High Gradient Testing of a Two-Cell C-band Accelerator Cavity with NiCr Higher-Order Mode Absorbers

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Outline of this talk

- Introduction and LANL C-band research and its alignment with DOE HEP high gradient research in other laboratories
- LANL C-band Engineering Research Facility CERF-NM
- High gradient tests of the two-cell cavity with NiCr absorbers
- Summary and near-term plans

LANL High Gradient C-band research

The goals for LANL's high gradient research are evolving

- To build a C-band (5.712 GHz) high gradient rf breakdown study facility (2019-2022).
- To build a C-band cryo-cooled photoinjector study facility (2022-2025).
- To conduct research in collaboration with other DOE research laboratories and universities in particular as a part of C3 efforts.

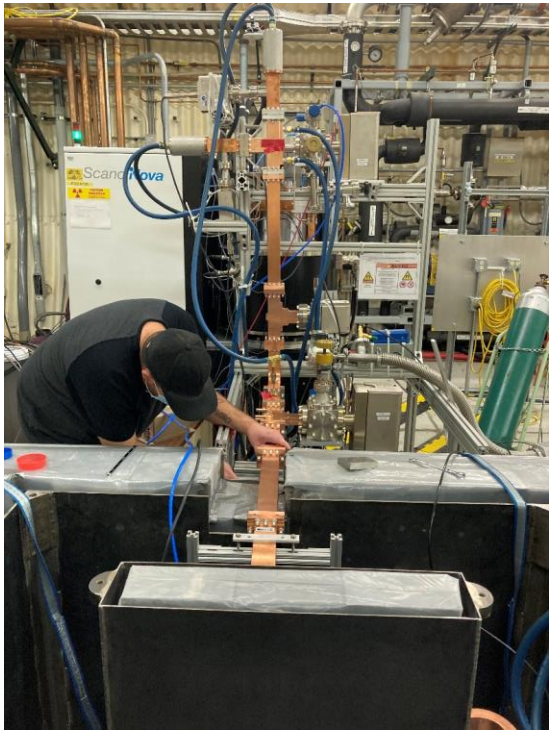
Los Alamos National Laboratory internal funding comes from LANL Laboratory Directed Research and Development (LDRD) program, LANL Internal Infrastructure Investments, and Technology Evaluation and Development (TED) funds.

Los Alamos National Laboratory external funding comes from the DOE HEP.

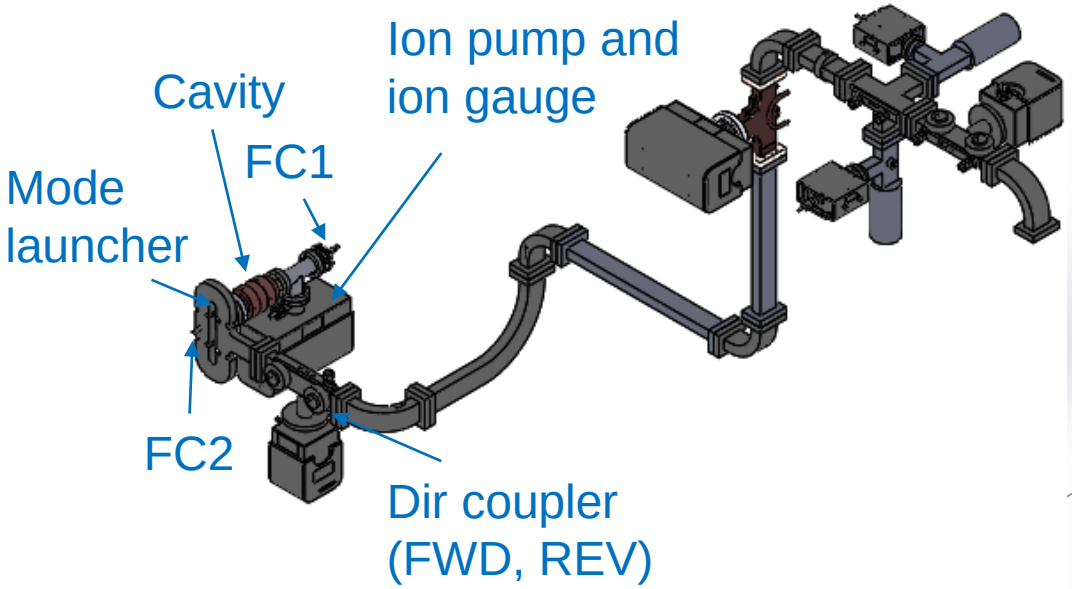
LANL C-band Engineering Research Facility (CERF-NM)

CERF-NM was built with $3M of LANL's internal infrastructure investment.

