Superconducting 1.3 GHz Cavities for European XFEL

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Presented by Waldemar Singer

Main issues: preparation phase are finished, production is going on

The European X-Ray Laser Project XFEL

Superconducting 1.3 GHz Cavities for Europen XFEL

Preparation Phase 2005-2010

Specification

Mechanical fabrication

Treatment

Documentation

Prototype cavities

Production Phase 2010-2015

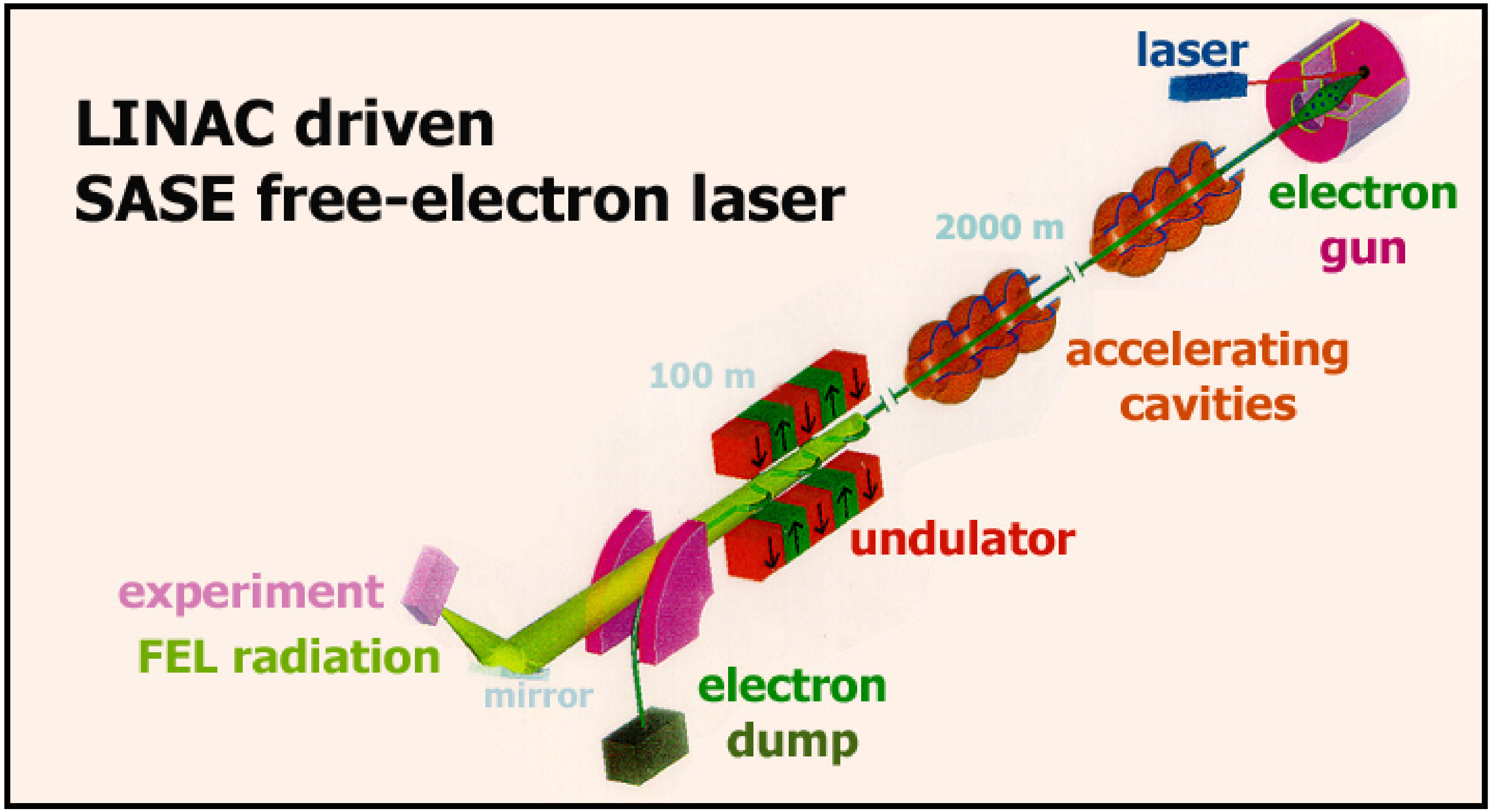
Current status of the cavity fabrication

The European X-Ray Laser Project XFEL : a revolutionary photon source

Synchrotron radiation user facility with SASE (Self Amplifying Spontaneous Emission) concept

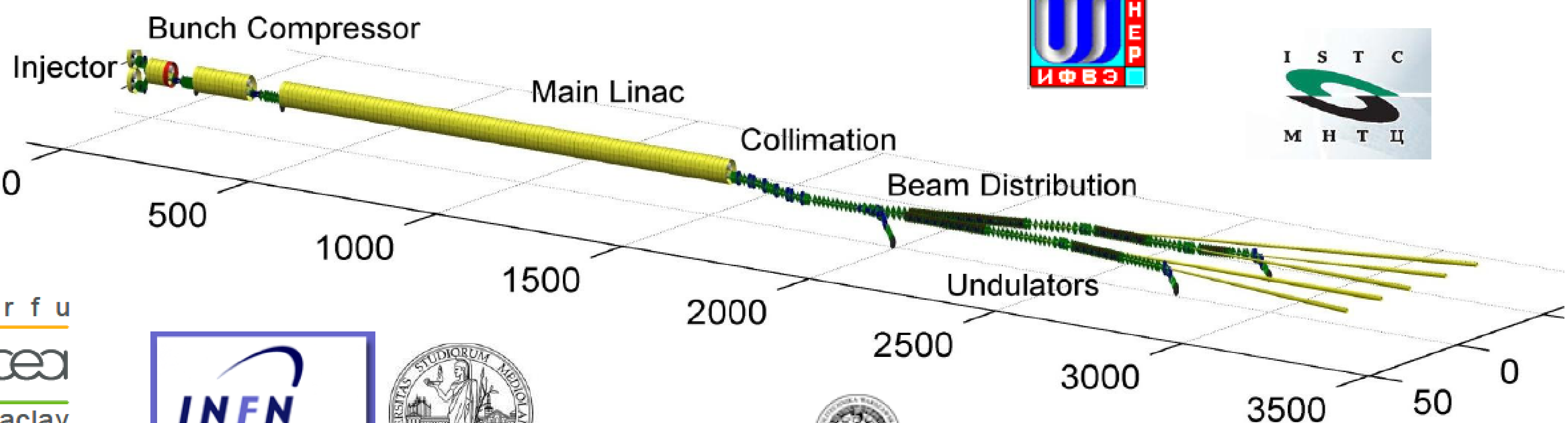
1-100 Angstroem wave length; 100 fs pulse length regime

