Normal Conducting Accelerating Cavities for the MRs and DR of SuperKEKB

Tetsuo ABE

For SuperKEKB-RF / ARES-Cavity Group

(T. Abe, T. Kageyama, H. Sakai, Y. Takeuchi, and K. Yoshino)

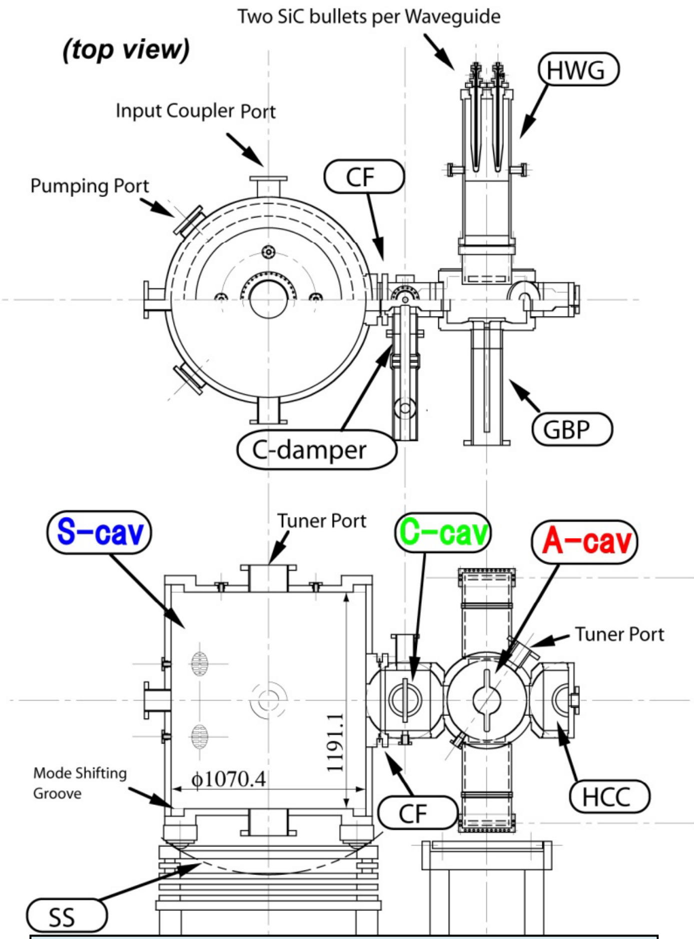
The 18th KEKB Accelerator Review Committee Meeting

March 4, 2013

Main Ring (MR) Cavities

Accelerator Resonantly-coupled with Energy Storage

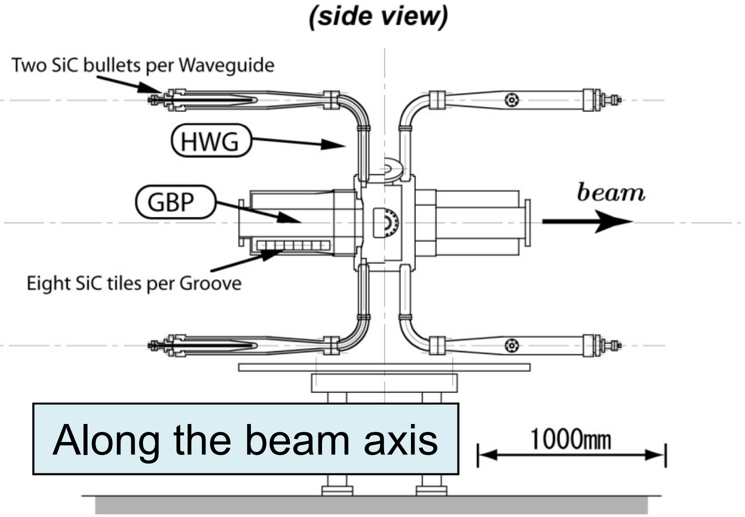
3-cavity system stabilized with the $\pi/2$-mode operation



Perpendicular to the beam axis

consists of

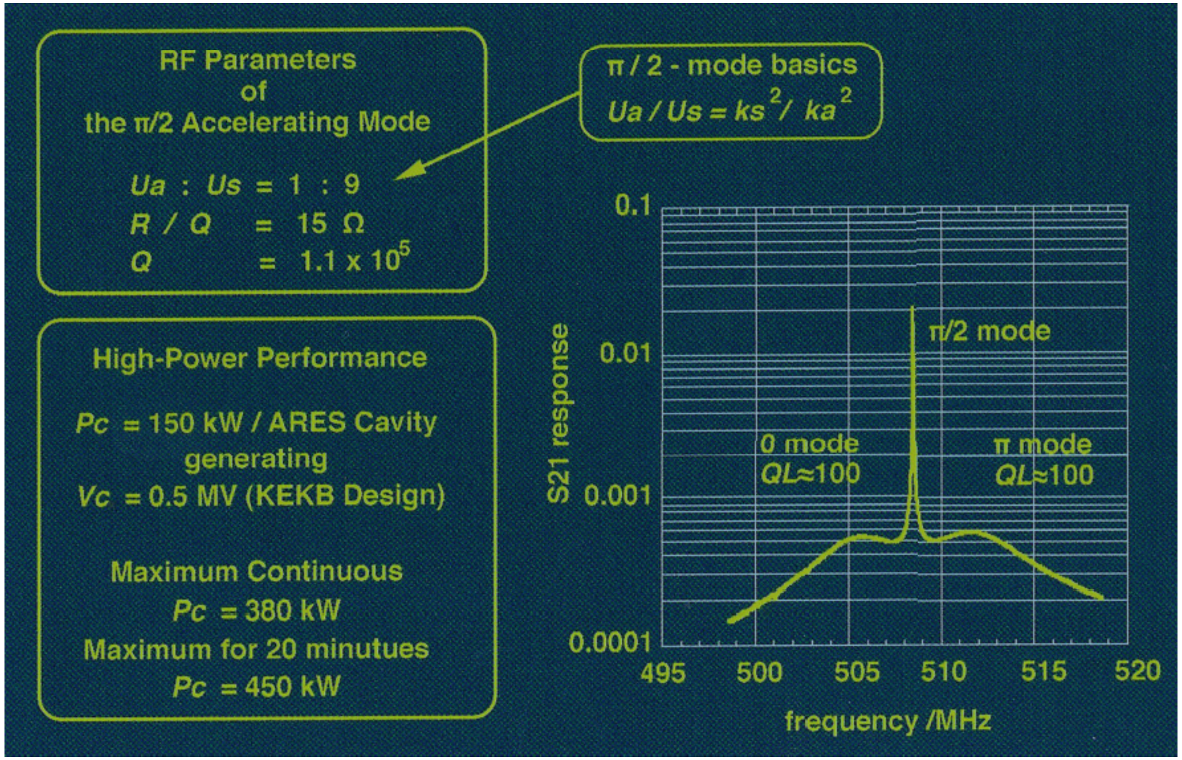
- HOM-damped accelerating cavity (**A-cav**),
- Energy-storage cavity with TE_{013} (**S-cav**),
- Coupling cavity (**C-cav**)
  with a parasitic-mode damper.

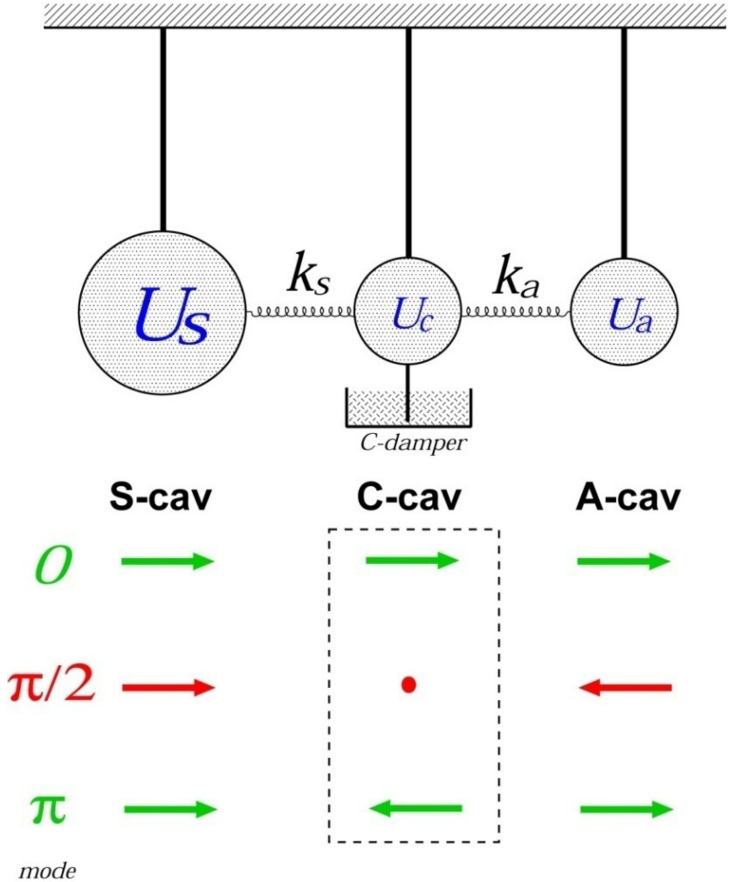


Along the beam axis

With Long Successful Operation at KEKB

Fundamentals of the ARES Cavity System





Detuning against beam loading: $\Delta f_{\pi/2} = \dfrac{\Delta f_a}{1 + Us/Ua}$ $= \Delta f_a / 10$

Upgrade/Work Main Items on the MR Cavities

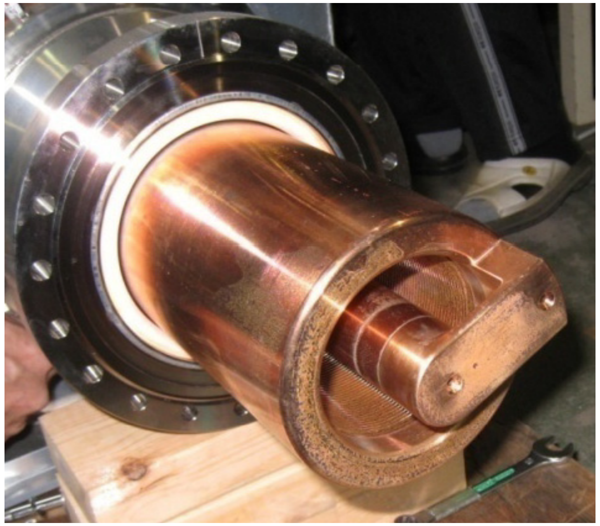
(*) For more details, see the Kageyama's presentation slides at MAC'11

1. Detuning against the beam loading at SuperKEKB-LER / 22 ARES cavities with 3.6A (Appendix A)
   - $\Delta f_{\pi/2} = \Delta f_a/(1+U_s/U_a) = -280\text{kHz}/10 = -28\text{kHz} < f_{rev}=99\text{kHz}$ (*)
   - Flywheel Energy Ratio: $U_s/U_a = 9$ not changed (*)
2. CBI issues for SuperKEKB-LER with 3.6A
   - lCBI due to the -1 mode (t = 4ms): cured by the RF FB (-1 mode damper) (*)
   - lCBI due to the impedance imbalance between the 0 - π modes (t = 21ms): cured by the longitudinal BxB FB (*)
   - lCBI due to the HOM impedance @1.85GHz (t = 13ms, Appendix B): cured by the longitudinal BxB FB (*)
3. HOM loads
   - WG Load: 5kW/WG verified at the test stand (> 3.3kW/WG at SuperKEKB-LER with 3.6A) (*)
   - GBP Load: 1.2kW/Groove verified at the test stand (> 0.93kW/Groove at SuperKEKB-LER with 3.6A) (*)
   - Increasing the cooling capabilities of the WG and C-damper loads
4. Installation of 2 ARES cavities to the D4 station for HER → done (*)
5. Relocation of the ARES cavities in the D5 station → done
   - 6 cavities: HER → LER
6. Removal of 4 sets of ARES cavities from the D7&D8 stations → done
7. Improving the vacuum evacuation system by introducing NEG pumps

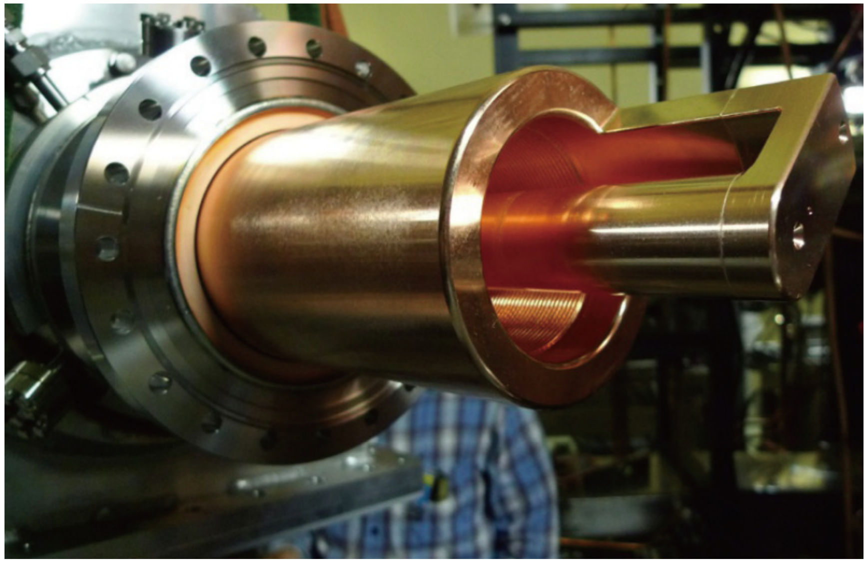
Upgrade/Work Main Items on the MR Cavities

(*) For more details, see the Kageyama's presentation slides at MAC'11

8. Input couplers with strengthen input coupling (β_{max} = 5→6) needed for stations with the Klys:Cav=1:1 configuration
   - The coupling loop extended (17 → 60mm) as shown in the photos below (*)
   - The prototype coupler successfully conditioned up to P_{in}=800kW at the D1-A test stand (*)
   - The prototype coupler verified up to P_{in}=770kW and P_{beam}=610kW (> SuperKEKB spec.: P_{beam}=600kW) at the D5-C station during the KEKB operation (*)
   - So far, we have 4 couplers successfully conditioned at the D1-A test stand.
   - Now one coupler is being high-power tested up to P_{in}=600kW (as of March 1, 2013).
   - In JFY2012 (JFY2013), we will obtain 5 (10) more couplers to be high-power tested.
   - It takes about one month in total for one coupler to be well-conditioned, including the setup work (Appendix O).

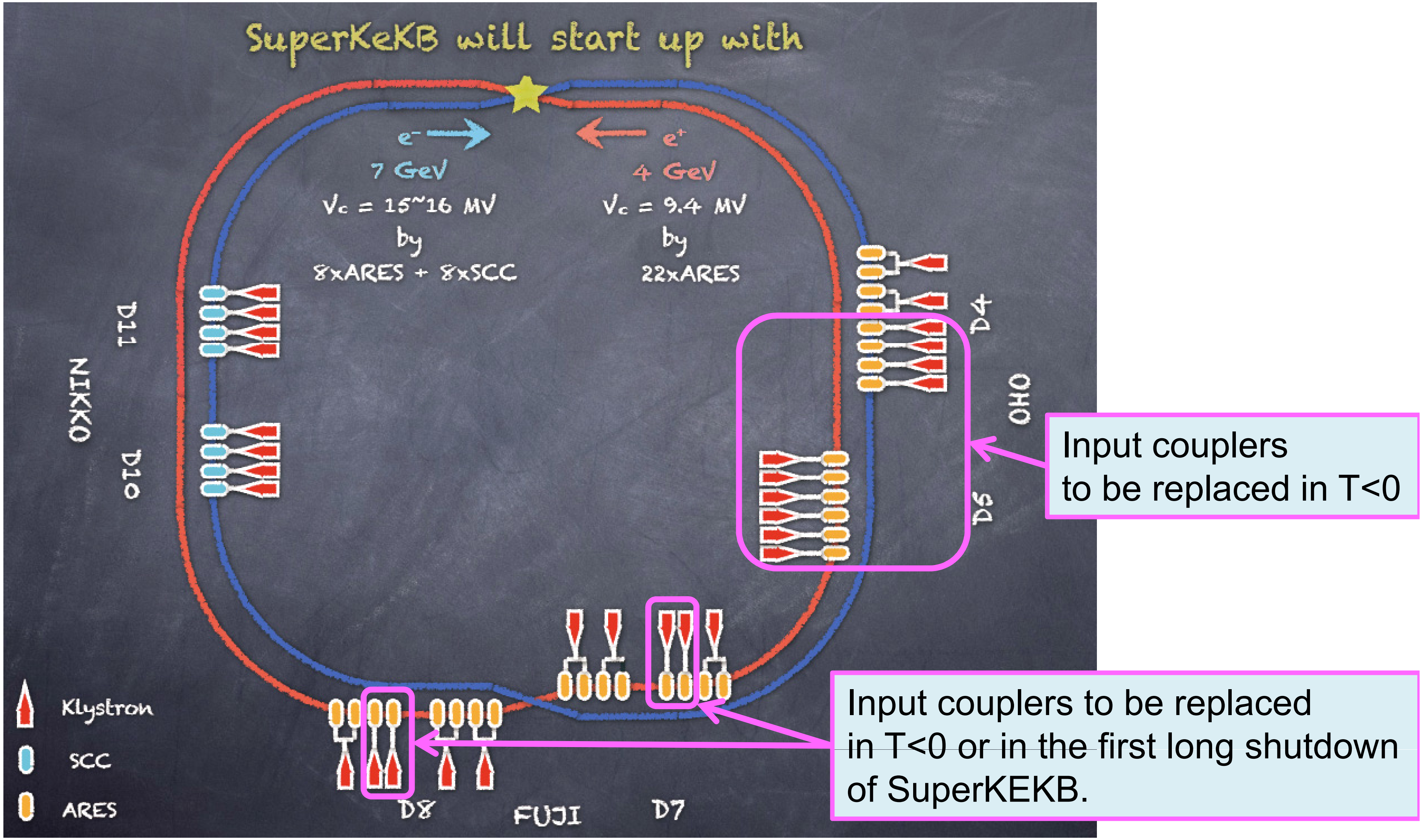


Used at the KEKB-MRs



With strengthen input coupling for the SuperKEKB-MRs

We need 14 well-conditioned input couplers with strengthen input coupling for stations with the Klys:Cav=1:1 configuration around T=0.

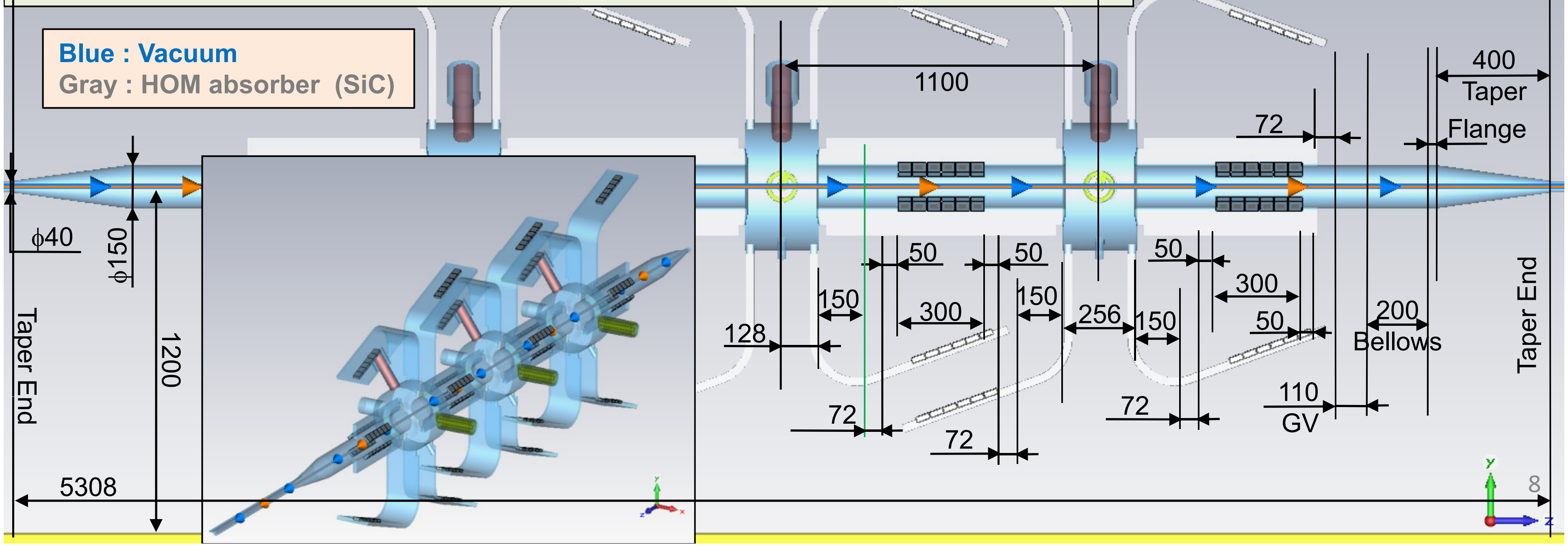


Damping Ring (DR) Cavities

RF Accelerating Structure for the DR

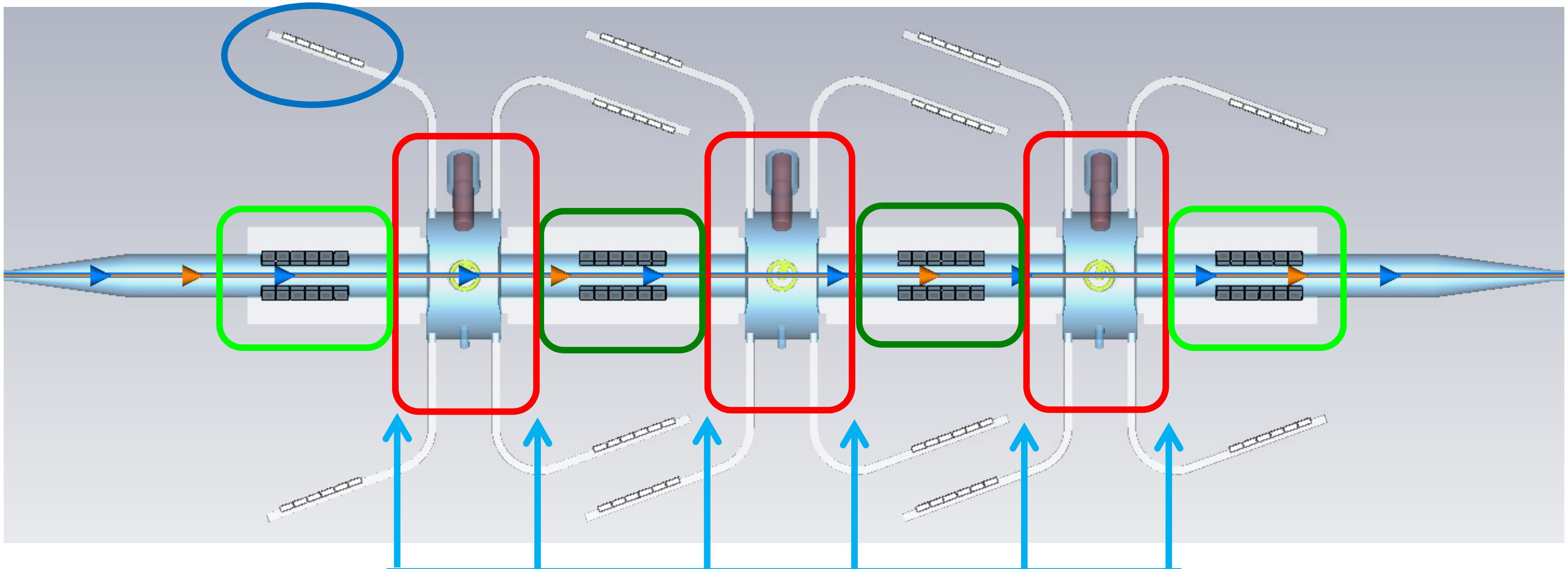
Based on the ARES cavity with the long successful operation at KEKB

1. Accelerating-Mode Frequency: 508.887[MHz] (same as for the Main Ring (MR)
2. Cavity Voltage (spec.): 0.7[MV/cav] (→Wall-loss power: ~120kW/cav) → We can supply total V_c : 2MV.
3. Cavity Voltage (challenge): 0.8[MV/cav] (→Wall-loss power: ~150kW/cav) → We will use a 1MW klystron.
4. Max. stored beam current: 70.8[mA] → Very low compared to the (Super)KEKB-MRs
5. HOM absorbers: Silicon Carbide (SiC) tiles (Appendix D) → More compact than the SiC bullets
6. Grooved Beam Pipe (GBP) common between cavities
7. Cavity-GBP Joint with a weld-ring gasket (not using a usual flange)
8. *"Multi Single Cell"* structure
9. Reuse of input couplers and tuners proven at KEKB-MRs/ARES
10. Good vacuum in cav. (~10^-6[Pa]) needed for high-power input couplers → Pumping port on each cavity
11. Loss factor (incl. the taper sections): 2.5 [V/pC] (for σ_z=6.0mm)
12. No coupled bunch instabilities (CBIs) due to this structure occur (Appendix N).



Four Types of Components

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



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

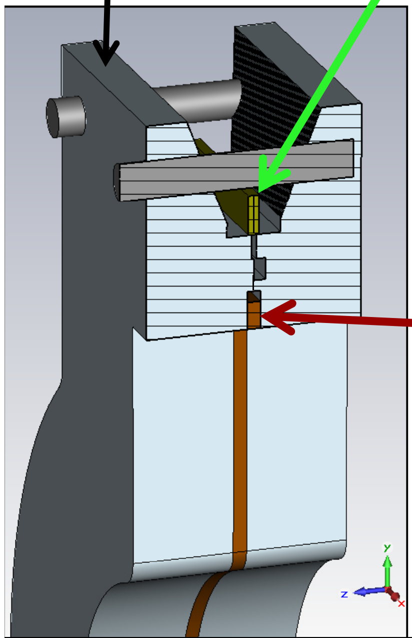
→ Assembly of the above components like LEGO blocks

Cavity-GBP Joint Structure

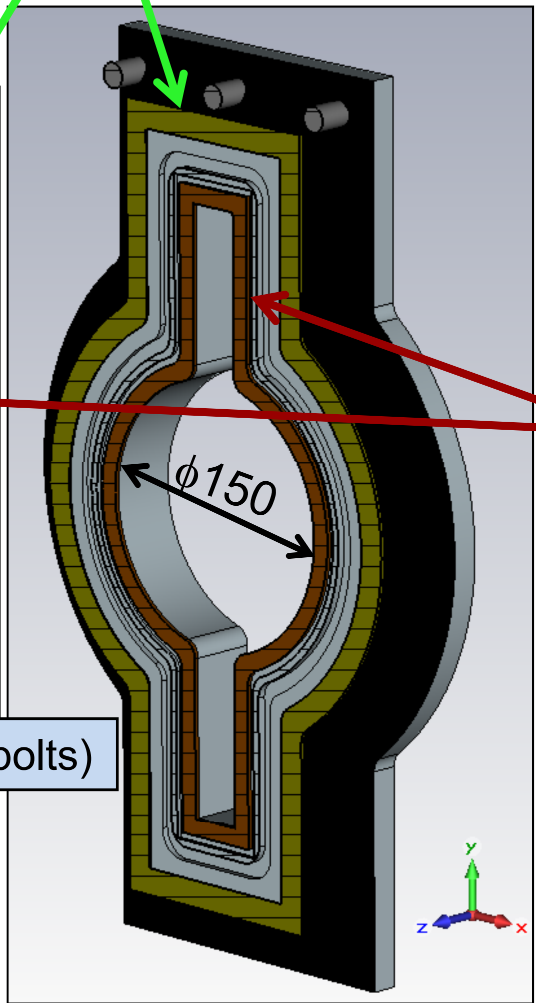
(For the details, see Appendix E.)

