Superconducting RF Cavity Materials Research at the S-DALINAC

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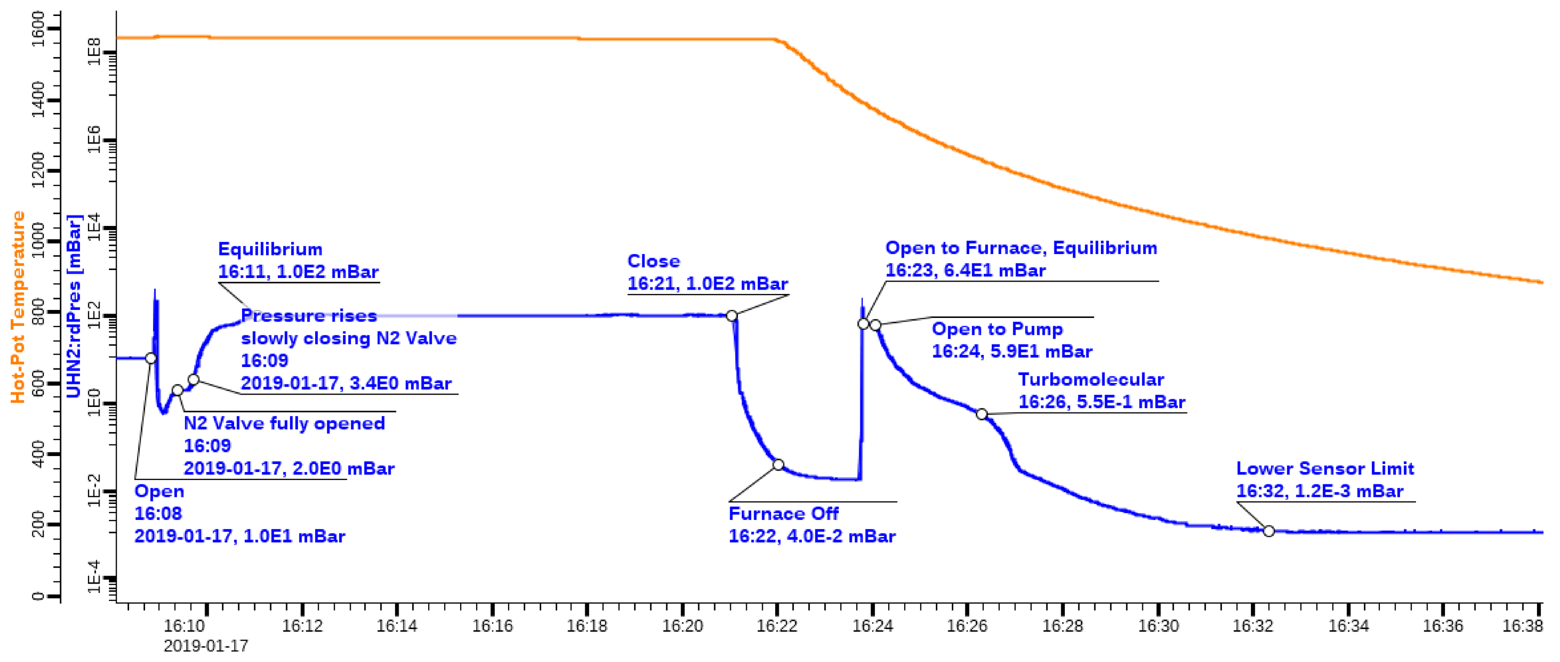
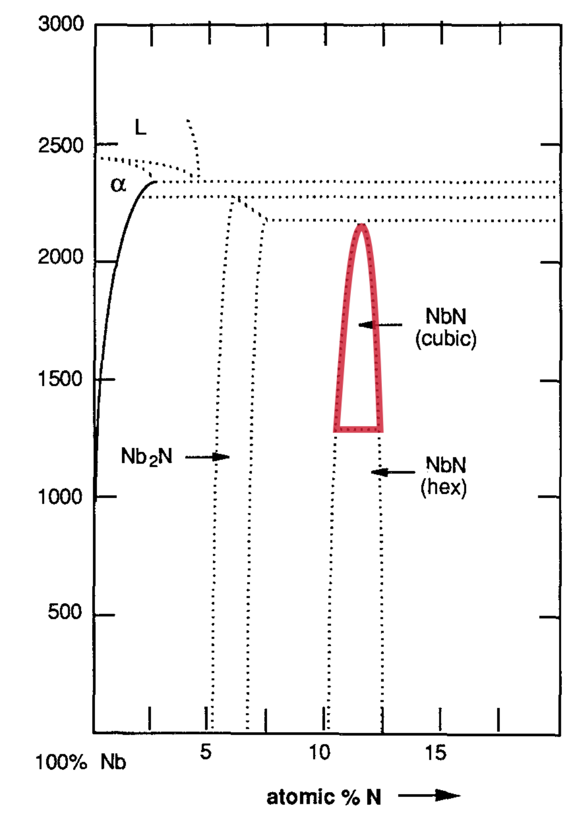
Abstract

