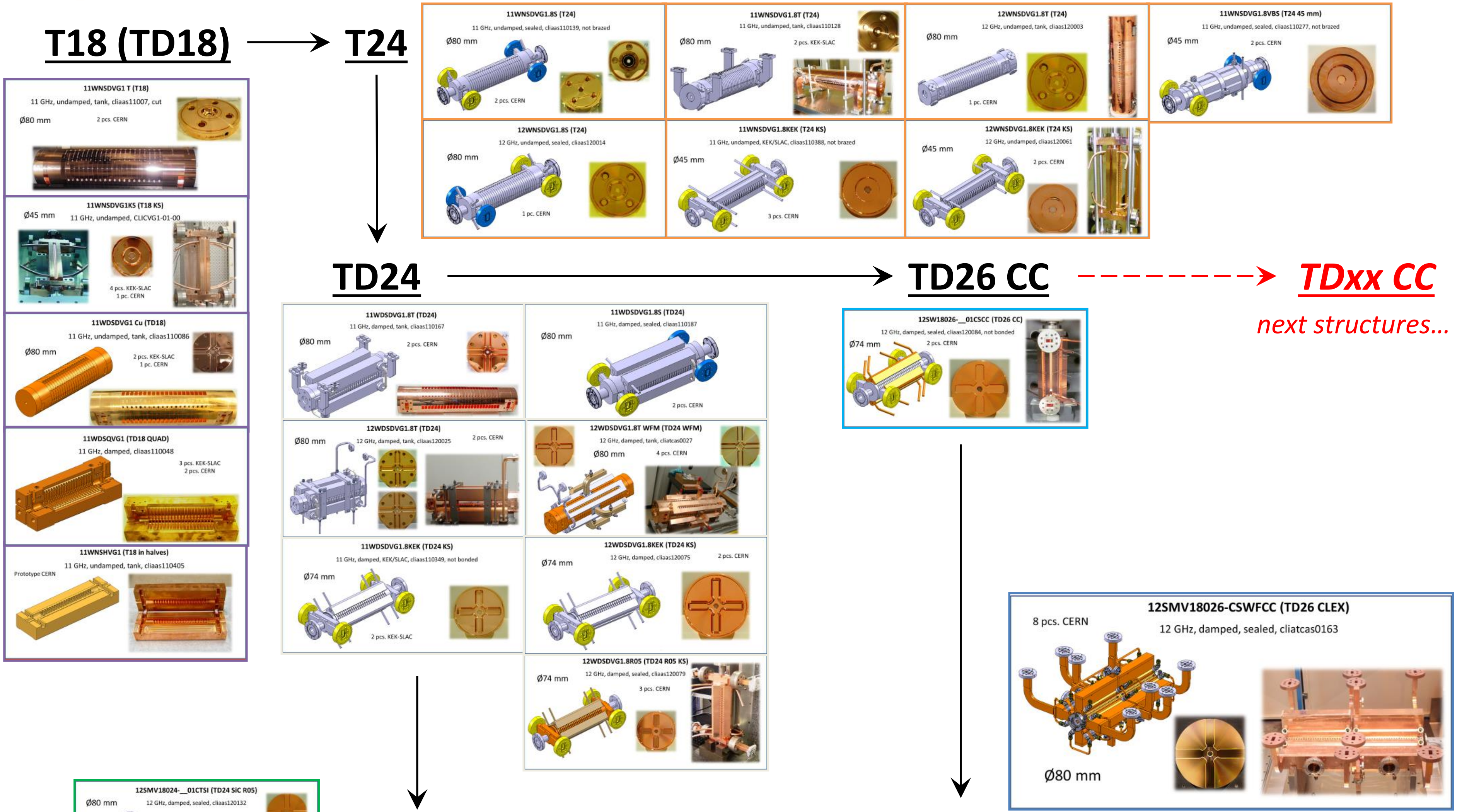
X-band structure production status

Anastasiya Solodko, on behalf of the CLIC study team, CERN

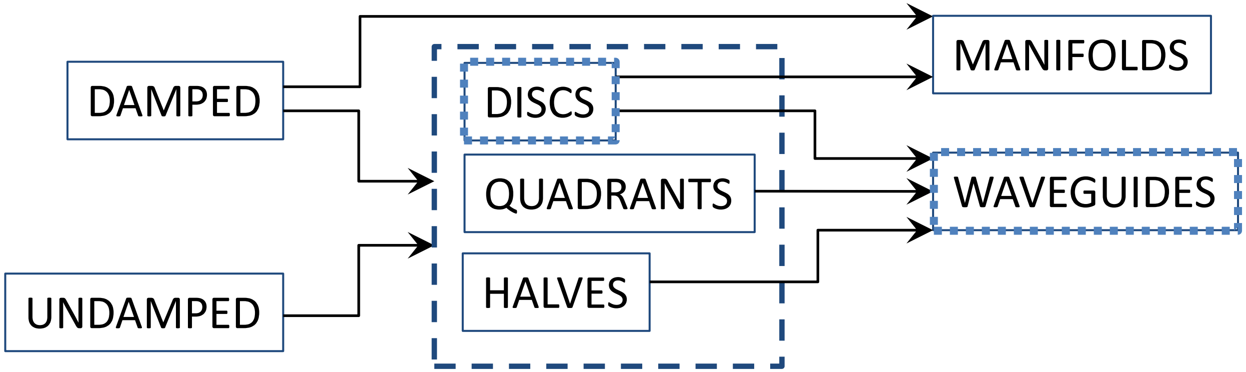
Test structures



A. Olyunin
A. Samoshkin

TAPER type STRUCTURE (T, TD):

Each structure cell has different geometry



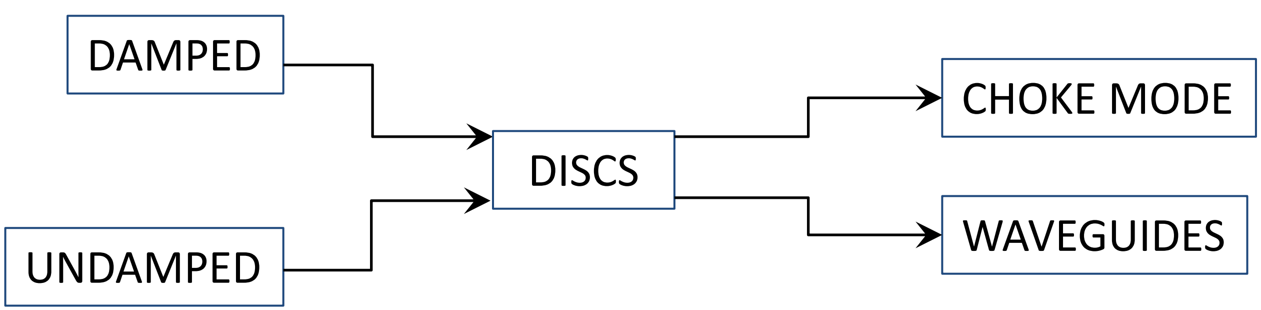
BASELINE

Study:

- Integrated version disc

CONSTANT type STRUCTURE (C, CD):

Geometry of the structure cells are the same



Production phases

ENGINEERING DESIGN

3D models and 2D drawings, including thermo-structural simulations

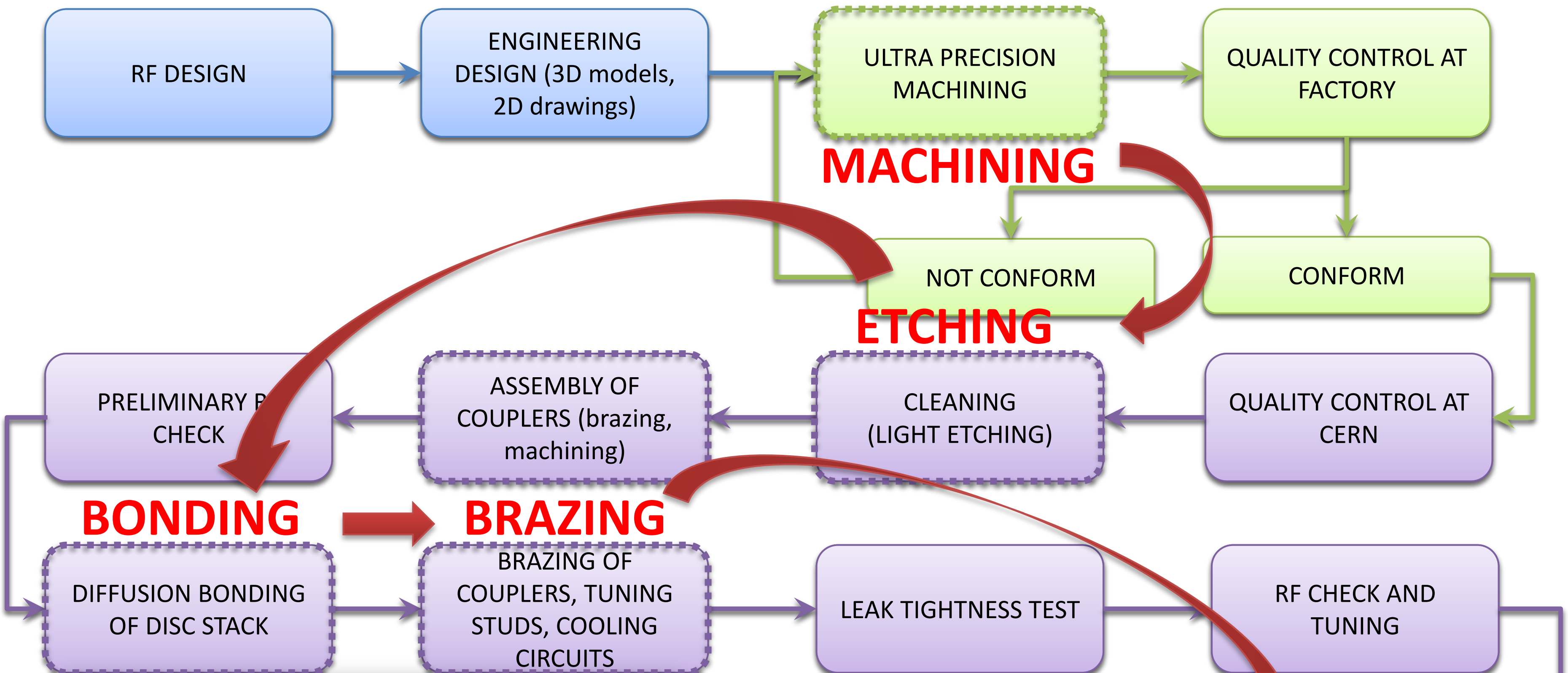
MACHINING

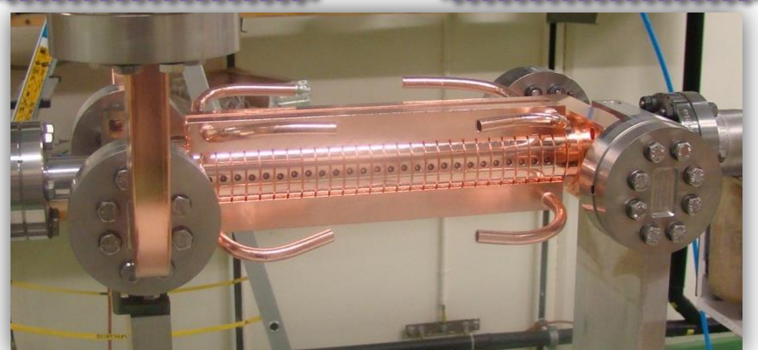
Tendering, contract adjudication, QC at factory (dimensional control, Ra)

