X-band manufacturing at CERN

Band
Prototypes
Production

On behalf of the team

Joel Sauza Bedolla

EN/MME/MA

Summary

- Production status
- Structures
  - T24 G Open (Halves)
  - TD24 R05 SiC
  - Rectangular disc
  - T24R05
  - TD26R1CC
  - TD31
  - Klystron base
  - TD26 Halves
- Components
  - Open Hardware
  - Under development

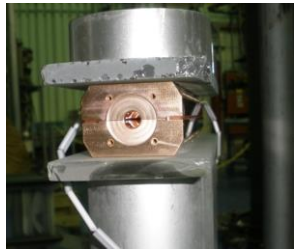
Status


X-band Production at CERN
RF Design
Mechanical design
Manufacturing
Assembly
High Power
Post-mortem
T24 (Halves)
N1
TD24 SiC
N1
Rectangular disc
N1
N1
T24 R05
N4
N5
TD26R1CC
N1
N1
N2
N3
N4
TD31
N1
N2
N3
N4
Klystron based
N1
N2
TD26 Halves
N1
N2

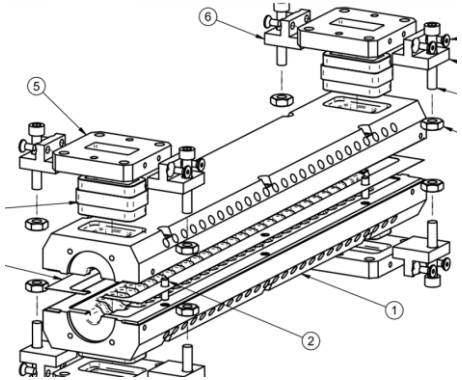
Structures

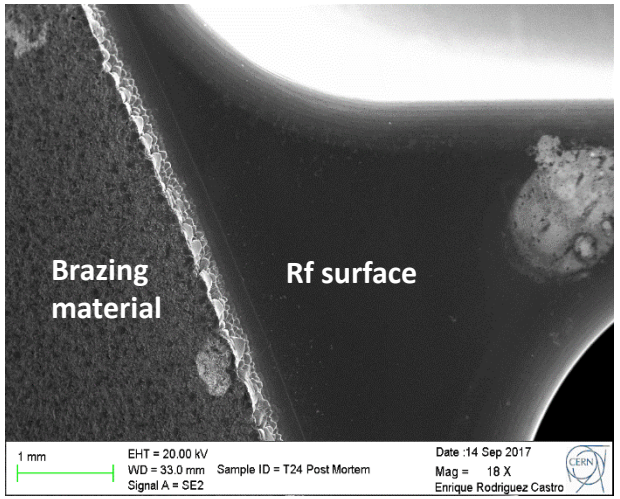
T24 G Open (Halves)

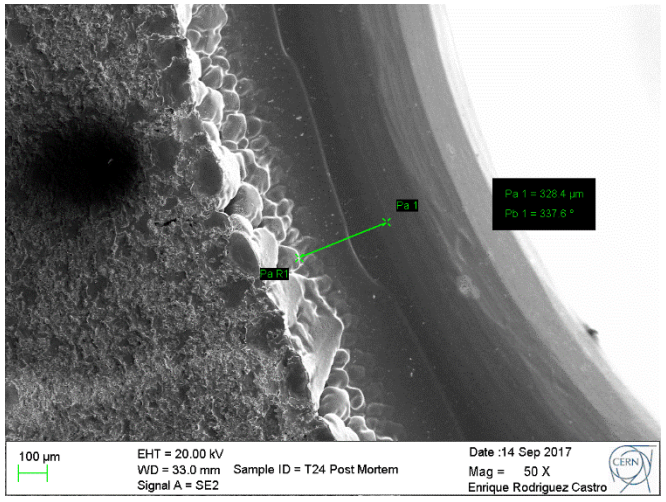
- KLY T24-CLIC-G-Open fabricated by SLAC. High power tested at CERN
- Conditioning: 200ns pulse length for 100 MV/m with BDR of 10^{-6} bbp
- Gold-copper (25-75) brazing shim.



