Preparation Phase for 1.3 GHz Cavity Production of the European XFEL

Presented by

Waldemar Singer

on behalf of the XFEL cavity team

Preparation phase 2006-2010. Construction phase is planned for 2010-2013.

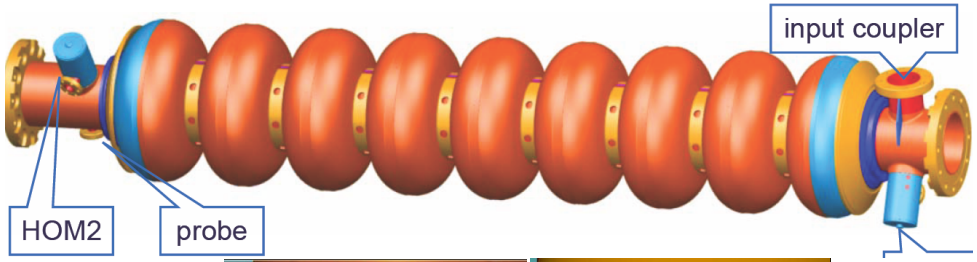
Main topics

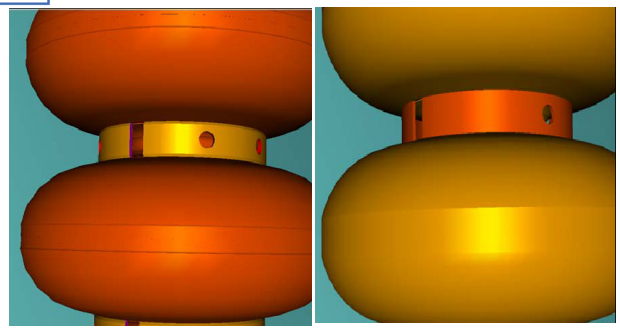
- Mechanical fabrication
- Treatment
- RF measurement
- Performance of prototype cavities
- Material for cavities
- Documentation
- Single cell cavity R&D program
- Current status

Prototype XFEL cavities

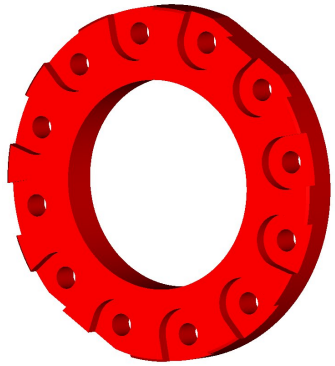
- Approx. 50 prototype XFEL cavities are produced during preparation phase
- Mechanical fabrication at industry
- Treatment (partially at industry and partially at DESY)
- RF-testing at DESY.

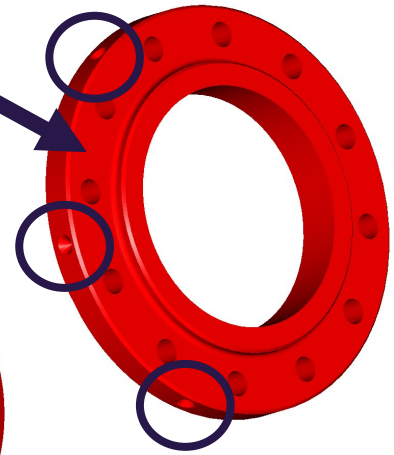
Mechanical fabrication: TESLA Design – minor design changes. Two European companies qualified





Reducing of flange machining

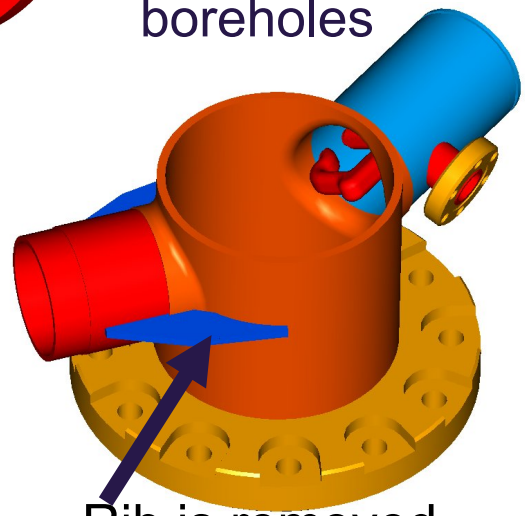




reference boreholes

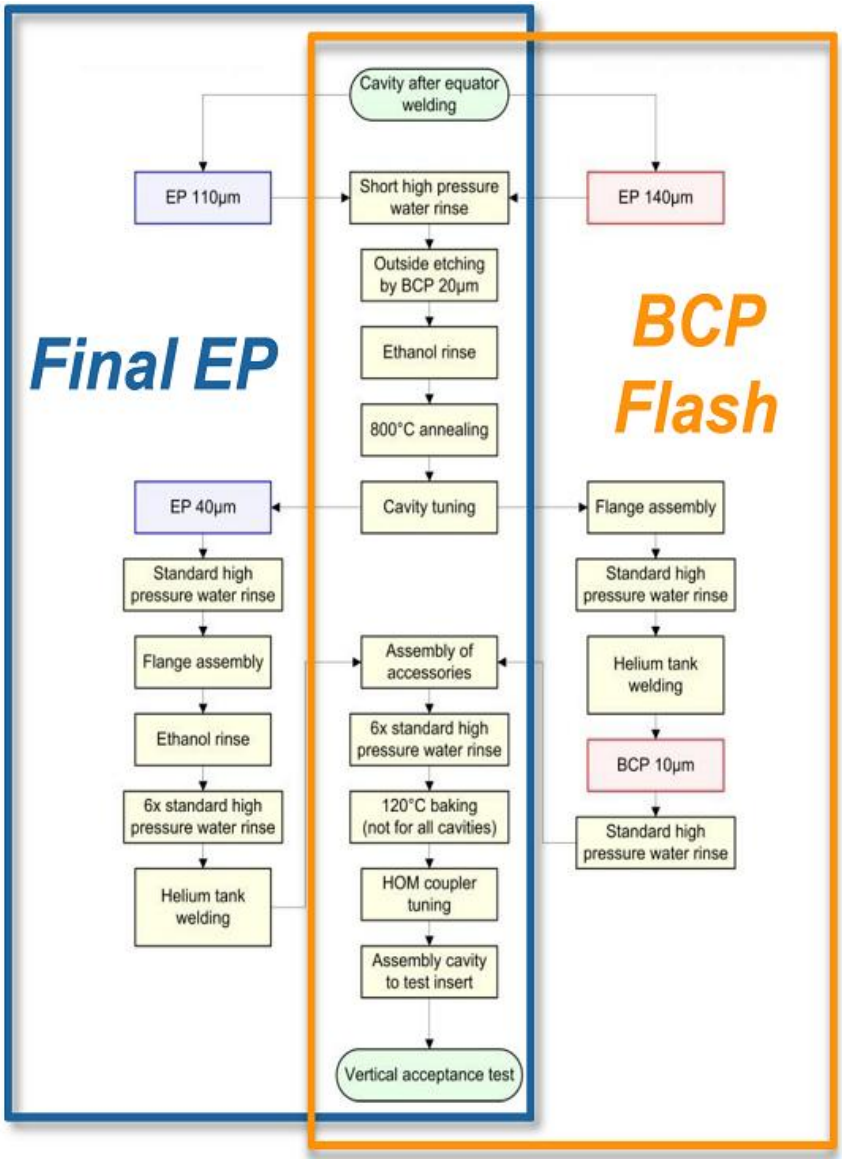
- Removal of coupler port stiffener (rib)
- Reducing of flange machining
- Removal of outside recess (equator area)
- Less holes and thinner the stiffener ring
- New reference boreholes for cavity-string-alignment
- Review tolerances

Stiffening ring



Rib is removed

Treatment: Establishing the XFEL treatment recipe



Prior surface treatment.

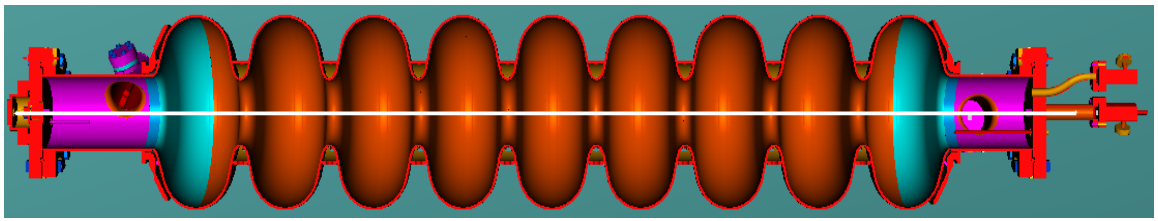
EP 110-140 µm removal, ethanol rinse, outside BCP etch, 800°C annealing

Final surface treatment - two alternative options

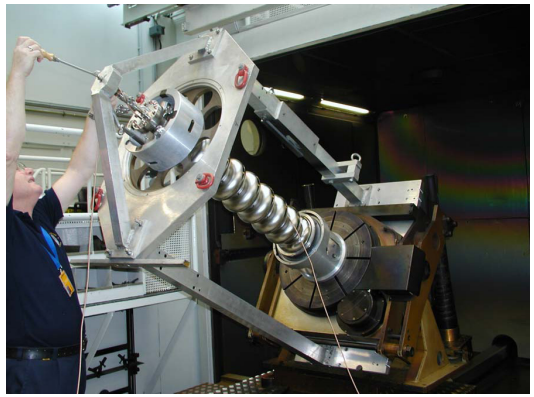
1. Final EP of 40-50 µm, ethanol rinse, high pressure water rinsing (HPR) and 120°C bake
2. Final BCP of 10 µm (BCP Flash), HPR and 120°C bake.

