Mechanical Issues SPL cavities/cryomodules Workshop CERN 30 Sep. 2009

Preparatory slides

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SPL cavities general parameters

Type of accelerating structure	β = 1/0.65	standing wave
Accelerating mode		TM_{010}, π-mode
Fundamental frequency	f_{RF} [MHz]	704.4
Nominal gradient	E_{acc} [MV/m]	25
Quality factor	Q_0	$1 \cdot 10^{10}$
Active length	L [m]	1.065
Cell-to-cell coupling	k_{cc} [%]	?
Iris diameter [mm]		~ 129
R/Q [Ω]		~ 570
E_{peak}/E_{acc}		~ 2.2
B_{peak}/E_{acc}	[mT/MV/m]	~ 4.4
Tuning range	[kHz]	?
$\Delta f/\Delta L$	[kHz/mm]	~ 250[1)]
Lorentz-force detuning constant	K_{Lor} [$Hz/(MV/m)^2$]	?
Q_{ext} of input coupler		$1 \cdot 10^6$
Cavity bandwidth	f/Q_{ext} [Hz] FWHM	704
Fill time	[μs]	460
HOM couplers	absorbing layer in between cavities	

Parameters of the five-cell β = 1 cavity (note: $R = V^2/P$, where P is the dissipated power and V the peak voltage in the equivalent LCR circuit).

[1)] Adopted from H. Saugnac et al., Preliminary design of a stainless steel helium tank and its associated cold tuning system for 700 MHz SCRF cavities for proton

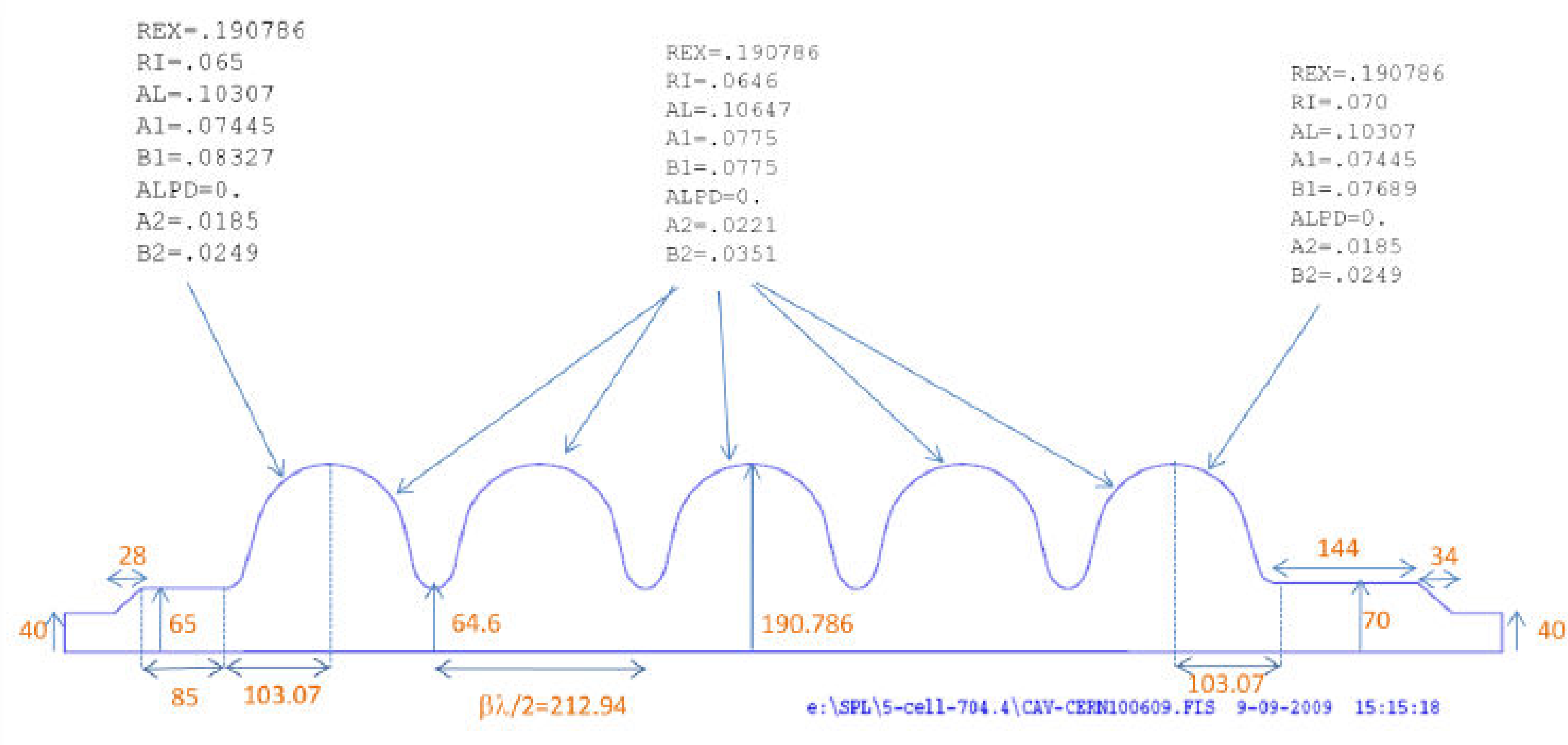
SPL cavities general parameters - Nb [1)]