Andy Haase 2015

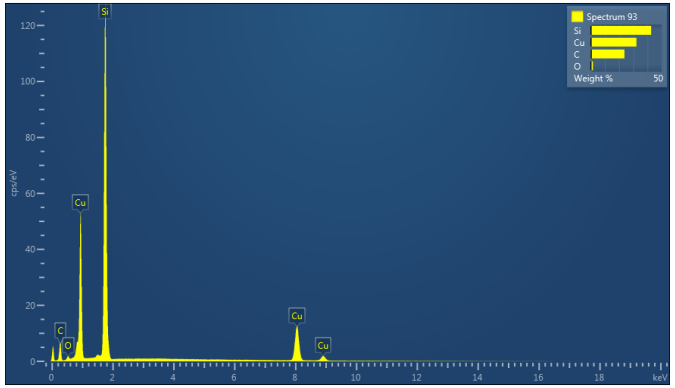




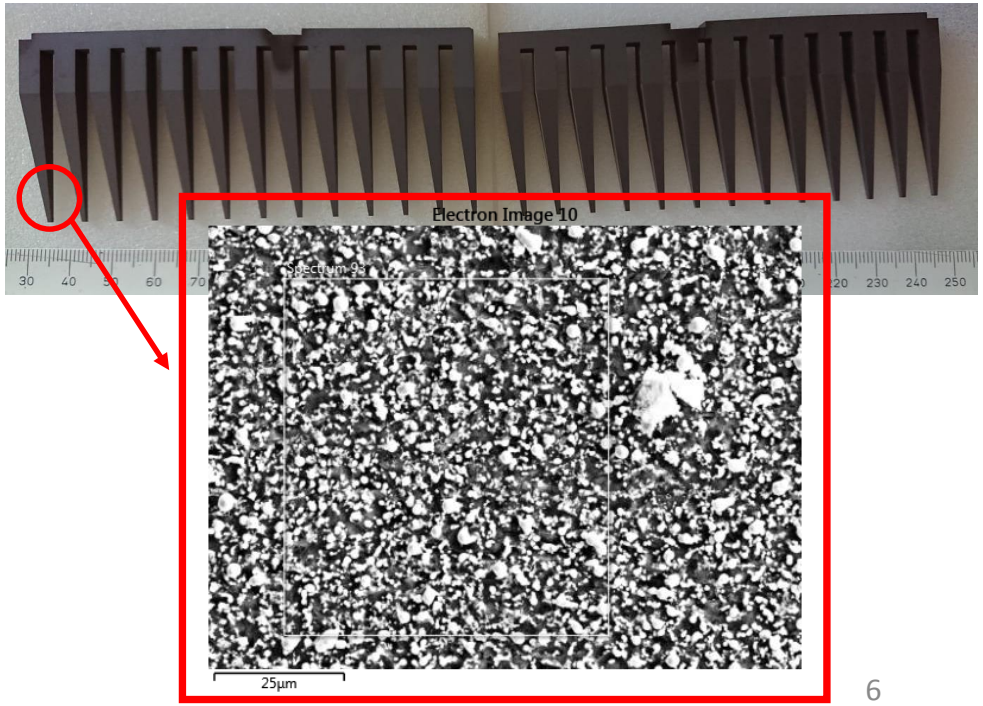


TD24 R05 SiC N1

- The gradient of structure was close to 100 MV/m
- Hot cell around 3rd
- SiC damps **copper coated**
  - During heating cycles? 4 heating cycles with SiC combs out of 10 total cycles
  - During high power test? Sputtering due to breakdowns? More Cu on the tip and near the hot cell

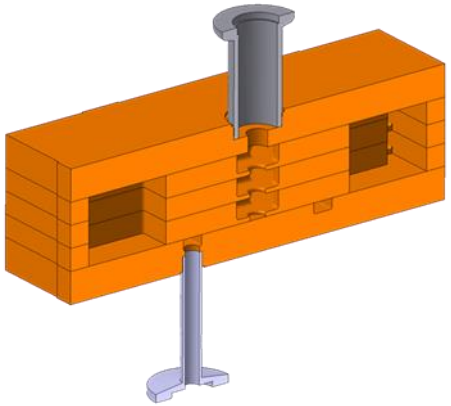


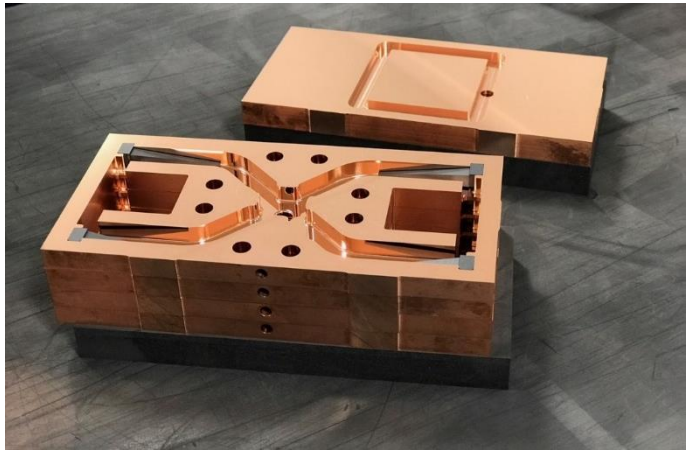
Element	Line Type	Wt%	Wt% Sigma
C	K series	23.72	0.32
O	K series	1.49	0.09
Si	K series	42.58	0.21
Cu	K series	**32.22**	0.20
Total:		100.00	

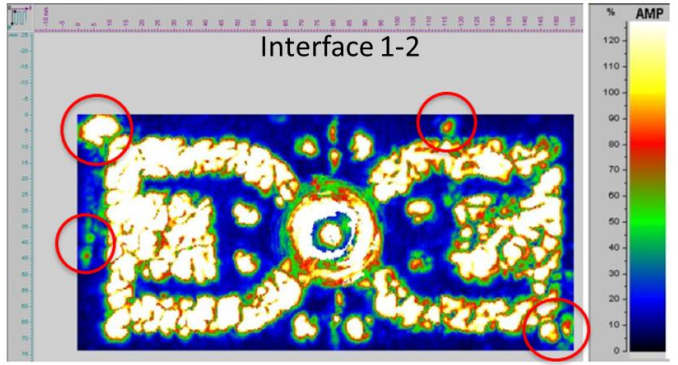


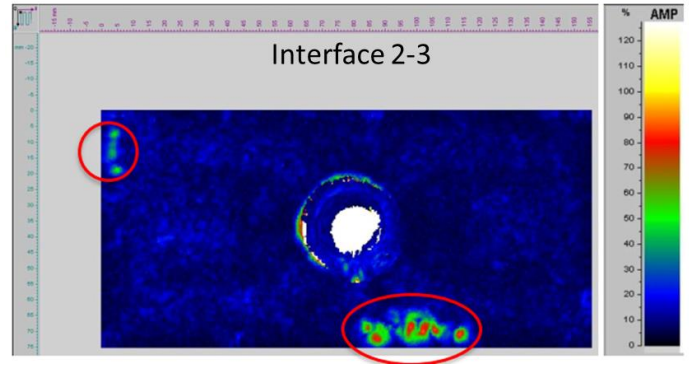
CLIC G bent WG prototype cell

- Rectangular cell
- Prototype for bonding test
  - Bonding successful at 95%. Unfortunately, it leaks.
  - SiC absorbers difficult to be placed. Wrong dimensions

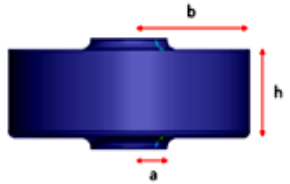
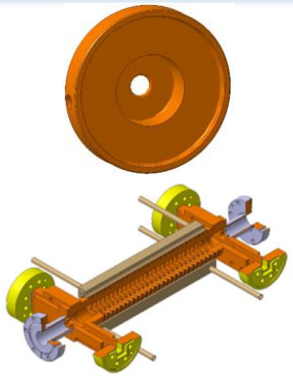
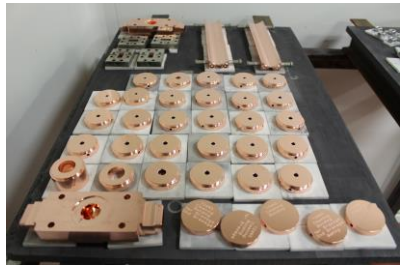
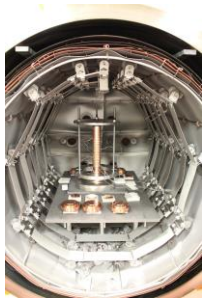
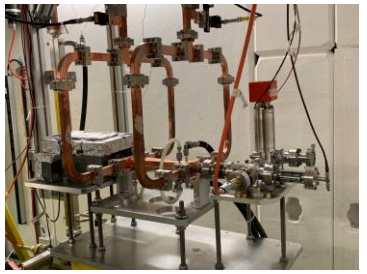








