CLIC test and prototype structure production

15/06/2017

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IFIC

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on behalf of the X-band production team

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- Feedback to the module
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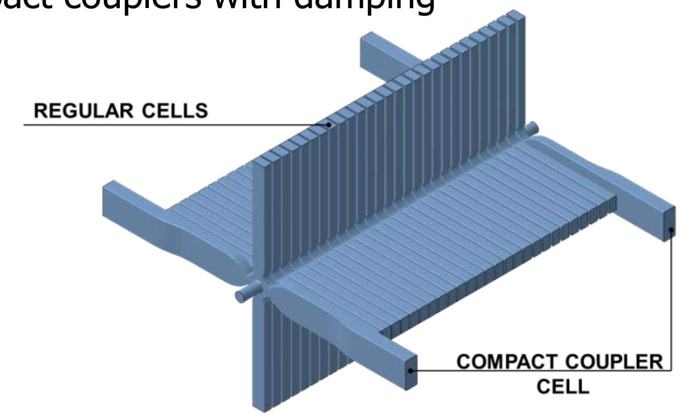
- Industrialization
- New technologies
  - Additive manufacturing

REVIEW OF STRUCTURE MECHANICAL DESIGN

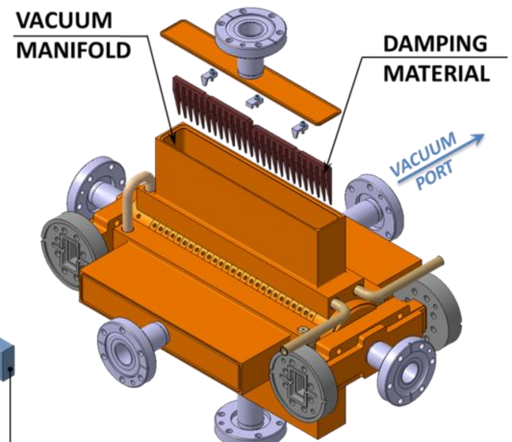
Baseline design of AS prototypes for CLIC

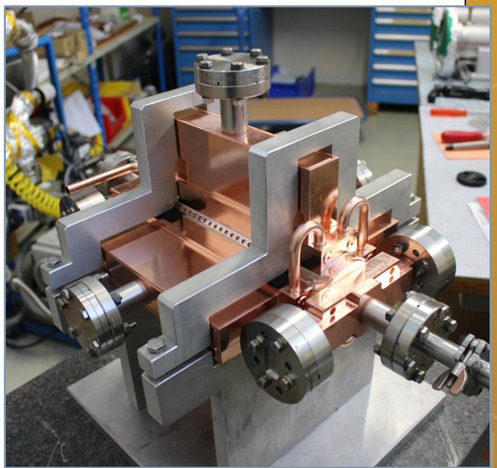
RF design

- TD26 CC (tapered damped AS with compact couplers)
- 26 cells with damping waveguides
- 2 compact couplers with damping



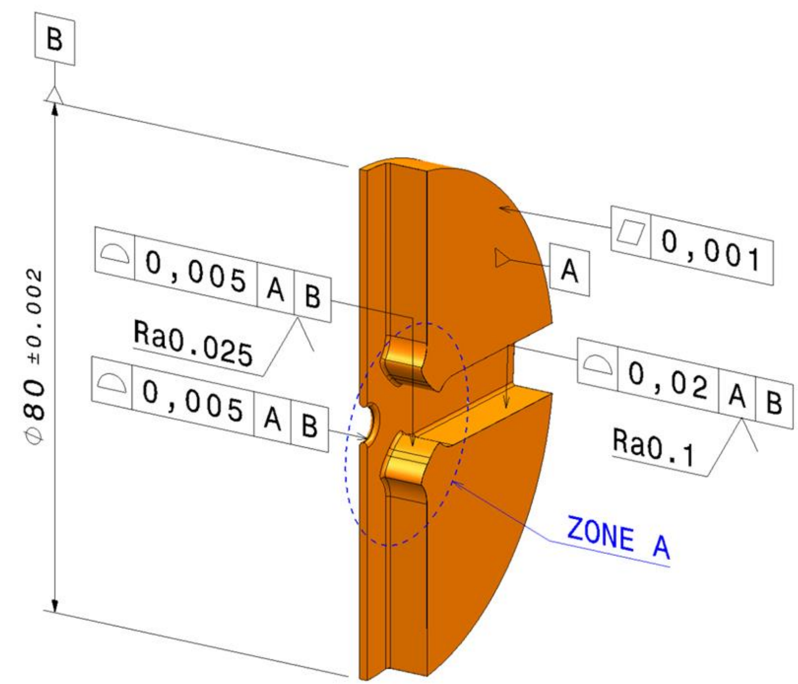
Assembly of AS with SiC absorbers

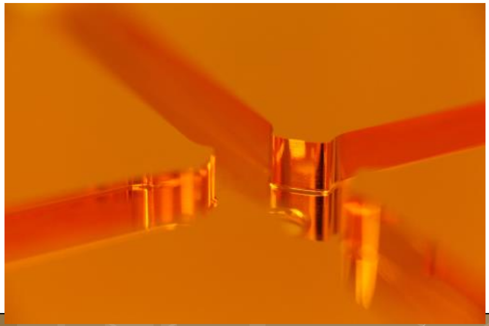


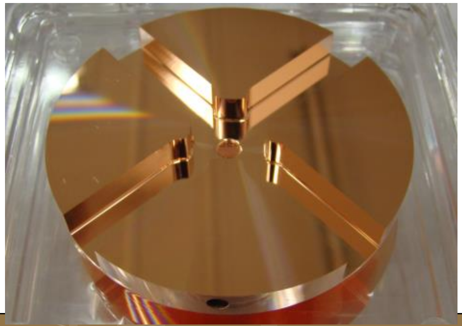


Engineering design of regular cell

- Cell iris shape accuracy (zone A) 0.005 mm
- Cell waveguide shape accuracy 0.02 mm
- Flatness accuracy 0.001 mm
- Cell iris roughness (zone A) Ra 0.025 µm
- Cell waveguide roughness Ra 0.1 µm

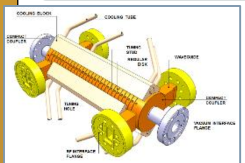
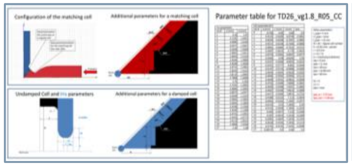
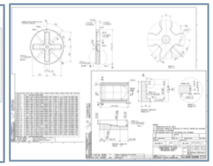
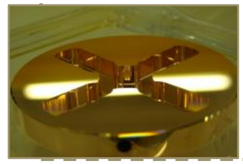




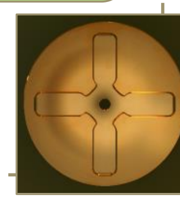


Baseline manufacturing flow

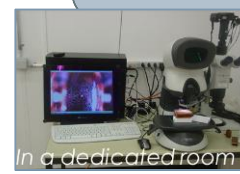
RF DESIGN → ENGINEERING DESIGN (3D models, 2D drawings) → ULTRA PRECISION MACHINING → QUALITY CONTROL AT FACTORY

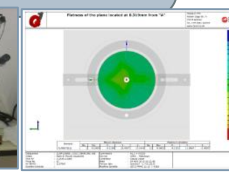





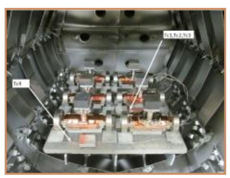
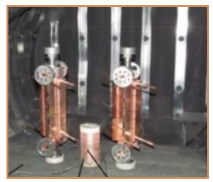
***4 qualified suppliers** can manufacture ultraprecision discs for AS*



QUALITY CONTROL AT CERN (visual, dimensional, SEM) → CLEANING *(optionally)* → ASSEMBLY OF COUPLERS (2 brazing steps, machining (optionally)) → PRELIMINARY RF CHECK





***3 qualified suppliers** can do brazing/bonding operations*

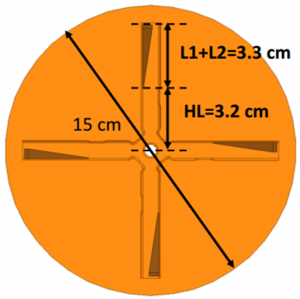
DIFFUSION BONDING OF DISC STACK → BRAZING OF COUPLERS, TUNING STUDS, COOLING CIRCUITS → LEAK TIGHTNESS TEST → FINAL DIMENSIONAL CONTROL

RF CHECK AND TUNING → BAKING (vacuum 650 °C, 3 days) → LEAK TIGHTNESS TEST → INSTALLATION / PACKAGING AND SHIPPING

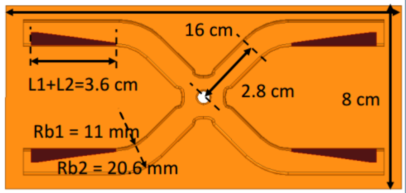

- CERN
- Companies for UP machining of components
- Companies for brazing/bonding

Alternative engineering solutions

CLIC-G* Matching Step



CLIC-G* Bend waveguide

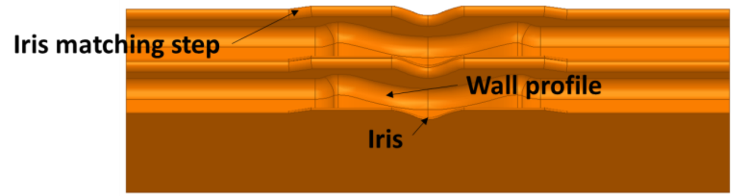


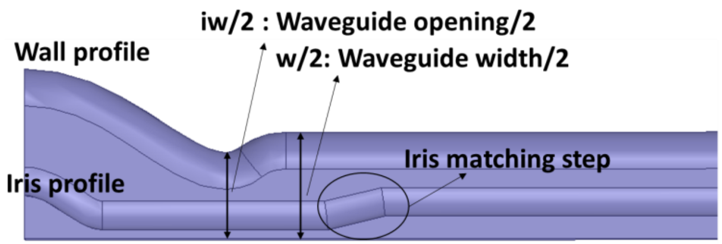
Hao Zha

HL	32 mm	D2	5 mm
L1	31 mm	T2	5 mm
L2	2 mm	Mx	0.75 mm
D1	0.8 mm	Mz	1 mm
T1	0.6 mm	Tx	0 mm
		Tz	0.7 mm

		D2	5.2 mm
L1	34 mm	T2	4.8 mm
L2	2 mm	Mx	0.2 mm
D1	1 mm	Mz	1 mm
T1	1 mm	Tx	0 mm
		Tz	0 mm

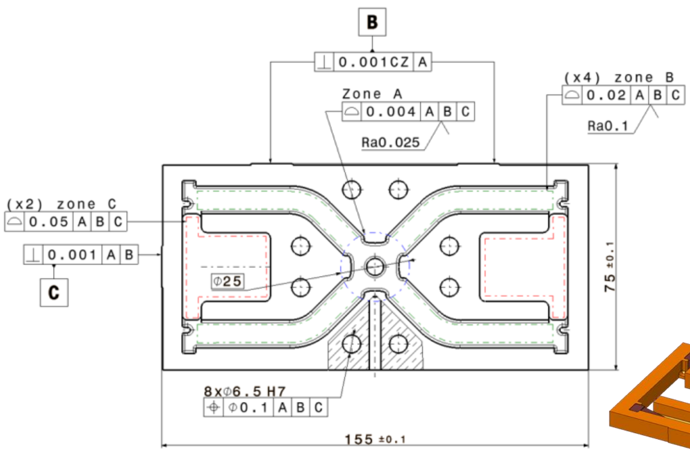
One half piece (Metal part view)

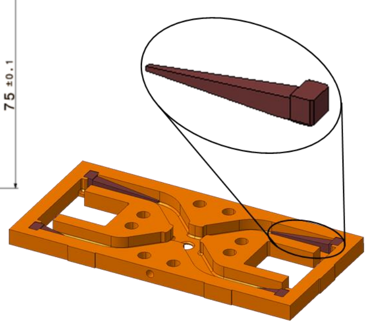




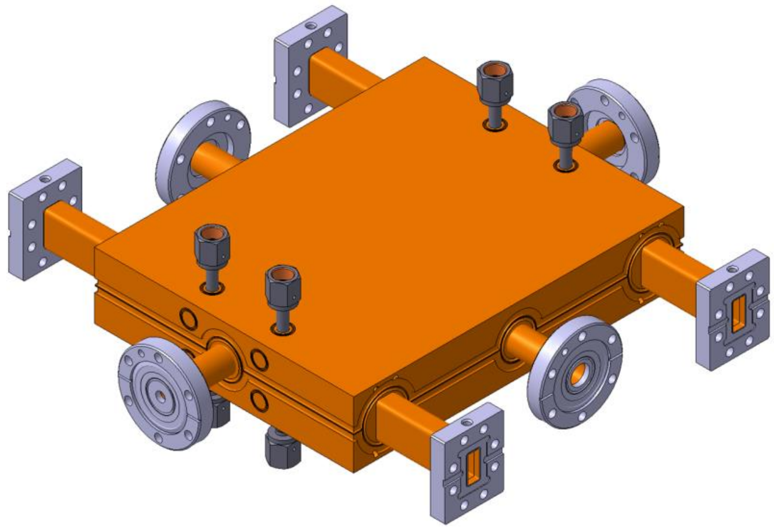
One quarter of cell (Vacuum part view)

