TTC－WG4：RF Power Couplers and RI and Zanon Visit

ERL検討会 （2014年 4月 8日）

加古 永治 （KEK）

WG-organization in TTC at DESY

(Three parallel sessions)

Tuesday 08:30 – 12:30					
WG1 Cavity Production	Building 3	WG 4 RF Power Couplers	Seminar Room 1b/4a	WG 6 Low Beta	Seminar Room 1b/4b
Tuesday 13:30 – 18:00					
WG 2 Cavity Material	Building 3	WG 5 Accelerator Modules	Seminar Room 1b/4a	WG8 Cavity Testing	AMTF
Wednesday 08:30 – 12:30					
WG 3 Cavity Treatment	Hall 3 or SR 1b/4a	WG7 Magnets & magnetic shielding	Building 55	WG8 Module Testing	AMTF

TESLA TECHNOLOGY TTC COLLABORATION

TTC meeting at DESY
WG-4: RF power couplers
SUMMARY
2014, March 27

Co-chairs

Eiji Kako (KEK)

Wolf-Dietrich Moeller (DESY)

1. Copper Plating (9 talks)
2. Coupler Preparation before RF Conditioning (4 talks)
3. New Power Coupler Design (4 talks)

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Copper plating

- Specs and requirements
  1. Copper Electrical and Thermal Quality
     - depends from application (CW vs. pulsed, power level) and design (counter flow cooling, one or two windows)
     - Relative easy to measure: RRR
  2. Copper thickness
     - depends from application (CW vs. pulsed, power level) minimum is skin depth
     - Mainly measured on accompanied samples
  3. Copper adhesion
     - has to be perfect in an SC environment, no compromise
     - tests: 400C firing, US bath, pealing test with tape

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Copper Plating

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5. RF Surface Roughness
   - Does increase the electrical losses (Ra=1.6um => 60% increase)
   - Mechanical measurement, optical measurement
6. Hydrogen Content, outgassing
   - Has do be low in a high quality beam vacuum (brazing in H2 atmosphere?!)
   - Often not specified nor measured
7. Defects
   - Specs ask for “defects free” surfaces, no blisters, no stains, no scratches
   - Defect definition is often very weak, depends very much from magnification during inspection
   - Almost every fabrication has to fight with defects during fabrication
   - There is no agreement on the kind of acceptable defects
   - Often compromises are done according to the schedule
8. Tests
   - RF test is standard on test bench

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Copper plating

- Plating methods
  - Electroplating
  - Sputtering
    - >10um is not possible
    - less outgassing
    - Lower electron stimulated gas desorption
  - No difference:
    - SEY
  - (Vacuum arc deposition was not discussed)

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Coupler Preparation before RF Conditioning

- All the labs use similar procedures:
  - Degreasing with ultra pure water and detergent in US bath
  - Ultra pure water rinse (low pressure, in ISO4)
  - Drying with ionized N2 in ISO4
  - Some labs use ultra pure alcohol rinsing for easier drying
  - Additional drying in clean room air flow
  - Test by ionized N2 and particle count
  - (sometimes excitation of bellows and particle count)
  - Assembly on test stand
  - 120-150C baking
  - Vacuum mass spectrum (RGA)

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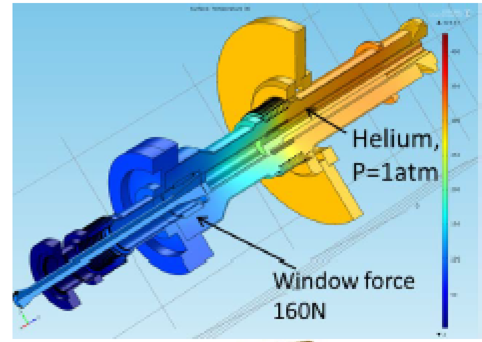
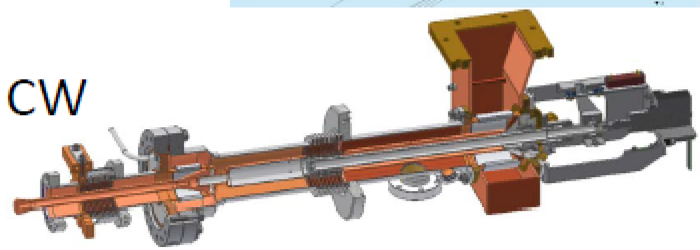
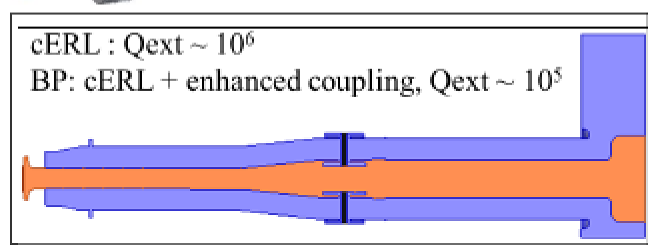
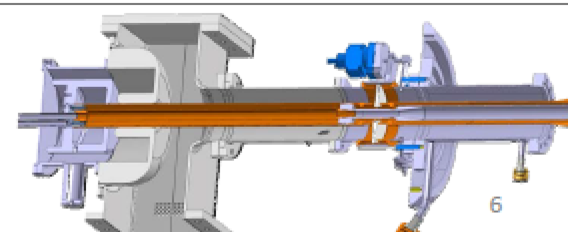
New Power Coupler Design

