

# Structure deformation: comparative analysis of RF and dimensional measurements

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CLIC Workshop 2015

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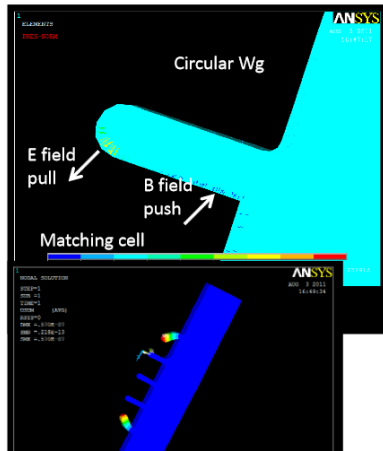
CERN

# Outline

- CLIC Accelerating Structure design and testing
- Questions:
  1. **Is the geometry of the disks preserved during bonding?**
  2. **Are the dimensions of the disks influenced by high power operations?**
- The case of the TD24R05 #1
  - RF measurements (before tuning, after tuning, after HP test)
  - Dimensional controls and measurements
  - Post mortem observations

# Acknowledgements

## Electromagnetic field



- Scaled to 150 MV/m Eacc
- $P = (-\epsilon_0 E^2 + \mu_0 H^2)/4$
- static simulation
- Material: Copper  $E = 110\text{GPa}$
- Max deform: 0.06um, very small.
- 0.06um  $\rightarrow$  12kHz
- not the right direction
- HFSS result: Iris deform 10um  $\rightarrow$  ~ 2MHz

## Comparison of detuning of different structures

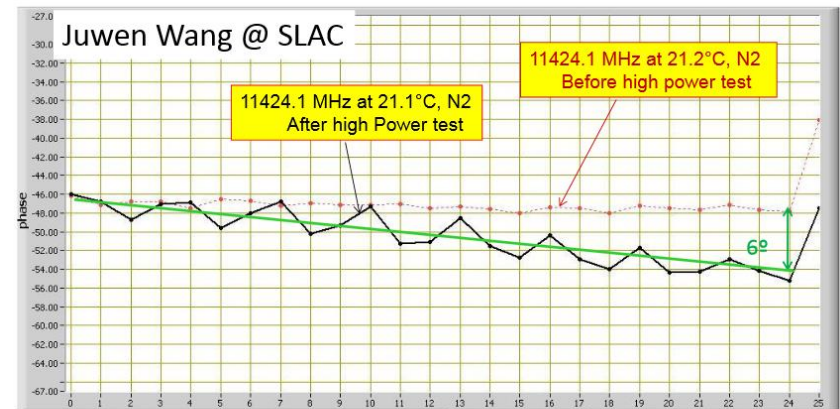
	T18 SLAC N1	TD18 SLAC	T24 SLAC	T18 CERN N2	TD24 CLEX	TD24 R05 N1 XBox1
Analysed at	SLAC	SLAC	SLAC	CERN	CERN	CERN
by	J.W.	J.W.	J.W.	J.S.	R.W.	R.W.
Output matching						
Standing Wave (VSWR)	1.06	1.22	1.05	1.11	1.05	1.15
R [%]	3.0	10	2.5	5.0	2.6	7.0
R [dB]	-30	-20	-32	-26	-32	-23
df <sub>end</sub> [MHz]	+2.0	+7.0	+2.5	+3.0	+0.1	-2.2
df <sub>end-1</sub> [MHz]					+1.0	+1.7
Regular cells						
Total phase shift [°]		-16	6		-9.2	~ -6
avg(df) [MHz]		+1.0	-0.3		+0.4	+0.2
std(df) [MHz]					+0.2	+0.3
notes	$\Delta\phi_{19 \rightarrow 20} \sim 100^\circ$		$\Delta\phi_{19 \rightarrow 20} \sim 100^\circ$		$\Delta\phi_{19 \rightarrow 20} \sim 100^\circ$	

Big acknowledgements to the work done before by

- Jiaru Shi (THU)
- Juwen Fang (SLAC)
- Rolf Wegner (CERN)

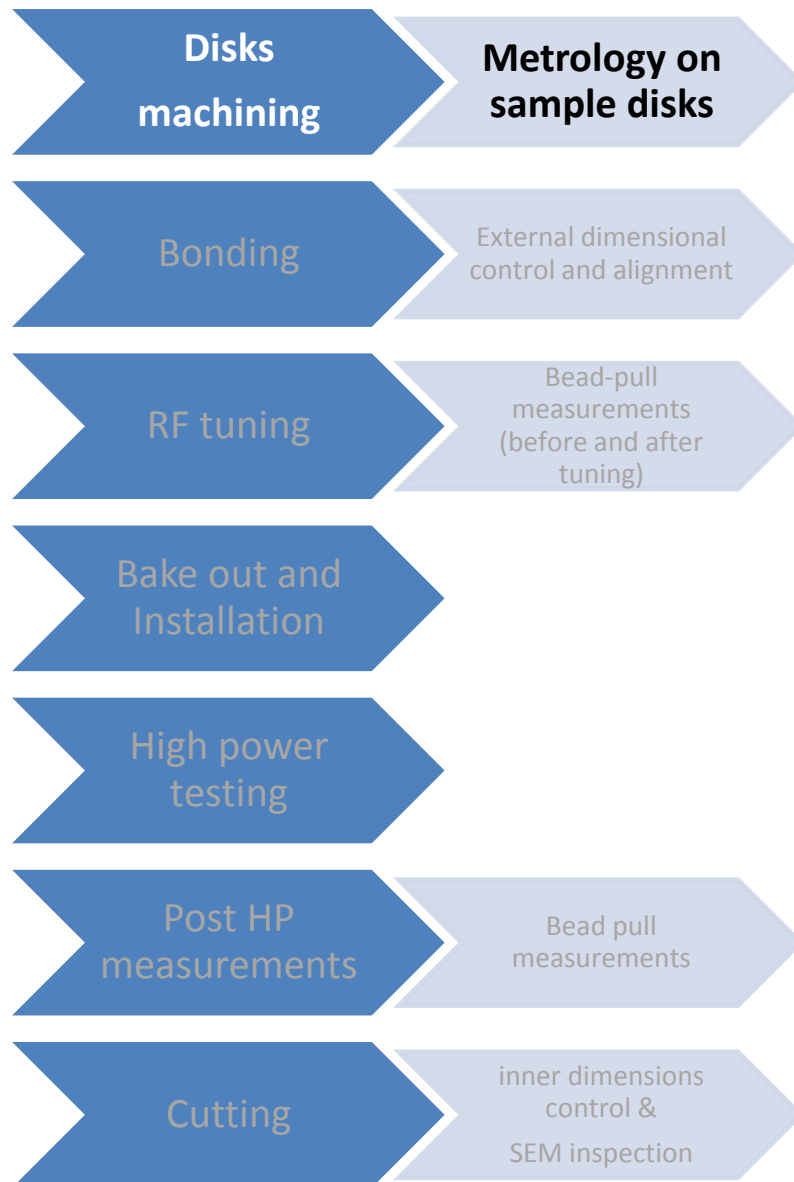


## Phase Measurement of T24-SLAC Before and After 800 Hours High Power Test



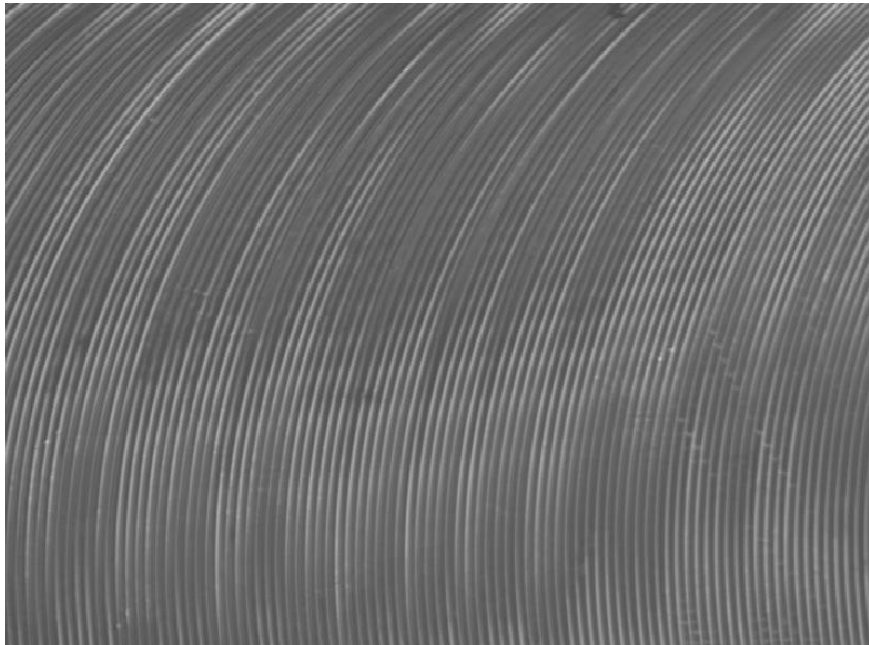
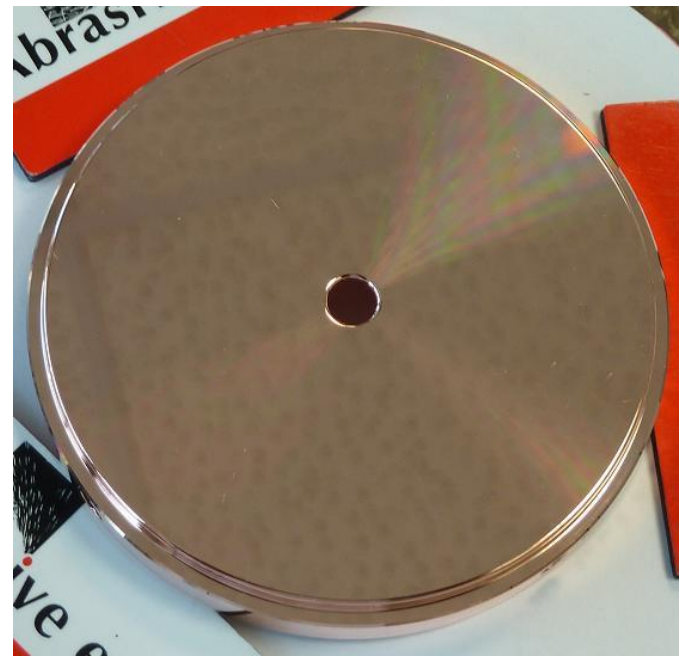
Select bead pulling frequencies based on the measurement condition to get  $2\pi/3$  phase advance for both before and after high power test

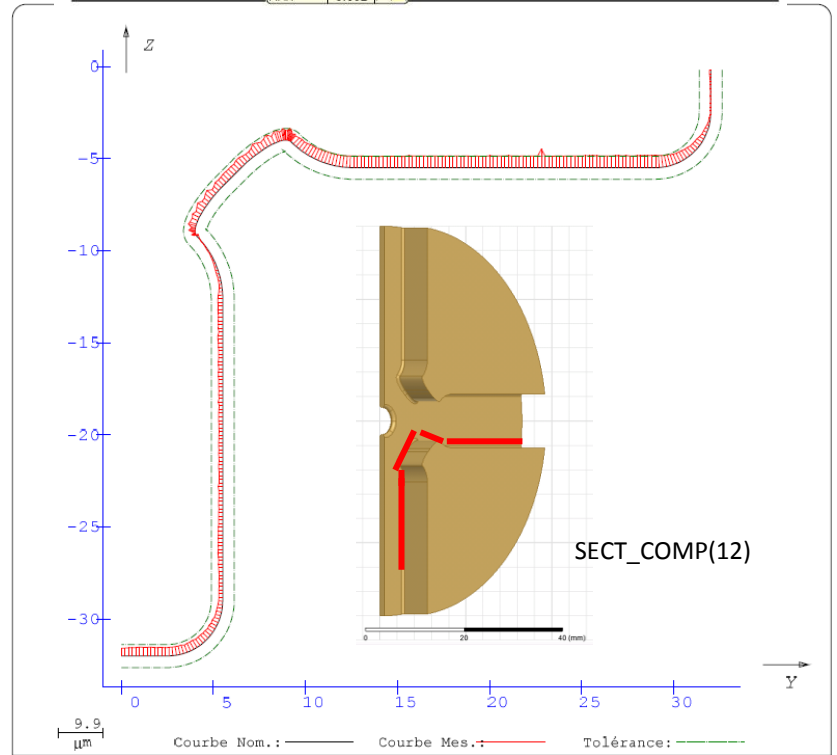
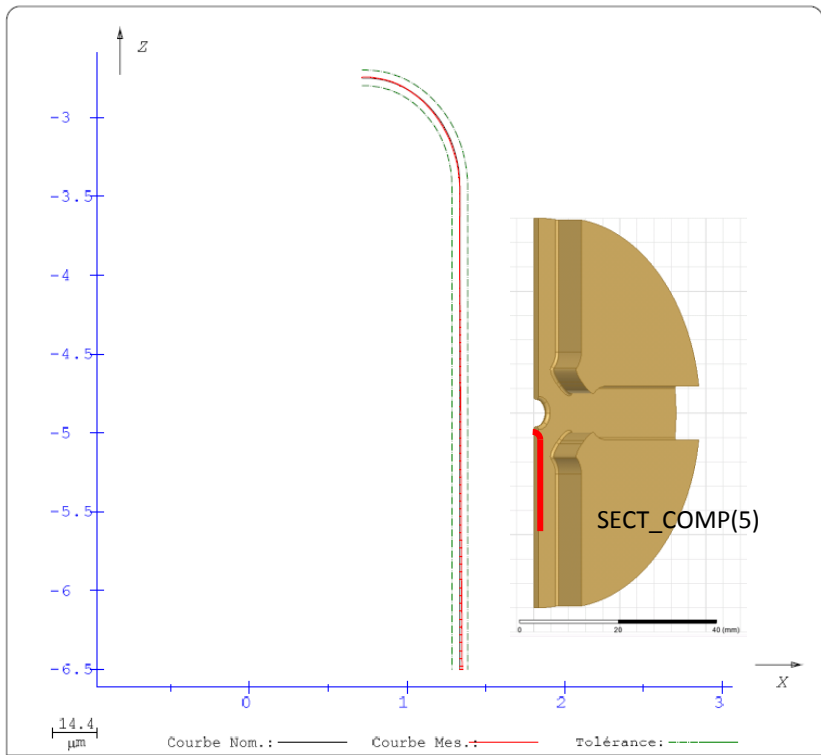
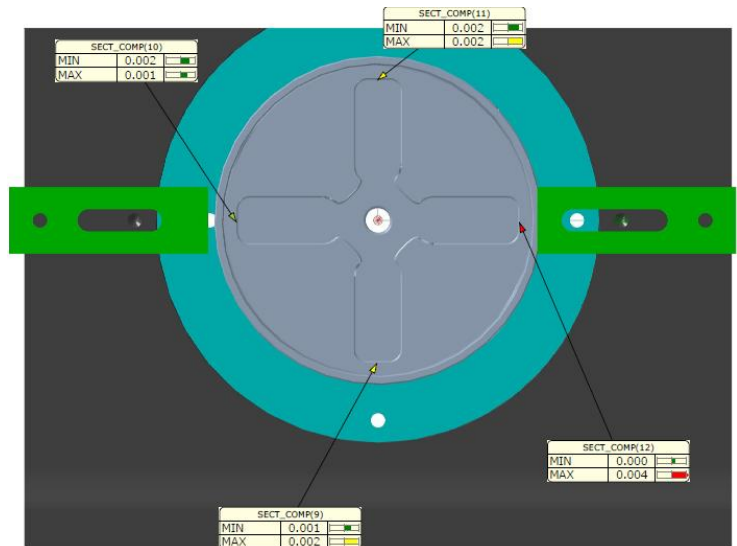
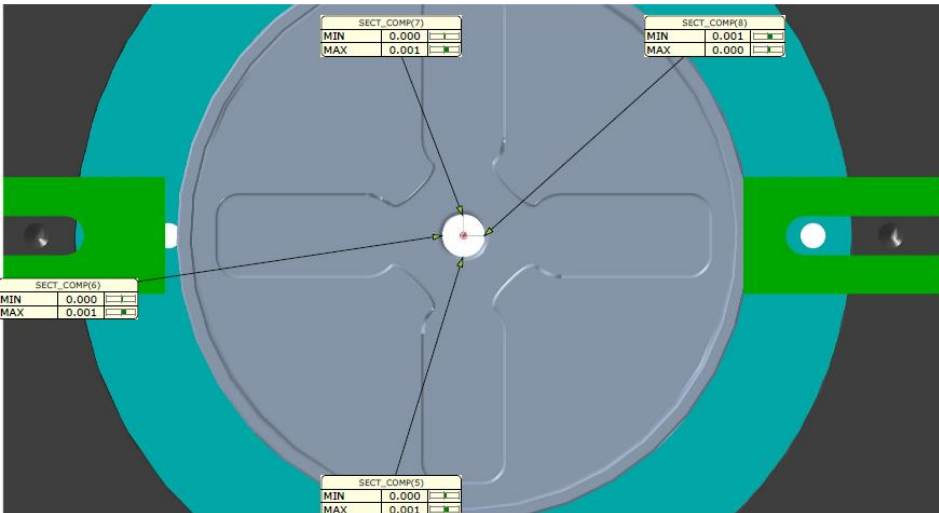
# CLIC acc. struct design and testing



