ARES Upgrade for Super-KEKB

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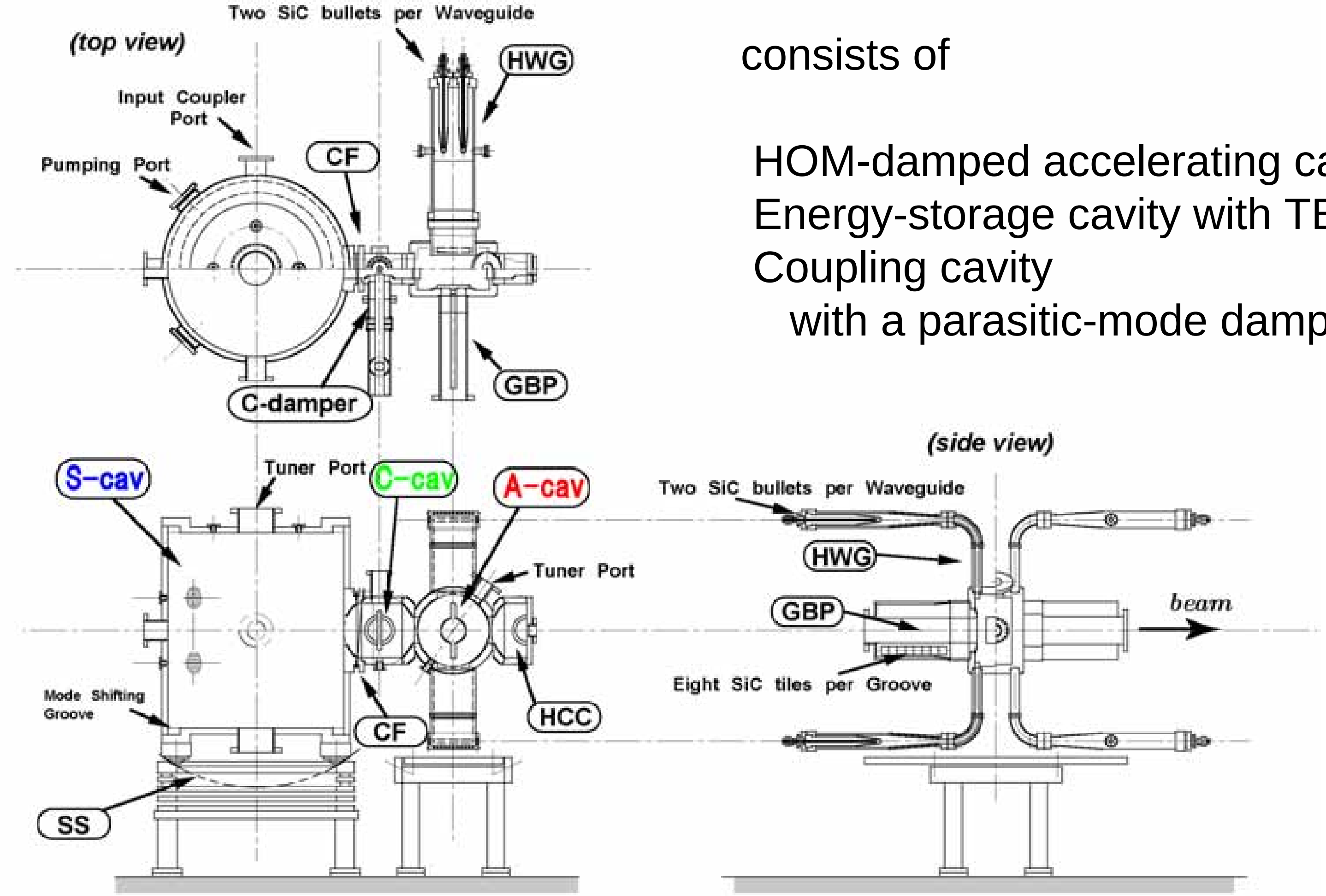
⟨Outline⟩

e^+e^- Factories 2003

Accelerator **R**esonantly-coupled with **E**nergy **S**torage

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



consists of

HOM-damped accelerating cavity (**A-cav**)
Energy-storage cavity with TE013 (**S-cav**)
Coupling cavity (**C-cav**)
with a parasitic-mode damper

Operation with the Accelerating π/2 Mode

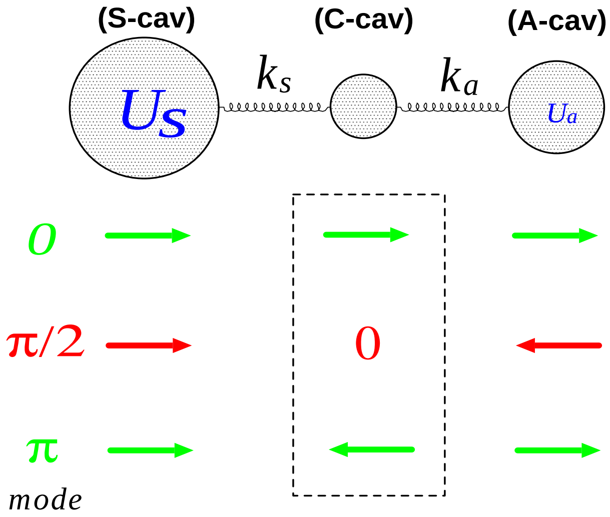
- **The stored-energy ratio: Us/Ua**
  → can be changed

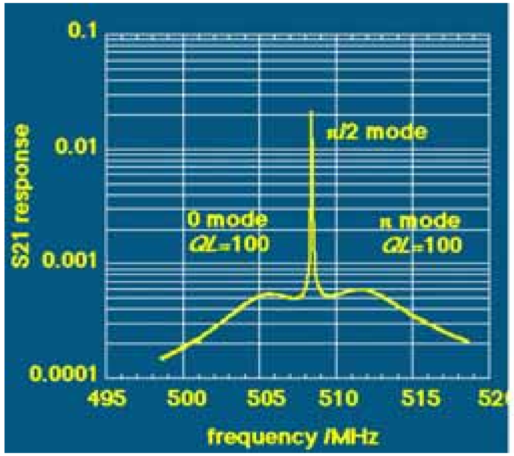
$$\frac{Us}{Ua} = \frac{k_a^2}{k_s^2}$$

- **The field of the π/2 mode is the most stable against**
  - Beam loading,
  - Detuning of A-cav $(= \Delta f_a)$.

$$\Delta f_{\pi/2} = \frac{\Delta f_a}{1 + Us/Ua}$$

- **The parasitic 0 and π modes**
  → can be damped selectively
  out of C-cav (C-damper)





Operation Status @ KEKB Quest for CPV

(Apr.~Jun., 2003)

- **LER: 20 cavities**
  - Total Vc=8.0MV
  - Beam current (max.): ~1.8A
  - Input RF power /cav: ~300kW
  - HOM power: >~ 5kW
  - Trip rate: ~1 /cav /3months

- **HER: 10 cavities (with 8 SCCs)**
  - Total Vc = 13MV
    = 2.84MV(ARES) + 10.16MV(SCC)
  - Beam current (max.): ~1.1A

ARES cavities in the LER RF section

Upgrade for SuperKEKB (Quest for BSM)

Measures against

Larger detuning

→ Change the energy ratio: *Us/Ua = 9 →15 (?)*

$$\Delta f_{\pi/2} = \frac{\Delta f_a}{1 + Us/Ua}$$

$|\Delta f_a| = 200$ kHz in KEKB (2.6A, 20 sets)

$|\Delta f_a| = 710$ kHz in SuperKEKB (9.4A, 28 sets)

Cf. $f_{rev} = 99$kHZ

Higher HOM power

→ HOM-load upgrade

Higher input RF power (400kW/cav →>800kW/cav)

→ R&D in the new coupler teststand

Change of the Energy Ratio

- π/2 mode & eq. circuit

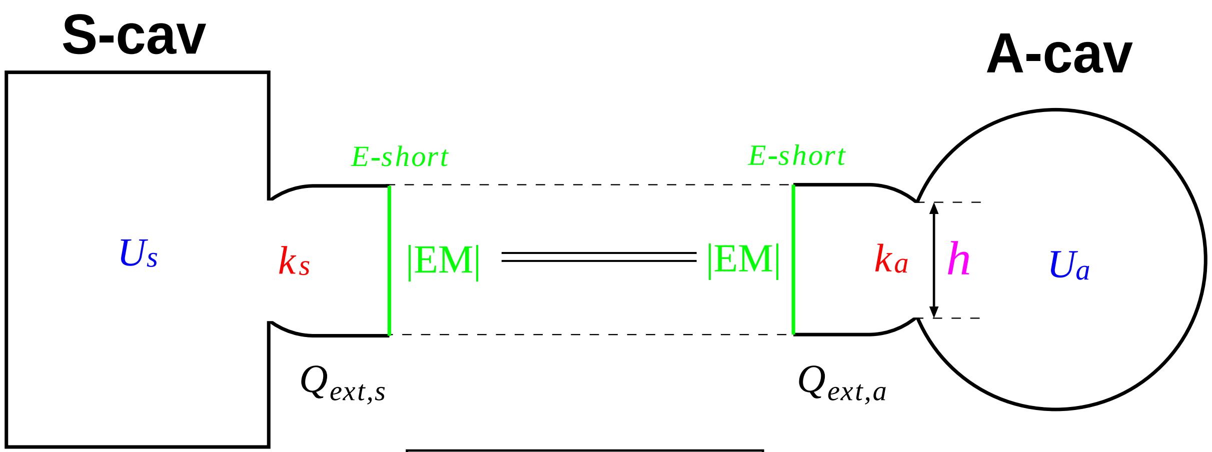
$$\frac{U_s}{U_a} = \frac{k_a^2}{k_s^2}$$

