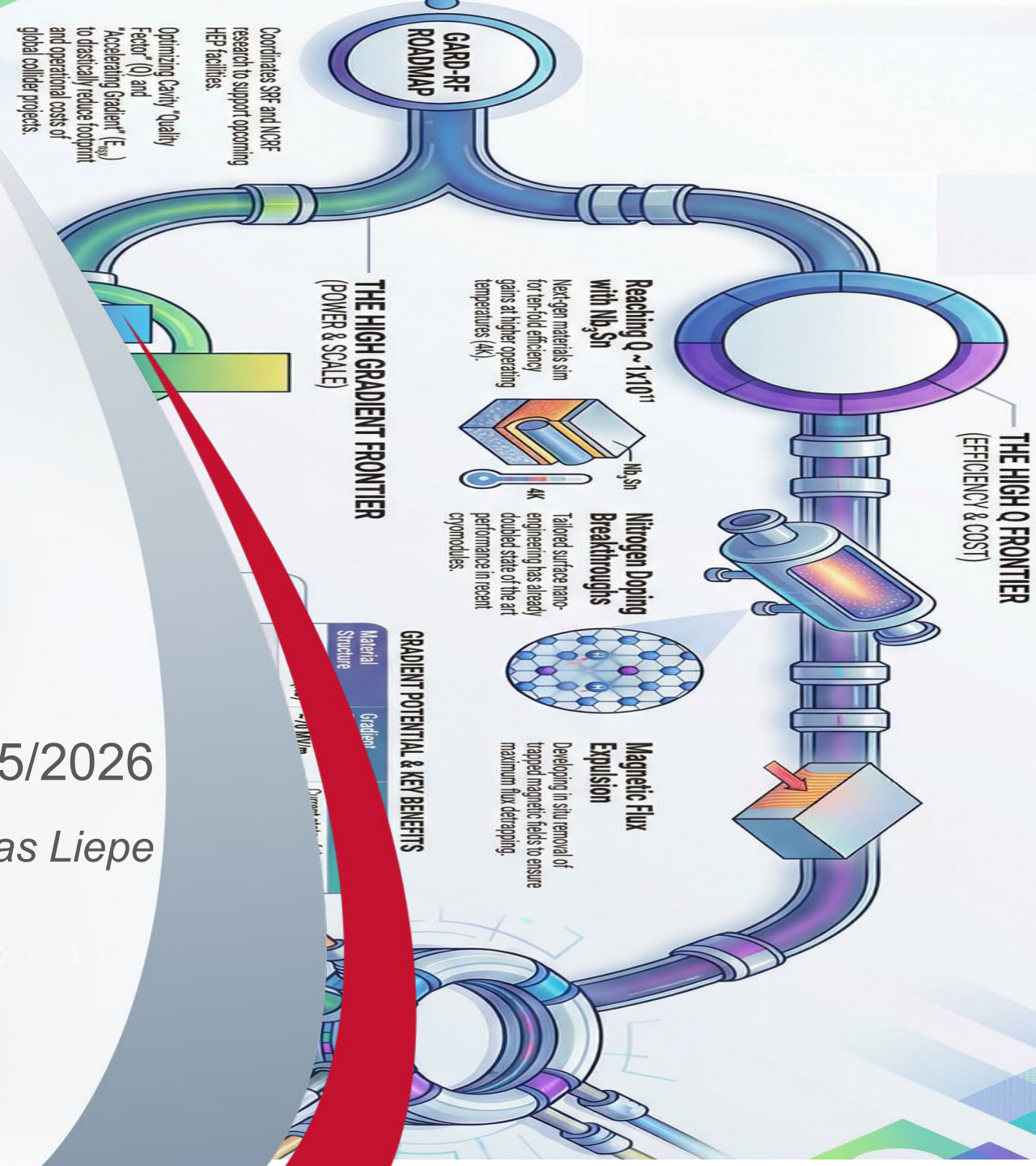


# DOE RF Roadmap Update

SRF Virtual Workshop

02/05/2026

Anne-Marie Valente-Feliciano & Matthias Liepe



# DOE GARD RF Roadmap - circa 2017



## Radiofrequency Accelerator R&D Strategy Report

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

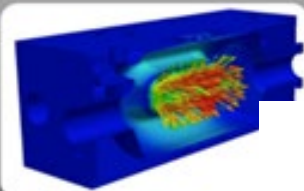
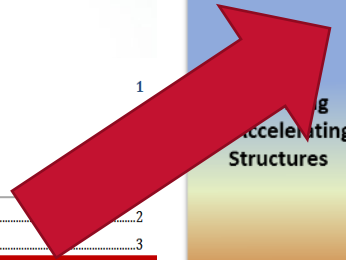


Image credits: left Fermilab/R. Right, upper right SLAC/ Kuncenakis et al., lower right SLAC/ Tardieu et al.

