Recent Upgrade Studies of Vacuum Components

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- R&D for
  - Beam Duct
  - Connection Flange
  - Bellows and Gate Valve
  - Movable Mask (Collimator)
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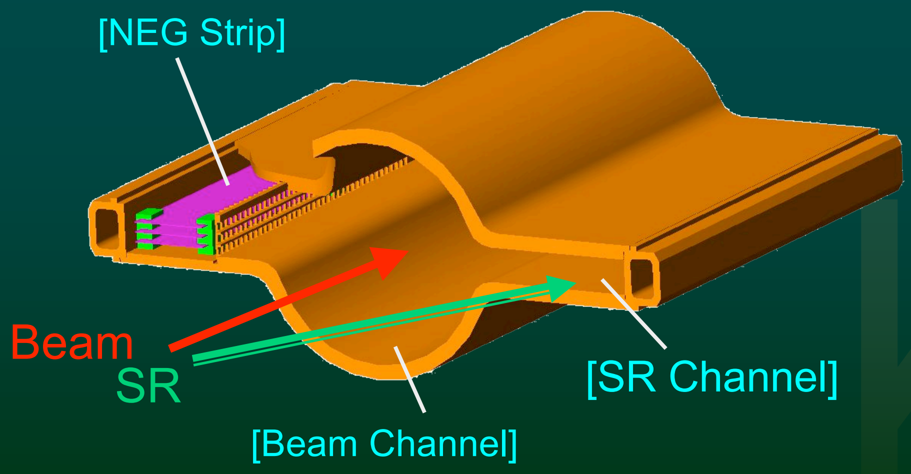
Introduction

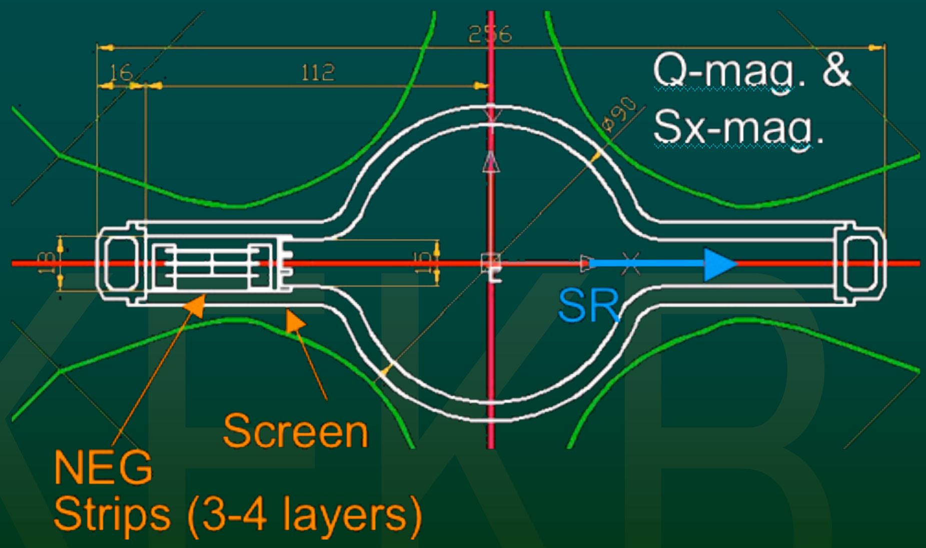
- R&D on vacuum components to meet the demands for future high-current accelerators has been progressing using intense beams of the KEK B-factory ring (KEKB).
  - Low Energy Ring (LER): 3.5 GeV, Max.1.8A (1389 bunches)
  - High Energy Ring (HER): 8.0 GeV, Max.1.4 A (1389 bunches)
- Studied Components:
  - ➡ Copper beam ducts with one or two ante-chambers.
  - ➡ Special connection flange with no gap at the connection point.
  - ➡ Bellows chambers and gate valves with high thermal strength and low beam impedance.
  - Next talks: Inner surfaces with a low secondary electron yield (SEY).
  - ➡ Movable mask (collimator) with low beam impedance.

Beam Duct

- Beam duct with ante-chamber (2003 ~)
  - Ante-chamber = additional chamber
  - Effective to reduce photoelectrons in the beam channel
  - Also effective to dilute the power density of SR
- Use copper

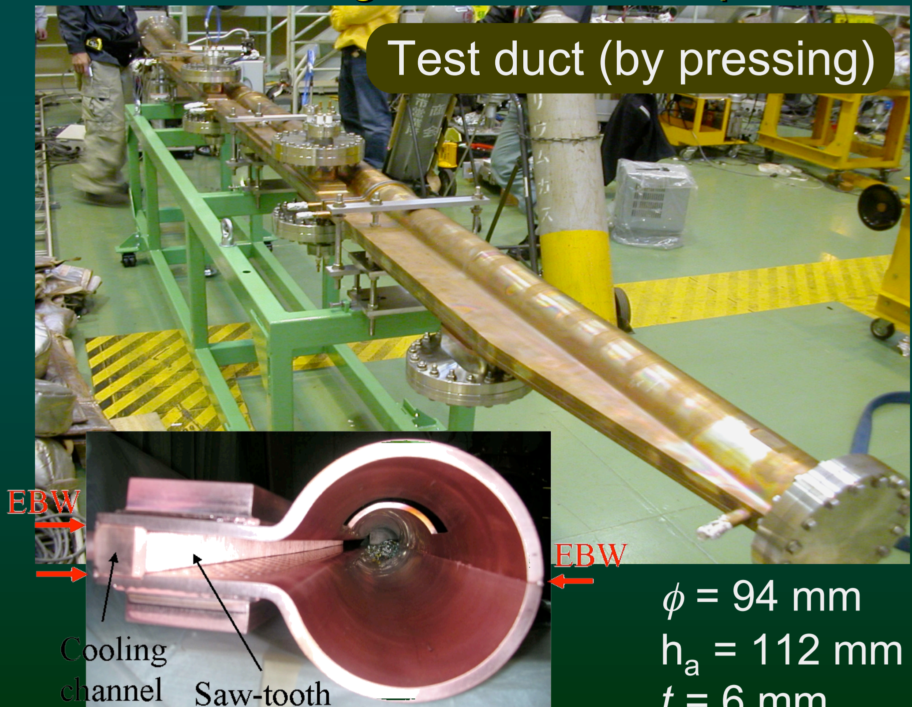
Beam duct with antechamber



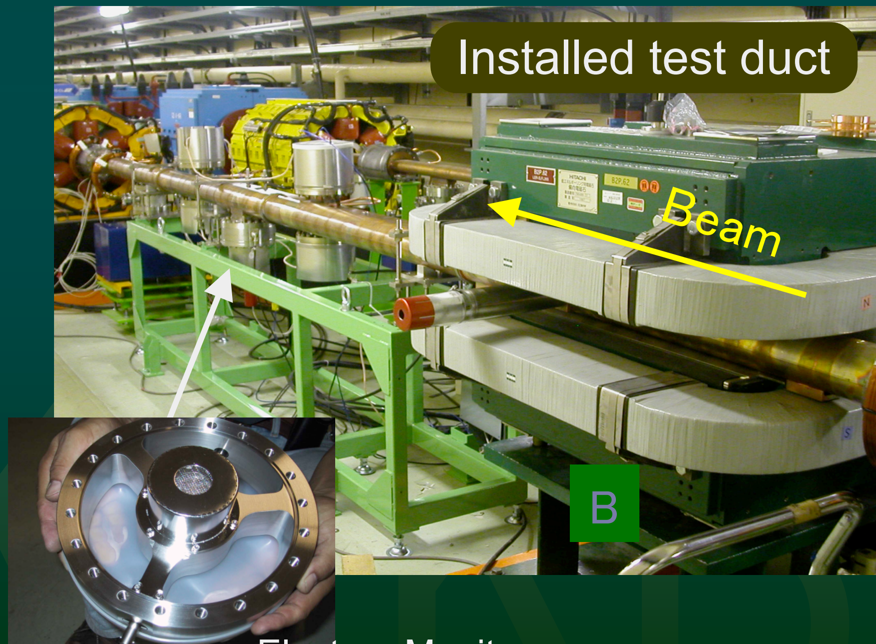


Beam Duct

- Copper ducts with an antechamber for arc sections (2003~)
  - Manufacturing properties were investigated.
  - Installed at an arc section of the KEKB positron ring
  - Electron number was estimated using a electron monitor.
    - Large reduction of photoelectron was found.



ϕ = 94 mm
h_a = 112 mm
t = 6 mm

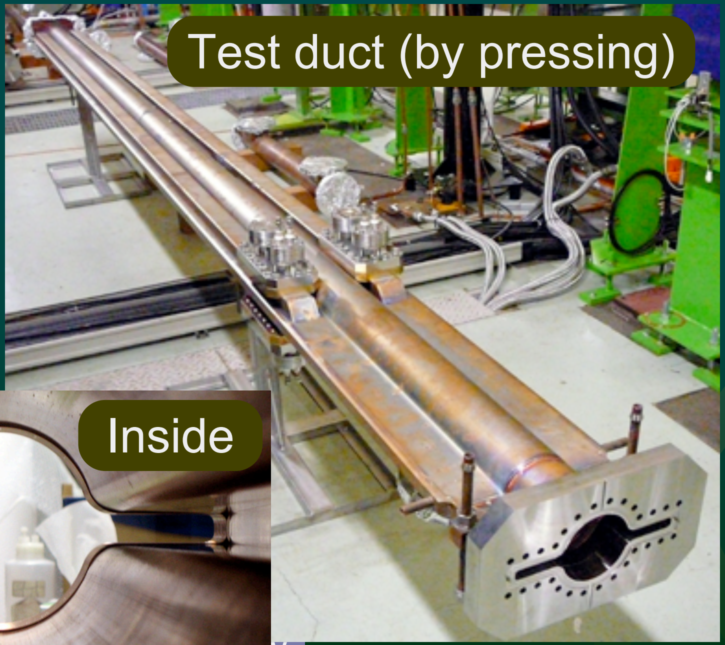


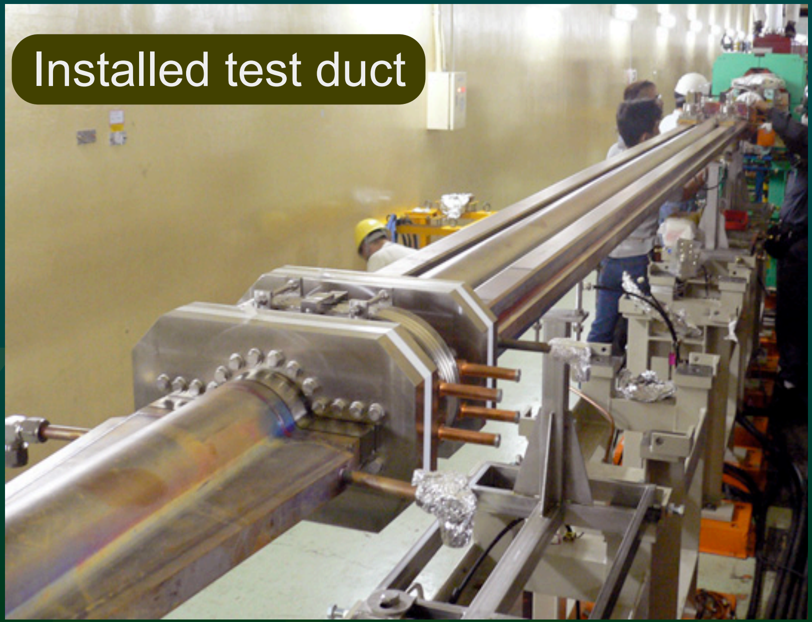
Electron Monitor
(DC, Collector:+100 V, Repeller:-30V)

Beam Duct

- Copper duct with two ante-chambers (2005~)
  - Installed into the LER wiggler section
  - ~3.6 m, with NEG strips, by pressing method
  - Reduction of photoelectrons was again confirmed.
  - No problem up to 1.7 A.