Driver: ca. 2 km Linac in superconducting technology; 17.5 GeV



CH CN DE DK ES FR GB GR HU IT PL RU SE

European XFEL: International collaboration



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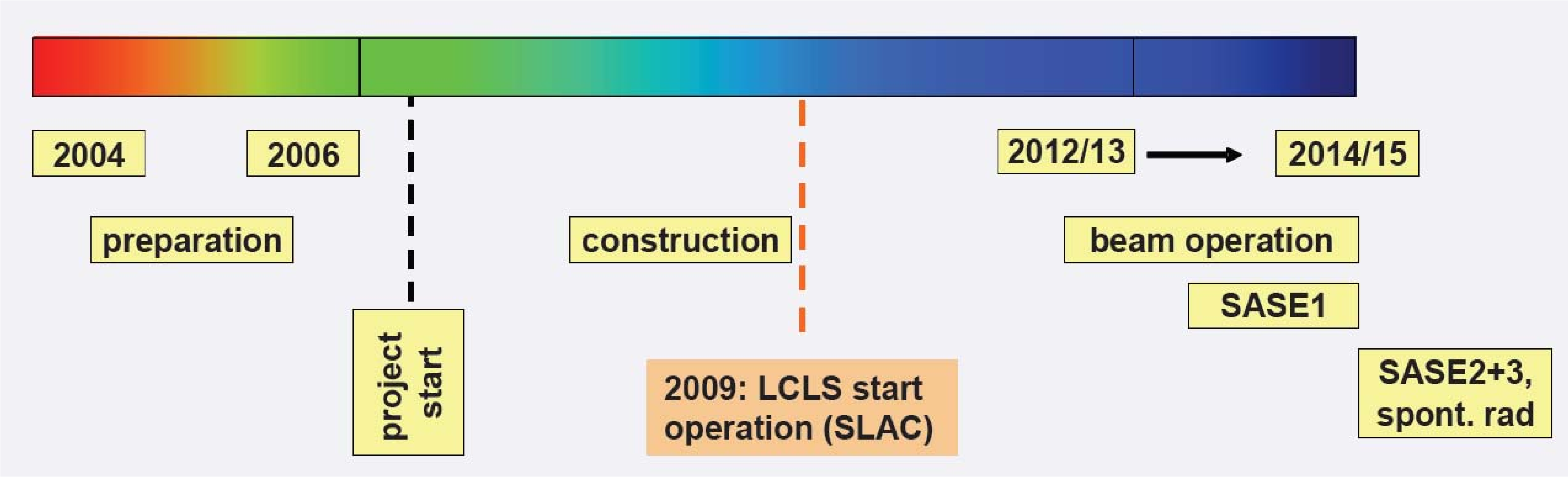
XFEL site (PC simulation)

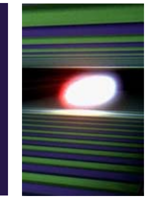
European XFEL site (PC simulation)

European XFEL time schedule:



Construction of European XFEL tunnel is finished

Superconducting technology



XFEL Accelerator Components

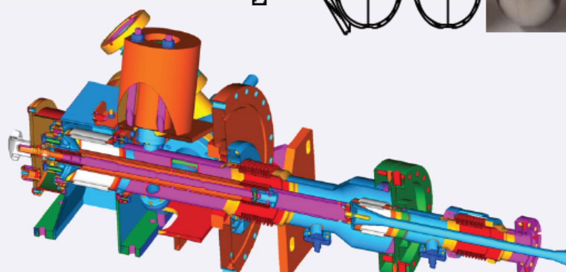
Cryo-module

Clean room technology

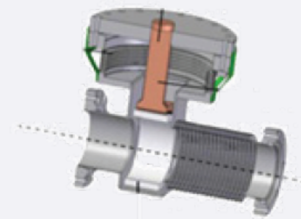
cavities

TESLA Technology

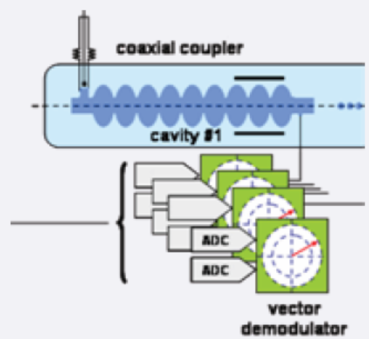
coupler



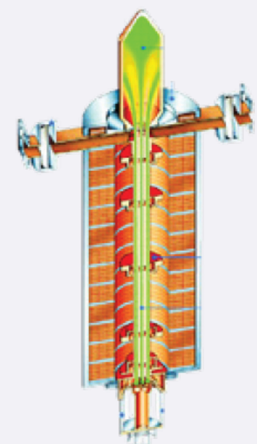
HOMs



LLRF



RF



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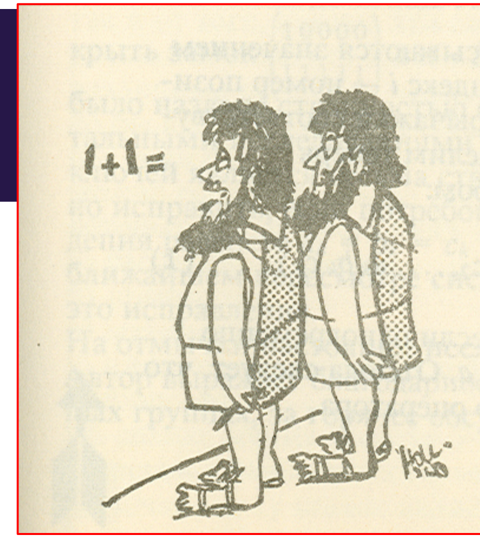
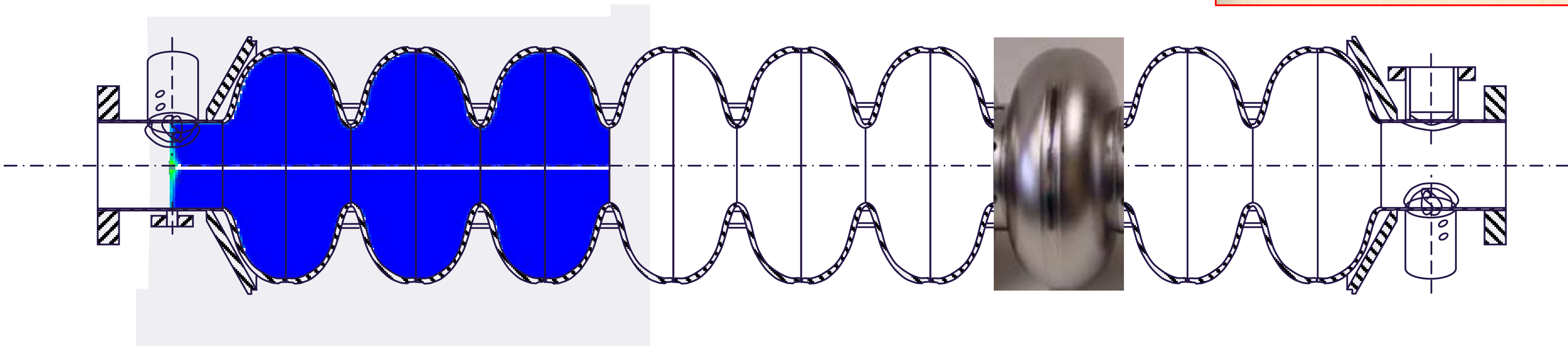
1.3 GHz SC Cavity





Frequency 1.3 GHz

High purity niobium RRR 300

Deep drawn from sheets

Welding with electron beam

Operating temperature 2K

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Technology Transfer: relevant main principles*

- The R&D process must be complete
- Documentation must be complete
- List of vendors must be complete
- In house technical review process
- Identifying the key project personal
- Work out the procurement schedule, delivery rate and completion date

*The main principles of TT are well known. See for example: http://technologytransfer.web.cern.ch/technologytransfer/
F. Sutter. Technology Transfer- when, why, issues and advantages. Proceeding of PAC07, MOZAC01. The Journal of Technology Transfer etc.

Specification

Specification is released. Contact person: waldemar.singer@desy.de.

