Commissioning of dedicated furnace for Nb_3Sn coatings of 2.6GHz single cell cavities

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Introduction

We present the results of commissioning a dedicated furnace for Nb_3Sn coatings of 2.6GHz single cell cavities. Nb_3Sn is a desired coating due to its high critical temperature and smaller surface resistance compared to bulk Nb. Usage of Nb_3Sn coated cavities will greatly reduce operating costs due to decreased dependance on cryo cooling. Tin is deposited by use of a tin chloride nucleation agent and tin vapor diffusion. Analysis of the resultant coating was performed using SEM/EDS to verify successful formation of Nb_3Sn. Witness samples in line of sight of the source were used in order to understand the coating efficacy.

Background and motivation

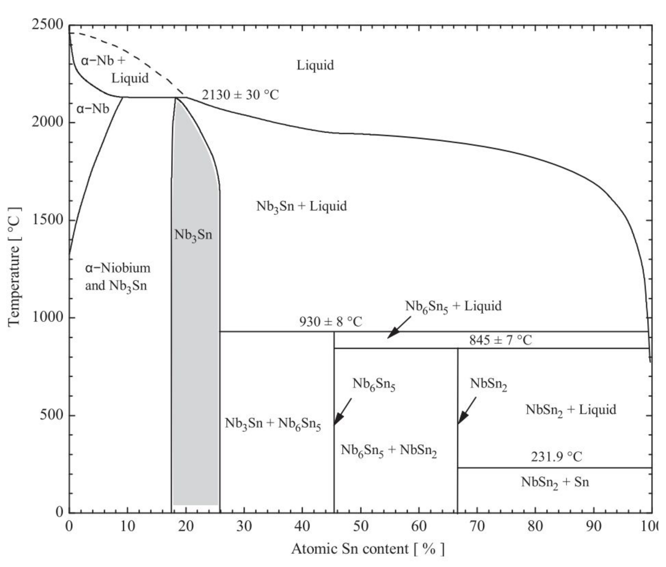
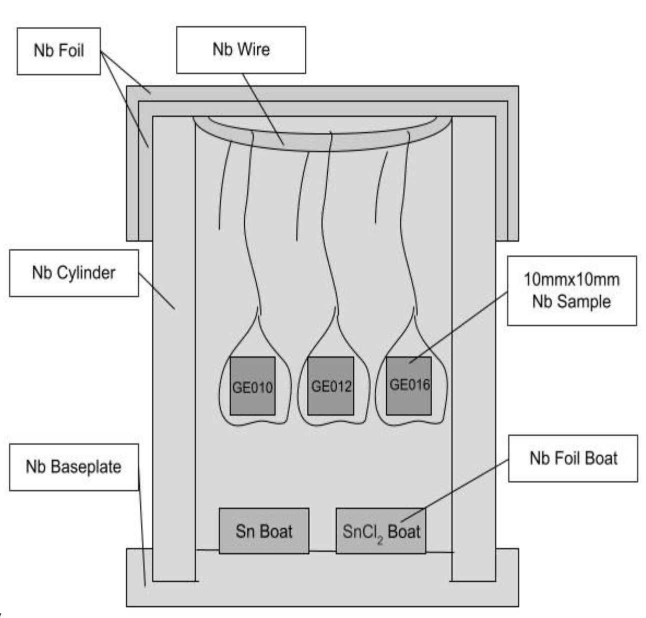


Figure 3. The phase diagram of the niobium–tin system, as measured by Charlesworth *et al* in 1970 (adapted from [29]). The Nb_3Sn-only region has been highlighted.[1]



