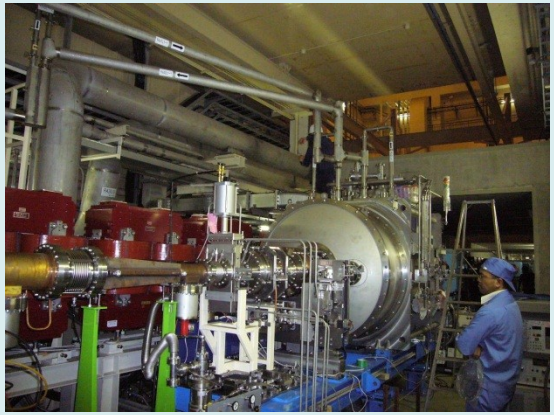
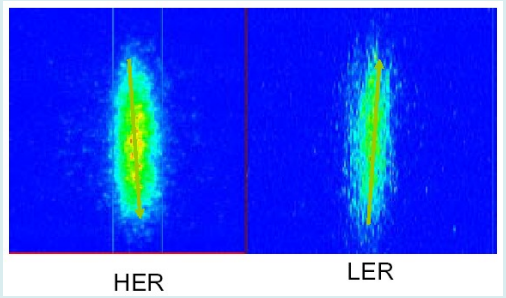
KEKB Crab Development

K. Hosoyama (KEK)



Crab Cavity for HER

Crab Cavity for KEKB
History of Crab Cavity R&D
Characteristics of Crab Cavty
Cryostat for Crab Cavity
Frequency Tuner
High Power Test at D10 Test Stand
Commissioning of Crab Cavities for KEKB
Summary



Crab Cavity for LER

Crab Cavities for KEKB

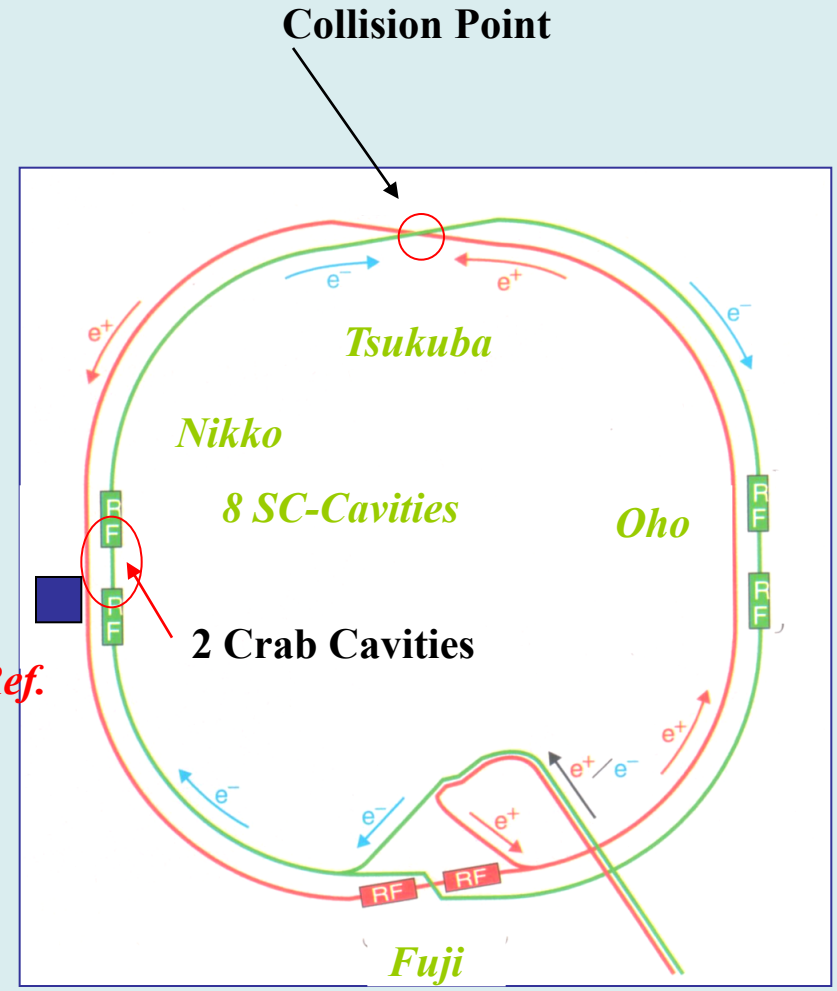
KEKB	
LER	*3.5 GeV*
HER	*8.0 GeV*
RF freq.	*508.9 MHz*
Cross. Ang.	*2 x 11 m rad.*

2 Crab Cavities at "Nikko"

Beam-bunch wiggle around the whole ring!

Helium Ref.