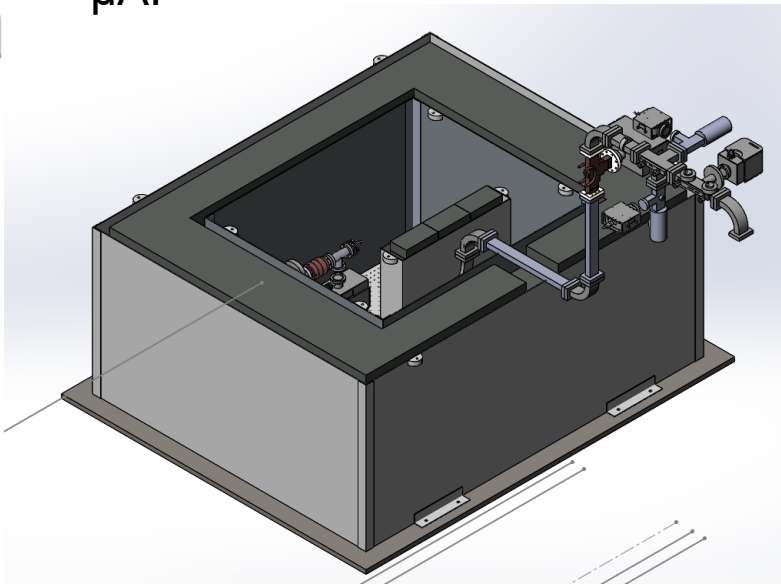
- Powered with a C-band Canon klystron
- Conditioned to 50 MW
- Frequency 5.712 GHz
- 300 ns – 1 µs pulse length
- Rep rate up to 200 Hz (typical 100 Hz)
- Nominal bandwidth 5.707-5.717 GHz



Schematic of CERF-NM test stand

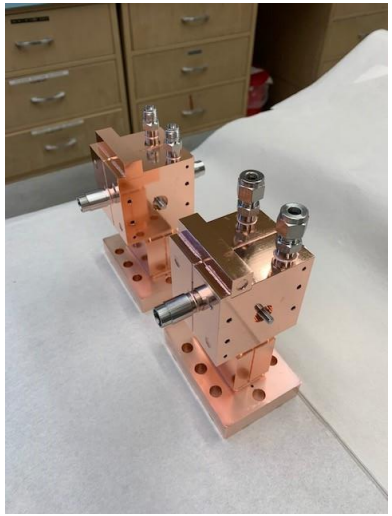


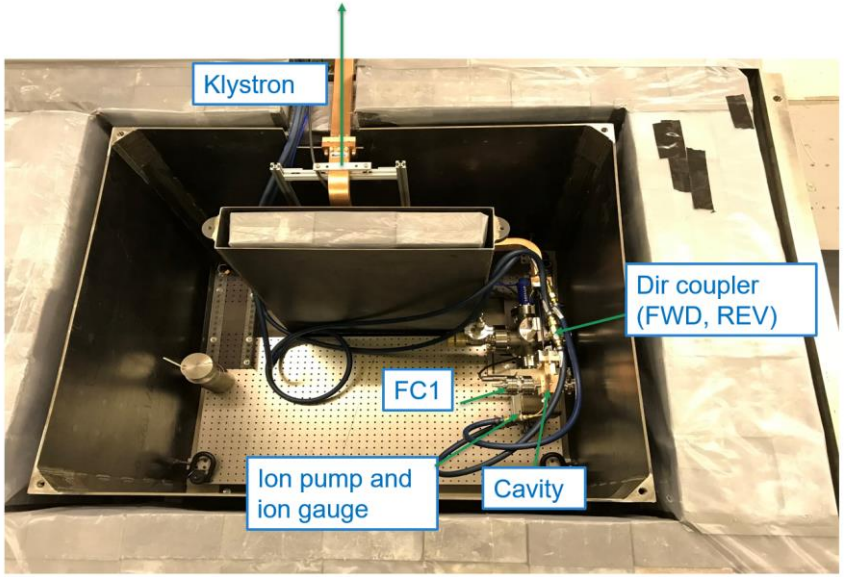
Radiologically certified for dark currents up to 5 MeV and 10 μA.

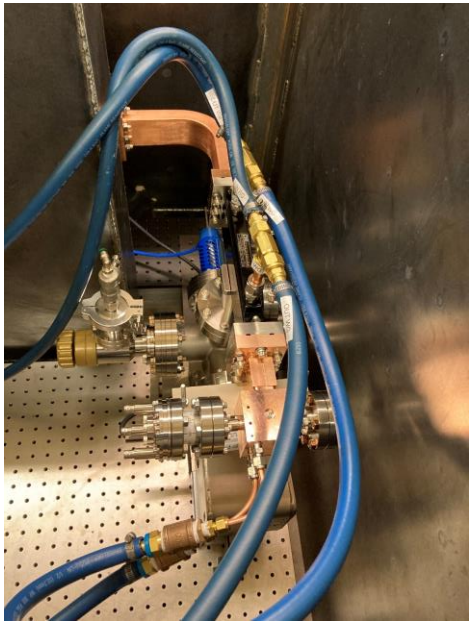


The first two high gradient cavities were tested at CERF-NM in FY21

This C-band high gradient test facility is nationally unique. The first cavities tested at CERF-NM were manufactured at SLAC.

