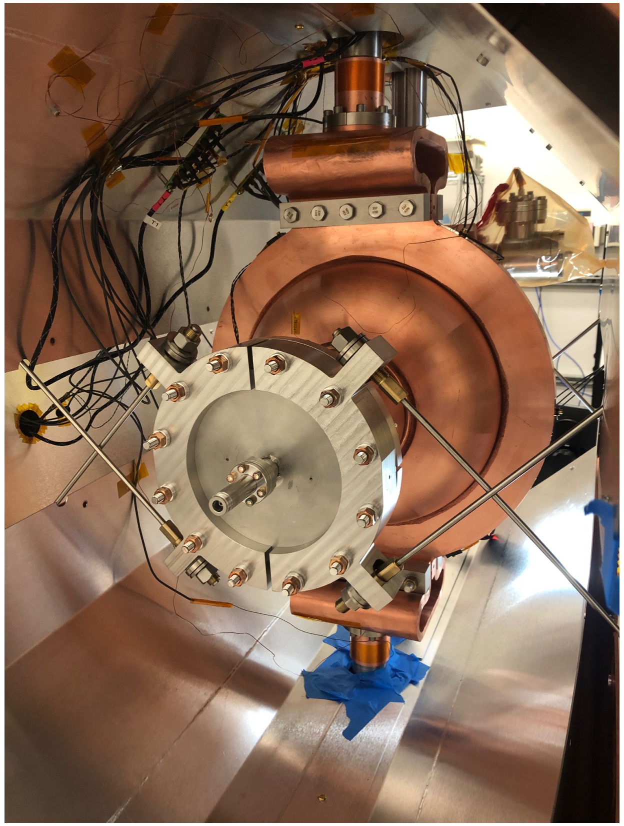
Introduction to Hot-Topic discussion

TESLA Technology Collaboration Meeting

Fermilab, Batavia, IL

4-8 December 2023



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JSA

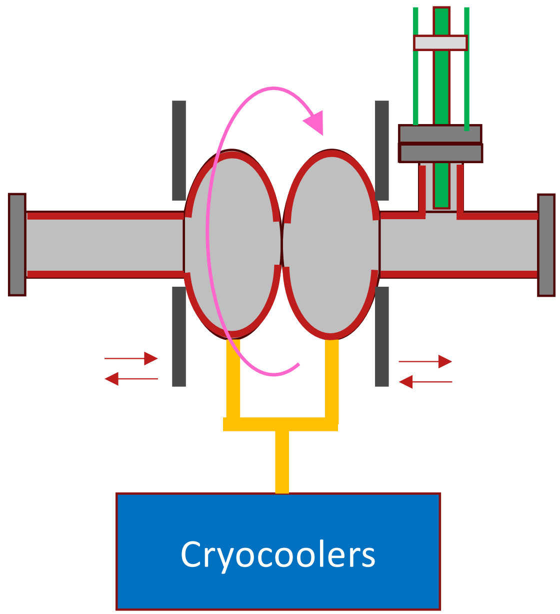
Conduction-Cooled SRF Cavities

- Why conduction-cooled SRF cavities?
  - Eliminate the need for liquid He cryoplants for SRF accelerators, thereby:
    - Reducing footprint
    - Reducing capital cost
    - Simplifying cryomodule design
    - Safer to operate
    - Enabling industrial applications

- Does conduction cooling of SRF cavities work?
  - Use high-quality Nb_3Sn thin films
  - Use commercial cryocoolers with high cooling power at 4 K
  - Single-cell cavities with frequency in the range 0.65 – 2.6 GHz cooled by cryocoolers have been tested up to an accelerating gradient of 10-12 MV/m

Challenges for Conduction-Cooled SRF Cavities

- Choice of cryocooler
  - GM, PT, GM-JT
- Thermal link design
  - Cu, Al, foils, straps, bulk
- Nb_3Sn thin-film performance
  - On Nb: thermal diffusion, magnetron sputtering, electroplating
  - On Cu: CVD, PVD, magnetron sputtering, bronze route
- Tunability of Nb_3Sn-coated cavities
  - Warm, cold
- Low-loss fundamental power coupler
- Thermoelectric magnetic flux

