Lecture B2 and C3a: Superconductive RF

Surface Preparation
RF Test of Cavity
Challenges for industrialization

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LC school 2015

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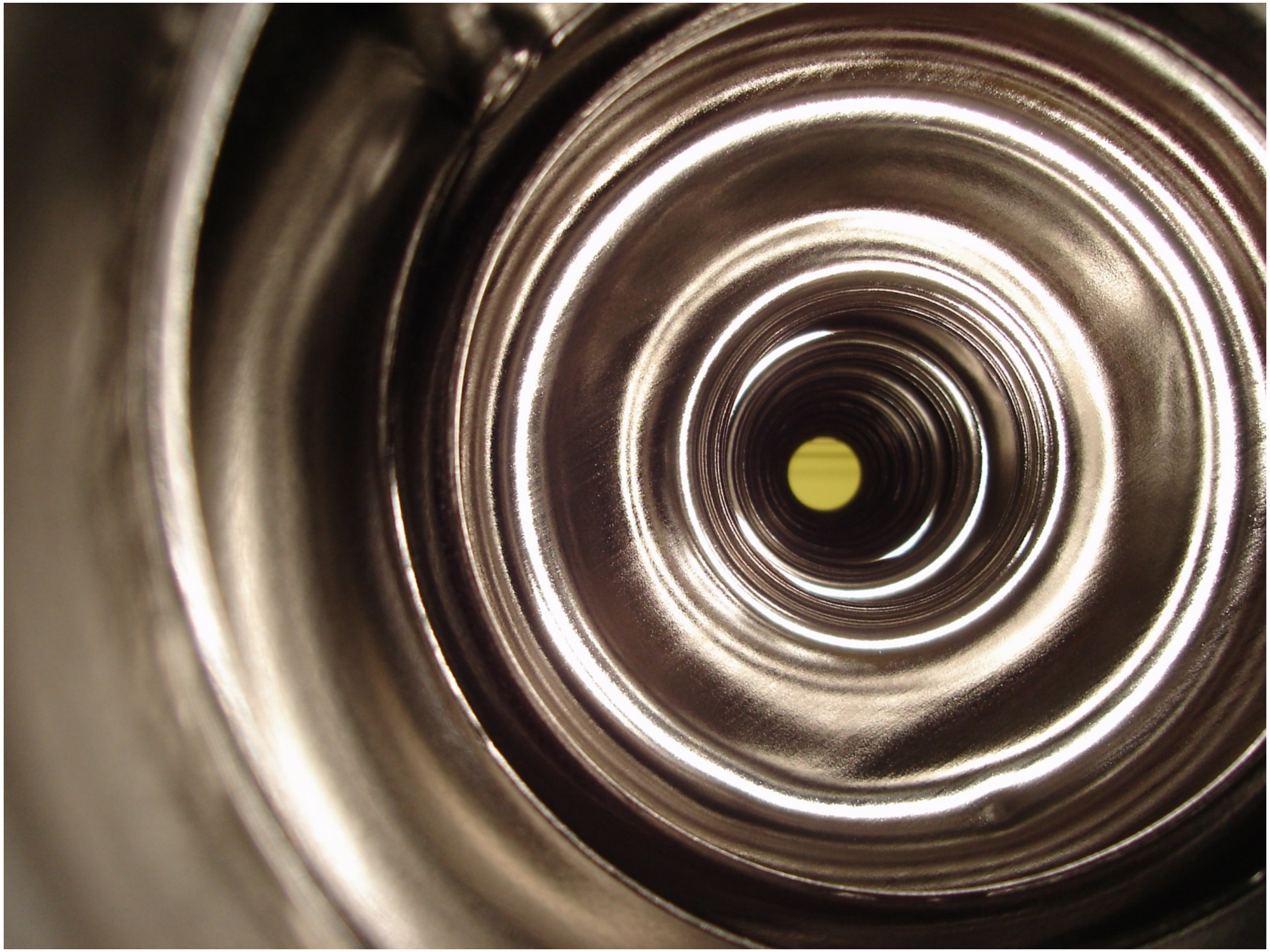
Inner Surface Preparation of SC Cavity



Overview of Inner Surface Preparation

- Thick/Rough Removal (>100 um)

  Three alternative methods:

  Buffered Chemical Polishing (BCP)

  Electro-Polishing (EP)

  Centrifugal Barrel Polishing (CBP)

- Annealing / Degassing (750 – 800 C, ~3 h)
- Final Thin Removal (10 – 30 um)

  Two alternative methods:

  Buffered Chemical Polishing (BCP)

  Electro-Polishing (EP)

- High Pressure Rinse (>7 h)
- In-situ Baking (120 – 140 C, 48 h)

Overview of Inner Surface Preparation

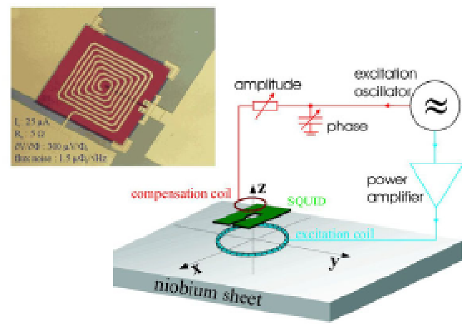
Process Name	Process	Removal Thickness (um)	Purpose
Centrifugal Barrel Polishing (CBP)	Mechanical removal with water and media (stones / plastic ….)	>100	Removal of damaged layer of Nb, or removal of defects
Buffered Chemical Polishing (BCP)	Chemical Reaction / Etching	Rough: > 100 Final: 10 - 30	Rough: Removal of damaged layer of Nb. Final : Smooth surface
Electro-Polishing (EP)	Electro-Chemical Reaction	Rough: > 100 Final: 10 - 30	Rough: Removal of damaged layer of Nb. Final : Smooth surface
Annealing / Degassing	750 ^{O}C, 3 hours Vacuum Furnace	-	Release of stress in material / Degassing of H
High Pressure Rinse (HPR)	High Pressure Rinse with Ultra Pure Water (UPW)	-	Removal of contamination / Clean surface
In-situ Baking	120 ^{O}C, 48 hours baking with Vacuum pumping inside of cavity	-	Diffusion of Oxygen