Advantage:
We can use existing cryogenic system
for Acc. S.C. cavities



Milestone of KEKB Crab Cavity Development

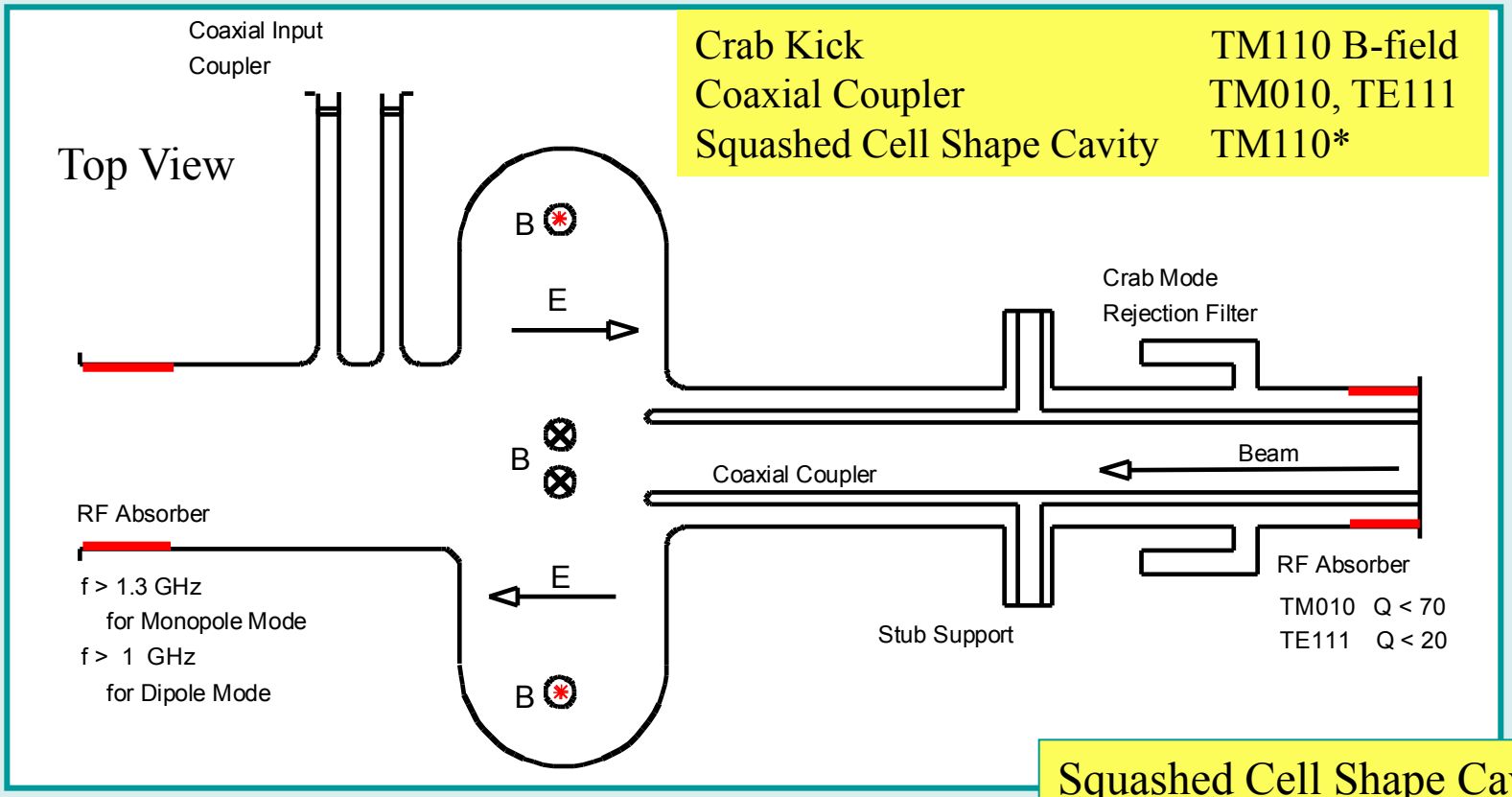
0) 1/3 scale 1.5 GHz model 1994

1) Full Scale 500MHz Prototype Crab Cavity 1996
   2 Nb Cavities # 1 & # 2
   Coaxial Coupler 2003
   Prototype Horizontal Cryostat
   (# 2 was Installed
   into Prototype Horizontal Cryostat for Cool down Test)

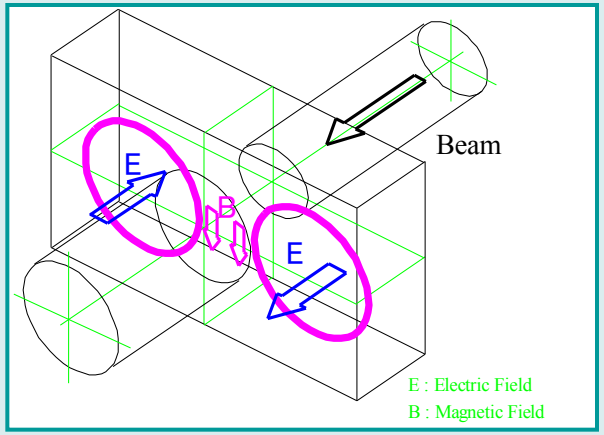
Installation of 2 crab cavities in KEKB was decided

2) KEKB Crab Cavity 509MHz 2004
   2 Nb Cavities for LER, HER
   Cold Tested in Vertical Cryostat
   Assembling and High power test 2005
   Installation 2006
   Commissioning and Operation 2007 ~ 2010

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”!

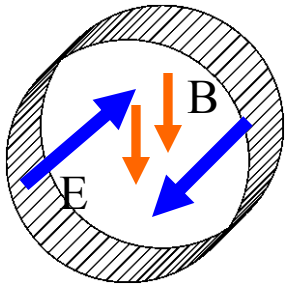
Characteristics of KEKB Crab Cavity

- "Squashed cell shape" design is adopted to push up the unwanted regenerative mode of the TM_{110} crab mode up 700MHz
- Higher Order / the Lowest Mode Damped Cavity;
  - Large beam pipe is designed for Higher Order Mode damping
  - Coaxial coupler is put into the cell through beam pipe for the Lowest TM_{010} acceleration mode damping
  - Coaxial coupler must adjust on axis of crab cavity
  - Head of coaxial coupler must cool to keep superconductive state
  - Notch filter in the coaxial coupler reject outgoing crab mode
  - Big concern for the Multipacting at coaxial coupler
- Non-axial symmetric and large in size cavity design
  - Need care in designing, fabrication and EP of the cavity

Why squashed cell shape cavity?