General Accelerator R&D RF Research Roadmap Workshop Report

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Accelerating Structures

RF Sources and Auxiliary Systems

2018	2023	2028
<b>Super Conducting High Q Roadmap</b> <b>Physics of Surface Resistance, Doping, New Materials, Magnetic Flux Losses</b>		
Q>3e10 at E <sub>acc</sub> >35 MV/m via doping	Cryomodule residual resistance < 2nΩ	Nb3Sn cryomodule
Explore Nb3Sn multicell		
<b>Super Conducting High Gradient Roadmap</b> <b>Fundamental Limits, Niobium, Nb3Sn, New Structure Topologies, Other Superconductors</b>		
Develop techniques to prevent & mitigate field emission	H <sub>pk</sub> >H <sub>gh</sub> of bulk niobium	E <sub>acc</sub> =70 MV/m
Outpace time scales of vortex dissipation, E <sub>acc</sub> > 100 MV/m		
<b>Normal Conducting Structures Roadmap: Accelerator topologies / Advanced materials and manufacturing / New regimes of operation in temperature and frequency / Virtual prototyping</b>		
Develop Accelerators w/ Advanced Materials		Advances with Multi-frequency, >200 MQ/m
Advances with Temperature and Frequency E <sub>acc</sub> >300 MV/m		
<b>RF Source Roadmap: High perveance, low voltage, high efficiency, multi-dimensional beams / Efficient modulators / Virtual prototyping tools / Prototypes</b>		
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:

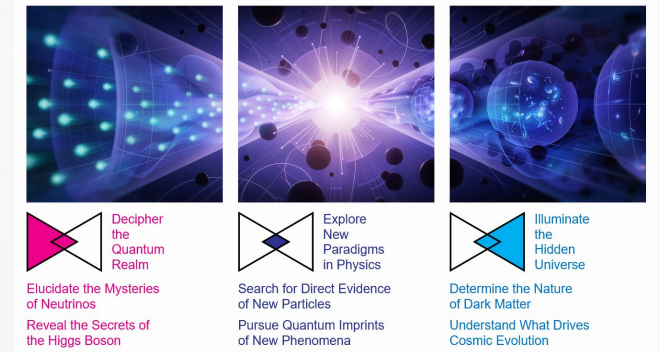
- ❑ Identify high impact R&D topics
- ❑ Define near, mid, and far term goals
- ❑ Ascertain the community's most urgent priorities
- ❑ Evaluate workforce development needs

