RF Accelerating Structure for the Damping Ring at the SuperKEKB Injector

Tetsuo ABE

For KEKB-RF/ARES Cavity Group

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The 15th KEKB Accelerator Review Meeting

February 16, 2010

Damping Ring (DR) / ARES

[Basic Conditions]

A) Frequency: 508.887MHz (= $f_{\mathrm{KEKB-MR}}$)
B) Based on KEKB-MR/ARES, but without **S-cav** and **C-cav**
C) Connection to ϕ40 beam ducts (→taper near the cavity)

[Main Topics]

1. Determination of the Cavity Diameter
2. Upgrade of the HOM Damper (GBP)
3. HOM Impedances for Longitudinal CBI

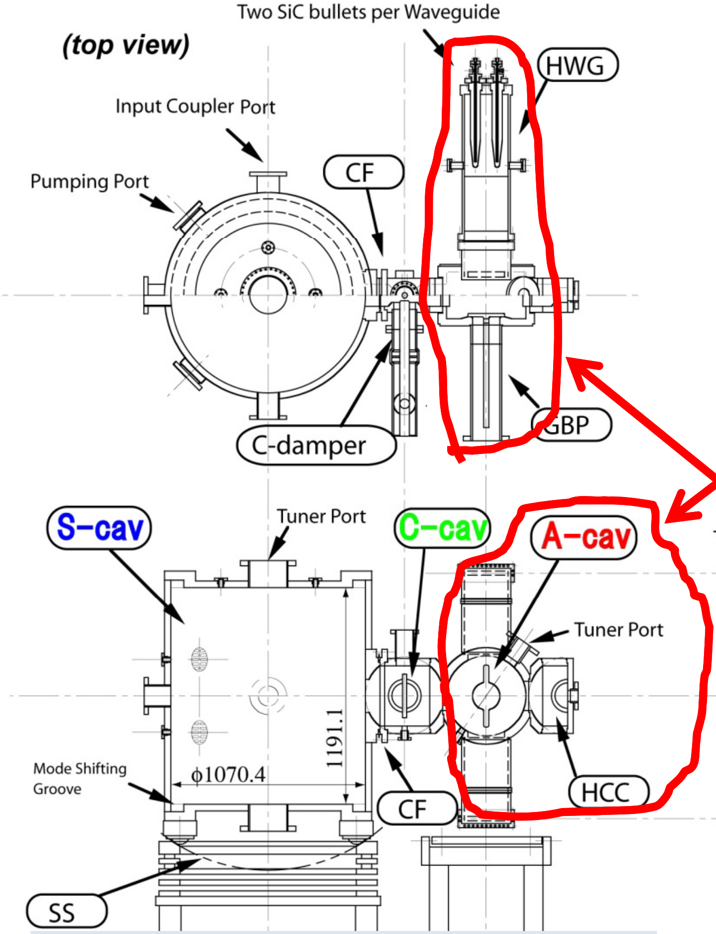
Accelerator Resonantly-coupled with Energy Storage

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

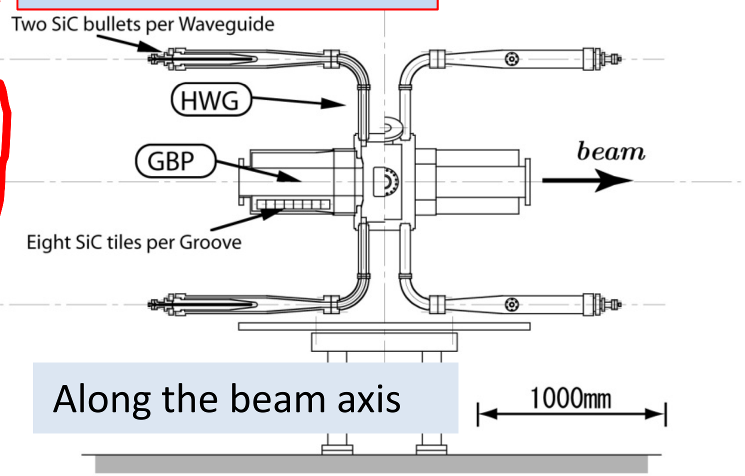
consists of

- 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.



Perpendicular to the beam axis



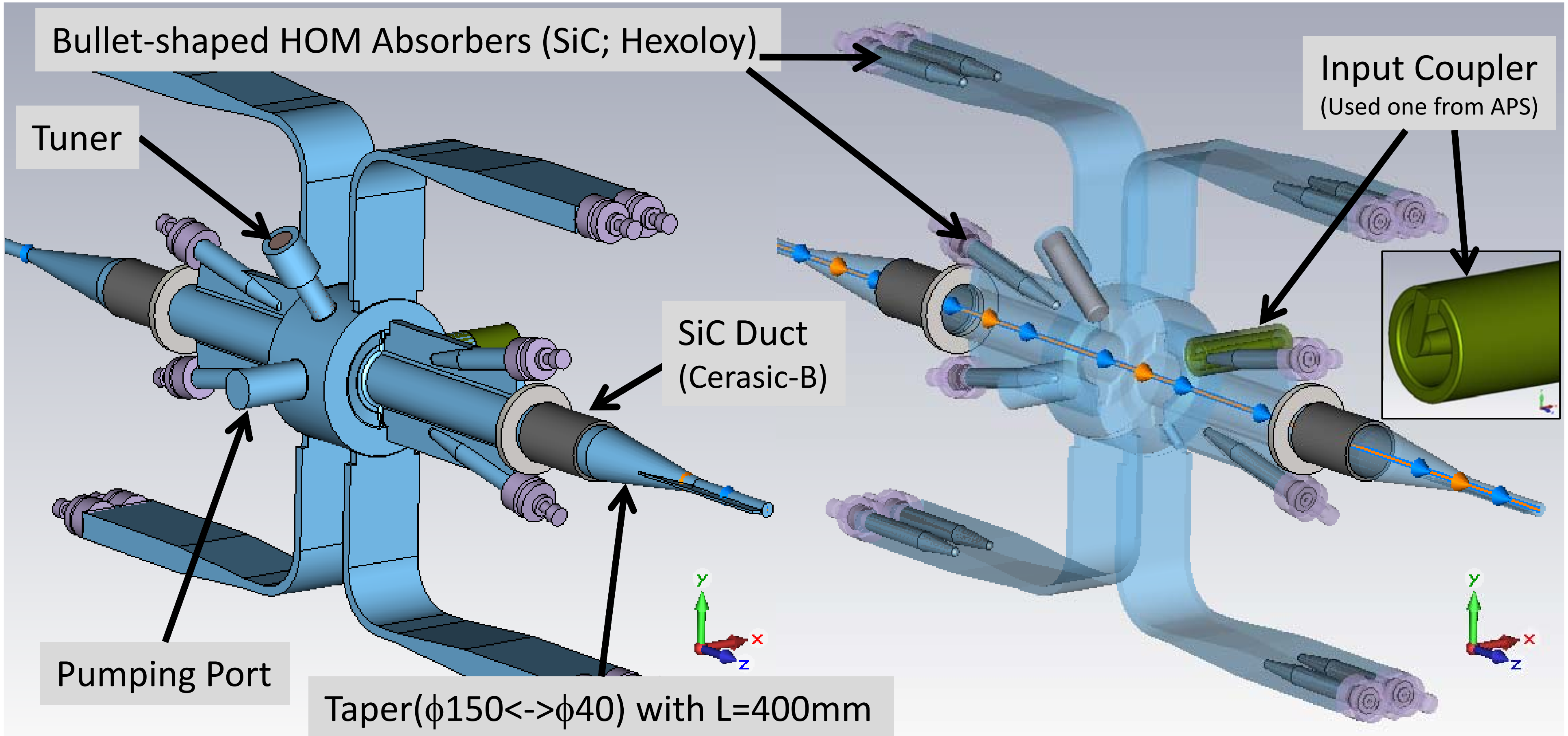
Along the beam axis

RF Model of DR/ARES

ver.2010-02-16

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

(Normal View) (Transparent View)

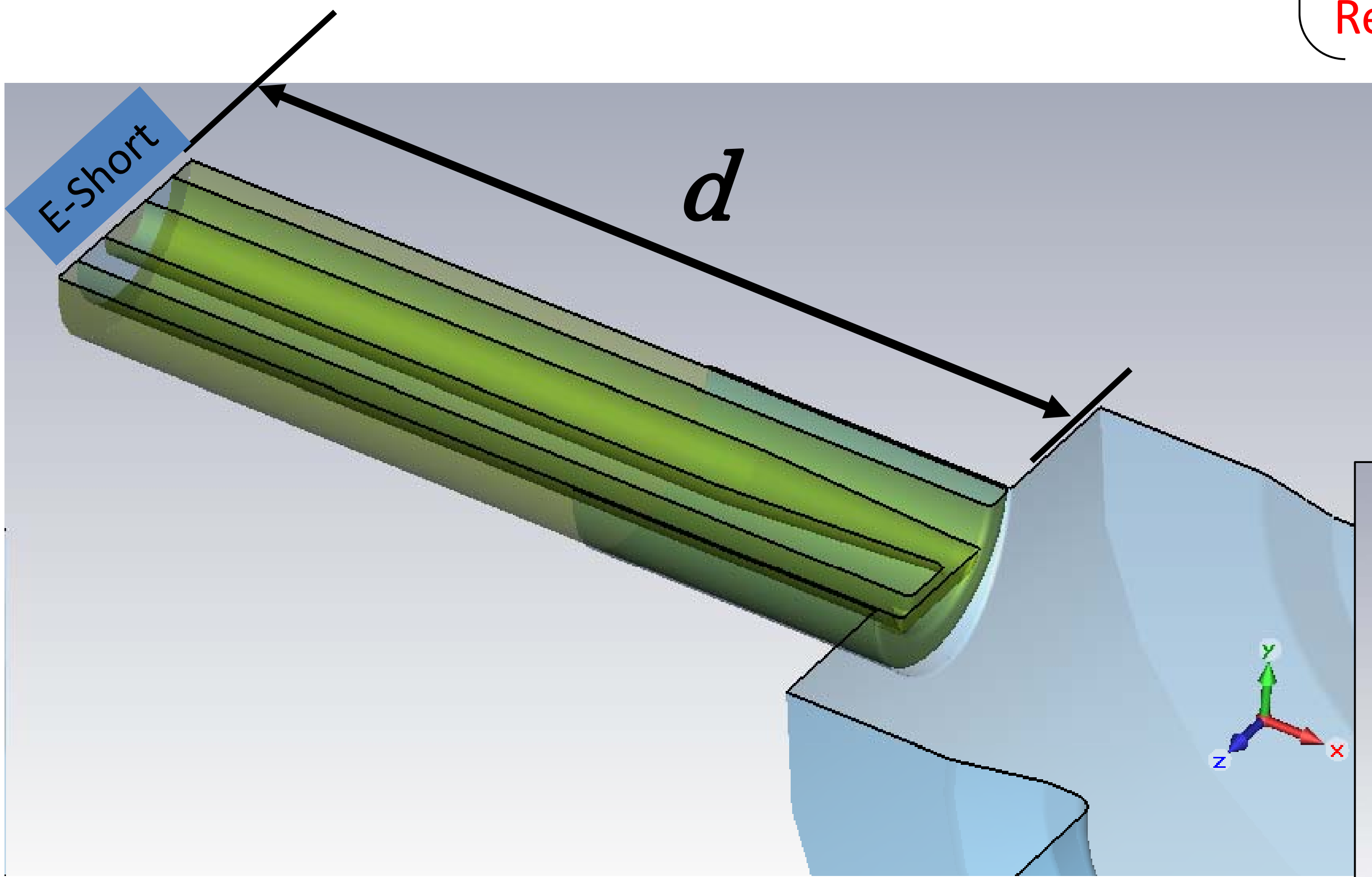


1. Determination of the Cavity Diameter

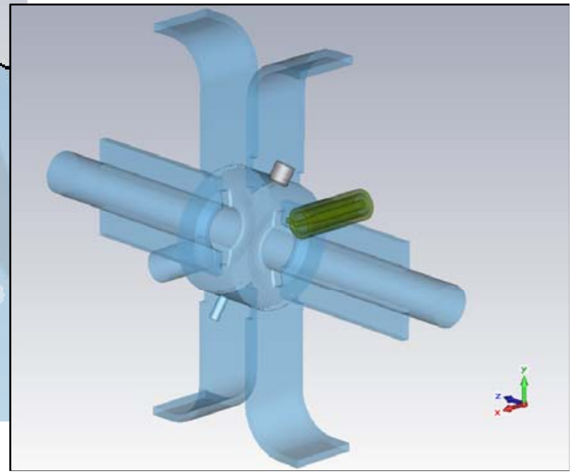
using the Slater's Tuning Curve Method

$$d - d_0 = \frac{\lambda}{2\pi}\tan^{-1}\frac{1/Q_{ext}}{f/f_a - f_a/f} + \frac{n}{2}\lambda$$

λ : guide wave length
f_a: *ACC-mode frequency*
n: integer
Red: floating in fitting