1. LCLS2 power coupler design proposal 7kW CW (based on TTF3)
   - Increased copper thickness on inner conductor
   - He filling in warm part for better thermal stability
2. CW power coupler design 10kW CW (derived from the Cornell ERL)
   - Inner conductor cooling
3. BERLinPro coupler, 130kW,CW (based on cERL)
   - Enhanced coupling
4. ESS design 1.1MW, 4% duty factor, 2.86 ms (derived from HIPPI coupler)









TESLA TECHNOLOGY TTC COLLABORATION

Conclusion

- Copper plating
  - Expectations are very high, but the 'perfect' plating can only realized after several attempts
  - For small numbers this can be accepted, for mass production it is not satisfactory
  - Often compromises are made because of the schedule
  - There is no agreement in the community on the kind of acceptable defects
- Coupler Preparation before RF Conditioning is very similar done at the different labs and is good understood
- Several different good coupler designs are developed in the recent past
- The community is aware of the complexity and importance of the High Power Coupler in a given project

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Acknowledgement

- Thanks to all the speaker of the WG4

  C. Adolphsen, SLAC, S. Calatoroni, CERN, D. Kostin, DESY, A. Ermakov, DESY, W. Kaabi, LAL, K. Premo, FNAL, O. Yushiro, TOSHIBA, V. Veshcherevich, CORNELL, H.Sakai, KEK, Y. Gomez Martinez, LPSC, N. Solyak, FNAL, V. Khan, HZB, S. Molloy, ESS

- Thanks to all the participants of WG4 for the intense and fruitful discussion

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RI and Zanon Visit

research instruments

RI Research Instruments GmbH
Company Presentation

Visit Eiji Kako, KEK and Katsuya Sennyu, MHI

Michael Pekeler
RI Research Instruments GmbH
Friedrich-Ebert-Str. 1
51429 Bergisch Gladbach
Germany

28.03.2014

RI Research Instruments GmbH

research instruments

Development, production and sales of rf accelerator components and systems and special manufacturing projects

- Former activity of Interatom/Siemens (80's to mid 90's) and ACCEL Instruments (mid 90's to 2009)
- More than 3000 Person Years of accumulated KnowHow and about 0,4 Bio € of business volume since 1985
- About 150 Employees, 30% Engineering & Project Management, 60% Manufacturing

- 51% of shares by Bruker EST, Inc.
- RI management holding a significant equity stake of the company

- Worldwide acknowledged as an advanced technology engineering and manufacturing specialist

E.ZANON Infrastructure for SC cavities production (A)

The company was founded in 1919
It is located in the North-east of Italy
90 KM from Venezia
Number of personnel 210
Shop's workers 160
Machining , forming , welding and testing facilities

Standard production for chemical industry (reactors, heat exchangers)

Production of special components for research institutes and laboratories (UHV , cryogenics , Fusion , Superconductivity)

E.ZANON S.p.A.

Via Vicenza 113 - 36015 Schio (VI)
Italia

Infrastructure for SC cavities production at Ettore Zanon s.p.a.

Ing. G. Corniani — Ettore Zanon s.p.a.

TTC Meeting –WG3 — DESY-Hamburg 24-27 March 2014

XFEL cavity production project

research instruments

420 Cavities by RI
(4cavities / week)

Order for 300 cavities received from DESY in September 2010
Order for additional 120 cavities received in March 2013

Niobium and
helium vessel supplied by DESY

RI scope:
- Mechanical manufacturing of cavity, respecting the pressure vessel code
- Complete Surface preparation and helium vessel welding
- Shipping to DESY under vacuum and "ready for cold RF test"
- Extensive documentation and QA is crucial and will ensure that cavities are manufactured and treated according to detailed DESY specification. No performance guarantee.

DESY:
- Cavities will be cold RF tested at DESY (vertical test) with helium vessel already welded
- After successful test, DESY will ship the cavities under vacuum to CEA for module assembly

XFEL coupler production project

research instruments

- The consortium Thales Electron Devices (TED) and RI Research Instruments won the contract for production of 670 TTF3 couplers in 2010.
- TED and RI agreed on the following work share:

TED:
inner conductor warm (copper coated)
outer conductor warm (copper coated)
outer conductor cold (copper coated)
Antenna
capacitor
motor drive

RI:
TiN coated cold ceramic assembly
TiN coated warm ceramic assembly
EB welding of couplers
hard brazed waveguide box
push rod
cleaning and assembly of couplers ready for RF conditioning in ISO4 clean room

670 TTF-3 Input couplers
by RI

420 Cavities by Zanon
(4 cavities / week)

E.ZANON Infrastructure for SC cavities production (C)

Actual involvement to the XFEL project
August 2010 to 2011 , Award of DESY contracts for

A) Manufacture and final treatement of 420 units of the 9 cells , 1,3GHz SC cavities
Scope of work includes :
- Manufacture of the 1,3GHz cavities / Manufacture of their Titanium Helium tanks
- Integration of the cavities into their tank /Treatments and Surface cleaning treatments
- Components manufacture and certification according to PED (Presssure Equipment Directive)
- Delivery production rate 4 units/week

