X-band design activities

Ping Wang, Alexej Grudiev

CERN, European Organization for Nuclear Research

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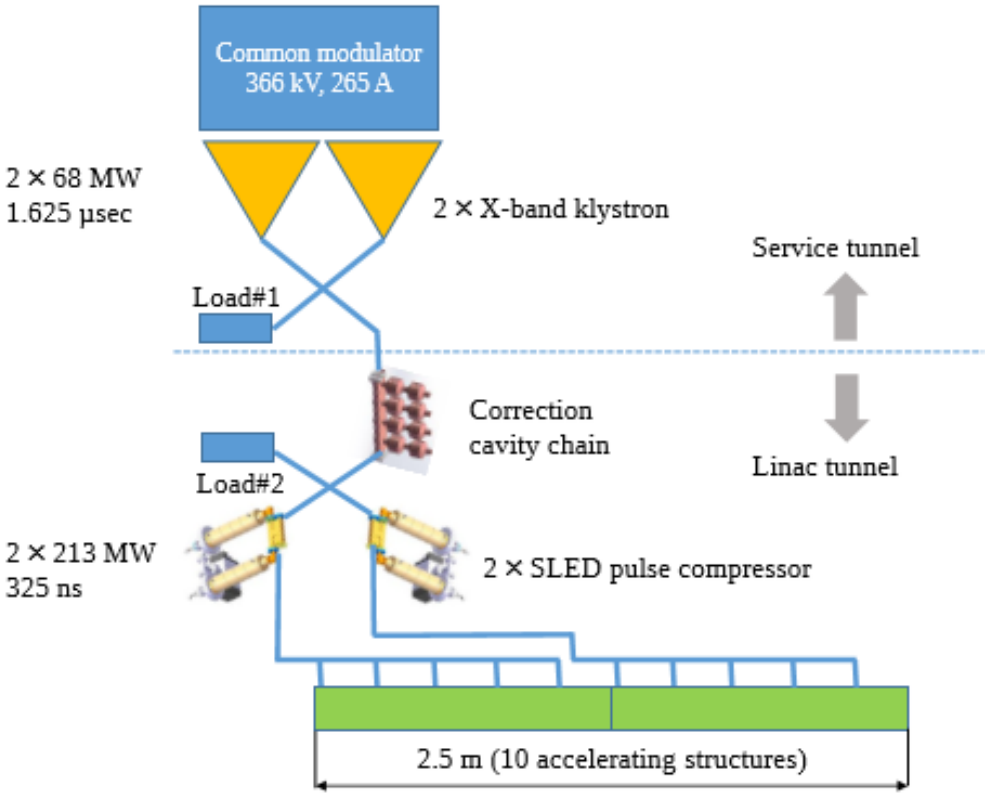
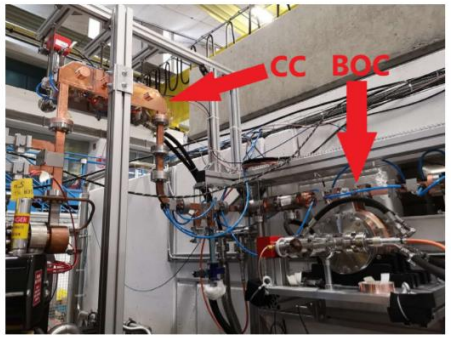
Outline

- ❑ Introduction
- ❑ CLIC-K with bended damping waveguides
- ❑ X-band BOC pulse compressor for klystron-based CLIC
- ❑ Summary

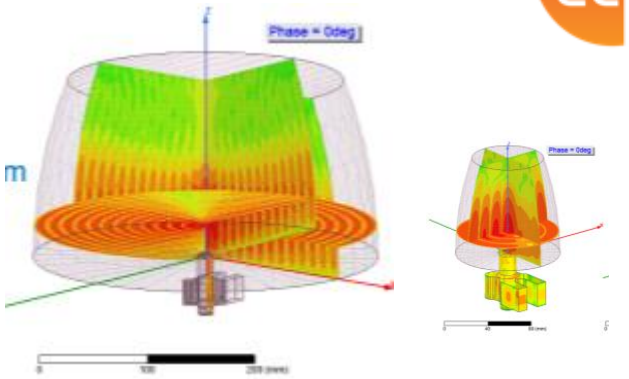
Introduction



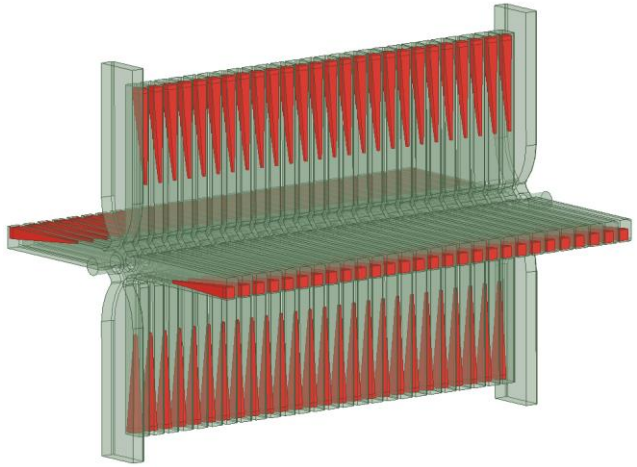
[1] Updated baseline for a staged Compact Linear Collider, edited by P.N. Burrows, P. Lebrun, L. Linssen, D. Schulte, E. Sicking, S. Stapnes, M.A. Thomson, CERN–2016–004 (CERN, Geneva, 2016),



[2] Yuliang Jiang et al., Demonstration of a cavity-based pulse compression system for pulse shape correction, Phys. Rev. Accel. Beams 22, 082001



[3] Xiaowei Wu and Alexej Grudiev, Novel open cavity design for rotating mode rf pulse compressors, Phys. Rev. Accel. Beams 24, 112001



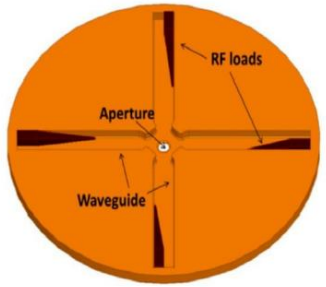
CLIC-K

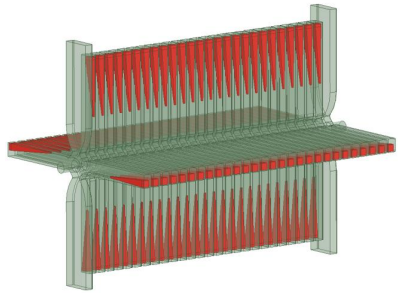
[4] Jiayang Liu, Alexej Grudiev, CERN-ACC-2018-0034

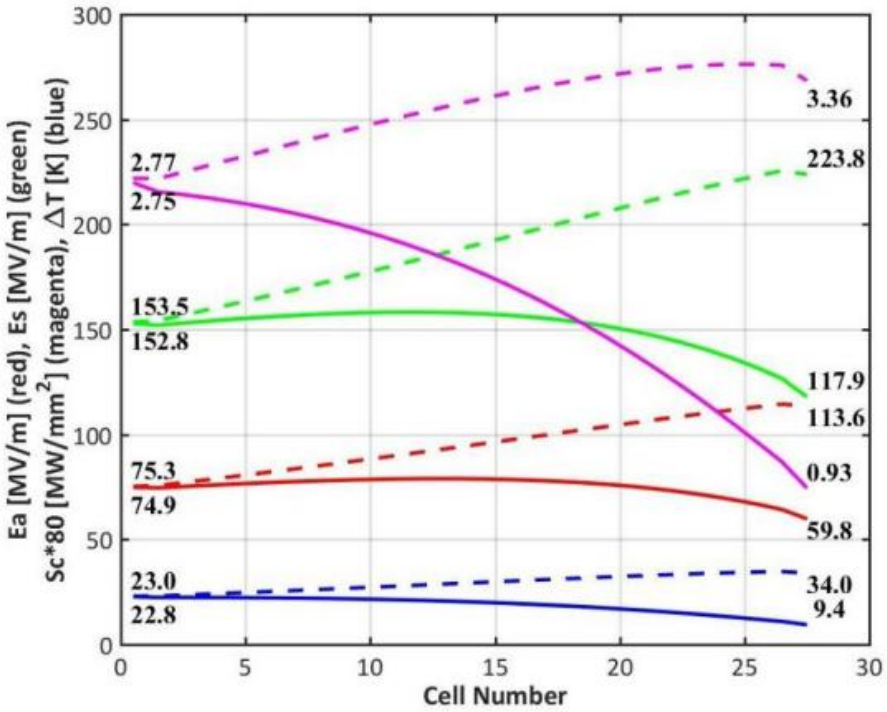
CLIC-K with straight damping waveguides

Table 1. Comparison between CLIC-G and CLIC-K

Parameters	CLIC-G	CLIC-K
Frequency	11.994 GHz	11.994 GHz
Accelerating gradient	100 MV/m	75 MV/m
Active length	0.23 m	0.23 m
RF phase advance per cell	120 °	120 °
Number of cells	28	28
Average iris radius / RF wavelength	0.11	0.1175
First iris radius / RF wavelength	0.126	0.145
Last iris radius / RF wavelength	0.094	0.09
First iris thickness / cell length	0.2	0.25
Last iris thickness / cell length	0.12	0.134
Bunch spacing	0.15 m	0.15 m
Number of particles per bunch	3.72×10^9	3.87×10^9
Number of bunches per train	312	485



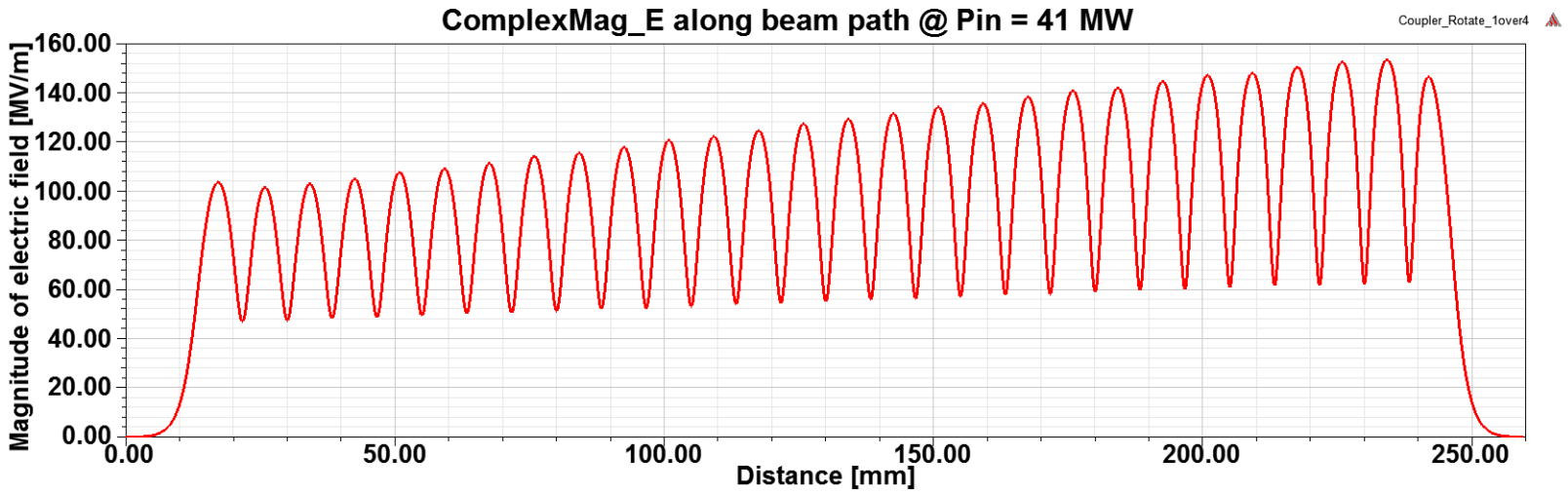


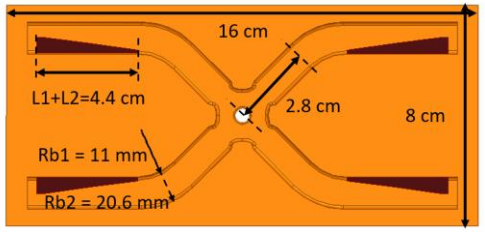


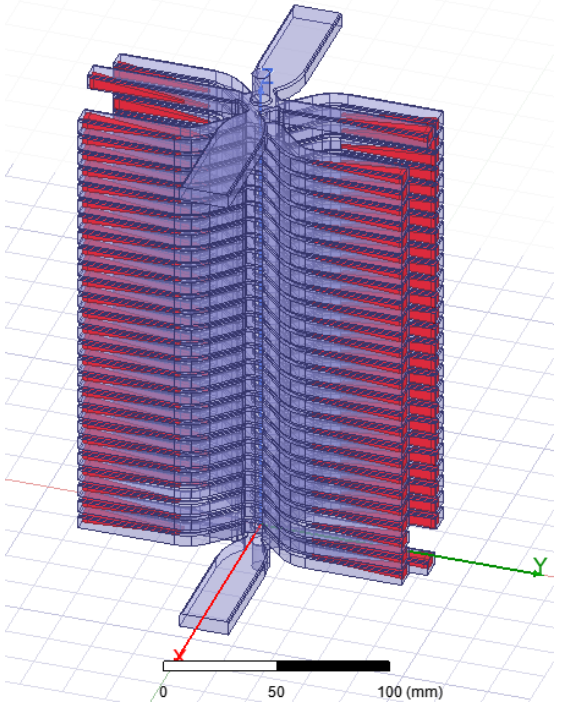
Jiayang Liu, Alexej Grudiev, CERN-ACC-2018-0034

