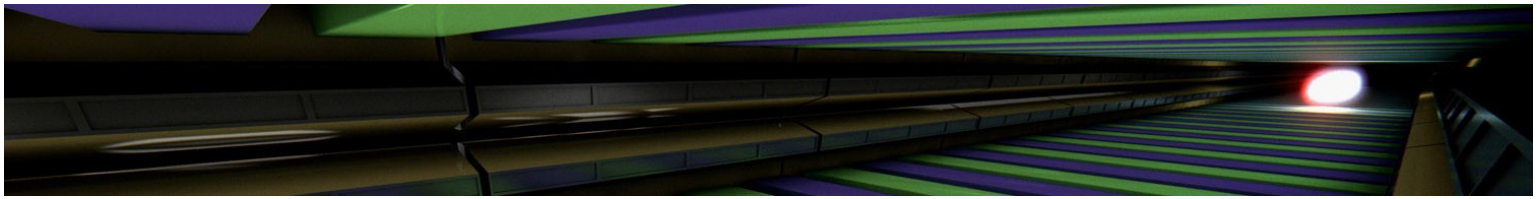


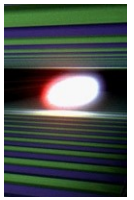
1.3 GHz SC Cavities for the European XFEL

Presented by

Waldemar Singer

on behalf of the XFEL WP4 cavity team

Main issues: preparation phase are finished, production started



Preparation Phase 2005-2010

Specification

Mechanical fabrication

Treatment

RF measurement

Documentation

Prototype cavities

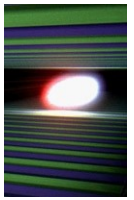
Production Phase 2010-2014

Current status of the cavity fabrication contract

Contract related issues (PED, Transport, Spec. changes)

Specification

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



Specification documents:

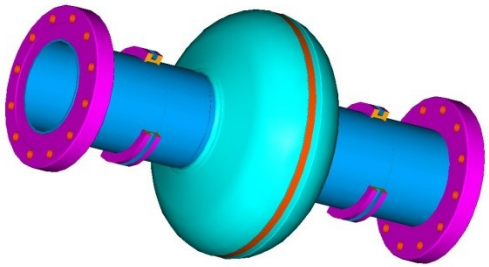
- SERIES MECHANICAL FABRICATION: (XFEL/001- XFEL/018)
- SERIES SURFACE AND ACCEPTANCE TEST PREPARATION (XFEL/A - D)
- HARDWARE AND PROCESSES USED AT DESY (XFEL/Appendix I - IV)
- ILC-HI GRADE CAVITIES AS A TOOL OF QUALITY CONTROL (XFEL/HiGrade)
- SETS OF DRAWINGS

Two main aims have been pursued:

- Spec. has to contain all detailed requirements for the cavity mechanical fabrication, treatment and assembly for RF test
- DESY experienced has to be included.

The work was done by the assistance of the experienced external advisers from the industry. Many thanks to the contributing DESY and INFN experts, whose enthusiastic effort allowed us to bring forward the work on cavity specifications for the XFEL project.

Single cell cavity R&D program (D. Reschke) was a good tool for specification

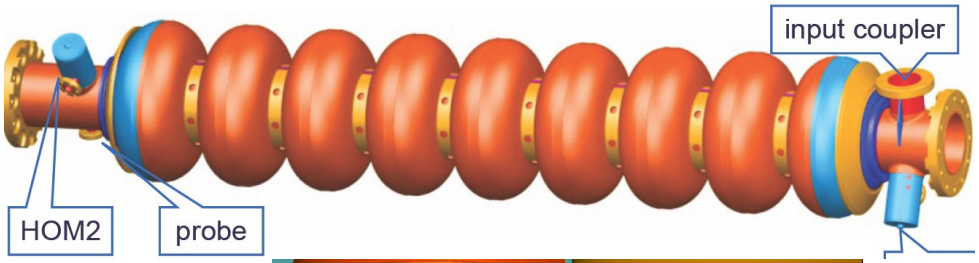


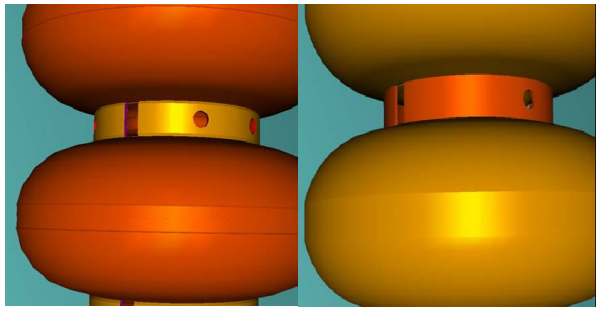
Iris seam

DESY EBW machine

- **Rework the specification for cavity mechanical fabrication**
- **Qualifying of new material suppliers**
- **Rework of the material specification:**

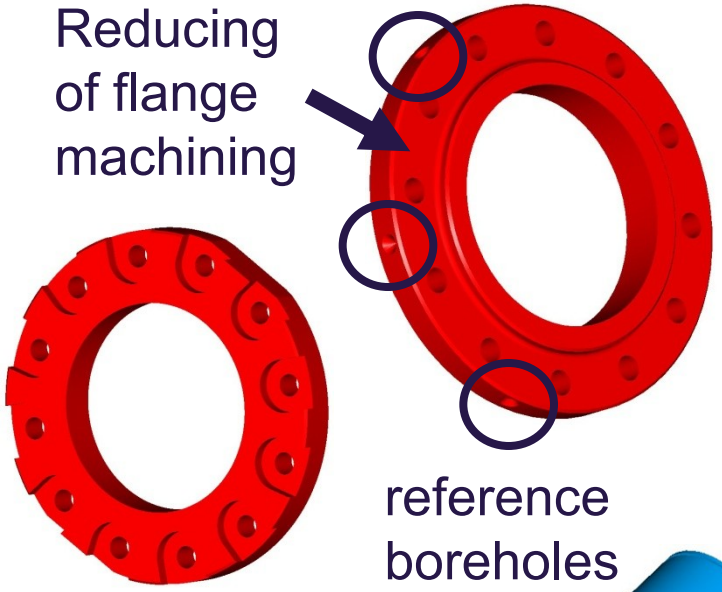
Mechanical fabrication: TESLA Design – minor design changes. Four cavities of XFEL design produced





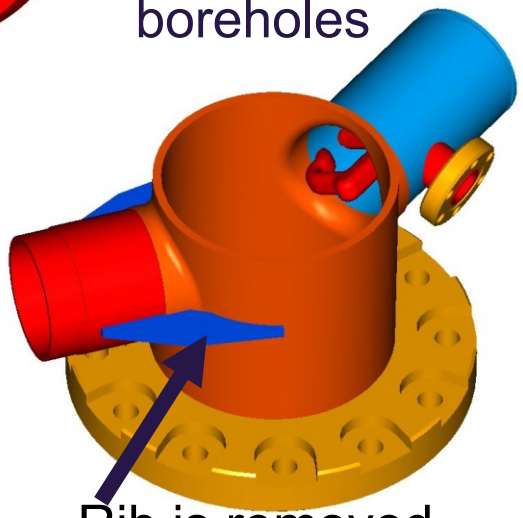
- Removal of coupler port stiffener (rib)
- Reducing of flange machining
- Removal of outside recess (equator area)
- Less holes and thinner the stiffening ring
- New reference boreholes for cavity-string-alignment
- Review tolerances