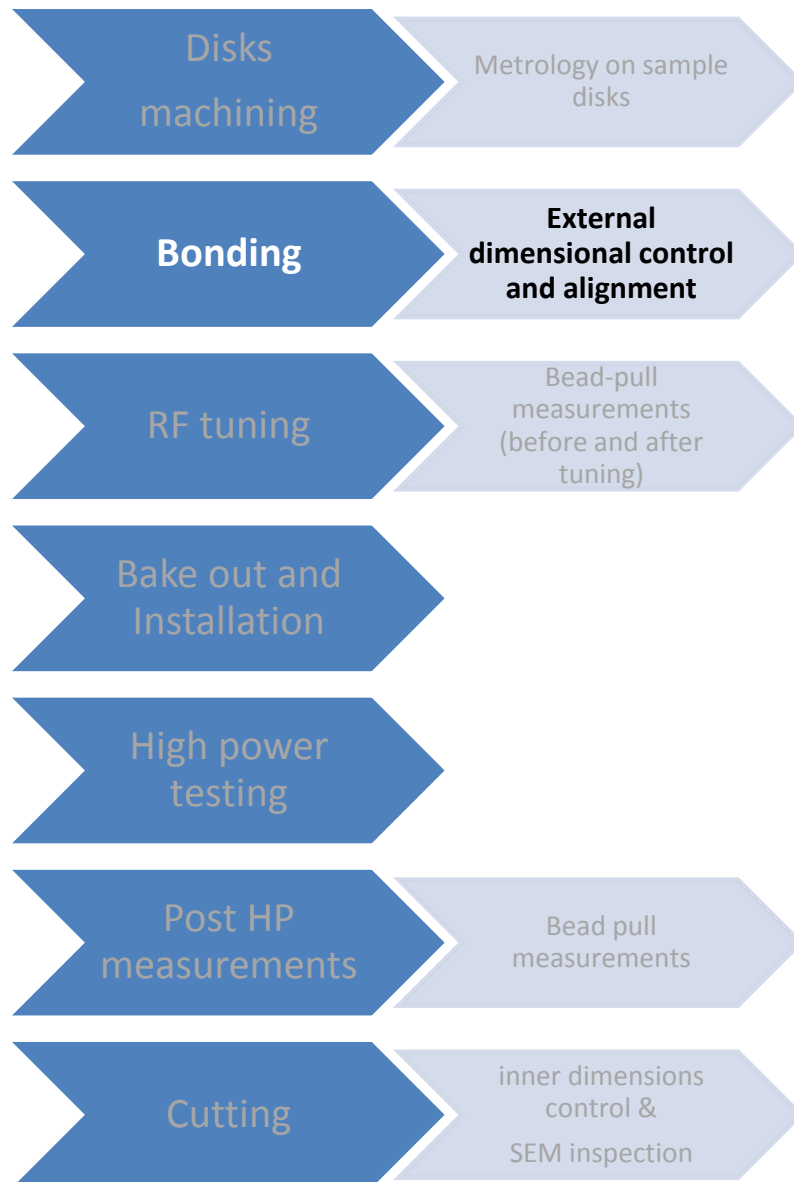
**1. Is the geometry of the disks preserved during bonding?**

**2. Are the dimensions of the disks influenced by high power operations?**





# CLIC acc. struct design and testing



**1. Is the geometry of the disks preserved during bonding?**

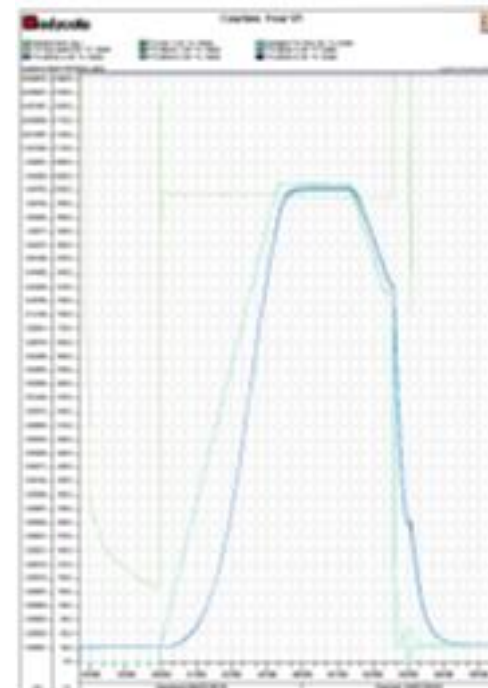
**2. Are the dimensions of the disks influenced by high power operations?**



# Rectitude après Bonding (The straightness after bonding)



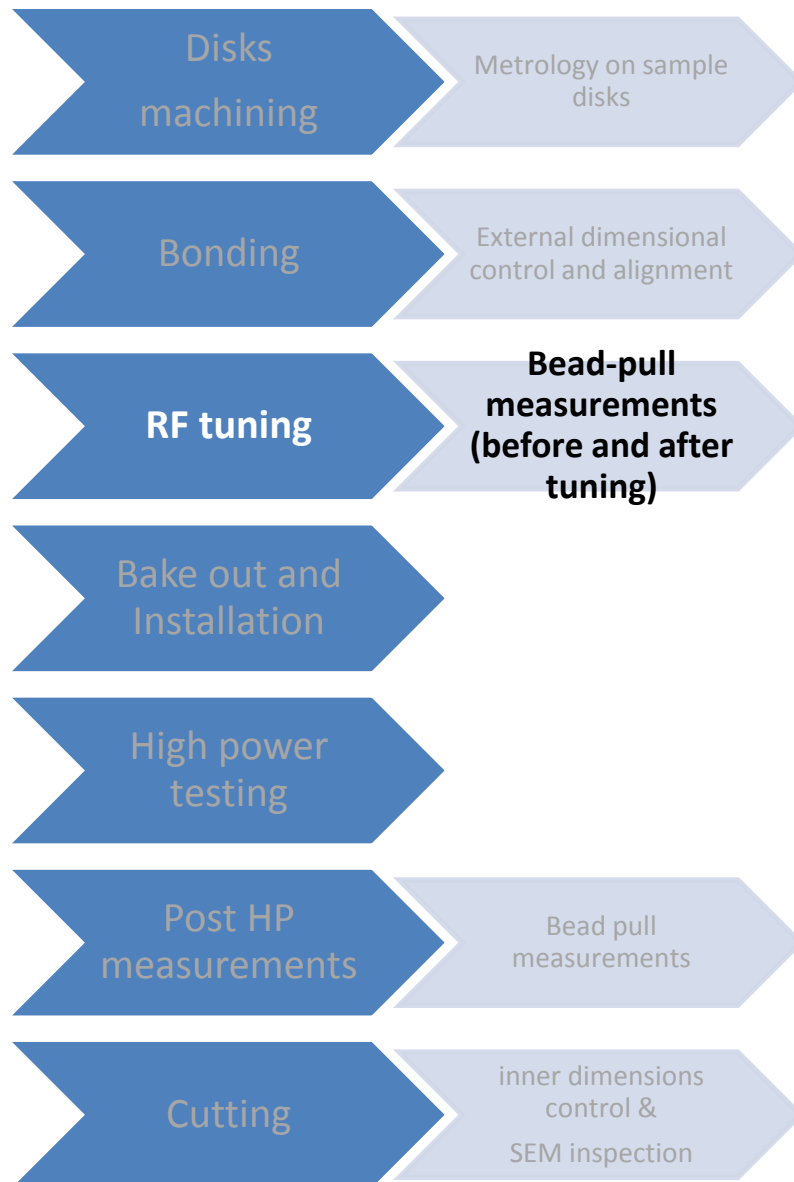
Bonding temperature: 1030 °C



VT = 0.041 [mm]  
A = 90.022 [DEG]  
F = 0.008 [mm]  
ENTER]: Fin de commande  
=N], [ü(c)]: Affichage graphique



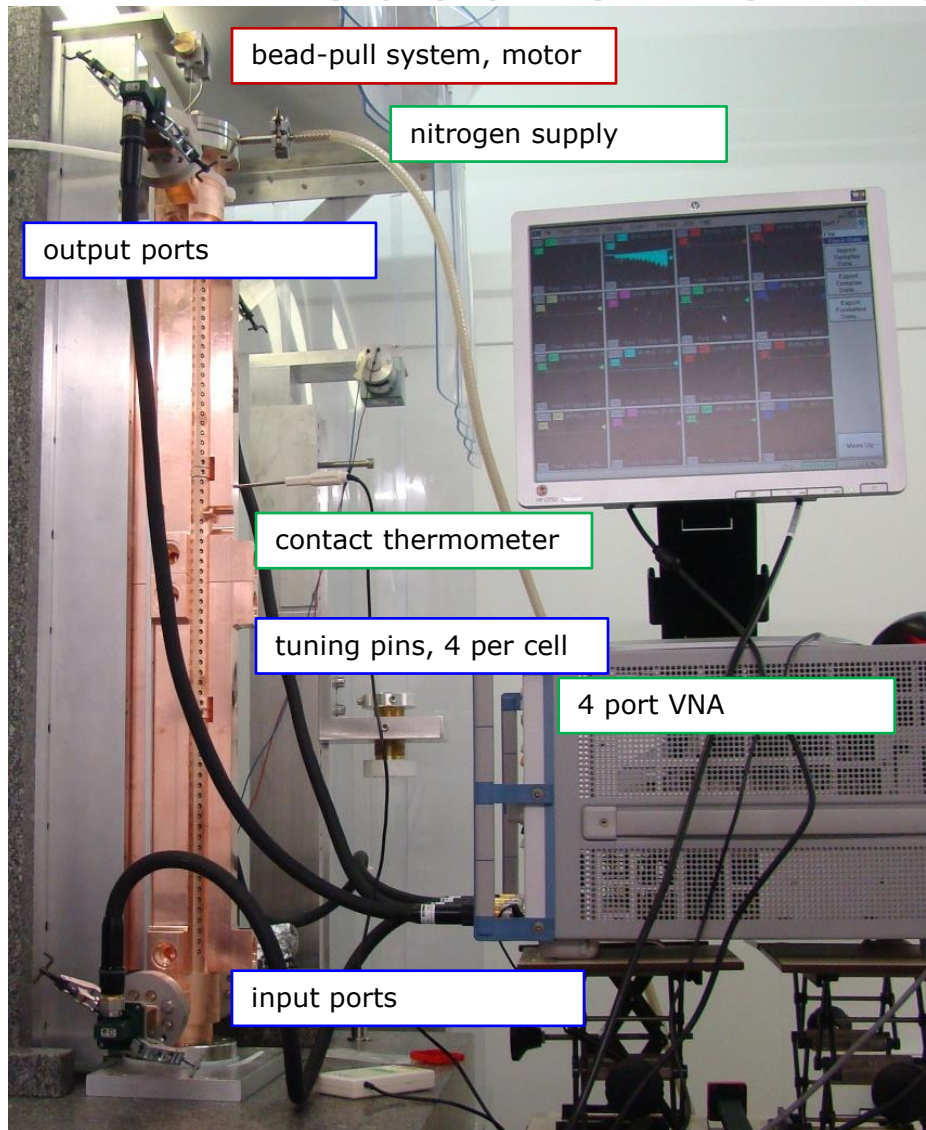
# CLIC acc. struct design and testing



**1. Is the geometry of the disks preserved during bonding?**

**2. Are the dimensions of the disks influenced by high power operations?**

# RF measurement and tuning setup

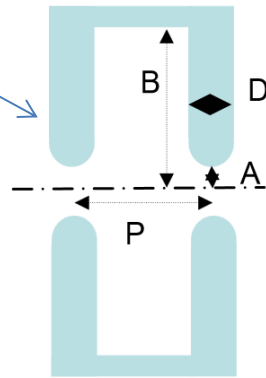
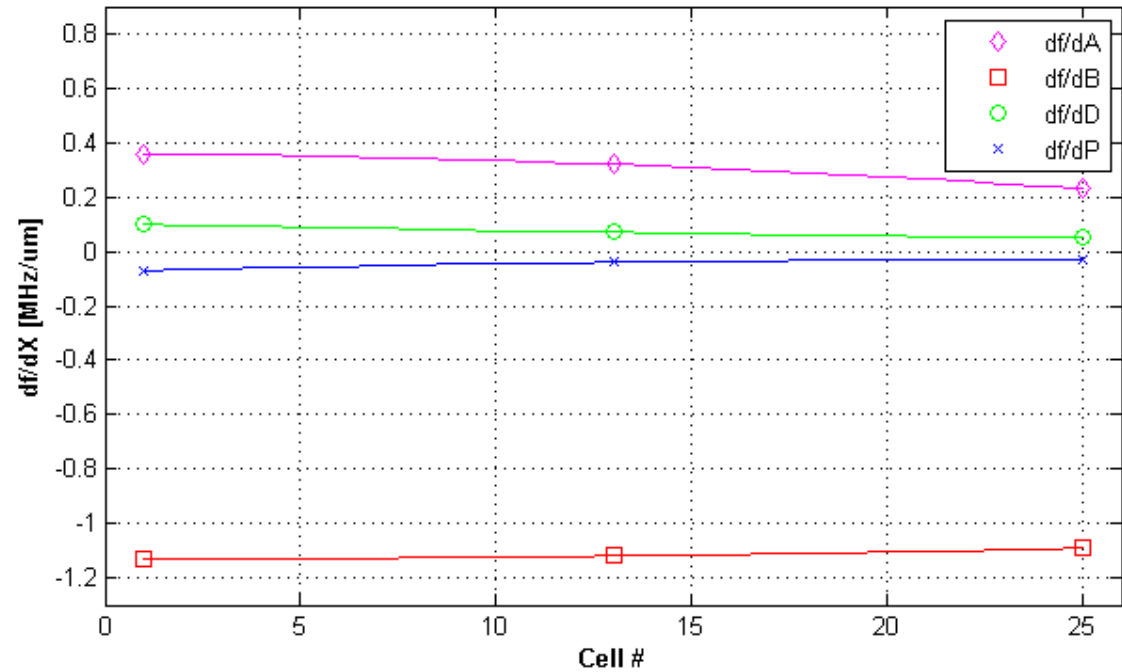
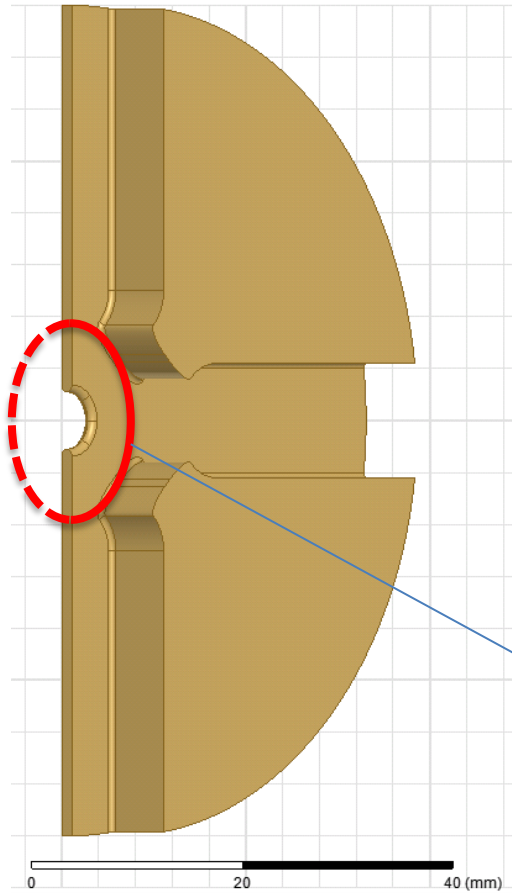


tuning hammer

# Tuning record TD24R05\_N1

# cell	tuning record of  ds11 *sign(df) (mU)															$\Delta f$ (MHz)
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
1		9.9	9.8	-5.4		-6.5			15.3					3.2		2.5
2	49.3	6.4	6.2	-4.1				23.3	9.1		12.3			20.4		11.9
3		1.0	4.6	5.4								2.1				1.3
4		1.8		-3.5			3.5					2				0.4
5		-4.6								-2.2						-0.7
6		-14.5					2									-1.2
7		-13.5					1.9					1.3				-1.0
8		10.7								-6.1		2.2			-5.7	0.1
9		2.1		4.0								-0.5				0.5
10		7.0										2.6				0.9
11		14.2								-3.7		-0.7				0.9
12		3.3		5.1			-1.8									0.6
13		19.8		-3.9			2.2									1.7
14		12.3		-5.6			3.1			-4						0.6
15		14.3		6.1			-2.1									1.8
16		5.2					1.9									0.7
17		12.2		-4.1			3.5			-2.9						0.8
18		19.0					-2.2									1.6
19		-9.0					3									-0.6
20		-8.5					1.5			-2.3						-0.9
21		4.4			-4.4					1.7						0.2
22		17.2		4.9												2.2
23		12.4								-3.3	0.2					0.9
24		-14.5														-1.4
25		24.5		3.5						-2.9	1.2					2.6
26		6.7									-3.2		2.4			0.6

