RF Cavities for SuperKEKB MRs and DR

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ALERT2014 Workshop
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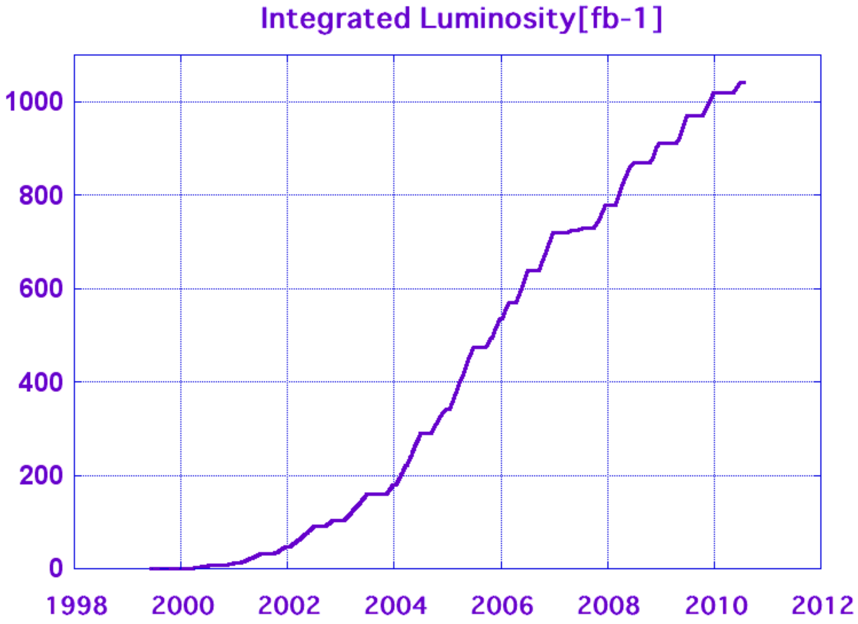
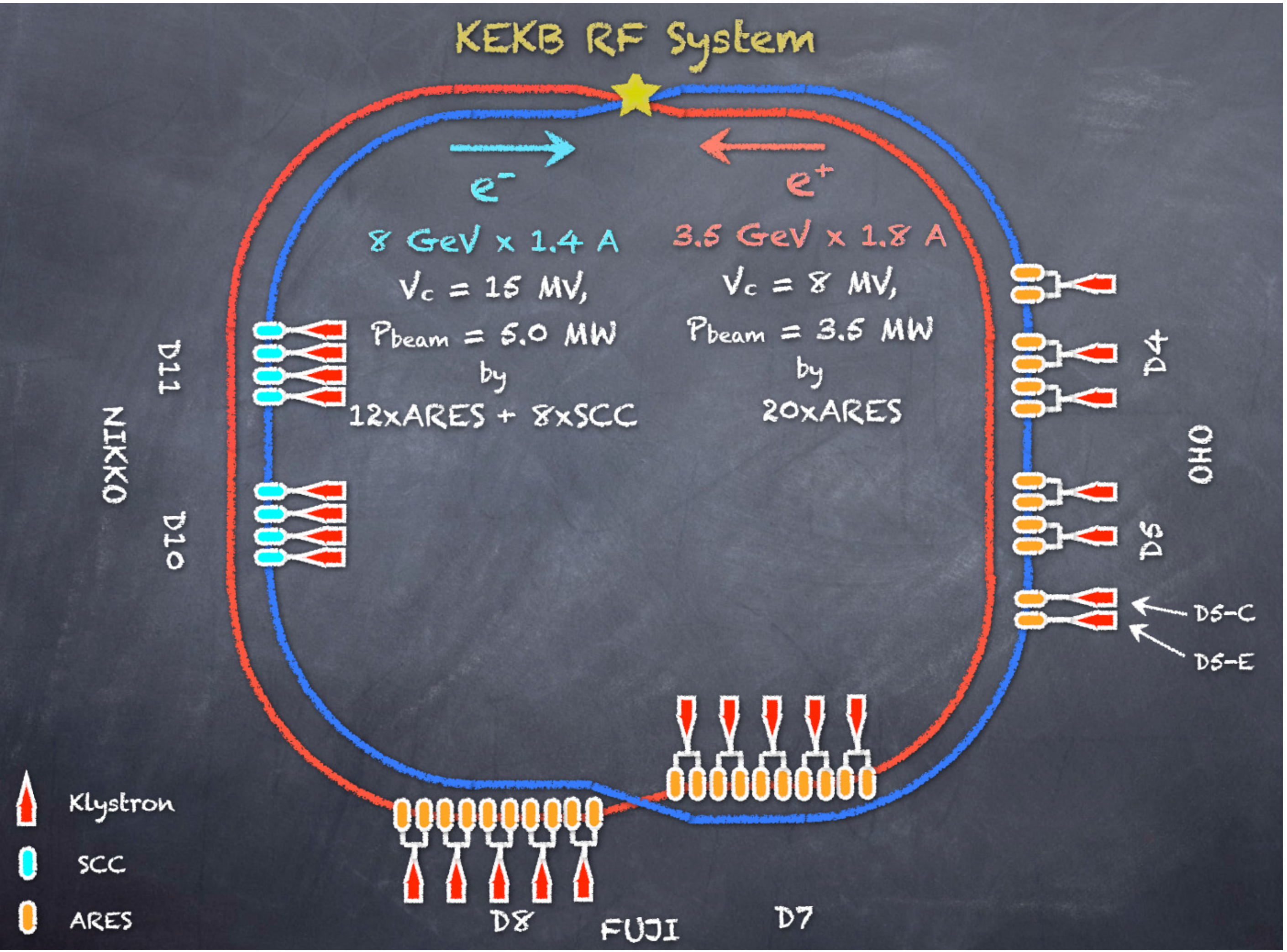
KEKB Asymmetric-Energy e^+e^- Collider

- Started its operation in 1999.
- Achieved the world's highest luminosity among the colliders: 2.11×10^{34} cm^{-2}s^{-1}
- Total integrated luminosity (not delivered, but logged): 1041 fb^{-1}
- Ended at 9:00 on June 30, 2010.



RF Cavities used for the KEKB Main Rings (MRs)



(Shown by T. Kageyama at KEKB Review 2011)

20 NC cavities ("ARES")
for LER (Low Energy Ring)

12 NC cavities ("ARES")
+ 8 SCCs
for HER (High Energy Ring)

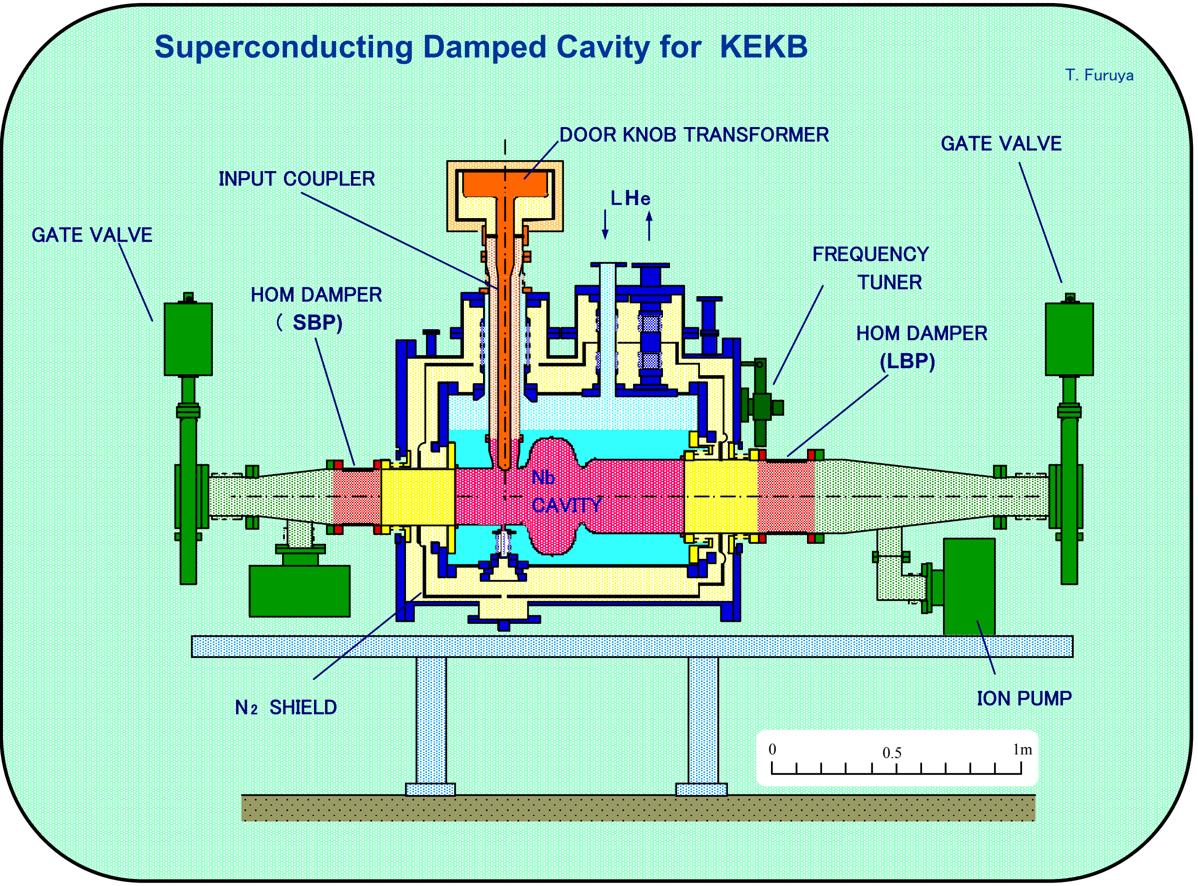
Common:

- ✓RF Operation Frequency: 508.9MHz
- ✓Single Cell
- ✓HOM-damped structure

Super-Conducting Cavities (SCCs) for KEKB

SCC for KEKB

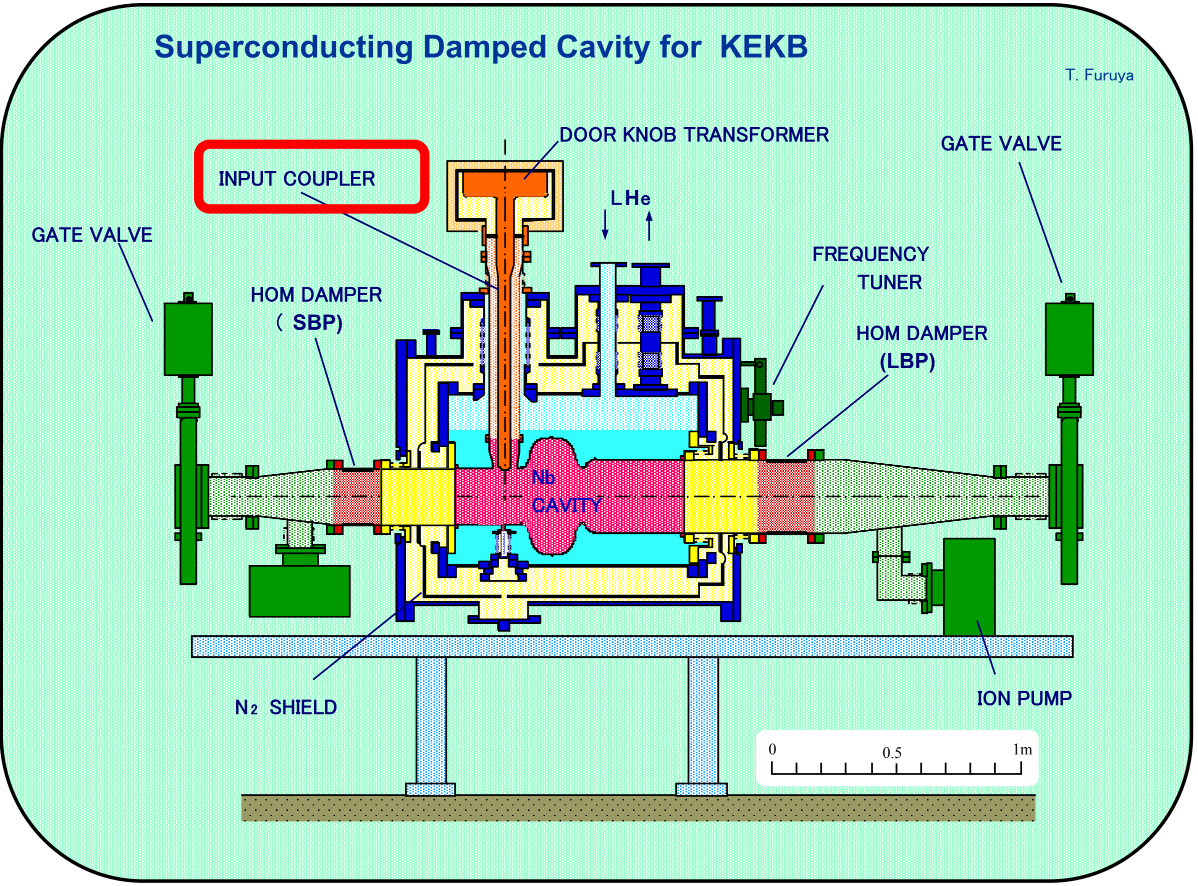
-- Overview --



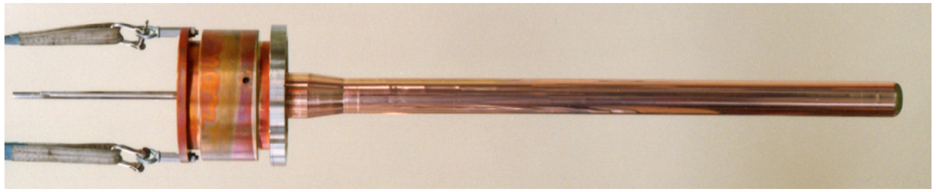
- Pure-Niobium Resonators
- Gap length: 243 mm
- R_{sh}/Q_0 = 93 Ohms
- $Q_0 = 10^9$ at 2 MV/cav
- E_{sp}/E_{acc} = 1.84
- H_{sp}/E_{acc} = 40.3 Gauss/(MV/m)
- Design voltage (field): 1.5 MV/cav (6 MV/m) at 4.4 K
- Conditioned up to 2.5 MV/cav (10 MV/m)
- Processes of the inner-surface treatment
  - ①Electro-Polishing (~100μm)
  - ②Ozonized ultrapure-water rinsing
    - →Carbon contamination removed
- Loss factor of this structure: 1.8 V/pC (bunch length: 4 mm)
- When the quench detector detects a cavity-voltage drop, RF power is immediately turned off.
- (Cavity trip rate) < 1 /cav/month
- World record on the high-beam-current acceleration (1.4A)

SCC for KEKB

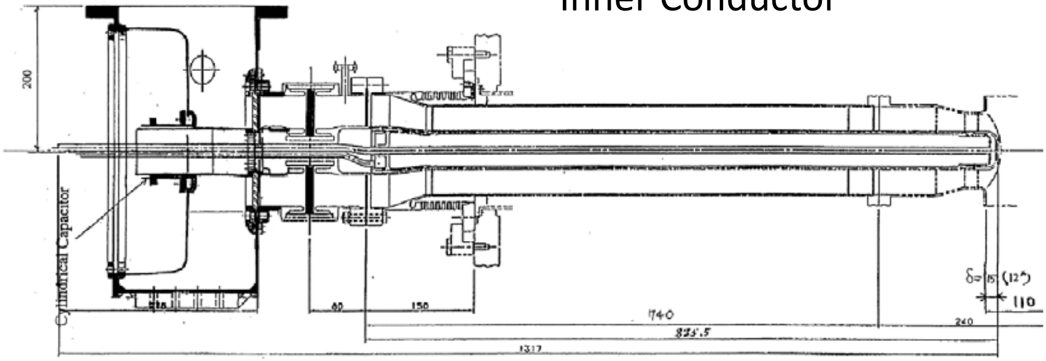
-- High-Power Input Coupler --



- Coaxial antenna
- Disk-type RF ceramic window with a TiN coating
  - Arc sensors to detect discharge
- Conditioned up to 800kW(traveling wave) and 300kW (totally reflected standing waves with a phase of 0-180deg)
- $Q_{ext} = 7\times10^4$
- DC bias applied to suppress multipactoring in the coaxial line

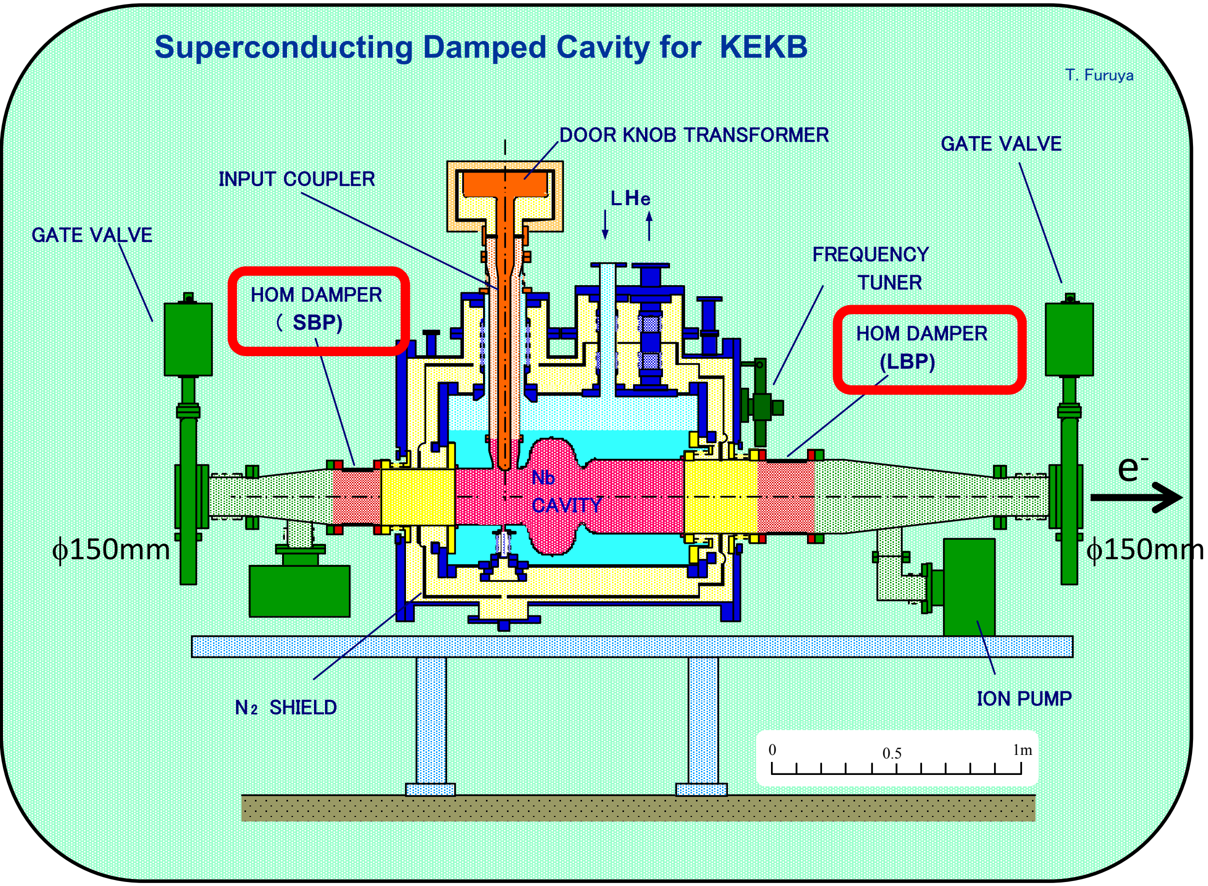


Inner Conductor



SCC for KEKB

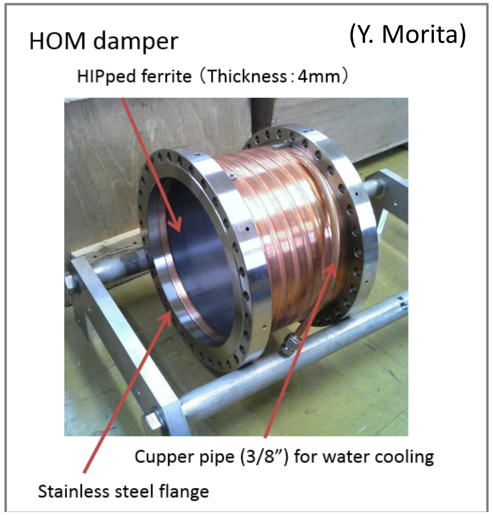
-- HOM-Damped Structure --



ϕ220mm duct
← TM_{011} , TM_{020} , etc.