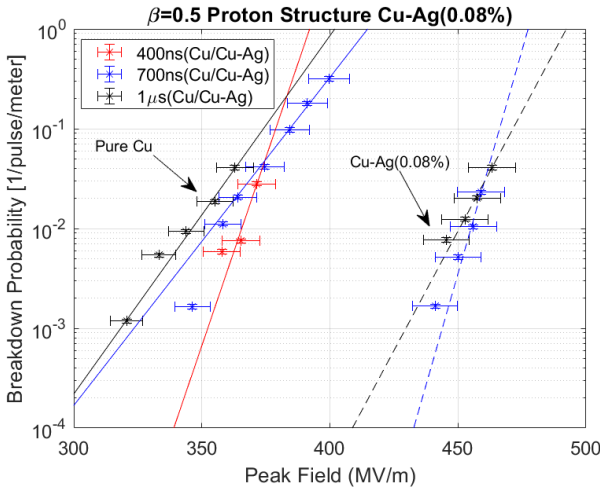


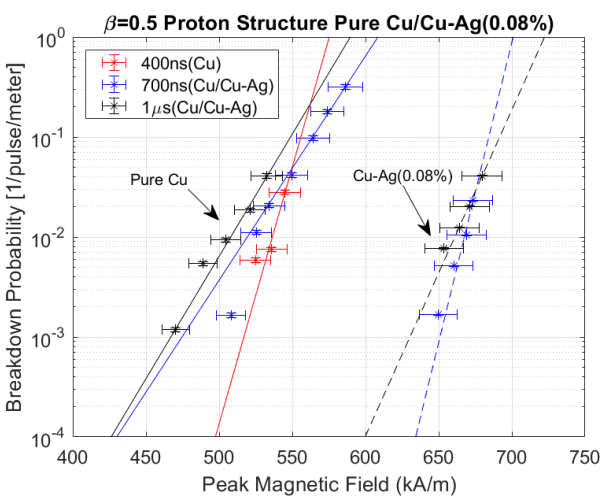


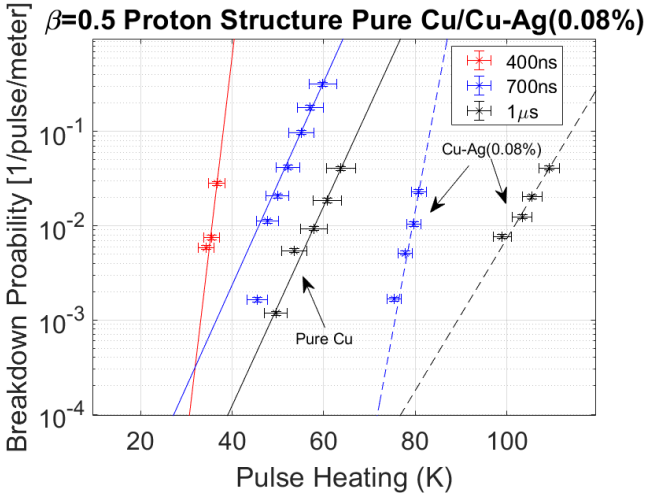


Peak surface electric fields in excess of 300 MV/m demonstrated in high gradient tests

Breakdown probabilities were recorded for three different pulse lengths for copper and copper-silver cavities.

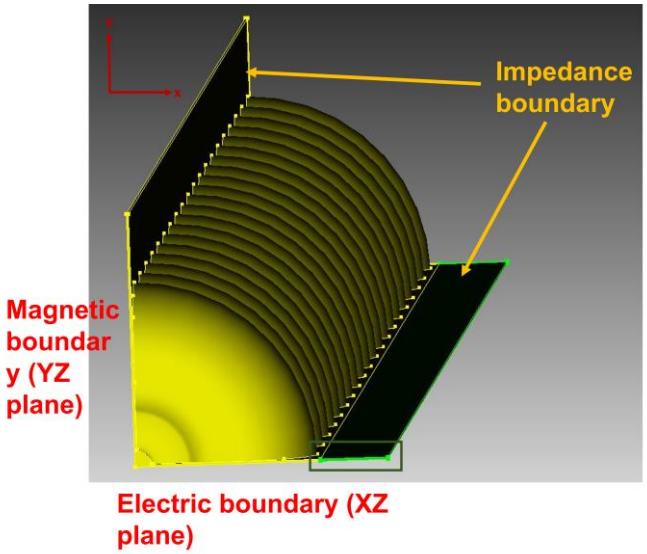


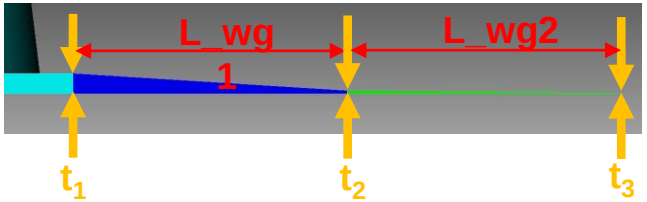


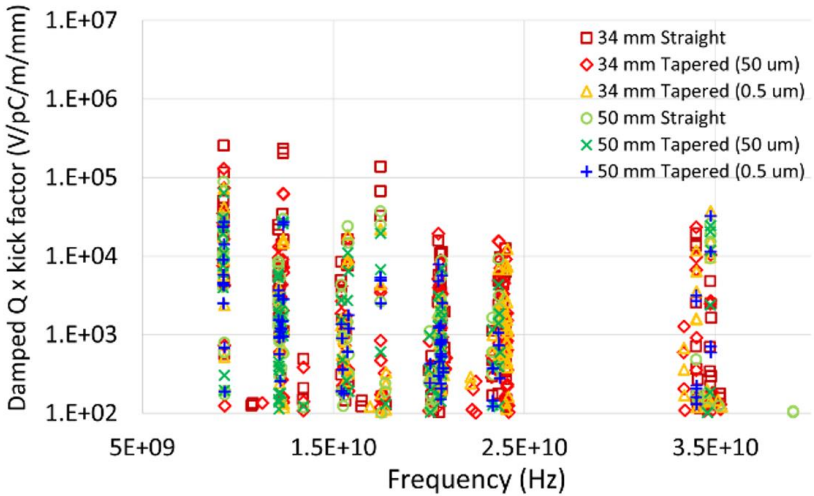


NiCr absorbers for HOM suppression

We conducted extensive optimizations of HOM suppression in a 20-cell C-band accelerating structure with NiCr absorbers.

