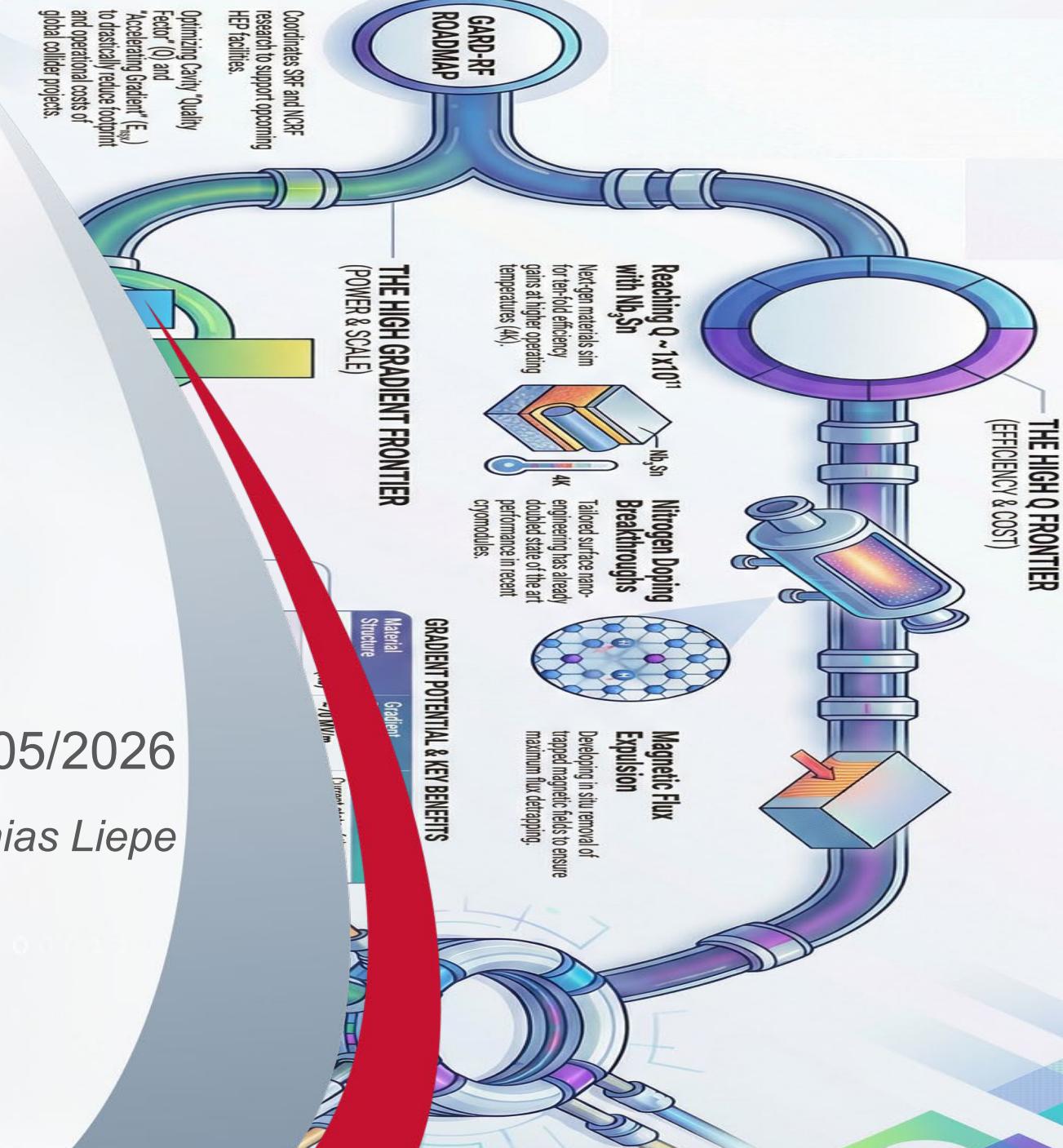


DOE RF Roadmap Update

SRF Virtual Workshop

02/05/2026

Anne-Marie Valente-Feliciano & Matthias Liepe



DOE GARD RF Roadmap - circa 2017

U.S. DEPARTMENT OF ENERGY Office of Science

Radiofrequency Accelerator R&D Strategy Report

DOE HEP General Accelerator R&D RF Research Roadmap Workshop
March 8-9, 2017



General Accelerator R&D RF Research Roadmap Workshop Report

Table of Contents

1	Introduction and Executive Summary	2
2	RF Accelerator Technology for HEP	3
3	3.1 Superconducting RF Structures Roadmap and Milestones	4
	3.2 High Q Frontier	5
	3.3 High Gradient Frontier	6
	3.3 Common SRF Roadmap Elements	8
4	4 Normal Conducting RF Structures Roadmap and Milestones	10
5	5 Advanced RF Source Roadmap and Milestones	13
6	6 Auxiliary Systems Roadmap and Milestones	16
7	7 Synergies	18
	7.1 SRF/NCRF Synergies	18
	7.2 RF Accelerator Technology Synergies within the Office of Science and DOE	19
	7.3 RF Accelerator Technology Synergies with Federal Sponsors and Industry	20
8	8 Facilities	20
	8.1 SRF Facilities	21
	8.2 NCRF Facilities	23
9	9 Modeling and Simulation	24
10	10 A Comment on the RF Workforce	27
	Appendix A DOE HEP GARD RF Workshop Charge	28
	Appendix B DOE HEP GARD RF Workshop Agenda	30
	Appendix C DOE HEP GARD RF Workshop Participants	31
	Appendix D References	32

