

Module related RF structures R&D (high gradient next steps and RF aspects of TBA module)

+

*Presentations should follow, whenever possible, the following scheme:*

- *Status of activity, compared to required CLIC performances.*
- *Short term program, expected results by end 2012.*
- *R&D planning for the next phase (2011-2016).*

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20+10 min

## **Recent test and hardware results:**

- Results from recent PETS high-power test in ASTA (Roberto)
- High-power accelerating structure tests and analysis
- Two-beam tests in TBTS (Roberto)
- Micron precision machining and assembly
- rf components

## **Design, simulations, developments and next steps:**

- Fully featured accelerating structures – compact couplers and integrating loads
- Accelerating structure design directions – evolution and alternatives
- On/off/ramp system progress and definition of operational scenarios
- Wakefield validation and coupled drive-to-main linac wakes
- Wakefield monitors and accelerating structure alignment
- BDR with beam – calculation and measurement
- Dynamic vacuum
- Cooling system
- High-power rf phenomena
- Alternative designs
- Cost and many, many more subjects

## **Testing infrastructure:**

- Status of high-power testing capability

# CLIC main linac rf network

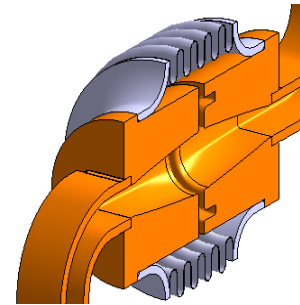
## PETS

- high-power
- as short as possible
- low longitudinal and transverse impedance

## Waveguide network

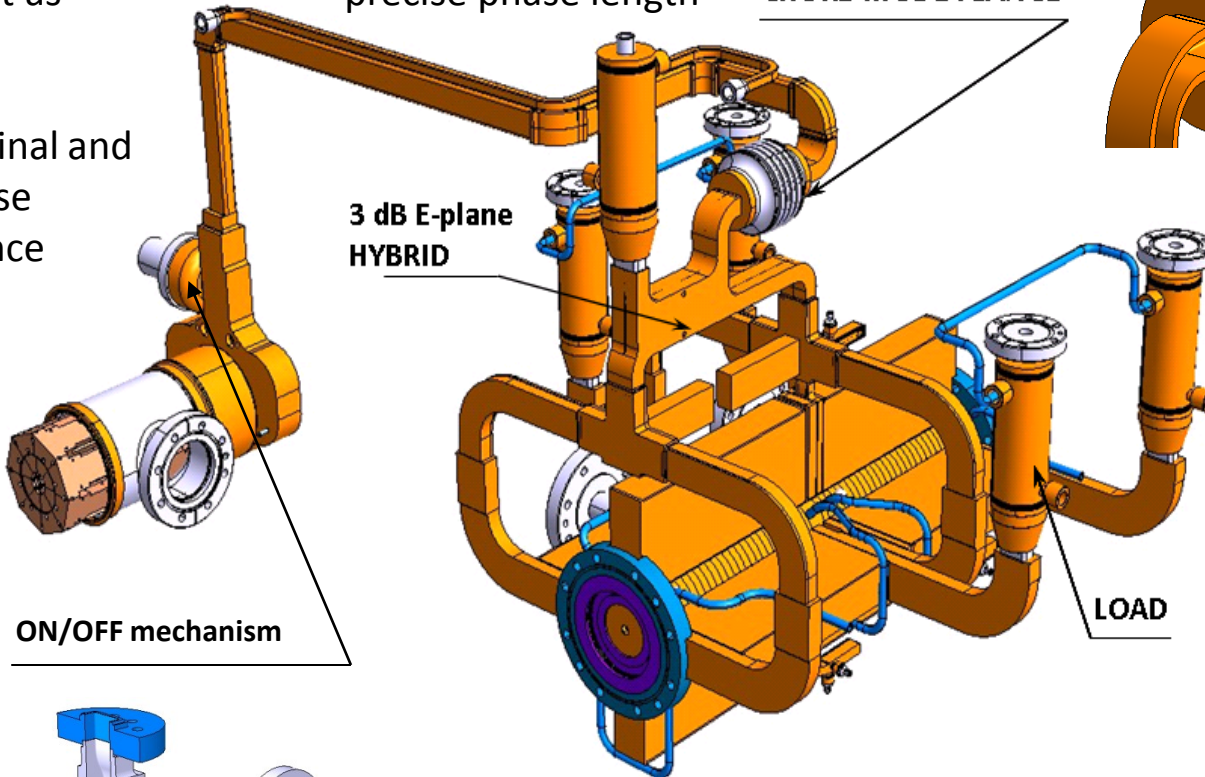
- high power
- precise phase length

## CHOKE-MODE FLANGE

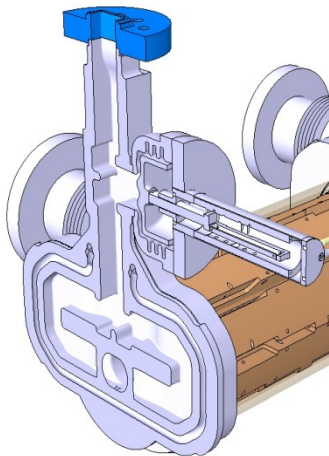


- Choke mode flange
- independent alignment of main and drive beam

## 3 dB E-plane HYBRID



## ON/OFF mechanism

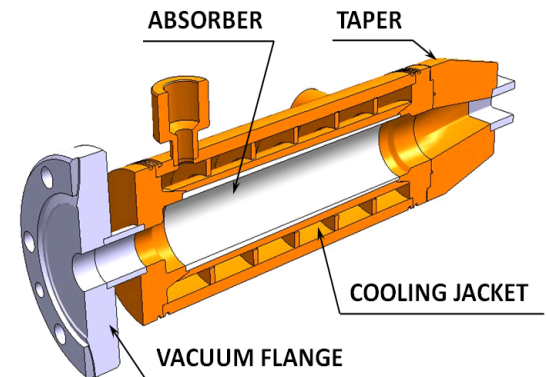


## On/ramp/off

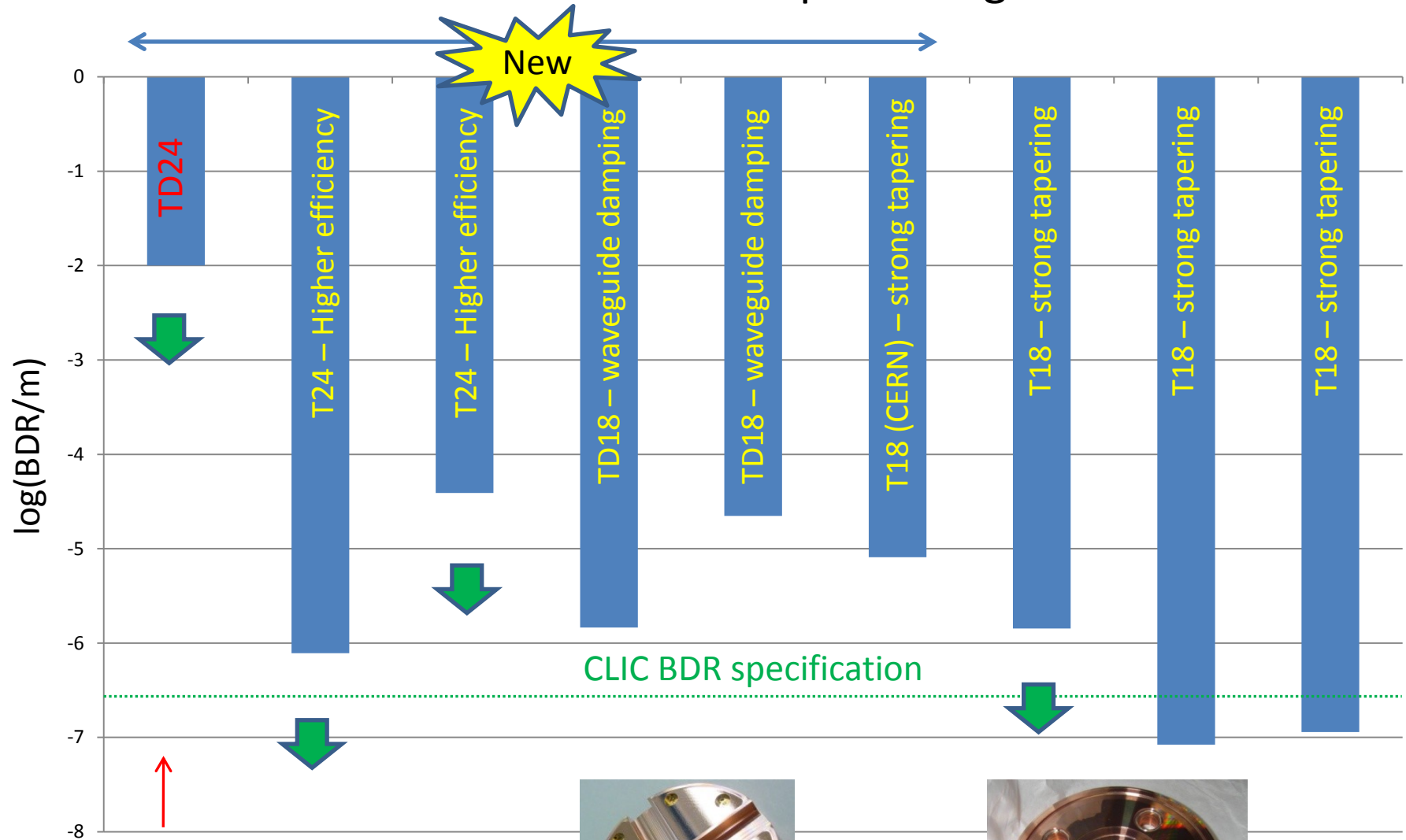
- necessary (?) to react to breakdown and/or failure

## Accelerating structure

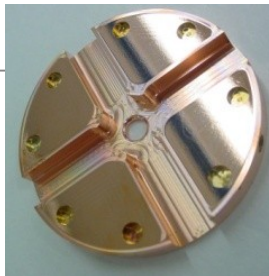
- high-gradient
- as long as possible
- micron precision
- transverse wakefield suppression



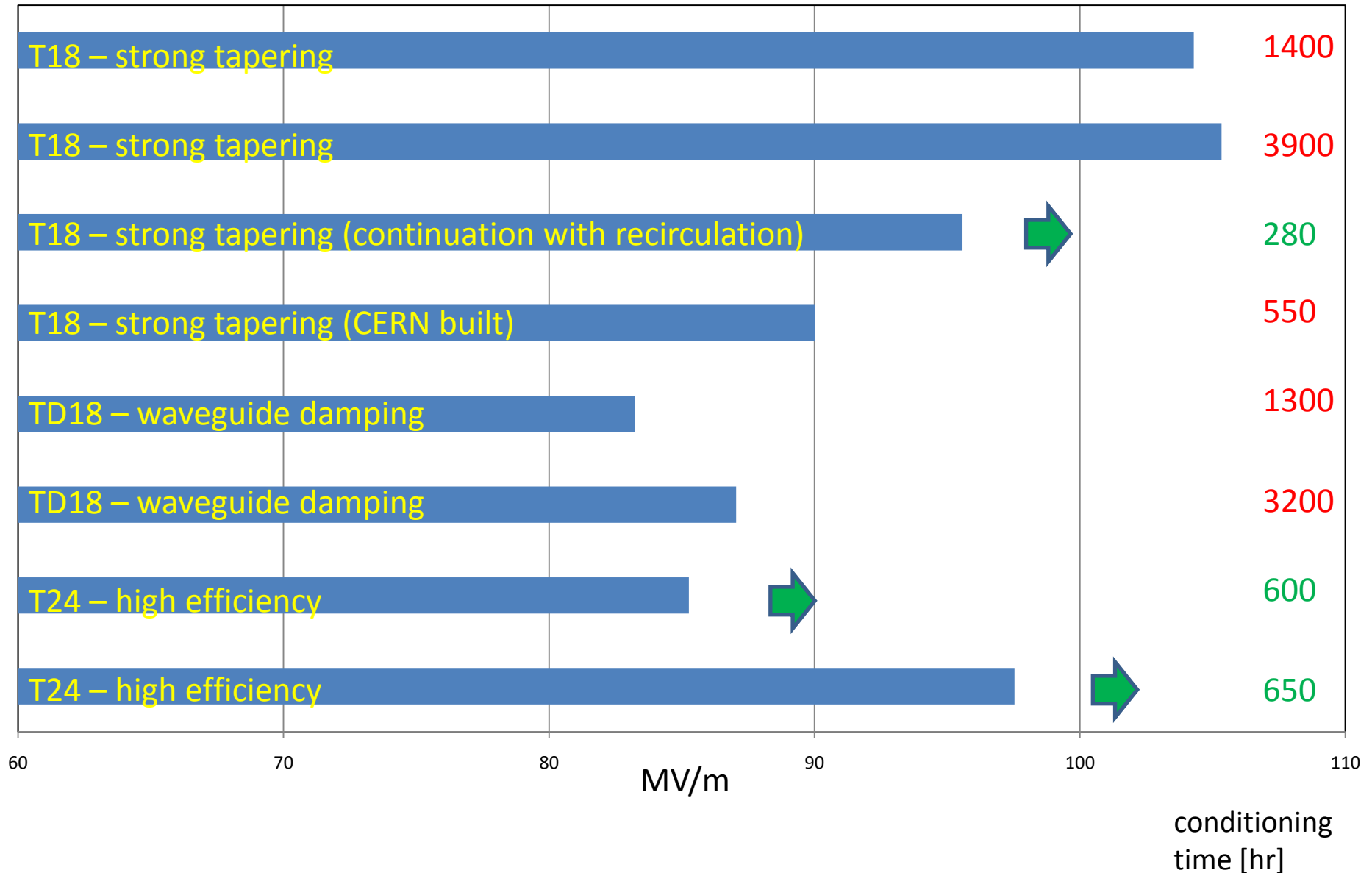
# Breakdown rate at 100 MV/m (unloaded) accelerating gradient and scaled to 180 ns pulse length



TD24 – CLIC nominal being tested with beam in CTF3 two-beam test stand.  
Processing just started.



# Unloaded gradient at CLIC $4 \cdot 10^{-7}$ BDR and 180 ns pulse length



## Accelerating structure development core program

Adopt NLC/JLC  
technology

Structure for 100 MV/m  
using high-power scaling  
laws – T18

Two successful tests, third underway, have shown that **100 MV/m, 240 ns,  $10^{-6}$  to  $10^{-7}$  range is feasible.**

Add damping features –  
TD18

Successful start of one test already shows damping features do not significantly affect performance. **Damped structures at 100 MV/m are feasible.**

CLIC nominal structure with better rf  
design for higher efficiency – TD24  
(and T24 to be systematic)

Predicted equivalent  
performance from high-  
power limits but more  
efficient. Needs verification,  
tests in spring.

Verification of features such as SiC loads,  
compact coupler, wakefield monitor

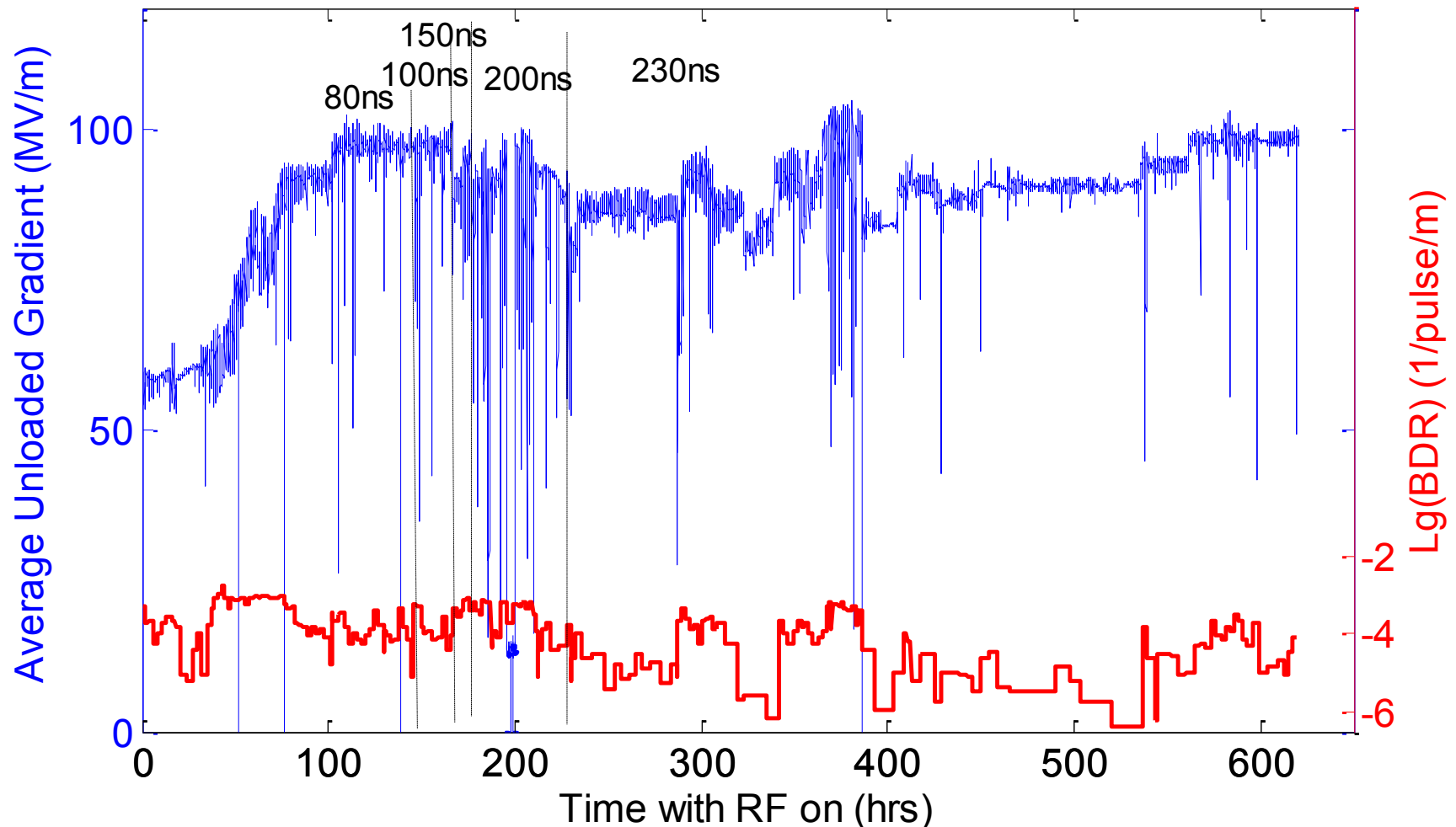
Mechanical design  
underway (tricky).

Fine tuning of design, optimization of  
process, medium series production  
and testing

**ACE 2-2-2010**

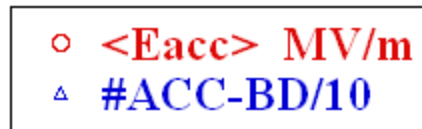
# RF Process Results T24\_SLAC\_Disk1

Started at Sept/21/2010  $1e-3(1/\text{pulse}/\text{m}) = 51.8/\text{hour}$  at 60 Hz for 0.24 m

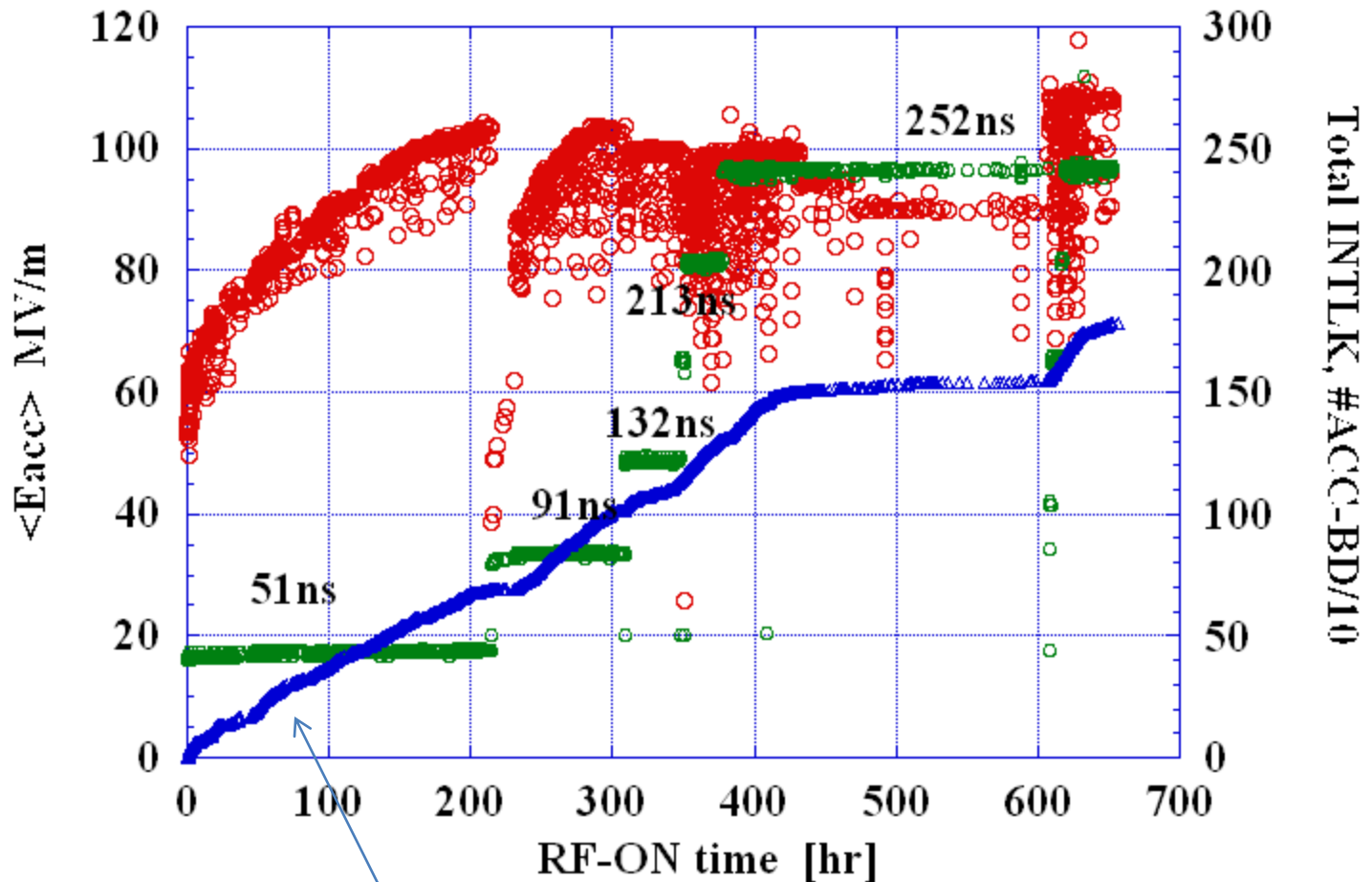
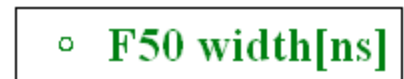


