Overview of CLIC main linac accelerating structure design

21/10/2010

A.Grudiev (CERN)

RF design constraints for CLIC

Beam dynamics (BD) constraints based on the simulation of the main linac, BDS and beam-beam collision at the IP:

- N – bunch population depends on $\langle a \rangle/\lambda$, $\Delta a/\langle a \rangle$ because of short-range wakes
- N_s – bunch separation depends on the long-range dipole wake suppression

RF breakdown and pulsed surface heating (PSH) constraints:

- $\Delta T^{max}(H_{surf}{}^{max}, t_p) < 56$ K (accelerating structure life time issues)
- $E_{surf}{}^{max} < 250$ MV/m
- $P_{in}/C_{in} \cdot (t_p)^{1/3} < 18$ MW/mm $\cdot$ ns$^{1/3}$
- $(S_c = \mathrm{Re}\{S\} + \mathrm{Im}\{S\}/6) \cdot (t_p)^{1/3} < 4$ MW/mm^2 $\cdot$ (200 ns)$^{1/3}$

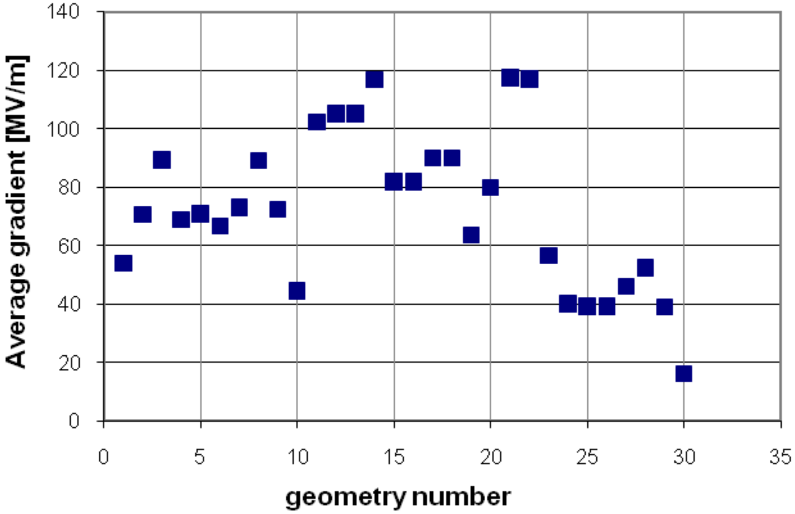
RF constraints: data analysis 1

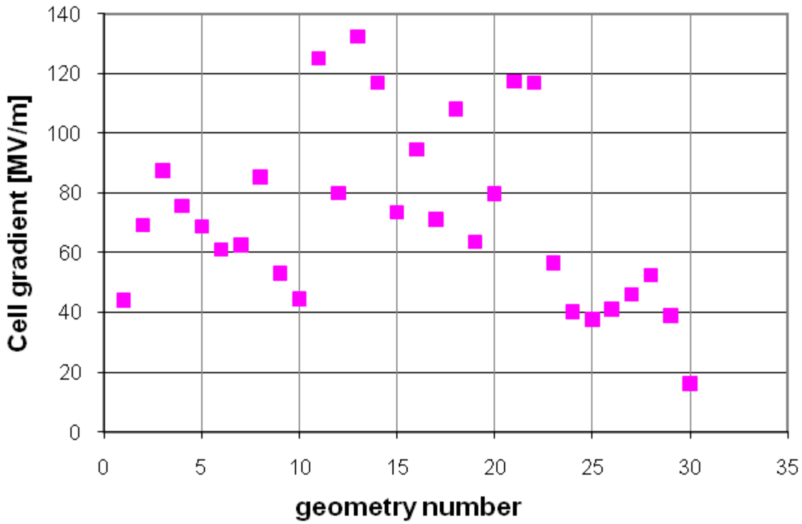
	RF design name	f [GHz]	dphi [deg]	vg1 [%]
1	DDS1	11.424	120	11.7
2	T53VG5R	11.424	120	5
3	T53VG3MC	11.424	120	3.3
4	H90VG3	11.424	150	3
5	H60VG3	11.424	150	2.8
6	H60VG3R18	11.424	150	3.3
7	H60VG3R17	11.424	150	3.6
8	H75VG4R18	11.424	150	4
9	H60VG4R17	11.424	150	4.5
10	HDX11-Cu	11.424	60	5.1
11	CLIC-X-band	11.424	120	1.1
12	T18VG2.6-In	11.424	120	2.6
13	T18VG2.6-Out	11.424	120	1.03
14	T18VG2.6-Rev	11.424	120	1.03
15	T26VG3-In	11.424	120	3.3
16	T26VG3-Out	11.424	120	1.65
17	TD18_KEK_In	11.424	120	2.4
18	TD18_KEK_Out	11.424	120	0.9
19	SW20A3p75	11.424	180	0
20	SW1A5p65T4p6	11.424	180	0
21	SW1A3p75T2p6	11.424	180	0
22	SW1A3p75T1p66	11.424	180	0
23	2pi/3	29.985	120	4.7
24	pi/2	29.985	90	7.4
25	HDS60-In	29.985	60	8
26	HDS60-Out	29.985	60	5.1
27	HDS60-Rev	29.985	60	5.1
28	HDS4Th	29.985	150	2.6
29	HDS4Th	29.985	150	2.6
30	PETS9mm	29.985	120	39.8

High power test results has been scaled to tp=200 ns BDR=1e-6 bpp/m using power scaling lower