"Rectangular" disc





Halves



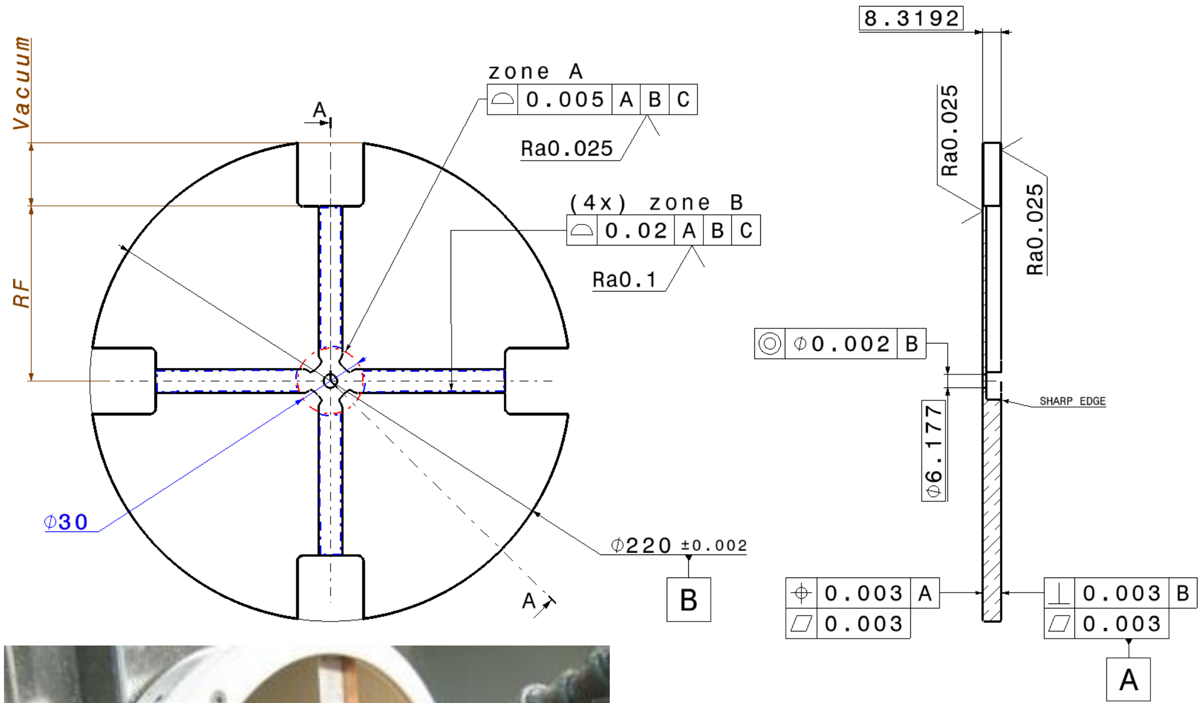
First prototype cells will be delivered to CERN end of June (from VDL)

EBW of a test set-up is under way

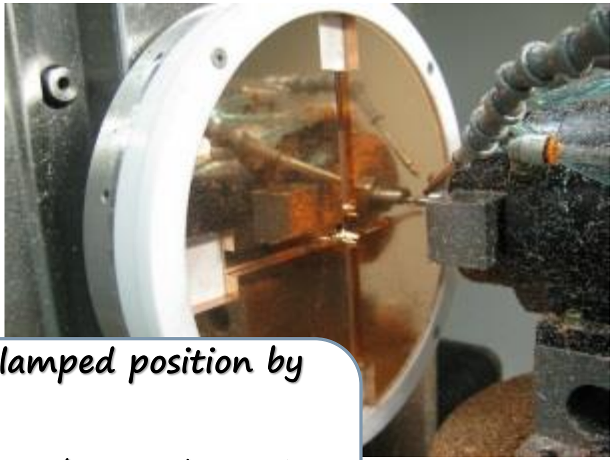
Integrated version disc

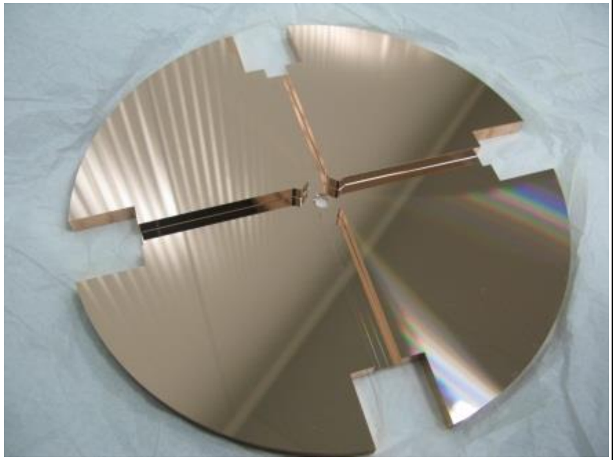
Aims:
- ➢ machining feasibility;
- ➢ bonding feasibility.

Advantages:
+ less components;
+ less assembly steps;
+ more accurate assembly;
+ cheaper.



Issues / open questions:
- ➢ Deformation during the machining;
- ➢ New tooling for machining, metrology (vacuum chuck) and bonding (combination of weight and compactness).



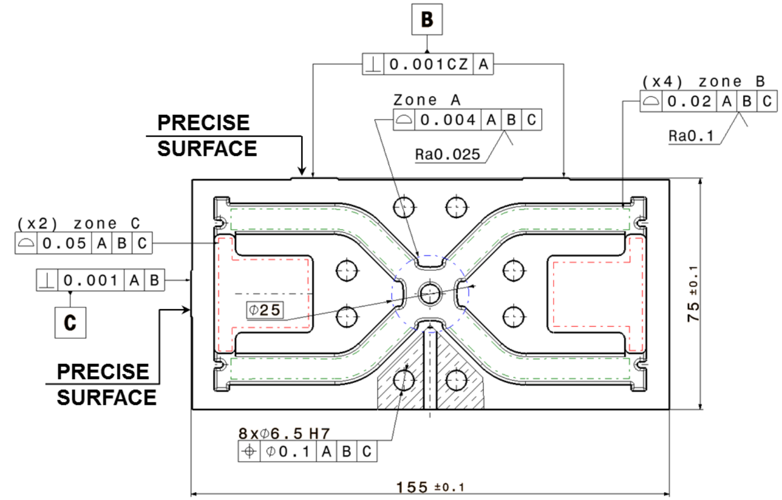


Achieved tolerances (measured in clamped position by a vacuum chuck)

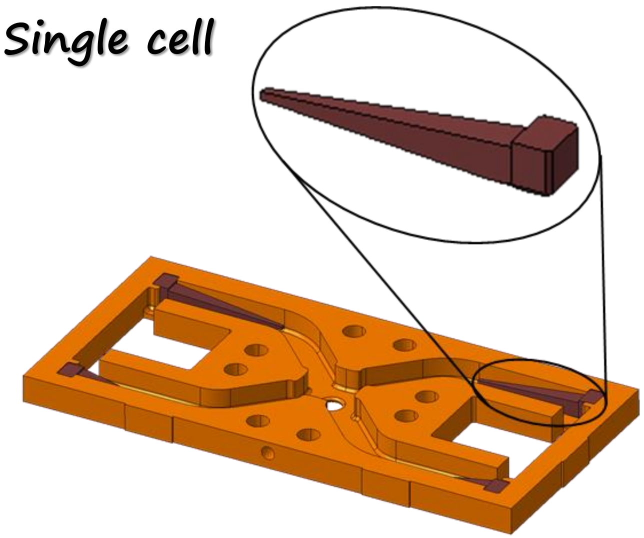
- *7 prototype cells produced (VDL and Mecachrome);*
- *Shape accuracy of 5 μm;*
- *Flatness of 2 to 5 μm;*
- *Ra 0.012 μm.*

CLIC G* bent waveguide. Test assembly

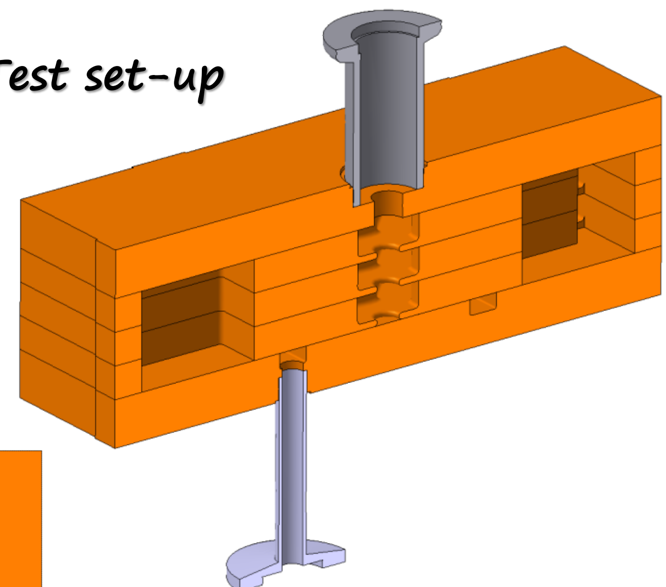
Aims:
- machining feasibility;
- bonding feasibility with integrated SiC absorbers;
- leak tightness test of the cavity;
- leak tightness test of cooling circuits;
- check a different alignment method.



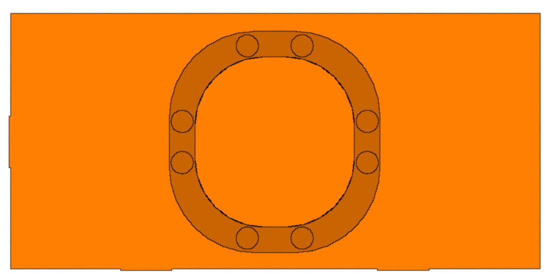
Single cell



Test set-up



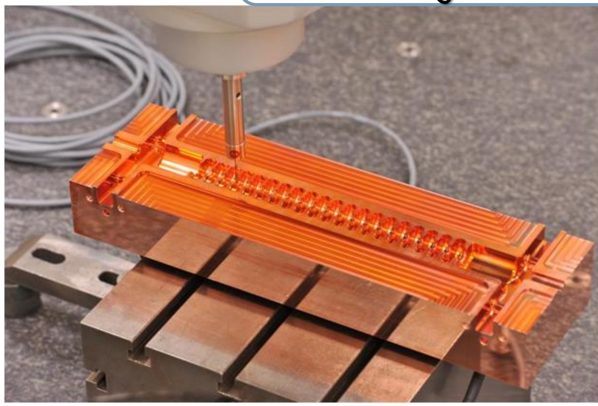
Cooling tightness



Structure in halves (previous test)

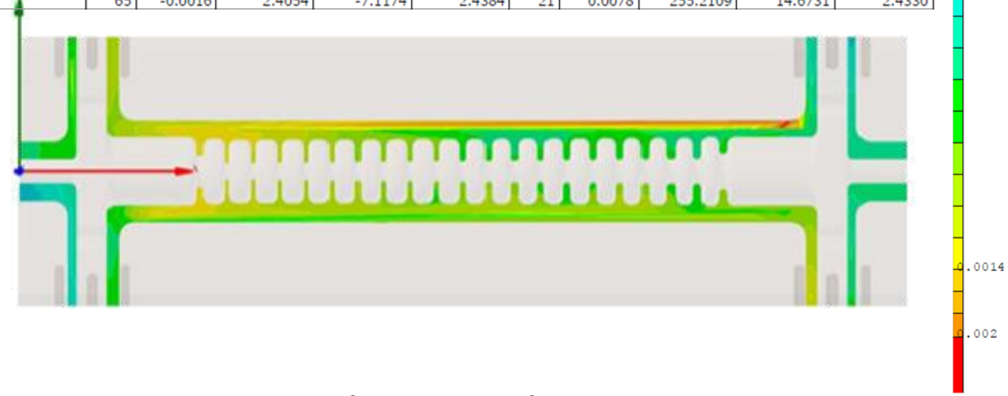
Machining

Produced at KERN
Shape accuracy :14 um;
Surface roughness: 186 nm

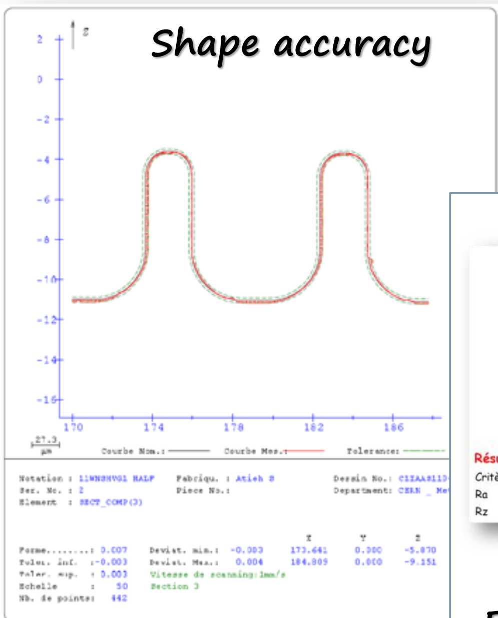


Planéité de la face de référence "A"

Element :	Minium deviation					Maximum deviation				
	No.	Dev.	- X -	- Y -	- Z -	No.	Dev.	- X -	- Y -	- Z -
PLAN(5)	65	-0.0016	2.4054	-7.1174	2.4384	21	0.0078	255.2109	14.6731	2.4330

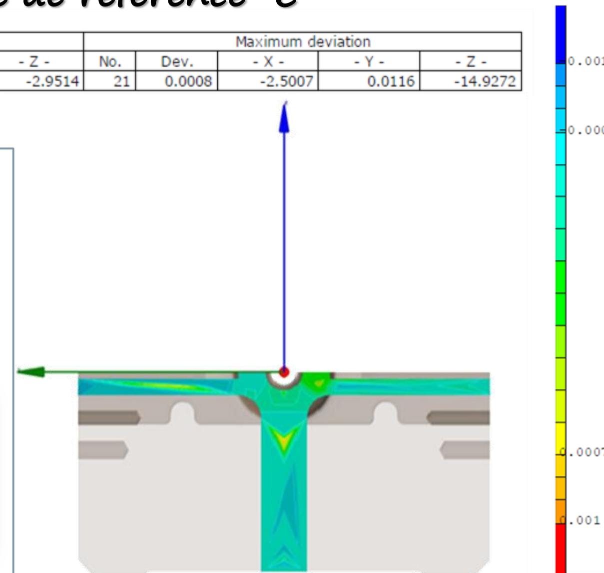


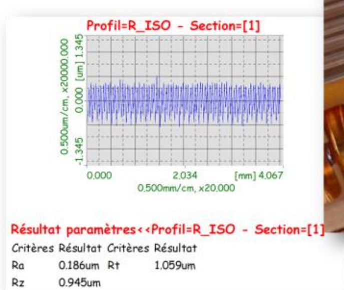
Shape accuracy



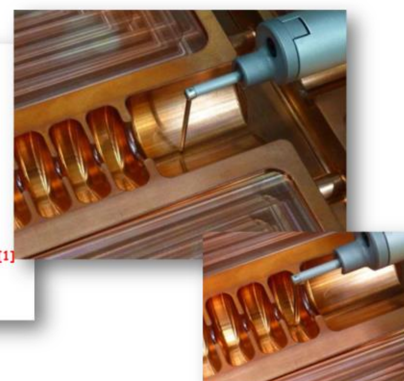
Planéité de la face de référence "C"

