Progress on TD24 accelerating structures fabrication and wakefield monitor experiment preparation

F. Peauger, CEA Saclay

Objectives of the wakefield monitors (WFM) experiment

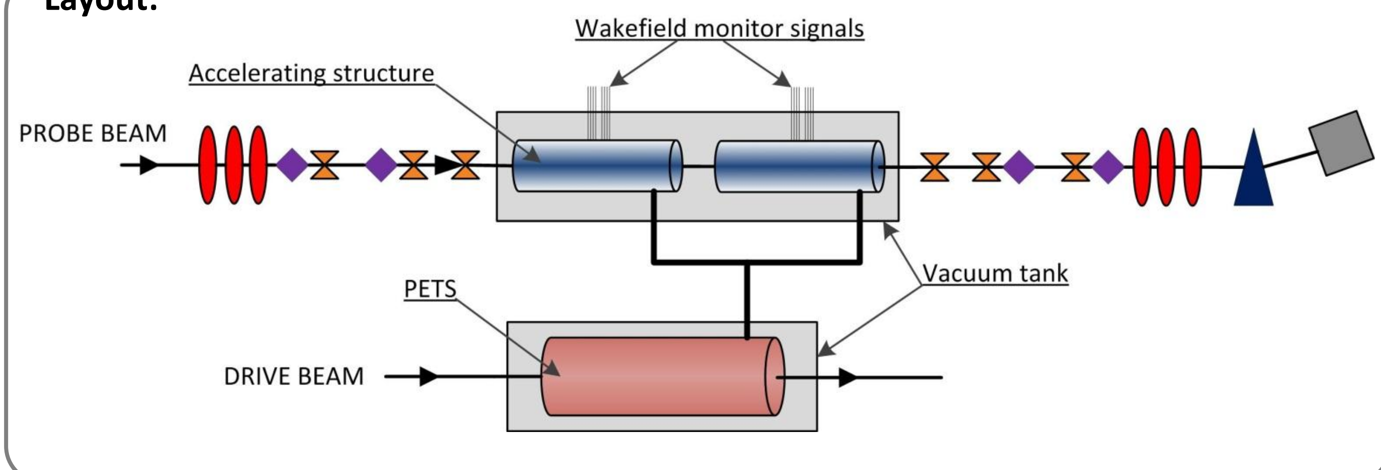
To achieve the luminosity in CLIC, the beam must be aligned in the main beam accelerating structures to an accuracy of about 5 µm

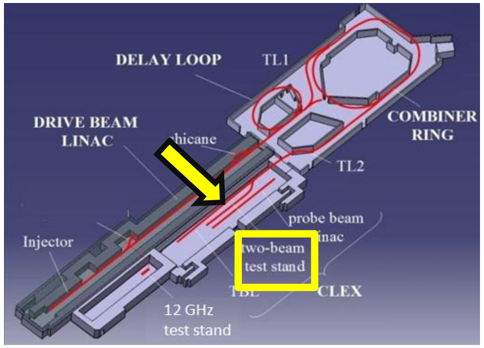
- **Beam based alignment technique**
  - use higher order modes in the accelerating structure to detect and correct a beam offset
- **Feasibility demonstration in CTF3**
  - build and equip two TD24 structures with wakefield monitors
  - test on Two-beam test stand with beam and high power RF at 100 MV/m accelerating gradient

Specifications:

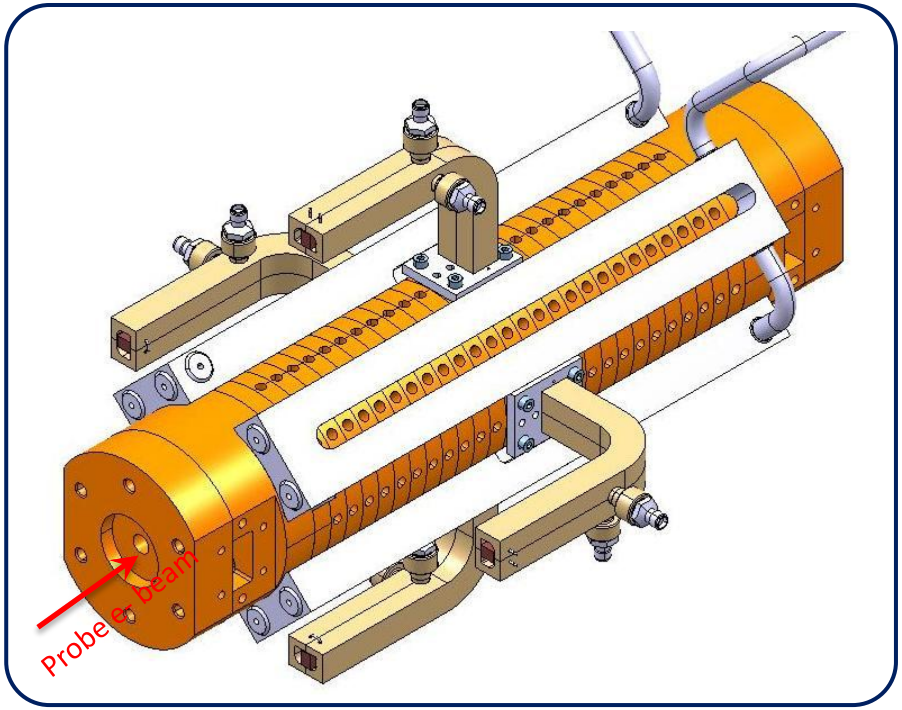
Parameters	CLIC commissioning	CLIC operation	CTF3
Charge / bunch (nC)	0.06	0.6	0.6
Number of bunches	1-312	312	1-226
Bunch length (µm)	45-70	45-70	400
Train length (ns)	156	156	150
Bunch Spacing (ns)	0.5	0.5	0.66
Accuracy (µm)	5	5	
Resolution (µm)	5	< 5	
Range (mm)	± 2	± 0.1	± 2
Beam Aperture (mm)	~5.5	~5.5	~5.5

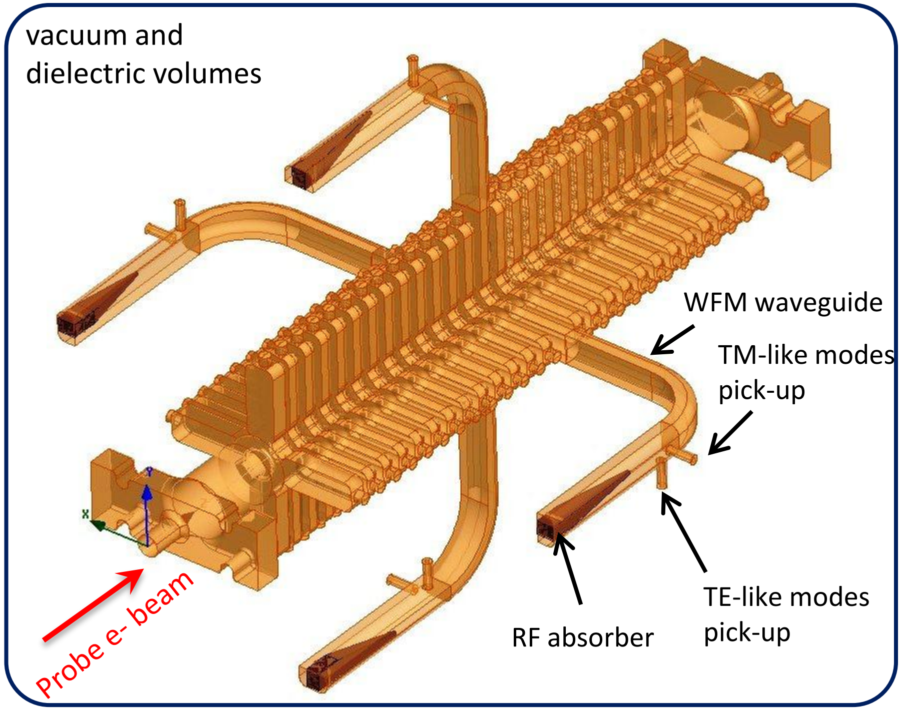
Layout:



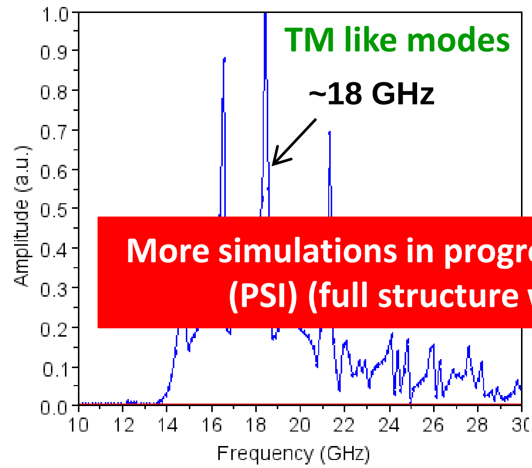


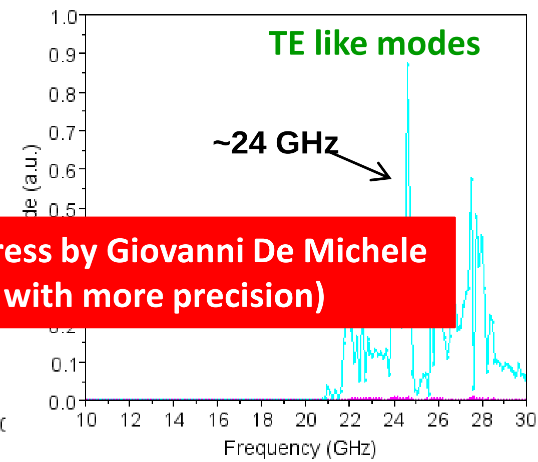
TD24-WFM accelerating structure design





- **TD24 structure**
  - 24 cells + 2 matching cells + mode luncher couplers
  - No rf absorbers in the damped waveguides
  - Diamond machining and diffusion bonding of the disks
  - Tuning studs in every cell
  - Cooling circuit brazed on the structure
- **WFM = 90 deg waveguide bend + pick-ups + rf absorber**
  - Implemented on the middle cell
  - Screwed on the structure with good electrical contact

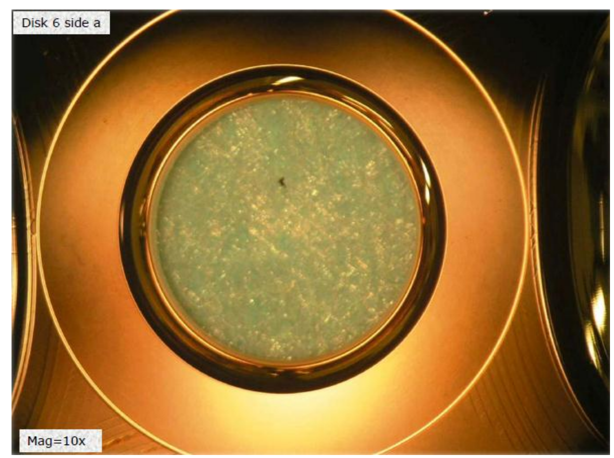




More simulations in progress by Giovanni De Michele (PSI) (full structure with more precision)