RF Accelerating Structures

RF Sources and Auxiliary Systems

2018 2023 2028

Super Conducting High Q Roadmap
Physics of Surface Resistance, Doping, New Materials, Magnetic Flux Losses

$Q > 3e10$ at $E_{acc} > 35$ MV/m via doping

Explore Nb3Sn multicell

Cryomodule residual resistance < 2nΩ

Nb3Sn cryomodule

Super Conducting High Gradient Roadmap
Fundamental Limits, Niobium, Nb3Sn, New Structure Topologies, Other Superconductors

Develop techniques to prevent & mitigate field emission

$H_{pk} > H_{sh}$ of bulk niobium

$E_{acc} = 70$ MV/m

Outpace time scales of vortex dissipation, $E_{acc} > 100$ MV/m

Normal Conducting Structures Roadmap: Accelerator topologies / Advanced materials and manufacturing / New regimes of operation in temperature and frequency / Virtual prototyping

Develop Accelerators w/ Advanced Materials

Advances with Multi-frequency, >200 MΩ/m

Advances with Temperature and Frequency $E_{acc} > 300$ MV/m

RF Source Roadmap: High perveance, low voltage, high efficiency, multi-dimensional beams / Efficient modulators / Virtual prototyping tools / Prototypes

Discrete Architecture

Distributed Architecture

Energy Recovery Concepts

High power SRF couplers / Broadband HOM dampers / Active cavity tuners / Circulators for high peak and high average power sources

High repetition rate and high brightness e-source

Polarized emitters

2018 2023 2028

GARD RF Roadmap Refresh initiative- CHARGE

There has been a lot of research progress since 2017, and the landscape of needs has continued to evolve

The GARD program manager Derun Li launched an initiative to update the GARD RF Roadmap with specific goals to:

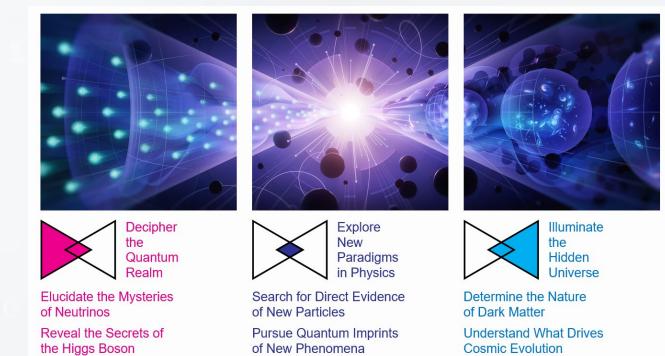
- Identify high impact R&D topics
- Define near, mid, and far term goals
- Ascertain the community's most urgent priorities
- Evaluate workforce development needs

Recent releases:



P5 report in 2023, Pathways to Innovation and Discovery in Particle Physics
The European Strategy for Particle Physics: 2026 Update