ASSEMBLY

Alignment, bonding/brazing cycles, QC, RF measurements, final vacuum baking

Baseline manufacturing flow





MACHINING

- *Tolerances*
- *Technology*
- *Dimensional control*
- *Machining defects*

Machining. Tolerances

… the tolerances required to satisfy the RF and beam dynamic constraints

Cell shape accuracy:

zone A - 0.005 mm

zone B - 0.02 mm

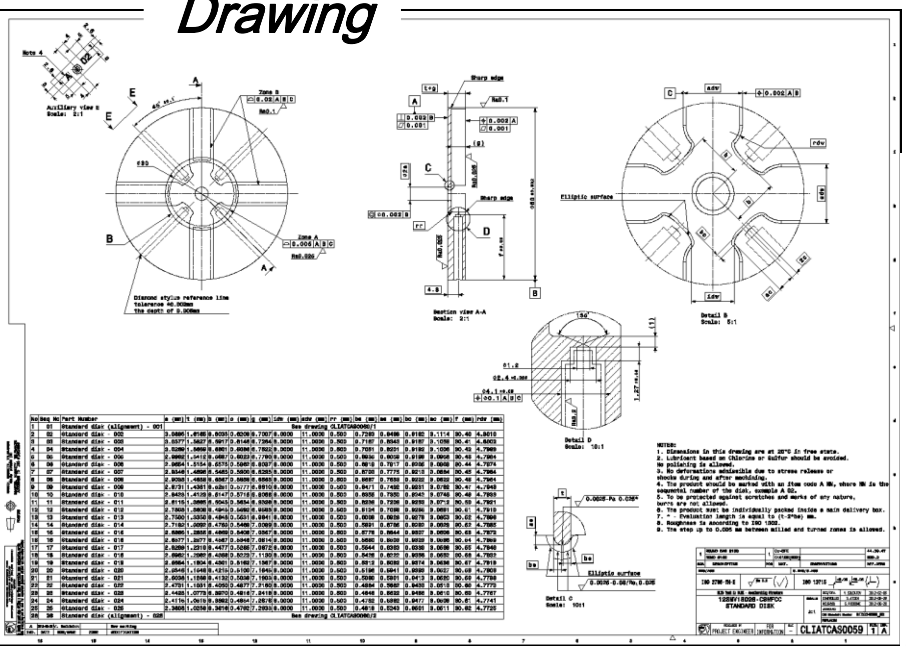
Flatness - 0.001 mm

Surface roughness:

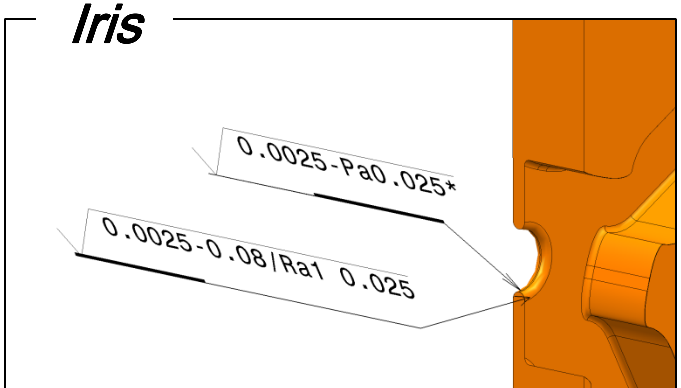
zone A Ra 0.025 µm

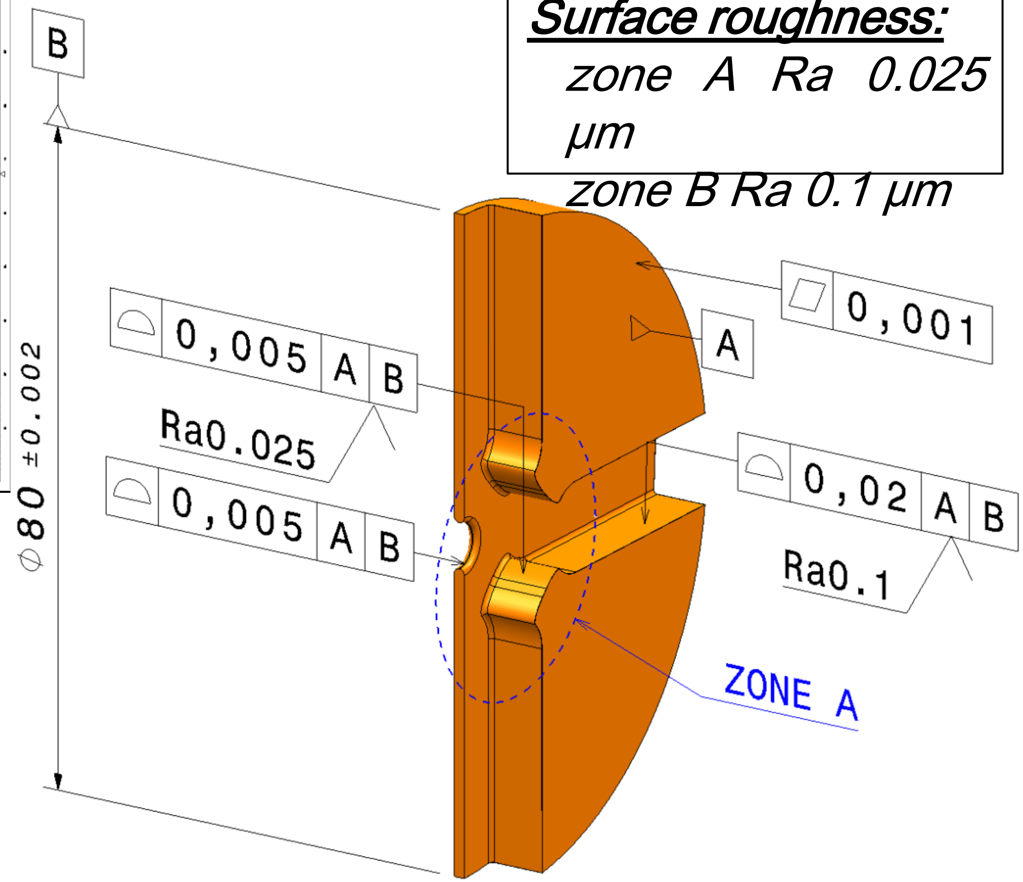
zone B Ra 0.1 µm

Drawing



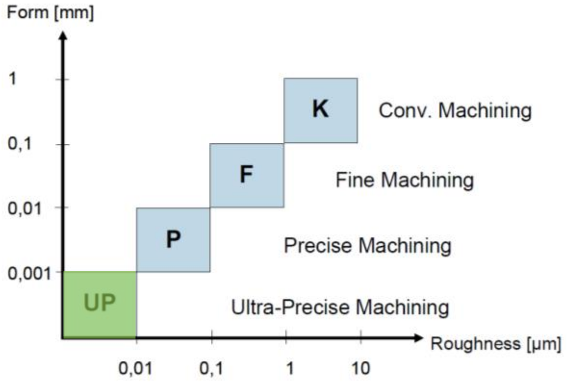
Iris





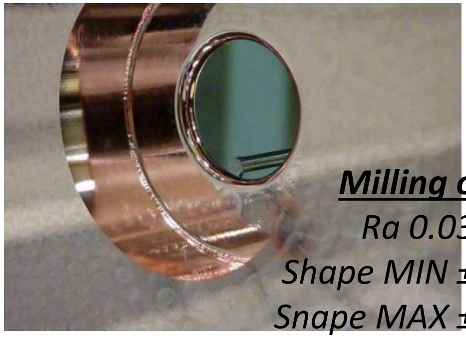
Machining. Technology

CLIC's needs:
shape accuracy± 2.5 µm
Roughness Ra 25 nm



S. Atieh

Study:
- Use only milling technology



Milling of iris:
Ra 0.032 µm
Shape MIN ±2 µm
Snape MAX ±5 µm

Damped disc

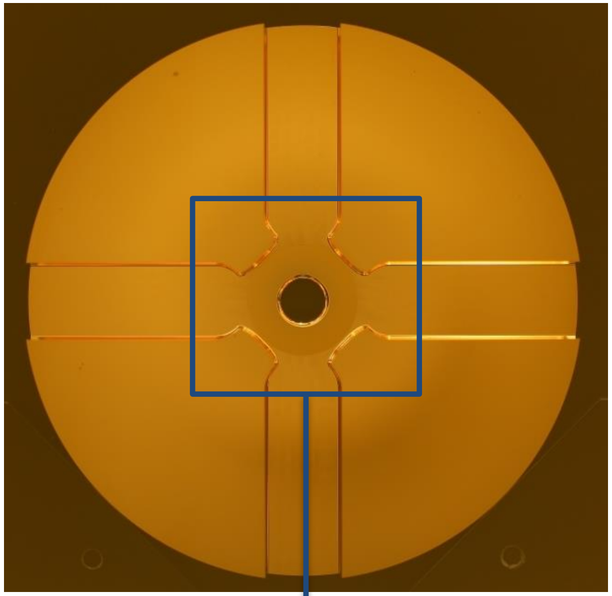
Machining strategy differs from company to company

