Accelerating Cavities for the Damping Ring (DR)

Tetsuo ABE

For KEKB-RF/ARES Cavity Group

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The 16th KEKB Accelerator Review Meeting

February 8, 2011

Old RF Model

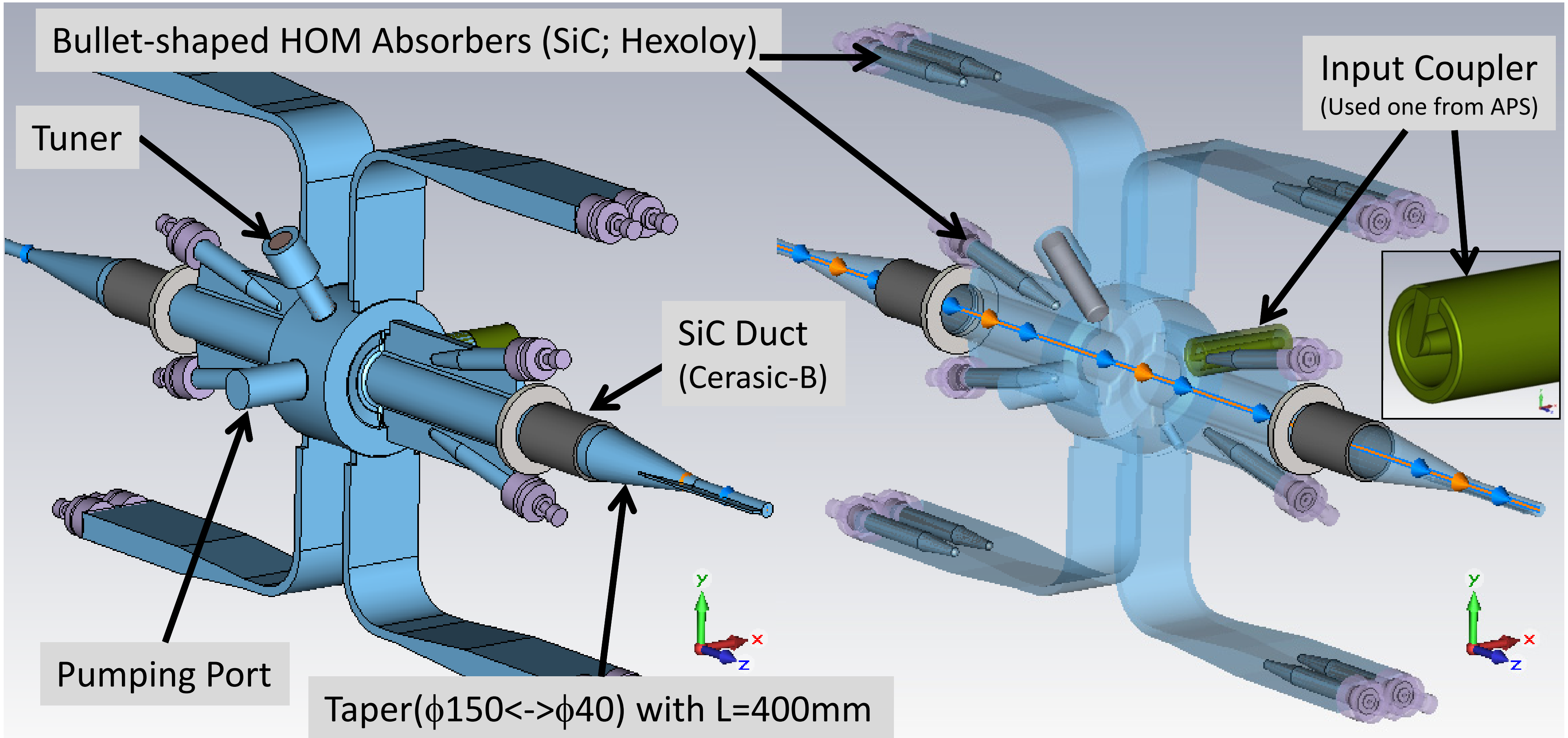
shown in the 15th KEKB Accelerator Review Meeting, February 16 (2010)

$$R/Q = 150\,\Omega$$
$$Q_0 = 29000 \;\; \text{(IACS90\%)}$$
$$V_c = 0.5\,\text{MV}$$

Loss Factor : 1.9 [V/pC]

(Normal View)

(Transparent View)



(**Changes** after Feb. 2010)

[Basic Conditions]

A) Frequency: 508.887MHz (= the freq. of the MR)

B) Based on KEKB-MR/ARES, but without S-cav and C-cav

C) Connection to ϕ40 beam ducts (→taper near the cavity)

D) Max. Total V_c: 0.5 → 2MV

- Against microwave instabilities from CSR effects
- Should be larger enough than the current design value: 1.4MV

[Main Topics]

(Space conserving)

1. **3 Cavities (max) with 0.7MV/cav** in the RF section (~5m-long)
2. **SiC tiles** for all the Higher-Order-Mode (HOM) dampers
3. Grooved Beam Pipe (GBP) made **common between the neighboring cavities**
4. Connection between the cavity and GBP
5. HOM Impedances for Coupled Bunch Instabilities (CBIs)
6. RF-absorption power in each HOM damper
7. Coupled oscillations of the accelerating (ACC) mode

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)

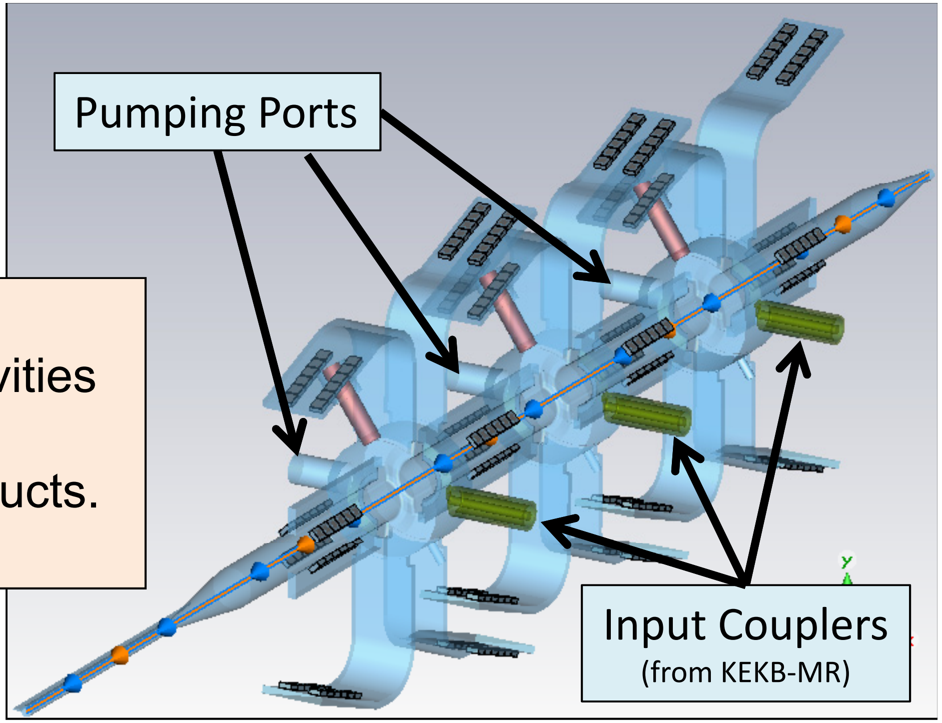
	Vc [MV/cav]	Wall Loss Power [kW]	Wall Temperature (calc.) [degC]
KEKB Design	0.50	60	50
Max. Continuous	**0.70**	133	74
Max. Instantaneous	0.82	193	94

(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)

