12．ILCに向けたKEK (特にWG5)での空洞開発

ILC 1st Workshop後の KEKの試験設備増強

Outcomes by the JFY2004 budget

ILC 9-cell cavity開発のために設備強化

要求項目	状況 H17.7.28日 現在	達成率 (%)	達成日	
大型真空炉(2500)	Done	200	4月21日に試運転	工作センター
高圧洗浄装置(900)	Done	100	4月20日に試運転	AR東 第２実験棟
X-線シールド(200)	Done	100	２月end	AR東 第２実験棟
真空排気系の更新 (800)	Done	100	3月end	AR東 第２実験棟
9-cell 空洞4台製作 (2800)	Done	100	1台目4月end完成 残り3台６月end	

共通施設の協力でoperation可能な状態へ
目標超過達成！

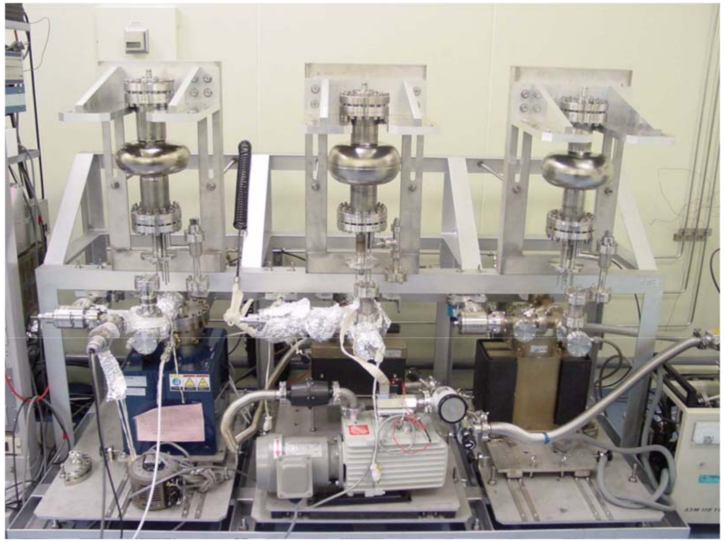
大型真空炉（KEK機械工作センター）
仕様：800$^{\mathrm{O}}$C, ~E-6 Torr,
Working zone 500$^{\phi}$x 3000L

純水高圧洗浄装置
9-cell cavity用
AR 東第2実験棟

従来使用のコンクリートシールド

今回製作した
クラッドシールド
（Fe(5cm)/Pb(6cm)/Fe(2cm)）

強化されたX-線シールド(Fe/Pb/Fe)



更新した超伝導空洞用
真空排気系システム

Power amp problem

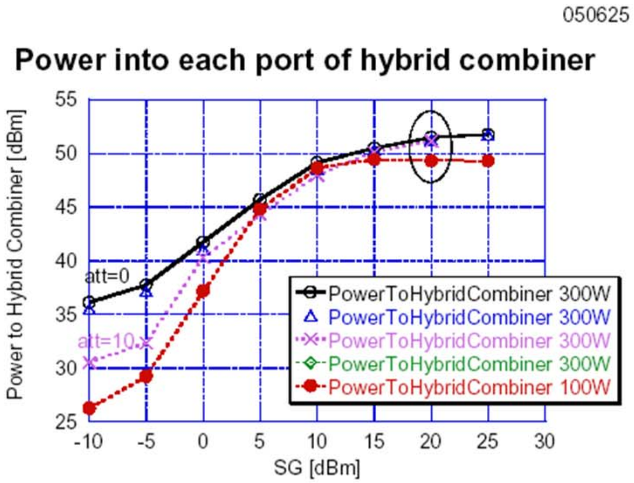
ICHIRO 9-cell空洞　Ploss 200W at 45MV/m, Net 300W必要
600W ampは入札、10月納入予定。7月の測定にまに合わない。

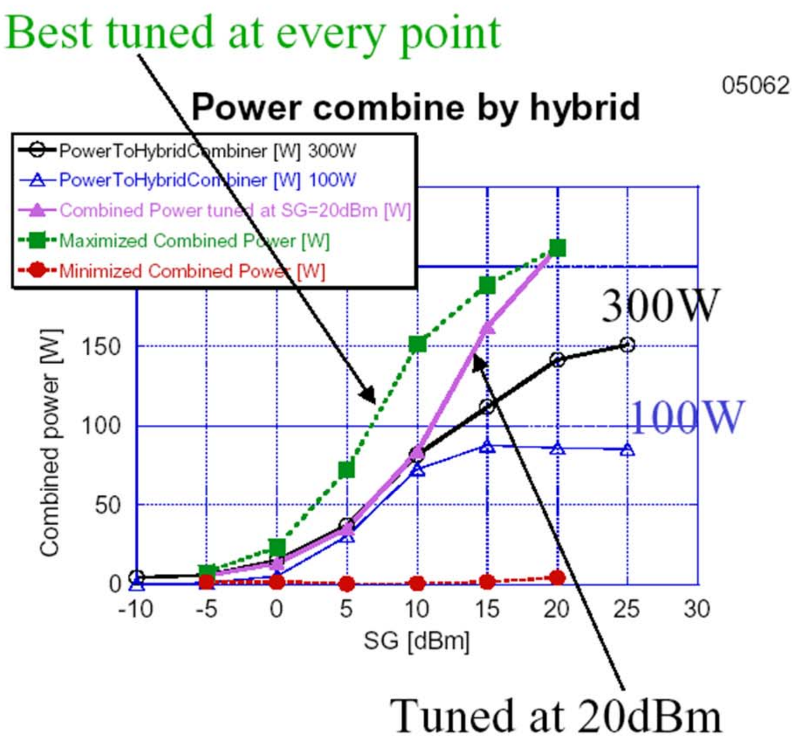
Cryostat and magnet shield for 9-cell cavity

Exchanged cryo-pit closer to 300W RF Amp

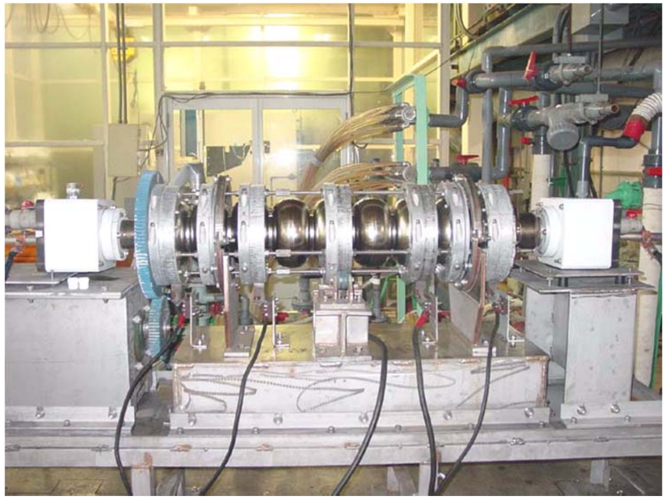
Combined power

By T.Higo





Pre-tuning after annealing
on May 21-24



Electropolishing @Nomura Plating
on May 27

HPR @ KEK on May 27-28

120^{O}C baking on May 29-31

Cavity assembly on May 28

ILC WG5 Asia activities

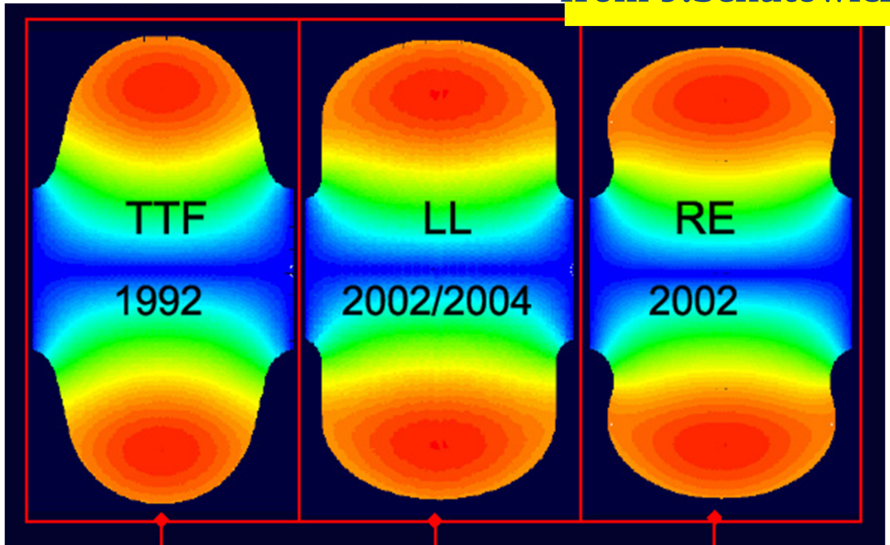
45MV/m cavityの開発戦略

Principle of 50MV/m

Cavity shape designs with low Hp/Eacc

from J.Sekutowicz lecture Note

TTF: TESLA shape
Reentrant (RE): Cornell Univ.
Low Loss(LL)： **JLAB/DESY**
Ichiro-Single(IS)： **KEK**



	TESLA	LL	RE	IS
Diameter [mm]	**70**	**60**	**66**	**61**
Ep/Eacc	**2.0**	**2.36**	**2.21**	**2.02**
Hp/Eacc [Oe/MV/m]	**42.6**	**36.1**	**37.6**	**35.6**
R/Q [W]	**113.8**	**133.7**	**126.8**	**138**
G[W]	**271**	**284**	**277**	**285**
Eacc max	**41.1**	**48.5**	**46.5**	**49.2**

ILC WG5 Asia Strategy and R&D Issues

- Push gradient higher for the future ILC energy reach
- Needs enough margin on 35MV/m operation
- Cavity operation cost saving by 10% by LL cavity shape
- Industrialization : Conventional baseline fabrication and advanced Nb/Cu clad seamless cavity for cost down

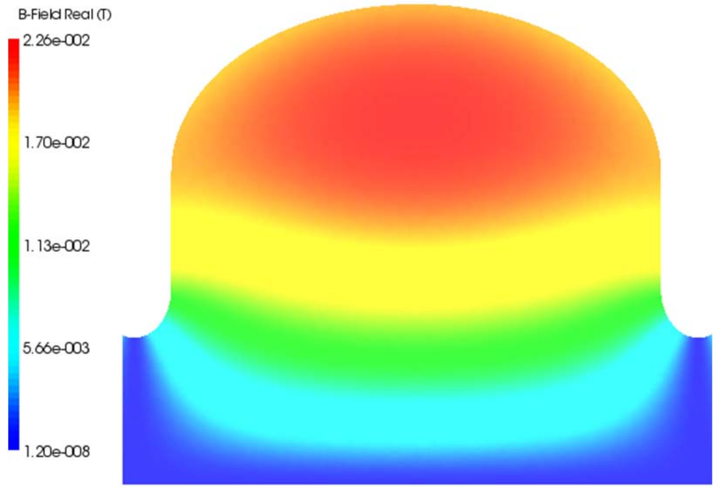
KEK decided to develop the LL shape 9-cell cavity for ILC and demonstrate the high gradient (45MV/m) module operation in STF at least by the TDR.

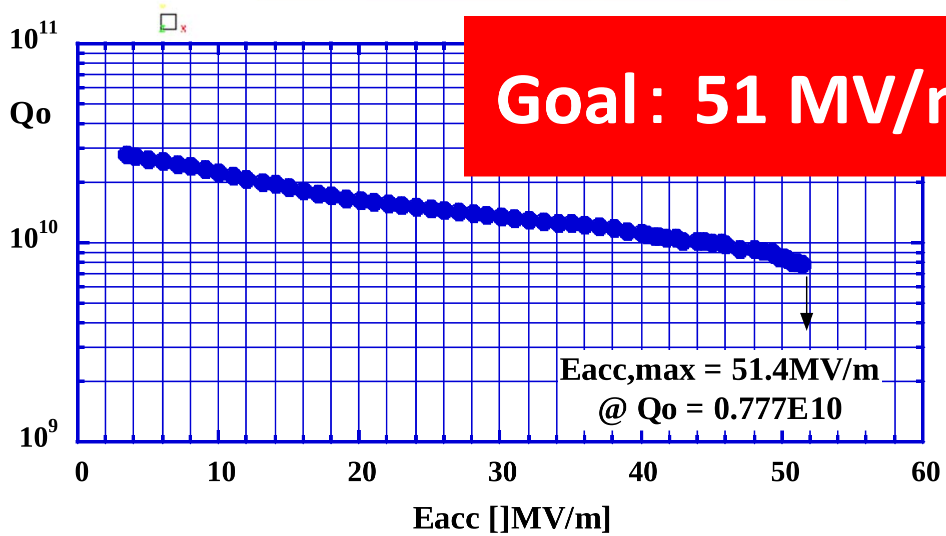
Need a wide dynamical range tuner for larger Lorenz detuning
Need a higher power (500kW) input coupler

R&D Issues :

1) 45MV/m high gradient cavity
2) Wide dynamical range tuner system
3) 500kW high power coupler
4) Baseline fabrication, Nb/Cu clad seamless cavity fabrication

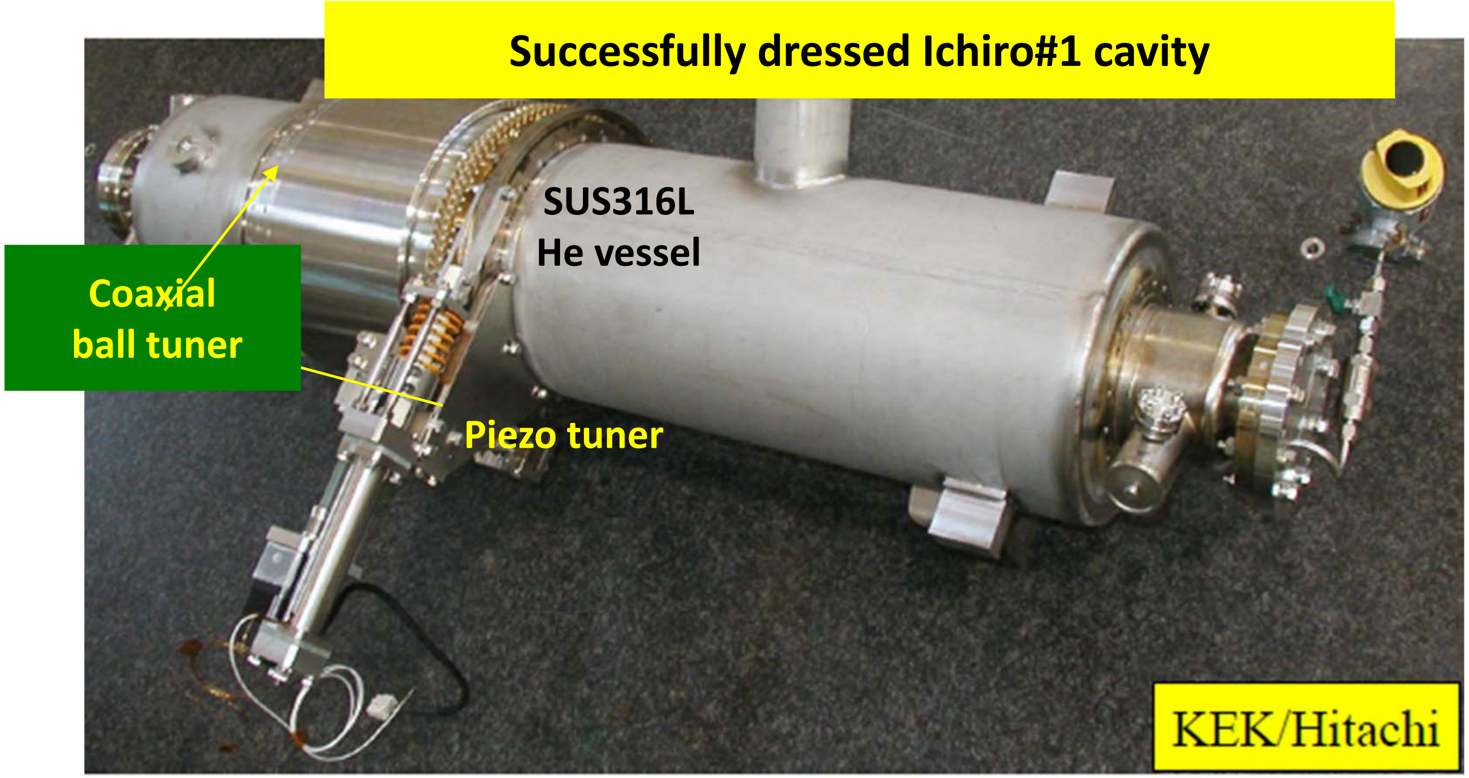
ICHIRO Cavity program in KEK for ILC



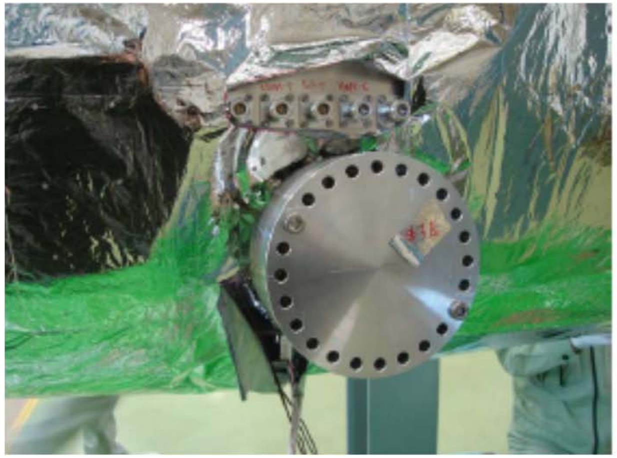


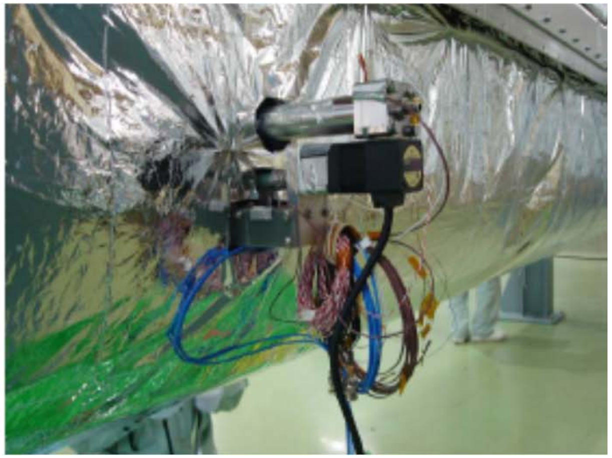
Goal：51 MV/m!

Development of Wide Range Tuner



String assembly and Cryomodule assembly

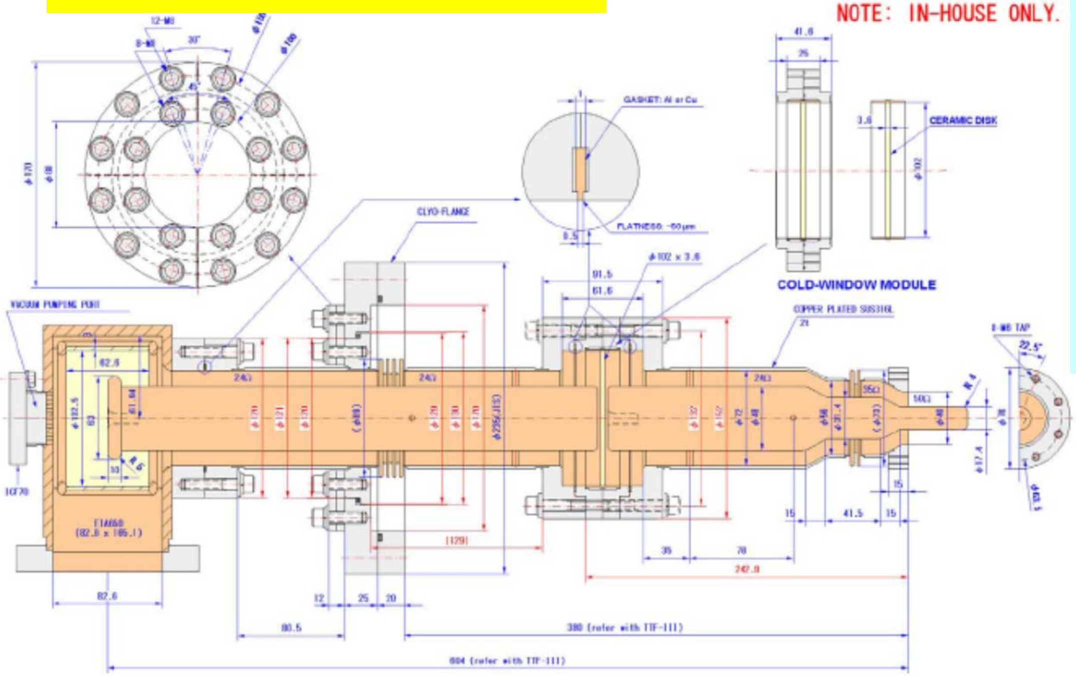




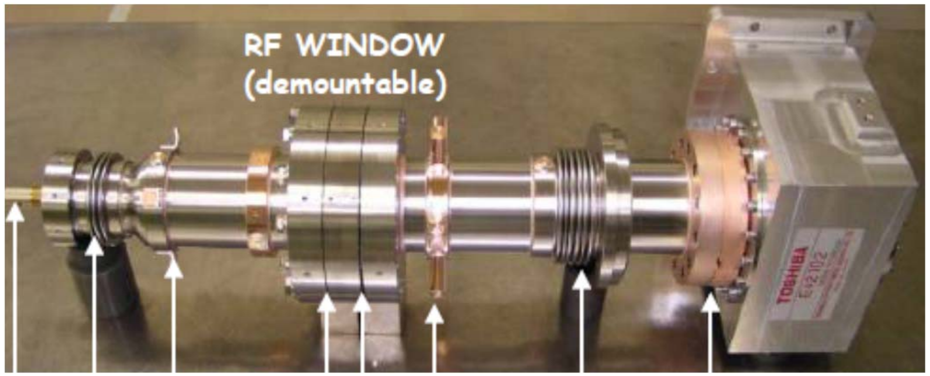
Investigate what kinds of problem are there in all the processes:
cavity fabrication to high power test in the cryomodule

Development of high power input coupler

By H.Matsumoto and S.Kazakov



The specification: 500kW,
1.5msec, 5Hz
@ 45MV/m operation



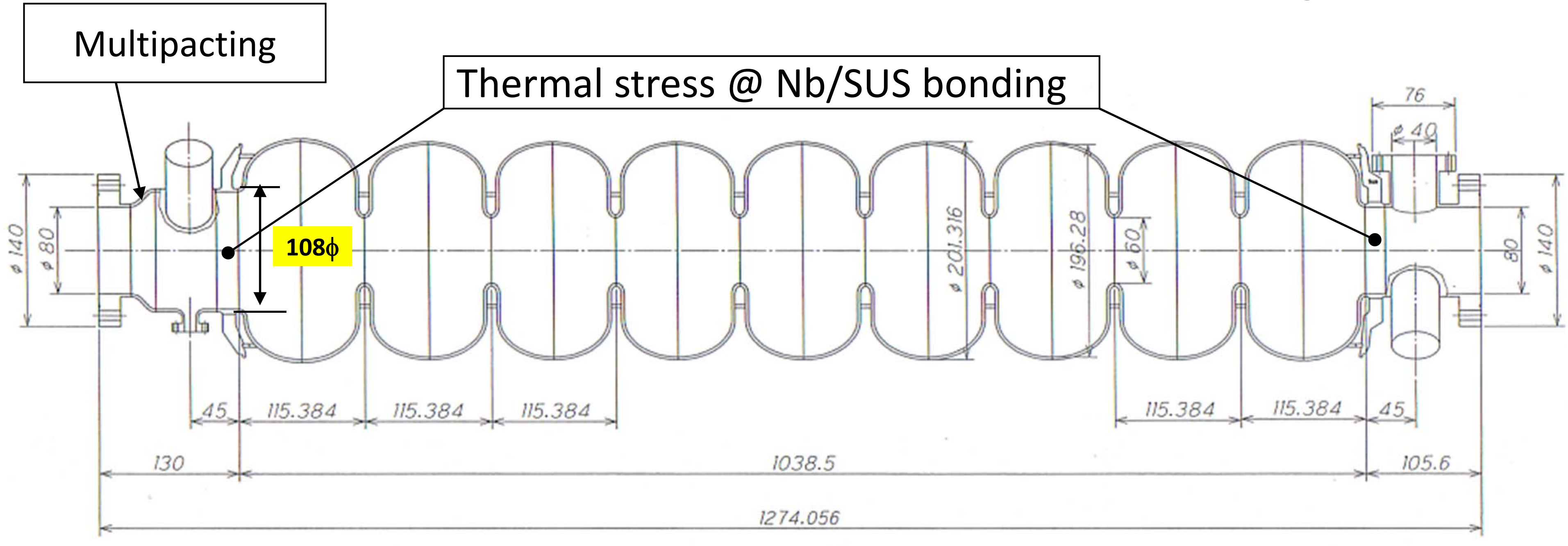
Schedule of STF 0.5

STF 0.5: Each cryomodule so called 35 baseline/45 High gradient
installs one cavity package,
Will be tested
Cavity performance
High power coupler
and Tuner

- Cryomodule assembly will be completed by the END of Feb 2007
- Cryogenic will be completed by the END of March 2007
- First cool down, April 2007
- Warm window connection, May 2007
- Second cool down for STF0.5, June 2007

Problems on Ichiro 9-cell cavities and what learned

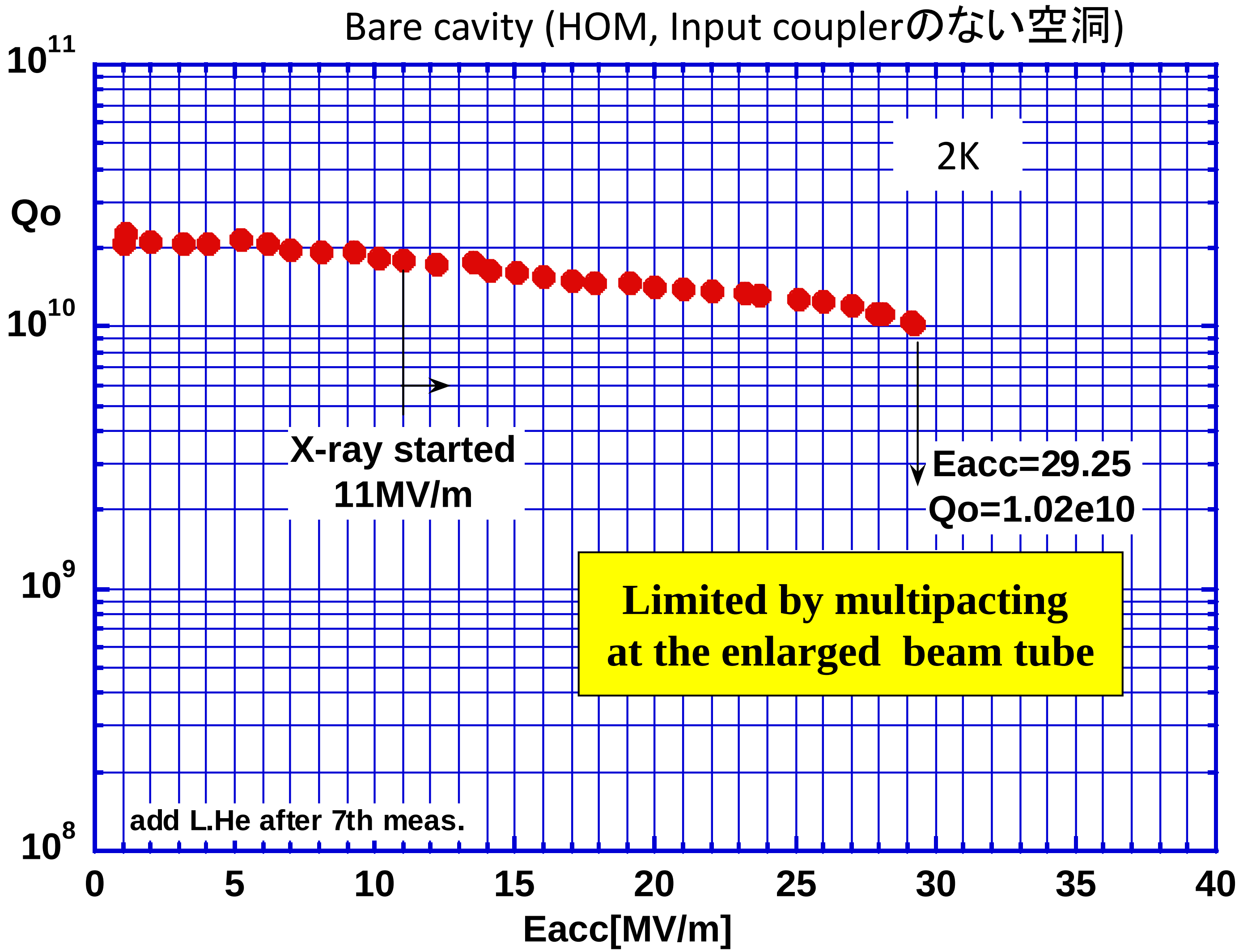
Ichiro 9-cell cavity



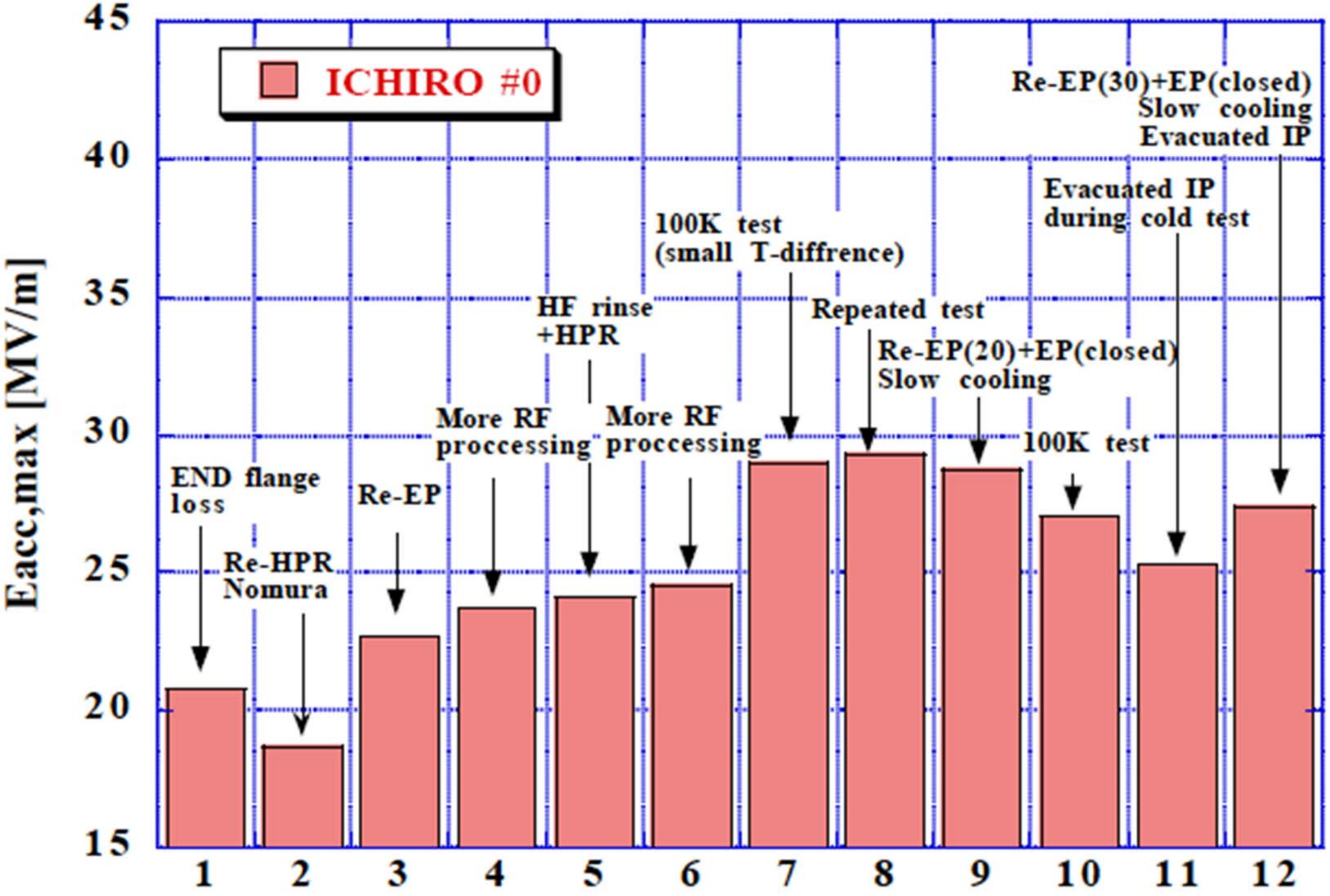
Problems on Ichiro 9-cell cavities (Ichiro#0, #1 ,#2, #3)

1) Low Q → understood
2) Multipacting at tapered beam tube → under testing with single cell cavities
3) Thermal stress on the Nb/SUS bonding → Analyzed
4) Too much coupling to fundamental at HOM pickup ports → under re-designing
5) Field Emission

Result of the ICHIRO 9-cell #0



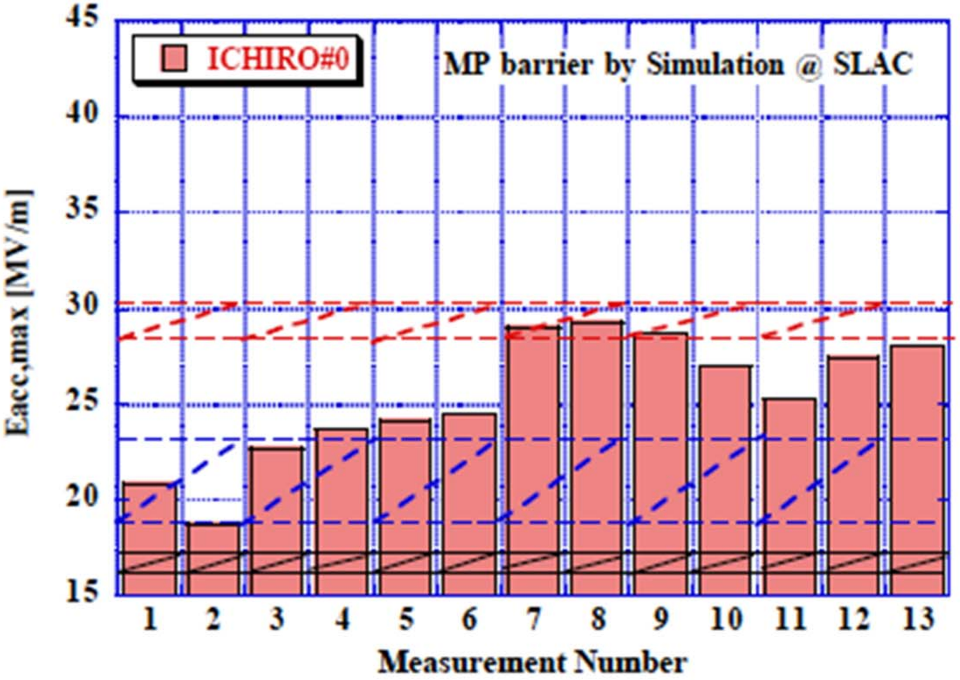
History of Ichiro#0



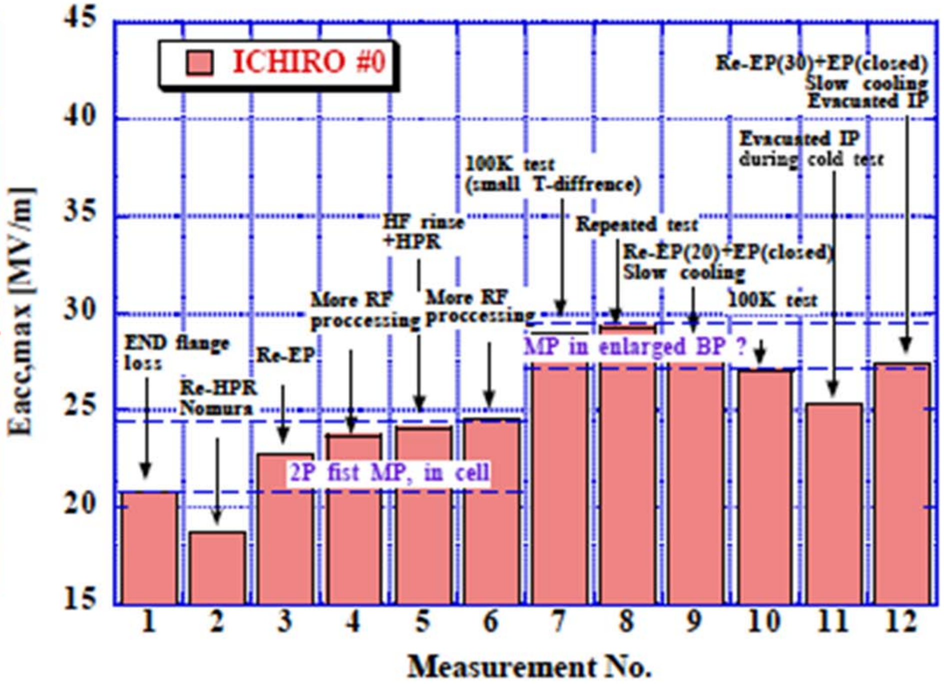
What we have learned from the history

1) The T-difference between Top and Bottom makes MP more sever.
2) Vacuum closed might be better than evacuating during the cold test.
3) Some physics should be there behind the limitation around 29MV/m. MP!?

Eacc,max v.s. MP simulation



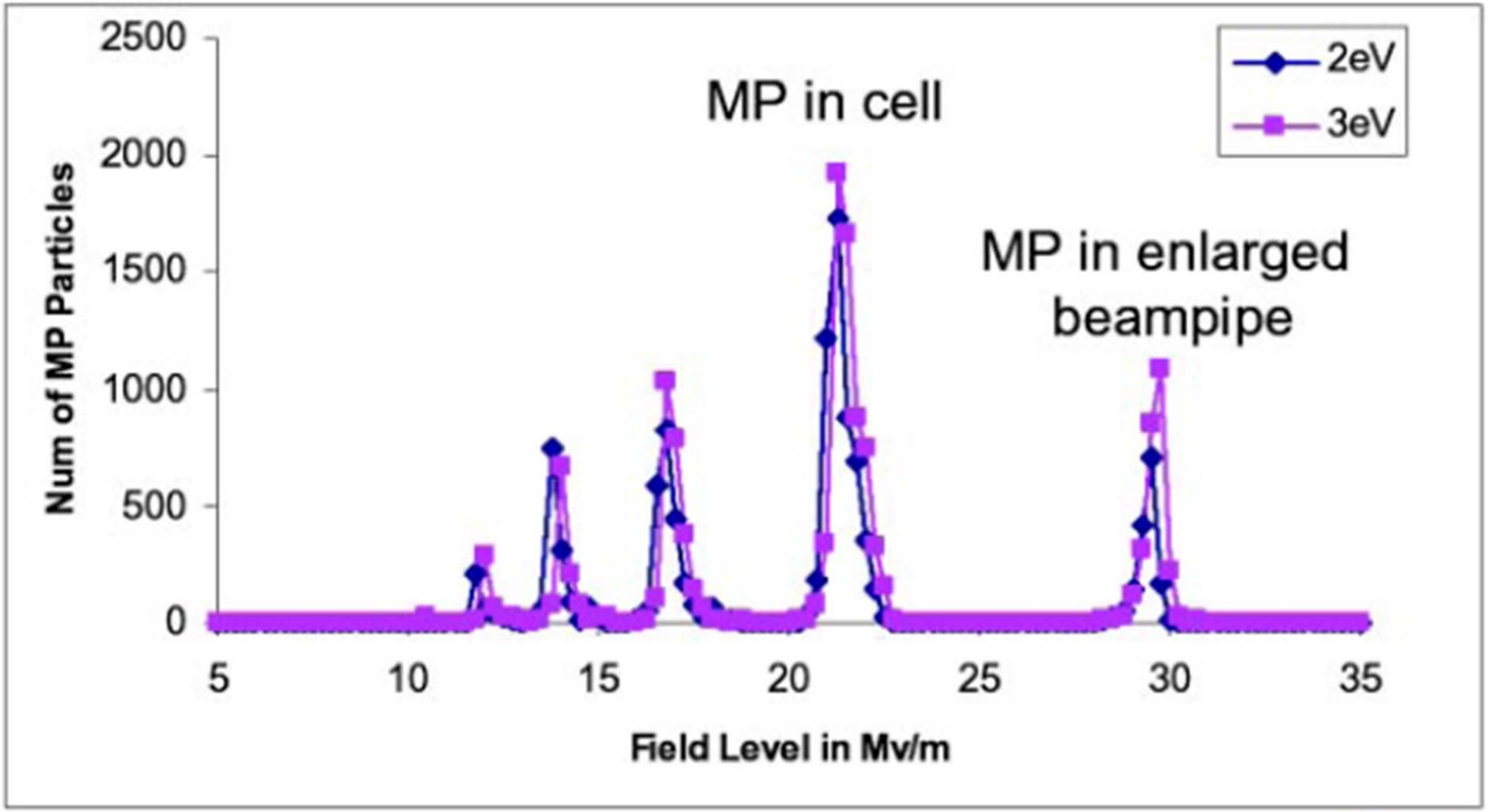
Simulated MP region by L.Ge @ SLAC



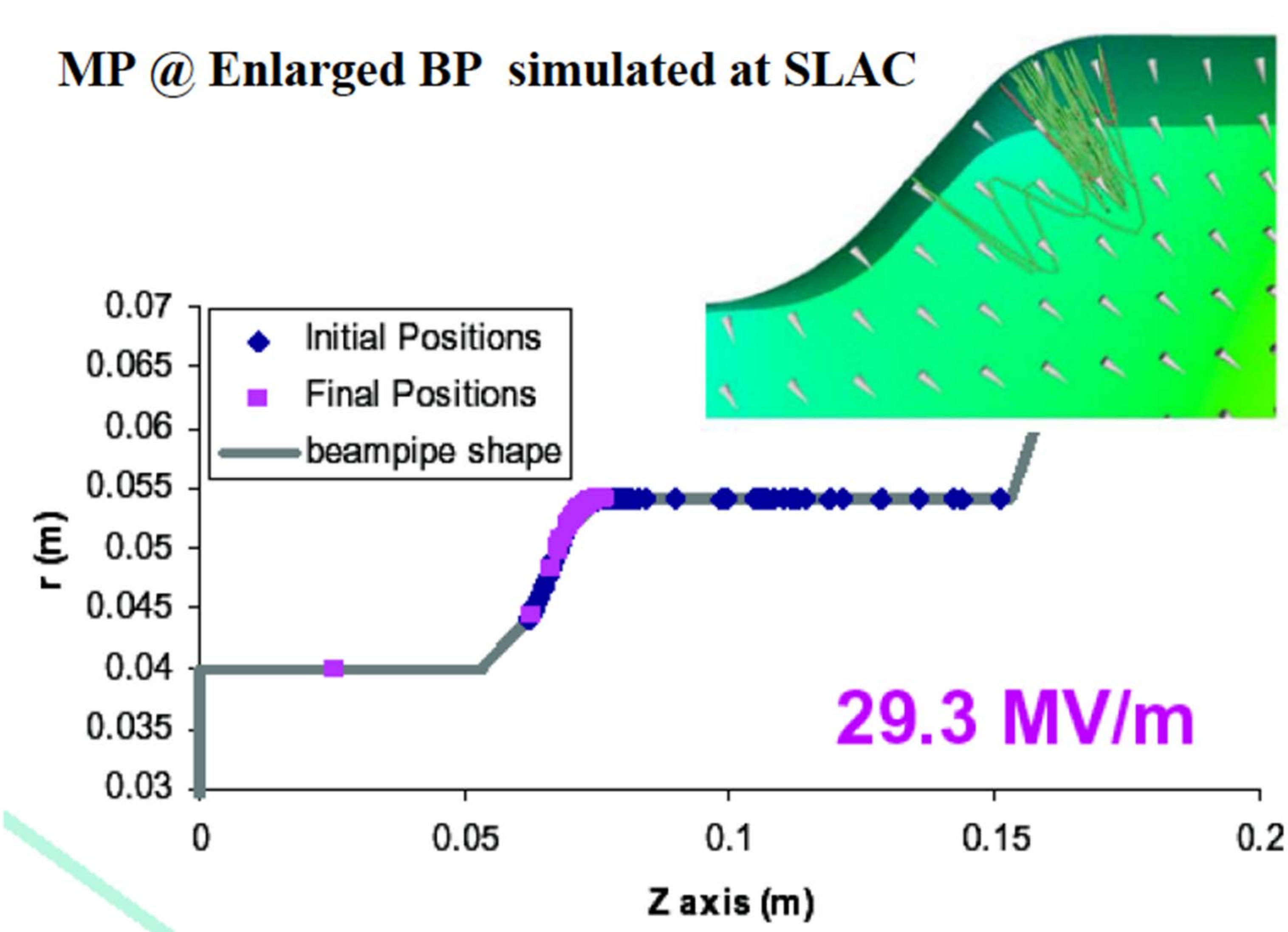
MP region expected from Exp.