TM110

500MHz



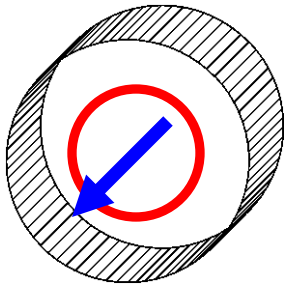
Crab Mode

Unwanted Modes

Degenerative Mode

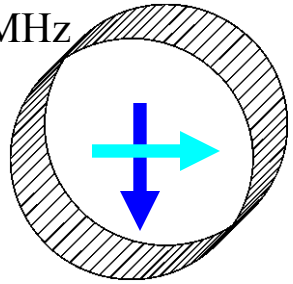
TM010

324MHz



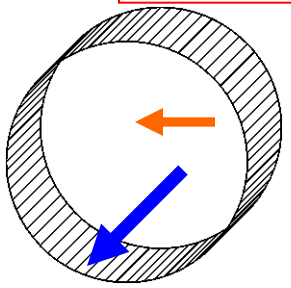
TE111

720MHz



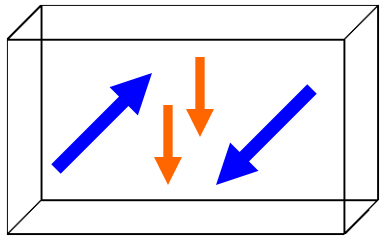
TM110

500MHz



TM110 - like Mode

500MHz

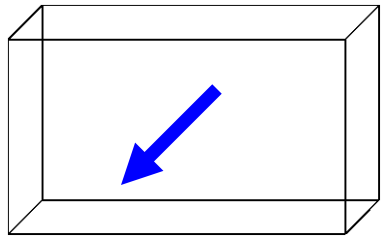


Crab Mode

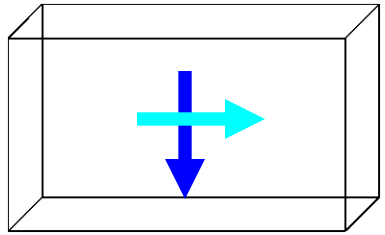
Unwanted Modes

TM010 - like Mode

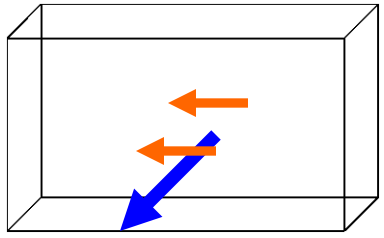
413.3MHz



