NORMAL-CONDUCTING RF CAVITIES FOR SUPERKEKB / MR & DR

MR: Main Ring
DR: Damping Ring

Tetsuo ABE

For SuperKEKB-RF / ARES-Cavity Group

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

The 21th KEKB Accelerator Review Committee Meeting

2016-06-13

Contents

- ■ RF cavities for the Main Rings (MRs) (“ARES”)
  - ● Introduction
  - ● Operational status in Phase 1
  - ● Two serious troubles

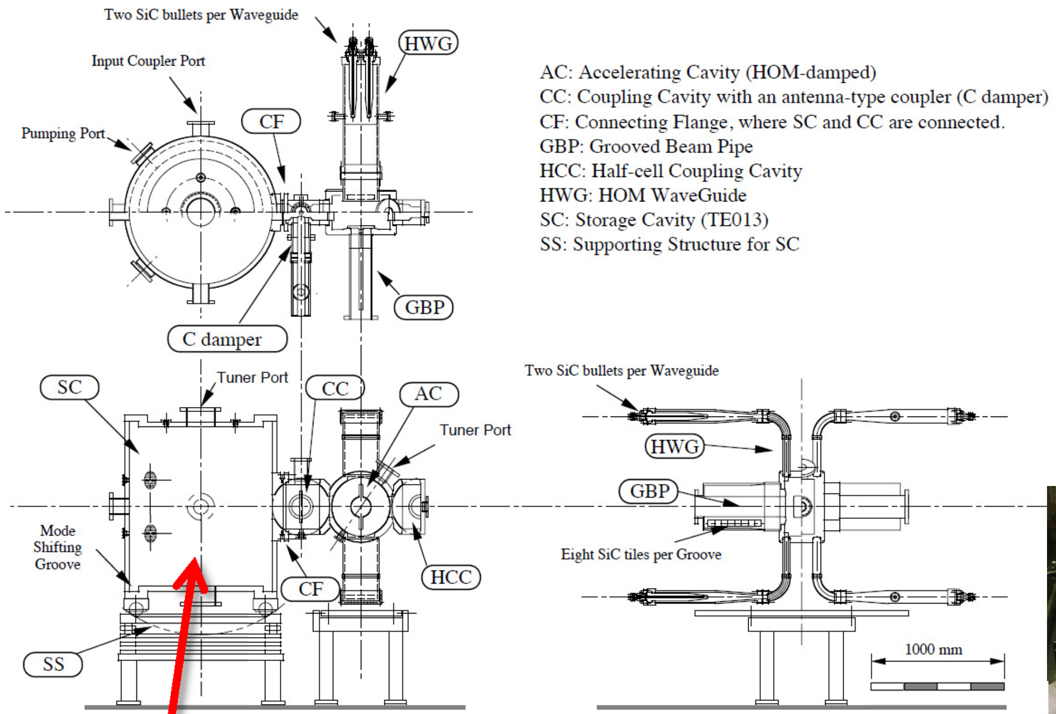
- ■ RF Cavities for the Damping Ring (DR) (“DR Cavity”)
  - ● Introduction
  - ● Results of the performance tests

ARES for the MRs

NC RF Cavity System for SuperKEKB (ARES)

(Accelerator Resonantly coupled with Energy Storage)

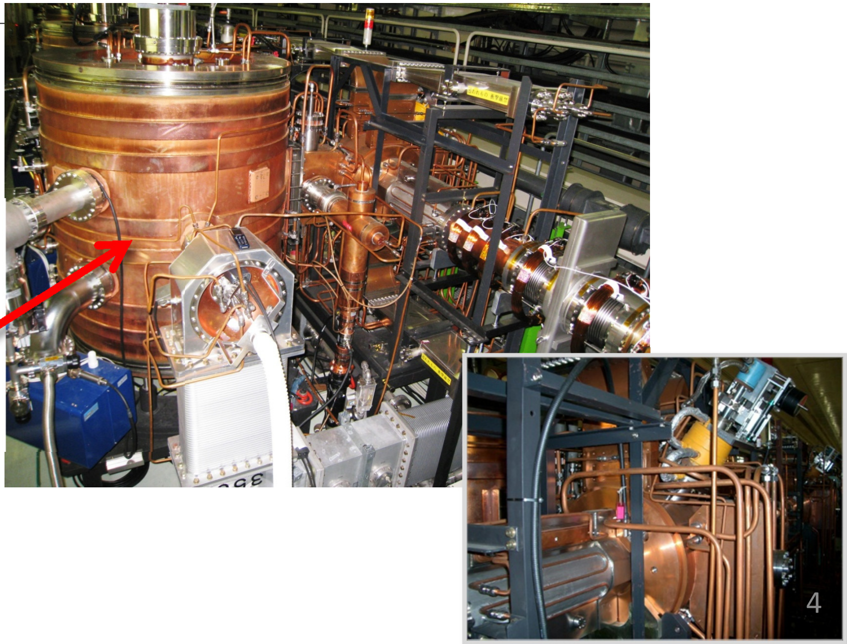
-- Three cavity system stabilized with the accelerating $\pi/2$ mode --



AC: Accelerating Cavity (HOM-damped)
CC: Coupling Cavity with an antenna-type coupler (C damper)
CF: Connecting Flange, where SC and CC are connected.
GBP: Grooved Beam Pipe
HCC: Half-cell Coupling Cavity
HWG: HOM WaveGuide
SC: Storage Cavity (TE013)
SS: Supporting Structure for SC

Figure 7.3: Top, front and side views of the ARES cavity.

- ■High-Purity Copper Resonators
- ■Gap length: 256 mm
- ■Three-cavity system (unique)
- ■R_{sh}/Q_0=15 Ohms
- ■Q_0=~$1.1\text{x}10^5$
- ■V_c=0.5 MV/cav
- ■P_c=150kW (60kW in AC, 90kW in SC)
- ■Loss factor: 0.48 V/pC (bunch length: 5 mm)
- ■E_{sp}/E_{acc} = 3.8
- ■(Cavity trip rate) < 1 /cav/3months
- ■U_s/U_a=9 (explained in the next page)



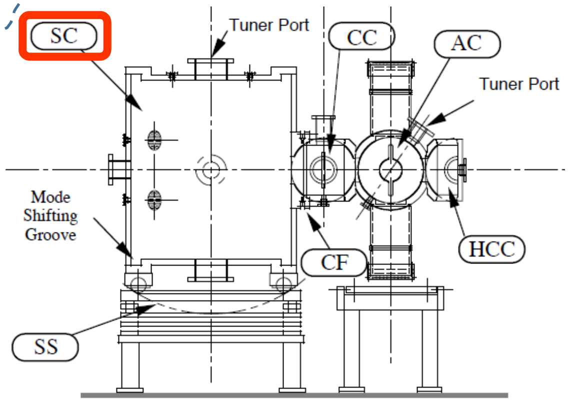
High energy (U_s) stored as a low-loss mode (TE_{013})

Three Main Characteristics of the ARES Cavity System

1. Large Storage Cavity (SC)

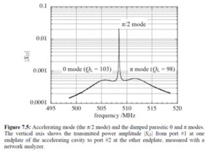
$$\text{Optimum detuning } \Delta f = -\frac{I\sin\phi_s}{2V_c}\frac{R_a}{Q_0}f_a = -\frac{P_b\tan\phi_s}{4\pi U}$$

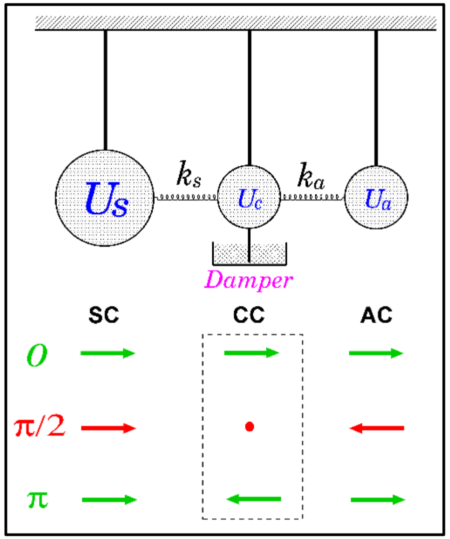
- Optimum detuning suppressed by $U_s/U_a(=9)$
  - ➢ SC acts as an electromagnetic flywheel.
  - ➢ $\Delta f_{\pi/2} = \Delta f_a / (1 + U_s/U_a) = \Delta f_a /10 < f_{rev}$
    - – Δf_a = -200kHz (KEKB design), -280kHz (SuperKEKB design)
    - – f_{rev} = 99kHz
  - ➢ Therefore, coupled bunch instabilities (CBIs) driven by the accelerating mode are suppressed (Appendix A).

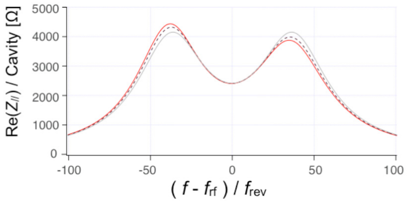


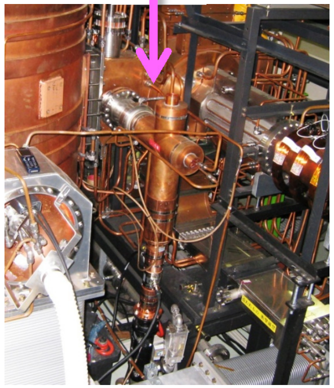
2. π/2-mode operation

- Stable against the detuning and deformation
- The stored-energy ratio: U_s/U_a changeable
  - ➢ $U_s/U_a = k_a^2/ k_s^2$
- Parasitic 0 and π modes
  - ➢ Damped selectively out of CC by an antenna-type damper ("Coupling-Cavity Damper")
  - ➢ Have a almost symmetric impedance w.r.t. f_{RF}









3. Hybrid HOM-Damped Structure

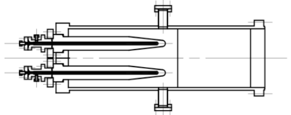
- Explained in the next page

SC : Storage Cavity
CC : Coupling Cavity
AC : Accelerating Cavity

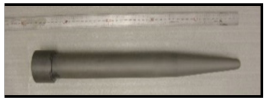
The ARES has

-- Two-types of HOM-Damped Structures. --

To suppress CBIs driven by HOMs (Appendix A)



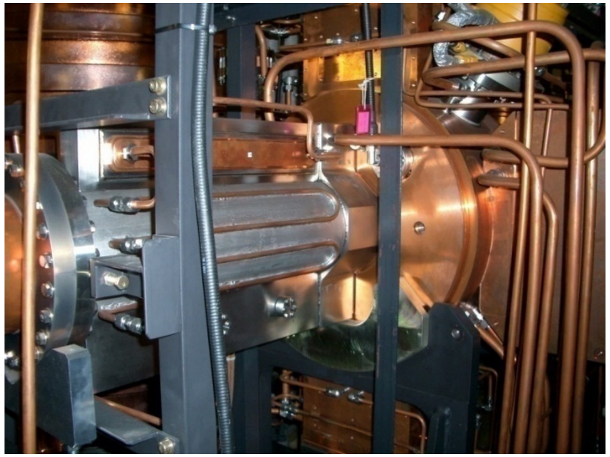
HOM absorber



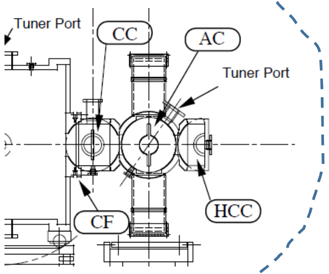
- ✓ Bullet-shaped SiC ceramics
- ✓ Directly water-cooled

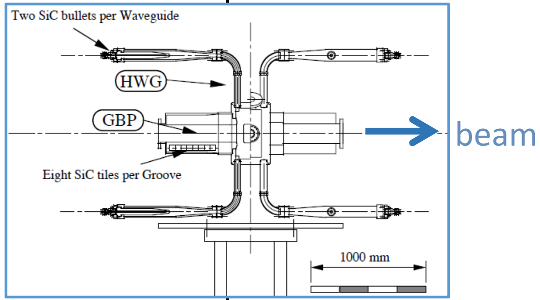
Type_1: HOM WG (HWG)

Type_2: Grooved Beam Pipe (GBP)

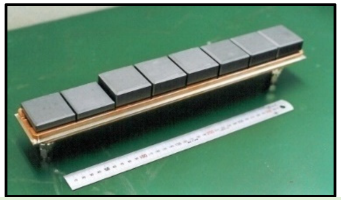


Note:
No HWG in the horizontal direction due to the (H)CC

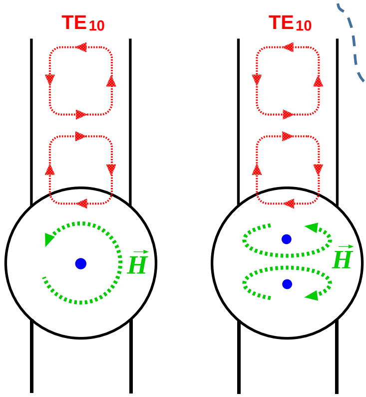




HOM absorber



- ✓SiC ceramics tiles
- ✓Indirectly water-cooled

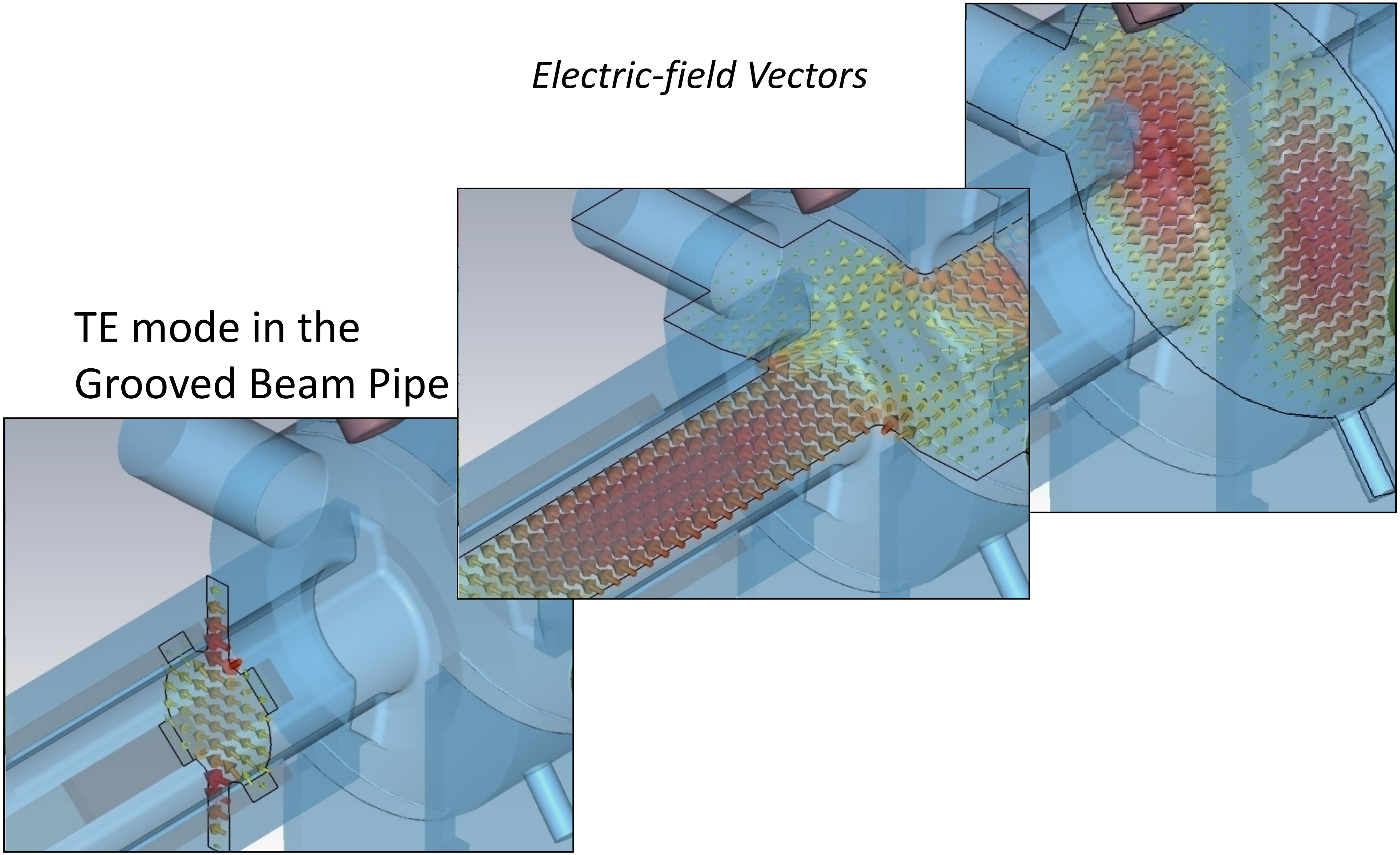


For damping
- ✓Monopole HOMs
- ✓Vertically-polarized dipole modes

For damping
- ✓Horizontally-polarized dipole modes

T. Kageyama, “Grooved Beam Pipe for Damping Dipole Modes in RF Cavities," KEK-PREPRINT- 91-133, 1991.

Type_2: Grooved Beam Pipe (GBP)



