Vertical Test Results of Tesla-type 9-cell Cavities for STF

E. Kako, H. Hayano, S. Noguchi, T. Shishido, K. Umemori,
K. Watanabe, Y. Yamamoto (KEK)
H. Sakai, K. Shinoe (ISSP, Univ. of Tokyo)
Moon Sung Ik (POSTEC) and Xu Qinjin (IHEP)

Outline

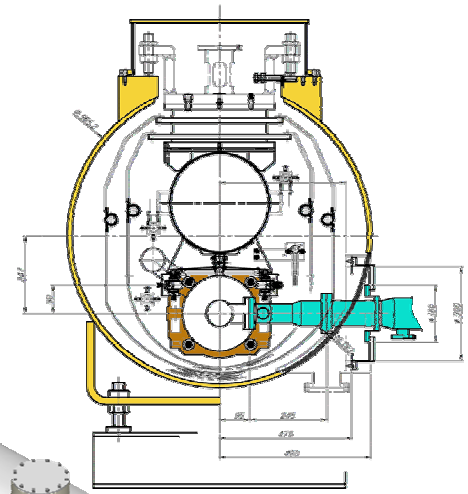
- Overview of the Baseline Cavity System
  - . System design feature
  - . Cavity fabrication and surface preparation
- Results of Vertical Tests
  - . Summary of 14 tests for 4 cavities
- Particular Observation
  - . Excitation of another passband mode
  - . Heating at HOM pickup antenna
  - . Multipacting at HOM couplers
- Summary

Overview of STF Baseline Cavity System

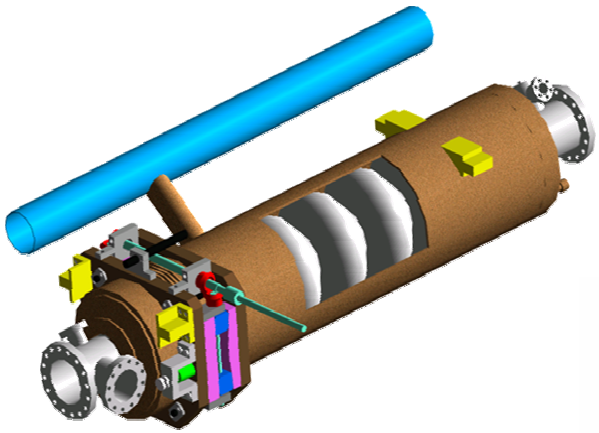
Cryomodule for STF Phase 1.0

Valve Box

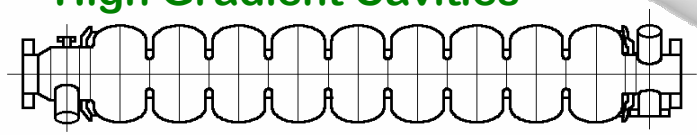
Cryomodule Cross-section



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



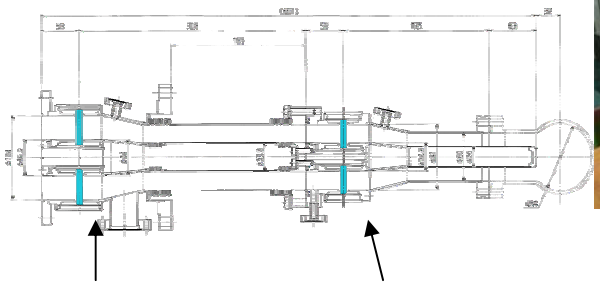
Low loss type
High Gradient Cavities



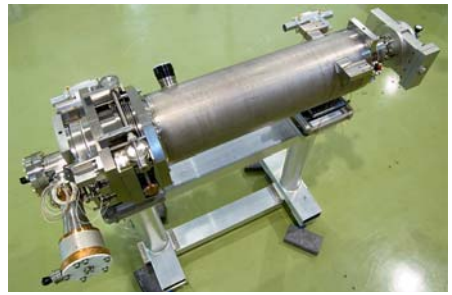
Construction of a real accelerator with a beam operation.
Checking of the reliability as a total SC cavity system.

Tesla-type STF Baseline Cavity Package

Two Disk Window Input Coupler



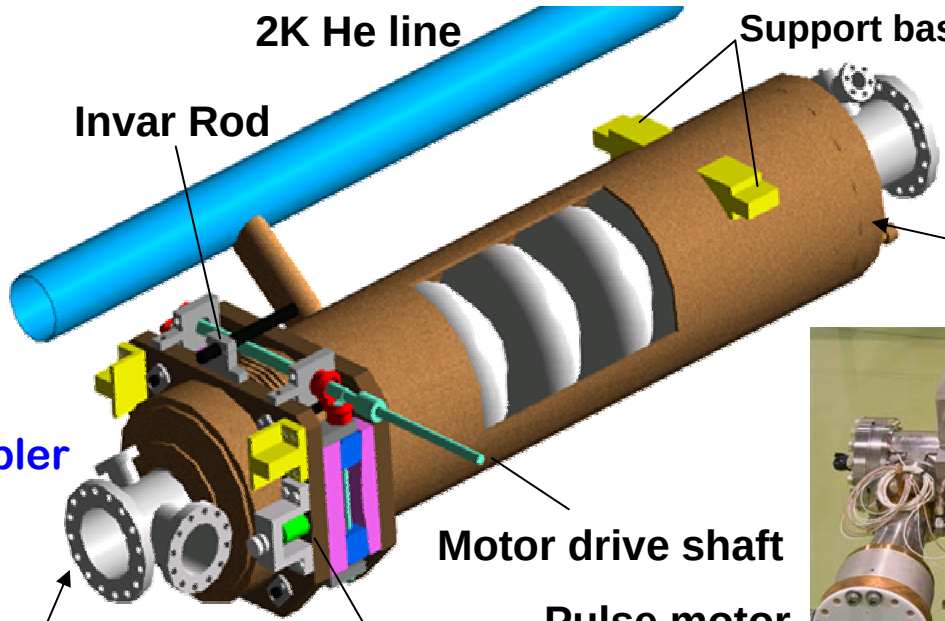
Warm Window Cold Window



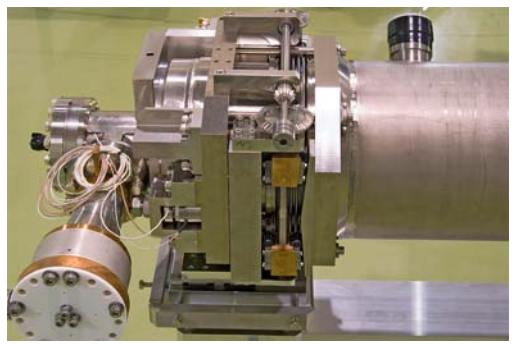
a Cavity covered with Ti Jacket

3 Cavities
(Vertical test)

Warm Coupler & Cold Coupler

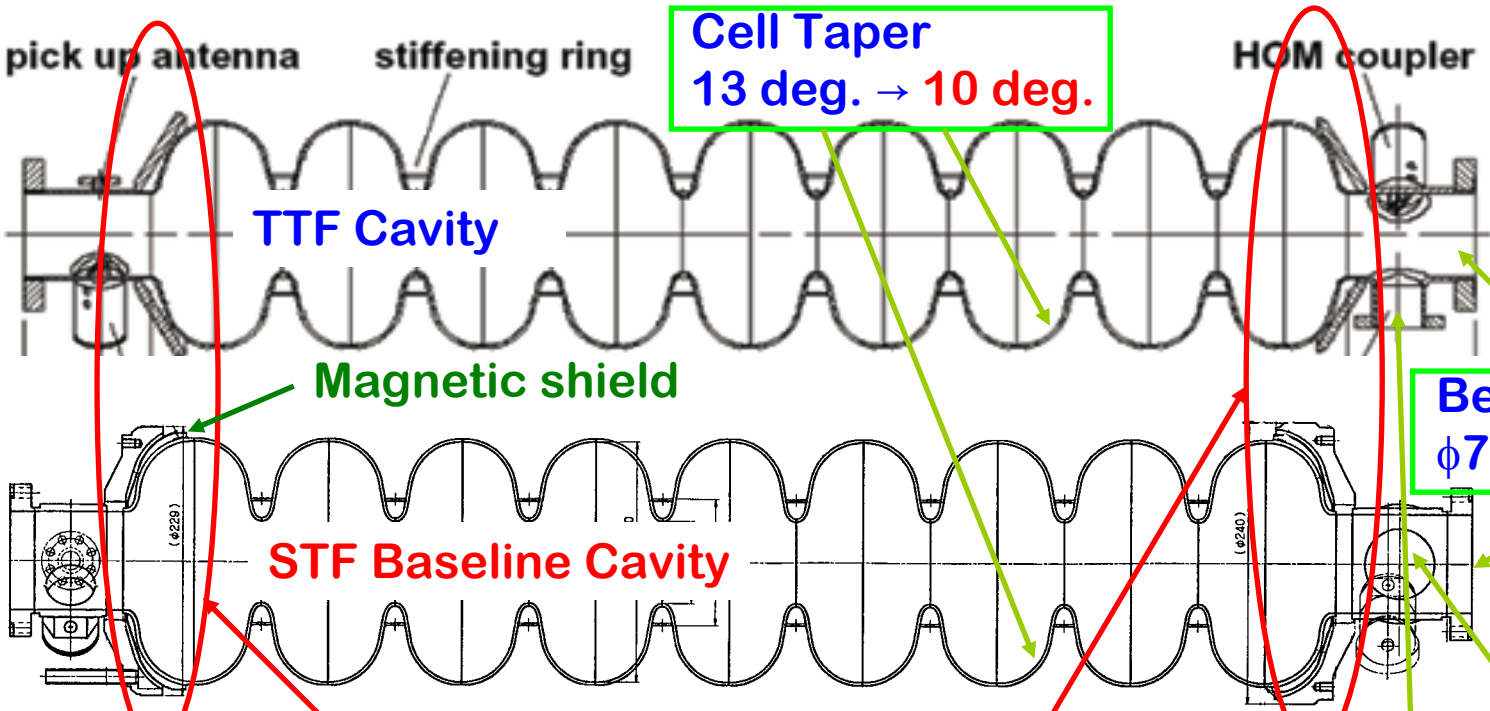


HOM Coupler



Slide Jack Tuner

STF Baseline Cavity ; Improved Stiffness



Cell Taper
13 deg. → 10 deg.