$$\frac{E_a^{30} \cdot t_p^5}{BDR} = const$$

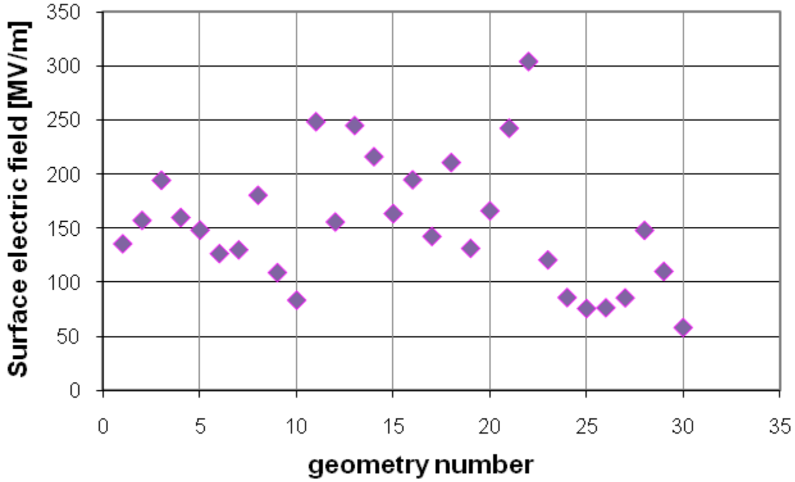
based on the fitting the data

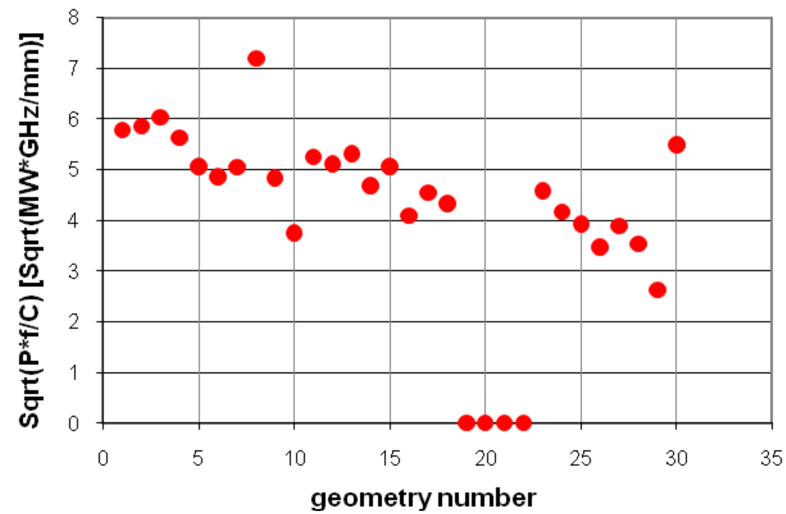


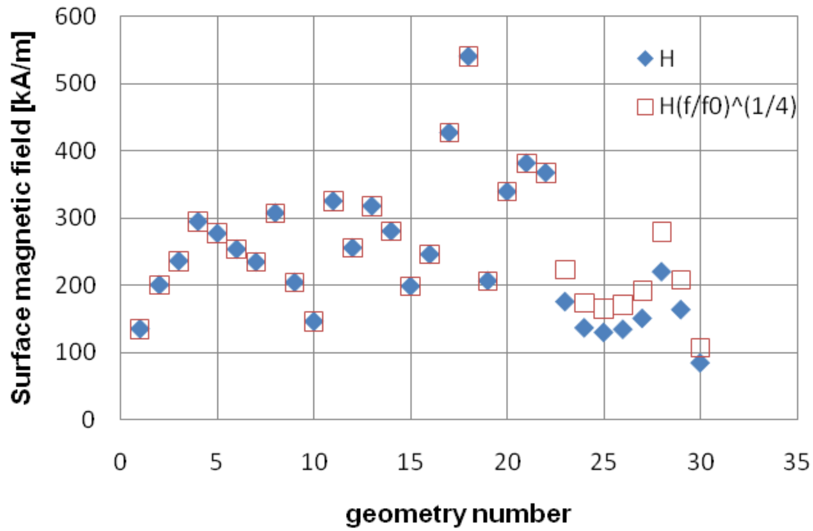


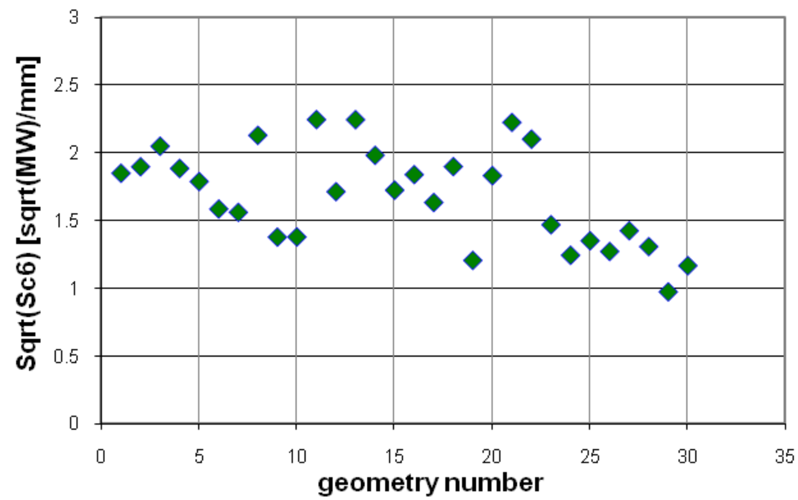
RF constraints: data analysis 2

Data has been scaled to tp=200 ns BDR=1e-6 bpp/m







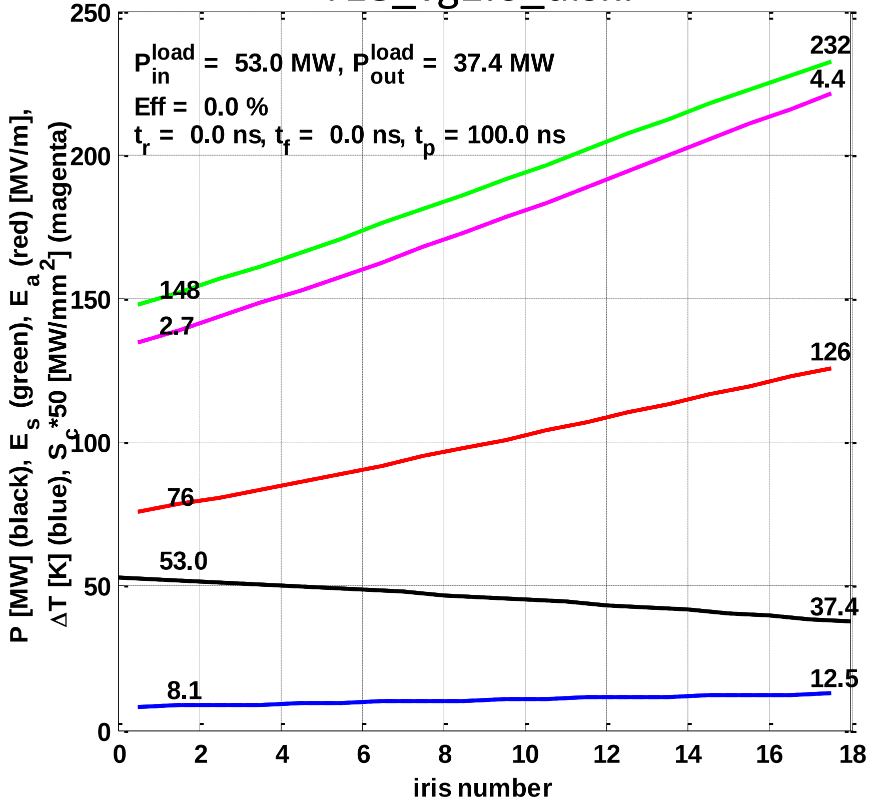


$$S_c = \mathrm{Re}\{S\} + \mathrm{Im}\{S\}/6$$

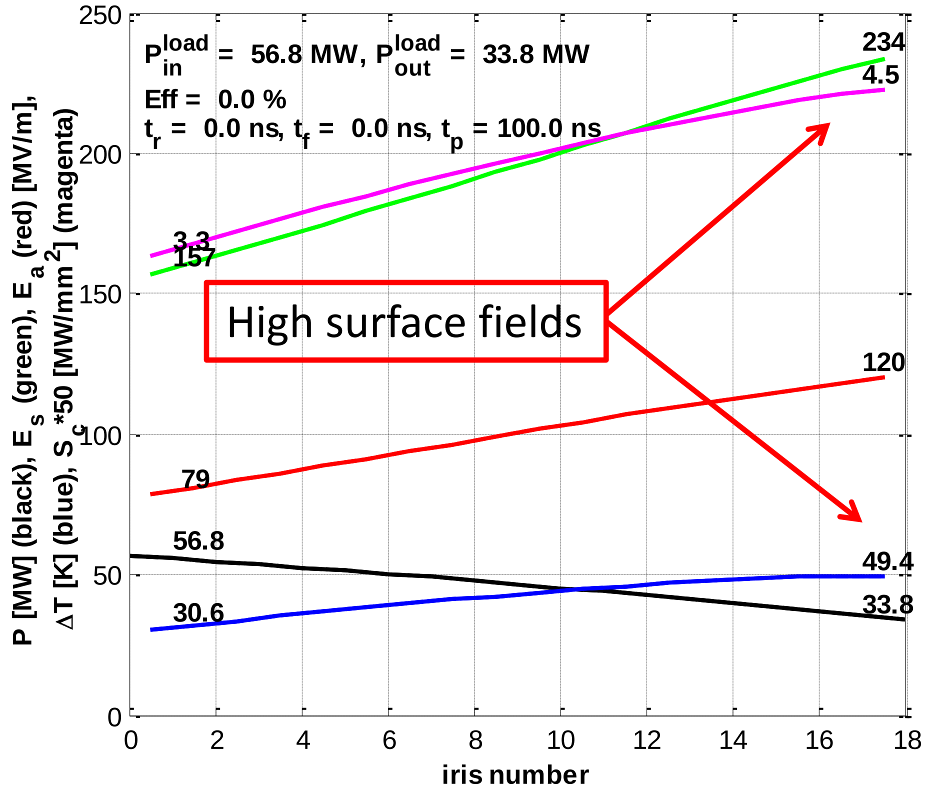
1st generation of CLIC X-band test structure prototypes T18/TD18

2007 Parameters at tp=100 ns, <Ea>=100 MV/m

T18_vg2.6_disk:



TD18_vg2.4_disk:



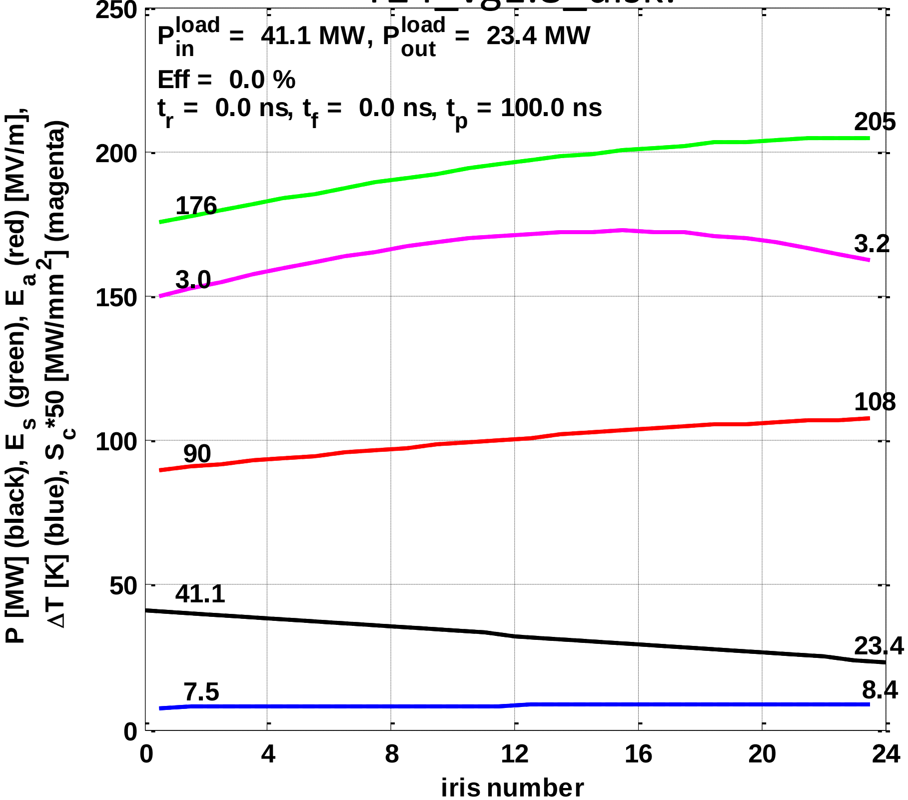
Very strong tapering inspired by the idea of having constant P/C along the structure

In TD18, all quantities are close to T18 at the same average gradient, except for the pulsed surface heating temperature rise which is factor 5 higher in the last cell.

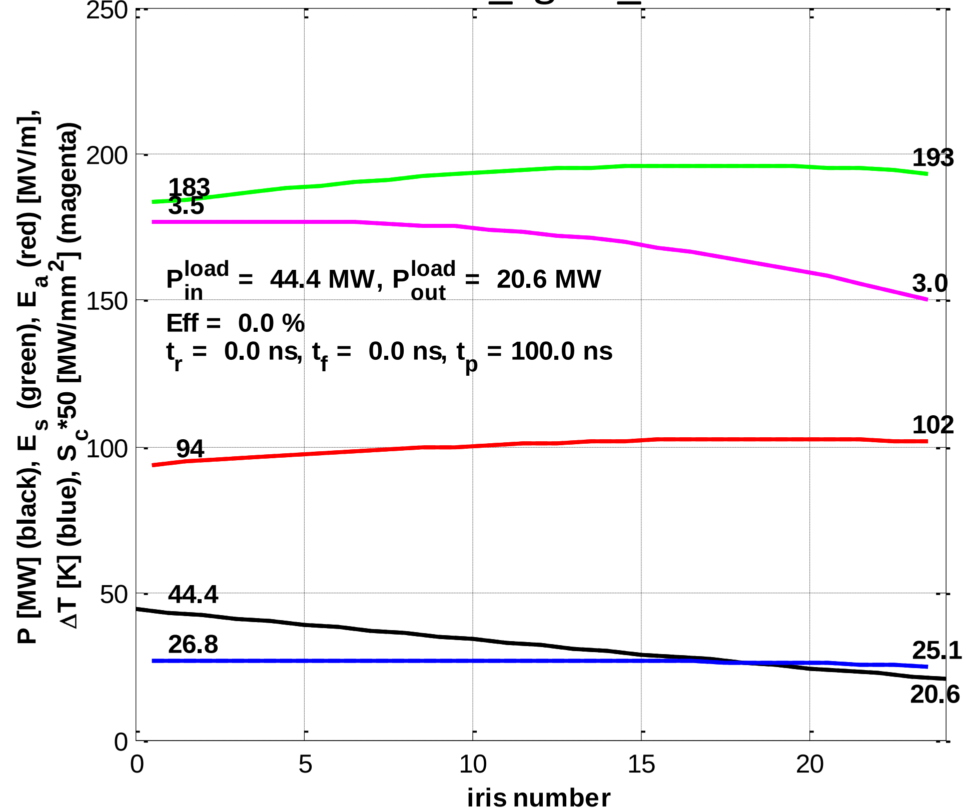
2nd generation of CLIC X-band test structure prototypes T24/TD24

2007 Parameters at tp=100 ns, <Ea>=100 MV/m

T24_vg1.8_disk:



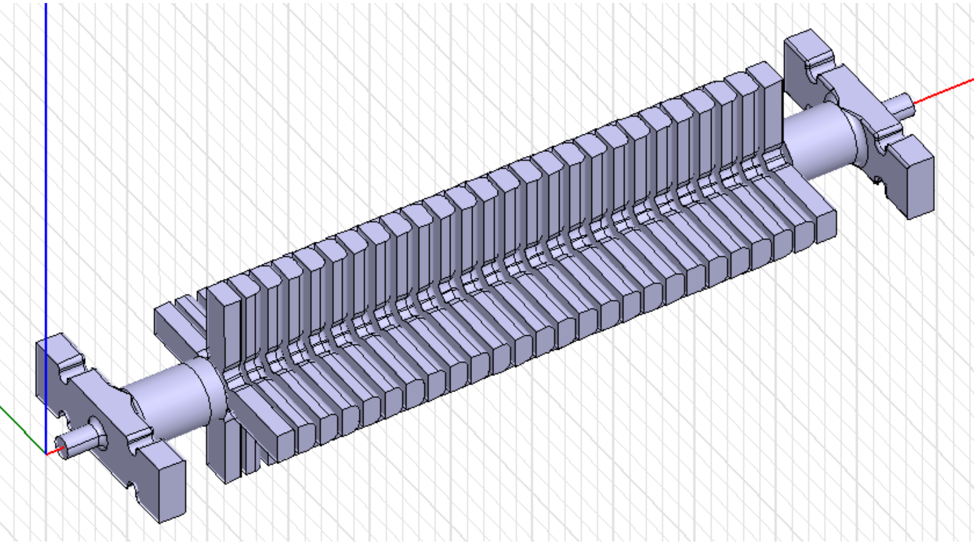
TD24_vg1.8_disk:

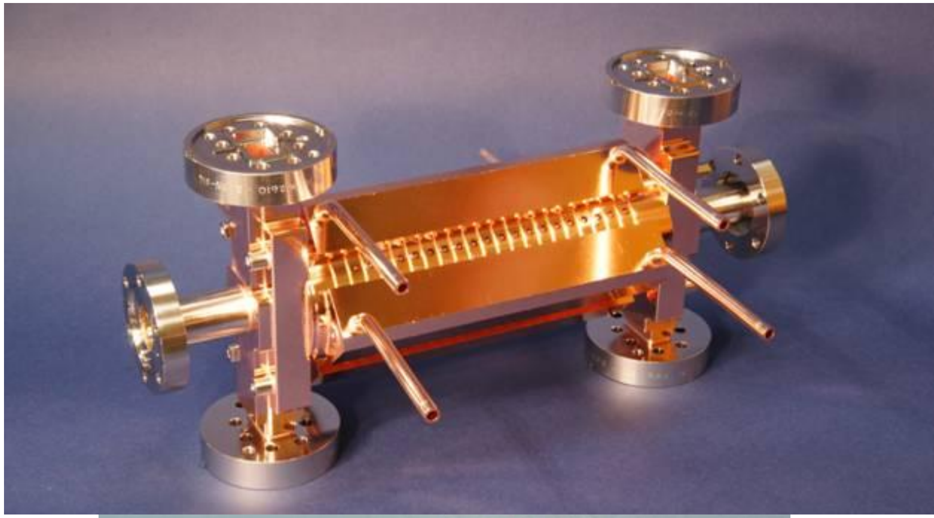


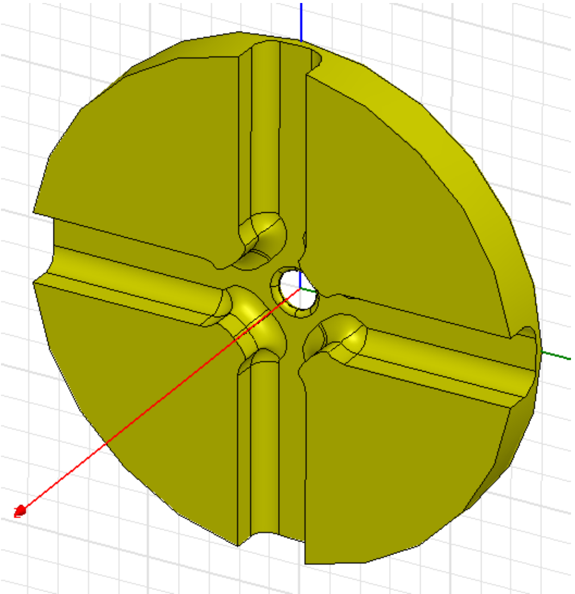
Weaker tapering (quasi const gradient) together with smaller aperture (11% instead of 12.8%) reduce surface fields significantly compared to T18/TD18.