- Applying Slater's tuning curve to the π/2 mode

$$\frac{U_s}{U_a} = \frac{Q_{ext,s}}{Q_{ext,a}}$$

Changing the window height: *h*,

→ **Us/Ua, Qext,s/Qext,a can be adjusted.**



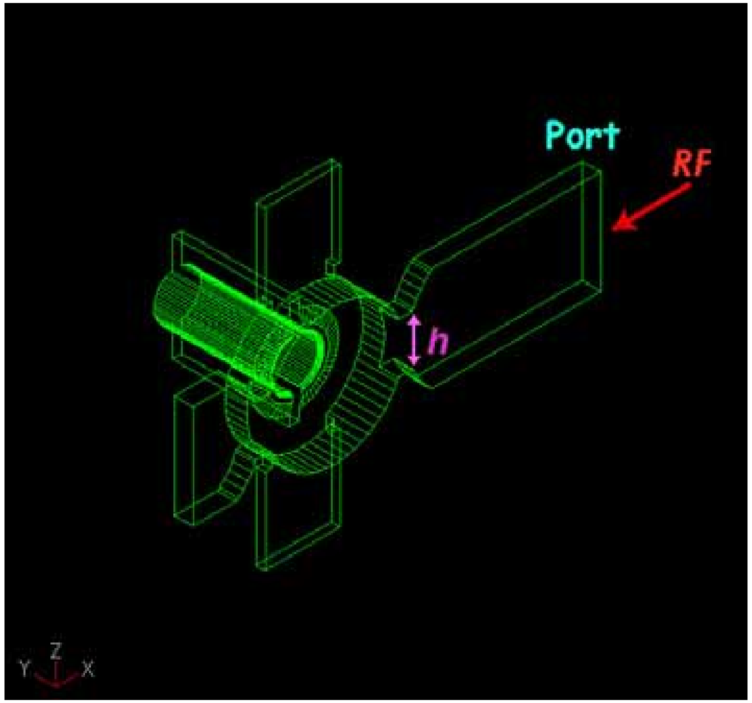
$$\frac{\omega U_s}{Q_{ext,s}} = \frac{\omega U_a}{Q_{ext,a}}$$

$(Q_{ext} >> 1)$

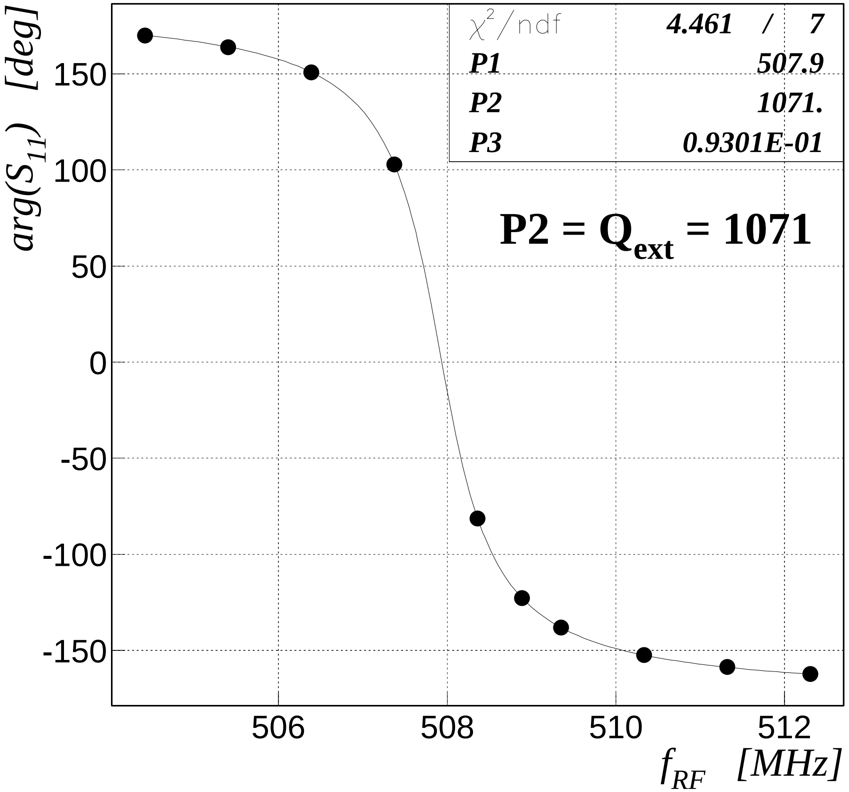
Adjusting the Window Height of A-cav

- **Simulation tool: HFSS**
  → S-parameter calculation

- **Geometry**



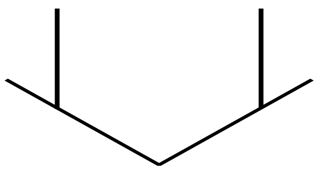
$$\arg(S_{11}) = -2\tan^{-1}\left\{P_2\left(\frac{f_{RF}}{P_1} - \frac{P_1}{f_{RF}}\right)\right\} + P_3$$



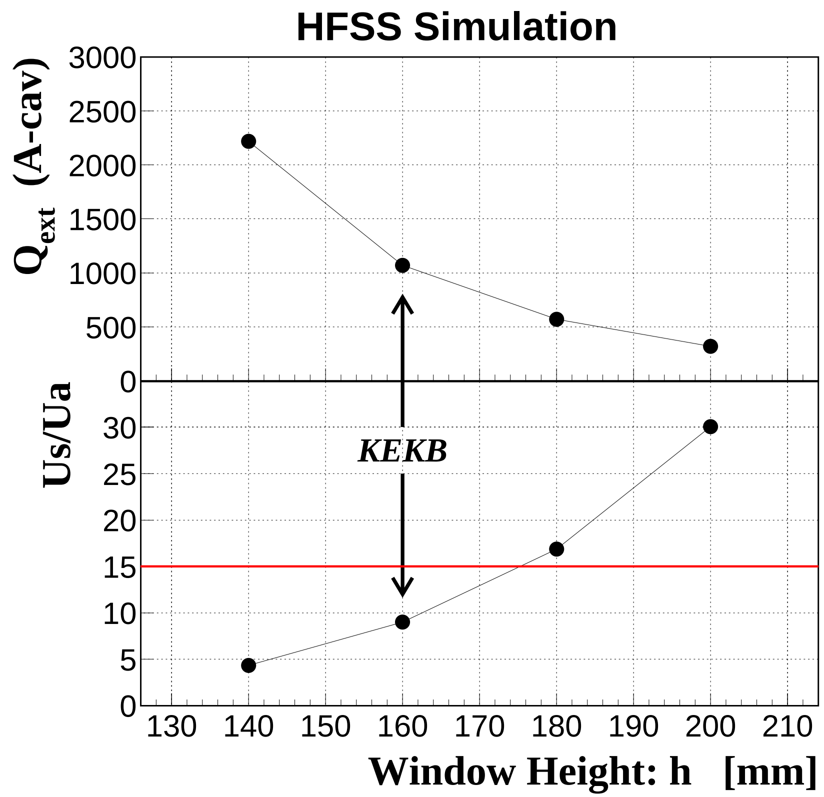
Window Height v.s. Energy Ratio

Modification of the window height: +15mm (160→175mm)

for Us/Ua=15



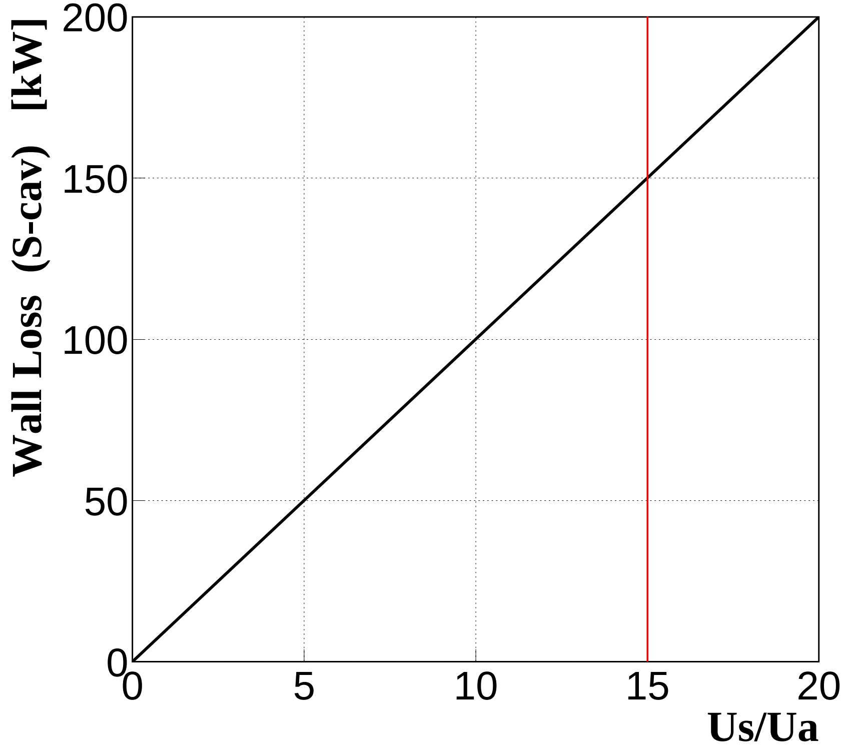
Acceptable for the current mechanical structure



Wall Loss in Energy-storage Cavity

Pwall=150kW
for Us/Ua=15

Record: Pwall>200kW
in the teststand



Longitudinal Coupled-bunch Instability driven by the π/2 mode

- **Larger detuning**
  - → Larger instability driven by the accelerating π/2 mode
  - → Cured by increasing the energy ratio: Us/Ua

