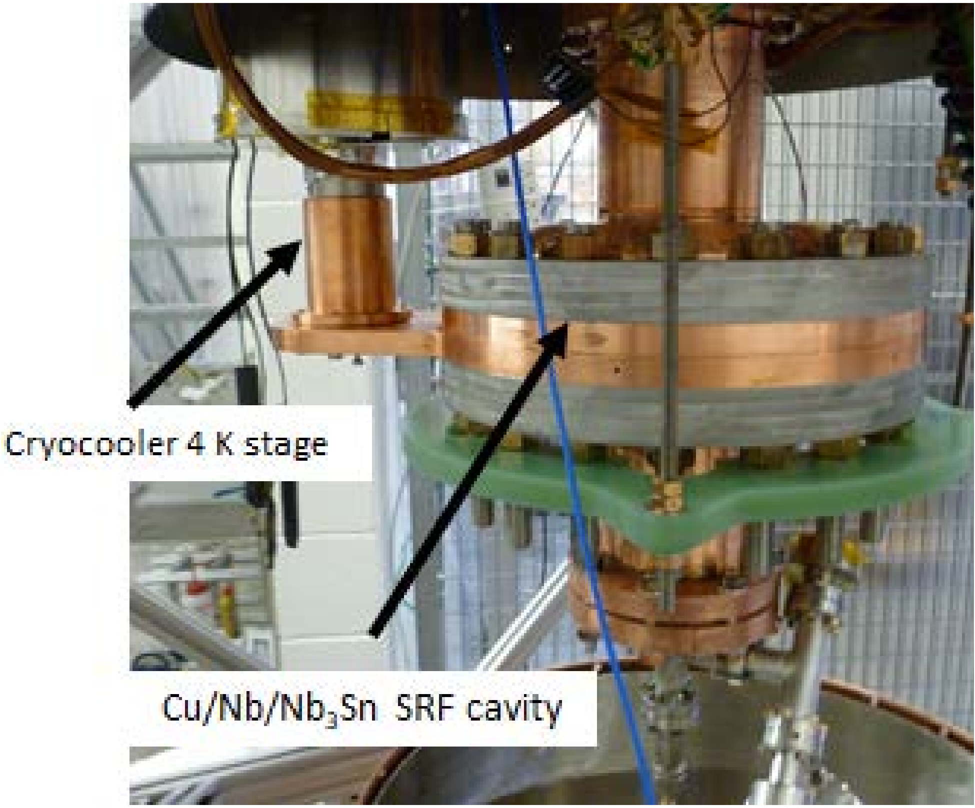
Accelerator Stewardship with Nb_3Sn at JLab

Virtual International Workshop on Nb_3Sn SRF Science, Technology, and Applications

November 10th – 13th, 2020



Conduction cooled SRF cavity at JLab

Gianluigi Ciovati

Thursday, November 12, 2020

Acknowledgments

JLab: R. Rimmer, G. Cheng, U. Pudasaini, K. Harding, E. Daly, F. Marhauser, F. Hannon, J. Fischer, Cavity Production Group

Consultants: J. Rathke and T. Schultheiss

General Atomics: B. Coriton

GENERAL ATOMICS

Key subcontractors:

Concurrent Technologies Corp.: B. Golesich

CTC

AJ Tuck Co: A. Tuck, T. Yoho

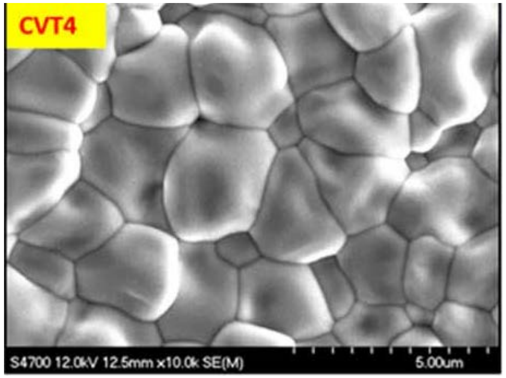
A.J. Tuck Company
Custom Electroformed Components
A Veteran Owned ITAR Registered Small Business

