Choke-mode damped accelerating structures for CLIC main linac

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Outline

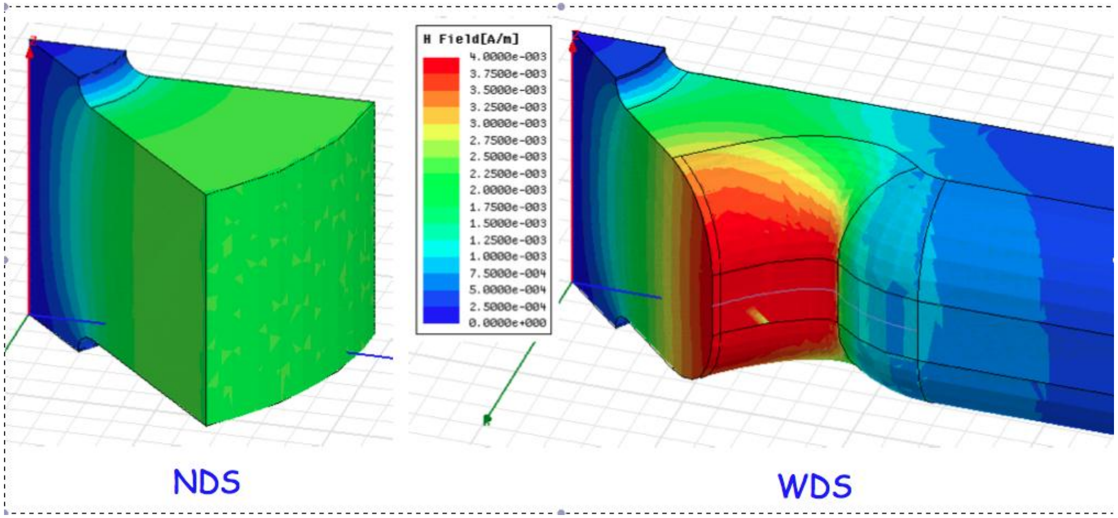
- Introduction
- Wakefield damping study
- RF parameters
- Recent activities

The choke-mode structure study at CERN

- Acknowledgement
  - Choke-mode damped structure being studied as an alternative to the baseline design
  - collaboration between CERN and Tsinghua University in China
  - Ph.D student from Tsinghua Univ., Hao ZHA
    - Visited CERN for 6 months in 2011
  - Possible hardware fabrication in Tsinghua

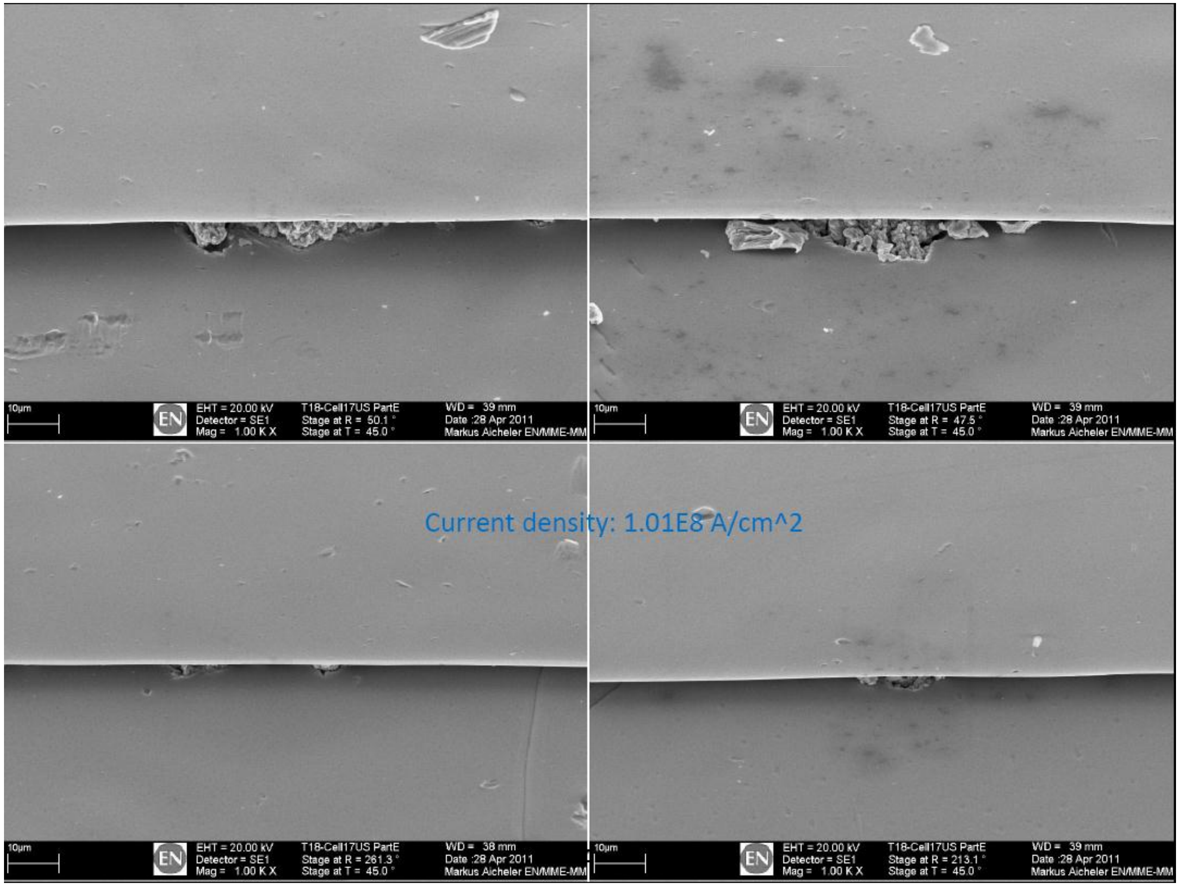
T(D)18 and T(D)24 results

- Damped structure has higher breakdown rate
  - TD18>T18, TD24>T24
  - Magnetic field enhancement
  - [illegible]

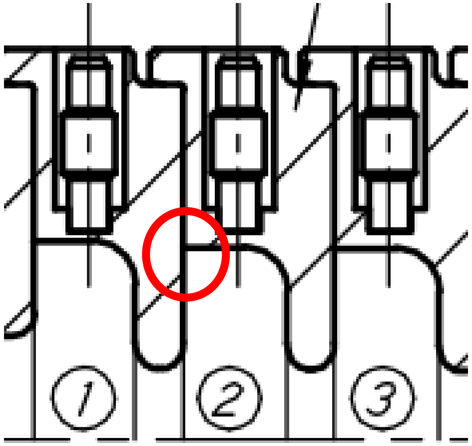


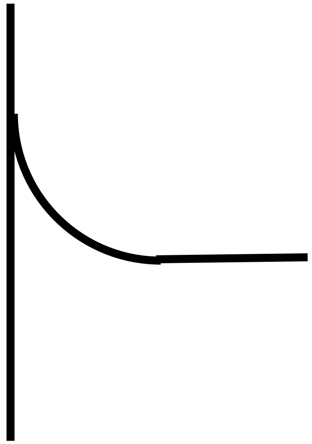
B-field arc in bonding joints

- Chamfer of ~10um radius



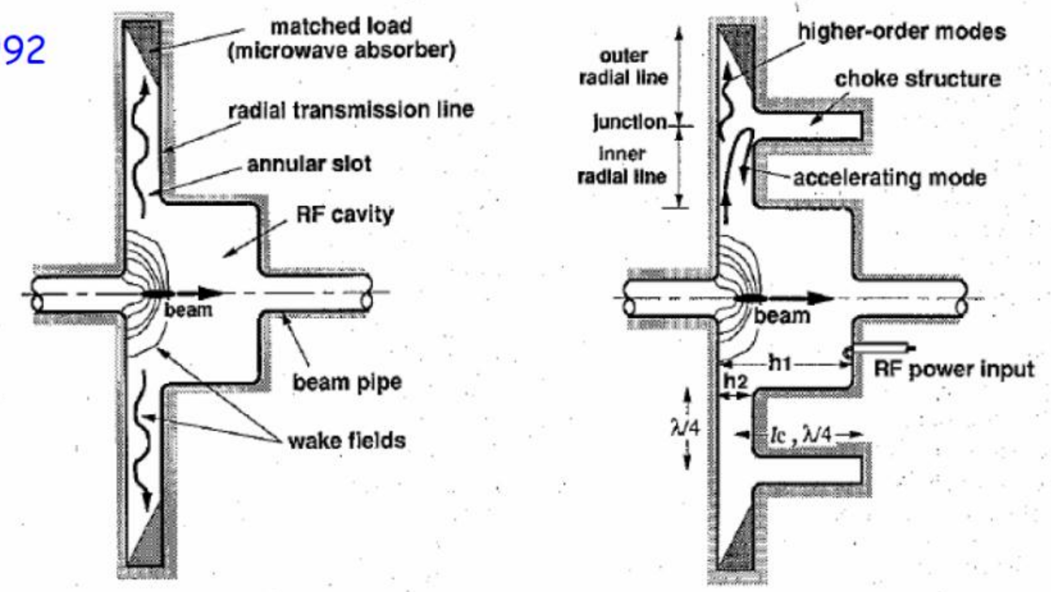
Current density: 1.01E8 A/cm^2





The choke-mode cavity

Shintake, 1992



(a) Radial Line Damper

(b) Choke Mode Cavity

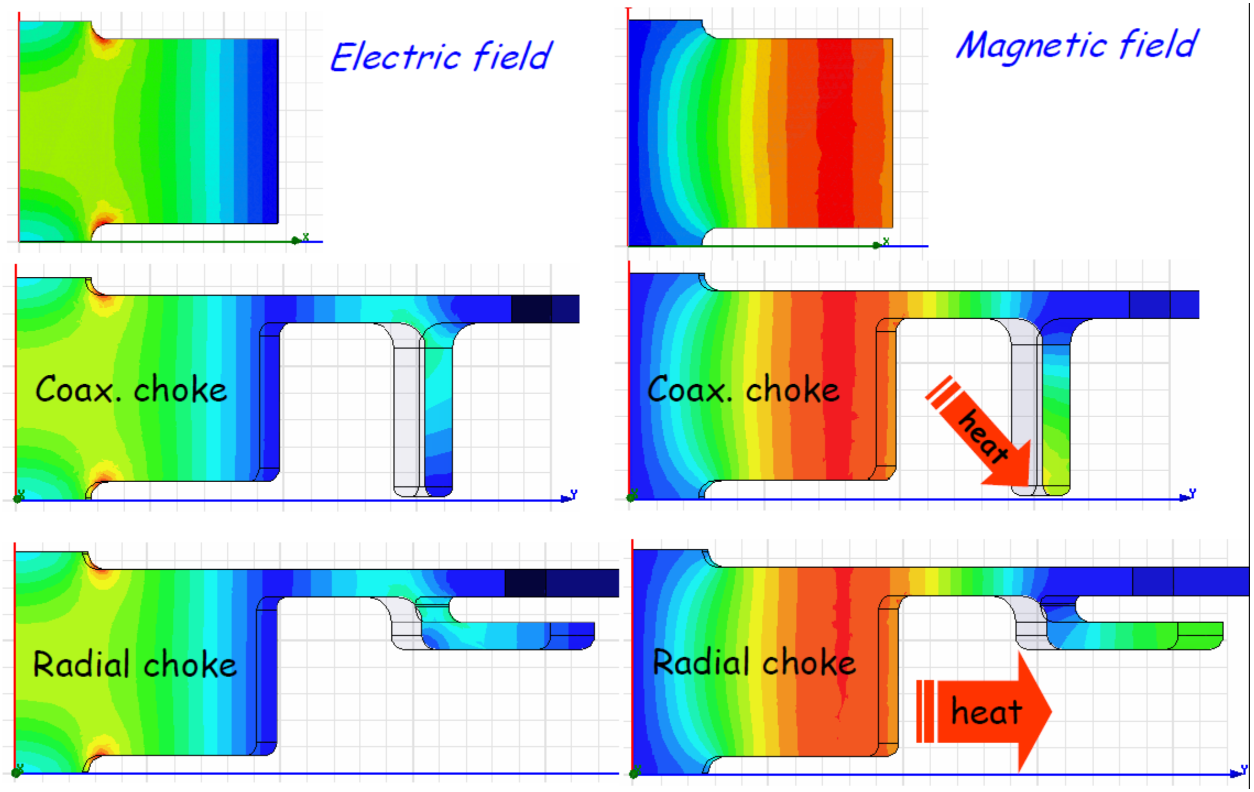
Fig. 1. Conceptual illustrations of (a) a radial line damper and (b) the choke mode cavity.