Your input and feedback is welcome



Process Timeline

Spring-Fall 2025

- ✓ Virtual and informal meetings during workshops/conferences

Nov 2025 – Jan 2026

- ✓ schedule meetings, develop agendas, and solicit speakers

Jan/Feb 2026

- Subtopic virtual group meetings

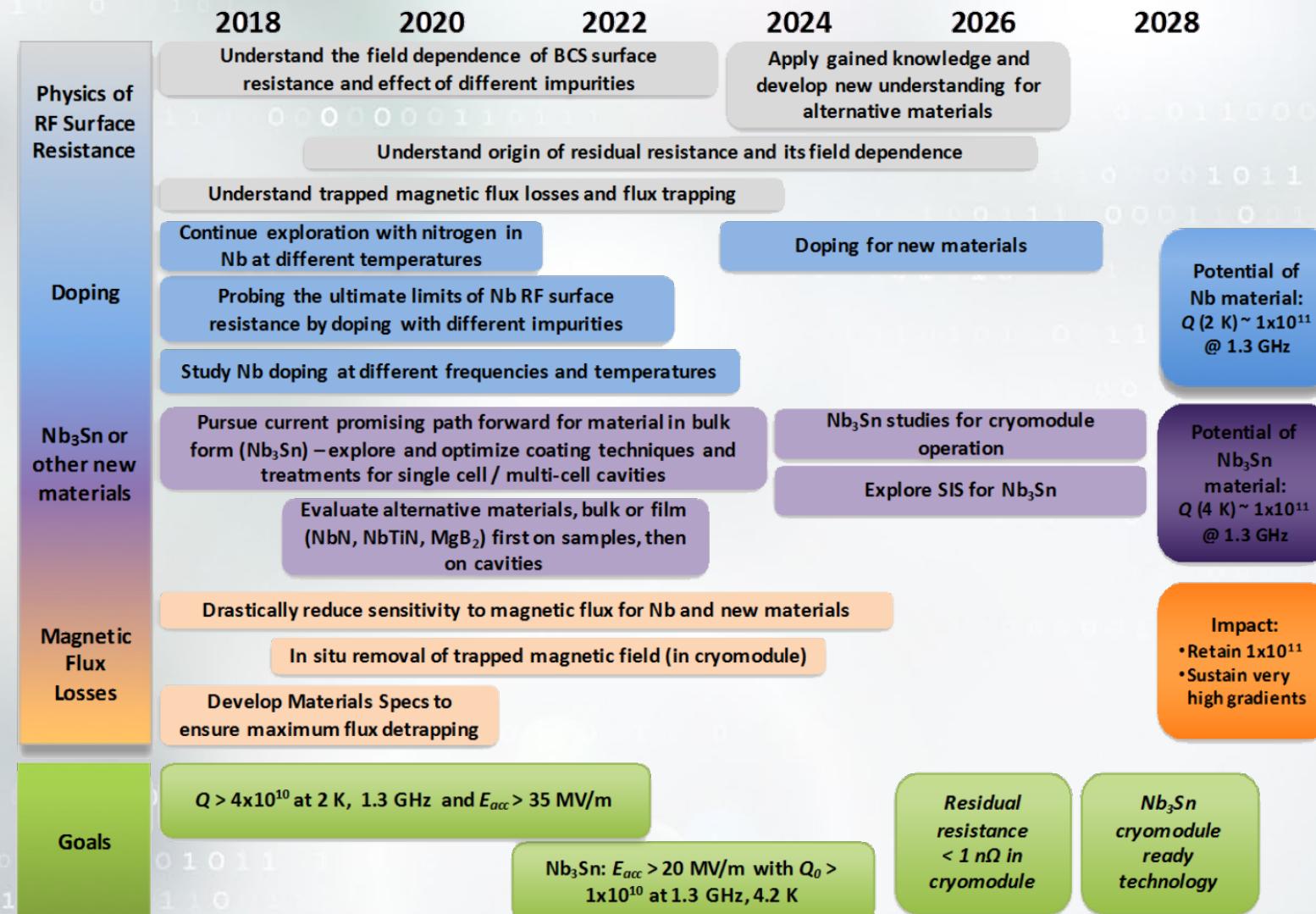
March 3 & 4, 2026

- large in person meeting in March with summaries of virtual meetings by subtopic leaders