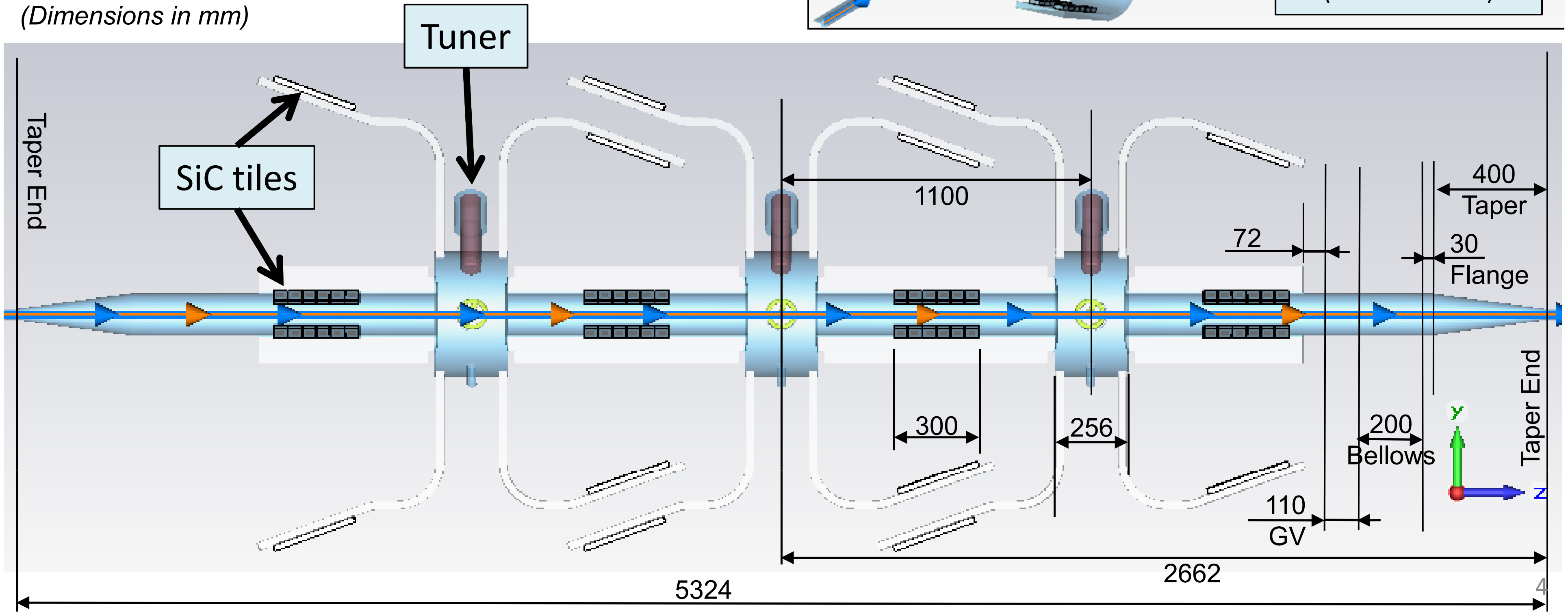
New RF Model

ver.2011-02-08



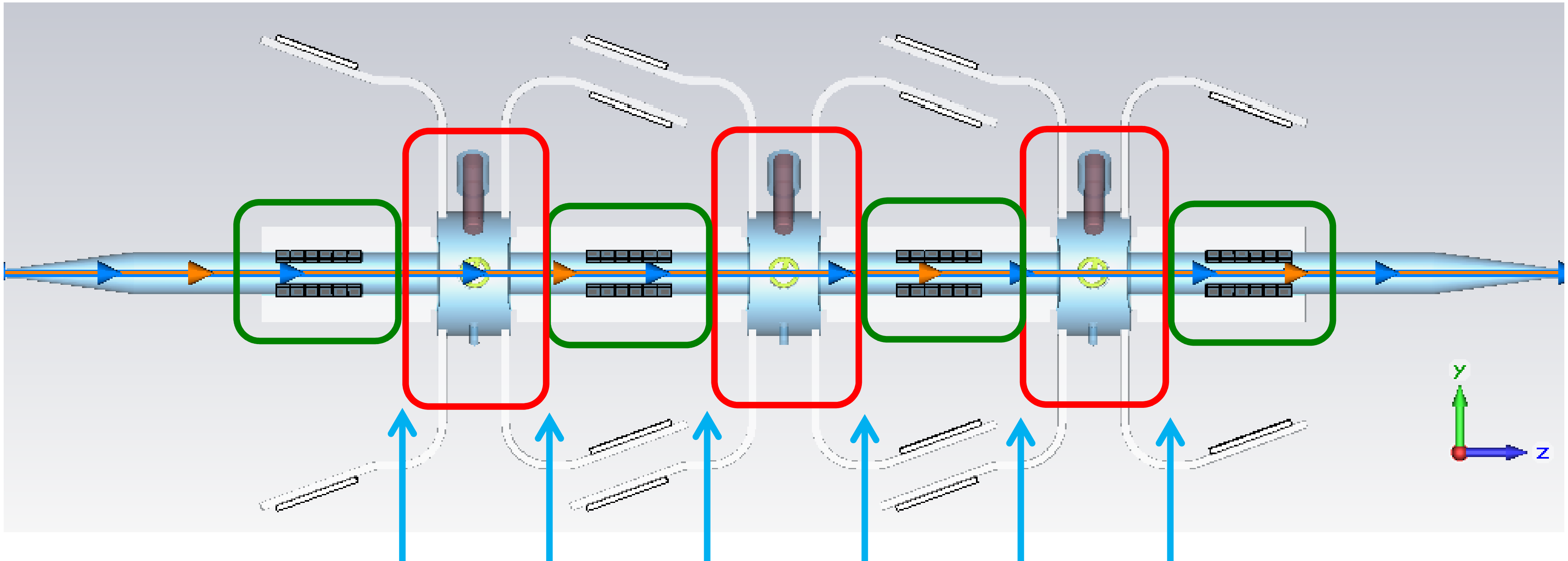
- ✓ 3 cavities with 0.7MV/cav
- ✓ GBP common between the neighboring cavities
- ✓ HOM dampers with SiC tiles
- ✓ SiC tiles on the duct work similarly to SiC ducts.
- ✓ Loss Factor : 2.5 [V/pC]

(Dimensions in mm)



Two Types of Components

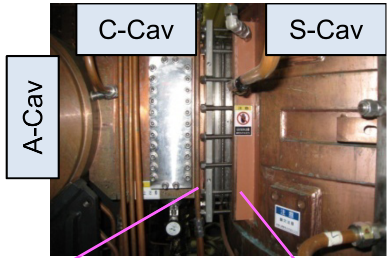
1. Cavity
2. GBP with SiC tiles



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

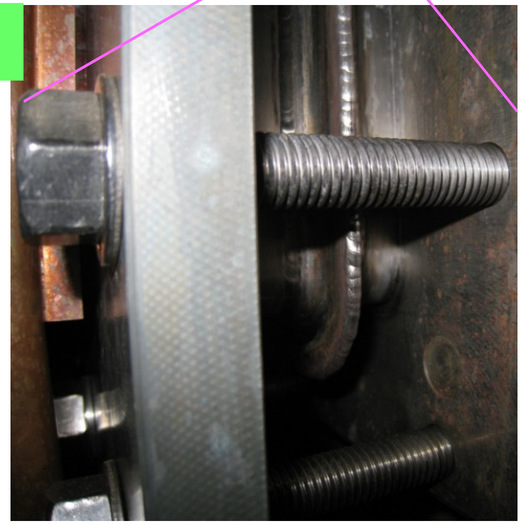
We do not use flanges because of
- •No space for bellows
- •Non-circular duct (GBP)
- •Thermal stress by the ACC mode

Connection between the Cavity and GBP

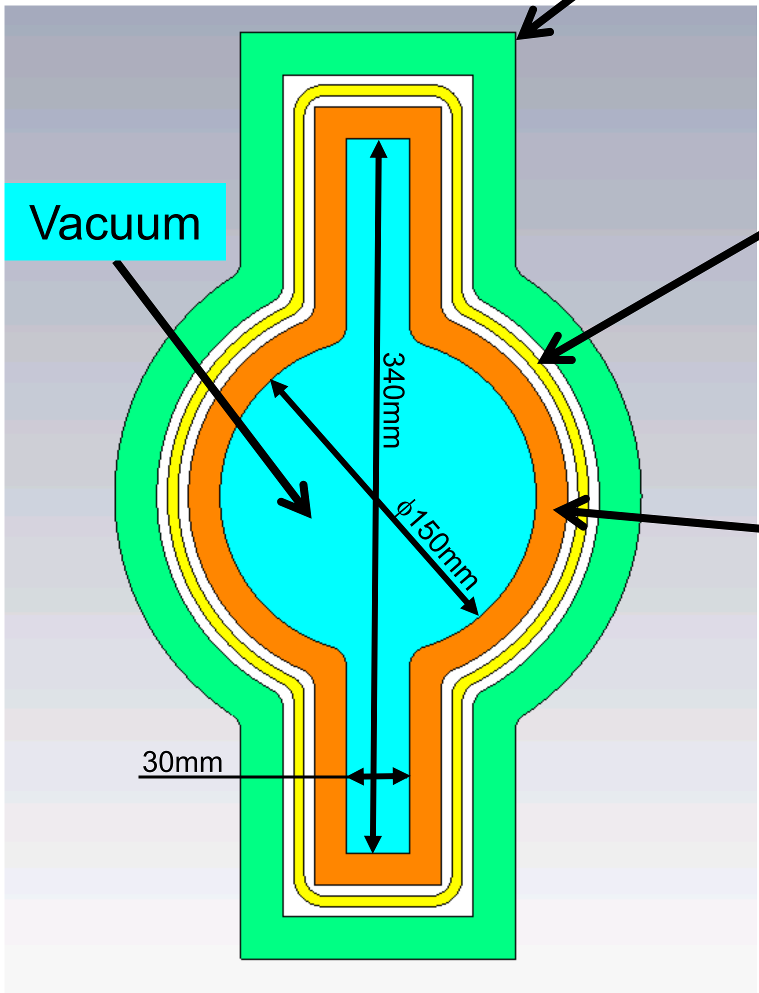


Lip welding for vacuum sealing, like:

5 cycles of "Welding → Cutting" are possible.



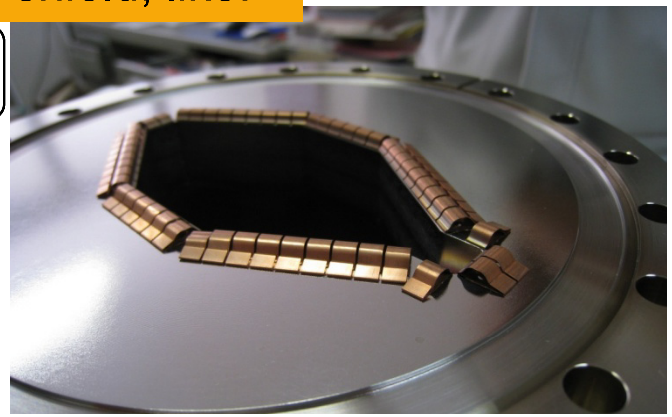
between C-Cav and S-Cav of ARES



Metal O or C ring

Finger-type RF shield, like:

Safe for low beam currents, such as 70mA

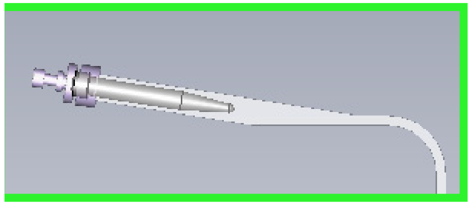


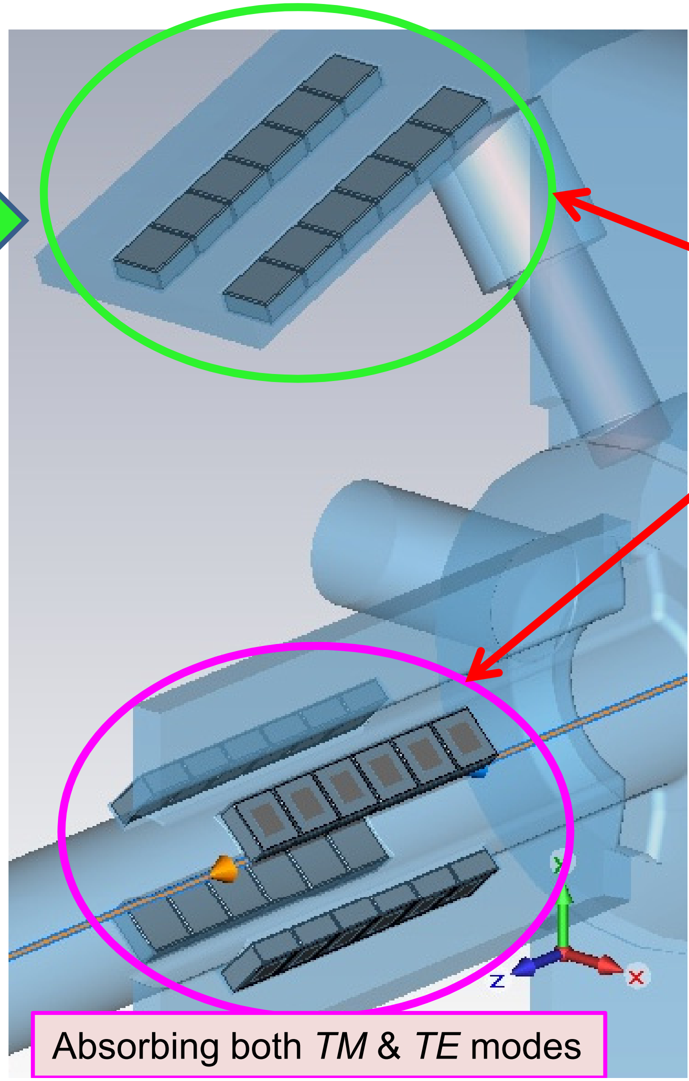
in the flange for KEK/PF;
Courtesy of T. Honda.