# Sensitivity

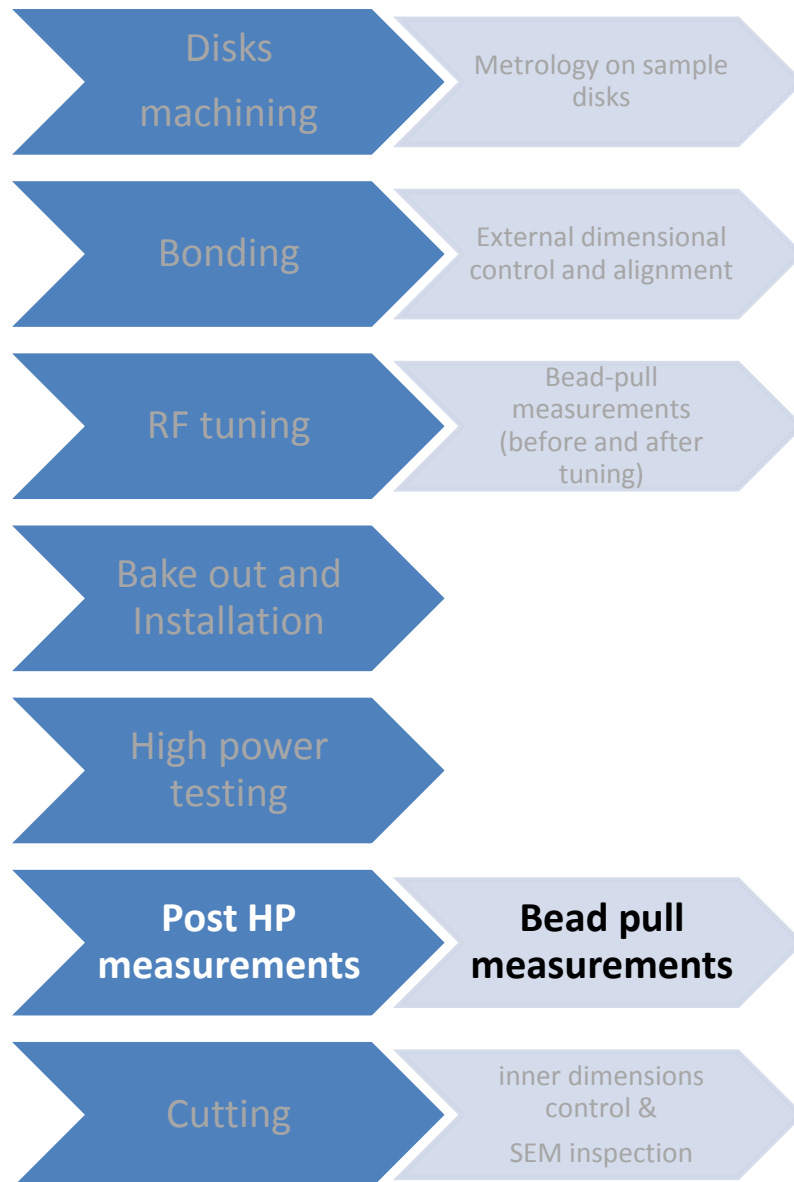


	$df/dA$ [MHz/um]	$df/dB$ [MHz/um]	$df/dD$ [MHz/um]	$df/dP$ [MHz/um]
First	0.36	-1.13	0.10	-0.07
Mid	0.32	-1.12	0.07	-0.04
Last	0.23	-1.09	0.05	-0.03

# Tuning record TD24R05\_N1

# cell	tuning record of  ds11 *sign(df) (mU)															Δf (MHz)	equiv. lumped deformation (μm)
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15		
1		9.9	9.8	-5.4		-6.5			15.3					3.2		2.5	
2	49.3	6.4	6.2	-4.1				23.3	9.1		12.3			20.4		11.9	-10.5
3		1.0	4.6	5.4								2.1				1.3	-1.1
4		1.8		-3.5			3.5					2				0.4	-0.3
5		-4.6								-2.2						-0.7	0.6
6		-14.5					2									-1.2	1.1
7		-13.5					1.9					1.3				-1.0	0.9
8		10.7								-6.1		2.2			-5.7	0.1	-0.1
9		2.1		4.0								-0.5				0.5	-0.5
10		7.0										2.6				0.9	-0.8
11		14.2								-3.7		-0.7				0.9	-0.8
12		3.3		5.1			-1.8									0.6	-0.6
13		19.8		-3.9			2.2									1.7	-1.5
14		12.3		-5.6			3.1			-4						0.6	-0.5
15		14.3		6.1			-2.1									1.8	-1.6
16		5.2					1.9									0.7	-0.6
17		12.2		-4.1			3.5			-2.9						0.8	-0.8
18		19.0					-2.2									1.6	-1.5
19		-9.0					3									-0.6	0.5
20		-8.5					1.5			-2.3						-0.9	0.8
21		4.4			-4.4					1.7						0.2	-0.2
22		17.2		4.9												2.2	-2.0
23		12.4								-3.3	0.2					0.9	-0.8
24		-14.5														-1.4	1.3
25		24.5		3.5						-2.9	1.2					2.6	-2.4
26		6.7									-3.2		2.4			0.6	

# CLIC acc. struct design and testing

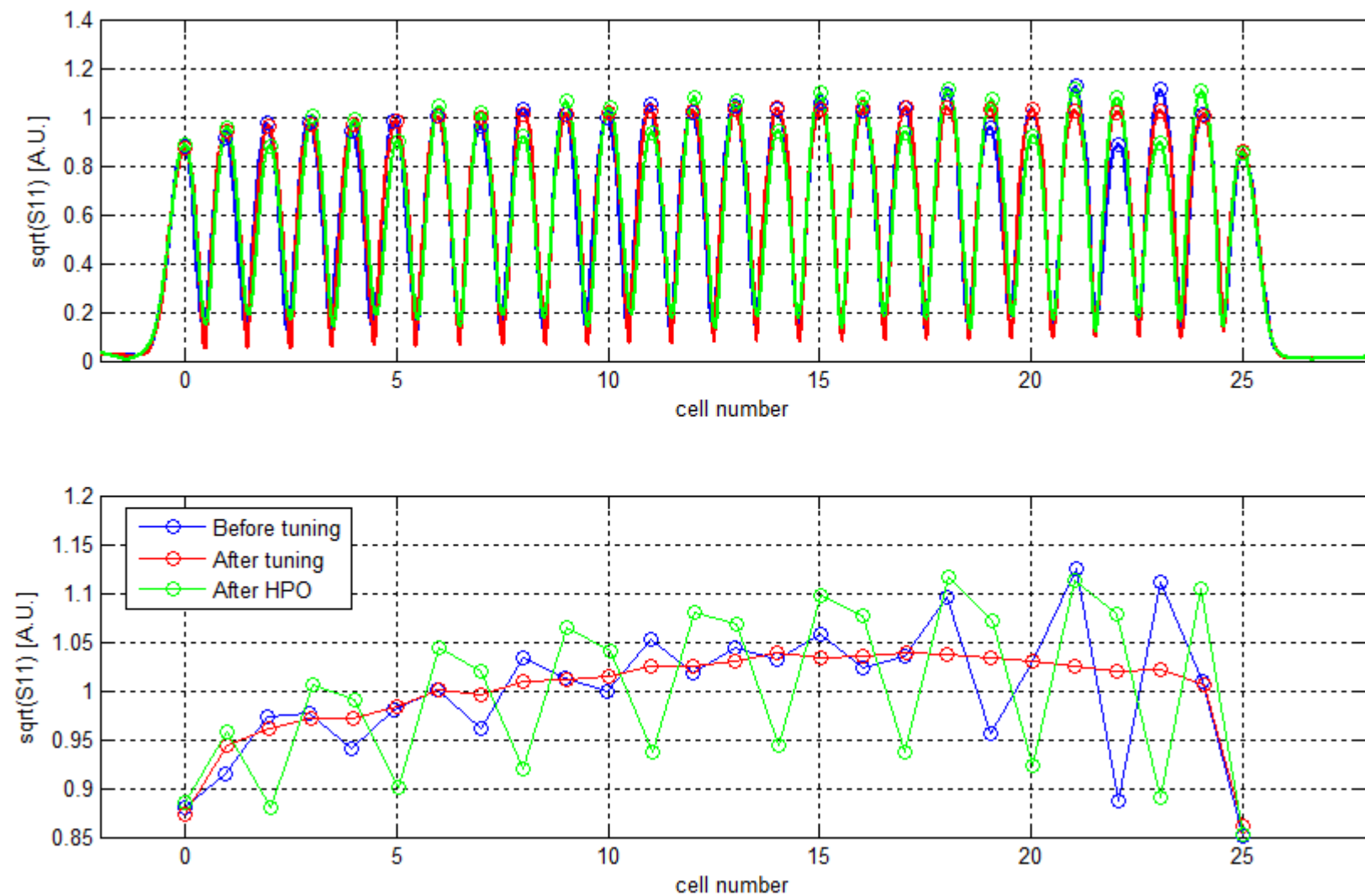


1. Is the geometry of the disks preserved during bonding?

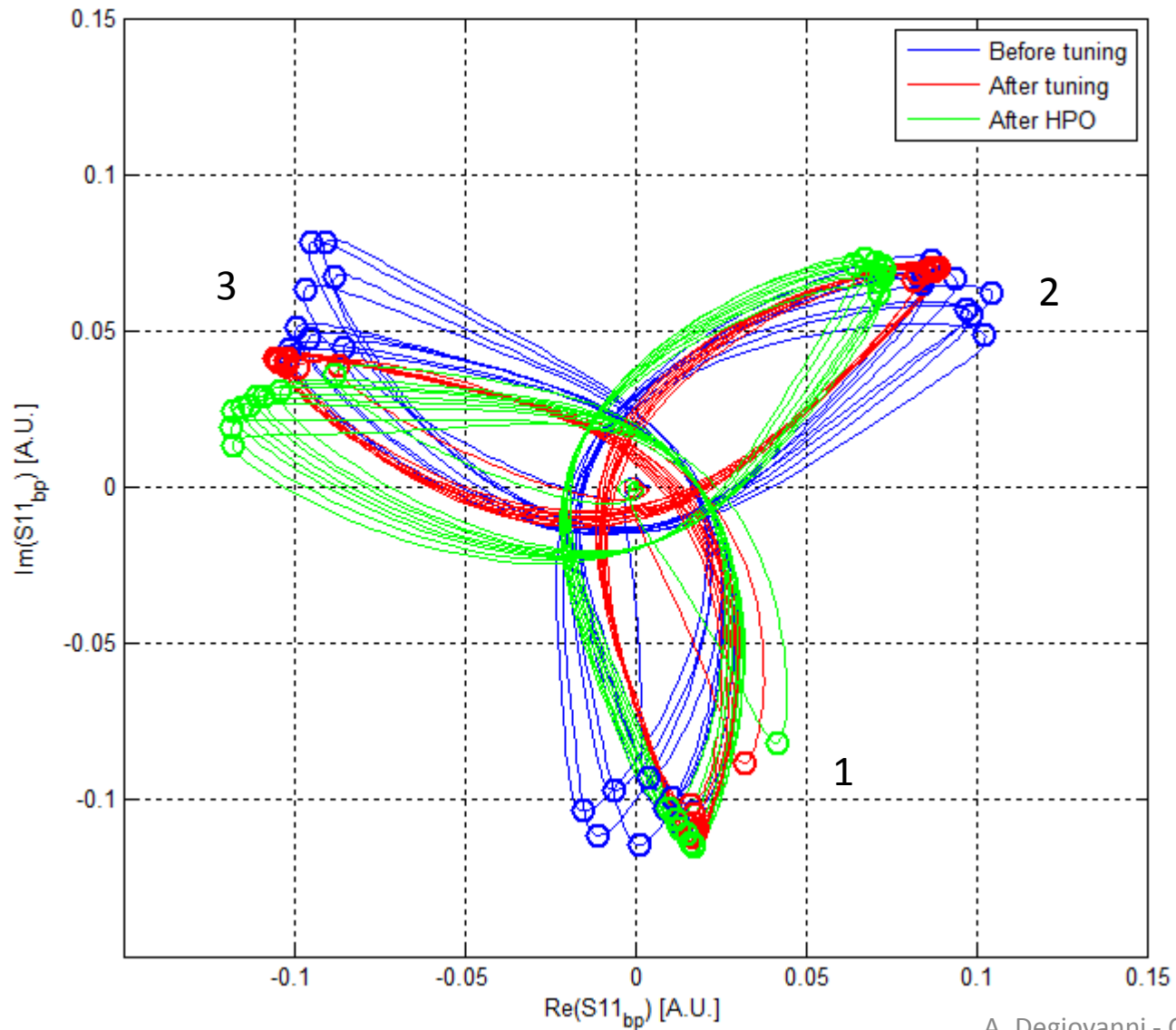
2. Are the dimensions of the disks influenced by high power operations?