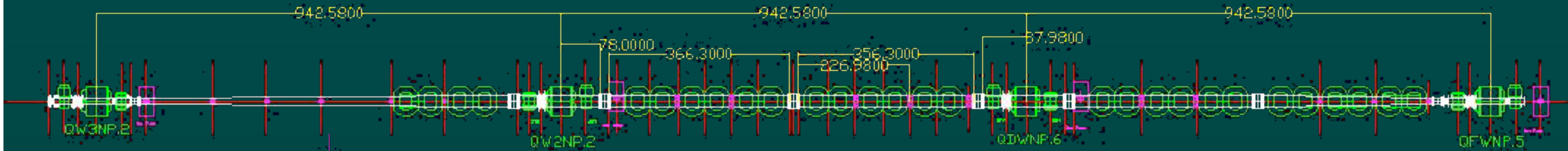
ϕ = 94 mm
h_a = 224 mm
t = 6 mm

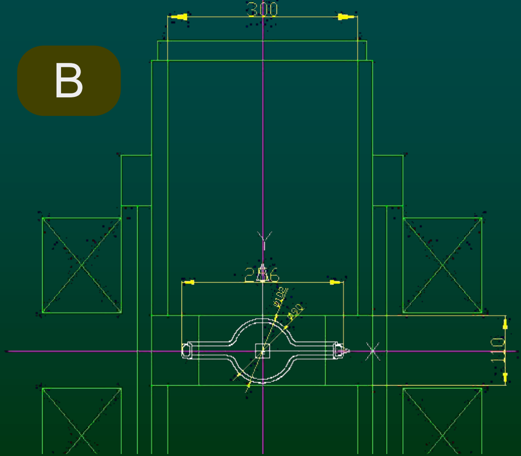


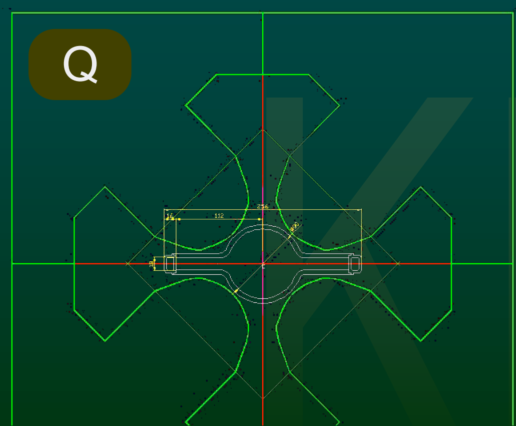


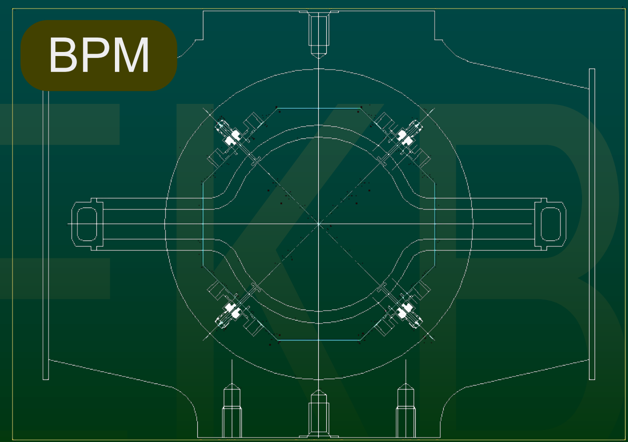
Beam Duct

- This year, a part of Nikko wiggler section will be replaced by beam duct with ante-chambers.
  - ~30 m in total, ϕ 90 mm, h_a=110 mm
  - Including Q-chambers with BPM
  - Manufacturing is now proceeding by cold drawing method.



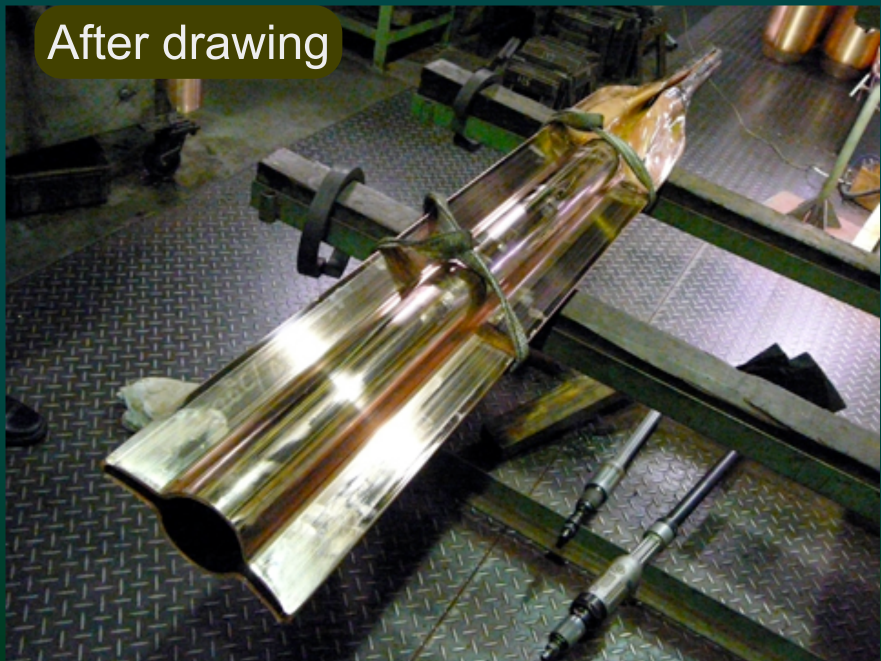






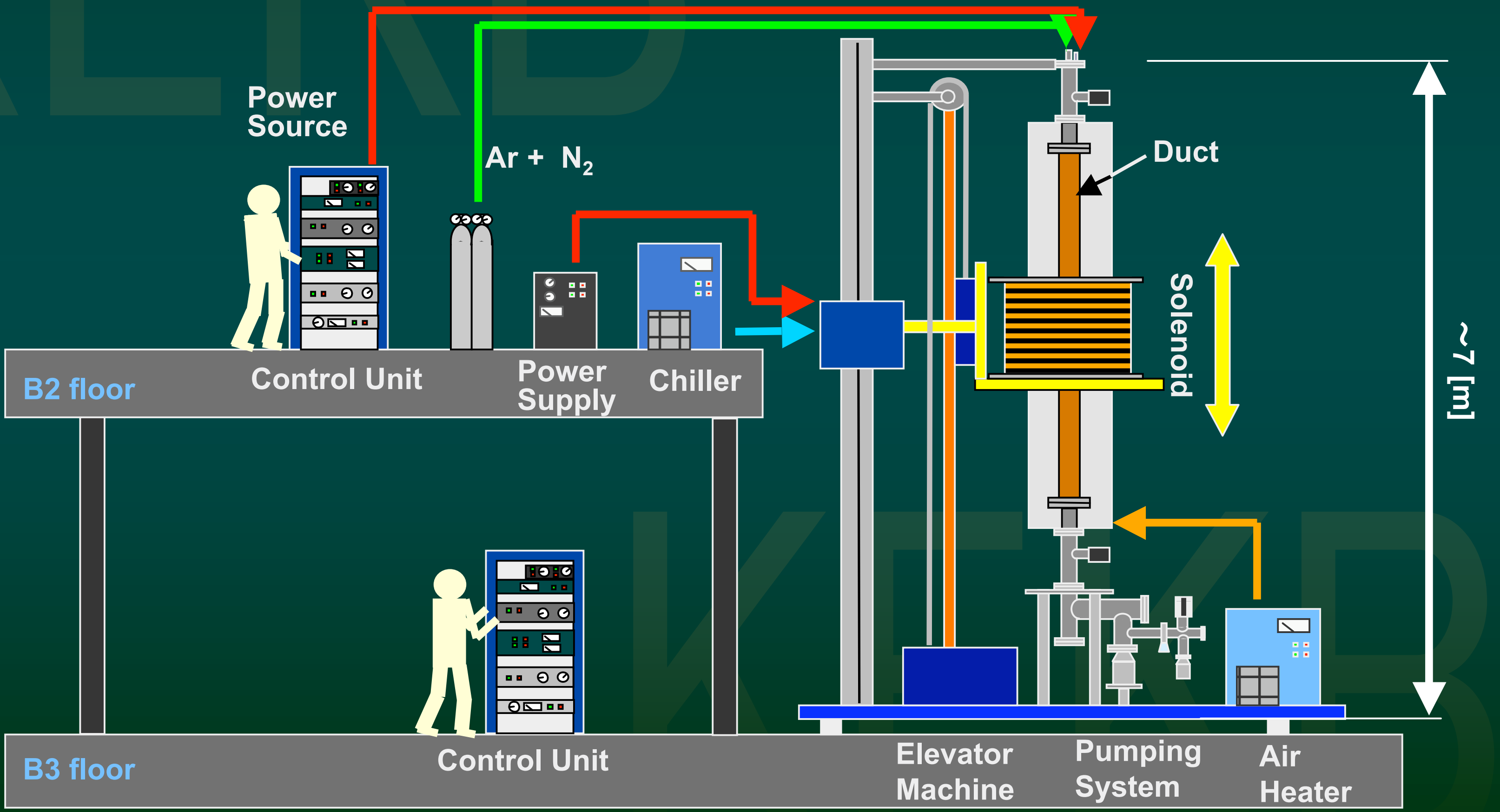
Beam Duct

- Cold drawing was successful.
  - More accurate than pressing method
  - Cost ?



Beam Duct

- Beam ducts will be coated by TiN.
  - Coating station is now being set up at an experimental hall.



Connection Flange

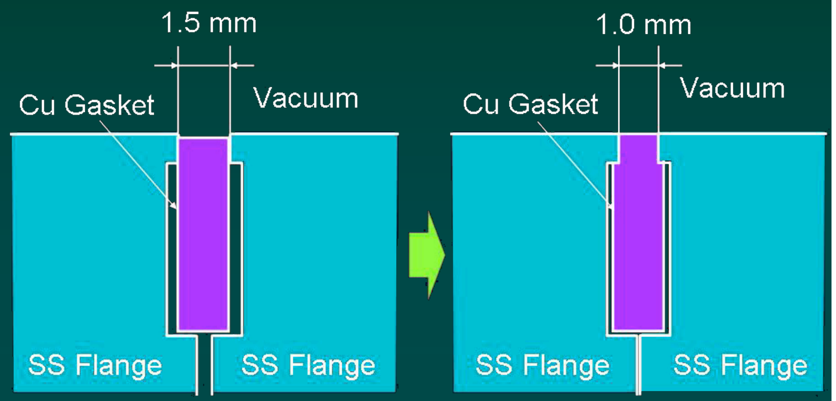
- MO (Matsumot-Ohtsuka) type flange

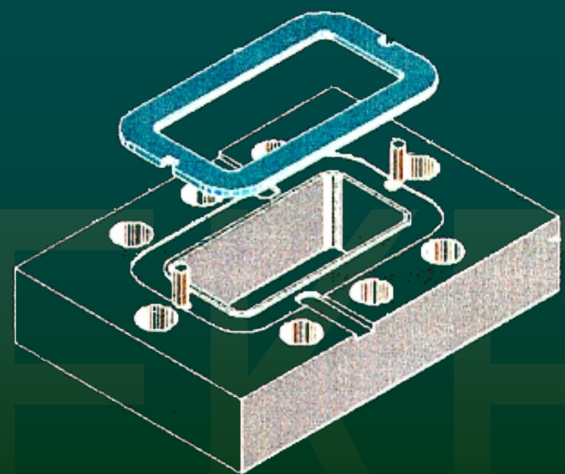
(2004~)

  - Seal a vacuum at only the inner surface.
  - Vacuum seal doubles as RF bridge.
  - No gap and step at the inner surface.
  - Can follow the complicated cross section.