HOM Absorbers

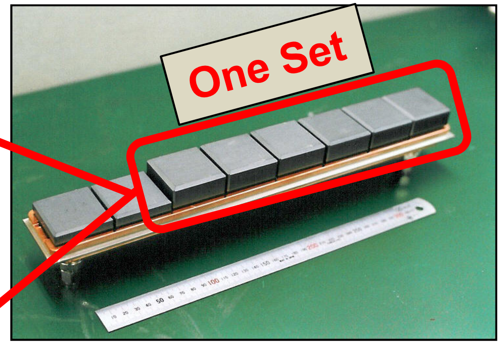
The basic HOM damped structure is the same as that of the KEKB-MR/ARES cavity, but the HOM absorbers are all SiC tiles: t20mm x 48 mm x 48mm.

Bullet-shaped SiC absorbers used for the KEKB-MR/ARES

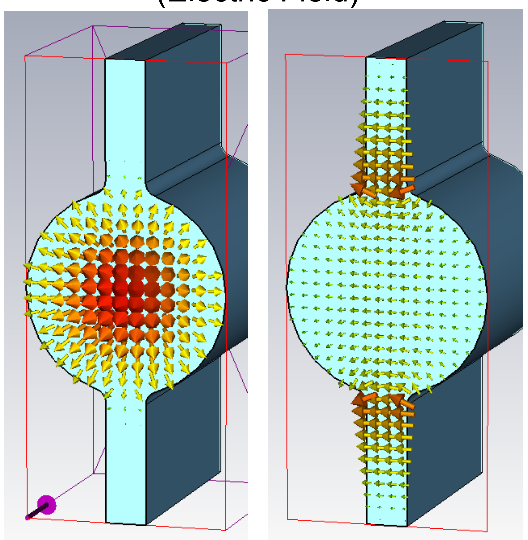




SiC tiles used in the GBP of the KEKB-MR/ARES



(Electric Field)



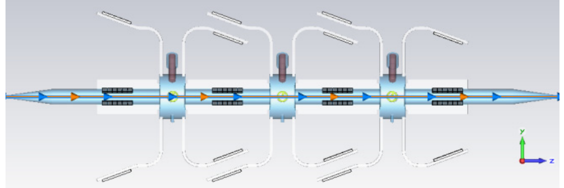
TM Mode *TE* Mode

SiC tiles are:
- brazed on a copper plate.
- water-cooled via the copper plate.

Power Capability: ~1 kW/Set

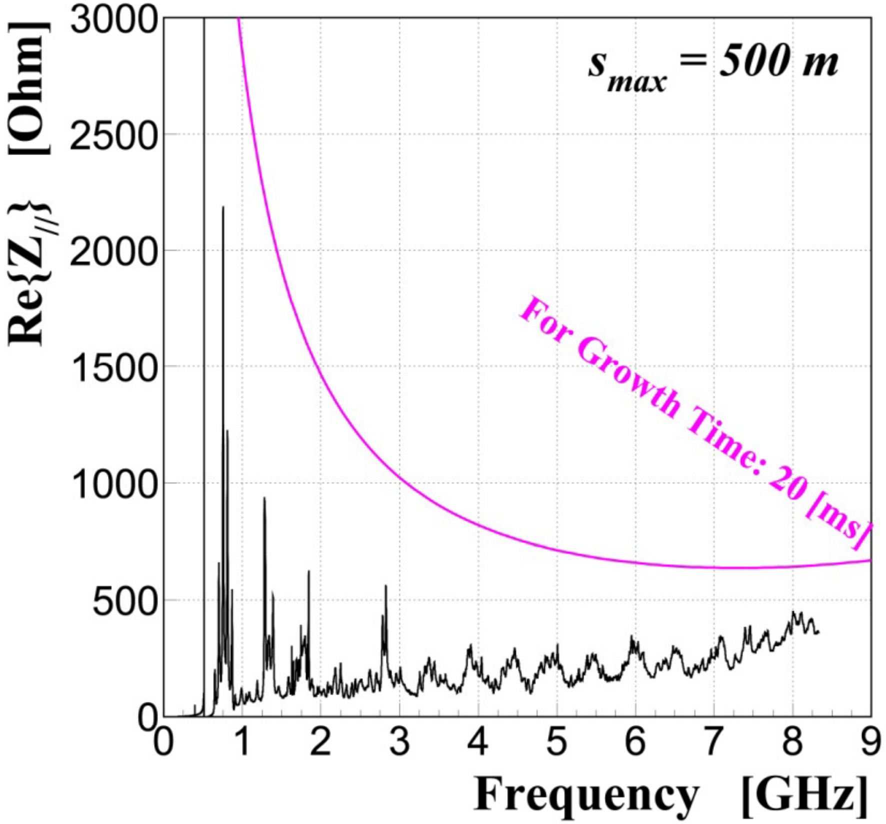
(@1.3GHz)

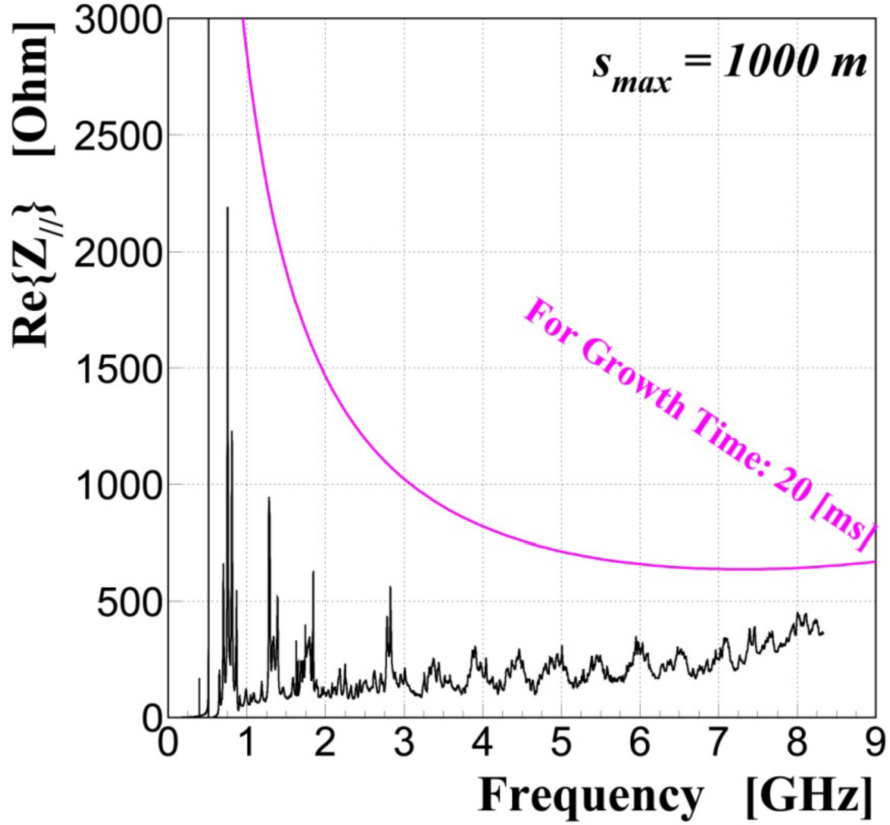
Longitudinal Impedance of the RF section: and CBI



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

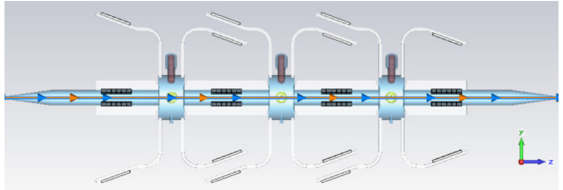
CBI threshold for Total Vc: 1.4MV





Growth Time ＞ 20ms
＞ 5ms (rad. damping time)

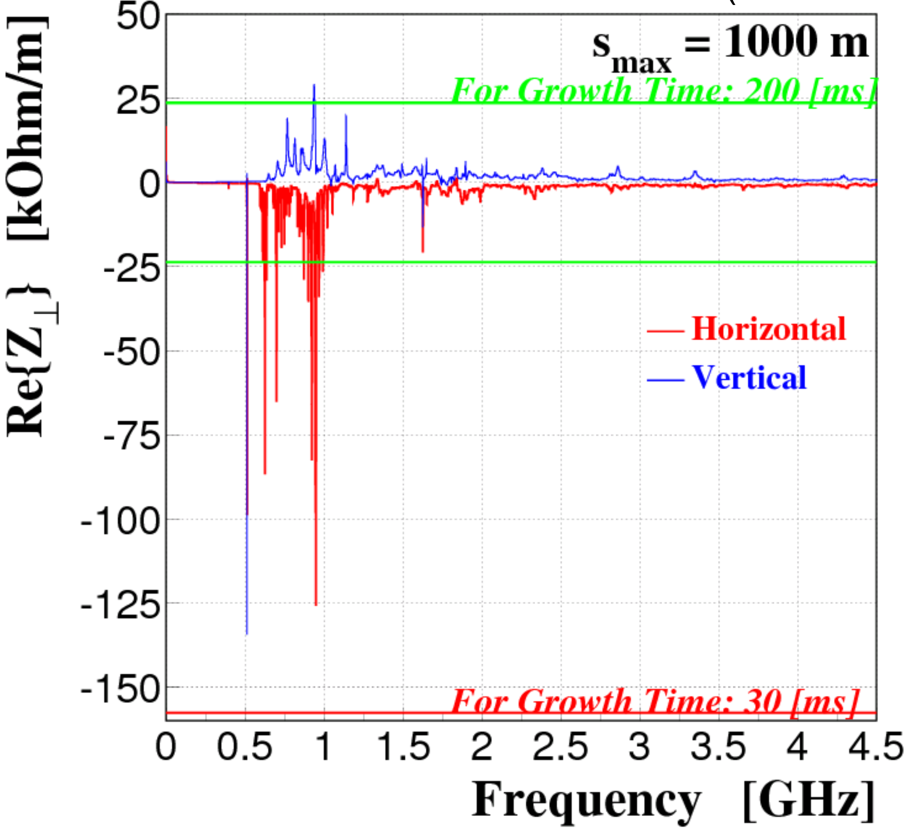
Transverse Impedances of the RF section: and CBI