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

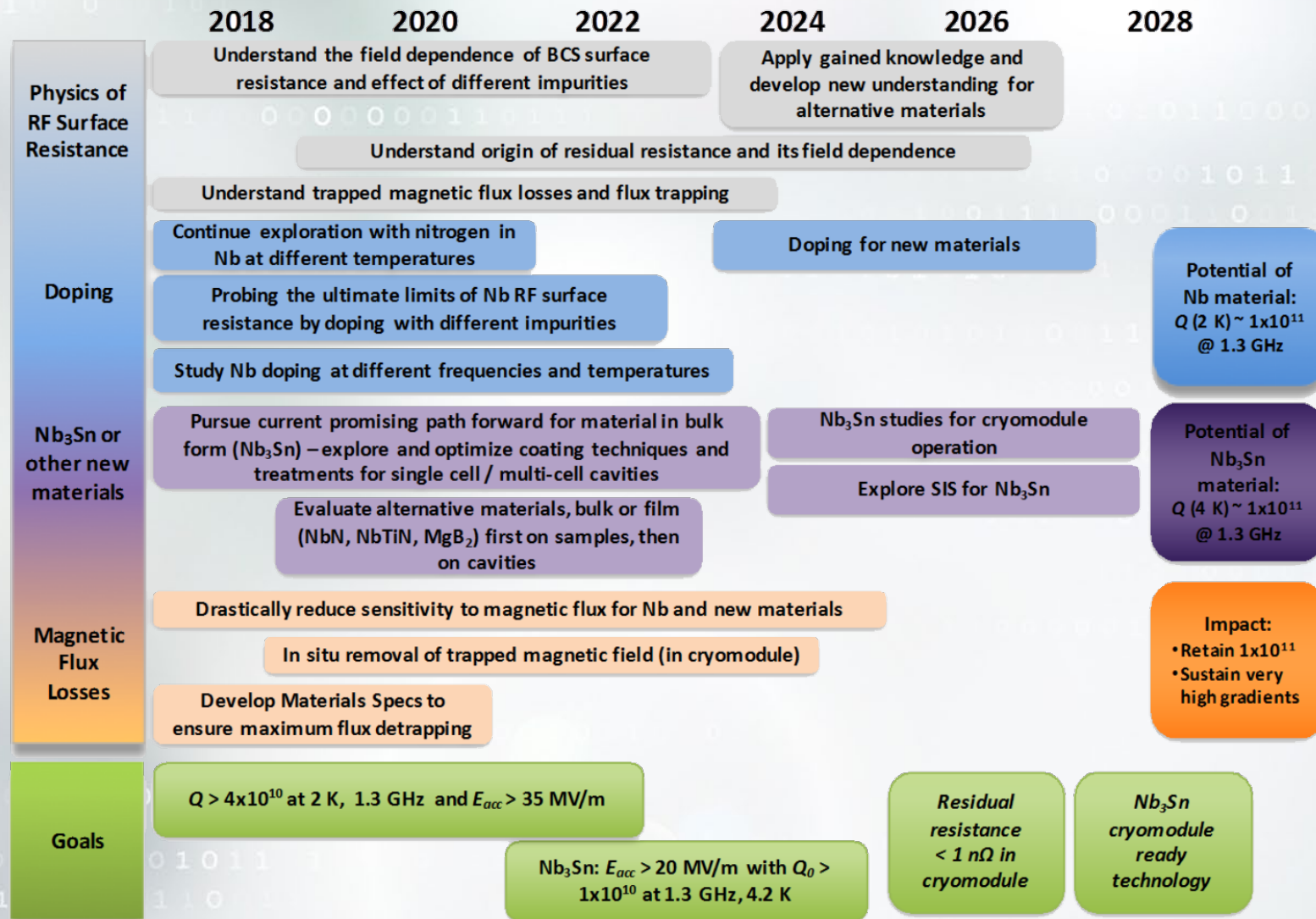
## March 3 & 4 , 2026

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

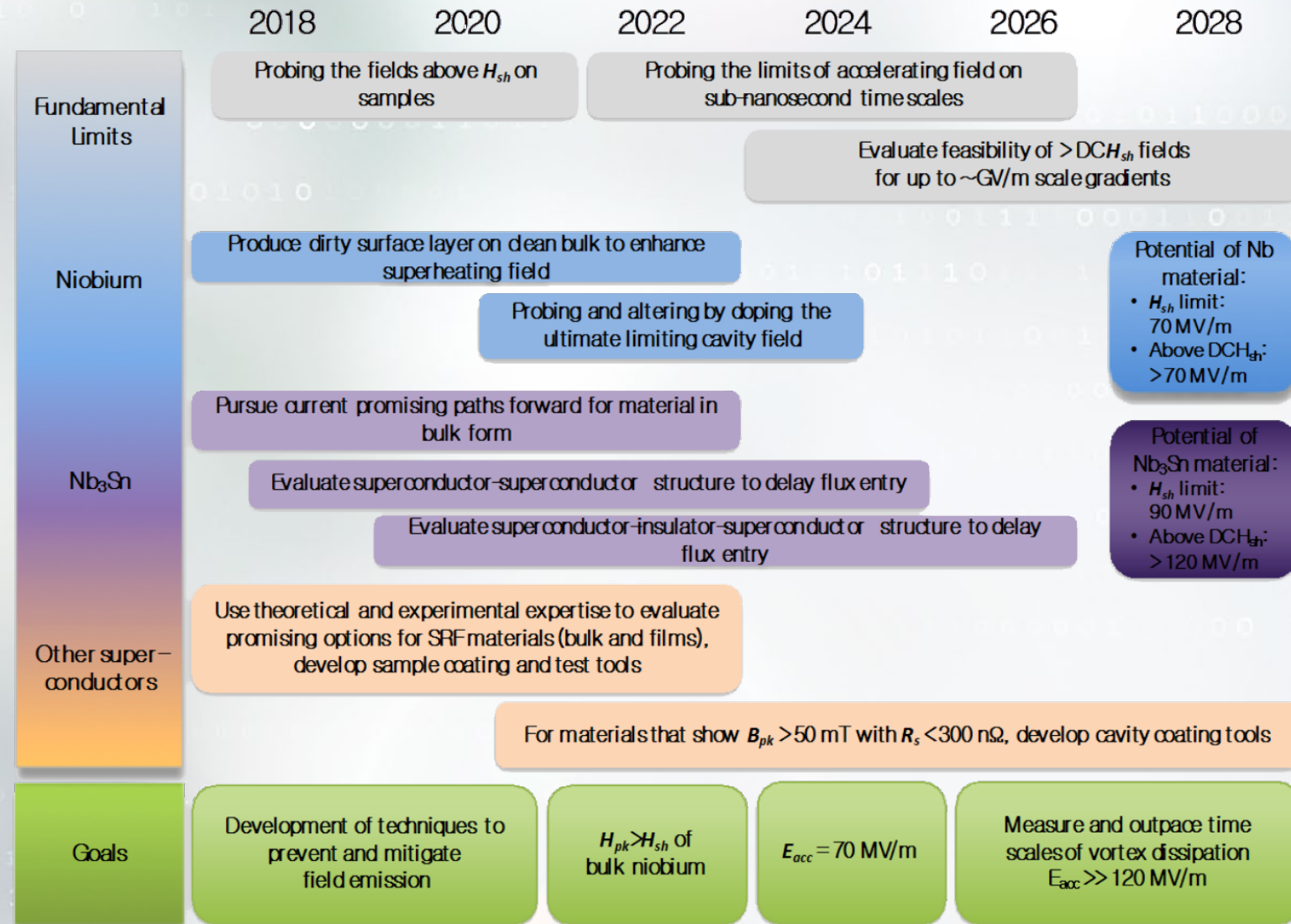
## Spring/early Summer 2026

- 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