Weld Ring Gasket with Lip Sealing, like:

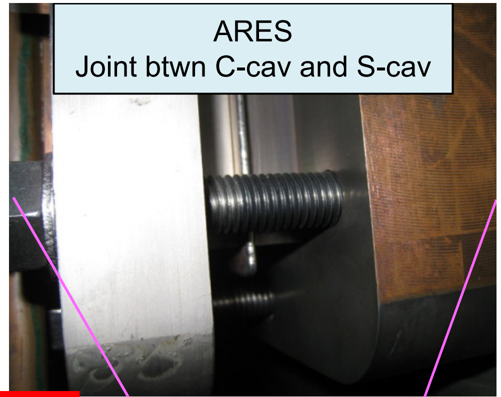
SUS

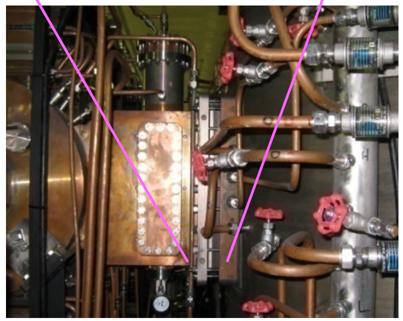


(Fixed with 16 M12 bolts)



ARES
Joint btwn C-cav and S-cav





“Welding → Disassembly
→ ReWelding”
Possible Several Times

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

Be-Cu, @KEK/PF

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

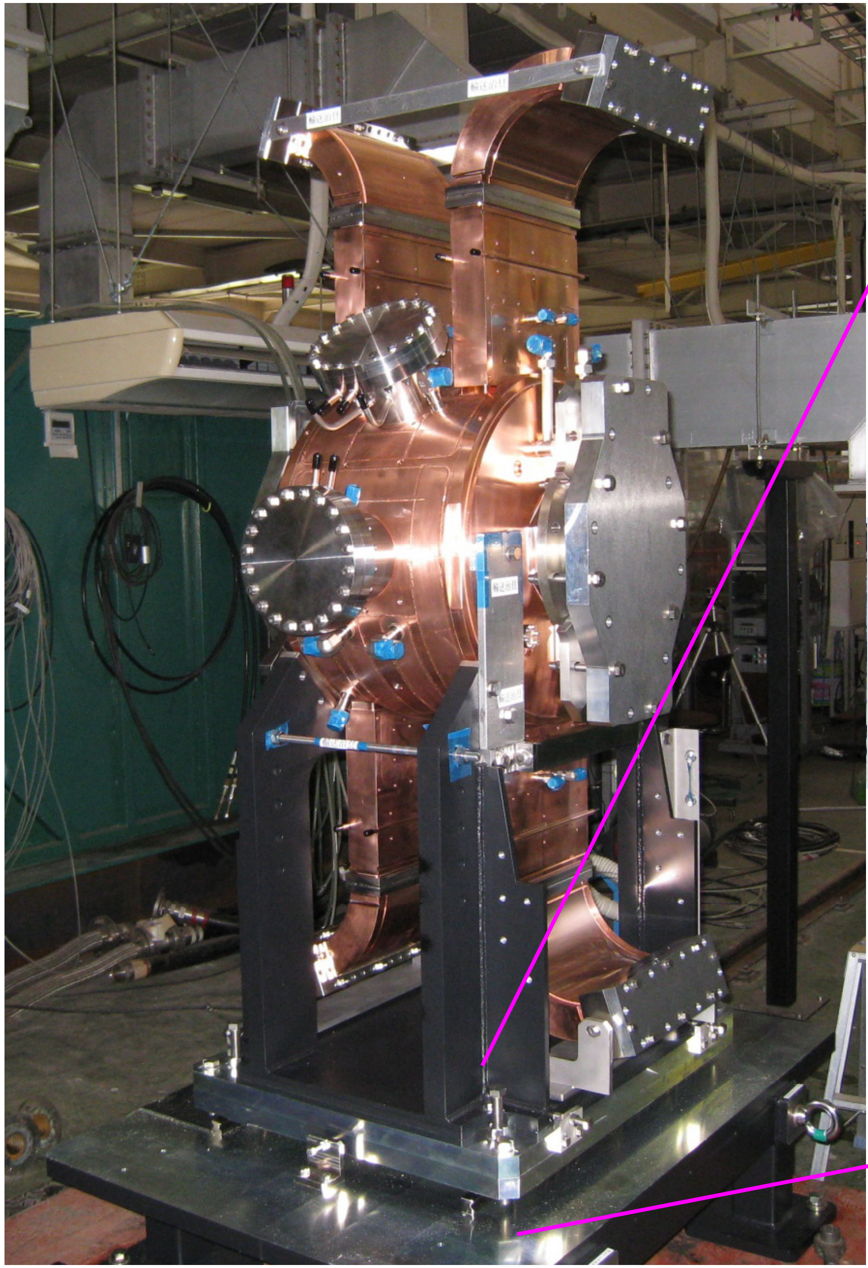
History and Schedule

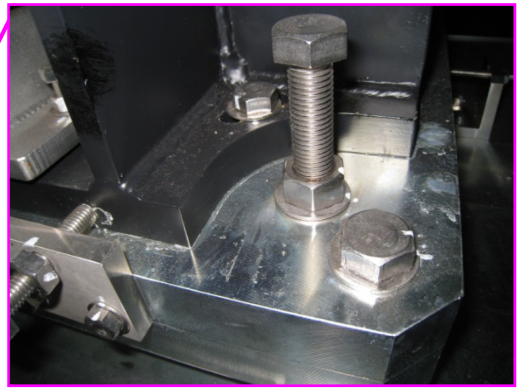
Year	Items	Remarks
JFY2011	Cavity No.0 (prototype) x 1 GBP(btwn) (prototype) x 1 HOM-WG load (prototype) x 1	→High-power tested at D1-A test stand (finished) →High-power tested at D1-C test stand (finished)
JFY2012	Cavity No.1 x 1 HOM-WG load x 4 GBP(btwn) x 1 GBP(end) x 1 GBP(dummy) x 1	←Feedback from the prototypes
JFY2013	Cavity No.2 x 1 HOM-WG load x 4 GBP(btwn) x 1 GBP(end) x 1	
JFY2014	Finish High Power Tests. Installation to the DR tunnel	
CY2015	Start of DR commissioning with Cavity No.1 and No.2 (Appendix F)	
20XX	Cavity No.3 HOM-WG load x 4	If needed

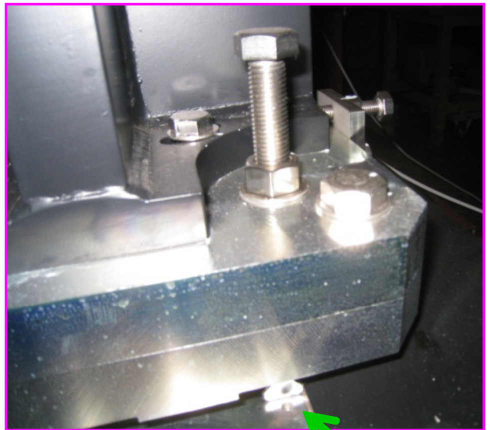
We are Here.

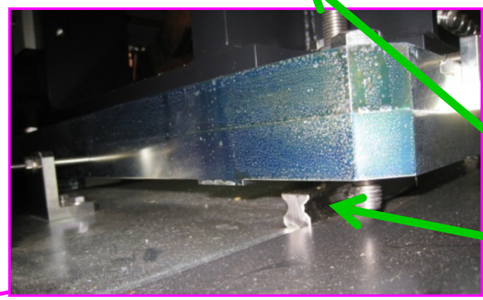
High Power Test (HPT)
of Cavity No.0 (Prototype)

Cavity No.0









- ✓ Just after the delivery
- ✓ No cooling pipes yet
- ✓ The support has complete alignment mechanism.

(LM: Linear Motion)

LM Guide

✓Perpendicular to the beam axis
✓LM guide along the beam axis to be added to Cavity No.1-3

Cavity-GBP Joint (Cavity No.0)

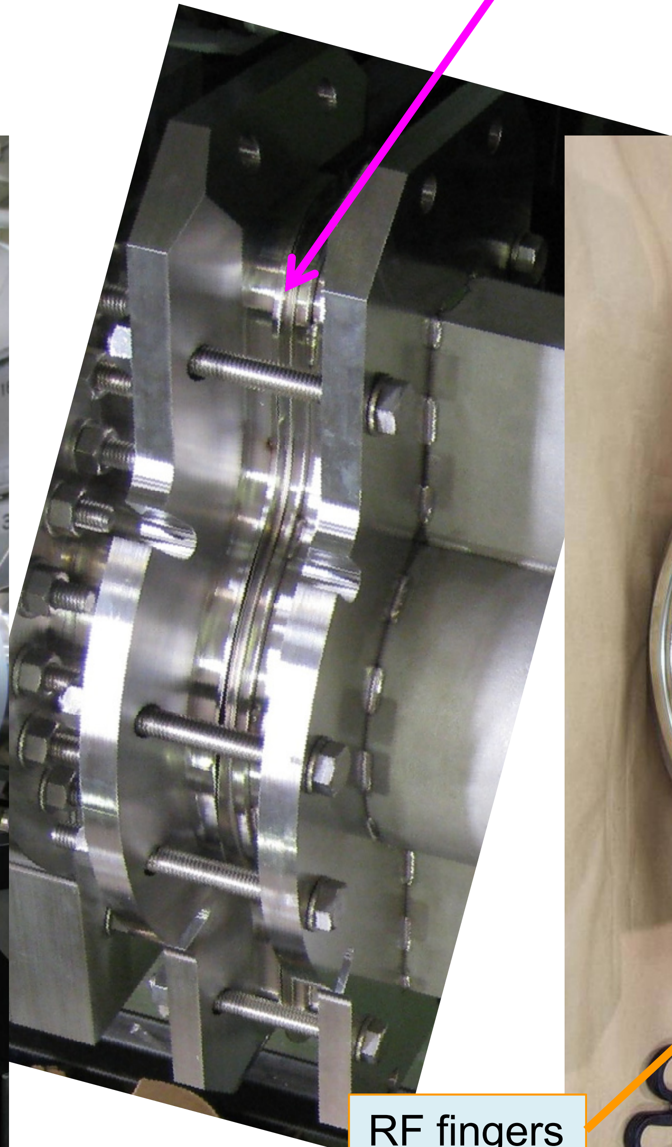
For the details,
see Appendix E.

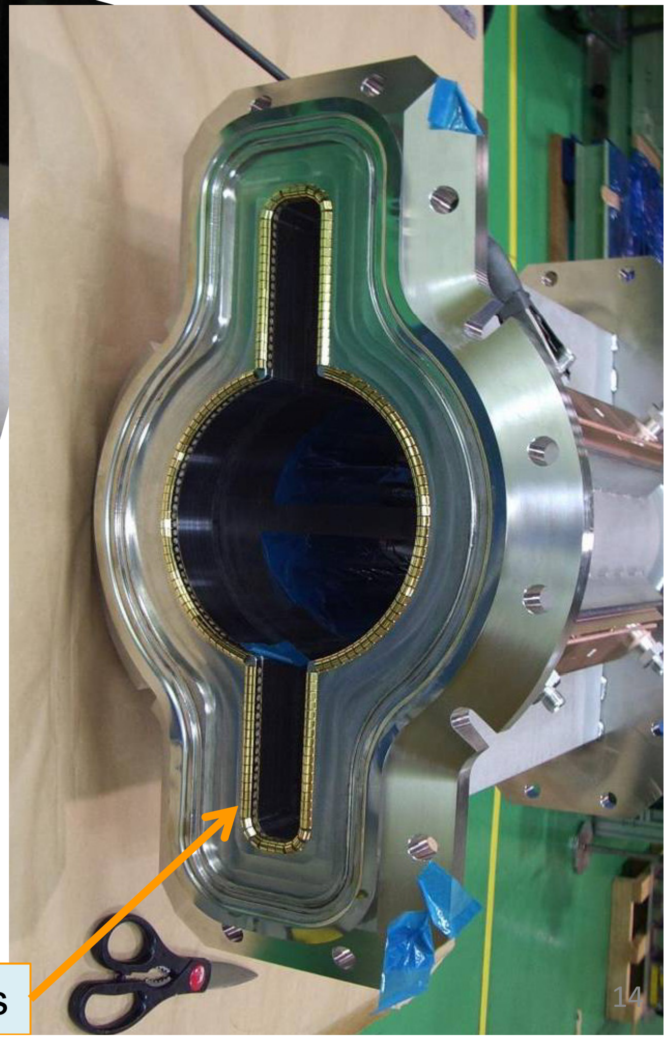
O-ring (rubber) for vacuum sealing during the HPT

Welding lip for vacuum sealing

Cavity Side

GBP Side

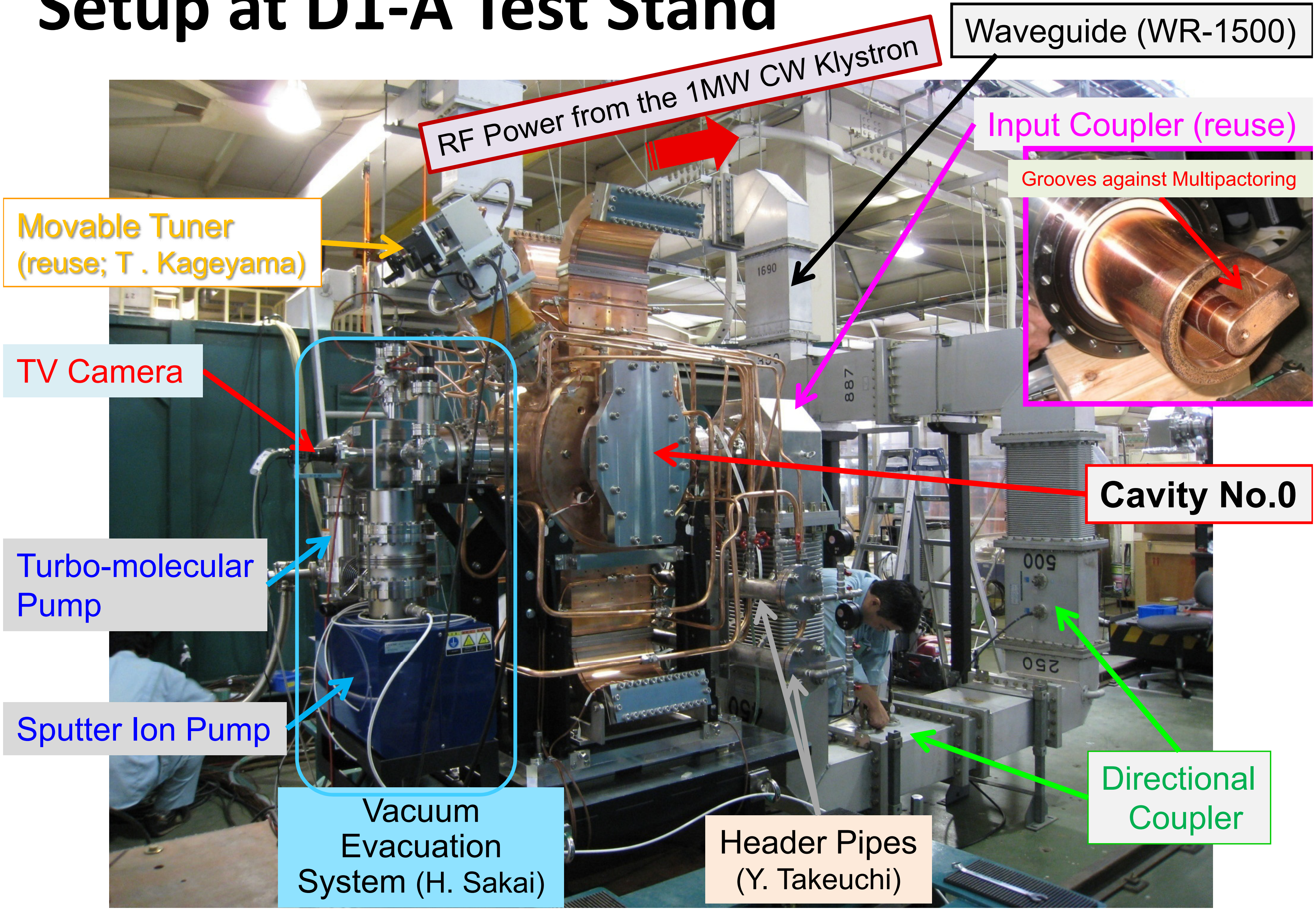




RF fingers

Note: this test stand is also used for input-coupler conditioning.

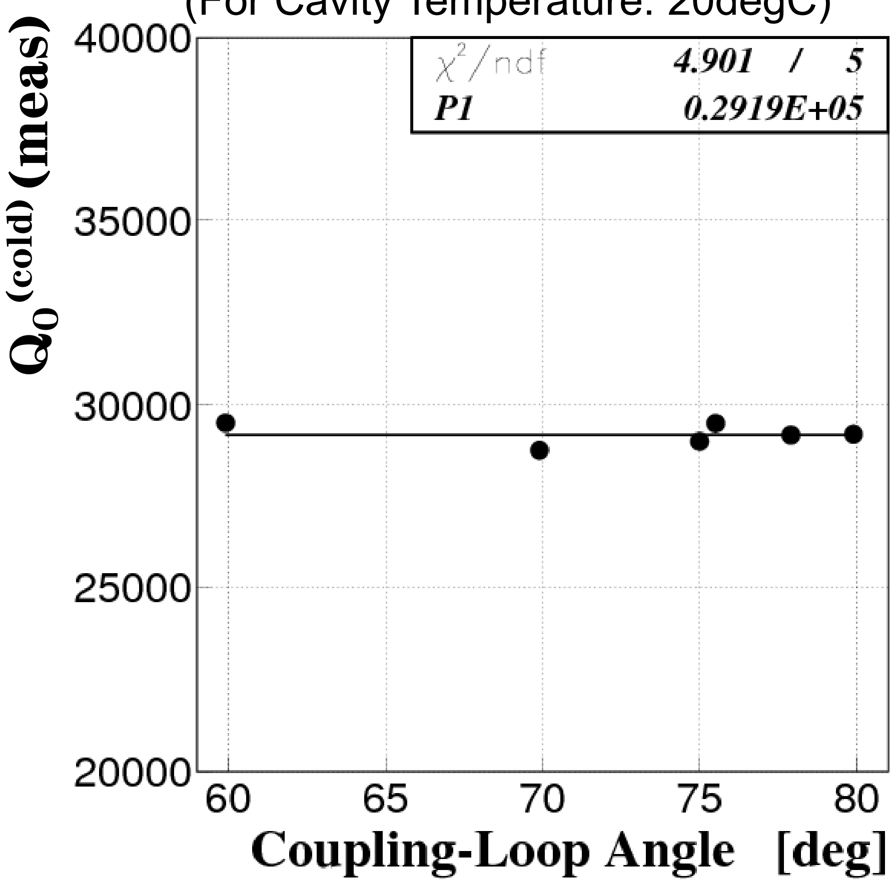
Setup at D1-A Test Stand



Check of the Unloaded Q (Q_0)

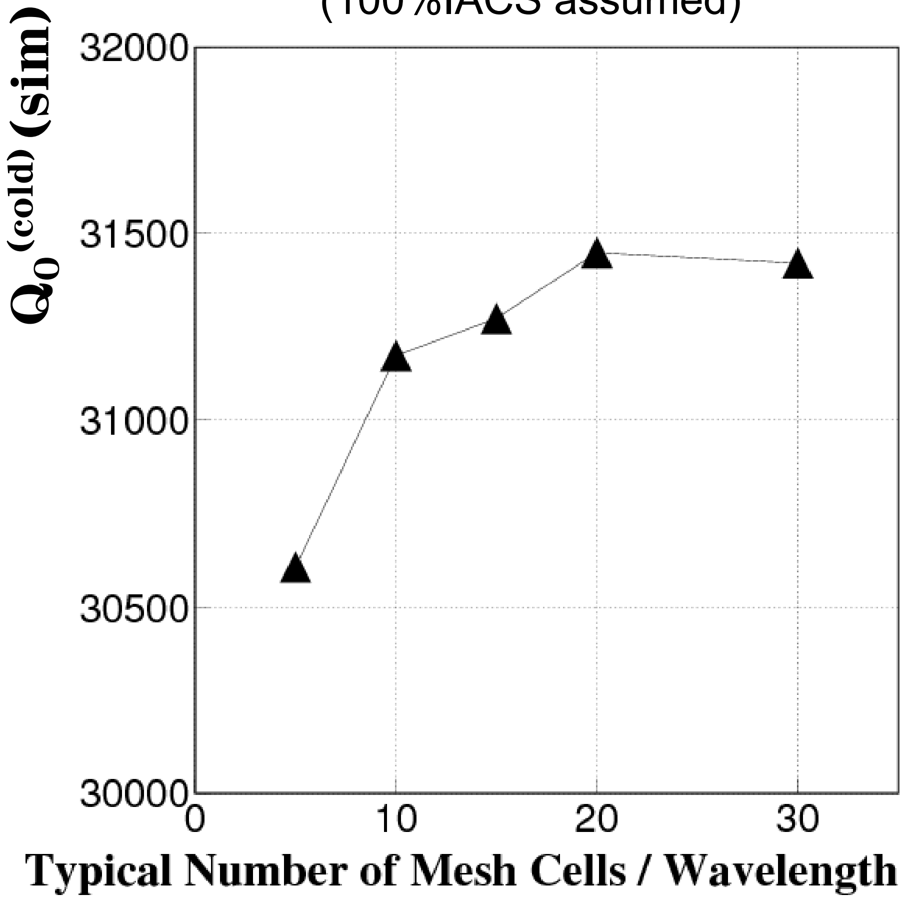
Low-Power RF meas.

(For Cavity Temperature: 20degC)



Simulation

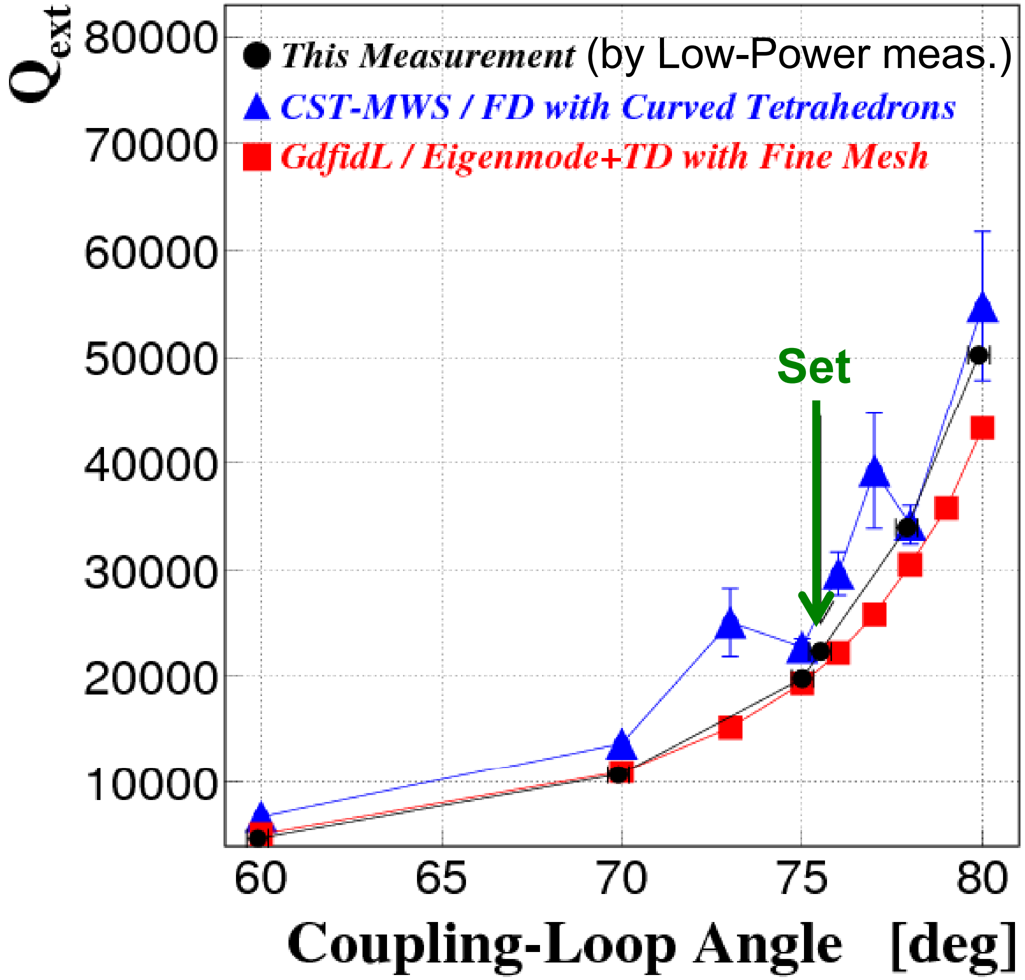
(100%IACS assumed)

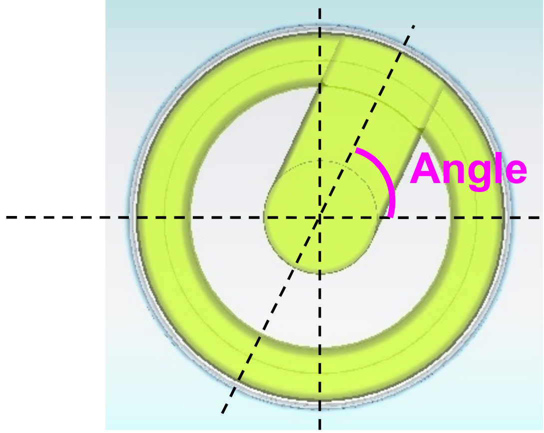


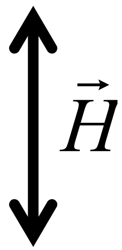
(Tuner Position: 15mm inside (home position))

$Q_0^{(cold)}$(meas) / $Q_0^{(cold)}$(sim) = 93% (OK)

Check of the External Q (Q_{ext}) of the Input Coupler







→ $\beta^{(cold)} = Q_0^{(cold)} / Q_{ext}$
=1.34 (over-coupling)
$> \beta^{(HP)}$

(HP: High Power)

Good Agreements between the meas. and simulation

How to Calculate Cavity Voltage (V_c)

✓P_{in} , P_{refl}: Input and Reflected RF powers measured, respectively
✓Assuming the cavity to be tuned

Input Coupling Factor : $\beta^{(HP)} = \frac{1+\sqrt{P_{\rm refl}/P_{\rm in}}}{1-\sqrt{P_{\rm refl}/P_{\rm in}}}$ (over-coupling)

Unloaded Q : $Q_0^{(HP)} = \beta^{(HP)} \times Q_{\rm ext}$ (We use Q_{ext}= 21814 from the LP meas.)