L 1567

- Progress at KEK and SLAC, application at Japanese XFEL

Radial choke

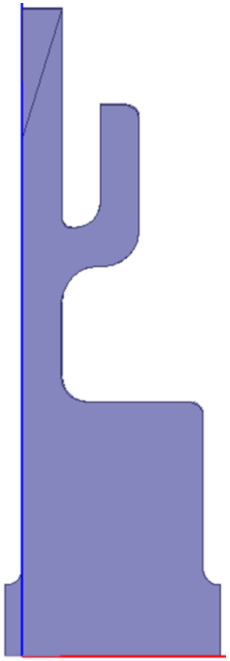
- 2*pi/3 cavity does not have enough space for coaxial choke.
- Radial choke provide better cooling effect and mechanical strength.

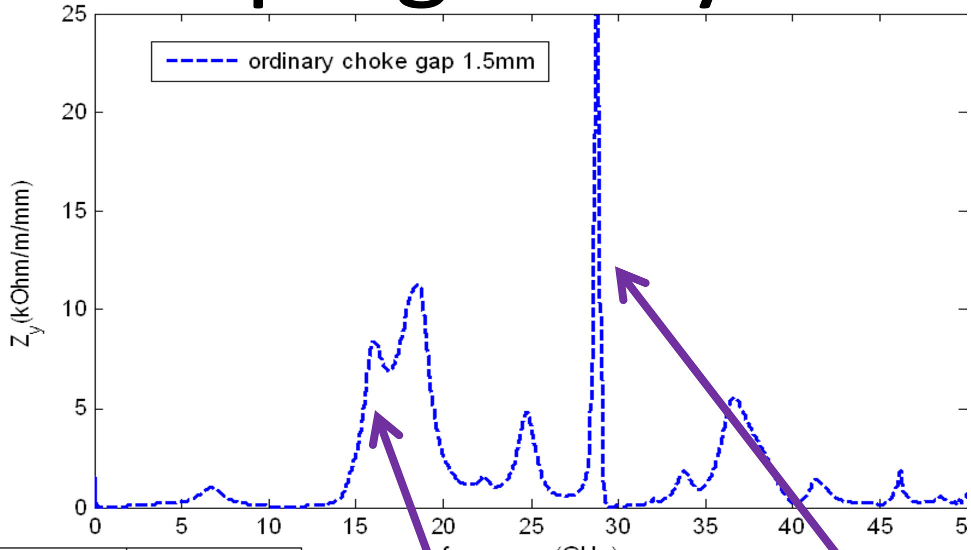


- Advantages
  - Lower pulsed surface heating, no magnetic field enhancement
  - Bonding joint at low magnetic field, no problem on the chamfer
  - Easy manufacturing, turning only

- Consideration
  - Lower shunt impedance: 60% of un-damped, 80% of waveguide damping
  - Possible breakdown inside Choke

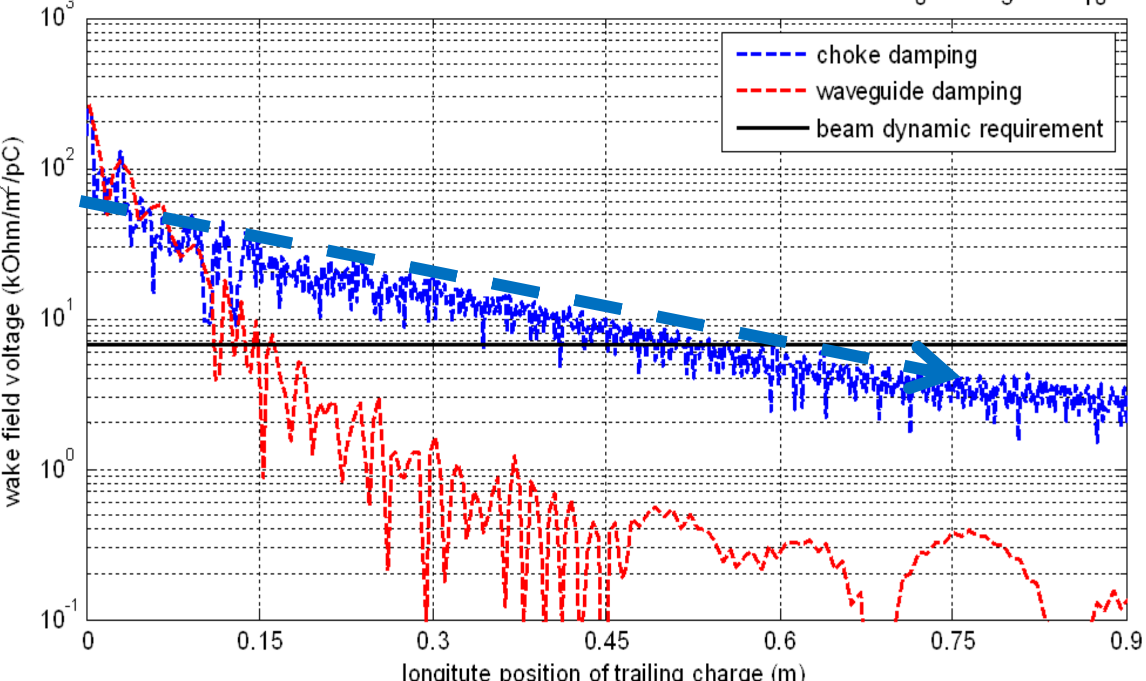
Wakefield damping study





16 & 18 GHz
Q≈10, but
R/Q>60!!

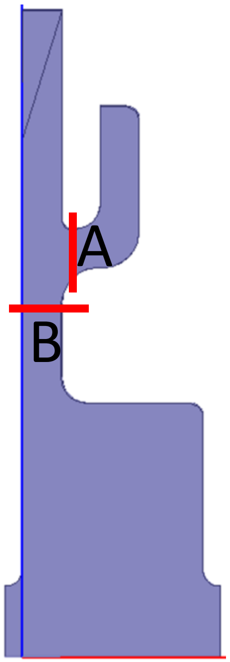
29 GHz
Q ≈ 100!!

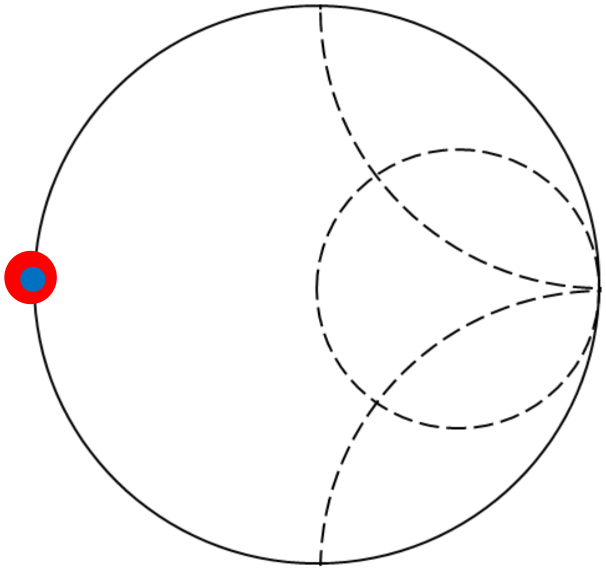


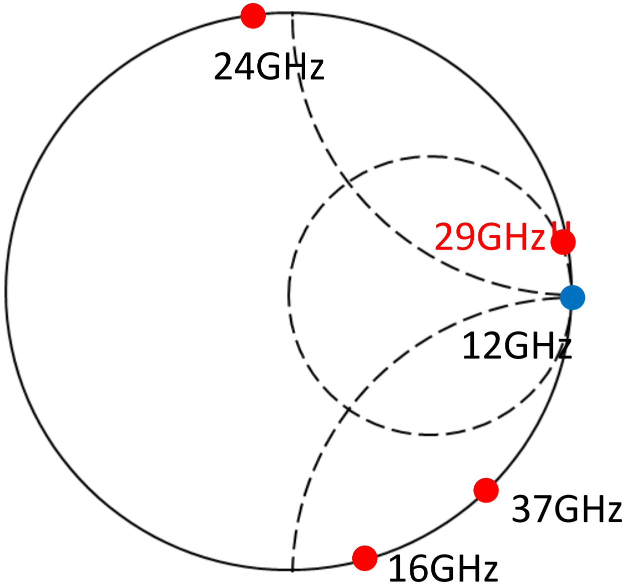
s	0.15	0.30
CDS	35.8	18.6
WDS	5.2	1.5

Smith chart

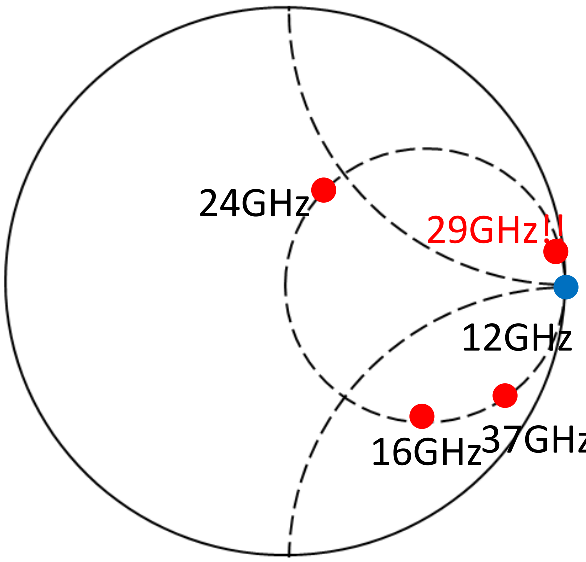
- There are several dangerous modes between 15GHz~40GHz. (16GHz, 18GHz, 24GHz, 29GHz, 37GHz)
- The frequency of 2nd reflection should be moved away from this range: [15GHz, 40GHz].