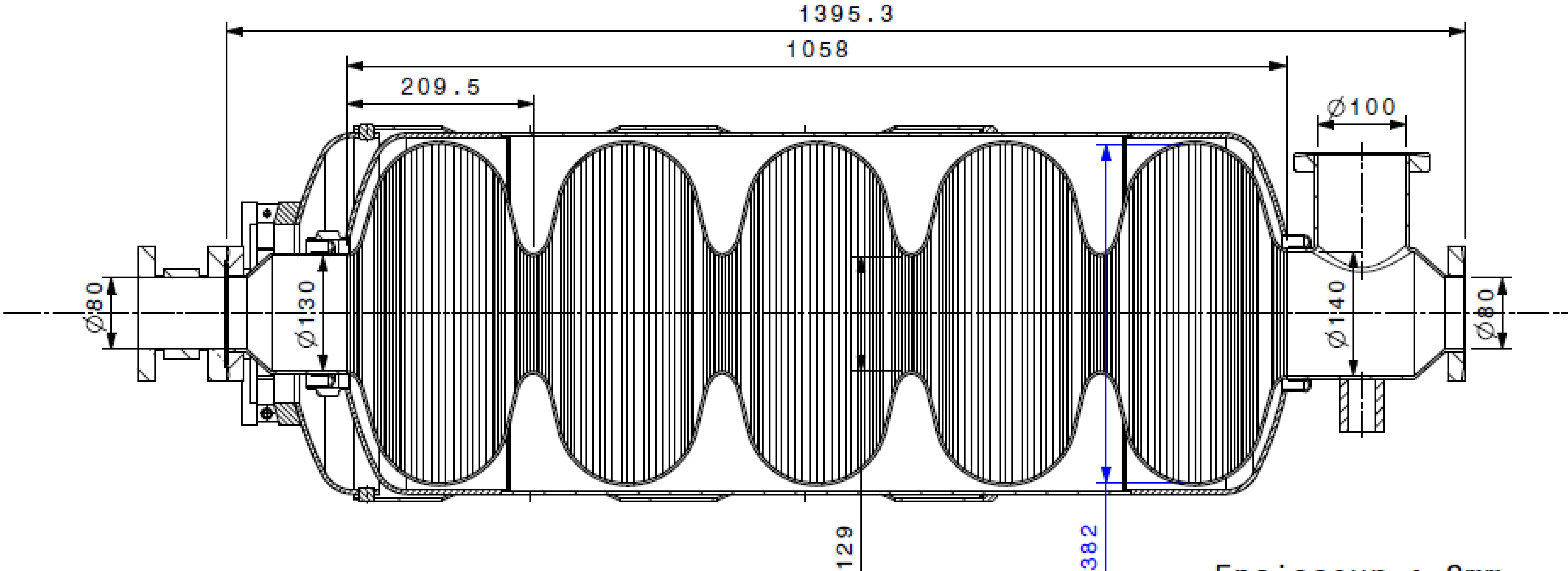
Electrical and mechanical properties of Niobium	**Content of the main impurities µg/g**
Residual Resistivity Ratio > 300	Residual Resistivity Ratio > 300
Thermal conductivity @ 4.2 K 10 - 100 W/(mK)	Ta ≤ 500
Grain size ≈ 50 µm	H ≤ 2
Yield strength > 50 N/mm^2	W ≤ 50
Tensile strength > 140 N/mm^2	O ≤ 10
Elongation at fracture > 30%	Mo ≤ 50
Vickers hardness HV 10 ≤ 60	N ≤ 10
Linear expansion $(L_{273}-L_{4.2})/L_{4.2}$ 1.3 ‰	Ti ≤ 50
Melting point 2468 - 2497 °C	C ≤ 10
Recrystallisation temperature 830 - 1230 °C	Fe ≤ 50
Stress relieving temperature 780 °C (1 h)	Ni ≤ 50

