Status of the RF Accelerating Cavity for the Damping Ring (DR)

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For SuperKEKB-RF / ARES-Cavity Group

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The 17th KEKB Accelerator Review Meeting

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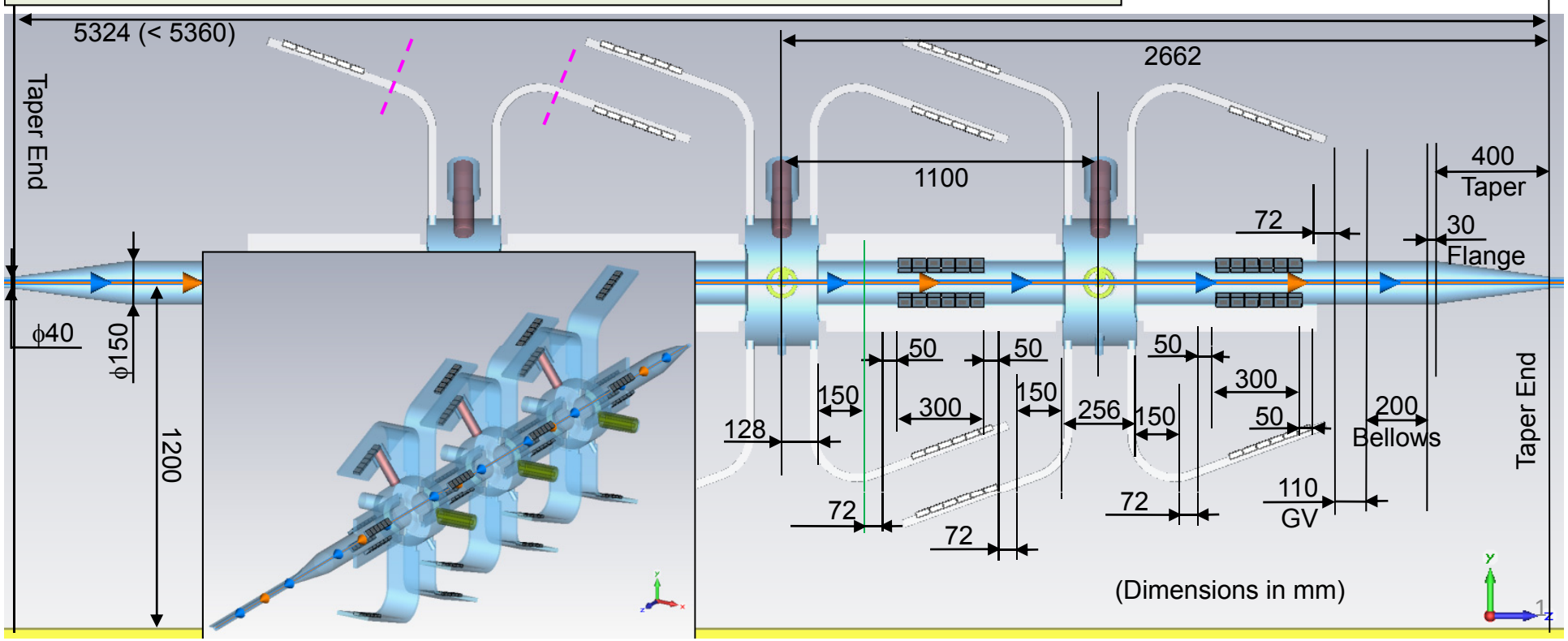
RF Accelerating Structure for the DR

Based on the ARES cavity with the long successful operation at KEKB

1. Accelerating-Mode Frequency: 508.887[MHz] (same as in the Main Ring (MR)
2. Cavity Voltage (spec.): 0.7[MV/cav] (→Wall-loss power: 133kW/cav)
3. Cavity Voltage (challenge): 0.8[MV/cav] (→Wall-loss power: 180kW/cav) → 1MW Klystron to be used
4. Max. stored beam current: 70.8[mA] → Very low compared to (Super)KEKB-MR
5. Grooved Beam Pipe (GBP) Common between cavities
6. Cavity-GBP Joint with a weld-ring gasket (not using a flange)
7. *Multi Single Cell* Structure
8. Reuse of input couplers and tuners proven at KEKB-MR/ARES
9. Good vacuum in cav. (< 10^-6[Pa]) needed for high-power input couplers → Pumping port on each cavity



Specification of the Vc and Wall Loss of the DR Cavity

Based on the results of the HPT of the ARES Prototype performed in the KEK/AR Tunnel (1997)

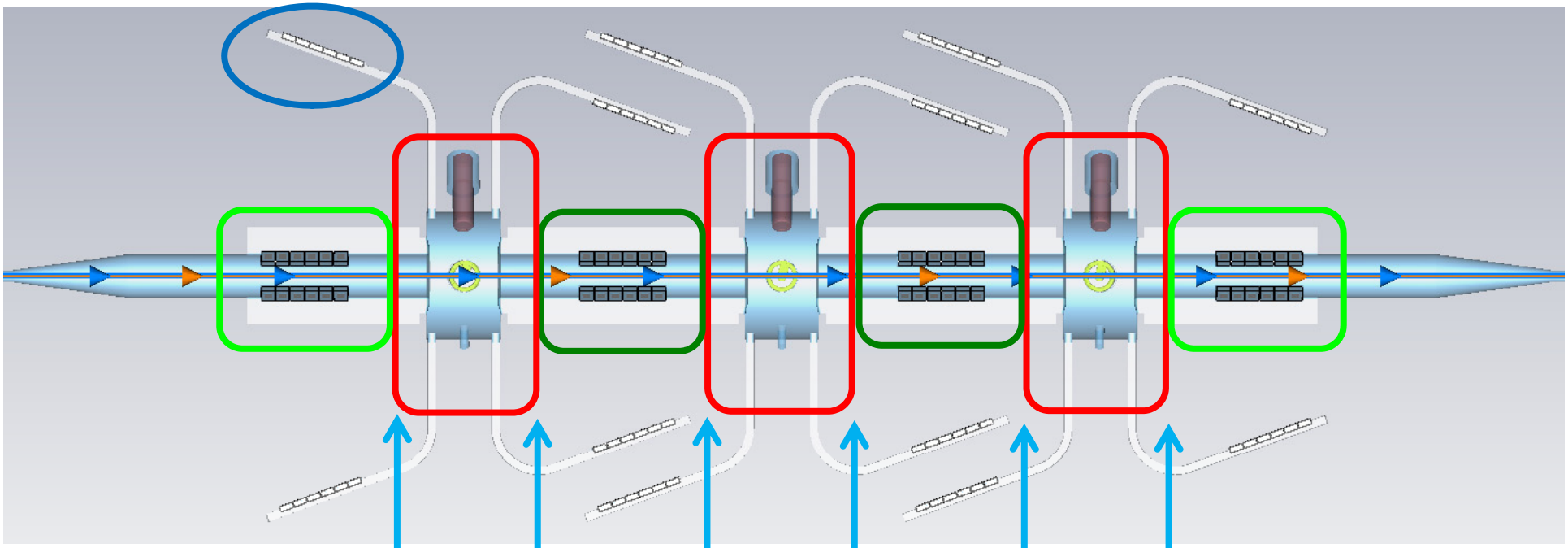
	Vc [MV/cav]	Wall Loss Power [kW]	Wall Temperature (calc.) [degC]
KEKB Design	0.50	60	50
Max. Continuous	**0.70**	133	74
Max. Instantaneous	0.82	193	94

(Appendix A)

Note: The DR cavity has been designed with the same basic structure as the ARES/A-Cav on the basis of its successful experiences. (Appendix B)

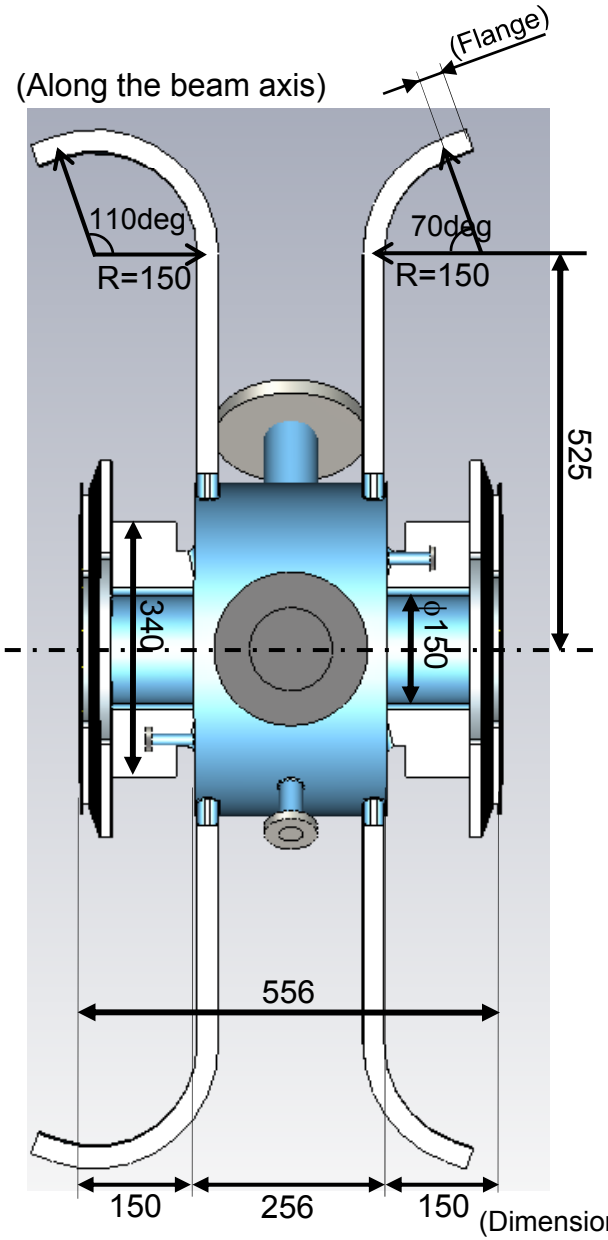
Four Types of Components

1. Cavity (main body)
2. HOM(Higher-Order-Mode)-WG(WaveGuide) load
3. GBP (btwn)
4. GBP (end)



Joint:
- ◆Welding for vacuum sealing
- ◆RF shield inside

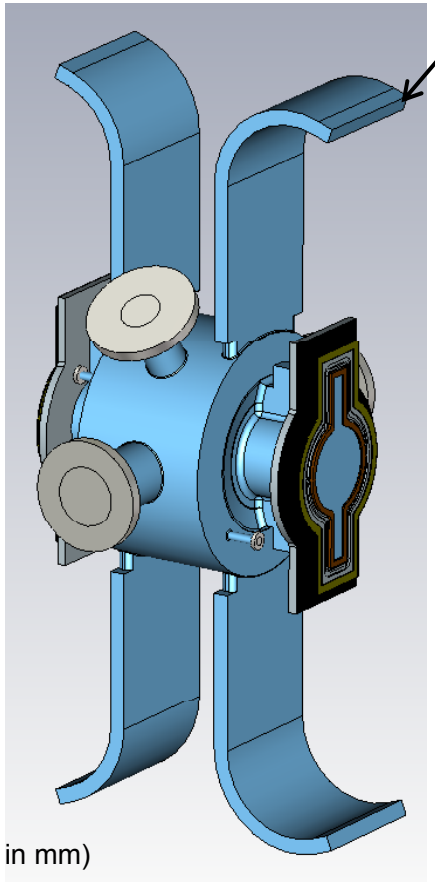
1. Cavity (main body)

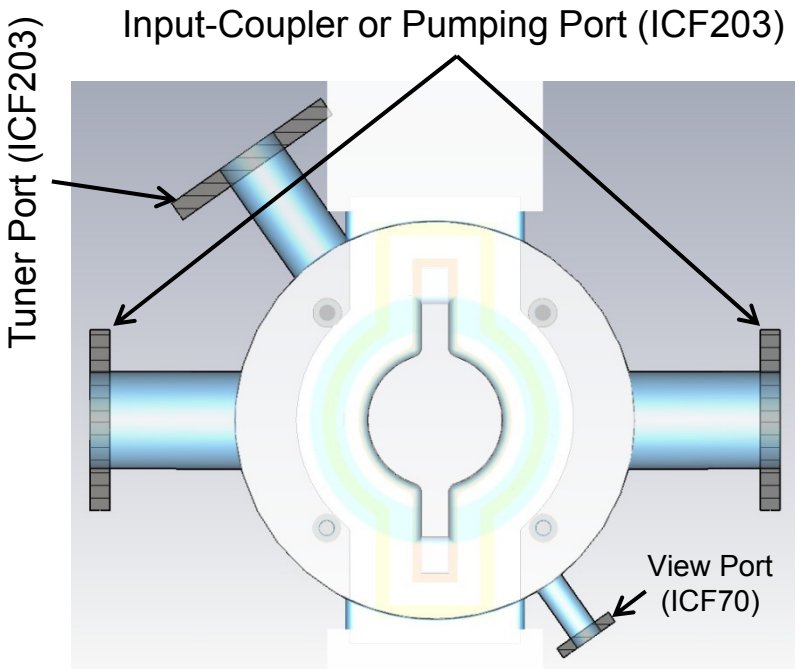


(Dimensions in mm)

- ✓Material: Highly-Pure Copper (C1011-C1)
  except for the ports, GBPs, and HOM-WGs
- ✓Mirror symmetry except for the E-bends, tuner, and monitor ports.
- ✓Two input-coupler ports, one of which is to be used as a pumping port

