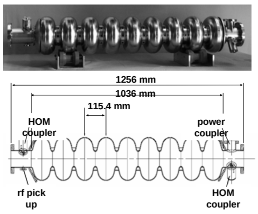
Superconducting Cavities

In collaboration with: CEA Saclay, CERN, Cornell University, INFN, KEK, TJNAF, Universität Hamburg

Cavity design

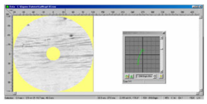
- **Superconductor offers low surface resistance**
  - Better efficiency
- Low frequency of 1.3 GHz
  - large aperture, smaller wakefields
  - good beam quality
- Large number of cells: higher fill factor
- 1 Fundamental mode coupler
- 2 HOM coupler
- Stiffening achieved via additional rings
- Individual tank and tuner



Cavity fabrication

Ta	≤ 500	H	≤ 2
W	≤ 70	N	≤ 10
Ti	≤ 50	O	≤ 10
Fe	≤ 30	C	≤ 10
Mo	≤ 50		
Ni	≤ 30		

Impurity content in ppm (wt)



Global view, rolling marks and defect areas can be seen

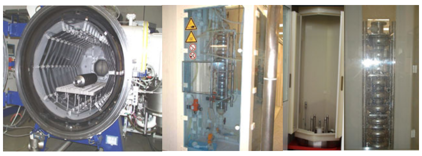
Real and imaginary part of conductivity at defect, typical Fe signal

Eddy current system for niobium sheets

- Detailed niobium material specification
  - Purity: RRR =300
  - Tantalum is most important substitutional impurity
  - Oxygen and hydrogen are the most important interstitials
  - Quality control using eddy-current system to avoid foreign inclusions like iron or tantalum
- Mechanical properties
  - The niobium grain size is very important to have good forming properties
- Detailed Welding Specification
  - 3 European companies qualified
    - Deep-drawing of subunits (half-cells, etc.) from niobium sheets
    - Chemical preparation for welding, clean room preparation
    - Electron-beam welding according to detailed specification

Electron-beam welding at industry

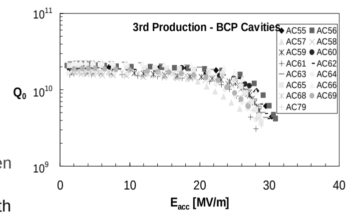
Cavity preparation

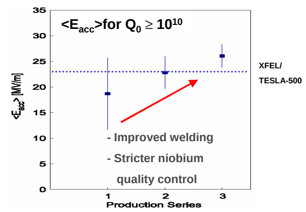


800°C furnace treatment | Etching facility | High pressure ultrapure water rinsing

Cleanroom assembly: Preparation for the acceptance test, for the high power test and module assembly

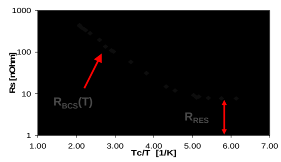
- 800 °C high temperature heat treatment to stress anneal the Nb and to remove hydrogen from the Nb
- 1400 °C high temperature heat treatment with titanium getter layer to increase the thermal conductivity (RRR=500)
- Cleanroom handling
- Chemical etching to remove damage layer and titanium getter layer
- High pressure water rinsing as final treatment to avoid particle contamination



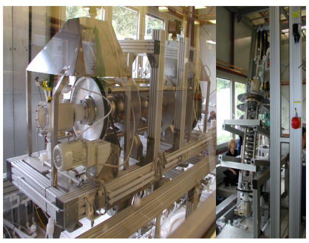


Experience with the TTF cavity production

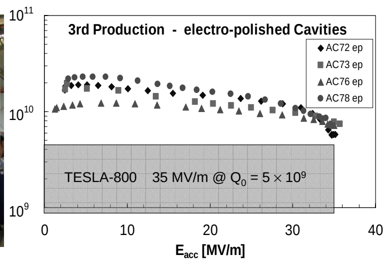
- Learning curve
  - 1st production suffered from
    - material defects
    - welding problems
- Third production cavities routinely achieve gradient and quality factor specification in acceptance test