650.5 MHz / 677.6MHz

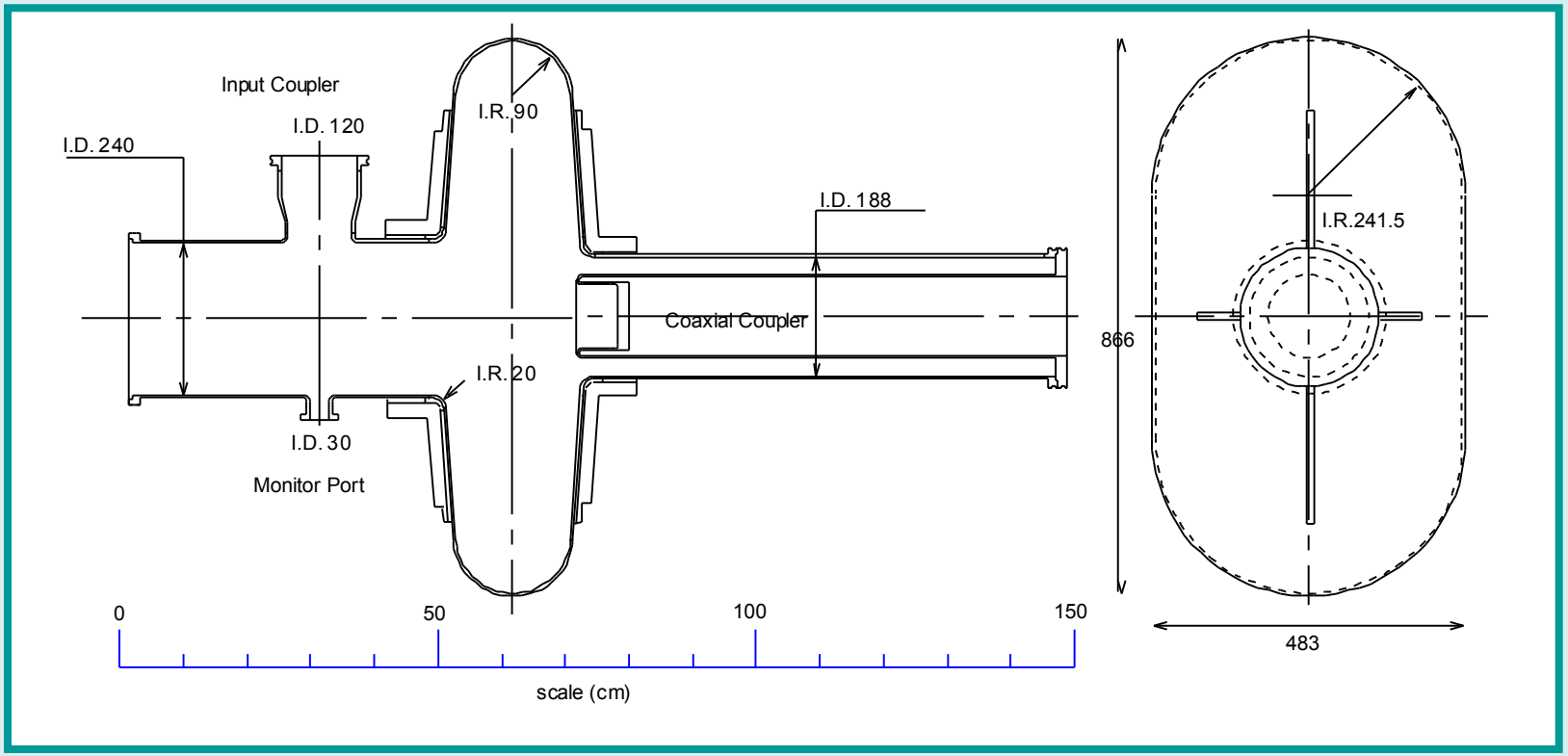


700MHz



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

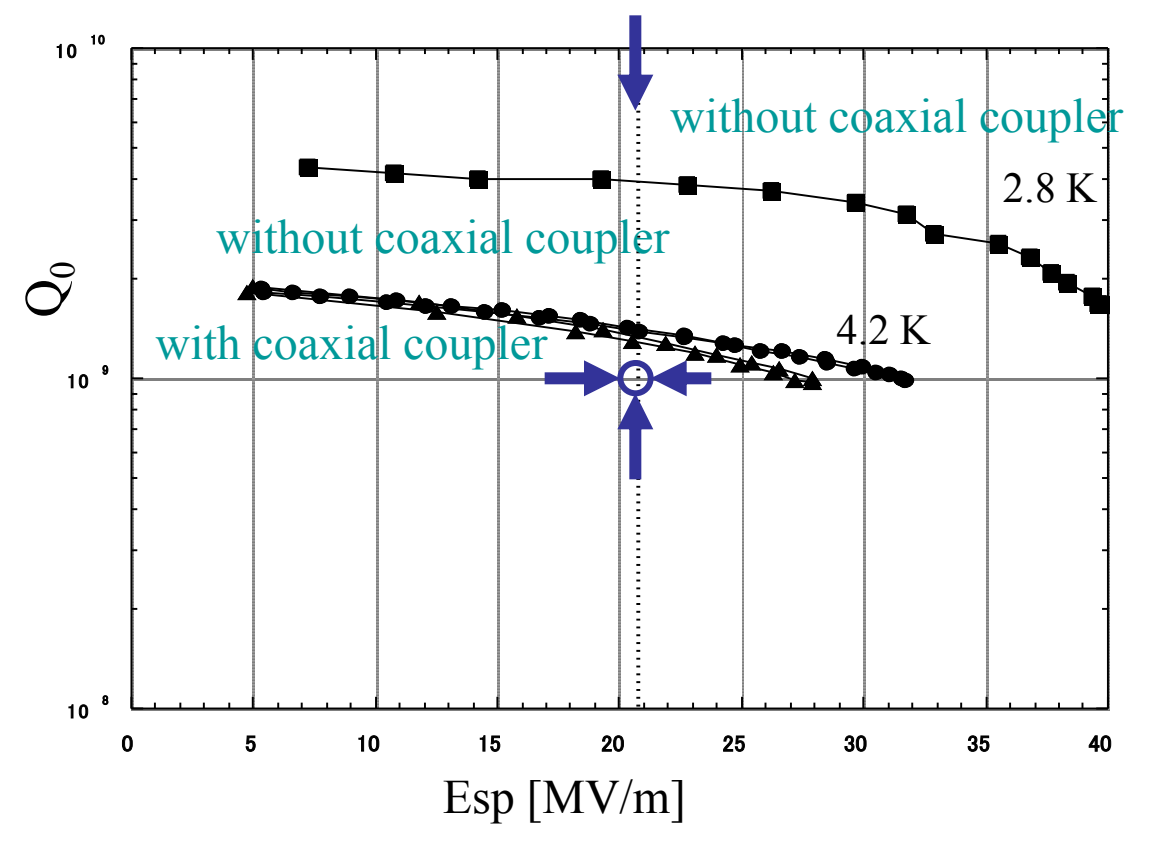
KEKB Superconducting Crab Cavity



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

Simplified Coaxial Coupler

Test Result of Prototype #1 Crab Cavity

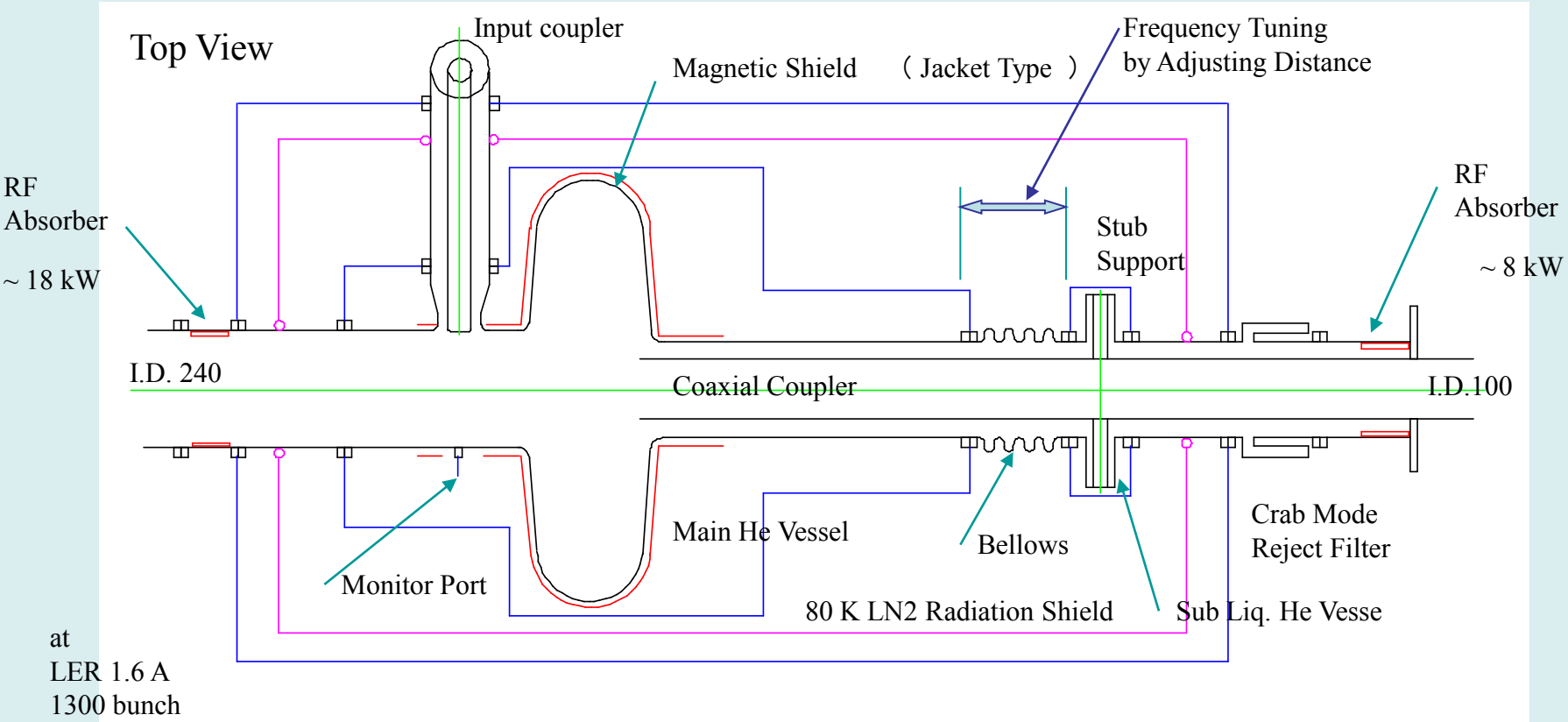


RF Performance Test with a Coaxial Coupler;
Multipacting was observed at very low RF power,
but we could overcome by RF process.