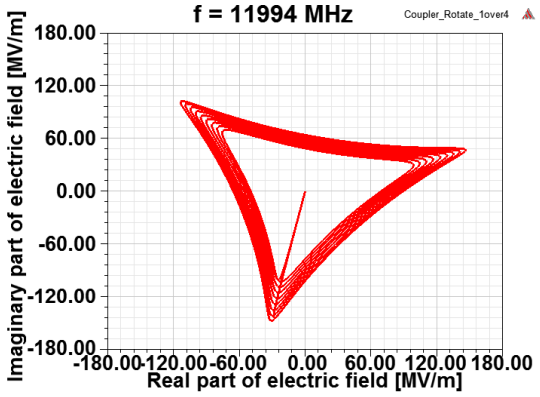
RF design of CLIC-K with bended damping waveguides

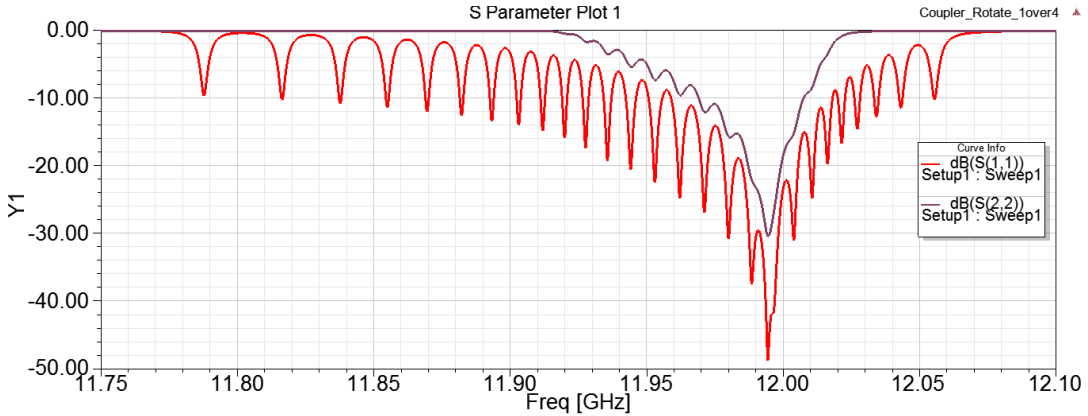
- CLIC-K with bended damping waveguides is more compact.





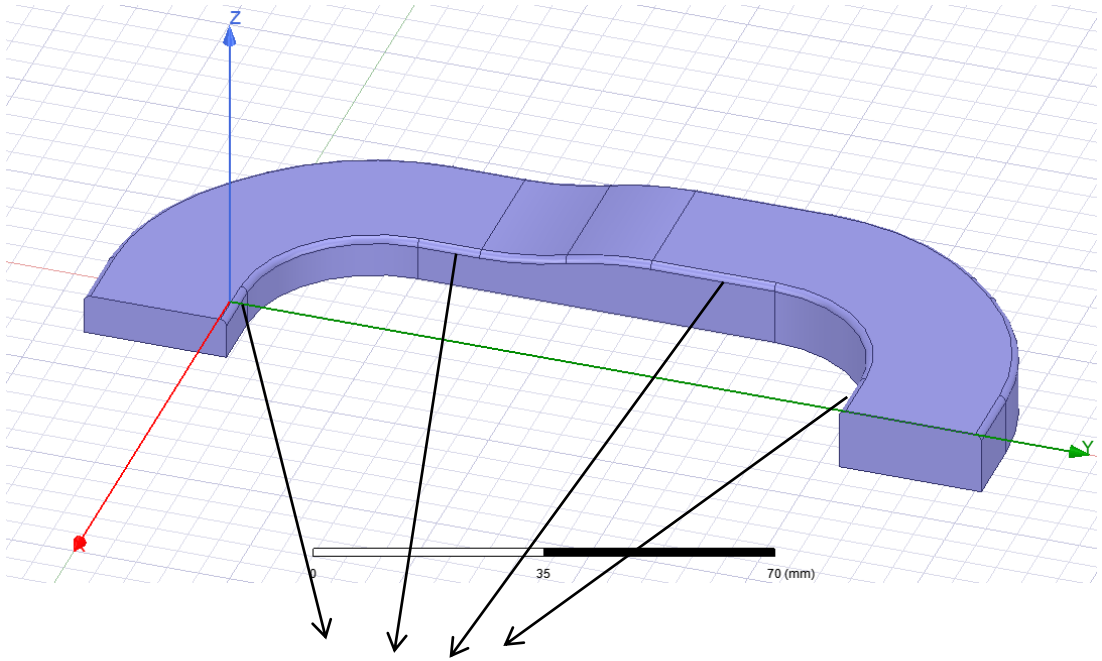




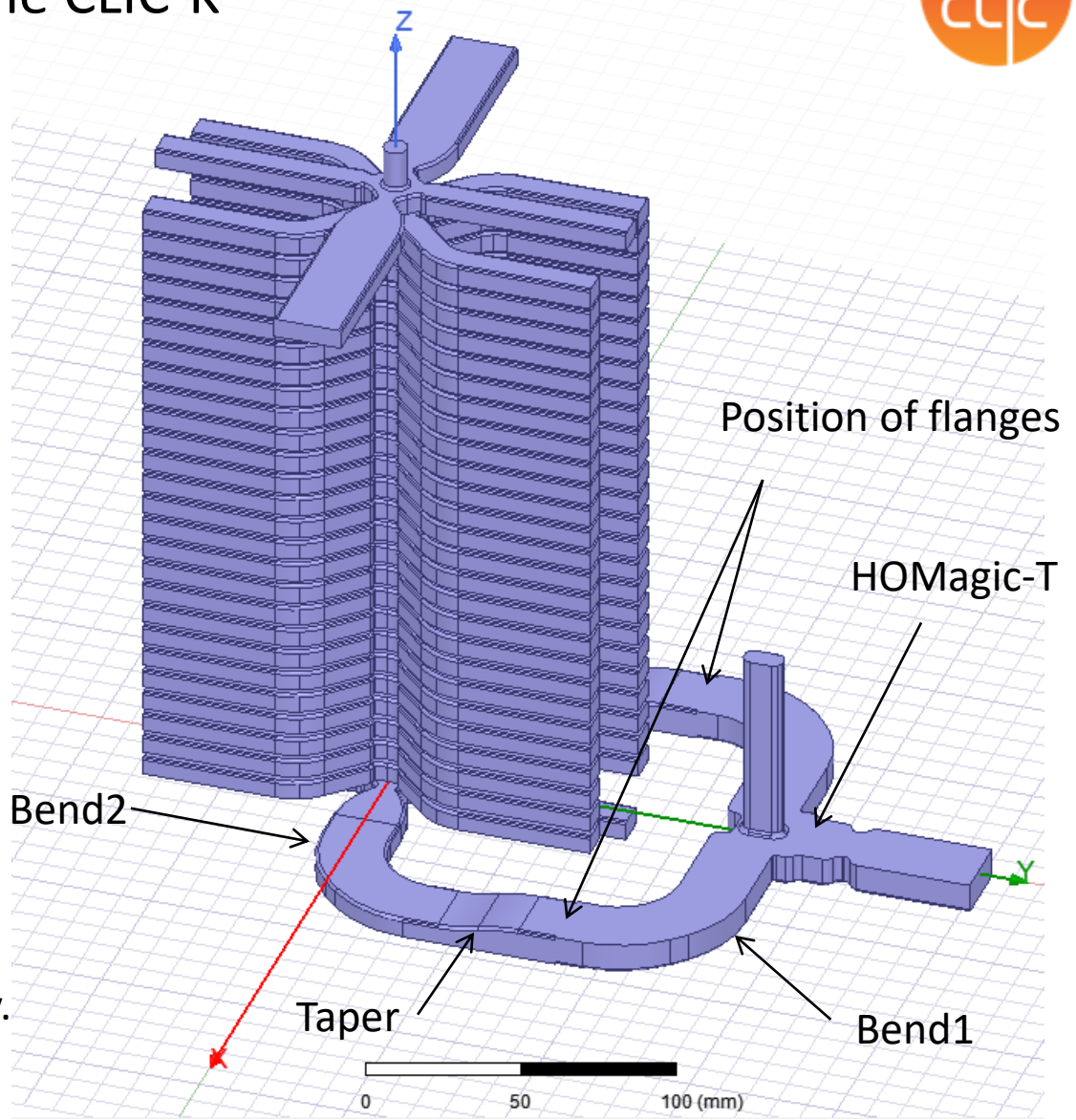


RF design of the distribution network around the CLIC-K

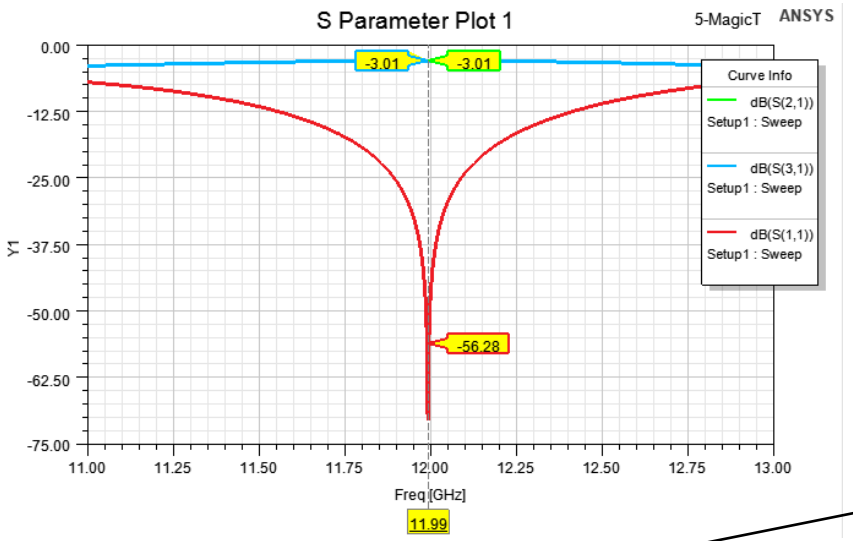
- HOM Magic-T
- Novel bending waveguides
- Compact taper