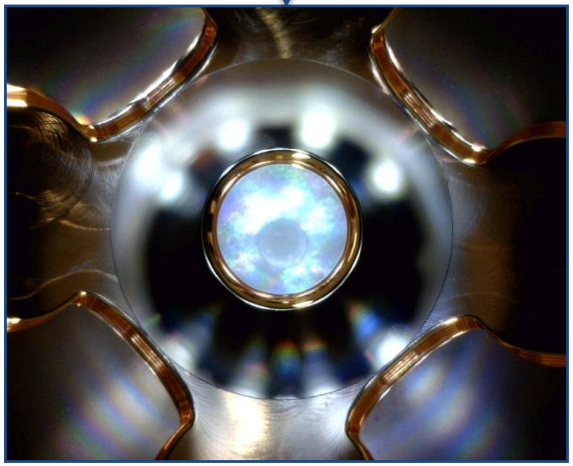
Pre machining

- **Sawing**
- **Pre-Turning**
- **Pre-milling**
- **Drilling tuning holes**
- (Measurement)
- (Annealing)

End machining

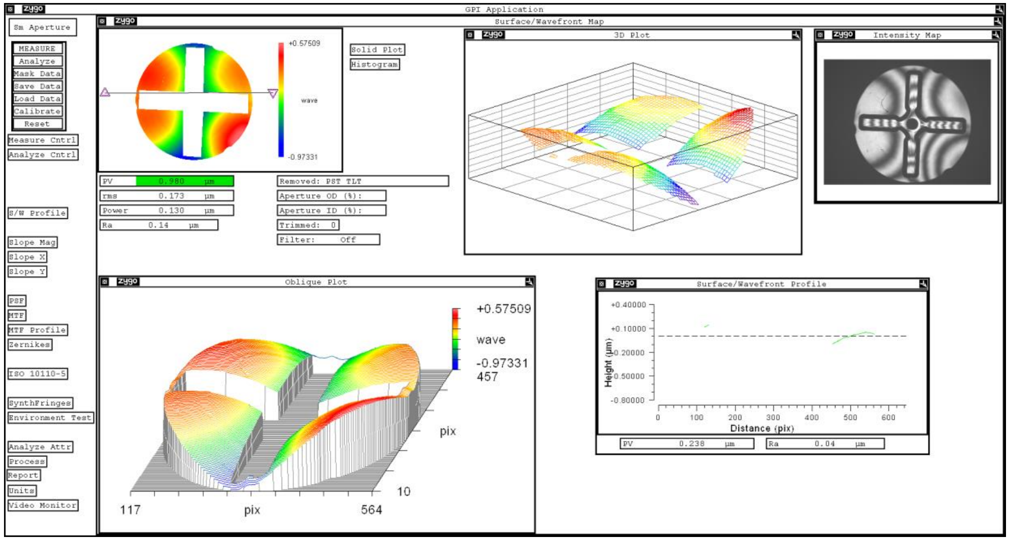
- **UP turning side waveguides**
- **UP turning opposite side**
- **UP milling waveguides**
- **Iris final turning**
- (Metrology)
- (Cleaning)





Machining. Dimensional control

Flatness / roughness control



All dimensional checks

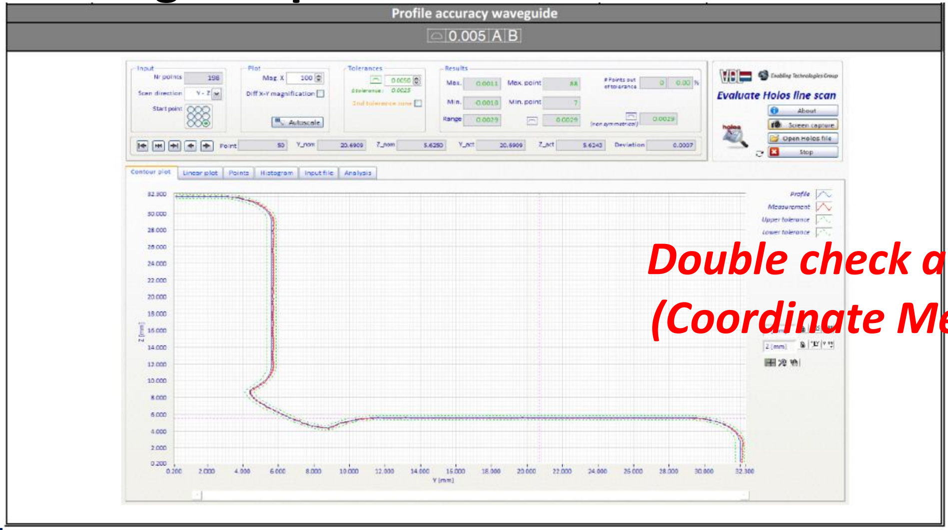
Enabling Technologies Group **Inspection Report**

Drawing no.	CLIAAS120064	Prod. Nr.	2
Description	Disk 01		

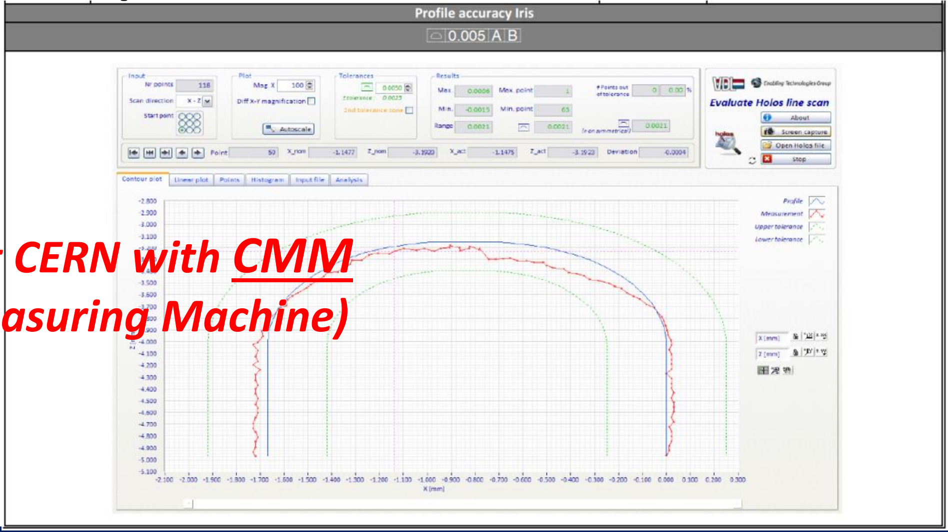
Dimensions

Measurand	Description	Nominal	Upper	Lower	Actual	Deviation	Pass √	Fail √	Remark
1	Ref A ⏥ 0.002	0.0000	0.0020	0.0000	0.0013	0.0013	√		
2	Outer diameter Ref B	74.0000	0.0025	-0.0025	74.0002	0.0002	√		
3	⏥ 0.002 ref B	0.0000	0.0020	0.0000	0.0009	0.0009	√		
4	⫽ 0.002 A	0.0000	0.0020	0.0000	0.0002	0.0002	√		
5	Diameter 70	70.0000	0.0000	-0.0100	69.9953	-0.0047	√		
6	◎ 0.005 B	0.0000	0.0050	0.0000	0.0003	0.0003	√		
7	Diameter 2xa	6.3000	0.0050	-0.0050	6.2996	-0.0004	√		
8	Distance d	8.3098	0.0020	-0.0020	8.3105	0.0007	√		
9	Plane at distance d ⏥ 0.002	0.0000	0.0020	0.0000	0.0014	0.0014	√		
10	Diameter 70	70.0000	0.0150	0.0100	70.0129	0.0129	√		
11	◎ 0.005 B	0.0000	0.0050	0.0000	0.0011	0.0011	√		
12	Distance t	1.6700	0.0025	-0.0025	1.6705	0.0005	√		
13	Distance g	6.6398	0.0025	-0.0025	6.6396	-0.0002	√		
14	Width cross Z+	11.2500	0.0025	-0.0025	11.2503	0.0003	√		
15	Symmetry cross Z +	0.0000	0.0025	-0.0025	-0.0003	-0.0003	√		
16	Width cross Z-	11.2500	0.0025	-0.0025	11.2510	0.0010	√		
17	Symmetry cross Z -	0.0000	0.0025	-0.0025	-0.0004	-0.0004	√		
18	Width cross Y-	11.2500	0.0025	-0.0025	11.2499	-0.0001	√		
19	Symmetry cross Y -	0.0000	0.0025	-0.0025	0.0007	0.0007	√		

Waveguide profile check



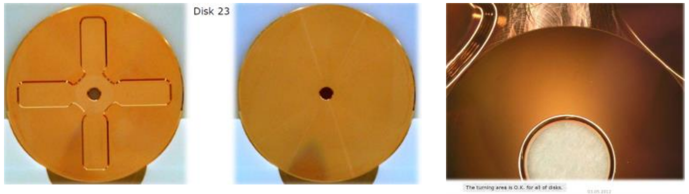
Iris profile check



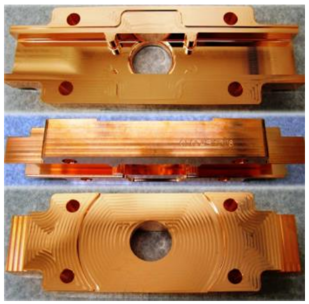
Double check at CERN with CMM
(Coordinate Measuring Machine)

Machining. Machining defects

Components for AS production

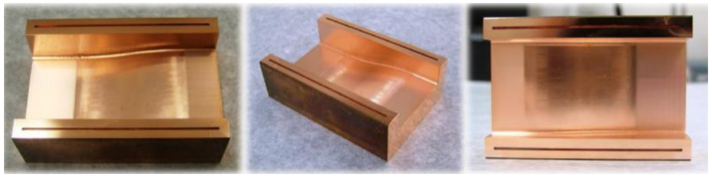


TD26 CC discs



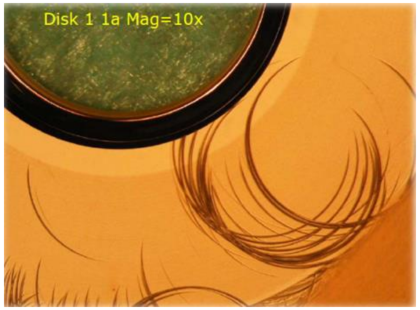
TD24 R05 couplers

TD24 R05 SiC manifolds



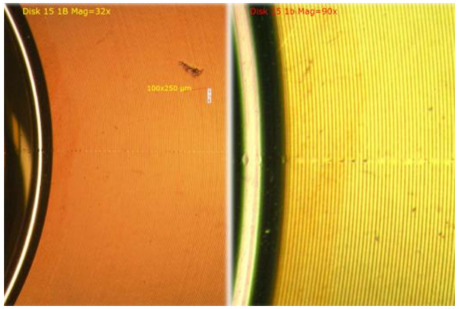
We cannot accept!