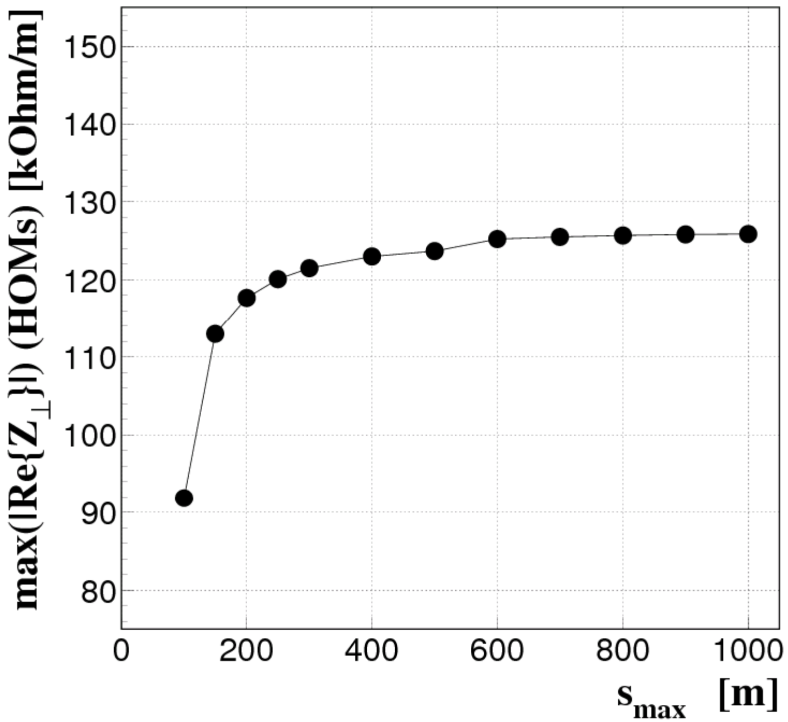


Estimated from Finite-Difference Time-Domain parallel computations of GdfidL with the PC cluster (256 cores & 512GB memory)

CBI threshold for Total Vc: 1.4MV

(Tuner Position: 30mm inside)





Growth Time > 30ms

> 10ms (rad. damping time)

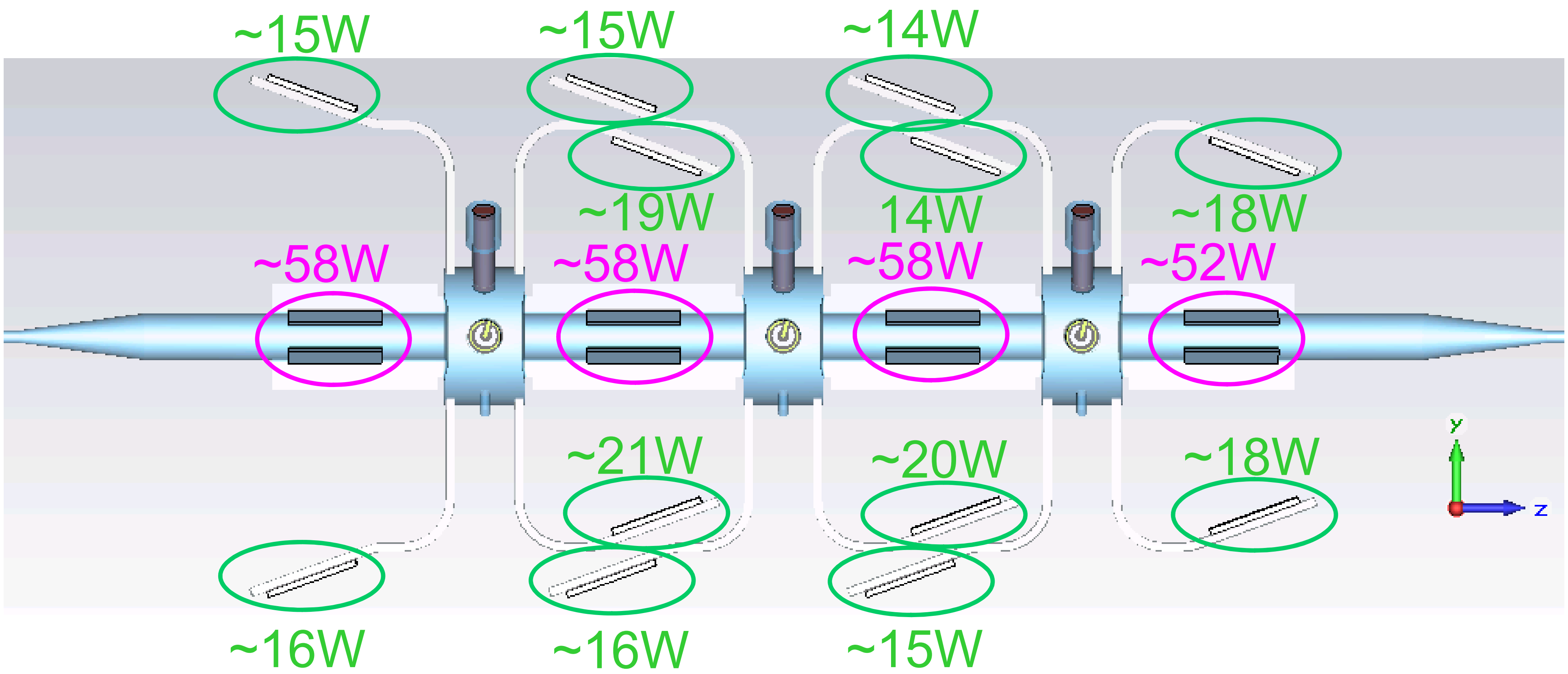
Power of RF Absorption in Each Set of SiC Tiles

HOM Power from the Long-Range Wakefield

Estimated from the time-domain computation of GdfidL (smax=1000m) with the conditions:

- Bunch charge: 8nC
- Bunch length: 6mm
- Beam offset: 2mm (X,Y)

Scalar sum over four bunches



<< (Power Capability: 1kW/set)

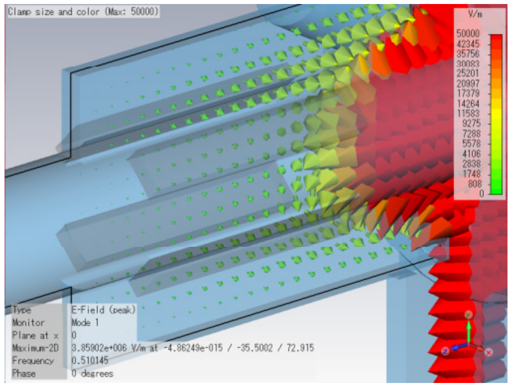
Heating Value by the ACC Mode for SiC Tiles

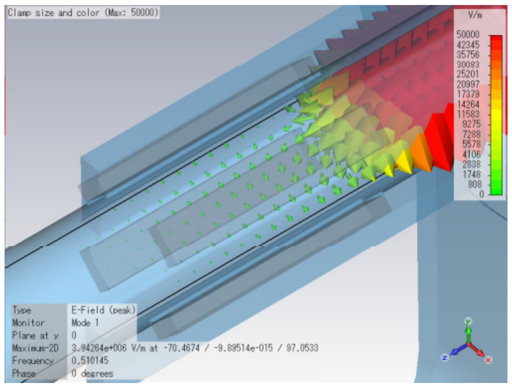
Eigenmode Analysis

- Using CST-MWS
- With 40 MeshLines/WaveLength

Tail of the Electric Field of the ACC mode

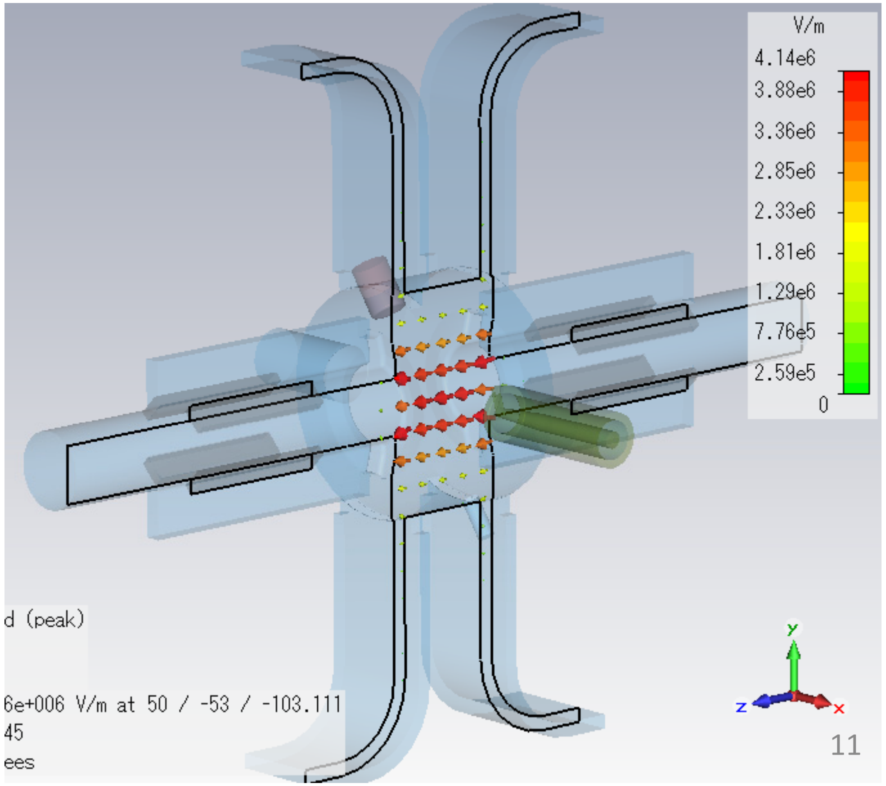
(magnification)





