Estimation of Loss Factors of Various Vacuum Components

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Contents

Introduction

- Upgrade to SuperKEKB

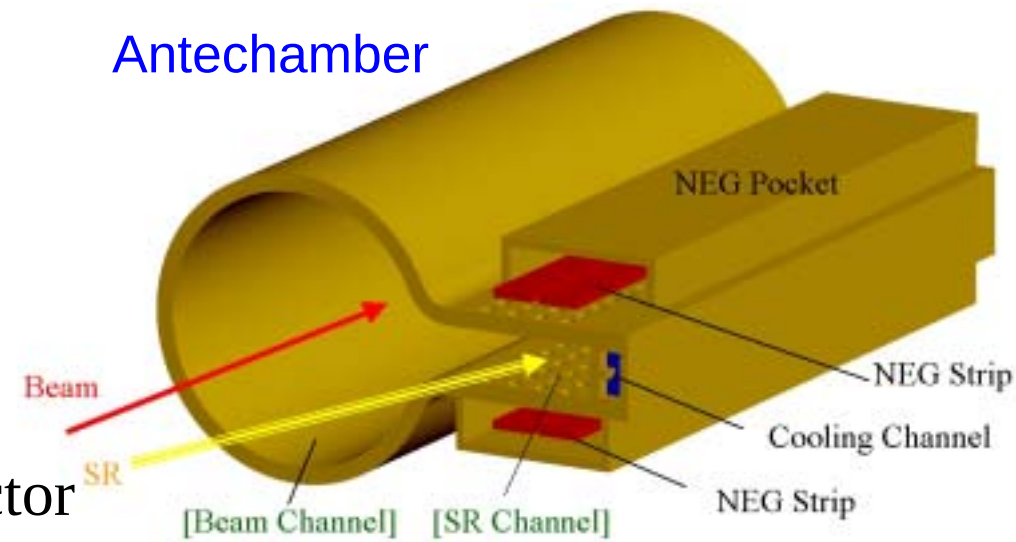
KEKB (design)	SuperKEKB
σ_z = 4 mm	σ_z = 3 mm
I = 1.1 A (HER)	I = 4.1 A (HER)
2.6 A (LER)	9.4 A (LER)

- Loss factor and HOM power will increase.

  ⇓

  Some vacuum components of KEKB need to be improved.

- Vacuum components considered here
  - Pumping port
  - Photon mask
  - Connection flange
  - Movable mask
  - Bellows chamber



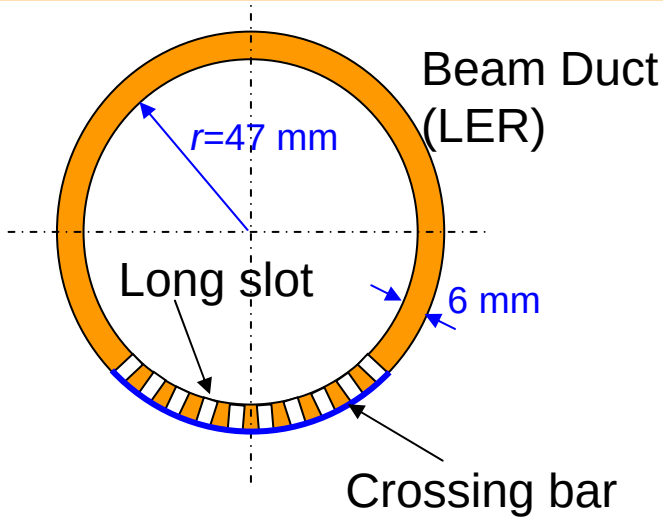
- Method of estimation of loss factor

  MAFIA T3 simulation code

Pumping Port – KEKB LER

- Features
  - "Hidden holes" structure
    - 10 slots / 1 pumping port
    - Long slot in the beam-axis direction

      Length : 100 mm, Width : 4 mm
  - 1800 pumping ports / 1 ring



- Loss factor (σ_z = 4 mm)
  - No step

    k(4 mm) =0.64×10^9 [V/C]