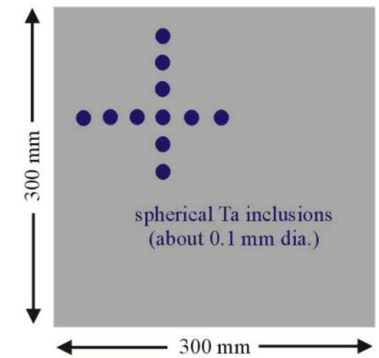
Scanning of defects with eddy current

Successfully developed at DESY to pre-screen Nb

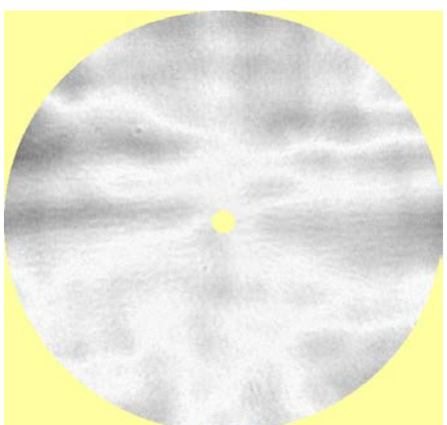
Sheets for defects: eddy current, resolution ~ 100 μm

squid, resolution < 50 μm

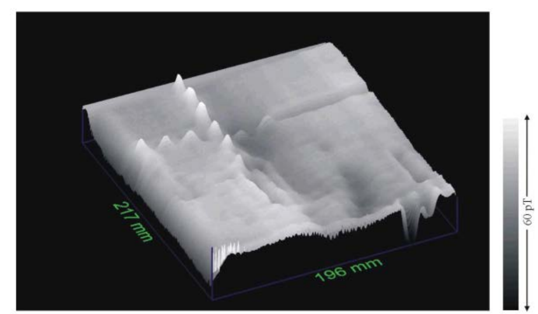




Low Tc superconducting SQUID system for eddy current testing of niobium sheets is in development



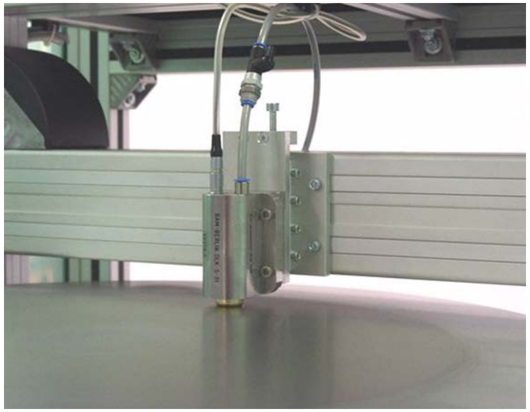
(W.Singer, X.Singer)

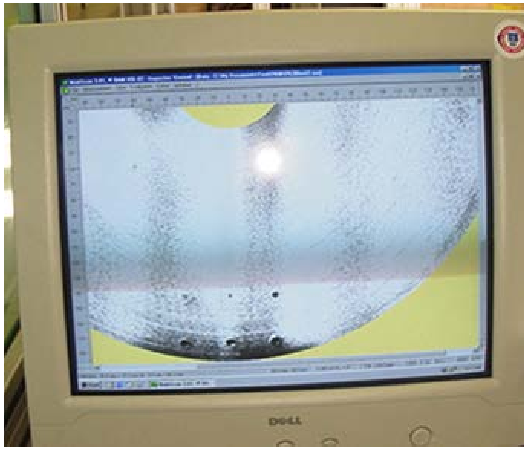


Two-dimensional distribution of eddy-current field above the niobium test sample, measured from the back side of the sample. The excitation coil had 30 turns and a diamter of 3 mm; the excitation frequency was 10 kHz. The reference phase of the lock-in amplifier was chosen such that the lift-off effect was minimized.

Scanning of defects with eddy current

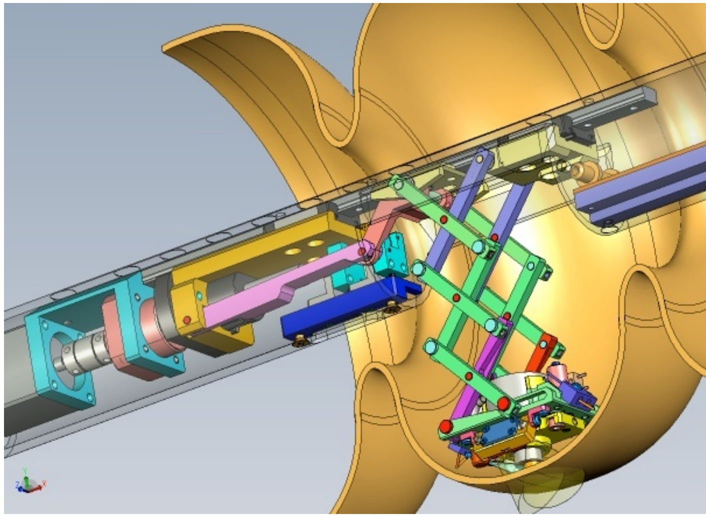
Eddy Current Scanning system for SNS high purity niobium scanning

