Recent progress on CLIC accelerating structure design

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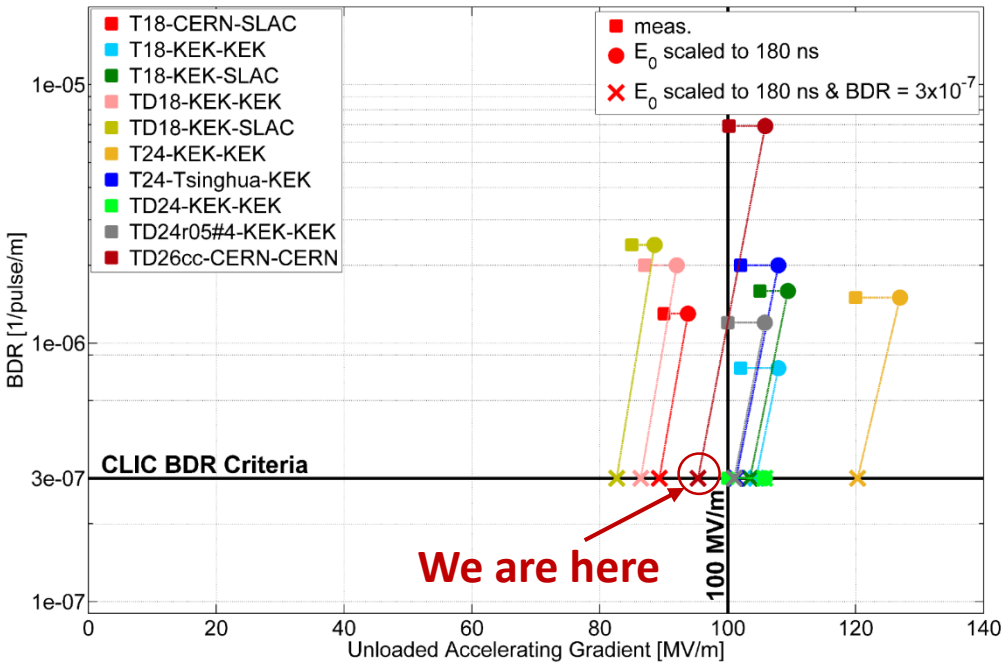
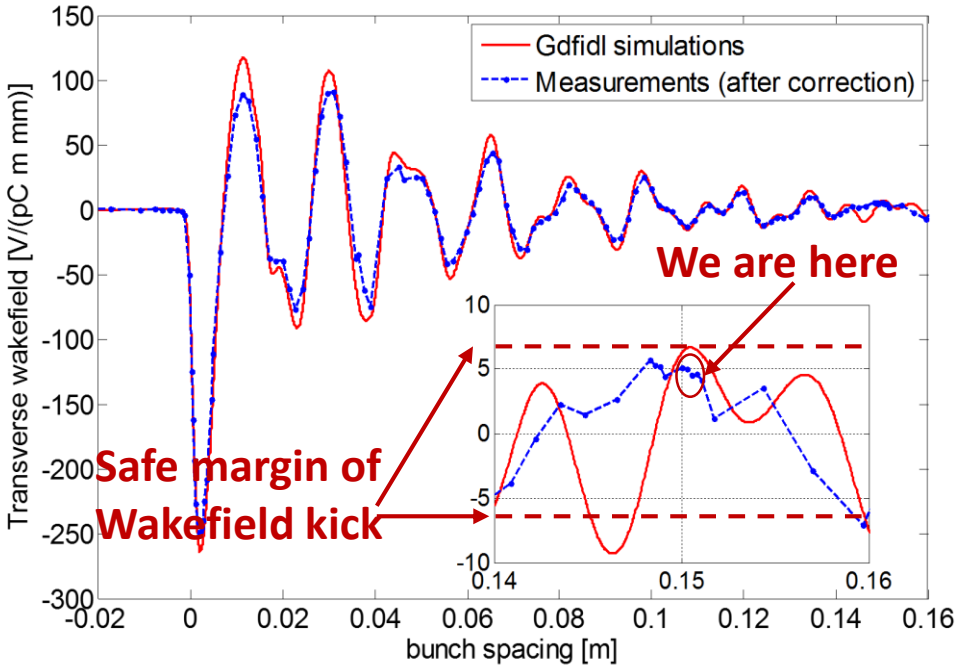
Outline

- **New CLIC-G* geometry**
- New CLIC-G* HOM damping design
- Alternative structure design: Hybrid damped structure.

Old CLIC-G structure design

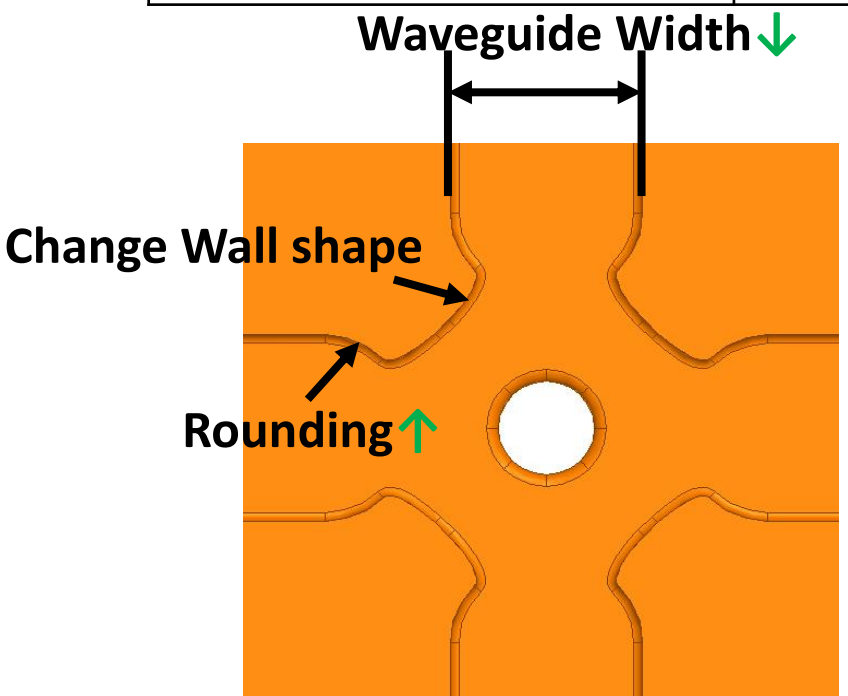
Working frequency[GHz]	11.994
Number of Cell	26+2
Active length[mm]	230
Average Gradient [MV/m]	100
Phase advance per cell	120°
Bunch charge	$3.72*10^9$
Bunch train number	312
Bunch separation [ns]	0.5
Shunt impedance [MΩ/m]	92.0
Peak input power [MW]	63.4
RF to beam efficiency	27.9%
Total pulse length [ns]	242
Filling time [ns]	67
Maximum electric field [MV/m]	248
Maximum *Sc* [MW/mm^2]	5.70
Maximum temperature rise [K]	**47(51)**

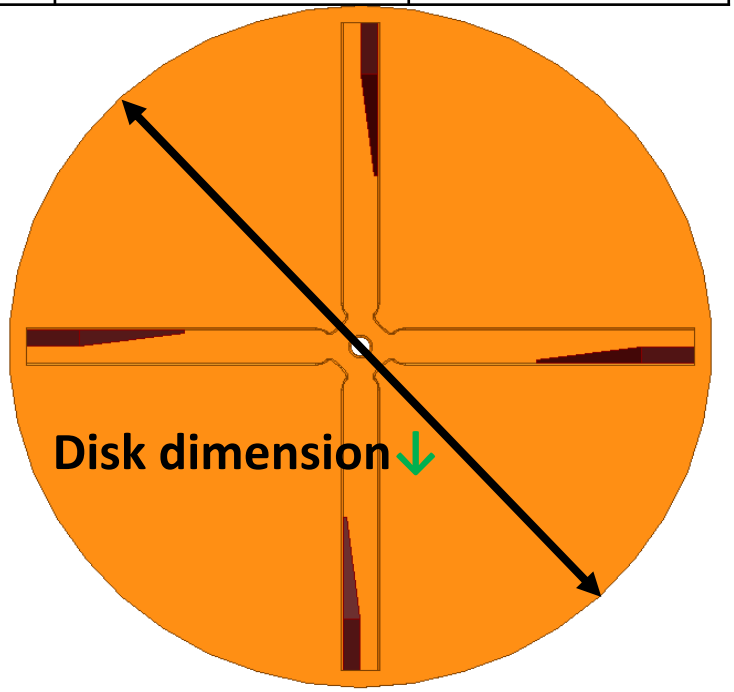




Still have some space to improve

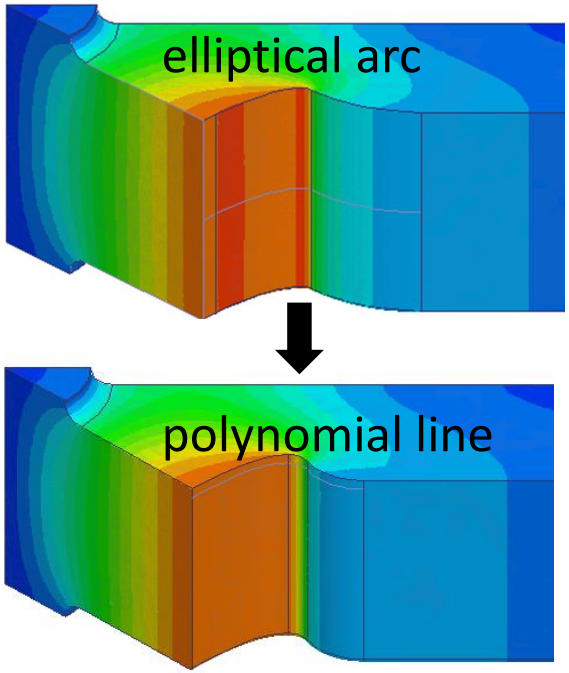
	Cost	Max H-field	Efficiency
Waveguide Width↓	😀	😀	😀
Change Wall shape	😐	😀	😐
Rounding↑	😀	😭	😀
Disk dimension↓	😀	😐	😐