1. Milling marks in turning area

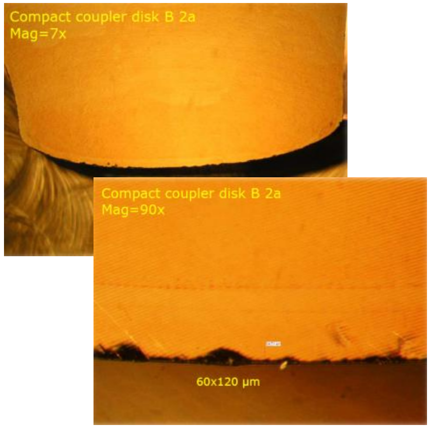


2. Scratches in RF area

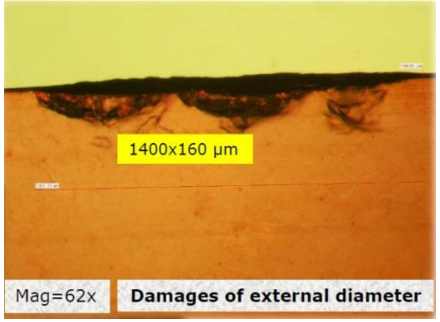
3. Visible indents/caverns in RF area



4. Burrs in sharp edges



5. Damages on external diameter



All other observed defects (foreign material inclusions in the surface, caverns etc.) have to be analysed.

Andrey Olyunin
Nerea Mouriz Irazabal

ETCHING

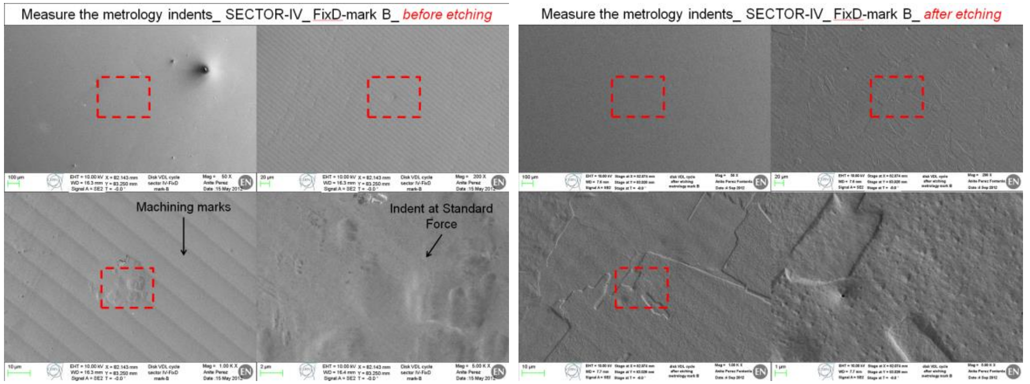
- *Purpose*
- *Process*

Etching. Purpose

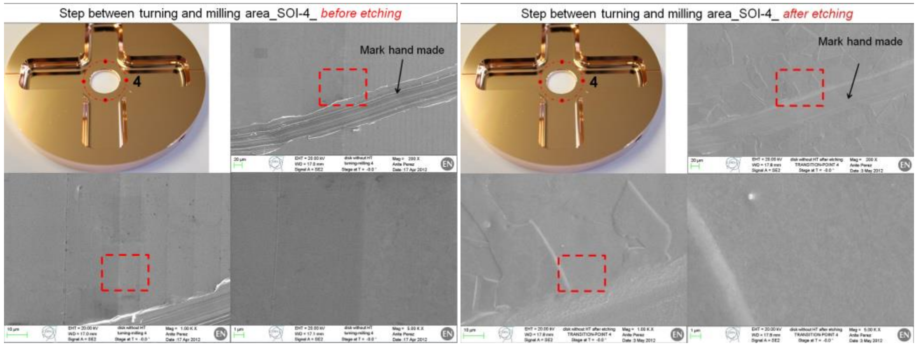
Purpose of etching

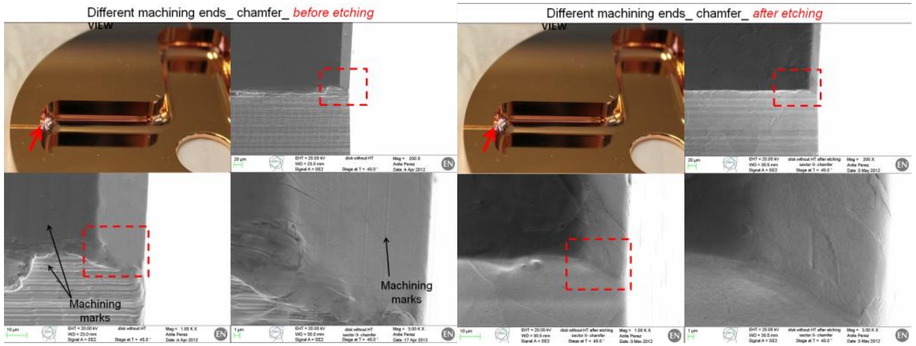
- To prepare the surface for the bonding;
- To remove any pollution;
- To remove burrs, scratches or other surface defects;
- To remove any oxidation.

Remove metrology indents



Smooth edges and machining transition





Study:

- To find optimal etching parameters and to see the effect on the surface

Nerea Mouriz Irazabal
Ana Teresa Perez Fontenla

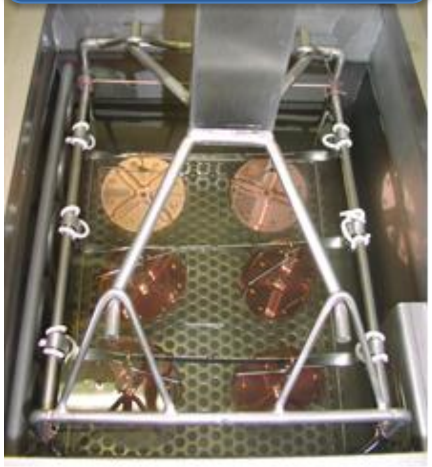
Etching. Process

- **SLAC cleaning procedure as a baseline.**

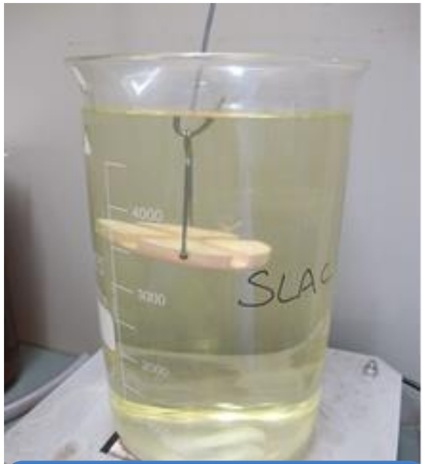
1. Unpacking, visual inspection, fixing of the support clip and mounting of the disk in the special basket.
2. Degreasing with solvents Topklean MC 20A and Promosolv 71IPA.
   This treatment is repeated twice if there are more than two blind holes. After the first degreasing the piece is removed from the basket and it put onto tissue paper. The support clip is removed and is then inserted into the other holes. The disk is placed in the basket and is degreased for the second time. See appendix n° 1 for the sequence of work.
3. Removal of the support clip, drying the blind holes with nitrogen, packaging with tissue paper and placing in the plastic boxes for transport to a different area.
4. Unpacking and fixing of the support clip.
5. Degreasing with detergent NGL 17.40 spec. ALU III and ultrasound.
   - Concentration: 10 g/l.
   - Temperature: 50 °C.
   - Time: 10 – 15 minutes.
6. Rising with water jet and by immersion.
7. Pickling (deoxidation) with hydrochloric acid.
   - Concentration: 50 %.
   - Temperature: room.
   - Time: ~ 1 minute.
8. Rising with water jet and by immersion.
9. Etching with SLAC solution.
   - Concentration:
     Phosphoric acid 70 %
     Nitric acid 23.3 %
     Acetic glacial acid 6.6 %
     Hydrochloric acid 0.49 %
   - Temperature: room.
   - Time: 30 seconds (etching of about 1.7 µm).
10. Rising with water jet.
11. Immersion in demineralised water, removal of the support clip, rinsing of the holes using a syringe and fixing of the support clip.
12. Final rinsing with demineralised water and ultrasound, followed by rinsing with ethylic alcohol and ultrasound.
    - Temperature: 30 °C. Time: ~ 1 minute.
13. Drying with nitrogen.
14. Drying in an oven.
    - Temperature: 60 °C. Time: ~ 5 minutes.
15. Mounting of the disk in the special basket. Degreasing with solvents Topklean MC 20A and Promosolv 71IPA. This step ensures the final deoxidation and the neutralisation of the SLAC solution.
16. Removal of the support clip, drying the blind holes with nitrogen, packaging with tissue paper and placing the disks in the plastic boxes.

<u>2. Degreasing with solvents</u>
Topklean MC 20A and Promosolv 71IPA.
This treatment is repeated twice if there are more than two blind holes.

Degreasing solvents



<u>9. Etching with SLAC solution.</u>
- Concentration:
Phosphoric acid 70 %
Nitric acid 23.3 %
Acetic glacial acid 6.6 %
Hydrochloric acid 0.49 %
- Temperature: room.
- Time: 30 seconds (etching of about 1.7 µm).