Cross-section: 240mm x 28mm

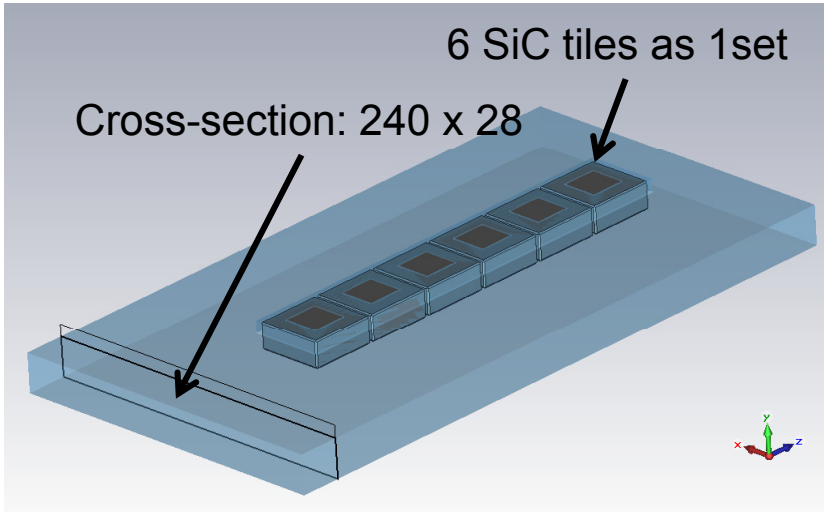


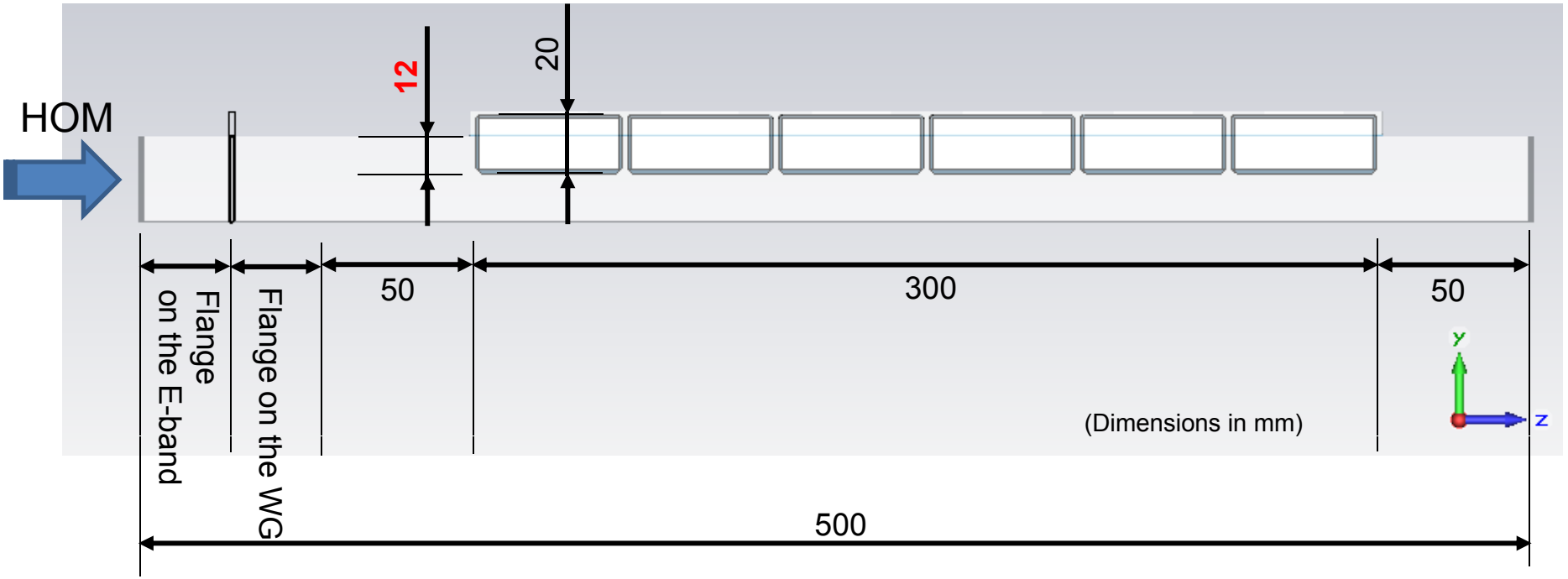


(Cross-section perpendicular to the beam axis)

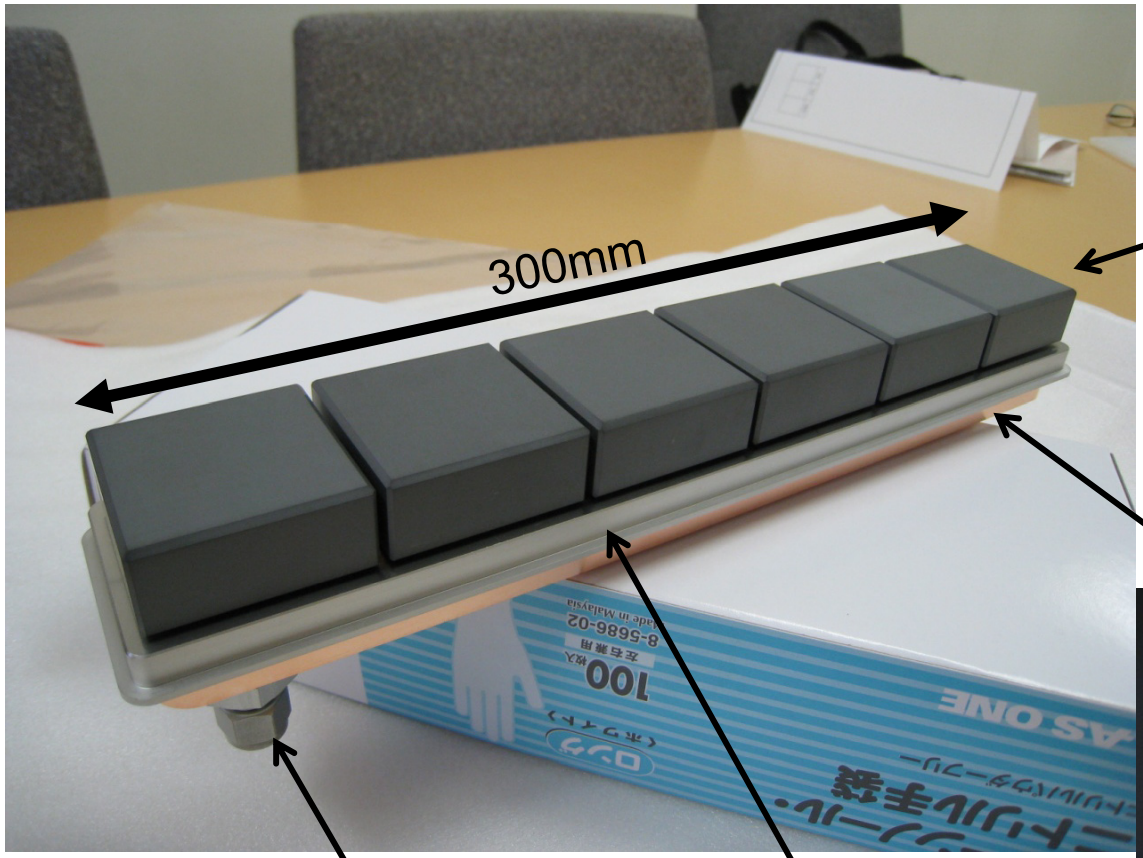
2. HOM-WG Load

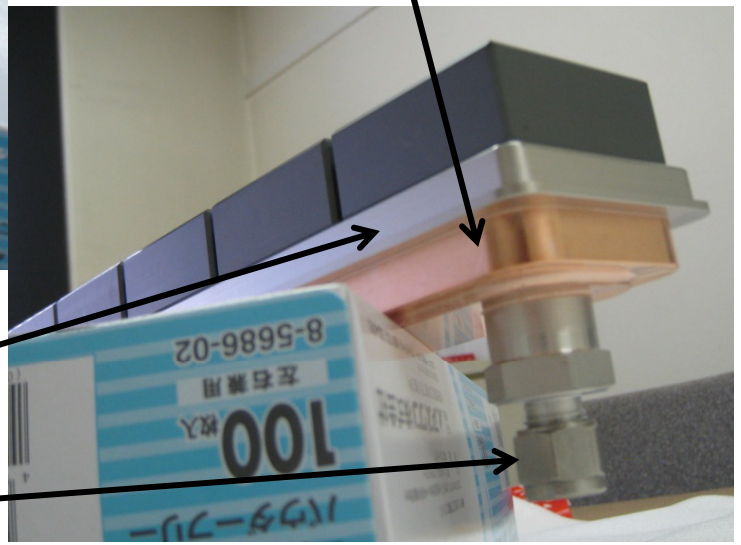
- ✓Material of the WG: SUS
- ✓HOM Absorber: SiC (Silicon Carbide) ceramics
  - •Brazed on a copper plate
  - •Water-cooled via the copper plate
  - •Same as used in the KEKB-MR/ARES
- ✓Power Capability: ~1kW/1set(@1.3GHz)
- ✓Max. HOM Power: ~30W/WG



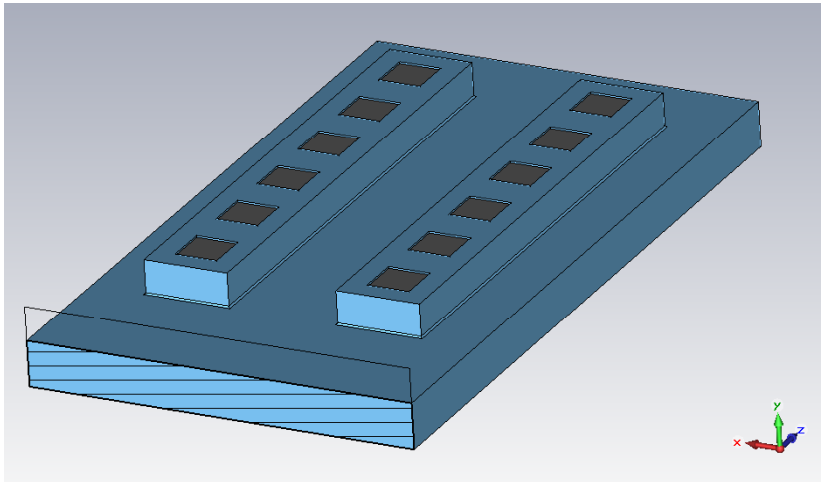


A First Set of SiC Tiles for the DR Cavity/HOM-WG or GBP To be Delivered Soon

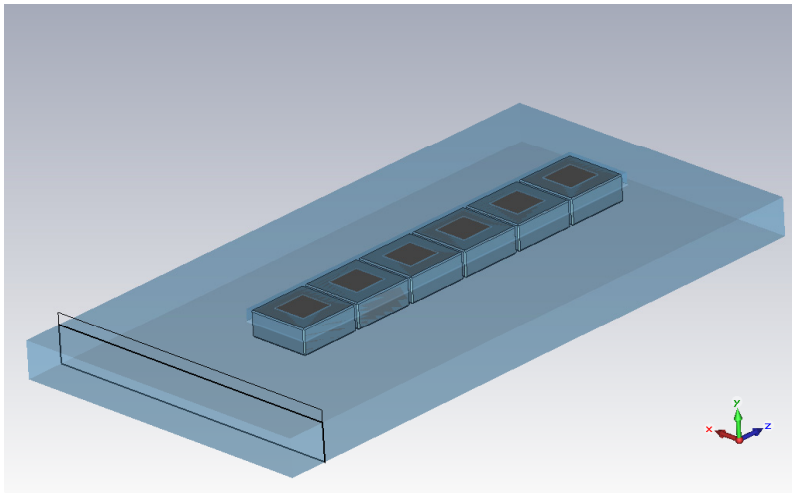


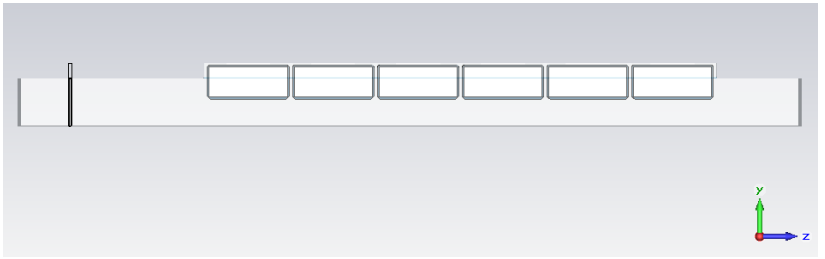


OLD (Shown last year)