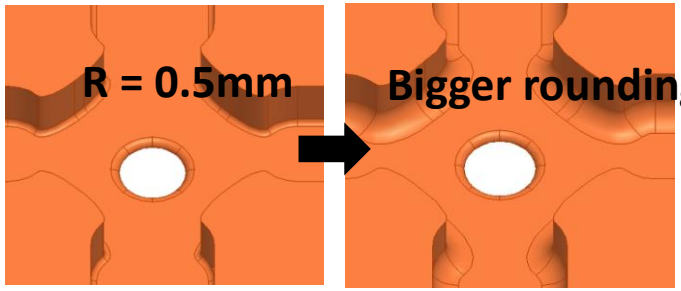


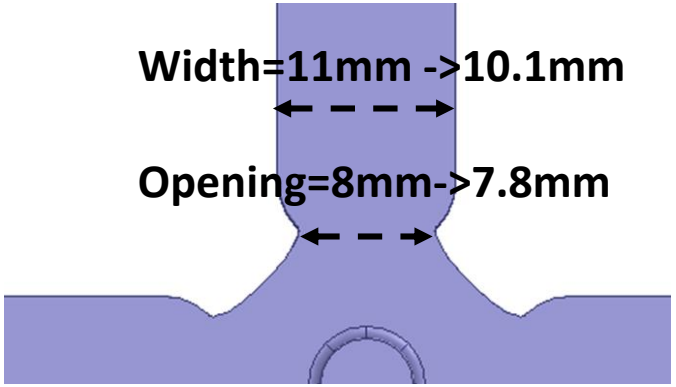


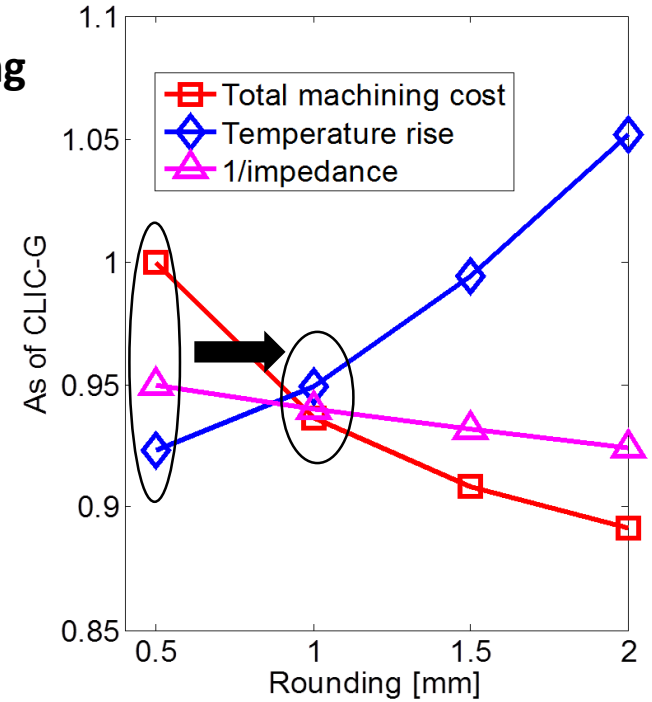
New-CLIC-G design

- Elliptical arc -> polynomial line, surface H-field ↓ by 3.5%;
- Optimize the waveguide geometry: cell diameter ↓ by 3 cm, surface H-field ↓ by 2.5%;
- Larger rounding (from 0.5 mm to 1mm): input power ↓ by 1 MW, manufacturing cost ↓ by 7%





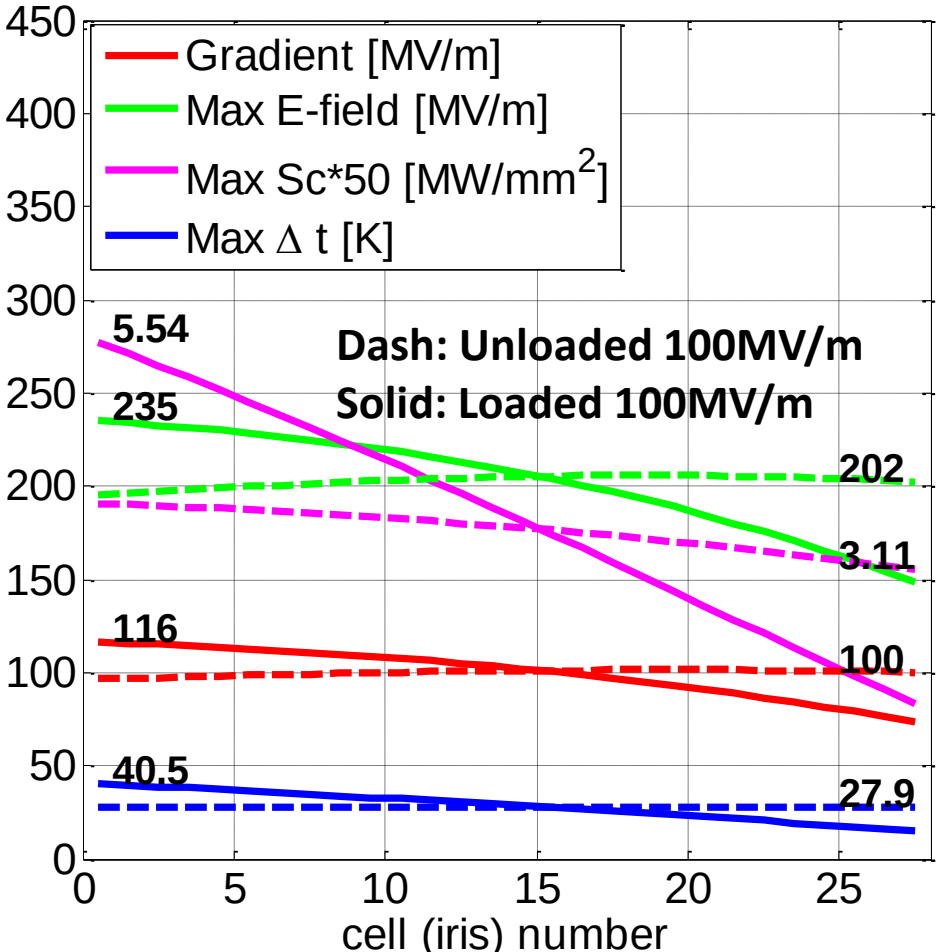


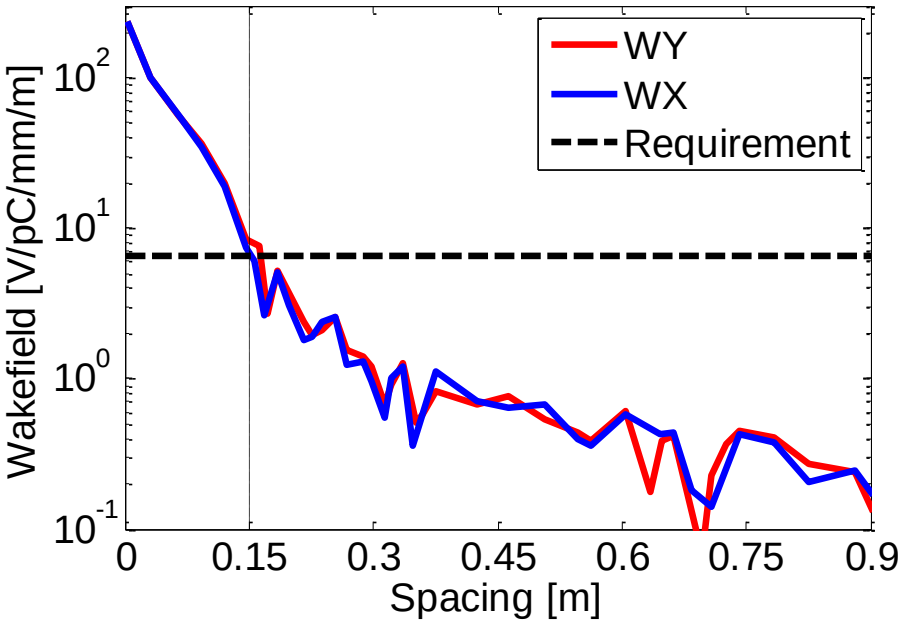


4.New-CLIC-G* structure parameters

- The New CLIC-G* design improved many parameters significantly.

	CLIC-G	CLIC-G*
Rounding[mm]	0.5	1.0
Manufacturing cost	**100%**	**<93%↓**
Shunt impedance [MΩ/m]	92.0	95.4↑
Peak input power [MW]	63.4	62.3↓
RF to beam efficiency	27.9%	28.4%↑
Filling time [ns]	67	66↓
Maximum electric field [MV/m]	248 (230)	250↑
Maximum Sc [MW/mm^2]	5.70	5.54↓
Maximum temperature rise [K]	**52(47)**	**41↓↓**





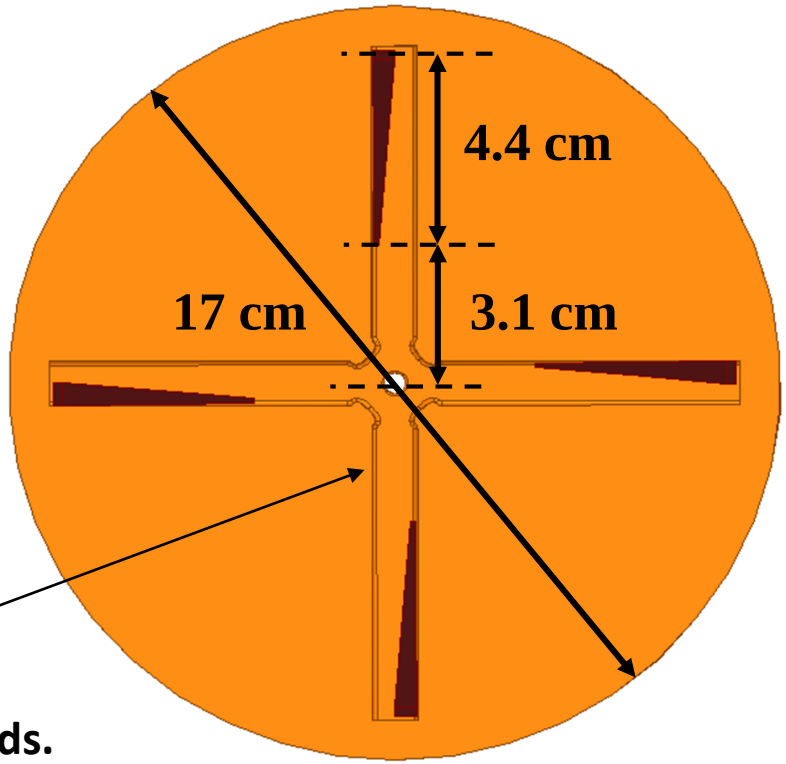
Outline

- New CLIC-G* geometry
- **New CLIC-G* HOM damping design**
- Alternative structure design: Hybrid damped structure.

