S0 Status for the 9-cell Cavities

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  1. Construction of the STF Cryomodule at KEK
  2. Cryomodule Tests of ACC#6 at DESY

PART - I

S0 Activities ;
Cavity Vertical Tests

1. KEK Tesla-type
2. DESY
3. JLab

Tesla-type STF Baseline Cavities at KEK

- Overview of the Baseline Cavity System
  - . System design feature
  - . Cavity fabrication and surface preparation
- Results of Vertical Tests
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- Particular Observation
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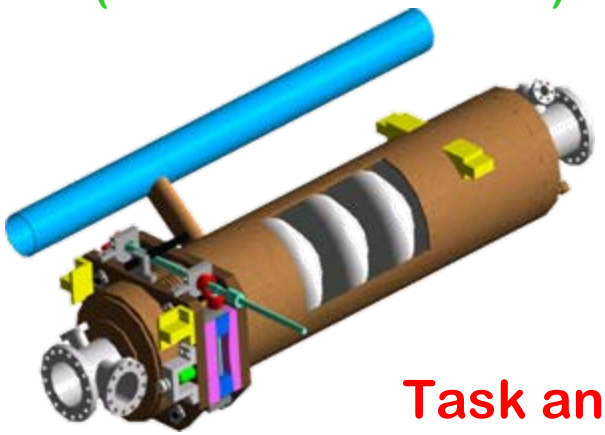
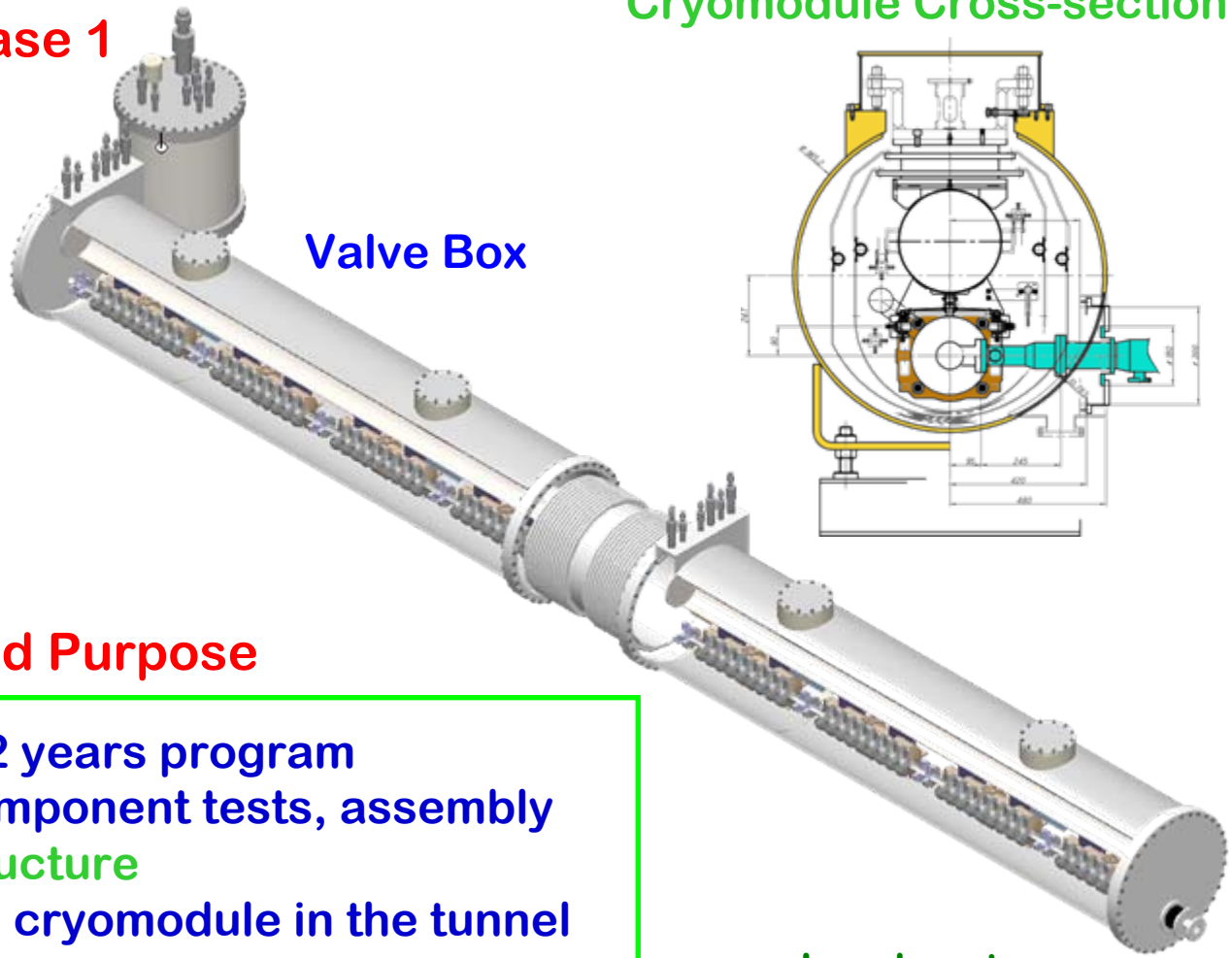
  - . Change of Field Flatness
- Toward the next step

Overview of STF Baseline Cavity System

Cryomodule for STF Phase 1

Tesla-type
STF Baseline Cavities
(Four 9-cell cavities)





Low loss type
High Gradient Cavities

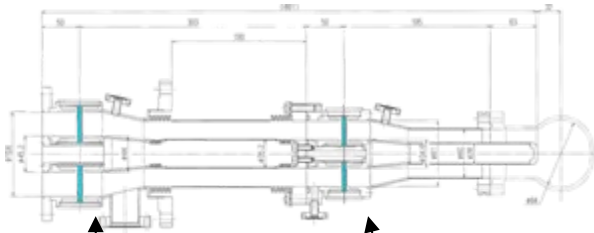
Cryomodule Cross-section

Task and Purpose

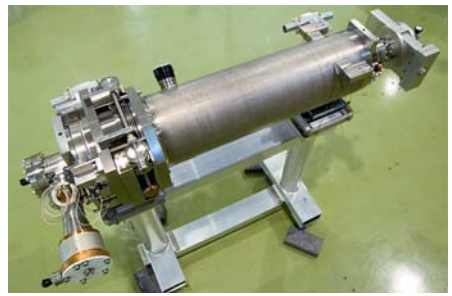
Started in April, 2005' ; 2 years program
. Design, fabrication, component tests, assembly
; using present infrastructure
. High power tests of the cryomodule in the tunnel
. Pulsed operation with beam
→ Construction of accelerator for beam operation
Check reliability as a total system with sc cavities

Tesla-type STF Baseline Cavity Package

Two Disk Window Input Coupler



Warm Window Cold Window

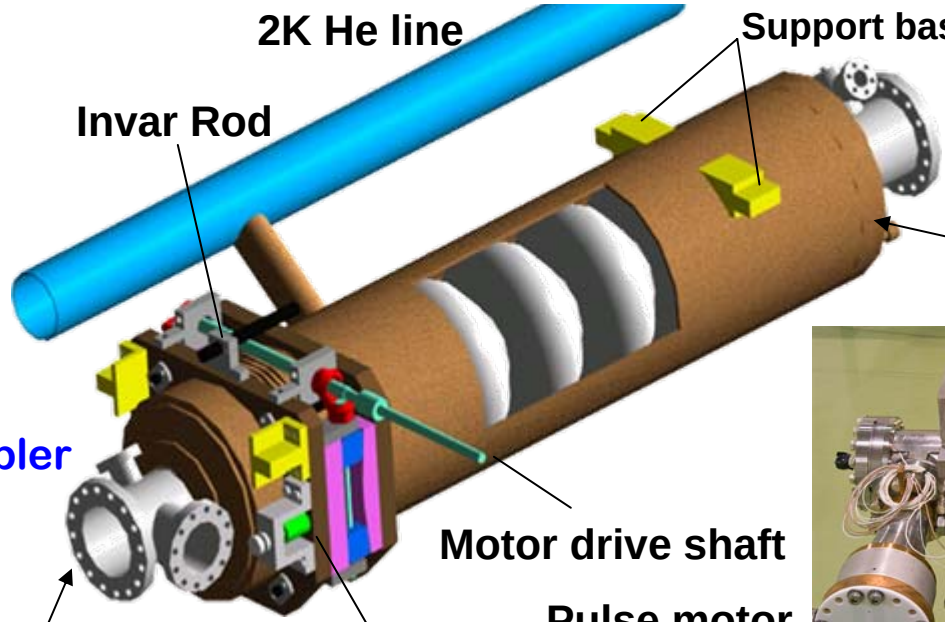


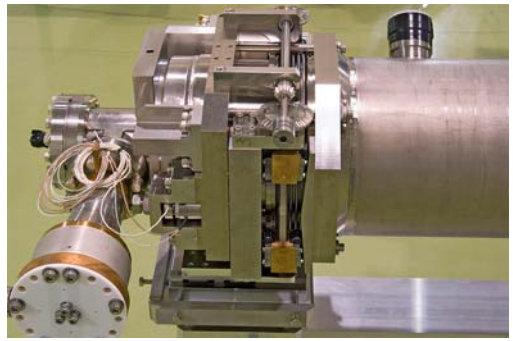
a Cavity covered with Ti Jacket

3 Cavities
(Vertical test)

Warm Coupler & Cold Coupler

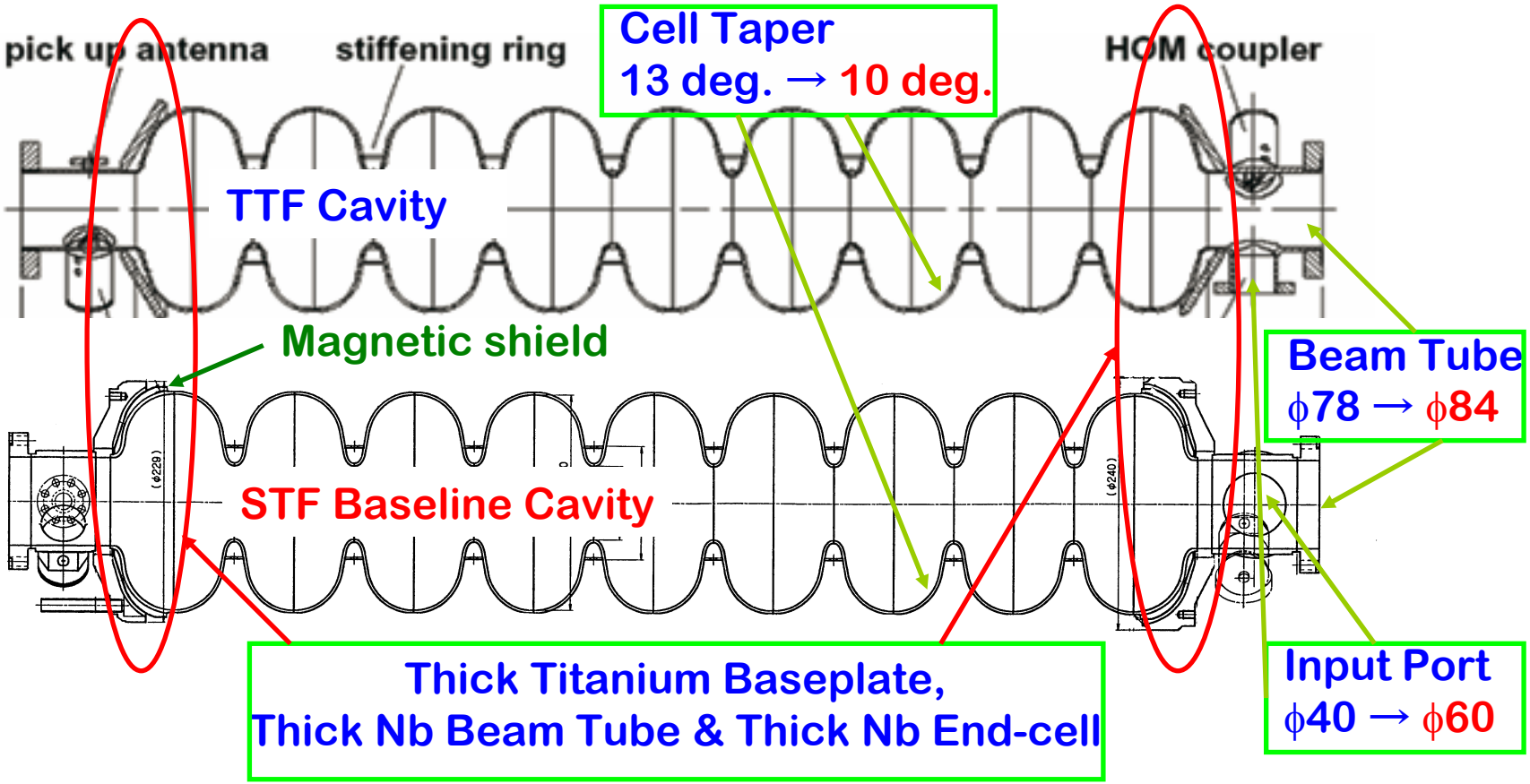
HOM Coupler





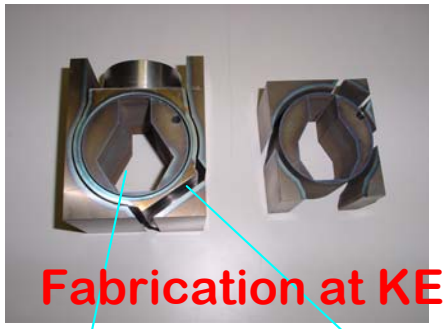
Slide Jack Tuner

STF Baseline Cavity ; Improved Stiffness



	STF Baseline Cavity	TTF Cavity	
Stiffness of Cavity			
Fixing Support	80 kN/mm	13 kN/mm	
Lorentz Detuning	-500 Hz	-1000 Hz	(31.5 MV/m)

Fabrication of STF Baseline Cavities

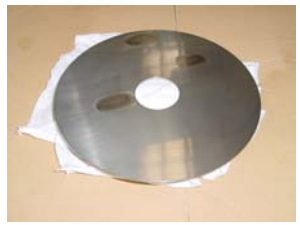


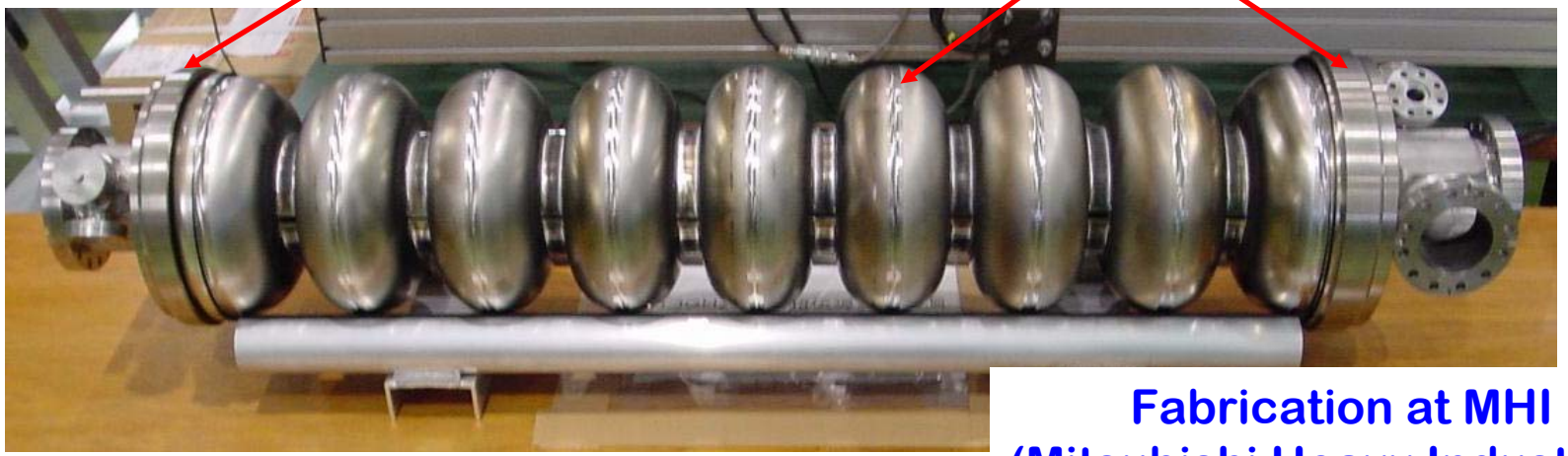
Fabrication at KEK-M.C.