Current state-of-the-art superconducting rf (srf) accelerators are mostly using cavities made of high RRR bulk niobium. The maximum field gradients and quality factors (Q_0) of these cavities are basically reached now. To further increase the srf cavity properties for future accelerator facilities, research of new materials for srf cavity applications is necessary. The current research at the S-DALINAC is focused on the development of bake-out procedures of Nb samples and cavities in nitrogen atmosphere of 100 mbar and up to 1750°C to nucleate the δ-phase of the Nb-N binary system. The δ-phase has superconducting properties which exceed the properties of bulk Nb. This makes the δ-phase attractive for srf applications. The vertical test cryostat (VT) at the S-DALINAC has been upgraded and recommissioned to allow investigations of the quality factor and accelerating field gradients of cavities before and after bake-out. The VT upgrade includes a newly developed variable input coupling to allow matching of the external q-factor (Q_{ex}) to Q_0. The results of the ongoing research of the nitrogen atmosphere bake-out procedures and the upgrade of the VT will be presented.

UHV Furnace nitrogen bake-out process

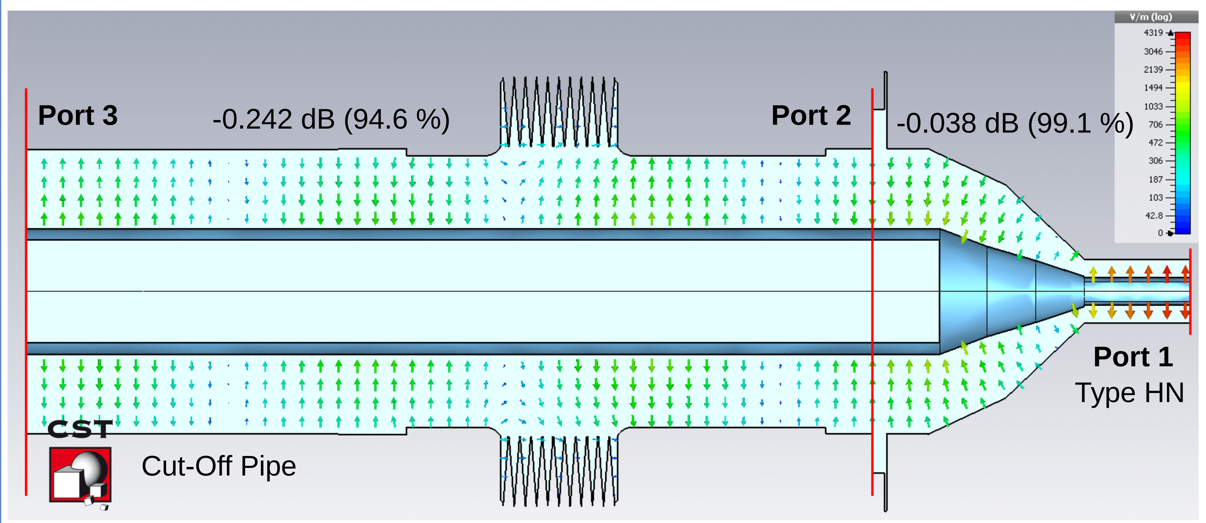


- Hot-Pot pressure before nitrogen bake-out: $5.6\cdot 10^{-5}$ mbar
- Up to 100 mbar for 10 minutes at 1550°C
- Results: MOP028, M. Major, this conference

