Crab Cavity Development

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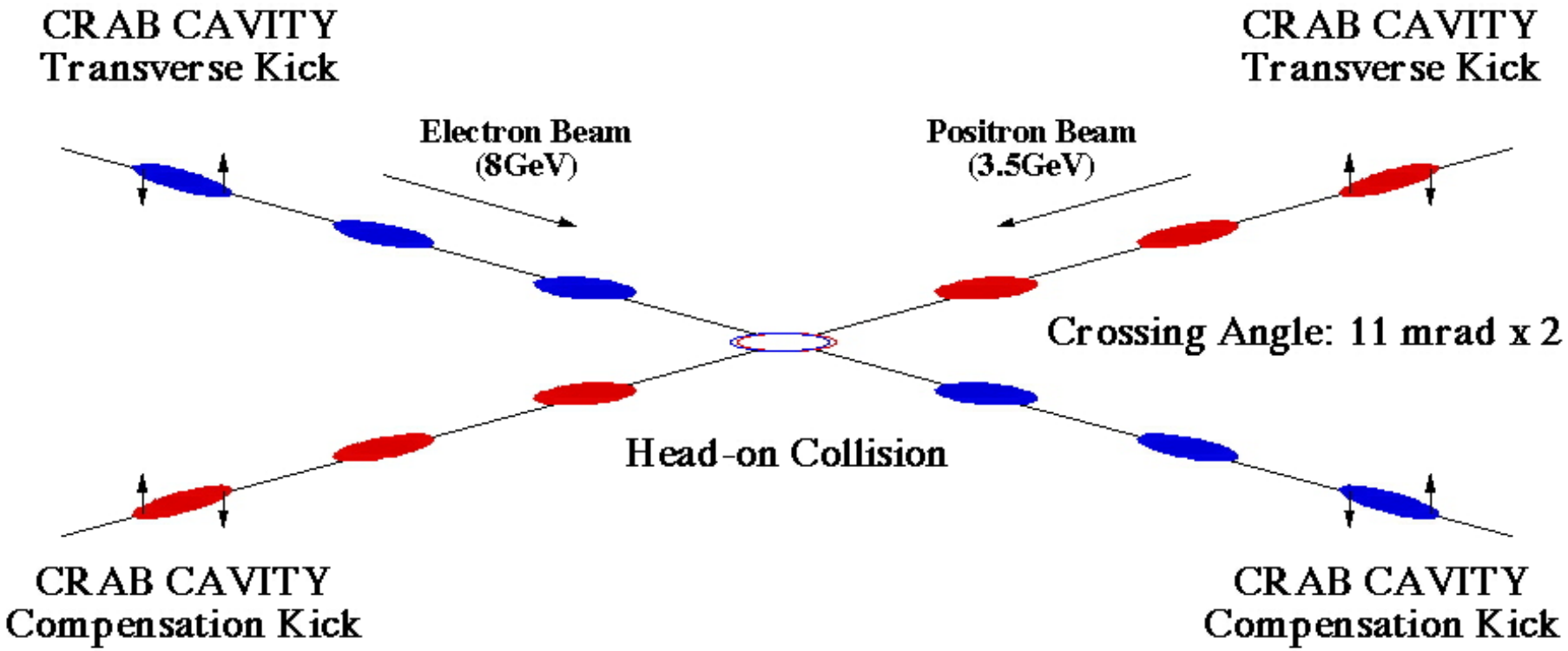
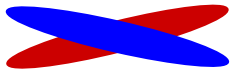
Crab Crossing Scheme
KEKB B-factory
Conceptual Design of Crab Cavity
R&D Status
Crab Cavity for KEKB
High Power Test
Summary

Crab crossing
Original scheme

R. B. Palmer for linear colliders
K. Oide and K. Yokoya for ring colliders

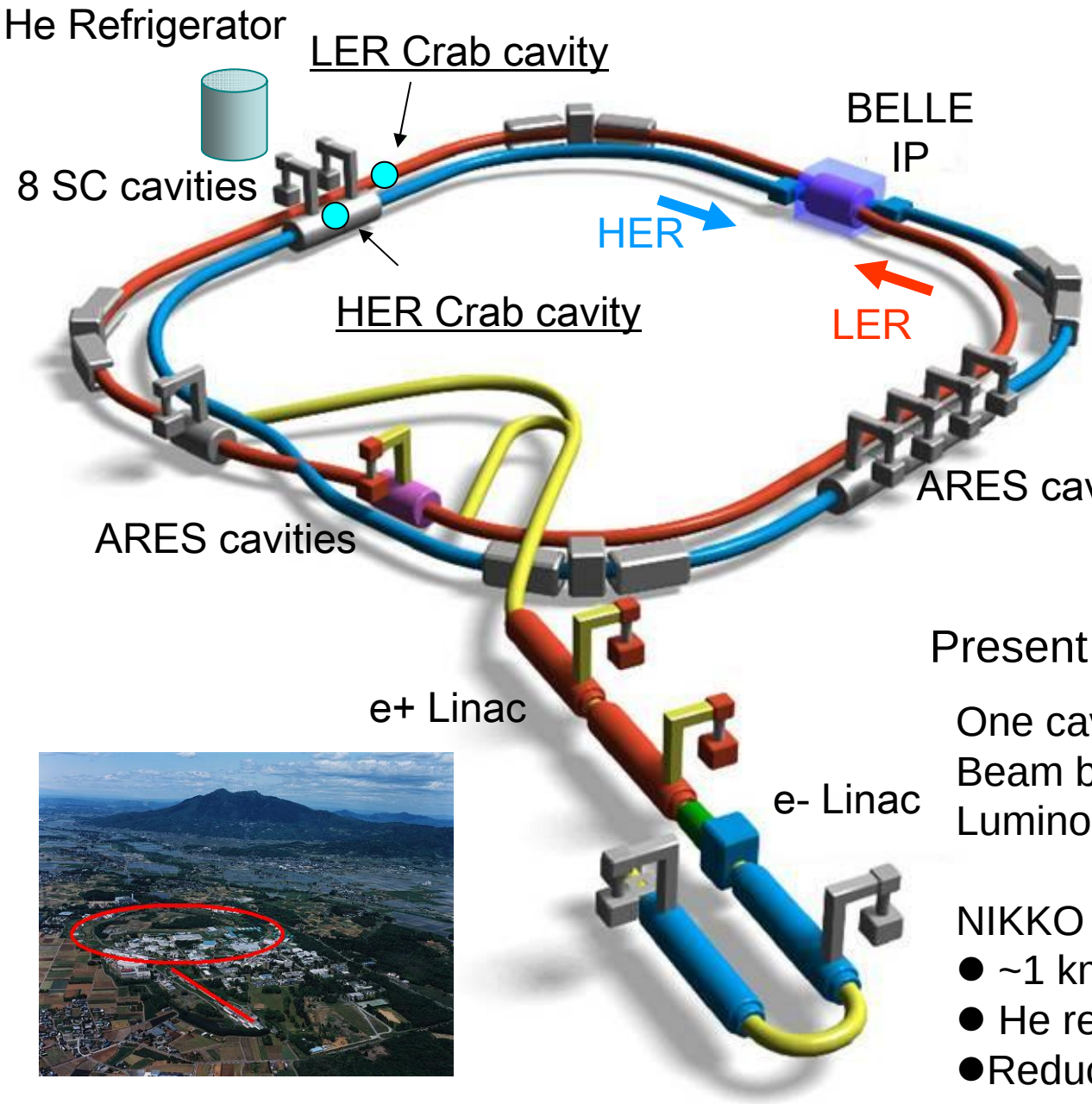




Non-crab crossing

KEKB

LER: e+ 3.5 GeV 1.3A
HER: e- 8.0 GeV 1.7A
RF freq.: 509 MHz
Cross. Angle: 22 mrad



Present crab crossing scheme

One cavity in one ring
Beam bunches wiggle in the ring
Luminosity increase (K. Ohmi)

NIKKO AREA

- ~1 km away from the IP
- He refrigerator (8 kW@4.4K)
- Reduce the construction costs

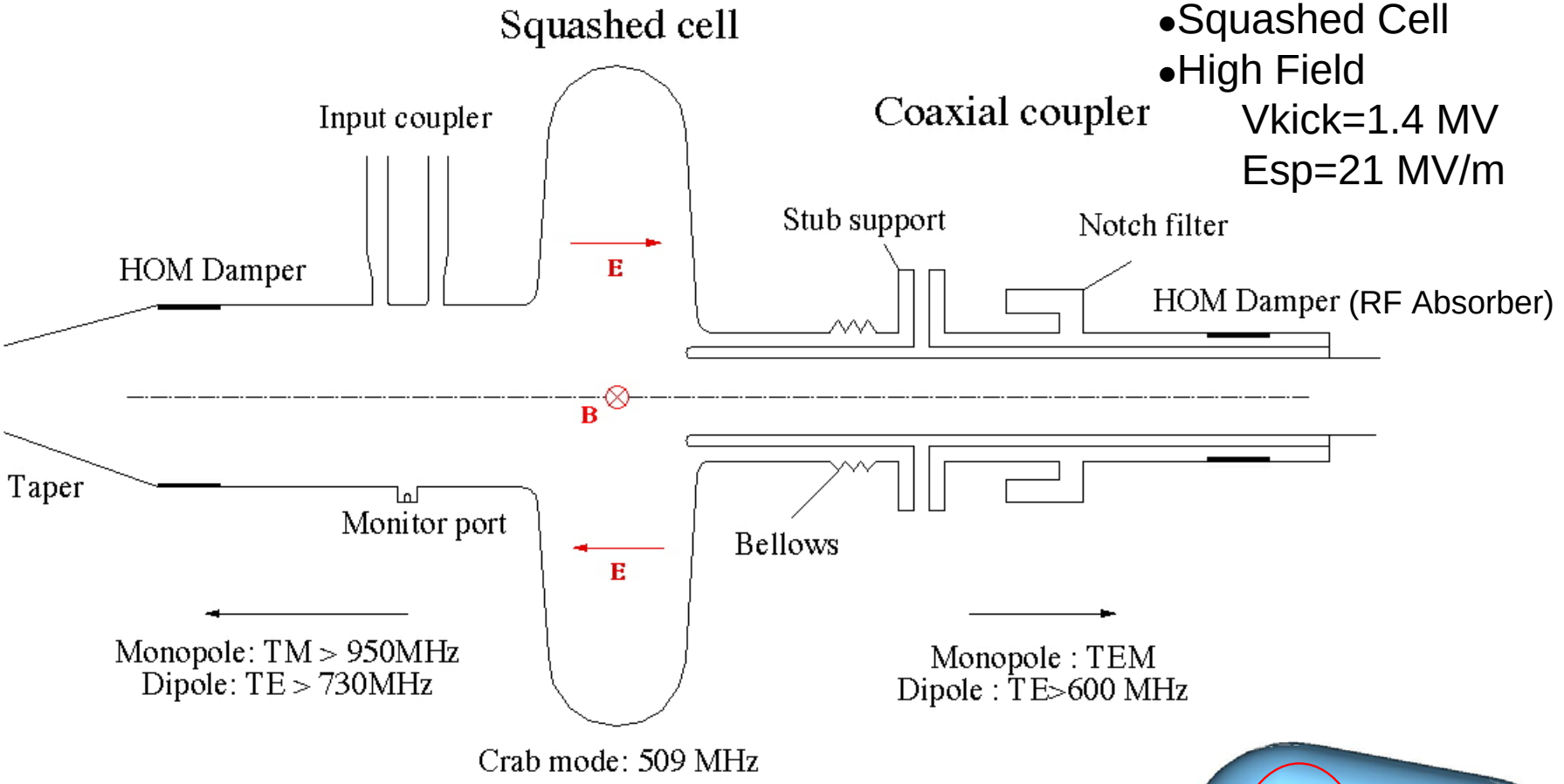
Crab Cavity
Conceptual Design

K. Akai

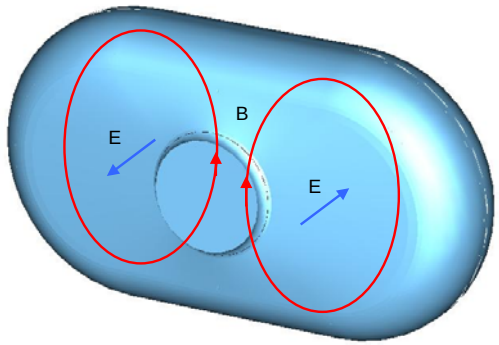
Unique characteristics
- Coaxial Coupler
- Squashed Cell
- High Field

  Vkick=1.4 MV

  Esp=21 MV/m



Crab Mode: TM110-like mode (high R/Q)
Coaxial coupler: LOM damping
Squashed cell: UWP > 600 MHz
Notch filter: TEM-coupled Crab mode rejection
Stub support: support for inner conductor