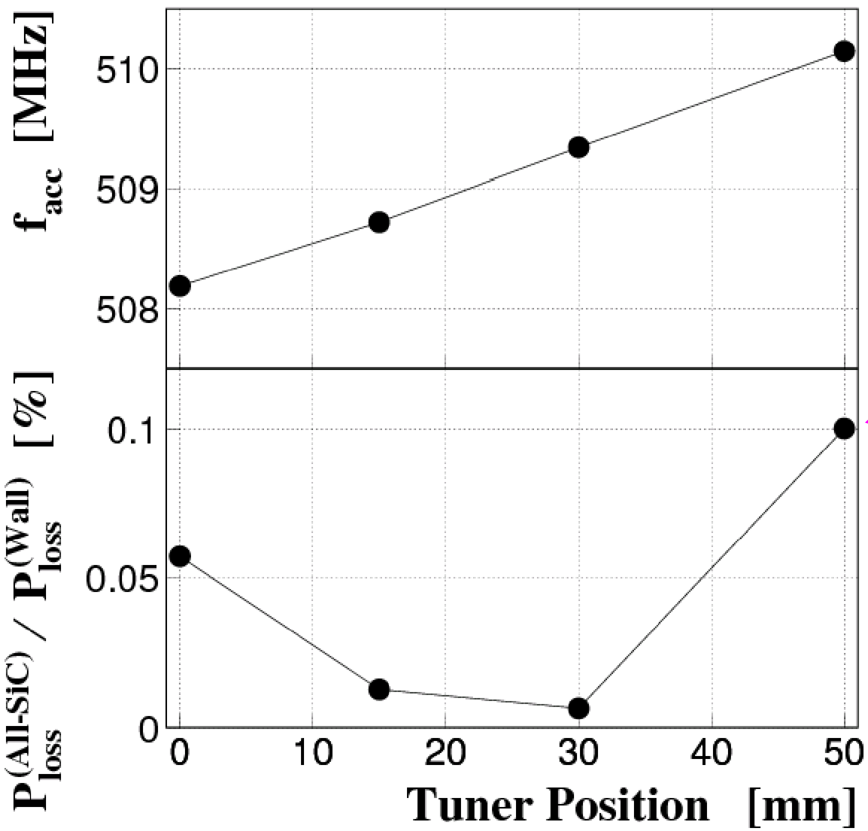
(6 SiC tiles are approximated by one plate.)

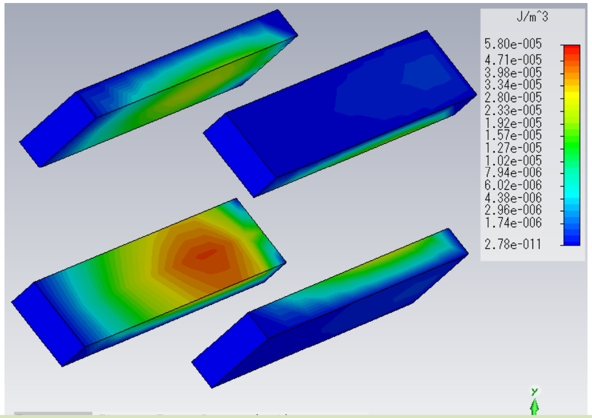
Electric Field of the ACC mode



Heating Value by the ACC Mode

Simulation Results





("All-SiC" means these 4 plates(=sets).)

For the mechanically innermost position

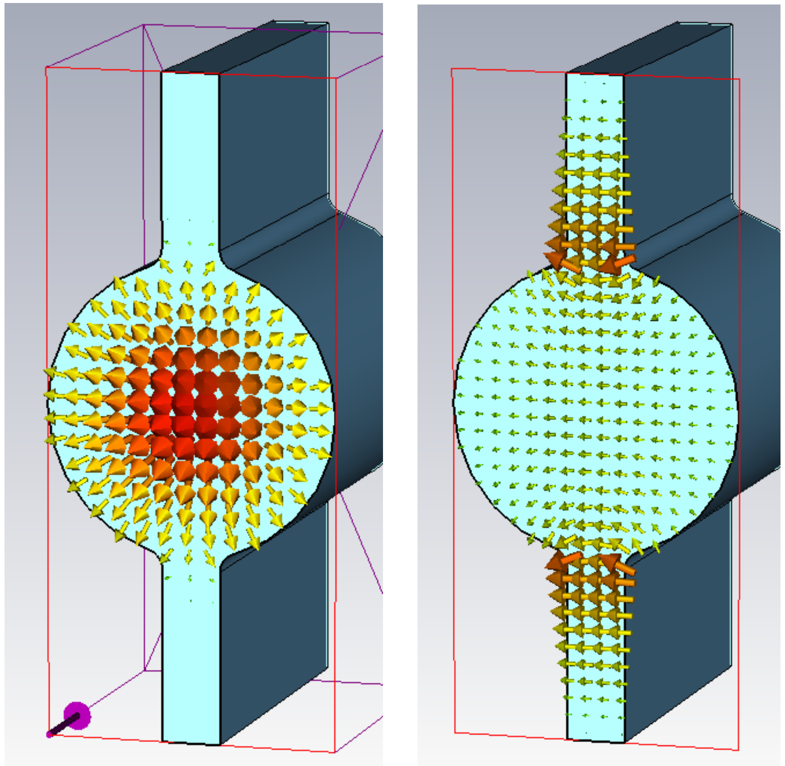
$$\begin{cases} \dfrac{P_{loss}^{(All-SiC)}}{P_{loss}^{(Wall)}} = 0.1\,\% \\ P_{loss}^{(Wall)} = 133\text{kW} \quad \text{for 0.7MV/cav} \end{cases}$$

$$P_{loss}^{(All-SiC)} = 133\text{ W}$$

Heating value < 100W/set << Power Capability: 1kW/set

Coupled Oscillations of the ACC Mode

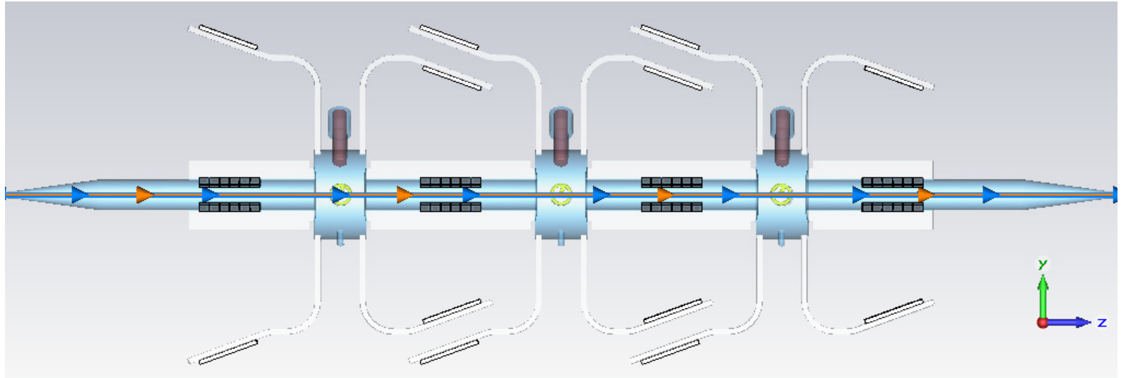
Electric Field



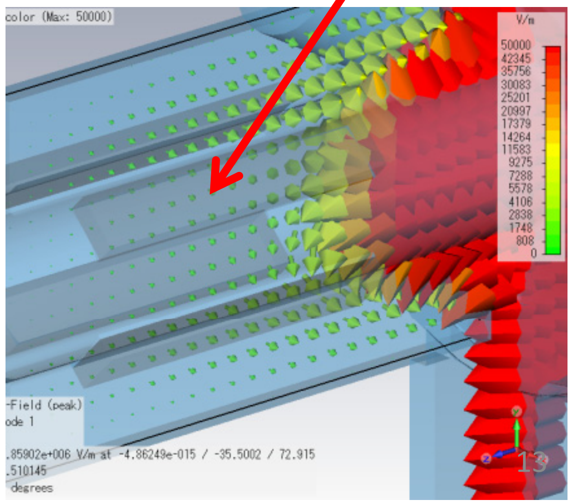
TM mode
Cutoff: 1.51 GHz

TE mode
Cutoff: **<u>588 MHz</u>**

Close to the ACC-mode Frequency: 508.9MHz



Coupled Oscillations of the ACC Mode might be non-negligible via the <u>TE mode</u>.