HOM coupler

End-groups

Center-cells
(Tokyo Denkai ; RRR~300 Nb)





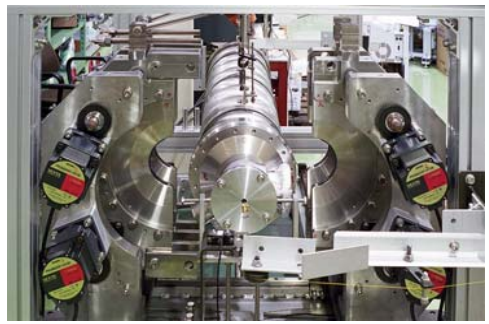
Fabrication at MHI
(Mitsubishi Heavy Industries)

Surface Preparation of STF Baseline Cavities

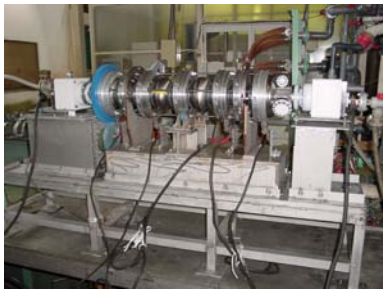
Barrel Polishing
~100 μm

Initial EP
100 μm

Anneal
750°C, 3h



Pre-tuning
fo, flatness, HOM filter

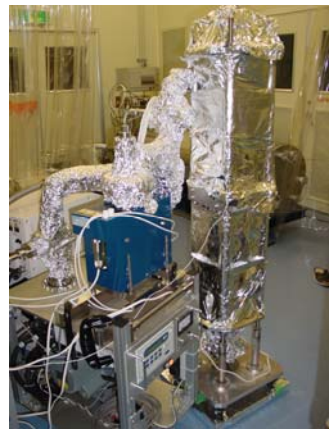


Final EP
50 μm
(20, 30 μm)

Hot Rinse with
ultra-sonic bath
50°C, 1h

HPR 8MPa, 6~16h

Assembly



Baking 120°C, 40h

Vertical Tests

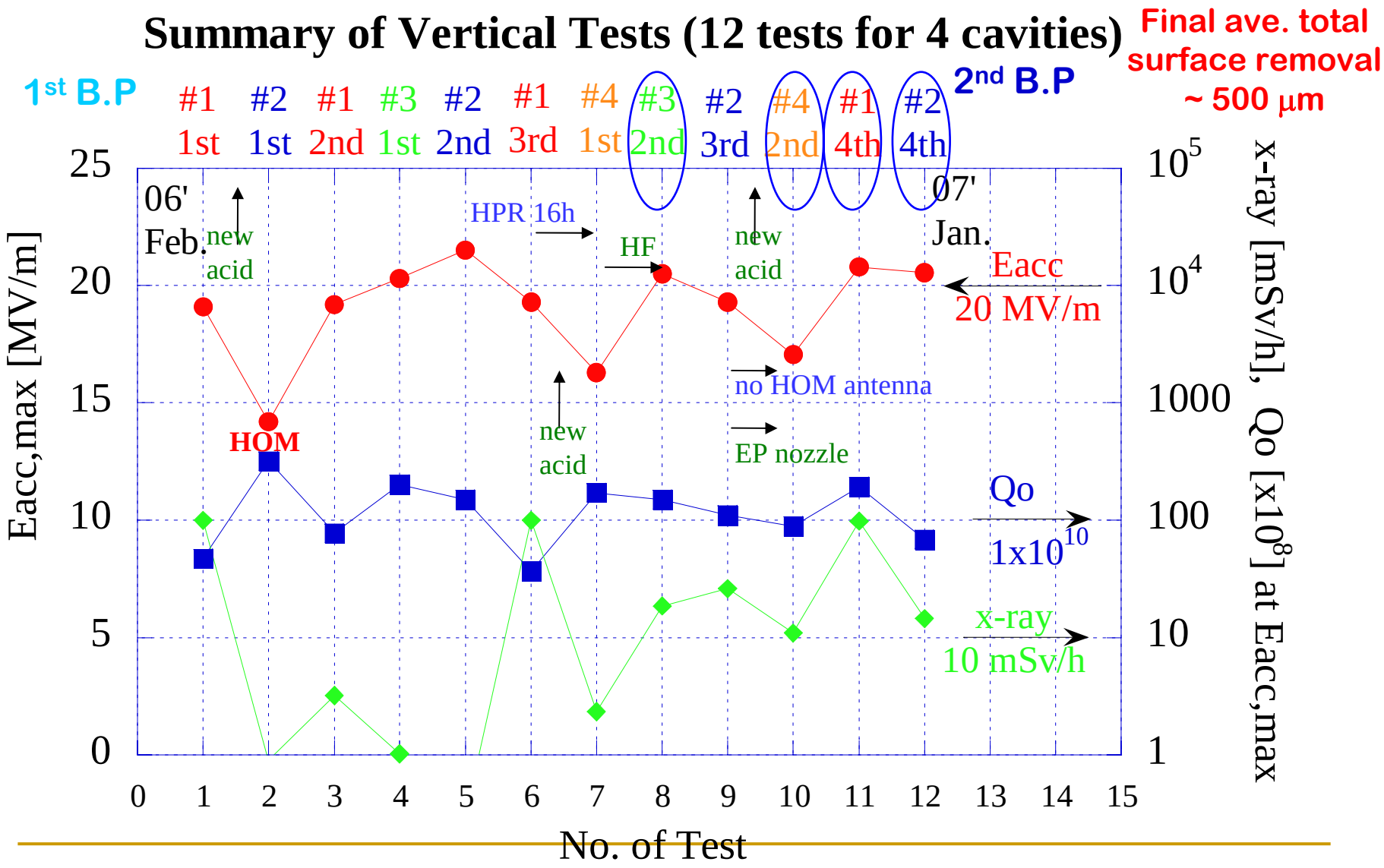
Making clear the performance level of four 9-cell cavities fabricated by a Japanese company (MHI) and prepared by existent infrastructures at KEK.
→ Starting point in the first step for us

- **Check and adjust of frequency, field flatness, HOM filter characteristics → consideration for a beam operation.**
- **Qo-Eacc curve, Eacc,max and x-ray radiation are standard data → Both Eacc (cell) by passband modes and heat spot (cell) by thermometry are also important.**
- **Cold leak test of vacuum seals in the same time**

→ confirmation of reliability.

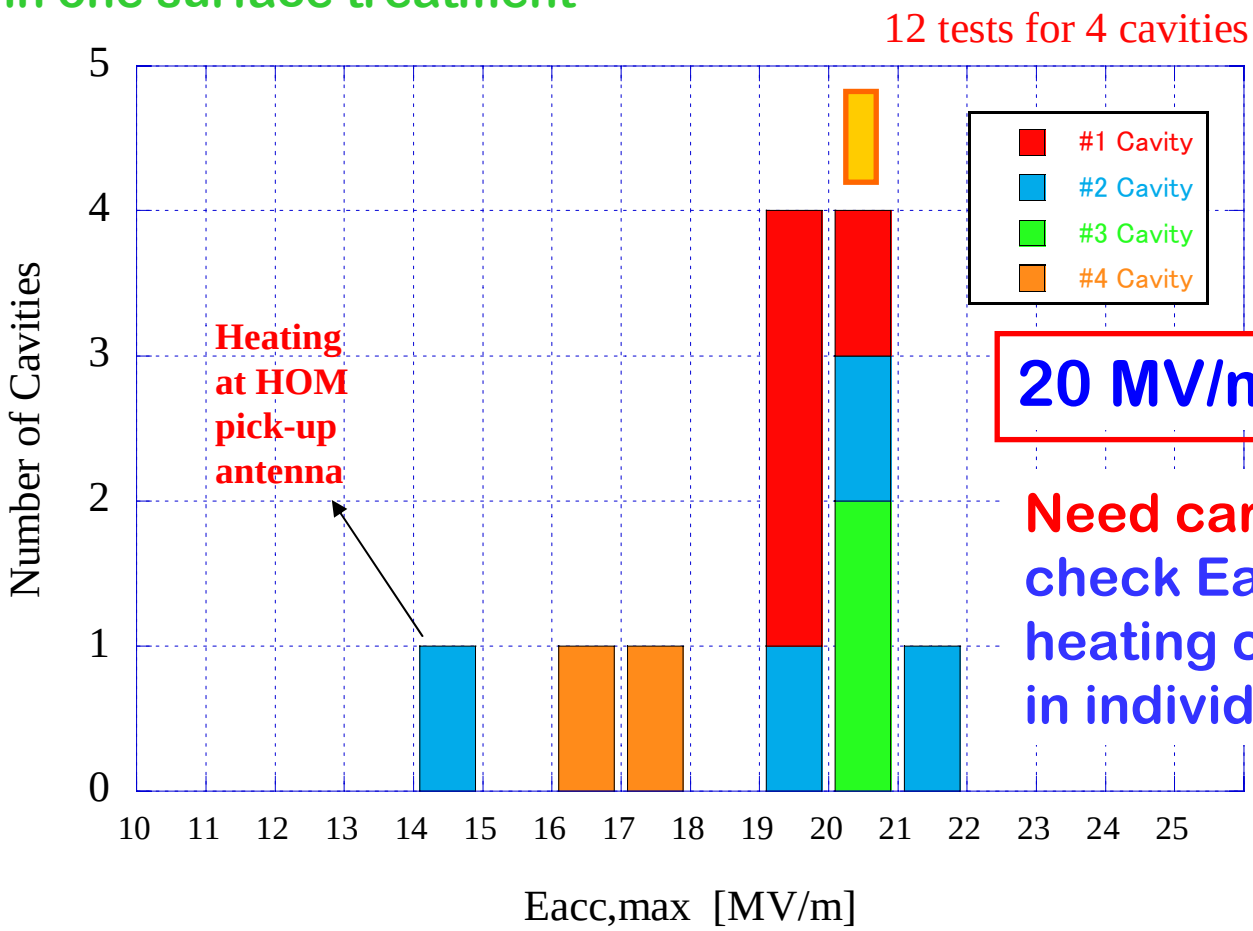
!! no hardware trouble and no vacuum leak in the V.T!!

Vertical Test Results (1), Eacc,max, Qo, x-rays



Vertical Test Results (2), Eacc,max

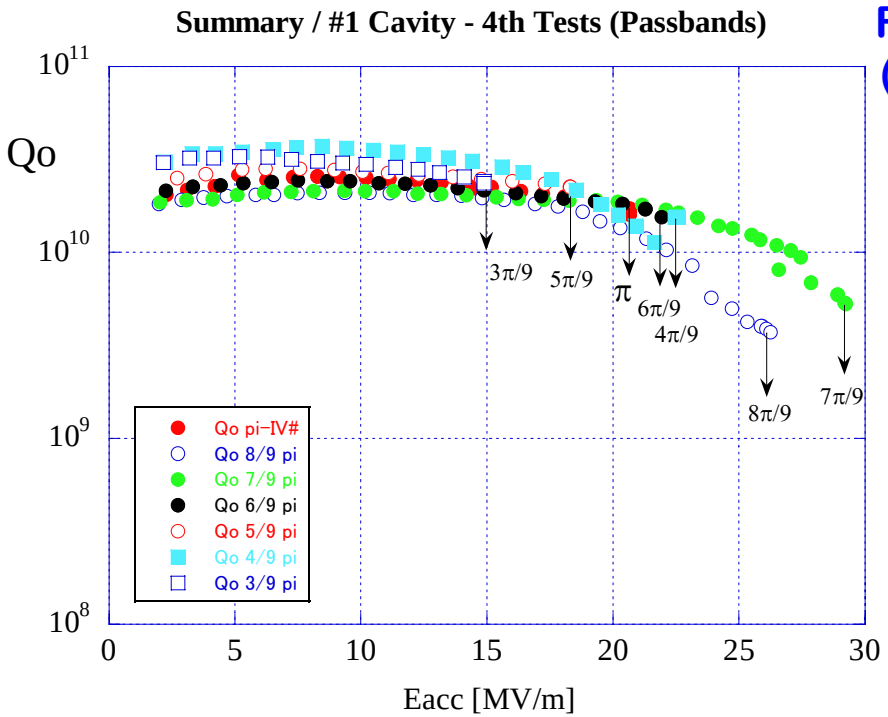
One Result ;
a final performance after processing in one surface treatment



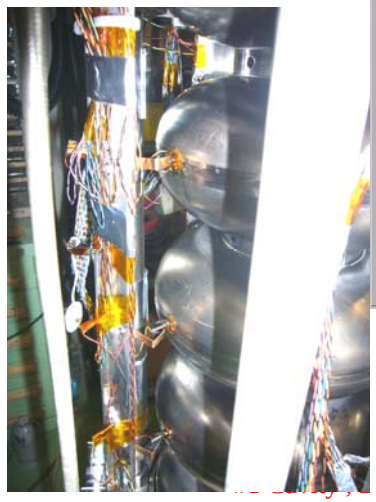
20 MV/m for 4 cavities

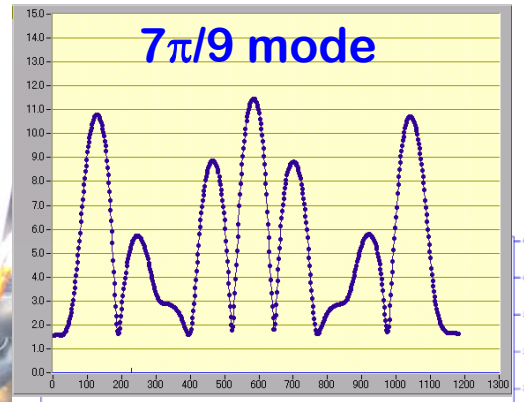
Need careful observation ; check Eacc of cell and heating cell by quench in individual cavity !!

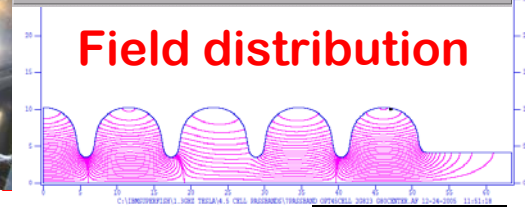
Vertical Test Results (3), Passbands meas.