[1)] adopted from XFEL Design Report

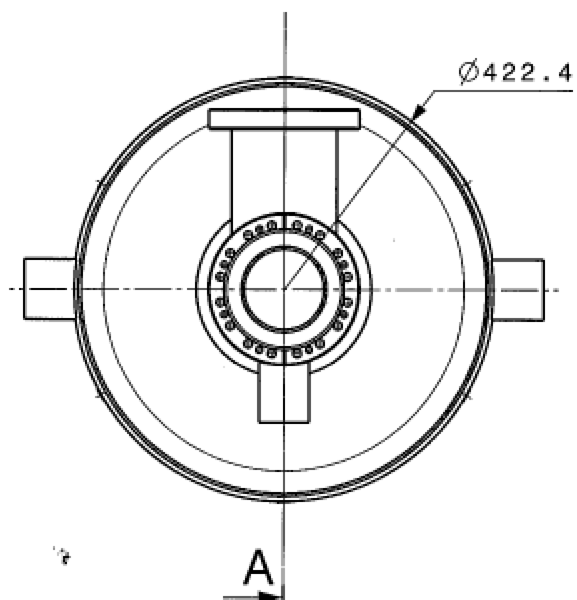
DIMENSIONS DE LA CAVITE SPL β = 1

DESIGN CEA-SACLAY

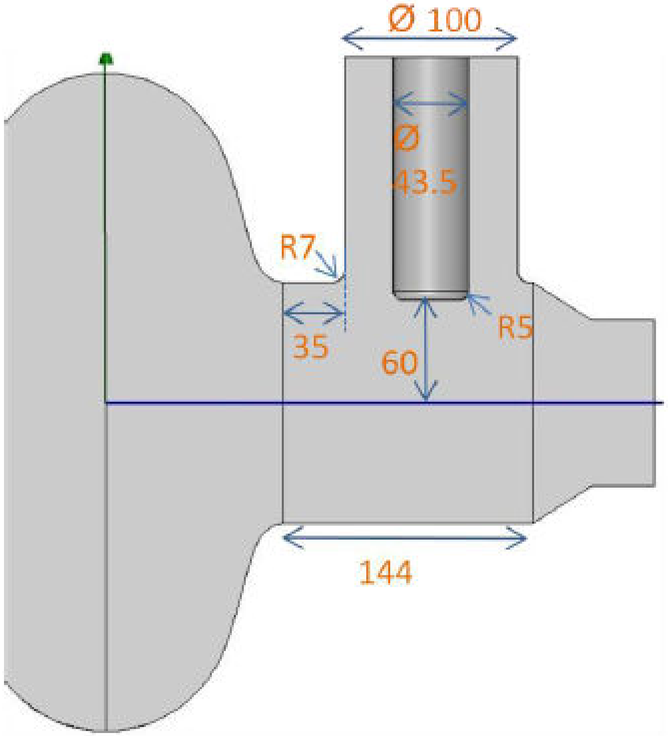




Epaisseur : 3mm



POSITION ET DIMENSIONS DU COUPLEUR DE PUISSANCE



Experience from DESY - Important production steps [1)]

- Deep drawing (die from anodized Al alloy)
- EB welding at iris and equator
- Annealing for re-crystallization under avoiding to grow large grains @ 750-800°C in a vacuum oven at a pressure of 10^{-5}-10^{-6} mbar for 1-2 h
- Full penetration EB welding (preferably from the inside) in good vacuum ($p < 5 \cdot 10^{-5}$ mbar)
- Removal of roughness and defects by grinding
- Intermediate frequency checks and possibly trimming mandatory
- Flanges from NbTi alloy (about 50%Ti)