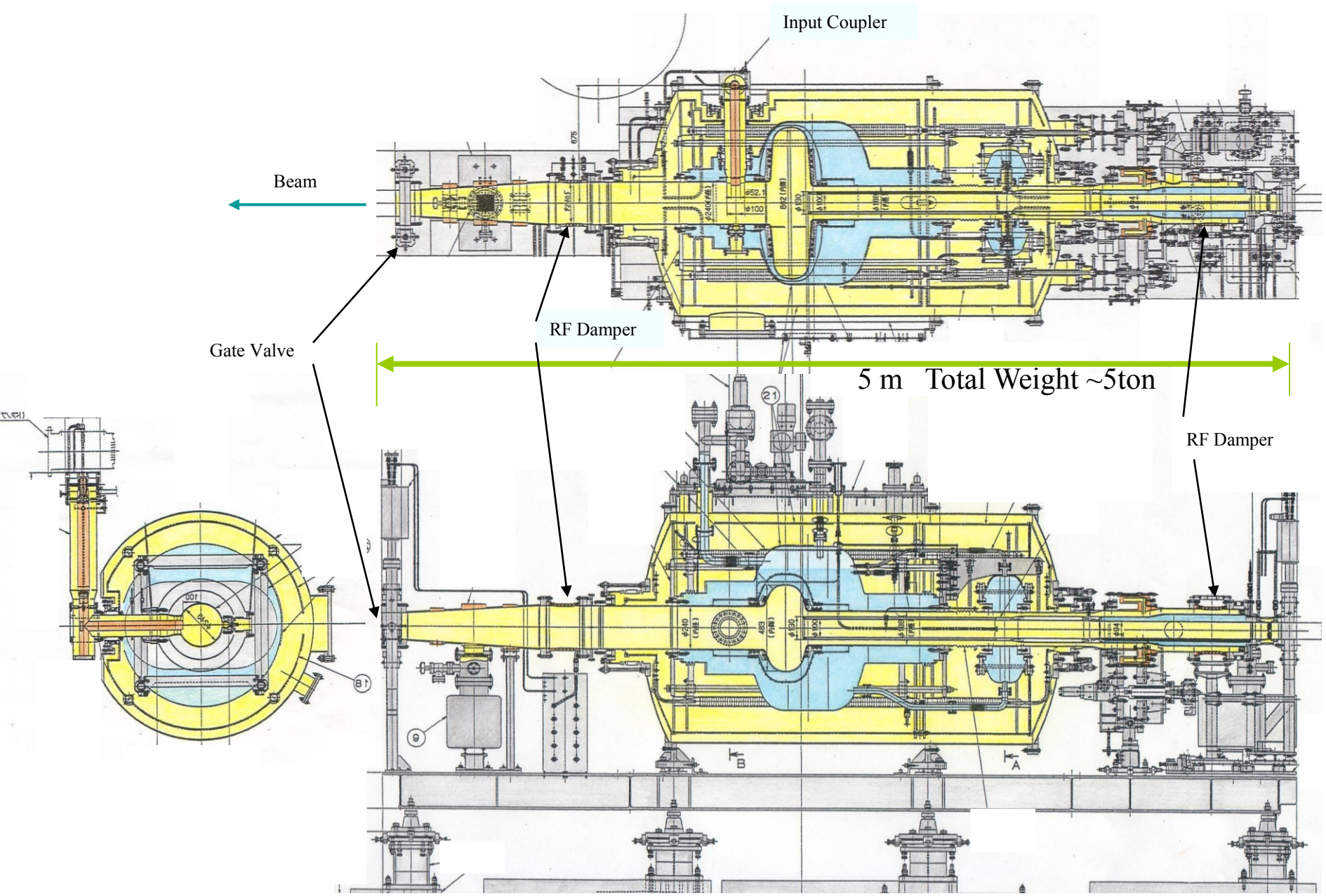
Conceptual Design of Cryostat for KEKB Crab Cavity

Characteristics

- Frequency Tuning Coaxial Coupler ~30 kHz / mm
- Stub-Support -- Mechanical Support & Cooling of Coaxial Coupler
- Jacket-type Helium Vessel (Main He Vessel and Sub He Vessel)
- Jacket-type Magnetic Shield