Currently BDR at 98 MV/m@230ns is  $7.4e-5/\text{pulse}/\text{m}$  ( $\sim 3.8\text{BKD}/\text{hr}$ )

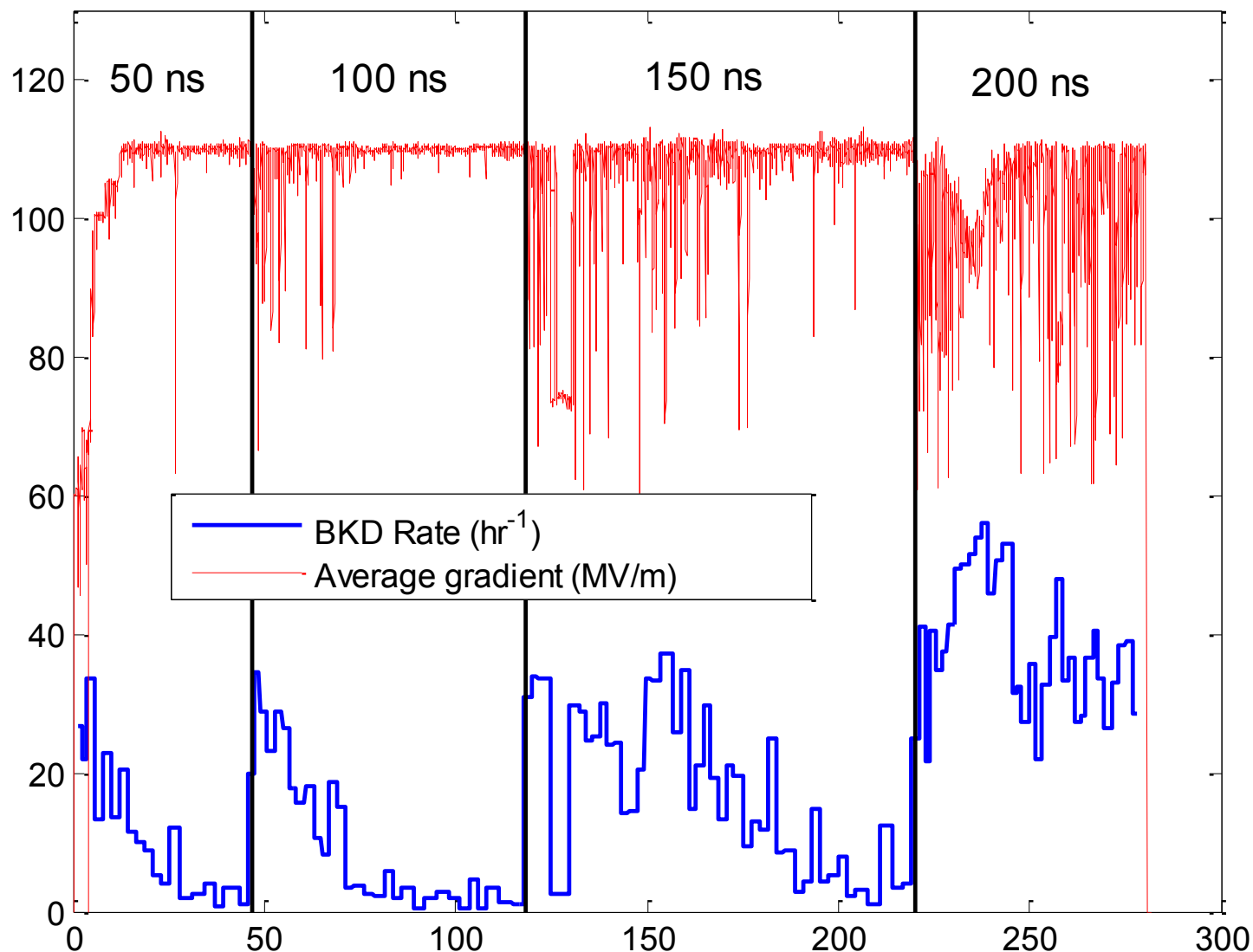
# T24 at KEK



## T24#3 History run1-16



## Pushing structure to longer pulse width with constant gradient (110 MV/m)



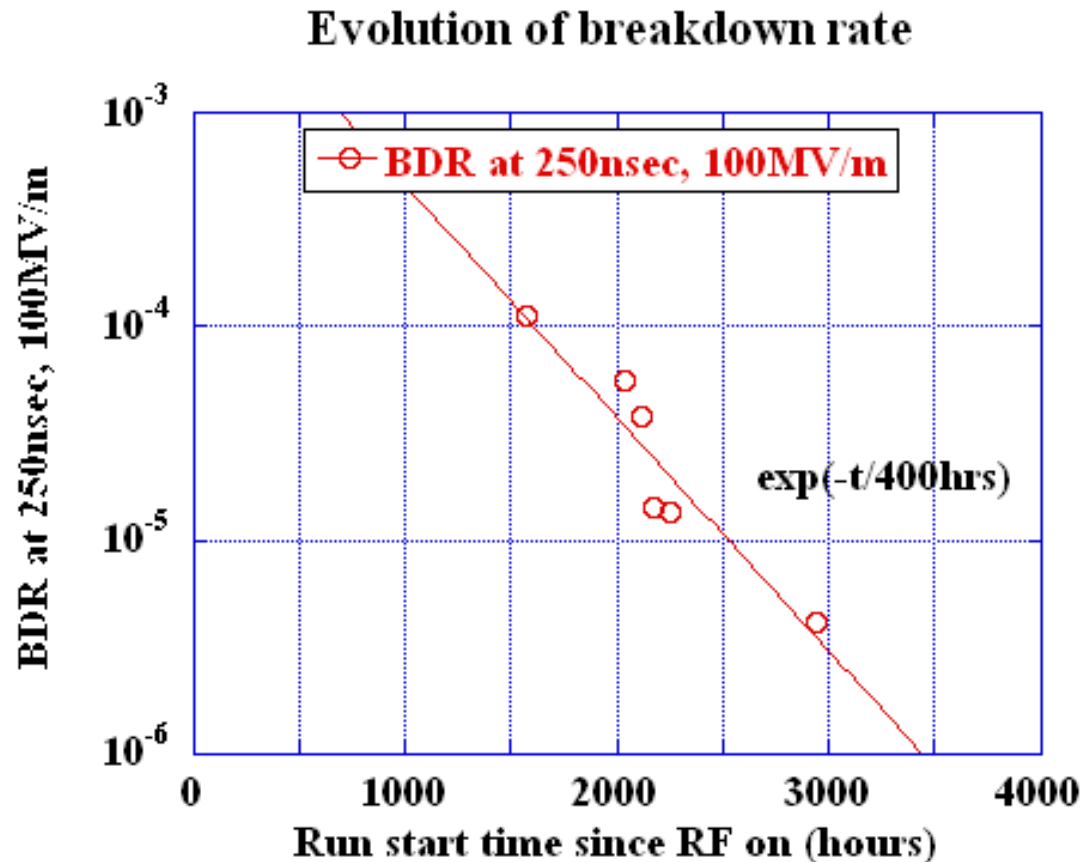
T18 which is now in resonant ring

# ASTA: Test of T18 in Resonant Ring

## Status (31 January 2011)

- Structure processed with  $\sim 100$  ns input pulse (no flat part) up to  $\sim 60$  MW peak power at the input of the structure ( $106$  MV/m).
- Pulse shape changed to  $\sim 100$  ns charging time and  $\sim 100$  ns flat part. The structure run at  $\sim 52$  MW at the input of the structure ( $\sim 100$  MV/m). **System limited not by rf breakdowns in the structure but by outgassing in transport line (A waveguide section will be replaced soon).**

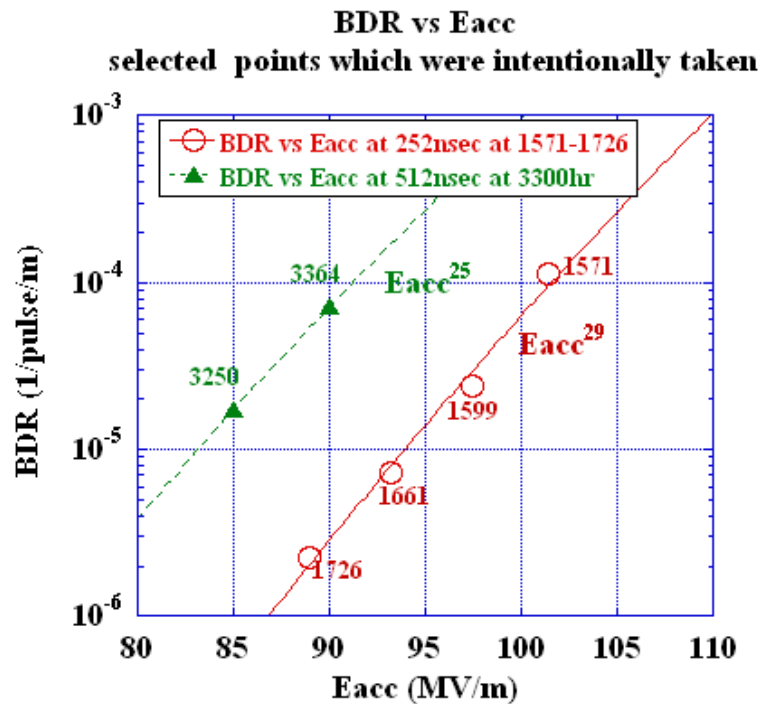
# Steady reduction of breakdown rate



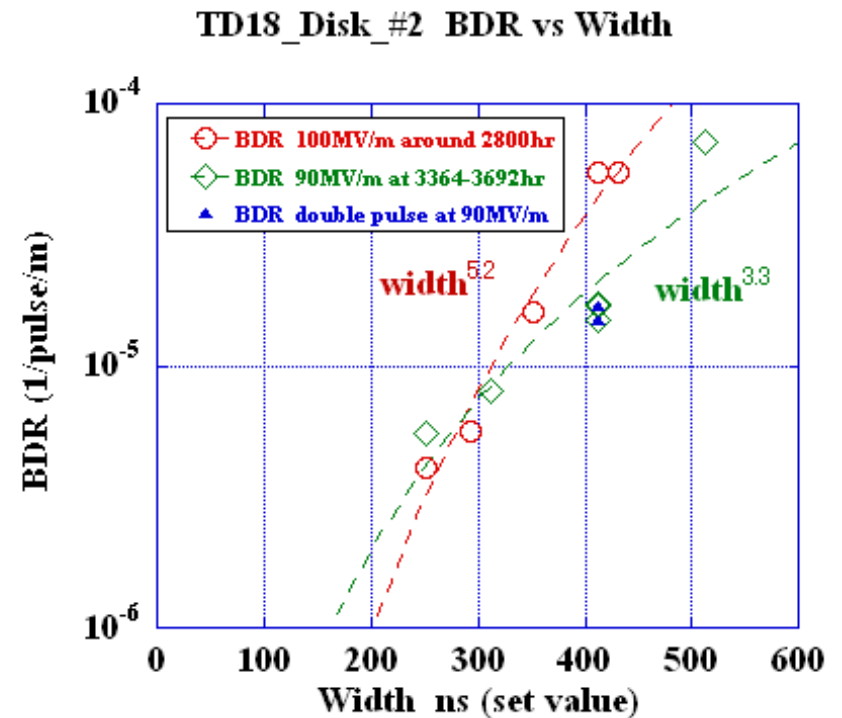
This data is from a TD18. In seven structures the breakdown rate decreased similarly during extended running while one T18 developed a hot cell and breakdown rate went up. Structure performance statistics is a priority for future tests.

Crucial dependencies:  $E^{29} \tau^5 / BDR = \text{const}$

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101017



Data taken at KEK on TD18

# Difference between T and TD18 explained?

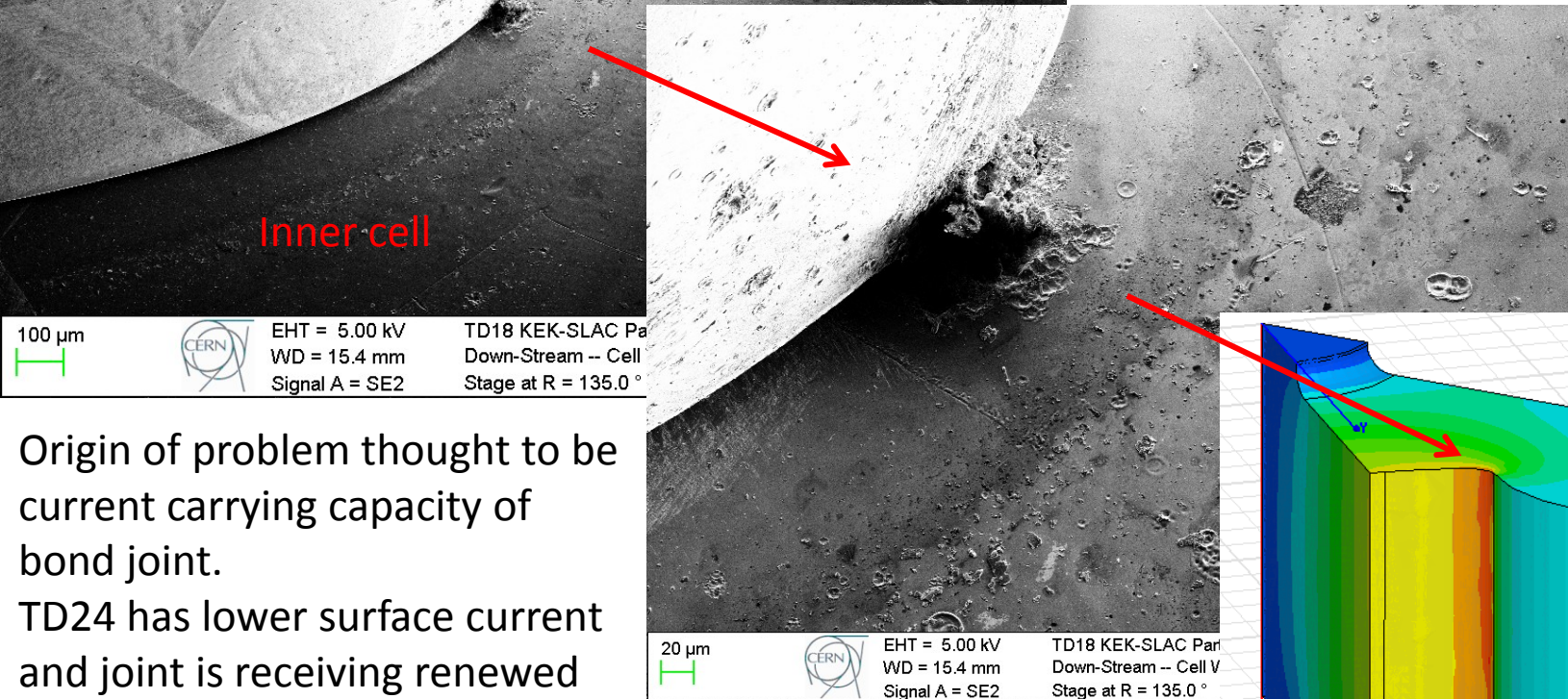


Damping waveguide

Inner cell

Points of enhanced breakdown rate in TD18 tested at SLAC probably identified.

Location is point of maximum surface current.

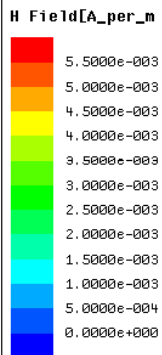
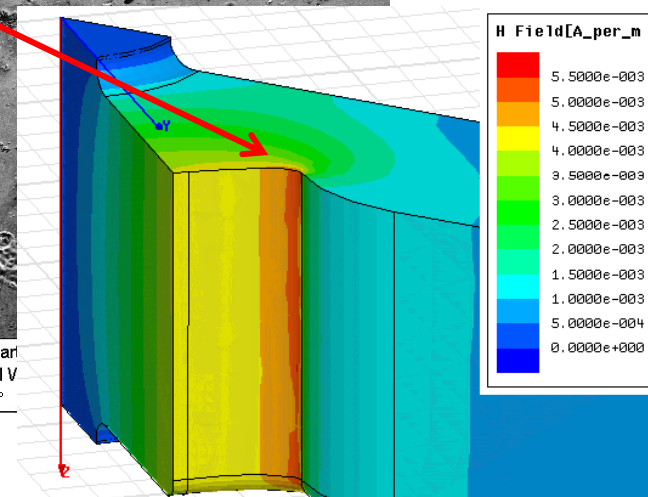


20 µm



EHT = 5.00 kV  
WD = 15.4 mm  
Signal A = SE2

TD18 KEK-SLAC Part  
Down-Stream -- Cell V  
Stage at R = 135.0 °

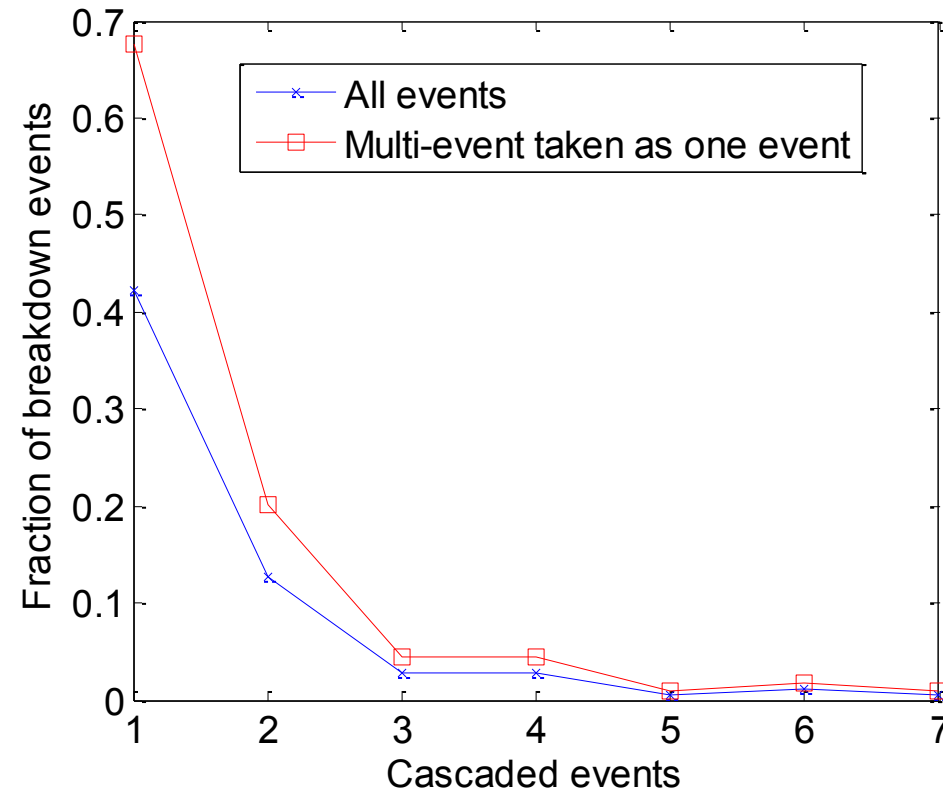


Origin of problem thought to be current carrying capacity of bond joint.  
TD24 has lower surface current and joint is receiving renewed scrutiny.