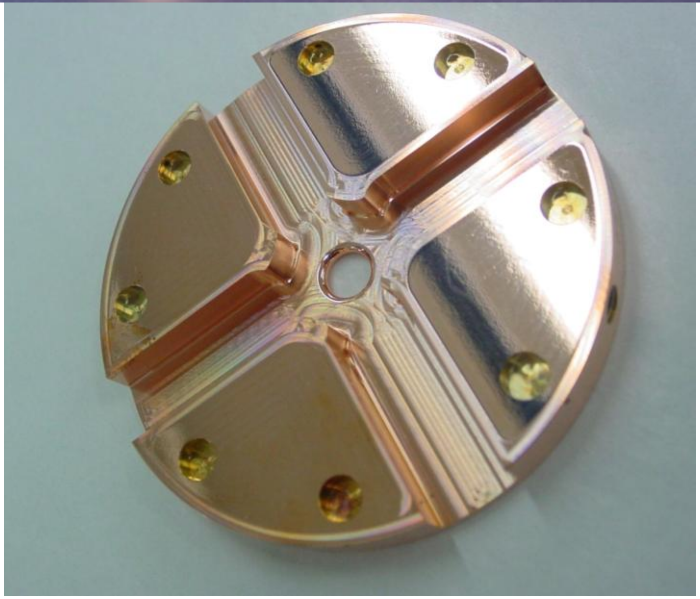
In TD24, all quantities are lower than in TD18 at the same average gradient. In particular pulsed surface heating temperature rise reduced by factor 2.

From RF design to a piece of Copper

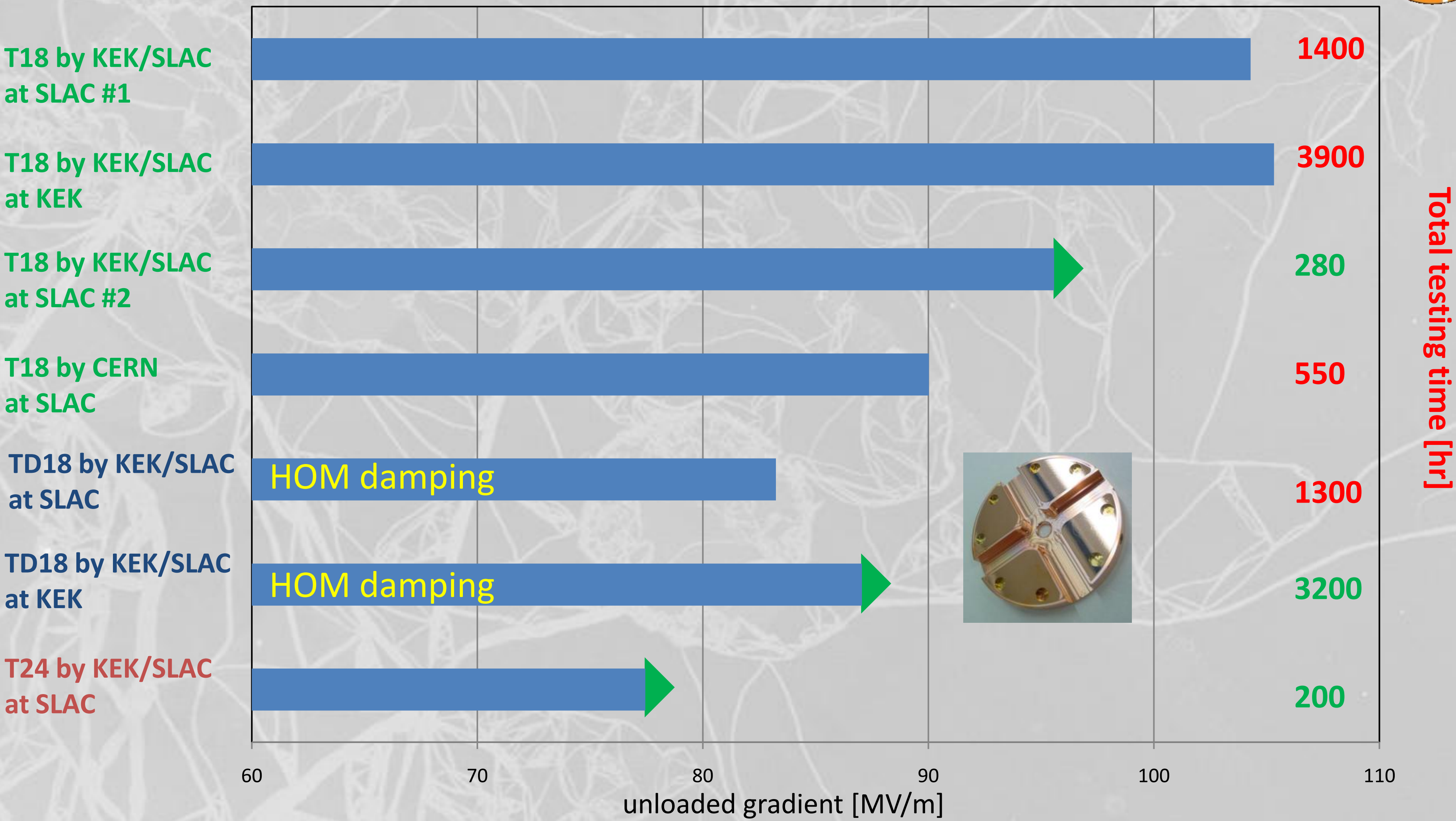








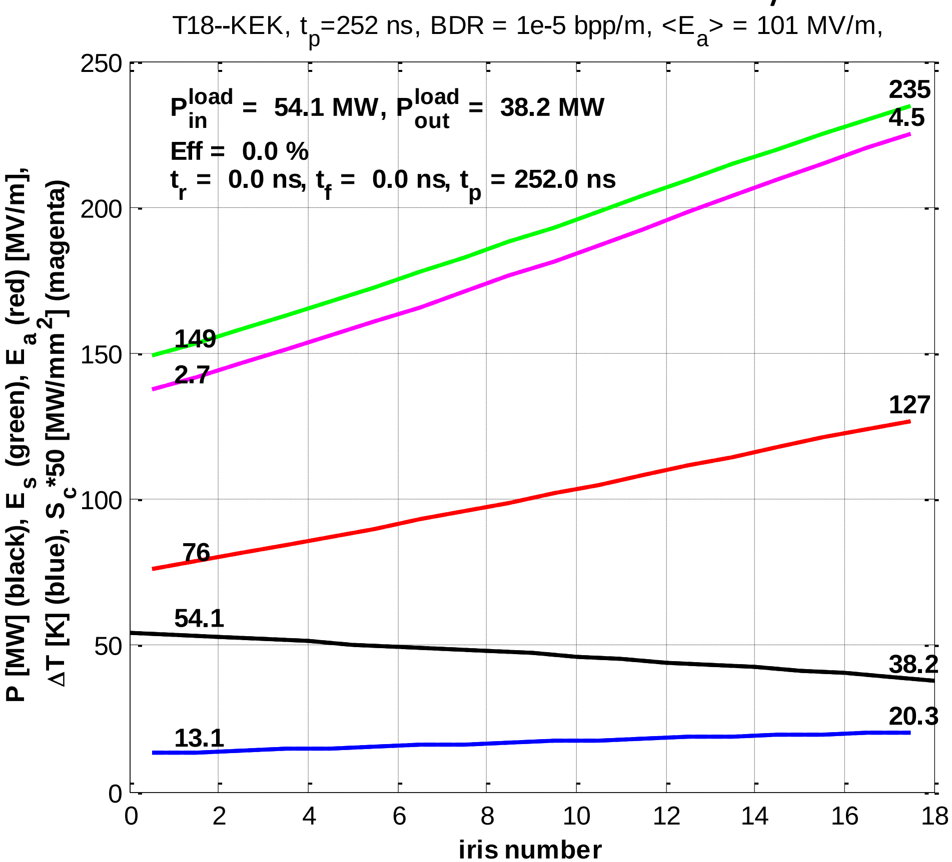
Synthesis of accelerating structure test results scaled to CLIC breakdown rate



Scaling to CLIC conditions: Scaled from lowest measured BDR to BDR=4*10^{-7} and τ=180 ns (CLIC flat-top is 170 ns), using standard $E^{29}\tau^5/BDR$=const. Correction to compensate for beam loading not included – expected to be less than about 7%.

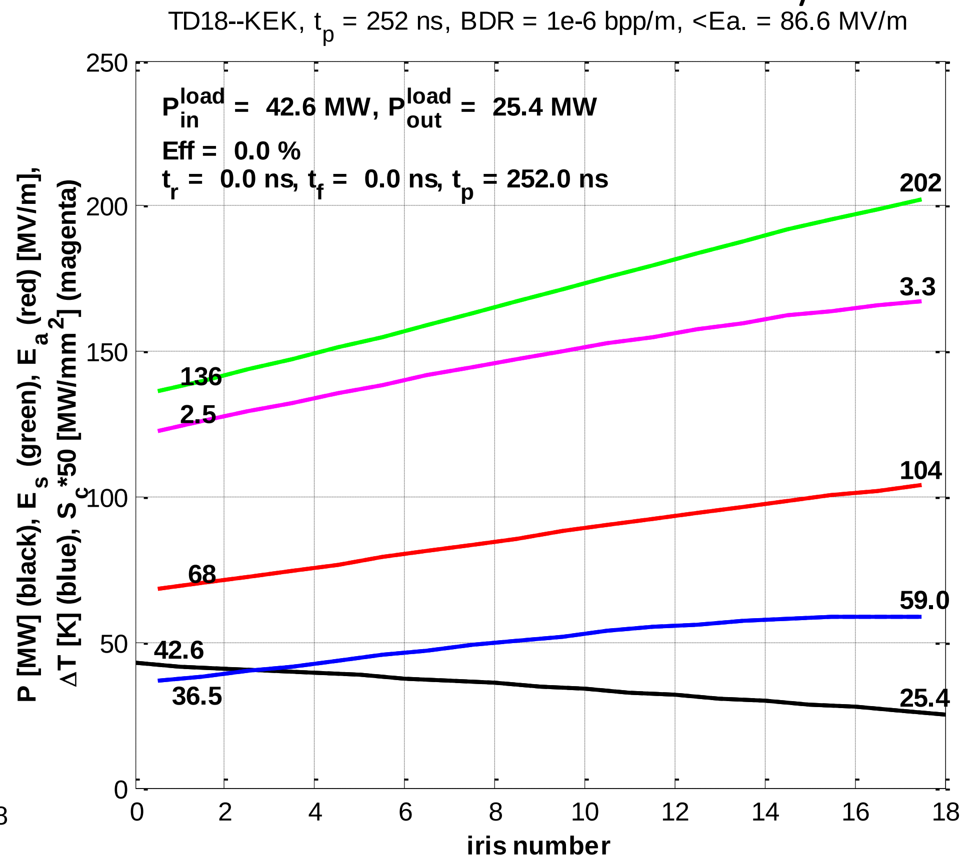
Comparison at tp=252 ns, BDR=1e-6 bpp/m

T18: <Ea> = 101 MW/m



P/C*tp^(1/3) = **13.4** [MW/mm*ns^(1/3)]

