Construction and Commissioning of KEKB Superconducting Crab Cavities

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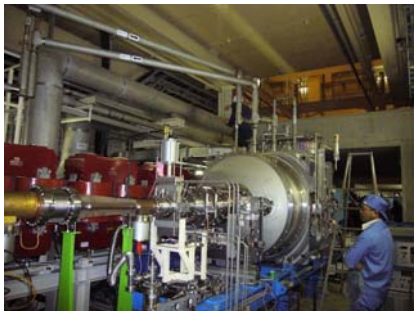
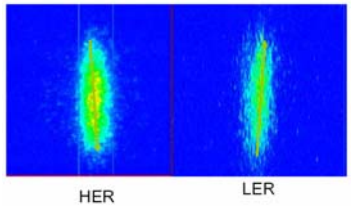


Crab Cavity for HER

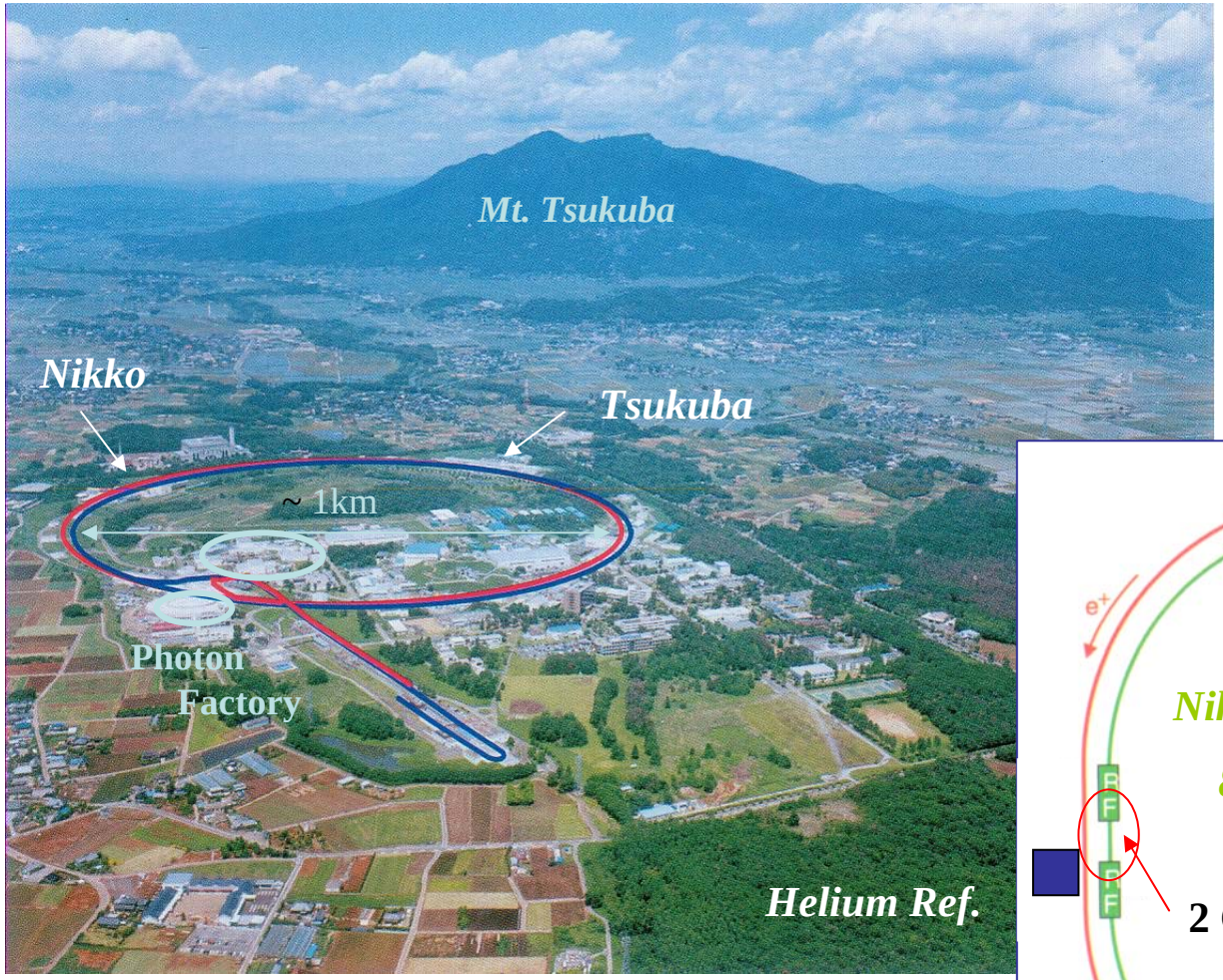


Bunches kicked
by crab cavity

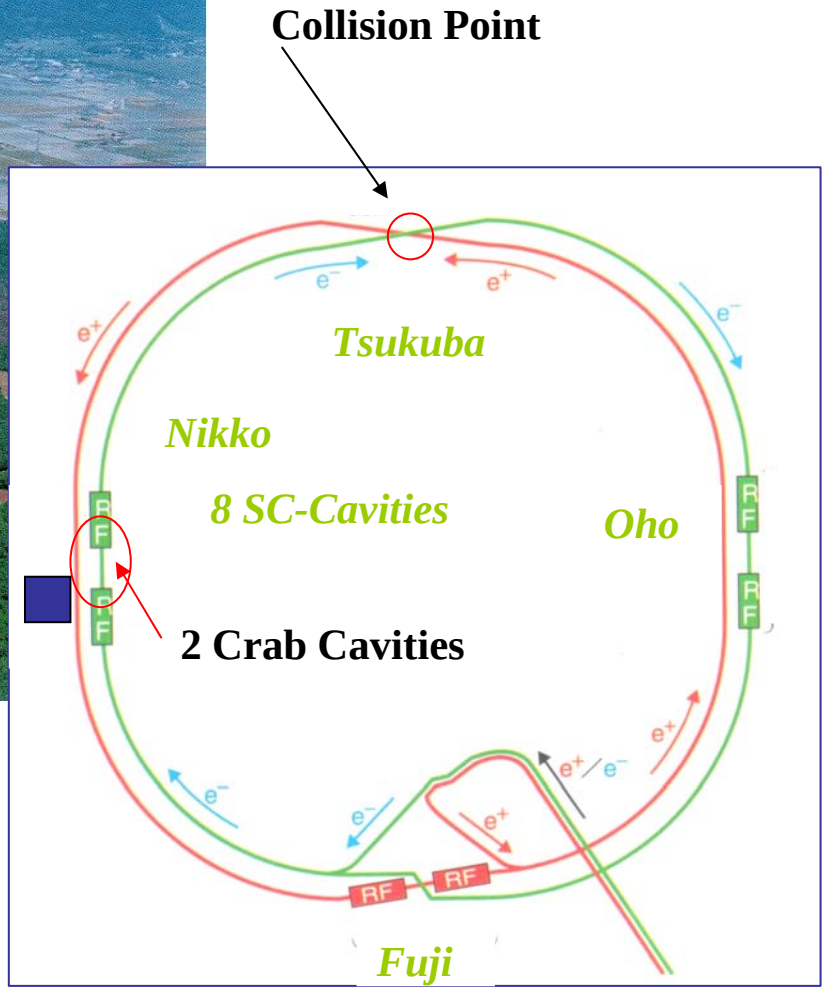
KEKB and Crab Crossing
Crab Cavity
Fabrication of Crab Cavities
Cold Test in Vertical Cryostat
Cryostat for Crab Cavities
Frequency Tuner
High Power Test at Test Stand
Installation & Commissioning of crab cavities (1) Phase instability - Tuner issue -
Commissioning of crab cavities (2)
Application of Crab Cavity

Crab cavity related topics will be presented at poster session!
Poster II on Wednesday

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.



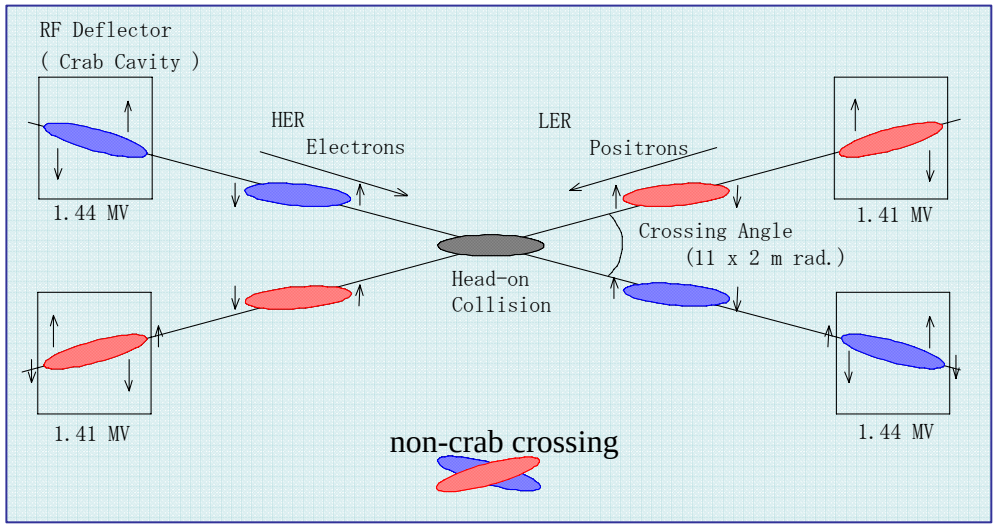
KEKB Crab Crossing

The crab crossing scheme allows a large crossing angle collision without introducing any synchrotron-betatron coupling resonances. [1, 2)]