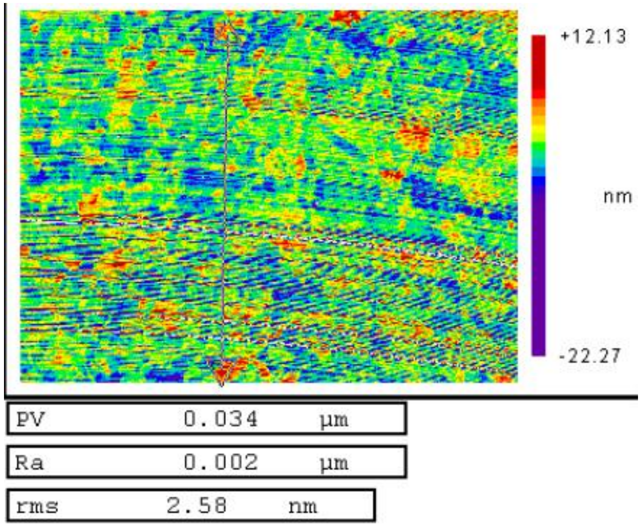
Precise machining of couplers and disks

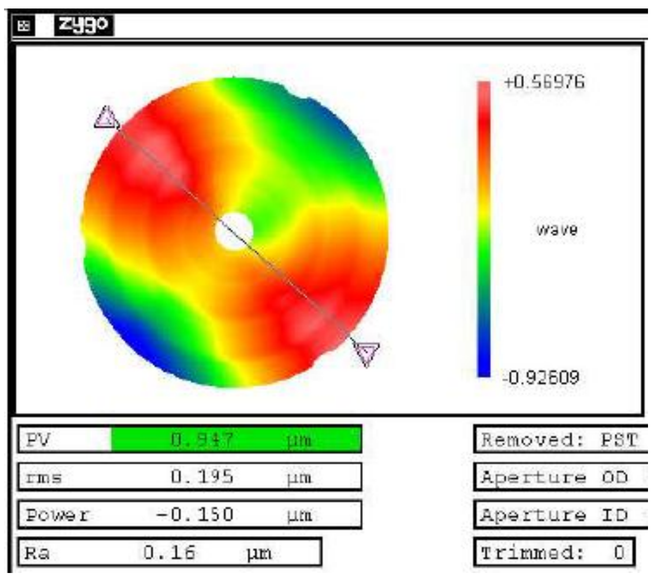
- Made by Mecachrome – Vibraye (France)
- New Moore machine with linear motors and air bearing spindle
- Monocrystal diamond tools for turning and milling
- Non destructive control of flatness and roughness using interferometers
- Tridim control on test parts only



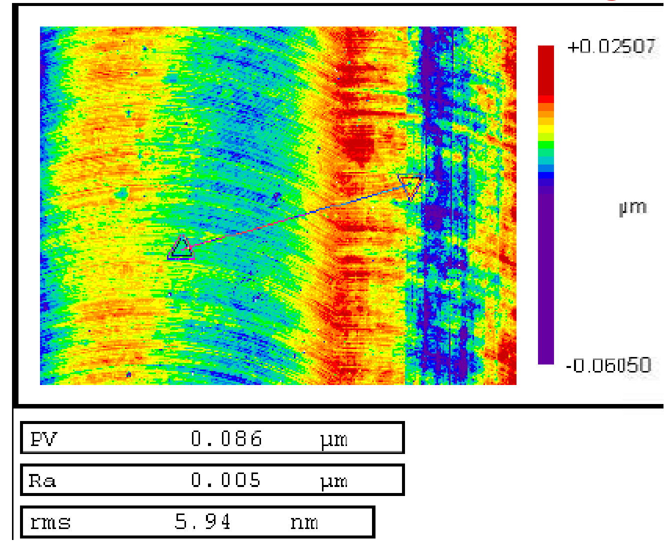
Example of non destructive control of disks

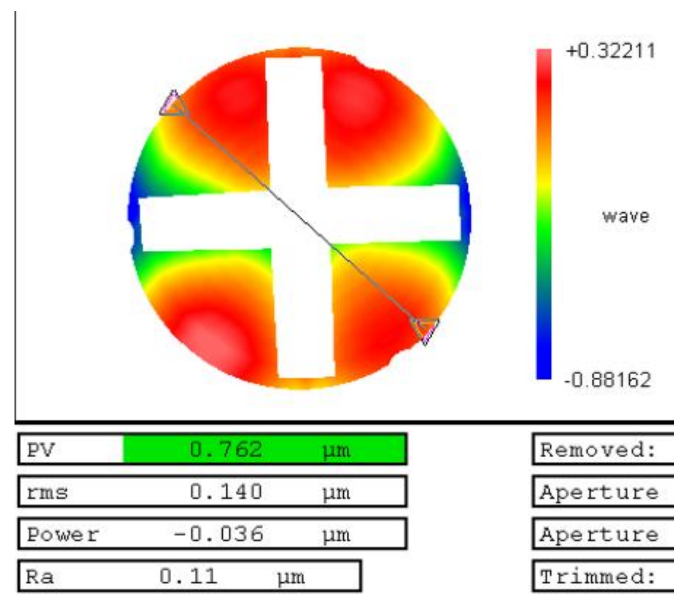
- Disk004-B/structure N1: Face Ref A - turning area





- Match iris B-C/structure N1 - milling area



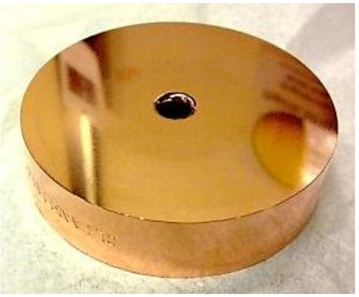


Diffusion bonding of couplers under H_2 at 1 bar

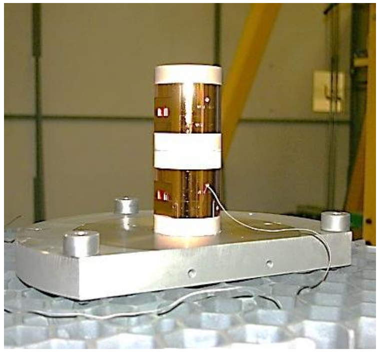
- Done at Thales Electron Devices (TED) – Velizy (France)
- Degreasing and etching at CERN before bonding
- Applied weight: 43 kg equivalent to ~ 0.13 MPa; thermal cycle: flat top at 1035° C during 1h30
- Process validated on a test coupler: observation of crossing grains in the joint plan
- Some deformations observed on the outer faces after bonding : ~0.1 mm -> re-machining done

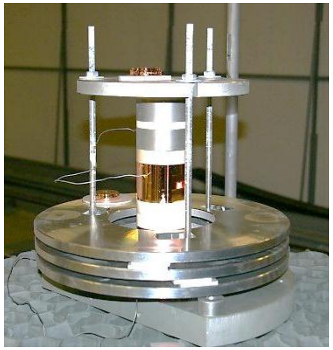
Coupler

Extremity cell

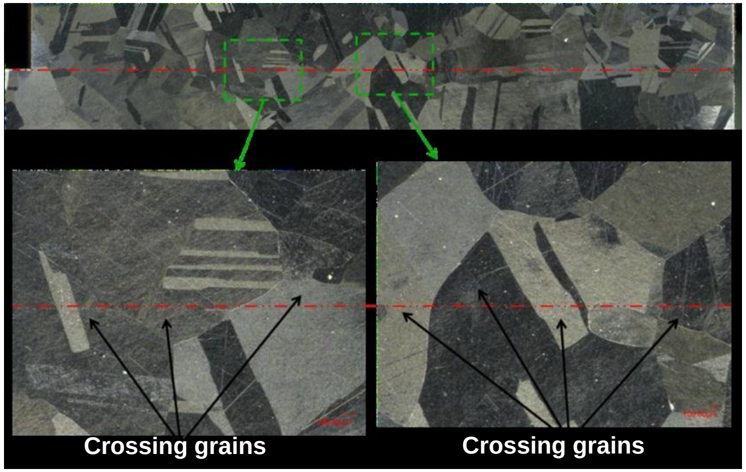


Assembly of couplers in the furnace

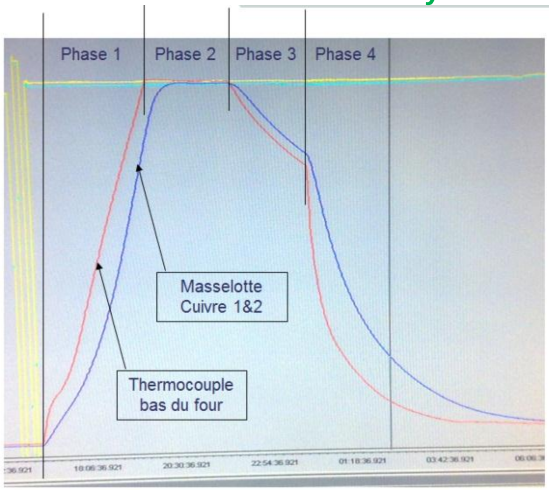




SEM observation of bonding plan after cutting



Thermal cycle



Phase 1 :
16H40 –19H40

TC bas 1044°C
M1 & M2 : 916°C

Phase 2 :
19H40 -20H20

TC bas 1044°C
M1 & M2 : 1035°C

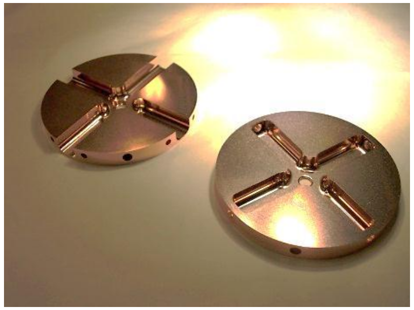
Phase 3 :
20H20 -21H50
TC bas 1037°C
M1 & M2 : 1033°C

Phase 4 :
21H50 – 23H50
TC bas 808°C
M1 & M2 : 840°C

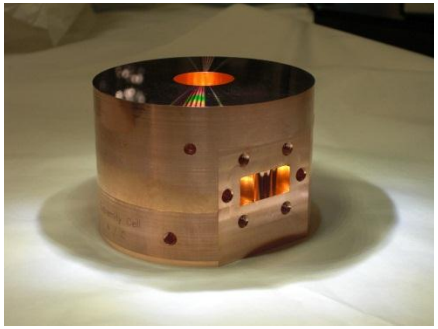
Diffusion bonding of structure under H_2 at 1 bar

- Also done at TED with degreasing and etching at CERN before bonding
- Applied weight: 33.7 kg equivalent to ~ 0.08 – 0.12 MPa;
- Same thermal cycle as couplers but with flat top at 1010° C
- No deformations observed on the external diameter after bonding