(LP: Low Power)

Shunt Impedance : $R_{\rm sh}^{(HP)} = (R_{\rm sh}^{(HP)}/Q_0^{(HP)}) \times Q_0^{(HP)}$

(We use $R_{sh}^{(HP)}/Q_0^{(HP)} = R_{sh}^{(cold)}/Q_0^{(cold)} = 150\Omega$ from the simulation.)

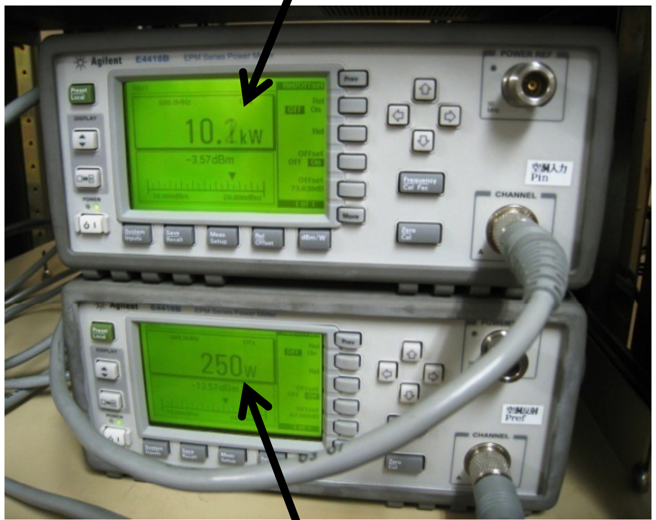
Cavity Voltage : $V_c = \sqrt{R_{\rm sh}^{(HP)} \times \underline{(P_{\rm in} - P_{\rm ref})}}$

$(P_{\rm in} - P_{\rm ref}) = P_{wall}$

RF Power Measurements
with Power Meters located in the D1 Control Room

In the D1 Local Control Room

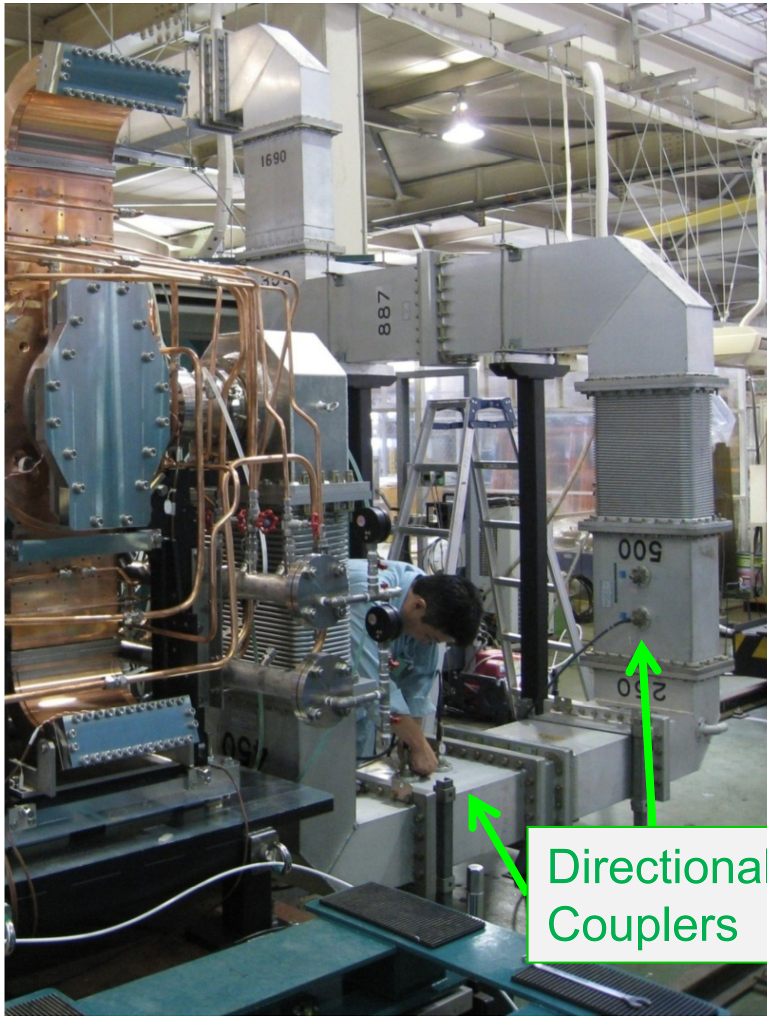
Input Power to the Cavity: P_{in}



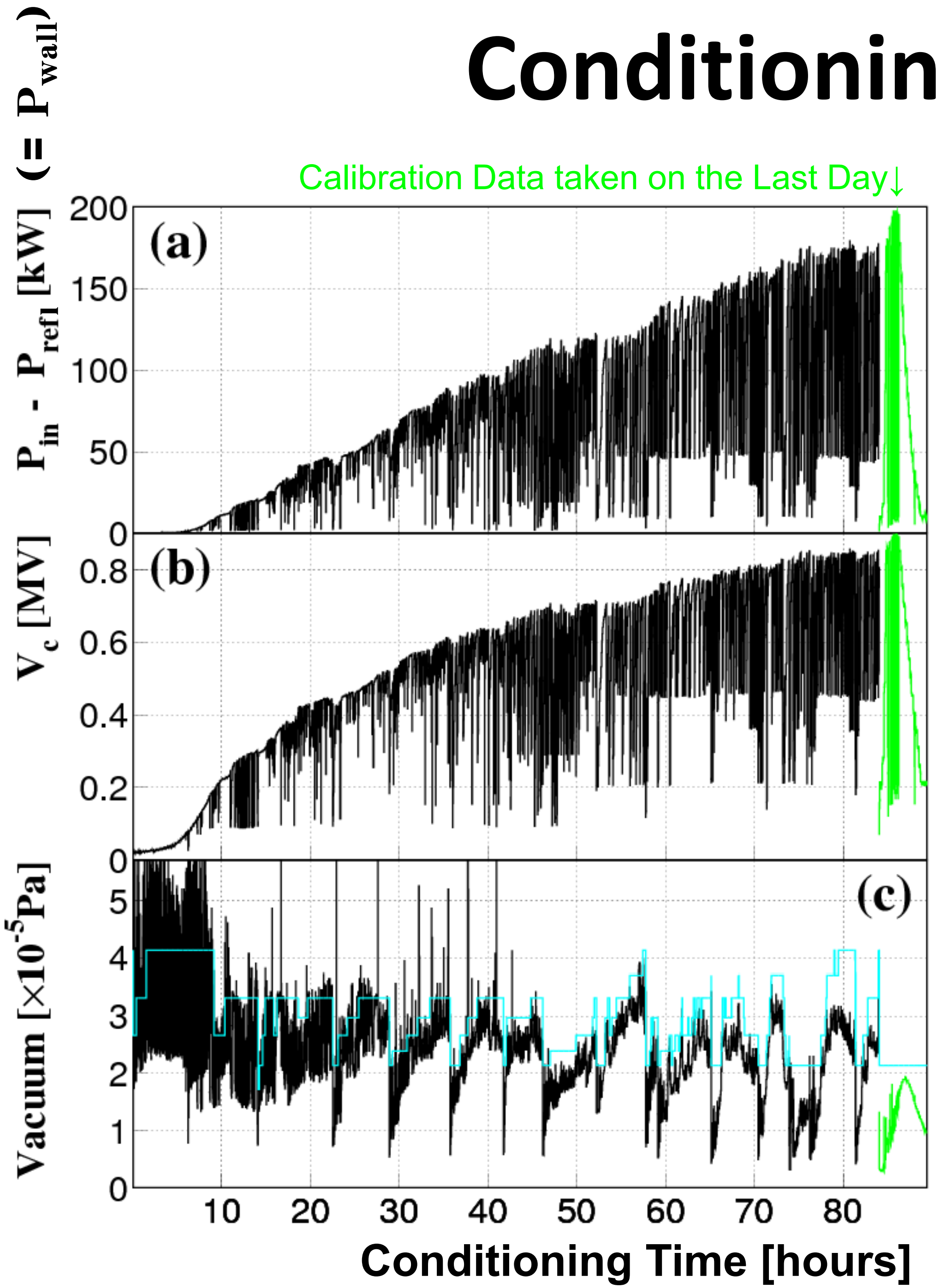
Reflected Power from the Cavity: P_{refl}

~70m-long Coaxial Cables

In the Radiation Shield



Conditioning History



180kW (max.)

200 kW (max.)

Plotting Conditions →

- ● ● P_{in} > 0
- ● Automatic Aging On
- ● P_{in} < P_{target}

0.86MV(max.)

0.9 MV (max.)

- ✓ P_{in} and P_{refl} calibrated for calorimetric powers to have $\delta V_c/V_c$<3%
- ✓ P_{in} controlled to have the vacuum pressure lower than the specified value (shown as a light-blue line) in the automatic conditioning program.
- ✓ As the conditioning progressed,
  - ➢ Better vacuum
  - ➢ Continuous emission in the cavity observed with the TV camera darker
- ✓ V_c=0.9MV/cav : max. limit due to the radiation level outside the facility.

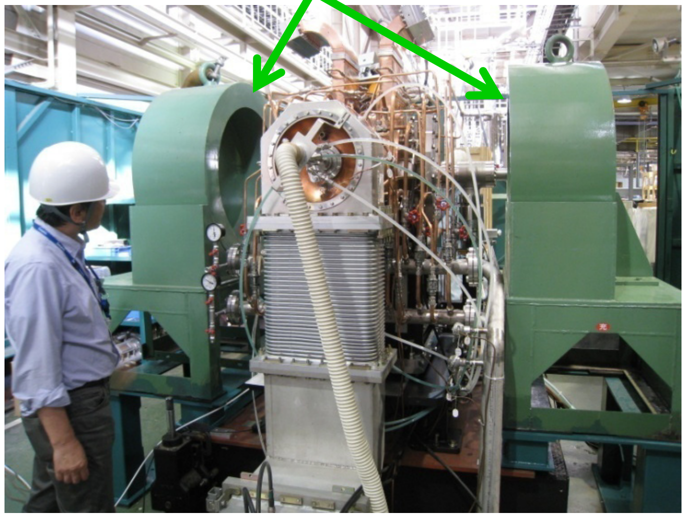
If we weld the lip at the Cav.-GBP joint without a O-ring (→all metal), we expect ~1x10^-6 Pa during HP operations.

More Radiation Shields at D1-A

(T. Kageyama)

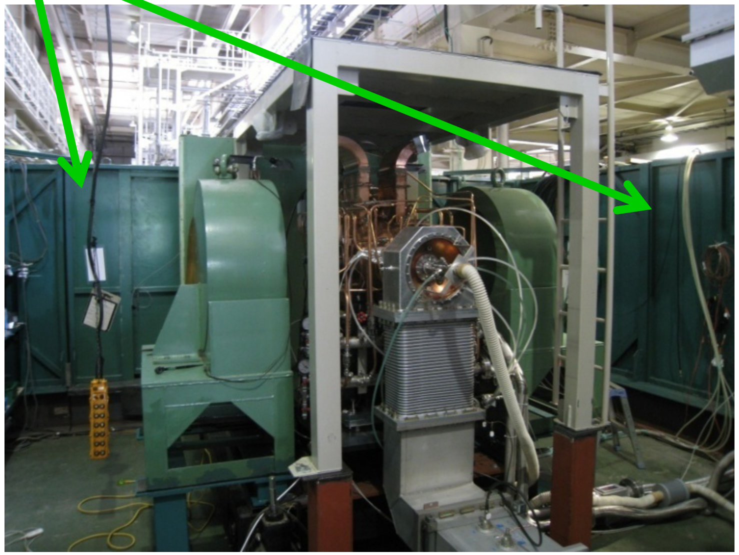
in addition to the permanent lead wall surrounding the cavity

At the beginning of this HPT,
we put lead blocks.



Then

toward higher V_c



Then more

And

more

Finally,,,

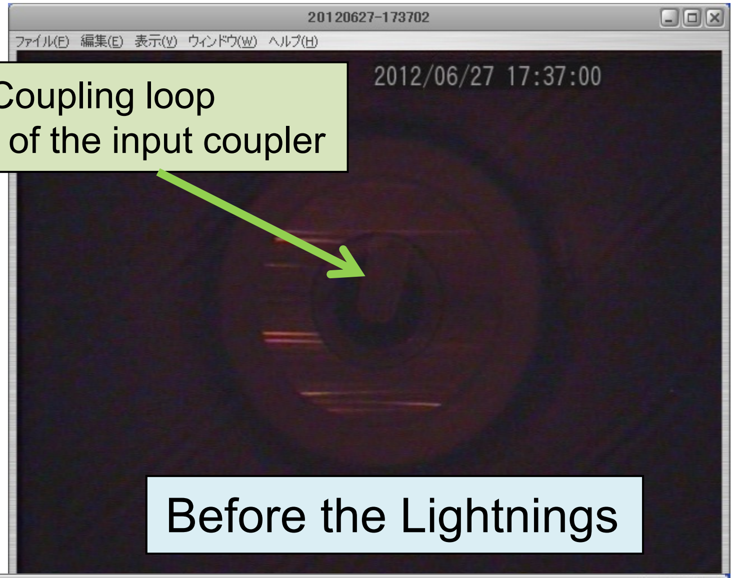
(with a usual sensitivity)

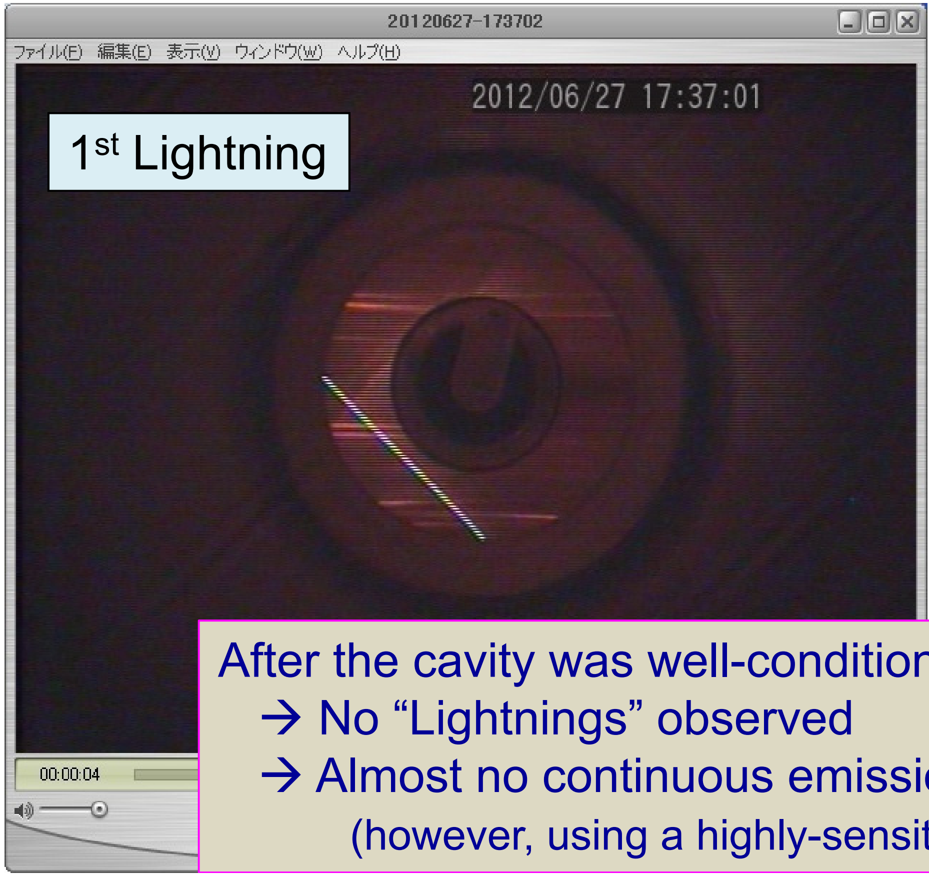
"Lightnings" observed with the TV camera in the early hours of the conditioning

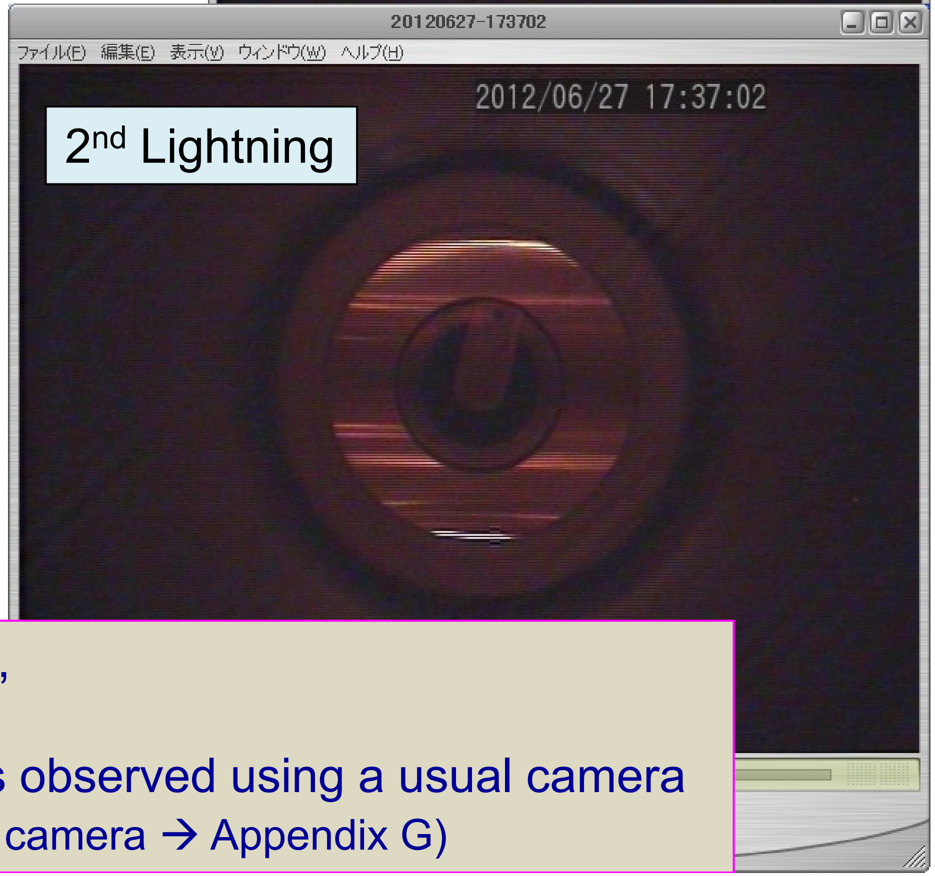
E.g. P_{in} = 20kW (V_c = 0.3MV)

✓Just after the 2nd lightning, I/L(refl.) worked.