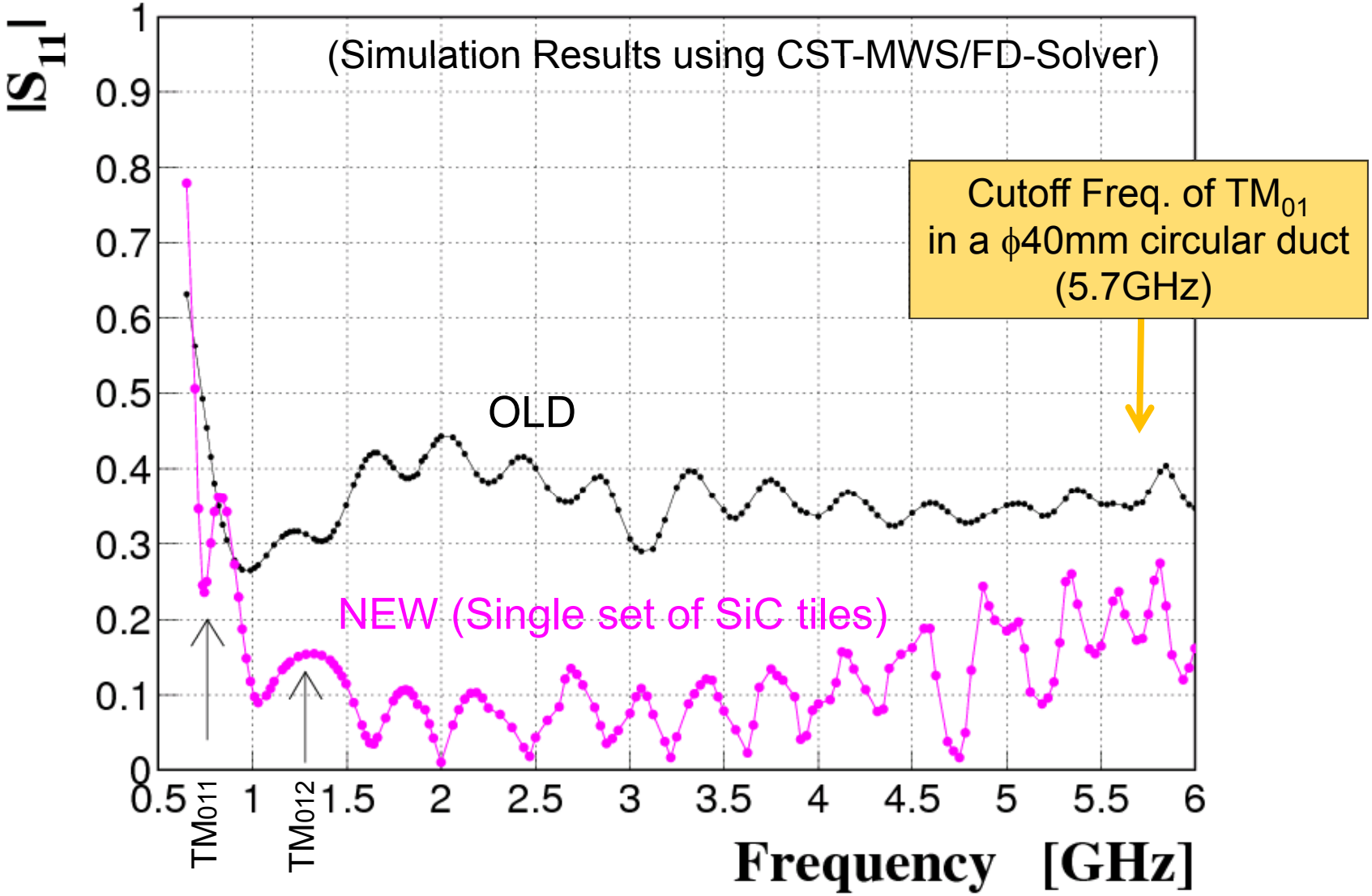


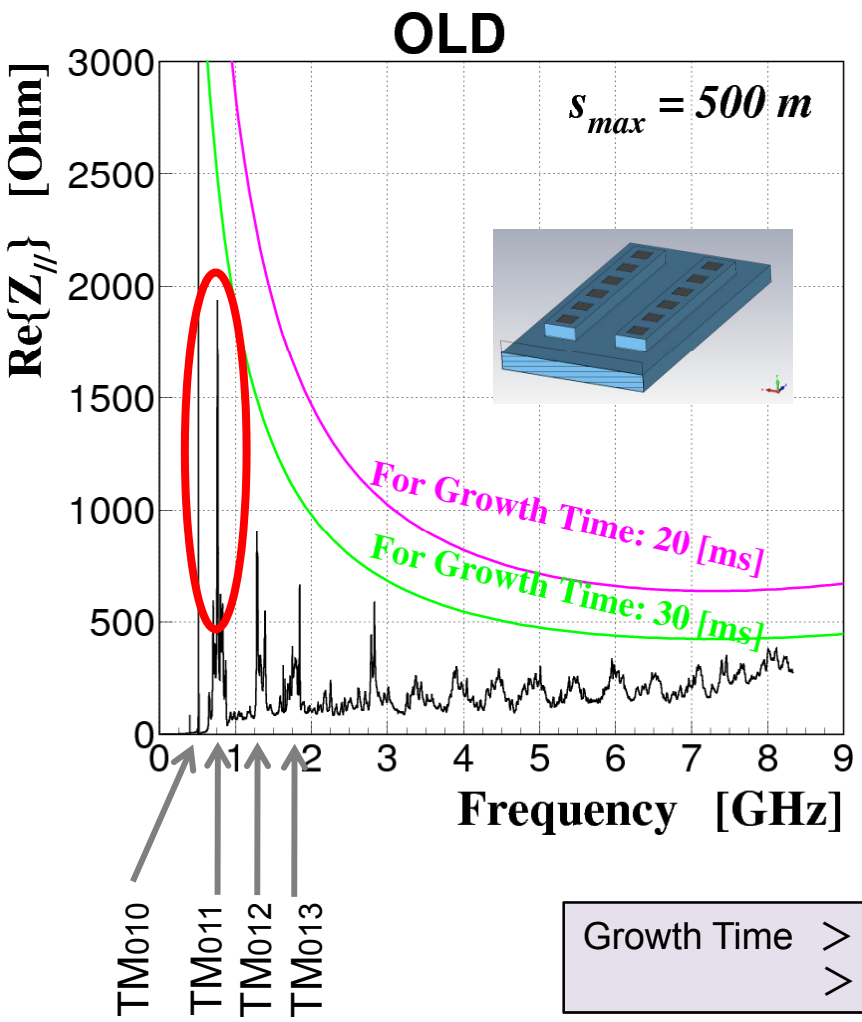
NEW

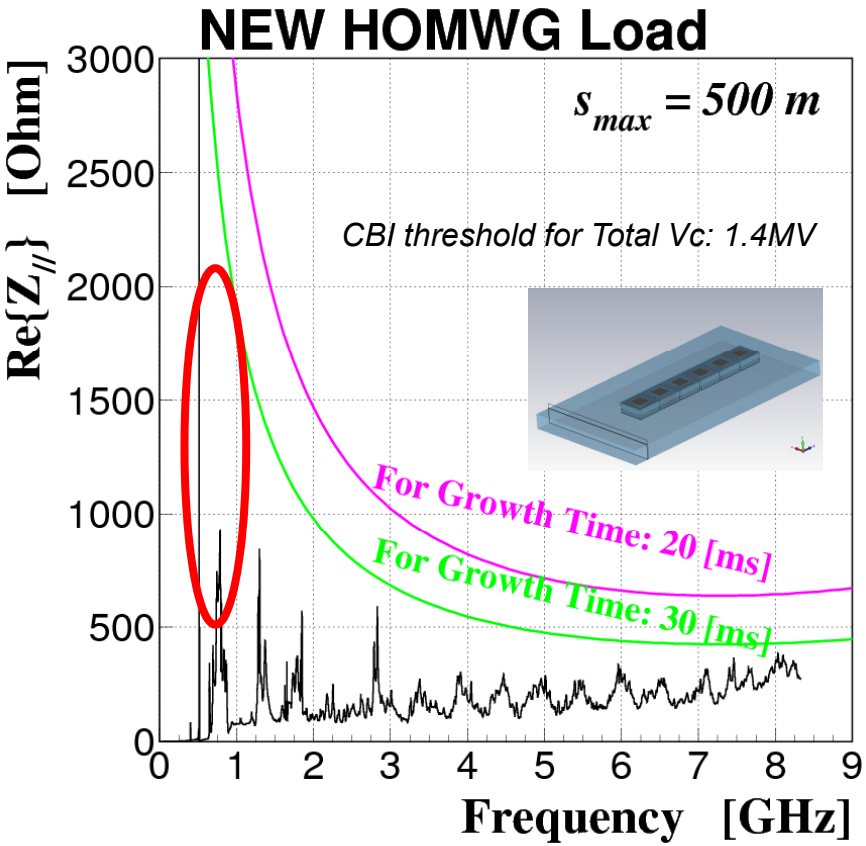




HOM-WG Load Optimized for the Broadband Performance

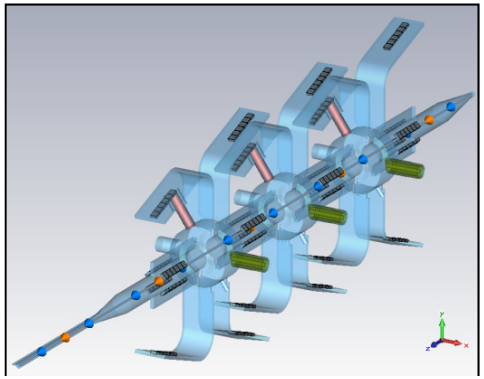


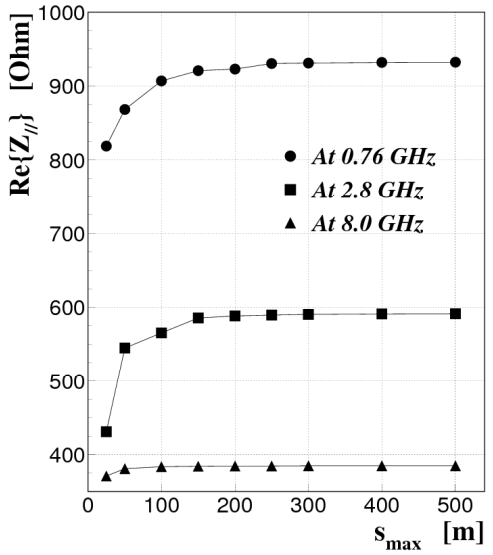




Growth Time > 30ms
> 5ms (rad. damping time)

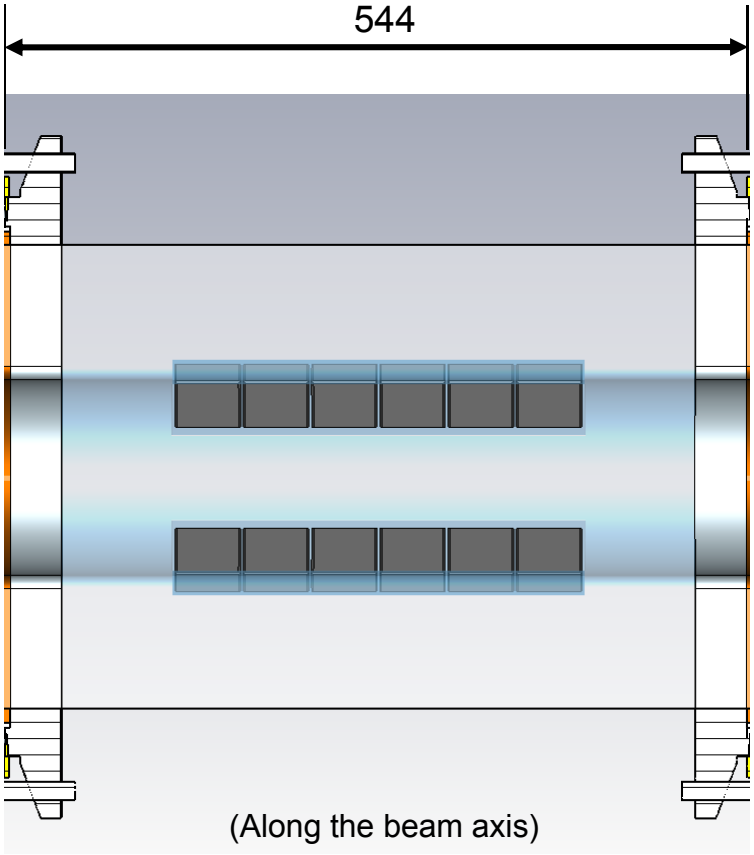
Simulation by GdfidL for



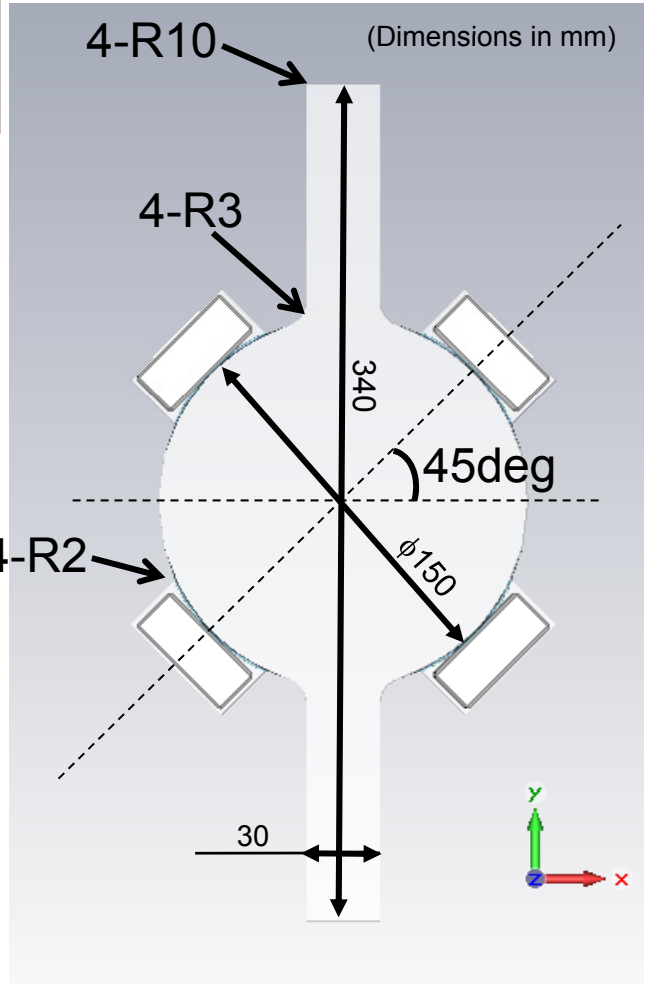


3. GBP (btwn)

- ✓Material: SUS
- ✓4 sets of SiC tiles (same one as used for HOM-WGs)
- ✓Max. HOM + Accl.-mode: ~300W/duct



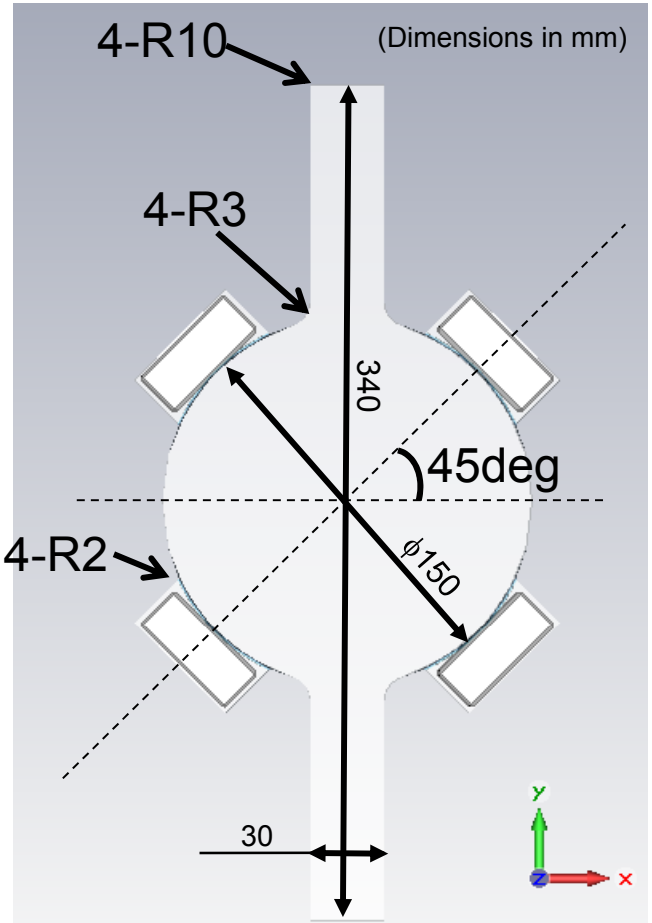
(Along the beam axis)