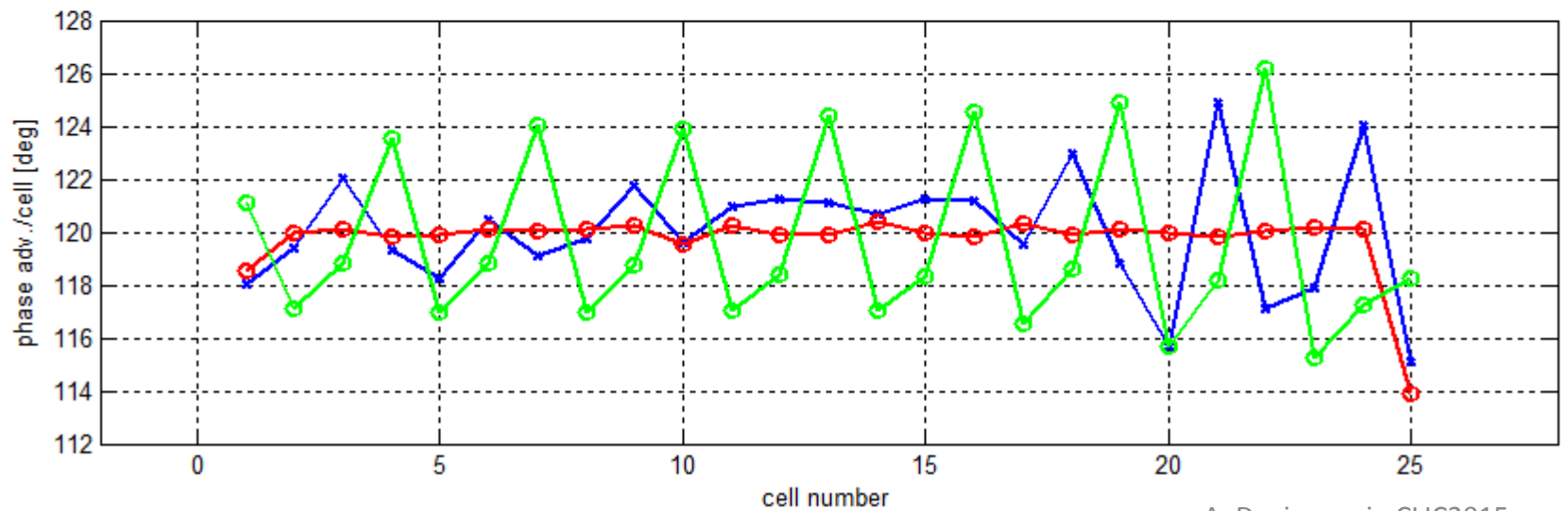
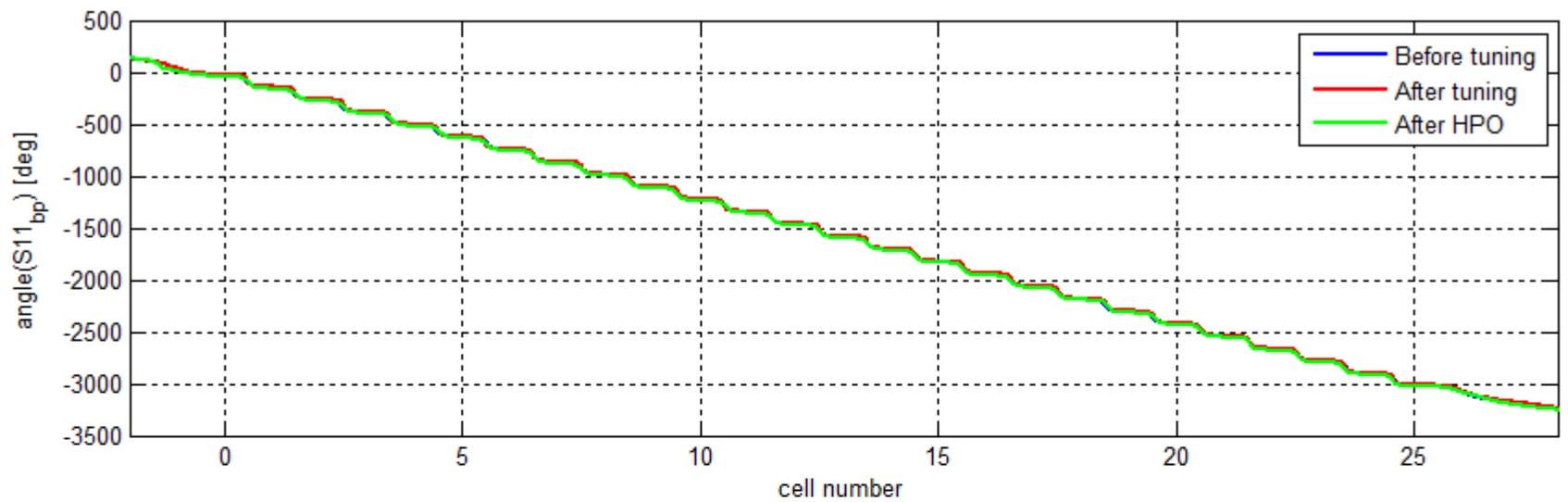
# Bead pull measurements – Field prof



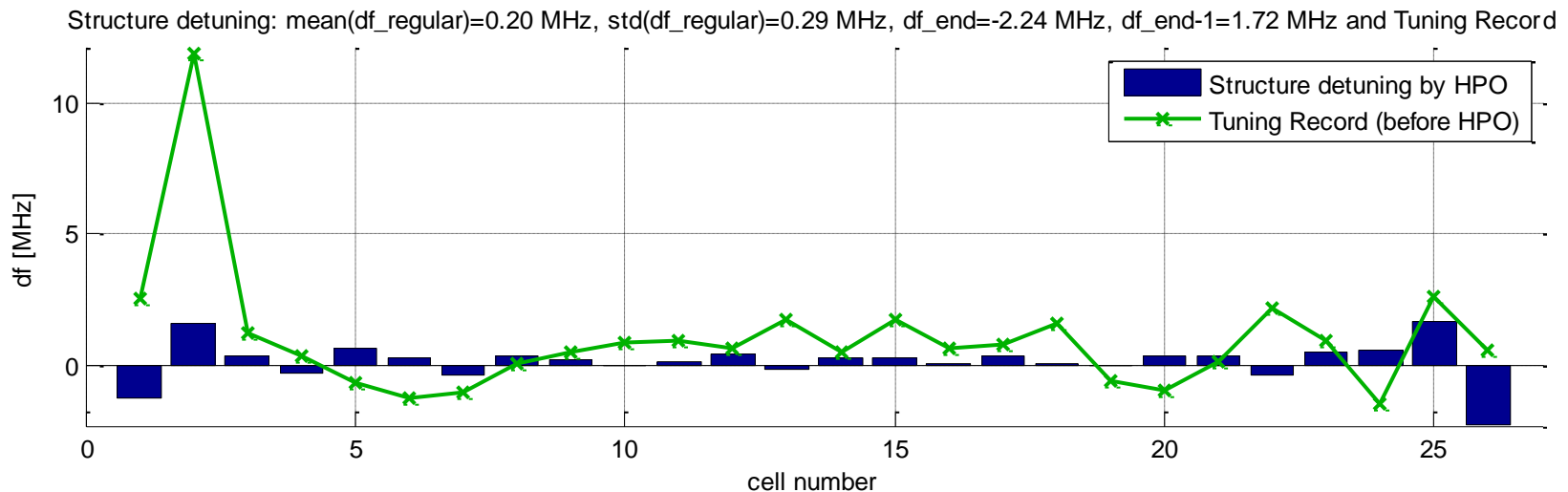
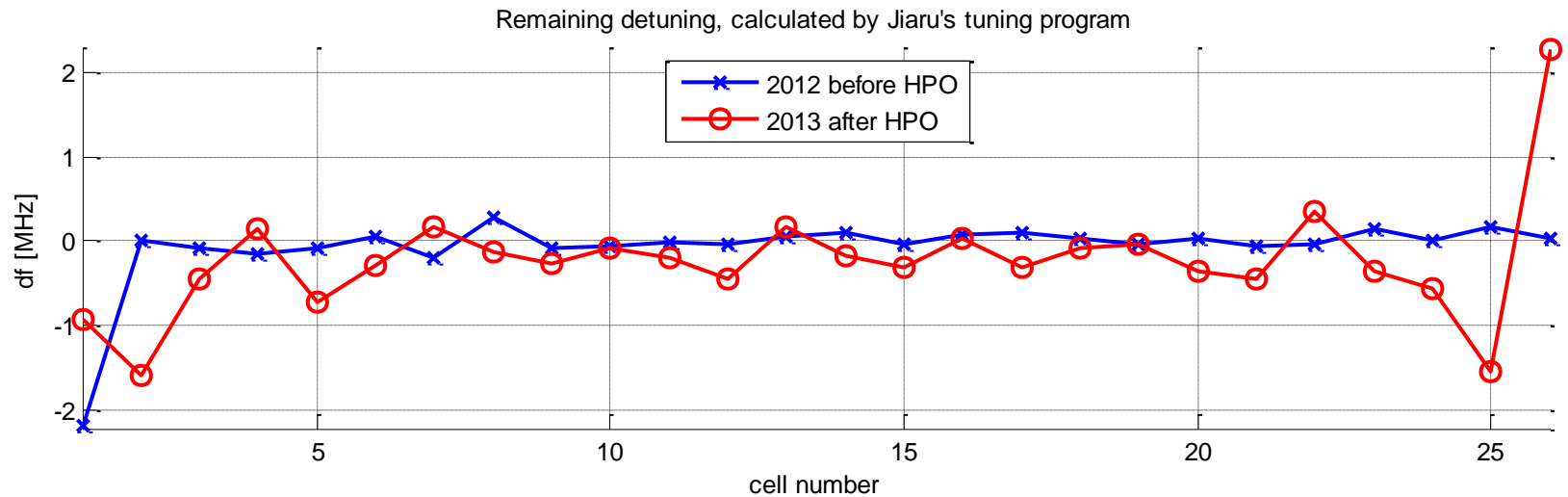
# Bead pull measurements – complex S11



# Phase advance



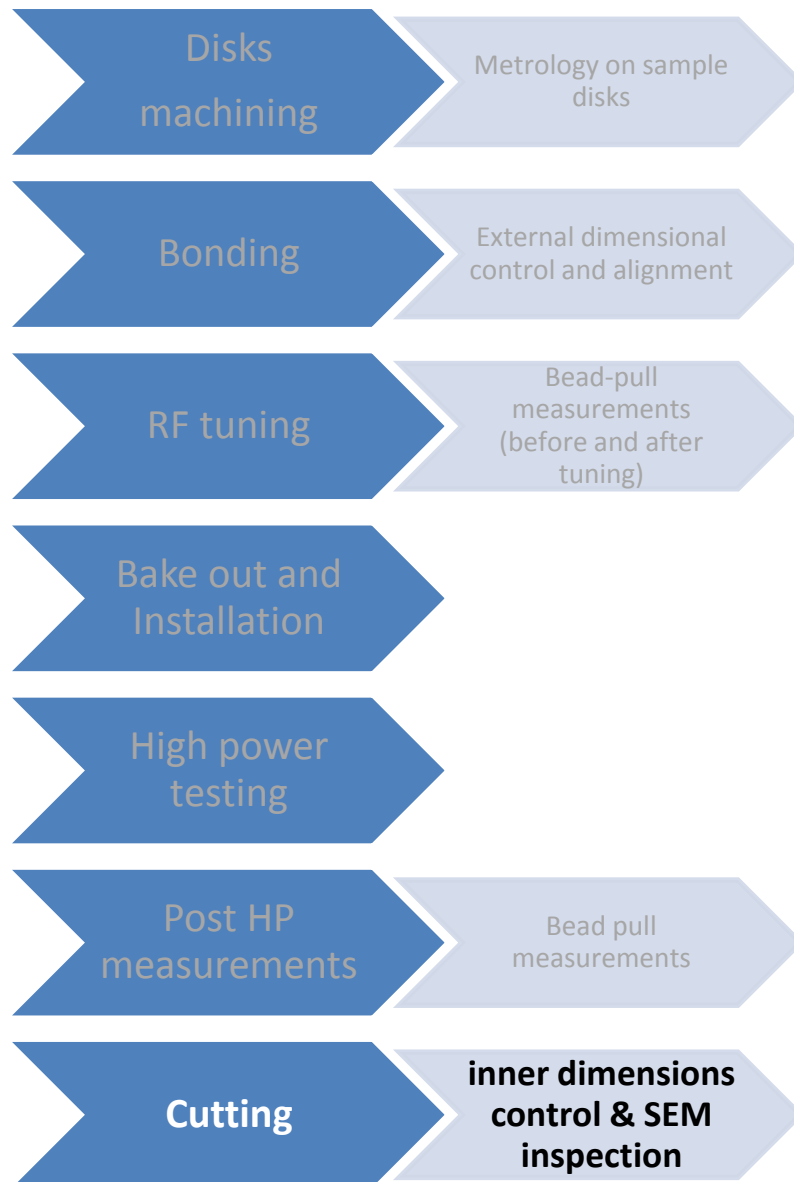
# Comparison of Beadpull measurements



# Comparison of detuning of different structures

	T18 SLAC N1	TD18 SLAC	T24 SLAC	T18 CERN N2	TD24 CLEX	TD24 R05 N1 XBox1
Analysed at	SLAC	SLAC	SLAC	CERN	CERN	CERN
by	J.W.	J.W.	J.W.	J.S.	R.W.	R.W.
Output matching						
Standing Wave (VSWR)	1.06	1.22	1.05	1.11	1.05	1.15
R [%]	3.0	10	2.5	5.0	2.6	7.0
R [dB]	-30	-20	-32	-26	-32	-23
df <sub>end</sub> [MHz]	+2.0	+7.0	+2.5	+3.0	+0.1	<b>-2.2</b>
df <sub>end-1</sub> [MHz]					+1.0	+1.7
Regular cells						
Total phase shift [°]		-16	6		-9.2	~ -6
avg(df) [MHz]		+1.0	-0.3		+0.4	+0.2
std(df) [MHz]					+0.2	+0.3
notes	$\Delta\phi_{19 \rightarrow 20} \sim 100^\circ$	$\Delta\phi_{19 \rightarrow 20} \sim 100^\circ$		$\Delta\phi_{19 \rightarrow 20} \sim 100^\circ$	structure retuned	

# CLIC acc. struct design and testing



**1. Is the geometry of the disks preserved during bonding?**

**2. Are the dimensions of the disks influenced by high power operations?**



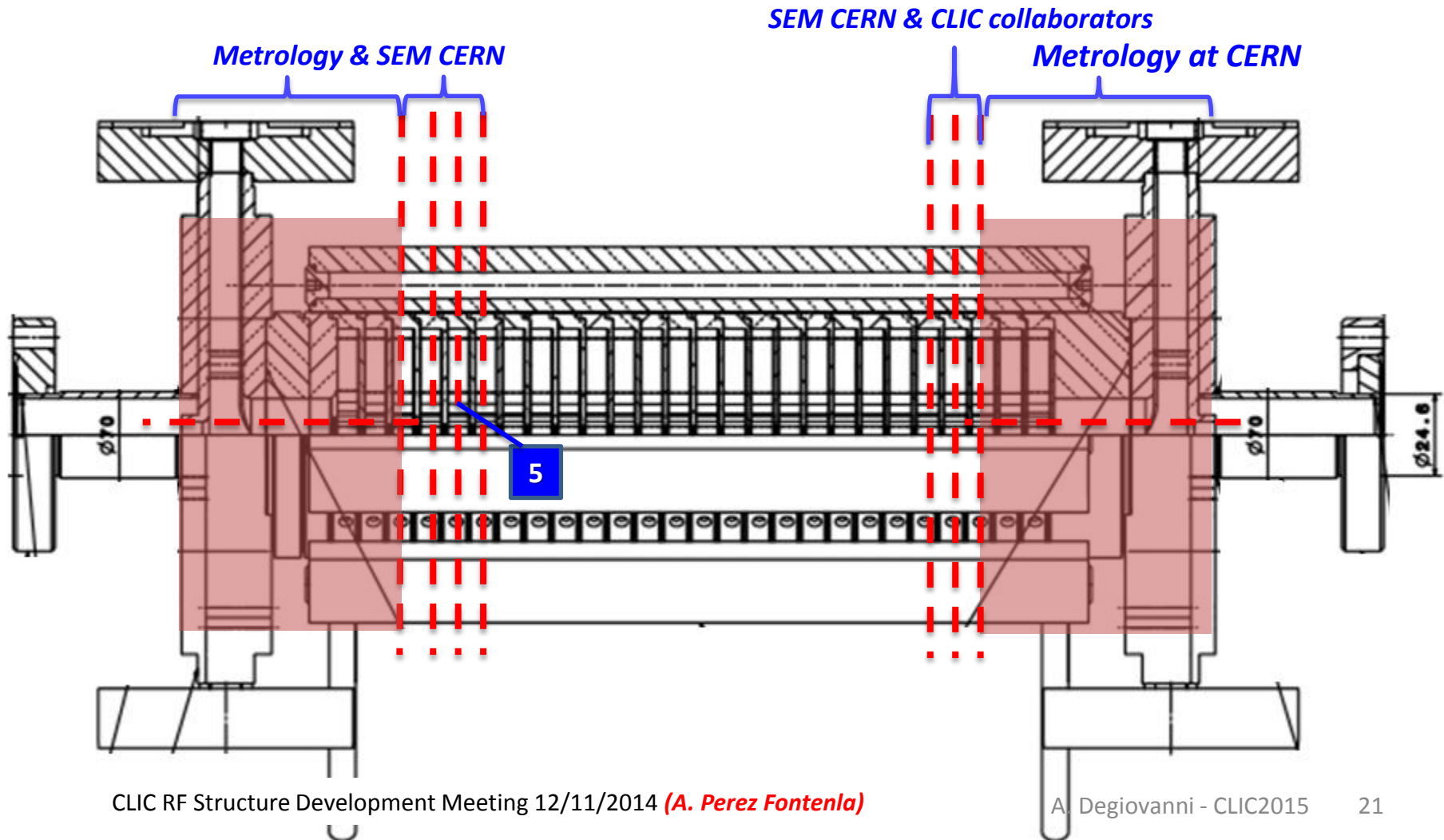
## EDM wire cutting at CERN\*

Transverse cutting of the two extremities

Longitudinal cut for Metrology inspection of input and output coupler

Slicing of cells number 4-5-6 & 22-23 for iris inspection by SEM

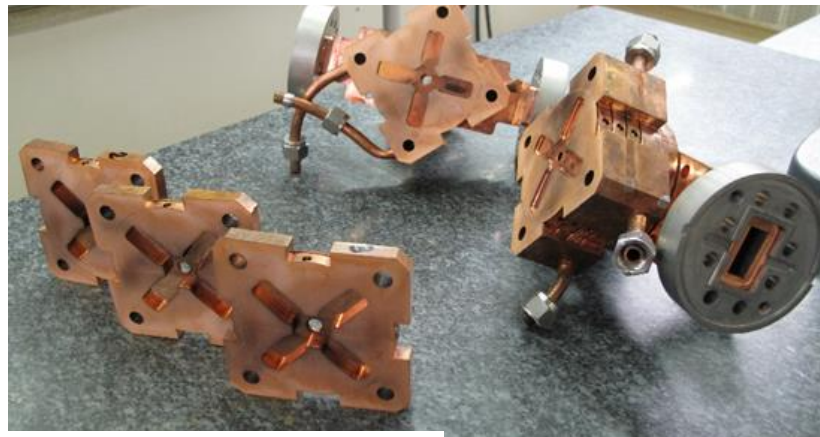
Cell 22 (cutting in quarters) → sent to collaborators