Specification documents:

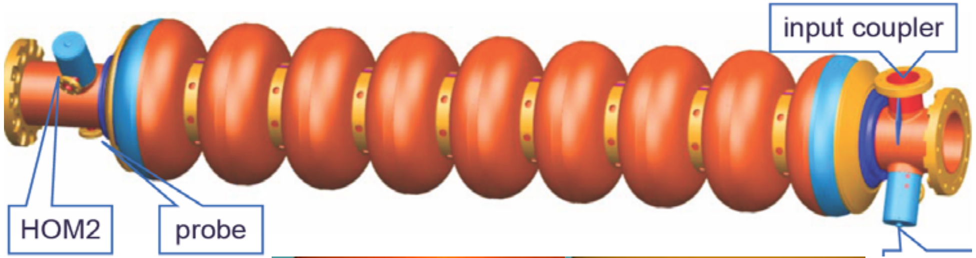
- •SERIES MECHANICAL FABRICATION: (XFEL/001- XFEL/018)
- •SERIES SURFACE AND ACCEPTANCE TEST PREPARATION (XFEL/A - D)
- •HARDWARE AND PROCESSES USED AT DESY (XFEL/Appendix I - IV)
- •ILC-HI GRADE CAVITIES AS A TOOL OF QUALITY CONTROL (XFEL/HiGrade)
- •SETS OF DRAWINGS

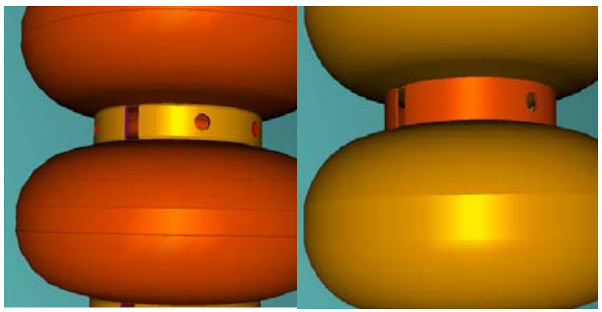
Two main aims have been pursued:

-Spec. has to contain all detailed requirements for the cavity with helium tank mechanical fabrication, treatment and assembly for RF test

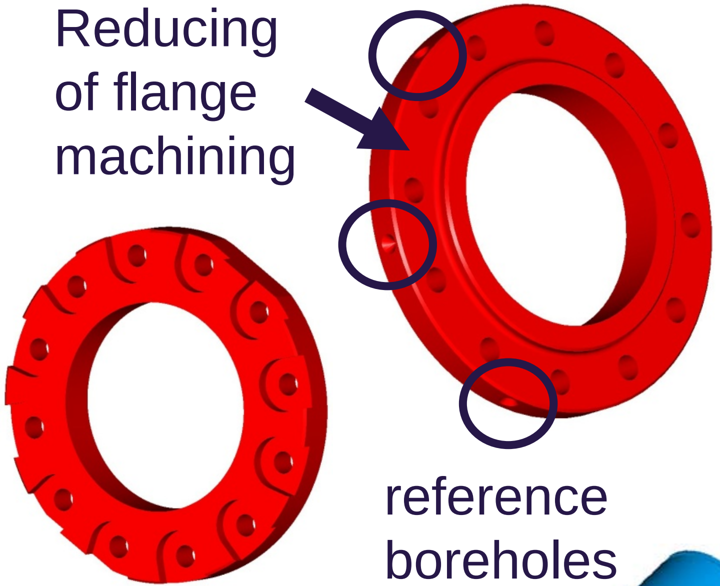
-DESY experiences has to be included.

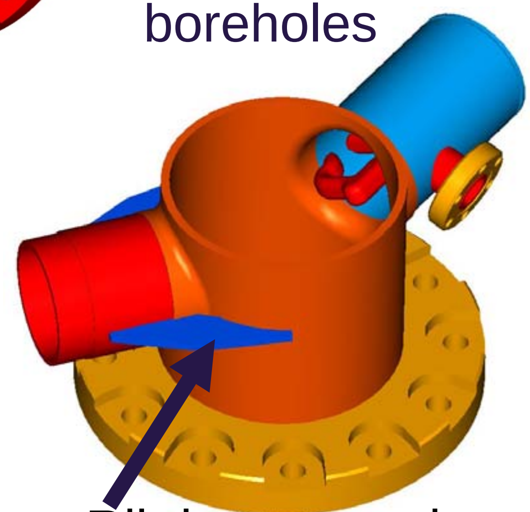
Mechanical fabrication: XFEL Design is the TESLA Design – minor changes. Four cavities of XFEL design produced





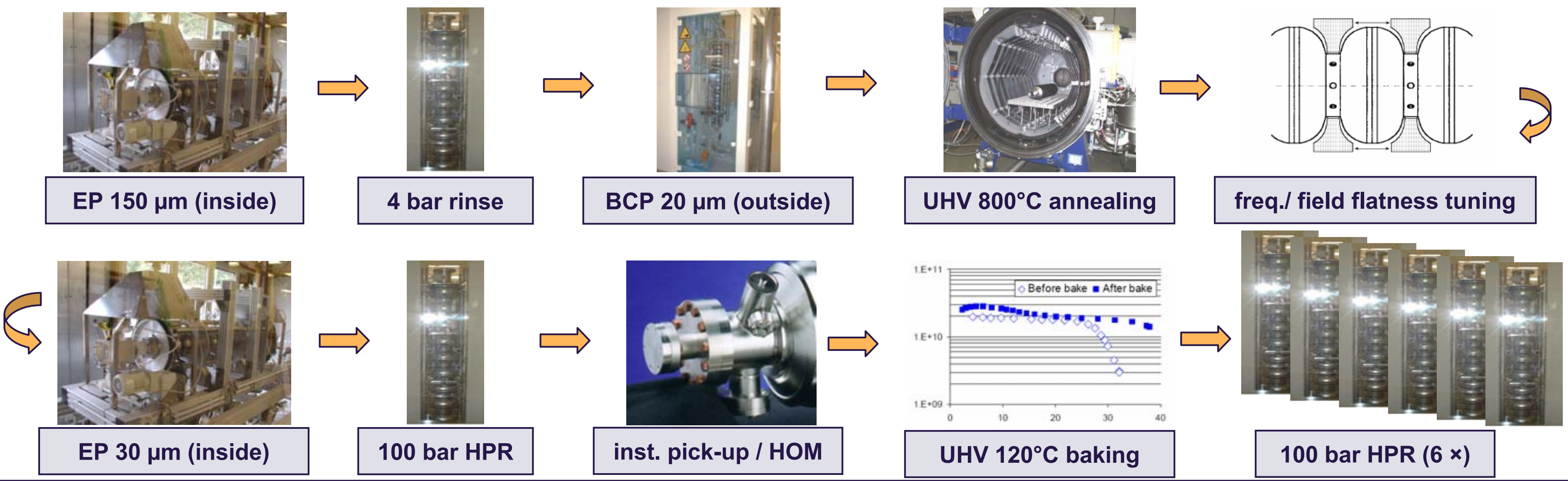
- Removal of coupler port stiffener (rib)
- Reducing of flange machining
- Removal of outside recess (equator area)
- Less holes and thinner the stiffening ring
- New reference boreholes for cavity-string-alignment
- Review tolerances