1) R.B.Palmer, SLAC-PUB-4707,1988
2) K.Oide and K.Yokoya, SLAC-PUB-4832,1989

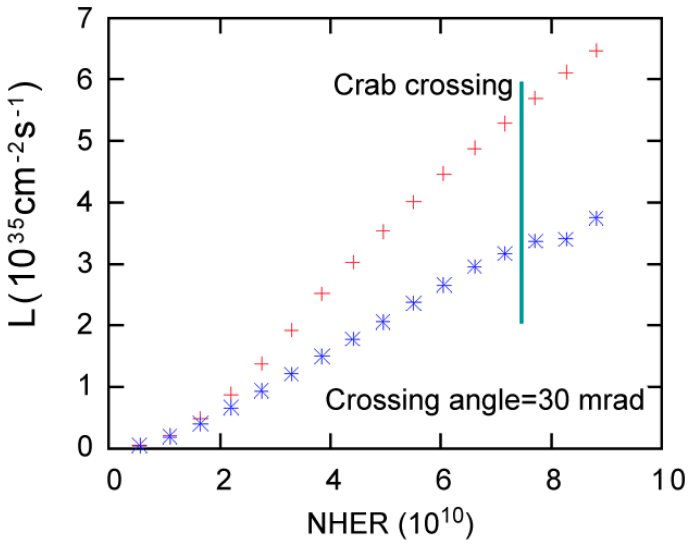
Original Crab Crossing Scheme

4 Crab Cavities at Colliding Section



Effect of Crab Crossing

(Simulation by Ohmi)

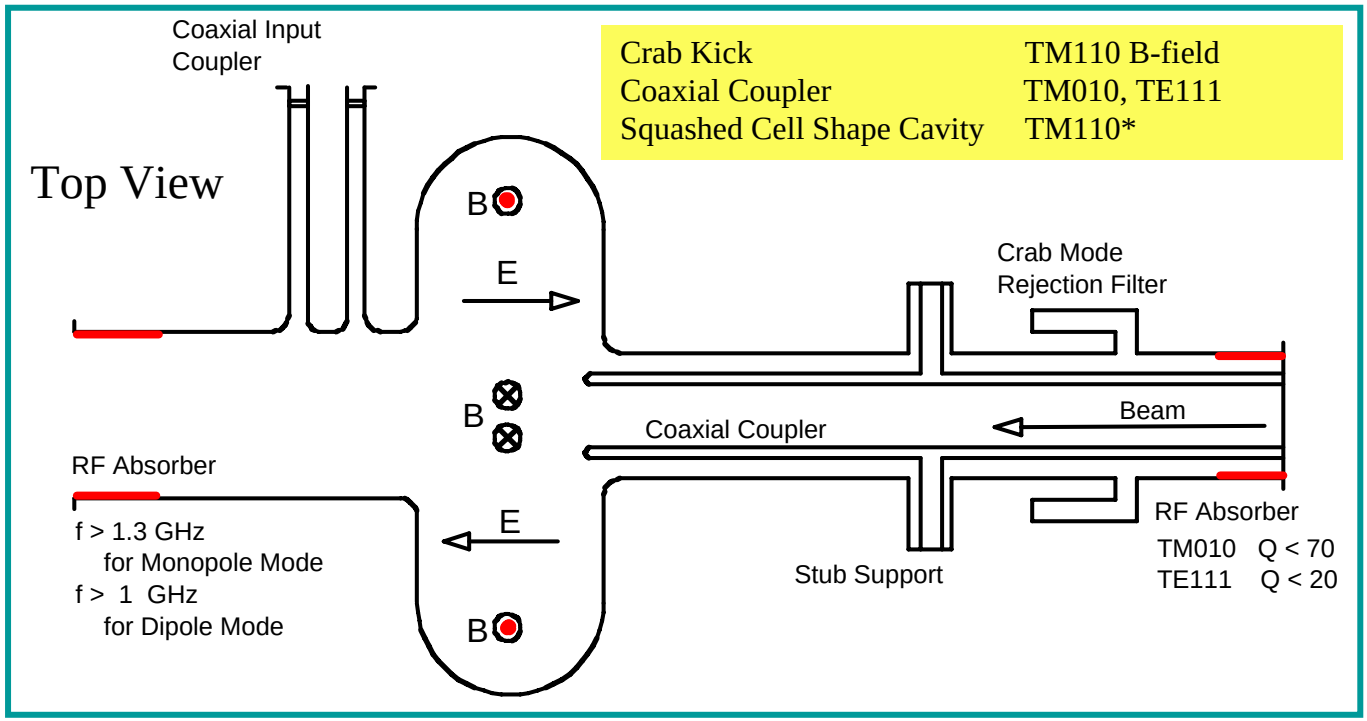


New Crab Crossing Scheme

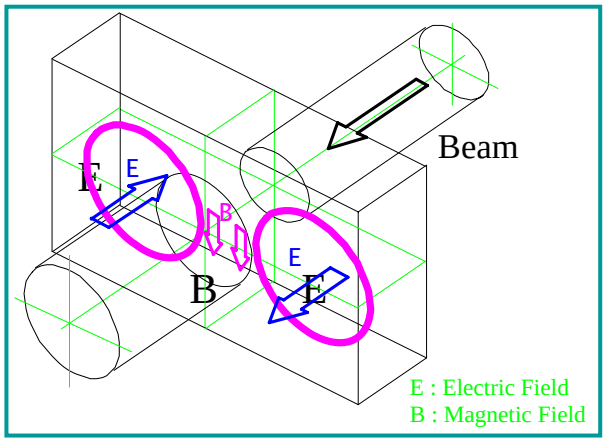
2 Crab Cavities at "Nikko" → Beam-bunch wiggle around the whole ring!

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

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"!

Milestone of KEKB Crab Cavities

0) 1/3 scale model 1.5 GHz 1994

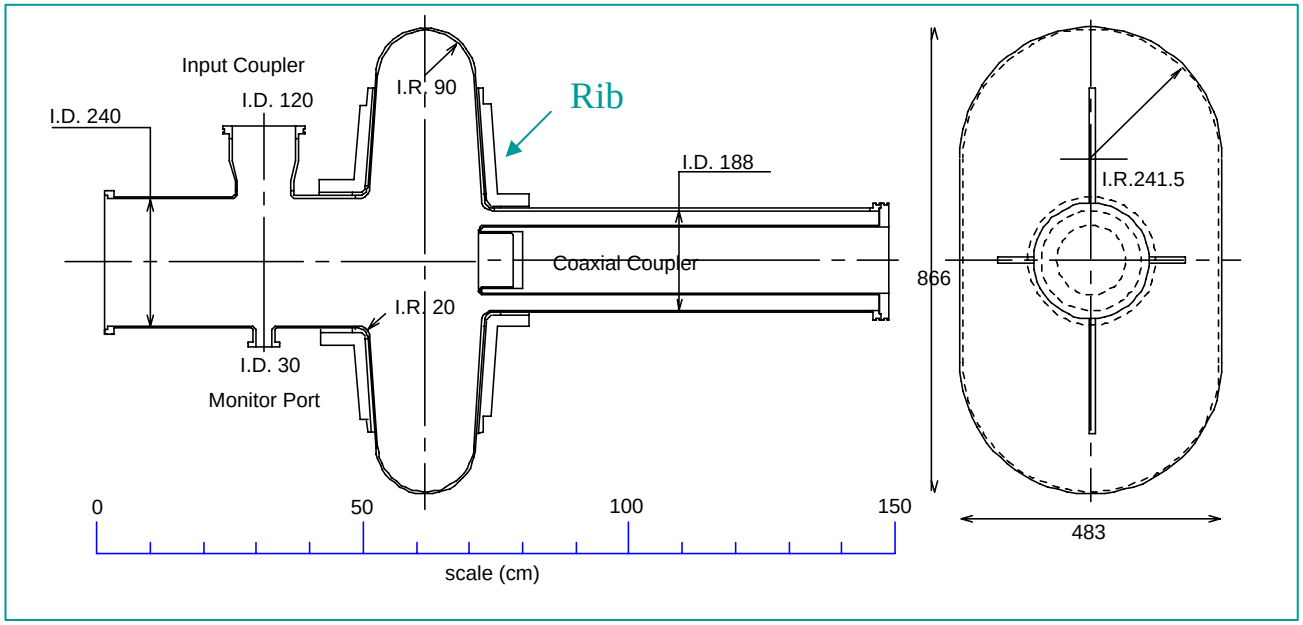
1) Full Scale Prototype Crab Cavity 500MHz 1996

2 Nb Cavities # 1 & # 2 2003
Coaxial Coupler
Prototype Horizontal Cryostat
(# 2 was Installed
into Prototype Horizontal Cryostat for Cool down Test)

Installation of 2 crab cavities in KEKB was decided 2004

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

KEKB Superconducting Crab Cavity

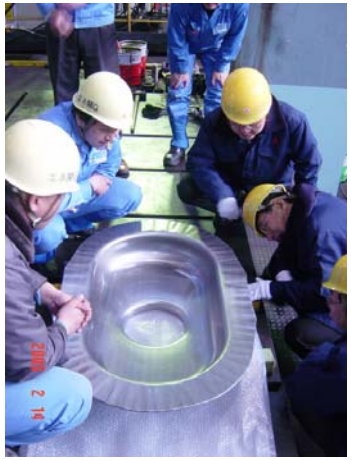


Frequency	501.7 MHz
R / Q	46.7 Ω
G	220
Esp / Vkick	14.4 MV / m / MV
Hsp / Vkick	415 Oe / MV

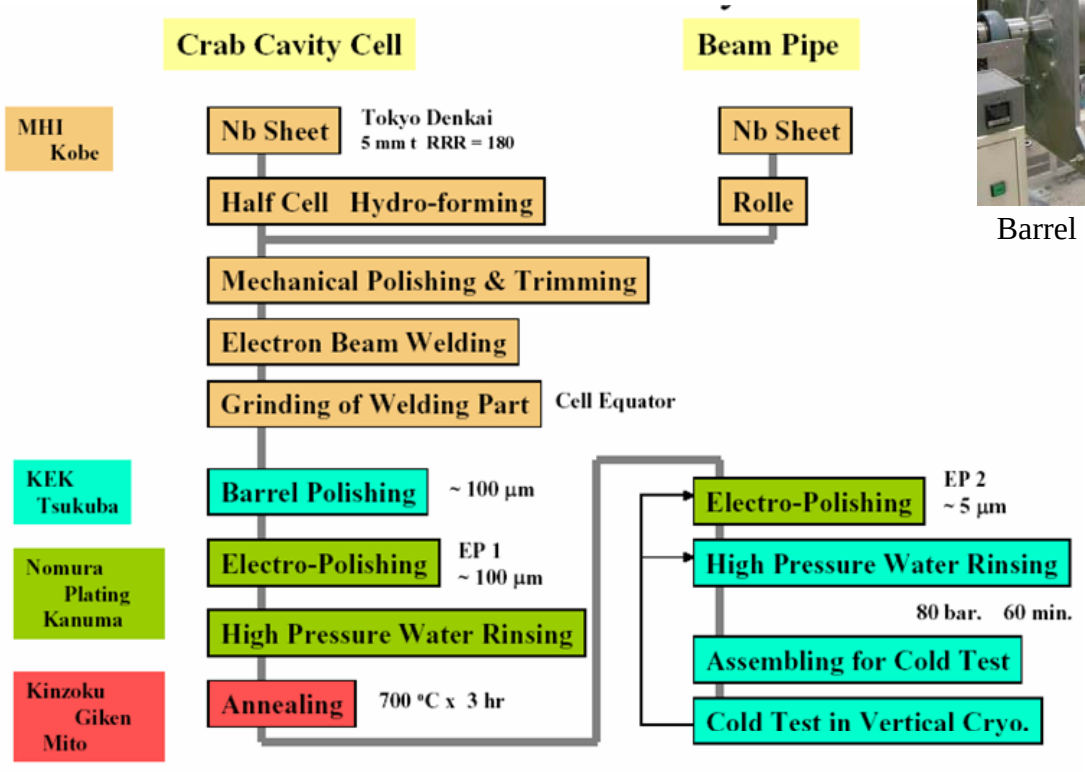
⇨ Non-axial Symmetric Structure
Thickness of 4.5 mm Nb Cavity
Reinforced by Ribs