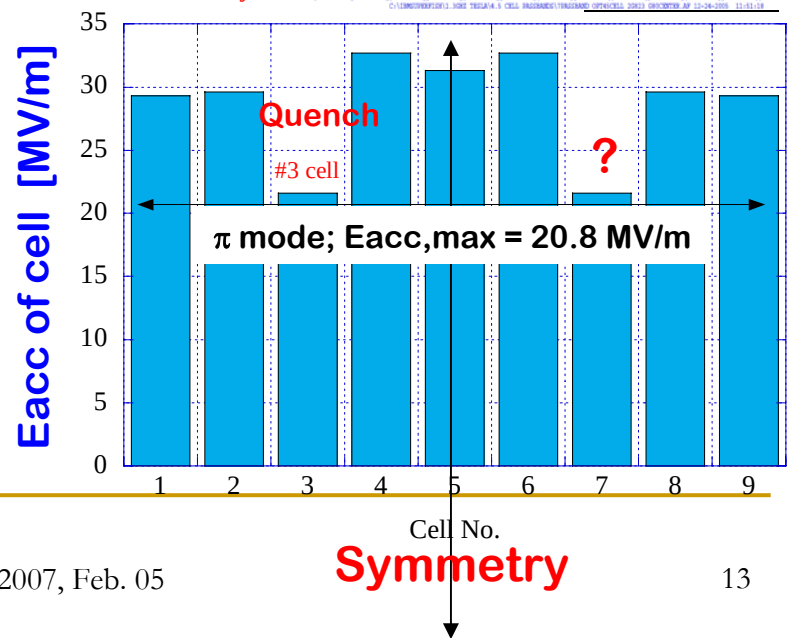
Fixed temp. sensors (every 90°, total~40)







Mode cell	π	8π/9	7π/9	6π/9	5π/9	4π/9	3π/9	Eacc, max
#1, #9	20.8	26.3	29.3	21.9	18.3	22.6	14.9	29.3
#2, #8	20.8	23.4	15.5	0	12.5	29.6	29.6	29.6
#3, #7	20.8	17.3	5.9	21.9	21.6	12.9	14.9	21.9
#4, #8	20.8	9.7	22.8	21.9	3.7	32.7	14.9	32.7
#5	20.8	0	31.3	0	23.3	0	29.6	31.3
Heating at	#3	#9	#9	#3	#3	?	?	MV/m

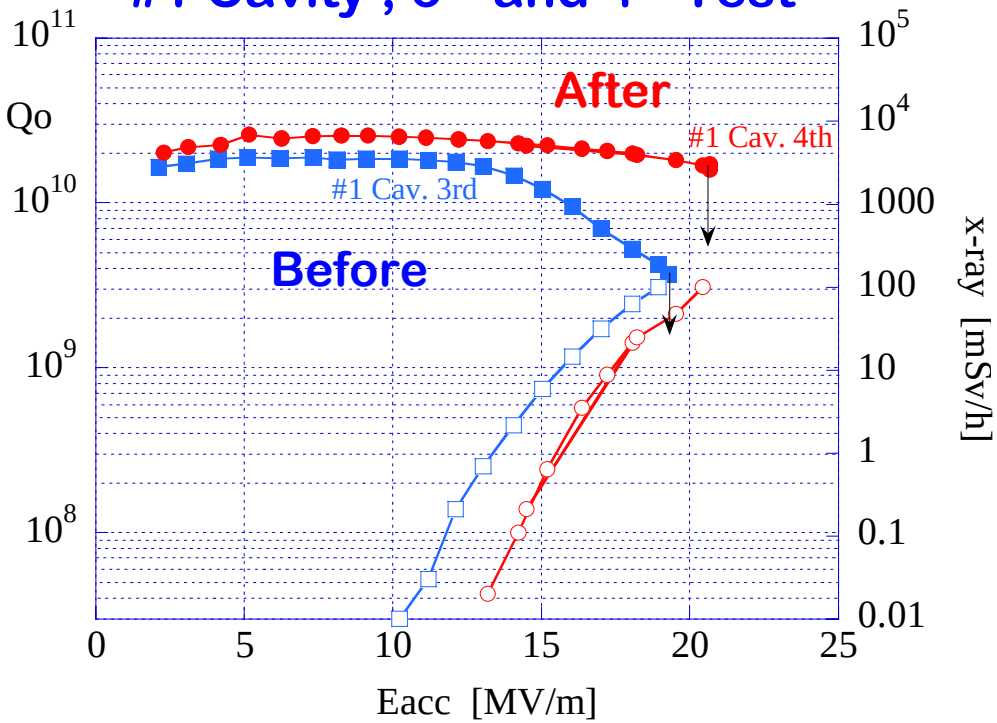


Vertical Test Results (4), #1 Cavity

Comparison before/after 2nd B.P.

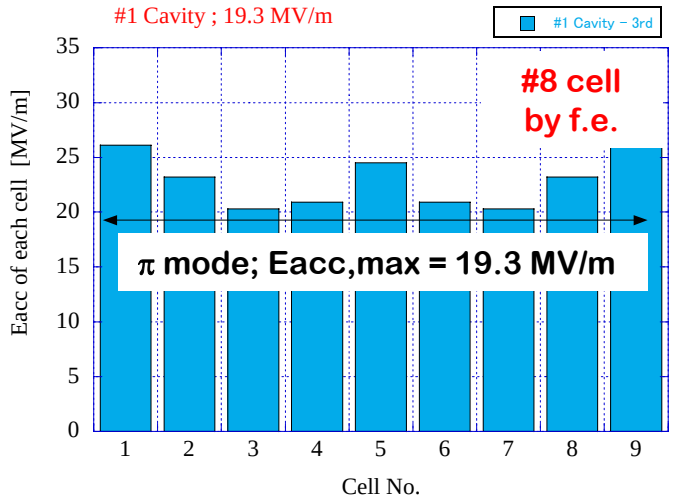
(additional surface removal of ~250 μm)

#1 Cavity ; 3rd and 4th Test

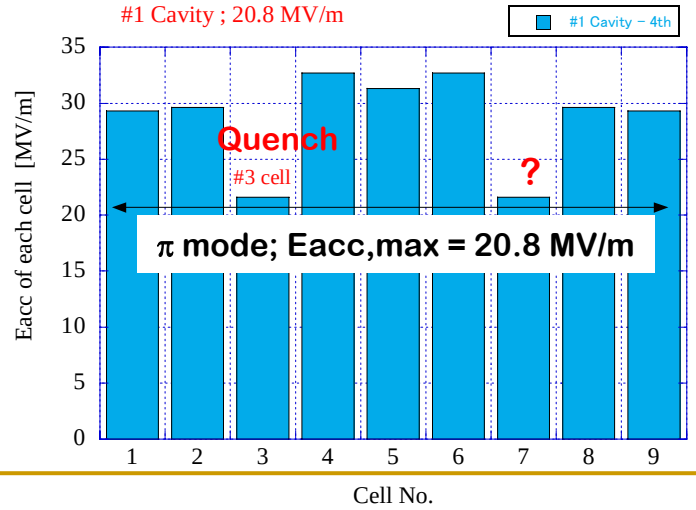


One cell is limited at ~20 MV/m (? #7), but others are ~30 MV/m.

#1 Cav. 3rd

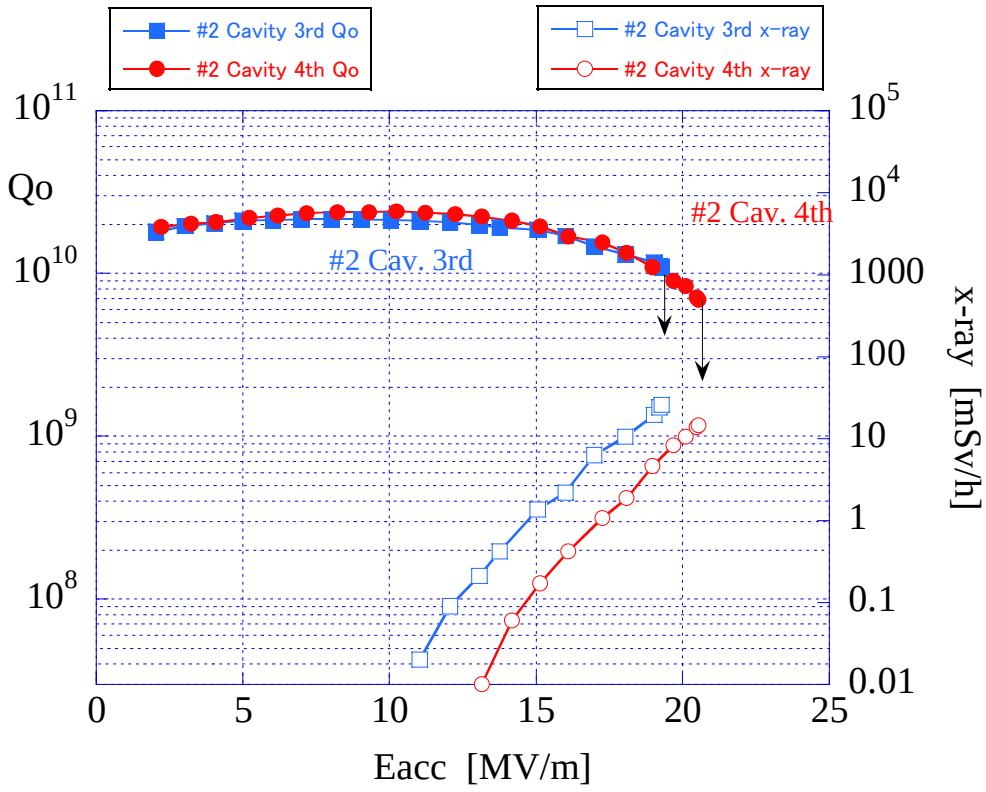


#1 Cav. 4th aft. 2nd Barrel Polishing



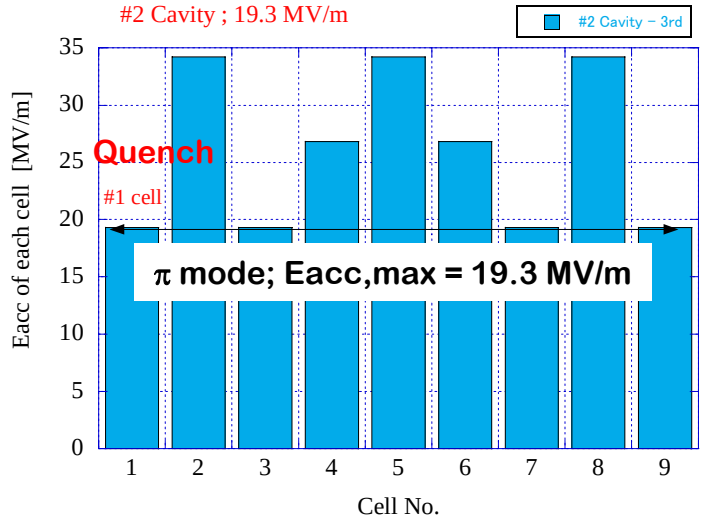
Vertical Test Results (5), #2 Cavity

#2 Cavity ; 3rd and 4th Test

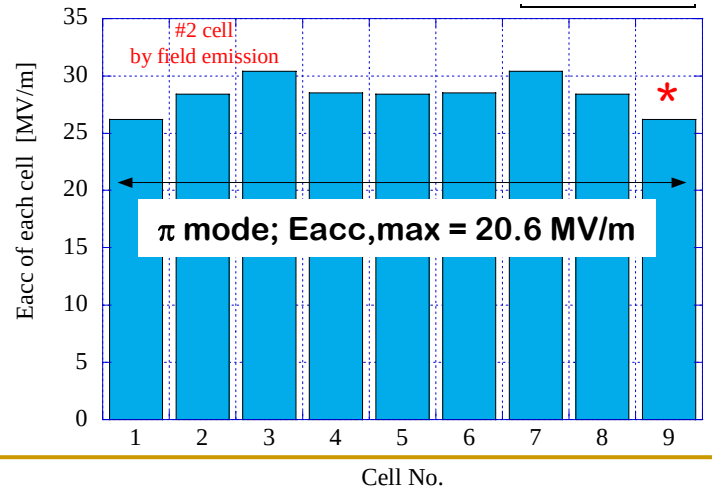


If no field emission,
Eacc,max~25 MV/m (#9) will be possible.

#2 Cav. 3rd

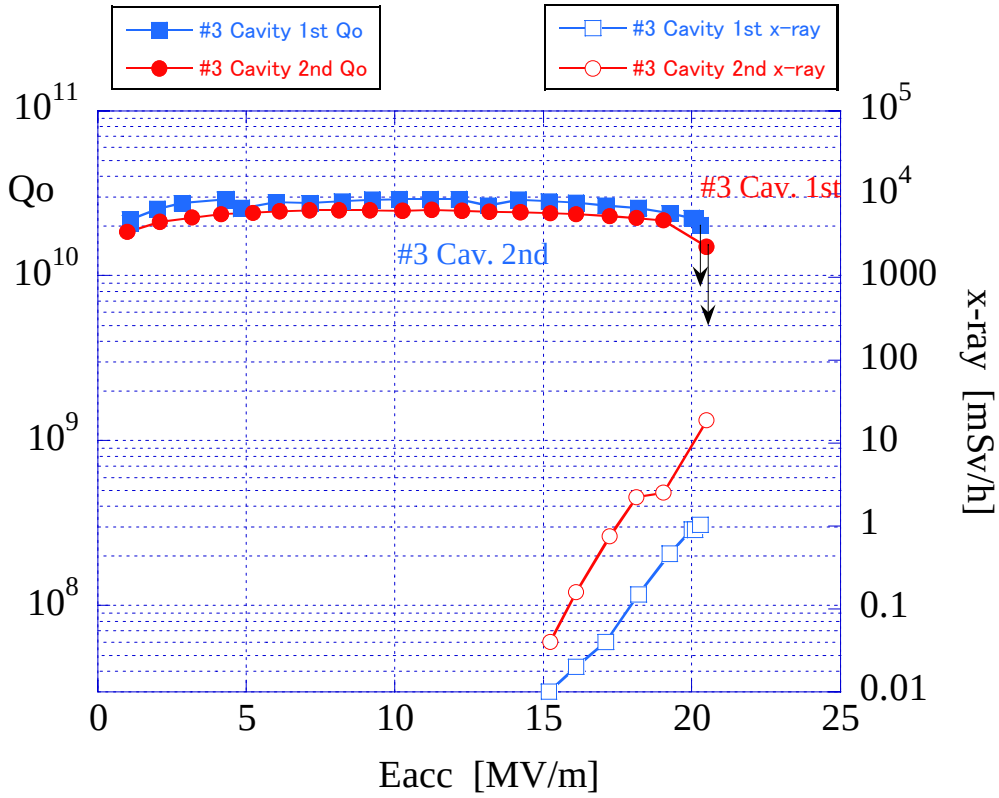


#2 Cav. 4th aft. 2nd Barrel Polishing



Vertical Test Results (6), #3 Cavity

#3 Cavity ; 1st and 2nd Test



Only one cell is limited at ~21 MV/m, but others are ~ 30 MV/m.

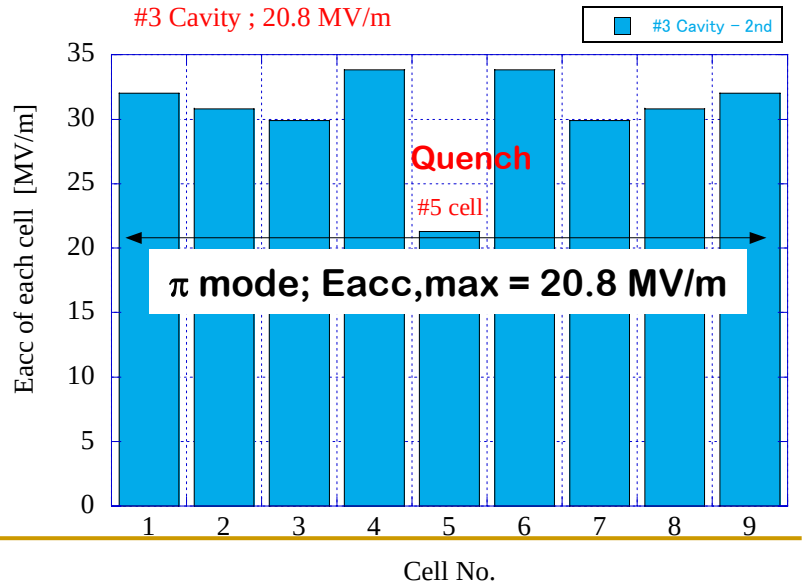
#3 Cav. 1st

#3 Cavity ; 20.3 MV/m

Sorry, no data !!

