

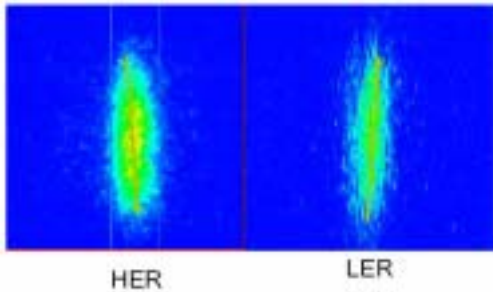
Crab Cavity Overview

K. Hosoyama



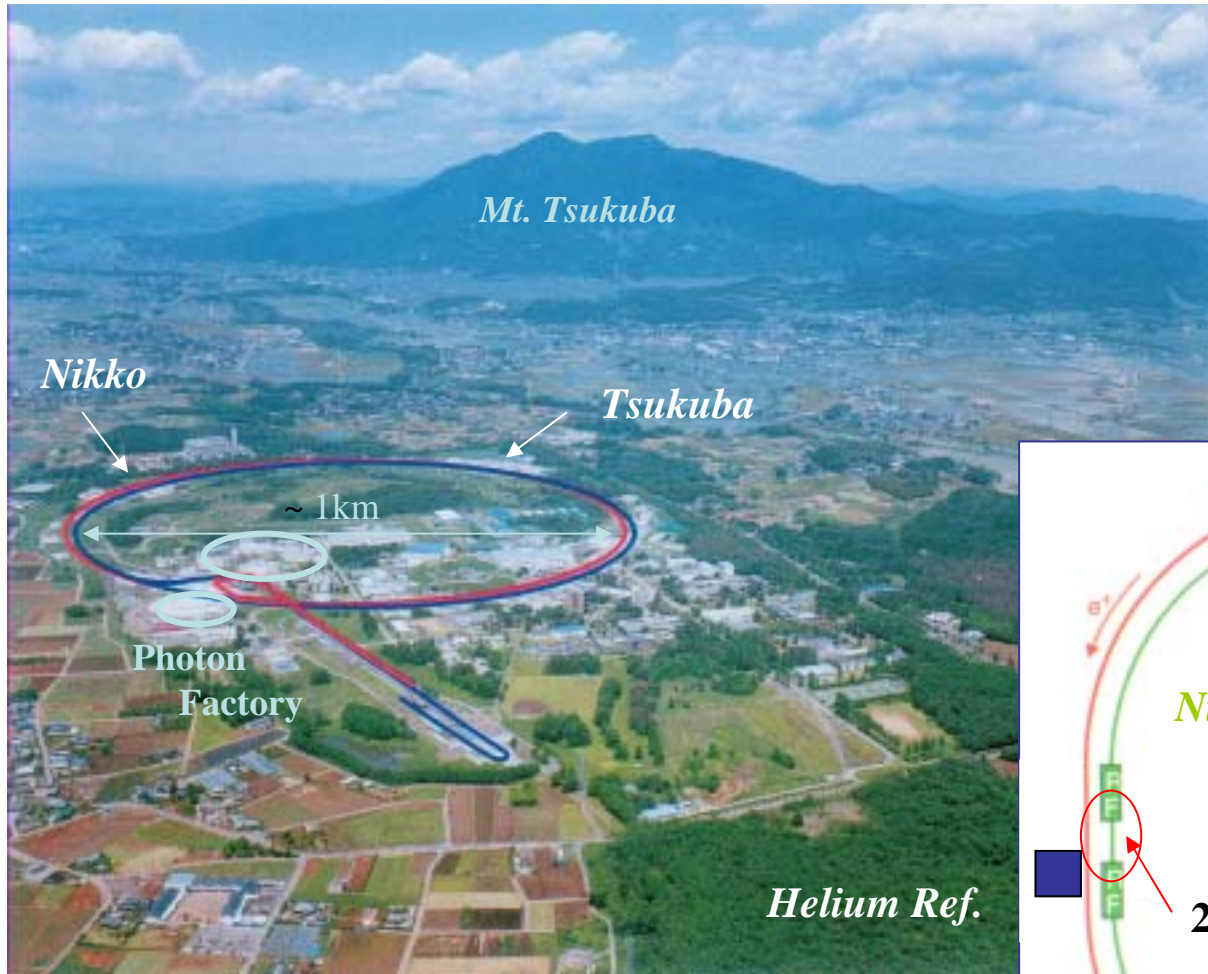
Crab Cavity for KEKB
Fabrication and RF Performance of Crab Cavities
Cryostat for Crab Cavity
Cool Down and High Power Test at D10 Test Stand
Tuner
Commissioning of Crab Cavities for KEKB

Crab Cavity for HER



Crab Cavity for LER

Crab Cavities for KEKB



KEKB

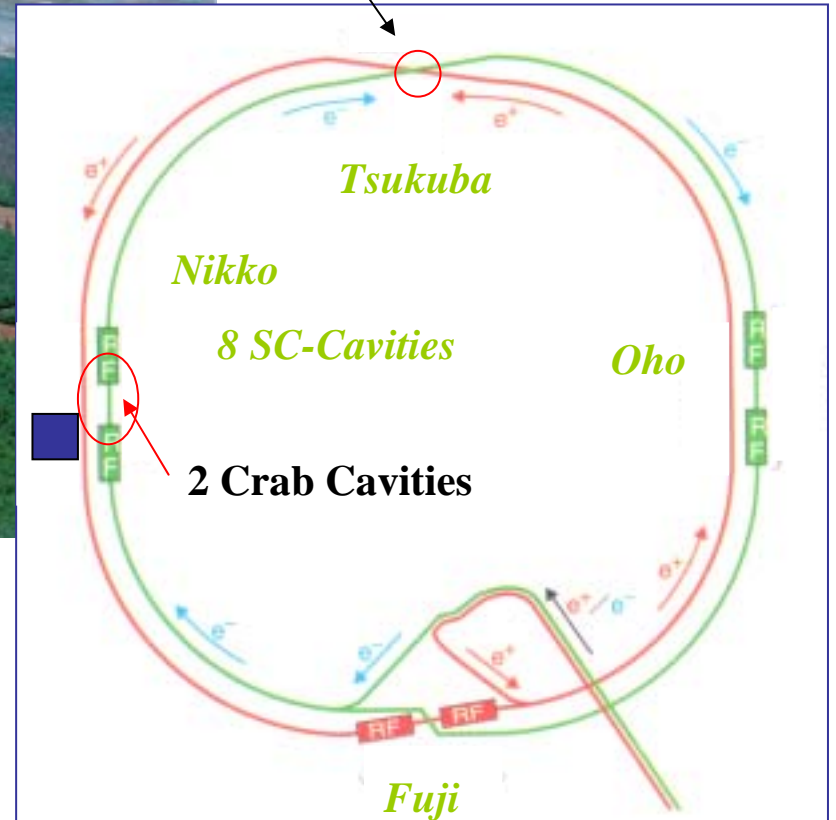
LER *3.5 GeV*

HER *8.0 GeV*

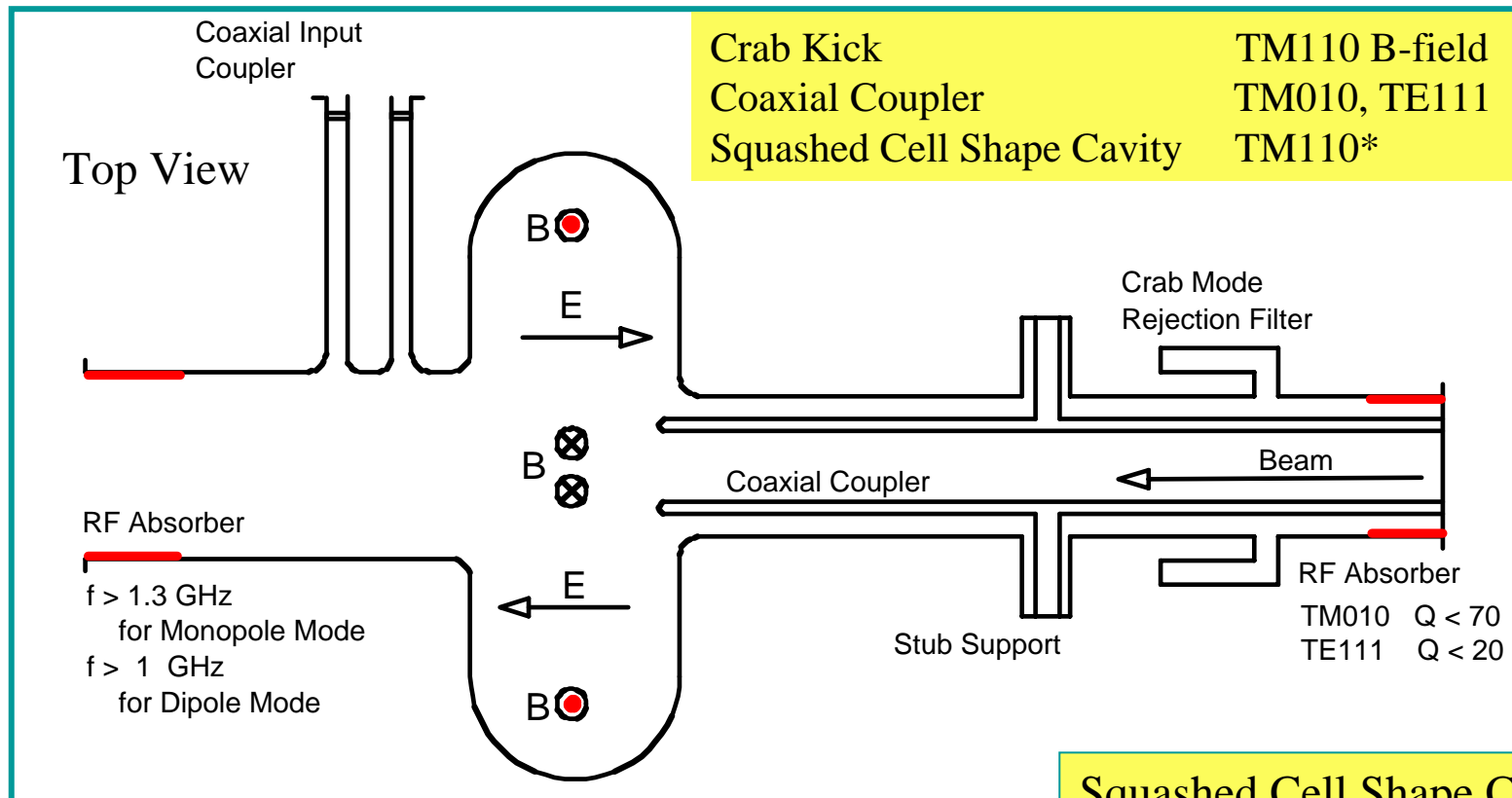
RF freq. *508.9 MHz*

Cross. Ang. *2 x 11 m rad.*

Collision Point



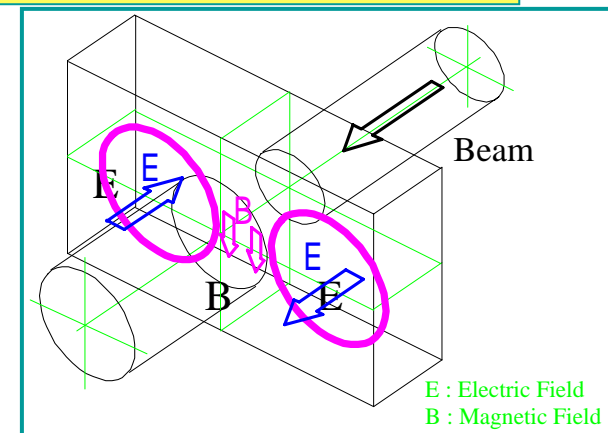
Conceptual Design of KEKB Crab Cavity



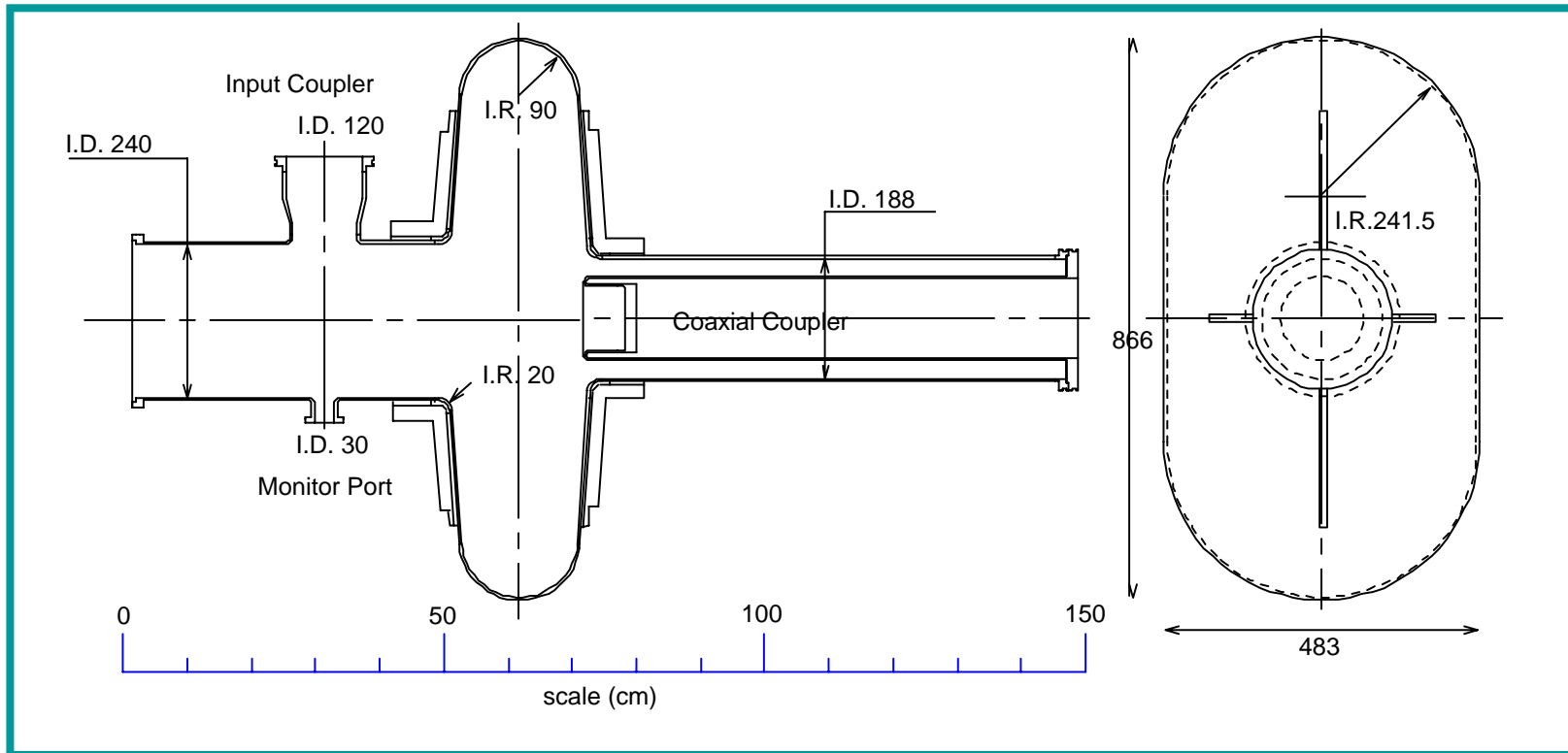
Squashed Cell Shape Cavity

➔ The squashed cell shape cavity scheme was studied extensively by Akai at Cornell in 1991 and 1992 for CESR-B under KEK-Cornell collaboration.