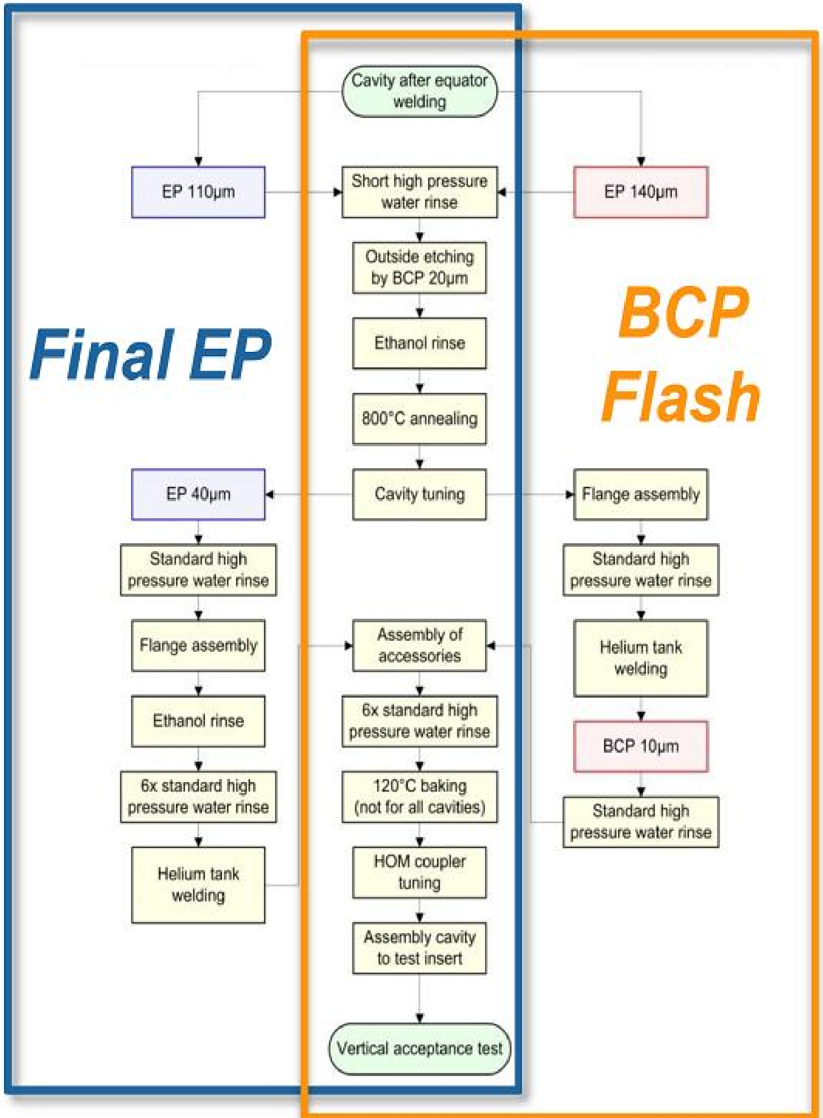
European XFEL

Cavity Preparation (XFEL Industrial Production)



1. electro-chemical removal of a thick niobium layer (so-called damage layer) of about 150 µm from the inner surface
2. a rinse with particle free / ultra-pure water to remove residues form the electro-chemical treatment
3. outside etching of the cavities of about 20 µm
4. ultrahigh vacuum annealing at 800°C
5. tuning of the cavity frequency and field profile
6. removal of a thin and final layer of about 30 µm
7. rinsing with particle free / ultra pure water at high pressure (100 bar) to remove surface contaminants
8. assembly of auxiliaries (pick-up probe and HOM pick-up)
9. baking at 120°C in ultra high vacuum
10. additional six times rinse with high pressure ultra-pure water (100 bar)

Treatment: XFEL treatment recipe was worked out on base of prototype cavities



Prior surface treatment.

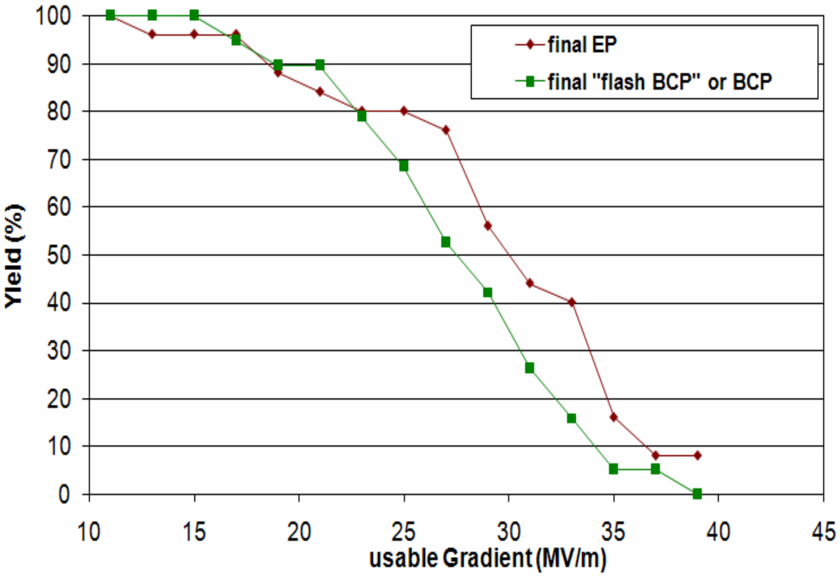
EP 110-140 µm (main EP), ethanol rinse, outside BCP, 800°C annealing, tuning

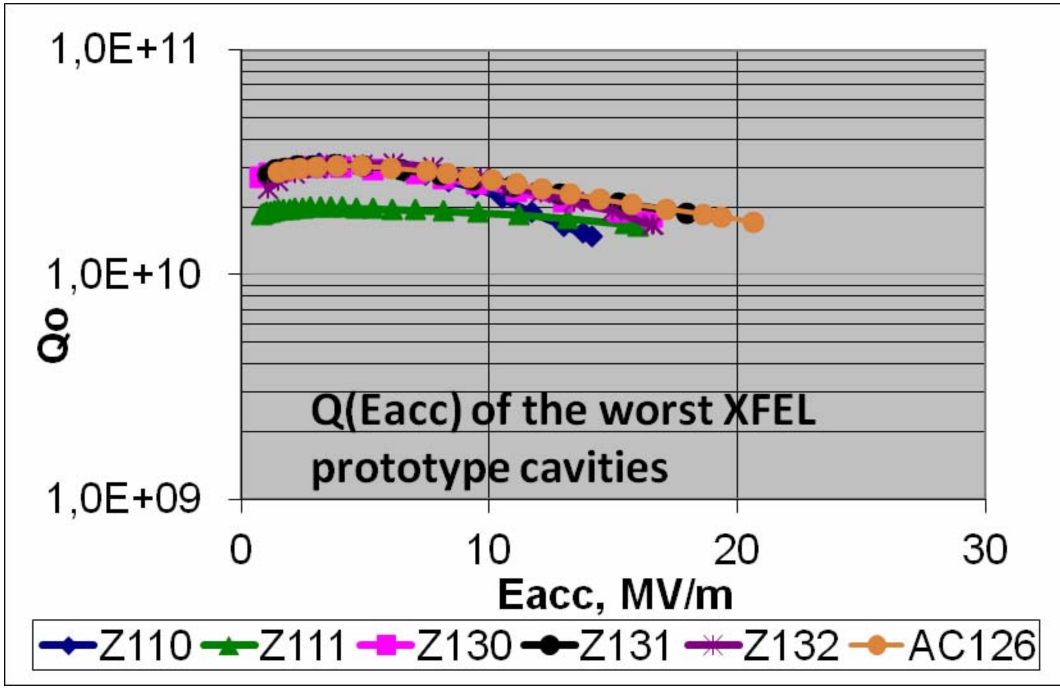
Final surface treatment - two alternative options

1. Final EP of 40 µm, ethanol rinse, high pressure water rinsing (HPR) and 120°C bake
2. Final BCP of 10 µm (BCP Flash), HPR and 120°C bake.