TM_{110}

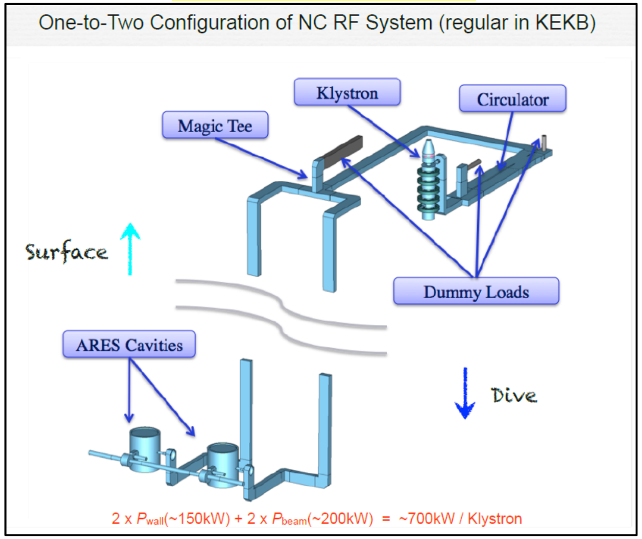
Electric-field Vectors

TE mode in the Grooved Beam Pipe

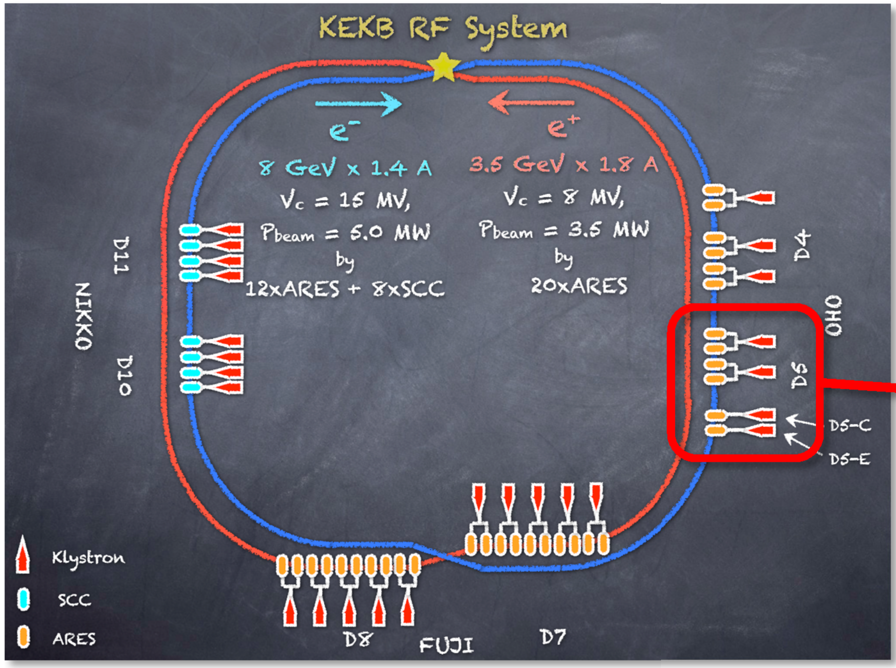
Upgrade of the ARES for SuperKEKB

(Selection)

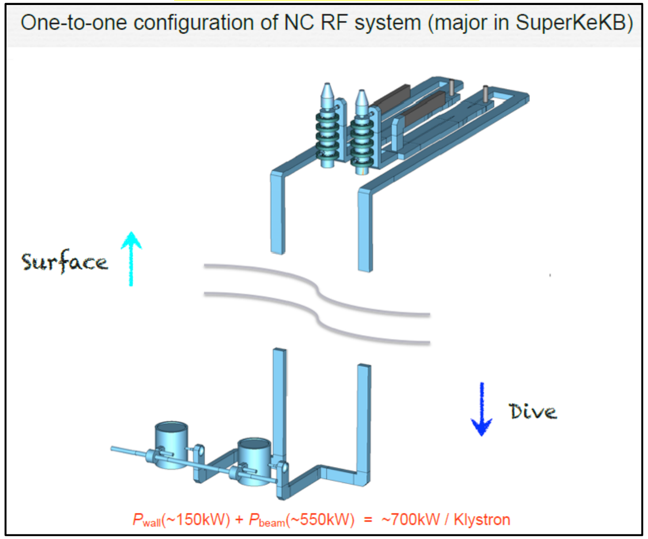
$N_{Klys}:N_{Cav}=1:2$



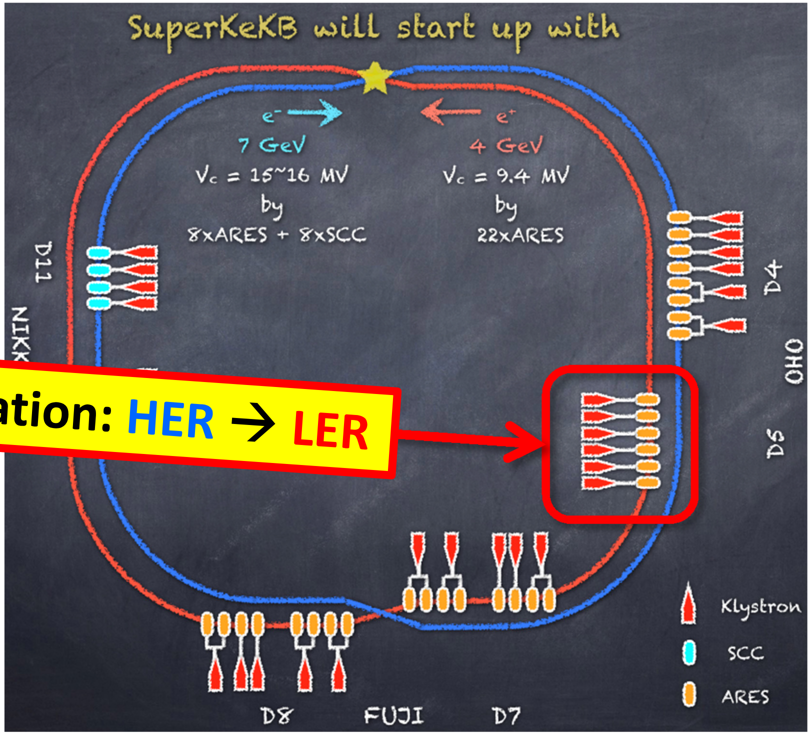
KEKB



$N_{Klys}:N_{Cav}=1:1$



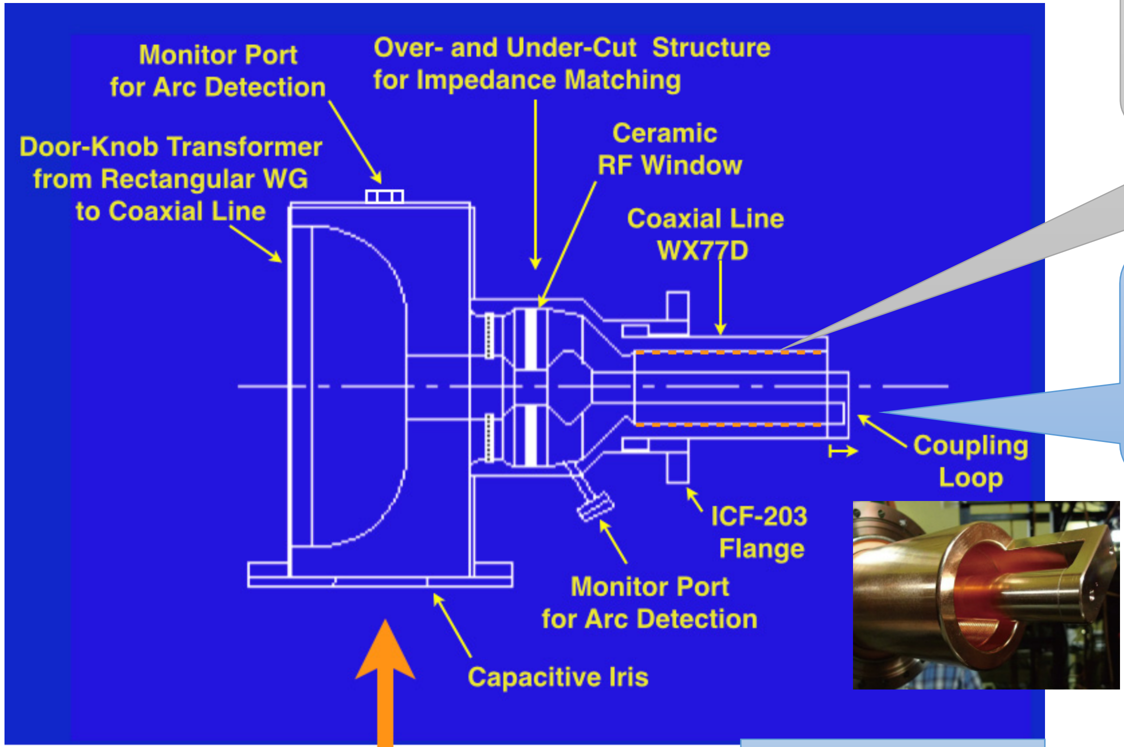
SuperKEKB Phase 1



Relocation: HER → LER

(Shown by T. Kageyama at KEKB Review 2011)

High-Power Input Coupler / Performance Upgrade



Input Coupler

1. **Fine grooving** inside the outer conductor of the coaxial line to suppress multipactoring discharge.

(Appendix B)

2. The coupling loop is extended to increase the input coupling factor (up to β = 6).

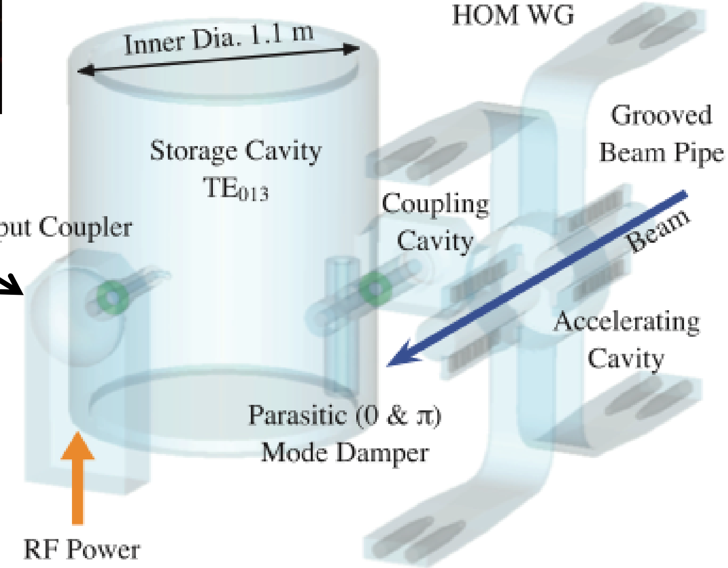
The optimum input coupling factor β_{opt} is given by $\beta_{\text{opt}} = 1 + P_{\text{beam}}/P_{\text{c}}$.

(T. Kageyama, et al., Proc. of PASJ, TUPS126, 2011)

Power Handling Capability (Spec.)

	P_{input}		P_{c}		P_{beam}
SuperKEKB	: 750 kW	=	150 kW	+	600 kW
KEKB	: 350 kW	=	150 kW	+	200 kW

P_{c} = 150 kW generating V_{c} = 0.5 MV per ARES cavity.



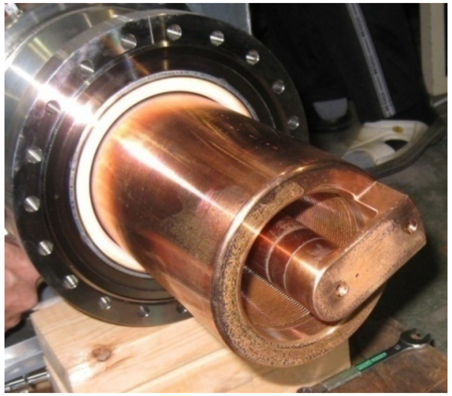
3D Transparent View of ARES Cavity System

T. Kageyama

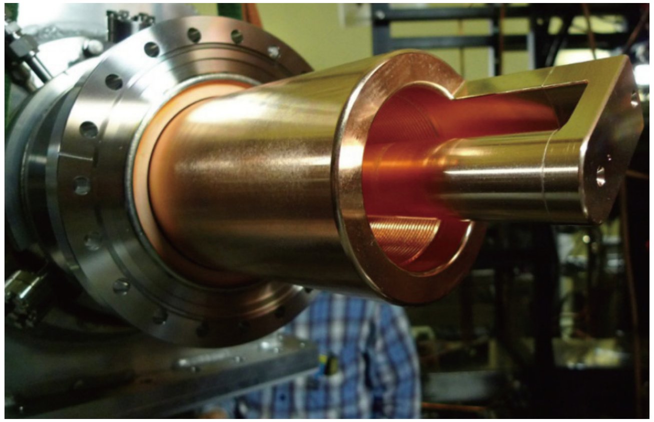
Upgraded Input Coupler

Increasing the Input Coupling Factor

Input couplers with increased input coupling (β_{max} = 5 $\rightarrow$ 6) needed for the stations with the N_{klys}:N_{cav}=1:1 configuration to accelerate beams with the design current.



Used at the KEKB/MRs

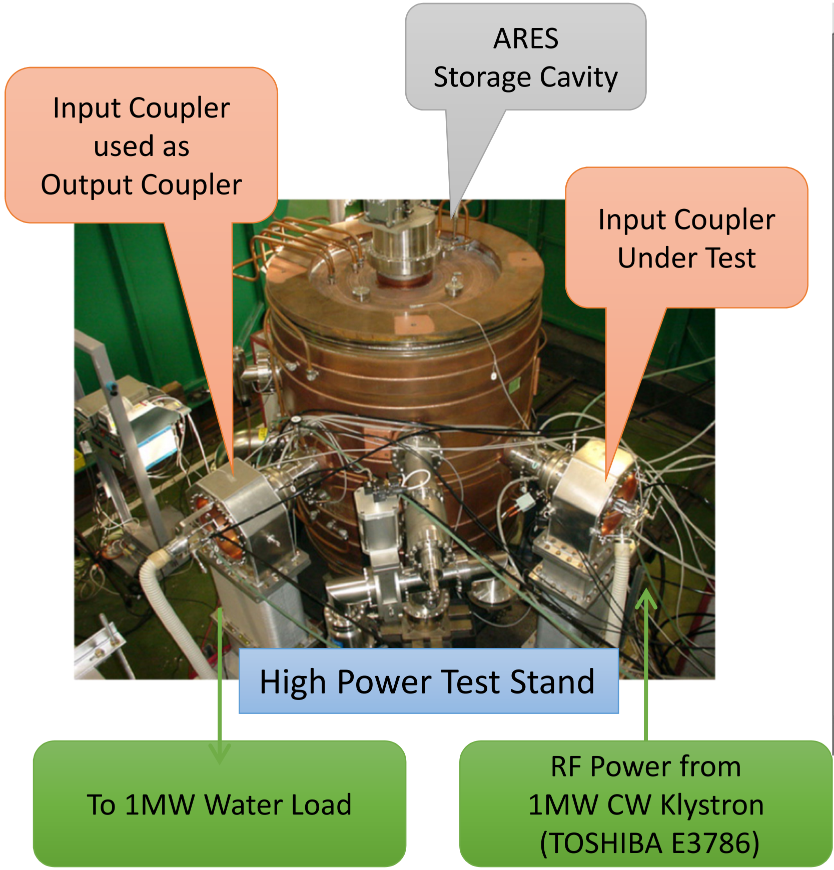


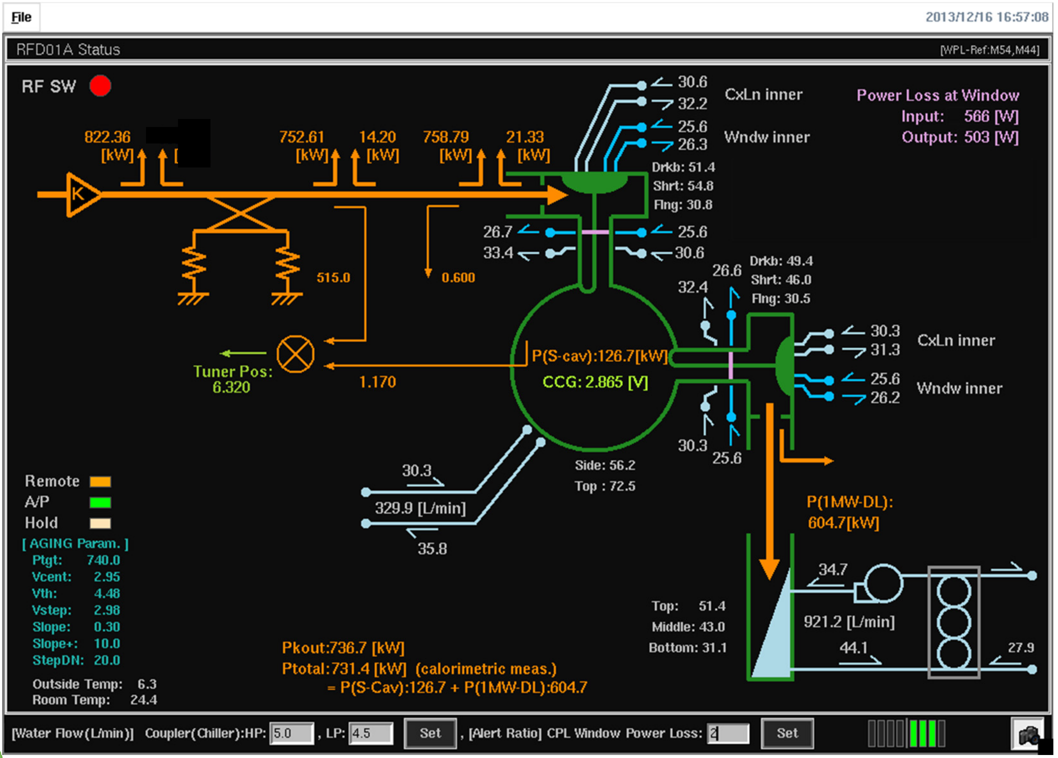
With increased input coupling for the SuperKEKB

The high-power performance was demonstrated both at the test stand and in the KEKB operation.