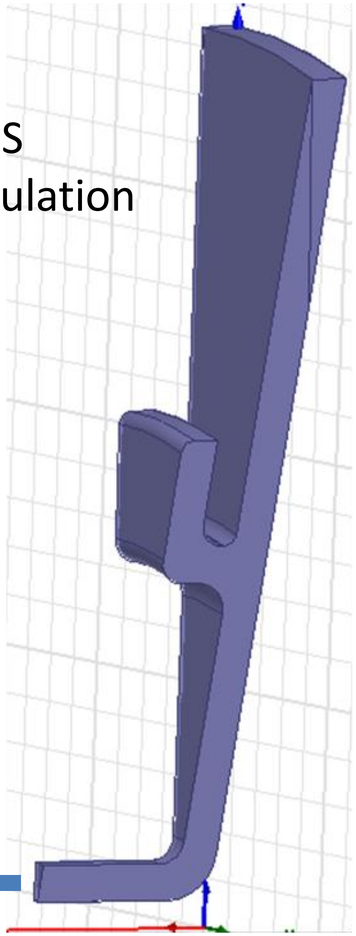
A:Bottom of the choke



B:Junction

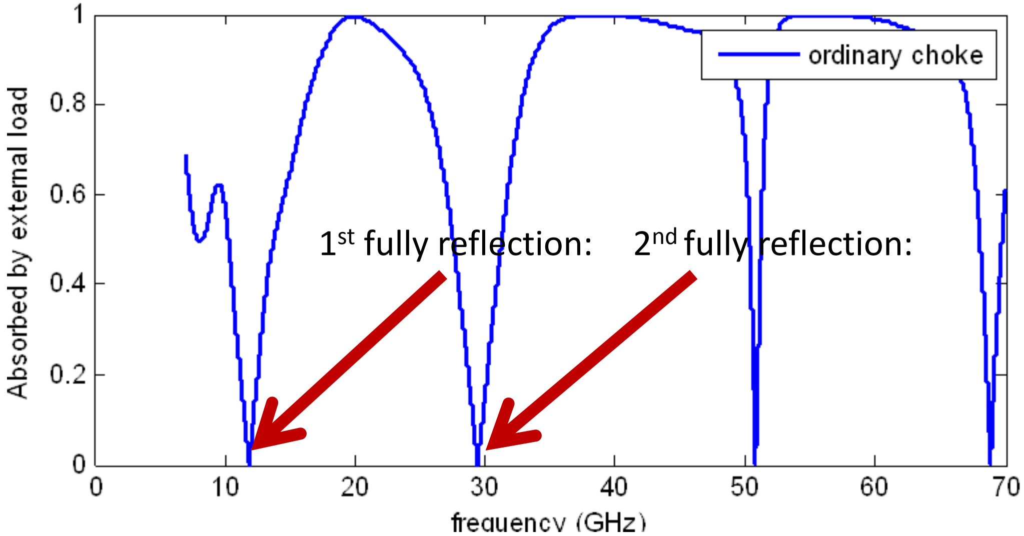
Wakefield damping study

HFSS Simulation

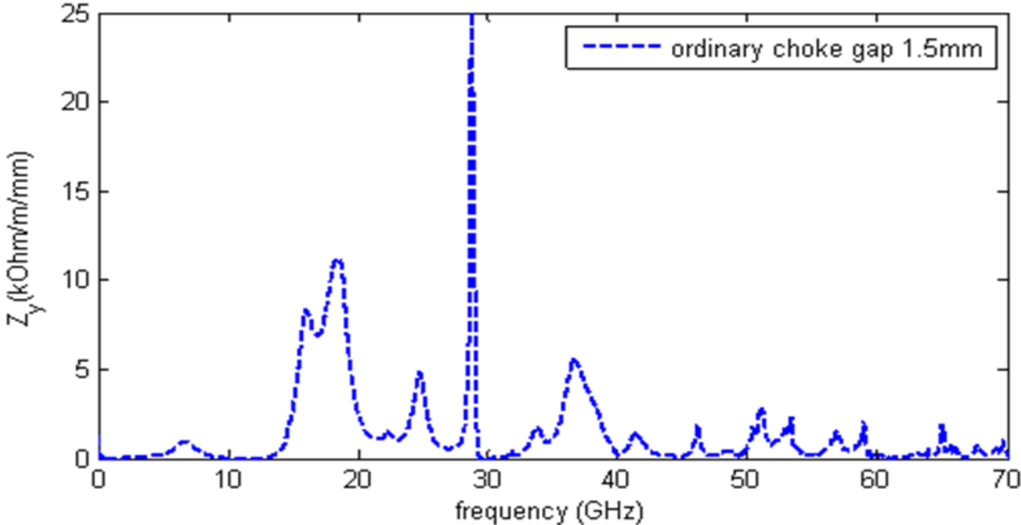


RF measurements possible

Absorption = sqrt(1-S11^2)

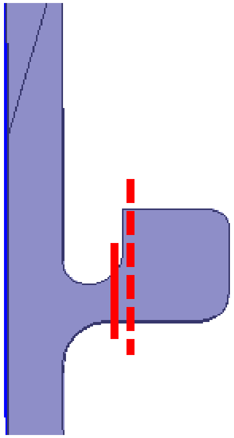


Gdfidl simulation

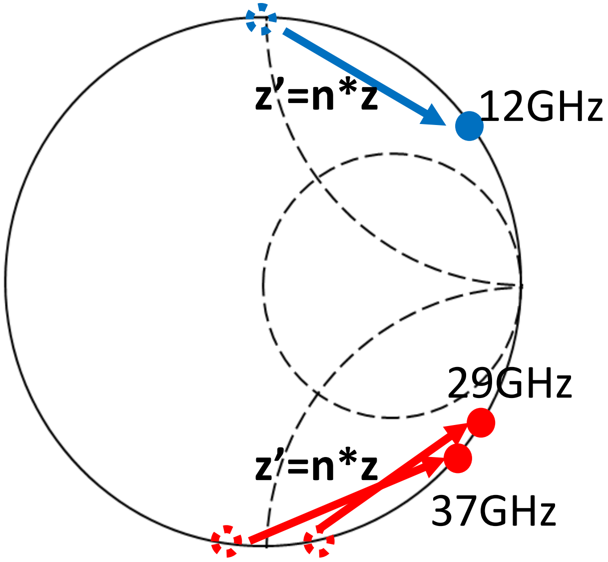


Use **prefect matched load** instead of the absorber

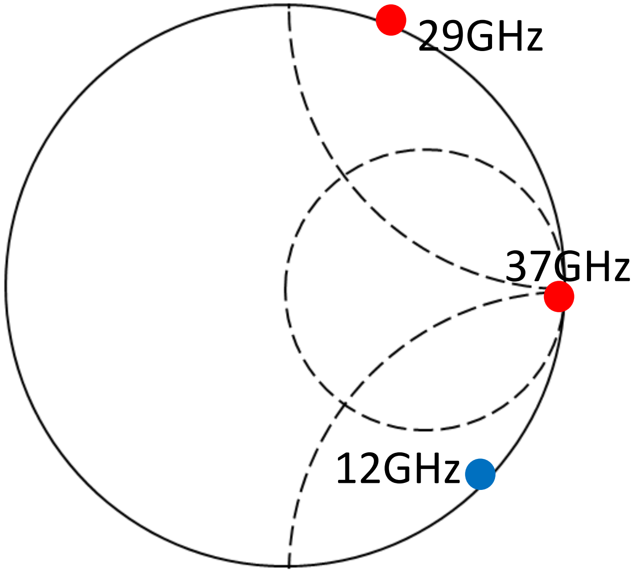
Choke with two section



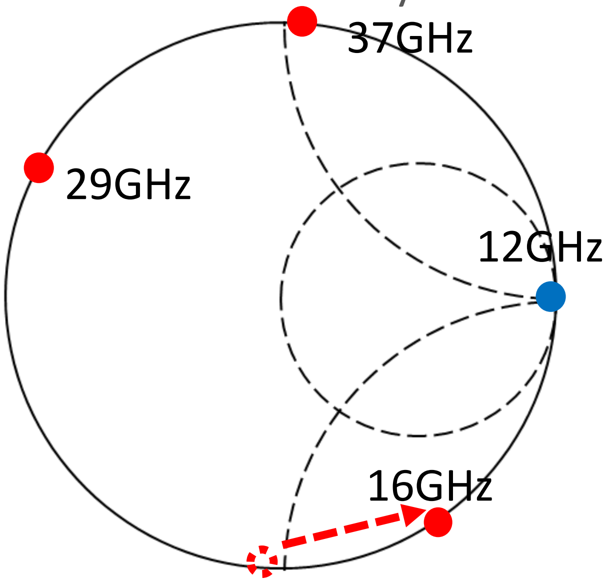
- The joint plane can be equivalent as N:1 impedance transformer.



