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Development of High-Q SRF Structures by Nitrogen Doping for Superconducting Electron Linacs.

Cooperative Research and Development Agreement Final Report

CRADA Number: FRA-2018-0057

Fermilab Technical Contact: Anna Grassellino

Summary Report
2 March 2022

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In accordance with Requirements set forth in Article X of the CRADA document, this document is the final CRADA report, including a list of Subject Inventions, to be forwarded to the Office of Science and Technical Information as part of the commitment to the public to demonstrate results of federally funded research.

CRADA number: FRA-2018-0057

CRADA Title: Development of High-Q SRF Structures by Nitrogen Doping for Superconducting Electron Linacs

Parties to the Agreement: Niowave, Inc. and Fermi Research Alliance, LLC

Sponsoring DOE Program Office(s): Office of Science – High Energy Physics

DOE Funding Commitment Table: N/A

Abstract of CRADA work:

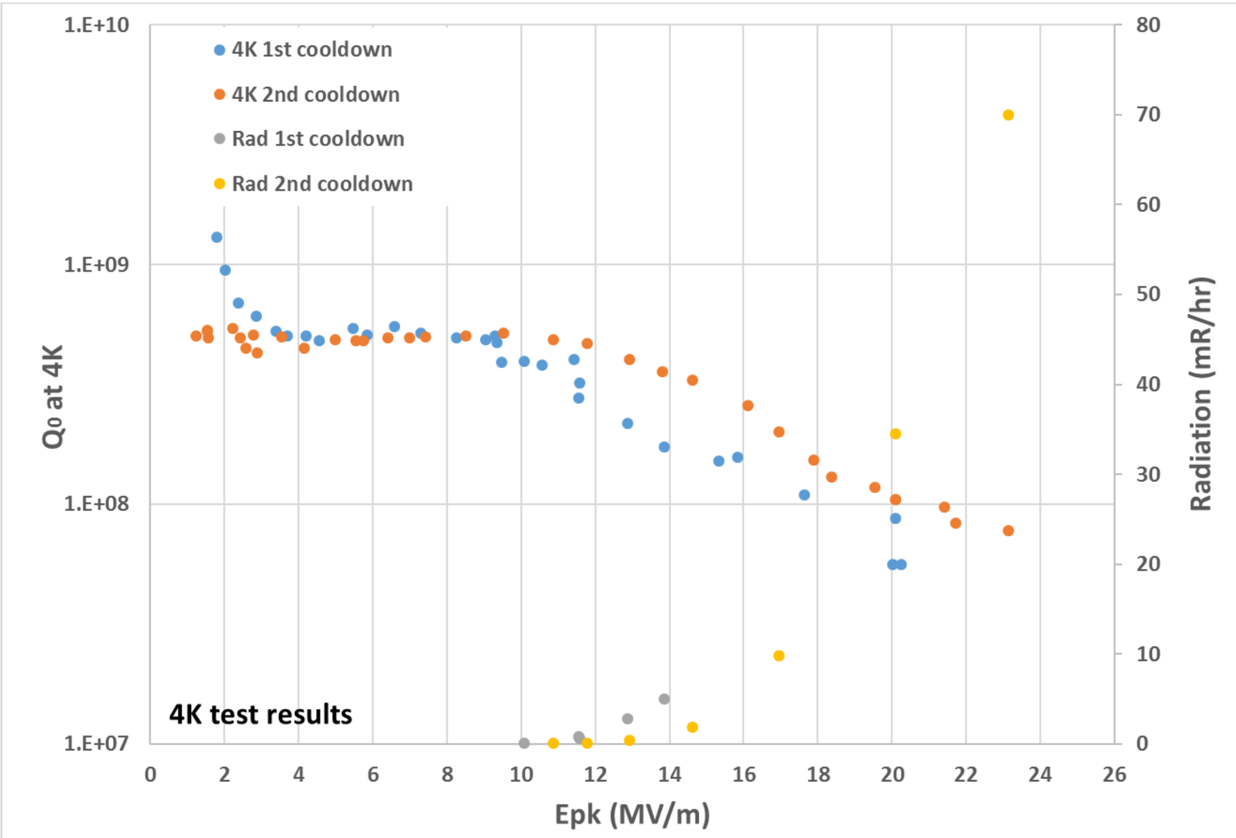
One of the most exciting recent developments in superconducting RF technology has been the discovery of a nitrogen-doping process which can reliably increase the superconducting quality factor of niobium resonators well above 10^{10} at high frequency (>1 GHz). This process is now well demonstrated in particular for TESLA-style 9-cell cavities at 1.3 GHz. Nitrogen doping is part of the plan for the production of the cavities for LCLS-II, significantly increasing the cryogenic efficiency of the machine, and allowing significant capital cost reductions. This project will investigate and quantify effects on the quality factor in low frequency superconducting structures from the nitrogen doping process.