We adopted this design as “base design”!



KEKB Superconducting Crab Cavity



➔ Non-axial Symmetric Structure
Thickness of 4.5 mm Nb Cavity
Reinforced by Ribs

Simplified Coaxial Coupler



Milestone of Crab Cavity for KEKB

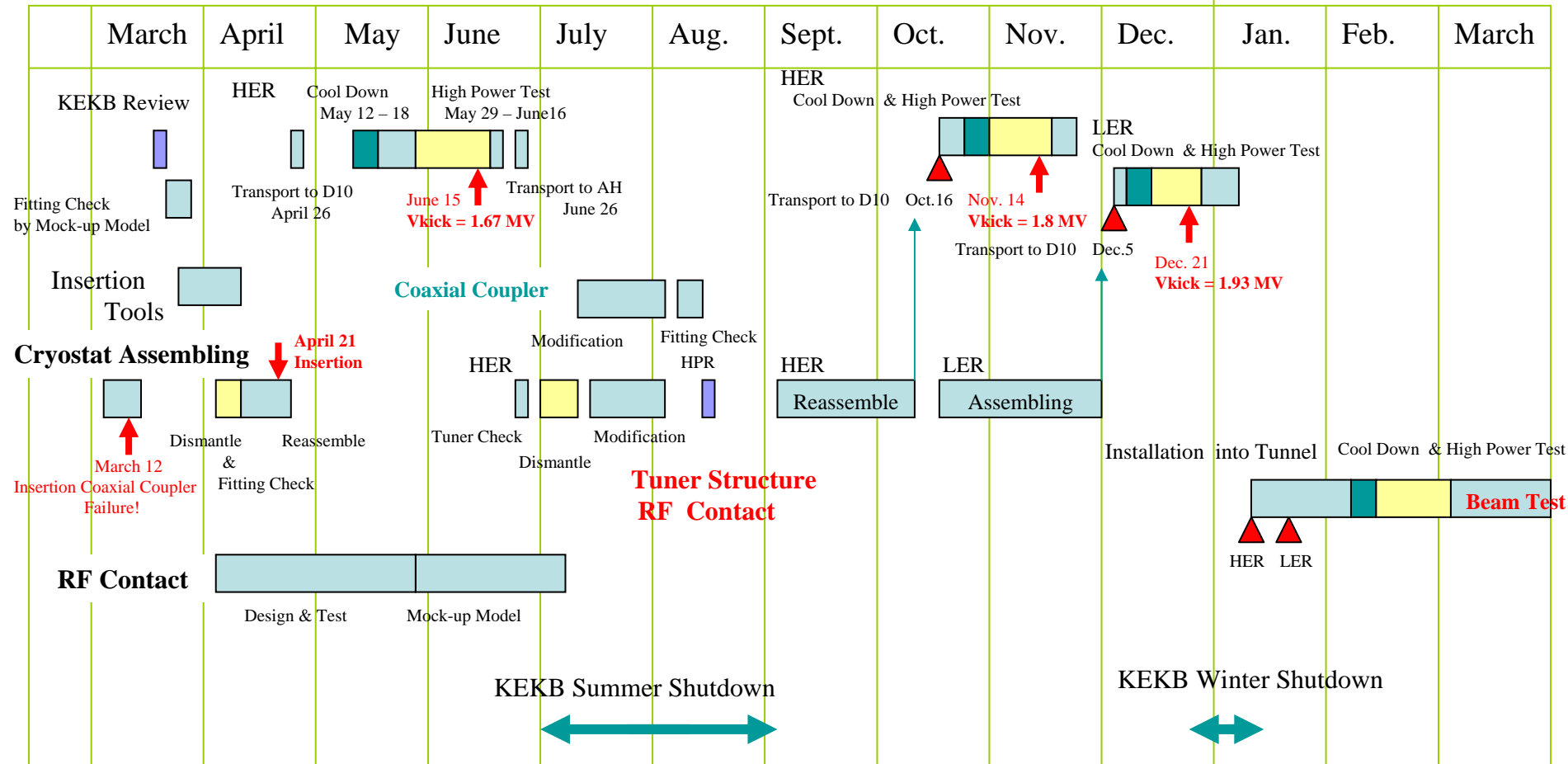
- 1994 Crab 1/3 Scale 1.5 GHz Model
- 1996 Crab Full Scale 500 MHz Model
- 2005
- Jan. Start the Fabrication of 2 Crab Cavities
 - Dec. RF Test of Crab Cavity HER in Ver. Cryostat $V_{\text{kick}} = 1.9 \text{ MV}$
- 2006
- Jan. RF Test of Crab Cavity LER in Ver. Cryostat $V_{\text{kick}} = 2.7 \text{ MV}$
 - Feb. Cool-down Test of Prototype Cryo-module
 - Feb. Start the Assembling of Cryo-module for Crab Cavity HER
 - Mar. **Insertion Failure of Coaxial Coupler**
 - Apr. Improved the Insertion Tool
Finished the Assembling Crab HER
 - May. Cool-down & High Power Test at Test Stand $V_{\text{kick}} = 1.65 \text{ MV}$
 - July Dismantle the Cryo-module
Improved RF Contact of Coaxial Coupler and Bellows
 - Aug. Reassemble the Cryo-module
 - Sep. Cool-down and High Power Test of Crab HER at Test Stand $V_{\text{kick}} = 1.8 \text{ MV}$
 - Oct. Assembling the Cryo-module for Crab LER
 - Nov. Cool-down and High Power Test of Crab LER at Test Stand $V_{\text{kick}} = 1.93 \text{ MV}$
- 2007
- Jan. 8,11 Installation of Crab Cavities for HER and LER into KEKB Ring
 - Jan.29,31 Start the Cool-down of Crab Cavities for HER and LER
 - Feb. 9,10 Start of RF Aging $V_{\text{kick}} = 1.7 \text{ and } 1.43 \text{ MV}$ for HER and LER
 - Feb. 19 Crab Kick

Construction & High Power Test of Crab Cavities

Jan. 20, 2007
K. Hosoyama

2006

2007



Fabrication and RF Performance Test of Crab Cavity

- Fabrication of two crab cavities for LER and HER started in Jan. 2004 and finished in Nov. and Dec. 2005.
- The crab cavities for LER and HER were cold tested in vertical cryostat.

The test result of crab cavity for HER was satisfactory.

$$V_{\text{kick}} = 1.9 \text{ MV}$$

The result of crab cavity for LER
was no good at 2nd and 1st Test.

We could improve the RF performance,
by removing “lint” and EP2 processing.

$$V_{\text{kick}} = 2.7 \text{ MV}$$



Fabrication Procedure of Crab Cavity

Crab Cavity Cell

Beam Pipe & Flange

MHI
Kobe

Nb Sheet

Tokyo Denkai
5 mm t RRR = 180

Nb Sheet

Half Cell Hydro-forming

Rolle

Mechanical Polishing & Trimming

Electron Beam Welding

Grinding of Welding Part Cell Equator

KEK
Tsukuba

Barrel Polishing ~ 100 μm

Nomura
Plating
Kanuma

Electro-Polishing EP 1
~ 100 μm

High Pressure Water Rinsing

Kinzoku
Giken
Mito

Annealing 700 °C x 3 hr

Electro-Polishing EP 2
~ 5 μm

High Pressure Water Rinsing

80 bar. 60 min.

Assembling for Cold Test

Cold Test in Vertical Cryo.

Forming and Barrel Polishing



Forming of 4 Half-Cells for Crab
Cavity for LER and HER

Feb. 14, 2005 at Mitsubishi Heavy
Industries, LTD. Kobe

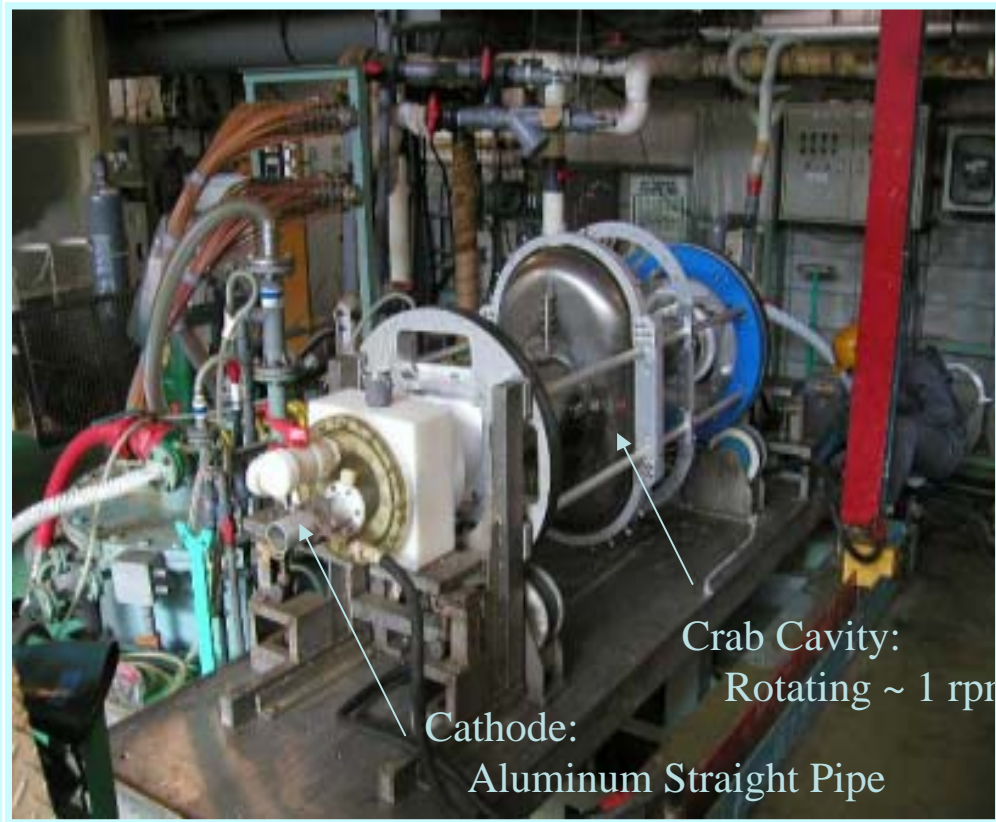


Barrel Polishing

Polishing Time 312 Hr

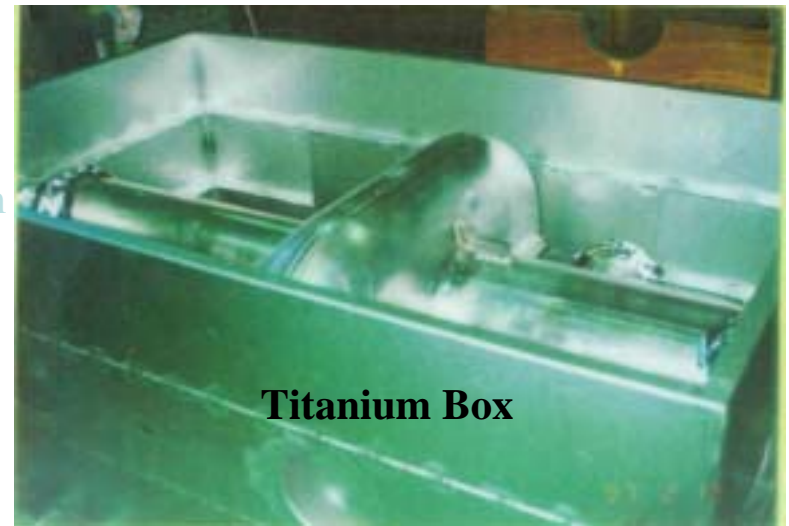
Nov. 11, 2005 at KEK

Electro Polishing & Annealing



Electro Polishing at Nomura Plating Ltd.

EP 1 ~ 100 μm
EP 2 ~ 5 μm



Annealing at 700°C for 3 hours
at Kinzoku Giken Ltd.