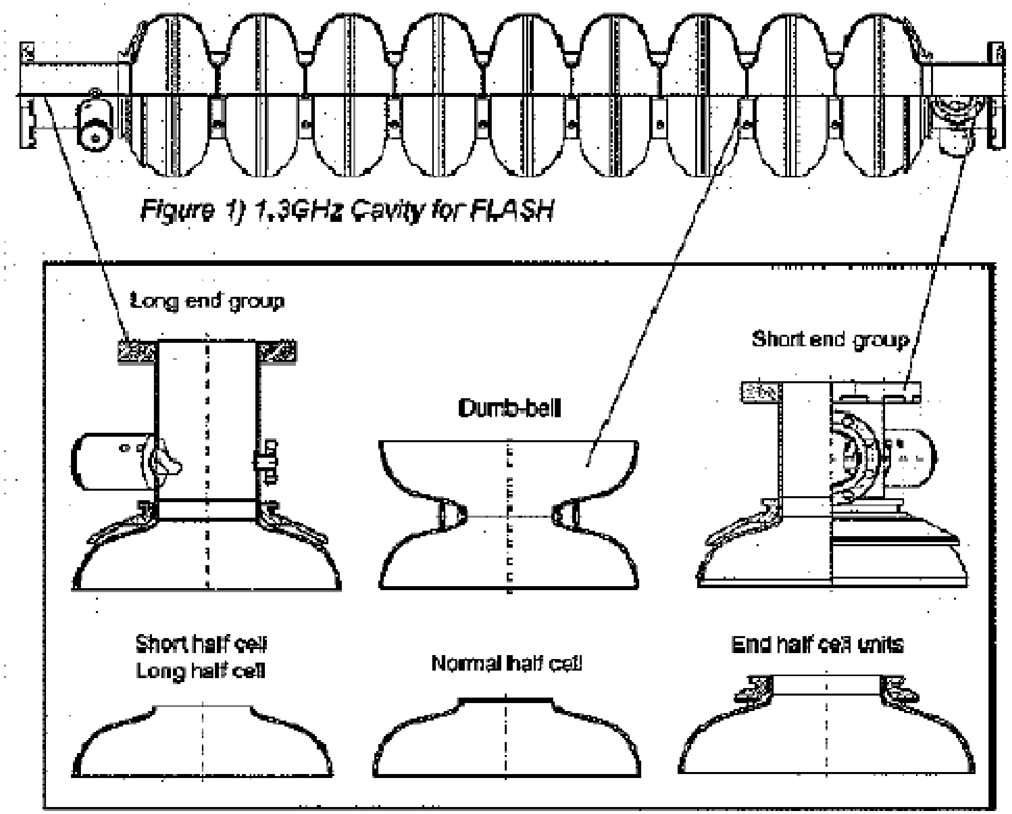


Figure 1) 1.3GHz Cavity for FLASH

Figure 2) Measurable parts and subassemblies of the 1.3GHz cavity

[1)] adopted from XFEL Design Report

Experience from DESY -

Important preparation steps for cavities [1)]

- electrochemical removal of a thick Niobium layer (so-called damage layer) of about 150 µm from the inner cavity surface
- a rinse with particle free/ultra-pure water at high pressure (~100 bar) to remove residues from the electrochemical treatment
- outside etching of the cavities of about 20 µm
- ultra-high vacuum annealing at 800°C (out-gas possibly dissolved hydrogen / relieve mechanical stress)
- tuning of the cavity frequency and field profile
- removal of a thin and final layer of about 30 µm by EP prior to the low power acceptance test done in a vertical dewar
- rinsing with particle free/ultra-pure water at high pressure (100 bar) to remove surface contaminants and drying in class 10 clean room
- assembly of auxiliaries (pick-up probe and HOM pick-up)
- baking at 120°C in an ultra-high vacuum
- additional six times rinse with high pressure ultra-pure water (100 bar)
- low power acceptance test at 2 K temperature

[1)] adopted from XFEL Design Report

Experience from DESY -

Important preparation steps for string assembly[1)]

- disassembling cavities in clean room from vertical test insert
- measurement of field profile and frequency in clean room
- tank welding in normal workshop area
- provisional input antenna replaced by the power coupler
- cavities are rinsed six times with ultra-pure high pressure water
- insertion of a bellows between the beam pipes of the individual components in a class 10 clean-room
- integral leak check