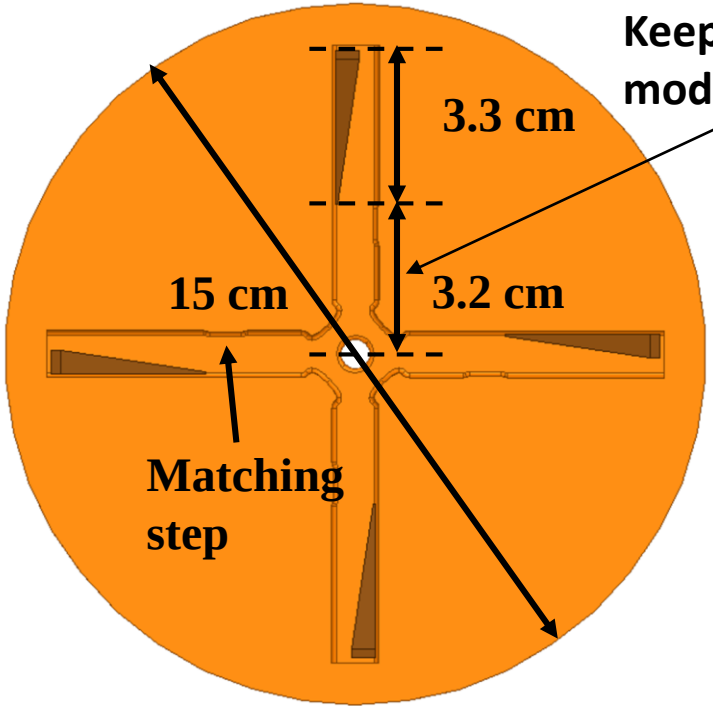
Load designs

- Dimension of original CLIC-G design: 20 cm.
- We have three more compact designs here.

New CLIC-G* design + regular waveguides

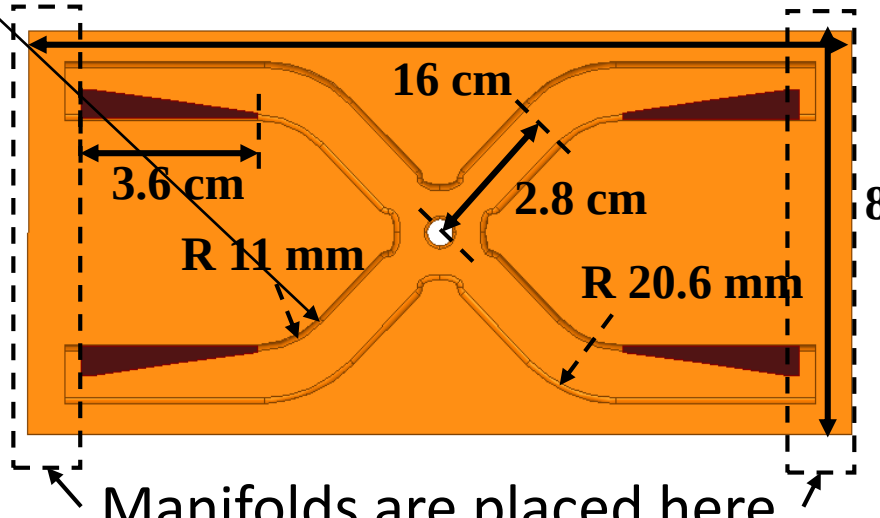


New CLIC-G* design + waveguides with matching step



Keep fundamental mode away from loads.

New CLIC-G* design + bended waveguides

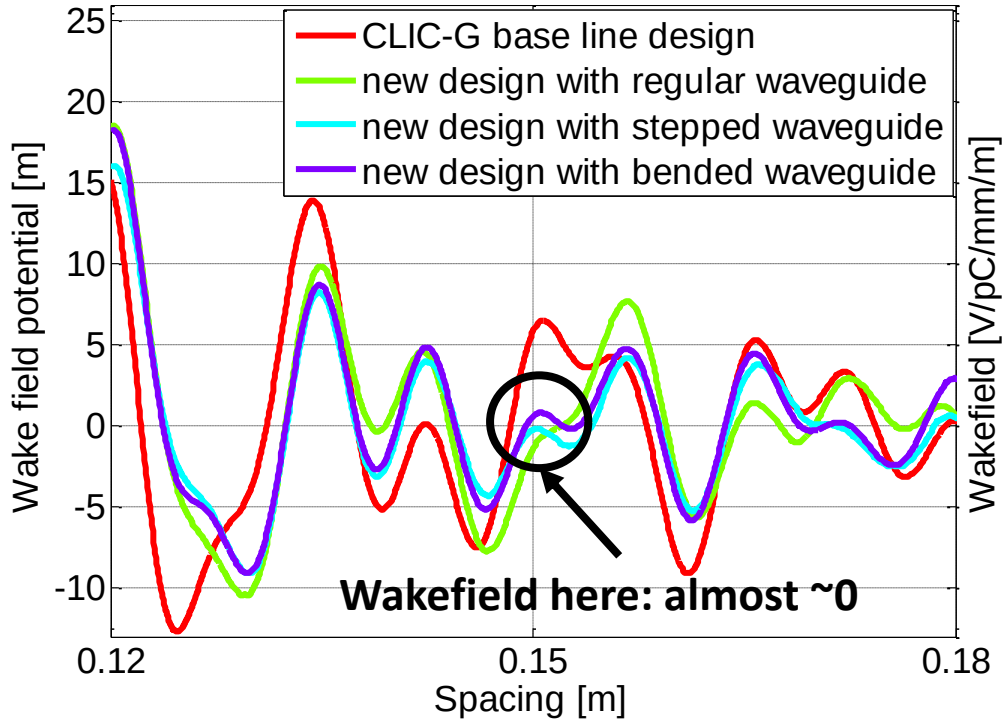


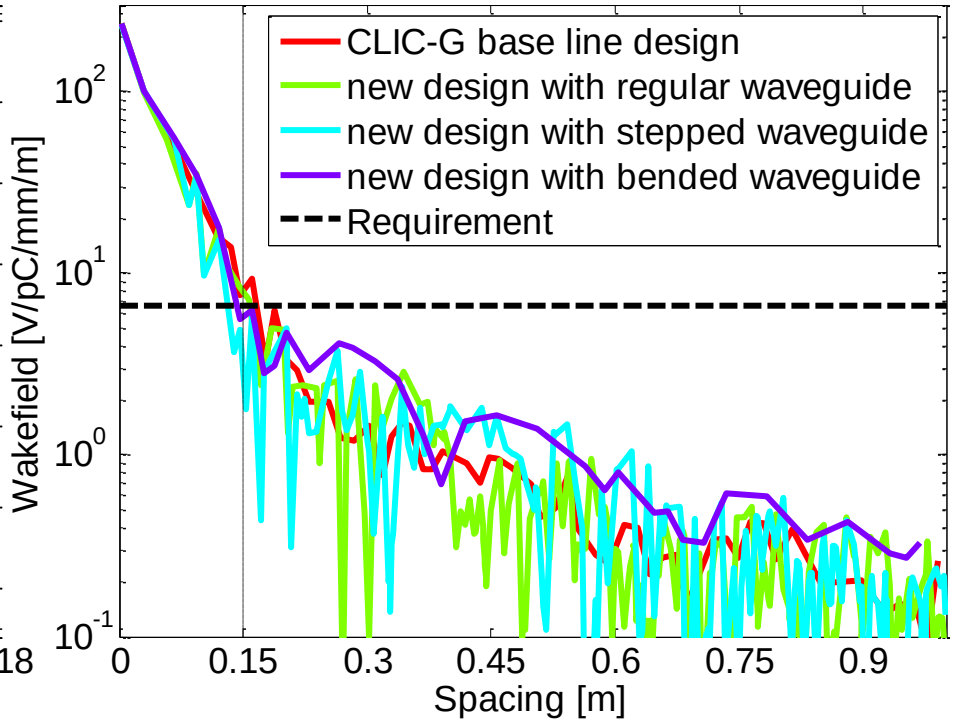
Manifolds are placed here

Wakefield of all designs

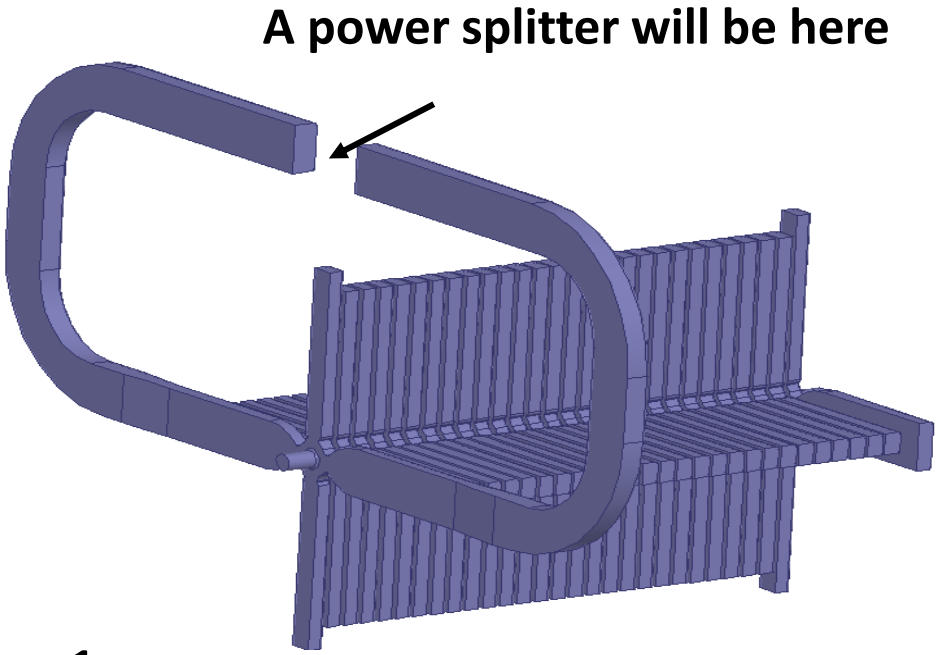
- Three factors are listed (Amplification of transverse jitter or structure misalignment):
- $\mathbf{F_c}$: coherence jitter.
- $\mathbf{F_{rms}}$: random jitter
- $\mathbf{F_{worst}}$: worst cases.