Nb enclosed in the chamber with Sn and $SnCl_2$

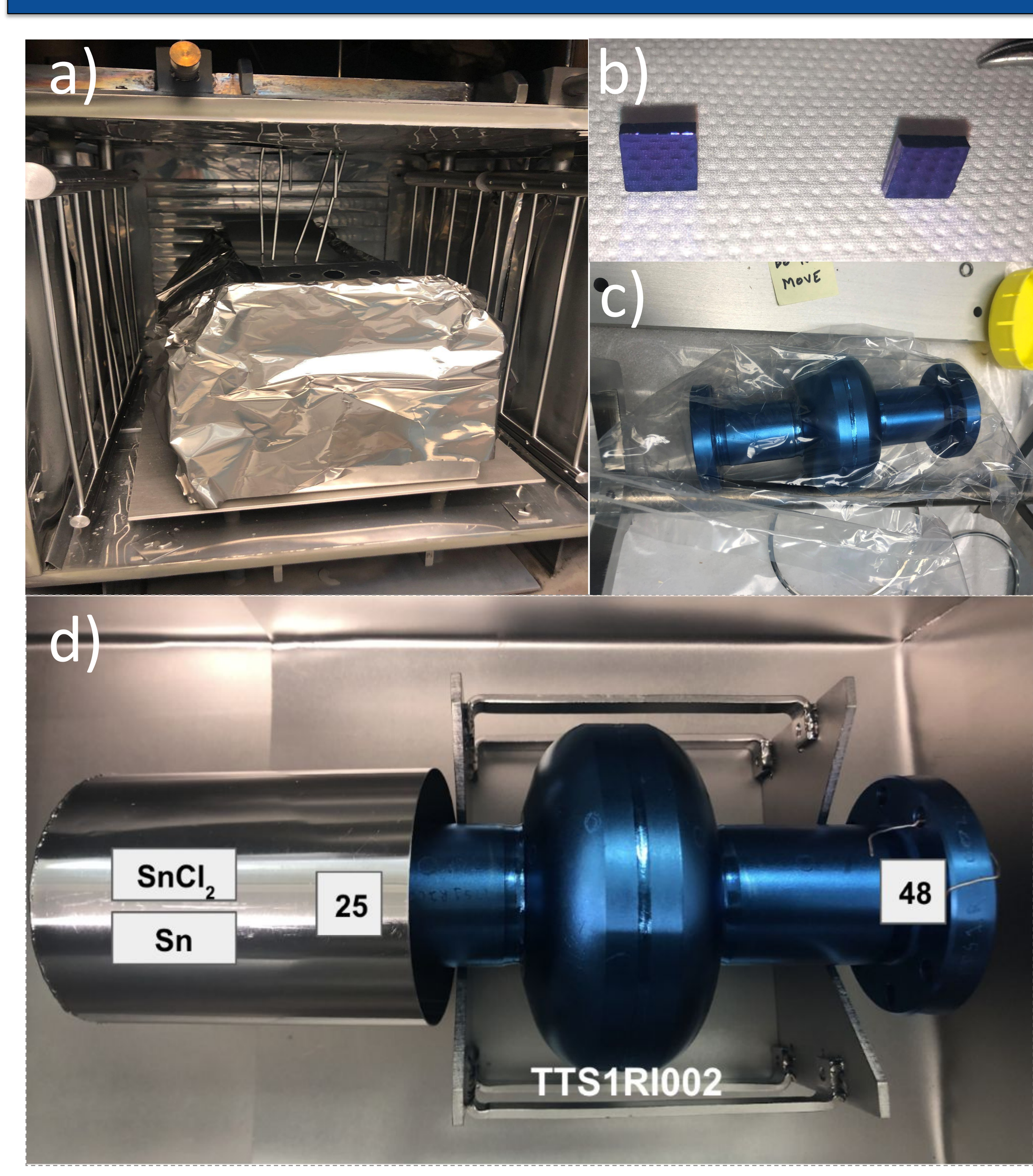
Above about 930 C only Nb_3Sn phase is stable

Several μm thick Nb_3Sn film is formed after annealing about 1100 C for several hours