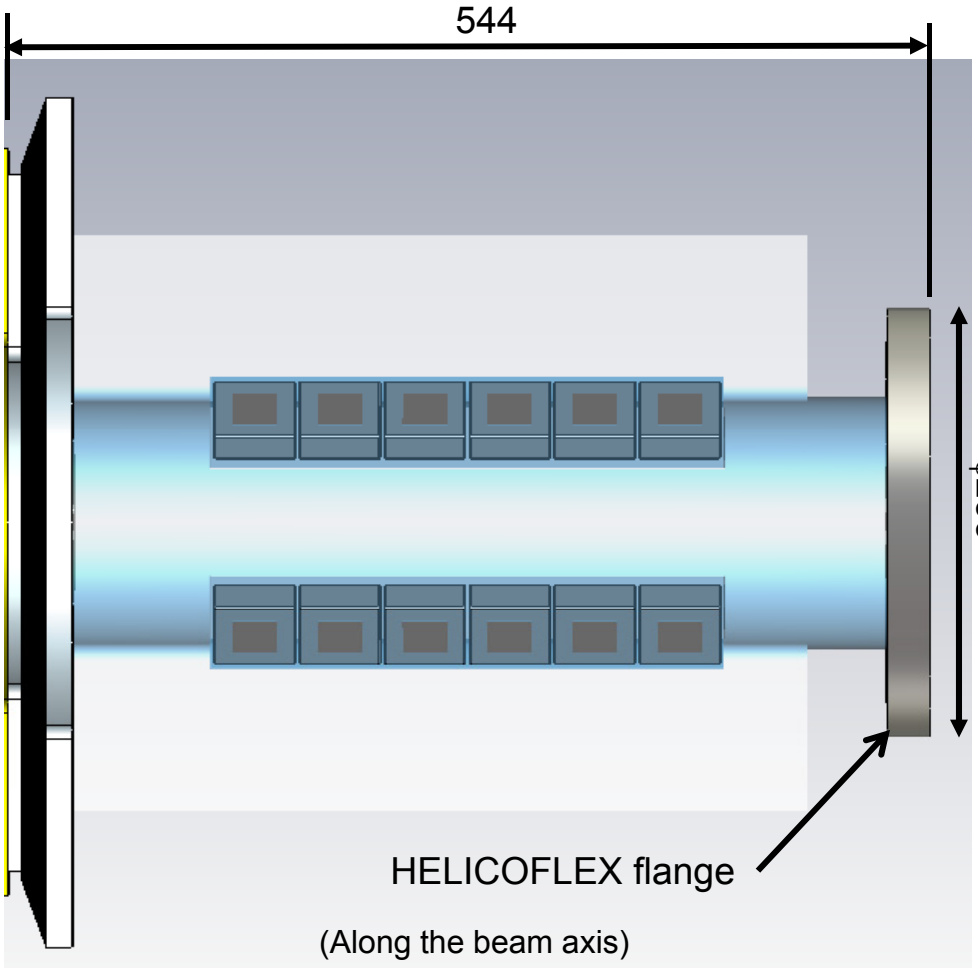
(Cross-section perpendicular to the beam axis)

4. GBP (end)

- ✓Material: SUS
- ✓4 sets of SiC tiles
- ✓Max. HOM + Accl.-mode: ~300W/duct



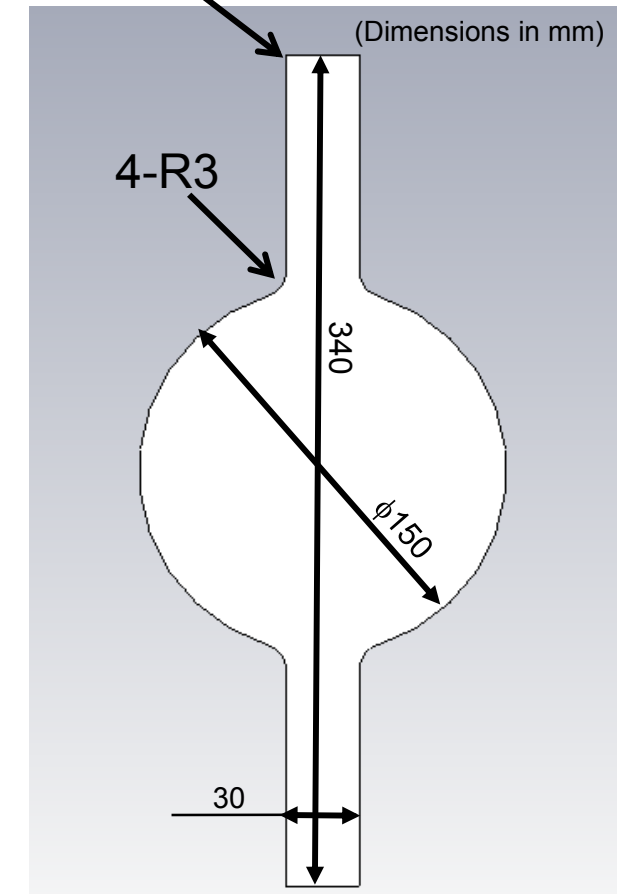
(Cross-section perpendicular to the beam axis)



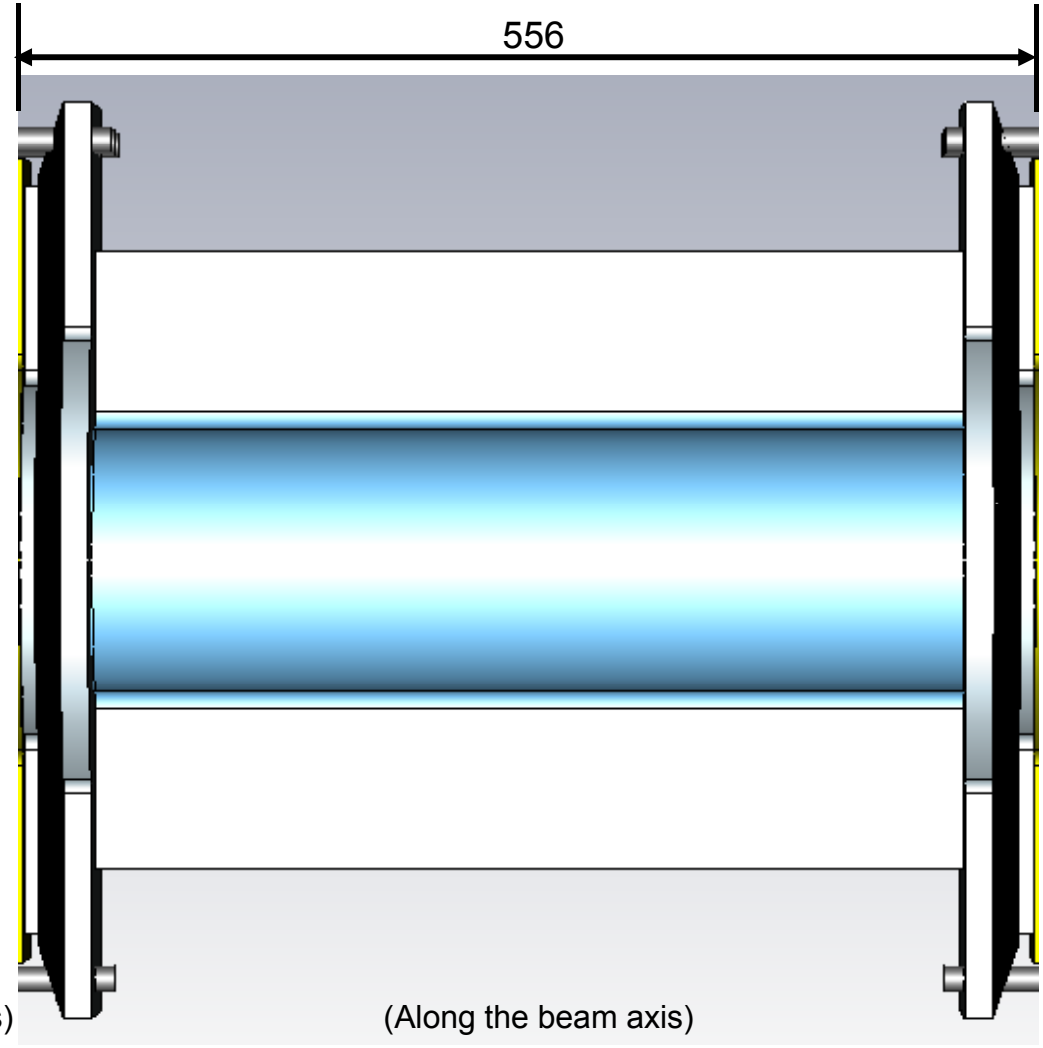
(Along the beam axis)

GBP(dummy)

- ✓Material: SUS
- ✓No HOM absorbers
- ✓To be used for the two-cavity configuration

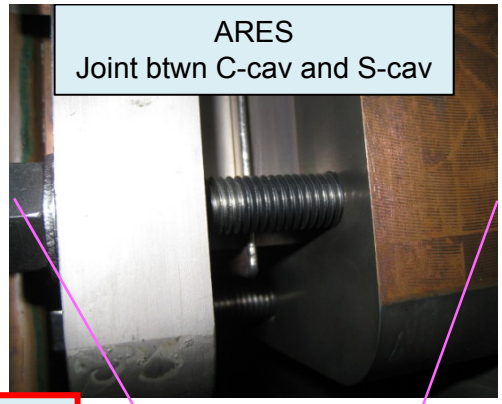


(Cross-section perpendicular to the beam axis)



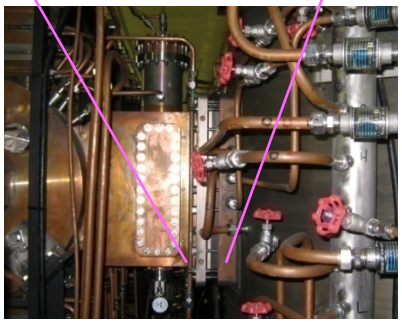
(Along the beam axis)

Cavity-GBP Joint

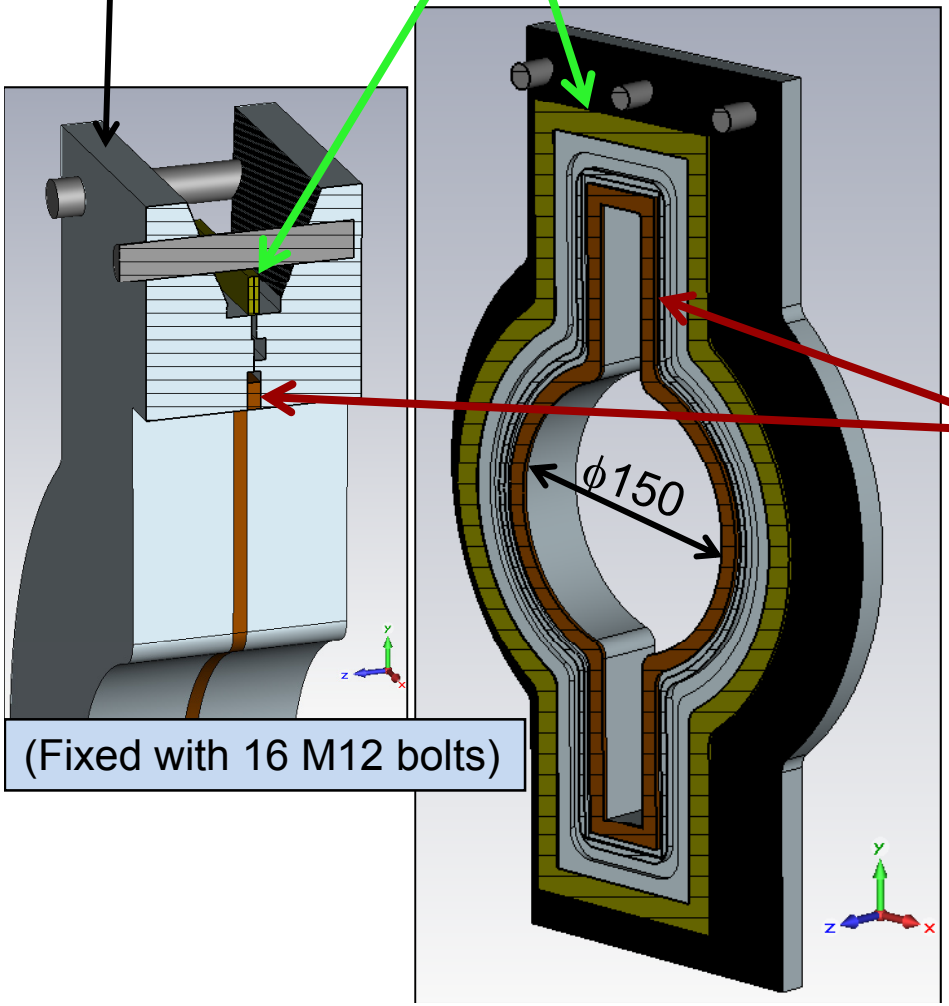


Weld Ring Gasket with Lip Sealing, like:

"Welding → Disassembly
→ ReWelding"
Possible Several Times



SUS



(Fixed with 16 M12 bolts)

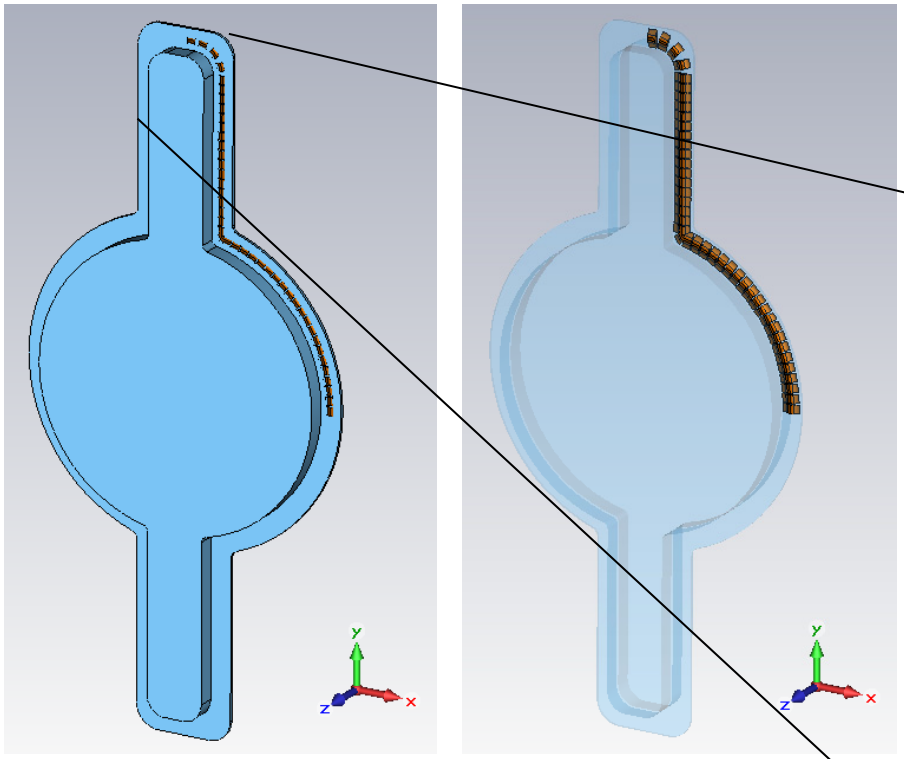
Finger-type RF shield
- Successful experience at KEK/PF:

Single-Bunch-Mode Operation
- Beam current: 70 mA (max.)
- Bunch length: 24 mm

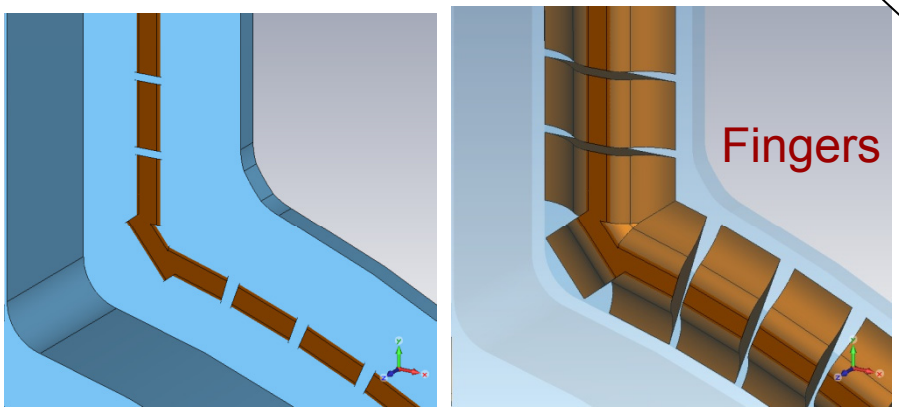
Reasons why we adopted the structure mentioned in the previous slide for the Cavity-GBP joint

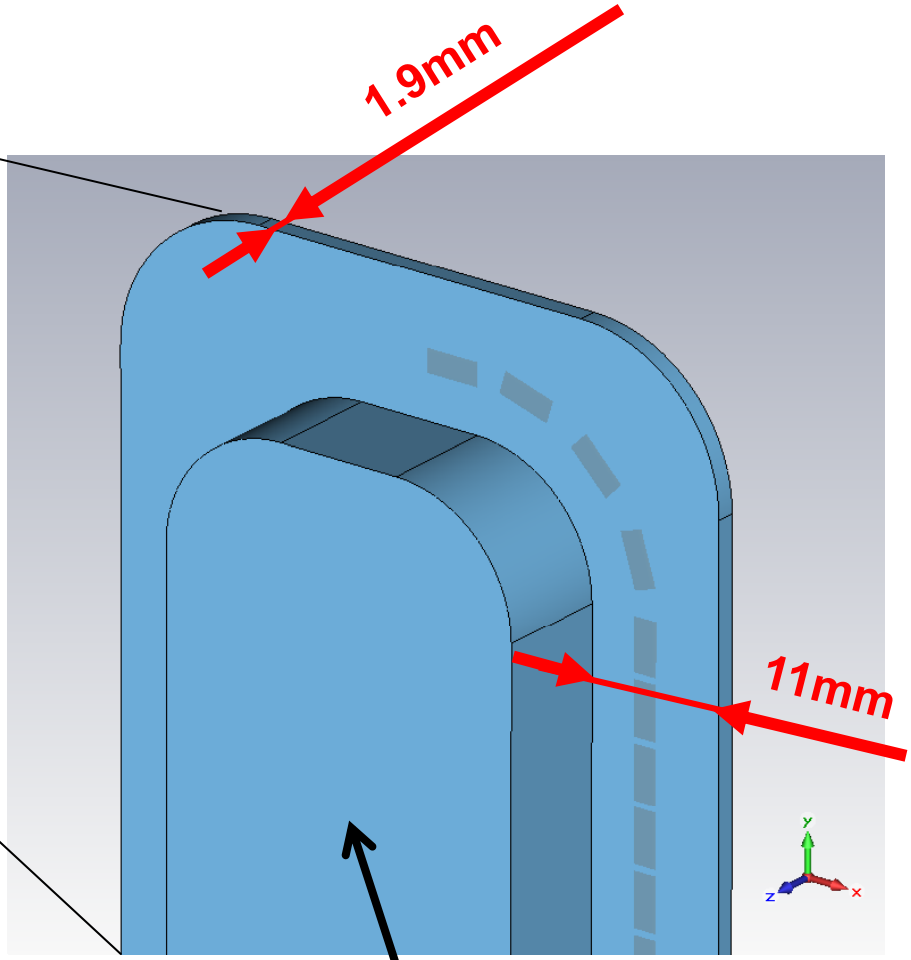
- **Successful experience** at KEKB-MR/ARES (C-cav and S-cav) on **leakproof** vacuum sealing during high power operation with heat deformation of the cavity
- We do not need to disassemble the structure so often. (twice at max. from our experience at KEKB-MR/ARES)
  - "Welding→Disassembly→**ReWelding**" possible 3 times in the spec.
- Finger-type RF shield
  - Measure **against heat deformation** of the cavity during high power operation
  - Should be **safe** for low beam currents, such as the DR.
  - **Successful experience** at KEK/PF.
  - **Negligible** wakefield and HOM heating (see the following slides)

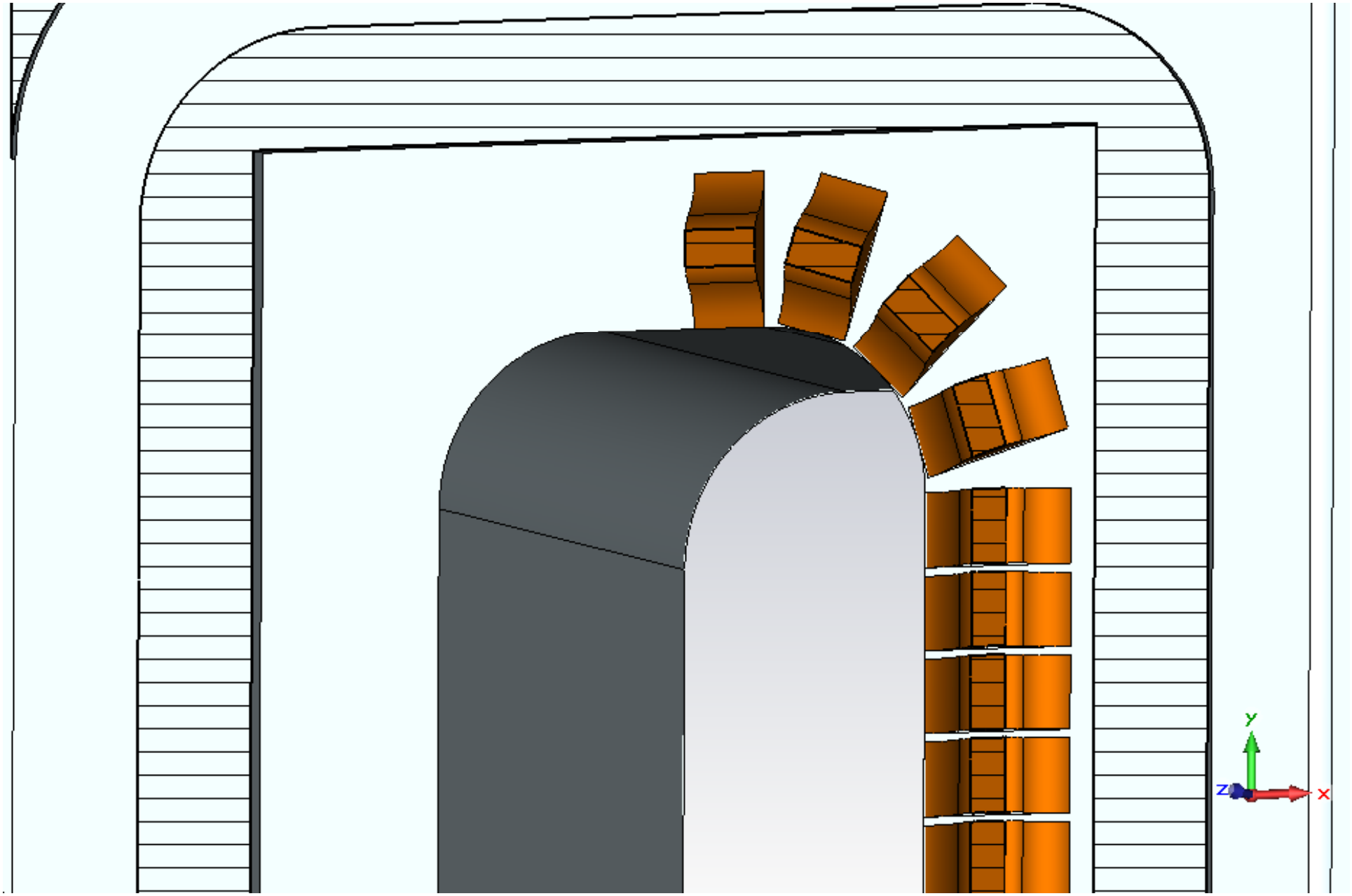
Solid Model of the Cavity-GBP Joint with RF Fingers



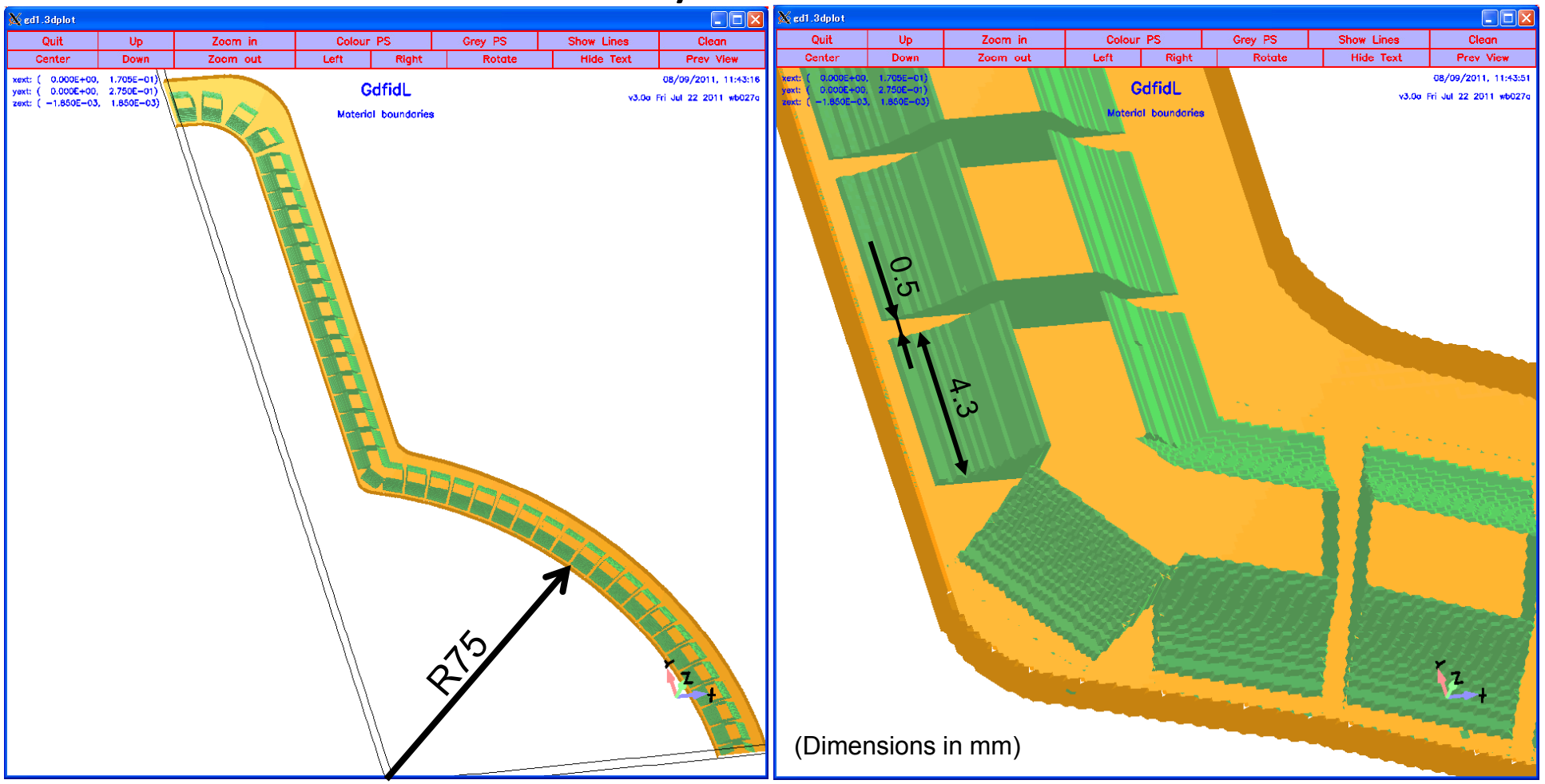
(Created by using CST STUDIO SUITE)






