Cold tests of bulk Nb cavities at CERN

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on behalf of

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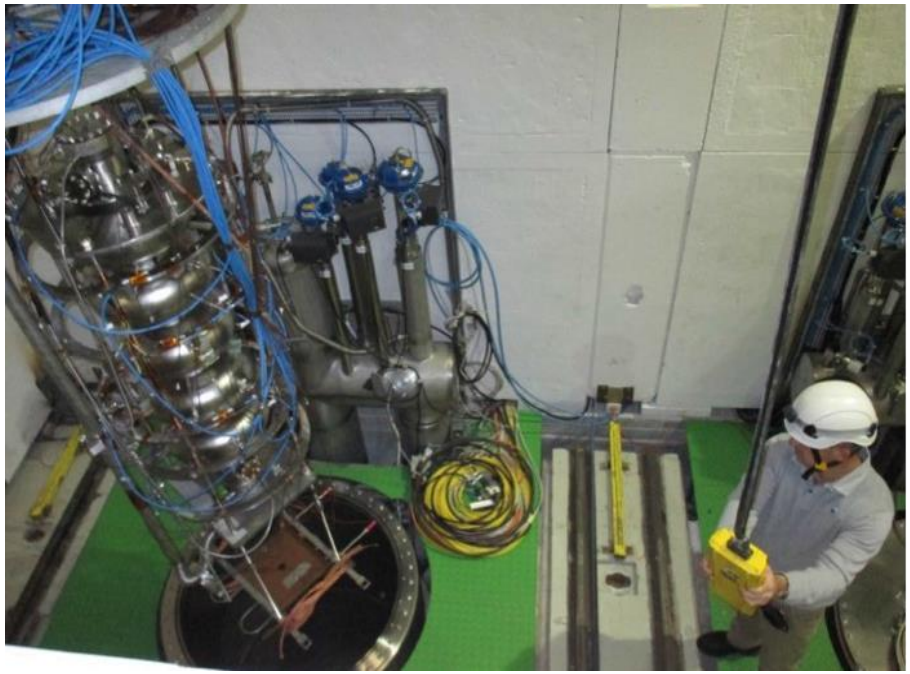
Bulk Nb Cavity Testing at CERN

- **RF cavity testing at CERN's SM18 Facility:**
  - 400 MHz Crab Cavities (Bare & Dressed) & Cavity Tuners
  - 704 MHz High Gradient Program,
  - 1.3 GHz cavity R&D

1980



2017

CERN's Bulk Niobium Program: Overview

- **HL-LHC Crab Cavity**
  - RF validation of bare and dressed 400MHz cavities for SPS
  - Cryomodule assembly and validation
  - Installation into CERN SPS for validation with proton beams (2018)

- **High Gradient Cavity Program**
  - Prepare and validate 5-cell ß=1 704 MHz cavities
  - Bring 4 cavities to specification for assembly
  - Assembly into a cryomodule for RF validation in CERN's SM18 facility

- **Process and Diagnostics development**
  - Cleanroom techniques and cavity assembly procedures
  - RF surface preparation improvement
  - Diagnostics for Quench localization,
  - Bulk and surface RRR measurements
  - Cooldown techniques, control of flux trapping

Recent Activities: Key Points

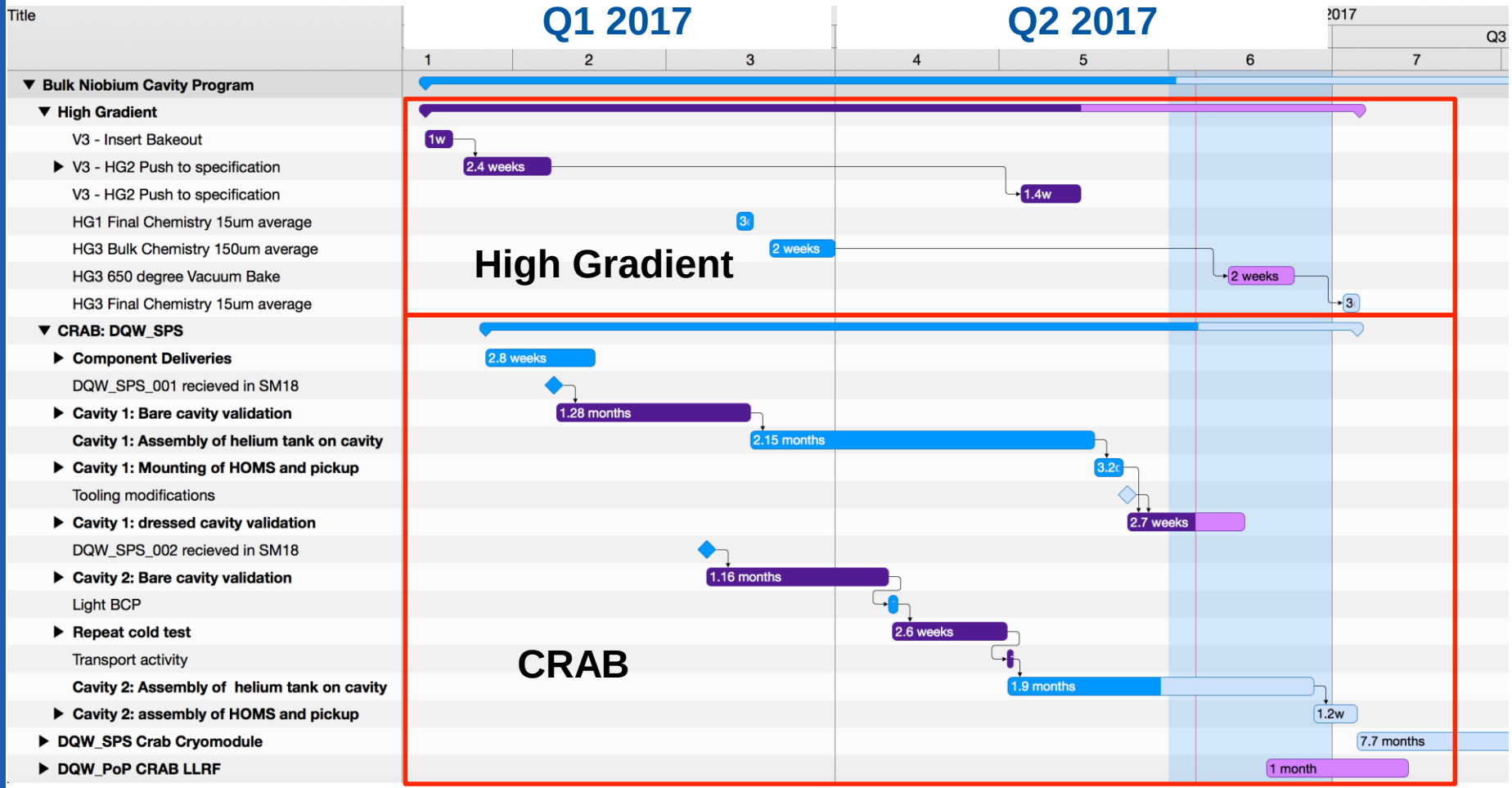
- **Over the last 12 months**
  - Upgrade of infrastructure interleaved with cavity testing
  - Ongoing upgrade of our 4m & 2m cryostats
  - ~ 9 months for RF Testing
    - Dominated by RF tests on Crab Cavities