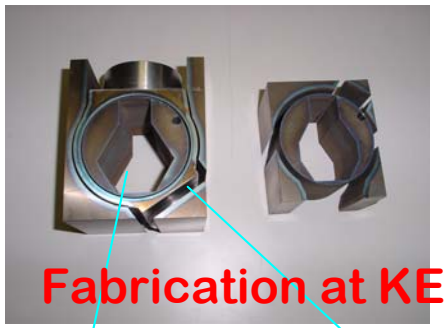
Beam Tube
ϕ78 → ϕ84

Input Port
ϕ40 → ϕ60

Thick Titanium Baseplate,
Thick Nb Beam Tube & Thick Nb End-cell

	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

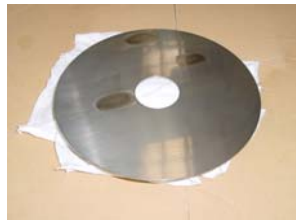


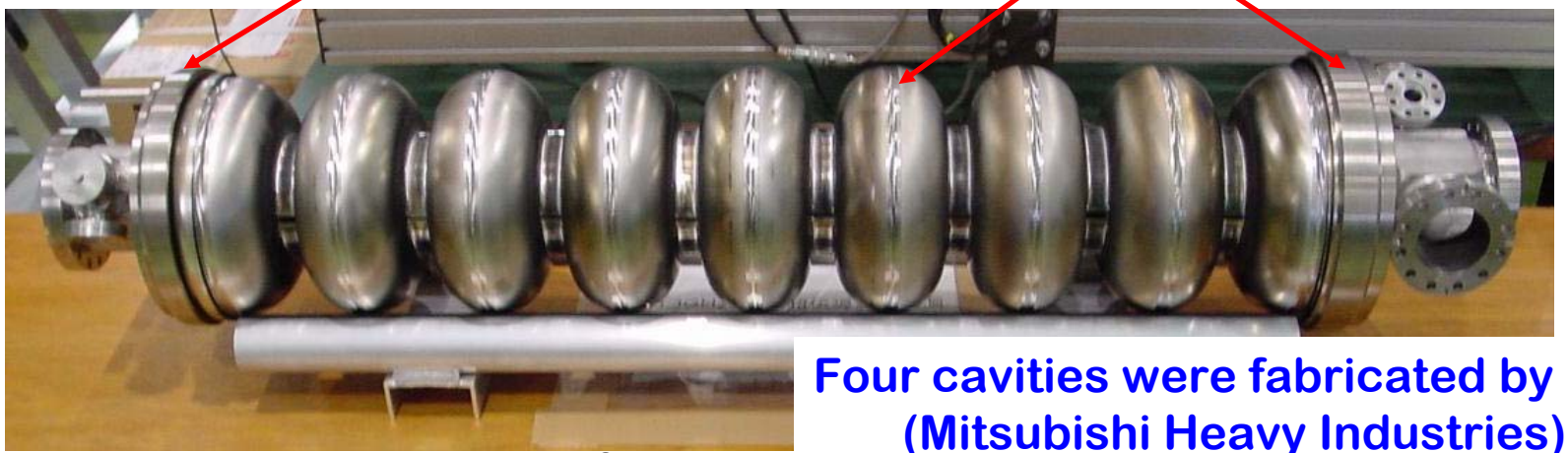
Fabrication at KEK-M.C.

HOM coupler

End-groups

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





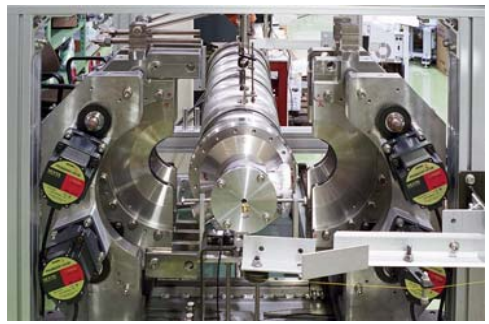
Four cavities were fabricated by MHI
(Mitsubishi Heavy Industries)

Surface Preparation of STF Baseline Cavities

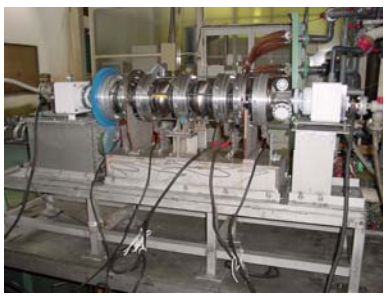
Barrel Polishing
~100 μm

Initial EP
100 μm

Anneal
750°C, 3h



Pre-tuning
fo, flatness, HOM filter

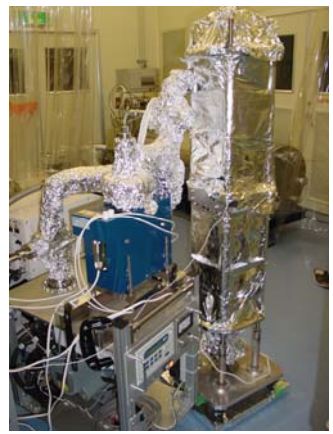


Final EP
50 μm
(20, 30 μm)

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

HPR 8MPa, 6~16h

Assembly



Baking 120°C, 40h

(HF or H_2O_2 Rinse, 1h)

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.

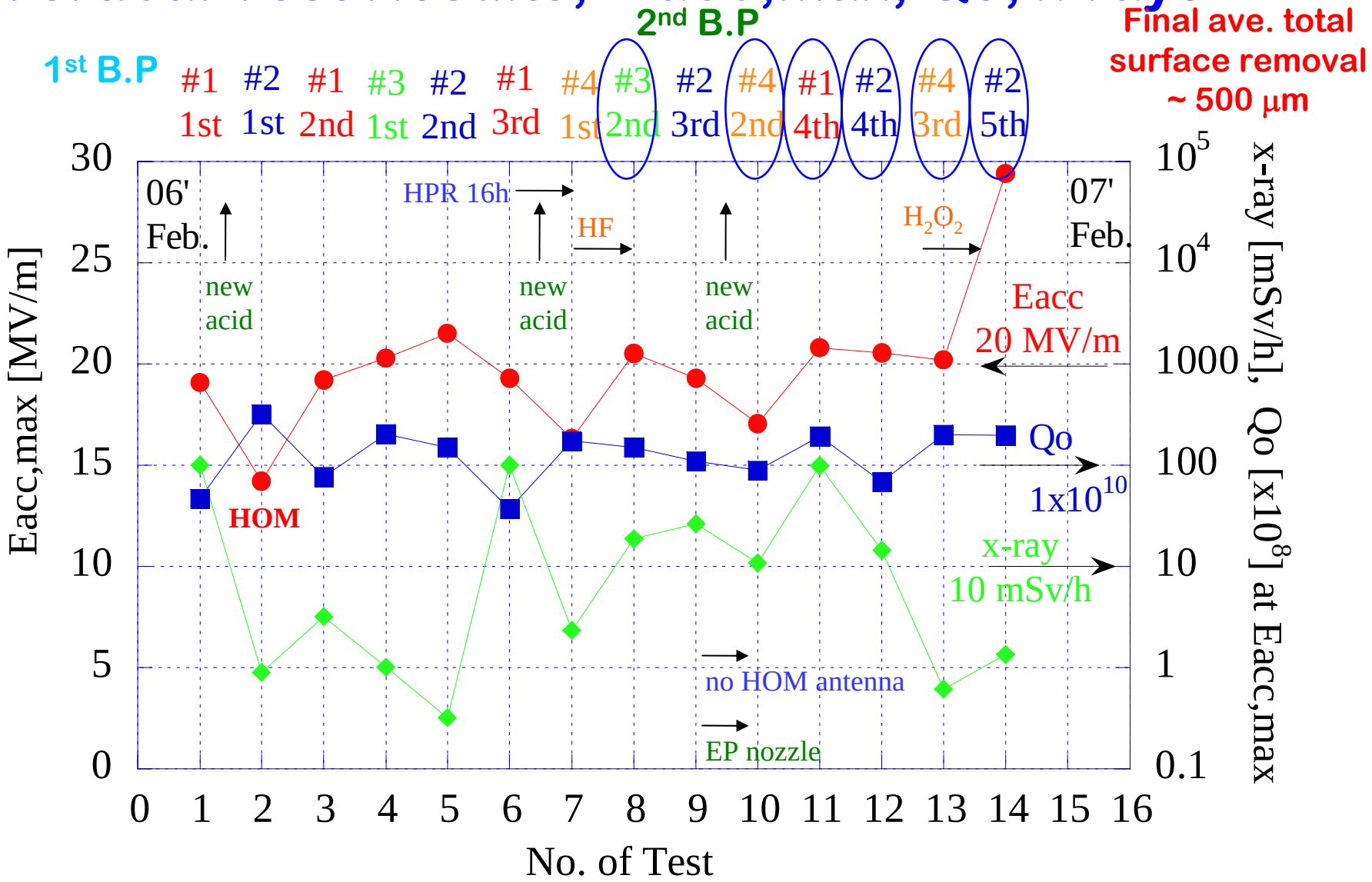
→ Starting point in the first step for us

- **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 vacuum leak in the V.T !!