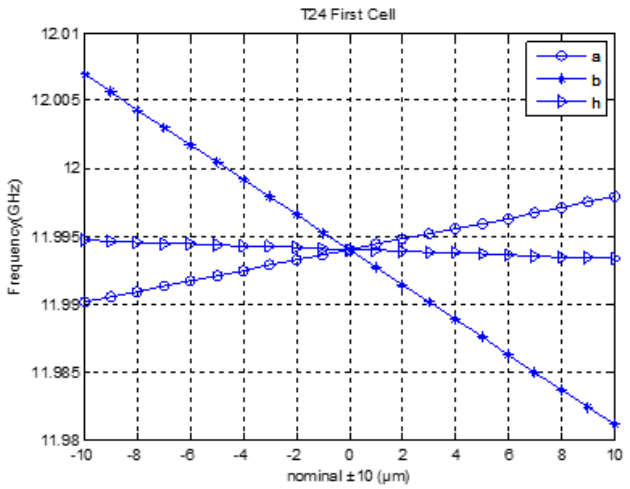
T24R05

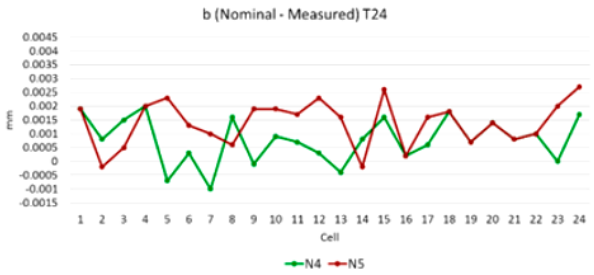
X-band Production at CERN					
	RF Design	Mechanical design	Manufacturing	Assembly	High Power
T24				 	

- 24 undamped cells
- Weak tapering of the irises
- Ø 45 mm
- Interlock design

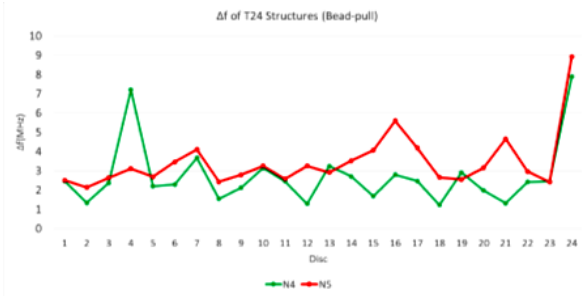
T24R05

- To **assess** the **changes on the geometry** of the cells **before** and **after bonding**
  - Sensitivity analysis of most important parameters
  - Correlation of RF measurements (bead pull measurement) vs mechanical measurements (CMM and optical measurements): **b parameter**

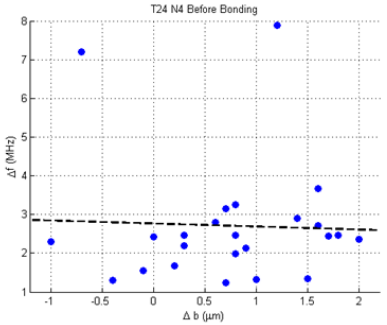




b parameter was always smaller than nominal
Data range: N4– 4 µm, N5-3 µm



Frequency deviation are uniform with reduced variability

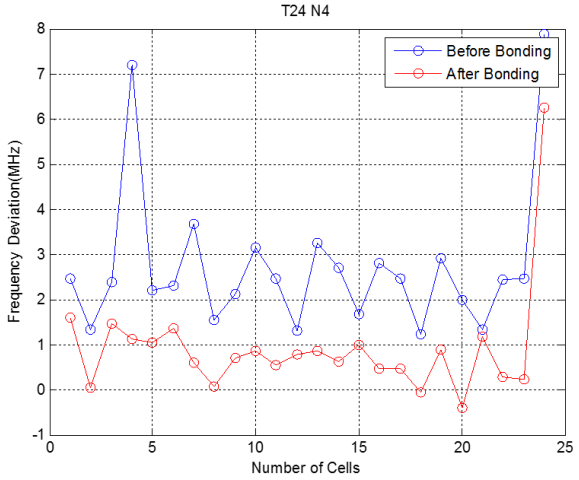


r=-0.038
No correlation

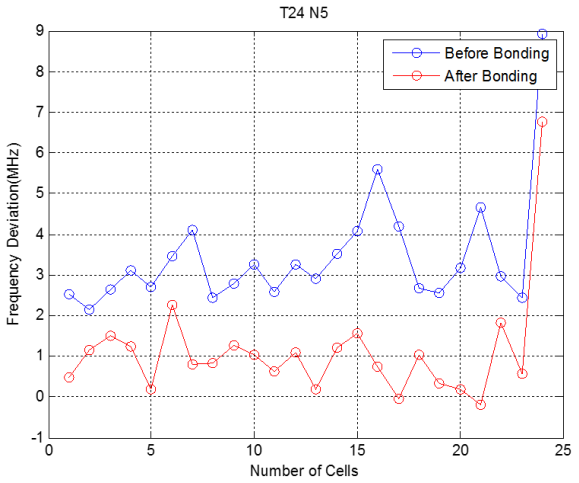
- Another type of correlation different than linear? Combined effect of more than one factor?