✓No vacuum-pressure spike





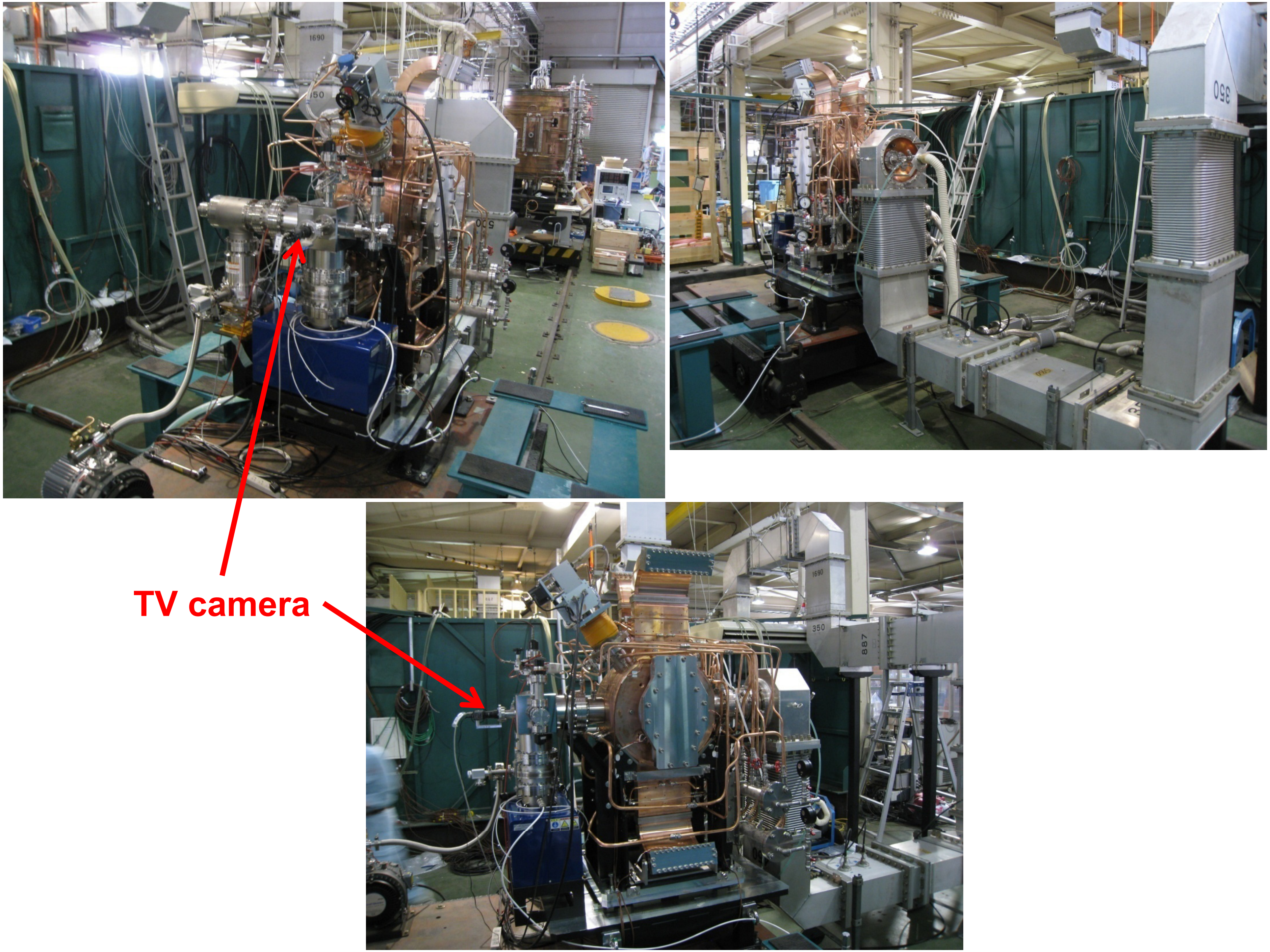


After the cavity was well-conditioned,

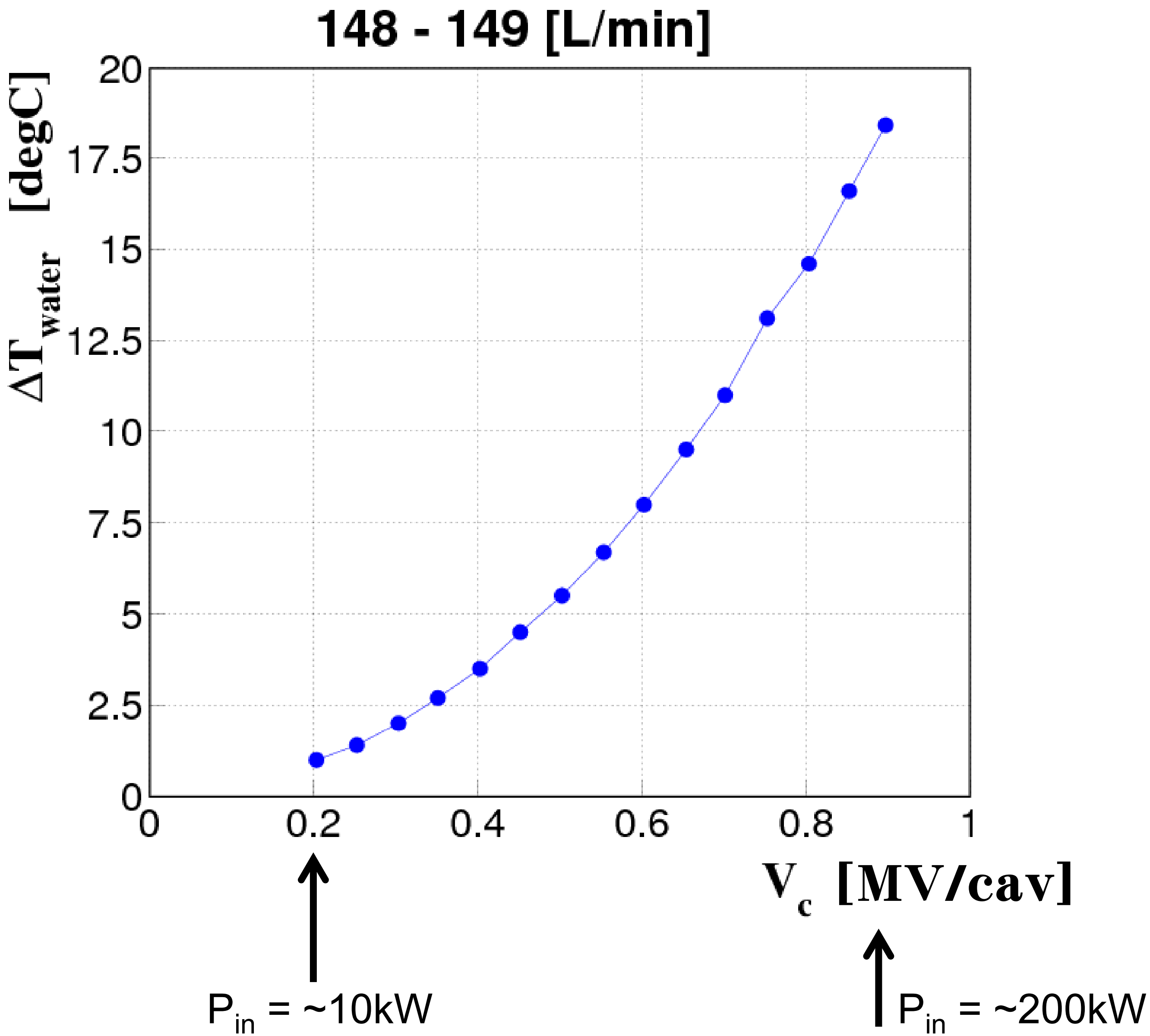
→ No "Lightnings" observed

→ Almost no continuous emissions observed using a usual camera

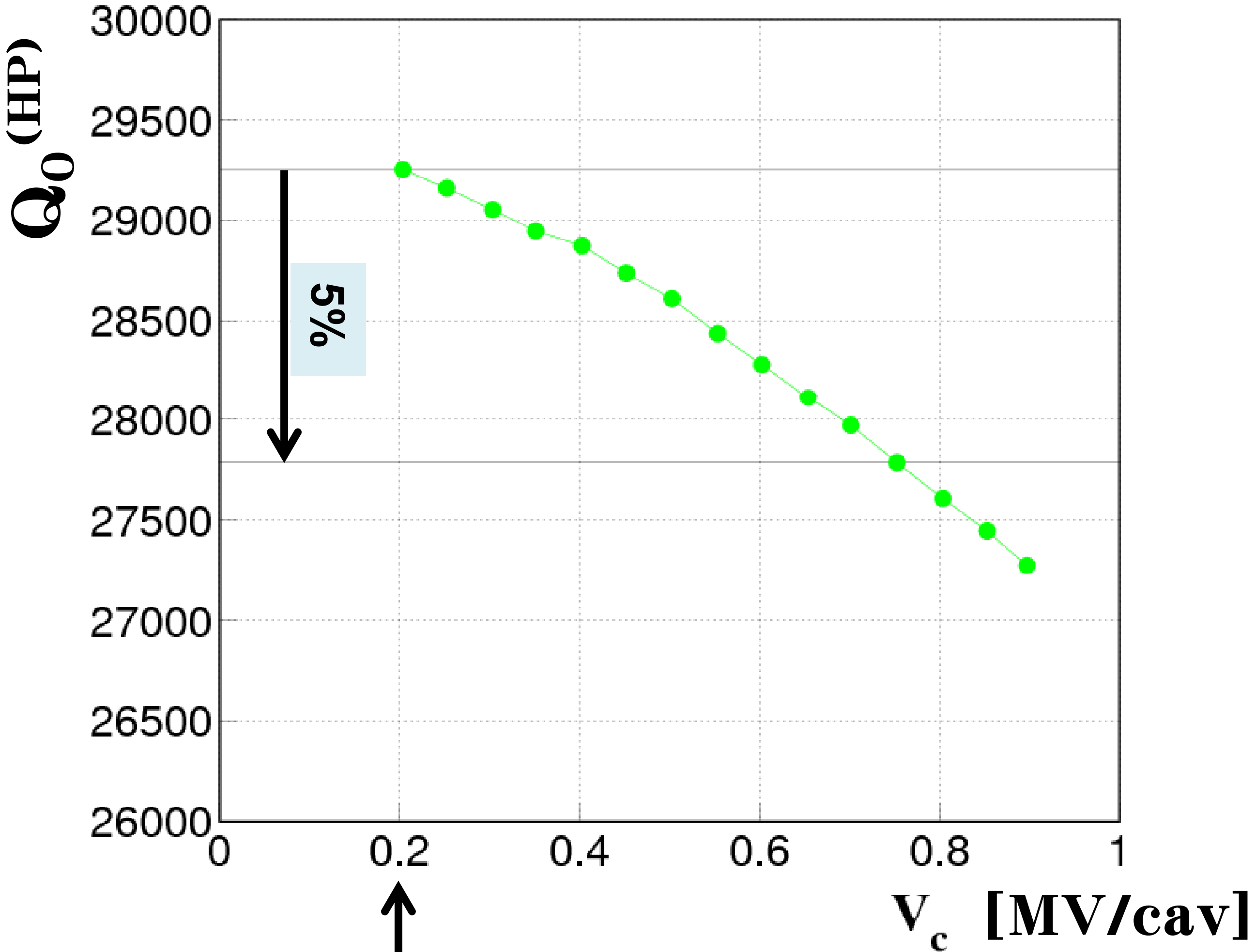
(however, using a highly-sensitive camera → Appendix G)


TV camera

Measurements of the Temperature Increase of the Cooling Water for the Cavity



Measurements of Q_0 v.s. V_c



P_{in} = ~10kW

P_{in} = ~200kW

Longest V_c Holding Times

- **0.9MV/cav** (P_{wall}=200kW) => **8 min.** (2012-09-07_11:03:30-11:11:30)
  → Terminated by I/L(refl.) with no vacuum-pressure spike and no discharge in the TV camera
  → We could not perform longer runs due to the radiation level outside the facility.

- **0.8MV/cav** (P_{wall}=150kW) => **8 hours** (2012-07-25_09:38-18:12)
  → Terminated by I/L(refl.) with no vacuum-pressure spike and no discharge in the TV camera
  → We cannot distinguish where is the primary cause, in the cavity or the LLRF control system.
  In addition, we met the following two problems: (1) and (2) related to the LLRF control system.

(1) The cavity was not tuned automatically in case of higher cavity frequencies.
→ Solved with replacing the f-1 module by new one late in this HPT
(with the help of the RF Control Group)

After replacing all the relevant LLRF modules, the following problem still remains unsolved.

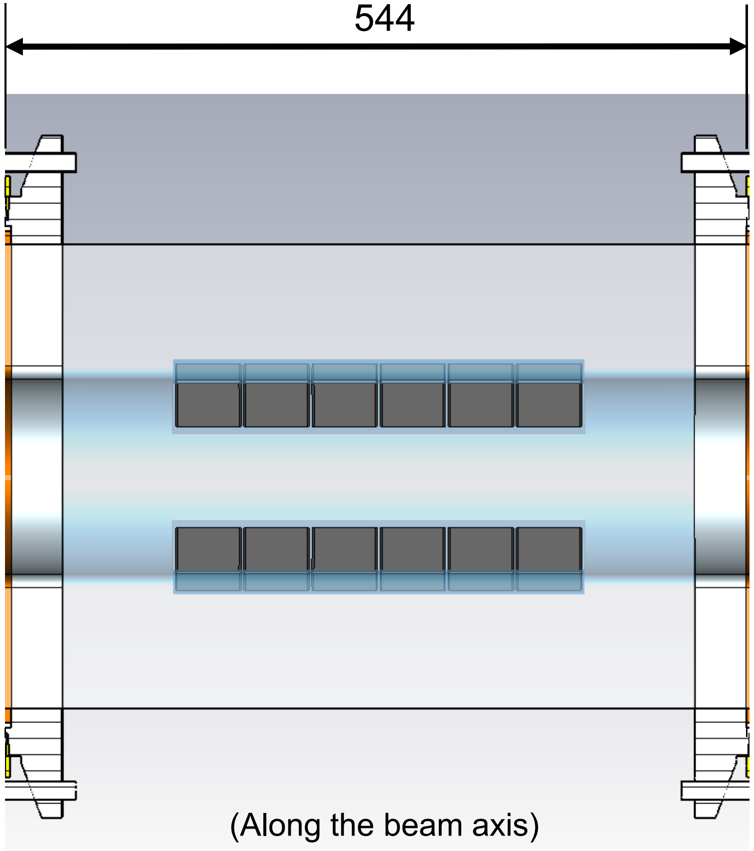
(2) RF powers (P_{in} and P_{refl}) measured in the D1 control room fluctuated.
✓ RF powers measured in the radiation shield did not fluctuate.
→ Cable deterioration?

Solving the above problems,
we will perform V_c-holding endurance tests for Cavity No.1 (Appendix M).

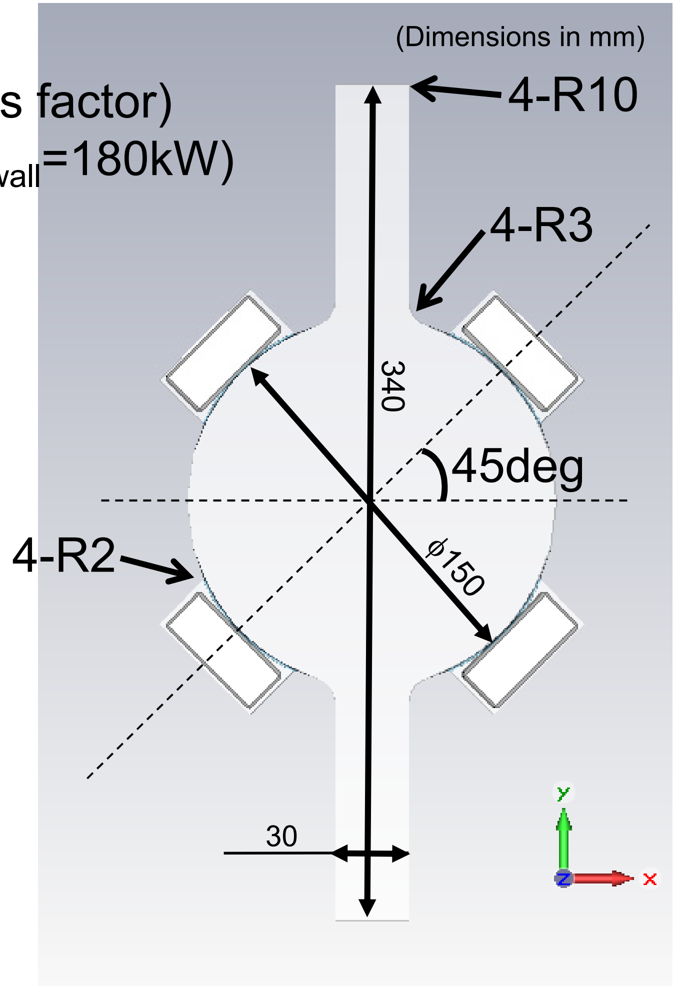
High Power Test (HPT)
of the GBP Prototype

GBP (btwn)

✓Material: SUS
✓4 sets of SiC tiles (same as used for the HOM-WGs)
✓Max. HOM Power absorbed: ~200W/GBP (incl. the loss factor)
✓Max. Accl.-Mode Power absorbed: ~100W/GBP (for P_{wall}=180kW)
✓Loss factor: 0.2 [V/pC] (for σ_z=6.0mm)



(Along the beam axis)

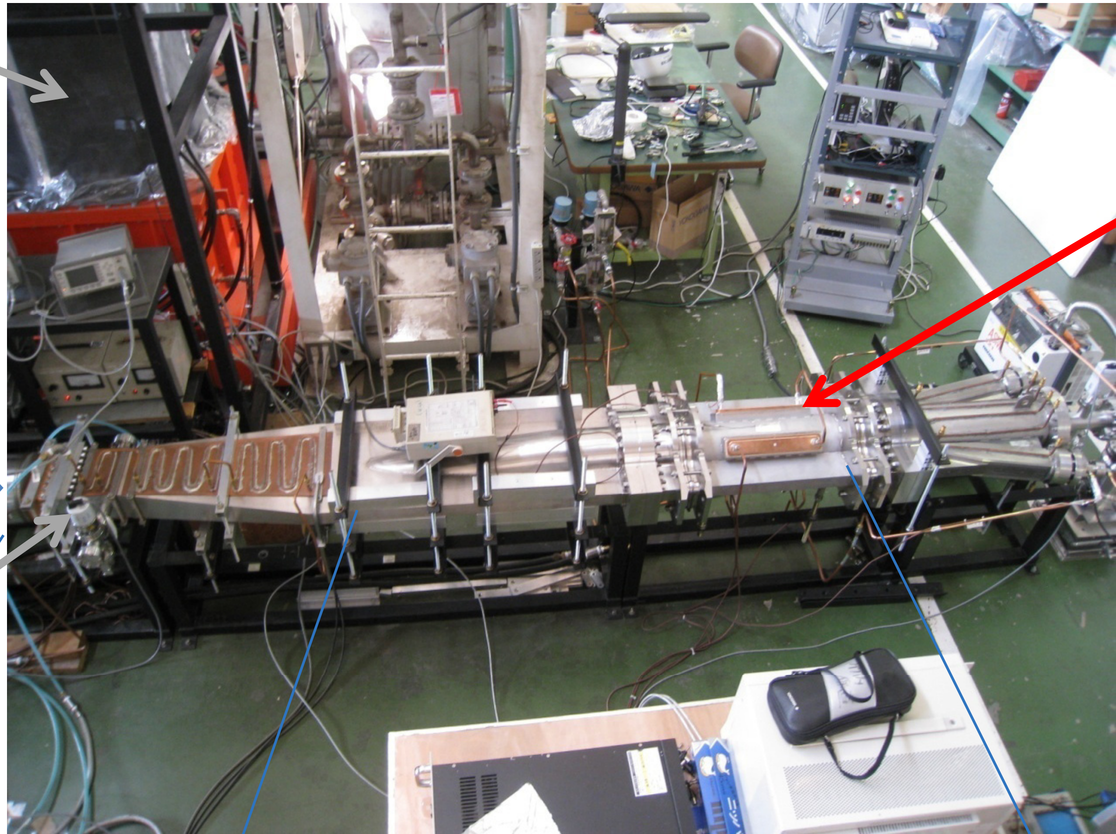


(Cross-section perpendicular to the beam axis)

Setup at D1-C Test Stand

L-band Klystron
(1.25GHz)

(Y. Takeuchi)



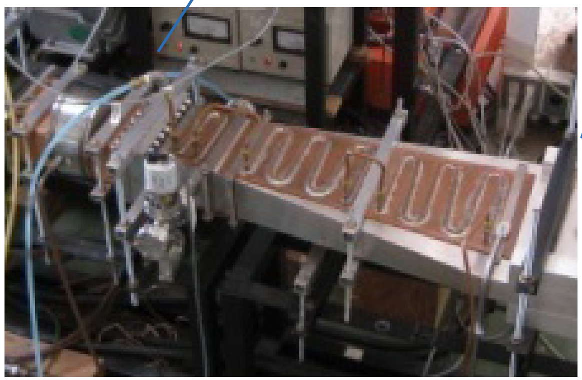
GBP

Gauge #1

←TV camera

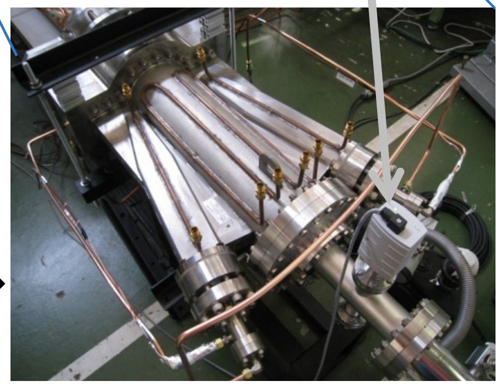
RF Power

Gauge #2

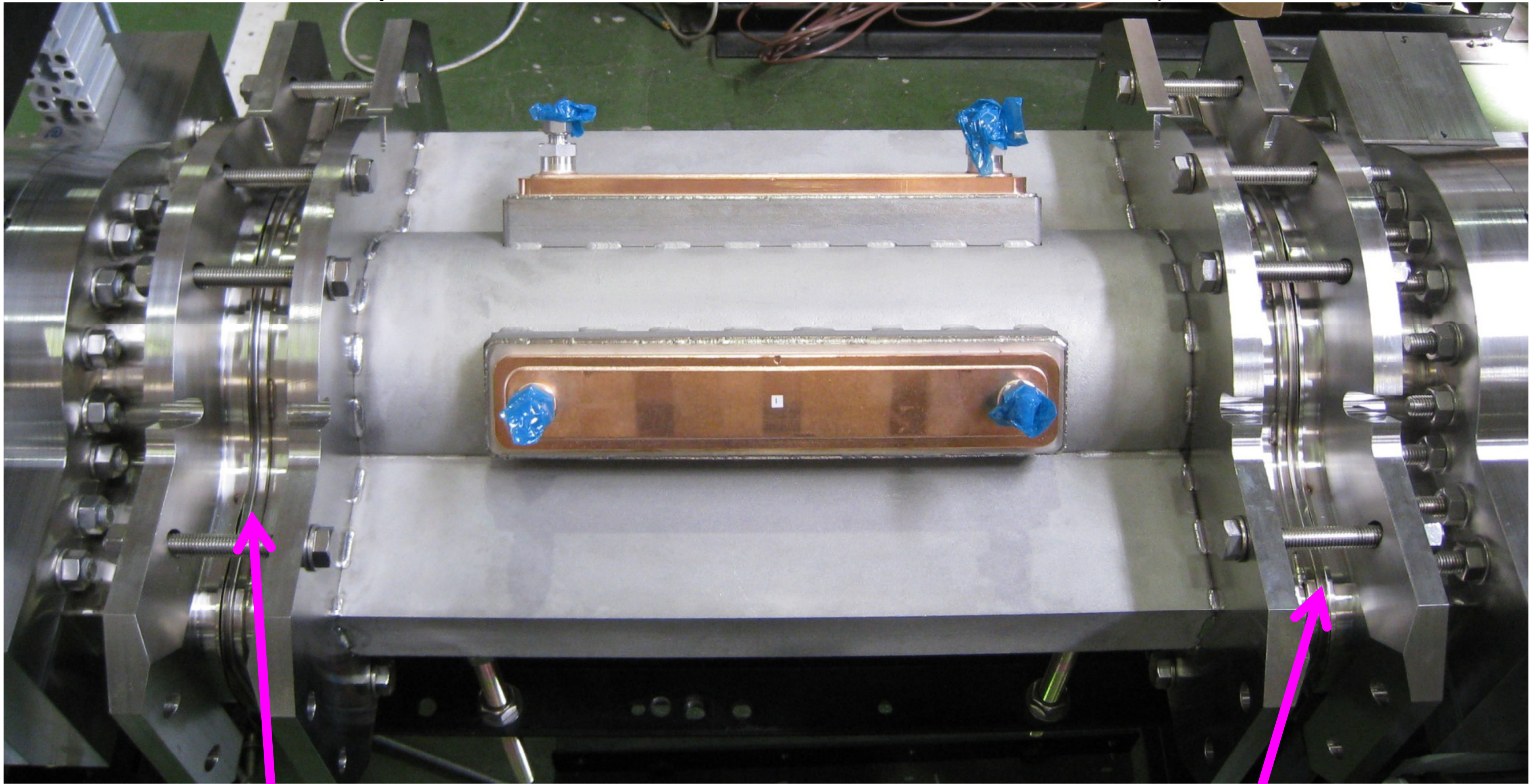


← Converting WG (WR-650→GBP)

Load: Winged Chamber Prototype →
(see Appendix C)

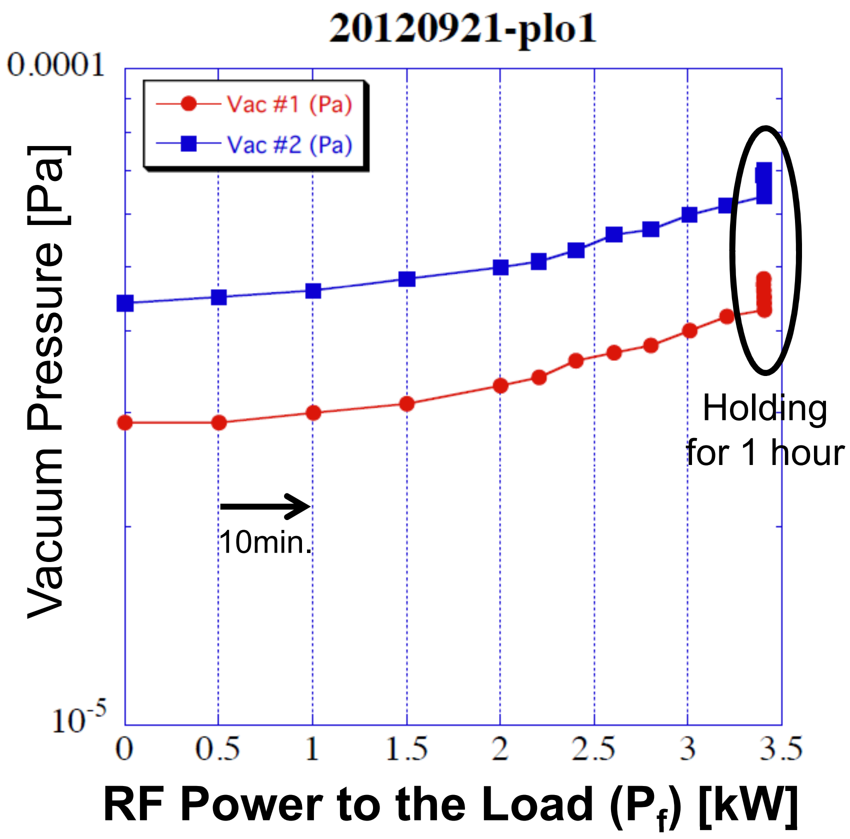


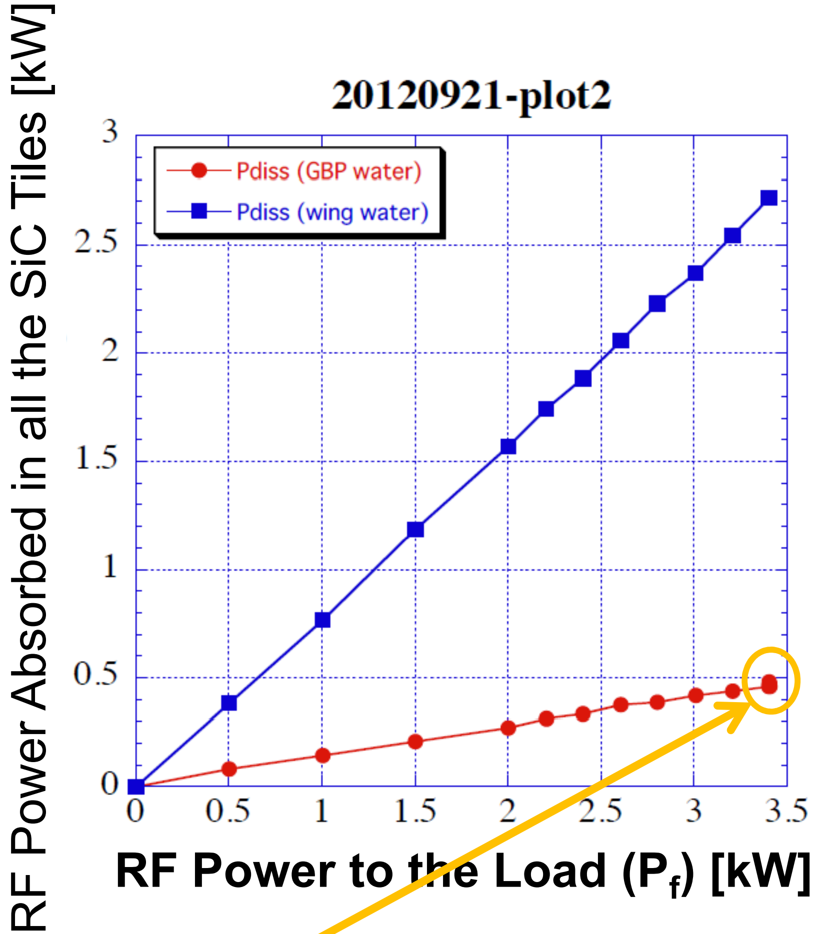
544mm



Lips not welded; O-rings used for vacuum sealing

Results of this HPT (1/3)