Vertical Test Results, Eacc,max, Qo, x-rays

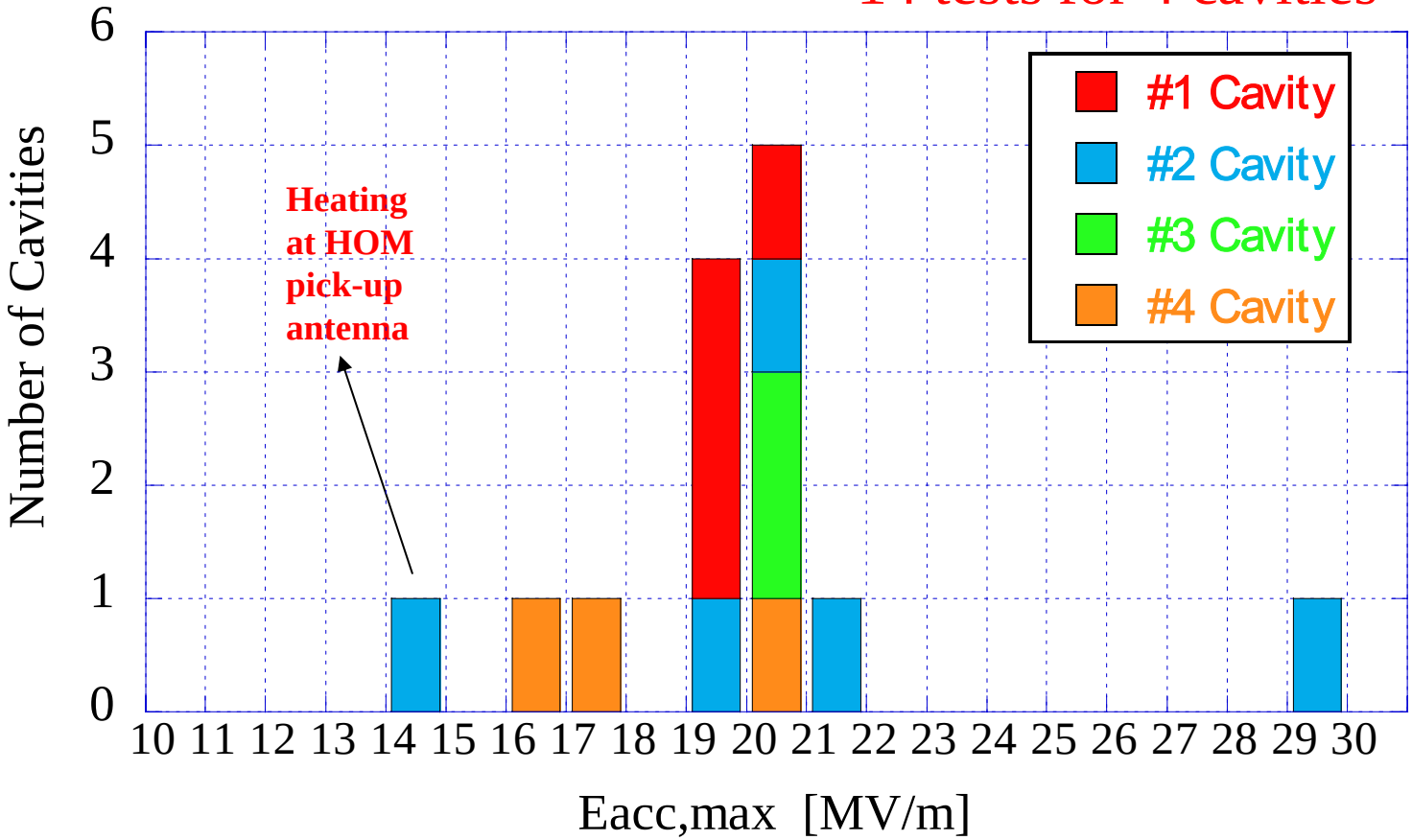


Vertical Test Results, Eacc,max

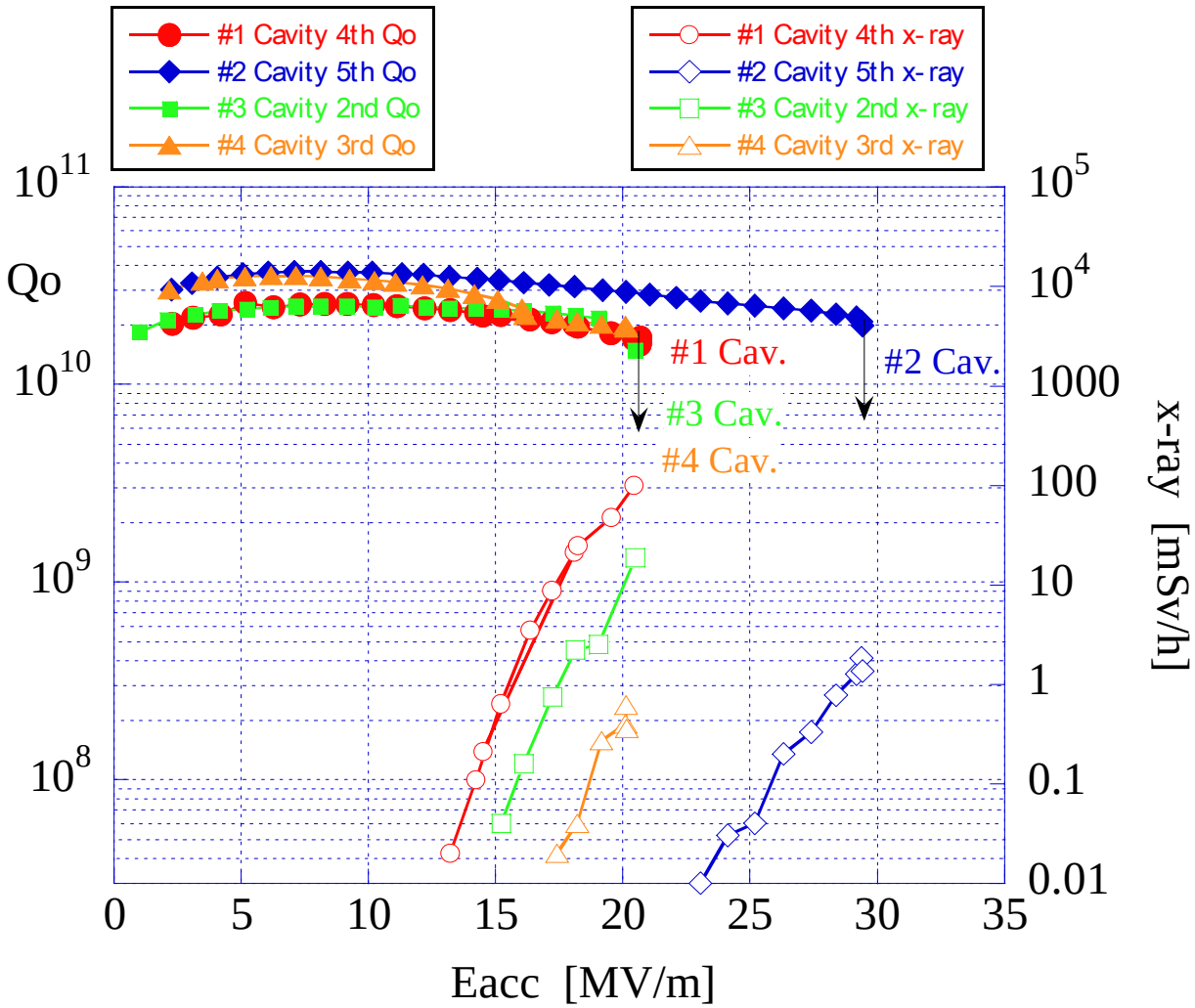
One Result ;
a final performance
after processing in one surface treatment