Disks after etching



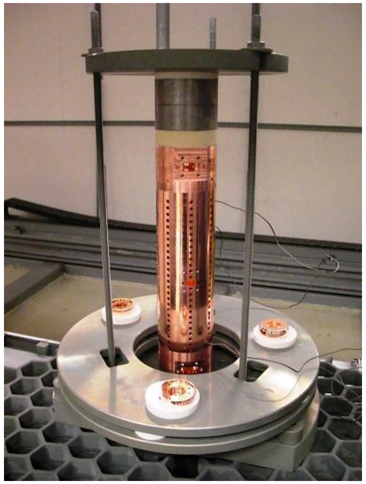
Coupler



Structure n°1

Structure n°2

Assembly of disks in the furnace



Geometrical measurements on external diameter after bonding
Alignment = 9µm for ACS#1 and 12.6 µm for ACS#2
Angle = 90.0514° for ACS#1 and 90.0087° for ACS#2

Assembly of accelerating structure accessories

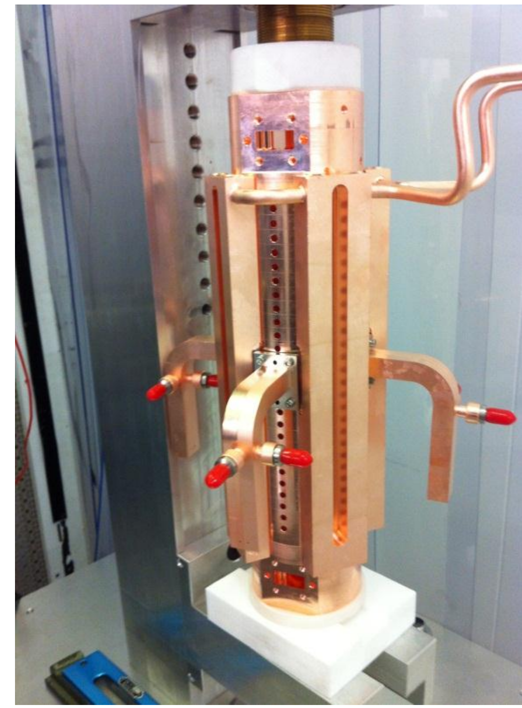
- Done at Bodycote – Villaz (France) and CERN
- Tuning studs and cooling circuits brazed with copper gold alloy below 1000° C under vacuum
- Good tightness and no drip of alloys observed in the cells
- Assembly test by screwing of WFM waveguides OK

Assembly of tuning studs

Assembly of cooling circuits

S. Lebet

Assembly of WFM waveguides



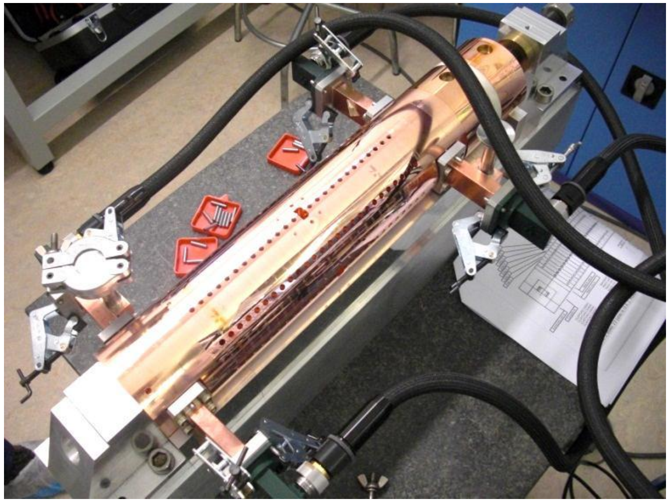
S parameters of the structures before tuning

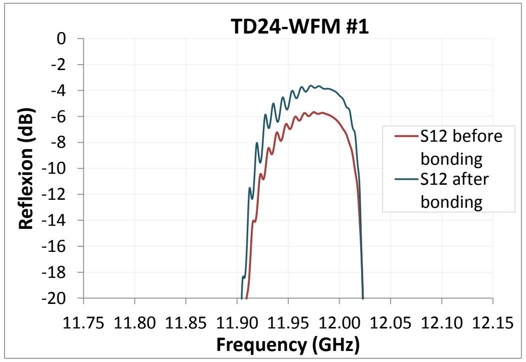
- RF Reflexion in acceptable value, below -25 dB
- Improvement of RF transmission after diffusion bonding, close to theoretical value
- Structure #1 slightly better than structure #2

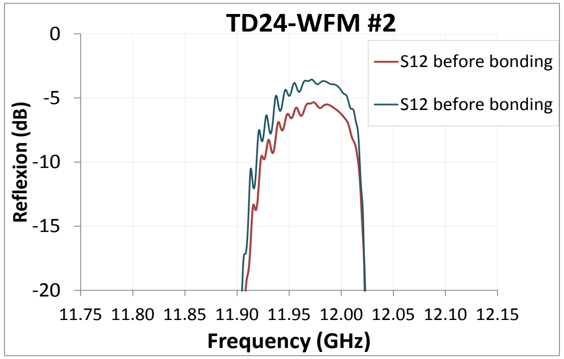
At 11.994 GHz:

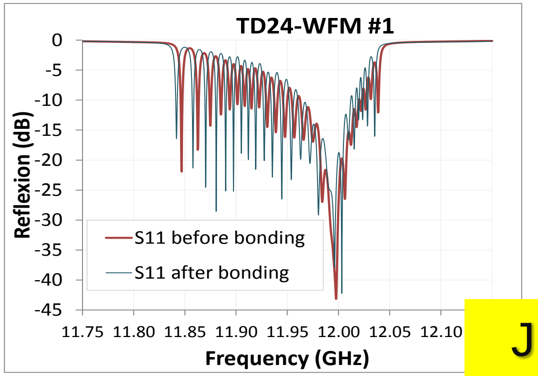
	Before bonding	After Bonding	Design (theory)
ACS #1	S11 = -35 dB	S11 = -27.2 dB	S11 = -40 dB
	S12 = -6.09 dB	S12 = -4.006 dB	S12 = -3.7 dB
ACS#2	S11 = -19.47 dB	S11 = -27.42 dB	S11 = -40 dB
	S12 = -5.855 dB	S12 = -3.9694 dB	S12 = -3.7 dB

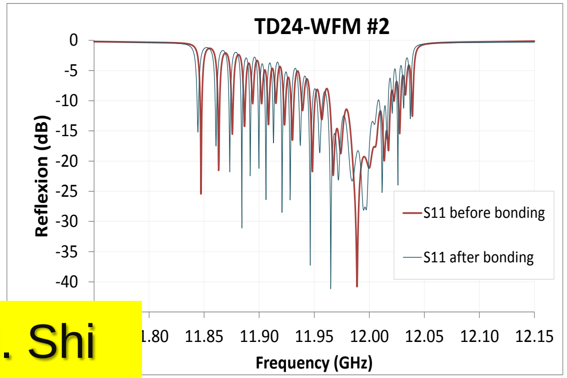
Structure connected to network analyzer







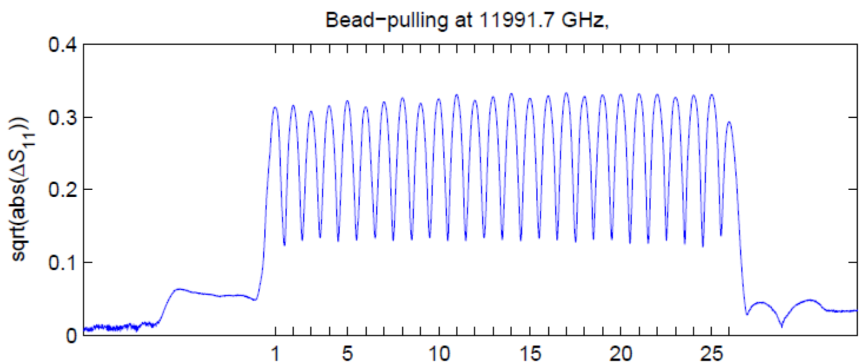


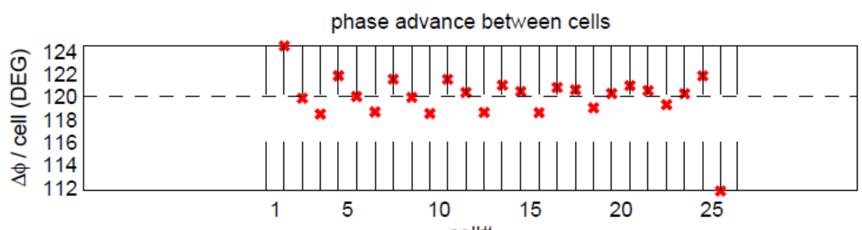


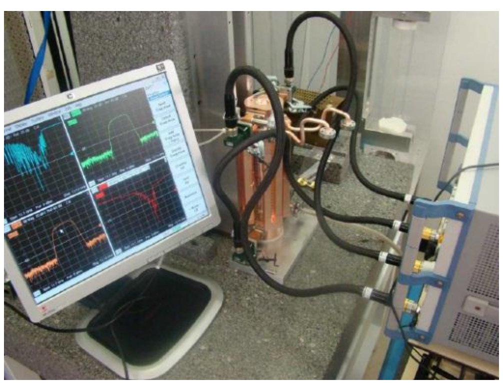
J. Shi

Bead-pull and RF tuning of structure n°1

- Done at CERN by Jiaru Shi the 22th of Feb. 2012
- Target frequency: 11991.65 MHz (considering freq. shift due to wire, nitrogen and temperature of 21.6 deg)
- All disks tuned with only one stud used for each disk
- <u>Very successful tuning</u>