Absolut system: T. Trollier

INNOVATIVE SOLUTIONS
ABSOLUT SYSTEM

SRF technology for industrial accelerators: potential

Gifford-McMahon **cryocooler**,
~2 W at 4 K (shicryogenics.com)



SEM image of **Nb_3Sn film** on Nb (U. Pudasaini *et al*. 2020 *Supercond. Sci. Technol.* 33 045012)

- Improvements in Nb_3Sn thin-film (T_c = 18.3 K) make it a viable option for SRF cavities operating at 4 K, rather than 2 K
- Improvements in the cooling capacity of commercial cryocooler make them a viable option to cool SRF cavities

Potential of SRF technology for environmental accelerators

- Because of the higher efficiency, SRF accelerators can result in lower treatment cost

U.S. DEPARTMENT OF ENERGY | Office of Science

Workshop on Energy and Environmental Applications of

eleratorsamerica.org)

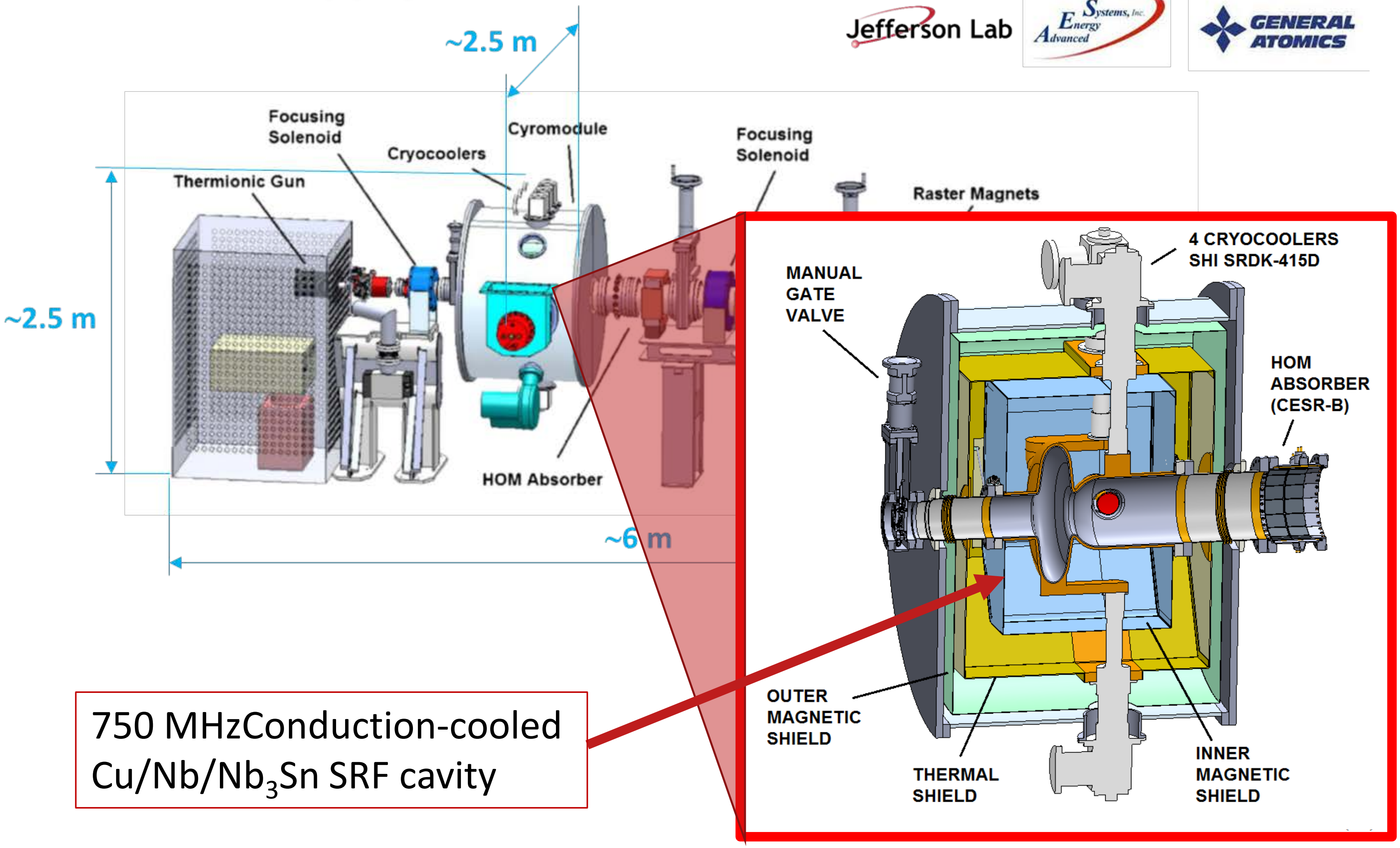
Table 2. Target performance for high power electron accelerators for E&E applications:

	Type 1 Demo/Small Scale	**Type 2 Medium Scale Low Energy**	**Type 3 Medium Scale High Energy**	**Type 4 Large Scale High Energy**
Example Applications	*R&D, Sterilization, industrial effluent streams*	*Flue Gas, Waste water*	*Wastewater, sludge, medical waste*	*Sludge, Medical waste, Env. remediation*
Electron Beam Energy	0.5-1.5 MeV	1-2 MeV	10 MeV	10 MeV
Electron Beam Power (CW)	>0.5 MW	>1 MW	>1 MW	>10 MW
Wallplug Efficiency	>50%	>50%	>50%	>75%
Target Capital Cost*	<$10/W	<$10/W	<$10/W	<$5/W
Target Operating Cost†	<1.0M$/yr	<1.5M$/yr	<1.5M$/yr	<12M$/yr

Jefferson Lab

Conceptual design of a 1 MeV, 1 MW SRF accelerator for e-beam irradiation

Accelerator Stewardship project, 2017



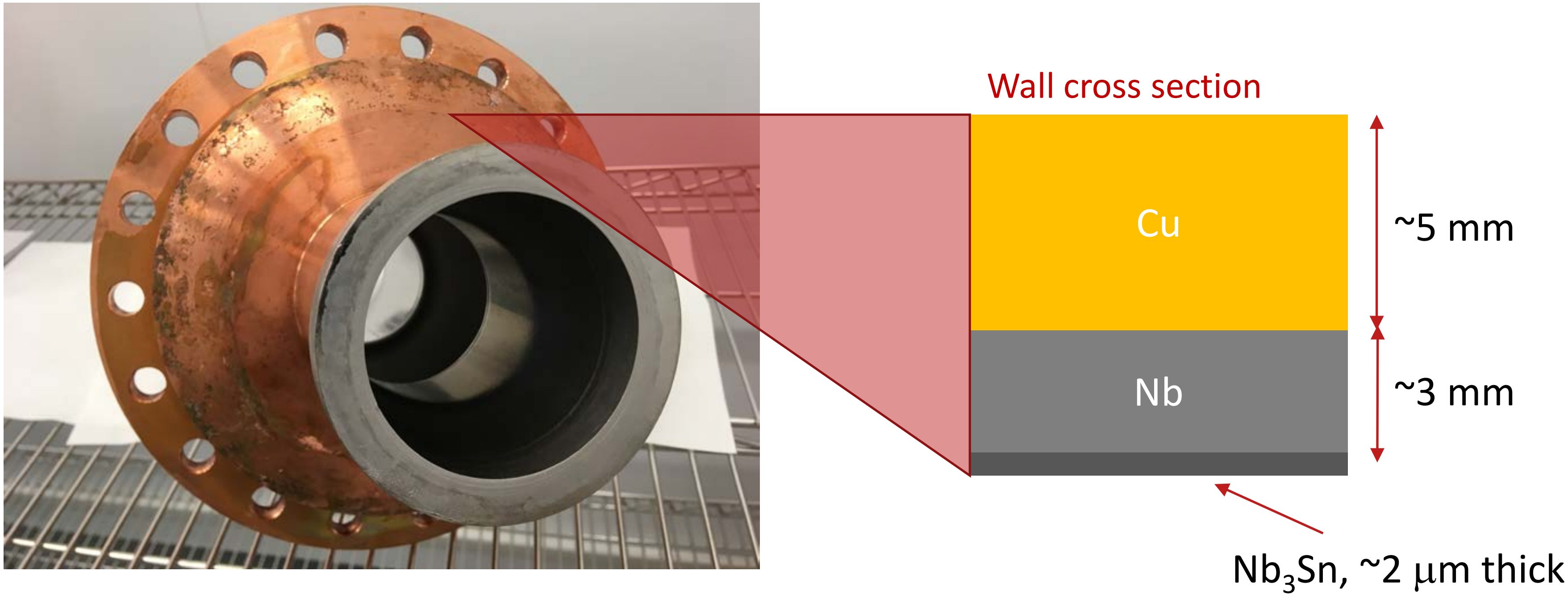
750 MHzConduction-cooled Cu/Nb/Nb_3Sn SRF cavity