P_{input} = 740 kW (= P_c: 130kW + P_{beam}: 610 kW)

ARES Cavity System / Upgraded Input Coupler / Production & Processing





Power Loss at Window
Input: 566 [W]
Output: 503 [W]

[AGING Param.]
Ptgt: 740.0
Vcent: 2.95
Vth: 4.48
Vstep: 2.98
Slope: 0.30
Slope+: 10.0
StepDN: 20.0

Outside Temp: 6.3
Room Temp: 24.4

Pkout:736.7 [kW]
Ptotal:731.4 [kW] (calorimetric meas.)
= P(S-Cav):126.7 + P(1MW-DL):604.7

[Water Flow(L/min)] Coupler(Chiller):HP: 5.0 , LP: 4.5 , [Alert Ratio] CPL Window Power Loss: 2

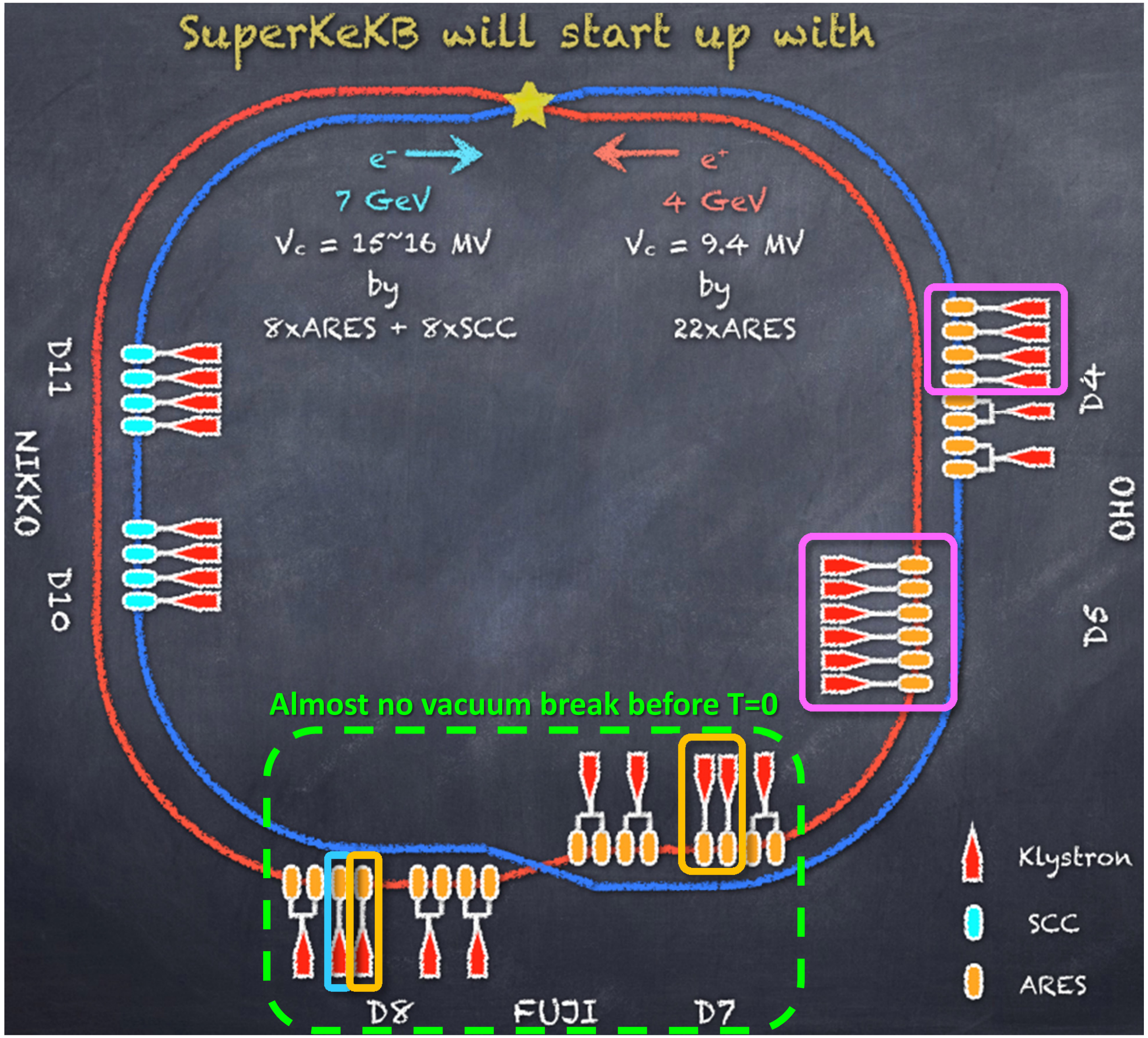
Snapshot of Status Monitor for RF Processing

(Photo and diagram by T. Kageyama)

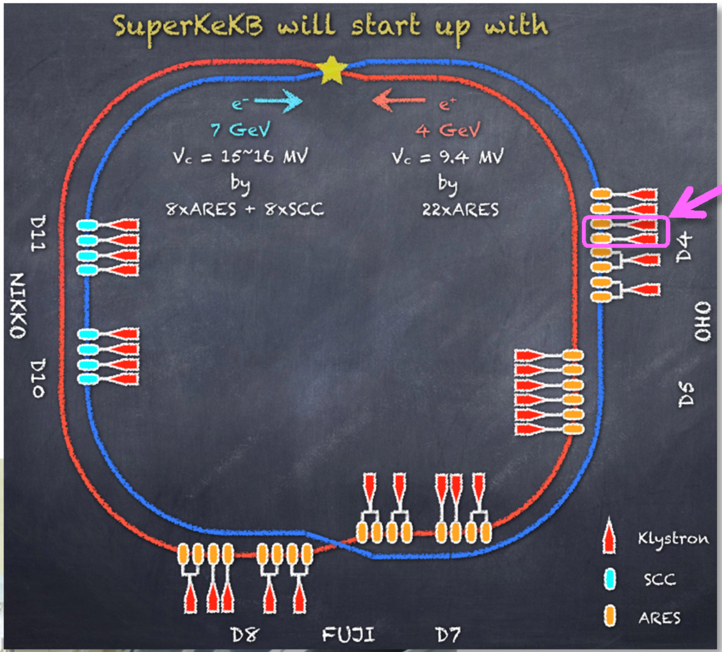
- ✓ For the first two production couplers, stable power feeding was demonstrated
  - ➢ Up to P_{input} = 800 kW (= 750 kW + 50 kW) at the test stand.
- ✓ So far, 13 couplers have been processed up to 750-800 kW.
  - ➢ The same shown in the last report
- ✓ As of June, 2016, 5 couplers are waiting for high power test.
  - ➢ P_{input} = 850 kW (= 750 kW + 100 kW) to be demonstrated (after Phase 1)

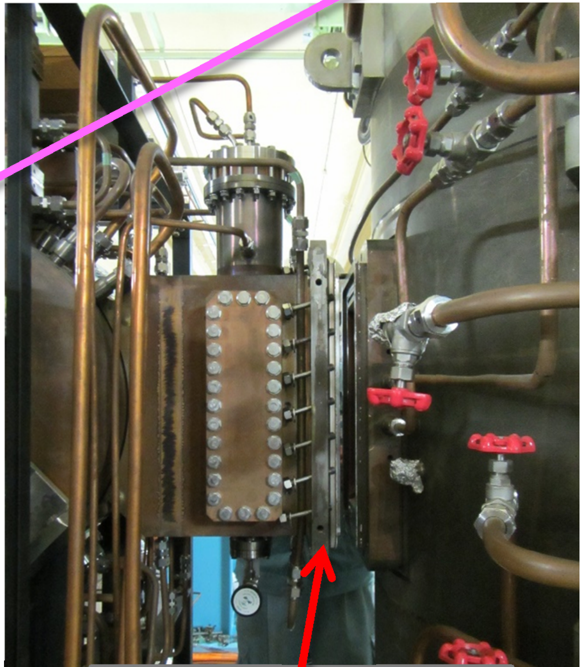
(Max. RF power stably supplied by the high power source)

- ✓ All the Input couplers for N_{Klys}:N_{Cav}=1:1 stations in OHO D4&D5 have been replaced by upgraded couplers.
- ✓ One coupler has been replaced by an upgraded one for one of the FUJI D8 stations.
- ✓ For other N_{Klys}:N_{Cav}=1:1 stations, to be replaced before starting Phase 2.



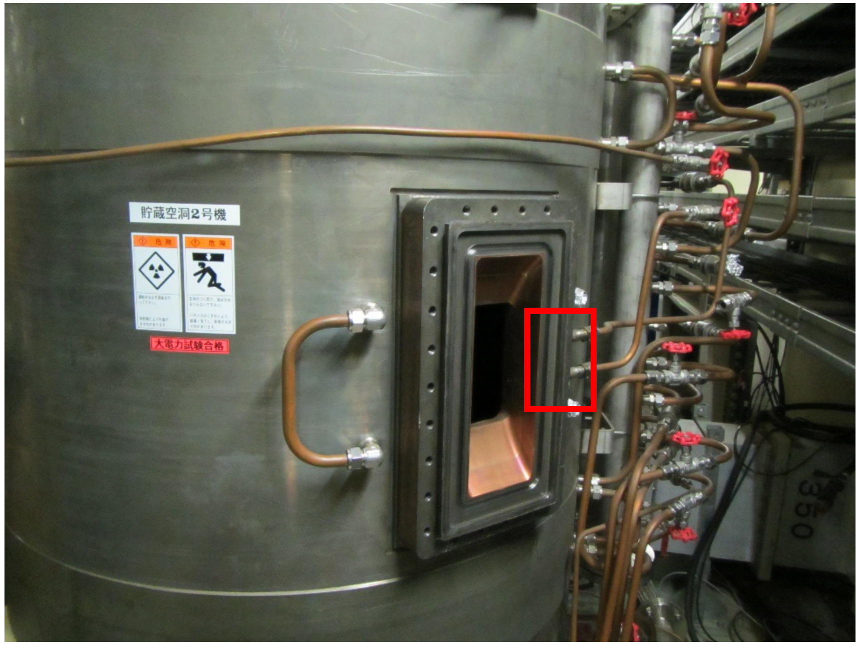
Two ARES Cavities Newly Installed in OHO D4-E,F



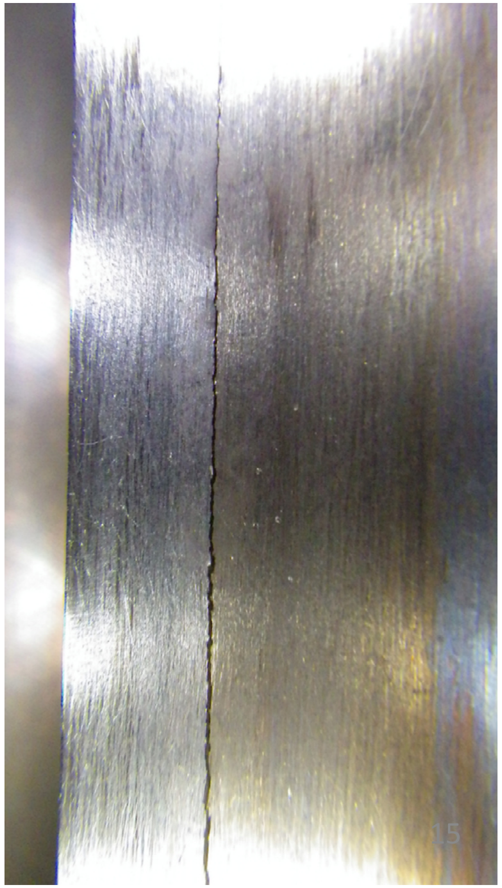


Pressure-sensitive paper → to check the RF contact between CC and SC

Crack found on the welding lip of the D4-F Cavity



→ Vacuum sealing impossible
with lip welding

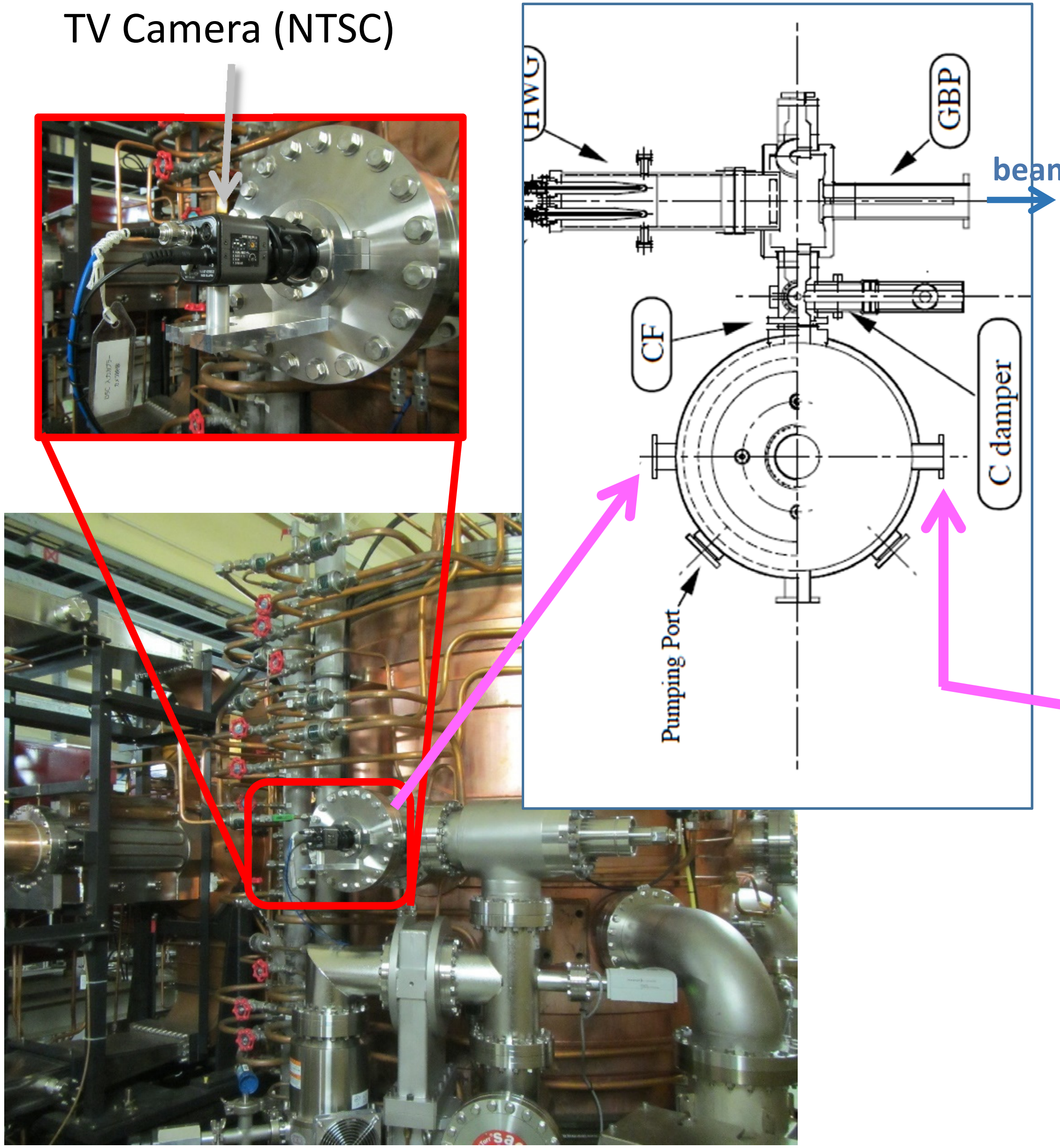


Sealed with a O-ring (non-metal)

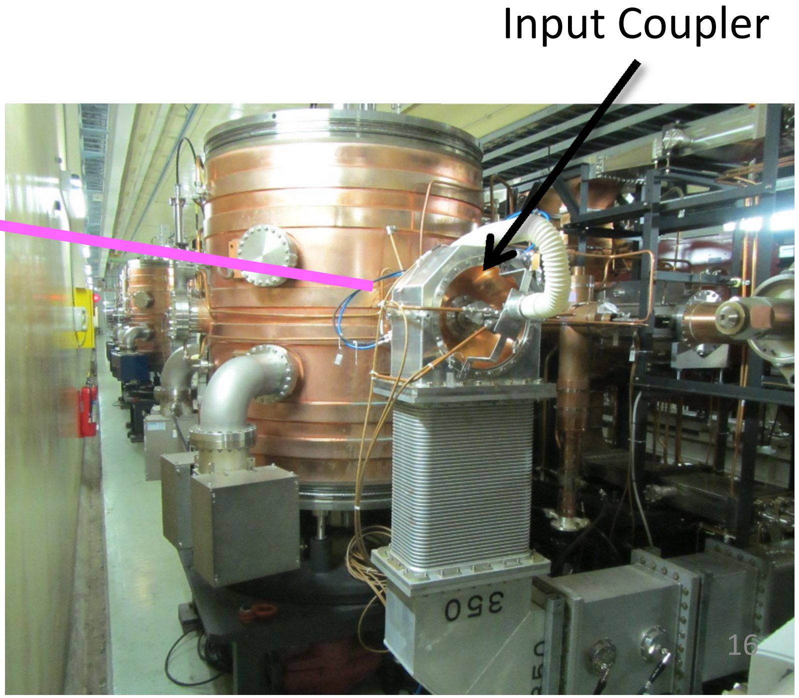
→The vacuum pressure in this cavity is one order of magnitude higher than others.

To be fixed after Phase 1

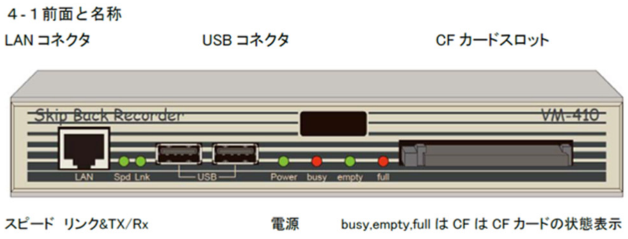
Monitoring ALL the Cavities with TV Cameras



- ✓ TV camera attached in the opposite side of the input coupler
- ✓ During the KEKB operation, only some cavities were monitored.
- ✓ For SuperKEKB, all the cavities are to be monitored and recorded.



Skip Back Recorder



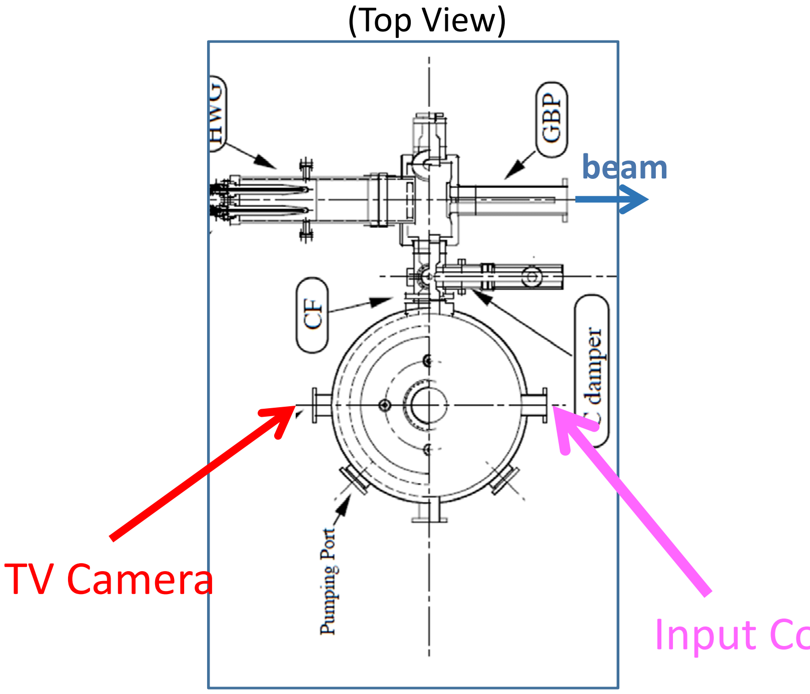
- ✓OS: Linux
- ✓**Input video: NTSC**
- ✓**Trigger: RF switch "ON → OFF"**

All of the cavity-breakdown events recorded *automatically*
(5 seconds before, until 1 second after this trigger)

Exhaustive observation

Example of the Recorded Videos

- ✓ D5-B cavity
- ✓ Vacuum interlock activated with RF input power of 60 kW during the RF conditioning.