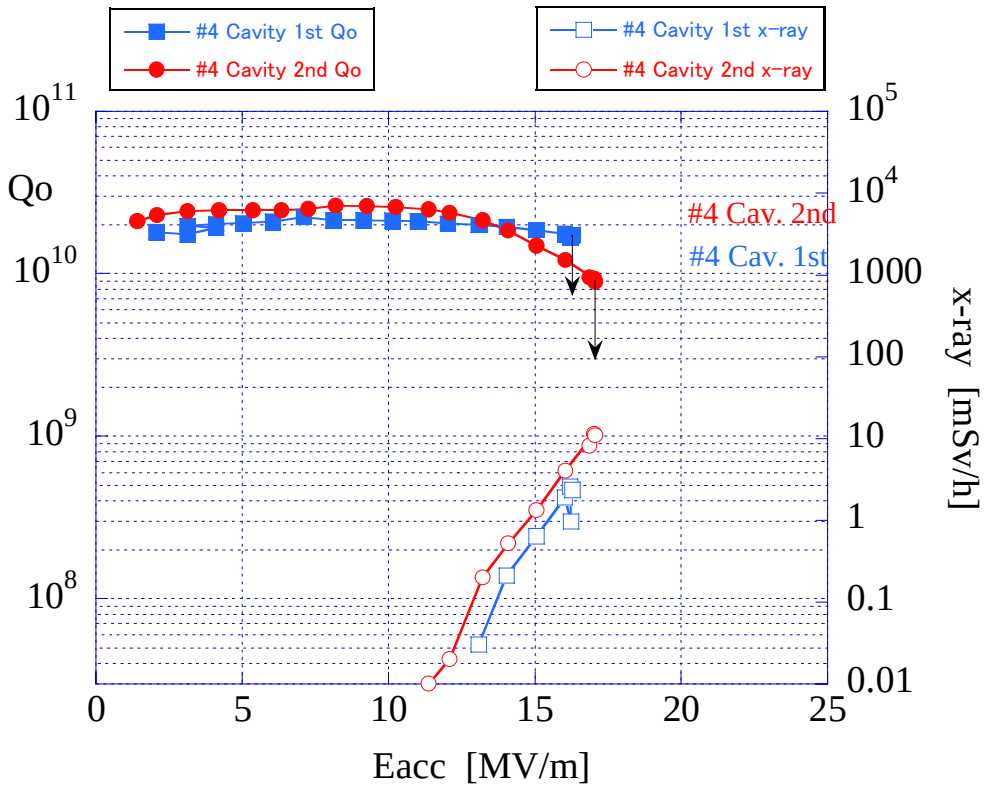
Every cell → 20.3 MV/m

#3 Cav. 2nd aft. 2nd Barrel Polishing

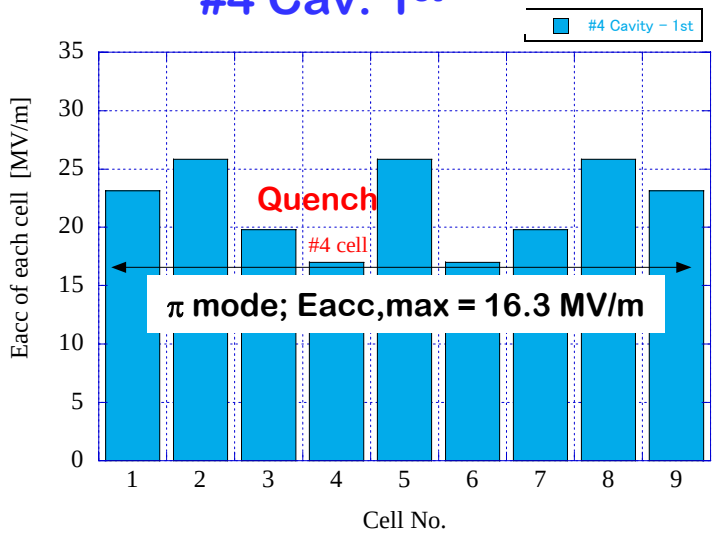


Vertical Test Results (7), #4 Cavity

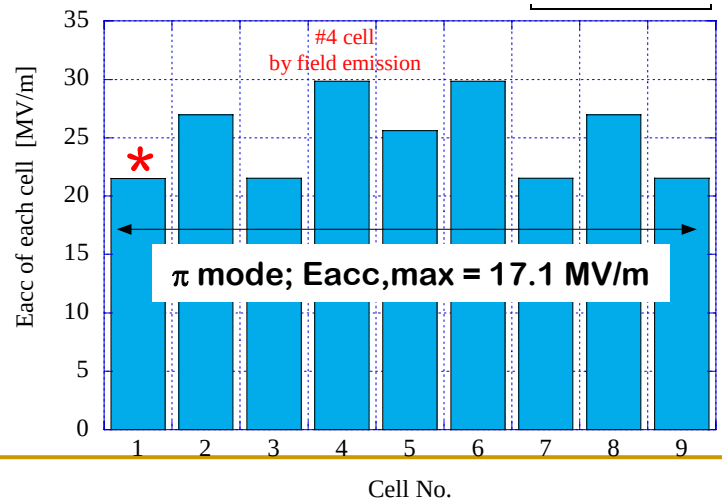
#4 Cavity ; 1st and 2nd Test



#4 Cav. 1st



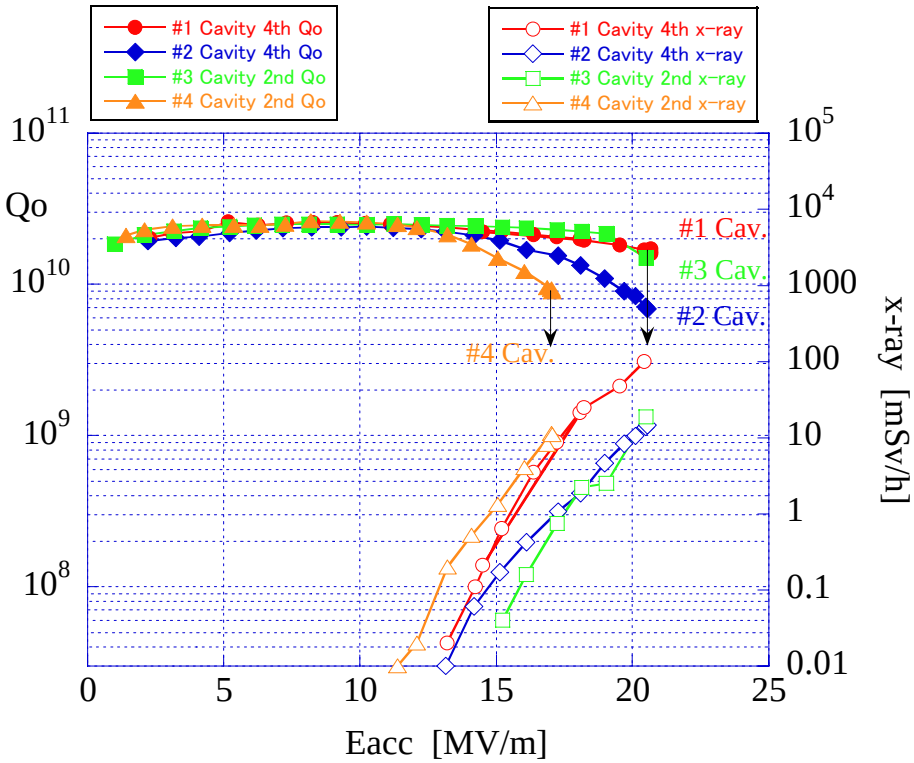
#4 Cav. 2nd aft. 2nd Barrel Polishing



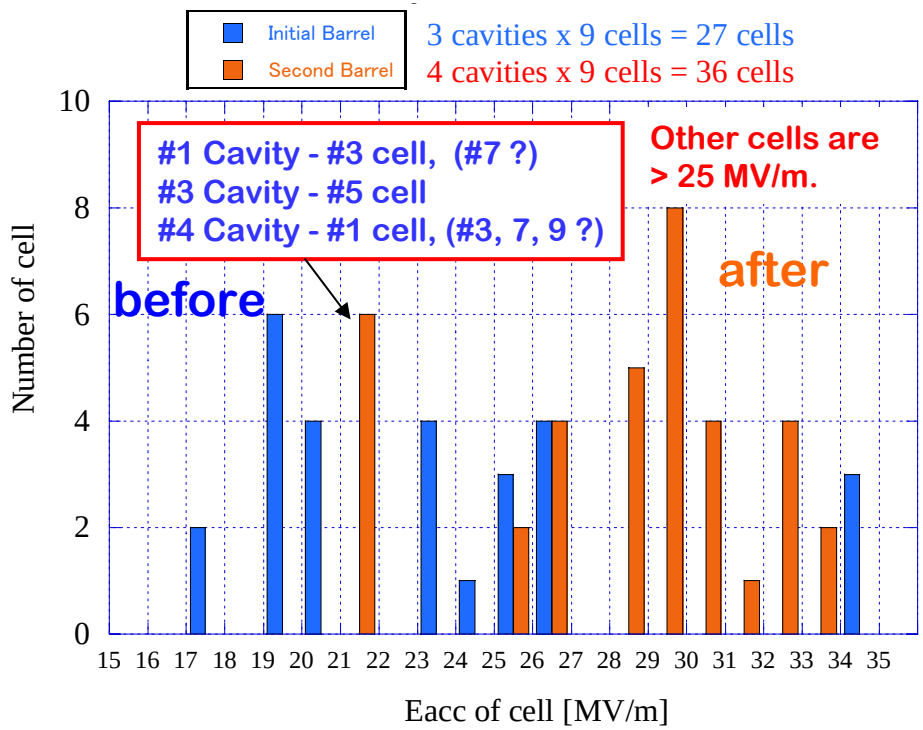
Even if no field emission,
Eacc,max is still limited at ~20MV/m (#1).

Vertical Test Results (8), Summary of 4 cavities

Final Results



Before (total~250 μm), after 2nd BP (total~500 μm)

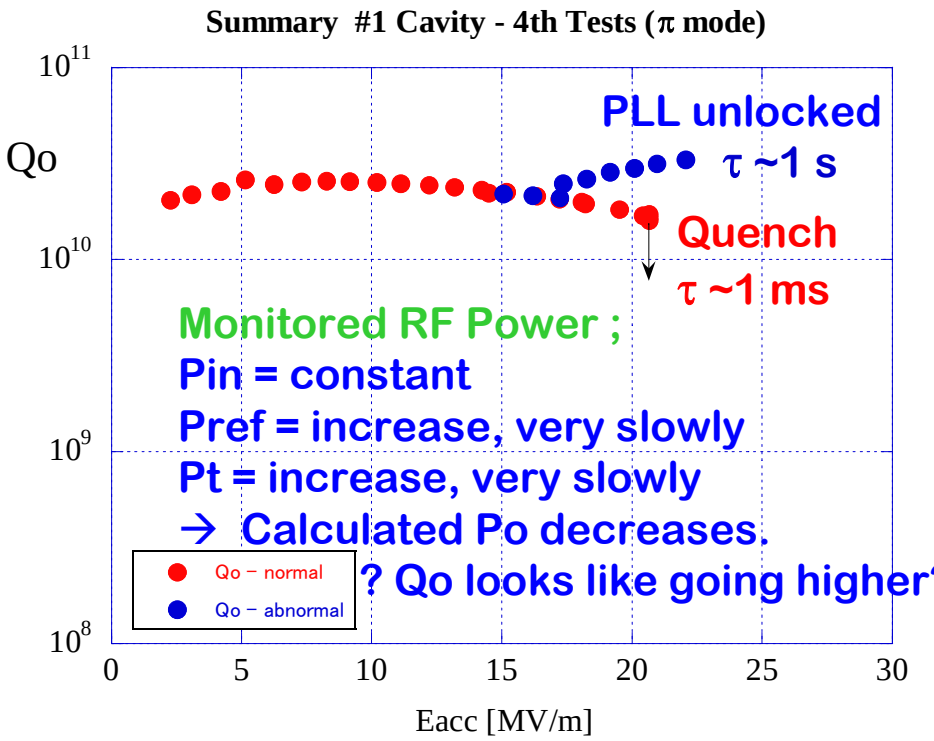


Two cavities were limited by quench caused by field emission.
X-rays started at 11~15 MV/m, and the level was 10~100 mSv/h at Eacc,max.
After the 2nd barrel polishing (total surface removal ~ 500μm), the distribution of Eacc-cell shifted to higher fields, but only one cell among nine cells was still ~20MV/m. The nine-cell performance was limited by the lowest cell. !!

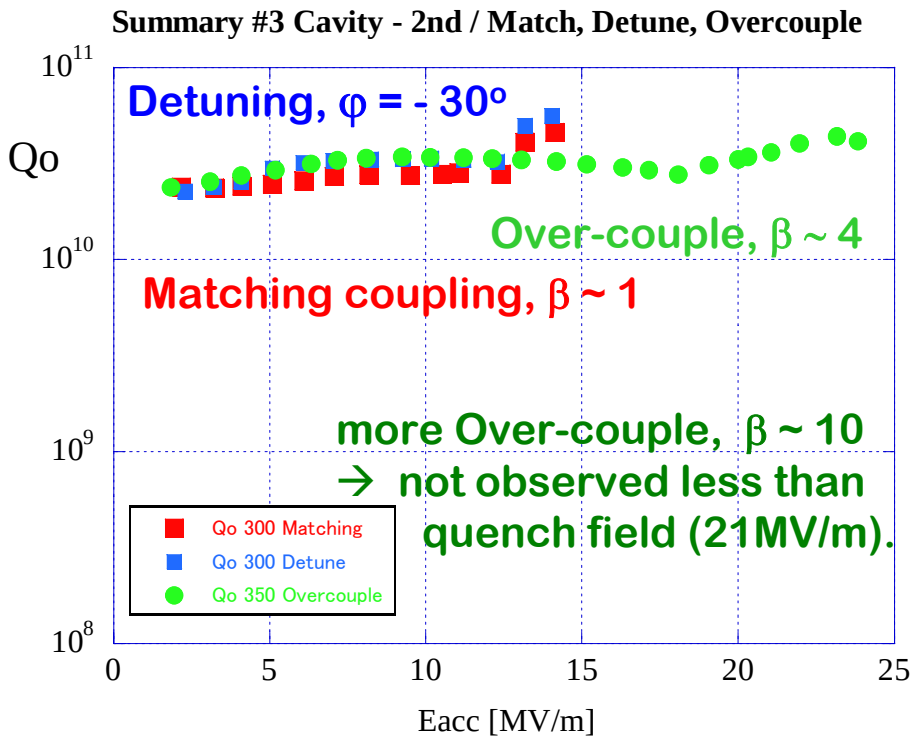
Passband Excitation (1)

Strange Phenomenon ;
?? The Qo value goes up with the Eacc ??

#1 Cavity – 4th Test



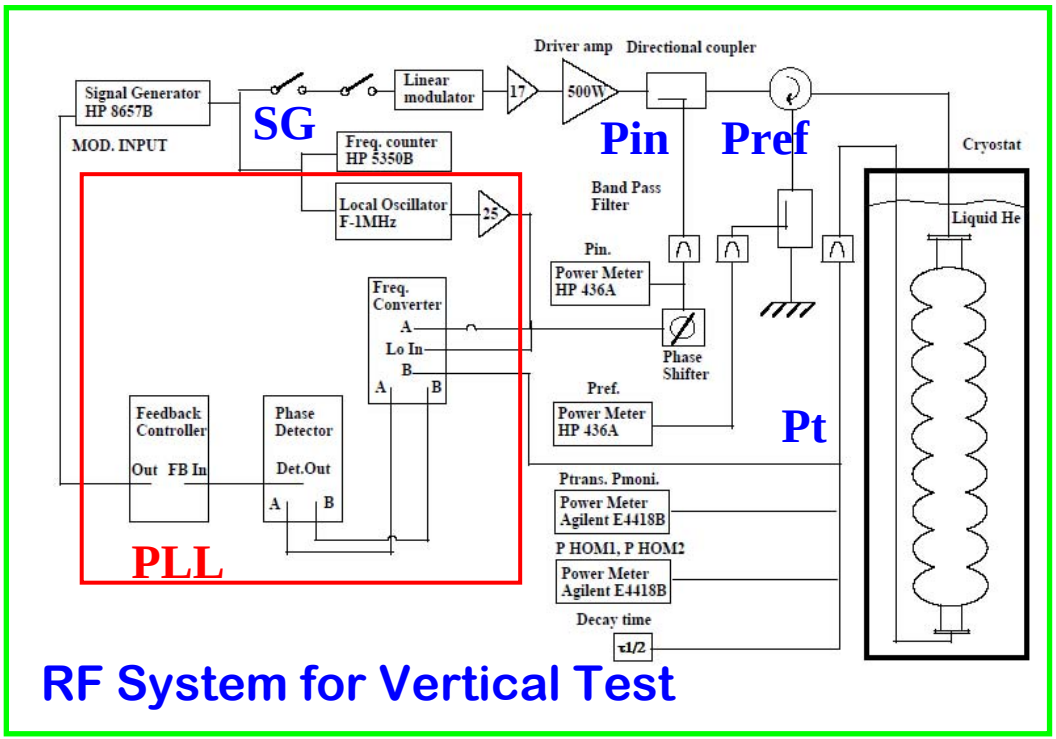
#3 Cavity – 2nd Test



Passband Excitation (2)

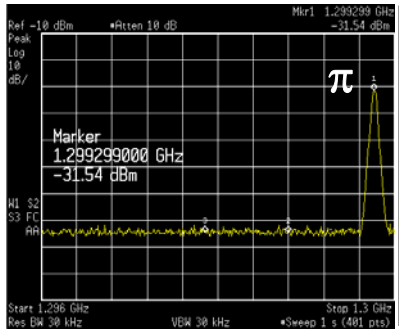
Abnormal state ;
Eacc = 16.2 MV/m
Qo = 2.4 x 10^{10}