SLAC etching

CERN – TE/VSC/SCC

DIFUSSION BONDING

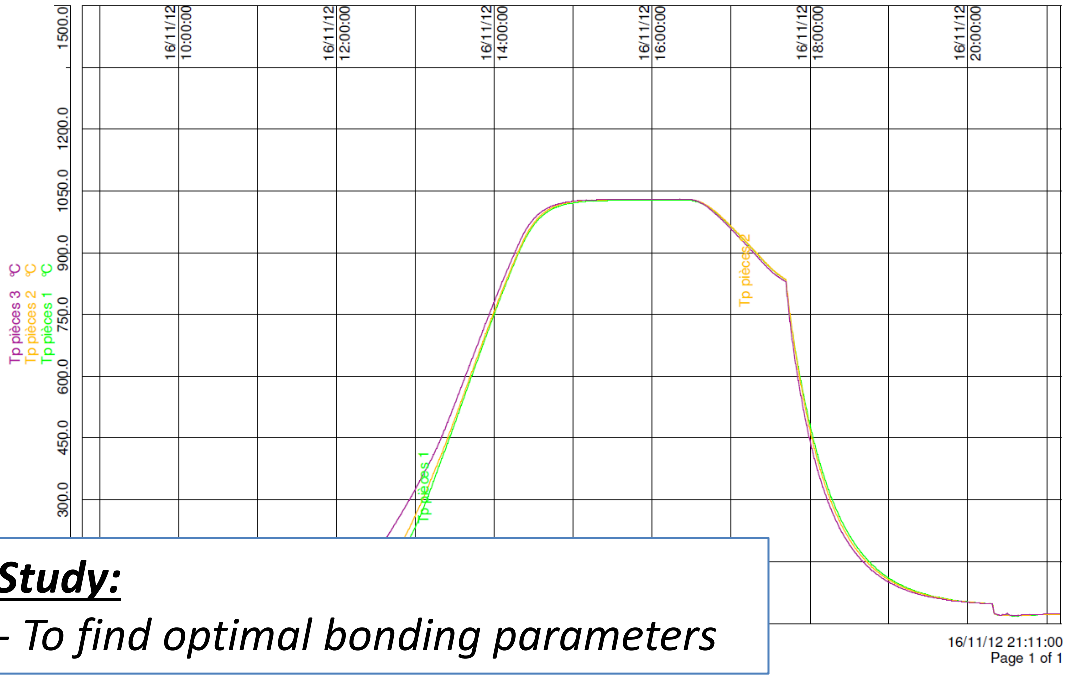
- *Requirements*
- *Process*
- *Alignment*
- *Issues*

Diffusion bonding. Requirements

Requirements

- Temperature ~ 1040 °C;
- Time ~ 1,5 h;
- Vacuum 10^{-6} mbar;
- H_2 partial pressure 20 mbar;
- Applied pressure 0.1 MPa

Temperature profile



Study:

- To find optimal bonding parameters

Bonding oven (outside)

Bonding oven (inside)

Diffusion bonding. Process

Assembly process

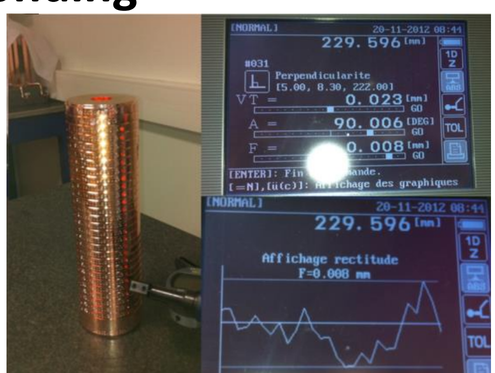
Process

- Assembly in V-shape column
- Straightness and tilt measurements before bonding
- Weight application
- Bonding
- Straightness and tilt measurement after bonding

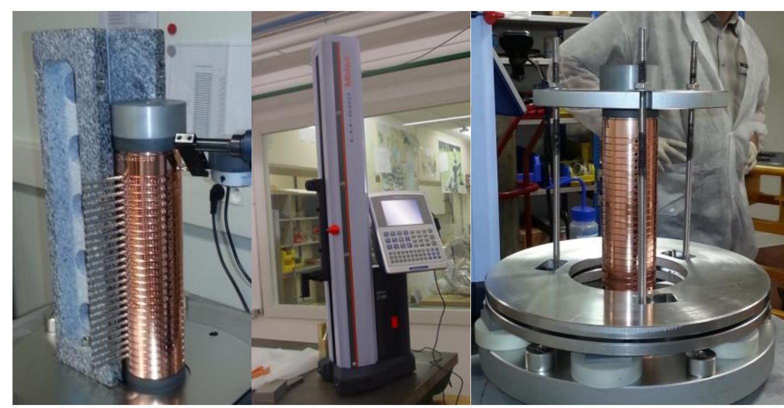
Equipment

- V-shape column
- Measurement column
- Tooling for the weight application
- Graphite/ceramic pads

Straightness measurements before and after bonding



Equipment

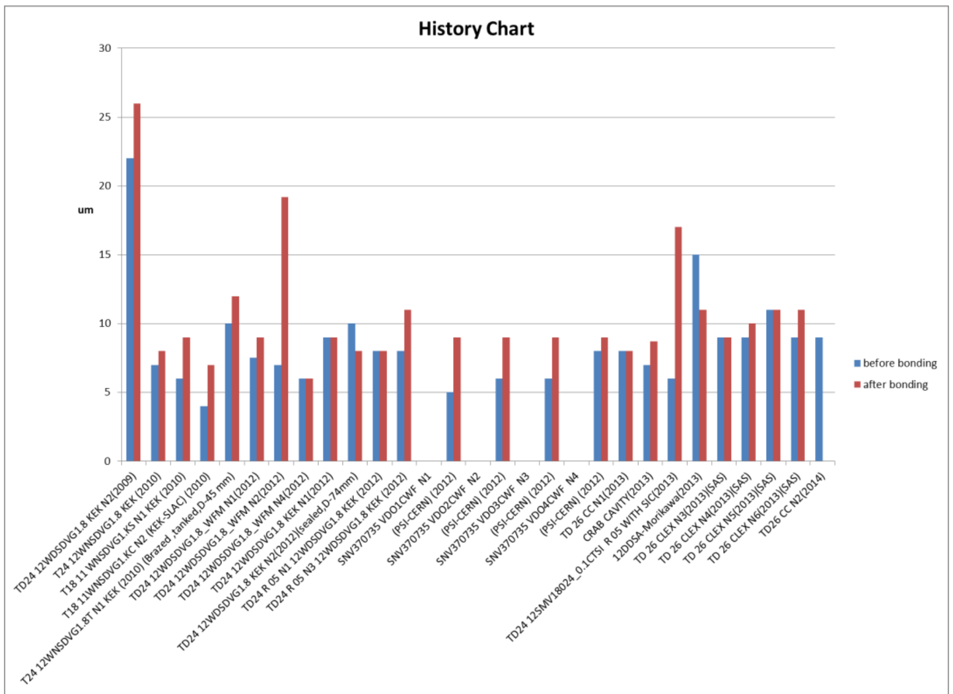


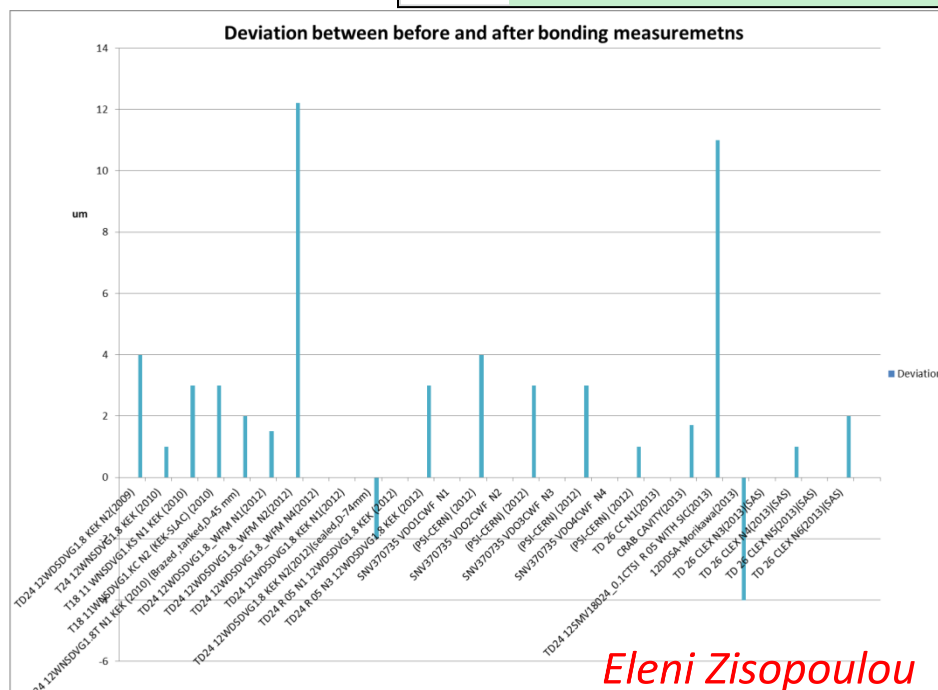
Diffusion bonding. Alignment

STRUCTURES	Max bef.bonding	Max aft.bonding	Deviation
TD24 12WDSDVG1.8 KEK N2(2009)	22	26	4
T24 12WNSDVG1.8 KEK (2010)	7	8	1
T18 11 WNSDVG1.KS N1 KEK (2010)	6	9	3
T18 11WNSDVG1.KC N2 (KEK-SLAC) (2010)	4	7	3
T24 12WNSDVG1.8T N1 KEK (2010) (Brazed ,tanked,D-45 mm)	10	12	2
TD24 12WDSDVG1.8_WFM N1(2012)	7.5	9	1.5
TD24 12WDSDVG1.8_WFM N2(2012)	7	19.2	12.2
TD24 12WDSDVG1.8_WFM N4(2012)	6	6	0
TD24 12WDSDVG1.8 KEK N1(2012)	9	9	0
TD24 12WDSDVG1.8 KEK N2(2012)(sealed,D-74mm)	10	8	-2
TD24 R 05 N1 12WDSDVG1.8 KEK (2012)	8	8	0
TD24 R 05 N3 12WDSDVG1.8 KEK (2012)	8	11	3
SNV370735 VDO1CWF N1			0
(PSI-CERN) (2012)	5	9	4
SNV370735 VDO2CWF N2			0

STRUCTURES	Max bef.bonding	Max aft.bonding	Deviation
(PSI-CERN) (2012)	6	9	3
SNV370735 VDO3CWF N3			0
(PSI-CERN) (2012)	6	9	3
SNV370735 VDO4CWF N4			0
(PSI-CERN) (2012)	8	9	1
TD 26 CC N1(2013)	8	8	0
CRAB CAVITY(2013)	7	8.7	1.7
TD24 12SMV18024_0.1CTSI R 05 WITH SIC(2013)	6	17	11
12DDSA-Morikawa(2013)	15	11	-4
TD 26 CLEX N3(2013)(SAS)	9	9	0
TD 26 CLEX N4(2013)(SAS)	9	10	1
TD 26 CLEX N5(2013)(SAS)	11	11	0
TD 26 CLEX N6(2013)(SAS)	9	11	2
TD26 CC N2(2014)	9		