Multipacting simulation for ICHIRO cavity @ SLAC

MP in end-group of ICHIRO Cavity with enlarged beampipe (L. Ge)

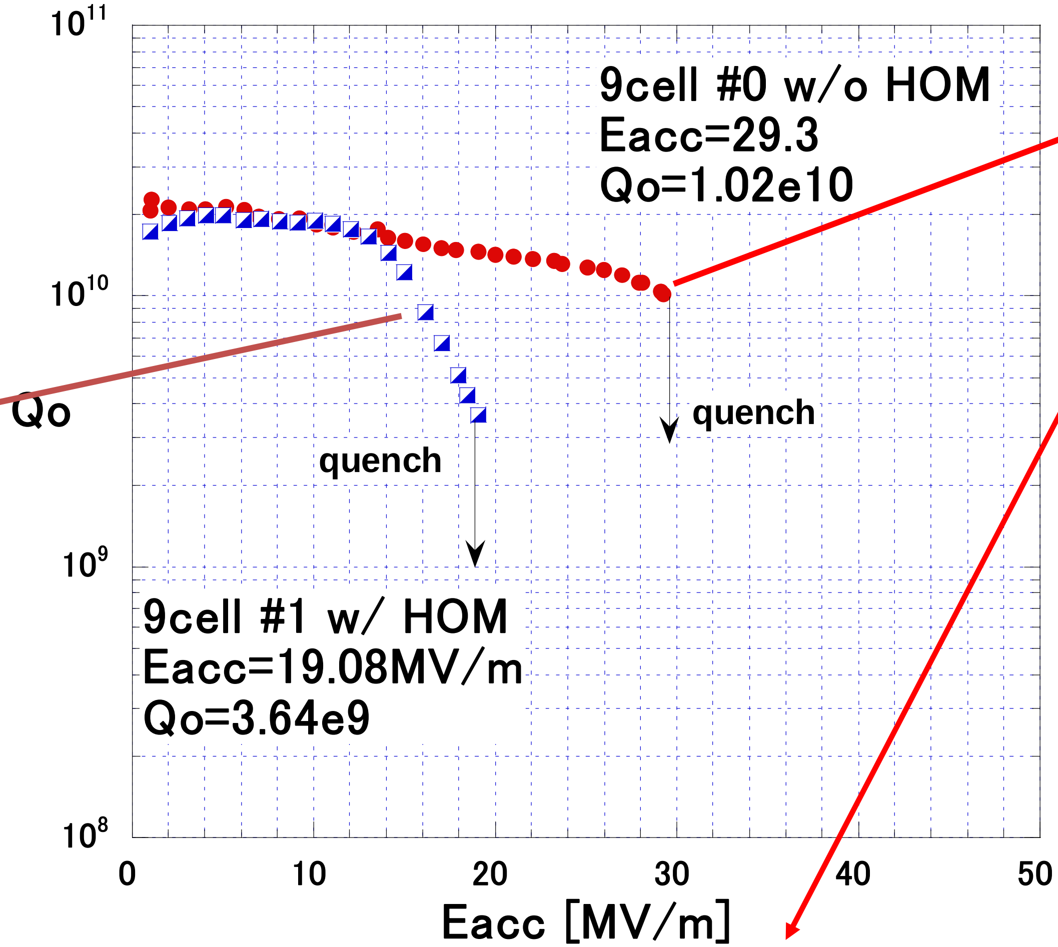


Multipacting @ enlarged beam pipe



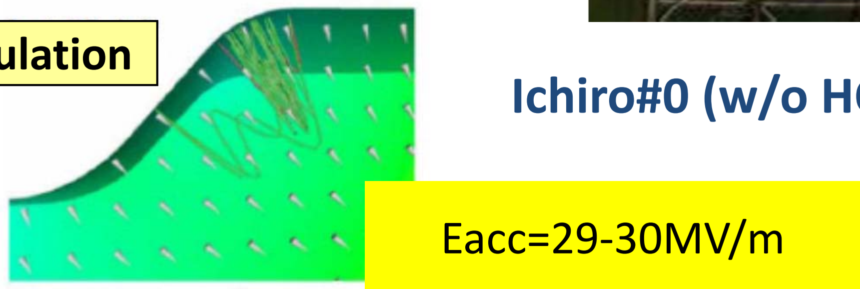
Result of Ichiro full 9-cell cavity

Ichiro#1 w/ HOM



Ichiro#0 (w/o HOM)

SLAC simulation



STF 0.5 Study

Demonstration of High Power Test (Cavity, Input coupler, Tuner)

Step-0: STF-0.5, Successfully Done on Mar. End 2008

Step-I: Join Global STF-1 Study, from Dec. End 2008 ?

STF R&D Plan @ KEK

STF-0.5

Old Box | Cavity | Cavity | Cavity | Cavity

Single 9-cell cavity in a sizes cryomodule
High power test
No beam
#STF BL cavity, Done
#LL cavity, Done on END of March 2008

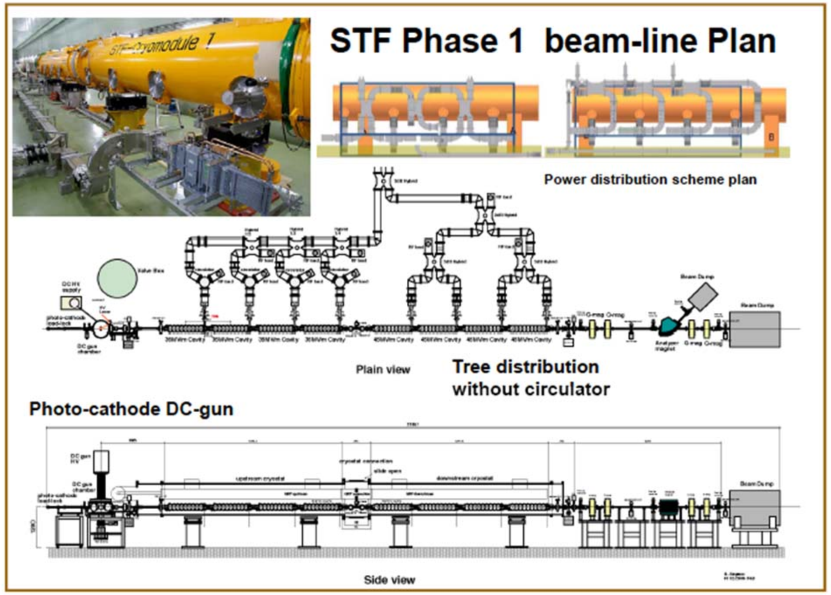
STF-I

X 2

Old Box | Cavity | Cavity | Cavity | Cavity

Four 9-cell cavities in a sizes cryomodule
High power test
Beam test
#STF BL cavity,   Will done in Autumn 2008
#LL cavity, Will start in Winter 2008

(Four 9-cell cavities in a sizes cryomodule) x 2
High power test
Beam test
Will be done in Autumn 2008



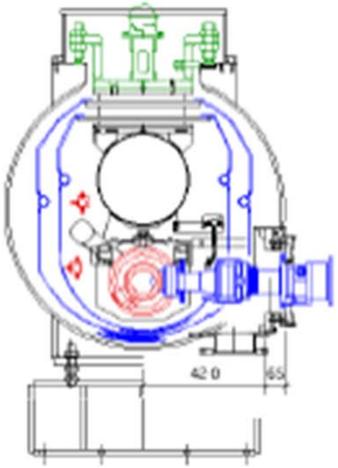
One ILC RF unit

STF-II: 2010-2011

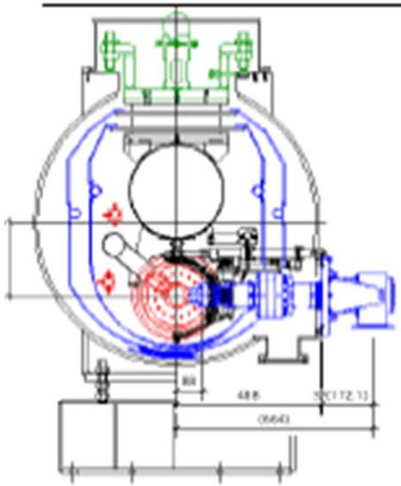
Old Box | 9 cavities | 8 cavities + QM | 9 cavities

STF0.5 Cavity Installation into Cryomodule

One TESLA shape Cavity, One LL shape cavity are installed into STF phase1 cryomodule. (STF Phase 0.5)



TESLA shape Cavity



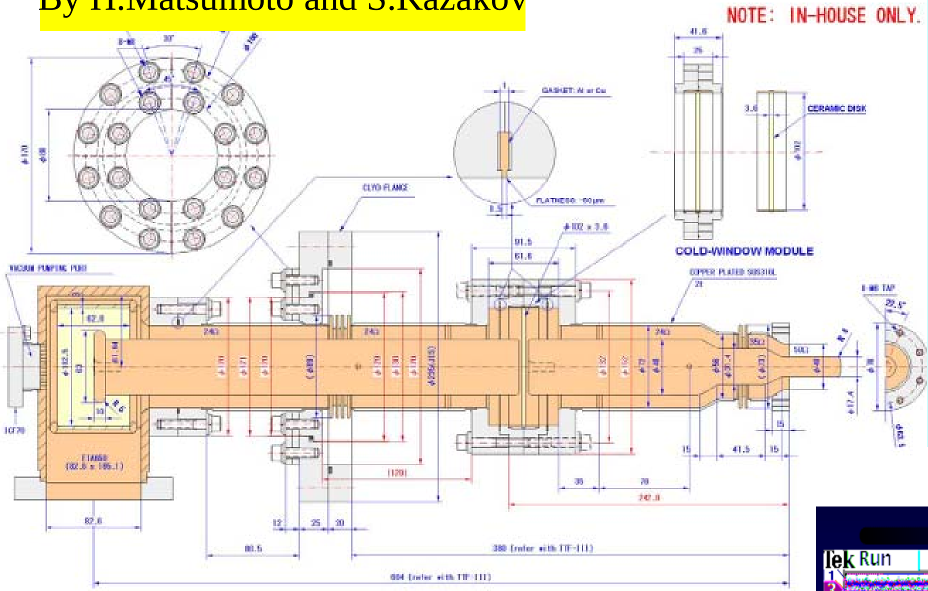
LL shape Cavity

High Power Coupler

For 4x9cell SST, 2MW coupler is needed but it almost exists.

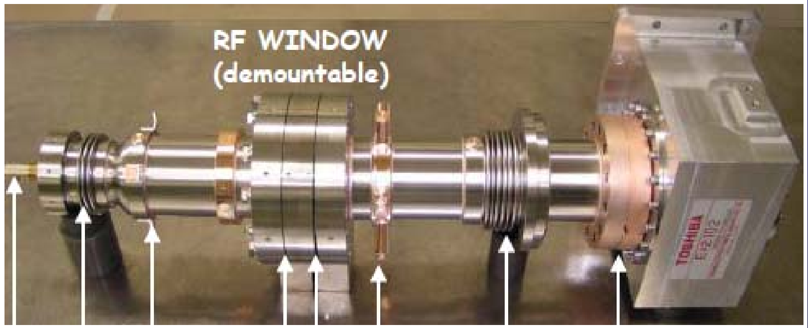
KEK STF 0.5 activity

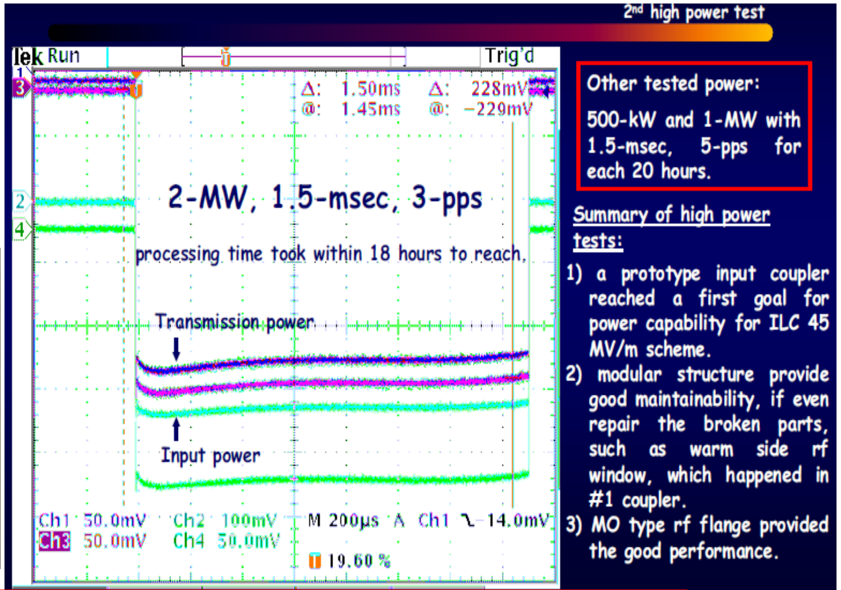
By H.Matsumoto and S.Kazakov



Successfully demonstrated the high power performance up to 2MW!

The specification: 500kW, 1.5msec, 5Hz @ 45MV/m operation

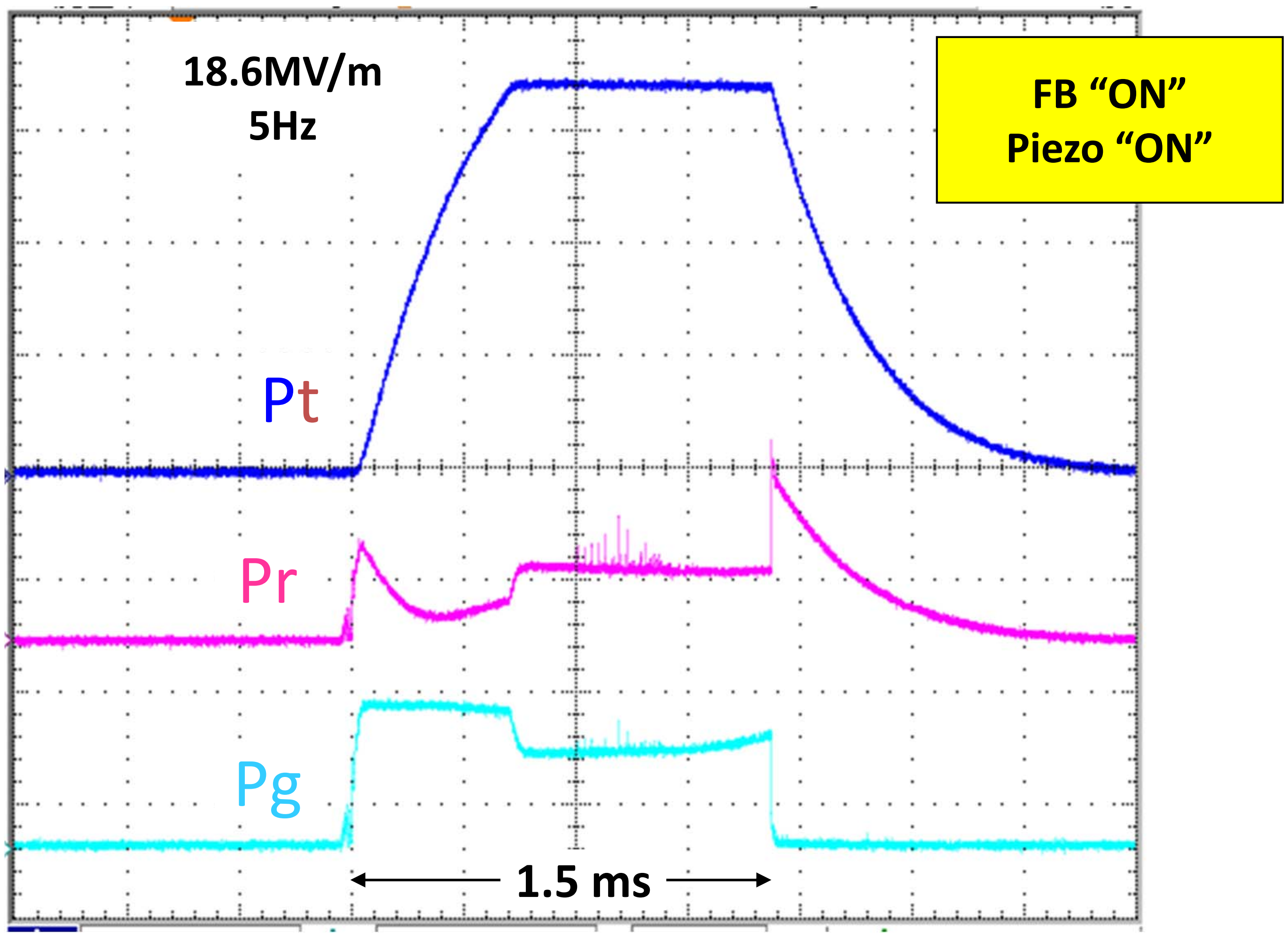




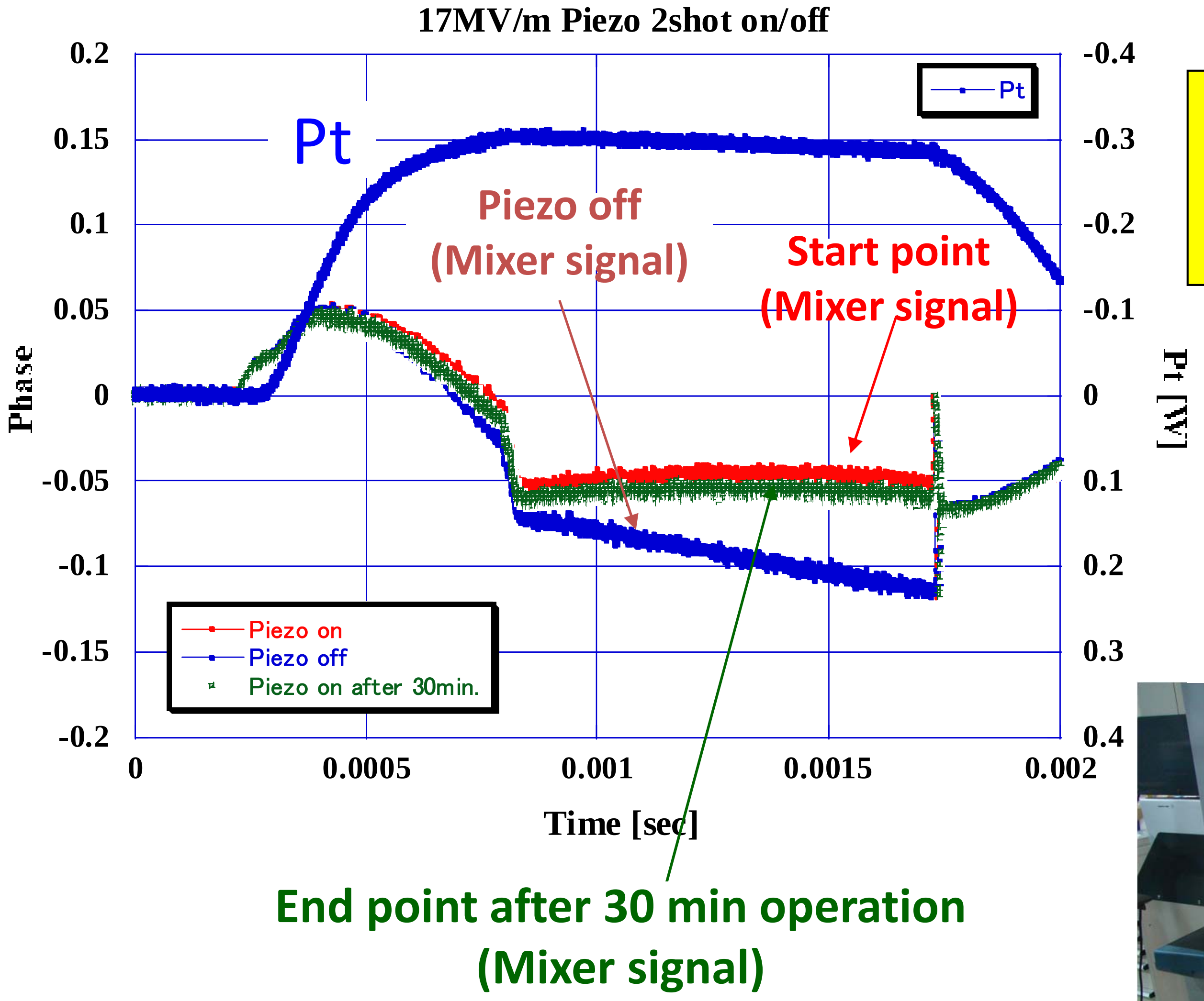
Successfully power loaded at 2MW, 1.5ms, 3pps.

Successful high power operation @ 18.6MV/m on Ichiro 9-cell cavity

STF0.5



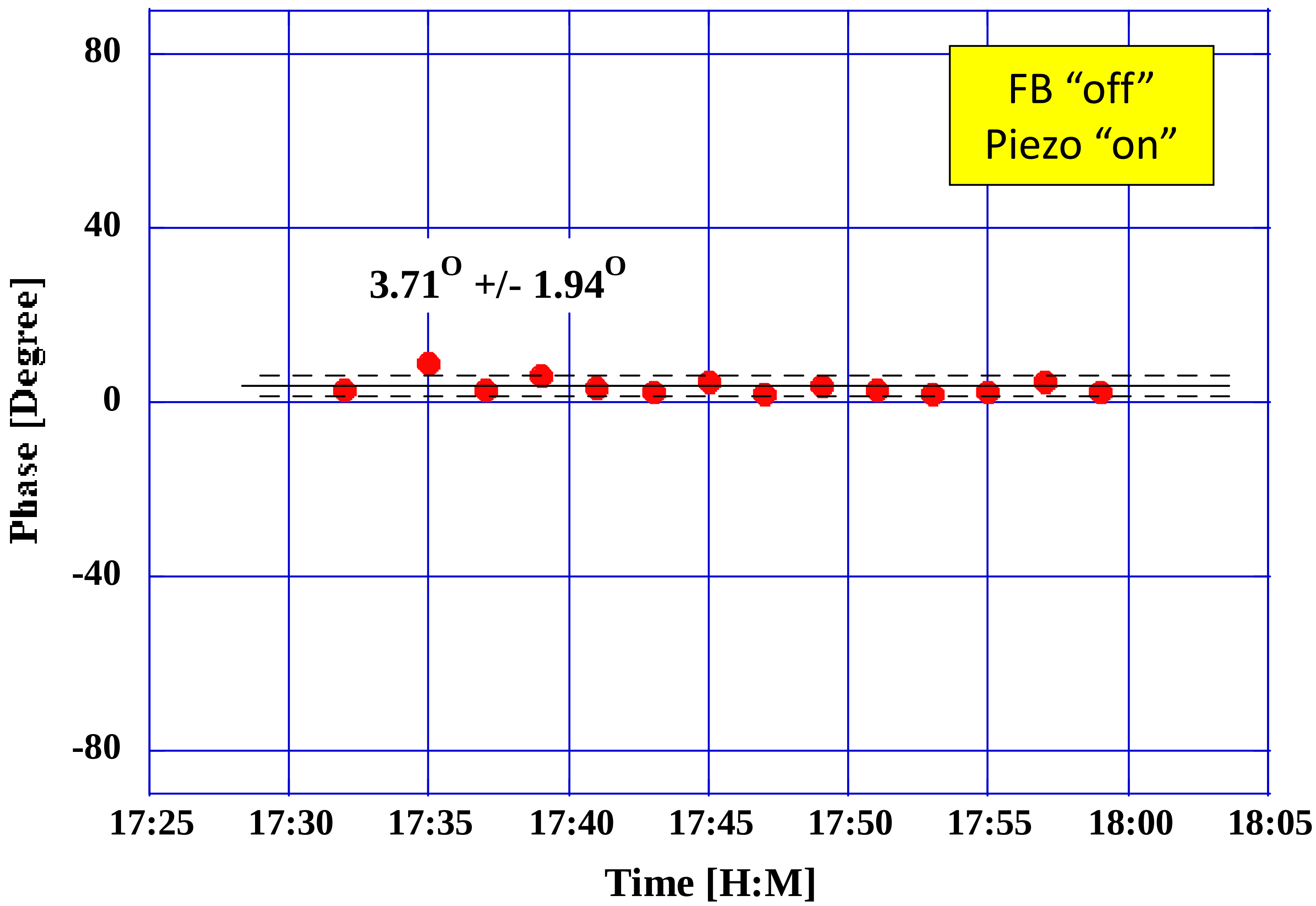
Phase variation at start/end of 30mim operation @ 17MV/m



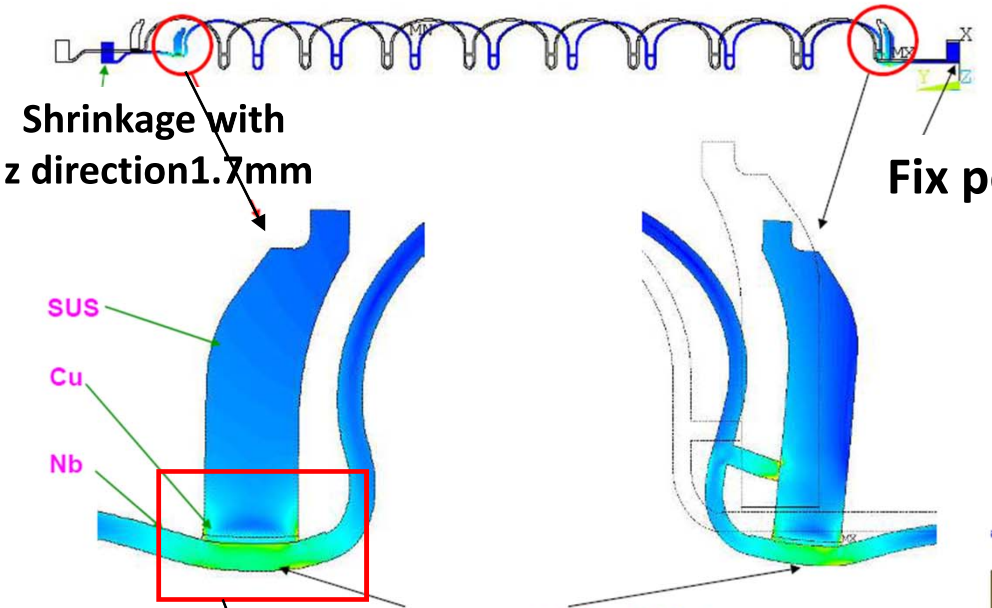
FB “off”
Piezo “on”

Watching the mixer signal
during the operation by Dr. Y.Higashi

Phase variation in 30 minutes operation @ 17MV/m



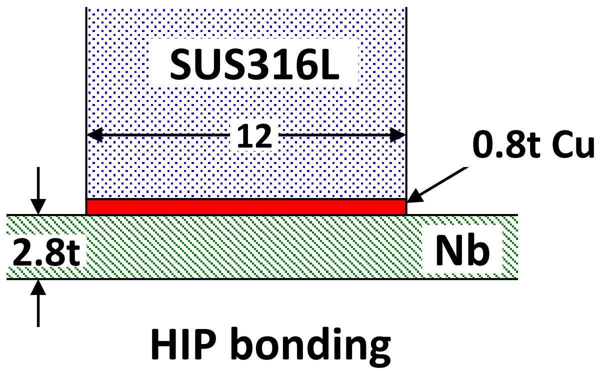
Thermal stress at the END Plate



Fix point

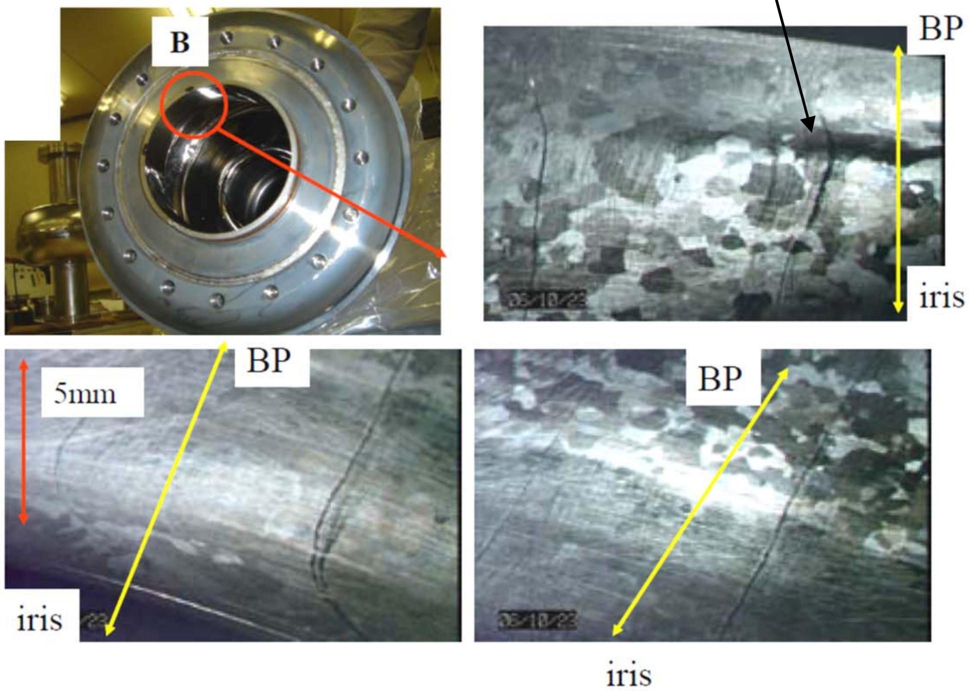
Simulated by H.Yamaoka

Stress concentration
~250MPa due to shrinkage 0.15mm



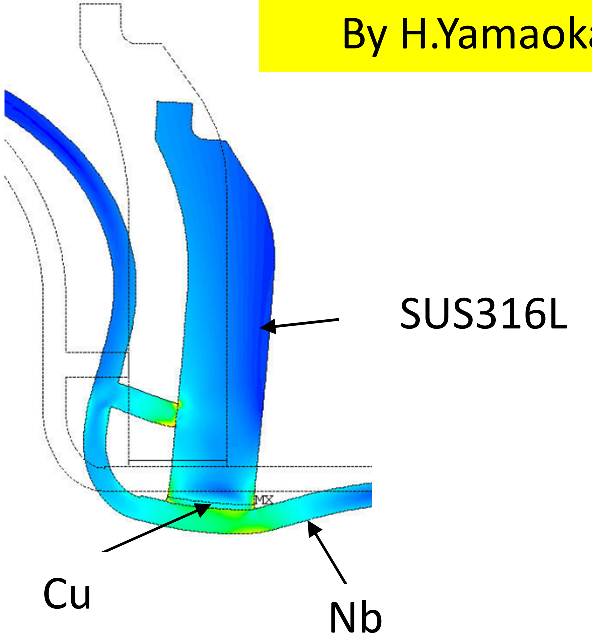
Stain marks?
No marks by visual inspection after light CP(20μm)

ICHIRO #0 BPϕ80 crack-B

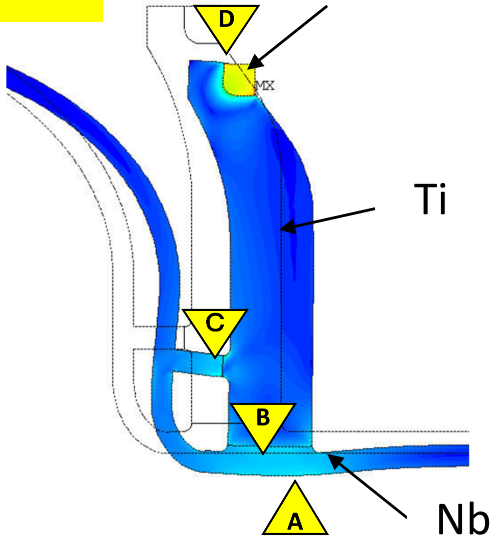


Cure for the thermal stress at the base plate

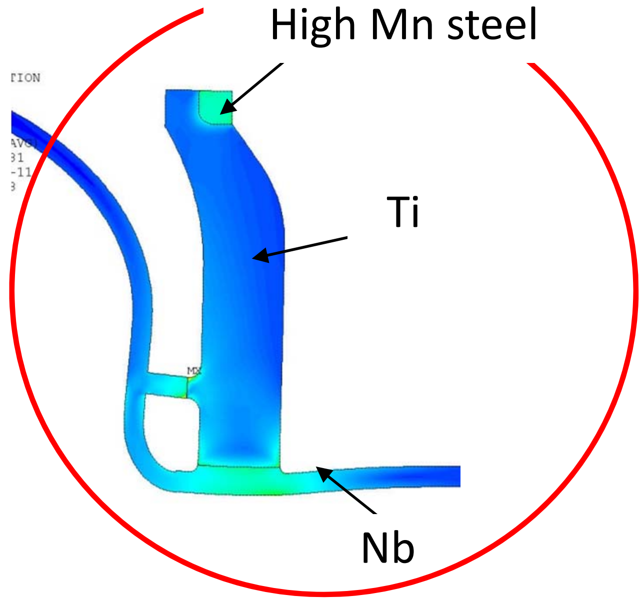
By H.Yamaoka



Nb/Cu/SUS316L



Nb/Ti+SUS316L



Nb/Ti+High Mn steel

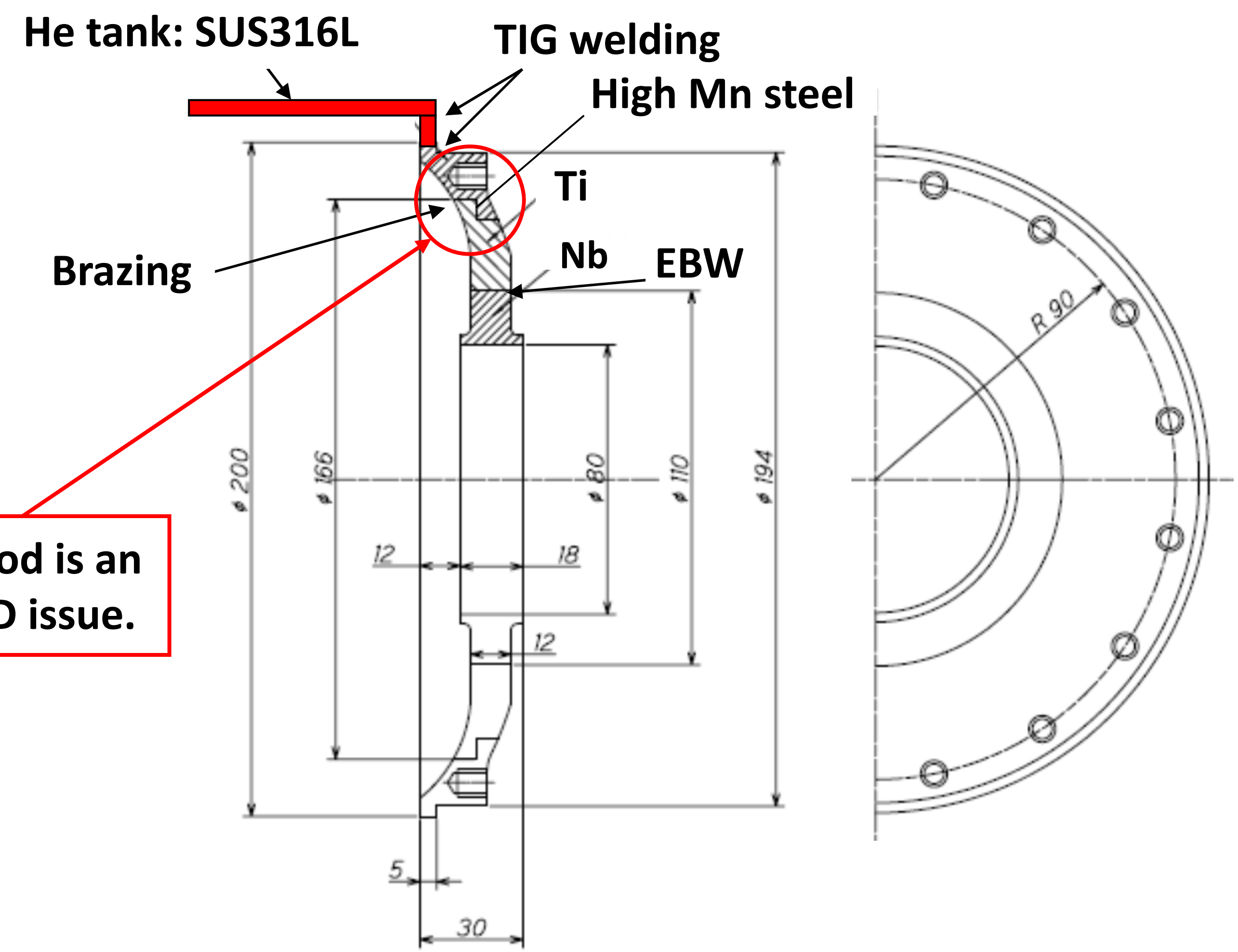
Stress concentration

	A [MPa]	B [MPa]	C [MPa]	D [MPa]
Nb/Cu/SUS316L	250	500	500	
Nb/Ti/SUS316L	100	100	200	470
Nb/Ti/High Mn Steel	100	100	200	80

Thermal expansion coefficient

	$\alpha = \frac{\int_{77K}^{300K} \alpha(T)dT}{300-77}$ [E-6/K]
SUS316L	16.0
Cu	17.0
High Mn steel	9.8
Ti	8.4
Nb	5.0

Design of new END base plate

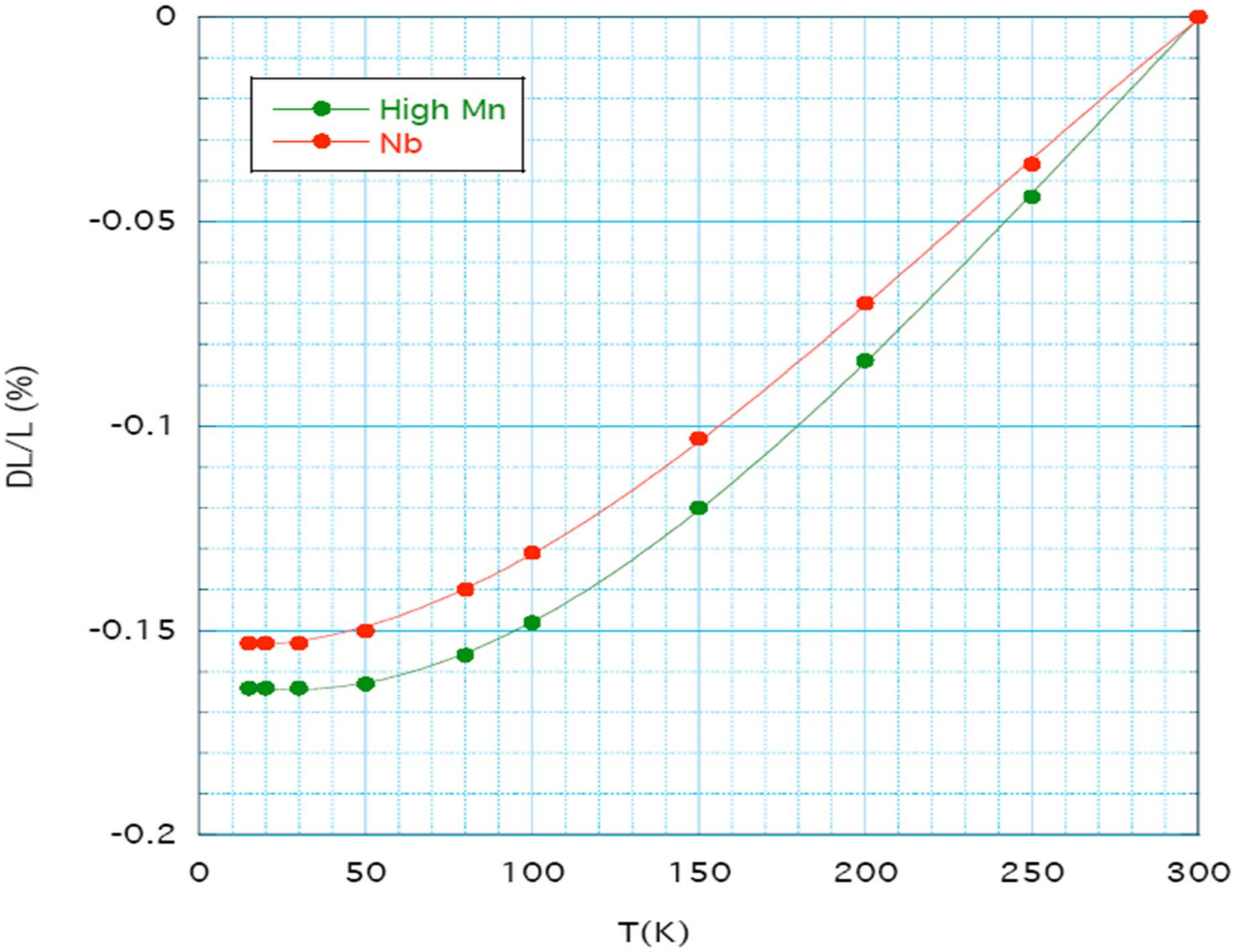


Welding method is an important R&D issue.

High Mn 鋼とNbの熱収縮率（１）

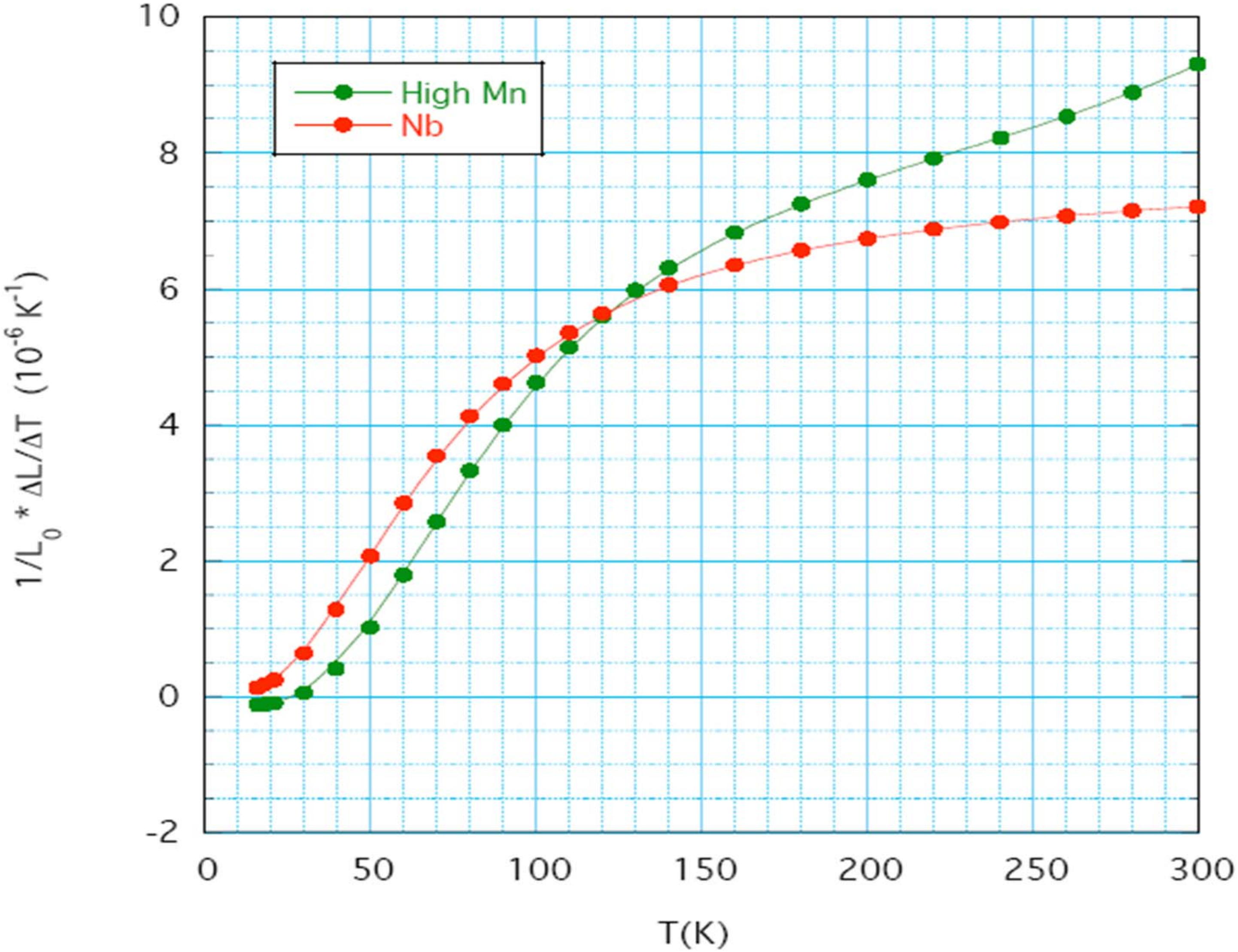
2008/3/12 K.T

measured by N. Yamada(AIST)



High Mn鋼とNb の熱収縮率（２）　2008/3/12 K.T

measured by N. Yamada (AIST)



Mechanical property @ cold Temperatures

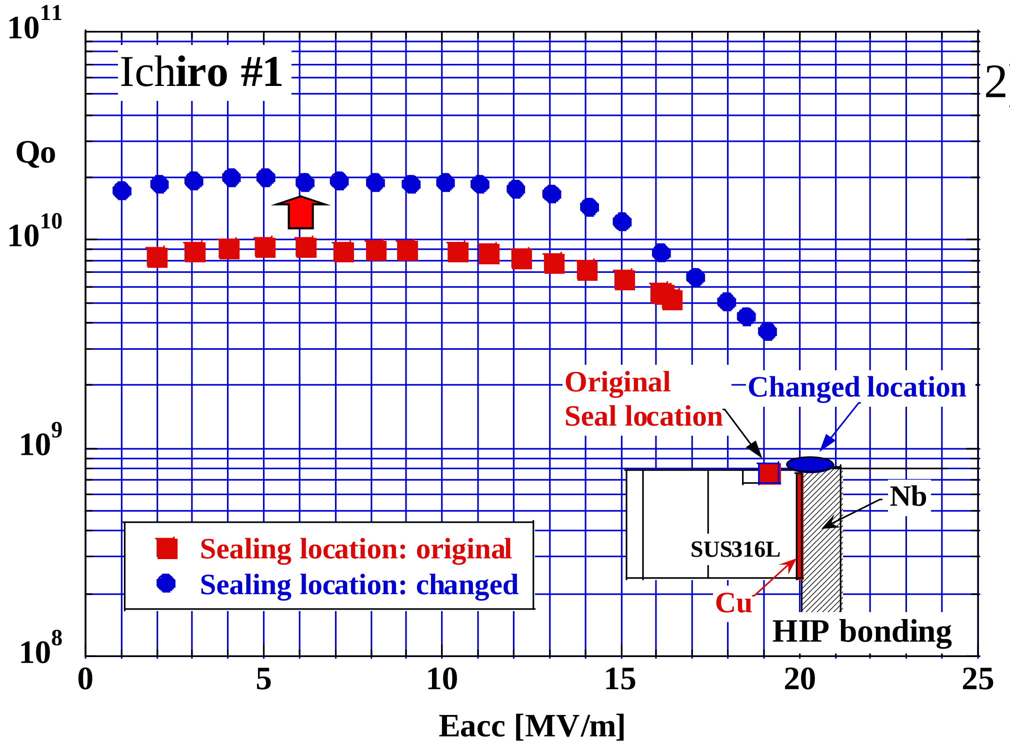
Materials	0.2% Yield Strength [MPa] 300K	77K	4.2K	Tensile [MPa] 300K	77K	4.2K	Charpy Impact Test [J] 300K	77K	4.2K
Nb	34.3 ~51.0		621.7 ±47.7	132.4 ~154.5		930.0 ±48.0			
Ti 1st Grade	204.3 ±4.2	346.3 ±5.5	408.3 ± 13.8	297.7 ±6.0	715.7 ±4.2	951.7 ±9.0	261.8 ± 4.6	213.8 ± 16.2	195.8 ± 12.7
Ti 2nd Grade	351.7 ±7.0	636.0 ±4.6	691.3 ±16.6	445.7 ±7.1	863.7 ±3.1	1093 ±5.3	101.0 ± 8.1	32.0 ± 2.5	27.8 ± 4.5
Ti Tsuchiya							114.6 ±6.9	88.3 ±75.8	
SUS 316L			615.6 ±2.3			1483.6 ±5.0			
Ti(2nd)/Ti (2nd) TIG welding	274.7 ±21.5	443.3 ±22.0	517.7 ±17.8	415.3 ±2.1	822.0 ±2.6	1041.7 ±3.1	50.6 ±0	38.4 ±2.0	34.8 ±1.0
Ti(2nd)/Ti (2nd) EBW	334.0 ±1.7	573.3 ±1.2	649.3 ±9.6	447.7 ±0.6	859.7 ±2.1	1088.0 ±3.5	59.6 ±1.5	55.7 ± 0	52.8 ±1.3
Nb/Ti(2nd) EBW							61.6 ±4.4	18.2 ± 3.8	19.5 ±7.9
Nb/Cu/SUS 316L HIP			276.4 ±8.4			694.4 ±28.9	79.0 ± 20.3	19.0 ± 5.5	
Nb/Ti HIP			ND			183.8 ±63.1	1.78 ± 0.11	1.71 ± 0.30	
Ti/SUS 316L HIP			ND			475.4 ±44.3			
Ti/SUS 316L HIP Tsuchiya (several conditions)				381 ~ 486	566 ~ 742		3.2 ~ 10.1	1.1 ~ 4.3	
Ti/SUS 316L HIP Tsuchiya (STF)		746 ±55.2					10.4 ±2.1	4.2 ±0.5	
Ti/Ni/SUS 316L Explosive Bonding			358.4 ±45.2			537.8 ±31.5			
Ti/Ni/SUS 316L Explosive Bonding Tsuchiya							25.3 ±1.4	20.0 ±1.3	
Ti/SUS 316L Friction & Compensation		778.3 ±55.2					2.9	1.7	

Charpy impact energy must be higher than 18-27 J @ 2K by Japanese high pressure vessel cord.