B) Manufacture and testing of 45 units of XFEL Cryomodules
Scope of work includes
- Vacuum vessel and cold-mass prefabrication and testing
- Delivery to the assembly site (CEA-France)

C) Manufacture and testing of 146 units of Titanium Helium tanks
Scope of work includes
- Tank prefabrication and He leak check
- Delivery to DESY

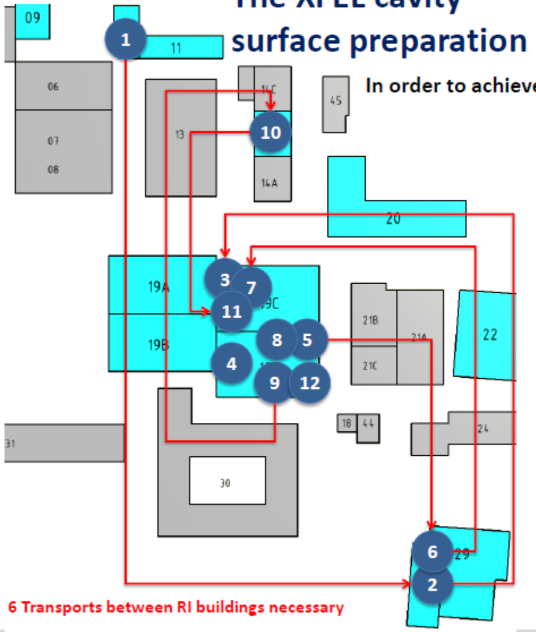
TESLA Test Facility – XFEL Project at DESY

Past production of cryomodule for R&D phase

Actual production of cryomodule for XFEL

45 XFEL cryomodules,
146 Ti He-Jackets
by Zanon

The XFEL cavity surface preparation recipe



6 Transports between RI buildings necessary

In order to achieve smooth, pure, dust free RF surfaces:

1. Outside etching (BCP)
2. Weighting, US-degreasing, Electropolishing (110 µm), rinsing
3. Cleanroom (1 x HPR, ethanol rinse, drying, weighting)
4. 800 ° C annealing
5. Tuning
6. Electropolishing (40 µm), rinsing
7. Cleanroom (1 x HPR, ethanol rinse, assemble blank flanges, leak check, 6 x HPR, drying, install FMS (field measurement system), leak check)
8. Check field profile (ev. tuning)
9. EB welding of ring and bellow
10. TIG welding of helium vessel
11. Cleanroom (disassemble FMS, install antennas (pick-up, HOM. High Q for vertical testing), leak check, 6 x HPR, assemble last flange, leak check and RGA
12. 120° C baking, leak check
13. Transport under vacuum to DESY for vertical test

research instruments

RI's specialized manufacturing technologies

research instruments

Brazing Furnace (1/2)

Electron Beam Welder (1/2)

Manufacturing Premises

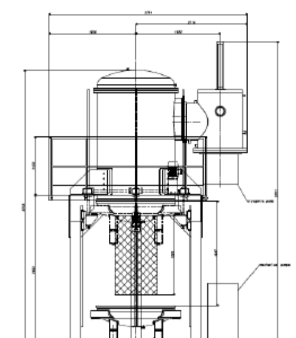
Manufacturing technologies:

- Turning (CNC)
- 5 axis milling (CNC)
- Metal working
- Surface technology (cleaning, etching, coating)
- Joining technology (EB, TIG, vacuum brazing)
- Heat treatment
- Assembly (partly in cleanroom) and testing
- RF, vacuum, cryogenic
- Quality Control

New infrastructure at RI for XFEL (1/2)

research instruments

- 150 kV EB welder from Pro Beam
- Replaces our old small EB welder
- Pallet system
- Lock chamber (1E-3 mbar)
- Weld chamber (1E-6 mbar)
- Turbo pumps



- 800° C all metal annealing furnace from TAV, Italy
- Diameter 800 x 1500 high
- 4 cavities in vertical position per run
- Cryo pump

- One more turning machine
- One more milling machine
- Two 120 C baking chambers
- 4 pumping stations including RGA for SRF cavities and dry leak checker

Tuning machine and HAZEMEMA (half cell measurement machine) supplied by DESY

New infrastructure at RI for XFEL (2/2)

research instruments

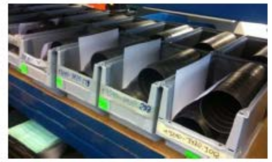
- 120 sqm ISO4 clean room
- 2 HPR systems including UPW system
- 2 assembly spaces
- 2 pumpdown and leak checking areas
- 2 rinsing stations
- 1 ethanol rinse
- 1 personal lock
- 1 area for cavity drying

XFEL cavity manufacturing impressions

research instruments



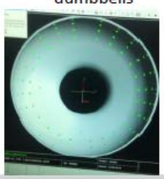





End tubes, HOM couplers

Dumbbells and stiffening rings, welded dumbbells

Metrological inspection of dumbbells


XFEL cavities / subcomponents

research instruments




We are now producing 16 cavities / month

RI infrastructure for XFEL

research instruments

Electropolishing plant for XFEL cavities

RI infrastructure for XFEL

research instruments


800 C annealing furnace for hydrogen degassing, hydrogen enters the niobium during the electropolishing process

RI infrastructure for XFEL

research instruments

Tuning for field flatness and frequency, tuning apparatus was developed and free issued by DESY