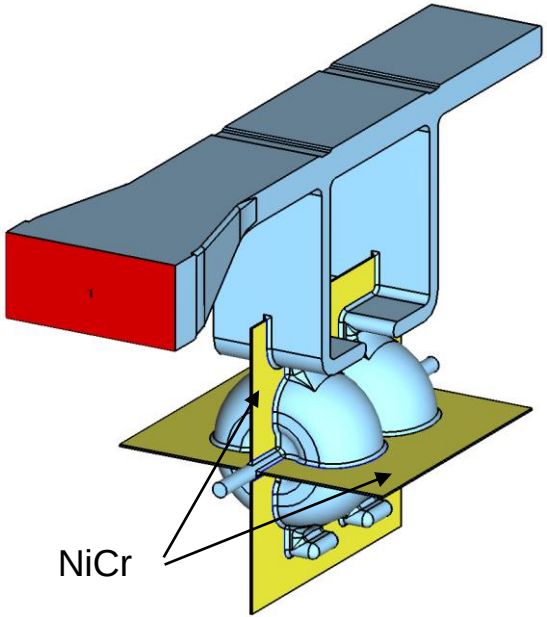


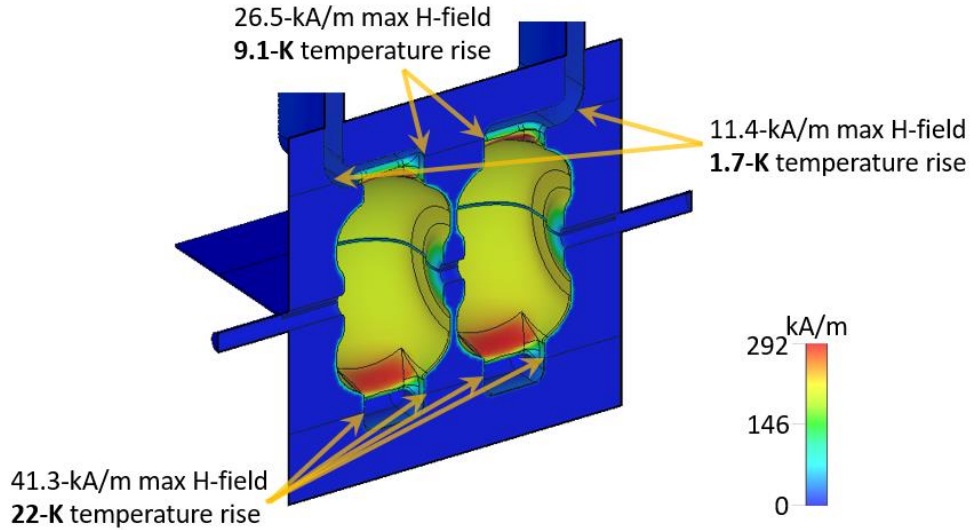




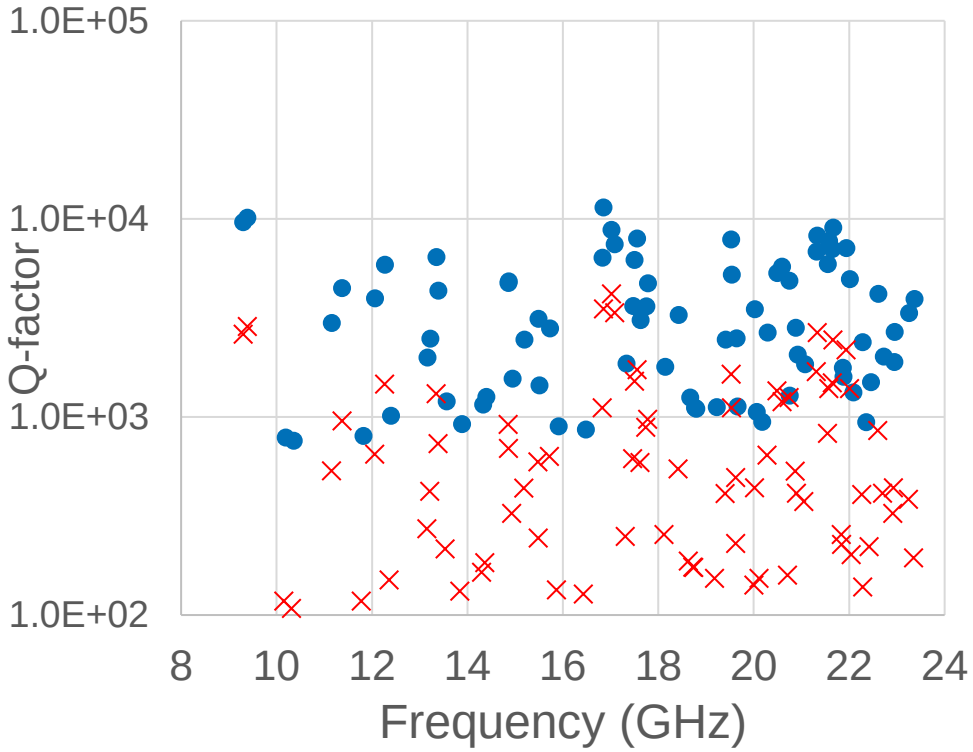
Two-cell test cavity with NiCr absorbers