Integration of the helium tank before vertical RF test

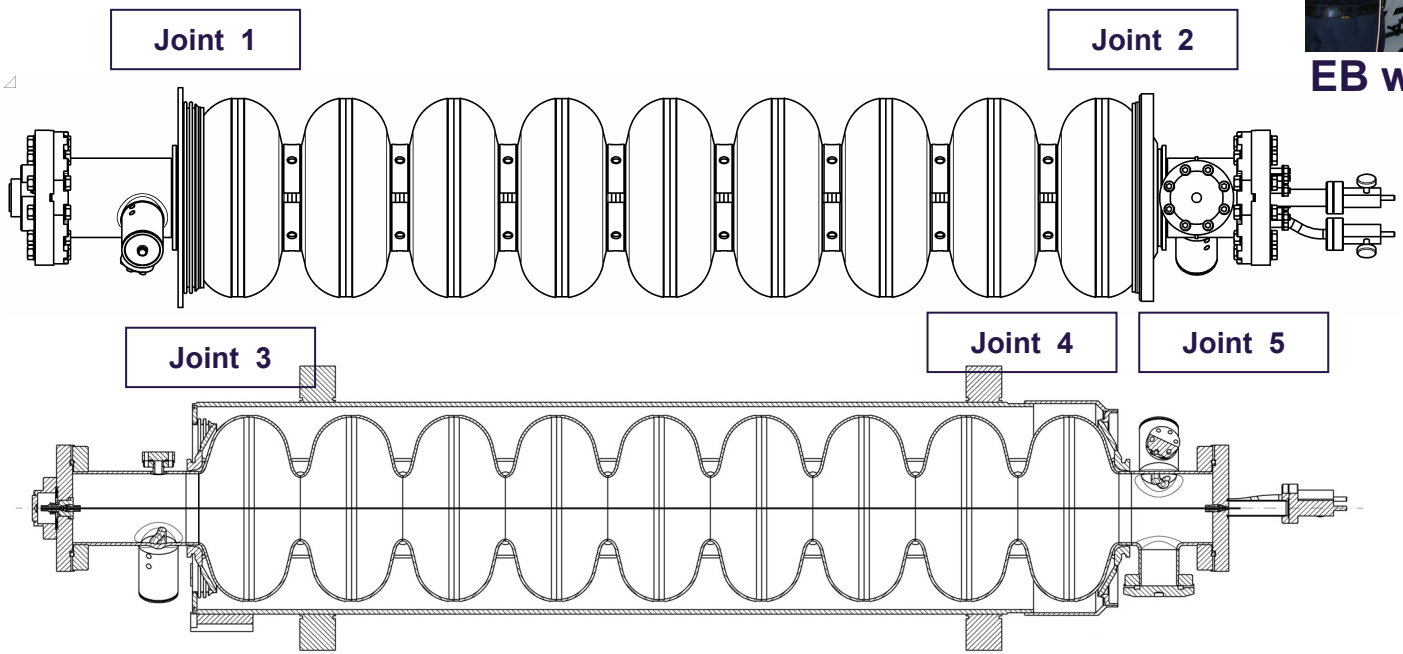
Optimized Helium Tank integration



Cavity with FMS. Teflon tube on cavity axis



EB welding of joint 1, 2

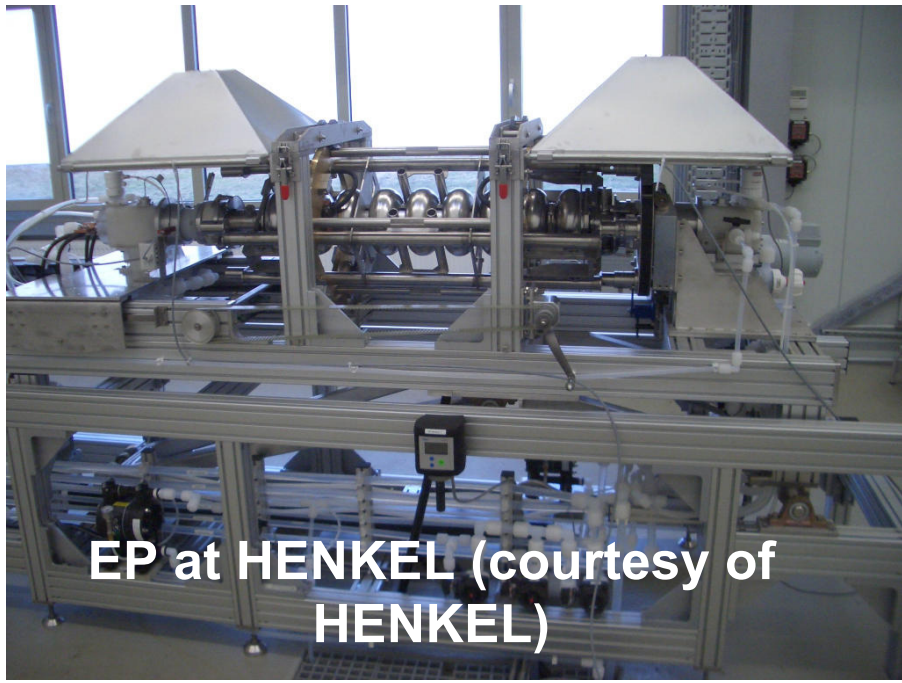


TIG welding of joint 3,4,5

A field profile measurement system (FMS) was developed to control the RF characteristic

Treatment: Industrialization of the main EP treatment done

EP at ACCEL (courtesy of RI)