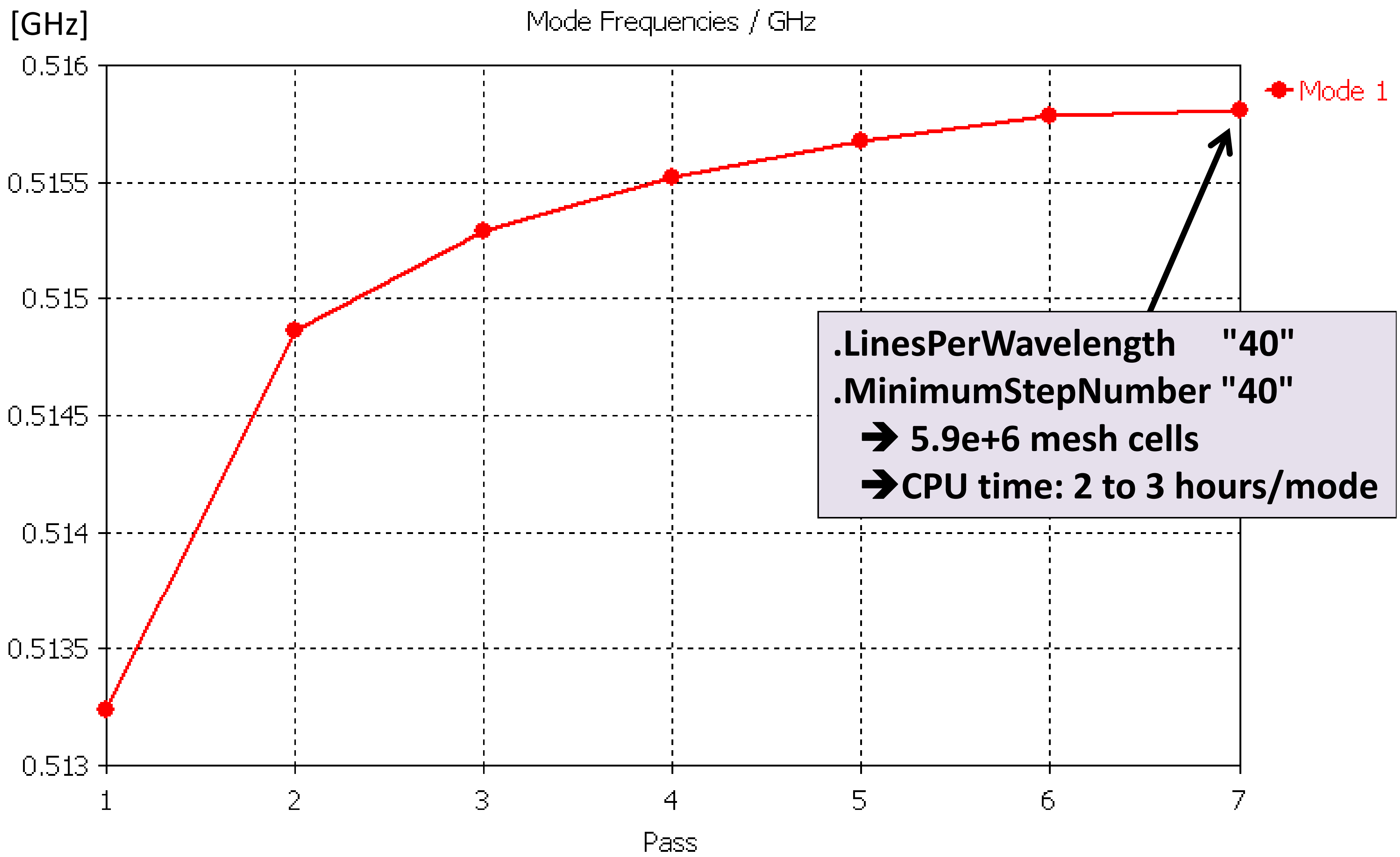


Simplified model
for eigenmode analyses



Eigenmode Ananyses using CST MW-STUDIO

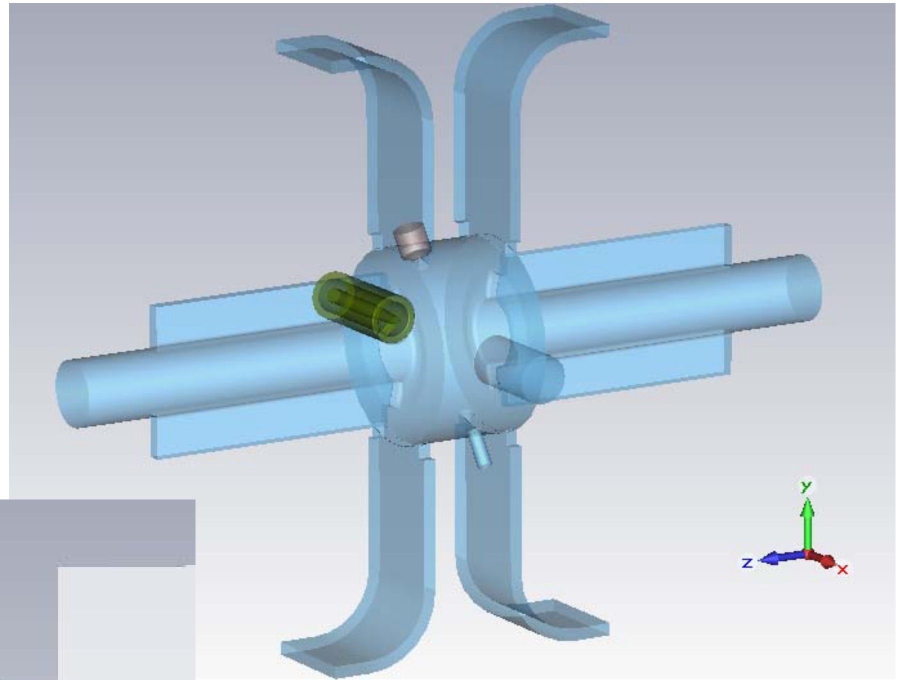
Increase the number of mesh cells so that $\underline{\Delta f_a < 100\text{kHz}}$



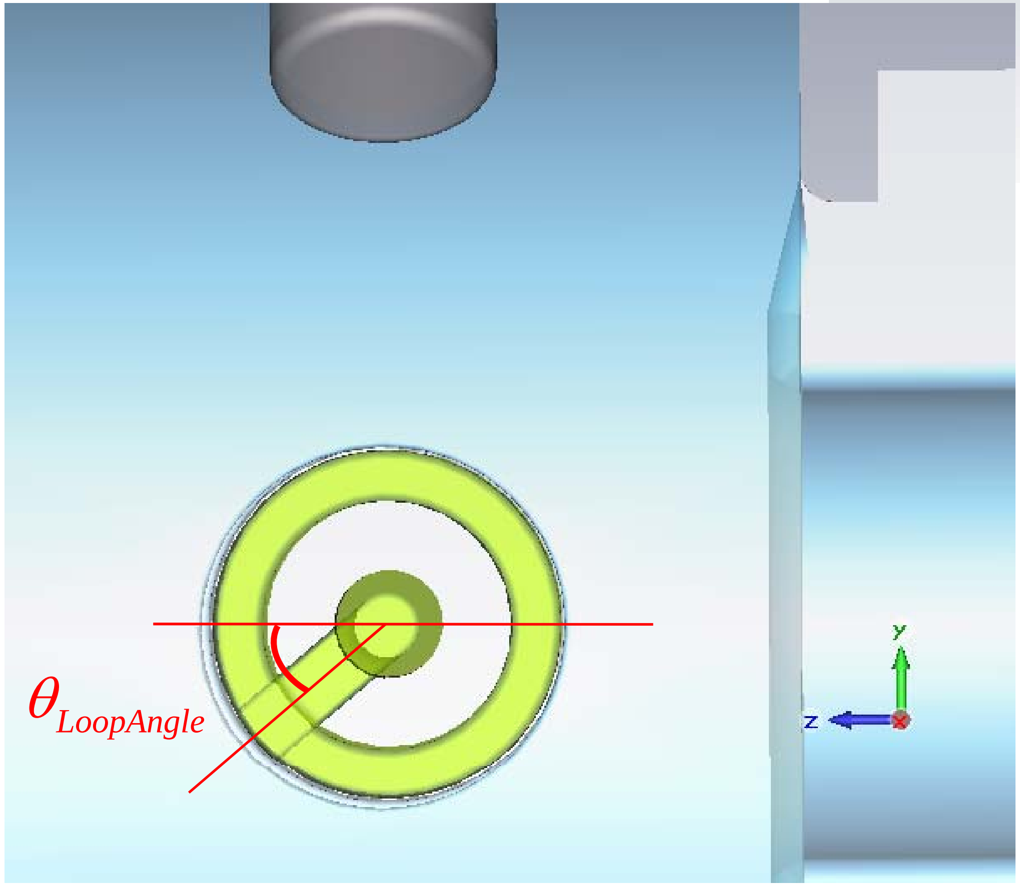
(Preparation)

Adjust the Coupling Factor:

$$\beta = \frac{Q_0}{Q_{ext}} \quad (\Rightarrow \approx 1\,(\text{optimum}))$$



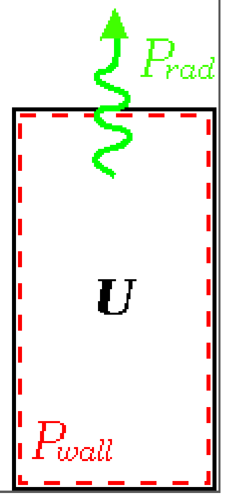
Simplified model
for eigenmode analyses



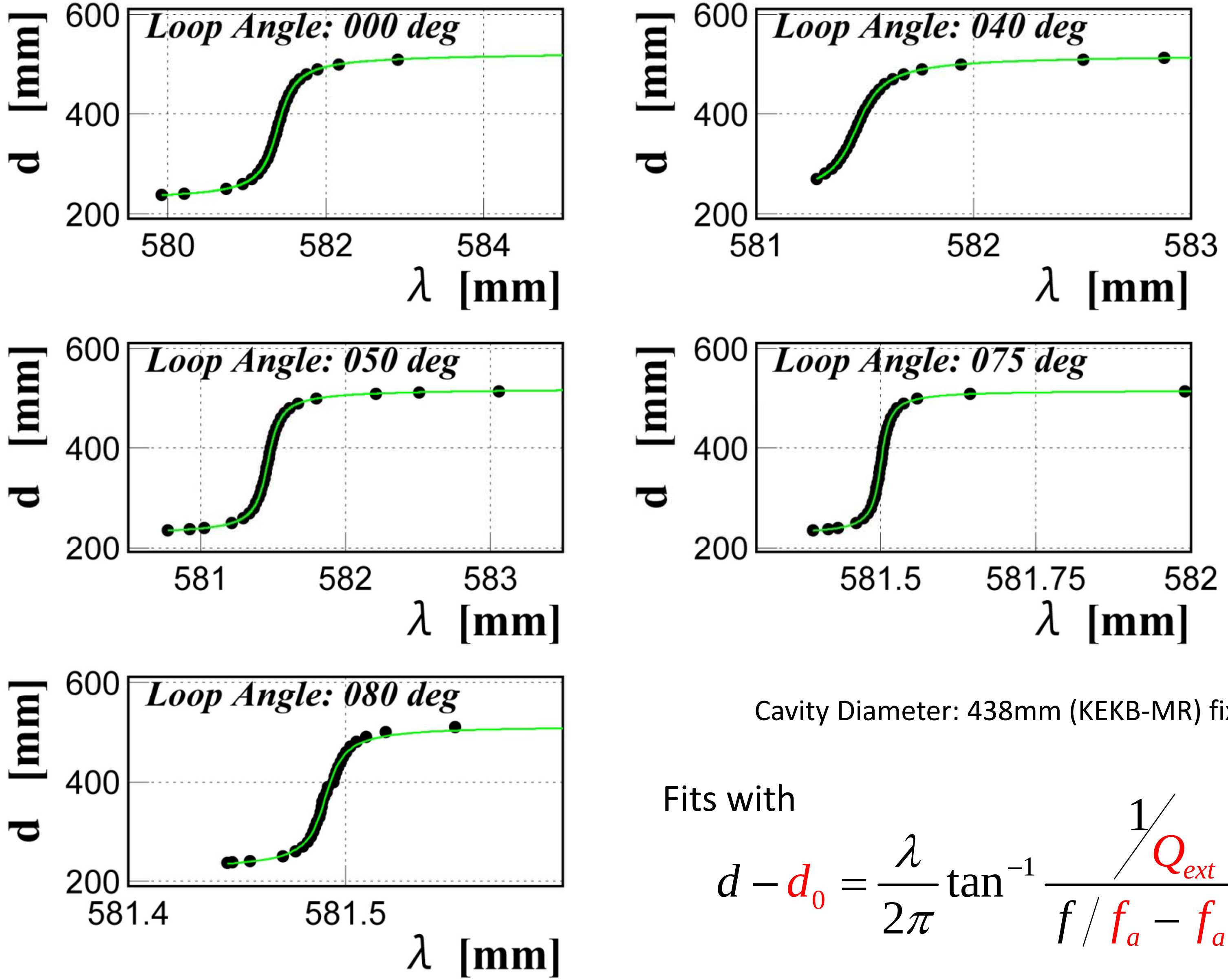
$$Q_0 = \omega_a \frac{U}{P_{wall}}$$

$$Q_{ext} = \omega_a \frac{U}{P_{rad}}$$

$$\beta = \frac{P_{rad}}{P_{wall}}$$



Fitting with the Tuning Curves for Different Loop Angles

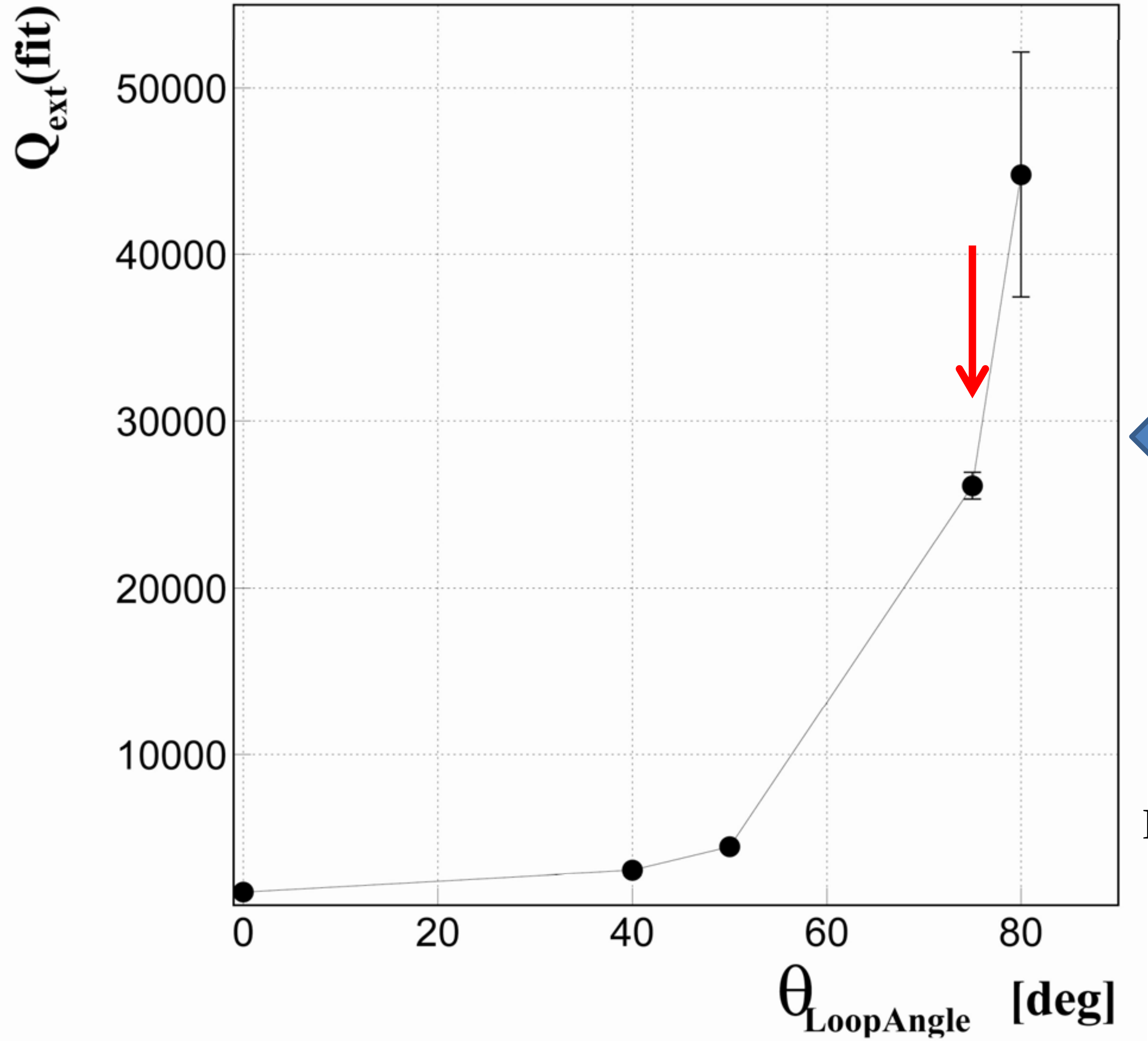


Cavity Diameter: 438mm (KEKB-MR) fixed

Fits with

$$d - d_0 = \frac{\lambda}{2\pi} \tan^{-1} \frac{1/Q_{ext}}{f/f_a - f_a/f} + \frac{n}{2}\lambda$$