T24R05

- Frequency deviation before and after bonding
- Reduction of frequency may indicate a change on the geometry
  - The results are in the range of the accuracy (lack of RF contact) of the bead-pull measurements: are we measuring noise?
  - However, disc diameter reduction has been observed in several structures

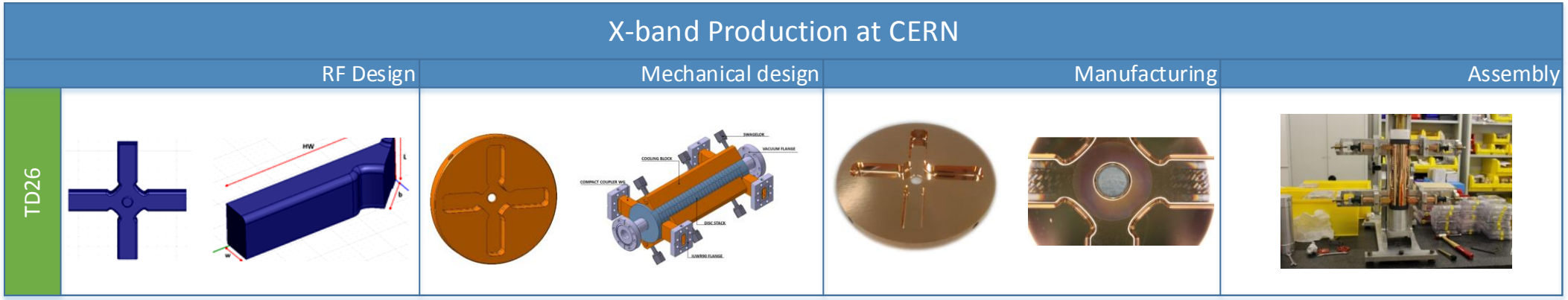


Diameter after bonding: Not measured
Straightness: 15 µm



Average diameter reduction (after bonding): 7 µm
Straightness: 30 µm

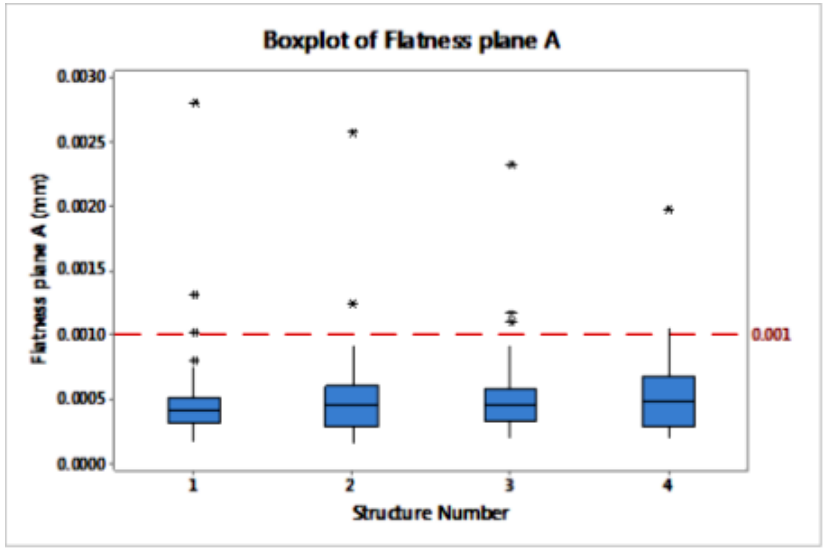
TD26R1CC

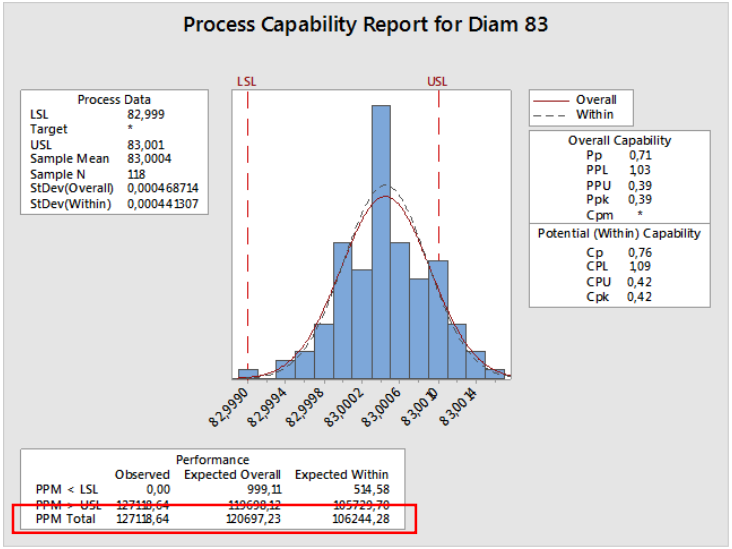


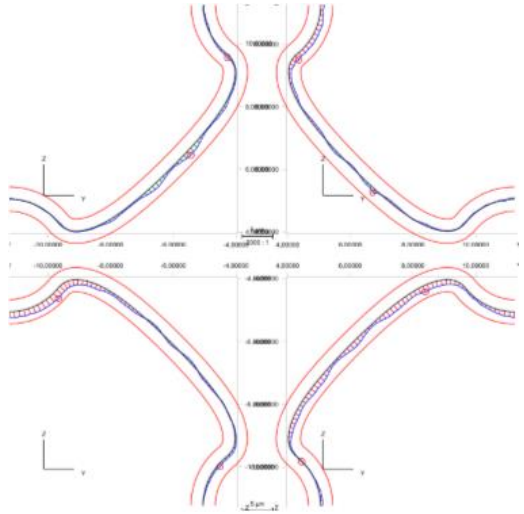
- 26 tapered cells with integrated coupling cells.
- Design changes:
  - “Nose” of the waveguide from an elliptical geometry to a **4-th order polynomial function**. RF Improvement
  - The **radius** at the bottom of the RF waveguide was **increased from 0.5 mm to 1 mm** to allow the use of bigger milling cutter. Economic
  - Disc **diameter was increased from 74 mm to 83 mm.** Design

TD26R1CC

- The total fabrication included four structures: 118 discs: the biggest amount of discs ever produced in a single order
- The parts were produced by a combination of Ultra-Precision diamond fly cutting, milling and turning