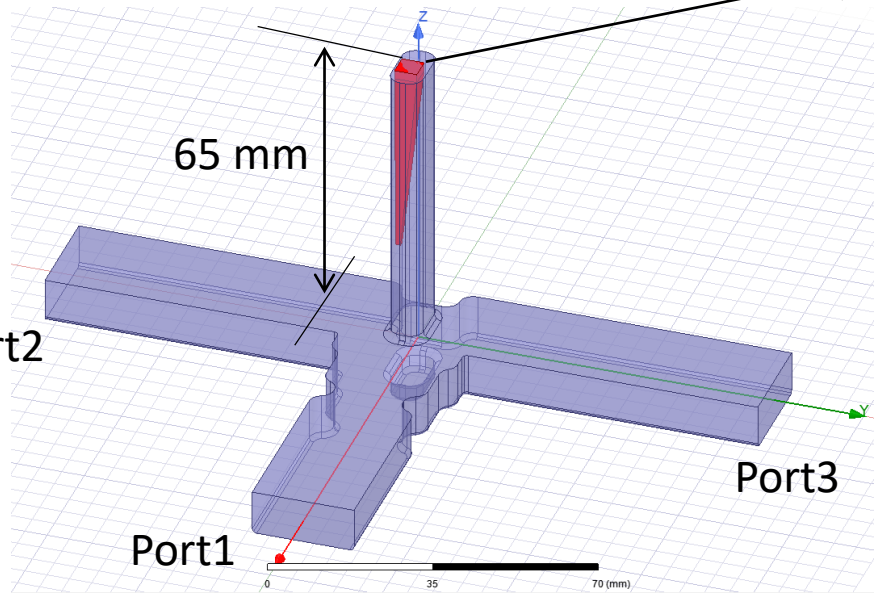


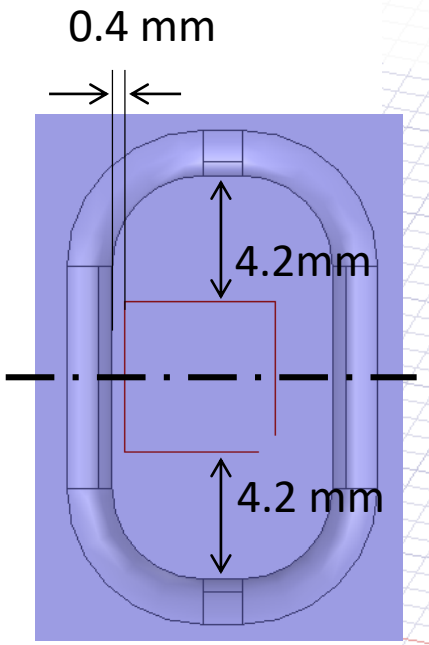
The length of the straight parts can be changed if necessary.



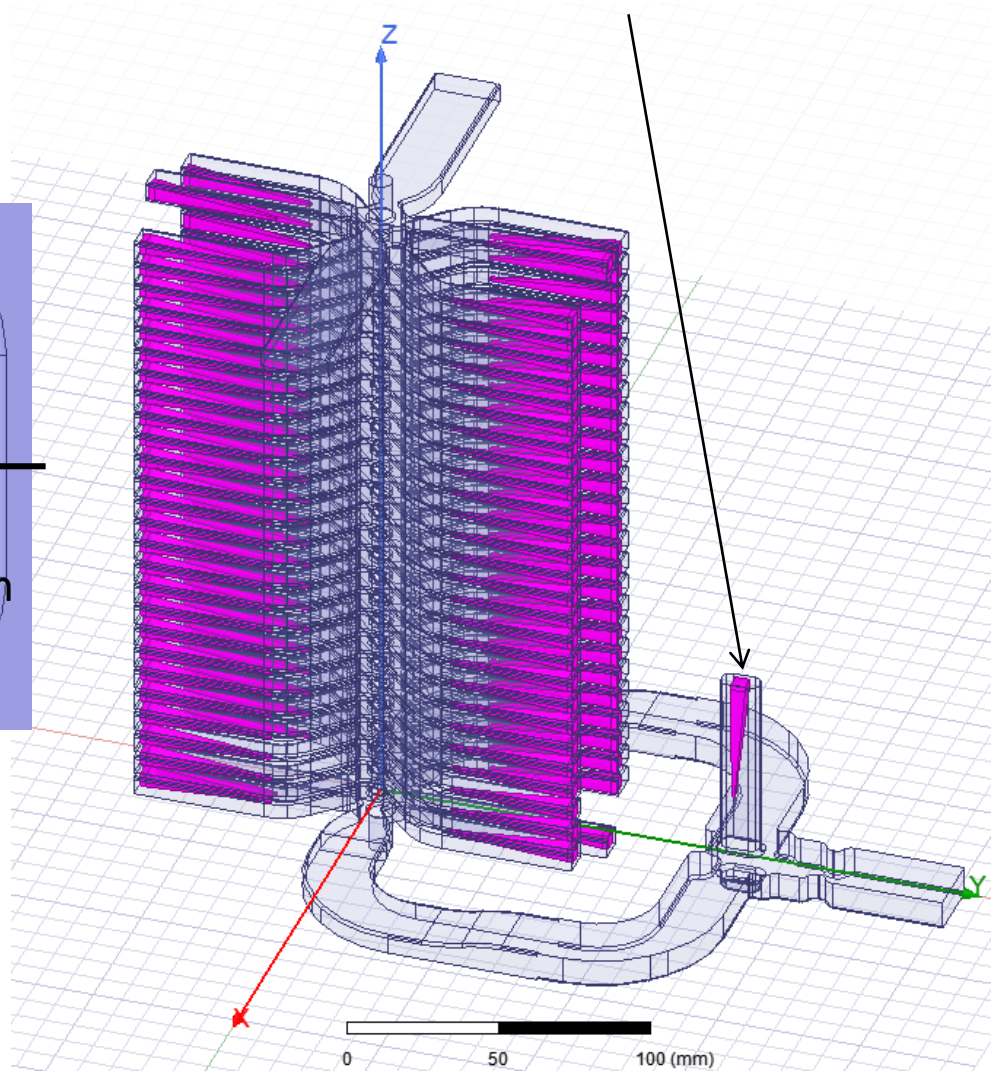
Application of the HOM Magic-T







The load of HOMagic-T is the same as that of a damping waveguide

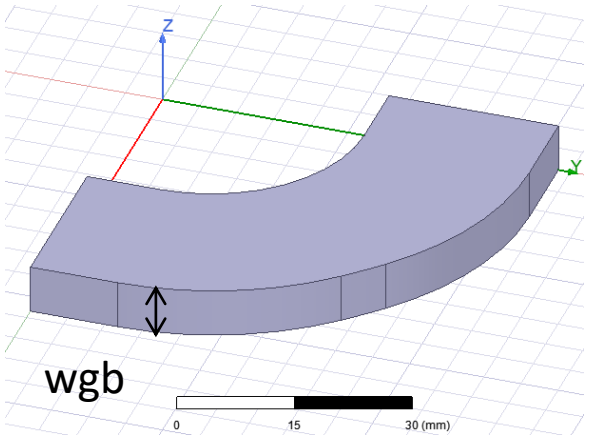


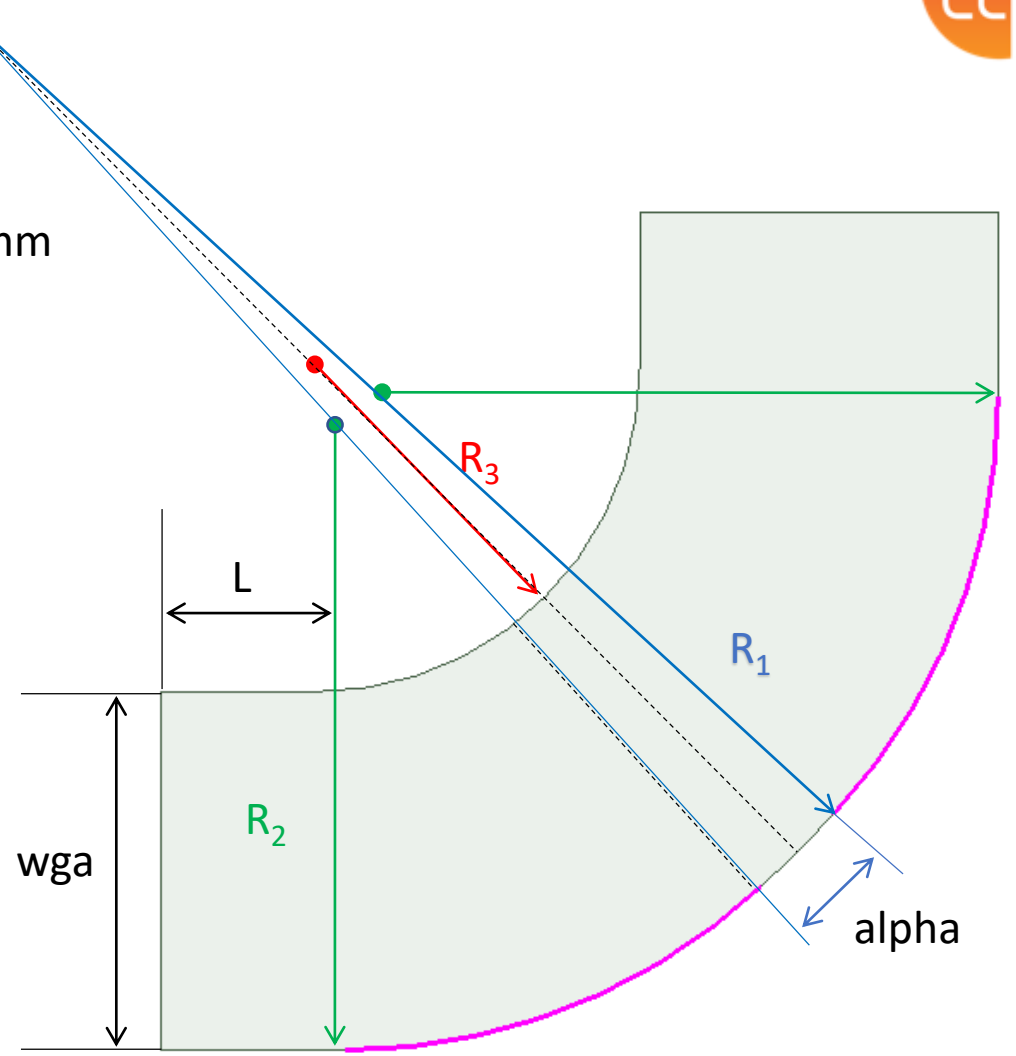
Geometry of the bending waveguides

- Bend 1 and bend 2

Two bends have different height (wgb) of 10.16 mm and 6.66 mm

wga	**22.86 mm**
wgb	10.16/6.66 mm
R1	92.875 mm
R2	39.000 mm
R3	20.600 mm
alpha	4 deg
L	>= 10.0 mm



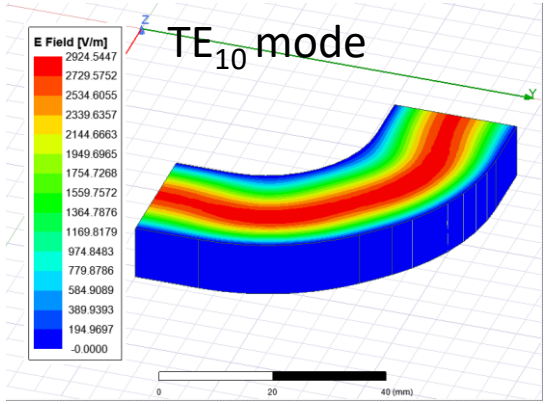


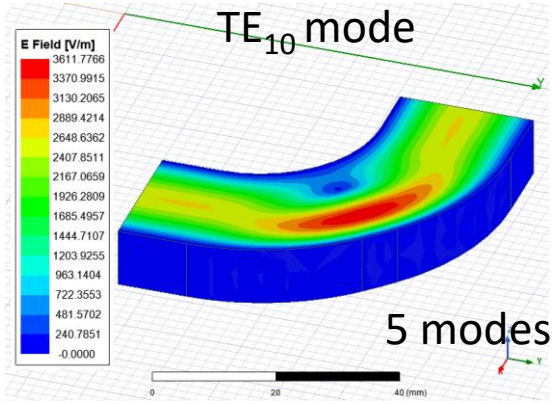
R_1 = (wga-R_3*cos(45deg)-wga*cos(45deg) +R_3-R_2+R_2*cos((90deg-alpha)/2))/(cos((90deg-alpha)/2)-cos(45deg))