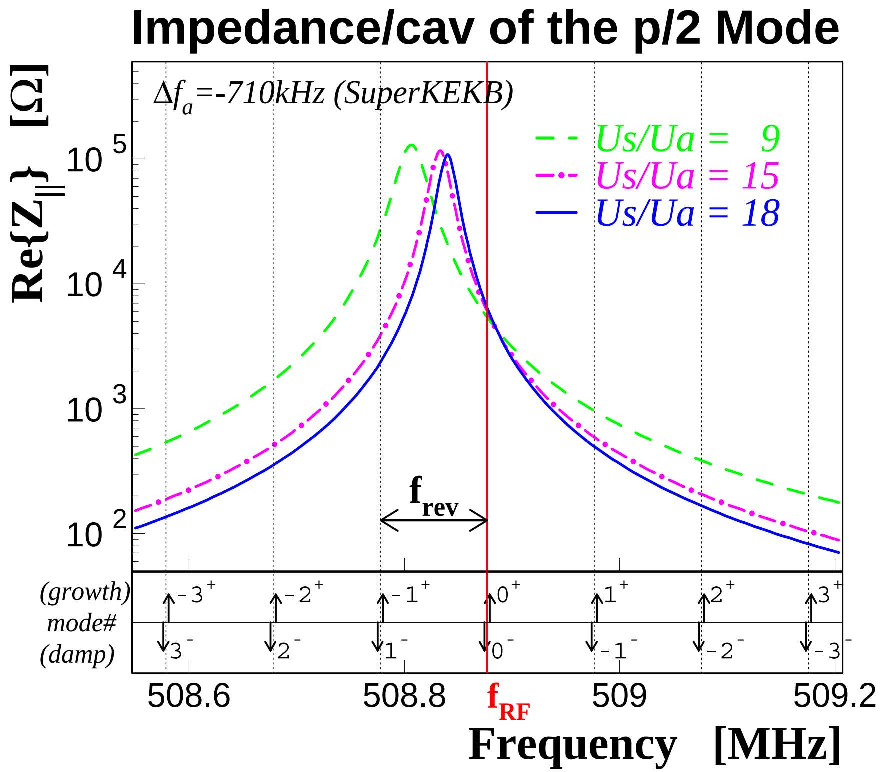
$$\Delta f_{\pi/2} = \frac{\Delta f_a}{1 + Us/Ua}$$

$|\Delta f_a| = 200$ kHz (in KEKB)

$|\Delta f_a| = 710$ kHz (in SuperKEKB)

Cf. f_{rev} = 99kHZ

- **We need a feedback?**

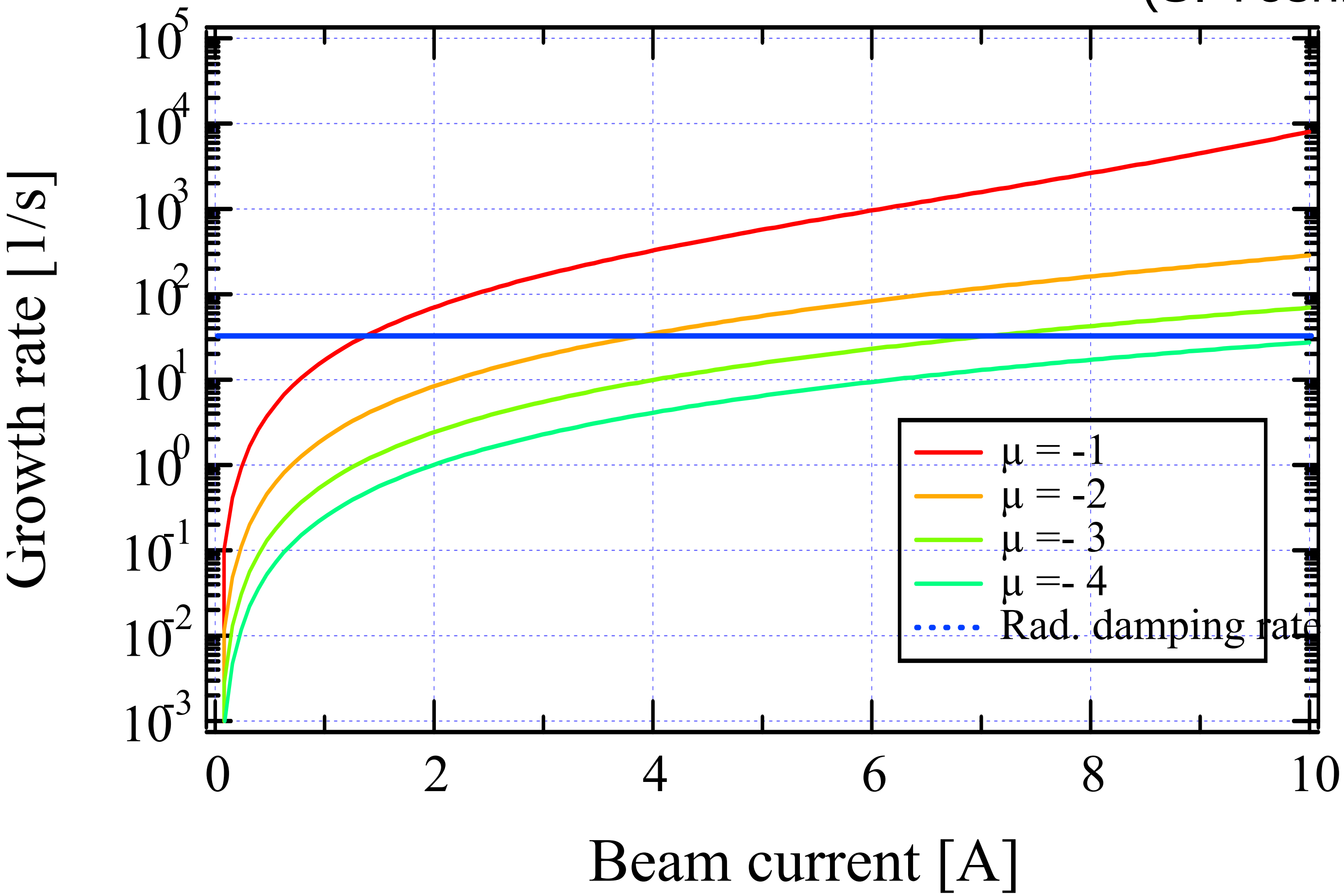


Growth Rate(1)

SuperKEKB
LER
ARES 28 sets

Ua : Us = 1 : 9, Vc = 0.5 MV

(S. Yoshimoto)

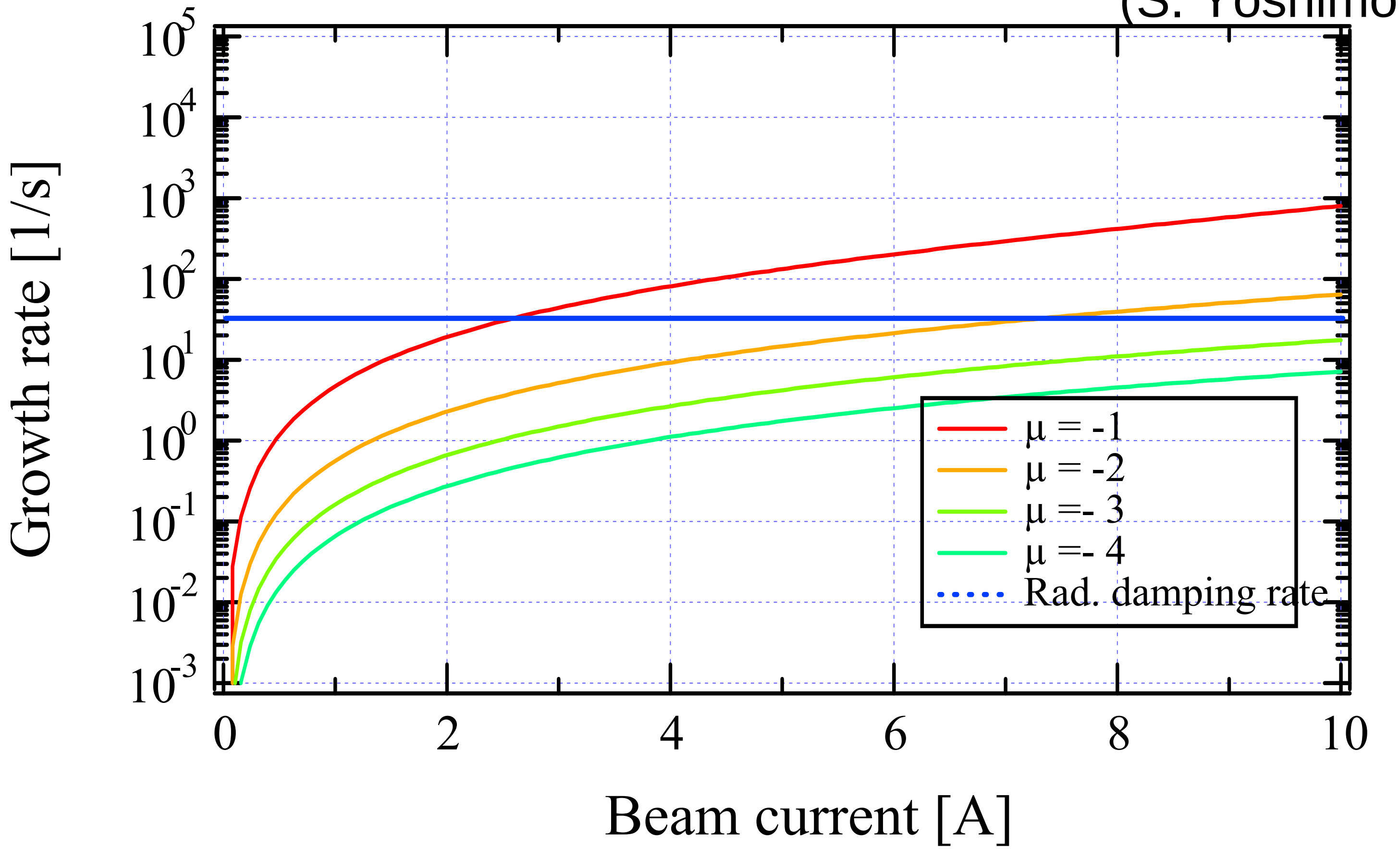


Growth Rate(2)

SuperKEKB
LER
ARES 28 sets

Ua : Us = 1 : 15, Vc = 0.5 MV

(S. Yoshimoto)