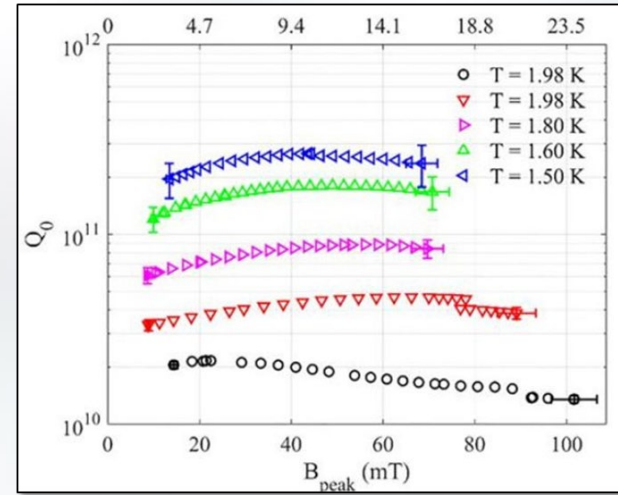


# Progress since 2017

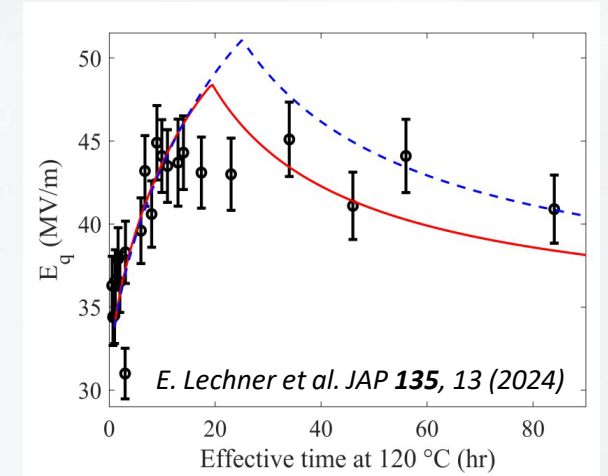
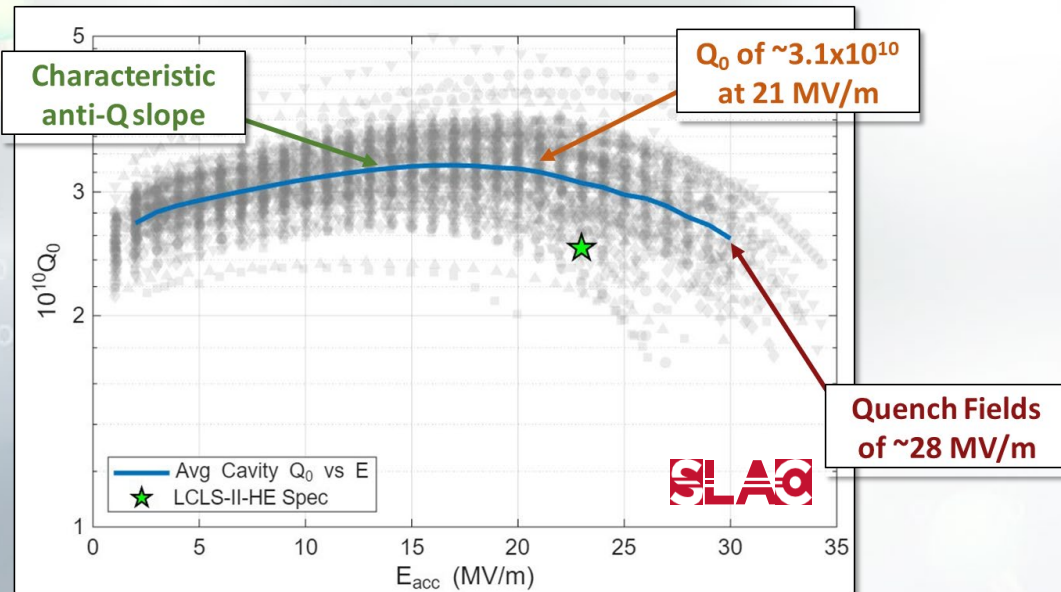
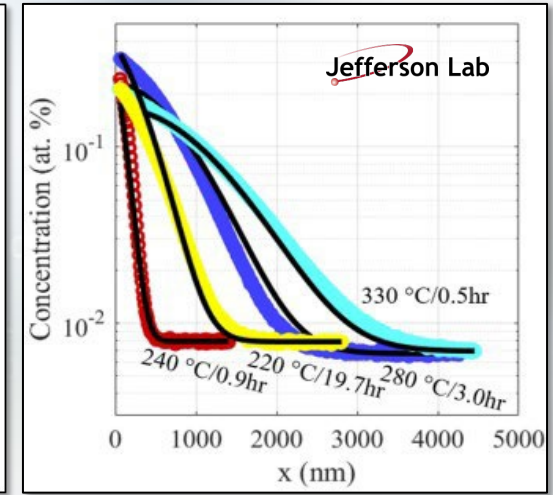
## Pushing the limits for bulk Nb