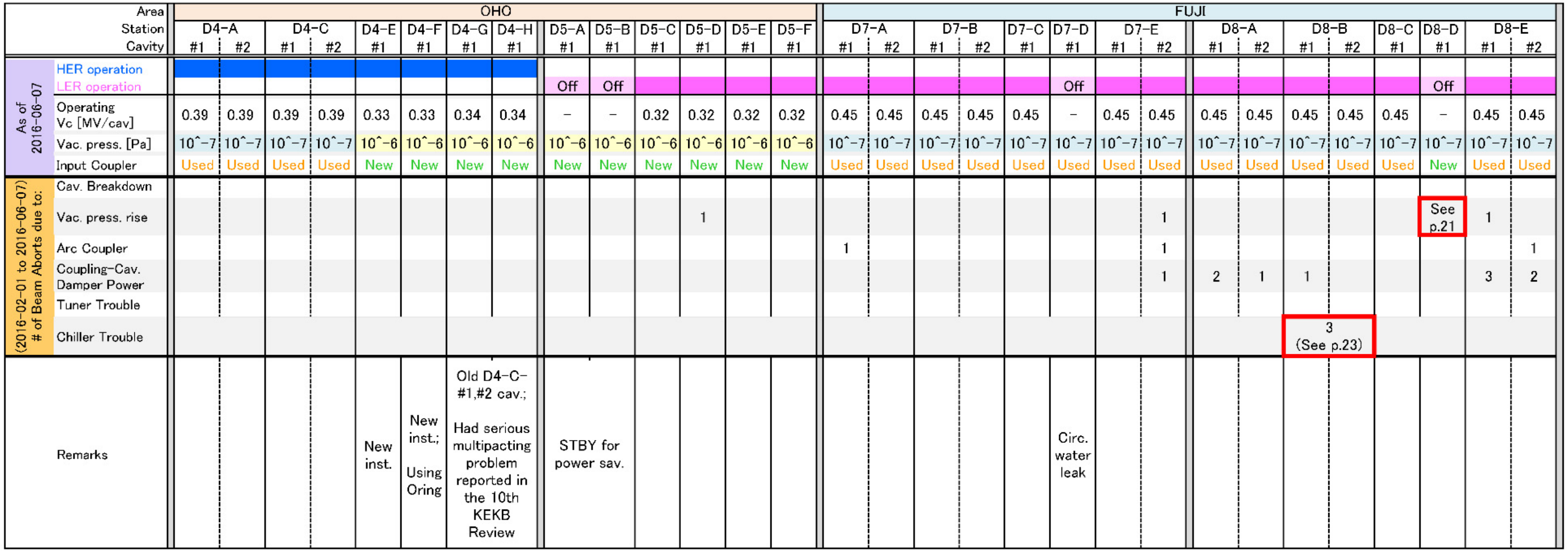
Useful for isolating problems caused by input couplers (Note: Input couplers are removable.)

Operational Status of the ARES in Phase1

Operation Summary in Phase 1

Successful operation except for

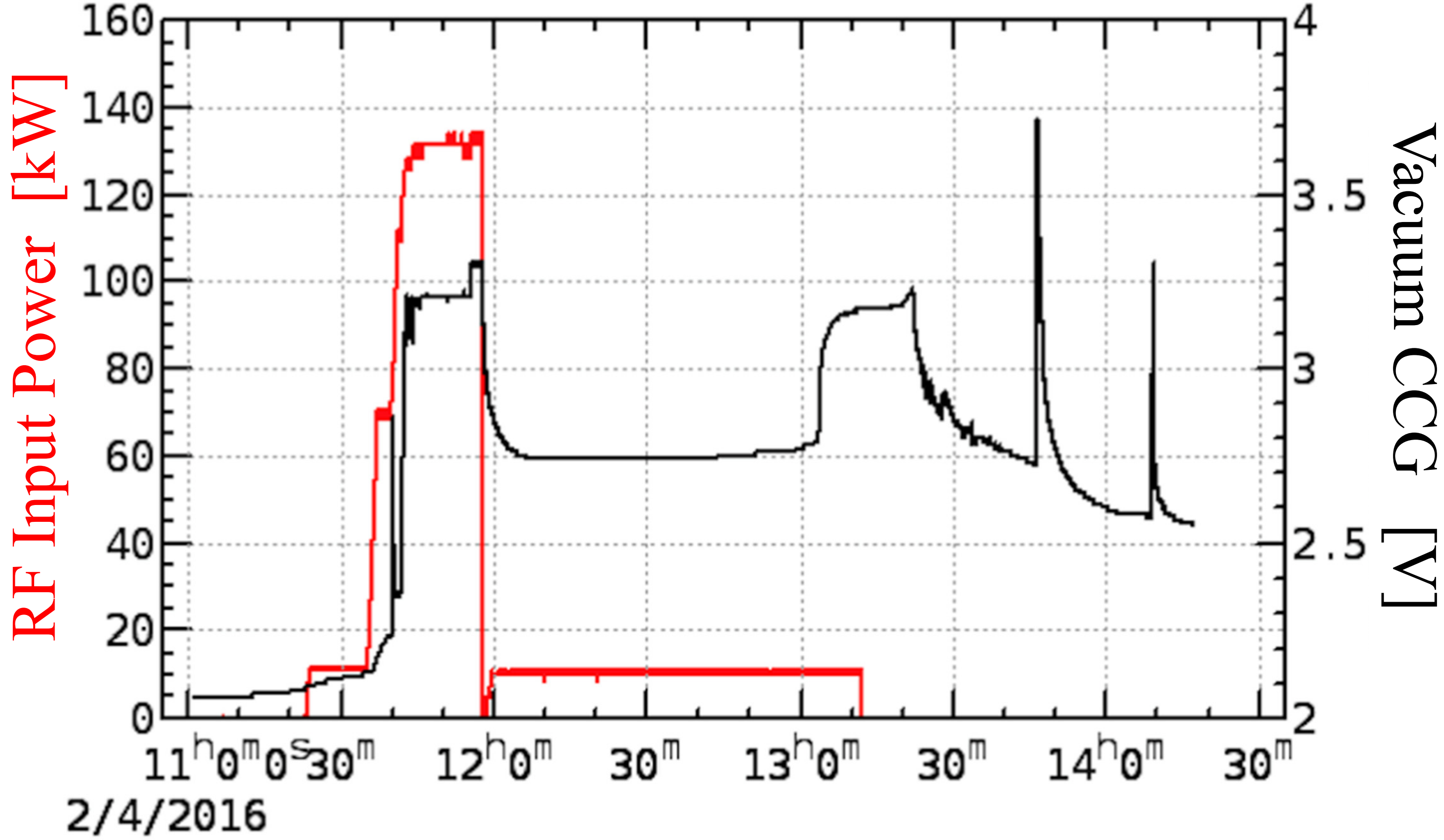
Two serious troubles



	Area	OHO													
	Station	D4-A		D4-C		D4-E	D4-F	D4-G	D4-H	D5-A	D5-B	D5-C	D5-D	D5-E	D5-F
	Cavity	#1	#2	#1	#2	#1	#1	#1	#1	#1	#1	#1	#1	#1	#1
As of 2016-06-07	HER operation	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦						
	LER operation									Off	Off	🟪	🟪	🟪	🟪
	Operating Vc [MV/cav]	0.39	0.39	0.39	0.39	0.33	0.33	0.34	0.34	–	–	0.32	0.32	0.32	0.32
	Vac. press. [Pa]	10^-7	10^-7	10^-7	10^-7	10^-6	10^-6	10^-6	10^-6	10^-6	10^-6	10^-6	10^-6	10^-6	10^-6
	Input Coupler	Used	Used	Used	Used	New	New	New	New	New	New	New	New	New	New
(2016-02-01 to 2016-06-07) # of Beam Aborts due to:	Cav. Breakdown														
	Vac. press. rise												1		
	Arc Coupler														
	Coupling-Cav. Damper Power														
	Tuner Trouble														
	Chiller Trouble														
Remarks						New inst.	New inst.; Using Oring	Old D4-C-#1,#2 cav.; Had serious multipacting problem reported in the 10th KEKB Review		STBY for power sav.					

	Area	FUJI															
	Station	D7-A		D7-B		D7-C	D7-D	D7-E		D8-A		D8-B		D8-C	D8-D	D8-E	
	Cavity	#1	#2	#1	#2	#1	#1	#1	#2	#1	#2	#1	#2	#1	#1	#1	#2
As of 2016-06-07	HER operation																
	LER operation	🟪	🟪	🟪	🟪	🟪	Off	🟪	🟪	🟪	🟪	🟪	🟪	🟪	Off	🟪	🟪
	Operating Vc [MV/cav]	0.45	0.45	0.45	0.45	0.45	–	0.45	0.45	0.45	0.45	0.45	0.45	0.45	–	0.45	0.45
	Vac. press. [Pa]	10^-7	10^-7	10^-7	10^-7	10^-7	10^-7	10^-7	10^-7	10^-7	10^-7	10^-7	10^-7	10^-7	10^-7	10^-7	10^-7
	Input Coupler	Used	Used	Used	Used	Used	Used	Used	Used	Used	Used	Used	Used	Used	New	Used	Used
(2016-02-01 to 2016-06-07) # of Beam Aborts due to:	Cav. Breakdown																
	Vac. press. rise								1						See p.21	1	
	Arc Coupler	1							1								1
	Coupling-Cav. Damper Power								1	2	1	1				3	2
	Tuner Trouble																
	Chiller Trouble											3 (See p.23)					
Remarks							Circ. water leak										

Vacuum Trouble of the D8-D Cavity



Vacuum-pressure behavior for the ARES D8-D cavity, plotted together with the RF input power.

(T. Kageyama)

Vacuum Trouble of the D8-D Cavity

- The ARES cavity D8-D at the FUJI RF section for LER could not be operated due to abnormal vacuum pressure rise, sometimes observed other than during the RF operation.

- The gas source may be some subsurface defects, possibly between the copper plating layer and the carbon steel structure of the storage cavity.

- Now detuned → out of operation

<Notes>
✓ Successful operation at KEKB
✓ No vacuum break since KEKB

- Plans toward Phase 2:
  - Plan A: hopefully locate and remove the defects in situ, followed by high power testing for confirmation.
  - Plan B: replace this ARES cavity by a spare one.

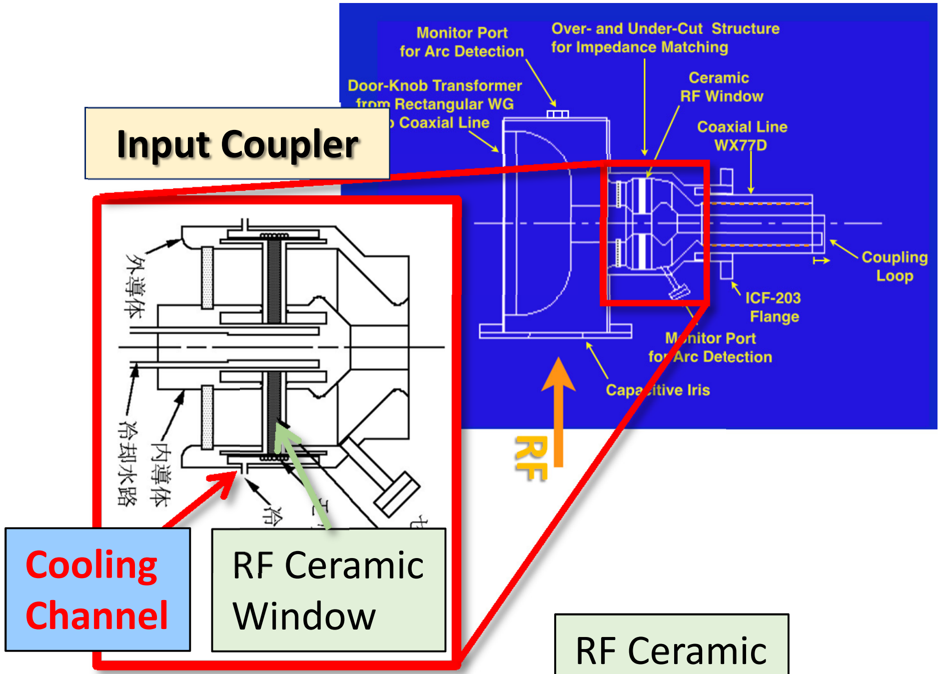
(Original version by T. Kageyama)

Other Serious Trouble: *Chillers* for RF Windows

- ✓ Object to be cooled: RF Ceramic Windows
- ✓ Coolant: water + antirust(5%), pH: 6 to 7 %
- ✓ Coolant pressure: 0.2 to 0.3 MPa (< 0.4 MPa)
- ✓ Put in the sub-tunnel (not seen from the beam)
- ✓ No trouble related to the chillers used at KEKB

We have replaced all the 15 chillers used at KEKB for a long time.

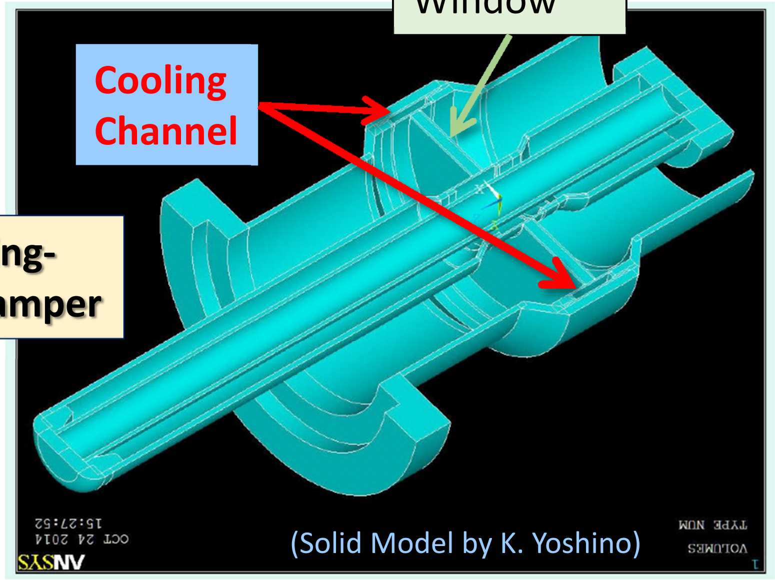
(Further details on the chillers are described in Appendix C.)



Input Coupler

Cooling Channel

RF Ceramic Window



RF Ceramic Window

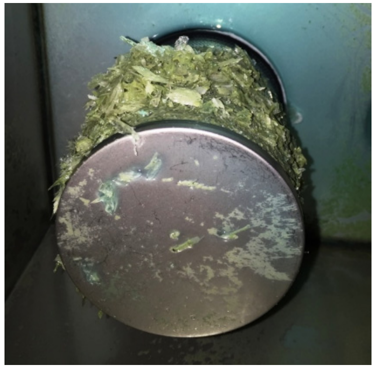
Cooling Channel

Coupling-Cavity Damper

(Solid Model by K. Yoshino)

During Phase 1 Operation

Example of the filters with small amount of precipitates→

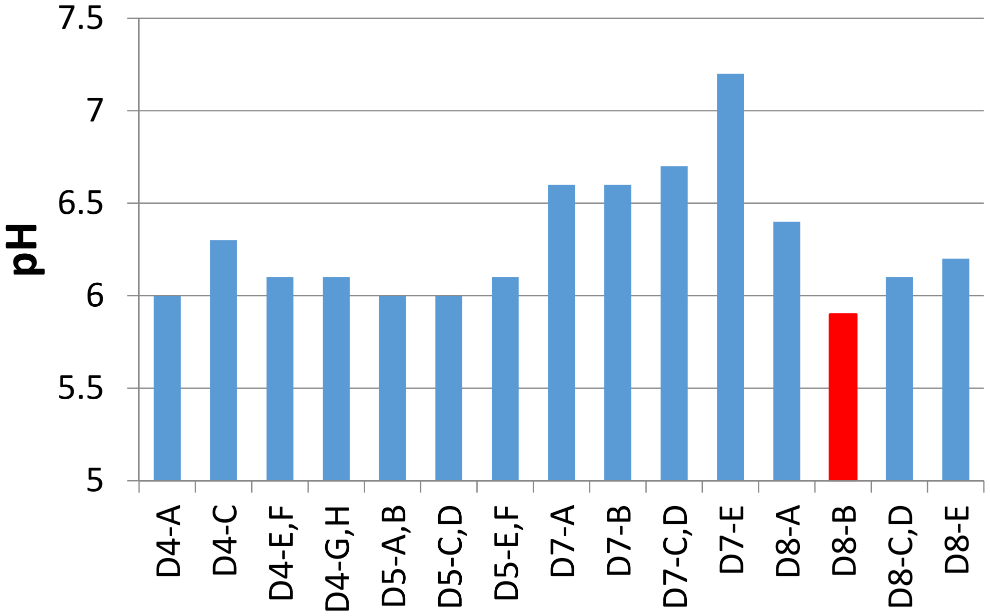


Example of the filters with
huge amount of precipitates

- We observed precipitates growing in the coolant.
  - Especially in the FUJI D8 stations
  - Triggered LER beam aborts at **D8-B** (3 times)
    - The flow rate of the coolant decreased with precipitates.
  - Principal component : para tertiary butyl benzoic acid
    - Widely used as antirust
- Temporary treatment
  - Cleaning the filers
  - Replacement of the coolant by new one
- Measures toward Phase 2
  - Understanding of the chemical process of the precipitate creation (on-going)
    - Including basic test (beaker test)
  - Sealing the reservoir tanks against the (activated) air in the tunnel
    - From the basic test (beaker test) with H_2O+antirust(5%)+Cu+Mo
      - Precipitates created in the beaker open to the air
      - No precipitates created in the beaker sealed against the air
  - Monitoring of pH of the coolant during operation

pH and Water Solubility

pH of the coolant in each chiller (measured on June 2, 2016)