- A two-cell cavity was designed to test if a structure with NiCr absorbers can be conditioned to high gradients.
- Issues to be studied: pulse heating, HOM generation during breakdown.





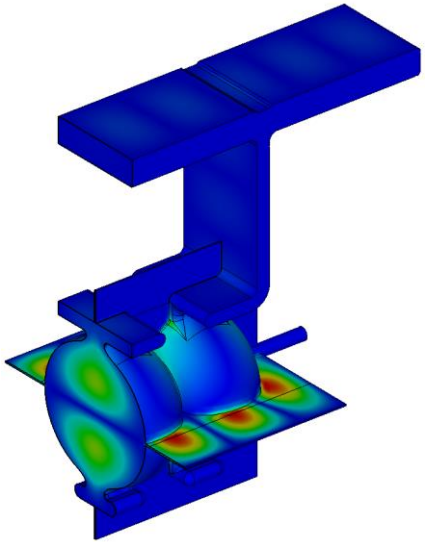
Q-factors of HOMs in two-cell cavity with HOM slots



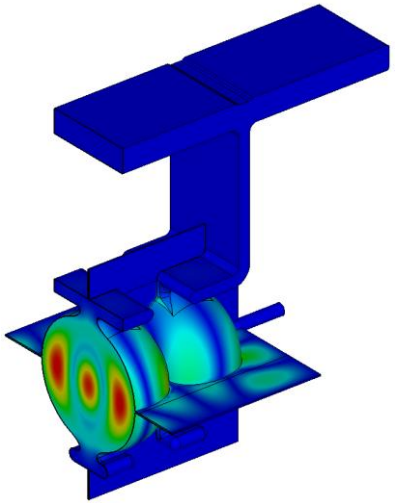
CST without damping		CST with straight damping slots	
Frequency (GHz)	Q-factor	Frequency (GHz)	Q-factor
9.3730	11521	9.3728	8239
12.250	8489	12.249	3292
17.509	7295	17.509	5382
17.569	10466	17.570	4442

Various HOMs

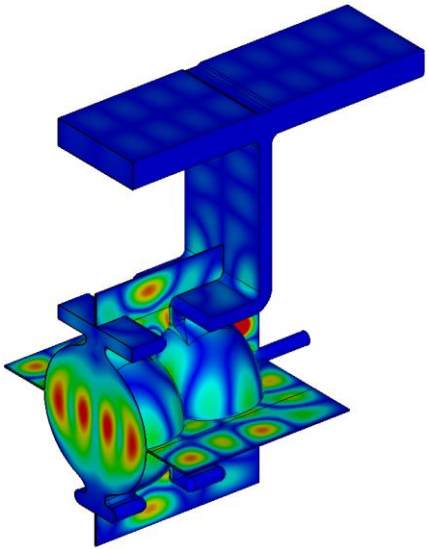
TM110 mode
9.21 GHz



TM021 mode
12.31 GHz



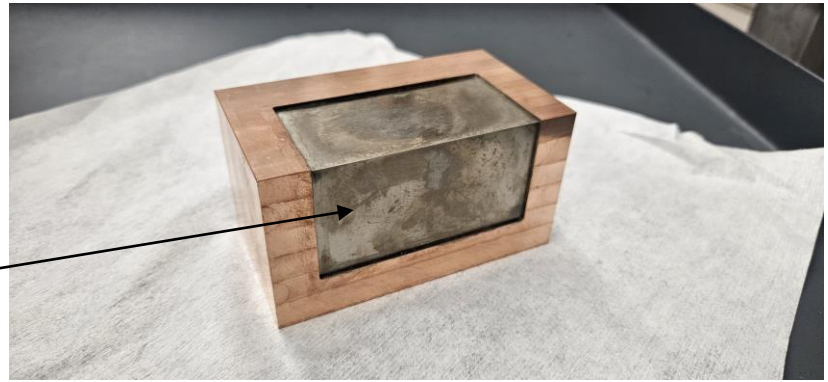
TM121 mode
17.62 GHz

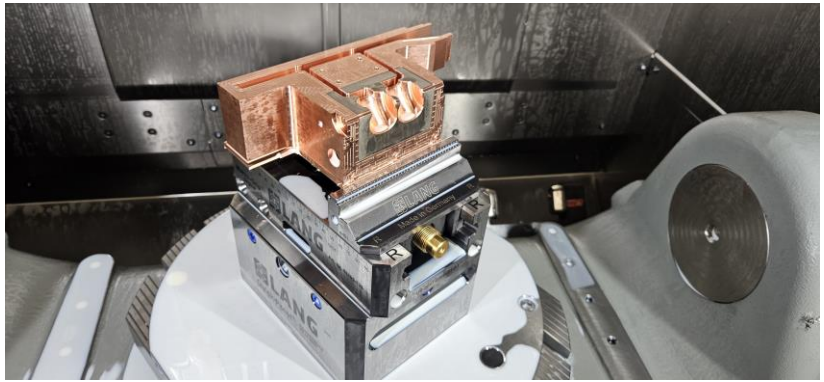


Fabrication process

- Pre-fabrication, and Nickel and chromium deposition performed.
- Cells were machined.
- Brazing and annealing step to follow.