Simplified Nb Coaxial Coupler

Fabrication of KEKB Crab Cavity



Forming of Half-Cells



Barrel Polishing 312Hr

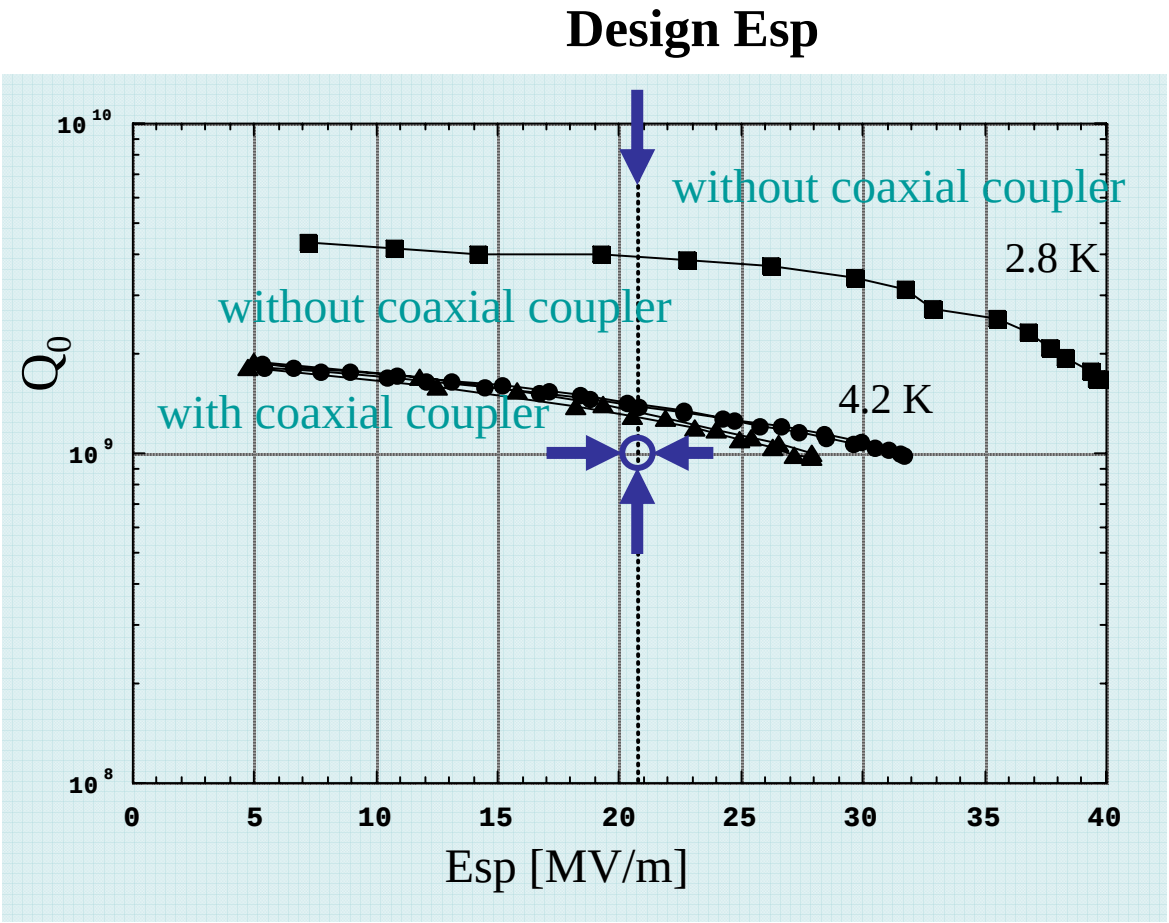
High Pressure Water Rinsing

Electro Polishing

Annealing

Assembling

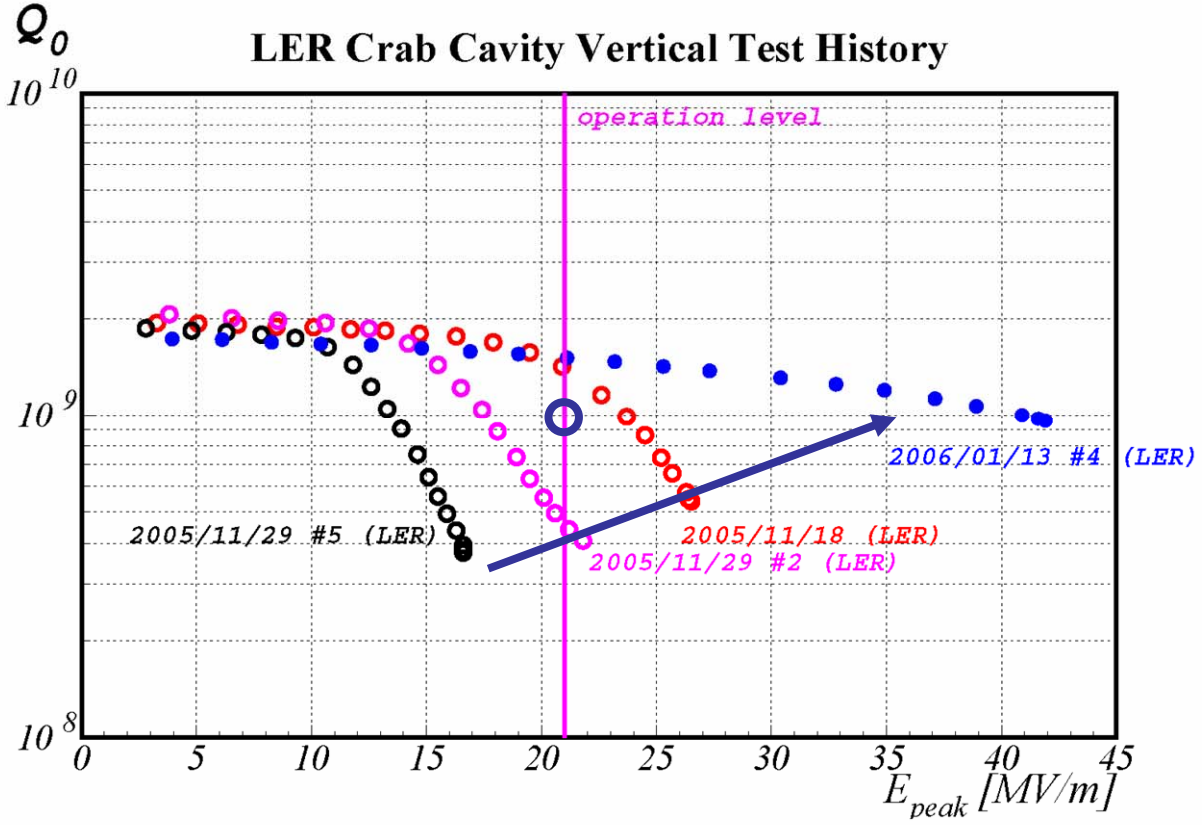
Test Result of Prototype #1 Crab Cavity



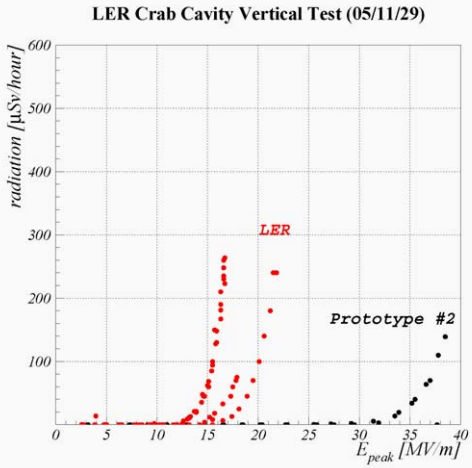
Crab Cavity #2
Same Performance!

⇨ Fabrication and Surface Treatment
RF Performance Test with a Coaxial Coupler
Multipacting could be overcome by RF process.

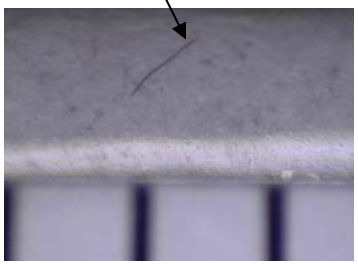
Test Result KEKB Crab Cavity #LER



X-Ray



Lint of cotton wiper



Nov. 18 1st Test

↓ H.P.R.