y
z
x

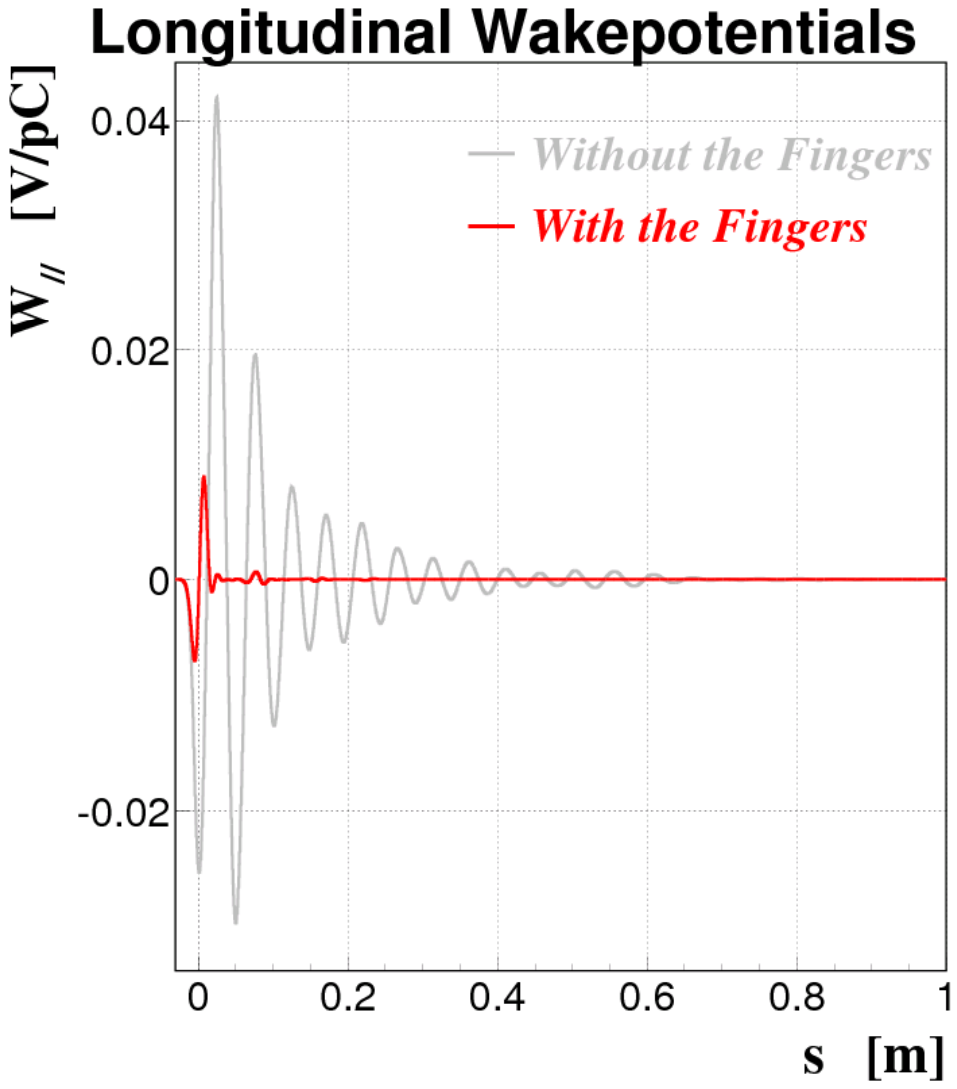
The Geometry Converted to GdfidL

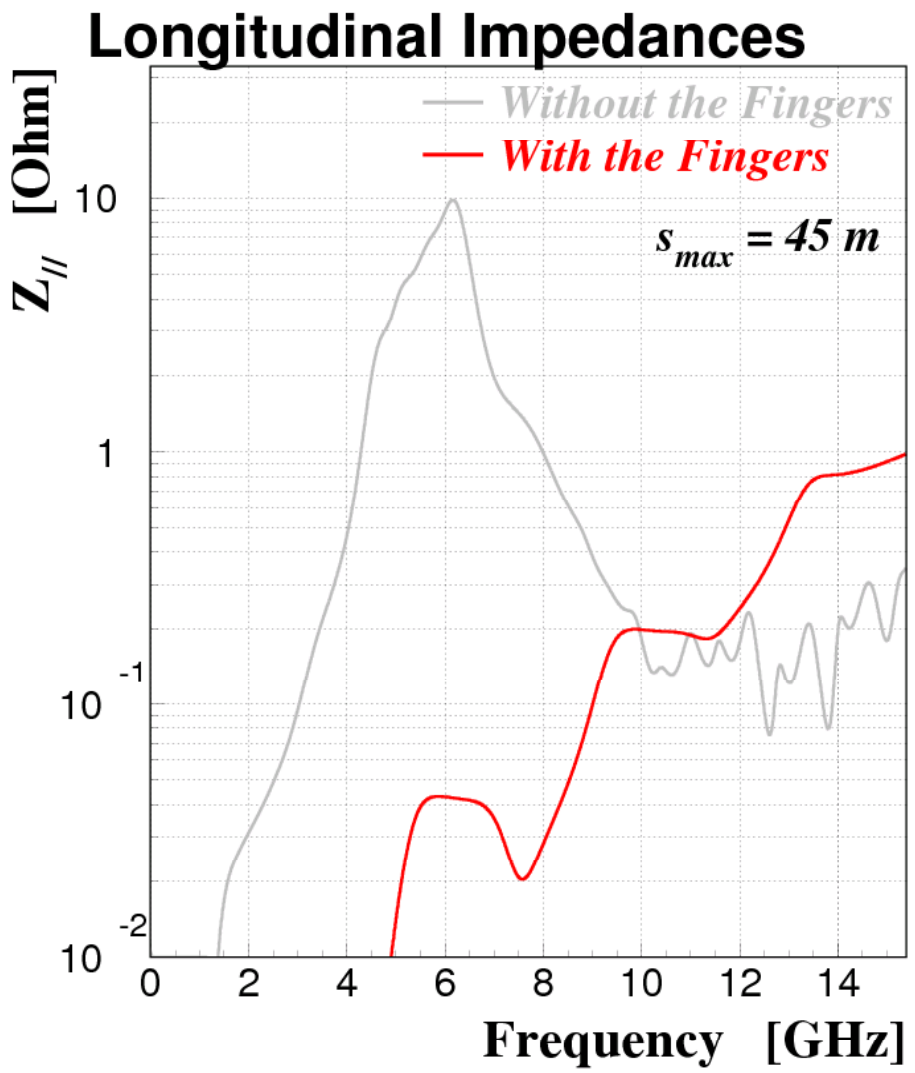


Wakefield Simulation
By GdfidL with 0.1mm Mesh Size

Finite-Difference Time-Domain parallel computation using 64 cores in the PC cluster

Results of the Calculation (1/2)





Suppressed and Damped!

No Resonance!

Results of the Calculation (2/2)

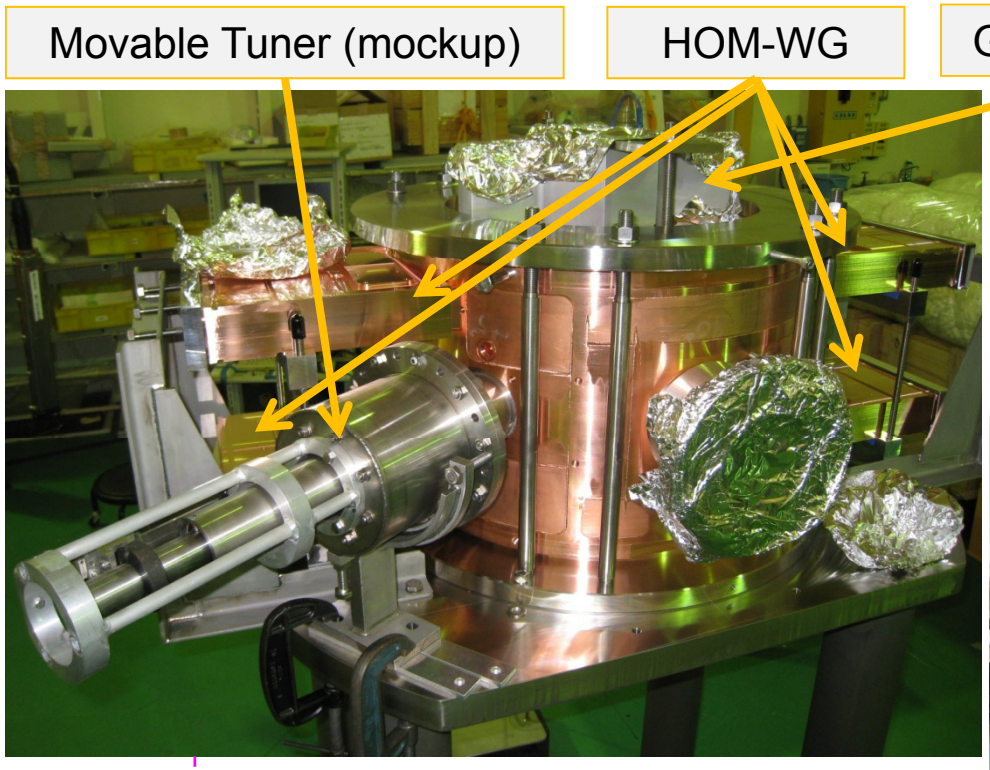
	Loss Factor [V/pC]	Loss Power from the Loss Factor [W]
Without the Fingers	0.017	9.7
With the Fingers	0.00048	**0.27**

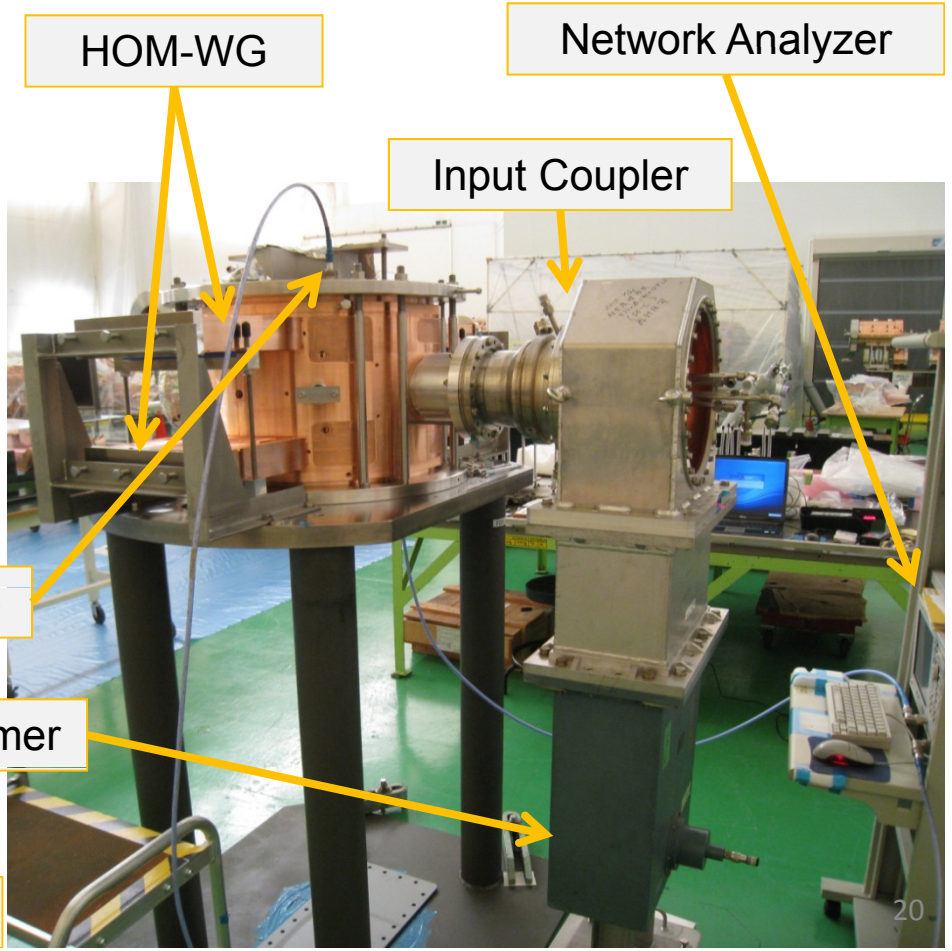
For the DR Parameters:
- Bunch Charge: 8nC
- Bunch Length: 6.5mm
- # of Bunches: 4/ring
- Circumference:135.5m

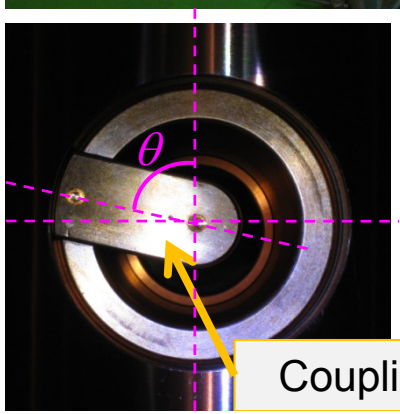
This loss power is negligible!!

Current Status of CavityNo.0(prototype)