TD18: <Ea> = 86.6 MW/m

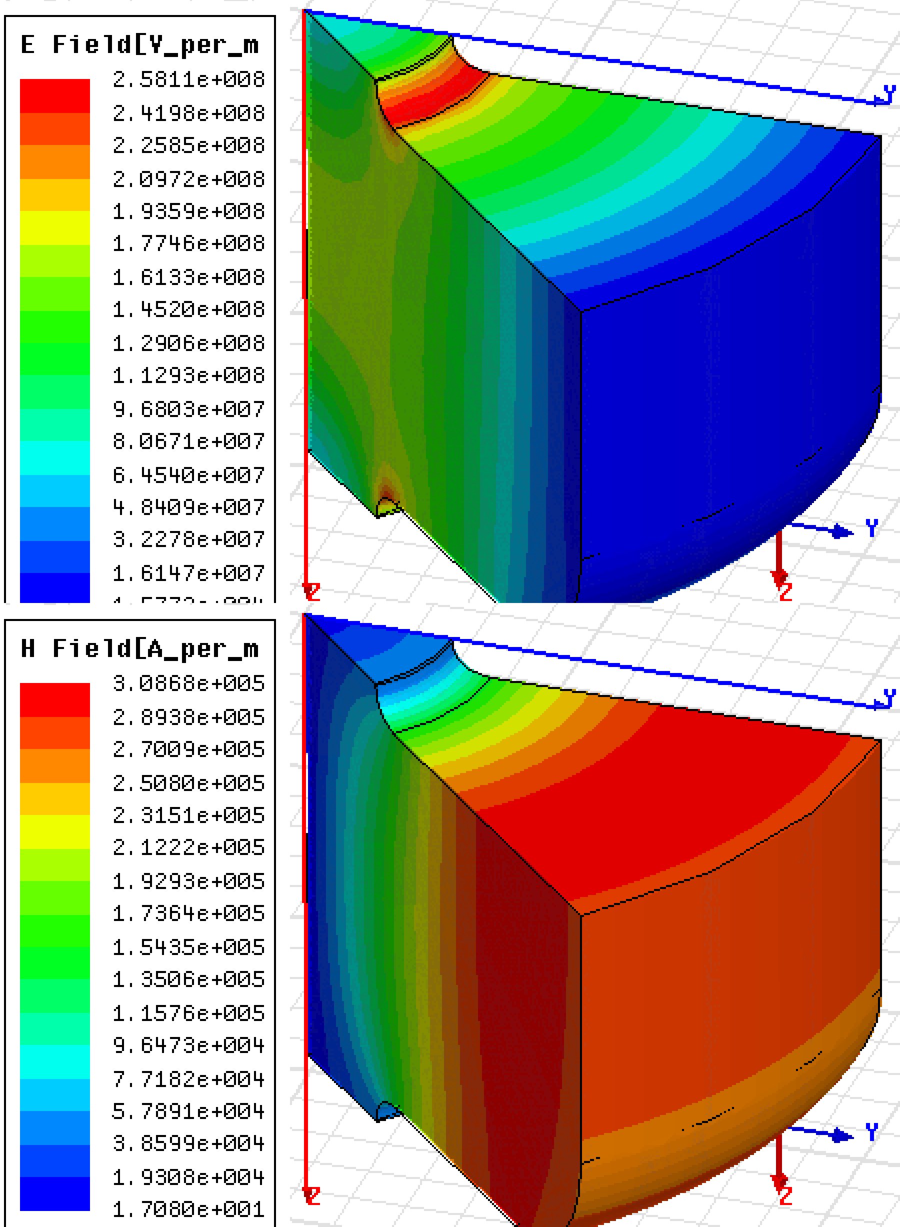


P/C*tp^(1/3) = **10.6** [MW/mm*ns^(1/3)]

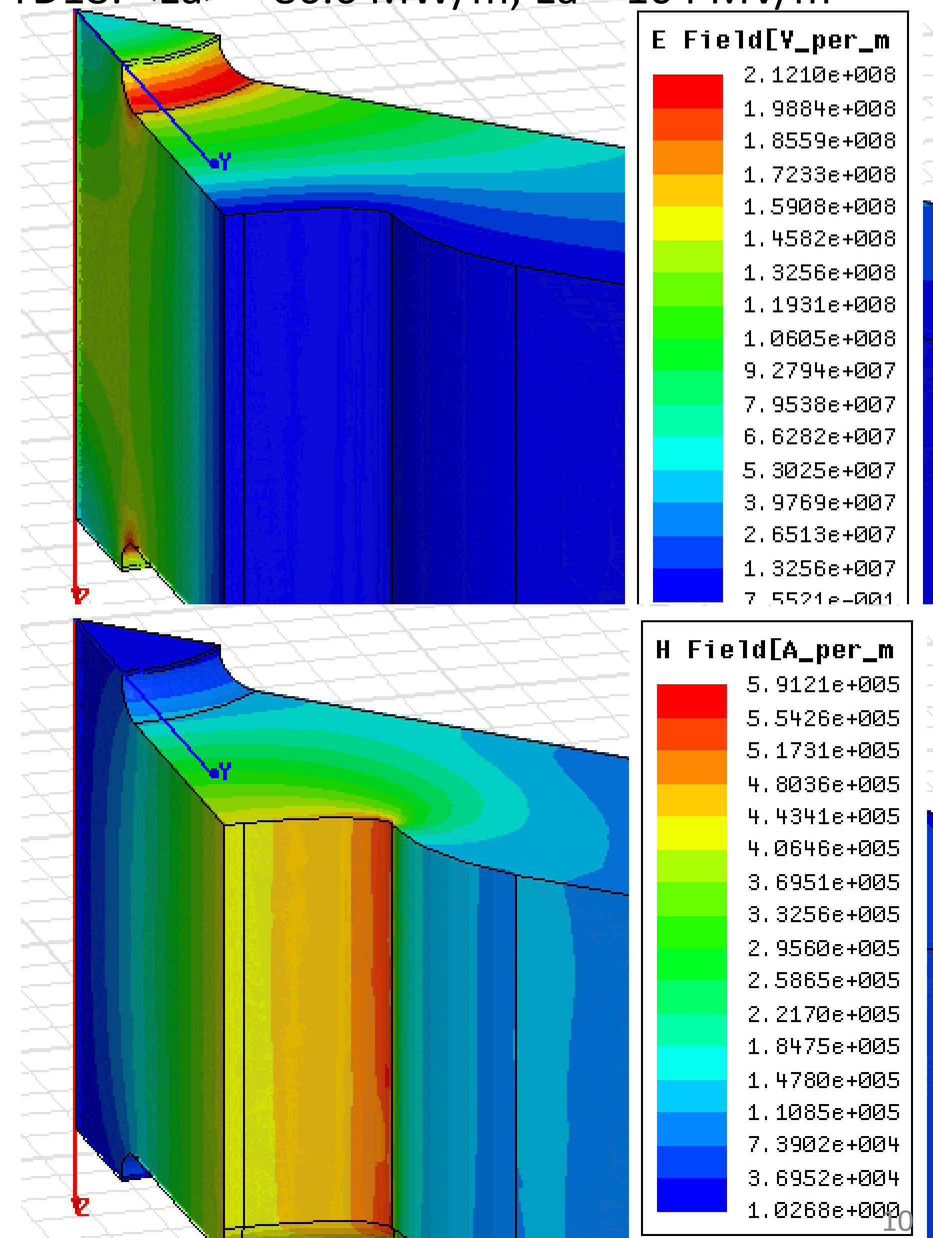
In TD18, all quantities are lower than in T18 measured at the same tp and BDR, except for the pulsed surface heating temperature rise which is factor 3 higher ???

Comparing last cell at tp=252 ns, BDR=1e-6 bpp/m

T18: <Ea> = 101 MW/m, Ea = 127 MV/m

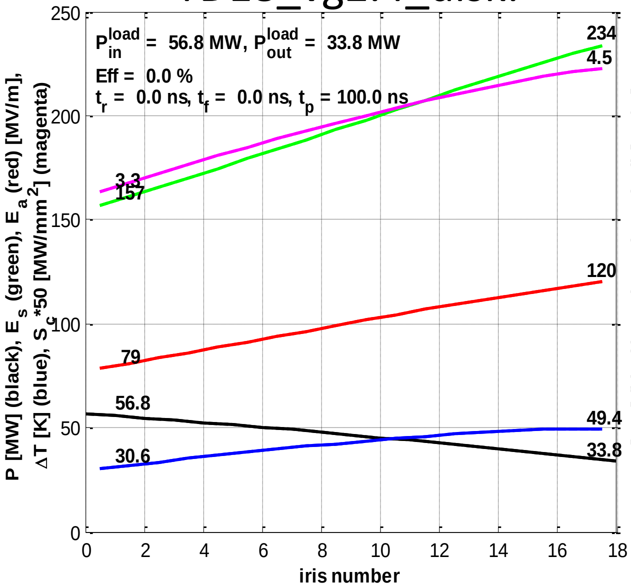


TD18: <Ea> = 86.6 MW/m; Ea = 104 MV/m

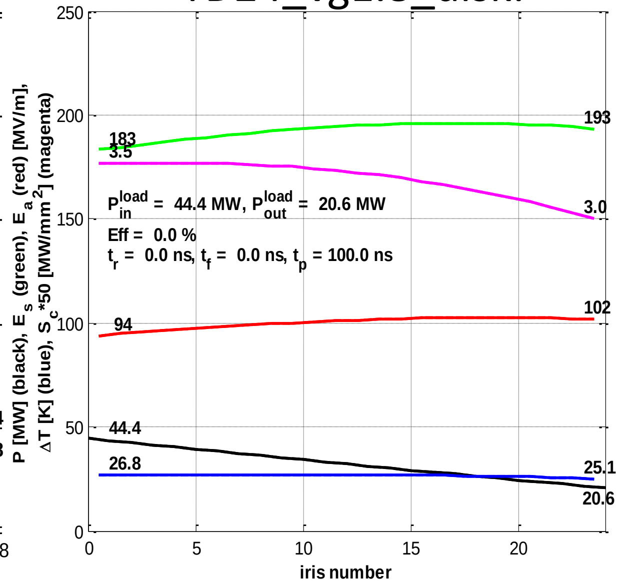


Near term plans

TD18_vg2.4_disk:



TD24_vg1.8_disk:



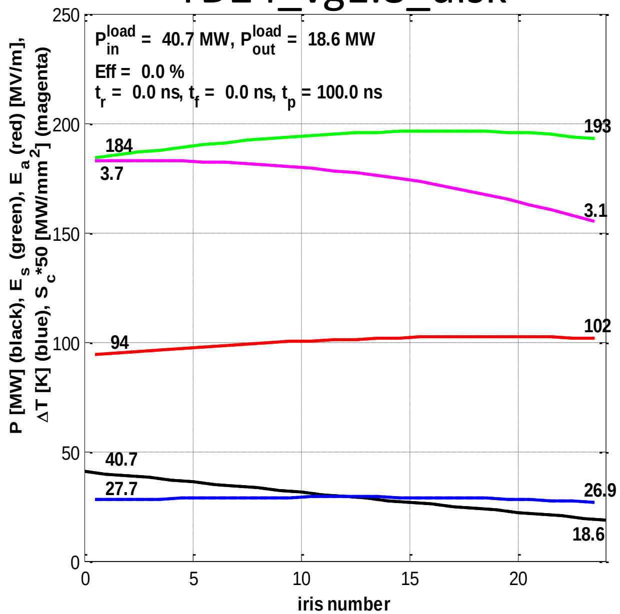
At 11.424 GHz testing of T24/TD24 should come this year.

Very interesting because TD24 has 2 times lower PSH ΔT than TD18

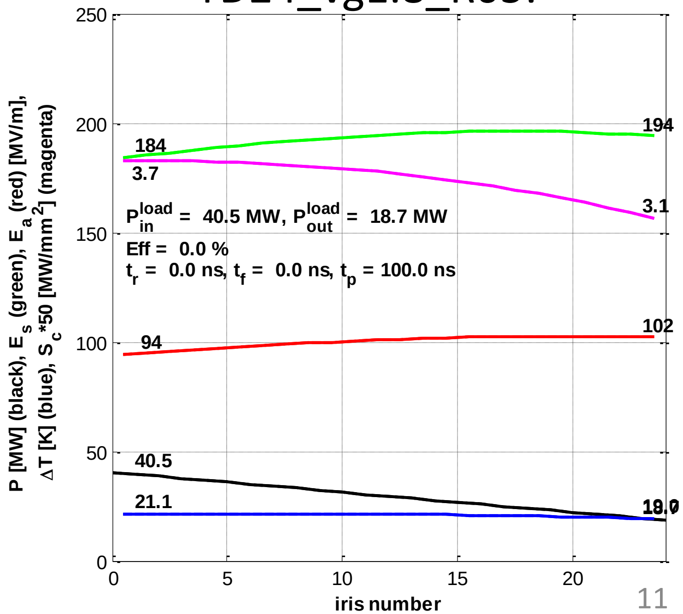
At **11.994 GHz** testing of T24/TD24/TD24_R05 are planed for the next year.