↓

Nov. 29 2nd Test

Field Emission

EP2

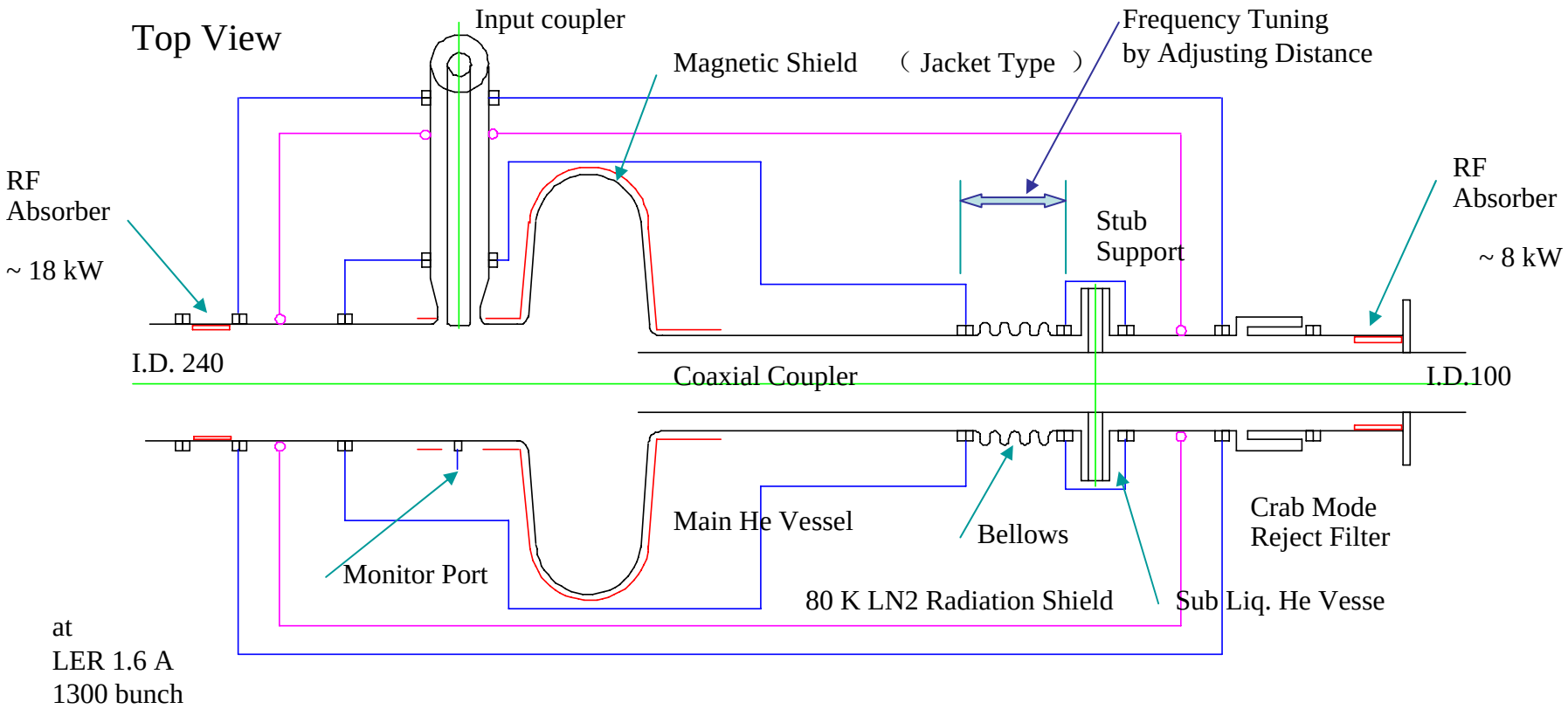
↓

Jan. 13 Test

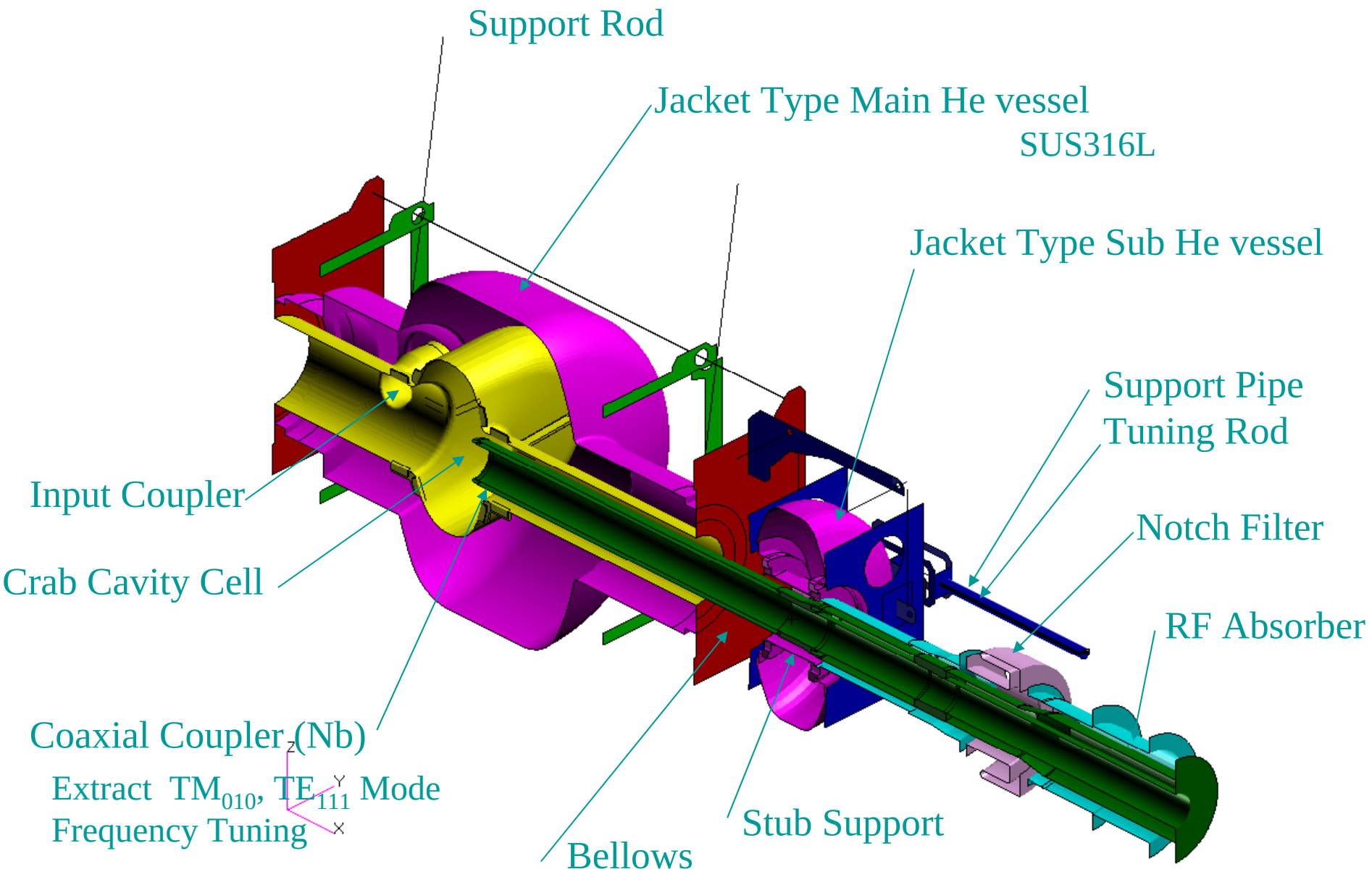
Recovered !

Conceptual Design of Cryostat for KEKB Crab Cavity

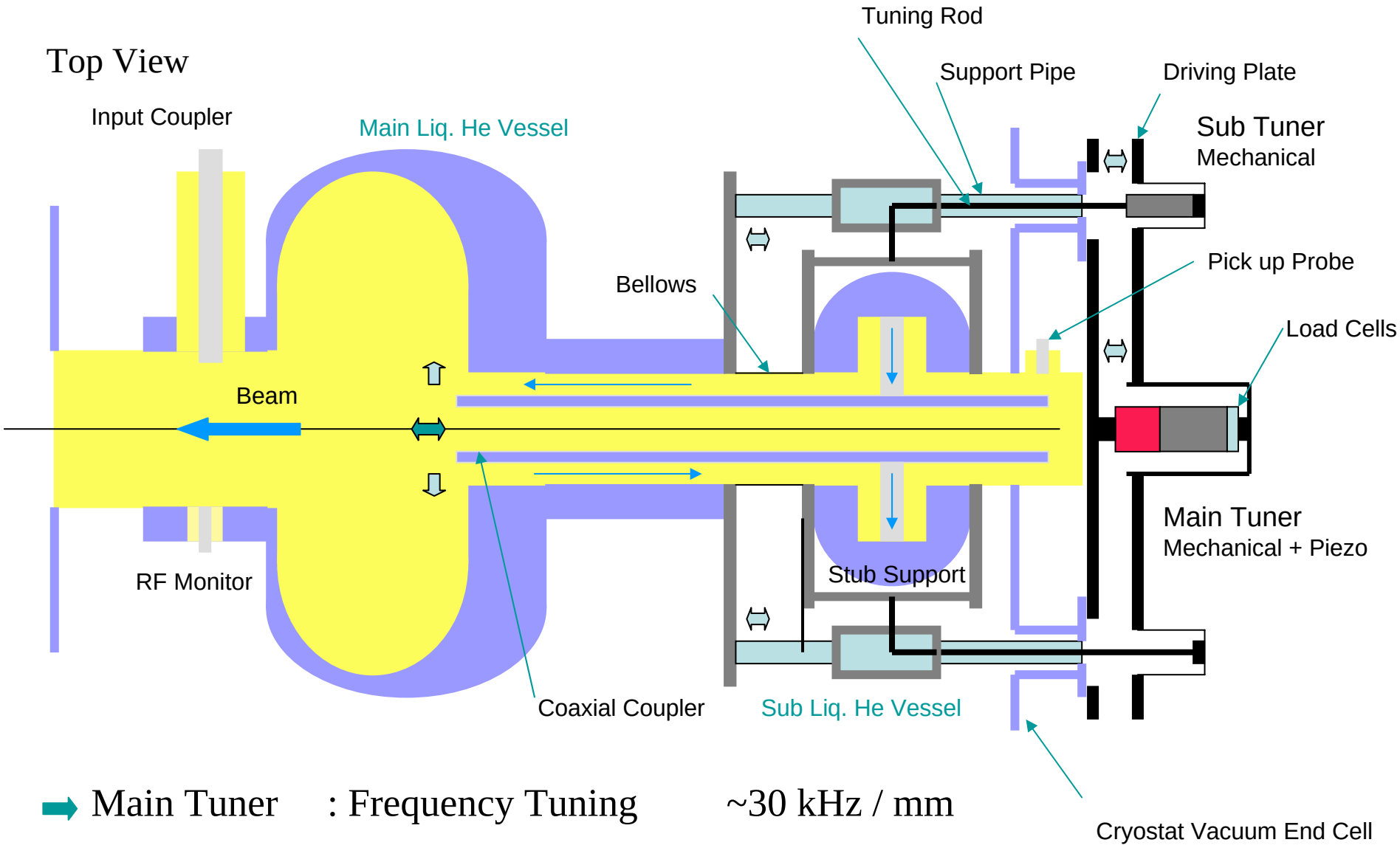
- ⇨ *Frequency Tuning Coaxial Coupler ~30* ***kHz / mm***
- ⇨ *Stub-Support -- Mechanical Support & Cooling of Coaxial Coupler*
- ⇨ *Jacket-type Helium Vessel*
- ⇨ *Jacket-type Magnetic Shield*