ϕ300mm duct
TM_{110} , TE_{111} , etc. →

- ■ Single mode cavity
  - HOMs to be extracted to the beam ducts
- ■ HOM dampers with 4mm-thick Ferrite (IB-004)
  - Ferrite bonded on the inner surface of a copper duct by HIPping
  - Ferrite Length: 120mm (150mm) for 220 (300) mm diameter damper as “SBP” (“LBP”)
  - Power-handling capability demonstrated: 11.7 (14.8) kW for 220 (300) mm diameter damper
- ■ Loss factor: 1.37 V/pC for bunch length: 5mm

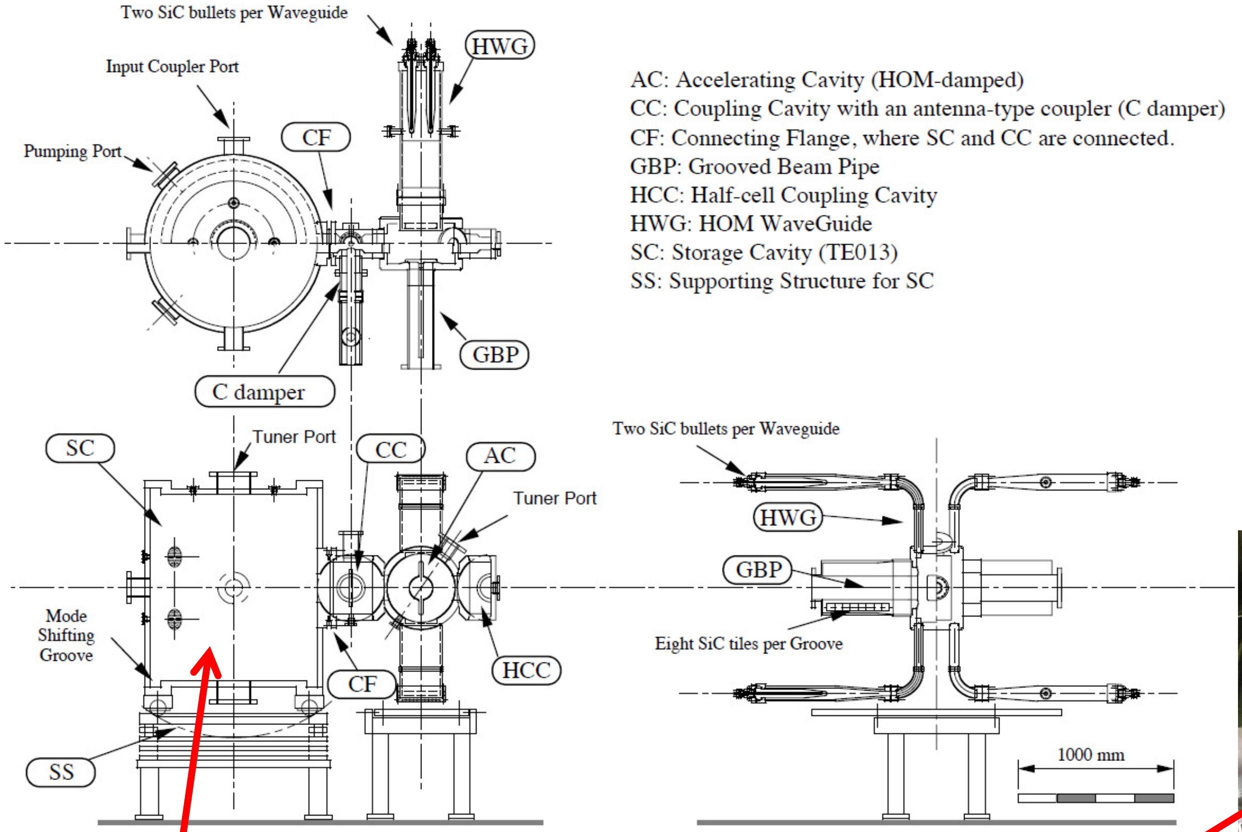


Normal-Conducting (NC) Cavities for KEKB

NC Cavity for KEKB (ARES)

-- *Accelerator Resonantly coupled with Energy Storage* --

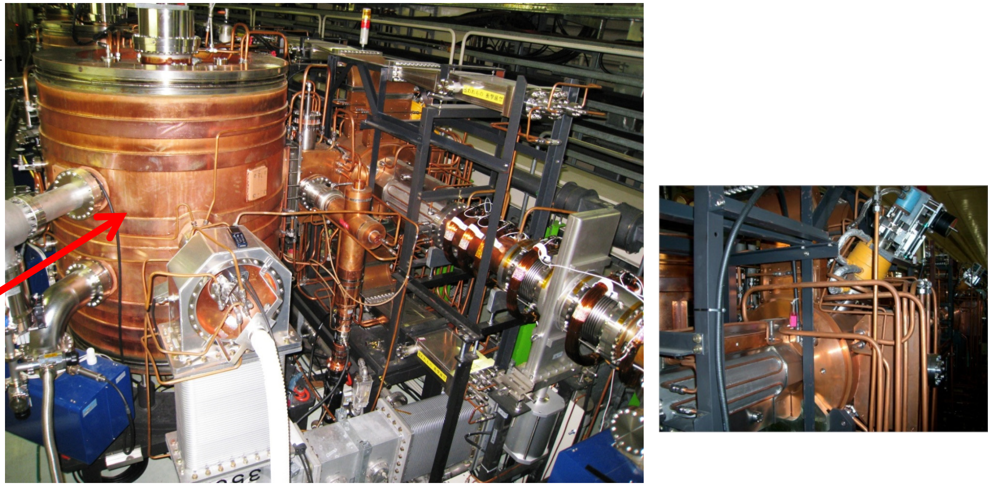
- High-Purity Copper Resonators
- Gap length: 256 mm
- Three-cavity system (unique)
- R_{sh}/Q_0=15 Ohms
- Q_0=~1.1×10^5
- V_c=0.5 MV/cav
- P_c=150kW (60kW in AC, 90kW in SC)
- Loss factor: 0.48 V/pC (bunch length: 5 mm)
- E_{sp}/E_{acc} = 3.6
- (Cavity trip rate) < 1 /cav/3months
- U_s/U_a=9 (see the next page)



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

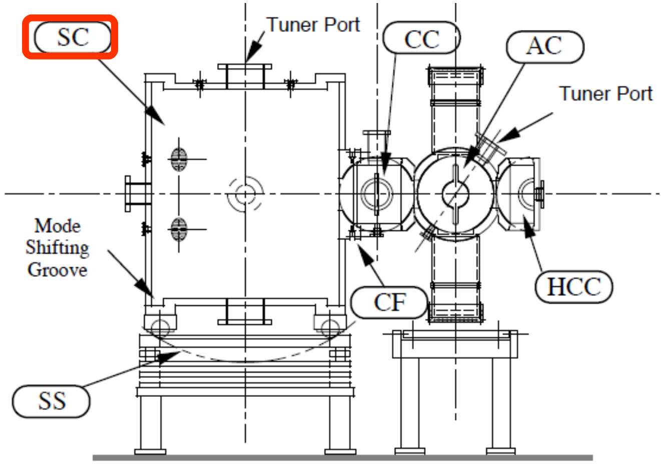


ARES

-- *Three cavity system stabilized with the accelerating π/2 mode* --

- Why do we need **SC**?
  - 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.

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



- Why π/2-mode operation with the three-cavity system
  - The stored-energy ratio: U_s/U_a changeable: $U_s/U_a = k_a^2/ k_s^2$
  - The parasitic 0 and π modes can be damped selectively out of CC by an antenna-type damper ("**C-damper**")

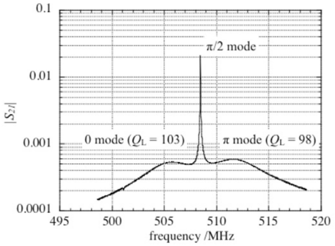
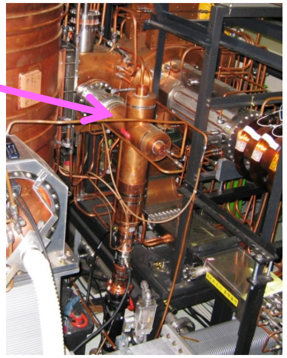
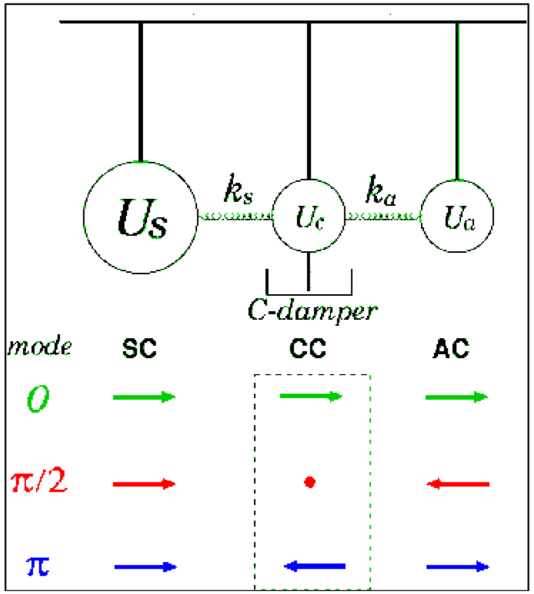


Figure 7.5: Accelerating mode (the π/2 mode) and the damped parasitic 0 and π modes. The vertical axis shows the transmitted power amplitude $|S_{21}|$ from port #1 at one endplate of the accelerating cavity to port #2 at the other endplate, measured with a network analyzer.

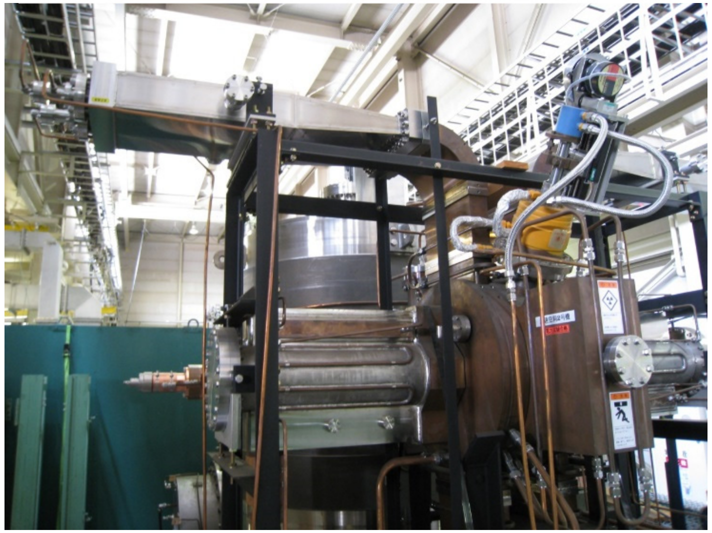




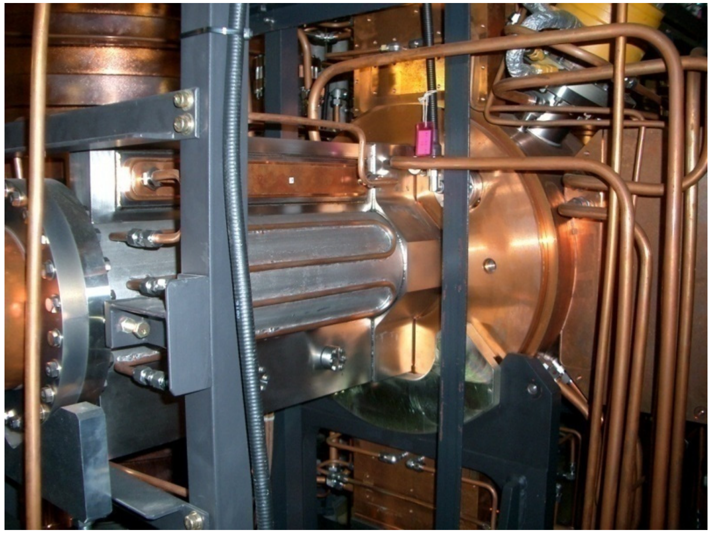
ARES

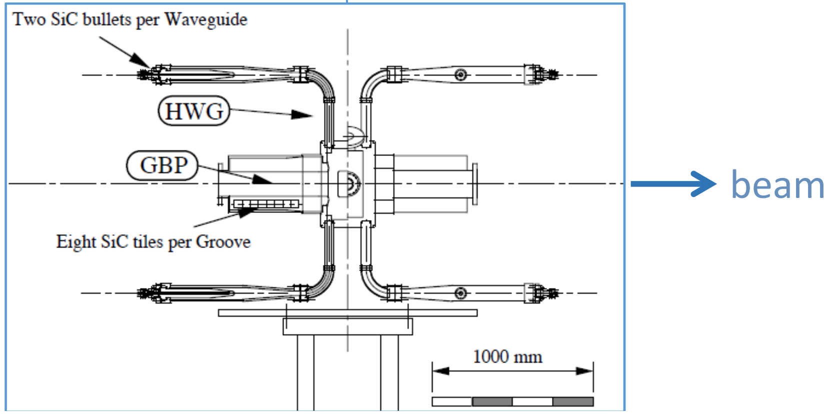
-- Two-types of HOM-Damped Structures --

Type_1: HOM WG (HWG)

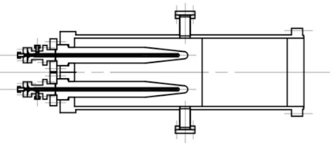


Type_2: Grooved Beam Pipe (GBP)

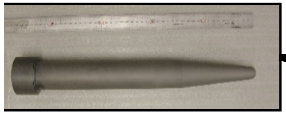


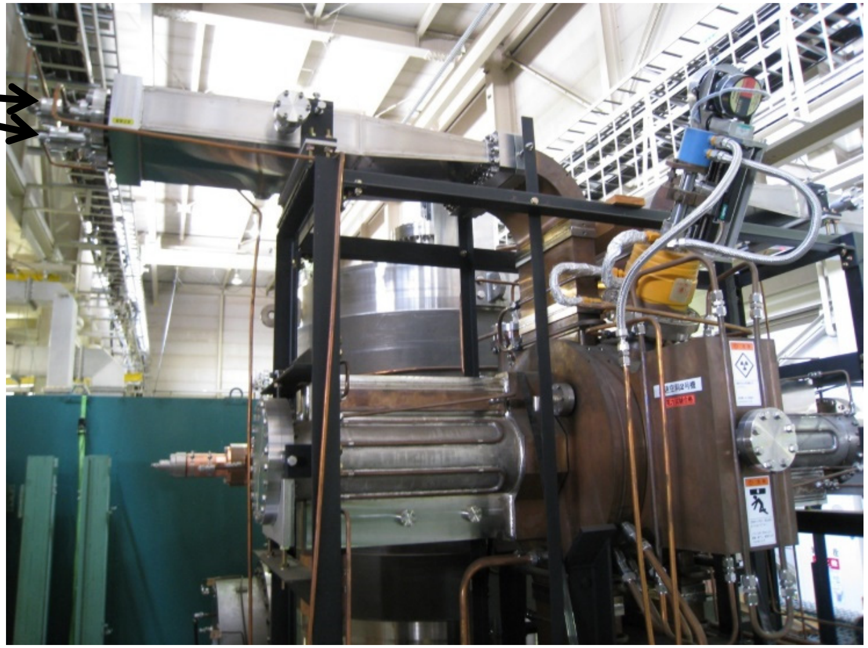


Type_1: HOM WGs (HWG)

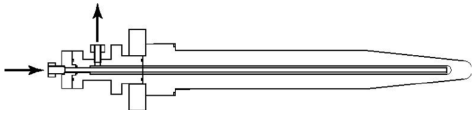


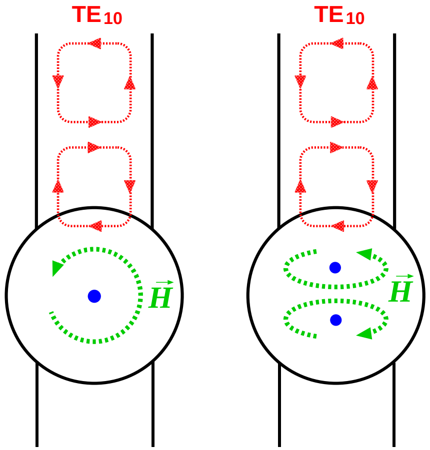
HOM absorber





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



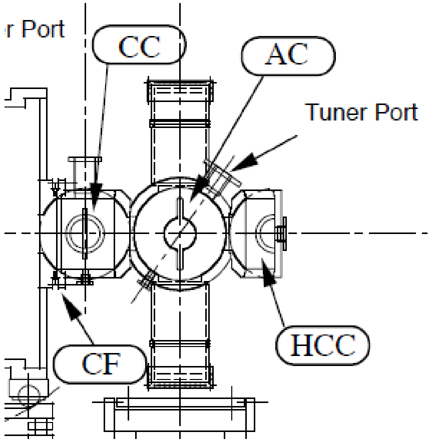


For damping

- ✓Monopole HOMs
- ✓Vertically-polarized dipole modes

Note:

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

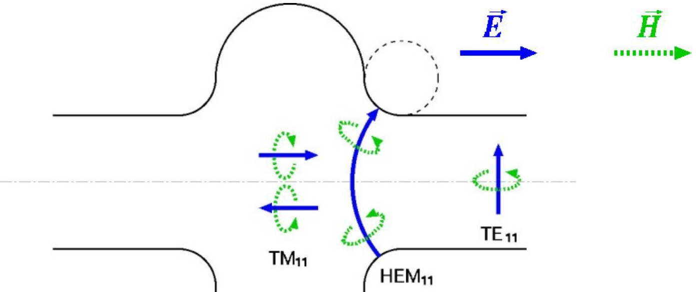


Type_2: Grooved Beam Pipe (GBP)

For damping

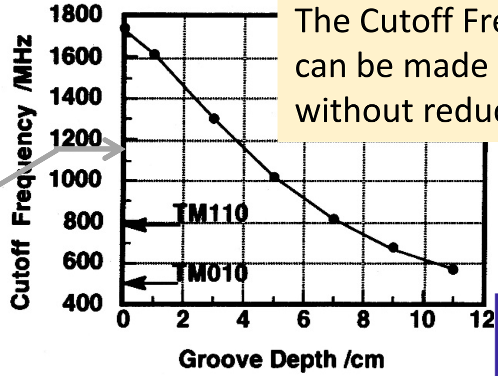
✓Horizontally-polarized dipole modes

In the case of SCCs



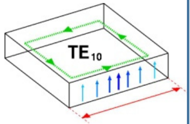
Needs large ducts, which reduce Rsh.