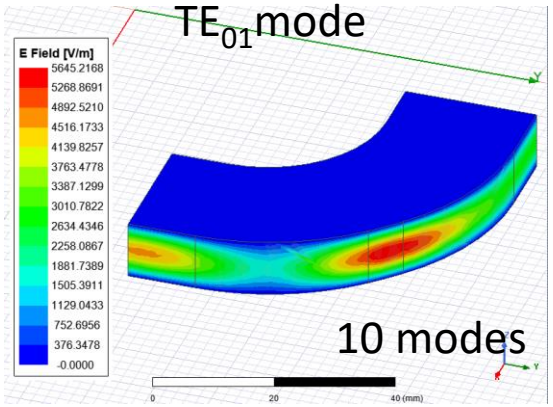
RF simulation of the bending waveguides

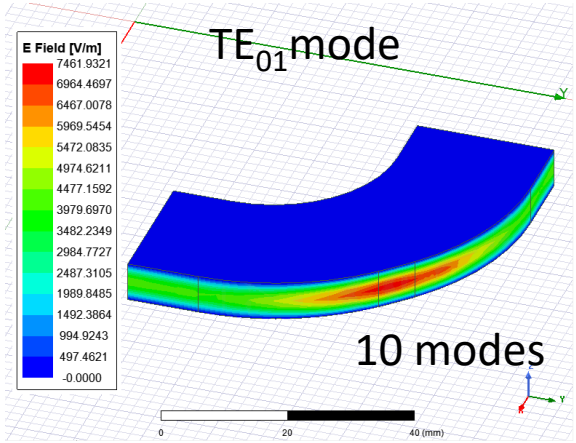
- The RF performance of the two bending waveguides are very similar in the first two pass bands with center frequency of 12 GHz and 17 GHz.

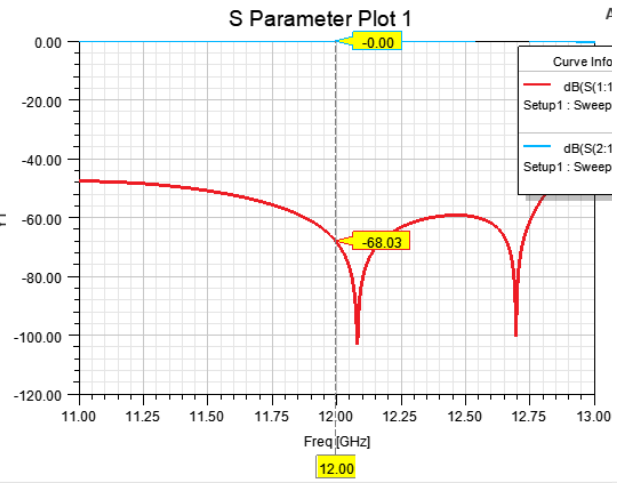
- Bend2: wgb = 6.66 mm

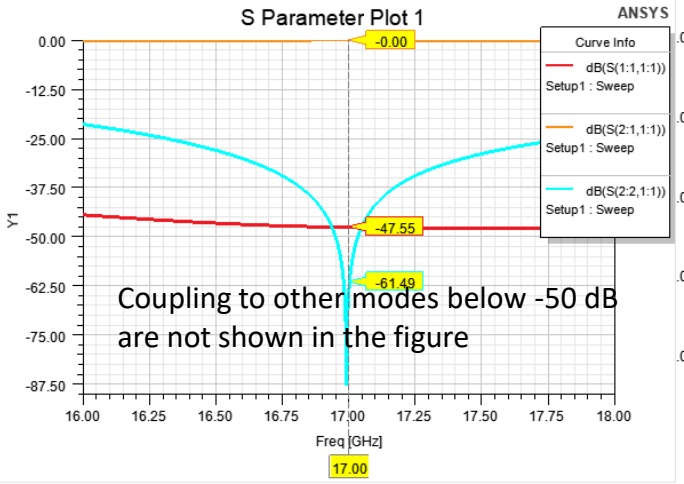


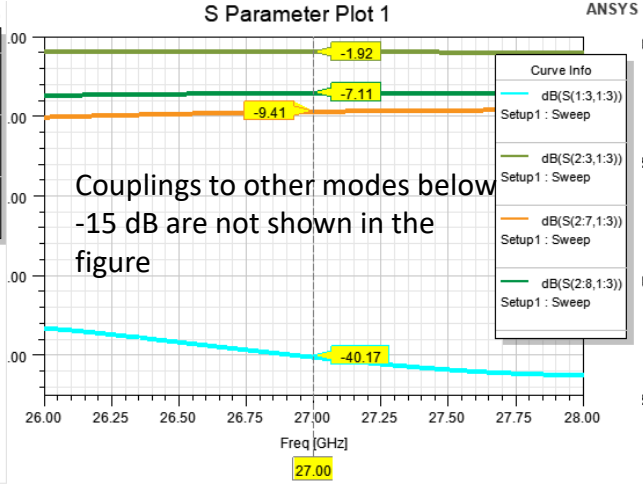


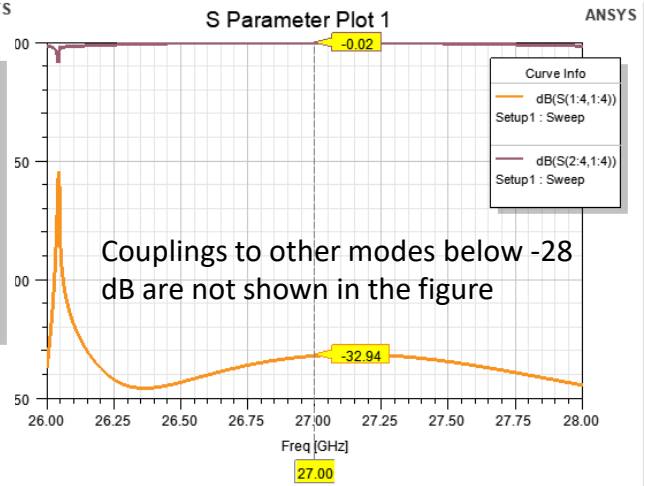




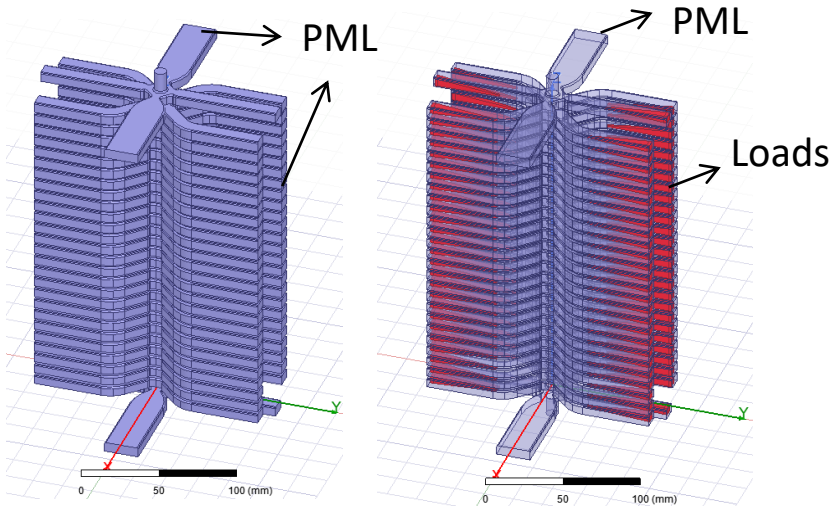








Wakefield calculation of the CLIC-K

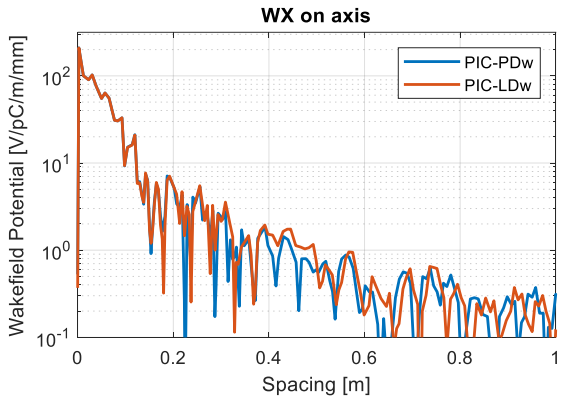


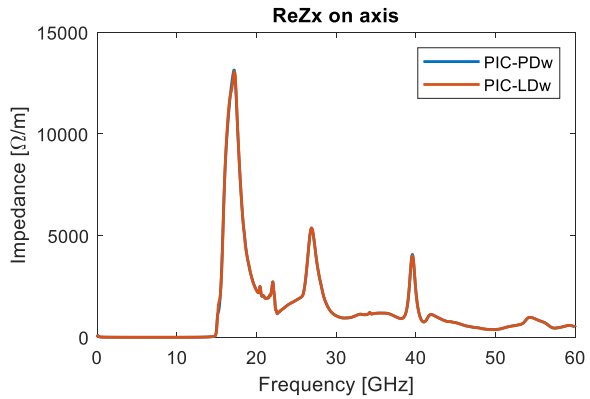
$$F_c = \frac{1}{n}\sum_k \left|\sum_j A_{kj}\right|^2 \qquad F_{rms} = \frac{\sum_{k=0}^{n-1}\sum_{j=1}^{k} A_{k,j}A_{k,j}^*}{n}$$

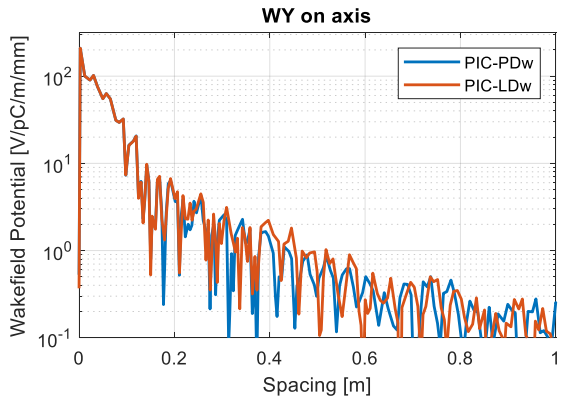
485 bunches	Fc	Frms	Fworst
PIC-PDw-x	1.0020	1.1749	2.9619
PIC-PDw-y	1.0011	1.1066	2.2825
PIC-LDw-x	1.0021	1.1623	3.0745
PIC-LDw-y	1.0011	1.0690	2.2665
Requirements		< 2	< 5

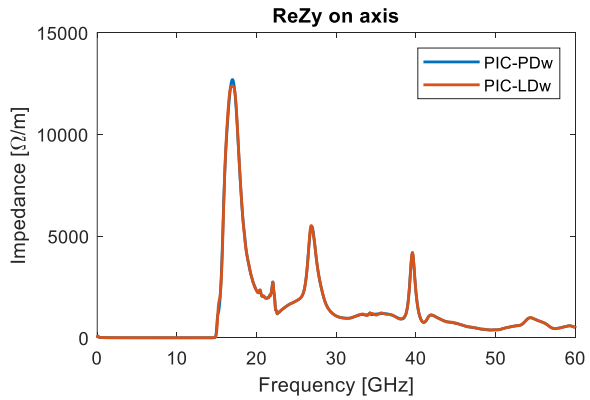
CLIC-K with bended damping waveguides can suppress the transverse wakefield very well.

- PML on input coupler and damping waveguides (PIC-PDw)
- PML on input couplersand Loads in damping waveguides (PIC-LDw)







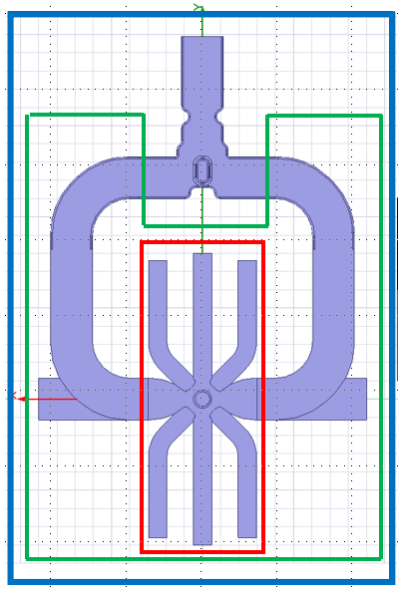


[1] D. Schulte, Multi-bunch calculations in the CLIC main linac, Proceedings of PAC09, Vancouver, BC, Canada, 2009.