Crab Cavity & Coaxial Coupler in Cryo-module



Frequency Tuning Mechanism



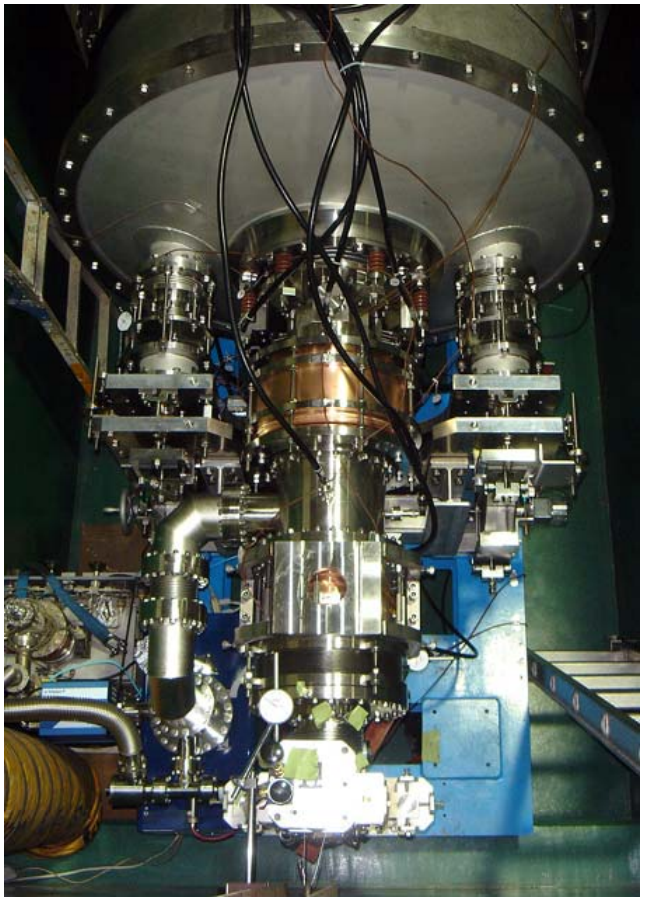
➡ Main Tuner : Frequency Tuning ~30 kHz / mm

⇨ Sub Tuner : Adjust Position of Coaxial Coupler

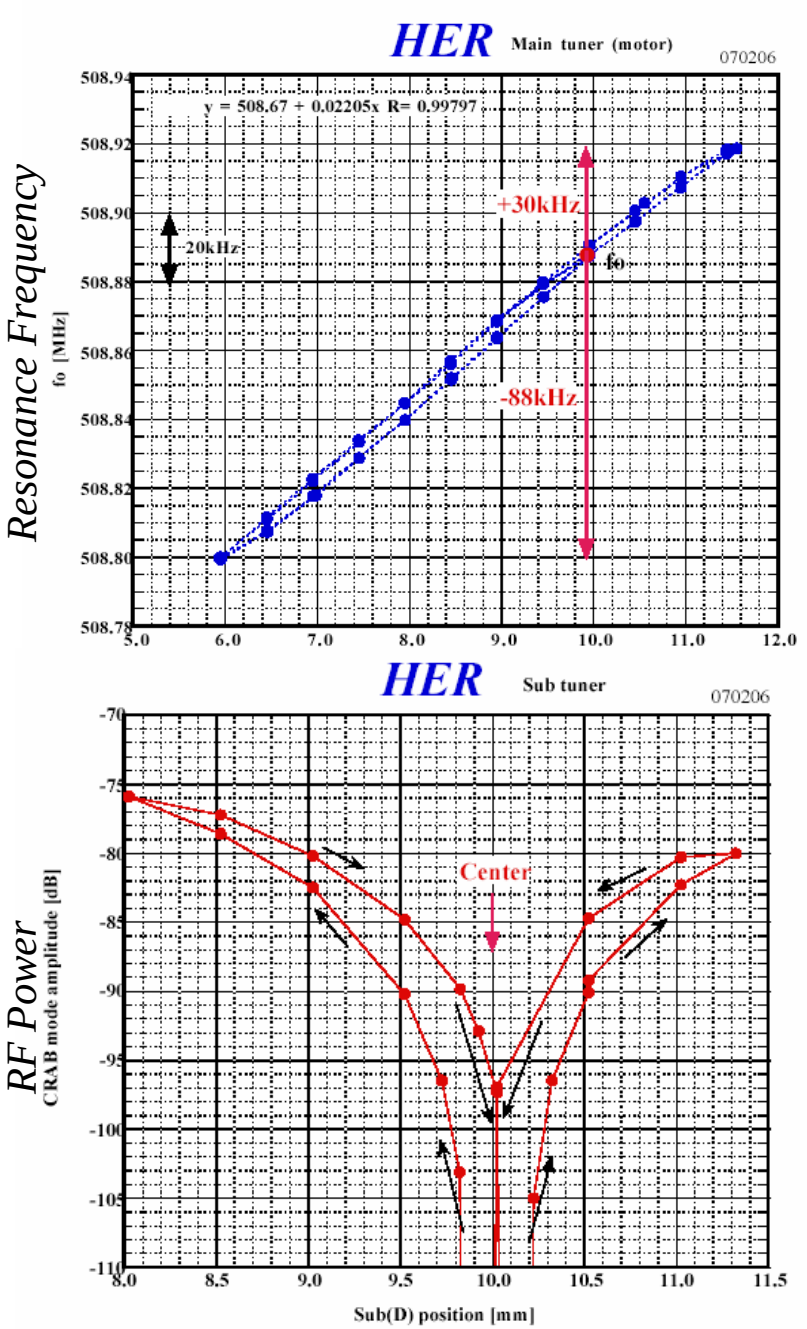
Frequency Tuner Test

Resonance frequency can be controlled by main tuner.

Coaxial coupler position can be controlled by sub-tuner.



Frequency Tuner Crab Cavity for HER

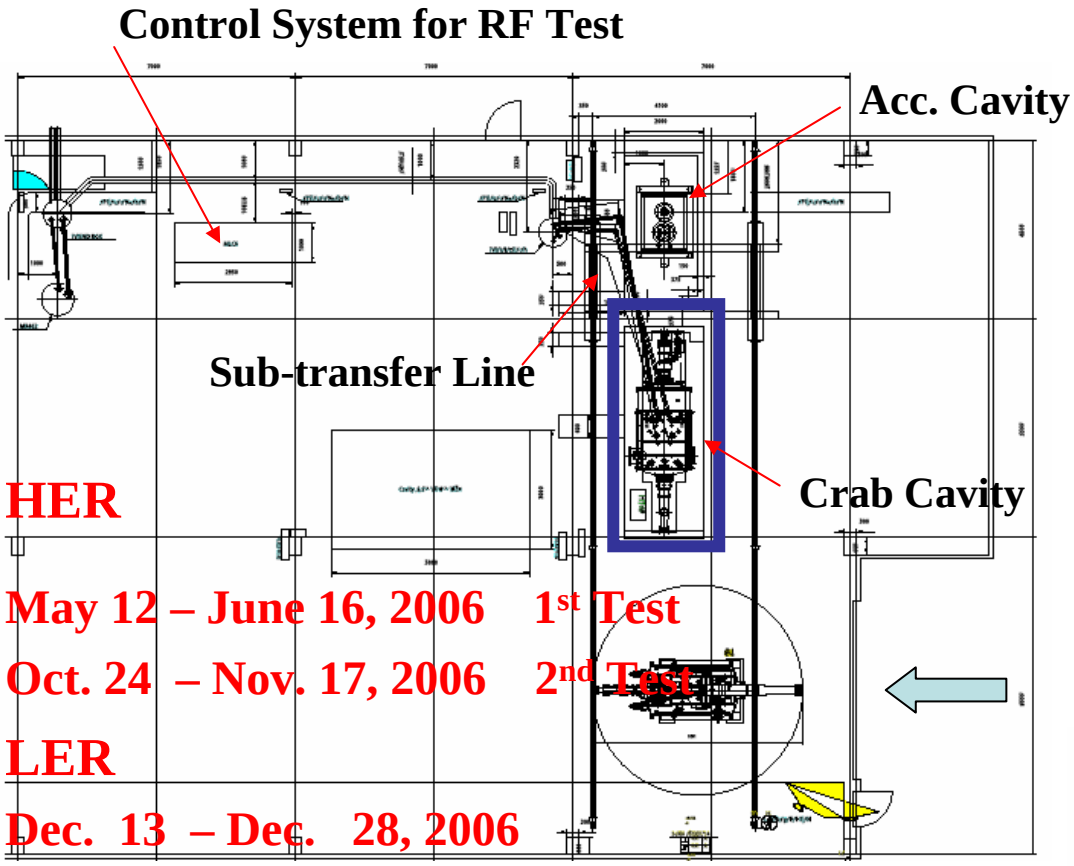


Complete Crab Cavity for HER

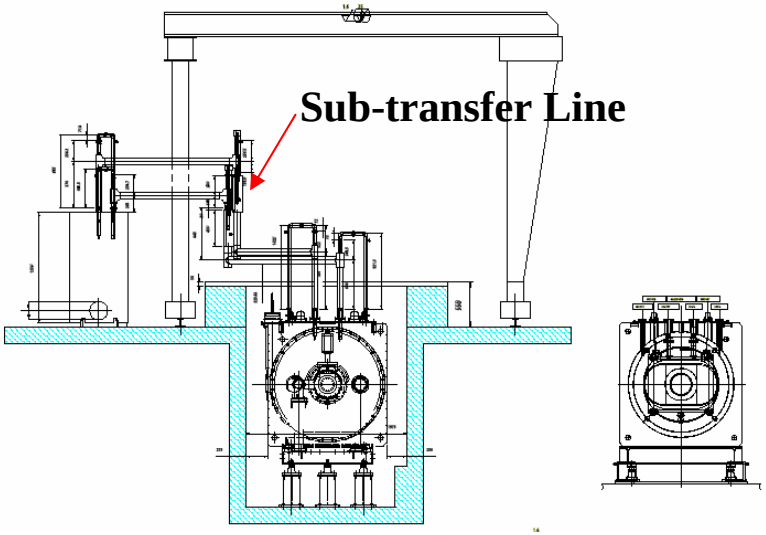
April 4, 2006
After struggling for insertion of coaxial coupler,
we could complete the assembling.