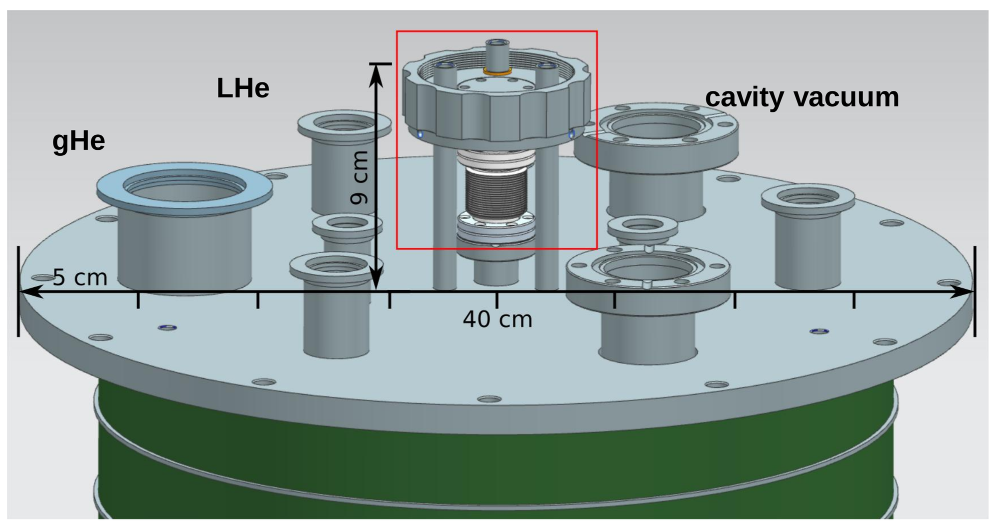


Hennessey *et. al*, Oxid. Met., vol. **38(1)**, p. 163, 1992

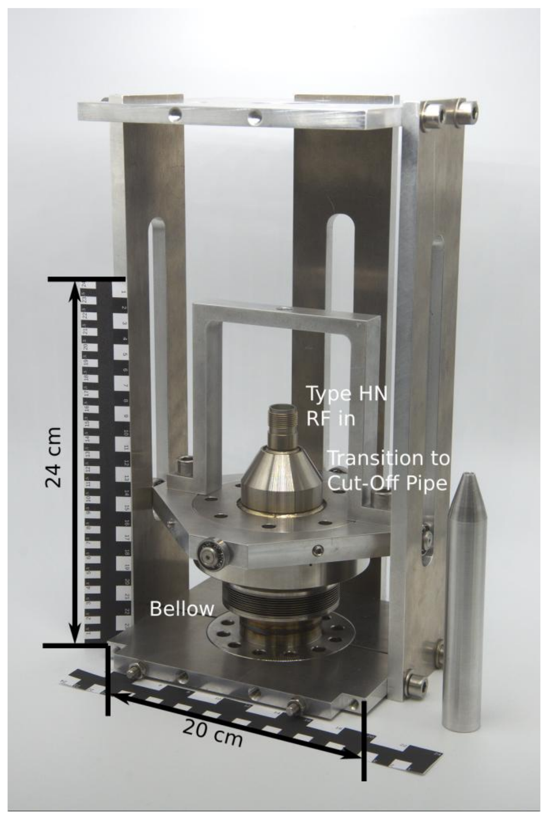
Vertical bath cryostat upgrade



Input coupler simulation of S-Parameters optimizing the geometry of the transition from Type HN RF input vacuum feedthrough (r_i=2.4 mm, r_o=5.6 mm) to cavity cut-off pipe (r_i=11 mm, r_o=25 mm).