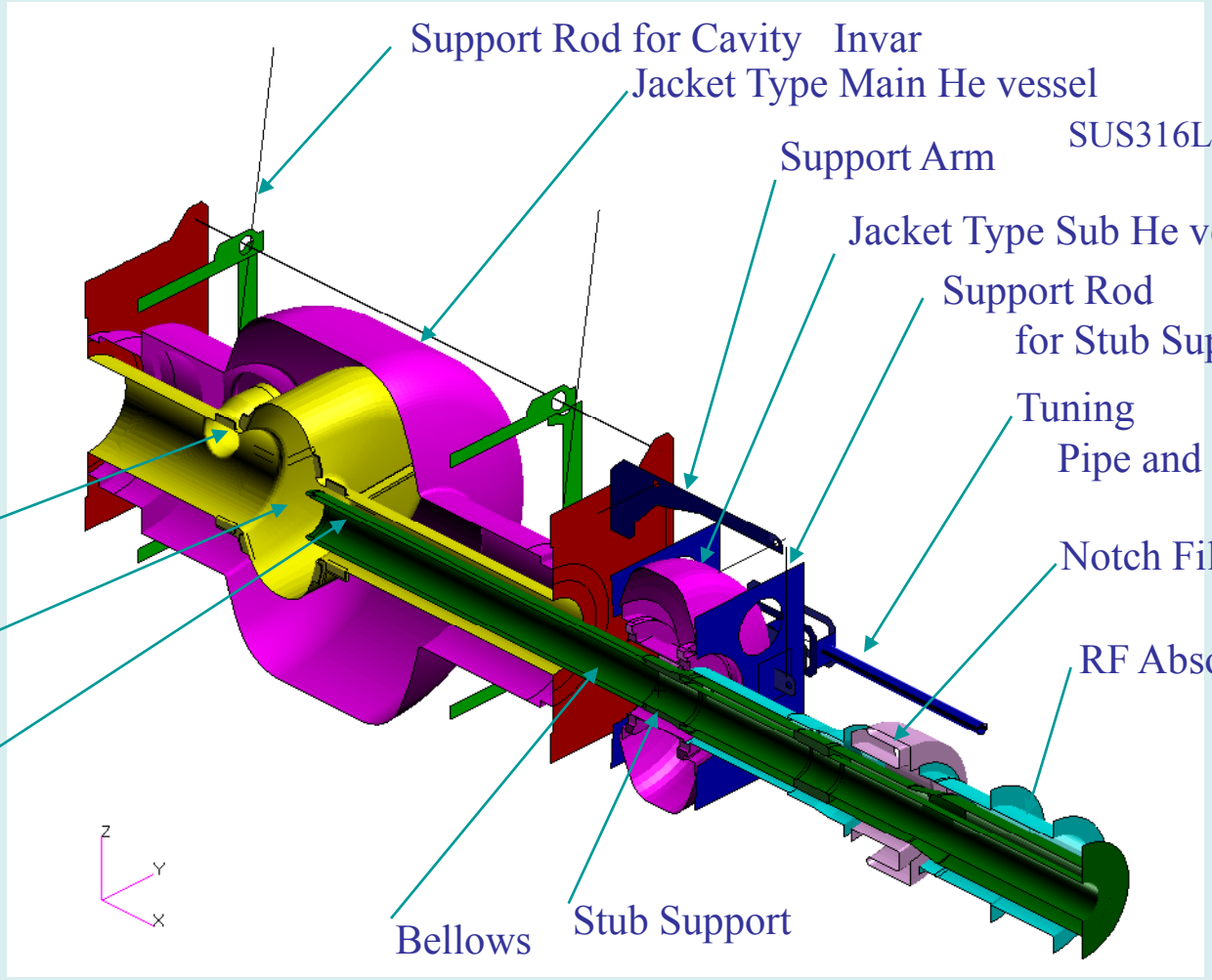


Cryostat for KEKB Crab Cavity



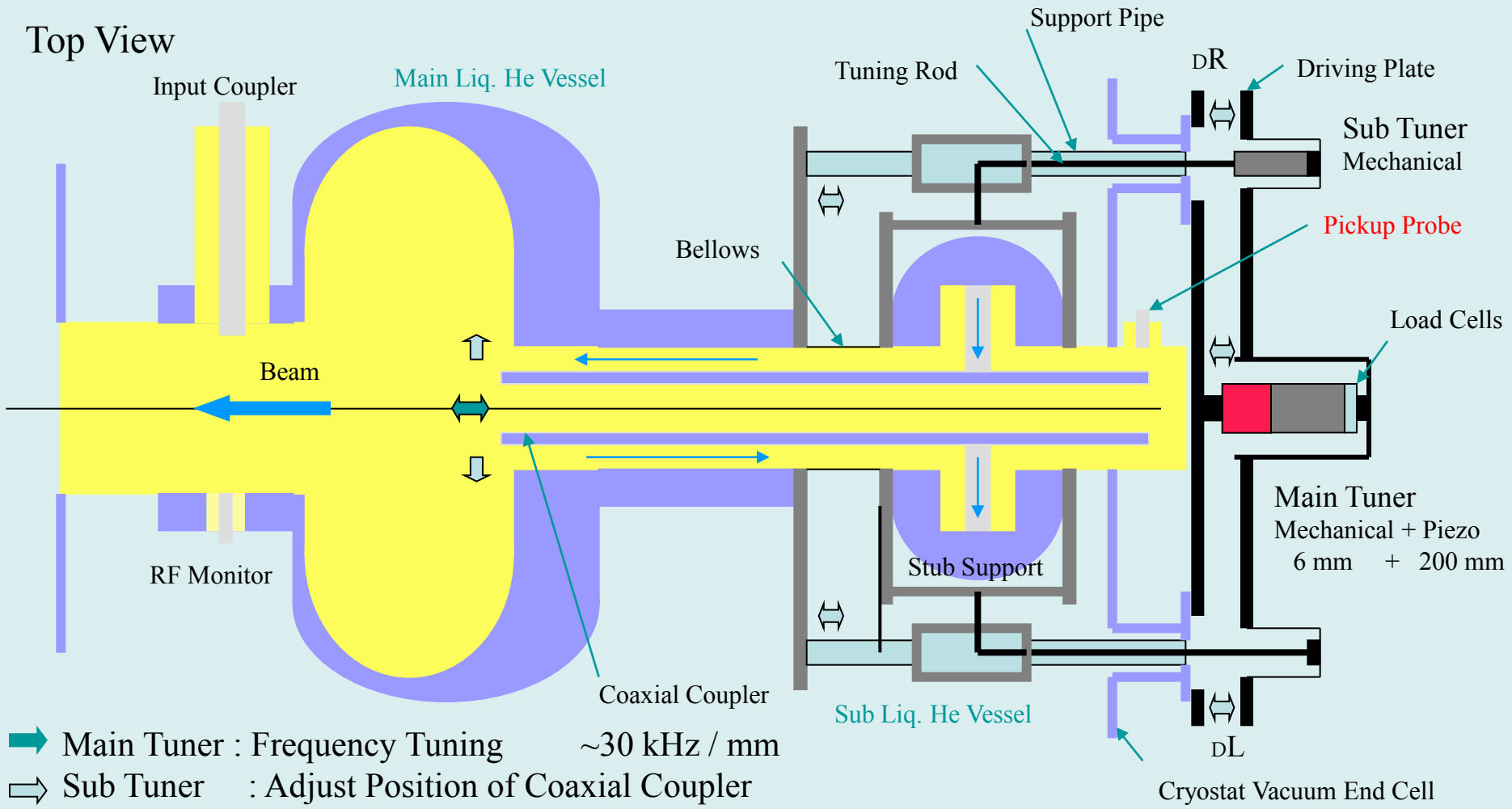
Crab Cavity & Coaxial Coupler in Cryo-module

1) Crab Cavity is hanged by 4 invar support rods.
2) Coaxial coupler is hanged by 4 stainless rods which are supported by 2 support arms.
3) Head position of the coaxial coupler is controlled by 2 tuning rods.
4) Head of coaxial coupler is cooled by liq. helium supplied from stub support.



KEKB Crab Cavity Frequency Tuner

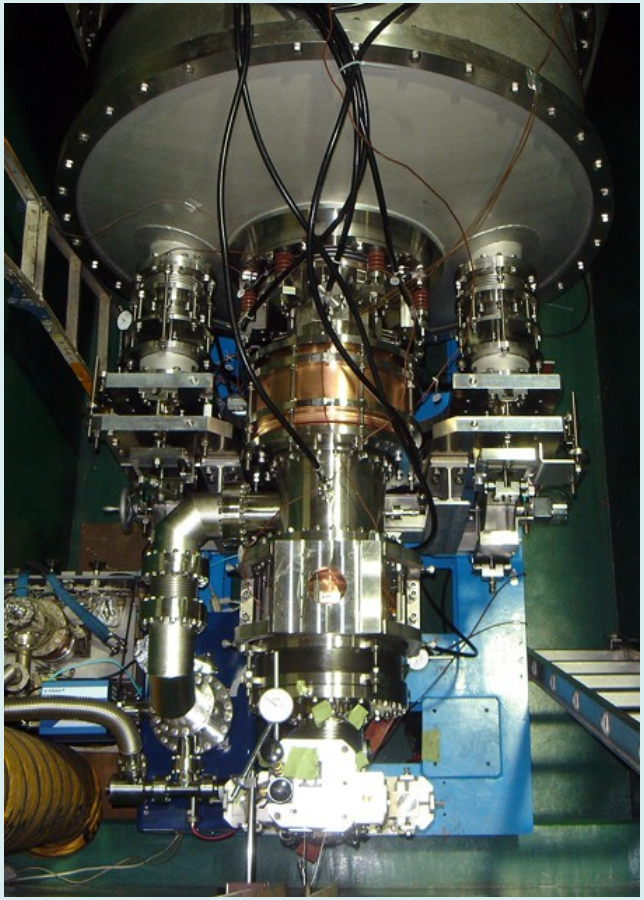
1) The jacketed crab cavity is fixed to the vacuum vessel.
2) Insertion of the coaxial coupler to the crab cavity is controlled by changing position of the sub liquid helium against the end plate by two driving rods.
3) Transverse position of coaxial coupler tip is controlled by adjusting distance DR and DL.