➡ Applied to beam ducts with ante-chambers

[Vacuum side]

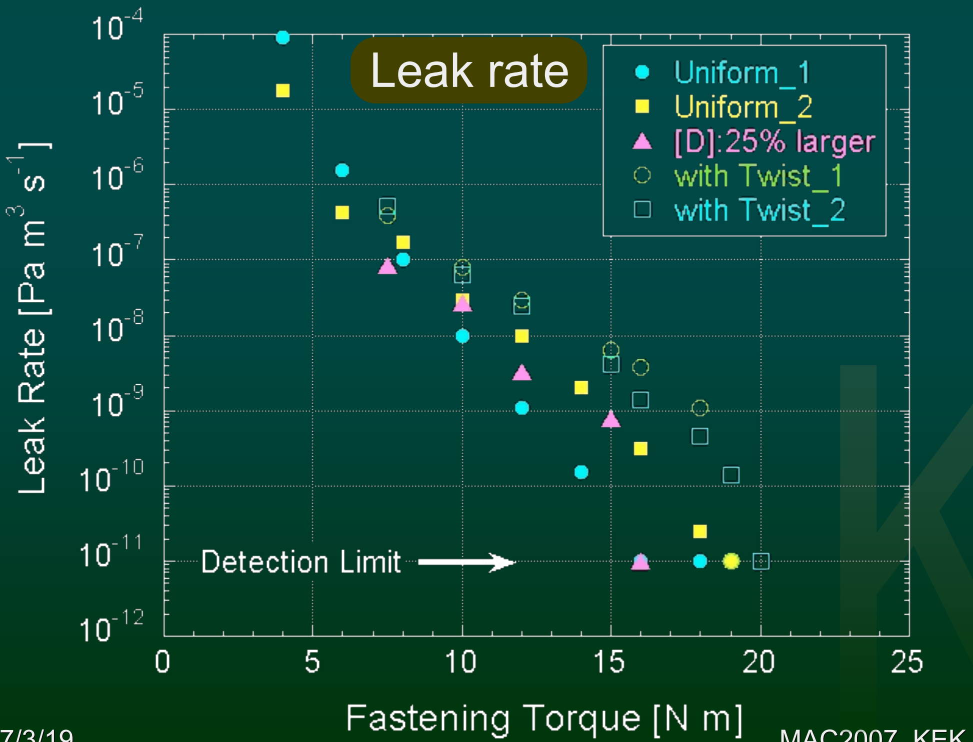




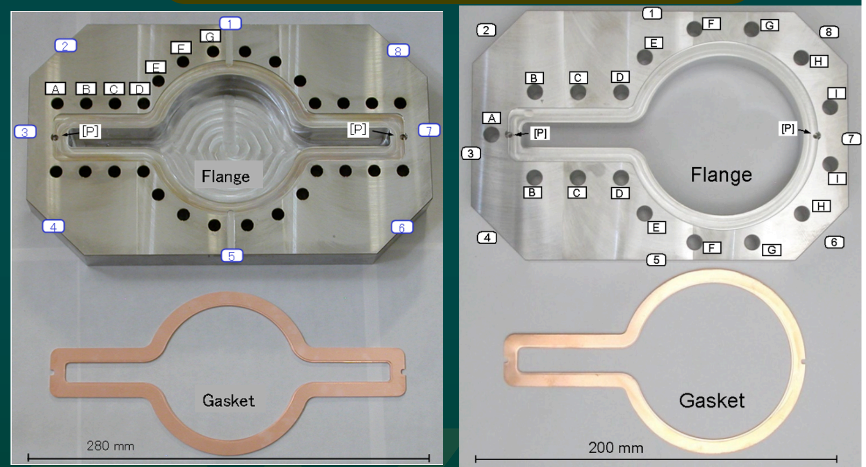
Rectangular model (for waveguide)

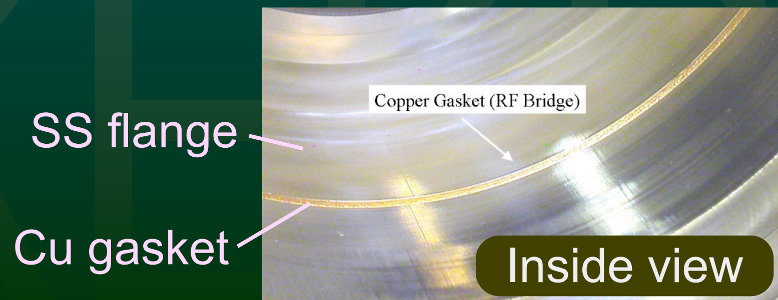
Connection Flange

- Bench test (2004~)
  - Stainless-steel flange and copper gasket (annealed)
  - 180x340 for ϕ 94 antechamber, 28 M8-bolts along aperture
  - Vacuum seal at a torque of ≤ 18 Nm
  - No problem after baking (200°C)



Trial models (only flanges)



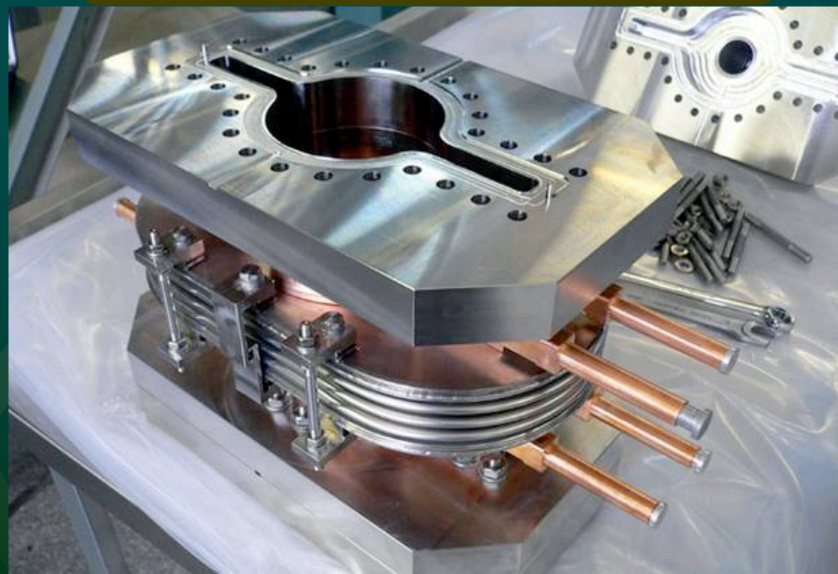


Connection Flange

- Application to bellows chambers and beam ducts (2005~)
  - No problem up to 1.7 A (8 flanges)
  - Applied to new test chambers for wiggler sections, and will be tested this year (28 flanges).

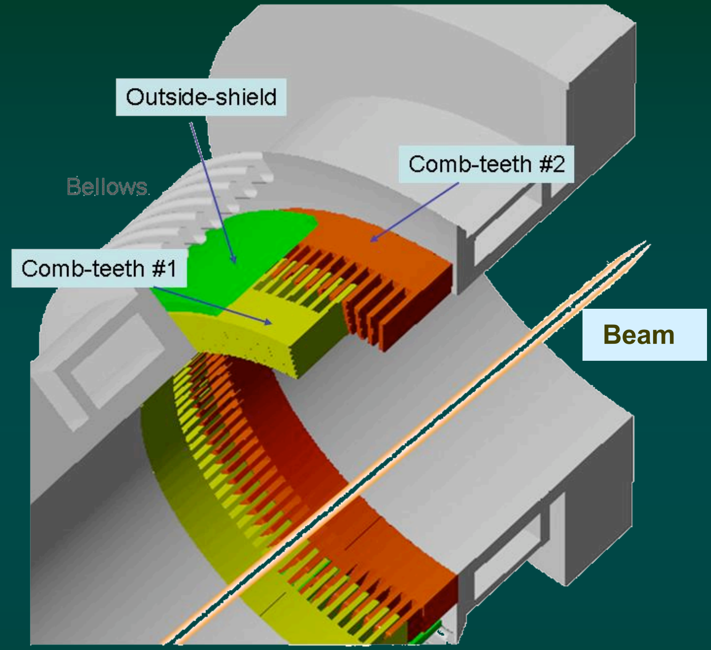
MO flange for beam duct

MO flange for bellows chamber

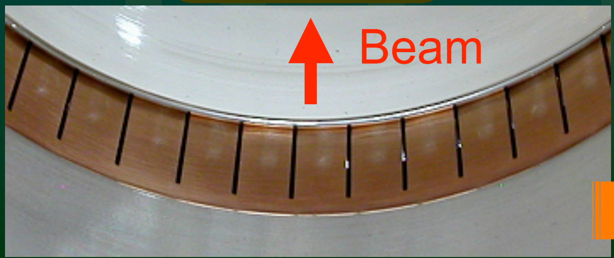


Bellows & Gate Valves

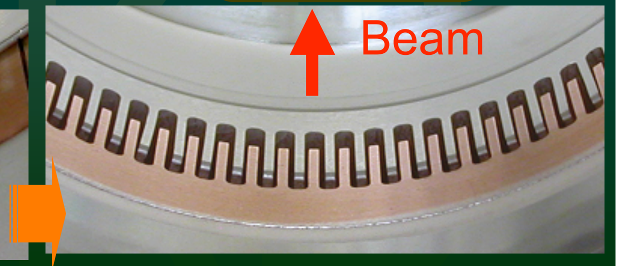
- Comb-type RF-shield (2003~)
  - Proposed at KEK
- Nested teeth instead of fingers
  - High thermal strength
  - Small leakage of HOM（TE-mode）
  - Low beam impedance
  - Applicable to various apertures
  - Limited offset
  - Complicated structure



Finger type

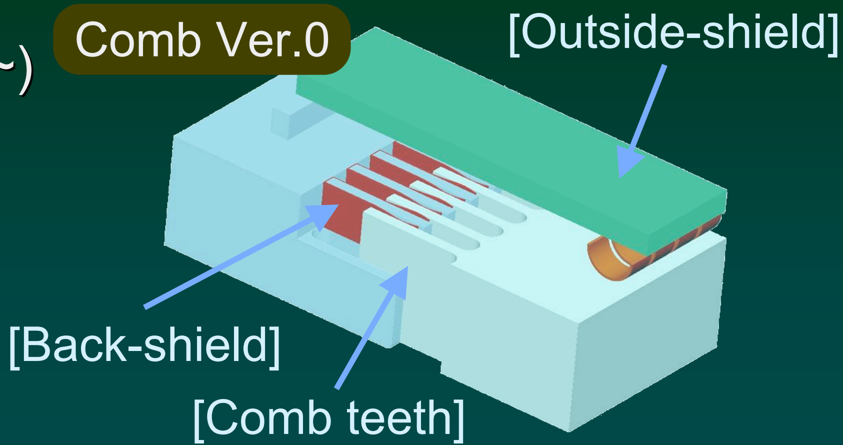


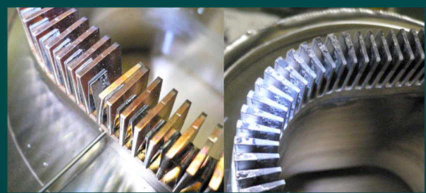
Comb type

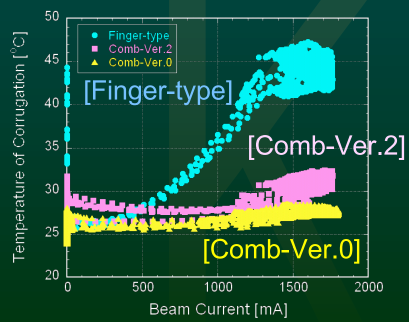


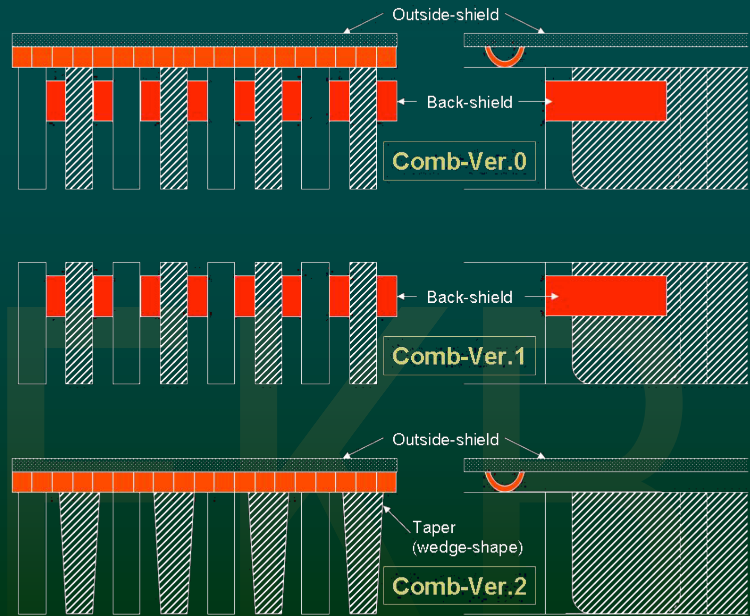
Bellows & Gate Valves

- Simplification of structure (2004~)
  - Ver.0 (Original)
    - With both outside- and back shield
    - Circular bellows → OK
  - Ver.1
    - With only back-shield
    - Racetrack bellows
      → NG (Discharge)
  - Ver.2
    - With only outside-shield
    - Racetrack bellows,
      Gate valves
    - Comparable to Ver.0
      → OK