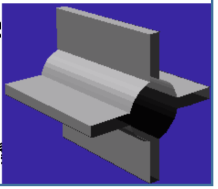
In the case of ARES (NC)



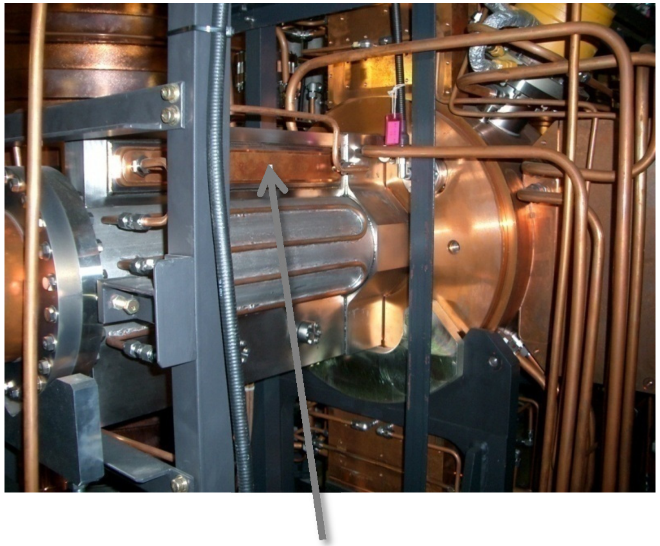
The Cutoff Freq. of TE in GBP can be made lower without reducing Rsh.

Cutoff Freq. of TE11 in a Regular ϕ150 Duct

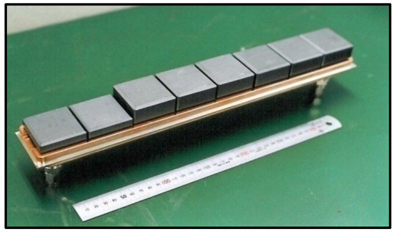




T. Kageyama, “Grooved Beam Pipe for Damping Dipole Modes in RF Cavities," KEK-PREPRINT- 91-133, 1991.



HOM absorber



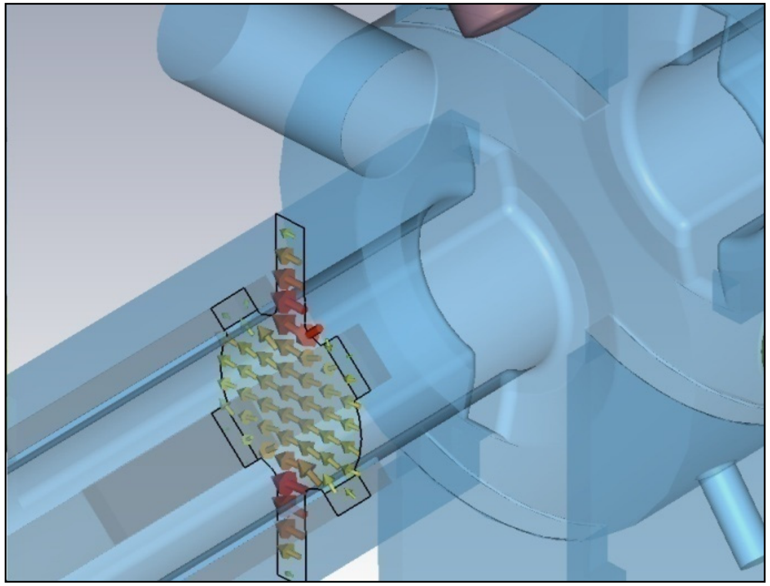
✓SiC ceramics tiles

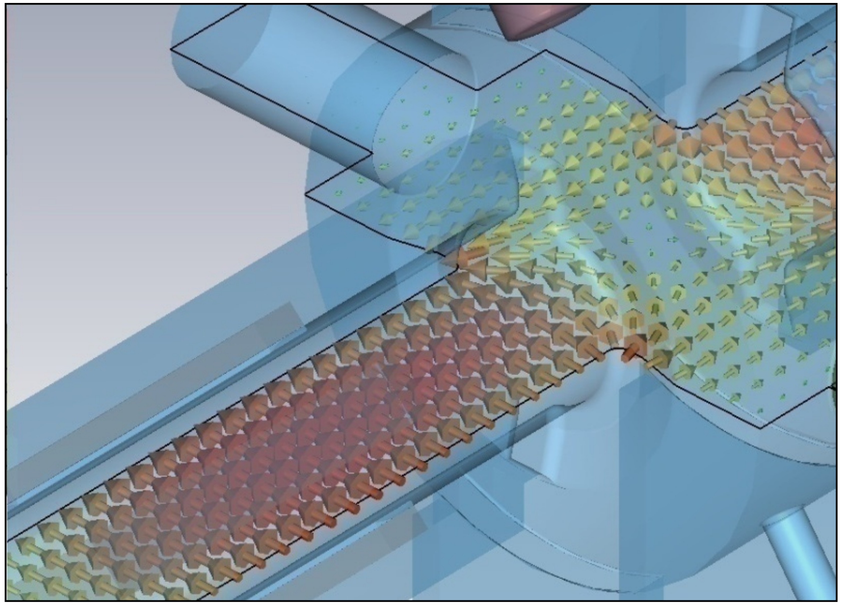
✓Indirectly water-cooled

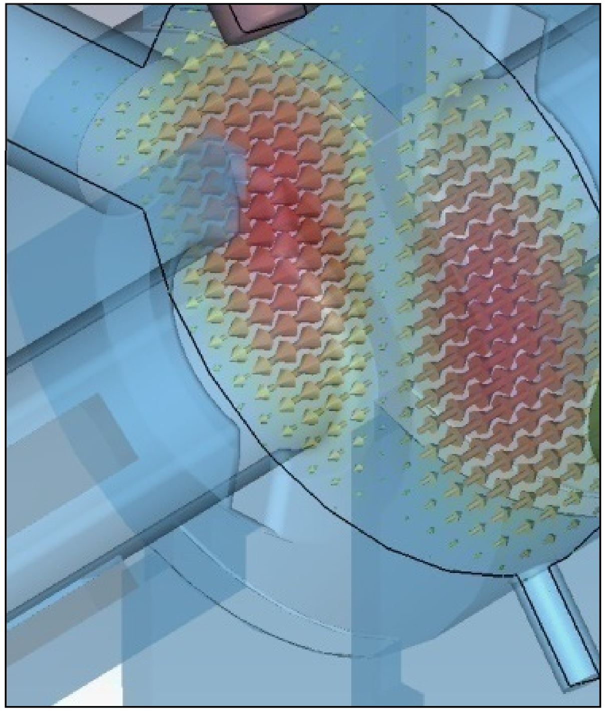
Type_2: Grooved Beam Pipe (GBP)

Electric-field Vectors

TE mode in GBP



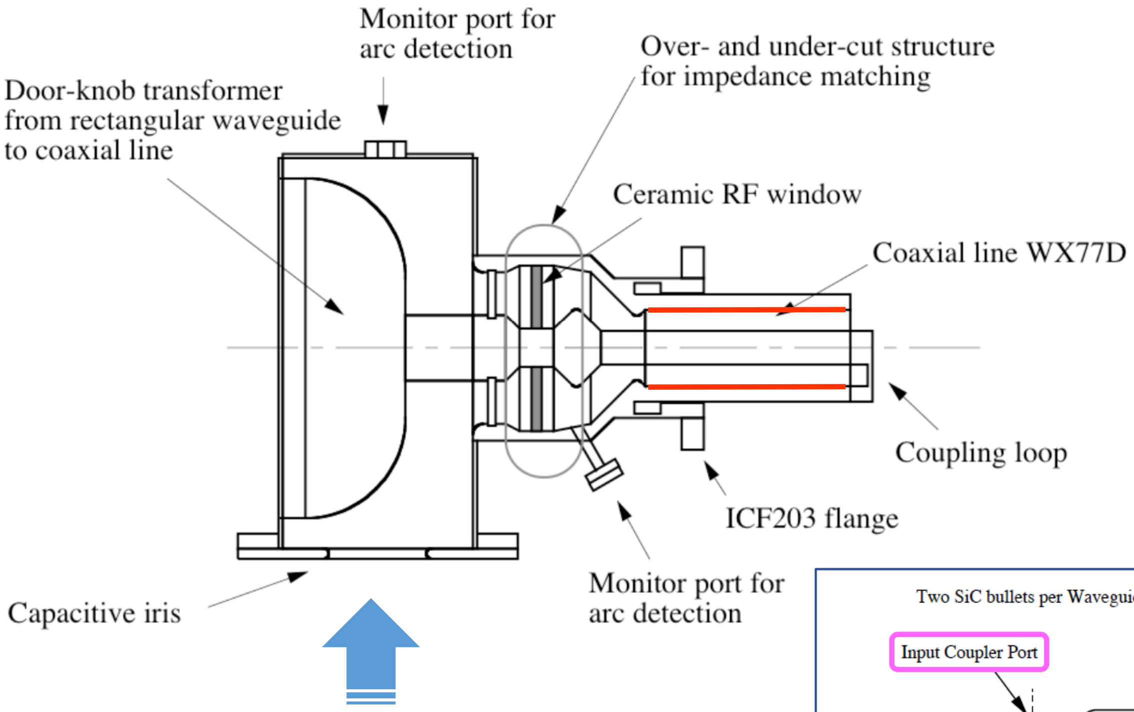




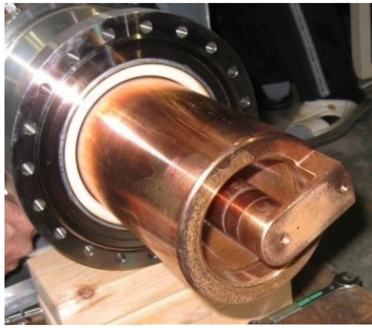
TM$_{110}$

ARES

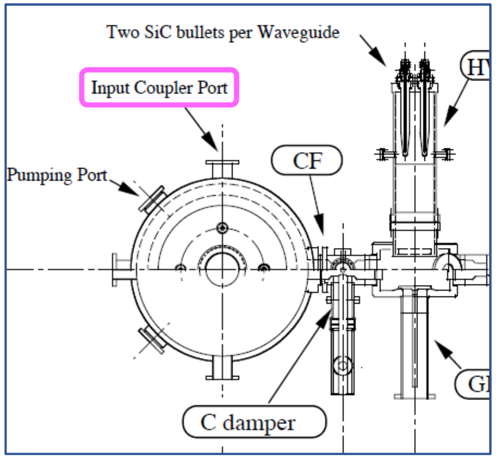
-- *High-Power Input Coupler* --

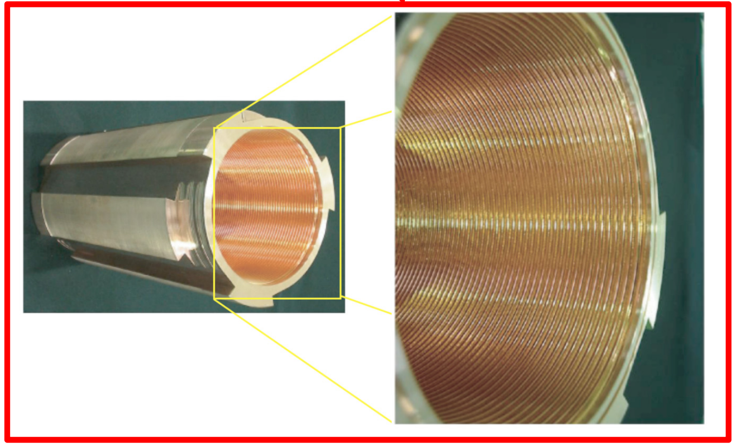


RF Power comes via a rectangular WG (WR-1500).



- Coaxial line with a coupling loop
- Couples to TE$_{013}$ in SC
- Disk-type RF ceramic window with a TiN coating
  - Arc sensors to detect discharge
- Conditioned up to 750-800kW (traveling wave)
- Input coupling factor: β=3
- Fine grooving on the outer conductor to avoid multipactoring in the coaxial line



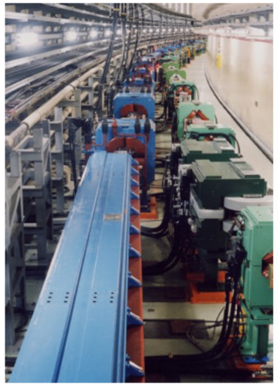


T. Abe, et al., Phys. Rev. ST Accel. Beams 13, 102001 (2010)

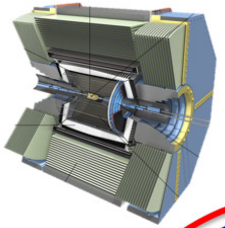
Upgrade to SuperKEKB

Upgrade to SuperKEKB

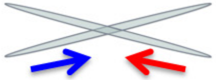
based on the "nan-beam scheme" (first proposed for SuperB in Italy)

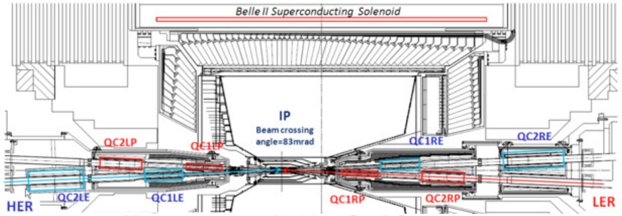


Upgrade to Belle II detector

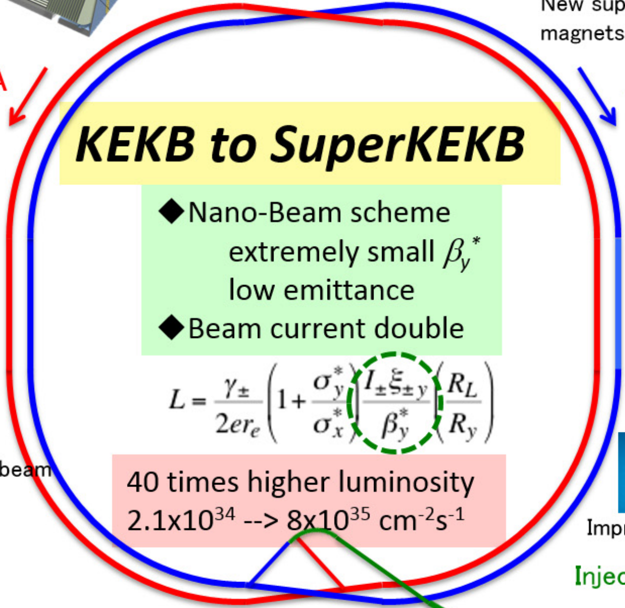


Colliding bunches





New superconducting final focusing magnets near the IP



e$^+$ 3.6A

LER

e$^-$ 2.6A

HER

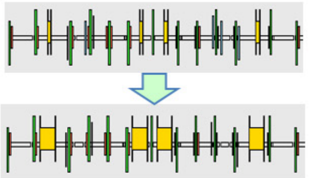
KEKB to SuperKEKB

- ◆Nano-Beam scheme
  - extremely small β_y^*
  - low emittance
- ◆Beam current double

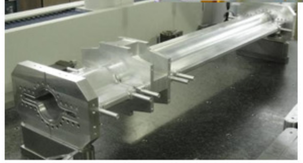
$$L = \frac{\gamma_\pm}{2er_e}\left(1+\frac{\sigma_y^*}{\sigma_x^*}\right)\left(\frac{I_\pm\xi_{\pm y}}{\beta_y^*}\right)\left(\frac{R_L}{R_y}\right)$$

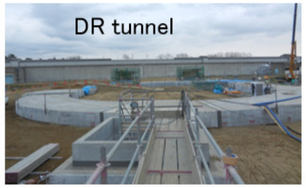
40 times higher luminosity
2.1x10^{34} --> 8x10^{35} cm^{-2}s^{-1}

Redesign the lattice to squeeze the emittance (replace short dipoles with longer ones, increase wiggler cycles)



Replace beam pipes with TiN-coated beam pipes with antechambers





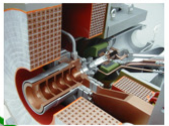
New e+ Damping Ring

Reinforce RF systems for higher beam currents

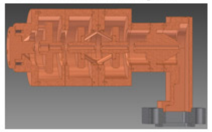
Improve monitors and control system

Injector Linac upgrade

Upgrade positron capture section



Low emittance RF electron gun



K. AKAI, Overview of ring construction status and schedule, 19th KEKB Accelerator Review, Mar. 3, 2014, KEK

Main Upgrade Items on the SuperKEKB/MRs

◆**Very Low Emittance**

  ➢LER/HER: 18/24 nm → 3.2/4.3-4.6 nm

  ➢With the upgrades of the magnet system, optics, and injector linac

◆**Squeeze β_y^* to be as small as possible**

  ➢LER/HER: 6.5/5.9 mm → 0.27/0.30 mm

  ➢With the upgrades of the magnet system / IR and optics

◆**Beam energy change**

  ➢LER/HER: 3.5 / 8 (KEKB) → 4 /7 GeV

  ➢To achieve longer Touschek lifetime for LER

◆**Higher beam currents**

  ➢LER/HER: 1.8A / 1.4A → 3.6A / 2.6A

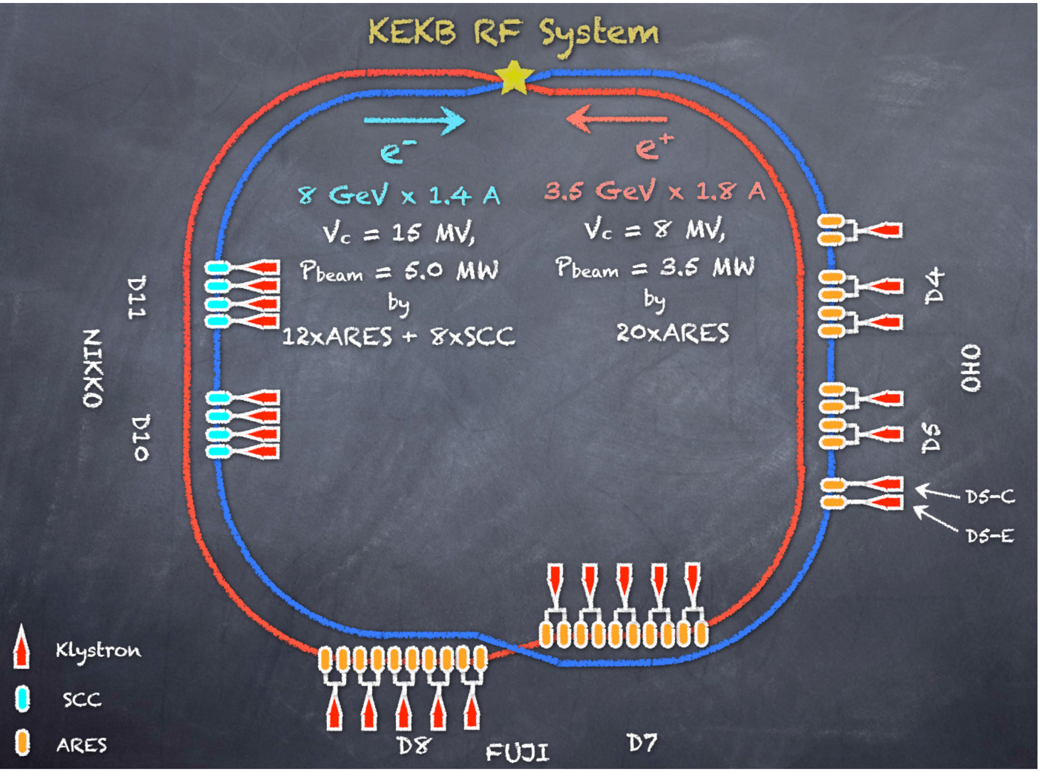
  ➢With the upgrades of various components (vacuum, RF, etc.)