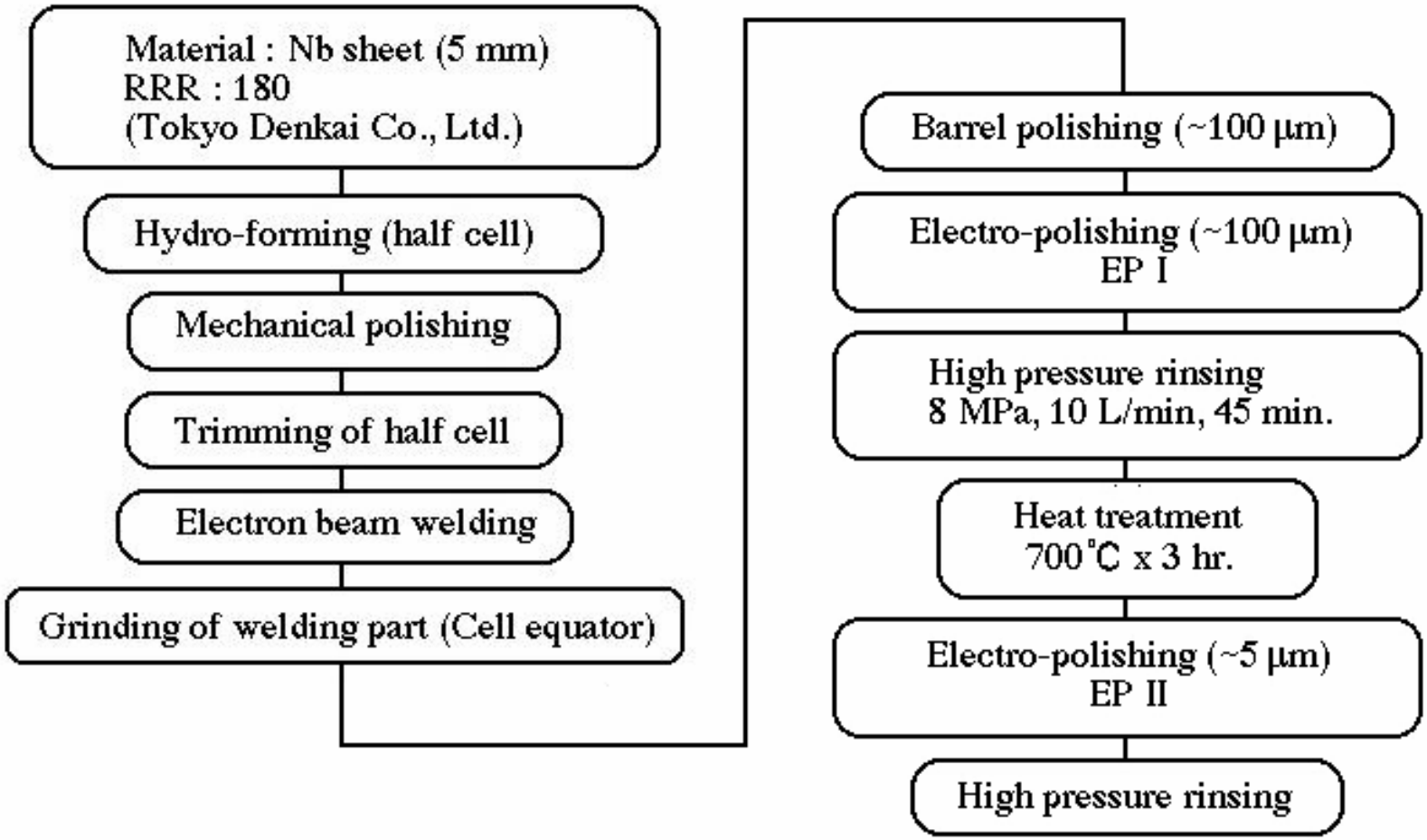


R&D History

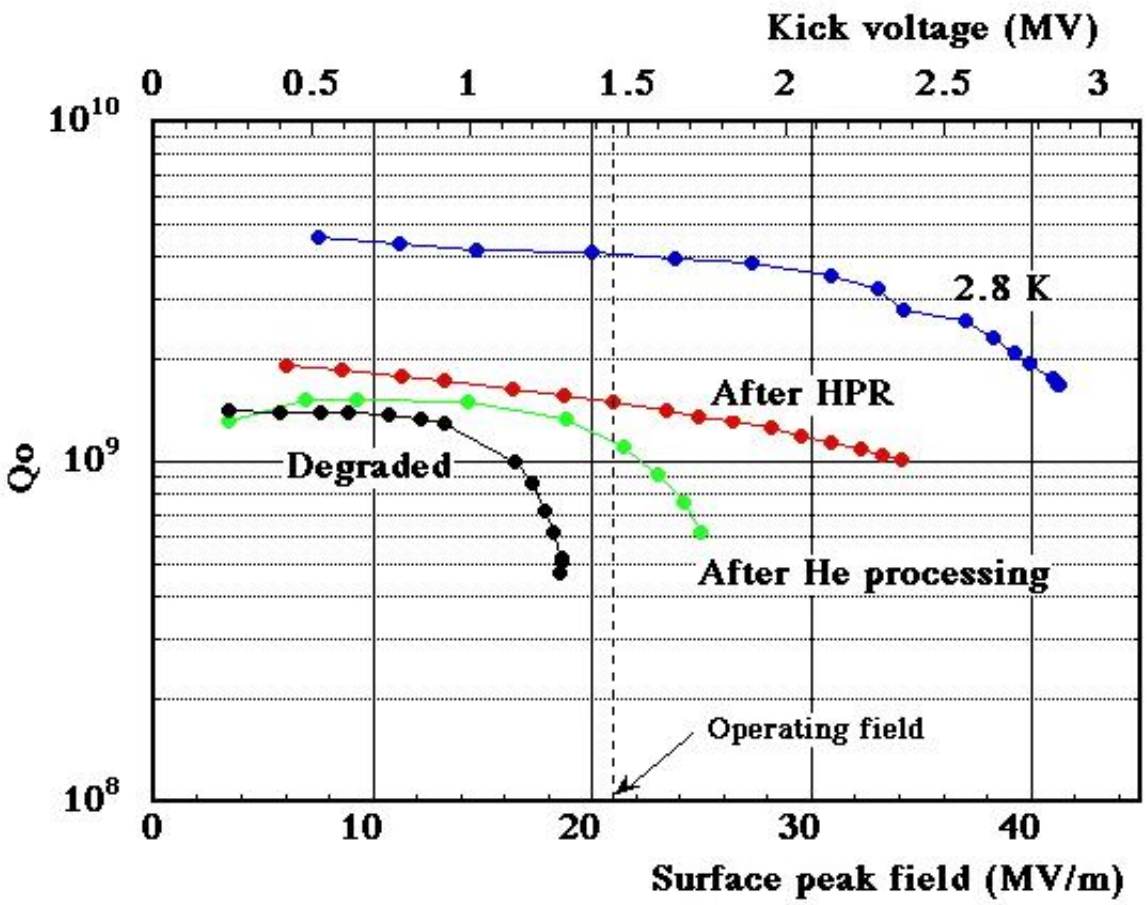
- 1994 1/3-scale models
- 1996 Full-scale prototype cavities Intensively studied
  - Fabrication method (squashed cell)
  - Surface treatments (high fields)
  - Model coaxial coupler (multipacting)
- 2005 Two crab cavities for KEKB
  - Cryostat, Input coupler, HOM damper, etc.
  - Vertical cold test and high power test

Fabrication and surface treatments

Intensively studied using prototype cavities

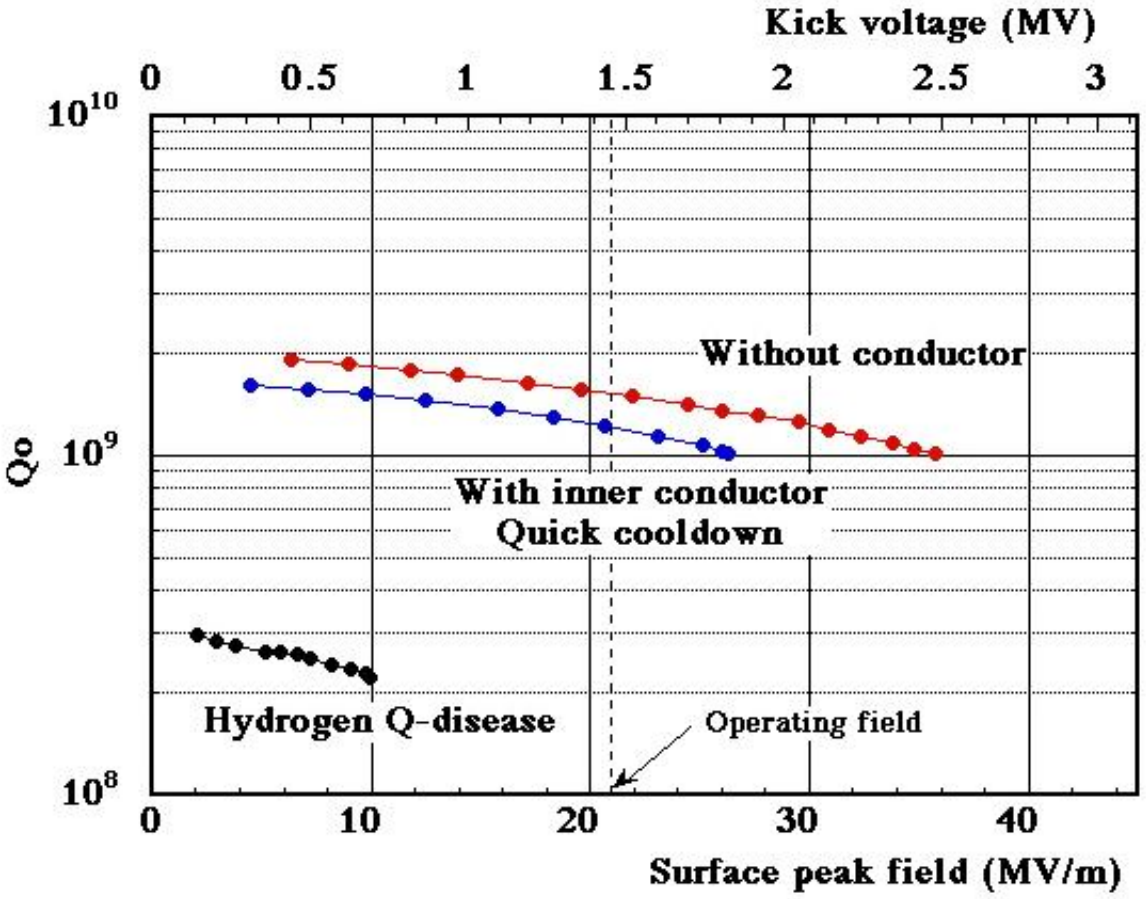


Vertical Cold Test (prototype cavity)

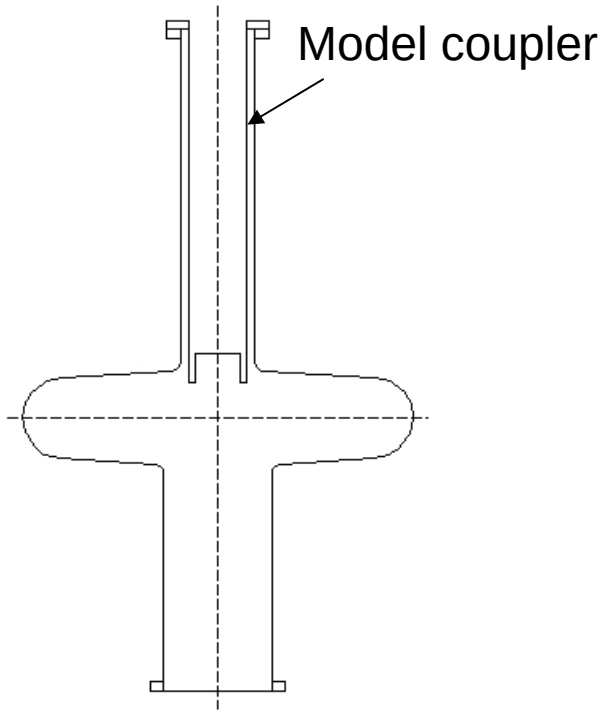


Degradation
(micro-particles)
HPR
(Effective for clean-up)
Low Temperature
(High field operation)

Vertical Cold Test (model coupler)



Effect of coupler tested
(short version)
Multipacting
(processed in an hour)
Hydrogen Q-disease
(can be avoid)
Required voltage achieved

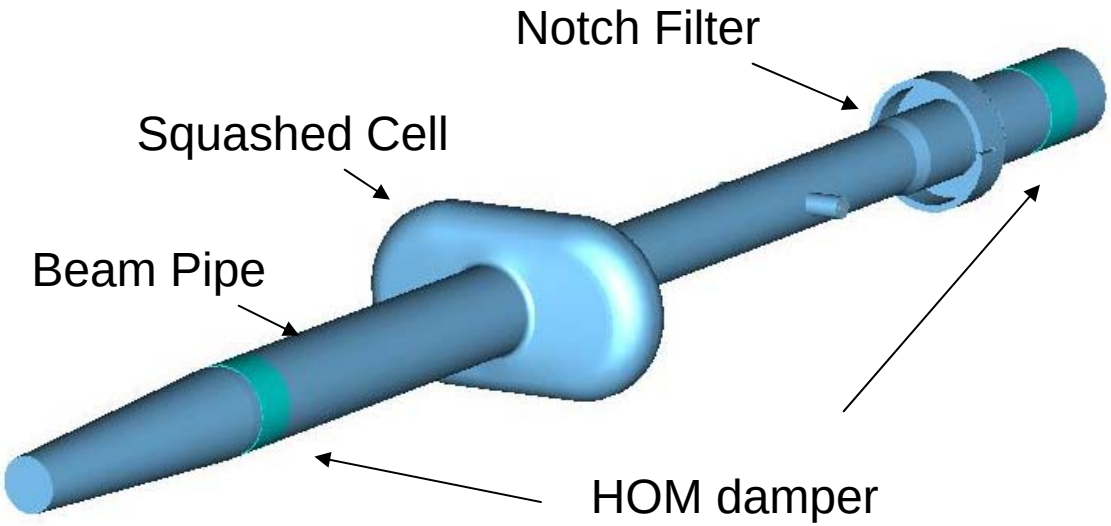


Crab Cavity for KEKB

Engineering design

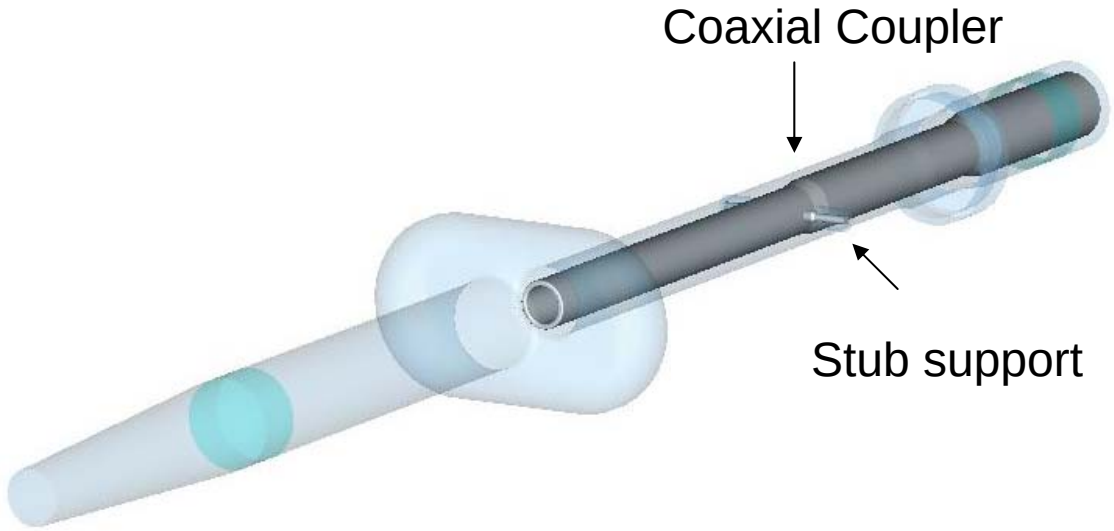
- Cavity design (LOM/HOMs damping)
  - – Coaxial coupler
    - stub support
    - notch filter
    - HOM damper
- Input coupler
- Cryostat (He jacket, Bellows, etc)
- Frequency tuner

