Industrial Fabrication and Treatment of European XFEL Cavities - Challenges of the Knowledge Transfer to Industry

ECFA LC 13, AC4, May 28, 2013

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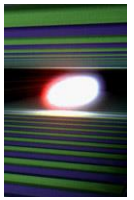
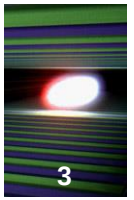
for the XFEL Cavity Team

Outline



- Main principles of the Technology Transfer TT
- Procurement strategy
- Strategy of supervision and quality management
- Material for SC cavities
- PED (Pressure Equipment Directive) activities
- Qualification of new infrastructure at industry
- Current status and time schedule
- Appendix: Images of new infrastructure at RI and E. Zanon

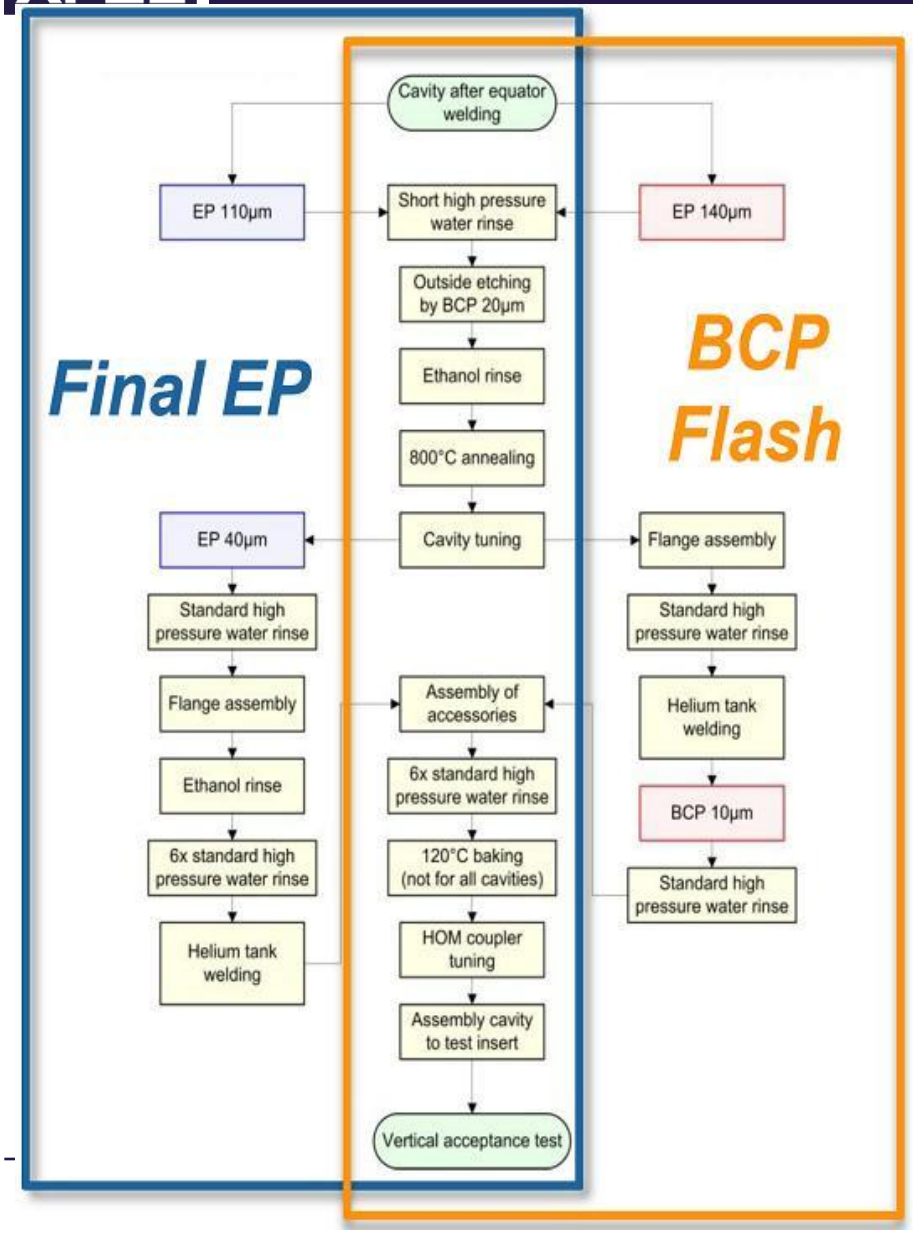
Main principles of the Technology Transfer TT*



- The R&D process must be complete: The treatment recipe for EXFEL worked out on base of ca. 50 prototype cavities (will be discussed below).
- List of vendors must be complete: Qualification of the material suppliers and cavity suppliers was done in preparation phase
- Documentation must be complete: EXFEL specifications worked out in preparation phase (Specs available for the community)
- In house technical review process: PRR in April 2009
- Work out the procurement strategy, delivery rate and completion date: Will be discussed below
- Identifying the key project personal: Done

***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.**

Treatment: XFEL treatment recipe was worked out on prototype cavities



Prior surface treatment.

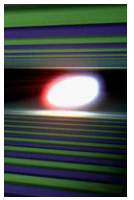
EP 110-140 µm (main EP), outside BCP, ethanol rinse, 800° C annealing, tuning

Final surface treatment - two alternative options

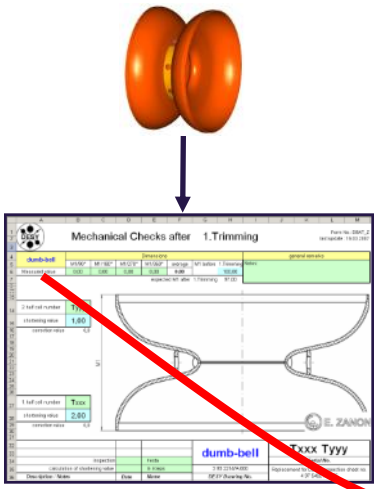
1. **Final EP of 40 µm, ethanol rinse, high pressure water rinsing (HPR) and 120° C bake**
2. **Final BCP of 10 µm (BCP Flash), HPR and 120° C bake.**

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

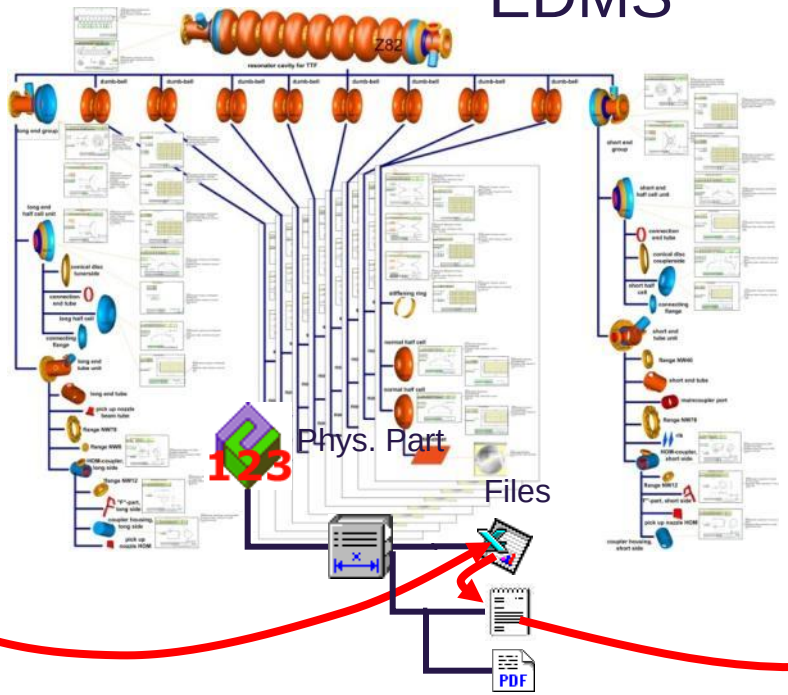
Documentation in EDMS. Data Bank for statistic. Three acceptance levels AL1, AL2 and AL3. Separated release for each acceptance level