Reducing of flange machining



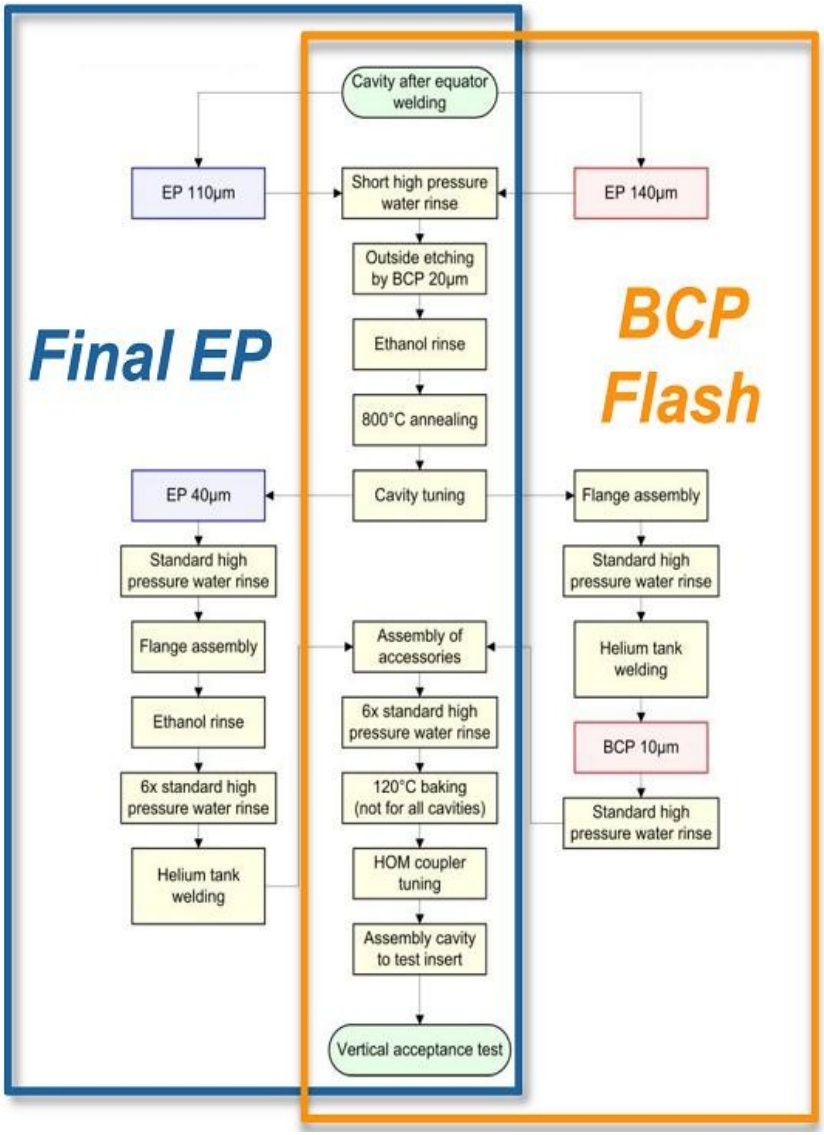
reference boreholes

Stiffening ring



Rib is removed

Treatment: XFEL treatment recipe was worked out on 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

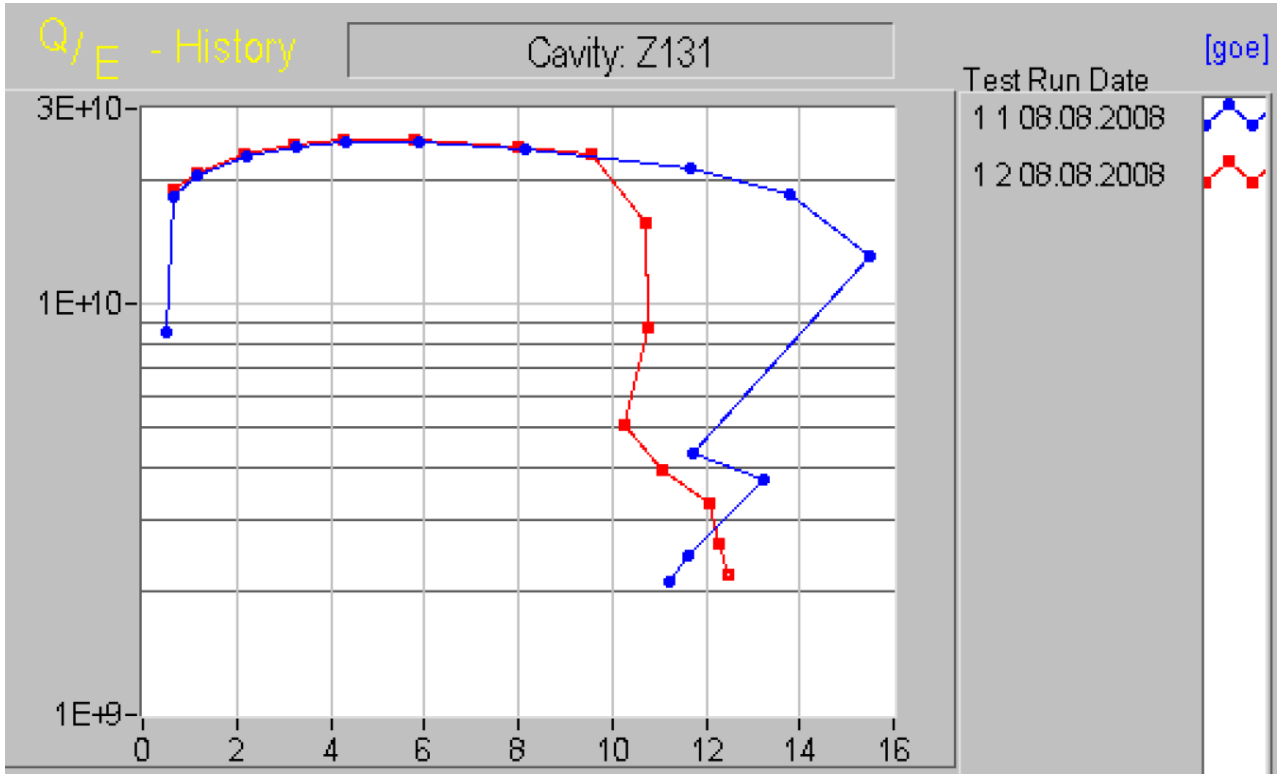
1. Final EP of 40 µm, ethanol rinse, high pressure water rinsing (HPR) and 120° C bake
2. Final BCP of 10 µm (BCP Flash), HPR and 120° C bake.

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

RF Measurement. Q-switch. Observed on several cavities

Cavity in tank with HOM couplers and feedthroughs

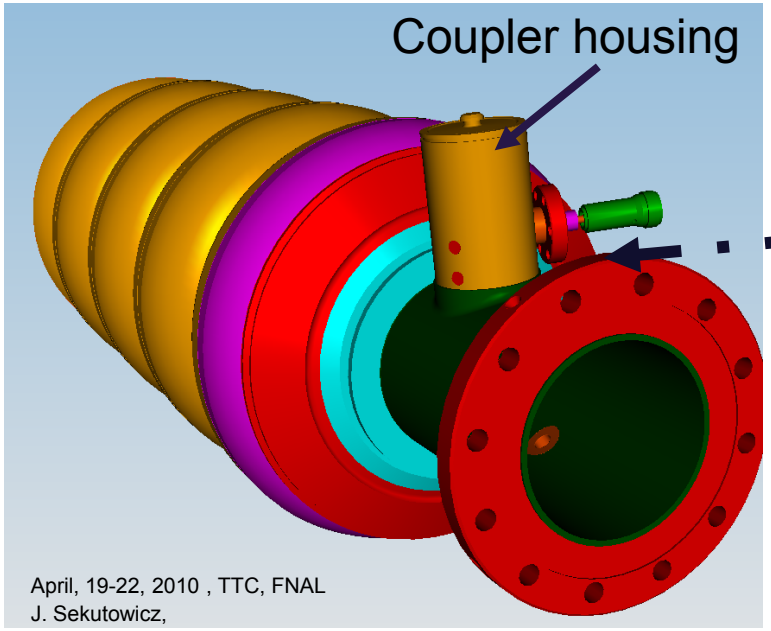
Cavity is limited by the Q-switch at 10..15 MV/m without FE. Q-switch is a thermal effect connected with HOM couplers. Without HOM couplers and feedthroughs no Q-switch.

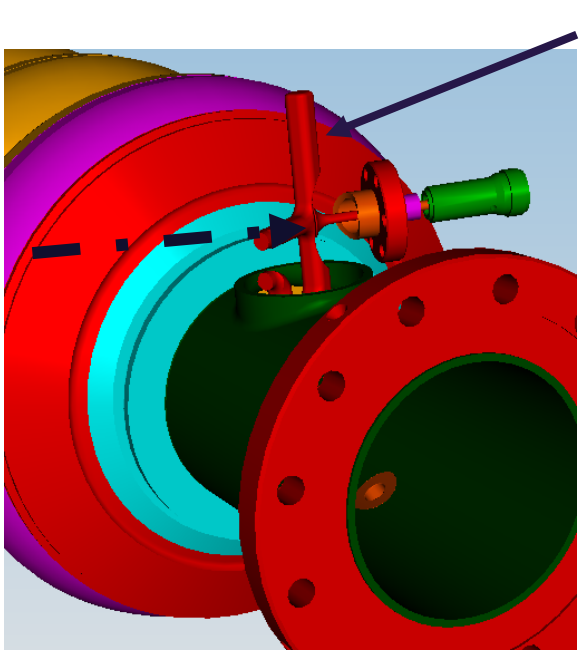


EP 110µm, alc. rinse, 800° C 2h, EP 48µm, HPR, alc. rinse, 6xHPR, tank welding, HOM feeds, 6xHPR, 120C bake out.