RI infrastructure for XFEL

research instruments

Cleaning of outer and inners surface of cavity prior entering ISO4 clean room

RI infrastructure for XFEL

research instruments

Work in ISO4 clean room

RI infrastructure for XFEL

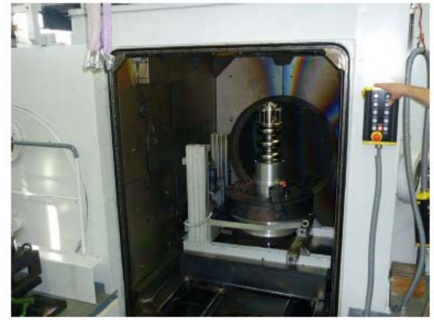
research instruments

- High pressure DI water rinsing station in ISO4 clean room
- The cavity is being rinsed in total 4 times during the surface preparation process
- Water pressure: 100 bar
- Total rinsing time: about 30 hours per cavity

RI infrastructure for XFEL

Assembly and leak checking in ISO4 clean room,
A new 160 m^2 ISO 4 clean room was installed for the XFEL production

RI infrastructure for XFEL



EB welding of helium vessel parts to finished cavity
Cavity inner surface is already cleaned to ISO4 standards and sealed to ambient during EB operation

RI infrastructure for XFEL

XFEL cavity after helium vessel welding

- During helium vessel welding, the inner surface of the cavity is cleaned to ISO4 standards and the frequency is controlled during welding to ensure no degradation of field flatness
- After welding the cavity enters the clean room again, final assembly and high pressure water rinsing are done and the 120 C bake is done as the last preparation step

RI infrastructure for XFEL

- 120 C baking stations for XFEL cavities
- This baking step is the last surface preparation step before shipping to DESY
- The baking is done with the cavity under vacuum for 48 hours
- The assembly to the pump stand is performed with a local ISO4 clean room

E.ZANON

Infrastructure for SC cavities production (D)

Cavities serial production lay-out and Infrastructures

•To fulfill the contractual requirements decision to separate this production from others Ettore Zanon s.p.a. production and strong effort to study and optimize the production lay-out

• Cavities production into two dedicated buildings (building lot I and building lot IV)

•Building lot I
prefabrication of cells , dumb-bell ,subassemblies , end groups
EB welding , chemistry

•Building lot IV (renewed building)
Final cavity welding , integration with Helium tank , surface treatments

(Prefabrication of the titanium Helium tank in the “standard” shop)

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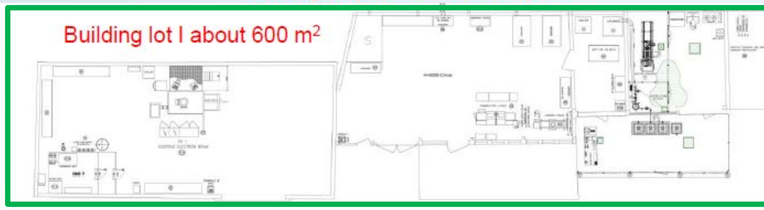
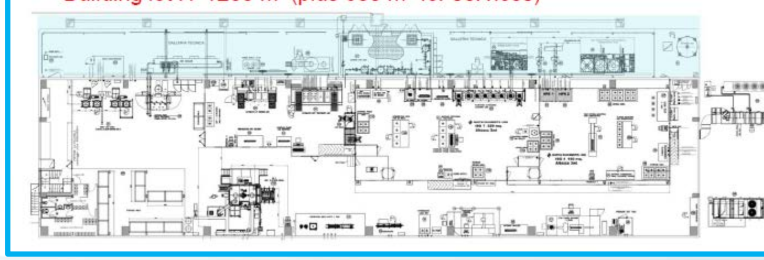
Infrastructure for SC cavities production (D)

Cavity's production lay-out

Building lot I about 600 m^2



Building lot IV 1200 m^2 (plus 600 m^2 for services)



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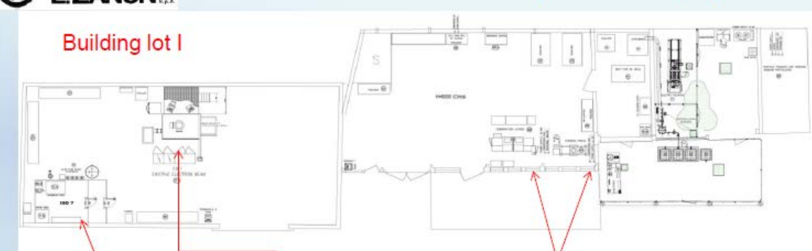
Infrastructure for SC cavities production (D)

Building lot I



Clean room ISO7
UPW production unit
(18MΩcm)

Dedicated 200T forming press (cells , tube's pulling , reshaping) CNC turning machine (cell Dumb-bell machining, others)

Electron beam plant
150KV-30KW
with cryogenic pump

E.ZANON

Infrastructure for SC cavities production (D)

Building lot I

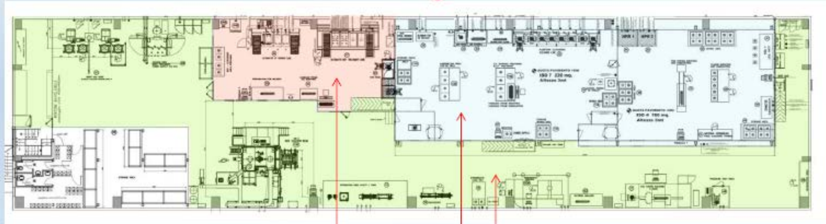
Material (Niobium) storage area and incoming controls
Dimensional controls