TD24 ➔TD24_R05 provides further reduction of PSH ΔT by 1/3

TD24_vg1.8_disk

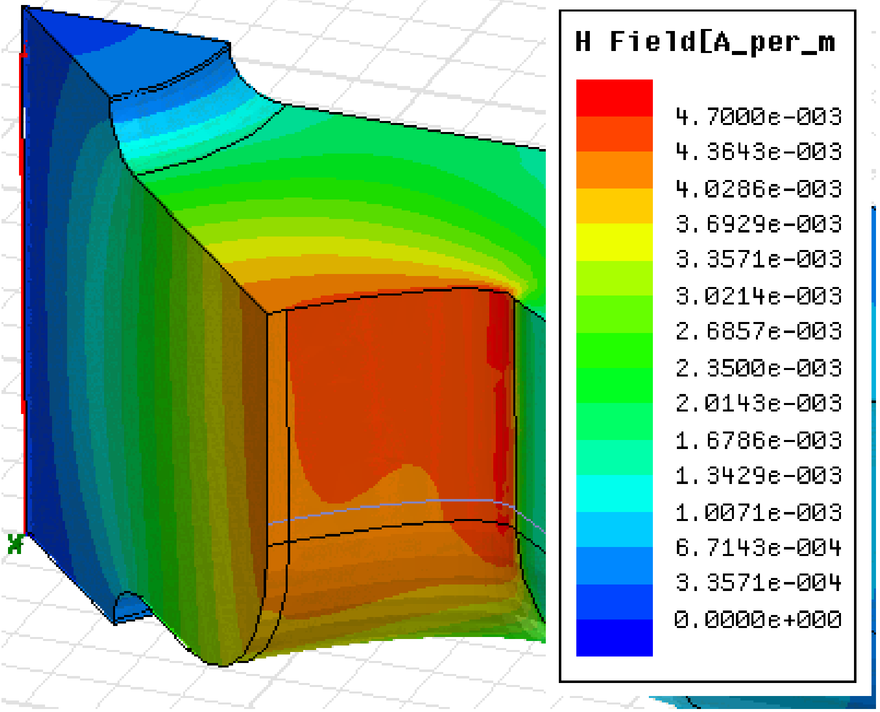


TD24_vg1.8_R05:

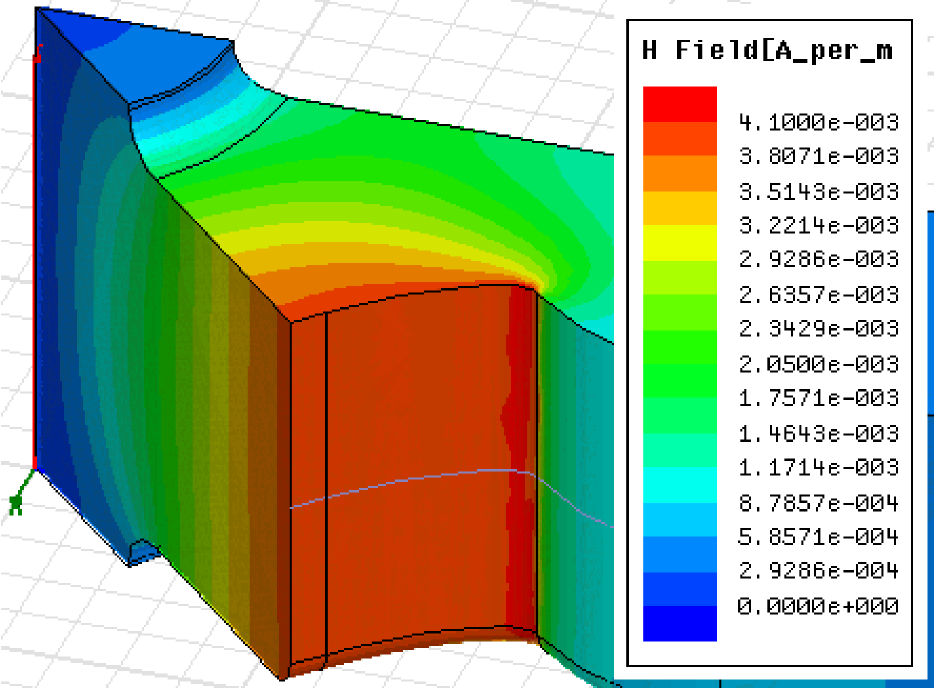


Geometry difference between

TD24_vg1.8_disk

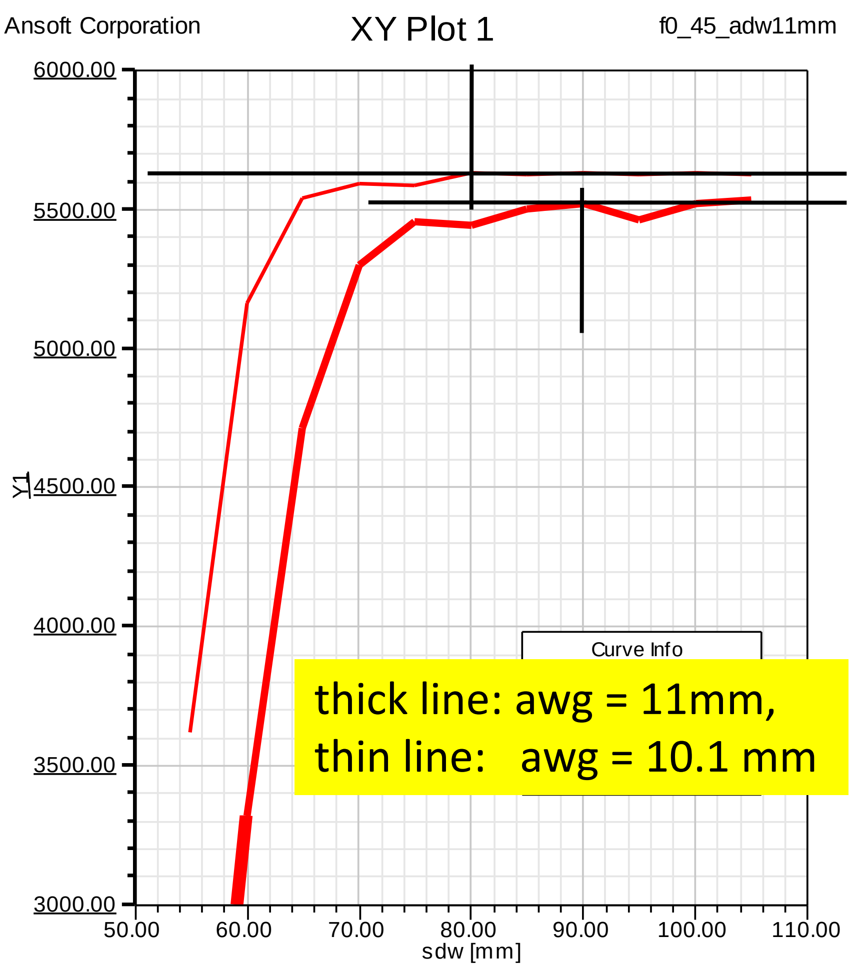


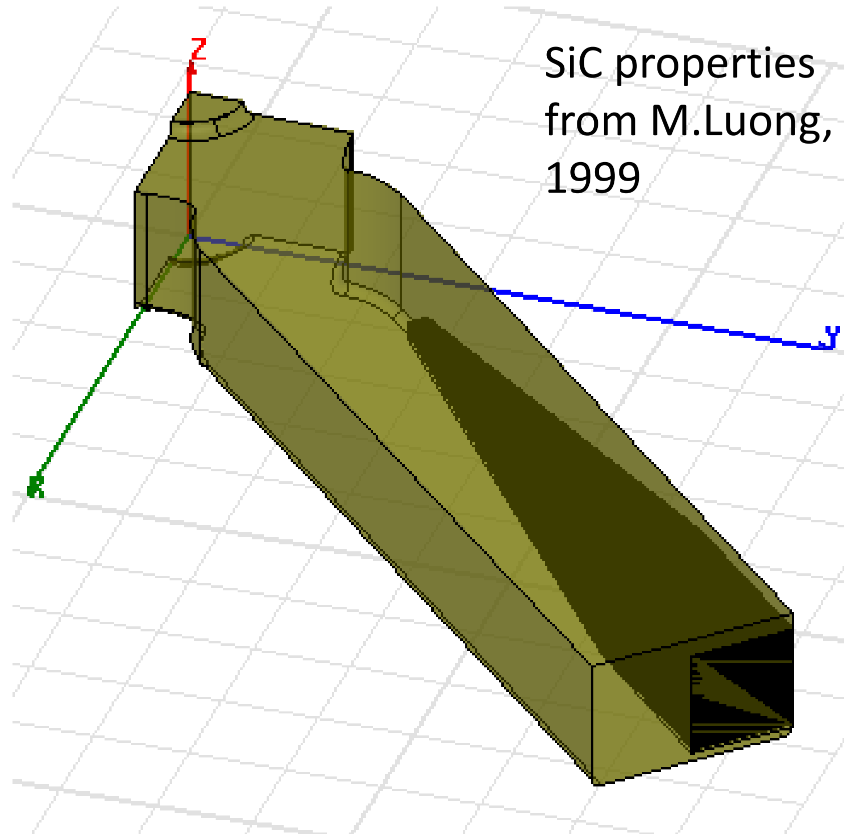
TD24_vg1.8_R05



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)