Element :	Minium deviation					Maximum deviation				
	No.	Dev.	- X -	- Y -	- Z -	No.	Dev.	- X -	- Y -	- Z -
Planeite_C	1	-0.0008	-2.4994	42.7278	-2.9514	21	0.0008	-2.5007	0.0116	-14.9272





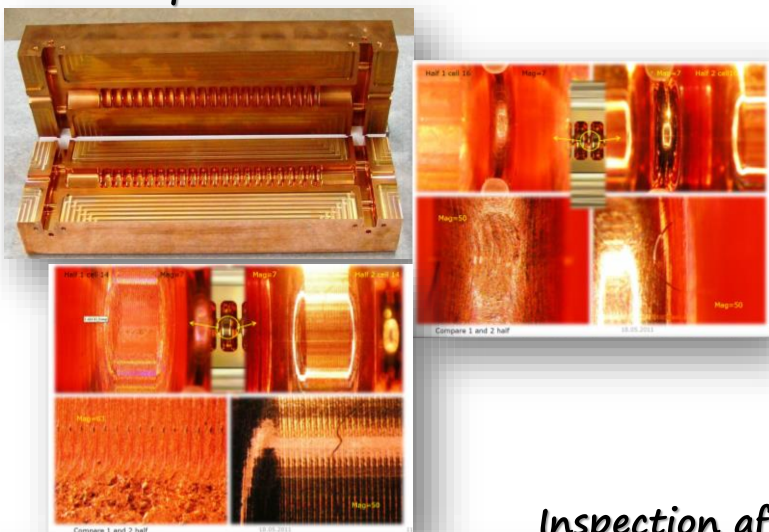
Roughness



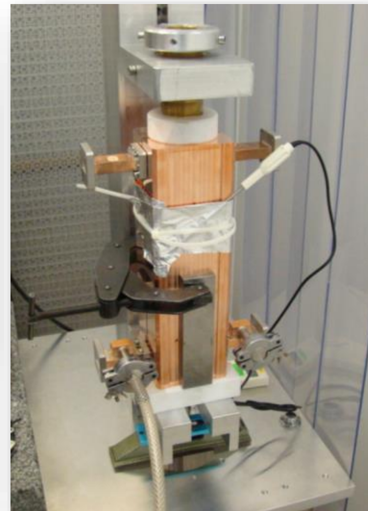
Said Atieh

Structure in halves (previous test)

Inlet inspection



RF measurements



(showed that the structure was good even without tuning)

RF Measurement Result of 11WNSHVG1(T18 11G Half) clamped

Jiaru Shi

14-Jun-2011

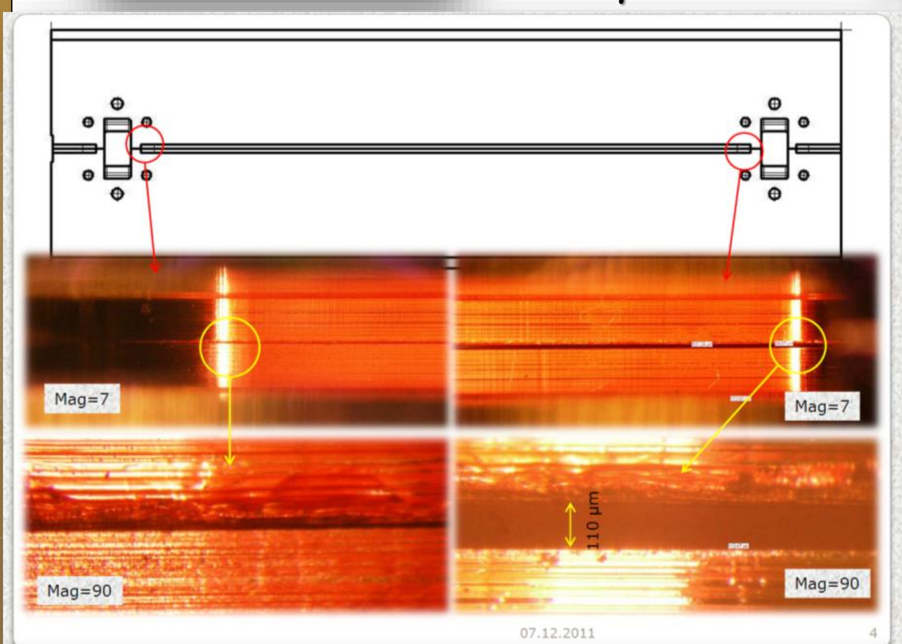
Abstract

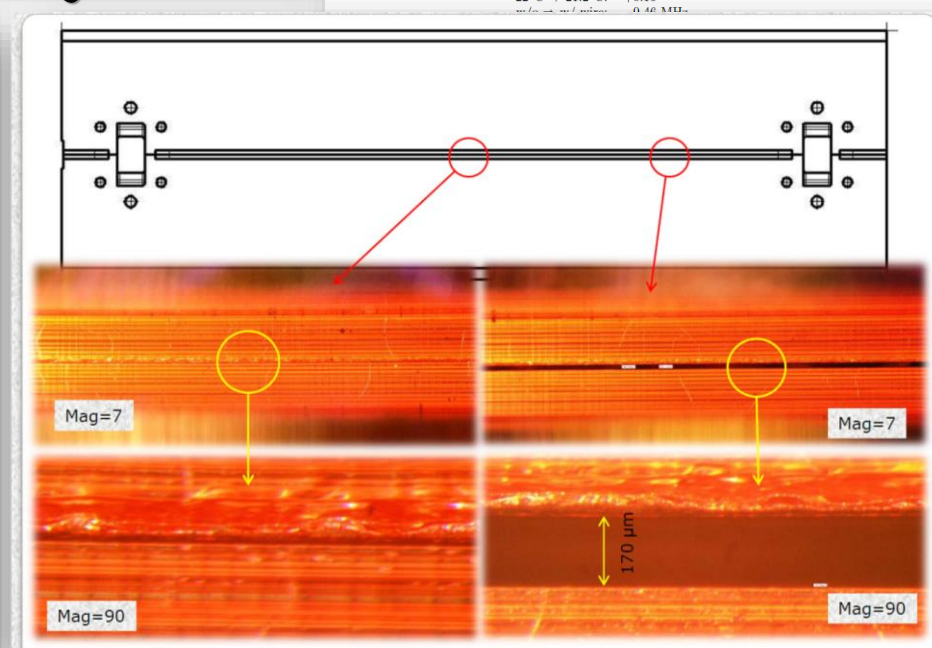
This report plots the RF measurement results of the structure 11WNSHVG1(T18 11G Half).

The structure is made in TWO HALVES and clamped together. "Bead-pull"s are done to check the frequency error of each individual cell, to compare the result after bonding.

Structure Name:	11WNSHVG1(T18 11G Half)
Measured by:	Jiaru SHI, Andrey OLYUNIN, Hao ZHA
date :	14-Jun-2011
location:	CERN
VNA Model:	RS ZVA24A
temperature:	21.2°C
Designed frequency at $2\pi/3$:	11.424 GHz
Δf due to vacuum $\Rightarrow N_2$:	−3.31 MHz
22°C $\Rightarrow$ 21.2°C:	+0.15

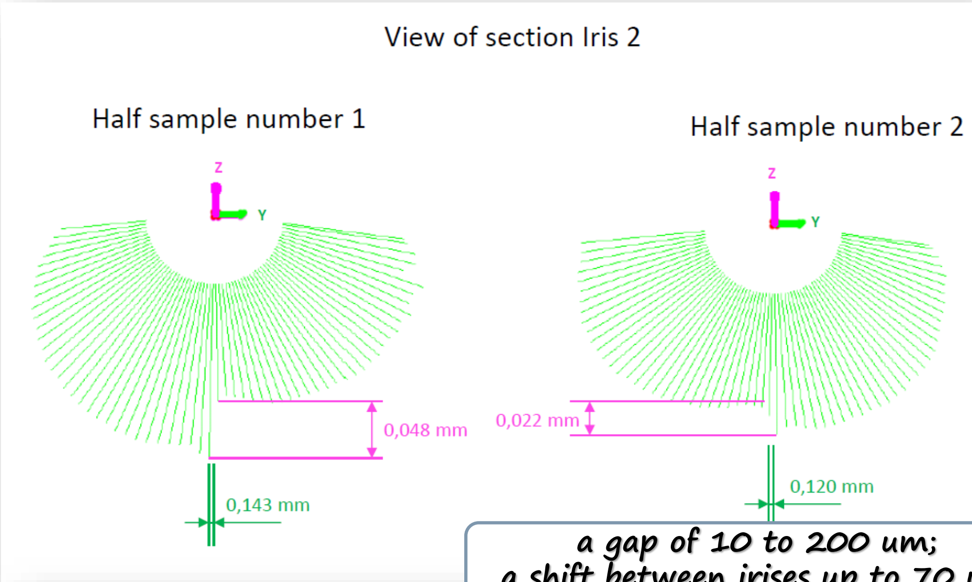
Inspection after bonding

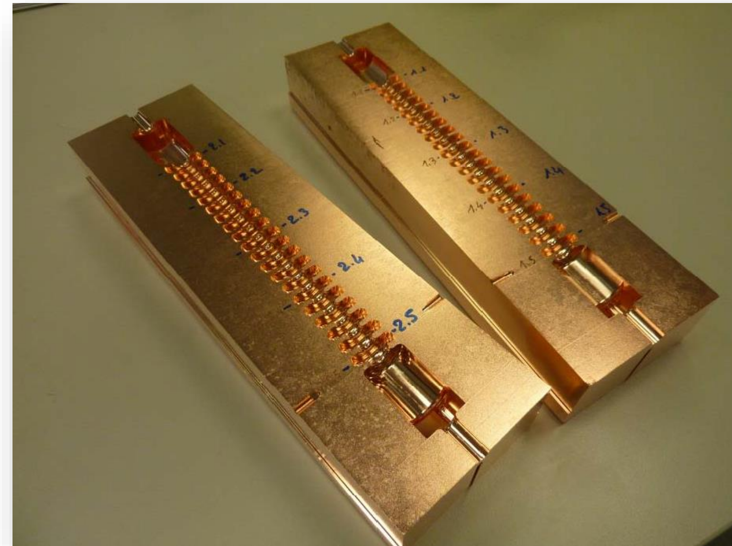




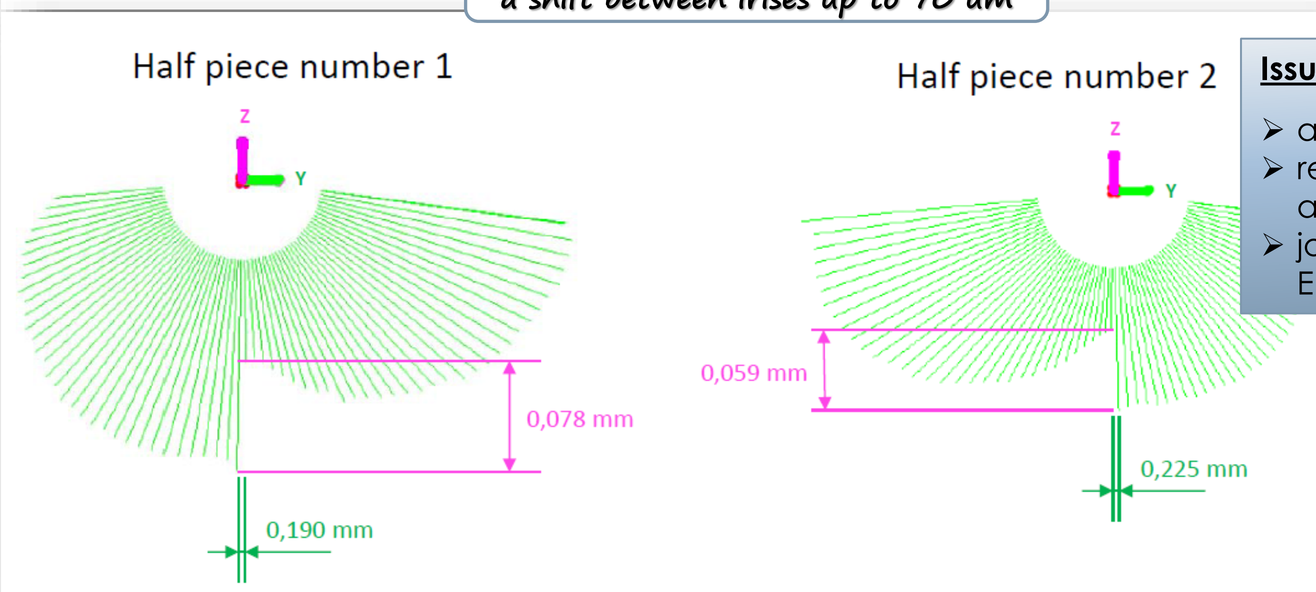
Structure in halves (previous test)

Metrology after bonding





a gap of 10 to 200 um;
a shift between irises up to 70 um



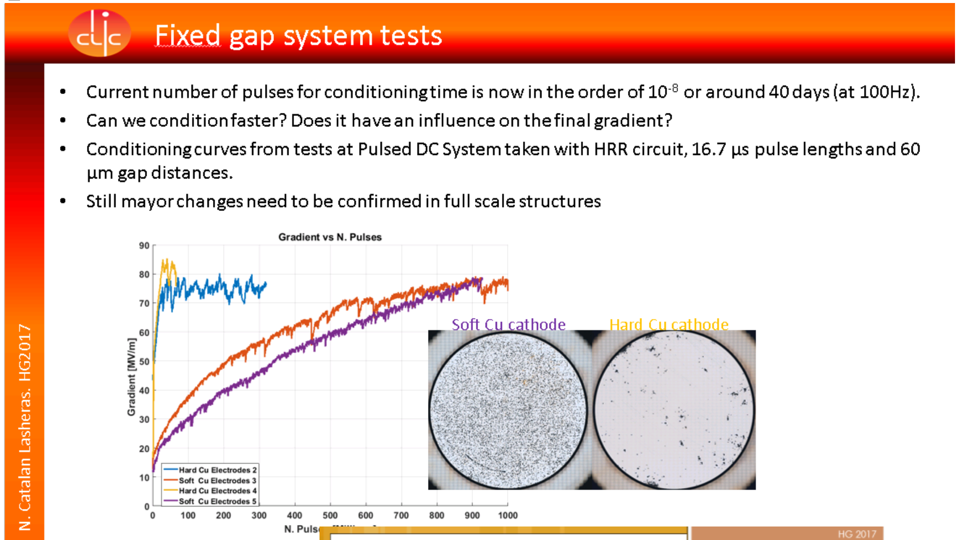
Issues / open questions:

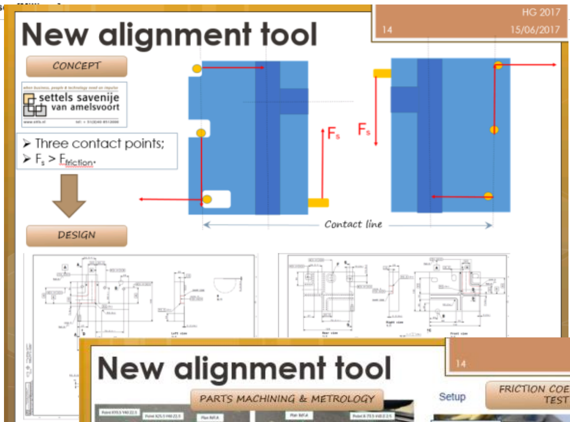
- alignment method;
- review of design (less material, another cross-section);
- joining method (brazing or/and EBW).