Ave. Eacc,max = 20.3 MV/m
Limitation → Quench

14 tests for 4 cavities



Final Performance in Vertical Tests

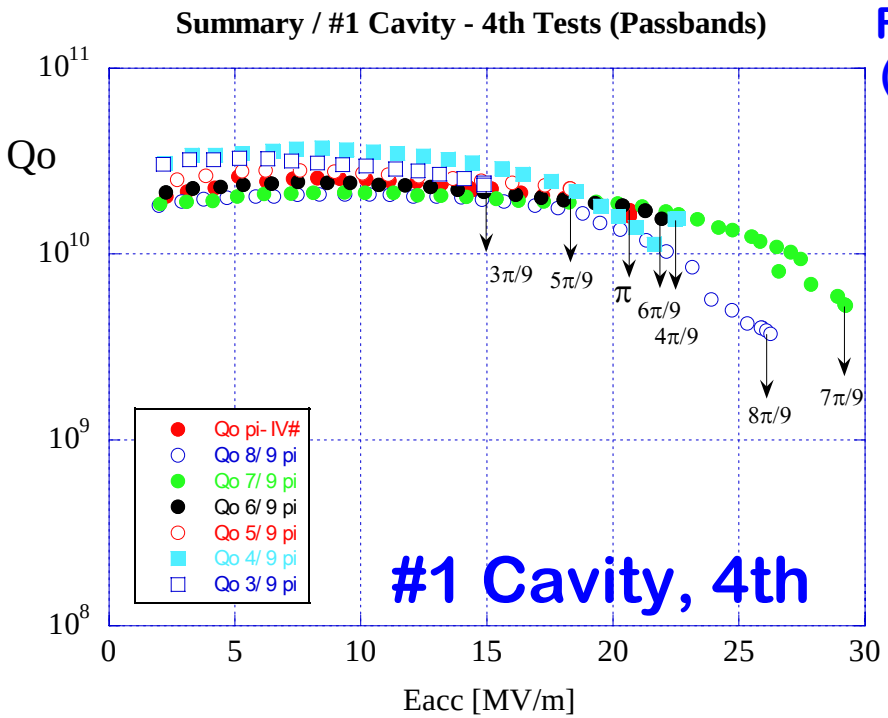


Eacc,max

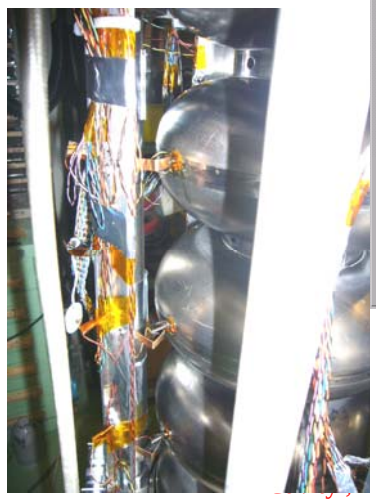
#1 20.8 MV/m
#2 29.4 MV/m
#3 20.5 MV/m
#4 20.2 MV/m

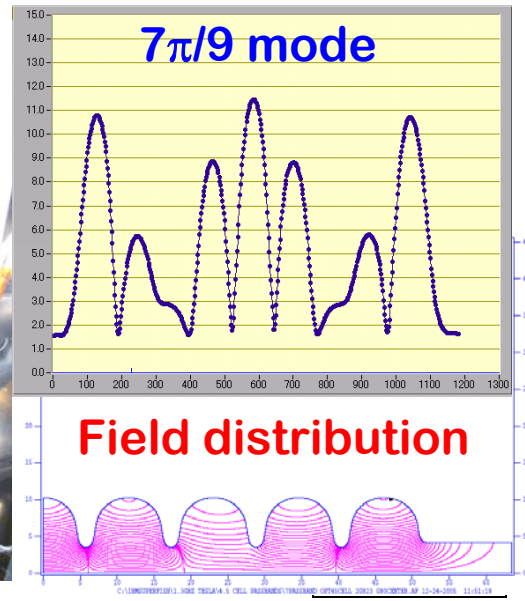
high Qo > 10^{10}

Vertical Test Results, Passbands meas.

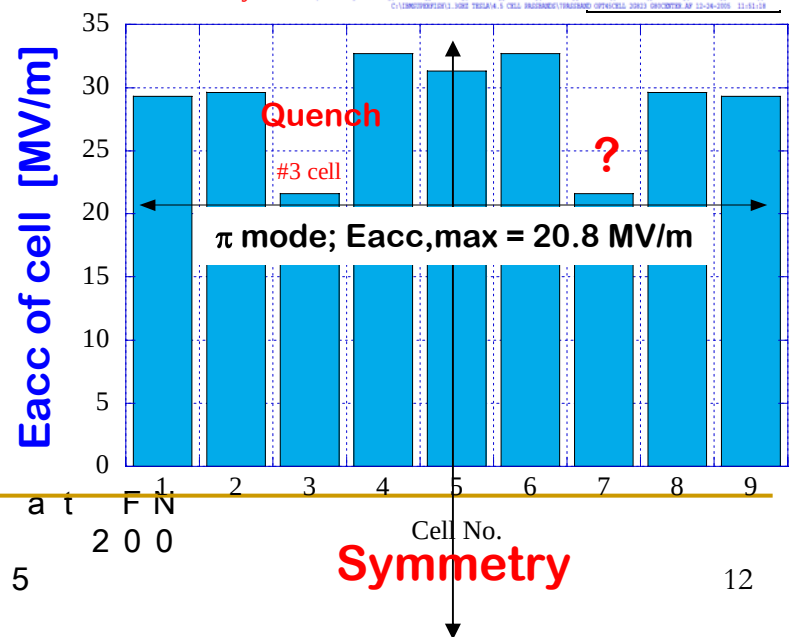


Fixed temp. sensors (every 90°, total~40)





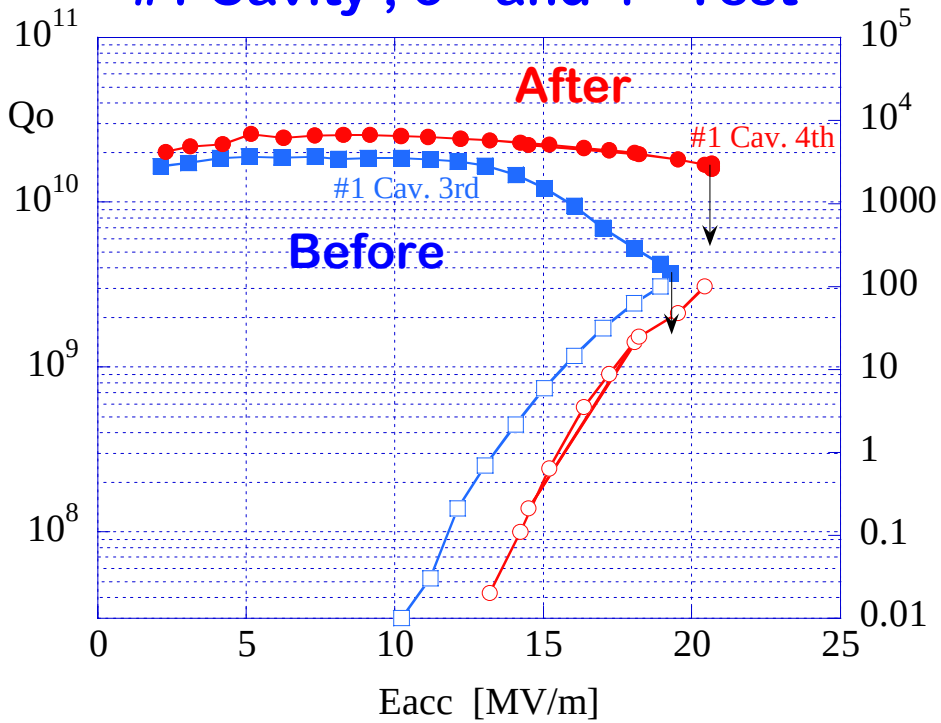
Mode cell	π	8π/9	7π/9	6π/9	5π/9	4π/9	3π/9	Eacc, max
#1, #9	20.8	26.3	29.3	21.9	18.3	22.6	14.9	29.3
#2, #8	20.8	23.4	15.5	0	12.5	29.6	29.6	29.6
#3, #7	20.8	17.3	5.9	21.9	21.6	12.9	14.9	21.9
#4, #8	20.8	9.7	22.8	21.9	3.7	32.7	14.9	32.7
#5	20.8	0	31.3	0	23.3	0	29.6	31.3
Heating at	#3	#9	#9	#3	#3	?	?	MV/m