(K. Yoshino)

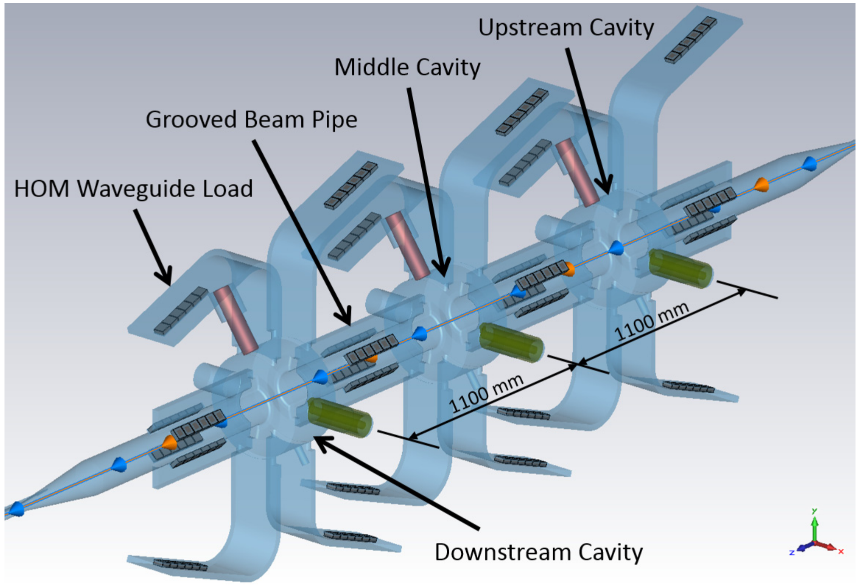
Water solubility of the antirust

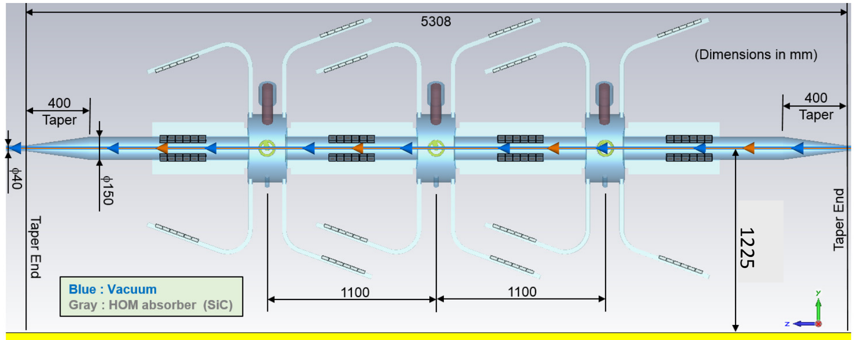
- 12600 mg/L at 20degC (pH7)
- 47.1 mg/L at 20degC (pH4.3)

RF Cavities for the DR
(“DR Cavities”)

NC RF Accelerating Structure for the DR

The blue, gray, green, and magenta regions indicate a vacuum, HOM absorbers, coaxial lines of input couplers, and plungers of movable tuners, respectively.
The colored arrows indicate the direction of the positron beam.





- RF operating frequency: 508.9 MHz
  - Same as that of the MRs
- Based on the HOM-damped structure of the successful ARES cavity system
- Three cavities at max. to be installed in a limited space originally designed for one cavity (3.8 m in the beam direction, excluding the taper sections)
  - Total V_c = 2.4 MV at max. with 0.8 MV/cavity
- Apart from the CC and SC of the ARES, this DR cavity has the following space saving features that are not included in the ARES:
  - The HOM absorbers are all compact tile-shaped SiC ceramics;
  - The neighboring cavities share a GBP in-between; and
  - The cavity is connected directly to GBPs with lip welding for vacuum sealing at the outer periphery ("weld ring gasket").
- "Multi Single Cell" structure
  - Coupling of the Accel. mode and HOMs among the cavities significantly suppressed by the HOM absorbers on the GBPs
  - One big mechanical structure with solid connections of the components
- Loss factor of this structure: 2.3 V/pC (bunch length: 6.0mm)
- Vacuum pumps directly attached to each cavity
- In the DR tunnel, we will assemble the cavities separating them with GBPs similar to LEGO blocks.

NC : Normal-Conducting
HOM: Higher Order Mode
MR: Main Ring
DR : Damping Ring
CC: Coupling Cavity
SC: Storage Cavity
GBP: Grooved Beam Pipe

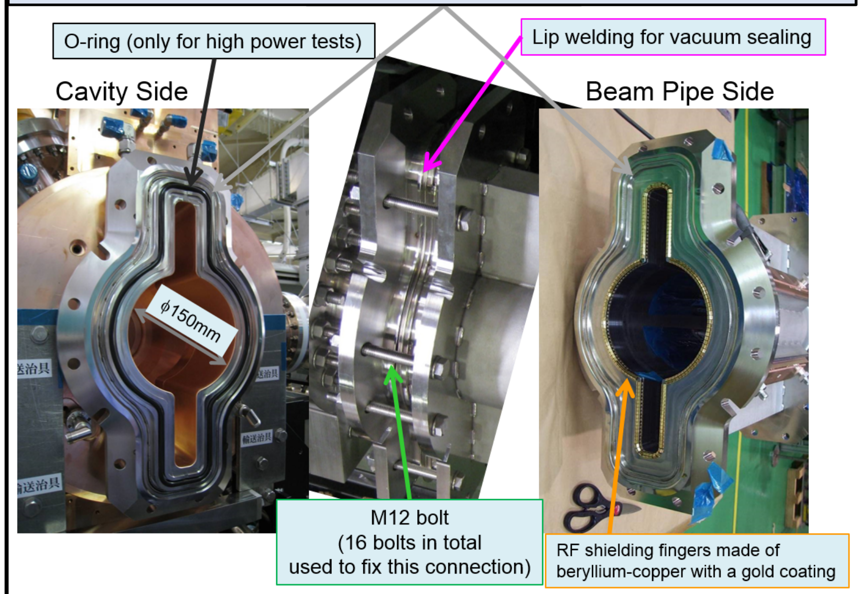
Main Characteristics of the DR Cavity

1. 3 cavities (max) in a limited space (3.8 m) originally designed for one cavity
    - Required Total V_c = 0.26 MV (until 2010) → 1.4 MV (from 2011)
    - Three cavities with 0.7 MV/cav (➔ tot. 2.1 MV) in operation
    - Up-down separation of the HOM waveguides
    - The neighboring cavities share a Grooved Beam Pipe in-between.
    - The cavity is connected directly to Grooved Beam Pipes with lip welding for vacuum sealing at the outer periphery (weld ring gasket)
    - Compact HOM absorbers (SiC tiles)

2. Complete HOM-damped structure
    - Based on the ARES cavity system
    - CBIs suppressed (Appendix D)

Components of the RF Structure except for the cavity

Solid connection between the cavity and GBP



O-ring (only for high power tests)

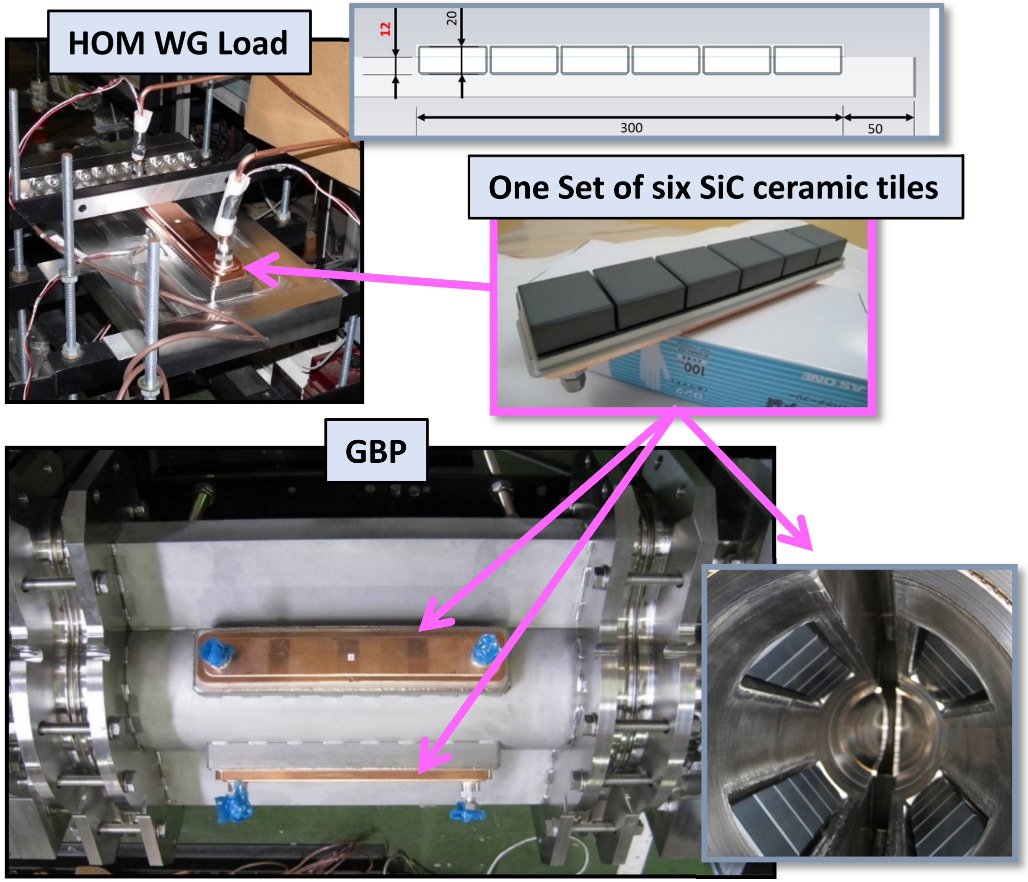
Lip welding for vacuum sealing

Cavity Side

Beam Pipe Side

M12 bolt
(16 bolts in total
used to fix this connection)

RF shielding fingers made of beryllium-copper with a gold coating

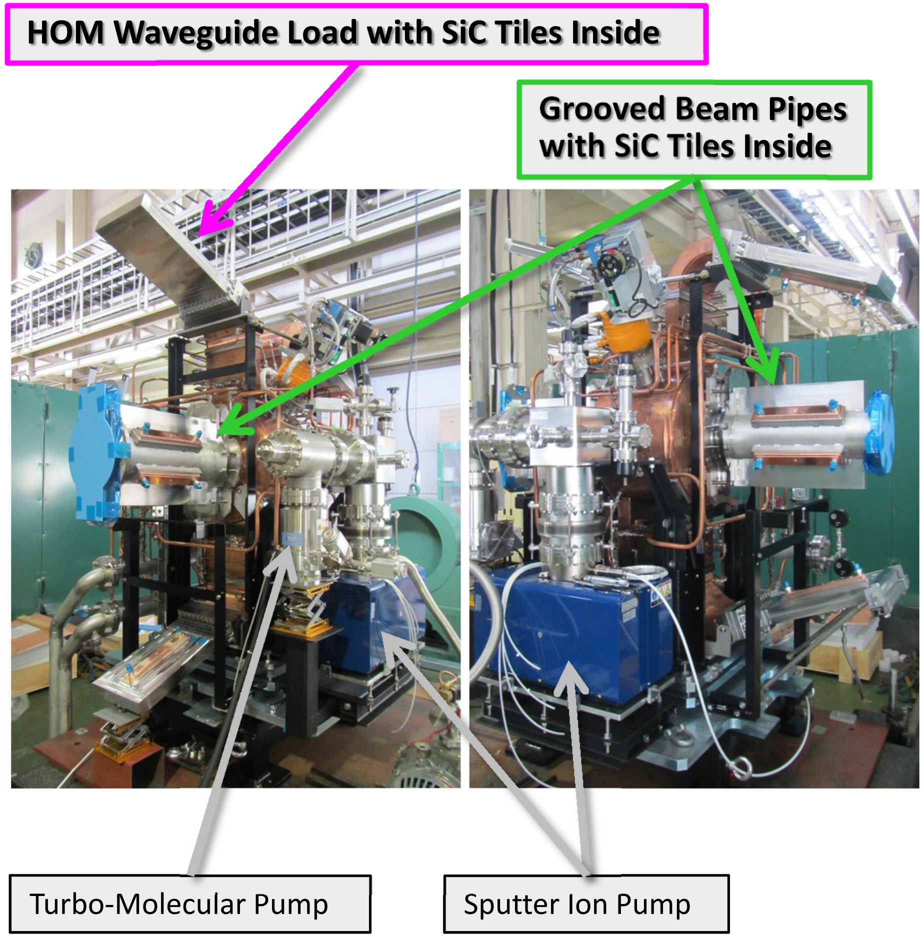


HOM WG Load

One Set of six SiC ceramic tiles

GBP

RF Cavity for the DR (DR Cavity)



HOM Waveguide Load with SiC Tiles Inside

Grooved Beam Pipes with SiC Tiles Inside

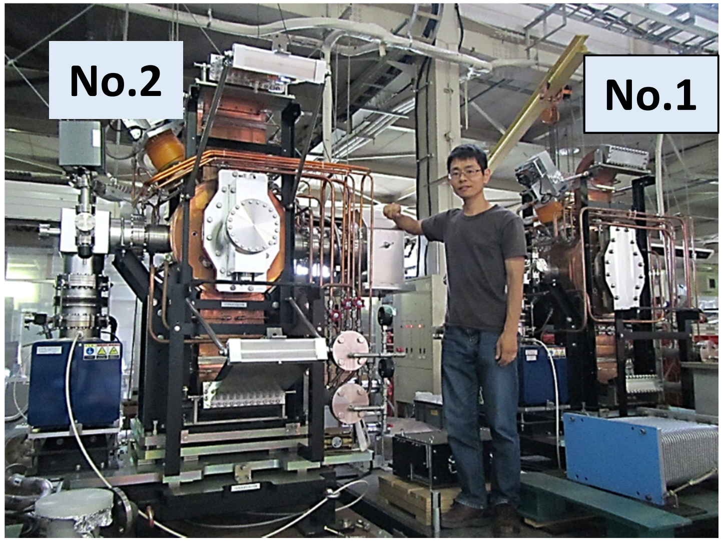
Turbo-Molecular Pump

Sputter Ion Pump

Design Parameters

RF operating frequency	508.9 MHz
R_{sh}/Q_0[a]	150 Ω
Q_0	≈ 30000 (97%IACS[b])
Input coupling factor	≈ 1.3
Gradient required in operation	$E_{\mathrm{acc}} = 2.7$ MV/m
	($V_c = 0.70$ MV)
Gradient of the specification	$E_{\mathrm{acc}} = 3.1$ MV/m
	($V_c = 0.80$ MV)
Wall loss power at $V_c = 0.70$ MV	≈ 110 kW
Wall loss power at $V_c = 0.80$ MV	≈ 140 kW
$E_s^{(\mathrm{max})\mathrm{c}}$ / E_{acc}	3.7
$H_s^{(\mathrm{max})\mathrm{d}}$ / E_{acc}	9.6 kA/m/(MV/m)
$S_C^{(\mathrm{max})\mathrm{e}}$ / E_{acc}^2	0.66 kW/mm^2/(MV/m)^2

History of the DR Cavity Development



0. Cavity No.0 (prototype) developed in JFY2011
   - Surface protection of the endplates: acid cleaning followed by chromating
1. **Cavity No.1** fabricated in JFY2012
   - Surface protection of the endplates: Electropolishing (EP)
2. **Cavity No.2** fabricated in JFY2013
   - Surface protection of the endplates: Electropolishing (EP)

No difference between No.1 and No.2 in the:
- ✓ **Electric design**
- ✓ **Mechanical structure, and**
- ✓ **Fabrication method**

(3. **Cavity No.3** to be fabricated in JFY2017?)