- **HG Cavity Performance: Specification achieved**
  - Validated upgraded electro-polishing cathode design
    - Chemistry now proceeding on remaining cavities

- **Cleanroom assembly process**
  - Process and infrastructure reviewed for Crab project
    - Cavity handling and assembly more controlled & cleaner

Schedule from first half of 2017

- **Last 12 months dominated by HL-LHC Crab activity**
  - High Gradient RF tests “squeezed in”



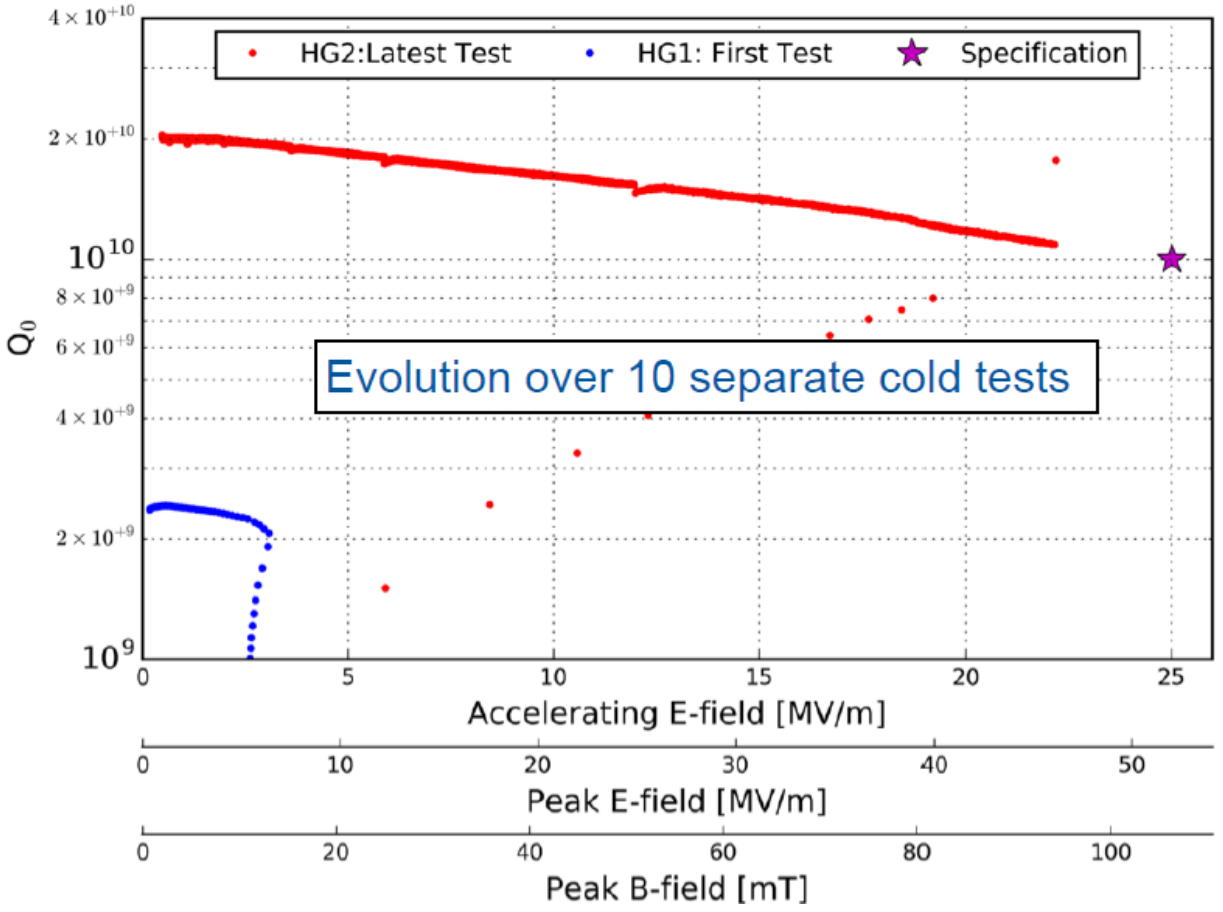
2016 Results: High Gradient

SLHiPP-6

- Improvements from cavity preparation significantly reduced field emission resulting in improved RF cavity performance

March 2016

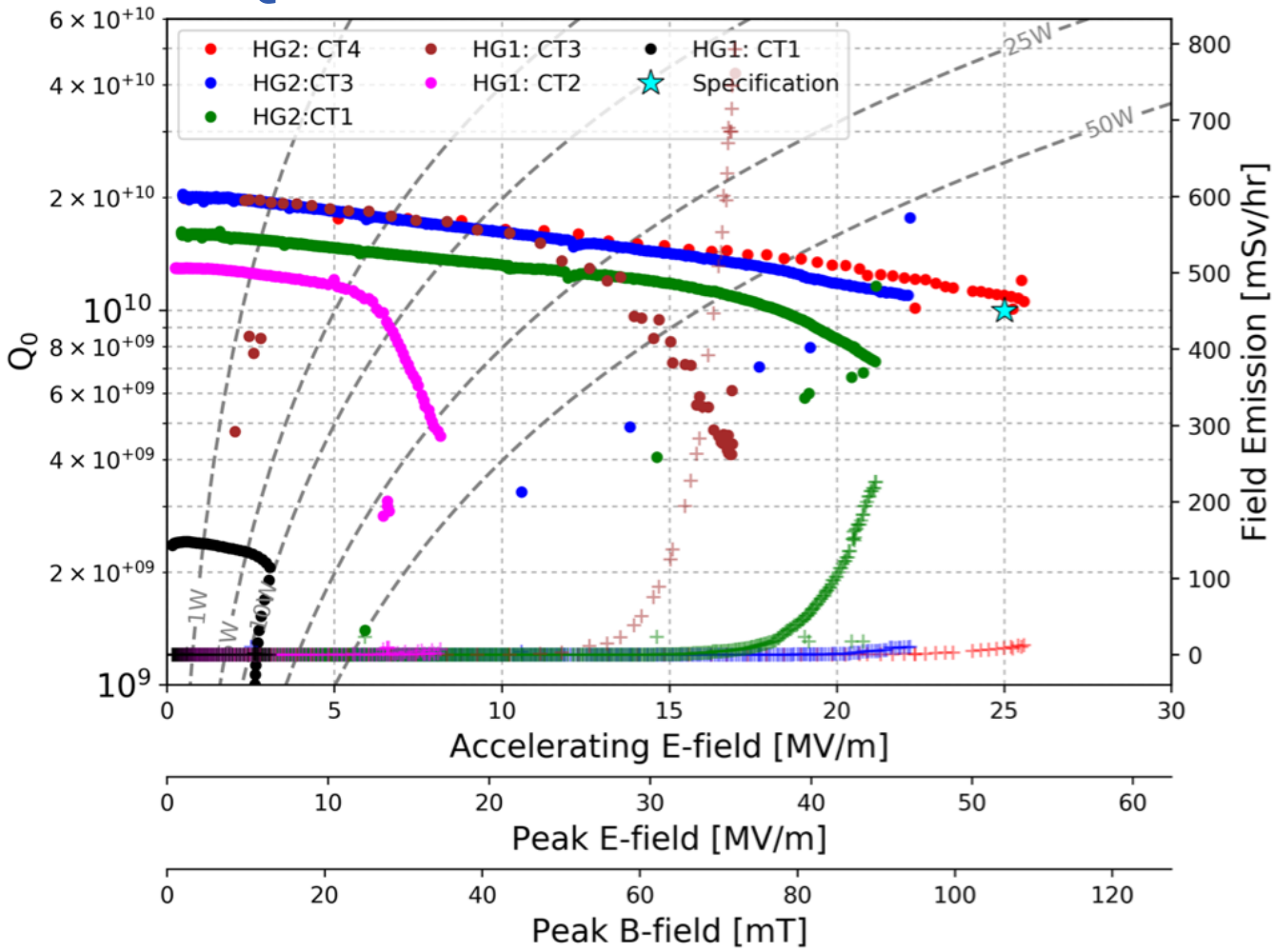
September 2014



2017 Results: High Gradient

- Continued improvement in preparation & test procedure
  => reduced field emission & reach specification