EDM wire cutting machine at CERN workshop:



Structure just after cutting:



Structure ready for SEM after degreasing:

US of the cells:



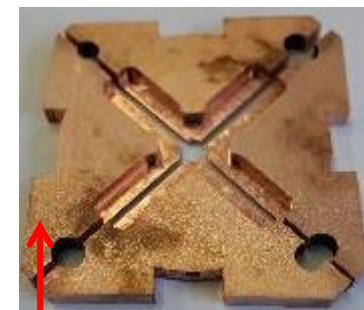
Iris #4

Cell #4

Iris #5

Cell #5

Iris #6



Cell #22

Iris #22

DS of the cells:



Iris #4

Iris #5

Iris #6



Iris #23

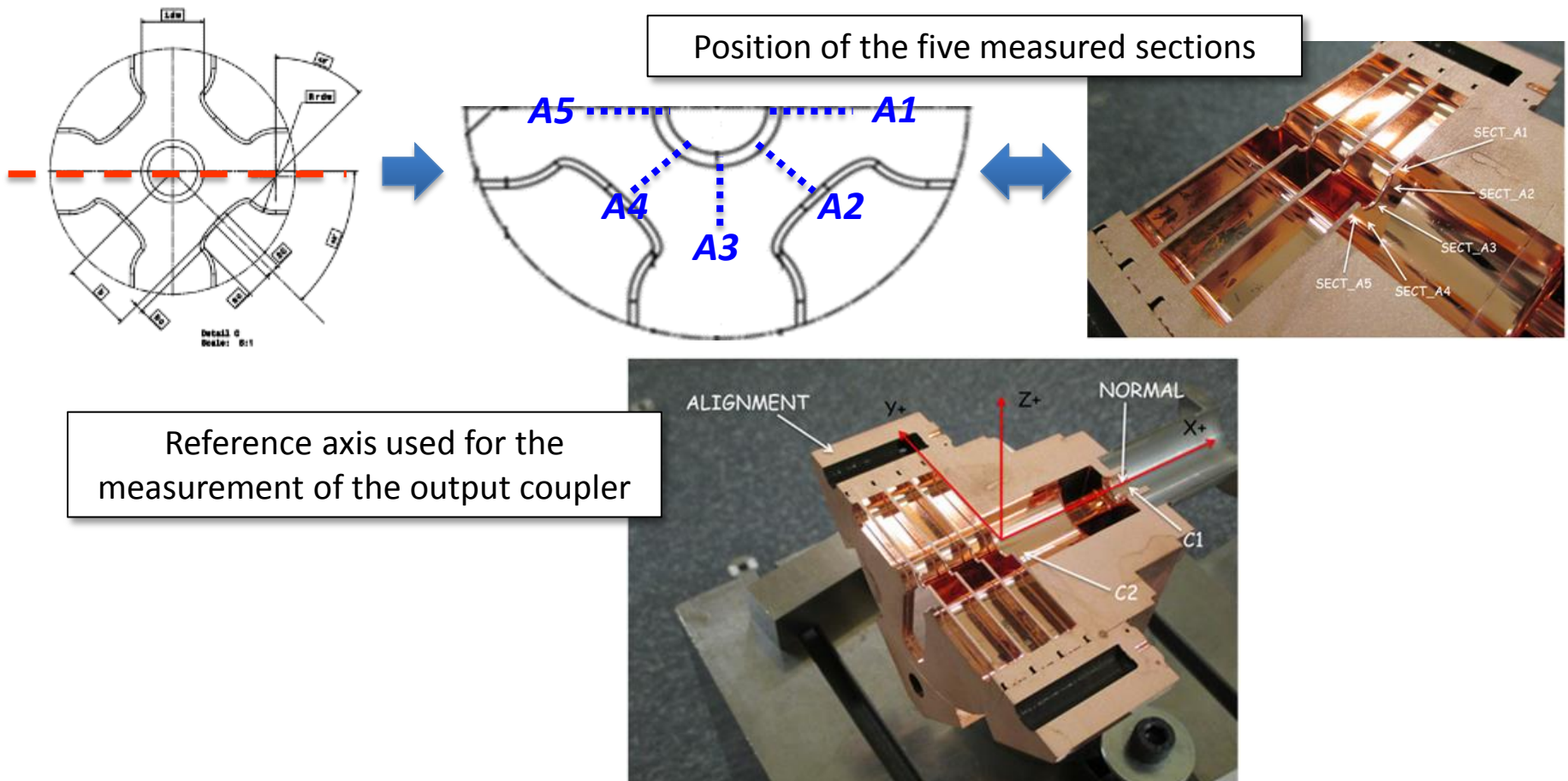
Metrology study was done for better understanding of detuning effect:

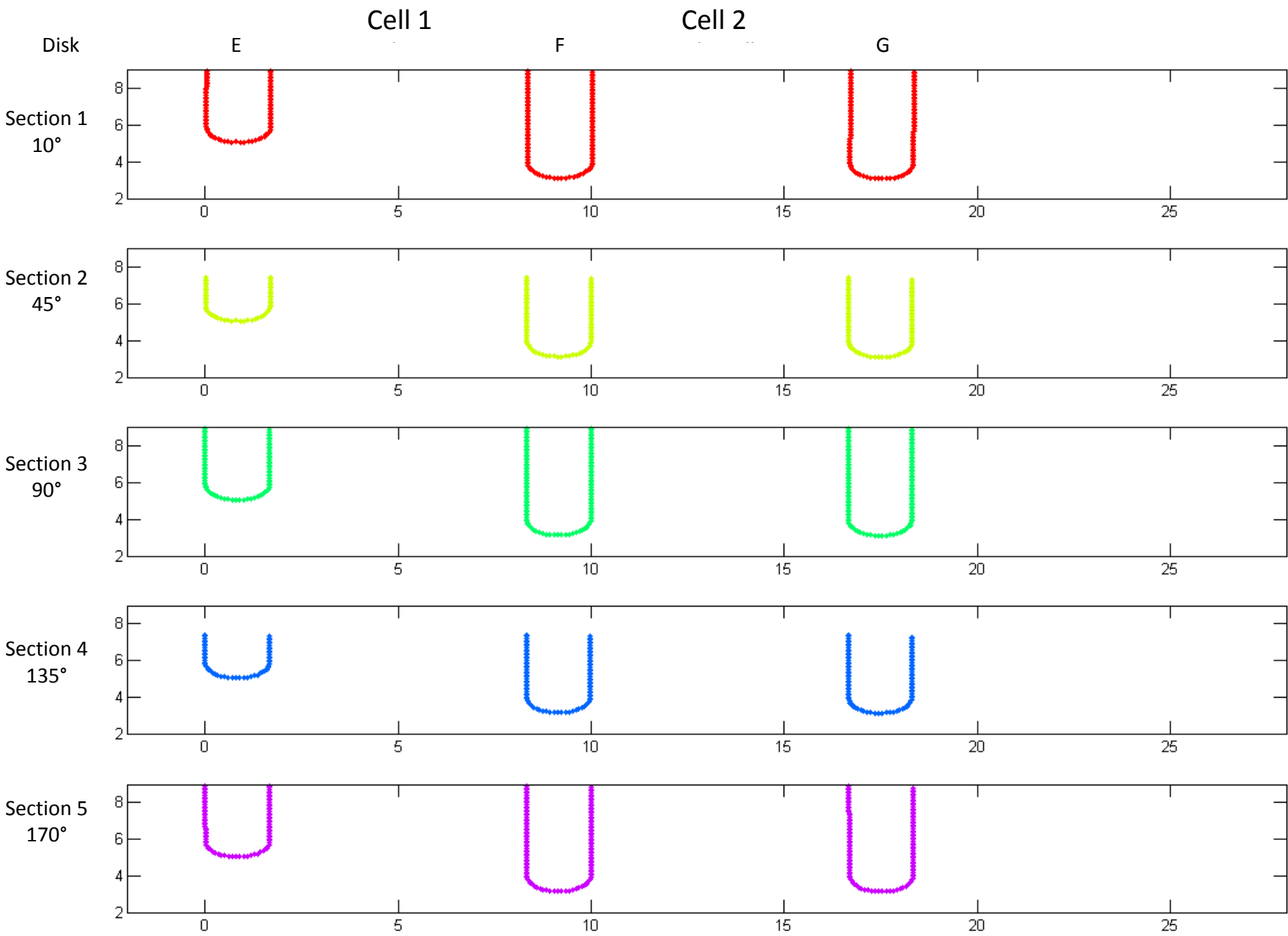
EDMS: [1239394](#) – RF tuning (22-24.08.2012, *Vasim + R. Wegner*)

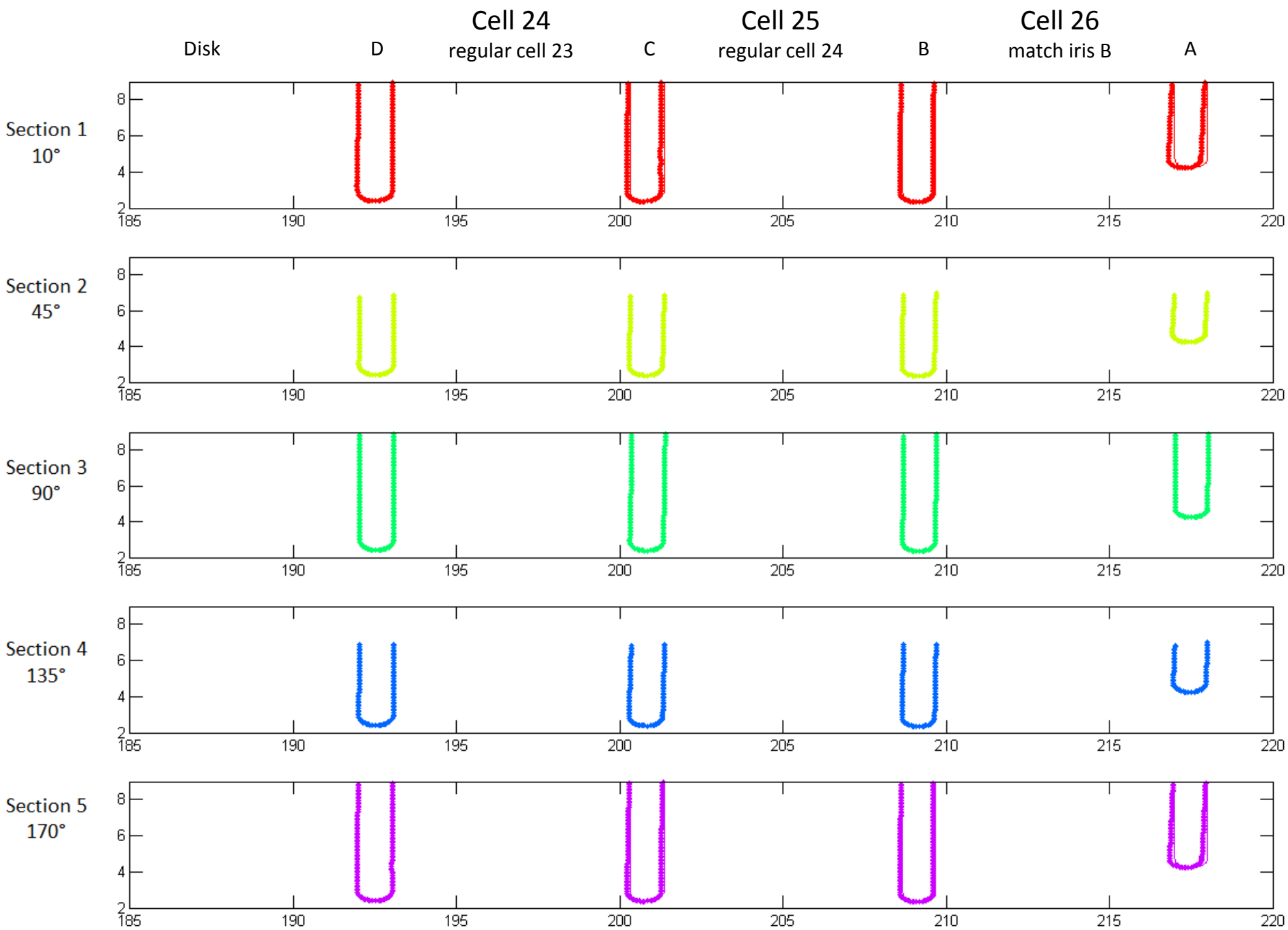
EDMS: [1306038](#) – post high power operation analysis (*R. Wegner*)

The measurements were performed on one of the two halves of the input and of the output coupler.