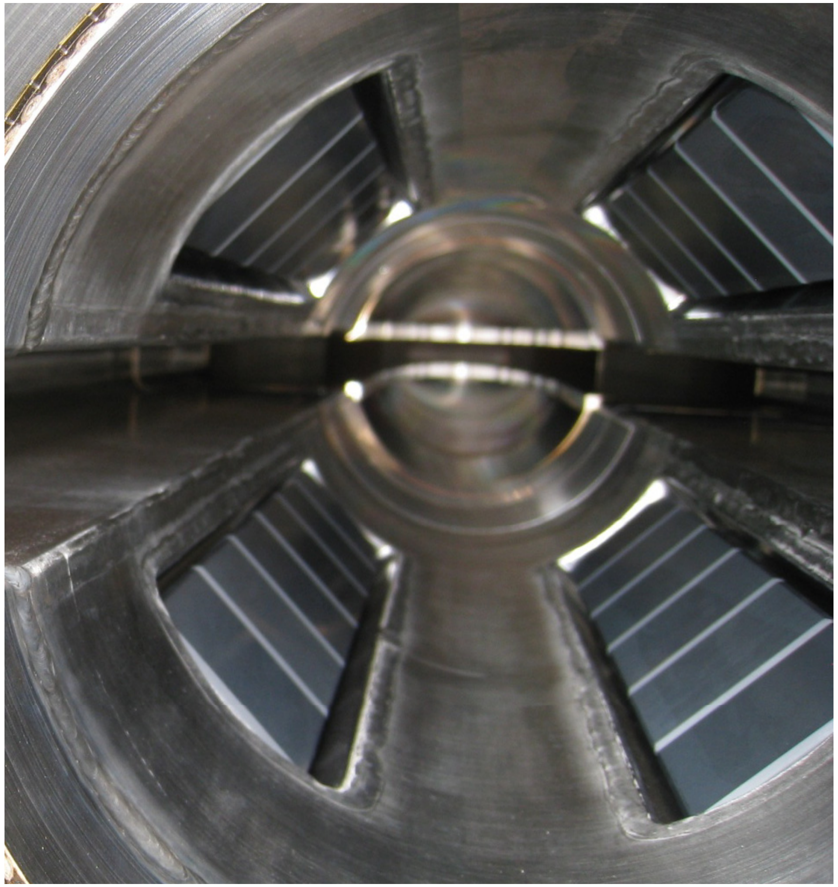


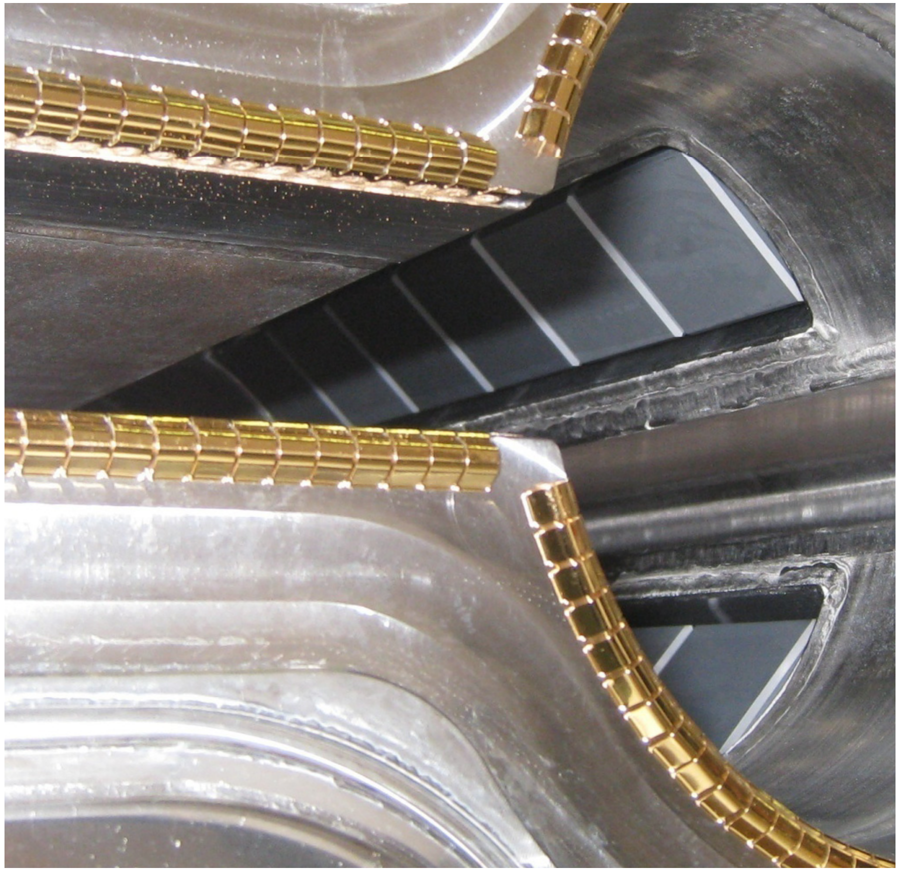
✓No Vacuum-Pressure Spike
✓No Abnormal Temperature Increase
✓No Discharge Observed with the TV Camera

P_f(max) = ~3.4kW
P_{refl}(max)= ~10W
Max. Power Absorbed at the GBP: ~400W/GBP (> 300W/GBP: max. power from the simulation)

Results of this HPT (2/3)

~~ Visual Inspection of the SiC Tiles ~~



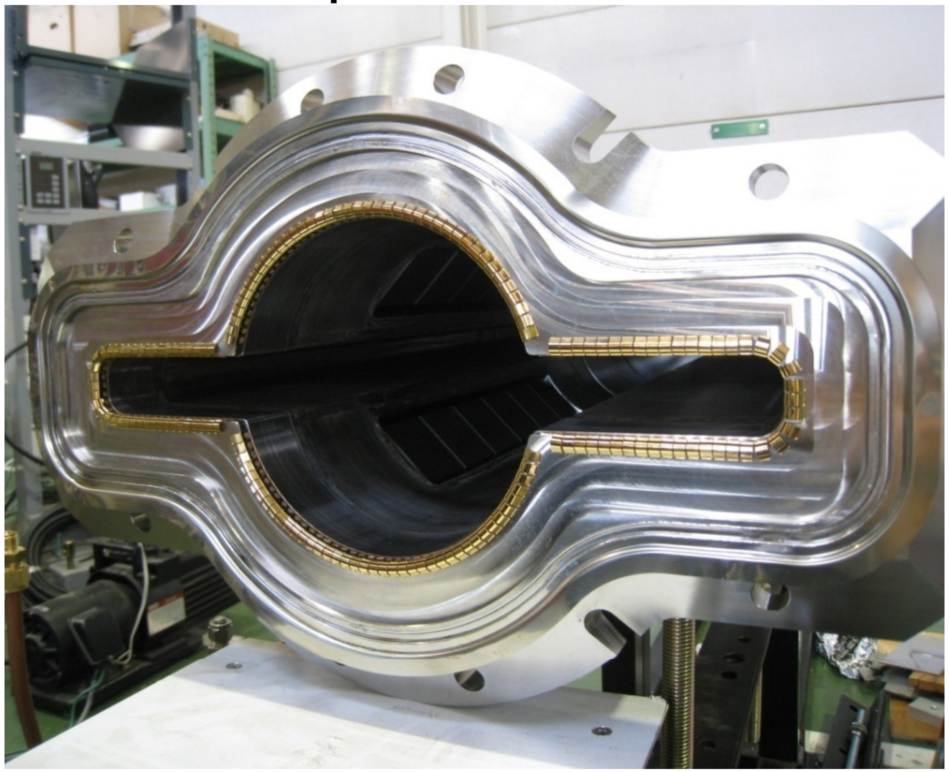


No Damage on the SiC Tiles!

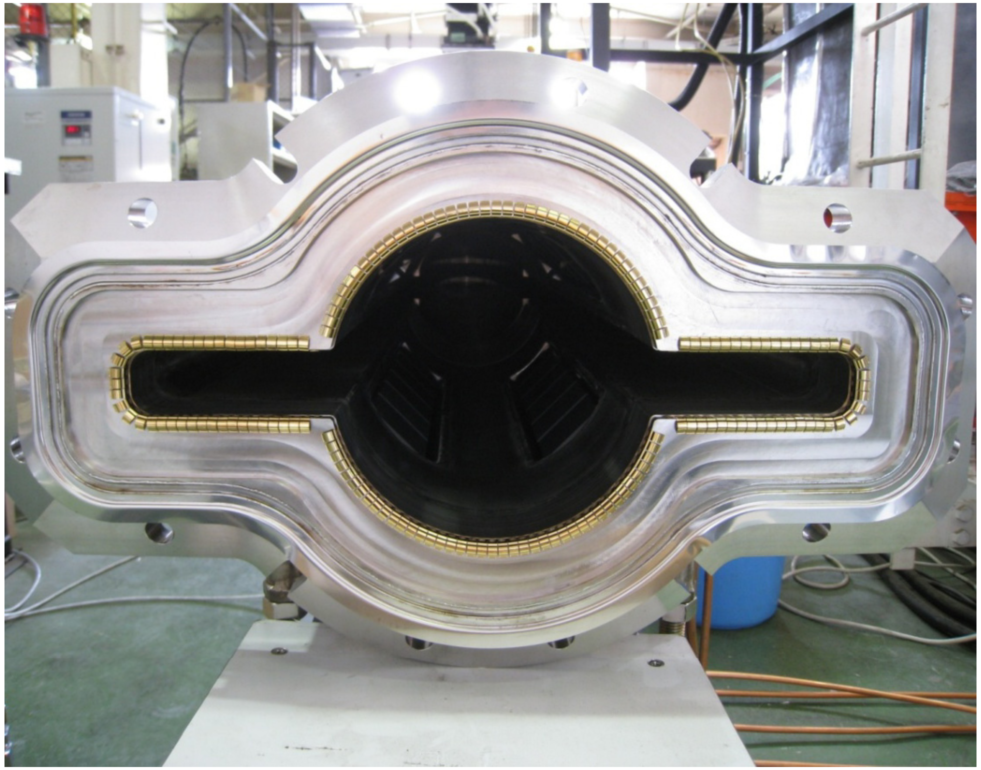
Results of this HPT(3/3)

~~ Visual Inspection of the RF Fingers ~~

Upstream



Downstream



No Damage on the RF Fingers!

Status of Cavity No.1

Status of Cavity No.1

- By scraping the tuning bump, the accl.-mode frequency was tuned into “508.904MHz” for the conditions:
  - Tuner position: 15mm inside (home position)
  - Cavity Temp.: 30degC
  - Inside: Vacuum

  (Only 17kHz away from the target frequency of 508.887MHz)
- Almost in the final stage of the fabrication

  → To be delivered soon
- News
  1. The inner surfaces of the two endplates of the cavity: Electro-Polished (EP).

     → Faster conditioning and/or lower trips rate are expected. (→next page)
  2. Preparing to take video pictures of the inner surfaces of the endplates during the high power test of Cavity No.1.

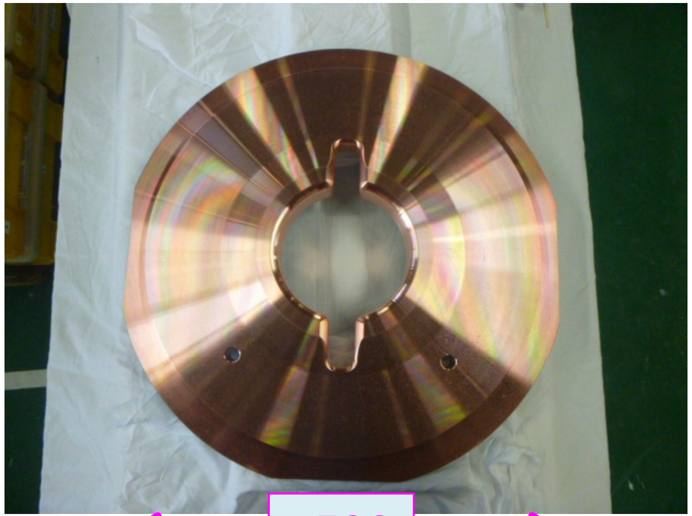
1. EP for the Endplates of Cavity No.1

Material: OFC Class1 (C1011-C1), ~40μm EP

Before R_a=~1.5μm, R_y=~8μm

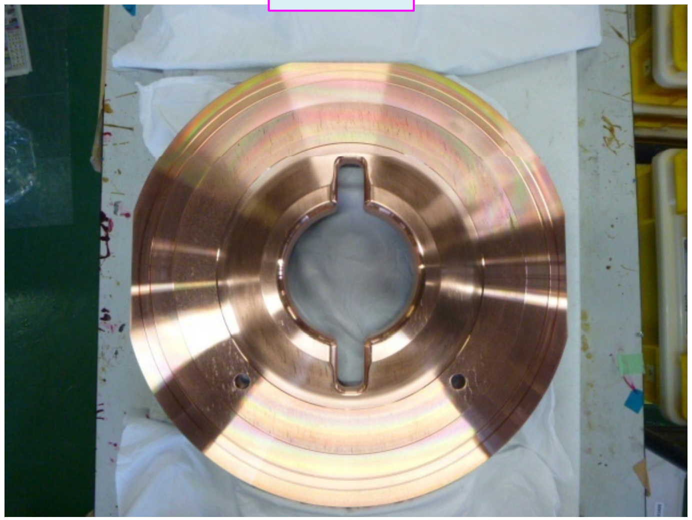
After R_a=~0.2μm, R_y=~1μm

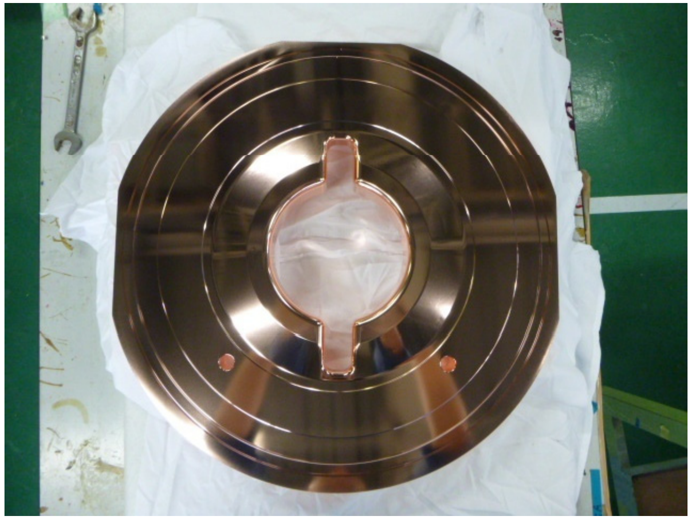
W/o the tuning bump



ϕ500

W/ the tuning bump





Status of Cavity No.1

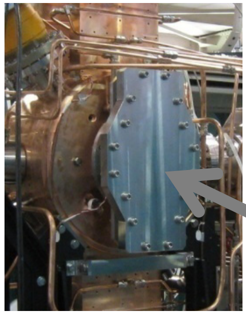
- By scraping the tuning bump, the accl.-mode frequency was tuned into “508.904MHz” for the conditions:
  - Tuner position: 15mm inside (home position)
  - Cavity Temp.: 30degC
  - Inside: Vacuum

  (Only 17kHz away from the target frequency of 508.887MHz)
- Almost in the final stage of the fabrication

  → To be delivered soon
- News
  1. The inner surfaces of the two endplates of the cavity: Electro-Polished (EP).

     → Faster conditioning and/or lower trips rate are expected.
  2. Preparing to take video pictures of the inner surfaces of the endplates during the high power test of Cavity No.1.

2. New Eye to See the Inside of the Cavity



What's going on, during HPTs, around the inner surfaces of the endplates where the surface fields are at maximum.

(H. Sakai)

TV camera
to be attached

Replace this blank flange by:

TV camera
to be attached

Mirror →
(Made of Al, packed yet in this photo)

Summary on the DR Cavities (1/2)

1. The accelerating structure for the DR

- Based on the KEKB-MR/ARES cavity with the long successful operation at KEKB
- Can supply total V_c = 2MV (spec.)

2. High Power Test of Cavity No.0 (Prototype)

- After 90hrs conditioning, V_c=0.9MV/cav (P_{wall}=200kW) achieved
  - > 0.8MV/cav (challenge)
  - >> 0.7MV/cav (spec.)

(These V_c values are corrected with recalibration for calorimetric powers and powers measured in the rad. shield)

→"Pass"

3. High Power Test of the GBP Prototype

- Up to the RF power absorbed in the SiC tiles: 400W/GBP
  - ✓ From the simulation, the max. power is 300W/GBP, including the HOMs, loss factor, and the accelerating mode with P_{wall}=180kW.
  - ✓ No vacuum-pressure spike, no abnormal temperature, no discharge
  - ✓ No damage on the SiC tiles and the RF fingers

→"Pass"

Summary on the DR Cavities (2/2)

4. **During this HPT at D1-A test stand, we found problems with the LLRF control system, suspecting its stableness.**
   - Measured RF powers, Q_0, V_c, etc. shown here are all corrected for calorimetric powers and powers measured in the radiation shield.
   - We have been improving the LLRF control system, with which D1-A is now running for input-coupler conditioning stably.
5. **We will perform V_c-holding endurance tests (Vc = 0.9 and 0.8 MV/cav) for Cavity No.1 with the improved and stable LLRF control system of the D1-A test stand.**
6. **Cavity No.1 is coming with the inner surfaces of the endplates electro-polished.**

   → To be high-power tested this coming spring

Fin

Appendices

Appendix A

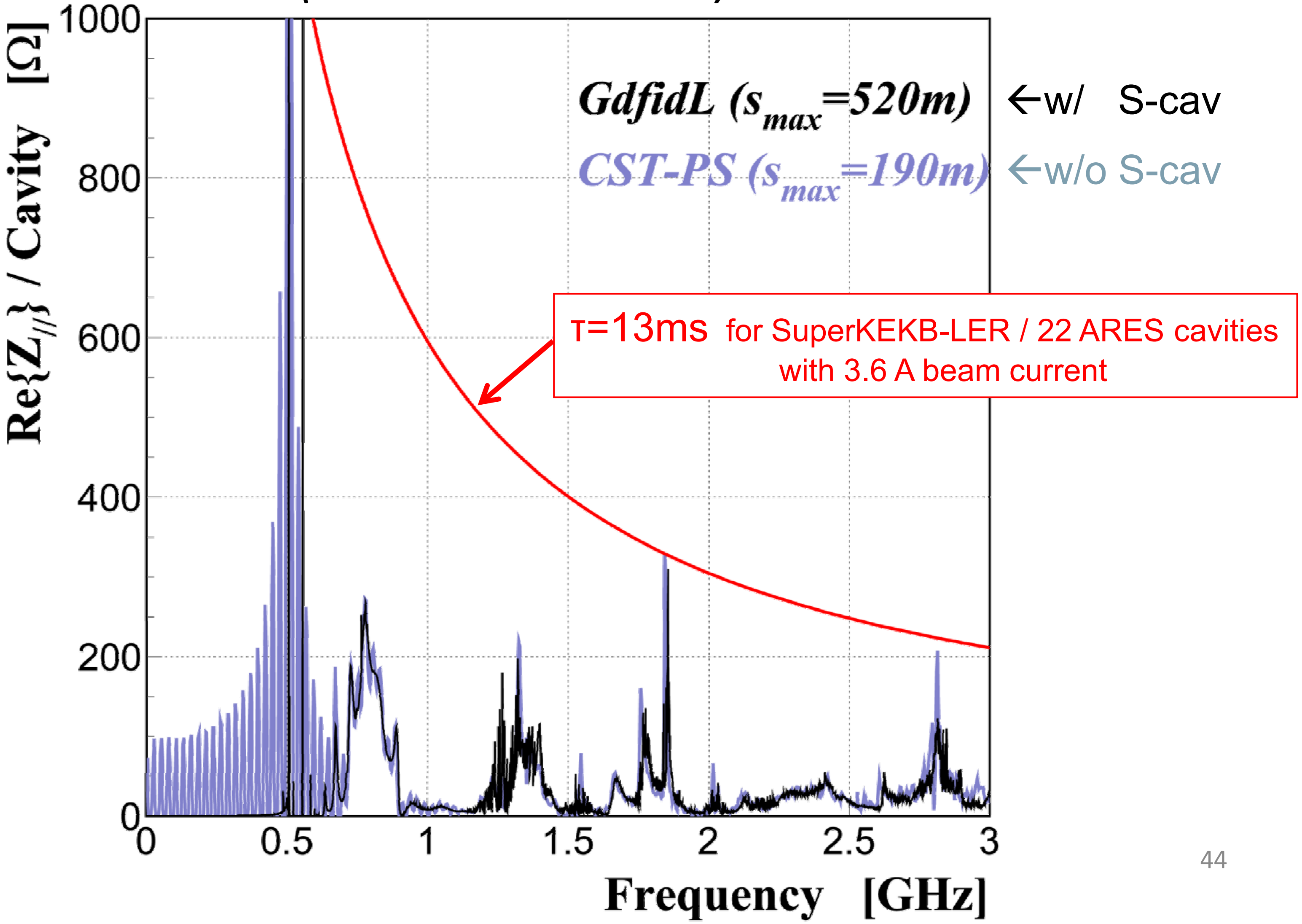
22 ARES Cavities operated for SuperKeKB LER (I_{beam} = 3.6 A)

RF frequency	508.869 MHz	
Flywheel Energy Ratio U_S / U_A	9	unchanged
Cavity Voltage V_C	0.48 MV	P(wall) = 140 kW
Detuning Frequency $\Delta f_{\pi/2}$ / Δf_{AC}	-28 kHz / -280 kHz	P(beam) = 460 kW
Input Coupling Factor β	5.0	β (optimum) = 4.3
CBI (-1 mode) due to the Acc. mode	τ = 4 ms	RF feedback
CBI due to the 0 and π modes	τ = 21 ms	bunch-by-bunch FB

(T. Kageyama, MAC'11)

Appendix B:
Longitudinal HOM Impedance and CBI Threshold at SuperKEKB-LER

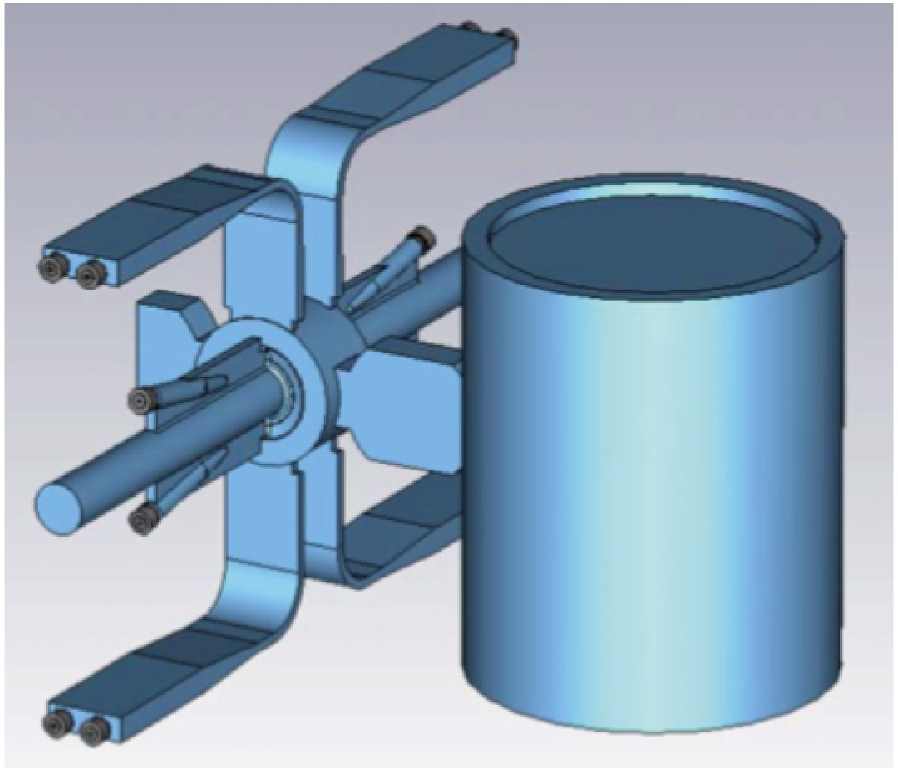
(Simulation Results)



Appendix C

R&D being continued.

ARES-*KAI*
(originally designed for SuperKEKB)

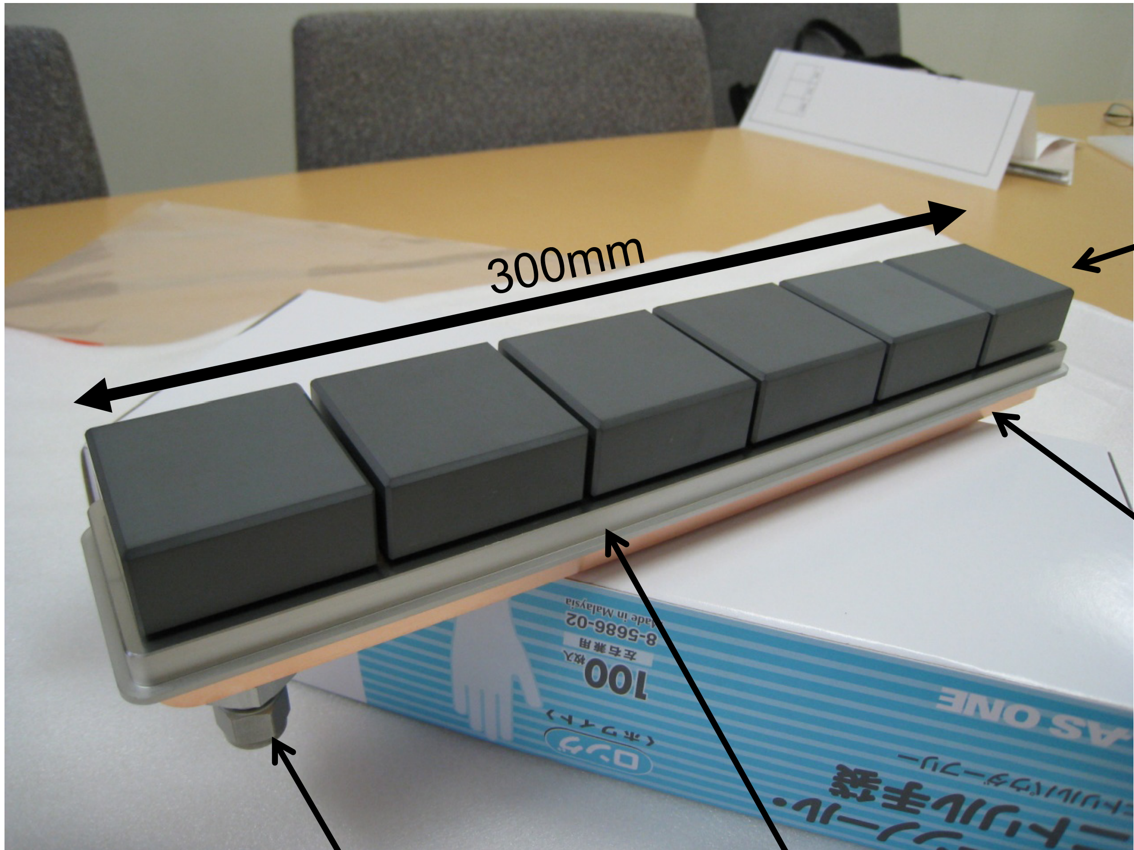


アレス改　　T. Abe and Y. Takeuchi

Replace the grooved beam pipes with winged chambers.
Each wing equipped with a bullet-shaped SiC absorber.