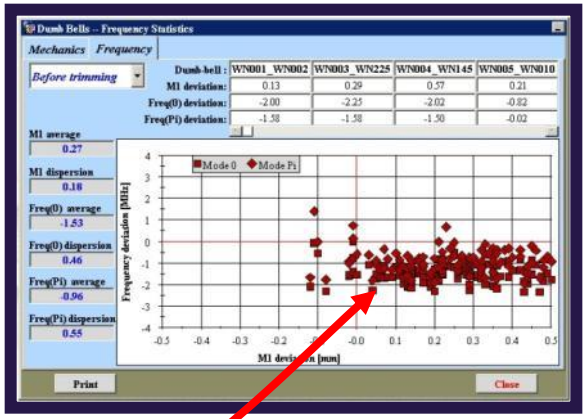
Fabrication



EDMS



Cavity-DB



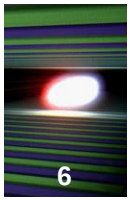
Inspection sheets for quality management

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)

Procurement strategy



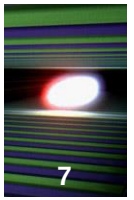
Three alternatives:

- 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** (possibly re-treatment at DESY)

Goal: average usable gradient Eacc=23.5 MV/m ($Qo=1x10^{10}$, X-Rays $<1x10^{-2}$ mGy/min)

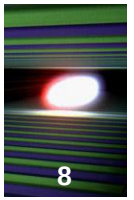
Status XFEL cavities production contracts



Research Instruments (RI) and E. Zanon (EZ) were contracted without performance guarantee.

- **560 series cavities (280 cavities per company)** allocated end 2010 at RI and E. Zanon.
- **240 cavities as additional option (120 at EZ and 120 at RI have been allocated** end 2012 - beginning 2013**)**
- **24 ILC HiGrade cavities (12 per company) allocated end 2010.** For XFEL HiGrade cavities used as a tool for QC.
- **Material for cavities Nb / NbTi provided by DESY.**

Strategy of supervision and quality management

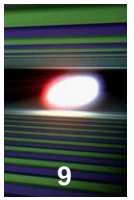


Jointly supervision of DESY and INFN (Milano): created structure of expert teams for:

- General coordination
- Material
- Mechanical fabrication
- Treatment
- Vacuum
- Documentation: EDMS, Data Bank
- RF

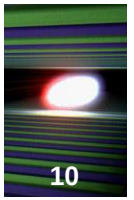
No steadily presence at the companies, but regularly visits. Hard to find one expert that could cover all fields

Strategy of supervision



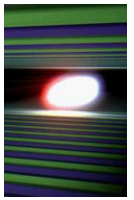
- Main principles of supervision: **Cavities have to be build strictly according to the specifications (build to print).**
- Main Technical documents for contract are WP04 -S.C. Cavities Technical Specifications + Change Reports
- Quality Process based on Quality Control Plan (also for PED)
- Company internal QA, QM system
- Non Conformity Reports NCR: If the required property of a component is not provided, a nonconformity report must be prepared in which the correction procedure is proposed by the contractor and has to be confirmed by orderer.

Strategy of supervision



- **Regularly expert visits** to the company by members of expert teams. After each visit a protocol will be created and distributed internally and to company.
- Regularly meetings "**Project Meeting**" (coordinators of expert teams) on the company location (ca. one time every 2 months, issues depending)
- **Quarantine zone** for "non conform" parts
- **Monthly progress report of the company to WP04**
- **Microsoft Project Plan** based on companies and DESY Time Schedules (use the plan for tracking the progress, tracking of the time schedule)

Current status material for EXFEL cavities



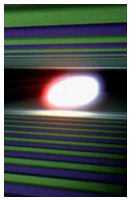
Material for Cavities has to be Provided by DESY to RI and E. ZANON

Contracted January 31st, 2011 to companies:

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

Aim: material production within 2.5 years (finish:- mid 2013)

Status: Delivering of cavity material (SFP) to DESY



lot	Semi-finished product	Fa. Heraeus		Fa. Ningxia OTIC		Fa. Plansee		Fa. Tokyo Denkai		sub total ordered
		order for 560 CAVs	order for 240 CAVs	order for 560 CAVs	order for 240 CAVs	order for 560 CAVs	order for 240 CAVs	order for 560 CAVs	order for 240 CAVs	
1	Nb-sheet 2.8mm			2943	1484	2943		5886	1484	**14740**
2	NbTi-ring 220x100x5			1366	330					**1696**
3	Nb-sheet 2mm			71	32	55				**158**
4	Nb-sheet 9mm			22	12	22				**56**
5	Nb-rod D20x800	73							18	**91**
6	Nb-tube 84x3x22	1366	330							**1696**
7	Nb-tube 84x3x105	683	166							**849**
8	Nb-tube 84x3x140	683	166							**849**
9	Nb-tube 45x2.5x45	683	166							**849**
10	Nb-ring 135x75x27	683		683	330					**1696**
11	Coupler Housing	1366	330							**1696**
12	NbTi-rod D142			36	8					**44**

- 100% delivered
- 90% delivered
- 50% delivered

Total: 24420

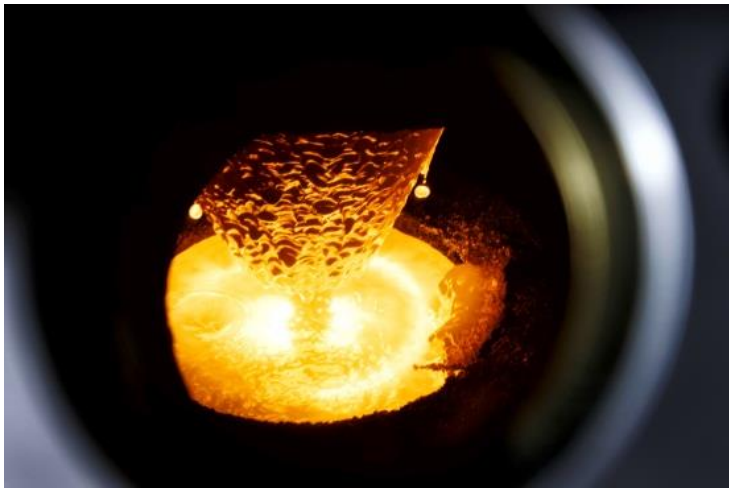
Ca. 300 pcs of 2,8 mm Nb-sheets has to be reordered

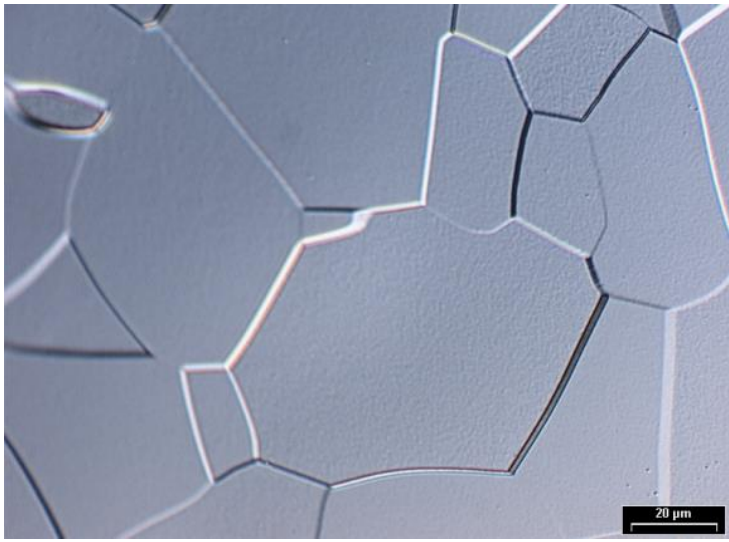
DESY responsibility for material procurement