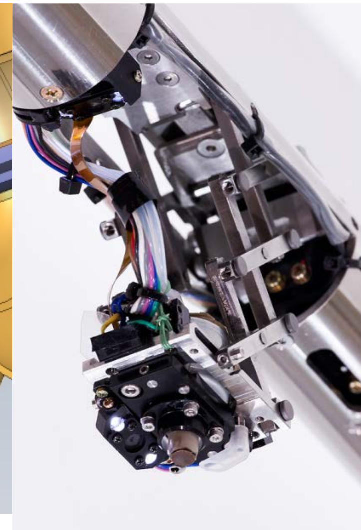


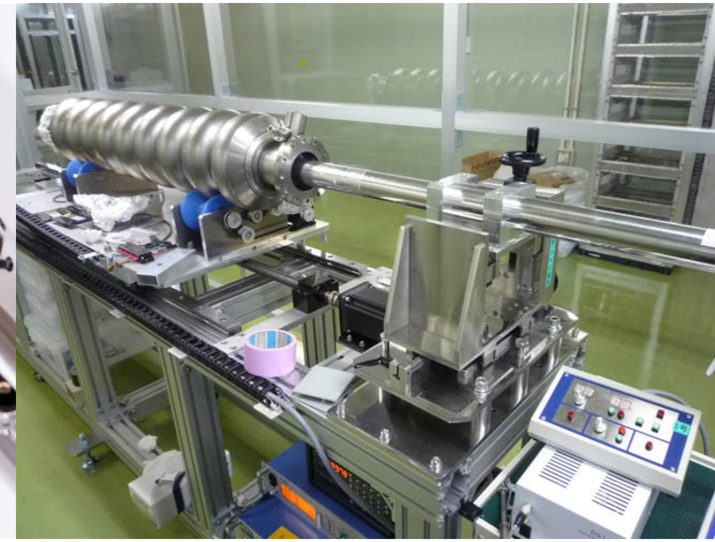


Scanning of Nb plate/disc before fabrication.
About 1 – 2 % of Nb plates/discs have defects.

Local grinding at KEK





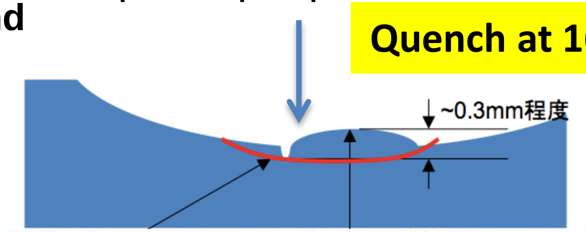


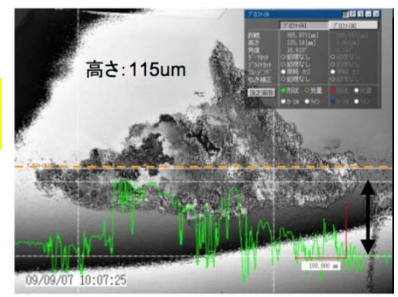
Grinding only for pit, without touching other surface

diamond powder compound with water in between were used.

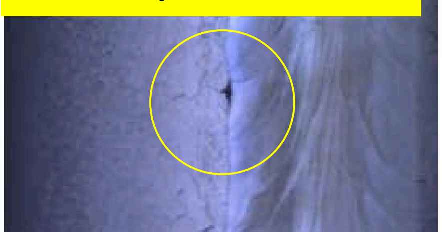
~115μm depth pit in MHI-08 cavity

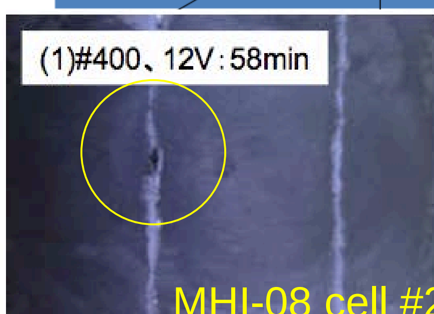
Quench at 16 MV/m

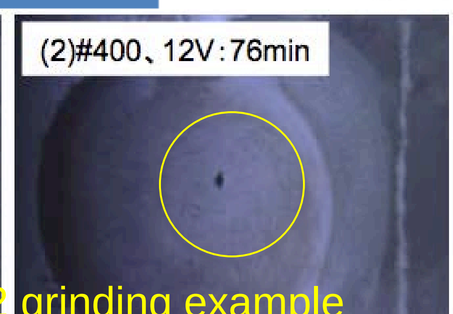


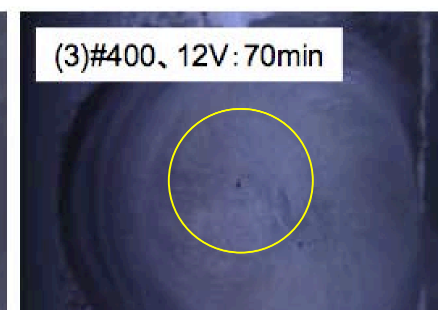


This pit caused quench at 16 MV/m



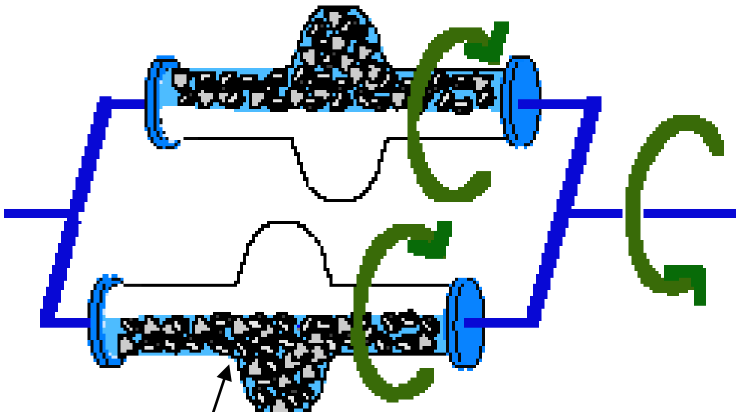






MHI-08 cell #2 grinding example

Centrifugal Barrel Polishing (CBP)
Mechanical grinding



Water and media (stone, plastic, etc.)