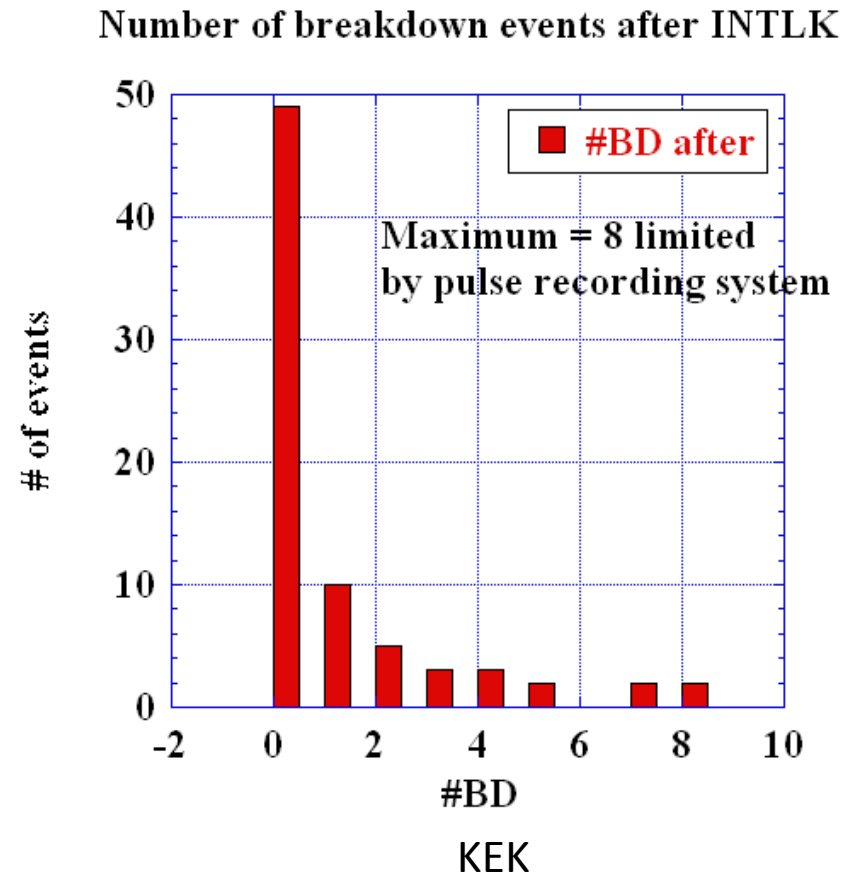
# Breakdown sequence statistics

Both sets of measurements were made on TD18s

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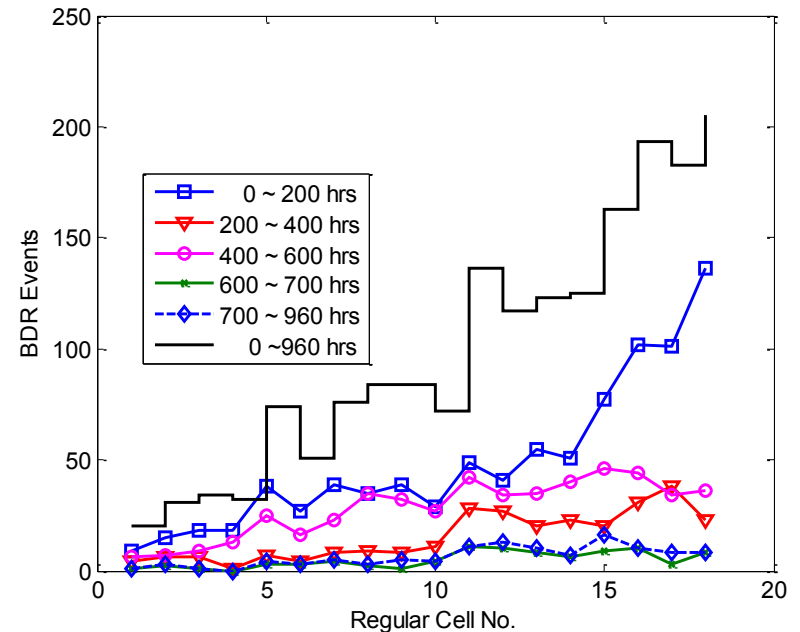
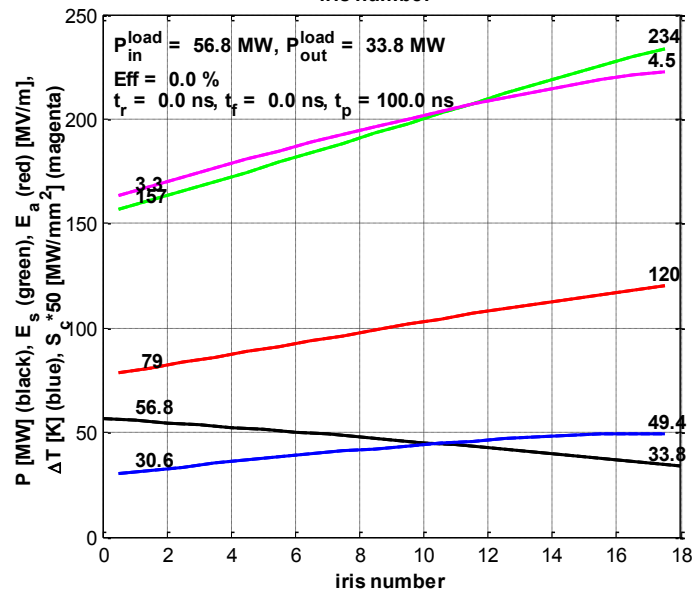
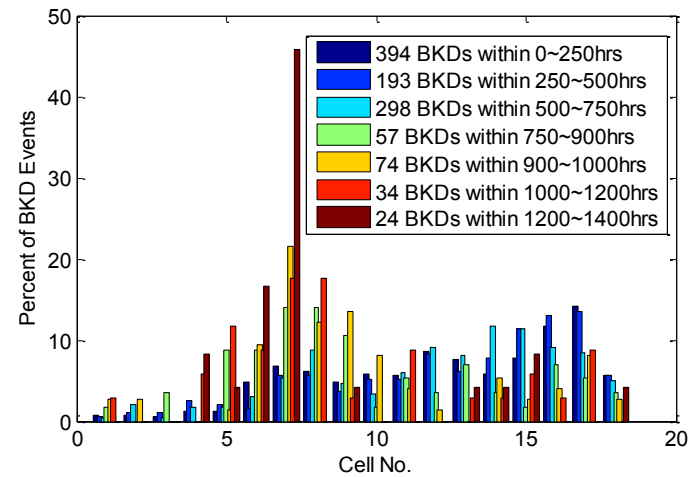
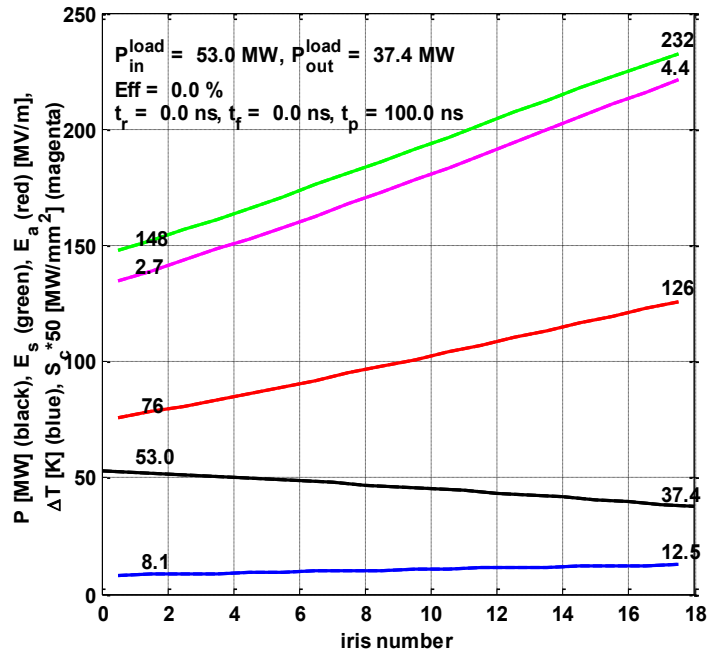


SLAC

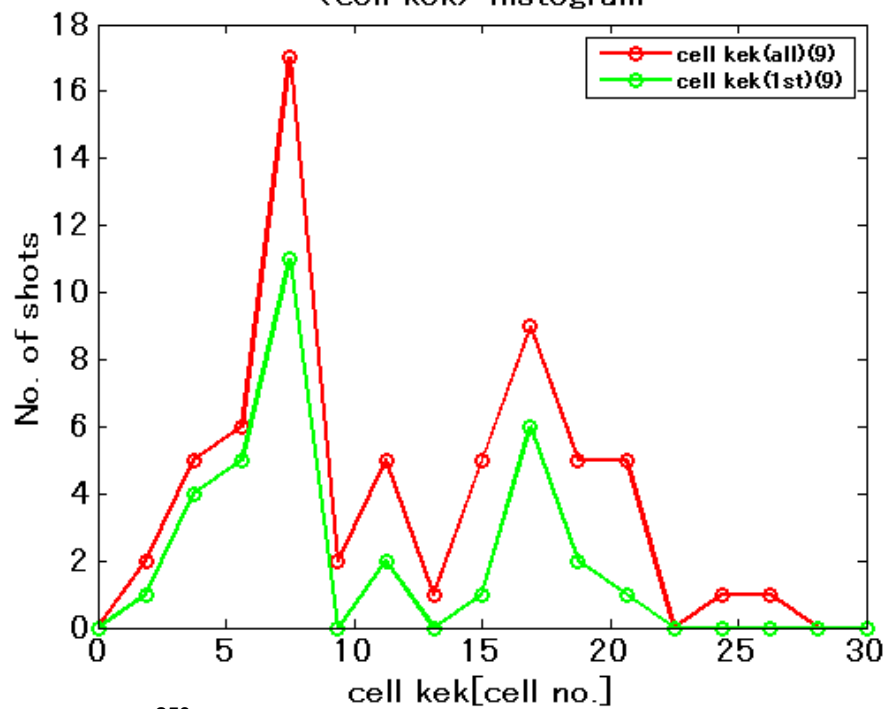


This kind of data is essential for determining rf hardware – on/off/ramp? – and establishing credible operational scenarios.

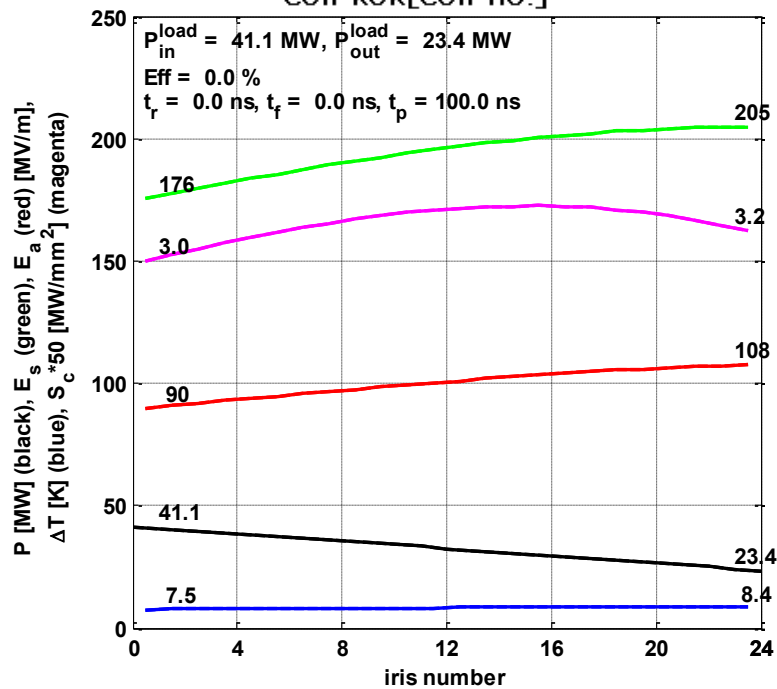
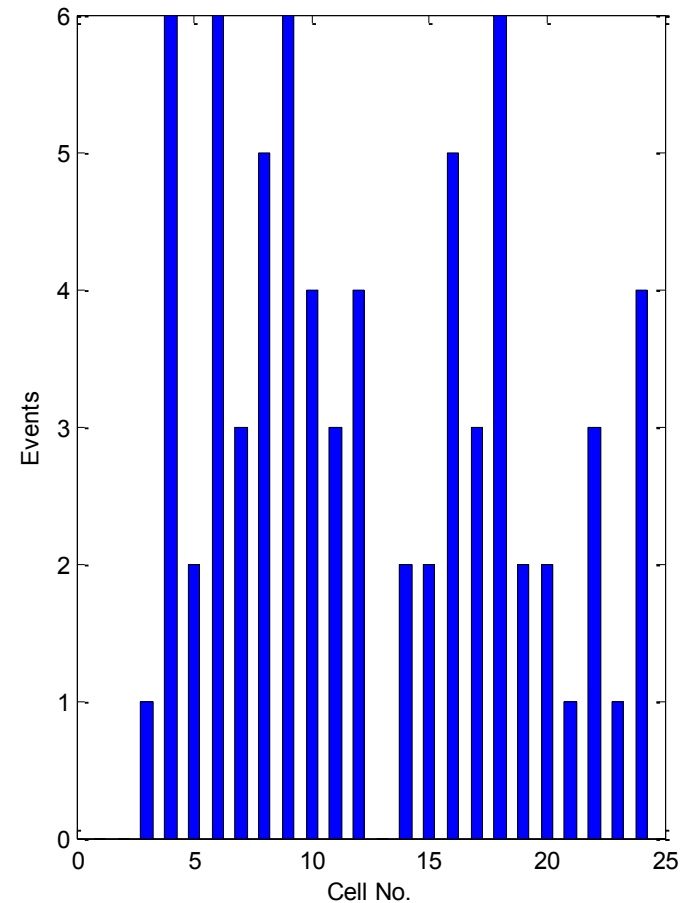
# 18 series breakdown rate distributions



<cell kek> histogram



T24 breakdown location distributions



SLAC

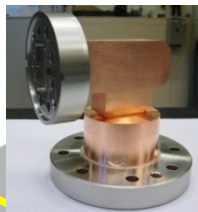
# Experiments to determine effect of beam on BDR

**CTF2** – Intentional beam loss in PETS did not directly induce breakdown.

**TBTS** – Two-beam configuration is correct for measuring beam-loaded breakdown rate but limited sensitivity due to low, order of one Hz, repetition rate and low,  $< 0.5$  A, main beam current.

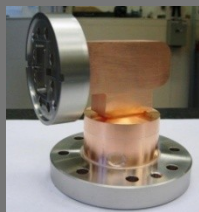
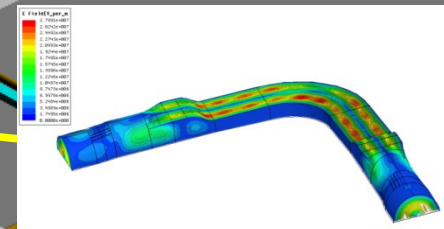
**Accelerating structure in drive-beam linac “30 GHz dog-leg” fed by klystron**  
– New idea, has only been discussed among a very small group of people, so not received full scrutiny yet. But sufficiently exciting to present here. 1-2 A trivial for drive beam linac, transport easier than 1.5 m long 30 GHz PETS, and 25 Hz accessible. All magnets, beam instrumentation, dump etc. in place. Over-moded power line from CTF2 to CTF3 drive beam linac in place too. Only needs replacement of mode converters and new bend. With around 4 A (and we used to run 30 GHz at around 5 A) we generate full accelerating structure power so could use recirculation for more testing capacity or install a T18 or, even better a PSI/Trieste H75 based structure, backwards and feed the CTF2 test area...

H  
s  
Gradient test  
F2



Two-beam 30 GHz power  
production in CTF3

High-power  
transfer line



PETs branch

CTF3  
linac

# Prototype accelerating structure test areas



NLCTA at SLAC



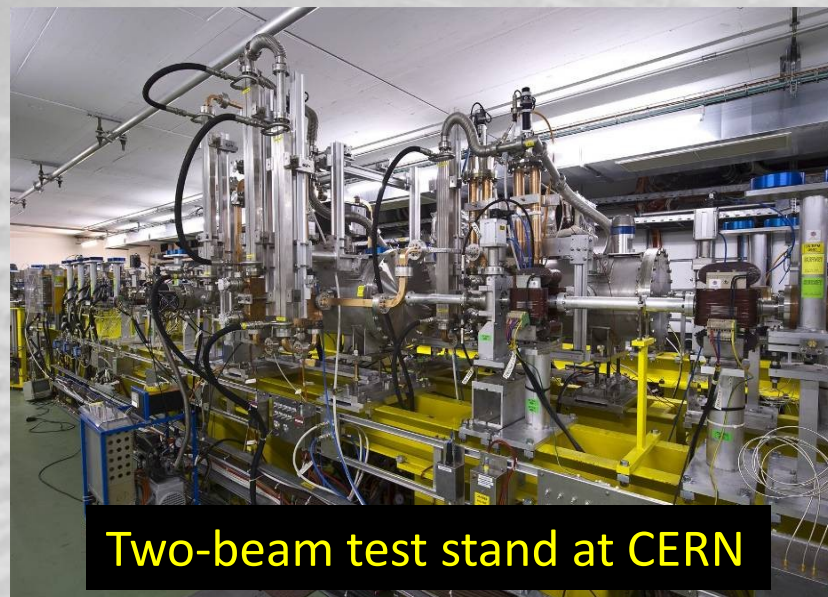
Nextef at KEK



New klystron at CERN



ASTA at SLAC



Two-beam test stand at CERN

# X-BAND STRUCTURE MASTER SCHEDULE

last update: 30.01.2011, G. Riddone

## Structures to be tested

Test station	Structure	2010		2011												2012				Remarks
		11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	
Nextef	T18_vg2.4_disk#4																			TD24s now under bonding/heat treatment
Nextef	T24_vg1.8#3																			
Nextef	TD24_vg1.8#3																			
Nextef	TD24_vg1.8_R05#1																			
Nextef	TD24_vg1.8_R05#2																			
NLCTA	T24_vg1.8#4																			now being tested in ASTA
NLCTA	TD24_vg1.8#4																			
NLCTA	T18_vg2.4_disk#7																			
NLCTA	TD24_vg1.8#5																			
NLCTA	T18_vg2.4_disk#3																			
ASTA	C10 /CD10																			6 structures available
ASTA	T18_vg1#3 recirculation																			
ASTA	PETS 11.4 damping +CMF																			
SATS	T24_vg1.8#3																			
SATS	TD24_vg1.8#3																			
SATS	TD24_R05 SIC#1																			
TBTS	TD24_vg1.8#1 (12)																			Under repair
TBTS	T24_vg1.8_5																			
TBTS	TD24_vg1.8_disk#WFM (12)																			
TBTS	PETS 12 no damping																			
Module	PETS double length																			
Module	TD26_full stucture																			first module to be ready by mid 2012

Legend	
	mechanical design
	machining
	bonding/assembly
	heat treatment
	testing

**ACE 2-2-201**

**CLIC**

# Testing schedule simplified

[illegible]

## Current effective testing capability for CLIC-related structures

Facility	Available testing slots
Nextef	1
NLCTA	0.5
ASTA	0.25
CERN klystron	0
TBTS	unique capabilities – will not be used for low BDR tests
Total	<2

Personal view – highlighting availability is not a criticism but an attempt to honestly evaluate our situation.

# Introduction to dynamic vacuum

- Main beam linac requirements : total  $p \leq 10^{-9}$  Torr (from G. Rumolo <https://edms.cern.ch/document/992778/2>), assuming CO, N<sub>2</sub> and/or H<sub>2</sub>O. H<sub>2</sub> is not harmful.
- Three separate issues:
  - Static vacuum
  - Dynamic vacuum due to breakdowns
  - Dynamic vacuum due to field emission / dark currents
- Static vacuum and dynamic vacuum due to breakdowns are not covered here. However for the design repetition rate they are not a limiting issue and can be simulated on the basis of known data. See C. Garion <https://edms.cern.ch/document/1109052/1> and <https://edms.cern.ch/document/1095288/1>

# Dark currents induced dynamic vacuum I

- Progress since last year's ACE
  - ❖ Necessary information: Electron Stimulated Desorption (ESD) coefficients of unbaked copper, processed according to manufacturing sequence of RF structures, at high energy
    - ⇒ A new laboratory test system has been prepared and is operational, for testing copper samples up to  $e^-$  energy of 35 keV (safe limit for lab equipment). Test of samples from a large matrix of [surface treatments]•[thermal treatments] has started (Chiara Pasquino thesis)
  - ❖ Necessary information: accurate dark current simulations, calibrated with actual dark currents measured in faraday cups, in order to obtain the # of molecules degassed at each pulse.
    - ⇒ Collaboration with SLAC / ACD on using ACE3D for the purpose has started. Kyrre N. Sjøbæk from CERN/Oslo U. Is working on this.
  - ❖ The two elements above will be combined to produce dynamic pressure profiles (simulation tools are available)

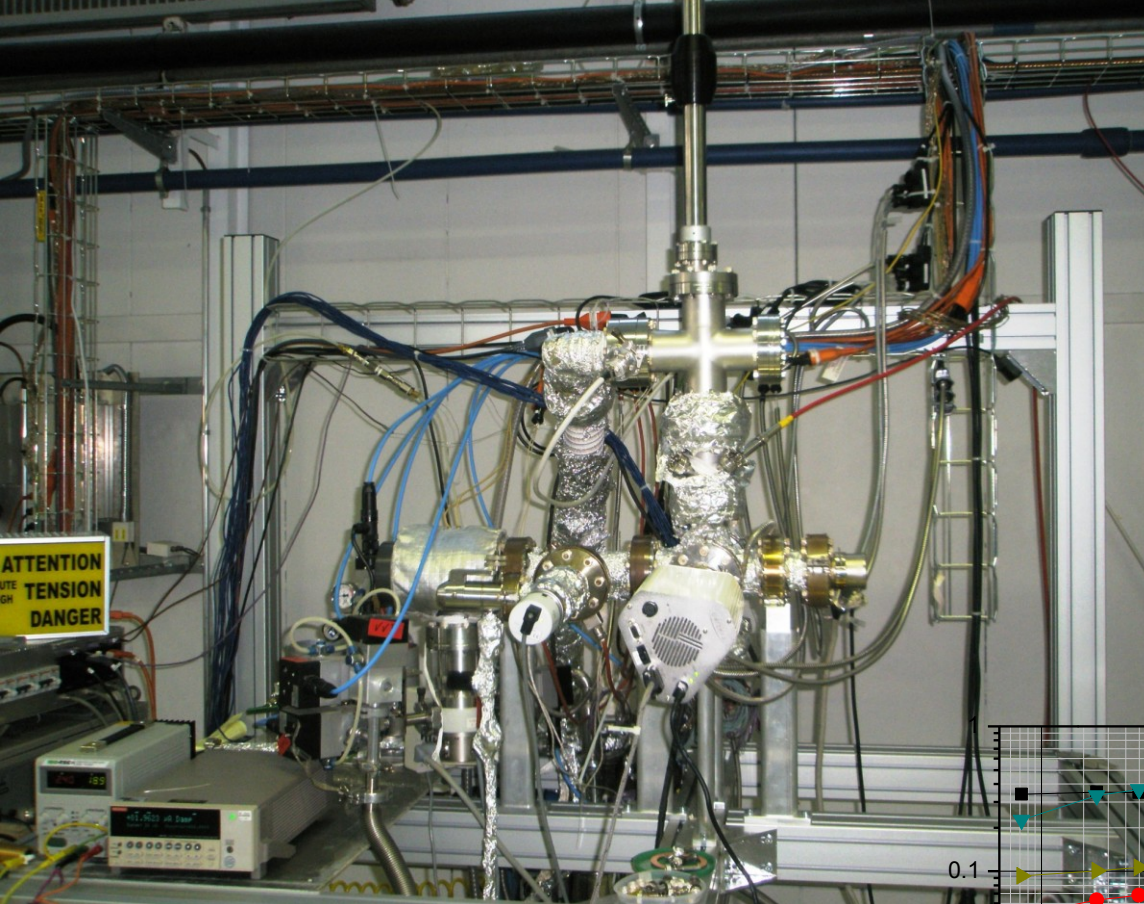
# Dark currents induced dynamic vacuum II

- Progress since last year's ACE

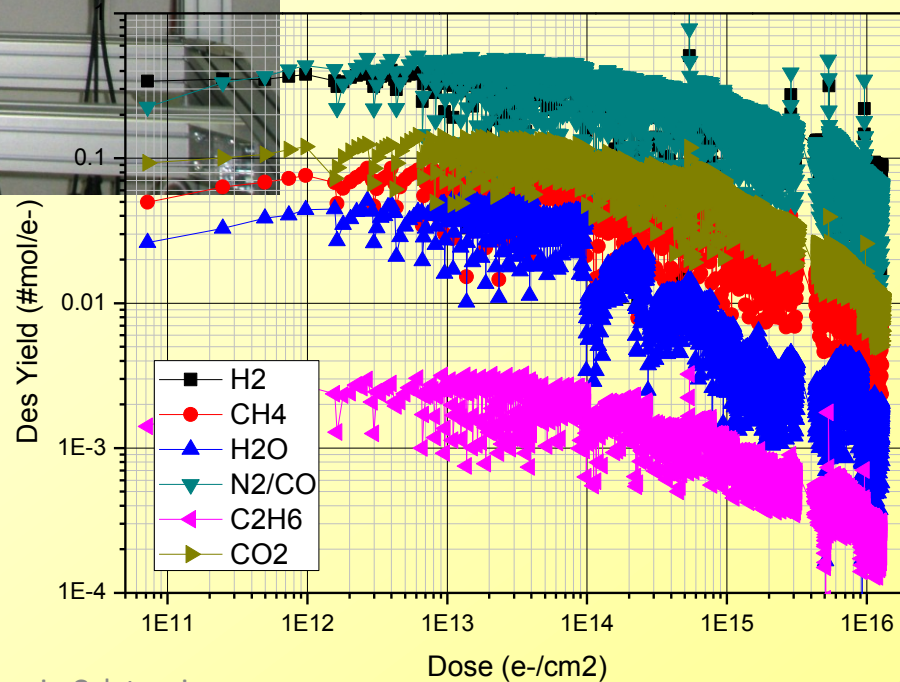
- ❖ Necessary information: Real experimental data for dynamic vacuum.