Joint plane



Bottom of choke

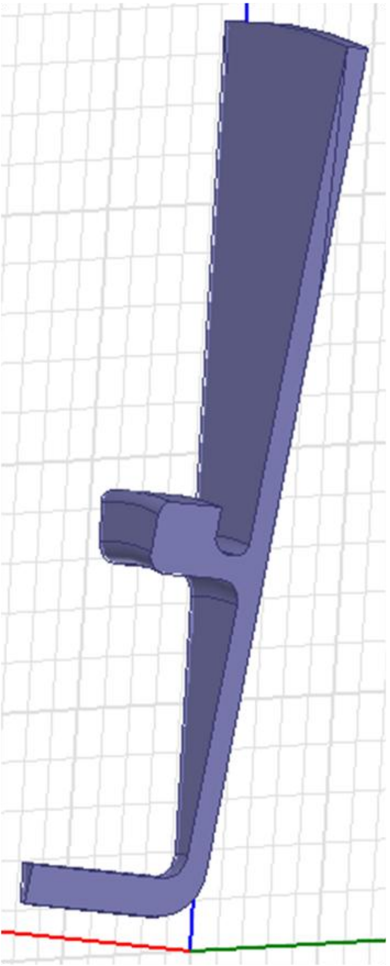


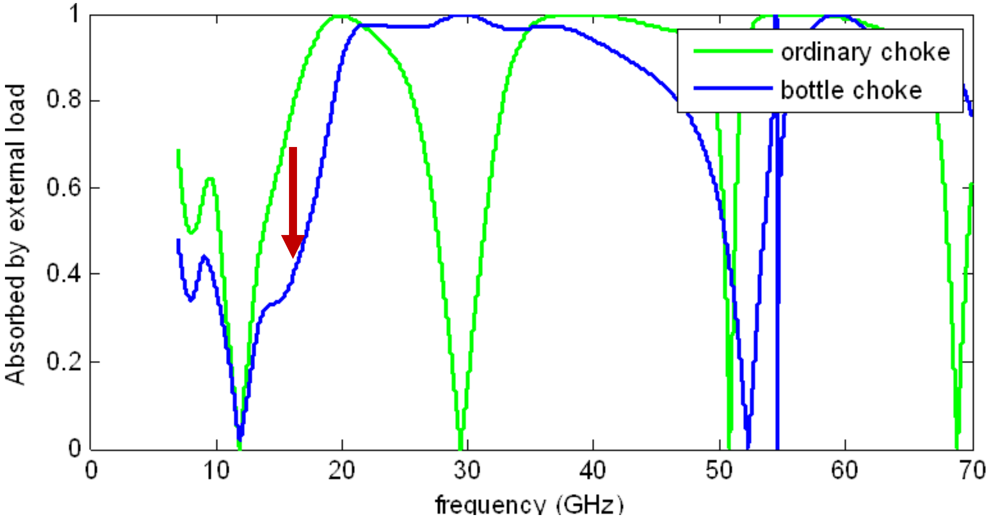
Tune back 12GHz

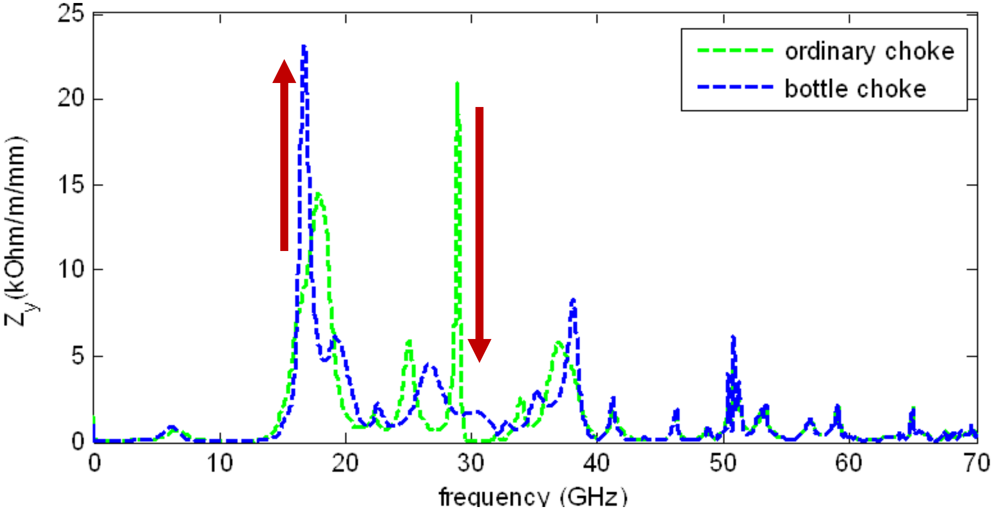
Dashed: ordinary choke

Absorption curve

Absorption = sqrt(1-S11^2)







$$\max(f_2)/f_1 = \pi/\tan^{-1}(n^{-1/2}) - 1$$

For double choke,

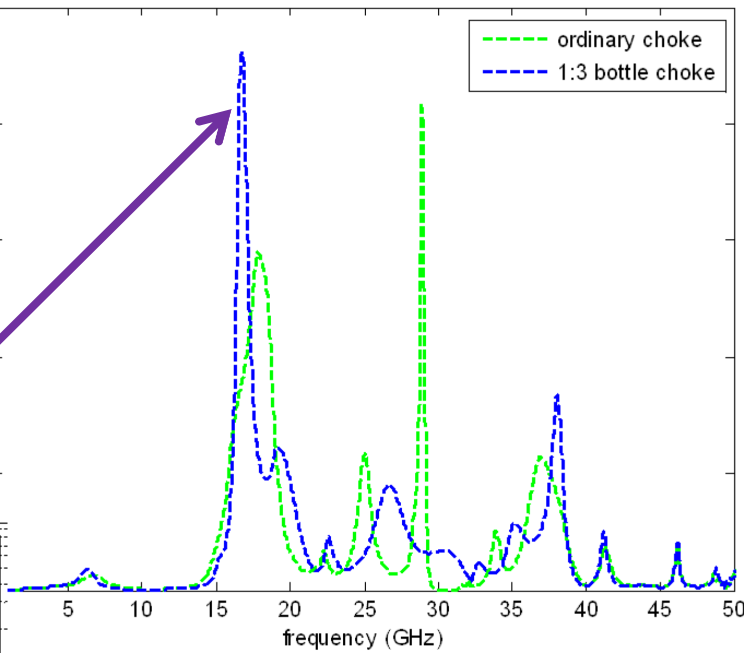
$n = 2, \max(f_2)/f_1 \approx 4.1$

For 1:3 bottle choke,

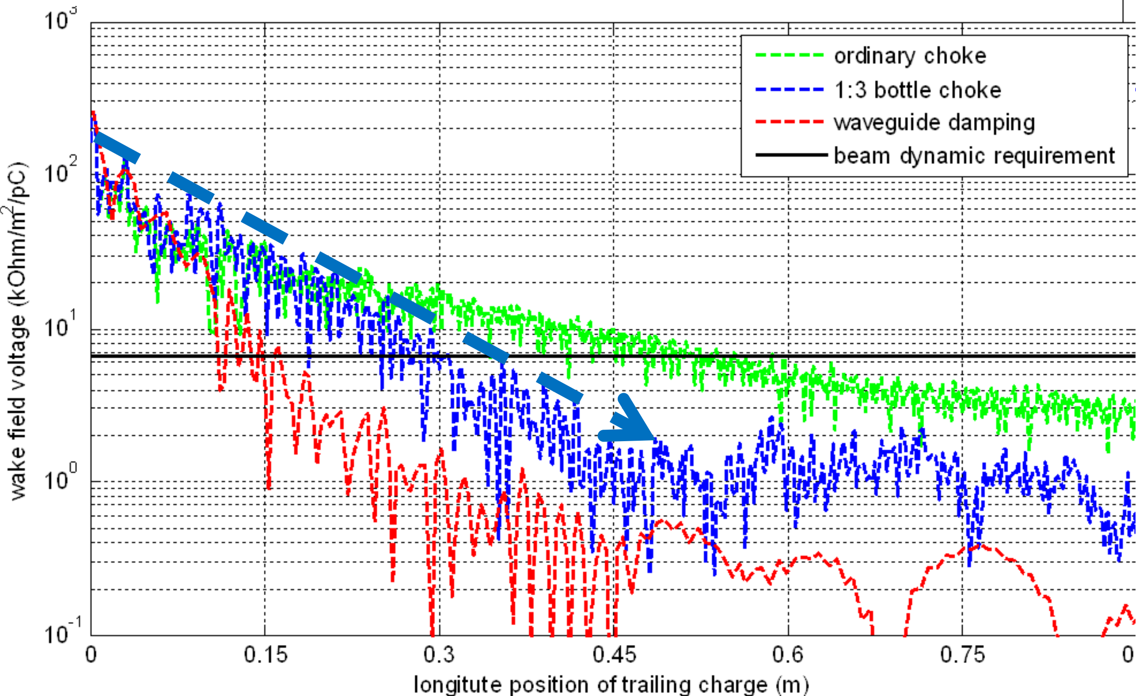
$n = 3, \max(f_2)/f_1 = 5$

1:3 bottle choke moves frequency of the 2nd fully reflection to 52GHz, but the absorption of lower frequency(16GHz) decrease.