New head cover with 40 mm cavity vacuum pumping ports, multiple ports for instumentation, LHe support and gHe outlet. In the center is the custom nut for controlling Q_{ex} of the input coupler.



New input coupler before final cleaning and assembly. The coupler is mounted on top of the cavity, allowing variation of the coupling strength.

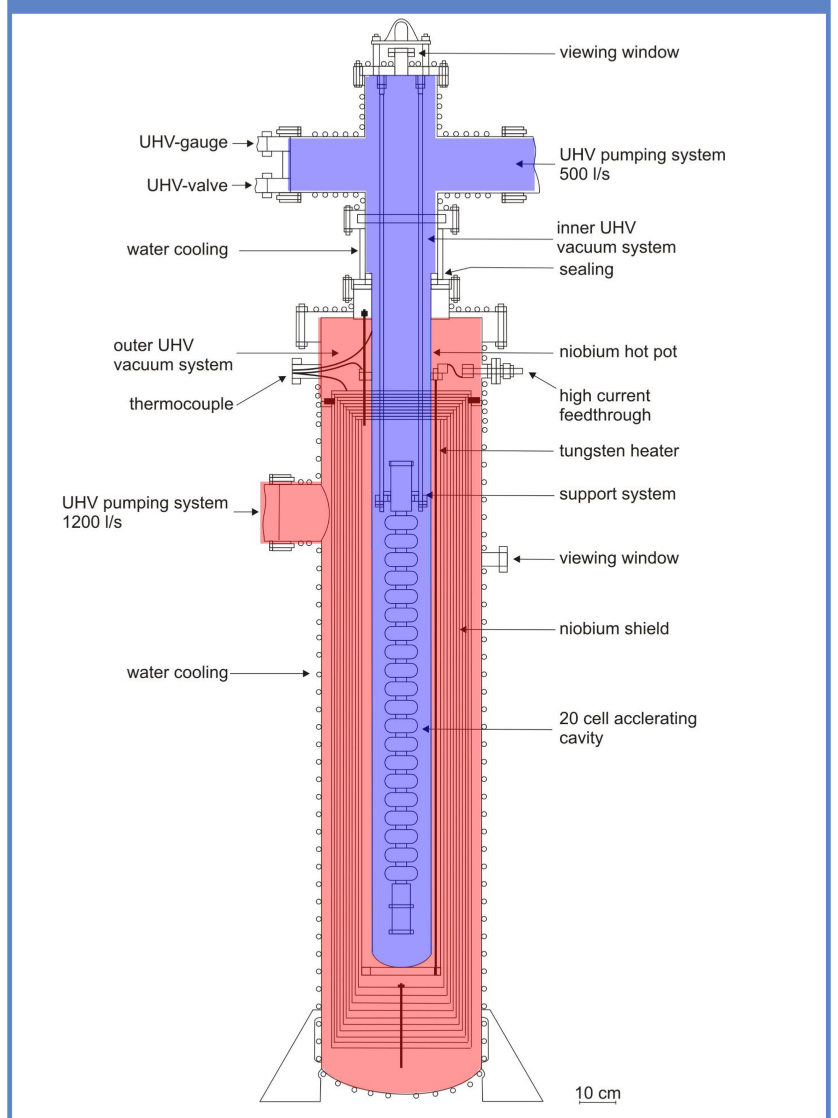
Ambitious redesign of VT

- new head cover with larger diameter vacuum feedthroughs
- new insert with variable input coupling
- coupling controlled with custom nut on head cover