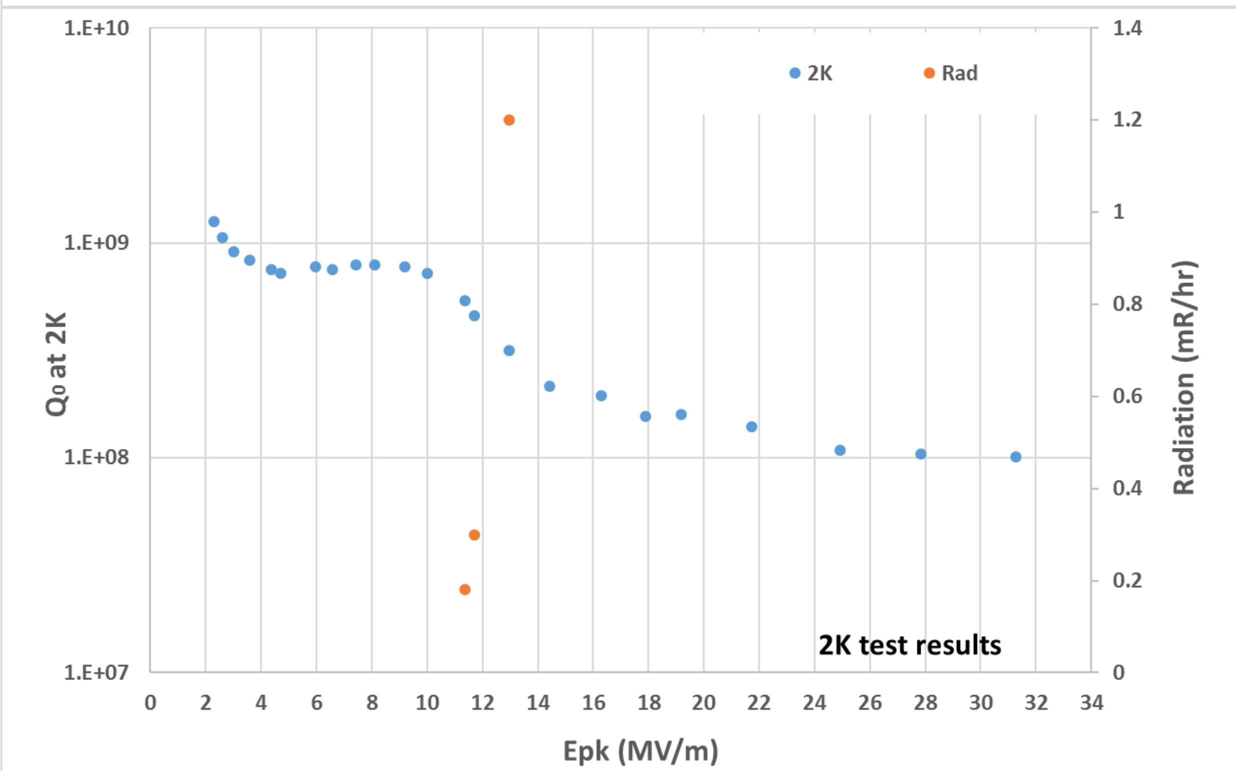
Niowave is currently developing commercial superconducting electron linacs for a number of important applications including high-power free-electron lasers, the production of medical and industrial radioisotopes, materials processing, sterilization, and cargo scanning applications. These systems typically operate at 350 MHz, but at 4 Kelvin operating temperature, where reduction of BCS losses would be an important efficiency enhancement. Pushing commercial linacs into a regime where a small cryocooler could provide for the cryogenic load of the accelerating cavity will have a huge impact.