Q_{ext} from the Fitting Results as a function of the Loop Angle

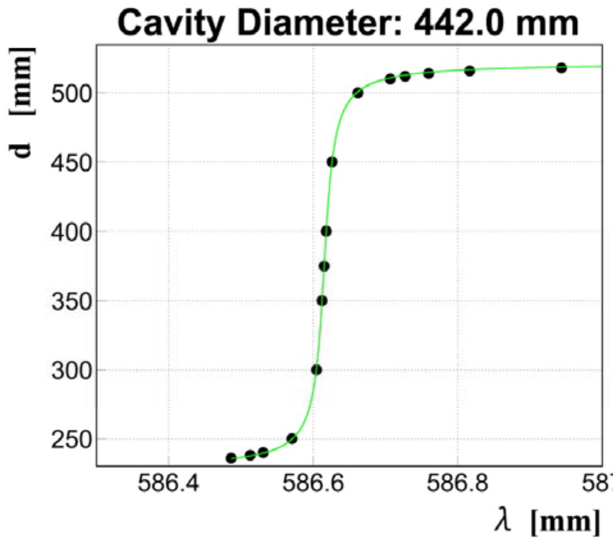


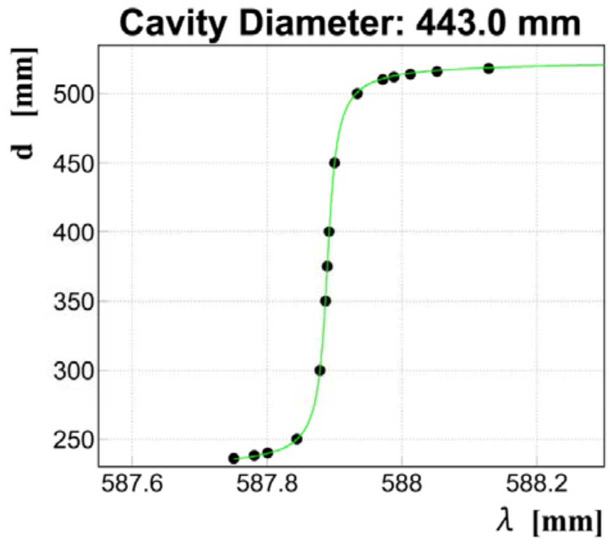
$Q_0 = 29000$ (IACS90%)

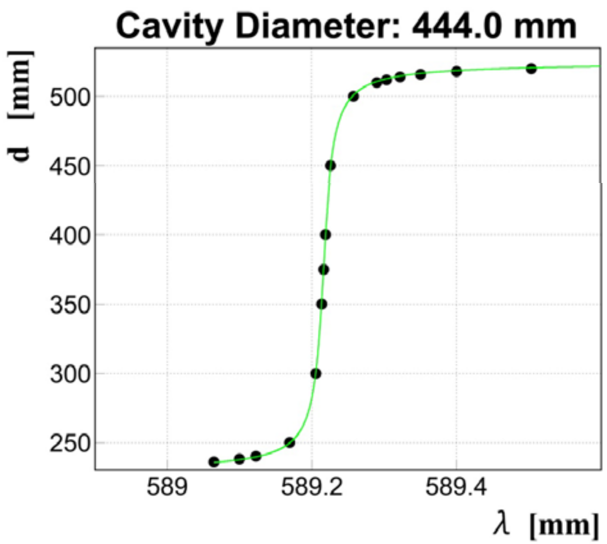
Error bars assuming $\chi^2 / ndf \equiv 1$

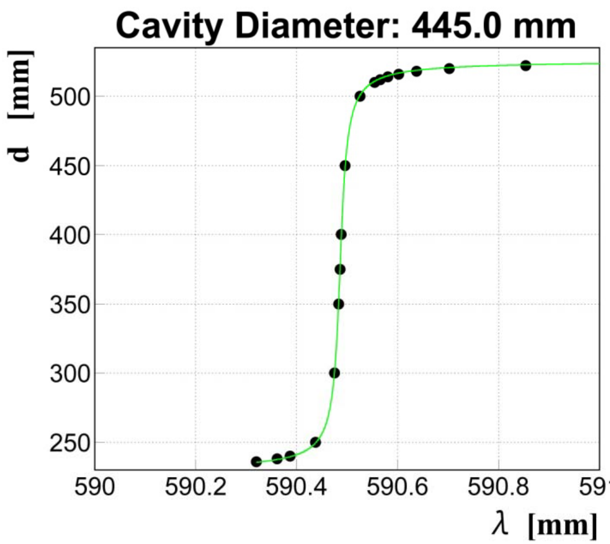
Fitting with the Tuning Curves for Different Cavity Diameters

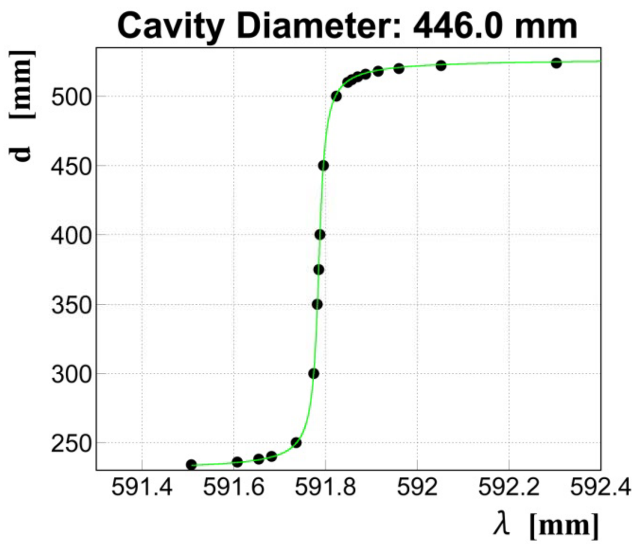
with the Loop Angle: 75deg fixed





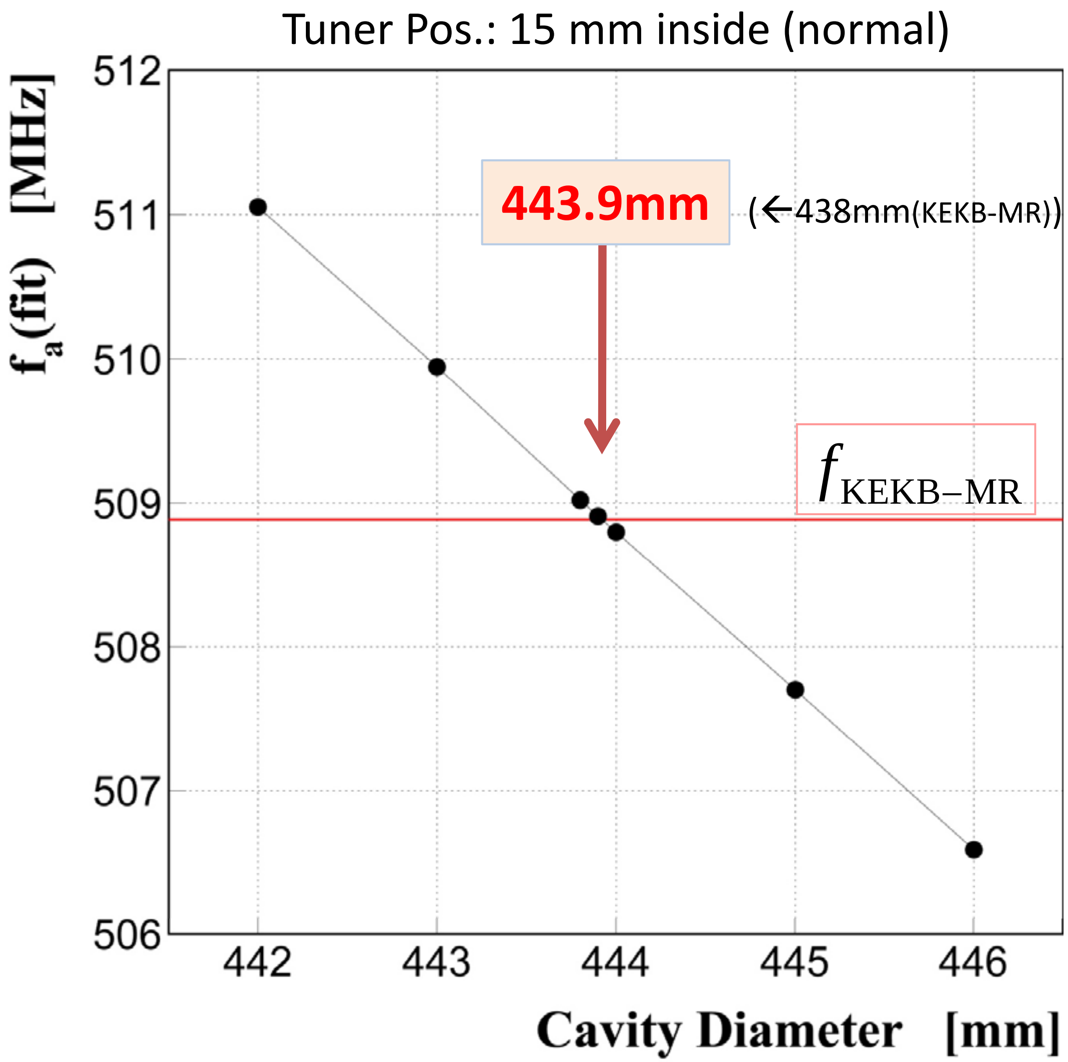


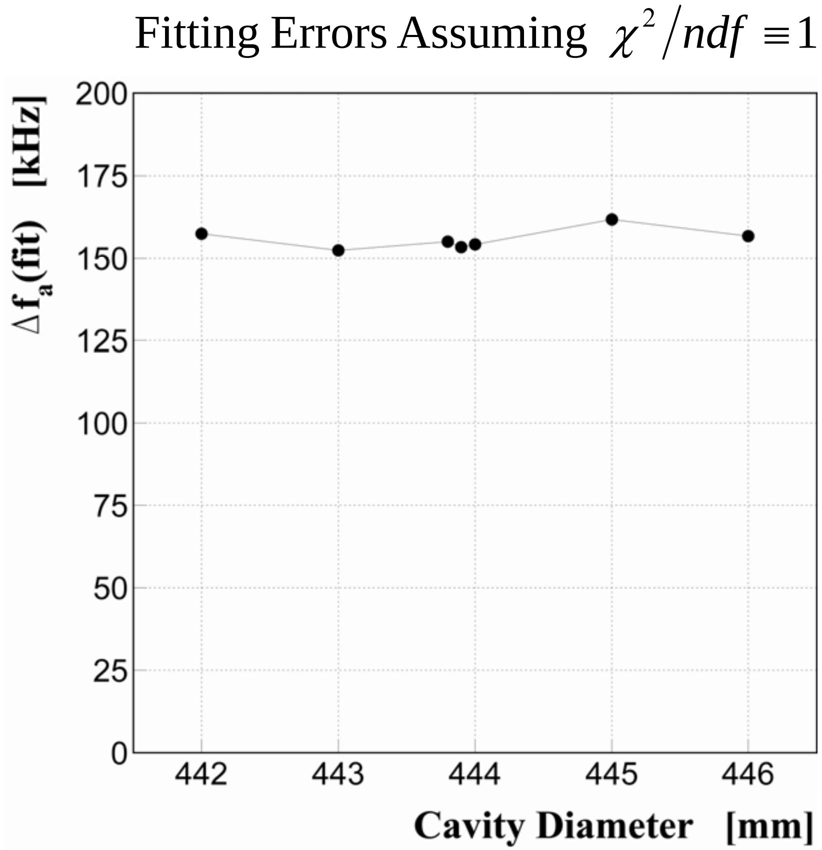




Determination of the Cavity Diameter

from Fitting to the Tuning Curves

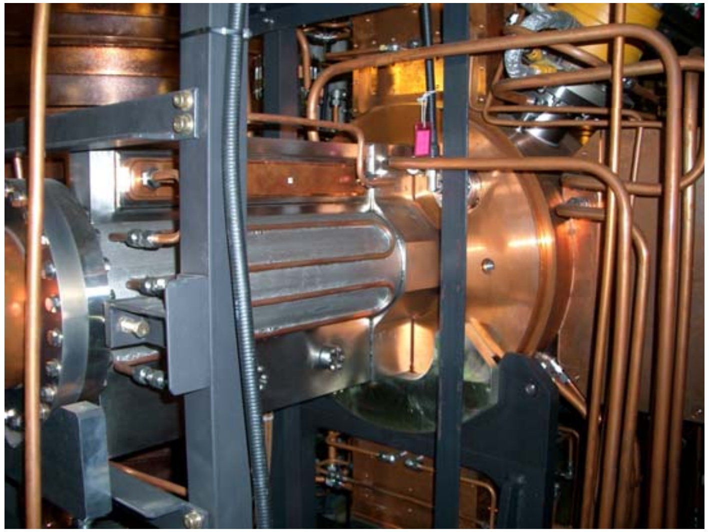


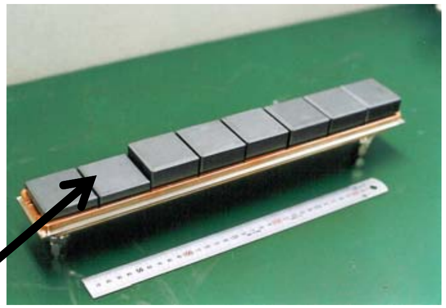


2. Upgrade of the HOM Damper

Grooved Beam Pipe with <u>SiC Tiles</u> Installed

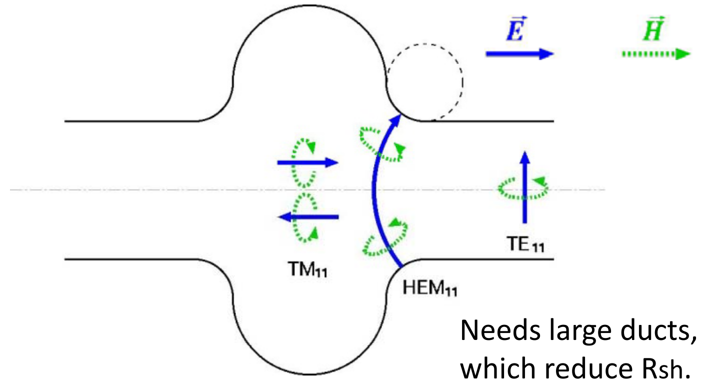
Absorbs Horizontally-Polarized Dipole Mode (TM_{11})





SiC *<u>Indirectly</u>* water-cooled

In the case of SC cavities

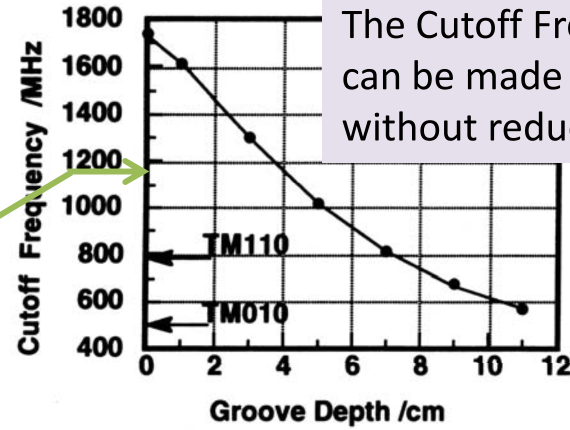


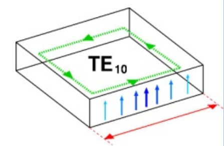
Needs large ducts, which reduce R_{sh}.