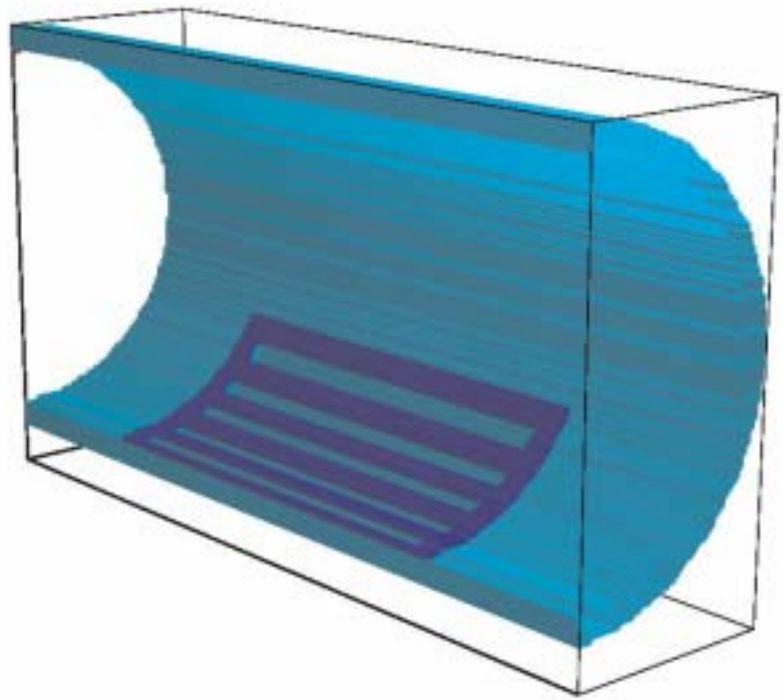
    ↓ ×1800

    Total :k(4 mm) =1.2 [V/pC]
  - Step with 1 mm height

    k(4 mm) =1.97×10^9 [V/C]

    ↓ ×1800

    Total :k(4 mm) =3.6 [V/pC]



Pumping Port – SuperKEKB

- Features
  - Pumps are equipped on the upper and lower sides of the SR channel.
  - The pump channels are connected through many holes with typical diameters of 4 mm.
- Loss factor (σ_z = 3 mm)

$k(3\text{mm})/L = 8.8\times10^5$ [V/C/m]

↓ × ~2000 [m]

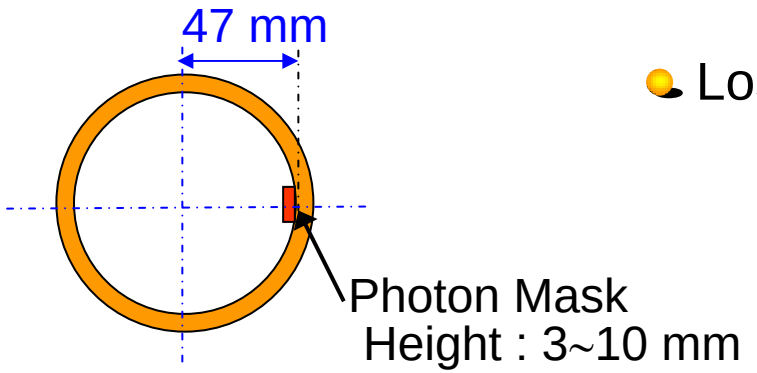
Total :

$k(3\text{mm}) \approx 0.002$ [V/pC]

Pumping slots (holes) have little effect on the beam.

Photon Mask

- KEKB
  - SR masks are located at the side wall of the beam chamber.



- Loss factor (from KEKB Design Report)

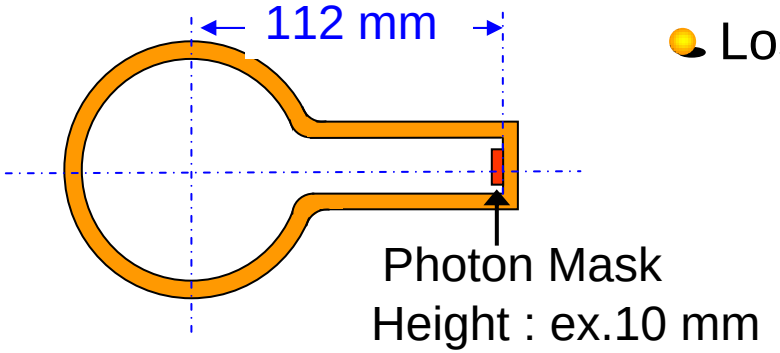
$k(4\text{mm}) = 4.6\times10^{9}$ [V/C]

(Mask height : 5 mm)

$\times 1000$

Total : $k(4\text{mm}) = 4.6$ [V/pC]

- SuperKEKB
  - SR masks are located at the side wall of the SR channel.



- Loss factor (estimated by MAFIA T3)

$k(3\text{mm}) = 1\times10^{4}$ [VC^{-1}]