Media : stones
(rough removal)

Media : plastic
(final removal)

Example (KEK recipe)

Step 1) Rough removal with stones + water : 4 hours x 3 times

Removal thickness = 25 um x 3 = 75 um

Step 2) Final removal with plastic + water : 4 hours x 3 times

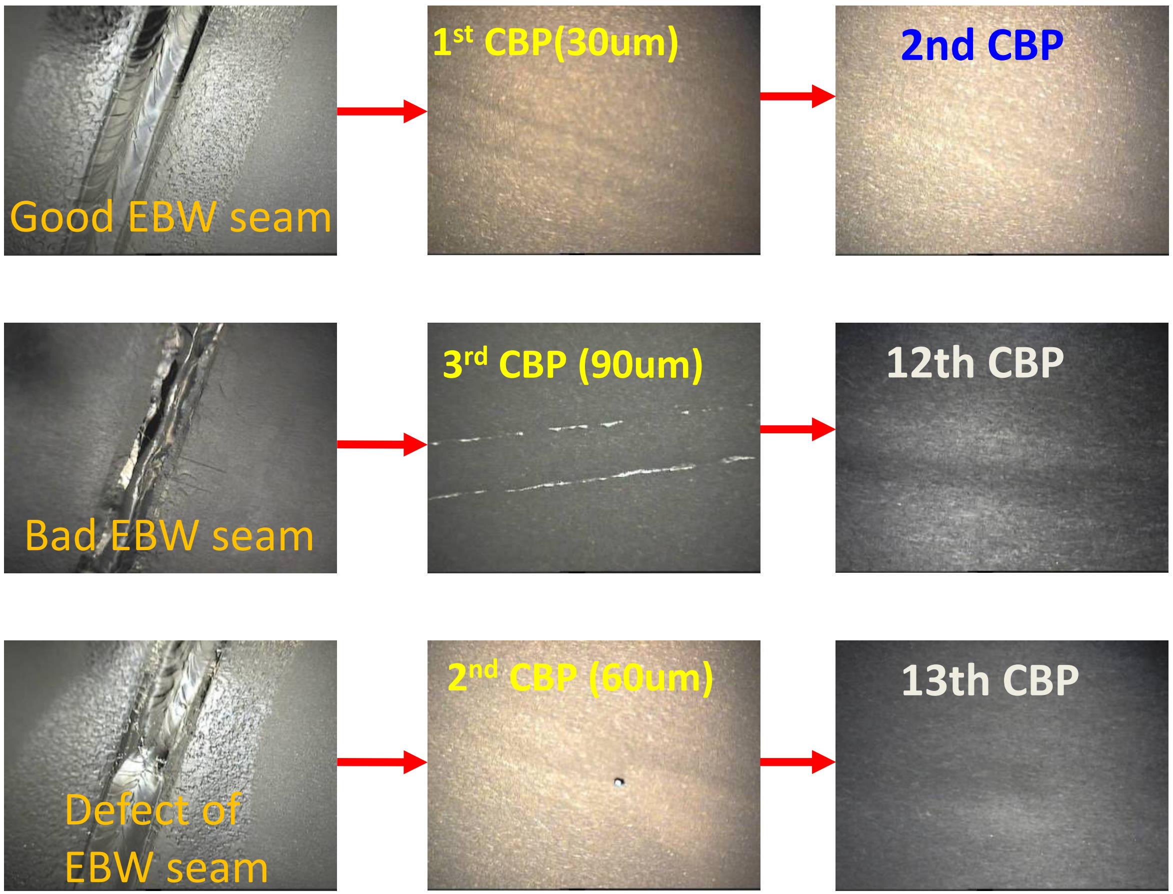
Removal thickness = 20 um x 3 = 60 um

Total removal thickness = 135 um

Centrifugal Barrel Polishing (CBP)
Mechanical grinding

Centrifugal Barrel Polishing (CBP)
Mechanical grinding

EBW seam before CBP



Removal thickness = 60 um.

Removal thickness > 200 um.

Removal thickness > 200 um.

Buffered Chemical Polishing (BCP)

Components of BCP acid (KEK recipe)
HF (HF 46%) : HNO_3 (HNO_3 60%) : H_3PO_4 (H_3PO_4 80%) = 1 : 1 : 1 (Volume Ratio)
H_3PO_4 can be increased if you like slow etching (1:1:2, 1:1:3, etc…)

Various BCP systems in the world

BCP:

Mixture of $HF/HNO_3/H_3PO_4$ in ratios 1:1:1 or 1:1:2 @ 10-15C

$2Nb + 5NO_3 \rightarrow Nb_2O_5 + 5NO_2$

$Nb_2O_5 + 6HF \rightarrow H_2NbOF_5 + NbO_2F \cdot 0.5H_2O + 1.5H_2O$

(H_2NbOF_5: soluble; $NbO_2F \cdot 0.5H_2O$: non soluble)

$NbO_2F \cdot 0.5H_2O + 4HF \rightarrow H_2NbF_5 + 1.5H_2O$

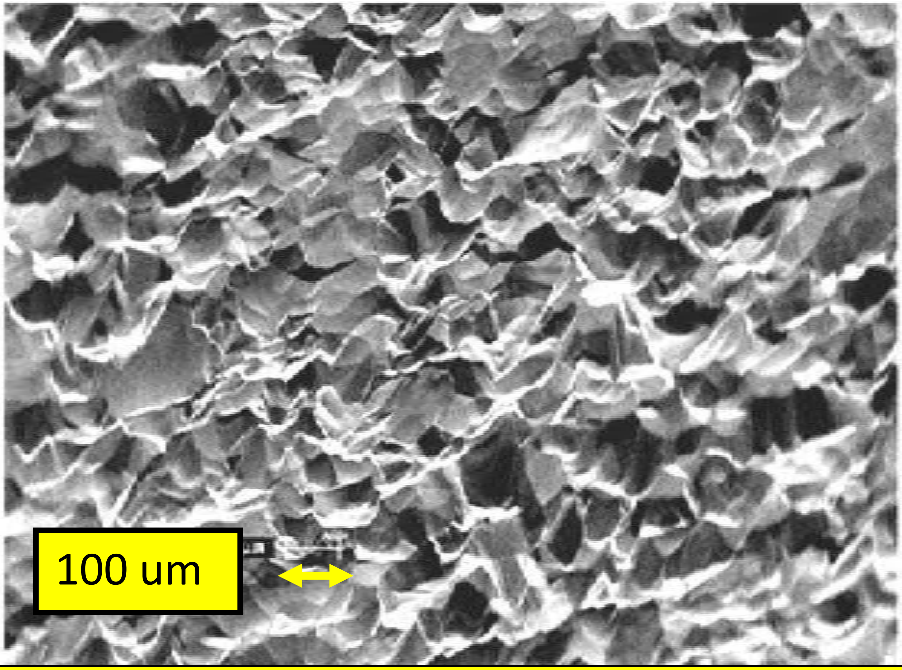
(H_2NbF_5: soluble)

Exothermic reaction

Removal rate ~ 2 μm/min @ 10C

Buffered Chemical Polishing (BCP)

Nb Surface after BCP



Simpler than EP, but the surface is rougher than EP.
The roughness is coming from the difference of etching among the grain. Steps are made along the grain-boundary.