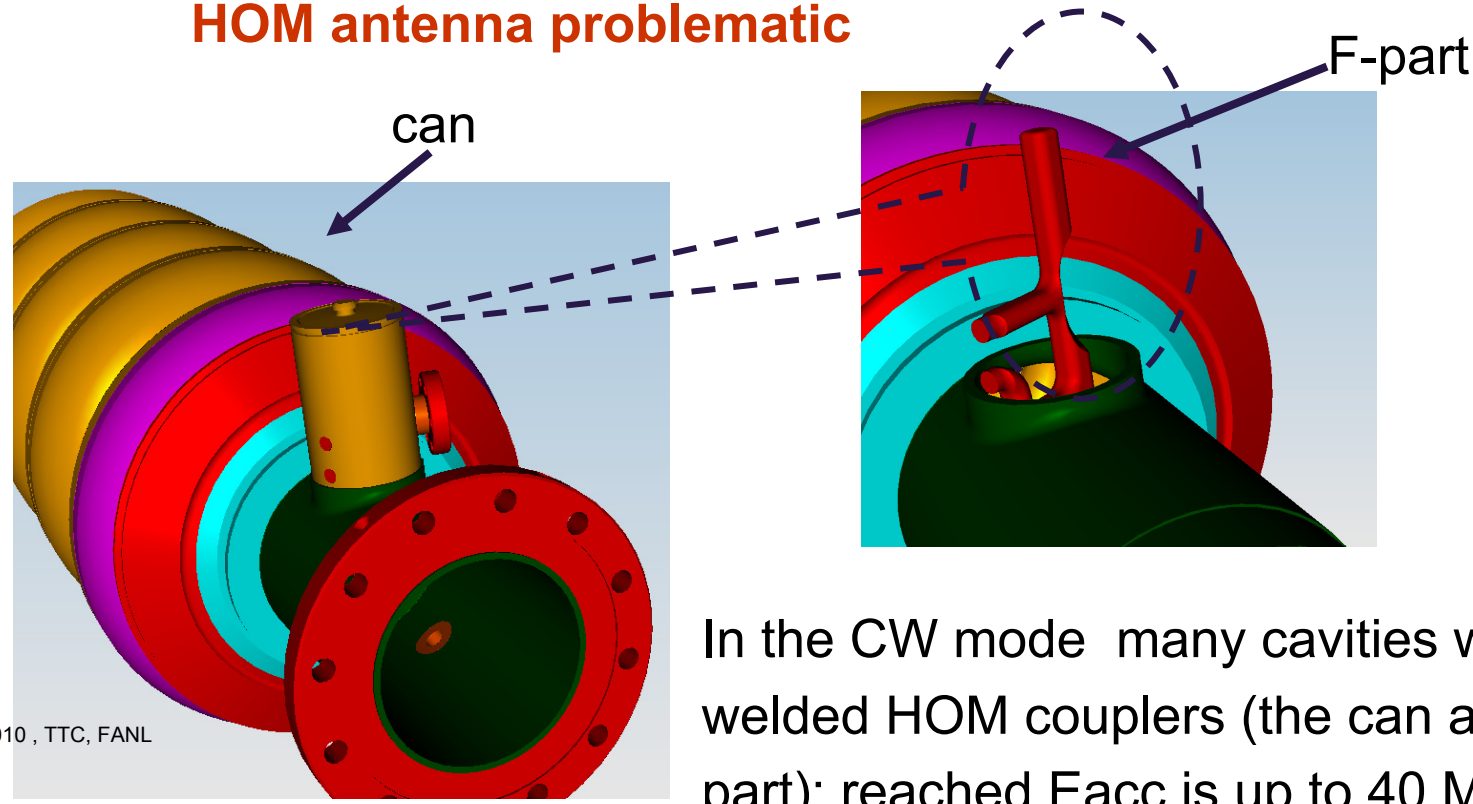

EP at HENKEL (courtesy of HENKEL)

Equipments for EP have been set up at companies ACCEL and HENKEL undo DESY supervision. First step of EP on ca. 30 prototype cavities (main EP: removal of ca. 110-140 µm) successfully done at the industry on ca. 30 cavities.

RF Measurement: Pulse Acceptance Test for XFEL Cavities

For XFEL it is foreseen that the industry will carry out the mechanical fabrication, integration the helium tanks, treatment, assembly of HOM – antennas, pick-up antennas, high Q fix antennas. Vertical RF test at DESY.

HOM antenna problematic

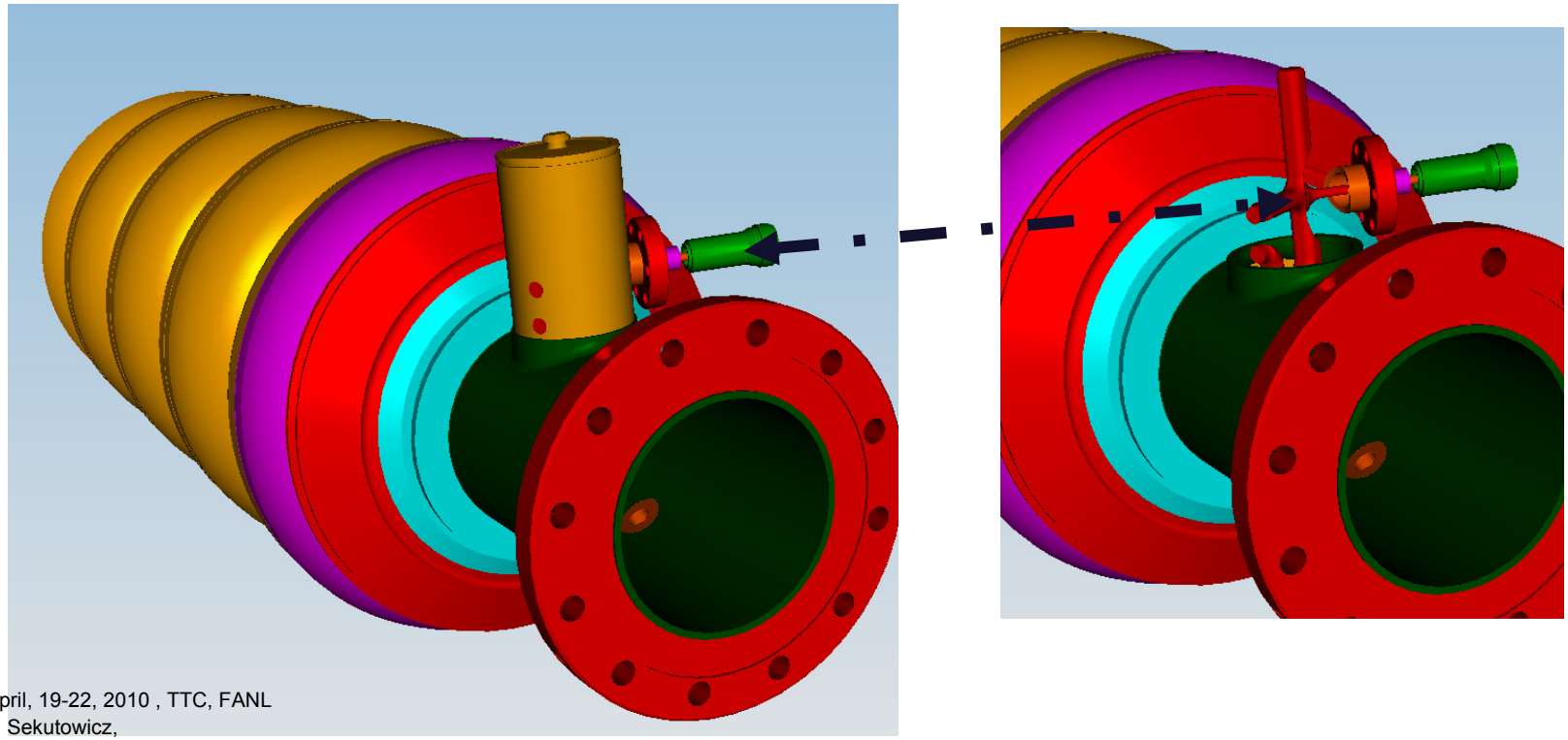


April, 19-22, 2010 , TTC, FANL
J. Sekutowicz,

In the CW mode many cavities with welded HOM couplers (the can and F-part); reached Eacc is up to 40 MV/m.

RF Measurement: Pulse Acceptance Test for XFEL Cavities

	Nominal operation	Acceptance cw RF test
Maximum E_{acc}	24 MV/m	24 MV/m
Maximum Cryogenic Load	**If nominal=1** (~TESLA design)	**x 100**

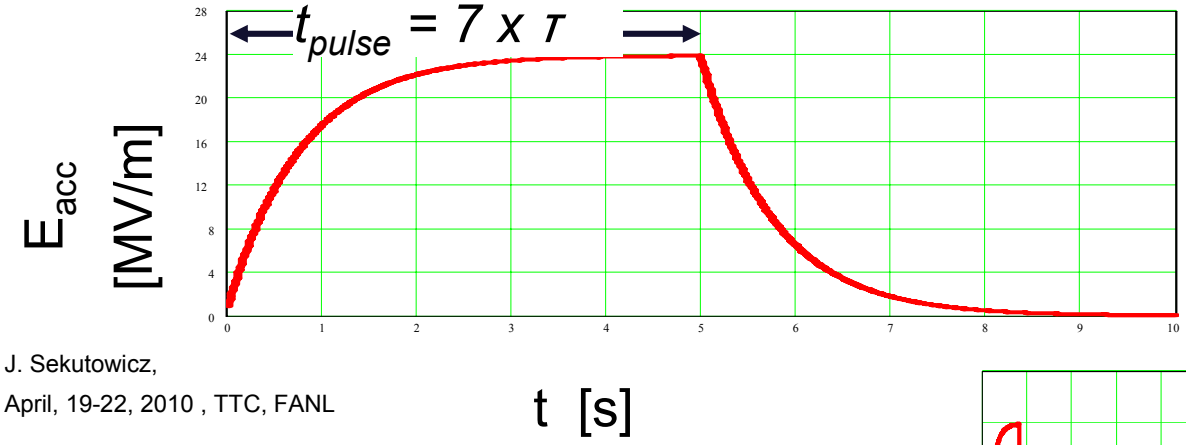


April, 19-22, 2010 , TTC, FANL
J. Sekutowicz,

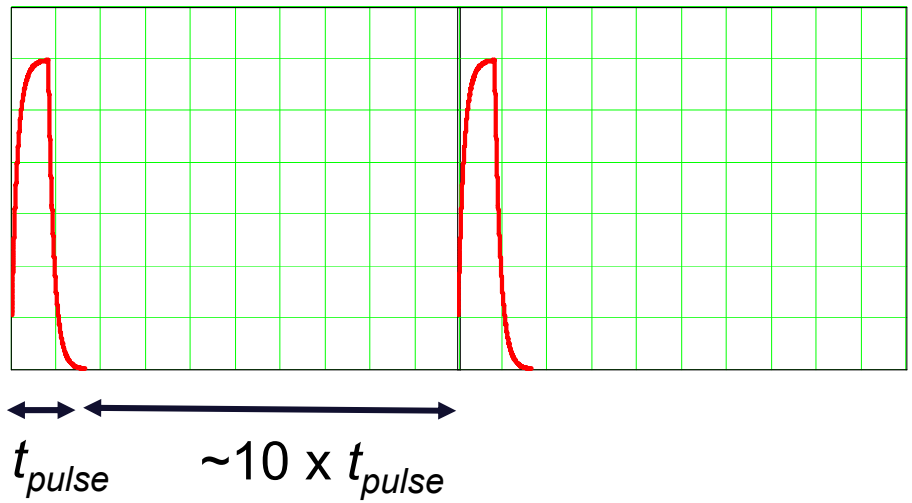
The difficulties come from the limited heat conduction of the HOM feedthroughs, when antenna is installed