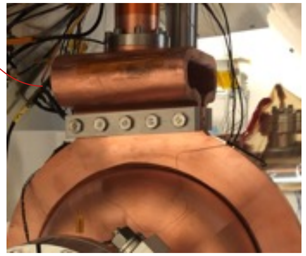


Choice of cryocoolers

GM-type	PT-type	GM-JT-type
		
• 7.5 kW for 2 W at 4 K • ~$45k • Limited mechanical loading to cold stage • Vibrations at 1.2 Hz	• 12.5 kW for 2 W at 4 K • ~$60k • No moving parts	• 14.1 kW for 9 W at 4 K • Fixed temperature • Limited mechanical loading to cold stage • Requires separate shield cooler

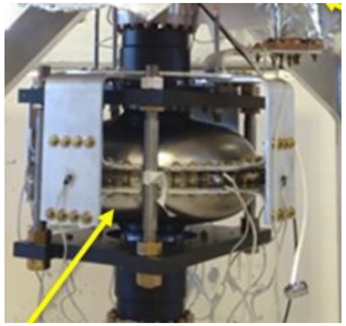
Thermal link design

Cu foils with press-welded terminals



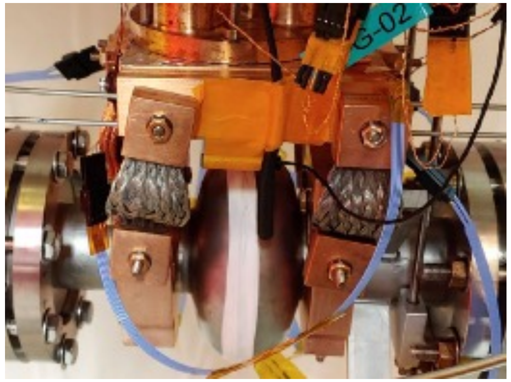
- 99.9% purity Cu foils
- Flexible connection
- Apiezon N grease used at interfaces

Aluminum bus-bars



- 99.9999% purity Al bars
- “rigid” connection
- Indium foil used at interfaces
- Time-consuming assembly

Cu thermal braids + Cu clamps

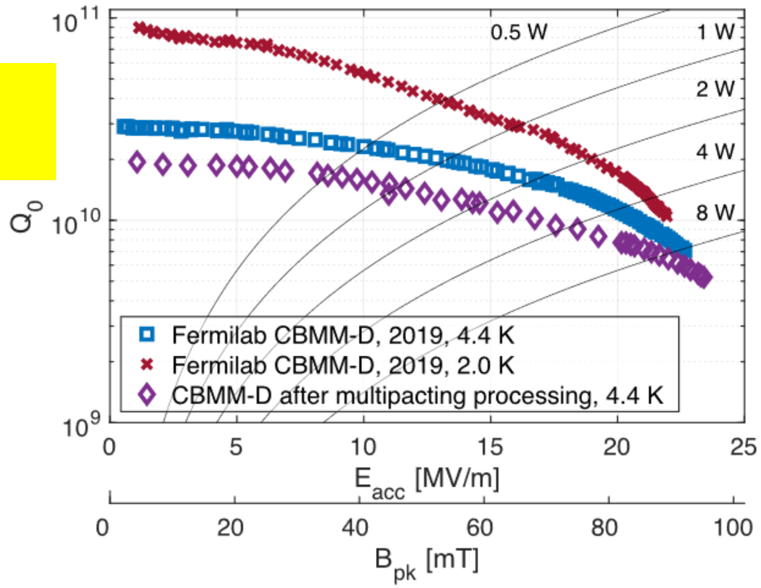


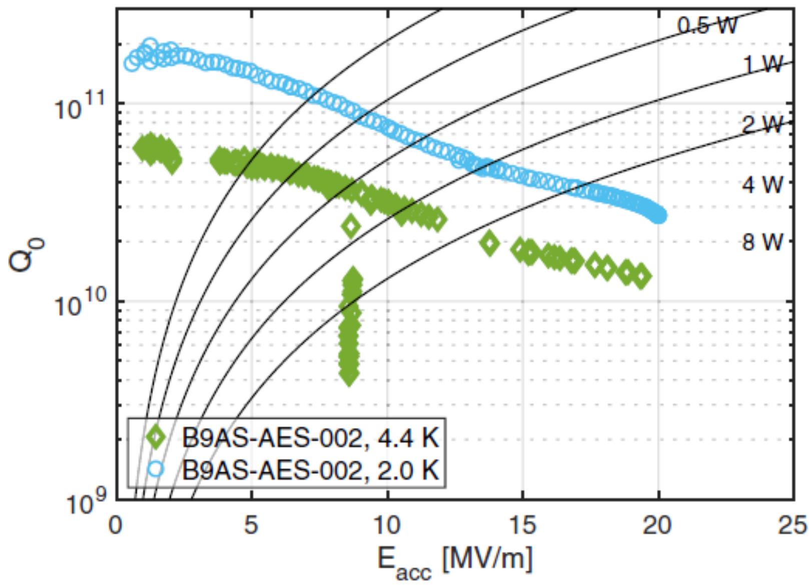
- Braided Cu straps
- Flexible connection
- Indium foil used at interfaces
- High clamping force (required for low thermal resistance) can damage the brittle Nb_3Sn film