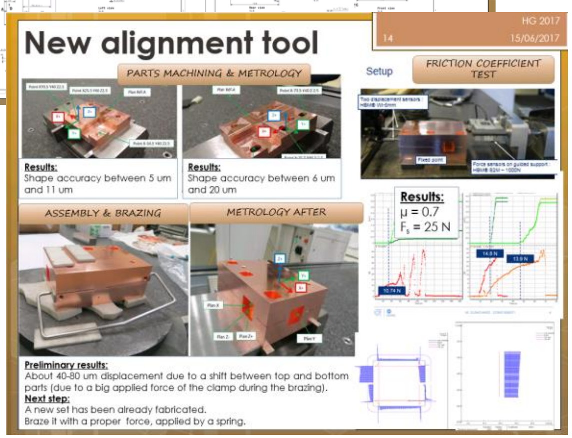
CLIC Half made Damped Structure (HDS)

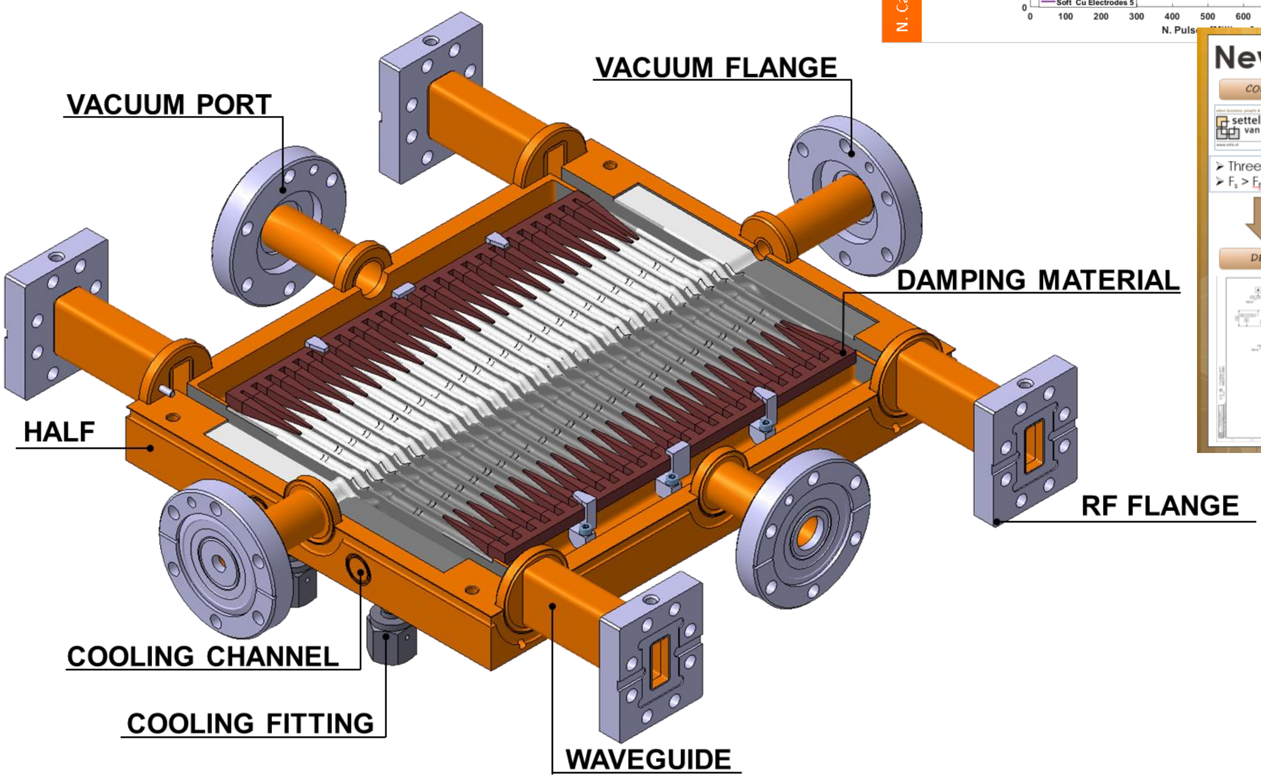
Advantages:
+ less components;
+ less assembly steps;
+ more accurate assembly;
+ avoid a "saddle" effect;
+ hard copper structure

Issues/open questions:
- longitudinal alignment



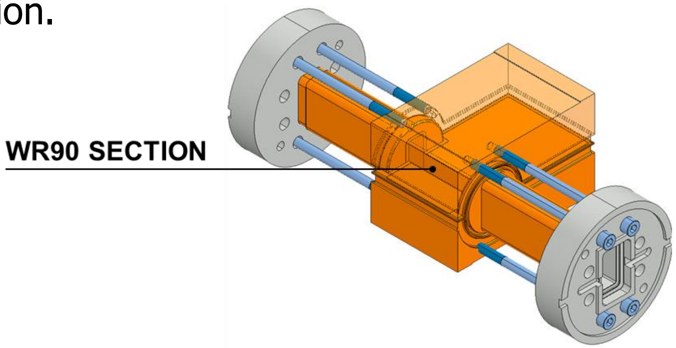


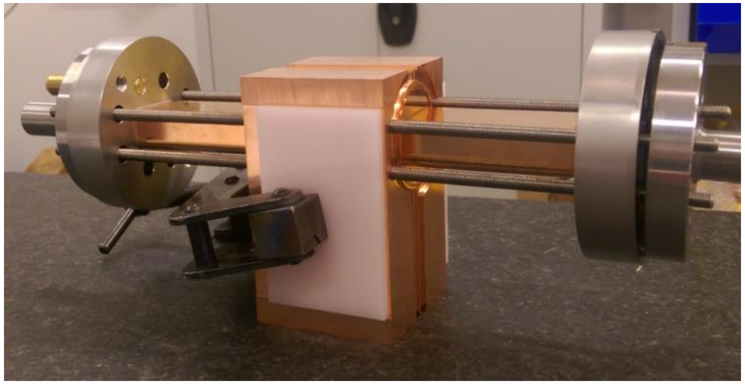




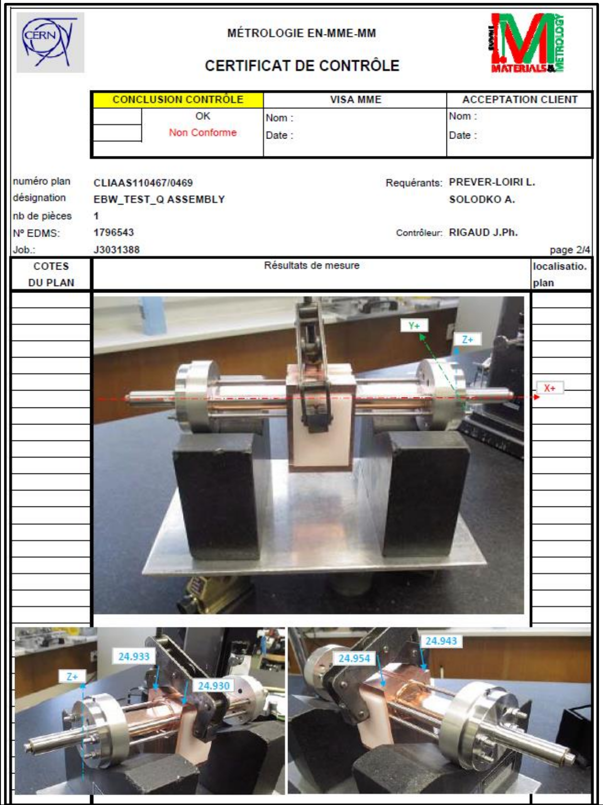
EBW test set-up

Test set-up for EBW is built to check the feasibility of new joining solution.





Metrology before spot welding	***Metrology after spot welding***	***Metrology after final welding***



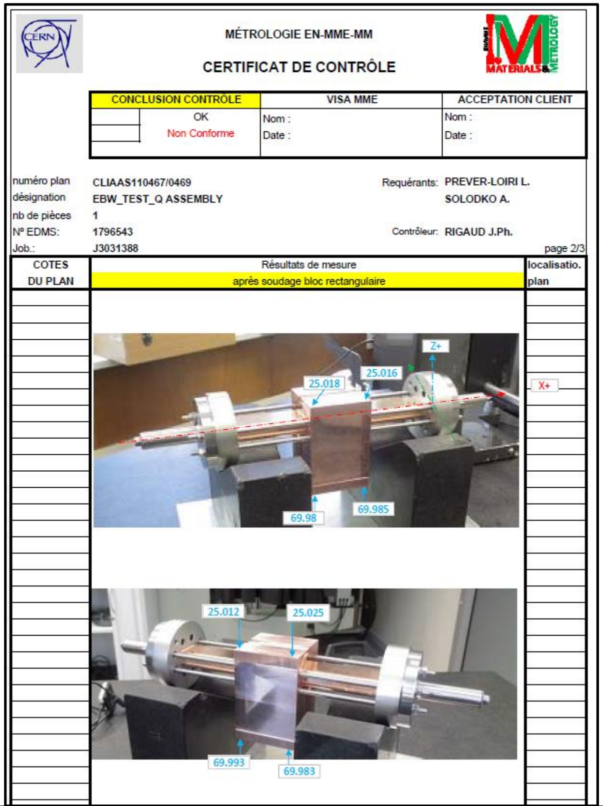
MÉTROLOGIE EN-MME-MM

CERTIFICAT DE CONTRÔLE

CONCLUSION CONTRÔLE	VISA MME	ACCEPTATION CLIENT
OK Non Conforme	Nom : Date :	Nom : Date :

numéro plan: CLIAAS110467/0469 — Requérants: PREVER-LOIRI L., SOLODKO A.
désignation: EBW_TEST_Q ASSEMBLY
nb de pièces: 1
N° EDMS: 1796543 — Contrôleur: RIGAUD J.Ph.
Job.: J3031388 — page 2/4

COTES DU PLAN	Résultats de mesure	localisatio. plan



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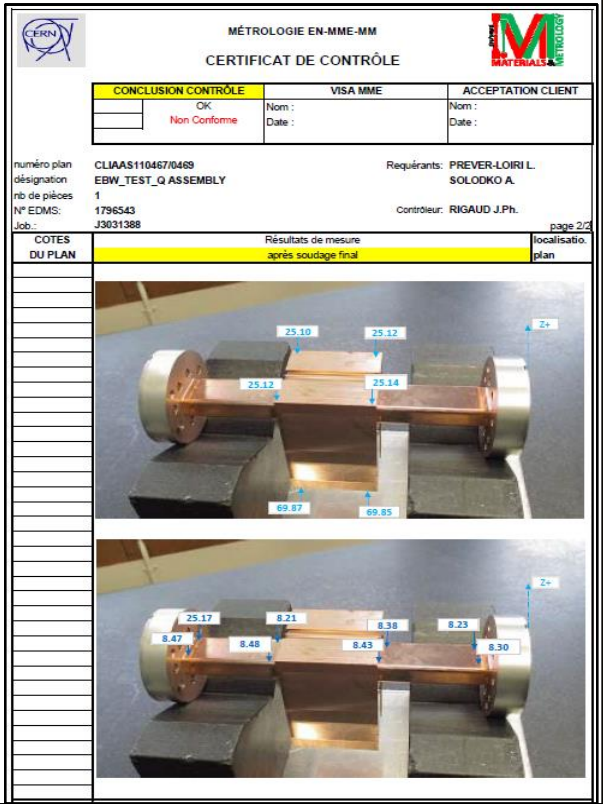
Job.: J3031388 — page 2/3

COTES DU PLAN	Résultats de mesure après soudage bloc rectangulaire	localisatio. plan



MÉTROLOGIE EN-MME-MM

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Job.: J3031388 — page 2/3

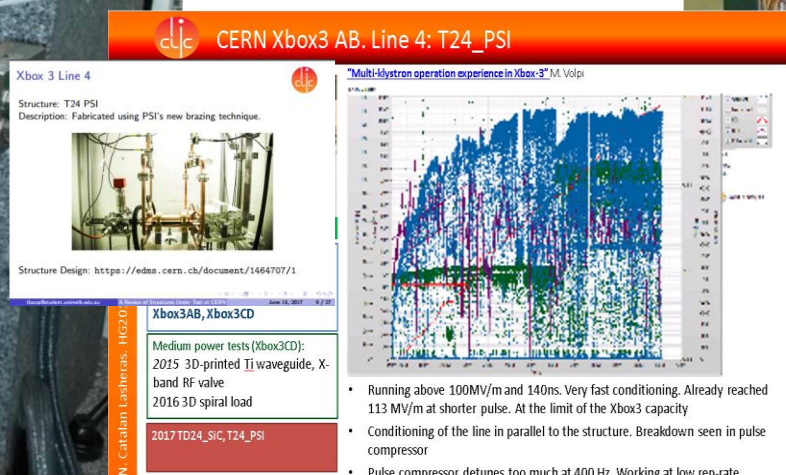
COTES DU PLAN	Résultats de mesure après soudage final	localisatio. plan

Vacuum brazing

- Two structure have been built at PSI;
- T24_PSI N1 is already under test in the Xbox-3;
- T24_PSI N2 is waiting for the bead-pull.