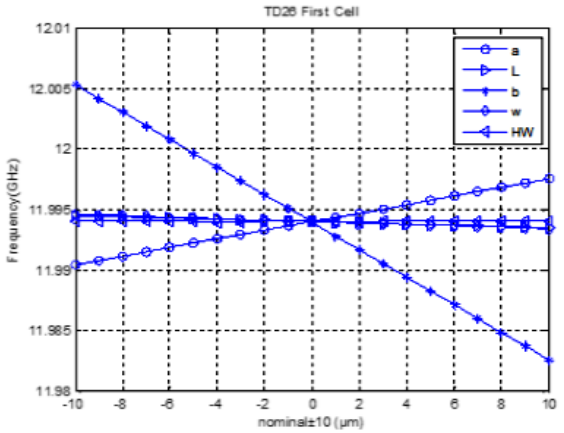


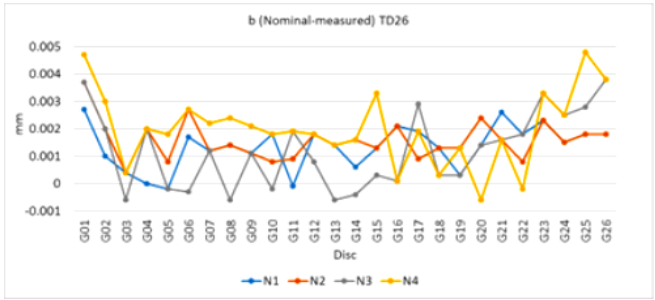


At the beginning of the fabrication the tolerance (disc diameter and flatness) was relaxed from ±1 µm to ±2 µm. The process reaches a Cpk = 1.1 thus 14 PPM

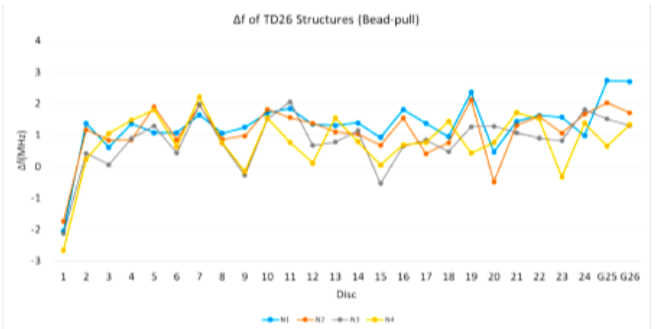
TD26R1CC

- Same procedure for T24: Sensitivity analysis (b and a), mechanical/optical measurements and frequency deviation before bonding
- No correlation in N1-N3 structures. Medium correlation in N2-N4

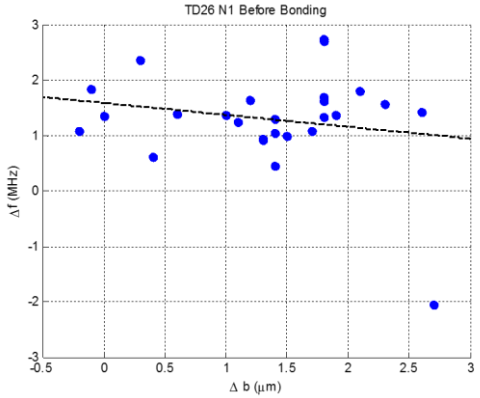




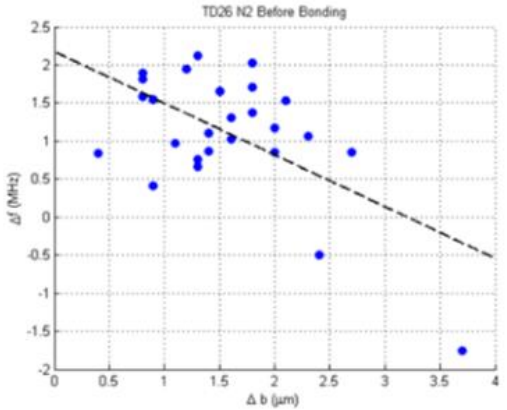
b parameter was always smaller than nominal
Data range: N1- 2 µm, N2-3 µm, N3-4 µm, N4-5 µm



Frequency deviation are uniform with reduced variability



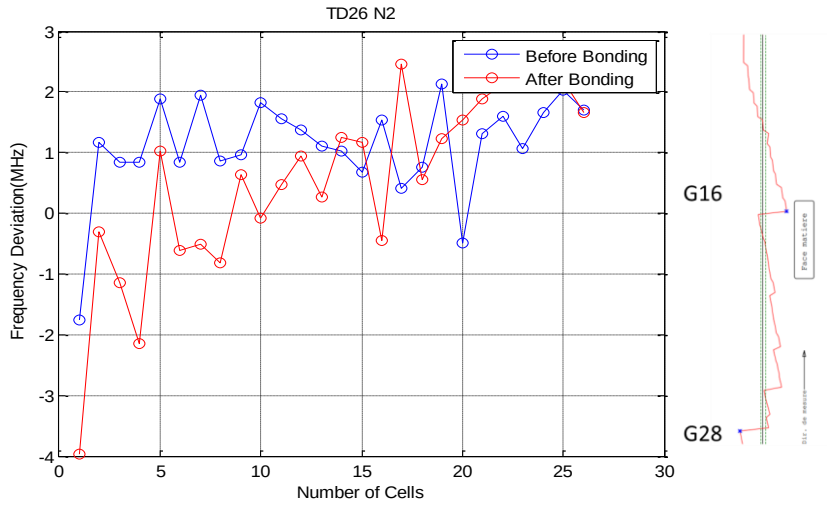
r=-0.193



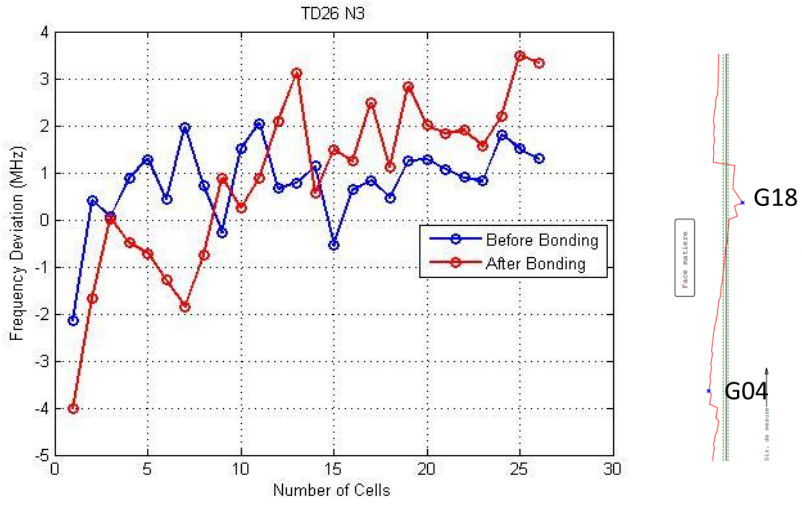
r=-0.59

TD26R1CC

- Frequency deviation before and after bonding
- Measurements affected by bonding stack straightness
  - Frequency deviation reduction not homogeneous
  - Difficult to tune (after bonding and brazing) structures N2 and N3