High Q developments

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



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



E. Lechner et al. JAP **135**, 13 (2024)

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

# Progress since 2017

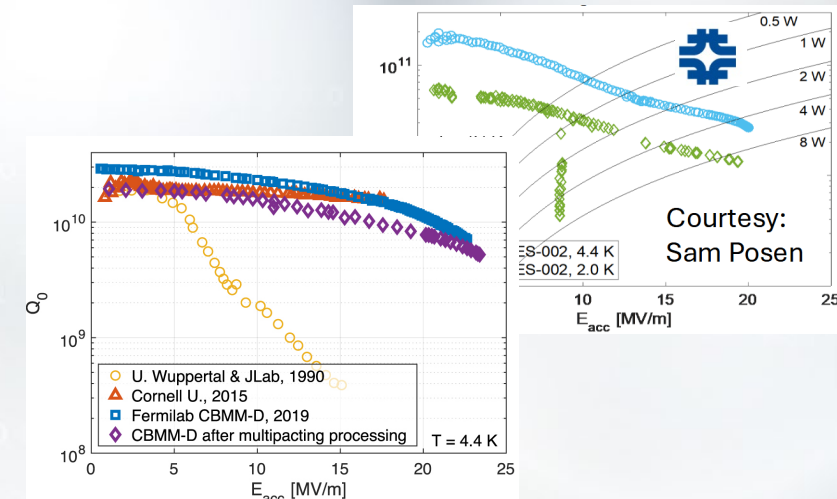
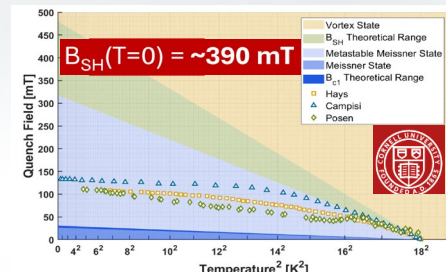
## Development of Nb<sub>3</sub>Sn as Practical SRF Material

❑ Sn vapor diffusion technology refinements progressively leading to improved performance

❑ Demonstration of achievable field for Nb<sub>3</sub>Sn

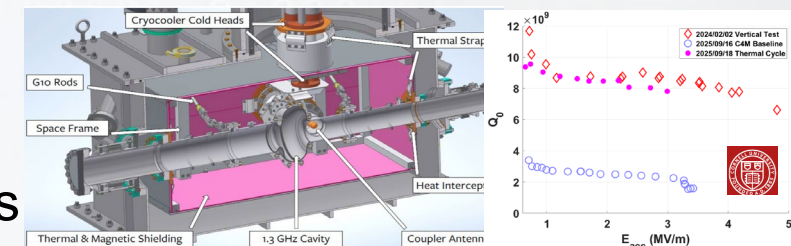
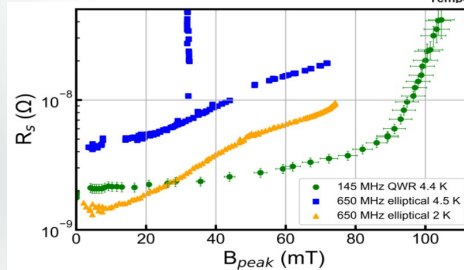
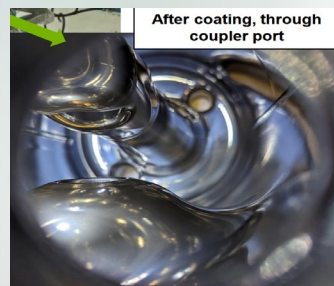
❑ Deployment to lower frequencies and QWR