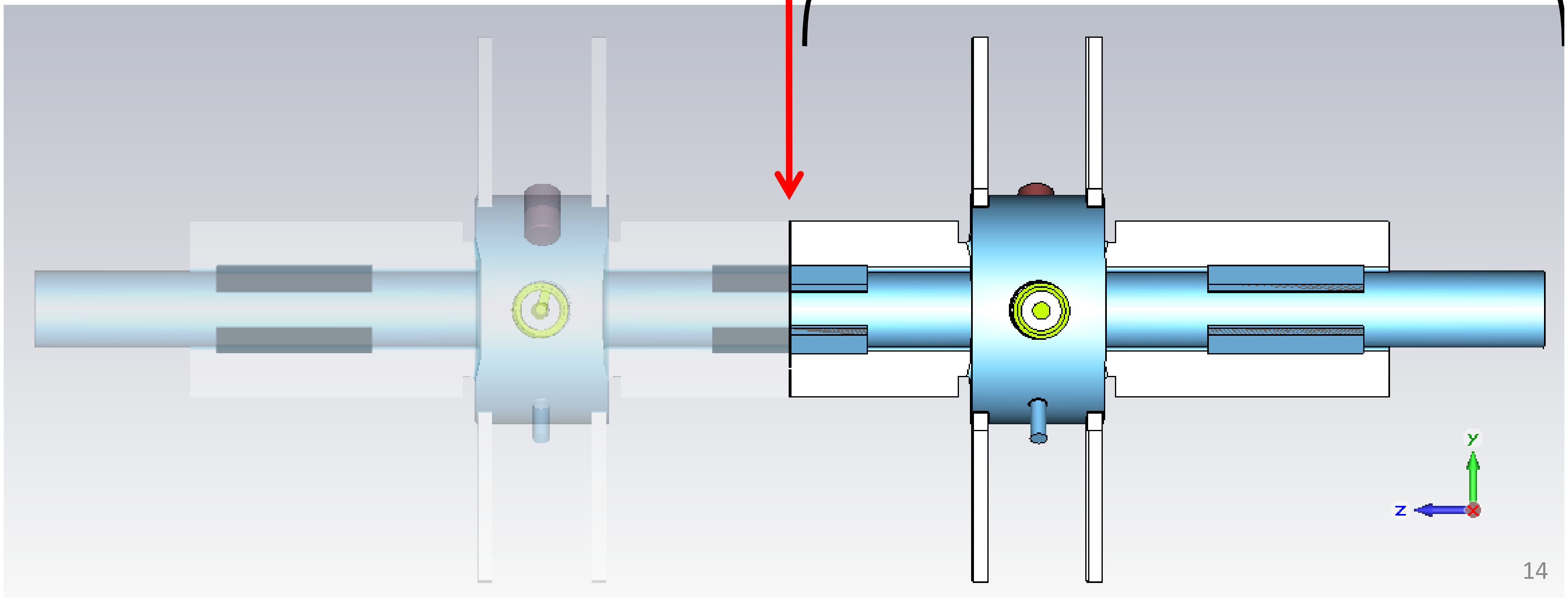


Step 1: Two-Cavity System

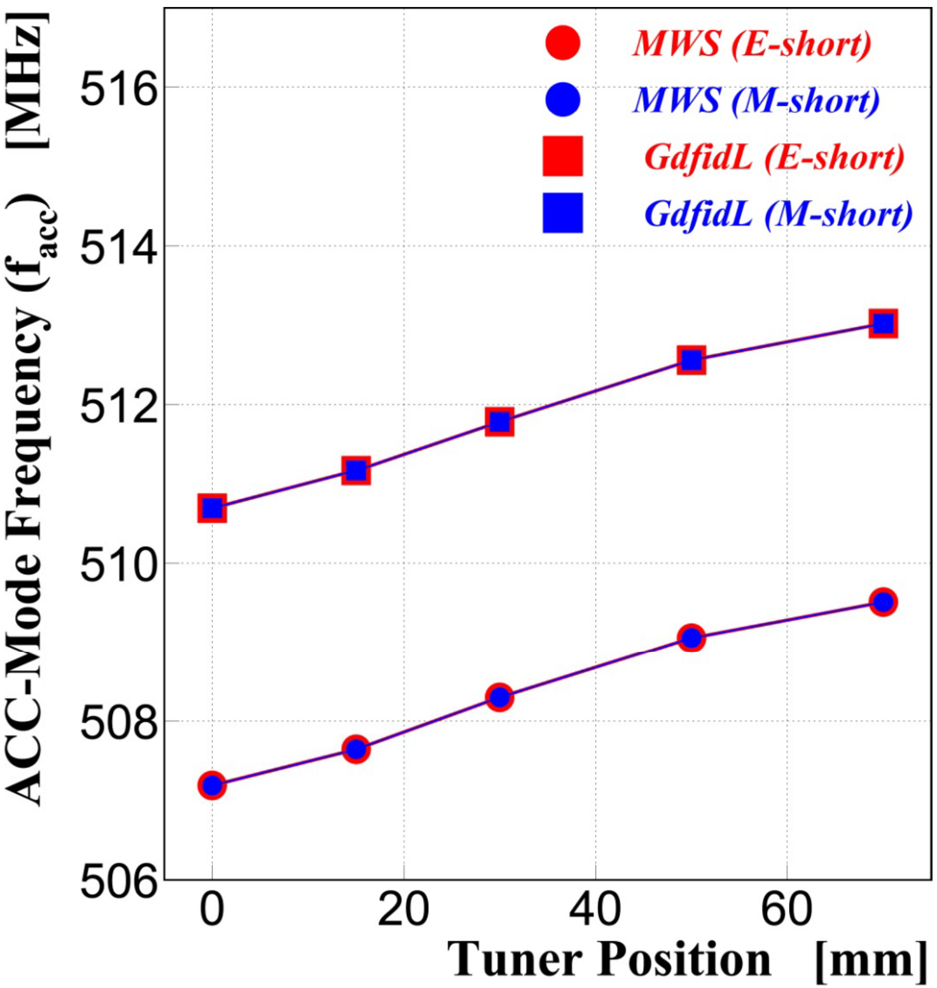
<u>"Electric Short" or "Magnetic Short"</u>

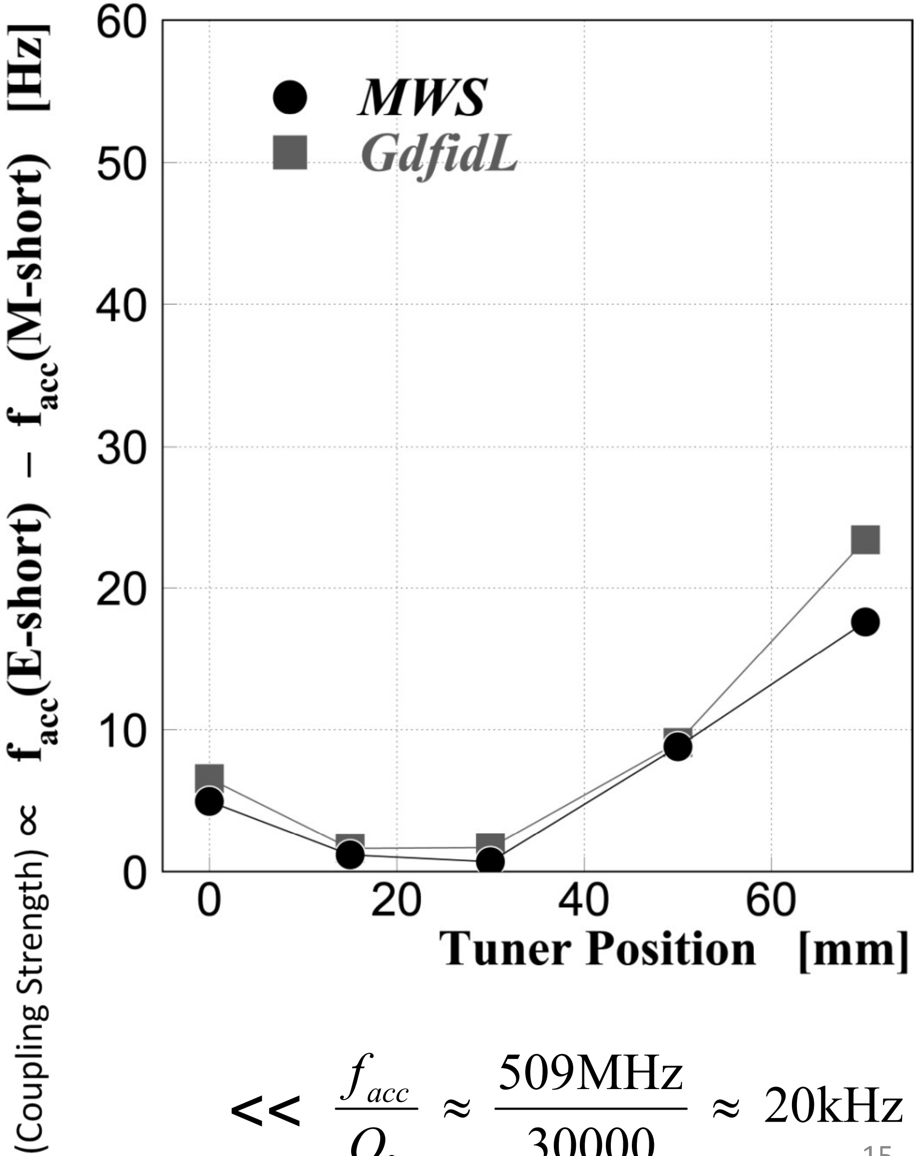
Conditions:
- Lossfree approximation
- Cavity interval: 956mm
- 6 SiC tiles approximated by one plate

Compute Mode Frequencies using CST-MWS and GdfidL.