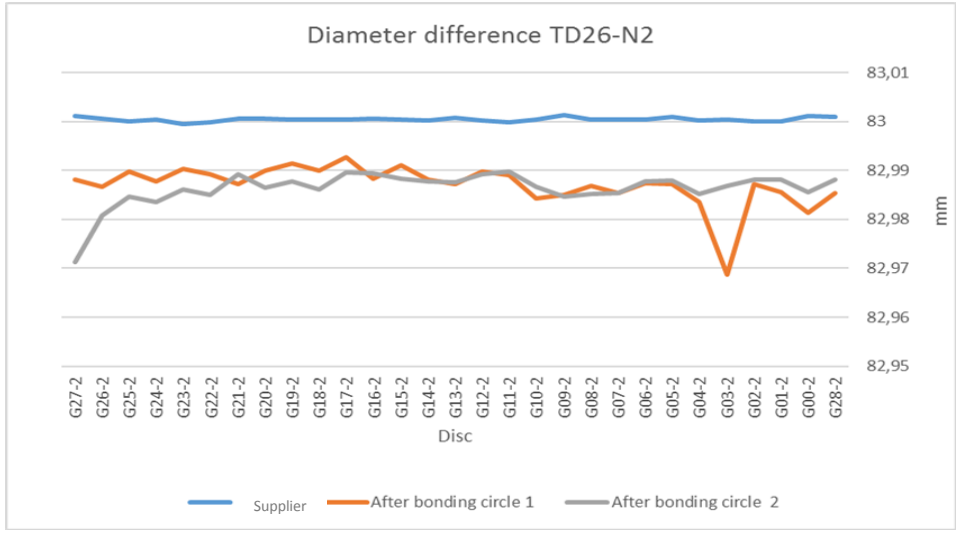
Average diameter reduction (after bonding): 13 µm
Average straightness: 70 µm



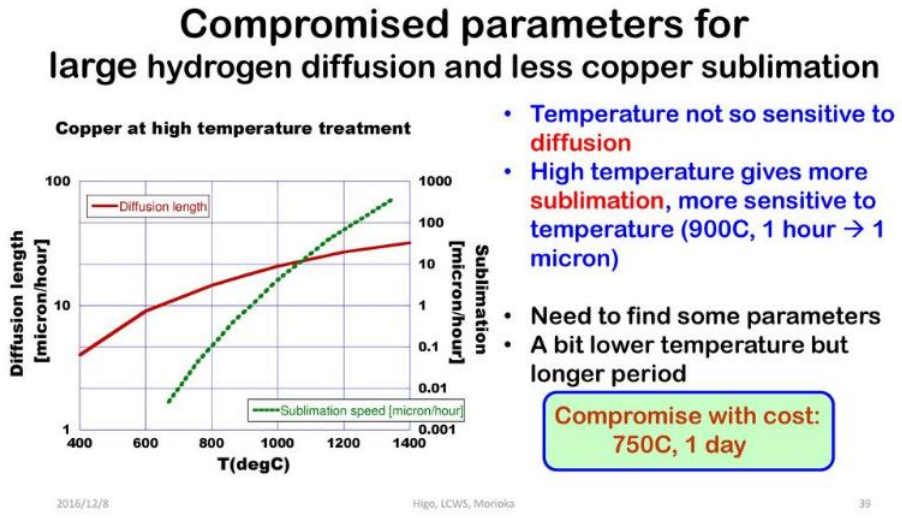
Average diameter reduction (after bonding): 12 µm
Average straightness: 50 µm

TD26R1CC

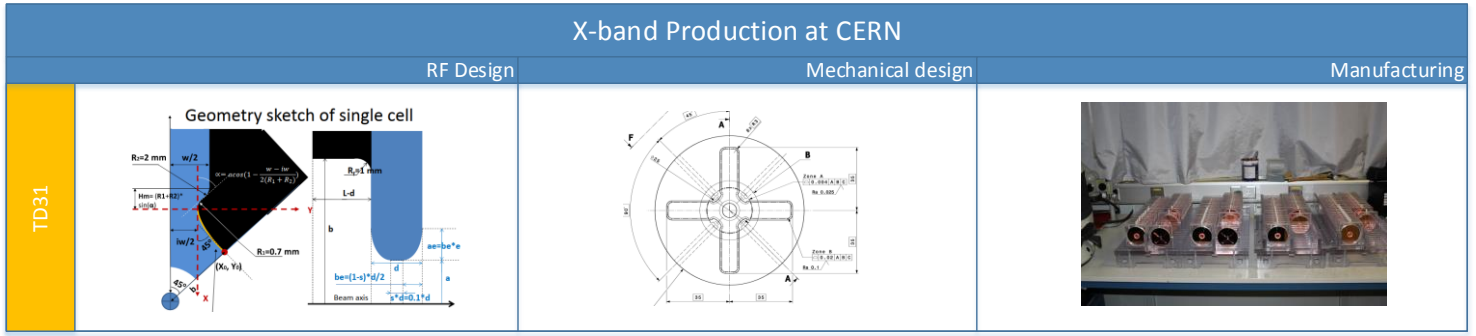
- Identical bonding cycles on different days for N1, N2 and N3: 1040 °C – 1.5 hours
- Observations:
  - There is a disc diameter reduction in the three structures: average 12 µm
  - There is a difference of diameter between two circles measured on the same disc: average 3 µm
  - There is a difference on height on measured after bonding N1: 25 µm
- Structure N1 will be thoroughly measured to have information about internal geometry changes.