The obtained data can be found in EDMS [1391907](#) (*Done by D. Glaude*)









*Disc*

*E*

*F*

*G*

*D*

*C*

*B*

*A*

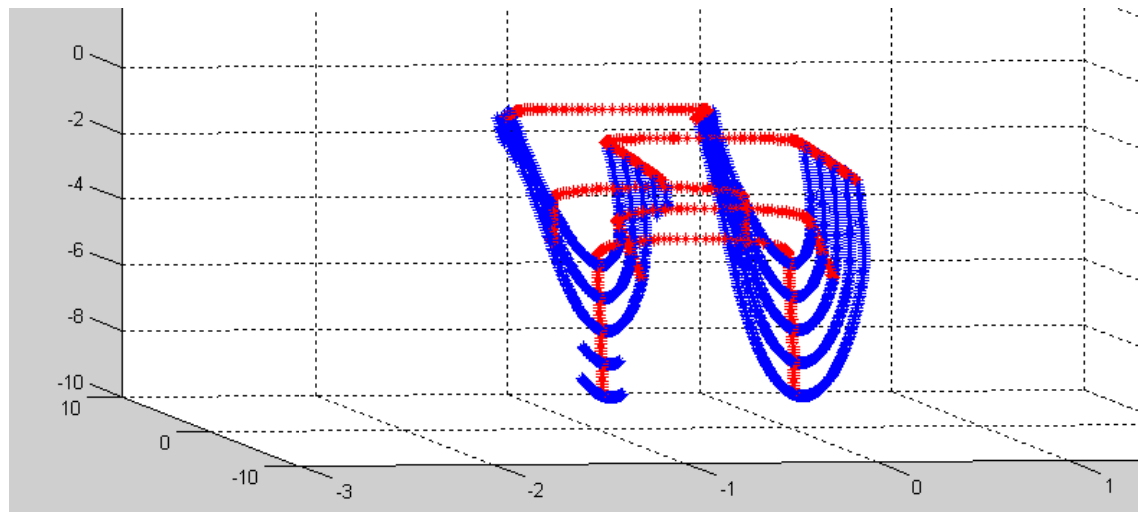
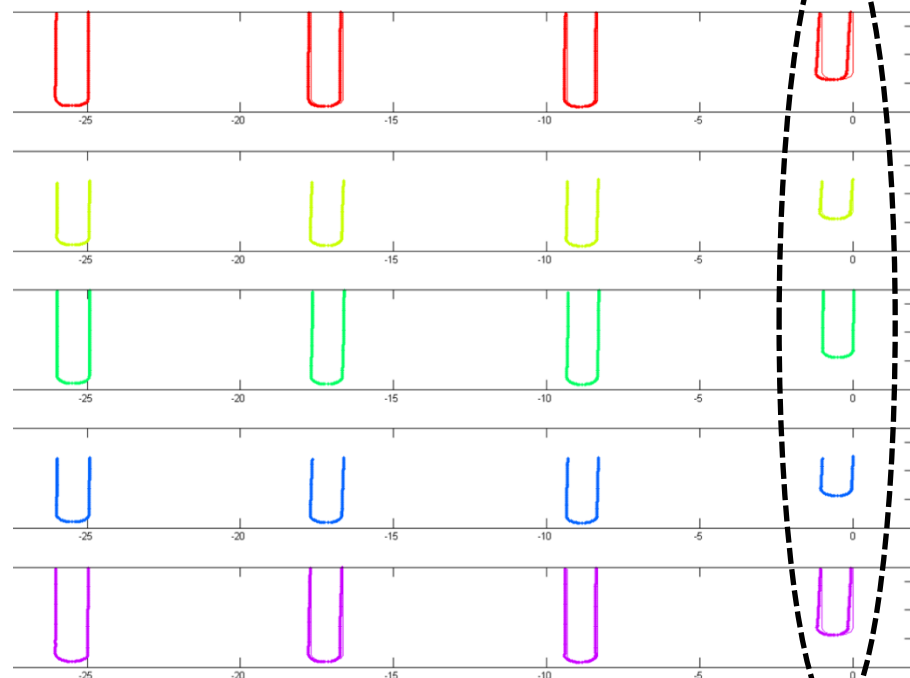
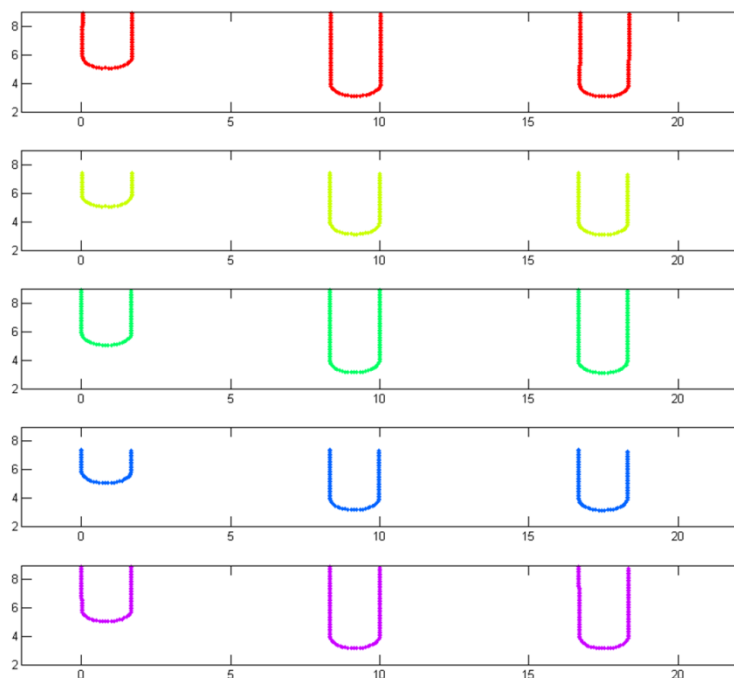
Section 1  
10°

Section 2  
45°

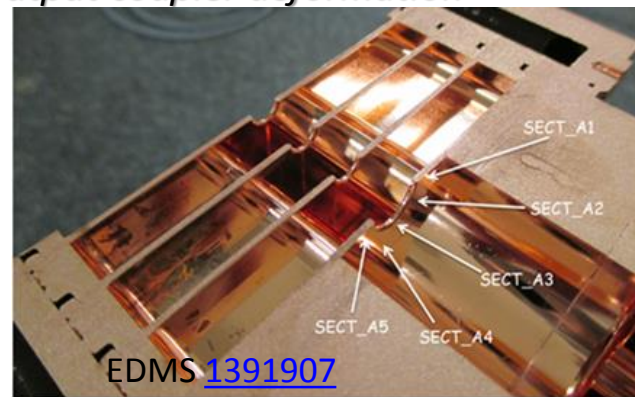
Section 3  
90°

Section 4  
135°

Section 5  
170°

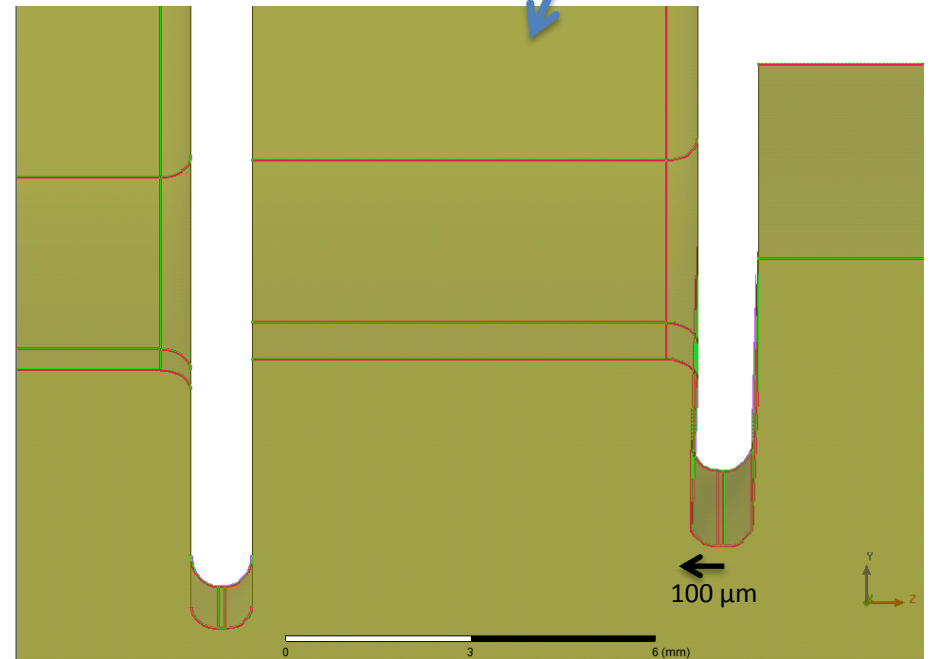
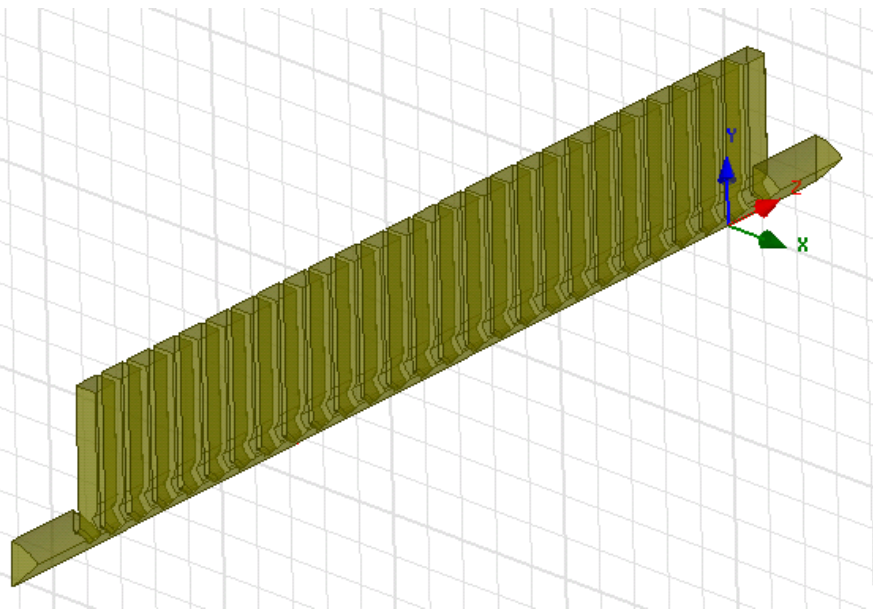
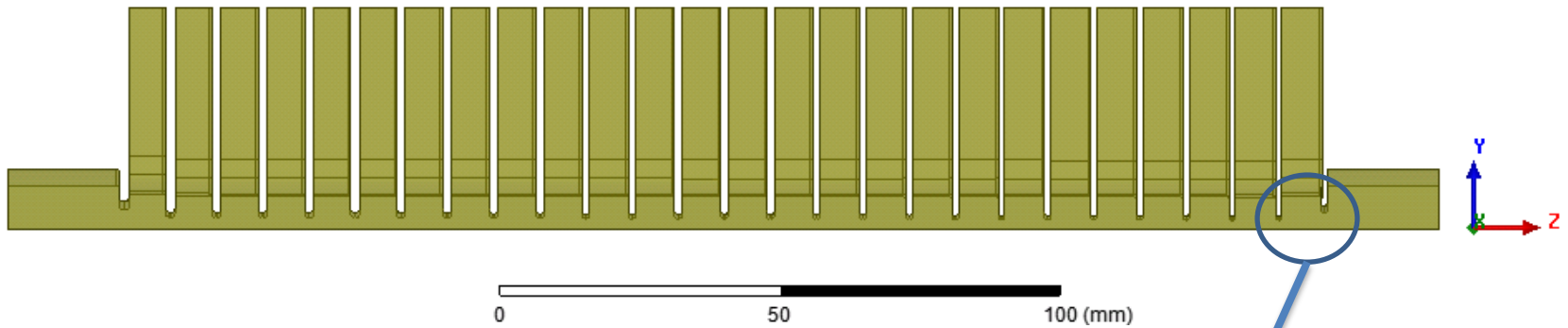


*Output coupler deformation*

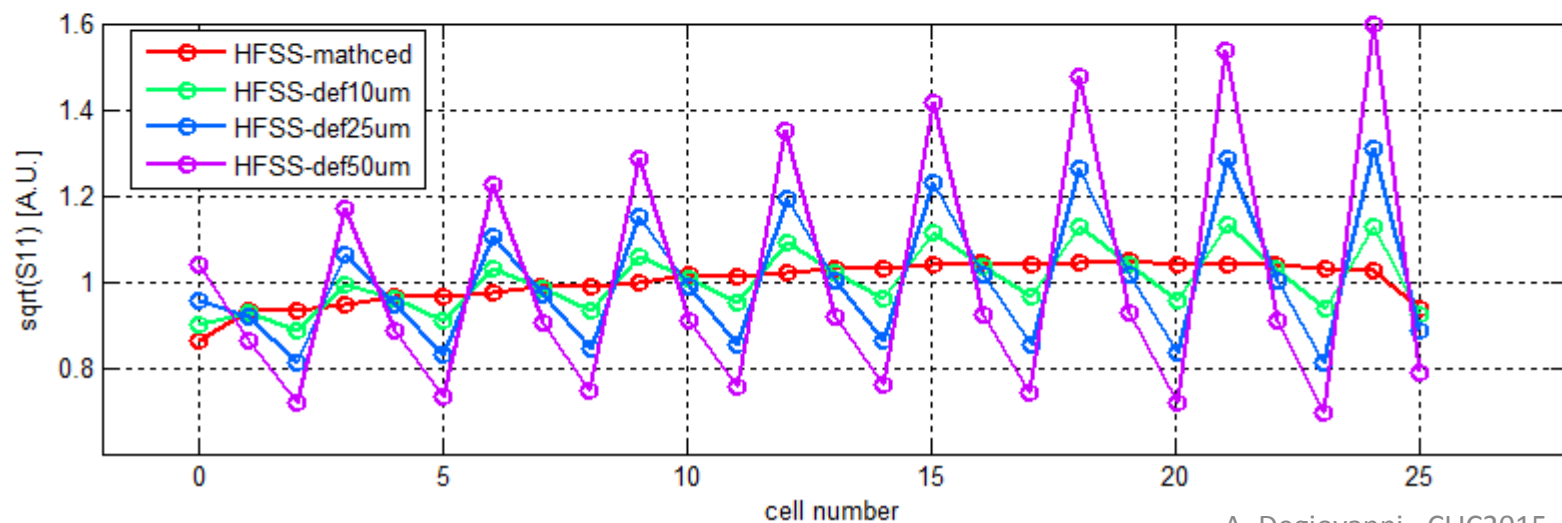
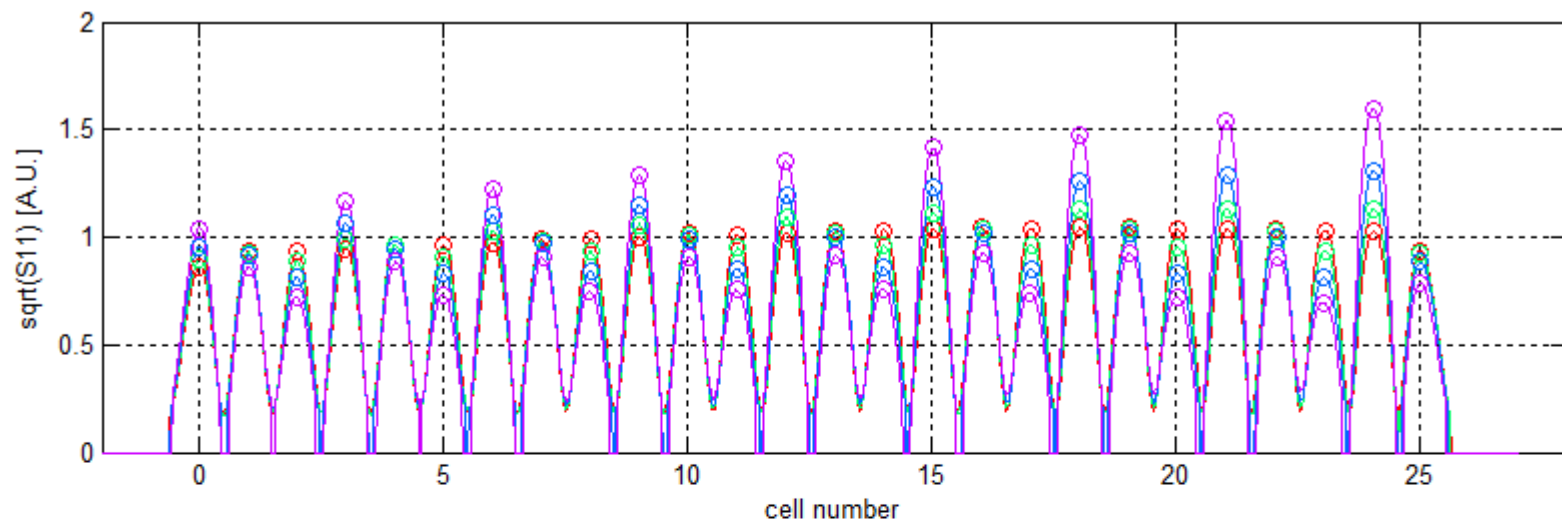