- procurement procedure
- incoming visual control
- independent QC for required

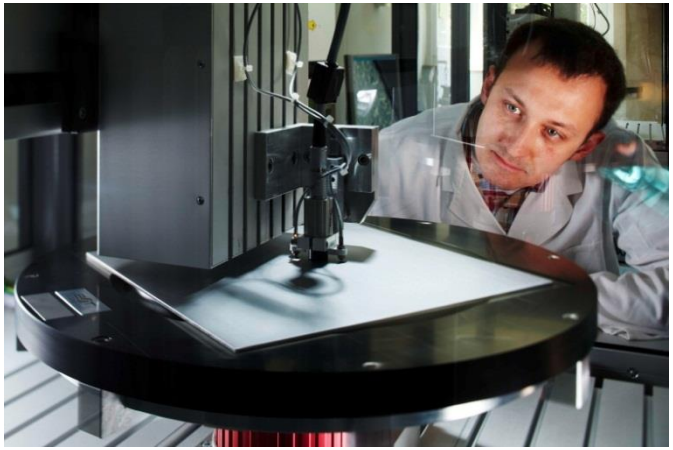
parameter (RRR, interstitial impurity (H, N, O, C), metallic impurities, metallography, tensile test, hardness, HV, surface roughness)

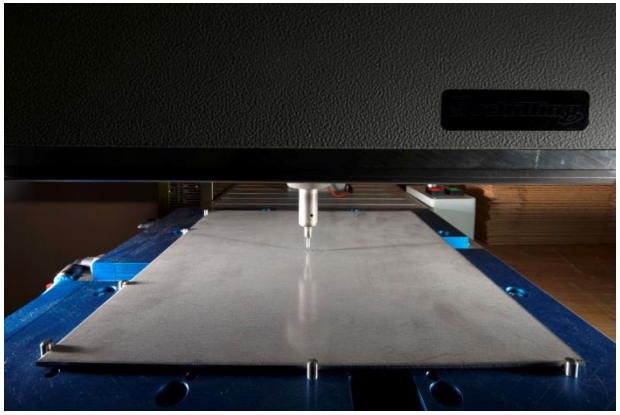
- Eddy-Current scanning of sheets
- documentation using the DESY EDMS (guarantee of traceability for pressure bearing parts)
- definition of numbering system and marking
- delivery to cavity producers





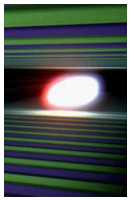
QC of the Cavity Material (SFP) at DESY

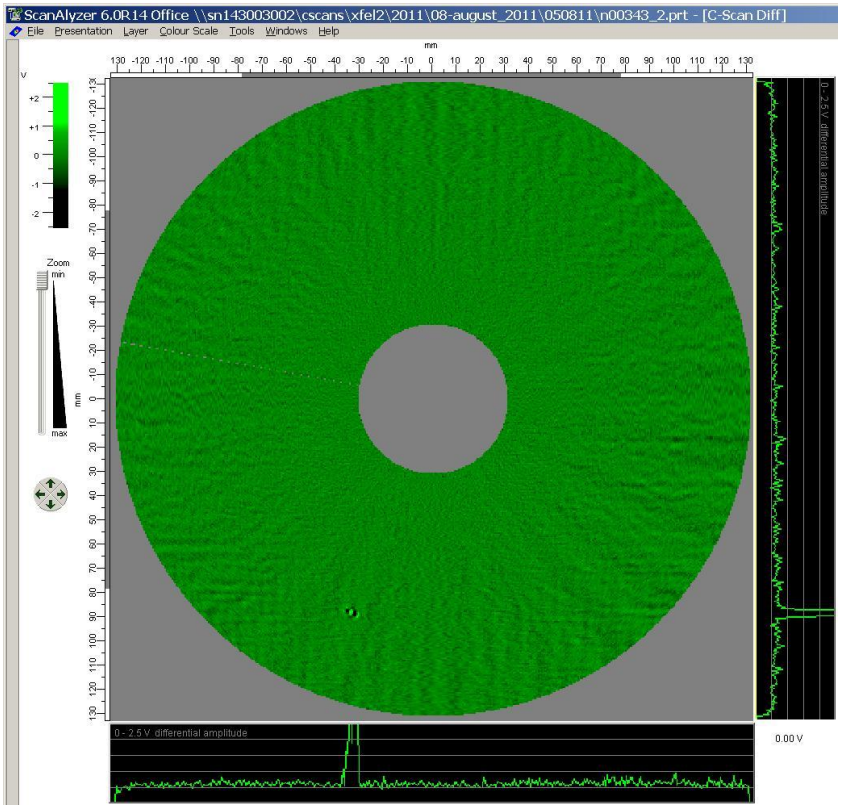


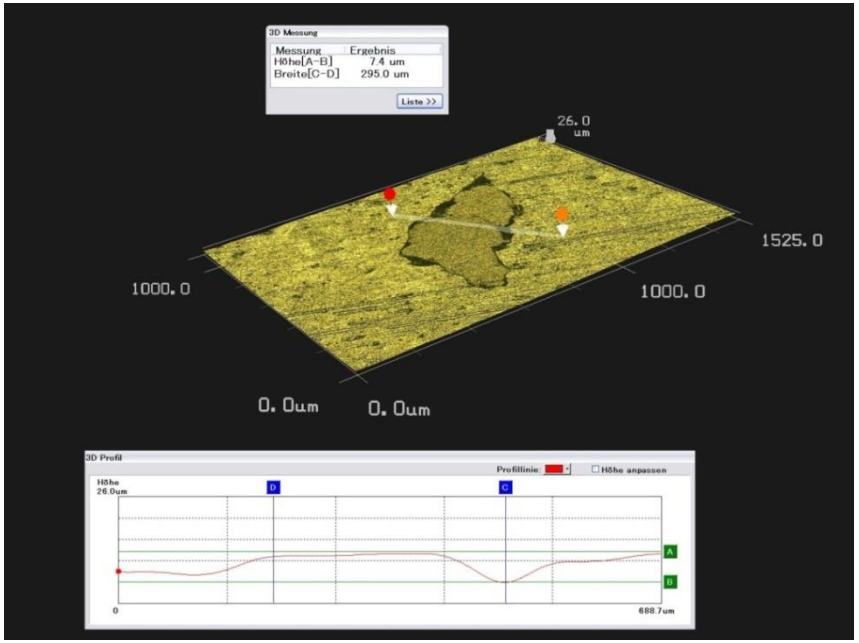


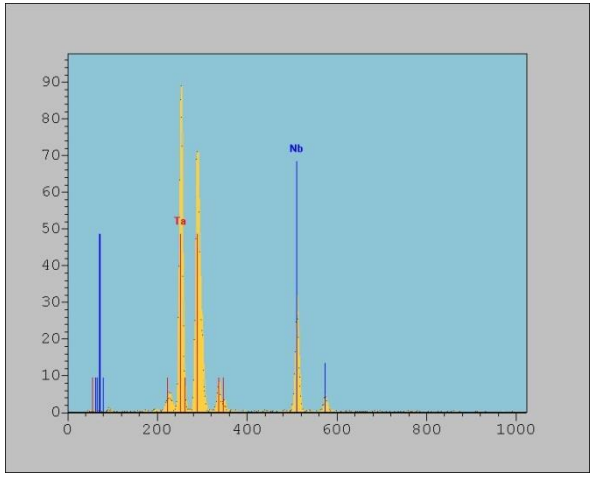
QC of SFP for 560 cavities finished. All SFP for 560 cavities delivered to RI and EZ. SFP for the option 240 cavities will be delivered till end 2013

One example of foreign material inclusion (Ta) detected in the Nb sheets



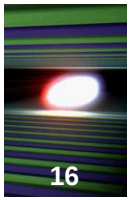






Eddy-Current scan, 3D - Microscope image and result of the nondestructive element analysis

PED (Pressure Equipment Directive) Activities for Material

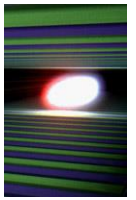


The cavity with helium tank **has to be build as a pressure bearing component** according PED/97/23/EC

PED Activities on Material for Cavities and Helium Tanks

- ☺ Qualification of cavity material Nb40, Nb300, NbTi, Ti1, Ti2 (creation the particular material appraisal (PMA)).
- ☺ Certification of QM system at the companies (producing cavity material) Tokyo Denkai and Ningxia OTIC are certified by TÜV NORD.
- ☺ Certification of QM system at the company Skodock (producing bellows for helium tank) by TÜV NORD.
- ☺ Supervising of the semi finished material products procurement (traceability, marking, 3.1 test certificates etc.). Mainly finished.