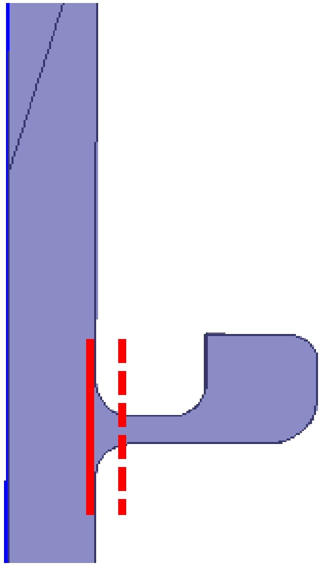
Wakefield results



Q of 16GHz:
8->18

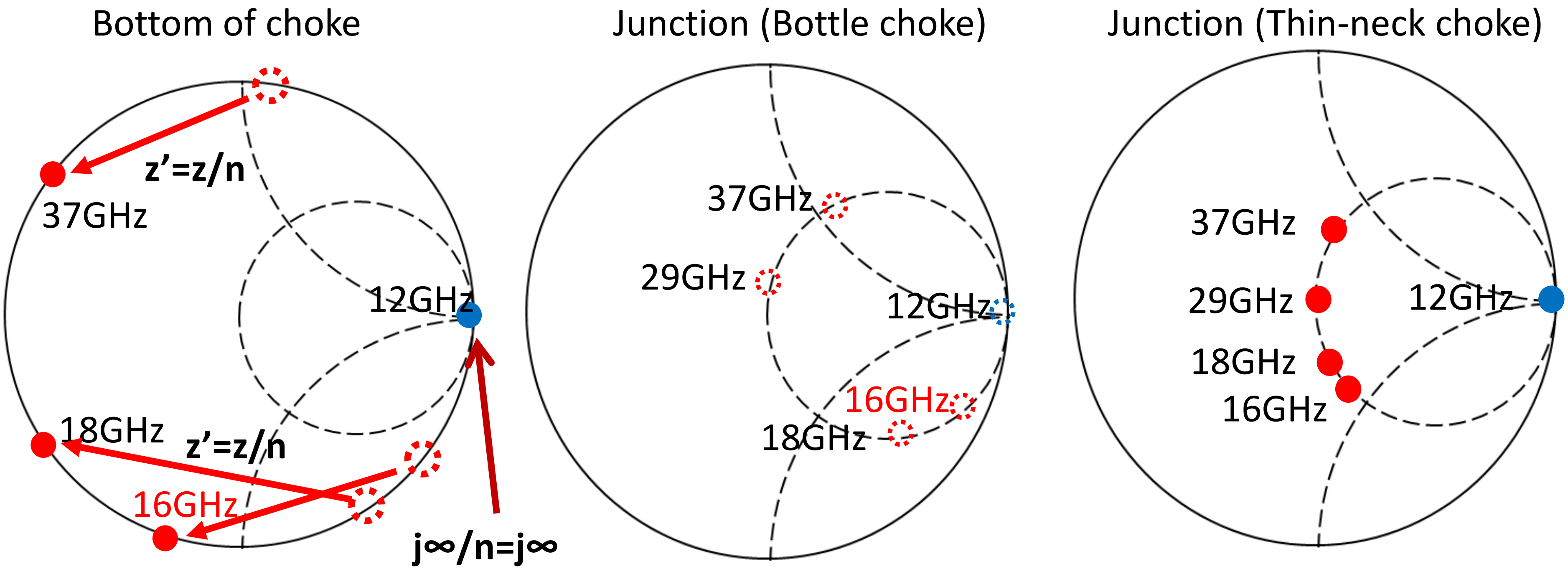


s	0.15	0.30
Ordinary	35.8	18.6
1:3 bottle	30.4	5.4
WDS	5.2	1.5



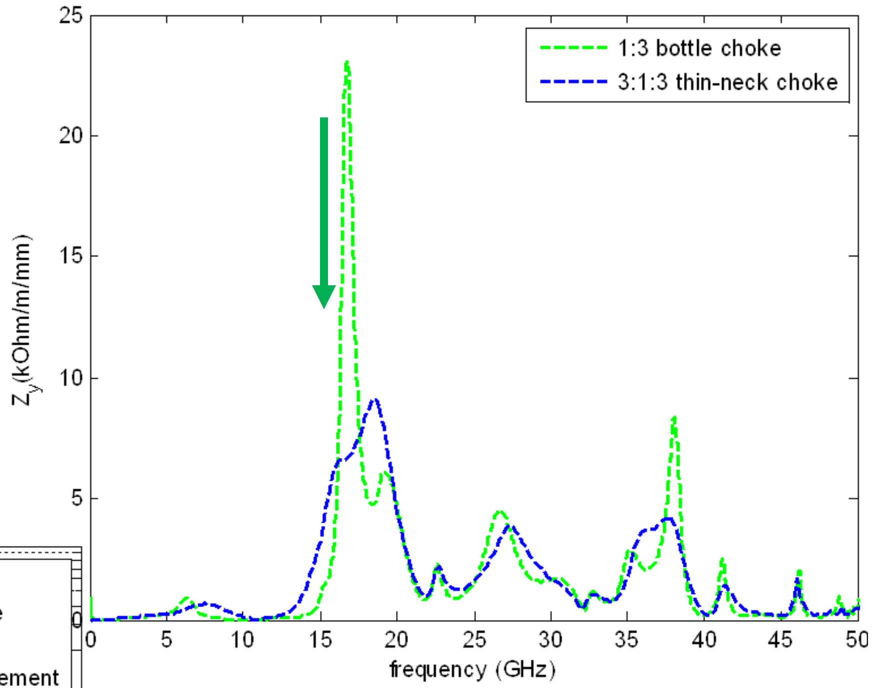
Thin-neck choke

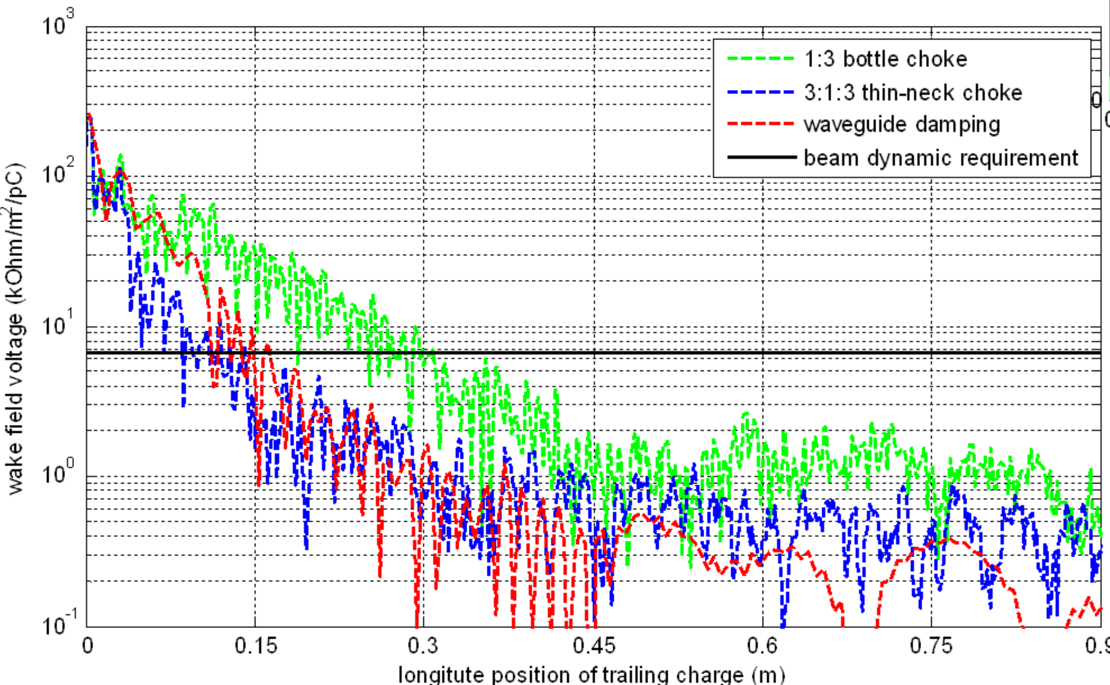
- Narrow the gap at bottom of choke, it can be equivalent as 1:N impedance transformer. The reactance of HOM will be reduced.



Wakefield results

3:1:3 thin-neck choke will reduce the Q of first dipole and also other modes. So the wakefield potential is very low.

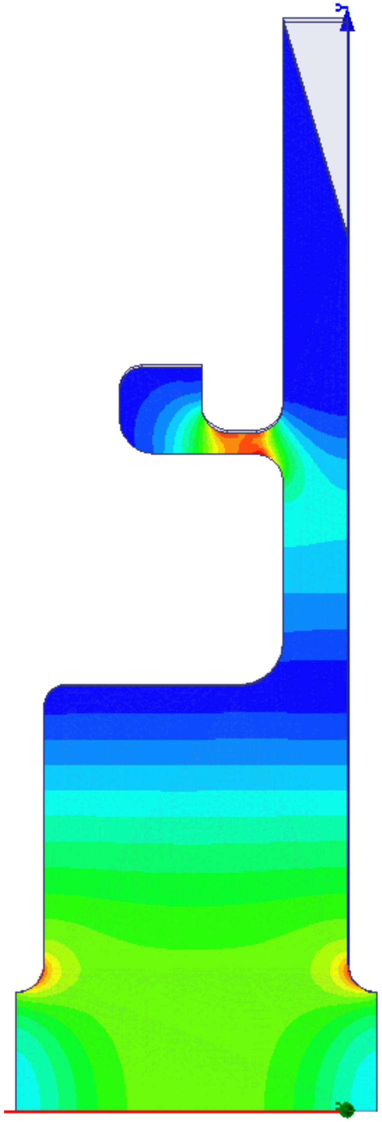




s	0.15	0.30
1:3 bottle	30.4	5.4
3:1:3 thin-neck	1.5	0.8
WDS	5.2	1.5

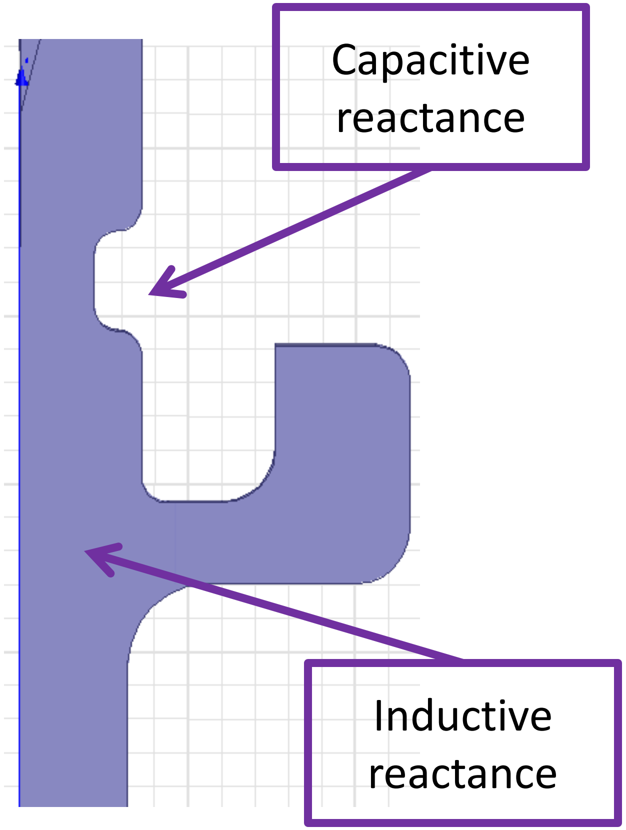
Surface field in choke v.s. Gap ratio

- The surface field of thin-neck choke was very high.
- For 3:1:3 thin-neck choke, the maximum E-field at choke is about 1.2 times as at iris.
- maximum field ~280MV/m
- The thin-neck ratio could not be very big.
- We choose 1.6:1.2:2 thin-neck choke:
  - Frequency of 2nd fully reflection is 41GHz
  - Max surface E-field at choke is 115MV/m (unloaded middle cell).



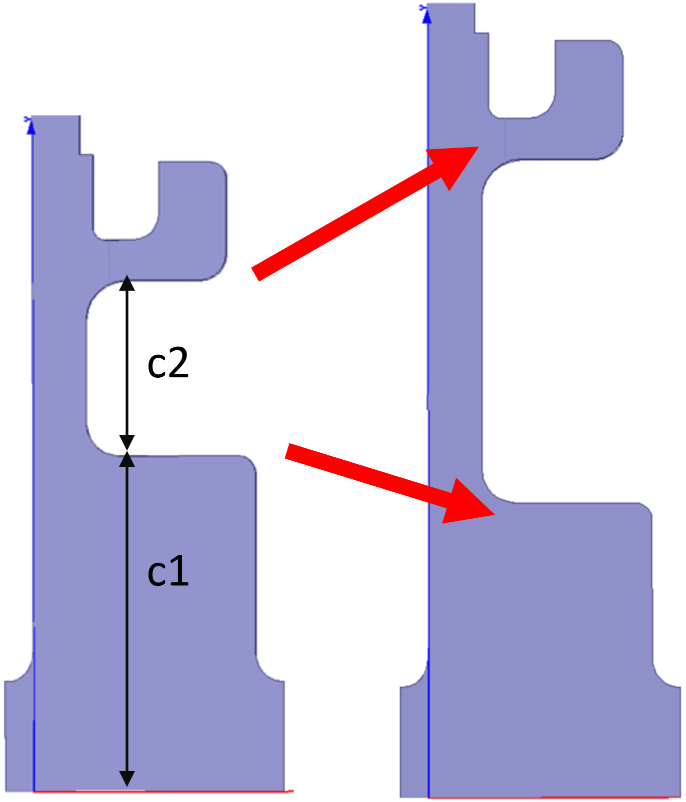
Impedance match & detuning

- Impedance match: use a step to reduce the capacitance of first dipole.
- Size of radial part is changed to detune the first two dipole modes. Frequency separation at 3GHz