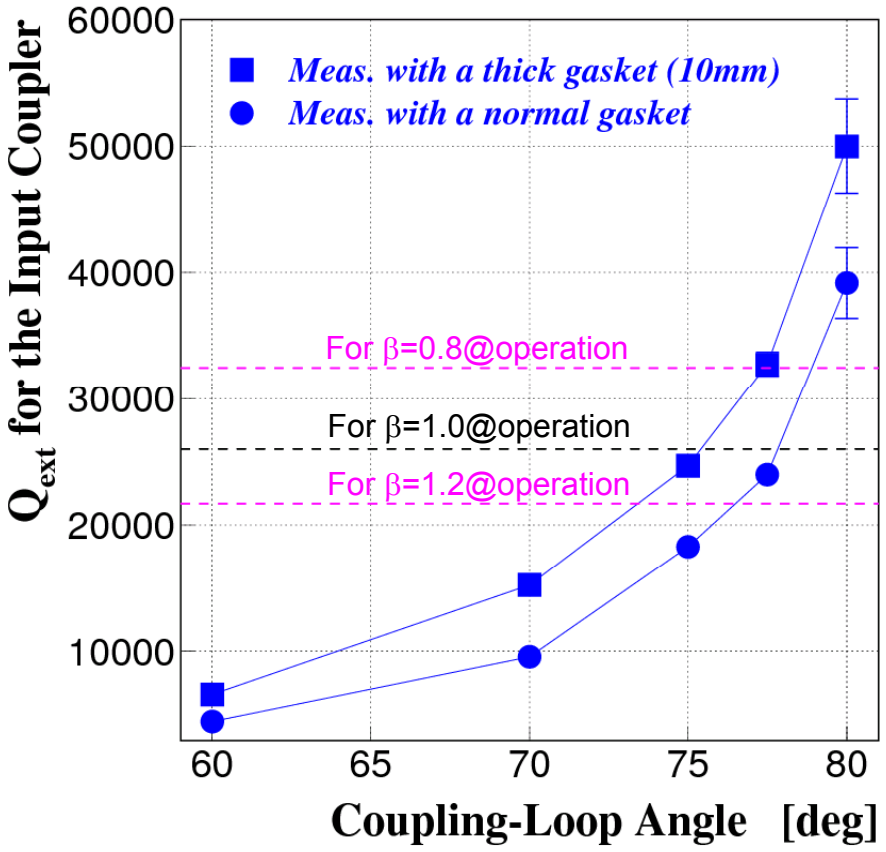
~ Low-Level RF Measurement Done ~

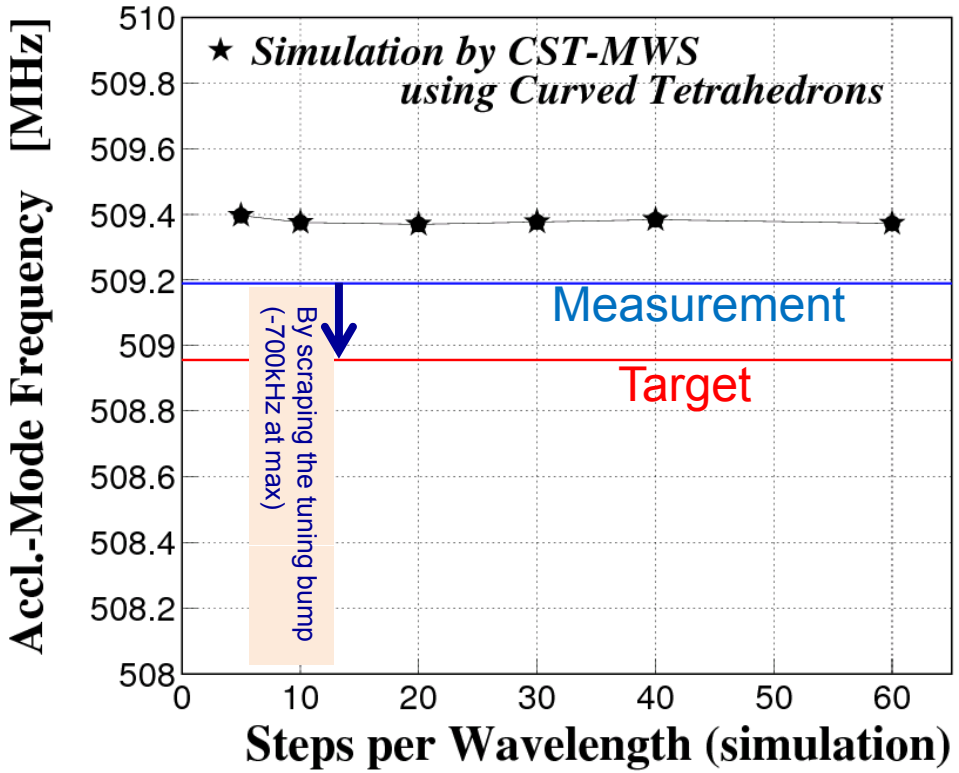






Examples of the Measurement Results

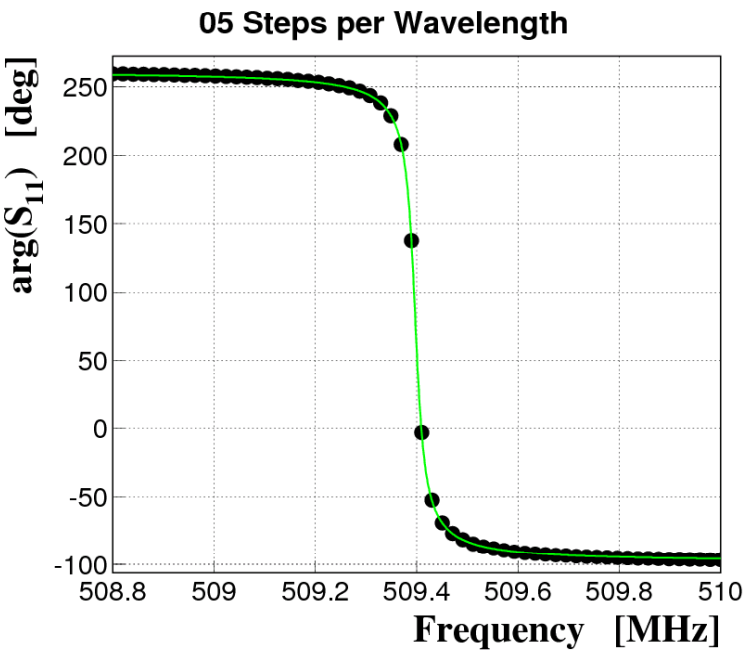




Q_0@operation = ~26000 (80%IACS)

Simulation by CST-MWS

An Example

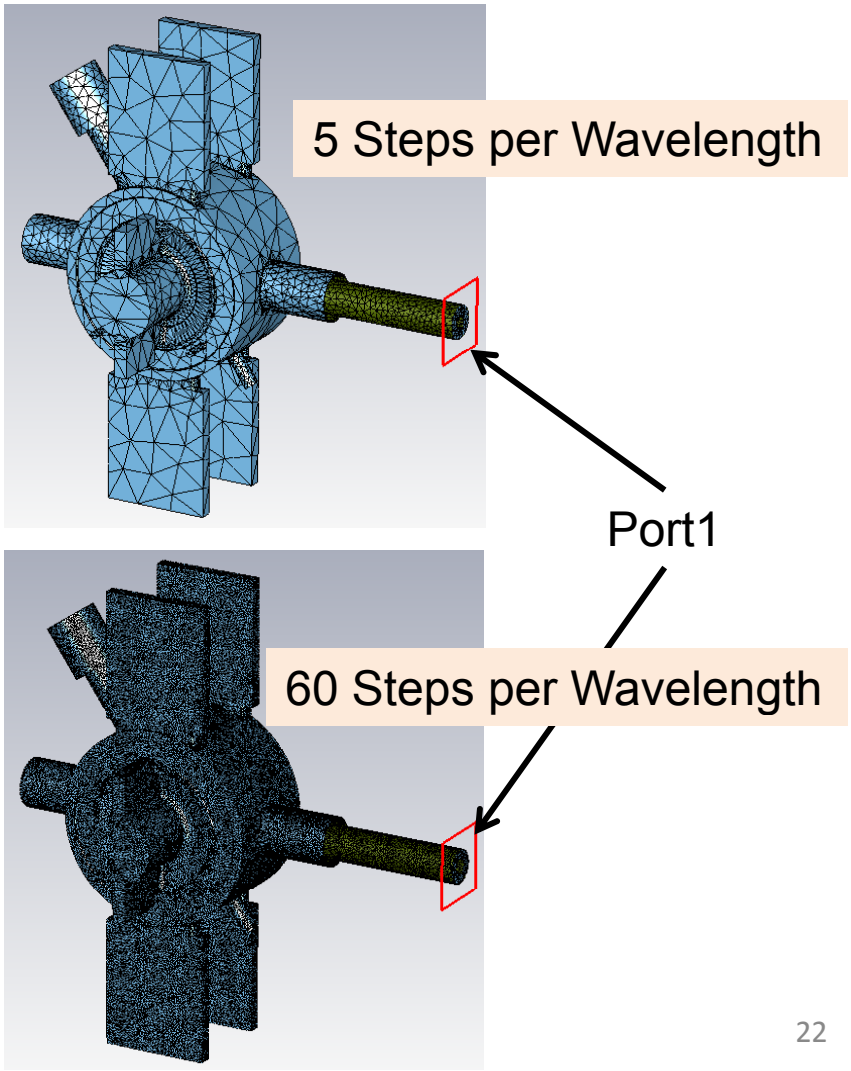


Fit with

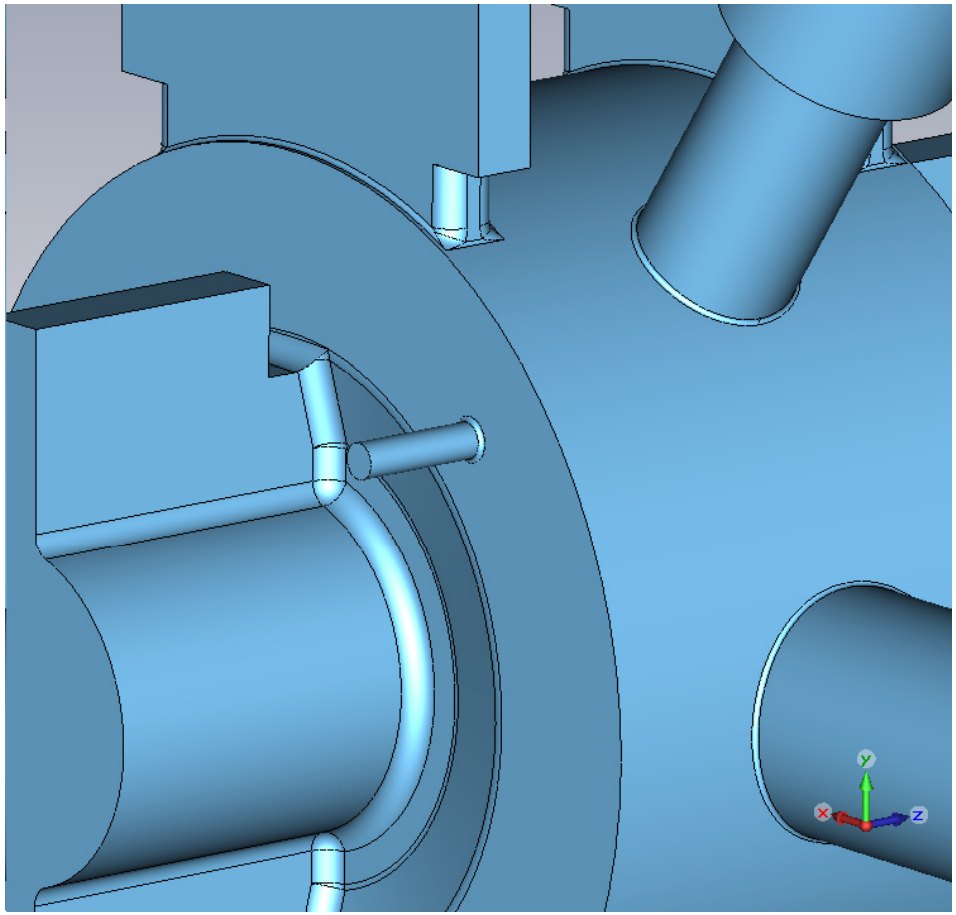
$$\arg(S_{11}) = -2\tan^{-1}\left[Q_{ext}\left(\frac{f}{f_a}-\frac{f_a}{f}\right)\right] + \theta_0$$

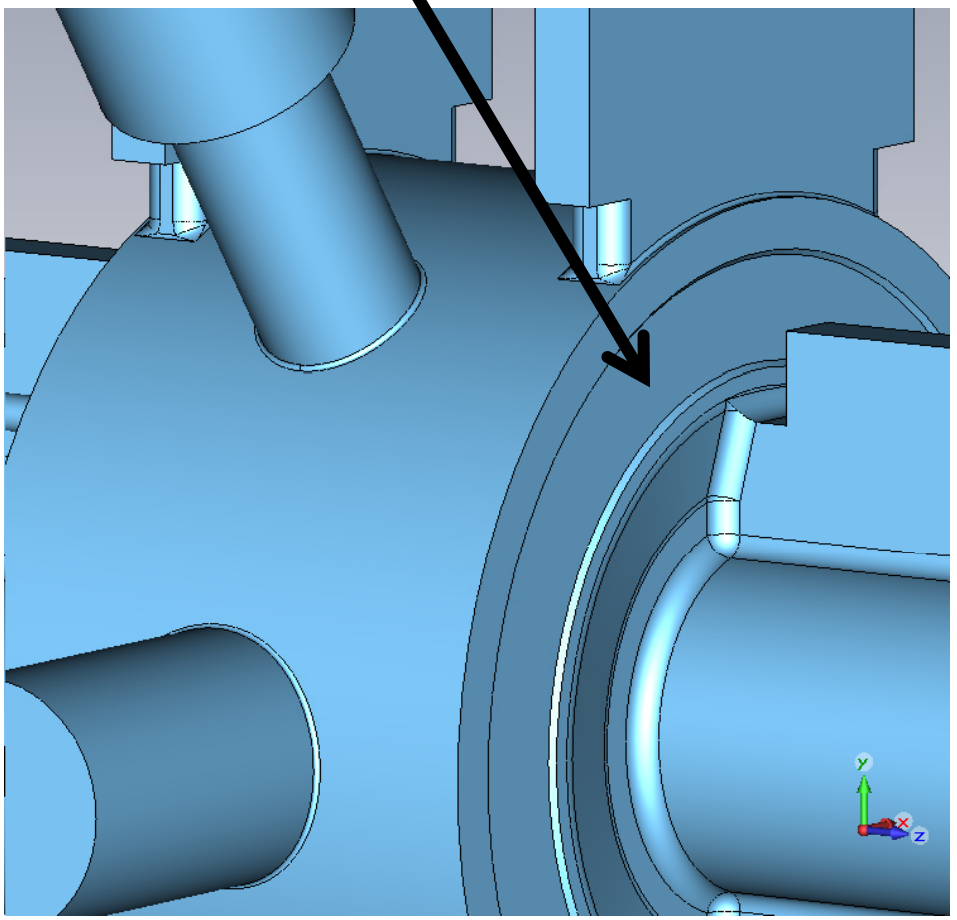
(Red: floating parameters in fitting)

Curved Tetrahedrons



Tuning Bump (2.5mm)





Schedule

JFY	Items	Remarks
2011	CavityNo.0 (prototype) x 1 HOM-WG load x 1 GBP(btwn) x 1	→to be high-power tested at the D1A test stand →to be high-power tested at the D1C test stand →to be high-power tested at the D1C test stand
2012	CavityNo.1 x 1 HOM-WG load x 4 GBP(btwn) x 1 GBP(end) x 1 GBP(dummy) x 1	←Feedback from the High Power Test of CavityNo.0
2013	CavityNo.2 x 1 HOM-WG load x 4 GBP(btwn) x 1 GBP(end) x 1	→Start of DR commissioning with Cavity No.1 and No.2
201X	CavityNo.3 HOM-WG load x 4	If needed

Summary

- **The accelerating structure for the DR**
  - Based on the KEKB-MR/ARES cavity with the long successful operation at KEKB
- **HOM-WG Load Optimized**
  - 2 sets → 1 set of SiC tiles /WG
  - Better Performance
- **Cavity-GBP Joint by**
  - Weld-Ring Gasket with Lip Sealing
    - ✓ Successful experience at KEKB/ARES (C-cav and S-cav) on leakproof vacuum sealing during high power operation with heat deformation of the cavity
    - ✓ "Welding→Disassembly→ReWelding" possible 3 times (enough from our experience)
  - Finger-type RF Shield
    - ✓ Flexible for heat deformation of the cavity during high power operation
    - ✓ Should be safe for low beam currents
    - ✓ Successful experience at KEK/PF
    - ✓ Negligible HOM heating (<< 1W)
- **The prototype cavity almost in the final stage**


Fin.