PED activities for cavity production



Module B (EC type-examination), contracted by DESY

- examination of design, FEM calculation
- qualification of welding processes (welding parameters, welders)
- qualification of another relevant processes (annealing, deep drawing)
- production of test pieces 2 pieces/company (qualification of each EBW machine) and destructive tests
- supervising the production qualification of the each company (Dummy cavities DCVs and Reference cavities RCVs)
- Supervising the production on first 8 cavities per company (pre-series cavities PCVs).

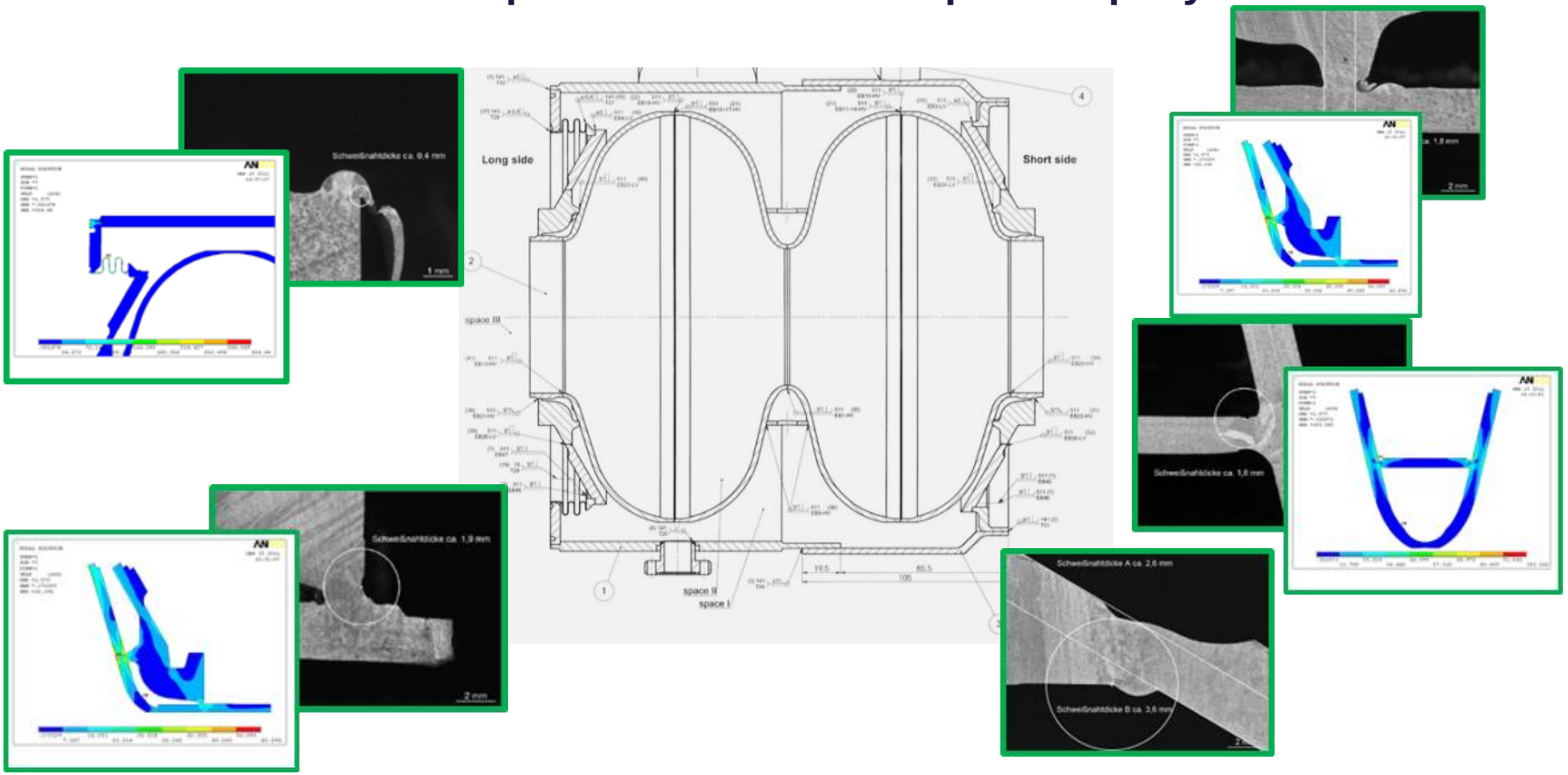
Module F (product verification), contracted by RI and EZ

- visual inspections and control of documents
- pressure test for each cavity

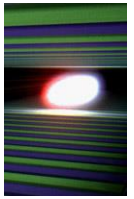
The **notified body is TÜV NORD (location in Germany and Italy)**

Test piece represents all pressure bearing parts: Destructive notified body analysis

Test piece (TP) is composed by 2 cell with helium vessel, representing all pressure bearing parts and welding seams. It is built using the same welding parameters that will be used in the series production. **Two EBW machines/company. Consequently two test pieces had been built per company.**



New infrastructure at RI and E. Zanon and qualification strategy (pictures see in appendix)



The new infrastructure comprises:

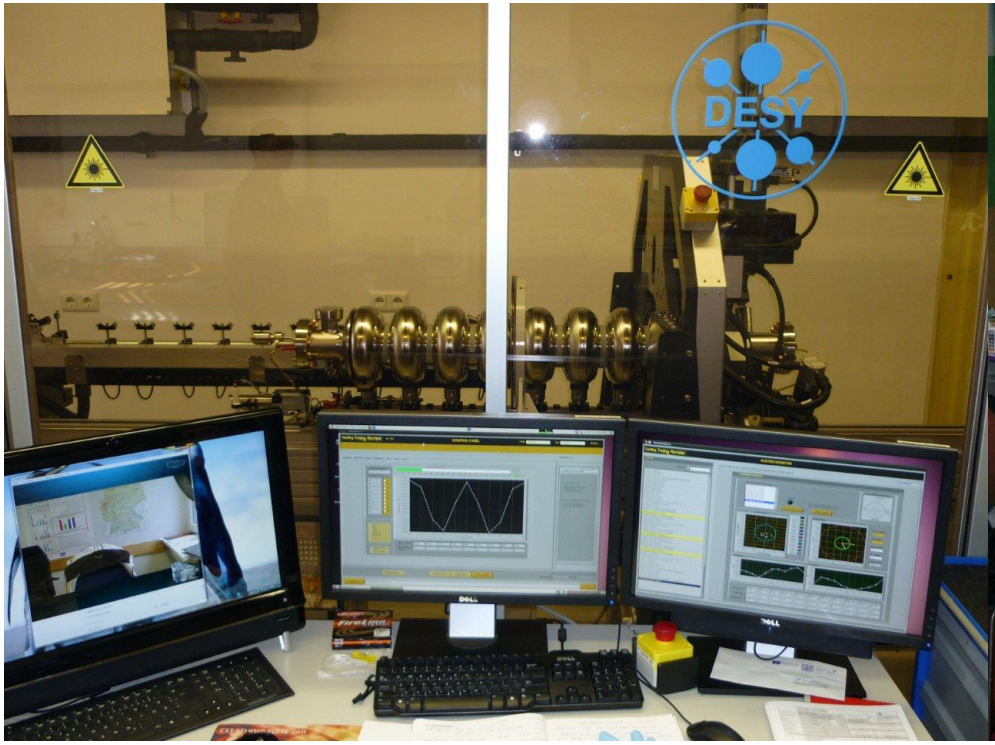
- ☺ Electron beam welding EBW equipment (2 per company)
- ☺ ISO 7 and ISO 4 clean rooms with cleaning, rinsing and BCP facility,
- ☺ ultra-pure water (UPW) systems, clean nitrogen and other gases
- ☺ High pressure water rinsing equipment HPR,
- ☺ Electropolishing EP facility (EP of EZ under commissioning)
- ☺ 800° C annealing furnaces,
- ☺ Tools for mech. measurement, cavity welding, integration in HT etc.,
- ☺ 120° C final baking oven (3-4 per company)
- ☺ Slow pumping slow venting vacuum system (SPSV)
- ☺ Systems for visual inspection of cavity internal surface, etc., etc..