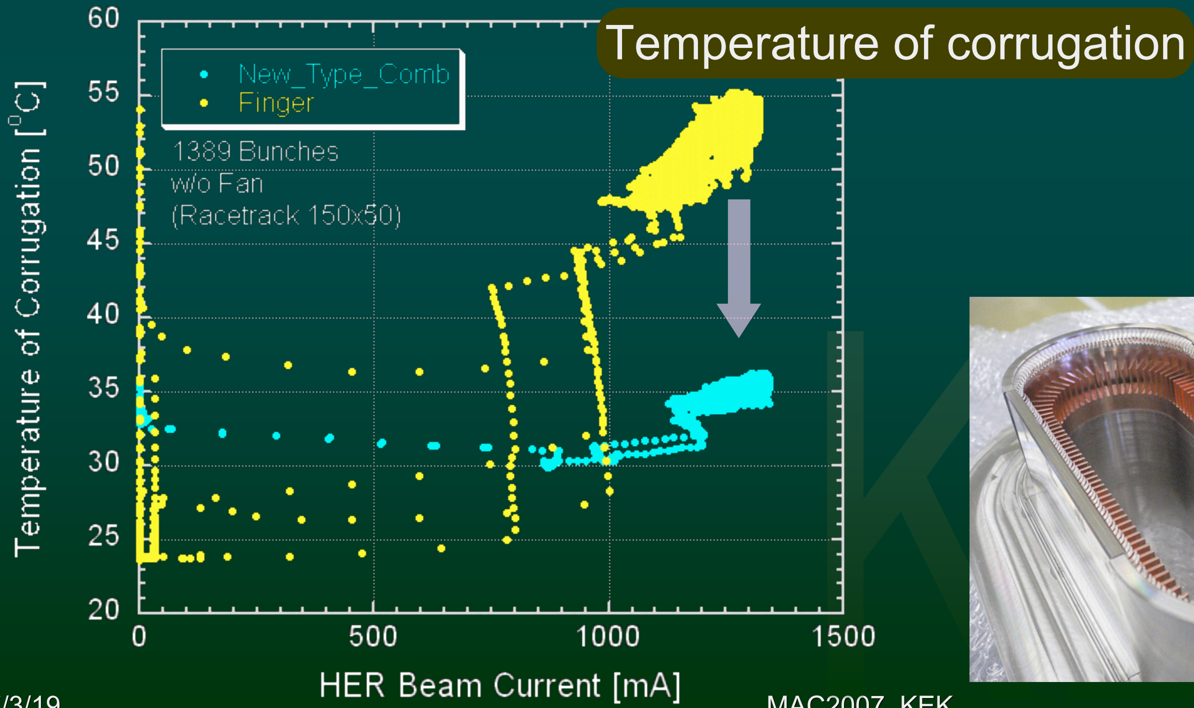


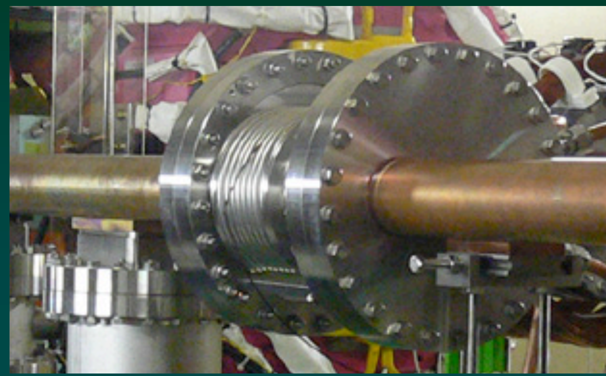


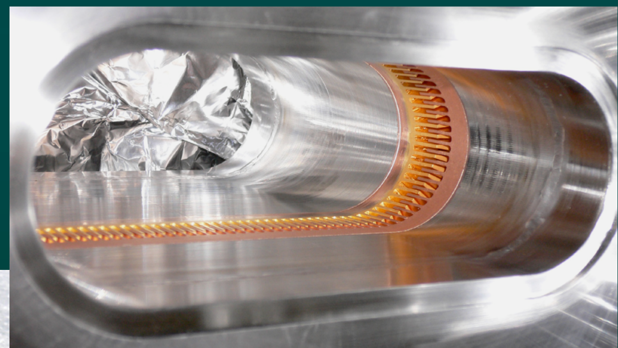


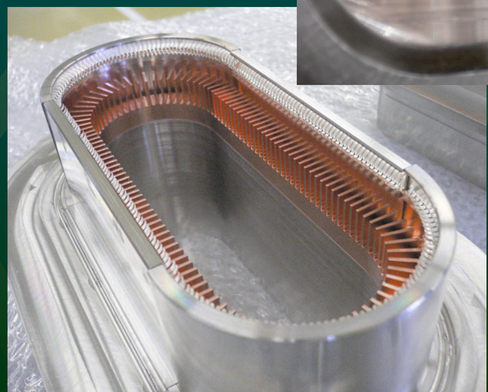
Bellows & Gate Valves

- Racetrack Bellows (2005~)
  - 150 x 50 mm racetrack, Comb-Ver.2
  - No problem up to 1.4 A (HER)
  - Temperature rise decreased to 1/3 of that of the conventional bellows.









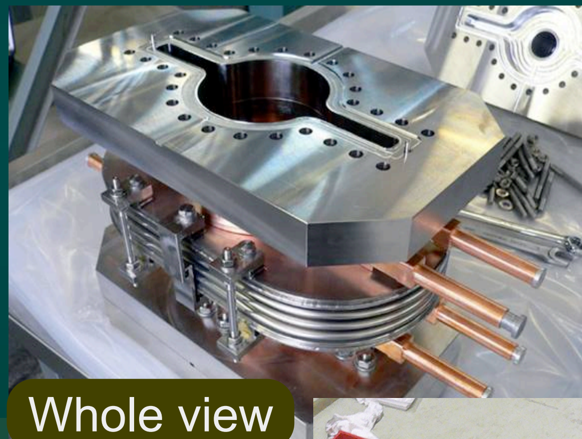
150x50 mm
L = 200 mm
Ver.2

Bellows & Gate Valves

- Bellows for a beam duct with ante-chambers (2005~)
  - Easy to apply to a complicated cross section (Comb-Ver.2)
  - No problem up to 1.7 A.
  - Inside was checked this winter, and no damage was found.

Comb teeth (Cu)

Inside view



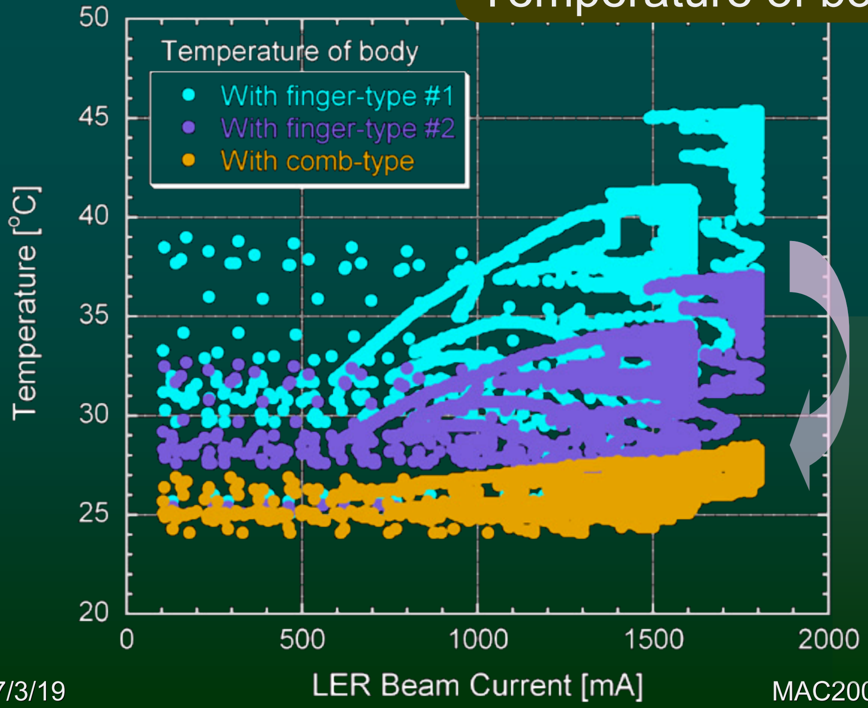
Whole view

ϕ = 94 mm
h_a = 224 mm
L = 200 mm
Ver.2

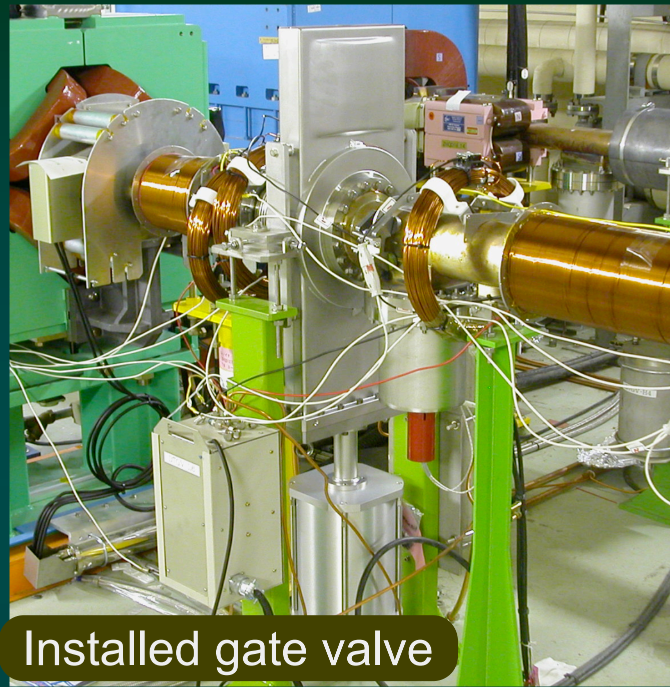
Bellows & Gate Valves

- Circular gate valves (2005~)
  - Comb Ver.2 = No sliding point
  - Collaboration with VAT Vakuumventile AG.
  - Temperature rise of body decreased to 1/3.

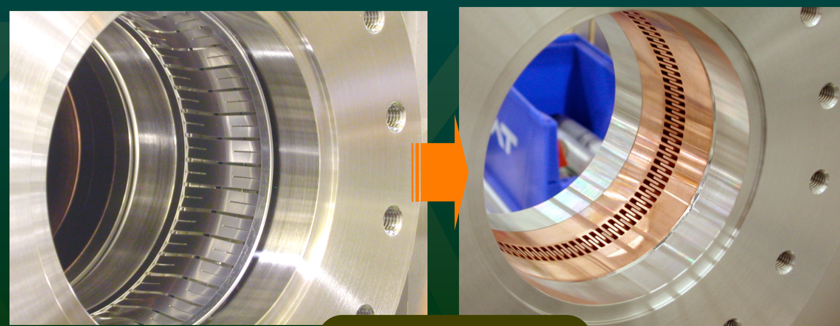
Temperature of body



ϕ = 94 mm
L = 95 mm
Ver.2



Installed gate valve



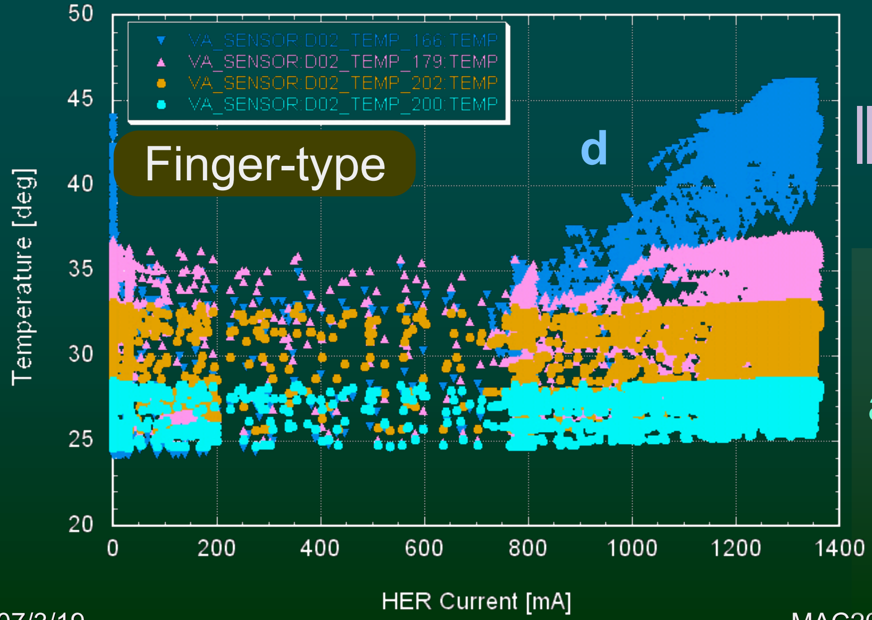
Inside view

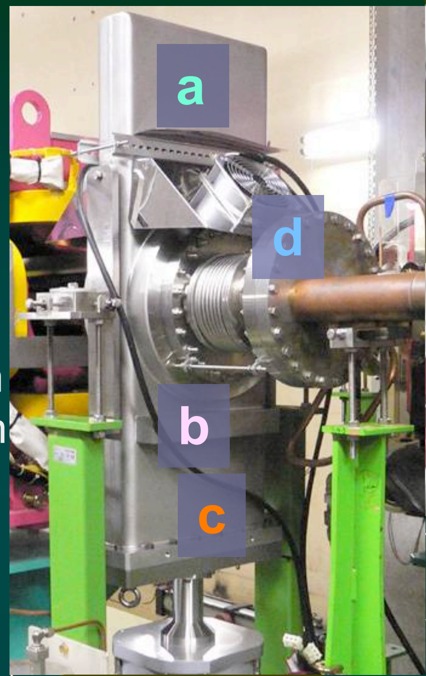
Bellows & Gate Valves

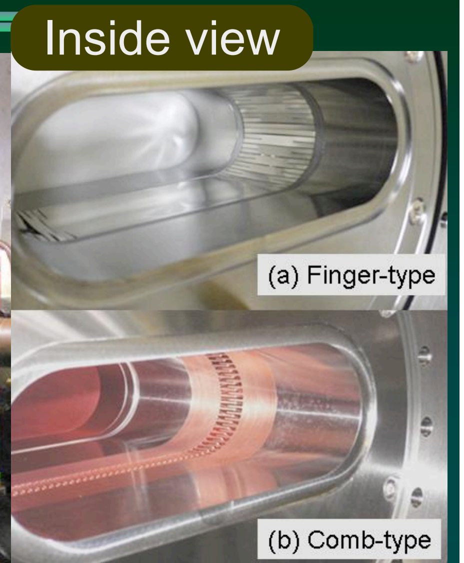
- Racetrack gate valves (2006~)
  - 150x50 racetrack, Comb-Ver.2
  - No problem up to 1.4 A
  - Temperature of adjacent bellows also decreased.