V_c = 0.95 MV/cav demonstrated at the Test Stand

(> 0.7 MV/cav required for DR operation)

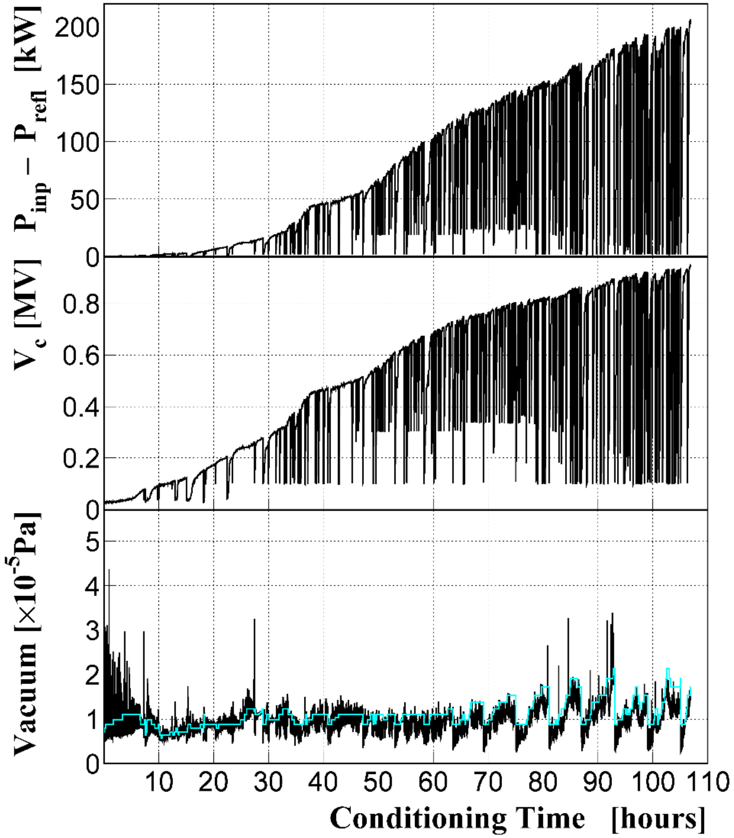
Cavity No.1

During the stability test
after the RF conditioning

V_c [MV/cav]	Wall-Loss Power [kW]	Total Holding Time [hours]	Number of Cavity Trips
0.80	144	30.5	1
0.85	164	18	0
0.90	186	14.5	3
0.95	210	8	1

Cavity No.2

During the RF conditioning

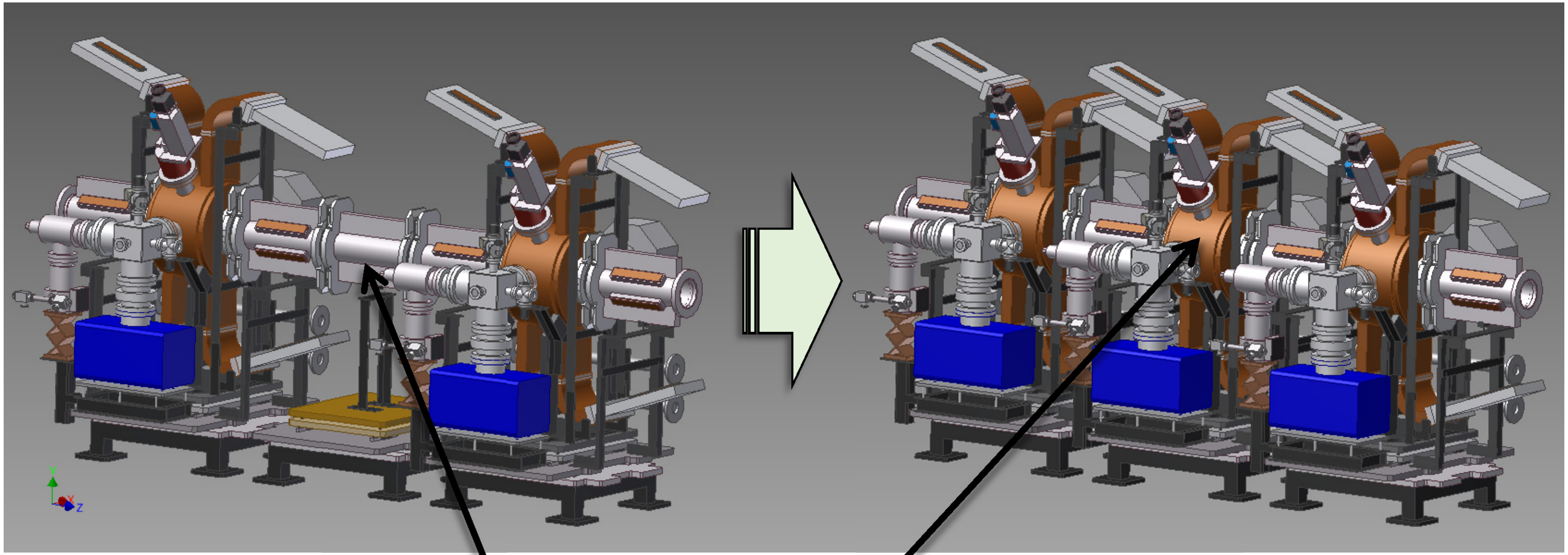


- ✓ P_{in} (P_{refl}) : input power to (reflected power from) the cavity
- ✓ Wall-loss power: $P_{wall} = P_{in} - P_{refl}$ = ~0.99 x P_{in}
- ✓ **Cavity No.2 reached 0.95MV/cav successfully.**

Configuration in the DR Tunnel

At the beginning of the DR commissioning

Ultimate



Total V_c = 1.4 MV

Dummy duct

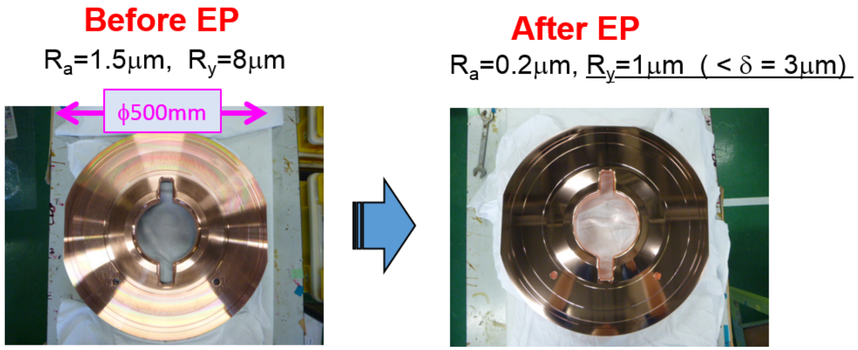
Cavity No.3

Total V_c = 2.1 MV

What We Learnt from the R&D of the DR Cavities

(Note: No EP applied to the barrel part.)

1. ***Electro-polishing (EP)*** for the end plates gives significant improvement in:
   - Q_0
   - Field emission during RF conditioning

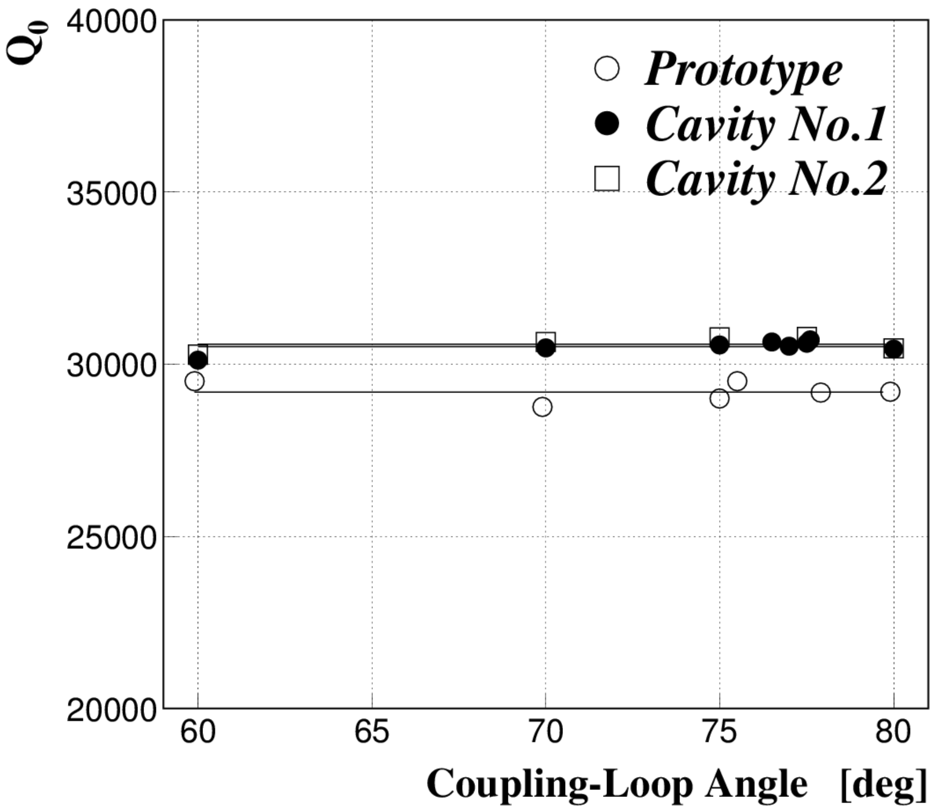


2. ***Same performance*** between DR Cavity No.1 and No.2 in:
   - ✓ Q_0
   - ✓ Field emission
   - ✓ RF conditioning speed
   - ✓ Vacuum performance
   - ✓ High-gradient performance:

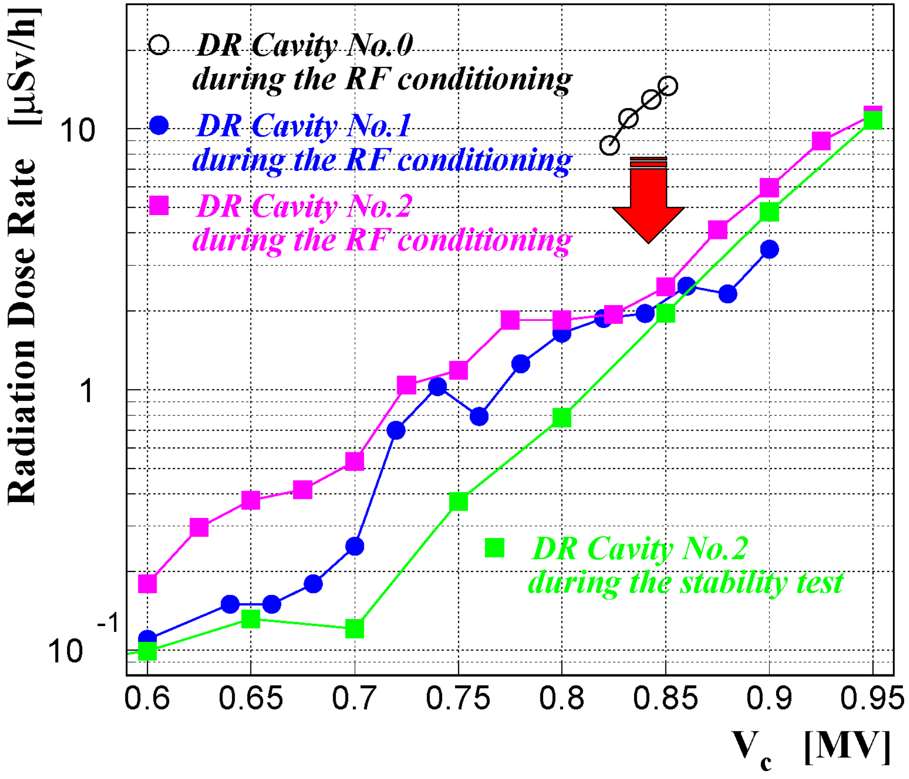
Breakdown Rate at V_c=0.90 MV/cav (after RF conditioning)
Cavity No.1: **$5.0^{+4.8}_{-2.7}$/24hrs**
Cavity No.2: **$3.3^{+1.3}_{-1.0}$/24hrs**

3. ***Significant Findings*** directly related to cavity breakdown

1. Improvements with the EP



	Q_0(meas) / Q_0(sim)
Prototype	92.9%IACS
Cavity No.1	97.1%IACS
Cavity No.2	97.3%IACS

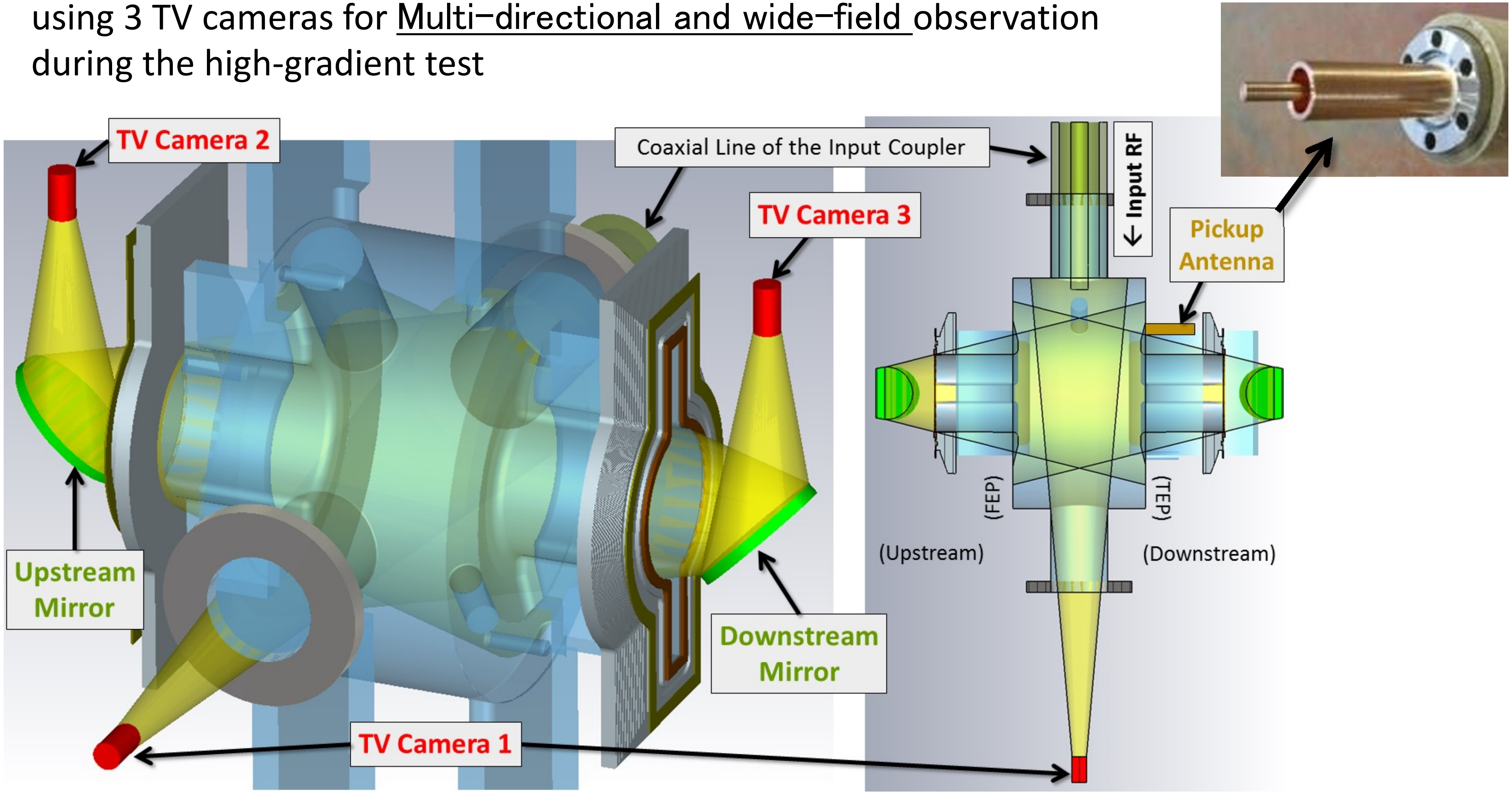


= Indirect observation of the dark current:

Field emission
- →Acceleration
- →Impact on the inner surface
- →Emission of X-ray

3. Significant Findings directly related to cavity breakdown

by the **direct in-situ observation** of the inside of DR Cavity No.2
using 3 TV cameras for Multi−directional and wide−field observation
during the high-gradient test



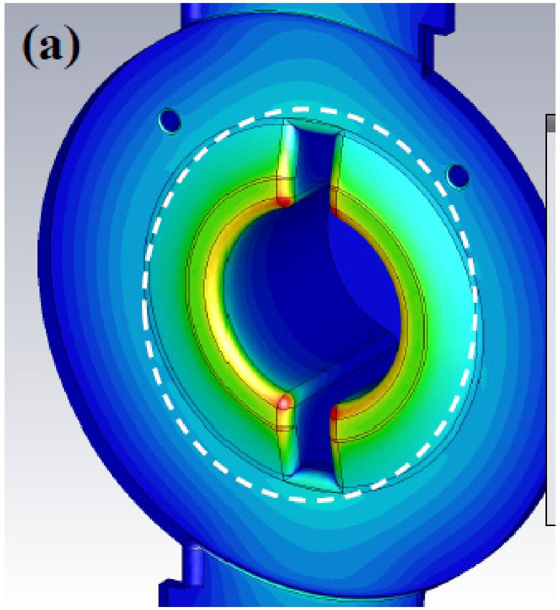
All of the cavity-breakdown events recorded in storage media *automatically*
(5 seconds before, until 1 second after the moment of the breakdown)

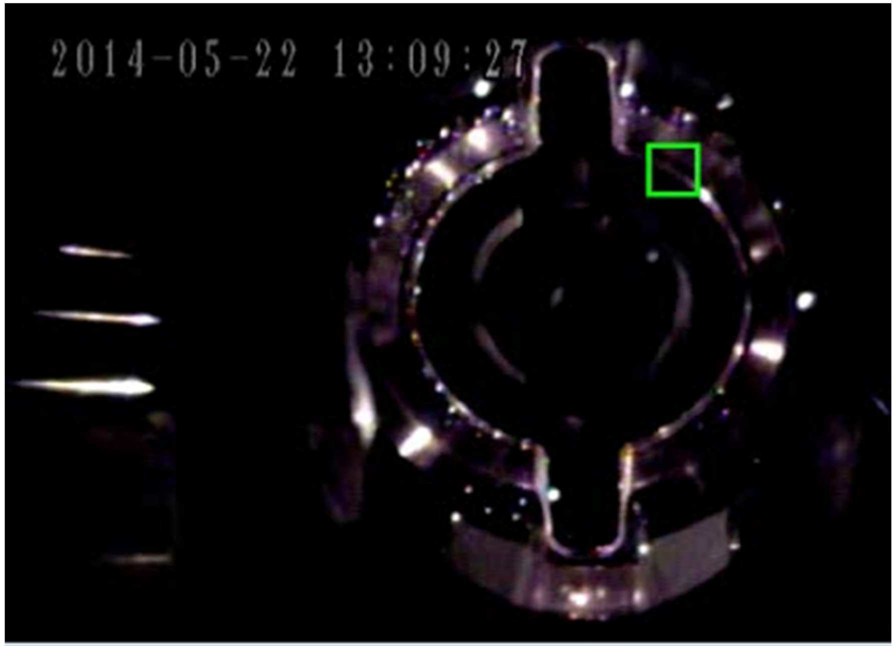
Significant Finding (1)

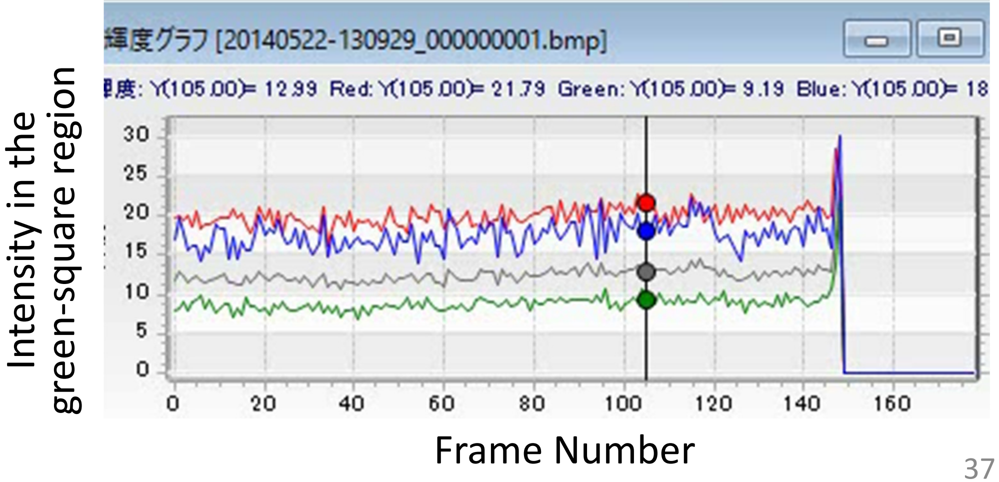
60% of the cavity breakdown events are accompanied with a spot-type explosion
without any other significant phenomena.