Revised Cavity Shape

Heating at the sealing gas due to field penetration

Q depends on the sealing location !



Low Q Problem Scenario

1) "Cold leak @ Nb/SUS bonding" ×

He absorption

Low Q

2) "Heating mechanism @ sealing gap" ◎

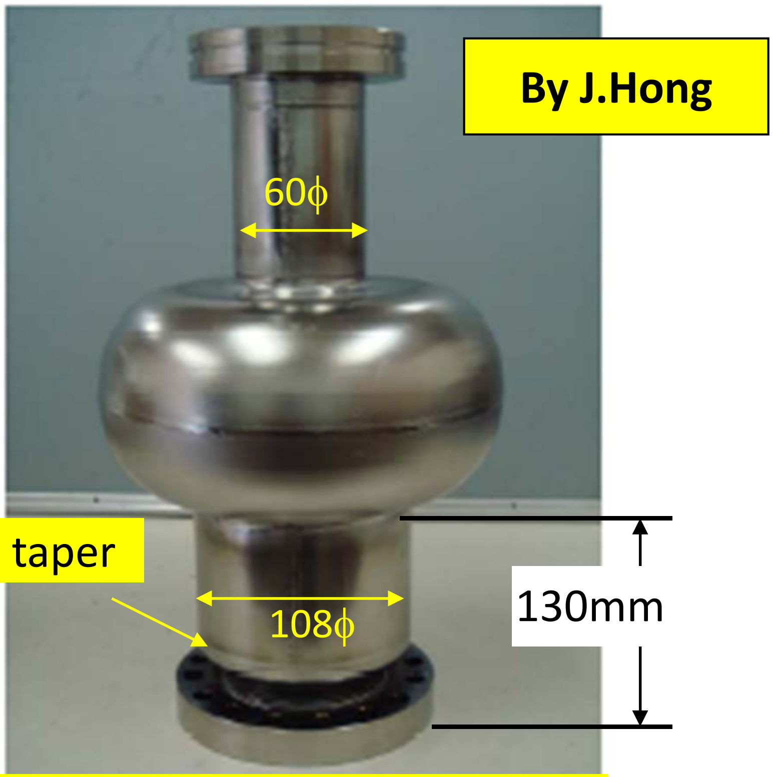
Large beam tube (108ϕ)

Large field penetration

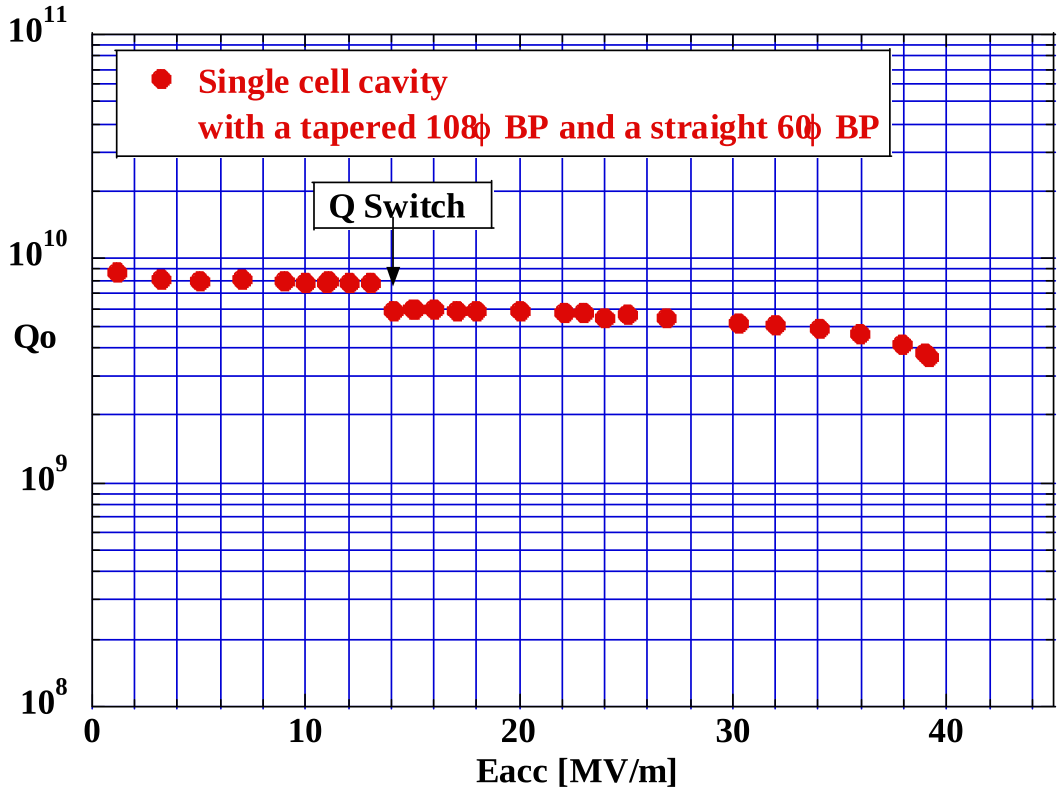
Heating at sealing gap

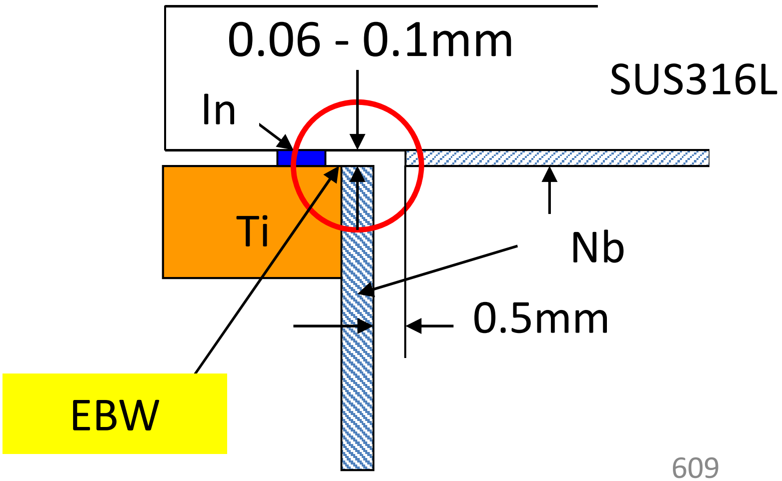
Observed the the same problem in the Ichiro END single cell, which was EB welded Ti flanges on Nb BP tubes

END single cell study result



Ichiro single END cell

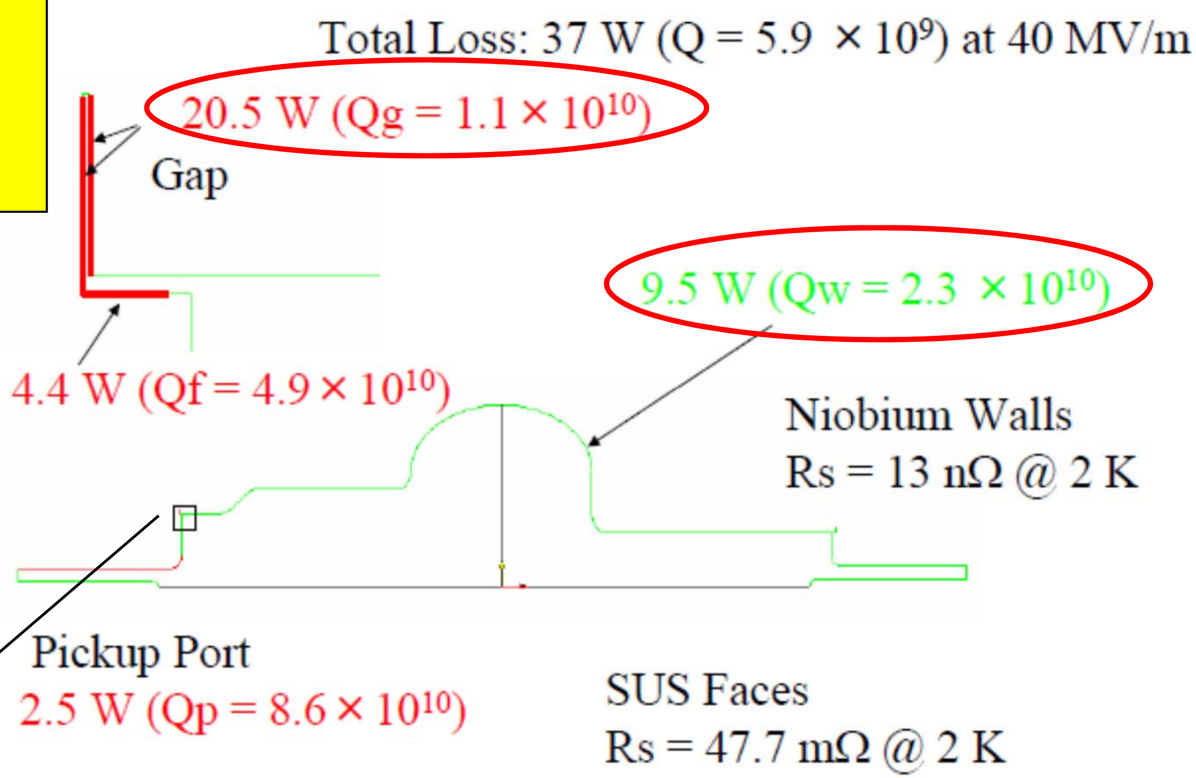


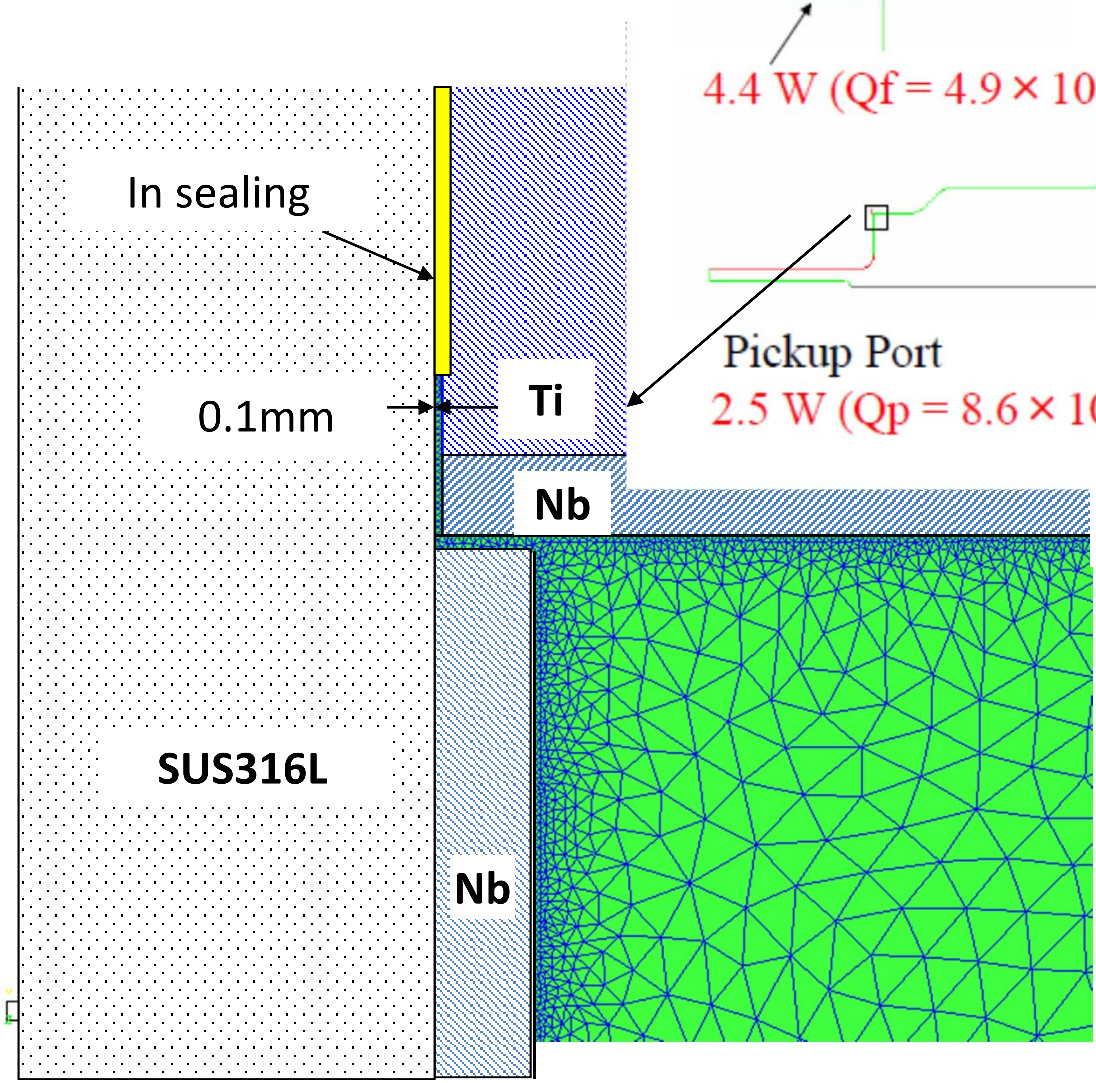


No T-mapping

Simulation suggests a heating at the sealing gap, by Y.Morozumi

RF simulation of the heating at the sealing gap heating by Y.Morozumi

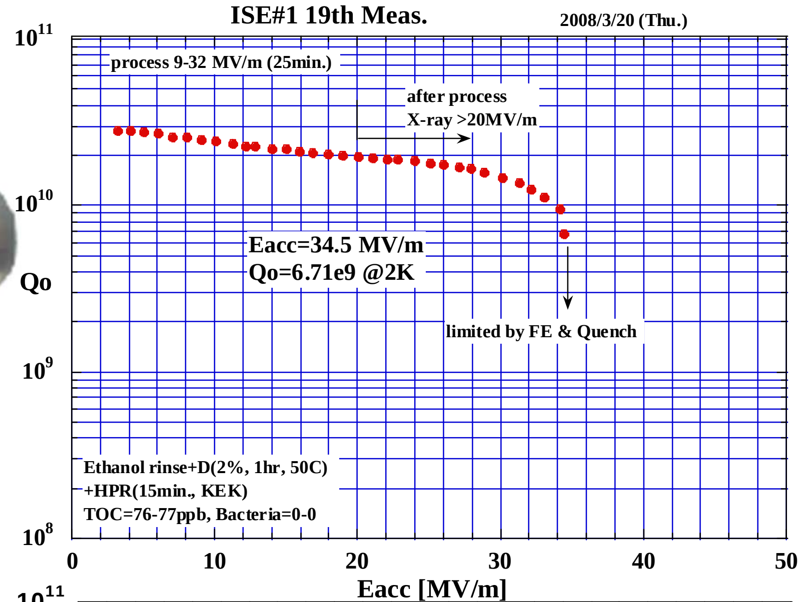




Heating @ the sealing gap is double of the cavity wall loss!

END cell of the Old Ichiro Cavity

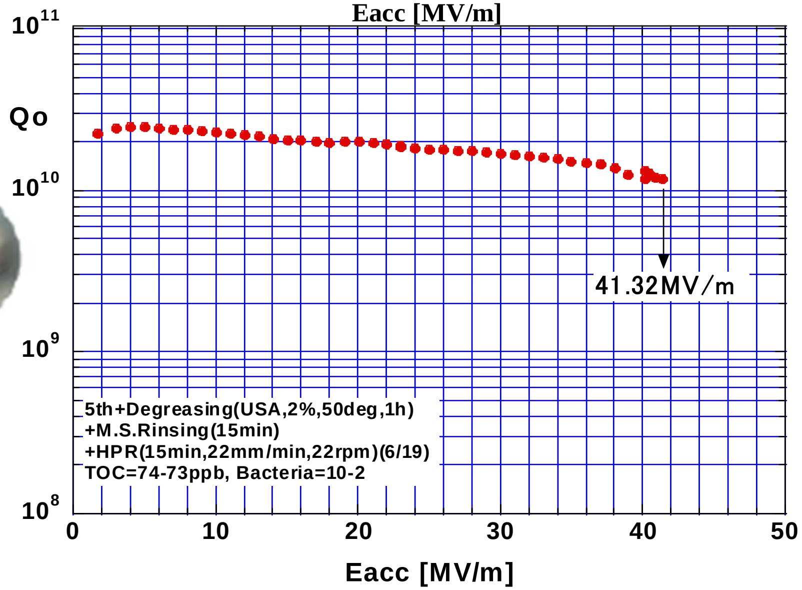
ISE#1



Replaced the SUS end plate to Cu one.

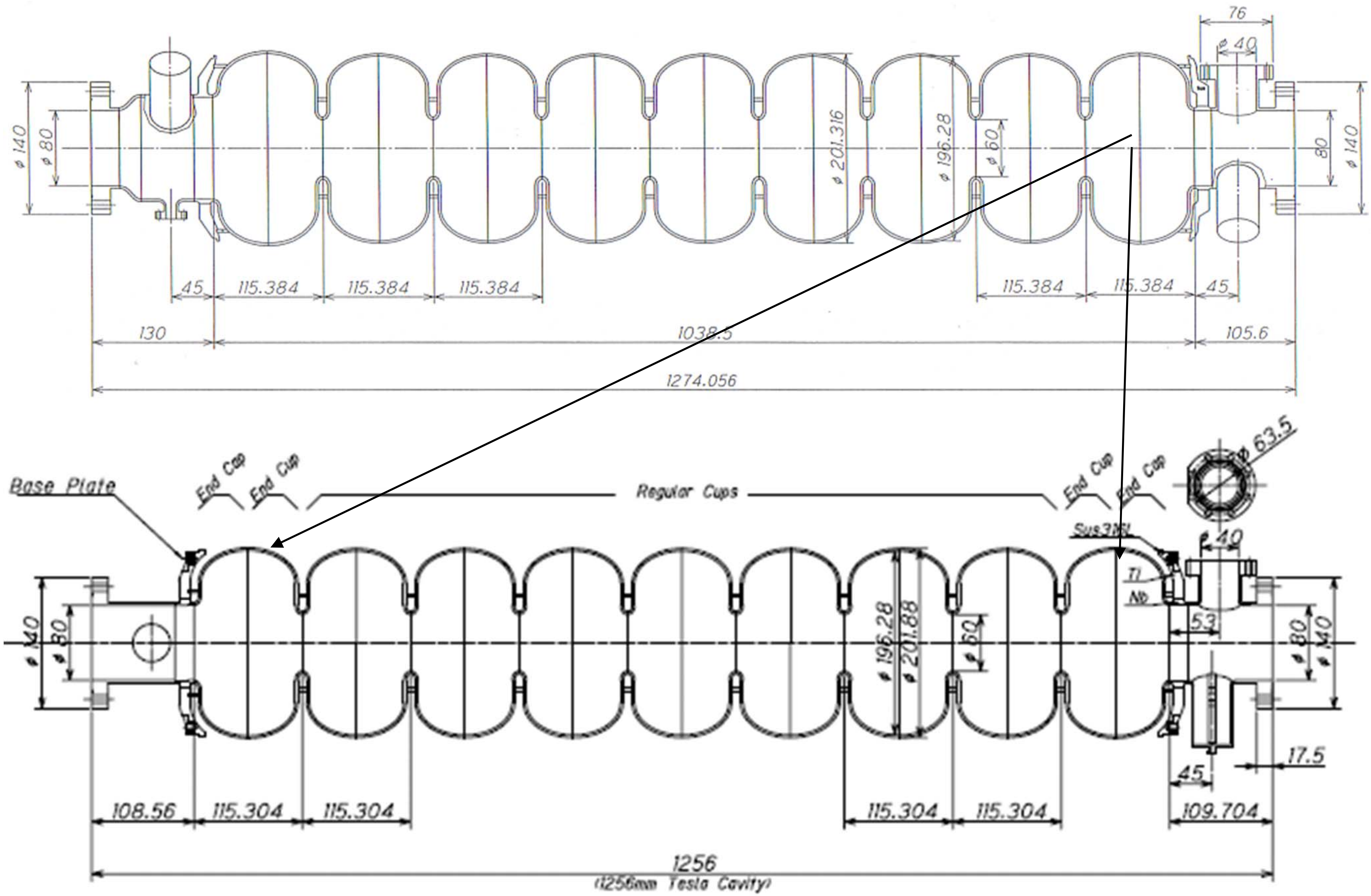
Hard Quench
@ the end of the Large BP(108ϕ) !?

ISE#2



Achieved the theoretical limitation
No Problem !

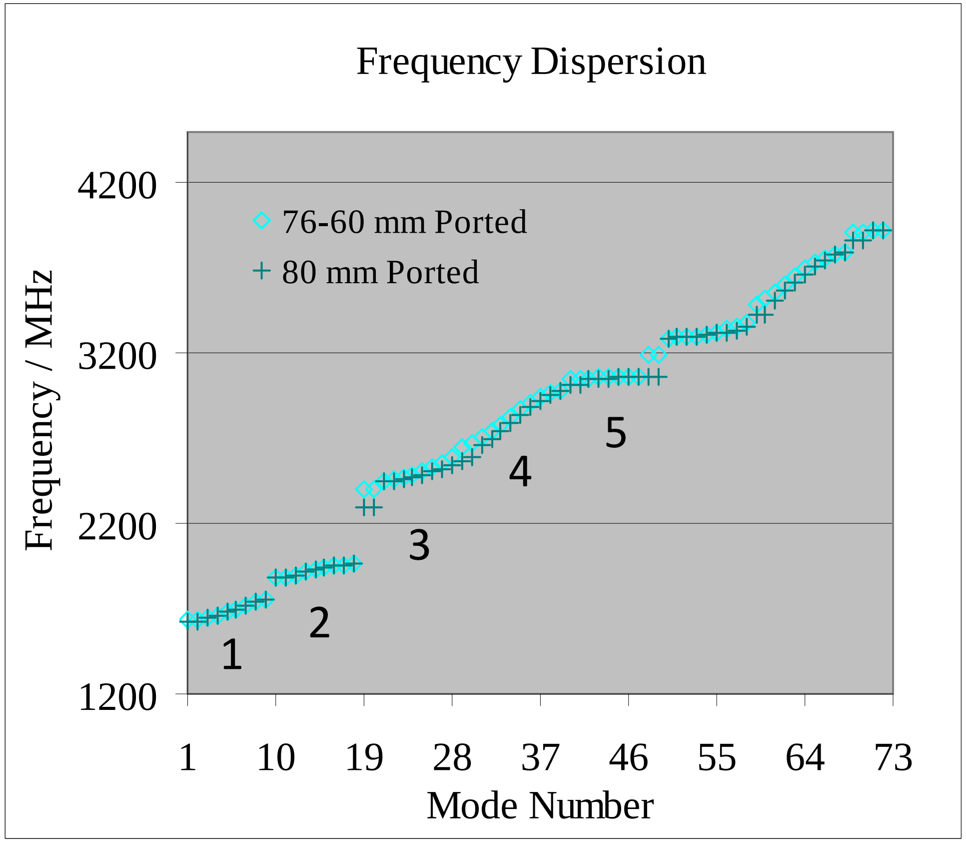
Cavity Shape: Ichiro/New Ichiro

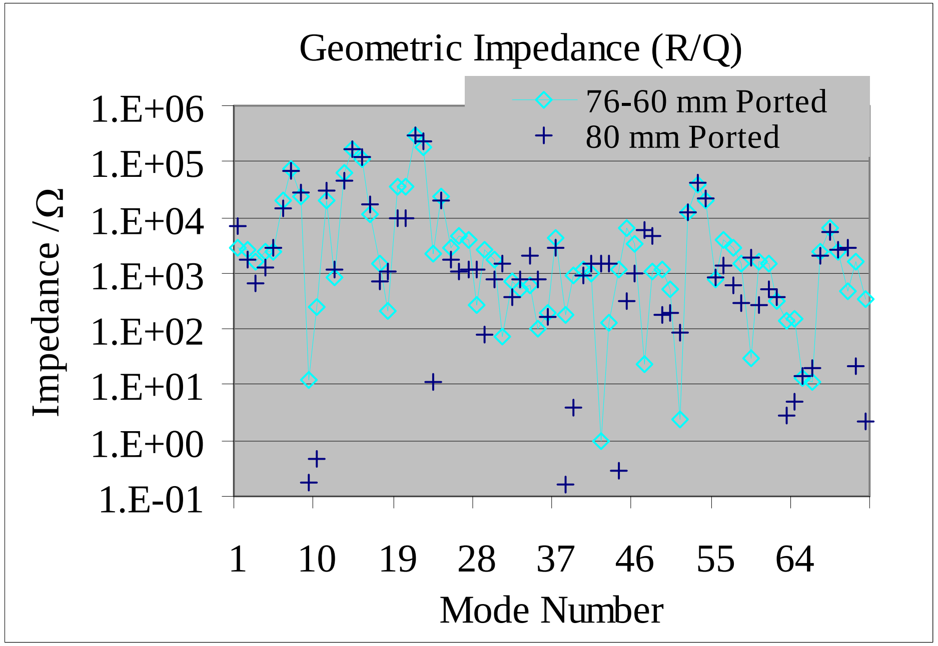


New Cavity Design by Y.Morozumi

Comparison of Dipole Mode Characteristics
between SLAC and KEK designs

By Y.Morozumi



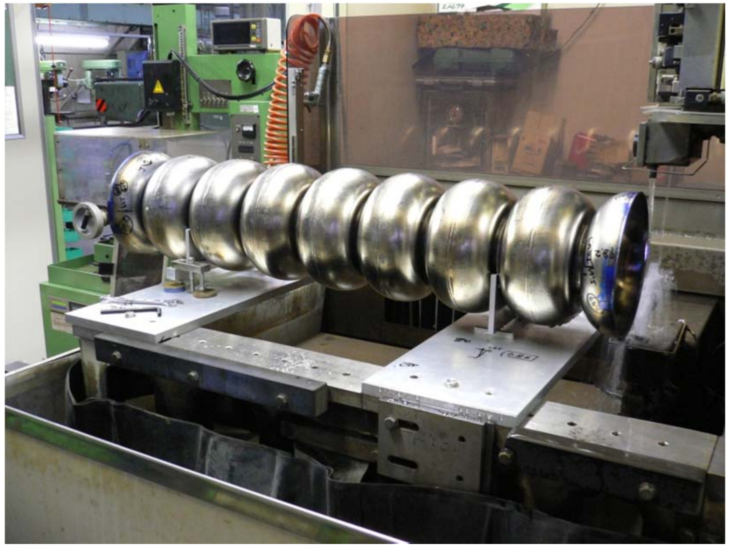


Axisymmetric 2D Simulation

Similar HOM characteristics to the improved design by SLAC with 76ϕ BP

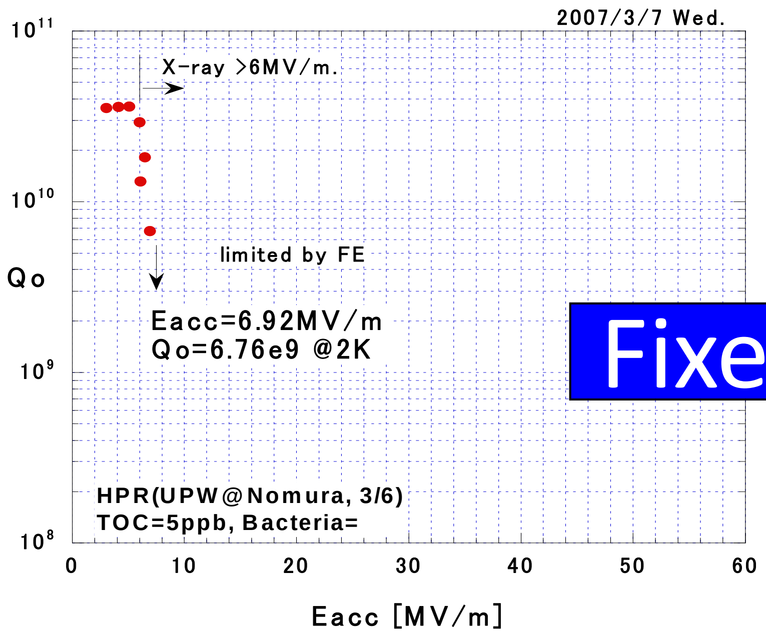
Repaired Ichiro#0 and #2 for S0 study

- **The END groups with HOM/input coupler port were cut at KEK.**
- **New END groups with straight BP has been EB welded.**
- **S0 study on the repaired Ichiro cavities will be started on middle of Feb 2007.**



Single Cell R&D in WG5
KEK

Field Emission by Plunger HPR Pump contamination



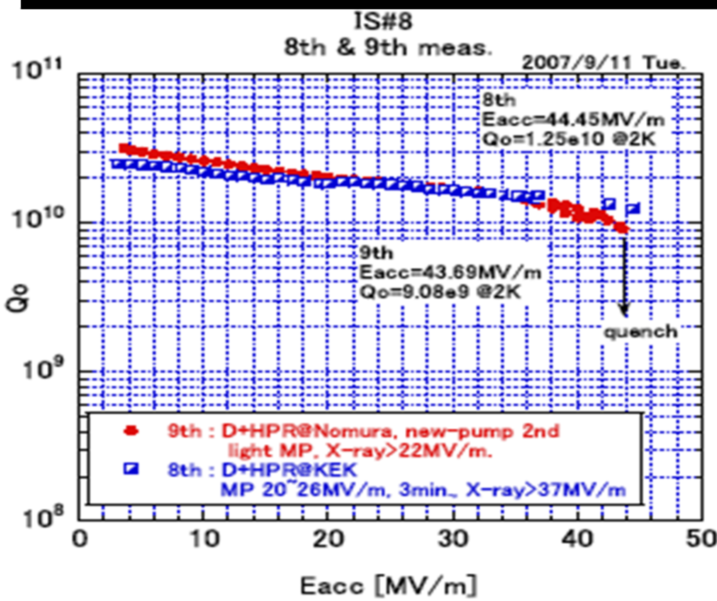
Fixed!

Before use

Contaminated

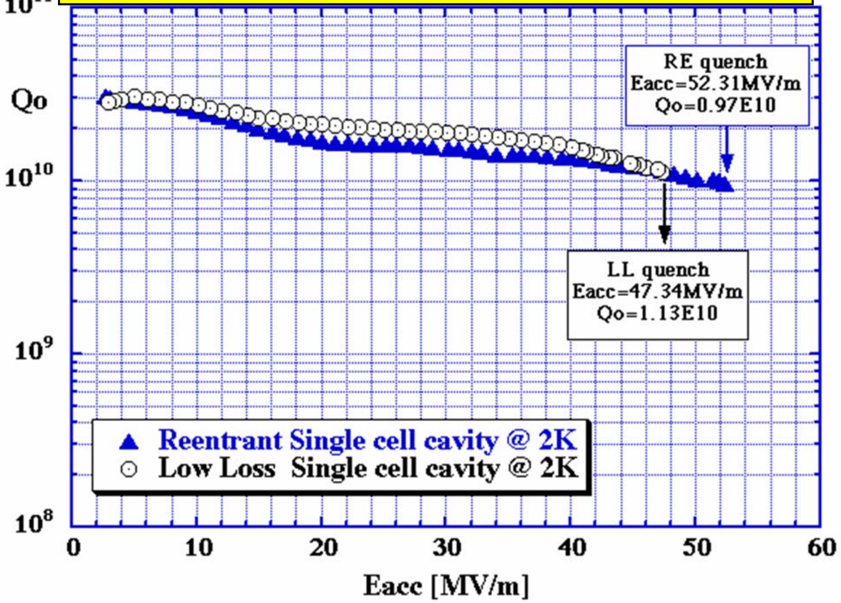
Silicon grease
used at plunger sealing of HPR pump!

HPR pump was replaced to diaphragm type
on beginning of Sep. 2007
Successfully Qualified by single cell cavity tests!

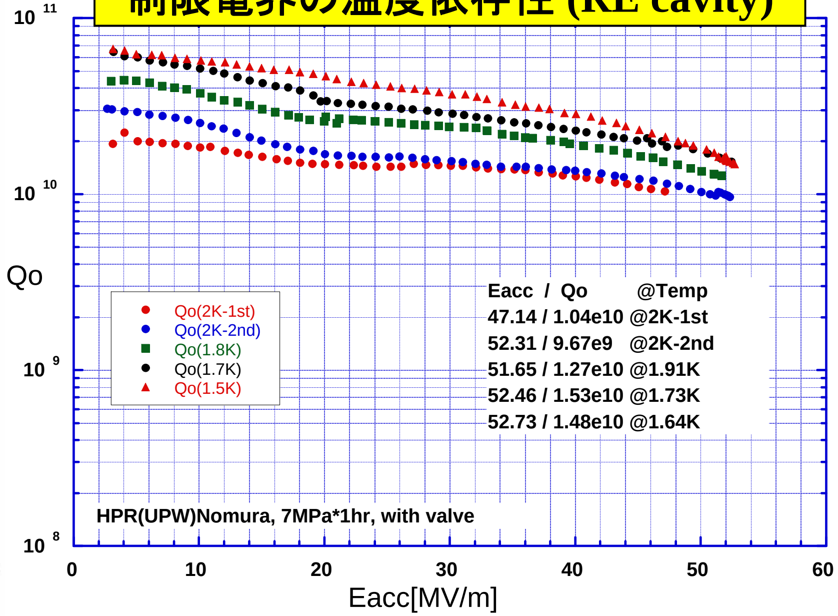


Reproducibility

新形状により40MV/mの壁を突破！(KEK)



制限電界の温度依存性 (RE cavity)



測定結果 @ 2K と誤差

再度、高圧洗浄と真空排気

Low Loss @ 2K

Eacc,max	Qo @ Eacc,max
46.5	1.20E10
47.3	1.13E10
46.6	1.50E10
45.0	1.03E10
44.0	1.20E10

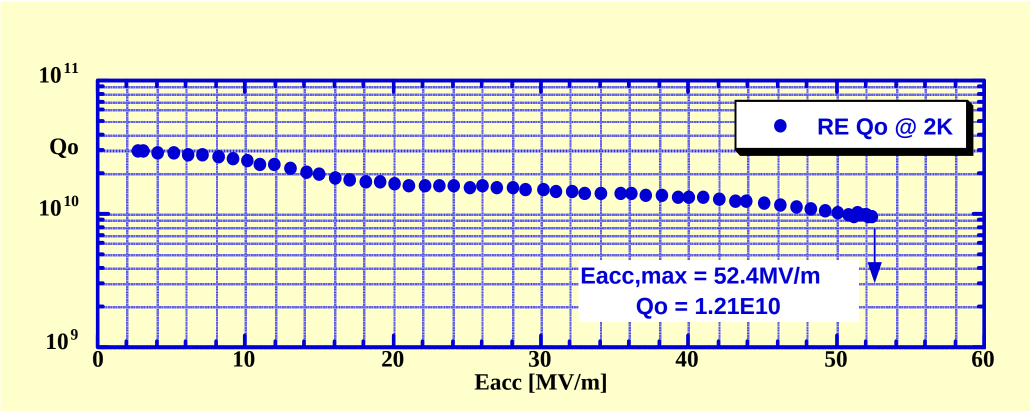
45.9±1.3 MV/m , Q0 = (1.21±0.18) E10

Reentrant@ 2k

Eacc,max	Qo @ Eacc,max
51.2	0.59E10
52.3	0.97E10
51.9	1.11E10
52.4	1.21E10
50.0	0.98E10

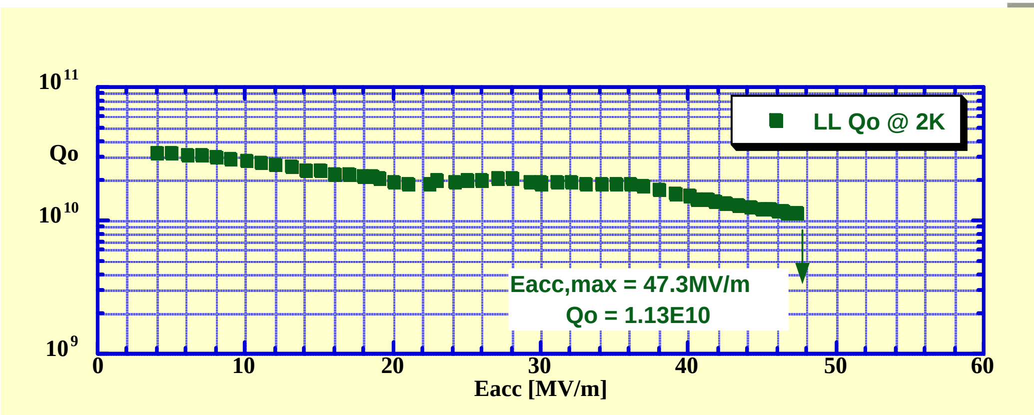
51.6 ±1.0 MV/m, Q0 = (0.97±0.24) E10

Done the Principle proof of the 50MV/m



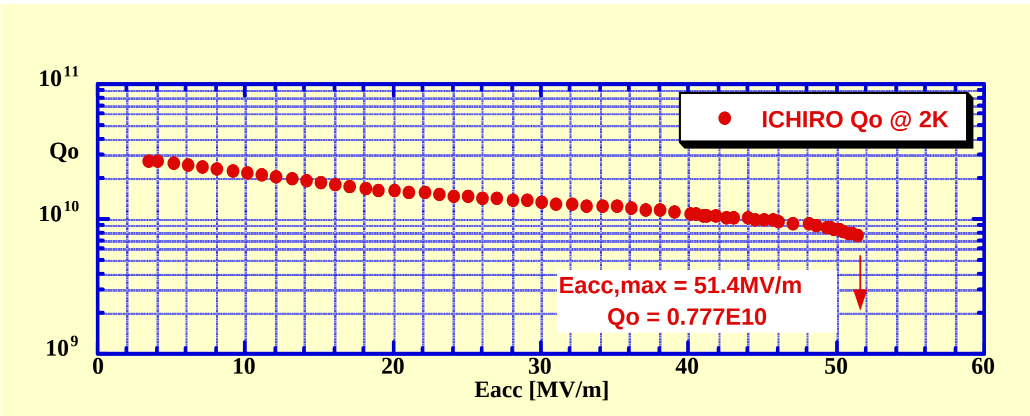
Reentrant

Diameter [mm]	60
Ep/Eacc	2.36
Hp/Eacc [Oe/MV/m]	36.1
R/Q [W]	133.7
G[W]	284
Eacc max	48.5



Low Loss

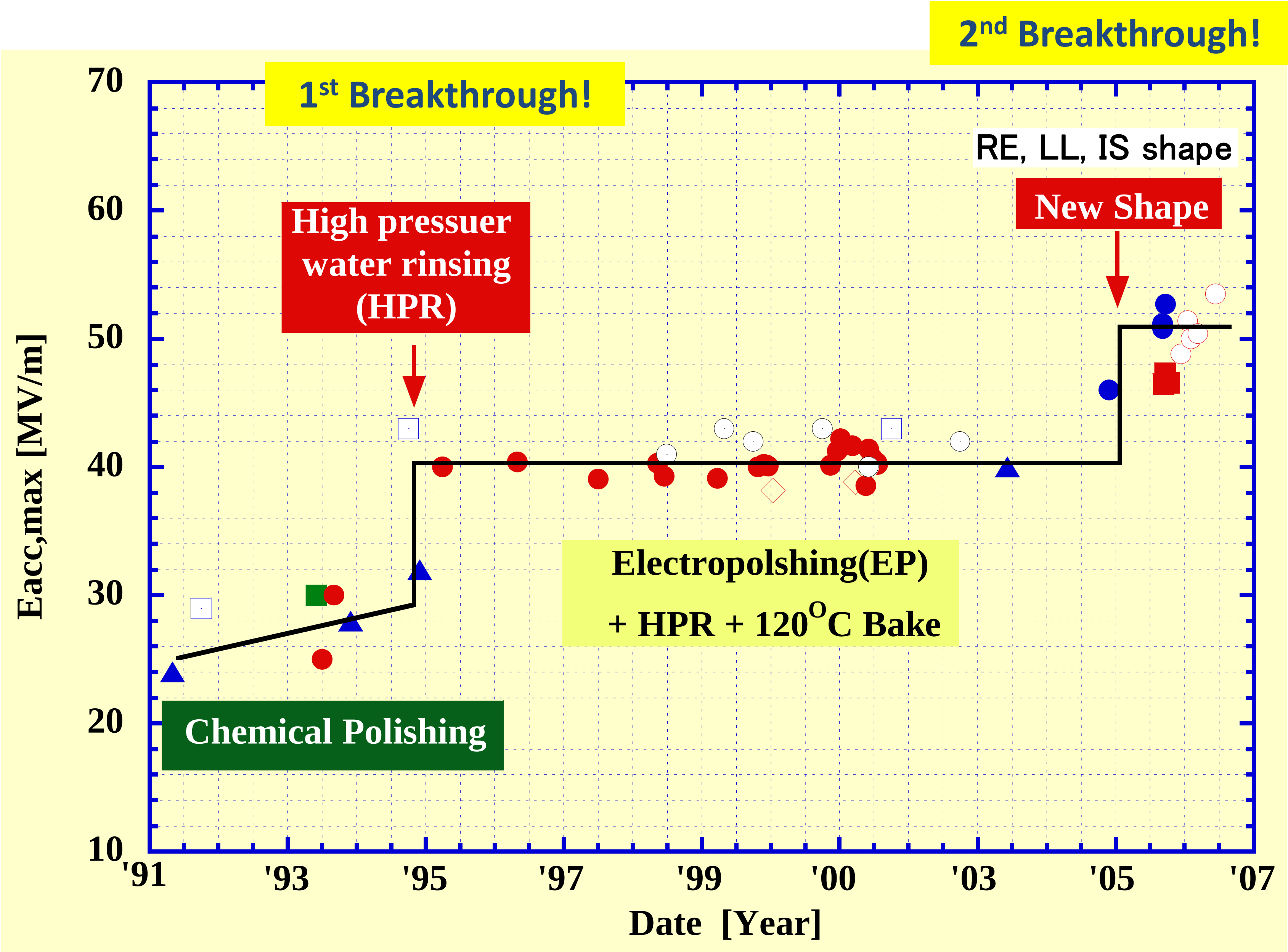
Diameter [mm]	66
Ep/Eacc	2.21
Hp/Eacc [Oe/MV/m]	37.6
R/Q [W]	126.8
G[W]	277
Eacc max	46.5