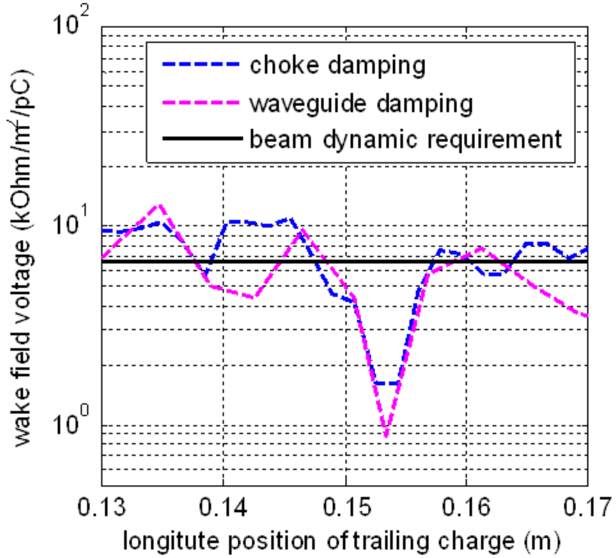


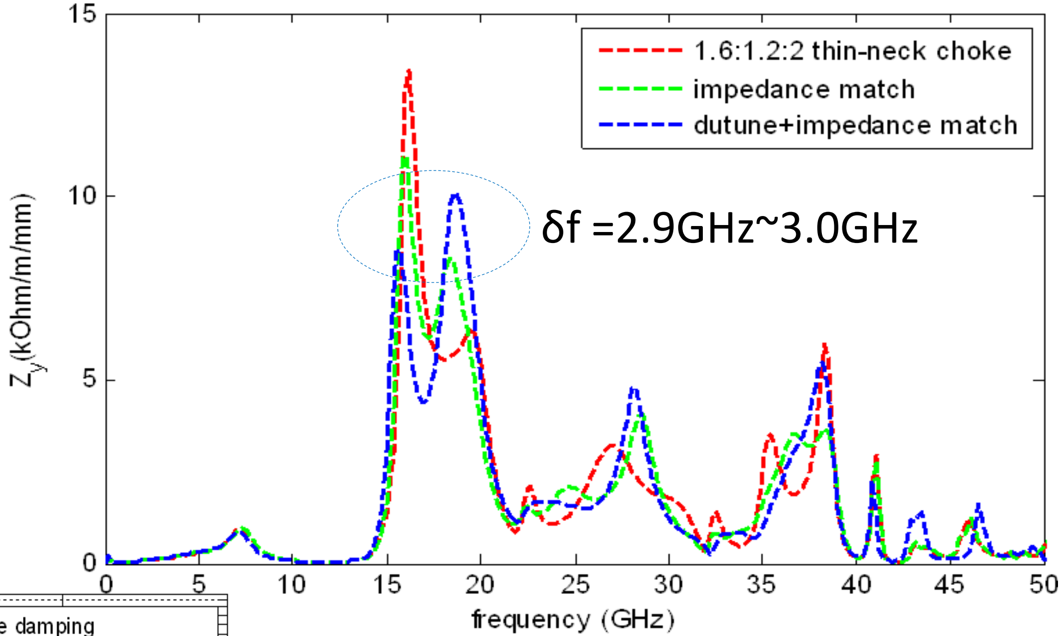
Capacitive reactance

Inductive reactance

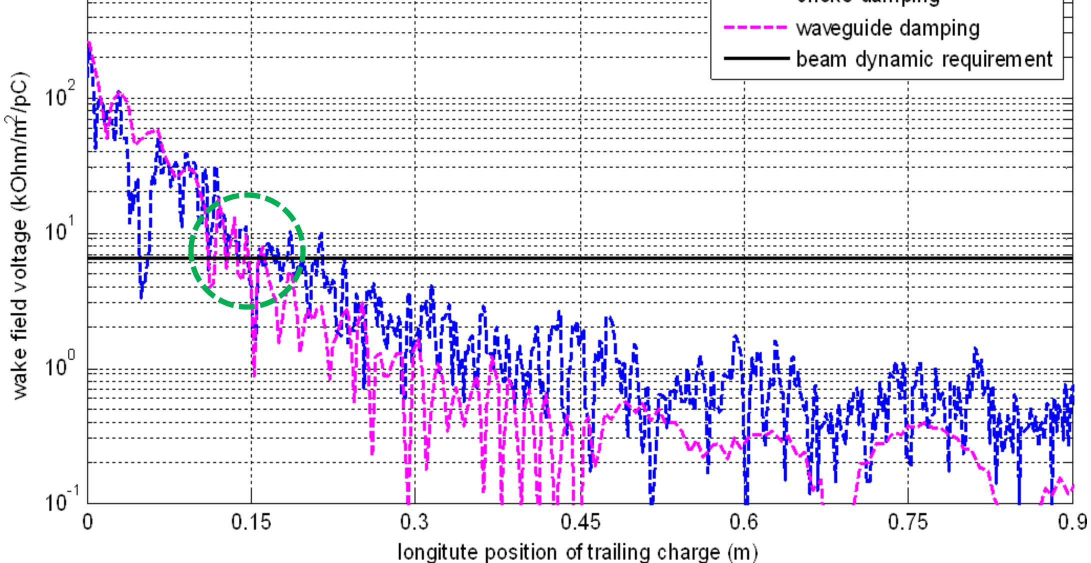


Wakefield results





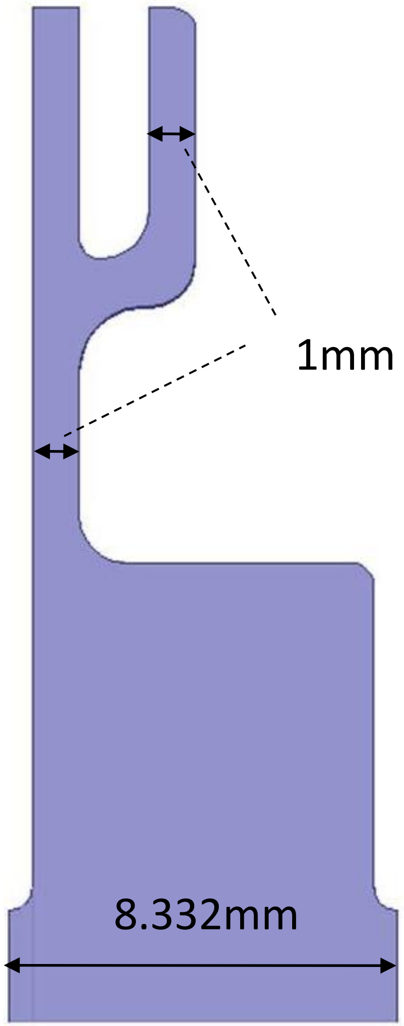
δf =2.9GHz~3.0GHz



s	0.15	0.30
CDS	4.1	1.7
WDS	5.2	1.5

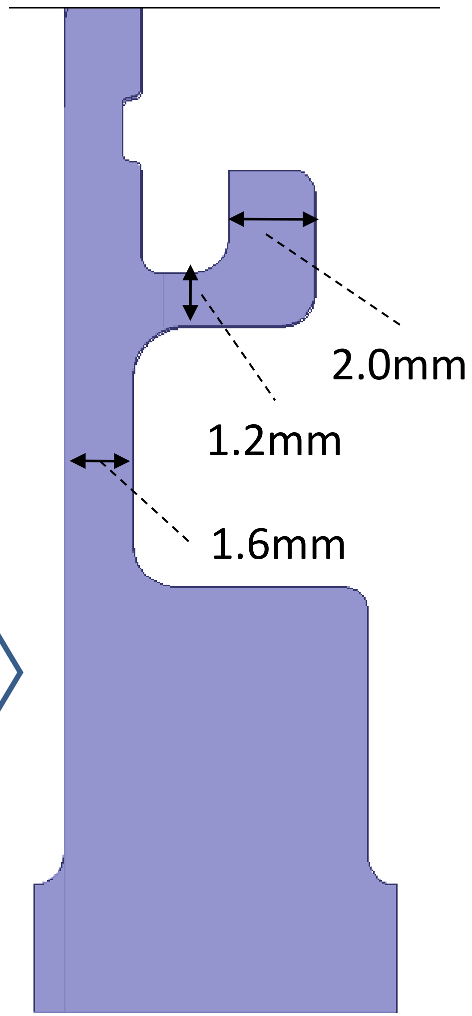
Baseline design (CDS-C)

CDS-A

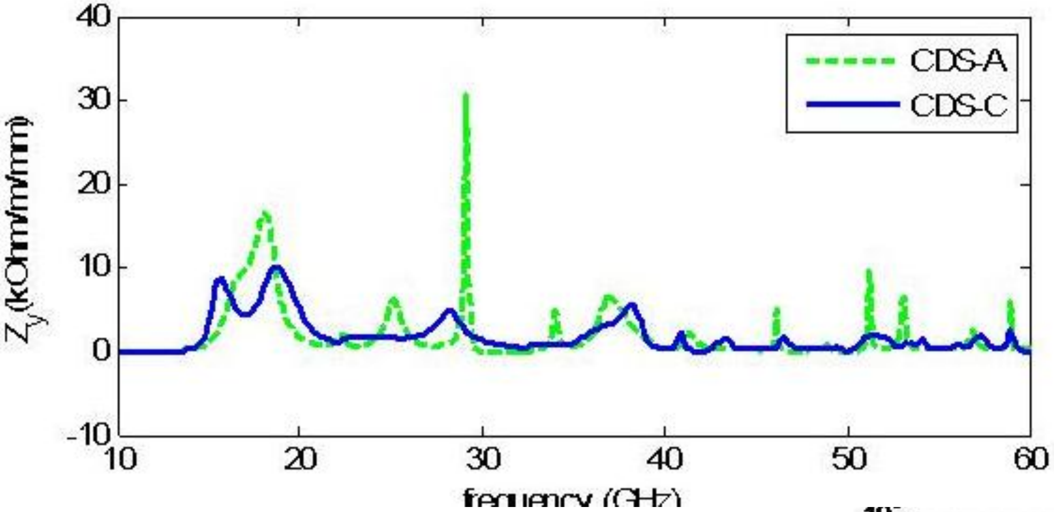


1. Choke with two sections
2. Narrower gap for the choke
3. Impedance match
4. Detune first pass-band dipoles modes.

CDS-C

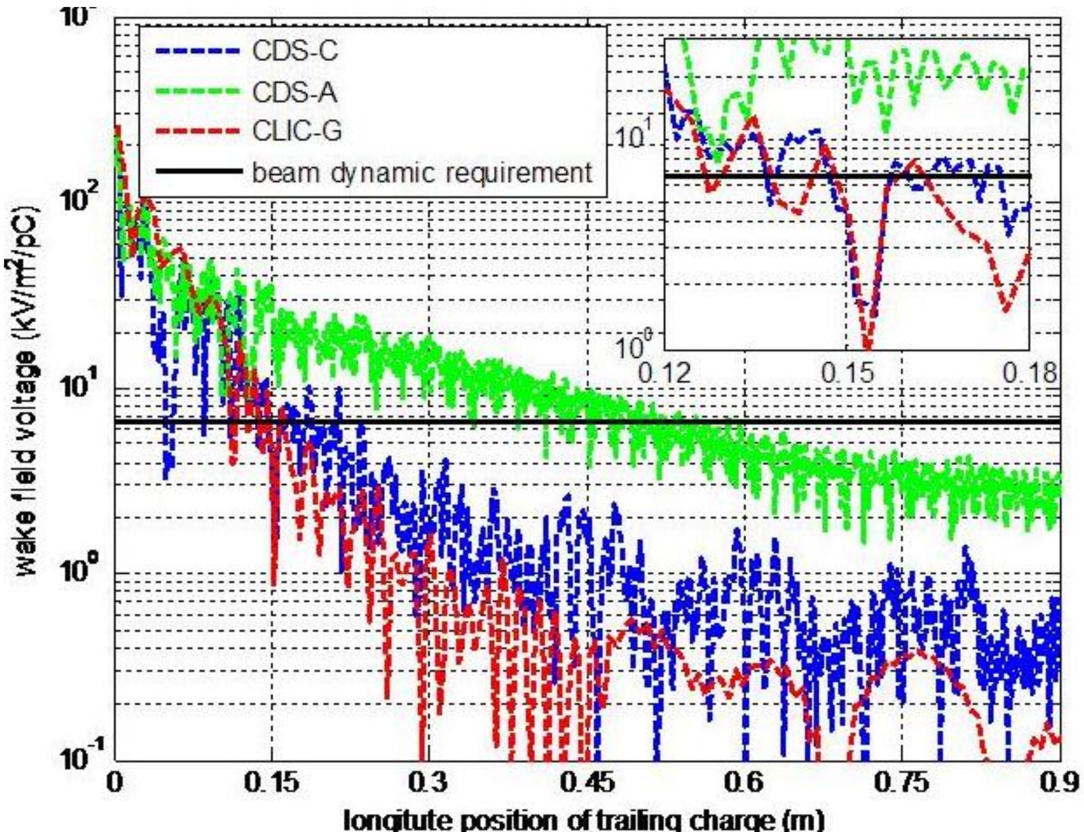


Wakefield simulation (using Gdfidl)