RF Measurement: Pulse Acceptance Test for XFEL Cavities

Proposed and successfully implemented



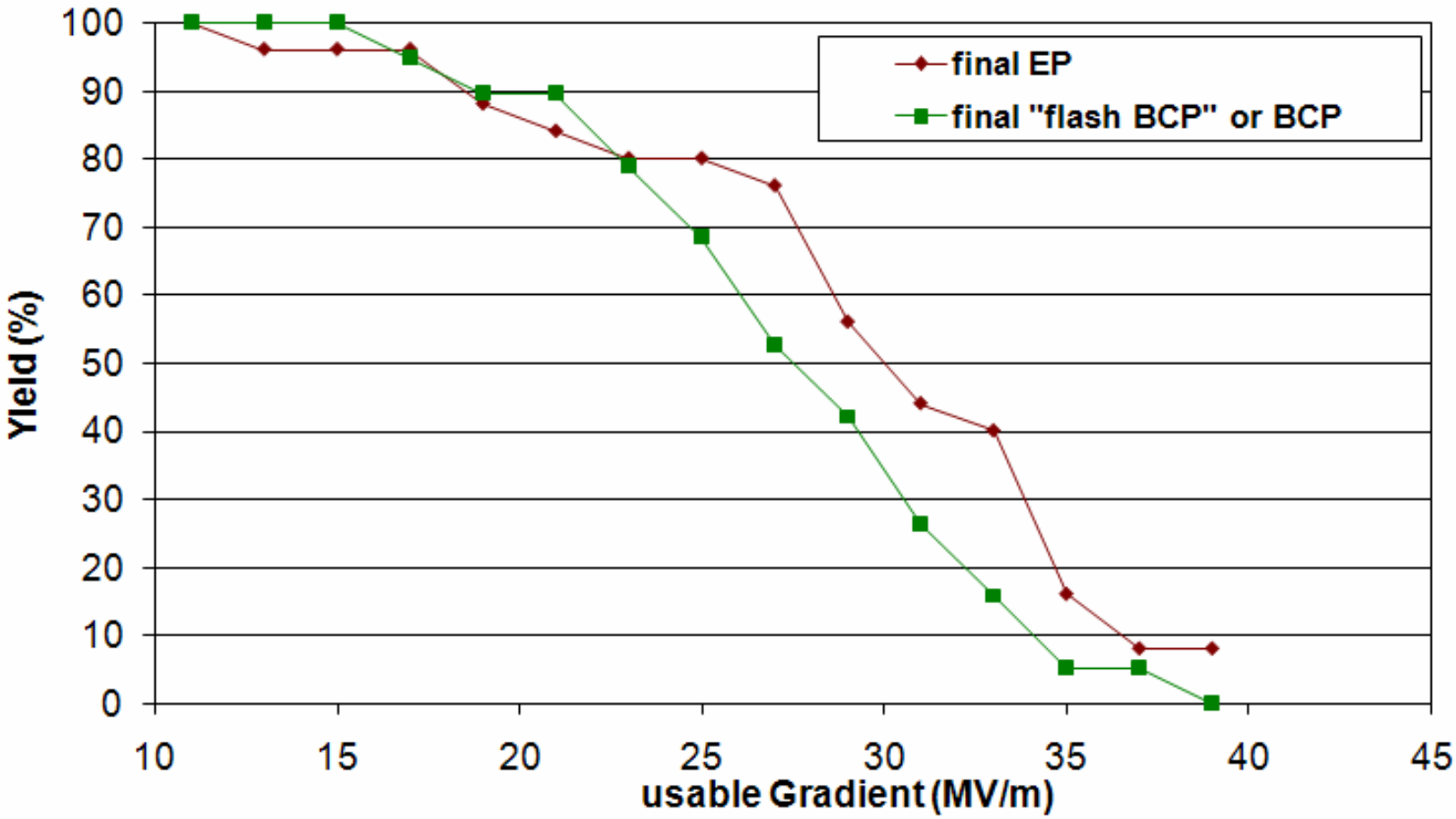
J. Sekutowicz,
April, 19-22, 2010 , TTC, FANL



This reduces the mean cryogenic load by factor of 10.

Cavities in the pulse test demonstrate similar or sometimes even higher Eacc compared to the cw RF test without HOM antennas

Performance of prototype XFEL cavities.

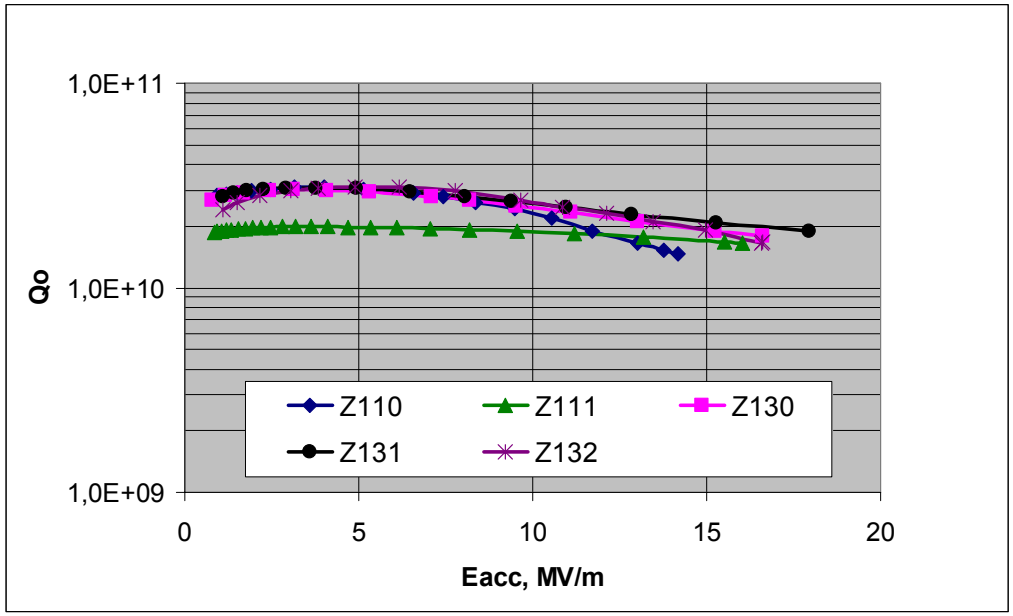


Required for XFEL Eacc=23,6 MV/m. Qo=1E+10.

Reached ca. 90% yield

W. Singer, IPAC 2010, Kyoto

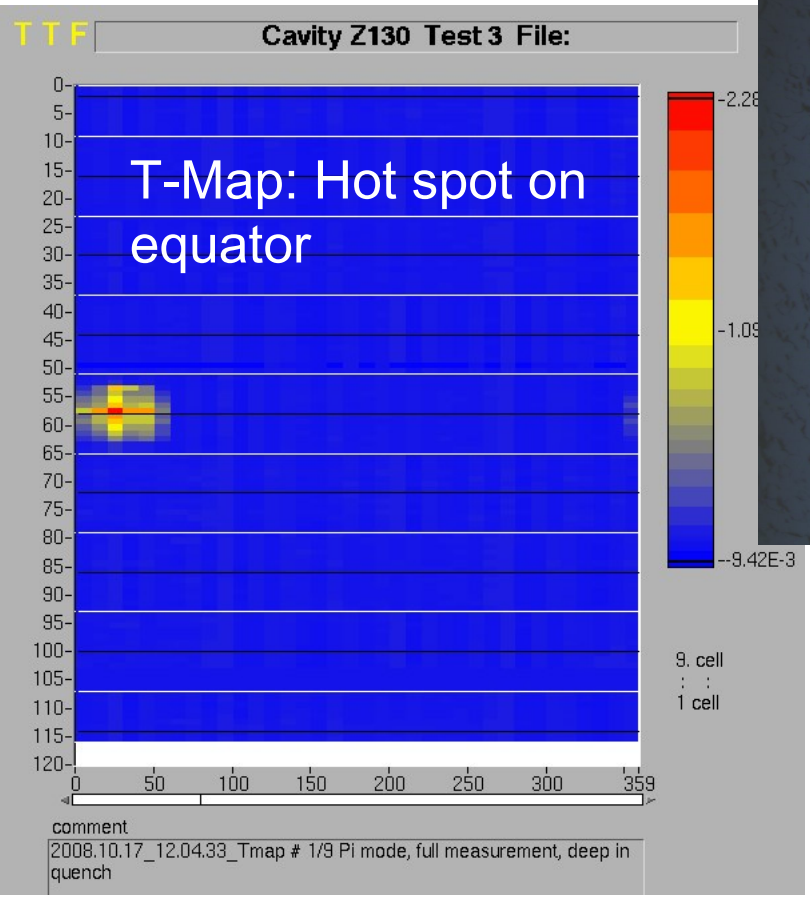
Performance of prototype XFEL cavities.