RF Measurement

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

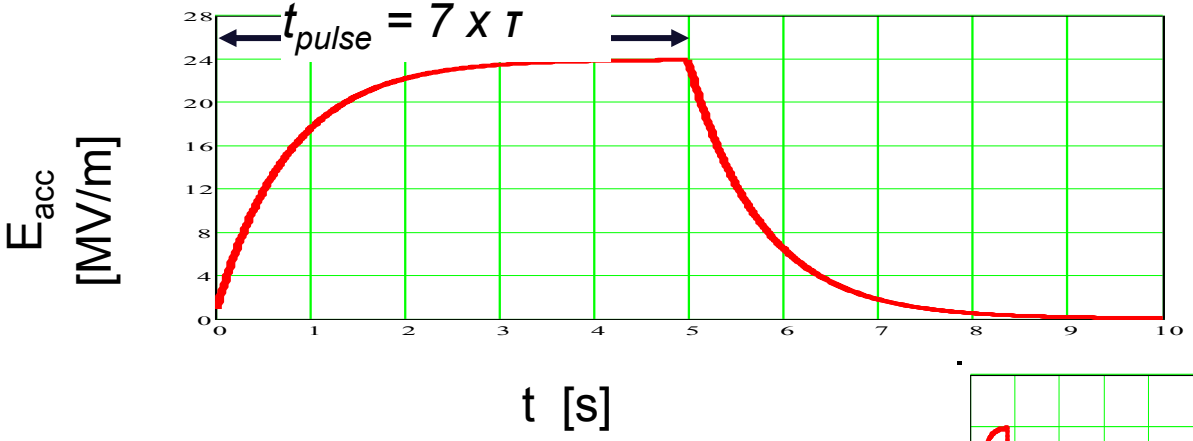




In past we tested in the CW mode many cavities with welded HOM couplers (the coupler housing and F-part); reached Eacc is up to 40 MV/m. The difficulties come from the limited heat conduction of the HOM feedthroughs, when antenna is installed

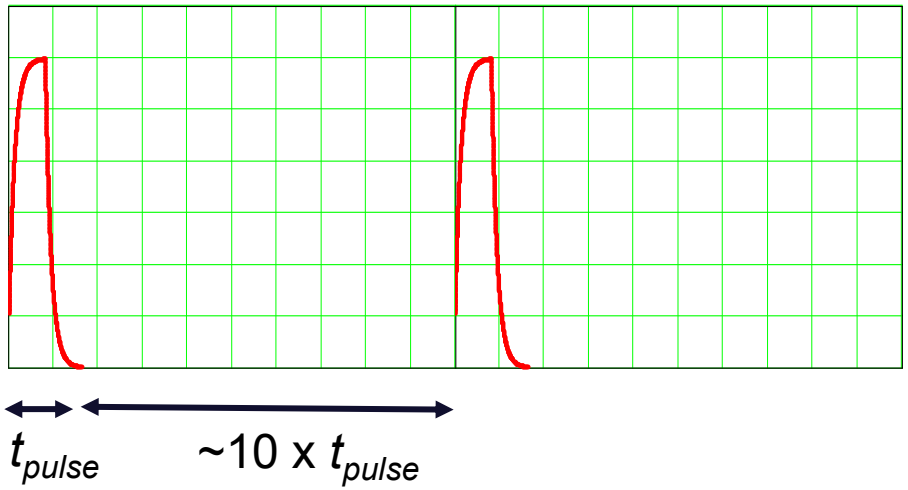
RF Measurement: Pulse Acceptance Test for XFEL Cavities

Proposed by J. Sekutowicz and successfully implemented



This reduces the mean cryogenic load by factor of 10.

Cavities in the pulse test demonstrate similar Eacc compared to the CW RF test without HOM antennas

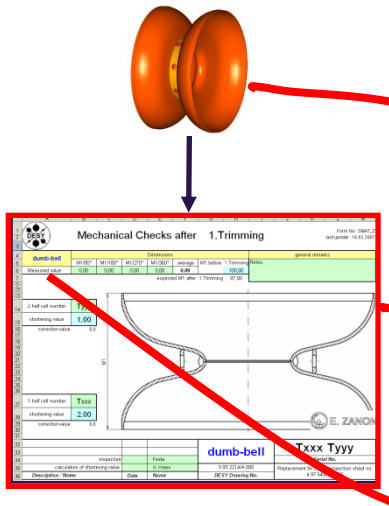


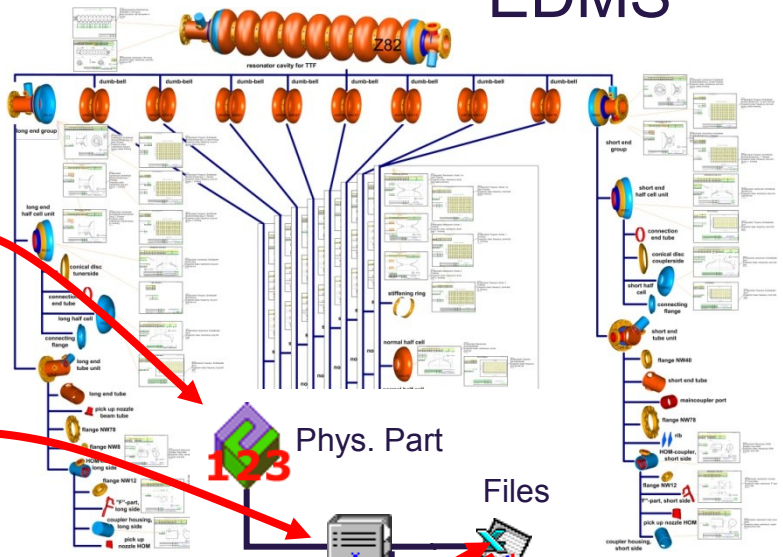
Electronically Documentation in EDMS. Data Bank for statistic