DESY provided both companies with in-house developed:

- ☺ machine for cavity tuning at room temperature (CTM)
- ☺ equipment for RF measurement of dumb bells and end groups (HAZEMEMA).

DESY developed, build and installed at both companies the CTM and HAZEMEMA

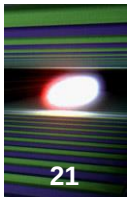
Service is in DESY responsibility. Equipment has to be robust, required trained personal that has special background



CTM installed at RI

HAZEMEMA installed at EZ

DCV / RCV: strategy for qualification of the surface treatment infrastructure at RI and EZ



Each company produced 8 “special” cavities

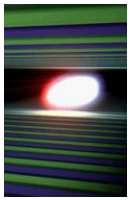
- 4 dummy cavities (DCV).

DCV has to be used at the company for operator training, mechanical test of devices, infrastructure set up and ramp-up, final treatments test, tuning test etc. (not treated at DESY).

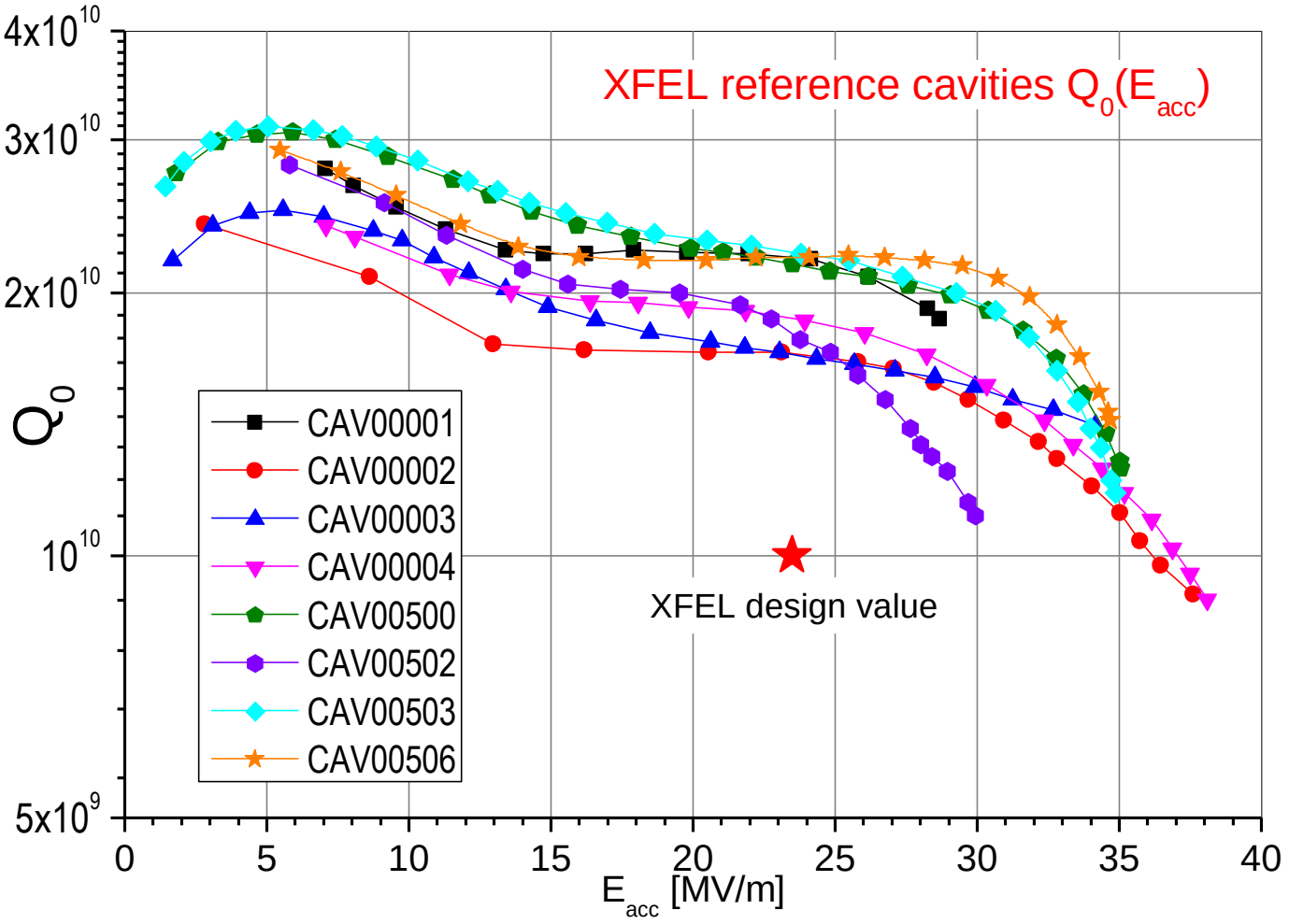
- 4 reference cavities (RCV)

After treatment at DESY the RCVs have to be used for stepwise qualification of surface treatment infrastructure (after infrastructure set-up using DCV has been done)

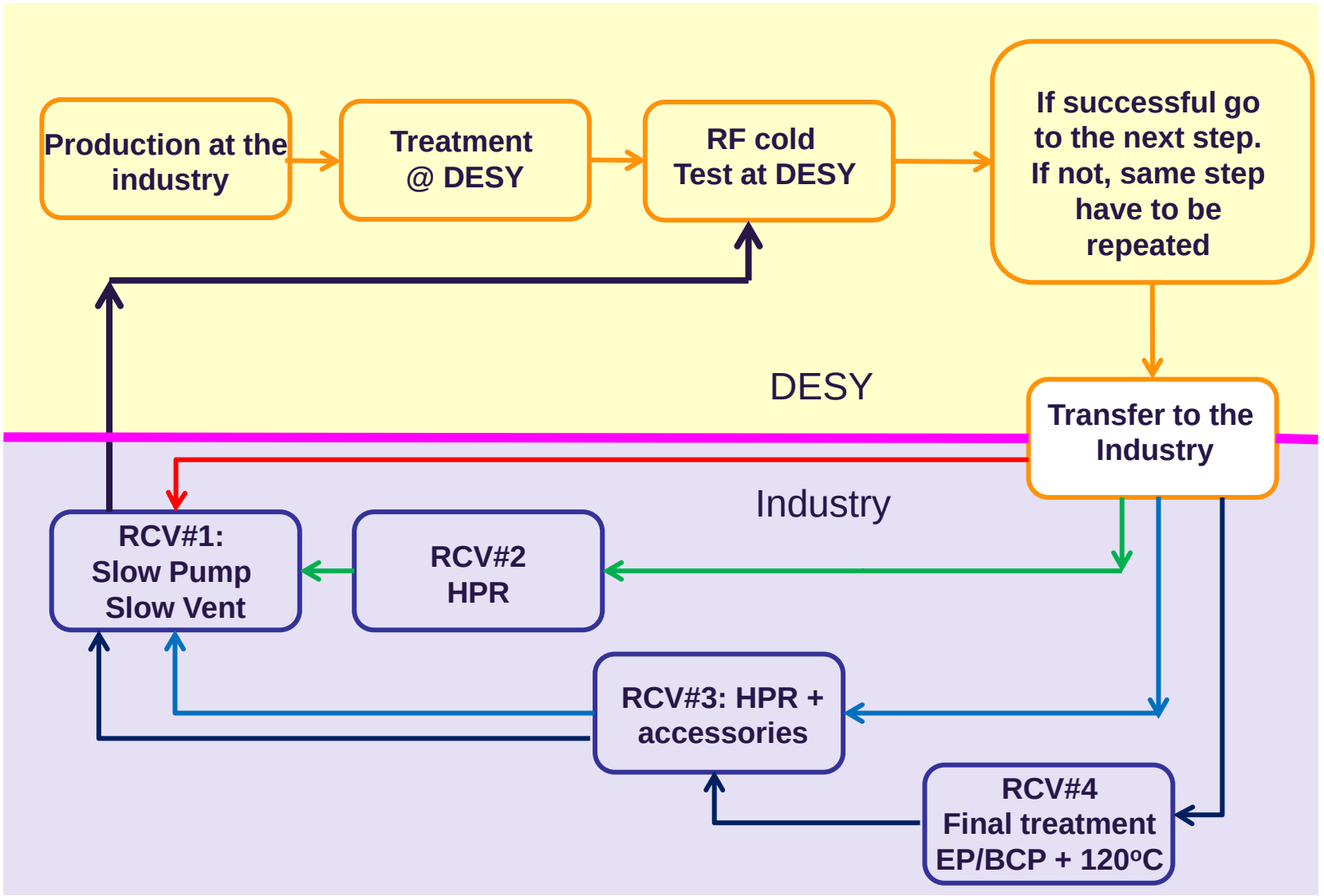
Performance of RCVs after treatment at DESY