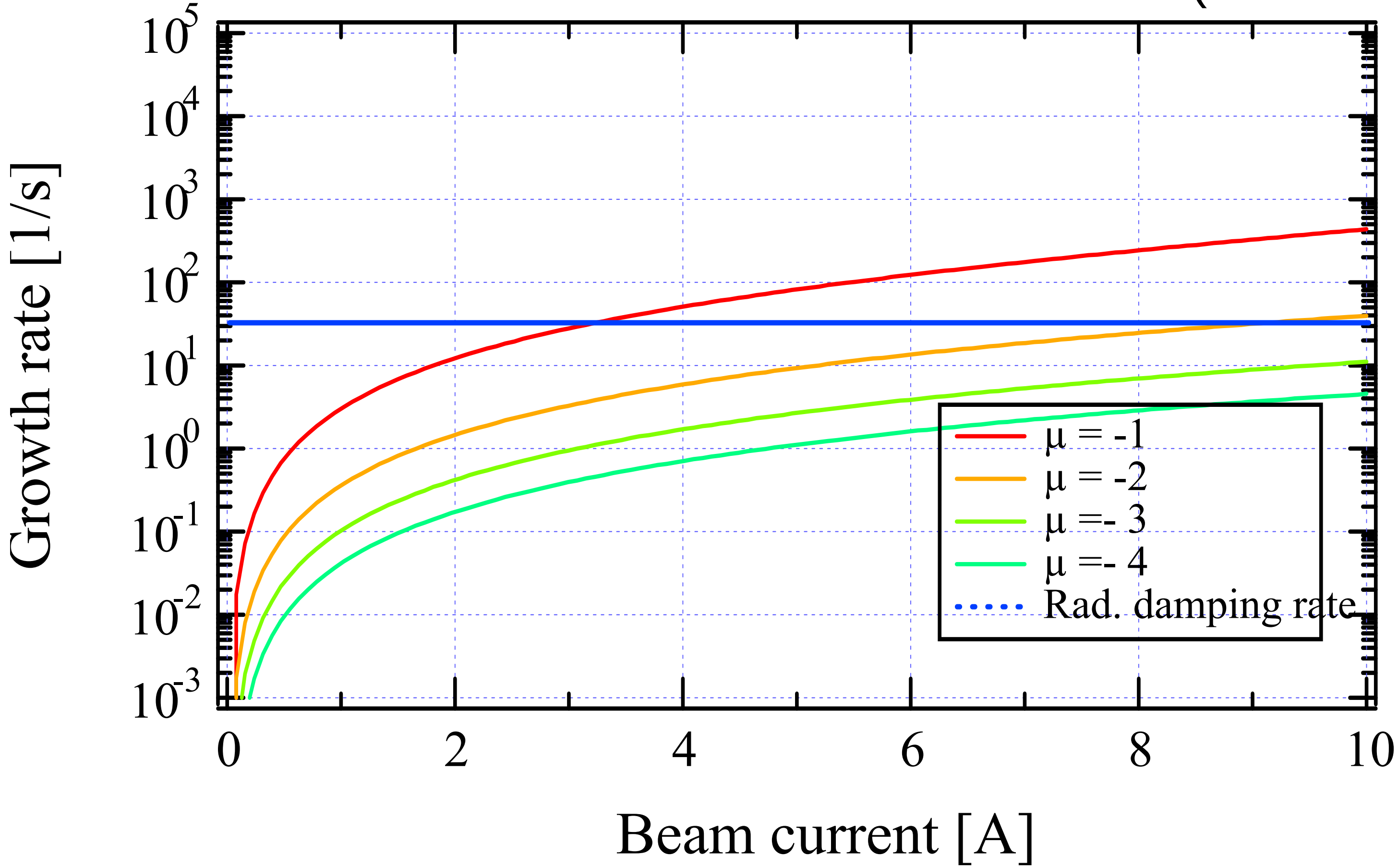


Growth Rate(3)

SuperKEKB
LER
ARES 28 sets

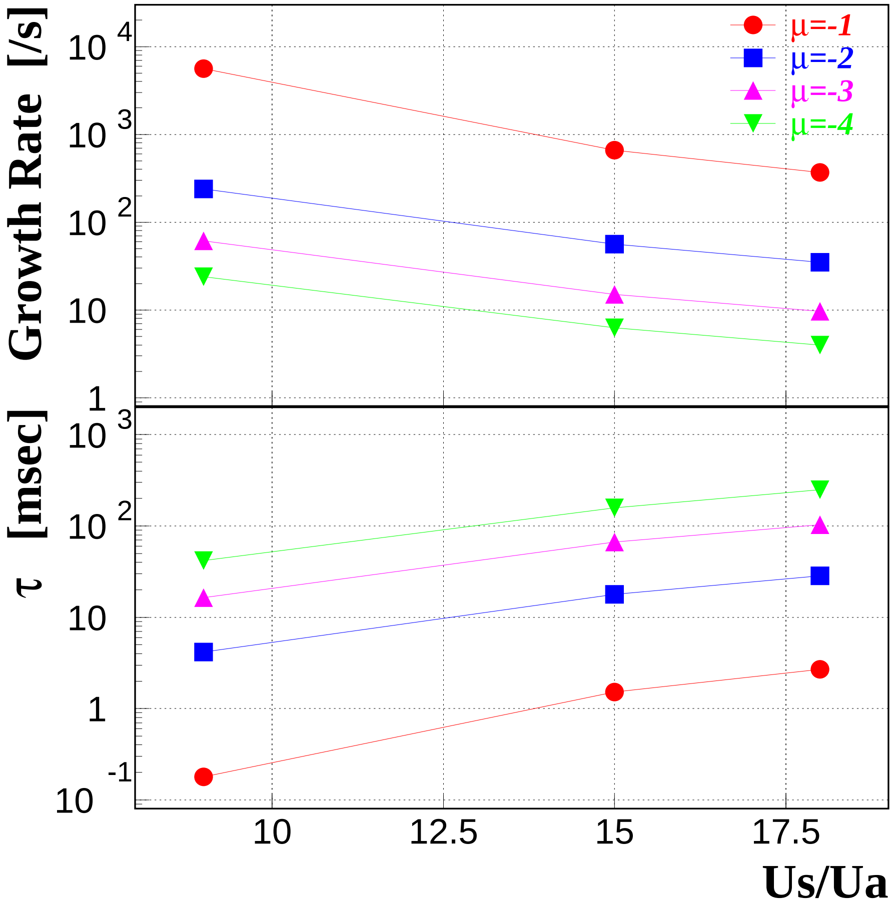
Ua : Us = 1 : 18, Vc = 0.5 MV

(S. Yoshimoto)



Longitudinal Coupled-bunch Instability (π/2 mode)

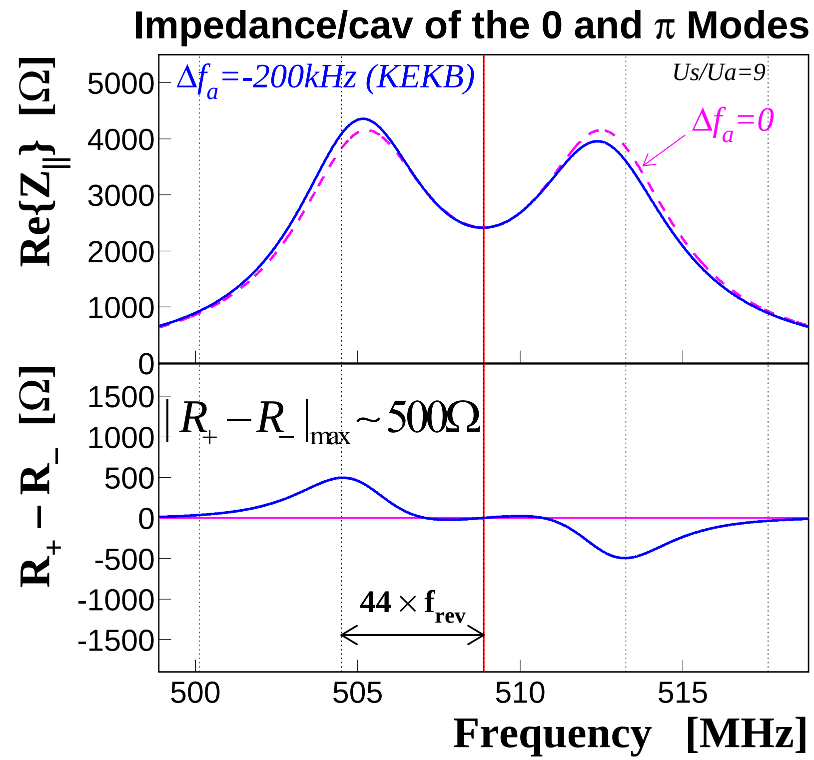
(SuperKEKB LER with 9.4A, ARES 28 sets, Vc=0.5MV/cav)



Longitudinal Coupled-bunch Instability driven by the 0 and π modes

- **Ua:Uc = 1:1 ($\Delta f_a = 0$)**
  subject to the perturbation
  of order of $\Delta f_a / (f_\pi - f_0)$
  where $f_\pi - f_0 \propto k_a \propto \sqrt{Us/Ua}$ (k_s: fixed)
- **Detuning: $\Delta f_a < 0$**
  → Ua>Uc (0 mode)
  → Ua<Uc (π mode)
  → Asymmetric $\mathrm{Re}\{Z_\parallel\}$
- **KEKB: $\Delta f_a = -200\mathrm{kHZ}$**
  → Small asymmetry on Re{Z||}
  → $\tau \sim 46\ msec$ (no problem)
  (Cf. $\tau_{rad} \sim 23\ msec$)
- **Super-KEKB: $\Delta f_a = -710\mathrm{kHZ}$**
  → ……

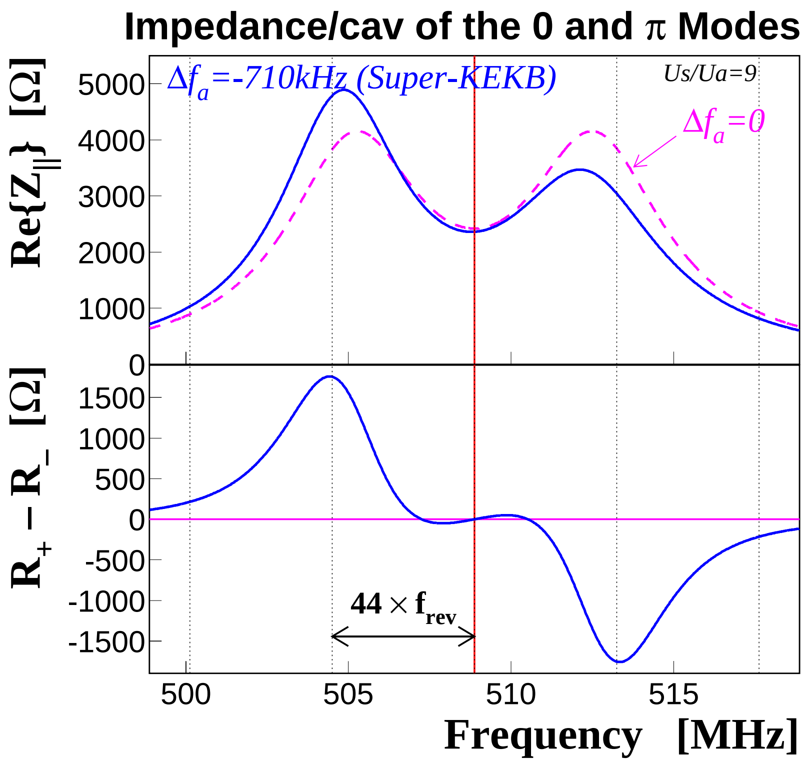
(KEKB LER 2.6A)