Checking of the Frequency Spectrum in each monitored RF Power

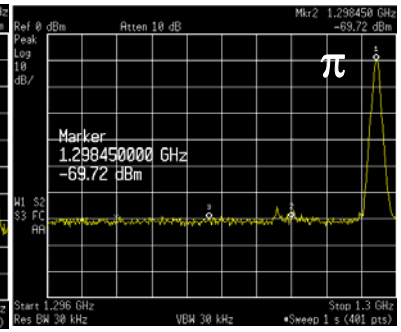


RF System for Vertical Test

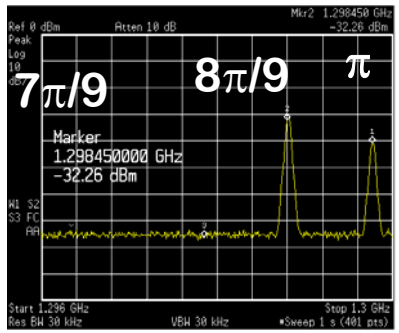
SG



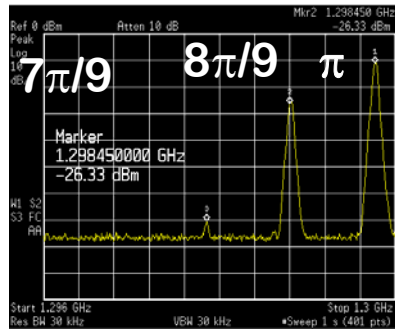
Pin



Pref



Pt

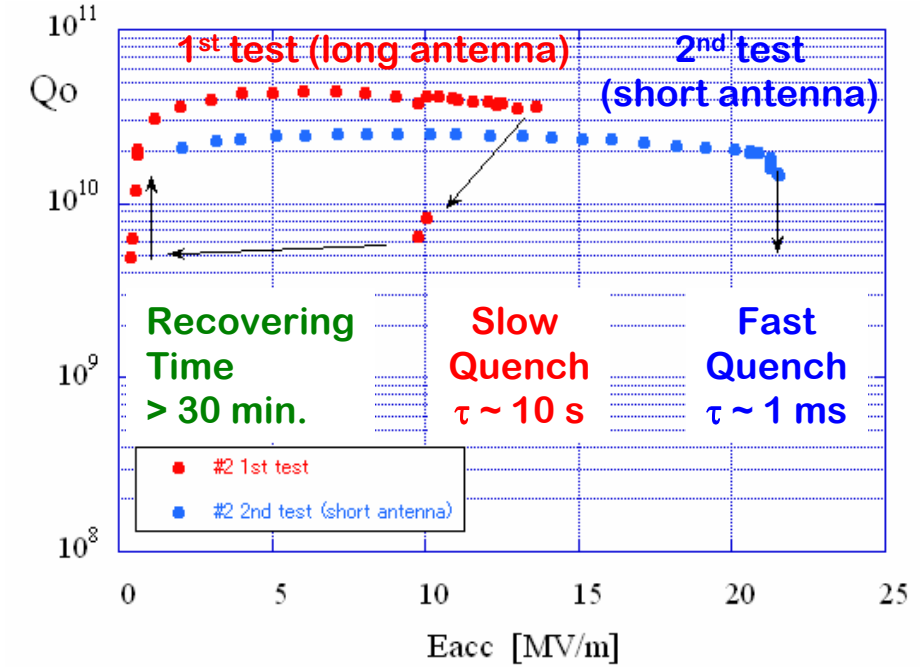


Incident power is only fundamental π mode.
But, 8π/9 mode is excited inside the cavity !!

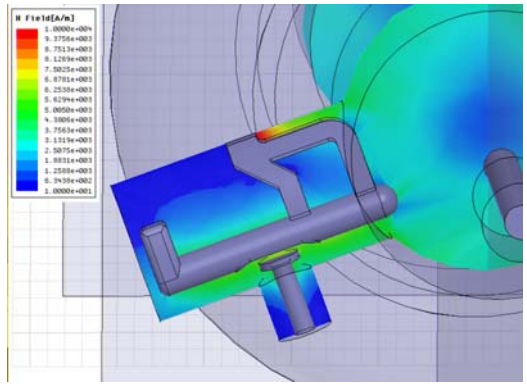
π mode : 1299.30 MHz
8π/9 mode : 1298.46 MHz
7π/9 mode : 1296.06 MHz

Similar excitation was also observed at DESY, but 7π/9 mode.

Heating at HOM pick-up antenna

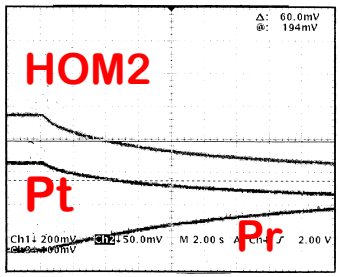


$H_{antenna\text{-}tip} \sim Hsp / 20.$



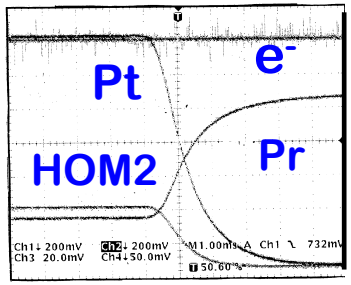
At Eacc = 10 MV/m,
ΔPo = 8 W
P-loss (cal.) = 2 W x 2

Slow Quench ~ 10 sec.



2 sec/div.

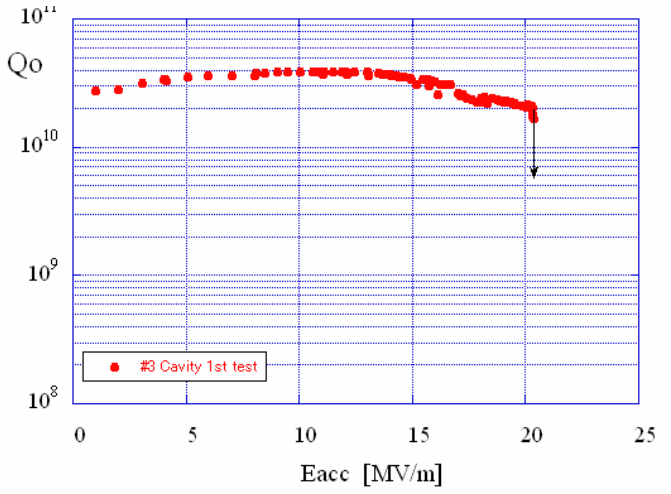
Fast Quench ~ 1 msec.



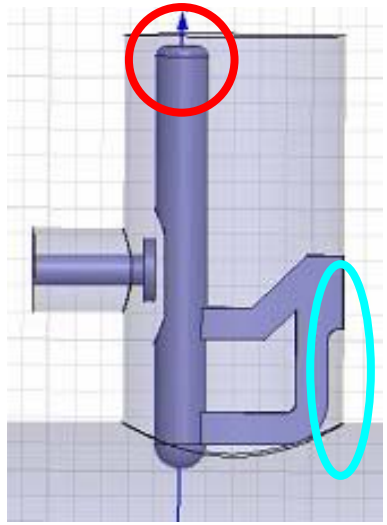
1 msec/div.

Transition from SC state to normal state occurred at the location isolated thermally.

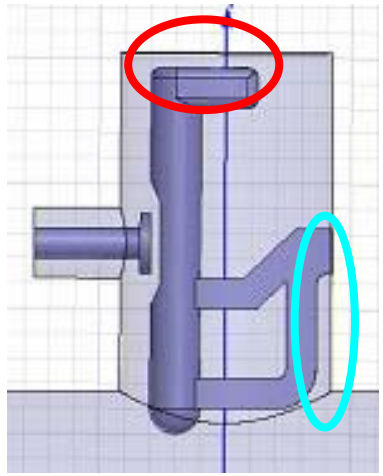
Multipacting at HOM couplers



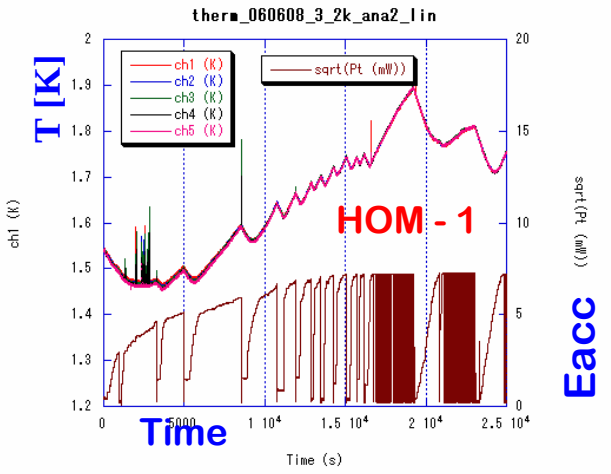
HOM - 1

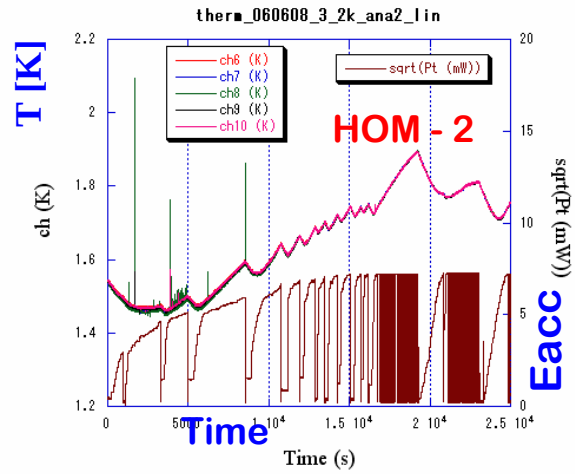


HOM - 2

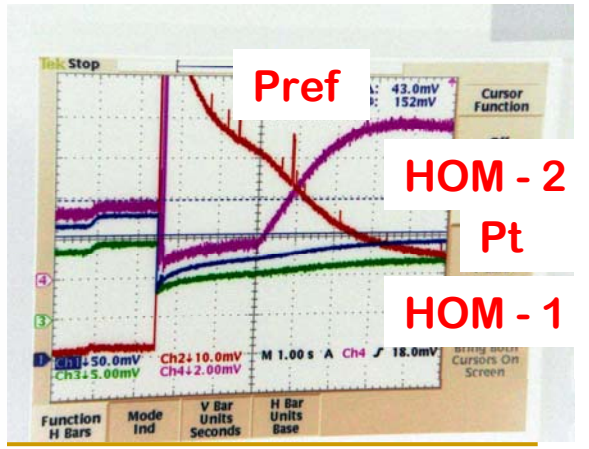


Heating at HOM couplers was observed at Eacc = 2~16 MV/m.

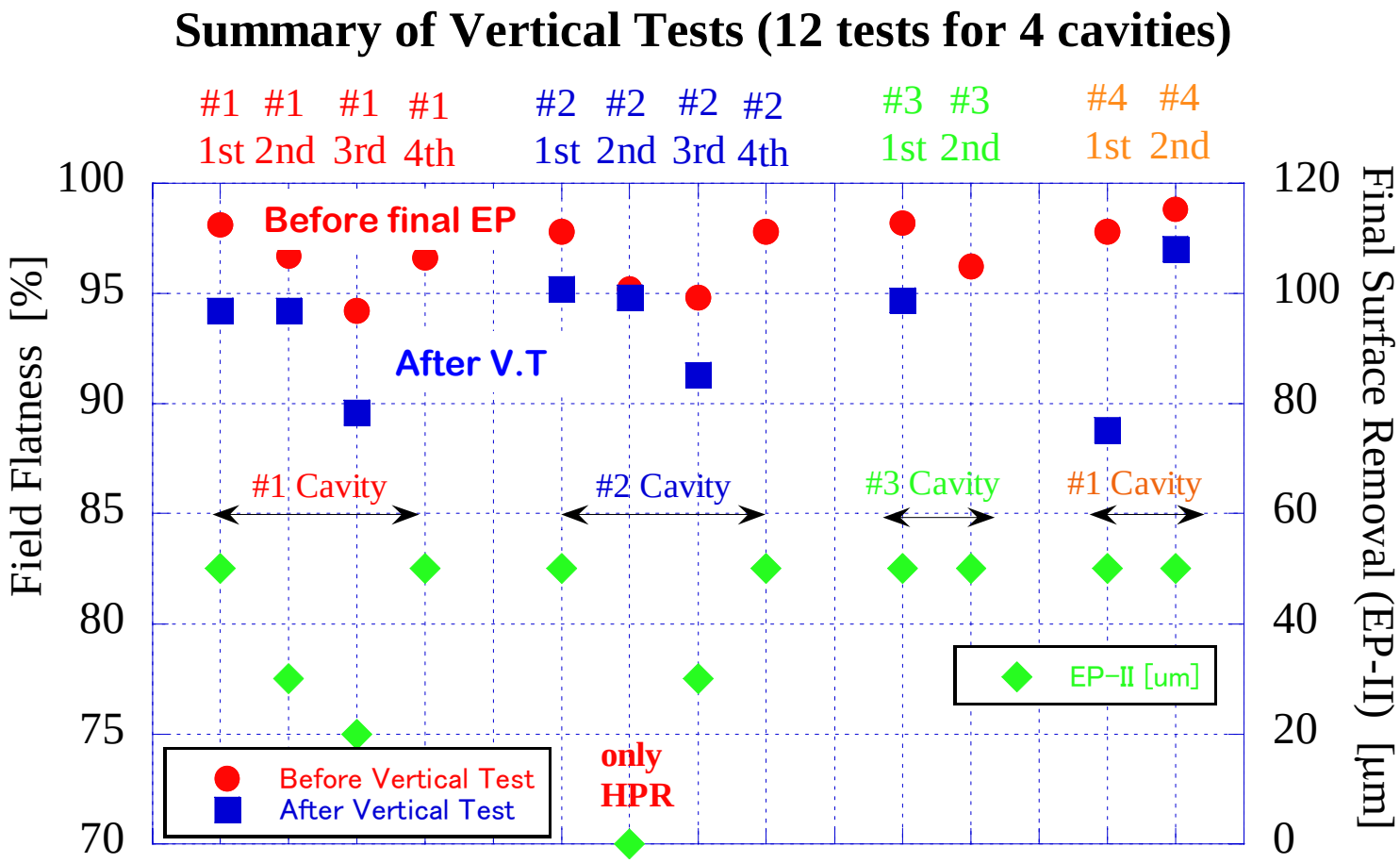




#1 2nd, Eacc = 2.4 MV/m, 1 s/div.



Change of Field Flatness (1)

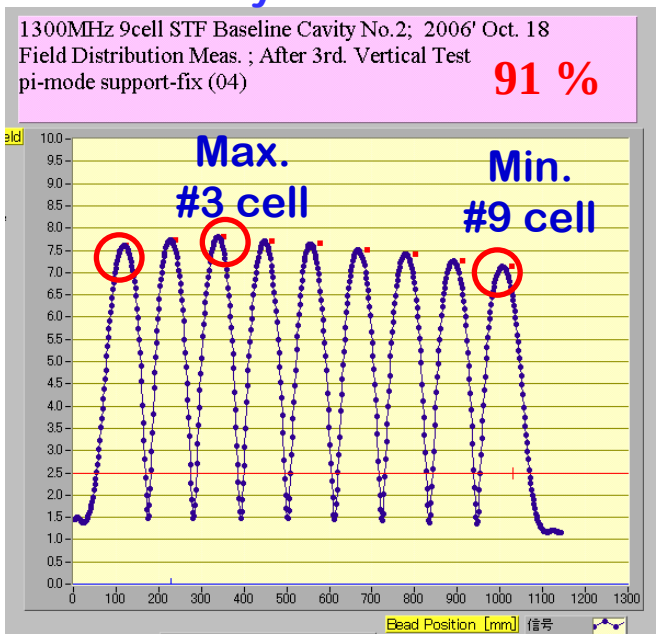


Change of Field Flatness less than ~ 4 % (excpt. 1 case)

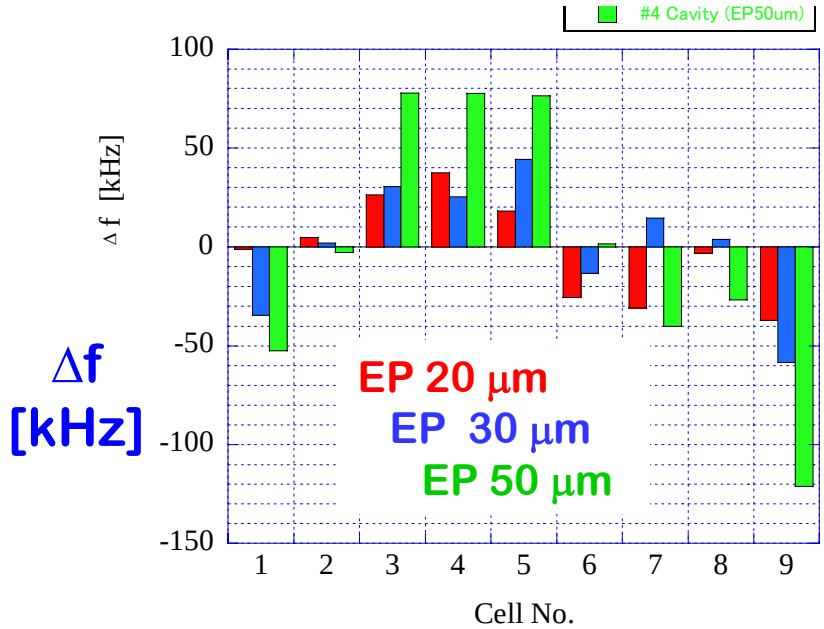
Potential cause; transportation, handing, not uniform EP, …

Change of Field Flatness (2)

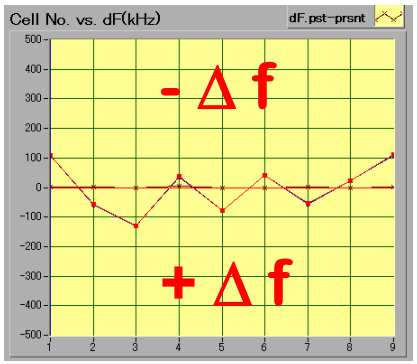
#2 Cavity after 3rd V.T



Frequency Change in each cell by EP



Deviation from ideal fo in each cell



Amount of surface removal by EP seems to be not uniform in each cell.
Temperature outside of cells and acid flow rate inside cells during EP have a very similar distribution.