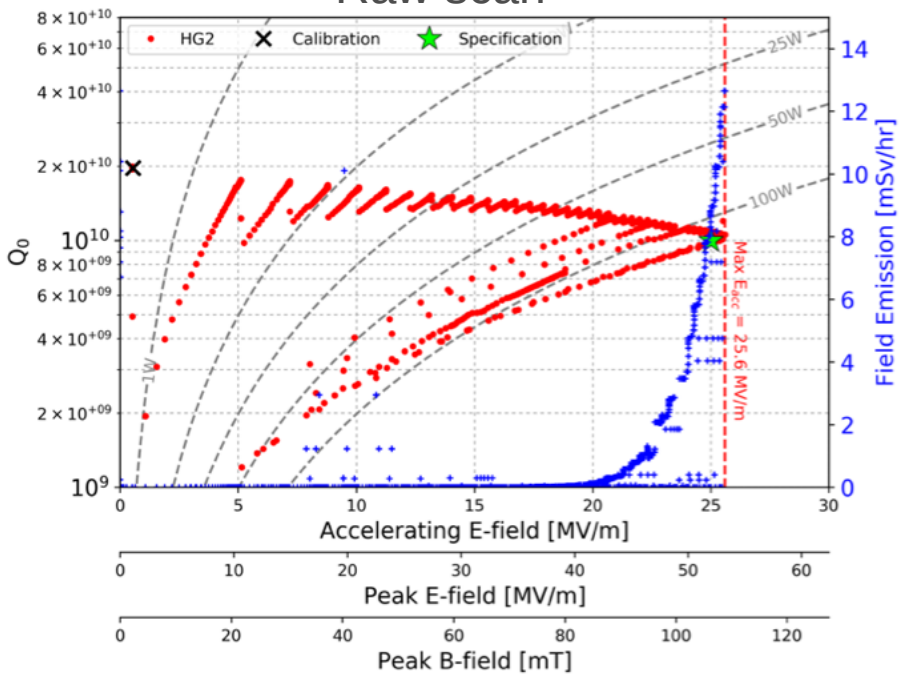
$Q_0 > 10^{10}$ at E_{acc}=25 MV/m



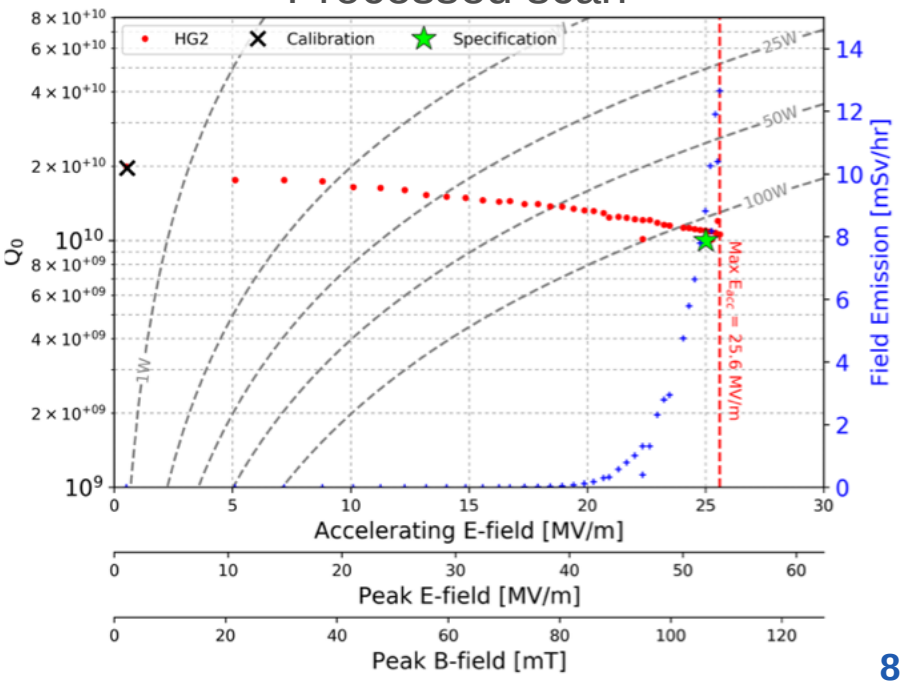
Performance Measurements

- **All scans performed in CW operation @ 2K**
  - Scan increments in watts => detailed scan at high power
- **Field emission above 20MV/m**
  - => Cavity assembly still to be improved
- **Moving to Self Excited Loop system**
  - Improvement of measurement uncertainties