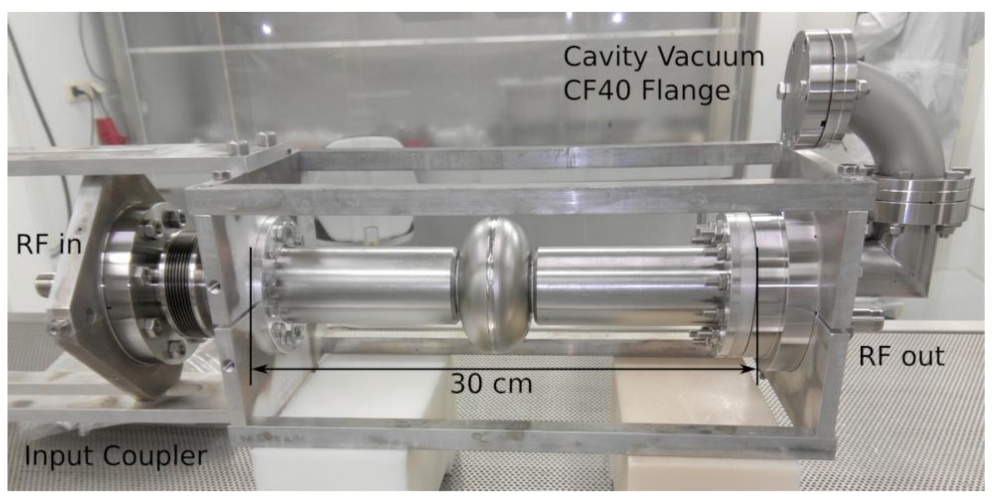
Allows matching of Q_{ex} from coupler to Q_0 of cavity minimizing measurement uncertainties.

New output coupler with Type N RF out and cavity vacuum pumping flange, upgrading from the previous CF16 diameter to CF40 allowing better vacuum performance.