Niowave sent a 350-MHz niobium resonator to Fermi Research Alliance, LLC (FRA) for nitrogen doping and a vertical test to demonstrate high quality factor.

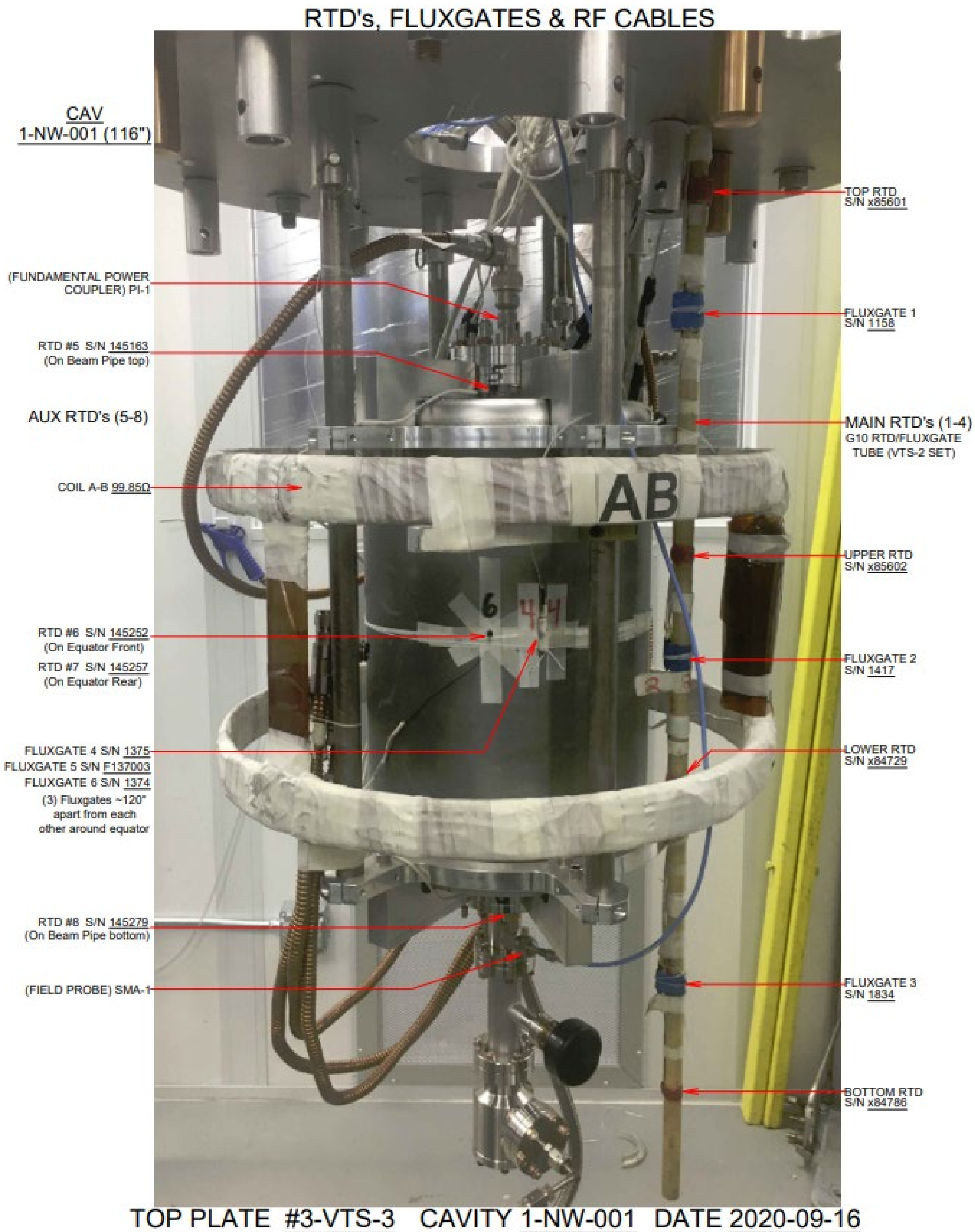
Summary of Research Results:

The cavity was baselined at Cornell after 150 um BCP. The results of the test at 4K and 2K are shown below.