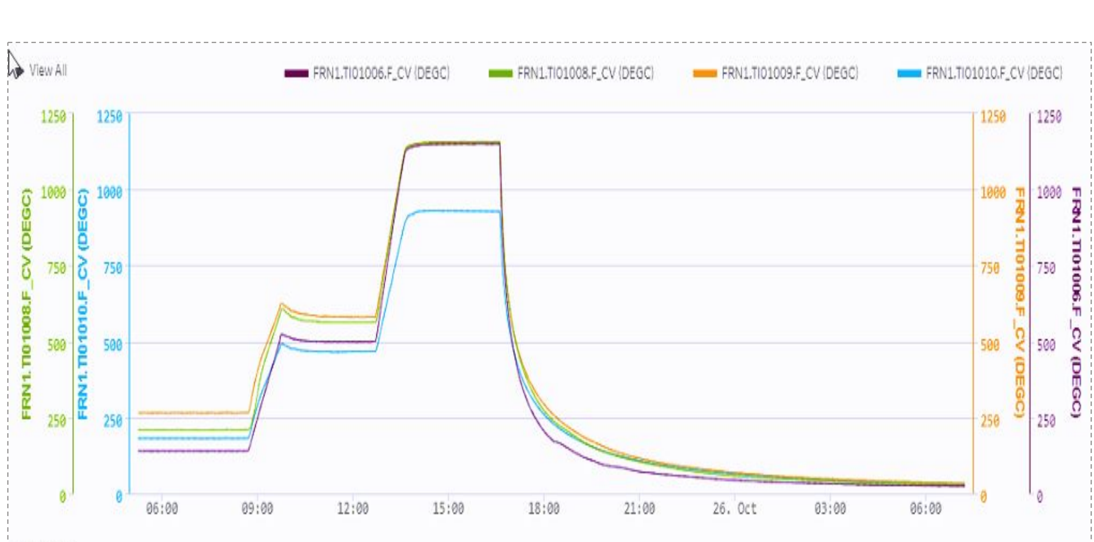
Material	Nb	Nb_3Sn
T_c [K]	9.25	18.3
ρ_n [μΩcm]	0.1	~ 5
$H_{sh}(0)$ [T]	0.24	~ 0.45
Δ [meV]	1.45	~ 3.1
Q^{BCS} @ 2K	~ $5\cdot10^{10}$	~ $5\cdot10^{14}$
Q^{BCS} @ 4K	~ $5\cdot10^{8}$	~ $5\cdot10^{10}$
E_{acc} [MV/m]	~ 50	~ 100

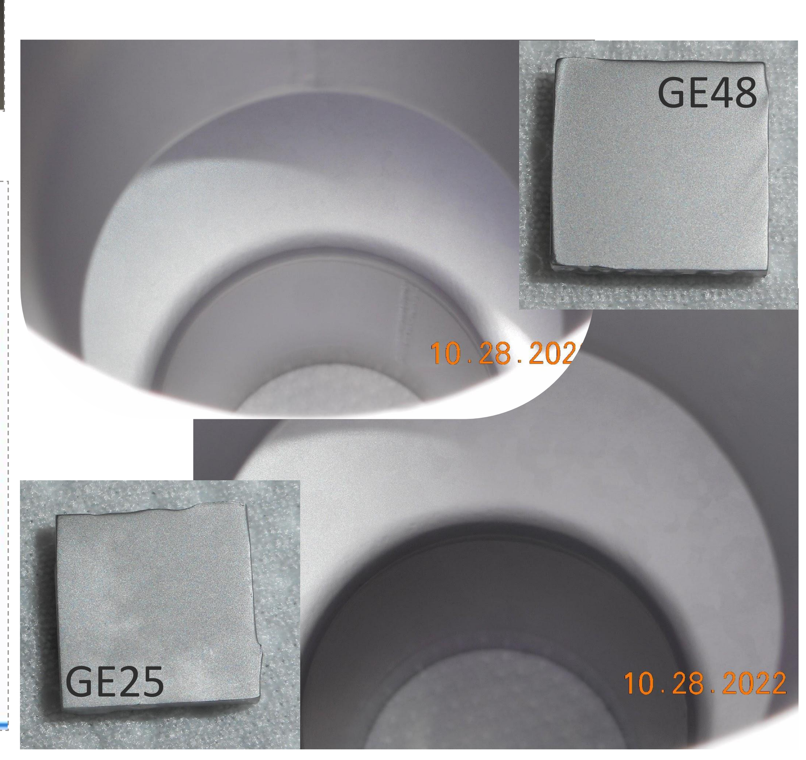
- s-wave superconductor -> isotropic, $R_s \sim e^{-\Delta/kT}$
- large energy gap -> ~ 2x that of niobium -> 100 reduction in R_s
- high H_{Sh} -> ~ 2x that of niobium -> potential for 2x accelerating gradient
- low normal-conducting resistivity -> low R_s

Experimental Setup



- IVI 3312-1212-120V furnace:
  - Horizontal front loading
  - 12” x 12” x 15” hot zone
  - Heaters: Molybdenum
  - Inner Shields: Molybdenum
  - Temperature : 1200 °C
  - Typical vacuum : 10^{-8}
- All niobium enclosure for 2.6 GHz cavity coatings
- Anodized 2.6 GHz cavity
- 2g Sn with 0.5g $SnCl_2$ used in the first coating with about 1.6g of Sn consumed
- Coating was done @ 1150 °C x 3 hrs