UT and BCP treatment of sub-components

Electropolishing with UPW plant(18MΩcm)

E.ZANON — Infrastructure for SC cavities production (D)

Building lot IV

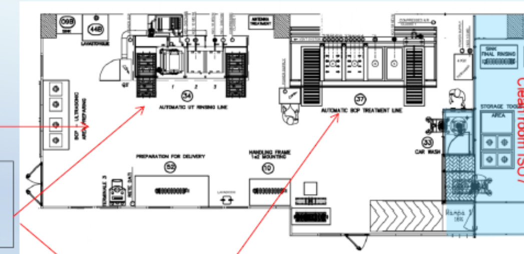


The buidling is organized in three main areas

A) Chemical treatment area
B) Clean room ISO7/ISO4
C) Controls , Integration , 800° C -120° C treatments and testing area

E.ZANON — Infrastructure status for XFEL (D)

Building lot IV
Chemical treatment area



Preparation and drying areas

Automatic pluritank station for UT cleaning , rinsing water 10 MΩcm and 18 MΩcm

Automatic BCP treatment line
2 cooled acid baths for Niobium and Nb-55-Ti
1 bath first rinsing 1 bath final rinsing water 10 MΩcm and 18 MΩcm
protection tunnel ,fumes extraction to the scrubber

E.ZANON — Infrastructure for SC cavities production (D)

Building lot IV Clean room ISO7/ISO4

ISO 7

100 bar UPW cleaning cabinet for ISO7 entrance

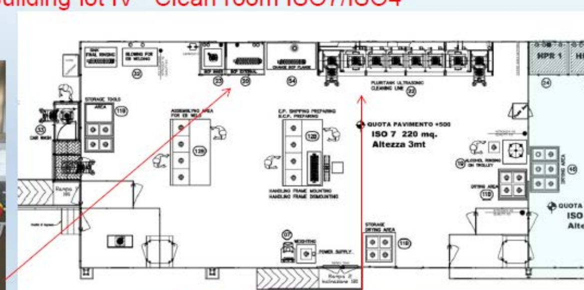
Pre-assembling stations for cavity EBW preparation

E.ZANON — Infrastructure for SC cavities production (D)

Building lot IV Clean room ISO7/ISO4

ISO 7

Cabinets for BCP close circuit of the inner / outer cavity surfaces



Automatic pluritank station for UT cleaning and rinsing baths water 10 MΩcm and 18 MΩcm

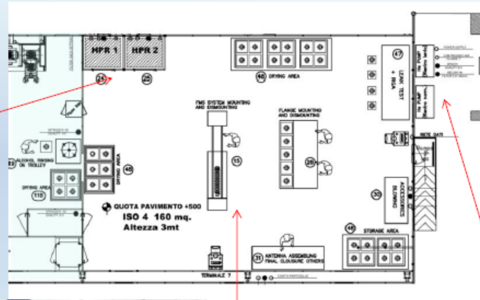
Alcol rinsing , Others

E.ZANON Infrastructure for SC cavities production (D)

Building lot IV Clean room ISO7/ISO4

ISO 4

N° 2 cabinet for final HPR
UPW 18 MΩcm water
p>100bar , 1.5m³/h
Cavity's rotation , vertical translation Nitrogen overlay



Station for final leak test special equiments for slow-controlled venting of the cavity ,…others

Assembling stations for FMS installation - RF antennas assembly

E.ZANON Infrastructure for SC cavities production (D)

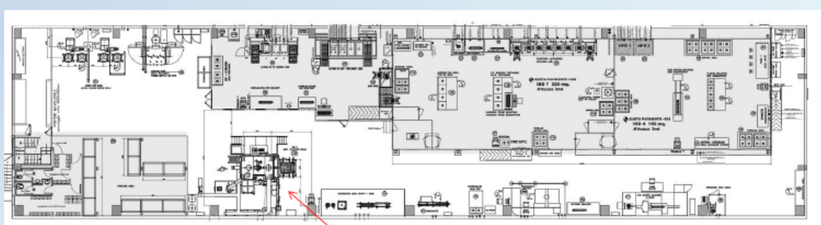
Building lot IV Clean room ISO7/ISO4

ISO 4

E.ZANON Infrastructure for SC cavities production (D)

Building lot IV Control , Integration , 800° C -120° C treatments and testing area

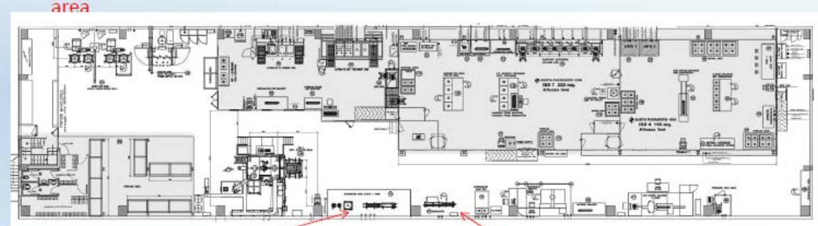
The area is organized to suit part of the production and control operations (good clean environment , not classified)