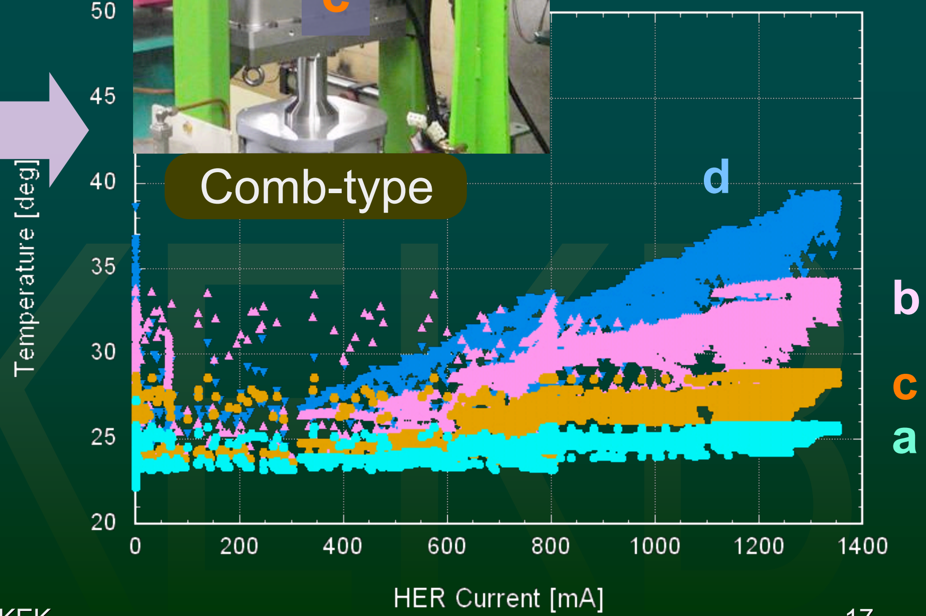
160x50 mm
L = 145 mm
Ver.2

d: Bellows







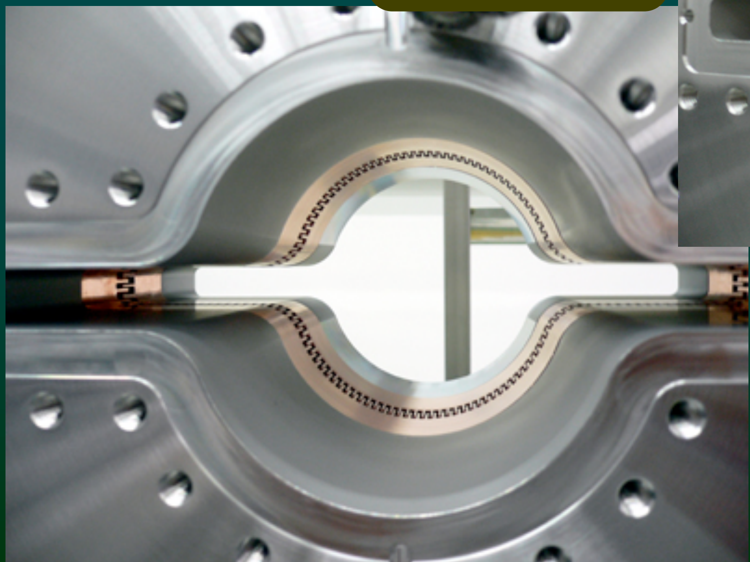


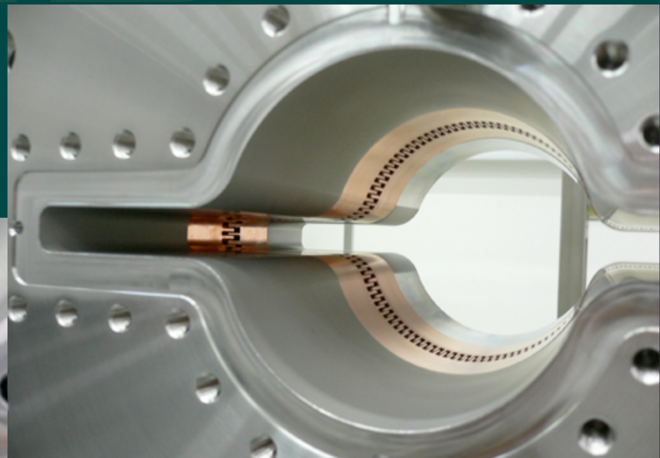
Bellows & Gate Valves

- Gate valve for a beam duct with two antechambers (2007)
  - For the LER wiggler section, $\phi 94$
  - Comb-Ver.2, and MO-Flange
  - Will be installed this summer, and tested.

Whole view

Inside view

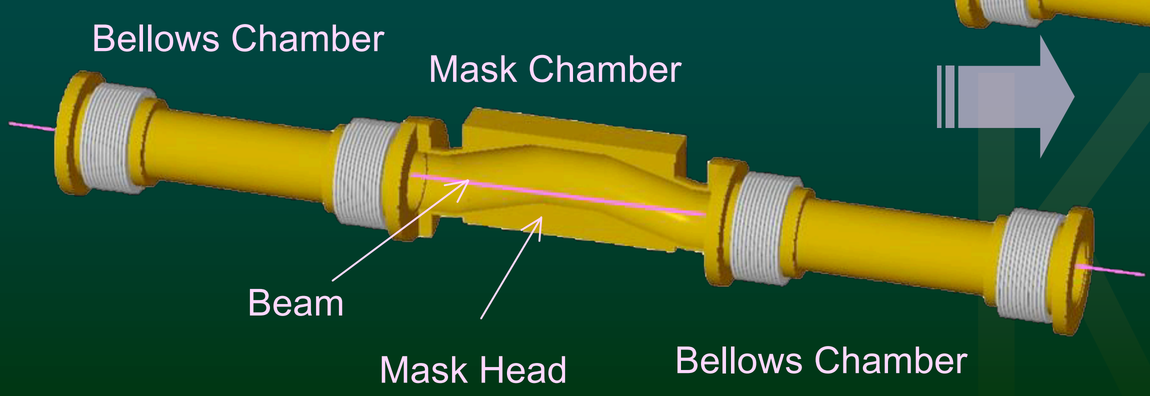




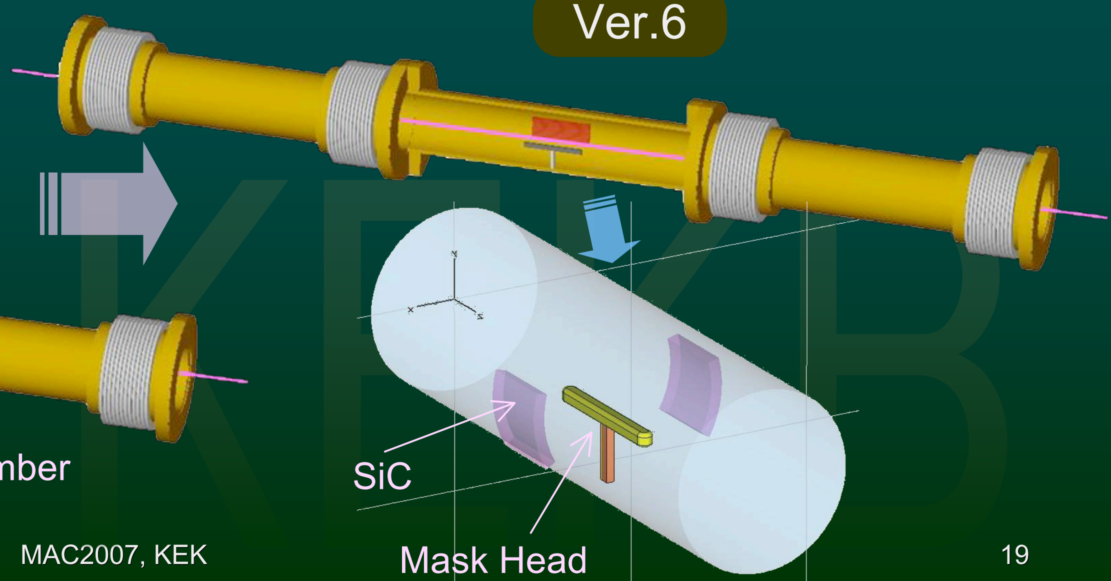
Movable Mask

- Proposal: Stealth type [Ver.6] (2003~)
  - Ceramic support →Little interference with beam
    With thin metal coating to avoid unwanted charge up of head
  - Ceramic or carbon head →Little damage by beam
  - HOM absorber (SiC) → Damp trapped modes
  - Similar idea to an "invisible electrode" by F. Caspers (1987)