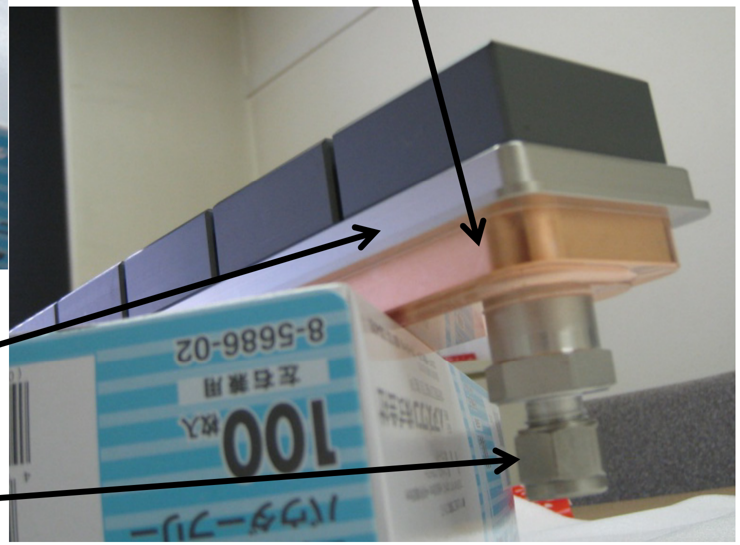
(T. Kageyama, MAC'11)

Appendix D:
A Set of SiC Tiles for the DR Cavity/HOM-WG or GBP



6 SiC Tiles

Copper Plate with a Cooling Channel

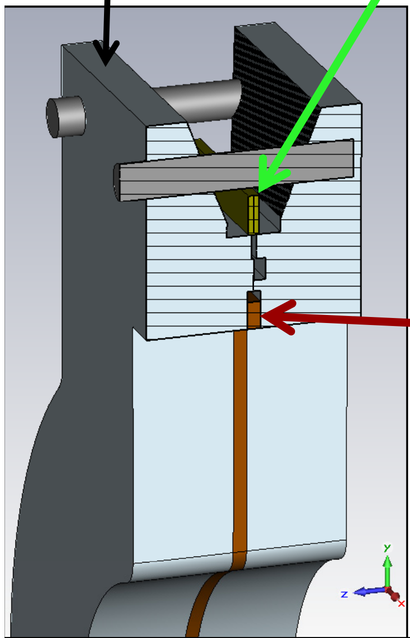
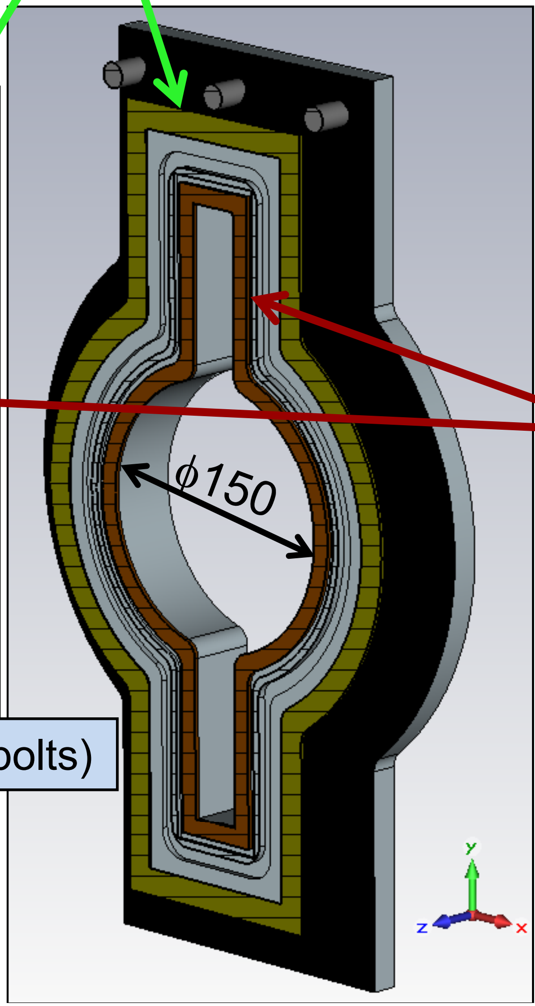


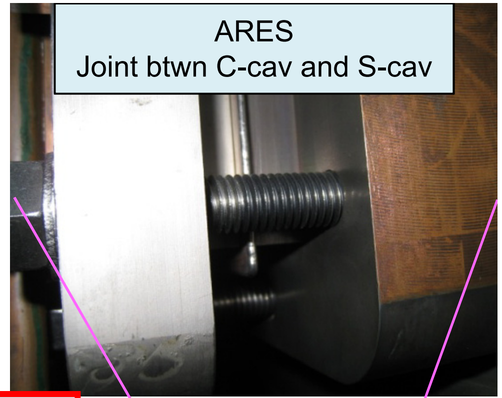
(Y. Takeuchi)

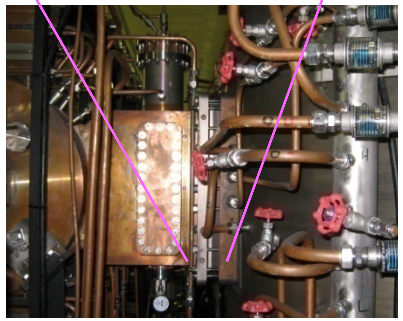
SUS Frame for Welding

Cooling-Water Pipe Joint

Appendix E (1/3):
Cavity-GBP Joint Structure





"Welding → Disassembly
→ ReWelding"
Possible Several Times

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

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

Appendix E (2/3): Reasons why we adopted such structure for the Cavity-GBP joint

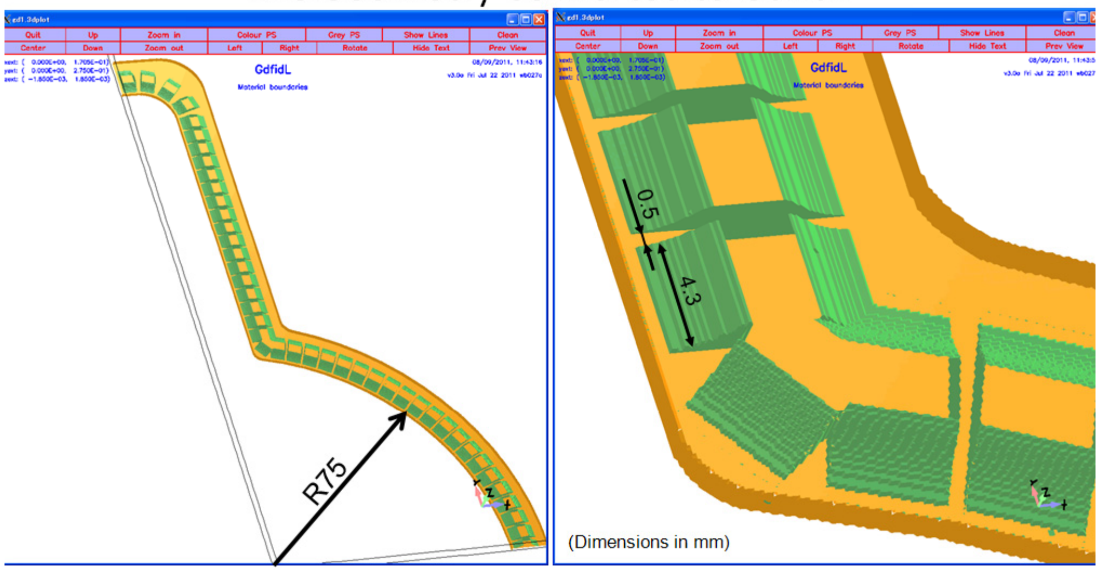
- **Successful experience** at KEKB-MR/ARES (C-cav and S-cav) on **leakproof** vacuum sealing during high power operation with heat deformation of the cavity
- We do not need to disassemble the structure so often. (twice at max. from our experience at KEKB-MR/ARES)
  - "Welding→Disassembly→**ReWelding**" 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 this DR.
  - **Successful experience** at KEK/PF.
  - **Negligible** wakefield and HOM heating (< 1W from the simulation (next page))

Appendix E (3/3): Results of the Simulation

	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**

This loss power is negligible!!

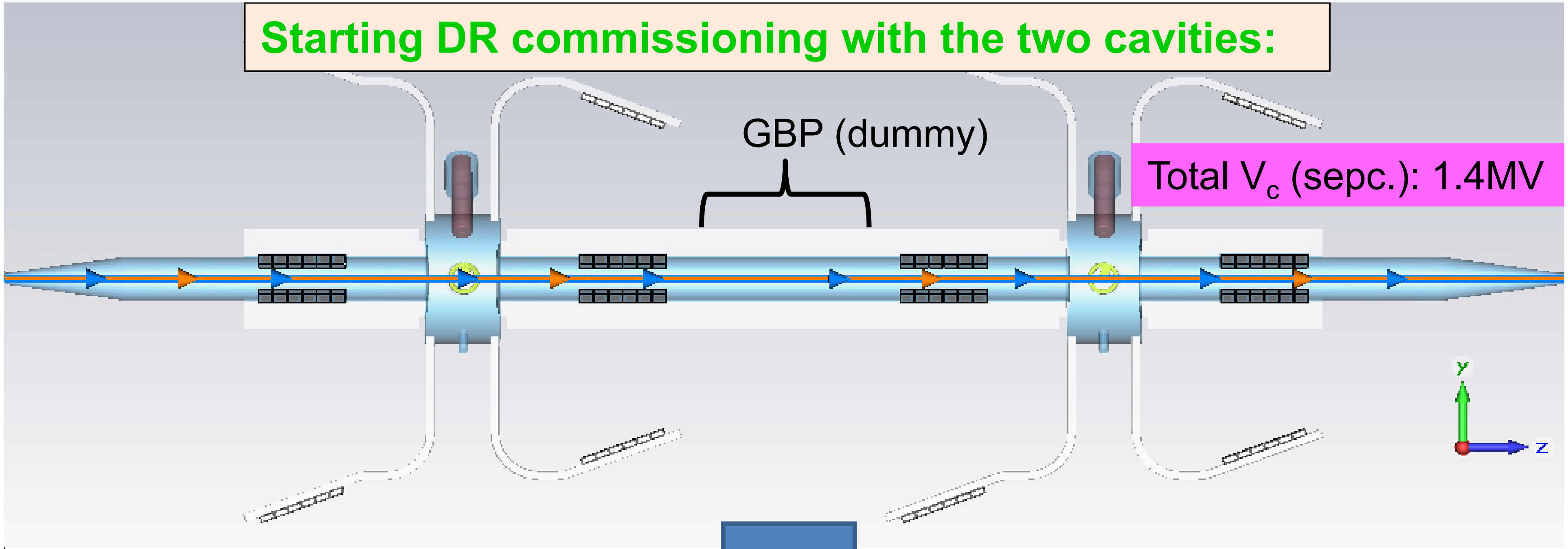
The Geometry Converted to GdfidL



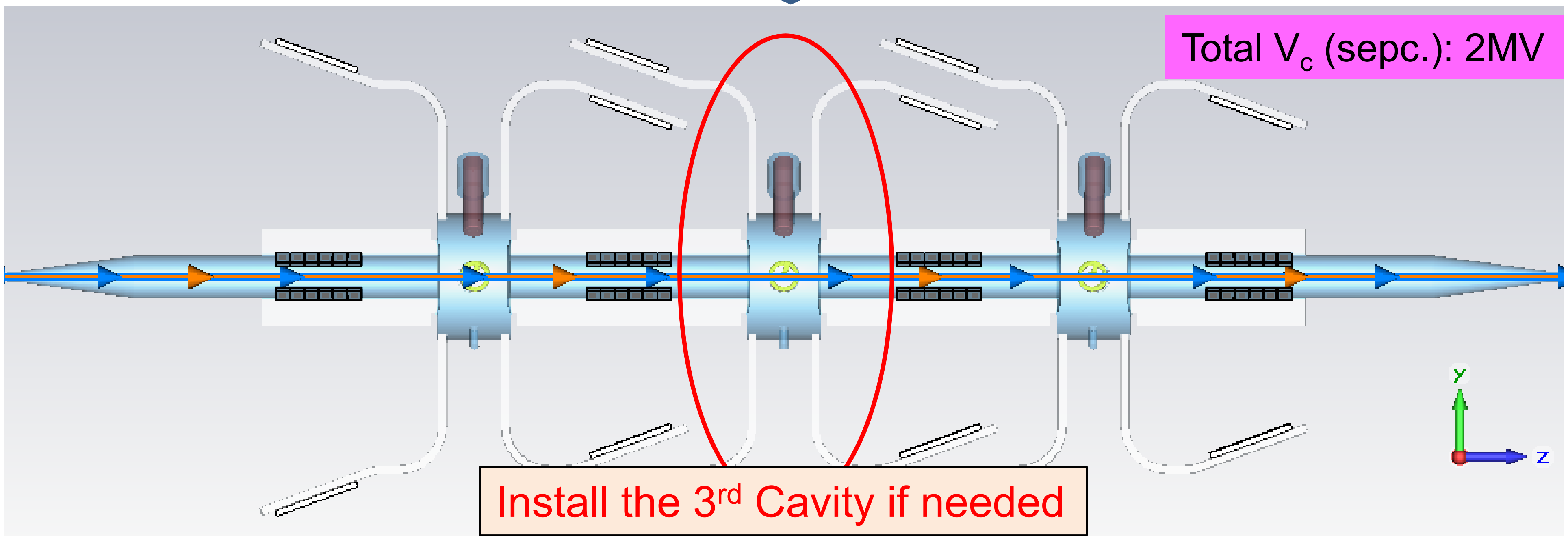
For the DR Parameters:
- Bunch Charge: 8nC
- Bunch Length: 6.5mm
- # of Bunches: 4/ring
- Circumference:135.5m

Wakefield Simulation
By GdfidL with 0.1mm Mesh Size

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


Starting DR commissioning with the two cavities:
GBP (dummy)
Total V_c (sepc.): 1.4MV
y
z

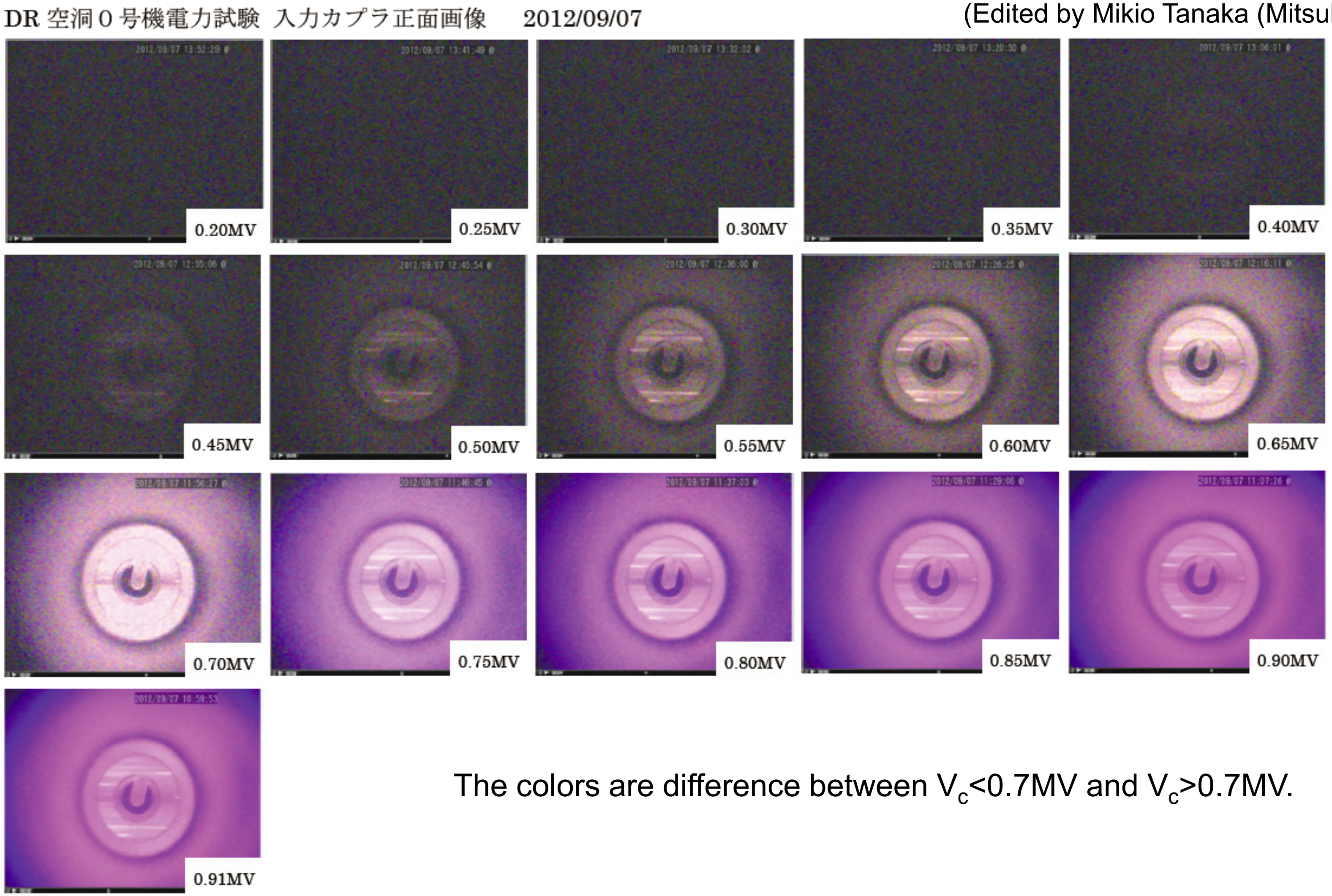
Appendix F


Total V_c (sepc.): 2MV
Install the 3rd Cavity if needed
y
z

Appendix G: Continuous Emission v.s. V_c

- ✓Taken on the last day of the HPT of Cavity No.0 (well-conditioned)
- ✓Using a highly-sensitive camera
- ✓If we use a usual camera, almost no emission observed.

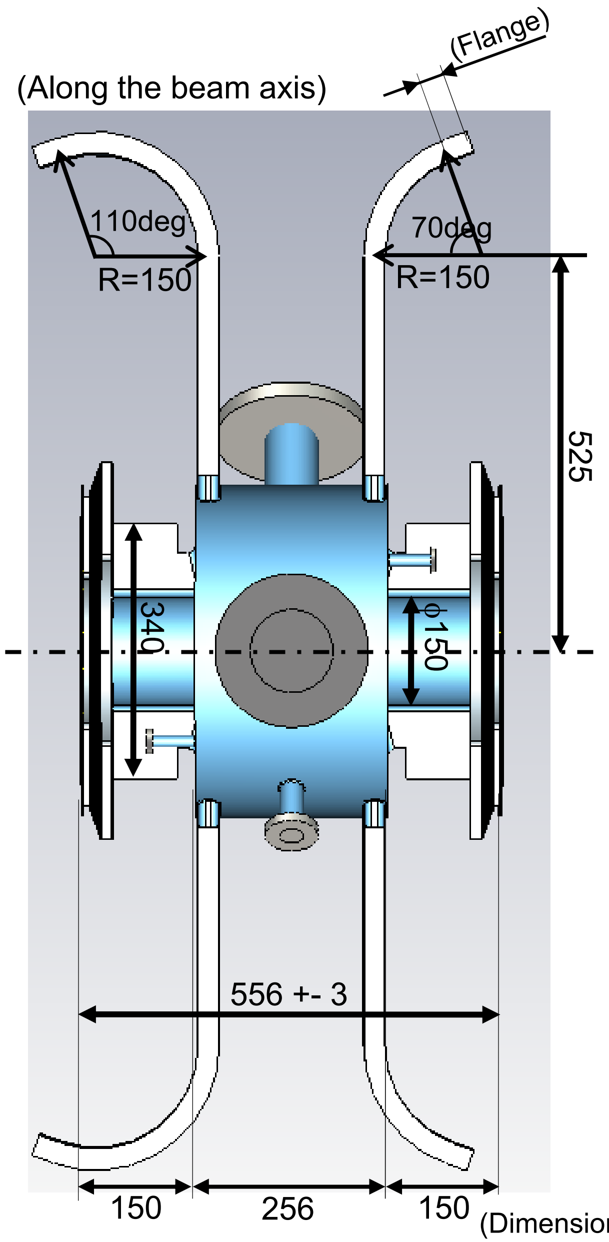
(Edited by Mikio Tanaka (Mitsubishi SC))



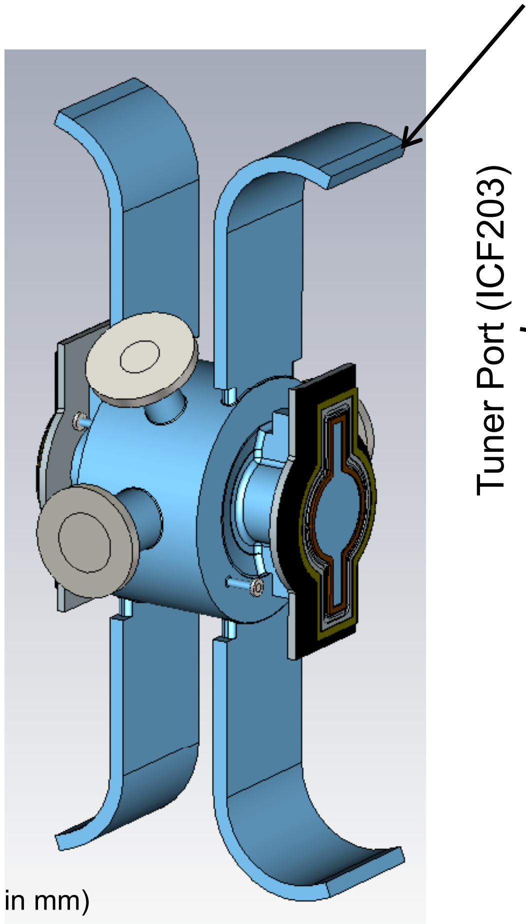
The colors are difference between V_c<0.7MV and V_c>0.7MV.

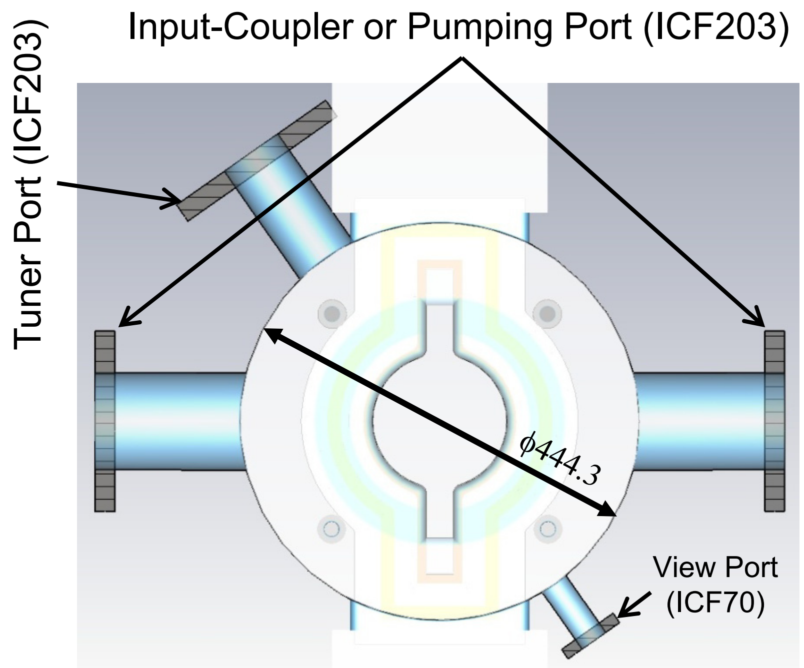
Appendix H (1/2): Cavity (main body)

✓Material: Highly-Pure Copper (C1011-C1)
except for the flanges, 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



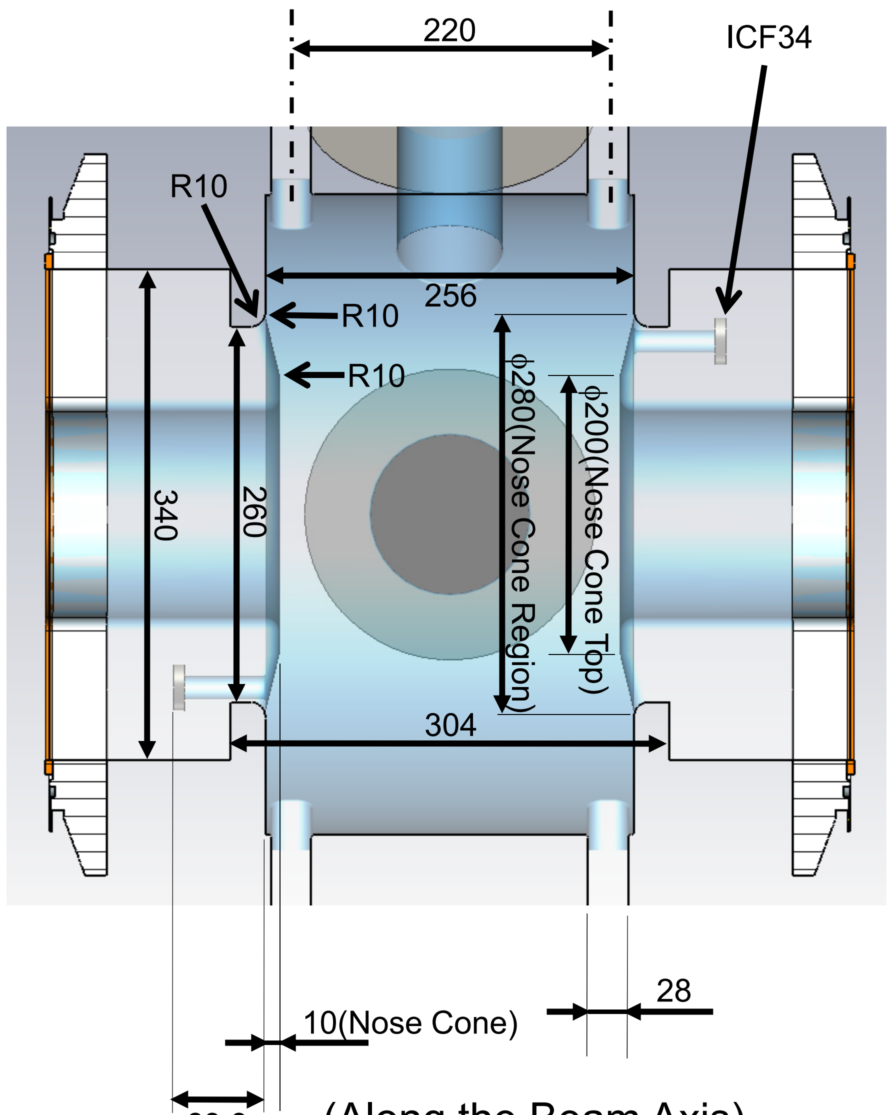
(Dimensions in mm)