Absorber slots will be covered with NiCr

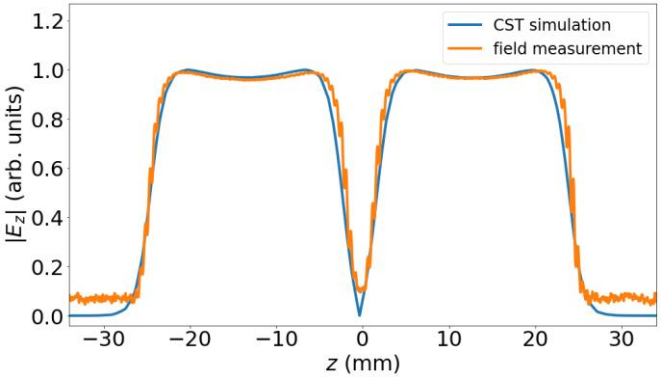


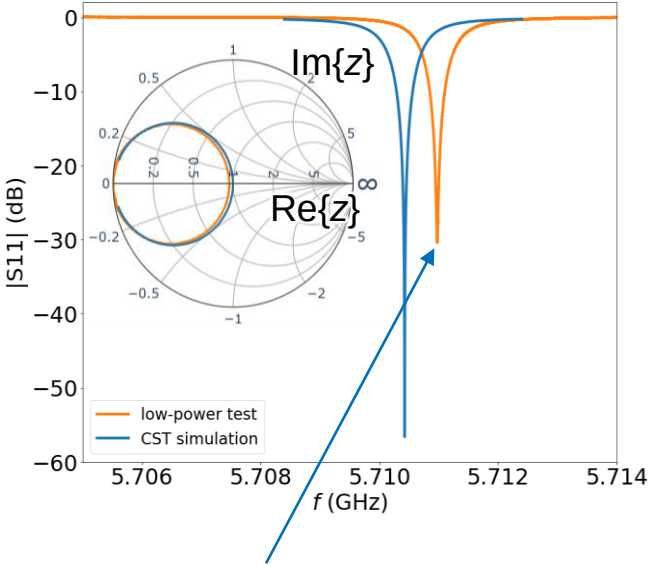


Cold-testing and tuning

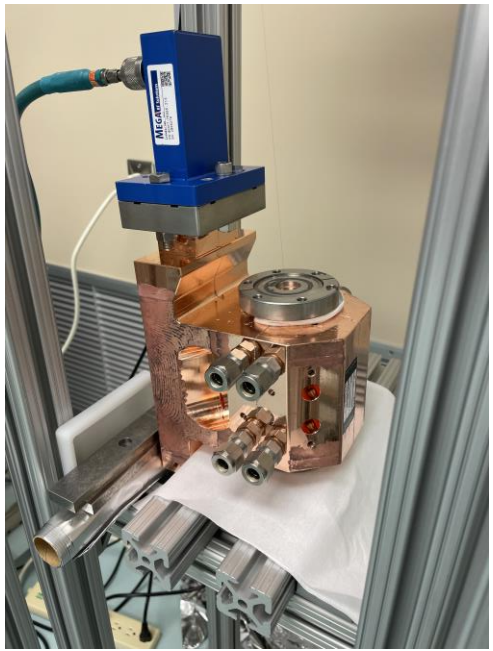
The cavity was received at LANL, cold-tested in March of 2025 and tuned in September of 2025.

Bead-pull results:



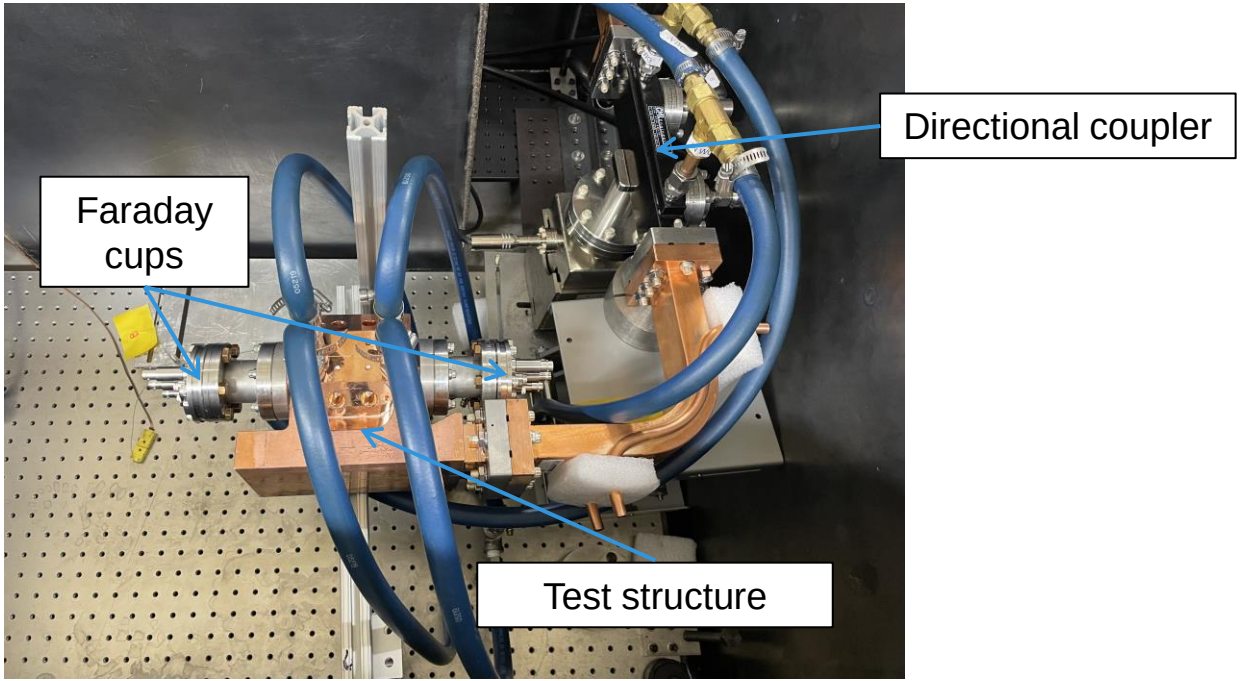


f=5.7111 GHz in air

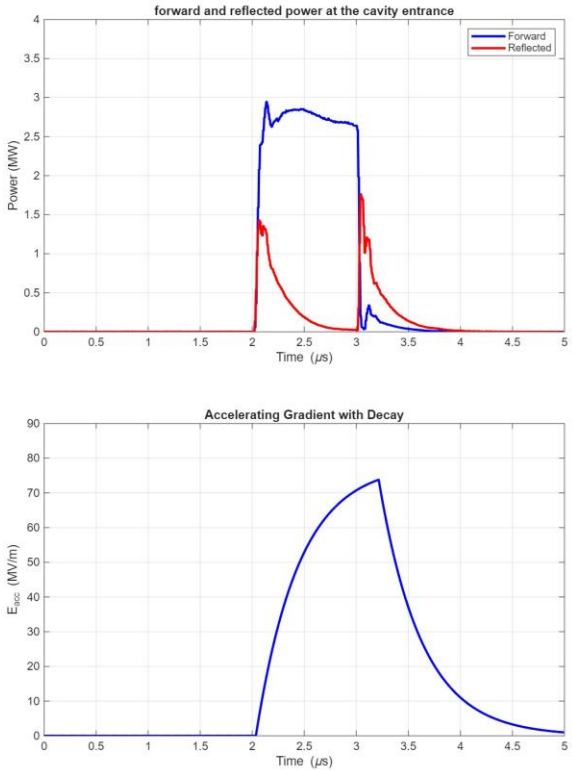


Two-cello cavity installed at CERF-NM

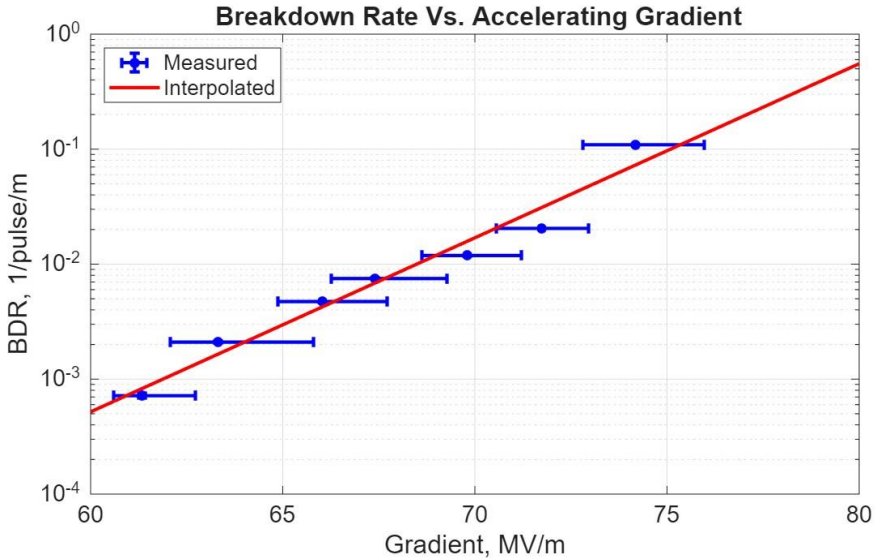
This is a photograph of the installation inside of the lead box at CERF-NM.