Raw scan



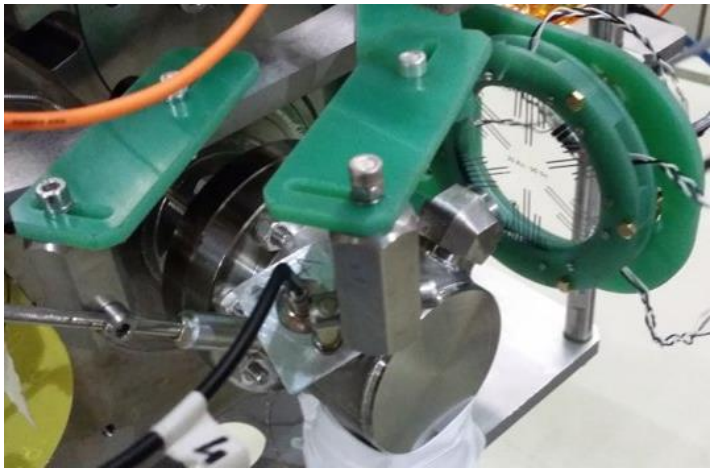
Processed scan

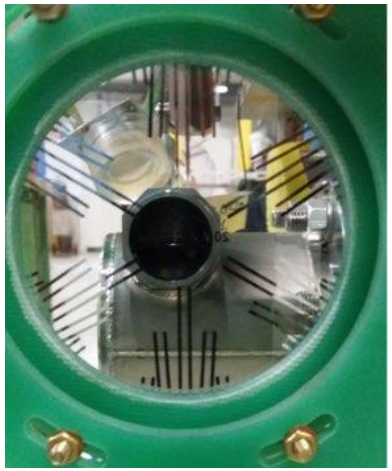


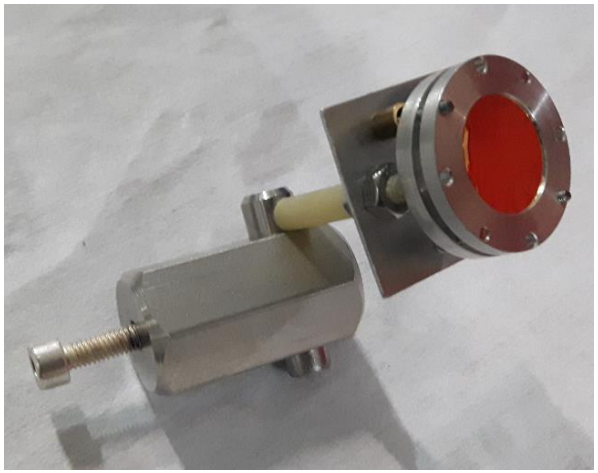
Quench studies

- **32 sensor array of OSTs**
  - Readout based on CEA-Saclay design
  - Resolved issues with signal loss
    - Signal lines in cryostat replaced (coax→ twisted pair)
  - Cleaned up signal to noise ratio by isolating OSTs from cavity and cryostat infrastructure
- **Test new Transition Edge Sensors for quenches**
  - Offers improved positioning resolution

Hernán Furci's talk

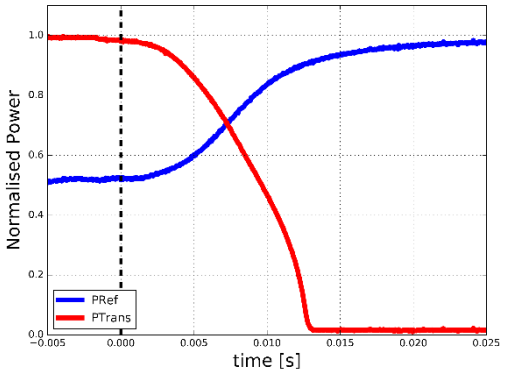


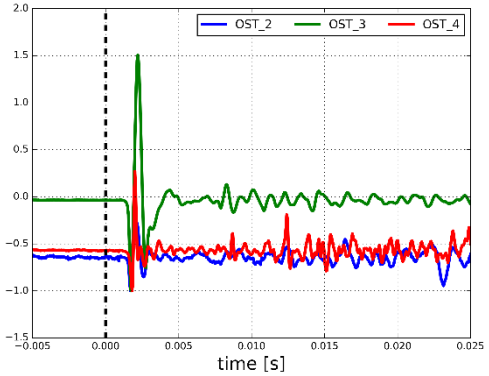


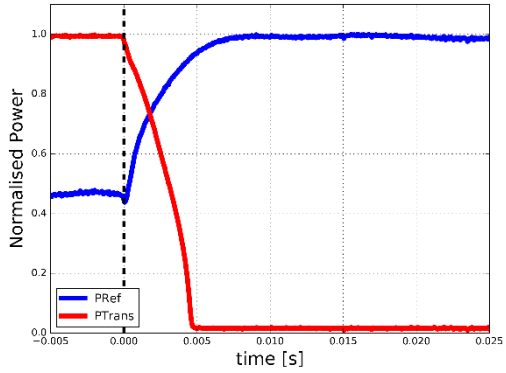


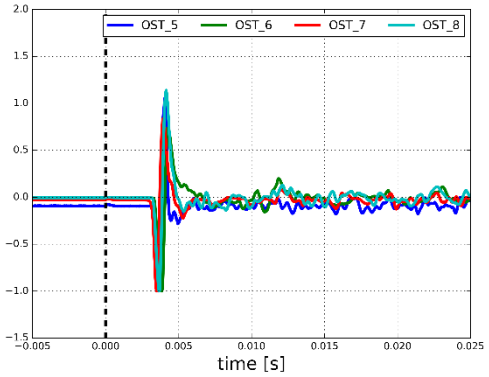
Quenches - 3 Varieties Observed

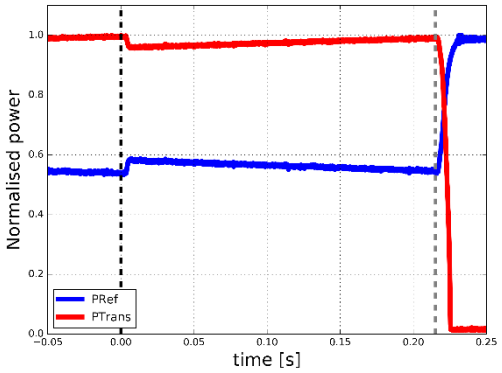
- **Local Quench**
  - Slow quench
    - Cell 1 equator
  - 2nd sound velocity
    - V = 12.4 m/s
- **Global Quench**
  - Fast quench
    - cell 3 equator
  - No localisation
  - 2nd sound velocity
    - V = 18 m/s
- **Double quench**
  - Small quench without cavity trip