Ver.4 at present

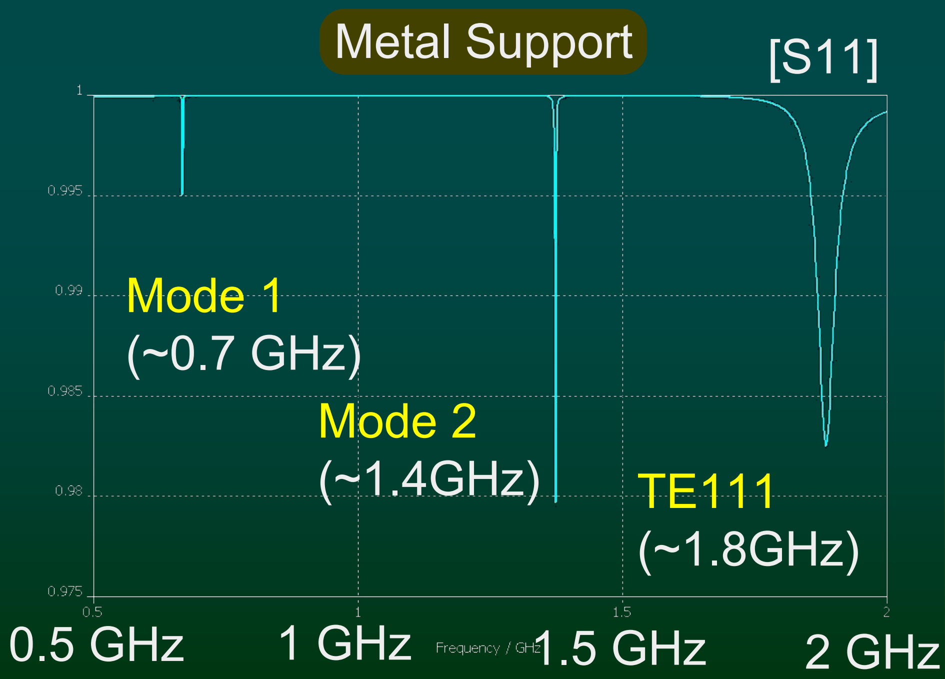


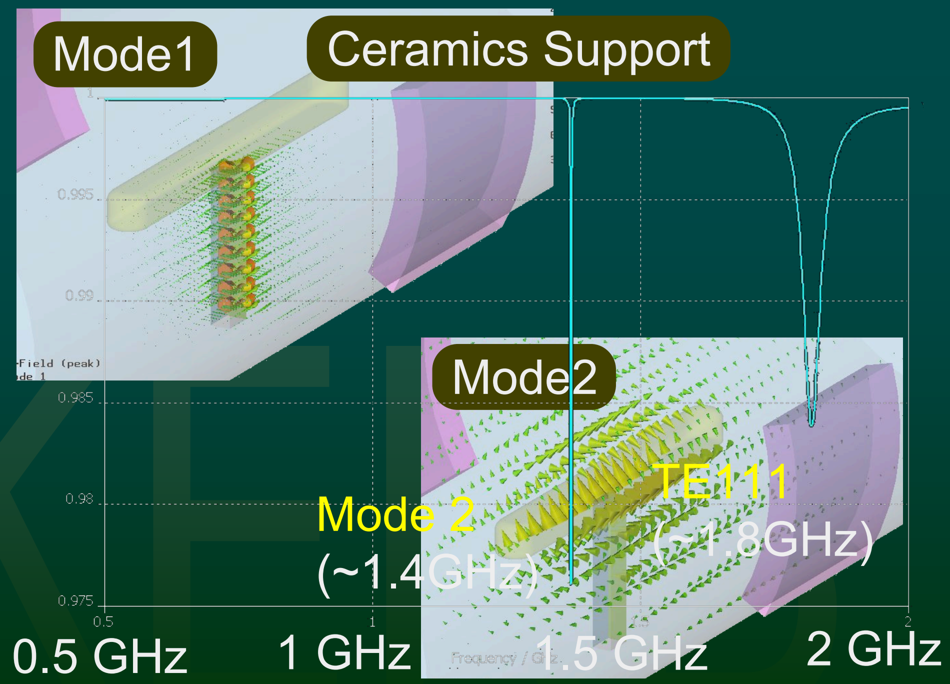
Ver.6



Movable Mask

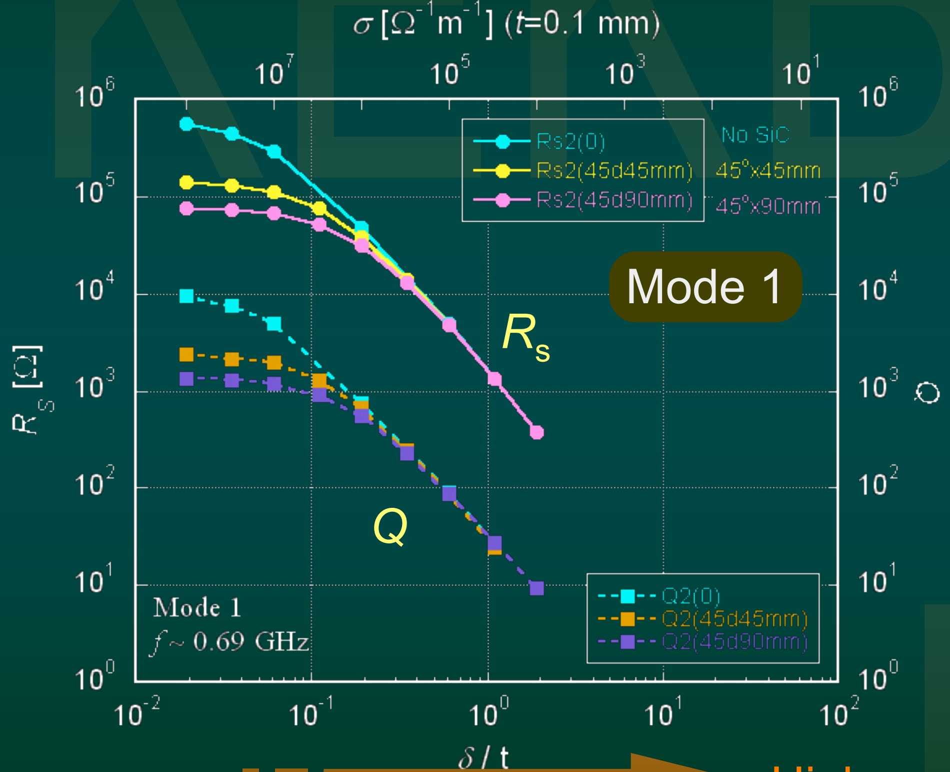
- Calculation of RF properties (by Microwave Studio, Mafia)
  - Impedances and Q of trapped modes, loss factors
- Ex. Trapped modes:
  - Two trapped modes (Mode 1 and Mode 2) were found.
  - Mode 1 (~0.7GHz) disappeared for ceramics support.

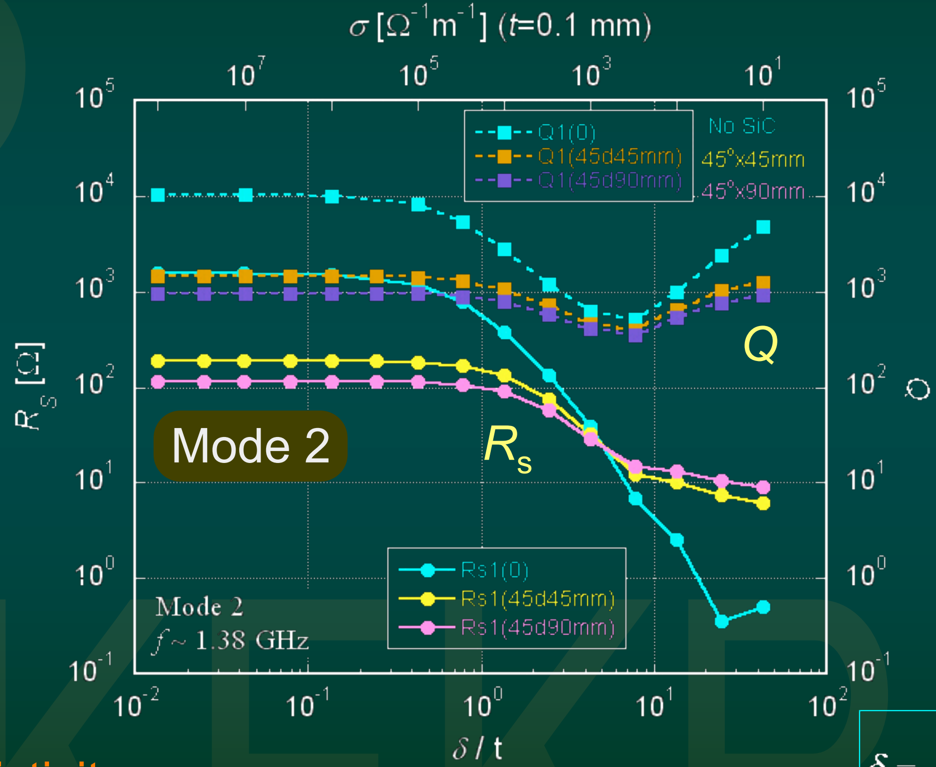




Movable Mask

- Ex. Calculation of longitudinal Impedances (R_s) and Q





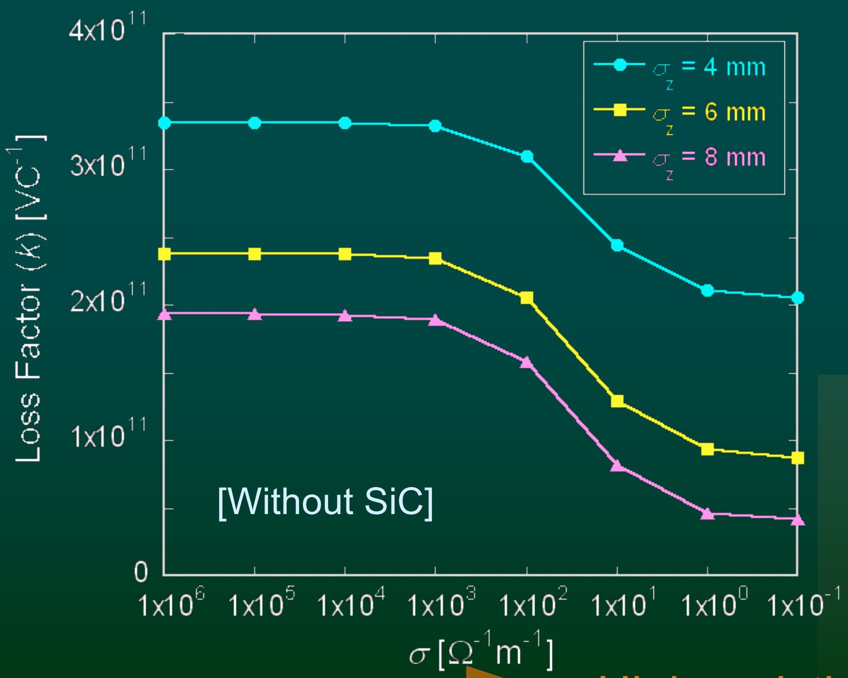
High resistivity

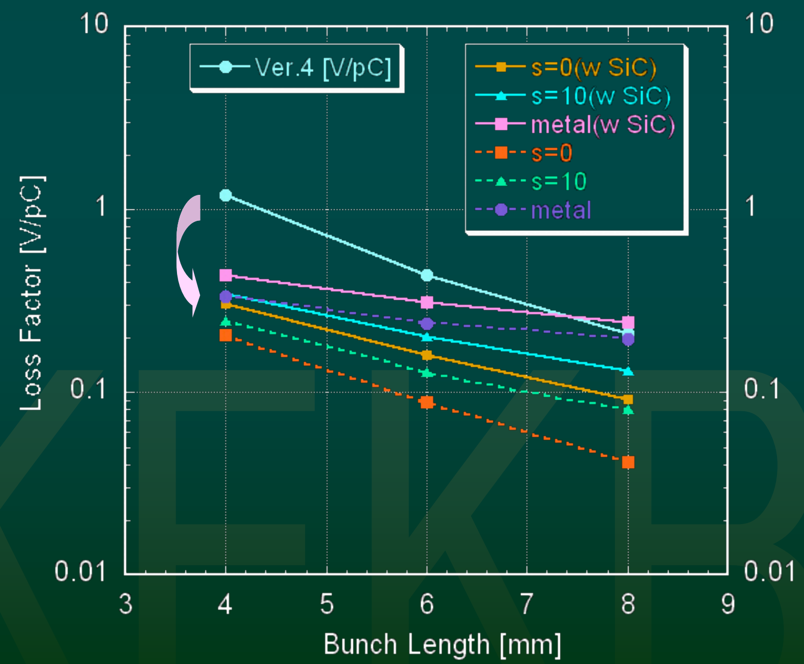
$$\delta = \sqrt{\frac{2}{\omega\mu\sigma}}$$

- R_s decreases as increasing the resistivity of coating on support.
- No CBI problem for KEKB even at full current operation.

Movable Mask

- Ex. Calculation of Loss factor
  - Loss factor decreases as increasing the resistivity of coating on support.
  - Loss factor is about 1/4 of the present Ver.4 mask at $\sigma_z = 4$ mm, when the coating is 1 μm titanium, for example.

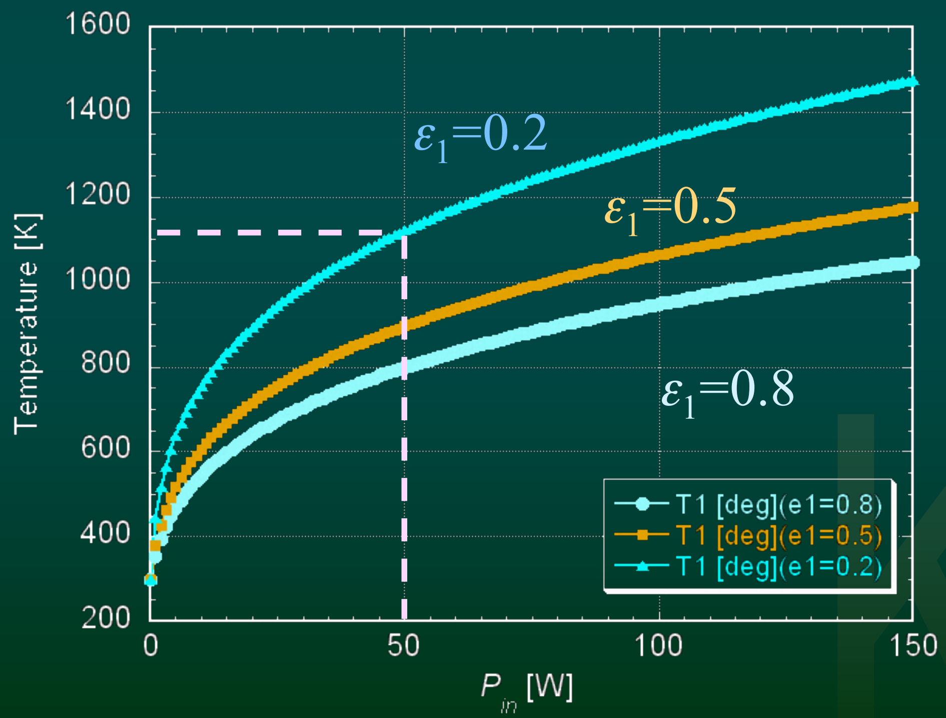




High resistivity

Movable Mask

- Ex. Estimation of head temperature
  - Total power ~ 50 W even at 10 A (#5000)
    → ~ 900 °C at ε = 0.2
  - May be OK, but with large ambiguity…..