New EB welding plant : S.S. Chamber , size 3,4x2x2 m , oil free pumping group with cryogenic pump ($3x10^{-5}$ mbar 35 minutes) nitrogen venting , RGA

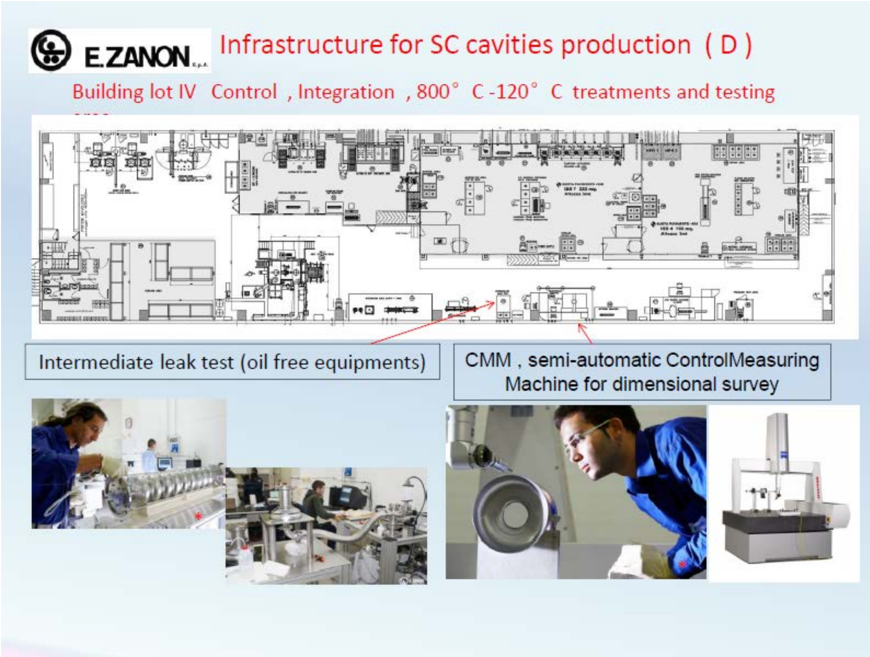
E.ZANON Infrastructure for SC cavities production (D)

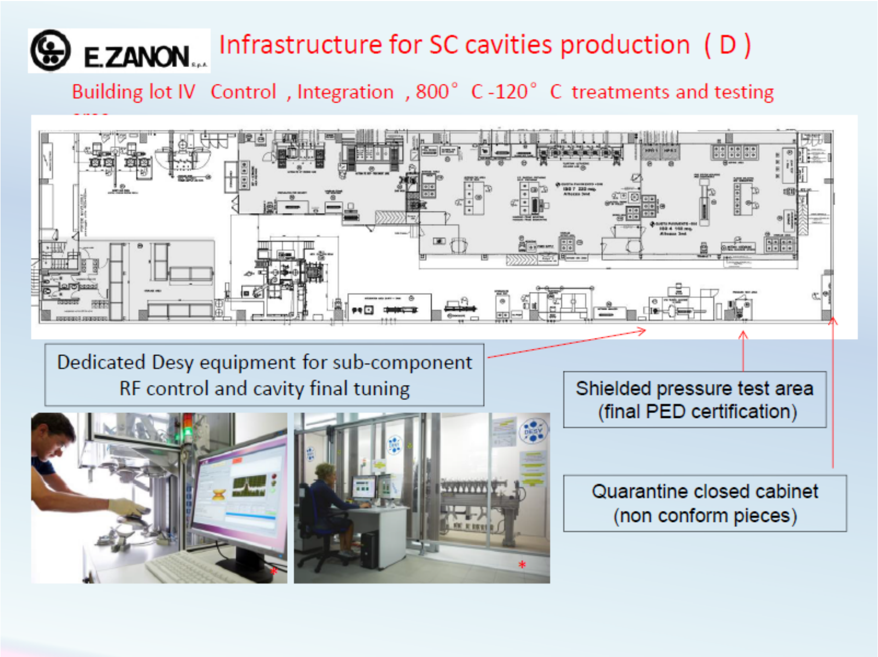
Building lot IV Control , Integration , 800° C -120° C treatments and testing area