G. Ciovati *et al.*, *Phys. Rev. Accel. Beams* **21**, 091601 (2018)

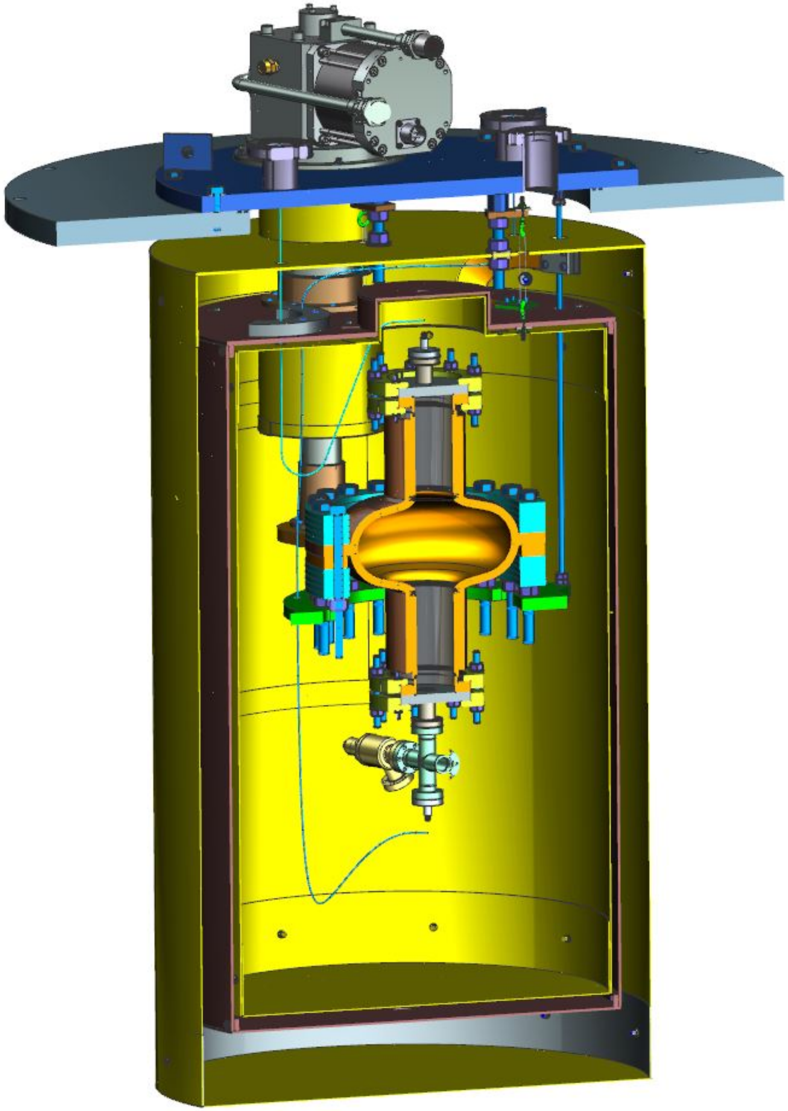
Can a conduction-cooled SRF cavity operate at usable E_{acc}?