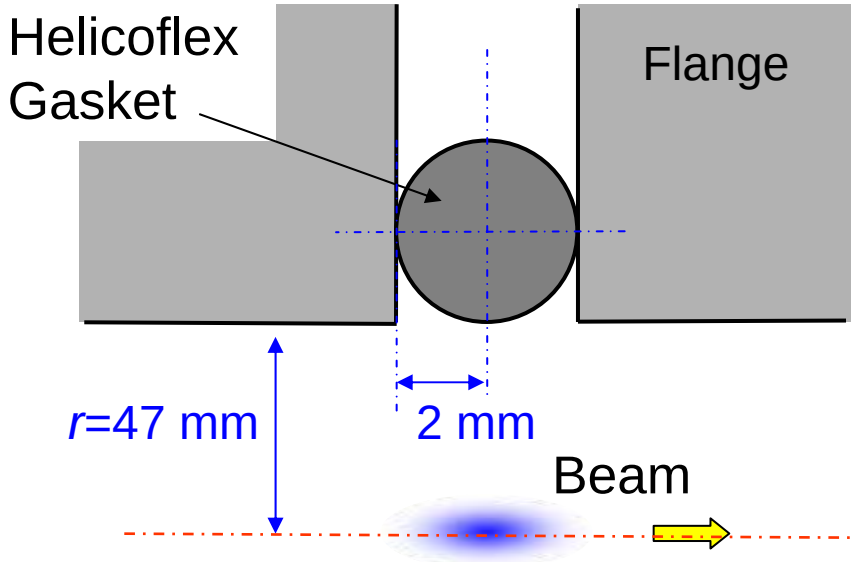
$\times 1000$

Total : $k(3\text{mm}) = 1\times10^{-5}$ [V/pC]

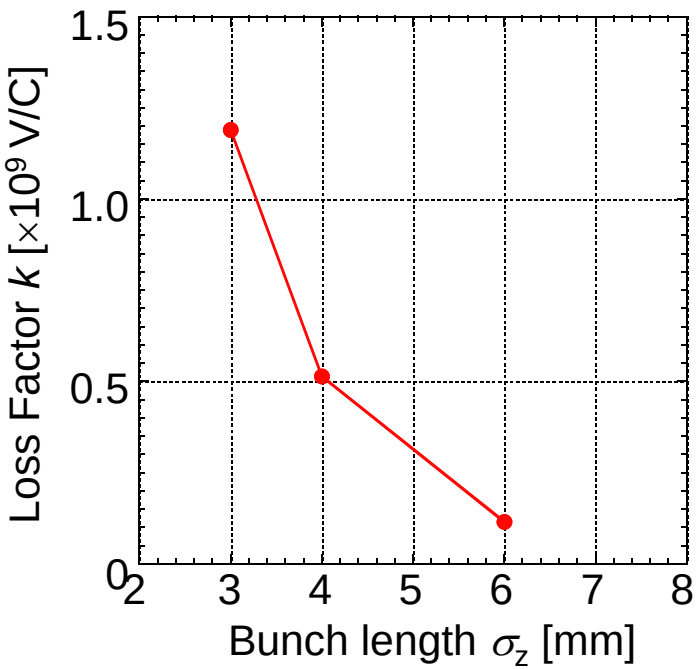
Loss factor for SuperKEKB is negligible small.

Connection Flange - KEKB

- Features
  - Helicoflex gasket
    - Same inner diameter as a beam duct
    - Double role of vacuum seal and rf bridge
  - 2000 connections / 1ring



- Loss Factor



× 2000

- Total loss factor

KEKB LER (present)

k(6 mm) = 0.2 [V/pC],

P_{HOM} = 3 [kW]

KEKB LER (design)

k(4 mm) = 1.0 [V/pC],

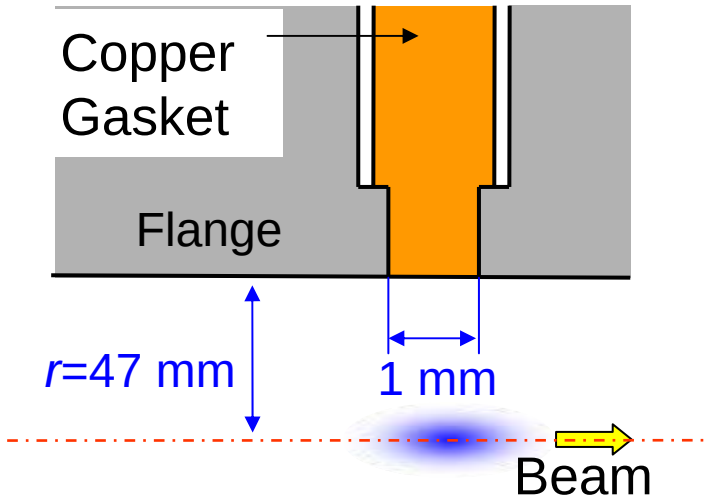
P_{HOM} = 14 [kW]

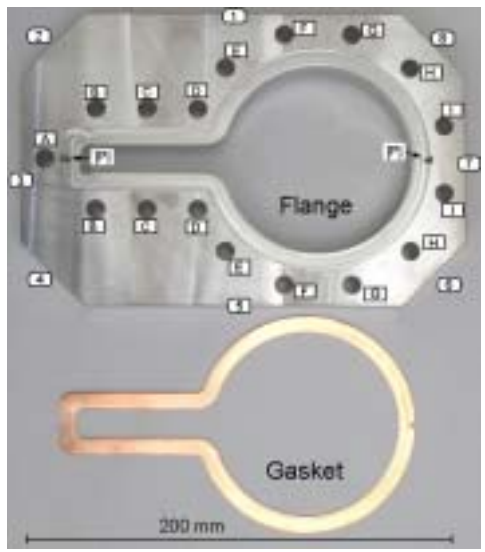
Connection Flange - SuperKEKB

- Connection of antechamber
  - It is difficult to use conventional connection flange.
- MO-type Flange
  - Features
    - Developed for C-band wave guide
    - Smooth inner surface
  - Possibility with antechamber type aperture
    - Promising results were obtained.
- Loss Factor (σ_z=3 mm, 0.2 mm steps)
  - k(3 mm) < 6.8×10^7 [V/C]