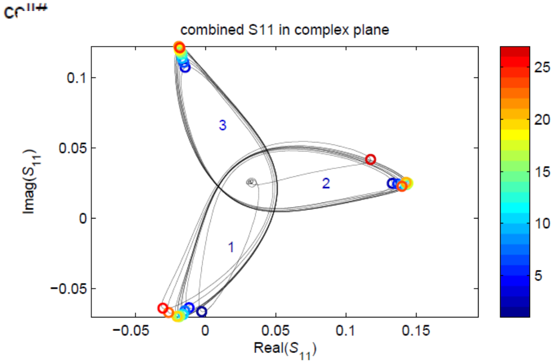


Figure 12: Bead-pulling at 11991.7 GHz

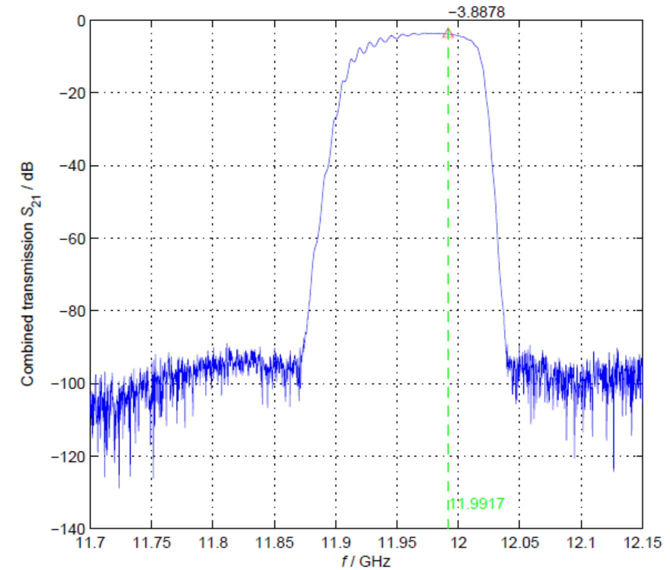


Figure 8: Combined transmission from input to output

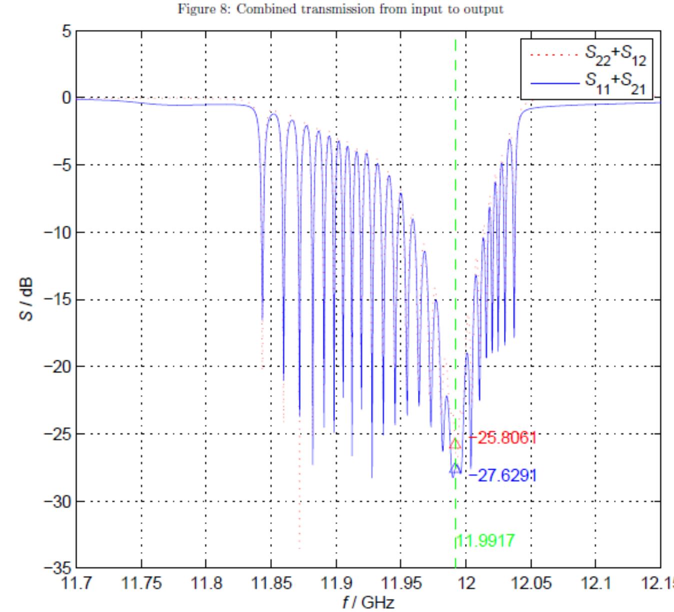
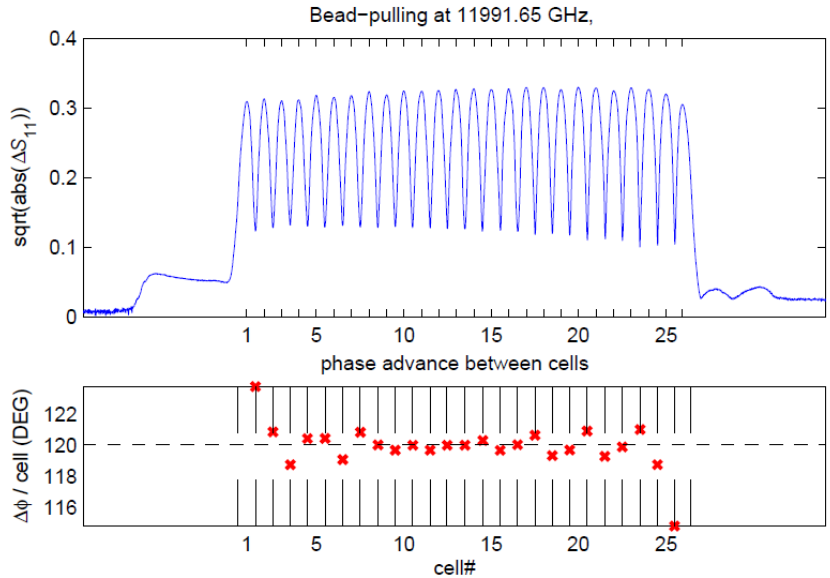
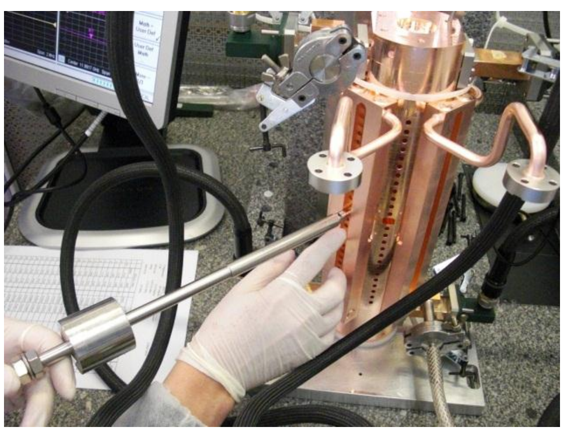


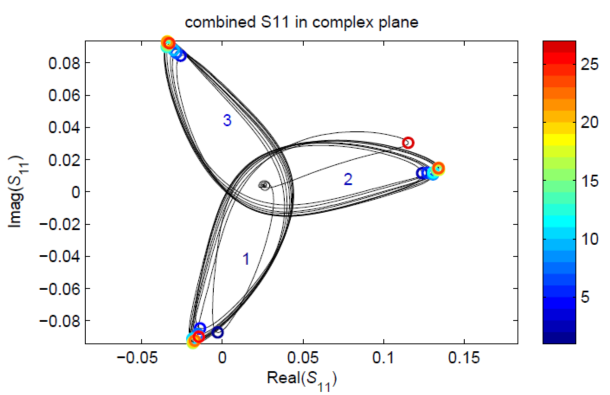
Figure 4: Reflection at input

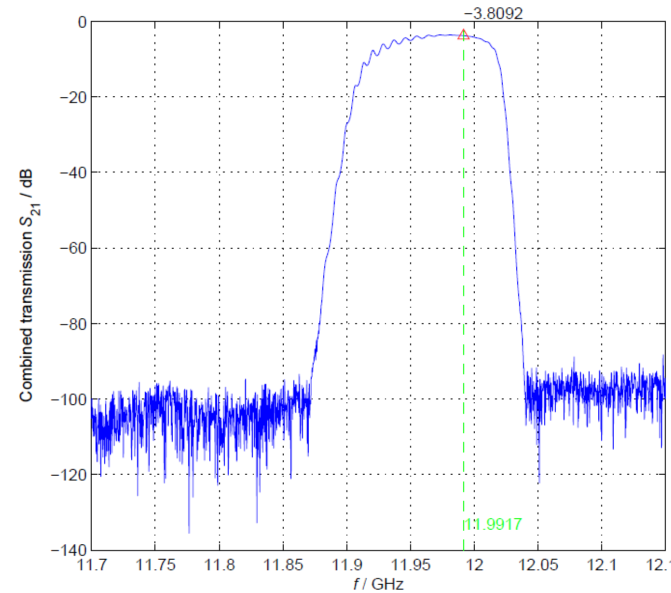
Bead-pull and RF tuning of structure n°2

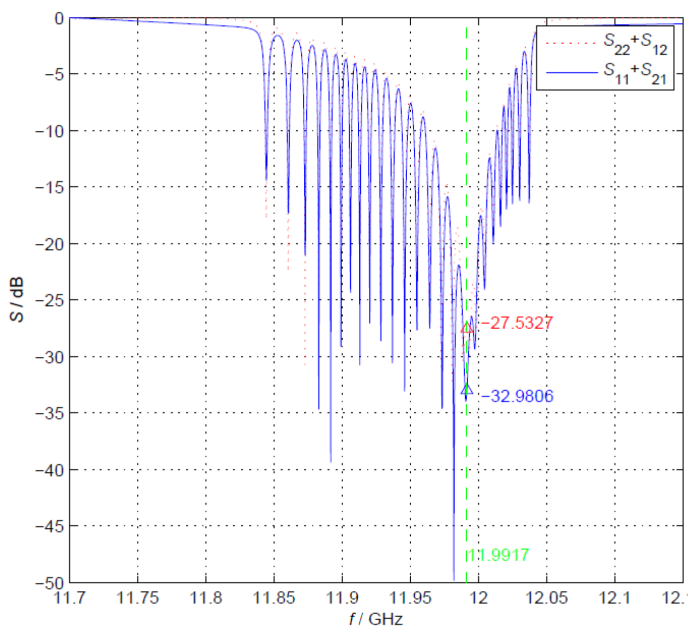
- Same procedure as structure N1, done the 6th of March 2012
- Disk 13 tuned by -10 MHz (the 4 studs were used), all the other disks were tuned +/- 3MHz like structure N1
- <u>Very successful tuning also</u>