Super-KEKB

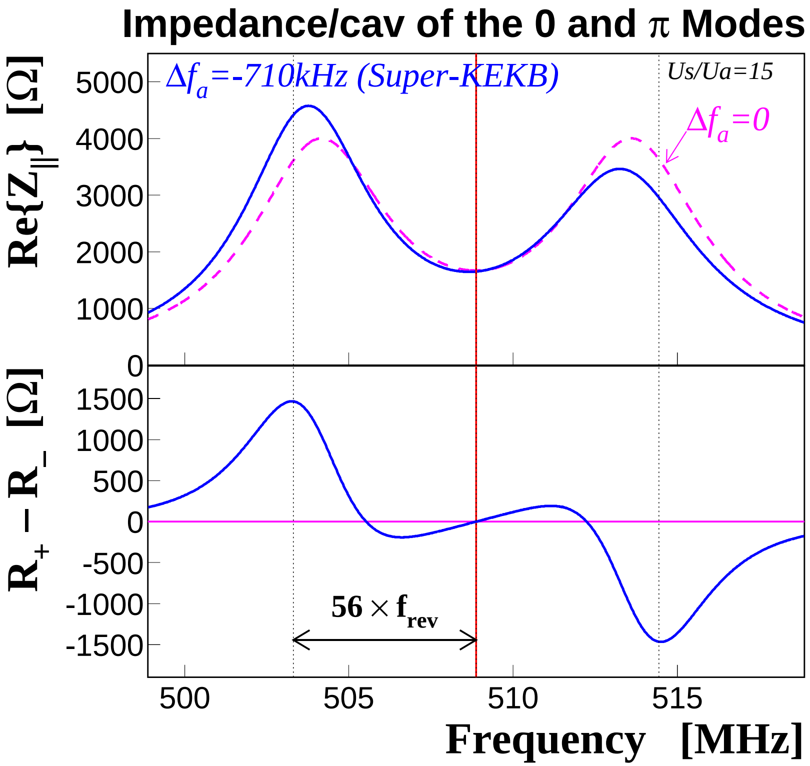
LER 9.4A
ARES 28 sets

Us/Ua=9



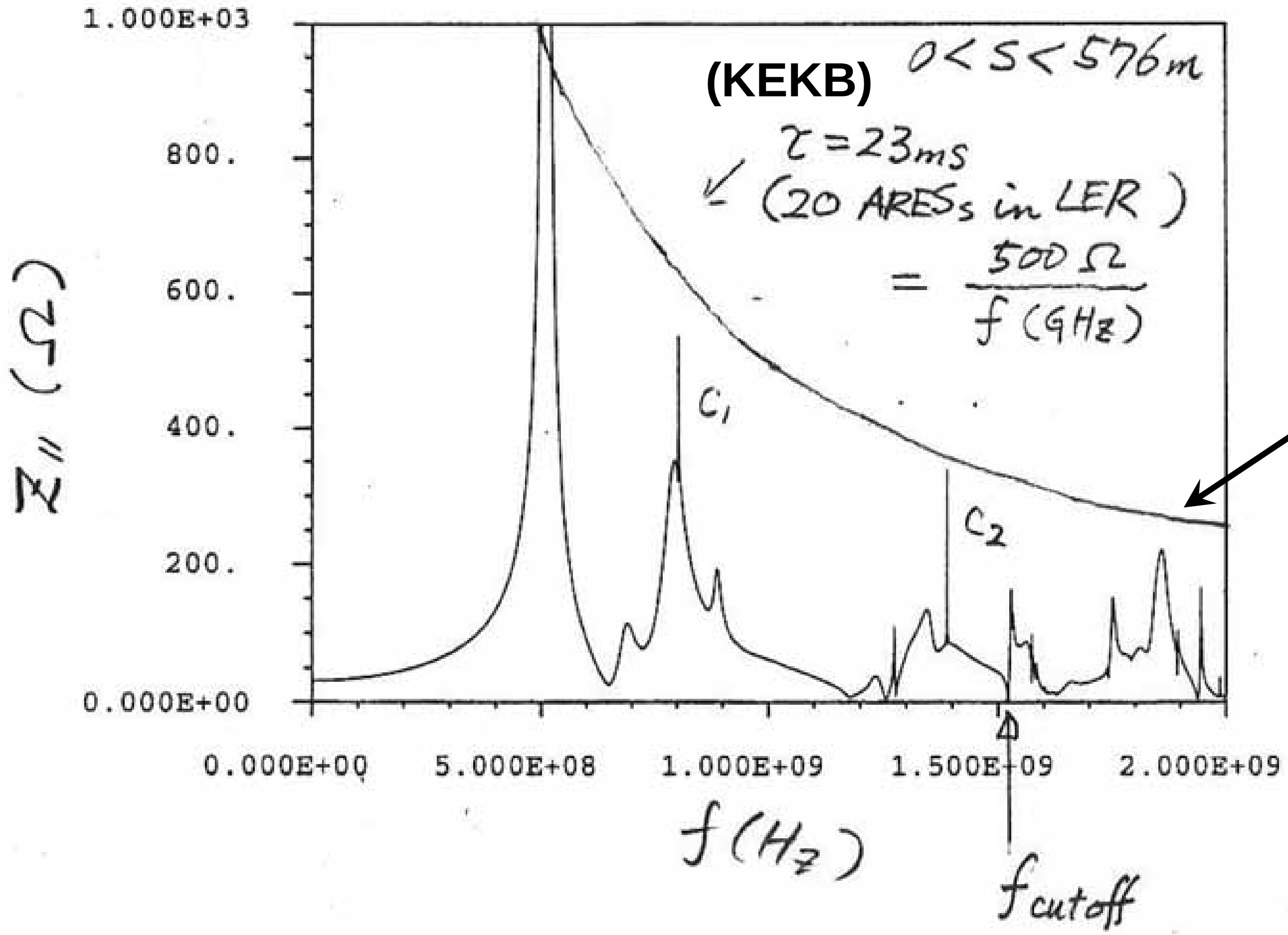
$$\rightarrow \tau \sim 3.3\ m\sec$$

Us/Ua=15



$$\rightarrow \tau \sim 4.0\ m\sec$$

Longitudinal Coupled-bunch Instability driven by the HOMs



(Super-KEKB)

$\tau \sim 4\ m\sec$

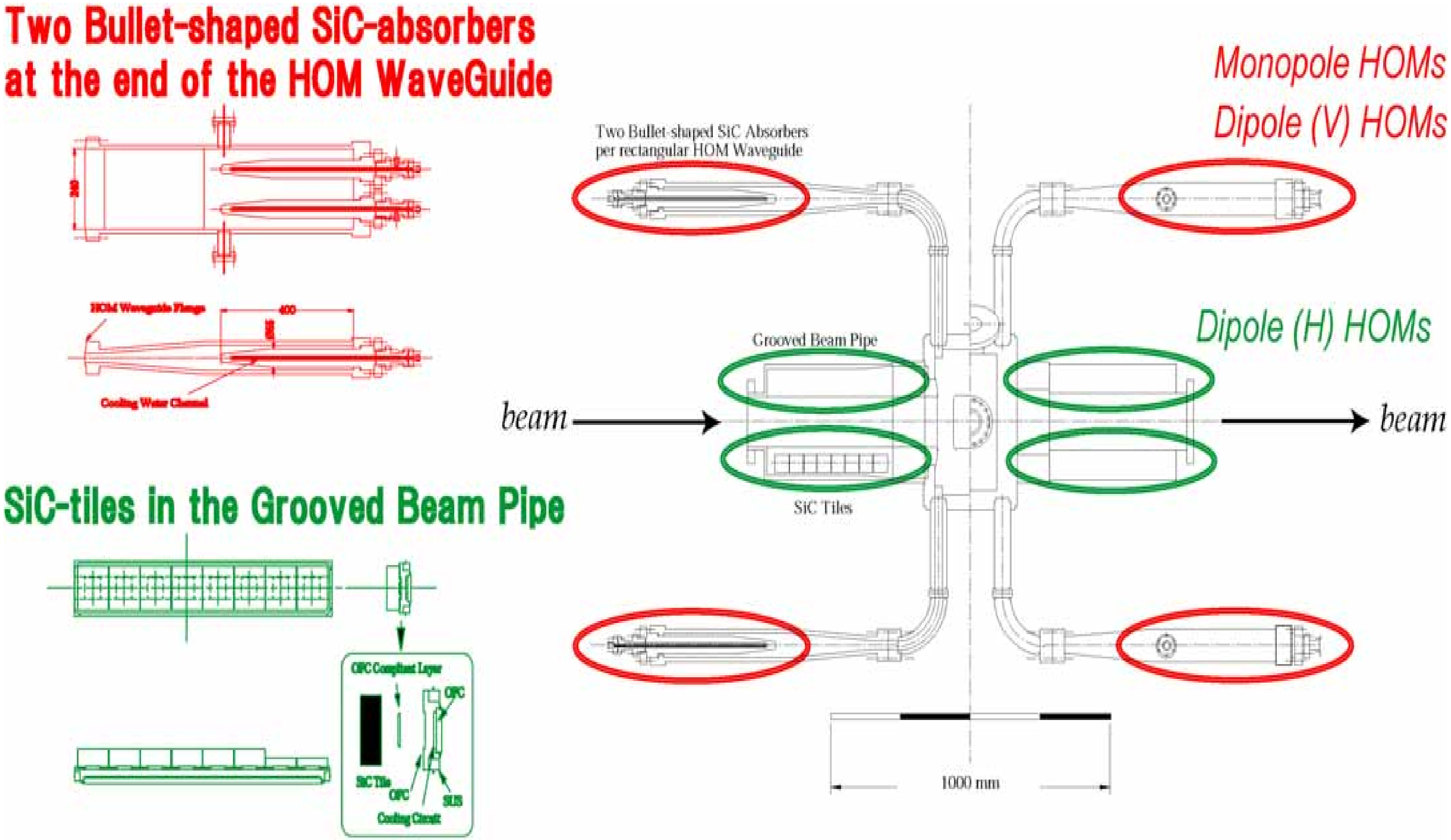
(28 ARESs in LER)