Improvement of flow rate in each cell

→ Change of field flatness < ~2%

Towards the next step
(Summary of the vertical tests at KEK)

Achieved Eacc,max in vertical tests :
→ 20 MV/m for four cavities
lower than our expectation (> 25 MV/m)

- **Need further strict quality control in both cavity fabrication process and surface preparation for the next cavities (Phase 1.5)**
  - → improve welding procedure and clean environment at MHI
  - → construction of new infrastructures at STF, (now ongoing)

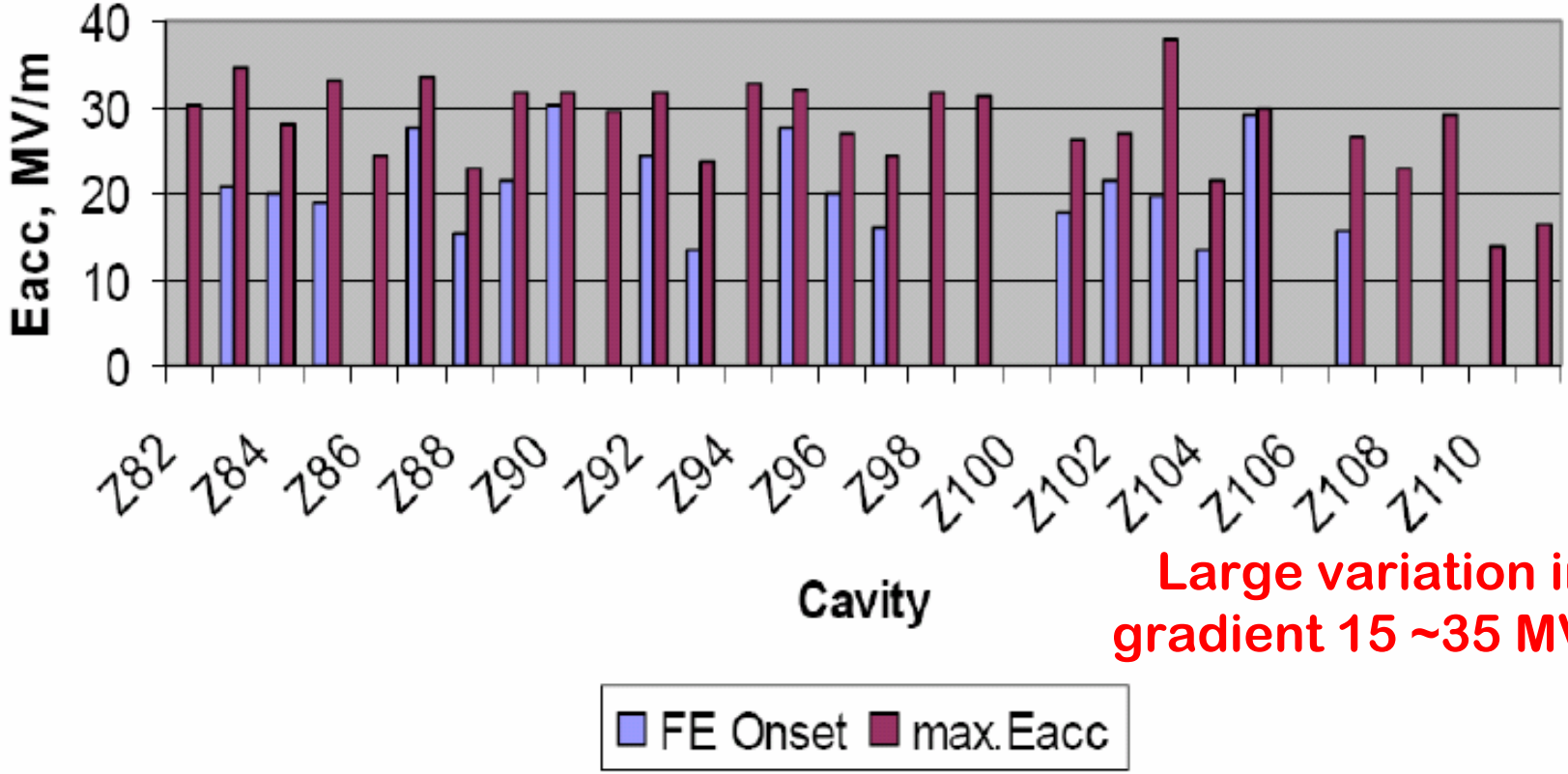
- **Cryomodule test after string assembly of four cavities:**
  1. Pulsed operation at 20 MV/m without degradation
  2. Suppression of Lorenz force detuning by improved cavity stiffness
  3. Compensation of Lorenz force detuning by a piezo-tuner

Low-Power Test Results of Recent Cavity Production (DESY)

By L. Lilje (DESY)

Z82-Z111, best RF result

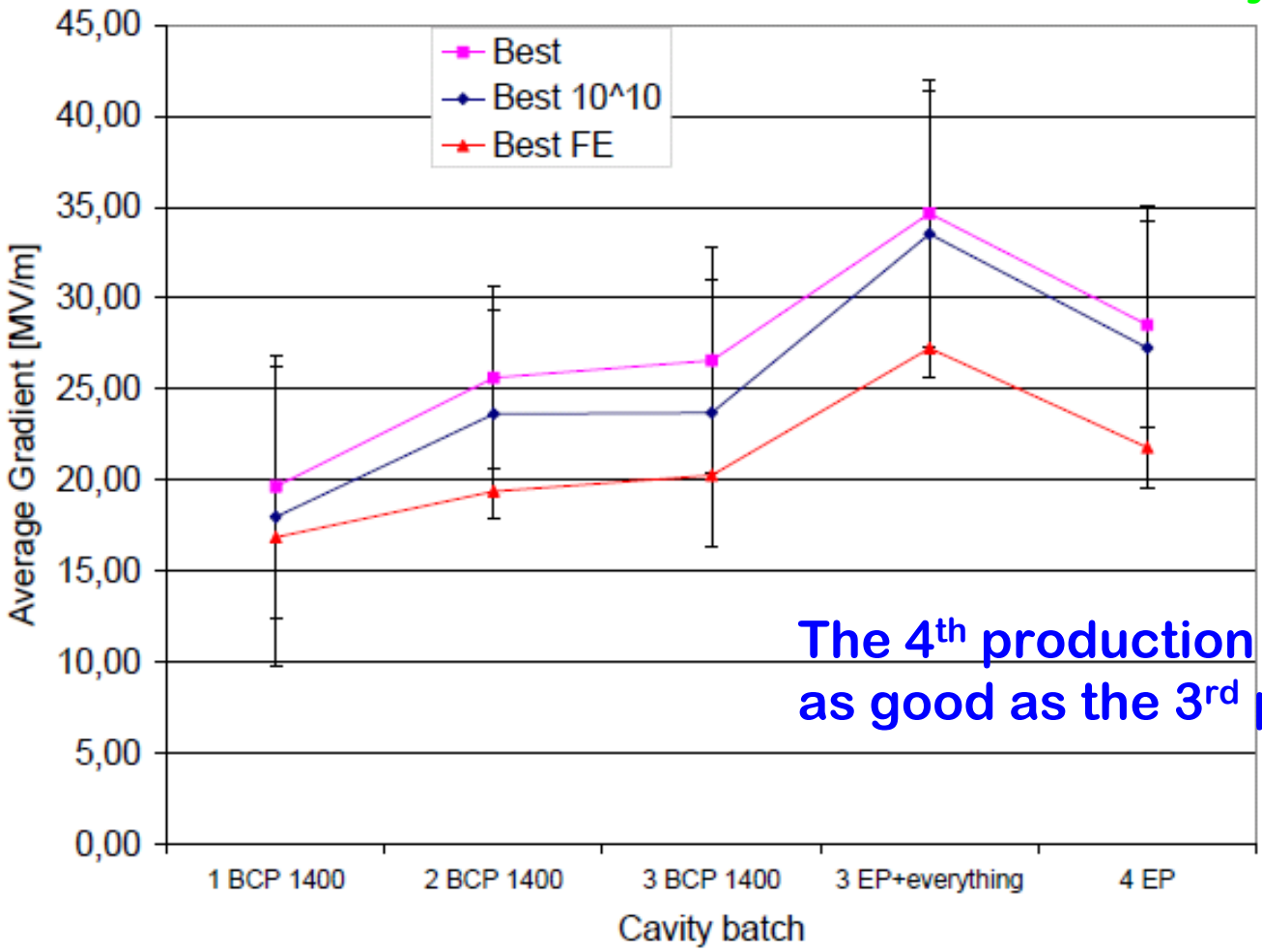
28 tests for 15 cavities



Large variation in gradient 15 ~35 MV/m

Cavity Production Cycles History (DESY)

By L. Lilje (DESY)



The 4th production was not quite as good as the 3rd production.

Cavity Production at DESY

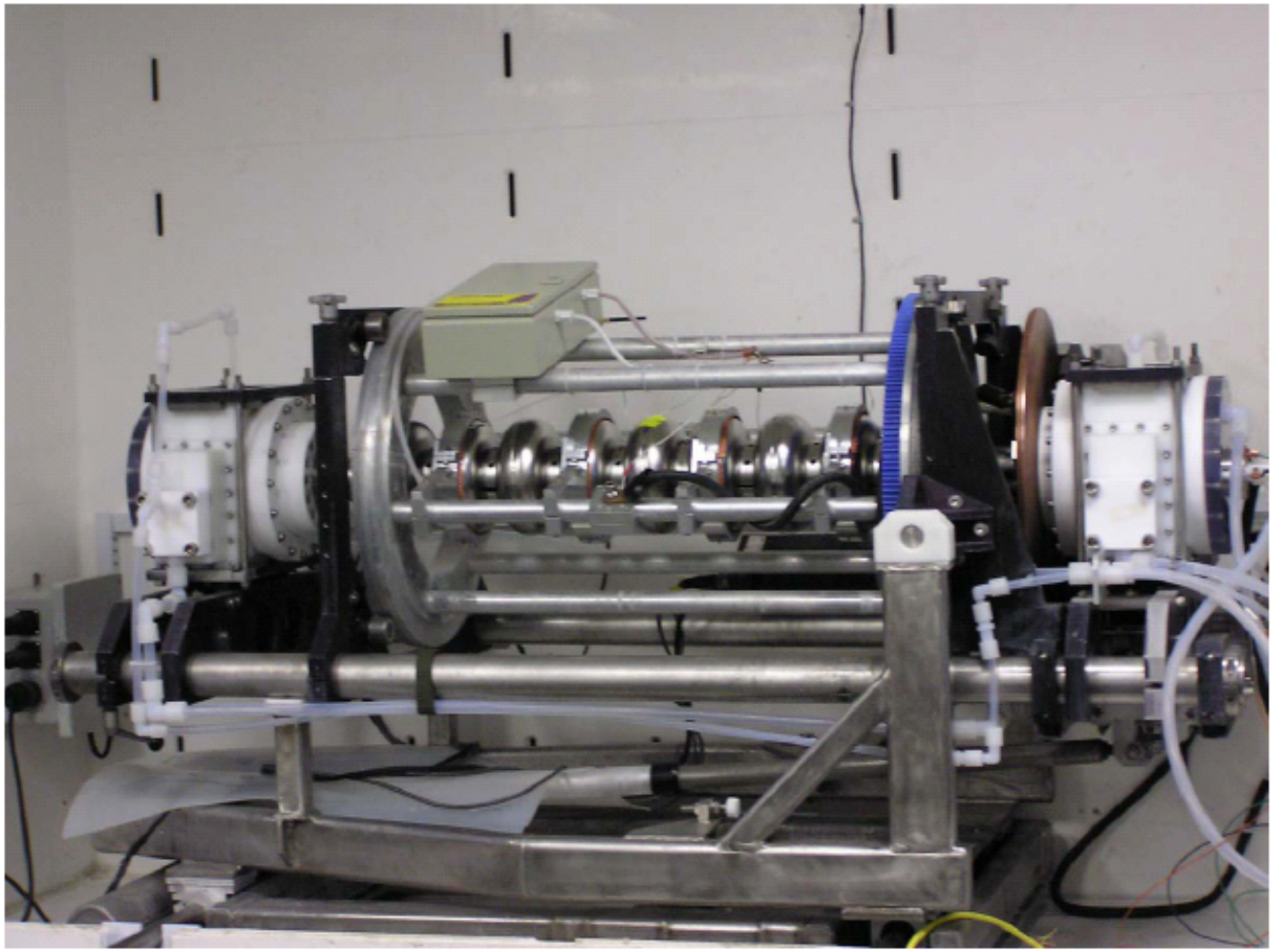
By L. Lilje (DESY)

- Continuously in production mode
  - 4 productions with 24-30 cavities each done
- Current production series No. 4 (single vendor)
  - All cavities tested
  - Two preparation recipes tried
    - 120 um EP + 800C + 30um EP + 120° C bake
    - 120 um EP + 800C + 30um etch + 120° C bake
  - Some cavities are under re-treatment
- Results
  - Not quite as good as third production
    - Lower number of re-tests on 4th production so far
  - Large variation in gradient
    - Field emission needs to be reduced further
    - Some manufacturing defects identified with T-maps
      - Need to establish tighter quality control for XFEL production

Next production at DESY

By L. Lilje (DESY)

- **Goal:**
  - XFEL Industrialisation
  - Fabrication and Preparation
- **30 cavities, 2 vendors**
- **Long EP cycle in industry, furnace and final treatment at DESY**
- **Probably continue to test both recipes**



EP System at JLab

By J. Mammosser (JLab)

Jefferson Lab

Current Issues:

By J. Mammosser (JLab)

- Process cabinet takes more maintenance then expected, many subcomponents have failed
- Had several leaks on seals (our fault)
  - Wrong torque spec used
  - Misaligned seal or mating flange dimensional problem
- Difficult to keep schedule
  - Bake-out oven power trips
  - Competing projects with higher priorities
  - Long procedures increase delays
  - Maintenance downs
- Cavities must be tuned each chemistry do to field flatness 5%→15%

Drop of field flatness from 95 % to 85 % was observed at JLab.