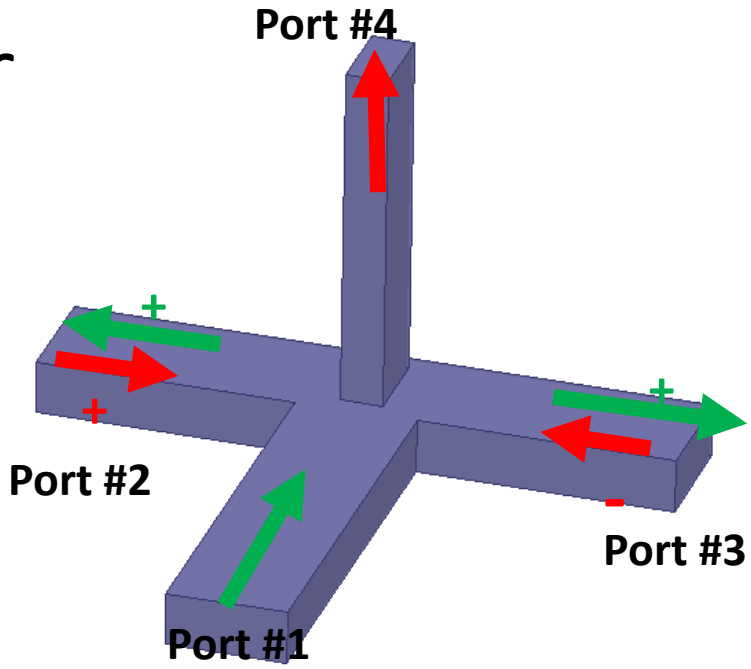
	CLIC-G base line	CLIC-G* regular waveguides	CLIC-G* stepped waveguides	CLIC-G* bend waveguides	require ment
$\mathbf{F_c}$	1.07	1.02	1.02	1.03	--
$\mathbf{F_{rms}}$	3.9	1.1	1.2	1.5	< 5
$\mathbf{F_{worst}}$	15.6	2.9	2.7	6.3	--





HOM-free power splitter





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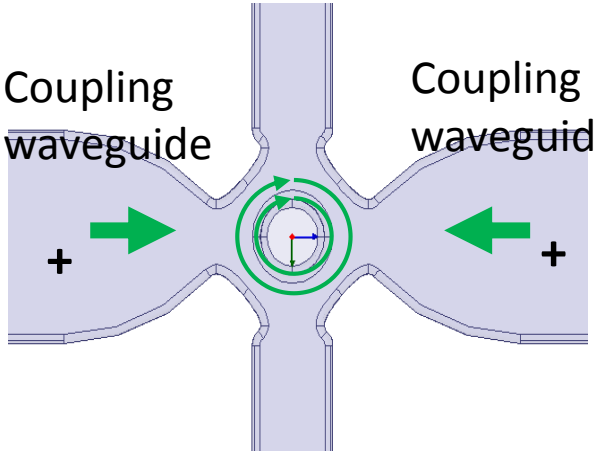
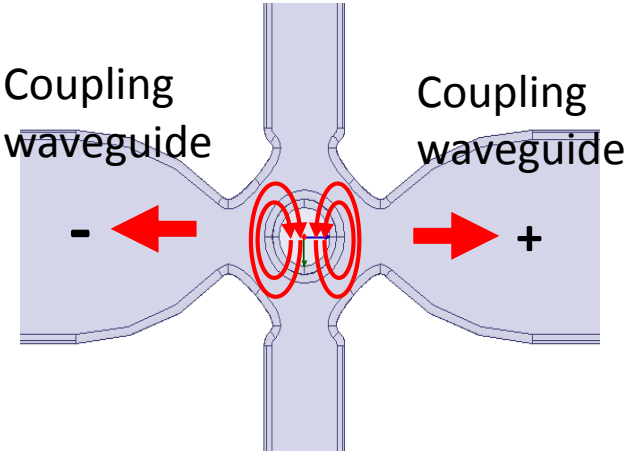
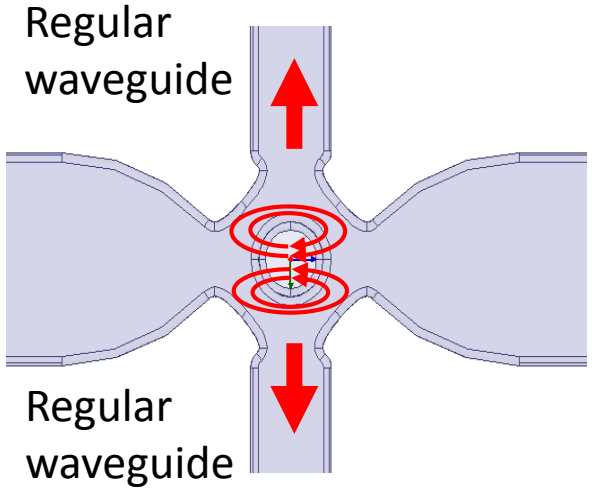
Working frequency