[1)] adopted from XFEL Design Report

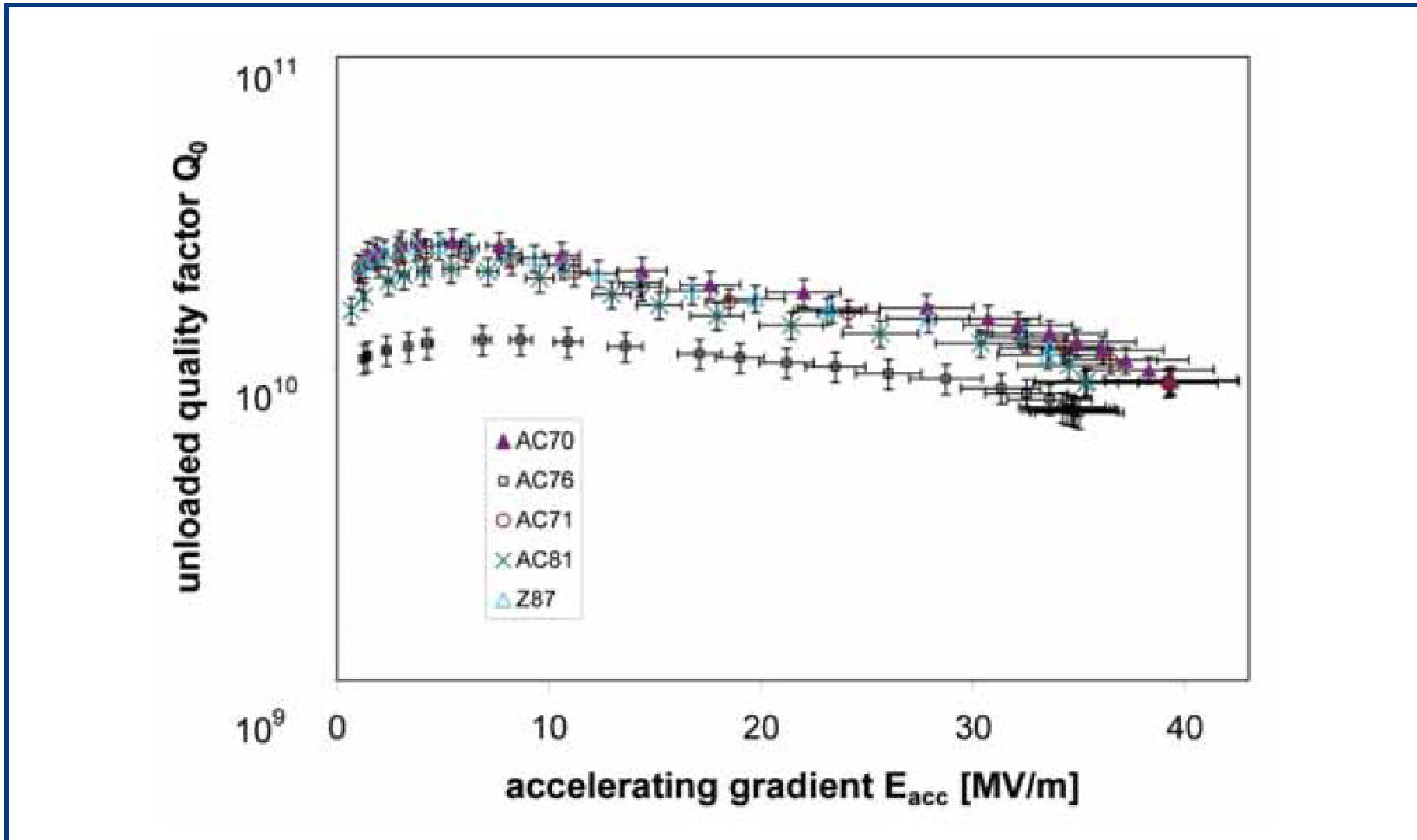


Figure 4.2.4 *"Excitation curves" of the best cavities treated with 800°C furnace treatment and EP. The XFEL baseline gradient of 23.4 MV/m is exceeded by a significant margin.*