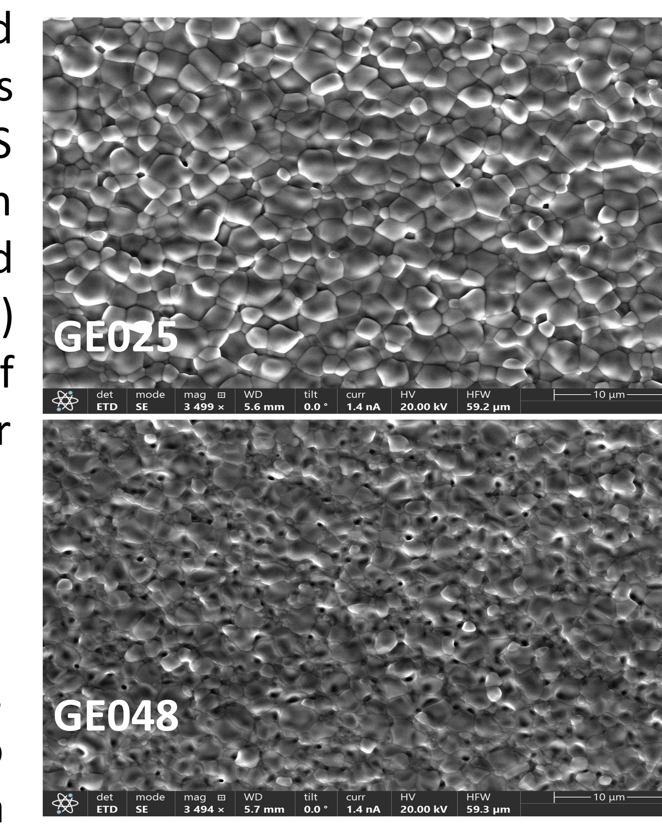


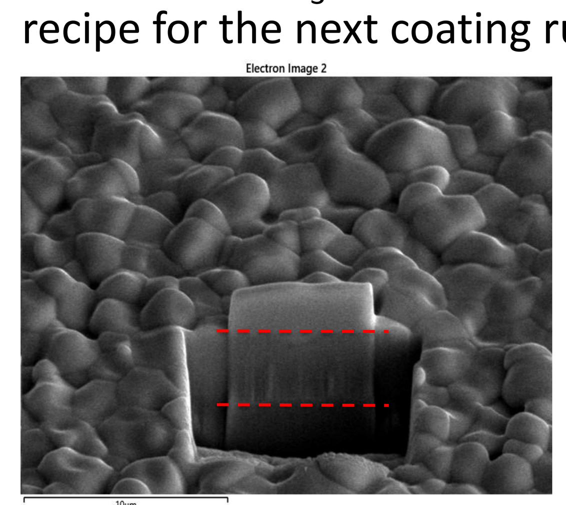


Measurements and results

SEM/EDS/FIB

Samples were studied with FEI Helios dual beam system and Oxford EDS. Nearside (GE025) and far side (GE048) samples were compared to understand the quality of the coating. EDS was performed to establish that the At% of Nb:Sn was in desired range. Visual comparison of the samples revealed more frequent pits or holes on the far sample (GE048) surface. FIB showed that these spots may be areas of insufficient Nb_3Sn formation, which guided us to adjust our recipe for the next coating run.