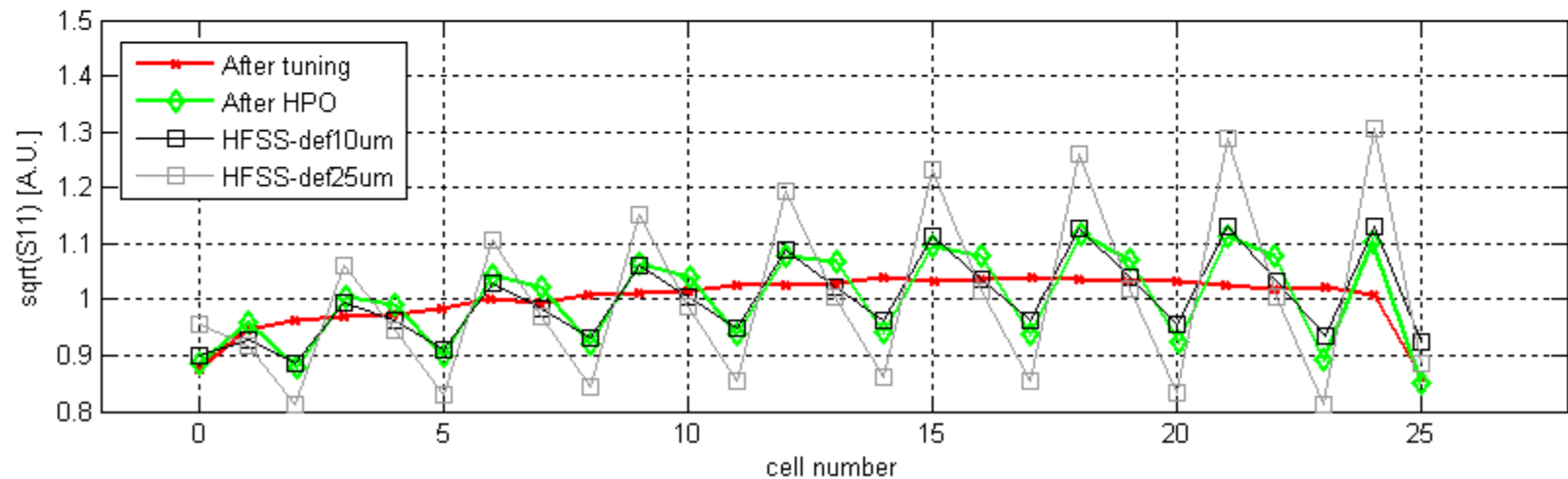
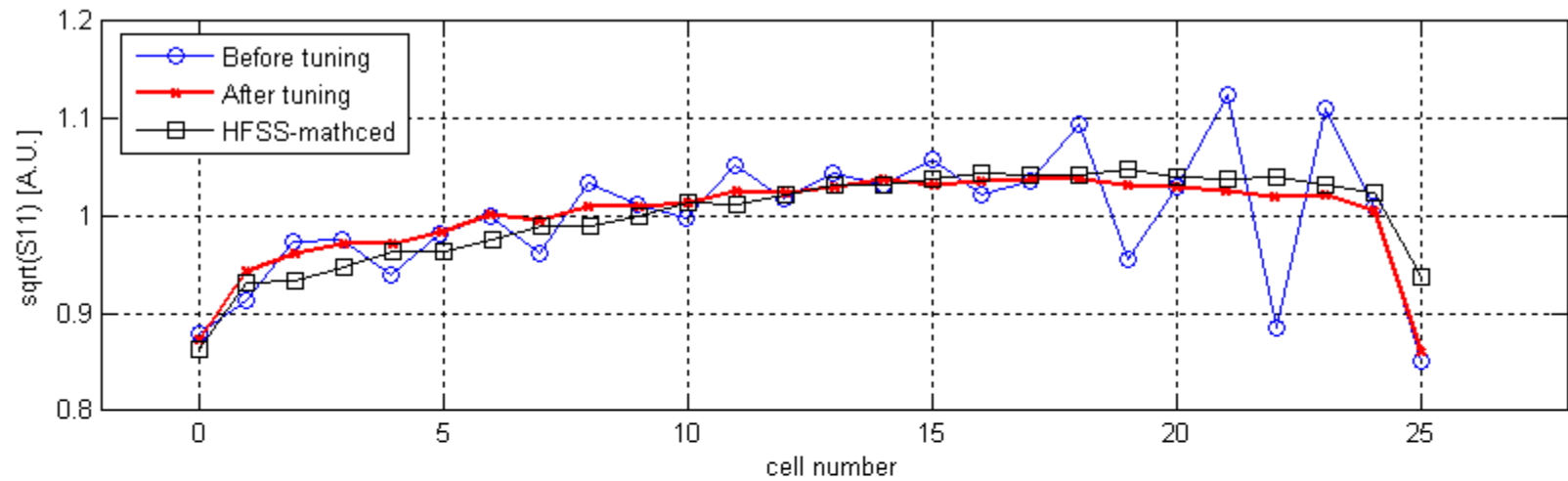
# HFSS simulations



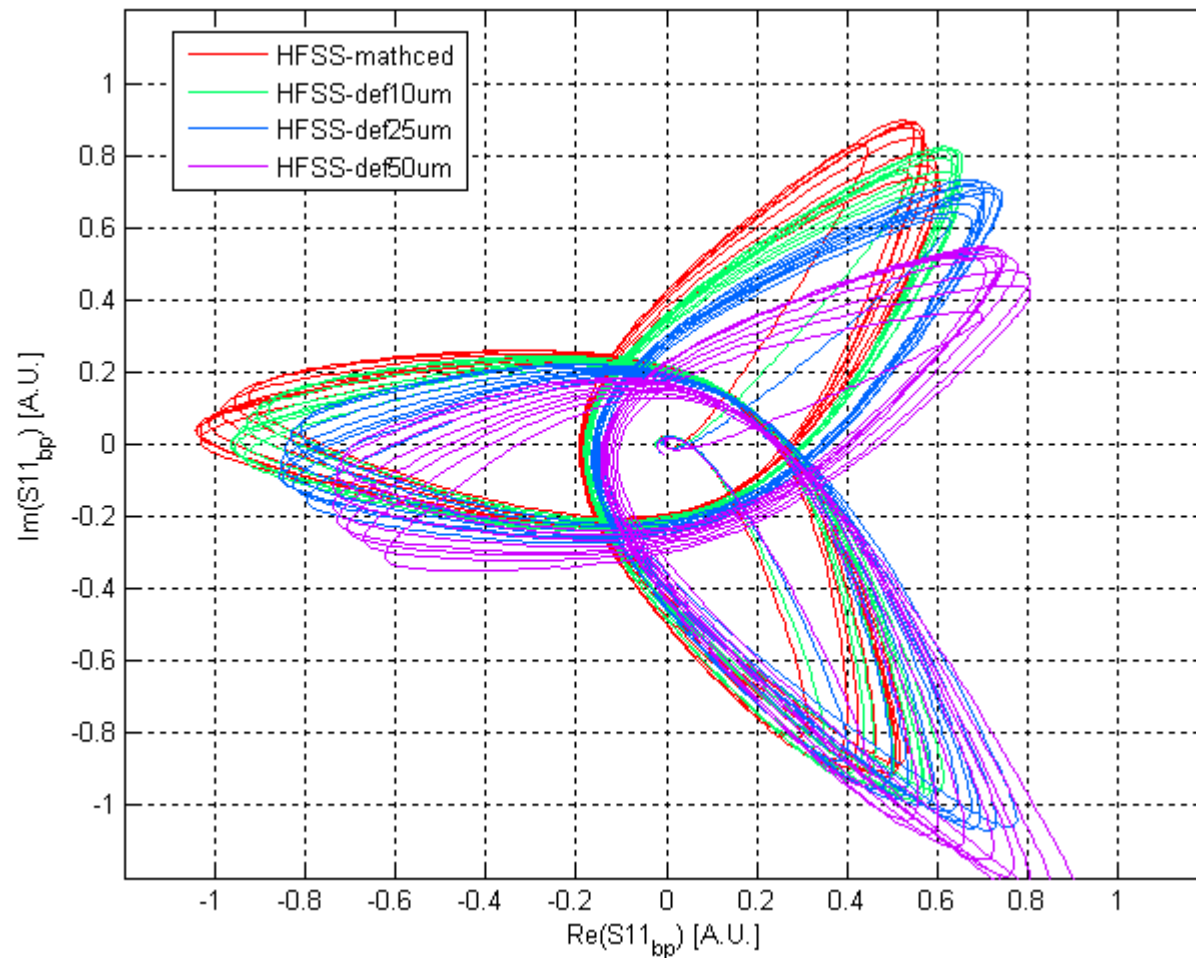
# HFSS simulations results



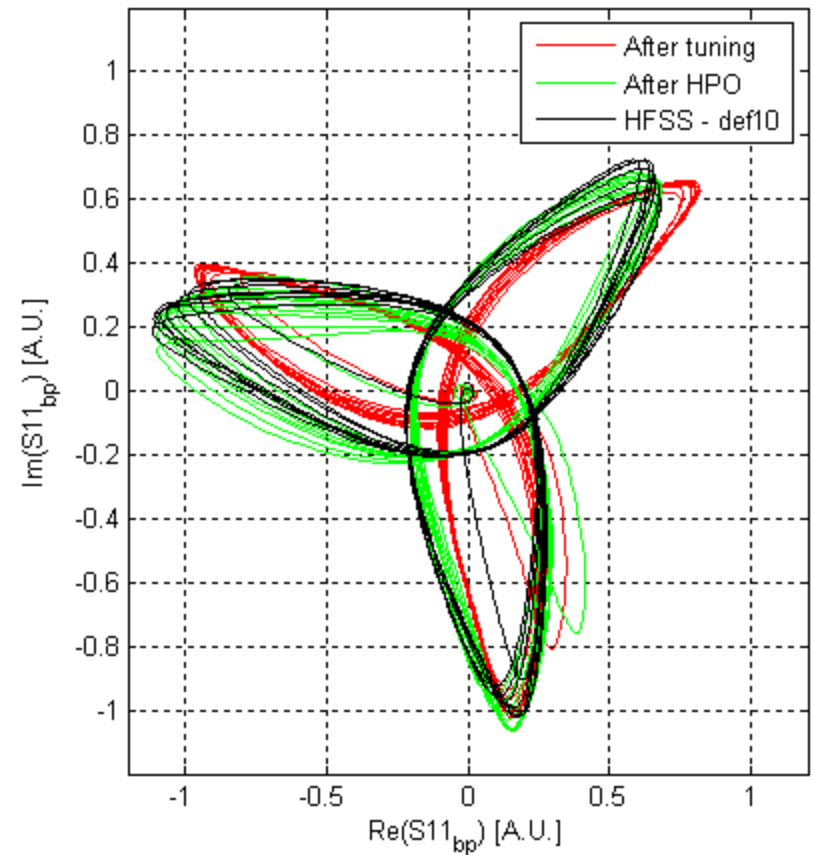
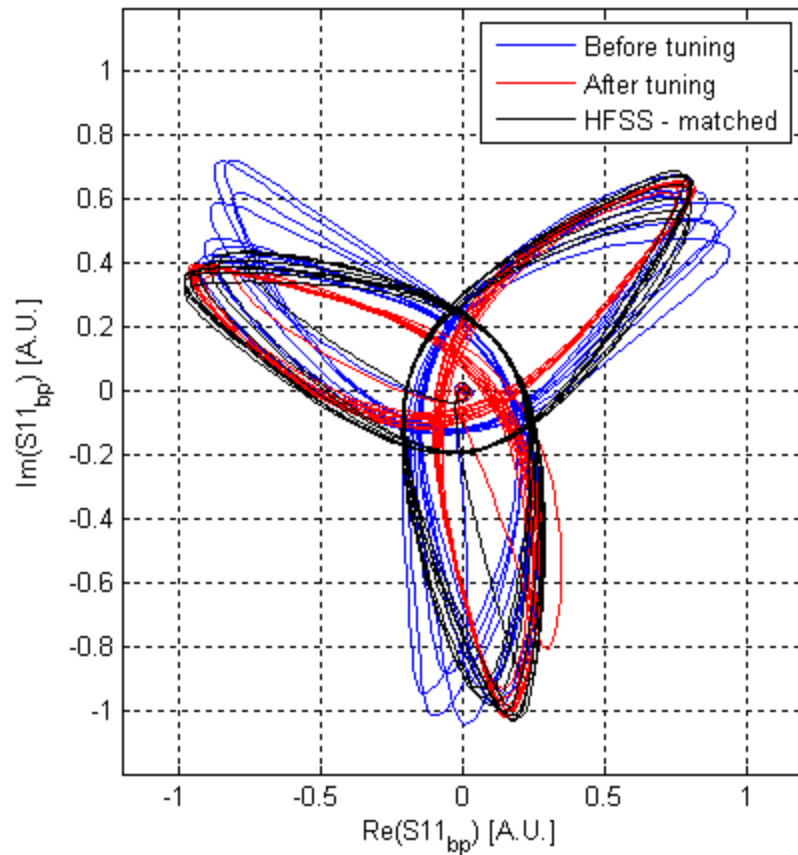
# HFSS simulations results