UHV Furnace

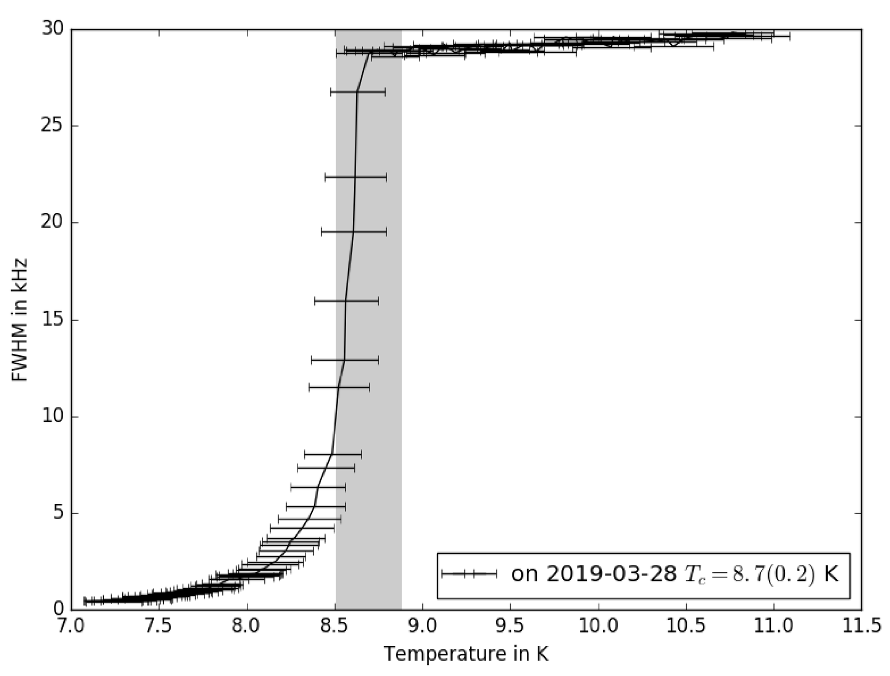


First test of the new vt insert

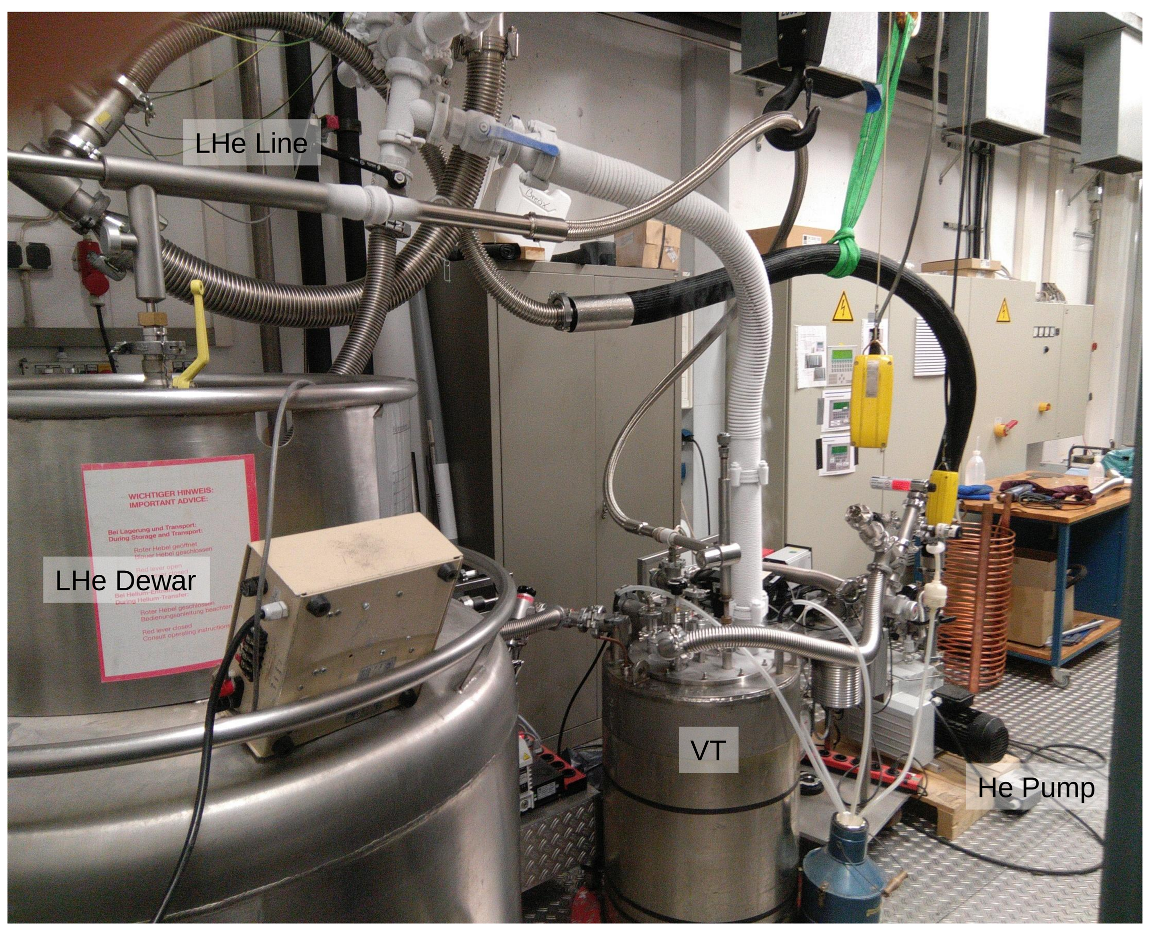


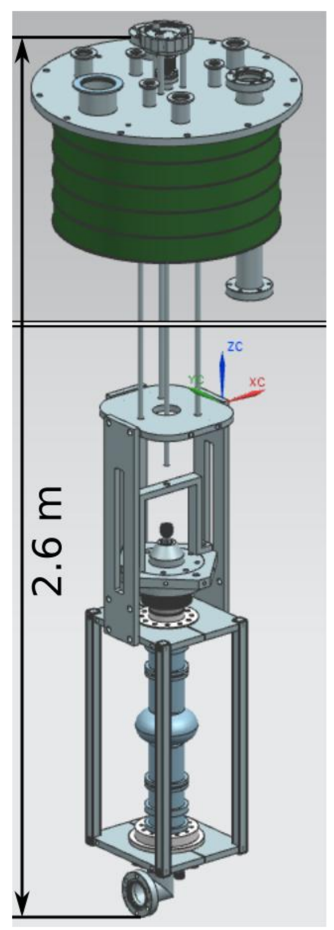
Clean room assembly of a single cell 3 GHz cavity in the new vt insert. Left of the cavity is the variable input coupler (top in vt), right of the cavity the new output coupler with CF40 cavity vacuum flange.