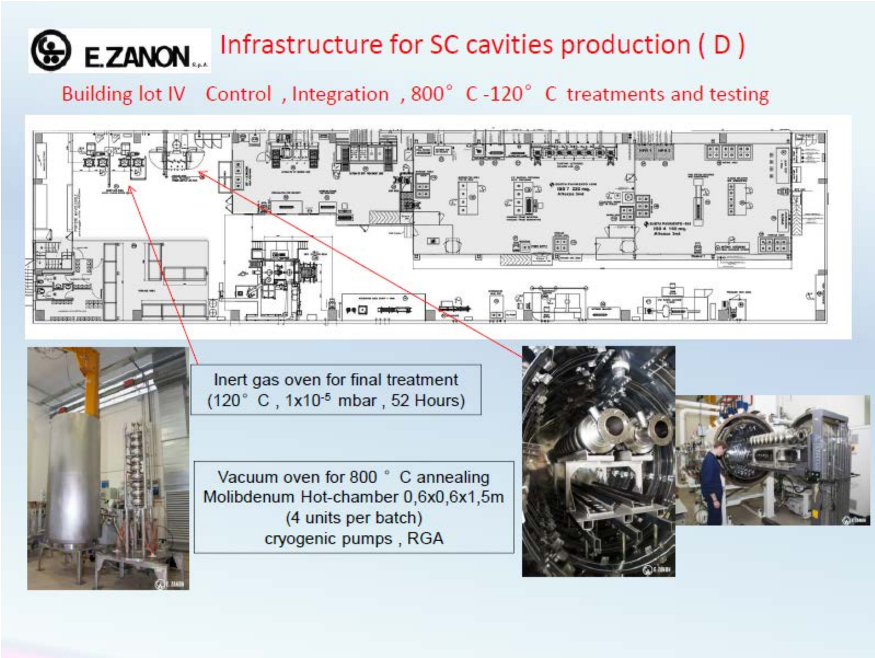


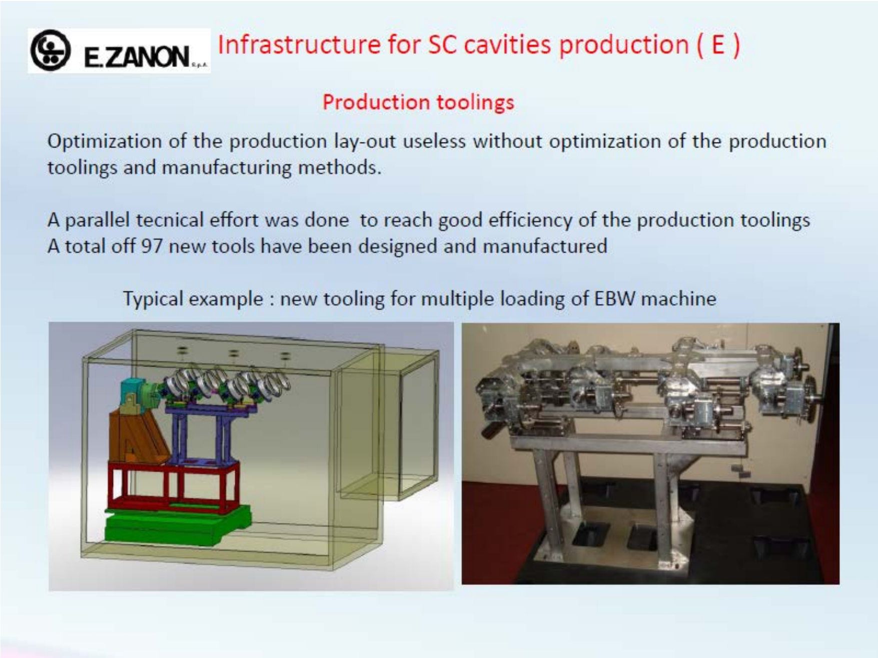
Station with automatic TIG equipment for Cavity-tank final integration

Visual examination with photo recording of the cavity inner welds and surfaces (boroscope)


E.ZANON
Infrastructure for SC cavities production (D)
Building lot IV Control , Integration , 800° C -120° C treatments and testing
Intermediate leak test (oil free equipments)
CMM , semi-automatic ControlMeasuring Machine for dimensional survey


E.ZANON
Infrastructure for SC cavities production (D)
Building lot IV Control , Integration , 800° C -120° C treatments and testing
Dedicated Desy equipment for sub-component RF control and cavity final tuning
Shielded pressure test area (final PED certification)
Quarantine closed cabinet (non conform pieces)


E.ZANON
Infrastructure for SC cavities production (D)
Building lot IV Control , Integration , 800° C -120° C treatments and testing
Inert gas oven for final treatment (120° C , 1x10-5 mbar , 52 Hours)
Vacuum oven for 800 ° C annealing
Molibdenum Hot-chamber 0,6x0,6x1,5m
(4 units per batch)
cryogenic pumps , RGA


E.ZANON
Infrastructure for SC cavities production (E)
Production toolings
Optimization of the production lay-out useless without optimization of the production toolings and manufacturing methods.
A parallel tecnical effort was done to reach good efficiency of the production toolings
A total off 97 new tools have been designed and manufactured
Typical example : new tooling for multiple loading of EBW machine

E.ZANON Infrastructure for SC cavities production (F)

Nowaday results

Ettore Zanon s.p.a. has finished his big effort and investements to organize the dedicated lay-out for the production of SC cavities (priority XFEL project) in December 2012 performing successfully the all required qualifications steps.

-Cavity serial production is running and more than 160 units have been delivered.
-First series of 25 cryomodule delivered
-First series of 96 helium tank delivered

E.ZANON SC cavities production at Ettore Zanon s.p.a.