Ichiro Single

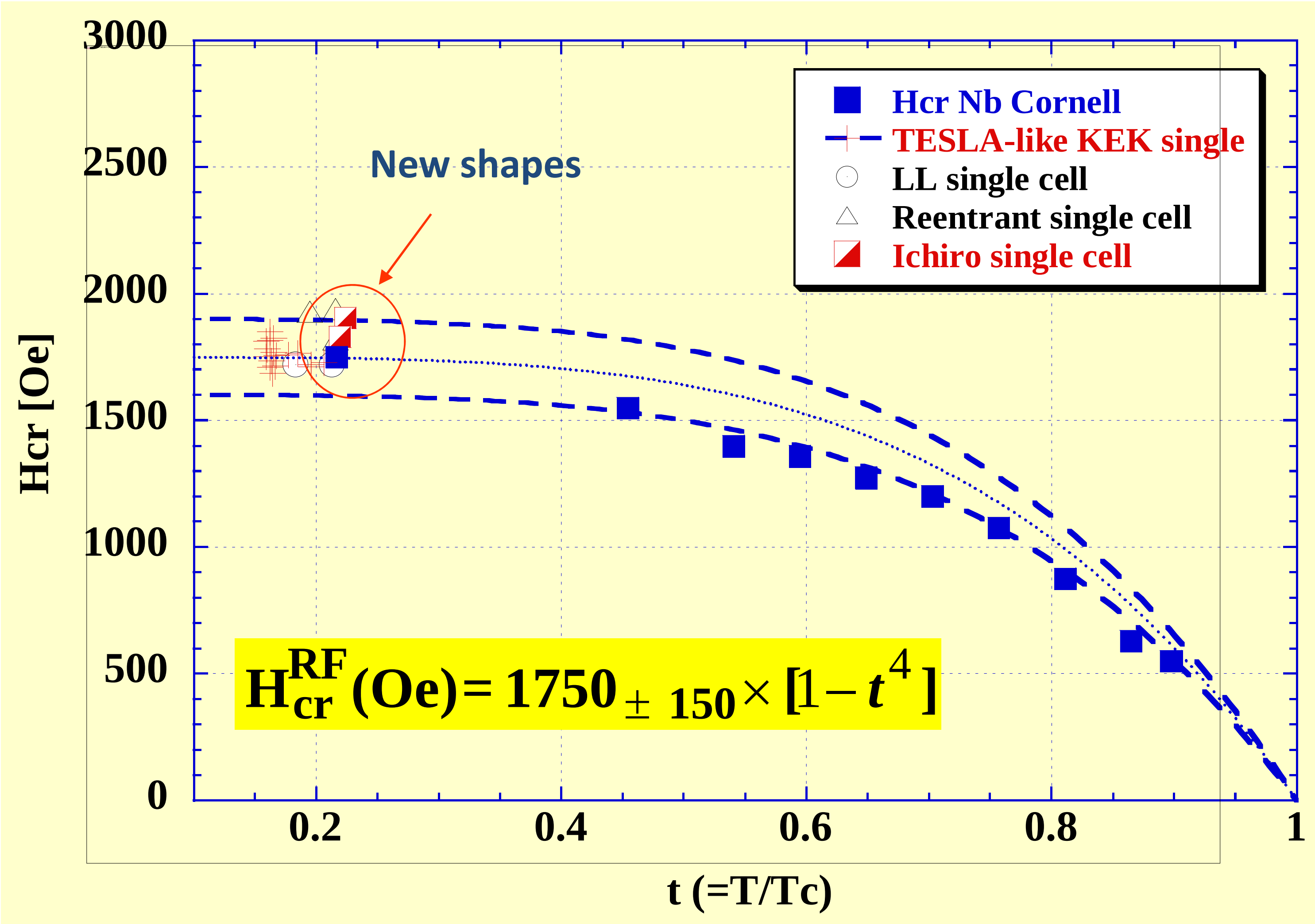
Diameter [mm]	61
Ep/Eacc	2.02
Hp/Eacc [Oe/MV/m]	35.6
R/Q [W]	138
G[W]	285
Eacc max	49.2

Eacc vs. Year



2nd Breakthrough!
1st Breakthrough!
RE, LL, IS shape
New Shape
High pressuer water rinsing (HPR)
Electropolshing(EP) + HPR + 120^{O}C Bake
Chemical Polishing
Eacc,max [MV/m]
70
60
50
40
30
20
10
'91
'93
'95
'97
'99
'00
'03
'05
'07
Date [Year]

RF critical field analysis



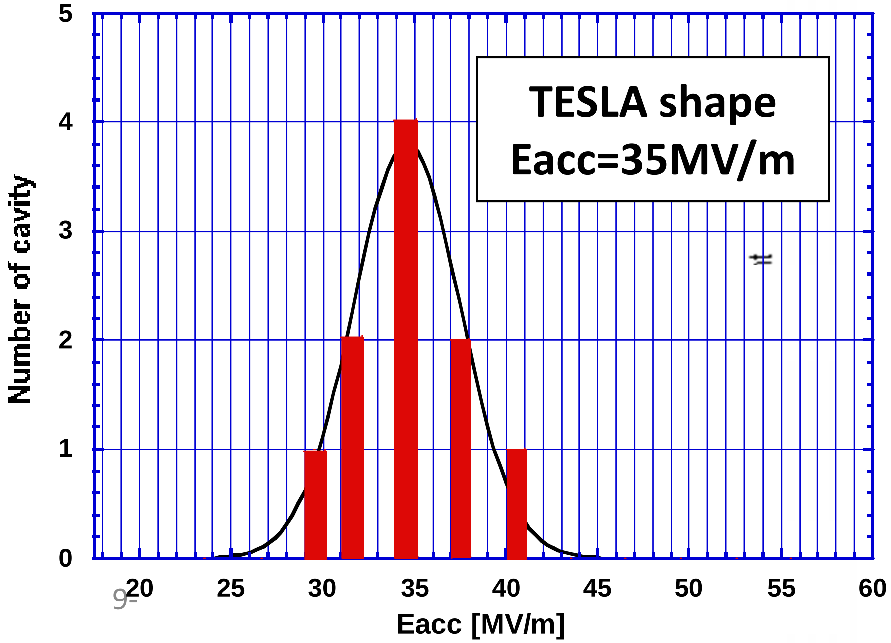
Single cell Study Summary

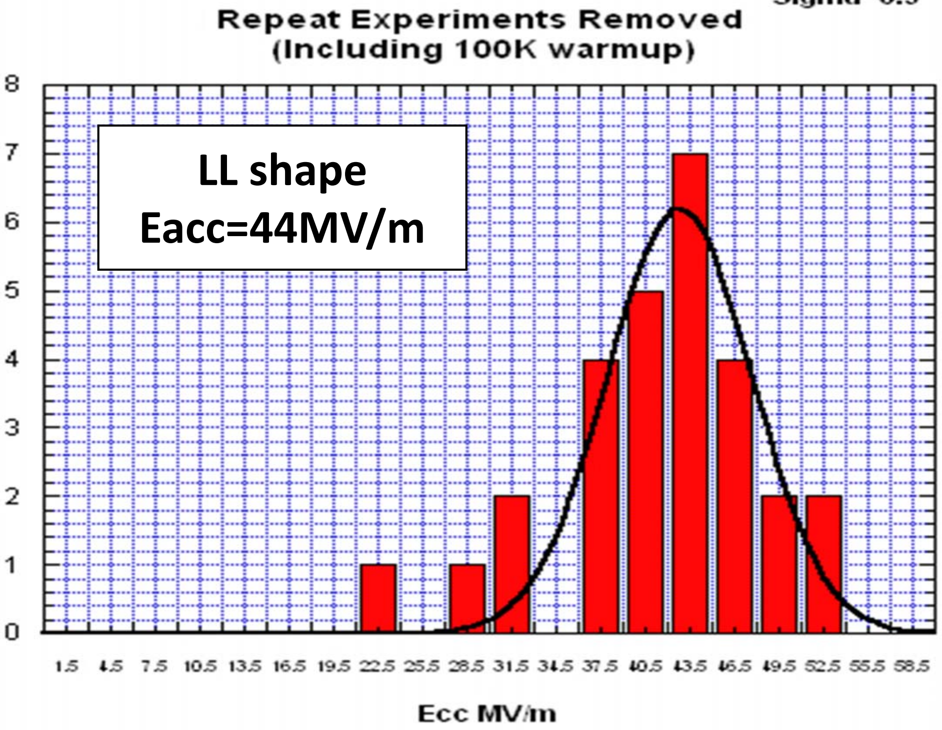
- New cavity shapes with low Hp/Eacc made a breakthrough in high gradient of 50MV/m.
- Proof of reproducibility was done.
- Statistics shows IS shape is superior to TESLA shapes with high gradient.
- Establishment of recipe is ongoing

Cavities prepared by KEK recipe

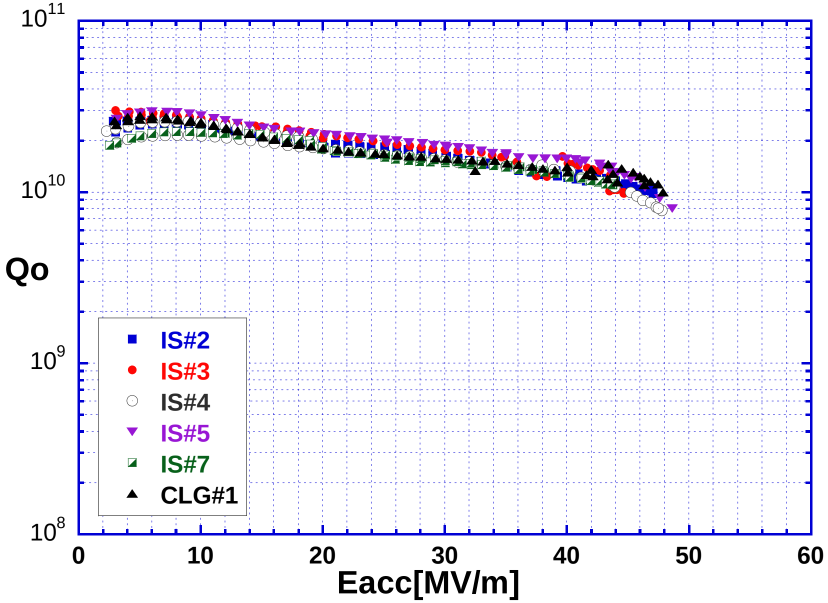
Mean=44.3MV/m, Sigma=6.9

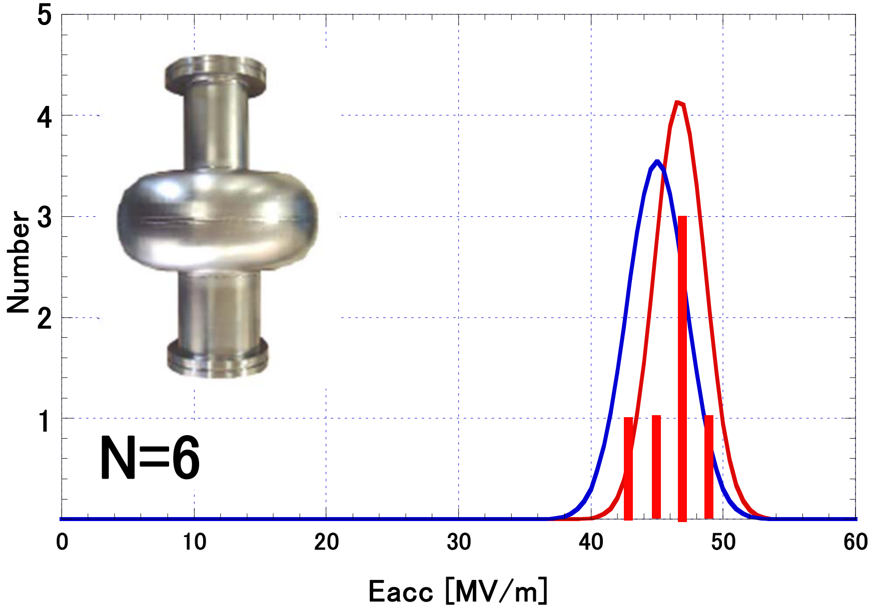
by R.S.Orr





+EP(20μm)+EP(3μm, fresh, closed) +(HF*or No HF)+HPR+Baking





HF rinsing is no effective.

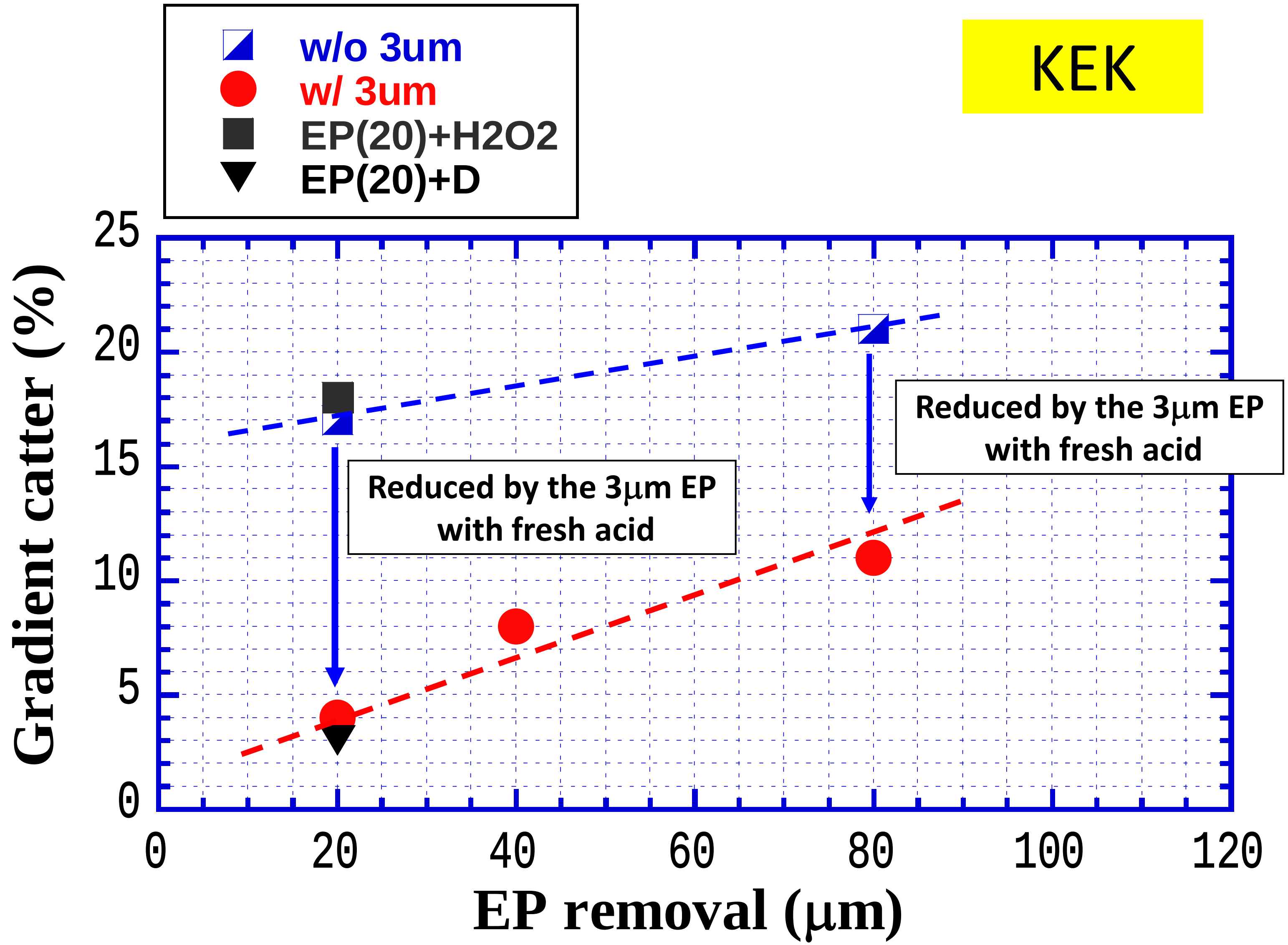
Light EP +EP(3) is effective for both high gradient and narrow scatter.

Ave. Eacc=46.7±1.9MV/m

Scattering:4%, Acceptability@40MV/m(ACD):100%

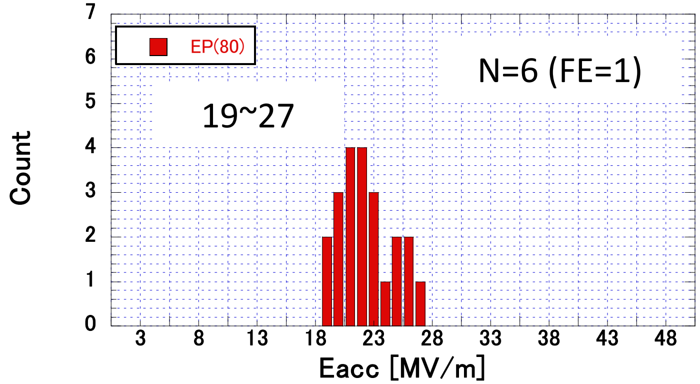
		IS#2	IS#3	IS#4	IS#6	IS#7	CLG#1
+EP(20+3) +HF*	Eacc	47.07	44.67*	47.82	48.60*	43.93*	47.90*
	Qo	1.06e10	0.98e10	0.78e10	0.80e10	1.17e10	1.0e10

Gradient Scatter vs. EP removal

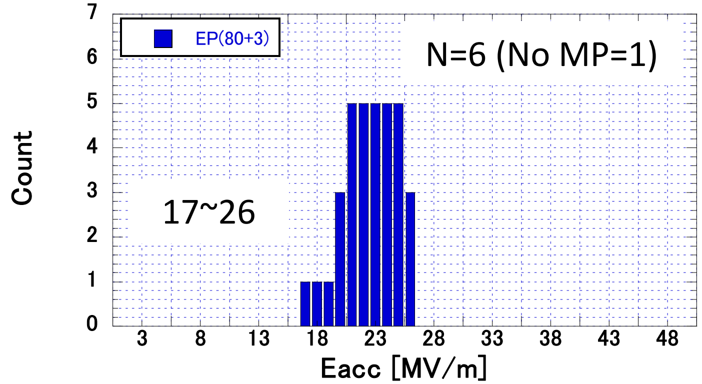


Multipacting

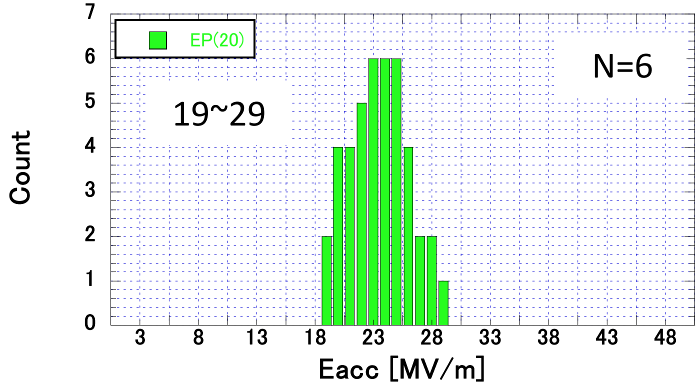
EP 80um



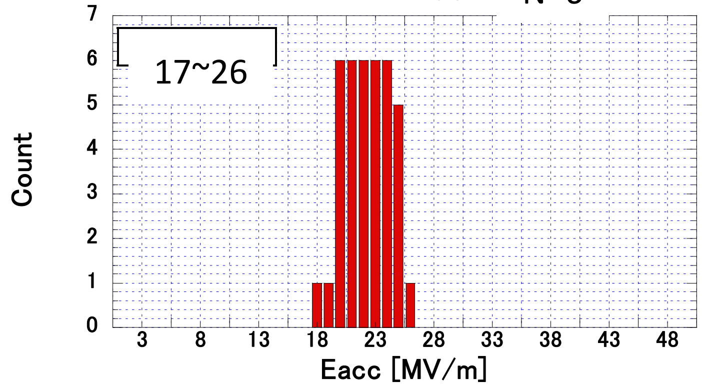
EP 80+3um



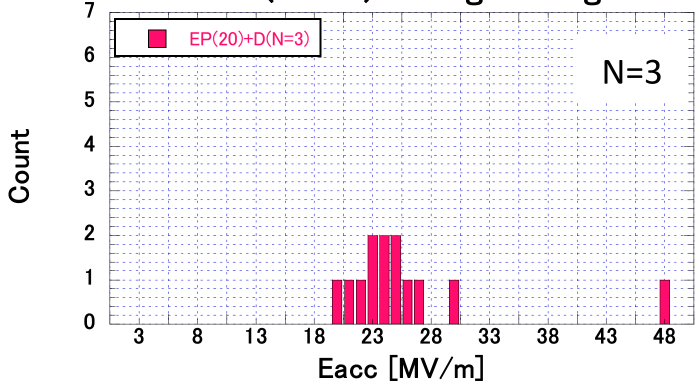
EP 20um



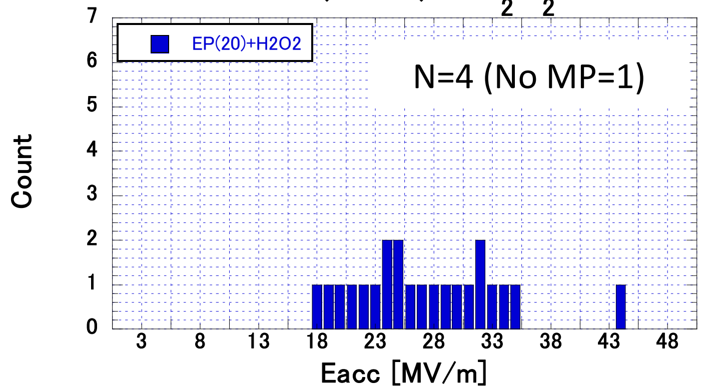
EP 20+3um N=6



EP(20um) + Degreasing



EP(20um) + H_2O_2



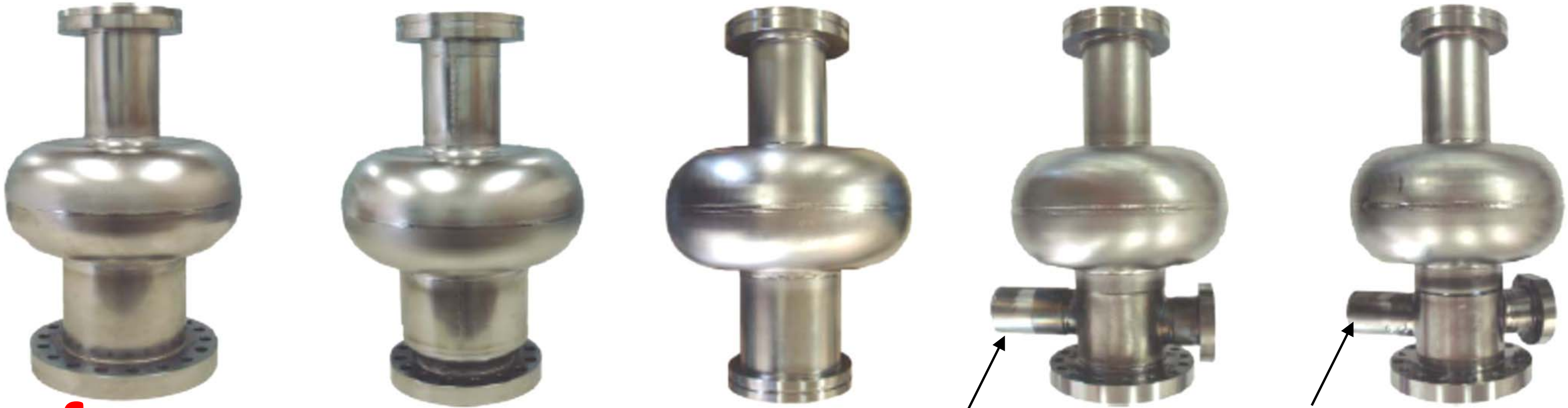
END Group Study

We have to understand why so such different result happened between single and multi-cell .

9-Cell =  + $\sum_{i}^{7}$  +  = 50MV/m ?!

ISE#1 ISE#2 ISE#3 ISE#4 ISE#5

Ichiro Cavity END Cell | **Redesigned END Cell**



So far:

34.5MV/m | 41MV/m | 50MV/m | 51MV/m | 45MV/m

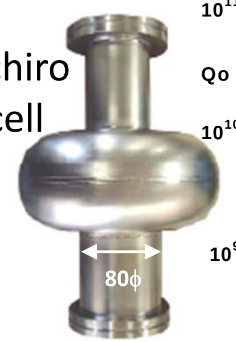
Theoretical limitation : ~ 40MV/m (ISE#1, ISE#2)

Theoretical limitation ~ 50MV/m (ISE#3, ISE#4, ISE#5)

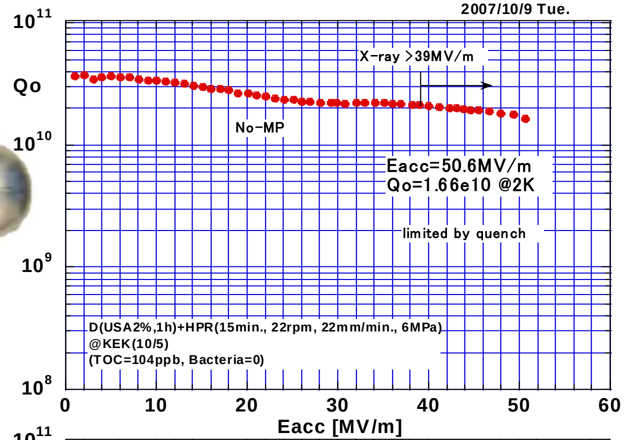
New END Cell

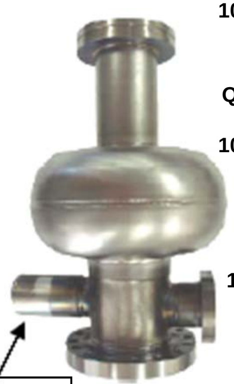
New END cell itself has no problem !

New Ichiro
End cell



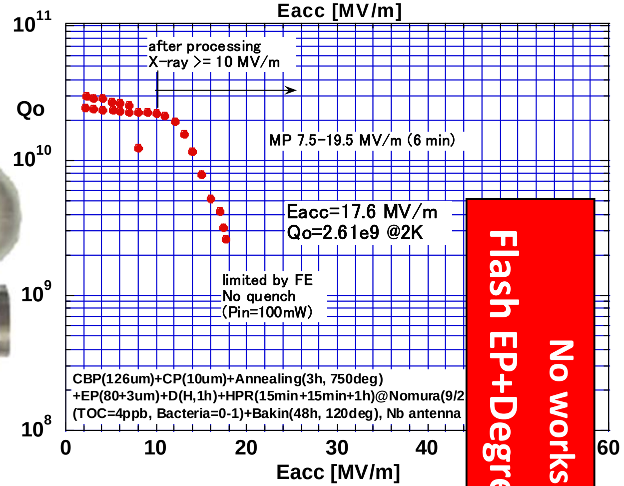
ISE#3





Just HOM cylinder

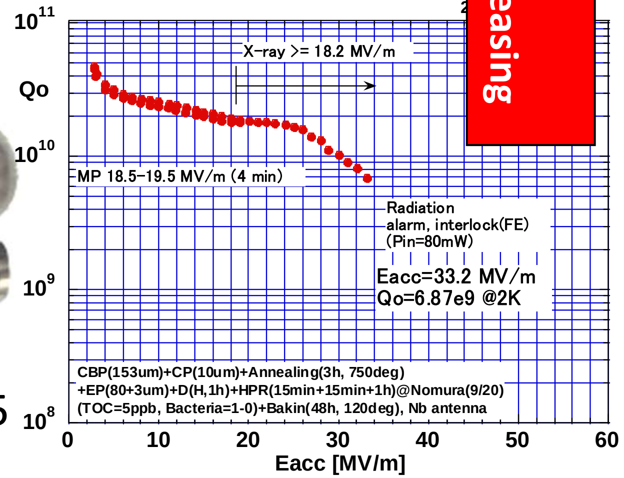
ISE#4



No works
Flash EP+Degreasing

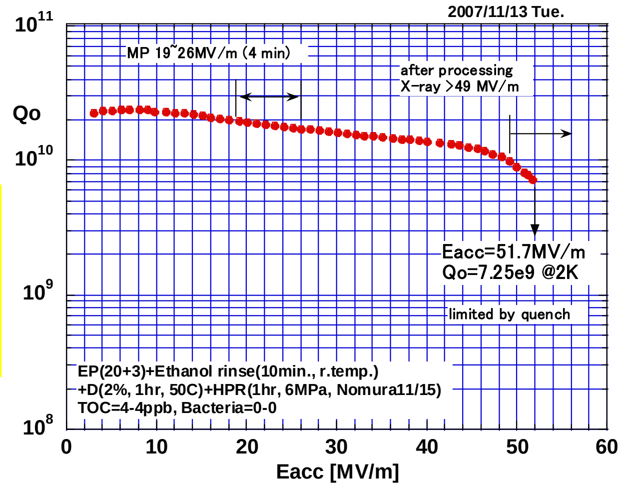
Full HOM

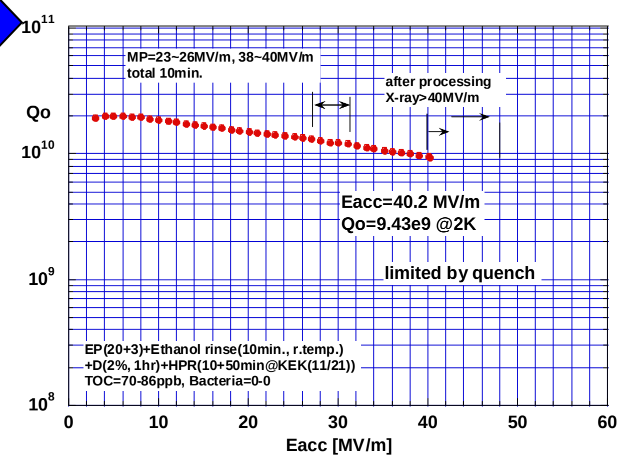
ISE#5



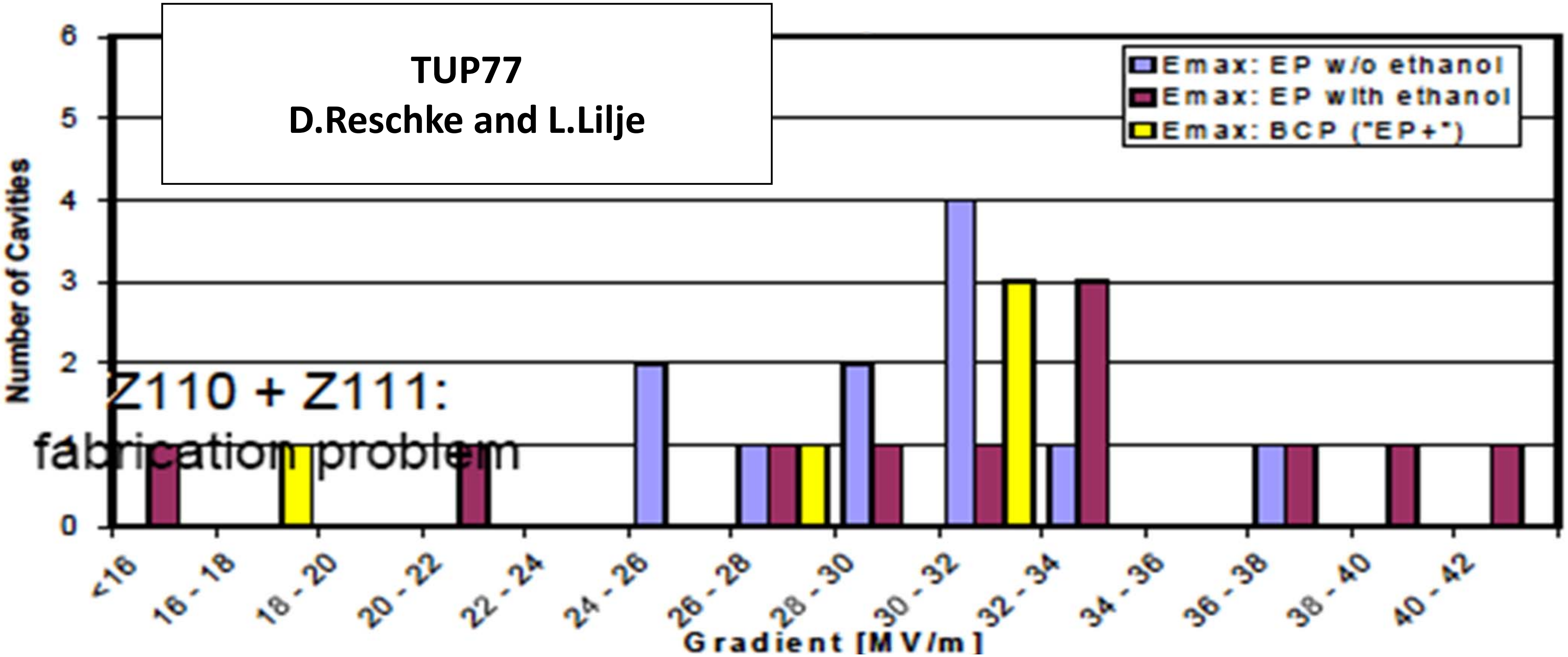
Sulfur contamination might remain on the complicated beam pipe.

+ Ethanol Rinsing





Ethanol Rinsing @ DESY 9-cell



⇒ **EP w/o eth:** $< E_{acc,max} > = (30 \pm 4)$ MV/m
$< E_{acc,usable} > = (29 \pm 3)$ MV/m

Ethanol rinsing is effective!

⇒ **EP with eth:** $< E_{acc,max} > = (32 \pm 6)$ MV/m (w/o Z110)
$< E_{acc,usable} > = (30 \pm 4)$ MV/m

⇒ **BCP ("EP+"):** $< E_{acc,max} > = (30 \pm 2)$ MV/m (w/o Z111)
$< E_{acc,usable} > = (29 \pm 2)$ MV/m

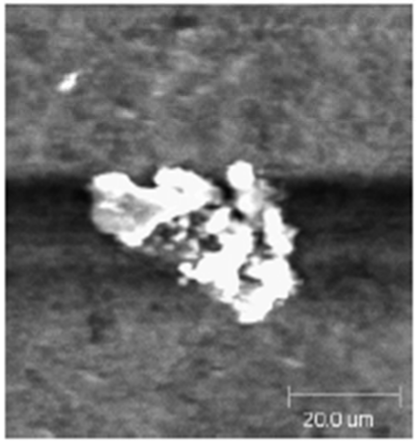
Basic Studies to Identify EP Residues That May Cause Field Emission

Cornell

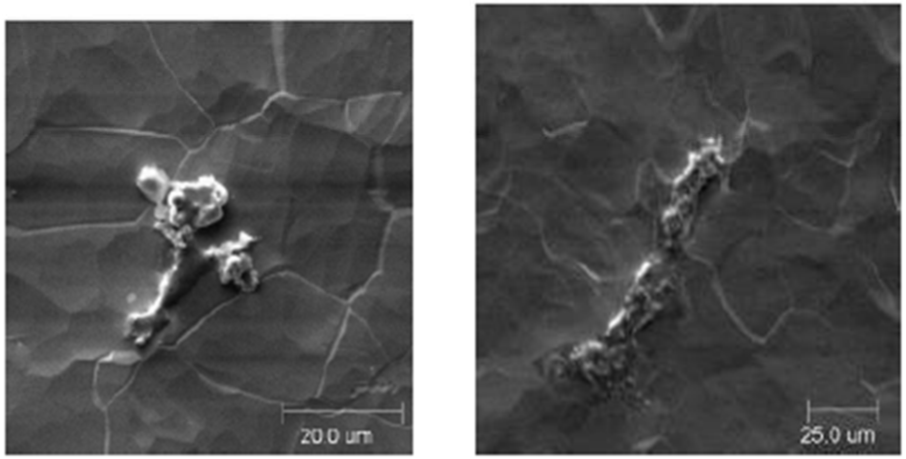
- Two main types of particles captured during EP,
  - S and niobium-oxide
  - Traces of Al also found with Auger, as expected due to Al cathode
- S particles dissolve in ethanol rinse but leave an imprint
- Oxide particles dissolve in HF rinse
  - But did not dissolve in EP !

Nb sulfide !?

Oxide Particle

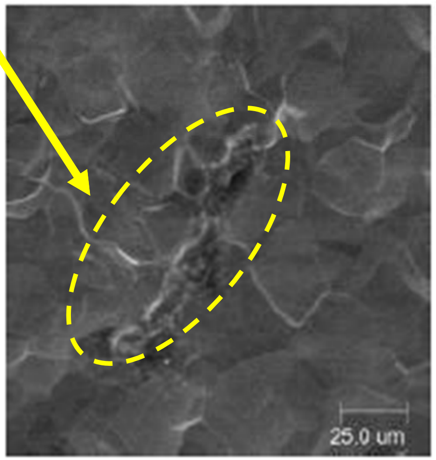


Typical S particles Deposited on Nb Surface During EP

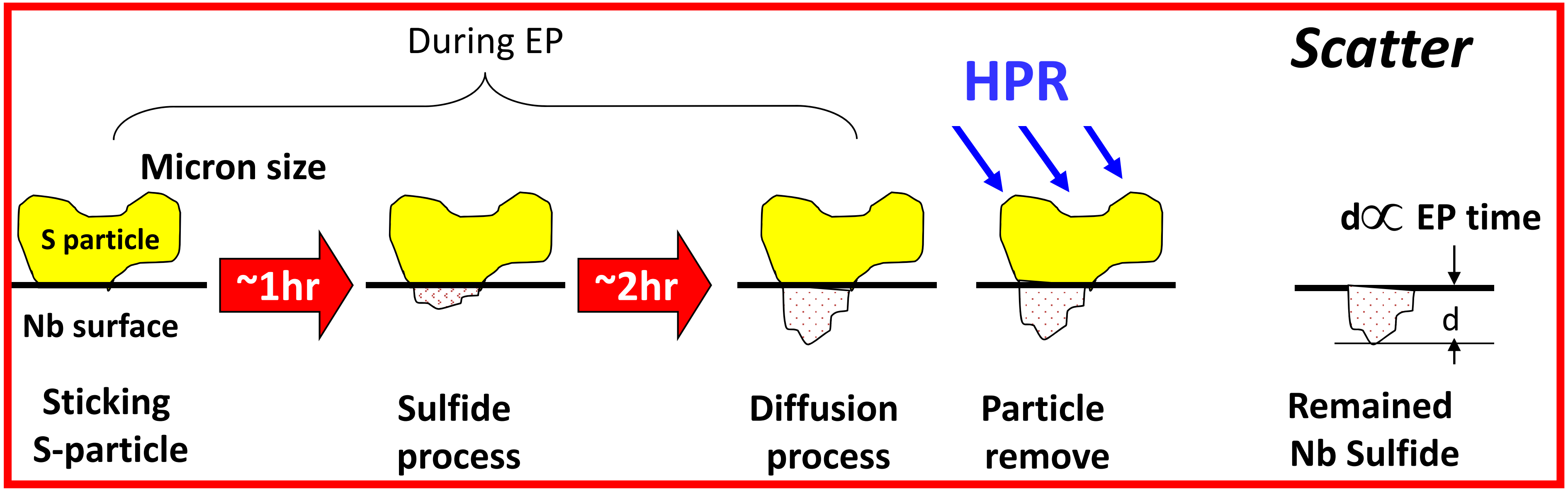


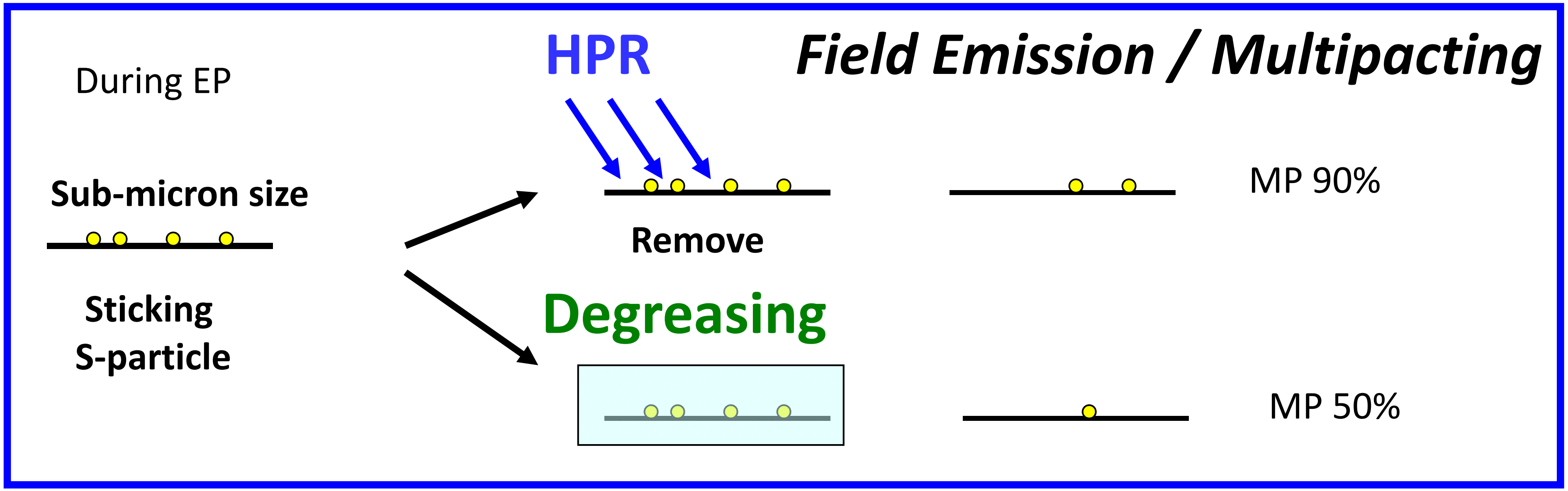
S-Particle

After Ethanol Rinse



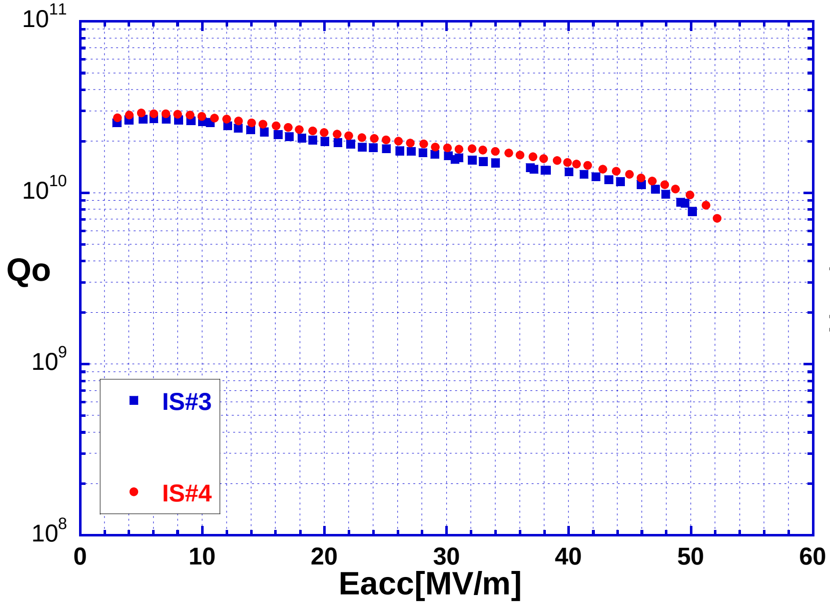
Mechanism of the scatter

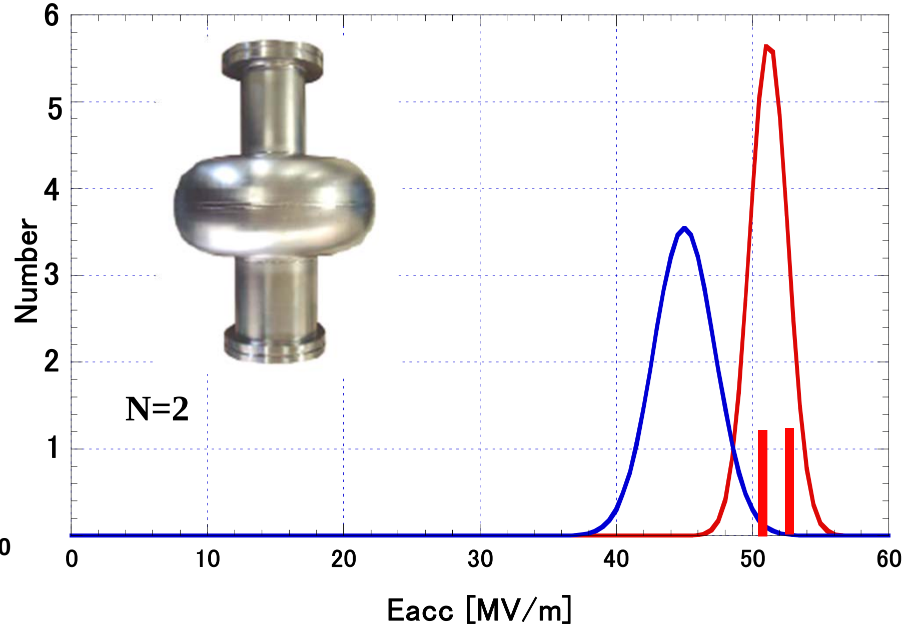




Only strength of the rinsing method could not fix the scatter problem.
The flash EP would be important to make narrow scatter.