× 2000

Total: k(3 mm) < 0.1 [V/pC], P_{HOM} < 4.4 [kW]

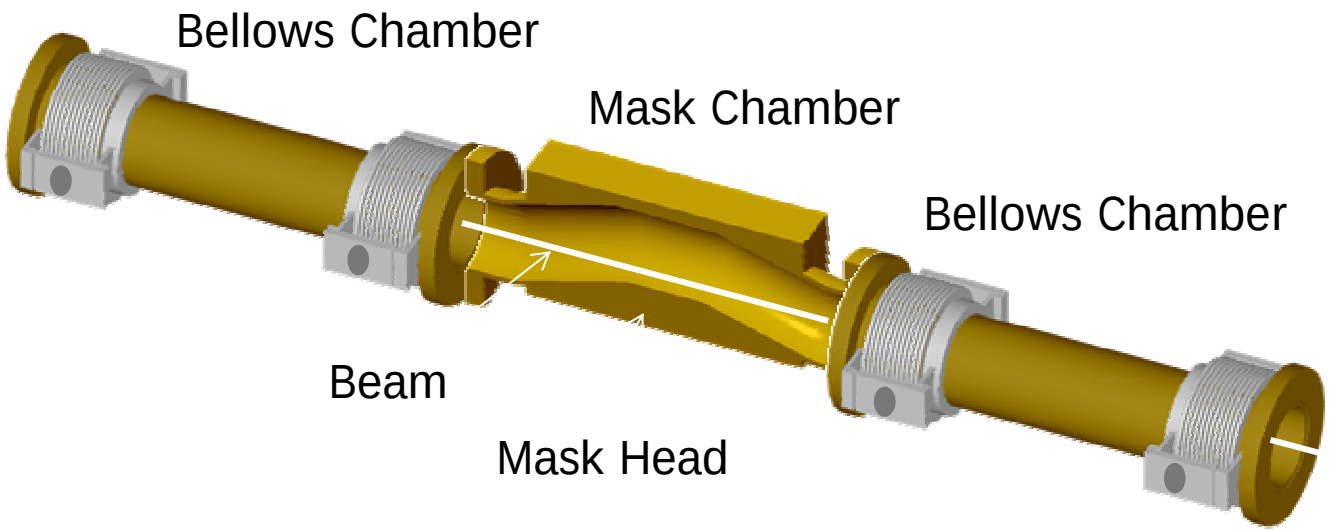




The loss factor of MO-type flange is much less than conventional one.

Movable Mask - structure

- Movable mask with reduced HOM design (KEKB)
  - Features



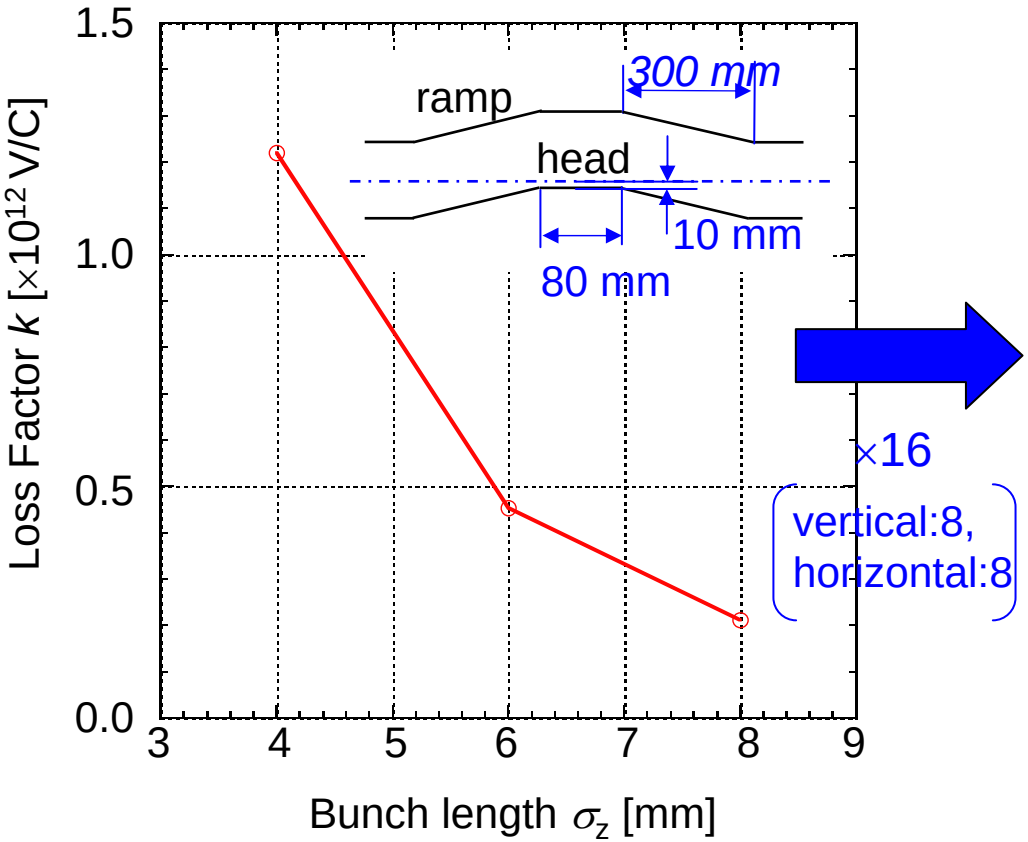
- A device to reduce the background noise in Belle detector