[1)] adopted from XFEL Design Report

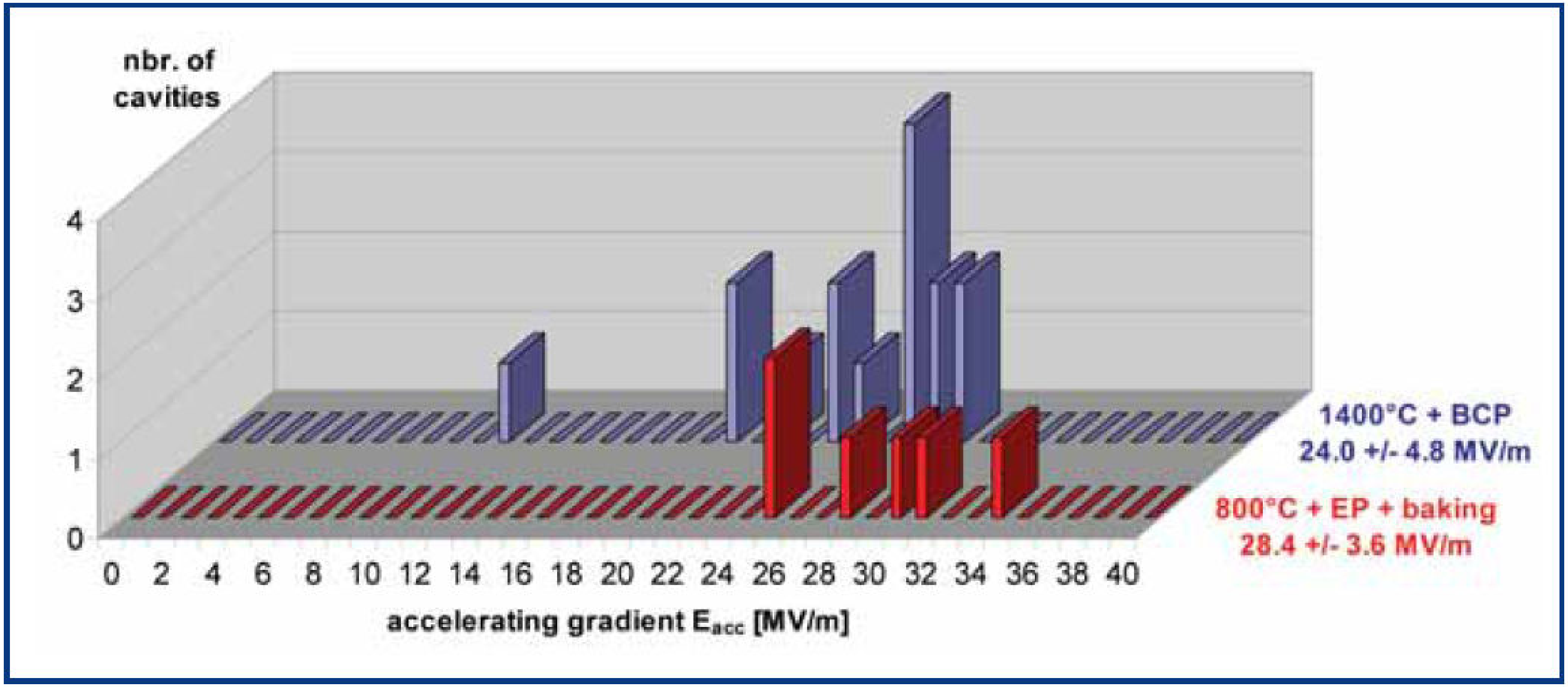


Figure 4.2.5 *Comparison of the accelerating gradients at $Q_0=10^{10}$ in the first performance test after the full preparation sequences using etching with post-purification at 1,400°C (blue) and EP with 800°C annealing (red).*