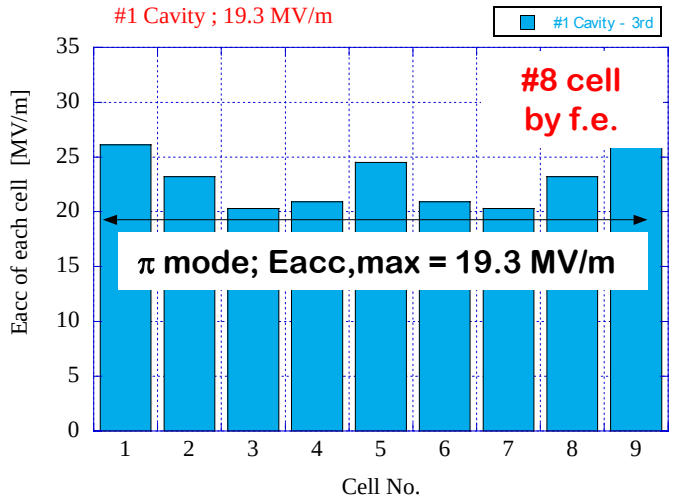
Vertical Test Results, #1 Cavity

Comparison before/after 2nd B.P.
(additional surface removal of ~250 μm)

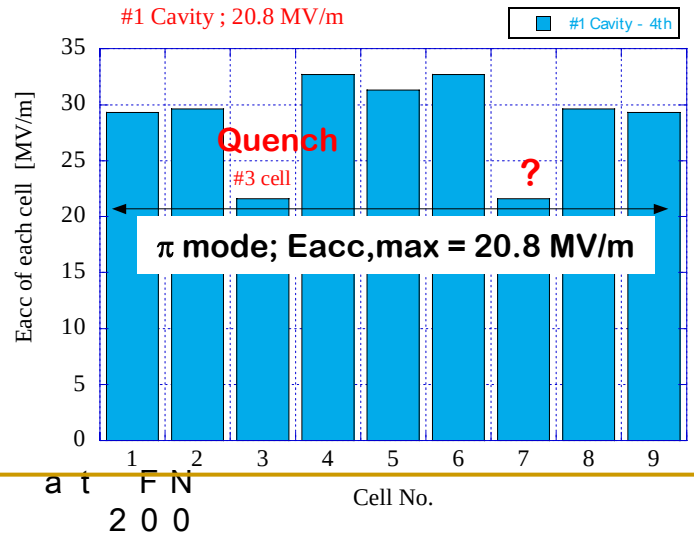
#1 Cavity ; 3rd and 4th Test



#1 Cav. 3rd



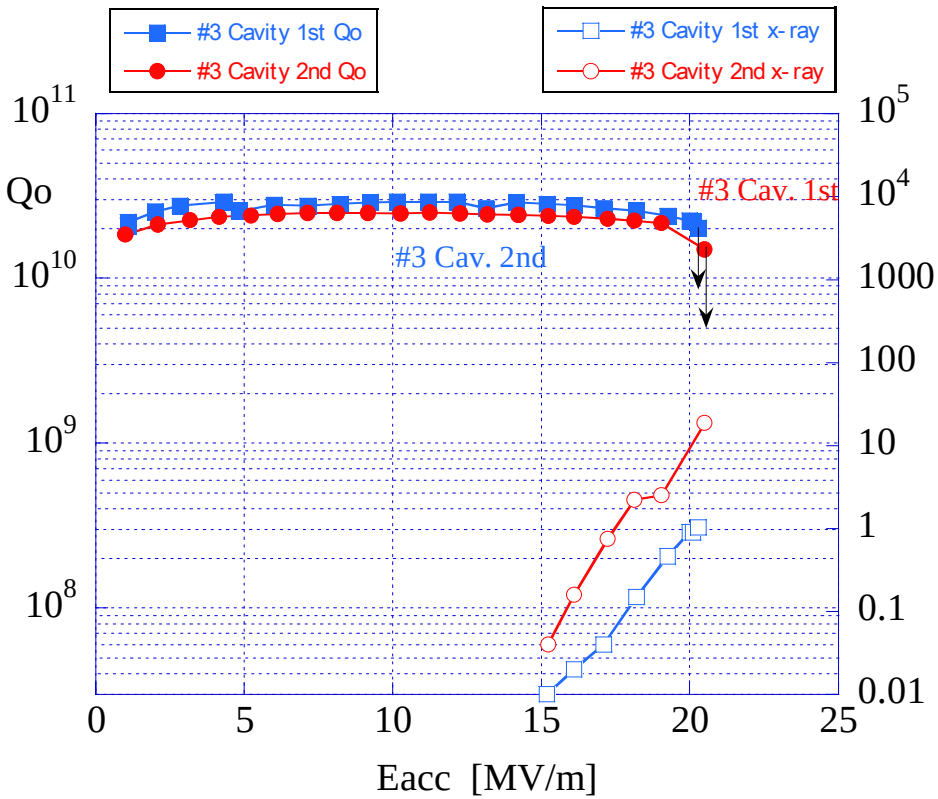
#1 Cav. 4th aft. 2nd Barrel Polishing



Vertical Test Results, #3 Cavity

#3 Cavity ; 1st and 2nd Test

Comparison before/after 2nd B.P.
(additional surface removal of ~250 μm)



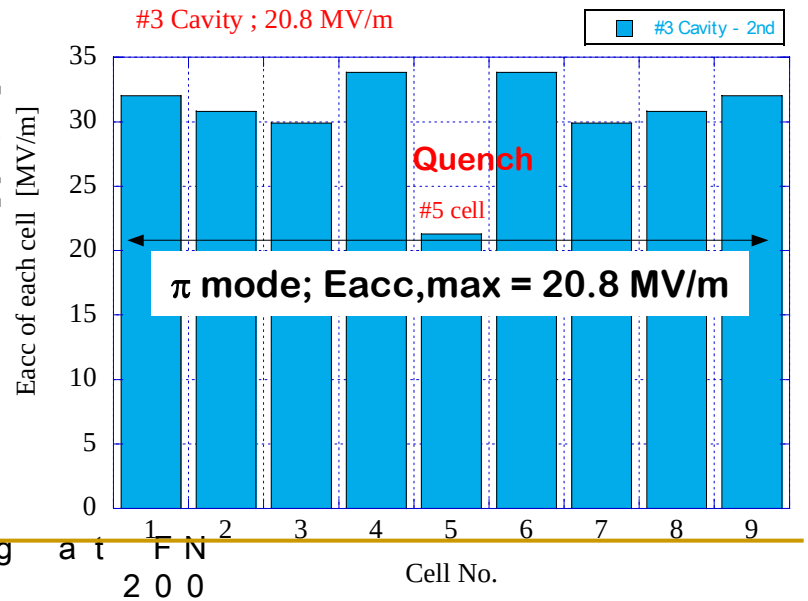
#3 Cav. 1st

#3 Cavity ; 20.3 MV/m

Sorry, no data !!