◆x40 higher peak luminosity (→$8\times10^{35}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$)

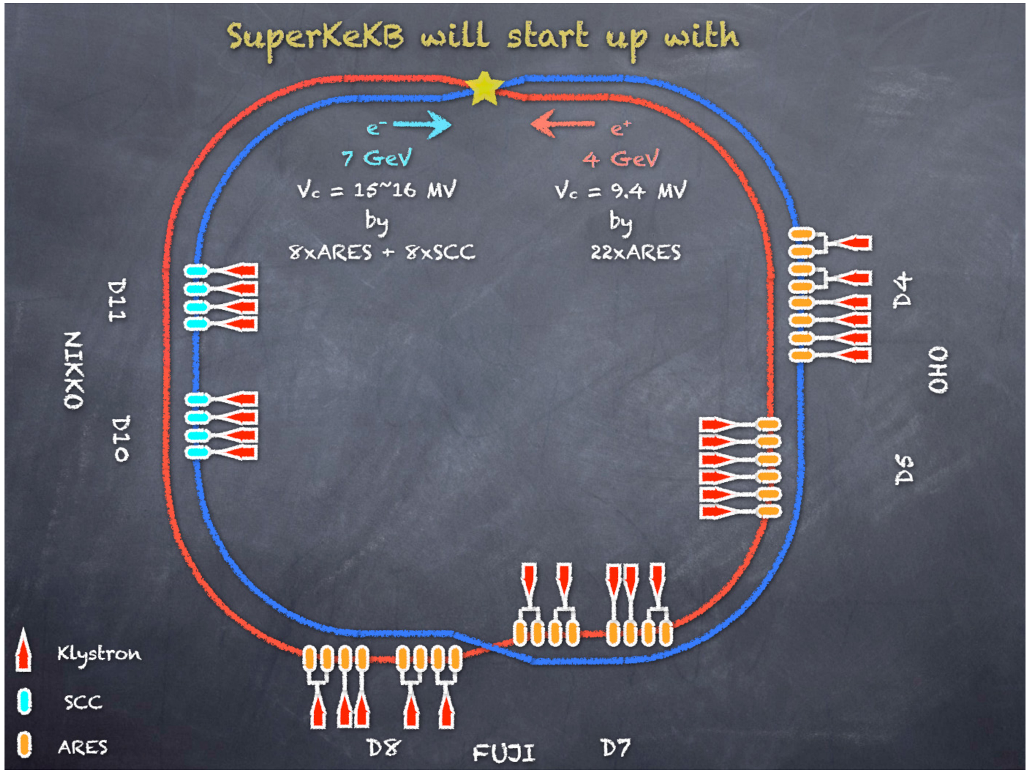
◆x50 integrated luminosity in several-years operation (→$50\ \mathrm{ab}^{-1}$)

RF Cavities for SuperKEKB

In KEKB



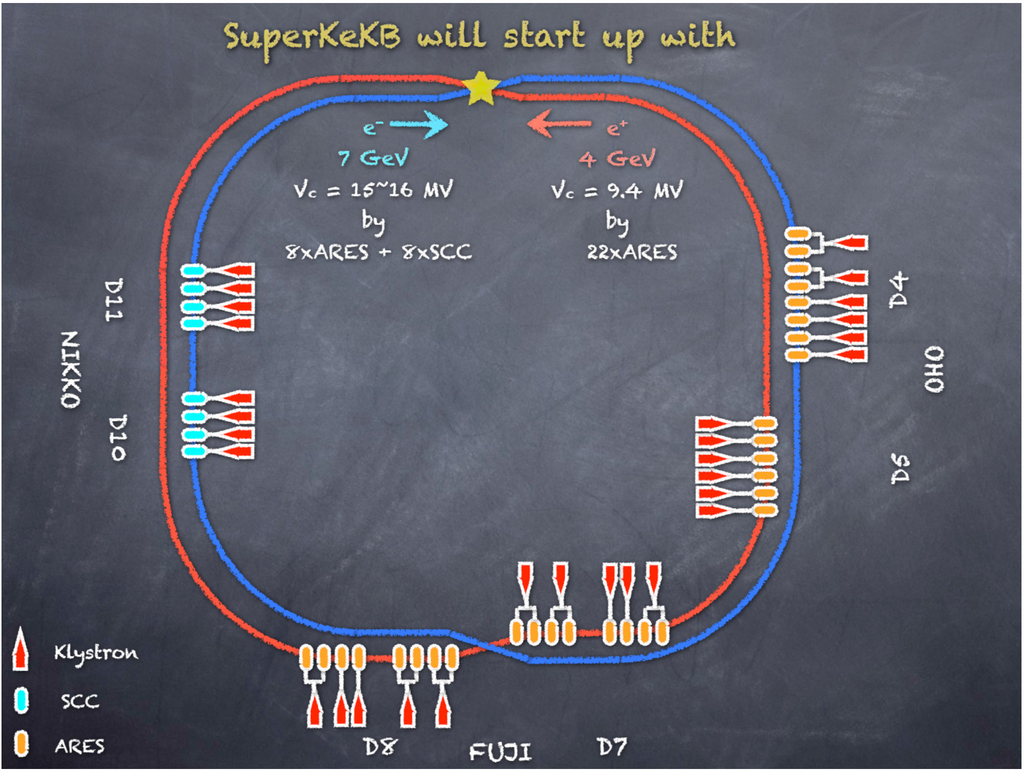
"T=0" in 2015



(Shown by T. Kageyama at KEKB Review 2011)

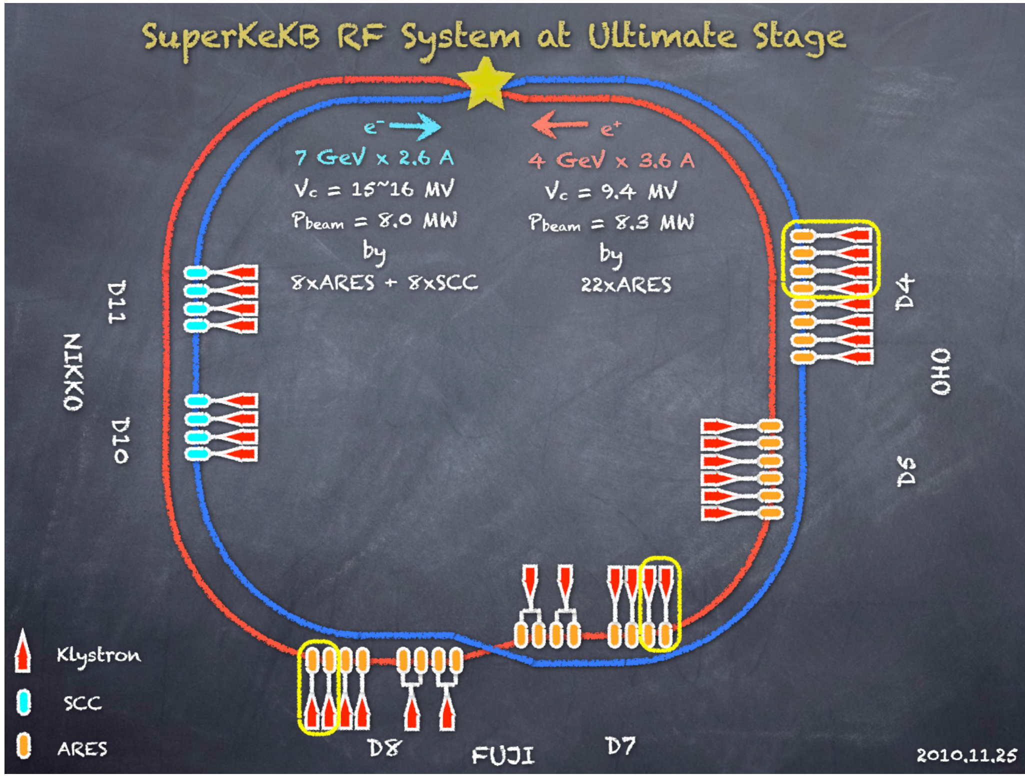
RF Cavities for SuperKEKB

“T=0” in 2015



SuperKeKB will start up with

In 20XX



SuperKeKB RF System at Ultimate Stage

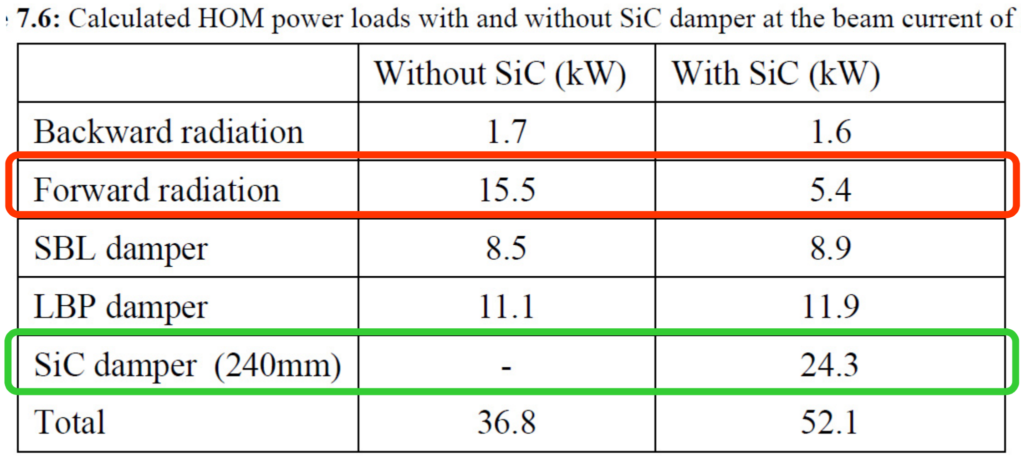
(Shown by T. Kageyama at KEKB Review 2011)

Upgrade on SCC

Parameter	KEKB (design)	KEKB (achieved)	SuperKEKB (design)
Beam energy [GeV]	8.0	8.0	7.0
Beam current [A]	**1.1**	**1.4**	**2.6**
Bunch charge [nC]	2	10	10
Bunch length [mm]	4	6	5
Cavity voltage [MV]	1.5	1.2-2.0	1.5
Beam power [kW/cav]	250	400	400
HOM power [kW/cav]	**5**	**16**	**37**

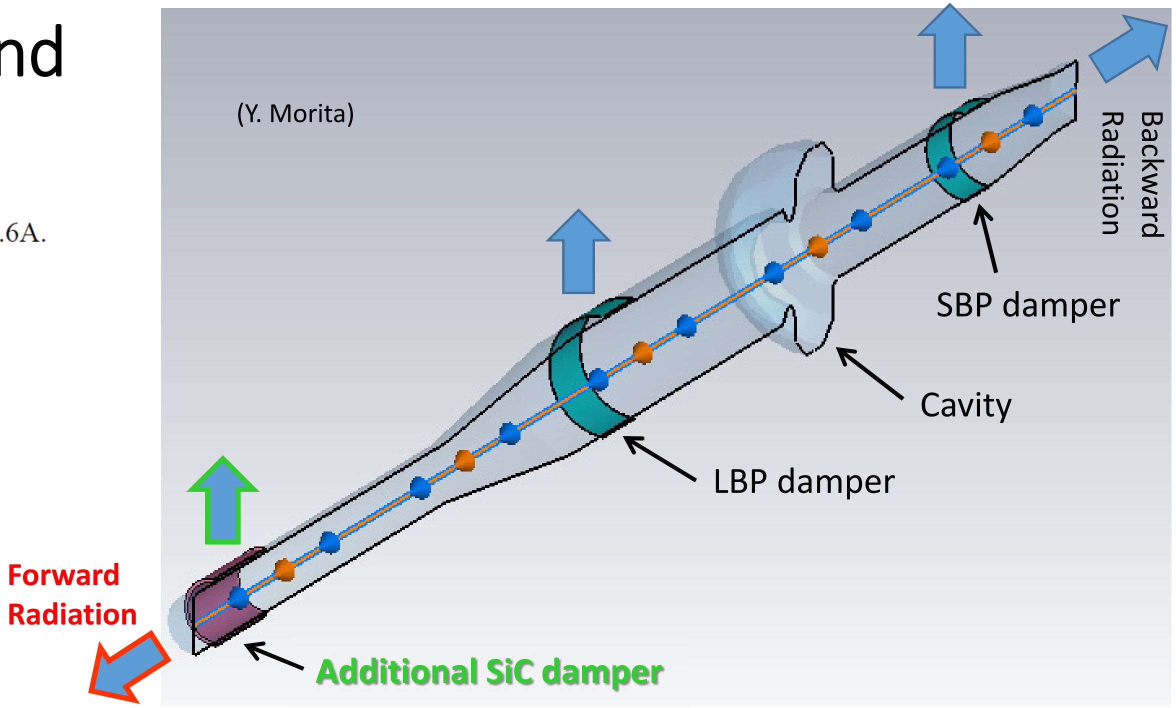
- ✓ **Re-use of the cavities with their main bodies not changed**
- ✓ **Adjustment of Q_{ext} of the input couplers by changing the thickness of the gaskets for the inner conductors**
- ✓ **Measures for such large HOM power absorption to be taken**
  - **Reduction of HOM power loads to decrease Ferrite temperature and outgas**
  - **Additional HOM damper (SiC duct)**

Full simulation of the Wakefield and Power Flow using CST-PS



7.6: Calculated HOM power loads with and without SiC damper at the beam current of 2.6A.

	Without SiC (kW)	With SiC (kW)
Backward radiation	1.7	1.6
Forward radiation	15.5	5.4
SBL damper	8.5	8.9
LBP damper	11.1	11.9
SiC damper (240mm)	-	24.3
Total	36.8	52.1

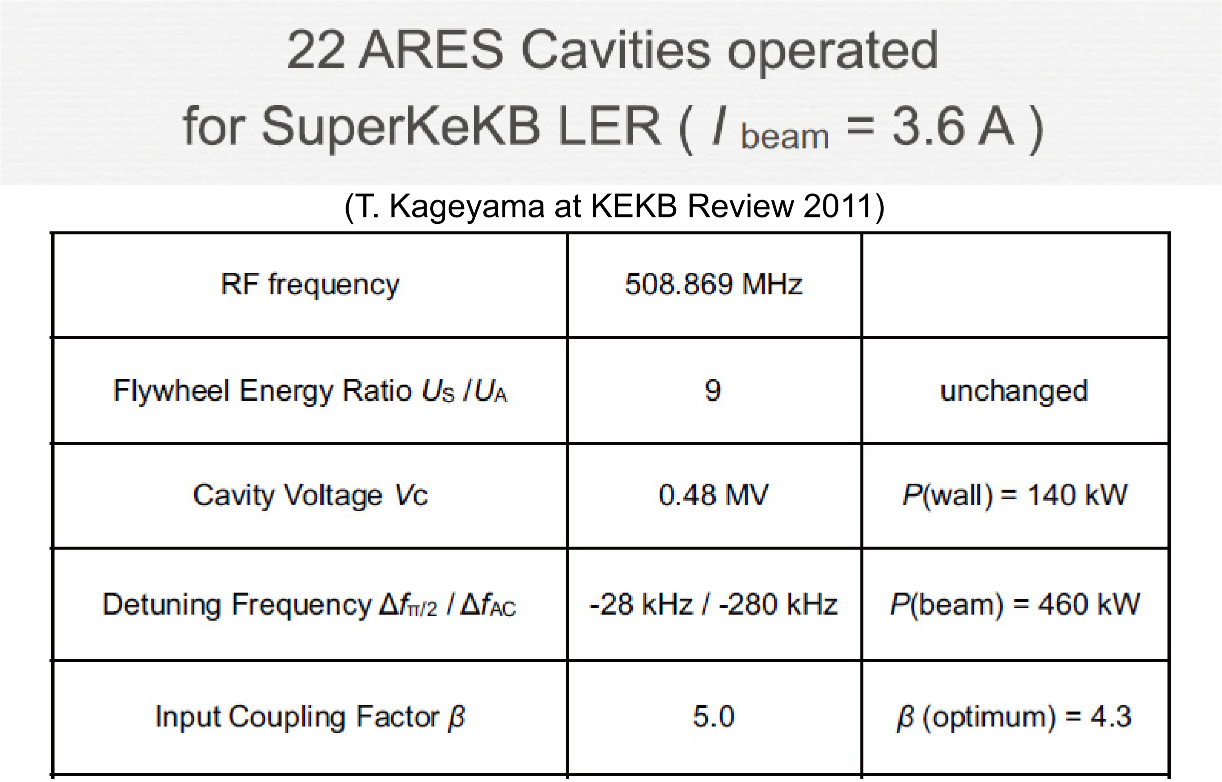


We have found that:

- ✓ **RF power absorbed in each damper is under the capability demonstrated at the test bench (@508.9MHz):**
  - **SBP damper: 19kW**
  - **LBP damper: 25kW**
- ✓ **The forward radiation power w/o the SiC damper is too high (15.5kW), which reaches a neighboring cavity.**
- ✓ **With the SiC damper,**
  - **The forward radiation power becomes acceptable (5.4kW).**
  - **No need to change the present Ferrite dampers**

R&D of the additional SiC damper is on-going.

Upgrade on ARES



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

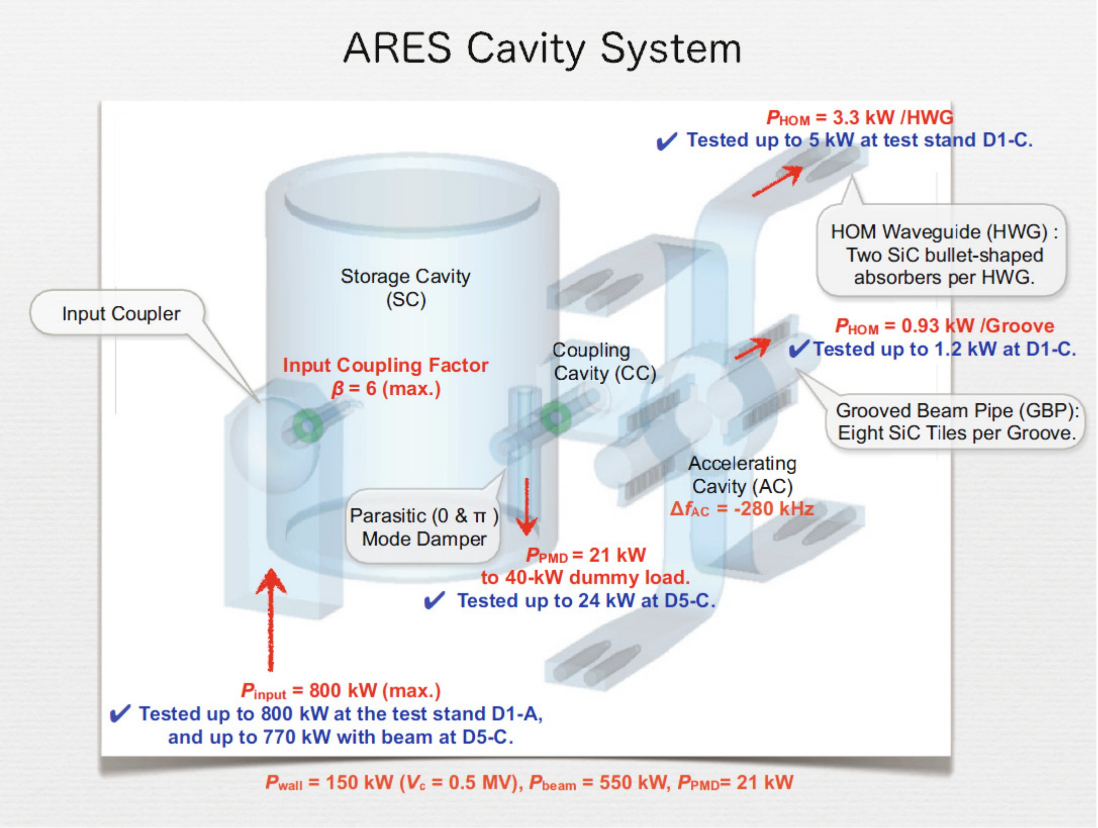
(T. Kageyama at KEKB Review 2011)

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

At KEKB
- β(optimum) = 3
- β_{max} = 5

✓ Re-use of the cavities with their main bodies not changed (U_s/U_a=9)
✓ Twice the input power (~800kW) for the Klys:Cav=1:1 stations
✓ Increase max. β (β_{max} = 5→6)
✓ Check the HOM powers

Check the HOM powers at SuperKEKB/LER



ARES Cavity System

P_{HOM} = 3.3 kW /HWG
✔ Tested up to 5 kW at test stand D1-C.