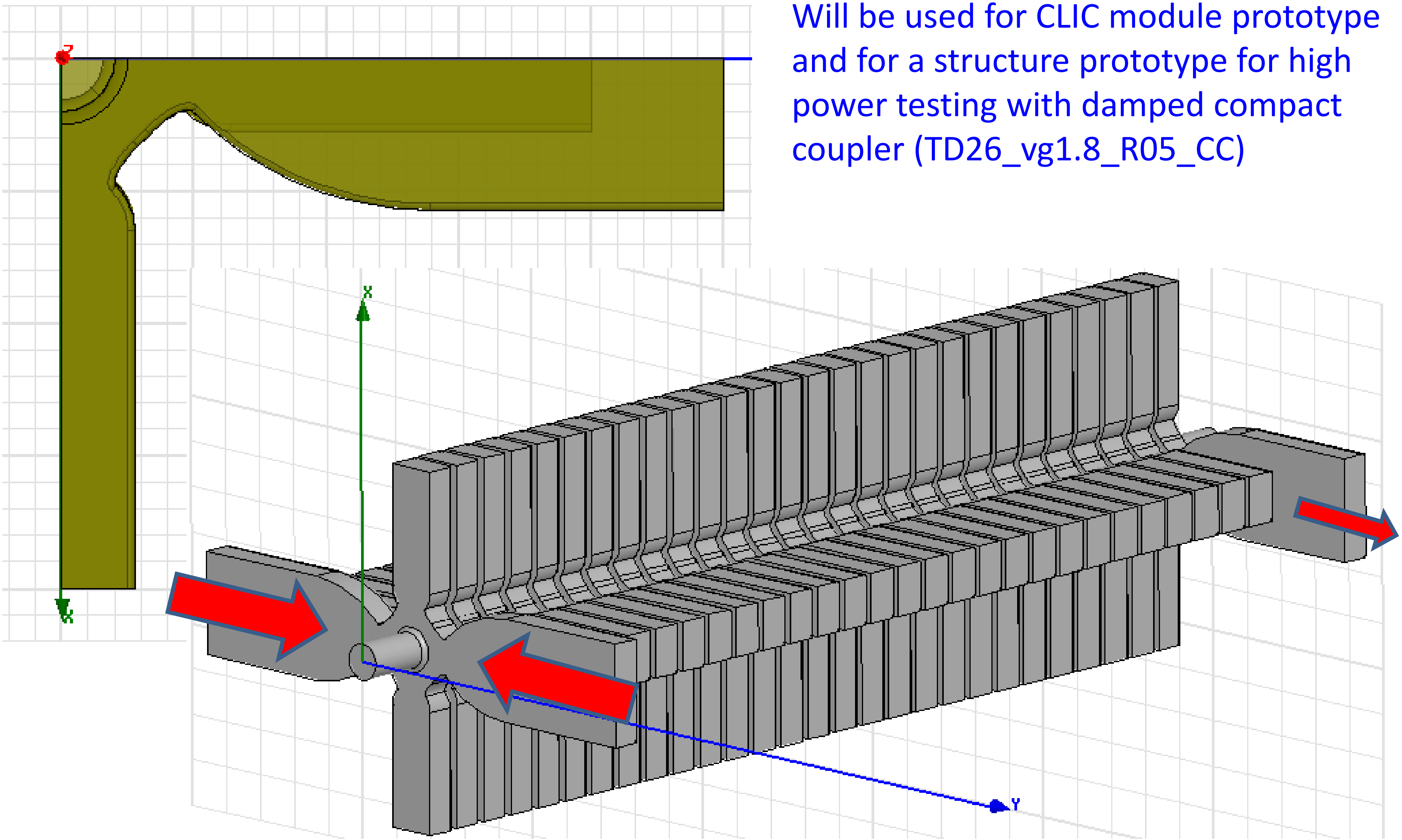




SiC properties from M.Luong, 1999

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

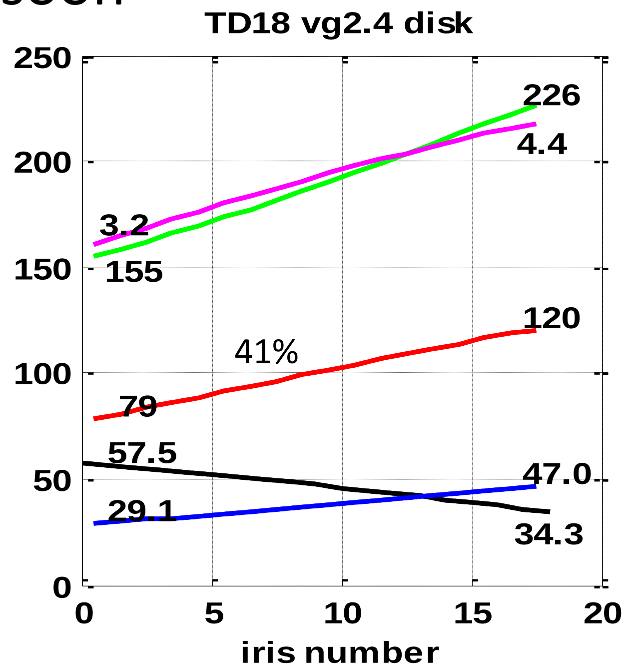
Design of the damped compact coupler

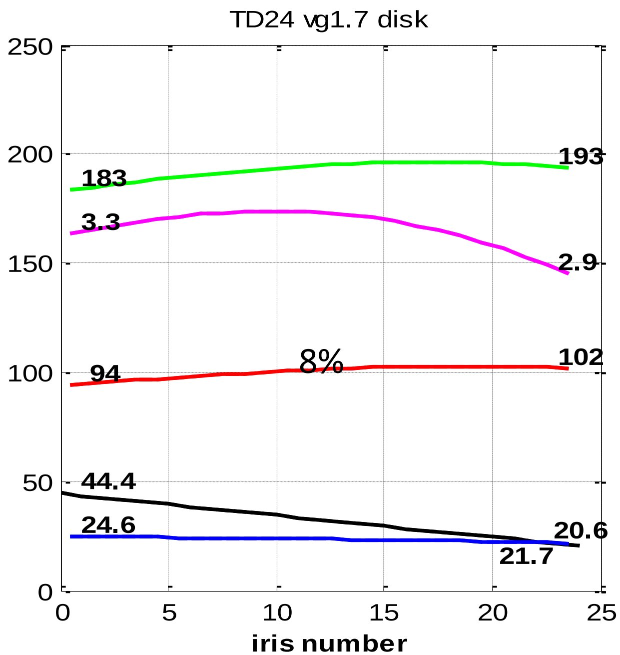


Will be used for CLIC module prototype and for a structure prototype for high power testing with damped compact coupler (TD26_vg1.8_R05_CC)

Beyond CLIC_G

- Next step in rf design will be a structure with a degree of tapering lower than TD18 (41%) and TD24 (8%)
- For example, ~ 20-25 %
- It will probably have bigger average aperture if CLIC main beam bunch charge can be increased accordingly.
- A detailed optimization of the parameters and rf design will be done soon





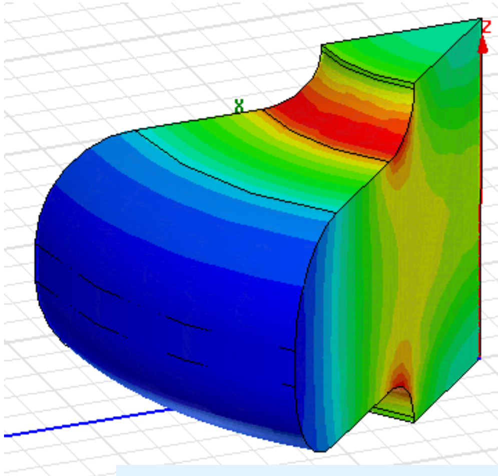
Quadrants/halves family

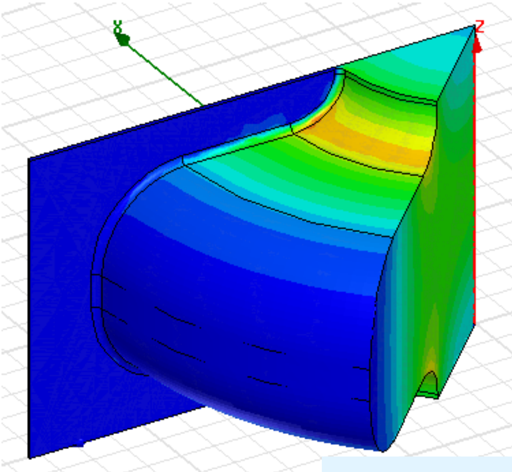
HALVES

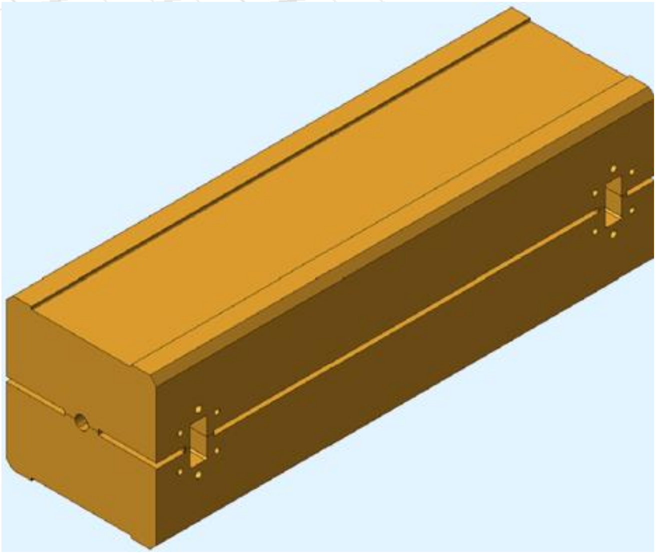
Here T18_vg2.6_quad design is used. It has no slots.

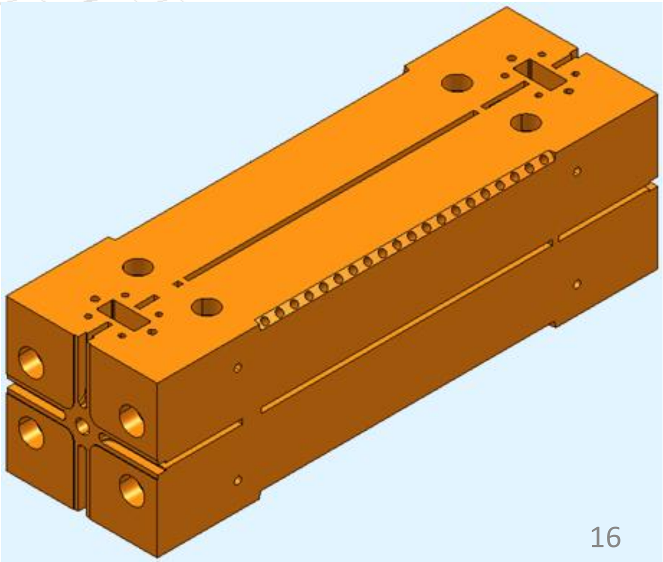
QUADs with SLOTS

T18_vg2.6_quad design is used but rounded 4 slots of 0.2 mm are introduced.





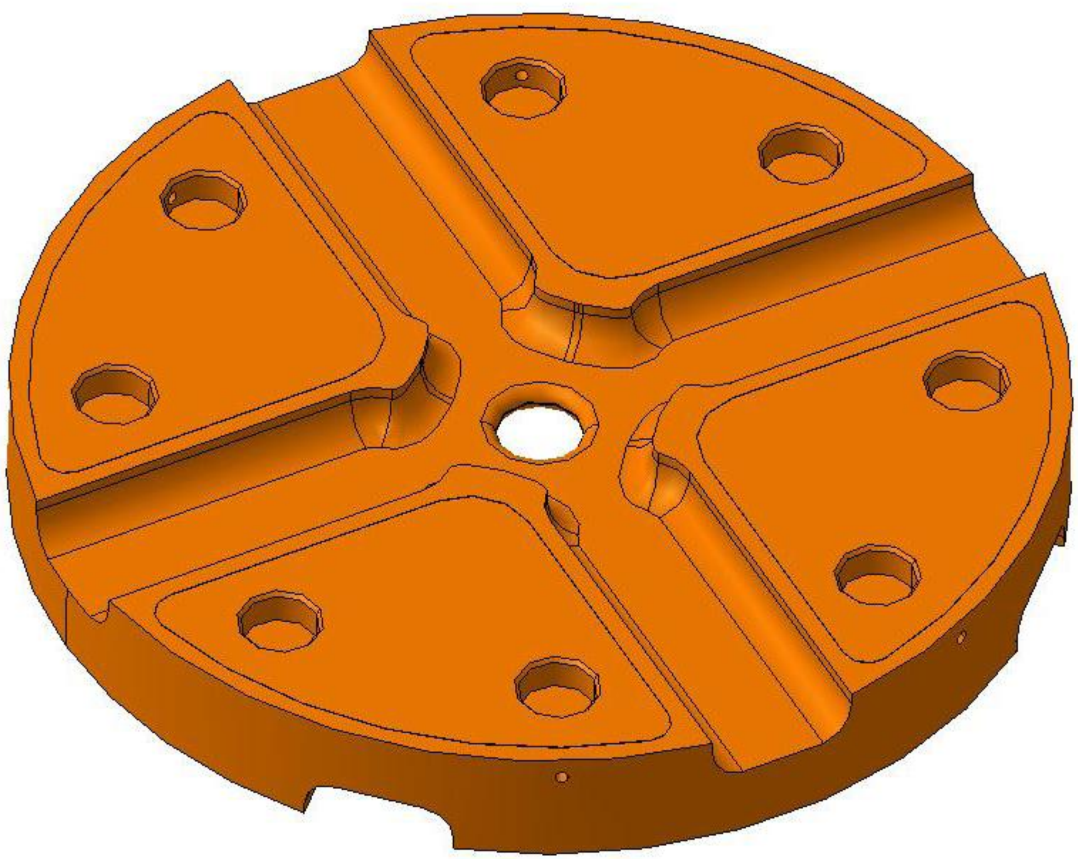




Symmetrical disk design

It has a number of pros and cons:
+ higher Q
— higher cost
— requires axial alignment
— tuning is more difficult and it is not implement
—

The structure is in the production



Alternative damping designs

1. DDS type is underdevelopment at 12 GHz by Cockcroft Institute and Manchester University (R. Jones, A. D'Elia, V. Khan).
2. Choke-mode type is under development in collaboration with Tsinghua University (J. Shi)
   1. Minimum gap acceptable from the point of view rf breakdowns to be determined using CD10_choke with different gaps: 1mm, 2mm, etc.
   2. Damping design of the full structure is under way aiming at full structure prototype high power test

The choke mode cavity and radial choke

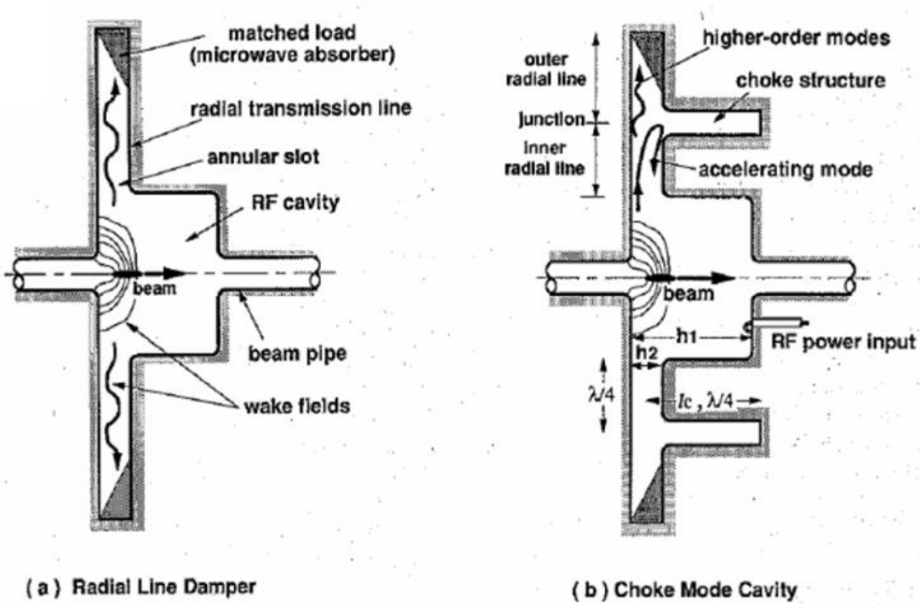
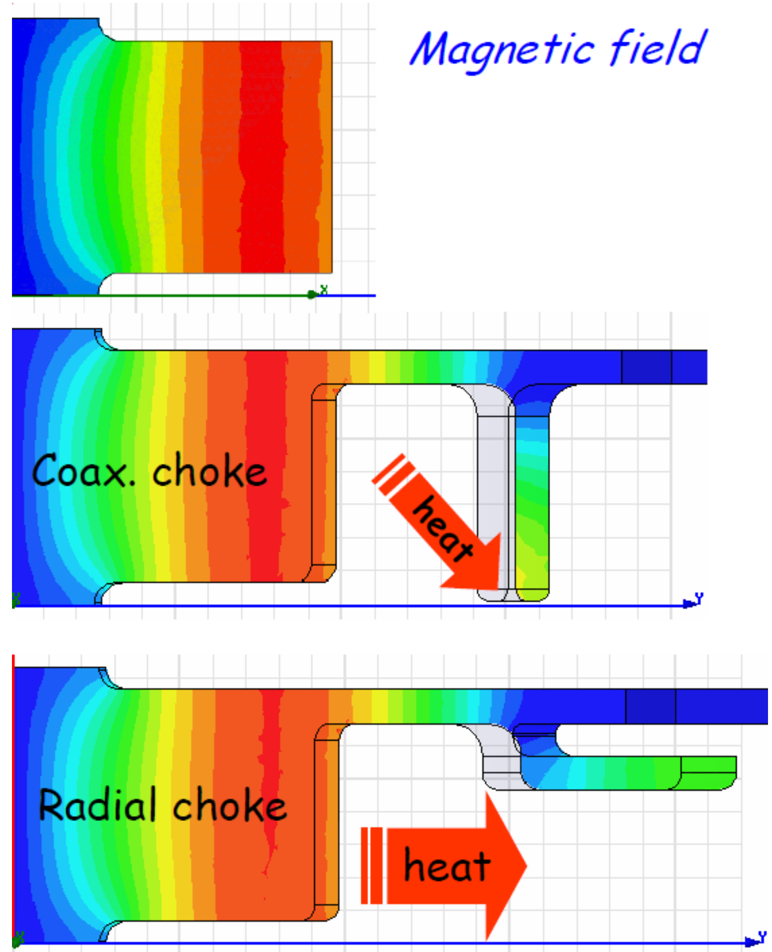