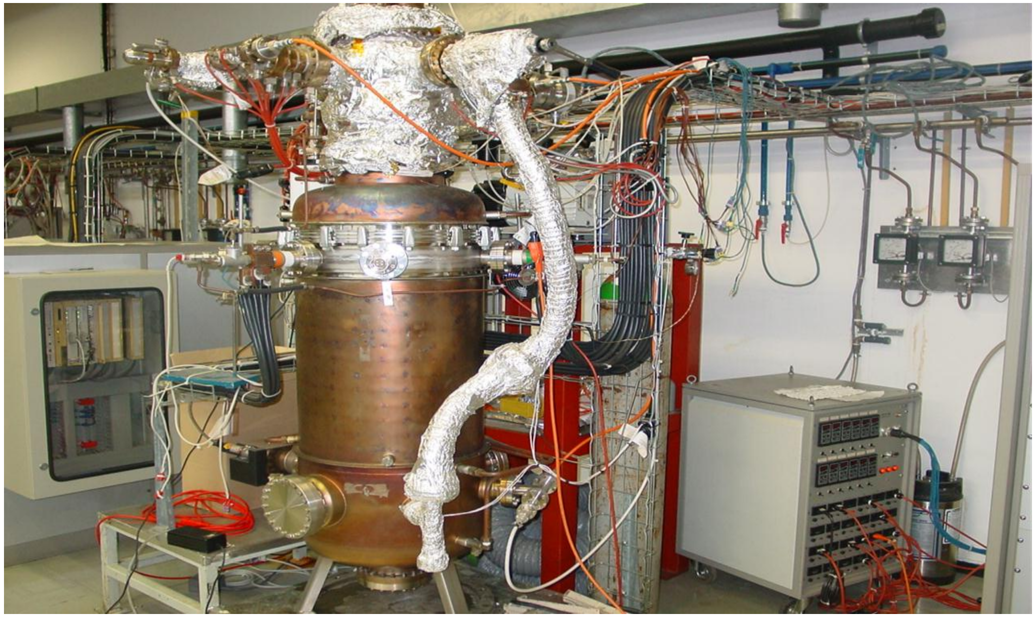




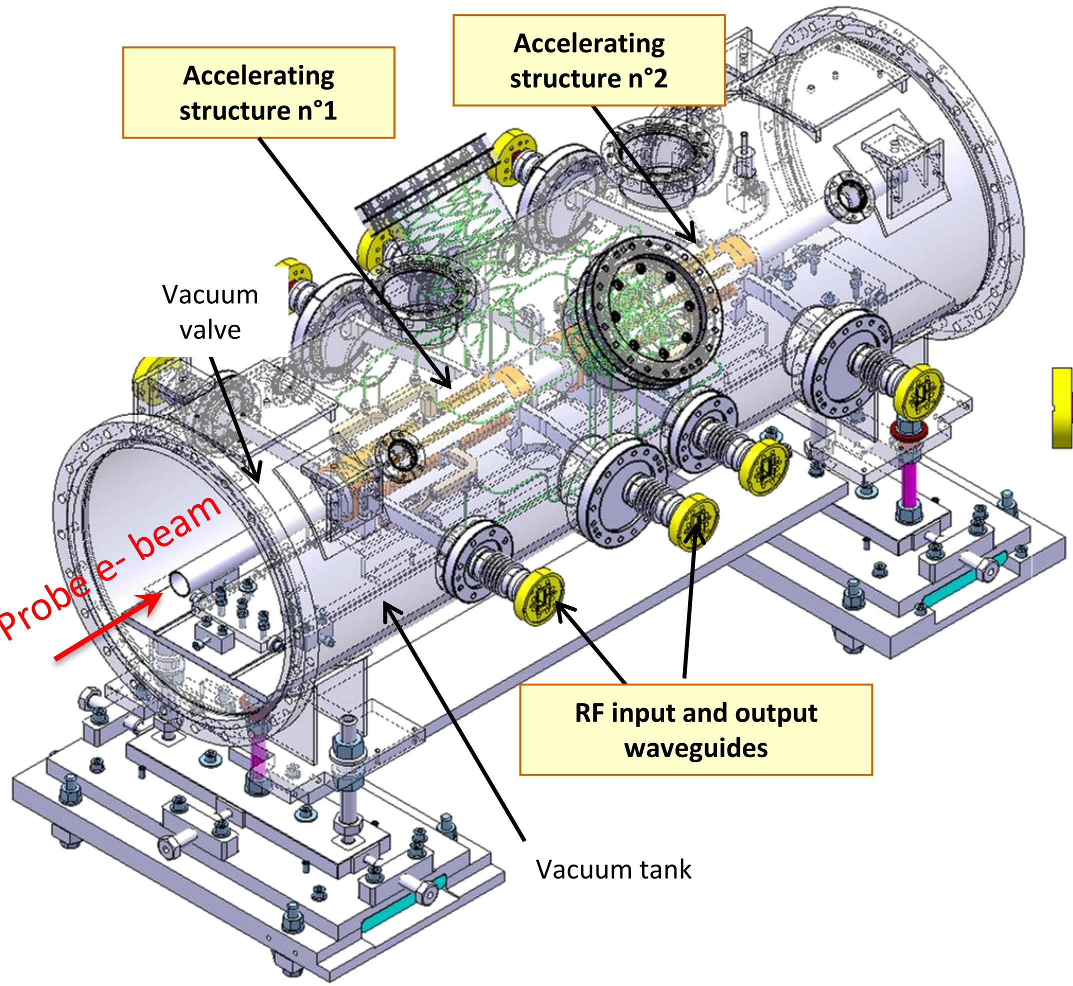


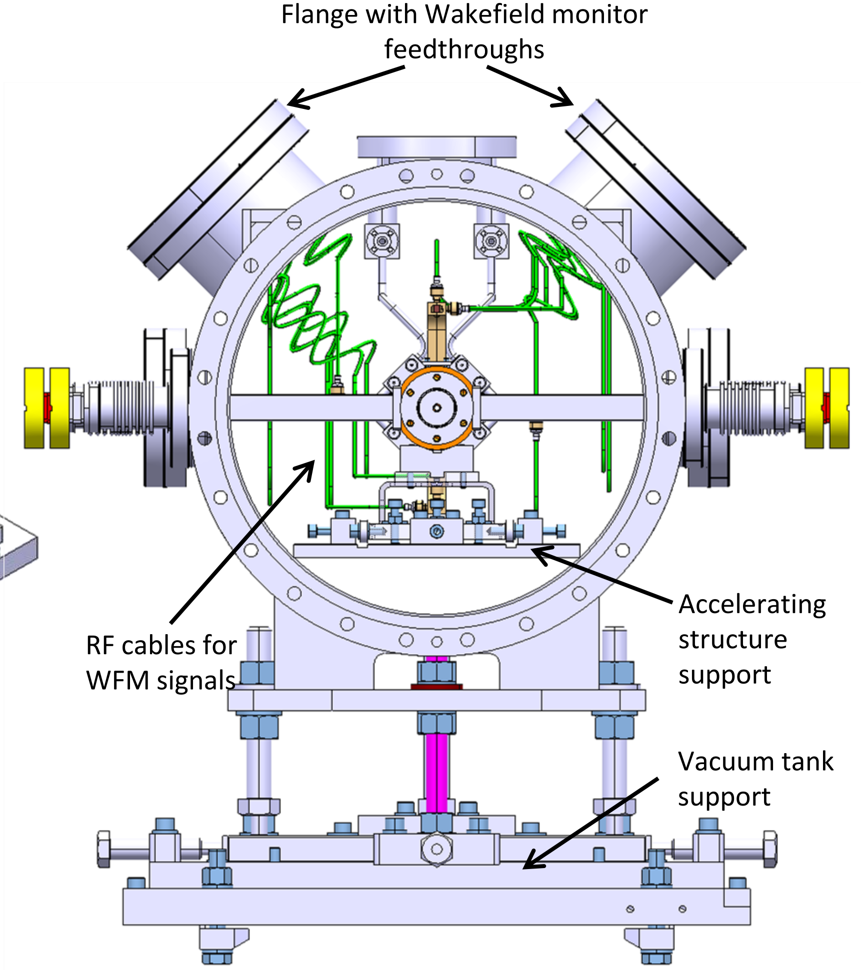
- Baking at 650° C at CERN under vacuum during 20 days to remove hydrogen
- Not enough place to put Two structures at the same time
- Baking of structure #1 is done and structure #2 will be finished this week

CERN furnace



Accelerating structures tank in TBTS

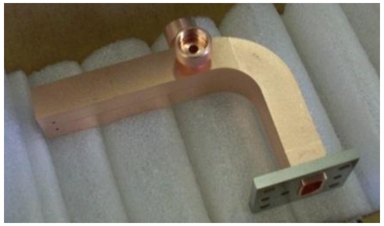
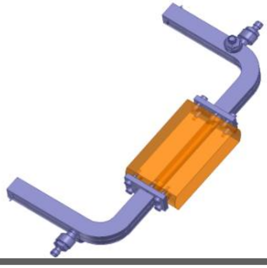




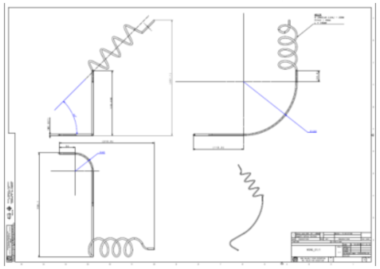
- Waveguides, supports, beam tubes, cooling circuits and flanges received
- Assembly at CERN
- RF calibration of the two structures after assembly

Accelerating structures tank accessories preparation

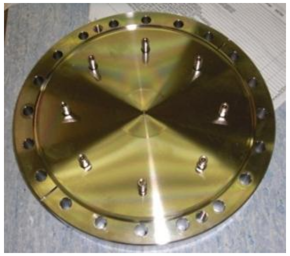
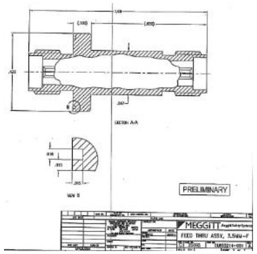
- WFM waveguide finished, need to do RF measurement with SiC loads and a special test piece

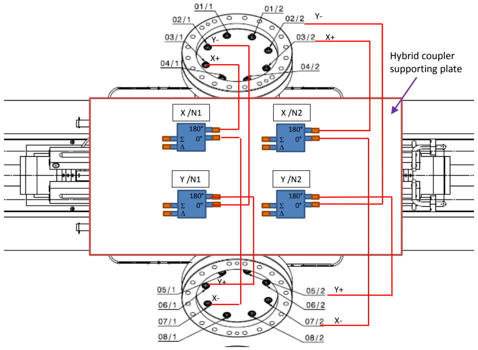
- Vacuum coax cables in SiO_2 received, need to bend it with precise shape to allow assembly inside the tank