High Pressure Rinsing and Assembling for RF Cold Test



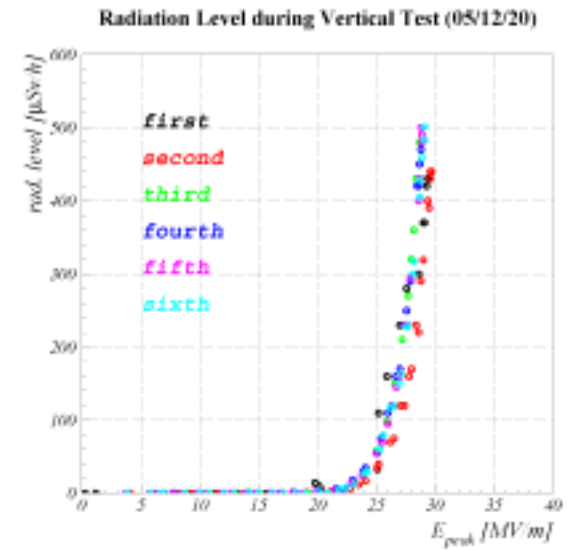
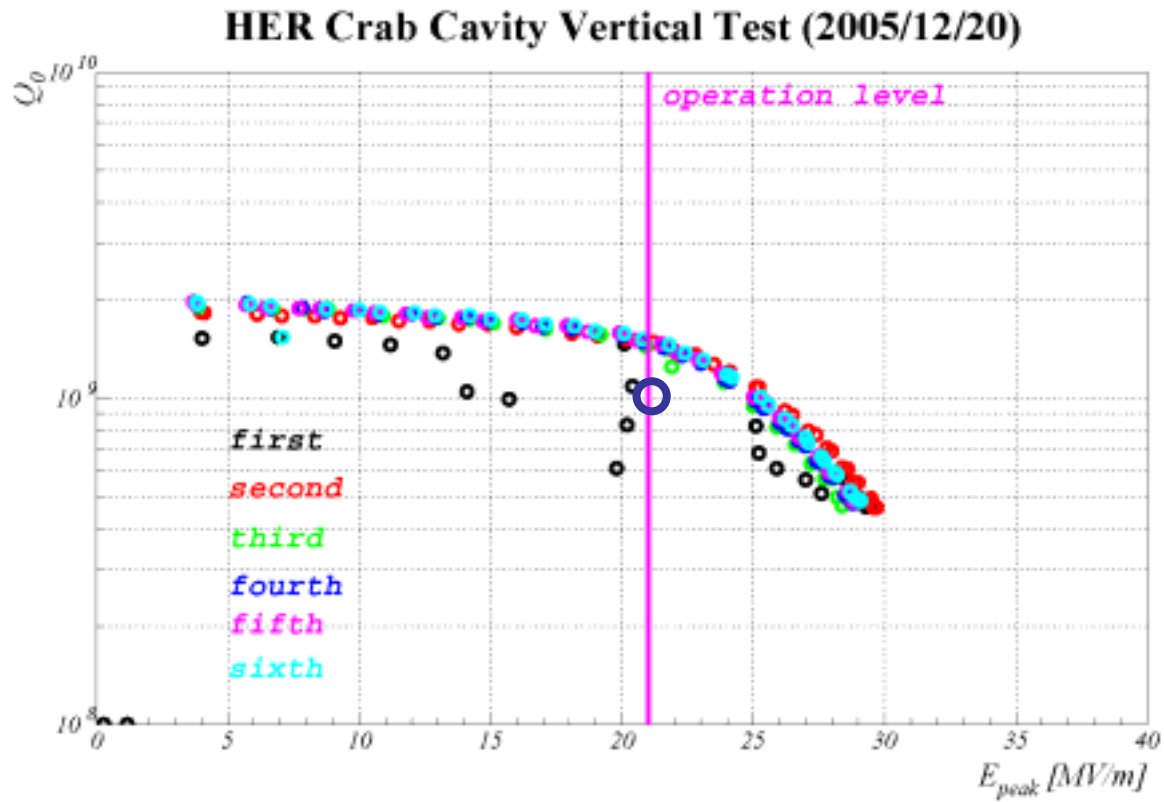
Set Flanges of Beam Pipes and Ports
in Class 100 Clean Room



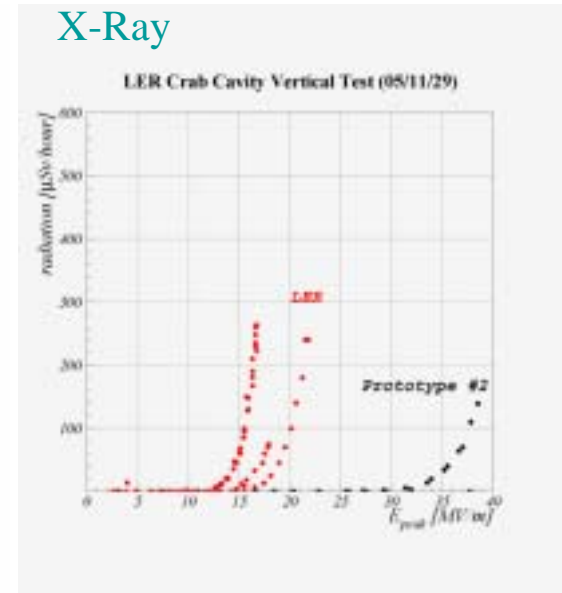
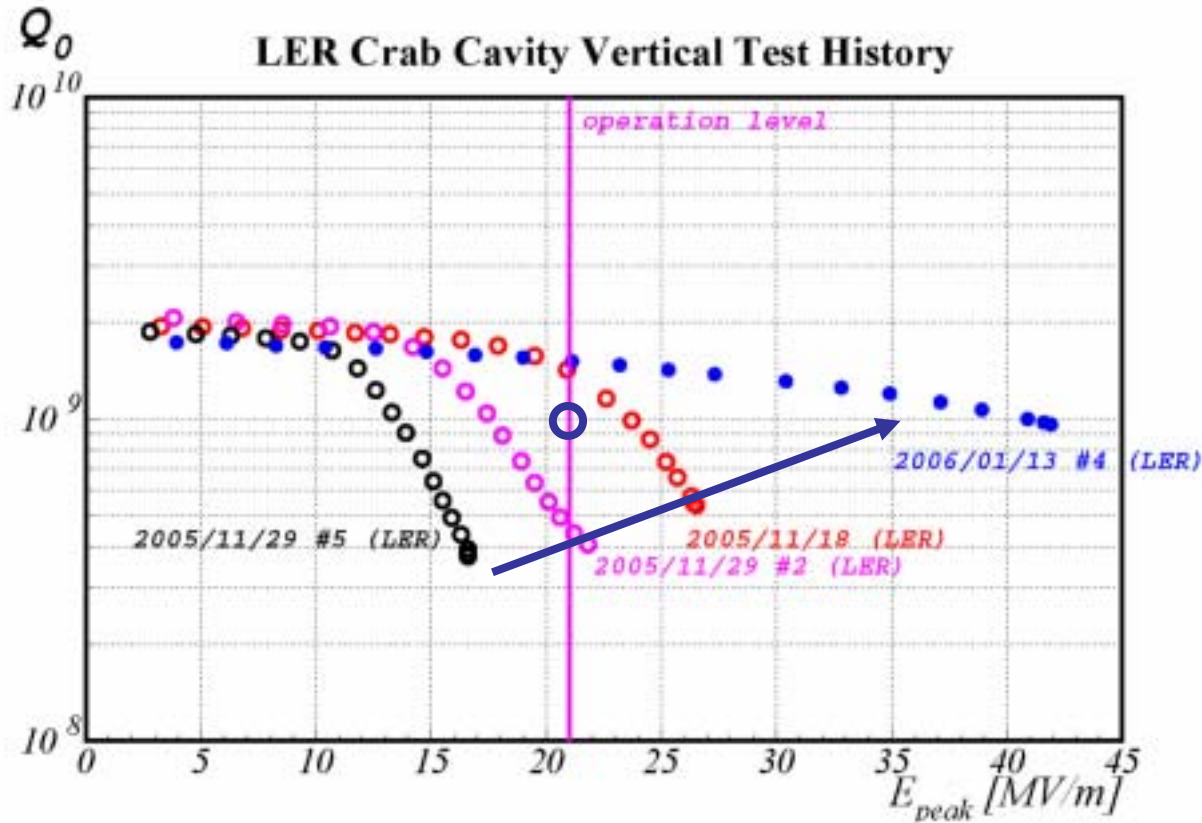
High Pressure Water Rinsing
by 80 bar Ultra-Pure water

Rotation & Up-Down Motion

Test Result Crab Cavity for HER



Test Result Crab Cavity for LER



Nov. 18 1st Test

↓
H.P.R.

Nov. 29 2nd Test

Re-processing

Field Emission

EP2

Jan. 13 Test

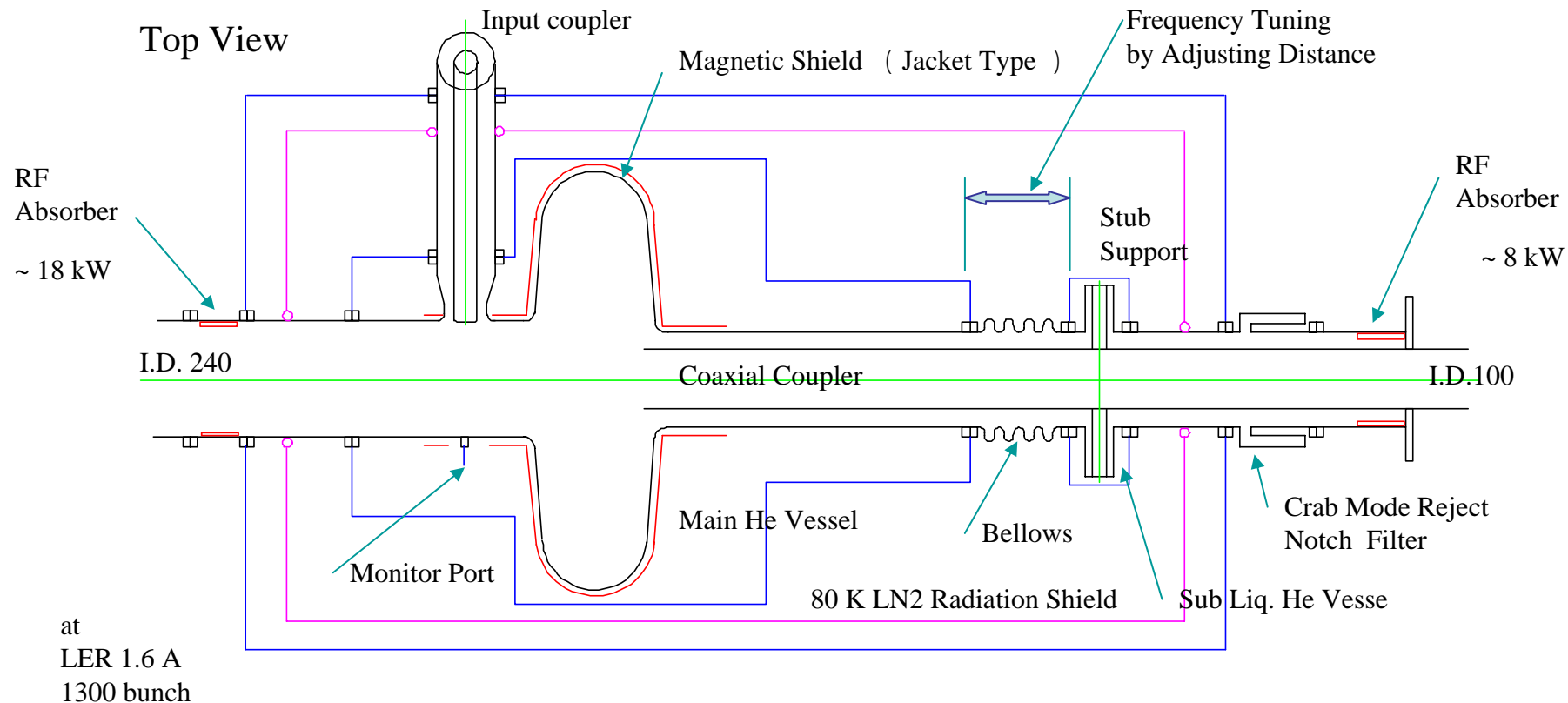
Recovered !

Cryostat for Crab Cavity

- Jacket type helium vessel is adopted for the cryostat design of KEK crab cavity.
- Nb-coaxial coupler is inserted in the cell of part of crab cavity to extract a LOM and HOMs, and to adjust frequency, i.e. as for frequency tuner.
- Assembling the coaxial coupler to the cryostat was very “tough job”. We could not connect the bayonet type joint of coaxial coupler. We could assemble it by using improved Insertion tool.
- RF contact of the connection parts were improved.