Summary on the Energy Ratio

Us/Ua = 9 (KEKB) → 15 (Super-KEKB) (tentative)

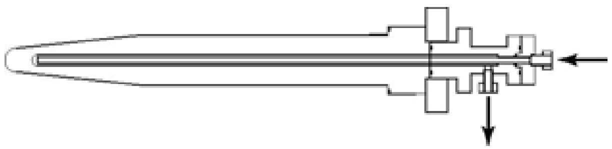
- → Small modification on the window size of A-cav
- → The wall loss in S-cav is acceptable.
- → The CBI driven by the π/2 mode can be reduced into $\tau^{\pi/2\ \mathrm{mode}}_{\mu=-1} > 1\ m\sec$.
  - ➢ to be feedbacked by the RF control system
- → The CBI driven by the 0 and π modes can be slightly reduced into $\tau^{0,\pi\ \mathrm{modes}}_{\mu\sim-56} \sim 4\ m\sec$.
  - ➢ to be feedbacked by longitudinal feedback kickers
  - ➢ comparable with $\tau^{\mathrm{HOMs}} \sim 5\ m\sec$ driven by the HOMs

Upgrade of HOM loads

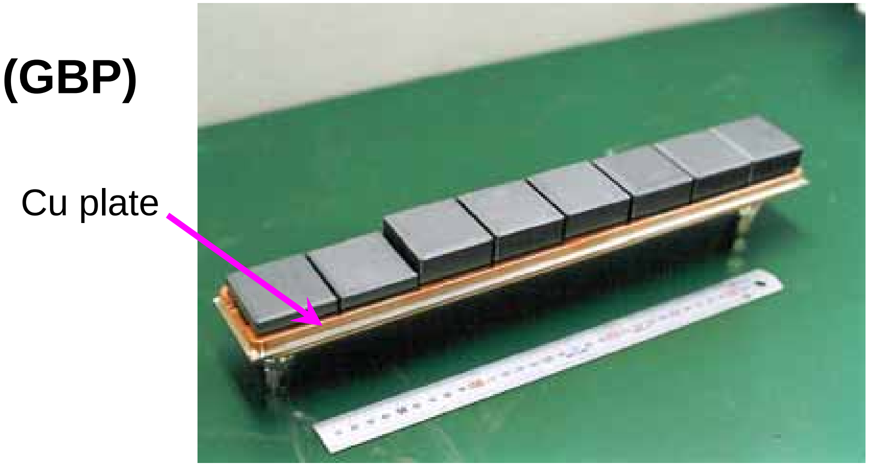


SiC Absorbers

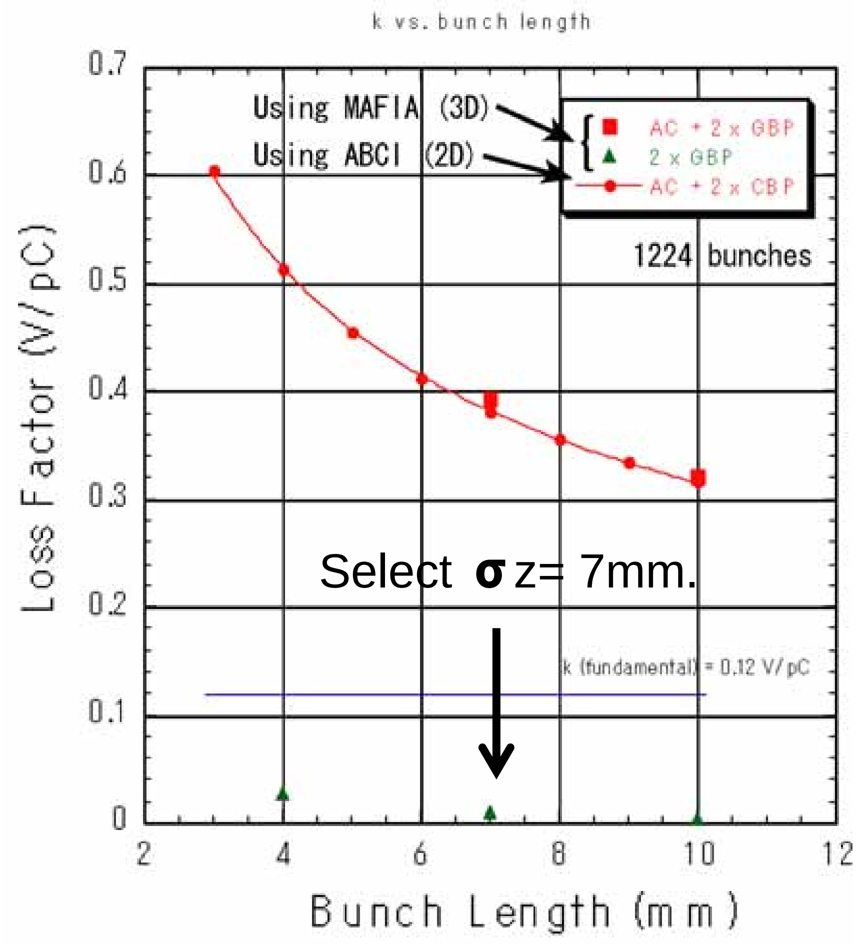
✐ **In the HOM WaveGuide(WG)**
- Limit: >3.3kW/bullet (HPT)
- Direct water cooling

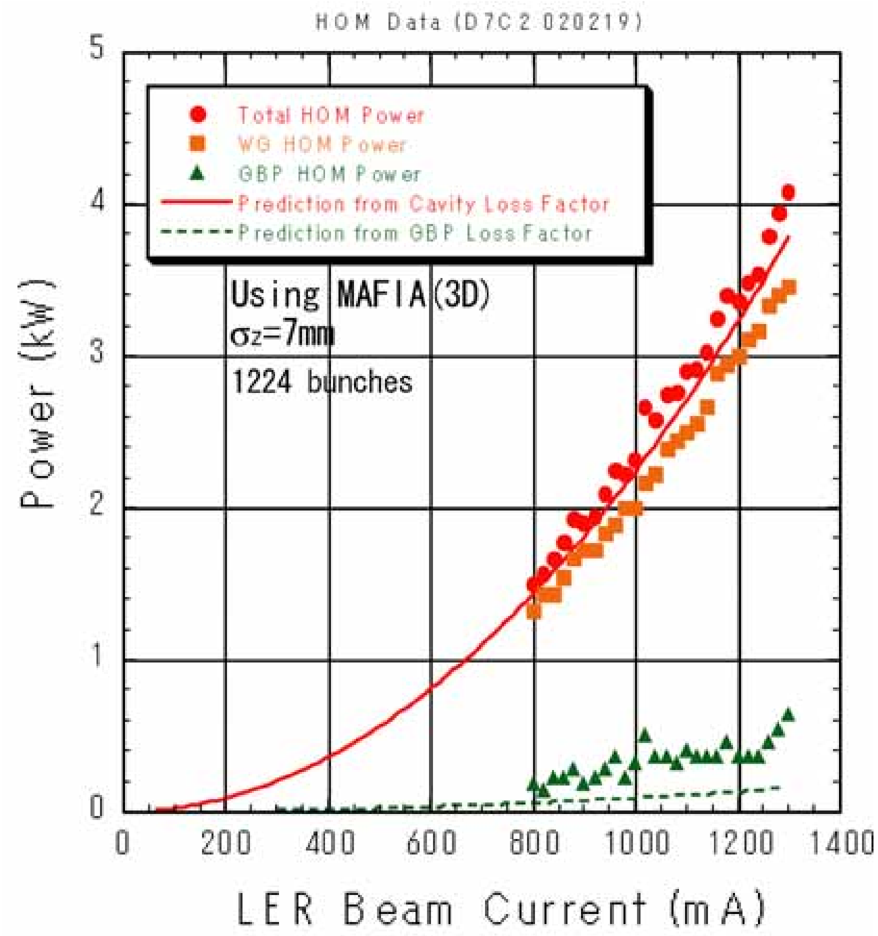


✐ **In the Grooved Beam Pipe (GBP)**
- Limit: ~0.5kW/unit (HPT)
- Indirect water cooling