Cavity design



Using RF simulation codes (MWS and HFSS),

- Stub support length
- Notch filter geometry
- HOM damper size and position determined



Cryostat

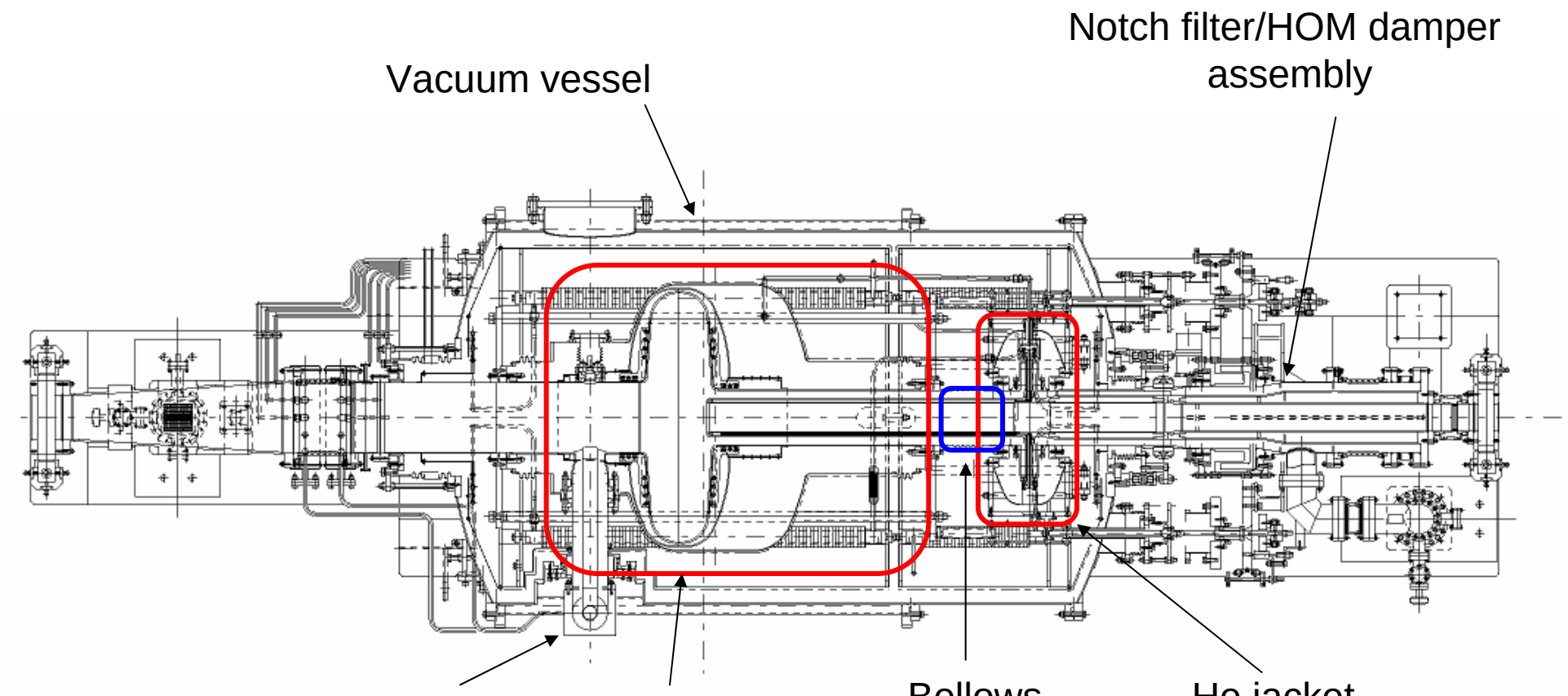
- Jacket-type He vessel for the cavity cell
  - handling of the large cavity cell

- Jacket-type He vessel for coaxial coupler
  - cooling for the inner conductor

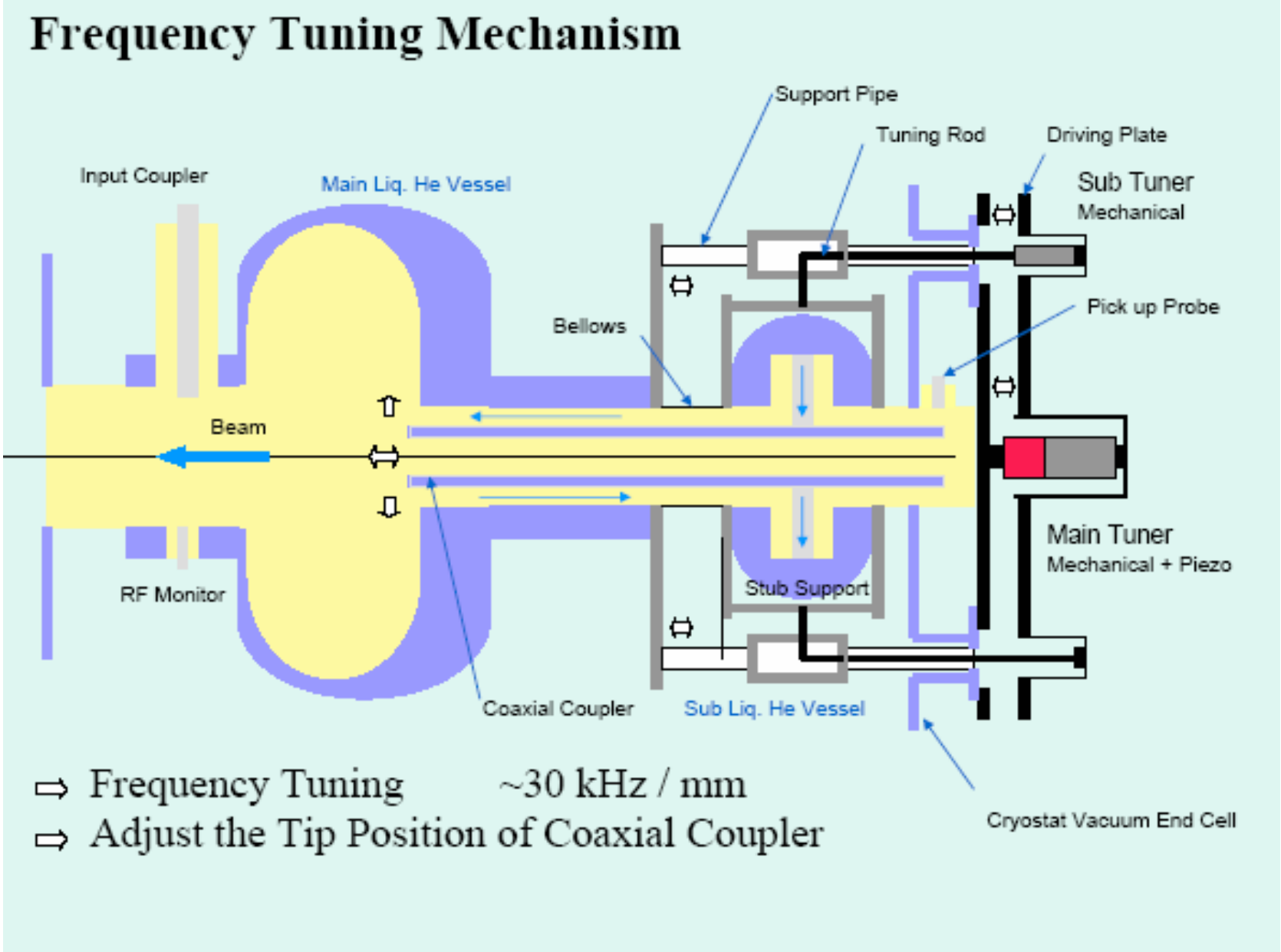
- Large-size bellows (ϕ188)
  - connects both jackets
  - alignment of the coaxial coupler
  - frequency tuning

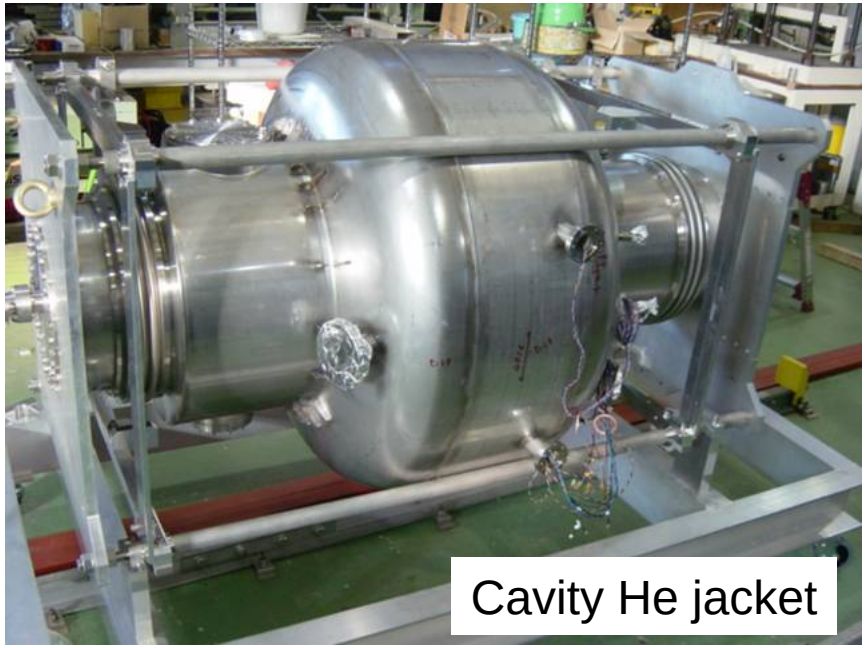
- Jacket-type magnetic shield
- LN2 cooled 80 K thermal shield (Al plate, Cu strips)
- Vacuum vessel (stainless steel)

Cryostat Design (top view)