Nb_3Sn thin-film performance

State-of-the-art performance of Nb_3Sn thin-film on Nb by vapor diffusion in liquid He:

1.3 GHz
single-cell



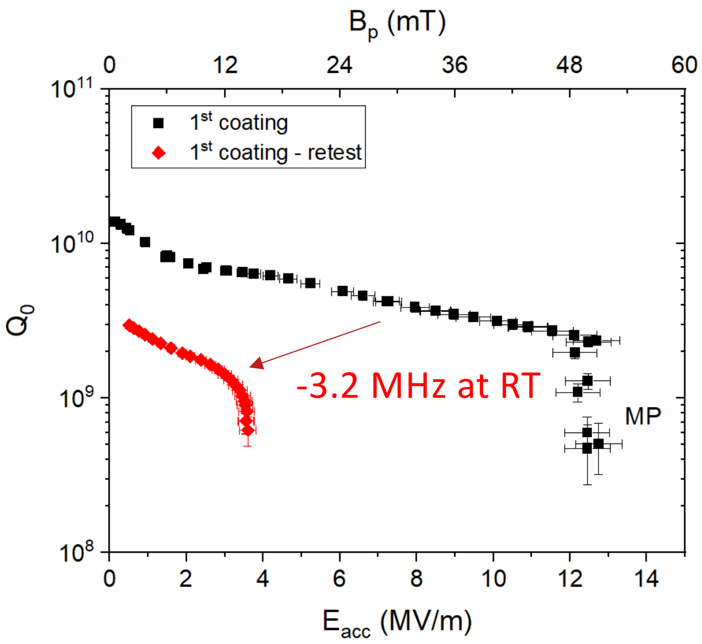


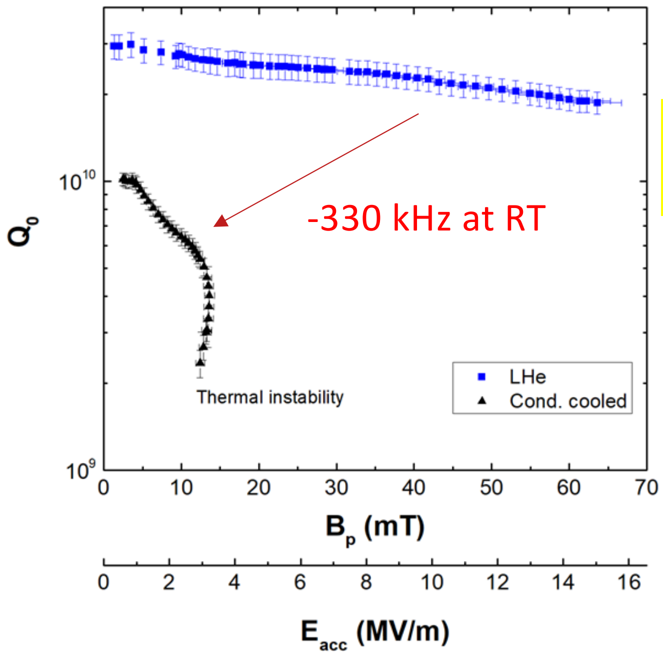
650 MHz
single-cell

- How do we achieve this type of performance reproducibly?
- Is Ti contamination of the film from the Ti45Nb flanges as issue?
- How do we achieve this type of performance on Cu?

Tunability

952 MHz single-cell





1.3 GHz single-cell

- How to overcome the brittleness of Nb_3Sn?
- What is the maximum tuning range at 300 K before degrading performance?