Fabrication

EDMS

Cavity-DB

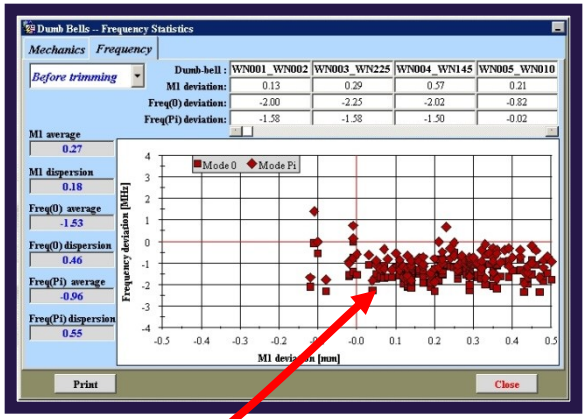




Phys. Part

Files

Inspection sheet



Inspection sheets for quality management

Fabrication structure.
Subassembly parts related.
Procedure related

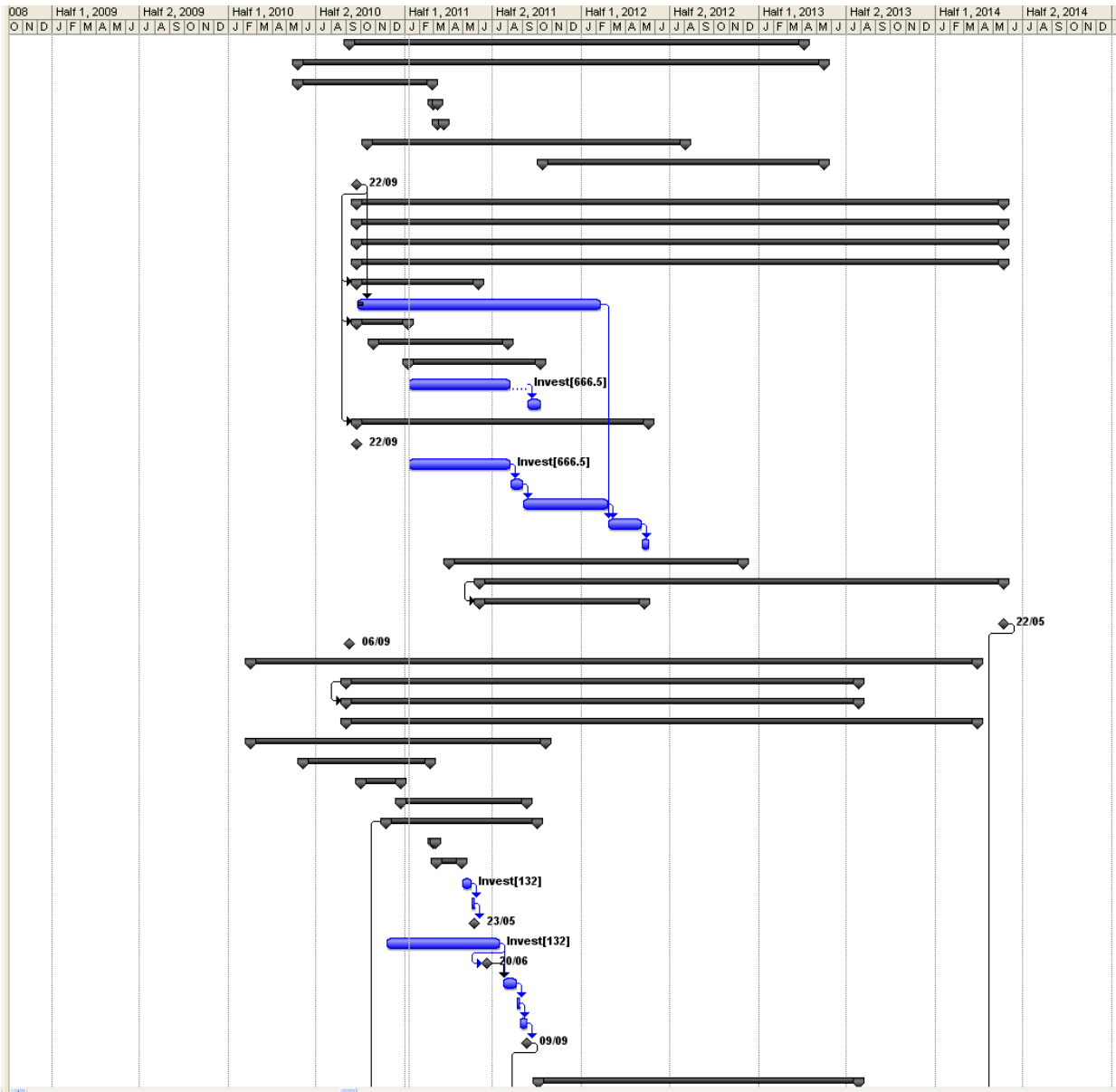
Statistical analysis

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

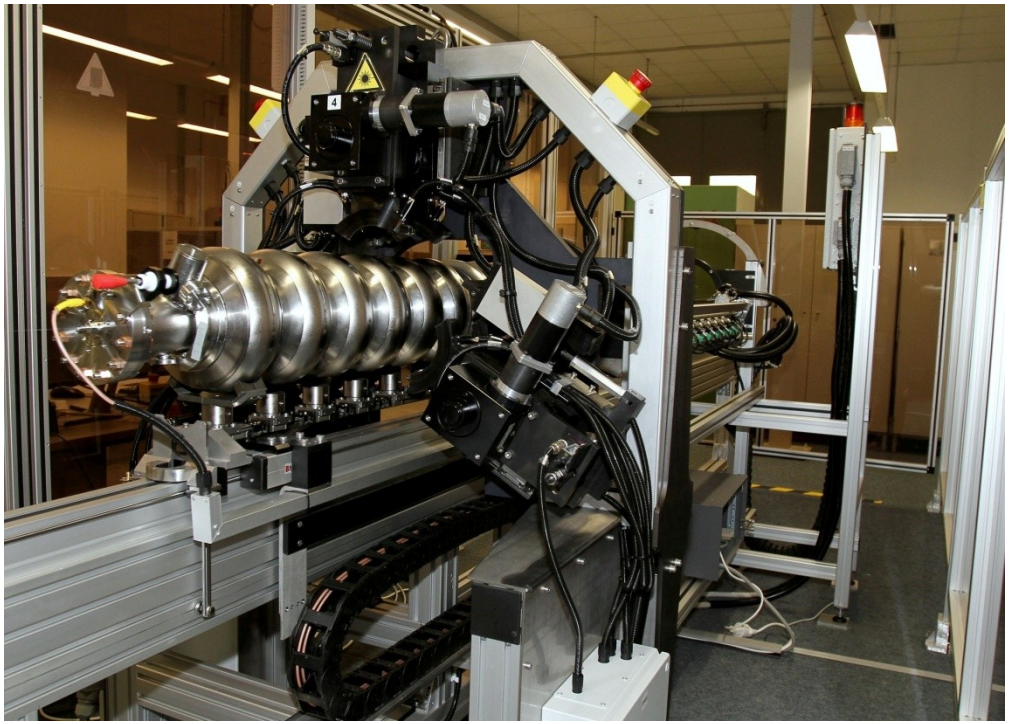
MP Plan with incoming and outgoing milestones and tracking possibility (example, not actual)

European XFEL

		Task Name
80		**Purchase of Nb and NbTi material by DESY for Fa. RI & Fa. EZ**
133		**Purchase of Helium tanks for Fa. RI**
134		**24 tanks for qualifaction for EU call for tender**
139		**DCV Cavities**
141		**RCV Cavities**
143		**EU contract allocation for 288 helium tank units XFEL**
149		**Start series helium tanks delivering to Fa. RI**
170	✓	Contract signature Fa. RI
171		**Main series cavity fabrication, Fa. RI**
172		**Supervise main series cavity mechanical fabrication Fa. RI**
181		**Supervise main series cavity treatment Fa. RI**
187		**Contractual Milestones**
208		**Infrastructure for mechanical series fabrication**
211		Infrastructure for series preparation
259		**Mechanical Engineering**
265		**PED related work**
285		**Fabrication of 4 DCVs**
286		Mechanical fabrication of 4 DCVs (2 with tanks, 2 without tanks)
287		Welding of PED related parts
288		**Fabrication of 4 RCVs**
289		Supply of material by DESY
290		Mechanical fabrication of 4 RCVs
291		Welding of PED related parts
292		Treatment and test of 4 RCVs at DESY
293		Re-treatment of 4 RCVs with upgraded infrastructure
294		Test of 4 RCVs at DESY
295		**Supply of material for series cavities by DESY**
302		**Fabrication of 280 Series Cavities and 12 HiGrade Cavities**
372		**APPROVAL by TUEV**
376		Fa. RI: CV mechanical fabrication finished
377	✓	Award of order Fa. EZ
378		**Main series cavity fabrication, Fa. EZ**
379		**Supervise main series cavity mechanical fabrication Fa. EZ**
385		**Supervise main series cavity treatment Fa. EZ**
390		**Contractual milestones**
394		**Design for infrastructure & tools**
441		**Engineering**
454		**Materials**
458		**Helium tanks fabrication**
462		**Cavities fabrication**
509		**Completition of test piece**
516		**Examination of test piece**
522		Start welding of DCVs and RCVs Cavities
523		Shipment of 4 DCVs to DESY
524		Start of treatment & testing of 4 DCVs at DESY
525		Fabrication of 4 Reference Cavities (RCVs)
526		Desy accessories supplying
527		Treatment & testing of 4 RCVs
528		Shipment of 4 RCVs to DESY
529		Testing of 4 RCVs at DESY
530		Release for cavities series production
531		Cavities series subassemblies production
532		**Cavities series production**



DESY support production with special equipment build at DESY (W.-D. Moeller) and installed at RI and EZ