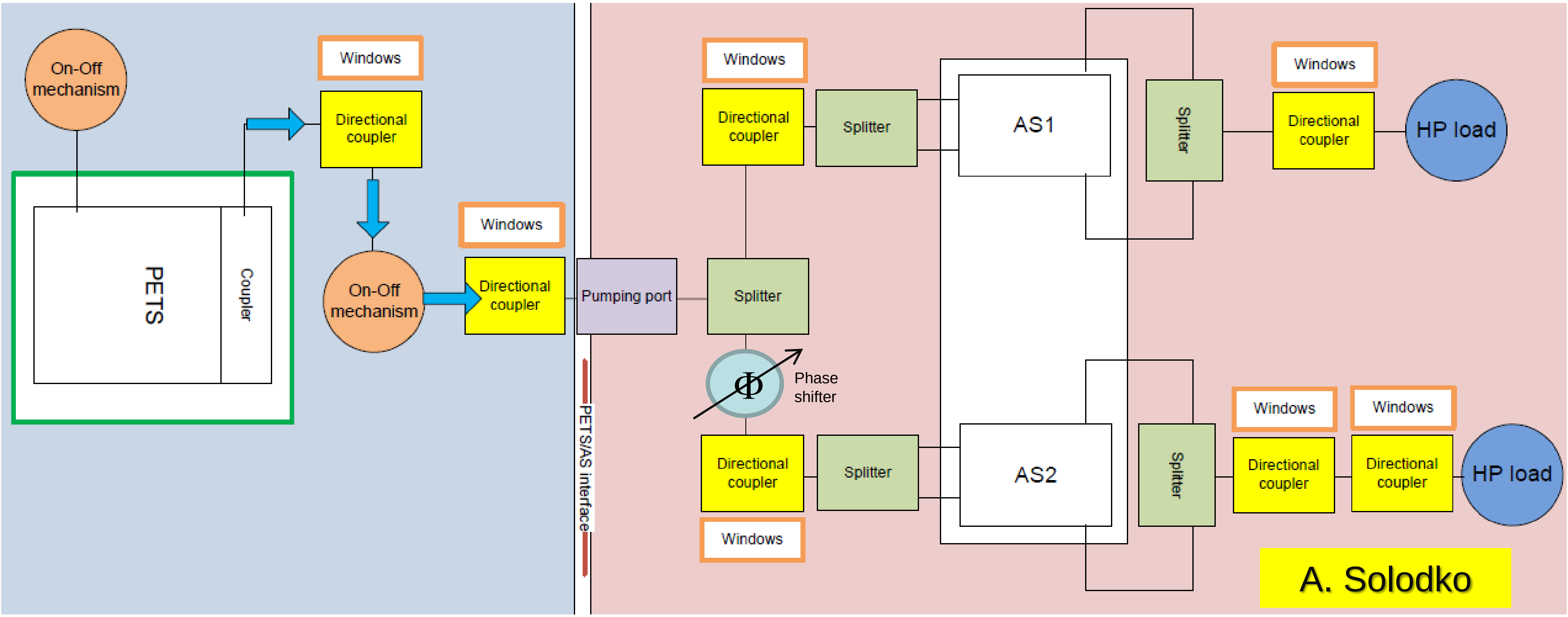


- Two CF flanges with 8 pick-ups EB welded

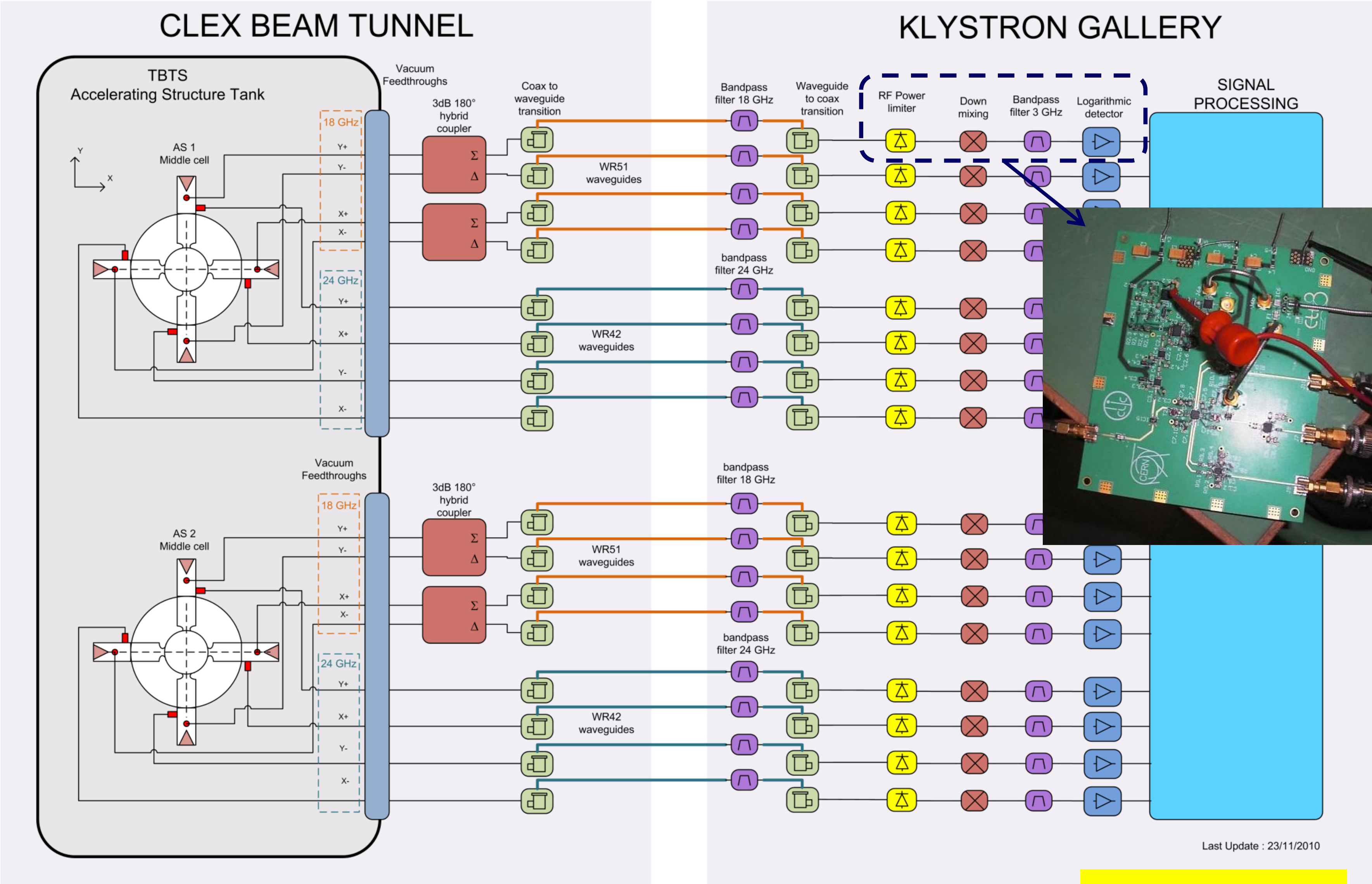
- 180° Hybrid couplers received, need to be calibrated and integrated on the tank





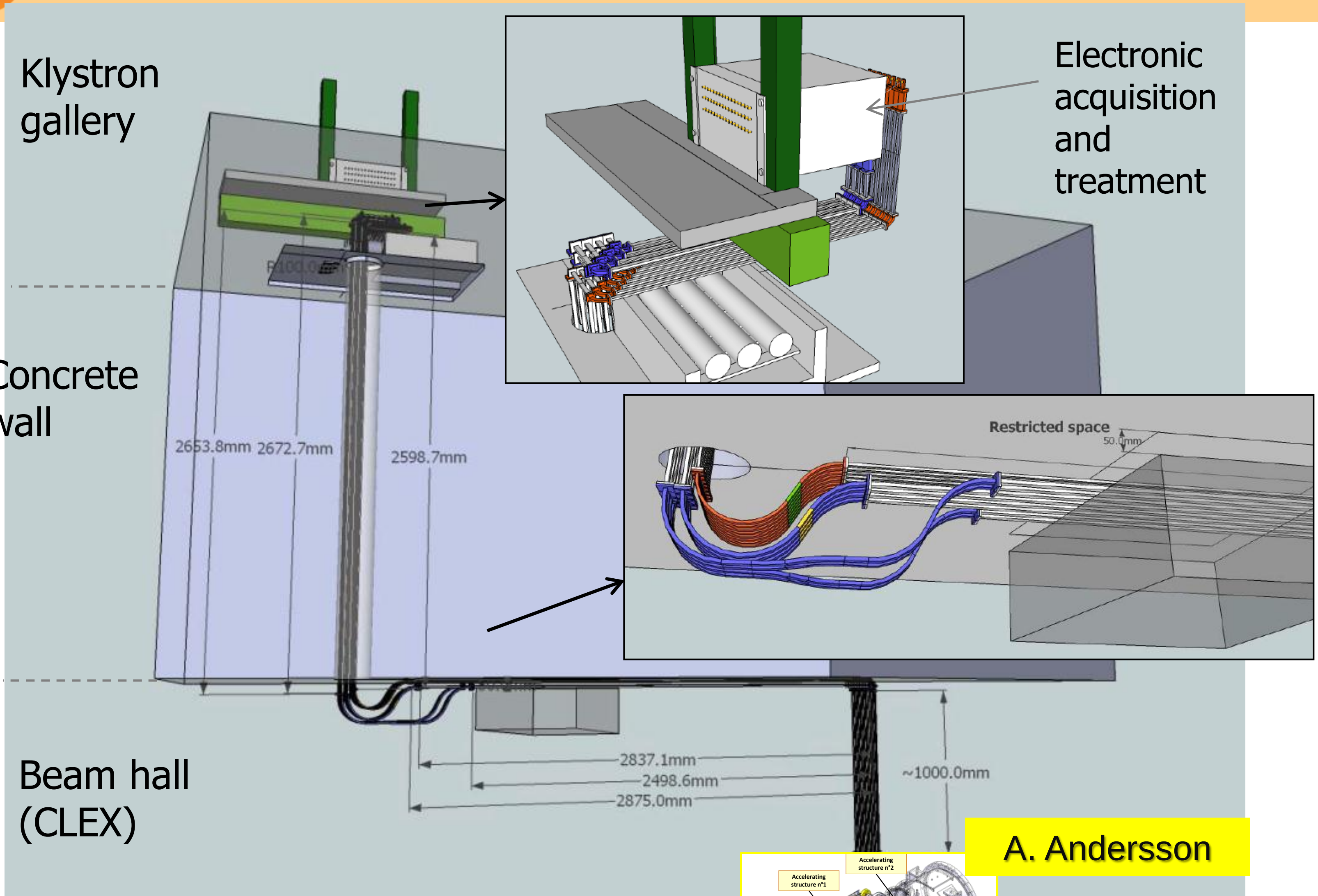
- Keep the new PETS On-off mechanism
- Add phase shifter in one of the accelerating structure waveguide lines
- Some adjustments needed to avoid conflict in the layout (displacement of the tank, change of waveguide lengths…)