Example of the spot-type explosion →
at the moment of the breakdown
 (V_c = 0.56 MV/cav)

E-Field



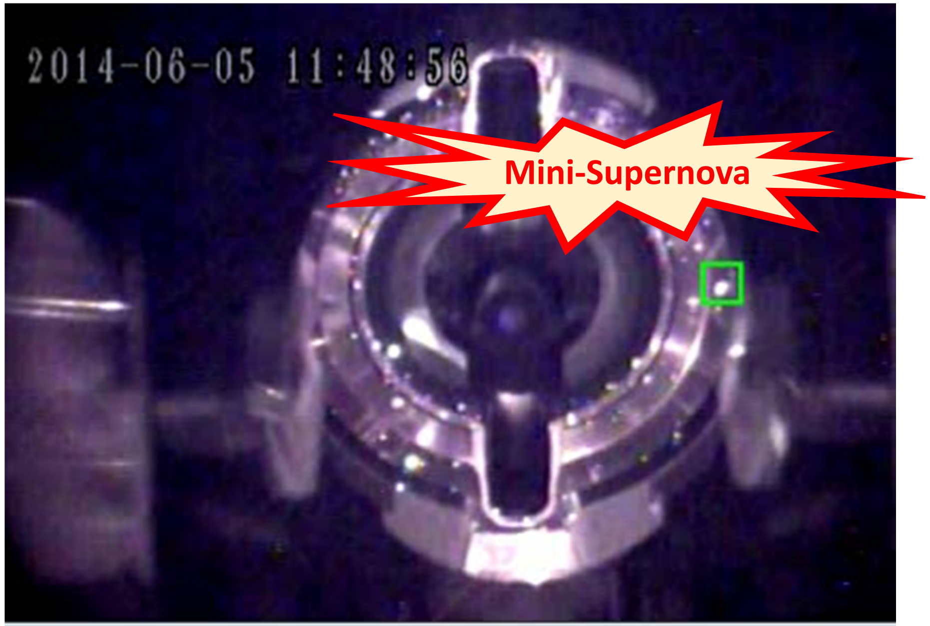




Significant Finding (2)

20% of the cavity breakdown events are accompanied with an explosion and disappearance of a stable bright spot without any other significant phenomena.

Example of the bright-spot explosion → at the moment of the breakdown (V_c = 0.95 MV/cav)



度グラフ [Fig.09_20140605-114858__000000001.bmp]

E: Y(104.00)= 118.58 Red: Y(104.00)= 126.14 Green: Y(104.00)= 105.52 Blue: Y(104.00)= 1

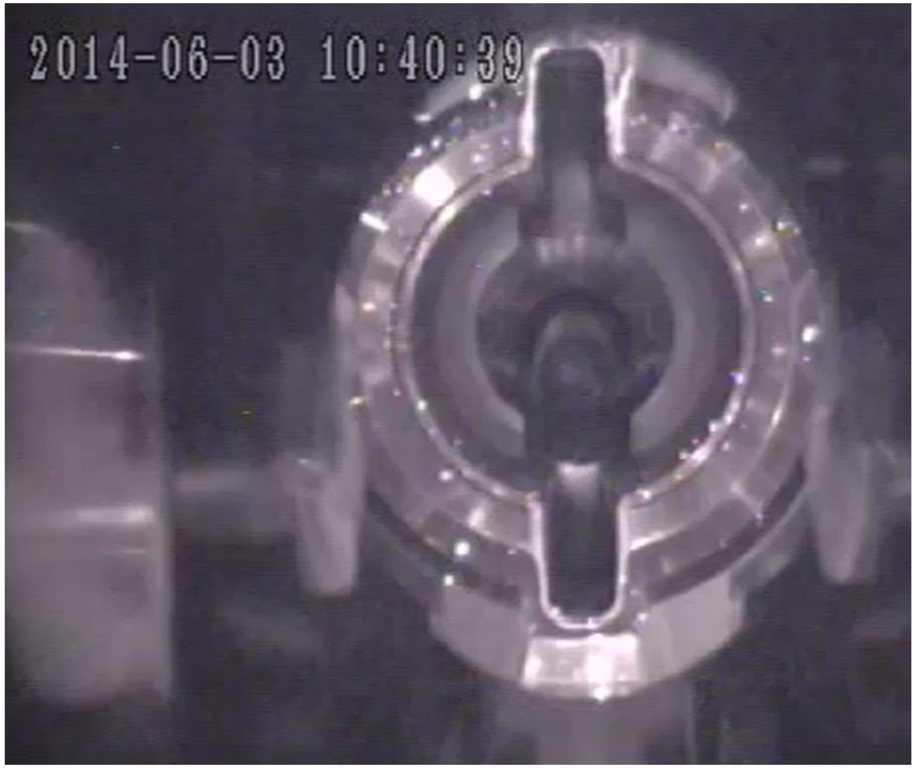
➔ This bright spot disappeared

(c) Shortly after recovering from the cavity breakdown, at V_c = 0.95 MV.

Pyrotechnical phenomena are minority!

Flash

Lightning



A few % of the cavity breakdown events

For more details ➔T. Abe *et al*., "Breakdown study based on the direct in-situ observation of inner surfaces of an RF accelerating cavity during a high-gradient test", submitted to PRAB.
(Preprint: KEK-Preprint_2015-25)

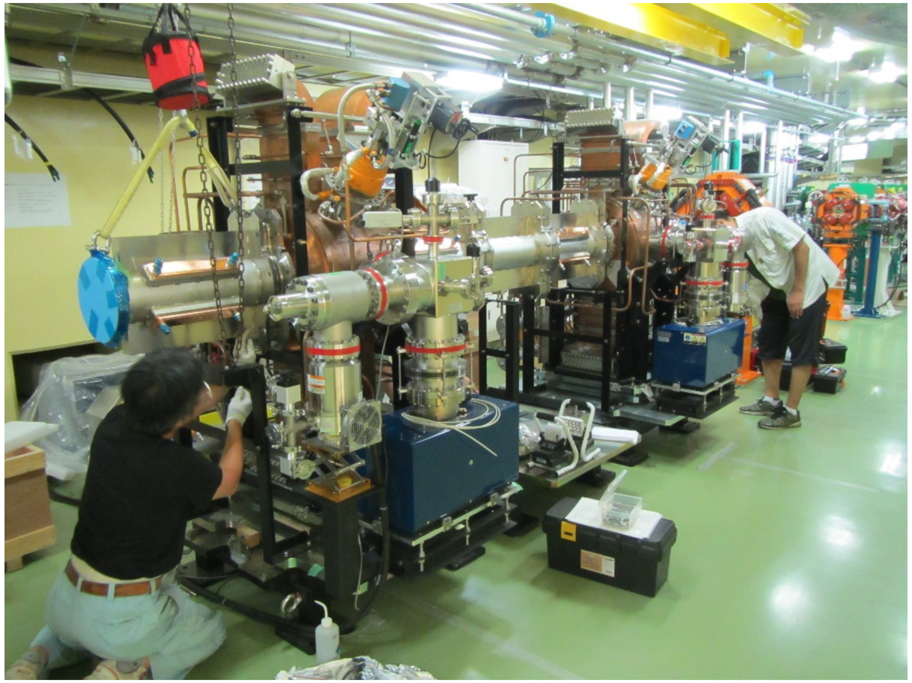
Summary

- ARES cavities for the MRs
  - Successful operation except for the two serious troubles:
    - Vacuum trouble on the D8-D cavity
    - Precipitate growth of the antirust in the chillers

MR: Main Ring
DR: Damping Ring
NC: Normal-Conducting
CW: Continuous Wave
UHF: Ultra High Frequency

- DR Cavities
  - Good performance demonstrated
  - Significant findings directly related to cavity breakdown on the NC CW UHF cavities obtained through the high-gradient test

Photo on June 10, 2016, in the DR/RF section



(Assembly testing)

Thank You!

Appendices

Longitudinal CBI driven by the accelerating π/2 mode

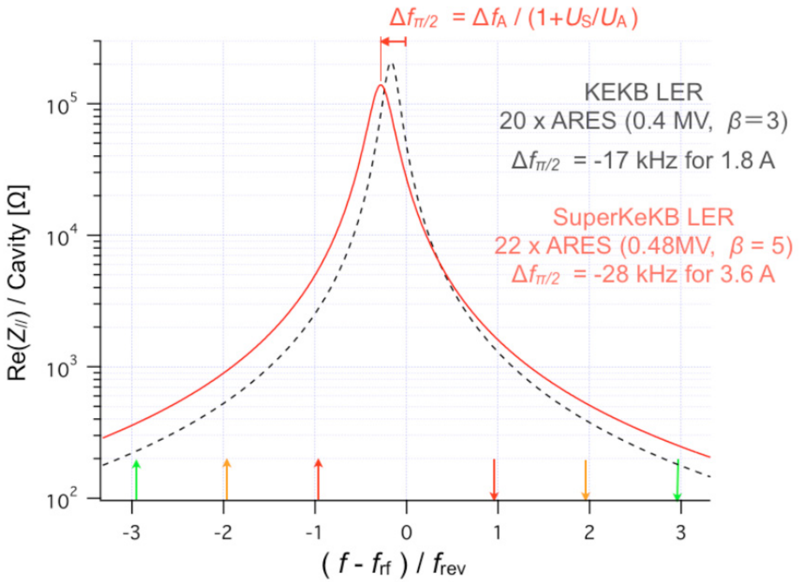


Figure 7.8: Coupling impedance of the π/2 mode calculated for the SuperKEKB LER where the design beam current of 3.6 A being accelerated with 22 ARES cavities, compare with that for the KEKB LER.

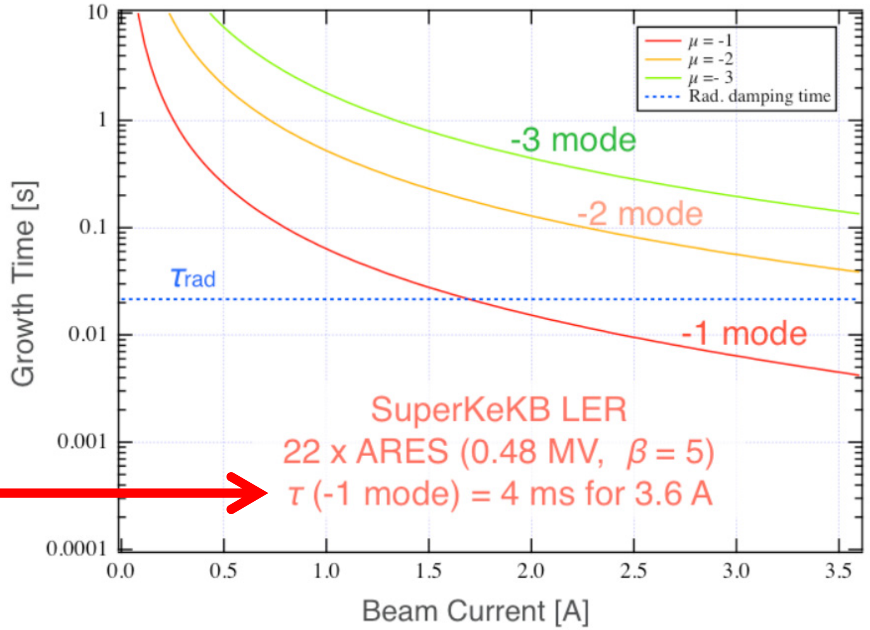


Figure 7.9: Growth time constants of the CBI modes of μ = -1, -2, and -3 due to the π/2 mode, plotted as a function of the beam current in the SuperKEKB LER.

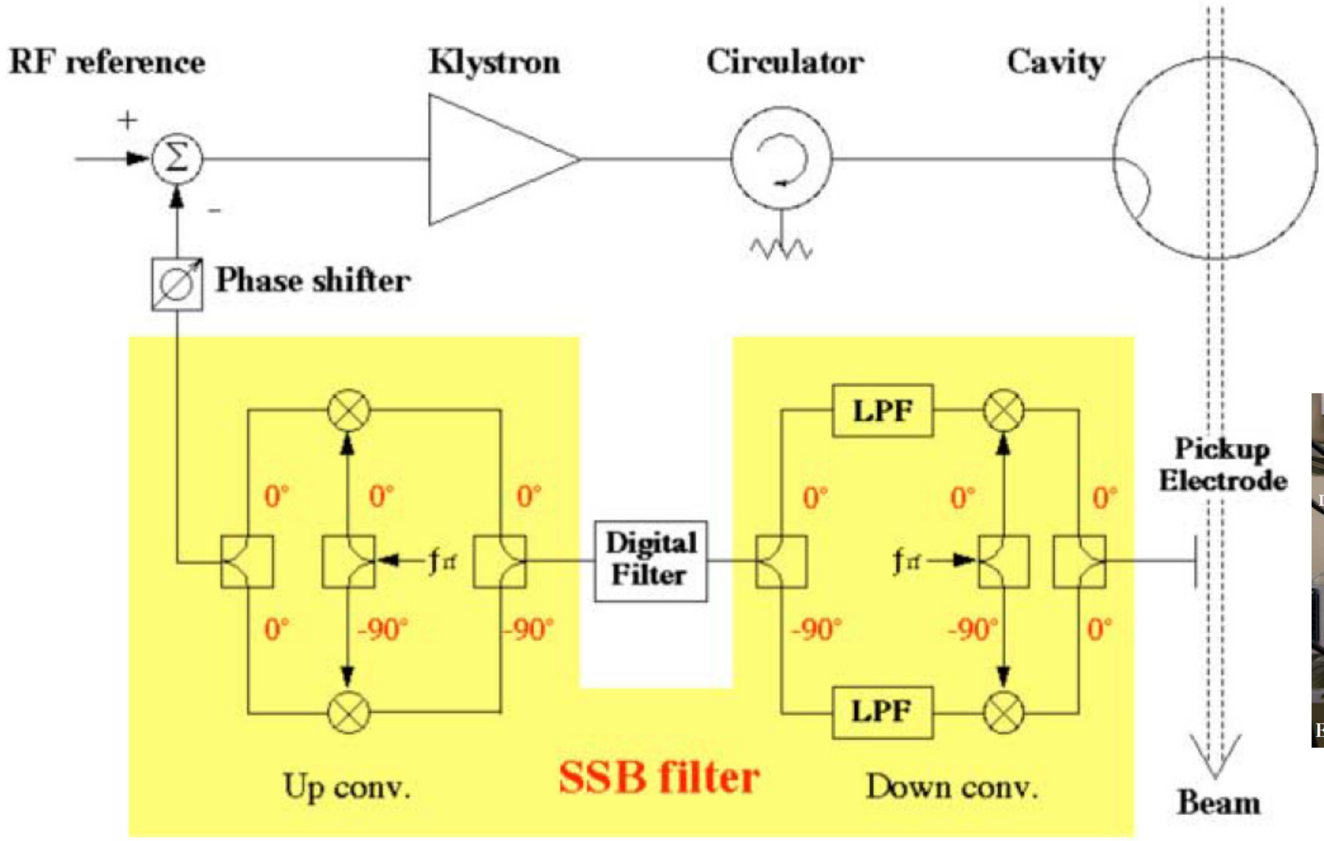
To be cured by the RF feedback systems

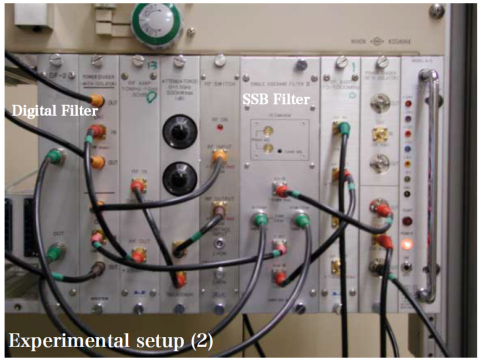
(shown in the next page)

KEKB Review February 10, 2003

-1 mode damping system at KEKB

(S. Yoshimoto)





S. Yoshimoto, et al., presented in the 14th Symposium on Accelerator Science and Technology, Tsukuba, Japan, 2003 (PaperID: 1P072)

Longitudinal CBI driven by the parasitic 0 and π modes

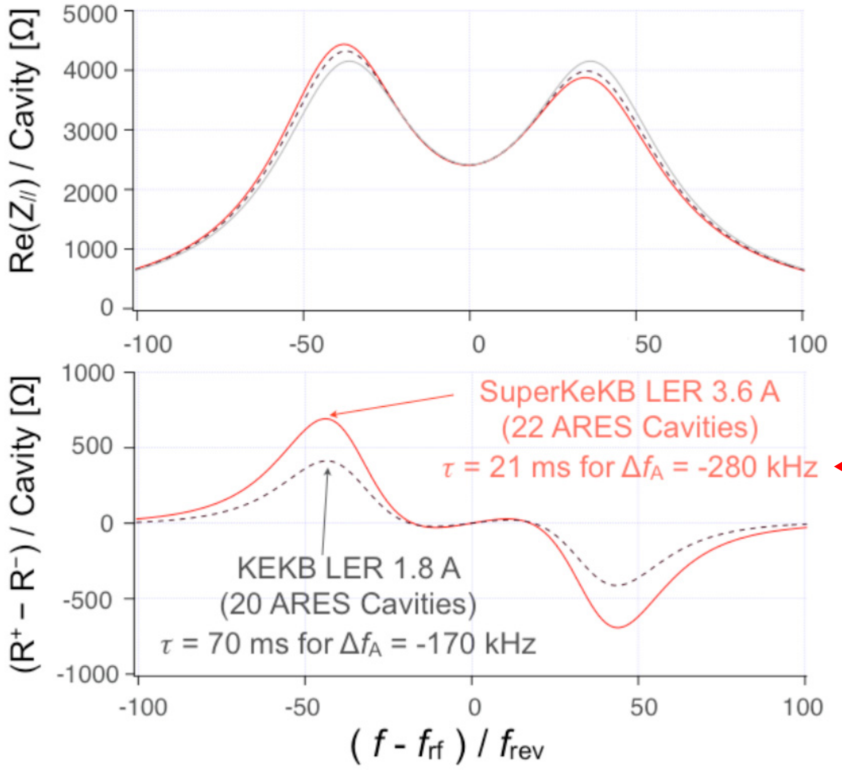
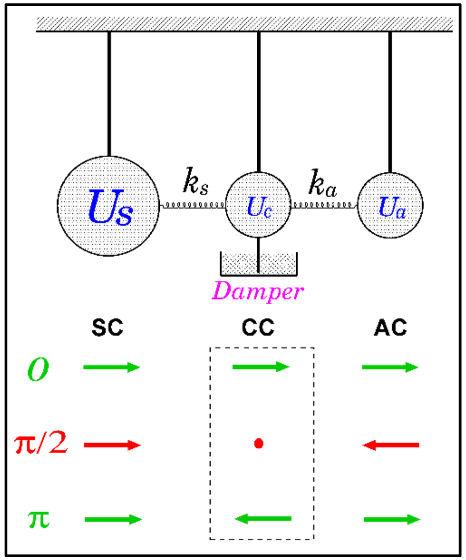