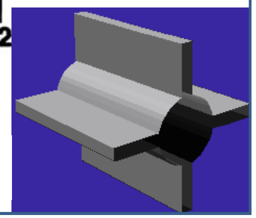
In the case of ARES (NC)

The Cutoff Freq. of TM11 can be made lower without reducing R_{sh}.

Cutoff Freq. of TE11 in a Regular ϕ150 Duct







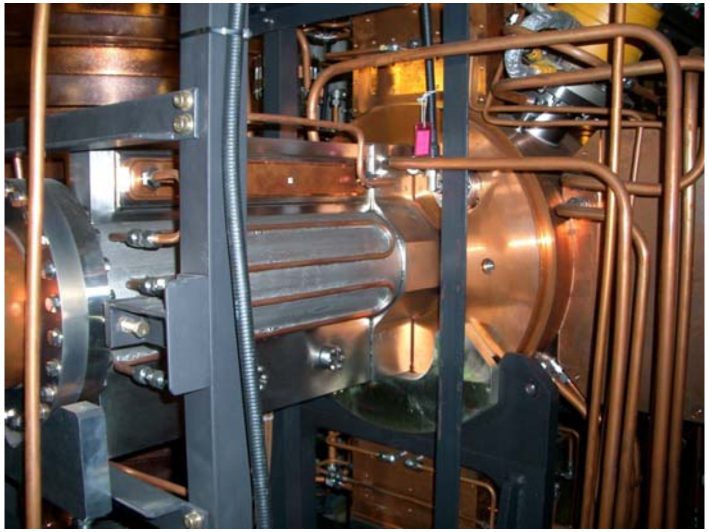
(by T. Kageyama using MAFIA)

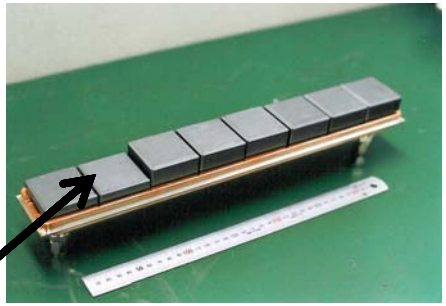
2. Upgrade of the HOM Damper

More Power Capability

Grooved Beam Pipe with SiC Tiles Installed → ***Winged Chamber Loaded with SiC Bullets***

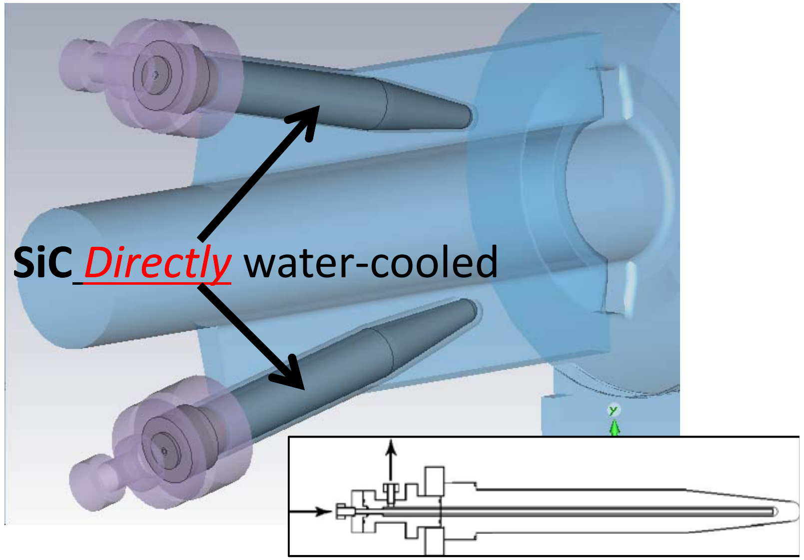
$P_{HOM}^{Capability(1.3\mathrm{GHz})} \approx 1\,\mathrm{kW}$





SiC ***Indirectly*** water-cooled

$P_{HOM}^{Capability(1.3\mathrm{GHz})}$ to be $5\,\mathrm{kW}$



SiC ***Directly*** water-cooled

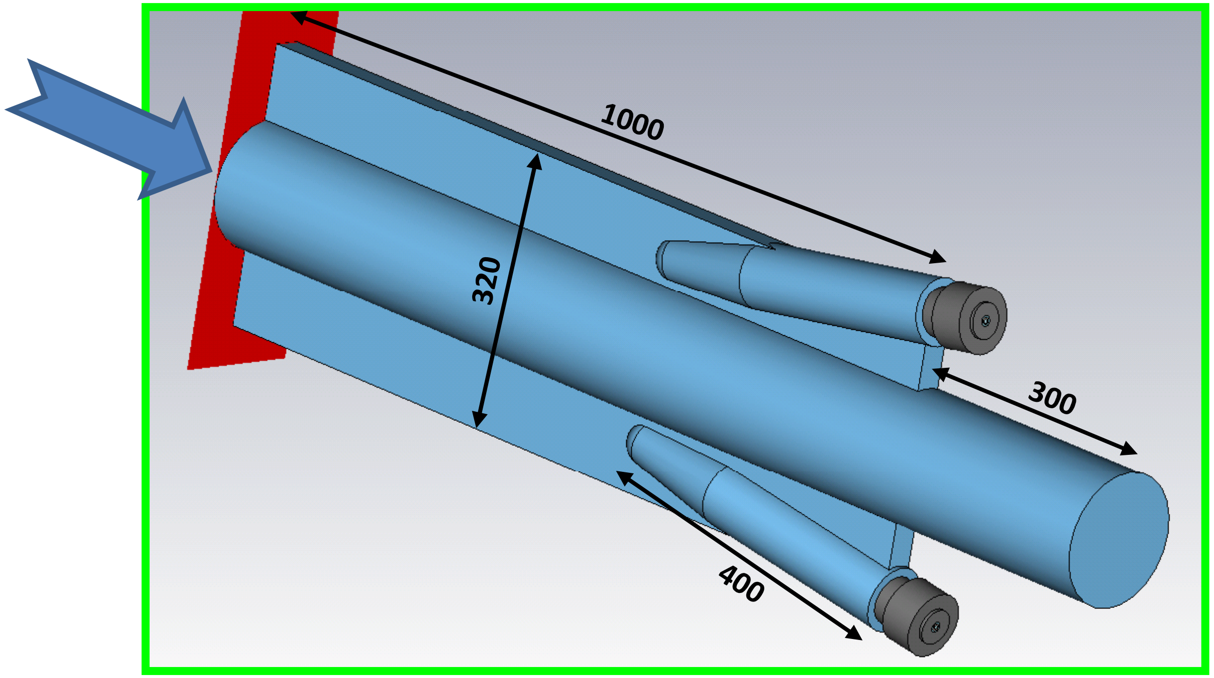
Like the HOM damper
at the Movable Mask Section

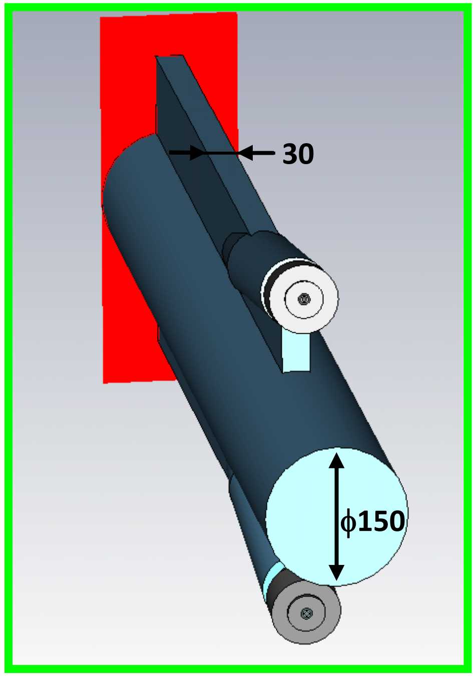
Y. Suetsugu et al., "Development of Winged HOM Damper for Movable Mask in KEKB", Proc. PAC2003.

Search for the Best Position of SiC Bullets

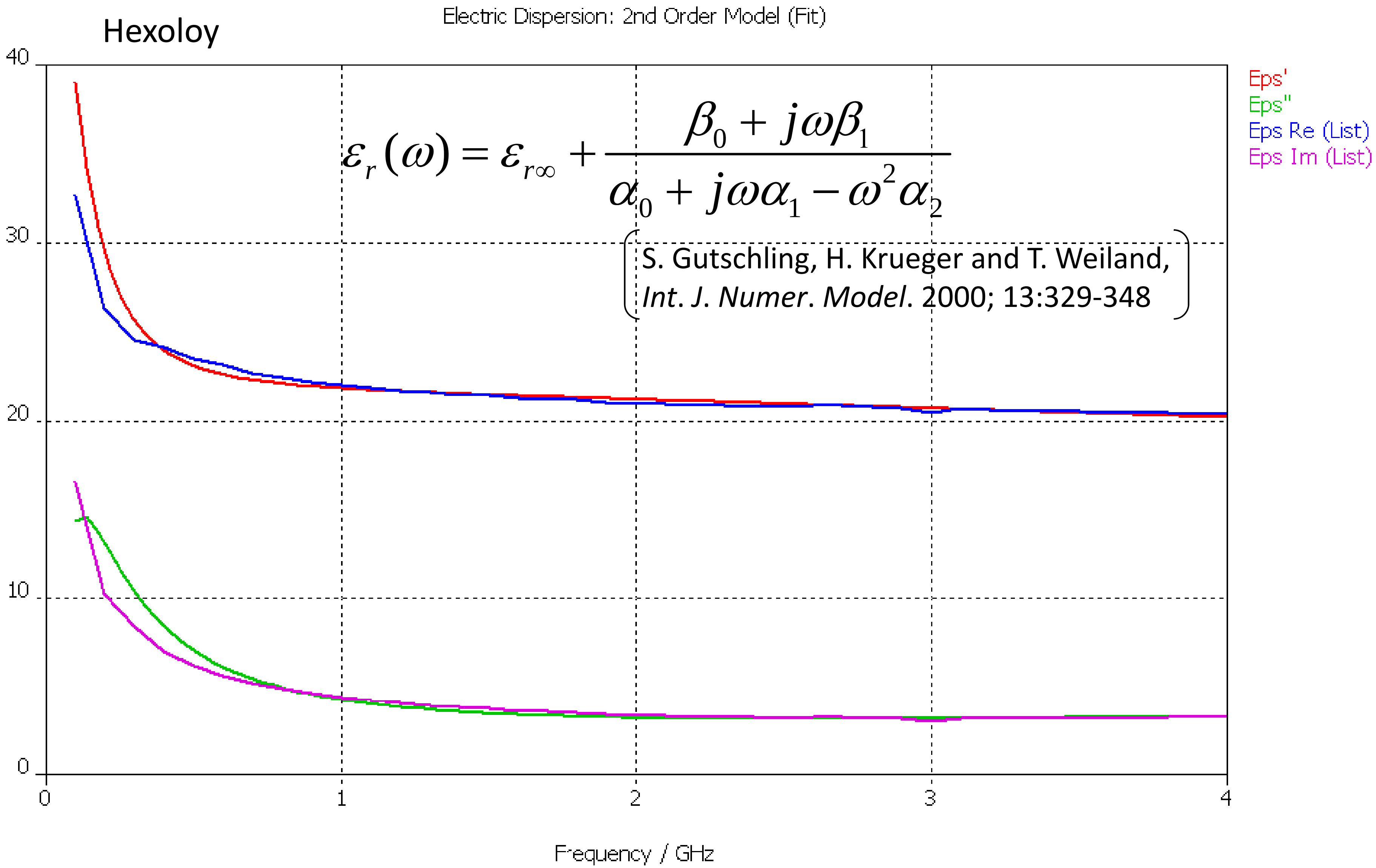
Looking at $|S_{11}|$

Freq. Domain Computation using CST MW-STUDIO





Permittivity Measurements (by Y. Takeuchi) of SiC and the General 2nd-order Model

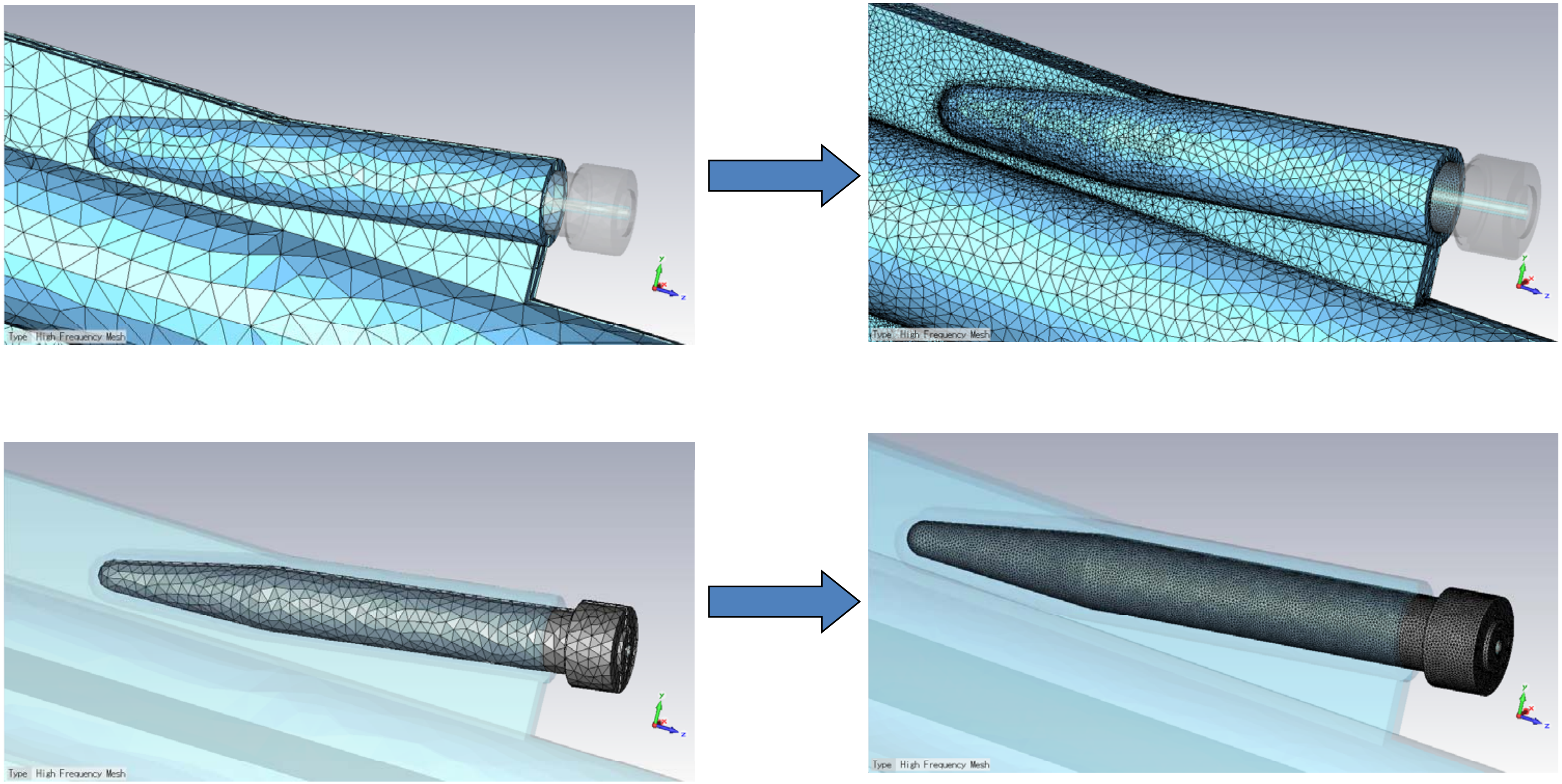


$$\varepsilon_r(\omega) = \varepsilon_{r\infty} + \frac{\beta_0 + j\omega\beta_1}{\alpha_0 + j\omega\alpha_1 - \omega^2\alpha_2}$$