JLab R&D funding, 2018-2020

- 1.5 GHz Nb single-cell cavity coated with Nb_3Sn
- Deposit thick Cu outer shell for good thermal conduction
- Minimize number of joints between the 4 K stage of cryocooler and the cavity

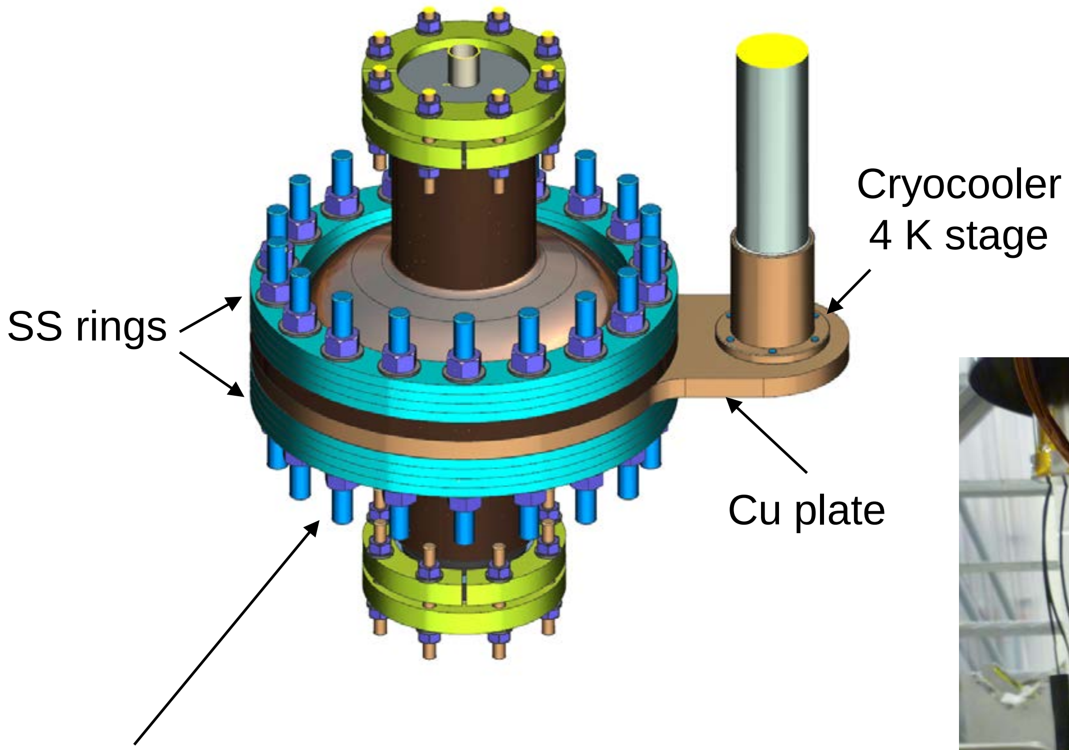


Test stand design



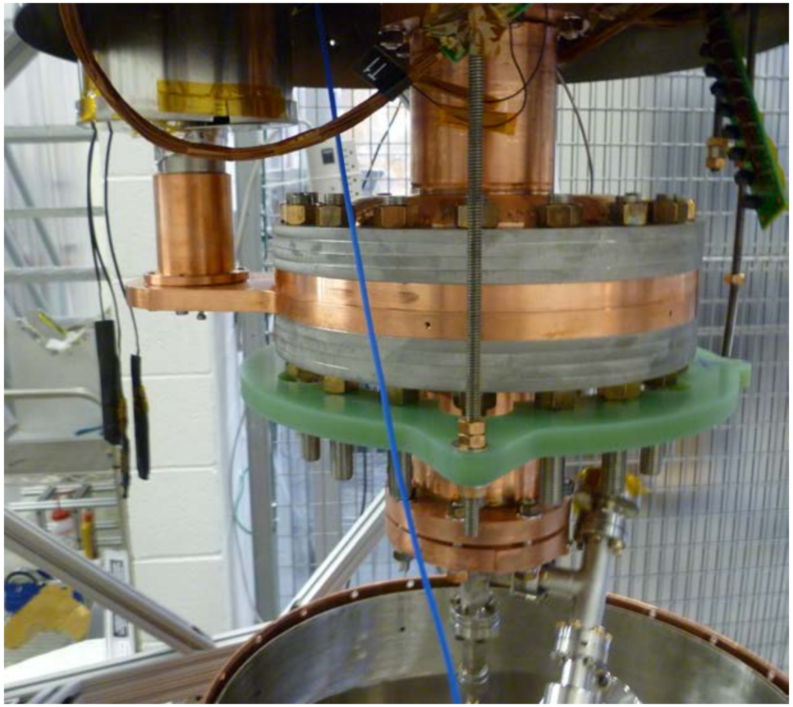
- 2-layers magnetic shielding
- Cu thermal shield anchored to 1st stage