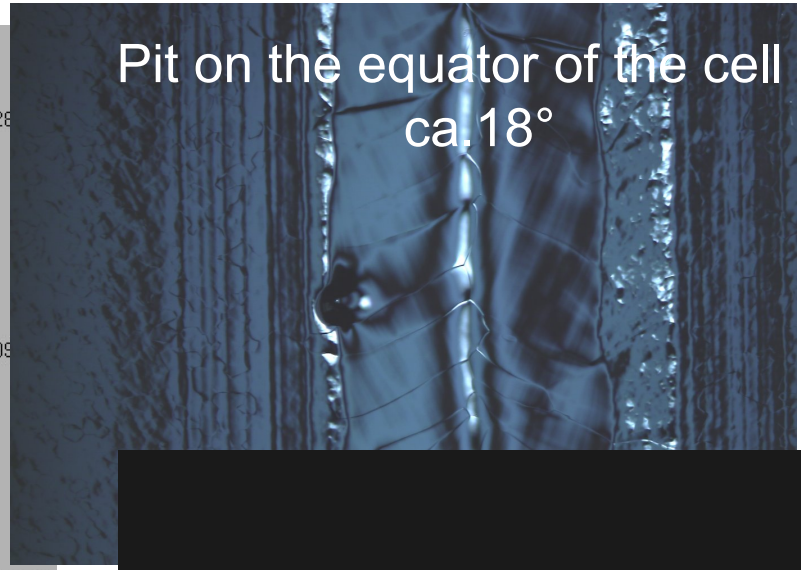


Q(Eacc) of the worst 10% XFEL prototype cavities

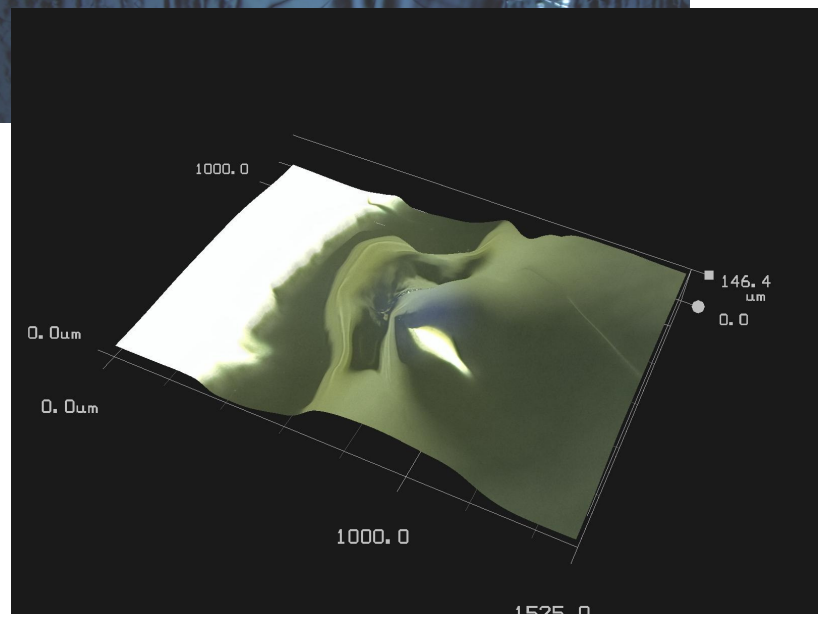
Decision: destroy few worst cavities and investigate the inside surface

Performance: Topographical defects.





Poster WEPEC007

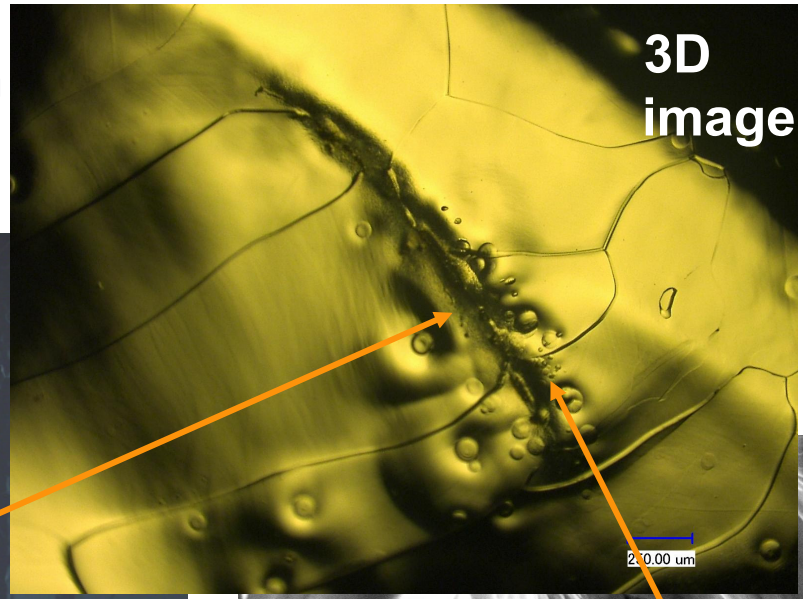


Quench on equator at 22 MV/m

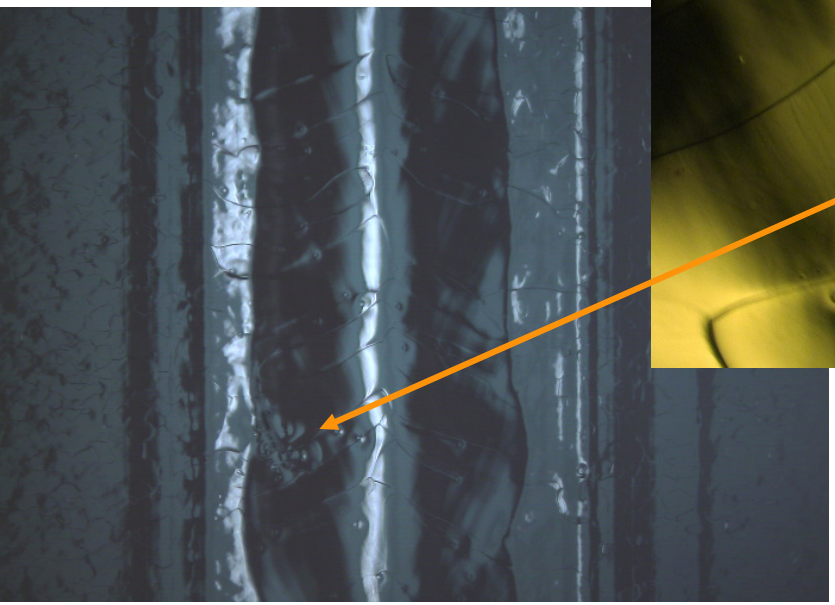
Bump and hole up to 150 µm deep in the spot area

Performance: Topographical defects.