- ⇒ Several efforts started:

- Collaboration with Helsinki U. / HIP for direct measurement with a multipass laser system. PhD work is starting (CERN will provide test structure to implement the measuring hardware)
    - Stand alone 12 GHz CERN test stand: is being instrumented .
    - KEK 11 GHz test stand: data is collected and correlated with dark current. Vacuum improvements of the test stand are foreseen (now limited by baseline vacuum)
    - SLAC 11 GHz test stand. Old data will be revaluated and analysed



ESD @ 10 keV



# Prototype development overview

## **Test structures include all feasibility-level features/issues:**

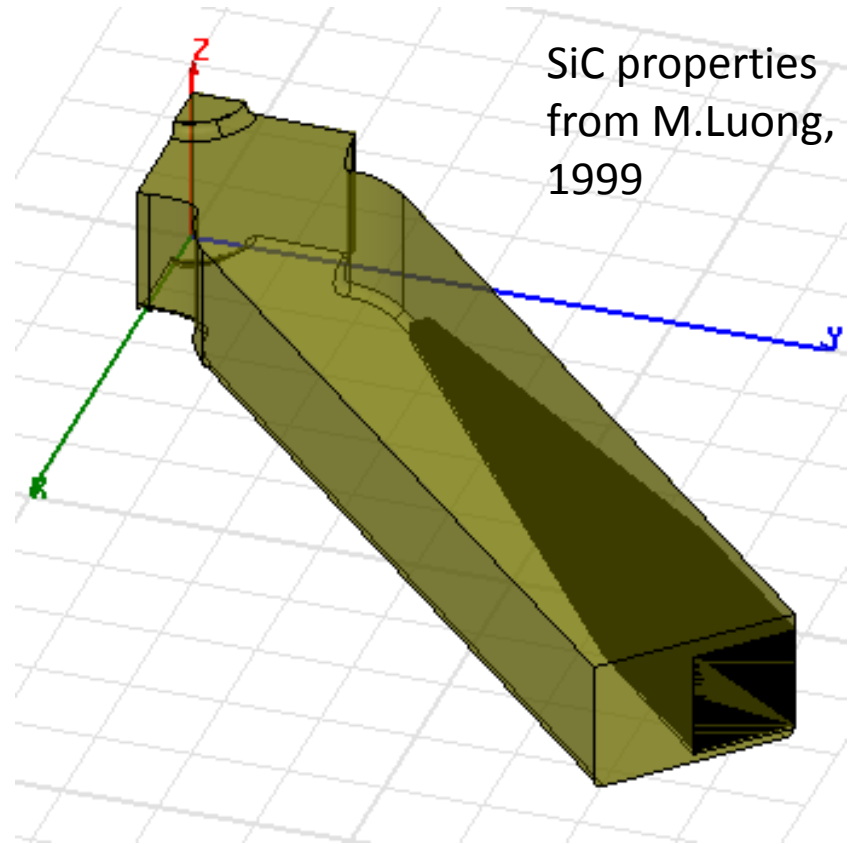
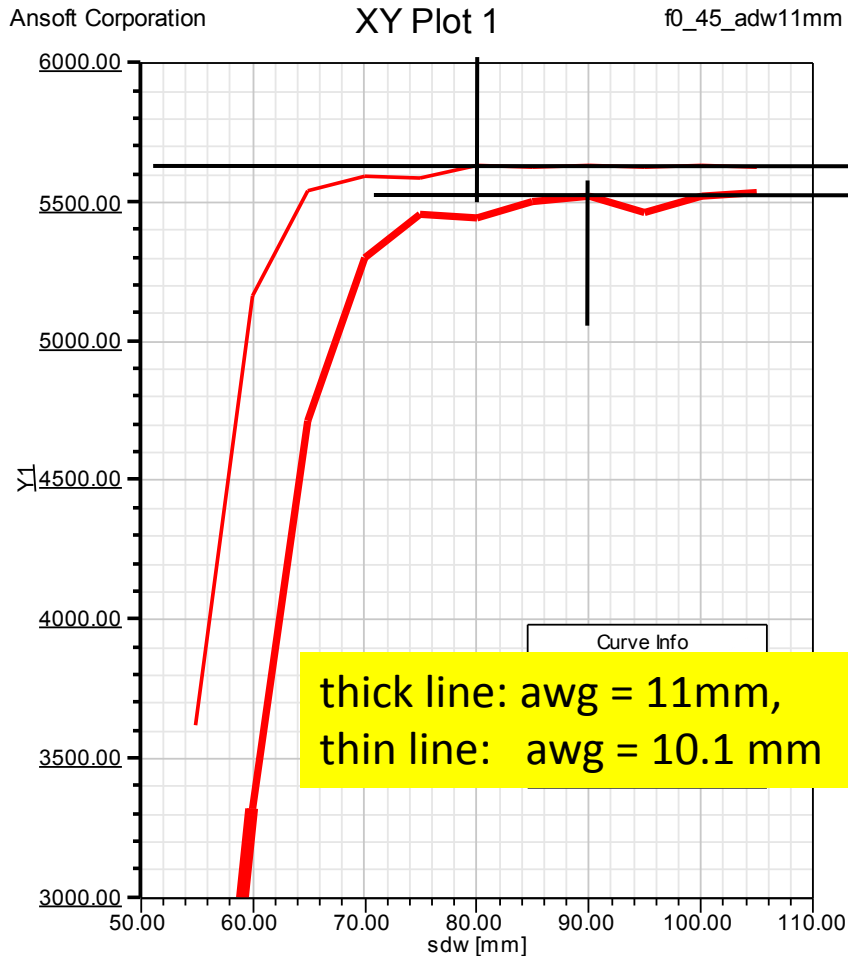
- Correct iris aperture range
- Damping waveguides

## **Completeness, cost and performance features/issues are next:**

- Compact coupler. We now use a “mode-launcher” coupler which works fine but is too long. There are many options for compact couplers, and at least a few should work, but it could take a number of high-power tests to work it all out.
- SiC loads. Loads can be pulled back to arbitrarily low fields, although this would result in a more expensive structure. Field emitted electron bombardment, and resulting dynamic vacuum issue are the main known unknown. However the CTF3 drive beam accelerator has thousands of loads, PETS with SiC in ASTA worked fine and there are lots of high-power C-band loads with SiC in them.
- We now have the basic high gradient data, better understanding of breakdown and (soon) a cost model to make a significantly better optimization.
- New structures for different energy machines e.g. 500 GeV.

# Design of the HOM Damping Load

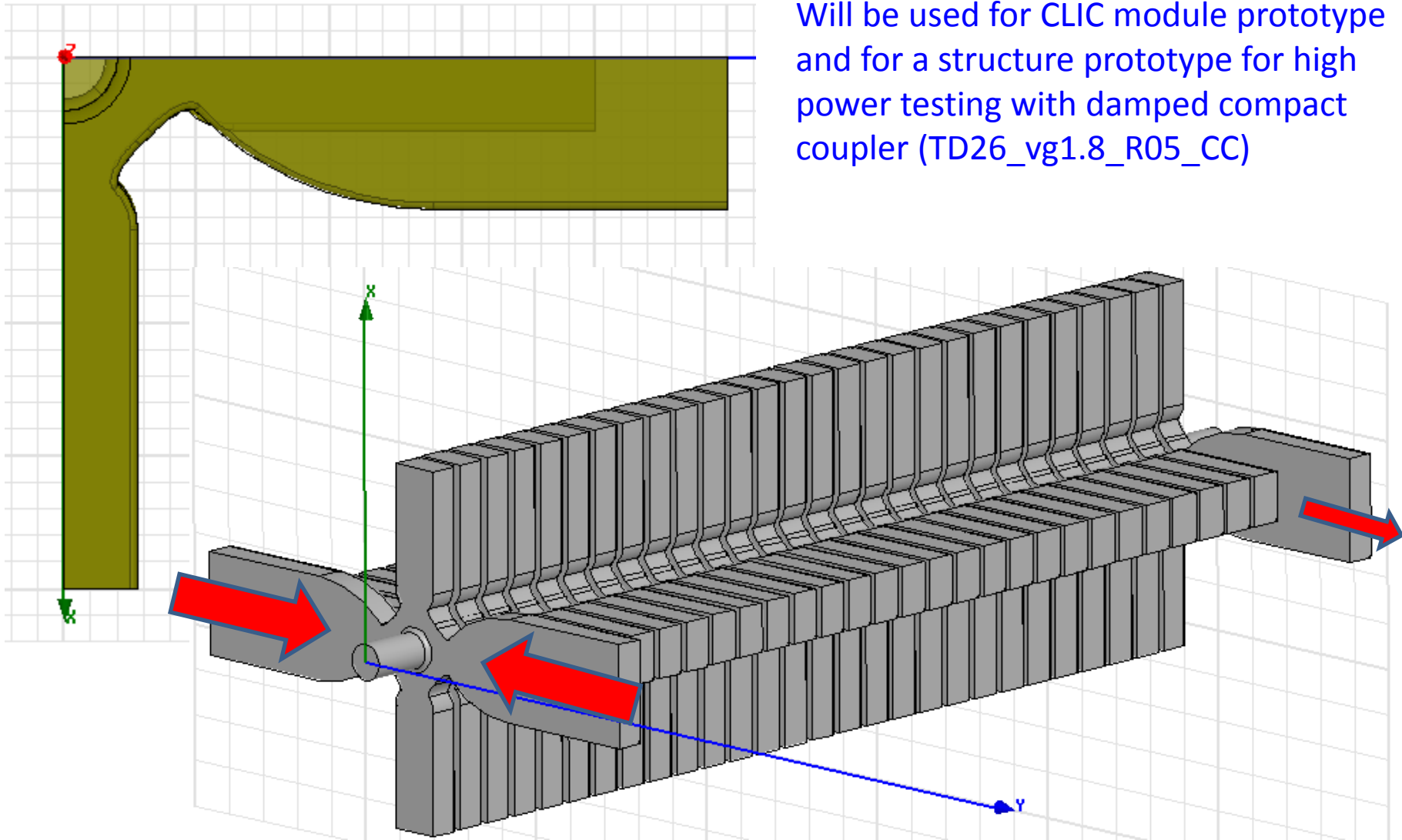
Will be used for CLIC module prototype and  
for a structure prototype for high power  
testing with damping load inside  
(TD24\_vg1.8\_R05\_SiC)



Tip size 1x1 mm  
Tip length 20 mm or 30 mm  
Base size 5.6 x 5 or 5.5 mm  
Base length 10 mm  
Waveguide width  
awd = 10.1 mm or 11 mm

# Design of the damped compact coupler

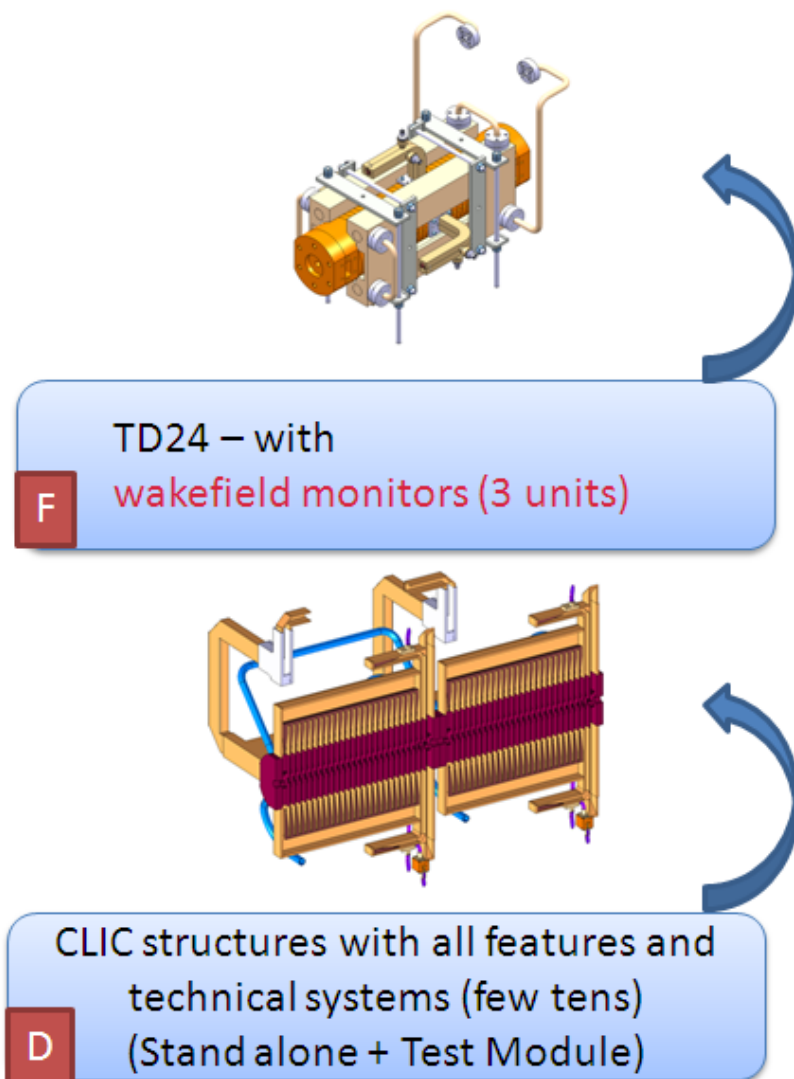
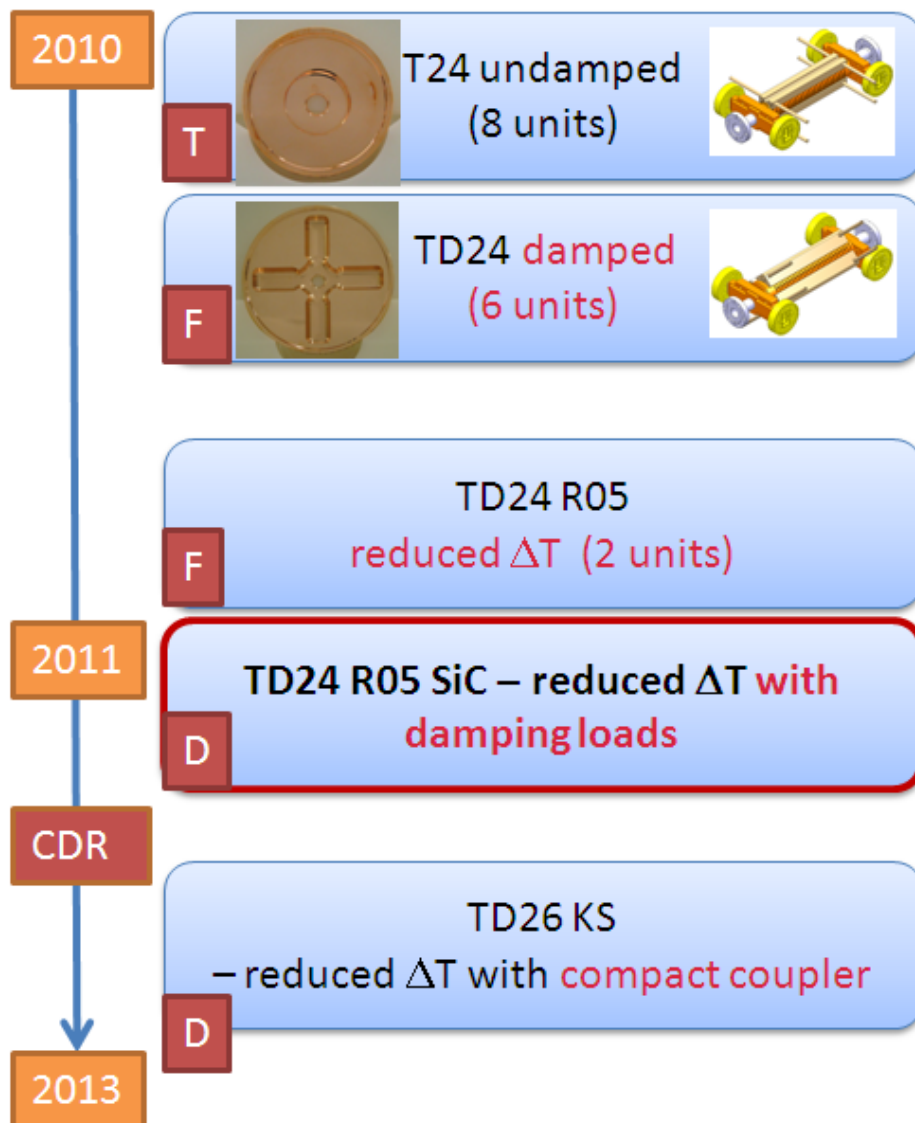
Will be used for CLIC module prototype  
and for a structure prototype for high  
power testing with damped compact  
coupler (TD26\_vg1.8\_R05\_CC)



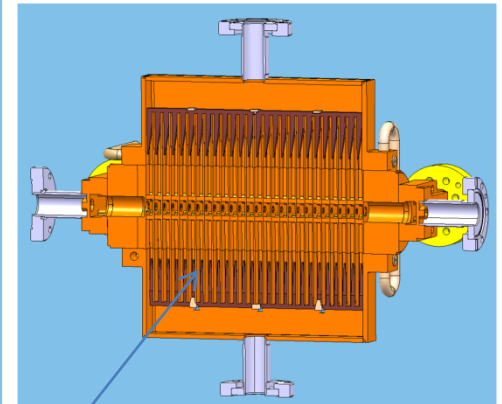
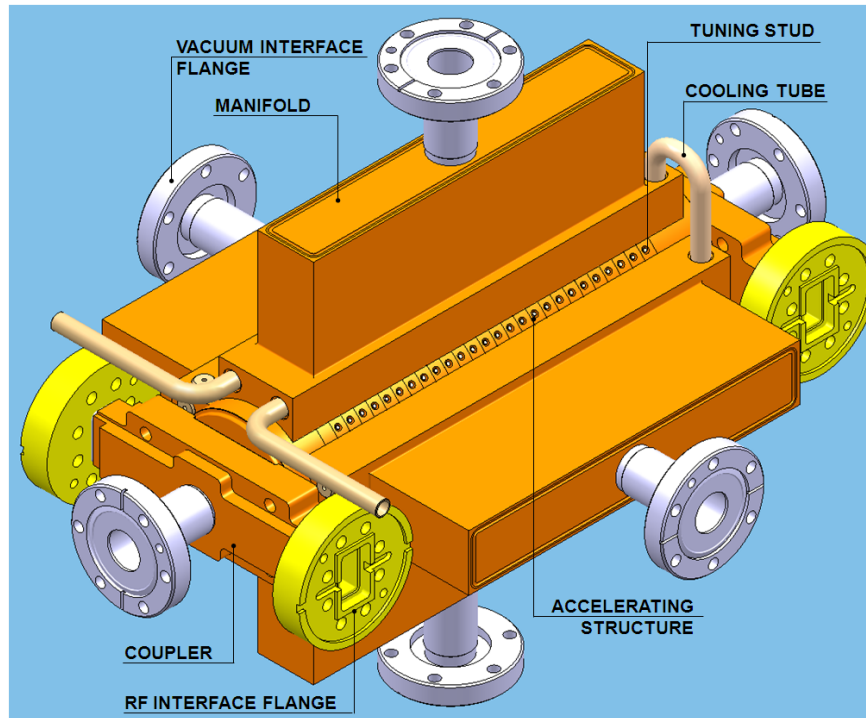
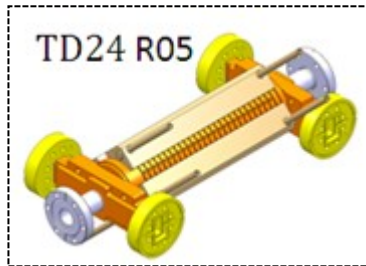
# Accelerating structure program

G. Riddone

T = under testing  
F = under fabrication  
D = under eng. design



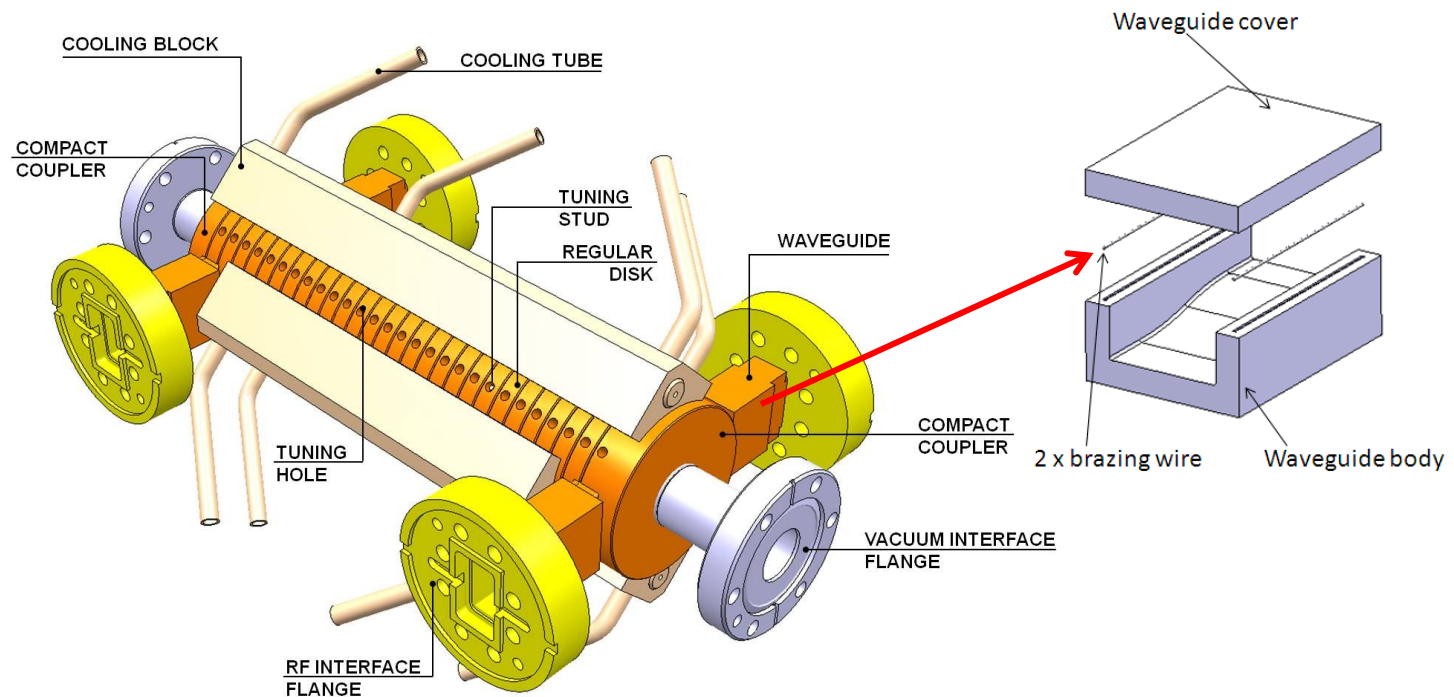
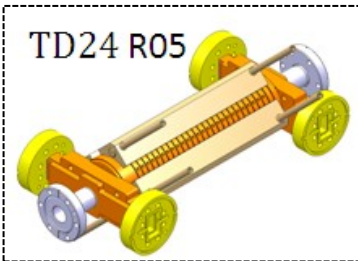
# TD24 R05 SiC