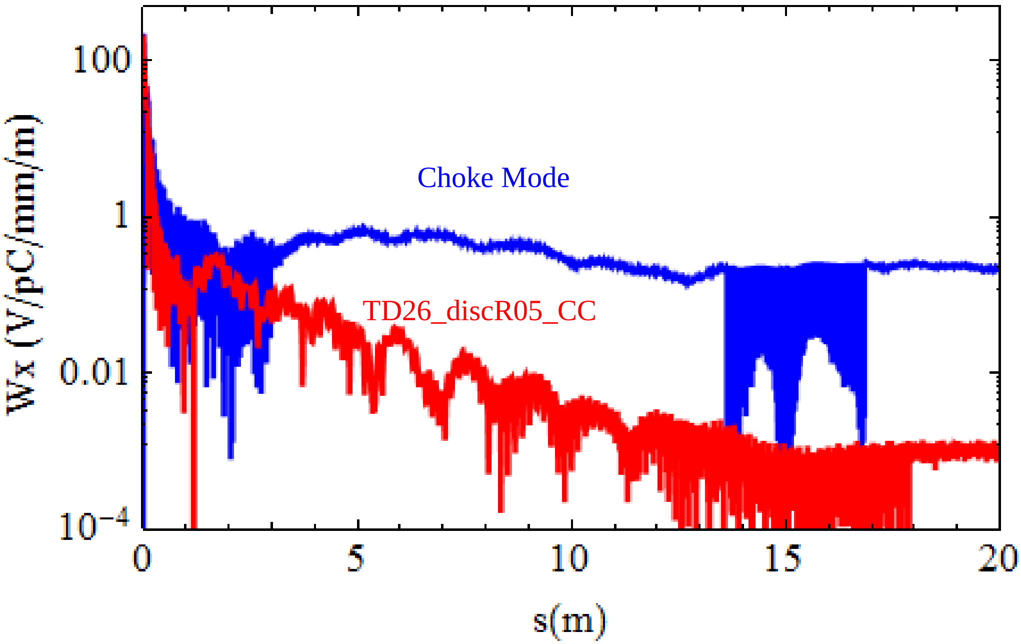


	s=0.15m
Beam dynamic	< 6.6
CLIC-G	~5
CDS-A	~25
CDS-C	~4.5

Freq(GHz)	Q	(R/Q)⊥
15.7	5.4	80.3
18.6	6.9	63.2
23.7	3.8	14.8
28.4	12.4	10.9
38.2	11.6	9.9



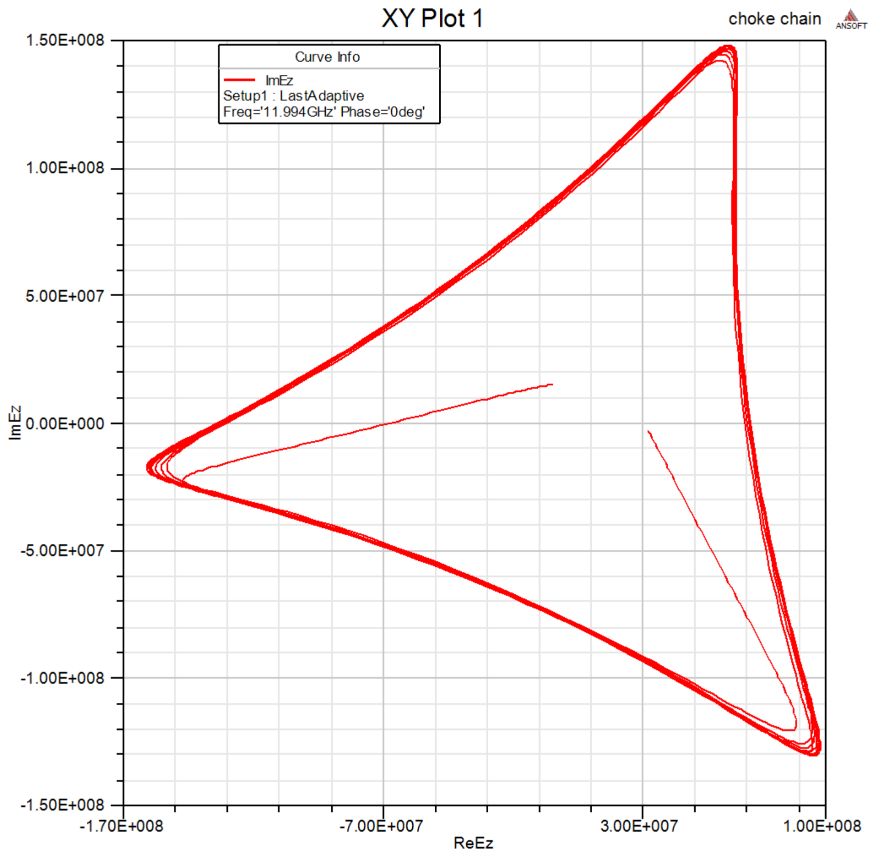
Long distance simulation

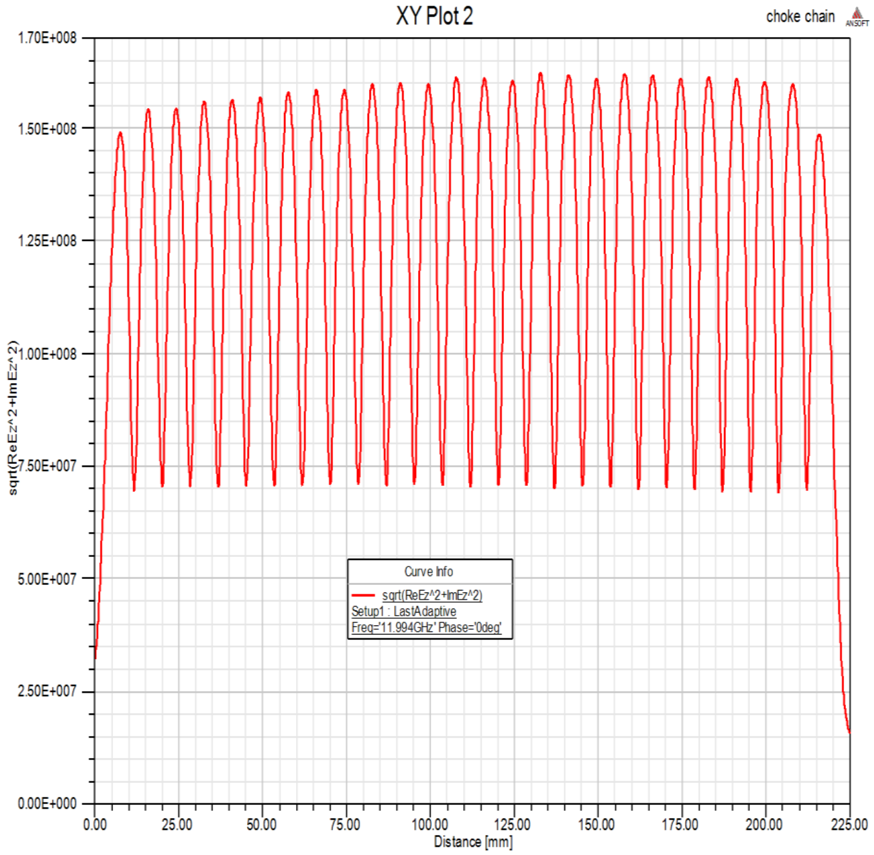


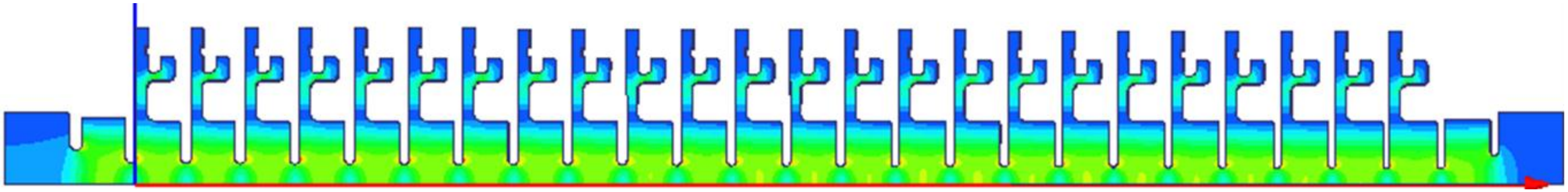
- Multiple bunch effect
- Mode with extremely high Q
- FFT shows frequency at ~55GHz
- Numerical? Refine mesh
- Mode detune

Courtesy Vasim Khan

CDS-C (TD24-Choke)