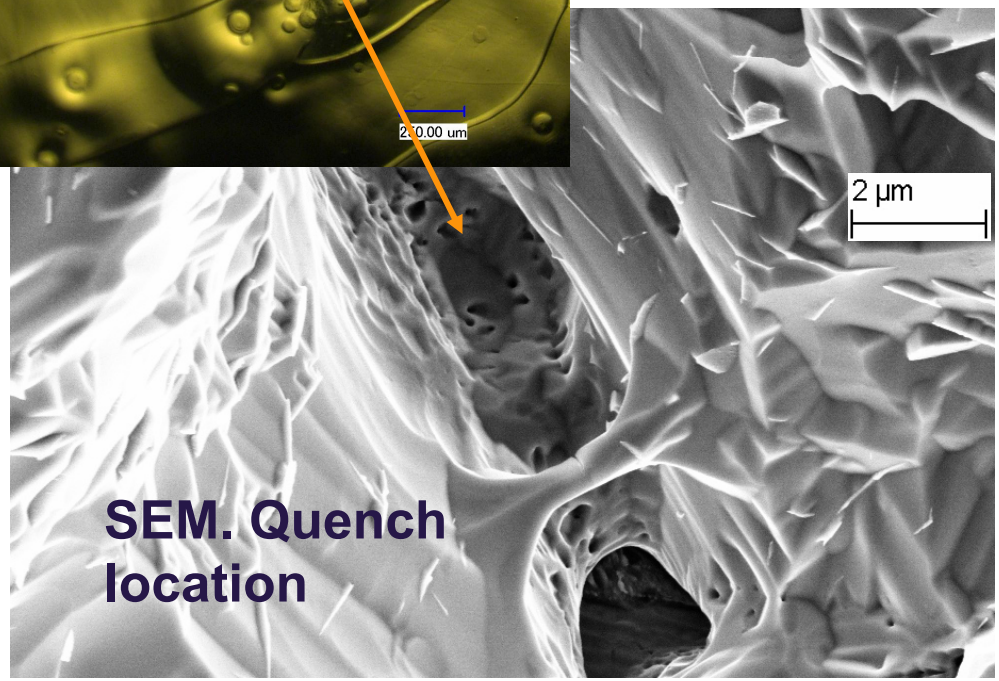
Quench at 16,2 MV/m on equator



Poster WEPEC007

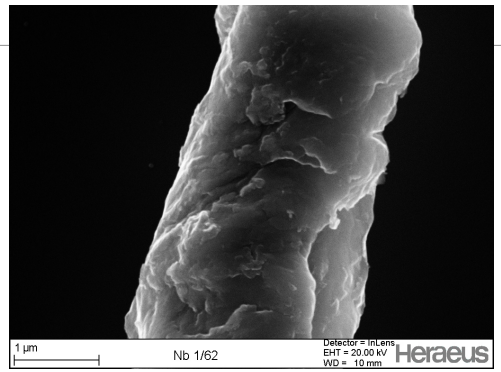


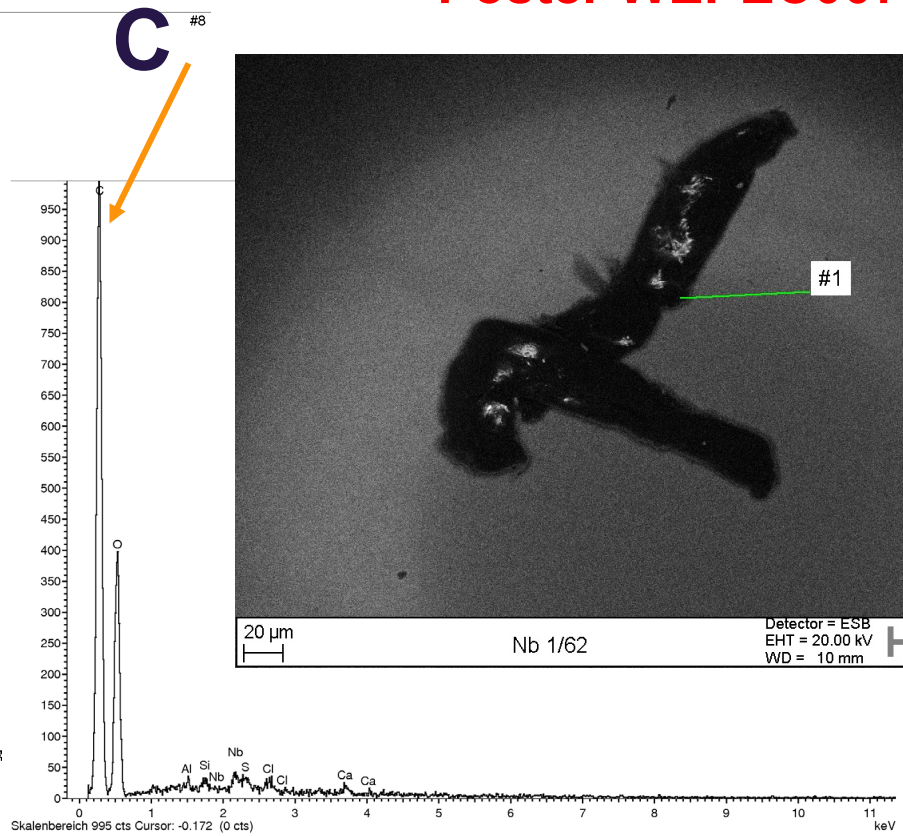
Optical inspection by high resolution camera



Performance: Defects with foreign materials

Poster WEPEC007





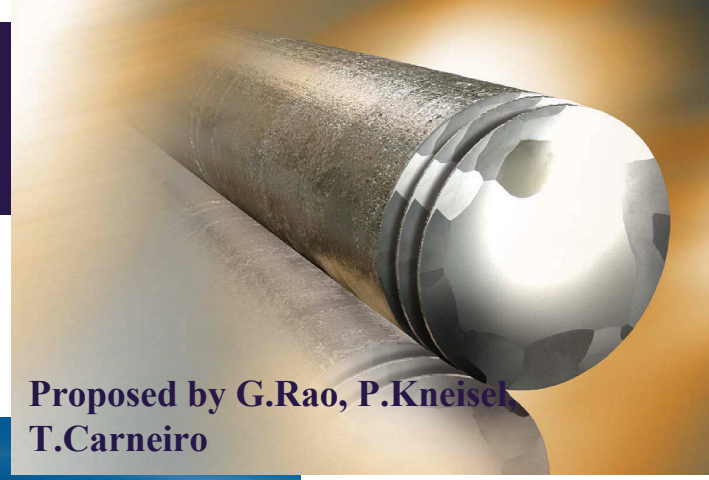
Iron particle found

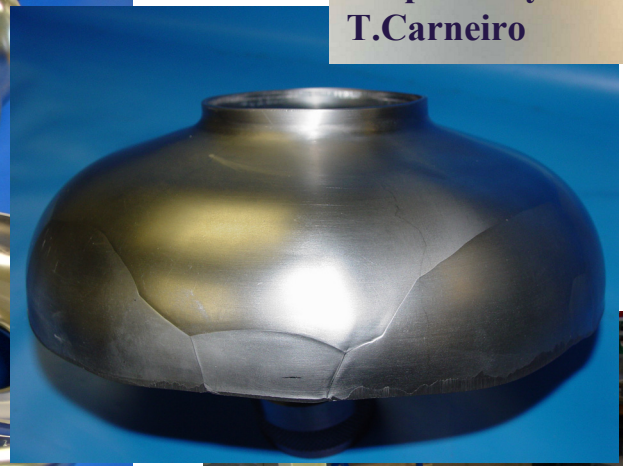
Many spots are detected. EDX of the biggest spot: C and O found

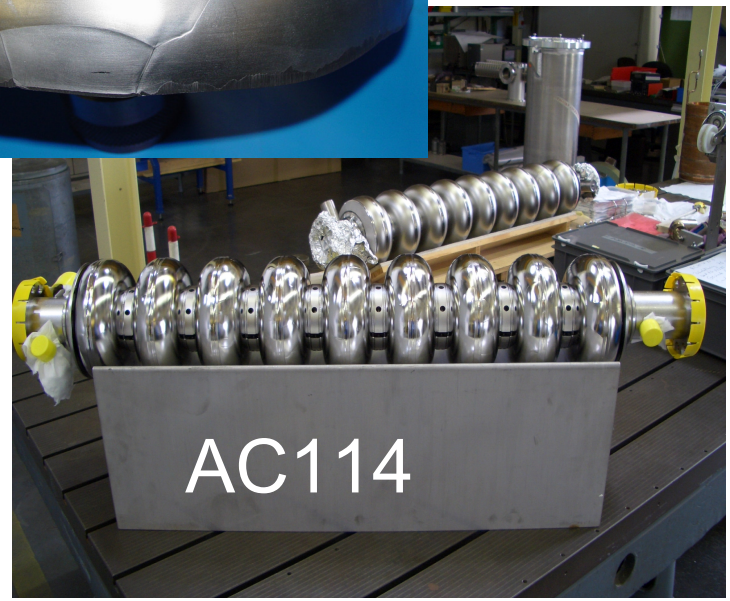
Further improvement of mechanical fabrication sequences are required