[1)] adopted from XFEL Design Report

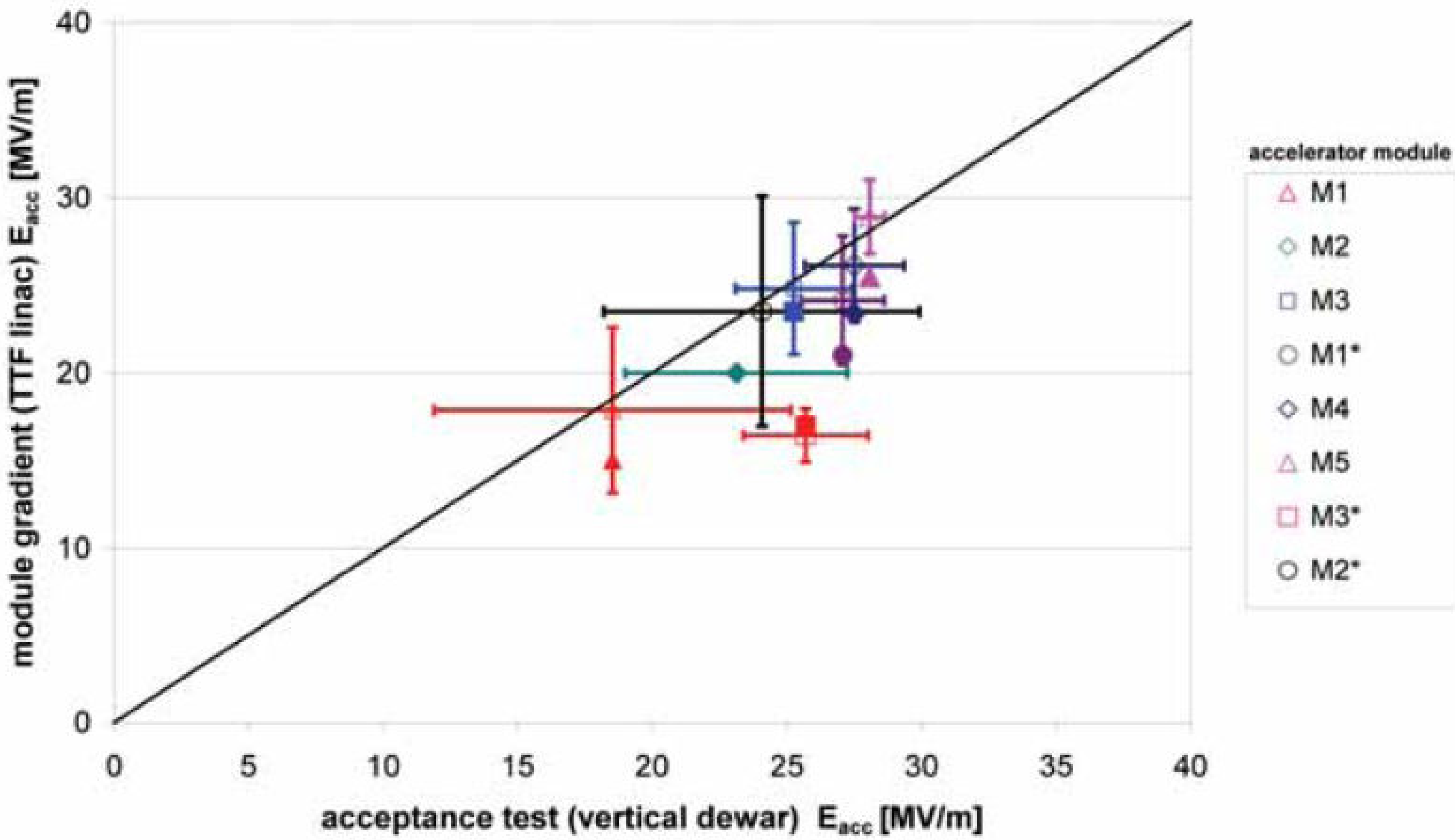


Figure 4.2.7 *Performance of the TTF accelerator modules. The plot shows the average maximum gradient in the accelerator modules against the average gradient achieved in the acceptance tests at Q=10^{10} (open symbols). In addition, the operational gradient of the modules is plotted against the acceptance test gradient (closed symbols) which is based on equal RF power feeding.*

[1)] adopted from XFEL Design Report

Experience from DESY -

Cavity weld to He vessel issues

- keep E_a, f, field flatness
- welding done after vertical test @ 2 K
- *Is welding possible before 120 °C baking and before vertical test?*
- *Yes, but under stepwise check of f and field flatness by field profile measurement system (automated system operational, J. Iversen, SRF2009, THPPO071)*

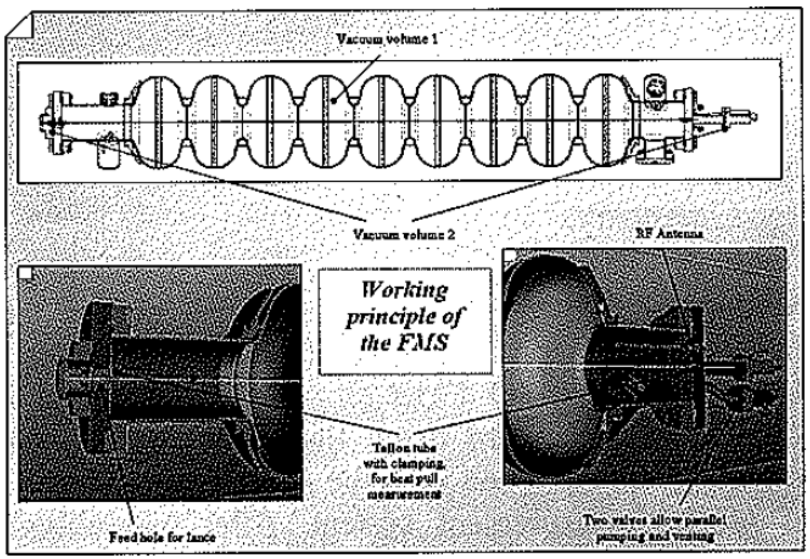


Figure 2: Layout of the FMS.