Integration of the helium tank, assembly of HOM, pick up and high Q antennas before vertical RF test

Ca. 50 prototype cavities produced. The companies Ri and E. Zanon qualified for XFEL





Required for XFEL average Eacc=23,6 MV/m. Qo=1E+10.

Performance statistic:

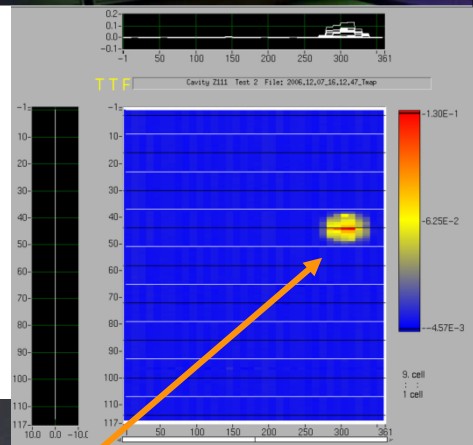
- **Difference between first and last test dominated by FE reduction**
- **Final surface treatment influences yield at higher gradients**

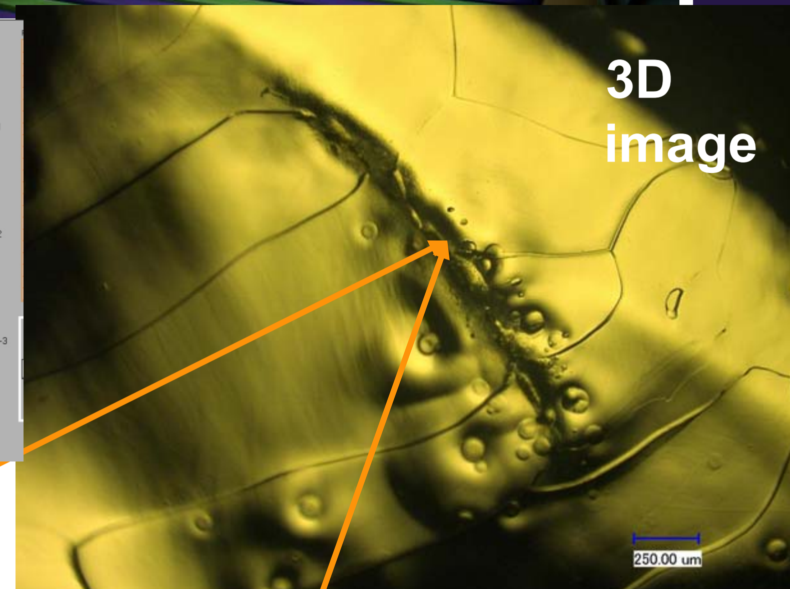
Decision: destroy few worst cavities and investigate the inside surface

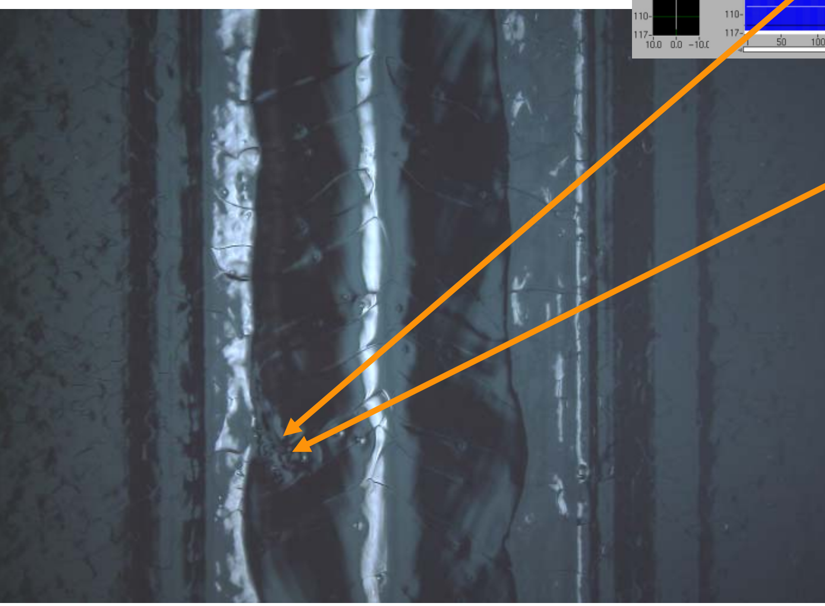
Four types of cavity defects

Type 1: Topographical defects at the welding seam.

Quench at 16,2 MV/m on equator





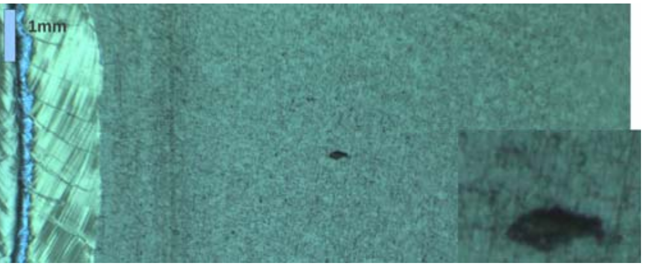


Optical inspection by high resolution camera

2 µm

SEM. Quench location

Type 2: Foreign elements (Aluminium): Cavity Z161, Cell2, 128°. Quench in π-mode at 13,7 MV/m



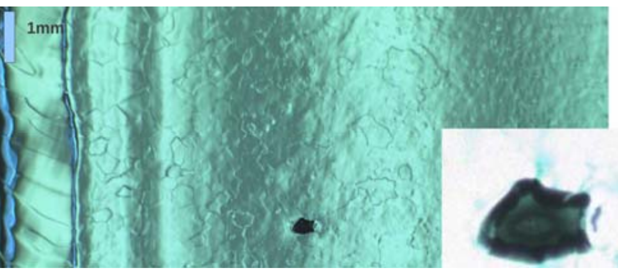
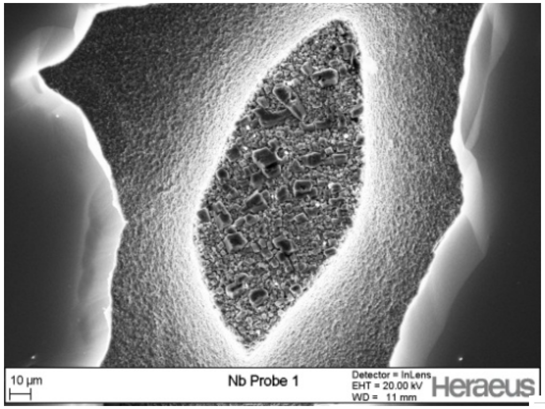
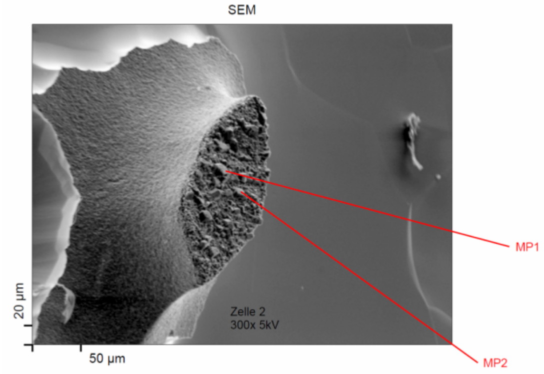
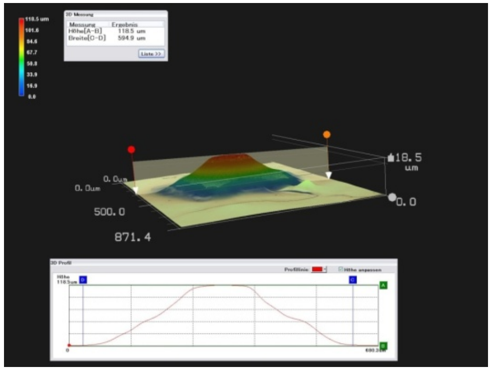
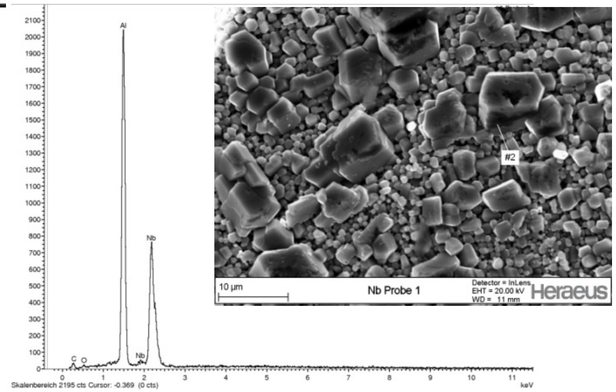