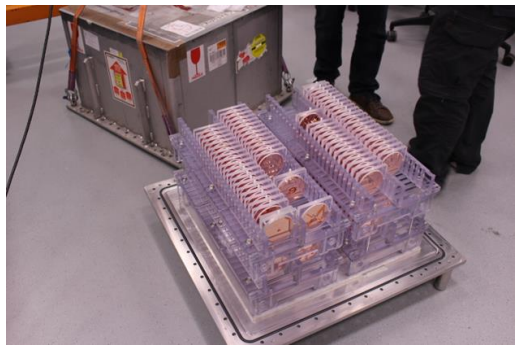
Higo, 2016

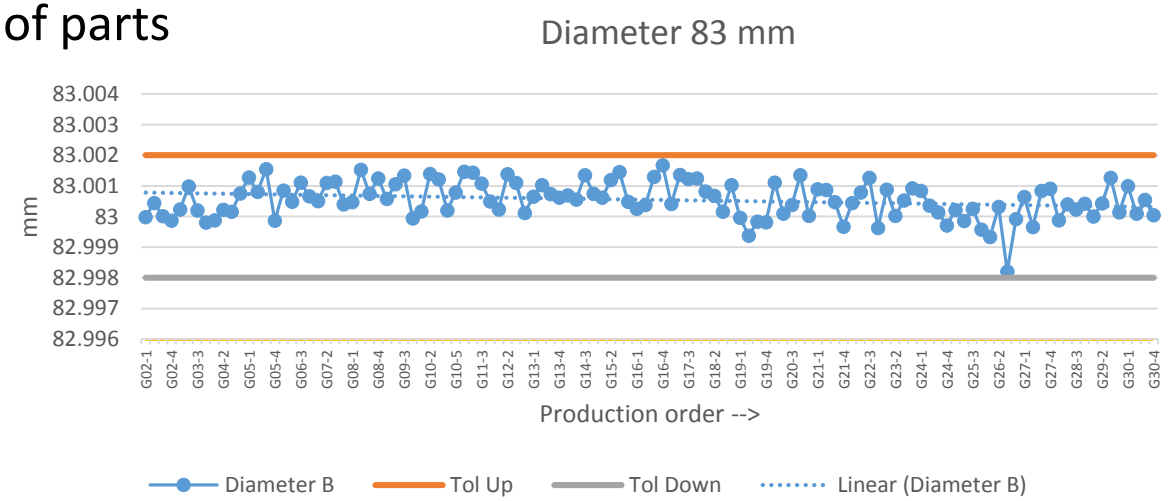


TD31R1CC

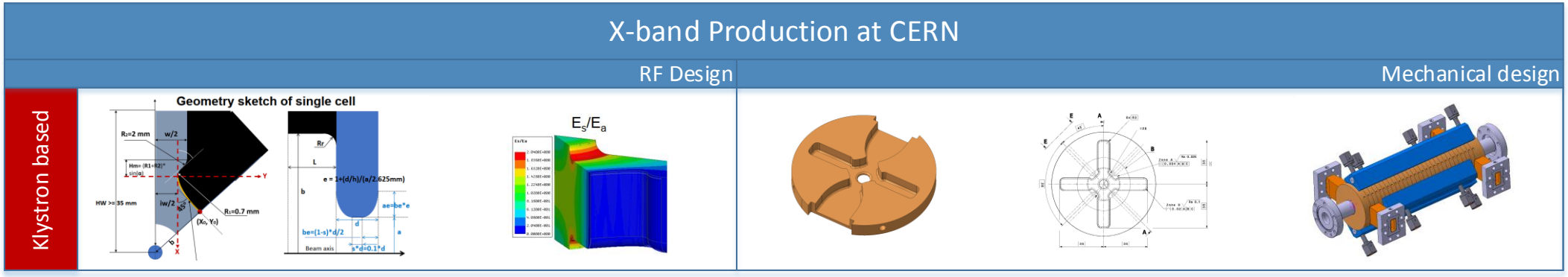


- Similar geometry of TD26 (Ø83 mm)
- Production of 138 cells + components
- Confirmed the Cpk with ± 2 µm Tolerance: **0 defectives parts**
- Improvements on transport and handling of parts





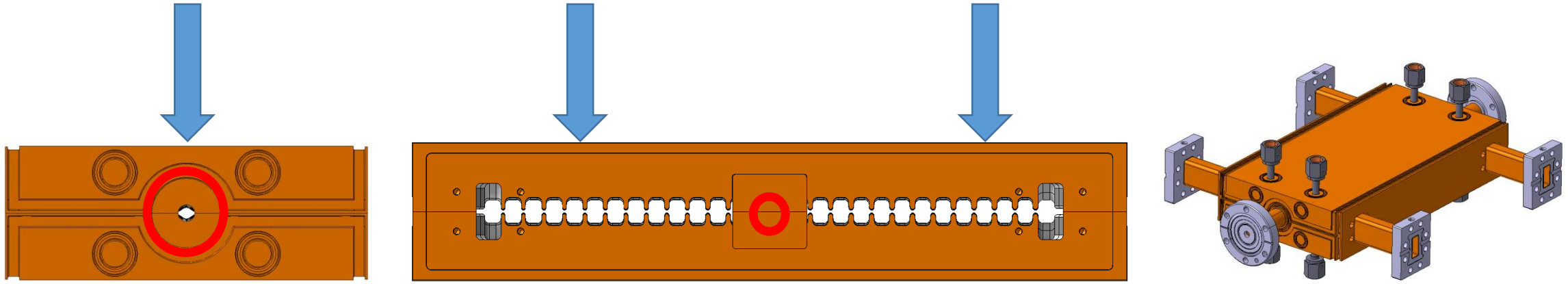
Klystron based



- Alternative scenario for 380 GeV
- 75 MV/m accelerating gradient
- It can be easily tested and implemented faster than two-beam modules
- Competitive cost at lower energy
- From the manufacturing point of view similar to TD26 and TD31
  - Smaller irises
  - Smaller height
  - Similar tolerances

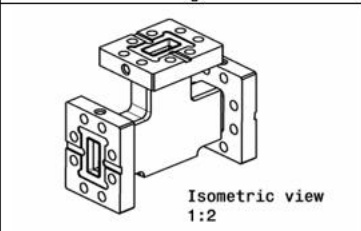
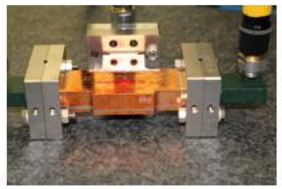
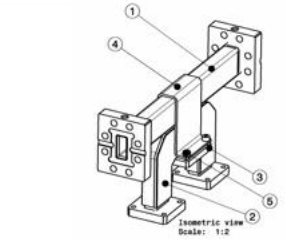
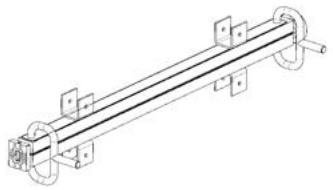
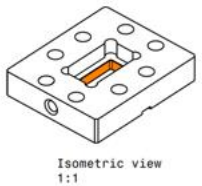
TD26 Halves