❑ Deployment of technology in cryomodule and for industrial applications

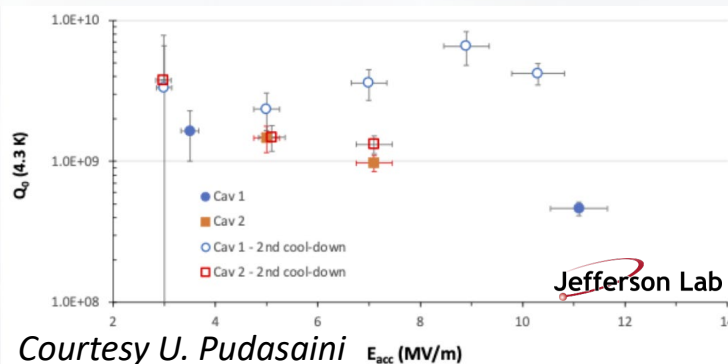


Courtesy: Sam Posen

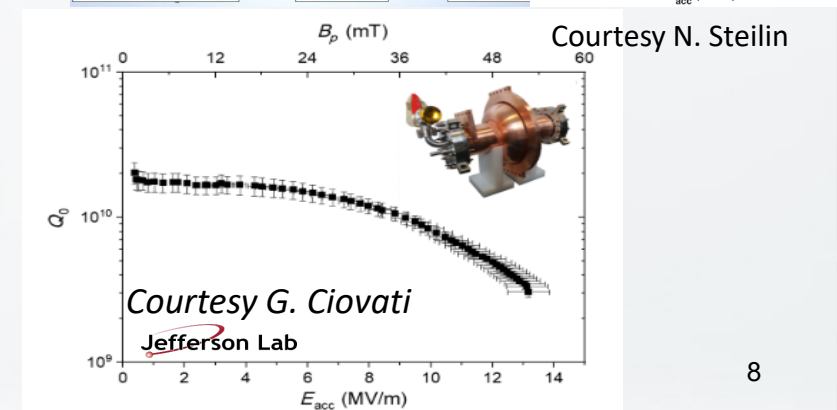
Courtesy T. Petersen



Courtesy N. Steilin



Courtesy U. Pudasaini



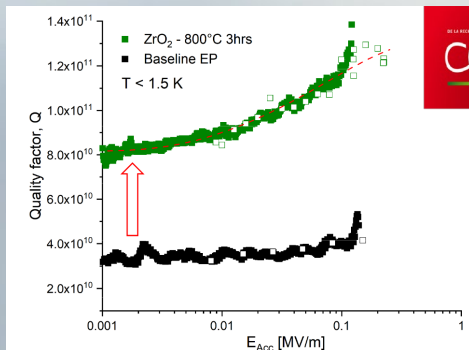
Courtesy G. Ciovati



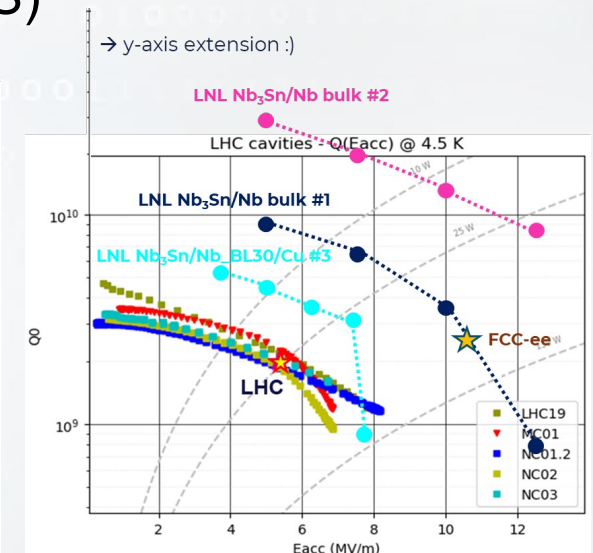
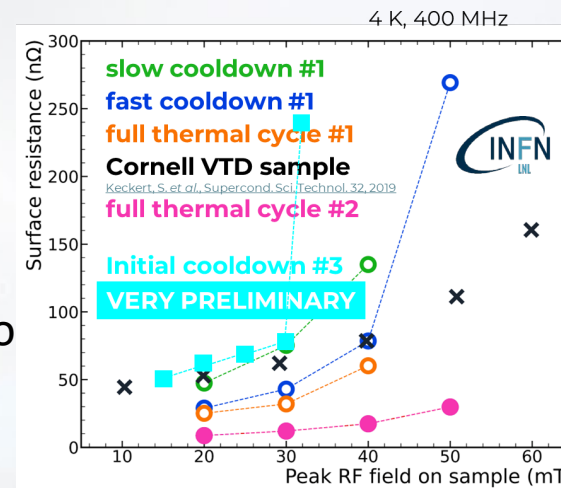
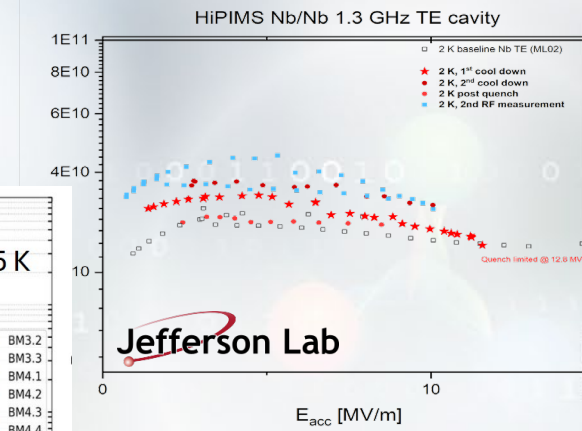
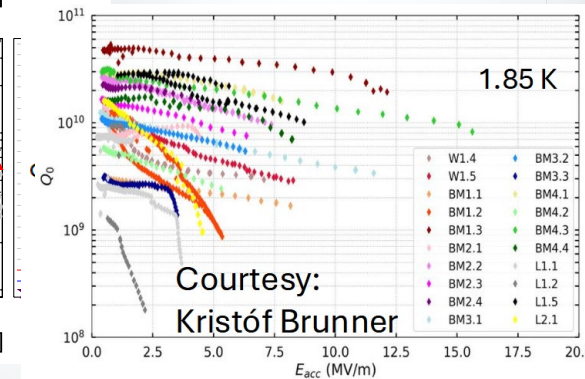
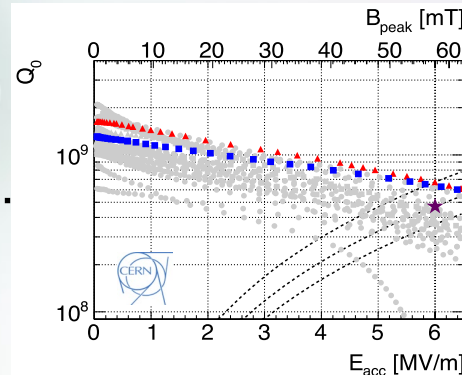
# Progress since 2017