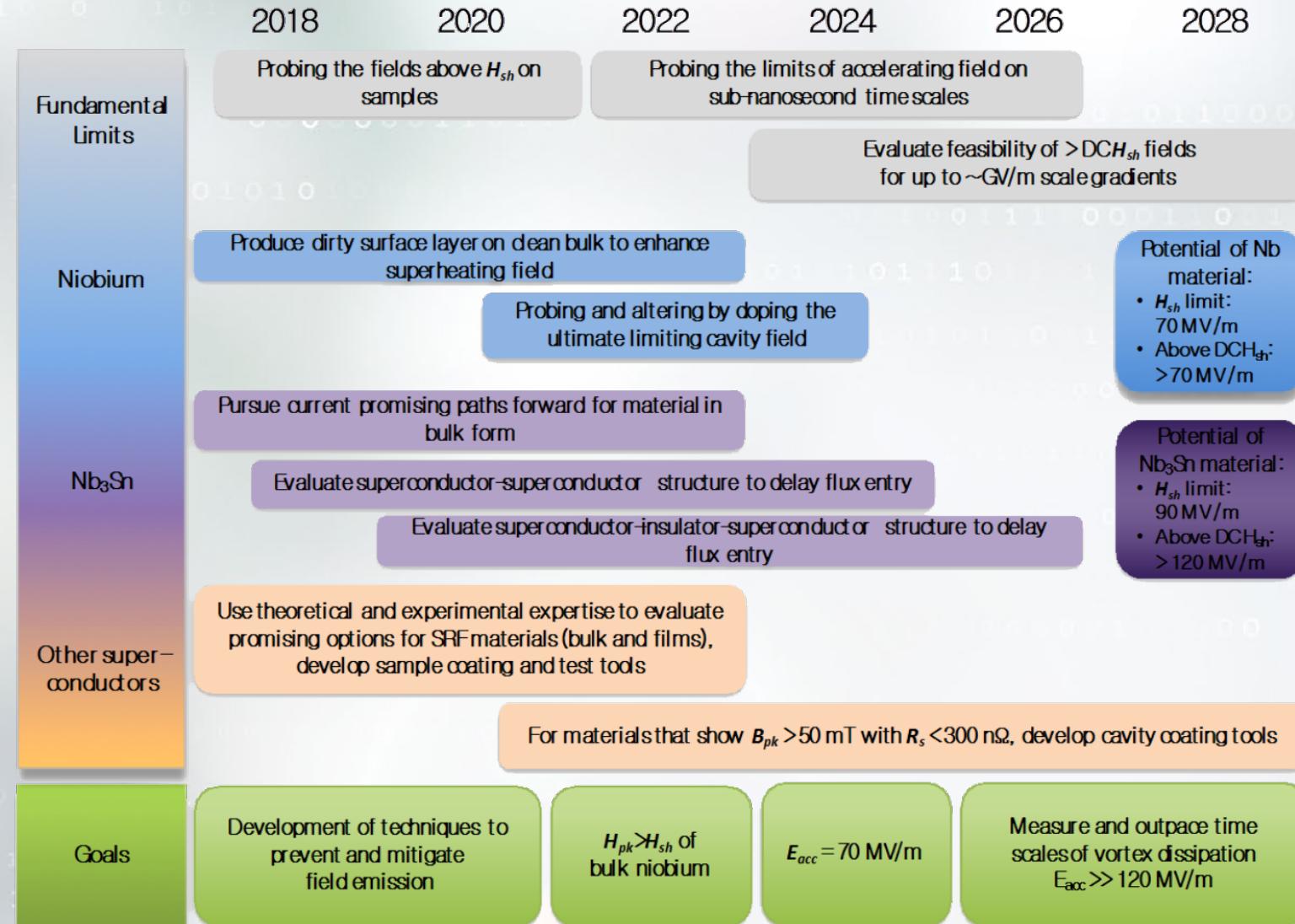
Spring/early Summer 2026

- Report writing
- Calibration step with DOE

Decadal roadmap and milestones for the high Q SRF frontier



Decadal roadmap and milestones for the high Gradient SRF frontier

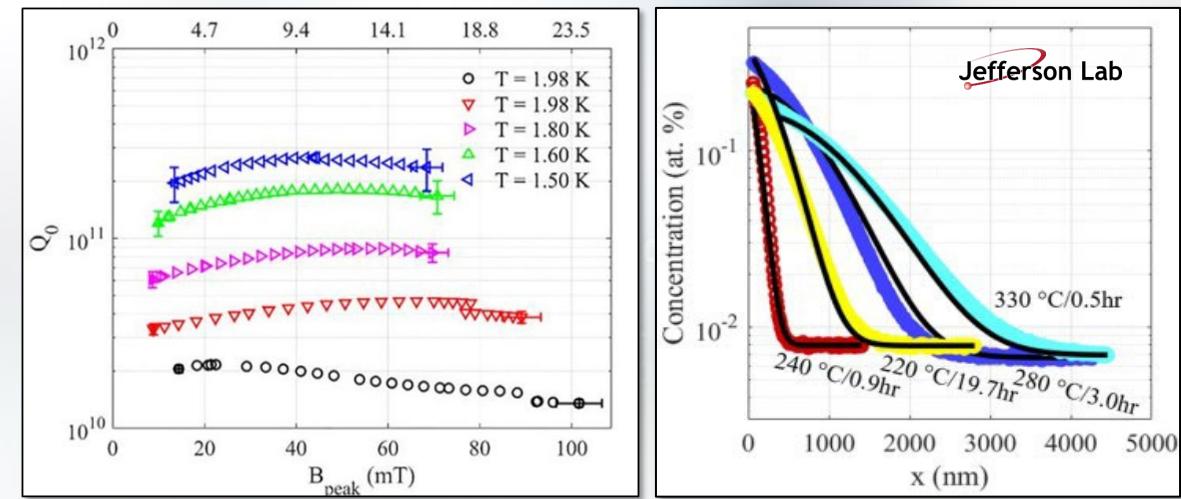
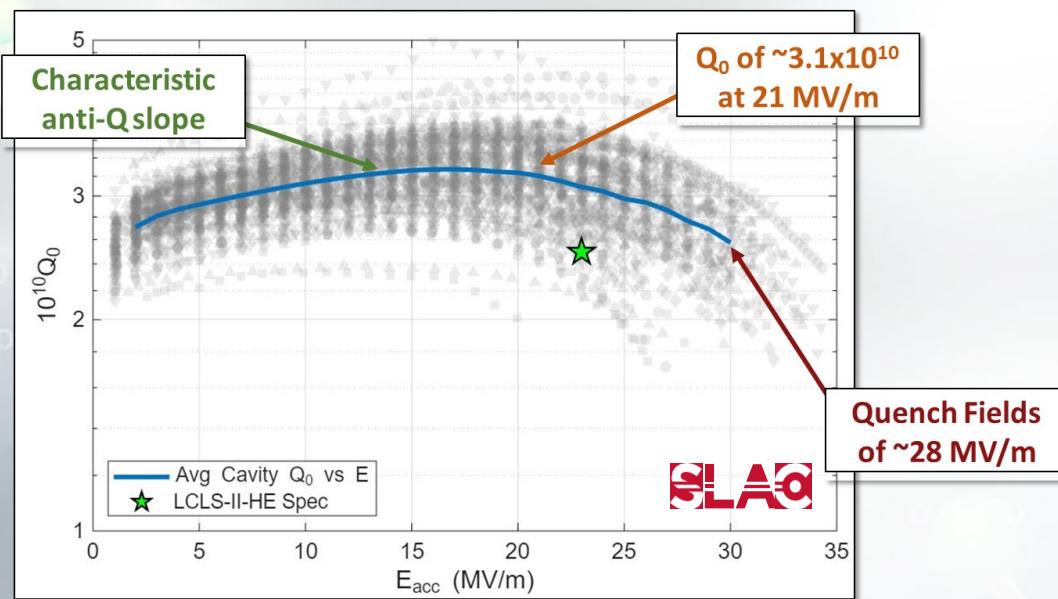