  Wall of the bent chamber has the function as a mask head.
- 16 movable masks / 1 ring
- Large loss factor

  Strong HOM is excited at the mask head where the beam passes of center of the beam chamber.

Movable Mask – loss factor

- Loss Factor



- Total loss factor

KEKB LER (present)

k(6 mm) = 7.2 [V/pC],

P_{HOM} = 140 [kW]

KEKB LER (design)

k(4 mm) = 19 [V/pC],

P_{HOM} = 260 [kW]

SuperKEKB LER (Expectation)

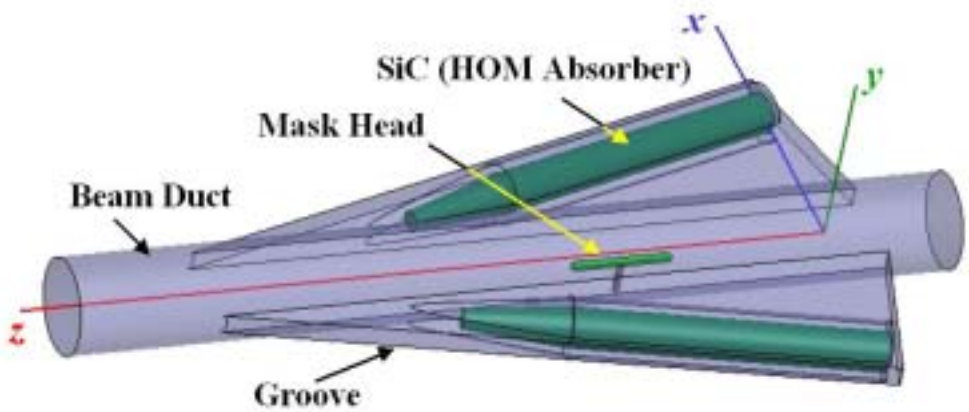
k(3 mm) = 32 [V/pC],

P_{HOM} = 5655 [kW]

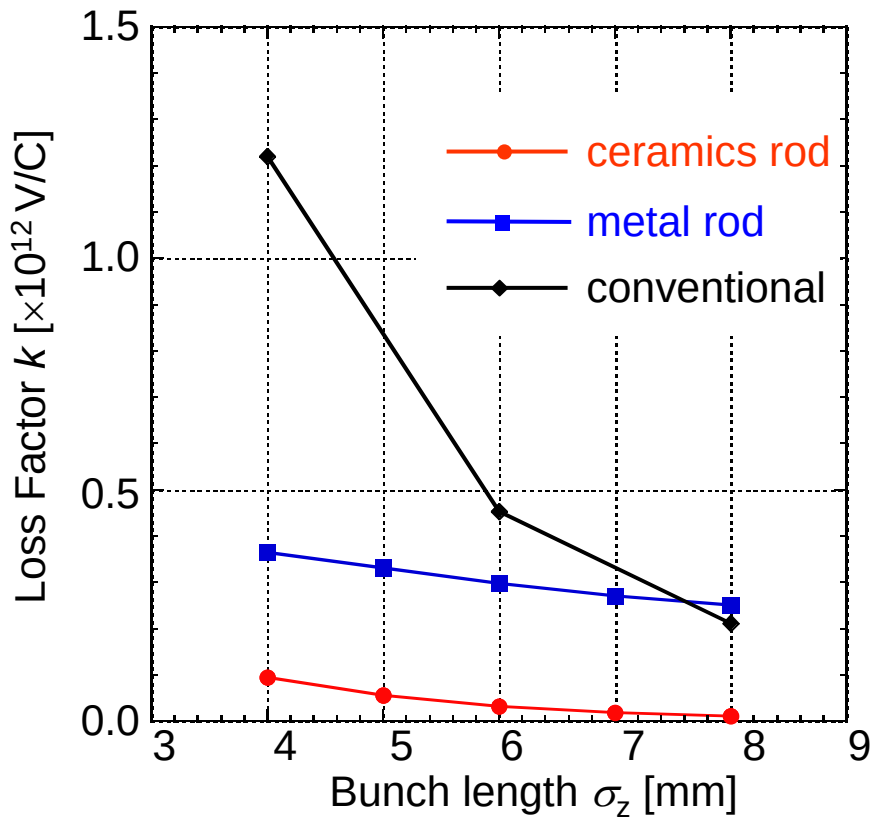
It is difficult to use this movable mask at SuperKEKB.