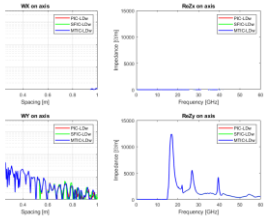
Wakefield calculation of the CLIC-K

HOM Magic-T is necessary to suppress the wakefield in the input coupler

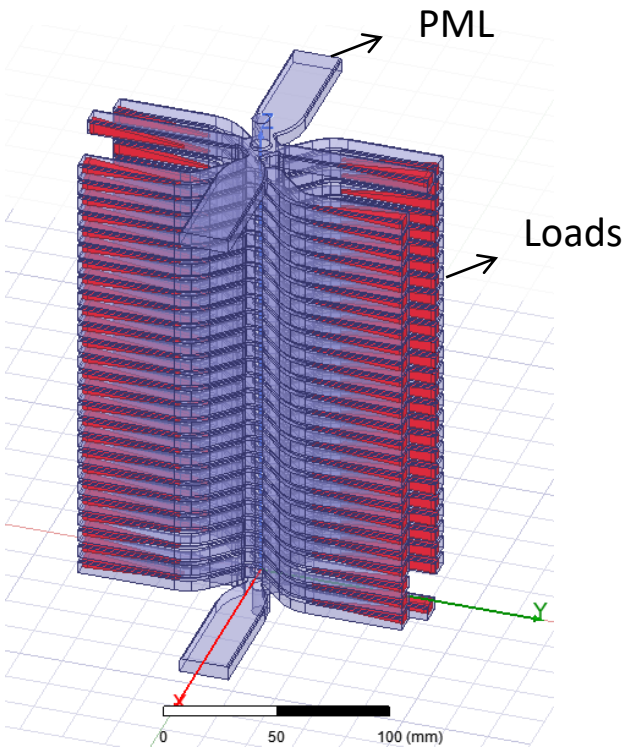
- PML on input coupler and Loads in damping waveguides (PIC-LDw)
- Shorted Bends on input coupler and Loads in damping waveguides (SFIC-LDw)
- HOMMagic-T on input coupler and Loads in damping waveguides (MTIC-LDw)

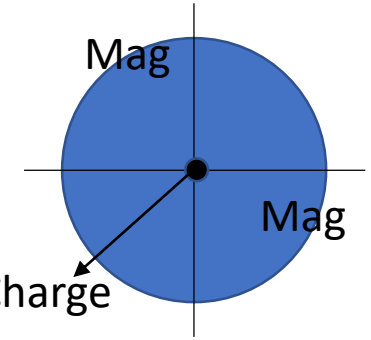


485 bunches	Fc	Frms	Fworst
PIC-LDw-x	1.0021	1.1623	3.0745
PIC-LDw-y	1.0011	1.0690	2.2665
SFIC-LDw-x	1.0044	1.2392	**64.366**
SFIC-LDw-y	1.0011	1.0687	2.2460
MTIC-LDw-x	1.0020	1.1577	3.5042
MTIC-LDw-y	1.0011	1.0692	2.2577

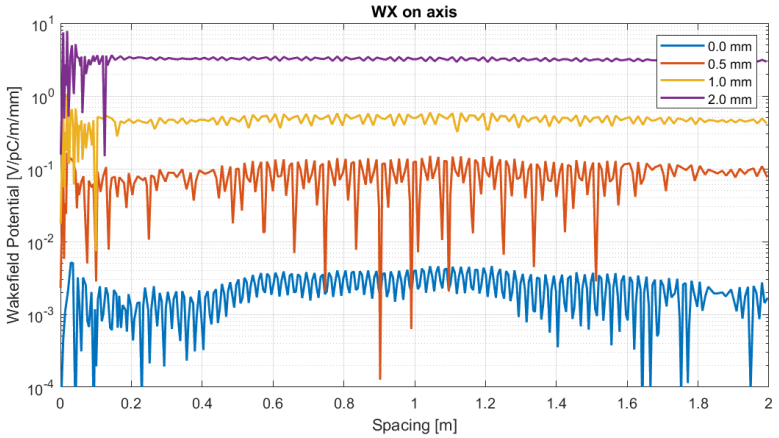


A monopole wakefield and transverse kicks





Position of wakefield integration (x , y)

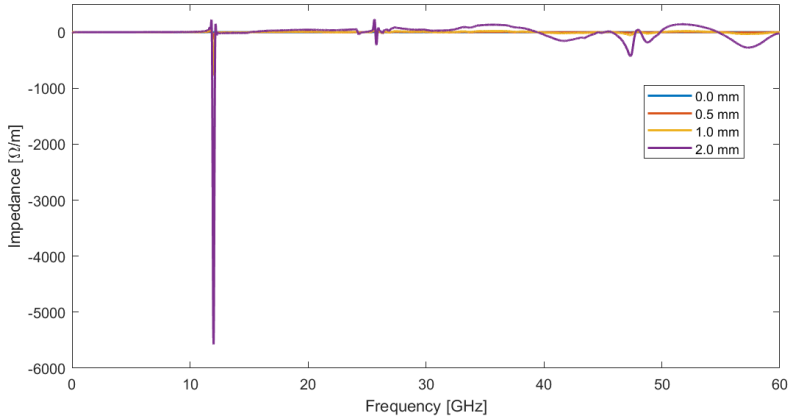


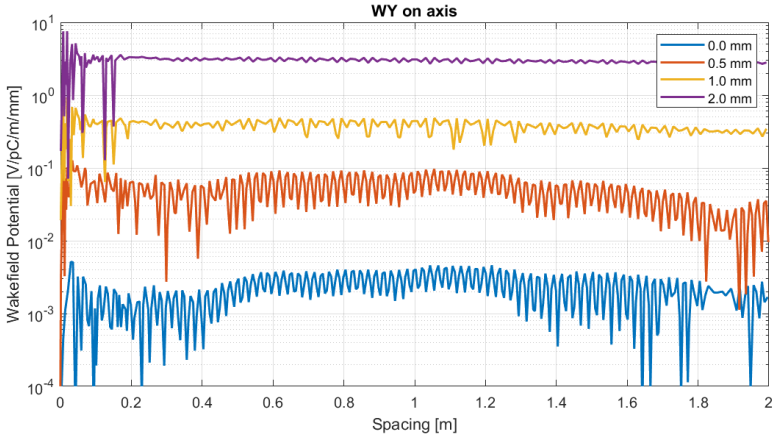
(0.0,0.0)

(0.5.0.0)

(1.0,0.0)

(2.0,0.0)



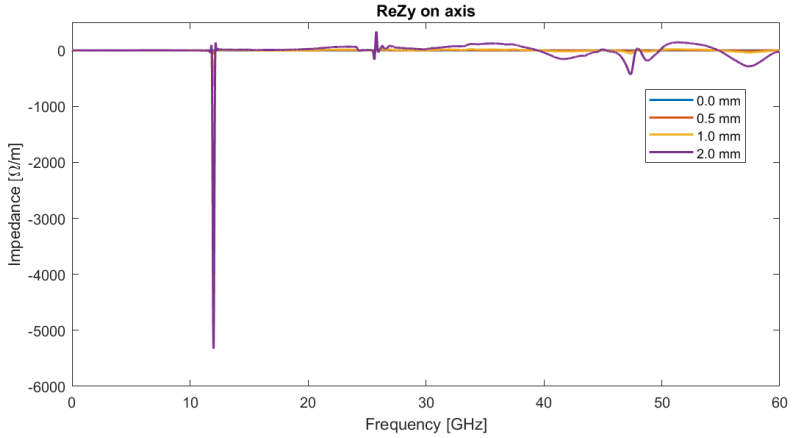


(0.0,0.0)

(0.0,0.5)

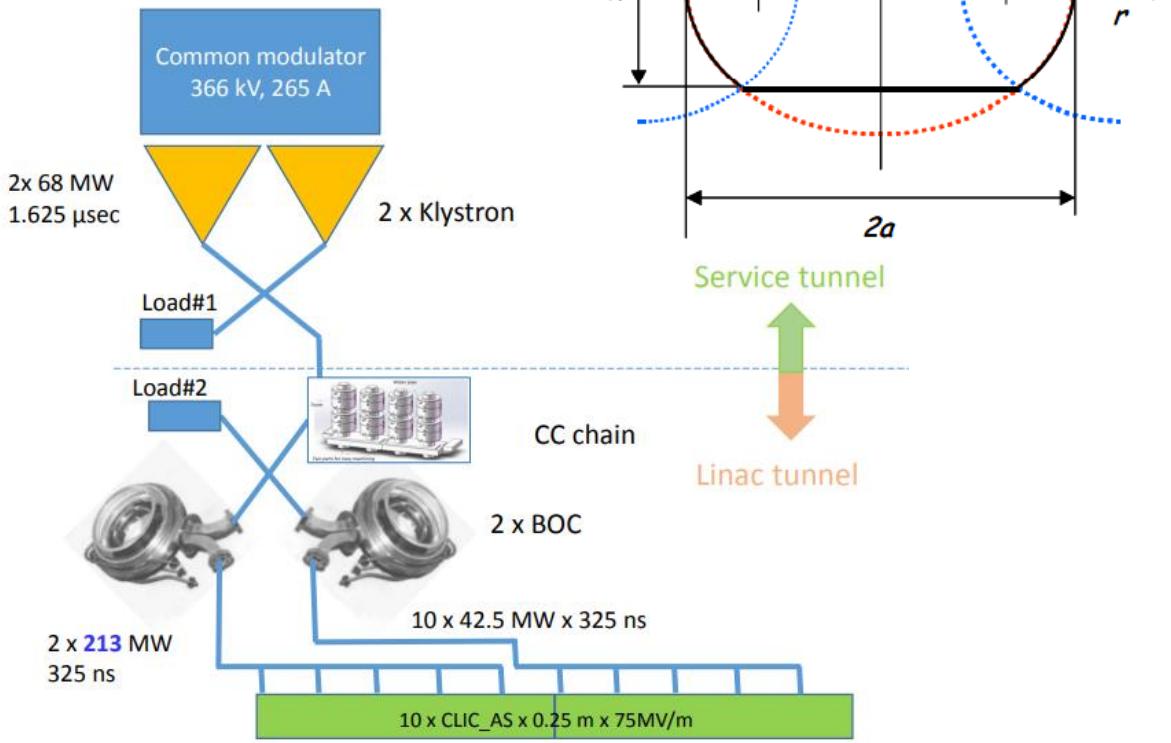
(0.0,1.0)

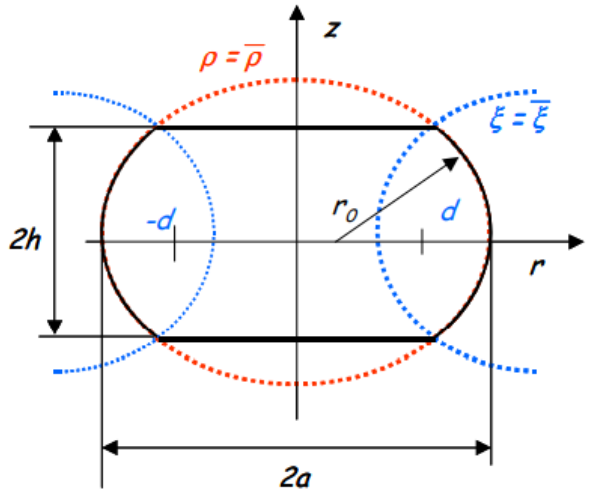
(0.0,2.0)