Image of high resolution camera done on the cavity Z161 as delivered (top) and after EP (bottom)







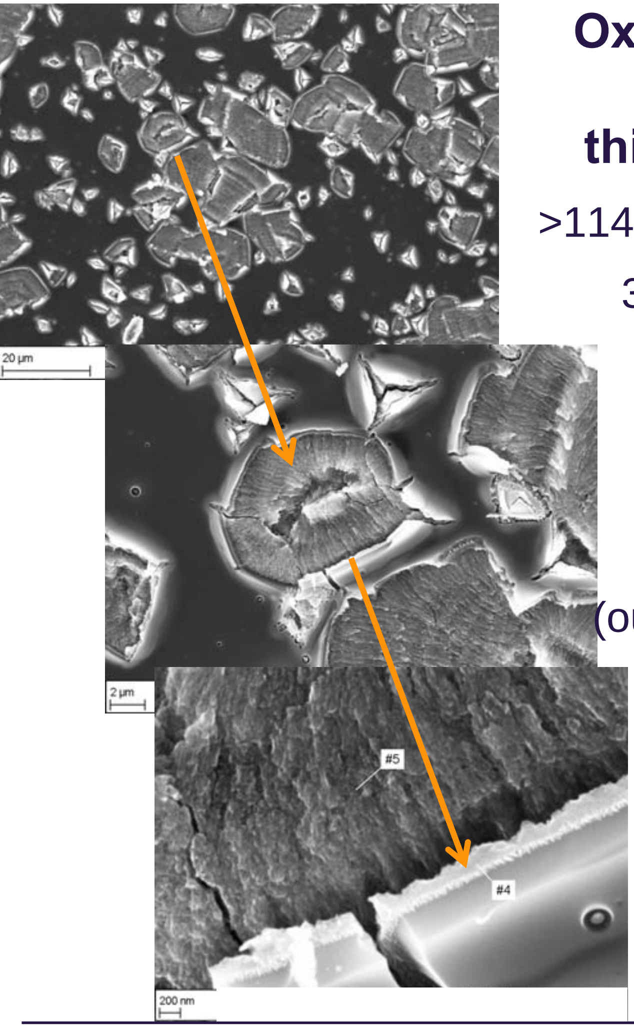


3D microscope, SEM Images and EDX analysis of samples

Auger analysis on separated samples. The aluminum signal does not disappeared after ca. 3 µm removed (not thin layer)

Type 4: Damaged surface; evidently by high pressure water rinsing, caused quench at 21 MV/m (AC126)

Auger spectrums indicates very high presence of oxygen.



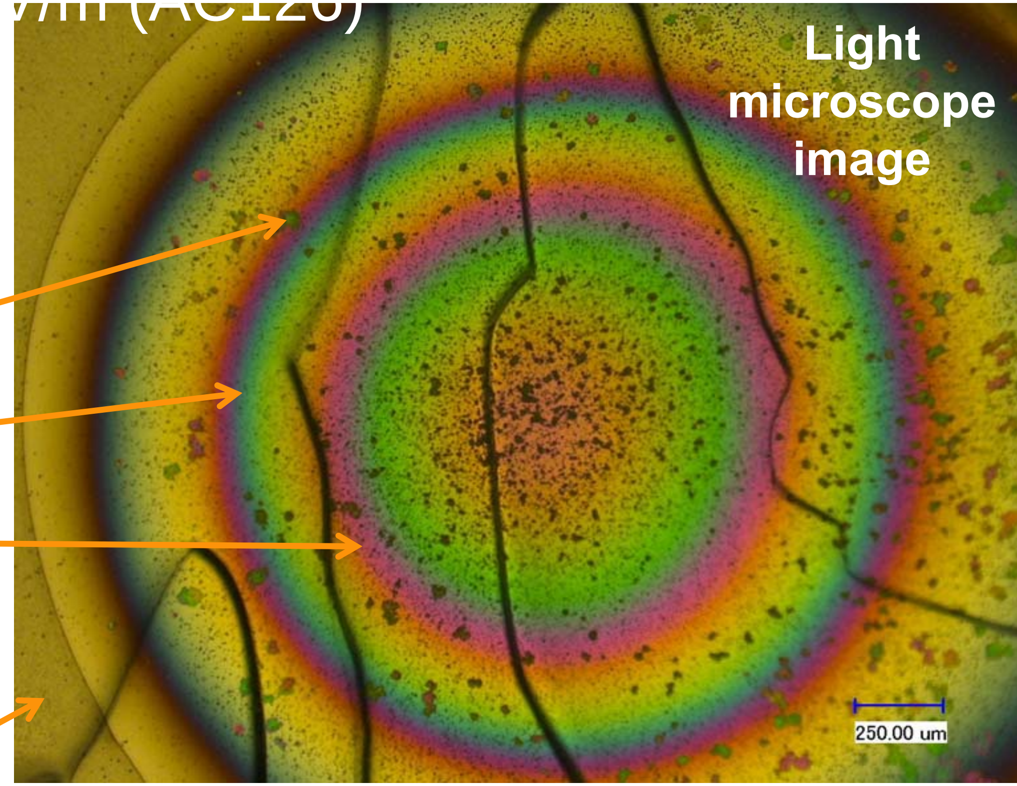
Oxide layer with thickness:

>114 nm (spot)

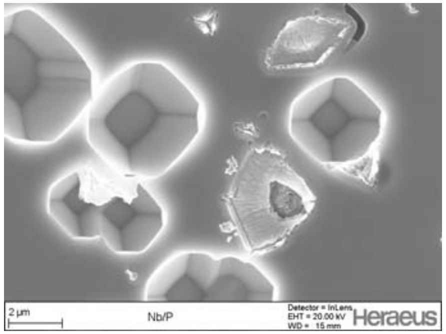
32.5 nm (blue)

195 nm (red)

13 nm (outside rings)



SEM Images



Procurement strategy

Three alternatives:

- Build in house
- Ask industry to design, develop and produce the product
- Industry build the product that was developed during R&D program at the laboratory (build to print)

The **build to print** strategy was chosen for procurements of XFEL SC cavities. Production has to follow precisely the in detail worked out specifications which also include the exact definition of infrastructure to be used. **No performance guaranty by the vendors**, i.e. the risk of low performance is taken over by DESY (re-treatment at DESY); goal: average usable gradient Eacc=23.6 MV/m (Qo=$1x10^{10}$, X-Rays <$1x10^{-2}$mGy/min)