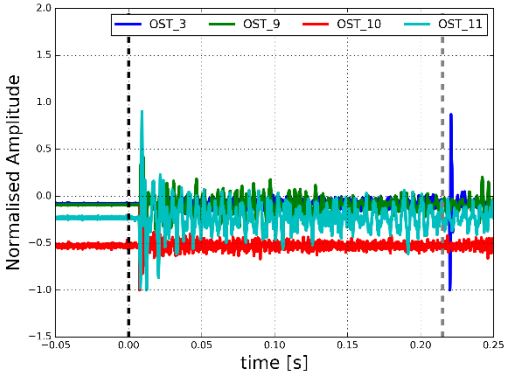






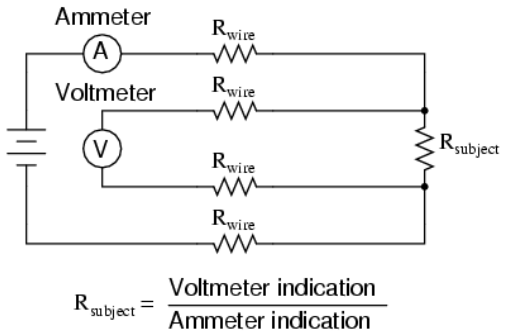






In-situ bulk RRR measurement

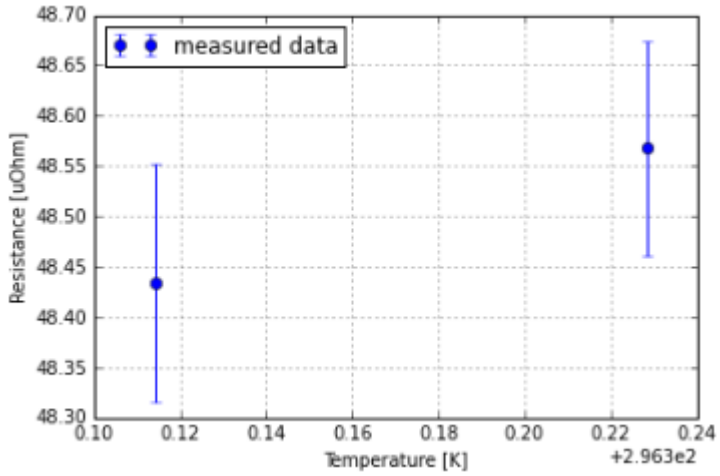
- **Standard 4-wire resistance measurement**
  - Measurement at 300K and at 10K
  - Resistance at 10 K: R~0.2 μΩ
  - **Fixation of wires to cavity is critical**

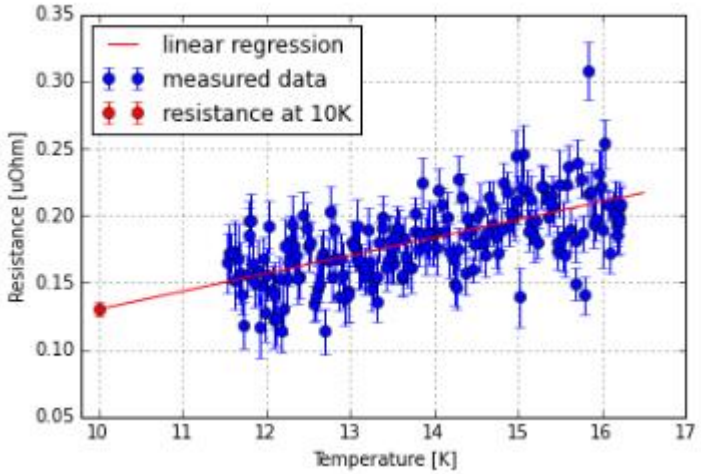


- **Procedure validated on Crab Cavities**

Cavity	Resistance at 300K μΩ	Resistance @ 10K μΩ	RRR
DQW SPS 1	64.247 +- 0.282	0.189 +- 0.025	340 ± 45
DQW SPS 2	49.022 ±0.112	0.130 ± 0.005	377 ± 15