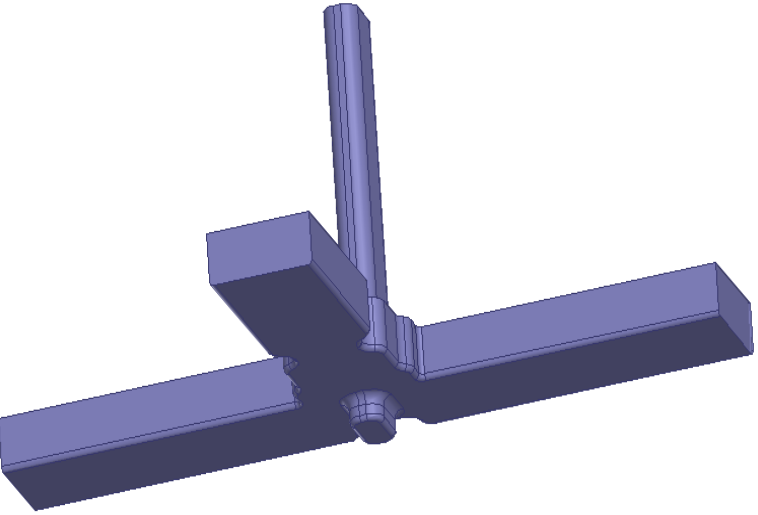
Dipole frequency



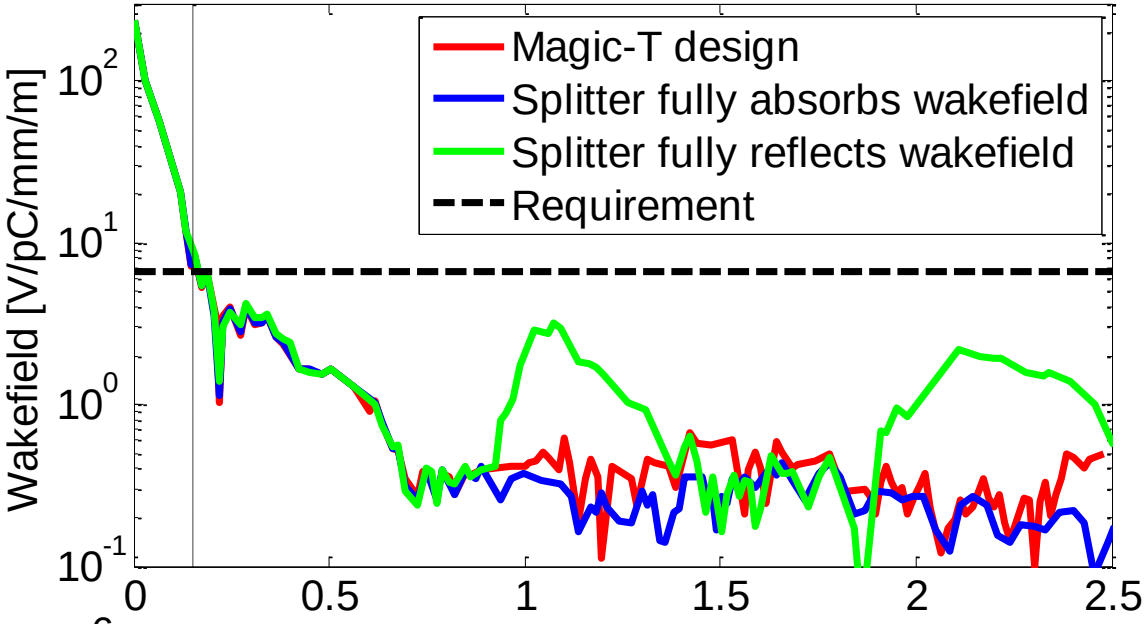


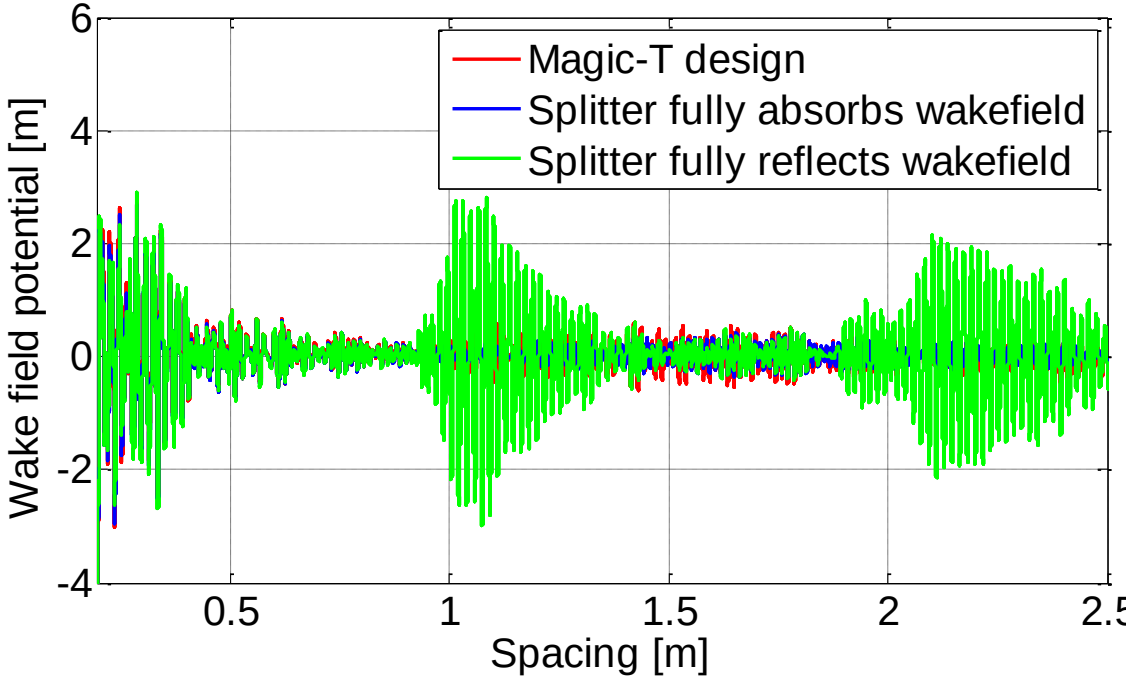


Wakefield of the HOM-free Magic-T



35 MV/m @ 62.5 MW input power
Bandwidth: 2 GHz





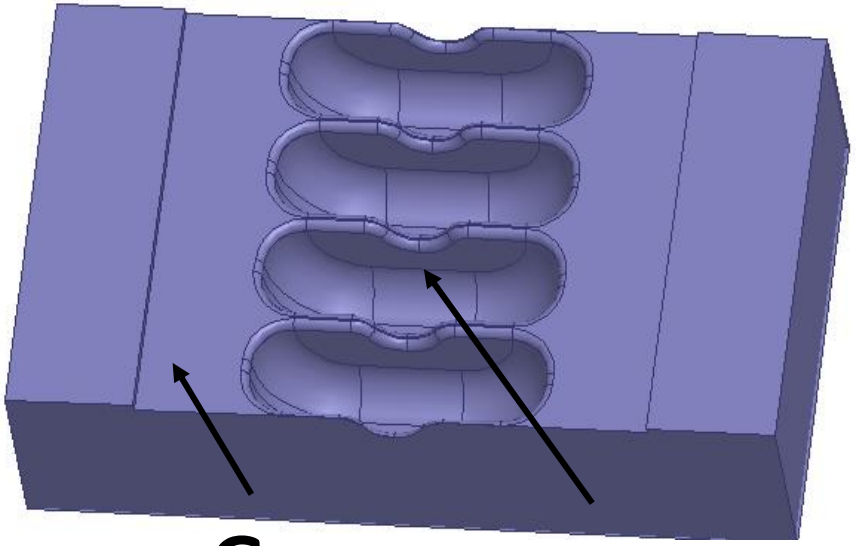
	fully reflect	fully absorb	Magic-T
F_c	1.05	1.01	1.02
F_{rms}	3.4	1.1	1.12
F_{worst}	>100	3.1	2.8

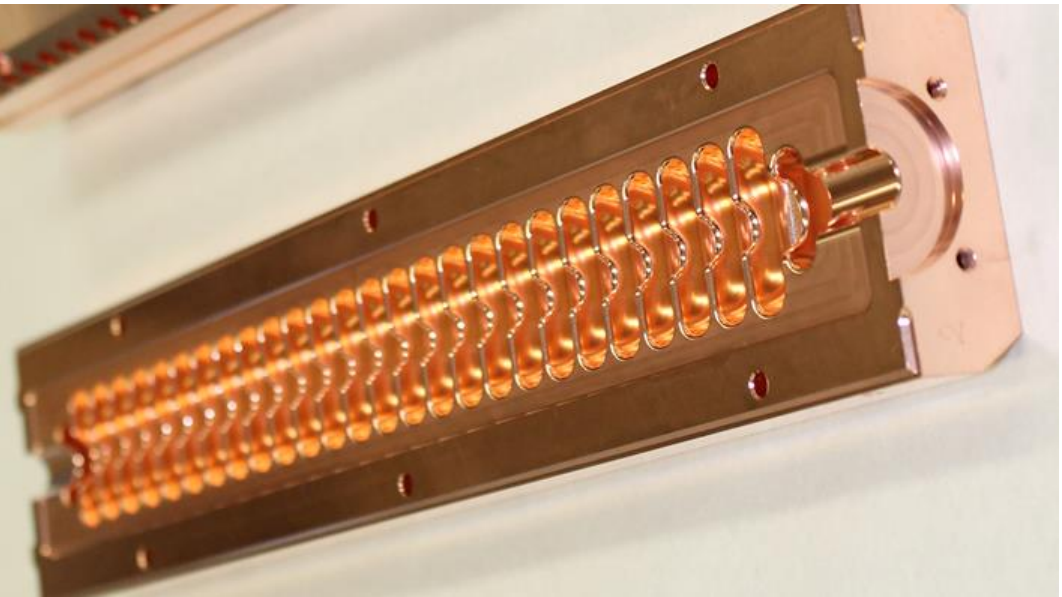
Outline

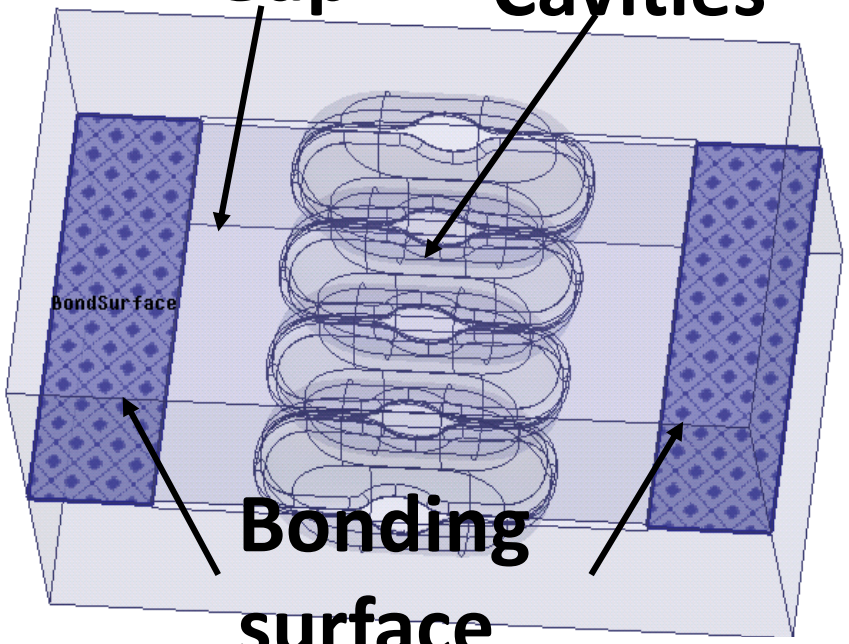
- New CLIC-G* geometry
- New CLIC-G* HOM damping design
- **Alternative structure design: Hybrid damped structure.**

Structure made from halves

- CLIC-Open with 1 mm gap.
- Easy manufacturing, aligning and bonding.
- Manufactured in SLAC, high power test in Xbox2.





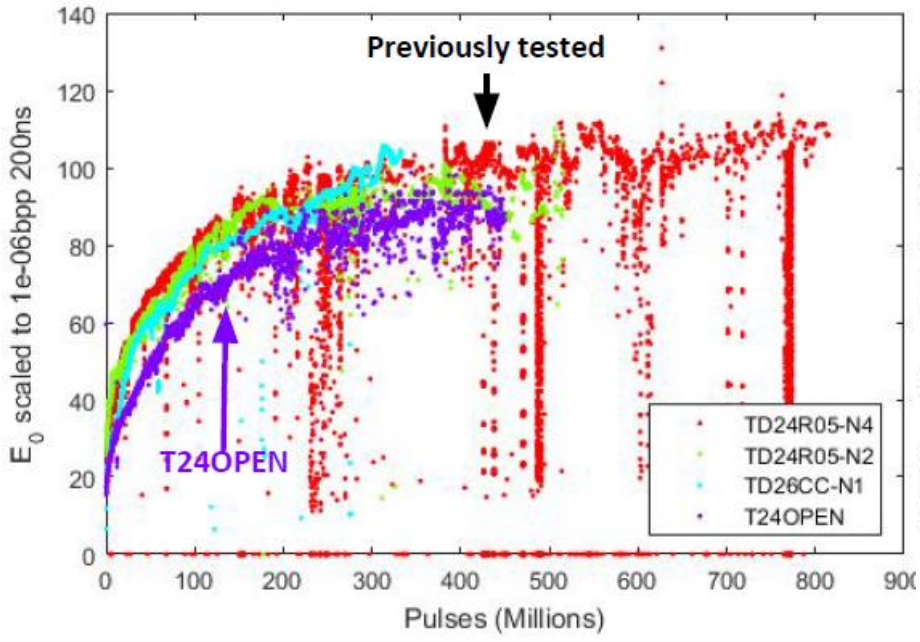


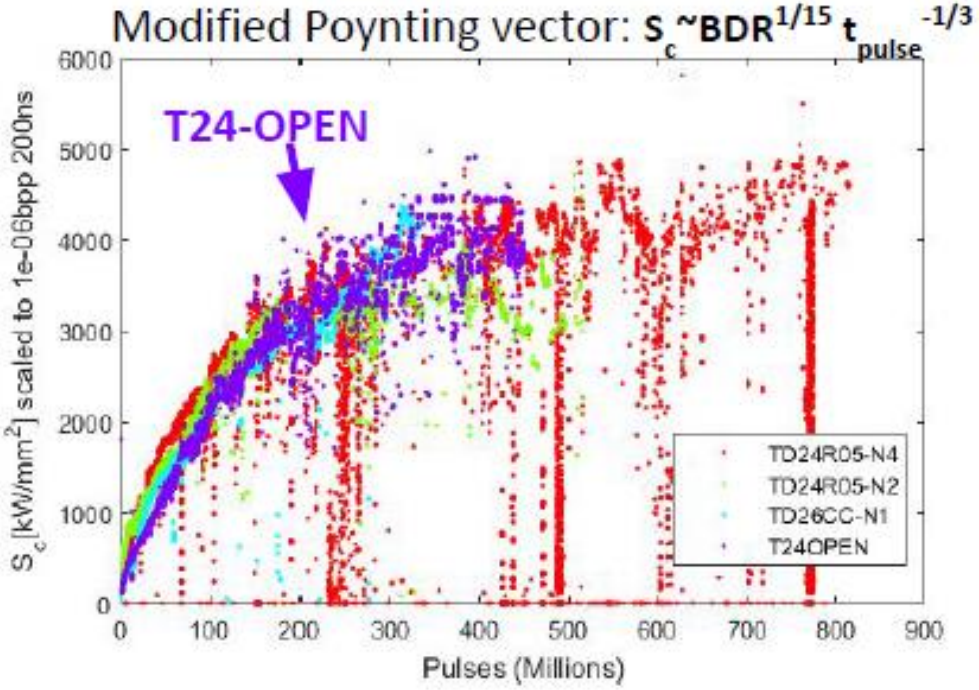
High power test

- Reached 90 MV/m in the high power test (Still growing).
- Same Sc Level.