Conceptual Design of Cryostat for KEKB Crab Cavity



Jacket-type Helium Vessel

Coaxial Coupler Frequency Tuning

Stub-Support -- Mechanical Support & Cooling of Coaxial Coupler

Jacket-type Helium Vessel

Jacket Type Helium Vessel

Prototype



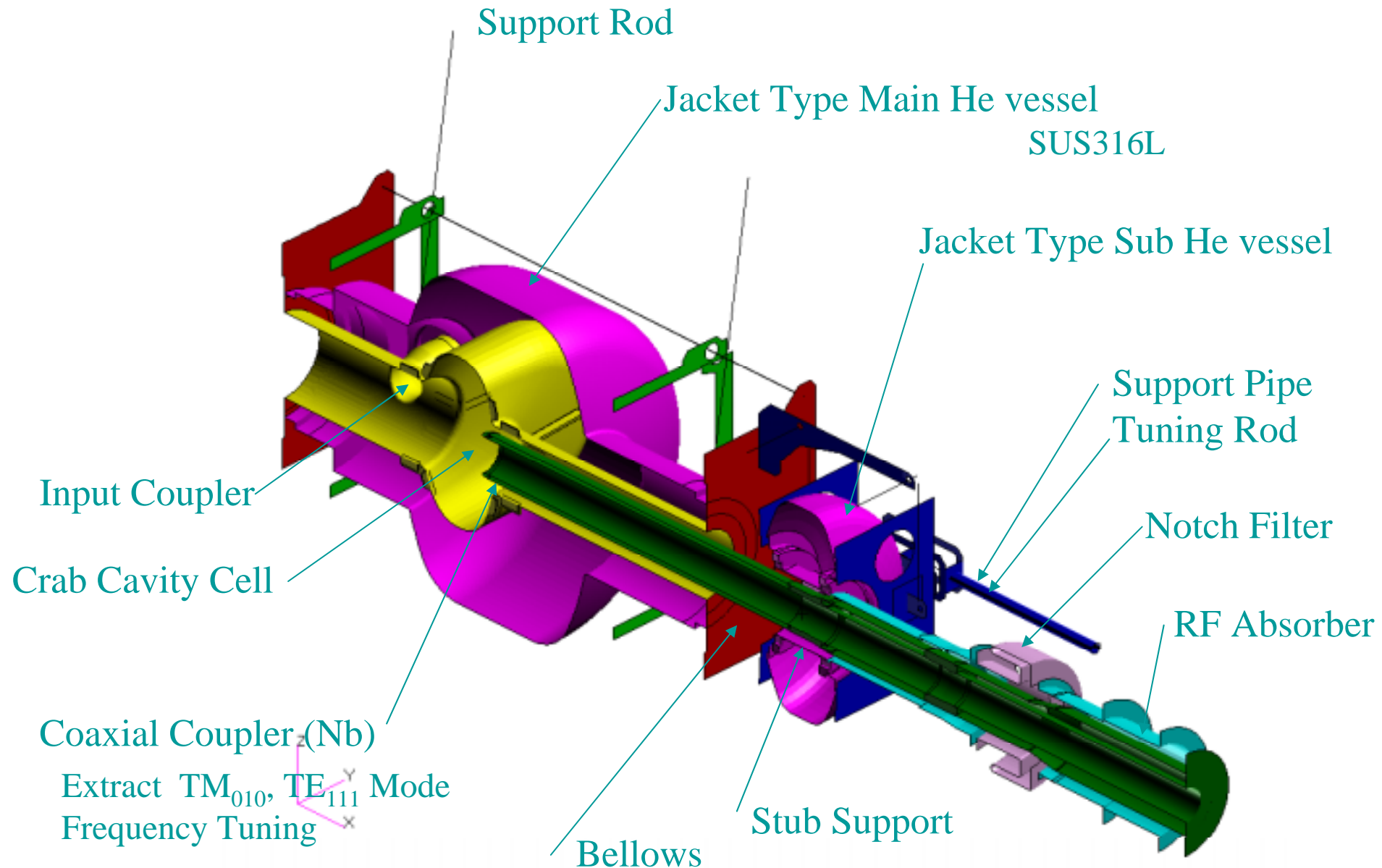
Jacket Type Helium Vessel

Jacket Type Magnetic Shield

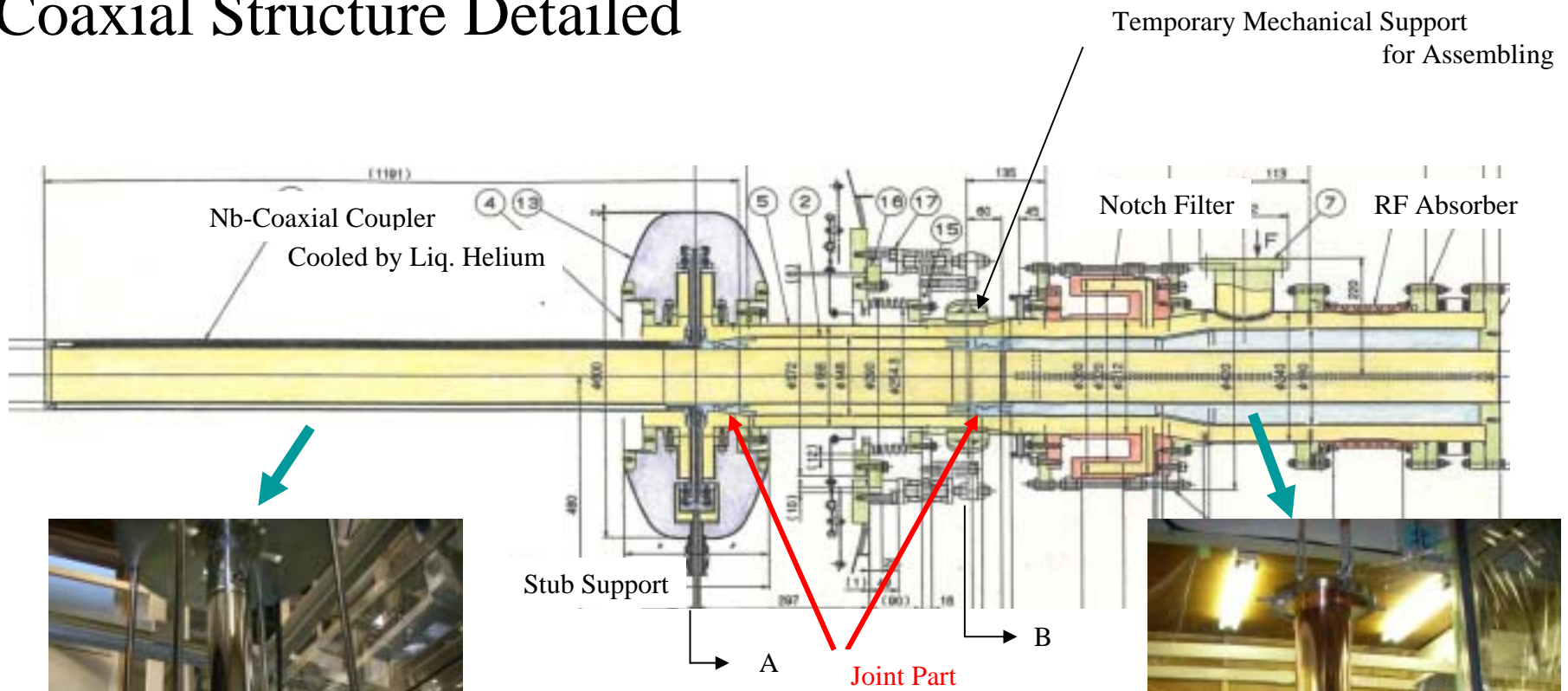
Permalloy 3t



Crab Cavity & Coaxial Coupler in Cryo-module



Coaxial Structure Detailed



Nb-Coaxial Coupler
Cooled by Liq. Helium

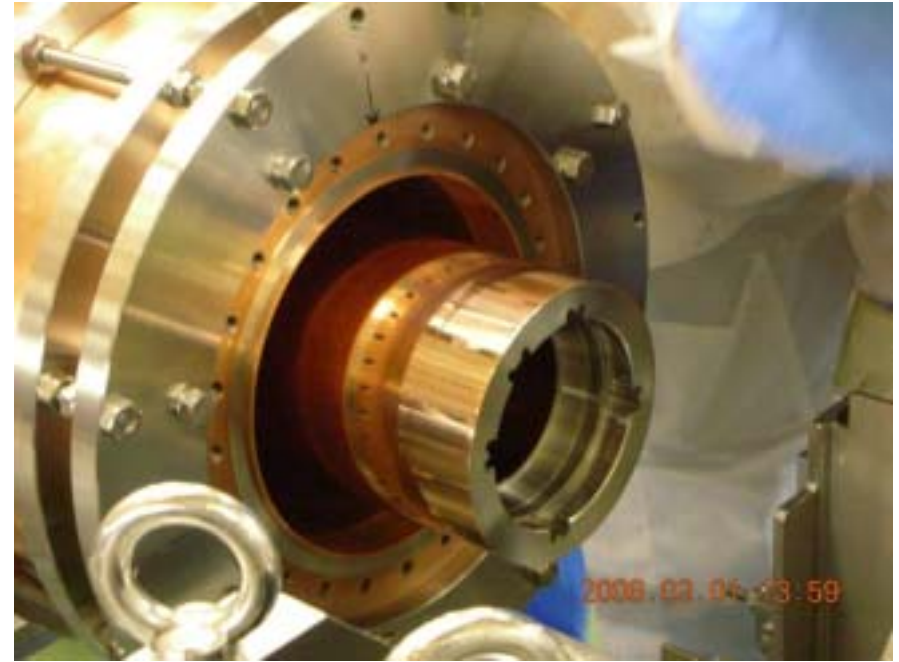


Copper Plating SUS Inner Conductor
Cooled by Water

Assembling of Coaxial Coupler



Crab Cavity (Cryostat) Side



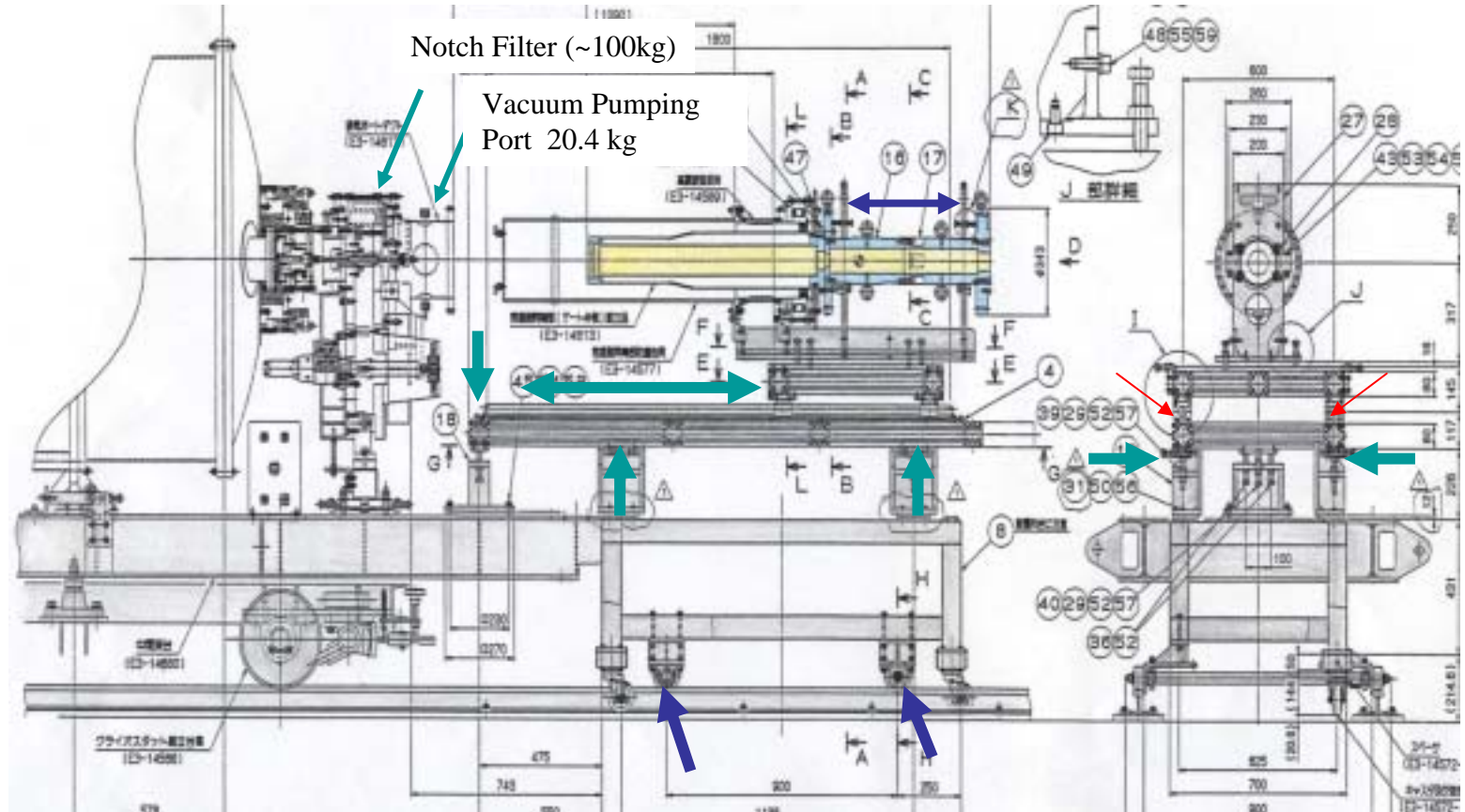
Notch Filter Side

Bayonet Type Connection

Step 1 Insert

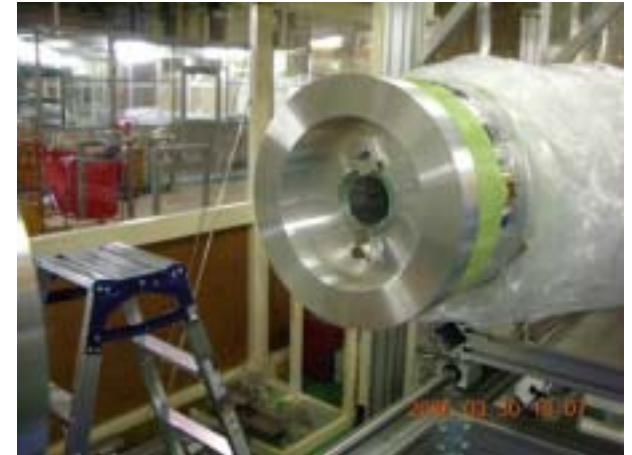
Step 2 Rotate Clockwise 30 degree

New Insertion Setup



- 1) Rigid structure
- 2) Easy to adjust position and axis direction

Alignment of Coaxial Coupler



Decide the axis of the coaxial coupler set in the cryostat by using transit.

Align the axis of the coaxial coupler which will be connected to the coaxial coupler of cryostat side.

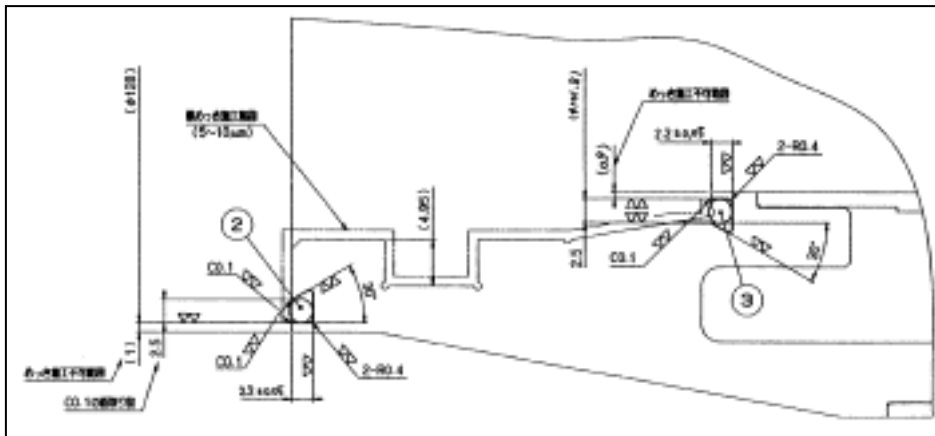
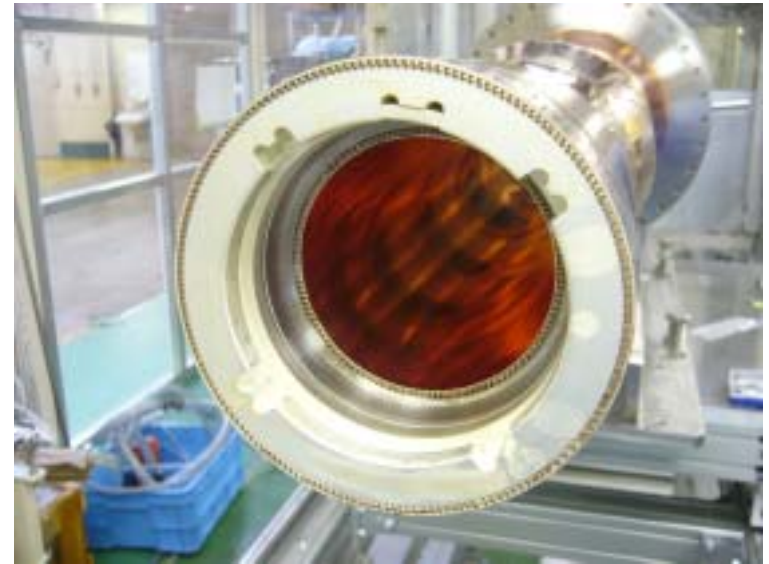