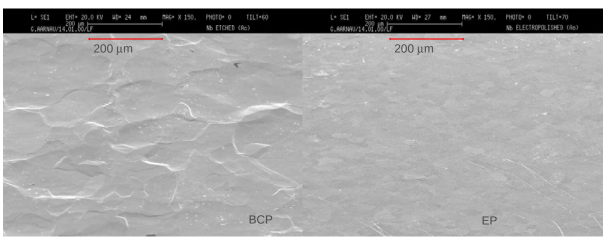
Electropolishing as improved surface treatment



Electropolishing setup at DESY



- Electropolishing offers:
  - better surface quality
  - higher accelerating gradients as demonstrated on several single-cell cavities and nine-cell cavities
    - explored first at KEK (with Nomura Plating) on single-cells resulting in accelerating gradients up to 40 MV/m (1998)
    - collaboration of CEA-CERN-DESY reproduced these results (2000-2002) on single cells
    - nine-cells were electropolished in collaboration of KEK and DESY (2001-2002)
    - four cavities yielded gradients of 35 MV/m in low power cw tests
  - potentially allows to omitt 1400°C firing
- First high power tests:
  - Installation of high power coupler etc. and final high pressure rinse in DESY clean room
  - Experimental setup for fast active tuning introduced



Etching - "Buffered chemical polish" | Electropolishing

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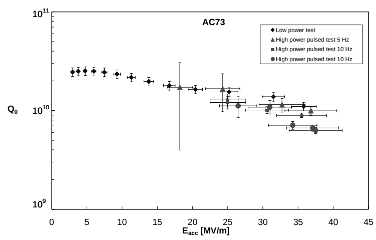
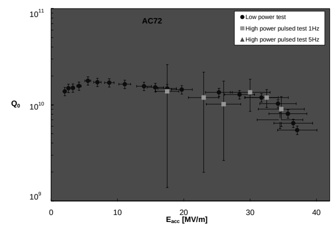
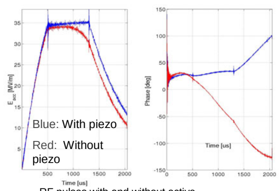
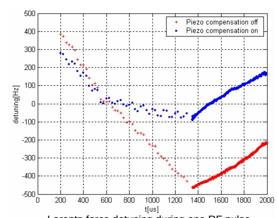
High power tests on two electropolished cavities



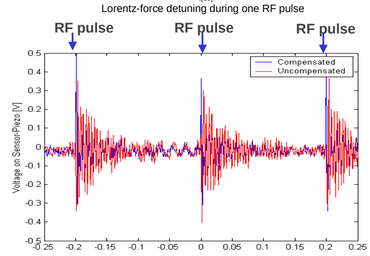




RF pulses with and without active compensation of Lorentz force detuning



Lorentz-force detuning during one RF pulse



Mechanical ringing of the cavity due to Lorentz-forces between RF pulses

- **Two electropolished cavities could be operated at 35 MV/m with a quality factor above specification**
- **Endurance test on AC73**
  - RF operation of the coupler
    - cavity off-resonance and not at 2 K
    - power between 150 – 600 kW
    - 5 Hz operation very smooth
    - 10 Hz causes heating of the warm ceramics
    - Total time RF on ~ 2400 hours
  - RF operation of the cavity
    - **1100 hours at around 35 +/-1 MV/m**
      - ~110 hours without interruption
      - 57 hours at 36 MV/m +
  - Piezo compensation
    - 500 Hz compensated
    - running about 700 hours
  - Cavity and coupler did not cause a single event
  - Of course the cavity quenched (20-30 times) or the coupler brofe down (10-20 times), but those events were caused by
    - Klystron/Pre-amp power jumps
    - LLRF problems
  - No degradations were observed
    - As expected the quality factor of the cavity did not change due to these quenches
    - The breakdowns did not degrade the coupler