RRR on treated Nb samples = 290 ± 30

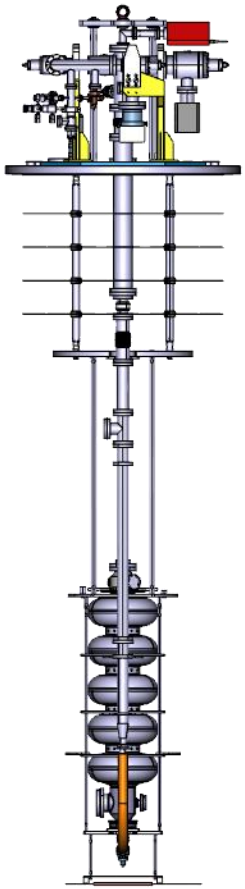


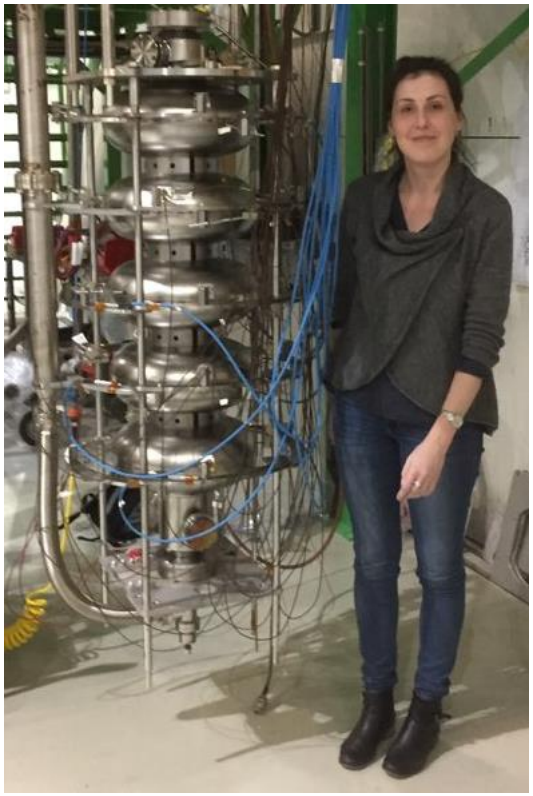


Upgraded Cryo Insert - Validated in 2016

- **Improved insolation & cryostat now leak free**
  - Infux heat flow reduced & electrical grounding scheme
- **Cavity positioned lower in cryostat**
  - Larger head of liquid Helium above cavity

OLD INSERT

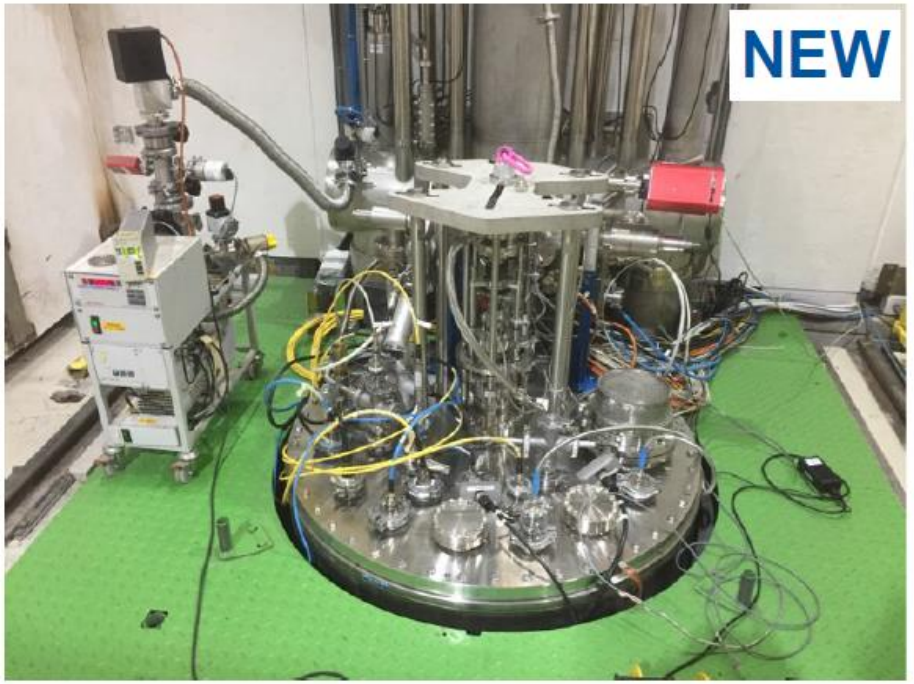




NEW INSERT

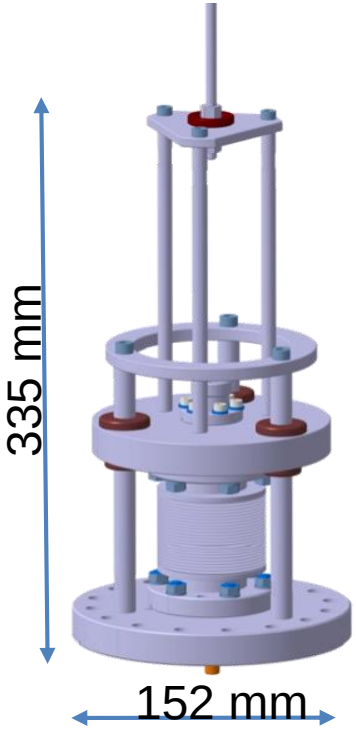
Infrastructure: Cryostat insert upgrade

- **New ‘top’ of vertical cryostat commissioned**
  - Insert assembly, installation & load balancing
- **Vacuum pumping system replaced**
  - Increased diagnostics (including RGAs added)
  - Pneumatic valves on pumping line:
    - Avoids ambient B-field issues when opening shielding