Movable Mask - SuperKEKB

- Proposal: Invisible Movable Mask **(still only an idea)**
- Small mask head supported by ceramics and HOM absorber
  - Head is fixed to chamber.
  - Position is adjusted by moving the chamber.
  - SiC absorber is combined to damp HOM excited at the mask head.
  - Loss factor is about 1/10 of conventional one.
  - More R&D is necessary.

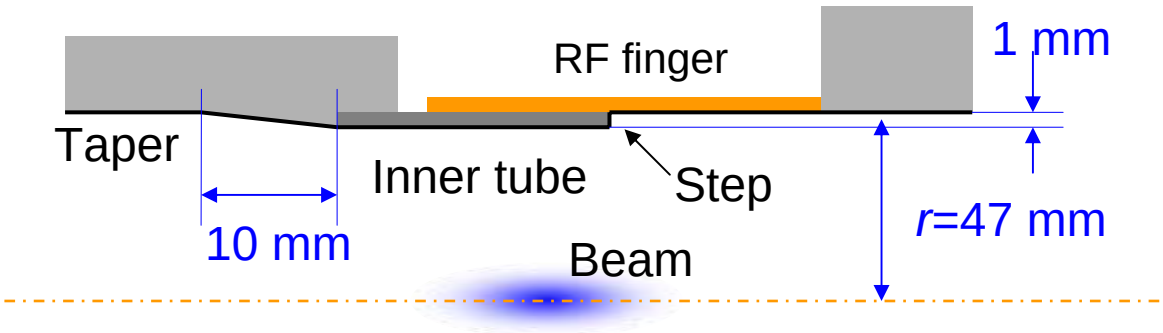


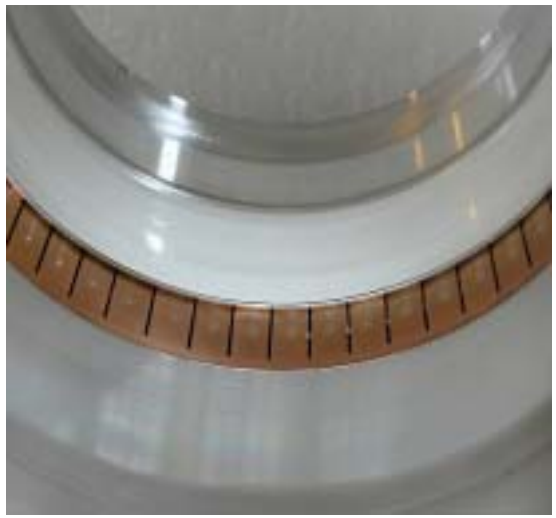
New movable mask
(conceptual drawing)



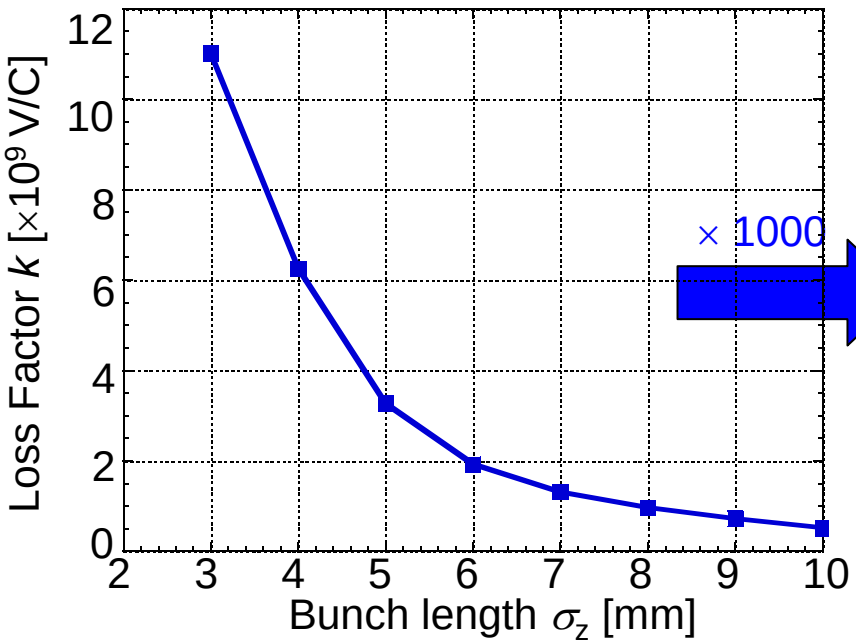
Bellows – KEKB

- Bellows chamber with a finger-type RF shield
  - Structure





  - Loss Factor



- Total loss factor

KEKB LER (present)

k(6 mm) = 1.9 [V/pC], P_{HOM} = 37 [kW]