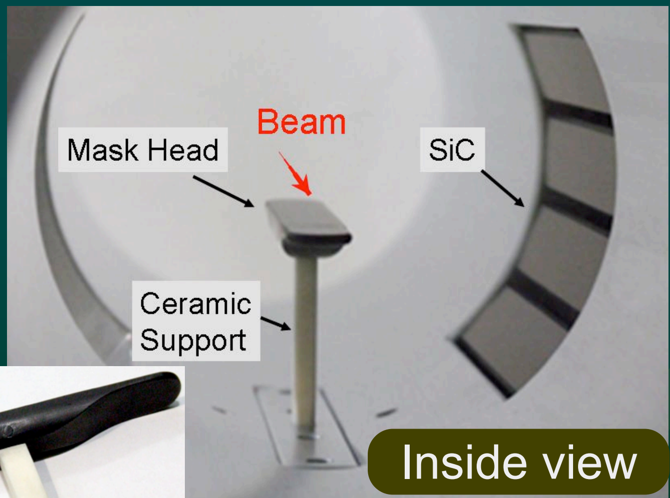


- Only radiation
- Joule loss (Cu)
  - ~30 W
- Trapped mode: Mode 2
  - ~25 W (total)
- Trapped mode: Mode 1
  - ~0
- High frequency components
  - Will propagate……

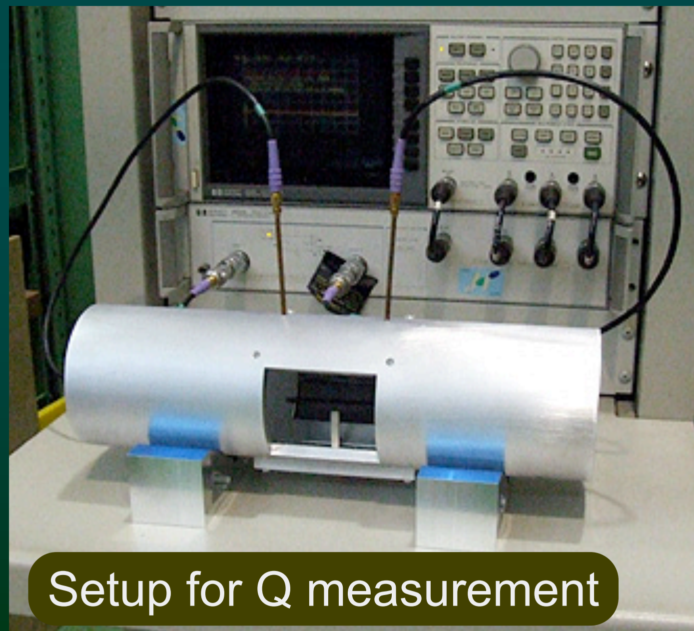
Movable Mask

- Bench test using a test model
  - An atmosphere version was manufactured to check the calculation, and to see the manufacturing property.
  - Measured behavior of trapped modes were well consistent with the calculated one.

Mask head and support



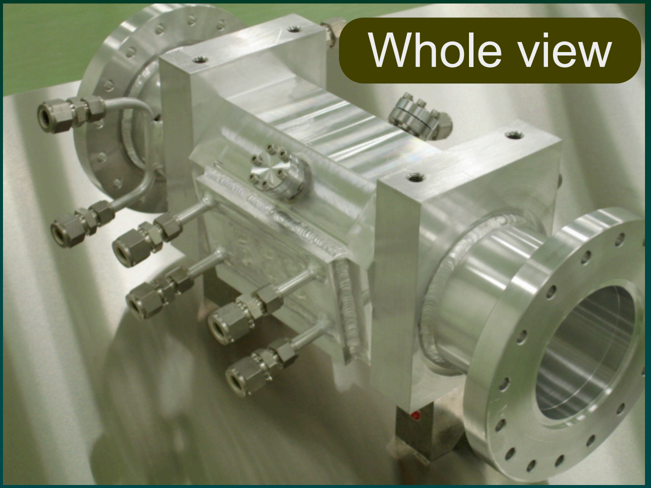
Inside view

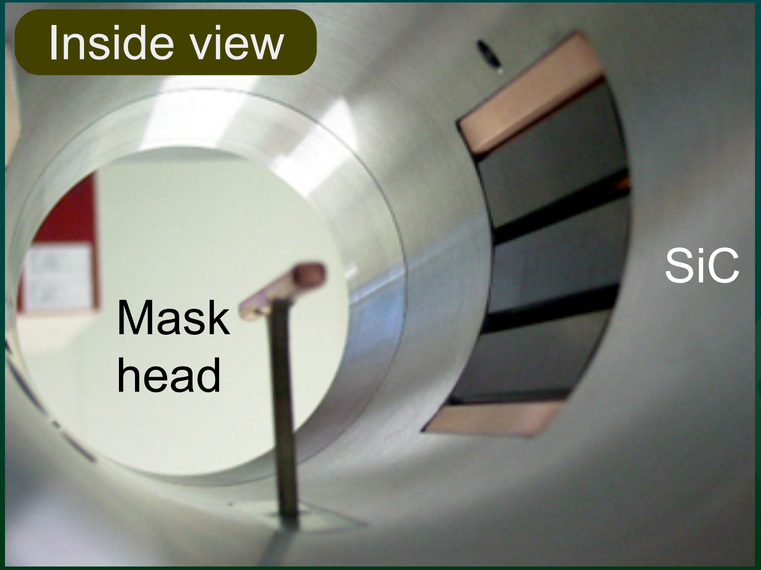


Setup for Q measurement

Movable Mask

- First trial model for beam test
  - A vertical mask for LER was installed this winter.
    - Al_2O_3 head with Cu coating (~10 μm)
    - Al_2O_3 support with Ti coating (~1 μm)
  - Beam test has just begun.



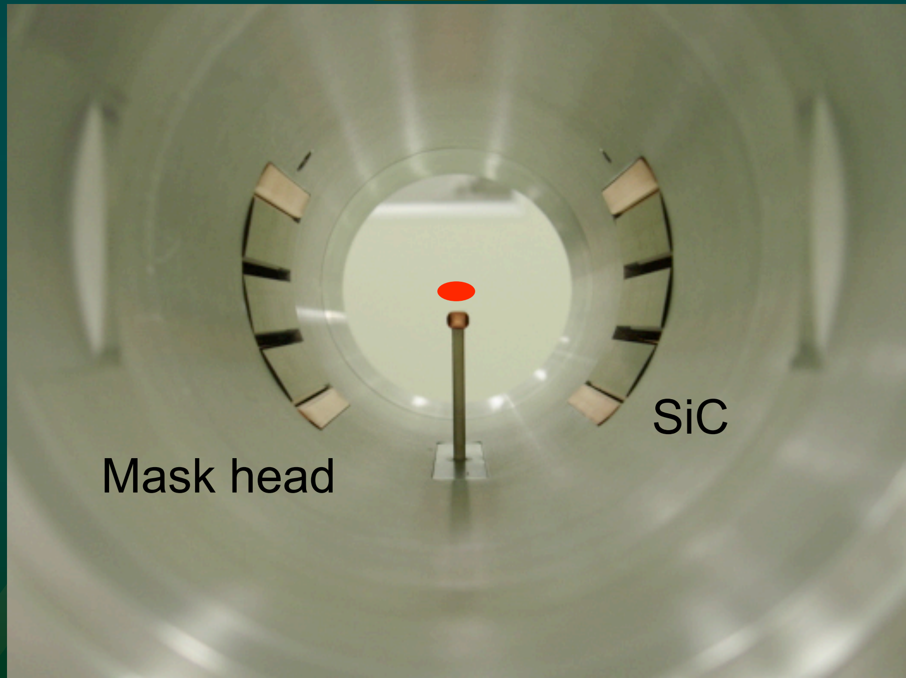


Movable Mask

- Inside view

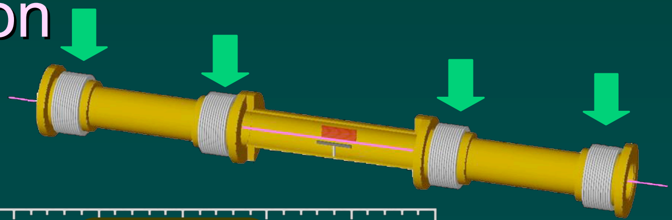
Ver.4

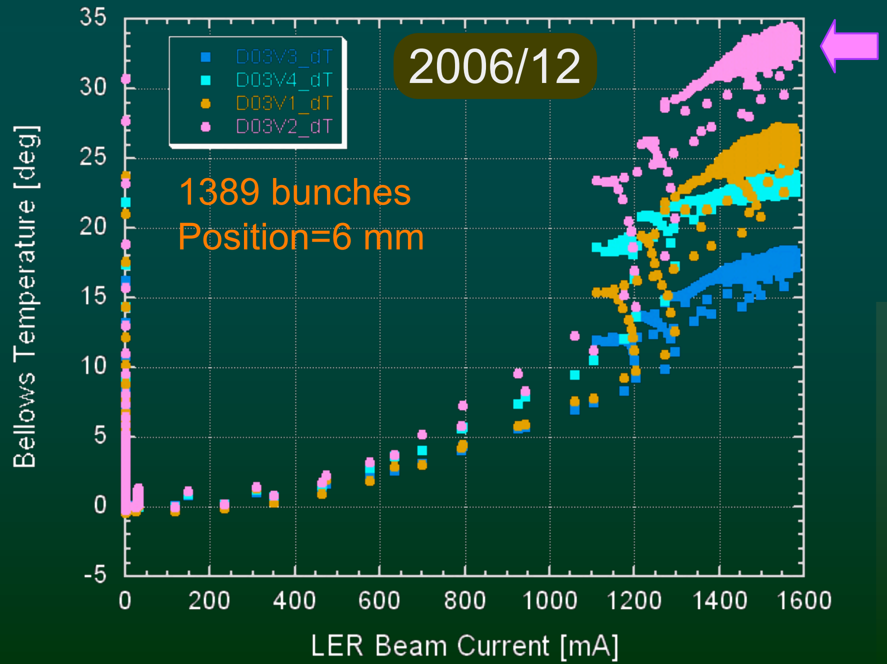
Ver.6

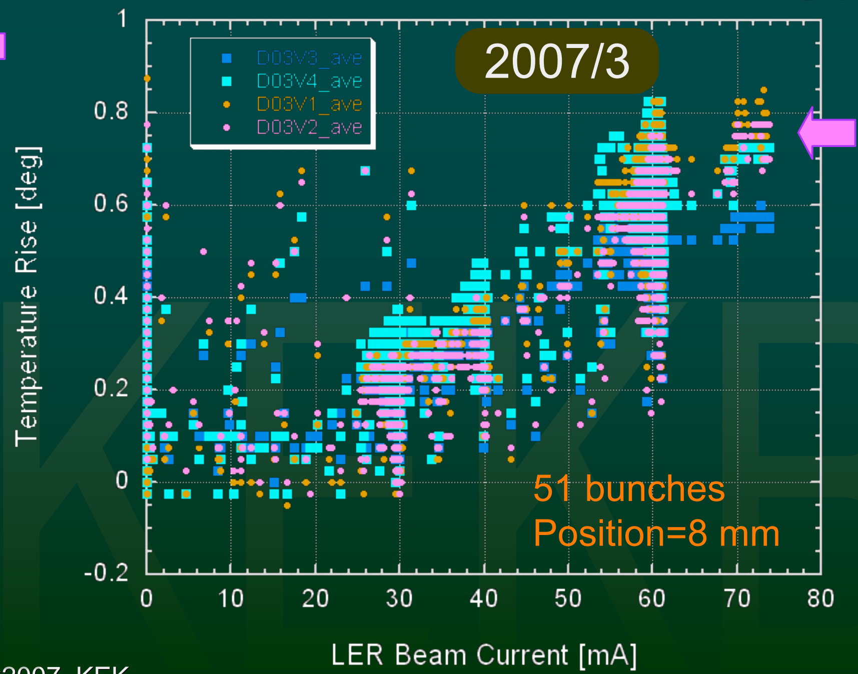


Movable Mask

- Mask looked working
  - Decrease of beam life time was observed as the head approached to beam.
- Average temperatures of 4 bellows of 4 V-masks
  - Beam current is still low, but an indication of HOM reduction can be seen (?)
    - Note: Different bunch patterns and positions