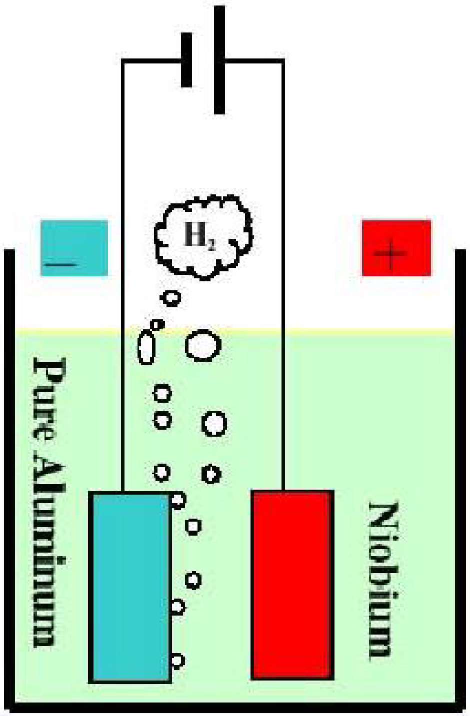
Chemical reaction:

$$6Nb + 10HNO_3 \rightarrow 3Nb_2O_5 + 10NO\uparrow + 5H_2O$$

$$Nb_2O_5 + 10HF \rightarrow 2NbF_5 + 5H_2O$$

$$6Nb + 10HNO_3 + 30HF \rightarrow 6NbF_5 + 10NO\uparrow + 20H_2O$$

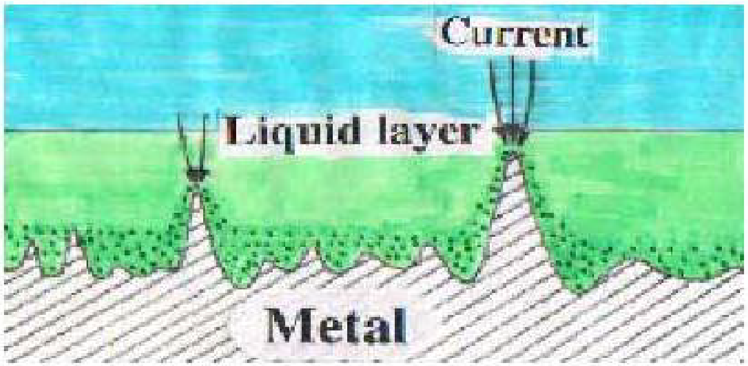
Electro-Polishing (EP)