HOM loss in KEKB

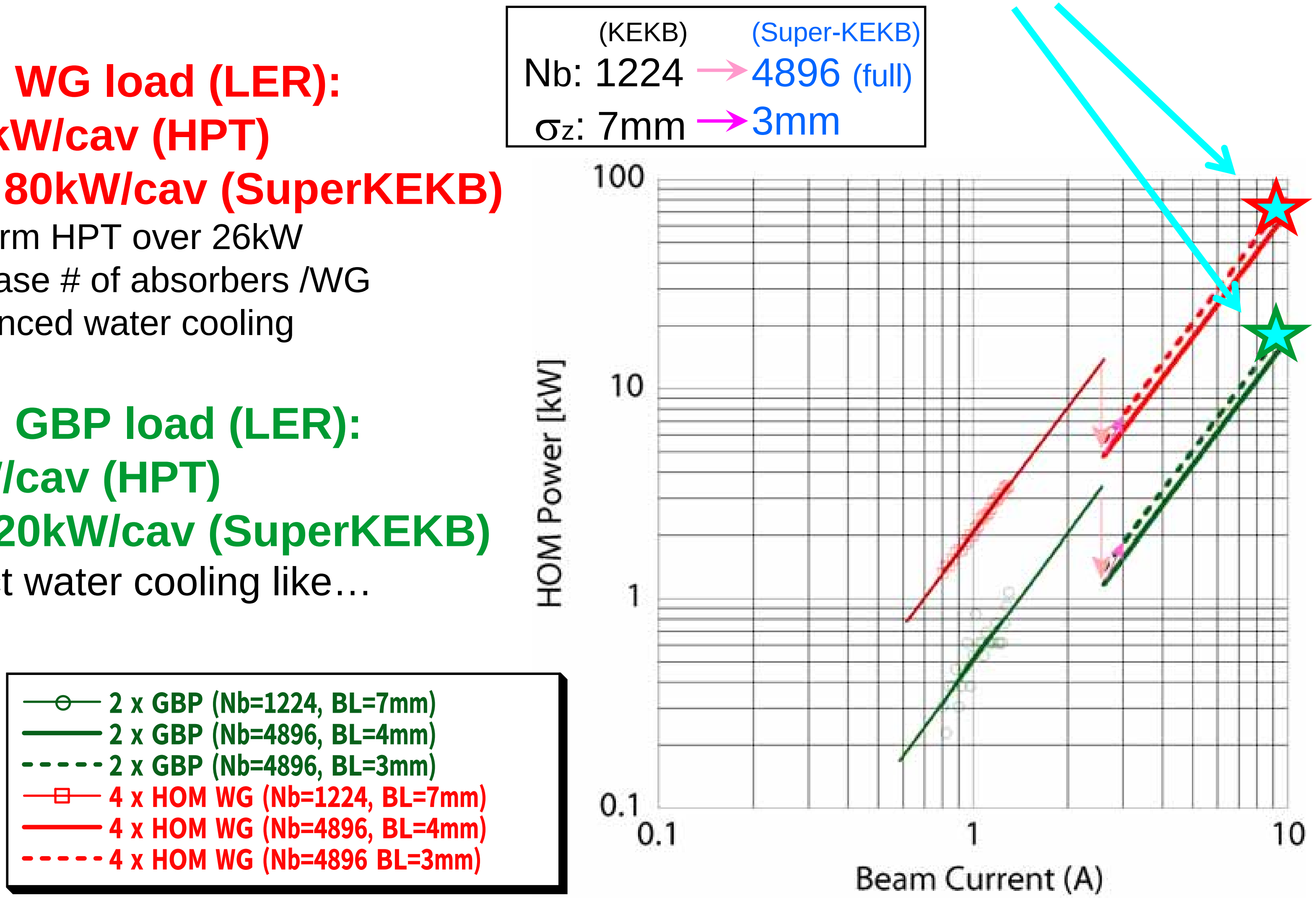




HOM Extrapolation for Super-KEKB LER

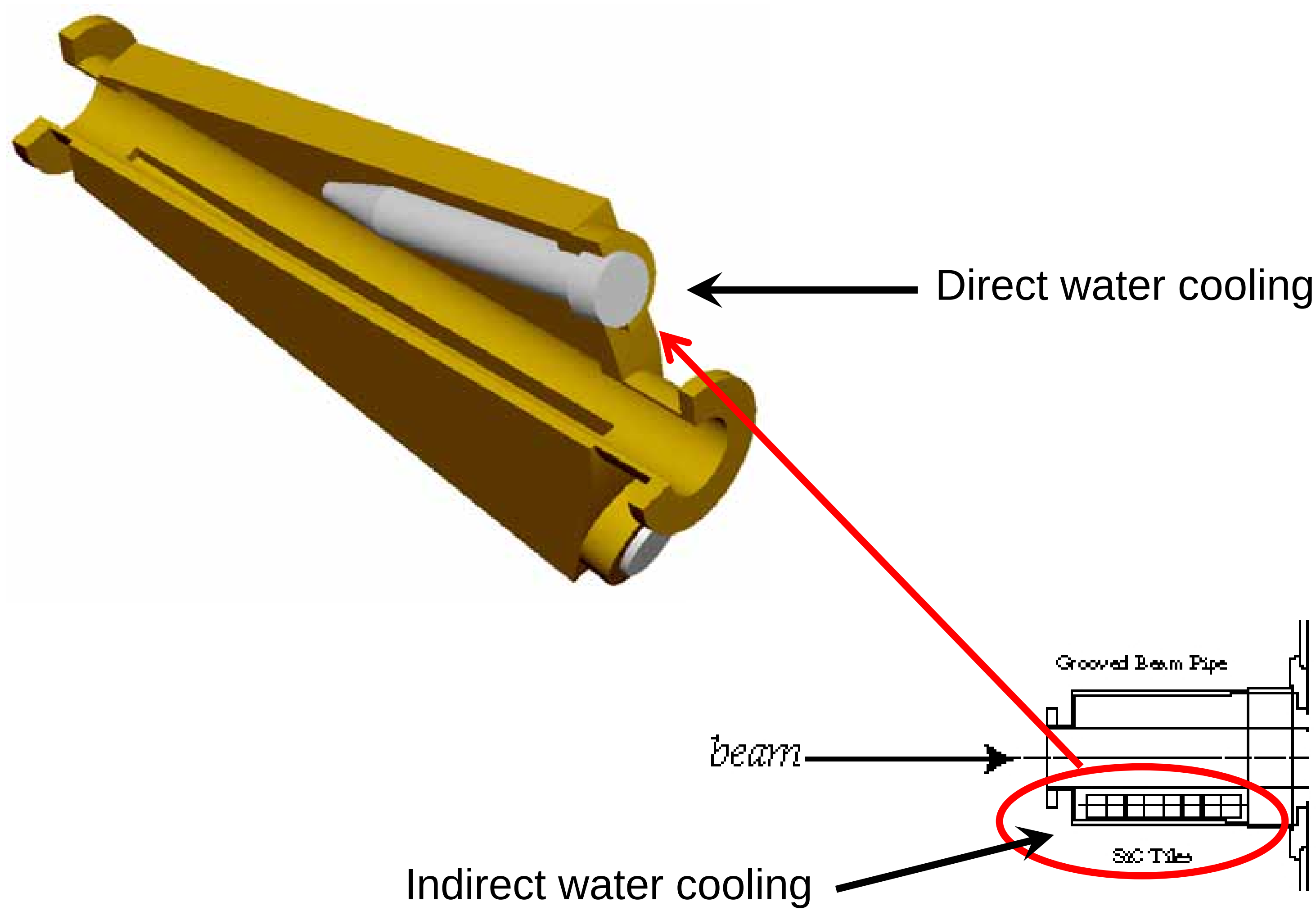
- **HOM in WG load (LER):**
  26kW/cav (HPT)
  → 80kW/cav (SuperKEKB)
  - → Perform HPT over 26kW
  - → Increase # of absorbers /WG
  - → Enhanced water cooling

- **HOM in GBP load (LER):**
  2kW/cav (HPT)
  → 20kW/cav (SuperKEKB)
  - →Direct water cooling like…



Winged chamber loaded with SiC Absorbers

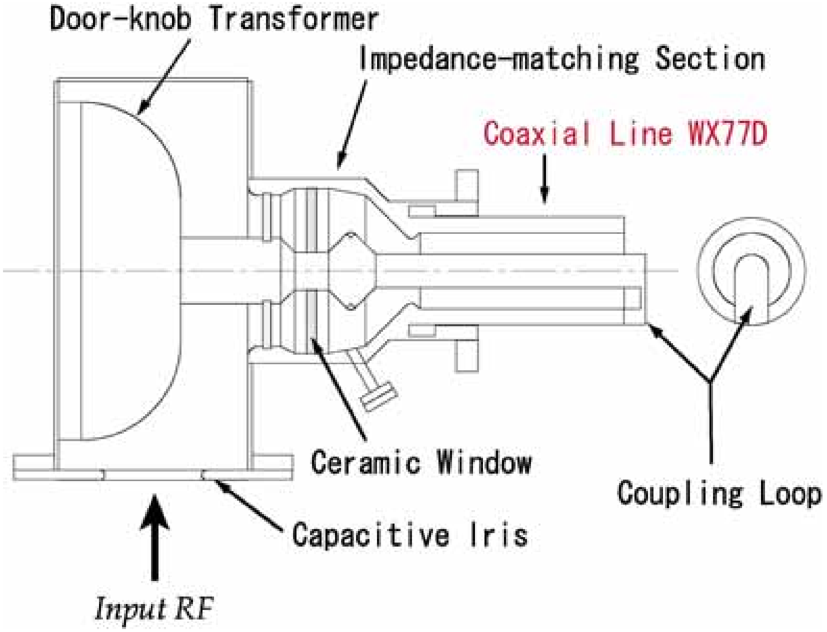
(used in the movable-mask sections)



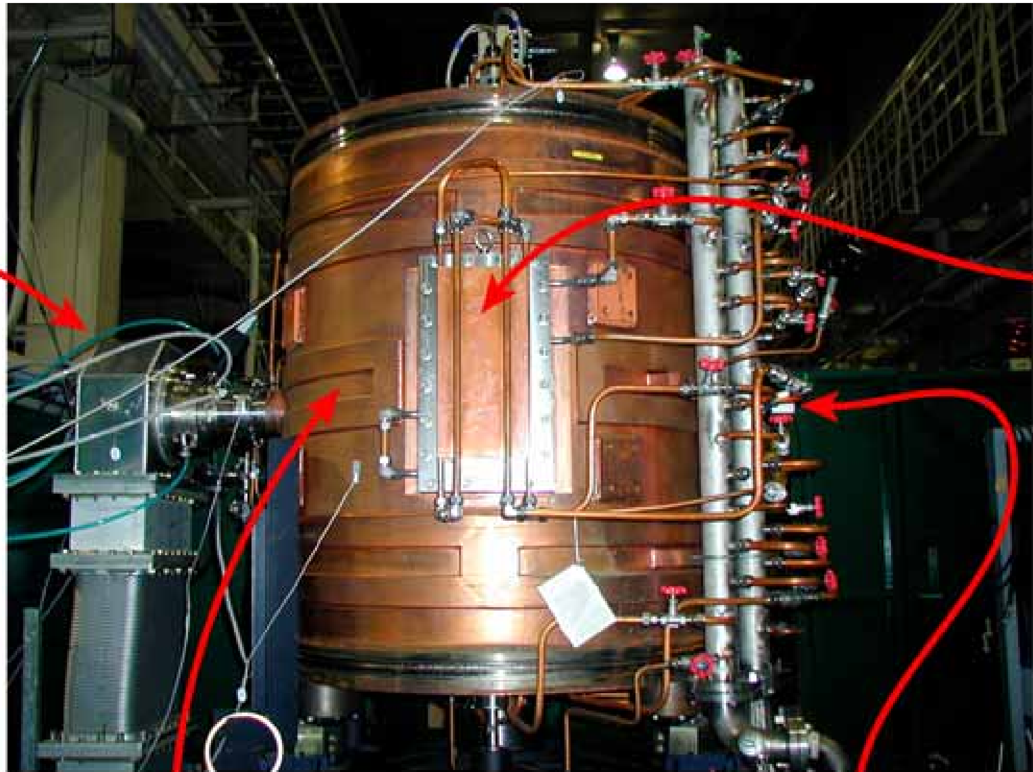
Coupler R&D

- **Over- and under-cut type for impedance matching**
  - HPT done up to 1MW in the testbench with a 1MW dummy load
  - Good performance in KEKB
  - But **multipacting problem in the coaxial line**