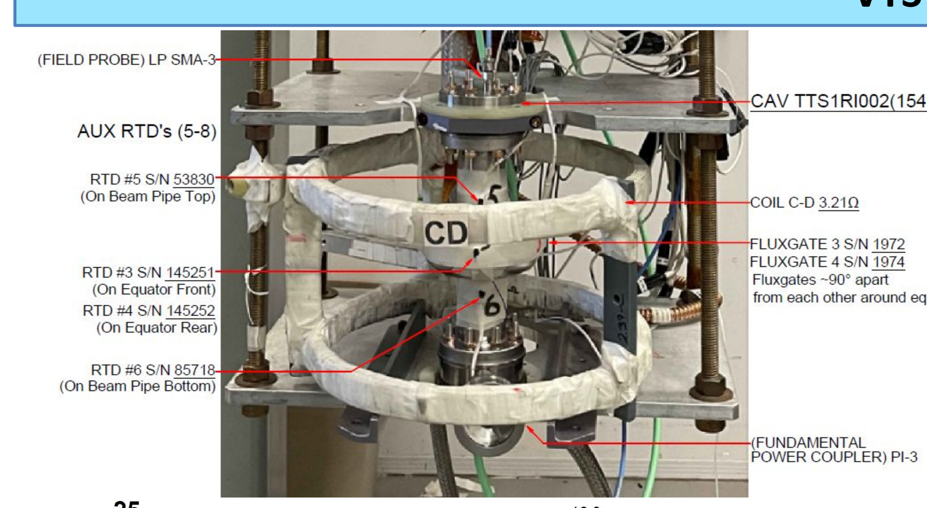




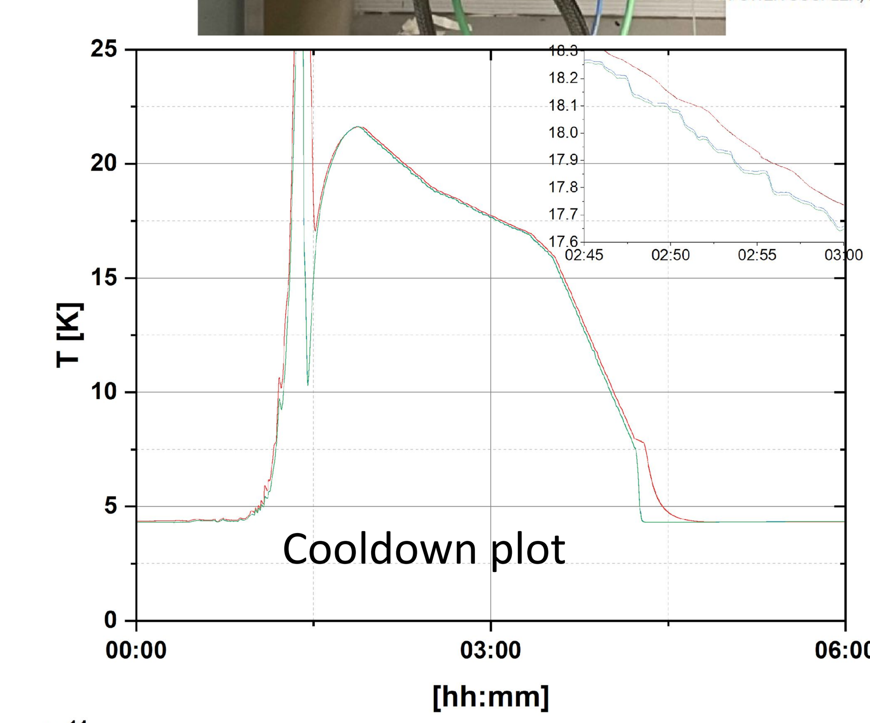
The dual beam system was used to perform FIB on the sample. Electron beam was used to image the sample while Ga beam removed material.

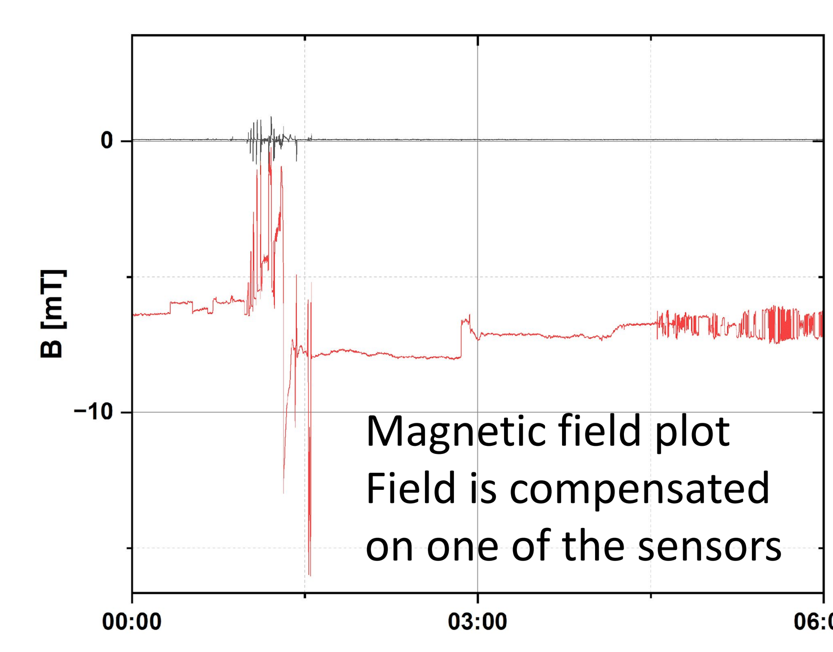
GE025 thickness of Nb3Sn layer as seen in FIB.