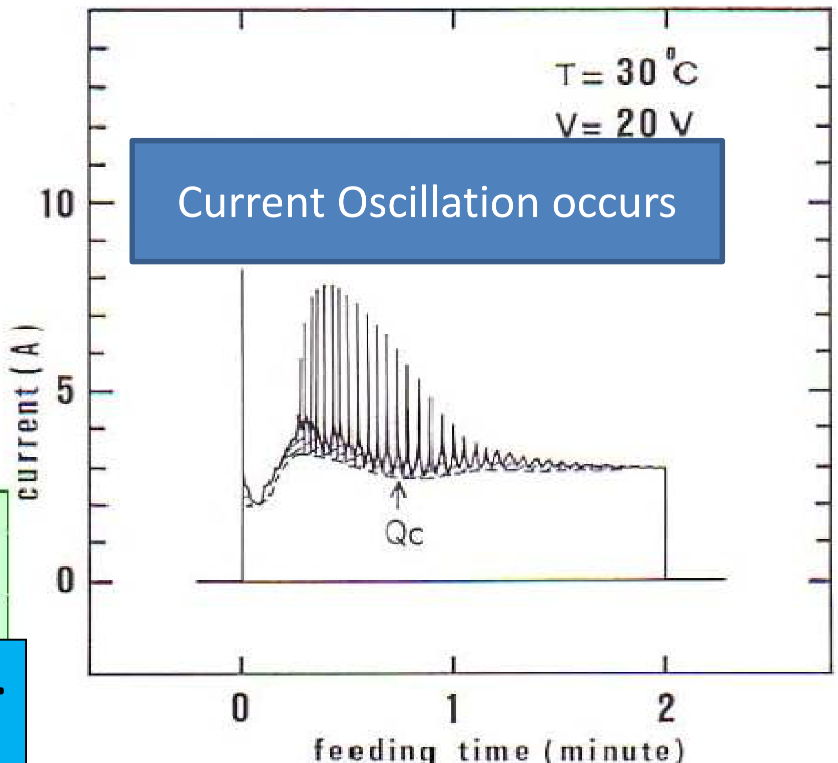


Acid:
H_2SO_4 (>93%): HF(46%)=10:1 V/V

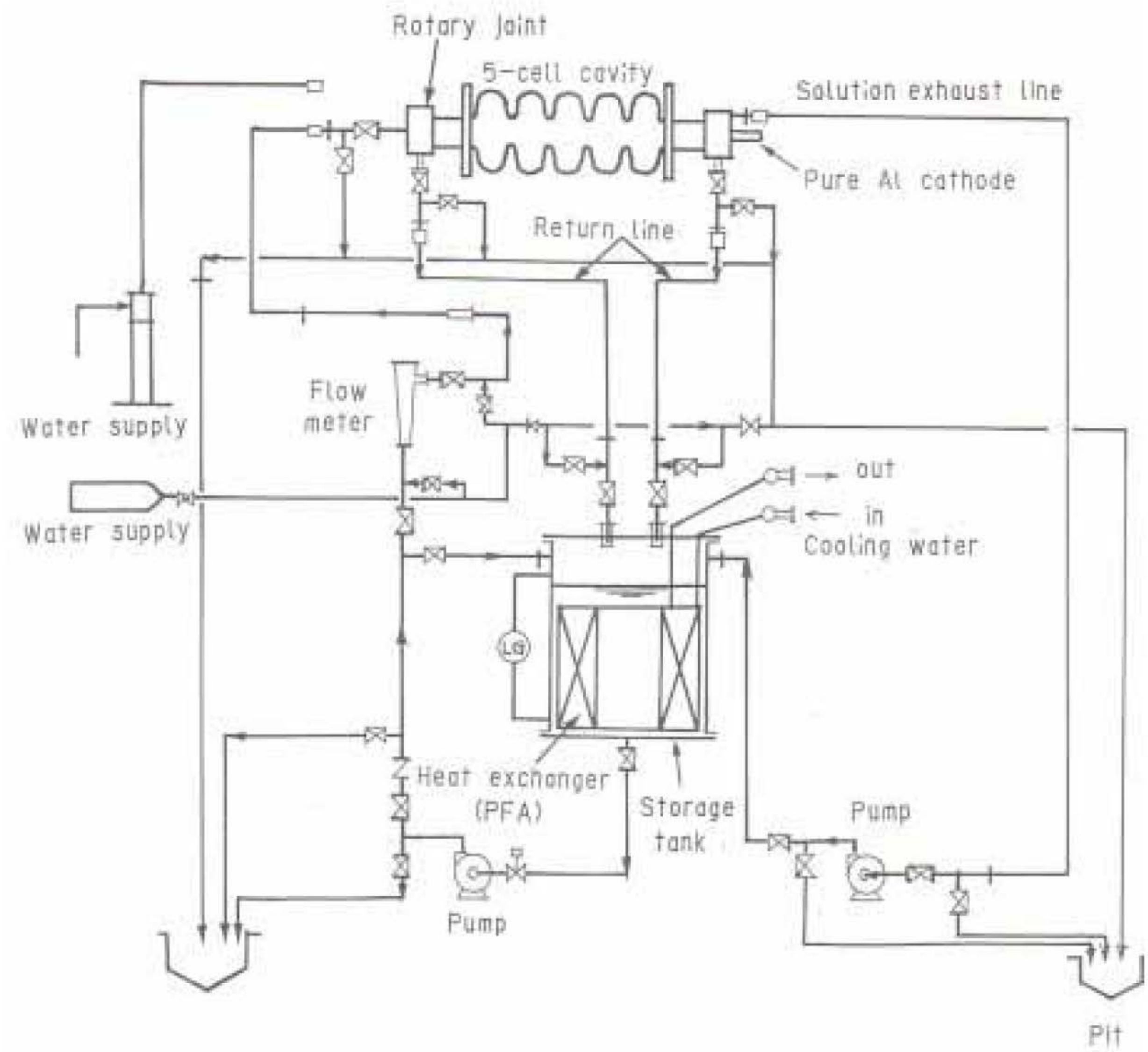
Chemical reaction:
$2Nb + 10HF + 2H_2O \rightarrow 2H_2NbOF_5 + 5H_2\uparrow$

Sulfuric acid is not included in the reaction.
It gives the viscosity to the electrolyte.