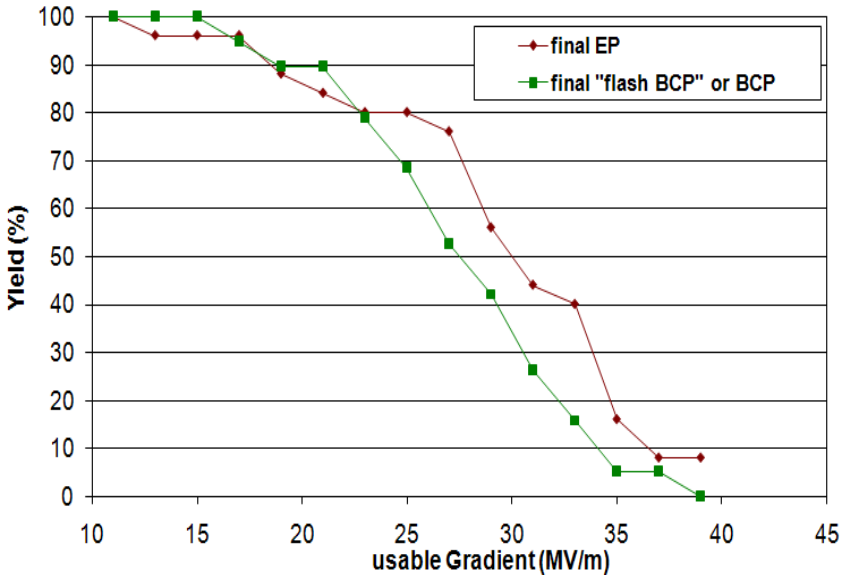


Machine for warm cavity tuning TM (tuning machine)

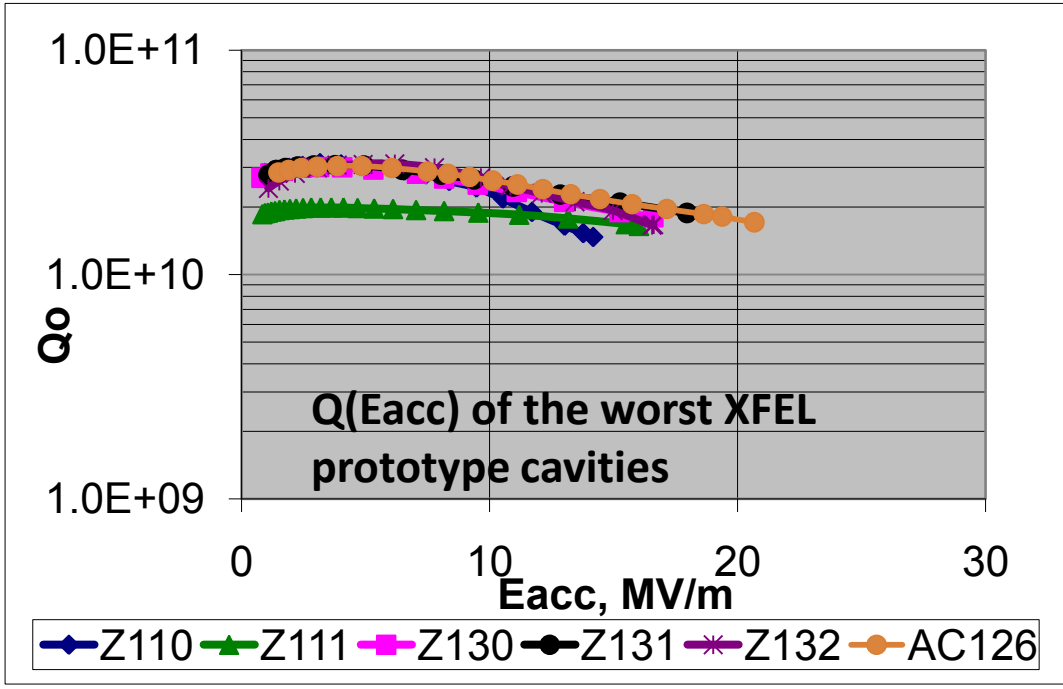
Equipment for RF measurement of half cells, dumb bells and end groups HAZEMEMA (Delivered to E. Zanon, will be delivered to RI in 2011)

Provided with CE certification according EU regulations

Performance statistic on prototype XFEL cavities. Ca. 50 prototype cavities produced



Required for XFEL Eacc=24,3 MV/m. Qo=1E+10.



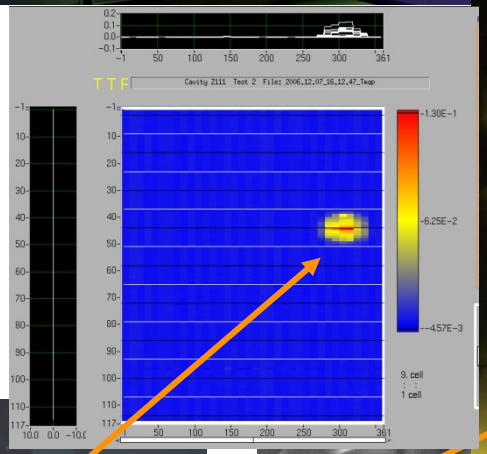
Performance statistic:

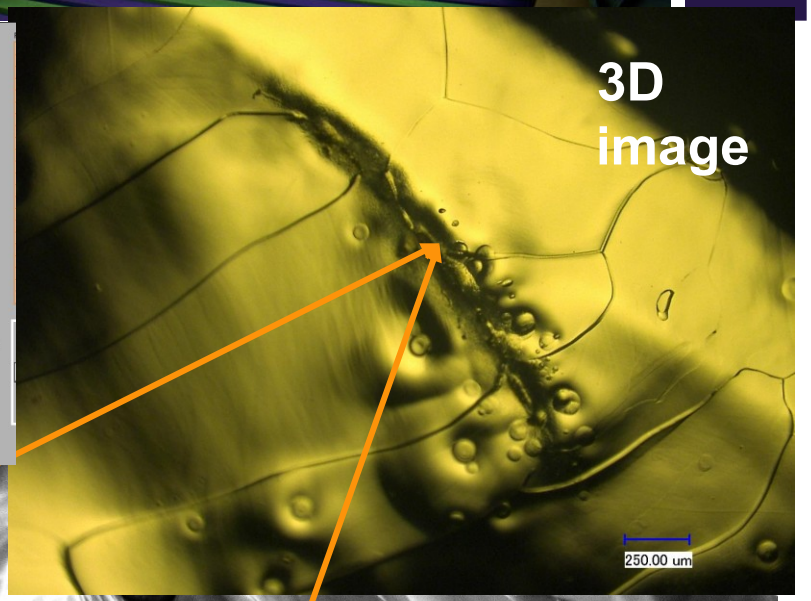
- **Difference between first and last test dominated by FE reduction**
- **Final surface treatment influences yield at higher gradients**

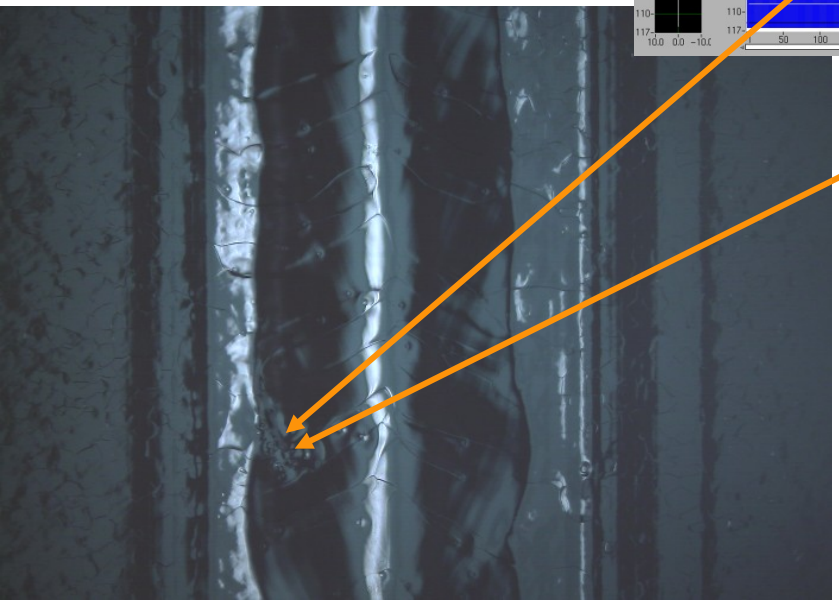
Decision: destroy few worst cavities and investigate the inside surface

Type 1: Topographical defects at the welding seam.