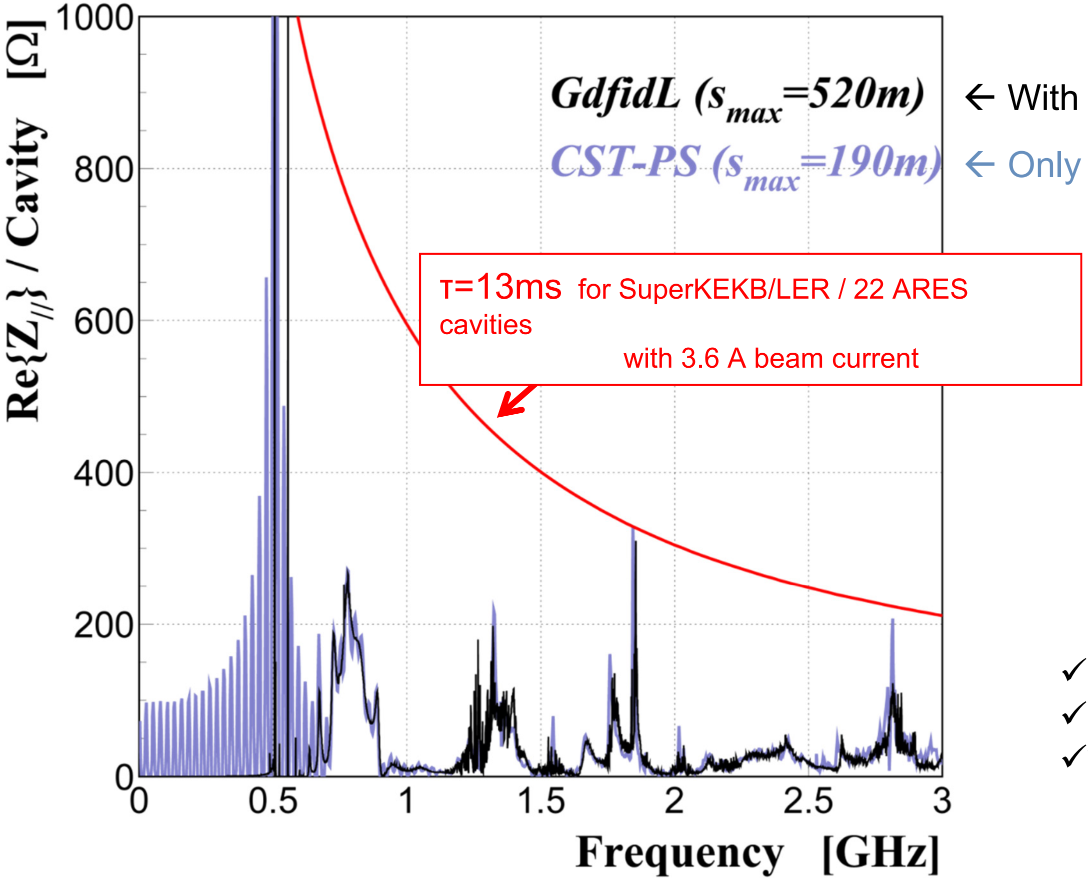
Figure 7.10: Coupling impedance (top) of the 0 and π modes, and the imbalance (bottom) with respect to the RF frequency.



To be cured by the longitudinal bunch-by-bunch feedback system

Longitudinal HOM Impedance *(Simulation Results)* and CBI Threshold at SuperKEKB/LER

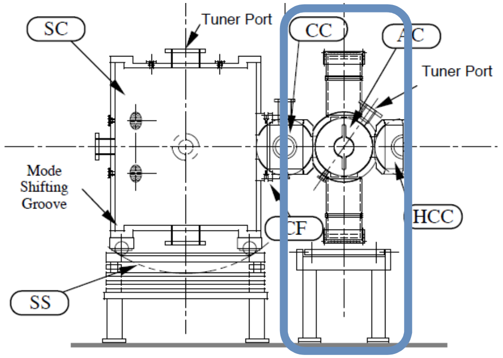
Both impedances from wakepotentials in time-domain



τ=13ms for SuperKEKB/LER / 22 ARES cavities
with 3.6 A beam current

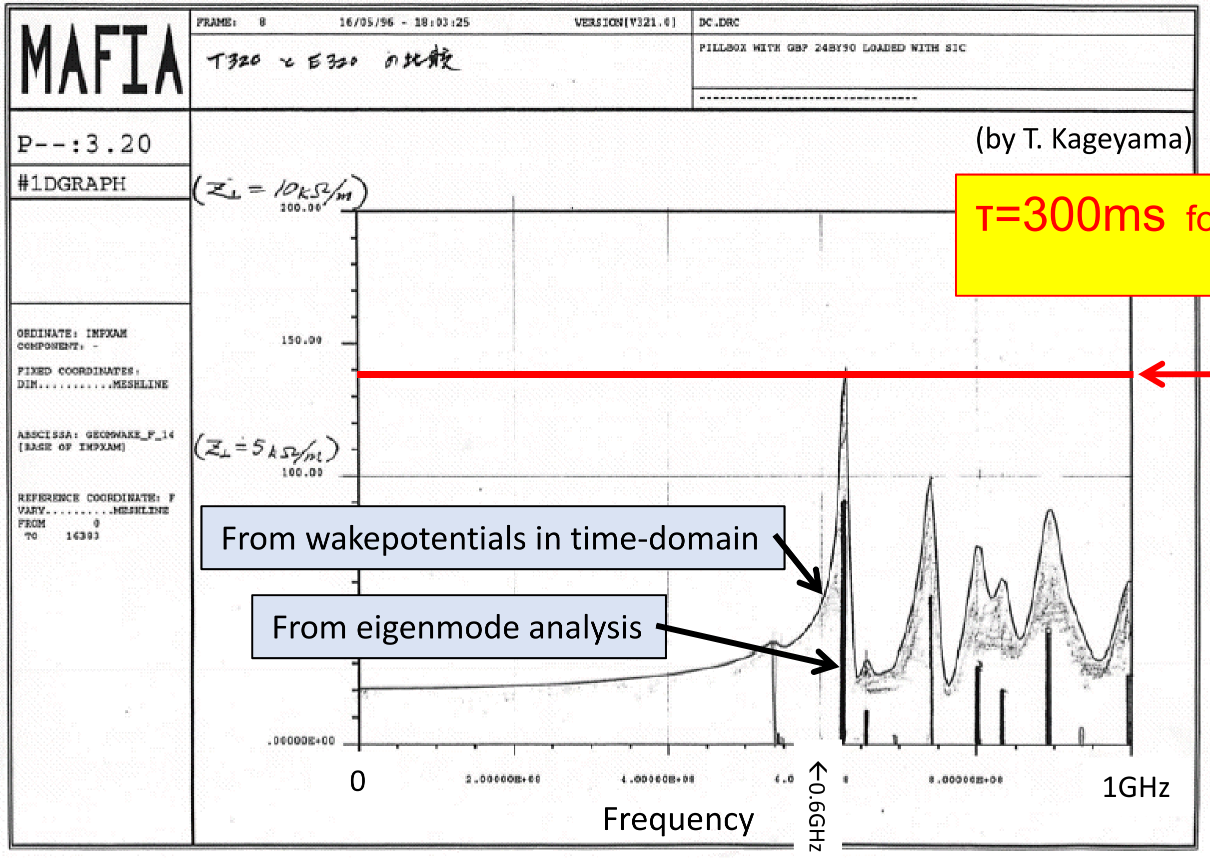
← With the full structure (including SC)

← Only AC + half CC (without SC)



- ✓< 21.6 ms (Longitudinal rad. damping time of LER)
- ✓Fastest longitudinal CBI source
- ✓To be cured by the longitudinal bunch-by-bunch feedback system

Horizontal HOM Impedance *(Simulation Result)* and CBI Threshold at SuperKEKB/LER



MAFIA

FRAME: 8 16/05/96 - 18:03:25 VERSION[V321.0]

T320 と E320 の比較

DC.DRC

PILLBOX WITH GBP 24BY90 LOADED WITH SIC

P--:3.20

#1DGRAPH

ORDINATE: IMPXAM
COMPONENT: -

FIXED COORDINATES:
DIM...........MESHLINE

ABSCISSA: GEOMWAKE_F_14
[BASE OF IMPXAM]

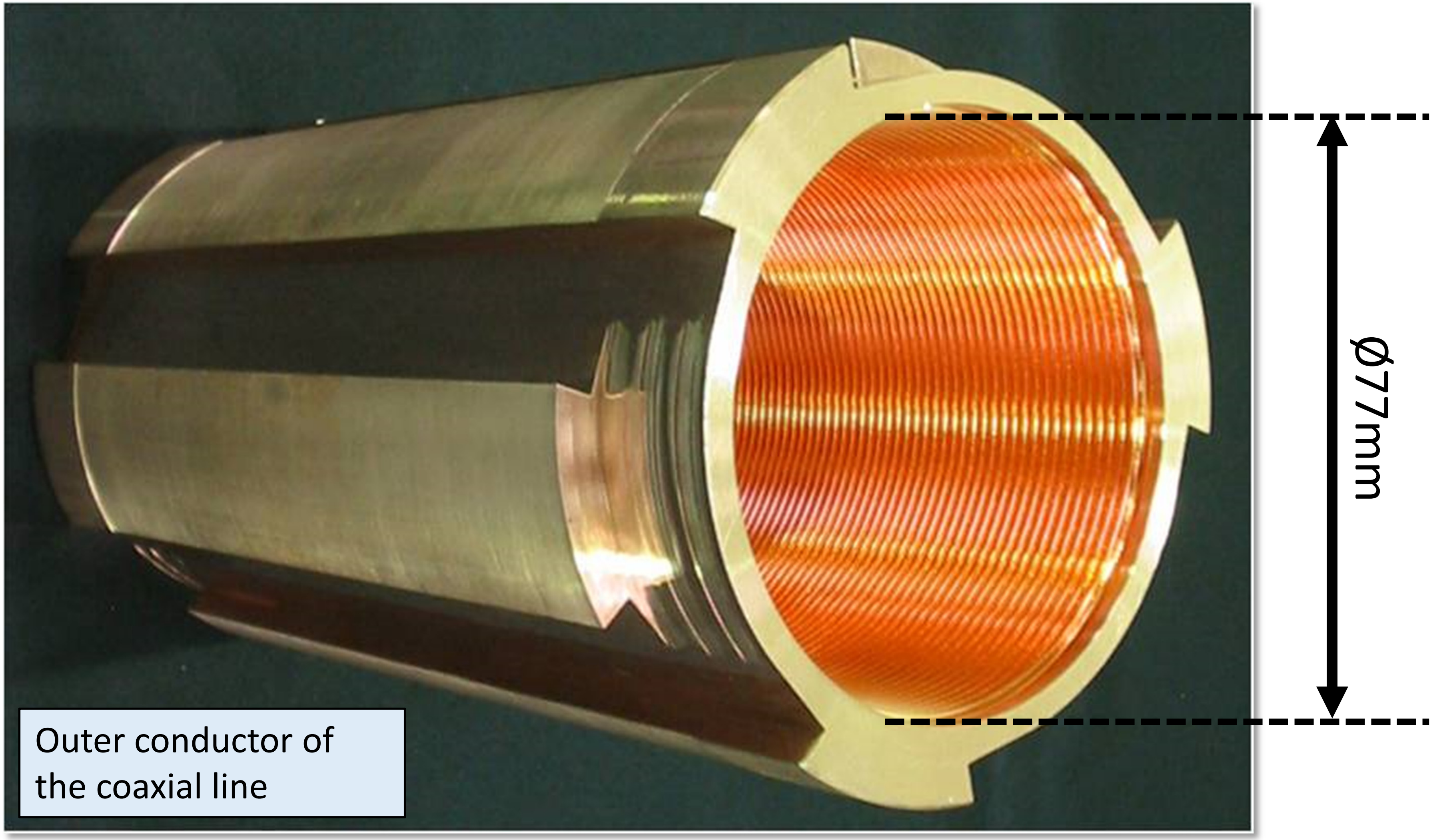
REFERENCE COORDINATE: F
VARY..........MESHLINE
FROM 0
TO 16383

τ=300ms for SuperKEKB/LER / 22 ARES cavities with 3.6 A beam current

\>> Transverse radiation damping time of LER: 43.2 ms

Appendix B

Multipactoring suppression by fine grooving of conductor surfaces of coaxial-line input couplers



Outer conductor of the coaxial line

T. Abe, et al., Phys. Rev. ST Accel. Beams 13, 102001, 2010

Appendix C (1/2)

We have replaced all the 15 chillers used at KEKB for a long time.

- First, we used the same type of chiller with the almost the same specifications (ORION RKE-1500A-VW) at the test stand (D1-A) on the ground.
  - Performance and stability demonstrated
  - No trouble so far for 8-year operation
- We purchased succession machines (ORION RKE-1500B1-V) for MR and DR operation, and replaced the old 15 chillers (ORION RKS-1500-V-C) by these (ORION RKE-1500B1-V).
  - Small amount of precipitates observed in the reservoir tanks in two of the chillers in FUJI D8 on 2015-10-07

Appendix C (2/2)

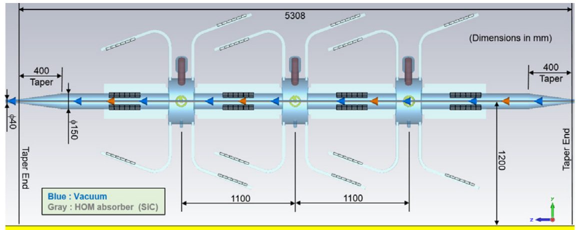
Comparison between the Chillers

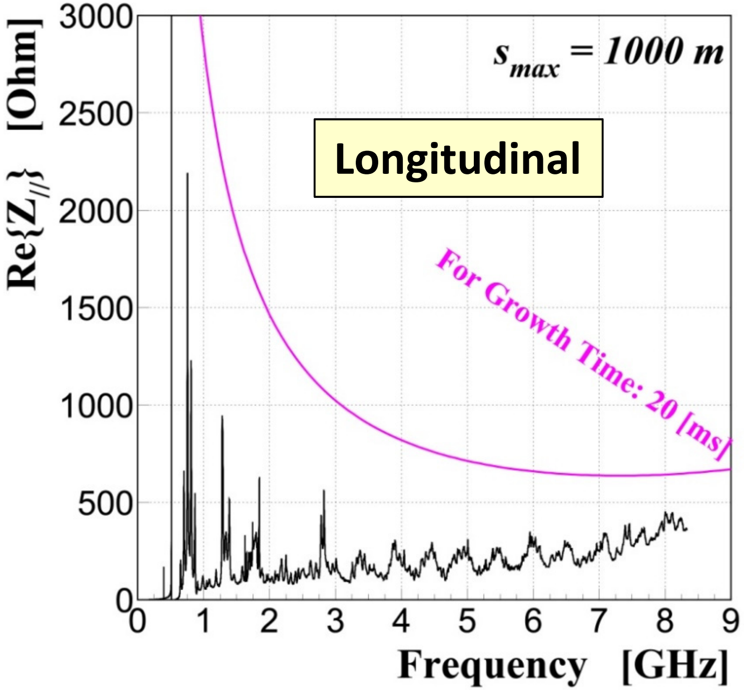
	Capacity of the reservoir tank	**Top cover on the reservoir tank**	**Feed-water inlet**	**Overflow-water outlet**
ORION RKS-1500-V-C (used in the KEKB tunnel)	45 L	Yes (in addition to the top cover on the chassis)	Closed in operation	Closed in operation
ORION RKE-1500A-VW (used at the test stand (D1-A) on the ground)	30 L	None (only the top cover on the chassis)	Closed in operation	Open always
ORION RKE-1500B1-V (used in the SuperKEKB tunnel)	**15 L**	None (only the top cover on the chassis)	Closed in operation	Open always

Appendix D

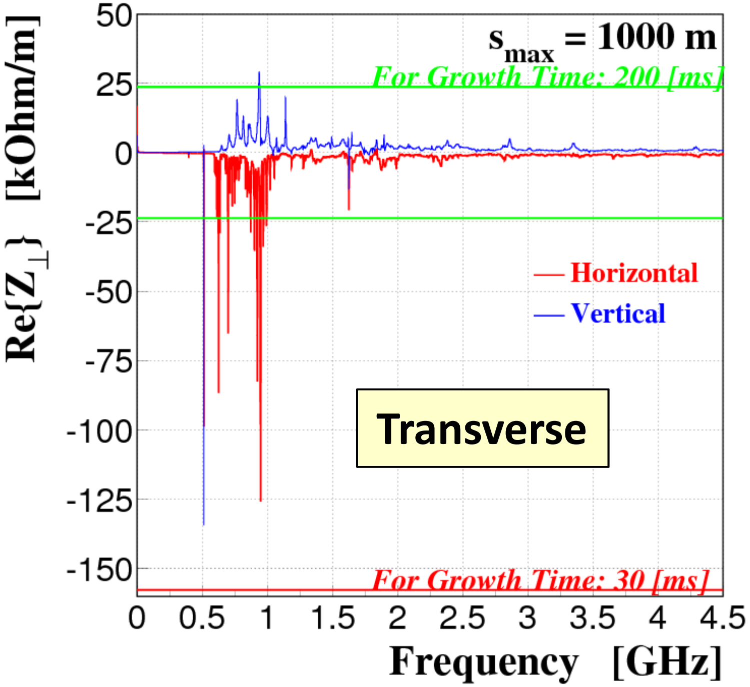
CBIs driven by the HOM Impedances

- ✓From wakepotentials calculated, using GdfidL, for the whole RF section→
- ✓CBI thresholds for the DR design





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



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

EOF