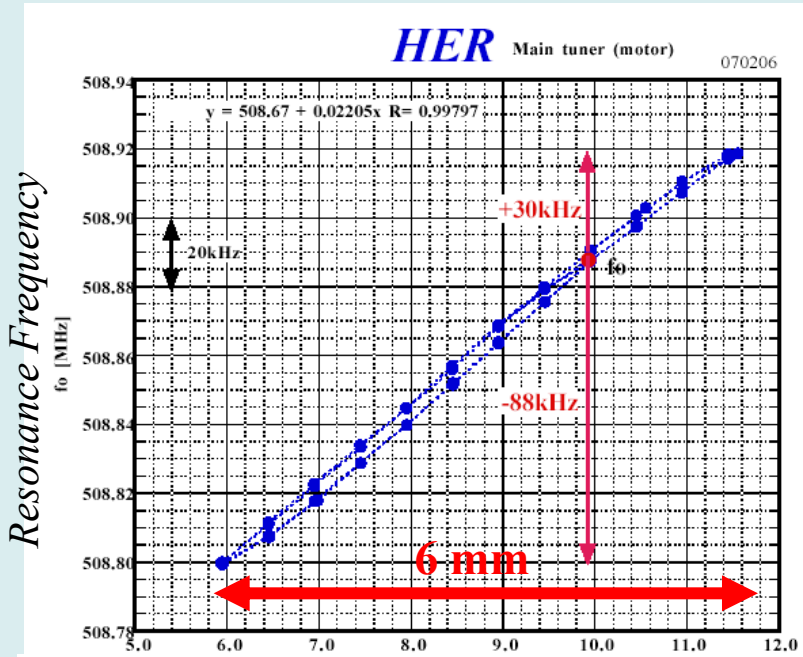
If the coaxial coupler set in center of crab cavity, there is no RF power flow to pickup probe.

Frequency Tuner Test

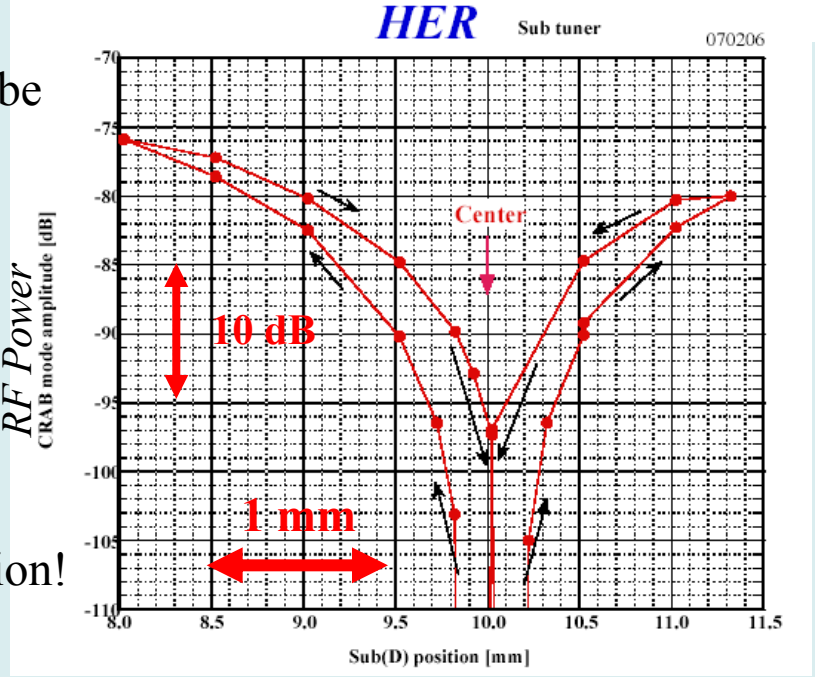
- Resonance frequency can be controlled by main tuner.
- Coaxial coupler position can be controlled by sub-tuner.