Unload 100 MV/m parameters	Open structure	CLIC T24
Group velocity [%c]	1.99/1.06	1.79/0.91
Shunt impendence [MΩ/m]	107/137	116/150
Input power [MW]	45.3	37
Filling time [ns]	53	61
Max E-field [MV/m]	264	207
Max Sc [MW/mm^2]	5.1	3.5
Temperature rise [K]	23	13

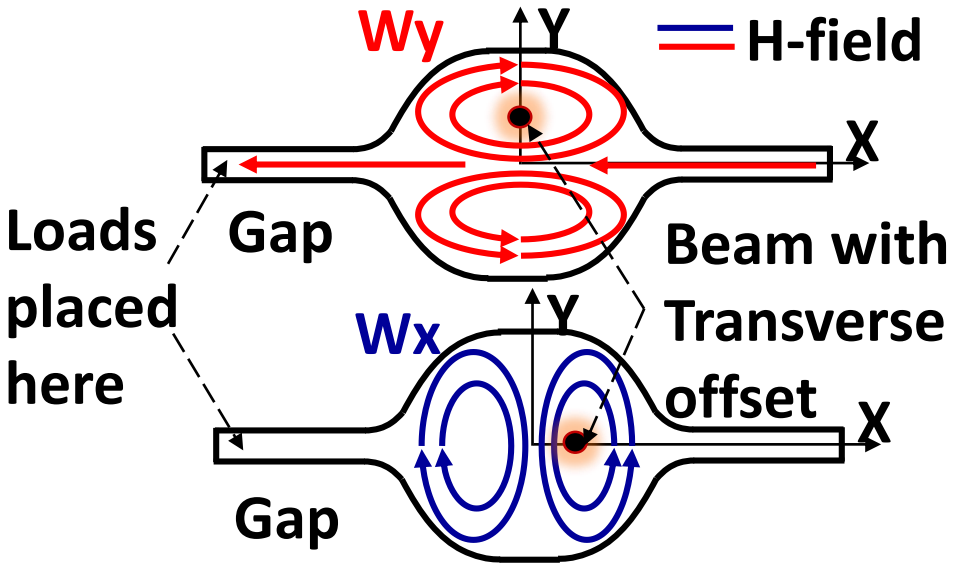
Courtesy T. Argyropoulos, HG2016



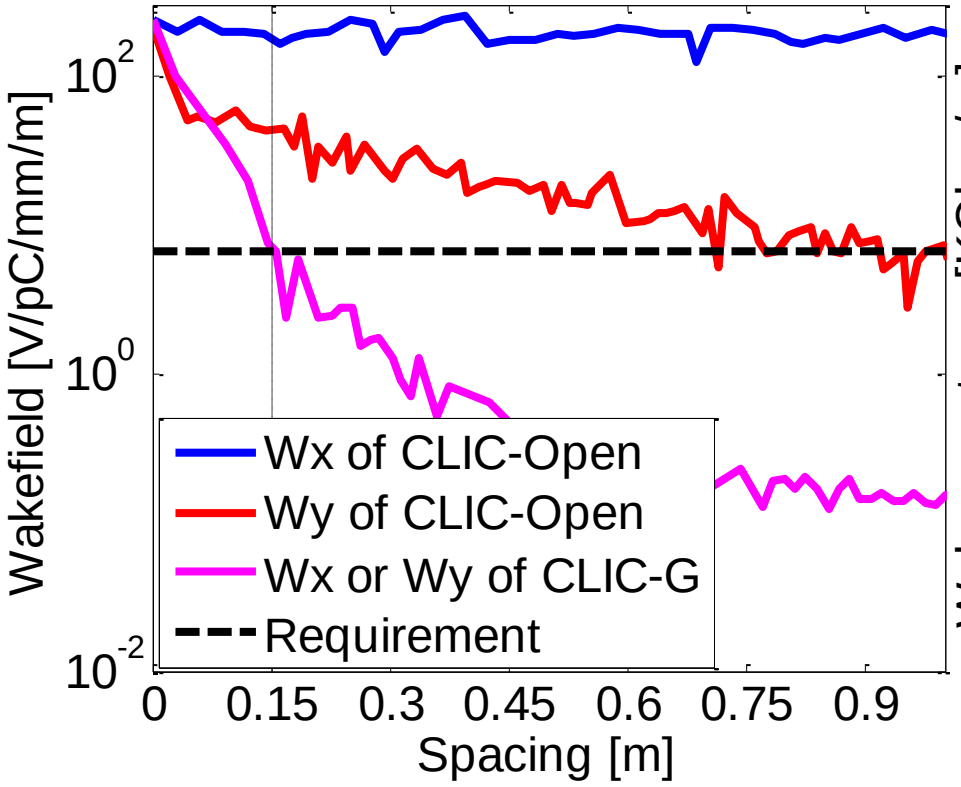


Wakefield suppression

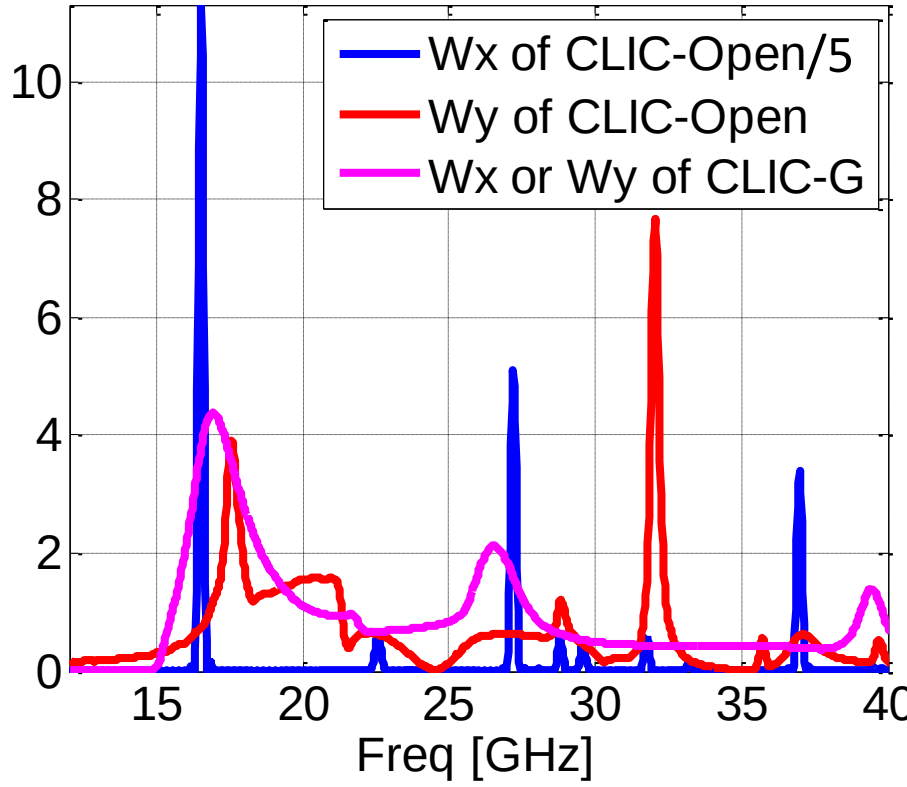
- Dipolar HOMs are excited in two polarizations:
- **Blue: No damp at all;**
- **Red: Weak damp**.