KEKB LER (design)

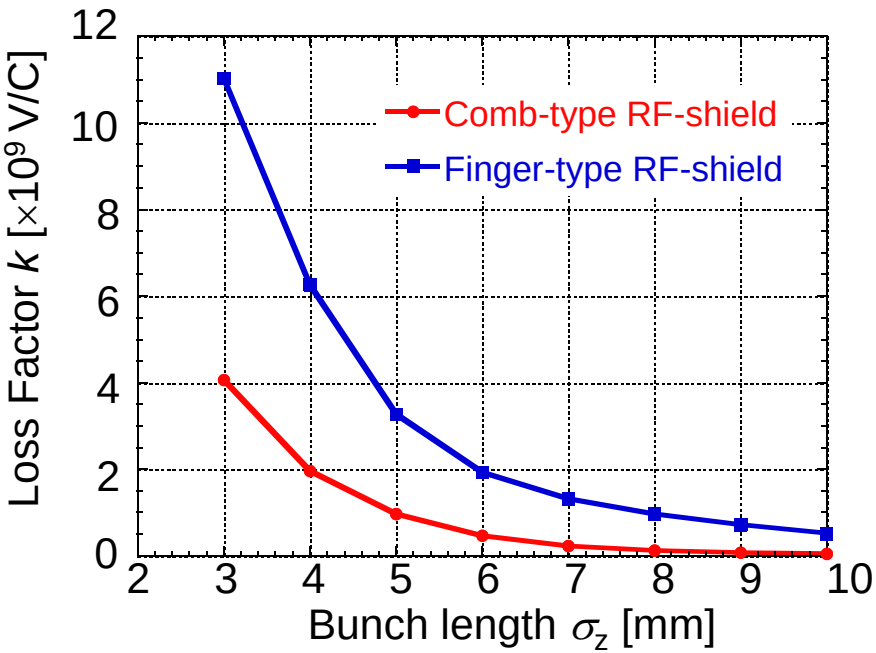
k(4 mm) = 6.3 [V/pC], P_{HOM} = 68 [kW]

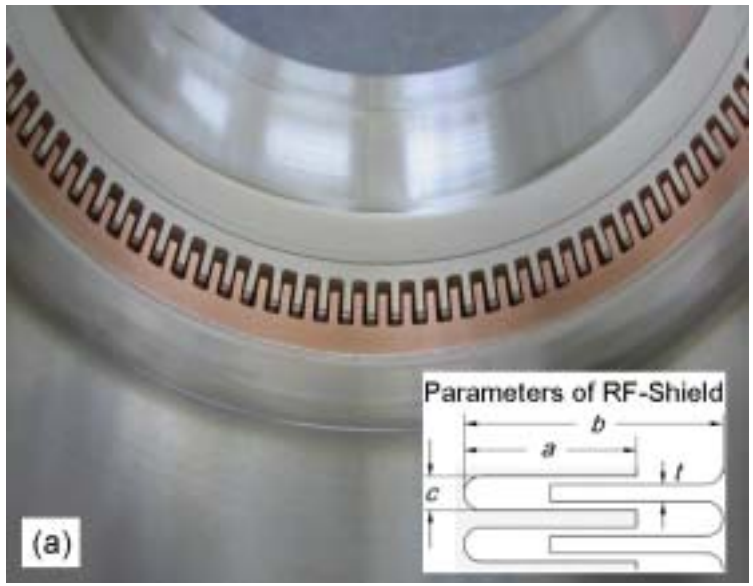
SuperKEKB LER

k(3 mm) = 11 [V/pC], P_{HOM} = 1944 [kW]

Bellows - SuperKEKB

- Bellows chamber with a comb-type RF shield
  - Features
    - RF shield : nested comb teeth
      Length: 10 mm, Width: 1 mm
      Radial thickness: 10 mm,
    - High thermal strength
    - No radial step on the inner surface
  - Loss Factor (estimated by MAFIA T3)





- k(3 mm) = 4.1×10^9 [V/C]

× 1000

Total : k(3 mm) = 4.1 [V/pC]

P_{HOM} = 707 [kW]

k(3mm) reduces to ~40 %.