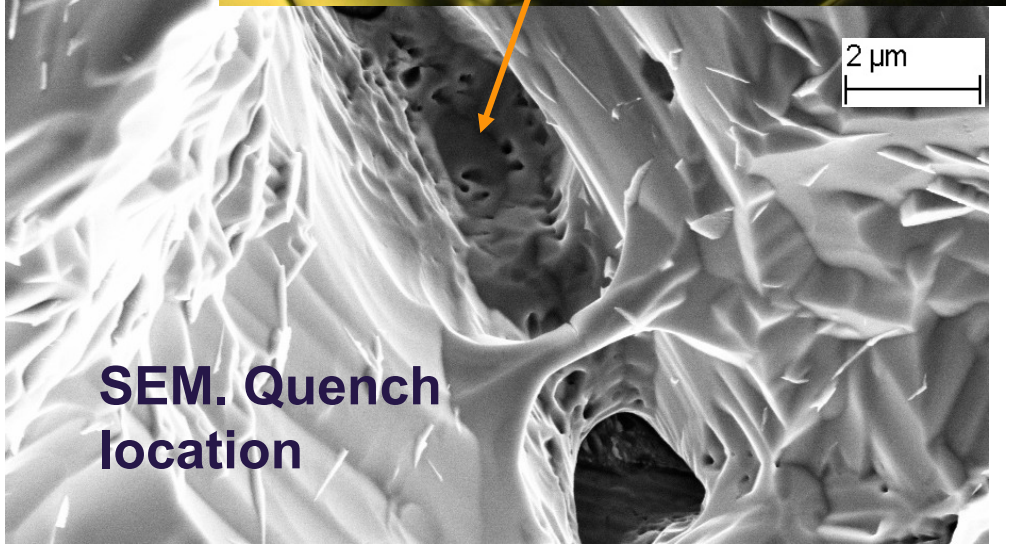
Quench at 16,2 MV/m
on equator



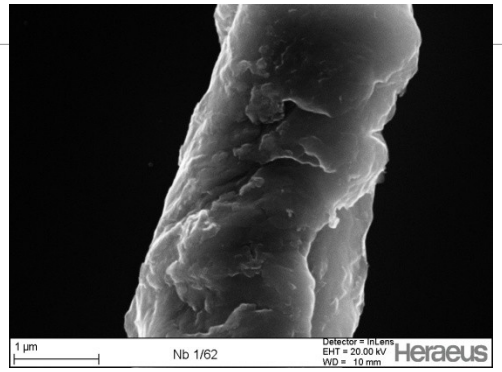


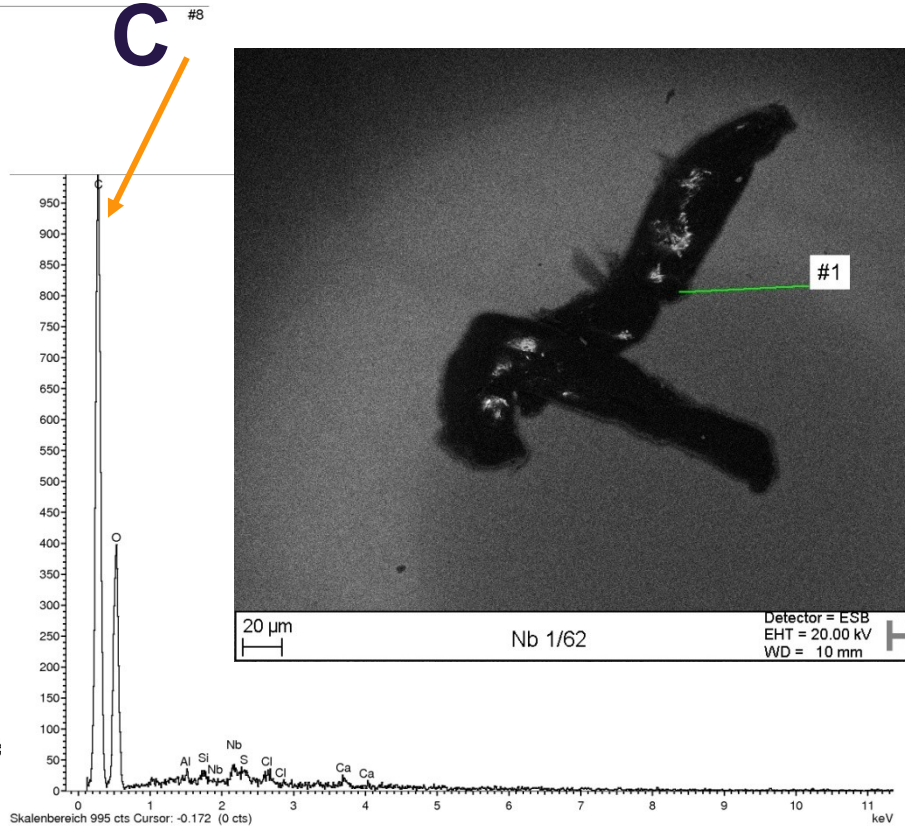


Optical inspection by high
resolution camera (S. Aderhold)



Type 2: Defects with foreign materials

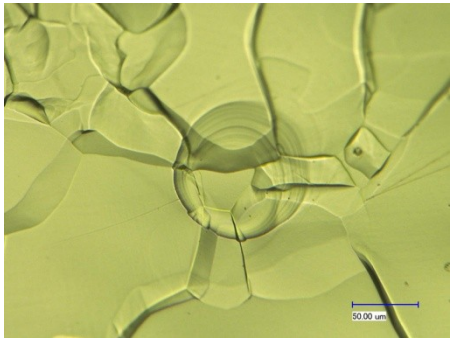


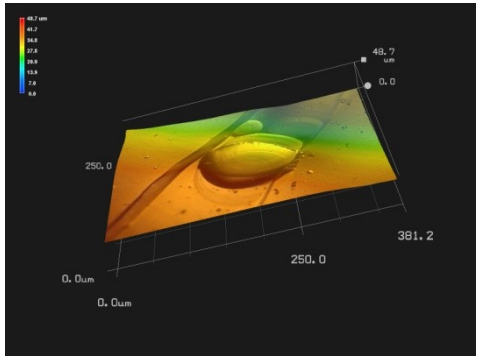


Iron particle found

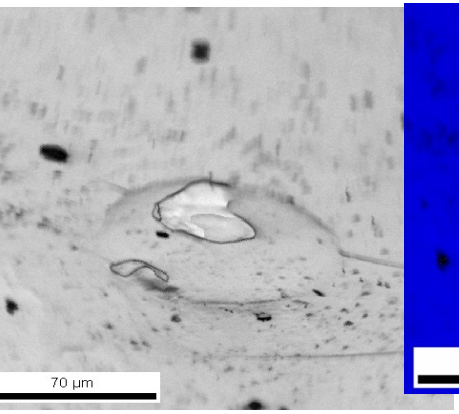
Many spots are detected. EDX of the biggest spot: C and O found

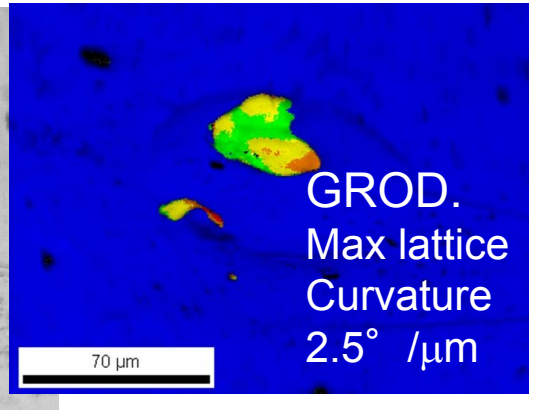
Type 3: Etching pits. EBSD with strain maps via grain reference orientation deviation (GROD)



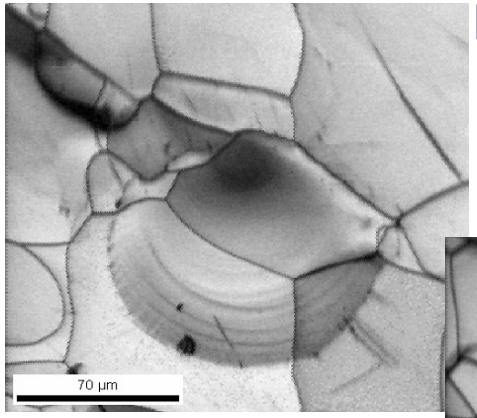


Cavity Z111: 3D Images of etching pits

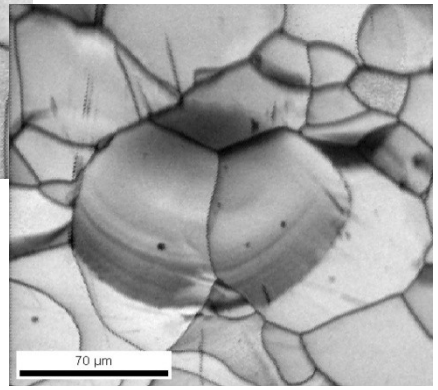




Z111: Pit in heat affected zone HAZ of weld, enclosing region of strain, all within one grain (R. Croocs)



Pits away from the weld, with grain boundary triple junctions



- **Pits don't seem to be related to grain orientation**
- **Pits in weld HAZ are near areas of remaining cold work (high dislocation density)**
- **Pits away from the weld, in fine grain area tend to be centered on grain boundary triple junctions**

Type 4: Damaged surface; evidently by high pressure water rinsing, can cause quench (AC126)

Auger spectrums indicates very high presence of oxygen.