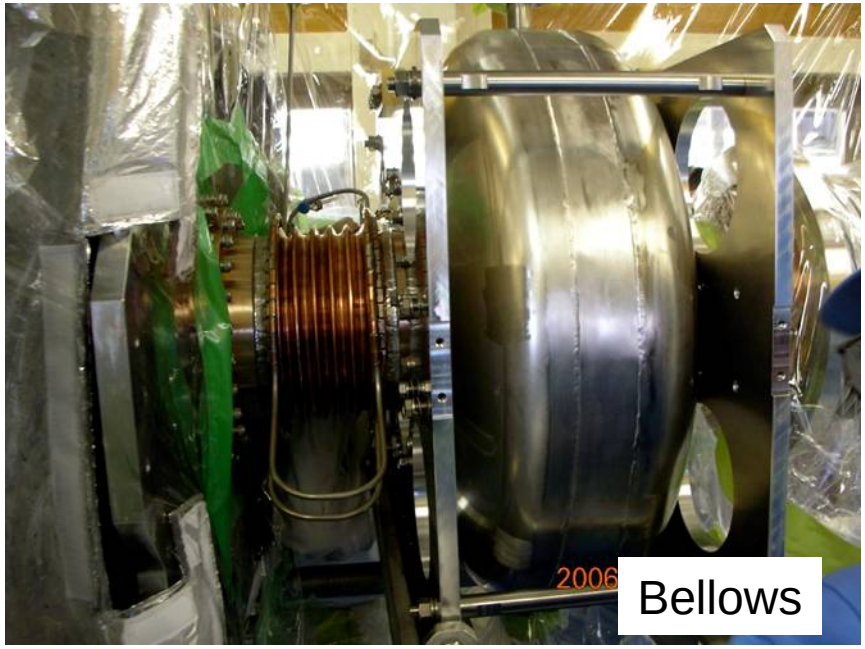


Frequency tuning

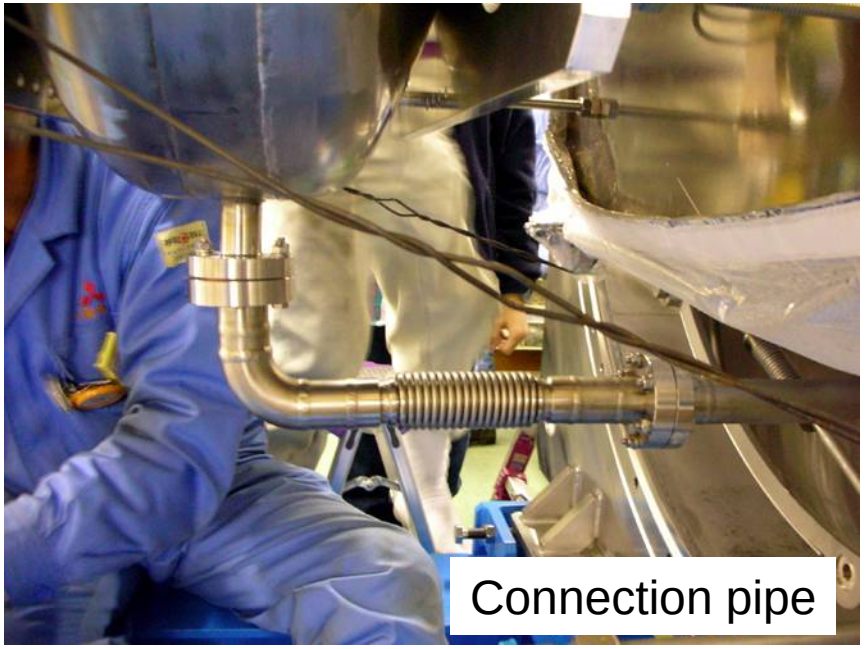



Cavity He jacket

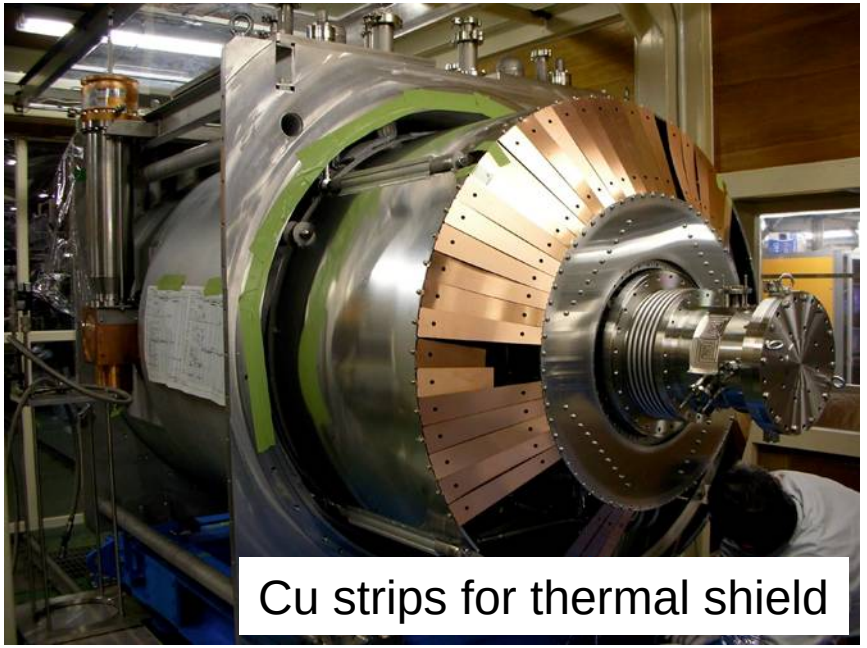

Coaxial coupler He jacket



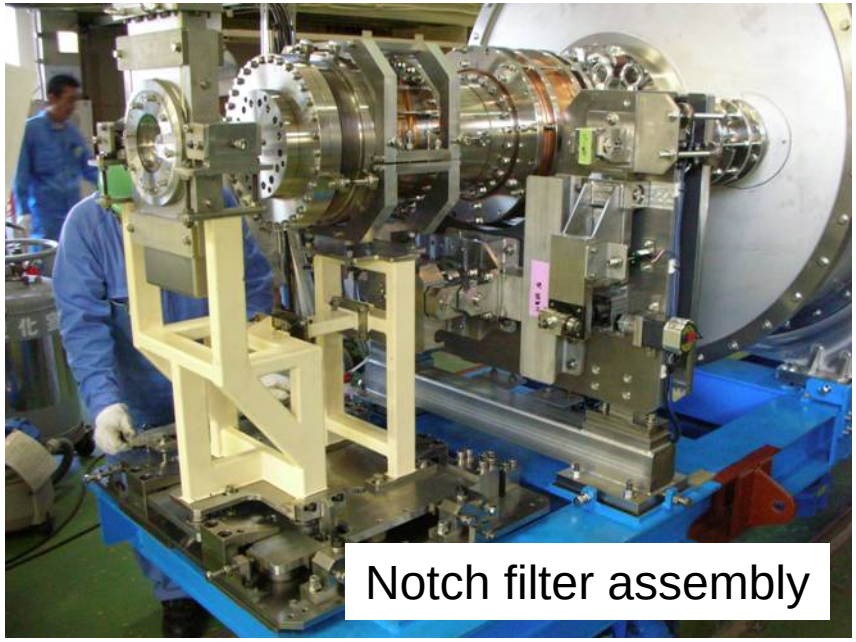
Bellows


Connection pipe

Vac. Vessel and thermal shield



Cu strips for thermal shield



Notch filter assembly

Ready for HPT

High Power Test

Assembled crab cavity is moving form the assembly yard to the high power test stand.

High power test

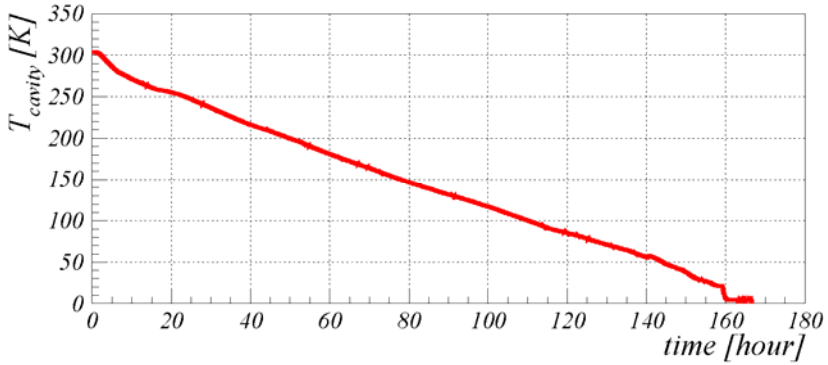
- Adjustment of the resonant frequency
- Alignment of the coaxial coupler
- Optimization of the tuner feedback system
- Conditioning of the cavity
- Qo measurement
- Static loss measurement of the cryostat

High Power Test Stand

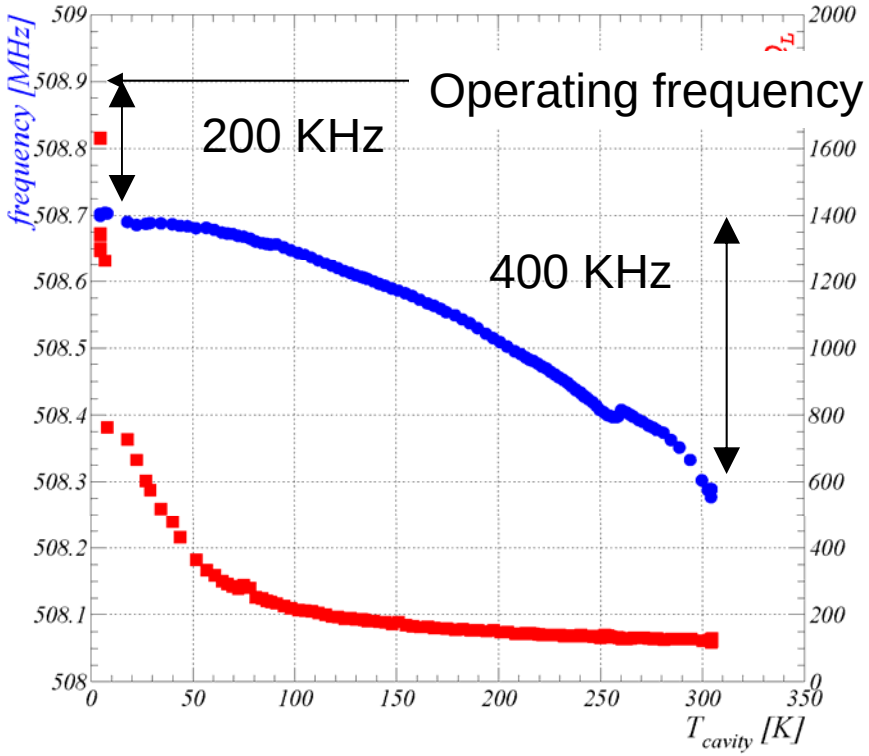
Installed in the pit

He Transfer tubes connected

Cool-down and frequency adjustment

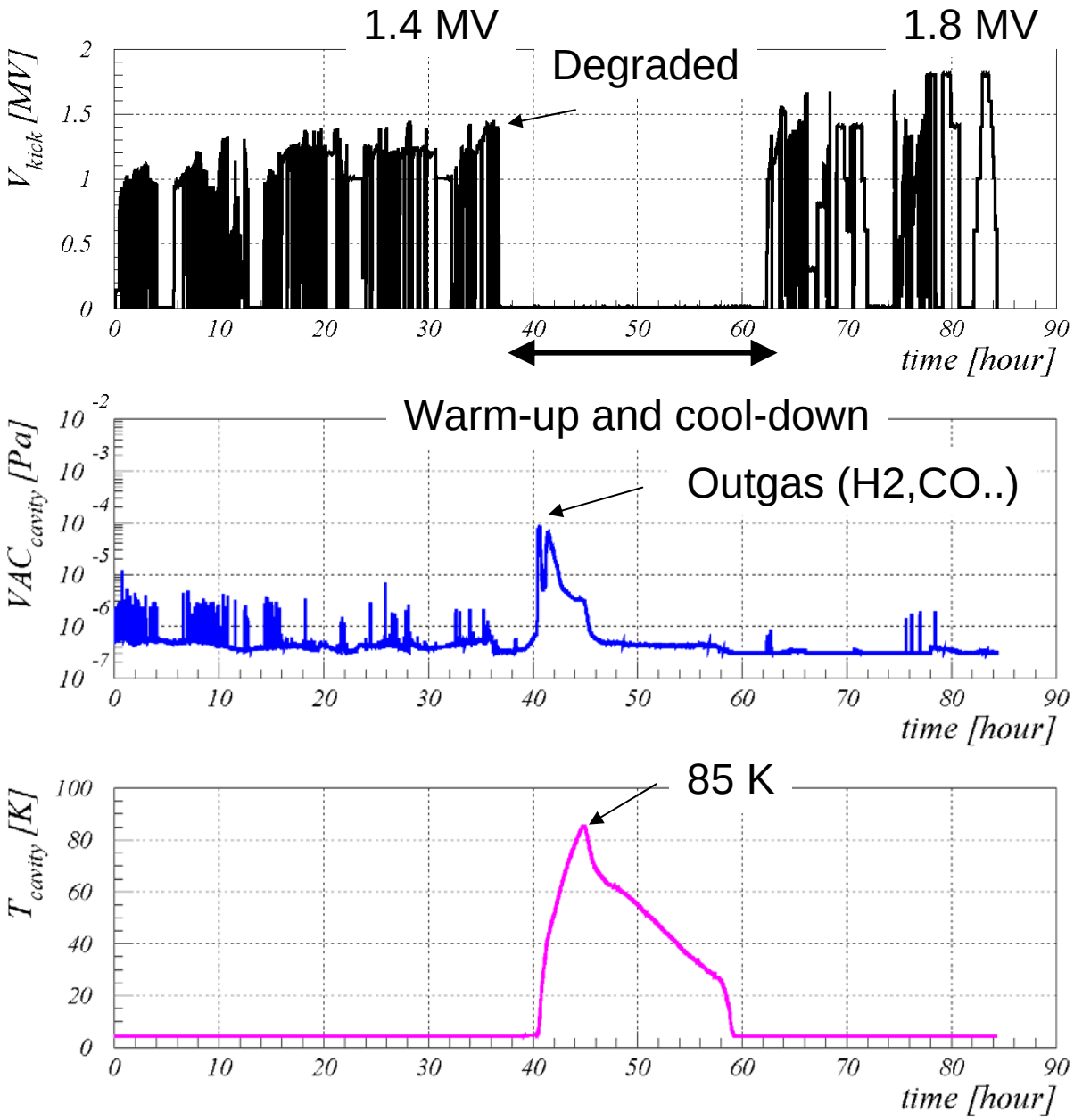


Cool-down rate: 2 K/h
1 week



Frequency shift during cool-down
400 kHz
Cell deformation
100 kHz
Coaxial coupler insertion
100 KHz

Conditioning status



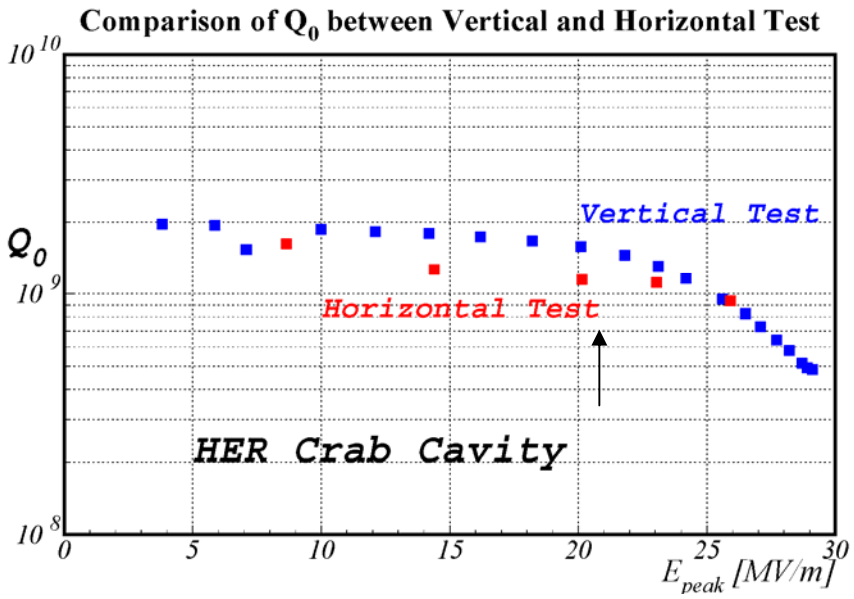
Hi power conditioning
Pulse conditioning

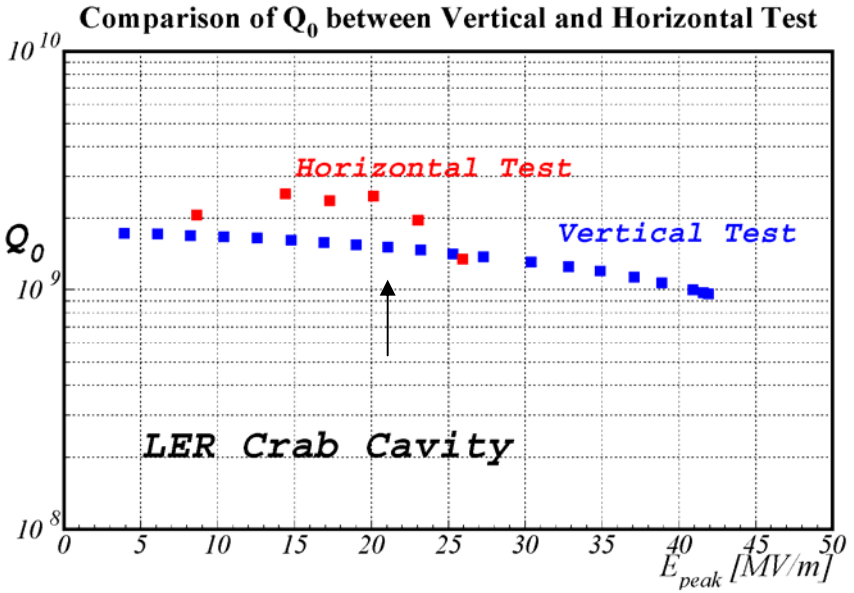
1.4 MV reached

Slightly degraded
due to vacuum pressure

Warm-up and cool-down
for evacuation

1.8 MV reached





Qo measurement

Heat load measurement of the cryostat
No significant Q-degradation observed
Static loss ~30W