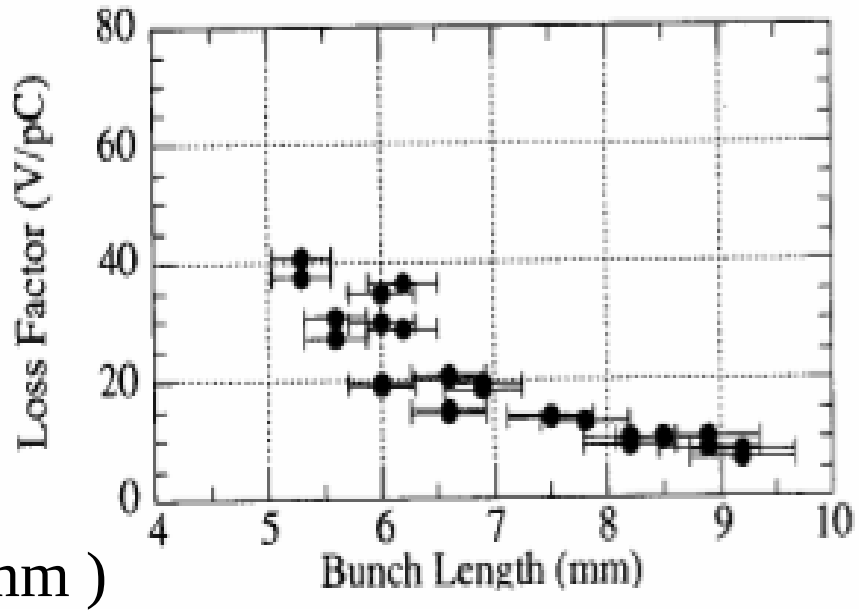
Comparison with measurement in KEKB LER - 1

- Estimation (σ_z = 4mm)
  - Total loss factor : k(4mm) = 60~62 + α V/pC

Component	k [V/C]	Number of items	Total k [V/pC]	
Resistive wall	1.5×10^{9}	2200 [m]	3.2	Formula
Pumping port	2.0×10^{9}	1800	3.6	Calculation(4mm)
Flange	5.1×10^{8}	2000	1.0	Calculation(4mm)
Bellows	6.3×10^{9}	1000	6.3	Calculation(4mm)
Photon mask	4.6×10^{9}	1000	4.6	Design report
Gate valves	1.0×10^{10}	30	0.3	Calculation(4mm)
Movable mask (ver.1)	$1.2\times10^{12}+\alpha'$	16	19.2 +α	Calculation(4mm)
IR chamber	2.9×10^{11}	1	0.29	Design report
Mask at IP	8.0×10^{10}	1	0.08	Design report
Recomb. Chamber	1.6×10^{12}	1	1.6	Design report
Dummy chamber for Crab cavity	1.8×10^{12}	2	3.2～4.0	Measurement(6mm)
Cavity (ARES)	8.3×10^{11}	16	13.3	Design report
BPM	2.0×10^{9}	400	0.8	Design report
Feedback system	3.2×10^{12}	1	3.0～3.8	Calculation(6~7 mm)

Comparison with measurement in KEKB LER - 2

- Experimental result (by Ieiri-san)
  - Measurement in 2000
    - Cavity: ARES×16
    - Movable mask: Ver.1×16
  - $k(\sigma_z=4\text{mm}) = 87\pm30$ V/pC



- Comparison(KEKB LER, σ_z=4 mm)
  - Measurement ≈ Estimation

    87±30 V/pC 60~62 + α V/pC

Measured loss factor agrees with estimated loss factor.

Improvement for SuperKEKB

- Loss factor and HOM power (σ_z = 4mm)

Components	KEKB (design) (σ_z=4 mm, I=2.6 A, n_b=5000)		SuperKEKB (σ_z=4 mm, I=9.4 A, n_b=5000)	
	k [V/pC]	P_{HOM} [kW]	k [V/pC]	P_{HOM} [kW]
Resistive wall	3.2	43	3.2	971
Pumping port	3.6	49	Negligible	Negligible
Flange	1.2	14	0.01	2.0
Photon mask	4.6	62	Negligible	Negligible
Bellows	6.3	85	1.96	346
Gate valves	0.3	4	0.06	10
Movable mask	19.2+α	260+α	1.5+α	269+α
Total	38+α	517+α	6.8+α	1200+α

Loss factor reduces to ~18 % for a 4 mm bunch length.

- Other components

  IR chamber, IP mask, Recomb. chamber, Cavity, Crab cavity, Feedback system, BPM, etc.

Summary

- Estimation of the loss factors of the vacuum components of KEKB and SuperKEKB
  - Pumping port
  - Photon mask

    ← Antechamber
  - Connection flange ← MO flange
  - Movable mask ← Invisible movable mask
  - Bellows ← Comb-type RF shield
- Comparison between estimation and measurement in KEKB (2000)
  - Estimation ≈ Measurement
- Improvement for SuperKEKB
  - Loss factor of improved vacuum components for a 4 mm bunch length reduces to 18%. (if everything goes well.)
- Future
  - Estimation of all other components
  - Investigation of the beam instabilities