## New Materials, Films, and Multilayers

- Nb/Cu (HiPIMS, ECR)
- Nb<sub>3</sub>Sn on Cu ( DCMS, HiPIMS...)
- Other materials - NbTiN, MgB<sub>2</sub>
- SIS Multilayers NbTiN/AlN/Nb, Nb<sub>3</sub>Sn /AlN/Nb(PE-ALD, DCMS, HiPIMS)
- Capping Layers: Al<sub>2</sub>O<sub>3</sub>, ZrO<sub>2</sub>, Ta<sub>2</sub>O<sub>5</sub>, Au



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

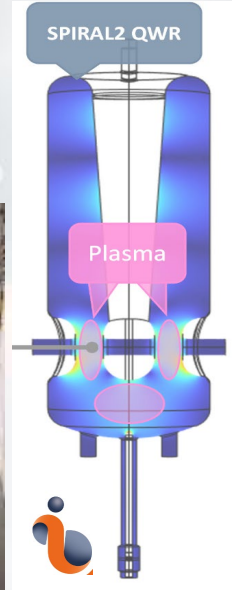


# Progress since 2017

## 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)

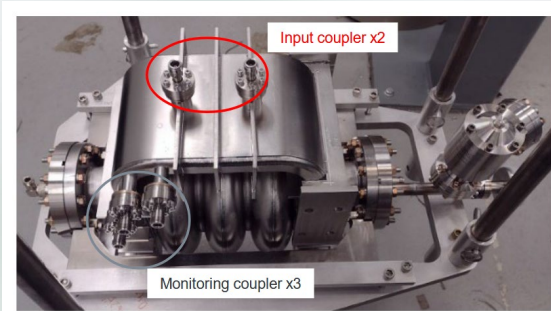
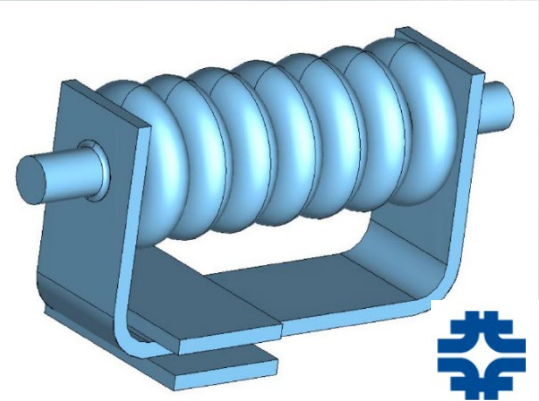