- 3 cryogenic flux gate magnetometer probes
- 16 Cernox thermometers
- 2 low-loss RF cables
- Gifford-McMahon Cryocooler (2 W at 4 K)

Cryocooler connection



½" SS rods, silicon-bronze nuts

- torque = 115 N*m
- estimated contact pressure ~46 MPa
- Apiezon N grease between joint



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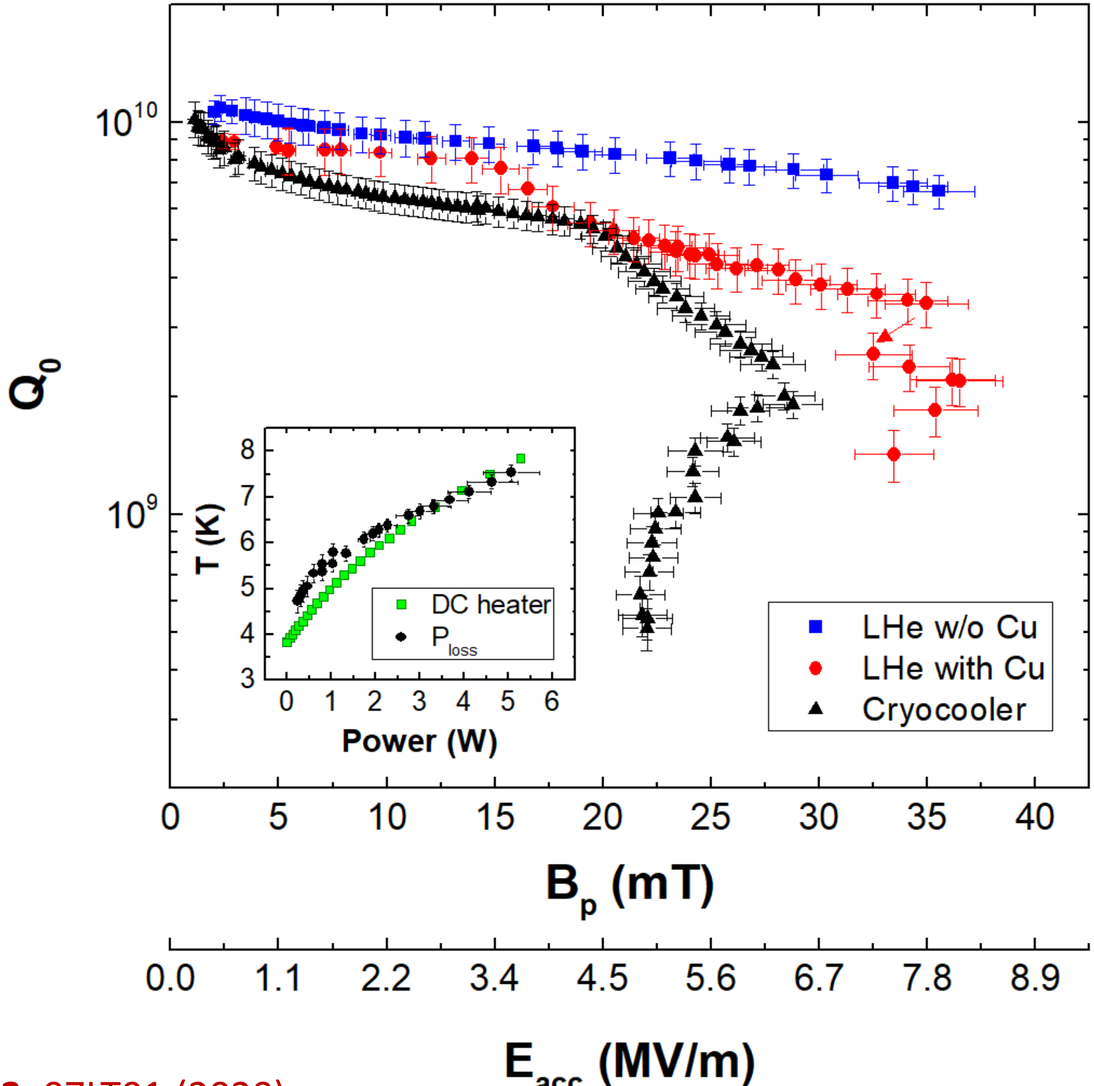
RF test results