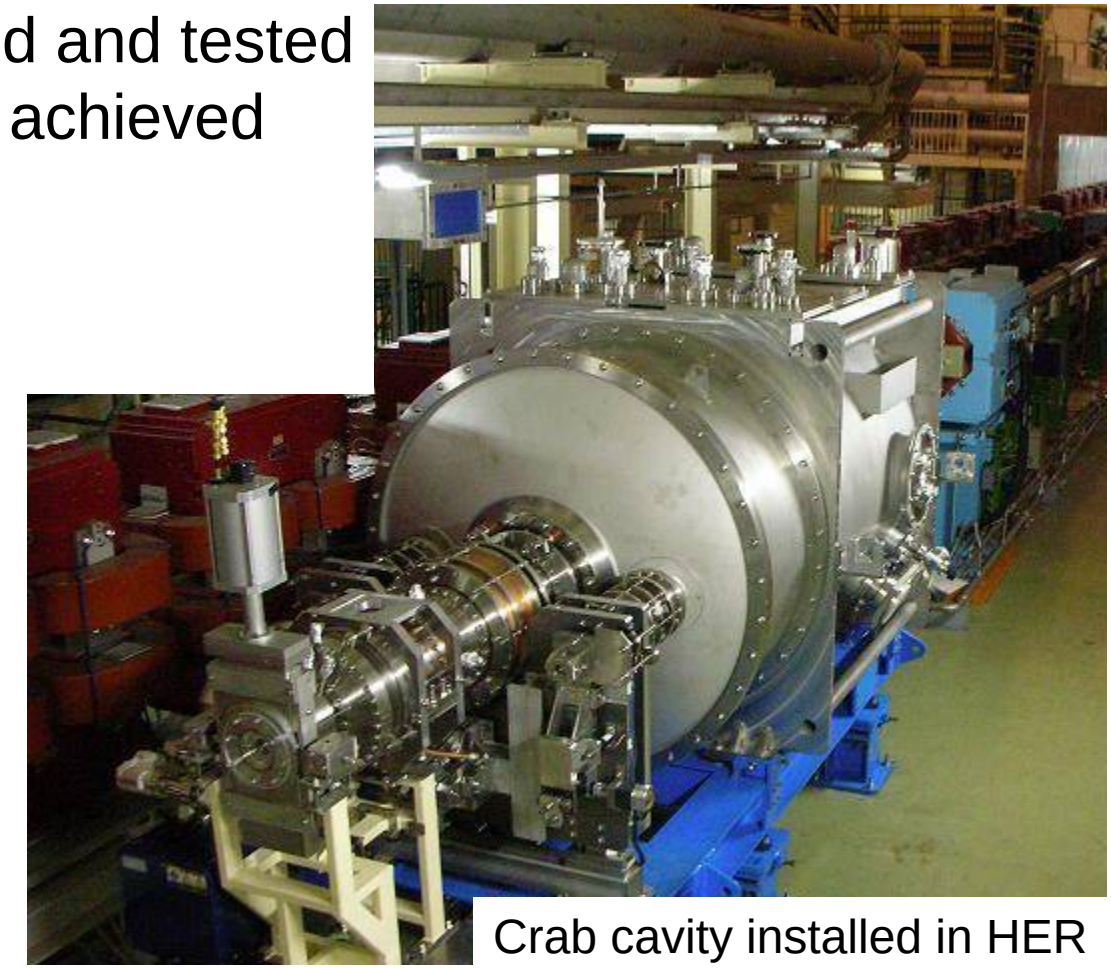
Tuner phase distribution

1 deg. (HER) acceptable for KEKB
Much larger (LER)
We need investigation

Summary

Crab cavity for KEKB developed
Two crab cavities fabricated and tested
Required voltage (1.4 MV) achieved

Installed in KEKB rings
Beam test will start soon

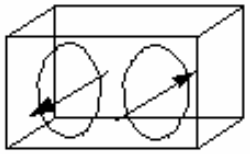


Crab cavity installed in HER

Backups

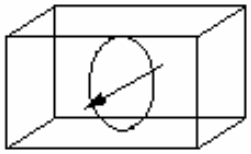
LOM and HOMs

Sufficiently damped
for High Current Operation

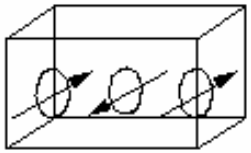


TM210
Crab Mode
509 MHz

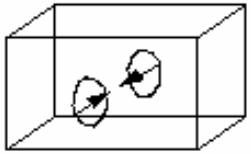
Monopole
410 MHz



TM110
LOM

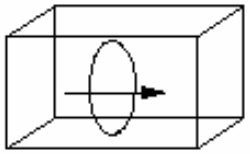


TM310



TM111

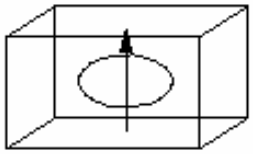
Dipole
Horizontal Polarization



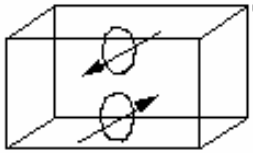
TE011

650 MHz

Dipole
Vertical Polarization
630 MHz

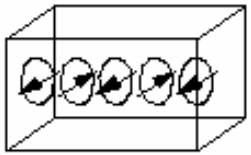


TE101

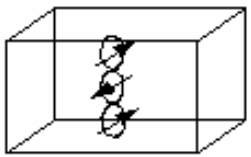


TM120

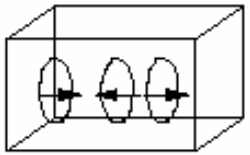
UPM
680 MHz



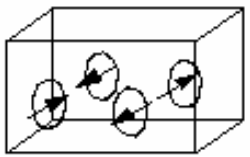
TM510



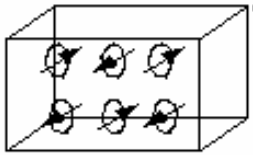
TM130



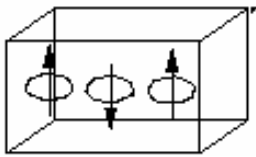
TE211



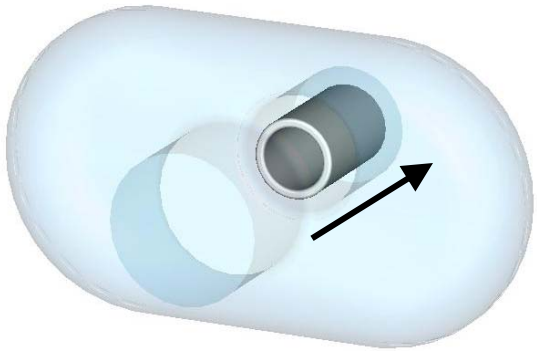
TM211



TE320



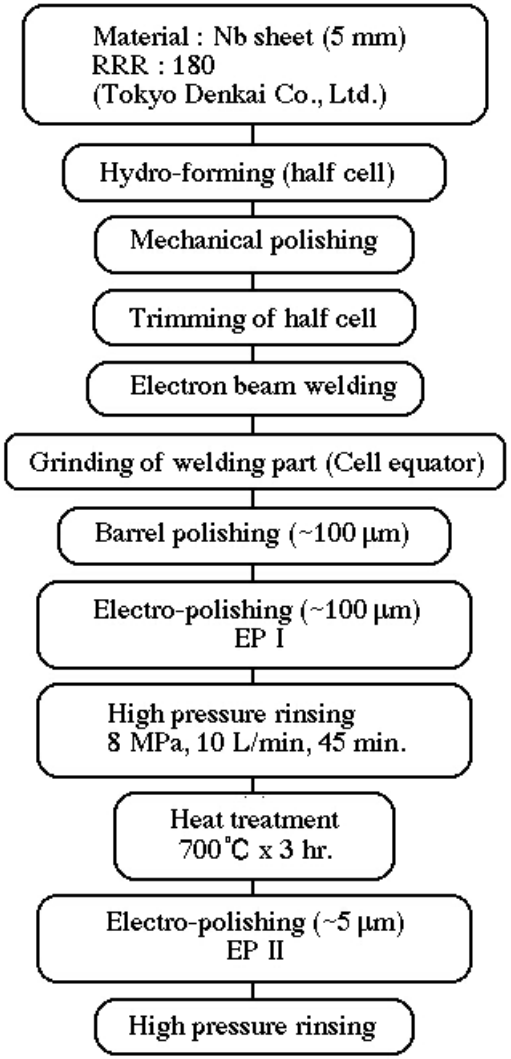
TM301



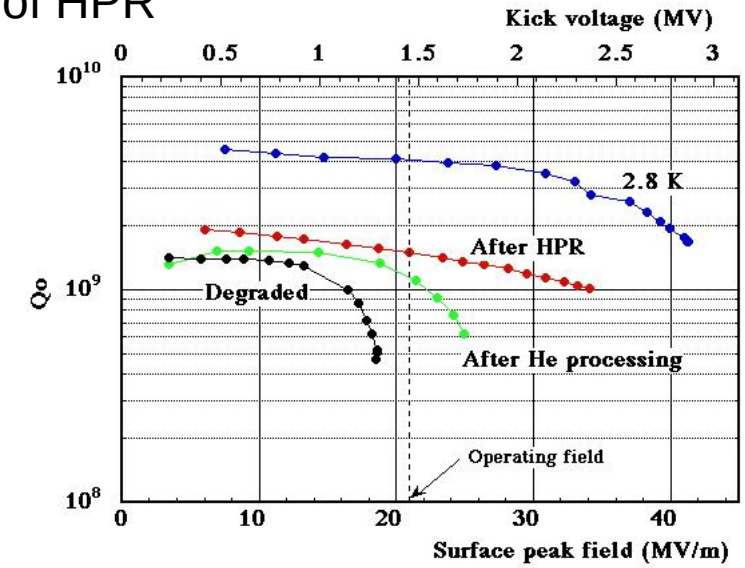
Coaxial coupler
Propagation mode
TEM: No cut-off (monopole)
TE11: fc=600 MHz (dipole)