Average	Before bonding	After bonding
	7.180851	9.011475

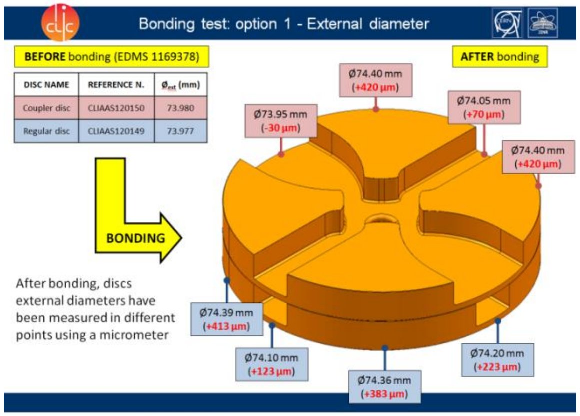




Eleni Zisopoulou

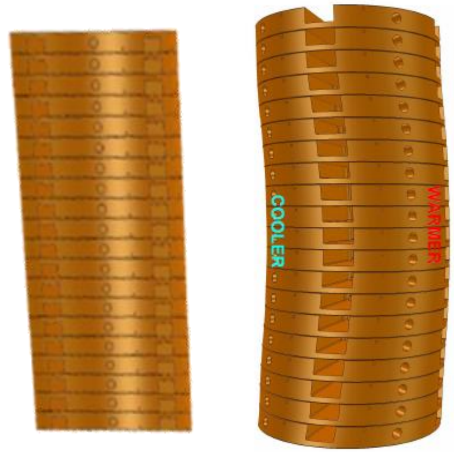
Bonding. Issues

Deformation (during the bonding process)

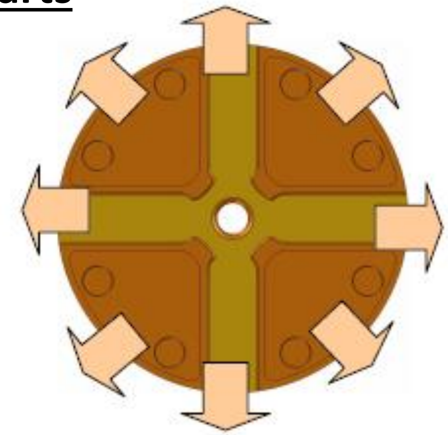


Fabrizio Rossi

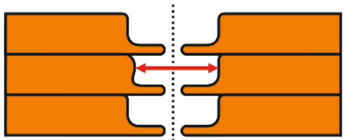
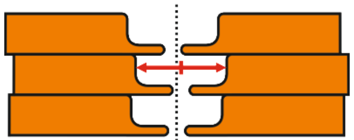
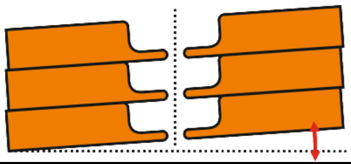
Unsymmetrical heating or weight application



Extension → difficulties in assembling with another parts



Misalignment (due to alignment and machining tolerances)

	Error in iris shape	Transversal offset	Tilt
Shape error			
Tolerance	1 µm [2,5]	5 µm [3]	140 µrad [2,5]

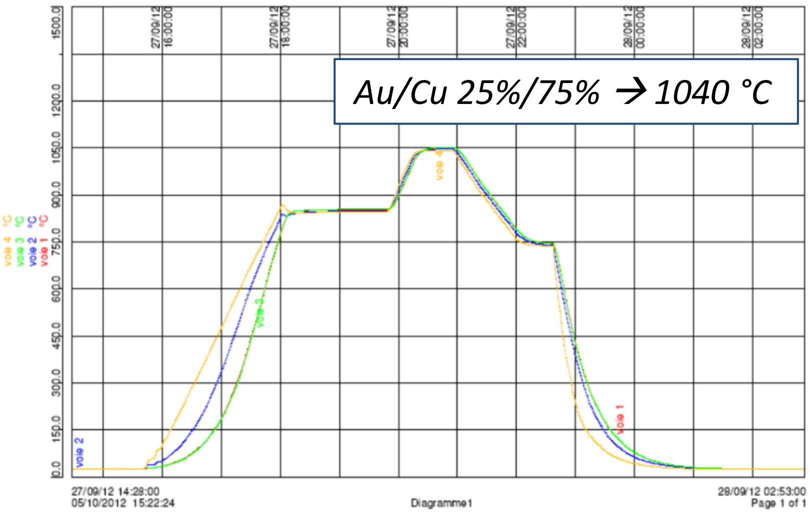
Risto Montonen

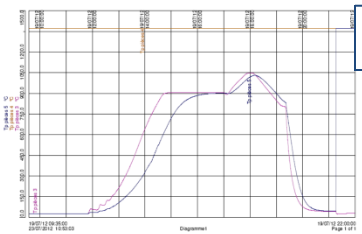
BRAZING

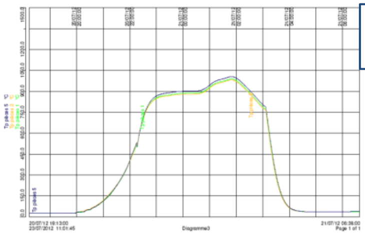
- *Requirements*
- *Process*
- *Issues*
- *SiC – Cu brazing*

Brazing. Requirements

Temperature profile







Brazing requirements:

- High temperature (depends on the brazing alloy);
- Time a few minutes;
- Vacuum 10^{-6} mbar;
- H_2 partial pressure 20 mbar.

Brazing material (configuration):

- Paste;
- Wire;
- Shim;
- Plating.

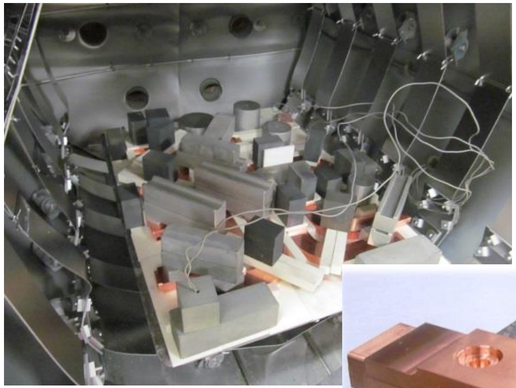
Brazing material (composition):

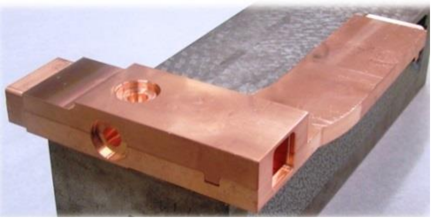
- Au/Cu;
- Ag/Cu/Pd.

MOST USED

Brazing. Process

Waveguide





Process

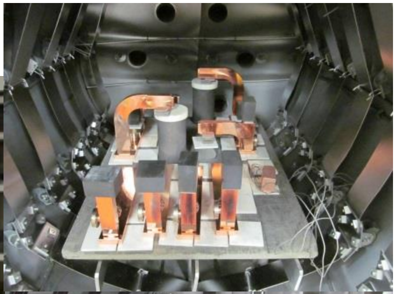
Brazing is mainly used for assembly of subassemblies (couplers, cooling circuits, manifolds etc) and for final assembly.

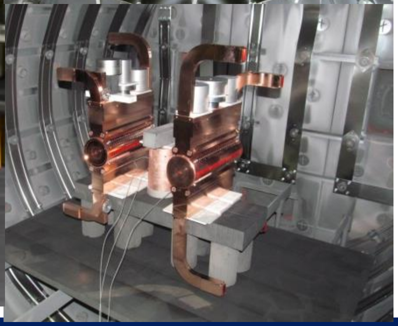
- **Insertion of brazing material**
- **Assembly and fixation of components**
- **Brazing**

Equipment

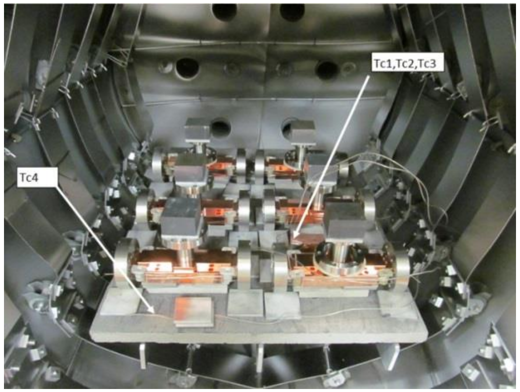
- **Graphite pads**
- **Weight**
- **Tooling (sometimes required)**

Manifolds

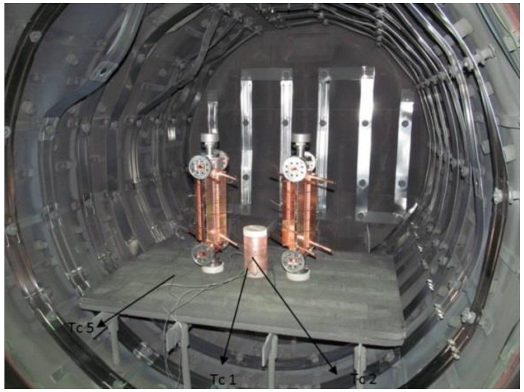




Couplers



Cooling circuits



Study:

- Brazing of SiC and copper (see next slide)

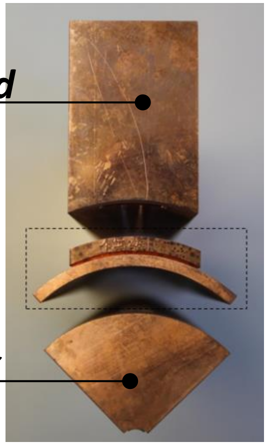
Brazing. Issues

Brazing joint not tight

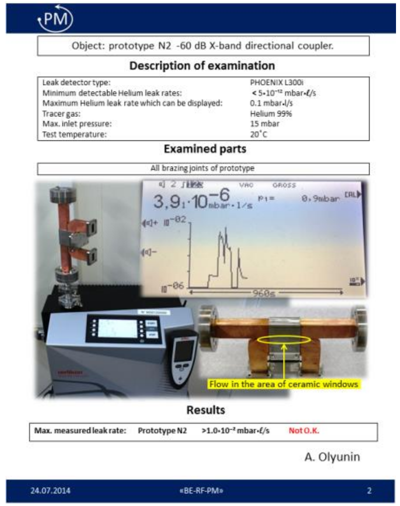
US test

Manifold

Disc stack



Leak test



PM

Object: prototype N2 -60 dB X-band directional coupler.