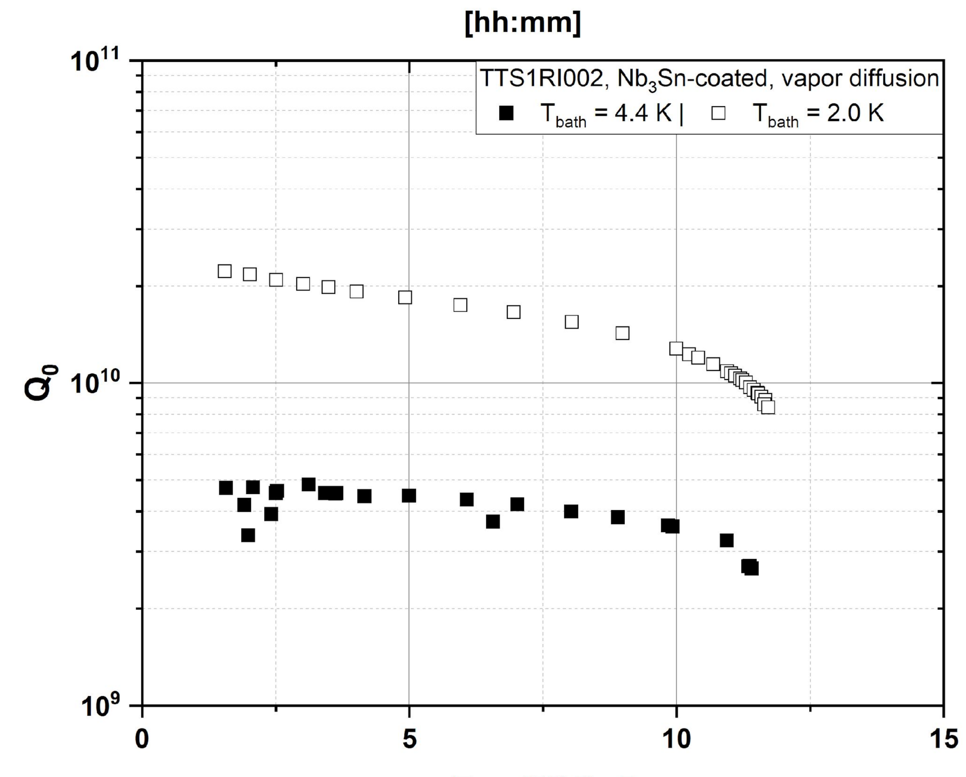
VTS Testing



- Nb_3Sn-coated 2.6 GHz cavity (TTS1RI002) was test under static vacuum
- Two fluxgates, four temperature sensors and magnetic compensation coil were used
- Special cooling procedures were employed to ensure slow cooldown close to 18 K







- First Nb_3Sn coating in this furnace in the new setup
- At 4.4K the cavity reached 11.5 MV/m limited by quench
- At 2.0 K the cavity reached 11.8 MV/m limited by quench
- Good performance for the first try!

Conclusion

In this contribution we presented the first results of Nb_3Sn coating on a 2.6 GHz cavity in the recently refurbished furnace. The coating appearance on the cavity was uniform. However, the detailed analysis of samples, coated with the cavity, presented evidence of low Sn flux during the coating. In the cryogenic RF test, the cavity showed Q_0 of about $5\cdot10^9$ and was limited to about 12 MV/m by quench at 4 K. At 2 K, the cavity Q_0 was about $2\cdot10^{10}$ at low fields and the cavity was limited to about 12 MV/m at 2 K. With these promising results, we started Nb_3Sn coating optimization using a mock cavity with the goal to control and improve Sn flow.

Acknowledgement & References

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[1] S. Posen https://doi.org/10.1088/1361-6668/30/3/033004