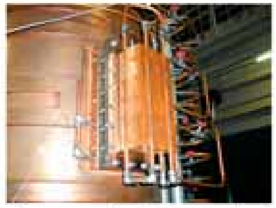
- **New teststand started…**
  - Coupler connected to S-cav alone
  - Without A-cav
  - Free from multipacting discharge in A-cav

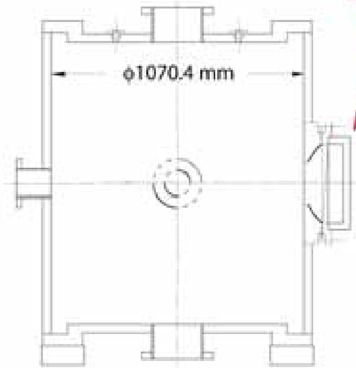


New ARES Coupler Teststand

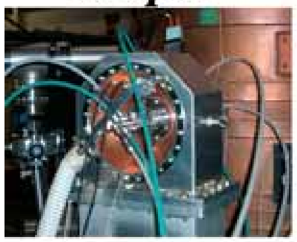


π/2-mode Terminator





Coupler

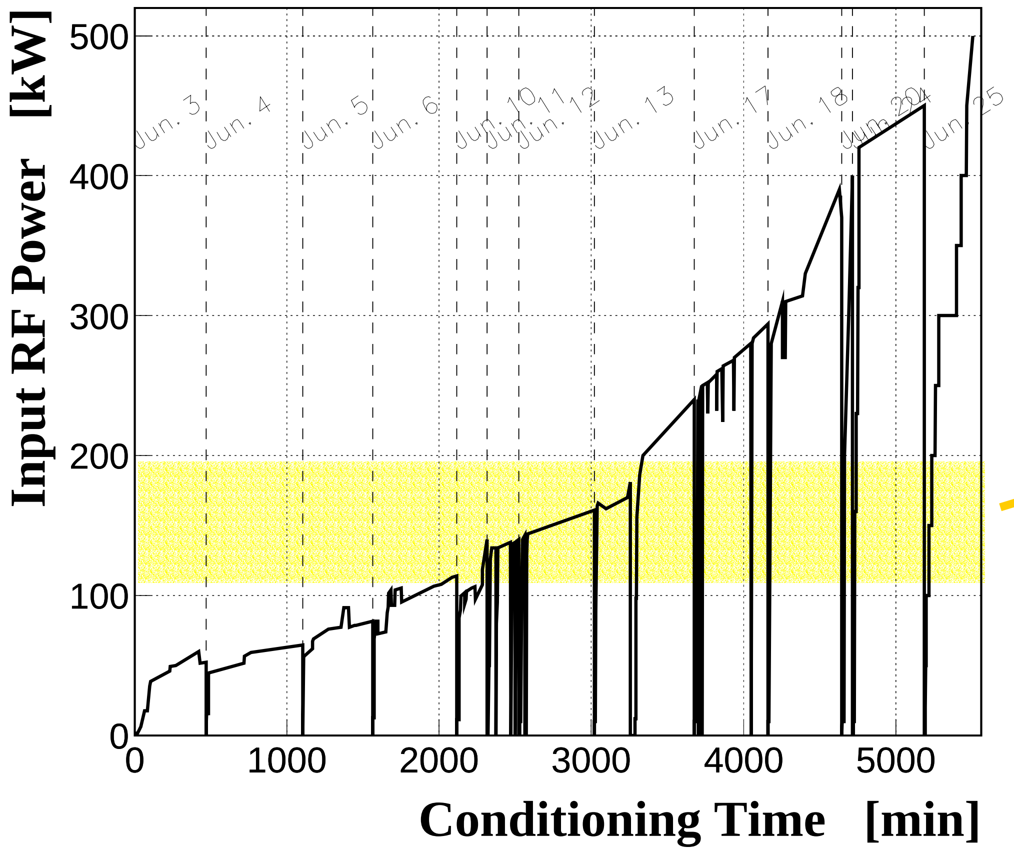


Well-conditioned
Energy-storage Cavity

CCD Camera

Example of the data

Power History for ~5506 min



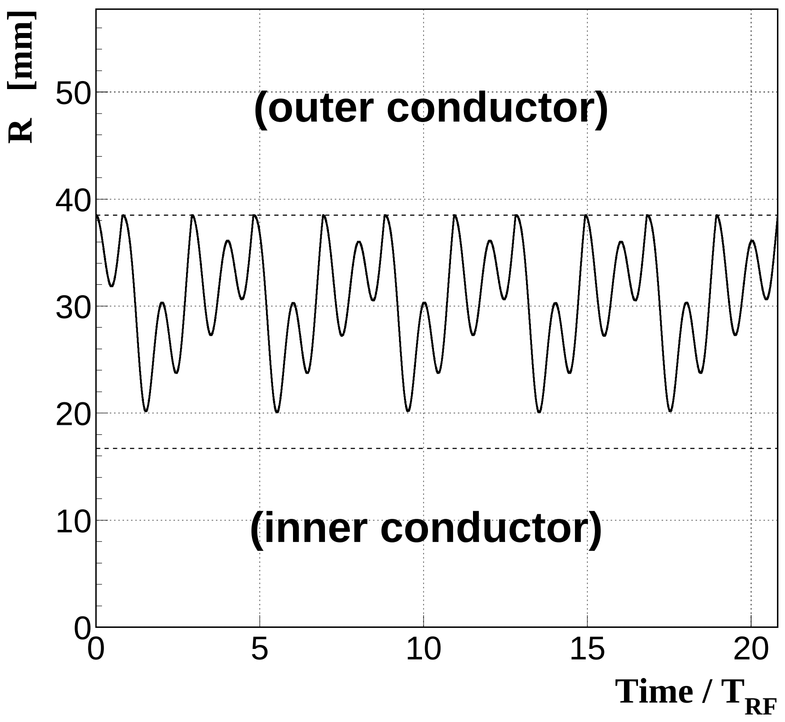
Discharge seen with the CCD camera @～180kW

One-side multipacting on the surface of the outer conductor?

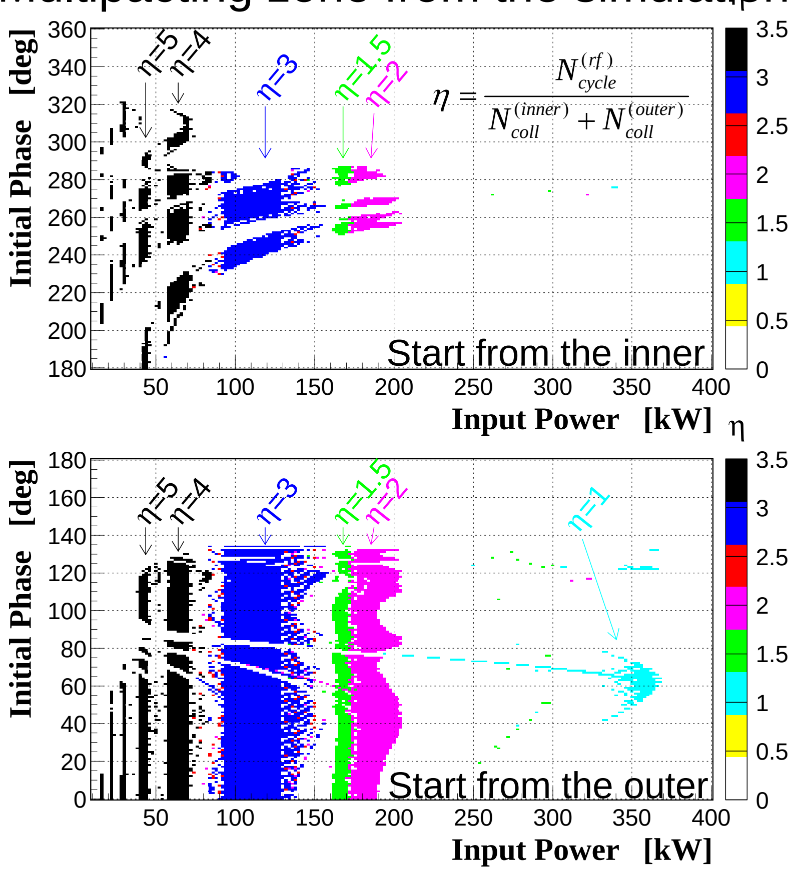
Consideration to the data

Simulation studies ongoing…

Example of the orbits



Multipacting zone from the simulation



Summary

- **Change of the energy ratio: Us/Ua = 9→15**
  - → No serious problems found so far
    - $\tau^{\pi/2\ \mathrm{mode}}_{\mu=-1} > 1\ m\sec$ to be feedbacked by the RF control system
    - $\tau^{0,\pi\ \mathrm{modes}}_{\mu\sim-56} \sim 4\ m\sec$ to be feedbacked by longitudinal FB kickers
    - $\tau^{\mathrm{HOMs}} \sim 5\ m\sec$
- **HOM-load upgrade**
  - → Resuming High Power Tests…

→ **Only the design of A-cav needed to be modified**

- **Coupler R&D**
  - → HPTs and simulation studies ongoing…

Future Plan

- **2003 A-cav design to be fixed**
- **2004 Prototype fabrication**
- **2005 High power tests** and **beam tests**
- **2006 Mass production**
- **2007 Mass production** and **Partial Installation**
  during the long shutdown
- **2008 Super-KEKB starts?**
- **2008~ Mass production** and
  Installation of remaining cavities