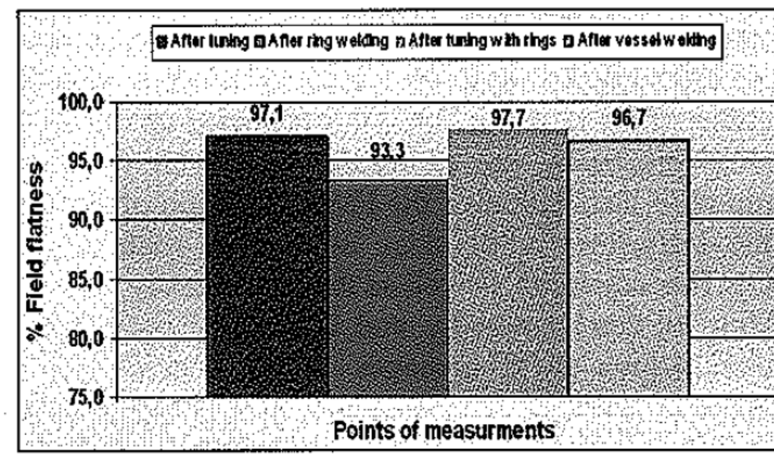


Figure 3: Average field flatness shift during welding

[1)] adopted from A. Schmidt et al., SRF2007, Beijing (China) & SRF2009 THPPO040

Experience from DESY -

Some engineering wisdom

- Shaping
  - Hydroforming avoids welds and hence is less time-consuming;

    Tubes are available at Plansee

    But: the larger the cavity the more difficult is the hydroformin
- Joining
  - Discouraging experience with Stainless Steel brazings at HERA (leaks)
  - Welding Nb – SS possibly seems not possible (melting temperature different)
  - Connection between cavity and He tank: Nb tube – Nb ring - NbTi flange - Ti tank
- Flanges and gaskets
  - Helicoflex not appreciated because it might emit particles
  - Al diamond shaped gasket OK for NbTi flange; no leak problems
  - But: 2 X higher etching rate for NbTi than for Nb (cover needed)

Experience from CERN -

Cavity weld to He vessel issues

J. P. Bacher , E. Chiaveri and B. Trincat, Brazing of niobium to stainless steel for UHV application in superconducting cavities, CERN/EF/RF 87-7, 5 December 1987

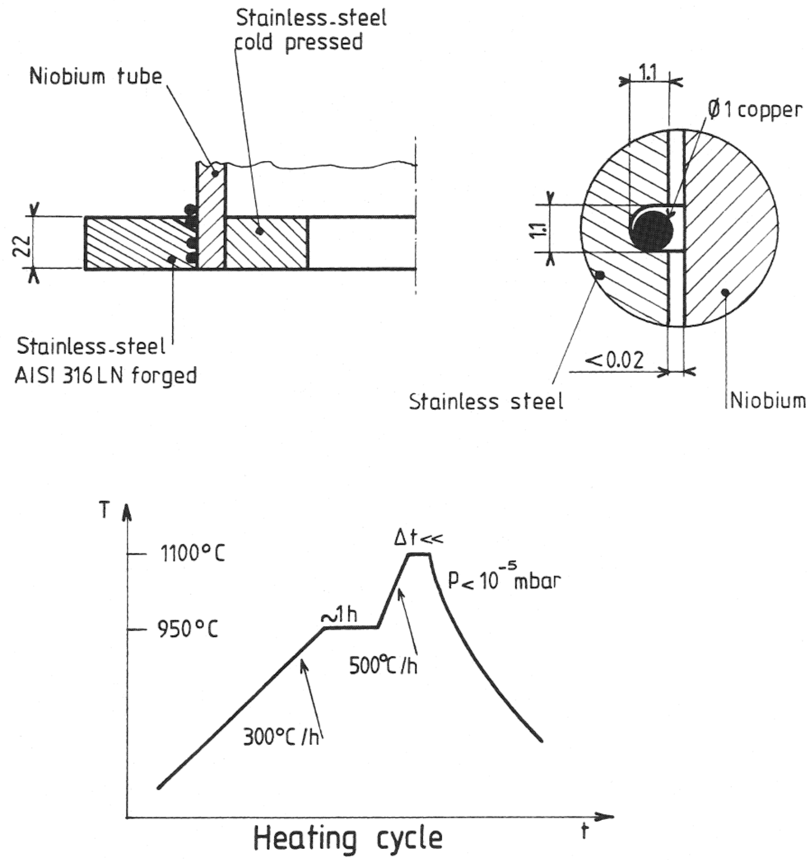


Fig. 3

The process shown in fig. 3 has been used to braze stainless steel flanges to niobium tubes which equip Nb superconducting cavities [3].

[3] G. Arnolds-Meyer et al., CERN/EF 87-9.