## New features: (from TD24 R05)

- damping loads (numerical simulation performed)
- brazing of vacuum manifolds (test under way to validate assembly procedure) → preservation of alignment!
- optimization of cooling circuit design

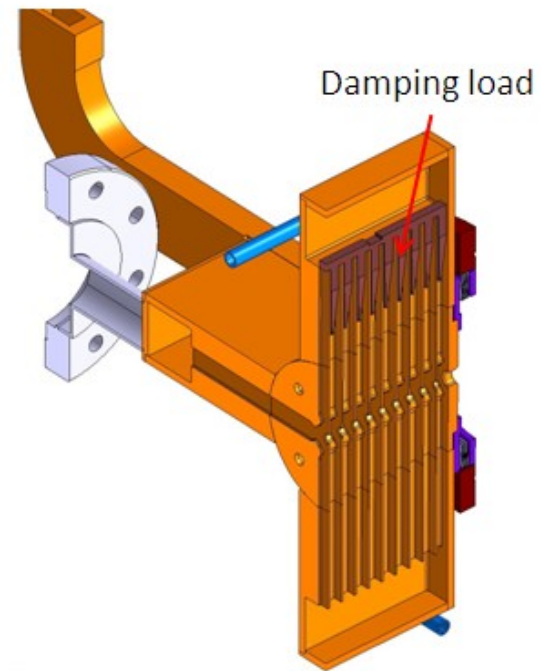
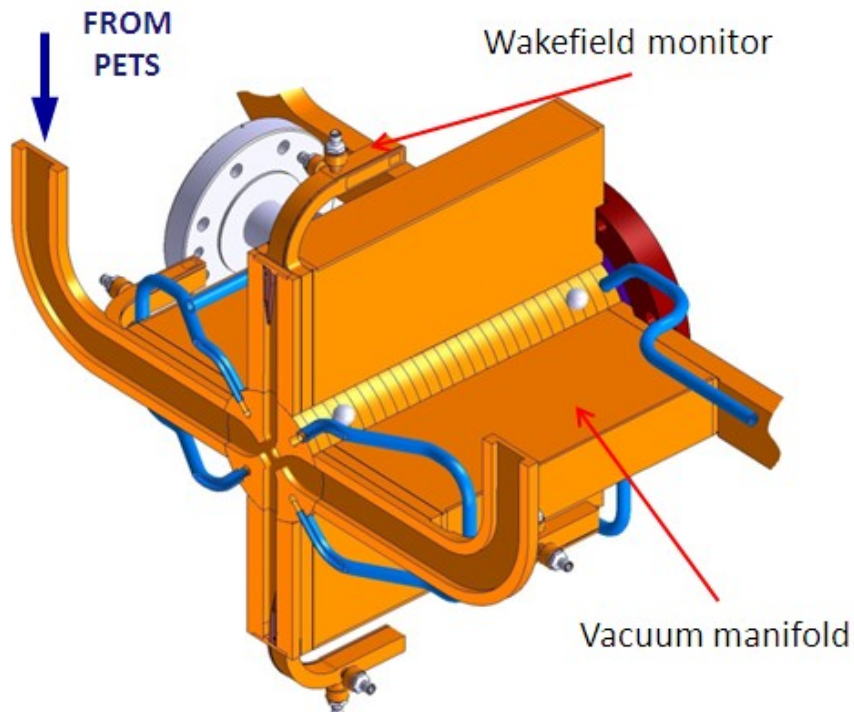
# TD26 Compact coupler



## New features (from TD24 R05):

- compact coupler
- new design of waveguides
- additional brazing steps (procedure validated)

# TD26 CC SiC (towards CLIC structures)



## **All features integrated:**

- compact coupler (as TD26 CC)
  - new design of waveguides
  - additional brazing steps (procedure validated)
- damping material and vacuum manifolds (as TD24 R05)
- WFM (as TD24 WFM from CEA)
- interconnection to adjacent structures/modules

- **Many brazing/bonding/EBW steps (validation on mock-ups from March 2011)**
- **Compactness and tolerance preservation are the main issues**

# Summary of a few key points

## Fundamental performance

- PETS in very good shape.
- Scaling laws for high-gradient,  $P/\lambda C$  and  $S_c$ , and understanding of breakdown have produced PETS and 100 MV/m-range accelerating structures.
- All CLIC-series accelerating structures made using the baseline fabrication technique, 1050 °C bond in hydrogen, have reached above 100 MV/m.
- T18's meet specification (unloaded). T24 tests are going well.
- **Reduced gradient from T18 to TD18 observed.** Weakness identified in disk-to-disk joint at highest surface-current point. **TD24s scheduled to be tested from March.**
- **We need to start getting statistics not just results on individual structures.**
- **Testing capability is a weak point.**

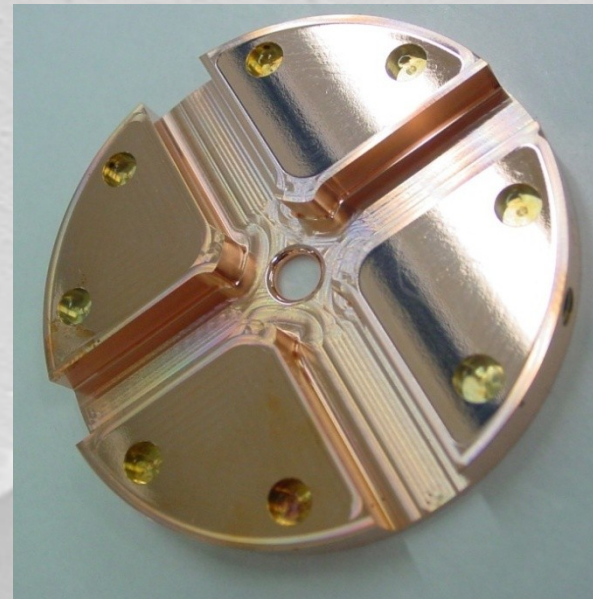
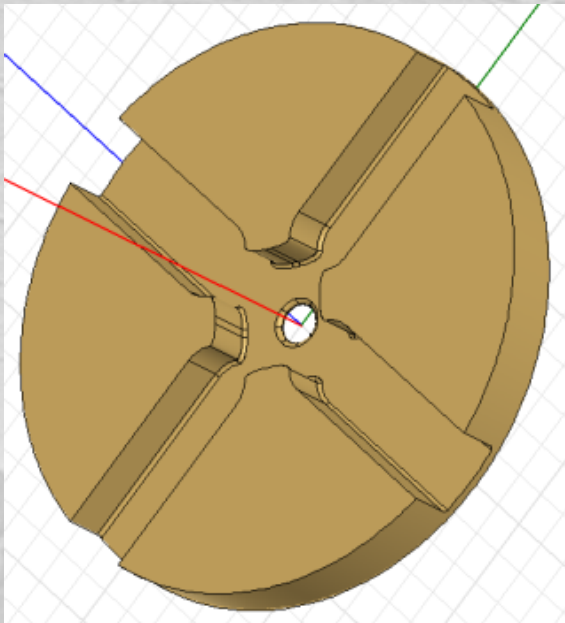
## Two-beam units

- Getting back on line with two-beam acceleration, now at X-band, and going well. Full program ahead.

## Engineering and integration in module

- Advancing well.

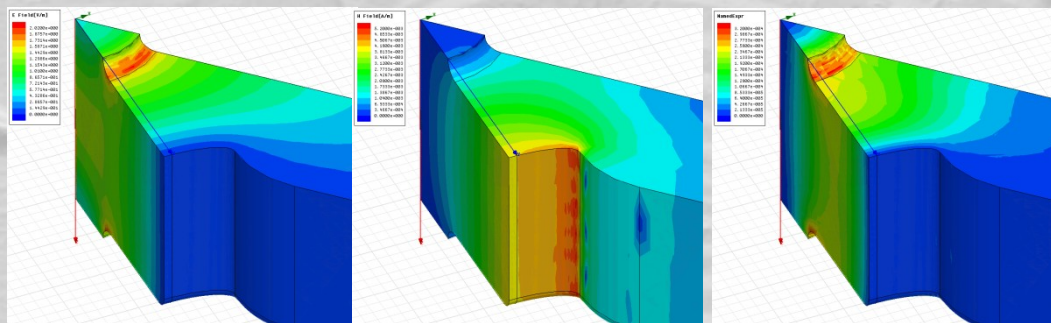
Extra slides

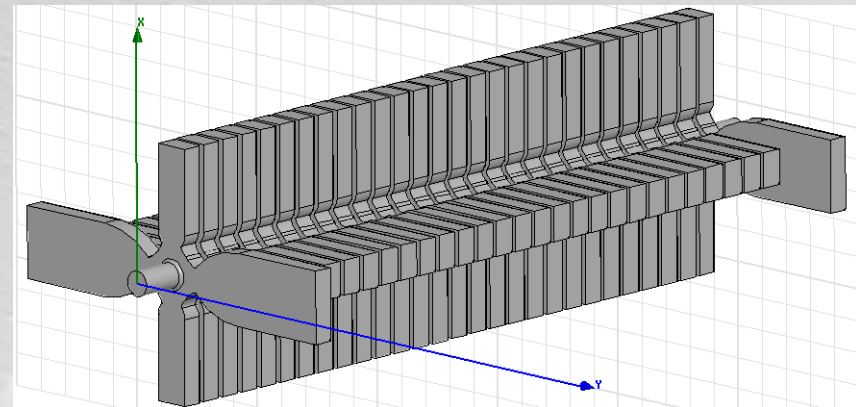
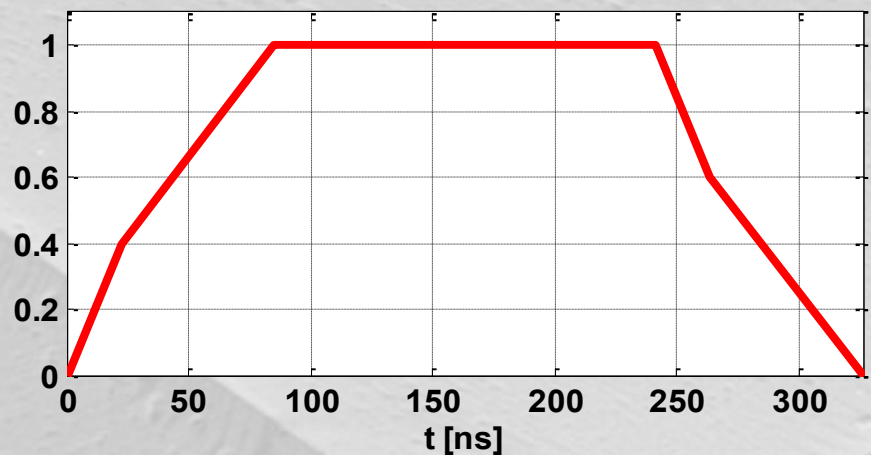


$$E_s/E_a$$

$$H_s/E_a$$

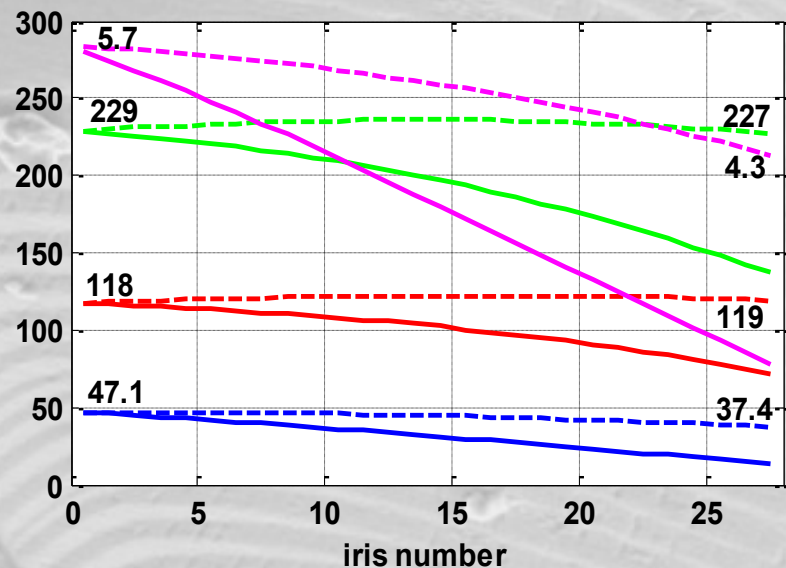
$$S_c/E_a^2$$





CLIC\_G  
(TD24)

$S_c^{1/2}$  [MW/mm<sup>2</sup>]  
 $E_s$  max [MV/m]  
 $E_{acc}$  [MV/m]  
 $\Delta T$  [°C]  
 dashed – unloaded  
 solid – loaded

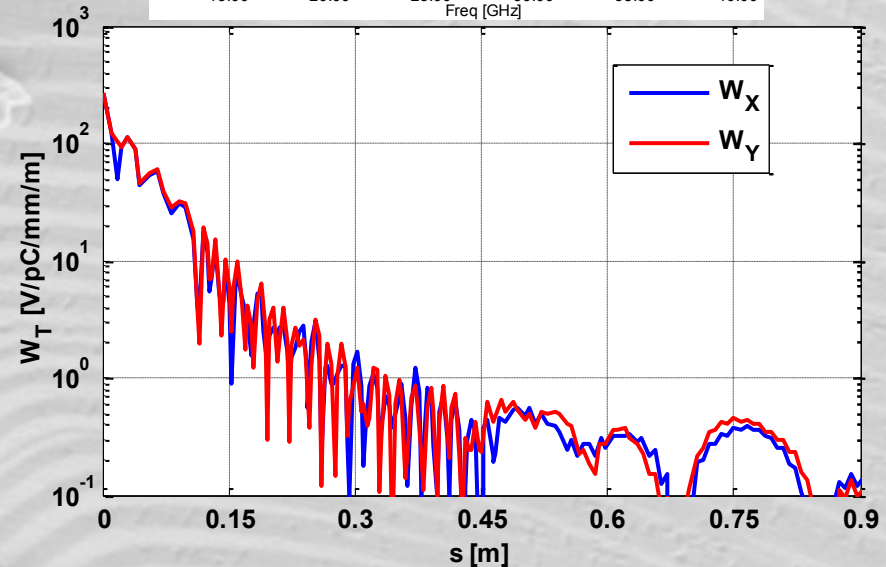
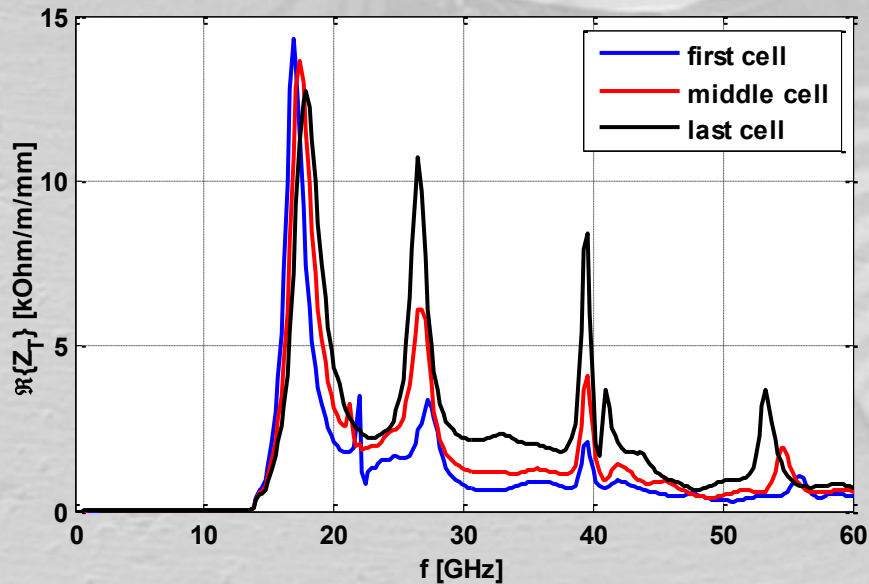
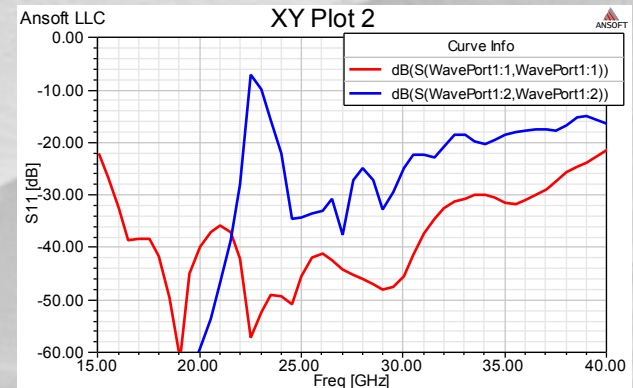
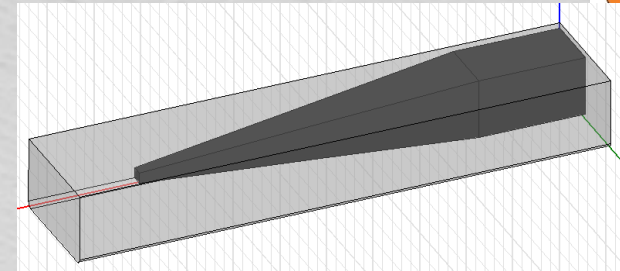


# CLIC\_G Parameters

Average loaded accelerating gradient	100 MV/m
Frequency	12 GHz
RF phase advance per cell	$2\pi/3$ rad.
Average iris radius to wavelength ratio	0.11
Input, Output iris radii	3.15, 2.35 mm
Input, Output iris thickness	1.67, 1.00 mm
Input, Output group velocity	1.65, 0.83 % of $c$
First and last cell $Q$ -factor (Cu)	5536, 5738
First and last cell shunt impedance	81, 103 M $\Omega$ /m
Number of regular cells	26
Structure length including couplers	230 mm (active)
Bunch spacing	0.5 ns
Bunch population	$3.7 \times 10^9$
Number of bunches in the train	312
Filling time, rise time	66.7 ns, 21 ns
Total pulse length	243.7 ns
Peak input power	61.3 MW
RF-to-beam efficiency	27.7 %
Maximum surface electric field	230 MV/m
Maximum pulsed surface heating temperature rise	47 K

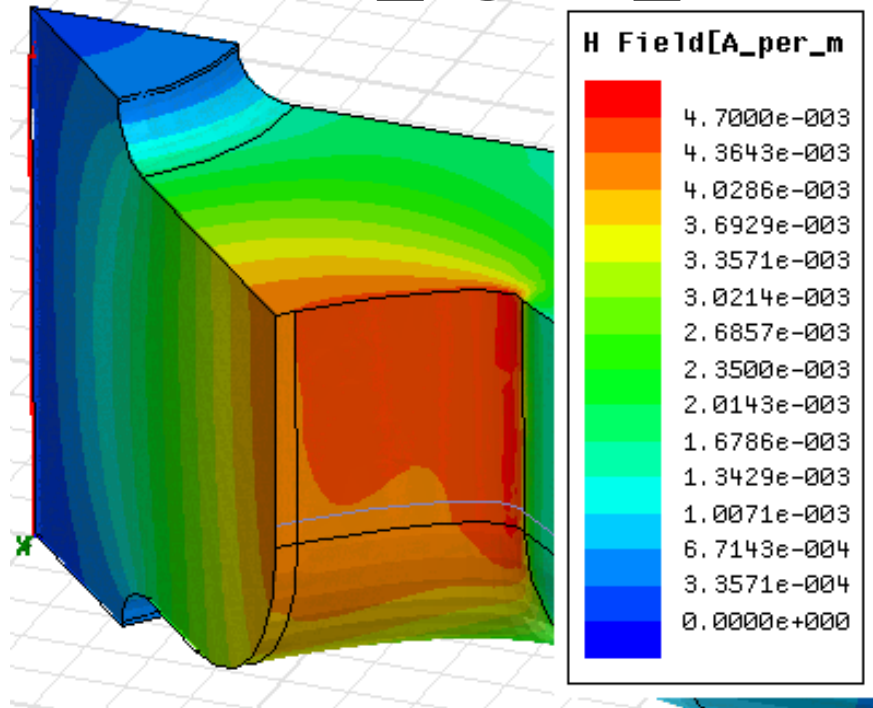
# Higher-order mode damping

Cell	First	Middle	Last
$Q$ -factor	11.1	8.7	7.1
Amplitude [V/pC/mm/m]	125	156	182
Frequency [GHz]	16.91	17.35	17.80

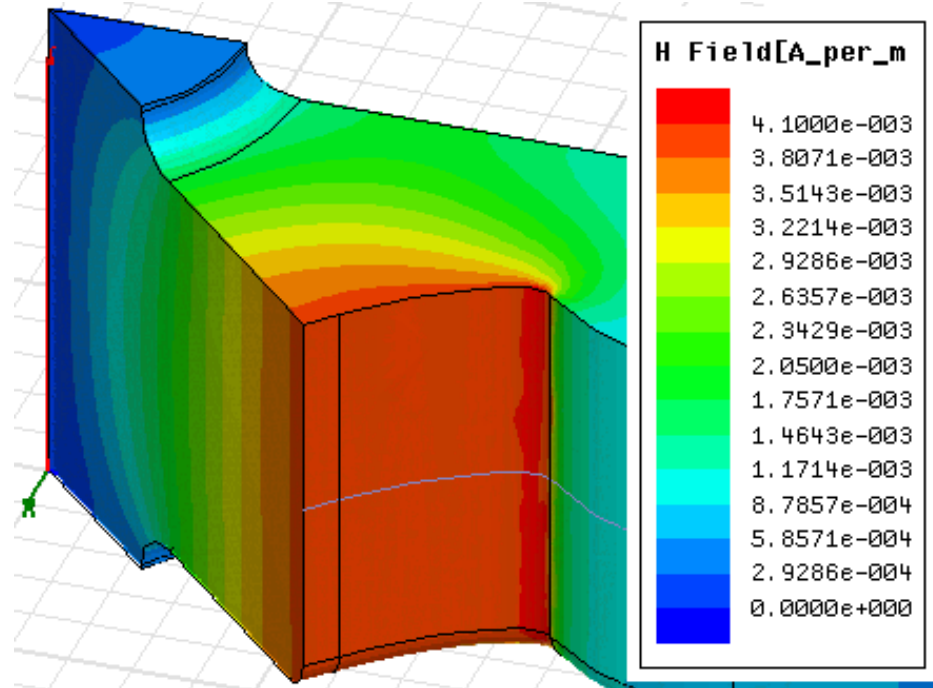


# Geometry difference between

TD24\_vg1.8\_disk



TD24\_vg1.8\_R05



Now I will spend a few moments on some analysis of some important high gradient experiments which illustrate the status of our understanding of high-power behavior.