Prototype cavity

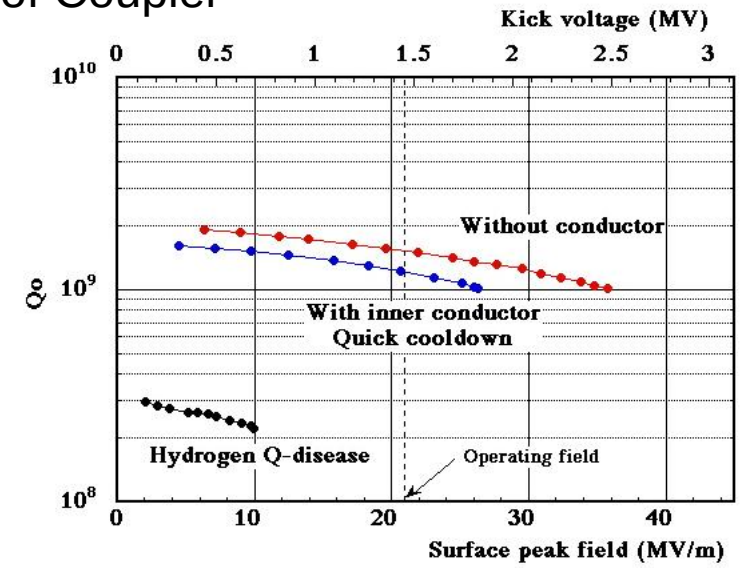
Fabrication and surface treatment



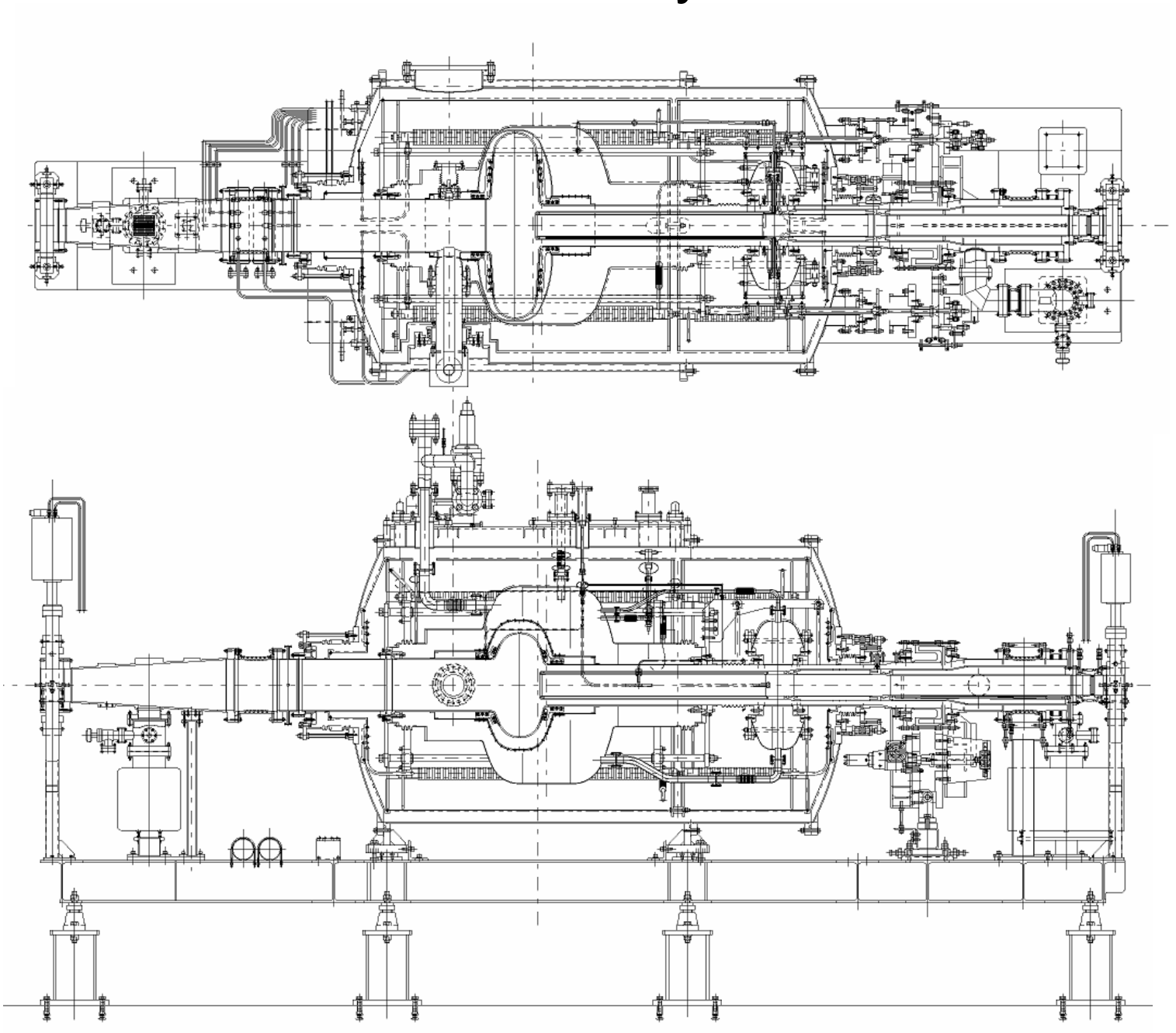
Effect of HPR



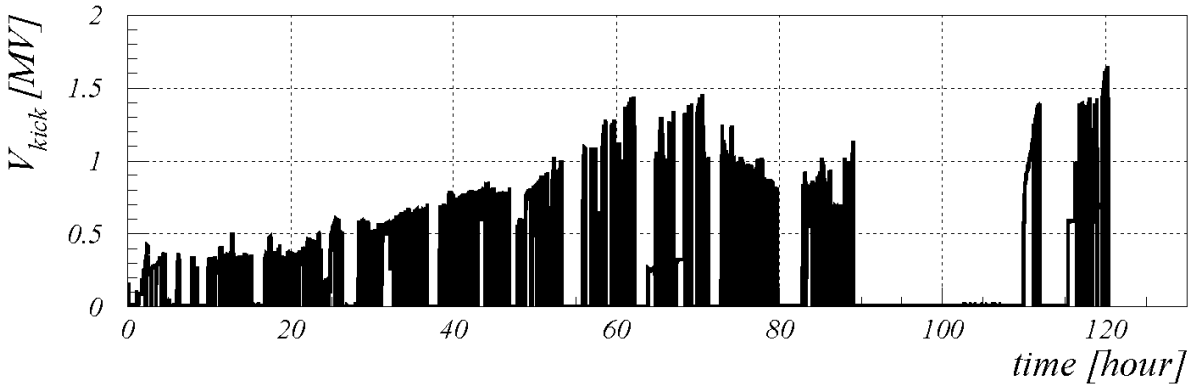
Effect of Coupler

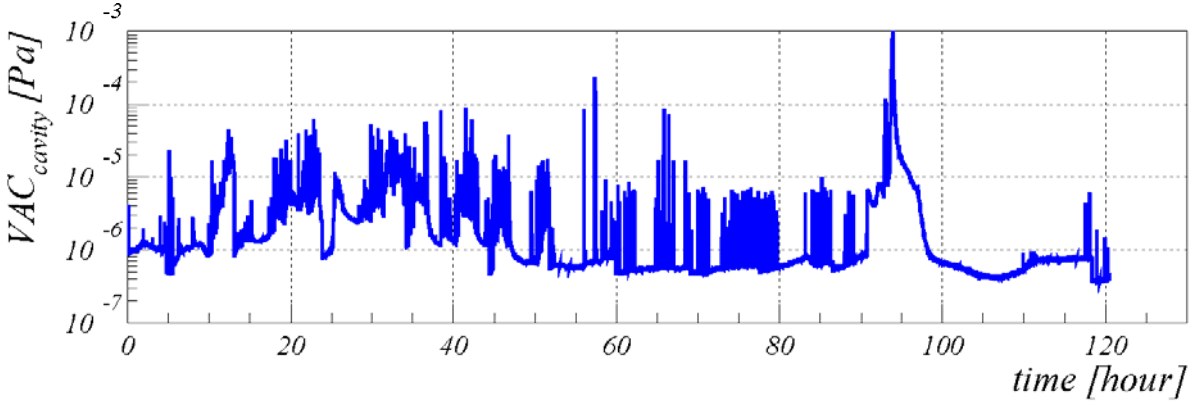


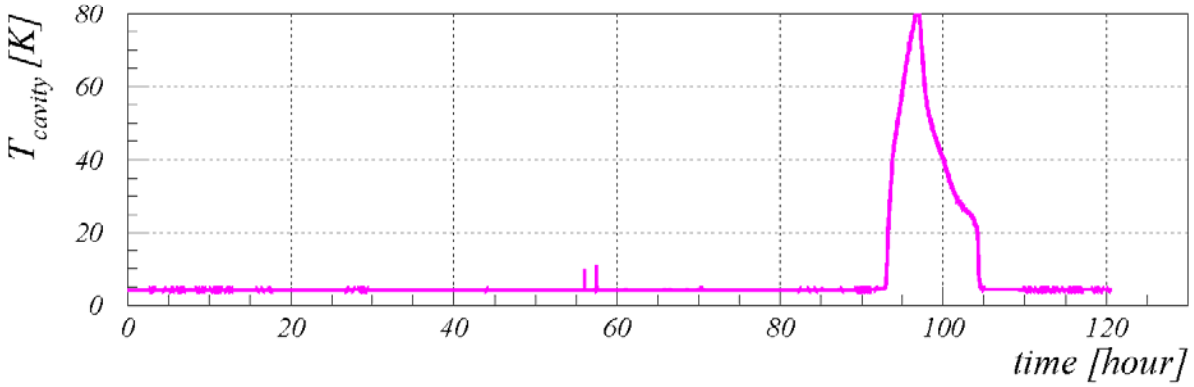
Crab cavity for KEKB



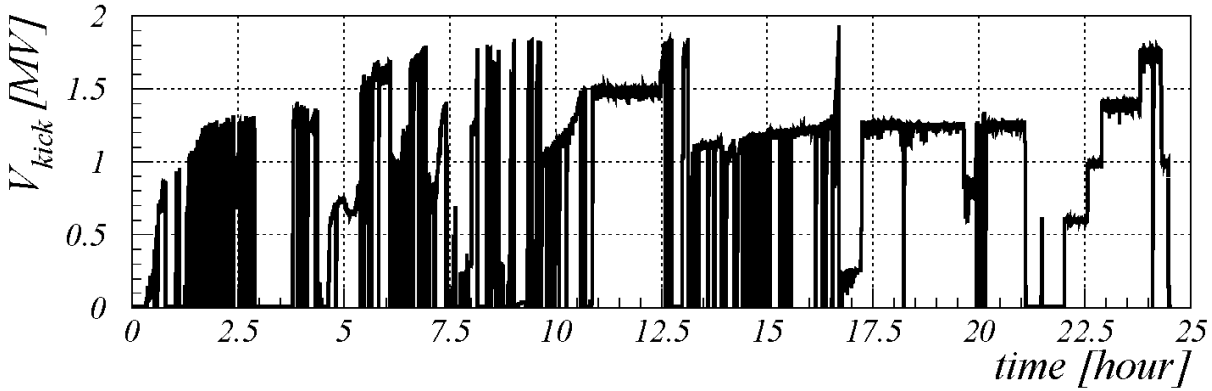
High Power Test 1(HER#1)

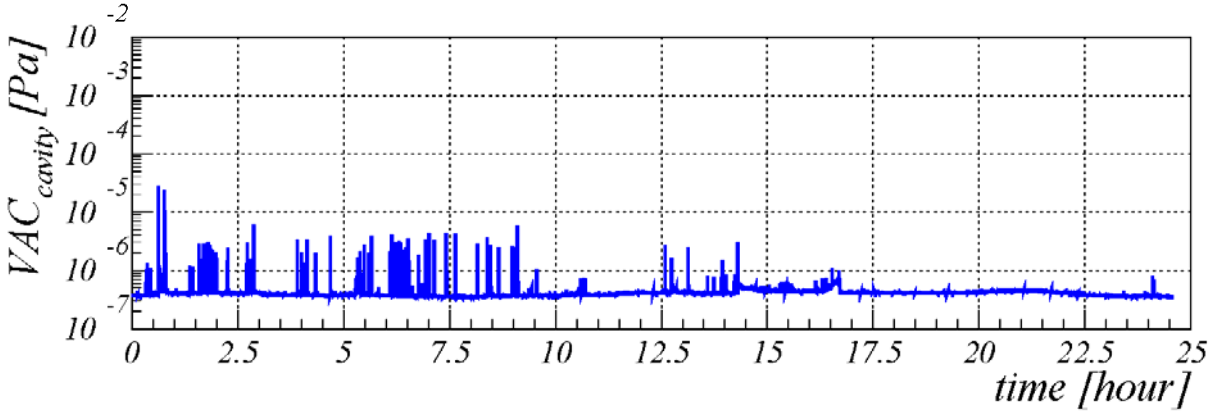


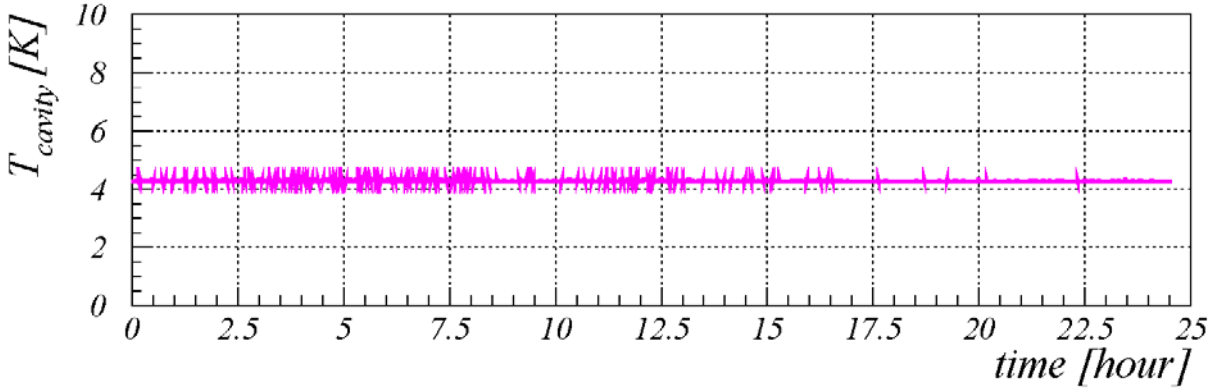




High Power Test 3(LER)