European XFEL

Research Instruments (RI) and E. Zanon (EZ) were contracted beginning of September 2010 to produce each

Contracted: 300 CVs – RI (Germany) and 300 CVs - E.Zanon (Italy)

- **8 Cavities** for qualification of the infrastructure
- **280 XFEL type series cavities**
- **12 ILC HiGrade cavities**

- Material for cavities **Nb / NbTi has to be supplied by DESY.**
- **He-vessels for RI** cavities has to be supplied by DESY
- Additional **80 +160 cavities as an option**
- First series cavities **to be delivered end of 2012**; all cavities to be delivered till **end of 2014.** Delivery rate **3-4 CVs/week**

Current status: Material for XFEL Cavities

Material for Cavities has to be Provided by DESY to RI and E.ZANON

Contracted January 31st, 2011 to companies:

- W.C. Heraeus (Germany) (ca. 90% for end groups)
- Tokyo Denkai (Japan) (50% sheets,)
- OTIC Ningxia (China) (25% sheets, 100% NbTi,..)
- SE Plansee (Austria) (25% sheets, ..)

Aim: material production within 2 Years (mid 2011- mid 2013)

Pressure Equipment Directive PED activities for cavity production

The **notified body (TUEV NORD)** supervises the production

PED Activities

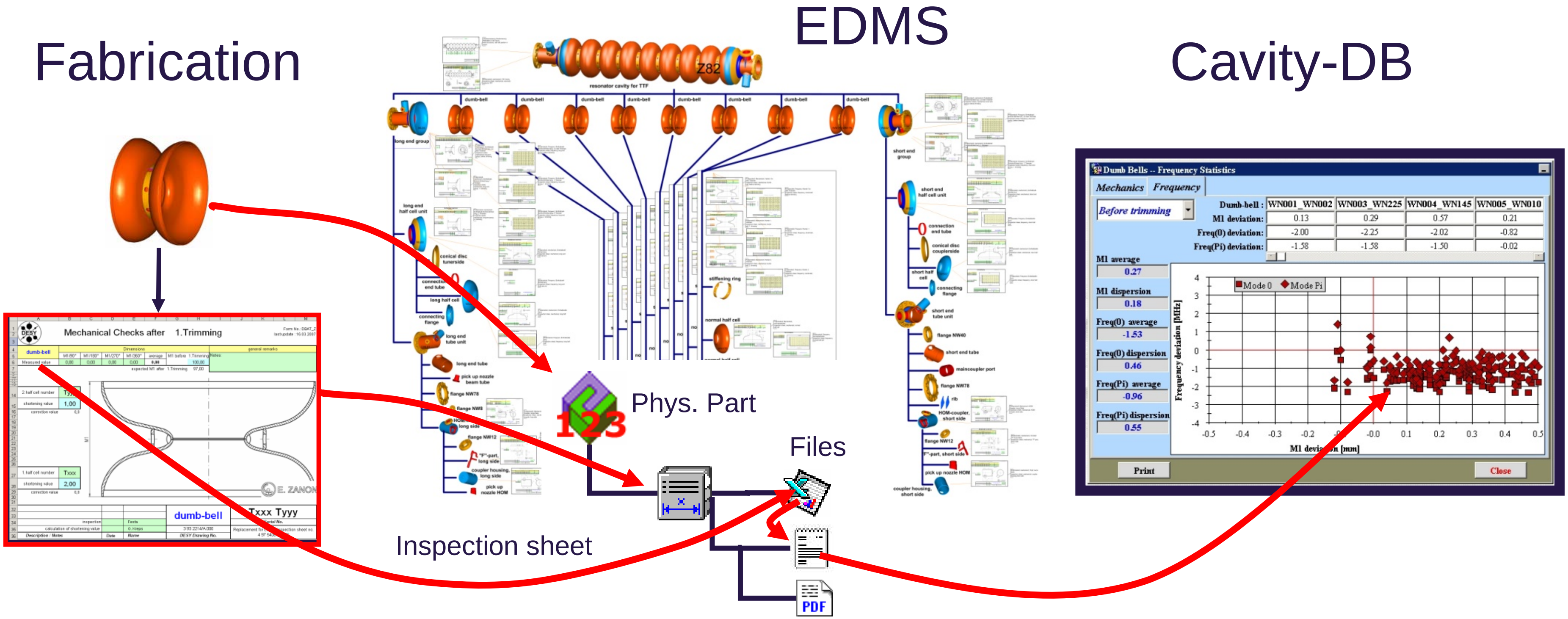
Module B (constr. example check)- contracted

- examination of design, FEM calculation
- qualification of welding processes
- qualification of another PED relevant processes (annealing, deep drawing)
- production of test pieces 2 pieces/Fa
- destructive tests on test pieces
- supervising the fabrication of pre-series (8 pre-series cavities)
- find PED relevant testing methods for the series production of the cavities

Module F (fabrication)- not contracted yet

Test piece TP03 of RI with helium tank of GMT. Courtesy of RI

Documentation in EDMS. Data Bank for statistic. Microsoft Project Plan with tracking possibility



Inspection sheets for quality management

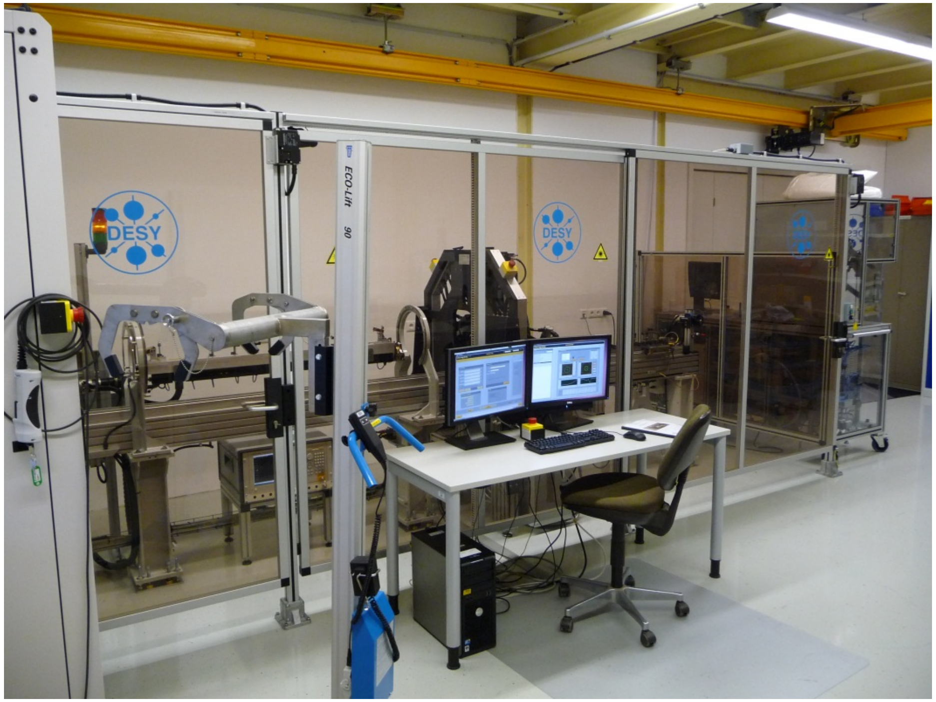
Fabrication structure.
Subassembly parts related.
Procedure related