Summary of Recent Vertical Test Data

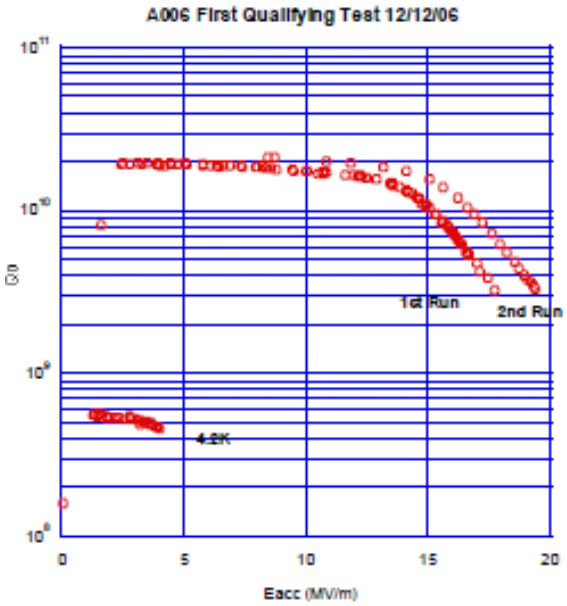
By J. Mammosser (JLab)

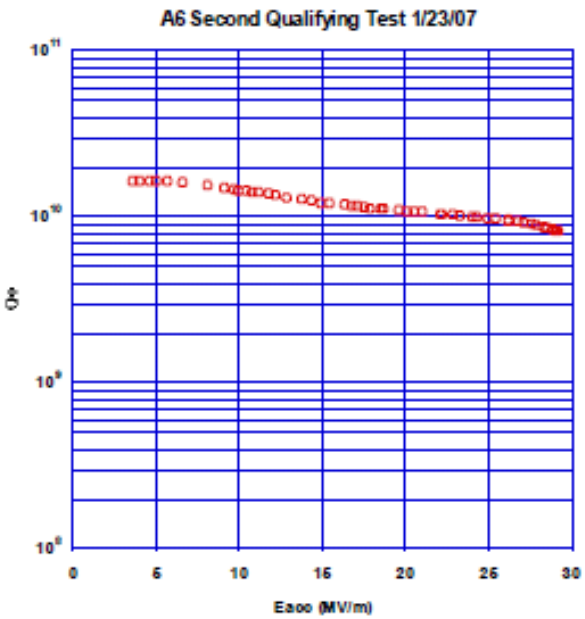
Qualification Runs				Qualification								
Test Date	Cavity #	Purpose of test	Processing Performed	Low Field Qo 5MV/m	Max Gradient (MV/m)	Q at Max	Rad onset	Max Rad (mRem/hr)	Limit	Q-disease	Mode Excited	Grad_excited
12/12/2006	A6	First qualifying test	EP20um,Degrease,HPR,Bake 120,100K soak 3days	2.00E+10	19.4	3.22E+09	17.3	0.3	Cable	No	not checked	
1/10/2007	A7	Second qualifying test	EP20um,Degrease,HPR,Bake 120	1.92	39.5	8.90E+09	28.3	100	unknown	NA	not checked	
			Soak at 100K 8 hours							yes	not checked	
			Warmup to 300K, cooldown	1.92E+10	41.25	8.00E+09	25.3	298	Quench	No	7/9th	24
1/23/2007	A6	Second qualifying test	EP20um,Degrease,HPR,Bake 120	1.66E+10	29.14	8.20E+09	none	none	Quench	NA	none	

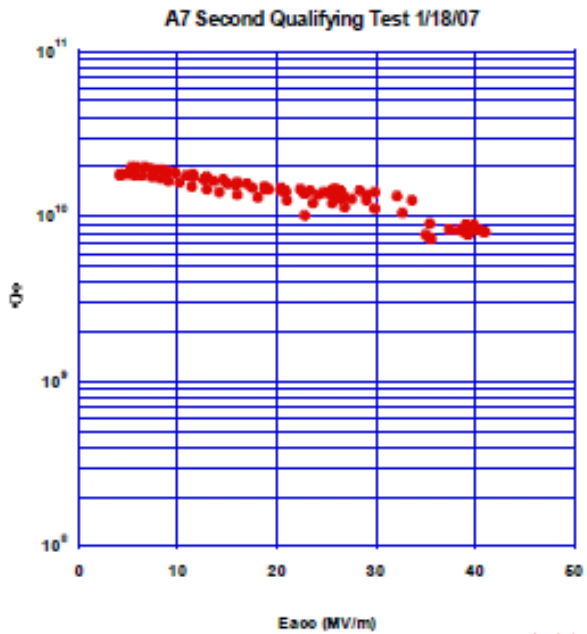
Passband Excitation

Jefferson Lab

By J. Mammosser (JLab)







Eacc,max = 20 MV/m

Eacc,max = 30 MV/m

Eacc,max = 40 MV/m

AC-6 1st test

AC-6 2nd test

AC-7 2nd test

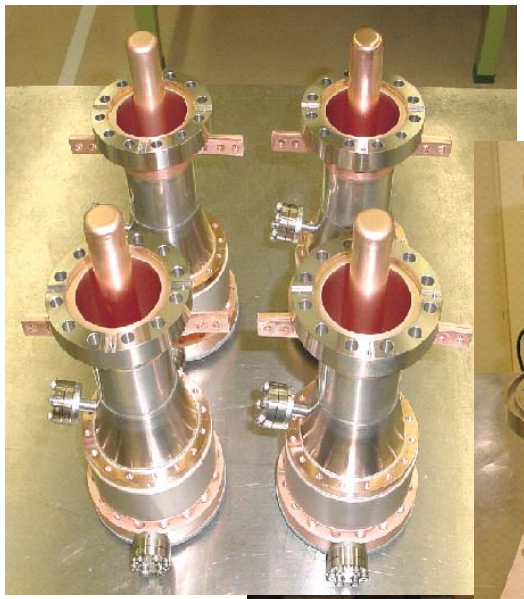
PART - II

S1 Activities ; Cryomodule Tests

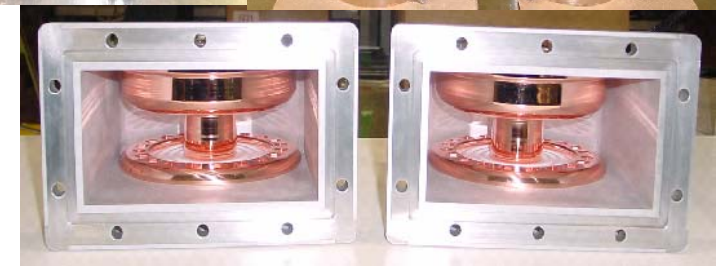
1. STF cryomodule
2. DESY ACC#6 module

STF Cryomodule at KEK (1), Components for High Power Couplers and Tuners

Cold Couplers

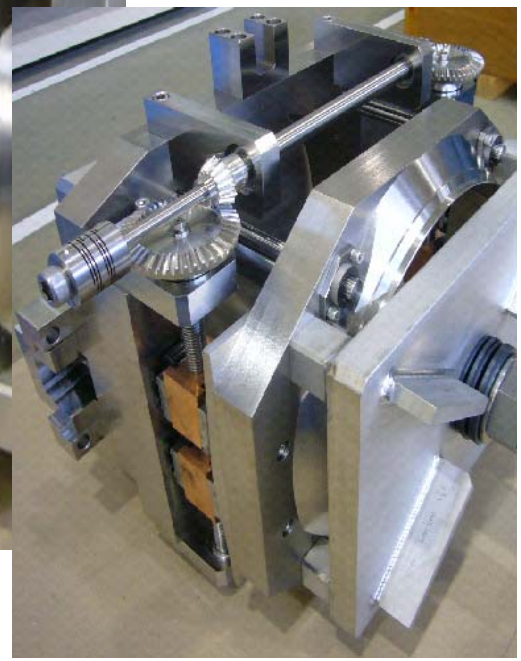


Warm Couplers

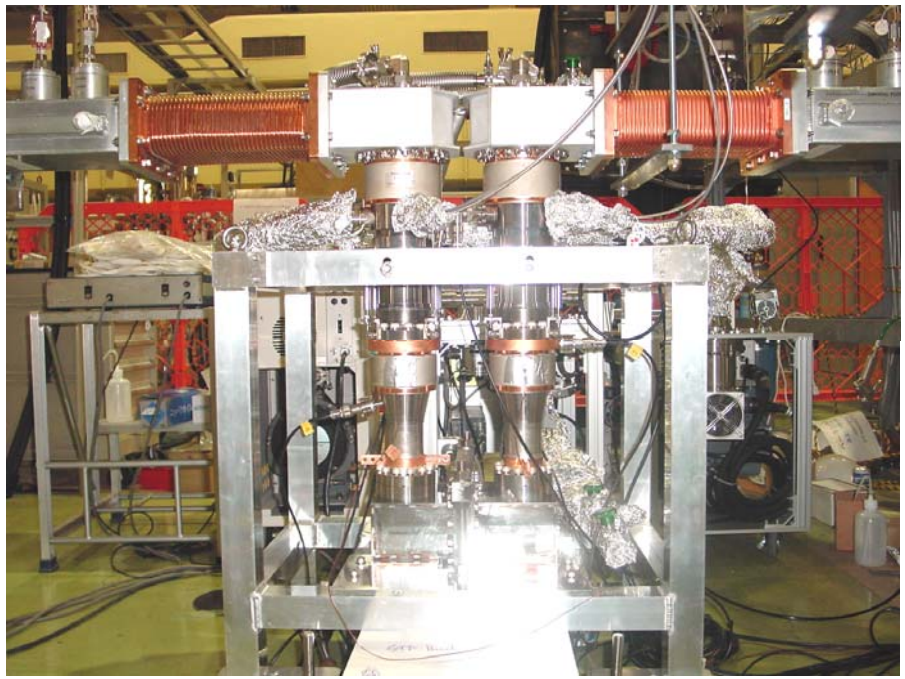


Doorknob-type Transitions

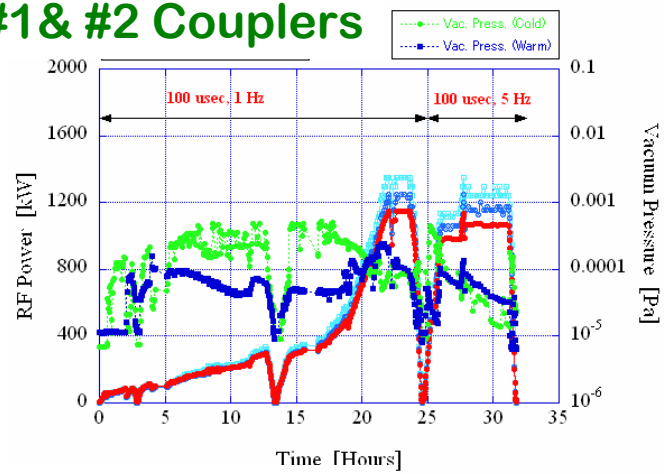
Slide-Jack Tuners



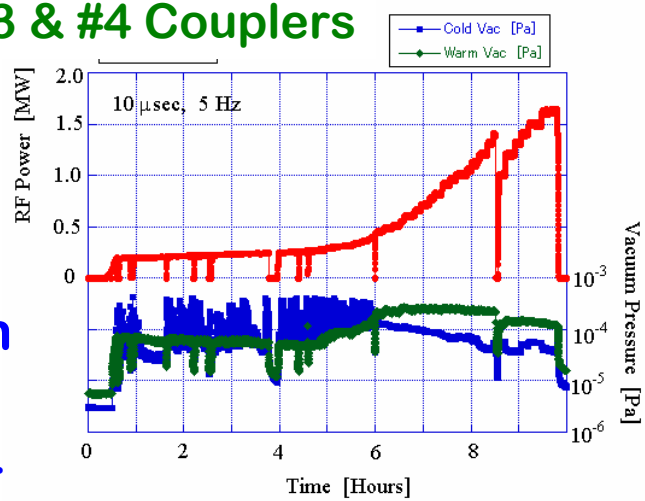
STF Cryomodule at KEK (2), High Power Test of Input Couplers



#1& #2 Couplers



#3 & #4 Couplers



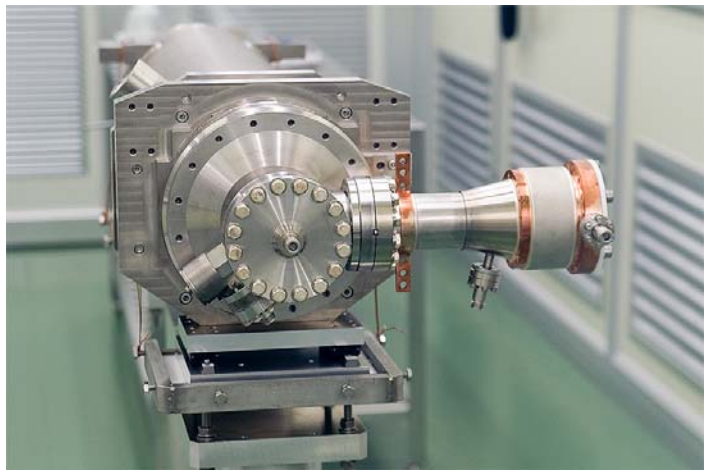
Four input couplers have been successfully processed up to 1.0 MW in a pulsed operation of 1.5 msec and 5 Hz, without any troubles.
Total processing time is ~ 50 hours, (very careful).

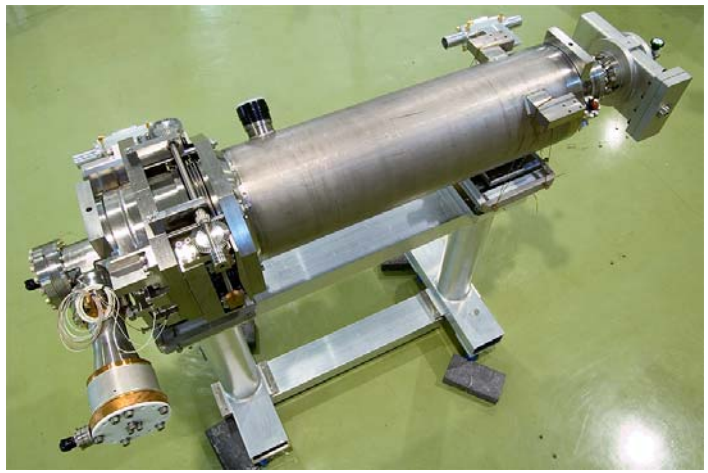
STF Cryomodule at KEK (3),
Cavity Assembly (#3 Cavity)

November, 2006'

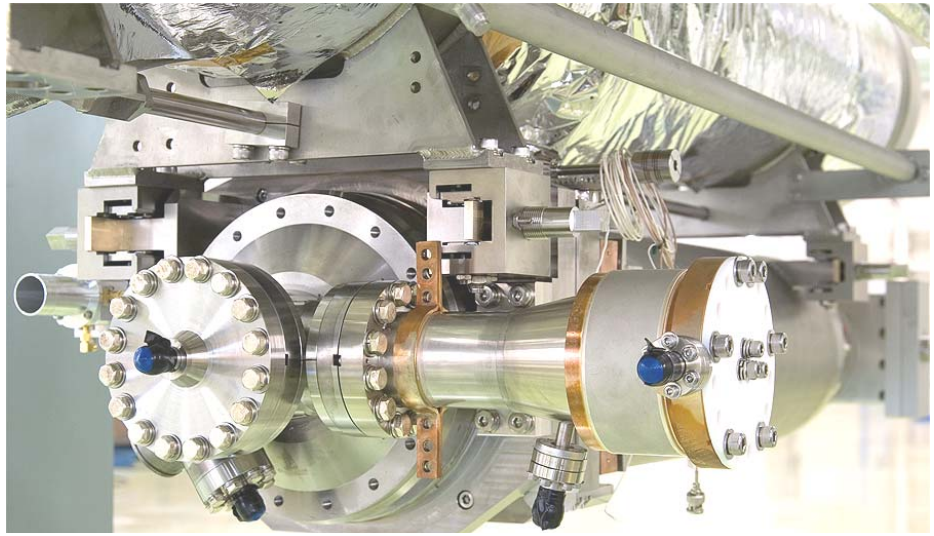
Installation of a cold input coupler

Attachment of a gate valve

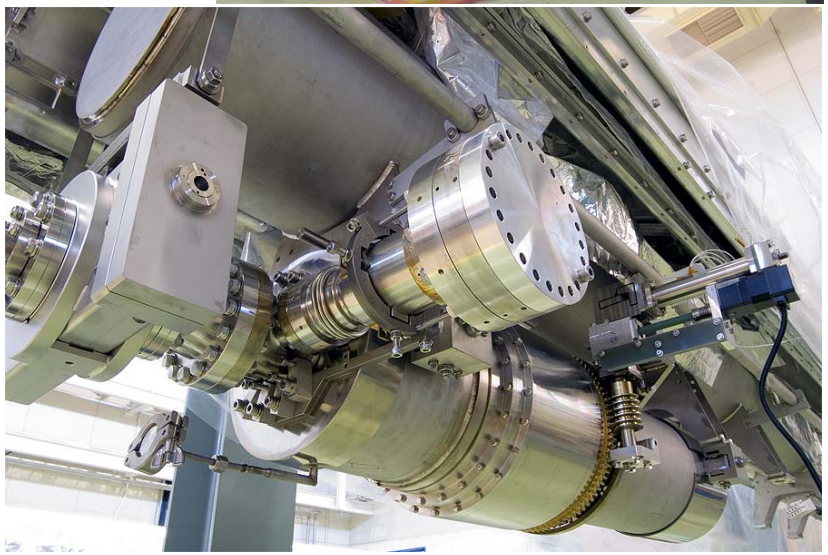




STF Cryomodule at KEK (4), Phase 0.5



One Tesla-type STF Baseline Cavity
(V.T; Eacc,max = 20.8 MV/m, Qo = 1.5×10^{10})