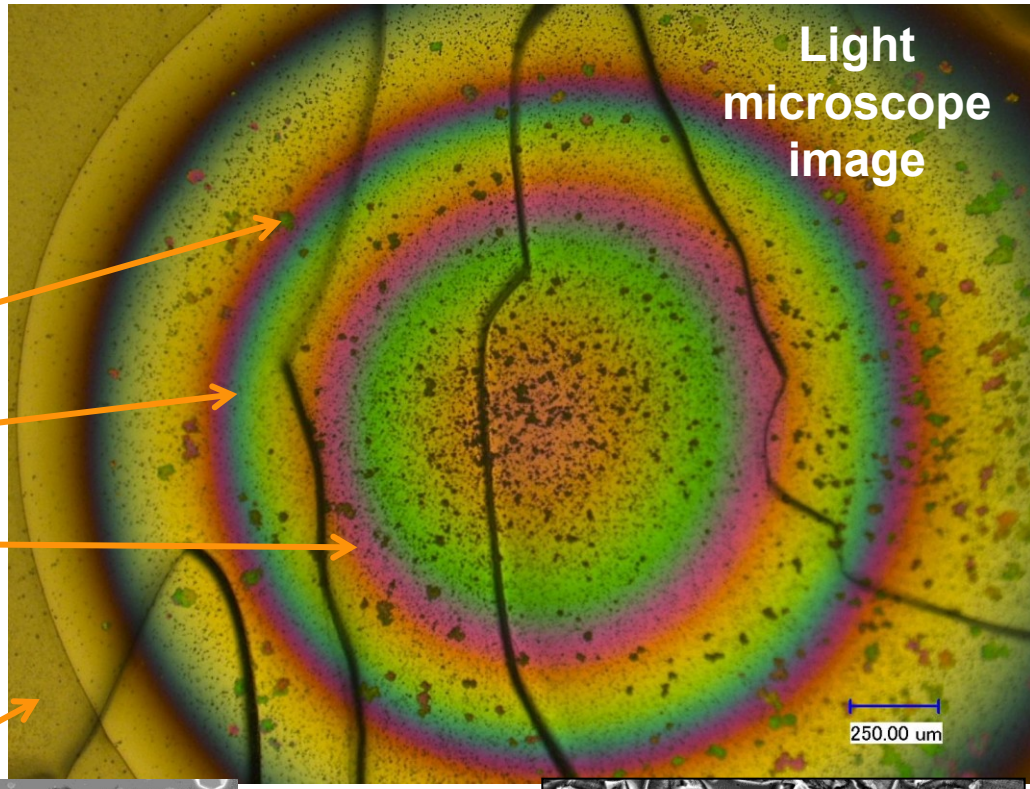
Oxide layer with thickness:

>114 nm (spot)

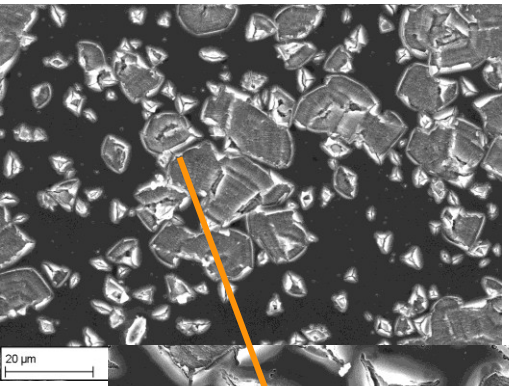
32.5 nm (blue)

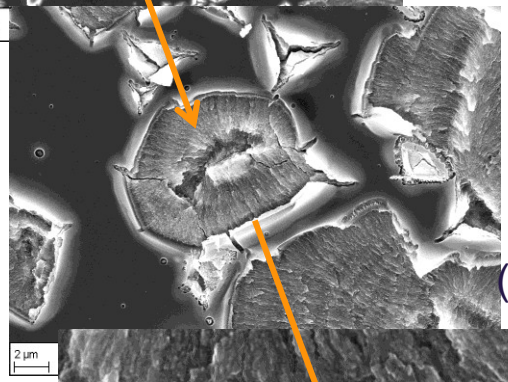
195 nm (red)

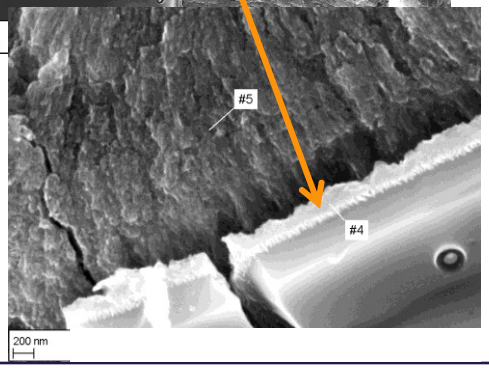
13 nm (outside rings)

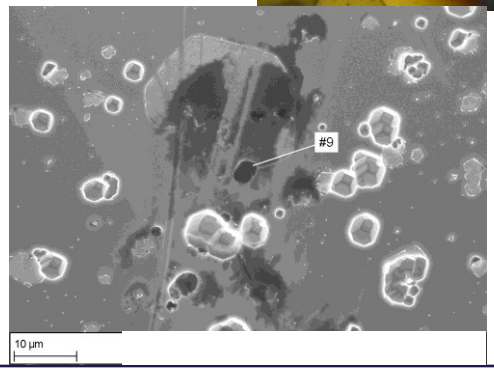


SEM Images

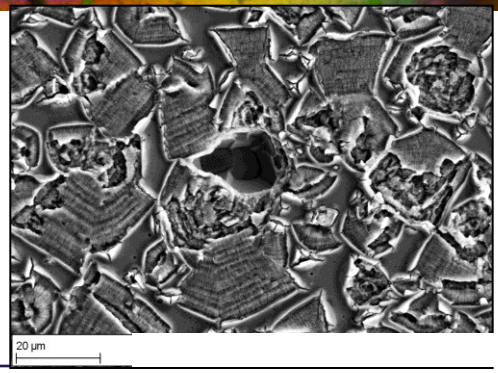








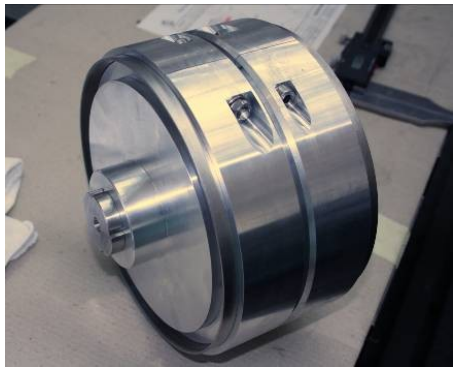
SEM image of the black spots EDAX indicates carbon



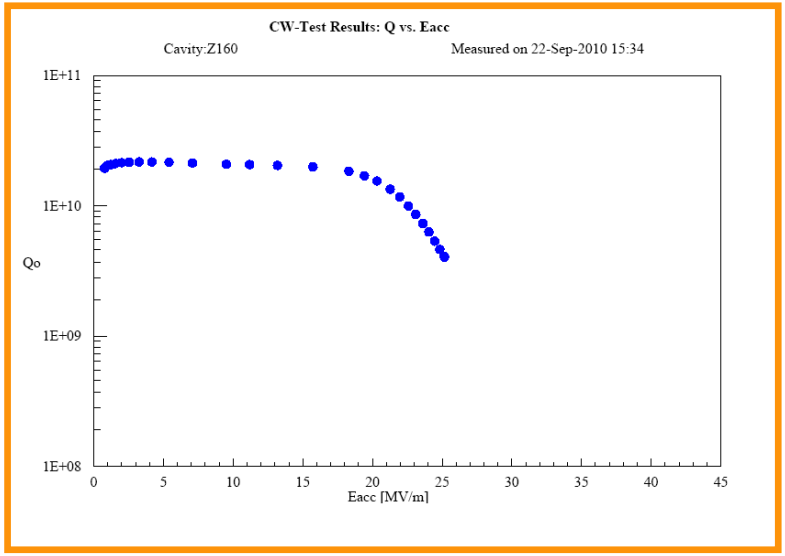
Triggered activities of Zanon and INFN/DESY towards improvement of XFEL cavity production