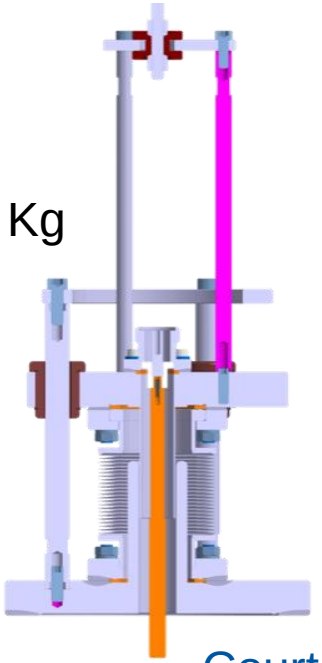


Improvements - Mobile Coupler

- **Switch to mobile coupler in Q3 2017**
  - Test power antenna re-designed for beam port
  - Coupler designed to work in 2K liquid helium
  - 50 mm range of movement
    => can have critical coupling from 10K to 1.8K
  - Will allow improved conditioning and cavity processing



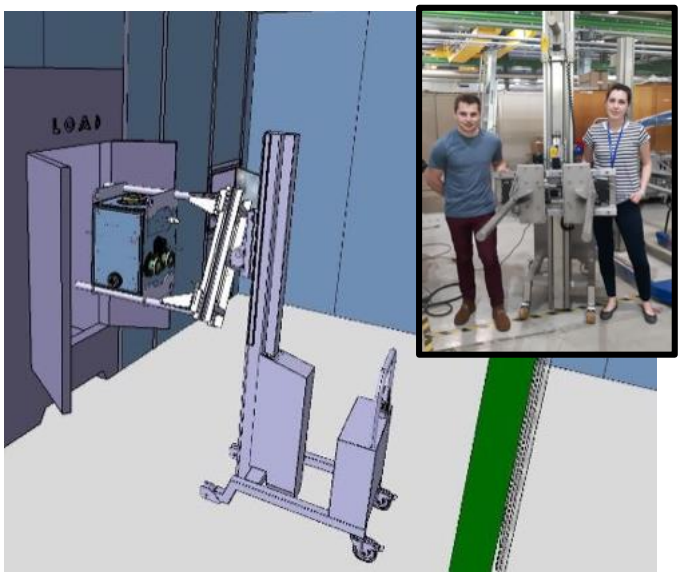
Mass 7 Kg



Courtesy of E. Montesinos and team

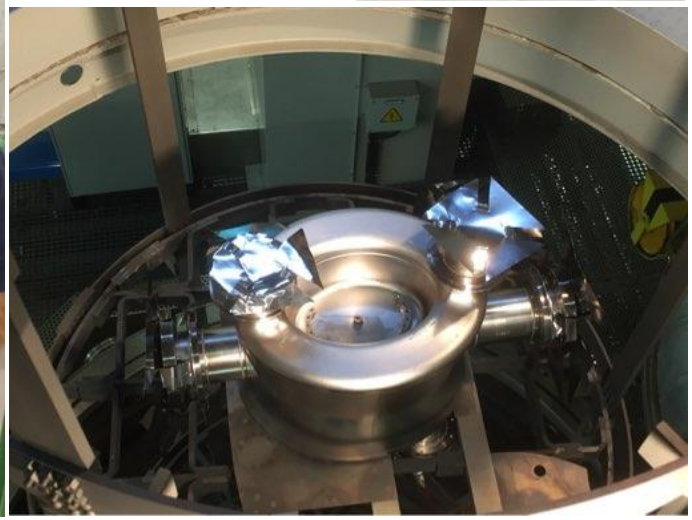
Cleanroom Practices

- **Post 2016 HL-LHC Crab Cavity cleanroom tooling review**
  - Re-tooling and improvement of ISO4 cleanroom infrastructure and practices
  - Reinforcement of cleanroom floor and purchase of cleanroom lifter matched to project needs
  - Removal of silver coated nuts/bolts from cavity assembly
    - Using silicon bronze nuts for flange assembly
  - Improved pre-assembly cleaning of pieces



Other Improvements

- **Cleaner connection of cavity to insert pumping line**
- **Reduction of contamination during 650ºC vacuum bake**
  - Use niobium caps on all ports during bakeout
- **Improved prep of cavity immediately prior to HPR**
  - Ultrasonic bath after final chemistry essential



Outlook

- **HL-LHC Crab Cavity Program**
  - Vertical Cryostat RF tests continue through 2017

- **High Gradient Program: 4 Cavities**
  - HG1: Chemistry re done → Preparing for RF Test
  - HG2: Achieved Specification: Now our reference cavity
  - HG3: Bulk EP done. Sent to vacuum oven for 650ºC bake
  - HG4: Waiting for EP

- **High Gradient Program: Cavity Testing**
  - RF tests to be interleaved with Crab program in 2017
  - Combine with commissioning of mobile coupler

- **Bulk Niobium program**
  - Target: 1 RF cold test per month per cryostat
  - 2nd cryostat coming on line in Q3 2017

Summary

- **CERN's Bulk Niobium program**
  - dominated by Crab cavity activities at present
  - … but still progressing with the High Gradient Program
  - Soon to have 2 vertical cryostats dedicated to RF testing of bulk Niobium cavities
- **High Gradient: One cavity has reached specification**
  - Other three cavities to under go same treatment/testing
  - Expect to finish initial test on all 4 cavities by Q1 of 2018
- **Ongoing developments**
  - Cataloging of quench behaviors and quench spot localisations prior to optical inspection
  - Validated deployment of Self Excited Loop LLRF system and semi automation of test procedures
  - Integration of mobile coupler into conditioning process

Thank you


CERN