European XFEL

Material: LG as a possible cost effective solution for XFEL

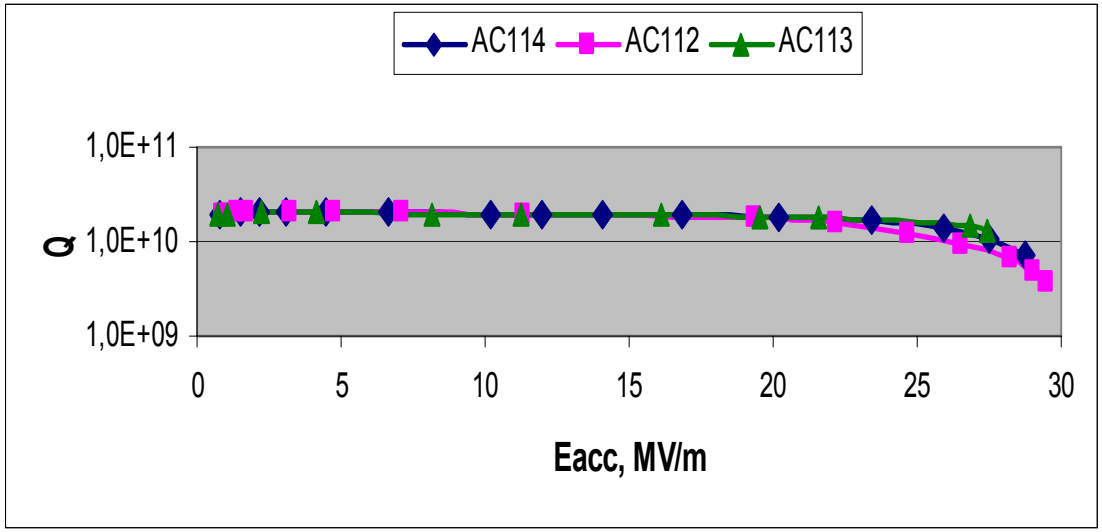






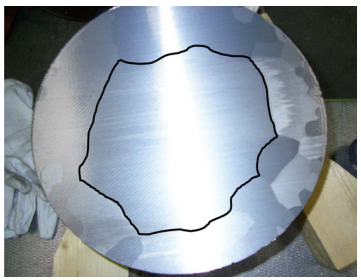
Several single cell and 3+8 nine-cell cavities from large grain LG Nb of Fa. HERAEUS are fabricated at Fa. RI (recently ACCEL)

Large Grain Cavities LG.



First preparation: Q(Eacc) curve of the LG nine cell cavities AC112- AC114 at 2K after 100µm BCP, 800°C 2h, 20µm BCP, HPR

One LG cavity is integrated in helium tank and used for FLASH. 8 LG cavities are in preparation for RF test



Promising, but unfortunately the amount of required LG Nb will be a shortage for XFEL.

Material for XFEL Cavities: Fine grain niobium. Qualification of companies

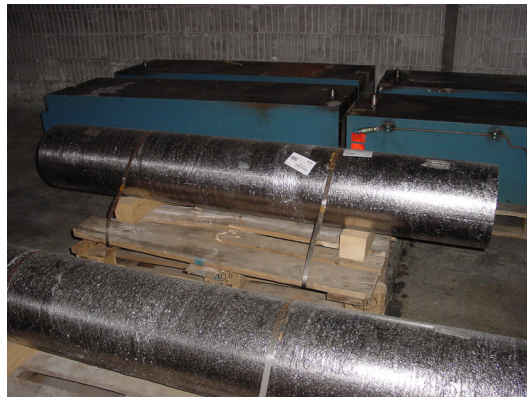
- About 20 t. of high purity niobium are required

Three steps of qualification for XFEL have been determined:

Step 1. Material testing (RRR, Microstructure, Eddy current scanning, Tensile test, Hardness, Impurity content).

Step 2. Single cell cavity fabrication at DESY, treatment and RF tests at DESY.

Step.3. Nine cell cavity fabrication at Industry, treatment at DESY and RF tests.

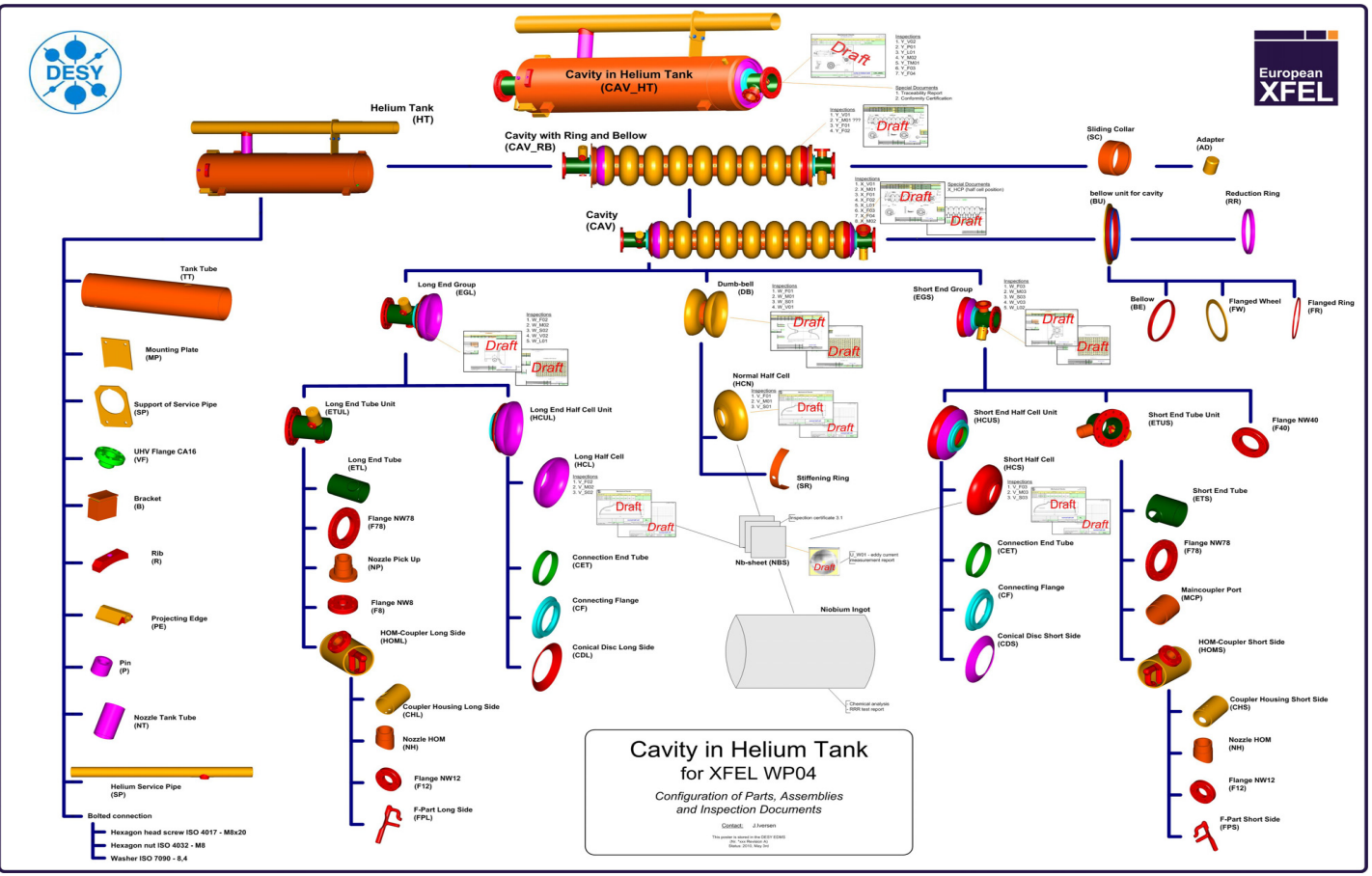


Several companies participated. Only two companies SE Plansee (Austria) and Ningxia Orient Tantalum Industry Co. (China) successfully passed all three steps

Currently 5 qualifies companies available: Wah Chang (USA), Tokyo Denkai (Japan), HERAEUS (Germany). SE Plansee (Austria) and Ningxia Orient Tantalum Industry Co. (China) .