WFM signals transport and treatment

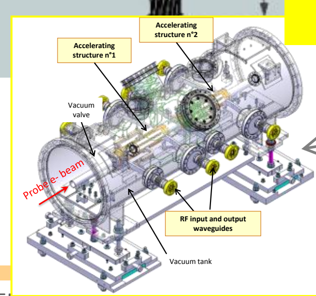


A. Andersson

18 and 24 GHz WFM signals in CTF3



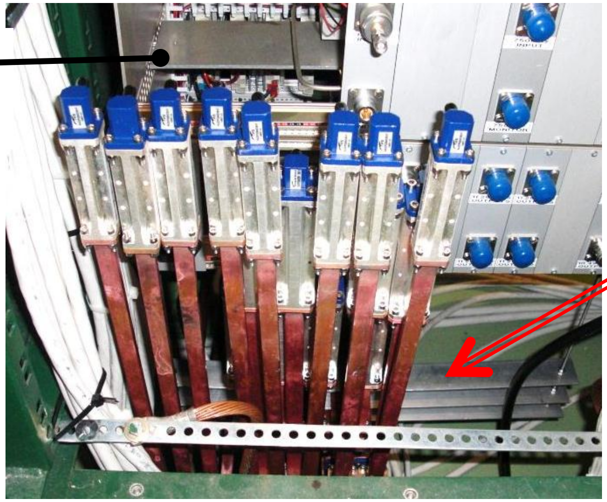
A. Andersson

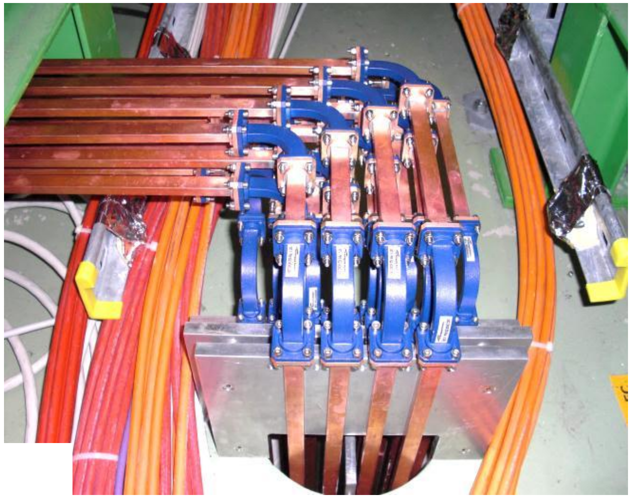


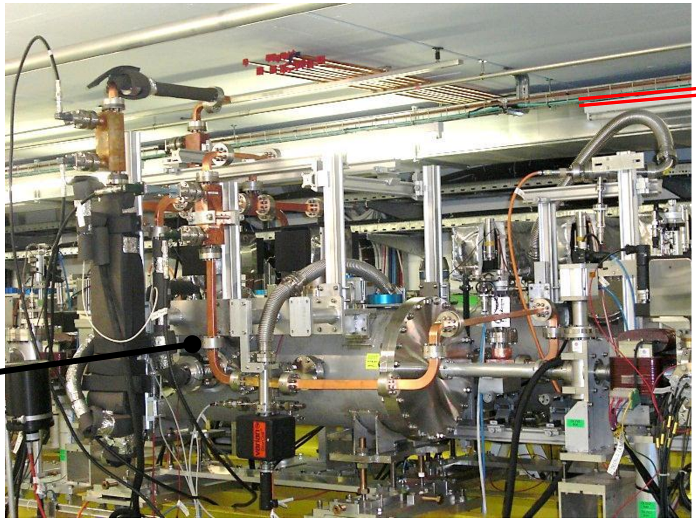
Accelerating structure tank

WFM waveguides installation

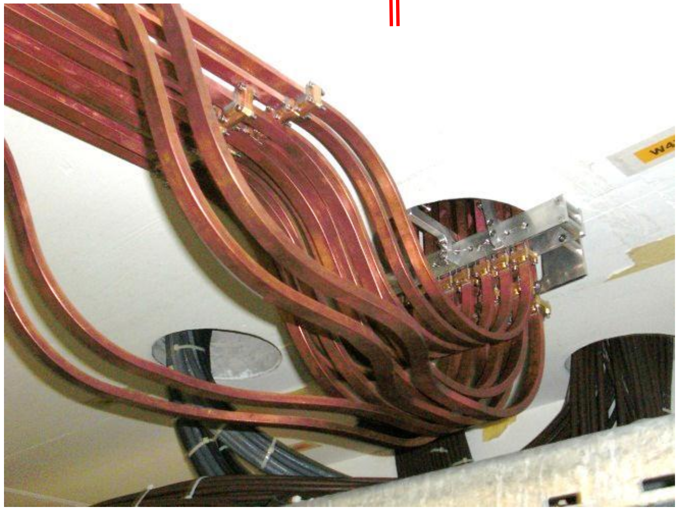
Electronic treatment crate







Accelerating structure tank

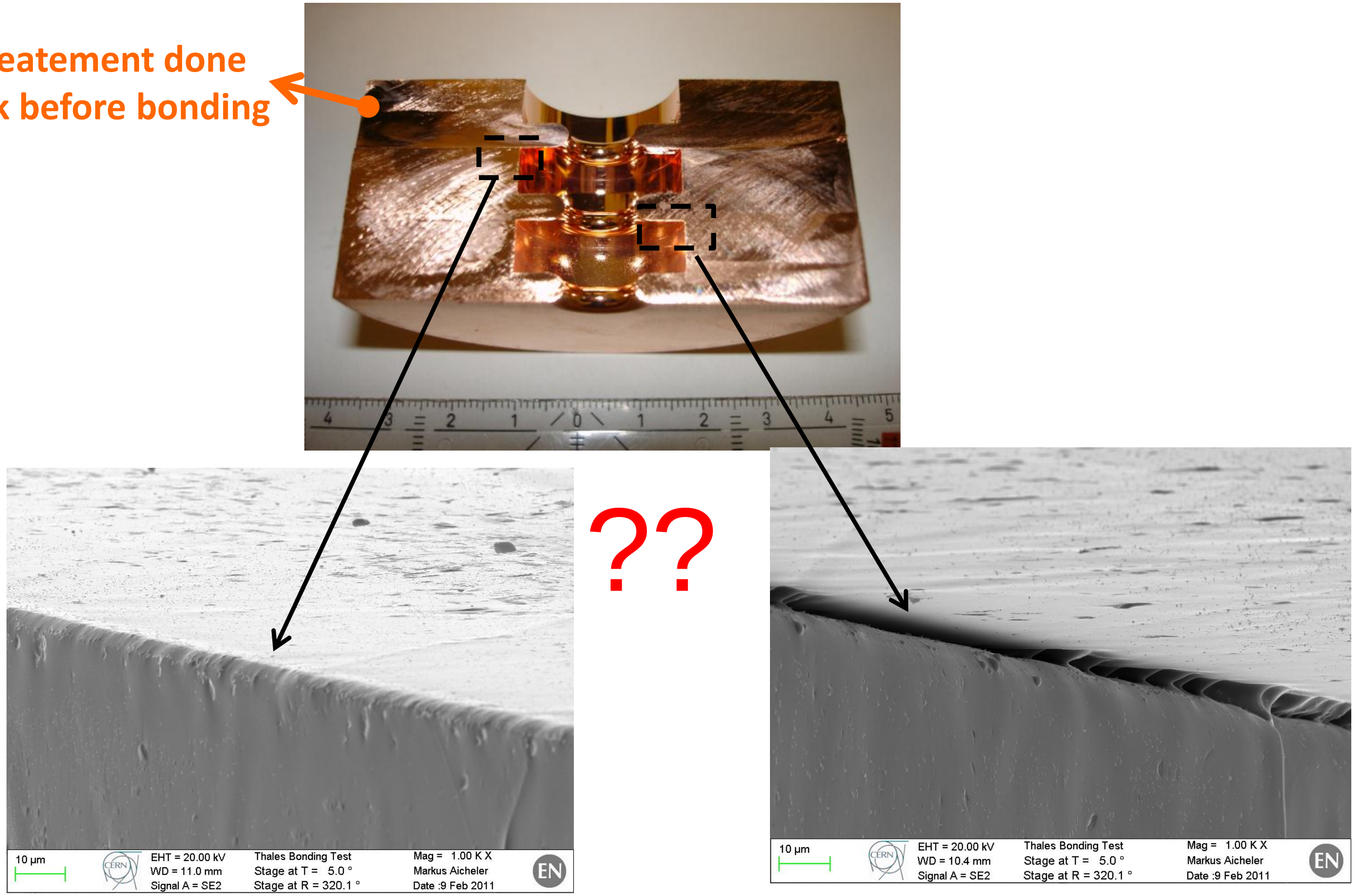


- 16 RF line WR51 (x8) and WR42 (x8) waveguide installed

Cell-to-cell contact improvements

- Understand the good bonded joint obtained on a test piece in Feb. 2011:

Thermal treatement done on this disk before bonding



- Second diffusion bonding test done last Dec. 2011 on a test coupler with same heat treatment
- Cut and SEM analysis in progress

TD24-WFM structures #3 and #4

- Two additional structures with the same design have been ordered as spares:
  - 1 in Mecachrome
  - 1 in VDL

- All the disks have been machined, received and visually checked at CERN (90% of the disks were OK)

- If nothing bad happens to structures #1 and #2, these two structures will be available for other experiments like:
  - Integration in a mini tank under ultra-clean condition, baking and high power tests with klystron
  - Wakefield monitor experiment with RF absorbers in every cells (but need a re-maching of all the cells and engineering design of manifold)

To be discussed…

- Very good progress in the structure fabrication with good RF properties at low level
- Still an important activity to prepare the WFM experiment (extra-simulations, calibration, procurements, …)
- Installation and start in TBTS hopefully in summer 2012

Many thanks to:

F. Ballester, P. Contrepois, W. Farabolini, P. Girardot, J. Novo, Y. Penichot

M. Aicheler, A. Andersson, A. Cherif, G. De Michele, Ph. De Suza, A. Grudiev, S. Lebet, M. Malabaila, A. Olyunin, A. Perez, G. Riddone, R. Ruber, J. Shi, A. Samoshkine, A. Solodko, R. Zennaro

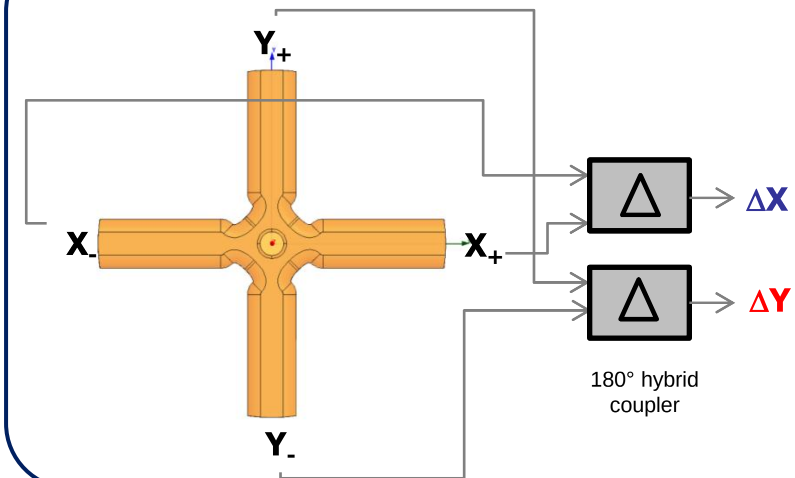
Bodycote, Mecachrome, Thales, VDL

Spare slides

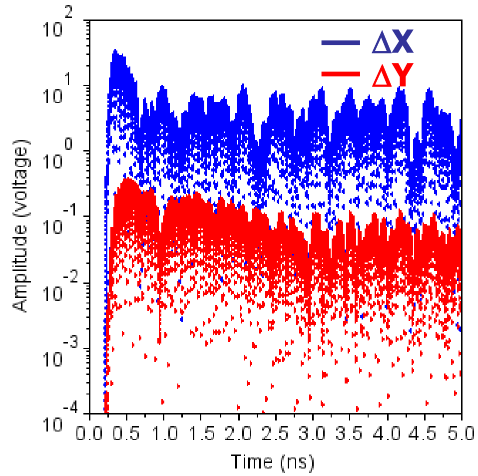
Wakefield monitor signals simulations

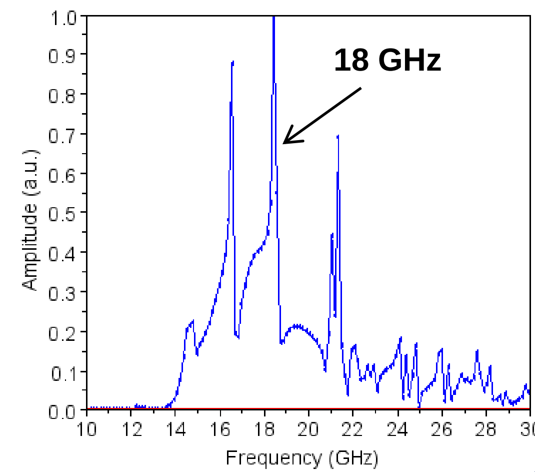
- Time domain simulations with GdfidL
  - Excitation of hybrid HEM modes in the structure by an offset beam
  - Record port signals in the of the middle cell damped waveguides on the two first modes

- First Port mode **(TM like modes)**

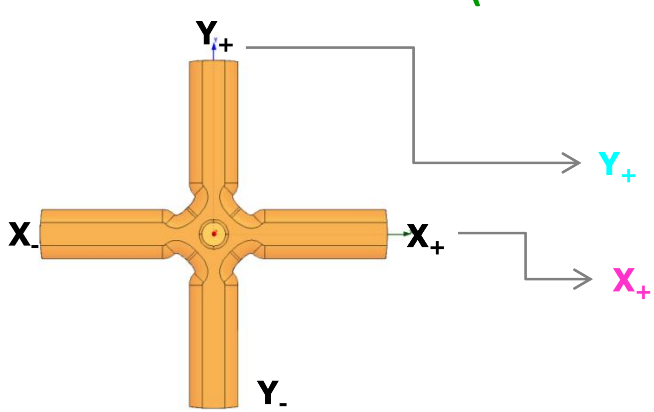


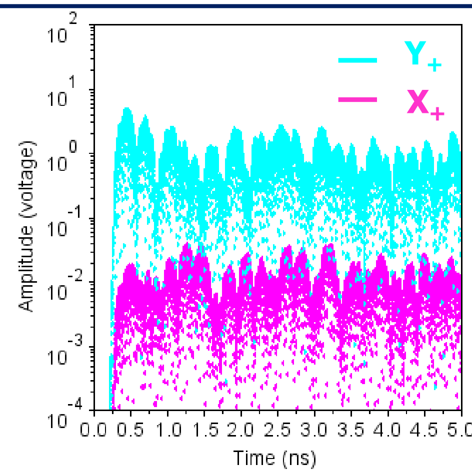
Simulation for a beam offset of δx = 1 mm