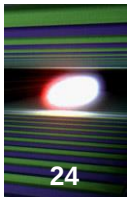
4 RCVs of RI and 4 RCVs of E. Zanon: acceptance test successful



Infrastructure qualification of RI and EZ is successfully finished and series production of cavities started

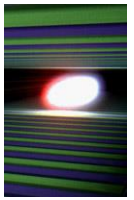


Current status of activities at RI and EZ



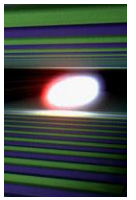
- **Mechanical fabrication** of **series cavities is going on** (more as **100 CAVs** in total fabricated)
- Delivering of **completely prepared series cavities started end 2012 - beginning 2013. First Eacc results encouraging (see below)**
- **Series cavities shipment current status:** table to shipment status (see next slide).
- All **800 series cavities** planned to be delivered till **mid of May 2015 (production rate: ca. 4 CAV/week at EZ and 4-5 CAV/week at RI)**

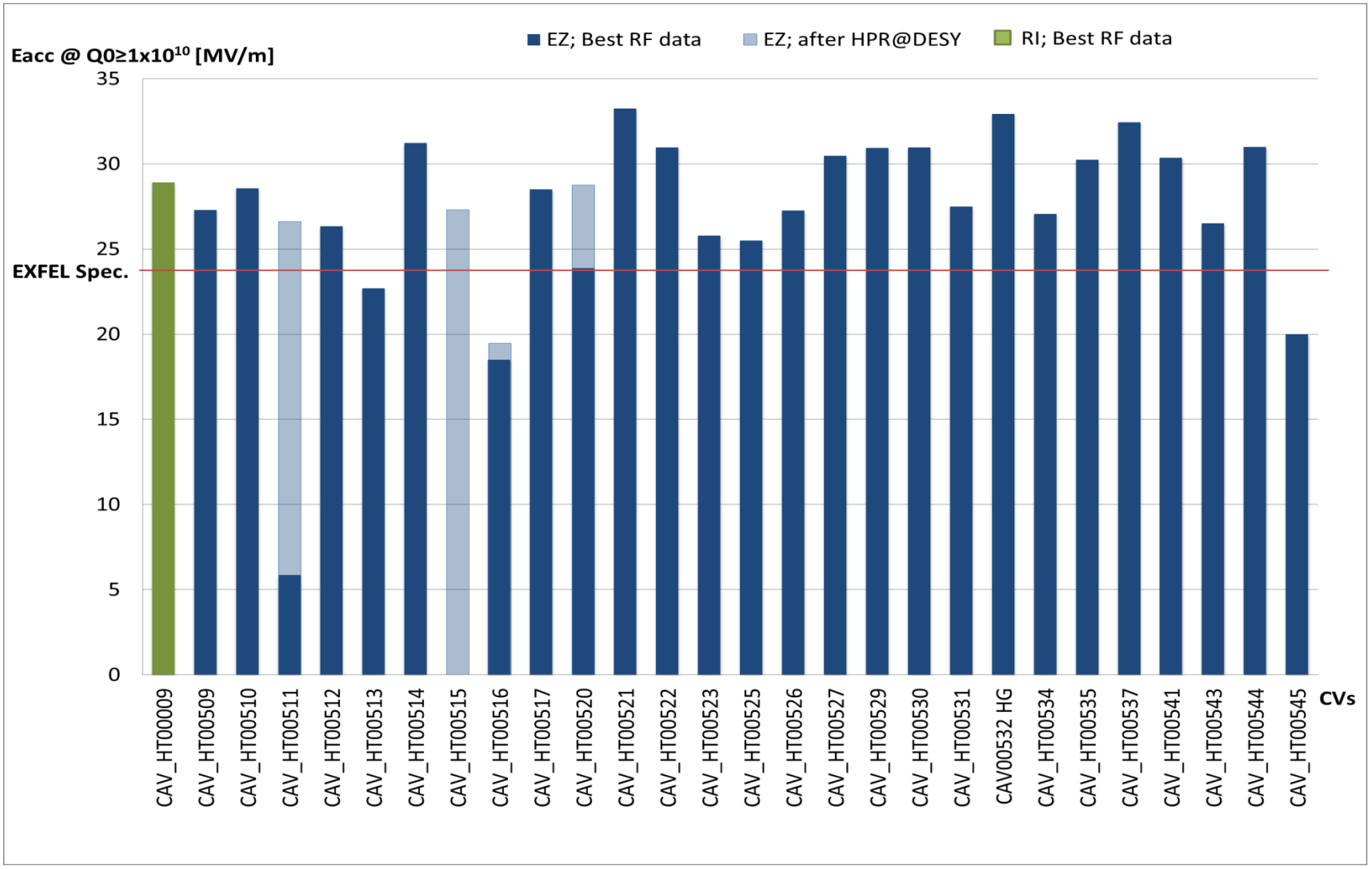
Cavity shipment status on 24.05.13

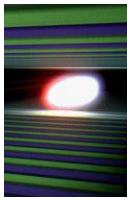


Cavities	EZ	RI	Total
Delivered to DESY:	37	4	41
Measured (RF):	28	1	29
Delivered to Saclay:	15	0	15

Performance (status 24.05.13): E_{acc} at Qo=1x10^{10} (or max Eacc for curves with Qo>1x10^{10})