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

Test Stand for Crab Cavity at D10 Station



High Power Test



1st High Power Test for Crab Cavity HER

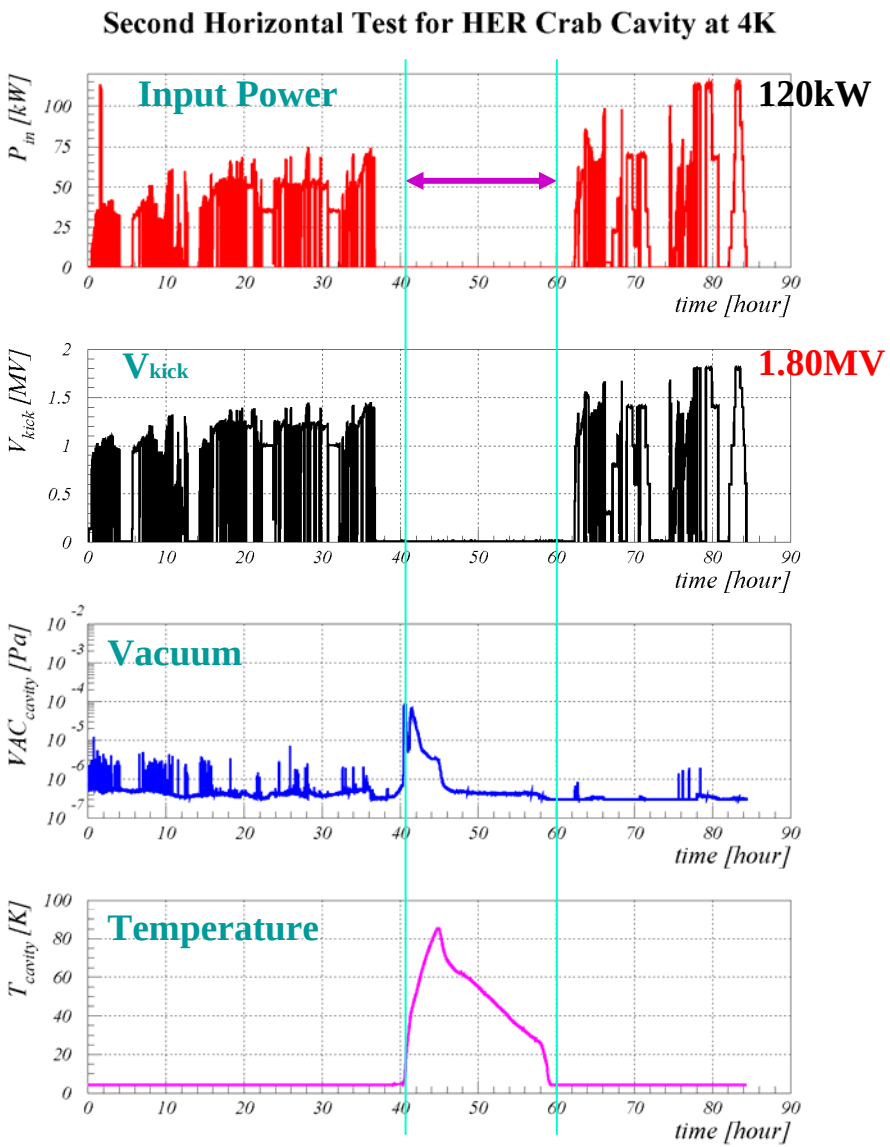
- Crab cavity for HER was cooled down without leakage.
- V_{kick} = 1.67 MV, exceed the design value of 1.44 MV.
- Cavity and coaxial coupler was cooled stably during the high power test. Cryogenic system worked very well.

Problems & Improvements (Disassemble & Re-assemble)

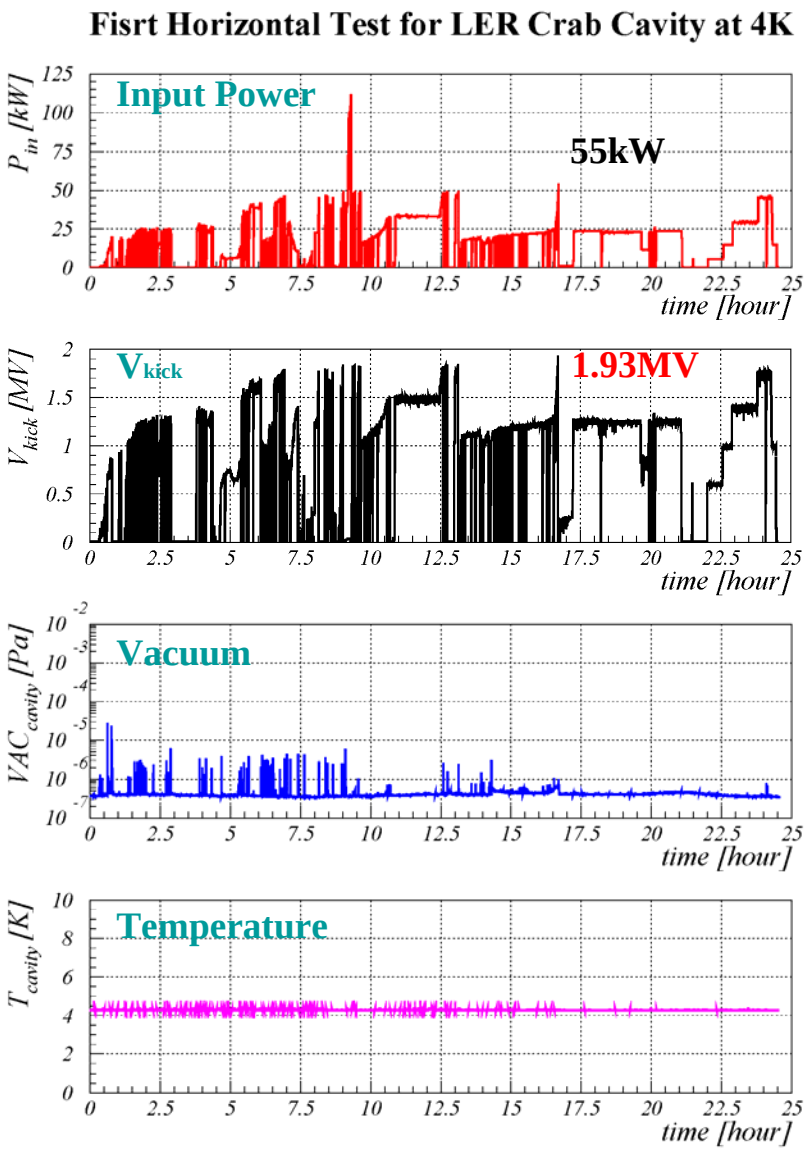
- Resonant frequency was lower than design value (~300kHz)
  → After cool down, the cavity was pre-tuned
- Narrow tuning range
  Main tuner & Sub tuner
  → Change to thin stainless bellows with copper plating
- Tuner feedback stability is not good
  → Reinforce the tuning structure
- RF contact at the joint part of the coaxial coupler: for high current operation

High Power Test for Crab Cavity HER & LER

Crab Cavity HER



Crab Cavity LER



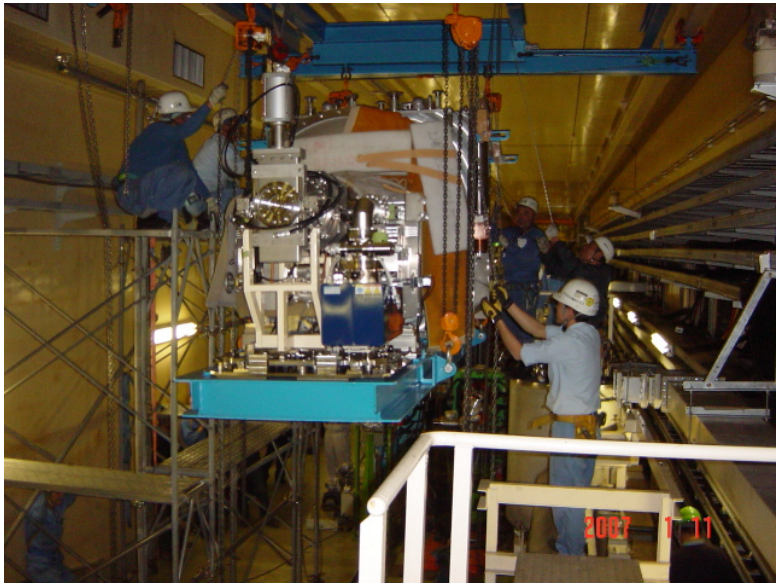
SUMMRY High Power Test at Test Stand

- 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.
  Phase stability of crab cavity HER is good.
  Phase stability of crab cavity LER is no good!