Every cell → 20.3 MV/m

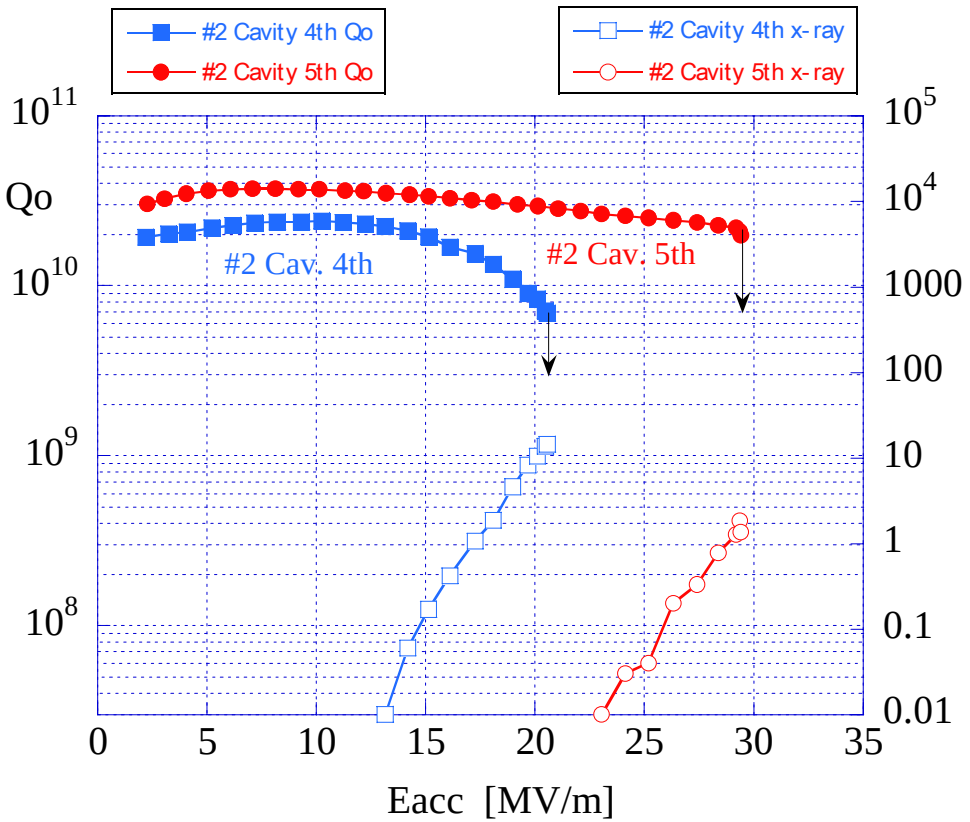
#3 Cav. 2nd aft. 2nd Barrel Polishing



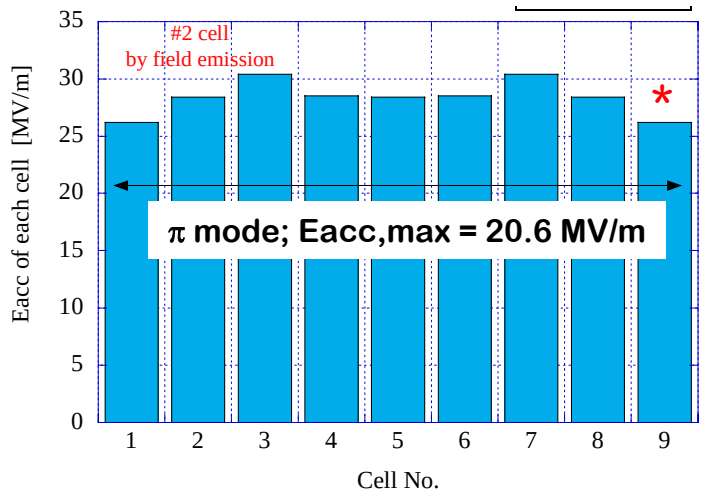
Vertical Test Results, #2 Cavity

#2 Cavity ; 4th and 5th Test

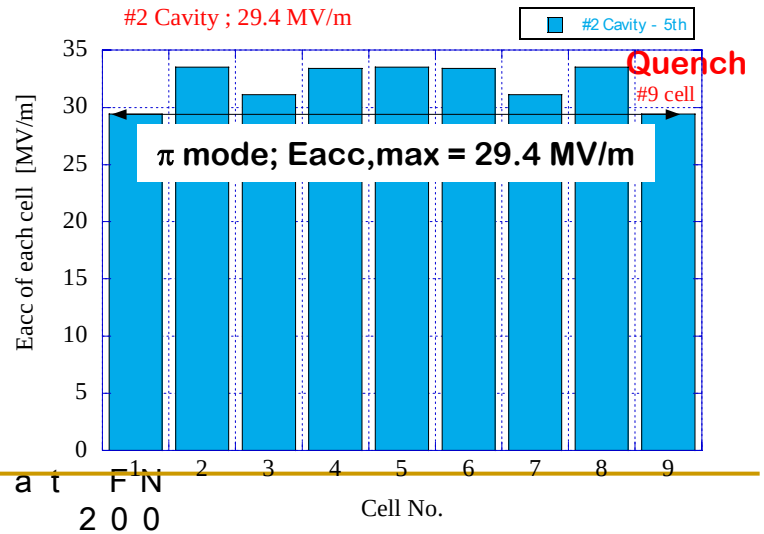
+ EP 20μm, H_2O_2 Rinse 1h,
Hot Rinse 1h, HPR 16h



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

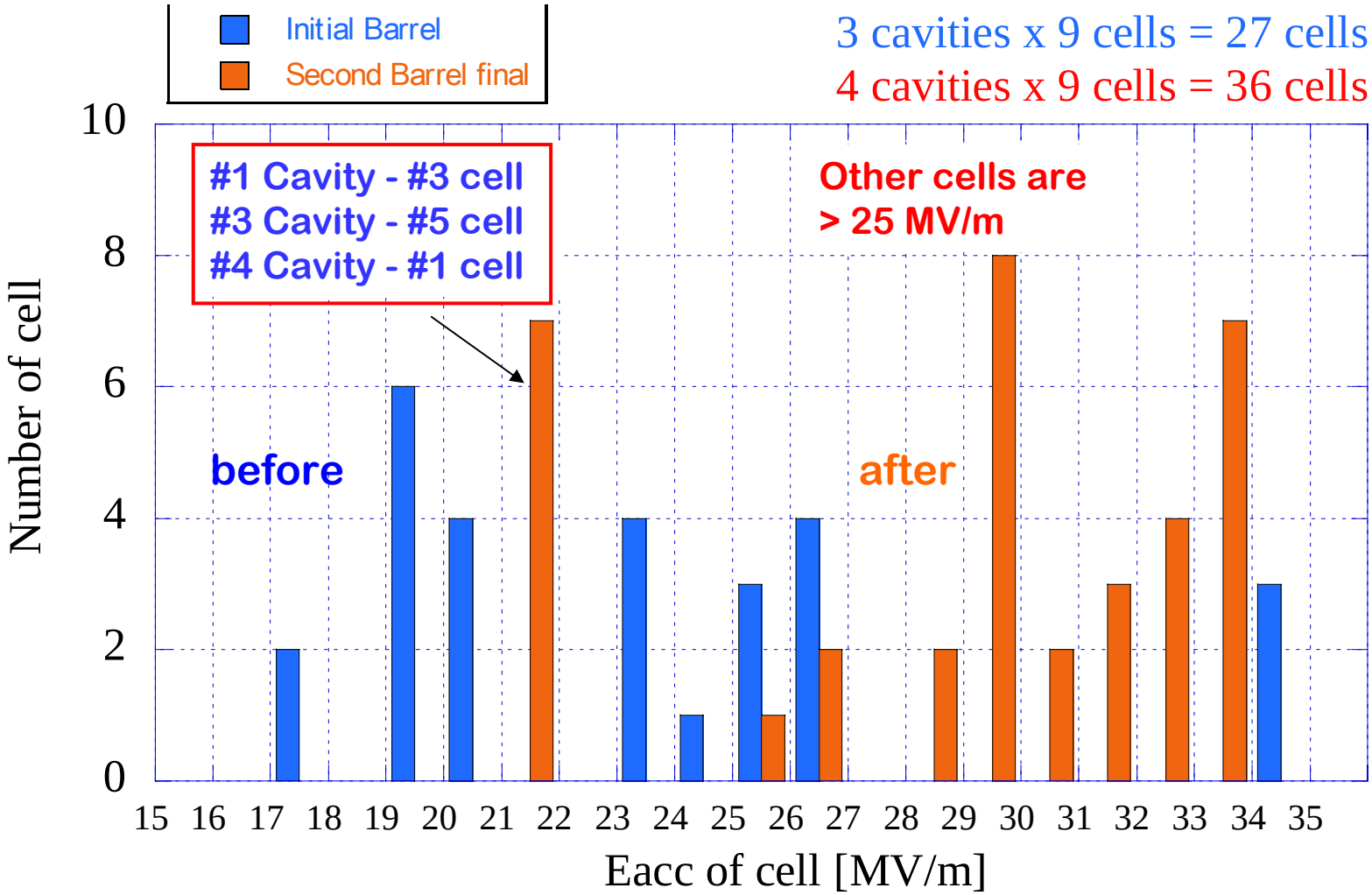


#2 Cav. 5th



Vertical Test Results, Eacc of cells

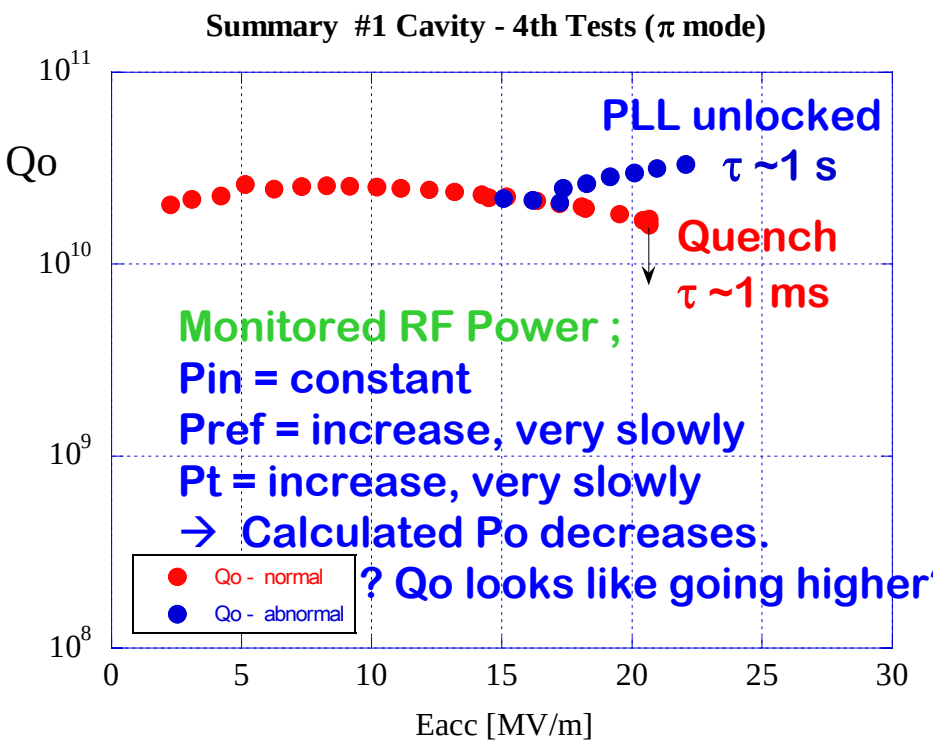
Before (total~250 μm), after 2nd BP (total~500 μm)