Two-Cavity System

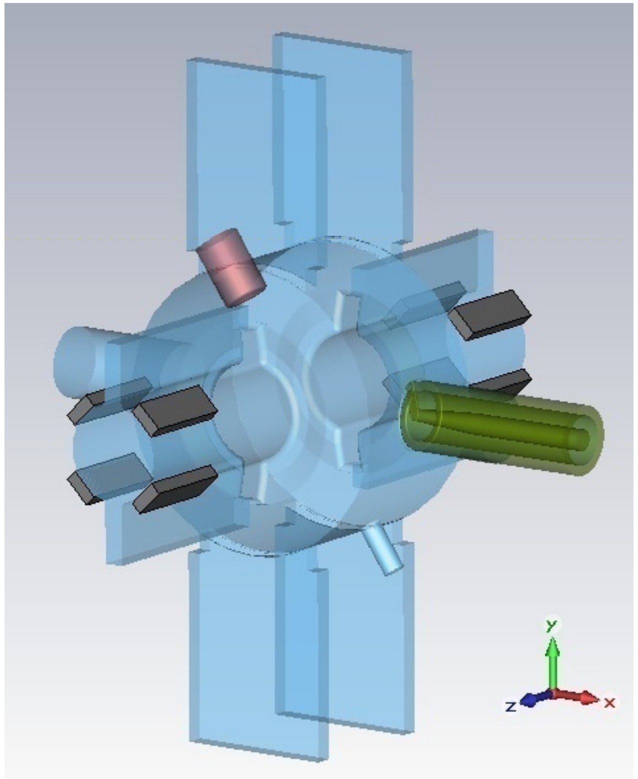




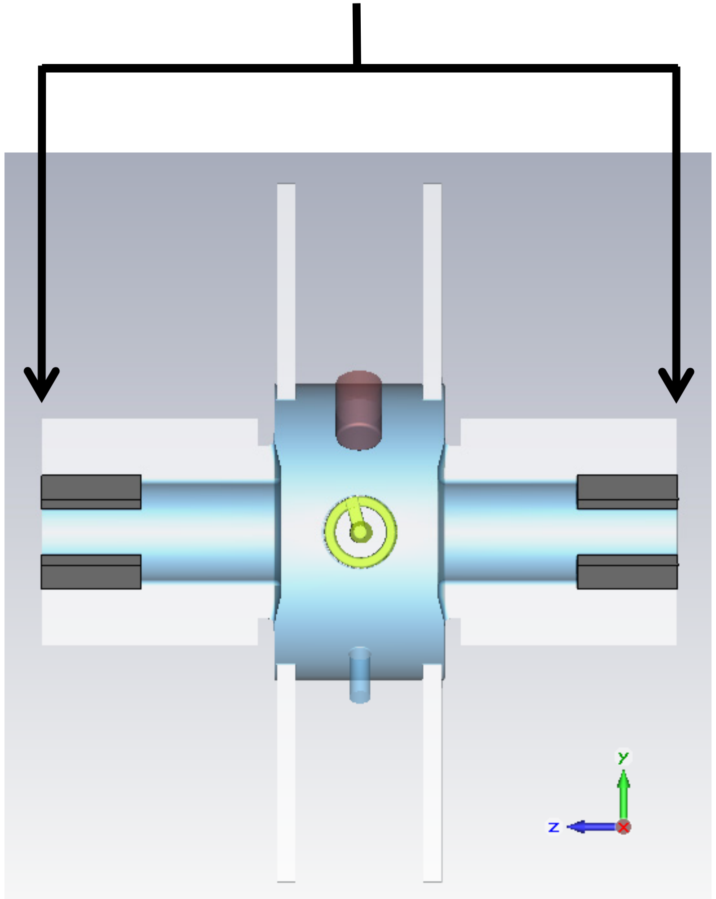
$$<< \frac{f_{acc}}{Q_0} \approx \frac{509\mathrm{MHz}}{30000} \approx 20\mathrm{kHz}$$