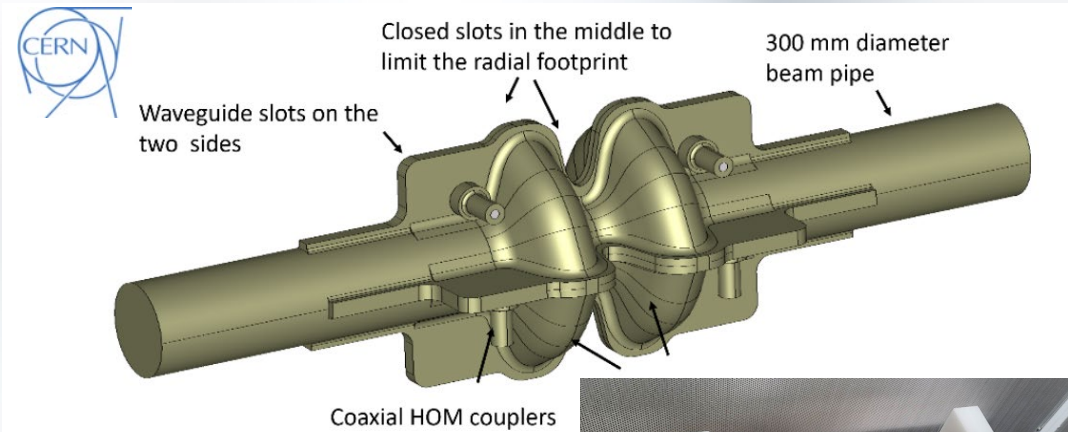
# Progress since 2017

## Novel SRF Cavity Shapes

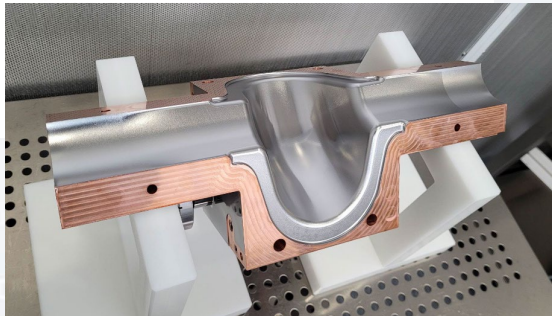
### Travelling waves



The 3-cell cavity on VTS support structure

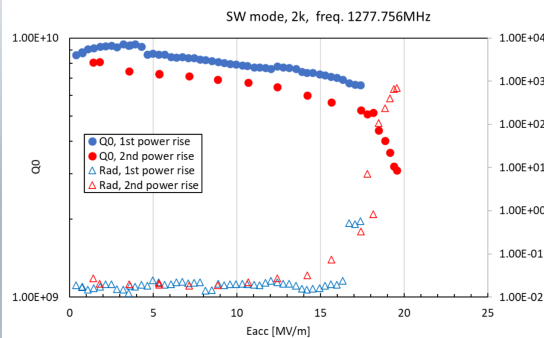


400 MHz 2-cell SWELL  
Courtesy F. Peauger



### 3-cell cold test

Standing-wave modes estimate TW gradient



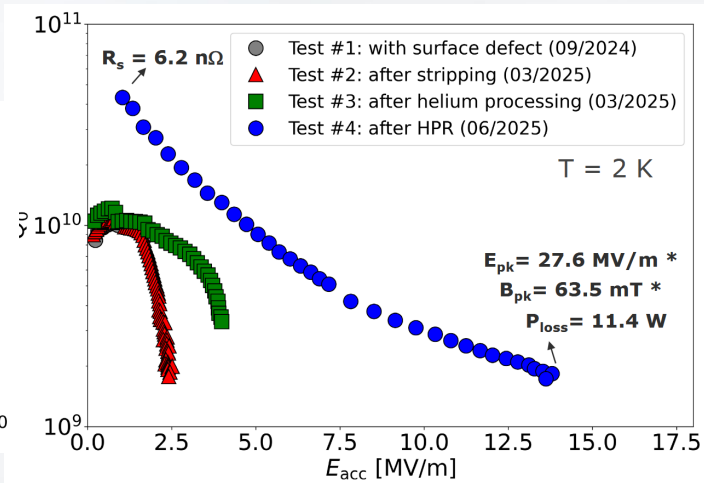
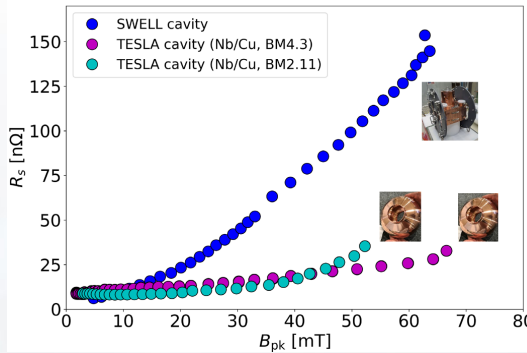
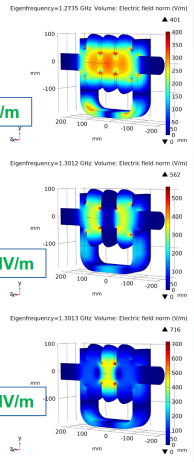
Note: the cavity was processed with BCP for TW demonstration purpose. EP will be applied to push the gradient higher.

Cavity SW Modes and Gradient achieved [3]

max  $E_{acc} = 20$  MV/m

max  $E_{acc} = 25$  MV/m

max  $E_{acc} = 28$  MV/m



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.