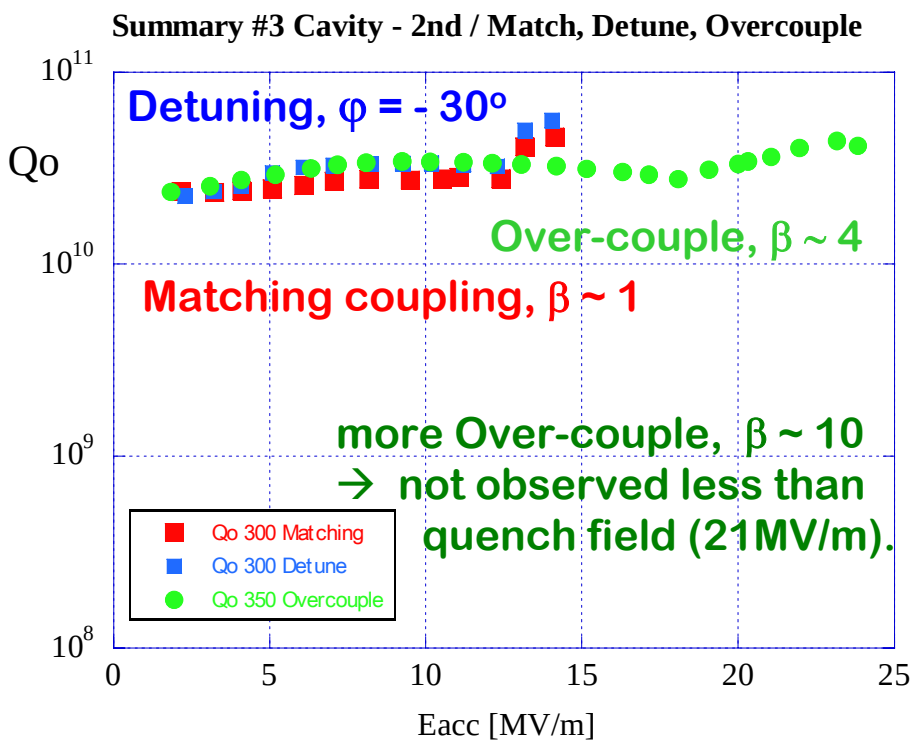
Passband Excitation (1)

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

#1 Cavity – 4th Test



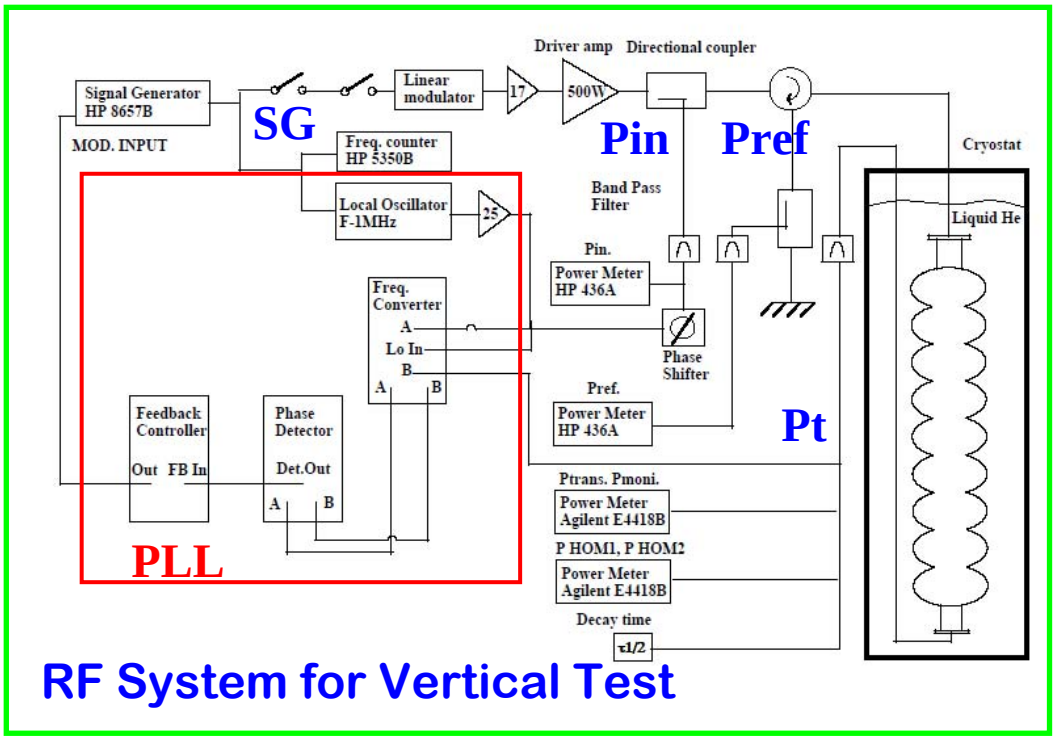
#3 Cavity – 2nd Test



Passband Excitation (2)

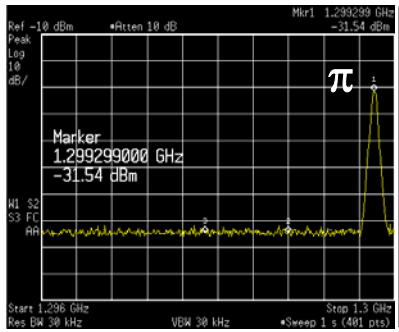
Abnormal state ;
Eacc = 16.2 MV/m
Qo = 2.4 x 10^{10}

Checking of the Frequency Spectrum in each monitored RF Power

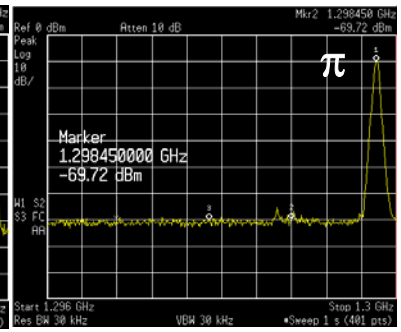


RF System for Vertical Test

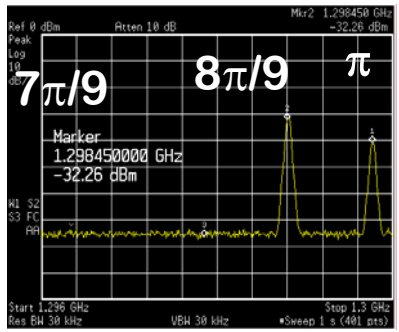
SG



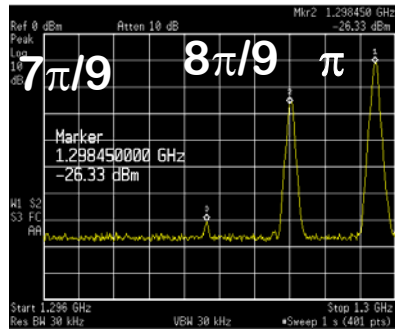
Pin



Pref



Pt



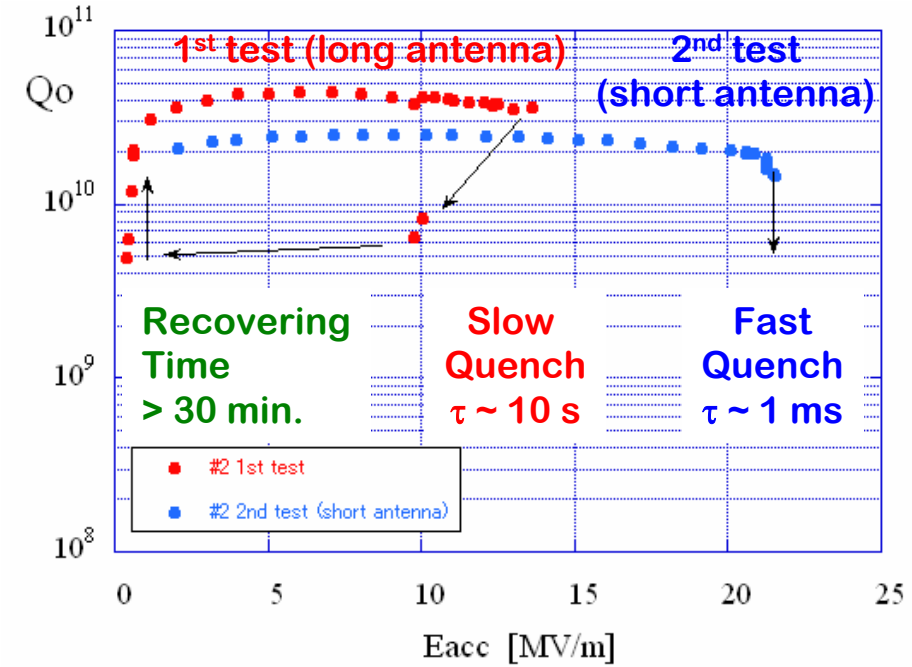
Incident power is only fundamental π mode.
But, 8π/9 mode is excited inside the cavity !!