HOM Waveguide (HWG) : Two SiC bullet-shaped absorbers per HWG.

Storage Cavity (SC)

Input Coupler

Input Coupling Factor
β = 6 (max.)

Coupling Cavity (CC)

P_{HOM} = 0.93 kW /Groove
✔ Tested up to 1.2 kW at D1-C.

Grooved Beam Pipe (GBP): Eight SiC Tiles per Groove.

Accelerating Cavity (AC)
Δf_{AC} = -280 kHz

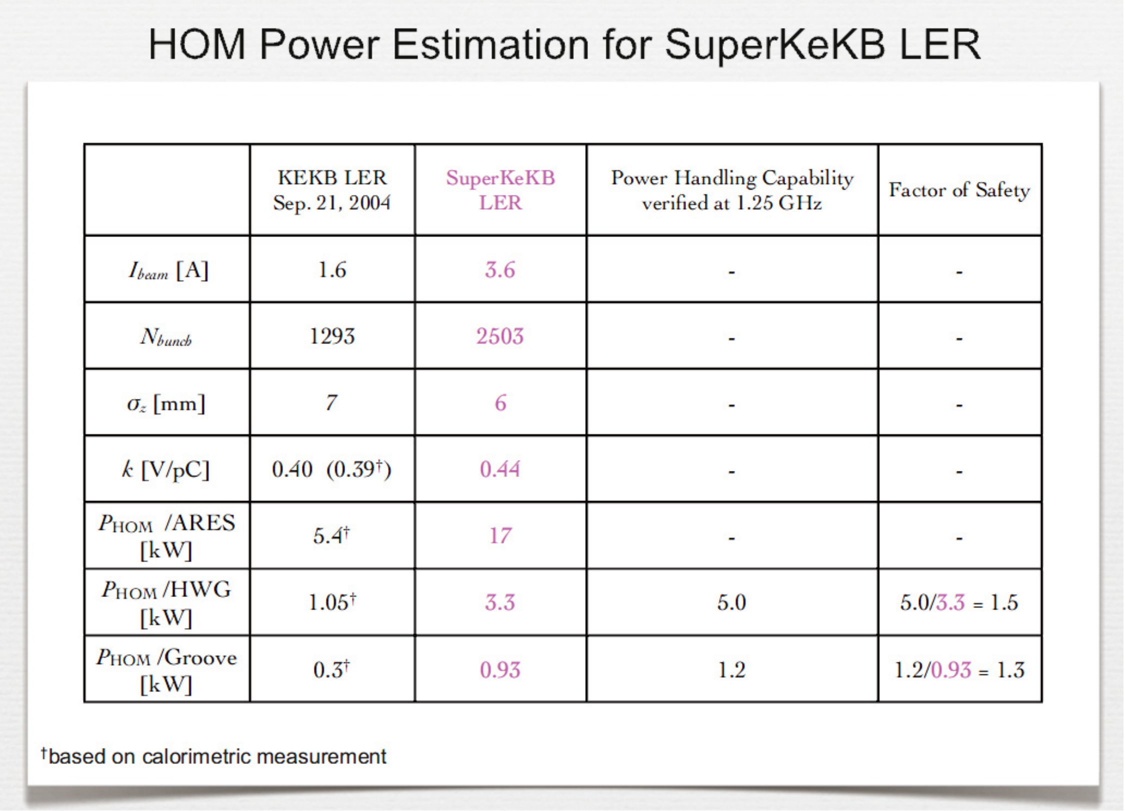
Parasitic (0 & π) Mode Damper

P_{PMD} = 21 kW
to 40-kW dummy load.
✔ Tested up to 24 kW at D5-C.

P_{input} = 800 kW (max.)
✔ Tested up to 800 kW at the test stand D1-A,
and up to 770 kW with beam at D5-C.

P_{wall} = 150 kW (V_c = 0.5 MV), P_{beam} = 550 kW, P_{PMD}= 21 kW

(T. Kageyama at KEKB Review 2011)



HOM Power Estimation for SuperKeKB LER

	KEKB LER Sep. 21, 2004	SuperKeKB LER	Power Handling Capability verified at 1.25 GHz	Factor of Safety
I_{beam} [A]	1.6	3.6	-	-
N_{bunch}	1293	2503	-	-
σ_z [mm]	7	6	-	-
k [V/pC]	0.40 (0.39†)	0.44	-	-
P_{HOM} /ARES [kW]	5.4†	17	-	-
P_{HOM} /HWG [kW]	1.05†	3.3	5.0	5.0/3.3 = 1.5
P_{HOM} /Groove [kW]	0.3†	0.93	1.2	1.2/0.93 = 1.3

†based on calorimetric measurement

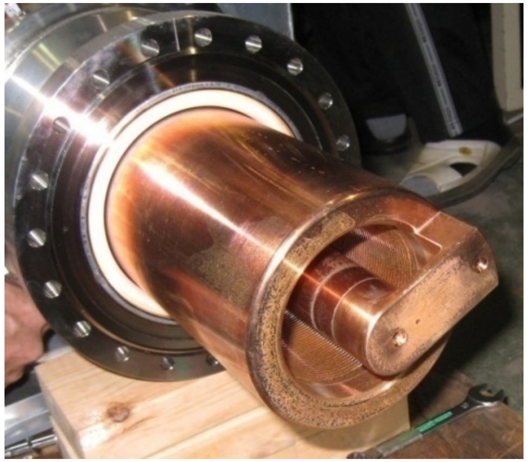
(T. Kageyama at KEKB Review 2011)

⇨ **No need to upgrade the HOM dampers of ARES**

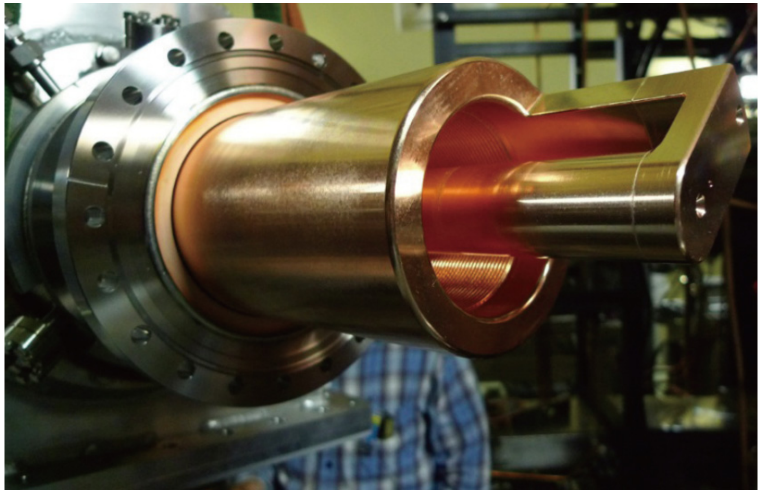
(just increase the cooling-water flow rates)

Increasing the Input Coupling Factor

Input couplers with increased input coupling (β_{max} = 5→6) needed for the stations with the Klys:Cav=1:1 configuration to accelerate beams with the design current of LER.



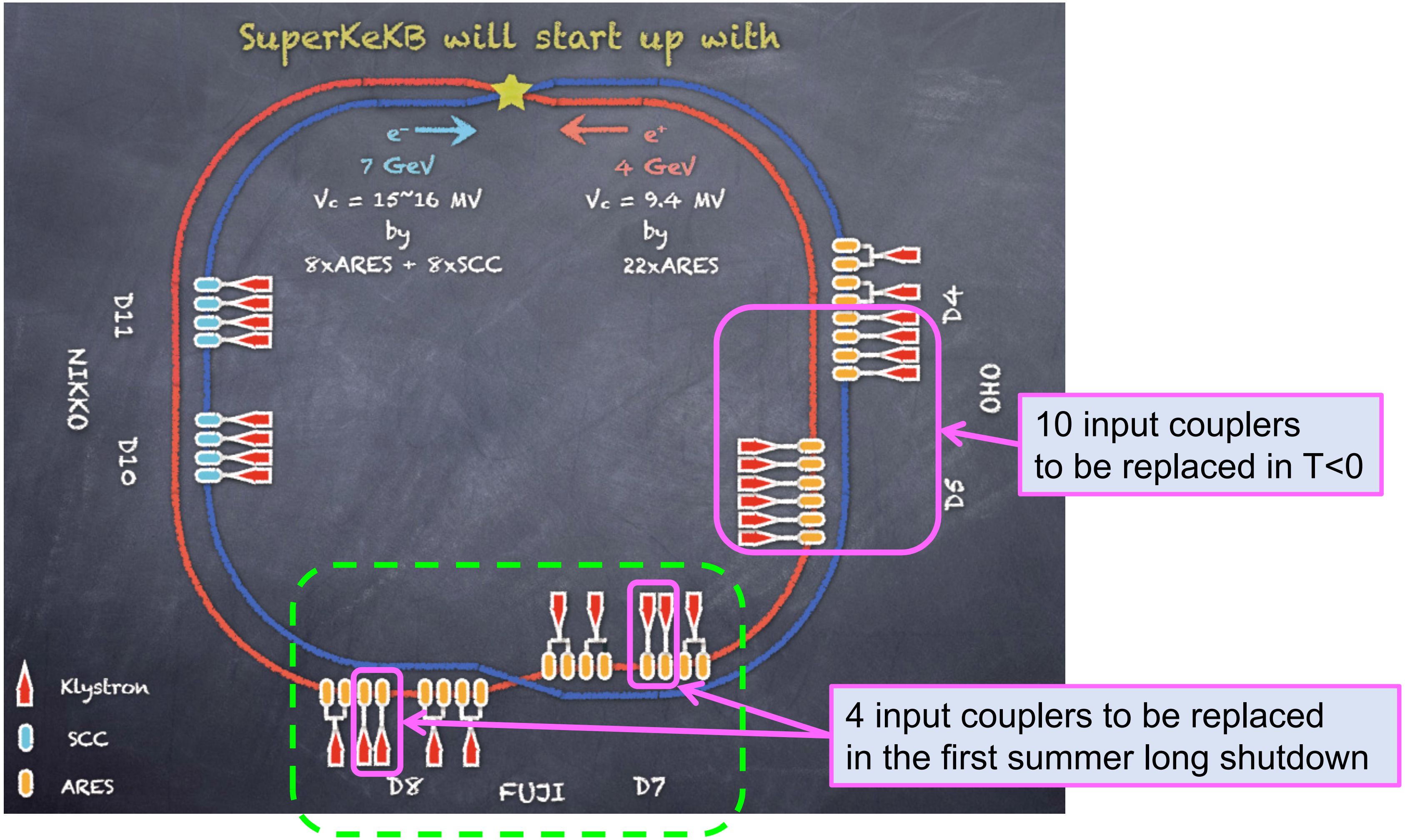
Used at the KEKB/MRs



With increased input coupling for the SuperKEKB/LER

Production and high-power test at the test stand on-going

For “T=0” in 2015

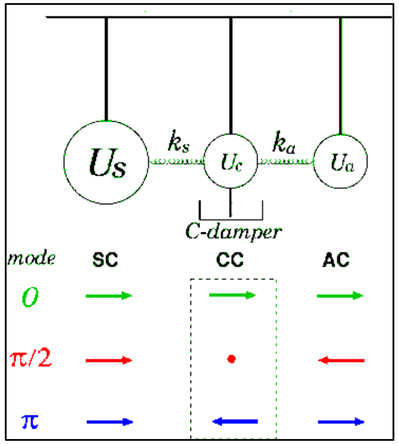


10 input couplers
to be replaced in T<0

4 input couplers to be replaced
in the first summer long shutdown

No vacuum break
since the KEKB operation ended.

CBIs at SuperKEKB/LER
driven by



■ Fundamental modes
- ● Accelerating mode (π/2 mode)
- ● Parasitic modes (0 and π modes)

■ HOM impedances
- ● Longitudinal
- ● (Transverse)

No problem from the simulation results

(For the details, see Appendix A.)

RF Cavity for the Positron Damping Ring (DR)

Positron Damping Ring

for low-emittance injection to SuperKEKB/LER

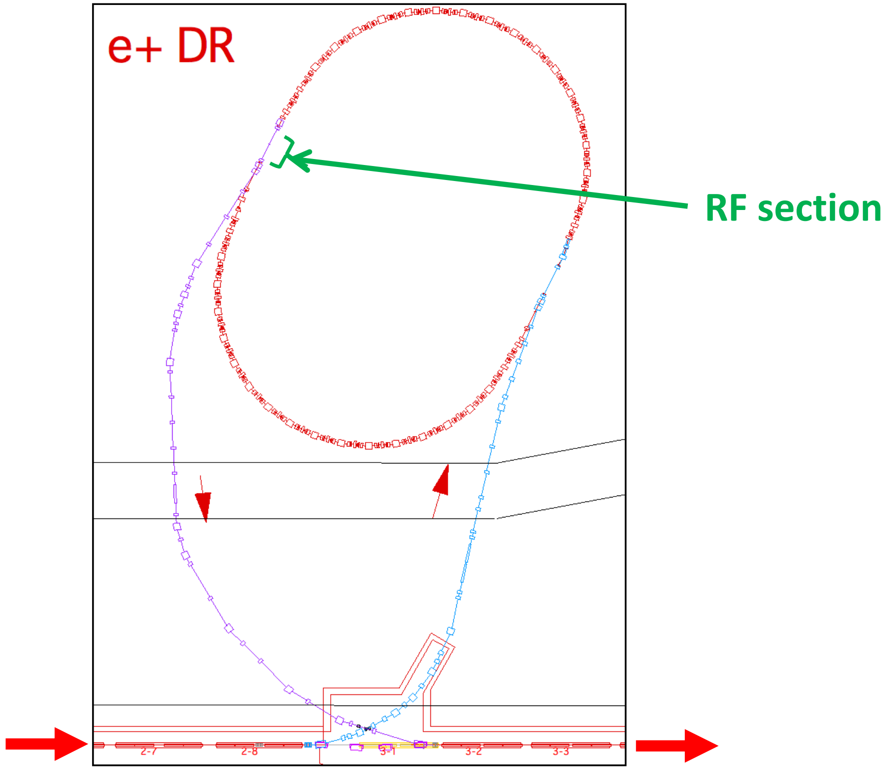
Parameters of the Damping Ring			MAC10
Energy	1.1	GeV	1.0
No. of bunch trains/ bunches per train	2 / 2		
Circumference	135.5	m	
Maximum stored current*	70.8	mA	
Energy loss per turn	0.091	MV	
Horizontal damping time	10.9	ms	12.7
Injected-beam emittance	1700	nm	2100
Equilibrium emittance(h/v)	41.4 / 2.07	nm	14 / 1.4
Coupling	5	%	10
Emittance at extraction(h/v)	42.5 / 3.15	nm	17.6 / 5.1
Energy band-width of injected beam	± 1.5	%	
Energy spread	0.055	%	
Bunch length	6.5	mm	5.4
Momentum compaction factor	0.0141		0.0019
Number of normal cells	32		
Cavity voltage for 1.5 % bucket-height	1.4	MV	0.26
RF frequency	509	MHz	
Inner diameter of chamber	32	mm	
Bore diameter of magnets	44	mm	

CSR

* 8 nC/bunch

(Shown by M. Kikuchi at KEKB Review 2011)

(N.Iida)

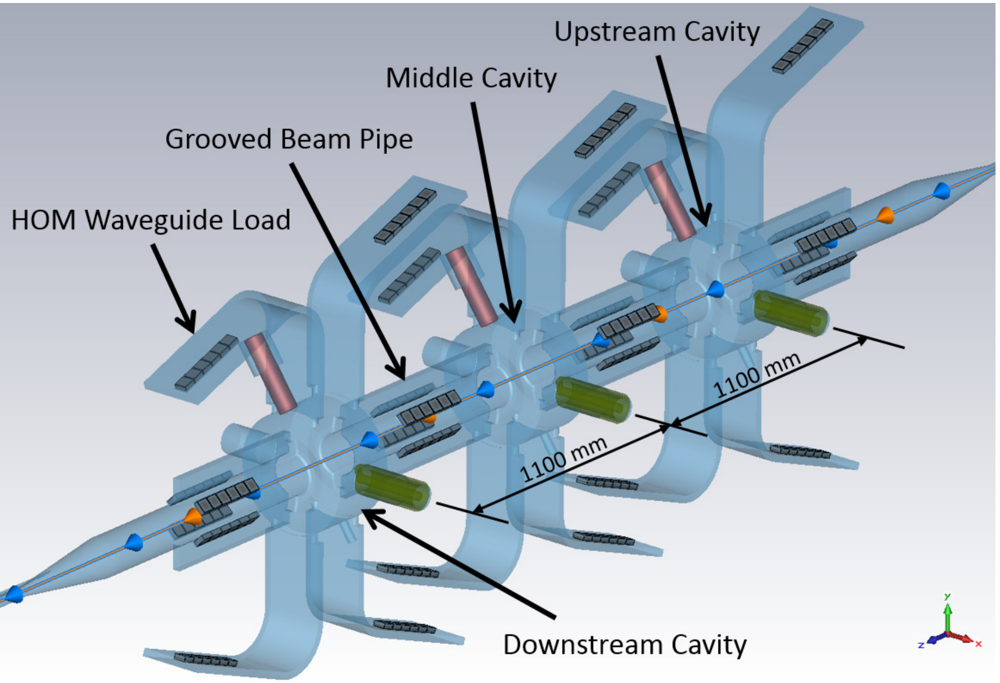


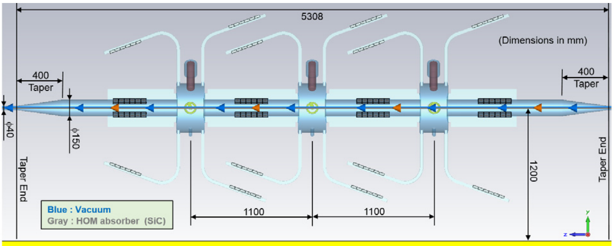
Injector Linac

- ✓Construction of the tunnel and facility finished
- ✓Installation of magnets, chambers, cavities, etc. this and next years

NC RF Accelerating Structure for the DR

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

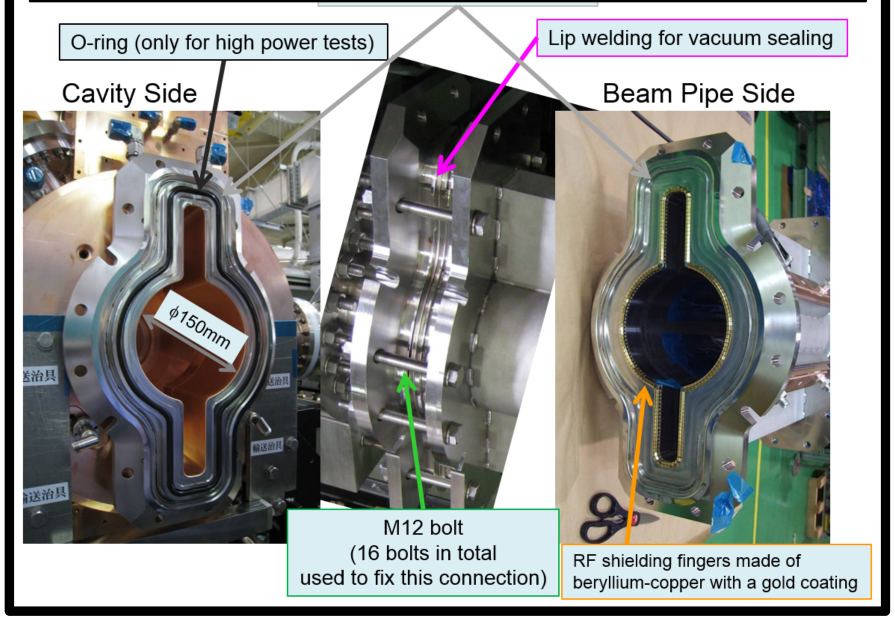




- ■ RF operation frequency: 508.9MHz
  - ● Same as that of the MRs
- ■ Based on the HOM-damped structure of the successful ARES cavity system
- ■ Three cavities at max. to be installed in a space originally designed for one cavity (~3m in the beam direction)
  - ● Total V_c = 2.4MV at max.
- ■ Apart from the CC and SC of 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
  - ● 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 dampers 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.