Progress since 2017

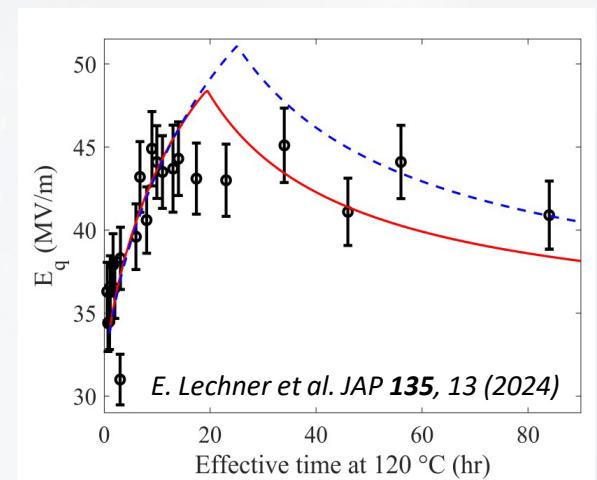
Pushing the limits for bulk Nb

High Q developments

- Low and mid T-bake
- Further understanding of Nb oxide layer



E. Lechner et al APL 119, 082601 (2021)

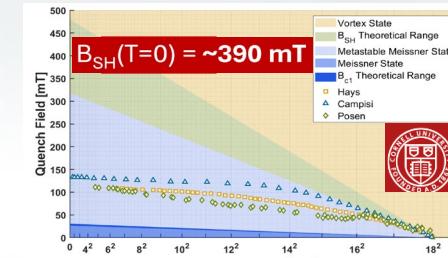


- N doping deployed at large scale – completion of LCLS-II and HE

Progress since 2017

Development of Nb_3Sn as Practical SRF Material

- Sn vapor diffusion technology refinements progressively leading to improved performance

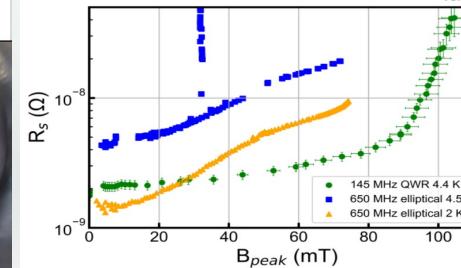


- Demonstration of achievable field for Nb_3Sn
- Deployment to lower frequencies and QWR

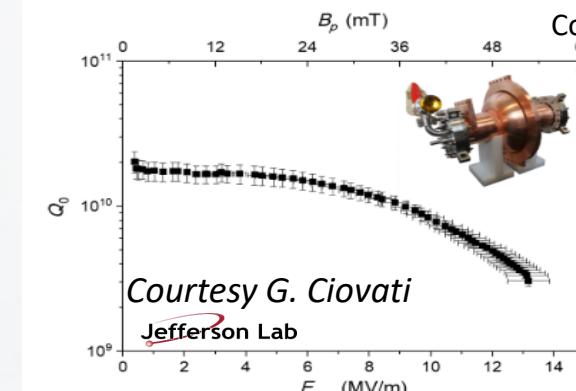
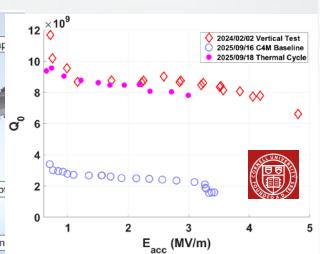
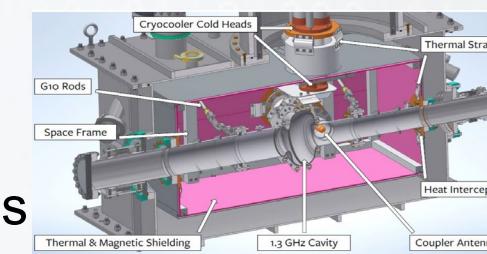
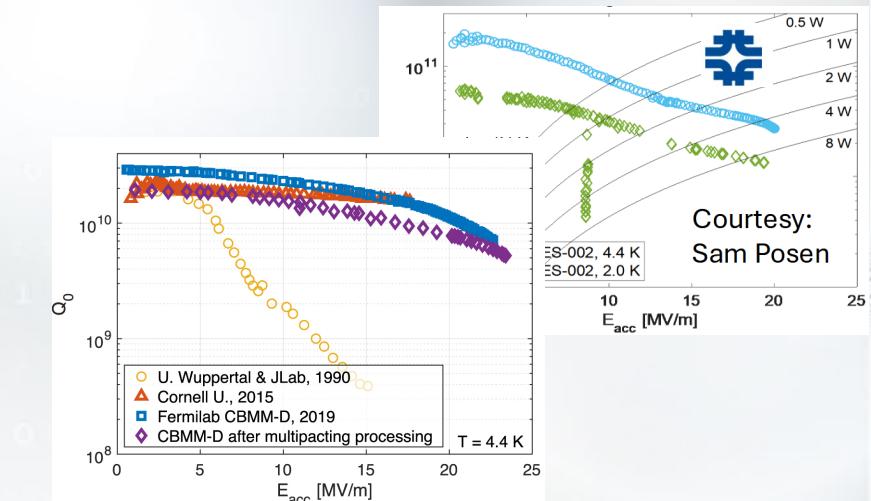
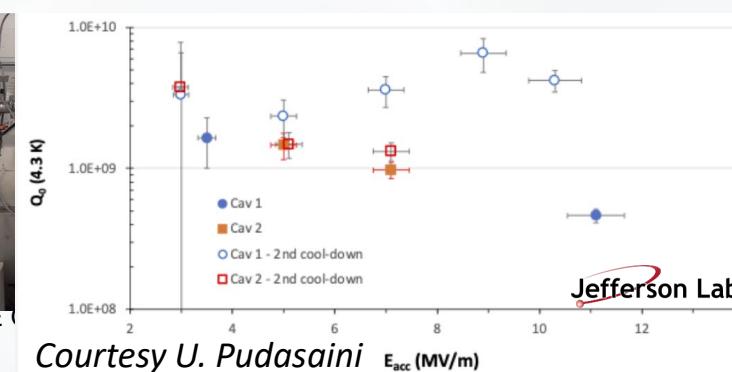
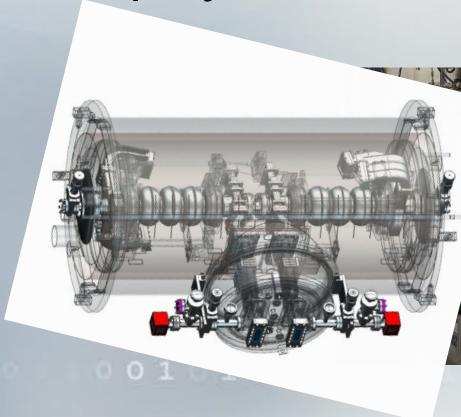