Installation & Commissioning of Crab Cavities

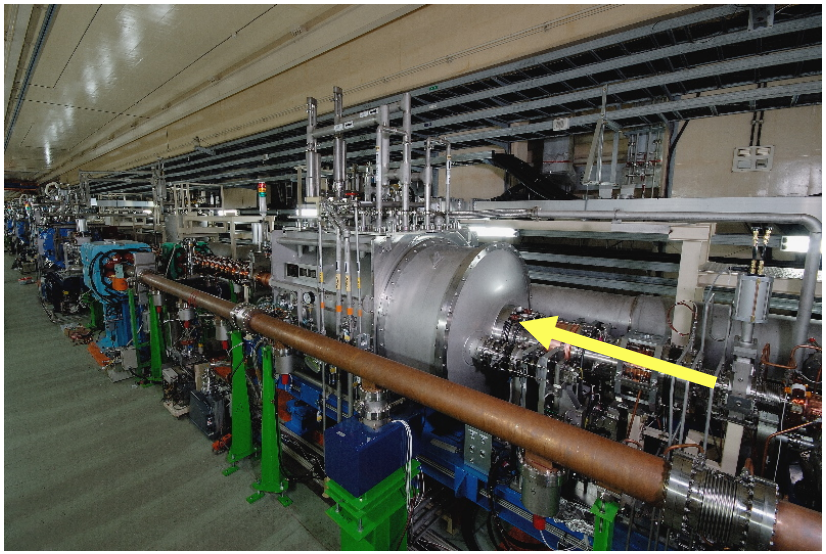
Installation of Crab Cavities
for HER Jan. 8, 2007,
for LER Jan. 11, 2007

Crab Cavity for HER



Carrying the Crab cavity using crane track

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



Crab Cavity for LER

SUMMARY Commissioning of Crab Cavities (1)

- Kick voltage of crab cavity HER and LER reached

  V_{kick} = 1.6 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.

  By using the RF feed back system, we could control within the design value.

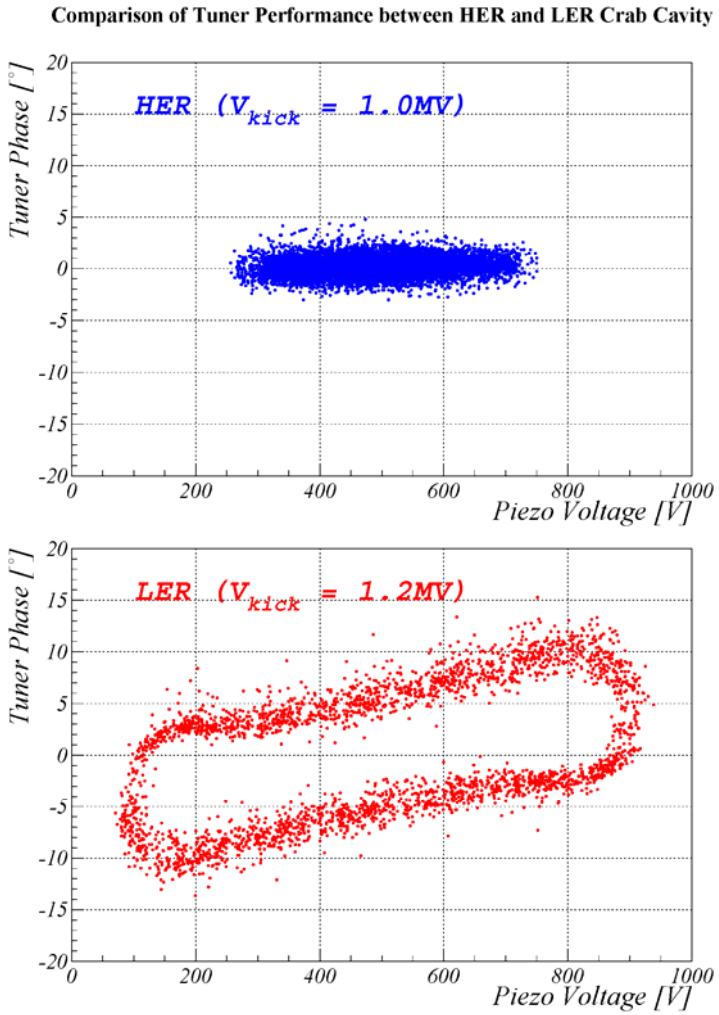
Troubles:

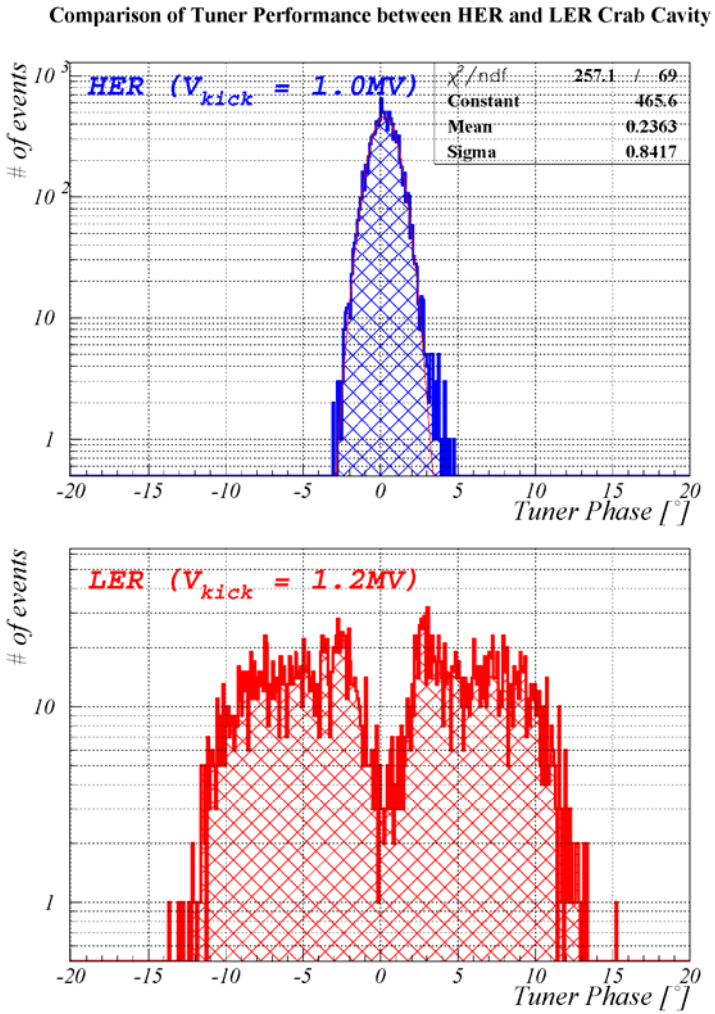
- Cold helium gas leak at connection part of recovery pipe.

  Tighten the connector and set a heater at connection part.
- Lack of cooling power at coaxial coupler.

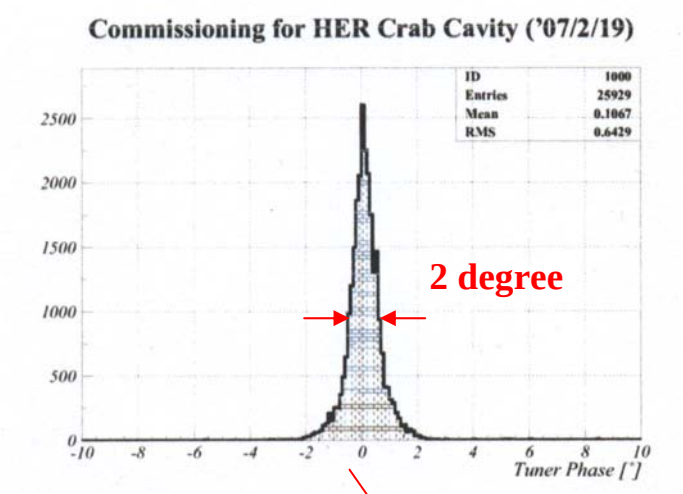
  Add bypass line to increase the gas flow.
- Poor vacuum at coaxial coupler part of crab cavity LER.

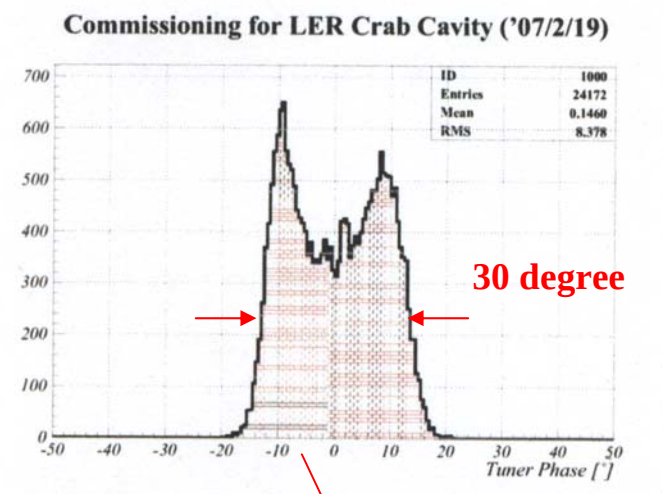
Phase Stability

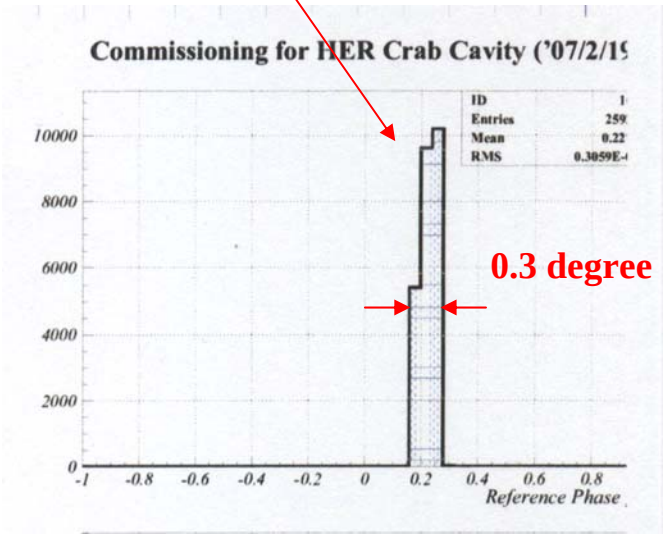


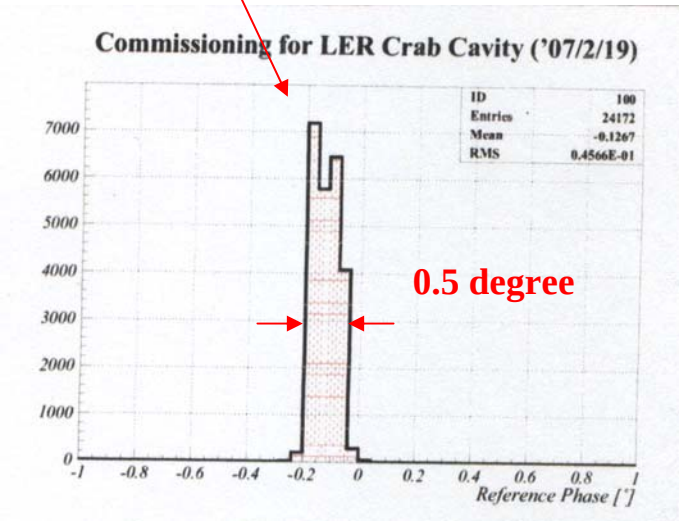


Phase stability could be improved by RF feed back system









SUMMARY Commissioning of Crab Cavities (2)