Components of the RF Structure except for the cavity

Solid connection between the cavity and GBP

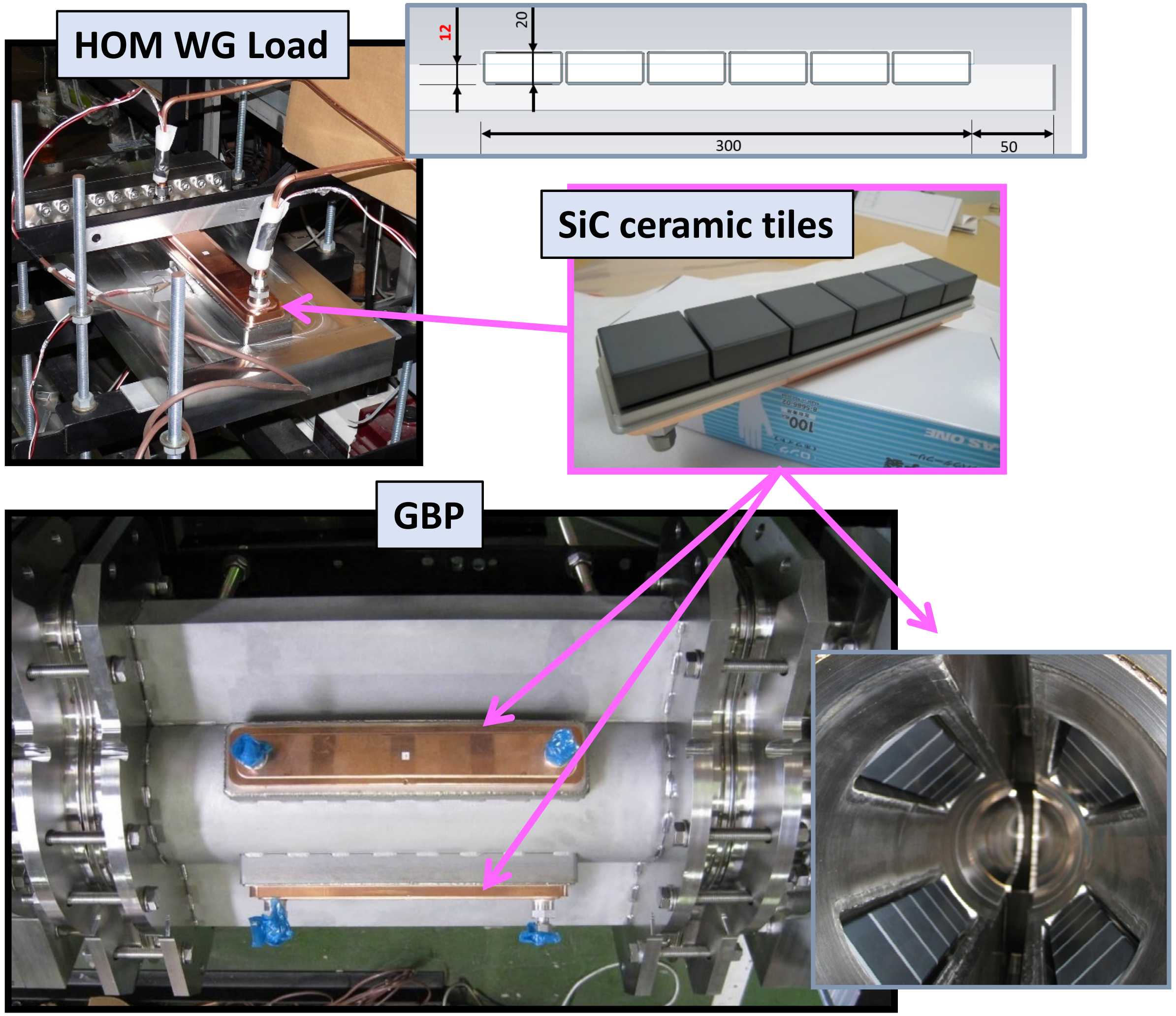


O-ring (only for high power tests)

Lip welding for vacuum sealing

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

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



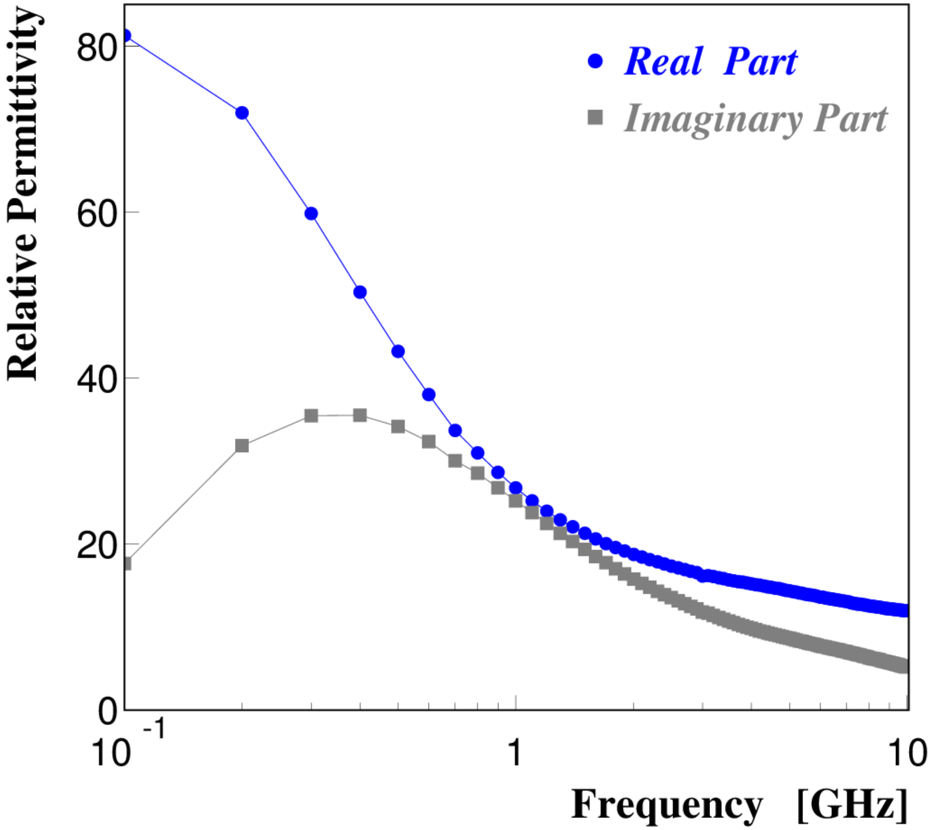
HOM WG Load

SiC ceramic tiles

GBP

Permittivity of the SiC ceramic tiles

Typical Measurements of SiC ceramics



Relative permittivity of the SiC ceramics (CERASIC-B), as a function of frequency, used in designing this accelerating structure.
These permittivity values are typical measurements on the SiC ceramic tiles used for the GBPs of the ARES.

Permittivity of SiC ceramics largely depends on

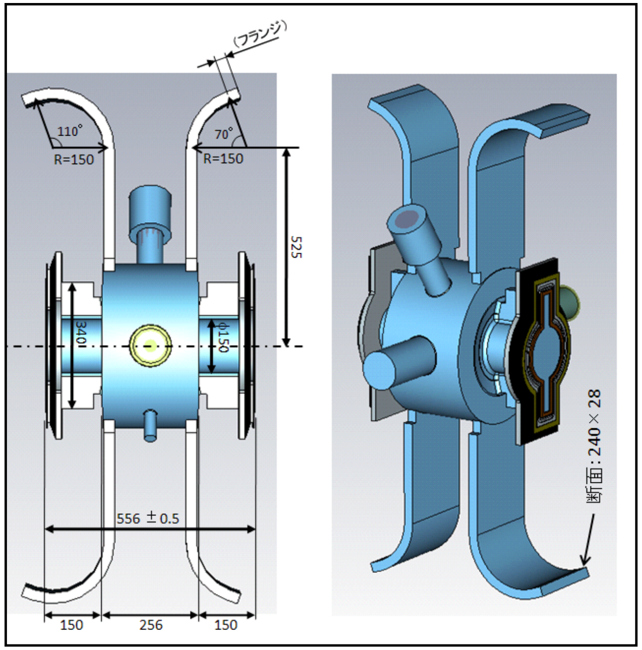
- Source SiC powders
- Sintering conditions of SiC ceramics

We aggressively controlled the permittivity by changing the amount of aluminum contained in the SiC powder so that the permittivity should be close to that used in designing the accelerating structure.

Y. Takeuchi, et al., “Control of RF Dielectric Properties of SiC Ceramics for HOM Absorbers", in Proceedings of the 8th Annual Meeting of Particle Accelerator Society of Japan, Aug. 2011 (Paper ID: TUPS137)

DR Cavity

Cavity No.1 just after its delivery, cooling pipes not yet attached



■Highest-Purity Copper Resonators
■Gap length: 256 mm
■R/Q_0=150 Ohms
■Q_0=~$3x10^5$
■V_c=0.8 MV/cav
■P_c=130kW
■E_{sp}/E_{acc} = 3.6

1. Prototype made in JFY2011
   - Surface protection of the endplates: acid cleaning followed by chromating
2. Cavity No.1 made in JFY2012
   - Based on the prototype
   - Surface protection of the endplates: electro-polishing
3. Cavity No.2 made in JFY2013
   - Surface protection of the endplates: electro-polishing

The Endplates of Cavity No.1 and No.2 Electro-Polished (EP)

✓Material: OFHC(class1)
✓Etching: 40μm

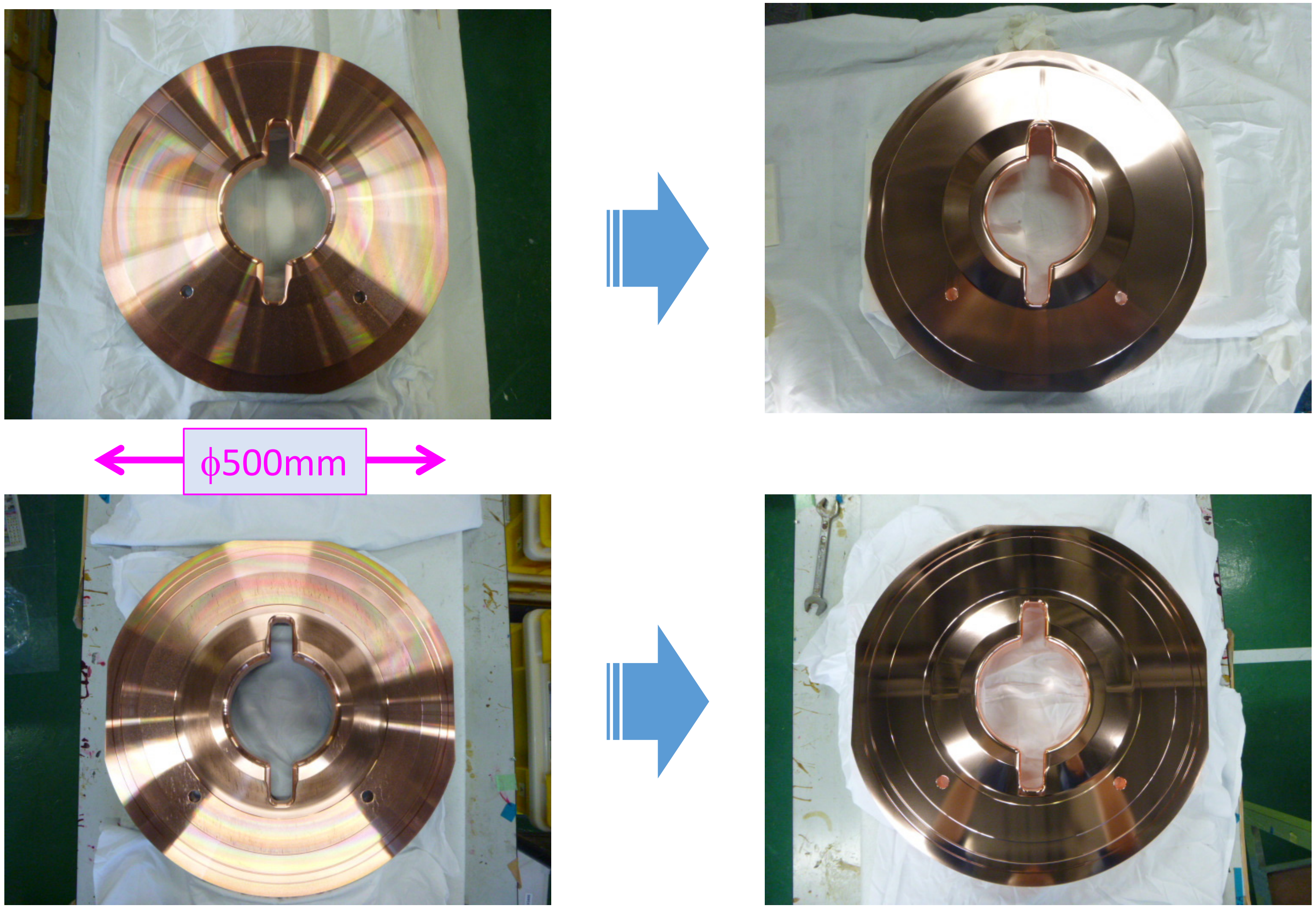
(Skin depth@500MHz: 3μm for copper)

Before EP
R_a=~1.5μm

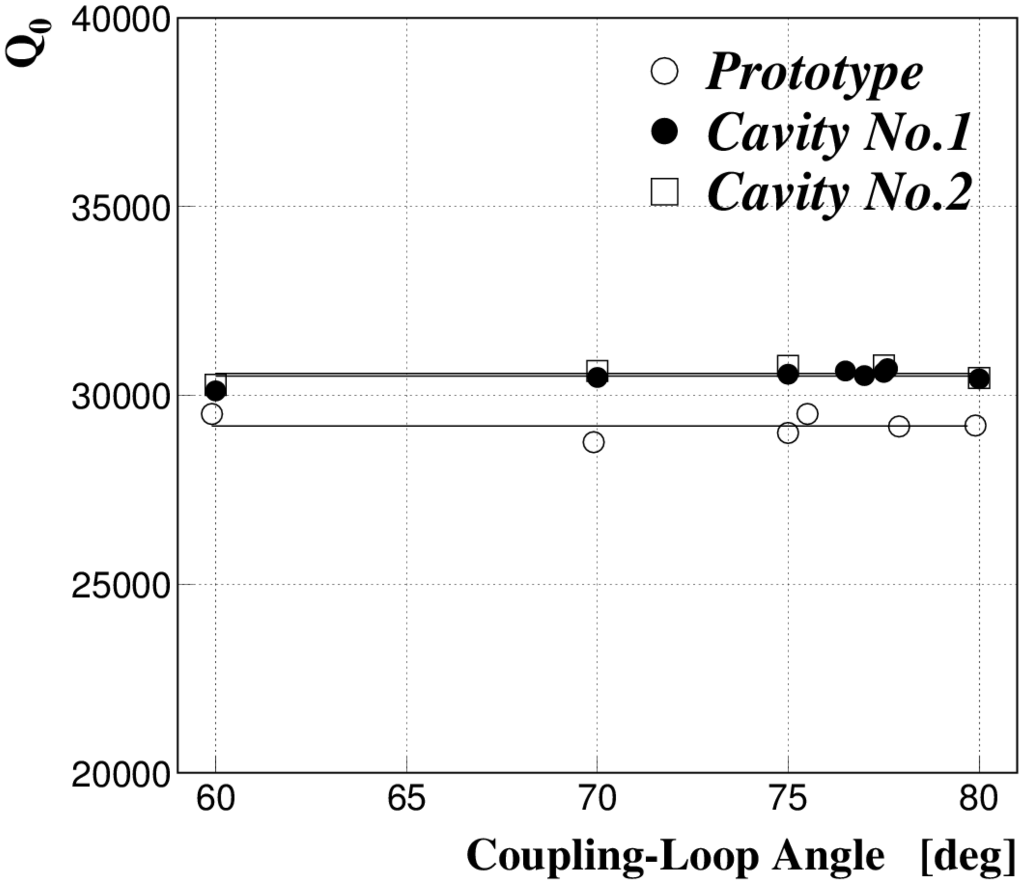
After EP
R_a=~0.2μm

Endplate
w/o the tuning bump

Endplate
w/ the tuning bump



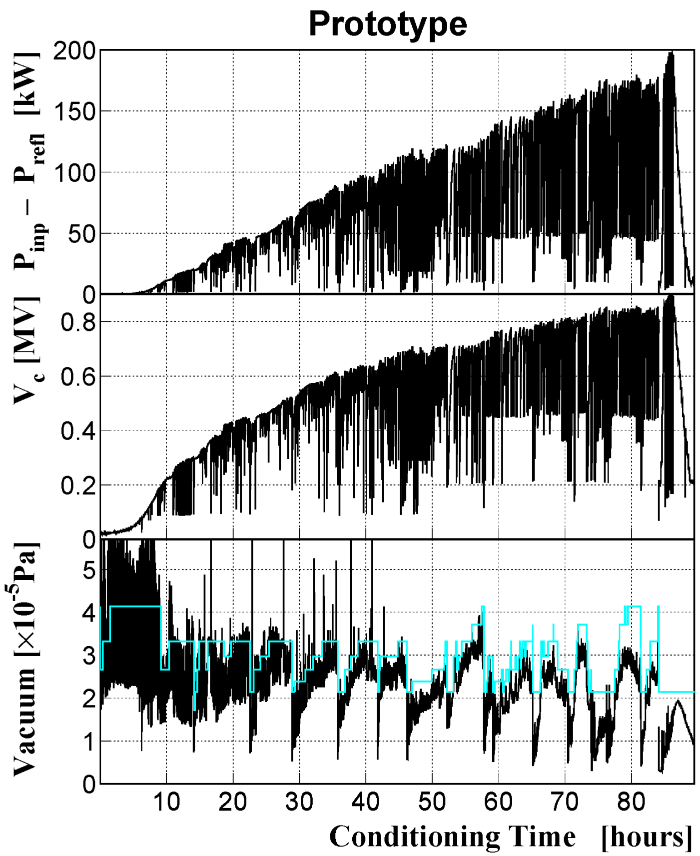
Low-Power Measurements of Unloaded Q-factor (Q_0)

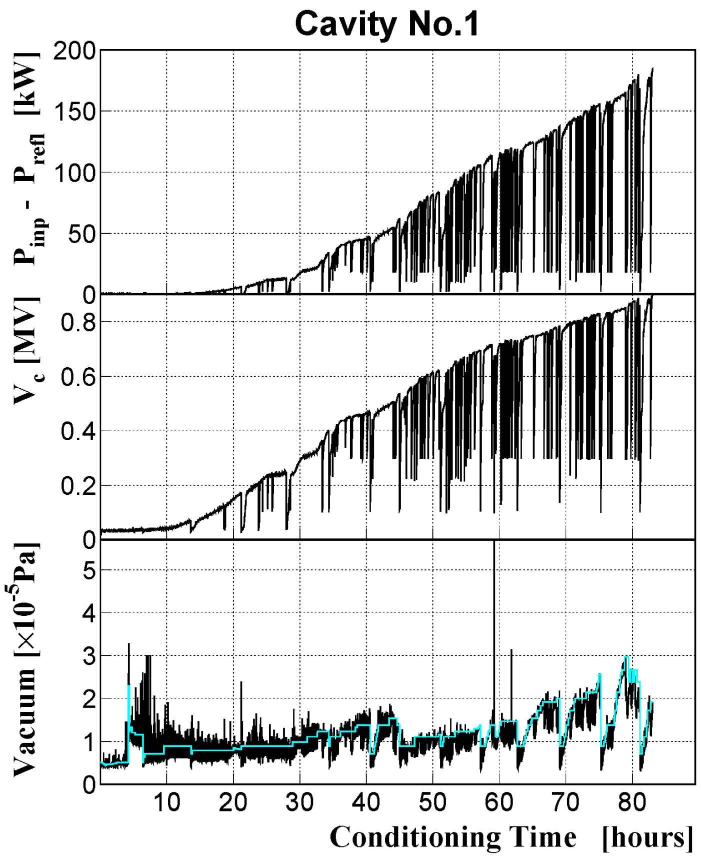


	Q_0(meas) / Q_0(sim)
Prototype	92.9%IACS
Cavity No.1	97.1%IACS
Cavity No.2	97.3%IACS

Significant improvement with EP

Conditioning Histories up to V_c=0.9MV/cav


Prototype


Cavity No.1

The light blue lines indicate the reference vacuum pressure specified by the computer controlled automatic aging.
If the vacuum pressure is higher than the reference, P_{in} is slightly stepped down until the vacuum pressure becomes lower than the reference, and then P_{in} is slightly stepped up as long as the vacuum pressure is lower than the reference.