S. Gutschling, H. Krueger and T. Weiland, *Int. J. Numer. Model.* 2000; 13:329-348

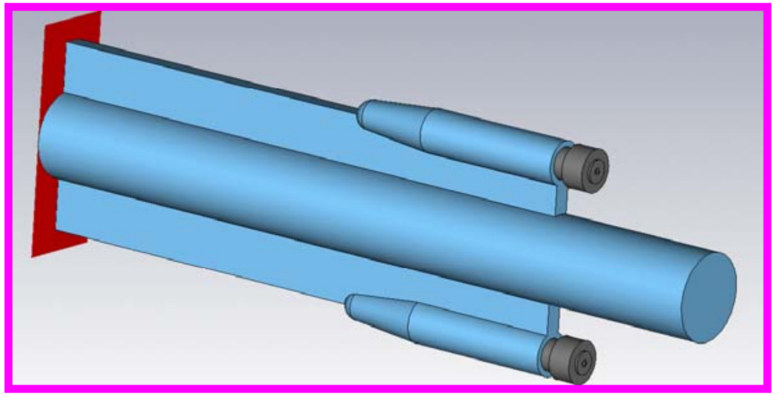
Number of Mesh Cells Increased

Default | This Simulation

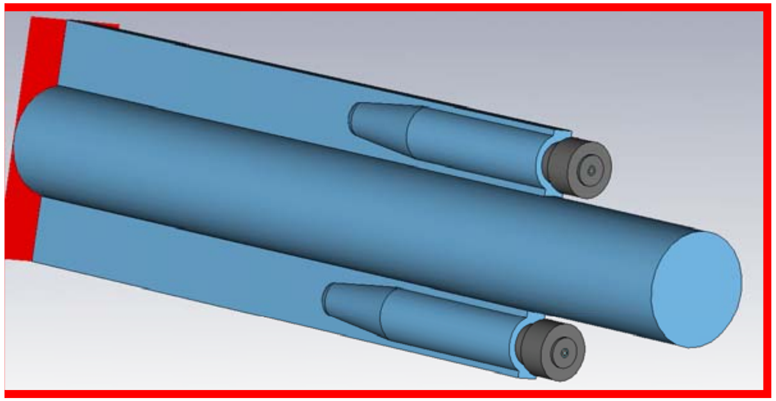


Positions to be Considered

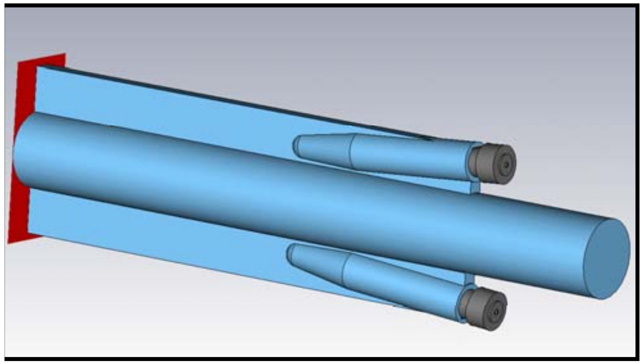
ParaH



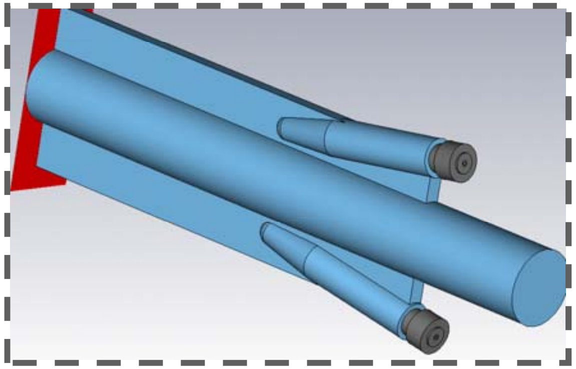
ParaL



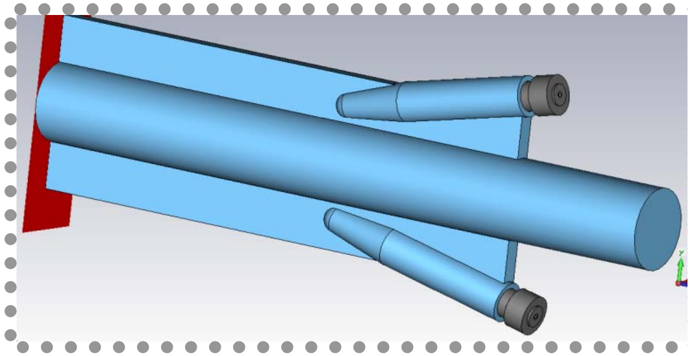
(←Just for reference)



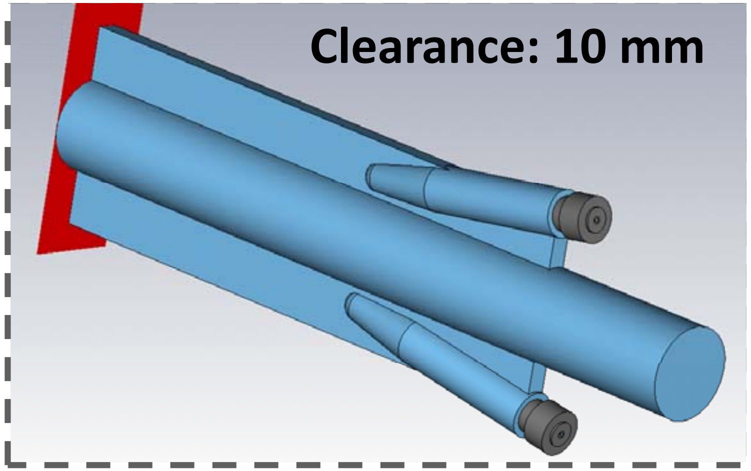
Slope1 (←Just for reference)

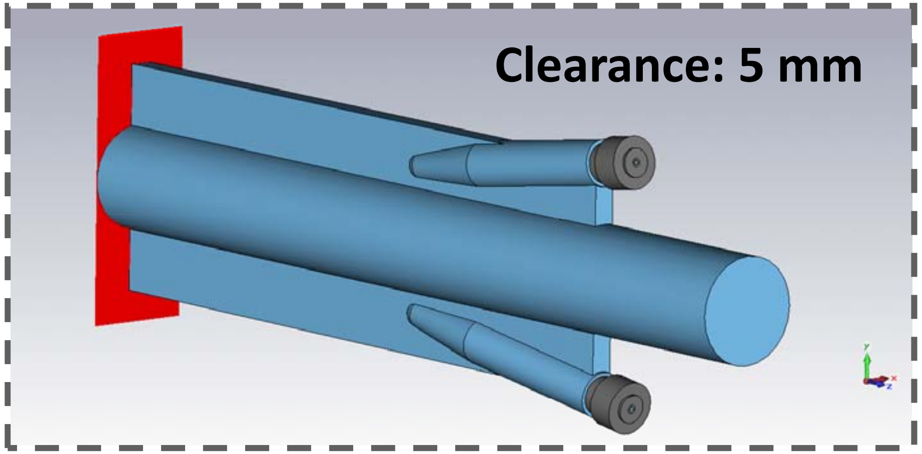


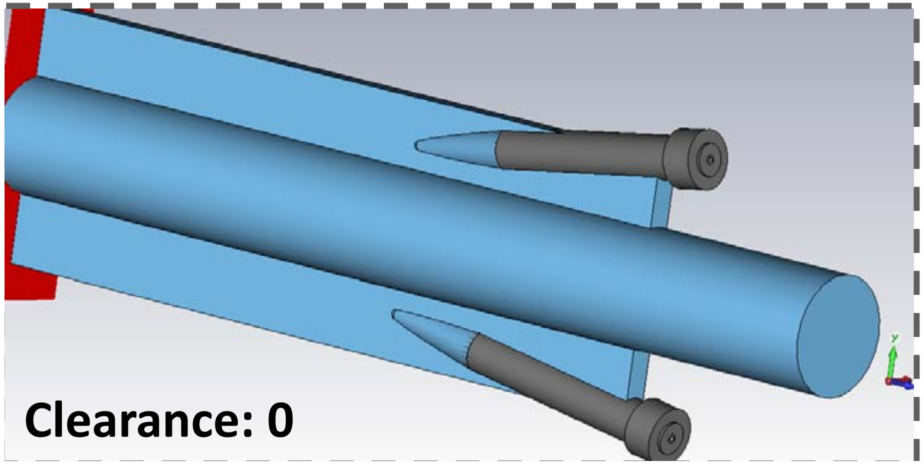
Slope2



Slope3



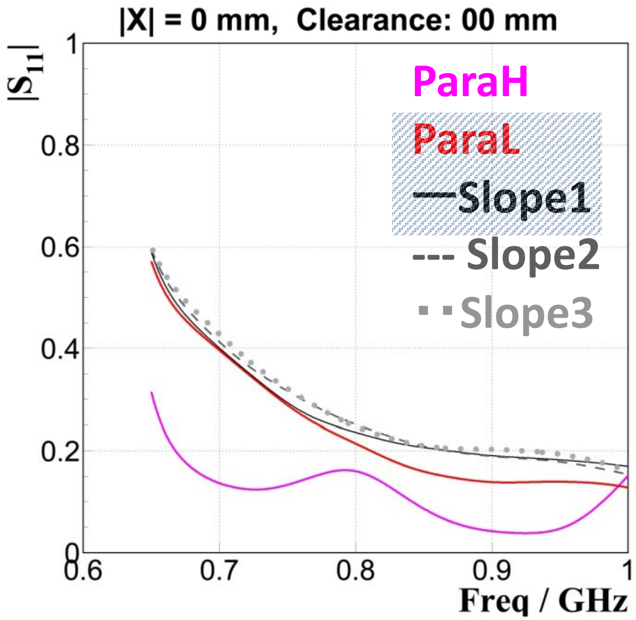




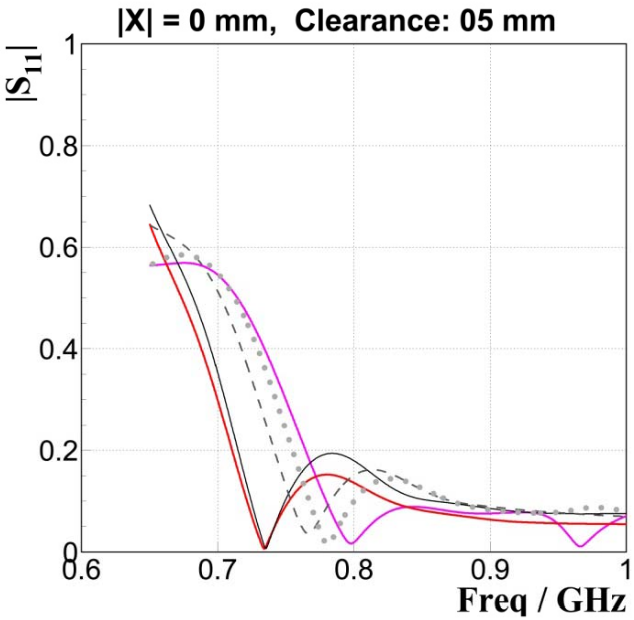
(←Just for reference)