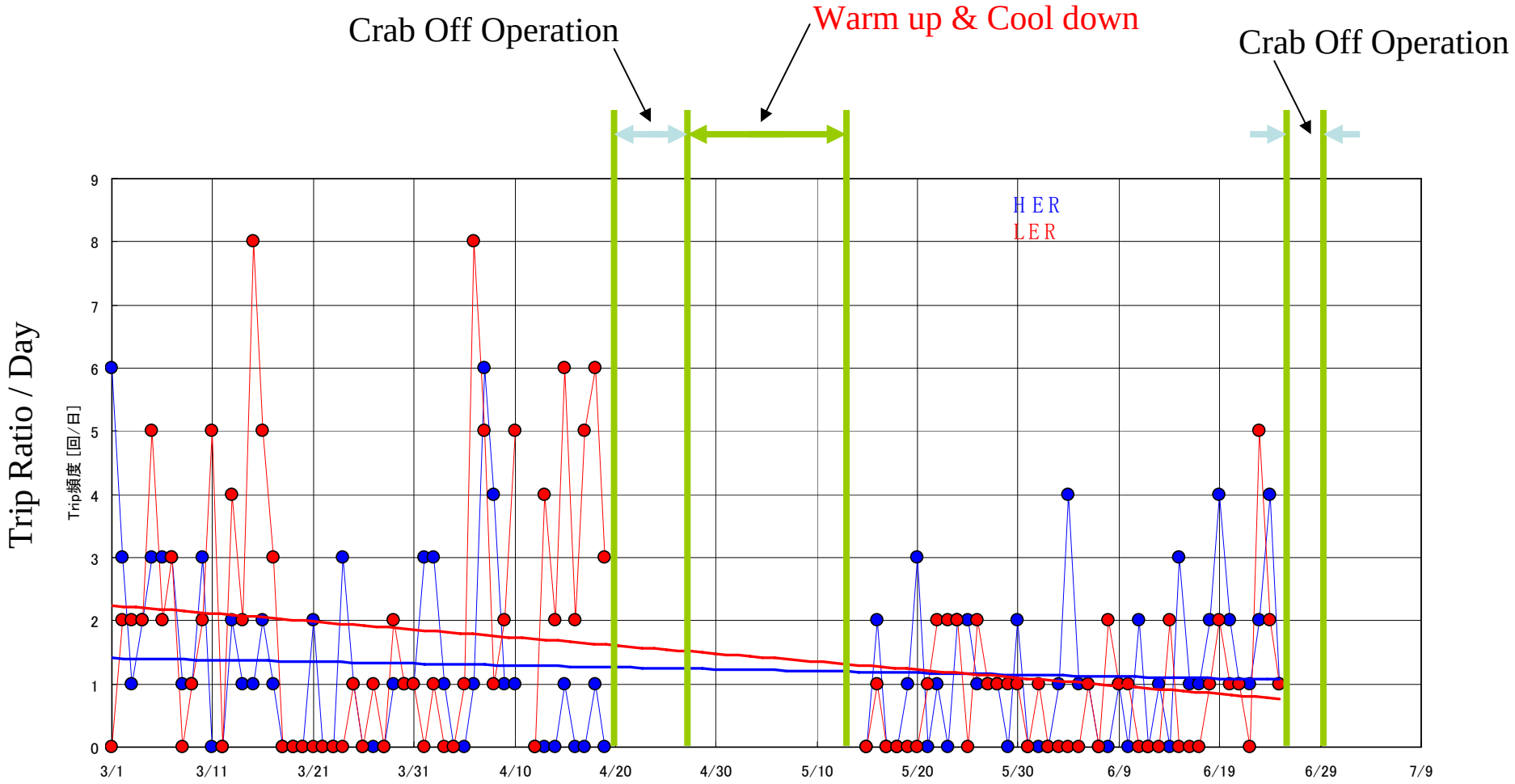
- L_{peak} =10.5 x 10^{33} /cm^2/s attained under crab on operation. (1.3A x 0.7A)
- High current beams of 1.7A (LER) and 1.35A (HER) could pass through the crab cavities under RF off operation.
- Crab cavity and coaxial coupler could keep cold under high current beam operation.
- The HOM power of about 10kW could absorb by HOM damper.
- The RF contacts at inner conductor of coaxial coupler worked well under high current operation.
- Trip ratio of crab cavity could decrease by warm up of cavity up to room temperature.

Troubles:

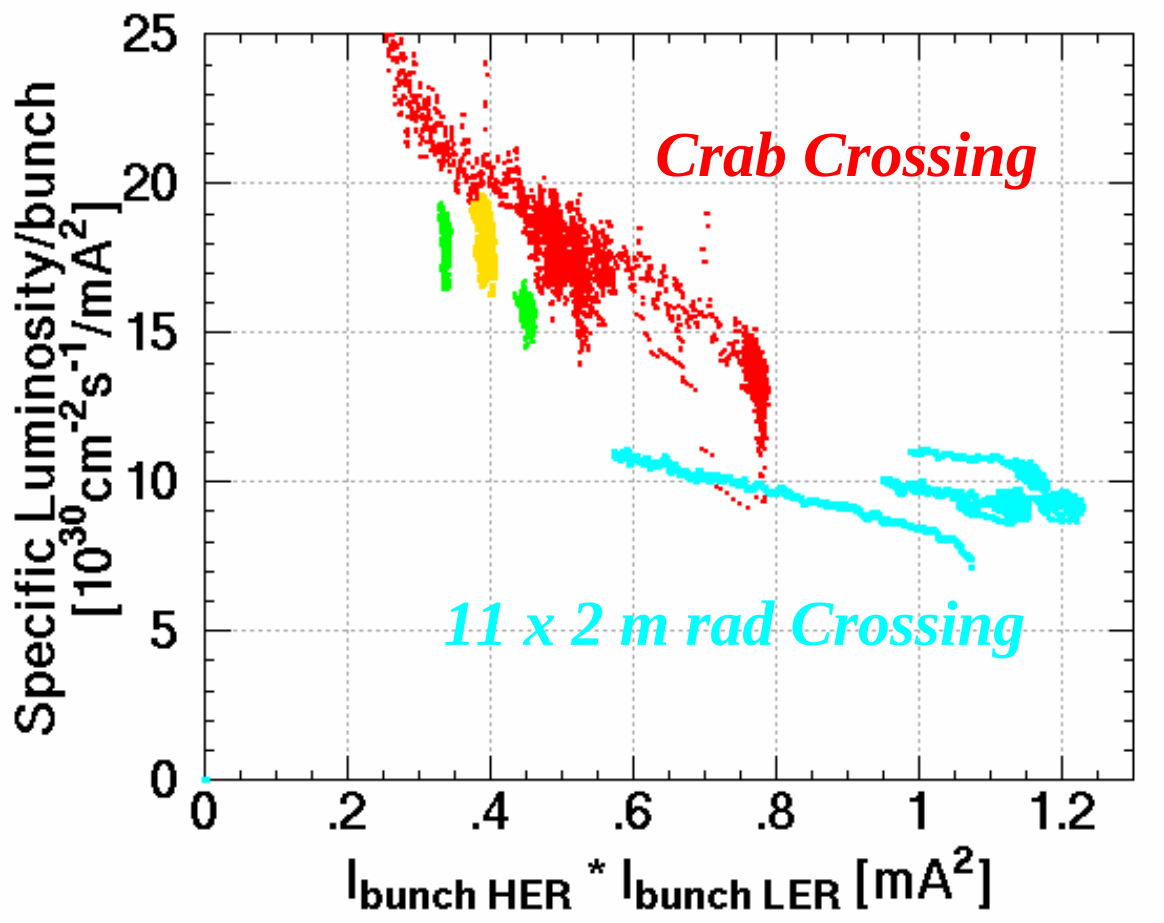
- Kick voltage of crab cavity LER has decreased to V_{kick} = 1.1 MV
- Piezo tuner of crab cavity LER failed.
- Lack of cooling power at coaxial coupler.

  Add bypass line to increase the gas flow.

Trip Ratio of Crab Cavities



Specific Luminosity of KEKB



Application of Superconducting Crab Cavity

Increase luminosity

- ILC 9-cell cavity 3.9 GHz
- LHC

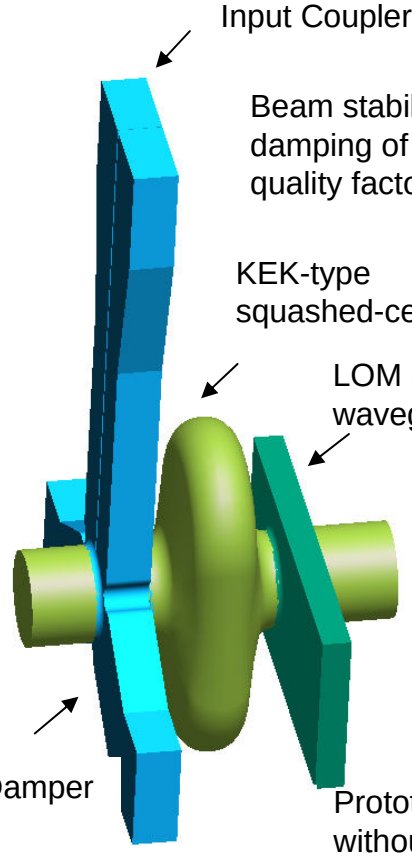
Short Pulse Light Source

- ANL APS 1-cell cavity 2.8 GHz
  (3-cell Normal cavity (Normal)
- LBNL ALS 2-cell cavity 1.5 GHz
- Spring-8 KEK type 500 MHz

Deflecting RF Cavity R&D
at LBNL
and
Tsinghua University

Courtesy Derun Li (LBNL)

APS
Superconducting Deflecting Cavity



Courtesy Katherine Harkay (ANL)