Step 2: Periodic Structure

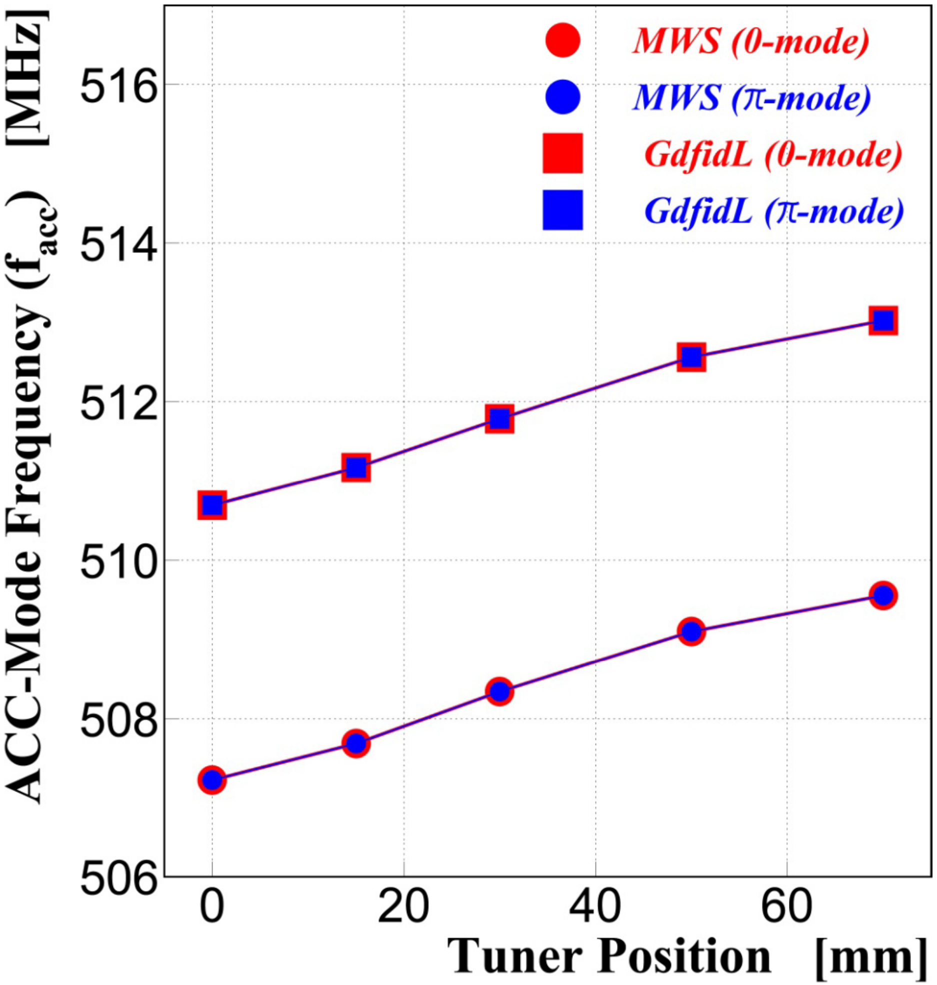
One Unit

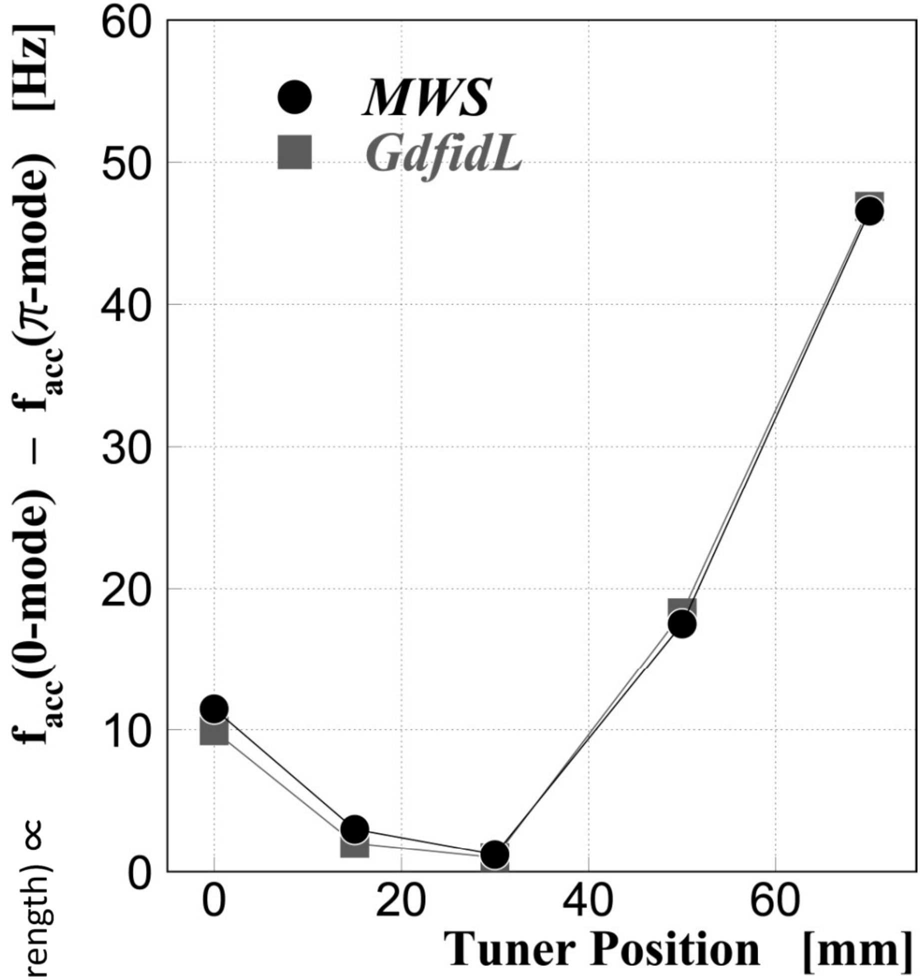


Periodic Boundary Condition with a phase shift: 0 or 180 deg



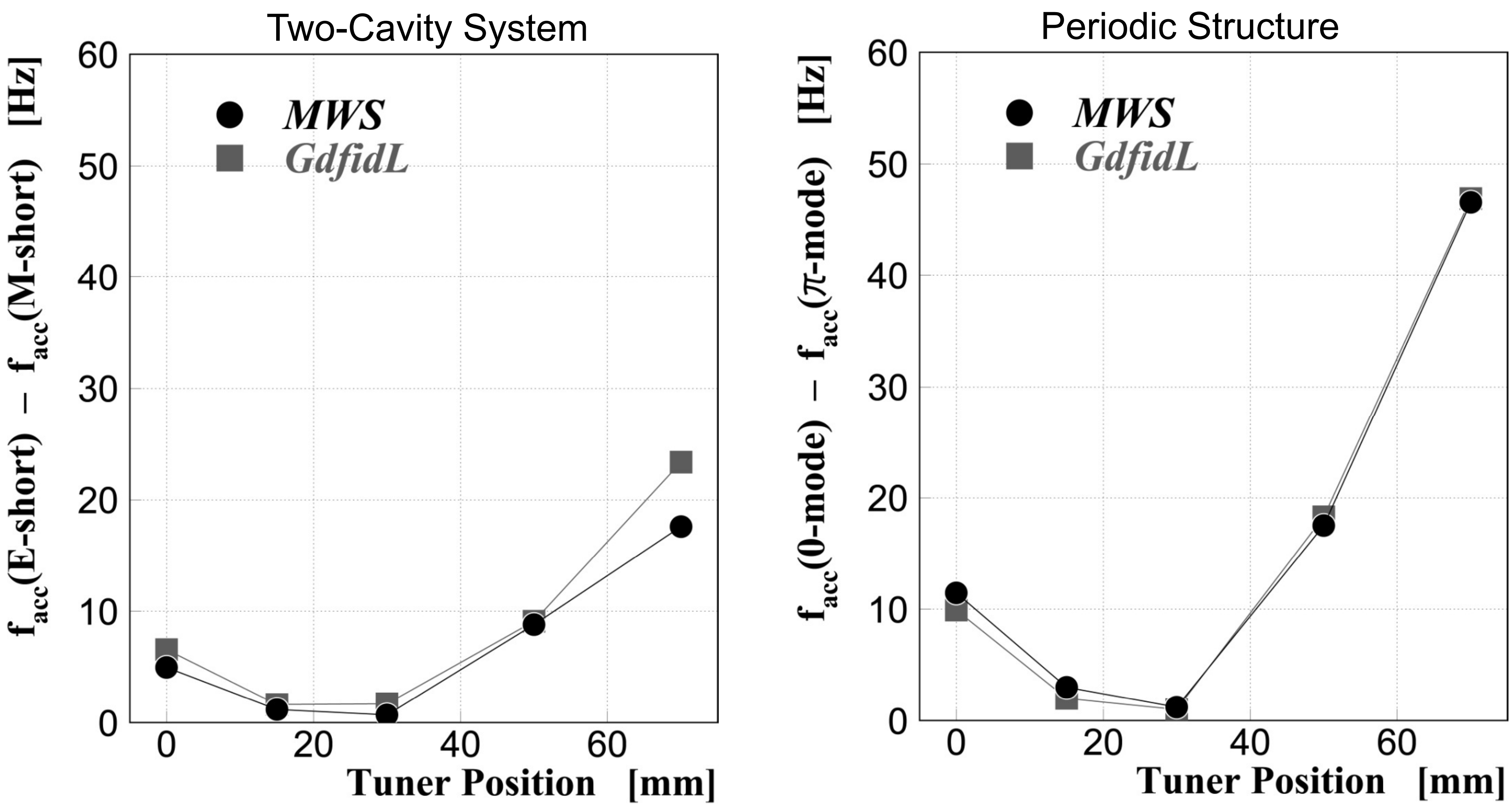
Periodic Structure





(Coupling Strength) ∝

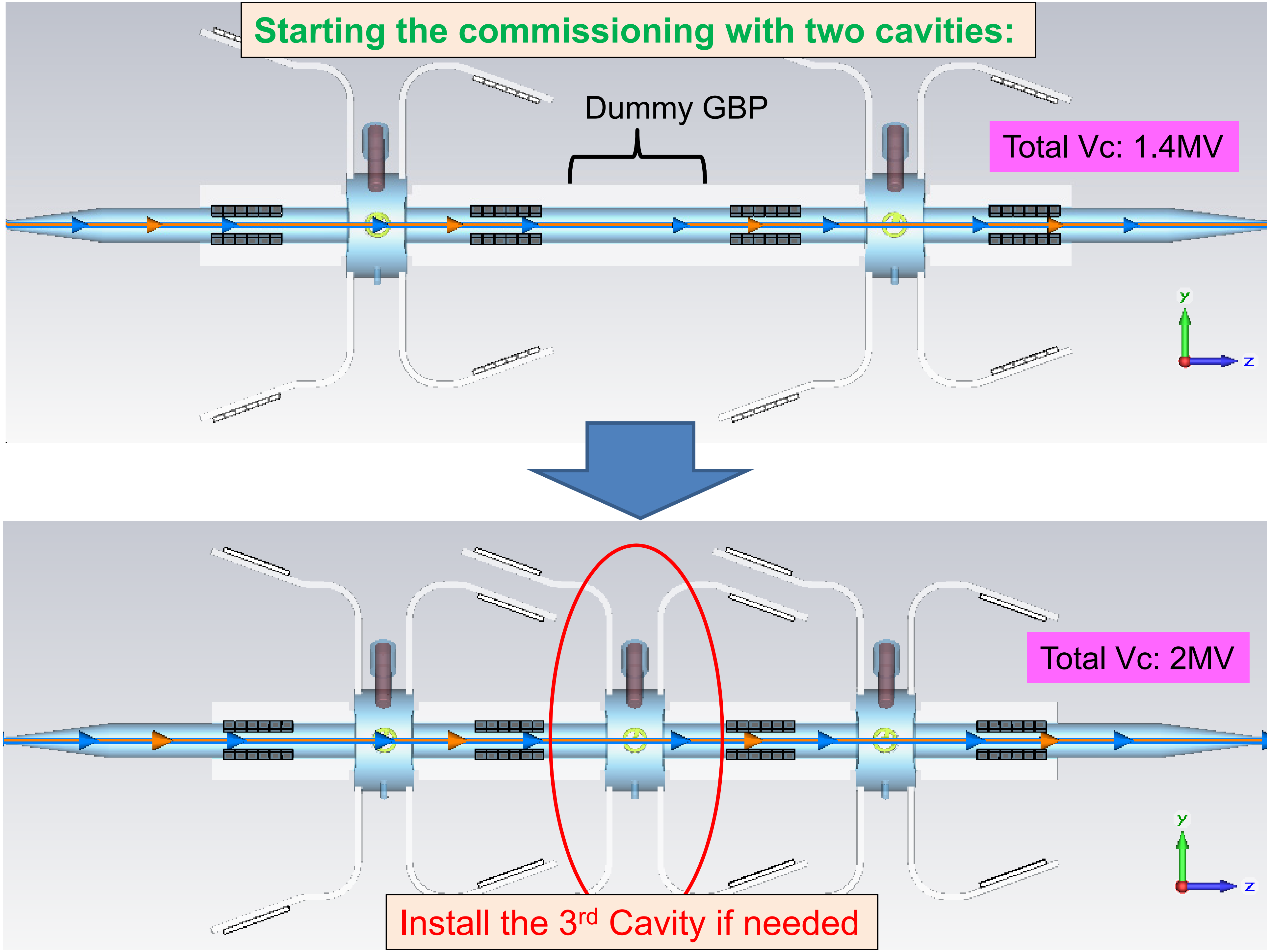
$$<< \frac{f_{acc}}{Q_0} \approx \frac{509\text{MHz}}{30000} \approx 20\text{kHz}$$



The Coupled Oscillations of the ACC Mode are negligible.

Schedule

JFY	Cavity No. to be made	Remarks
2011	0 (prototype)	HPT to be done by May 2012; Could be a spare.
2012	1	Feedback from the HPT of the Cavity No.0
2013	2	Get ready for the commissioning with the two cavities.
201X	3	If needed



Starting the commissioning with two cavities:
Dummy GBP
Total Vc: 1.4MV
y
z
Total Vc: 2MV
y
z
Install the 3rd Cavity if needed

Summary

- **The design of the accelerating structure for the DR has been modified for the total V_c: 2MV(max).**
  - Based on the KEKB-MR/ARES
  - Three cavities with 0.7MV/cav
  - GBP made common between the neighboring cavities
- **SiC tiles are used for all the HOM dampers.**
  - Based on the established technology used for KEKB-MR/ARES
  - (RF absorption power)/set < 180W << PowerCapability: 1kW/set
- **CBIs driven by the HOM impedances**
  - Longitudinal Growth Time ＞ 20 ms ＞ 5 ms (rad. damping time)
  - Transverse Growth Time ＞ 30 ms ＞ 10 ms (rad. damping time)
- **Coupled Oscillations of the ACC-mode: negligible**
  - OK

Fin.

Appendix A

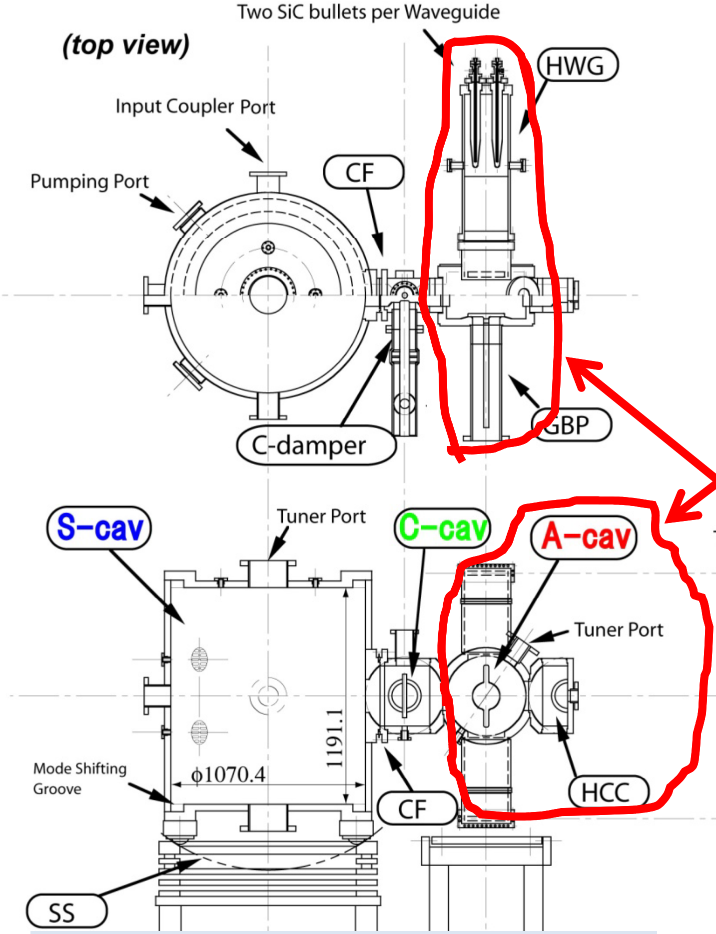
Assumptions for estimating wall temperatures of the DR cavity

- 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 $\pi/2$-mode operation

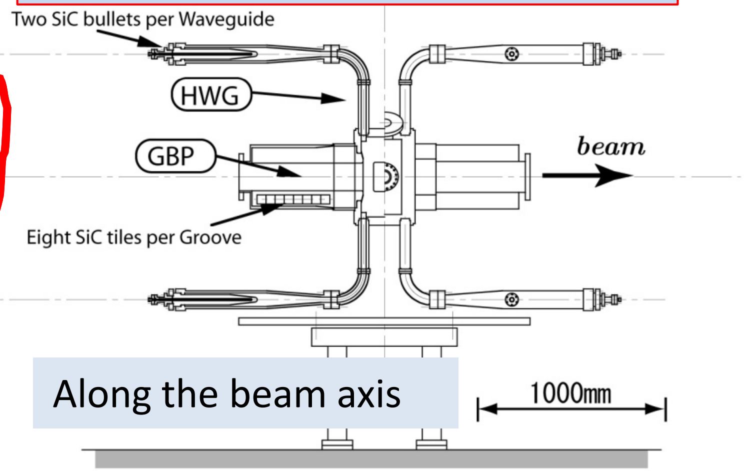


Perpendicular to the beam axis

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.



Along the beam axis