Brazed T24 structure
SwissFEL assembly procedure

Bonded T24 structure
CERN assembly procedure



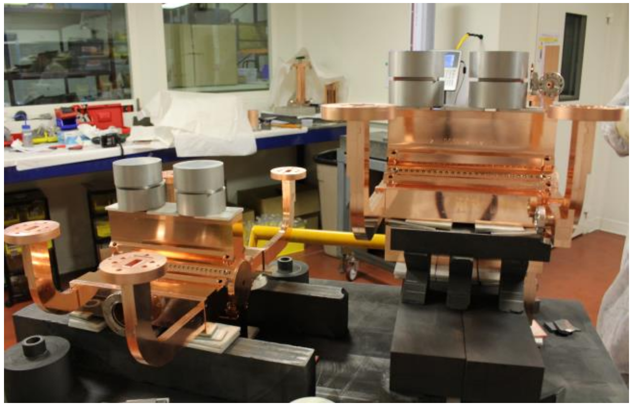
Advantages:
+ no tuning;
+ integrated cooling;
+ SwissFEL assembly procedure.

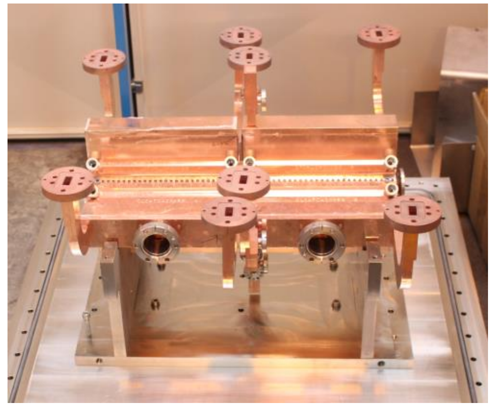
FEEDBACK TO THE MODULE

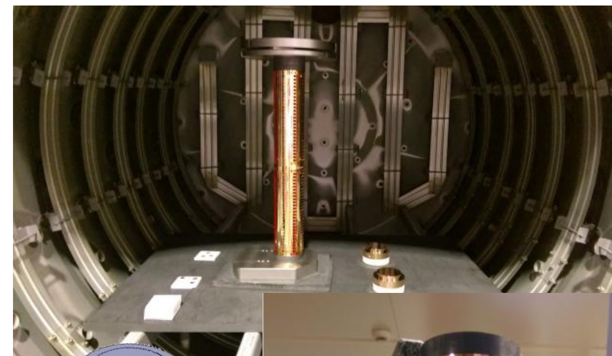
Feedback to the module

For the first superstructure two structures were assembled and at the final assembly step they were brazed together.

- *messy and complex;*
- *alignment between AS;*
- *one additional heating cycle;*
- *expensive.*

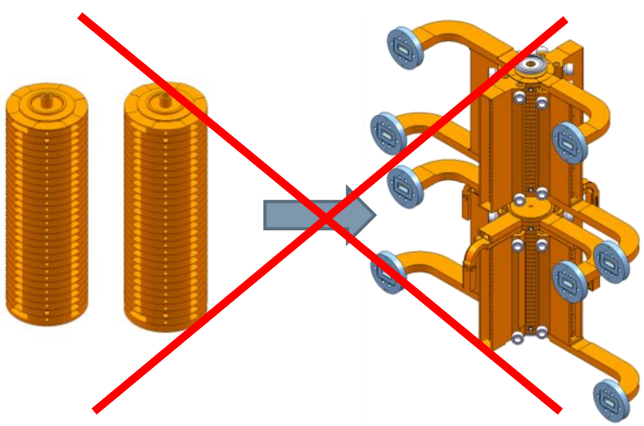






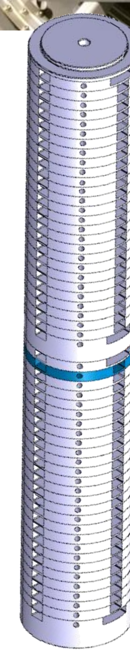
NEW DEVELOPMENT

To do diffusion bonding of the discs for two accelerating structures in one step (length is ~500 mm).



Diffusion bonding of all discs

+ less components;
+ less assembly steps;
+ more accurate assembly.

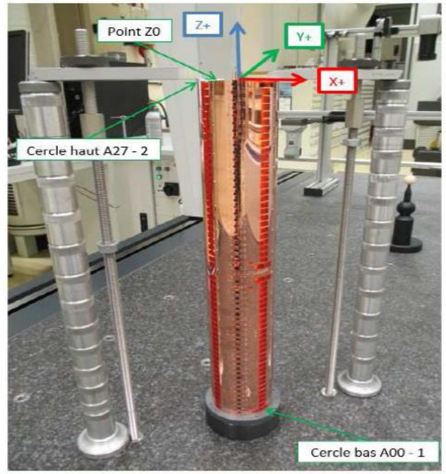


Bonding of 500 mm disc stack

BEFORE BONDING

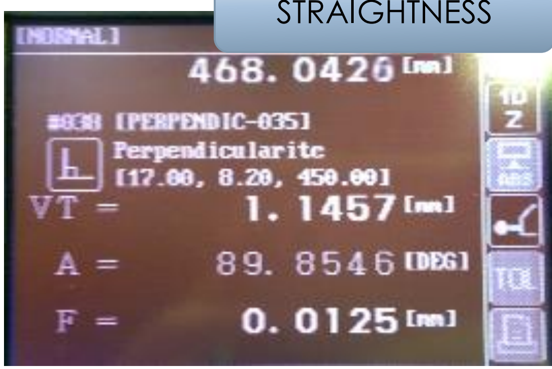
INCLINATION OF OVEN FLOOR
(see next slide)

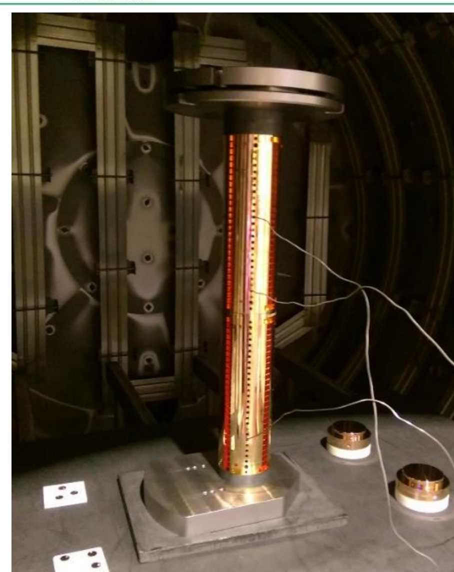
Informations relatives au référentiel de mesure



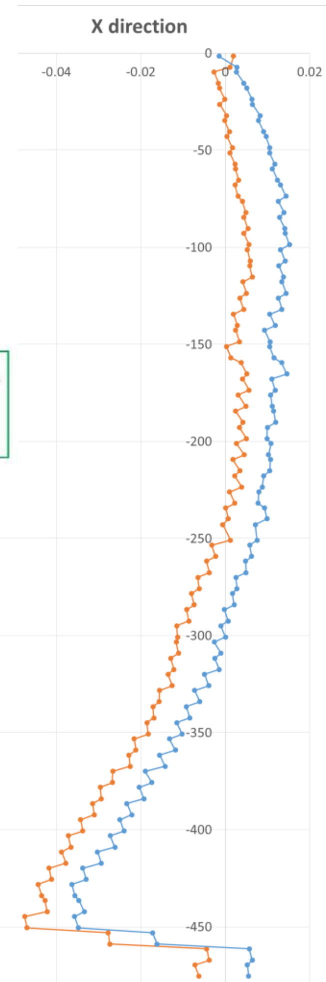
Construction du référentiel de base:
- Orientation primaire: Droite passant par le Cercle bas A00 - 1 et le Cercle haut A27 - 2
- Orientation secondaire: /
- Origine: X = Droite passant par le Cercle bas A00 - 1 et le Cercle haut A27 - 2
  Y = Droite passant par le Cercle bas A00 - 1 et le Cercle haut A27 - 2
  Z = Point Z0

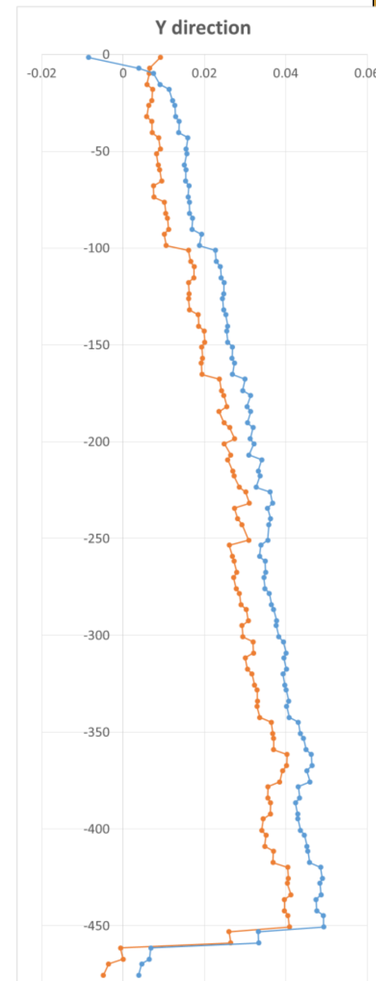
STRAIGHTNESS





AFTER BONDING

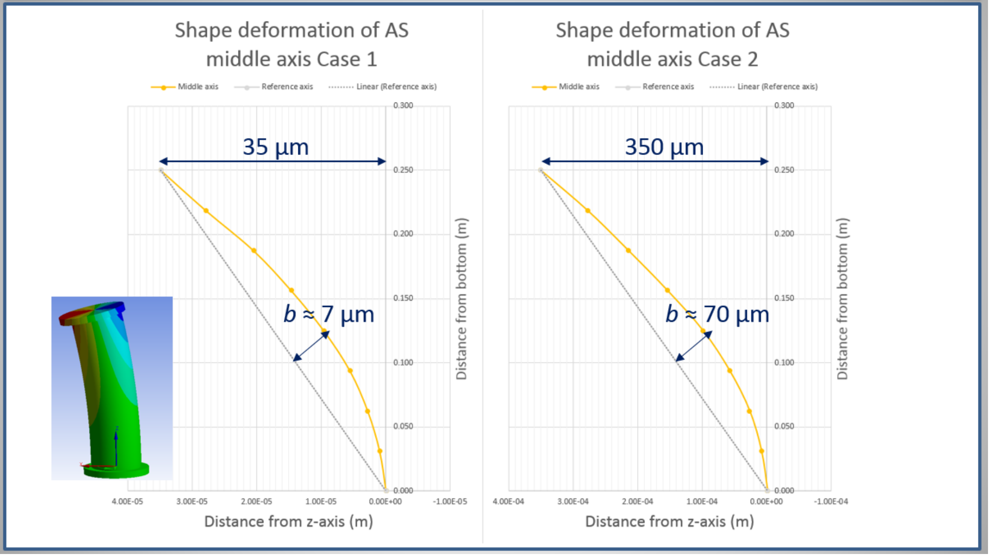




Next step review on engineering design

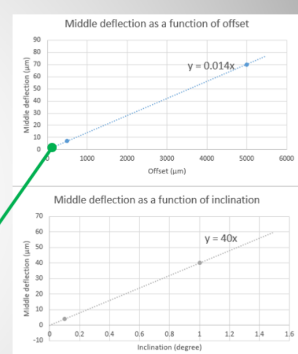
Banana-issue of a disc stack

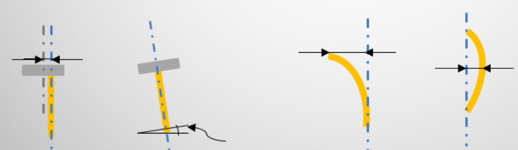
AS: results (Case 1 and Case 2)



AS: results summary

Case #	Offset of the load (µm)	Inclination angle (°)	Cooling	Bending of the upper end (µm)	Deflection in the middle (µm)
1	500	0	Fast	35	7
2	5000	0	Fast	350	70
3	500	0	Slow	33	7
4	0	0.1	Fast	23	4
5	0	1	Fast	230	40
ESTIMATE	100	0		7	1
6	100	0.1	Fast	30	5





Effects of load offset and incline surface on AS in diffusion bonding was simulated with FEM.

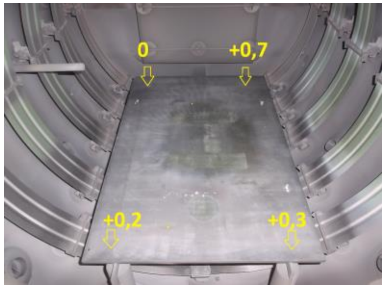
In total 6 cases with different offset or inclination angle setup were analyzed.

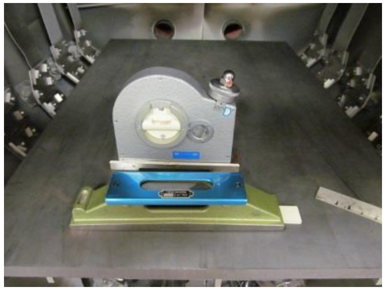
Based on this study, offset in load positioning is **transferred linearly** to bending (~7%) and deflection (~1–2%) of the AS. Similar conclusion applies for incline surface.

The effect of these two mechanisms **sums up linearly**.

Both mechanisms should be taken into account but load **offset seems be more critical**.