- Cooldown to 4 K with liquid helium (LHe)
- Further cooldown to 2 K using a rotary vane pump

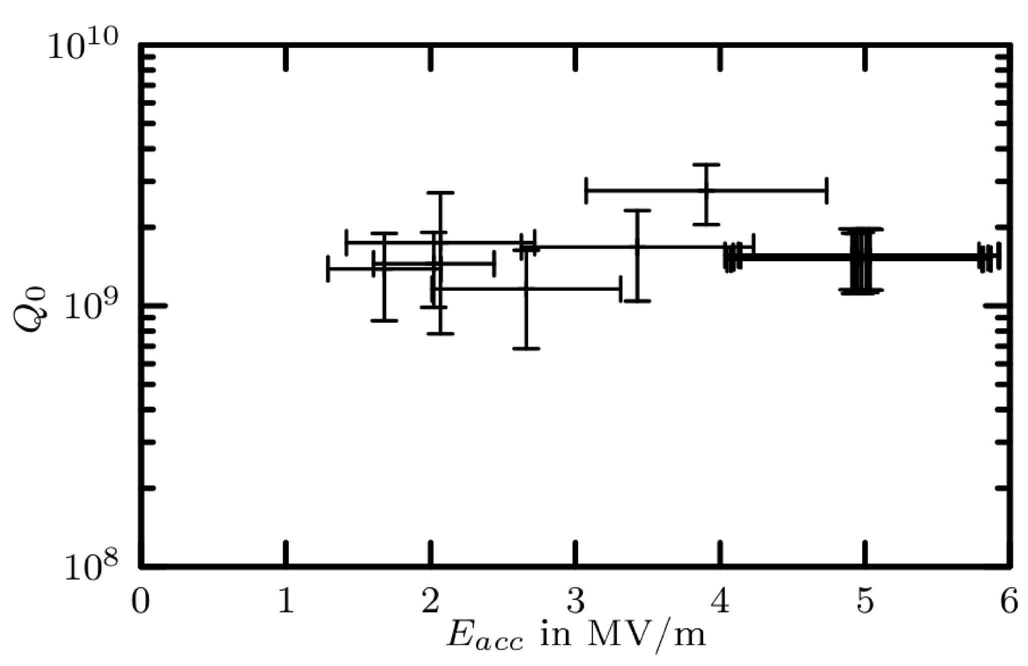


FWHM of the single cell cavity during cooldown. Below the critical temperature T_c = 9.25 K of Nb, a steep change of the slope occurs as the FWHM is drastically reduced due to the transition to the superconducting phase. This can be used as an first indication of a succesfull δ-NbN growth (T_c = 16.2 K).





Q_0 vs. E



Preliminary Q_0 vs. E measurement at T=2 K of a single cell cavity with the new vertical bath cryostat insert using a decay time method. During the measurement, the rf forward power did not exceed 1 W, the dissipated power at 5 MV/m is 400 mW.

- Expected Q_0 and E values for the single cell cavities have been reached

$Q_0 = 1.5(0.4)\cdot 10^9$
$E_{max} = 5(1)$ MV/m

Conclusion and outlook

- Ongoing sample bake-out in nitrogen atmosphere for δ-phase NbN growth
- Investigation of single-cell cavities bake-out with the same process will be done in the vt at the S-DALINAC
- Vt has undergone an ambitious redesign of the whole insert including new head cover
- Inital test of the new vt was successfull
- further tests with improved rf measrurment layout to reduce uncertainties and working out the Q_{ex} variation range of the input coupler

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