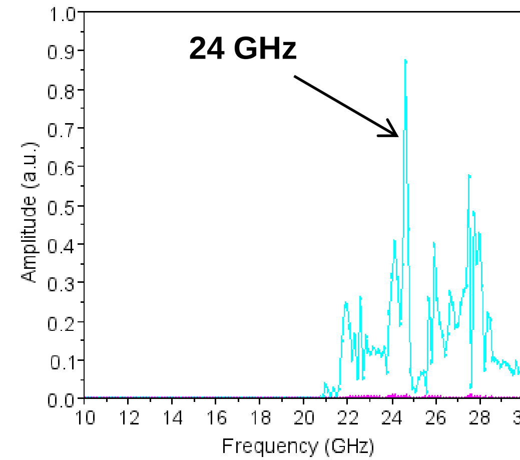




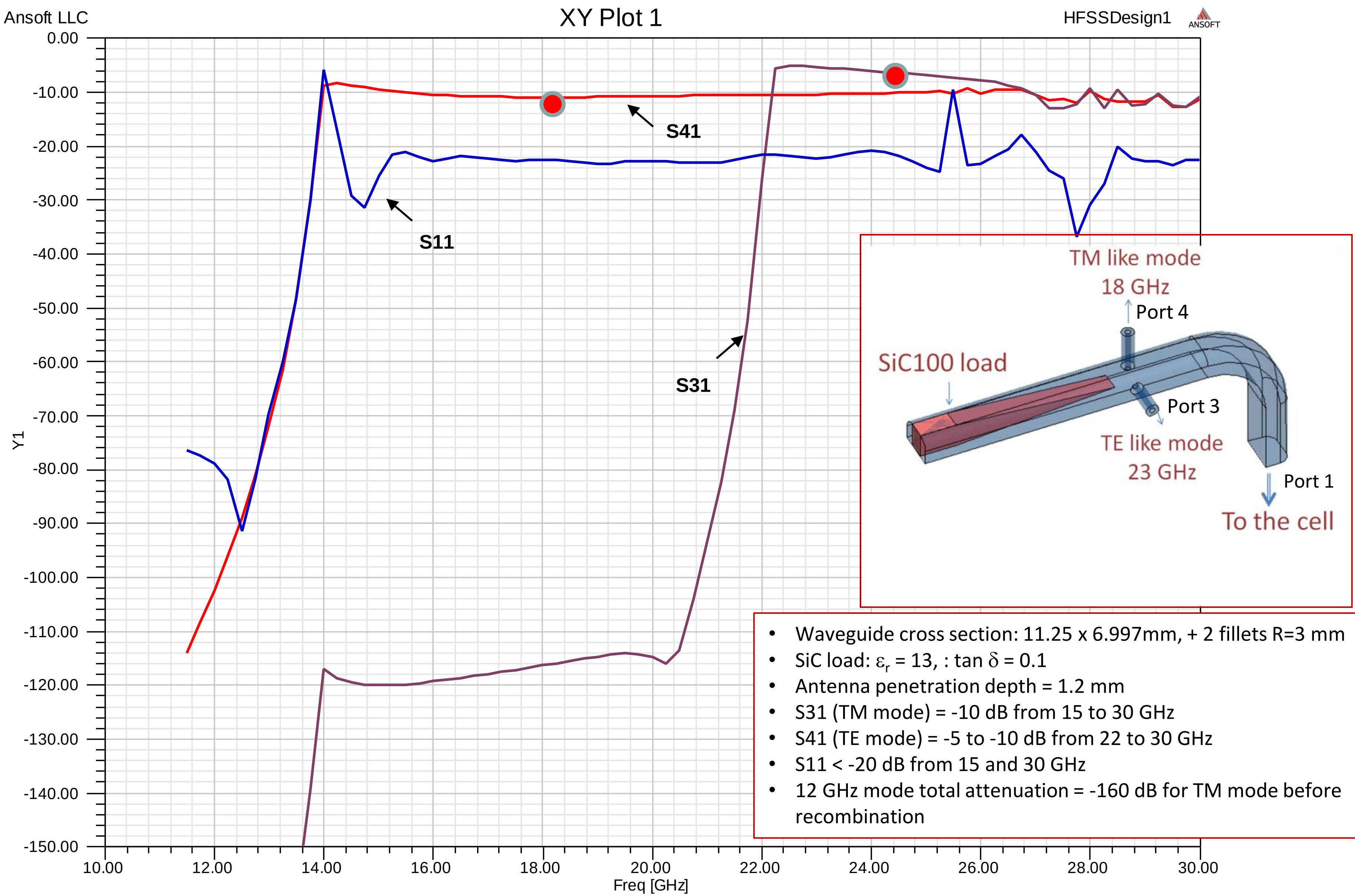
- Second Port mode **(TE like modes)**



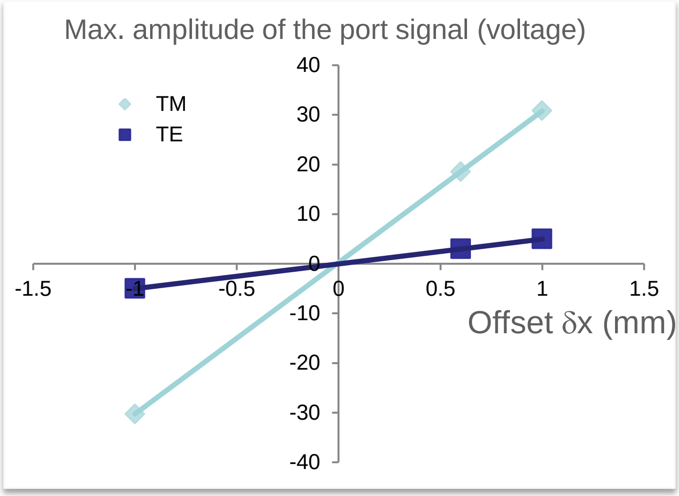


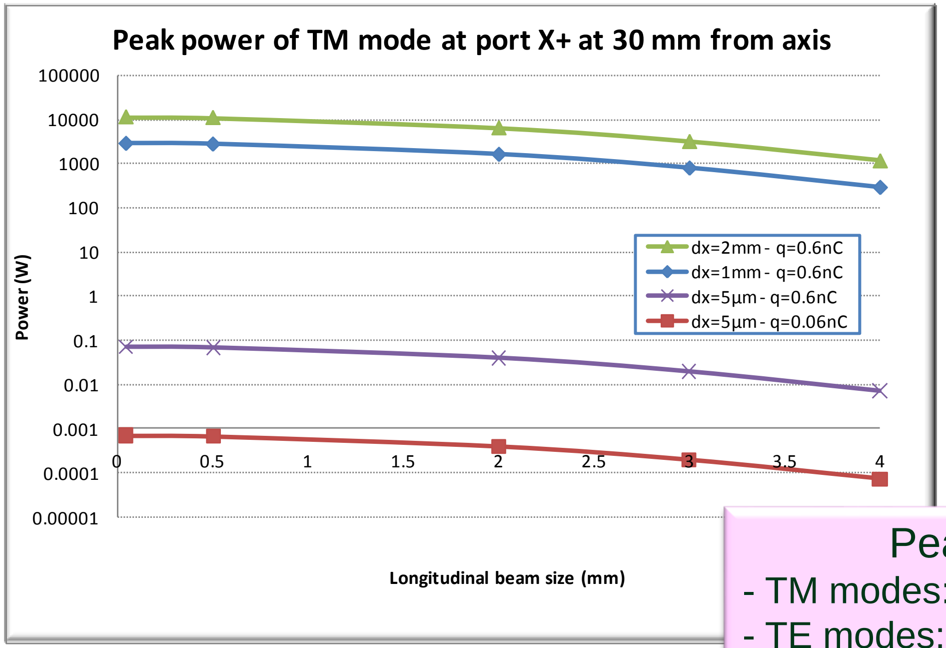


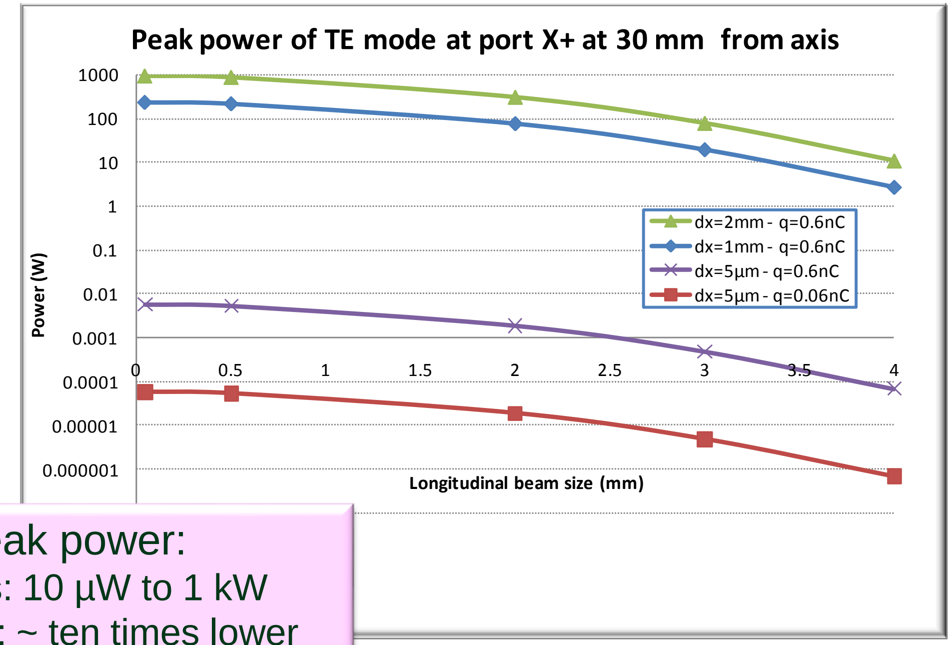
Wakefield monitor S parameters



- Waveguide cross section: 11.25 x 6.997mm, + 2 fillets R=3 mm
- SiC load: ε_r = 13, : tan δ = 0.1
- Antenna penetration depth = 1.2 mm
- S31 (TM mode) = -10 dB from 15 to 30 GHz
- S41 (TE mode) = -5 to -10 dB from 22 to 30 GHz
- S11 < -20 dB from 15 and 30 GHz
- 12 GHz mode total attenuation = -160 dB for TM mode before recombination







Peak power:
- TM modes: 10 µW to 1 kW
- TE modes: ~ ten times lower

The 24 cells of structure #1