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

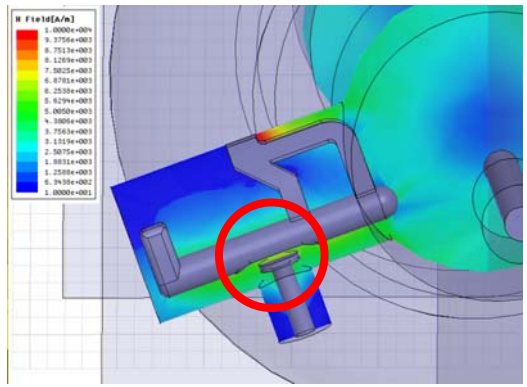
Similar excitation was also observed at DESY, but 7π/9 mode.

Noguchi-san analyzed "Field emission current might be possible to excite a parasitic mode".

Heating at HOM pick-up antenna

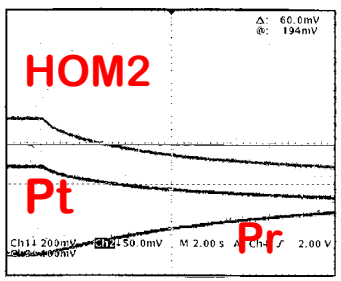


$H_{antenna\text{-}tip} \sim H_{sp} / 20.$



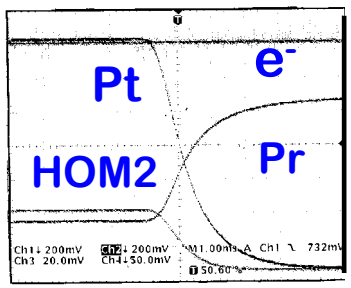
At Eacc = 10 MV/m,
ΔPo = 8 W
P-loss (cal.) = 2 W x 2

Slow Quench ~ 10 sec.



2 sec/div.

Fast Quench ~ 1 msec.



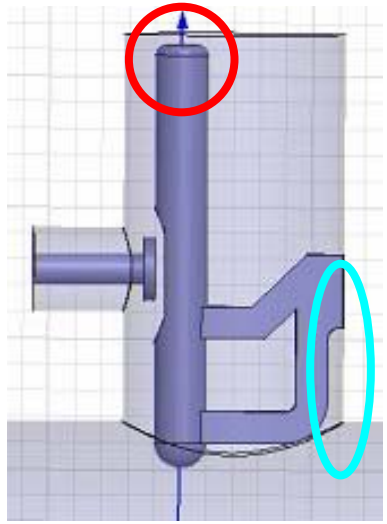
1 msec/div.

1st test (long antenna) 2nd test (short antenna)

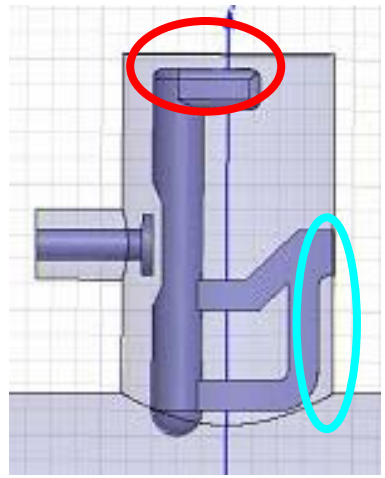
Transition from SC state to normal state occurred at the location isolated thermally.

Multipacting at HOM couplers

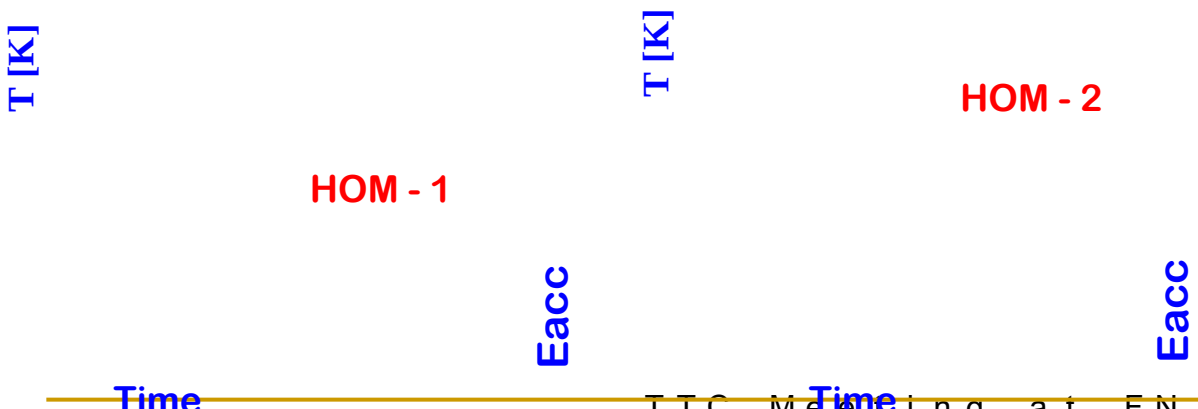
HOM - 1



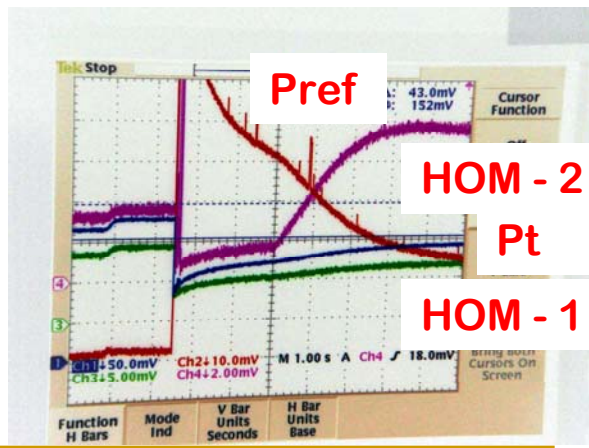
HOM - 2



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

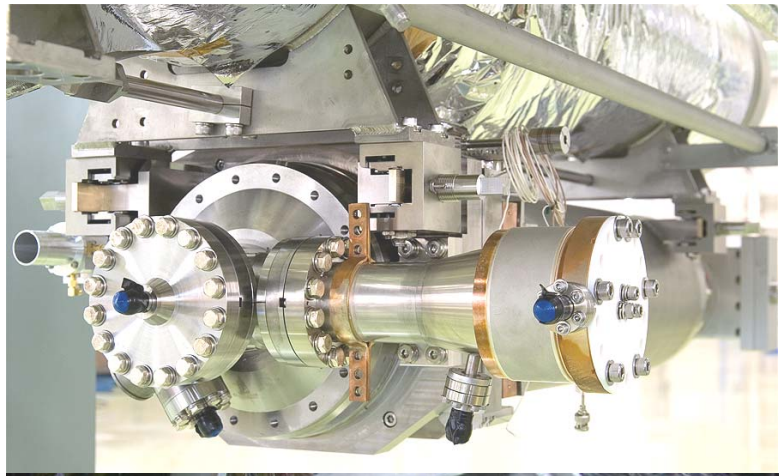


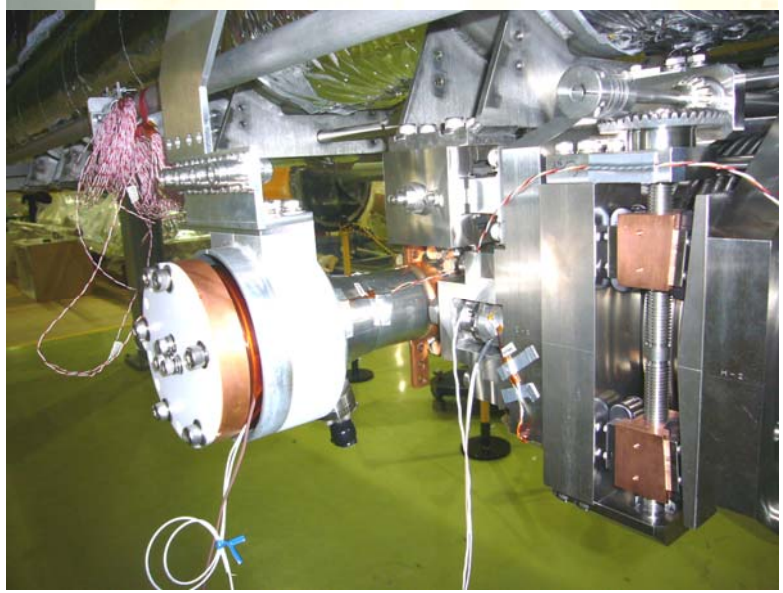
#1 2nd, Eacc = 2.4 MV/m, 1 s/div.



Cavity Assembly (#3 Cavity) ; Installation of Cold coupler and Tuner system

November, 2006'





Three cavities (#1, #2, #4 Cavity) covered with He Jacket

March, 2007'

Schedule of High Power RF Test in STF

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

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

Achieved Eacc,max in vertical tests :
→ max. 29 MV/m, but 20 MV/m for three cavities
lower than our expectation (> 25 MV/m)

- **Need further strict quality control in both cavity fabrication process and surface preparation for the next 4 cavities (in 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 29 and 20 MV/m without any degradation**
  2. **Suppression of Lorenz force detuning by improved cavity stiffness**
  3. **Compensation of Lorenz force detuning by a piezo-tuner**

END

Thank You for Attention !