Courtesy T. Petersen

 RadiBeam  Fermilab  Argonne



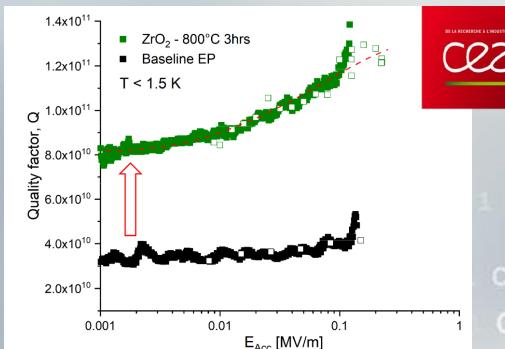
- Deployment of technology in cryomodule and for industrial applications



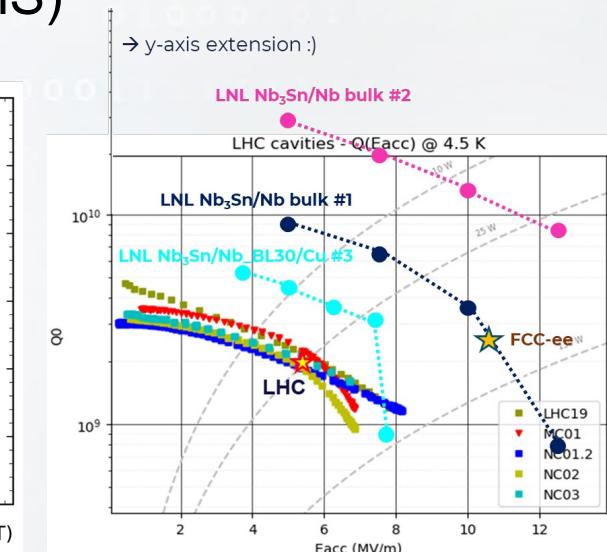
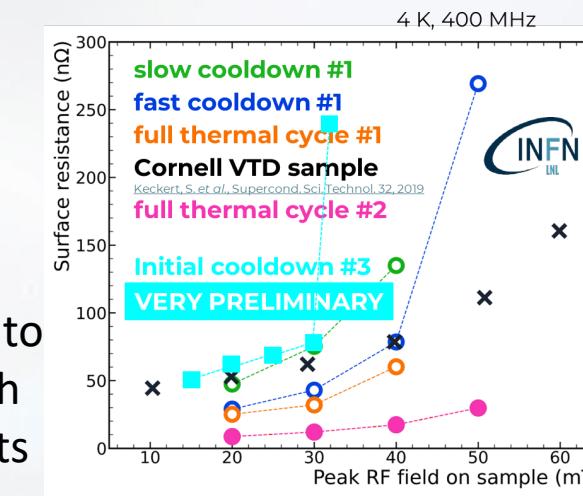
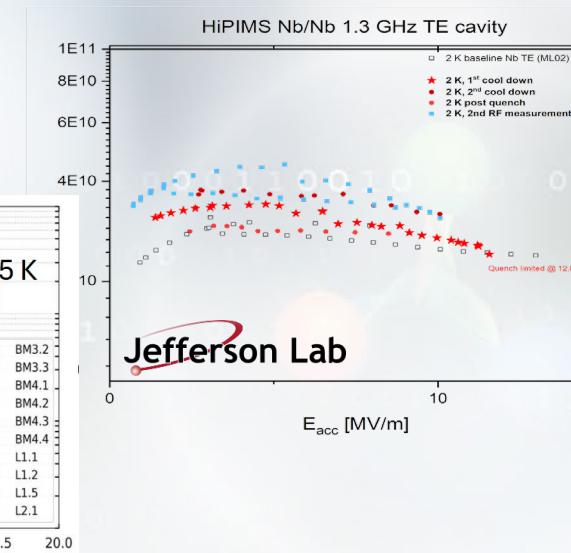
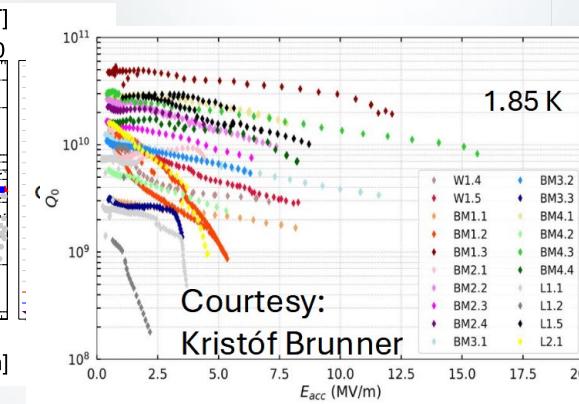
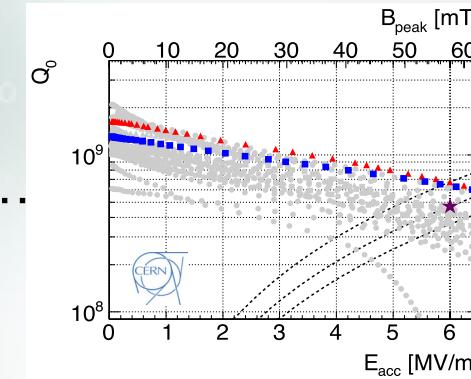
Progress since 2017