### Why is this not just an academic exercise?

1. We now almost have the minimum set of high-gradient data to necessary to further optimize the 3 TeV baseline structure. We're talking about 5-10% effects at least. This means also incorporating updated cost models.
2. Machines at energies other than 3 TeV are being discussed. We will soon be making optimizations at new energies and coming up with new structures.

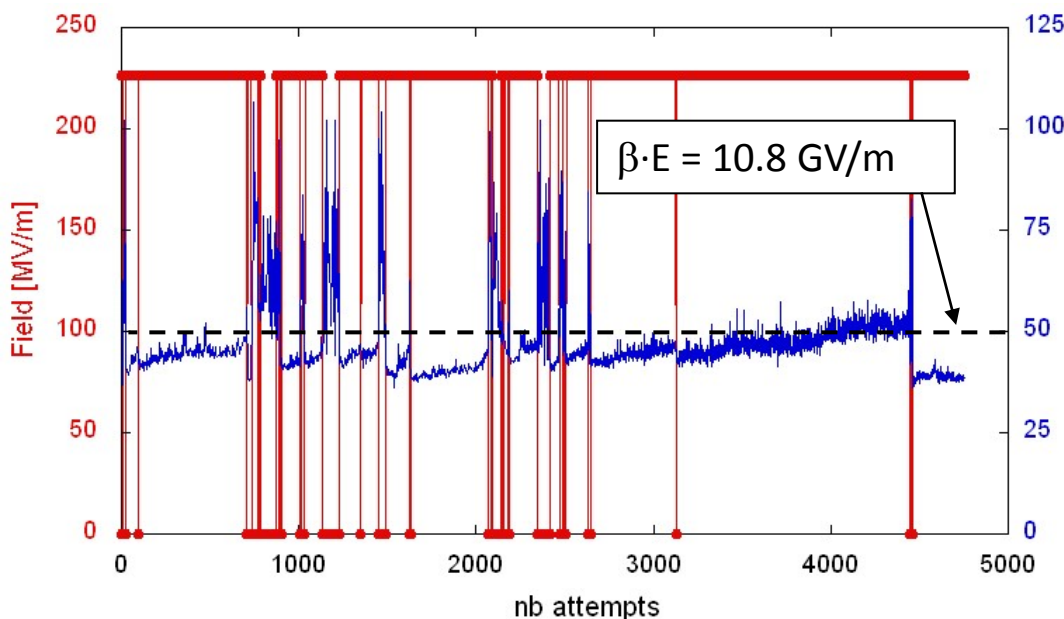
Our ideas will directly influence these designs and optimizations.

# Investigation of the statistical nature of breakdown

101017

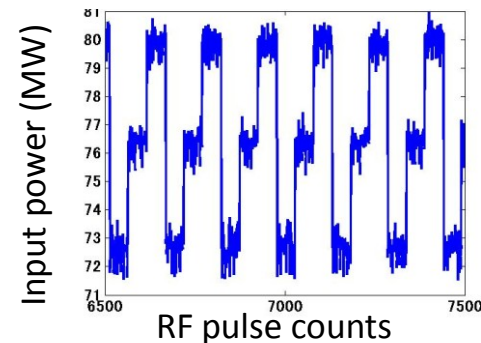
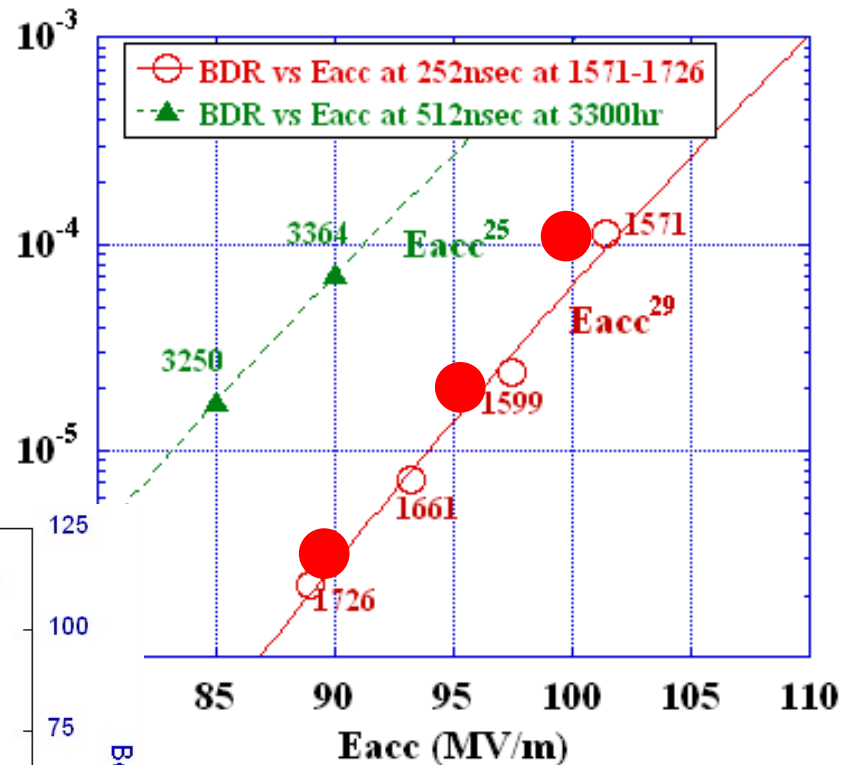
Same breakdown rate for interleaved (solid dots) and not indicates random trigger, rather than evolving surface.  
Test on TD18 at KEK.

Steady increase of  $\beta$  indicates evolving surface in dc spark system, rather than random trigger.

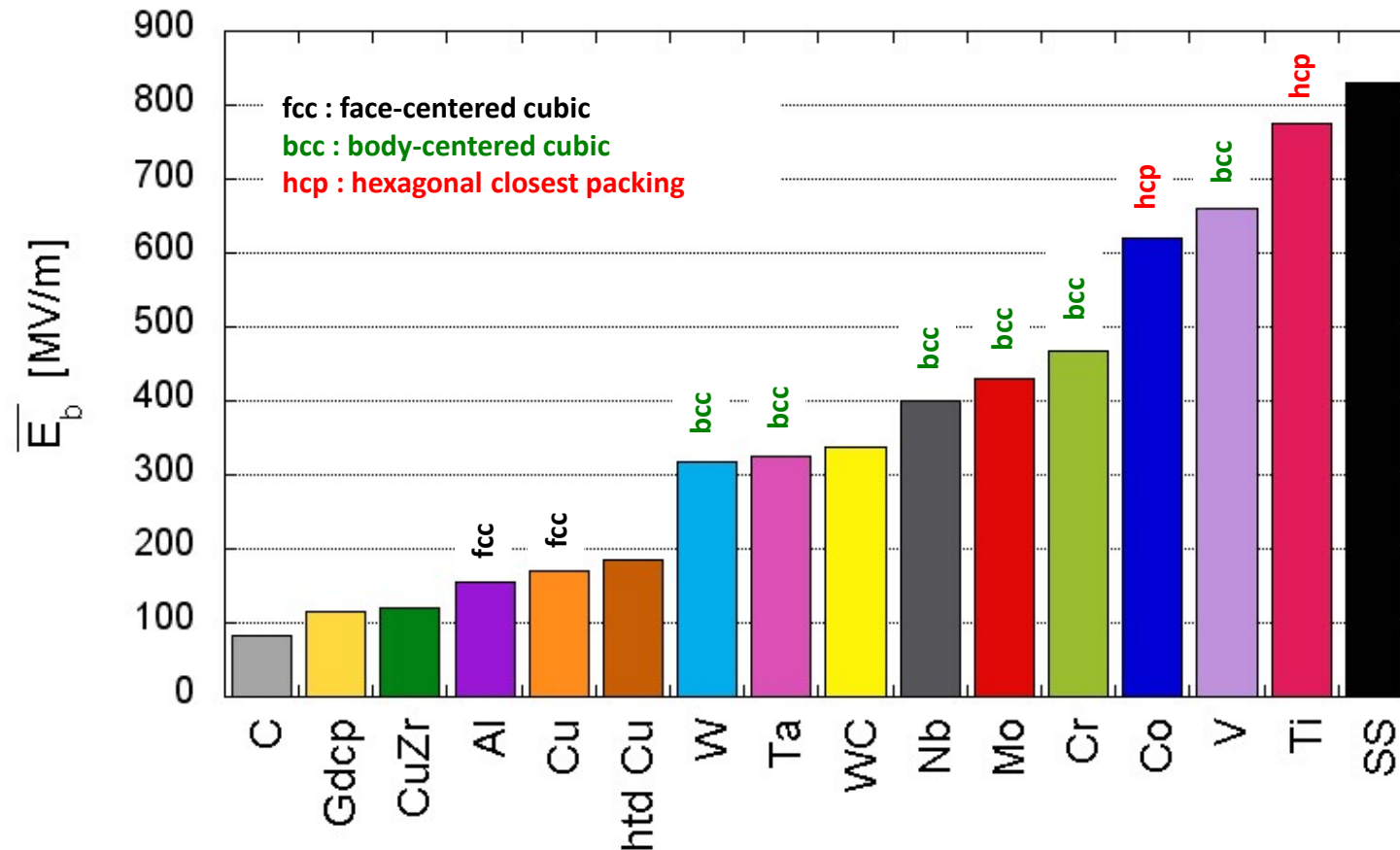


BDR (1/pulse/m)

**BDR vs Eacc**  
selected points which were intentionally taken



# Hints for origin of breakdown rate

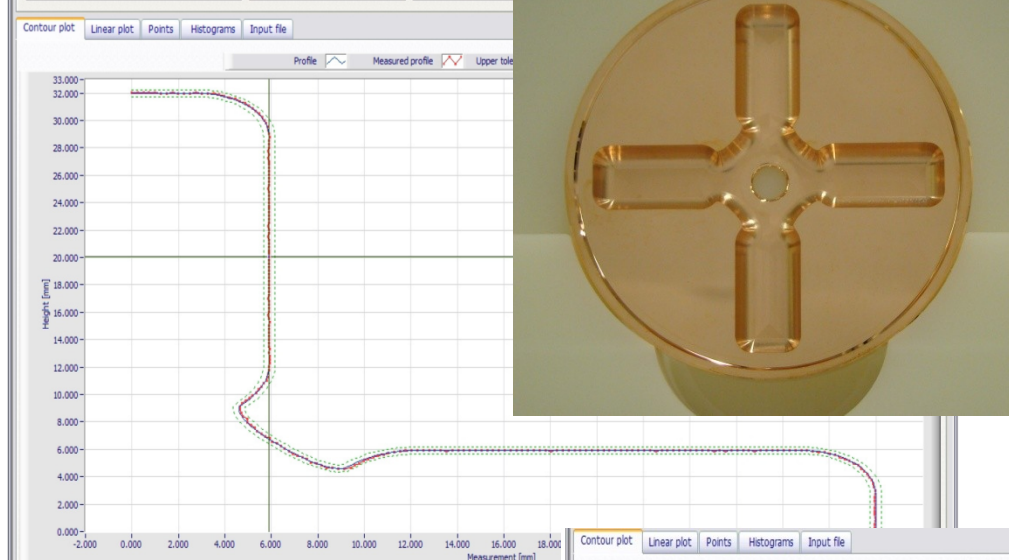


High gradient behavior of various materials measured in CERN dc spark system

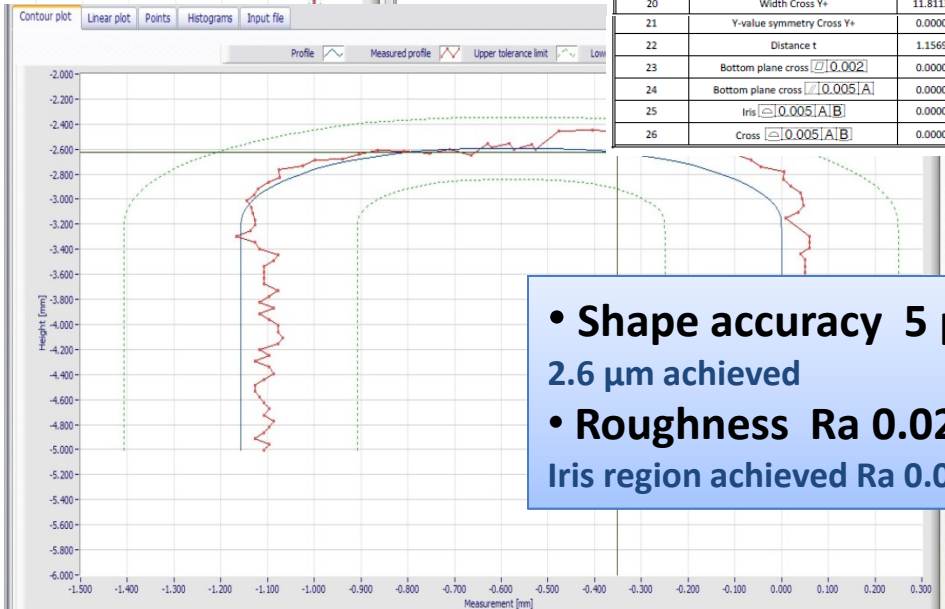
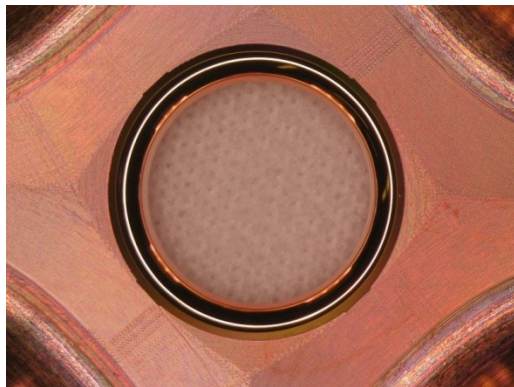


# DETUNED DAMPED DISK FROM VDL (TD24)

germ



Zeiss CMM, free state measurement



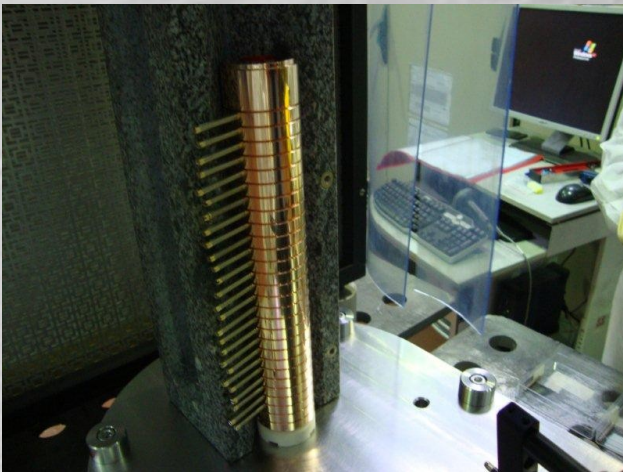
- Shape accuracy 5  $\mu\text{m}$   
2.6  $\mu\text{m}$  achieved
- Roughness Ra 0.025  
Iris region achieved Ra 0.016

Enabling Technologies Group						Inspection Report			
Drawing no. CLIAAS110337 Standard Cell Disk Z1							Prod. Nr.		
Description 11 WDS0VGL8KEK Standard cell									
Dimensions									
Measurand	Description	Nominal	Upper	Lower	Actual	Deviation	Pass	Fail	
1	Ref A [0.002]	0.0000	0.0020	0.0000	0.0011	0.0011	✓	✗	
2	Outer diameter Ref B	74.0000	0.0025	-0.0025	74.0015	0.0015	✓		
3	[0.002]	0.0000	0.0020	0.0000	0.0009	0.0009	✓		
4	[0.002]A	0.0000	0.0020	0.0000	0.0006	0.0006	✓		
5	ø 70	70.0000	0.0000	-0.0100	69.9957	-0.0043	✓		
6	ø 70 [0.005]B	0.0000	0.0050	0.0000	0.0010	0.0010	✓		
7	Diameter 2xa	5.1901	0.0025	-0.0025	5.1900	-0.0001	✓		
8	Distance d	8.7327	0.0020	-0.0020	8.7334	0.0007	✓		
9	Plane at distance d [0.002]	0.0000	0.0020	0.0000	0.0020	0.0020	✓		
10	ø 70	70.0000	0.0150	0.0100	70.0133	0.0133	✓		
11	ø 70 [0.005]B	0.0000	0.0050	0.0000	0.0007	0.0007	✓		
12	Distance t	1.1569	0.0025	-0.0025	1.1562	-0.0007	✓		
13	Distance g	7.5758	0.0025	-0.0025	7.5765	0.0007	✓		
14	Width Cross Z+	11.8113	0.0025	-0.0025	11.8131	0.0019	✓		
15	Y-value symmetry Cross Z+	0.0000	0.0025	-0.0025	0.0002	0.0002	✓		
16	Width Cross Z-	11.8113	0.0025	-0.0025	11.8134	0.0022	✓		
17	Y-value symmetry Cross Z-	0.0000	0.0025	-0.0025	0.0002	0.0002	✓		
18	Width Cross Y-	11.8113	0.0025	-0.0025	11.8122	0.0009	✓		
19	Y-value symmetry Cross Y-	0.0000	0.0025	-0.0025	0.0012	0.0011	✓		
20	Width Cross Y+	11.8113	0.0025	-0.0025	11.8120	0.0007	✓		
21	Y-value symmetry Cross Y+	0.0000	0.0025	-0.0025	0.0003	0.0003	✓		
22	Distance t	1.1569	0.0025	-0.0025	1.1563	-0.0006	✓		
23	Bottom plane cross [0.002]	0.0000	0.0050	0.0000	0.0005	0.0005	✓		
24	Bottom plane cross [0.005]A	0.0000	0.0025	-0.0025	0.0014	0.0014	✓		
25	Iris [0.005]A[B]	0.0000	0.0050	0.0000	0.0026	0.0026	✓		
26	Cross [0.005]A[B]	0.0000	0.0050	0.0000	0.0027	0.0027	✓		

## Individual inspection



## Operation done under laminar flow



## Boxes under N2

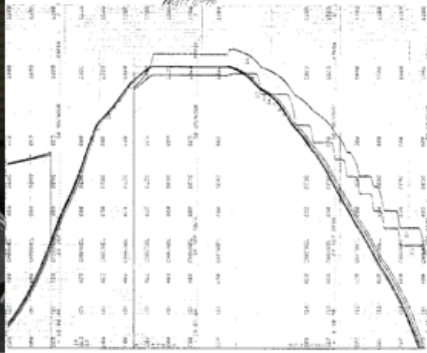
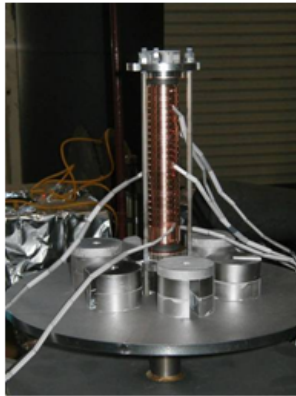


## Sealed bag under N2

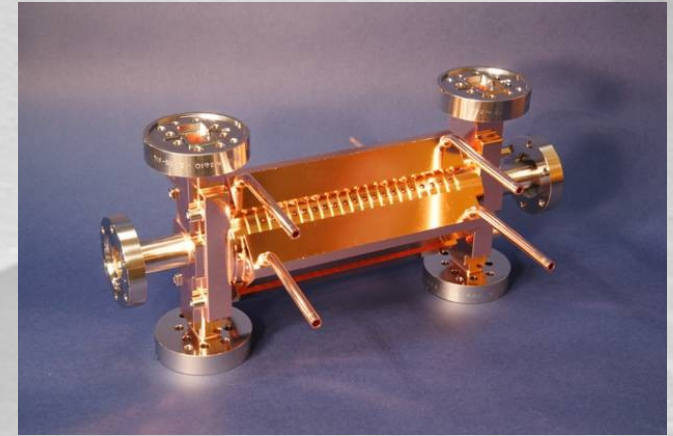
## RF measurement



## Diffusion Bonding of T18\_vg2.4\_DISC



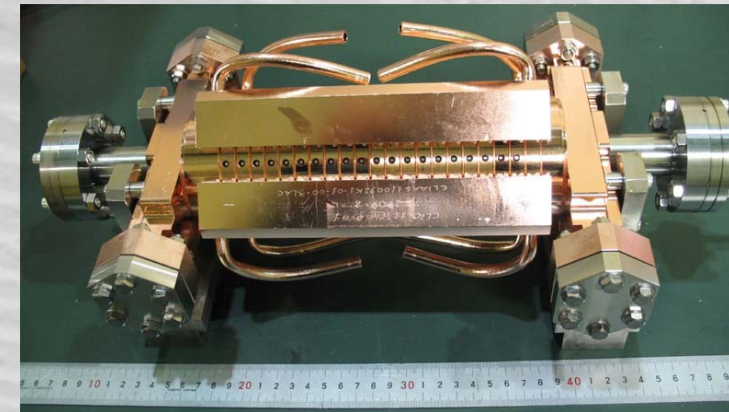
Pressure: 60 PSI (60 LB for this structure disks)  
Holding for 1 hour at 1020°C