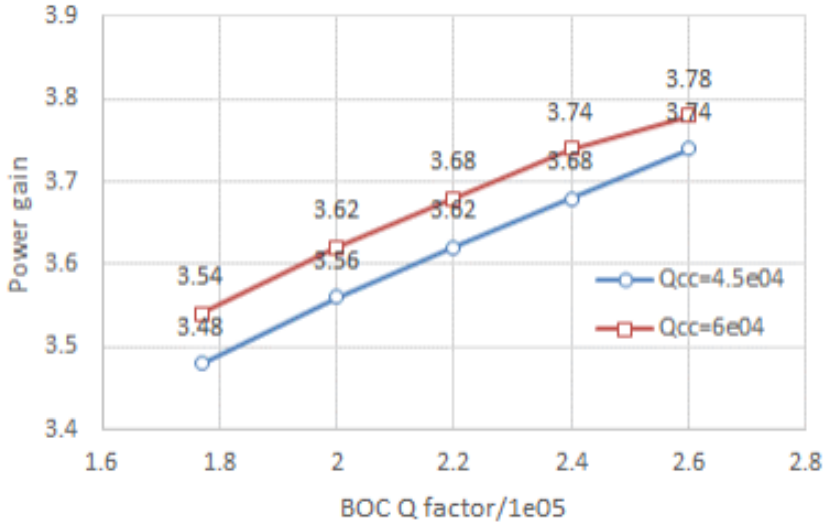


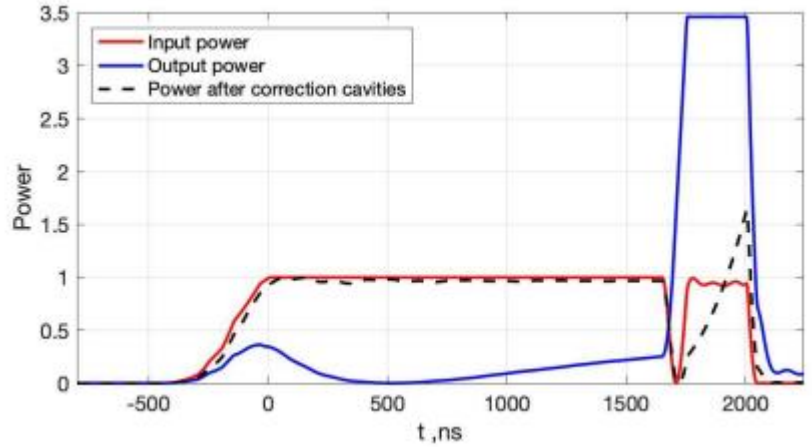
X-band BOC pulse compressor for klystron-based CLIC

- BOC has large unloaded quality factor and good suppression of other parasitic modes







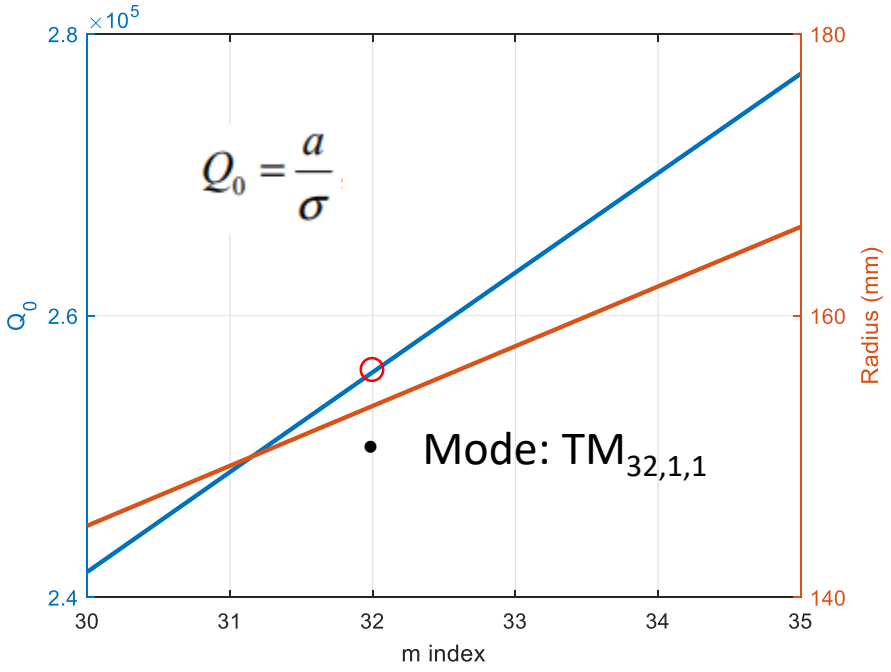


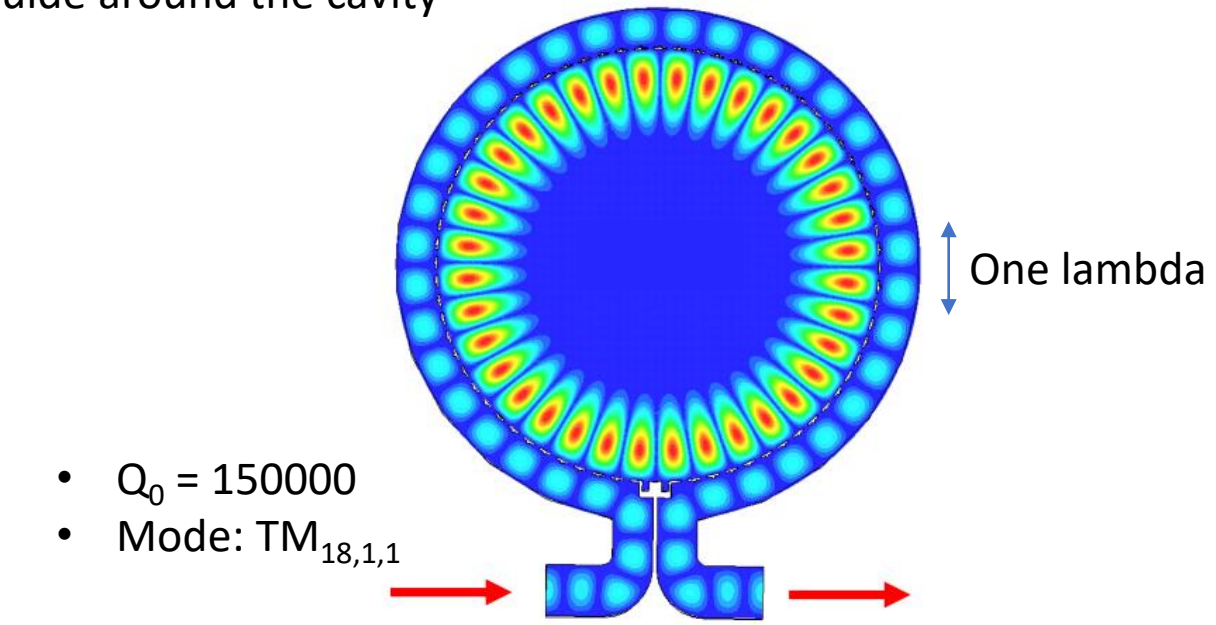
[1] Igor Syratchev, CLIC Klystron based. Updates 2017. CLIC WS, CERN, March 2017
[2] Jinchi Cai and Igor Syratchev, CERN-ACC-2020-0031
[3] Igor Syratchev, CERN/PS 2002-008 (RF)

X-band BOC pulse compressor for klystron-based CLIC

Targeted Parameters
- Q_0 = 240000
- Beta = 7.0

To be calculated geometry Parameters
- Radius of the cavity
- Width of the waveguide around the cavity

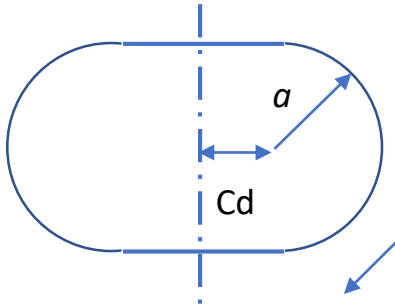


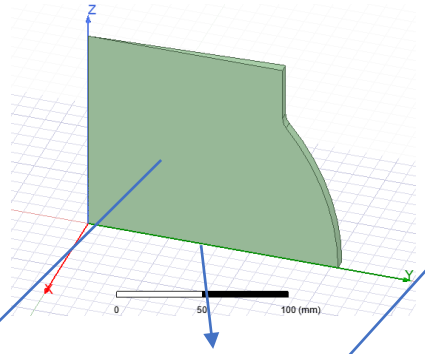


[1] Riccardo Zennaro, BOC production at PSI, RF meeting, 2021

Cavity outer wall optimization

- Quarter Lambda Model for cavity without coupling hole: Preliminary Radius of cavity
- Mode: $TM_{32,1,1}$





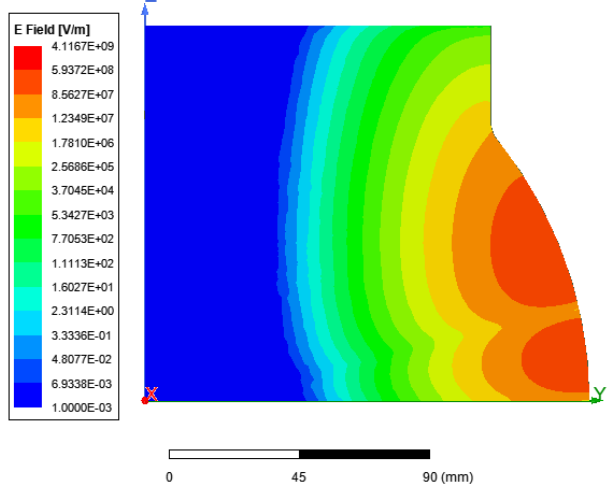
PerfH

- PerfE
- PerfH

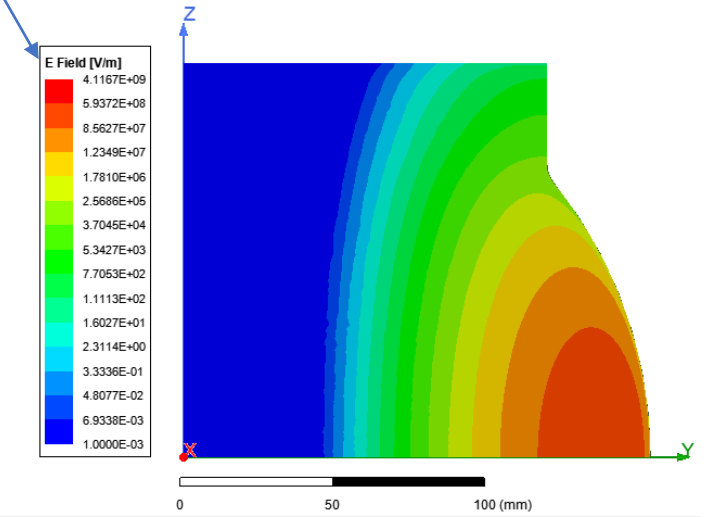
	Eigenmode	Frequency (GHz)	Q
	Mode 1	11.8823 +j 0.000167297	35512.4
	Mode 2	11.9940 +j 2.34818e-05	255389.
	Mode 3	12.5355 +j 0.000178454	35122.4

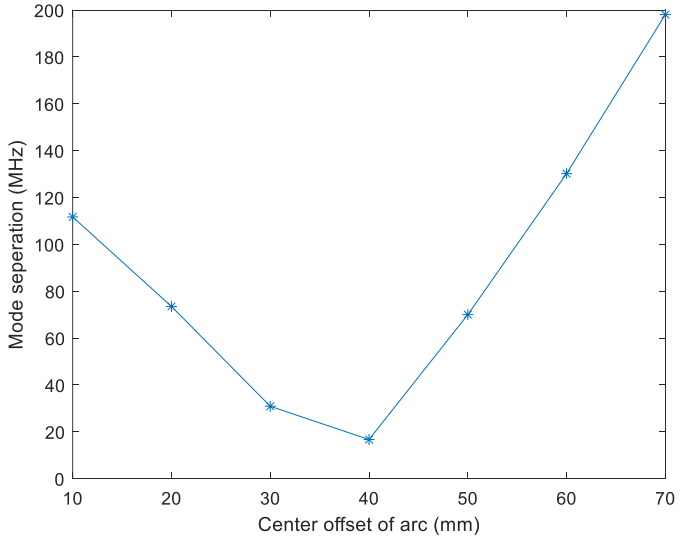
	Eigenmode	Frequency (GHz)	Q
	Mode 1	11.5545 +j 0.000161900	35684.1
	Mode 2	12.2095 +j 0.000172763	35335.9
	Mode 3	12.3334 +j 2.38419e-05	258650.