New Materials, Films, and Multilayers

- Nb/Cu (HiPIMS, ECR)
- Nb₃Sn on Cu (DCMS, HiPIMS...)
- Other materials - NbTiN, MgB₂
- SIS Multilayers NbTiN/AlN/Nb, Nb₃Sn /AlN/Nb(PE-ALD, DCMS, HiPIMS)
- Capping Layers: Al₂O₃, ZrO₂, Ta₂O₅, Au

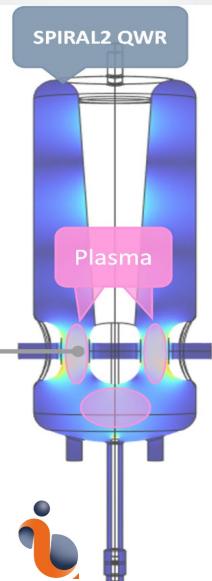


Various levels of maturity, efforts to deploy on cavities in parallel with material/technique developments



Progress since 2017 Field Emission Mitigation

- ❑ In-situ plasma cleaning
 - Deployment to other frequencies and geometries
 - Deployment in cryomodules (ORNL, FNAL, Cornell, SLAC, JLab...) and beam lines (ORNL, JLab)

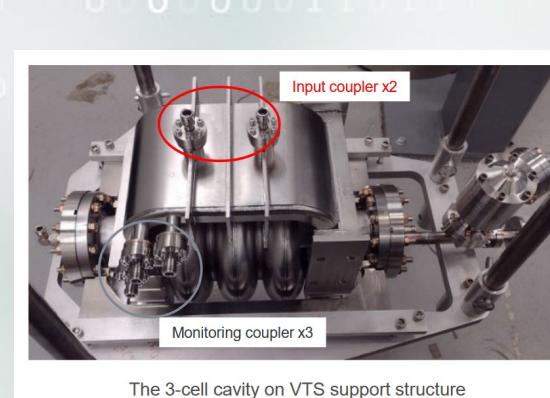
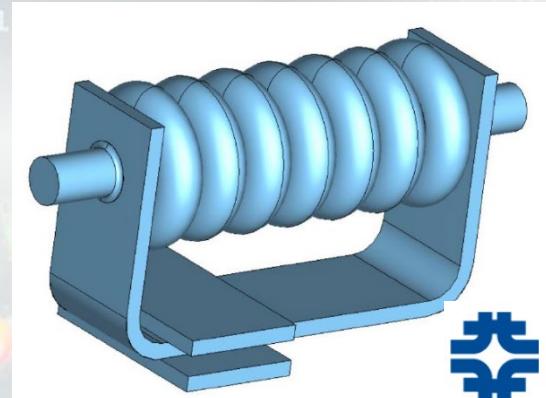


- ❑ Robotics
 - Cleanroom assembly and handling, precision component installation, automated cleaning (HPR)



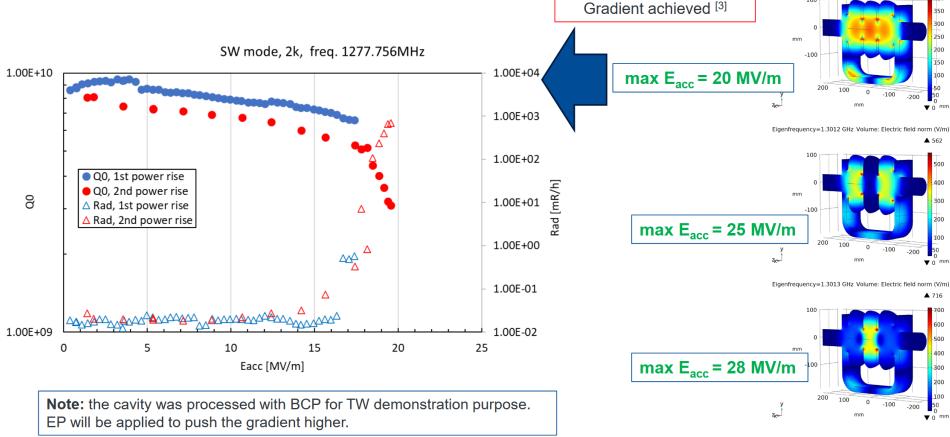
Progress since 2017 Novel SRF Cavity Shapes