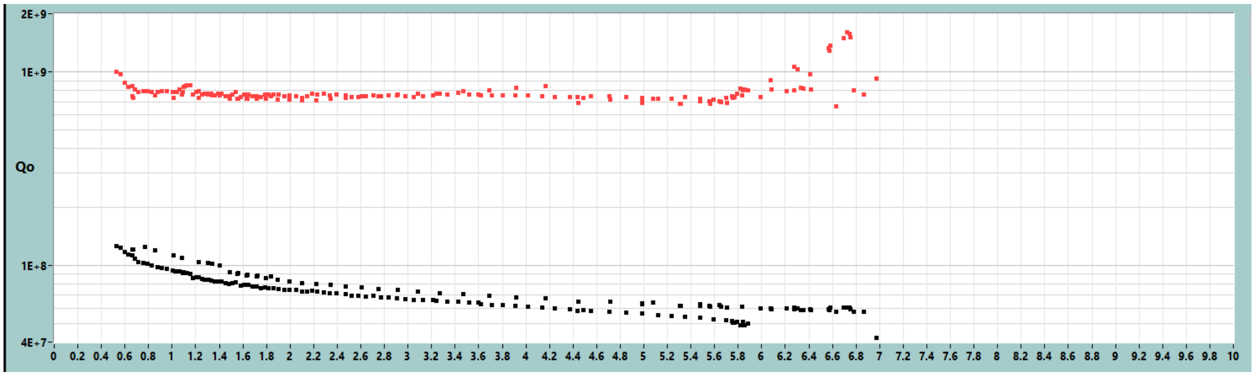

4K 1st cooldown
4K 2nd cooldown
Rad 1st cooldown
Rad 2nd cooldown
4K test results
Q0 at 4K
Radiation (mR/hr)
Epk (MV/m)
1.E+10
1.E+09
1.E+08
1.E+07
0 2 4 6 8 10 12 14 16 18 20 22 24 26
0 10 20 30 40 50 60 70 80


2K
Rad
2K test results
Q0 at 2K
Radiation (mR/hr)
Epk (MV/m)
1.E+10
1.E+09
1.E+08
1.E+07
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34
0 0.2 0.4 0.6 0.8 1 1.2 1.4

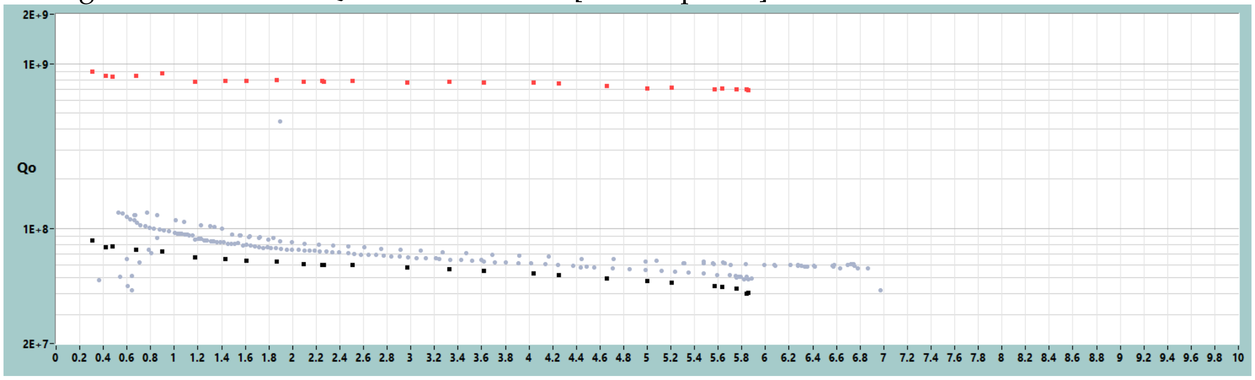
The cavity was then N-doped at Fermilab and tested in the Vertical Cavity Test Facility at Fermilab. The picture below shows the cavity assembled onto the vertical test and ready to be installed into the test dewar.



The figure below shows Q0 vs Eacc at 2.0 K and 1.5 K [black squares].



The figure below shows Q0 vs Eacc at 4.4 K [black squares].



Related Reports, Publications, and Presentations:

None.

Subject Inventions listing:

None.

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