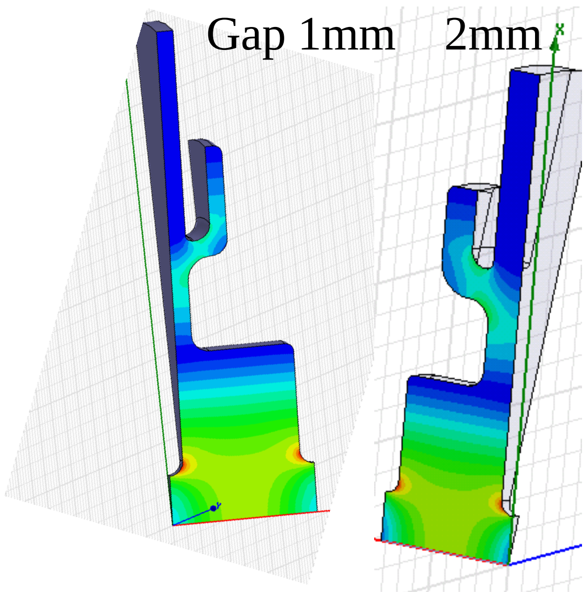
Fig. 1. Conceptual illustrations of (a) a radial line damper and (b) the choke mode cavity.

L 1567

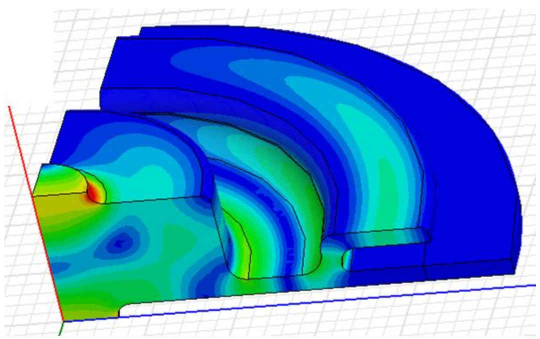
Shintake, 1992



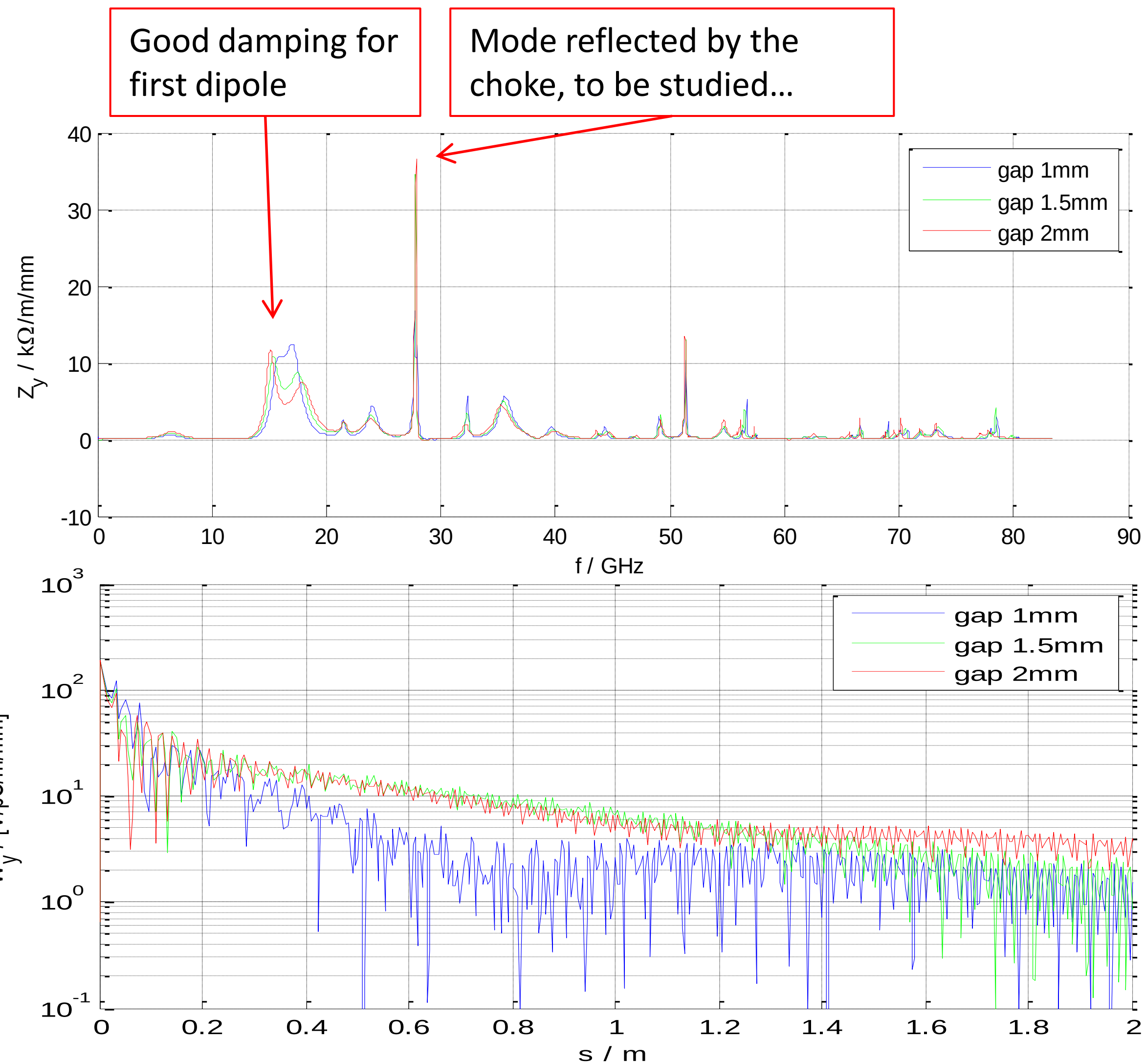
Damping simulation with Gdfidl/HFSS



E field, fundamental mode

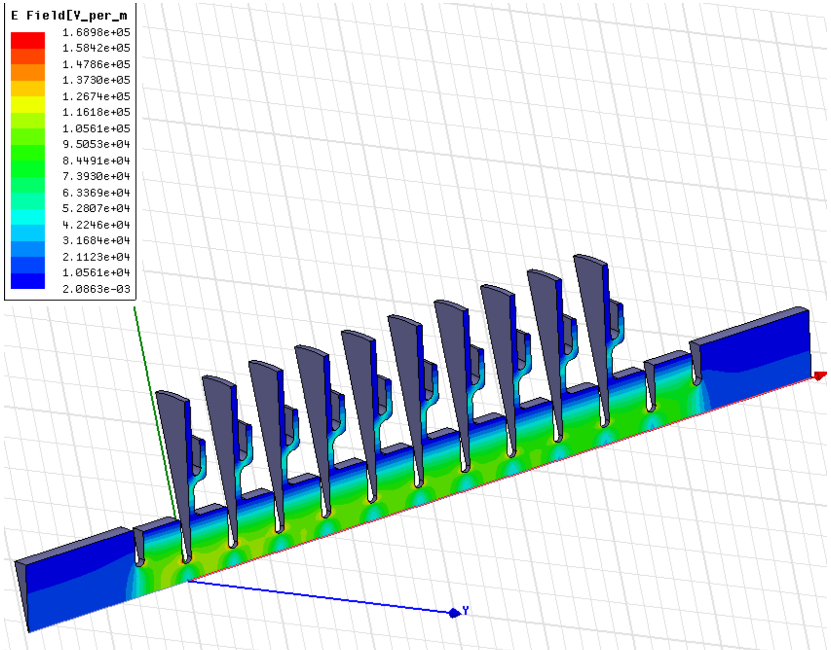


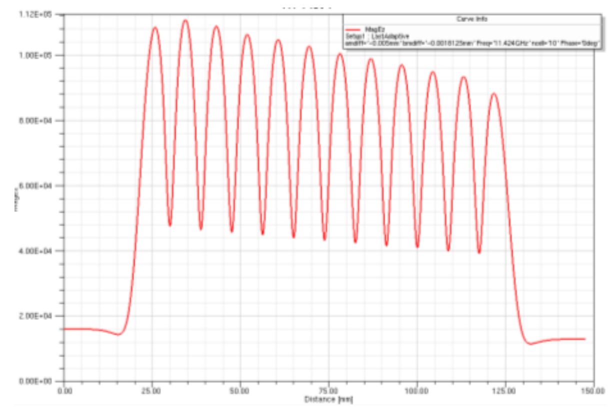
E field of a dipole mode that is reflected by the choke

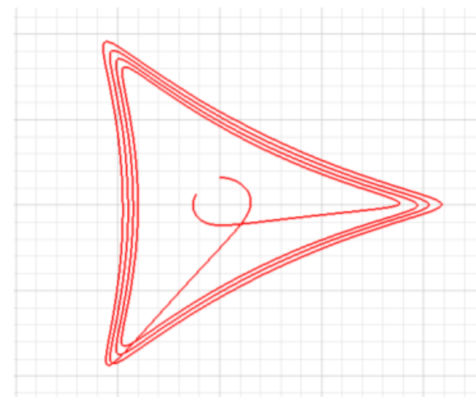


Impedance and wakefield simulated in Gdfidl

Design of CD-10-Choke



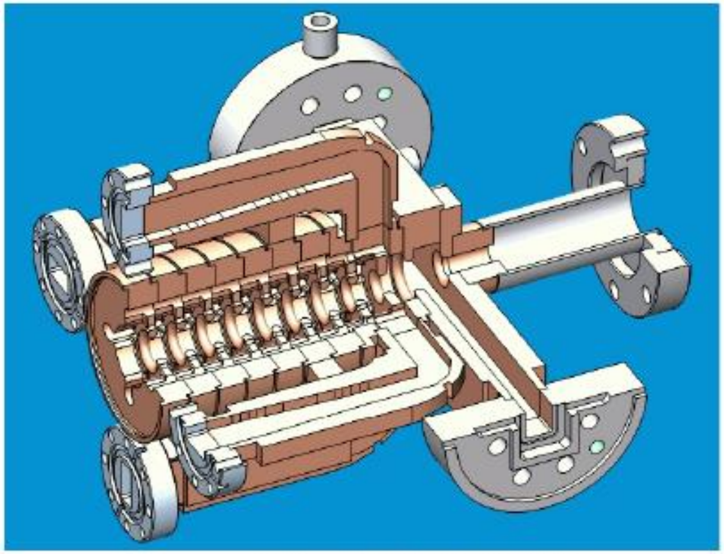




- CD10-Choke for demonstration
  - RF Design for Gap 1mm, 1.5mm, 2mm
  - Mechanical Design finished for 1mm-gap
  - Qualification disks and bonding test
- To the production pipeline and High Power testing

Damped Detuned Structure

- Gaussian distribution of cell parameters is chosen in this (CLIC_DDS) structure which causes Wakefield to decay in nearly Gaussian fashion for short time scale (few nsec)
- Limited number of cells (N=24) in a structure (poor sampling of a Gaussian) means truncation of Gaussian leading to re-coherence of the wake (t=1/Δfmin)
- Re-coherence of the wake is suppressed by moderate damping: Coupling out the HOMs using a waveguide like structure i.e. manifolds running parallel to the accelerating cells
- Interleaving neighboring structure frequencies improves wake suppression



R.M. Jones, PRSTAB 9, 102001 (2006)

- This is a similar technique to that experimentally verified and successful employed for the NLC/JLC program
- Potential benefits include, reduced pulse temperature heating (In principle true but not for CLIC_DDS_A: pulse heating is greater than CLIC_G), ability to optimally locate loads, built-in beam and structure diagnostic (provides cell to cell alignment) via HOM radiation. Provides a fall-back solution too!