Computation Results

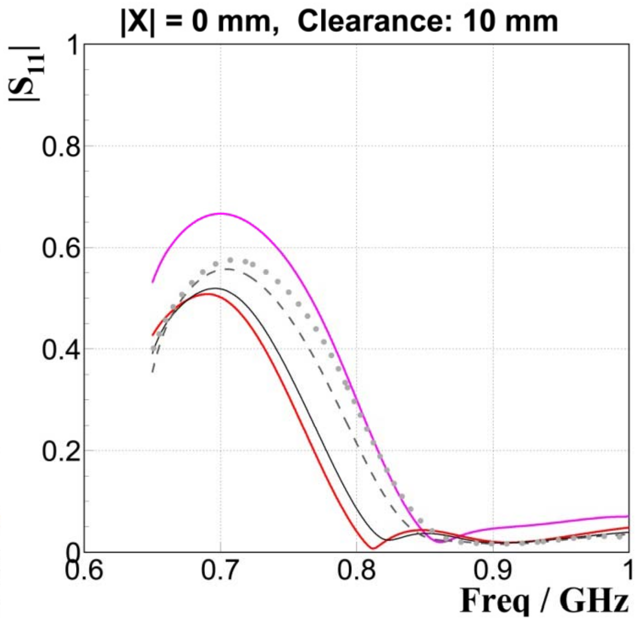
Clearance: 0mm



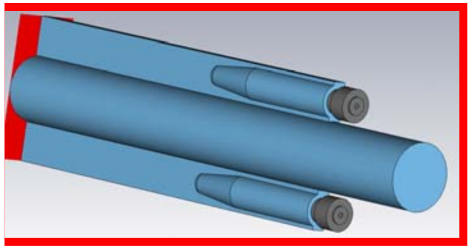
Clearance: 5mm



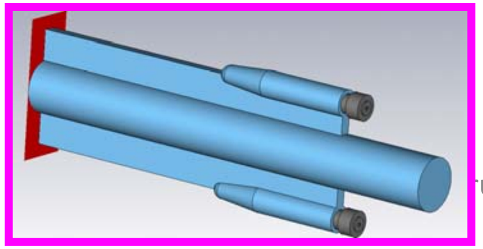
Clearance: 10mm



ParaL

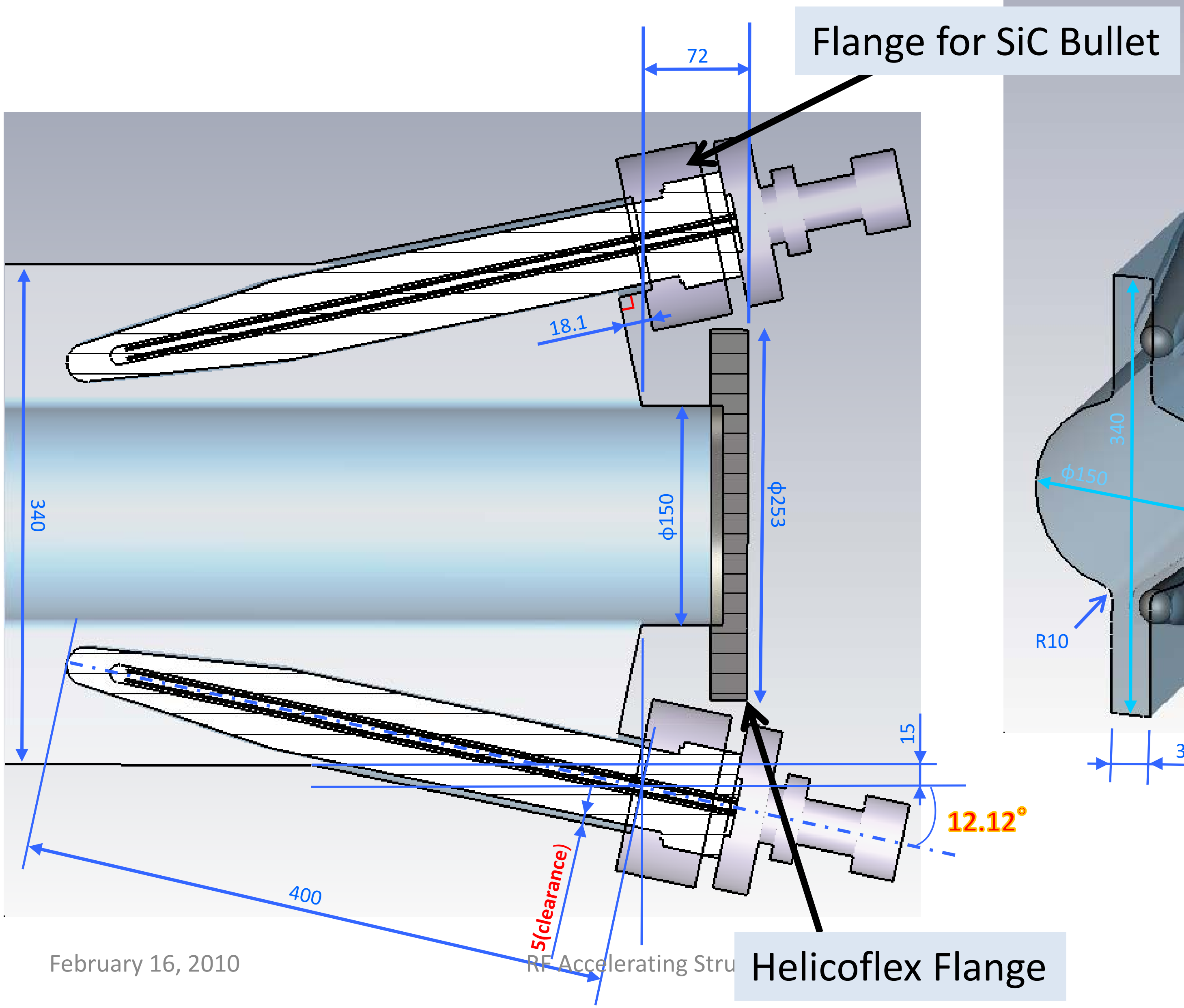


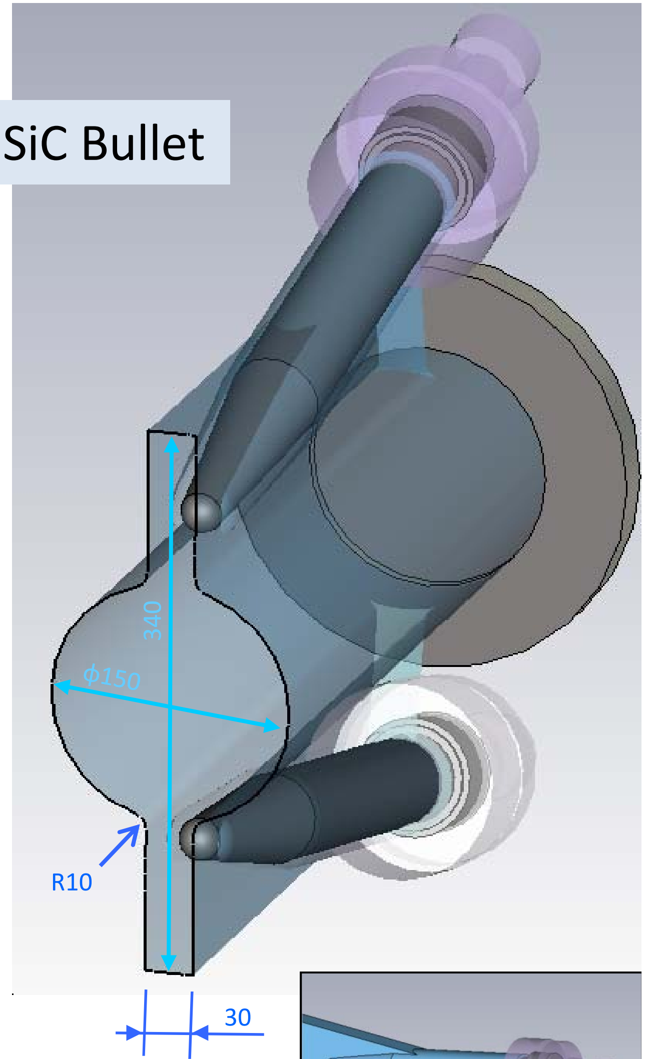
ParaH

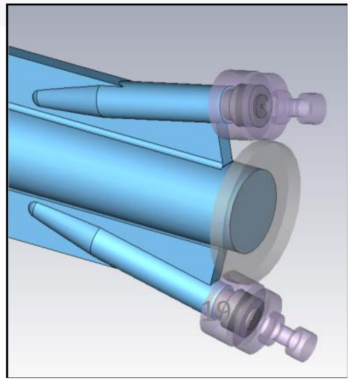


- ParaL:best, ParaH:worst
- Steeper slope worse
- Smaller clearance better

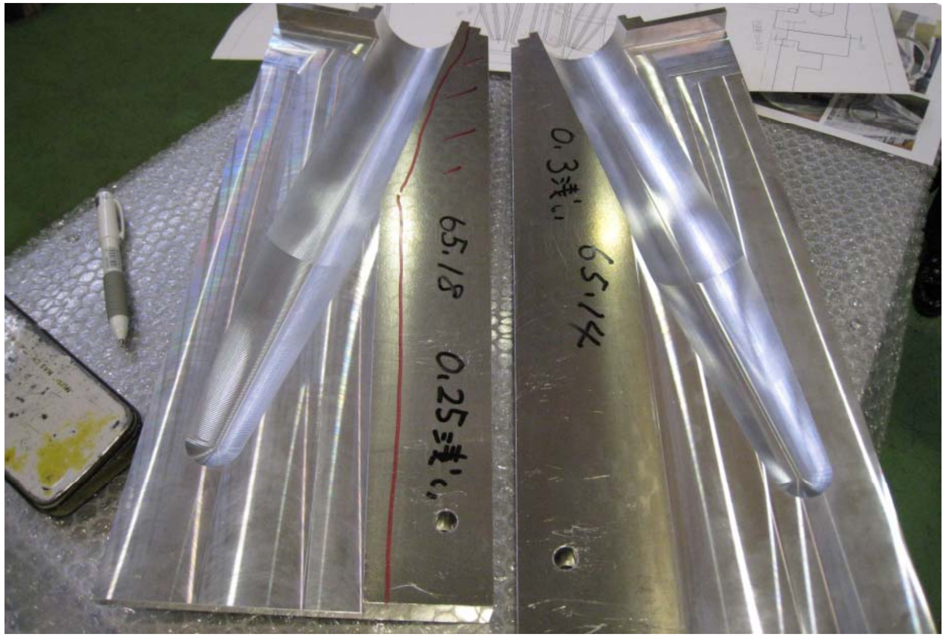
Final Position of the SiC Bullets

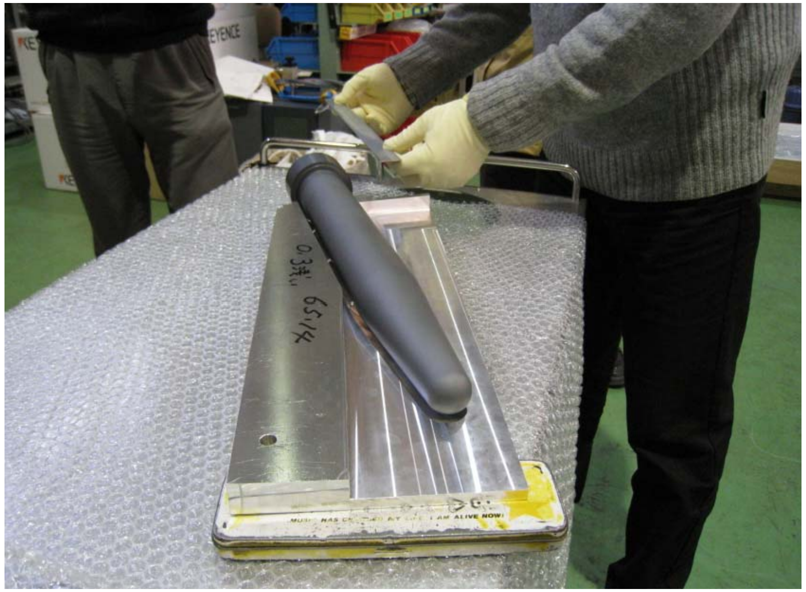


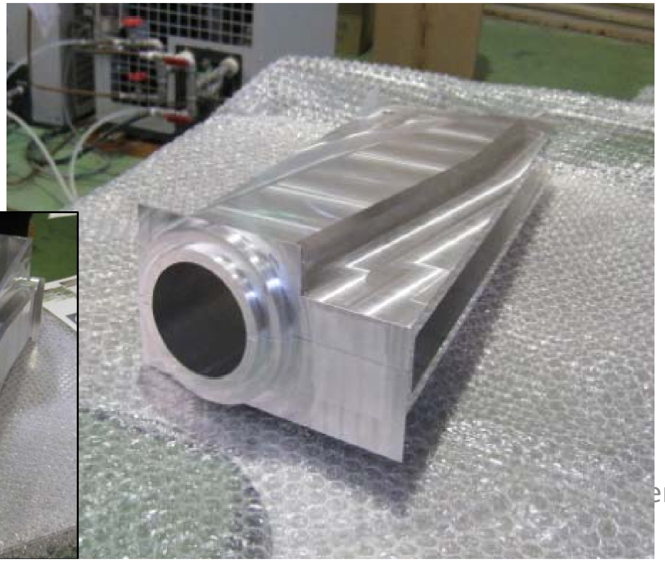


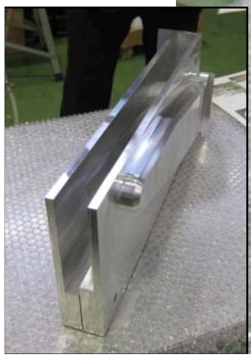


Mockup (Al) of the Winged Chamber arrived (Dec. 24, 2009)
A test chamber (SUS) for high-power tests is coming soon.