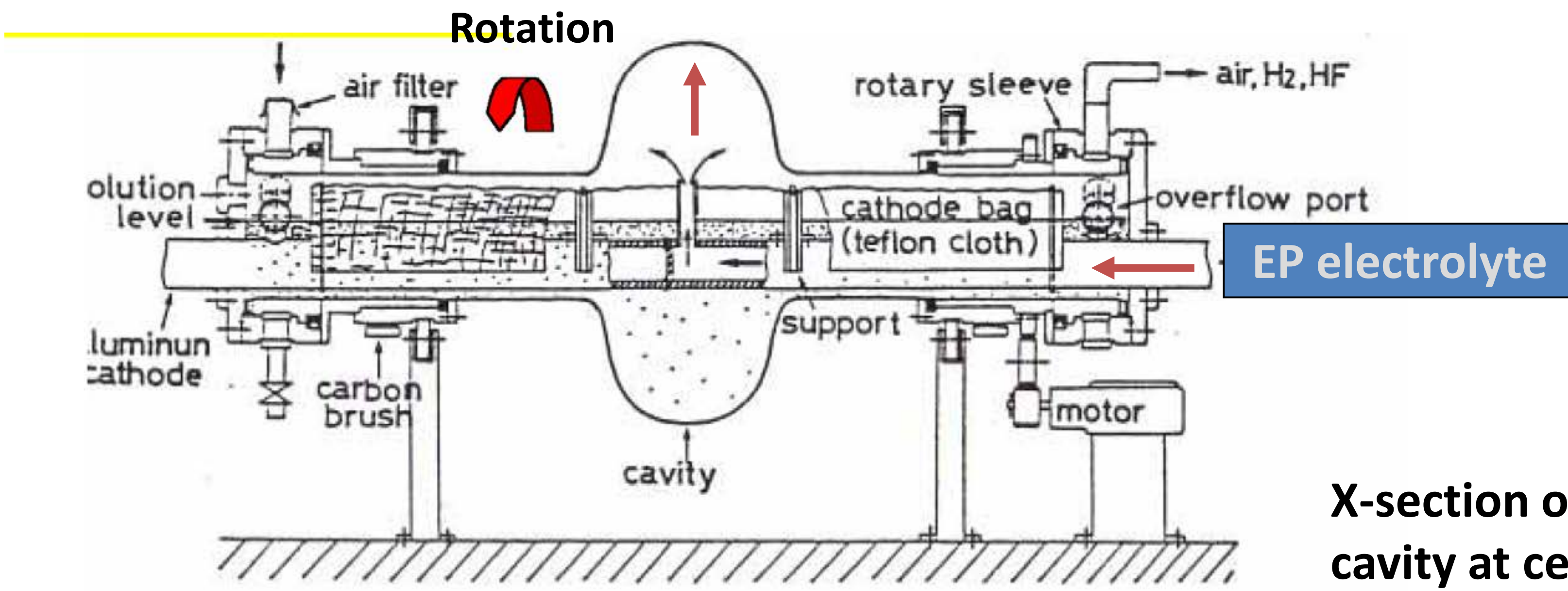


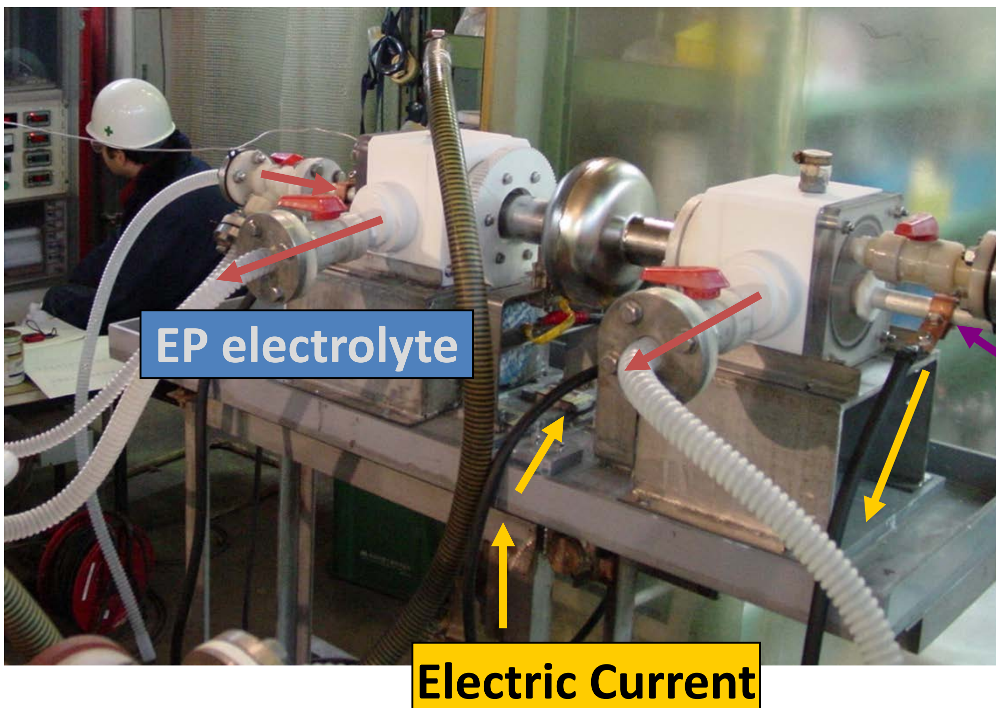


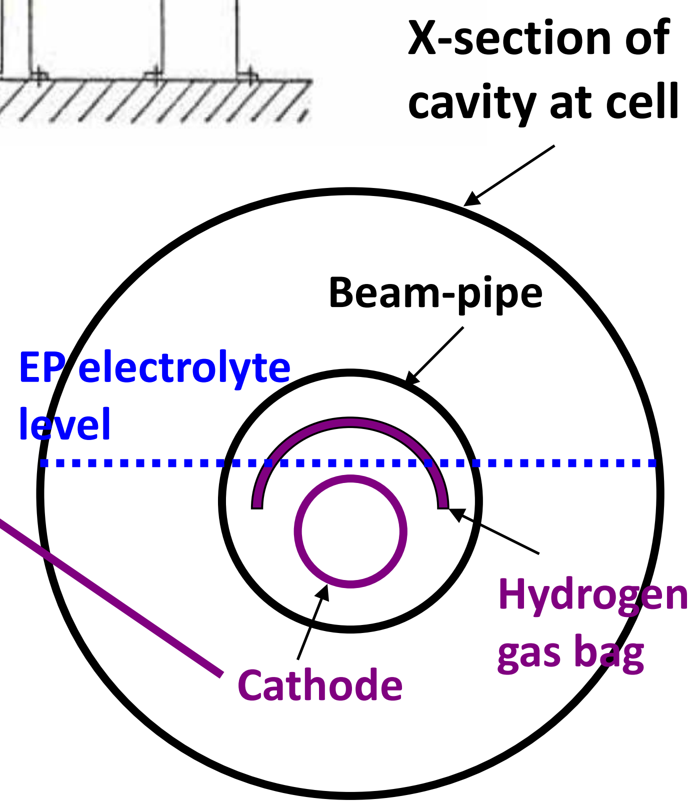
EP System Flow



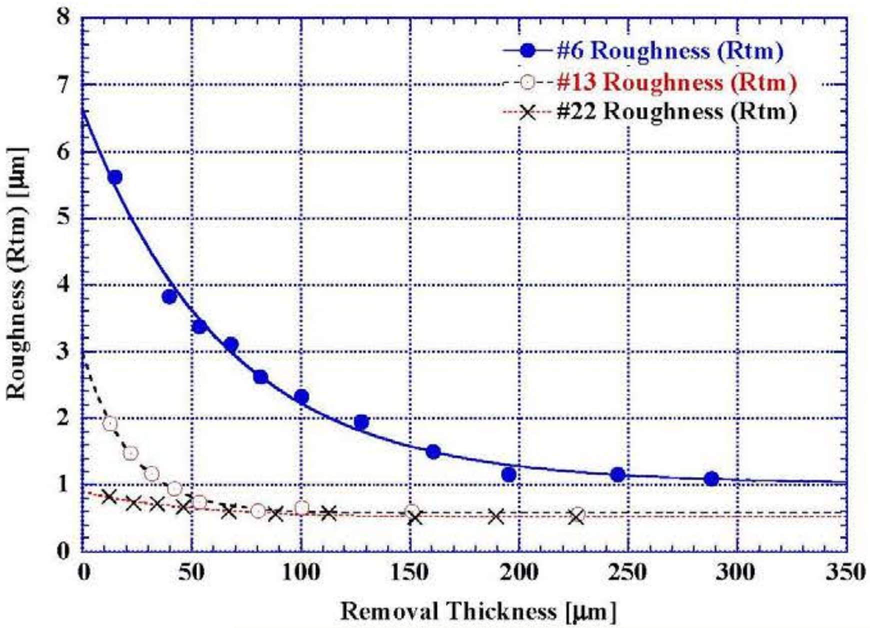
Horizontal EP system for single-cell cavity