Statistical analysis

All XFEL SC cavity documents (specifications, protocols, PED data etc.) recorded in EDMS. RI and E. Zanon have an access (to relevant data only)

Shipment and installation of the warm tuning machine at EZ and RI

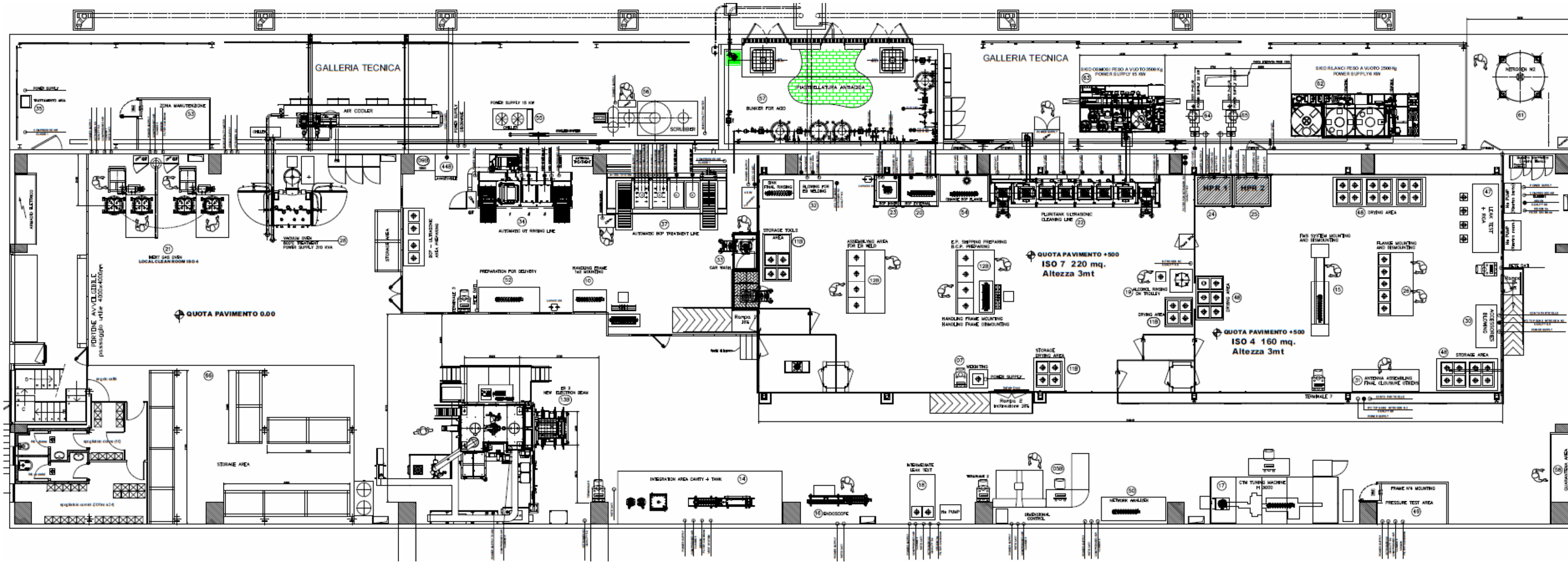
DESY developed, build and delivered to both companies a cavity tuning machine CTM and equipment for RF measurement on half cells, dumb-bells and end groups HAZEMEMA



CTM and HAZEMEMA installed at RI:

CTM in installation at EZ

Examples of E. Zanon Infrastructure (courtesy of E.Zanon)



Building layout: clean rooms ISO10, ISO7, ISO4, US and BCP treatment, 120°C baking, 800°C oven, EBW, tuning machine etc.

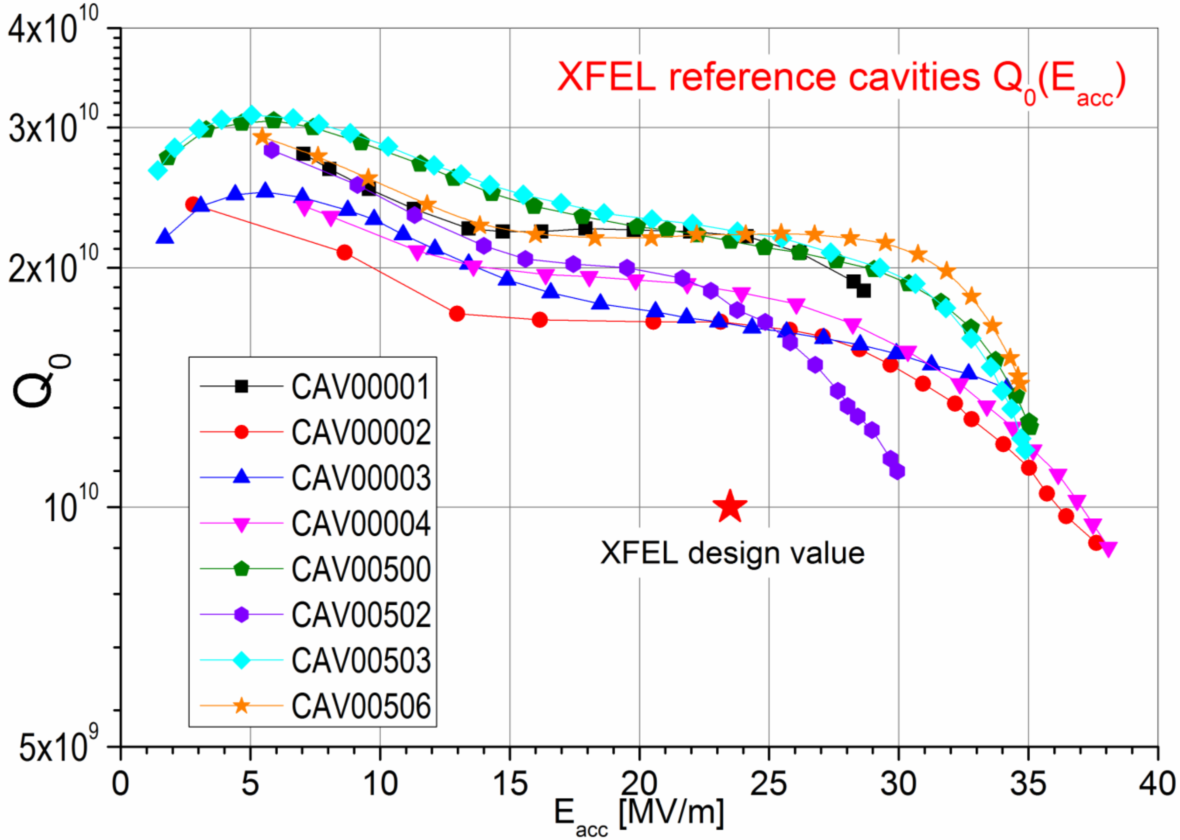
Examples of E. Zanon Infrastructure (courtesy of E. Zanon)

- 120°C bake furnaces
- Ultrasonic cleaning and BCP in ISO 10 room
- clean room ISO 4 installed in the new building
- UPW (Ultra Pure Water) production system

Examples of E. Zanon Infrastructure (courtesy of E.Zanon)

-New EBW machine
-Old EBW machine with a new oil free cryogenic pumping system
- New oven for 800°C treatment

Status of 4 RI Reference Cavities: fabrication at RI, treatment and RF test at DESY



- First surface treatment and vertical acceptance test w/o He-tank at DESY
- Stepwise qualification of surface treatment infrastructure at companies**.** After each step RF test at DESY.
- Production and treatment of 8 pre-series cavities using new vendors infrastructure

Thank you