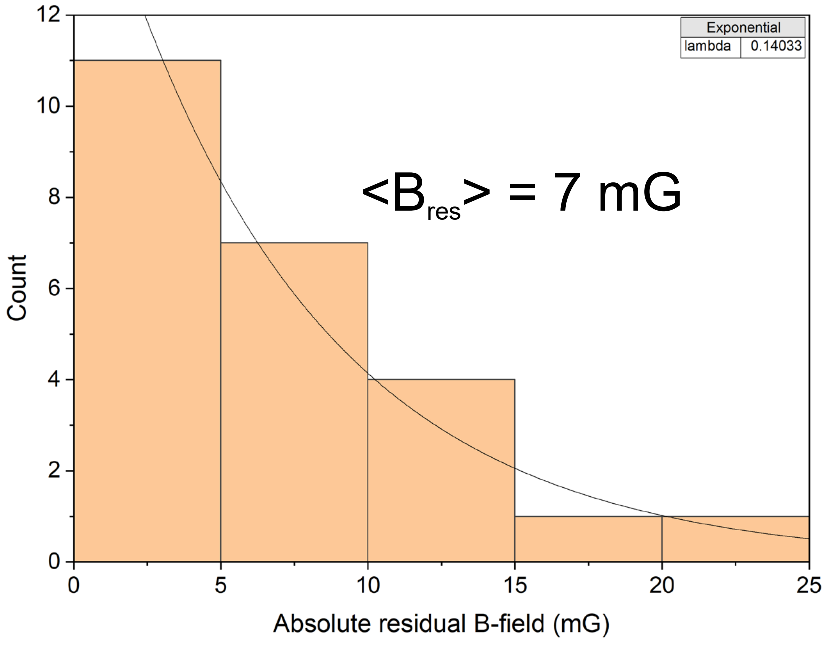


Evidence of increased radio-frequency losses in cavities from the fundamental power coupler cold window

Frank Marhauser and Gianluigi Ciovati*
Thomas Jefferson National Accelerator Facility, Newport News, Virginia 23606, USA

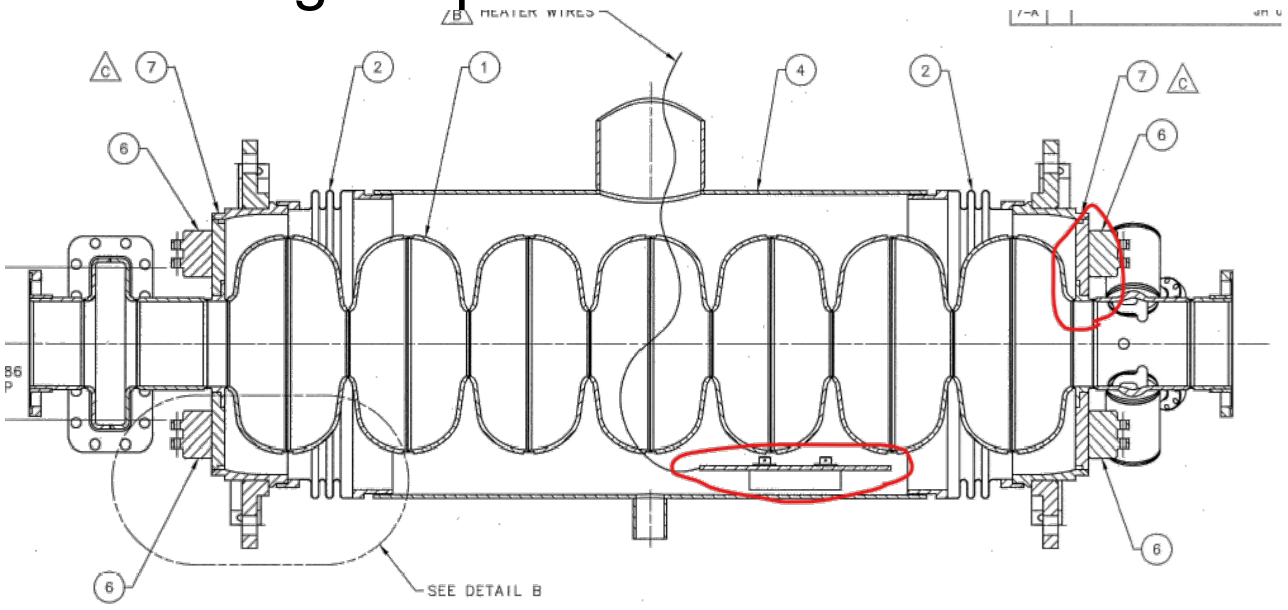
Improvement was made by increasing the distance between the waveguide and cavity cell in C75 Cavities

Unclear whether cooldown dynamics can be controlled to minimize the flux trapping



Challenges for using high-Q recipes in C100 cavities

- A C100 bare cavity has a SS-Nb brazed joint
  - The highest temperature it can be annealed as a bare cavity is 600 °C
- A refurbished C100 cavity has a SS He tank welded to it with a heater inside
  - Issues with differential thermal expansion and G10 used in heater assy, the highest annealing temperature is ~140 °C



Removal and reweld of Helium vessel is needed

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SUMMARY

- The CEBAF accelerator has been the workhorse of nuclear physics research since 1994.
- Over the past decade, significant progress has been achieved in developing high-Q_0, high-gradient SRF cavities.
- Currently, R&D efforts are underway to implement high-Q_0, high-gradient SRF cavities through refurbishment and upgrade initiatives.