Travelling waves

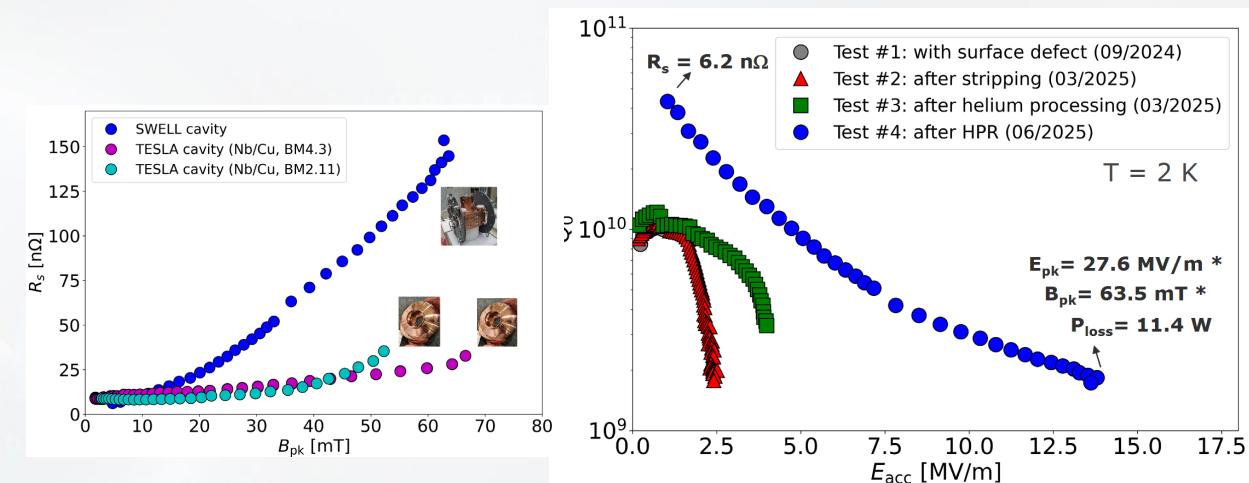
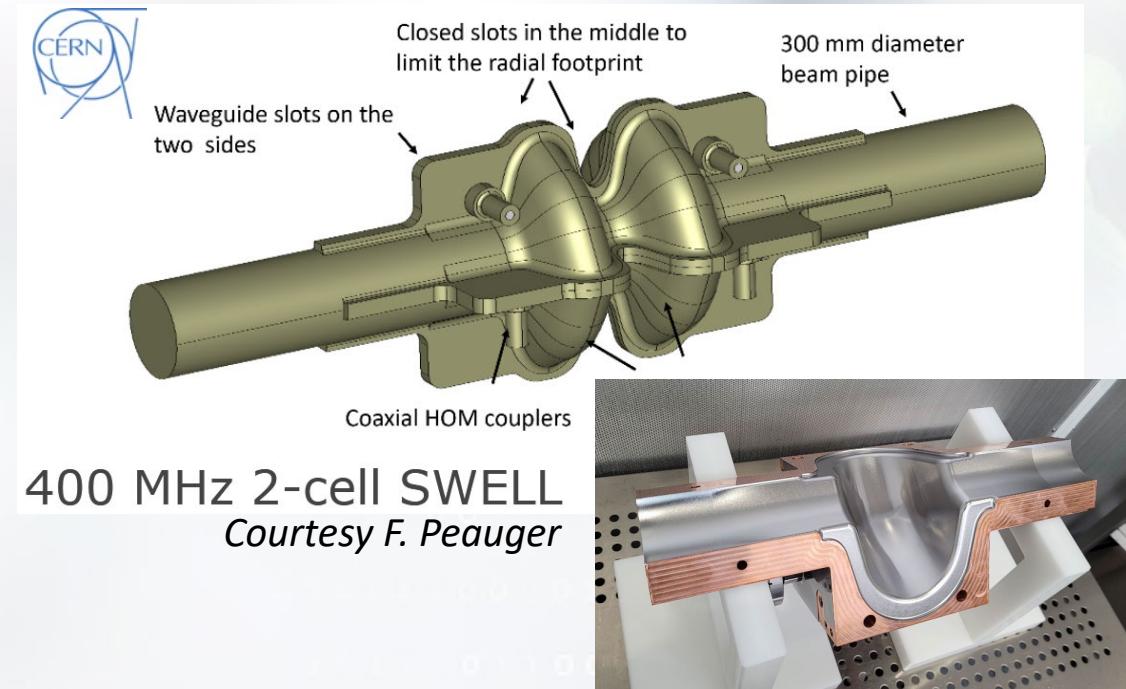


3-cell cold test

Standing-wave modes estimate TW gradient



Courtesy K. McGee



Today's Program & Organization

- Facilities: SRF needs for the next decade
- Niobium
- SRF thin films
- AI/ML for SRF R&D and Operations
- SRF Technology
- Short Talks

Each session has a 10-15' allocated slot for discussion.
The program is dense, so please respect the allotted time.
Please upload your presentations to the Indico site.