Furnace inclination measurement



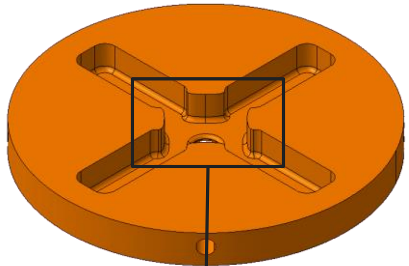


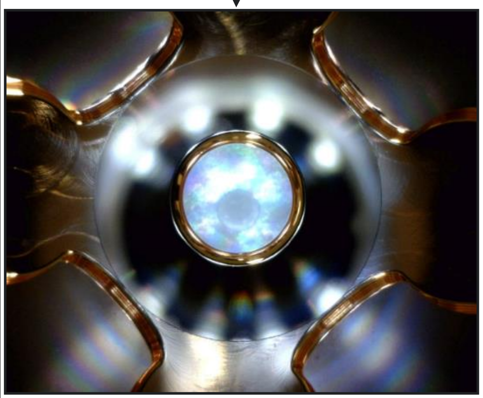
Antti Moilanen

INDUSTRIALIZATION

Industrialization

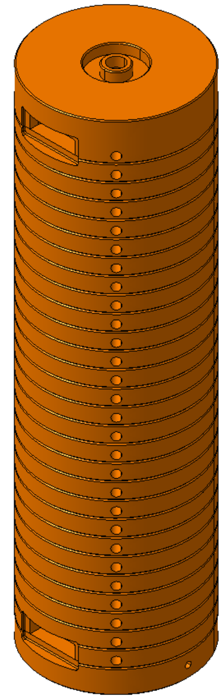
AS DISC





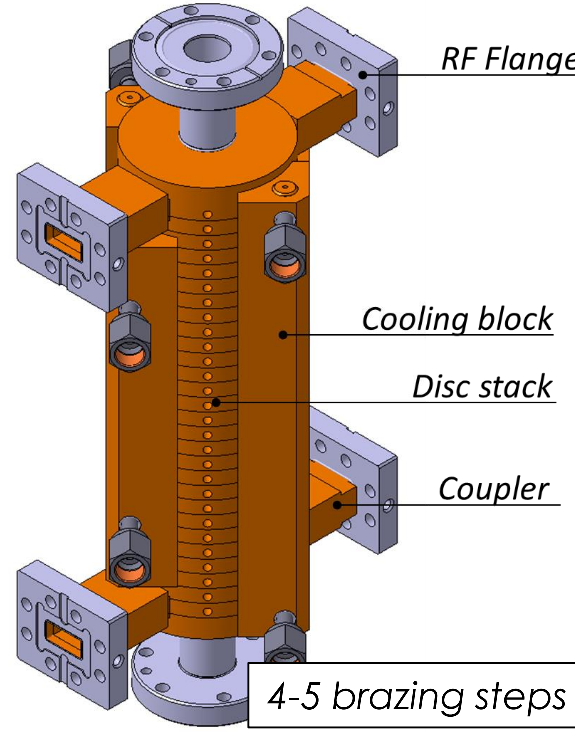
AS DISC STACK BONDING

Acceptance at CERN



AS ASSEMBLY

Acceptance at CERN



4-5 brazing steps

Cell shape accuracy - 0.004 mm
Flatness - 0.001 mm
Surface roughness - Ra 0.025 µm

Commercial suppliers:

- 4 qualified companies for UP machining (DMP (ES), LT Ultra (DE), VDL (NL), Yvon Boyer (FR));
- Single-crystal diamond tool required.

REQUIREMENTS:

- Alignment
- Special tooling
- Clean environment

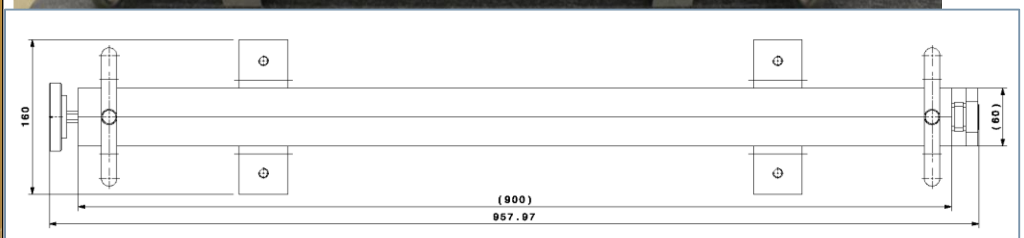
Suppliers:

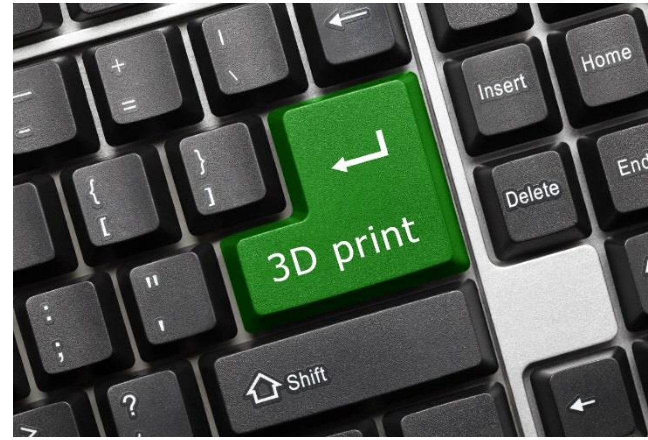
- 3 qualified companies for brazing/bonding operations, supervision by CERN (**Bodycote (FR)**, TMD (UK), Reuter (DE): two T24 under assembly);
- Collaborators.

NEW TECHNOLOGIES

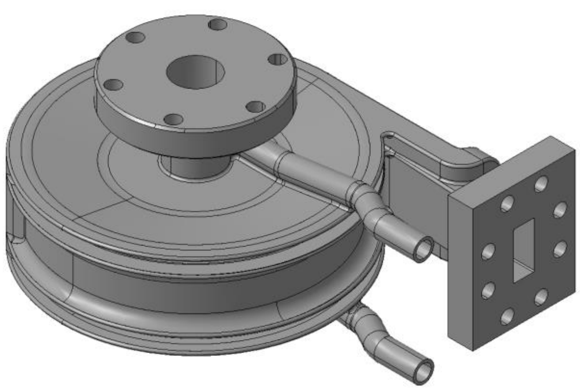
X-band load

CURRENT CONFIGURATION

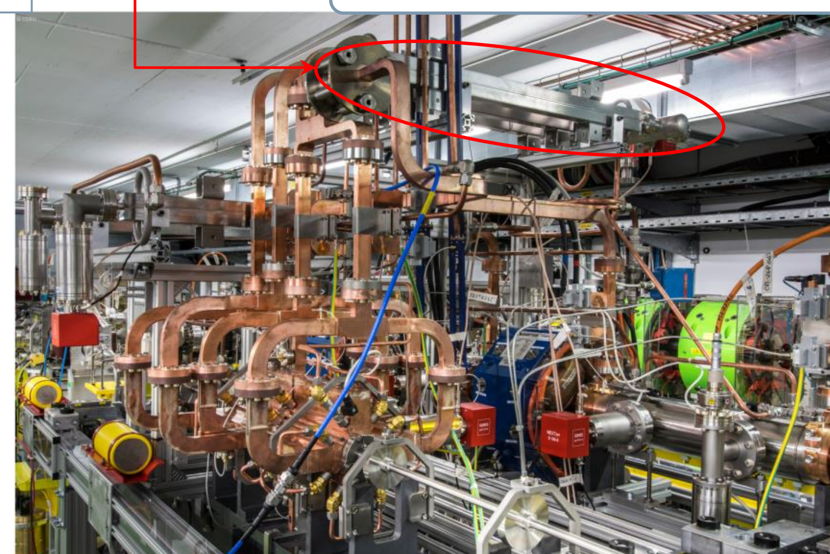




STUDY on ADDITIVE MANUFACTURING



Two Beam Module in CLEX

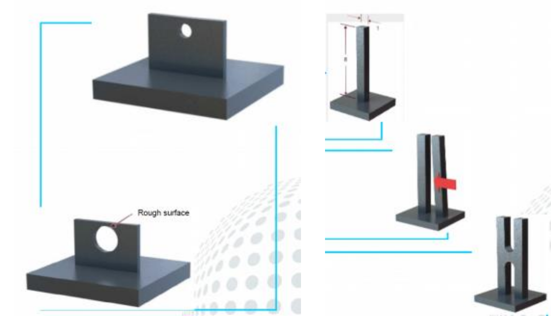


Additive manufacturing (AM)

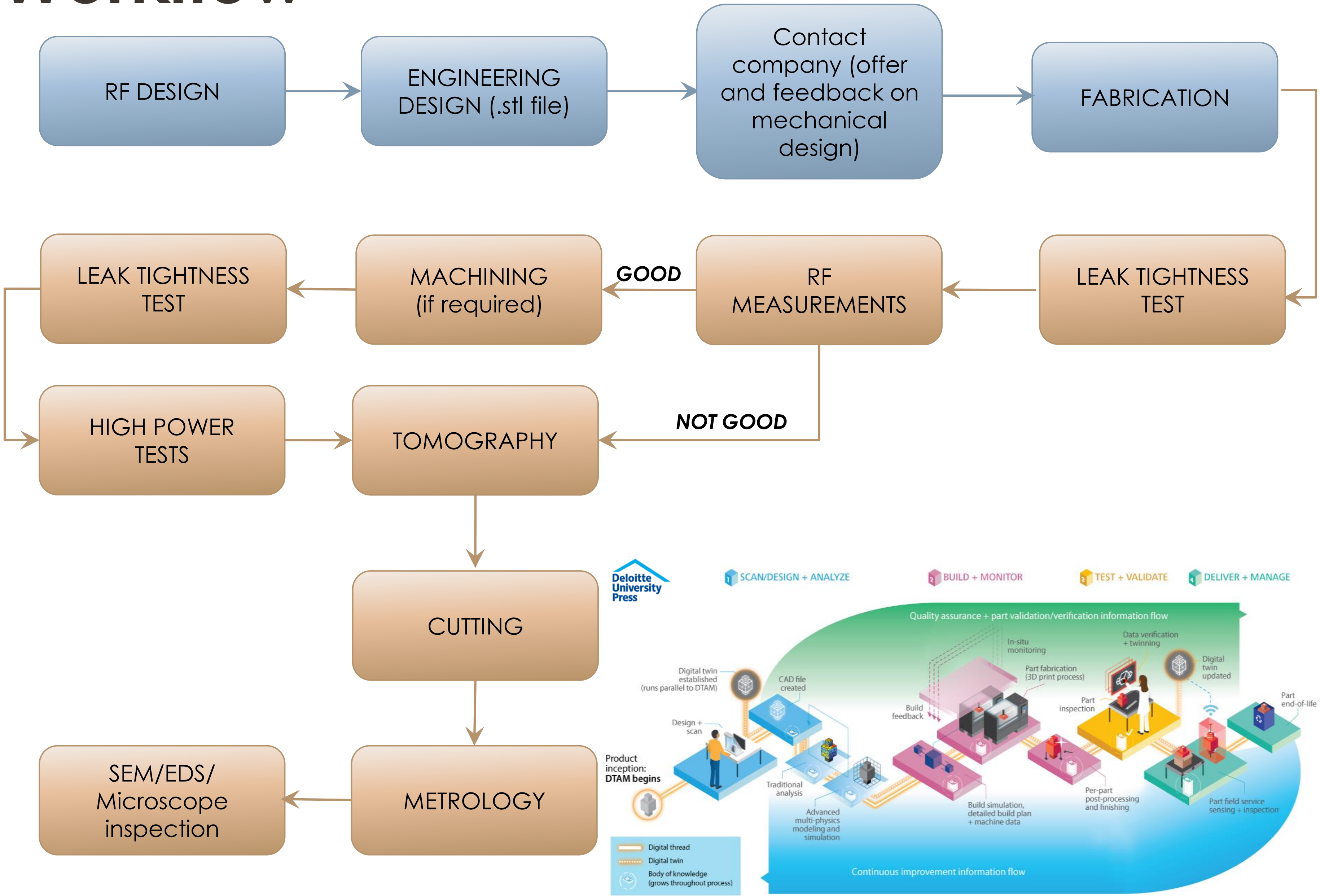
- Different companies
- Different applications:
  - Waveguides;
  - Electrodes;
  - Compact loads
    - Spiral load
    - Compact load
- Different materials:
  - Ti6Al4V
  - SS 316 LN
  - AlSi10Mg
- Requirements:
  - DC conductivity;
  - UHV compatibility: leak tightness and outgassing;
  - Shape accuracy and roughness;
  - gth.

- Advantages:
  - Highly complex geometry;
  - No soldering/brazing operations;
  - Less material;
  - Short time → fast prototyping;
  - Without any tooling;
  - Good mechanical properties.
- Difficulties and restrictions:
  - Not standard mechanical design solutions;
  - Supporting structure;
  - Design limitations (ø holes, wall thickness, angle etc.);
  - Not controlled distortion;
  - Surface quality: min Ra 1.6;
  - Accuracy: no better than ±0.1 mm;
  - Expensive.

