Performance Testing of Superconducting RF cavities at CERN in the Post-Construction Era of the LHC

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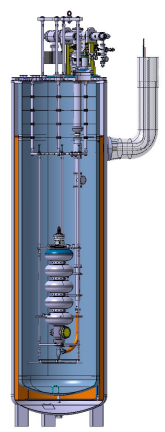
Validation of Superconducting RF Cavities at CERN

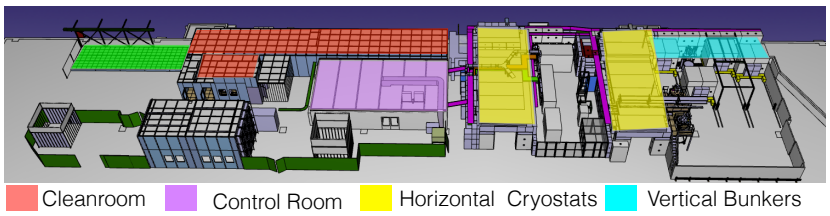
Recent infrastructure upgrades have permitted CERN to re-establish its SRF cavity testing program in the post LHC construction era, with bare and dressed cavity validation in vertical cryostats, and cavity cryomodule validation in horizontal test bunkers. Various of cavity types have been tested, ranging from standard elliptical cavities and quarter-wave resonators for beam acceleration, to crab cavities foreseen for beam manipulation at the HL-LHC upgrade of the LHC. Fully operational ISO5 and ISO4 clean rooms allow for the RF surface preparation and clean assembly necessary to achieve cavity performance targets. With measurements of niobium-coated copper cavities at 4.2K and bulk niobium cavities at superfluid temperatures down to 1.8K, attention has been taken to develop a full set of controls, procedures and diagnostics.

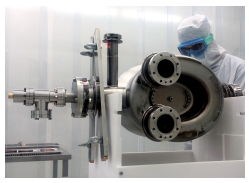
CERN's SRF Test Facility

- Test facility designed for cavity/cryomodule assembly and RF testing at cryogenic temperatures
  - 4 operational vertical cryostats + 2 Horizontal test bunkers (for cryomodules)
    - Largest cryostat: 2800 litres of LHe with cavity dynamic heat load up to 400W
  - Cryogenic operation: RF measurements between 1.8 and 4.5K
    - Full environmental control of test volume, including ambient B-field (to 30nT level)





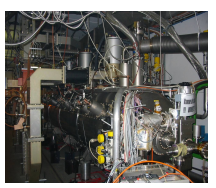


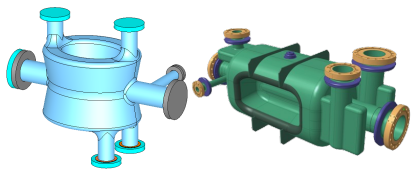


RF Tests at Cryogenic Temperatures

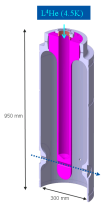
- Wide variety of cavity types tested at different stages throughout production
  - Testing of bare cavities, cavities with tuner and HOMS assembled, and cryo modules
  - Cavity diagnostics, mobile couplers, and quench localisation systems also deployed

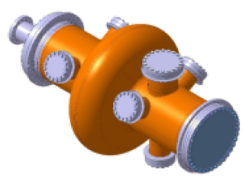






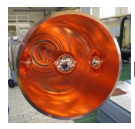

Cavity Types		RF Systems Tested at Cold	
Bulk Niobium	**Thin Film**	**Cavity**	**Assembly**
Transverse	1/4 wave	Bare cavity	Dressed cavity
5-cell Elliptical	Single cell	LLRF & cavity	Full cyromodule





RF Surface Preparation to Combat Field Emission

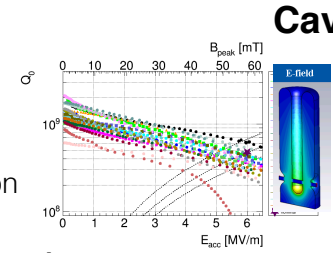
- ISO 4 cleanroom assembly + portable clean zones where need
- Cavity cleaning by ultrasonic bath & extensive High Pressure Rinse (HPR)
- Particulate control at all stages of assembly: both airborne and liquid (HPR) particulate monitoring



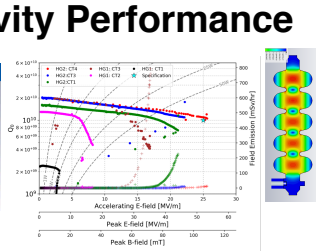

Cavity Performance

RF Perfomance

- Validation of cavity performance
- RF surface to 10nΩ level
- Acceptable levels of field emission



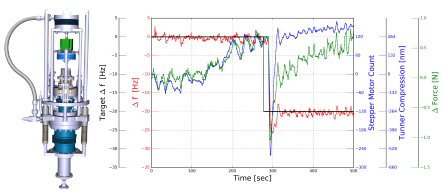
1/4 Wave Resonator



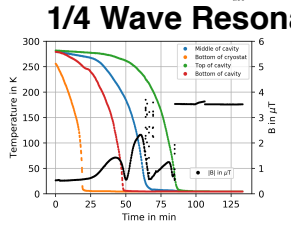
5-cell Elliptical

Measurement of Material Parameters

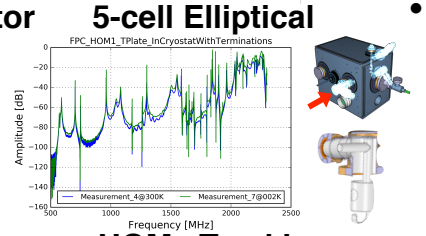
- Measurement of surface resistance
- RF field penetration depth
  - Frequency vs temperature from 2-10K
- Control of flux expulsion at T_C
- Monitoring of higher order mode evolution



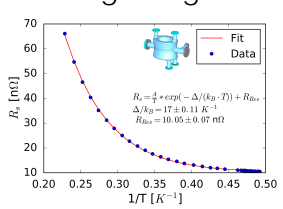
Tuner Control



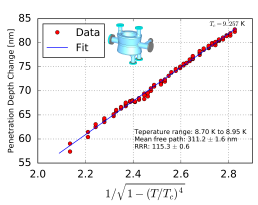
Flux Expulsion



HOMs Tracking



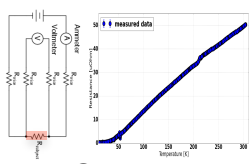
Surface Resistance



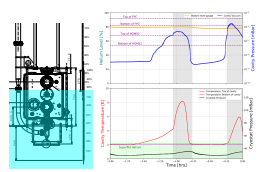
RF Penetration

Diagnostics

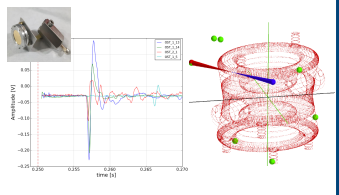
- In-situ RRR measurements on cavities: evaluation of cavity thermal conductivity
- Quench spot localisation: triangulation of 2nd sound waves in superfluid He
- Cavity response to tuner system: Crab LLRF - 70Hz resolution on 400MHz cavity
- In-situ localisation of leaks in superfluid Helium using LHe level and heaters



In Situ RRR Measurements



In-situ Leak Localisation



Quench Localisation

Conclusion

CERN's SRF facility is actively preparing and validating a variety of superconducting RF cavities through different stages from bare cavities to fully dressed systems and cryomodules. At each stage, quality control and diagnostics are optimised for RF performance and operation with manageable static heat load.

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