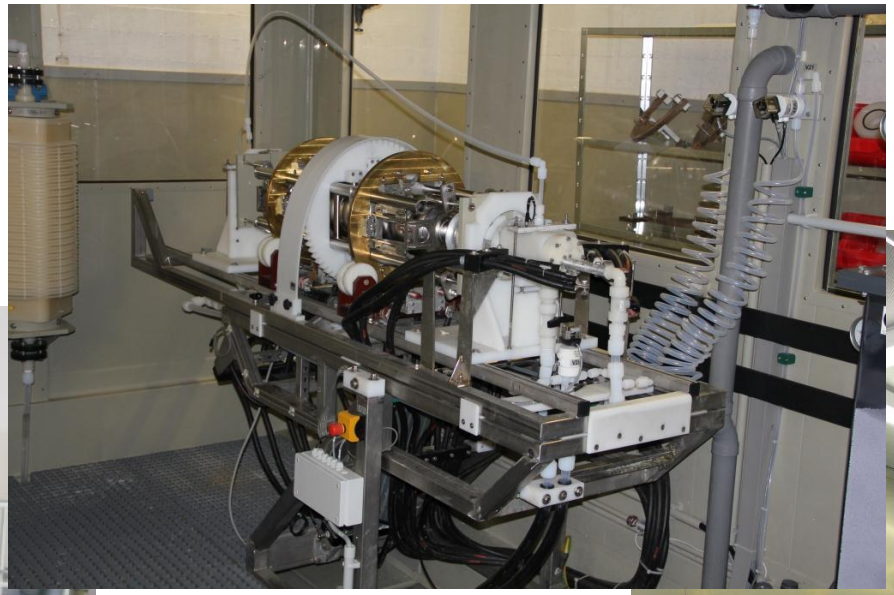






Appendix:
Photos to New Infrastructure of RI and E. Zanon

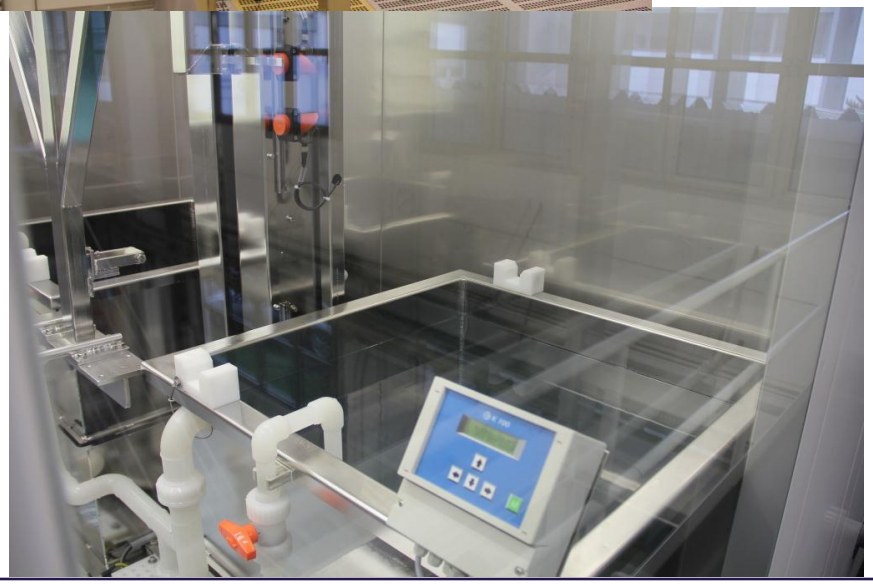
Furnace for annealing at 800°C. Equipment for EP treatment (courtesy of RI)



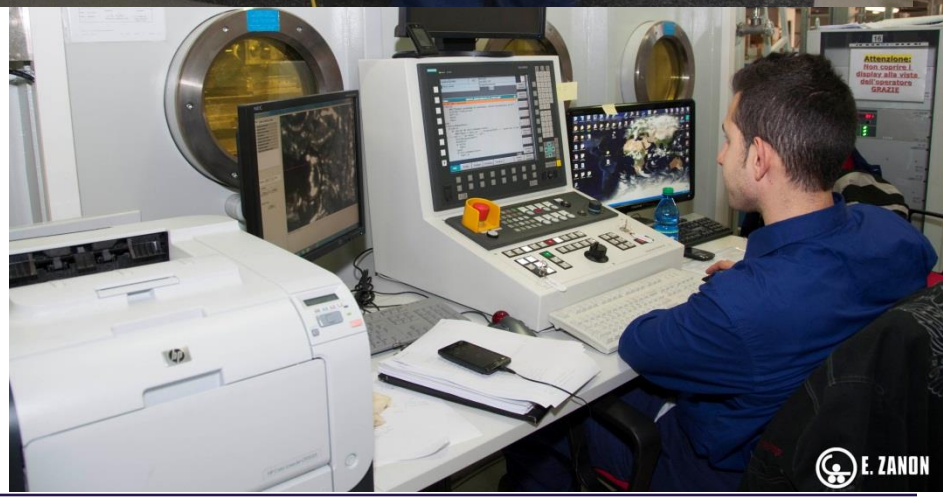
All RI cavities and first 40 E.Zanon cavities are electropolished at RI

Clean room ISO 4. Refurbished EBW equipment (courtesy of RI)

Ethanol rinsing, Ultrasonic rinsing and HPR at RI. (courtesy of RI)

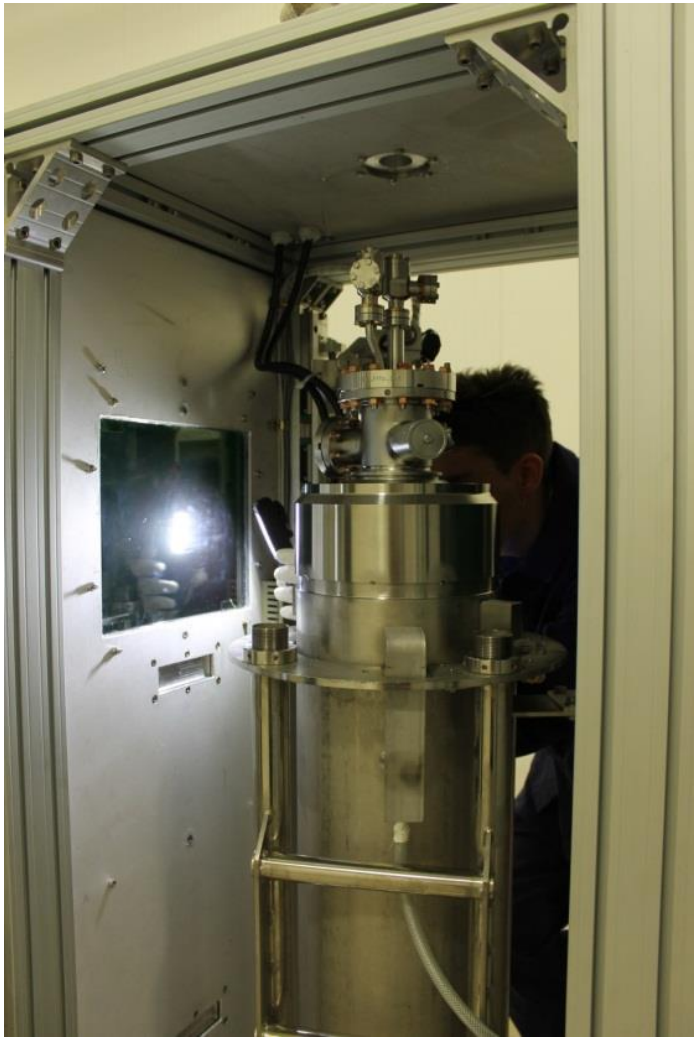


EB welding and 3D-measurement (courtesy of E. Zanon)