Enveloped transverse wakefield

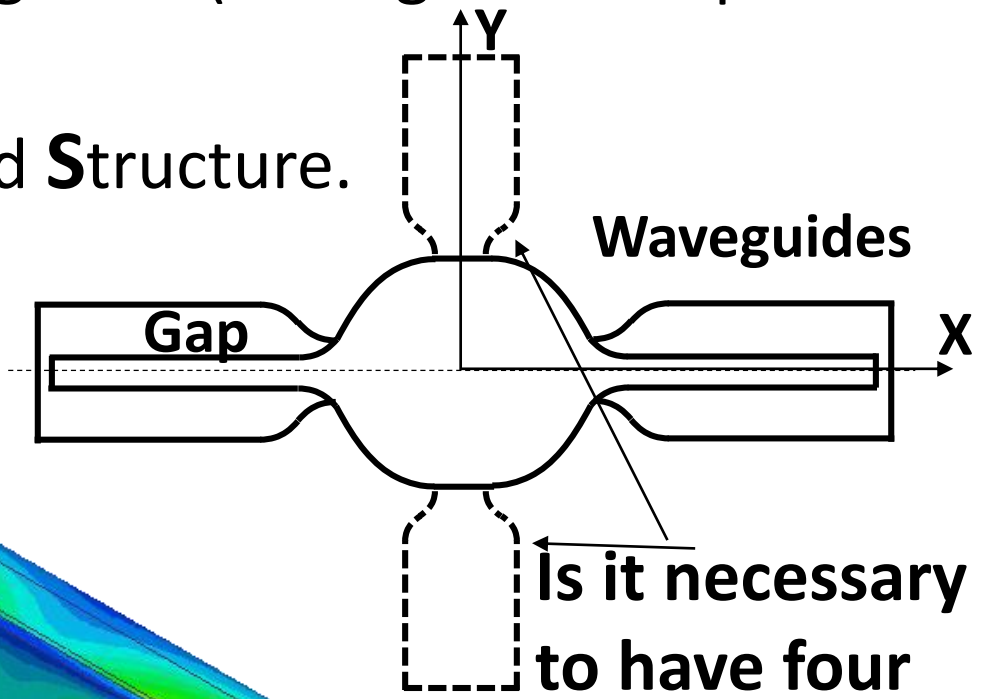


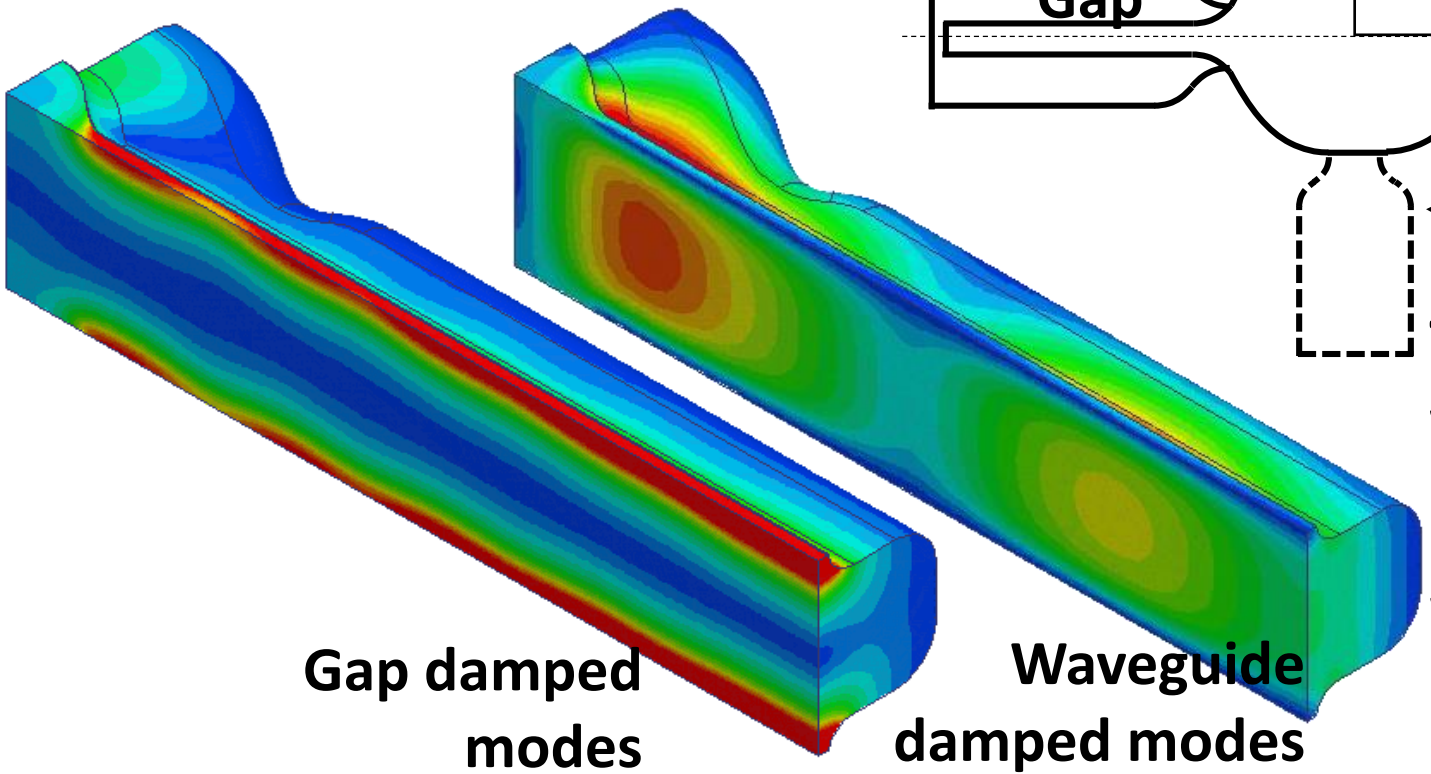
Wakefield impedance



Develop a made from **H**alves **D**amped **S**tructure

- Wy is damped by the gap (Gap damped modes);
- Wx is damped by two waveguides (Waveguide damped modes);
- Also named **H**ybrid **D**amped **S**tructure.





Gap damped modes

Waveguide damped modes

Is it necessary to have four waveguides to better damp Wy? No!

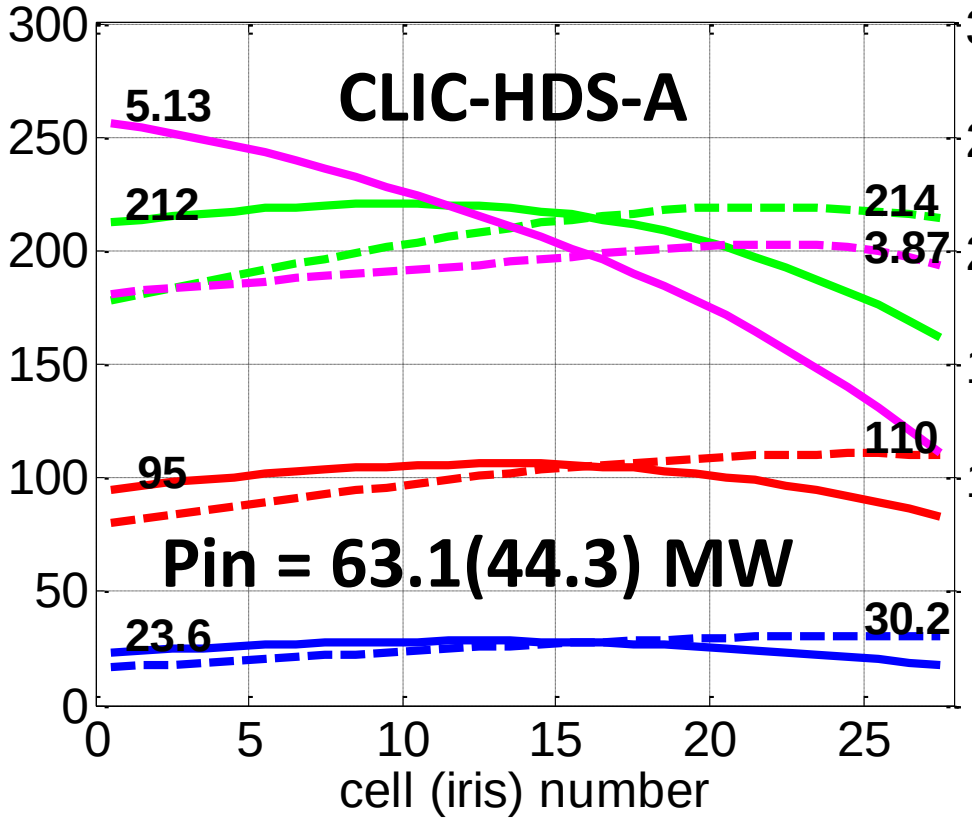
RF parameters

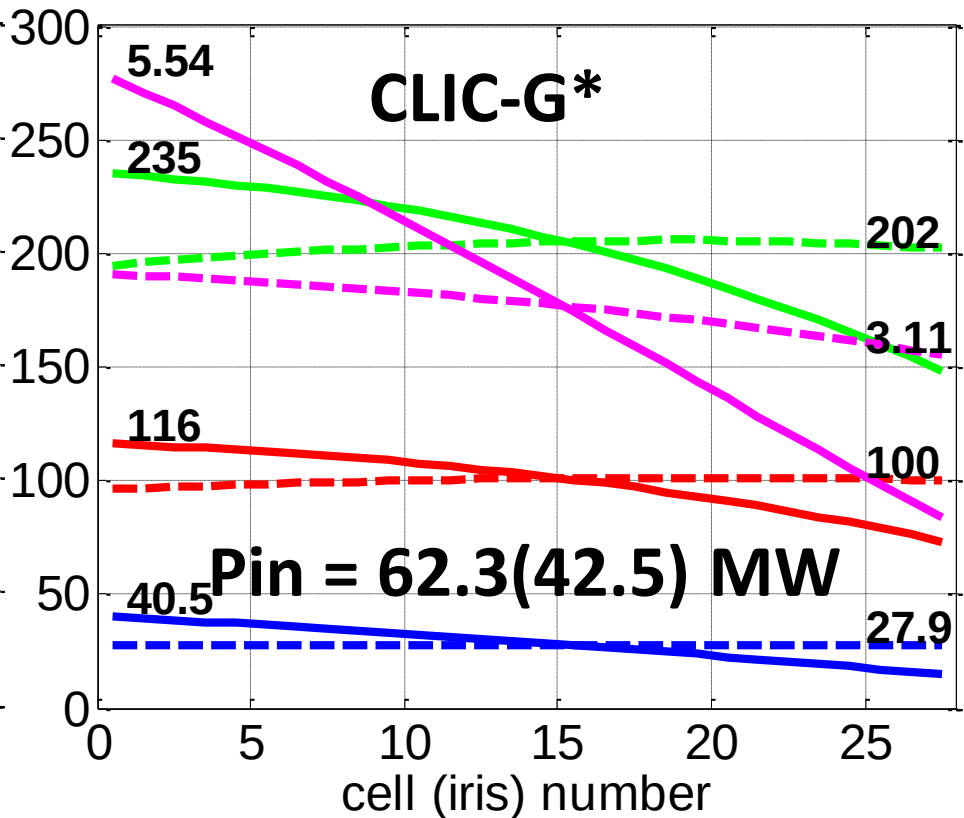
Unloaded/Loaded

- **/ : Accelerating Gradient [MV/m]**
- **/ : Maximum E-field [MV/m]**
- **/ : Maximum Sc*50 [MW/mm2]**
- **/ : Temperature rise [K]**

Loaded 100 MV/m parameters	Structure by milling	CLIC-G*
Group velocity [%c]	2.39/0.65	1.71/0.84
Shunt impendence [MΩ/m]	91/97	86/105
Input power [MW] *	63.1(44.3)	62.3(42.5)
Filling time [ns]	69	66
Max E-field [MV/m]	220	235
Max Sc [MW/mm^2]	5.13	5.54
Temperature rise [K]	30	40