Description of examination

Leak detector type:	PHOENIX L300i
Minimum detectable Helium leak rates:	$< 5\cdot10^{-12}$ mbar$\cdot\ell$/s
Maximum Helium leak rate which can be displayed:	0.1 mbar$\cdot$l/s
Tracer gas:	Helium 99%
Max. inlet pressure:	15 mbar
Test temperature:	20˚C

Examined parts

All brazing joints of prototype

Results

Max. measured leak rate:	Prototype N2	$>1.0\cdot10^{-2}$ mbar$\cdot\ell$/s	Not O.K.

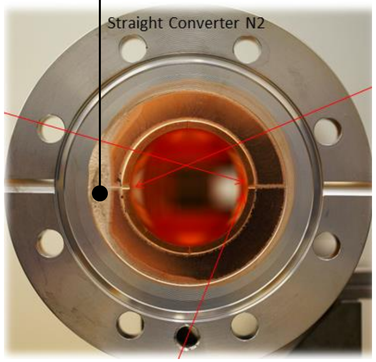
A. Olyunin

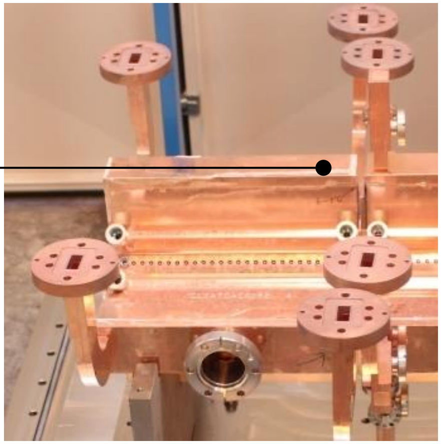
24.07.2014 «BE-RF-PM» 2

Brazing material leak

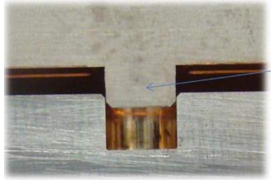
- Appears mainly with Ag/Cu brazing alloy.

Brazing material



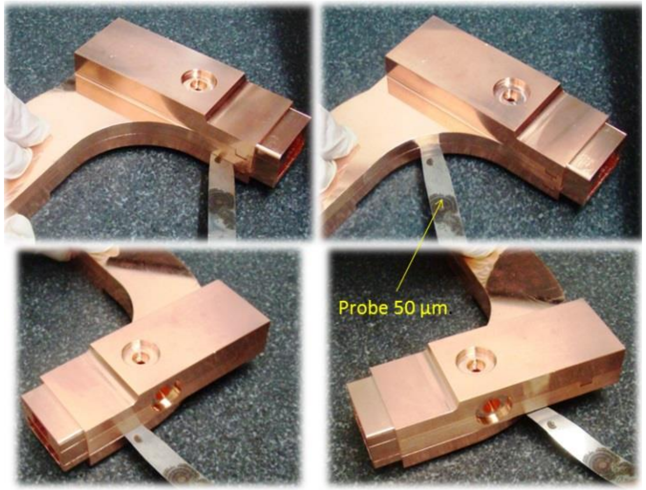


Dimension and tolerance issues



pins

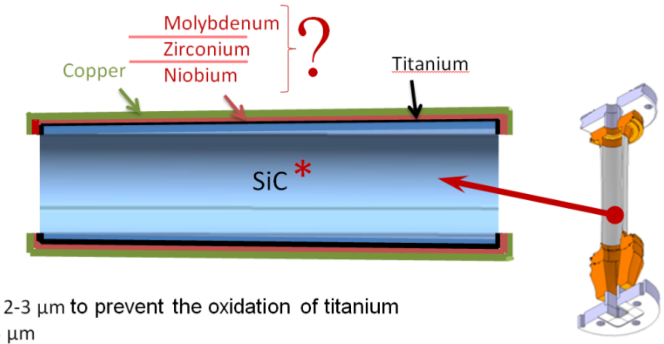
Assembly of the cover and the manifold is not possible due to difference of dimensions (Ø of pins or position of pins).



Brazing. SiC – Cu brazing

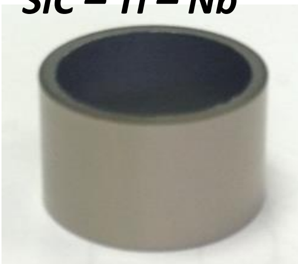
IN PAST

- For compact load assembly;
- Several tests were performed; FAILED
- Two configurations of metallization were tested.



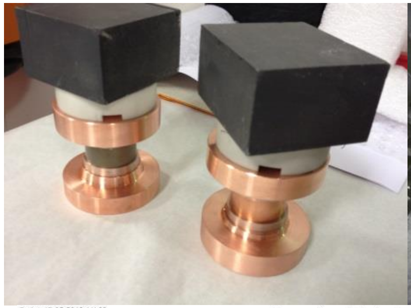
Coating :
Ti 2 µm
Mo/Zr/Nb 2-3 µm to prevent the oxidation of titanium
Copper 3-5 µm

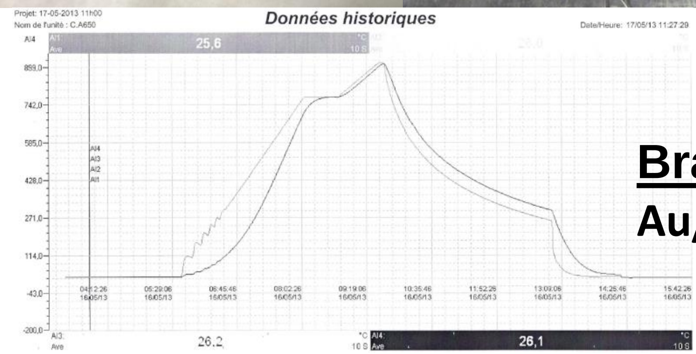
SiC – Ti – Nb



SiC – Ti – Mo – Cu

* *Simplified samples (SiC rings) are being used for testing of different metallization. The most successful option will be retained for the prototype.*



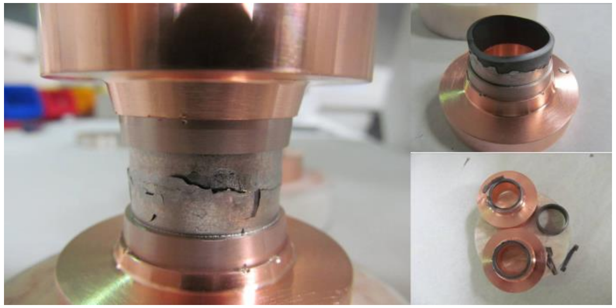


Brazing:

Au/Cu 80/20 → 910 °C

Results

SiC – Ti – Nb



SiC – Ti – Mo – Cu

A. Samoshkin

Brazing. SiC – Cu brazing

IN FUTURE

<u>LOW TEMPERATURE BRAZING</u>:

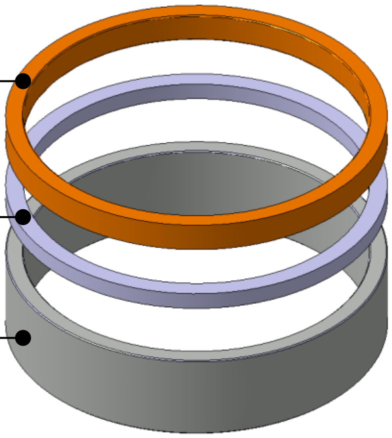
- SiC metallization: Ti+Mo+Ni+Cu (10 µm);
- Brazing alloy Sn 90%/Au 10%;
- Brazing temperature 325 ^{o}C.

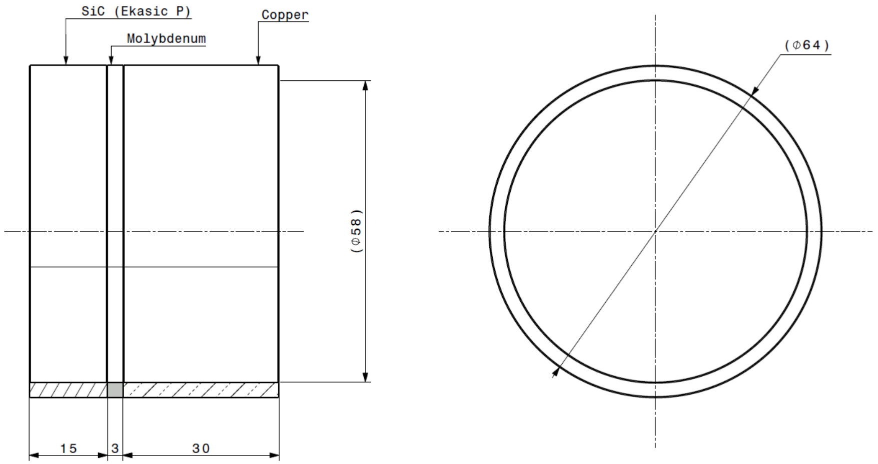
Some successful tests have been already done at KEK
But the test samples had a simple bar shape 2 cm in diameter and 5 cm long

http://accelconf.web.cern.ch/accelconf/e96/PAPERS/WEPL/WEP056L.PDF

<u>BRAZING</u>:

- To use molybdenum ring b/w SiC and Cu;
- Brazing alloy Cu/Ag/Ti;
- Brazing temperature 800 ^{o}C.