RF Contact

Type: Spiral

Material: BeCu

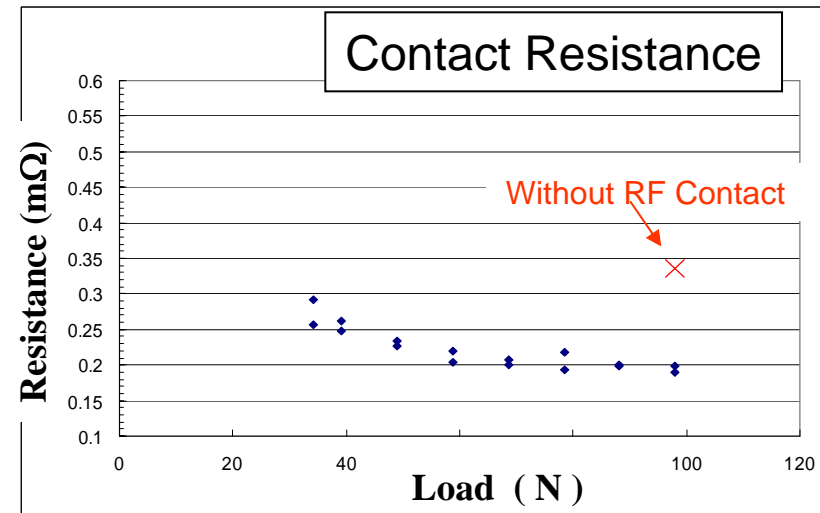
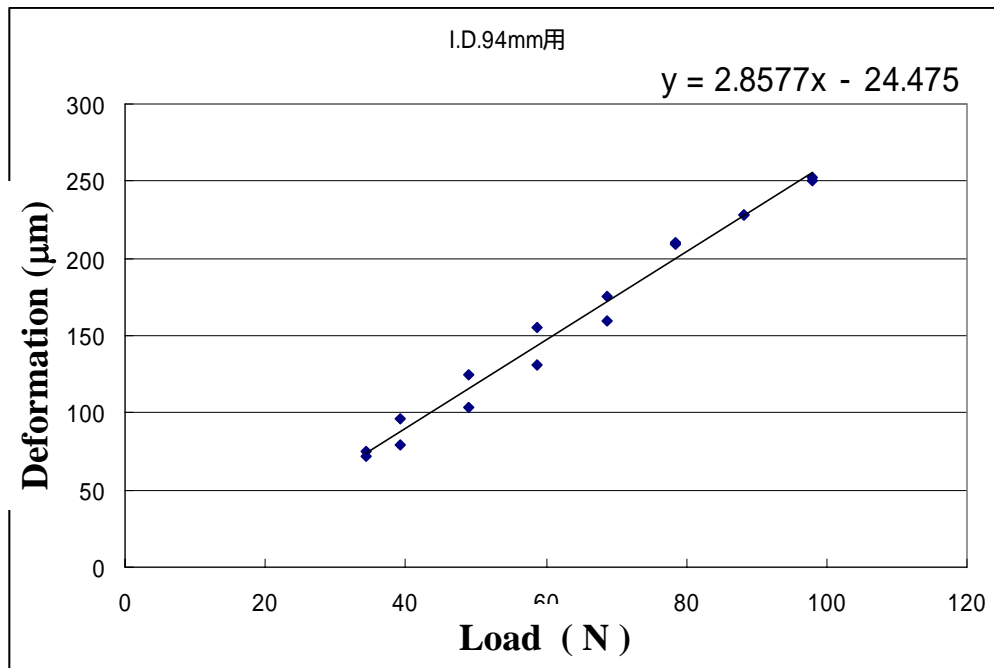
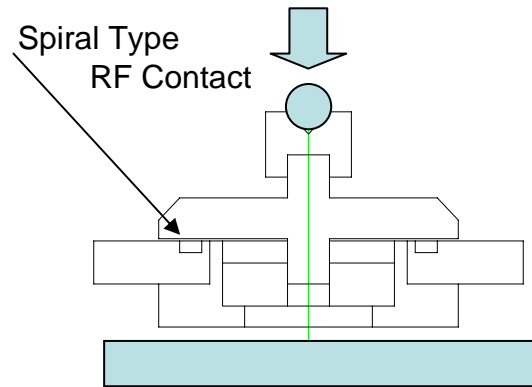
Spring Constant: 14kg/ 94mm (0.5kg/cm)



Mechanical & Electrical Properties of RF Contact



July 14, 2006



Cool-down and High Power Test at D10 Test Stand

- Crab cavity for HER and LER were cool down without leakage.
- Resonant frequency could adjust to operating frequency of 508.9MHz.
- $V_{\text{kick}} = 1.8 \text{ MV}$ and 1.93 MV respectively,
exceed the design value of 1.44 MV.
- Q_0 – values at design kick voltage were higher than 1×10^9 .
- Cavity and coaxial coupler was cooled stably during the high power test.
Cryogenic system worked very well.
- Frequency tuner of crab cavity HER work very well.
Phase stability of crab cavity HER is good.
- Phase stability of crab cavity LER is no good!

Move to Test Stand for Cool-down & High Power Test

April 26, 2006 1st

Oct. 16, 2006 2nd

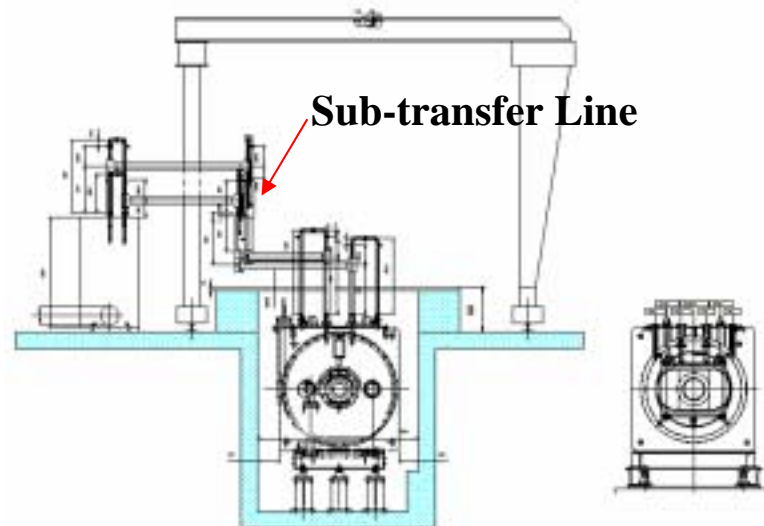
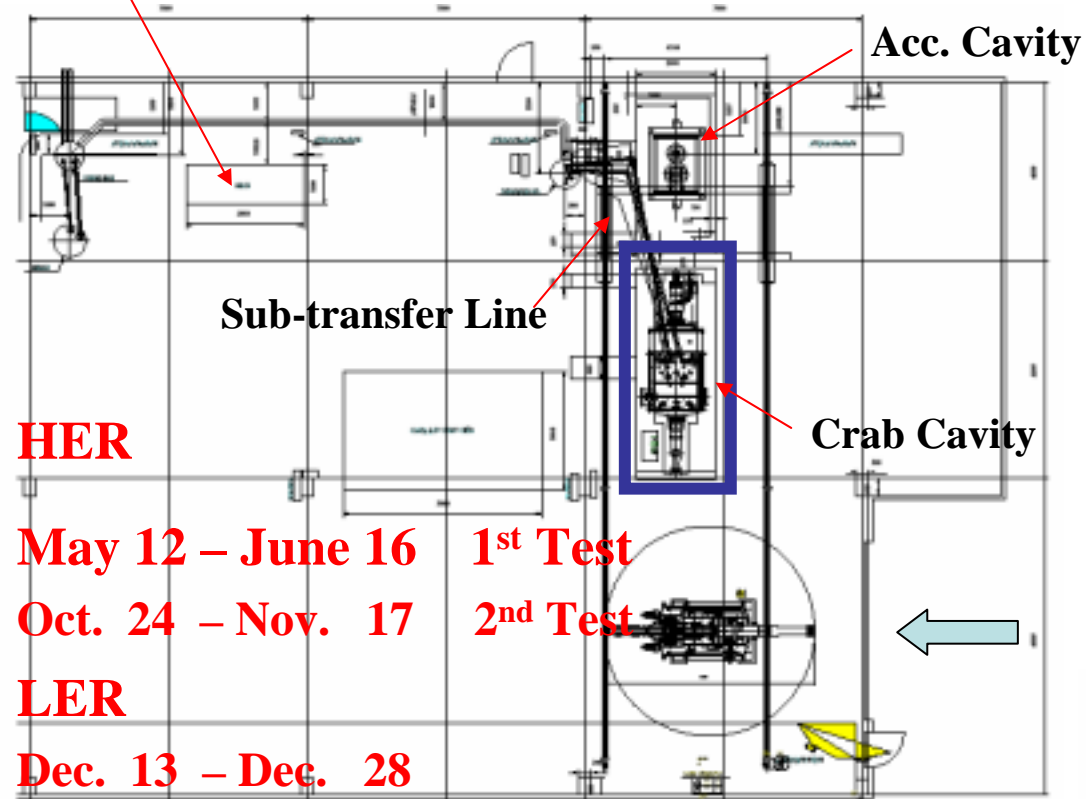
Mt. Tsukuba