No bottleneck for material

Documentation: PC based documentation in EDMS Data Bank for statistic

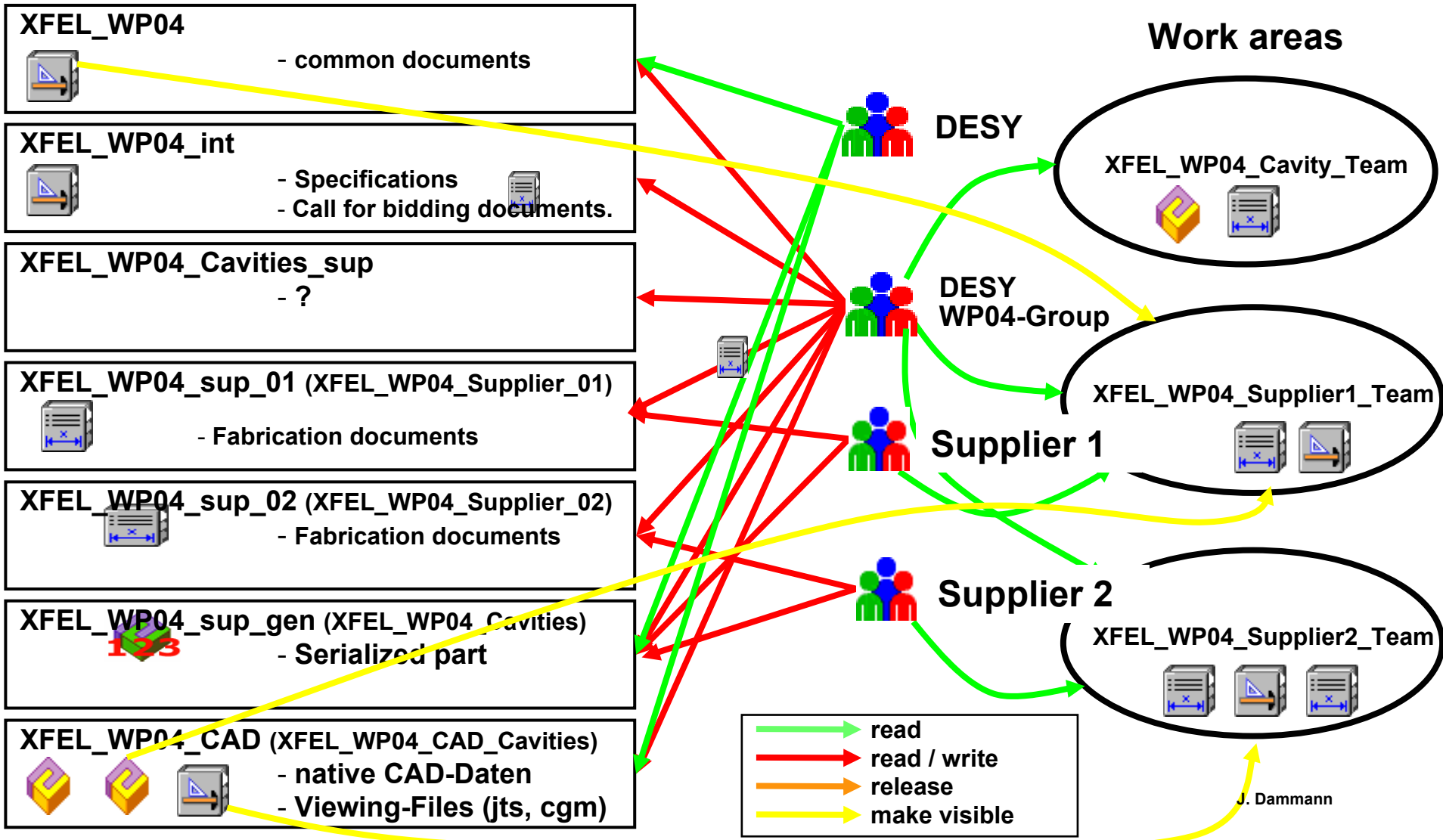


- Manufacturing data management
- Process support and coordination
- Change management

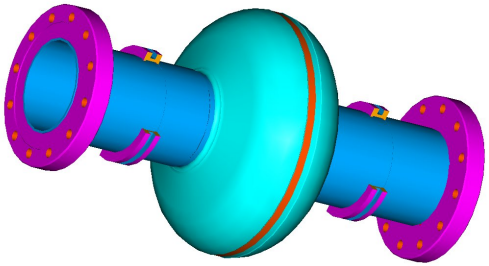
Poster WEPEC006

Developed and tested during preparation phase

Documentation: EDMS Project structure of the cavity production with accessibility strategy



Single cell cavity R&D program. Fabrication at DESY, treatment partially at industry, RF testing at DESY



Ca. 30 single cell cavities

Iris seam

DESY EBW machine

- **Qualifying of new Nb suppliers**
- **Rework of the material specification (e.g. Ta content)**
- **Rework the specification for fabrication of 9 - cell cavity (e.g. check the eight hours rule etc.)**
- **Large Grain Cavity**

Current status of XFEL cavity production

- **Specification for XFEL** is worked out. Spec. describes in details the foreseen at the industry mechanical fabrication and treatment
- Cavity **Call for Tender CFT in frame of EU regulations was published** on July 2nd, 2009. **Qualified at DESY companies** are asked for tenders.
- **Offers** received end of November 2009
- **Negotiations** (January 2010) led to a second CFT…

*) 1st XFEL MAC: With realistic assumptions on lower beam emittance, linac energy reduction by 20% to 14 GeV appears as a reasonable compromise between cost aspects and scientific potential

Current status of XFEL cavity production

- **Second CFT with modified constraints**
- - no performance guarantee. The orderer will insist on a mech. fabrication and treatment strictly following the detailed XFEL specifications (build to print)
- - procurement of material for cavity (Nb, NbTi) and /or helium tanks possibly by the orderer
- **Reasonable offers received**
- - decision is possible
- - contracts to be allocated by DESY and supervision of cavity production by DESY/INFN.
- - series cavities to be delivered in 2012 & 2013
- - total number of cavities reduced to 80%, order of ca. 650 CVs*
- **Intention to place contracts a.s.a.p.**

*) **1st XFEL MAC: With realistic assumptions on lower beam emittance, linac energy reduction by 20% to 14 GeV appears as a reasonable compromise between cost aspects and scientific potential**

Material procurement

DESY will possibly take over the responsibility for material procurement

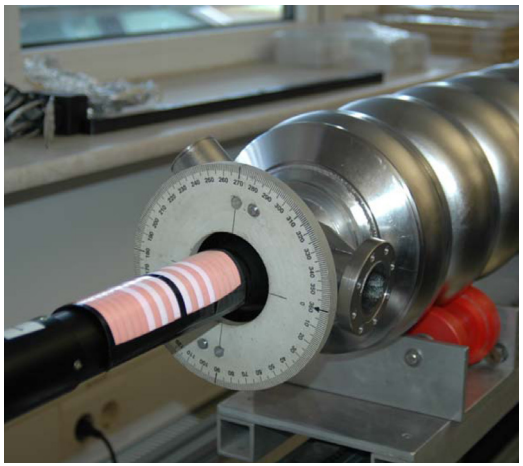
- quality control
- documentation of cavity material (guarantee of traceability)
- Eddy Current scanning of sheets
- definition of numbering system
- marking
- delivery to company

Material procurement: 2011-2012

New equipments for eddy current scanning of XFEL niobium

DESY support production with special equipments

Machines for warm cavity tuning in work (in cooperation with FNAL)

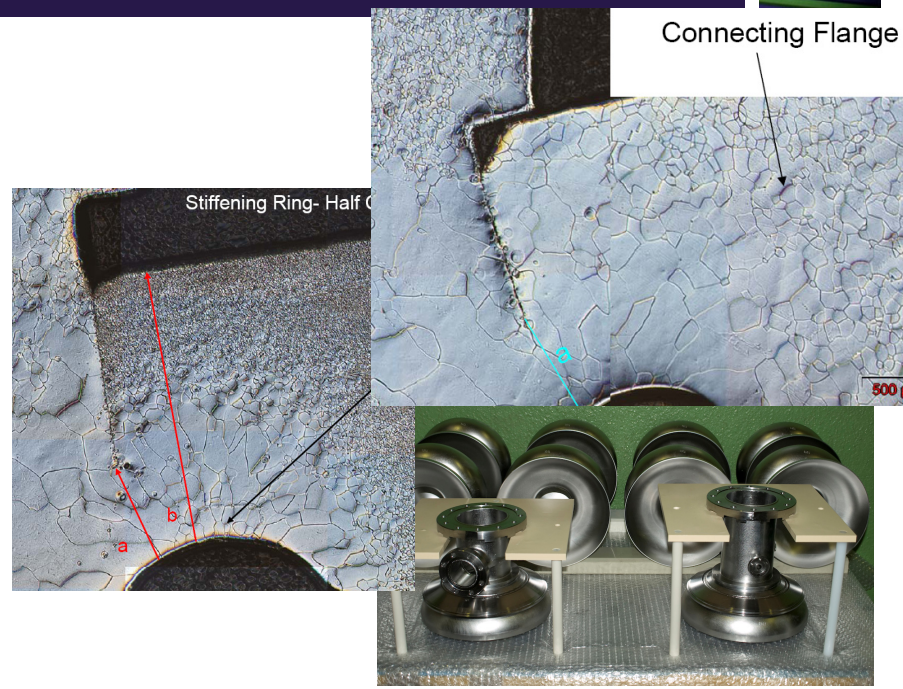


High resolution camera for optical control (developed by KEK). Poster WEPEC005

Equipments for RF measurement of half cells, dumb bells and end groups (HAZEMEMA)

QA: Pressure Equipment Issues

- The cavity with helium tank **has to be build as a pressure device** according PED/97/23/EC Pressure Equipment Directive
- The **identified body** will supervise the material procurement and cavity production



Activity of the identified body

- Examination of design, FEM calculation, analysis of welding connections realization. Destructive tests on welding connections
- Traceability (from material up to cavity in the helium tank)
- Qualification of material (creation the particular material appraisal (PMA)
- Examination of purchased semi products

Acknowledgement

Many thanks to all participating colleagues from DESY and INFN whose enthusiastic effort allows us to push forward the work on cavities for XFEL project