A. Samoshkin

BAKING

- ***Requirements***
- ***Process***

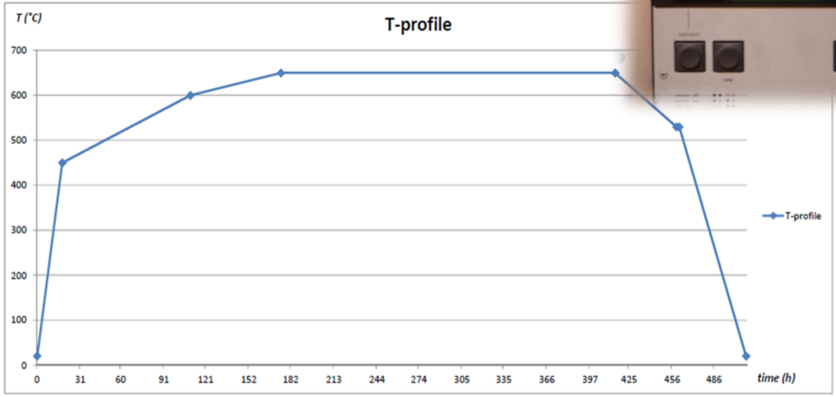
Baking. Requirements

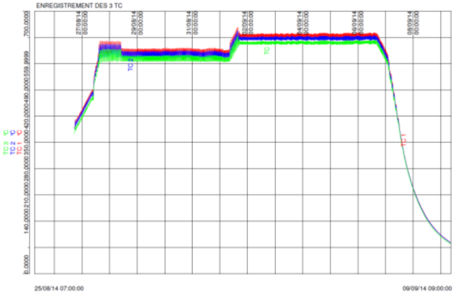
Requirements

- Temperature 650 °C;
- Time 10 days;
- Total time ~ 15 days;
- Vacuum 10^{-9} mbar.

Vacuum level

Temperature profile





1. RT -> 450C at 25 C/h
2. 450C -> 600C at 6.5 C/h
3. 600C -> 650C at 10 C/h
4. 650C during 10 days
5. 650C -> 530C at 12 C/h
6. 530C during 2 h
7. 530C -> RT

~ 15 days

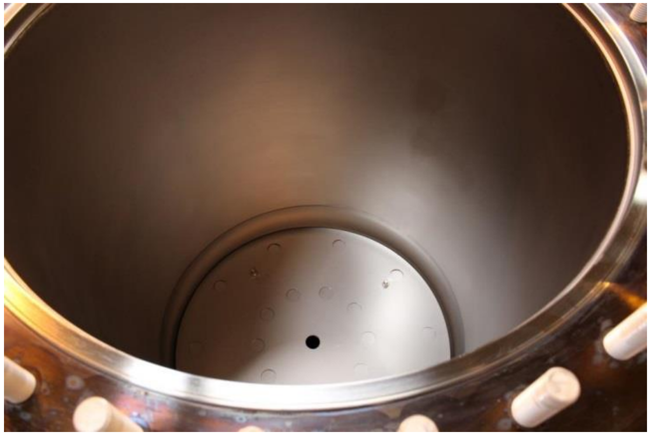
Pumping group

Baking oven (outside)

Control panel

Structure support

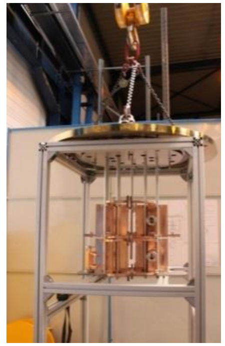
Baking oven (inside)



Baking. Process

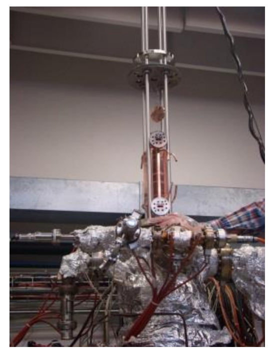
Bodycote

- Vertical load of the structures;
- Big volume ~ 0.44 m^3.



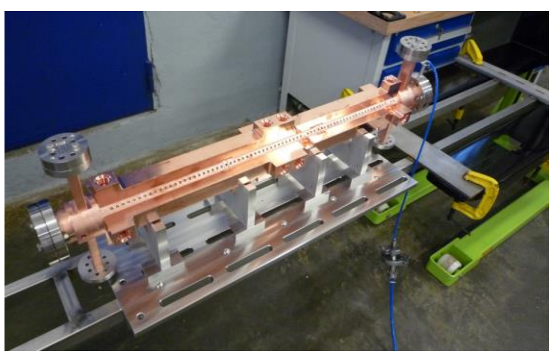
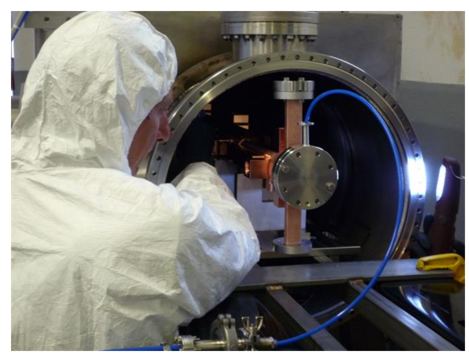
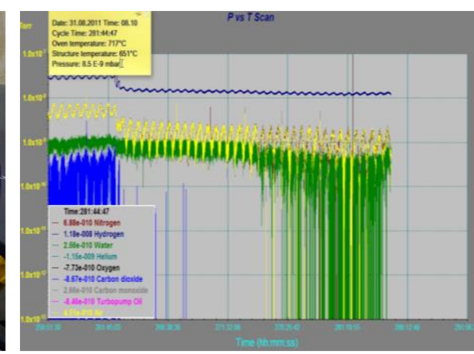
CERN

- Vertical load of the structures;
- Small volume: only one AS could be placed.

Comeb

- Horizontal load of the structures;
- Medium volume: ~ 0.2 m^3

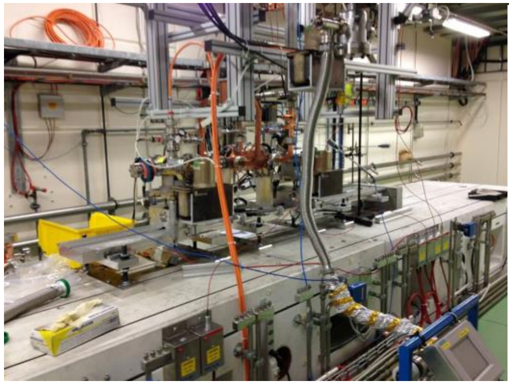




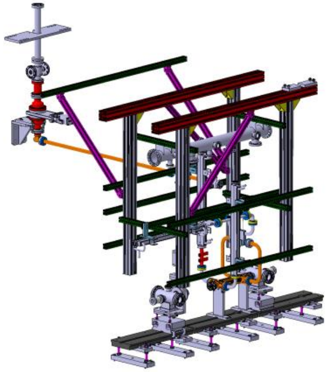
X-BAND TEST STANDS

X-band test stands

Xbox 1

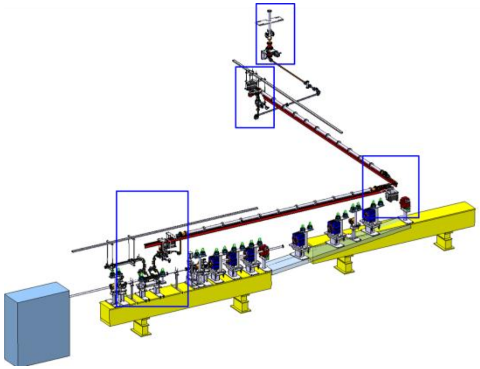
- for high power testing a CLIC prototype accelerating structure





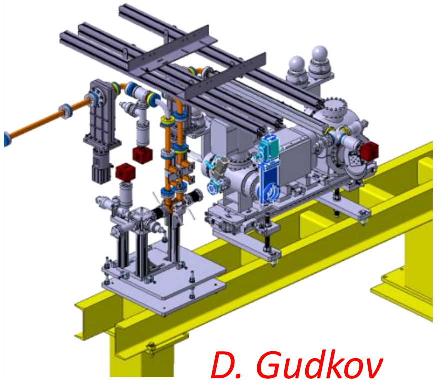
Dog Leg Test Stand

- for high power testing a CLIC prototype accelerating structure with a beam present



Xbox 2

- for high power testing a CLIC prototype accelerating structure

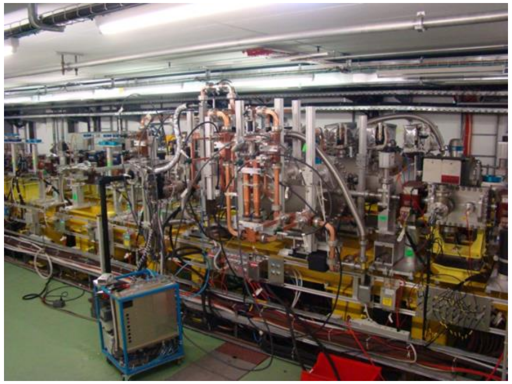


D. Gudkov

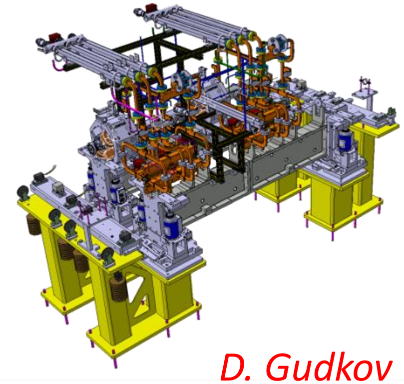
CLEX (CLIC EXperimental area)

- for testing CLIC acceleration scheme

July 2012



September 2014



D. Gudkov

STRUCTURES IN THE PIPELINE

Structures in the pipeline

High power testing of CLIC AS prototypes

- T24 N2 – Dog Leg Test Stand;
- TD26 Compact Couplers N1 – Xbox 1;
- Crab Cavity N1 – Xbox 2;
- (x2) TD26 superstructure – CLEX.

Production (2014)

FINISHED:

- FACET – aluminium structure for the wakefield measurements at SLAC;
- DDSA – damped detuned structure in collaboration with Manchester University;

UNDER PRODUCTION:

- TD26 CC N2 – with integrated Compact Coupler design;
- TD24 SiC N1 – AS with manifolds and integrated SiC damping material;
- PSI N5 – 900 mm long structure for PSI and Elettra with wakefield monitors.

In production (2015)

- TD24 RT – AS with relaxed tolerances: shape accuracy 20 μm, Ra0.1 μm.

Engineering design

- T24 12 GHz – AS design based on the SwissFEL C-band assembly procedure.

Conclusion

- Production of X-band accelerating structure is very challenging and it involves several steps, technologies and quality controls.
- Baseline procedure for accelerating structures has been established and tuned.
- Machining of discs improved (now within tolerances), but still few issues with scratches and spots (fruitful collaboration with industrial companies).
- Several studies are conducted in order to optimize and improve currently used procedures and technologies (see the presentation by Carlo Rossi).

ACKNOWLEDGMENT

I would like to thank all of the members of the collaboration for their valuable contribution.

THANK YOU FOR YOUR ATTENTION!