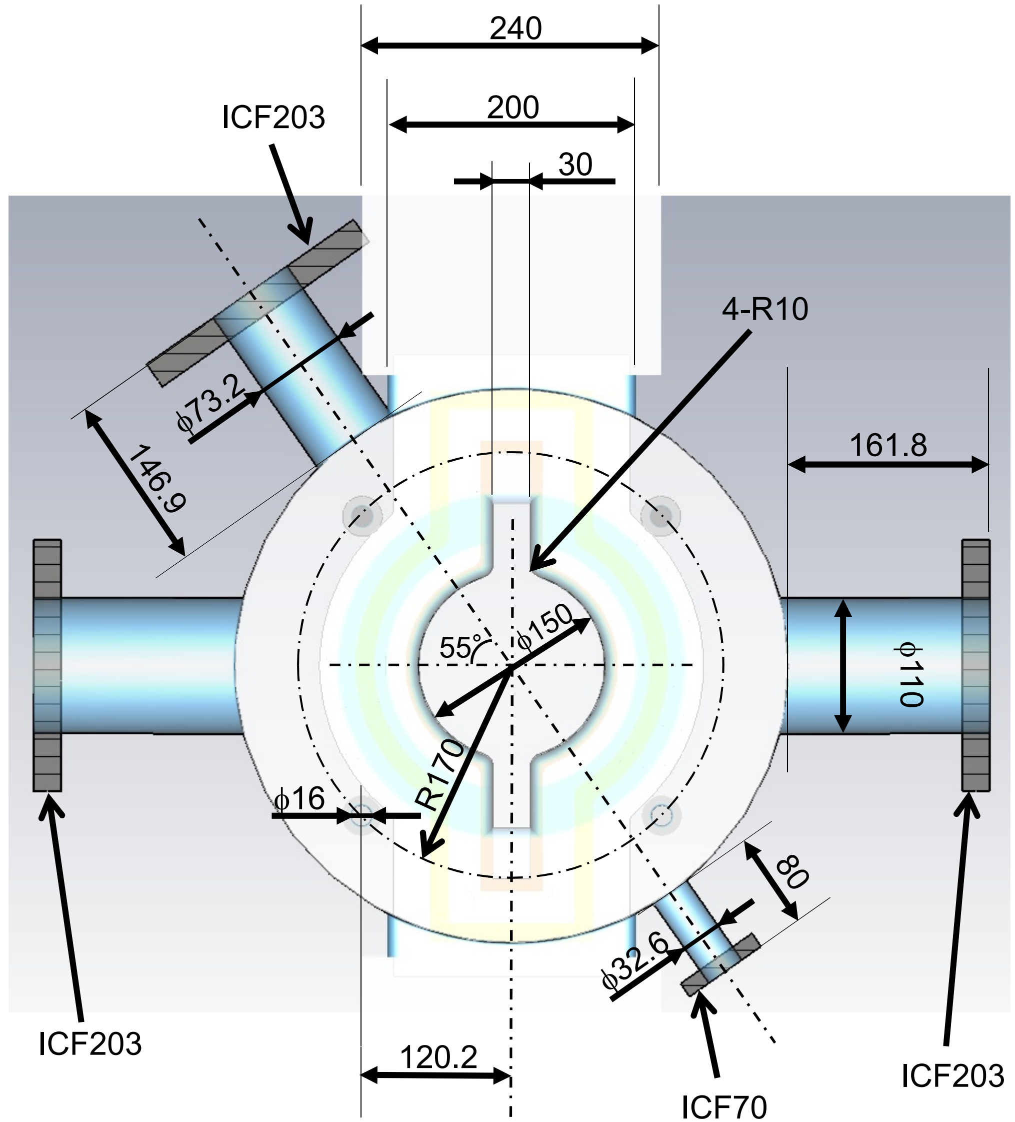


(Cross-section perpendicular to the beam axis)

Appendix H (2/2): Cavity (Main Body)

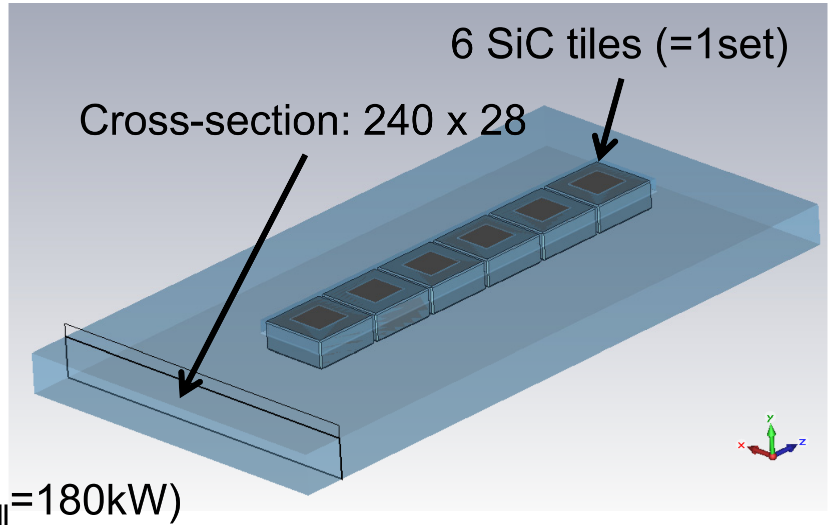


(Along the Beam Axis)



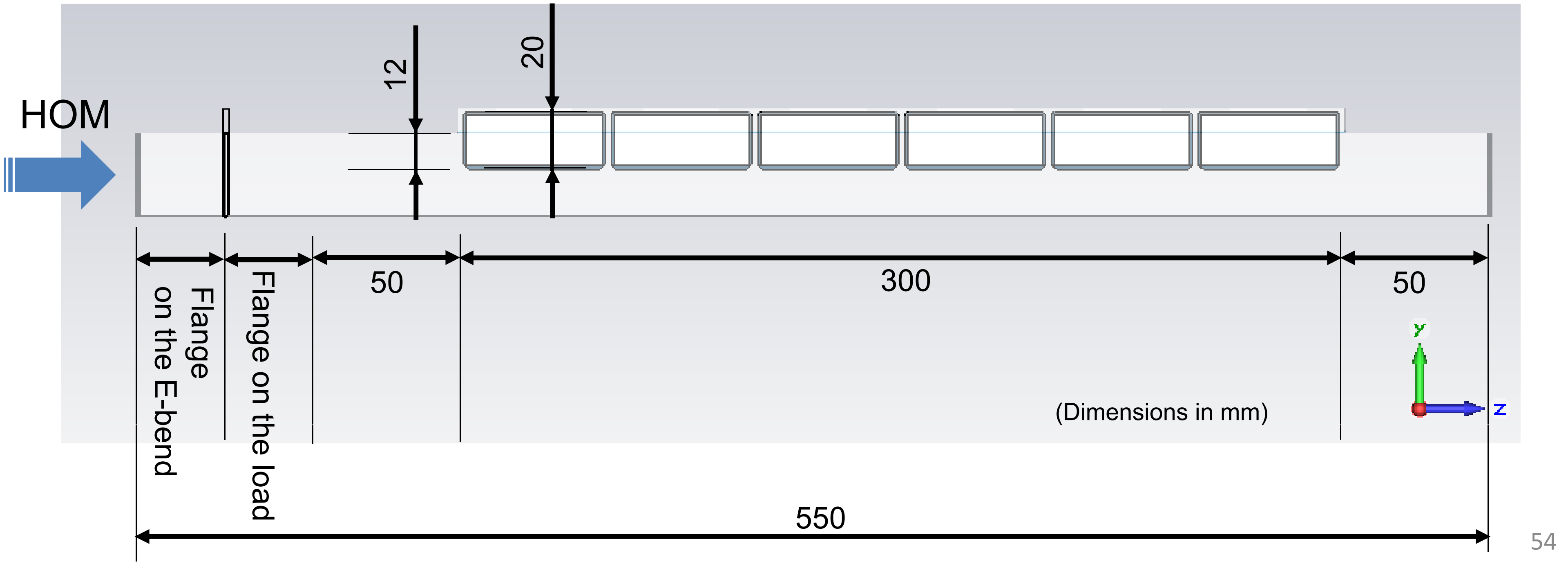
(Perpendicular to the Beam Axis)

Appendix I: HOM-WG Load



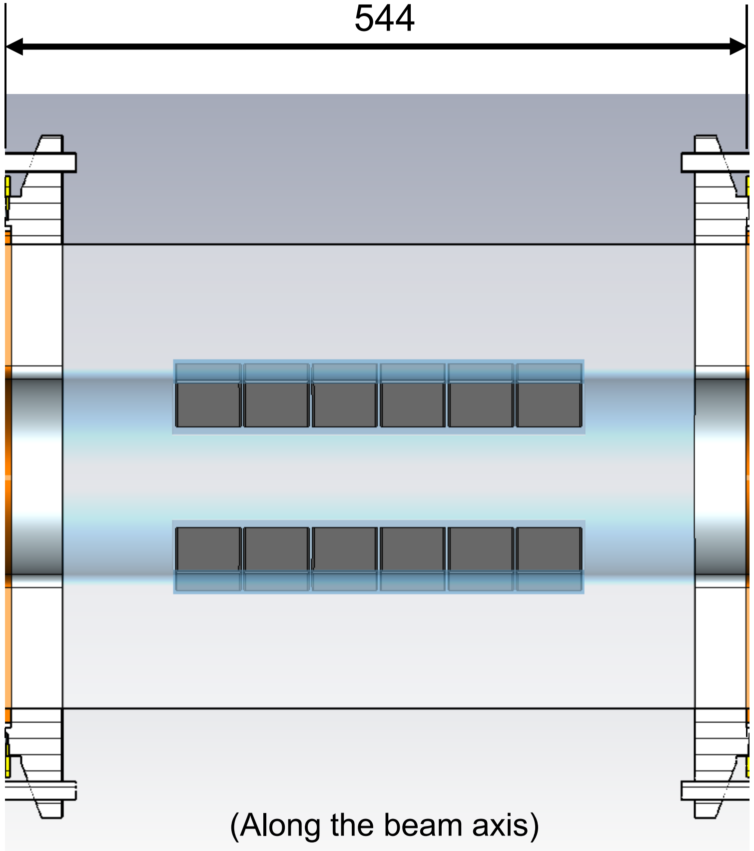
✓Material of the WG: SUS
✓HOM Absorber: SiC (Silicon Carbide) ceramics
- •Brazed on a copper plate
- •Water-cooled via the copper plate
- •Same as used for the KEKB-MRs/ARES

✓Power Capability: 1.2kW/set(@1.3GHz)
✓Max. HOM Power absorbed: ~30W/WG
✓Max. Accl.-Mode Power absorbed: ~130W/WG (for P_{wall}=180kW)

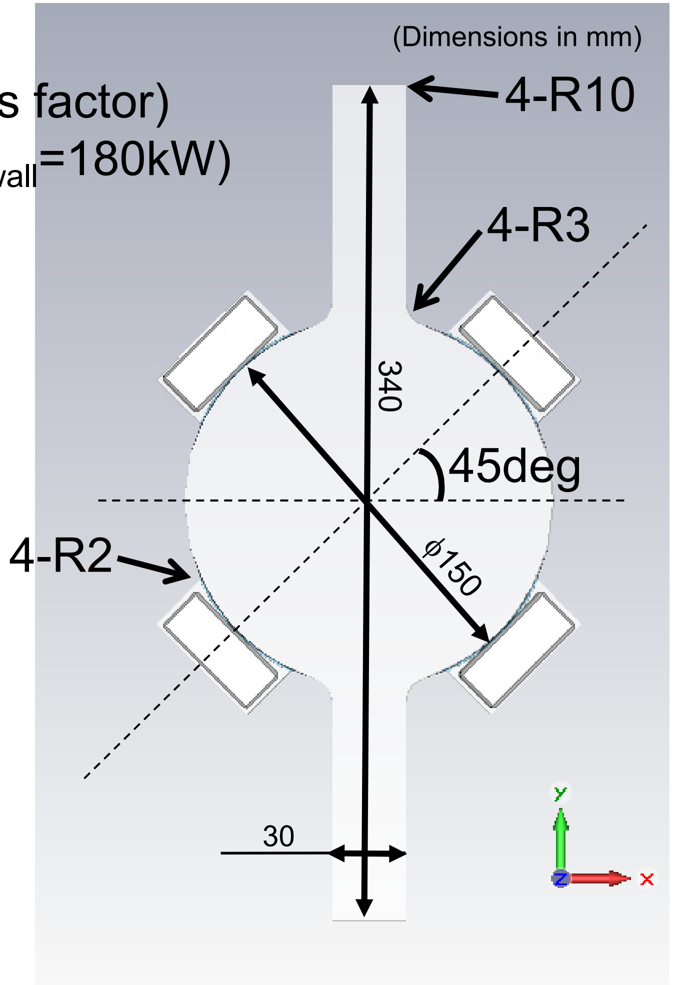


Appendix J: GBP (btwn)

- ✓Material: SUS
- ✓4 sets of SiC tiles (same as used for the HOM-WGs)
- ✓Max. HOM Power absorbed: ~200W/GBP (incl. the loss factor)
- ✓Max. Accl.-Mode Power absorbed: ~100W/GBP (for P_{wall}=180kW)
- ✓Loss factor: ~0.2 [V/pC] (for σ_z=6.0mm)



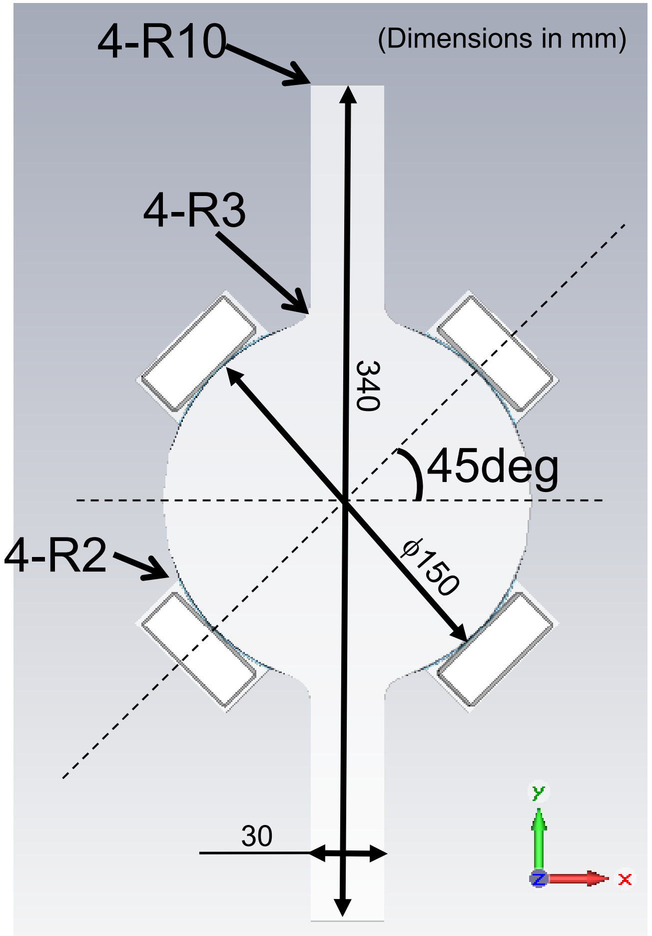
(Along the beam axis)



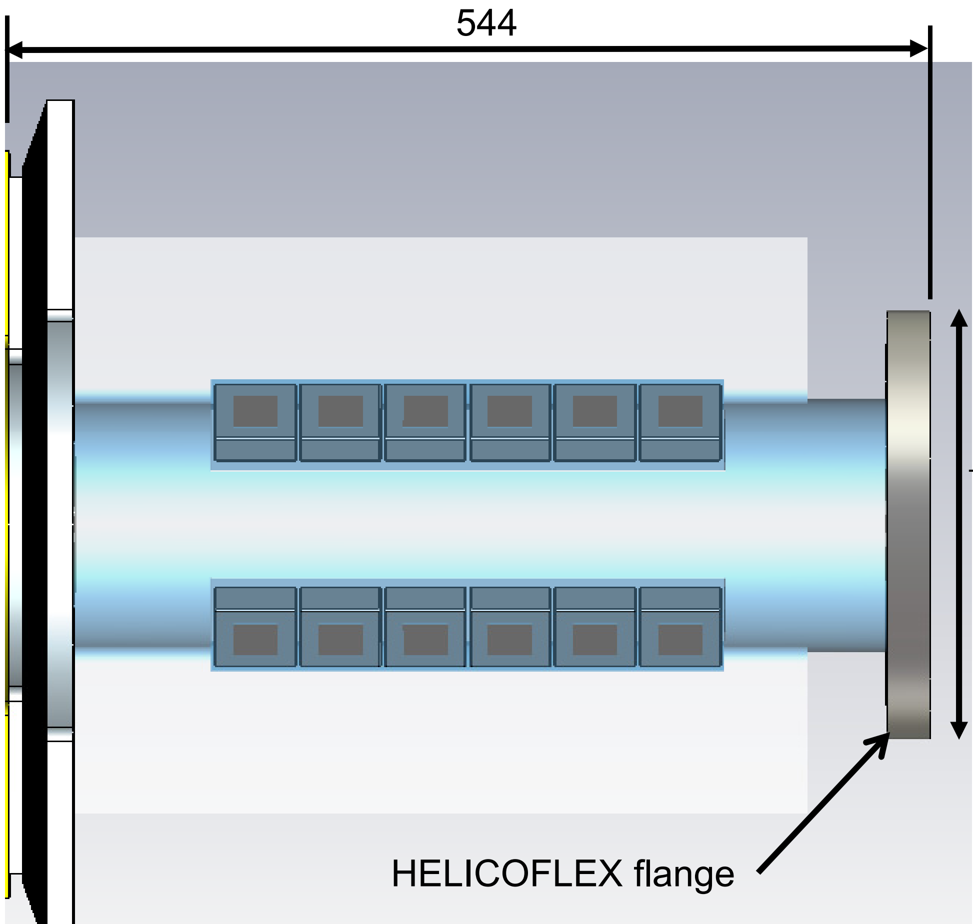
(Cross-section perpendicular to the beam axis)

Appendix K: GBP (end)

✓Material: SUS
✓4 sets of SiC tiles
✓Max. HOM Power absorbed: ~200W/GBP (incl. the loss factor)
✓Max. Accl.-Mode Power: ~100W/GBP (for P_{wall}=180kW)



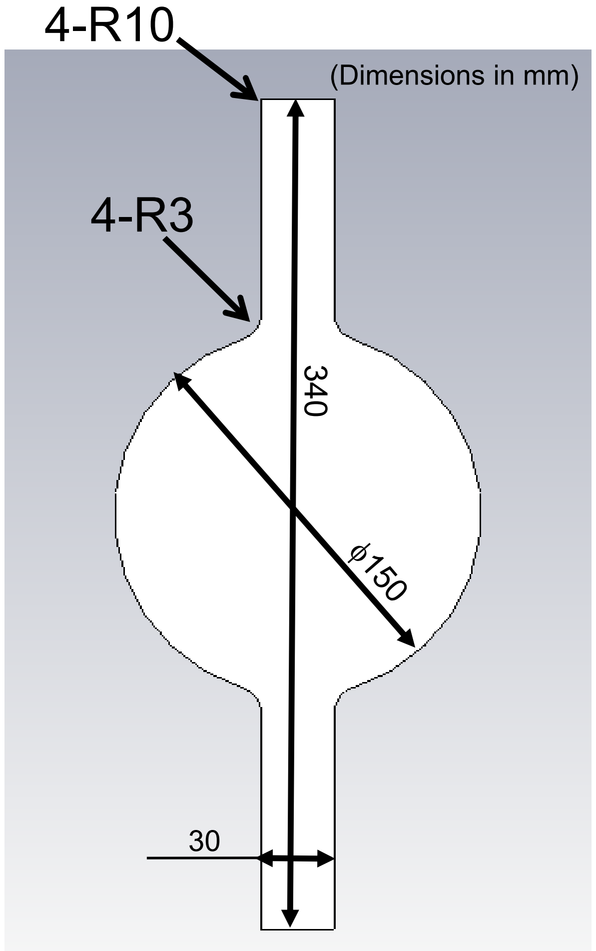
(Cross-section perpendicular to the beam axis)



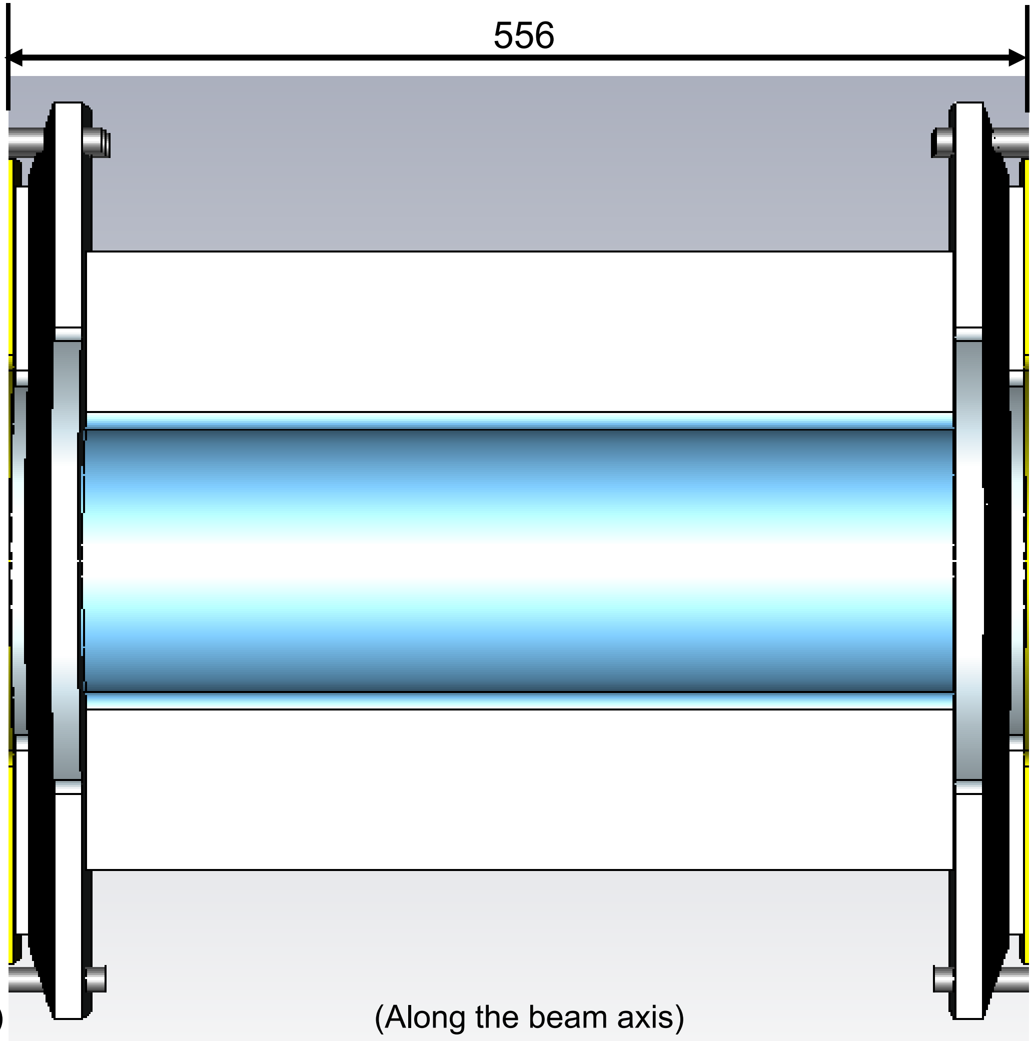
(Along the beam axis)

Appendix L: GBP(dummy)

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



(Cross-section perpendicular to the beam axis)

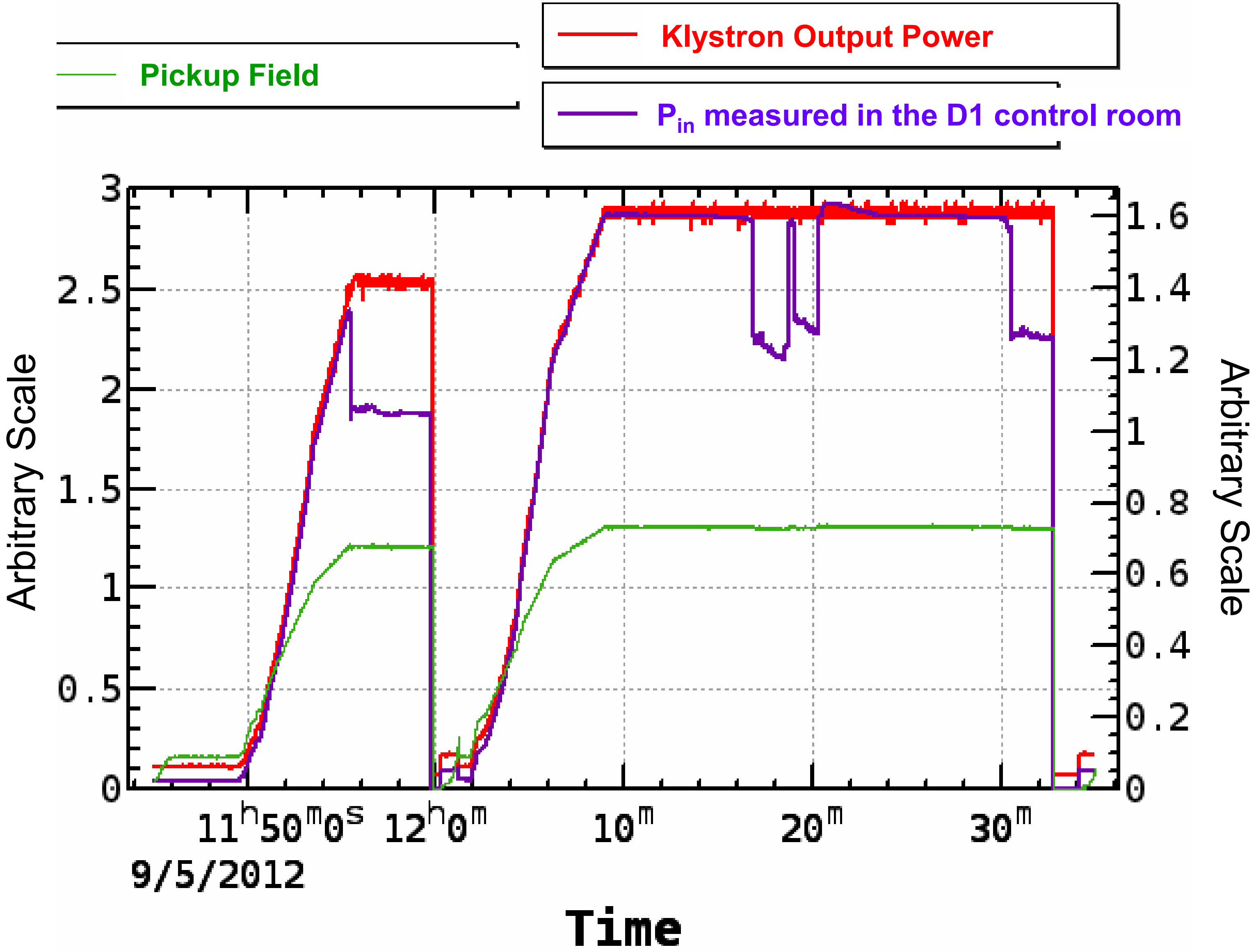


(Along the beam axis)