- ✓ P_{in} (P_{refl}) : input power to (reflected power from) the cavity
- ✓ Wall-loss power: $P_{wall} = P_{in} – P_{refl} = \sim 0.99 \times P_{in}$
- ✓ V_c calculation described in Appendix F
- ✓ The prototype cavity was not electro-polished.
- ✓ Better performance with electro-polishing for Cavity No.1
  - → Lower vacuum pressure and lower trip rate
- ✓ **Smooth conditioning for Cavity No.1**

V_c-Holding Endurance Test up to 0.95MV/cav for DR Cavity No.1

Time series →

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

(No vacuum-pressure spikes during this test)

Stable operation with V_c=0.8MV/cav demonstrated

☐ **Further conditioning effect expected**

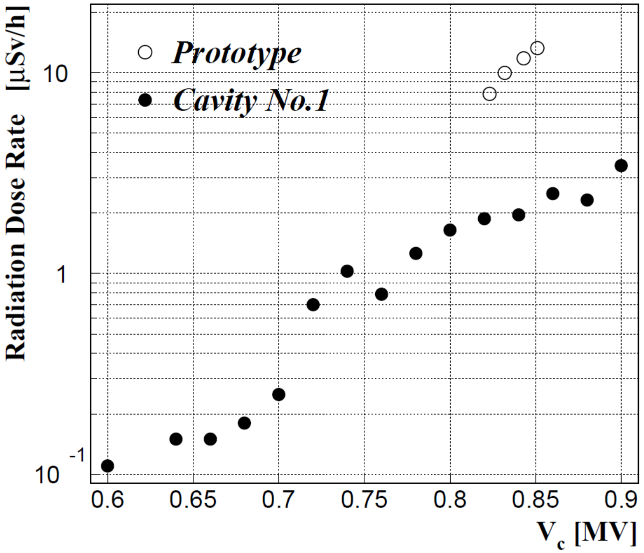
☐ **No performance limit observed during this test**

Effects of EP Observed

Comparing the results between the Prototype and Cavity No.1

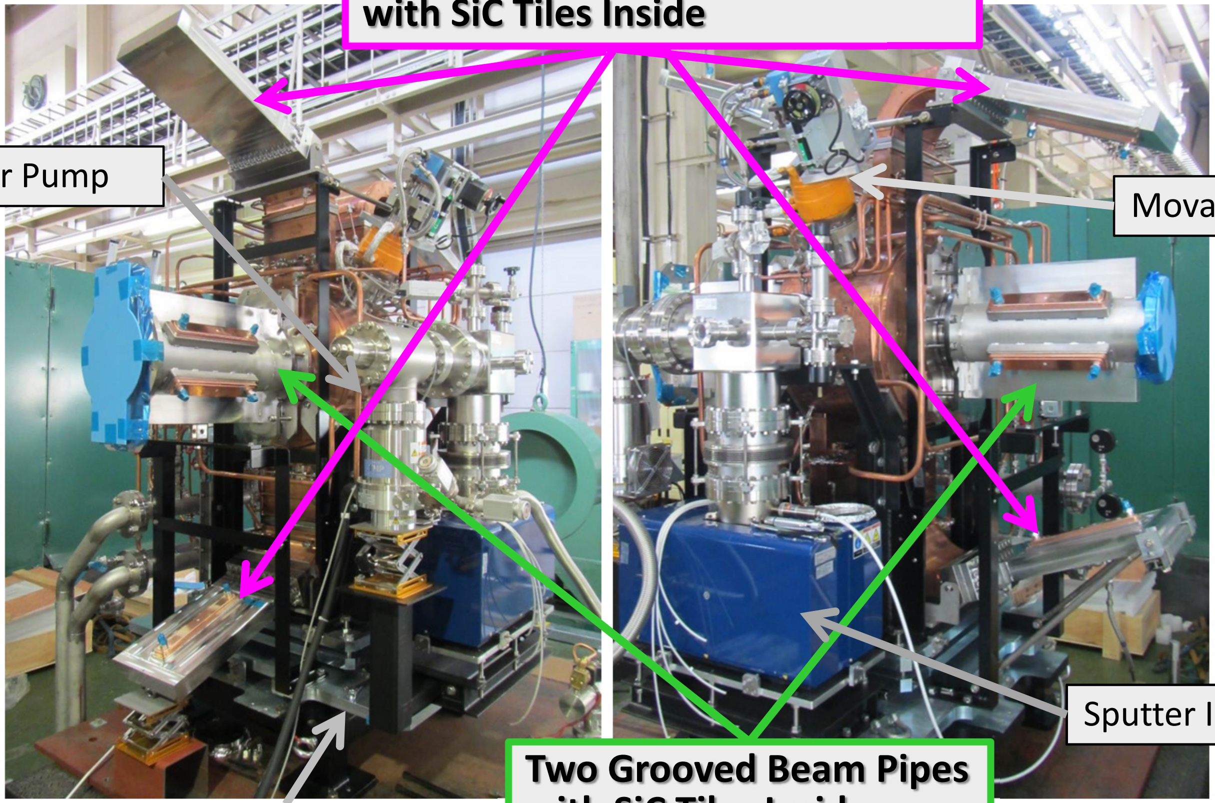
1. Higher Q_0
2. Lower vacuum pressure during the HPT
3. Lower cavity trip rates
4. Lower radiation
   - Less field emission
   - Smaller local-field enhancement factors

T. Abe, et al., "High Power Testing of the RF Accelerating Cavity for the Positron Damping Ring at SuperKEKB", in Proceedings of the 10th Annual Meeting of Particle Accelerator Society of Japan, Aug. 2013 (Paper ID: SAP057)



(Measured, in the radiation shield, at the same position about 2m away from the cavity)

Mounting Test with the 4 HOM Waveguide Loads and 2 Grooved Beam Pipes has been Performed Successfully with Vacuum Sealing.



Four HOM Waveguide Loads with SiC Tiles Inside

Turbo-Molecular Pump

Movable Tuner

Sputter Ion Pump

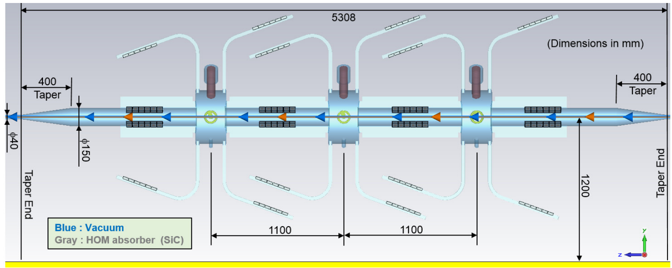
Baseplate

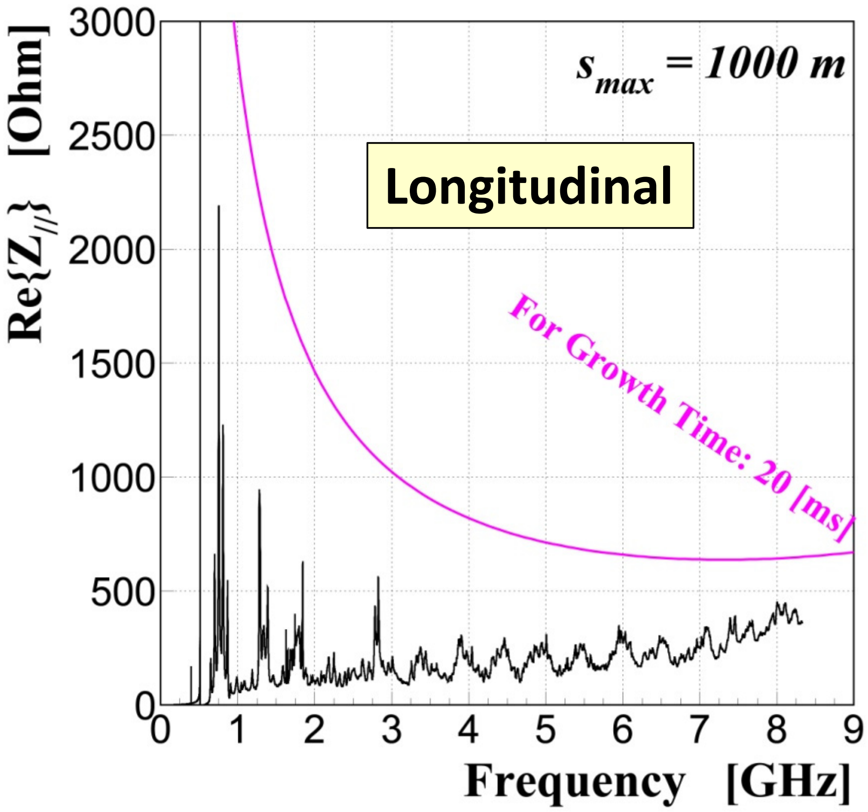
Two Grooved Beam Pipes with SiC Tiles Inside

CBIs driven by the HOM Impedances

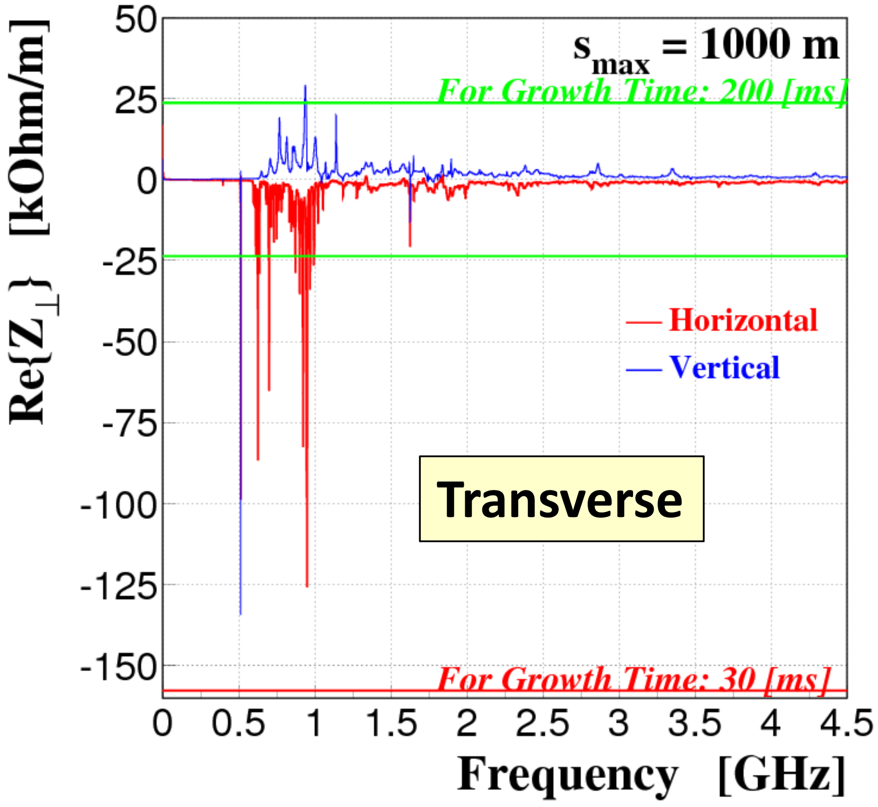
✓From wakepotentials calculated, using GdfidL, for the whole RF section→

✓CBI thresholds for the DR design





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

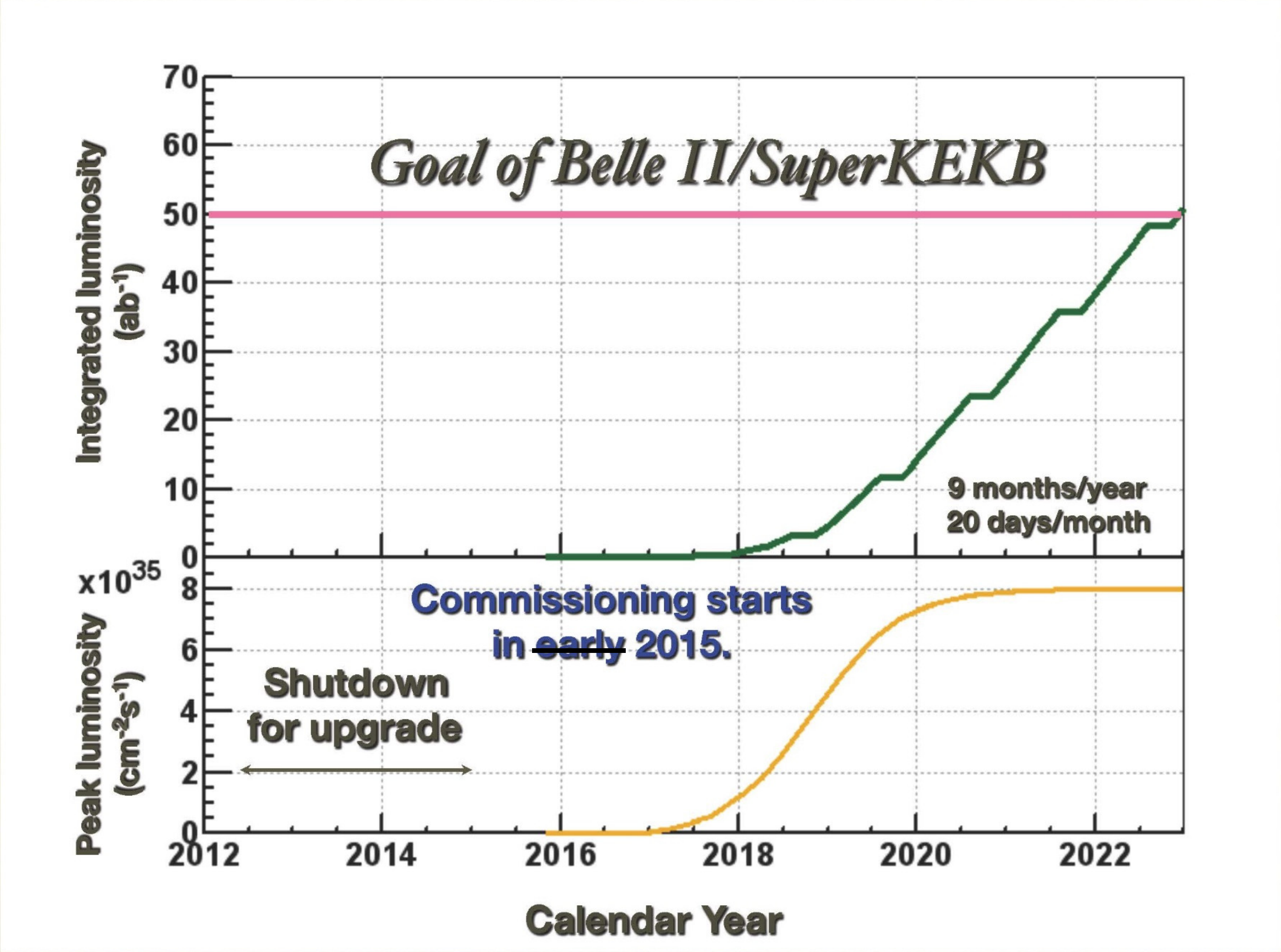


Growth Time ＞ 30ms
＞ 10ms (rad. damping time)

Summary

1. **8 SCCs and 32 ARES (NC) cavities in total used at the KEKB-MRs**
   - Successful operations
   - Significantly contributed to achievement of the world's highest luminosity
2. **Upgrades for the higher beam currents at SuperKEKB/MRs**
   - Cavity main bodies of both SCC and ARES to be re-used without any change
   - HOM damper upgrade on SCC
     - ✓ Basic design done
     - ✓ R&D on the additional SiC damper on-going
   - Input coupler upgrade on ARES
     - ✓ Input coupling factor increased by extending the coupling loop
     - ✓ New couplers with increased coupling, being fabricated and high-power tested
3. **RF cavities for the DR**
   - Designed based on the HOM-damped structure of ARES
   - Fabricated and high-power tested → OK
   - Will be installed in the DR tunnel in 2015

SuperKEKB luminosity projection



Fin.

Appendices

Appendix A (1/5)

Longitudinal CBI driven by the accelerating π/2 mode

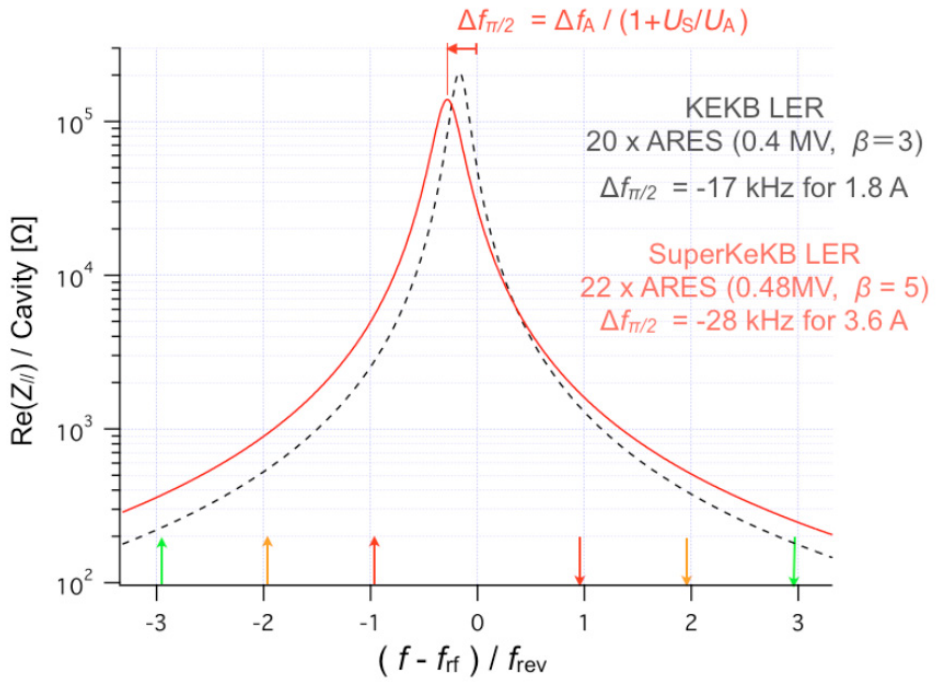


Figure 7.8: Coupling impedance of the $\pi/2$ mode calculated for the SuperKEKB LER where the design beam current of 3.6 A being accelerated with 22 ARES cavities, compare with that for the KEKB LER.