Dec. 6, 2006

Test Stand for Crab Cavity at D10 Station

Control System for RF Test

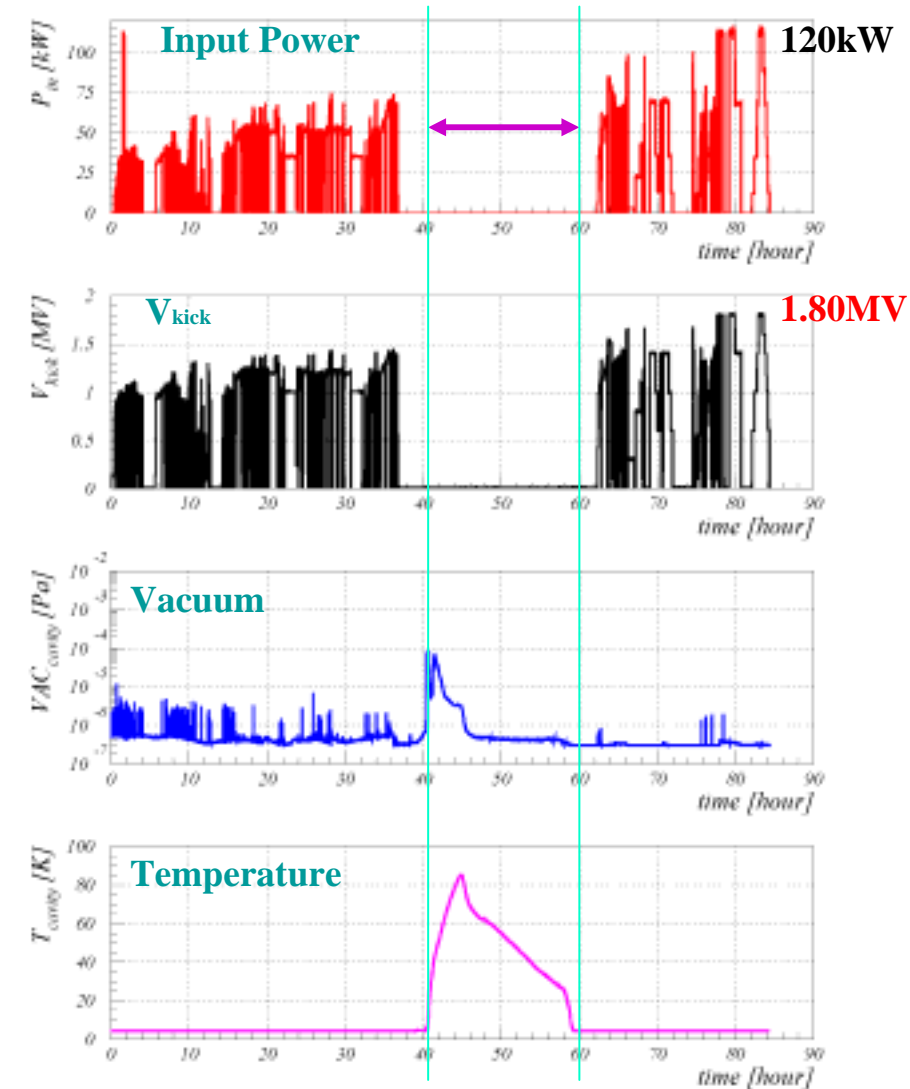


High Power Test

High Power Test for Crab Cavity HER & LER

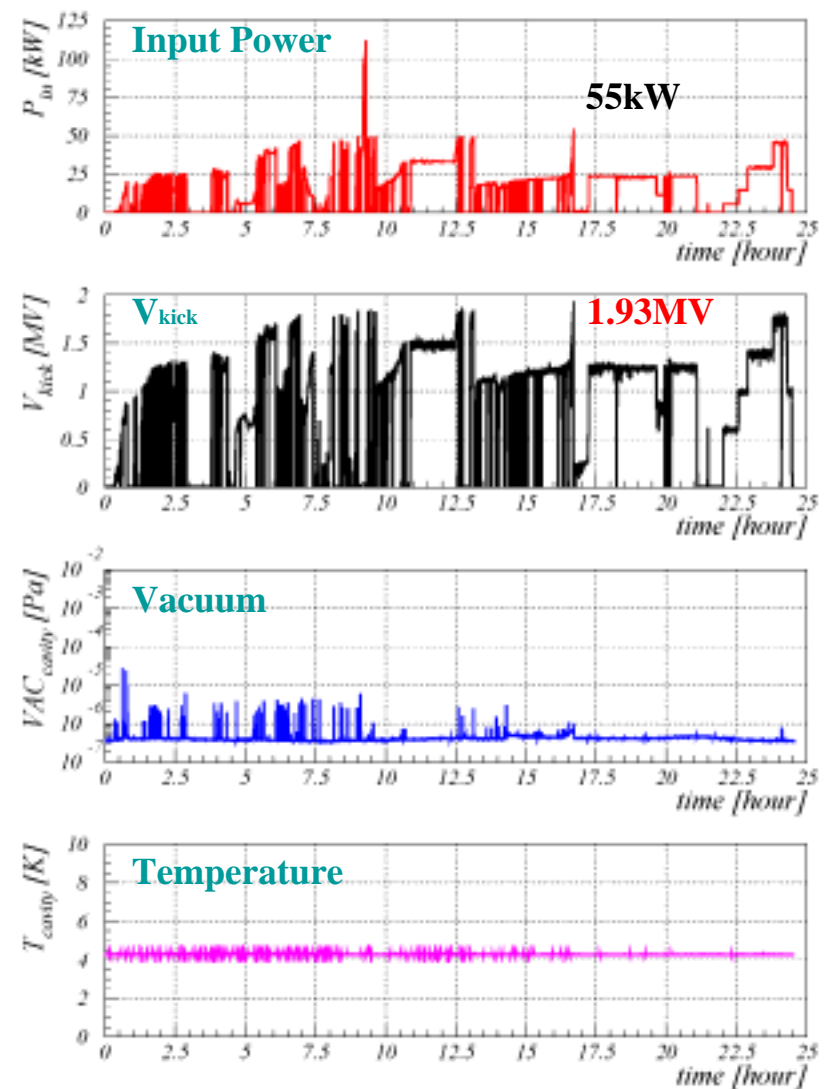
Crab Cavity HER

Second Horizontal Test for HER Crab Cavity at 4K



Crab Cavity LER

First Horizontal Test for LER Crab Cavity at 4K



Frequency Tuning

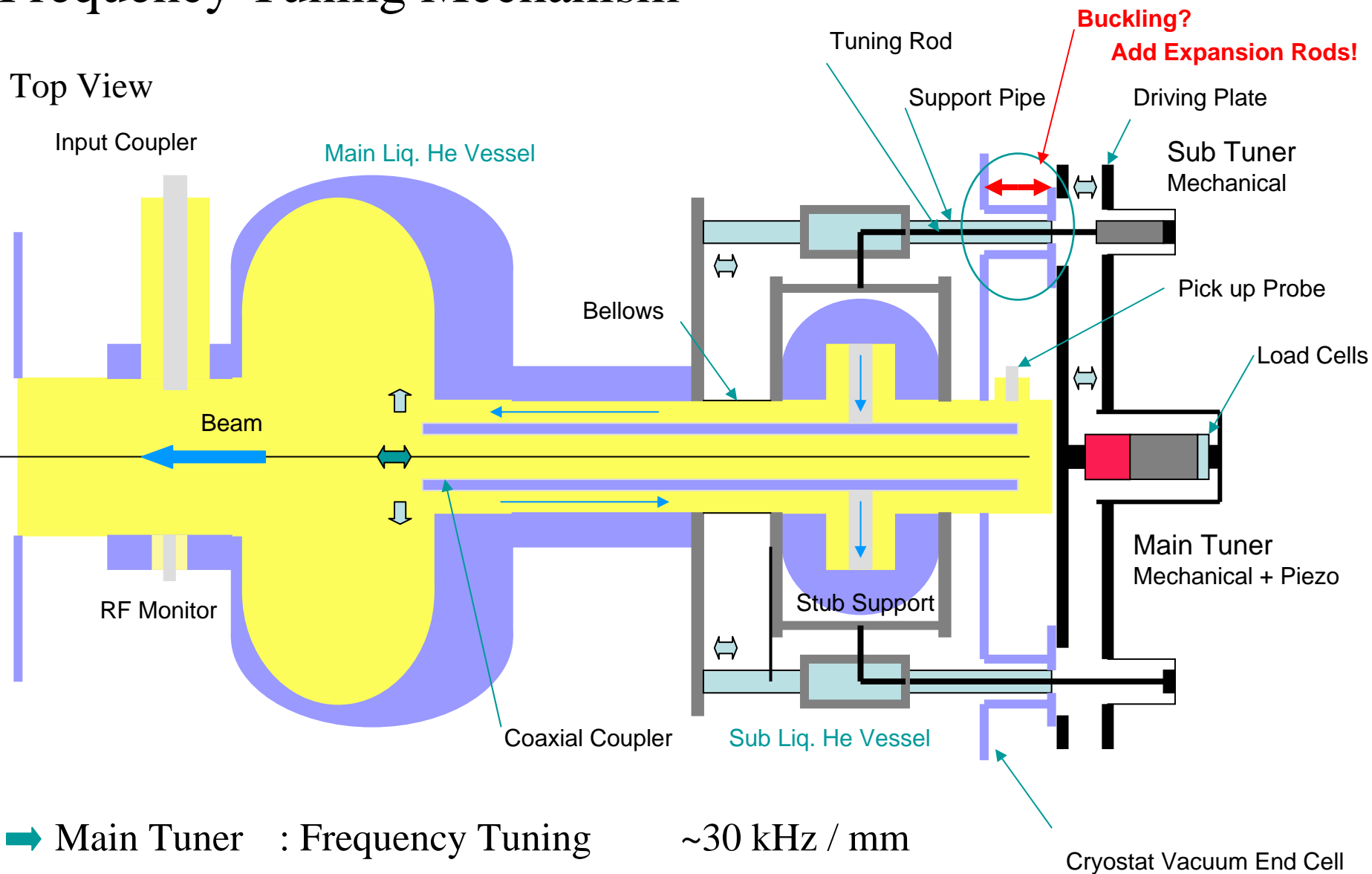
- Resonance frequency of the cavity can be changed by
 - 1) deforming the cavity cell shape for pre-tuning, and
 - 2) changing insertion depth of coaxial coupler for tuning.
- The insertion depth can be changed by two tuning rods in parallel.

These rods are driven by “main tuner”.
- Head position of coaxial coupler can be changed by “sub tuner”.

The sub tuner drives one tuning rod and shakes the head of coaxial coupler in horizontal direction.
- Tuning mechanism described above work very well for crab cavity HER
but, not good for crab cavity LER.
- We tried
 - 1) reinforcement of the mechanical structure, and
 - 2) improve the sliding mechanism to reduce friction, but not effective.
- We are now planning to reinforcement of “support bolts”.

Frequency Tuning Mechanism

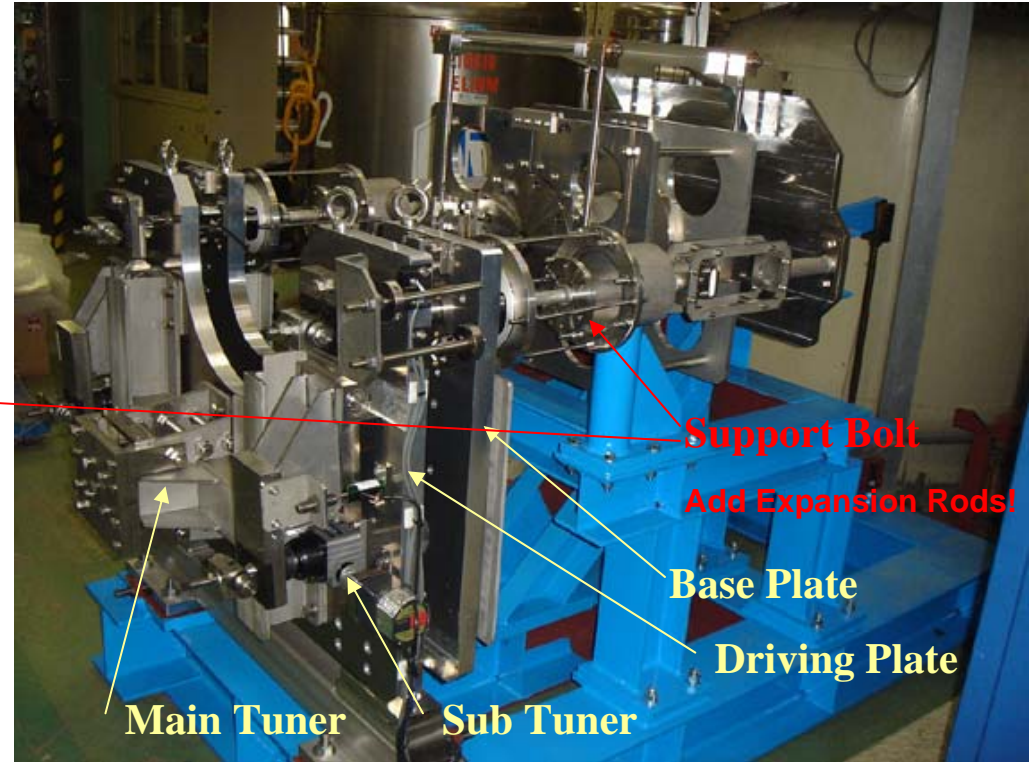
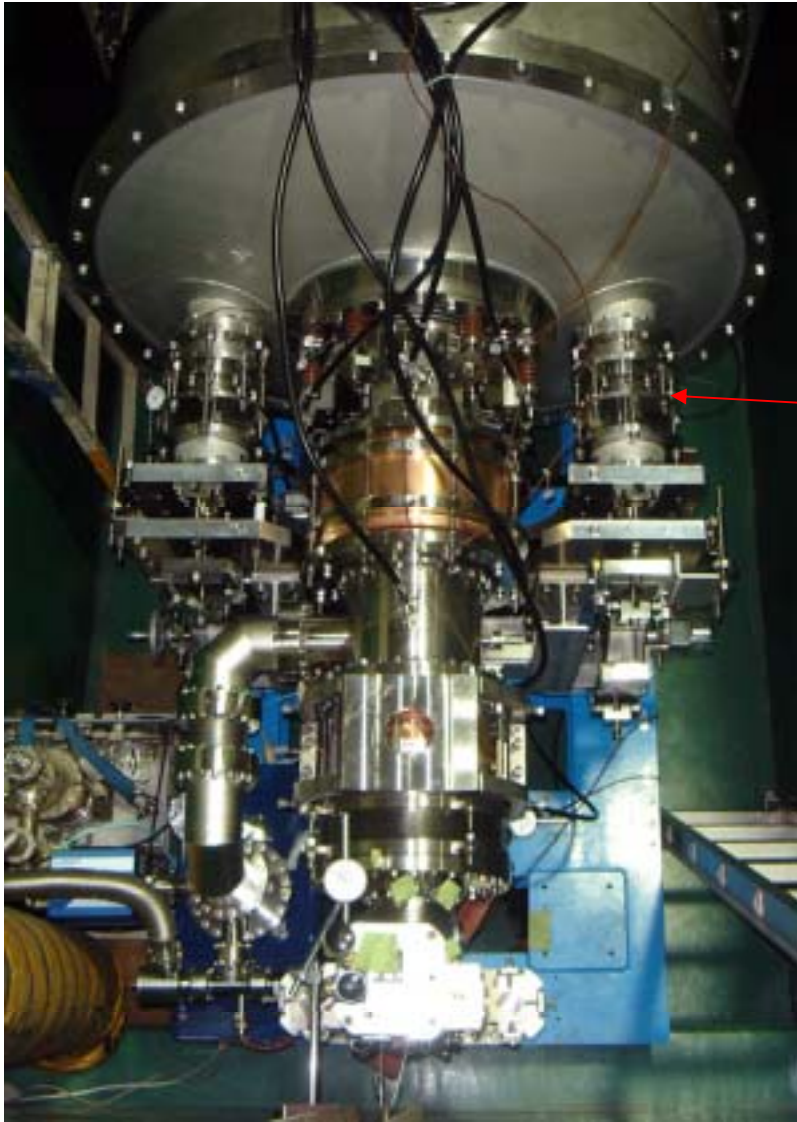
Top View