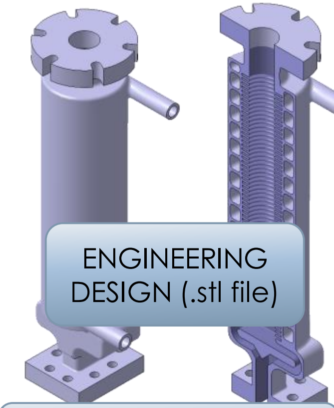




Workflow

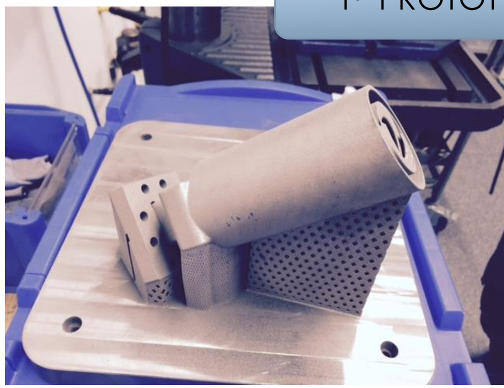

RF DESIGN
ENGINEERING DESIGN (.stl file)
Contact company (offer and feedback on mechanical design)
FABRICATION
LEAK TIGHTNESS TEST
RF MEASUREMENTS
GOOD
MACHINING (if required)
LEAK TIGHTNESS TEST
HIGH POWER TESTS
TOMOGRAPHY
NOT GOOD
CUTTING
METROLOGY
SEM/EDS/ Microscope inspection
Deloitte University Press
SCAN/DESIGN + ANALYZE
BUILD + MONITOR
TEST + VALIDATE
DELIVER + MANAGE
Quality assurance + part validation/verification information flow
Digital twin established (runs parallel to DTAM)
CAD file created
In-situ monitoring
Part fabrication (3D print process)
Data verification + twinning
Digital twin updated
Part end-of-life
Build feedback
Part inspection
Design + scan
Product inception: DTAM begins
Traditional analysis
Advanced multi-physics modeling and simulation
Build simulation, detailed build plan + machine data
Per-part post-processing and finishing
Part field service sensing + inspection
Digital thread
Digital twin
Body of knowledge (grows throughout process)
Continuous improvement information flow

Compact load

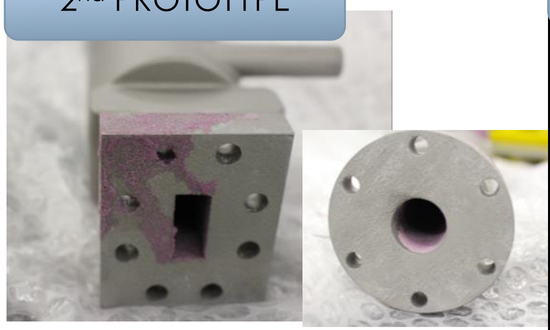


ENGINEERING DESIGN (.stl file)

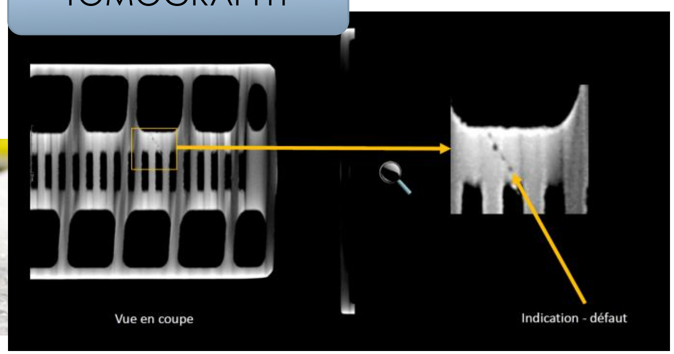
1st PROTOTYPE



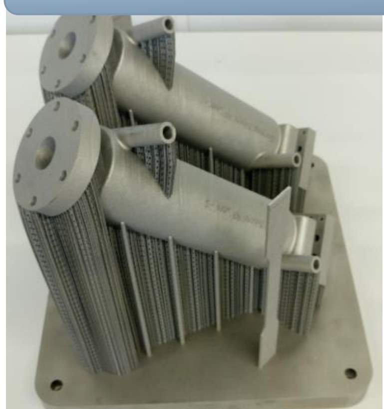
2nd PROTOTYPE



TOMOGRAPHY



3rd and 4th PROTOTYPE



<u>1st PROTOTYPE</u>

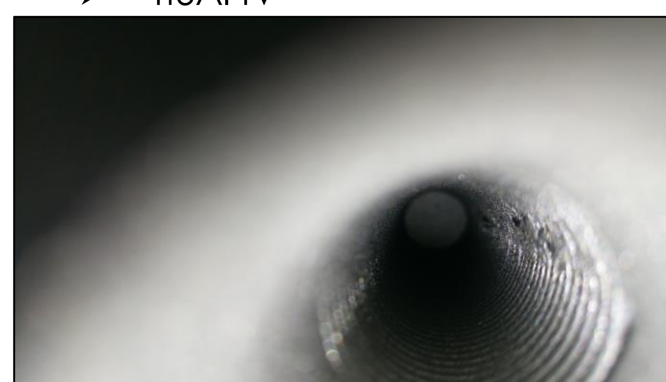
- Concept Laser
- Ti6Al4V
- TESTS (Ti6Al4V)
  - RF measurements
  - Metrology
  - Cutting by EDM
  - Metrology

<u>2nd PROTOTYPE</u>

- 3T RPD - British company
- Ti6Al4V
- TESTS
  - Leak test – not tight
  - RF measurements
  - Tomography

<u>3rd and 4th PROTOTYPES</u>

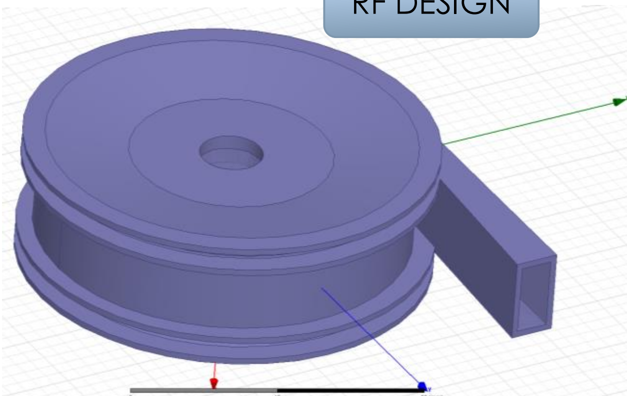
- CERN
- Ti6Al4V



Spiral RF load

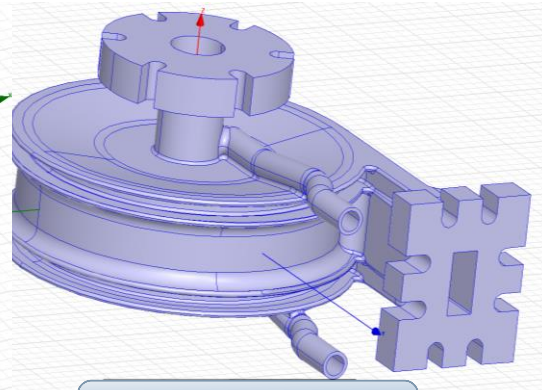
- HFSS

RF DESIGN



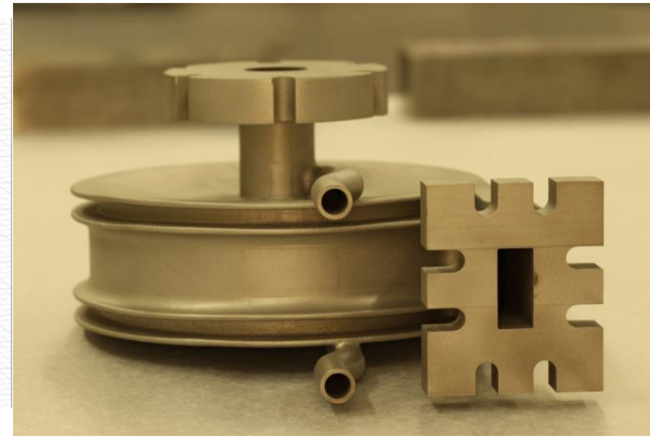
- CATIA

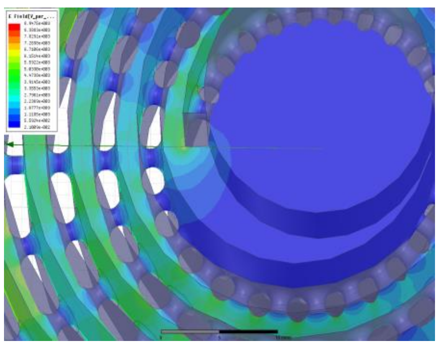
ENGINEERING DESIGN (.stl file)



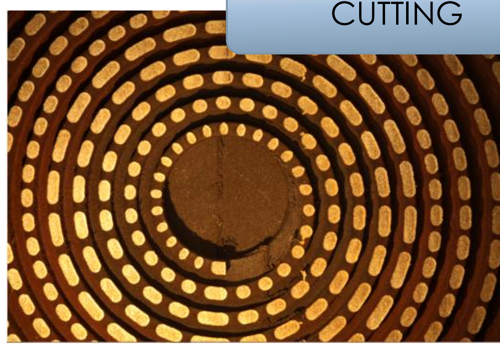
- BUILT StSt

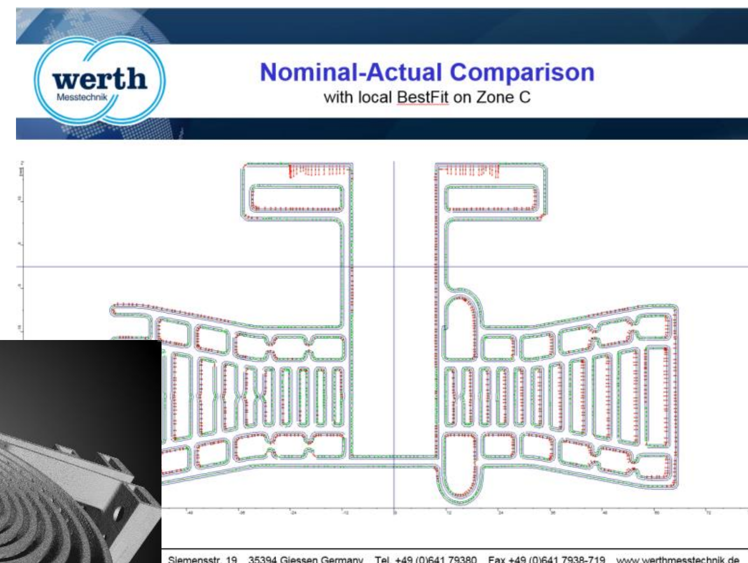
FABRICATION





CUTTING





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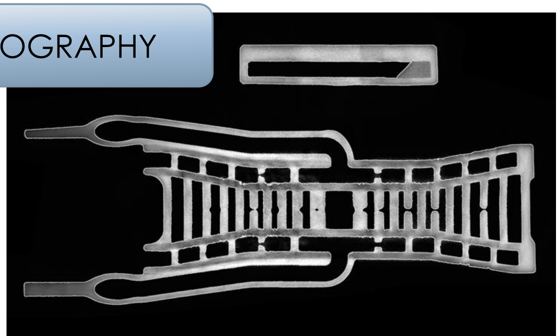


Spiral RF load

1st PROTOTYPE

- INITIAL – French company
- SS 316 L
- TESTS
  - RF measurements
  - Cutting by EDM
  - RF measurements after cutting

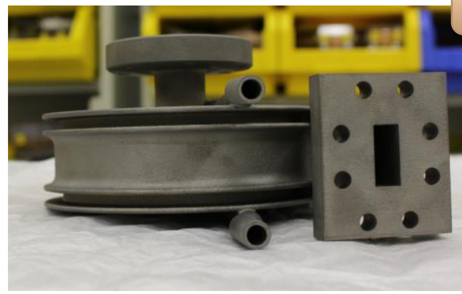
2nd PROTOTYPE

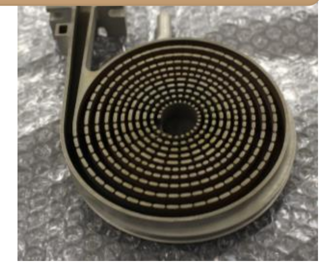
- 3T RPD - British company
- Ti6Al4V (under test in Xbox 3)
- TESTS
  - Leak test
  - RF measurements
  - Machining of flange interfaces
  - Leak test
  - RF measurement
  - Installation in Xbox 3

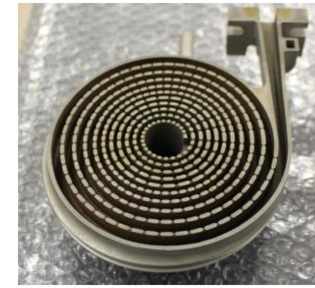
3rd PROTOTYPE

- CERN
- Ti6Al4V (under test in Xbox 3)
  - Leak test
  - RF measurements
  - Machining of flange interfaces
  - Leak test
  - RF measurement
  - Installation in Xbox 3