The final results of high-gradient tests of the structure with NiCr absorbers

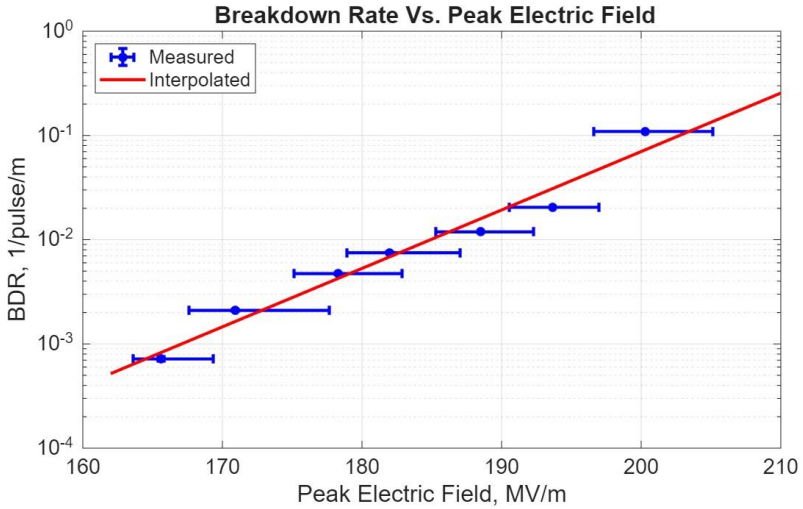


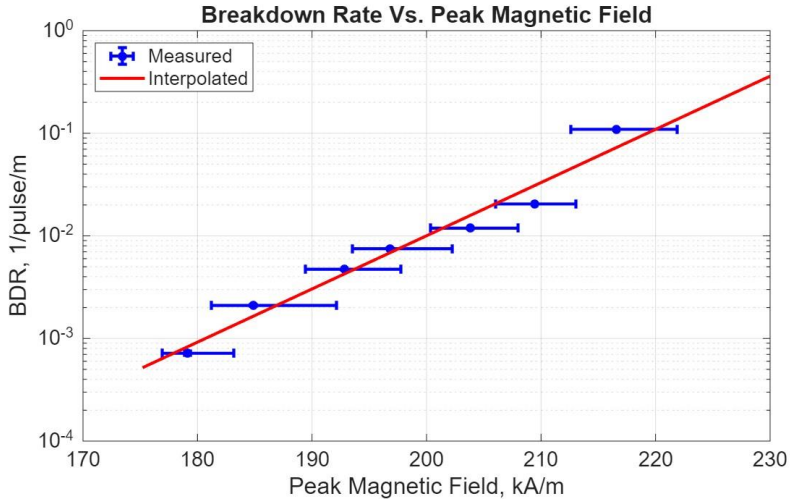
The final gradients achieved in the structure with NiCr absorbers were limited to 75 MV/m.



The final results of high-gradient tests of the structure with NiCr absorbers: peak fields

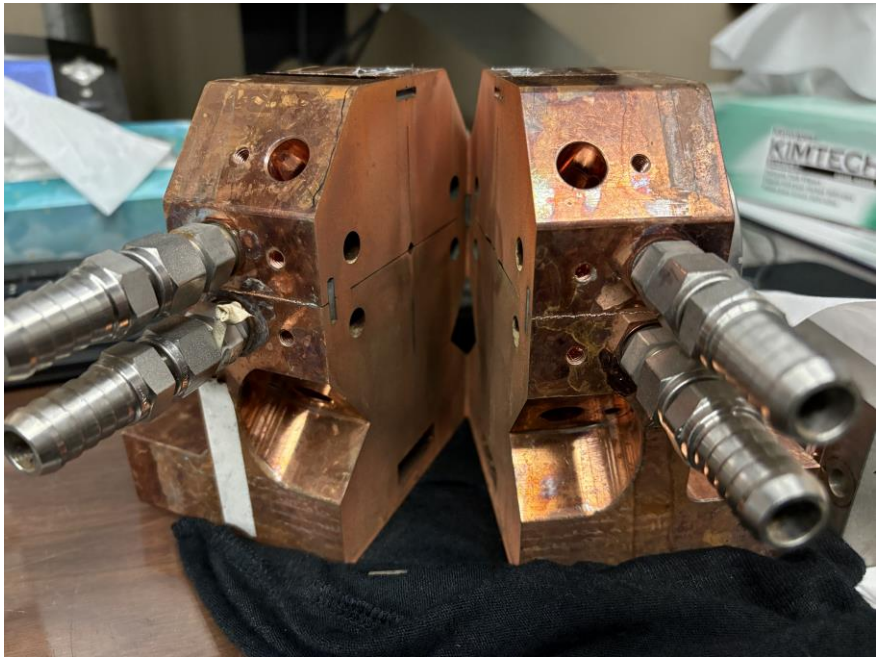
The final peak electric fields in the cavity were close to 200 MV/m. The final peak magnetic fields were below 220 kA/m.





Plans for the SEM inspection

The cavity is being cut with wire EDM to do the SEM inspection of the inside surfaces.



Conclusions and future plans

- LANL just concluded the high gradient testing of the two-cell structure with NiCr absorbers in July of 2026.
- Conditioning to higher gradients was slow and difficult due to very strong vacuum spikes during breakdowns.
- We are dissecting the cavity to study the damage to the cavity and NiCr absorbers under an SEM.
- Next step: design the cavity with NiCr absorbers for cryogenic testing.