Frequency Tuner Crab Cavity for HER

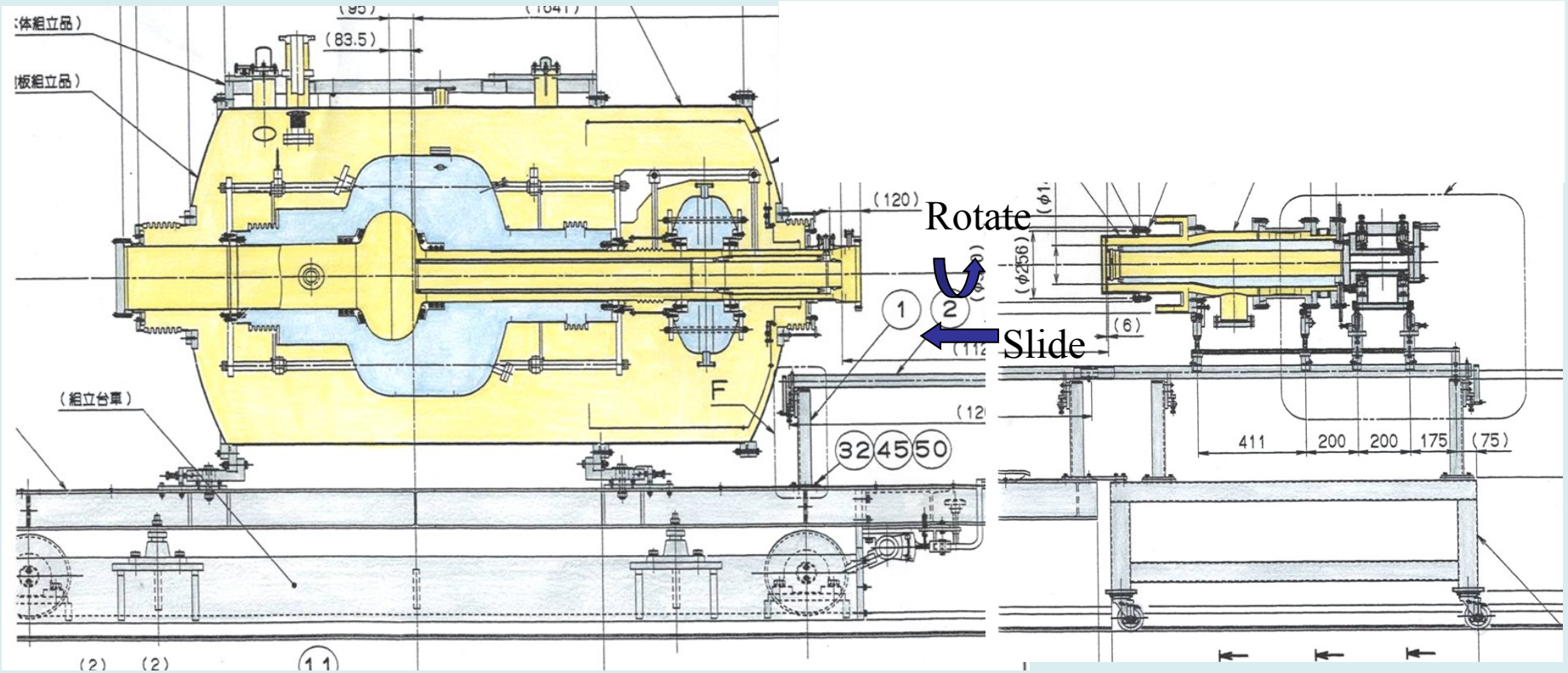


RF Power at Pickup Probe



Dip of RF power means good position!

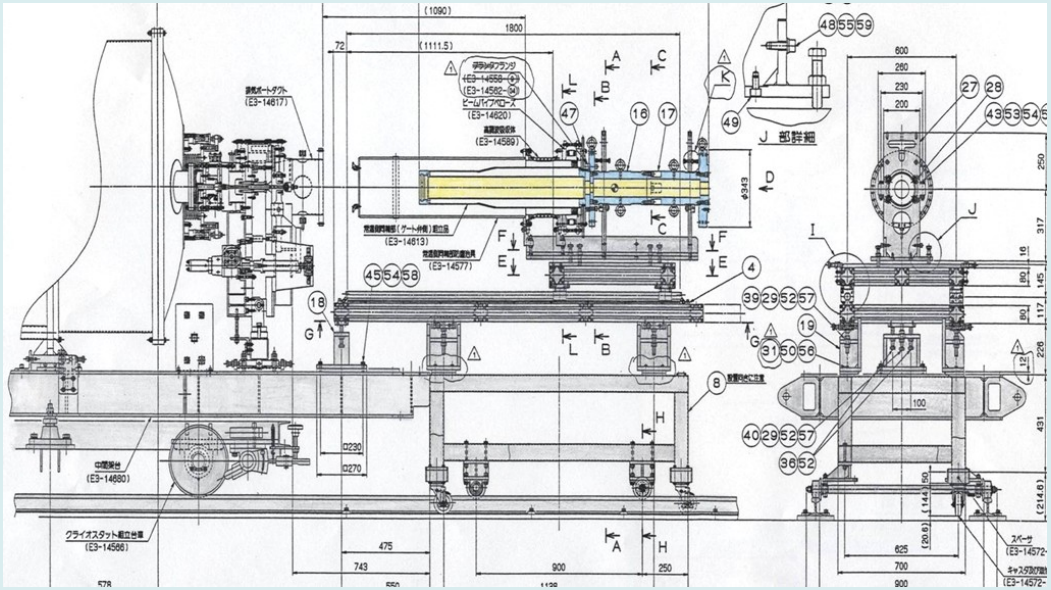
Insertion of Coaxial Coupler (1/2)



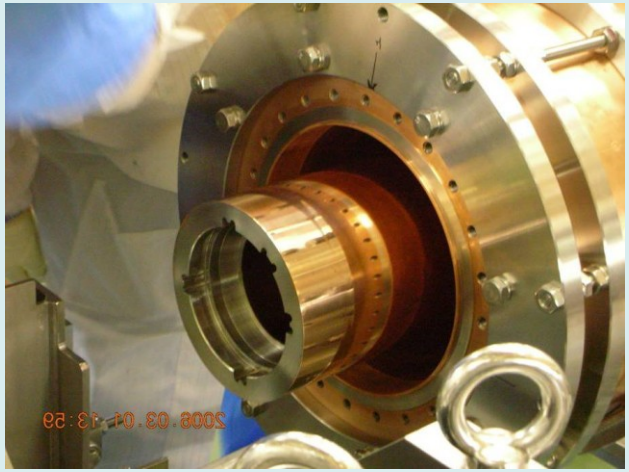
- Assembling the coaxial coupler to the cryostat was very “tough job”
- Inner conductor of coaxial coupler must be connect tightly without gap.
  ------ Bayonet type connection was adopted
- Precise alignment was needed;
  not only the position of axis but also direction of axis !
- The insertion tool must be rigid enough to support heavy component
  and need precise adjustment knobs.

Insertion of Coaxial Coupler (2/2)

We could assemble it by using improved Insertion tool!



Crab Cavity (Cryostat) Side



Notch Filter Side

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

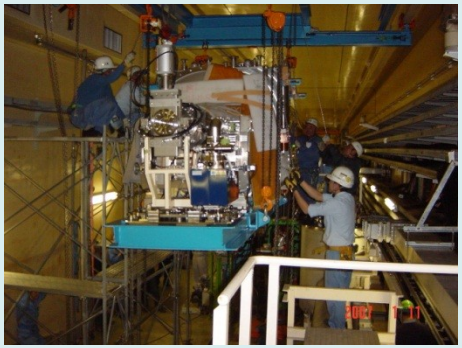
Final High Power Test at Test Stand

- Crab cavity for HER and LER were cooled down without leakage.
- Resonant frequency could adjust to operating frequency of 508.9MHz.
- V_{kick} = 1.8 MV and 1.93 MV respectively,
  exceed the design value of 1.44 MV.
- Qo – values at design kick voltage were higher than $1x10^9$.
- 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
  and Phase stability of crab cavity HER is good.
- Phase stability of crab cavity LER is not good,
  but this problem could be saved by RF feed-back system.

Installation & Commissioning of Crab Cavities

Installation of Crab Cavities
for HER Jan. 8, 2007,
for LER Jan. 11, 2007



Carrying the crab cavity using crane track

Crab Cavity for HER

Cool-down of Crab Cavities
Jan. 29 , 2007
Beam Operation Start
Feb. 13

Crab Cavity for LER

SUMMARY

- During more than 10 years of crab cavity development,
  We designed and fabricated the crab cavities and related components including the cryostat.
  We construct the facilities for assembling and cold RF test.

- 2 KEKB crab cavities have been constructed and installed in KEKB.
- The crab cavities operate more than 3 years without serious problems.
- The peak luminocity $L_{peak} = 20 \times 10^{33}$ /cm^2/s was attained under crab on operation.

- By the successful construction and operation of KEKB crab cavity, the reliability of superconducting crab cavity was proved for future application.