➡ Main Tuner : Frequency Tuning $\sim 30 \text{ kHz} / \text{mm}$

⇔ Sub Tuner : Adjust Position of Coaxial Coupler

Frequency Tuner

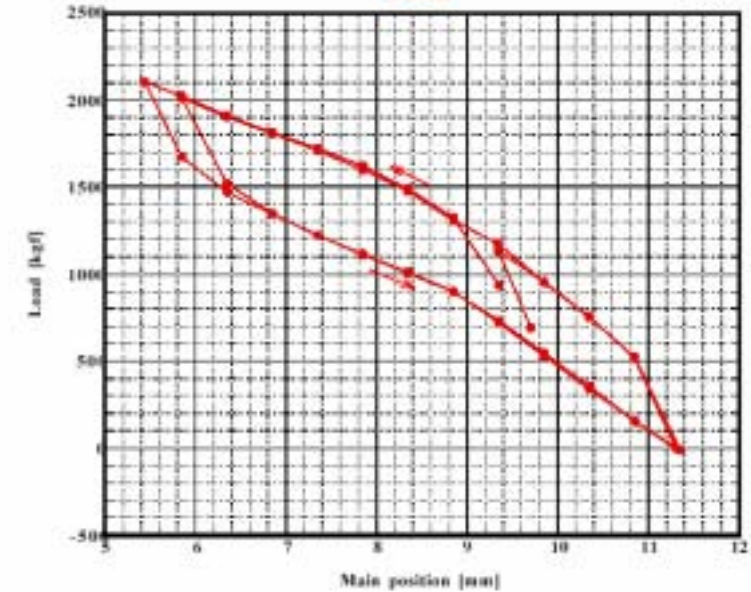
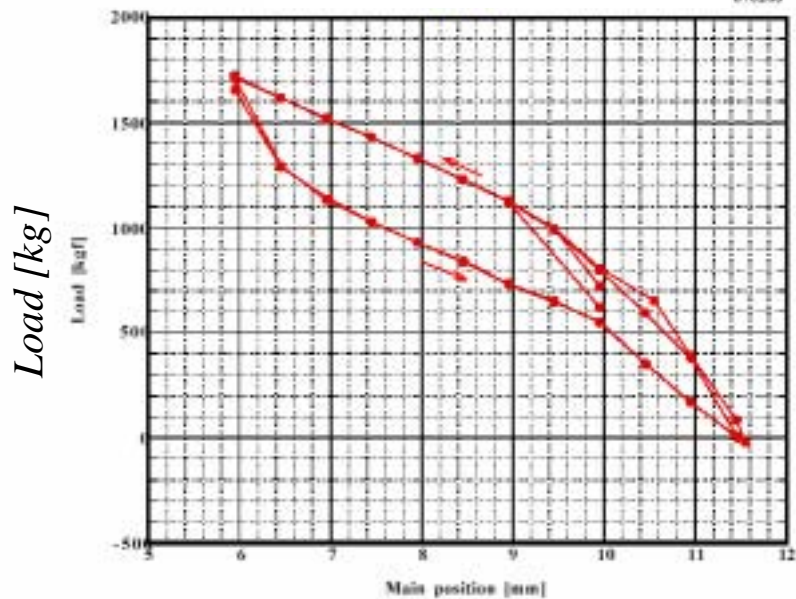
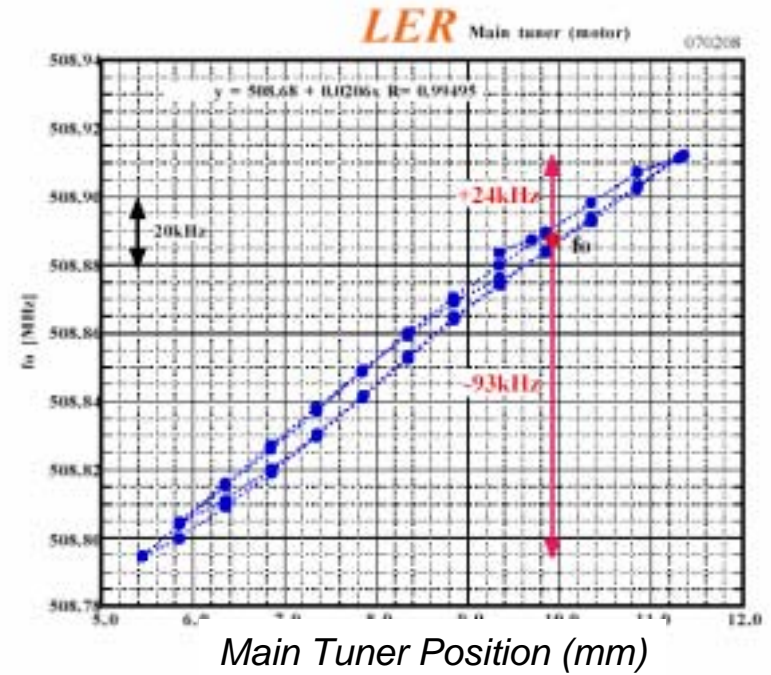
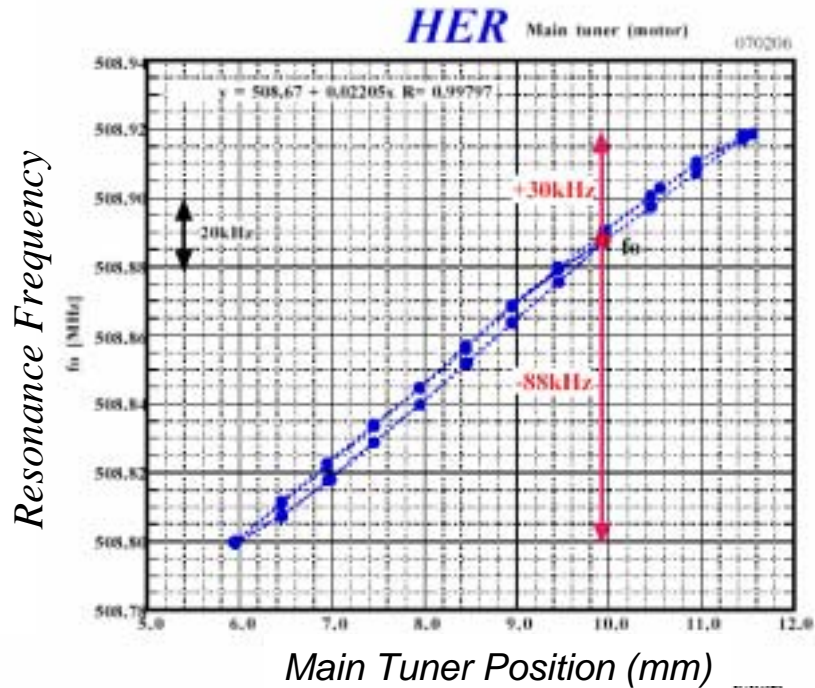


Test Stand for Frequency Tuner

Frequency Tuner Crab Cavity for HER

Frequency Tuning by Main Tuner

by A. Kabe

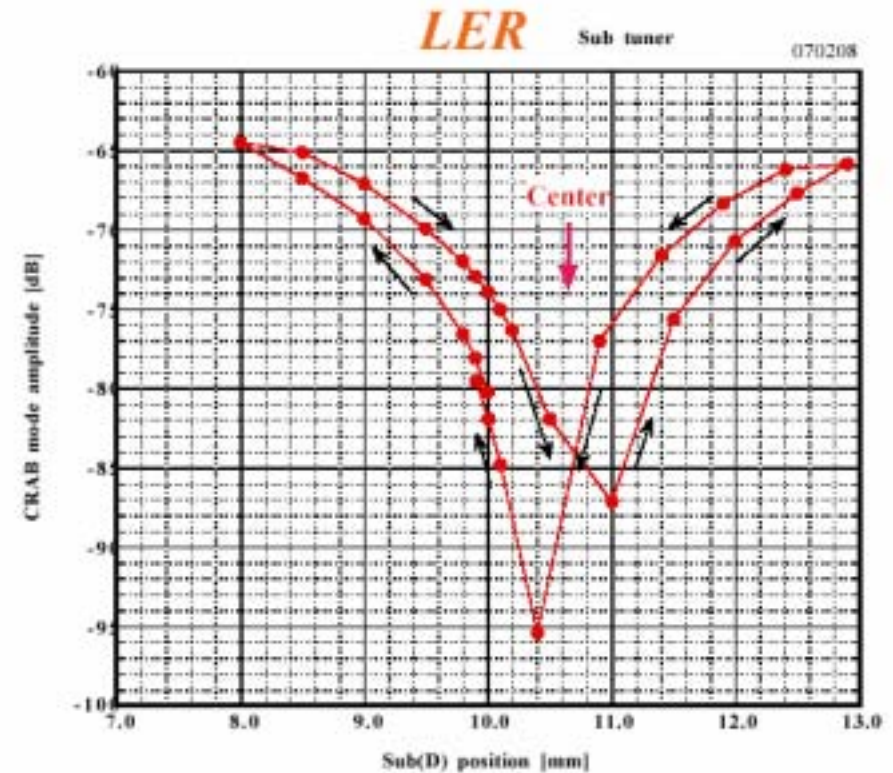
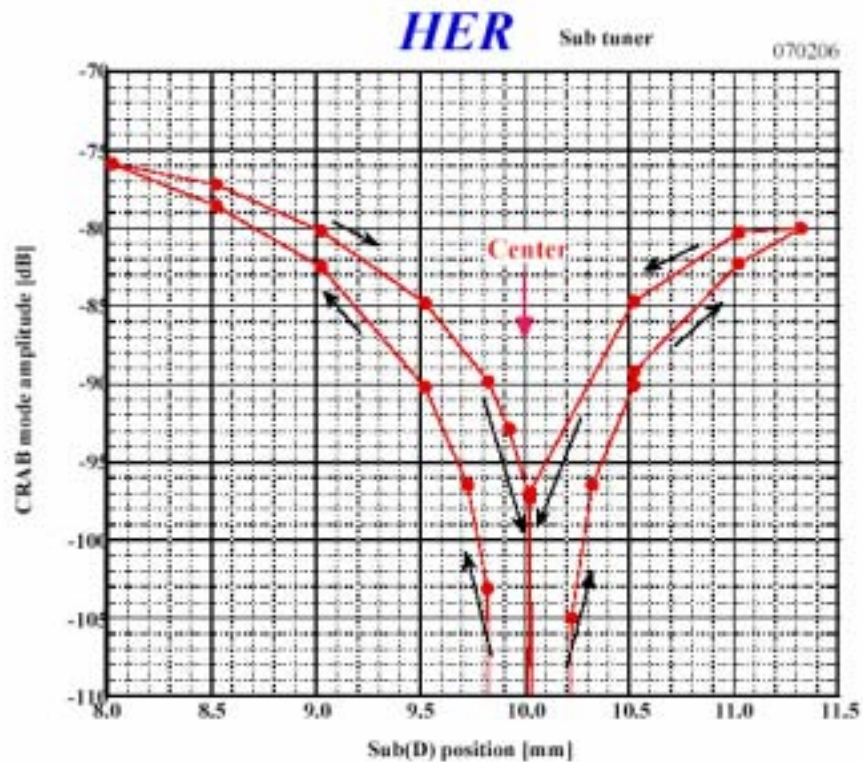


Adjustment of Coaxial Coupler Position by Sub Tuner

by A. Kabe

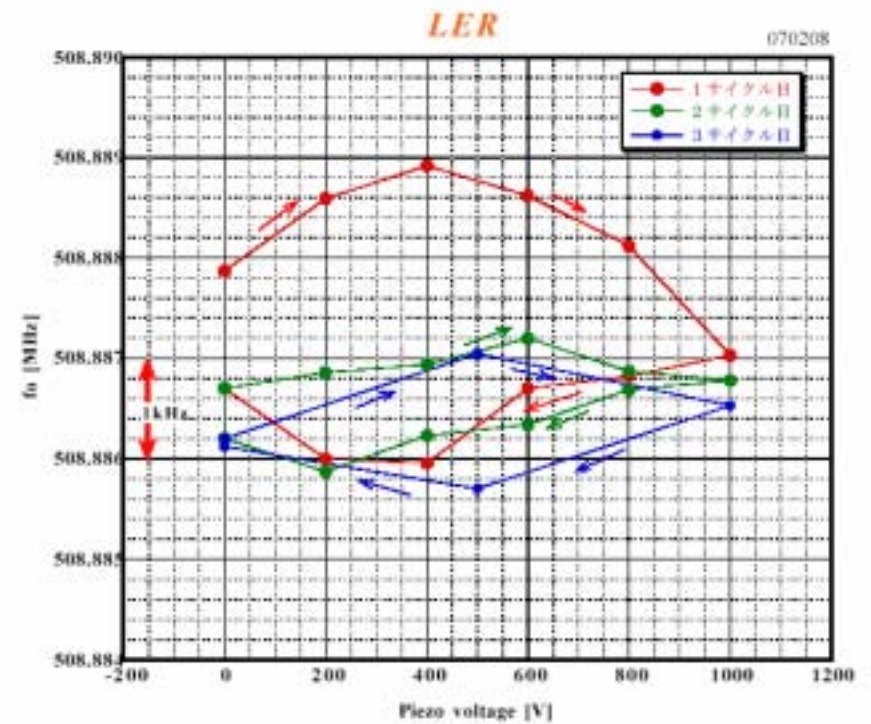
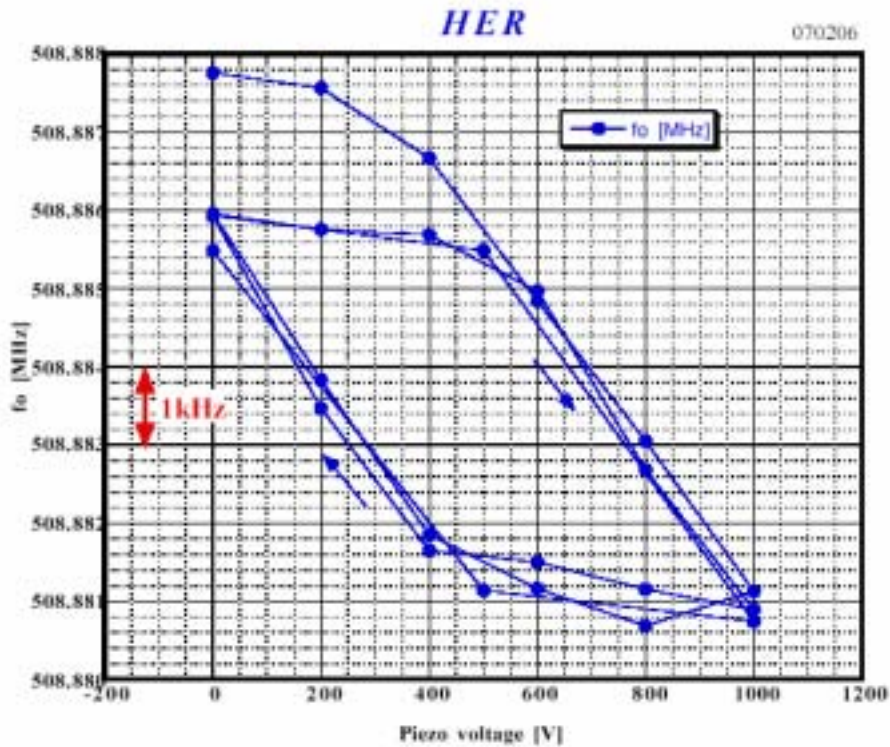
By adjusting coaxial coupler on the axis of crab cavity,
the crab mode can be prevented going out.

The coupler position can be controlled by sub-tuner.