- Cavity temperature after cooldown: ~3.8 K
- T-gradient at 18 K: ~0.09 K/cm
- Max residual B at 18 K: ~14 mG
- Amplitude of microphonics at B_p = 10 mT: 13.8 Hz pk-to-pk
- The cavity was thermally stable during a 1 h operation at P_{diss} = 5 W even with anomalous losses (Q_0 ~ 5e8 at 22 mT)

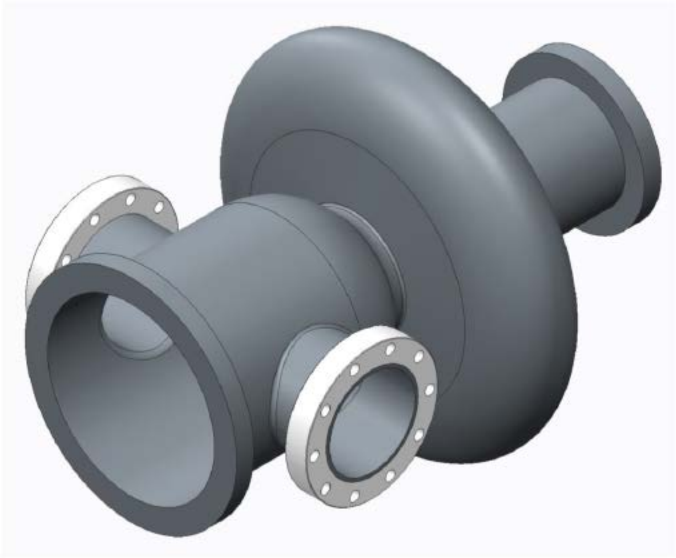


G. Ciovati *et al.*, *Supercond. Sci. Technol.* **33**, 07LT01 (2020)

Development of conduction cooled cavity capable of 1 MeV

Accelerator Stewardship project, 2019-2022

- The 1 MeV, 1 MW accelerator has been re-designed at 915 MHz (industrial magnetron frequency)



E-B fields of 915 MHz, $\beta = 0.53$ cavity for 1 MeV:

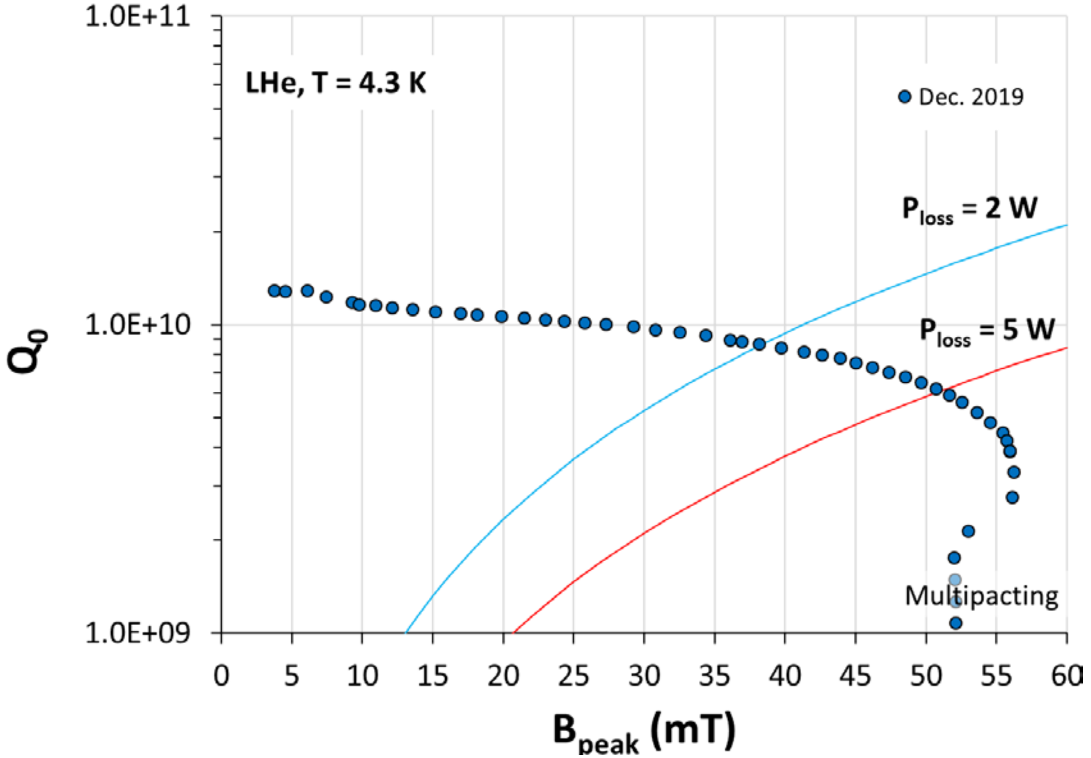
$E_{acc} = 7.5$ MV/m

$E_p = 30$ MV/m

$B_p = 45$ mT

Towards a proof-of-concept on a 952 MHz single-cell cavity

- The available funding was not sufficient for fabricating the prototype low-beta 915 MHz cavity
- We use an existing β=1, 952 MHz originally intended as a prototype for EIC (F. Marhauser)
- The 952 MHz cavity was coated by Nb_3Sn at JLab (U. Pudasaini)



Towards a proof-of-concept on a 952 MHz single-cell cavity

- The outer surface has been coated with a ~120 μm thick Cu layer by cold spray

- A 5 mm thick Cu layer will be grown by electroplating
- The cavity will be re-tested in LHe at JLab
- A horizontal cryostat with 3 cryocoolers is being designed and will be assembled with the cavity at General Atomics for the RF test of the conduction-cooled cavity

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Summary and outlook

- We have designed an SRF industrial accelerator for environmental remediation, based on a conduction-cooled Nb_3Sn SRF cavity

- We have developed a 1.5 GHz multi-metallic **Cu/Nb/Nb_3Sn** single-cell cavity and operated it with a commercial cryocooler up to B_p ~ 29 mT (E_{acc} ~ 6.5 MV/m), limited by defects in the Nb_3Sn film.

- We are applying the multi-metallic cavity technology to a 952 MHz single-cell cavity which will be tested in a horizontal cryostat at an industrial partner, aiming for operation at 45 mT