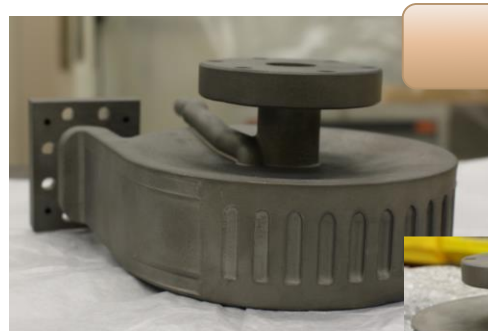
1st PROTOTYPE

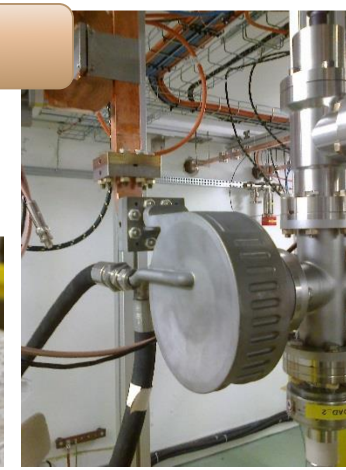




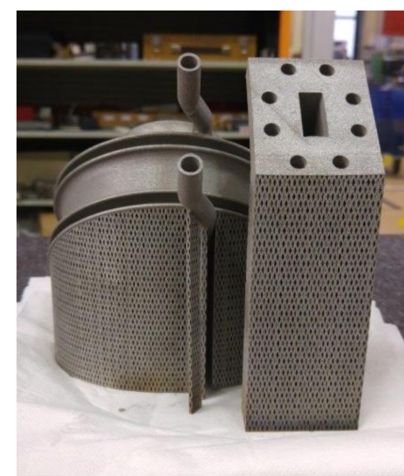


2nd PROTOTYPE





3rd PROTOTYPE



Test samples (large electrodes) for Fixed Gap System

1st PROTOTYPE

- Protoshape – German company
- Ti6Al4V
- Printed → re-machined

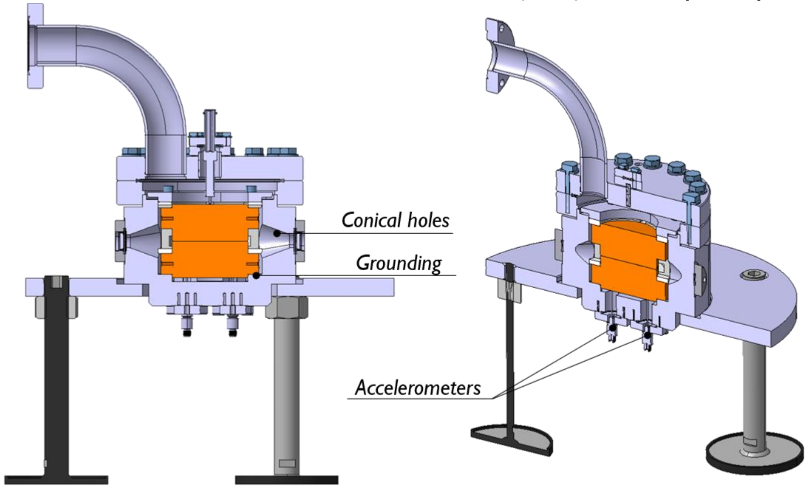
2nd PROTOTYPE

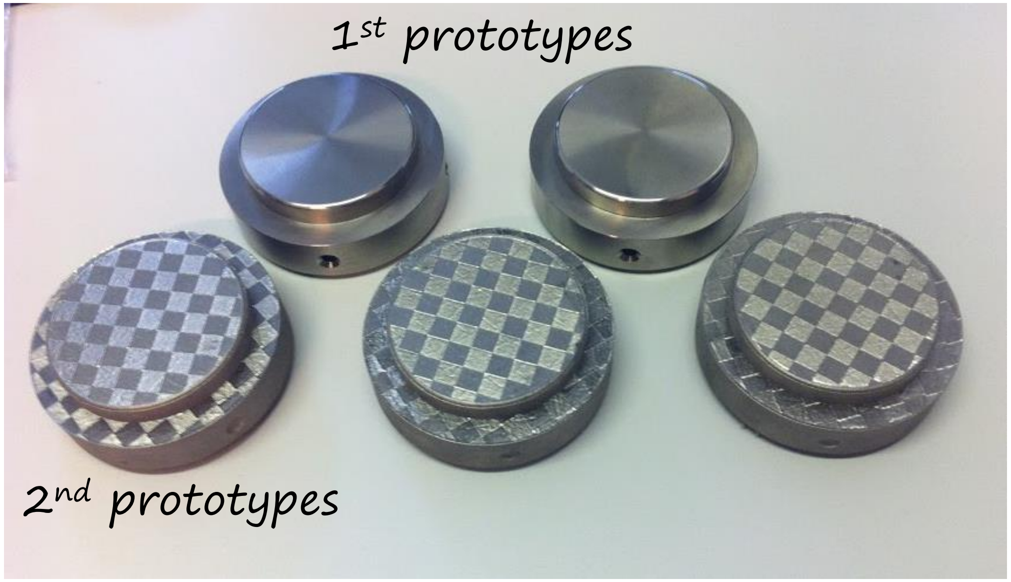
- Protoshape – German company
- Ti6Al4V
- Printed → not treated

PRINTED

RE-MACHINED

- TESTS
  - DC test in Fixed Gap System (FGS)





WR90 WG filter

1st PROTOTYPE

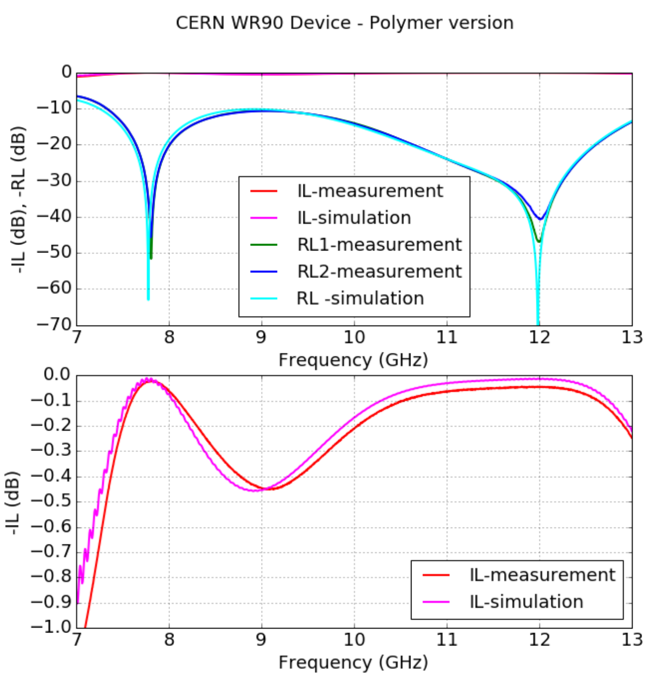
- 3T RPD - British company
- AlSi10Mg
- RF measurements

2nd PROTOTYPE

- SWISSto12 – Swiss company
- Polymer with 5 μm Cu plating
- RF measurements

1st PROTOTYPE

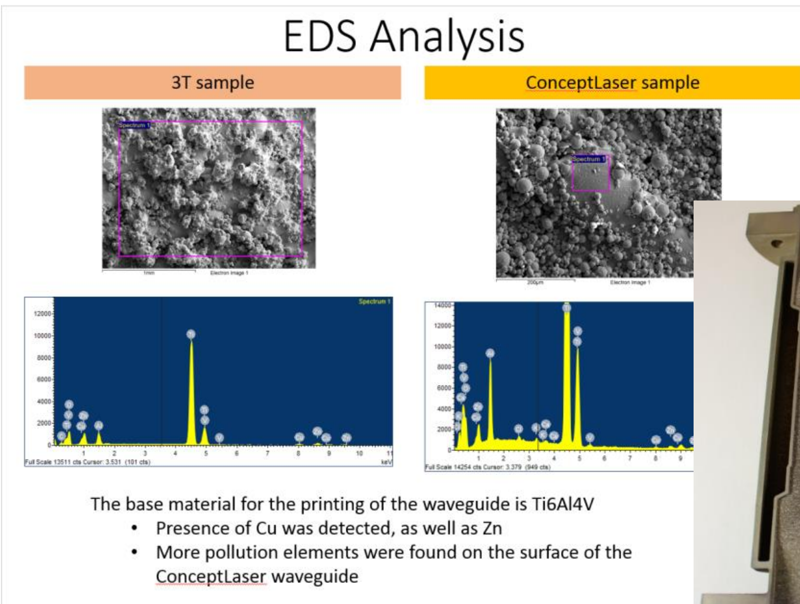
2nd PROTOTYPE

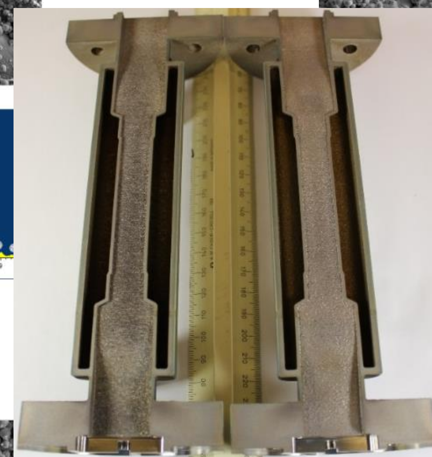


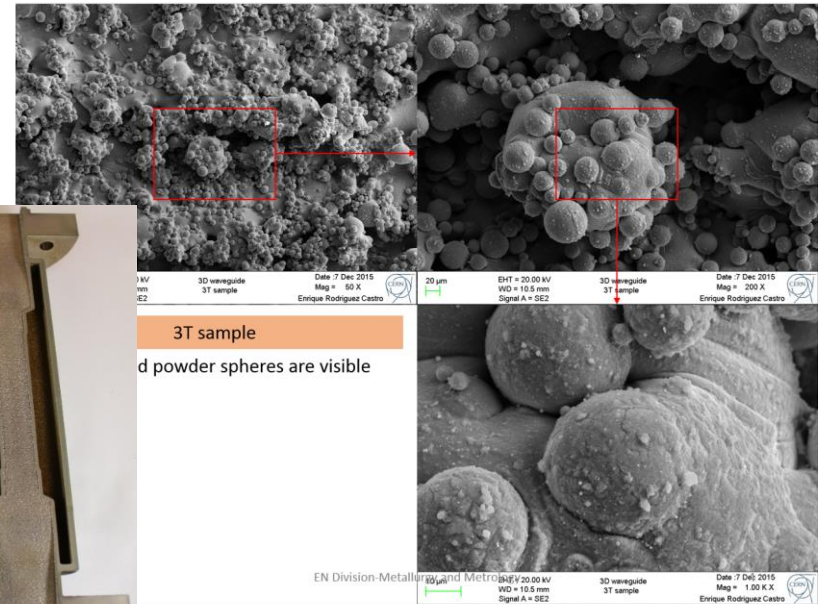
3rd PROTOTYPE

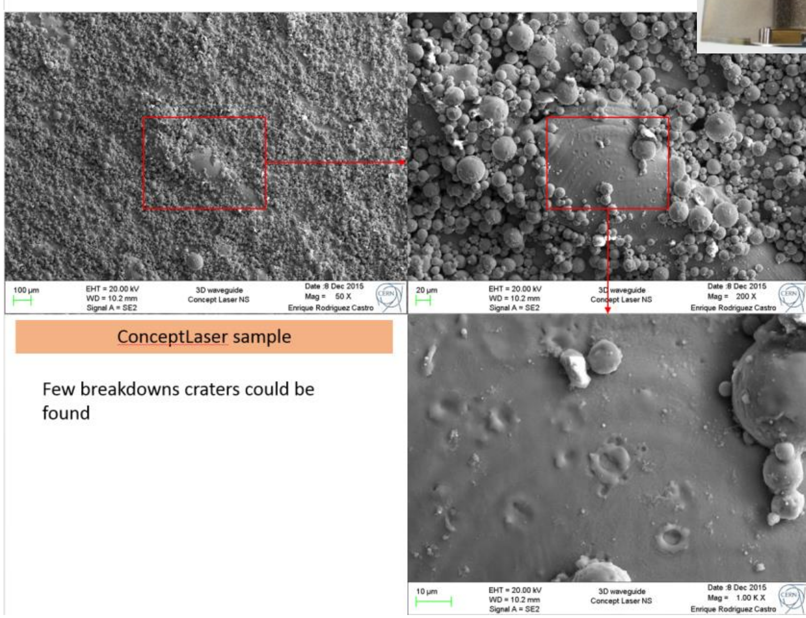
- SWISSto12 – Swiss company
- AlSi10Mg with 5 μm Cu plating
- Under production

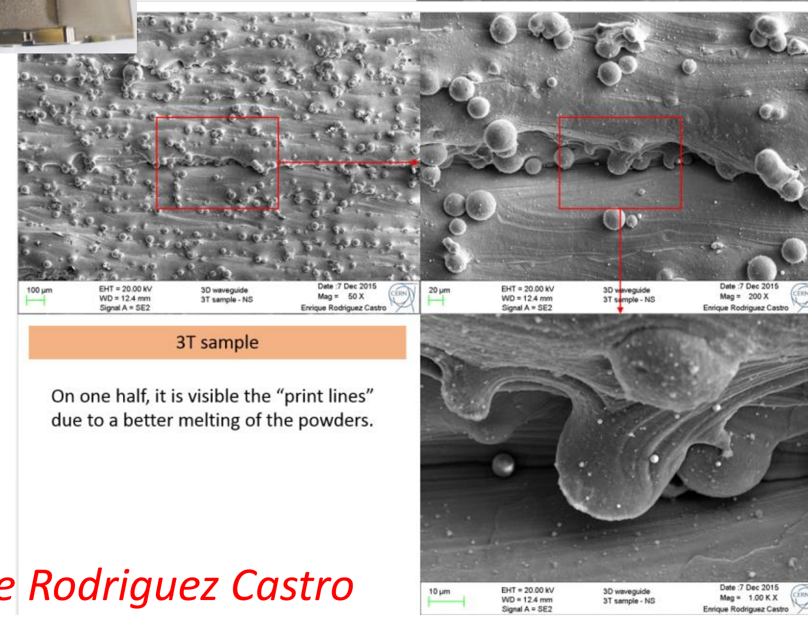
AM surface of WG after testing











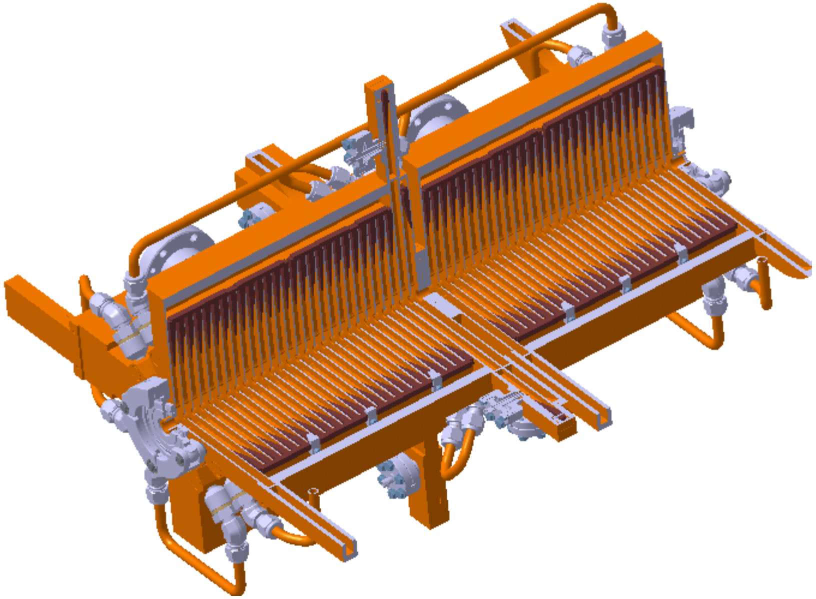
Enrique Rodriguez Castro

Future plans

FAST PROTOTYPING

NEW MATERIALS

MORE COMPLEX (AMBISIOUS) COMPONENTS



Conclusion

1. We are trying to introduce in fabrication:
   - Alternative engineering solutions;
   - Alternative joining methods;
   - Different assembly sequence.

2. New engineering design of an accelerating structure in rectangular "discs" and an accelerating structure in halves is under way with accompanying tests.

3. Close collaboration with industrial companies for:
   - New technologies;
   - Getting of feedback on mechanical design and assembly sequence;
   - Manufacturing and assembly of components and accelerating structures.

THANK YOU!