One LL-type High Gradient Cavity
(V.T; Eacc,max = 19.1 MV/m, Qo = 3.6×10^{9})

January, 2007'

STF Cryomodule at KEK (5), Schedule

- 2007’
- Mar. First cool-down test (Phase 0.5)
  Low power rf test (fo, Qext, HOM, Tuner, …)
- Apr. Installation of Warm coupler
  Coupler conditioning at room temp.
- May Second cool-down test
  High power rf test (Eacc,max, Lorenz detuning,
  Voltage control, Compensation by Piezo-tuner,..)
- June Disassembly of cryomodule
  String assembly of four cavities
- Oct. First cool-down test (Phase 1.0)
  Start operation with beam
- 2008’ Replace with improved cavities (Phase 1.5)

By L. Lilje (DESY)

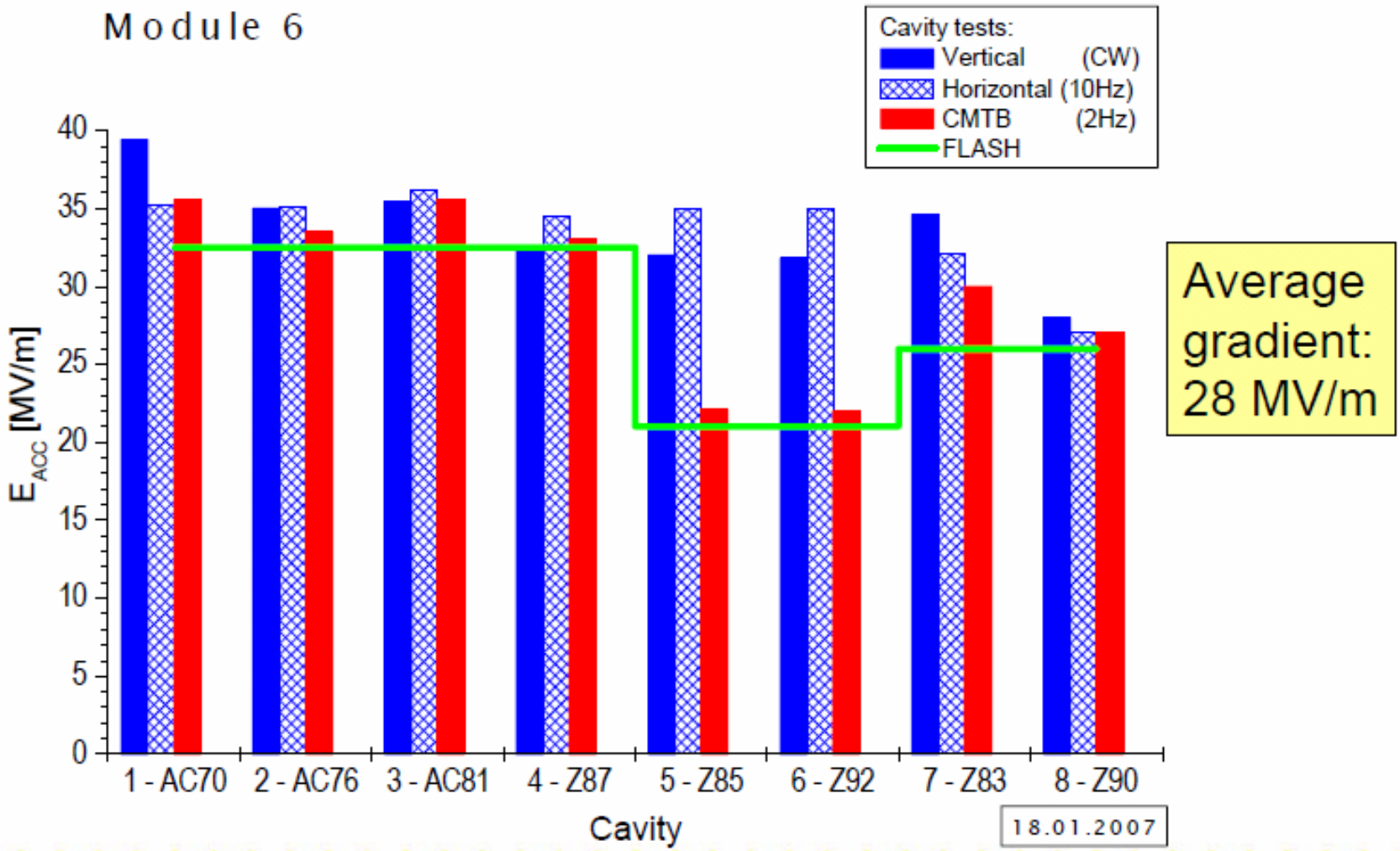
S1: Module Test at DESY

- A high gradient module has been assembled
- Test in dedicated test stand underway
  - Cavity performance
  - Coupler conditioning
  - Fast tuner performance
  - Thermal cycles
    - 10 cycles total
      - 7 done
    - No leaks
  - Details in parallel session on Tuesday (L. Lilje)

Cavity Performance

(courtesy D. Kostin – DESY)

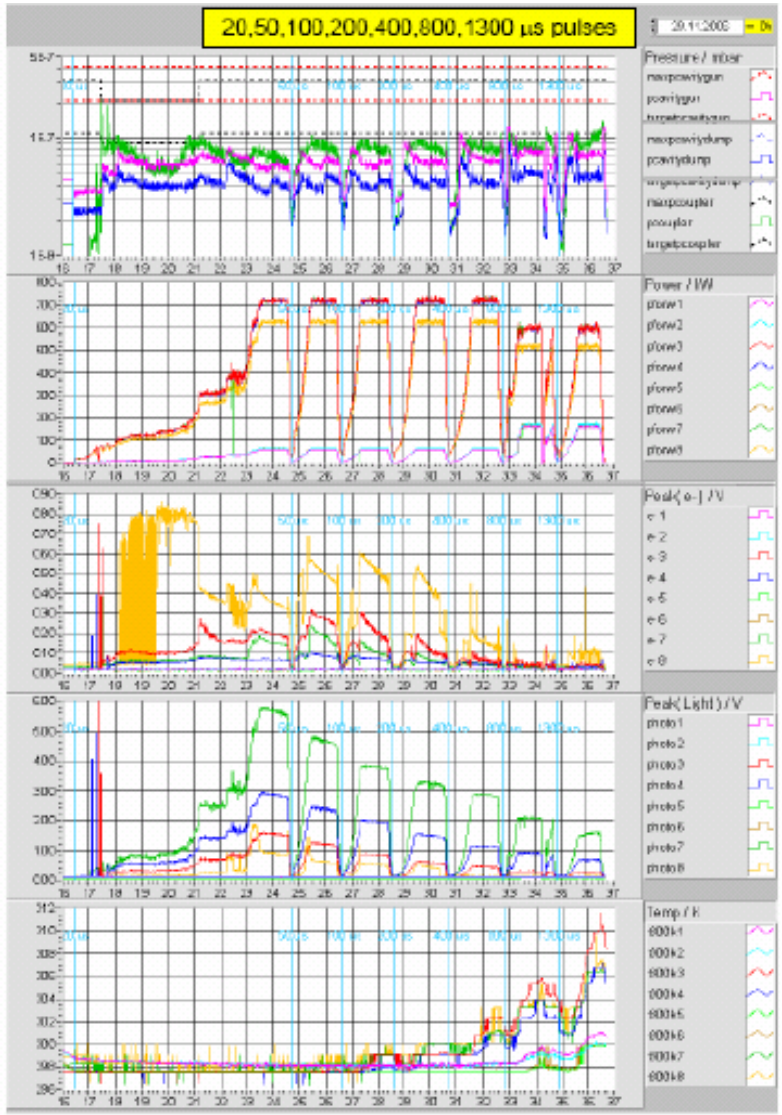
By L. Lilje (DESY)



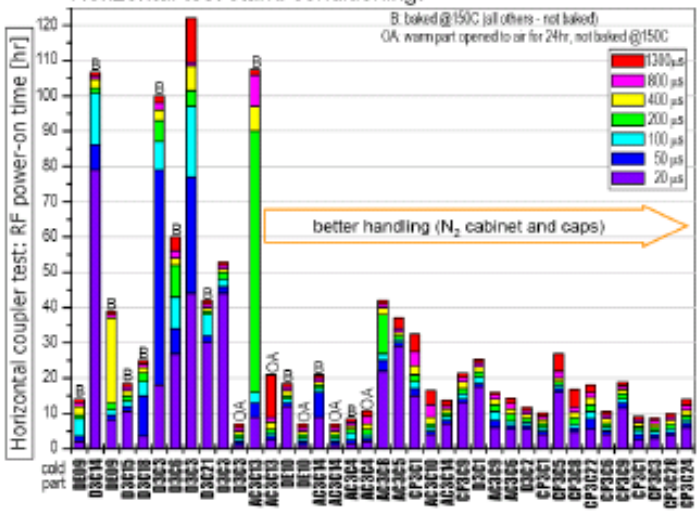
Coupler Processing

(courtesy D. Kostin – DESY)

- Very fast processing
  - Due to improved handling
  - Comparable to individual cavity high power test results



Horizontal test stand conditioning:

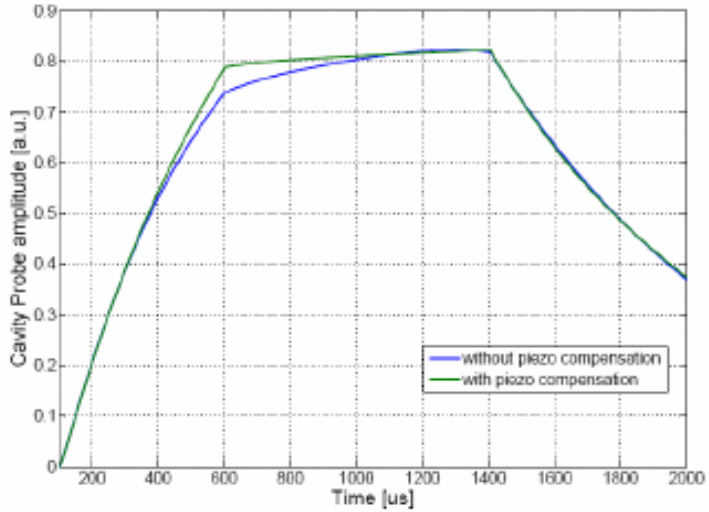


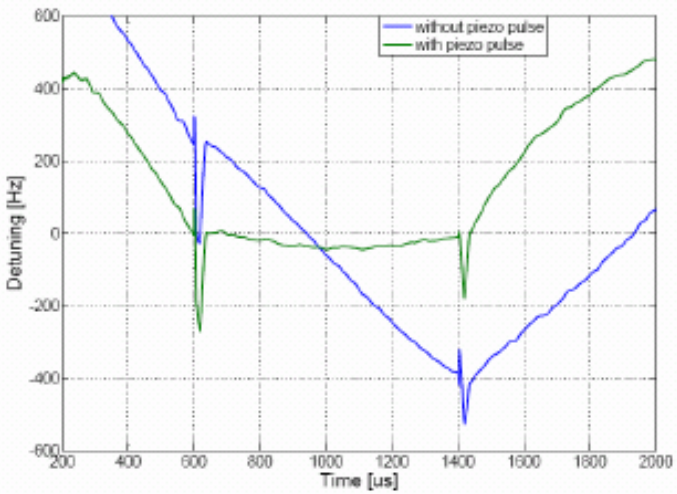
By L. Lilje (DESY)

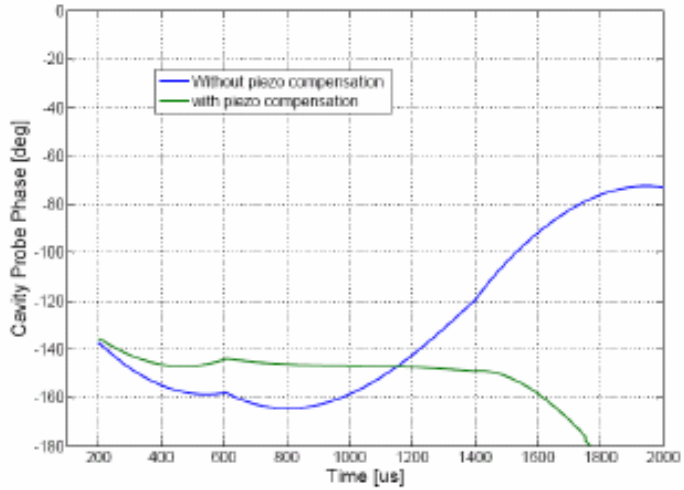
Fast Tuner Tests

By L. Lilje (DESY)

- Cavities have two piezos installed
  - sensor-actuator
  - redundancy
- All cavities compensated at maximum gradient with simple pulse
  - E.g. Cavity 3 at 35 MV/m







SUMMARY

- **S0, Vertical Tests :**

. Eacc,max in 4 STF baseline cavities was 20 MV/m at KEK.

. 15 ~ 35 MV/m in recent cavity production (15 cav.) at DESY.

. 30 and 40 MV/m in two tesla cavities at JLab.

- **S1, Cryomodule Tests :**

. First cool-down test of the STF cryomodule (Phase 0.5) will be ready in March, 2007' at KEK.

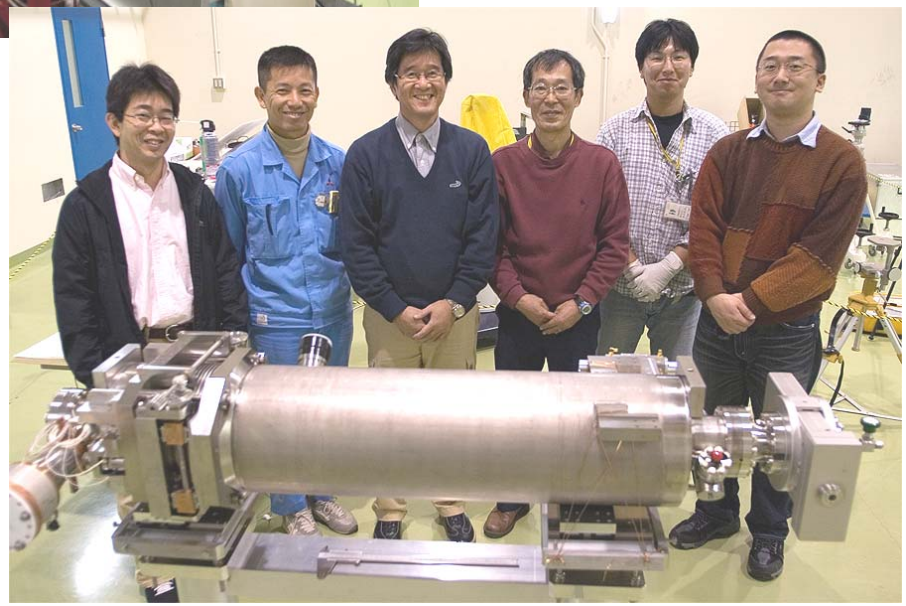
. Ave. Eacc,max of 8 cav. in ACC#6 was 28 MV/m at DESY.

Very fast coupler processing and successful piezo-tuner test has been carried out in the module.

Special thanks to

International Collaborators from Korea, China

KEK colleagues



L. Lilje (DESY)
and
J. Mammosser (JLab)