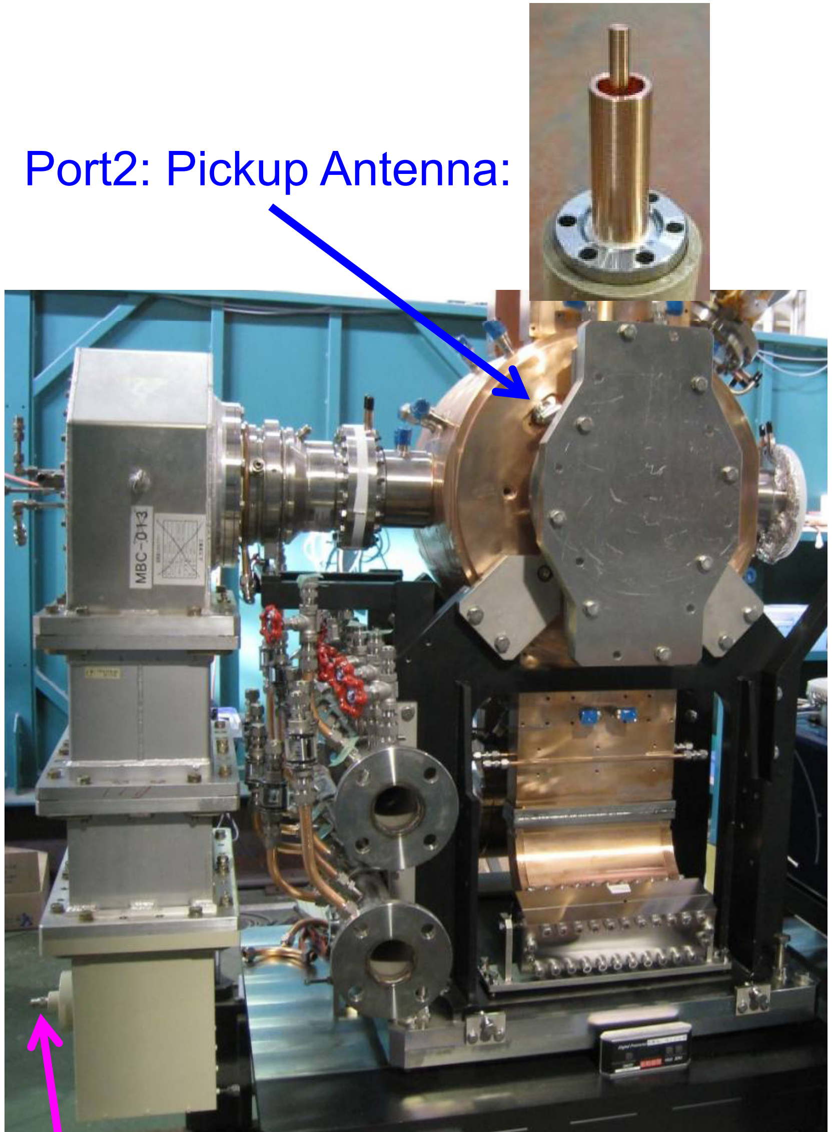
Appendix M (1/6)

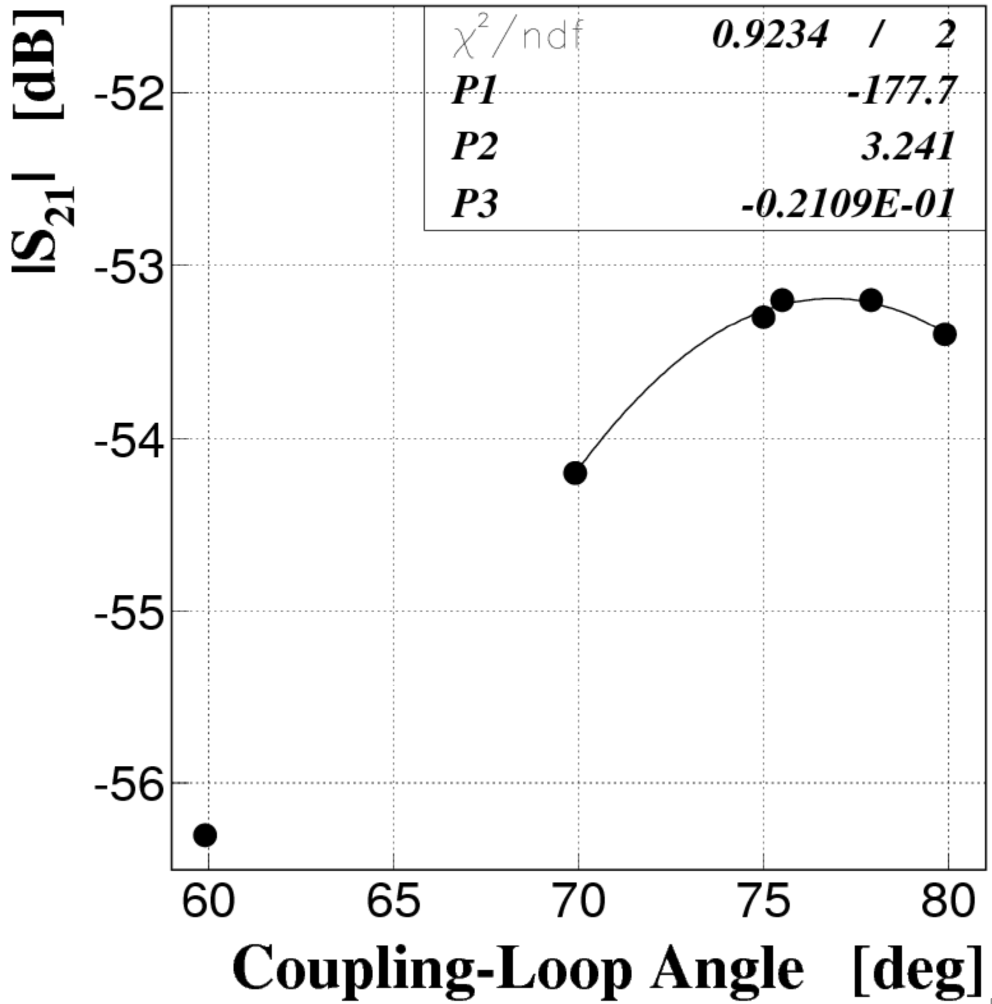
RF Power Fluctuation (1)

~~ Fast ~~



Appendix M (2/6)
High-Power Pickup Antenna





Appendix M (3/6)

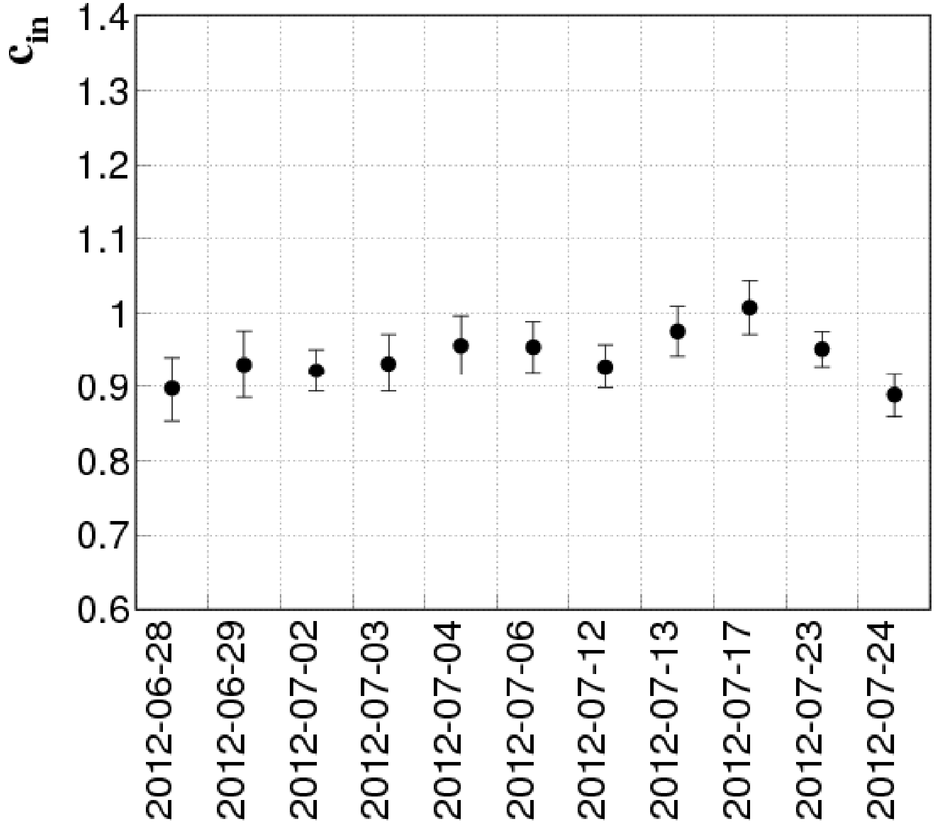
RF Power Fluctuation (2)

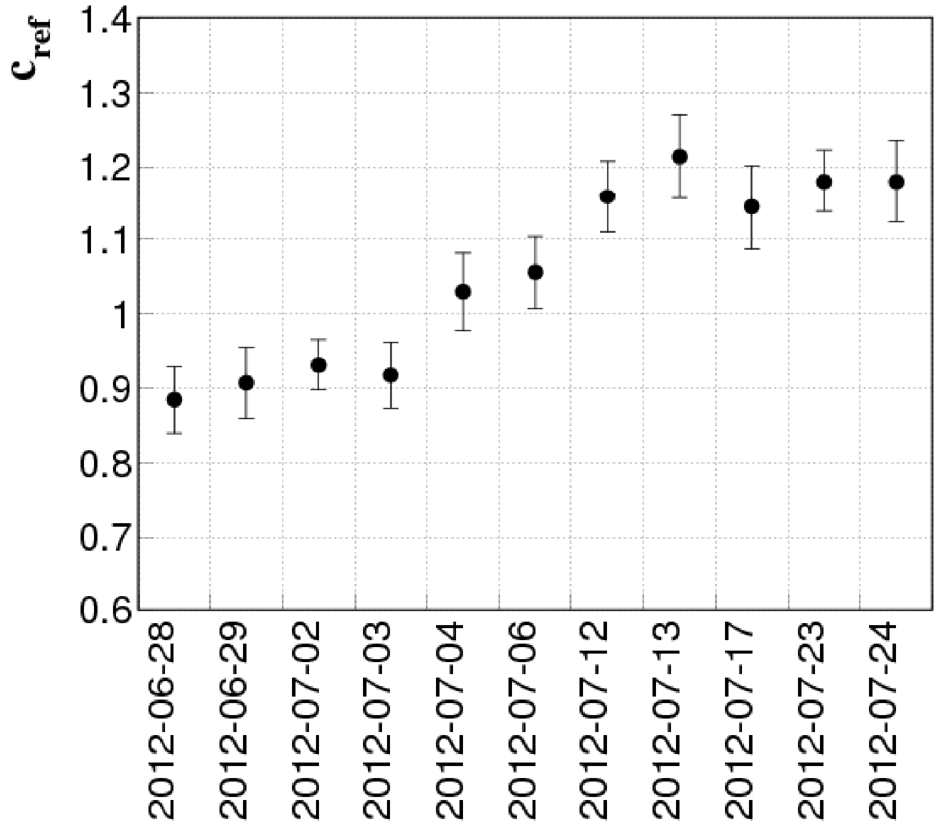
~~ Slow ~~

Recalibration Constants

$$P_{in}(corr) = c_{in} \times P_{in}(meas)$$
$$P_{refl}(corr) = c_{refl} \times P_{refl}(meas)$$

(Recalibrated for calorimetric powers and powers measured in the radiation shield)





Appendix M (4/6)

Measures toward the HPT of Cavity No.1

(I) We will measure P_{in} and P_{refl} with power sensors directly connected to the directional coupler in the radiation shield,
then transmit the values via the LAN to the D1 control room in digital.

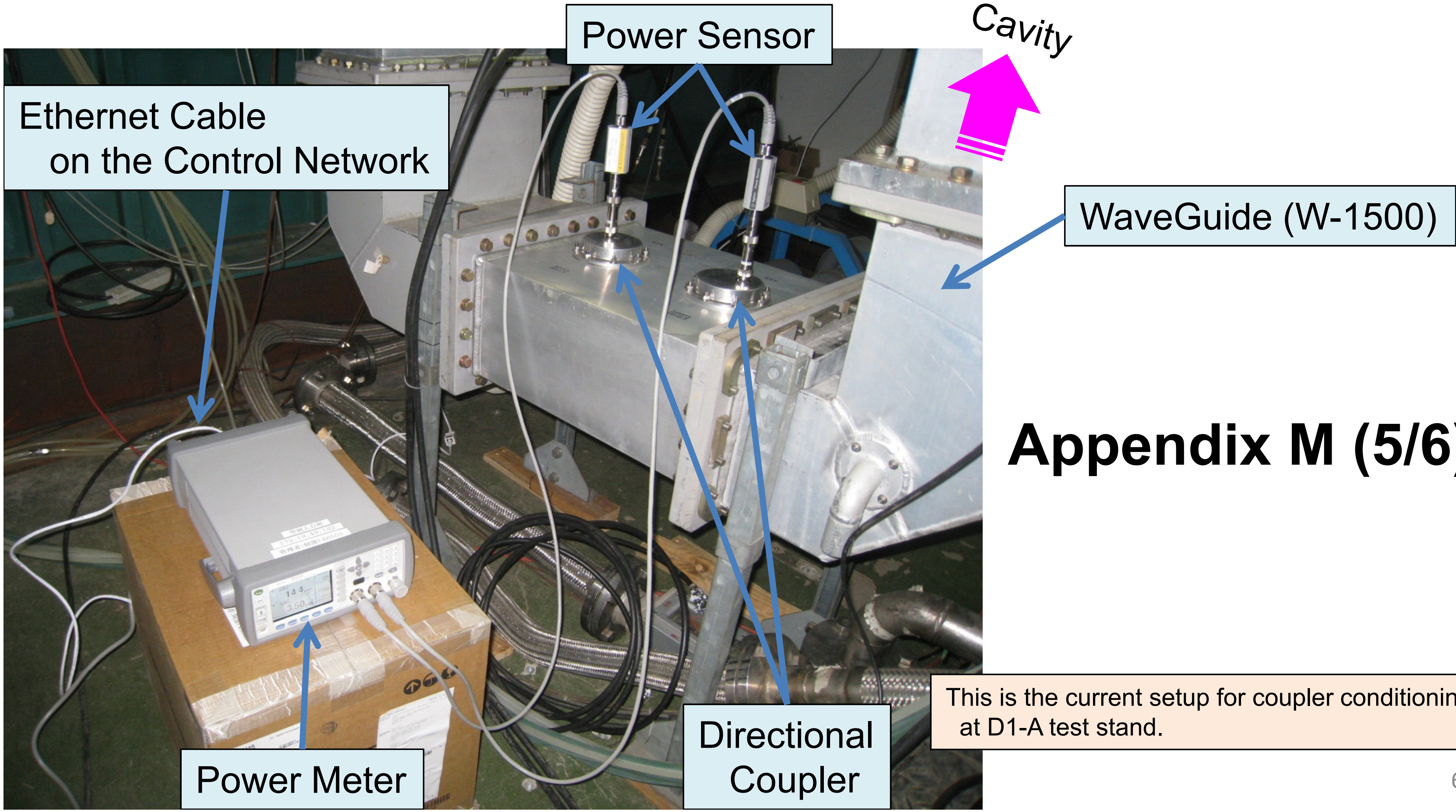
(II) We will lay new coaxial cables from the radiation shield to the D1 control room for the cavity pickup (used in the feedback) and reflection (used in the I/L).

We will perform V_c-holding endurance tests for Cavity No.1 with the improved environment.

(I) RF Power Measurements of P_{in} and P_{refl} close to the Cavity in the Radiation Shield of D1-A Test Stand

✓ The power sensors are directly connected to the directional coupler.

✓ The power meter is also put in the shield with its ethernet interface connected to the control network.



Appendix M (5/6)

This is the current setup for coupler conditioning at D1-A test stand.

Appendix M (6/6) (II) Coaxial Cables:
Radiation Shield <-> D1 Control Room

OLD

- ✓Laid ~30 years ago
- ✓~70m-long cables of 10D-WF-H50-S4
- ✓Total cable loss (meas.) : ~5.2dB (spec.: ~3.6dB)

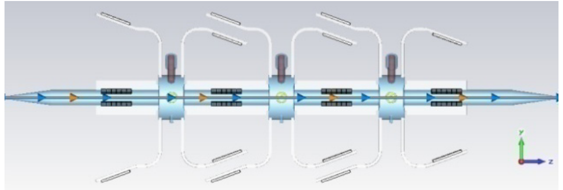
Under the ground
→ Low Accessibility

NEW

- ✓Laid in Jan., 2013
- ✓91m-long cables of 10D-WFLEX-FR
- ✓Total cable loss (meas.) : 4.4dB (spec.: 5.5dB)

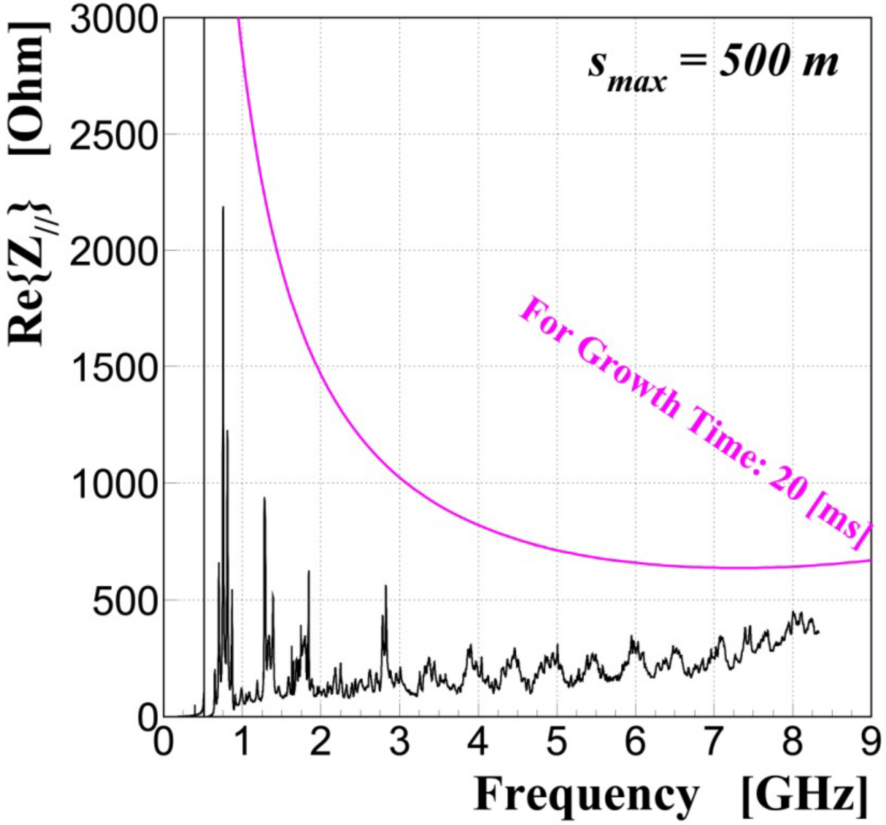
Above the ground
→ High Accessibility

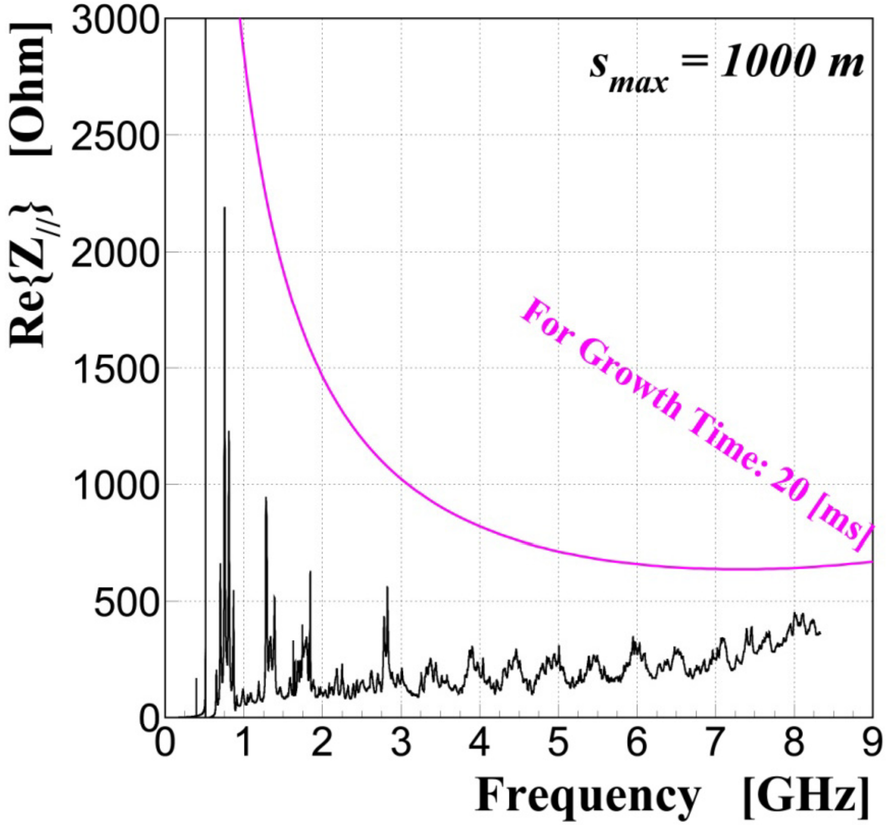
Appendix N (1/2): Longitudinal Impedance of the RF section: and CBI



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

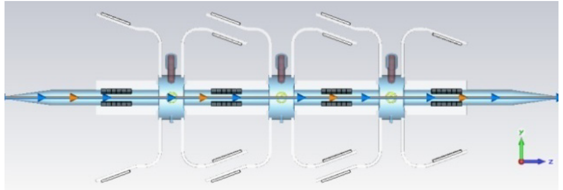
CBI threshold for Total Vc: 1.4MV





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

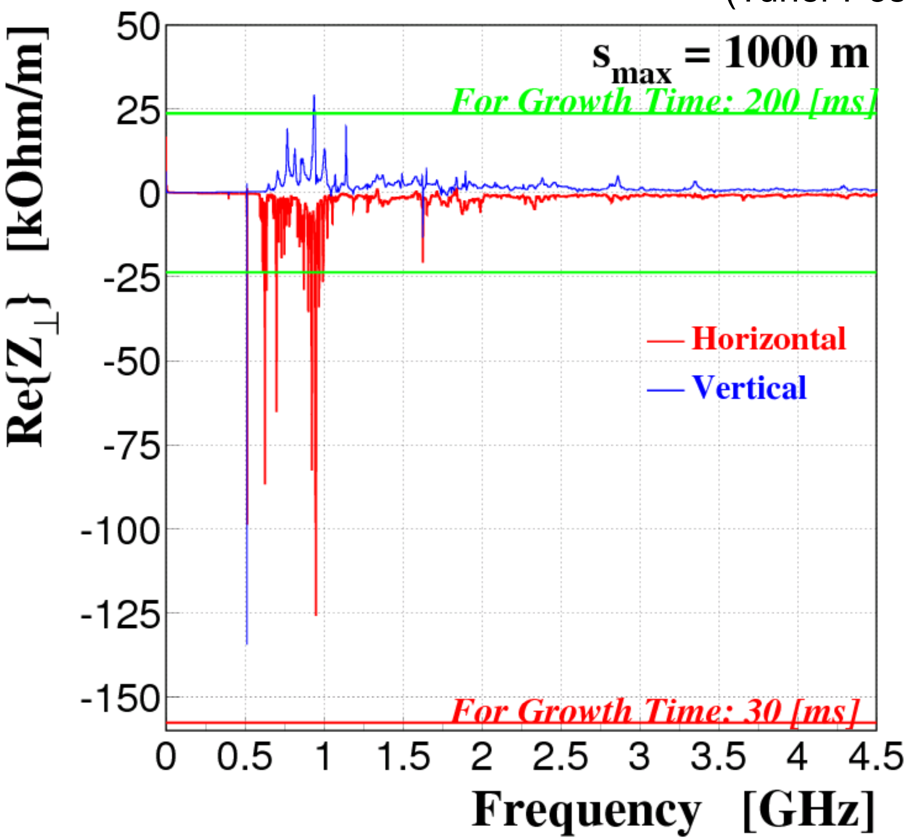
Appendix N (2/2) : Transverse Impedances of the RF section: and CBI

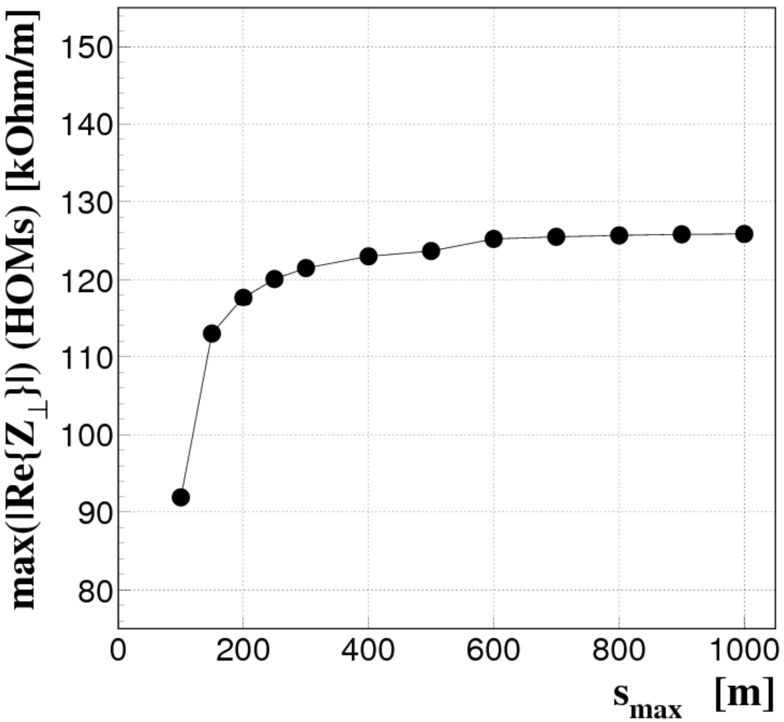


Estimated from Finite-Difference Time-Domain parallel computations of GdfidL with the PC cluster (256 cores & 512GB memory)

CBI threshold for Total V_c: 1.4MV

(Tuner Position: 30mm inside)





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

Appendix O

Typical cycle time of RF conditioning of one coupler includes:

1) Setup & low-level measurements : 2 days (net time: 8x2 = 16 hours),
2) Vacuum evacuation : 4-5 days (about 100 hours), and
3) RF conditioning up to P_{in}=800 kW : 15 days (weekdays only, net time: 8x15 = 120 hours),

so that the cycle time is 1) + 2) + 3) + weekends = ~1 month.

EOF