Progress status February 2014			
		N° off	
Welded cavities	Tot.	248	DCV/RCV+pre-series+series
Cavities EP treated		4	Desy (RCV)
		87	subcontractor
		124	Zanon
	Tot.	215	
Cavities into the final treatment cycle	Tot.	42	(from EP to entrance Clean room)
Cavities delivered to Desy	Tot.	155	First cavity delivered December 2012 after infrastructure qualification
Cavities back (retreatment/others)	Tot.	9	

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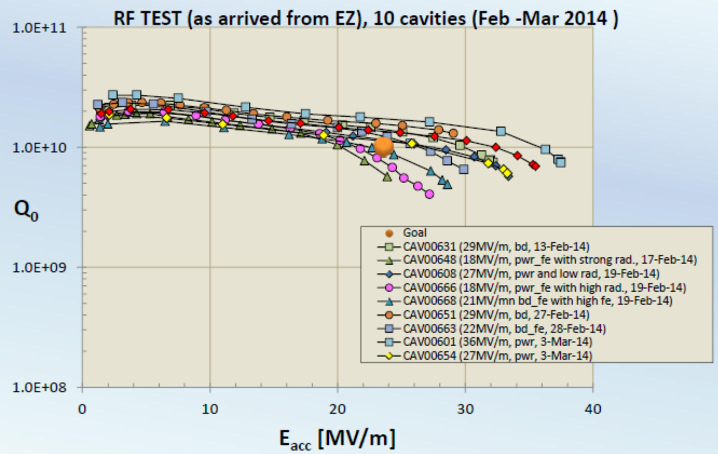
E.ZANON SC cavities production at Ettore Zanon s.p.a.

Some recent results of VT



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E.ZANON SC cavities production at Ettore Zanon s.p.a.

Some general info about production , possibile discussion topics

A) NCR report issued 430
Some for repetitive aspect subject of separate investigation (ex. RGA analysis results)

B) Items in Quarantine >650 (single parts – subassemblies)

Production processes

C) Mechanical production:
Required tight tolerances generally reached .
C1-Are all of them really necessary ?
C2-Cumulation of tolerances to be studied (ex: Final dimensional control - next slide)
C3- How a mechanical out-of-tolerance can influence performance? Is that clear?

C1-C2-C3 have impact to NCR and Quarantine

TTC Meeting – WG1 DESY-Hamburg 24-27 March 2014

Status Mar 14, 2014: Test Results for the Testing of 800 Series Cavities for the European XFEL

Sebastian Aderhold, Detlef Reschke, Jörn Schaffran / DESY
Laura Monaco / INFN Milano
for all colleagues working on European XFEL series cavities

1 VT = 4 cavities

2.5 VT / week = 10 cavities /week @ DESY

(??? 1 cryomodule / week @ CEA)

207 cavities tested (VT)

XFEL :

Eacc,max > 26 MV/m

1st pass = 80 %

2nd pass = 90 %

ILC :

Eacc,max > 35 MV/m

1st pass = 30 %

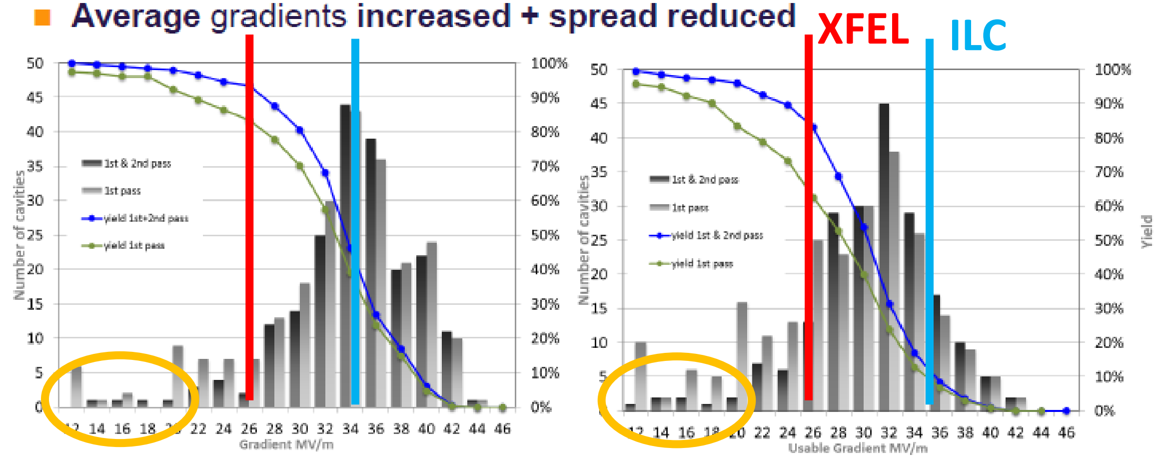
2nd pass = 40 %

* Eacc,max < 20 MV/m

2nd pass = ~3 %

Yield of gradients: After 1. re-treatment (2. pass)

- Yield of usable and maximum gradient of ~207 cavities (2.pass) => 85% (cavities that passed in 1. pass + results of cavities after re-treatment)
- **Average** gradients **increased + spread reduced**



Average **maximum** gradient: (32.8 ± 4.9) MV/m

Average **usable** gradient: (29.3 ± 5.1) MV/m

given errors are standard deviation

Detlef Reschke, DESY *Preliminary data; results are not published*

まとめ

- XFEL Cavity mass-production at company : routinely works well, now.
  (Fabrication + Surface-treatment + RF-tuning + Jacket-welding)
  - RI = 4 cavities/week
  - Zanon= 4 cavities/week

  -> 8 cav. X 45 weeks = 360 cavities /year

- XFEL Cavity performance : Eacc,max > 26 MV/m, 2nd pass = 90 %

- XFEL Cryomodule Assembly : delay, delay, delay, delay,,,,,,,,
  - Delivery of input couplers (copper plating issues)
  - Pores at TIG-welding of titanium 2K-He supply pipe