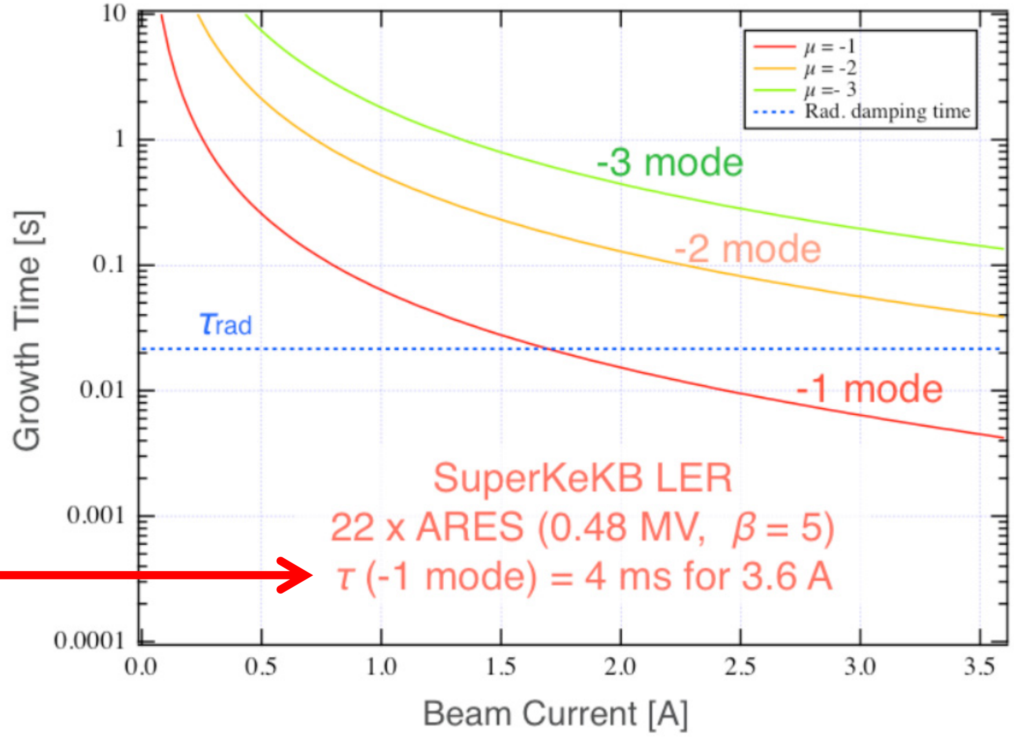


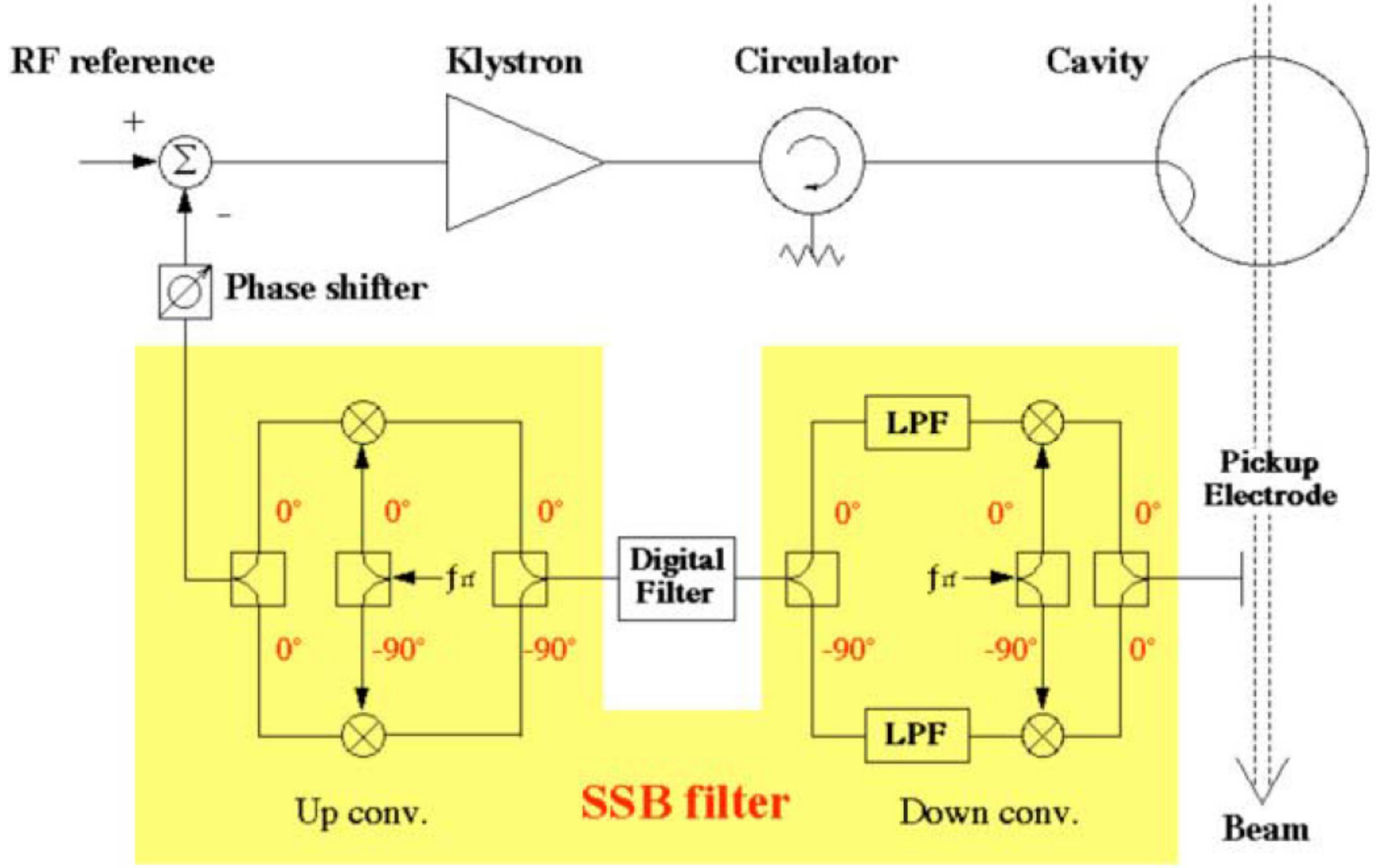
Figure 7.9: Growth time constants of the CBI modes of μ = -1, -2, and -3 due to the $\pi/2$ mode, plotted as a function of the beam current in the SuperKEKB LER.

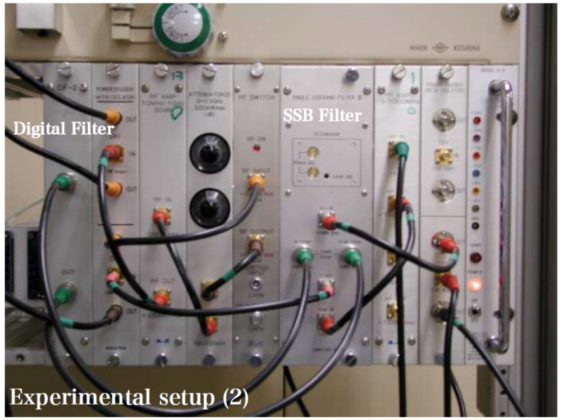
To be cured by the RF feedback systems

(shown in the next page)

KEKB Review February 10, 2003

-1 mode damping system at KEKB (S. Yoshimoto)





Experimental setup (2)

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

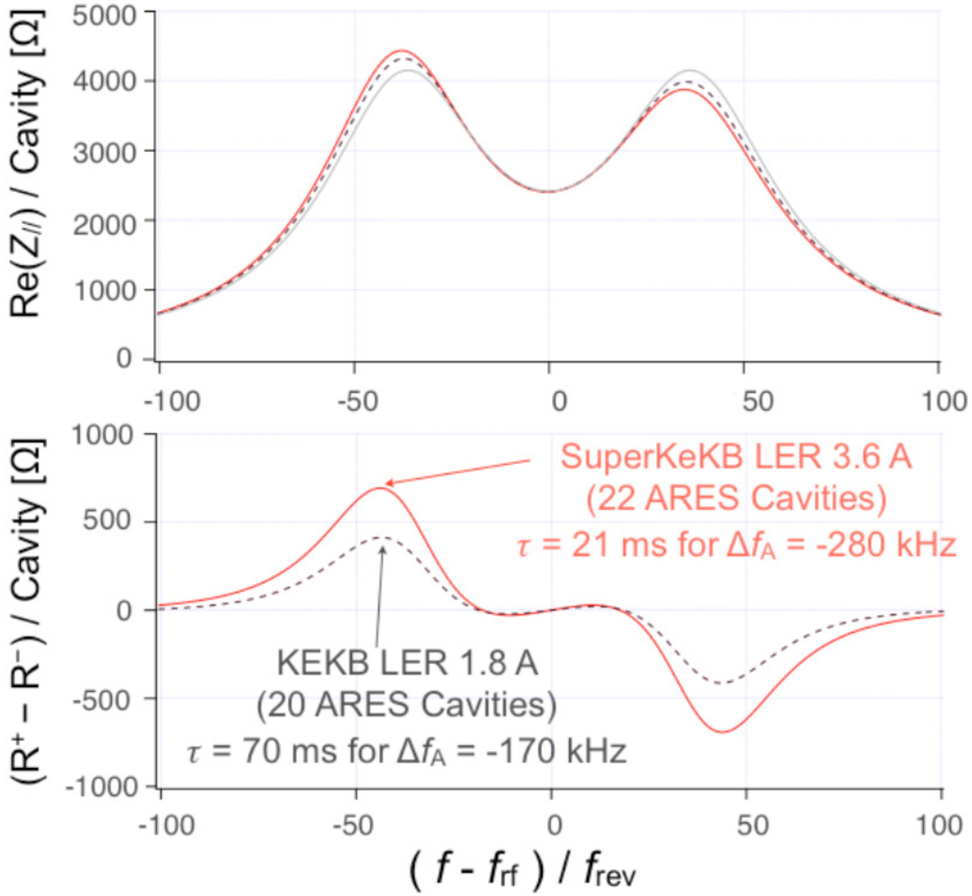
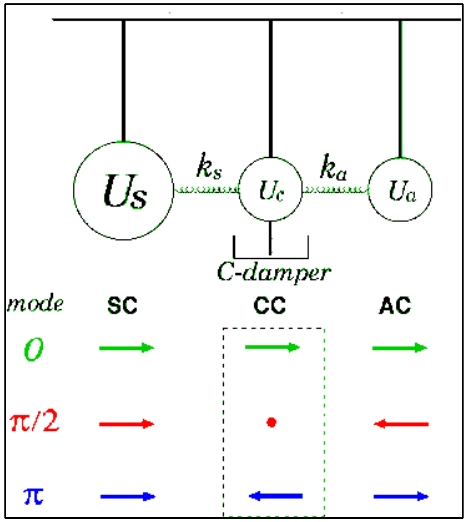


Figure 7.10: Coupling impedance (top) of the 0 and π modes, and the imbalance (bottom) with respect to the RF frequency.

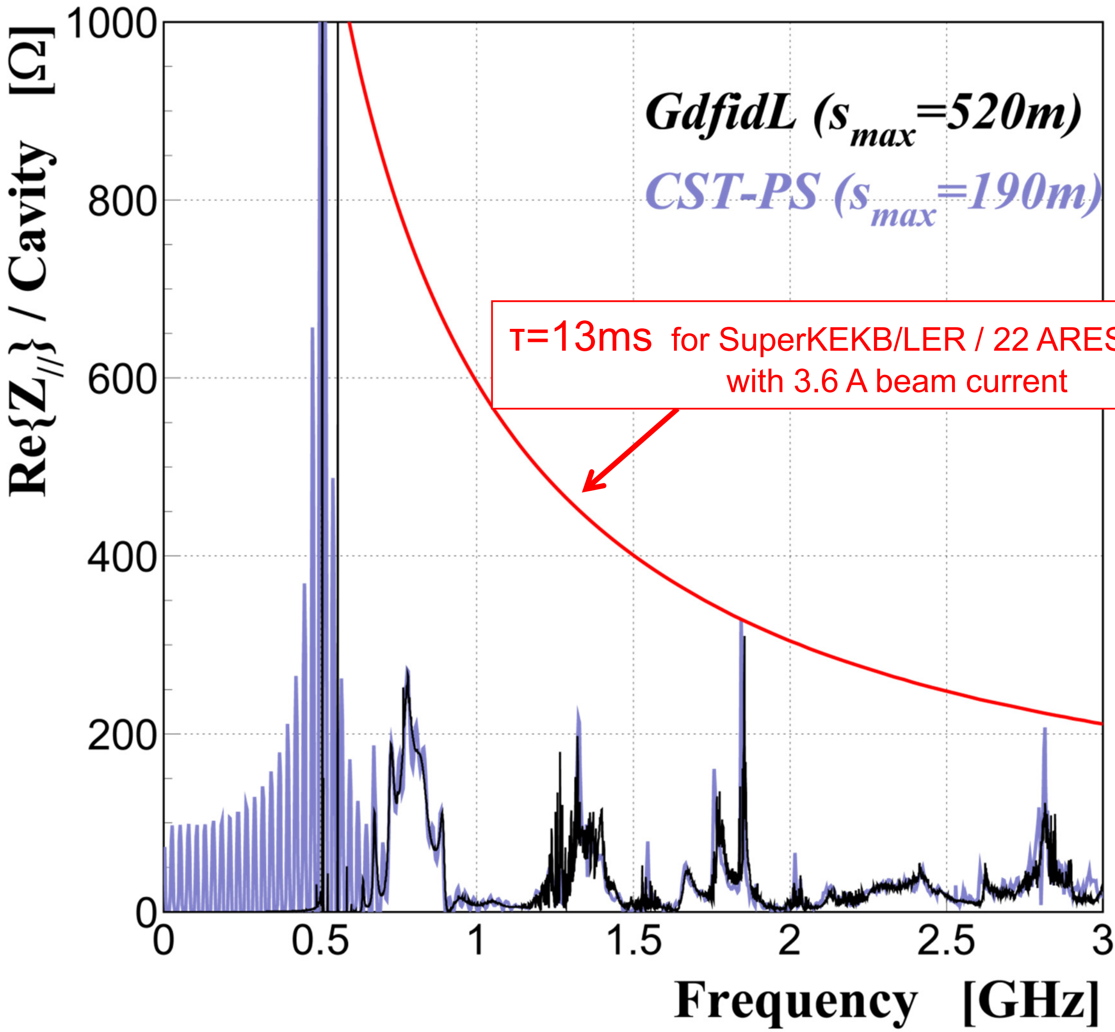


To be cured by the longitudinal bunch-by-bunch feedback system

Appendix A (4/5)

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

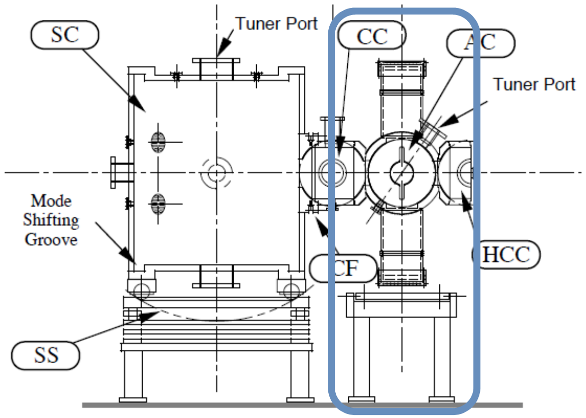
Both impedances from wakepotentials in time-domain



← With the full structure (including SC)

← Only AC + half CC (without SC)

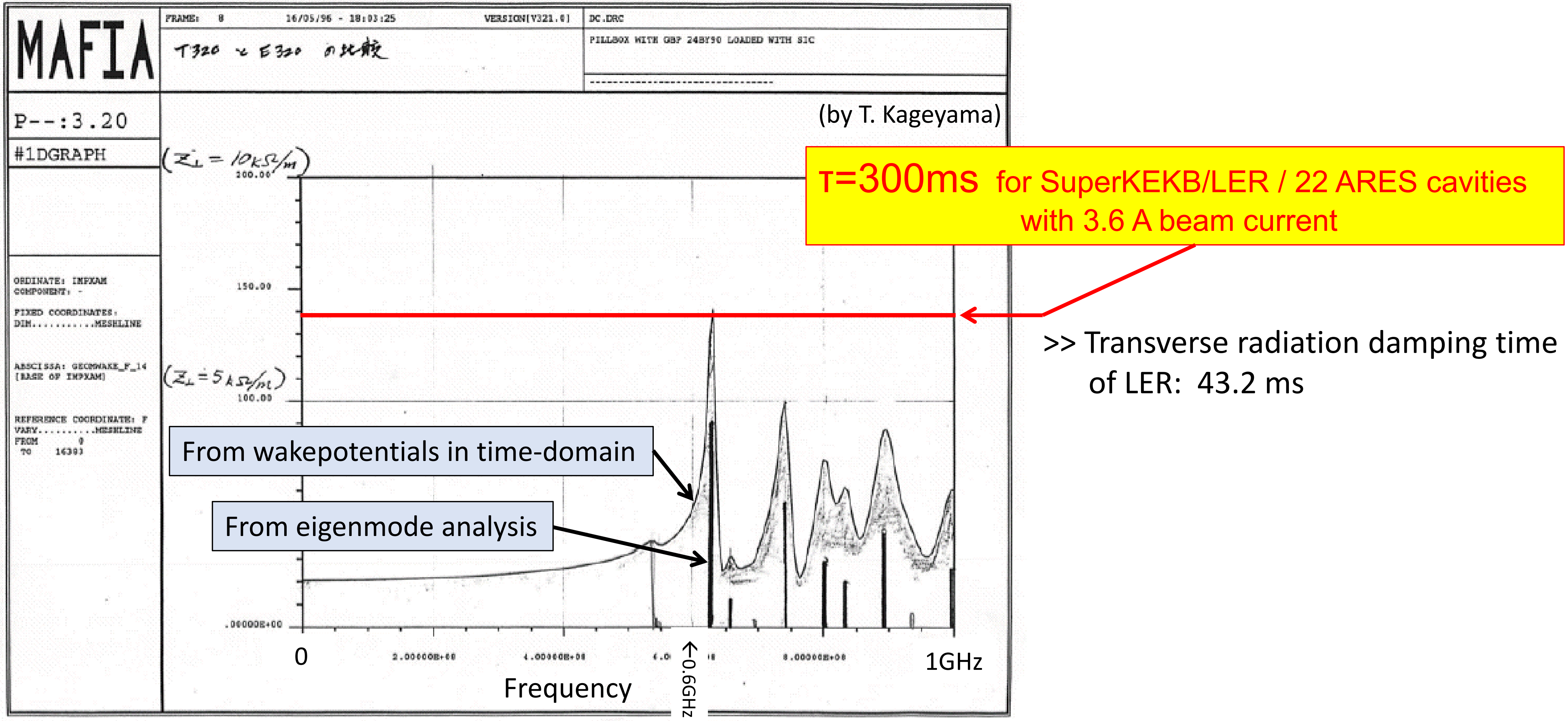
τ=13ms for SuperKEKB/LER / 22 ARES cavities
with 3.6 A beam current



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

Appendix A (5/5)

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



(by T. Kageyama)

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

>> Transverse radiation damping time of LER: 43.2 ms

From wakepotentials in time-domain

From eigenmode analysis

EOF