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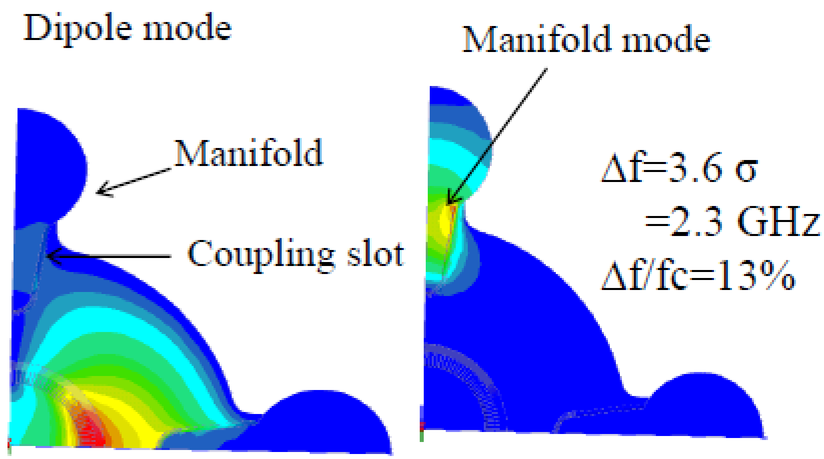

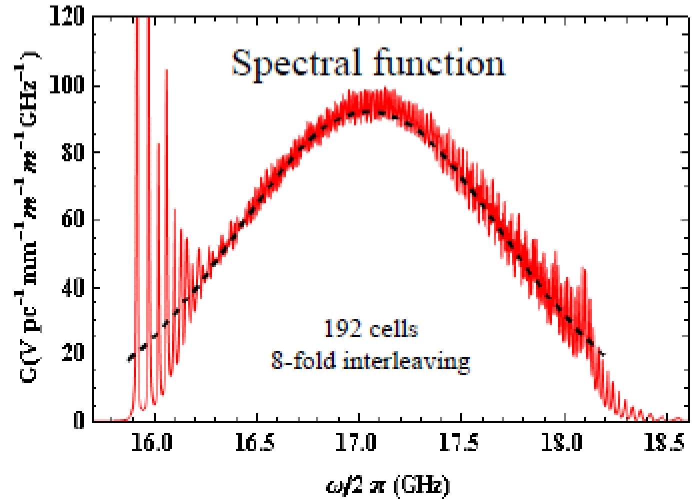

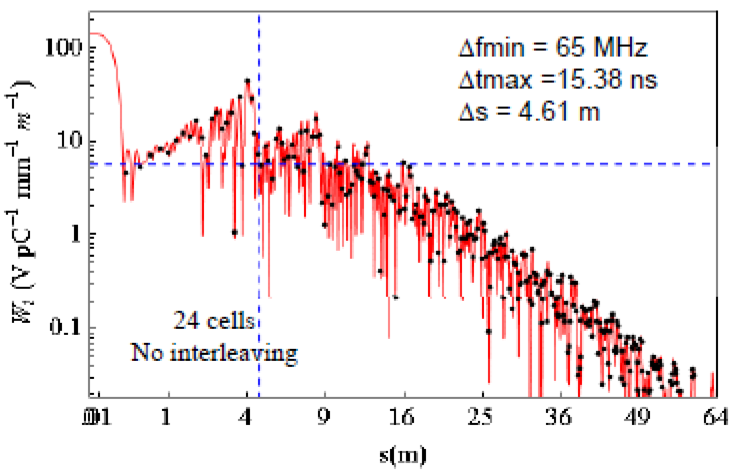

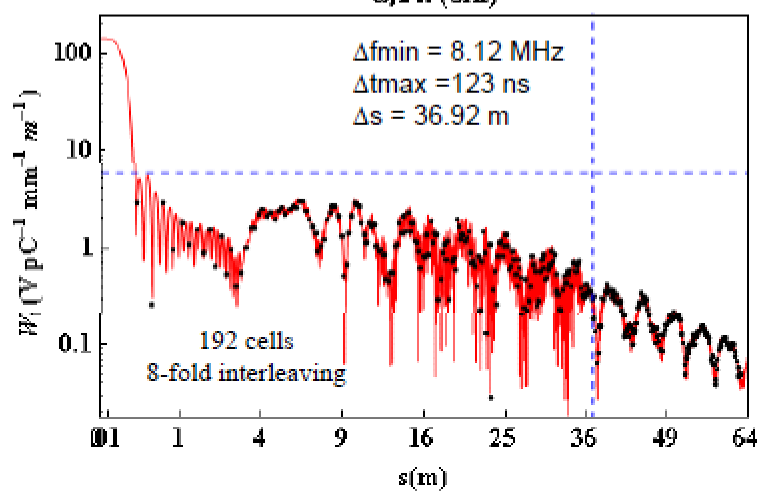

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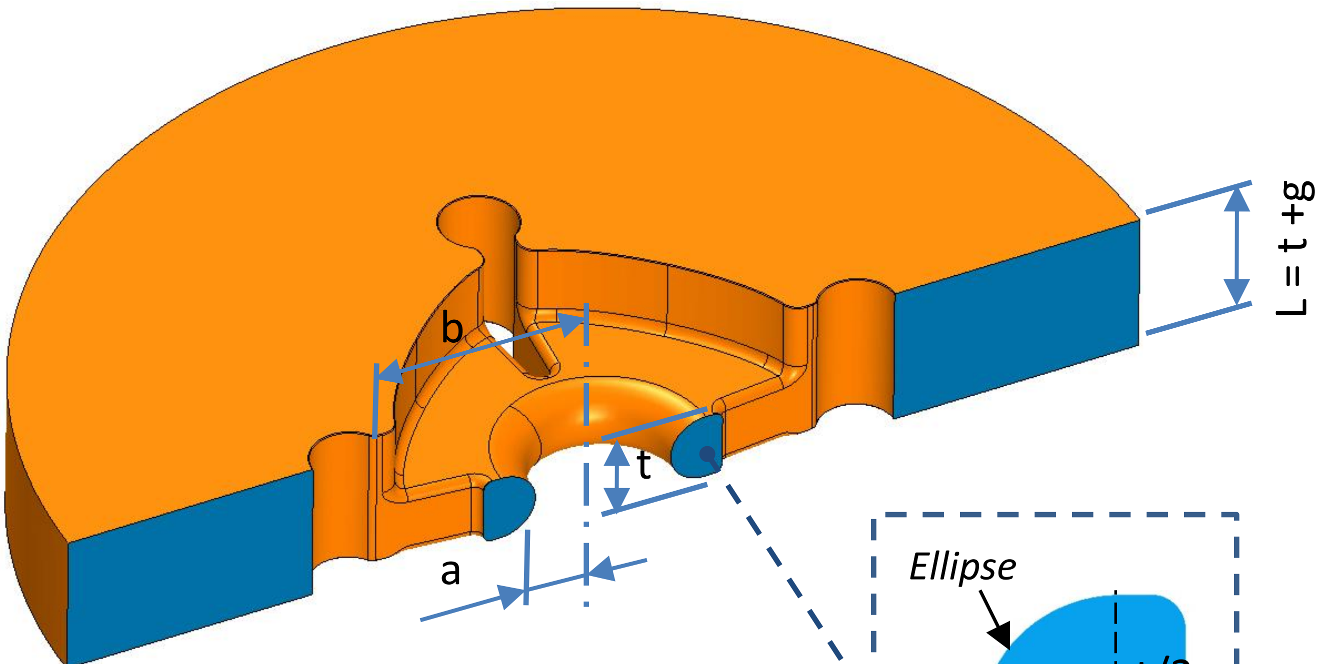
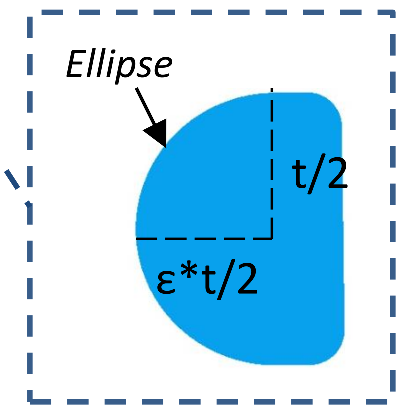
CLIC_DDS_A: Regular disk #1

Section profile and Parameters Table



Disk cross-section.



Parameter	Value
a (mm)	3.8523
b (mm)	11.0031
t (mm)	3.8884
ε	1.0203
g (mm)	4.3316

Parameters table.

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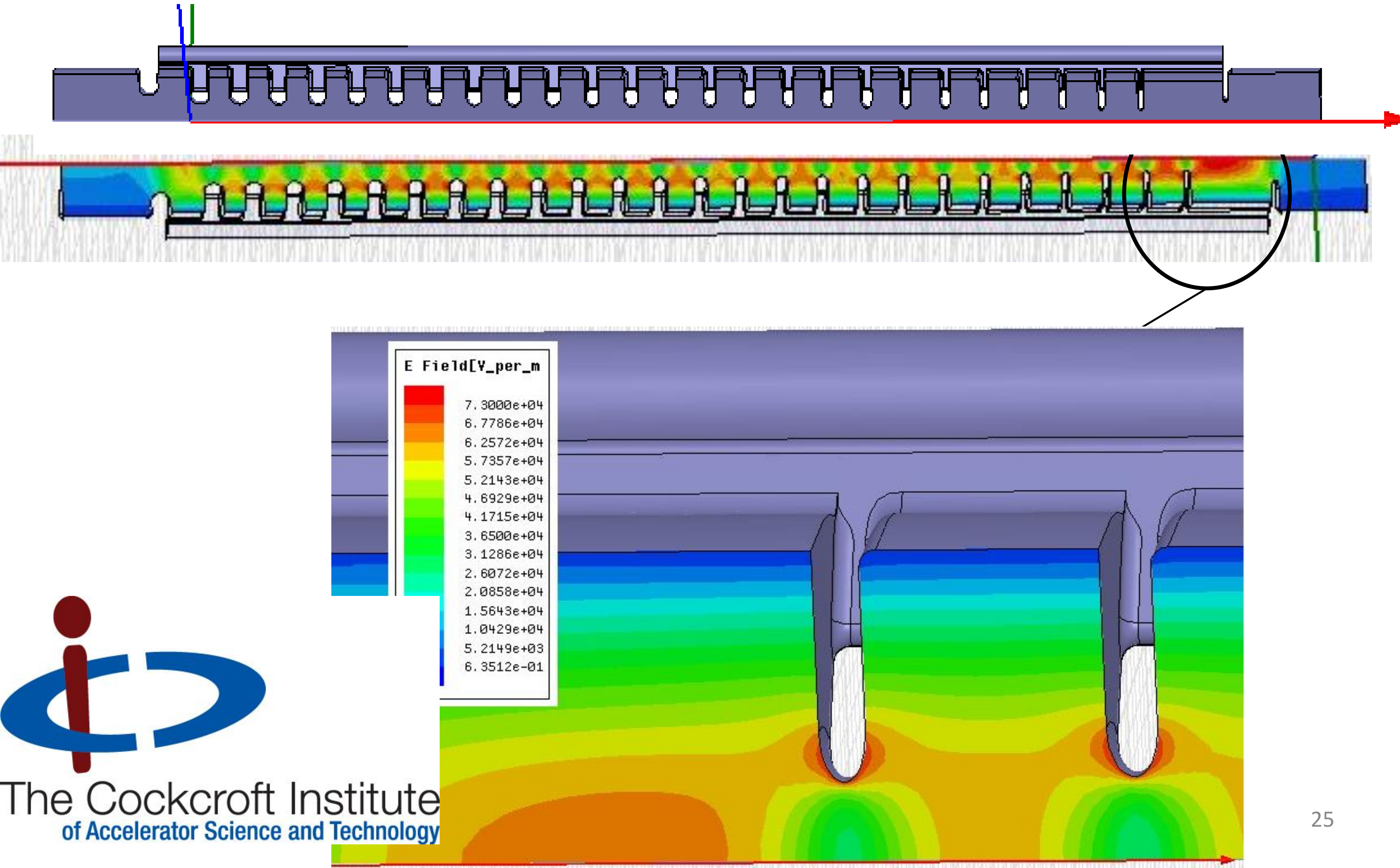
CLIC_DDS_A: E-Field profile along the structure



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Thank you