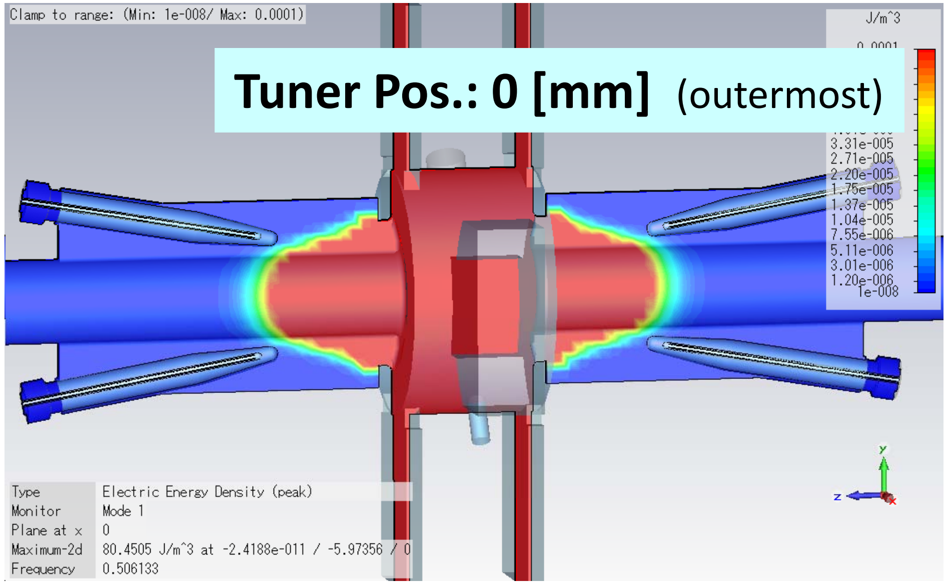


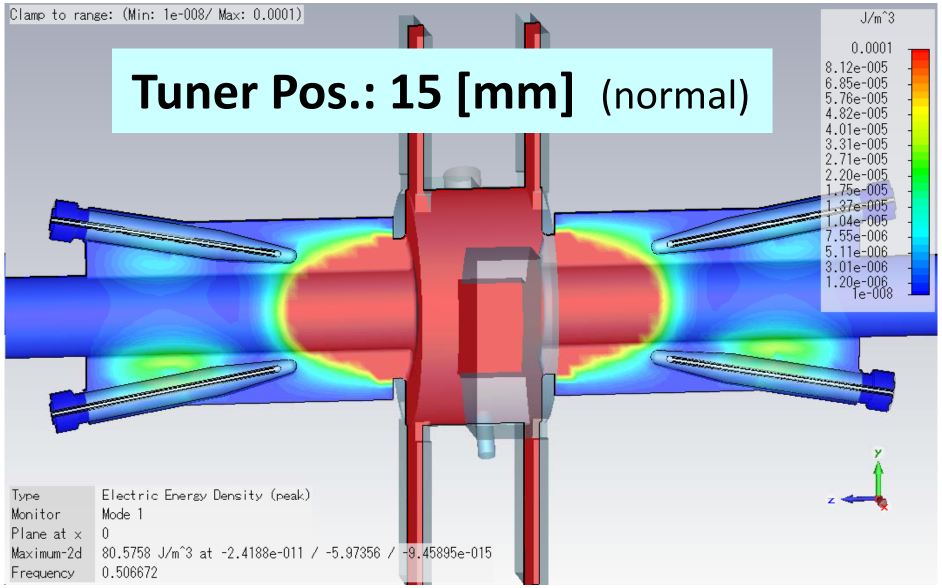


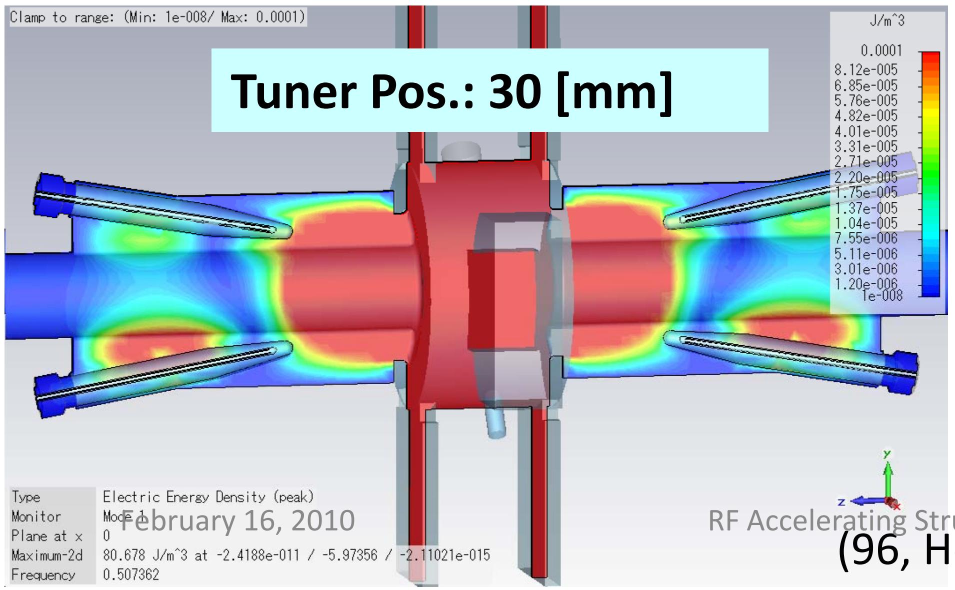


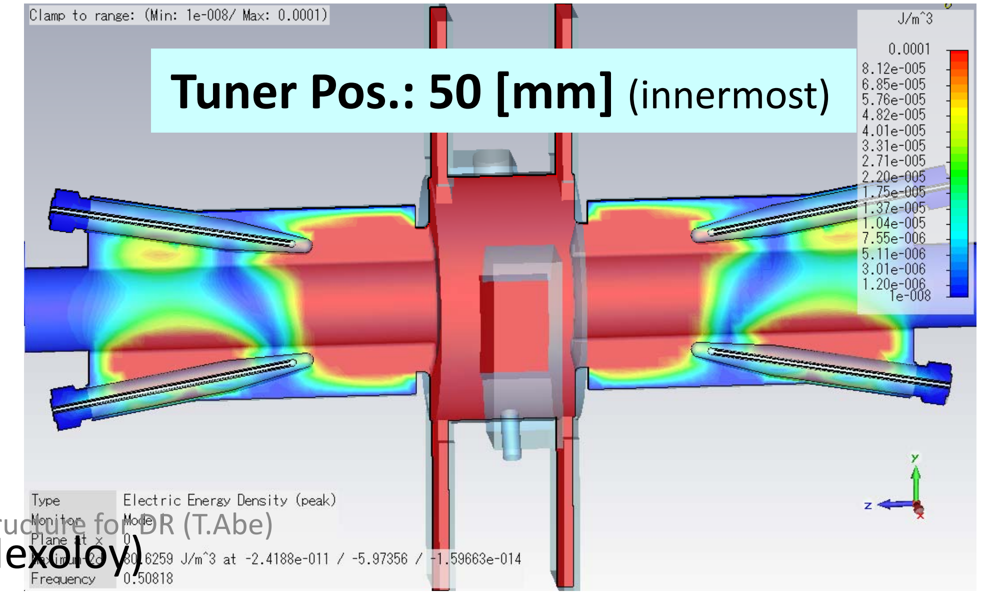
Caution! Leak of the ACC-Mode heats the SiC Bullets due to the asymmetry caused by the Tuner

The tails are magnified!





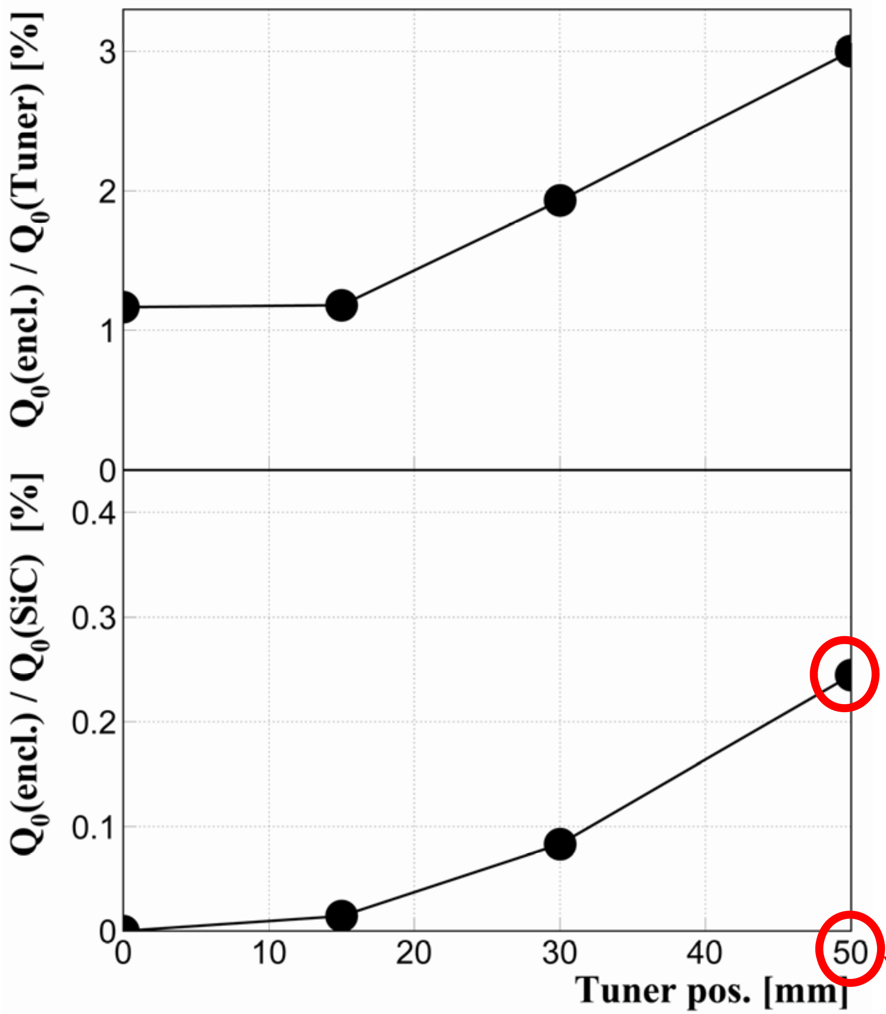




(96, Hexoloy)

Heating Power of the ACC-mode

Estimated from Eigenmode Analyses using CST-MWS



$$\frac{1}{Q_0} = \frac{1}{Q_0(\text{encl.})} + \frac{1}{Q_0(\text{Tuner})} + \frac{1}{Q_0(\text{SiC})}$$

$$\begin{pmatrix} Q_0 = \omega_a \dfrac{U}{P_{tot}} & Q_0(\text{Tuner}) = \omega_a \dfrac{U}{P_{Tuner}} \\ Q_0(\text{encl.}) = \omega_a \dfrac{U}{P_{encl.}} & Q_0(\text{SiC}) = \omega_a \dfrac{U}{P_{SiC}} \end{pmatrix}$$

Max. Heating Power

= Q_0(encl.)/Q_0(SiC) x P_{wall}

= 0.24%/2 x 60kW(max) = **72 W**

<< 5kW (capability/Groove)

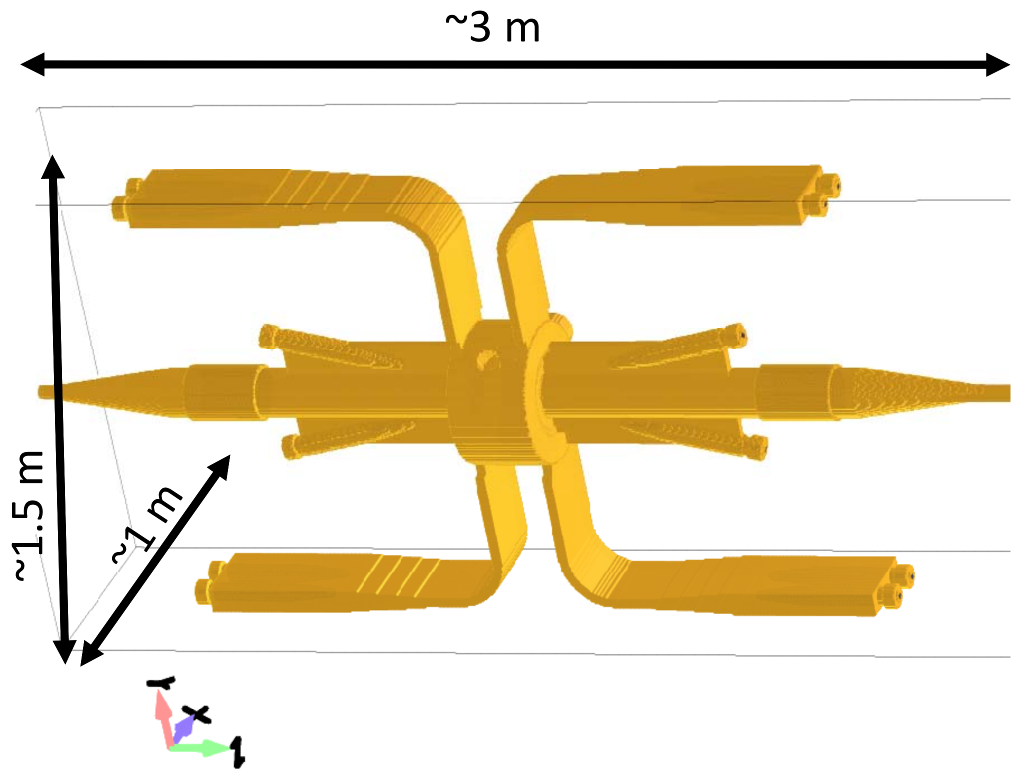
Innermost

3. HOM Impedances and Longitudinal CBI

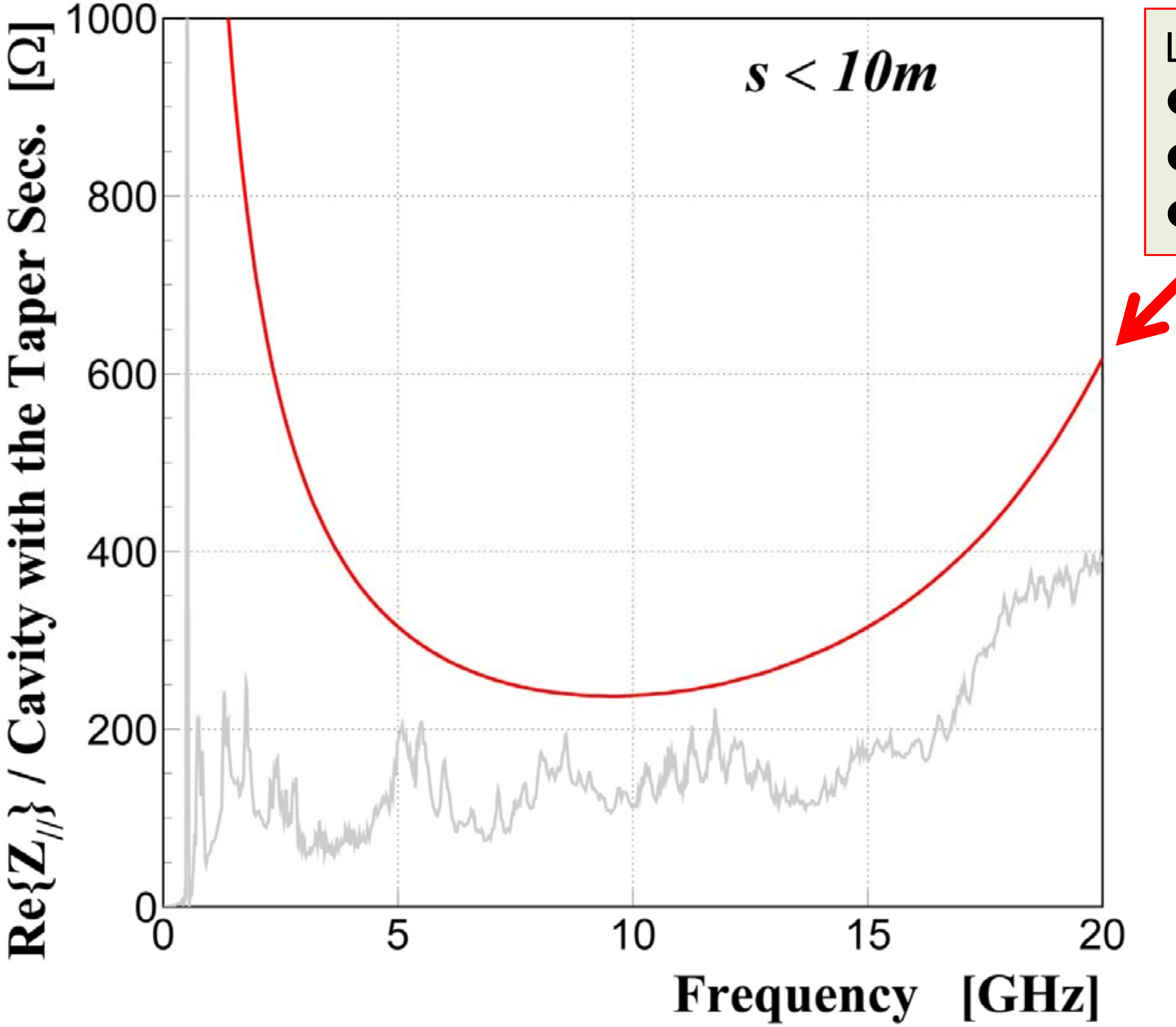
Any Troublesome Resonances?