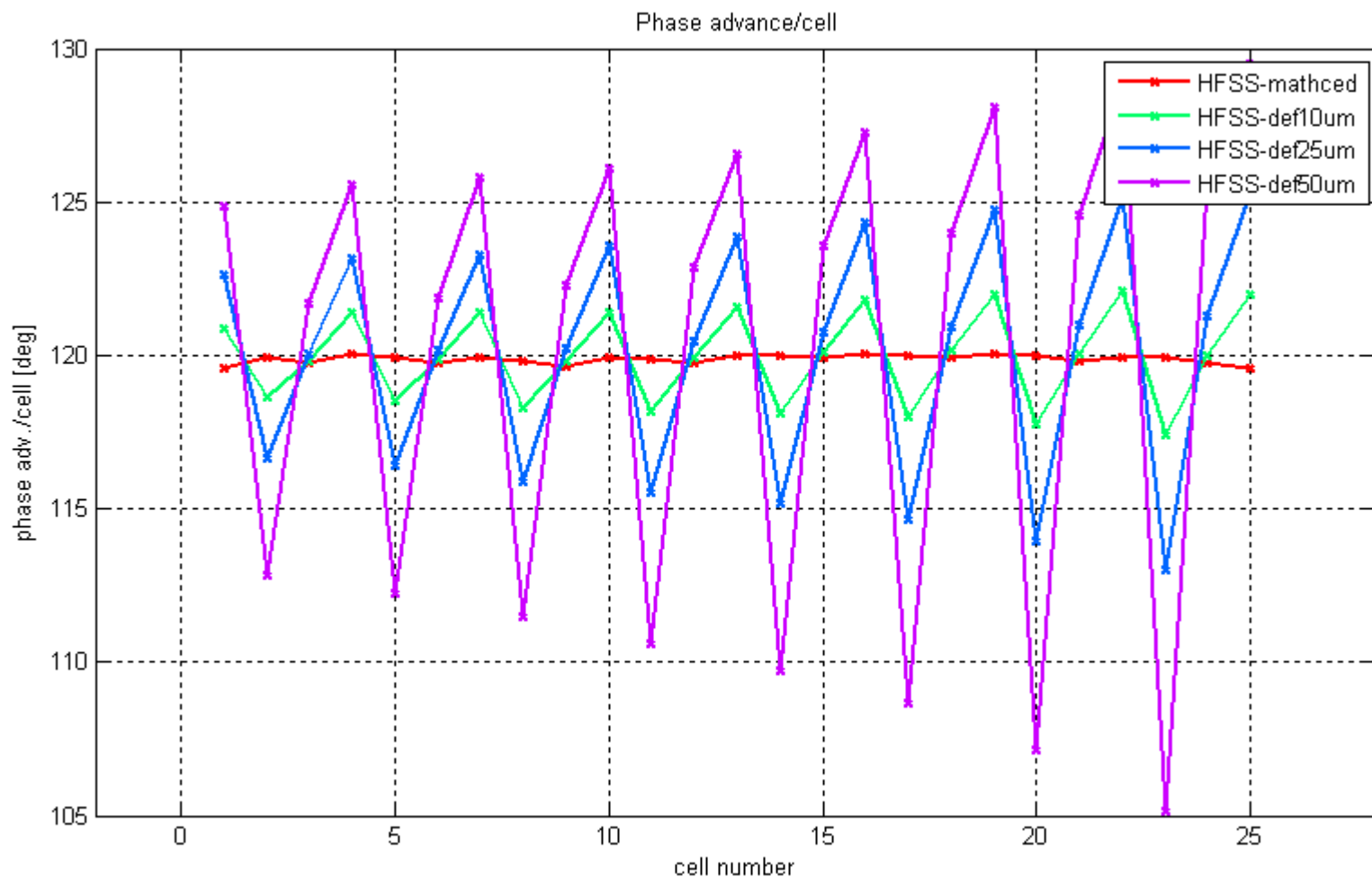
# simulations results – Complex S11



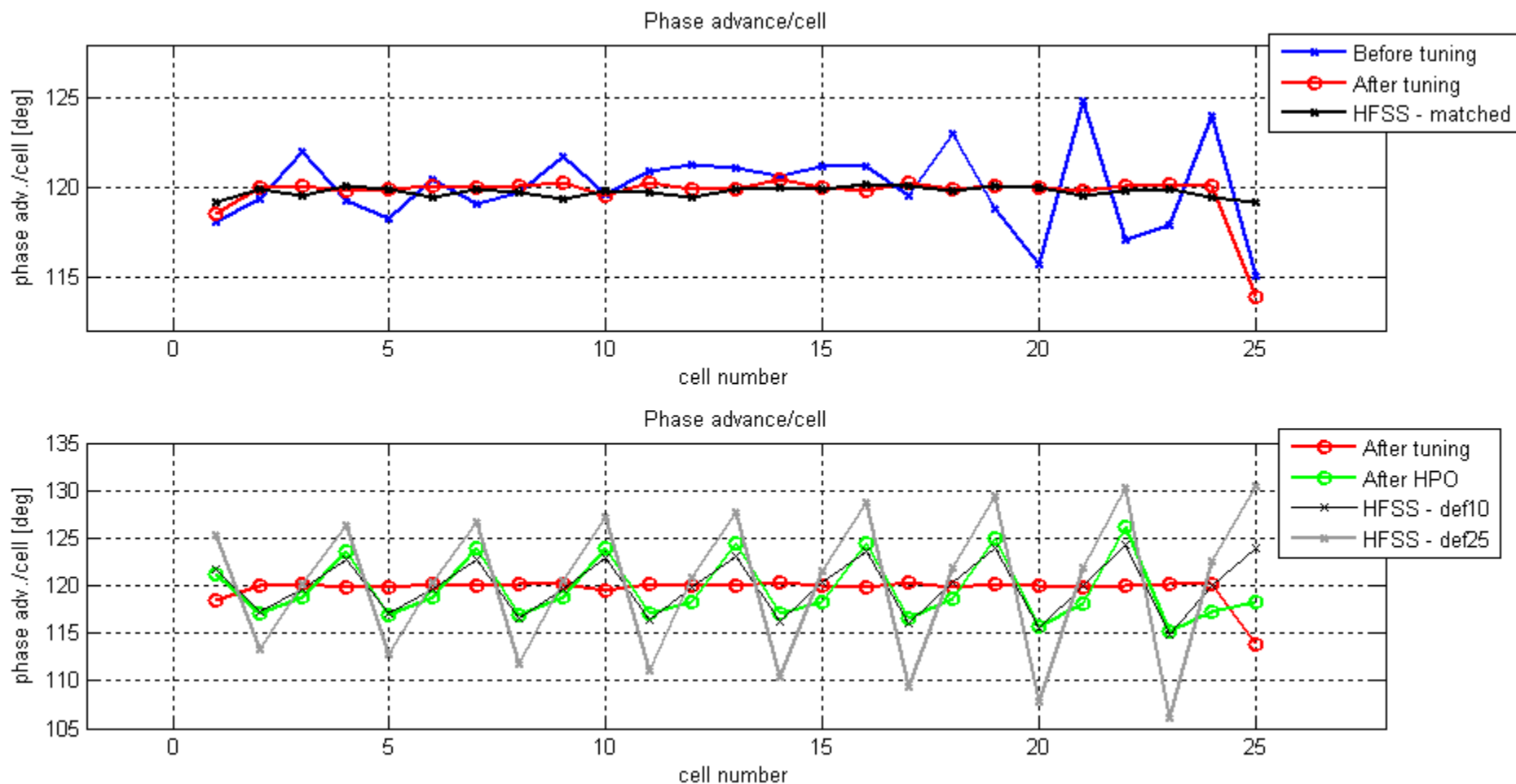
# Comparison measurements-simulations



# Simulations results – phase advance/cell



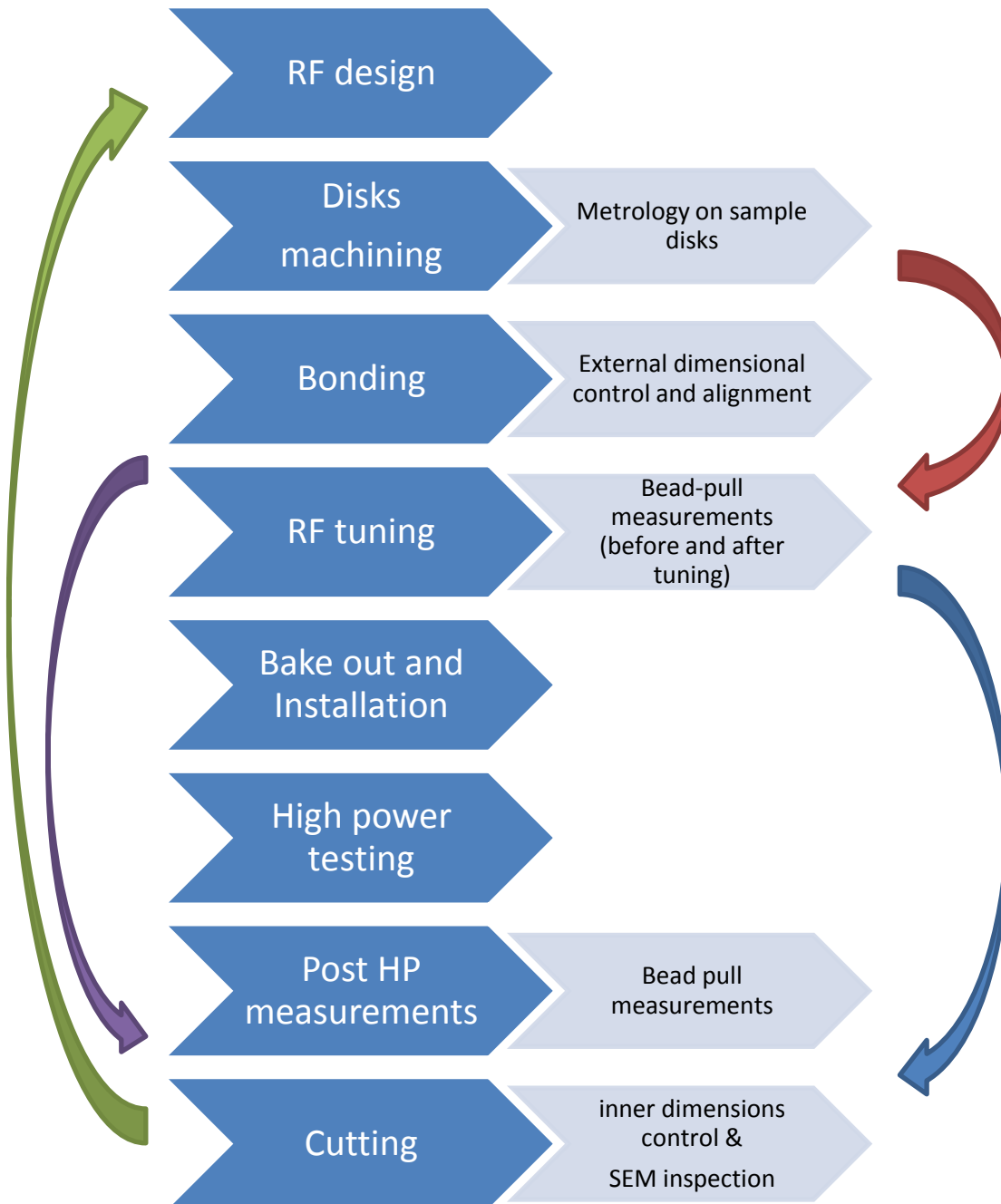
# Comparison measurements-simulations



# Conclusion

- Comparison of RF and dimensional measurements
  - ...is not something new:  
Jiaru Shi (<http://indico.cern.ch/event/217102/contribution/0/material/slides/1.pdf>)
- Questions:
  - 1. Is the geometry of the disks preserved during bonding?**
  - 2. Are the dimensions of the disks influenced by high power operations?**
- Bead-pull measurements data can be used as source of information about the status of the structure
  - after assembly: can we infer something about the status after the test?
  - after testing: can we see some effects ?
- Feedbacks to the design and assembly are important.
- Handling is a delicate aspect !





## CONCLUSION

1. Is the geometry of the disks preserved during bonding?
  2. Are the dimensions of the disks influenced by high power operations?
- 
1. Infer from bead-pull data if we will see something after HPO
  2. Feed-back to RF design and assembly

# THANK YOU FOR YOUR ATTENTION !

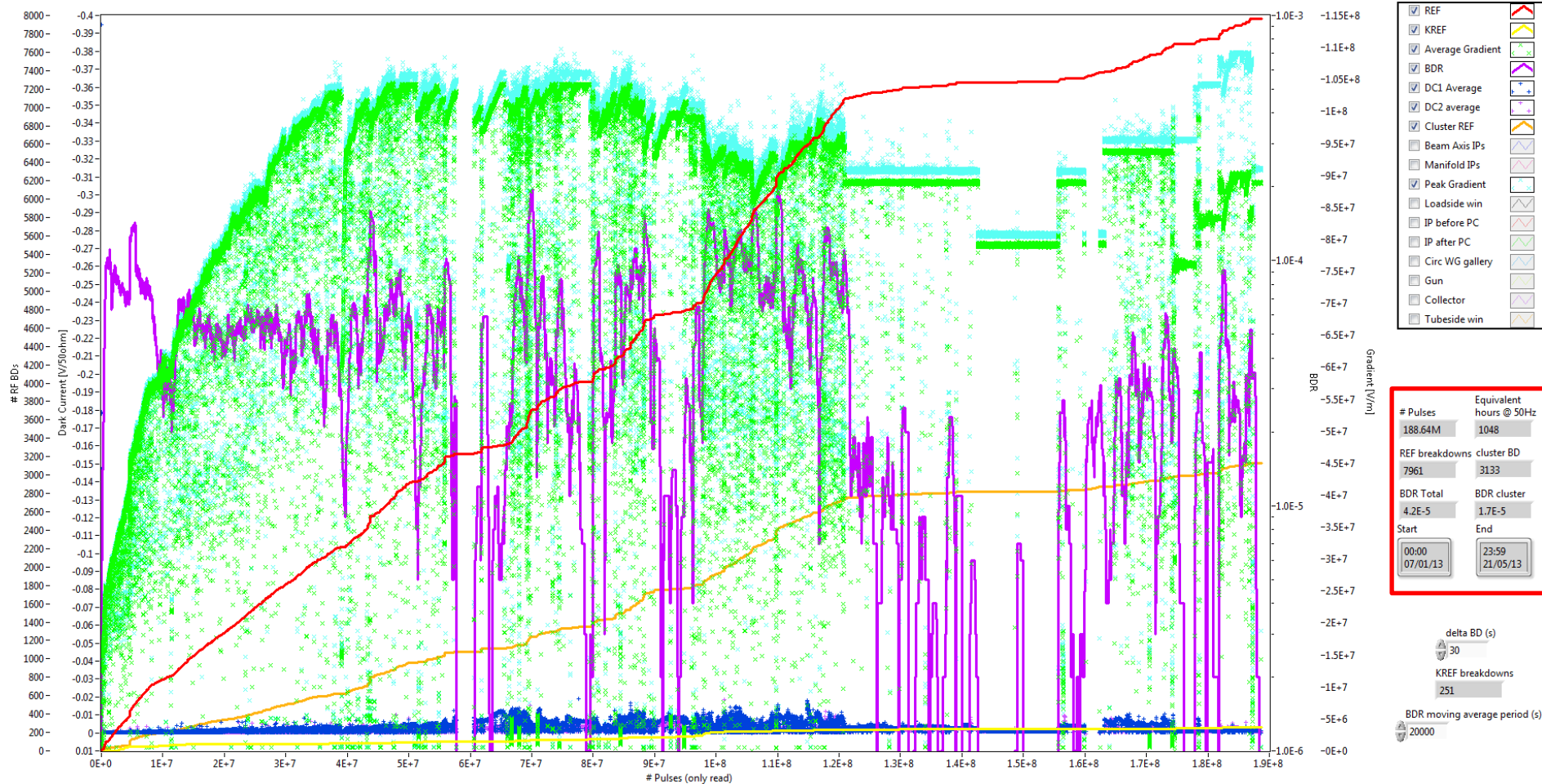
Thanks to all the people involved in this activity

Special thanks to Rolf Wegner and Walter Wuensch for useful discussion

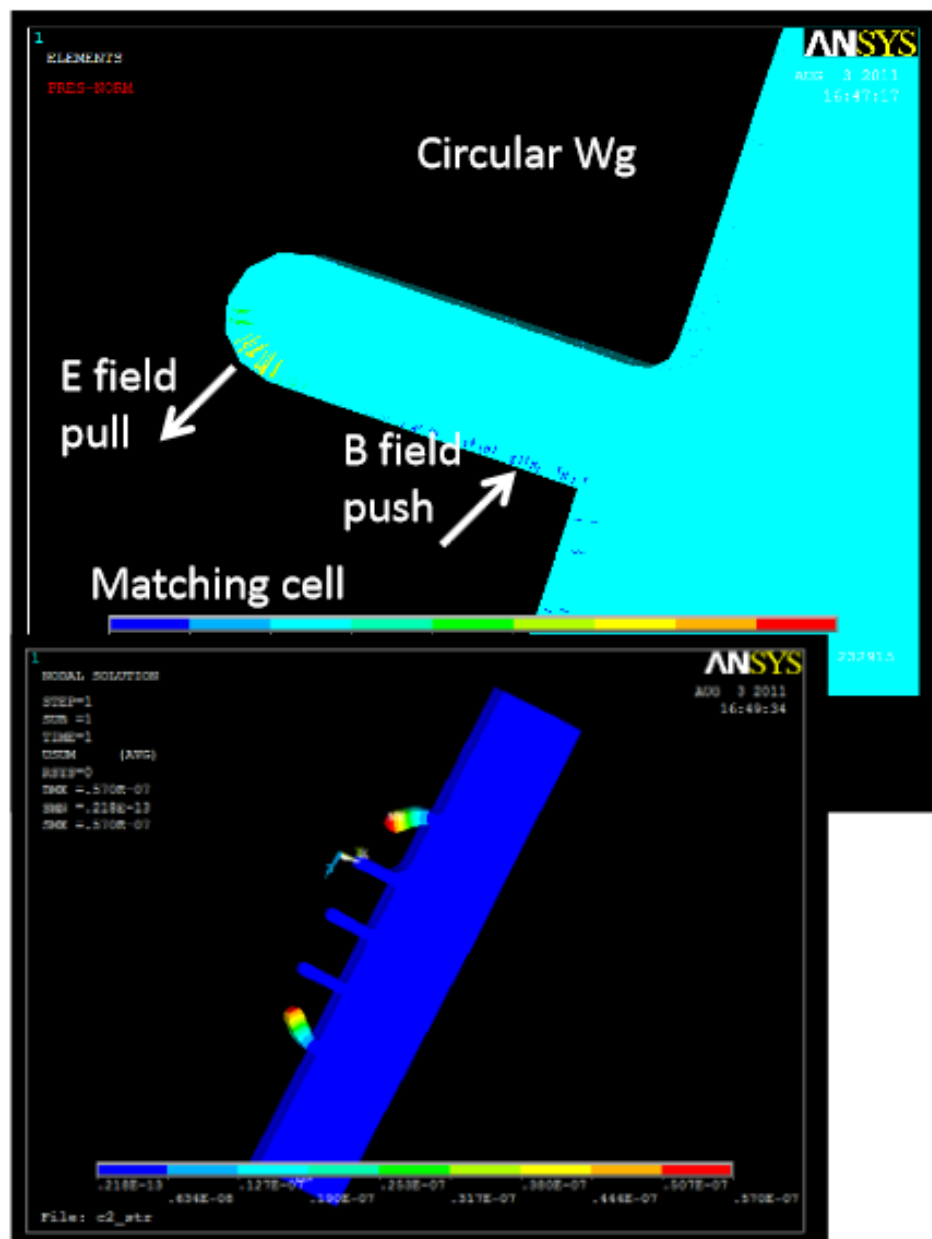
# EXTRA SLIDES

# TD24R05 tested in Xbox1

## History plot



# Electromagnetic field



- Scaled to 150 MV/m Eacc
- $P = (-\epsilon_0 E^2 + \mu_0 H^2)/4$
- static simulation
- Material: Copper  $E = 110\text{GPa}$
- Max deform: 0.06um, very small.
- 0.06um  $\rightarrow$  12kHz
- not the right direction
- HFSS result: Iris deform 10um  $\rightarrow$  ~ 2MHz