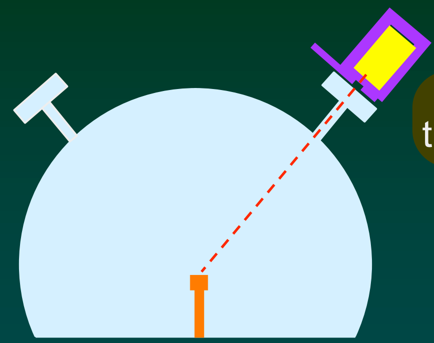


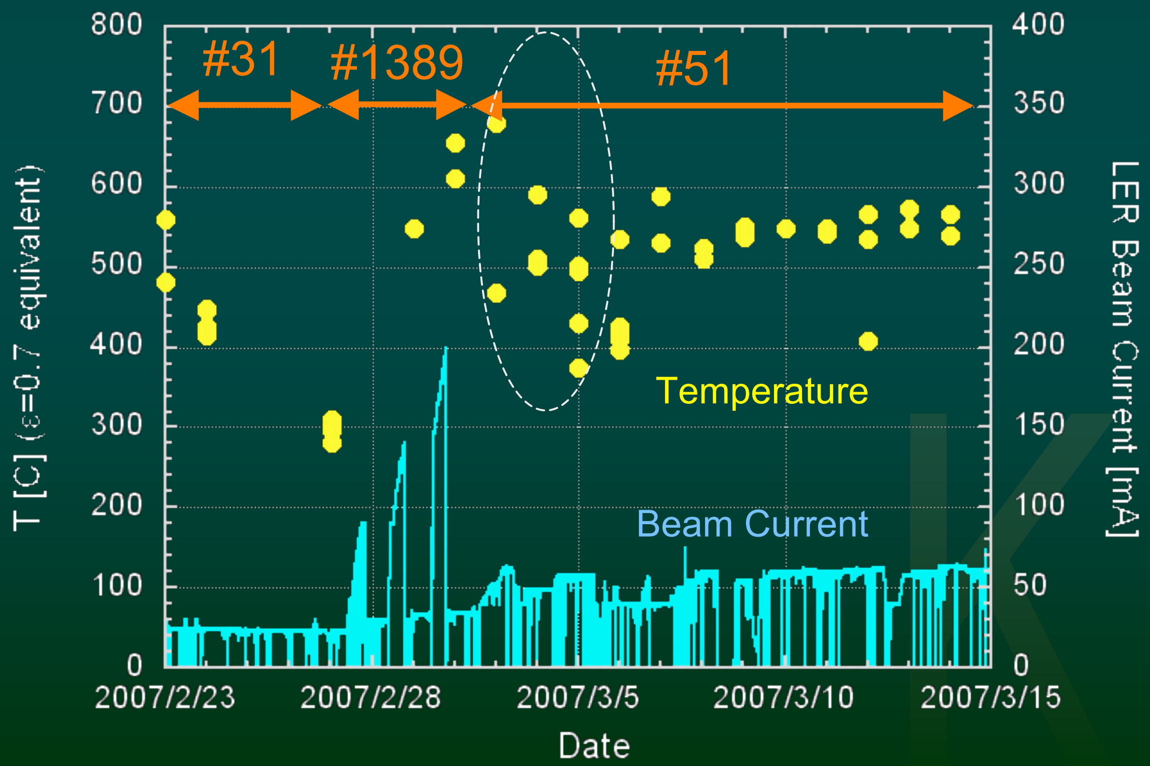




Movable Mask

- Problem: Heating of head!
  - Measured by a radiation thermometer
  - Much higher than expectation: by dozens of times!!



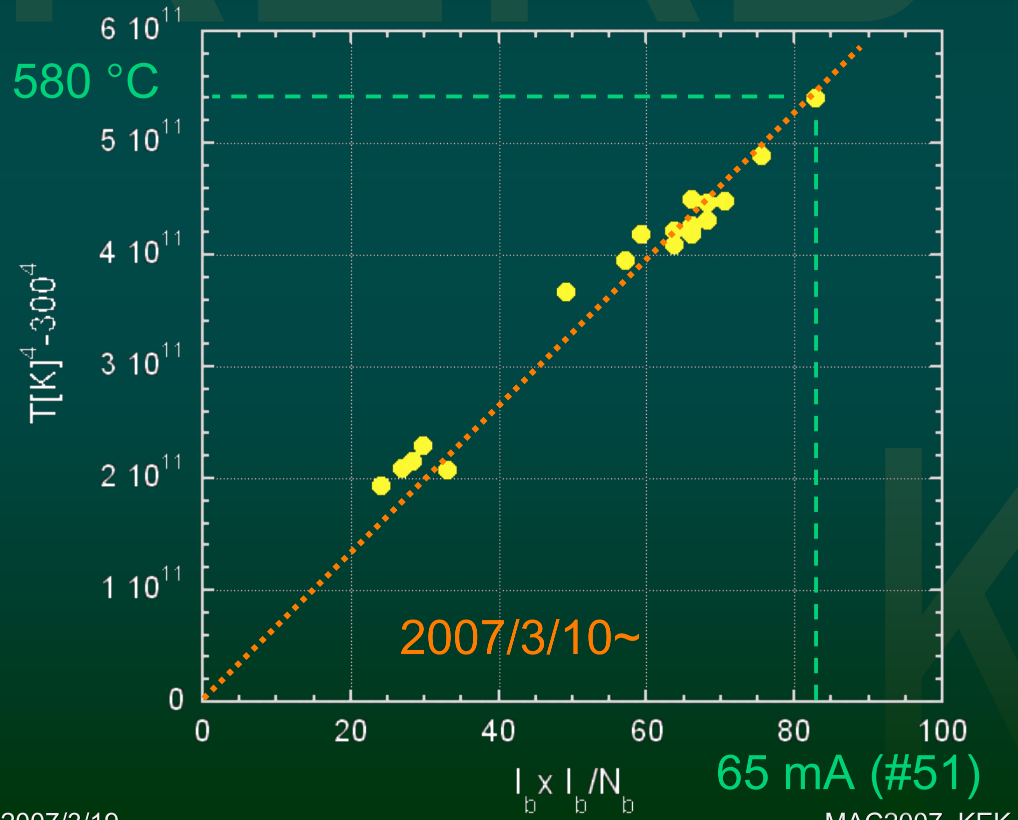


- T>600°C even at 40 mA (51 bunches) [~2007/3/3]
  - T (reading) relatively decreased around 2007/3/3 for the same current

    → Cu and Ti coatings had gone??
- Input power is about 14 W at 60 mA (51 bunches)
  - Estimated from T decay after a beam abort

Movable Mask

- Main input power source is HOM!
  - T^4 is proportional to I^2/N_b.
  - T depends on the position of mask head.
  - Not due to SR



- If the loss factor is 0.2 V/pC, HOM loss is 150 W at 60 mA (#51)

  → About 10 % was absorbed by head
- Affect of HOM from other masks is also included
  - T depends on the position of the next mask
- I_b = 300 mA (#300) → T =900 °C
- I_b=1600 mA (#1389) → T=1500 °C!!

Keep watching!

Movable Mask

- Further studies are required;
  - Understand the reason of misestimation of input power
    - High frequency HOM?, HOM from outside?
  - Optimization of structure to reduce HOM loss
    - Are SiC actually required?, Surface area, ε and loss?
  - Optimization of materials
    - Return to the original idea?
      Graphite head (high emissivity and high thermal strength) and BN support (low dielectric constant)?
  - Coating will be practically no use.
    - High temperature is structurally inescapable for use.
    - How much is the affect of charge up?
  - Long term stability ?

- **Got off to a rocky start ….?**

Summary and Future Plan

- R&D of various vacuum components to adaptable to high current accelerators are proceeding using KEKB.
  - Beam duct with ante-chambers has been developed for wiggler sections, together with bellows chambers and flanges.
  - Application of bellows chambers and gate valves with the comb type RF-shielding is expanding.
  - The first trial model of a new movable mask is under test with beam.
    - Way of mask is not that easy…

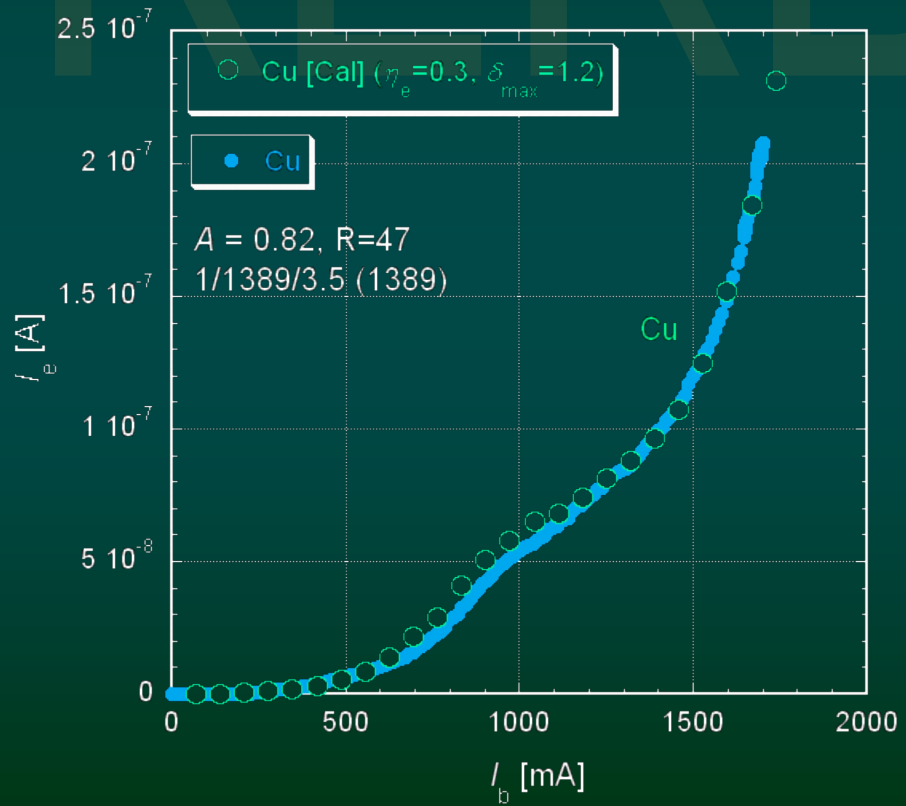
Summary and Future Plan

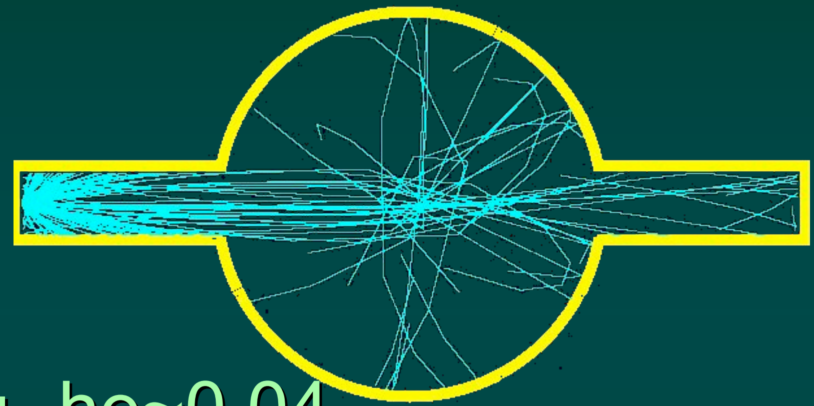
- Next step:
  - Replacement of the present circular beam ducts at a wiggler section (~30m) by that with ante-chambers [this summer], including BPMs.
  - Further test and optimization of the new movable mask.
  - R&D of a clearing electrode for ECI (plan).
  - More practical design of beam ducts for Super B

End

Beam Duct

- Measured electron current can be reproduced by a simulation,





- he~0.04
- dmaxはアーク部での値と矛盾しない。
- dmax ~1.2

Beam Duct

- Measured electron current can be reproduced by a simulation,