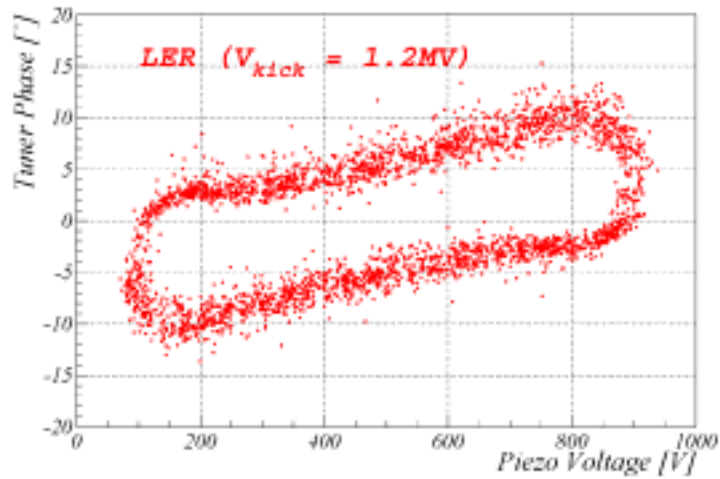
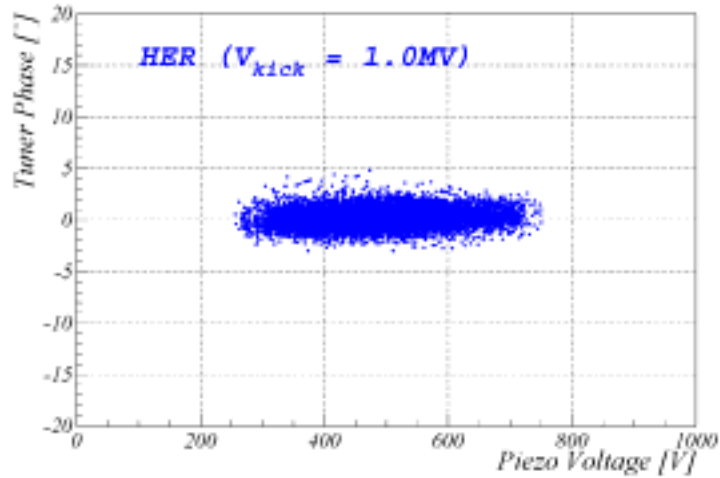
Frequency Tuning by Piezo Tuner

by A. Kabe

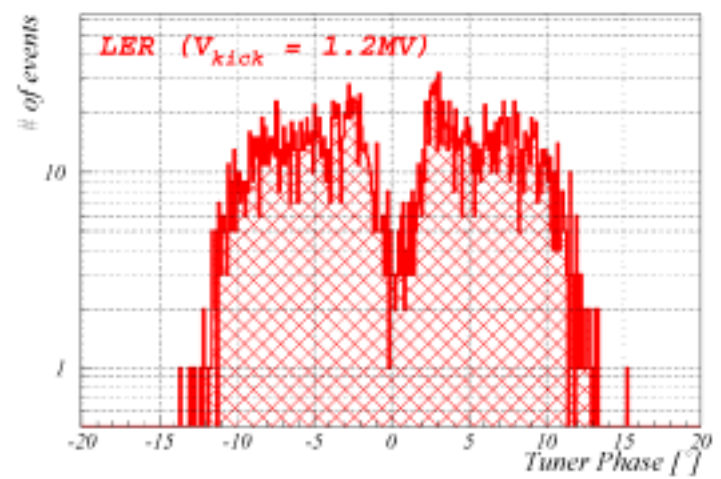
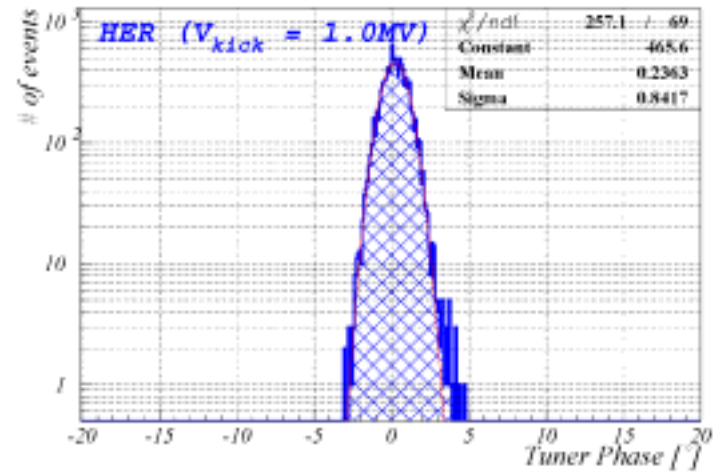


Phase Stability

Comparison of Tuner Performance between HER and LER Crab Cavity

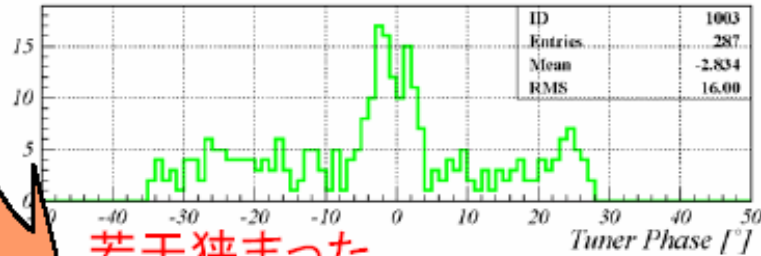
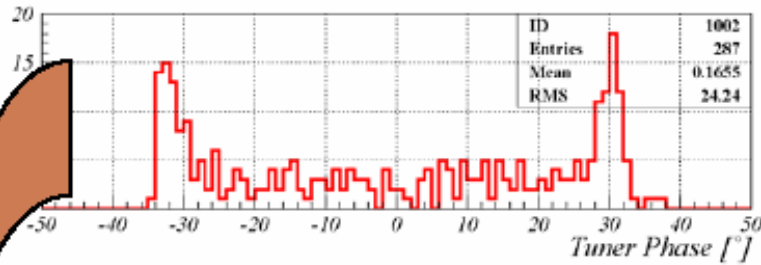
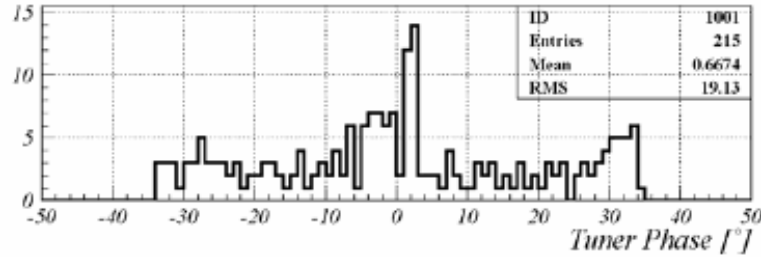


Comparison of Tuner Performance between HER and LER Crab Cavity

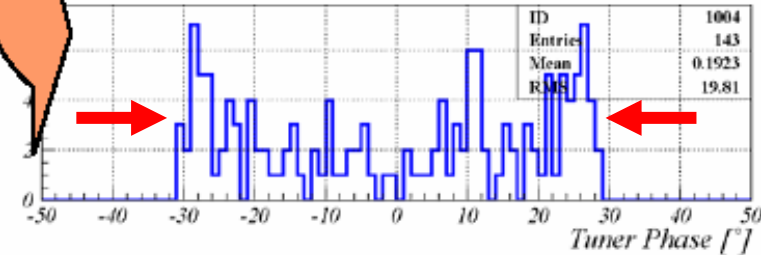


Improvement of phase stability by expansion rods

Commissioning for LER Crab Cavity ('07/2/13)

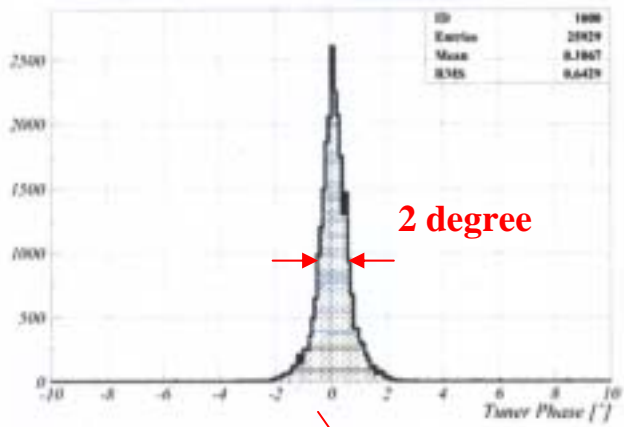


若干狭まった

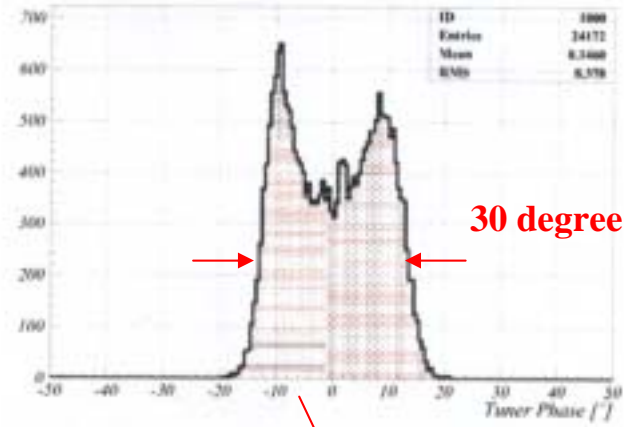


Phase stability could be improved by RF feed back system

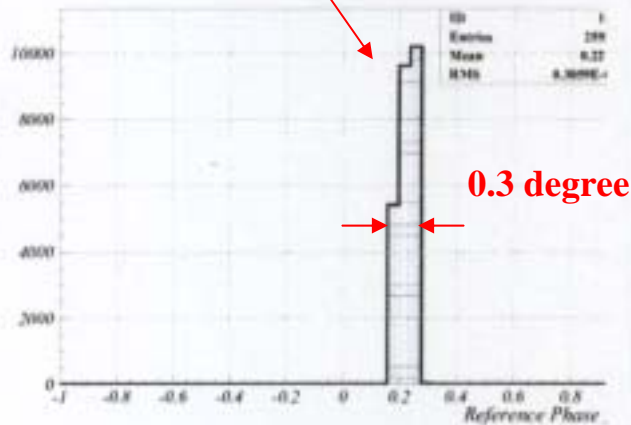
Commissioning for HER Crab Cavity ('07/2/19)



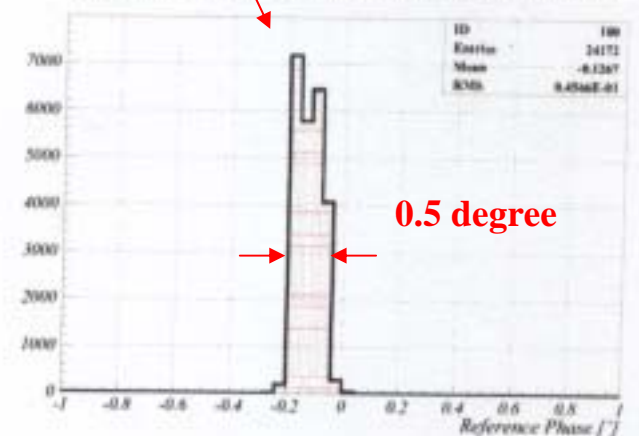
Commissioning for LER Crab Cavity ('07/2/19)



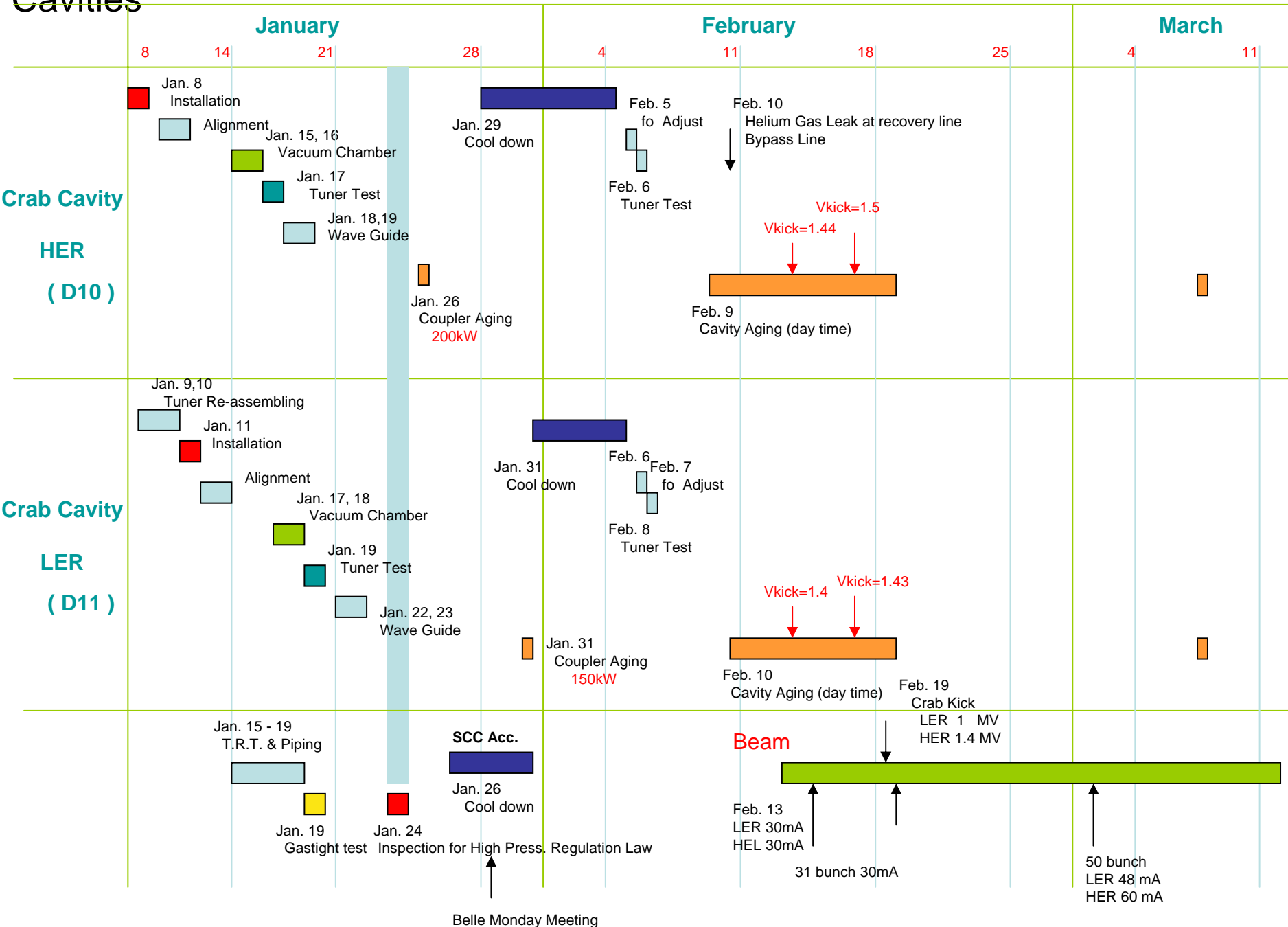
Commissioning for HER Crab Cavity ('07/2/15)



Commissioning for LER Crab Cavity ('07/2/19)



Installation & Commissioning Schedule for Crab Cavities



Commissioning of Crab Cavities for KEKB

- Crab cavity for HER and LER were installed in KEKB ring and cool down successfully.
- Resonant frequency could adjust to operating frequency of 508.9MHz.
- Kick voltage of crab cavity HER and LER reached
 $V_{\text{kick}} = 1.6 \text{ MV}$ and 1.5 MV respectively,
exceed the design value of 1.44 MV.
- RF phase tuner of crab cavity LER did not work well.
But by using the RF feed back system, we could control within the design value.
- Crab kick was confirmed by streak camera.
- Crab crossing has started!

Troubles:

- Cold helium gas leak at connection part of recovery pipe.
Tighten the connector and set a heater at connection part.
- Lack of cooling power at coaxial coupler.
Add bypass line to increase the gas flow.
- Frequent break down by vacuum burst at input coupler of crab cavity for LER.
 Need warm up ???

Cooling He Gas & Cooling Water