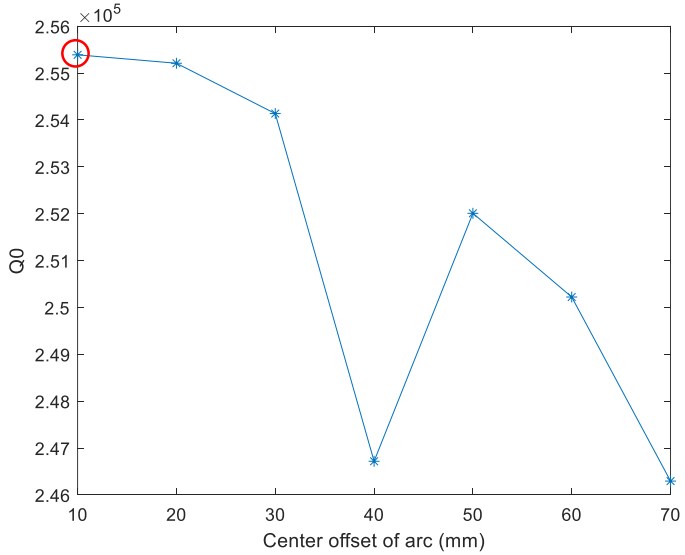
120 mm



130 mm







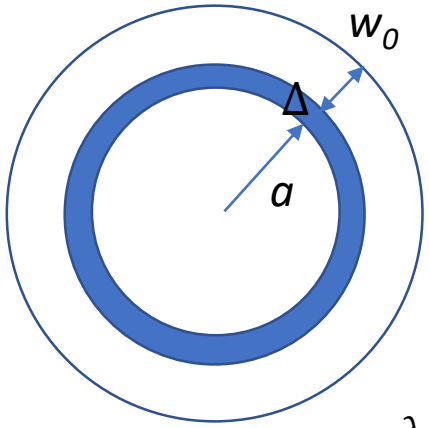
Calculation of the Width of the waveguide around the BOC

- a: Radius of resonant cavity
- Δ: Thickness of wall between resonant cavity and waveguide

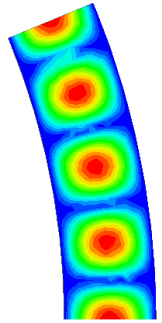
Coupling hole

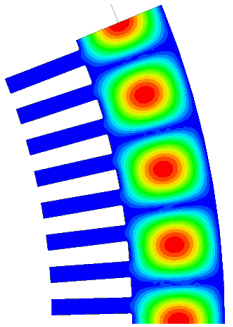
$$\frac{2\pi\left(a+\Delta+\frac{w}{2}\right)}{m} \cong \lambda_0 / \sqrt{1-\left(\frac{\lambda_0}{2w}\right)^2}$$

$$\lambda_g = \lambda_0 / \sqrt{1-\left(\frac{\lambda_0}{2w}\right)^2} \quad \lambda_{g0} = \lambda_0 / \sqrt{1-\left(\frac{\lambda_0}{2w_0}\right)^2} \quad w_0 = \frac{\lambda_0}{2} / \sqrt{1-\left(\frac{\lambda_g}{\lambda_{g0}}\right)^2\left(1-\left(\frac{\lambda_0}{2w}\right)^2\right)}$$



w = 19.50 mm

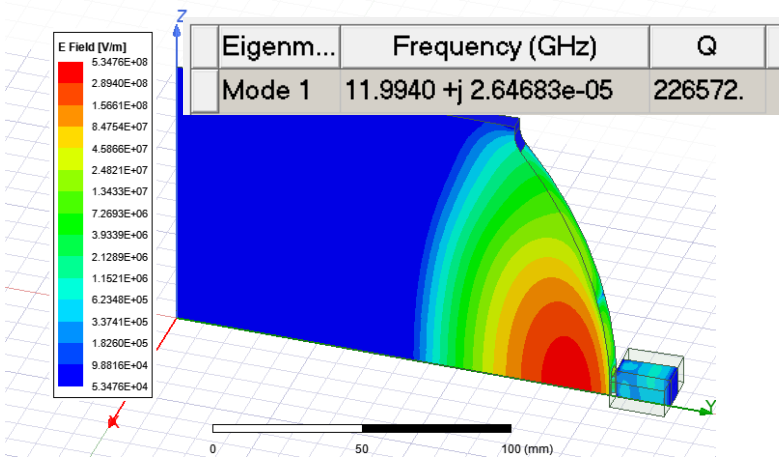


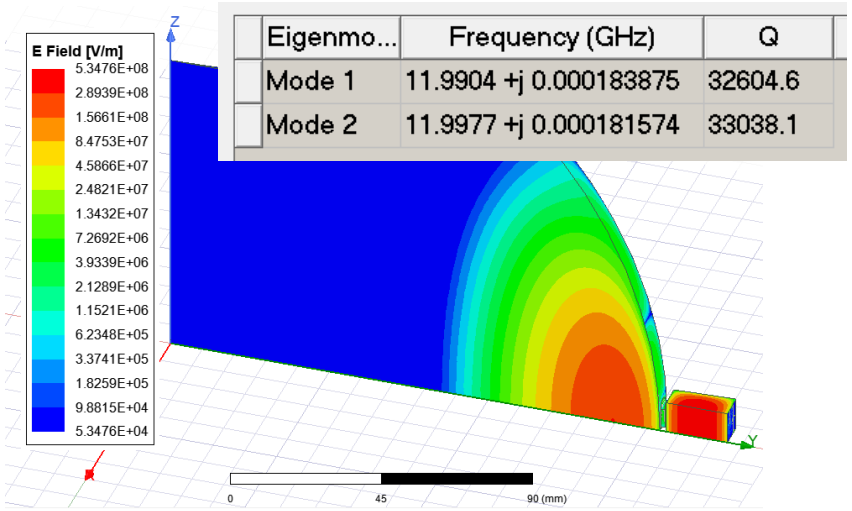


$\lambda_{g0} = 32.50\ mm$ $\lambda_g = 32.32\ mm$

Method1:w0 = 19.301 mm

Method2: 19.308 mm

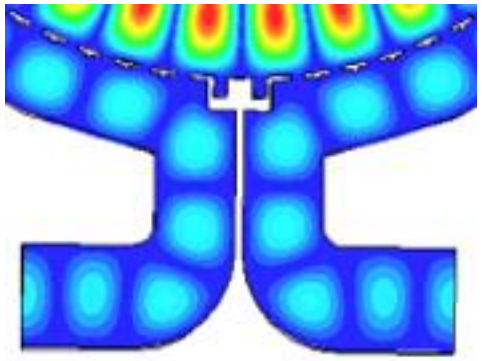


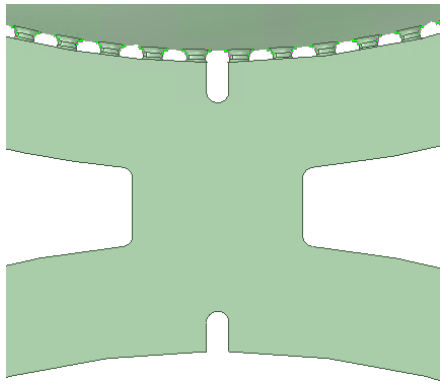


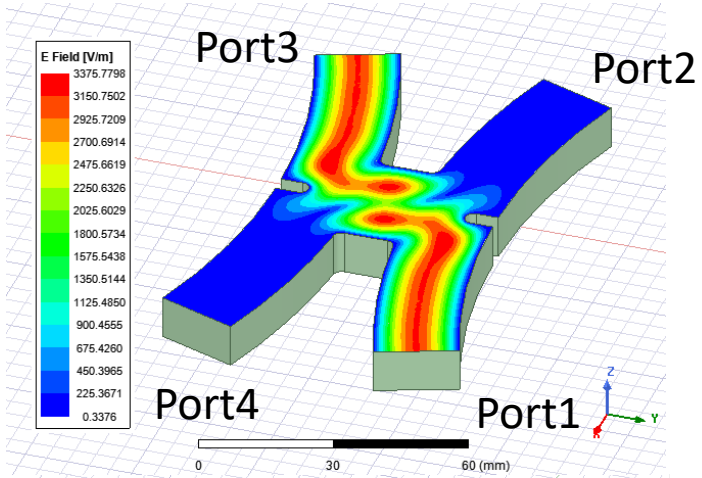
- Two coupled cavities should have the same frequencies

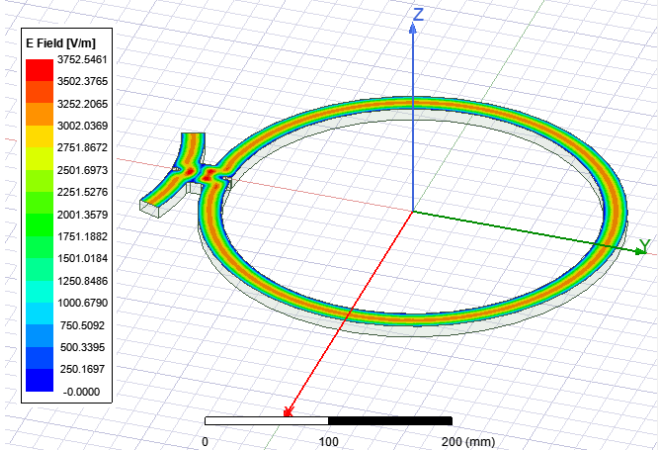
Novel coupler for BOC

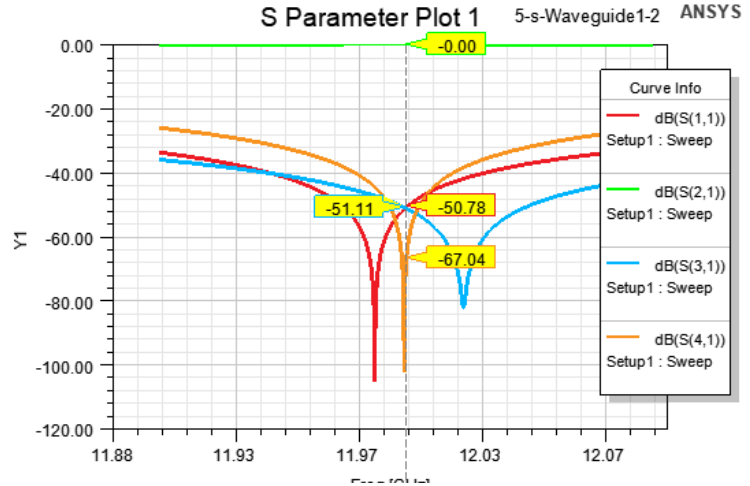
- Double height waveguide can reduce the loss and surface field of the waveguide.
- New coupler can avoid the thin wall between the input and output waveguides, which ease the machining.