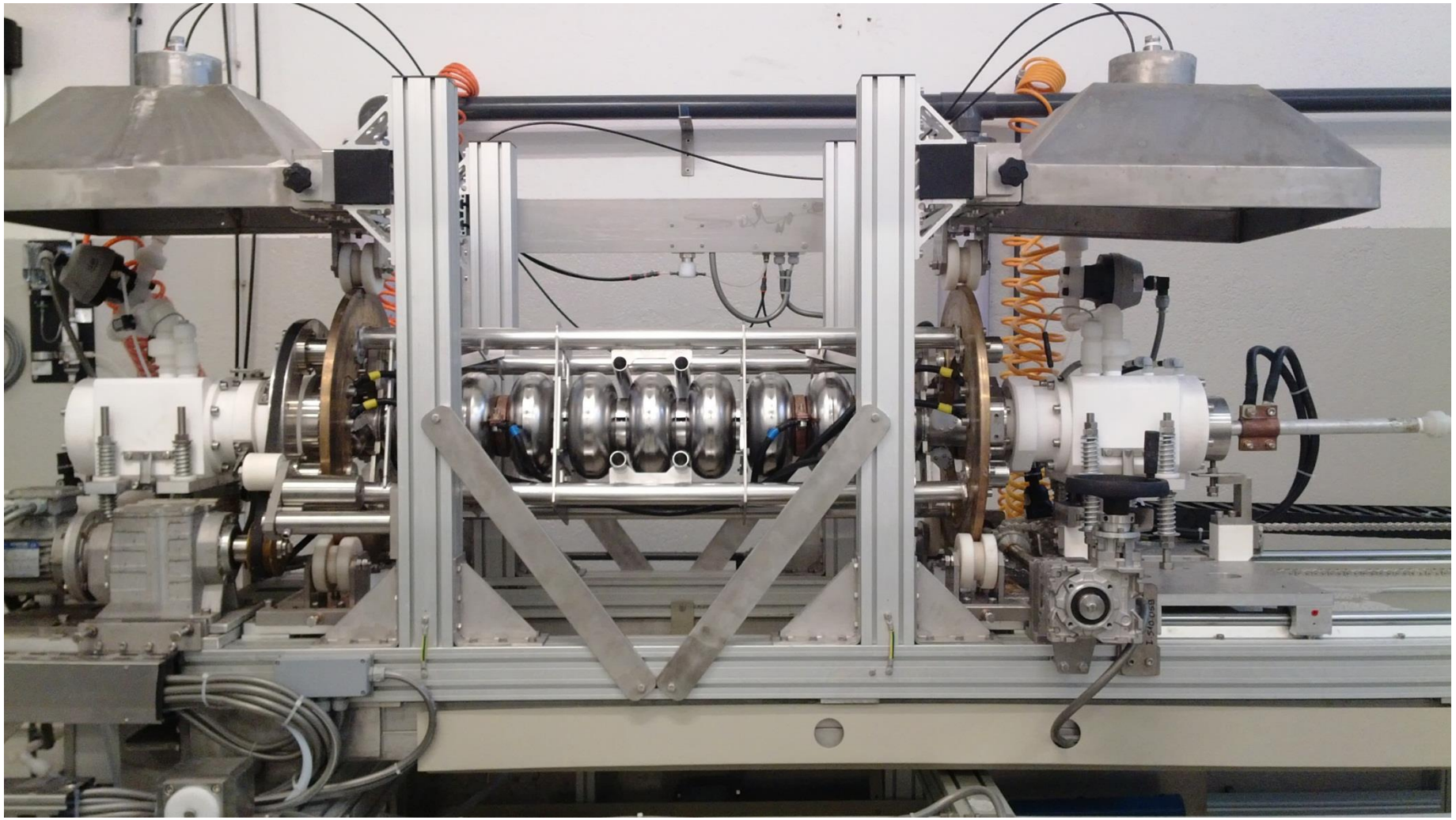
Helium Tanks HT Fabrication (courtesy of E. Zanon)

- ☺ Fabrication of 192 (done, HT at DESY) + 80 addition helium tanks HT (option ordered) at Fa. CSC (Italy) for RI is ongoing (in time)
- ☺ Fabrication and shipment of 92 HT at E. Zanon for RI is ongoing (in time). Order of additional 50 HT to EZ is allocated
- ☺ Fabrication of 400 HT for own EZ cavity production is ongoing (in time)



Fabrication of HT at E. Zanon

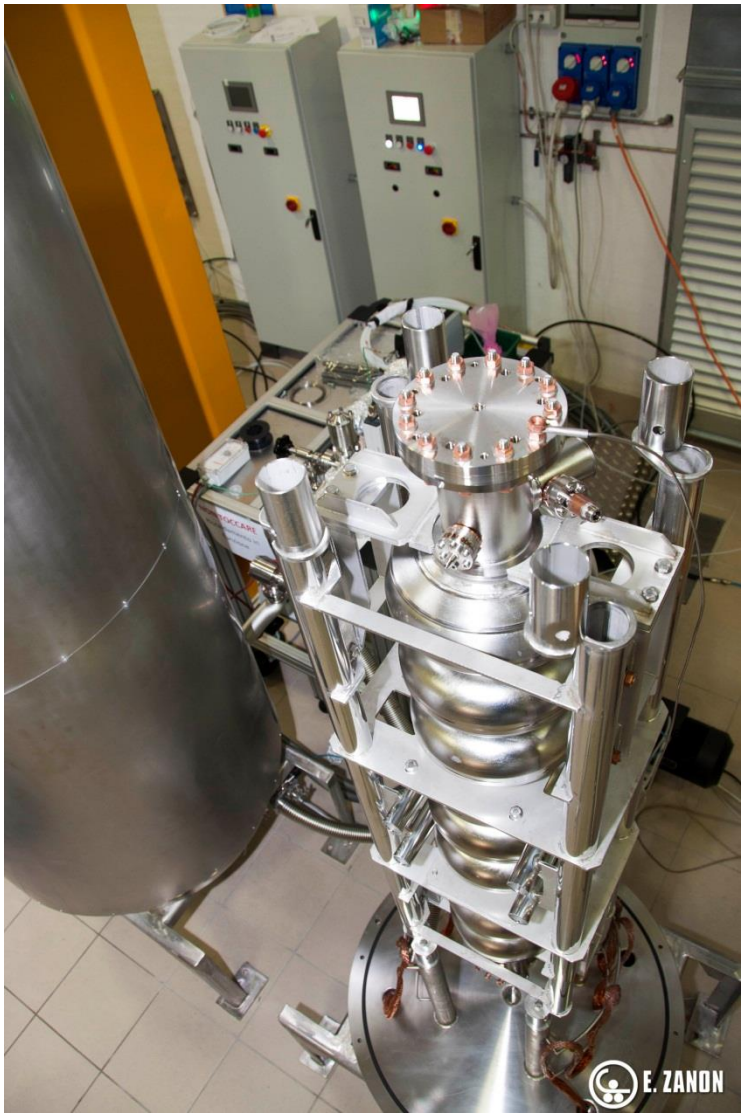
EP facility at E. Zanon (courtesy of E. Zanon)

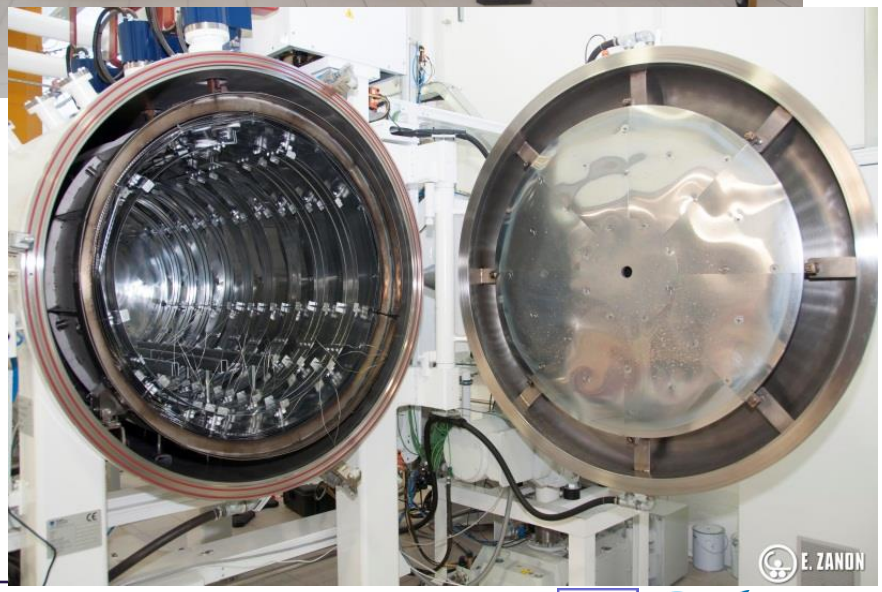


EP equipment of E. Zanon is in qualification

Cleaning, Rinsing, BCP and HPR at E. Zanon (courtesy of E. Zanon)

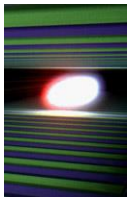
120 ° C and 800 ° C Oven at Zanon (courtesy of E. Zanon)





First experiences of the European XFEL demonstrate that industry is in position not only mechanically produce SC Cavities, but also do the complete cavity preparation up to vertical RF test

TT: Identifying the key project personal



Acknowledgement

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