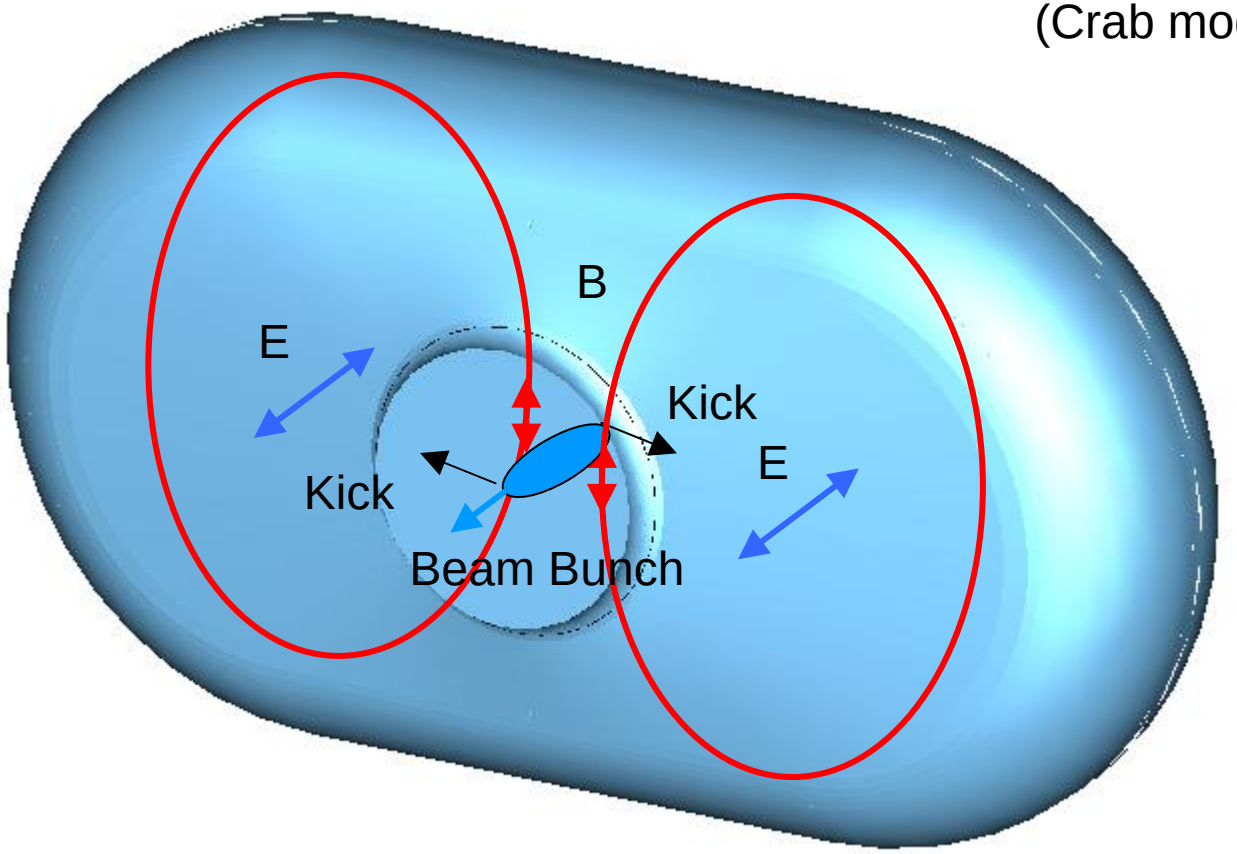





Propagation mode
TEM: no cut-off
TE11: fc=600MHz

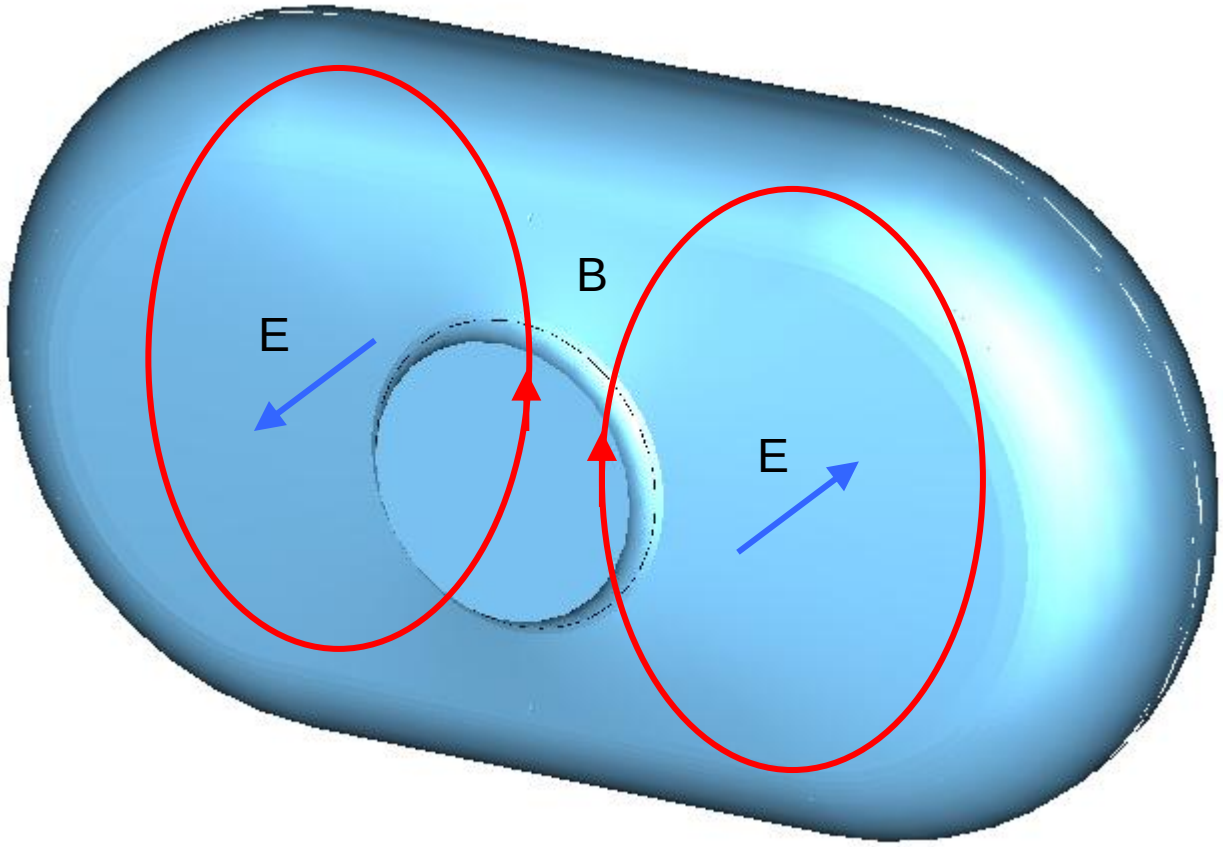
Crab mode kicks beam bunch

TM110-like mode
(Crab mode)

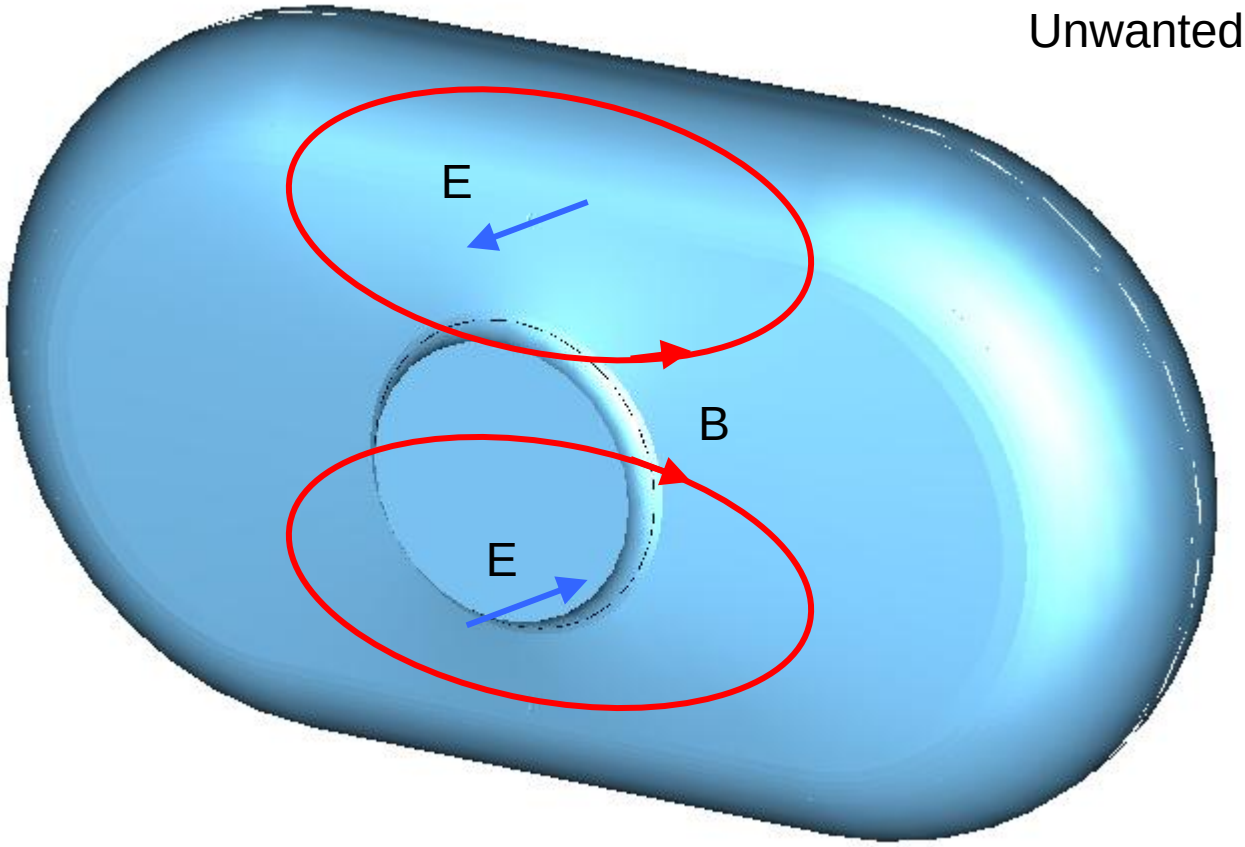


Time-varying magnetic field
Kicks head of bunch in horizontal direction
Kicks tail of bunch the opposite direction

Crab mode kicks beam bunch



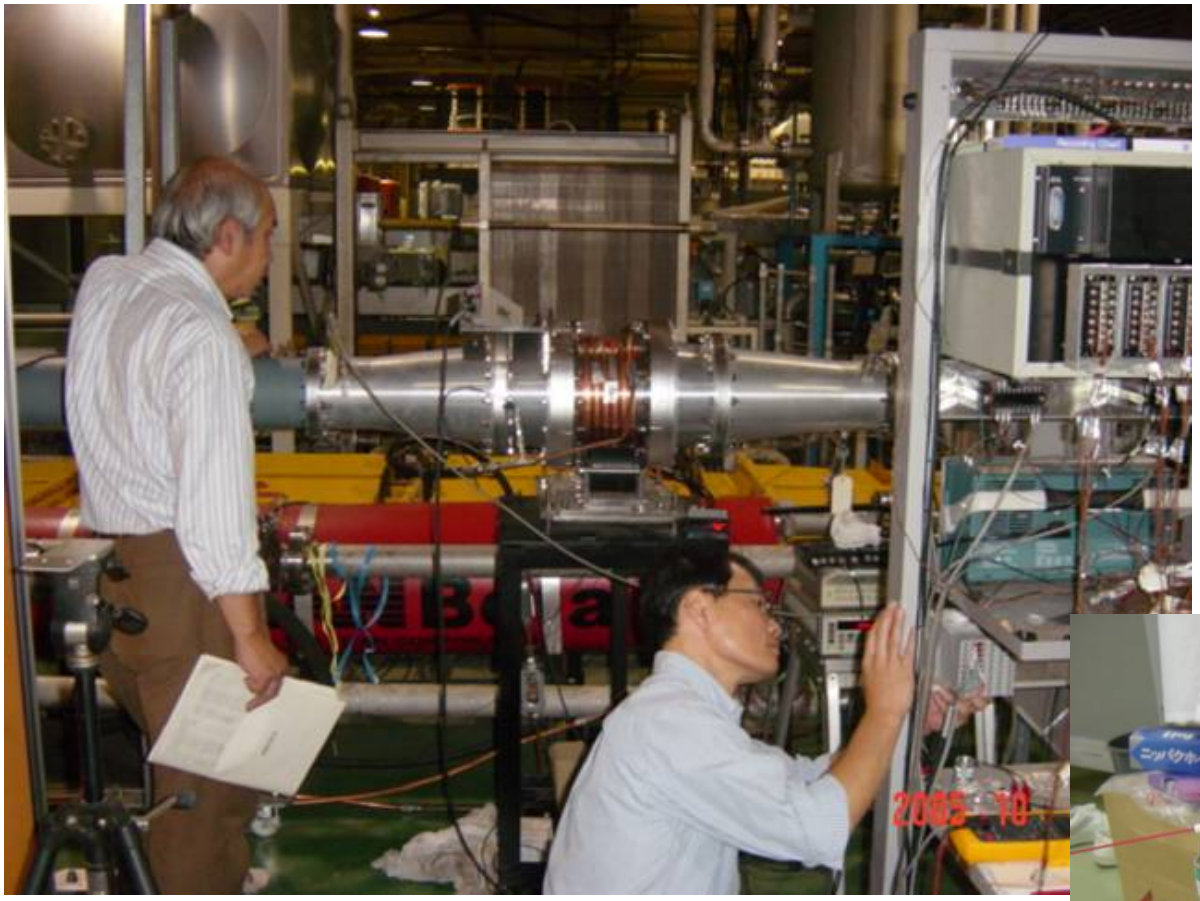
Squashed cell raises UPM frequency



Round Cell
509 MHz

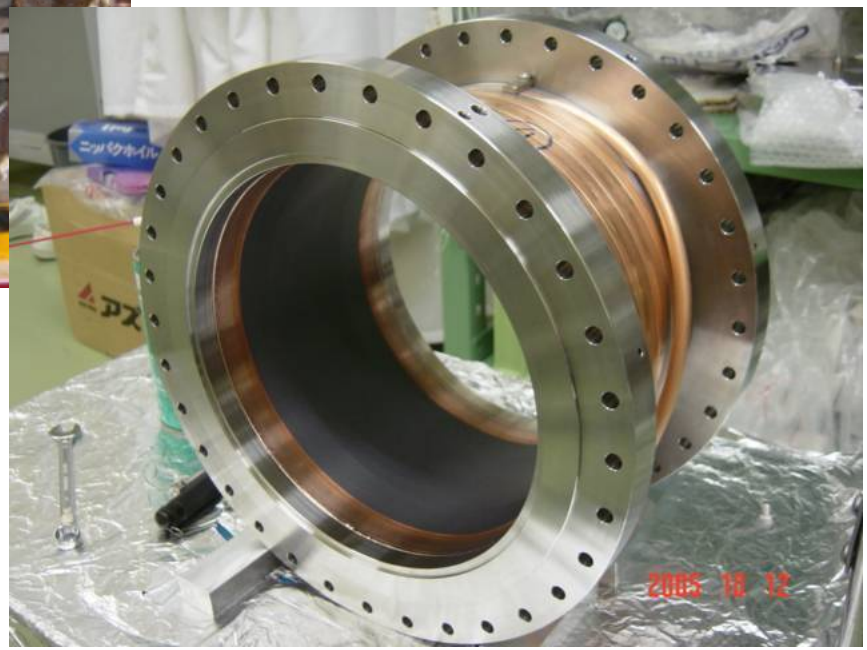
Squashed Cell
680 MHz

HOM damper



High Power Test Stand
Tested up to 10 kW

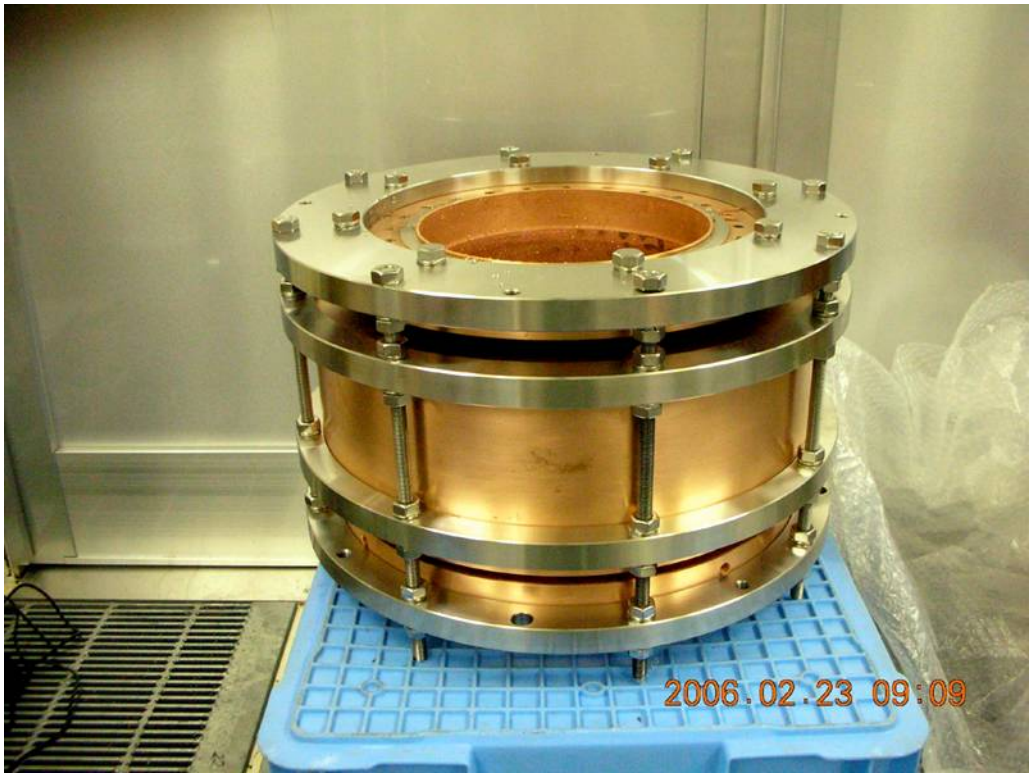
HOM damper
Ferrite absorber
Sintered with HIP method
(1500 atm, 900^{o}C)
240ϕ x 120 x 4t