## Vacuum Baking of T18\_vg2.4\_DISC



650°C  
10 days



Stacking disks

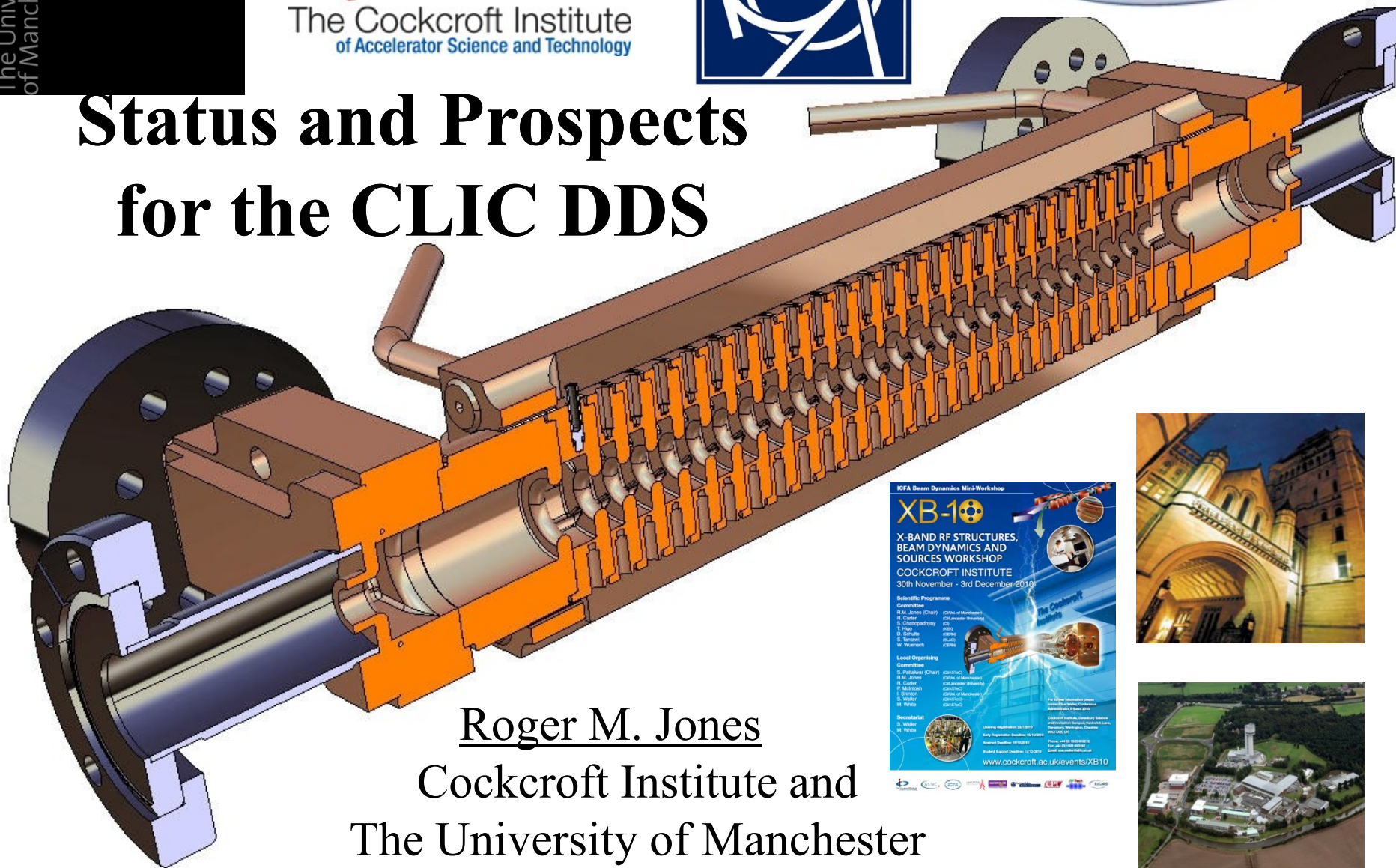
Structures ready for test

Temperature treatment for high-gradient

Walter Wuensch

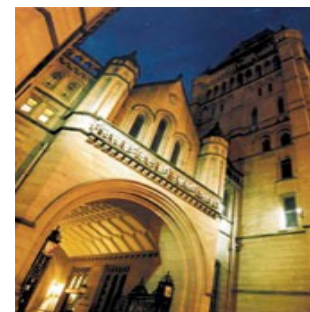
30 November 2010

# Status and Prospects for the CLIC DDS

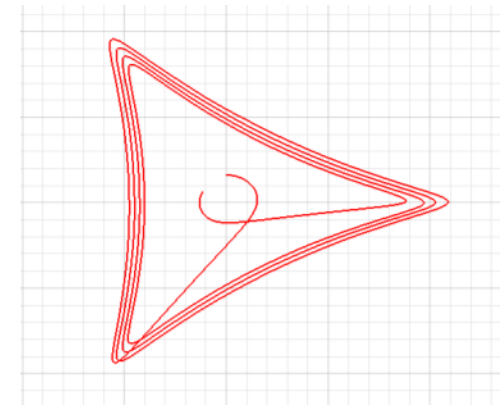
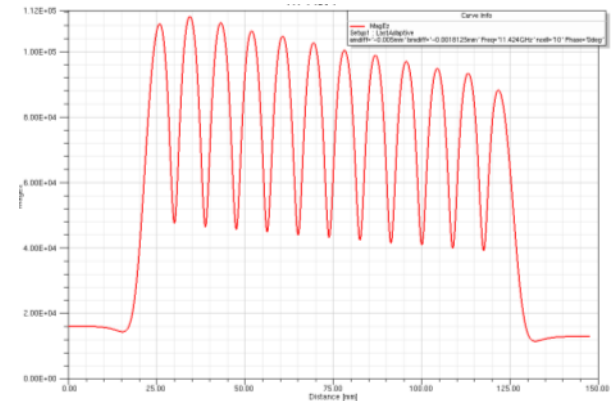
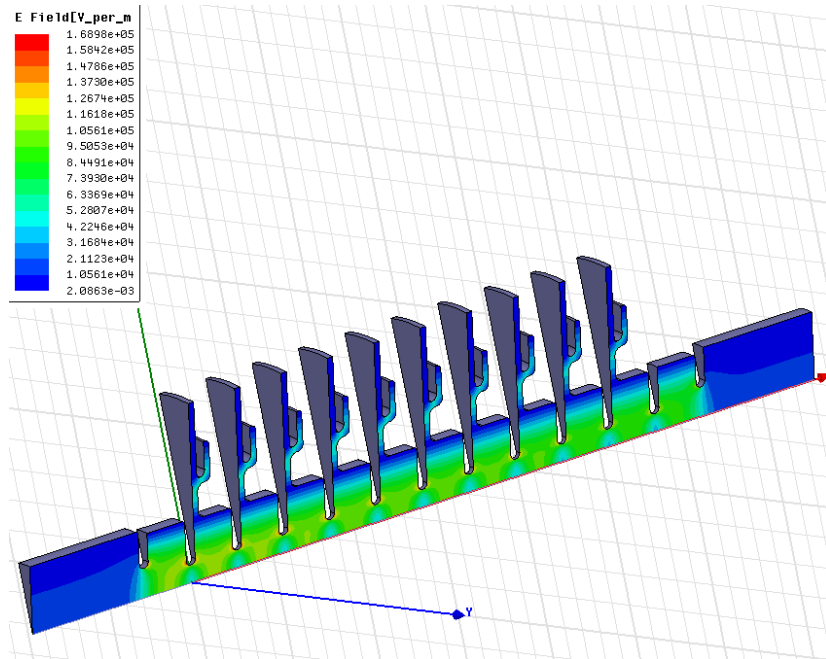


Roger M. Jones

Cockcroft Institute and  
The University of Manchester



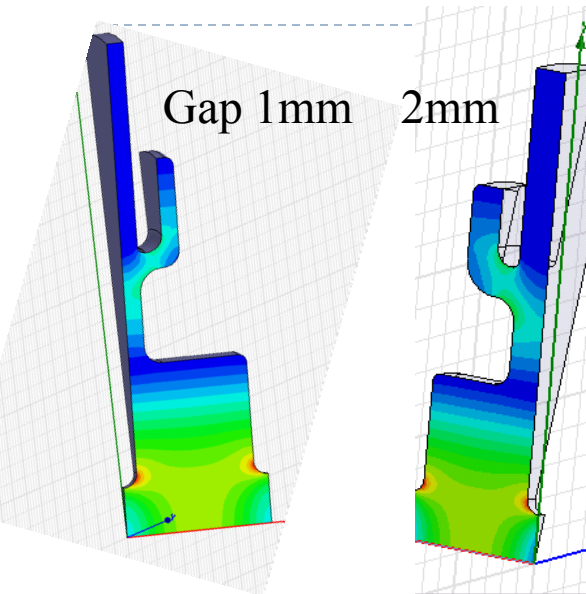
# Design of CD-10-Choke



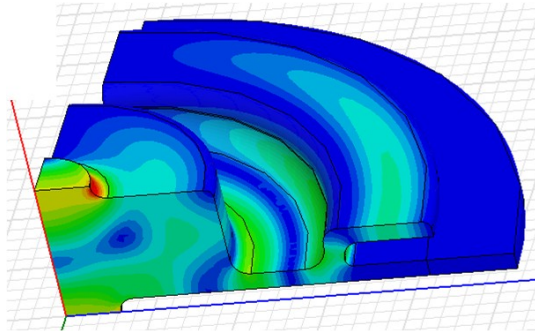
120 Degree

- ▶ CD10-Choke for demonstration
  - ▶ RF Design for Gap 1mm, 1.5mm, 2mm
  - ▶ Mechanical Design finished for 1mm-gap
  - ▶ Qualification disks and bonding test
- ▶ To the production pipeline and High Power testing

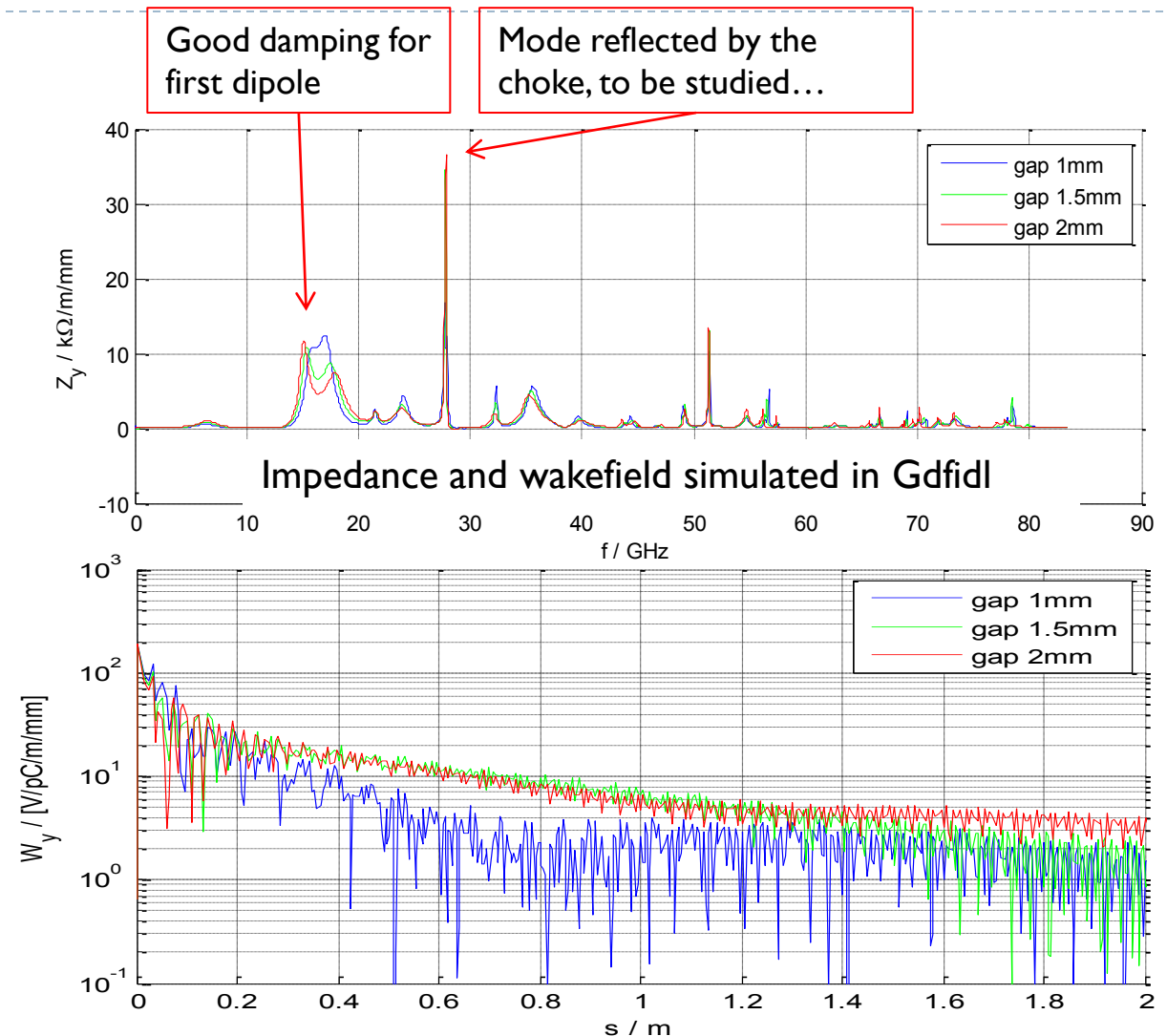
# Damping simulation with Gdfid1/HFSS



E field, fundamental mode



E field of a dipole mode that is reflected by the choke

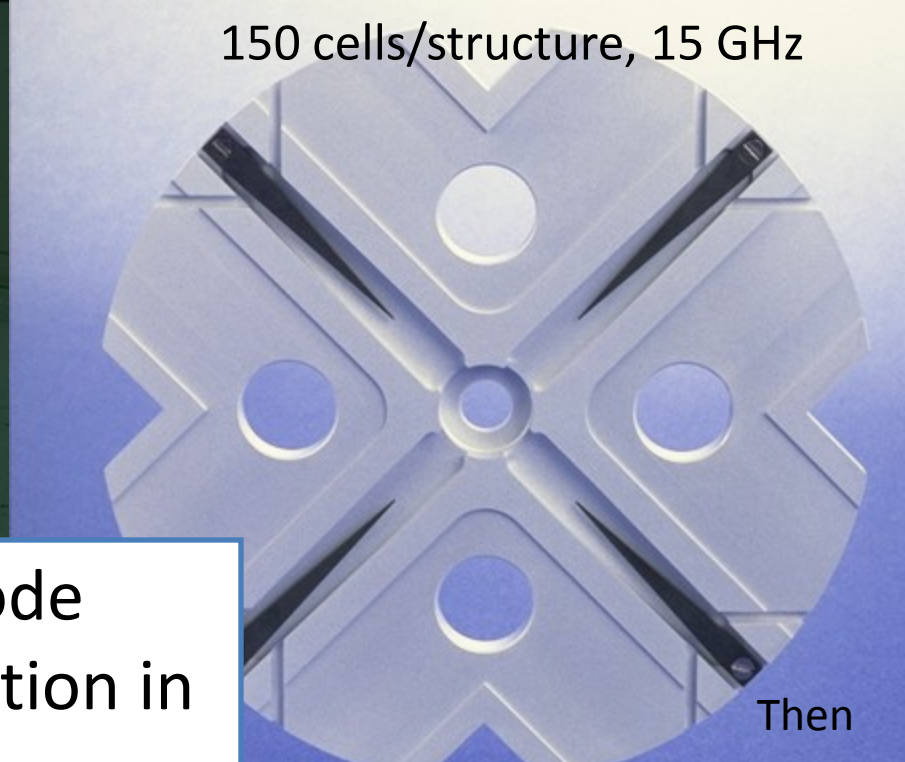
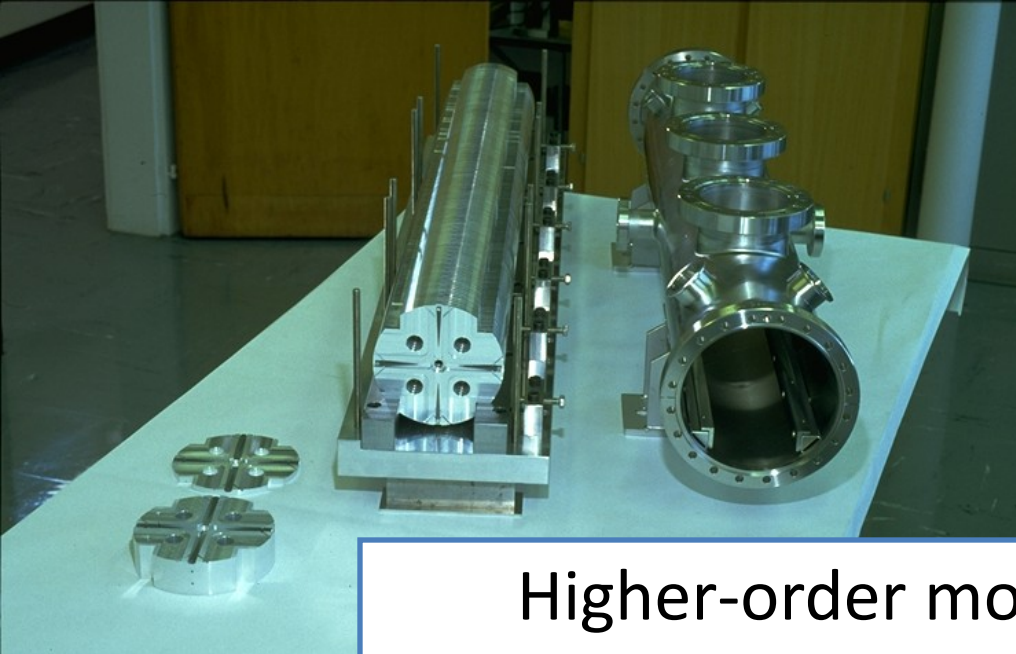


# Letter of Intent for Experiments at FACET

R. Jones, D. Schulte, R. Tomas, W. Wuensch for the CLIC  
team

Thanks to

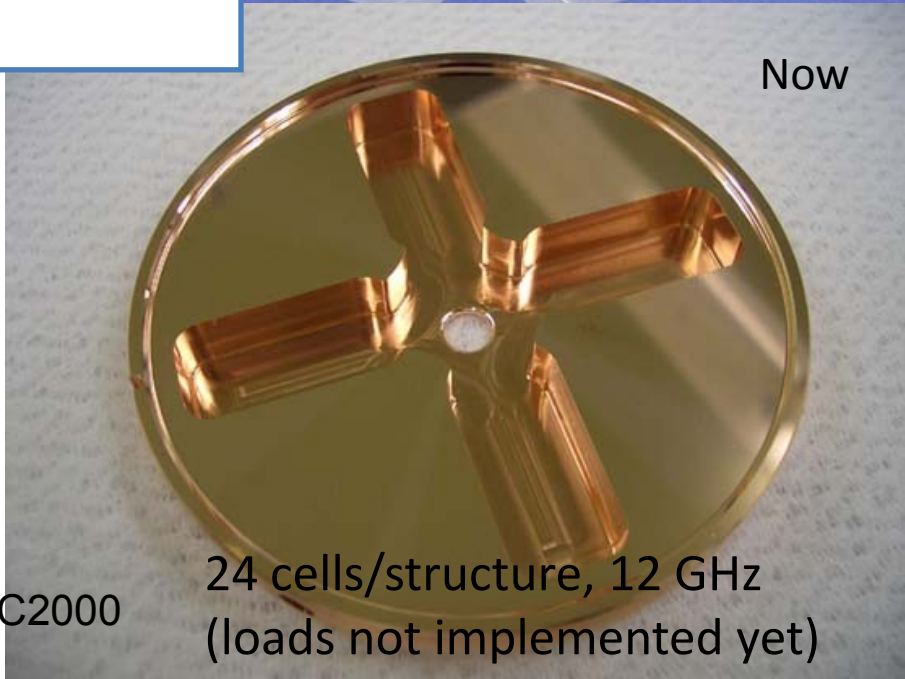
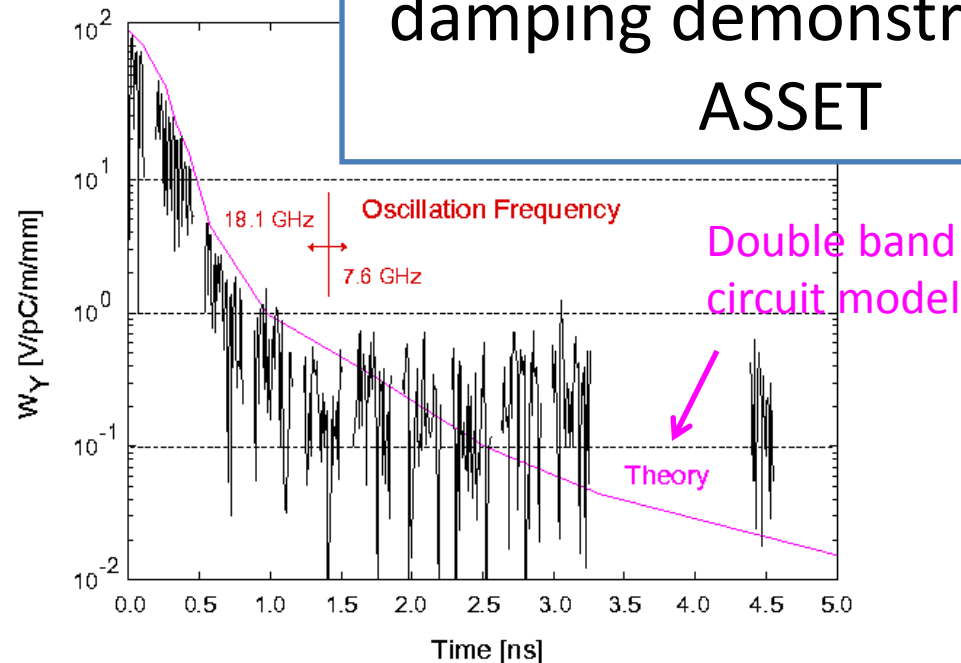
Juergen Pfingster, Alexej Grudiev, A. Latina, G. Sterbini, D  
Angal-Kalinin, J. Barranco, L. Fernandez, C. Hast, R. Jones, S.  
Jamison, J. Resta, G. Rumolo, A. Seryi, N. Watson