+EP(20μm)+Degreasing+HPR+Baking



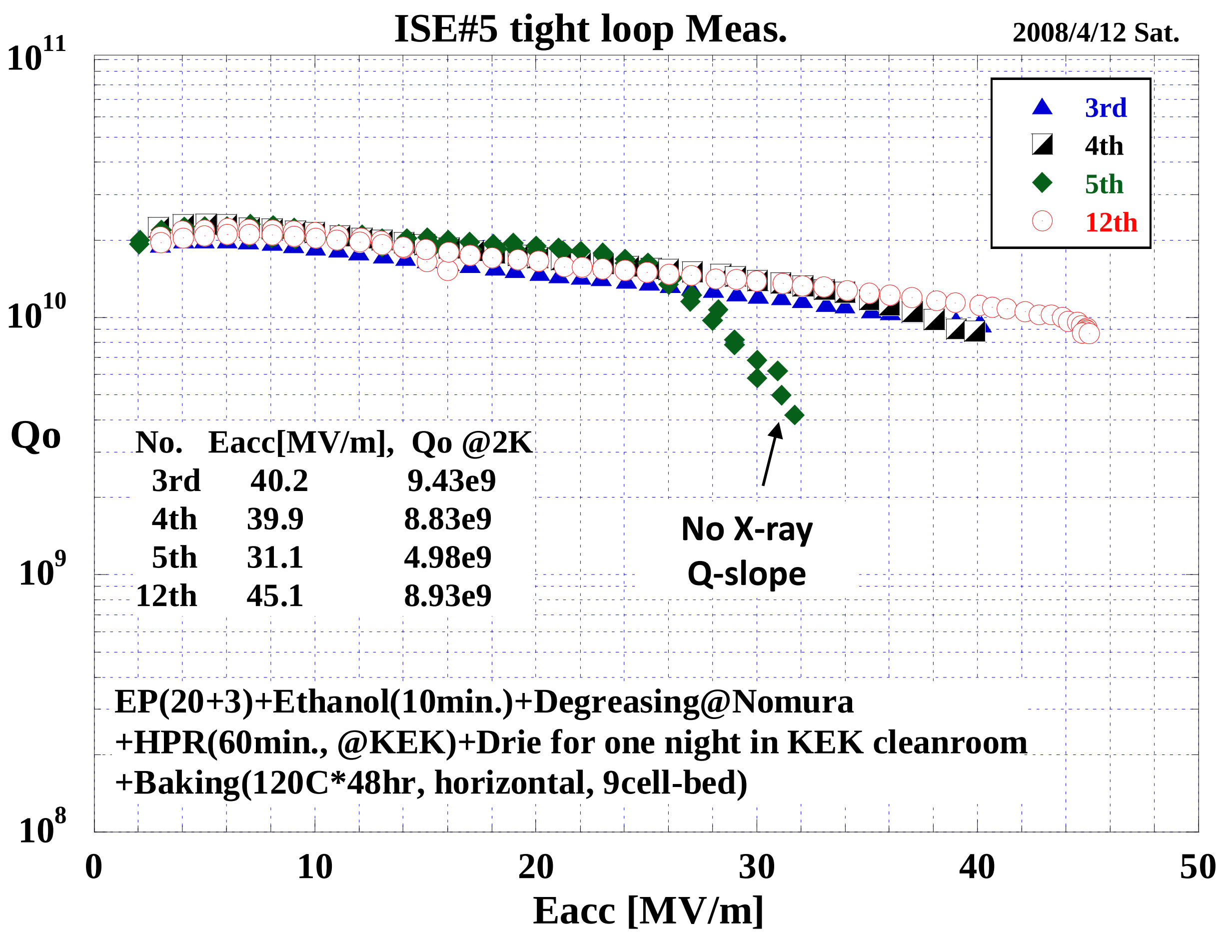


Ave. Eacc=51.2±1.4MV/m

Scattering:3%, Acceptability@40MV/m(ACD):100%

		IS#2	IS#3	IS#4	IS#5	IS#6	IS#7	IS#8
+EP(20) +Degreasing	Eacc		50.13	52.16				
	Qo		7.80e9	7.08e9				

ISE#5 tight loop test



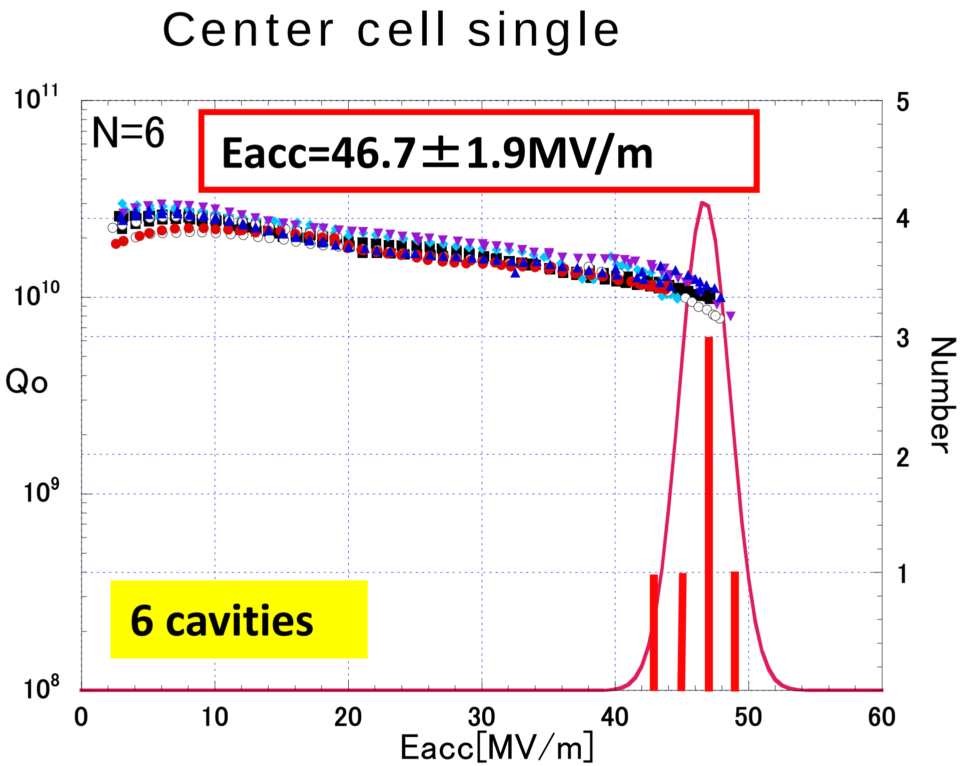
ISE#5

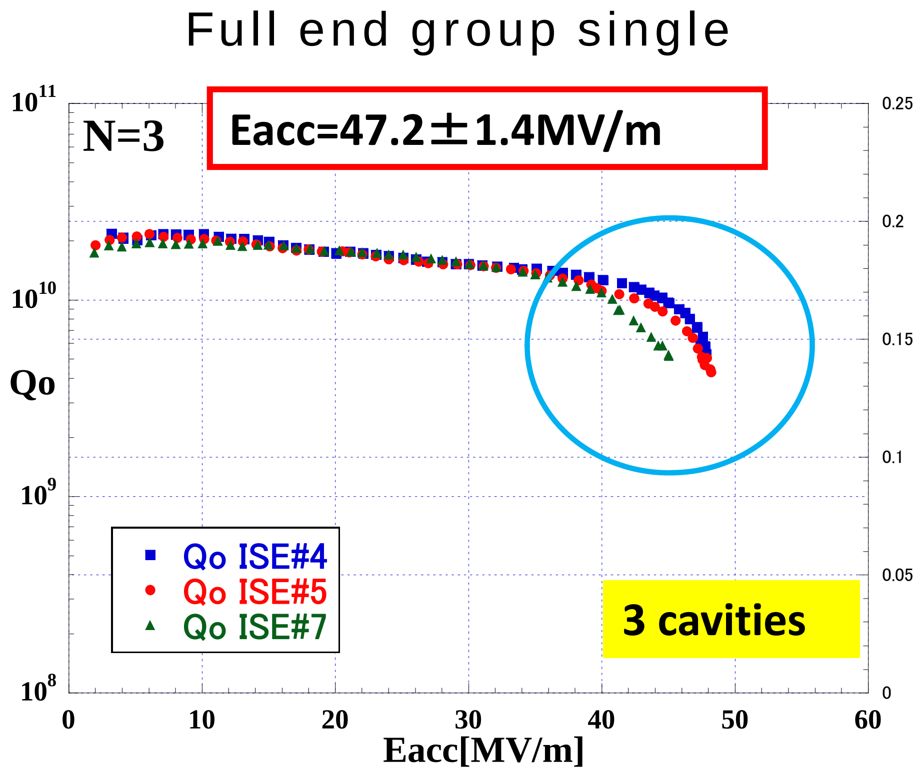
Full HOM

EP(20μm)+flash EP(3μm) +Ethanol rinsing (10-20min., r.t.) +Degreasing(MICRO-90, 2%, 1hr, 50C) +HPR +Baking(120C*48hrs)

➡ **Repeat 4 times (VT 3rd~12th)**

High Q-slope problem with the end group



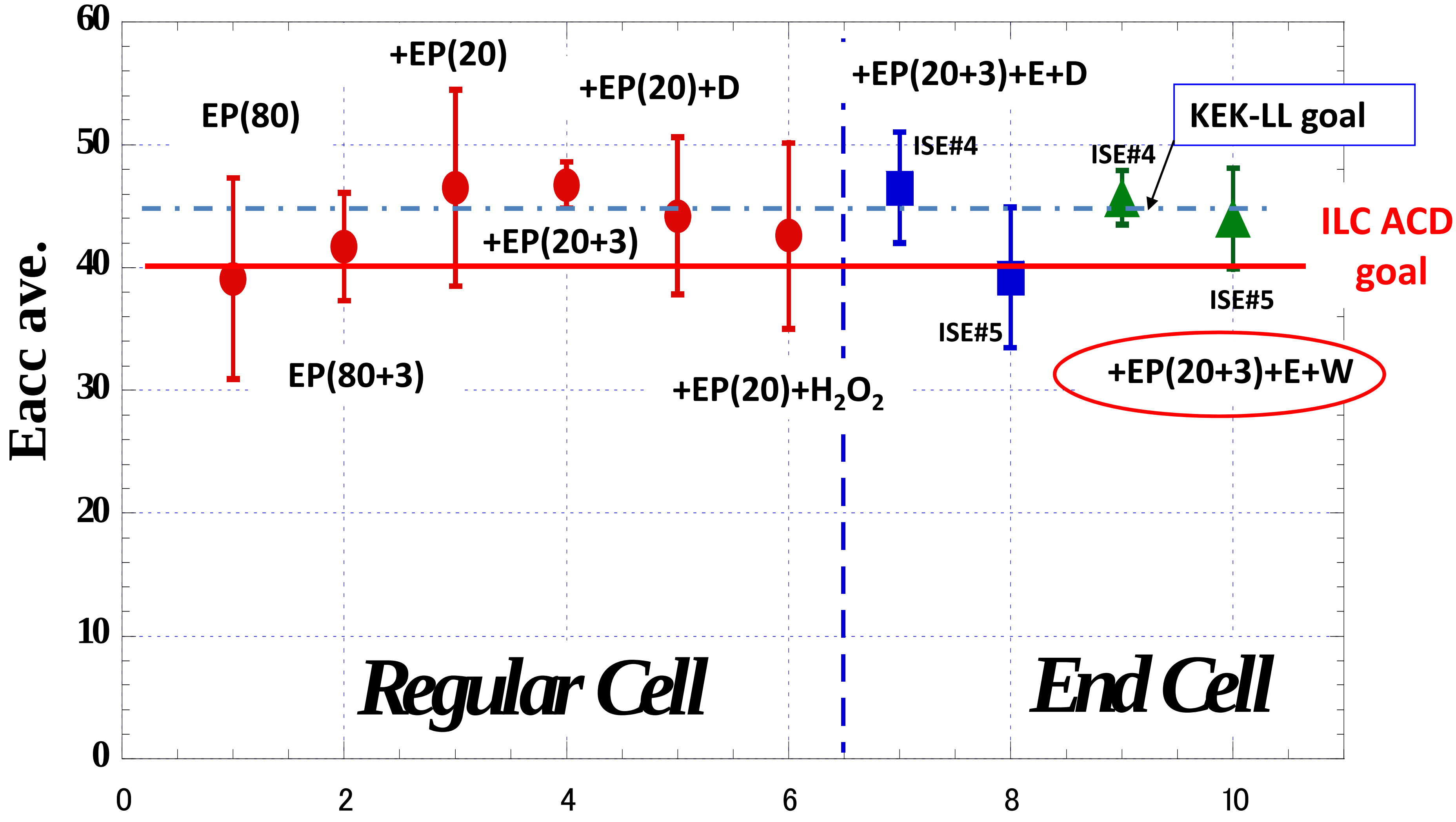


Current best recipe for ICHIRO

CBP+CP+AN+EP(80μm)+EP(20μm)+flash EP(3μm)
+Ethanol rinsing+Wiping+HPR+Bake

Q-slope issue remains.
- R&D for post EP cleaning
- new design, DDC.

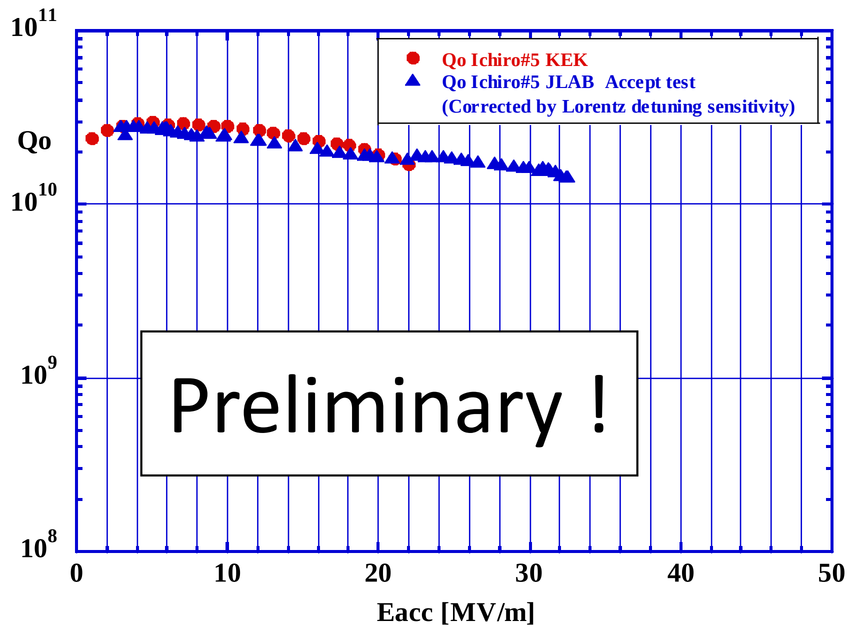
Scatter in the Max Gradient so far



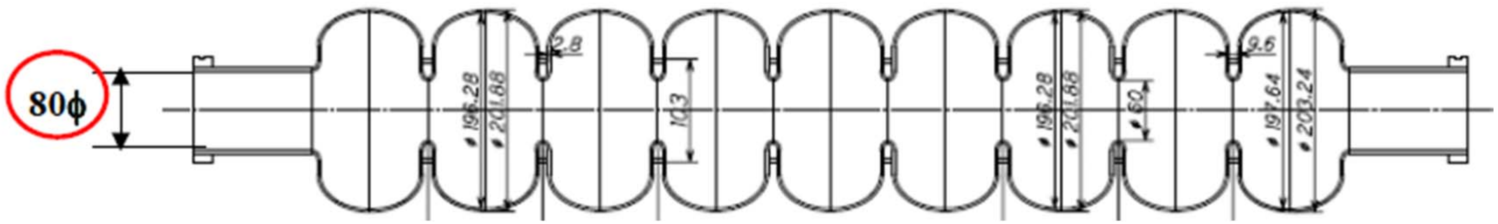
最終解決にはもう少し時間が必要。

Jlab Collaboration for S0 tight loop study with Ichiro 9-cell cavity

Preliminary result of JLAB Accept test on the Ichiro#5



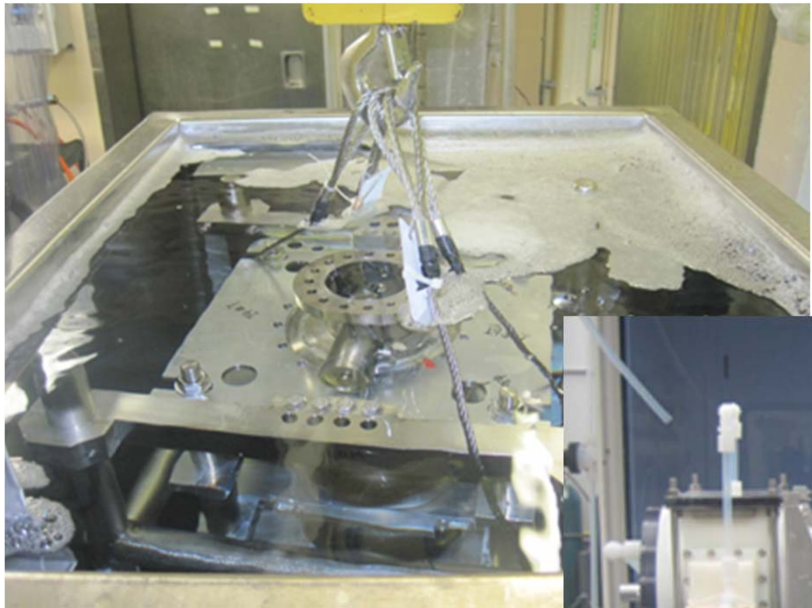
9-Cell =  + $\sum_{i}^{7} Center\ Cell$ +  = 50MV/m ?!

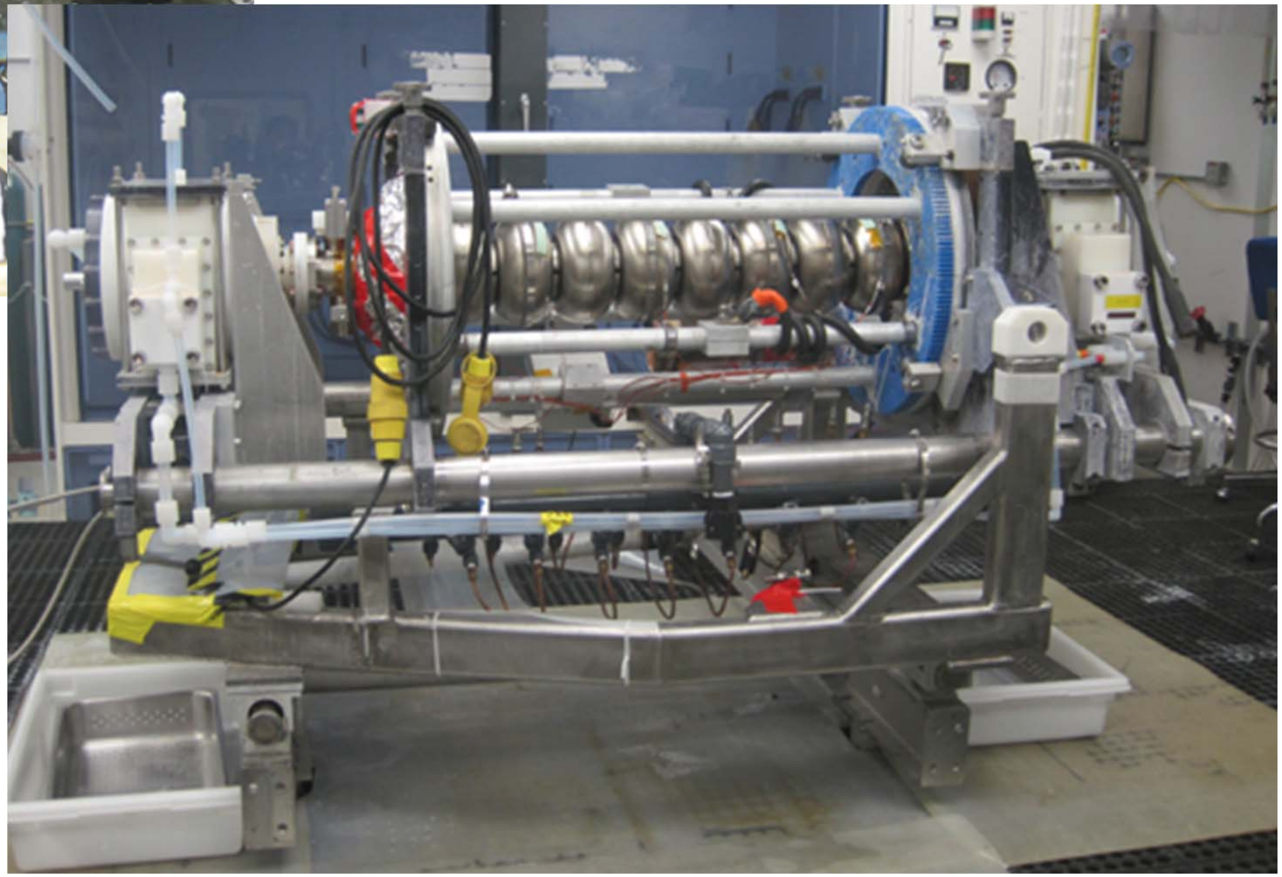


S0 study @ JLAB by KEK/US collaboration

USC~EP set-up

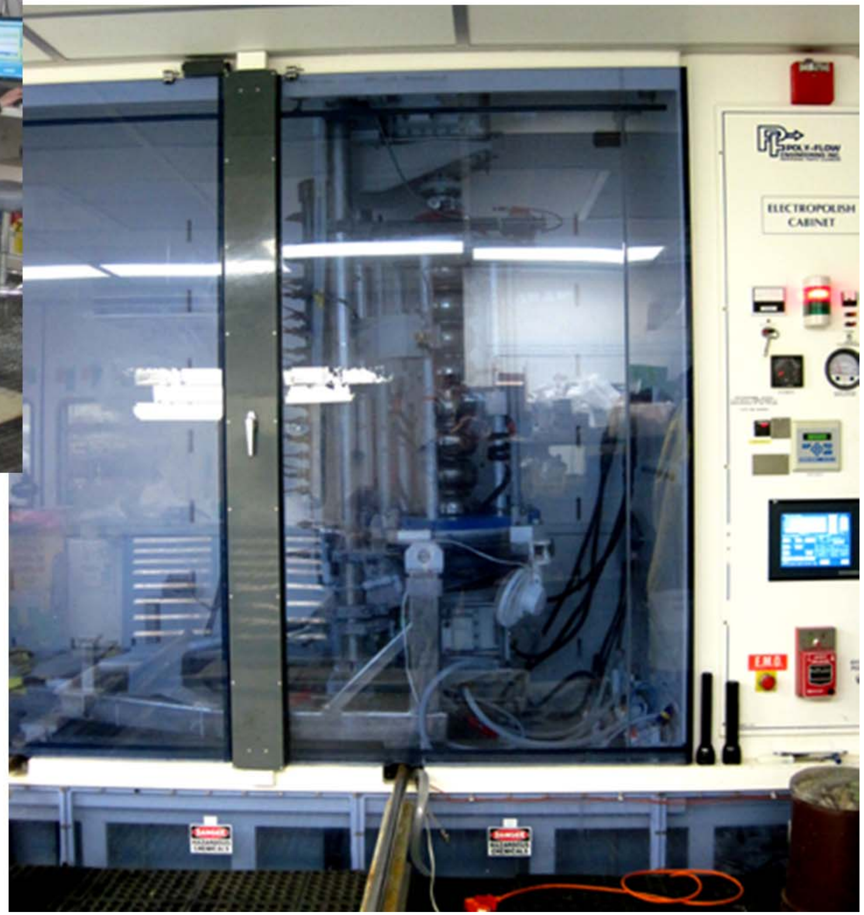
Nov. 9~10th 2010





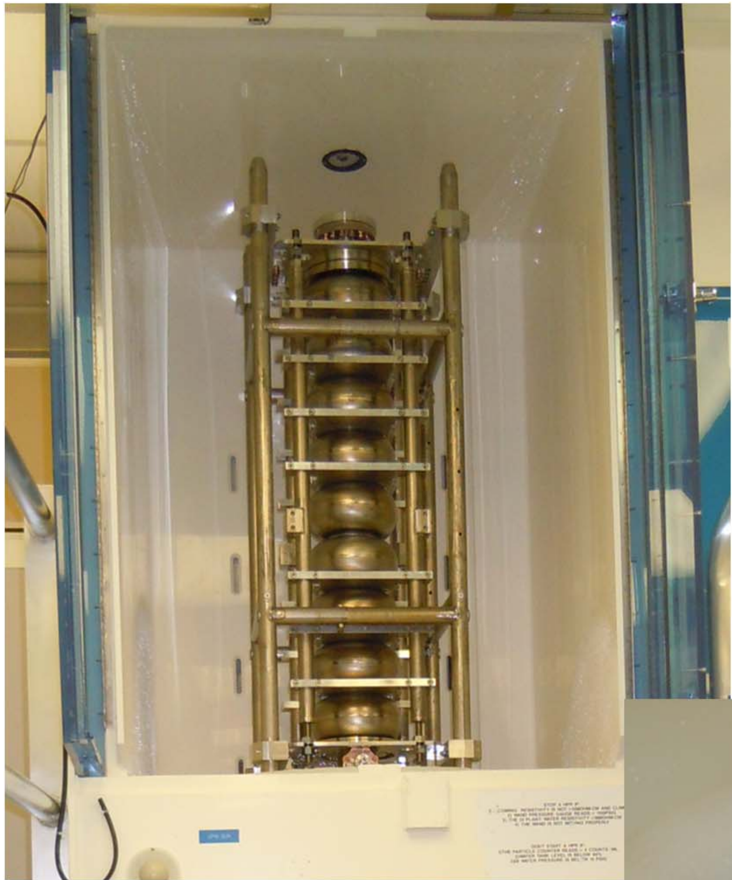
EP process, 20um

Nov. 11th 2010



HPR

Nov. 11,15th 2010

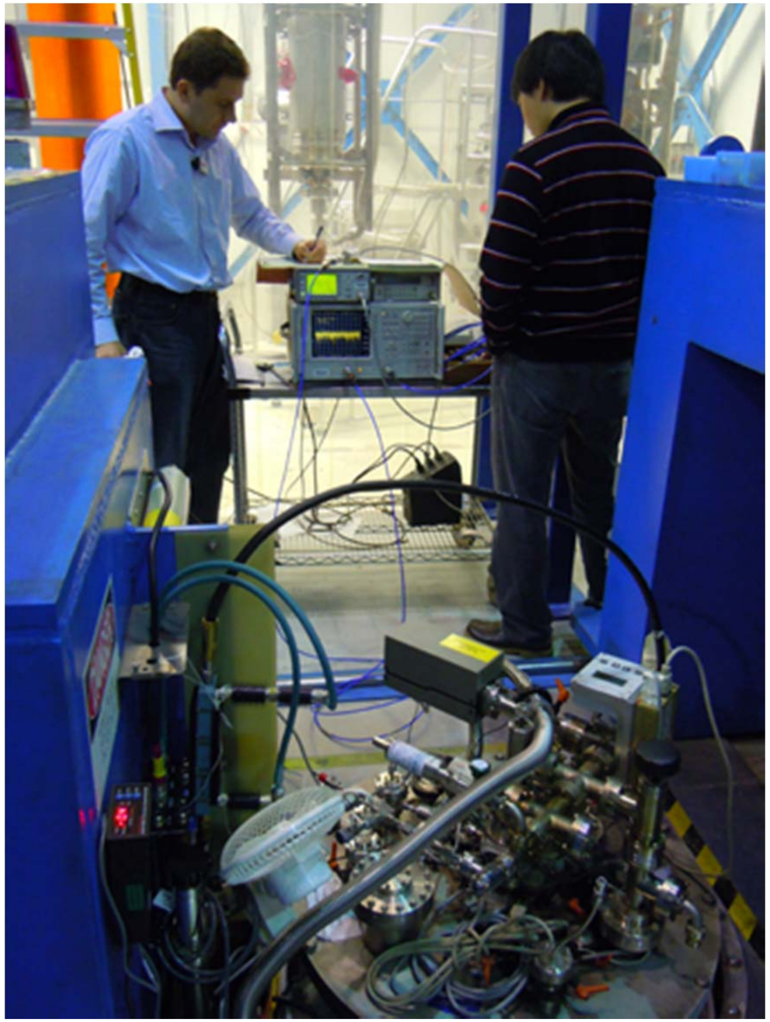


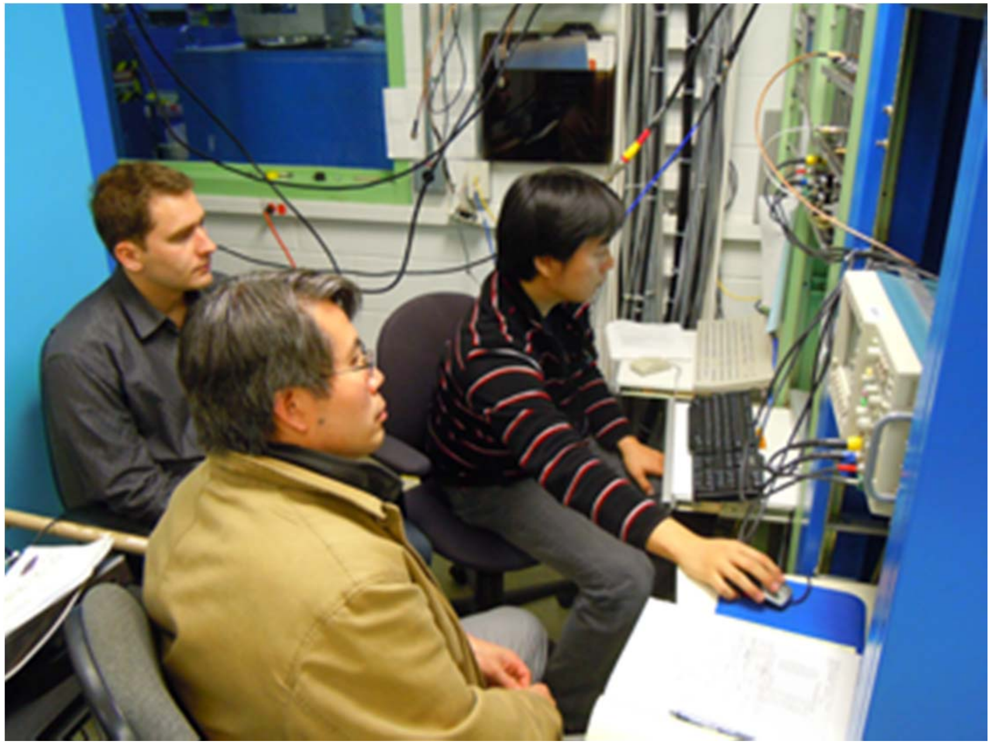
Assembly ~ bake out

Nov. 15~20th 2010

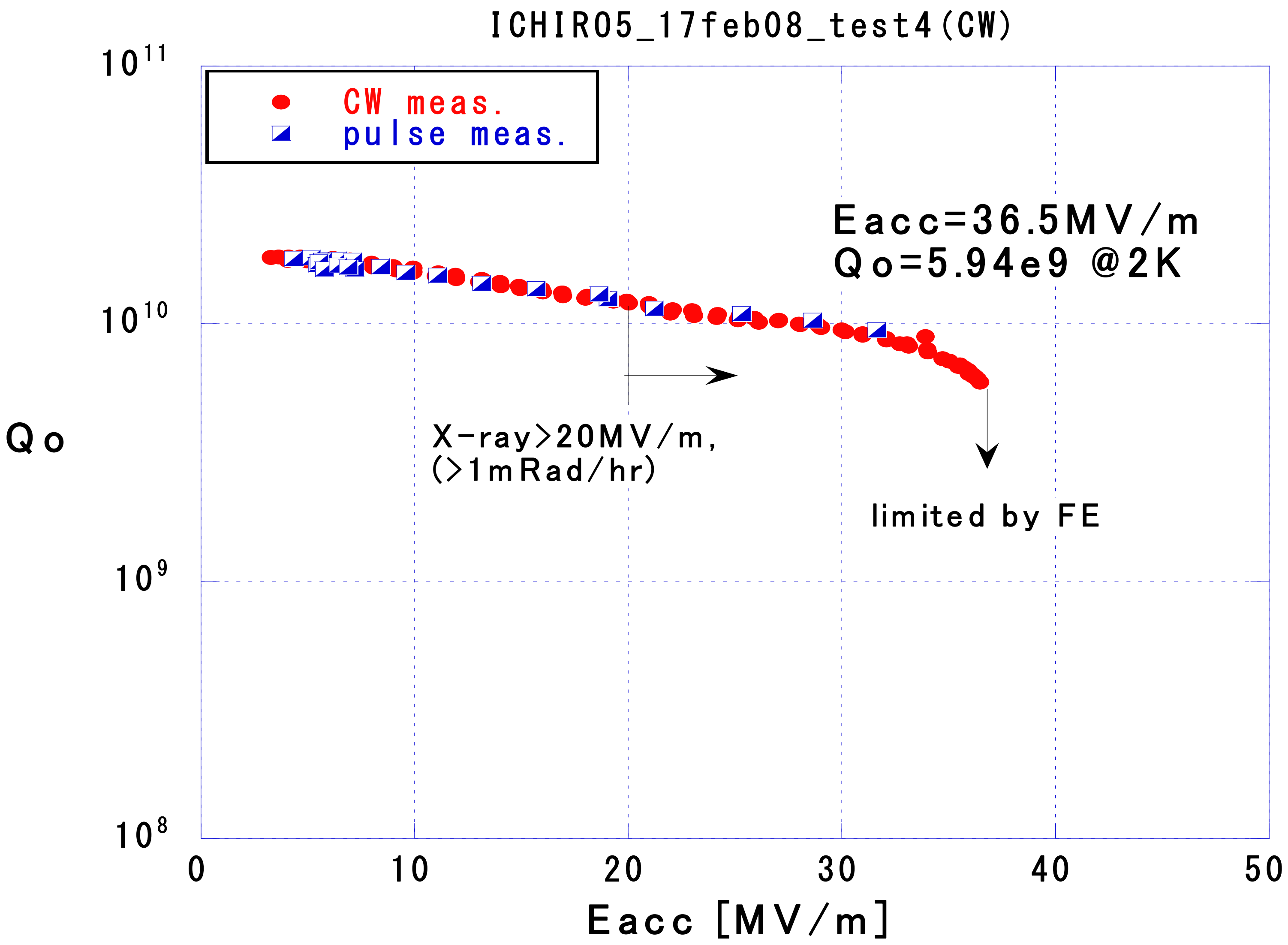
VT

Nov. 24^{th} 2010





Result of the first cycle of S0 Tight loop study @ Jlab



KEK/Jlab S0-study on ICHIRO Full 9-cell in 2010

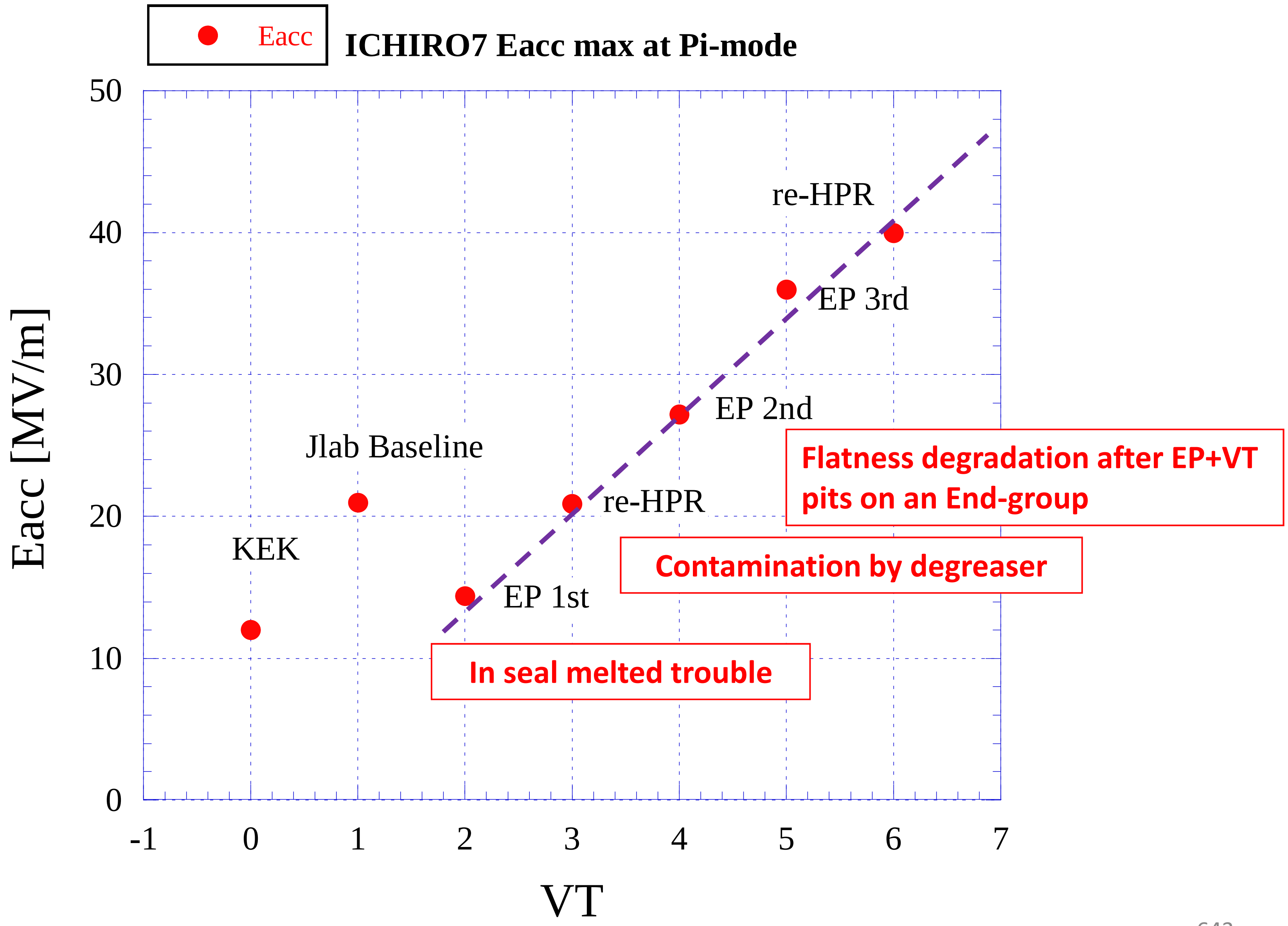
Step-II : full cavity

Ichiro#7

w/ end groups

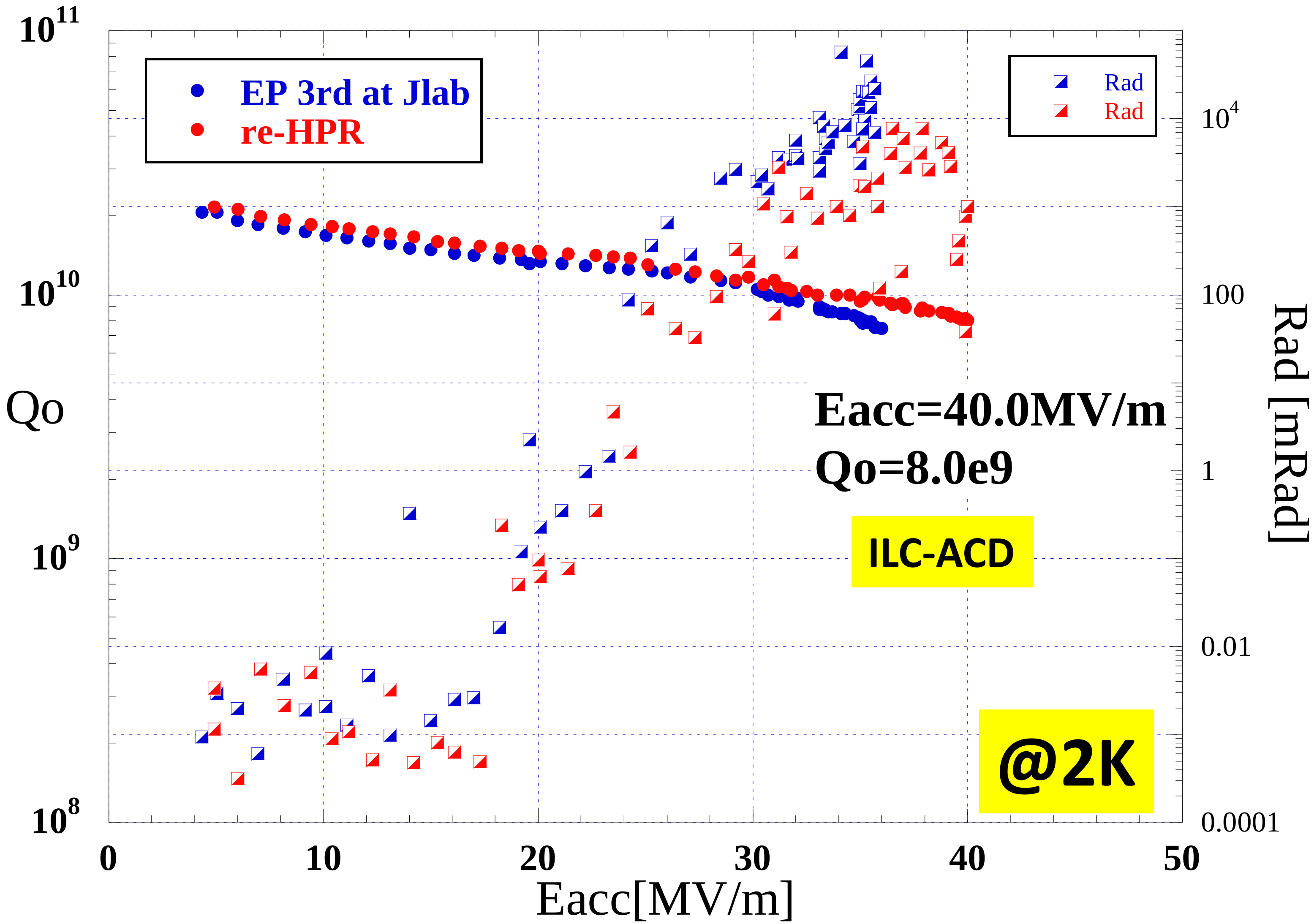
2010 Feb.	March	April	May	June	July
2weeks, Fumio, Kenji 1 RF test (baseline)				10weeks, Fumio 3 RF test (2 EP, 1 re-HPR) Commissioning done for ICHIRO7	
Aug.	**Sep.**	**Oct.**	**Nov.**	**Dec.**	**2011 Jan.**
	SSTIN @Jlab Fumio, Kenji			13weeks, Fumio 3 RF test (1 EP, 1 re-HPR, 1 re-test w/OSTs)	

ICHIRO#7 S0-study current summary



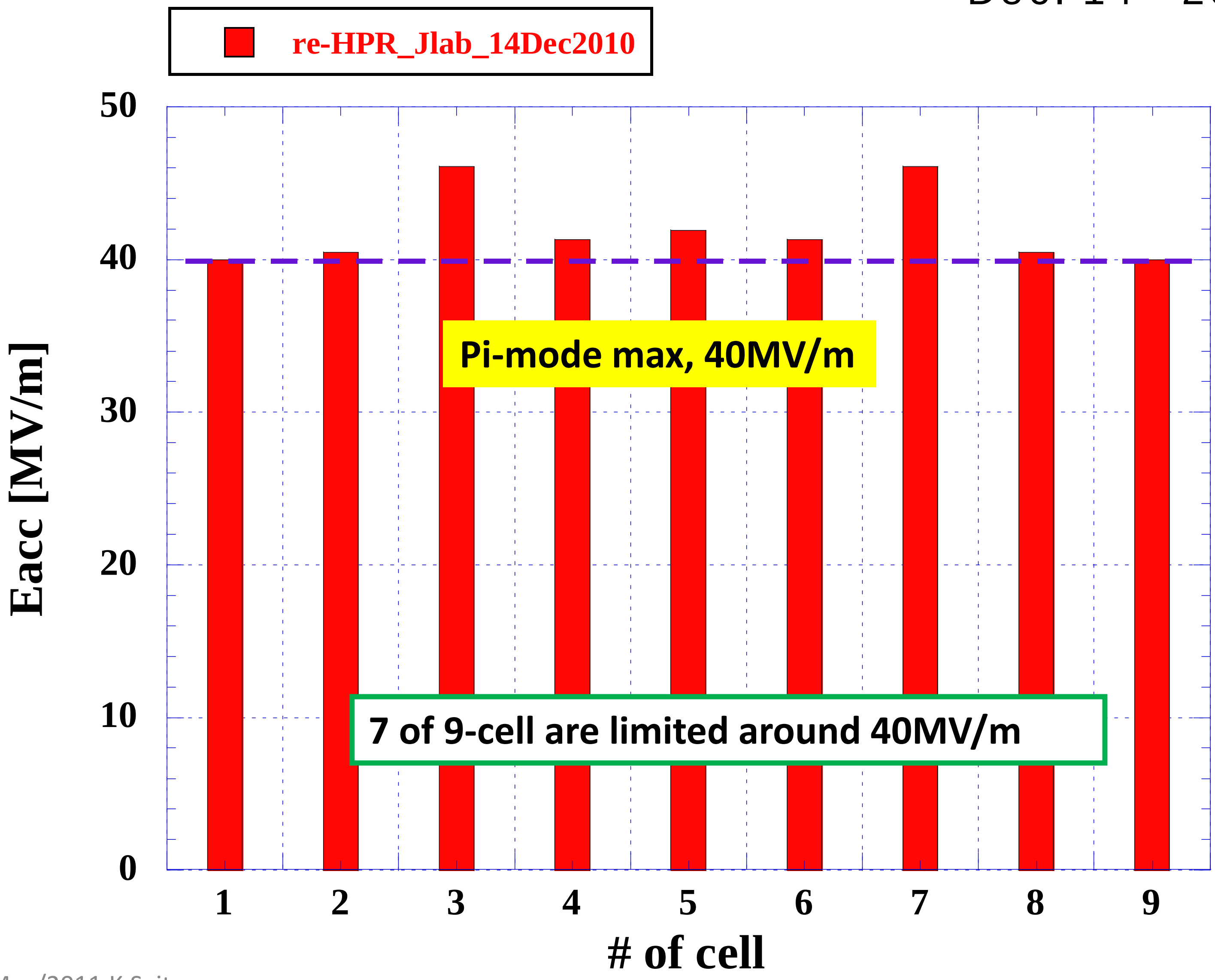
ICHIRO#7 VT after re-HPR at Jlab

Dec. 14th 2010



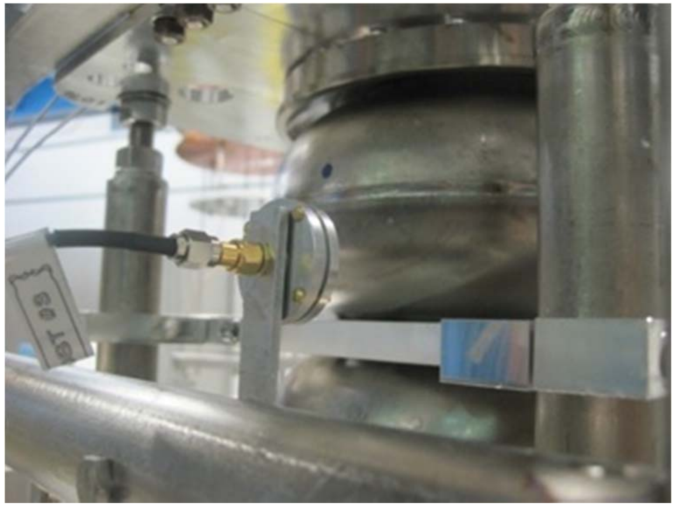
Pass-band meas.