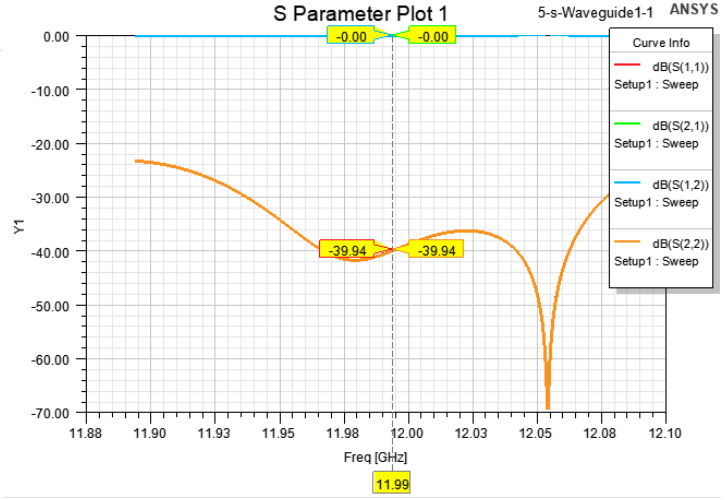










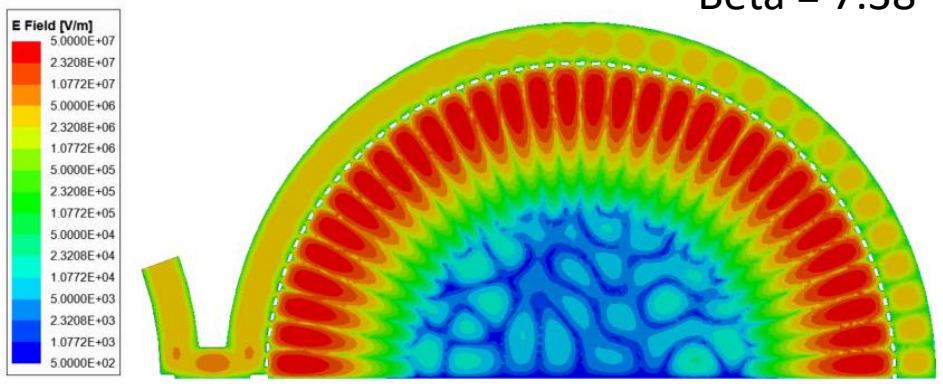


Eig mode simulation of the X-band BOC

Eigen...	Frequency (GHz)	Q
Mode 1	11.9940 +j 0.000214791	27920.1

E face:

- Q_0 = 23.4e5
- Beta = 7.38

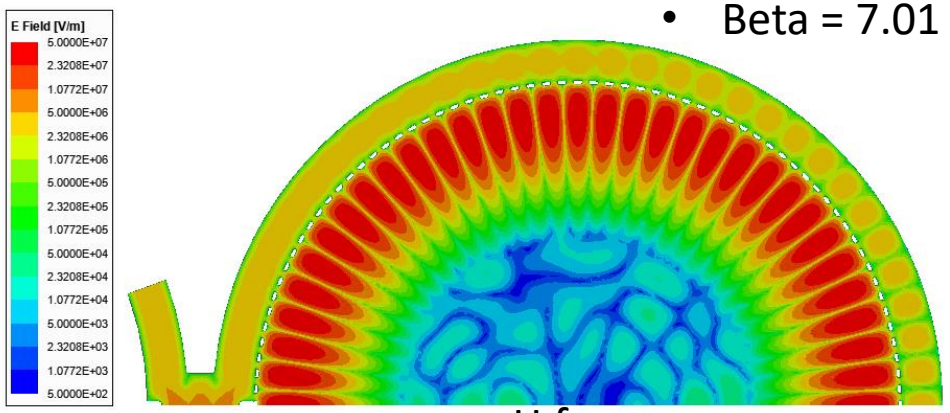


E face

Eigenm...	Frequency (GHz)	Q
Mode 1	11.9940 +j 0.000205214	29223.2

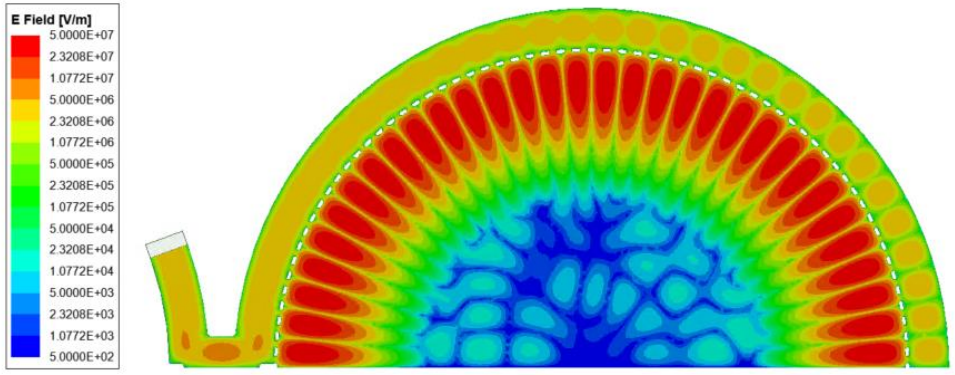
H face:

- Q_0 = 23.4e5
- Beta = 7.01



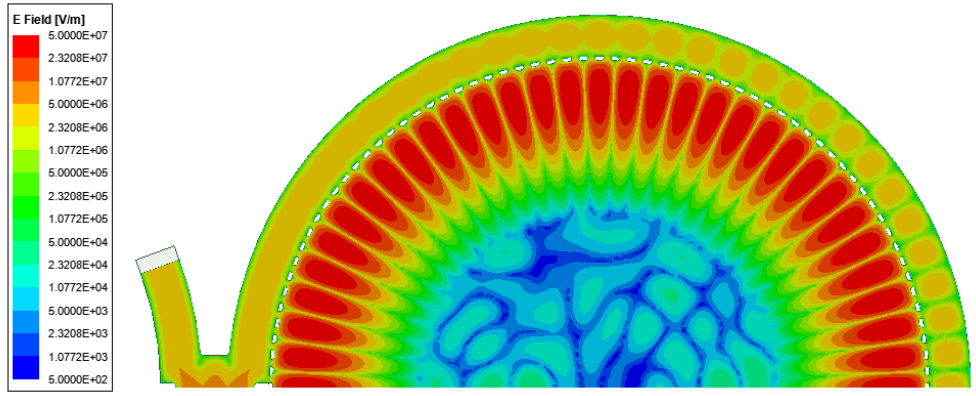
H face

Eigenm...	Frequency (GHz)	Q
Mode 1	11.9940 +j 0.000189153	31704.5



E face

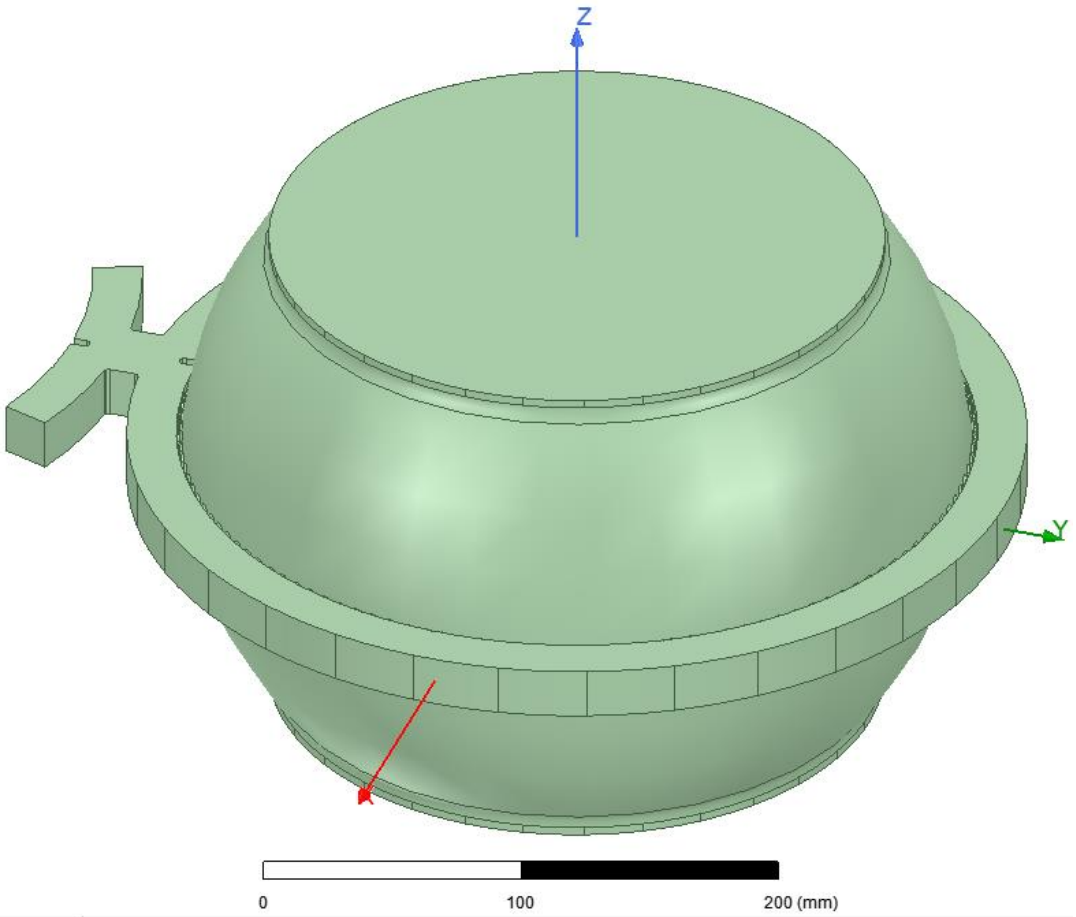
Eigenm...	Frequency (GHz)	Q
Mode 1	11.9940 +j 0.000179588	33393.1

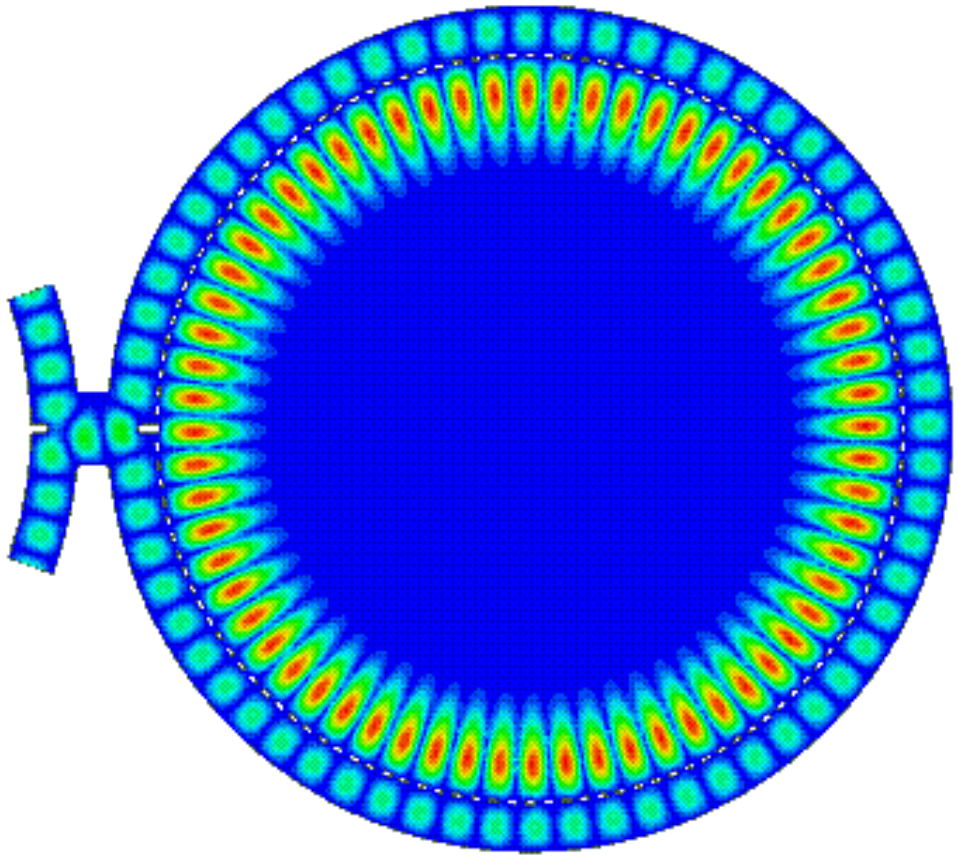


H face

Full geometry of the new X-band BOC pulse compressor

- Double height waveguide
- No fake coupling holes
- No thin wall between waveguides





- Outer radius of the waveguide: 351 mm
- Height of the BOC: 200mm

Summary

- RF design of the CLIC-K with bended damping waveguides was completed and the mechanical design is in progress.

- Preliminary RF design of the BOC pulse compressor was finished and the mechanical design will be discussed in the next step

Thanks for your attention!!!