Notch filter

Test stand (adjusting frequency)

Before assembling



Bellows

Old type

Cu
0.4 mm
+/- 3mm

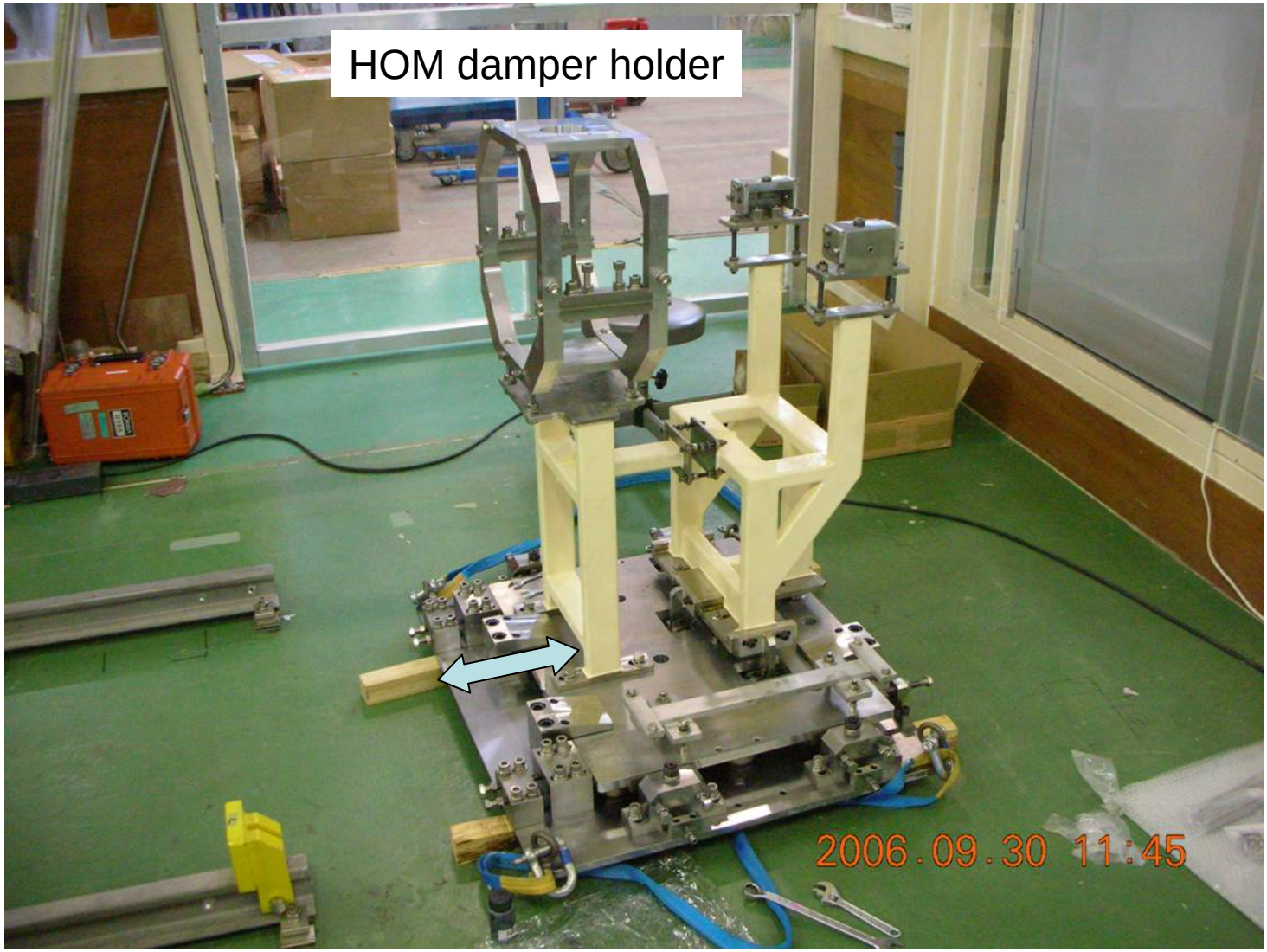
MAT: SUS316L
Thickness: 0.2 mm
Stroke: +/- 10mm

Before plating

Tuner rod

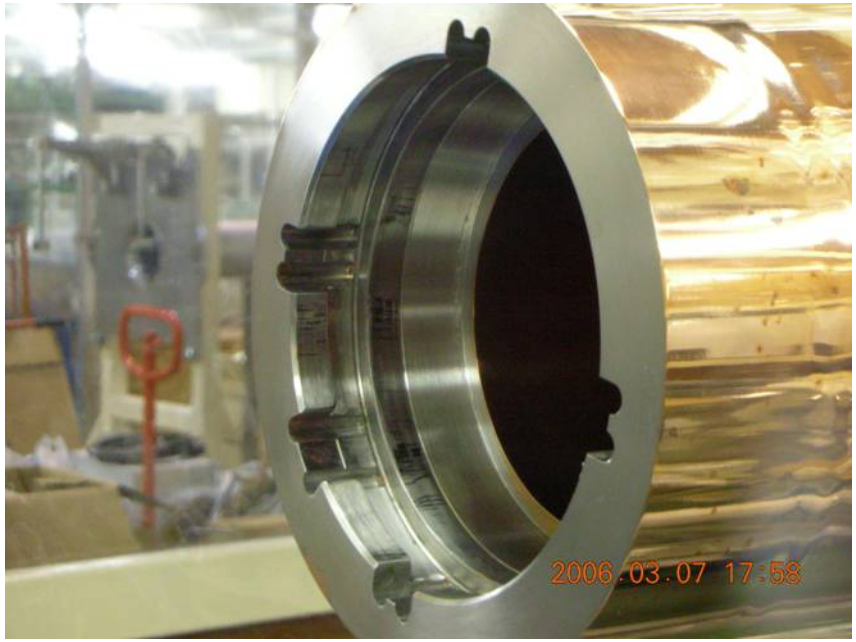
Attached to cryomodule

Movable plate

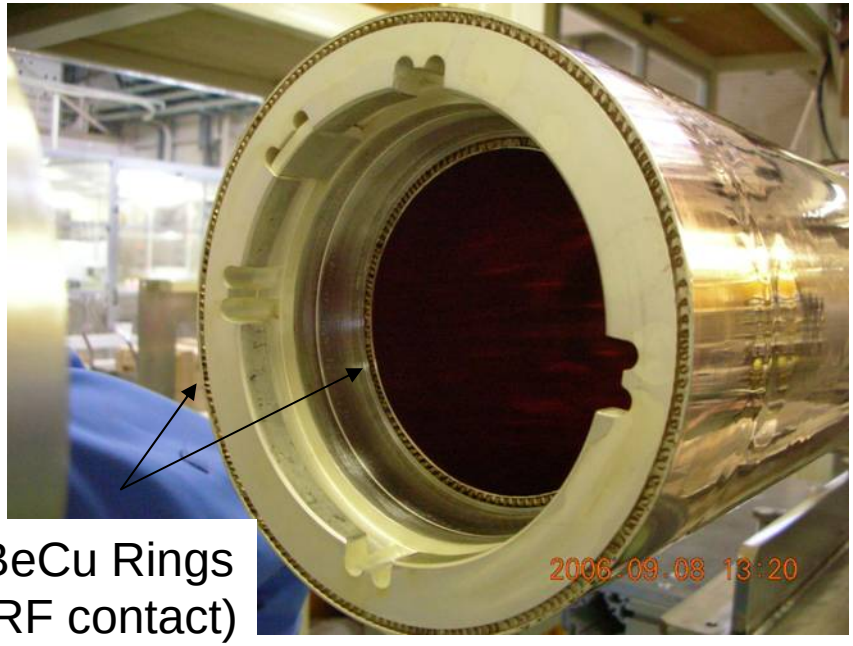


RF contact

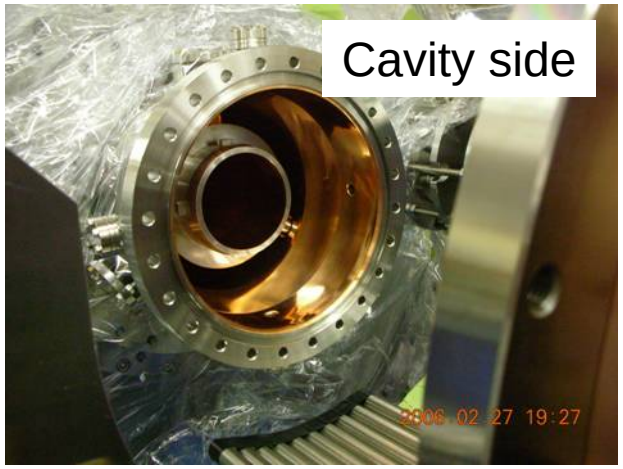
Old type

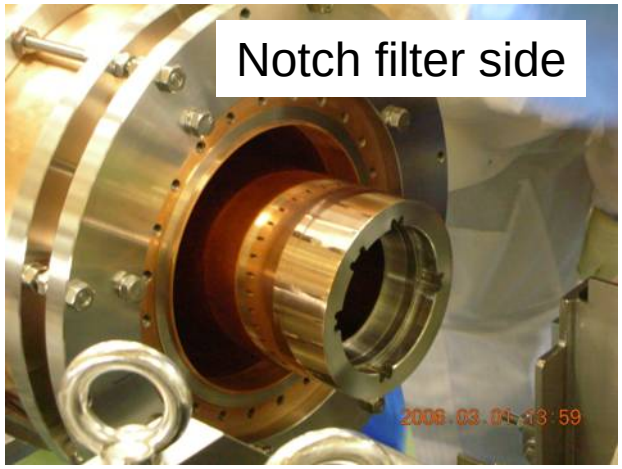


New type

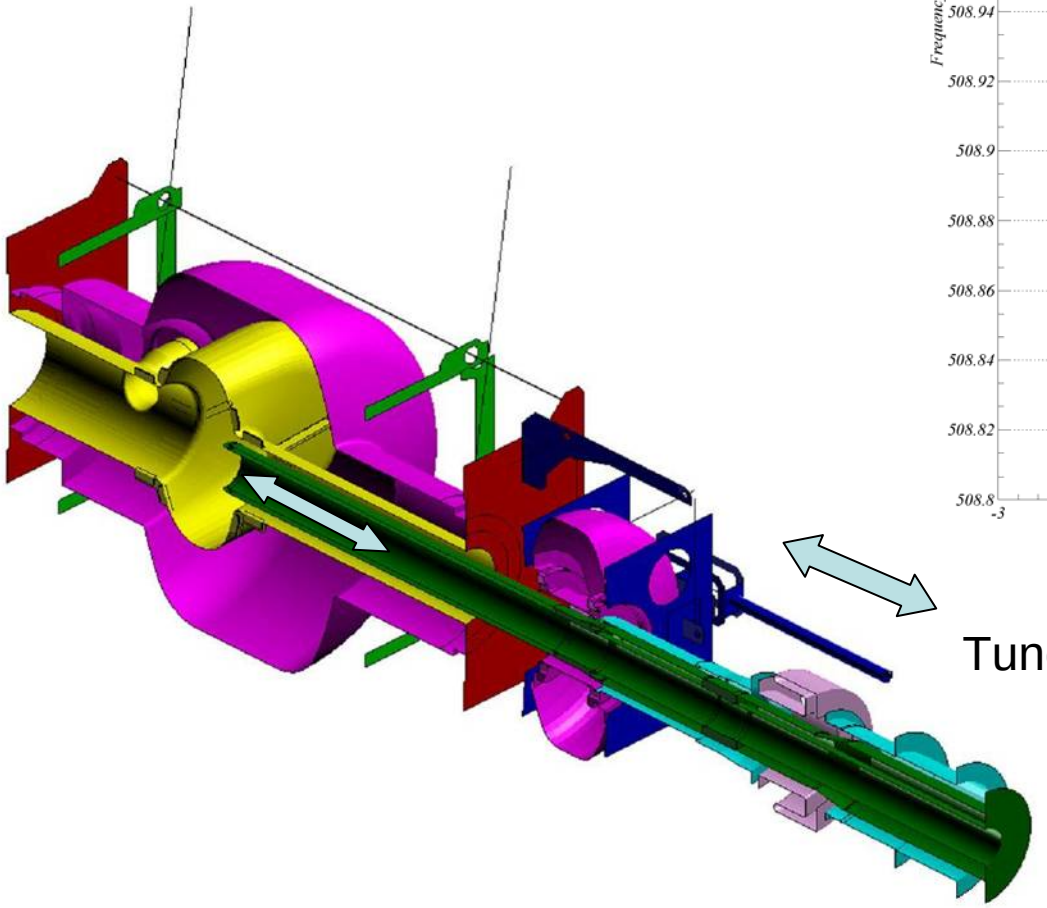


BeCu Rings
(RF contact)





Tuner test



Tuner rod