Appendix A

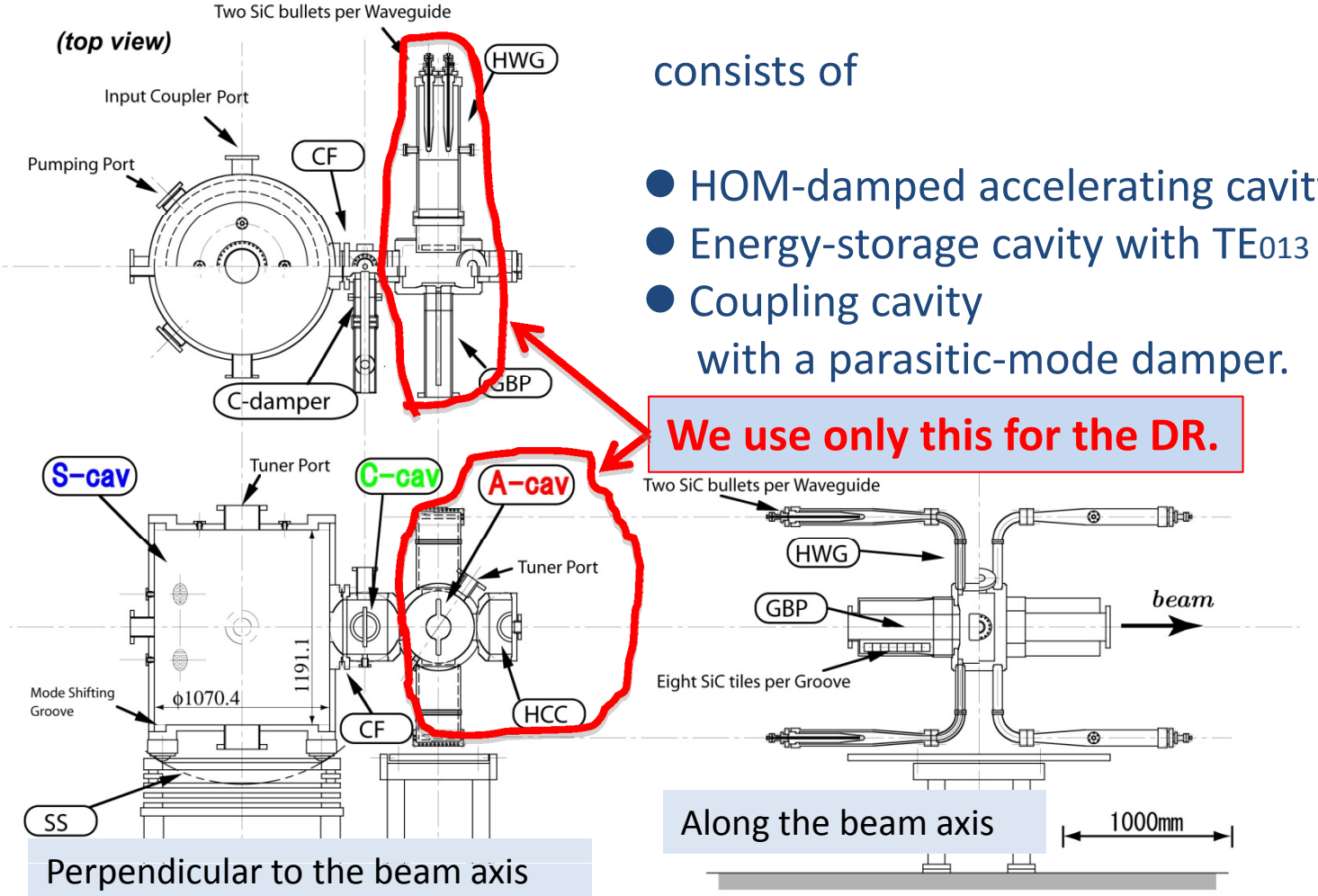
Assumptions for estimating wall temperatures of the DR cavity

- Cooling-water flow: 200 L/min
- Cooling-water temperature: 30 degC
- Cooling-water velocity: 2.0 m/s
- Hydraulic equivalent diameter of the cooling-water channel: 9.1e-3 m
- Reynolds number: 2.2e4 (turbulence)
- Heat-transfer coefficient from the channel to the water: 8.9e3 W/m^2/K
- Thermal conductivity of copper: 4.0e2 W/m/K

Appendix B

Accelerator **R**esonantly-coupled with **E**nergy **S**torage

3-cavity system stabilized with the π/2-mode operation

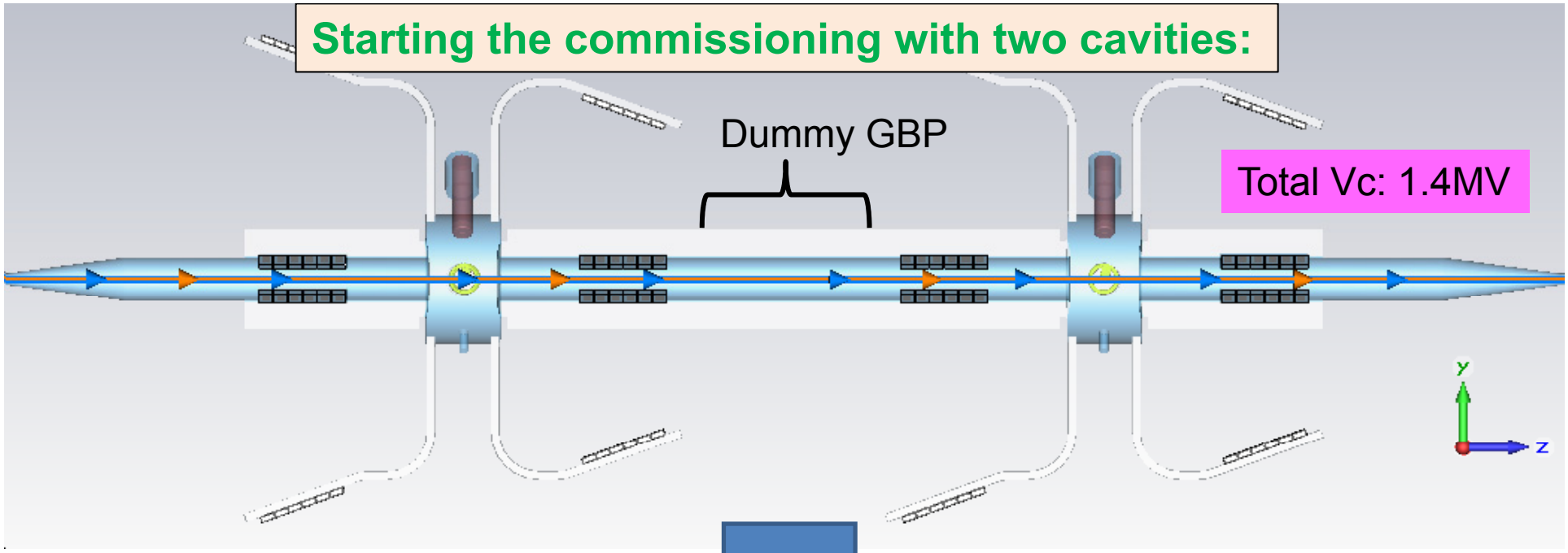


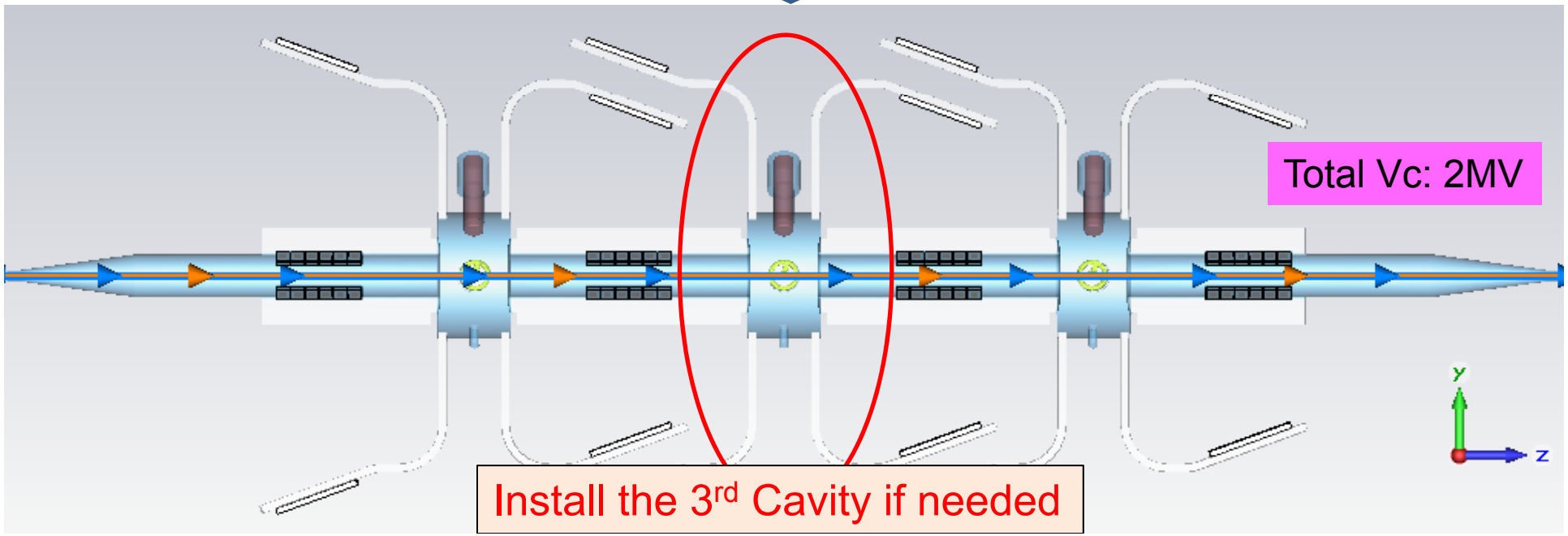
consists of

- HOM-damped accelerating cavity (**A-cav**),
- Energy-storage cavity with TE_{013} (**S-cav**),
- Coupling cavity (**C-cav**) with a parasitic-mode damper.

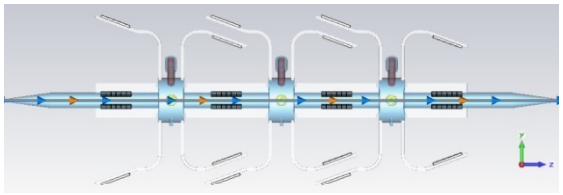
We use only this for the DR.

Starting the commissioning with two cavities:





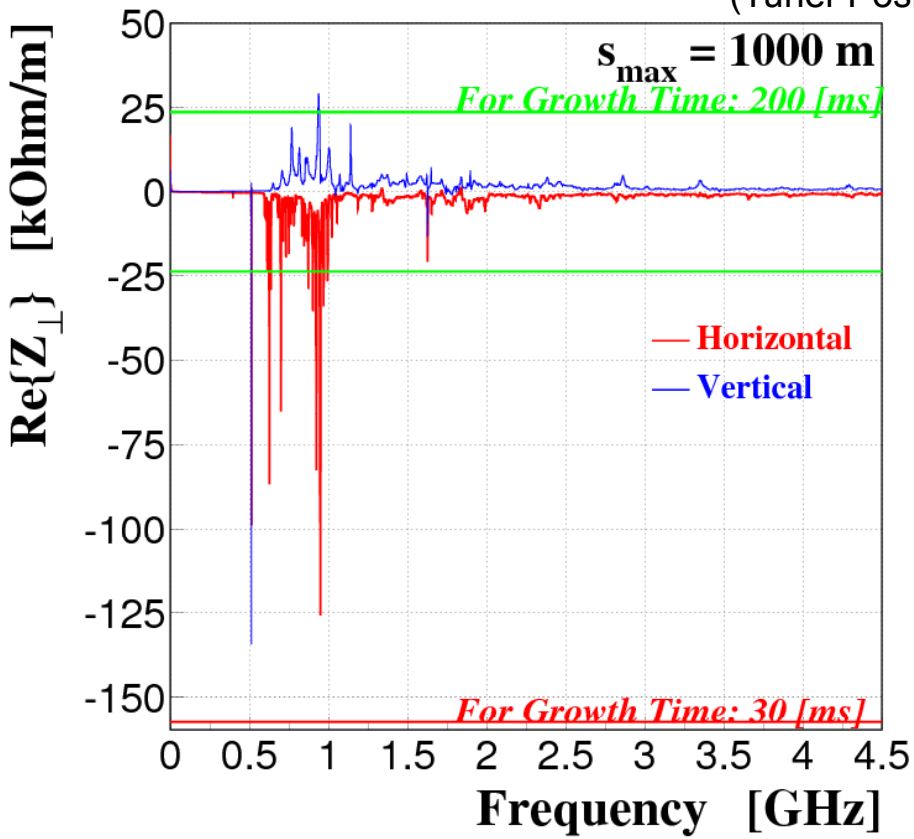
Transverse Impedances of the RF section: and CBI

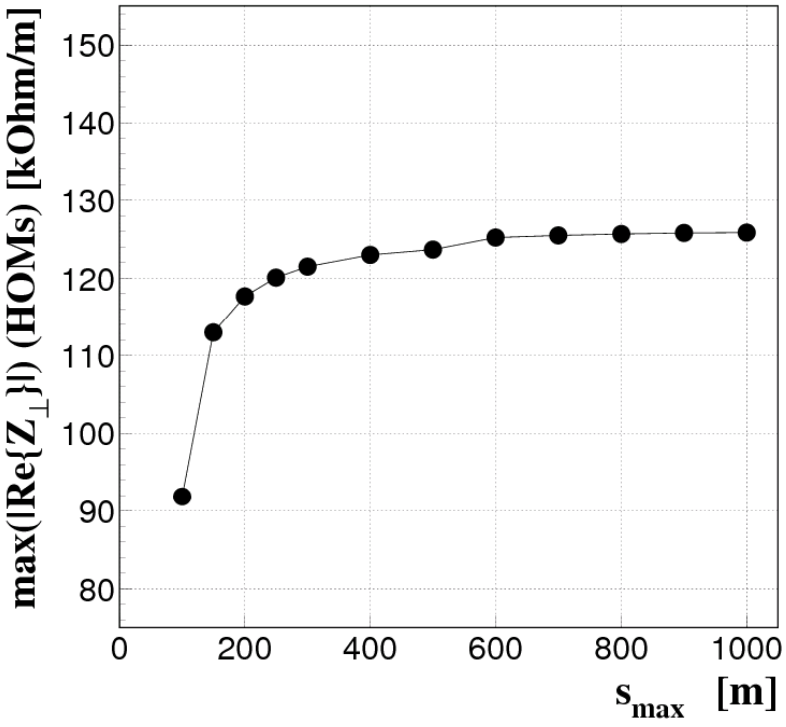


Estimated from Finite-Difference Time-Domain parallel computations of GdfidL with the PC cluster (256 cores & 512GB memory)

CBI threshold for Total Vc: 1.4MV

(Tuner Position: 30mm inside)





Growth Time > 30ms
> 10ms (rad. damping time)