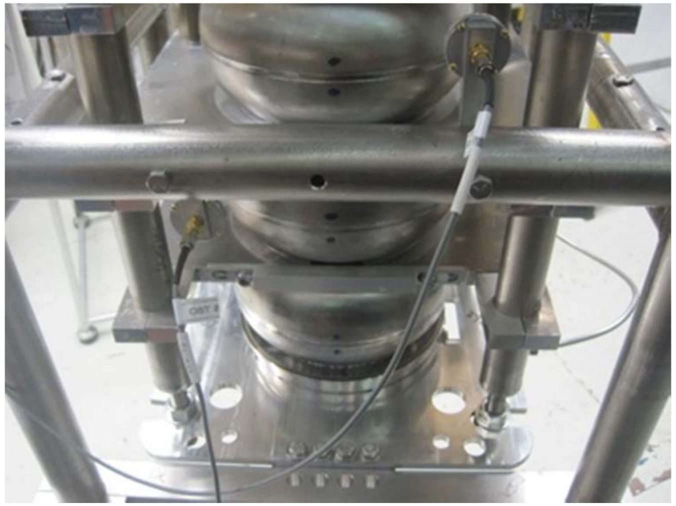
Dec. 14th 2010



ICHIRO7 re-test w/ OSTs

Jan. 11th 2010





黄丸がOST位置を示す。

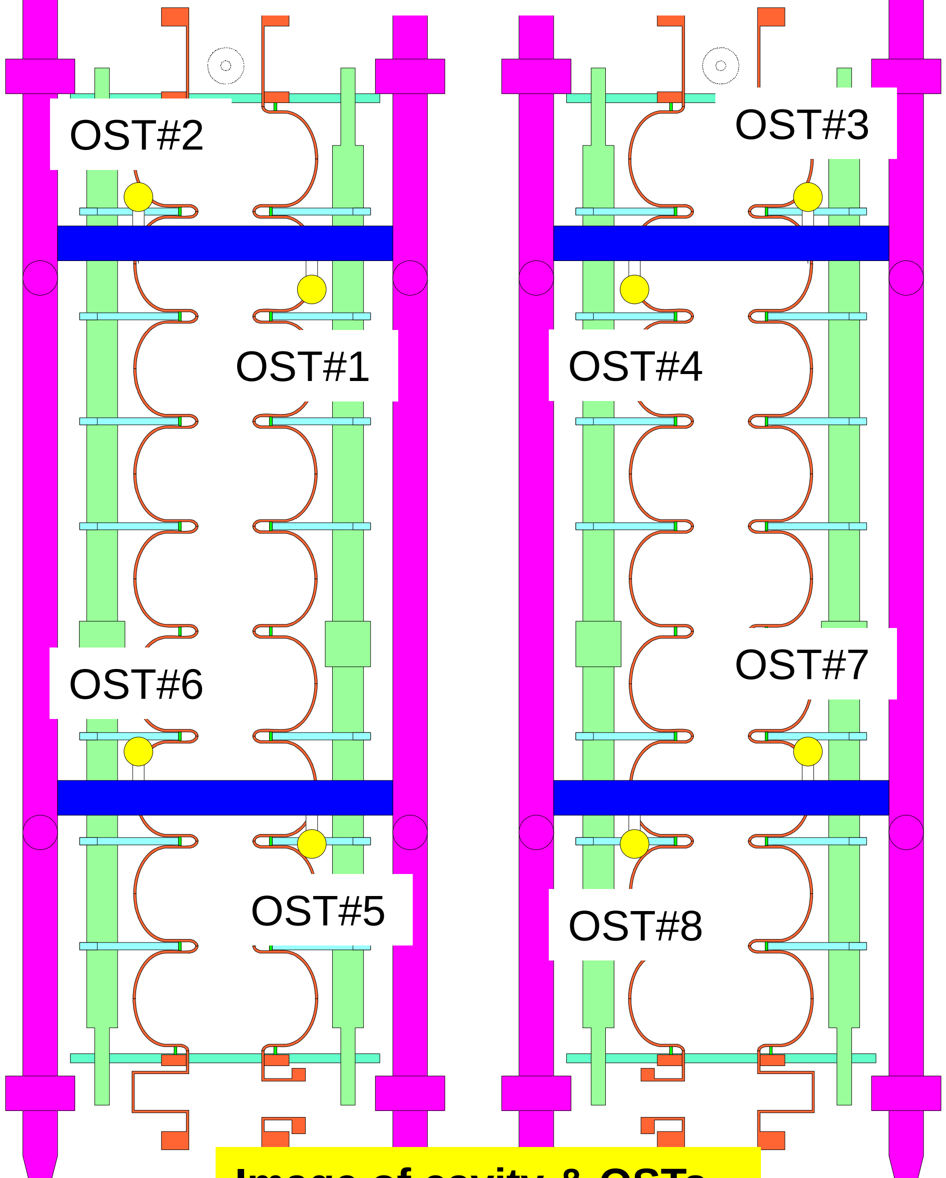
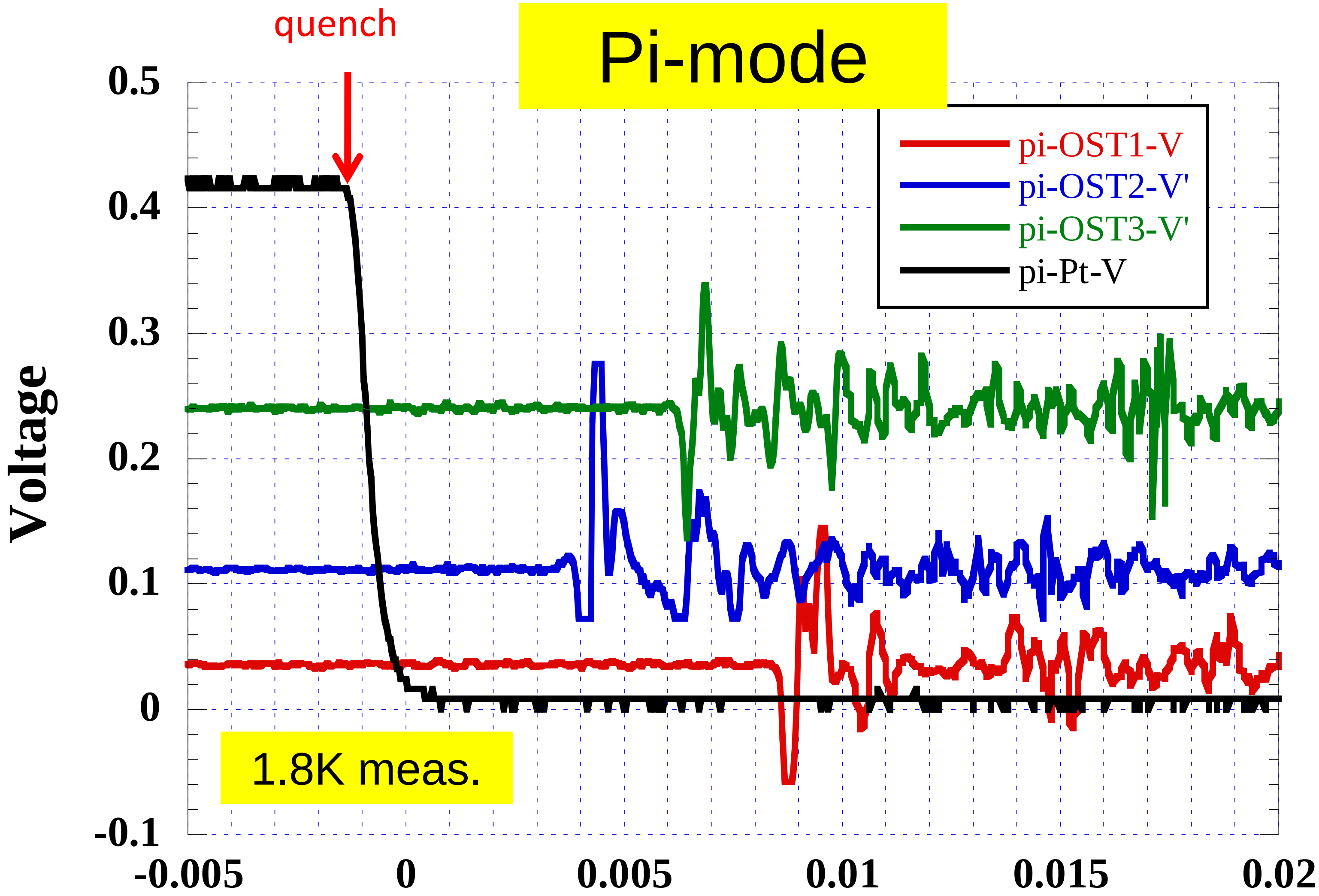


Image of cavity & OSTs

ICHIRO7 re-test w/ OSTs

Jan. 15th 2010

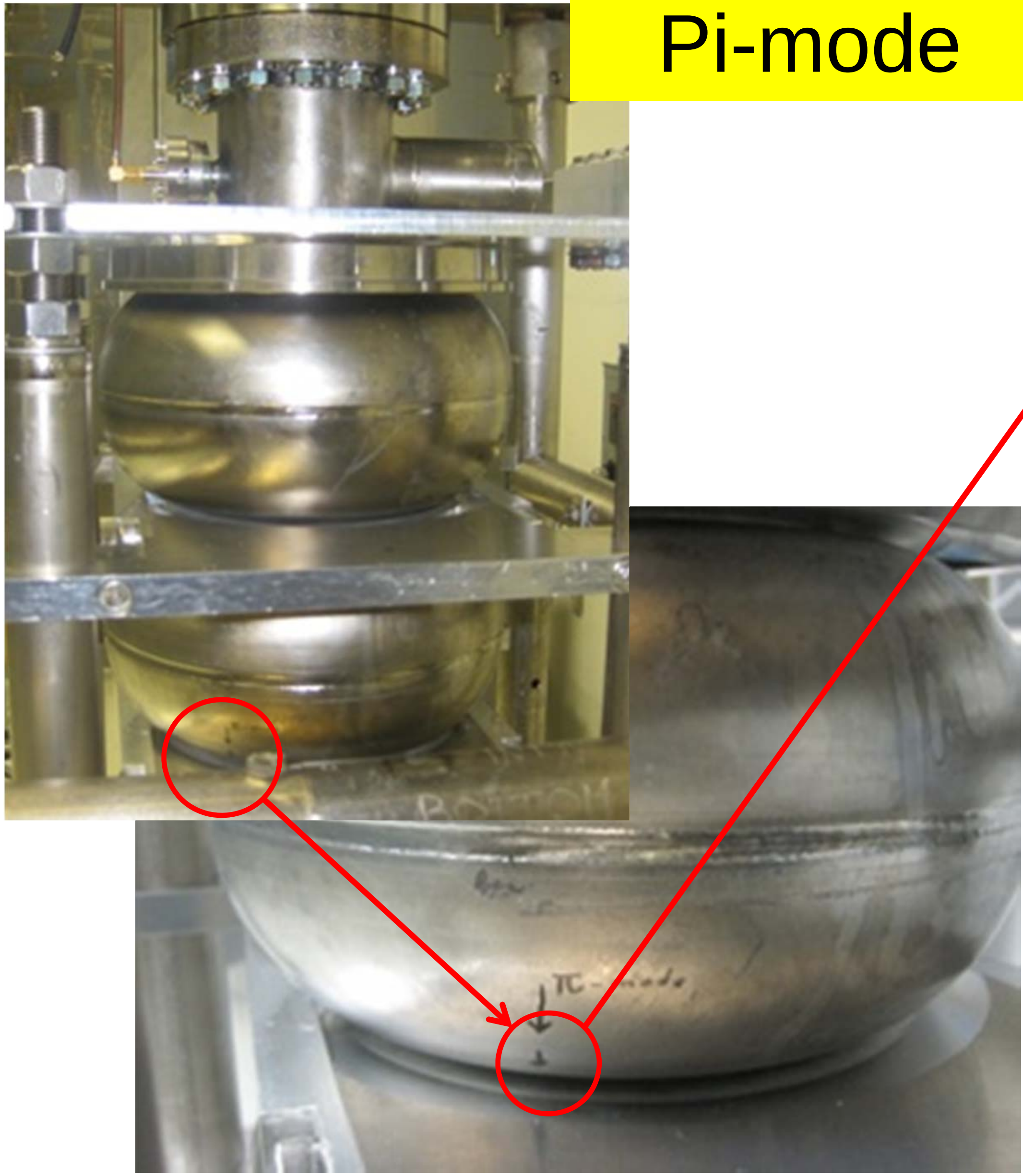


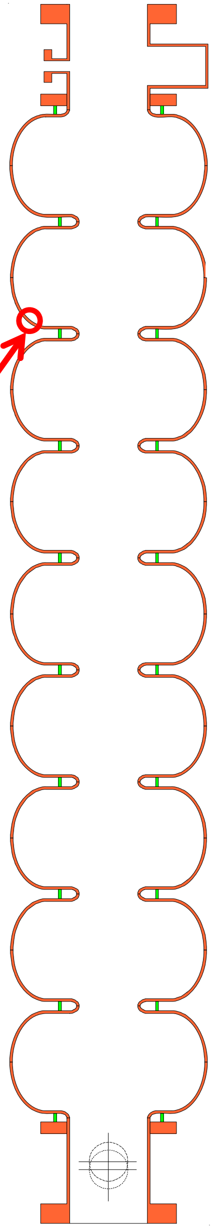
OSTs signal and Pt signal

Quench location check from OST signals

Jan. 19th 2010

Pi-mode

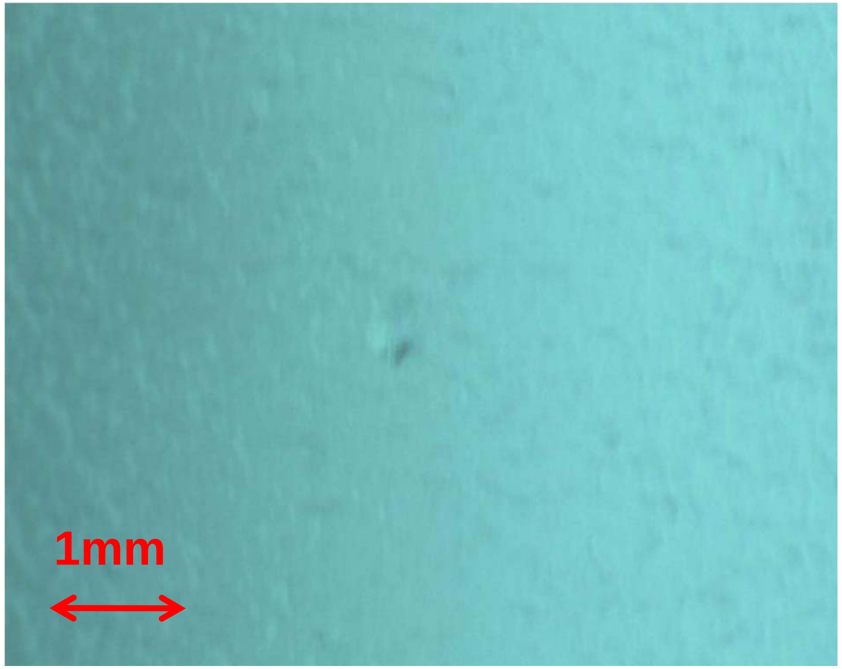




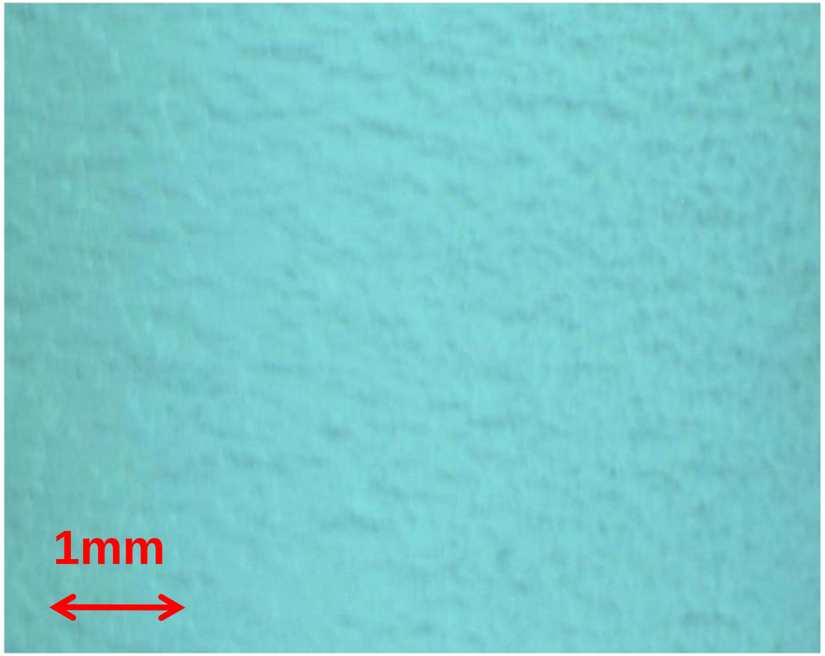
Cell#8

最近、KEK WG5でもOSTが使えるようになった。

Cell#8, quench location of pi-mode



quench area at pi-mode

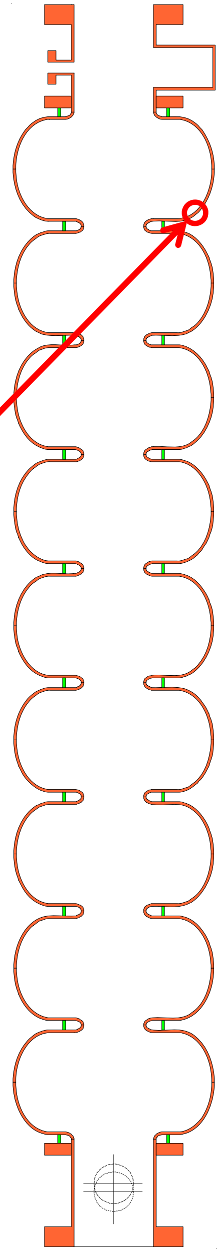


other area
for comparison

Quench location check from OST signals

Pass-band

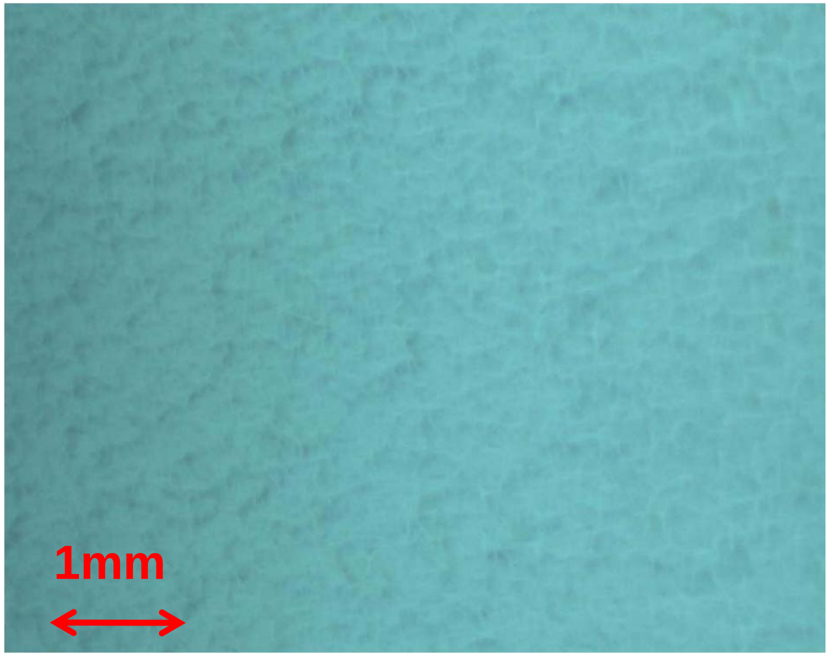
8pi/9~5pi/9 mode indicated similar area on Cell#9



Inspection after VT

2011 Jan. 28th

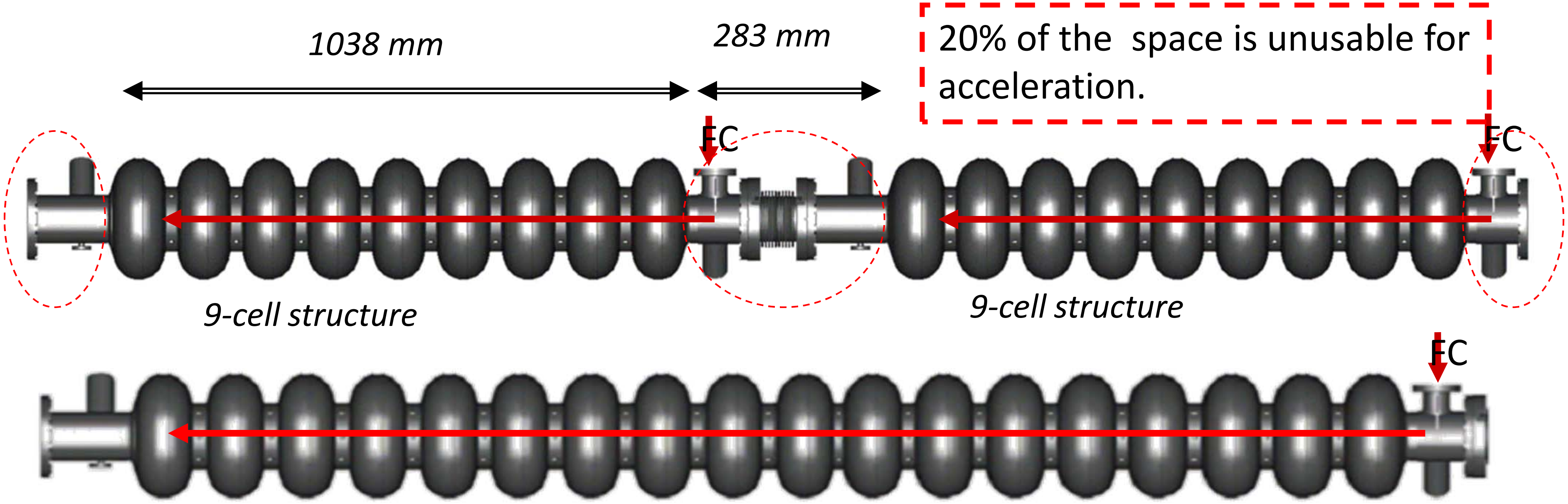
Cell#9, quench location of 8pi/9~5pi/9 mode

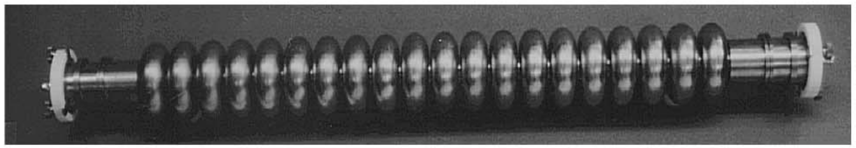


No difference between quench area and other area

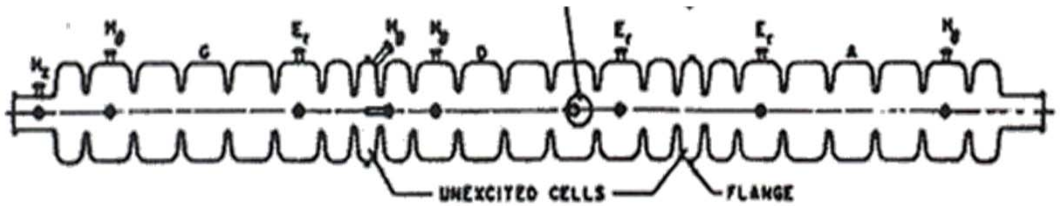
ILC 45MV/m運転に向けた今後のR&D戦略

Configuration : Superstructure





Darmstadt 20-cell *3GHz structures*



SCA at HEPL

There are 2 limitations in number of cells per structure:

1. ***Field unflatness (~ N^2/k_{cc})***
2. ***HOM trapping***

The beam currents of this structure does not exceed 500 µA and is well below ILC current of 9.5 mA.

Conclusion: we could not go this way for ILC (TESLA 1999).

Idea of the Superstructure (SST)

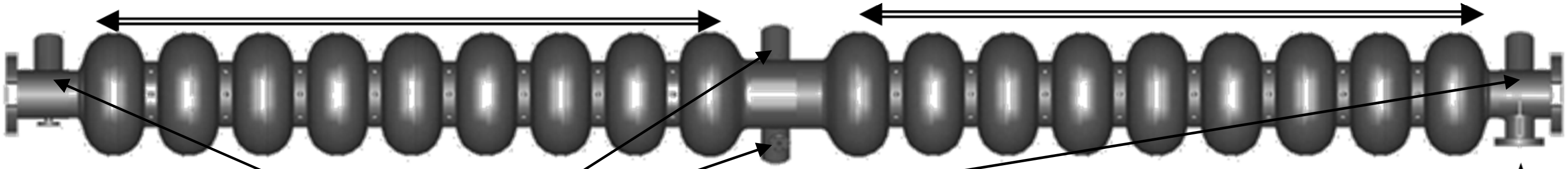
These ***limitations*** *could be relaxed* ***by <u>weakly coupled structures</u> (superstructures),*** *(JS, M. Ferrario, Ch. Tang, PRST-AB, 1999).*

SST layout: *Two (or more) N-cell structures are coupled by $\lambda/2$ long tube (synchronization).*
Each structure has its own cold tuner and HOM couplers.

$\lambda/2$ interconnection *Gain in real estate gradient*

Tuner *control of FF*

Tuner *Partial*
Partial control of FF



HOM couplers as for single structure *Good HOM damping*

One FPC/(2N) cells
Cost savings

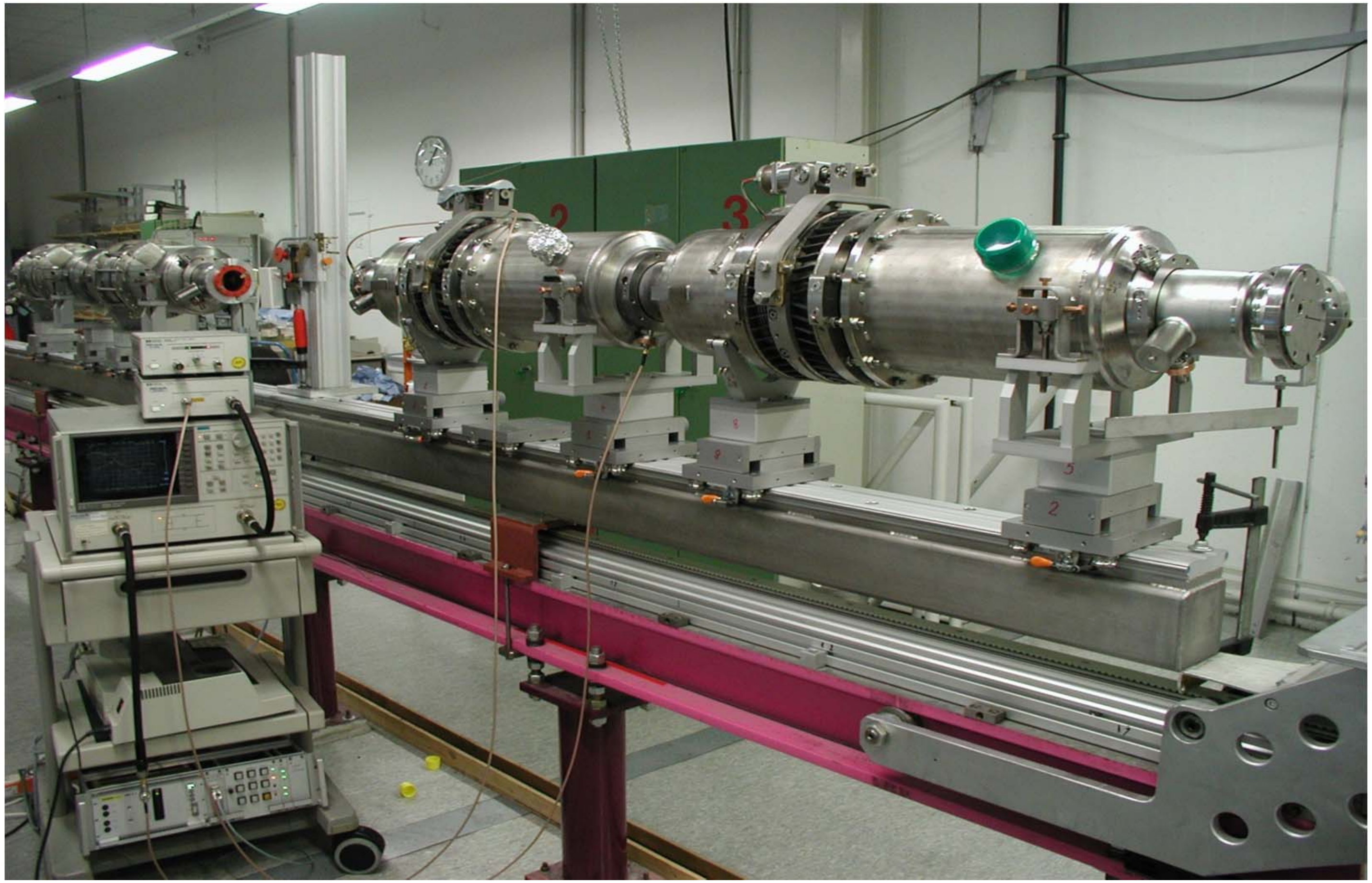
Will the RF power flow via extremely weak coupling to keep energy constant over a train of bunches ???

Pioneer Study of the SST (2x7cell) in TESLA R&D at DESY

Courtesy Jacek Sekutowicz, DESY

The preparation of the experiment begun in 1999.

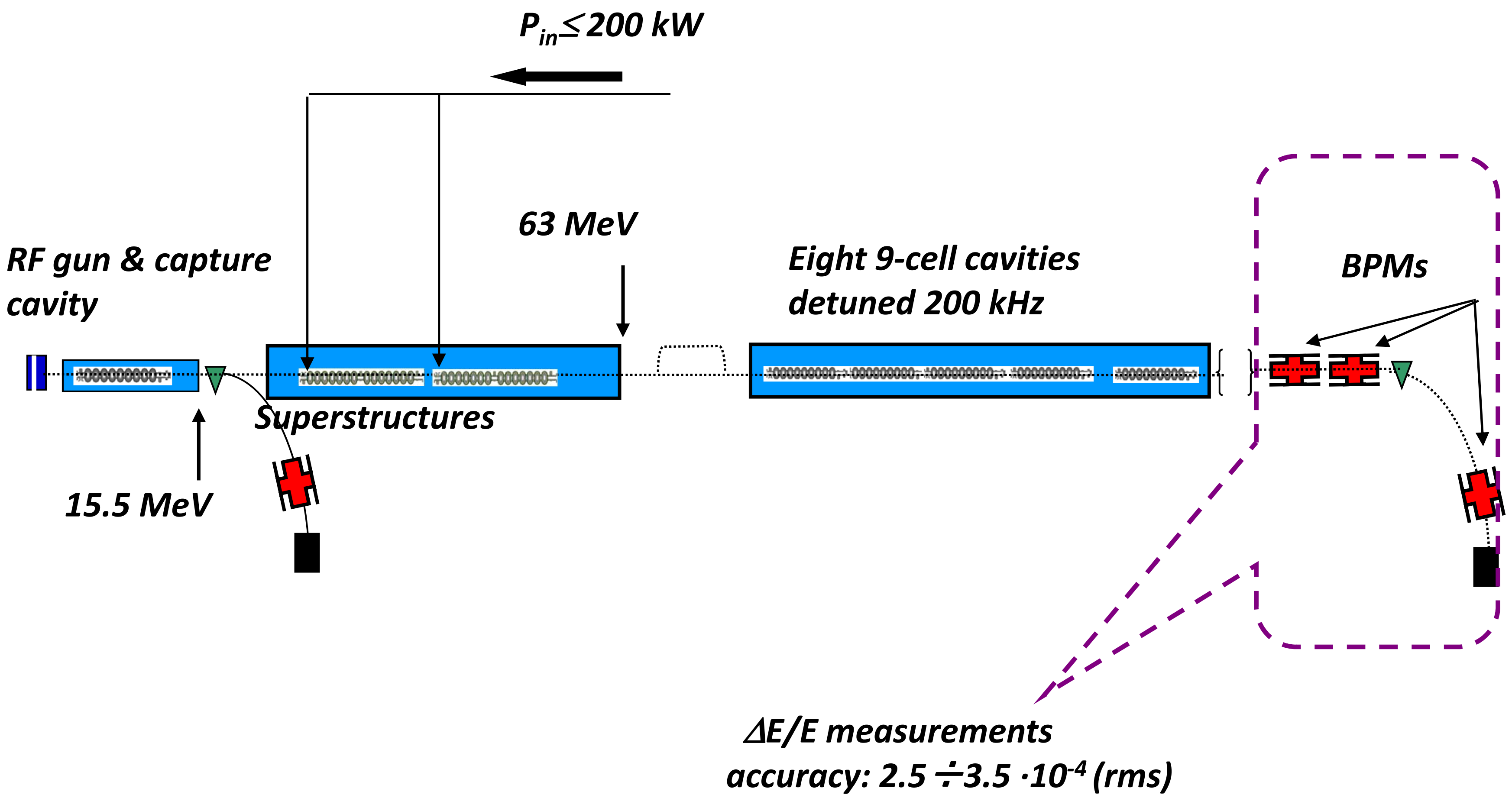
*In 2002, two **2x7-cells SSTs** were assembled in the cryomodule and installed next to the injector in the TTF linac for the test.*



Two 2x7-cell pairs for field profile adjustment and HOM measurements

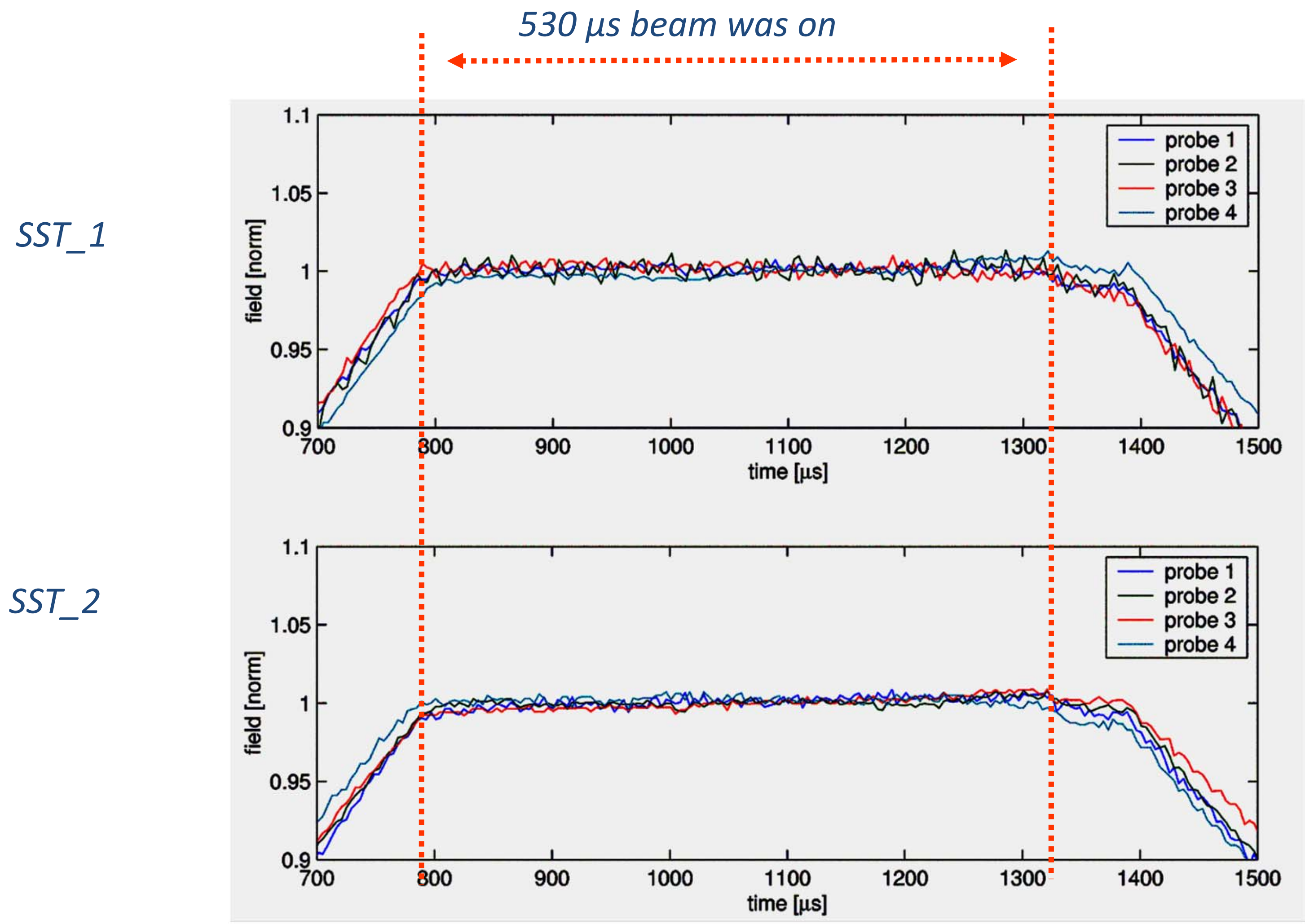
Beam TEST of the STT(2x7Cell) at DESY

Direct measurements of the energy gain for the whole train



Beam acceleration test was successfully performed at Eacc =15MV/m !

Successful Beam acceleration by the SST (2x7cell) at DESY



No voltage drop was observed.

This was the first hint that SSTs works!!

DESY's Conclusion on the STT

DESY's Conclusions from the experiment

- *The experiment showed that SST concept for acceleration works.*
- *The energy modulation $\Delta E/E$ =3.5 E-4 < the collider spec. $\Delta E/E$ =5 E-4, TESLA*
- *HOM damping is very good (at least for 7-cell units)*

But

- *Handling and preparation are more difficult.* → Demountable structure
- *Subunits should be produced with tighter tolerances.*

Combined Scheme for the ILC 1TeV Upgrade

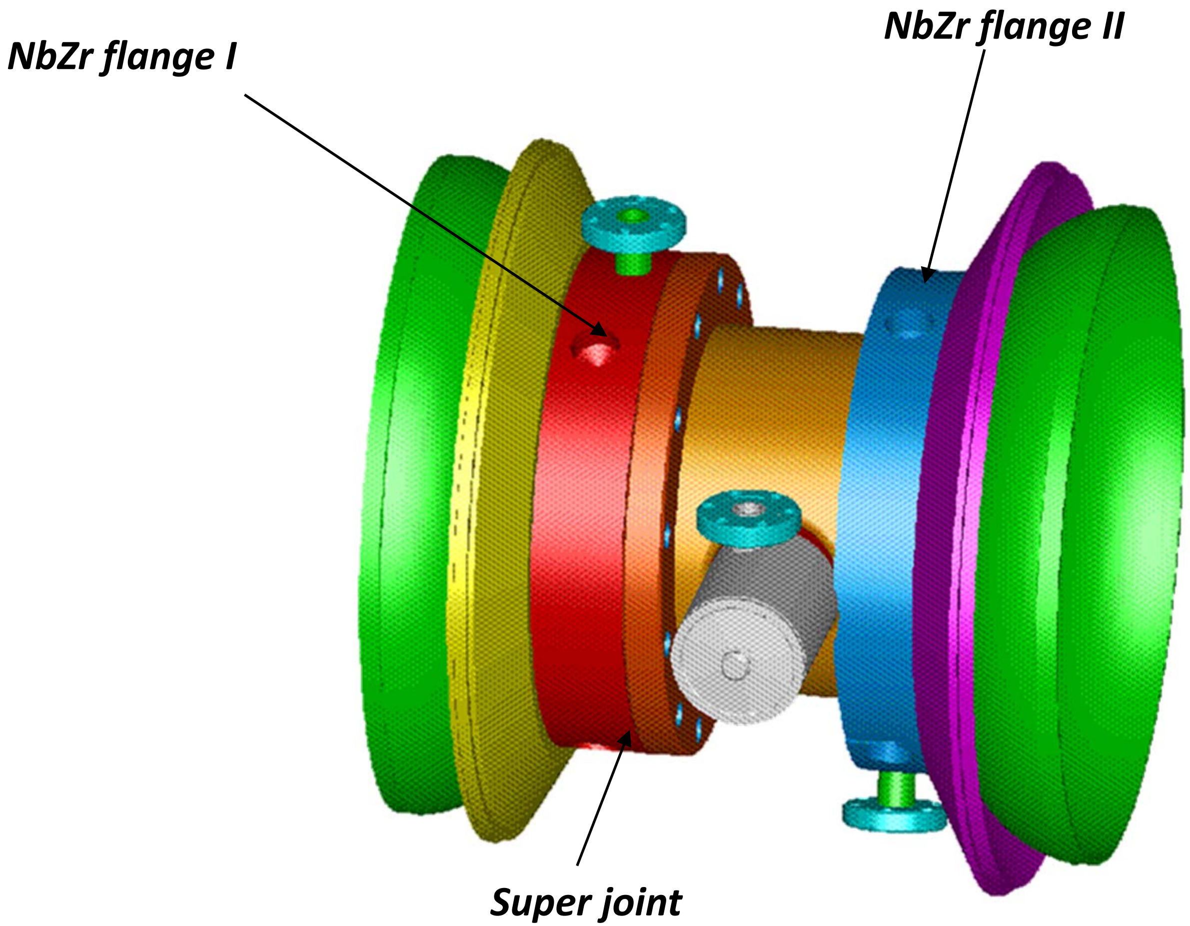
Operation Gradient	Real Gradient [MV/m] 1x9cell	Real Gradient [MV/m] 2x9cell SST	Real Gradient [MV/m] 4x9cell SST
Eacc=31.5MV/m ILC Baseline	24.7	26.4 (Eacc, eff=33.7)	28.2(Eacc,eff=35.9)
Eacc=36MV/m ILC ACD	28.2	30.2 (Eacc,eff=38.5)	32.1(Eacc,eff=41.0)
Eacc=40MV/m ILC Upgrade	31.4	33.6 (Eacc,eff=42.8)	35.8 (Eacc,eff=45.6)
Tunnel length for 1TeV [km]		31(baseline)+25.4=56.4 Combimed schem 50.7	31(baseline)+21.5=52.5 Combined schem 42.8

	Tunnel Length	Input Coupler	RF Distribution	LL Control	Cryogenic load	Gradient Performance	Cavity Fabrication Tolerance
Pros	shorter	Number reduces to 1/4 max.	Number of parts reduce to 1/4 max.	Station reduces to 1/4 max.	Reduces ~6kW max.@2K		
Cons		Power increases to 4 times max.				SST gradient is limited by the lowest gradient cavity	Becomes tighter

Key Technologies for Superstructure & Ongoing R&D

R&D 1 : Super joint

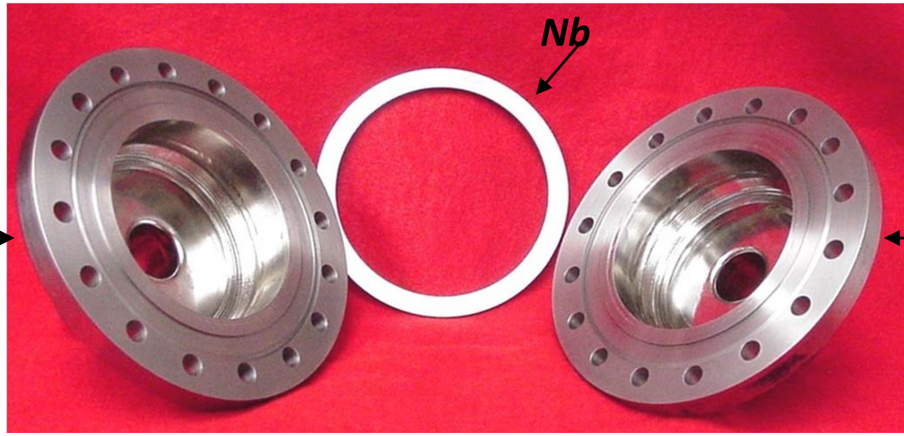
To make SST handling easy, demountable structure is desirable. Super joint is needed for it.