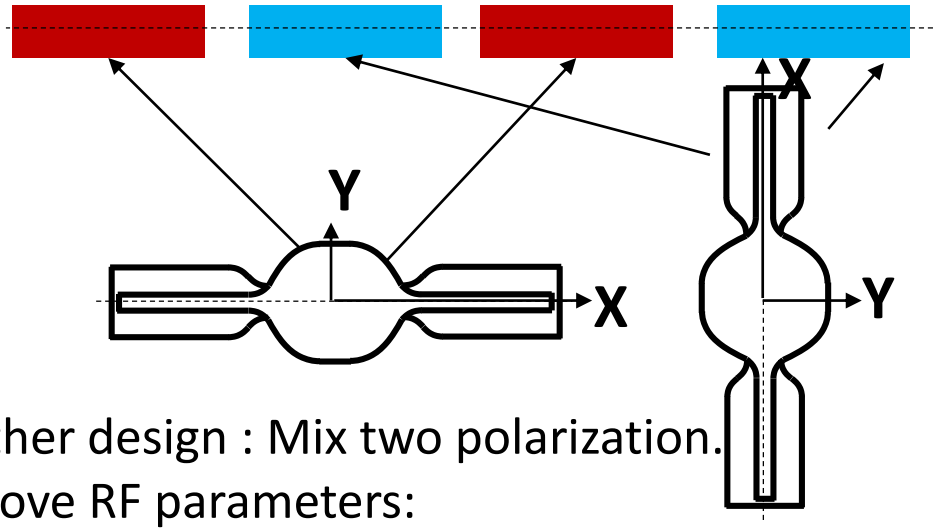
*** Input power in the bracket for unloaded 100 MV/m**



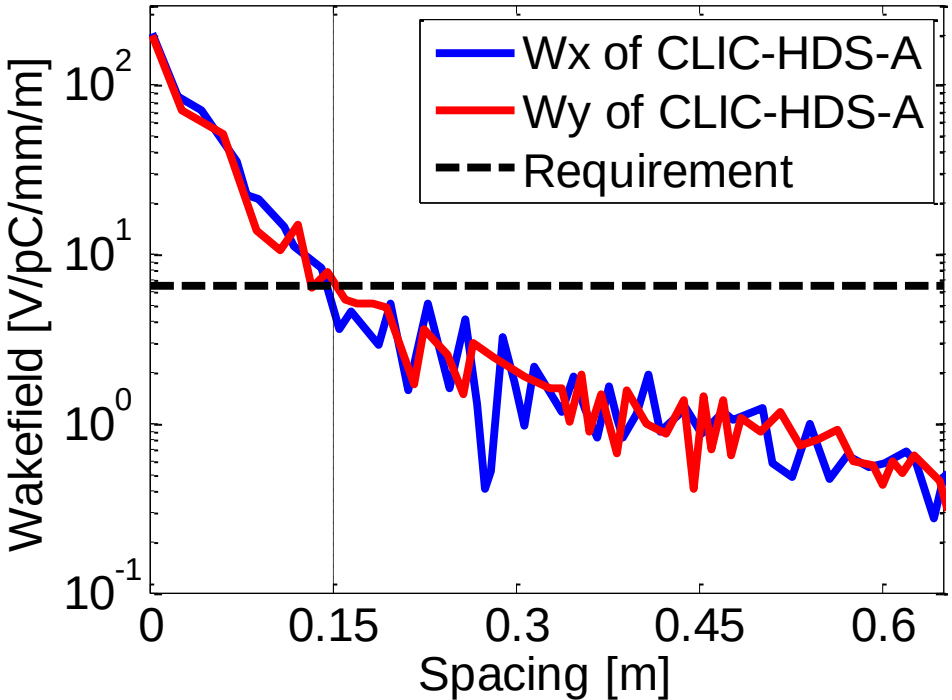


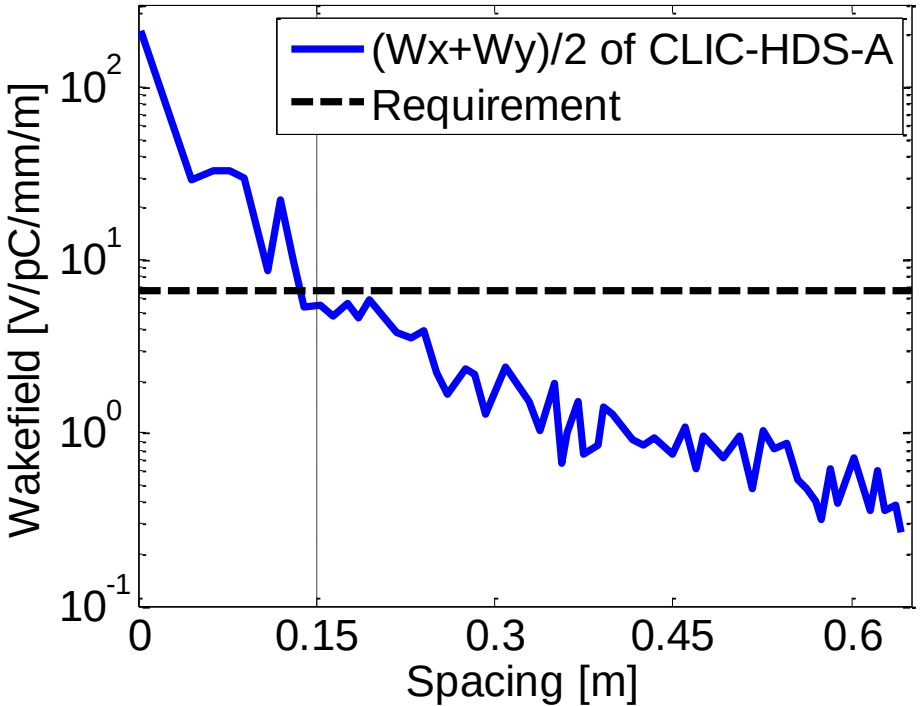
Wakefield suppression

	Wx	Wy	(Wx+Wy)/2
Fc	1.2	1.06	1.2
Frms	1.3	2	2.6
Fworst	6.2	5.3	9.1



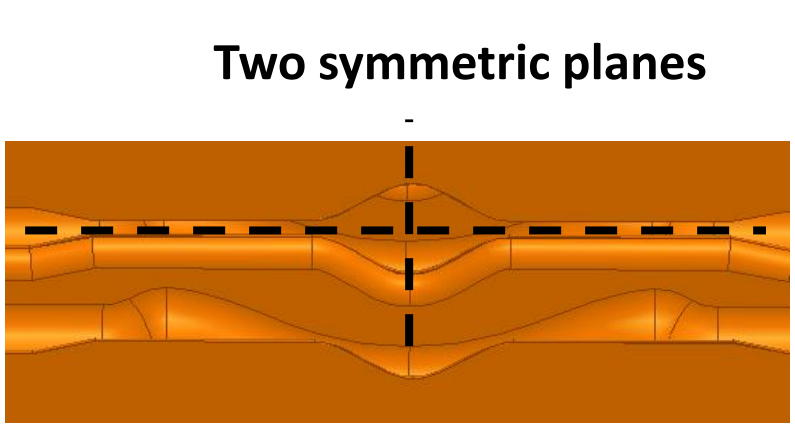
Another design : Mix two polarization.
Improve RF parameters:
Power 1.2 MW ↓

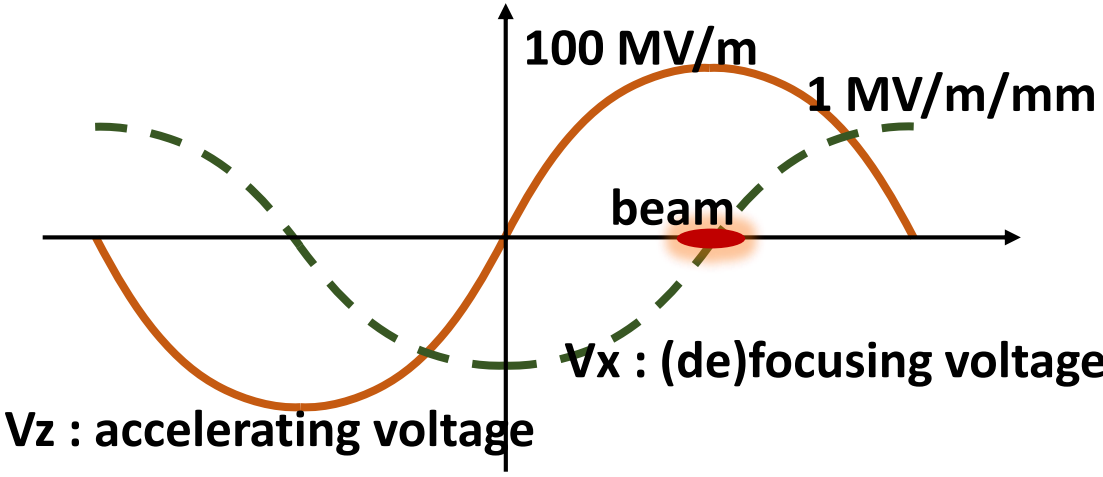




Quadruple components in the working mode

- Structure only has two symmetric plans -> quadruple components: Amplitude 1 MV/m/mm (3.3 T/m per 1 m structure).
- Beams see zero phase for quadruple field.
- But the slope make (focusing strength of) head and tail different.
- Head/tail has 11 kV/m/mm focusing /defocusing strength -> ±37 mT/m -> 0.18 % spread in beta function (BNS damping).





Summary

- We've designed the new CLIC-G* accelerating structure. Compared to old one, several improvements are achieved:
- Lower pulse temperature rise (51K -> 42K).
- Lower input power (63.5 MW -> 62.5 MW).
- Lower milling cost (30 a.u. -> 7% a.u.).
- Smaller transverse disk dimensions (20 cm -> 17 cm or 15 cm or 16*7 cm).
- Lower transverse wakefield kick (Frms: 4 -> 1.2).
- HOM free power splitter (HOMagic-T)
- We've designed the geometry of a hybrid damped structure made from halves, the RF parameters are comparable to CLIC-G*.

Material property sensitivity of HOM damper

- When material properties (ε': real part of permittivity, ε'': imaginary part of permittivity) change by +/- 10%, the change quality factors are nearly 10% (Very stable).