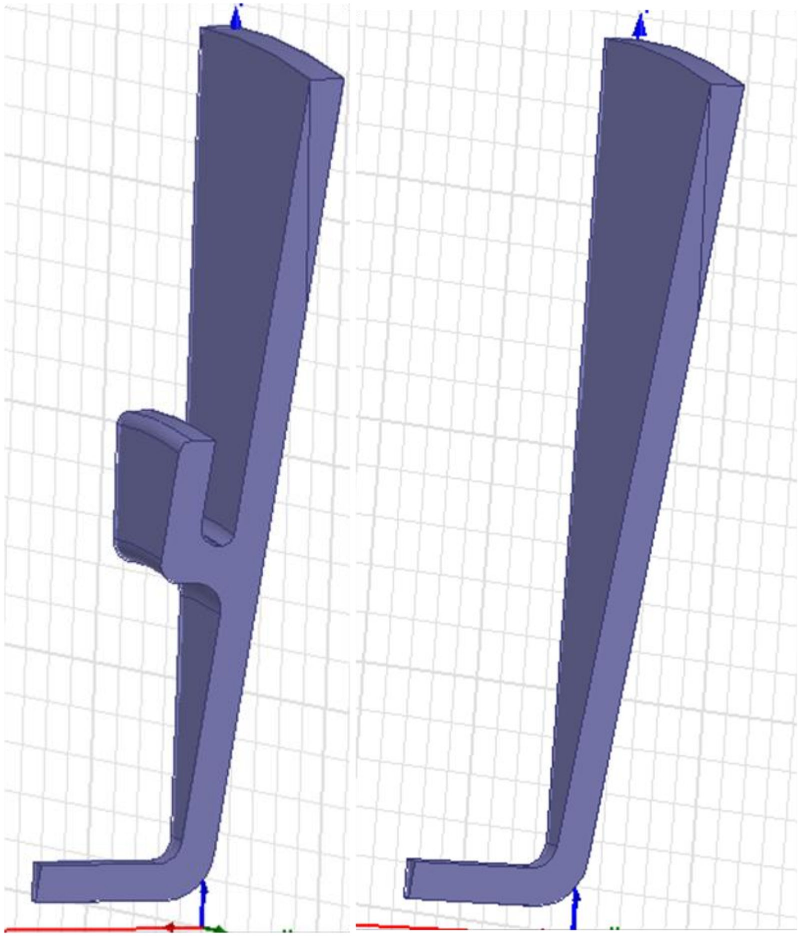


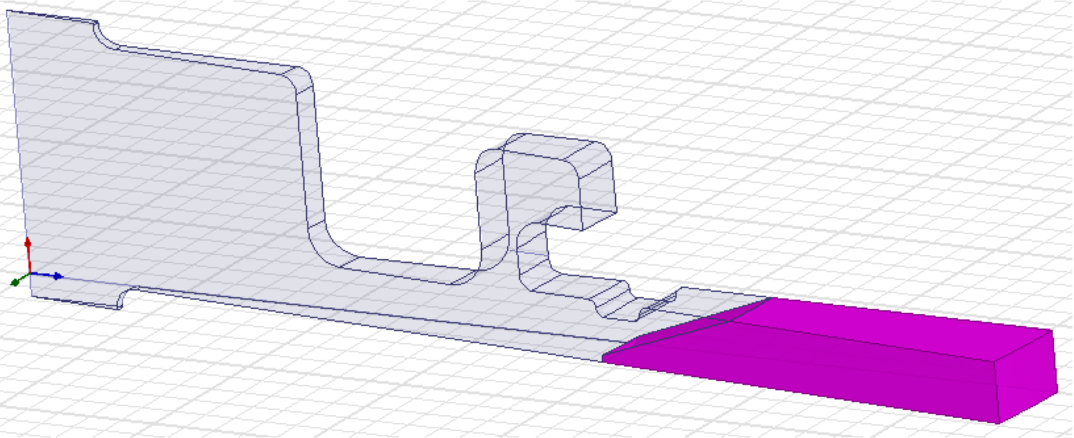
Comparison with CLIC-G

	CDS-C	**CLIC-G**
Iris aperture (mm)	3.15, 2.35	3.15, 2.35
Q-factor (Copper)	4895, 5385	5538, 5738
Shunt impedance (MΩ/*m*)	59, 83	81, 103
Group velocity (%c)	1.38, 0.73	1.65, 0.83
Max surface E-field (MV/m)	245	235
Max Sc (MW/mm^2)	5.66	5.39
Max temperature rise (K)	23.0	47.5
Peak input power (MW)	67.5	60.5
Filling time	75.4	64.8
RF-to-beam efficiency	24.7%	27.5%

Load design and RF model

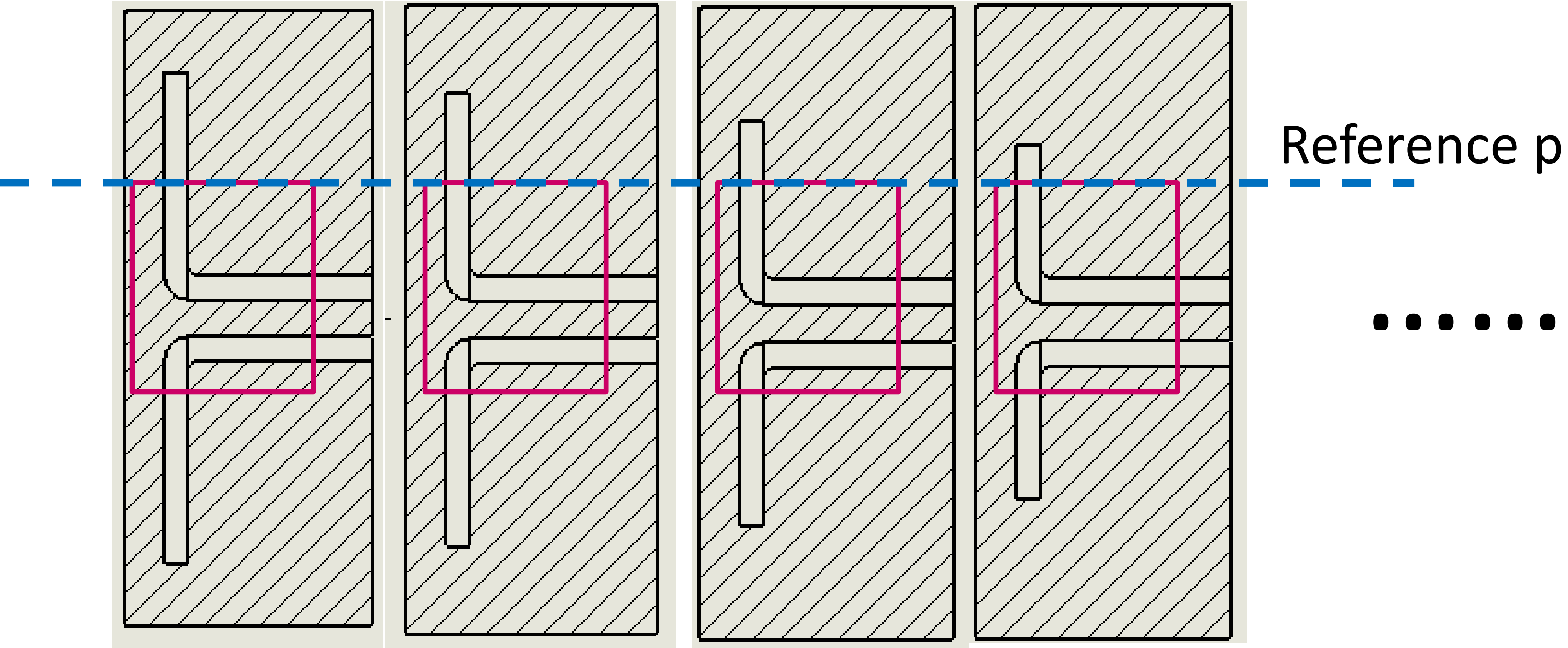
- Load design.
- RF measurement
  - To verify load design and assembly
  - To verify absorption curve of choke design





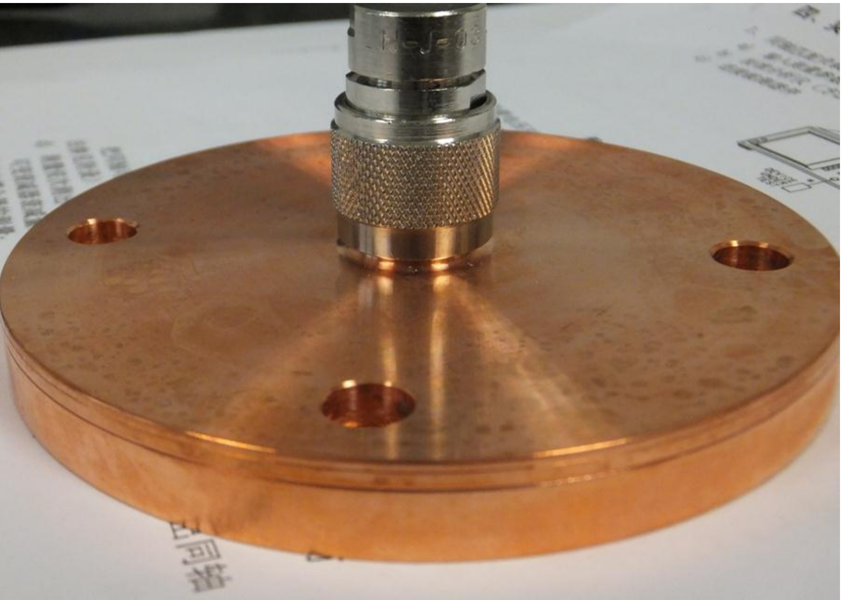
Multi-offset calibration

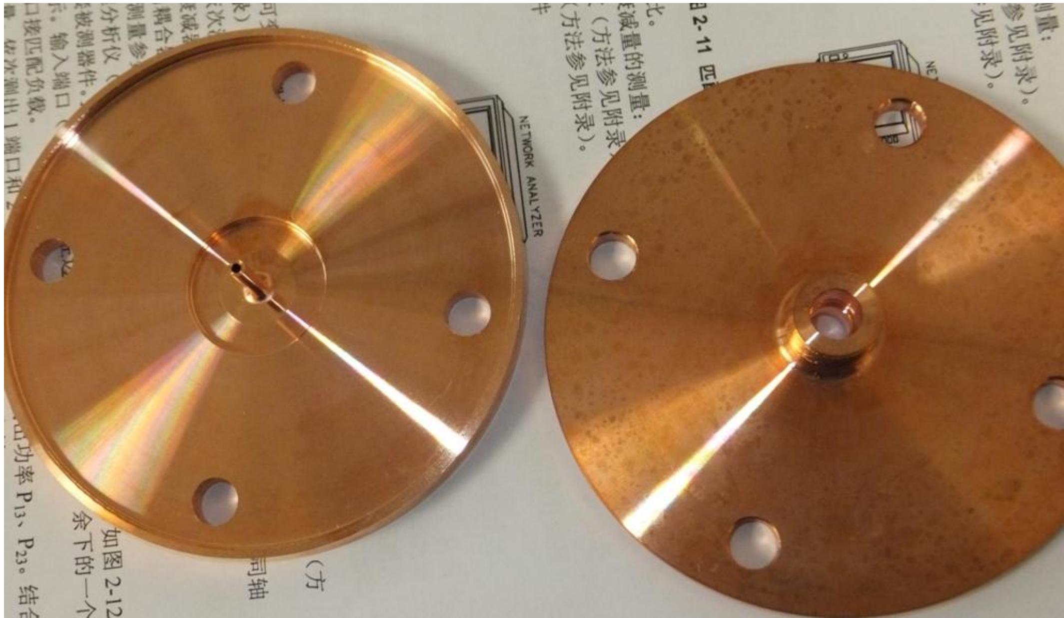
- Use short load with different radius to calibrate
- Define the red box as the 2-ports network, the reflection of each load at the plane A is difference.



Radial line to coaxial line

- We had made 10 radial short loads for the calibration. (h=1.8mm, R=12mm~32mm)
- The reflection of choke test structures could also be calibrated in this way.





Summary of choke-mode study

- transmission line used to study the reflection of the choke, with smith chart
- Simple model in HFSS
  - Fast simulation for optimization
  - also possible for a prototype to do RF measurement
- Choke mode damping with comparable result to waveguide damping

- RF parameters promising for a real structure design

Ongoing Works and Plans

- High Power prototype TD24-CHOKE
  - Breakdown in choke?
- RF design
  - machine parameter optimization.
  - RF Load with damping material
- RF measurement
  - Model with coaxial line and damping material to verify the absorption of choke
- Wakefield measurement
  - FACET at SLAC with positron/electron beam
  - AWA at Argonne
  - Other possibilities

Thank you!