Ongoing R&D on Super-Joint by P. Kneisel at JLab

Nb

Reactor grade

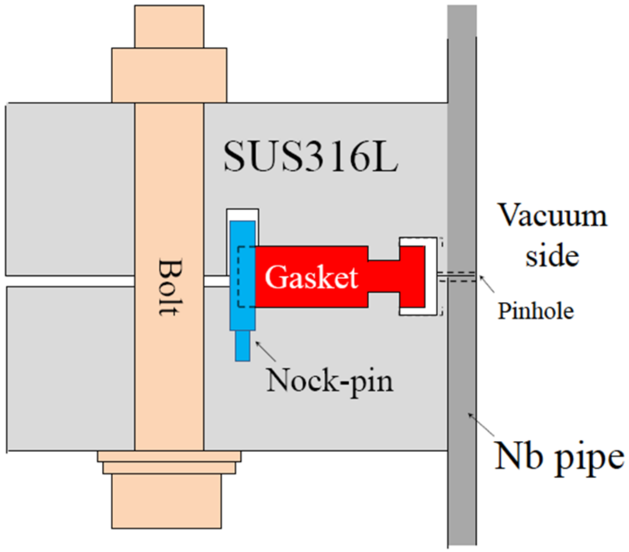


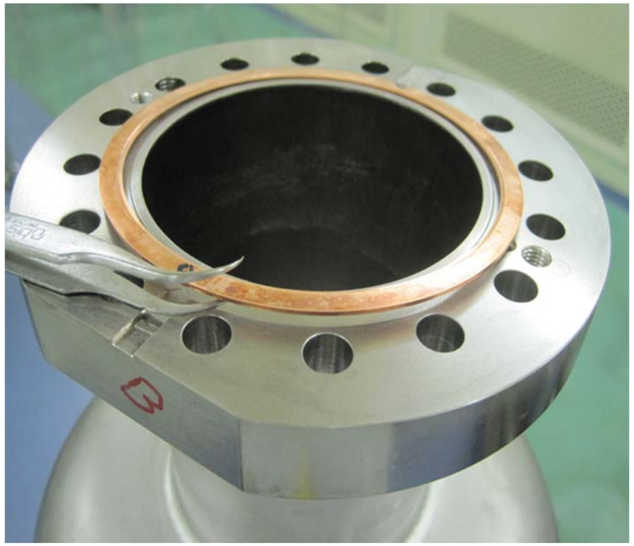
Nb

Reactor grade

2.7 GHz cavity for testing of sc gaskets

Application of MO seal for Super-Joint, to be started soon at KEK



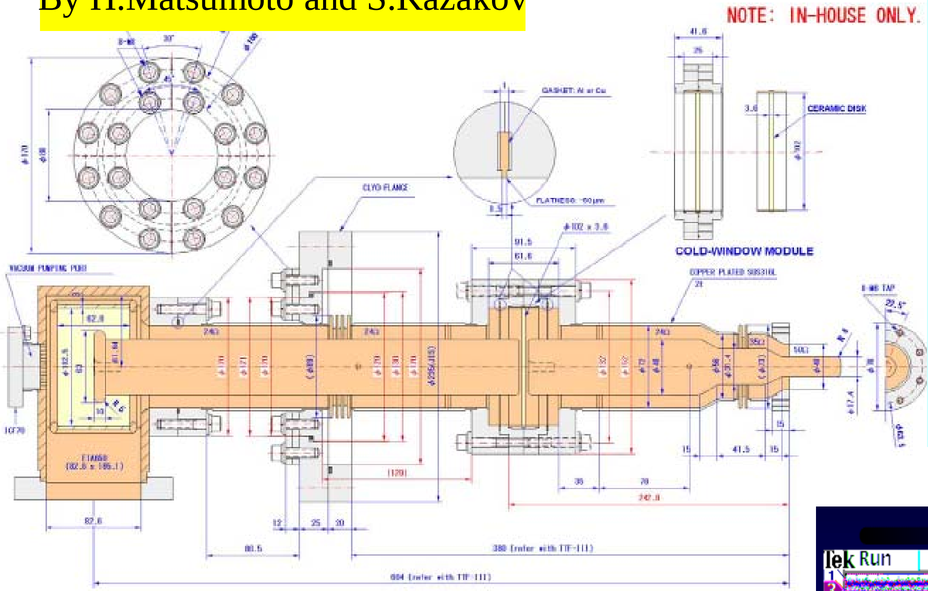


R&D 2 : High Power Coupler

For 4x9cell SST, 2MW coupler is needed but it almost exists.

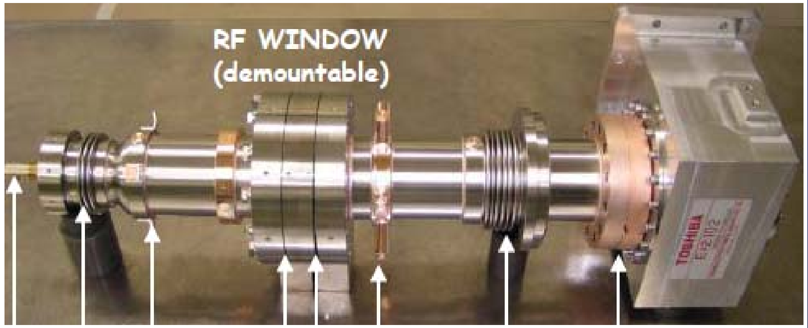
KEK STF 0.5 activity

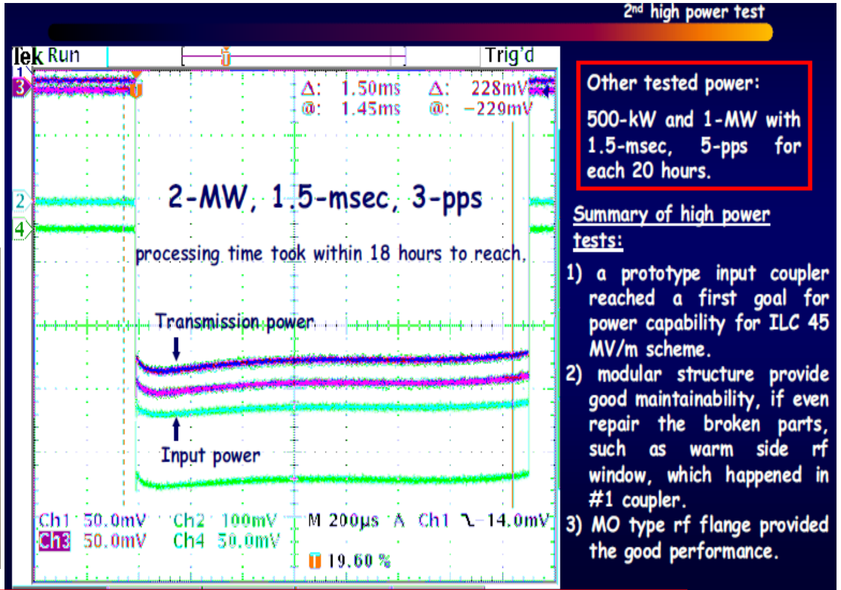
By H.Matsumoto and S.Kazakov



Successfully demonstrated the high power performance up to 2MW!

The specification: 500kW, 1.5msec, 5Hz @ 45MV/m operation





Successfully power loaded at 2MW, 1.5ms, 3pps.

STF @ KEK

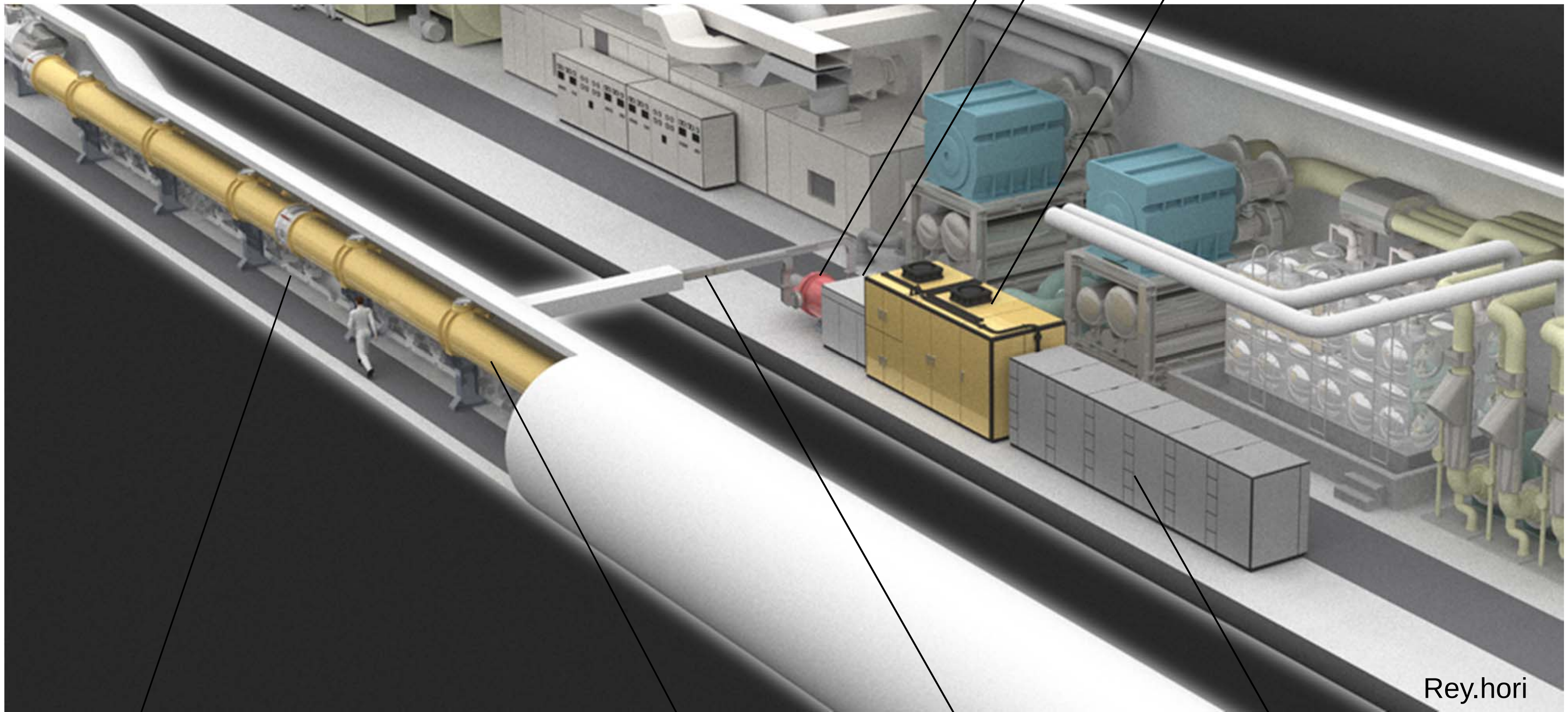
BCD RF unit cartoon (cryo-plant region)

Two tunnel configuration

Multi-beam klystron

Pulse transformer

Bouncer modulator



RF distribution

cryomodules

RF waveguides

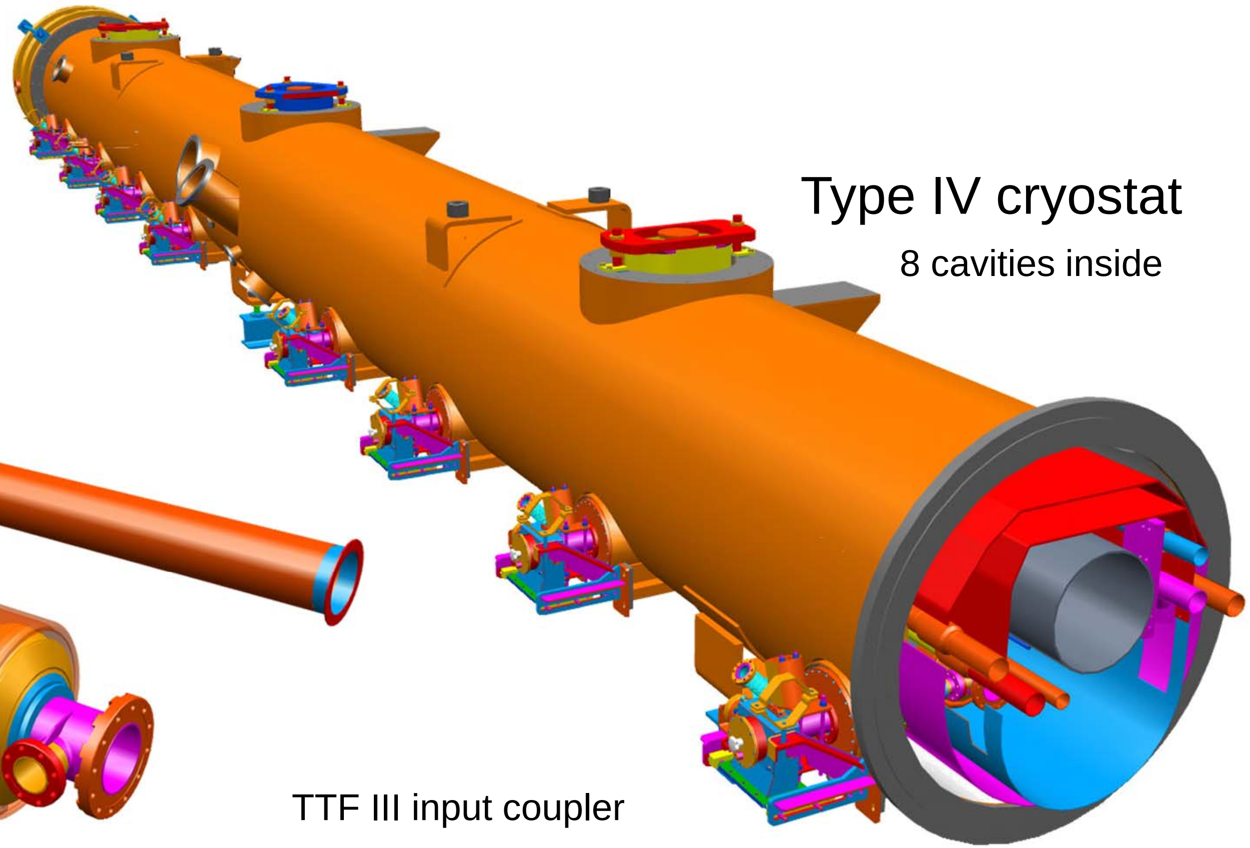
LLRF & instrumentation

Cryomodule R&D

- cryomodule meeting was held at CERN in Jan.16,17.
- CERN,DESY,FNAL,INFN,JLAB,KEK,SLAC meet together.
- TTF type III+ --> TTF type IV (will be ILC proto-type).
- discussion & work share for ILC proto-type.
- SMTF was a core, however, become global design team gradually.

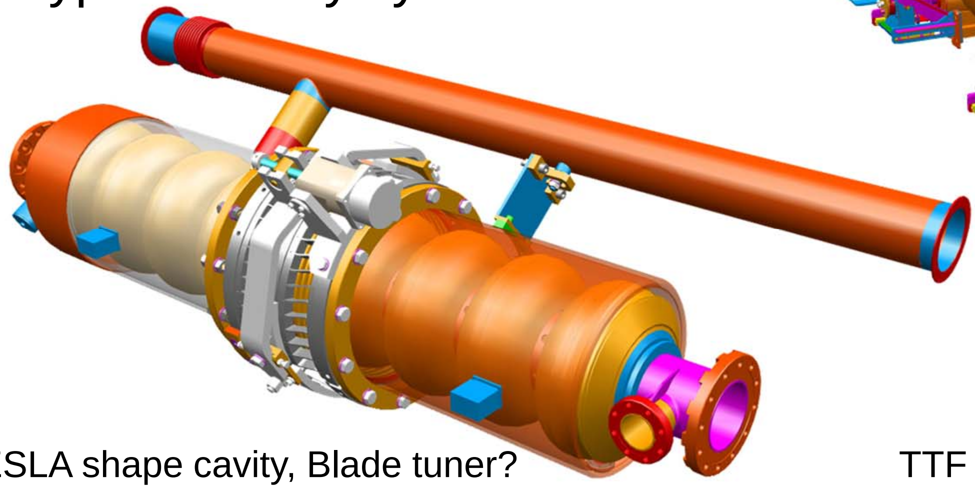
Type IV cryostat

8 cavities inside



TTF III input coupler

Type IV cavity system



TESLA shape cavity, Blade tuner?

For
detail engineering design & cost estimation,
development of regional production ability,

ILC Main Linac R&D
are proceeded in several place.
(STF, SMTF(ILCTA), TTF)

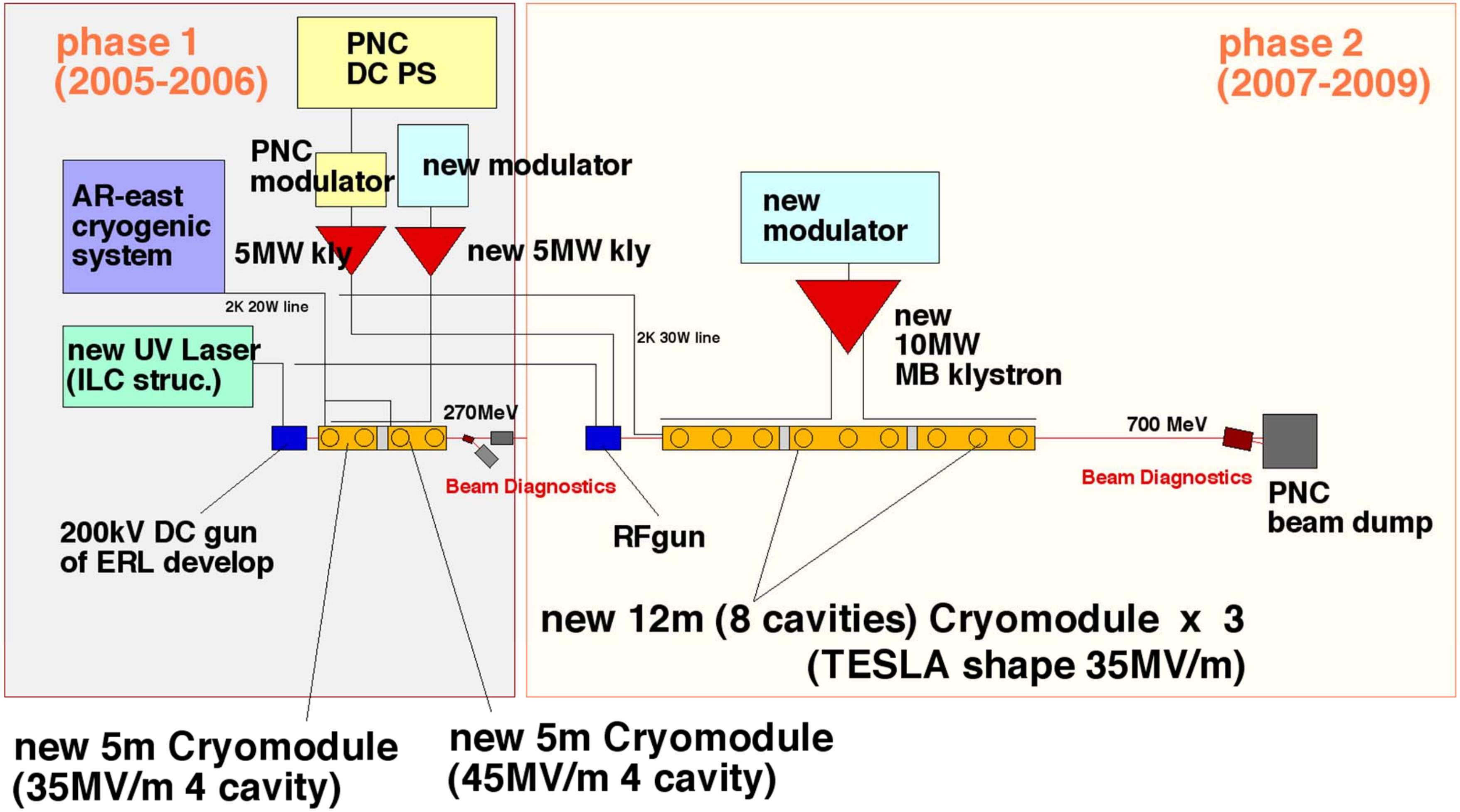
Major two R&D area

Cryomodule R&D:	Power source R&D:
Cavity system,	Klystron,
Cryostat,	Modulator,
Quad/BPM,	WG distribution,
	LLRF control,

*** STF = ILC Main Linac R&D in KEK**

STF holds two R&D area

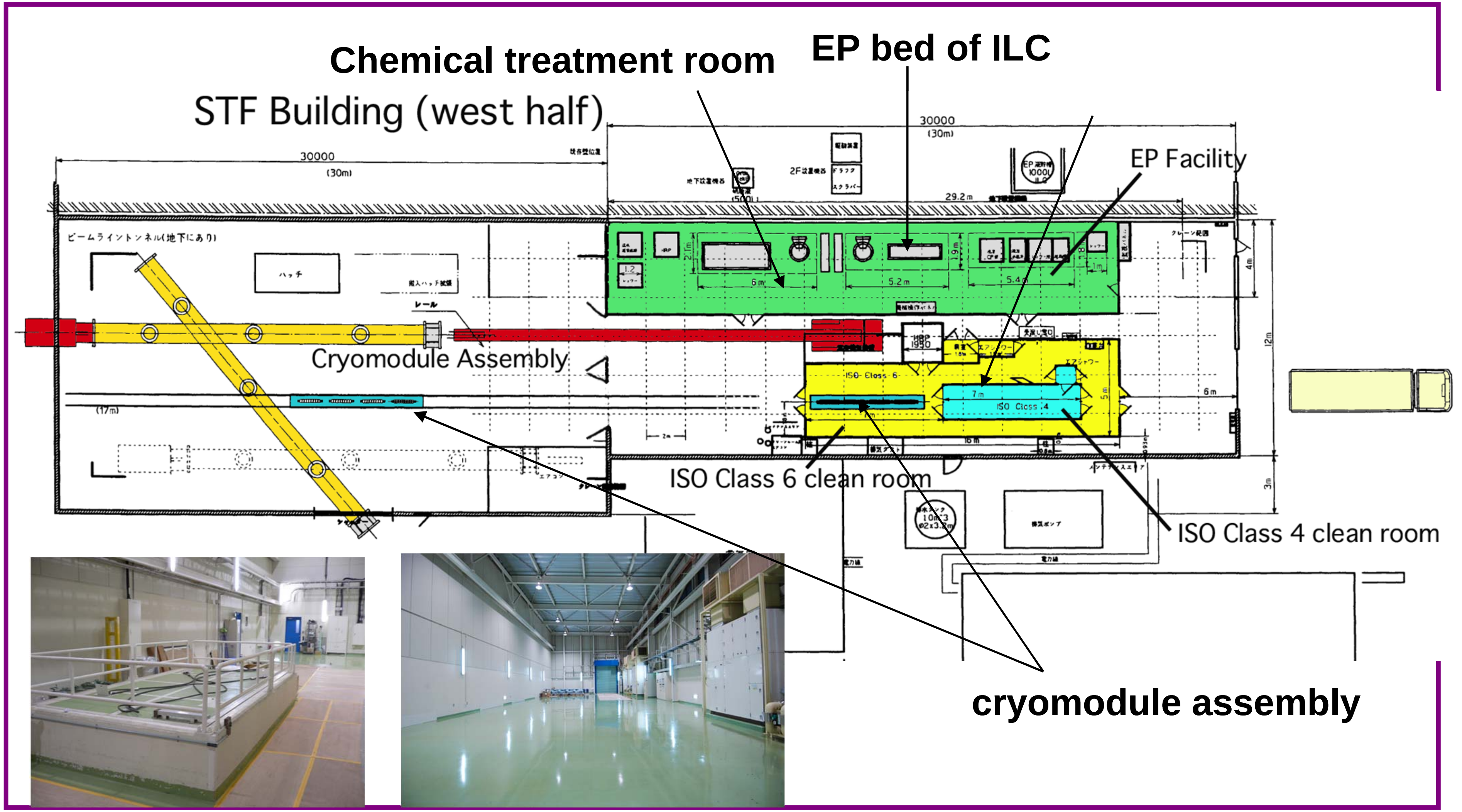
Plan of Superconducting RF Test Facility (STF)



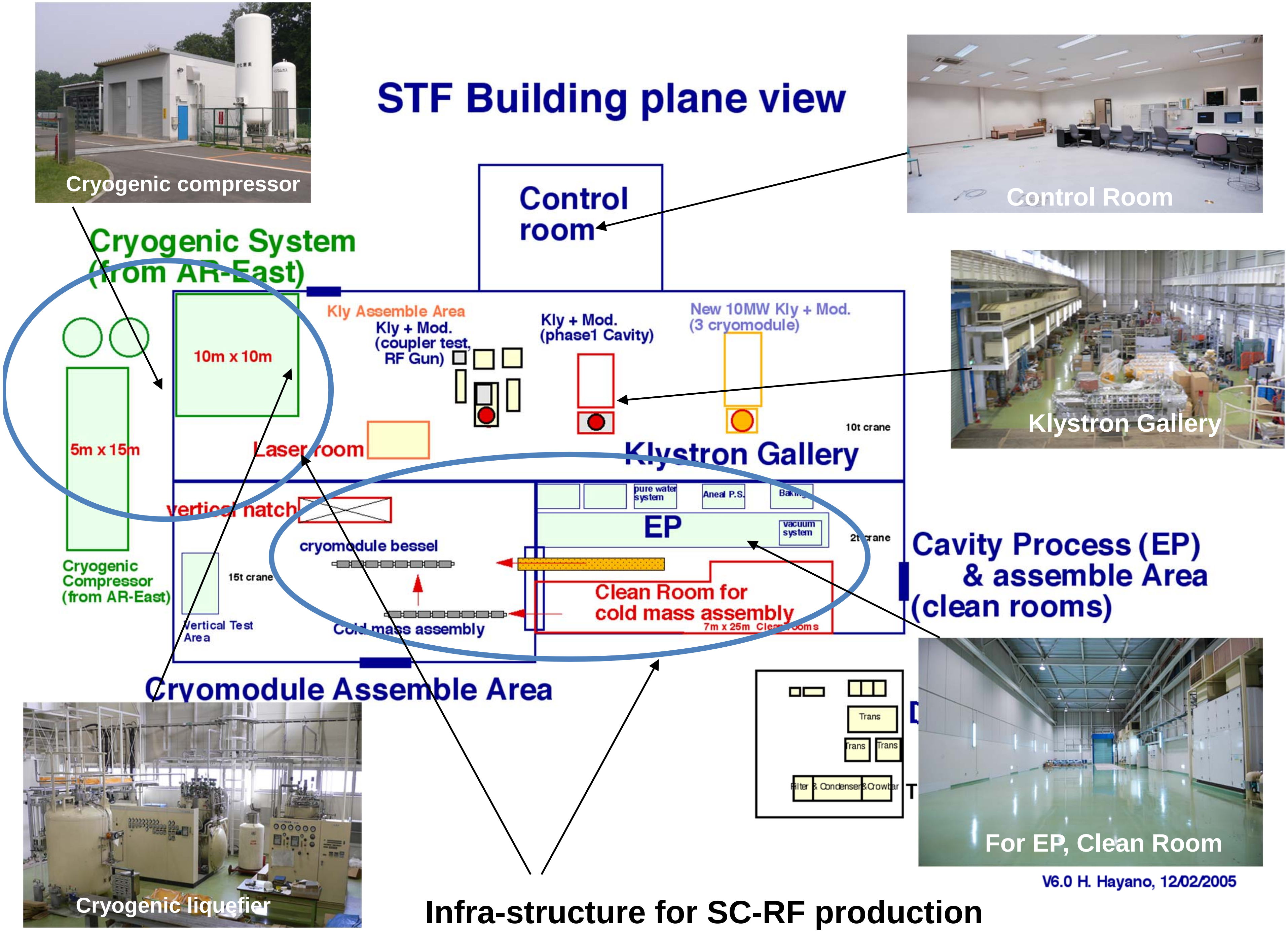
V3.0 Hitoshi Hayano, 12/02/2005

STF Infrastructure

EP: new EP(Electro chemical Polishing) facility to be built by March 2007.
Clean room: new clean room installation in March 2006.



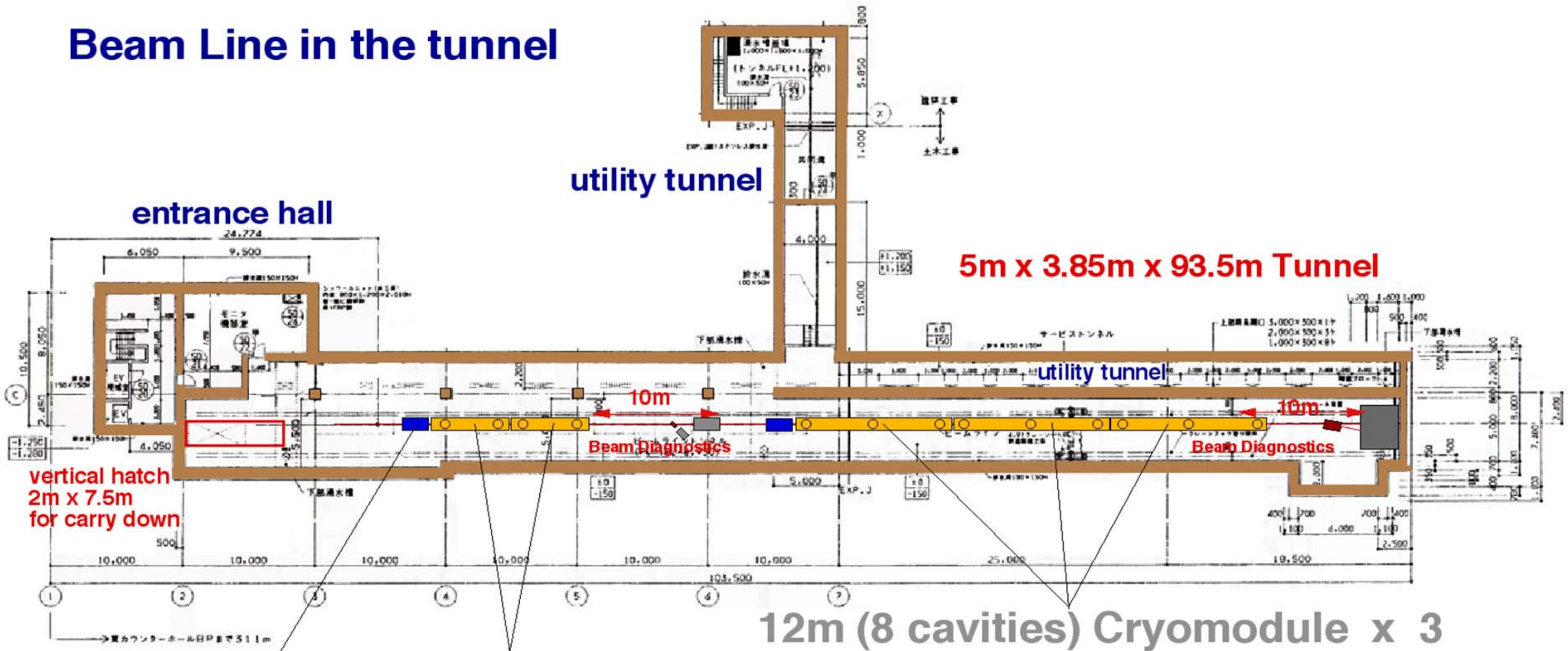
STF Building plane view



Infra-structure for SC-RF production

STF underground tunnel plane view

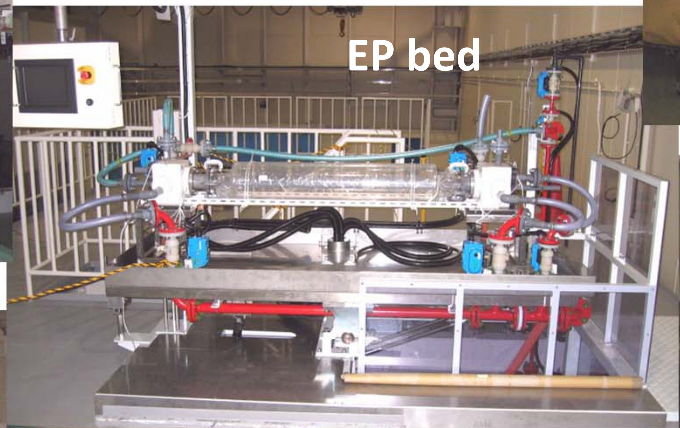
Beam Line in the tunnel



DCgun
(later RFgun)

5m Cryomodule(4 cavities)
+
5m Cryomodule(4 cavities)

STF Facility

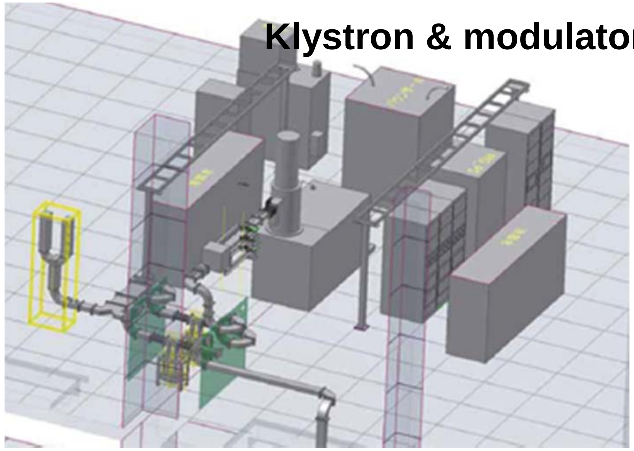


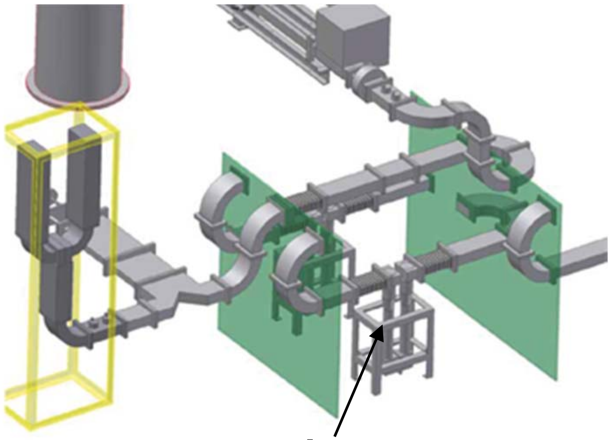
STF 1 Modulator, 5MW klystron plan&status

Reuse an old TH2104A 5MW klystron, driven by an existing PNC modulator by adding a bouncer circuit and a new pulse transformer.

Mod: by Mitsubishi-Electric, Nichi-Con; Puls trans: by Nihon-Denji-Kogyo

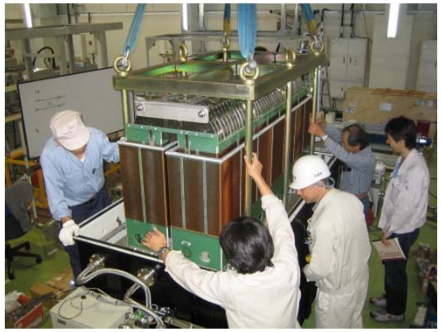
Initial operation is scheduled in Jan. 2006 for testing the cavity input couplers.
Relocate this system later for running an RF-gun.





Coupler HP test setup

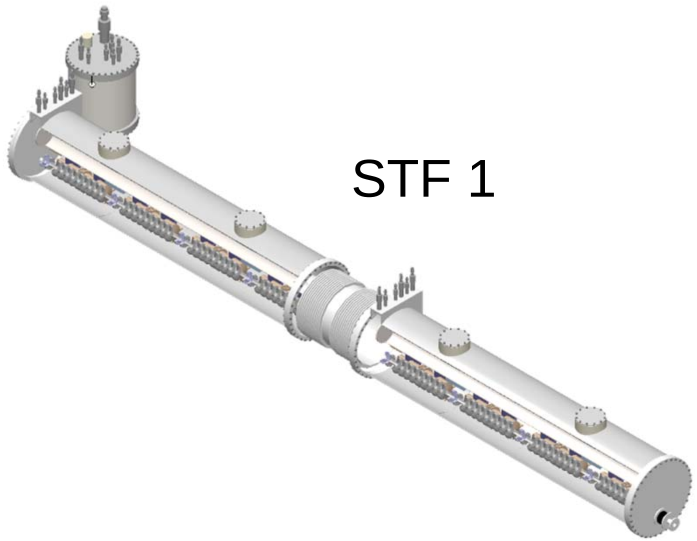
Pulse transformer installation was over.



Cryomodule (1)

cryostat : 4-cavities cryostat,

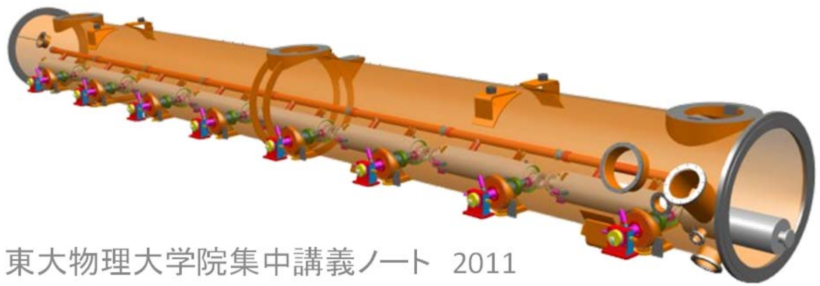
fabrication 2006, operation 2006-2007,
study of system assembly, maintenability,
temperature performance, heat-loss,
shrink distortions, vibrations,
magnetic shield, component alignment,



STF 1

cryostat : 8-cavities cryostat (ILC-type),

design 2006-2007, fabrication 2008-,operation 2009-
study of ILC system assembly, maintenability,
temperature performance, heat-loss, shrink distortions,
vibrations, magnetic shield, component alignment,



STF 2

FNAL drawing

Cryomodule (2)

Cavity system : ILC-BCD cavity system,

for STF1: fabrication 2006, operation 2006-2007,

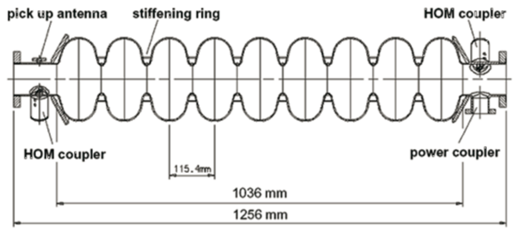
for STF2: design 2007, fabrication 2008, operation 2009-,

study of fabrication, surface treatment, system assembly,

gradient performance, Lorentz-force compensation,

microphonics, HOM dumping, BBA,tuner performance,

input coupler performance,



Cavity system : ILC-ACD HG cavity system

for STF1: fabrication 2006, operation 2006-2007,

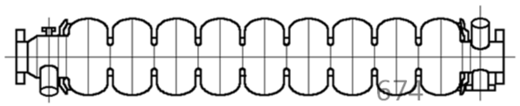
for STF2: design 2007, fabrication 2008, operation 2009-,

study of fabrication, surface treatment, system assembly,

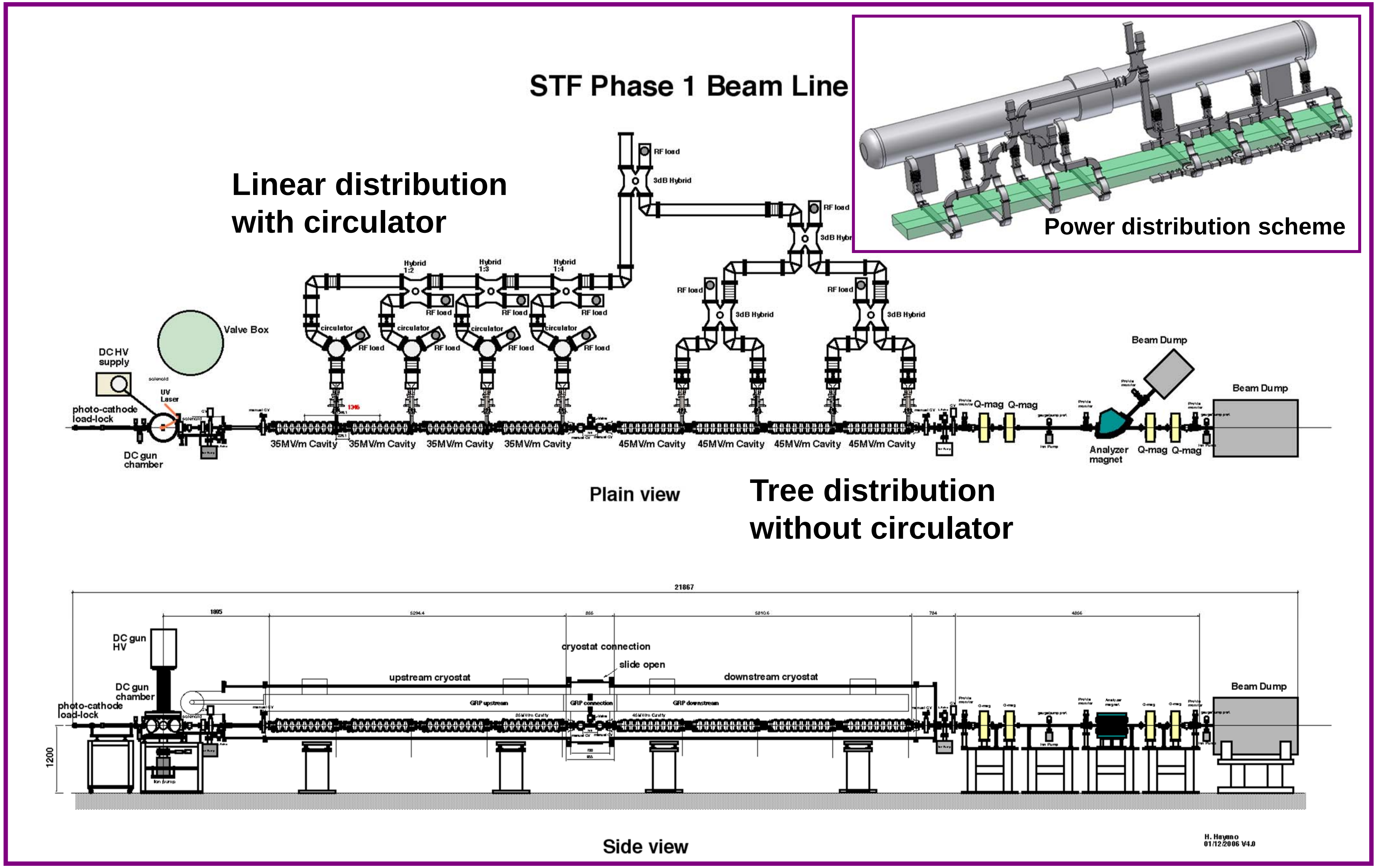
gradient performance, Lorentz-force compensation,

microphonics, HOM dumping, BBA, tuner performance,

input coupler performance,



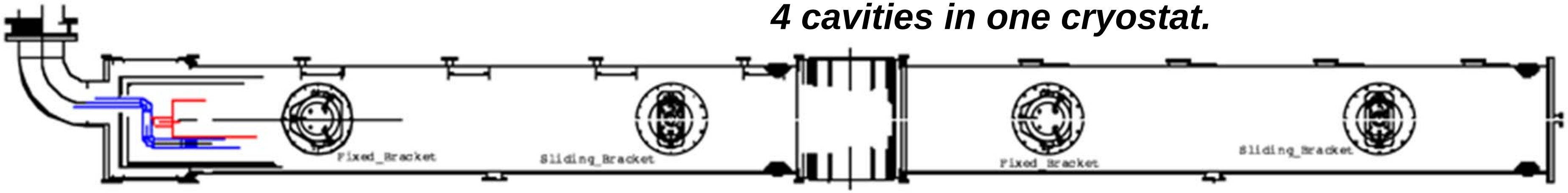
STF Phase 1 SC accelerator Plan



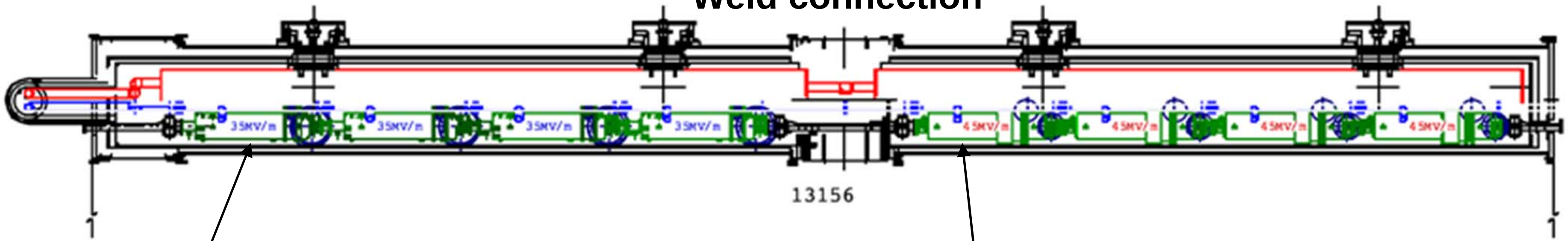
Cryomodule : Detail Cryostat Design done
(by Hitachi)

To Valve Box

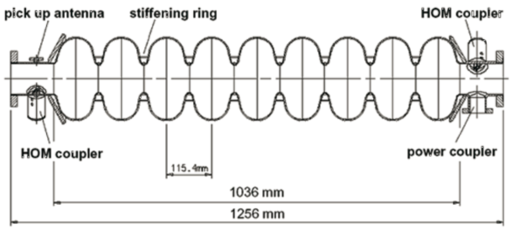
Two cryostat connection,
4 cavities in one cryostat.



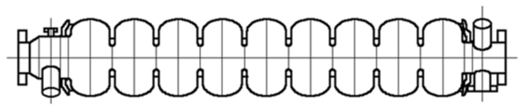
Weld connection



35MV/m TESLA style cavities (4)



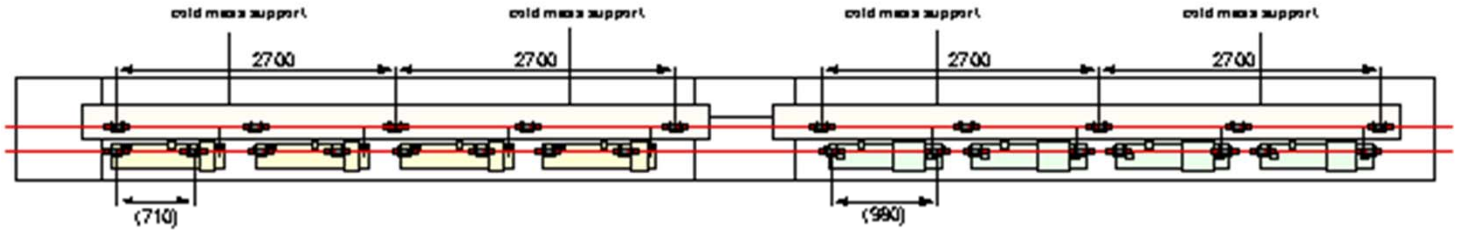
45MV/m Low-loss style cavities (4)



Fabrication was started.

WPM(Wire Position Monitor) study started

WPM installation position



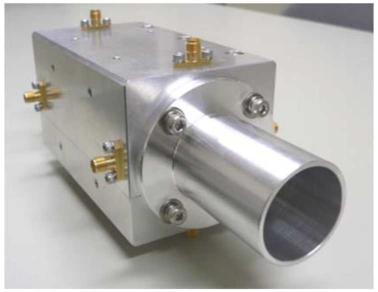
140MHz CW RF on wire;
Electronics development,
Resolution test. etc.