- Bunch Length: 5.0mm

- Simulator: GdfidL
- Full geometry
- Mesh Size: 0.5mm in Z, 1.0mm in X,Y
- 9e+9 grid cells, 40 GB Memory
- Using 64 cores in parallel computing

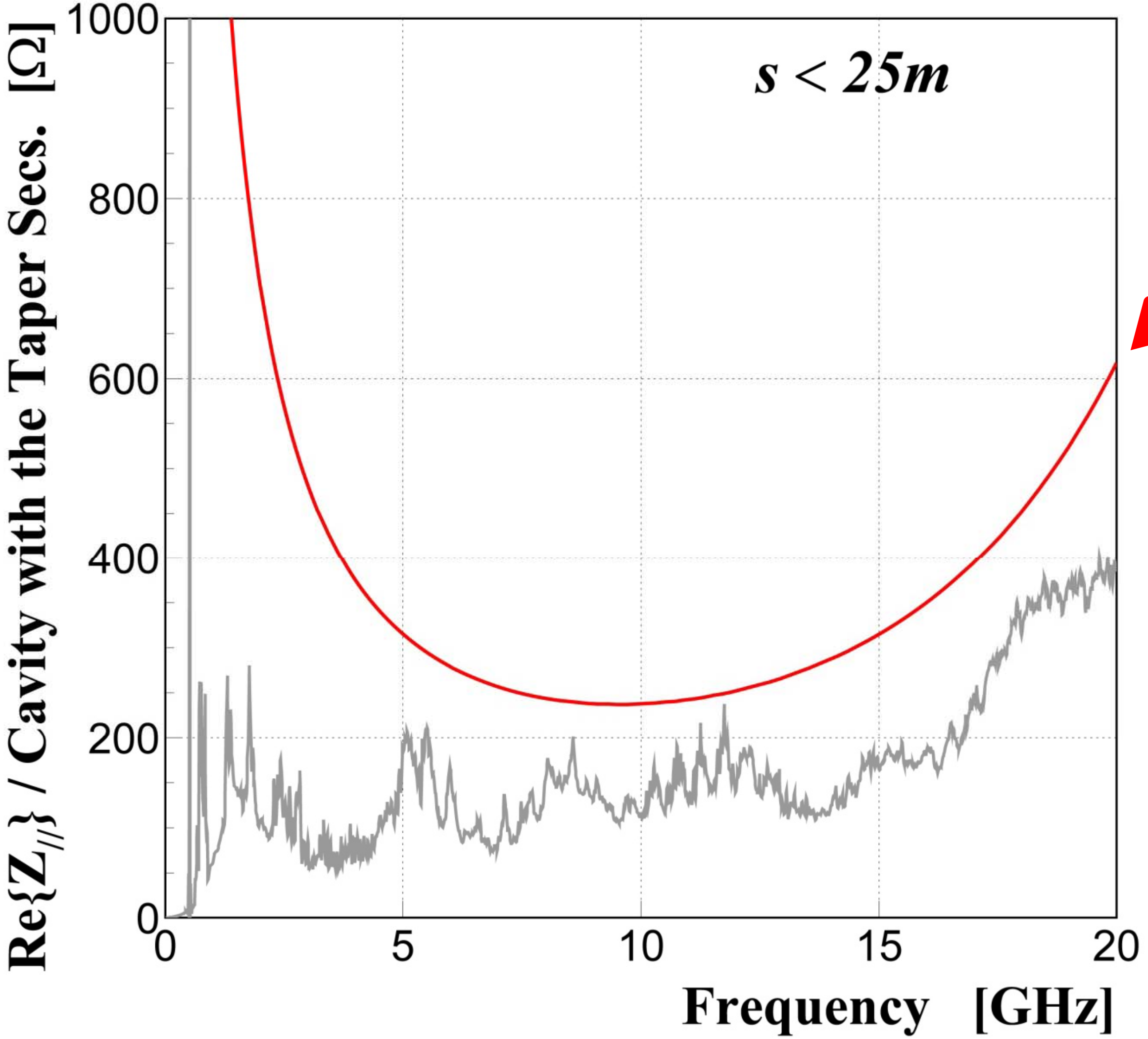


Computation Results of GdfidL/FDTD



Longitudinal CBI Threshold Line for
●Growth Time: **30**[msec]
●HOM LossFactor/ring: 4.88[V/pC]
●DR parameters on 2009-10-26

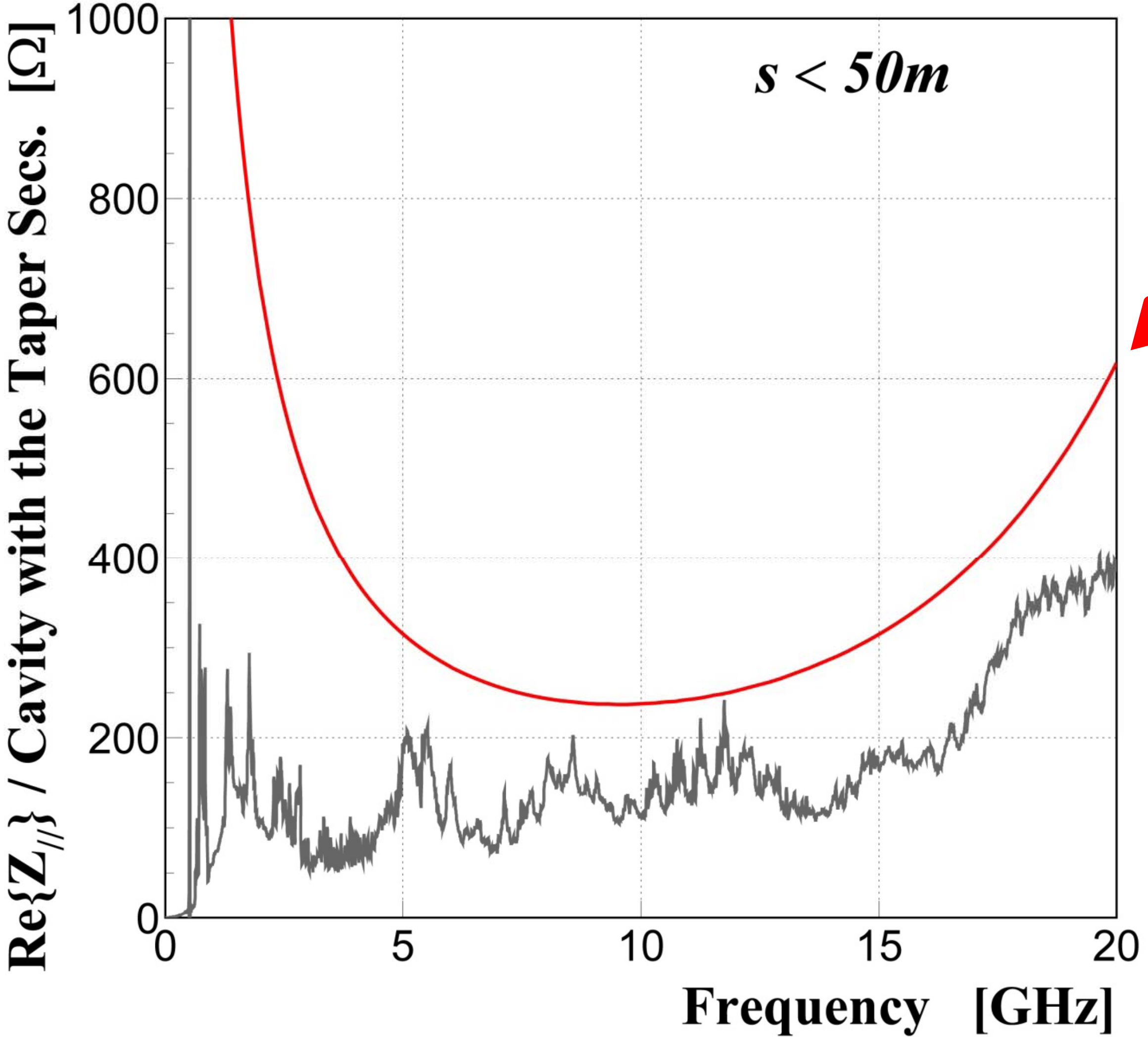
Computation Results of GdfidL/FDTD



Longitudinal CBI Threshold Line for

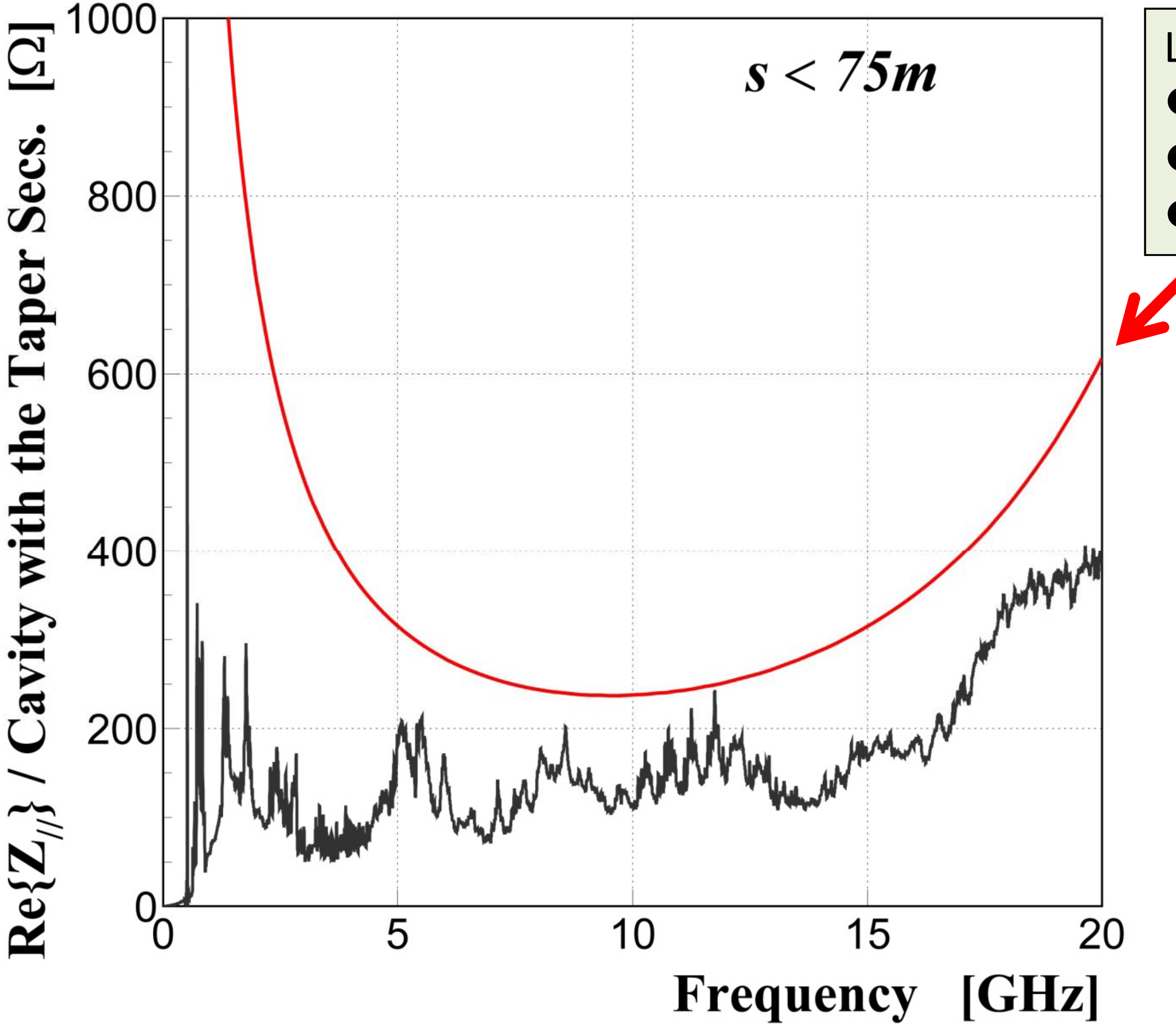
- Growth Time: **30**[msec]
- HOM LossFactor/ring: 4.88[V/pC]
- DR parameters on 2009-10-26

Computation Results of GdfidL/FDTD



Longitudinal CBI Threshold Line for
- Growth Time: **30**[msec]
- HOM LossFactor/ring: 4.88[V/pC]
- DR parameters on 2009-10-26

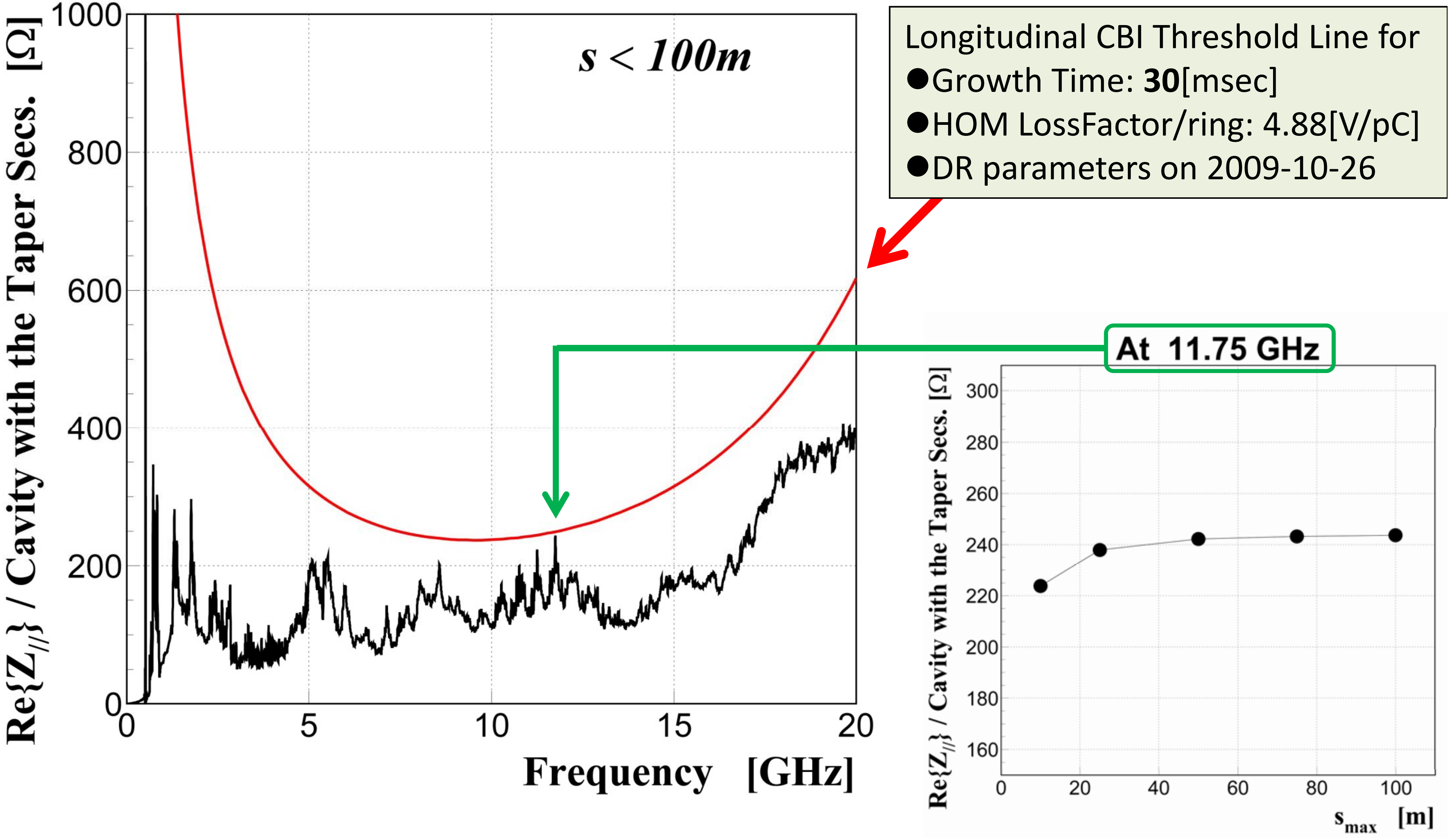
Computation Results of GdfidL/FDTD



Longitudinal CBI Threshold Line for
- ●Growth Time: **30**[msec]
- ●HOM LossFactor/ring: 4.88[V/pC]
- ●DR parameters on 2009-10-26

Computation Results of GdfidL/FDTD

Longitudinal CBI Threshold Line for
- Growth Time: **30**[msec]
- HOM LossFactor/ring: 4.88[V/pC]
- DR parameters on 2009-10-26



Summary

- **RF Model of the Accelerating Cavity for DR has been designed.**
  - Based on the successful KEKB-MR/ARES
- **Winged Chamber loaded with SiC Bullets**
  - For more capability of HOM powers (appl. to MR/ARES)
  - The test chamber is coming soon. → High-power tests to be done in the L-band test stand.
- **No serious HOM impedance for LCBI**
  - τ = 30 msec (from $ReZ_{//}$ at 11.75GHz)
    - >> Longitudinal Radiation Damping Time: 6 msec