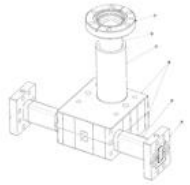
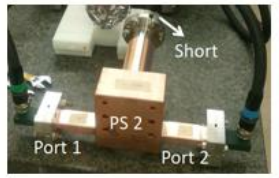
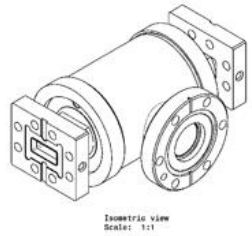
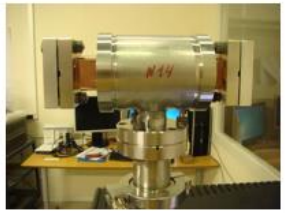
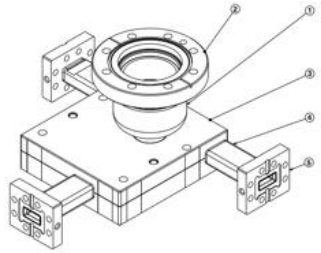
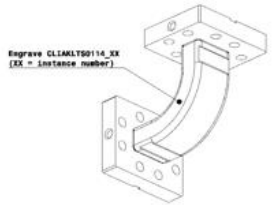
- New Electron Beam Welding
- Heat treatments are avoided
- There are less components
- Alignment is critical: deformation of rings, due to Herzian contact forces, by a load applied to the halves. Collaboration with Dutch company to define the alignment features



Components

Open Hardware catalogue

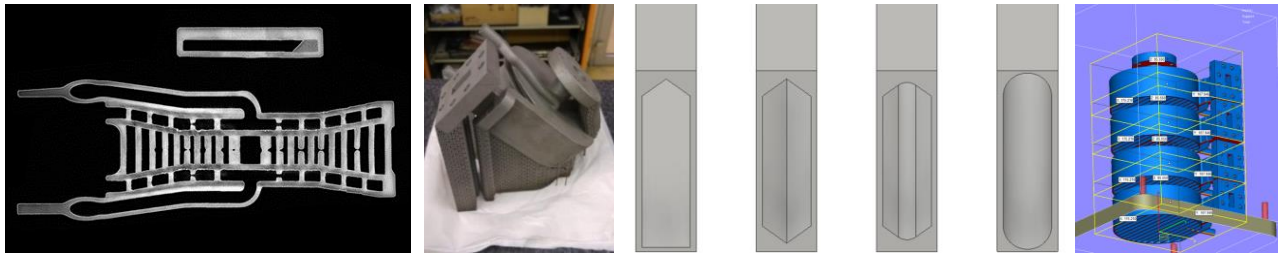
Component	Design	Photo
3db Splitter		
Directional Coupler 60 dB		
High Power loads		
IUWR90 flanges		

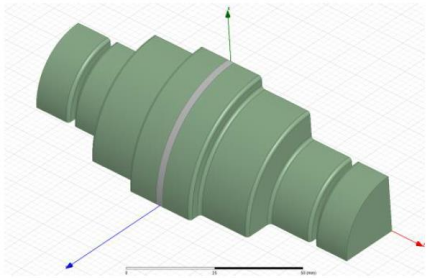
Component	Design	Photo
Phase Shifter		
Pumping port		
RF Switch		
Waveguides		

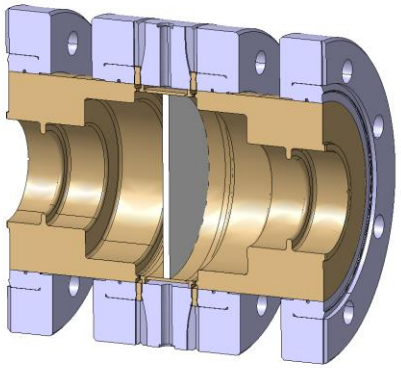
Scan me

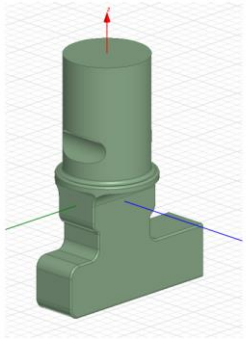
Components under development

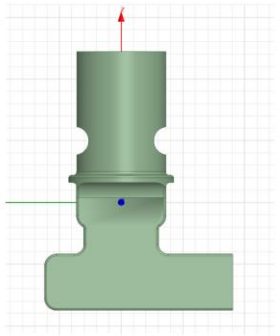
- Spiral load
  - Optimization for 3D printing
- Travelling Wave X-band RF Window
  - Peak Power 75MW
- Double height WR90 mode converter
  - TE_{10} (rectangular waveguide) to TE_{01} (circular waveguide)

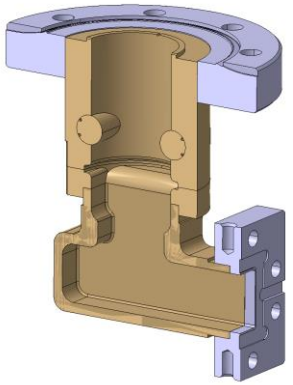












Conclusions

- Next structures for tendering:
  - Klystron based structure (production)
  - Halves (production)
  - TD31 (assembly)
  - Repeat bonding test of rectangular disc with similar parts
- Components
  - RF window and mode converter fabrication and testing (in house)
  - Spiral load (in house)
- Structure's internal geometry changes
  - SiC copper coated (TD24 R05 SiC and rectangular disc)
  - Frequency changes (T24 and TD26)
  - External diameter reduction and height changes (T24 and TD26)
  - TD26R1CC measurement will help us to better understand (started)

Thank you for your attention

Nuria Catalan Lasheras

Serge Lebet

Anastasiya Solodko

Kamil Tomasz Szypula

Joel Sauza Bedolla

Hikmet Bursali

Enrique Rodriguez Castro

Sergio Gonzalez Anton

Ready for questions


CERN