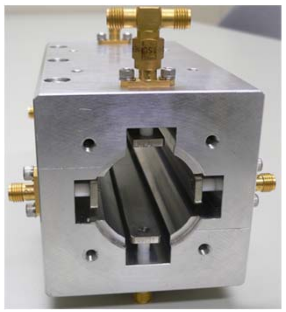
WPM: GRP 5 + 5 = 10
Cavity Jacket 2 x 4 + 2 x 4 = 16

total 28 (coax-cable 4 x 28 = 112)

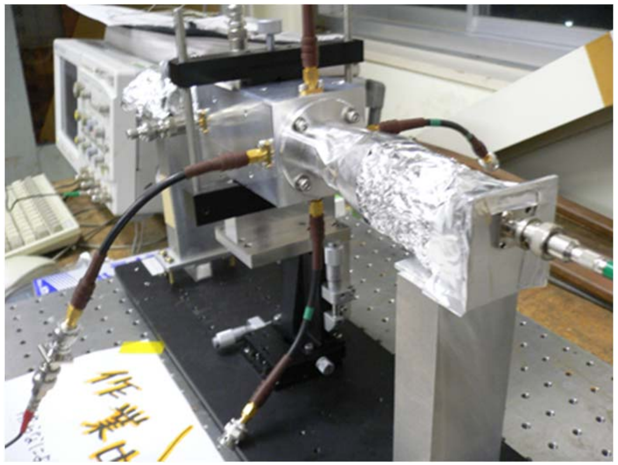
H. Hayano 11172005

Proto-type of stripline WPM detector





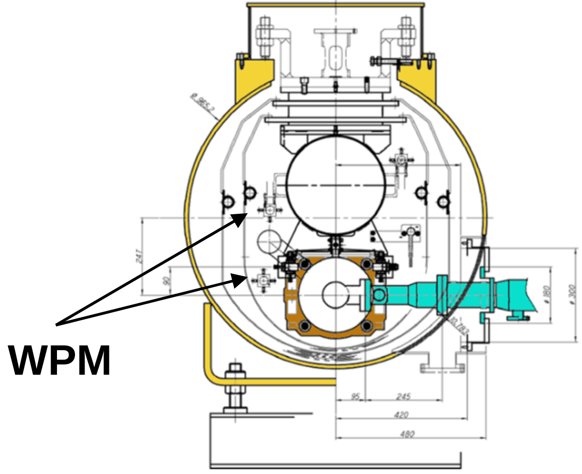
WPM calibration test bed

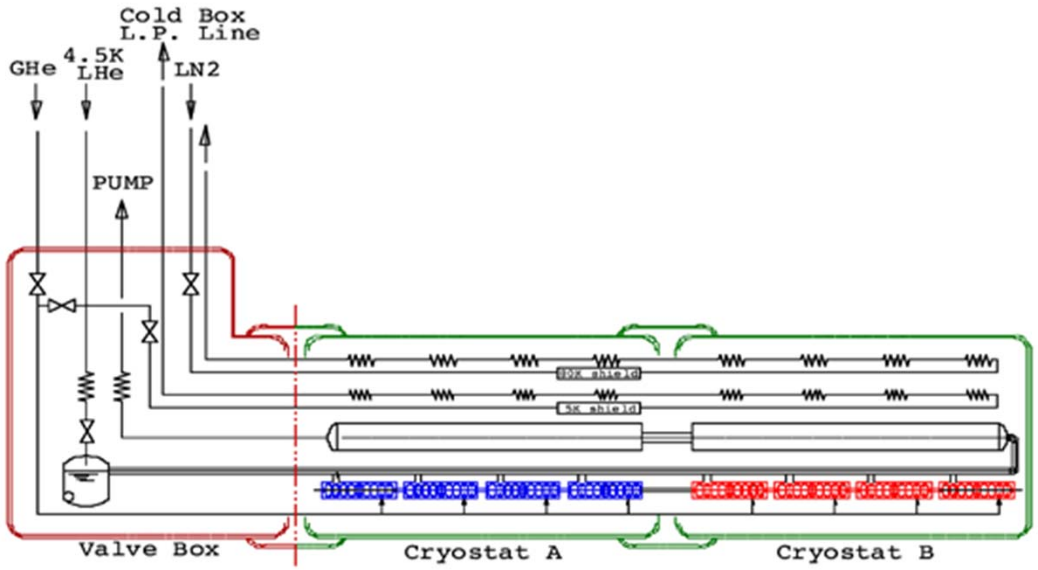


Cryostat Design detail

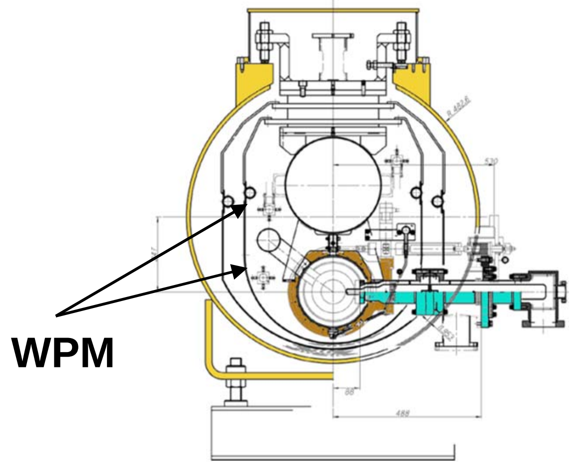
Description	OD (mm) STF	OD (mm) TESLA	Δt (mm) STF	Δt (mm) TESLA	Notes
Vacuum vessel	965.2	965.2	12.0	9.52	carbon steel
2 K gas return	318.5	300	10.3	8	SUS
2 K two-phase supply	76.3	89.1	2.1		Ti or SUS
Cool down / warm up	27.2	42.2	1.65	1.65	SUS
5 K shield supply	30.0	60.3	4.0	2.77	A1050
5 K shield return	30.0	60.0	4.0	5	A1050
90 K shield supply	30.0	60.3	4.0	2.77	A1050
90 K shield return	30.0	60.0	4.0	5	A1050

KEK cryomodule cross-section for 35MV/m cavities





KEK cryomodule cross-section for 45MV/m cavities

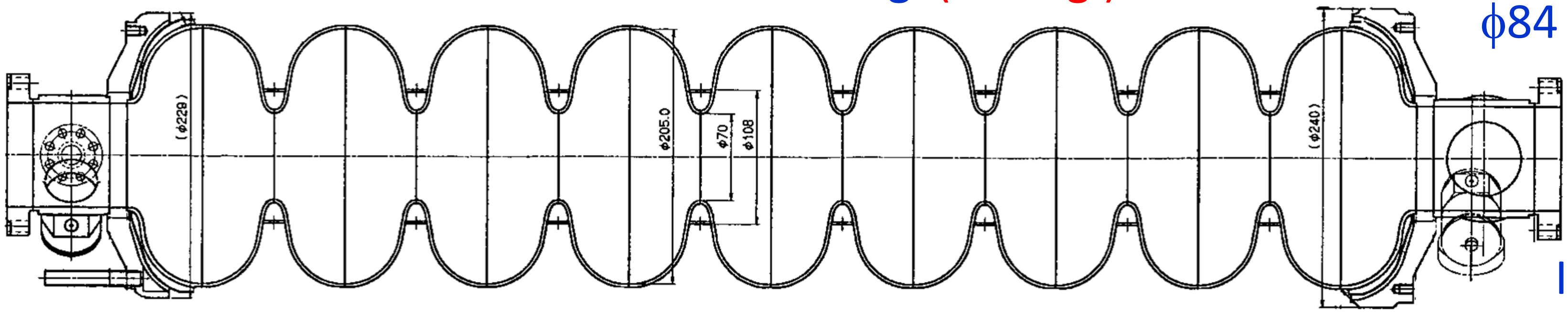


STF Baseline Cavity

Reoptimization of cell shape

Cell taper
10 deg. (13 deg.)

Beam Tube
ϕ84 (ϕ78)



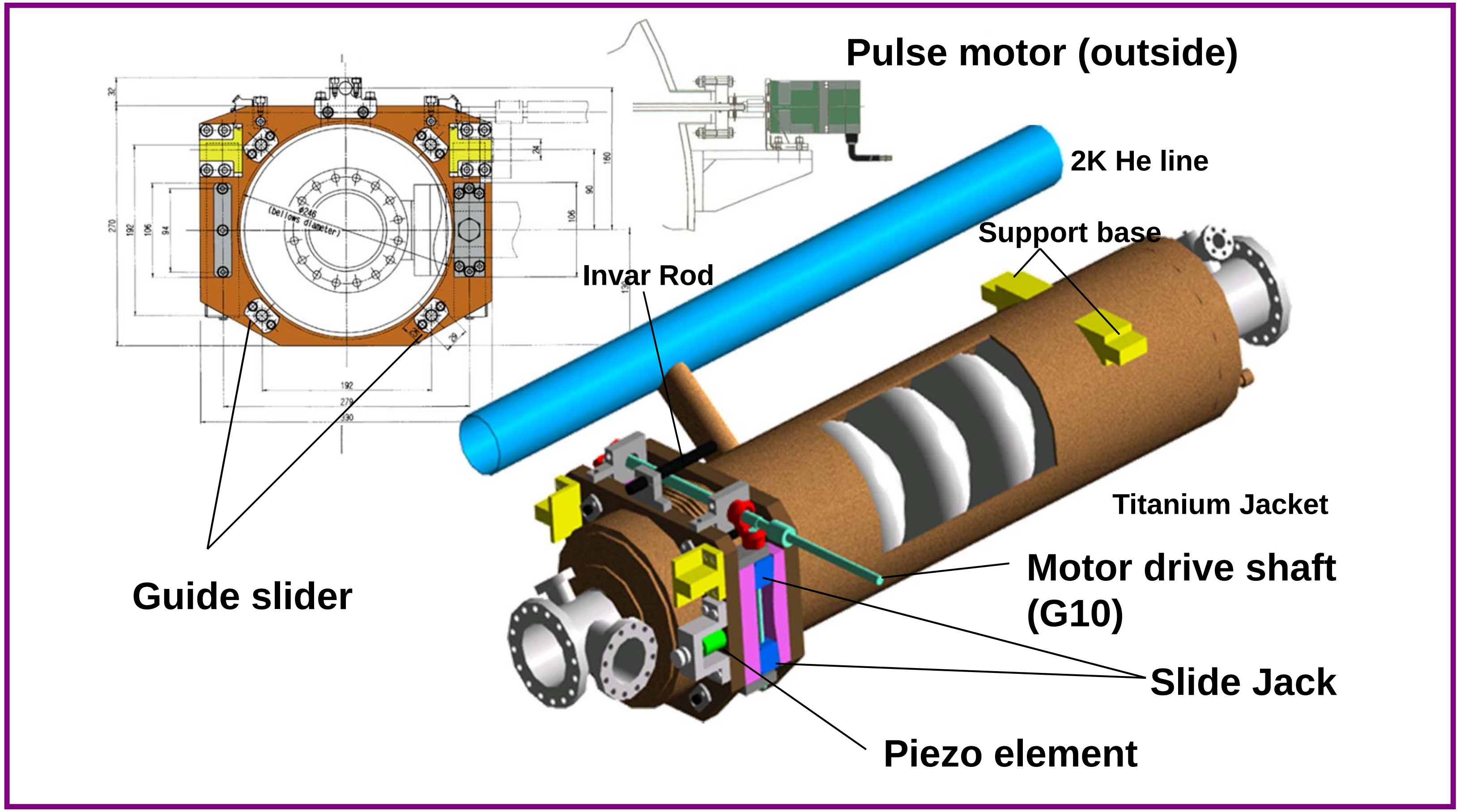
Input Port
ϕ60 (ϕ40)

	STF Baseline Cavity	(TESLA Cavity)
Cavity Length	1259 mm	1256 mm
Esp / Eacc	2.17	1.98
Hsp / Eacc	41.0 Oe/MV/m	42.6 Oe/MV/m
R / Q	1016 Ω	1036 Ω
Geometrical Factor	277 Ω	271 Ω
Cell-to-cell Coupling	2.0 %	1.9 %

Stiffness of Cavity

Fixing Support	**90 kN/mm**	**~13 kN/mm**	
Lorentz Detuning	**-480 Hz**	**-720 Hz**	(31.5 MV/m)

35MV/m TESLA style Baseline Cavity



The 1st cavity was delivered in Nov. 2005. CBP & 1st EP(100μm) done.
Pre-tuning done(98% field flatness). Now under HOM study.
2nd EP is scheduled in end of Jan. 2006, then vertical test.
Tuner & jacket will be in Feb. 2006.

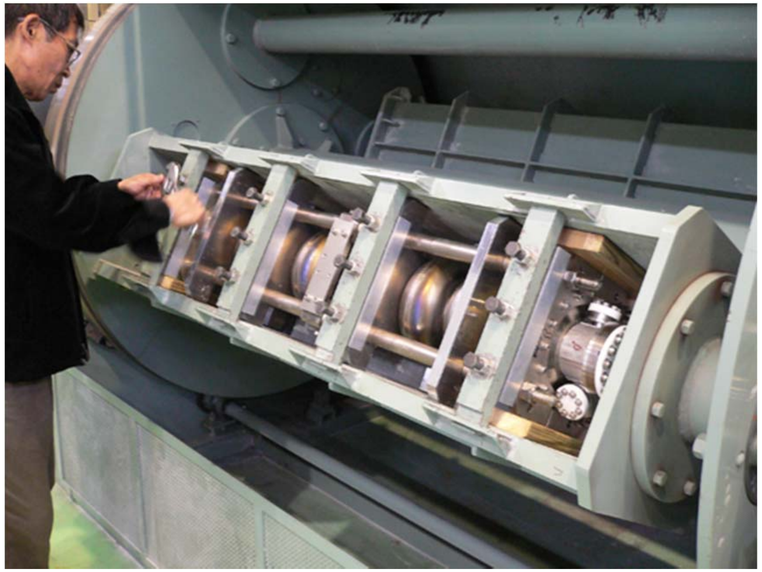
35MV/m STF Baseline Cavity Program

(by Mitsubishi Heavy Industry)

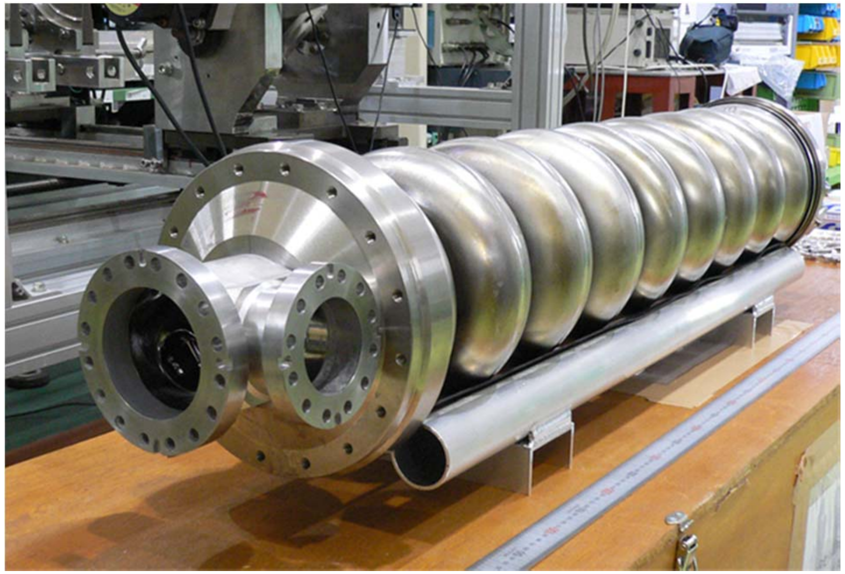
Dumbbell & end group

Ti Jacket end plates

End cell & end group



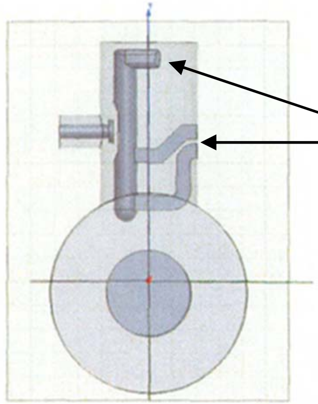
Baseline cavity No.1:
Setting to CBP(Centrifugal Barrel Polishing).



Baseline cavity No.1:
After CBP and 1st EP(Electro-chemical Polishing).

HOM study of Baseline Cavity

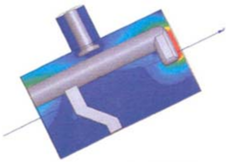
Design&test of Modified HOM coupler. Polarization measurement by bead.



New feature

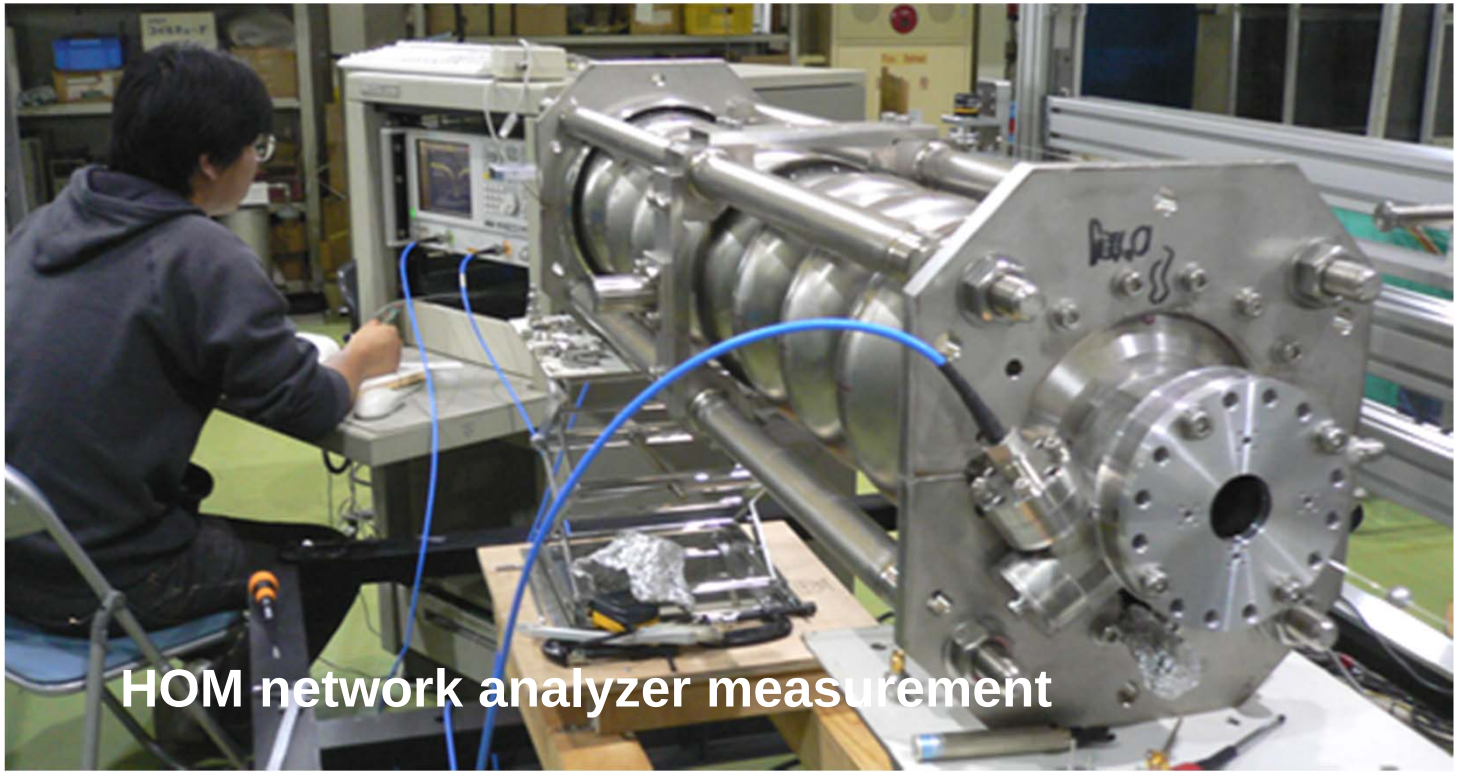
Short height HOM coupler.
Improved coupling at 4.5GHz region than TTF HOM.

Calculation example



1.3GHz

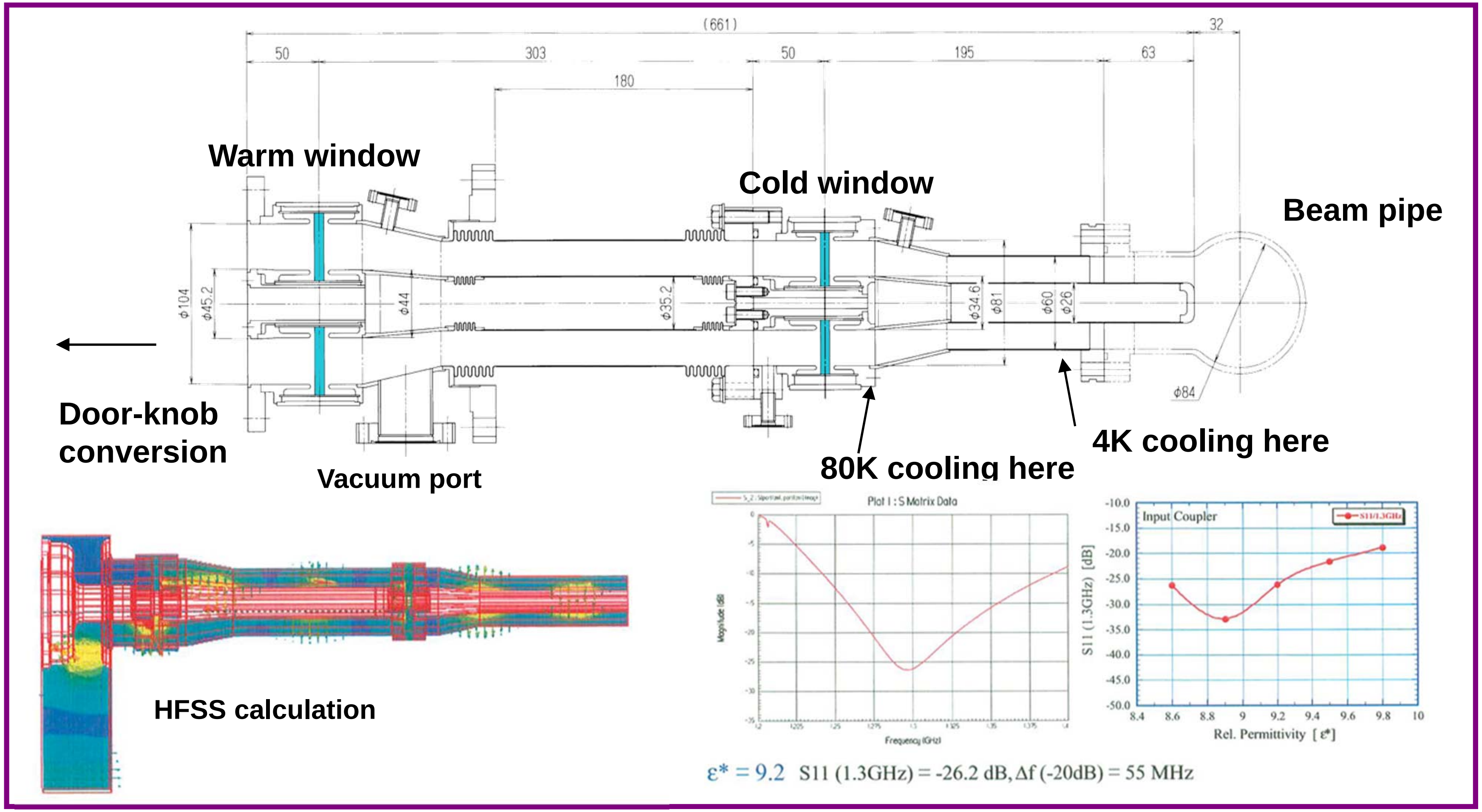
4.5GHz



STF Baseline Cavity Input coupler

(by Toshiba & MHI)

Improved input coupler design for simplicity & reduced cost (no tuning)



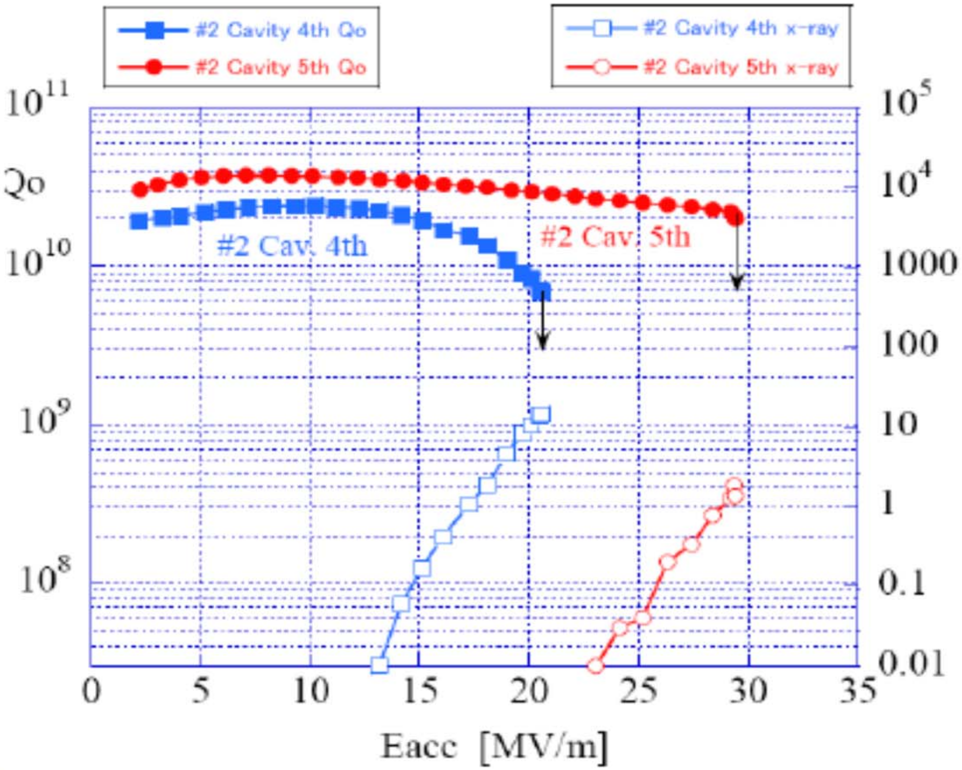
All the parts were fabricated for the 1st coupler.
Delivery is scheduled in Feb. 2006.

KEK TESLA-type: 3rd Alternative Rinse

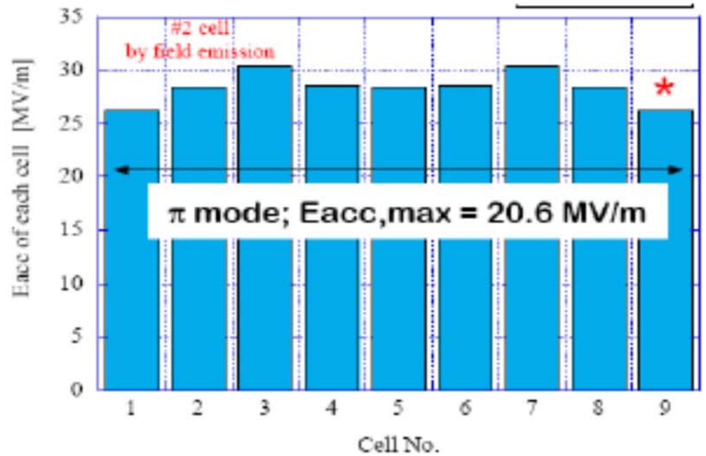
Vertical Test Results, #2 Cavity

#2 Cavity ; 4th and 5th Test

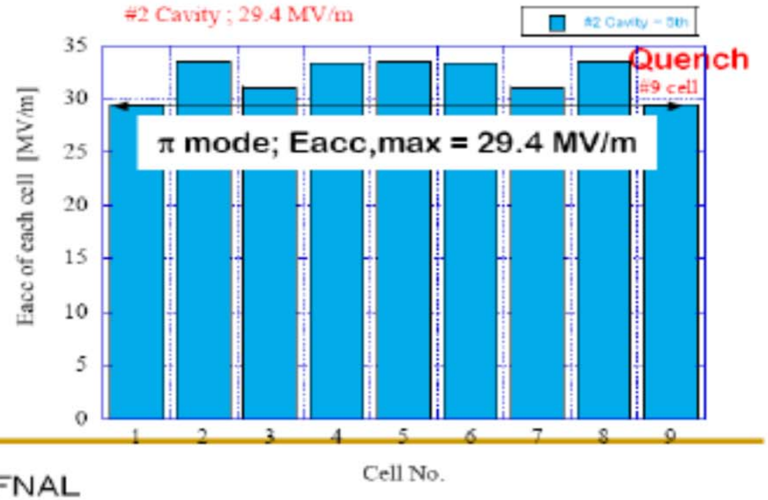
+ EP 20μm, H_2O_2 Rinse 1h,
Hot Rinse 1h, HPR 16h



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

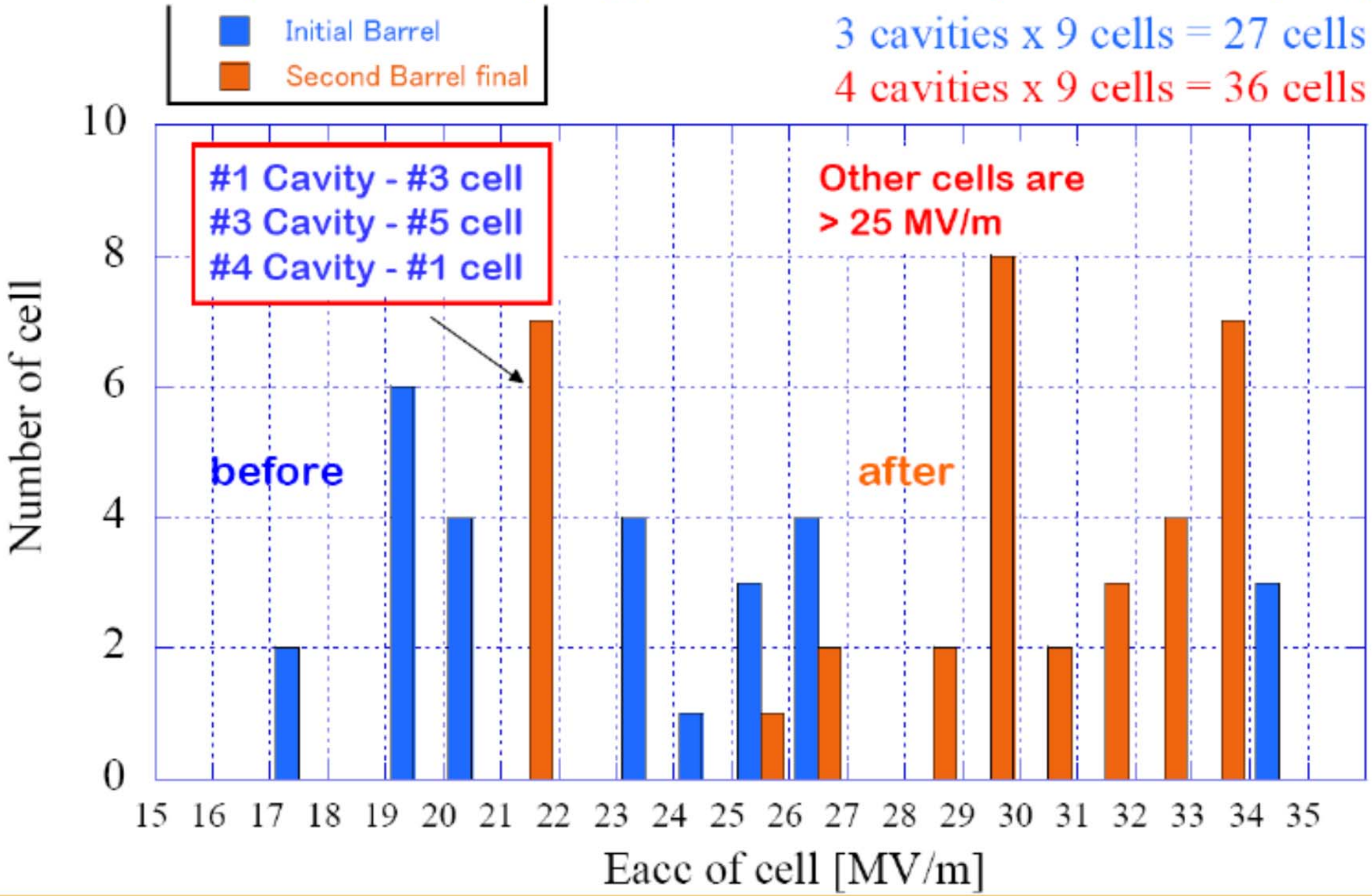


#2 Cav. 5th



Vertical Test Results, Eacc of cells

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

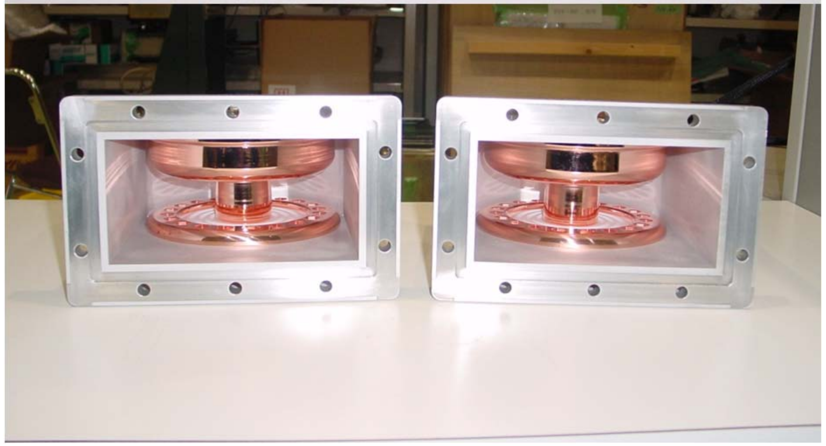


STF1に向けた空洞では、再現性に欠けるものの数台で40MV/mを達成している。

Components for High Power Test Stand

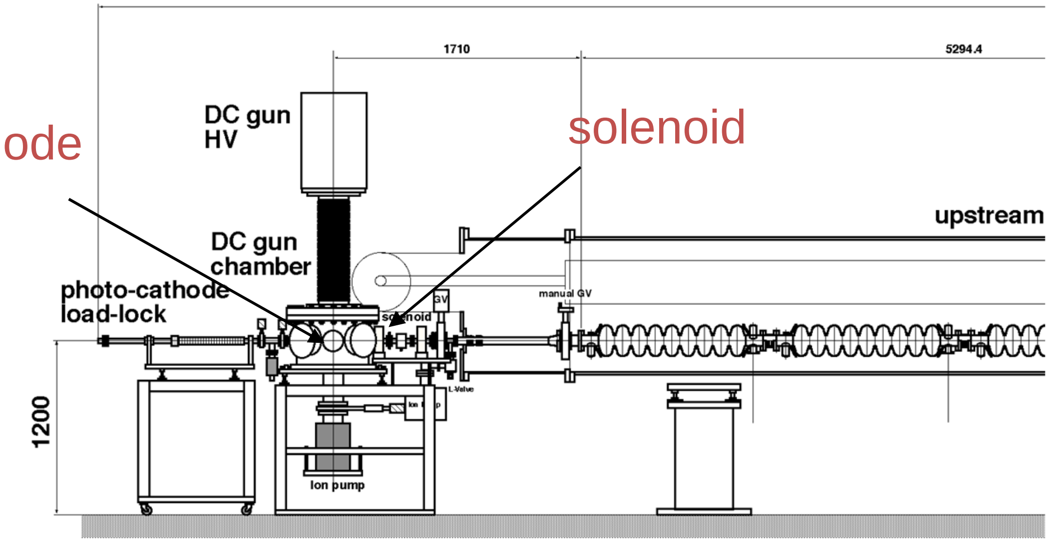
Coupling Waveguides

Input Couplers



Doorknobs

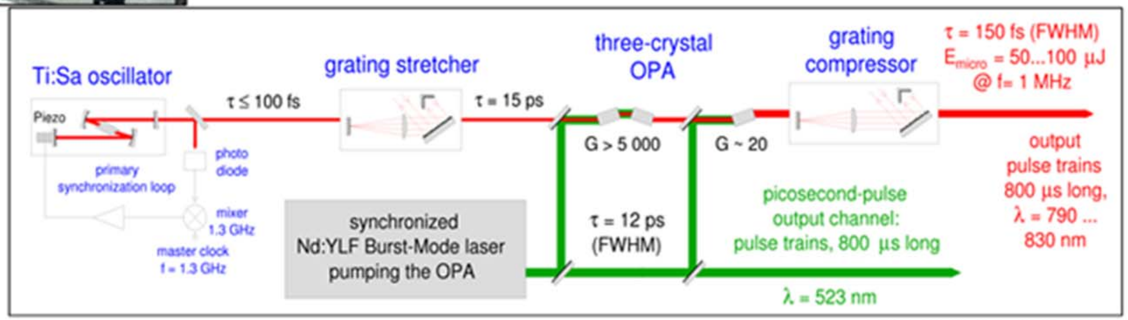
Plan of DC-gun



Existing photo-cathode DC gun

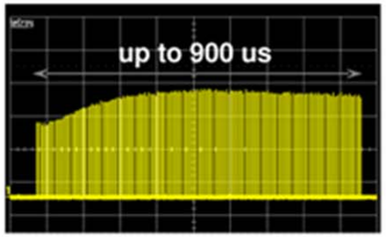
Example of Laser development at TTF

OPCPA system



I. Will, H. Redlin, MBI Berlin

- OPCPA system generates trains of pico- or femto-second pulses
  τ = 150 fs .. 20 ps (FWHM)
- Pulse energy: E_{micro} = 50…100 μJ
  E_{train} = up to 80 mJ
- Available wavelength: λ = 790…830 nm

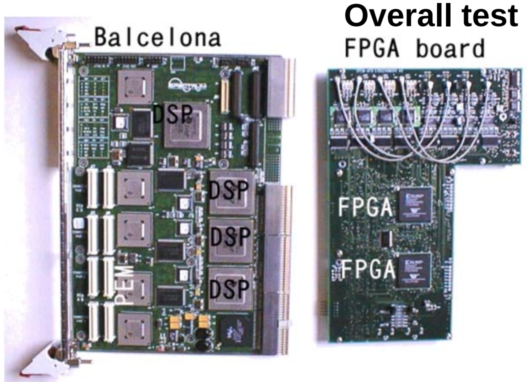


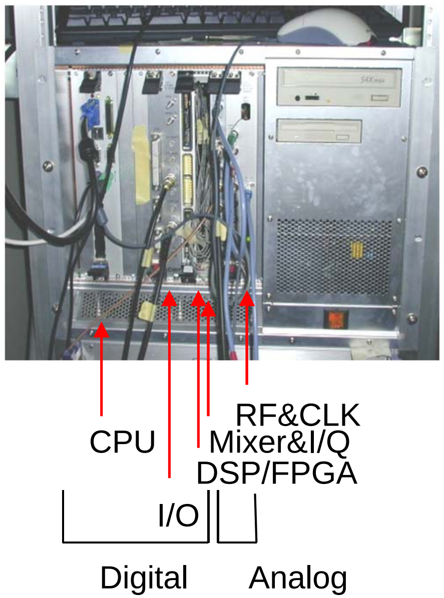
Output pulse train

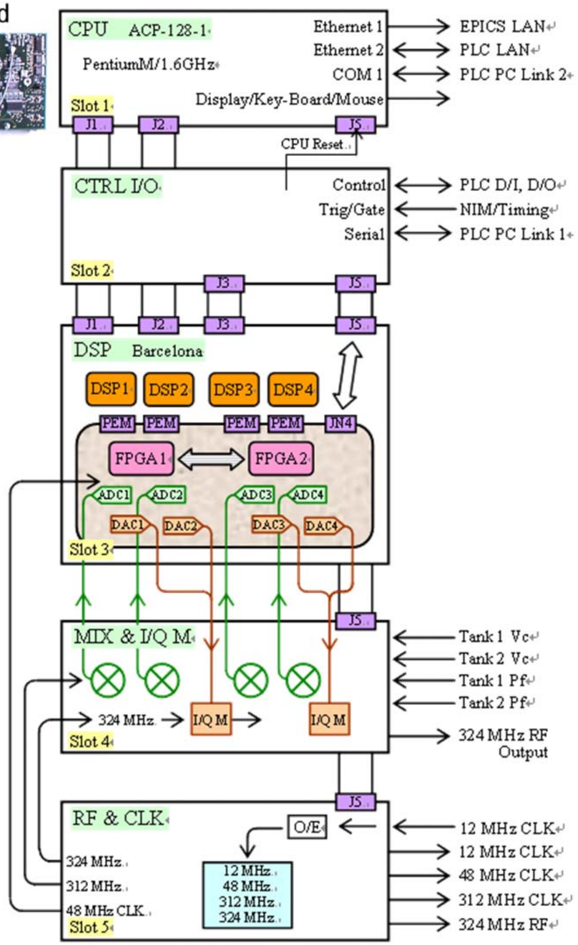
STF 1 Modulator, 5MW klystron plan&status cont.

LLRF control,
modified from J-PARC LLRF,
is under design.

Overall test with cavity simulator in May 2006.







Existing J-PARC LLRF

Bought a 5MW Klystron
from Thales (TH2104C),
and Build one more modulator
for running the cavities (in 2006).

TH2104C 5MW klystron

Follow BCD

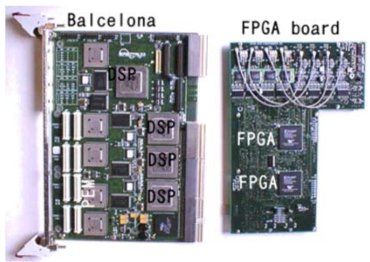
Power source

Klystron : 10MW Multi-beam klystron,

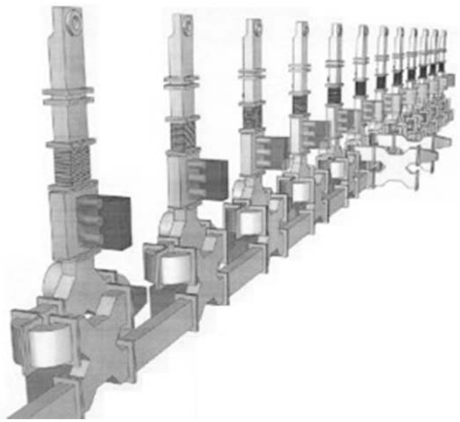
Modulator : bouncer modulator + pulse trans,

(Possible Alternative: Marx-generator type modulator)

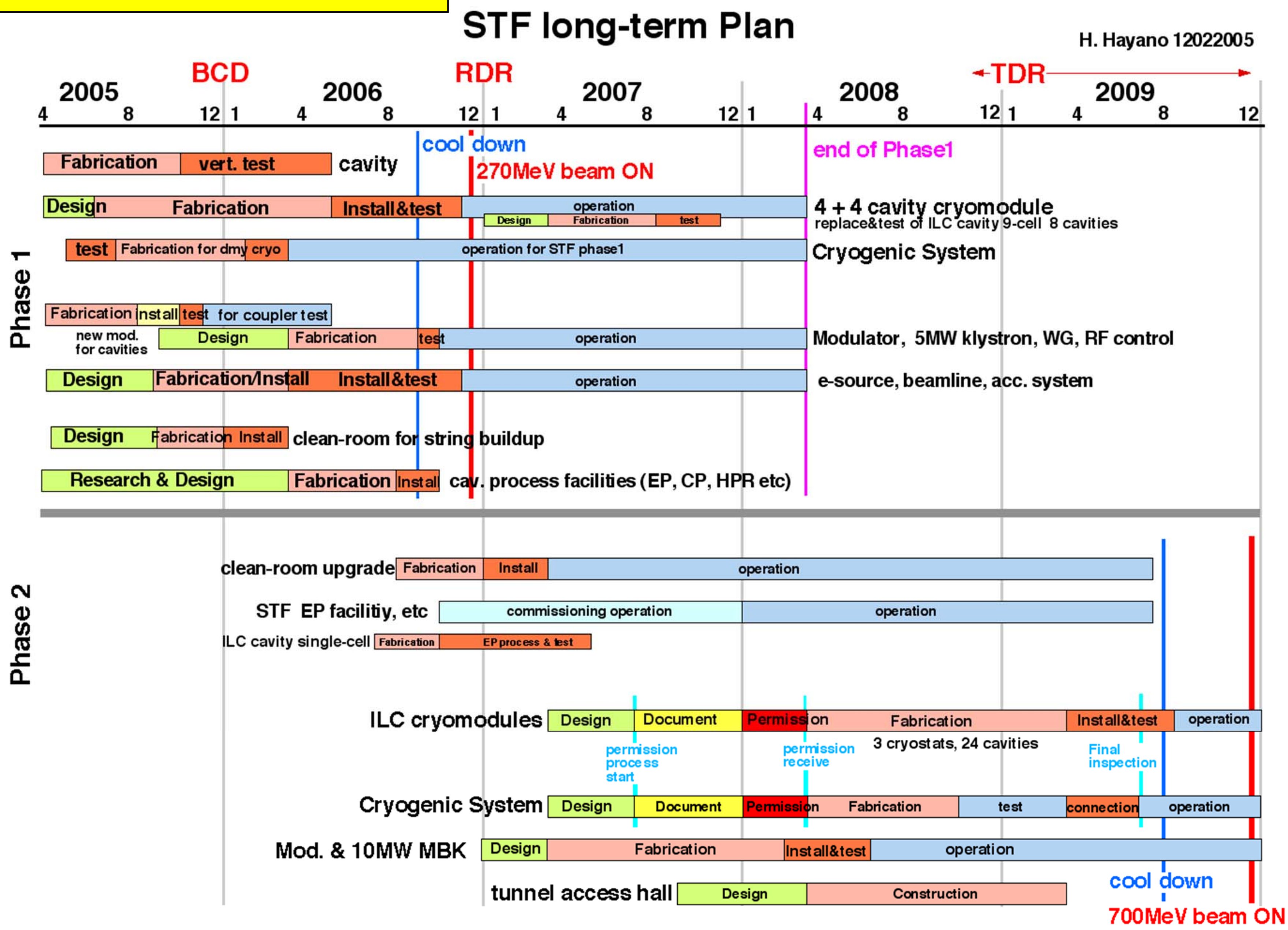
LLRF : FPGA-base,



Wave-guide : linear distribution,



Delayed 3 year!



* Phase 2 Schedule was changed(1 year delay).