150 cells/structure, 15 GHz

Then

# Higher-order mode damping demonstration in ASSET



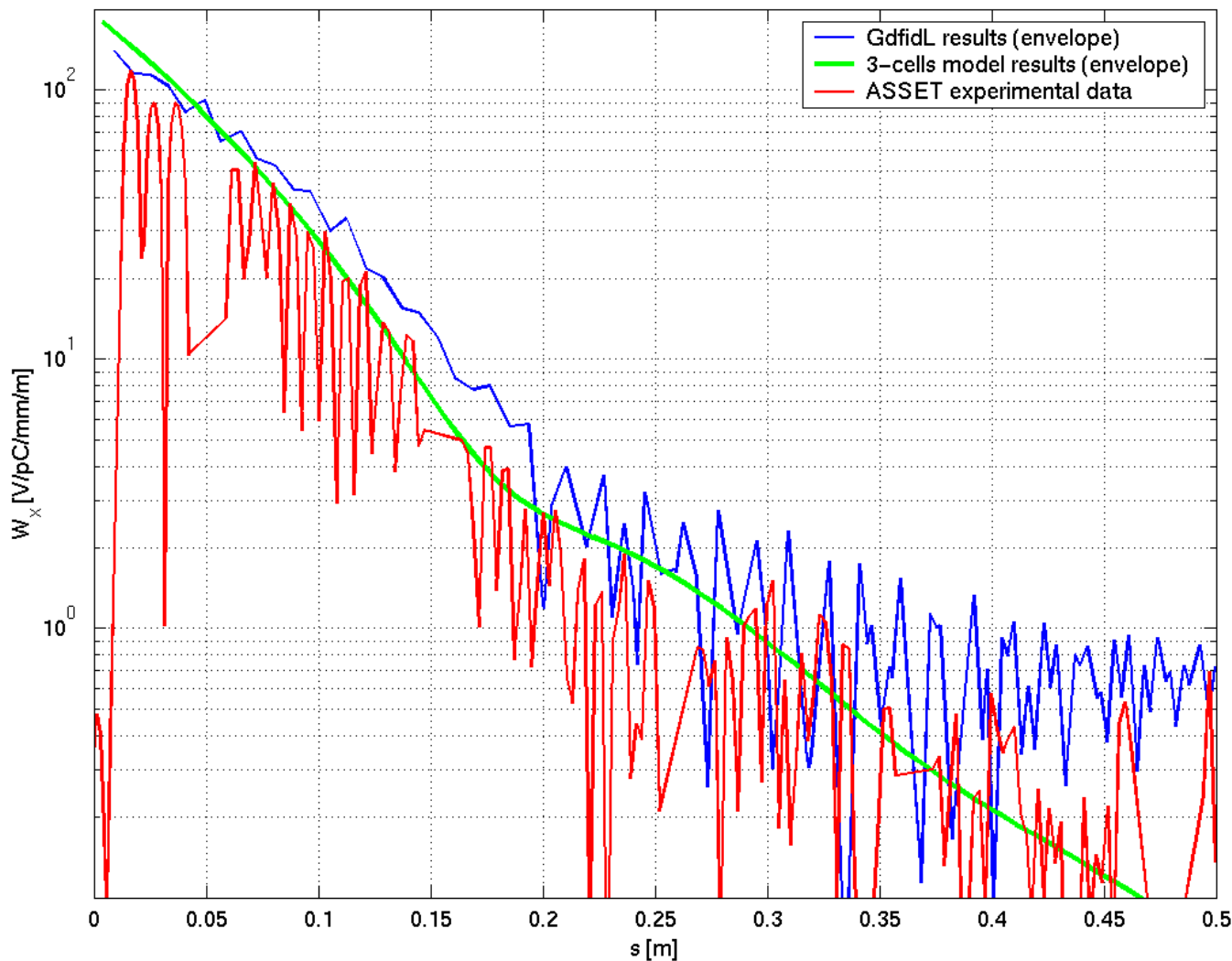
Now

24 cells/structure, 12 GHz  
(loads not implemented yet)

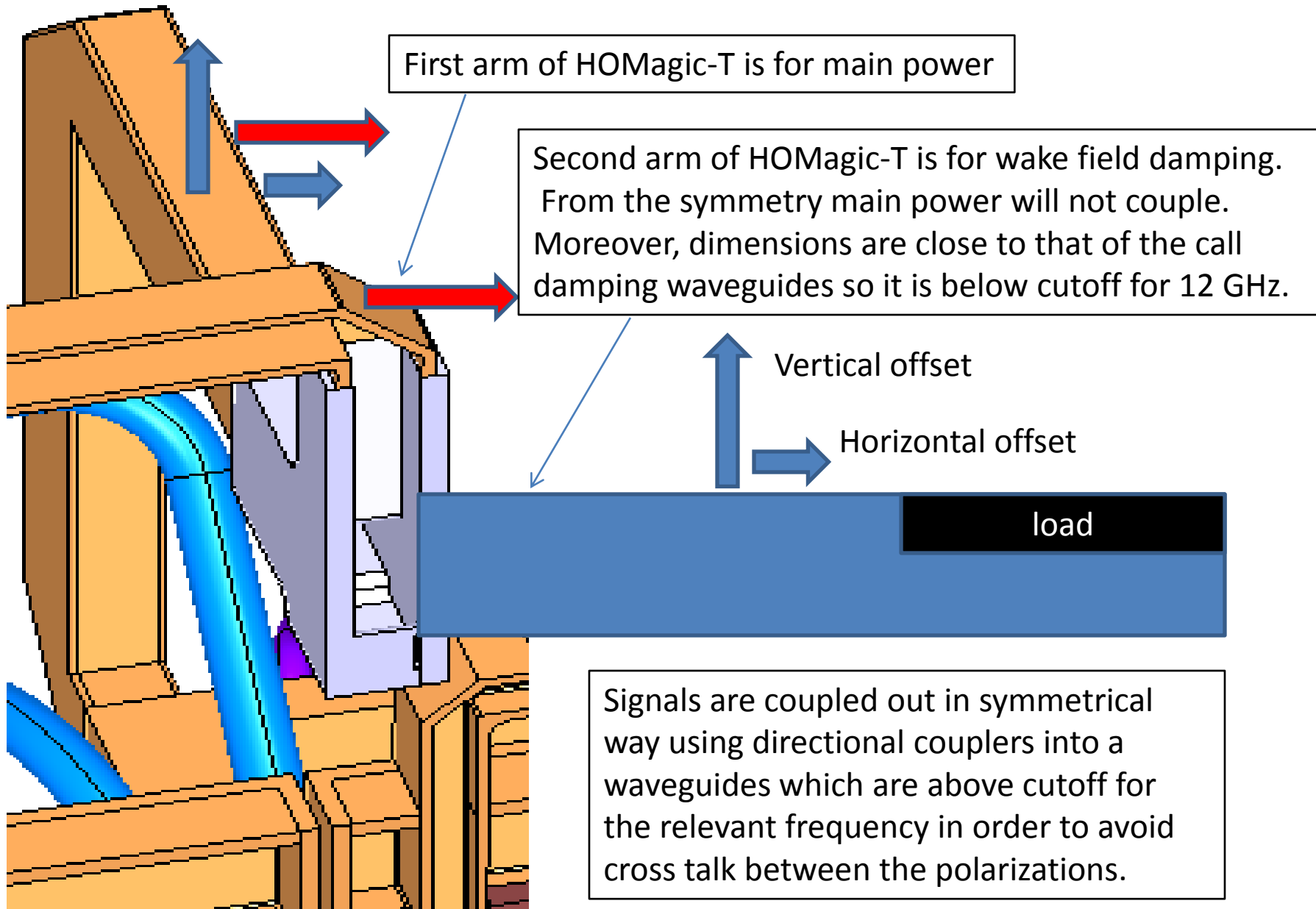
An Asset Test of the CLIC Accelerating Structure, PAC2000

# Full length TDS results comparison

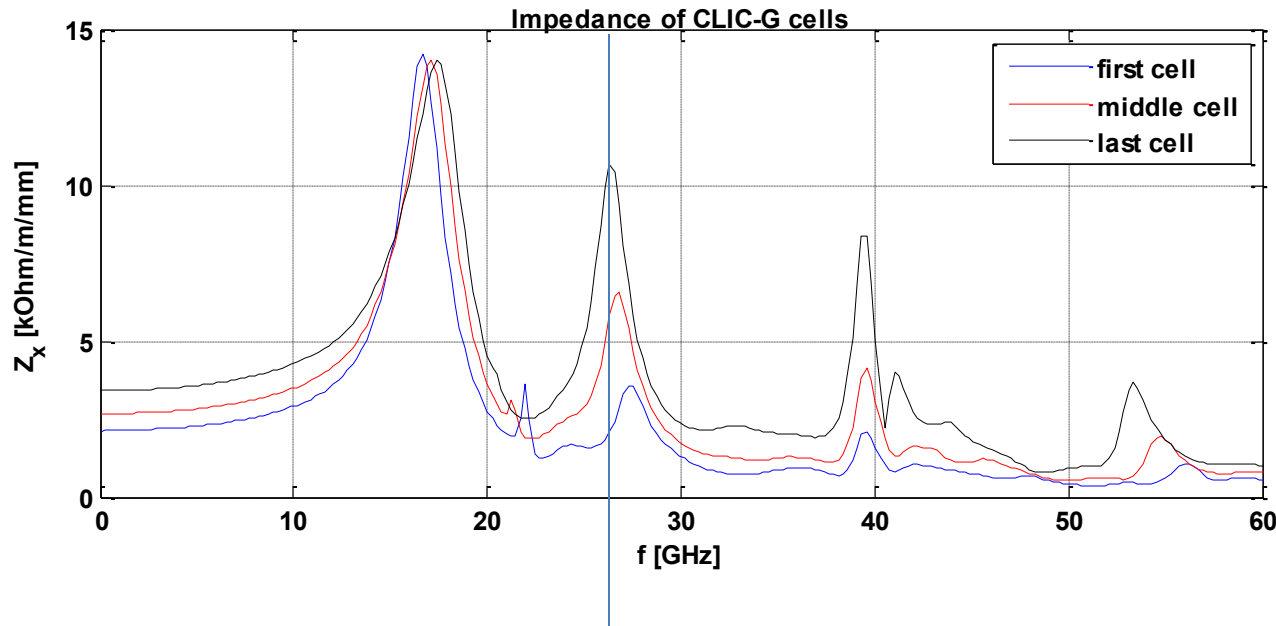
CLIC



# Option two: HOMagic-T



# Impedance of the dipole modes



$$Z'_{\perp} \sim 10 M\Omega / m^2$$

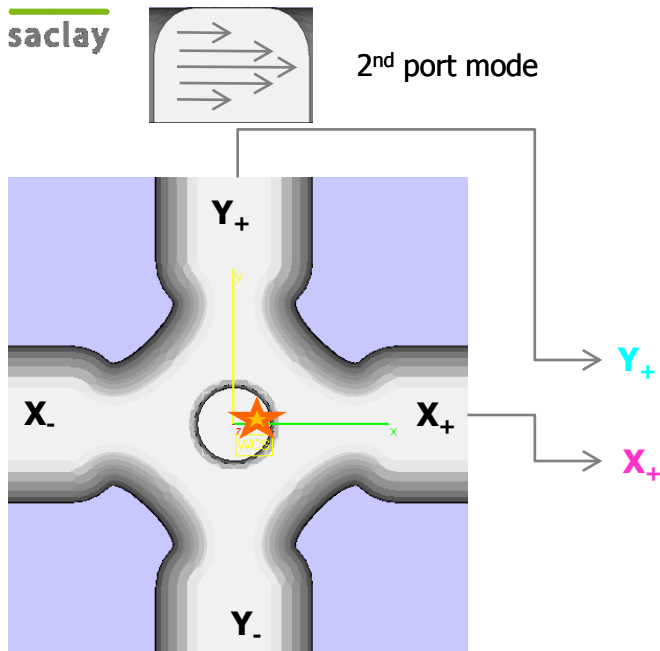
$$R'_{\perp} = Z_{\perp} \bullet \frac{\omega}{c} \sim 600 M\Omega / m^3$$

$$R_{\perp} = R'_{\perp} l_{cell} \sim 5 M\Omega / m^2$$

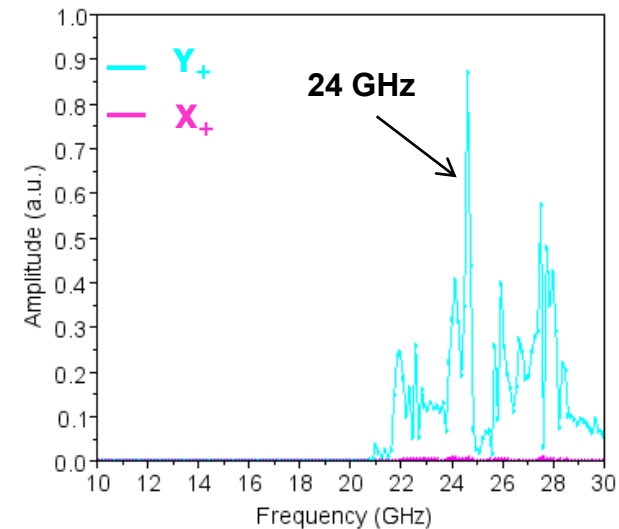
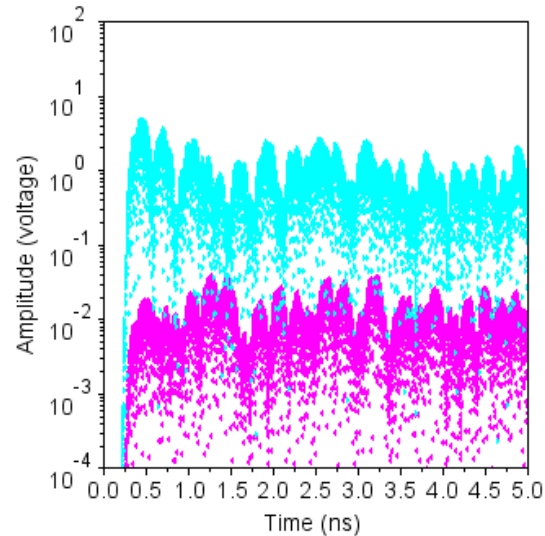
$$P_{\perp} = I^2 \bullet R_{\perp} \sim (1A)^2 \bullet 5 M\Omega / m^2 = 5 \mu W / \mu m^2$$

5  $\mu m$  offset  $\Rightarrow$  125  $\mu W$

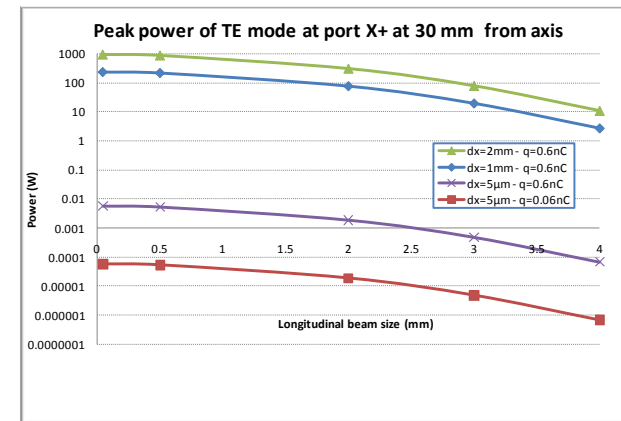
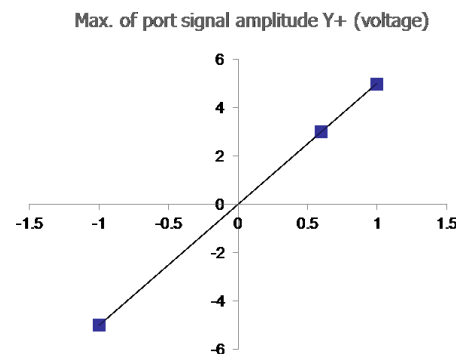
-10 : -20 dB coupling  $\Rightarrow$  12.5 -- 1.25  $\mu W$

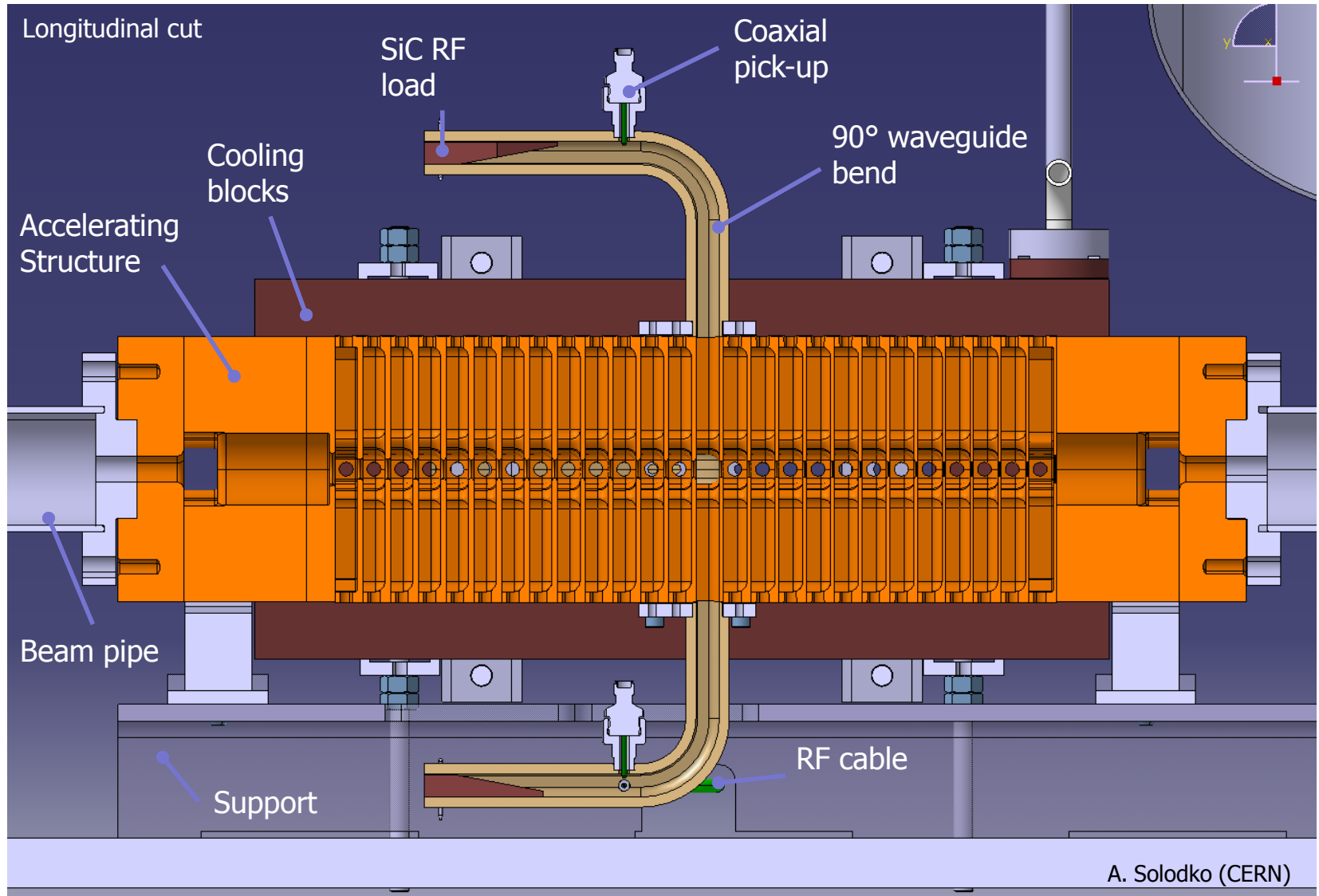


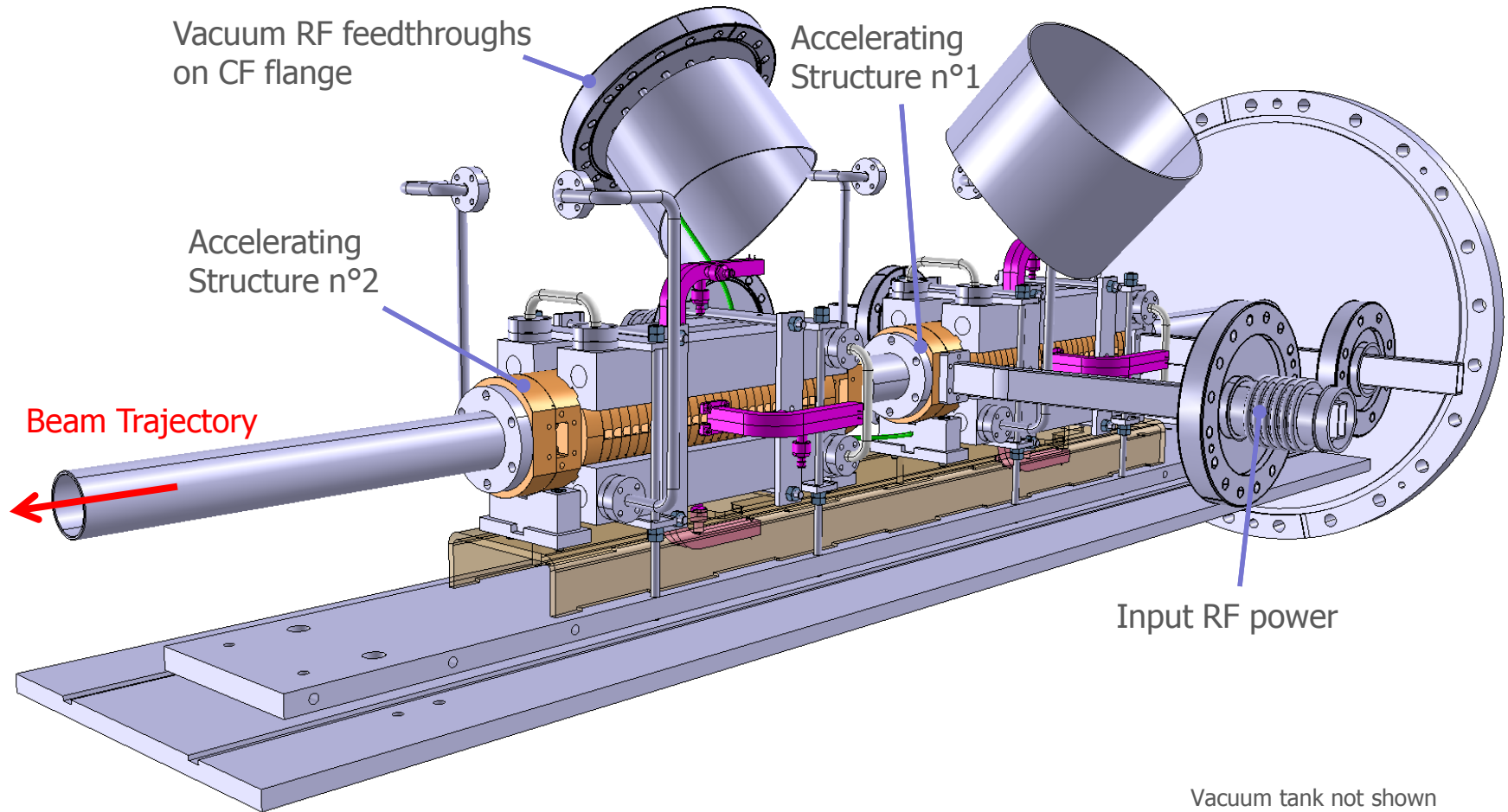
GdfidL results, beam offset  $\delta x = 1$  mm



- Highest amplitude at 24 GHz
- Intrinsic resolution  $\sim 5$   $\mu$ m
- Linearity OK
- Peak power from 1  $\mu$ W to 100 W







# Cost estimate of RF structures

## **CERN estimate**

- Identification of the manufacturing steps
- Prototype cost available
- For each manufacturing step, application of the learning curve and sum of each contribution

## **Cost studies with industries**

- 3 studies were launched with industries/institutes in Q4/2009
  - VDL, NL (manufacturing of several RF structures, experience with milling and turning, experience with series production)
  - KERN, DE (manufacturing of TBL PETS, machine constructors, mainly experience with milling, experience with series production)
  - VTT(HIP) FI (research organization, manufacturing of qualification pieces, contact with several Finnish companies, mainly experience in milling)
- The cost estimate study incorporated the whole fabrication process (including machining, quality control, assembly and RF checks): conventional machining and H2 diffusion bonding according to the baseline
- 3 production lines
- total production over 5 years
- Parametric study launched with VDL and KERN to understand how shape accuracy and roughness affects the machining cost

# RF system cost breakdown