Review & optimization of the cavity mechanical fabrication cycle at E.Zanon:

- new joint geometry for EBW optimized with several tests on single cell and 9-cell cavities
- tools for the production successfully tested: new tool for DB cutting, tool for EG cutting, tool for coupling of cavity components
- Three CVs produced. The up to now tested cavity achieved > 25 MV/m 100 μm BCP and 800 °C (w/o EP and w/o 120 °C). All three CVs EP treated and in preparation for RF test at DESY



Courtesy E. Zanon



Q(Eacc) of cavity Z160

Status: Contracts XFEL cavity production

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

Cavities for qualification of the infrastructure **(4 DCVs, 4 RCVs)**
280 XFEL type series cavities
12 ILC HiGrade cavities
- Material for cavities **Nb / NbTi to be supplied by DESY.**
- **He-vessels for RI** cavities to be supplied by DESY
- Production precisely following the in detail worked out specifications which also include the exact definition of infrastructure to be used (**build to print**)
- Final treatment after main electropolishing: **Final EP for RI** / **flash BCP for EZ**

Status: Contracts XFEL cavity production

- **No performance guaranty by the vendors**, i.e. the risk of unexpected low gradient or field emission is taken over by DESY (responsibility for re-treatment); goal: average usable XFEL gradient 24.3 MV/m at Qo=1x10^{10}
- Additional **80 cavities as an option** will be placed after the evaluation of the start of the series production
- First series cavities **to be delivered mid of 2012**; all cavities to be delivered till **mid of 2014**

Kick off meetings:

RI: 6th of September 2010

E.ZANON: 7th of September 2010

Both companies started: Infrastructure, Fabrication drawings, PED activities etc. (e.g. Talk of G. Corniani, E. Zanon)

Status: PED (Pressure Equipment Directive) Issues

The cavity with helium tank **has to be build as a component** according PED/97/23/EC Pressure Equipment Directive

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

PED Activities (started)

Module B (constr. example check)- contracted

- examination of design, FEM calculation
- qualification of material
- qualification of welding processes
- qualification of another PED relevant processes (annealing, deep drawing)
- destructive tests on specially build test pieces (2 cell cavity with helium tank)
- supervising the fabrication of Dummy CV and Reference CV
- find PED relevant testing methods for the series production of the cavities

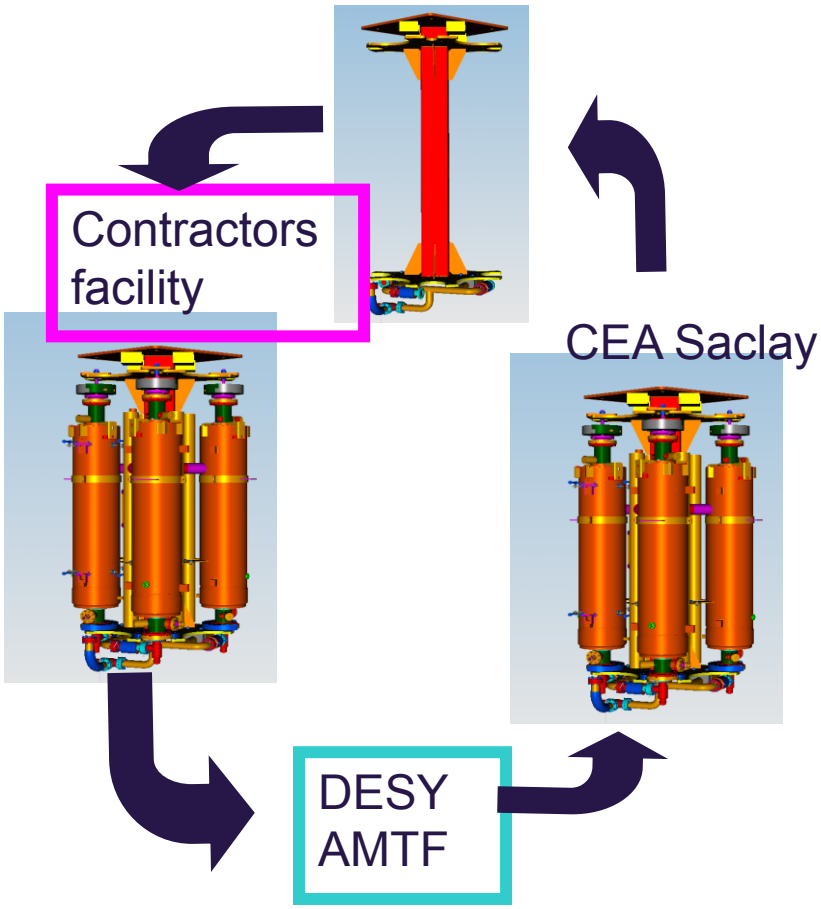
Module F (check of the products) - not contracted yet

- Supervision the serial cavity fabrication

More details in talk of Axel Matheisen tomorrow

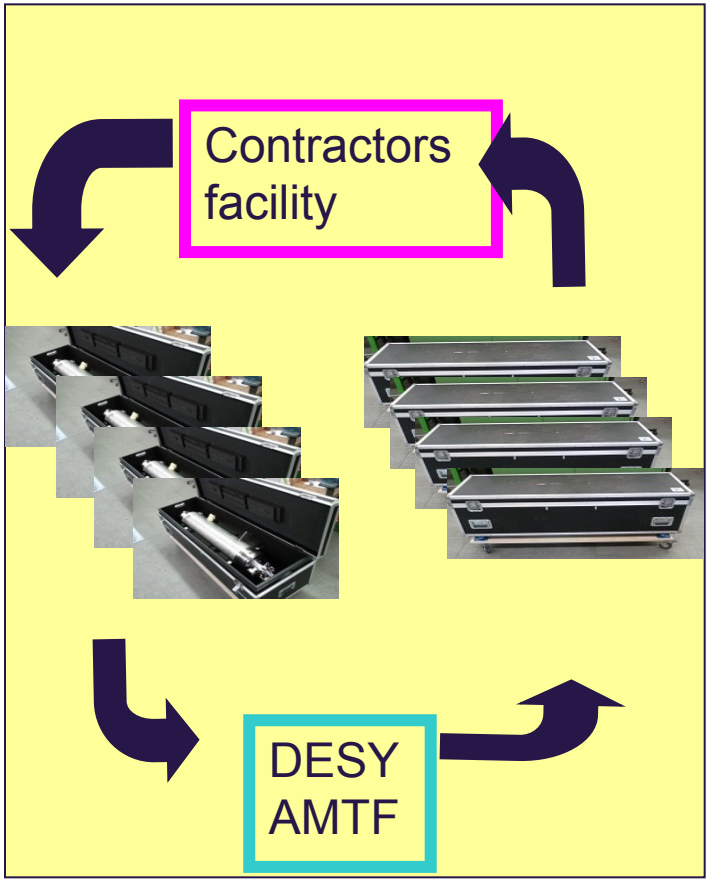
Waving the performance guarantee simplify the transport (proposed by A. Matheisen)

Version with Performance guaranty at Company



Transport frame

Version with best efforts request at Company



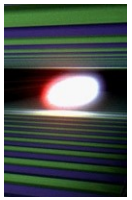
Transport boxes now

Specification

Some changes occurred as a result of negotiations with companies - cavity producers. In particular DESY has taken over:

- Material procurement
- Performance guaranty
- Organization and costs for PED issues
- He-vessels fabrication for one of the companies
- Cavity transport containers and transport conditions are changed

These changes forced us to adopt the specification documents to the order circumstances. Change reports linked to companies have been created. In addition companies asked for approval of some changes in the specifications (change requests)



Acknowledgement

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