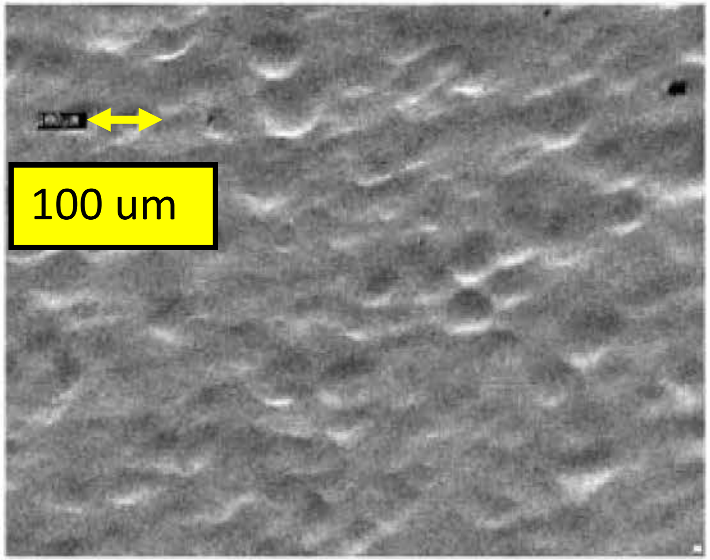

Rotation
air filter
rotary sleeve
air, H2, HF
olution level
cathode bag (teflon cloth)
overflow port
EP electrolyte
luminun cathode
carbon brush
support
motor
cavity


EP electrolyte
Electric Current


X-section of cavity at cell
Beam-pipe
EP electrolyte level
Hydrogen gas bag
Cathode

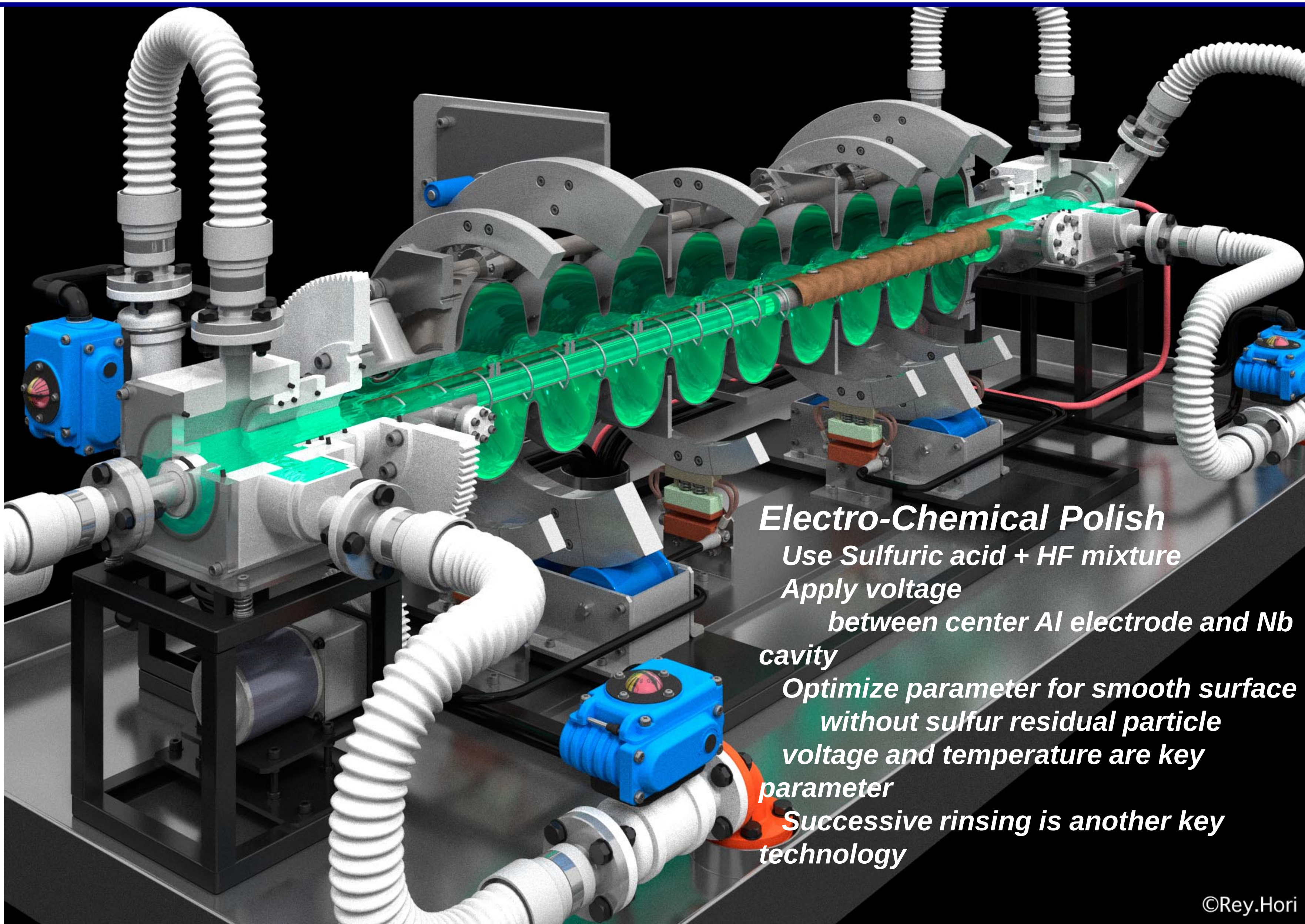
EP Finishing





1) The final roughness depends on the initial roughness.
2) The roughness goes down as the exponential function to the removal.
3) Steps are not created along the grain-boundary. This causes smooth surface.
4) If voltage is switched off, the process stops. The control of process is easier than BCP.

Electro-Chemical polishing inside 9-cell cavity

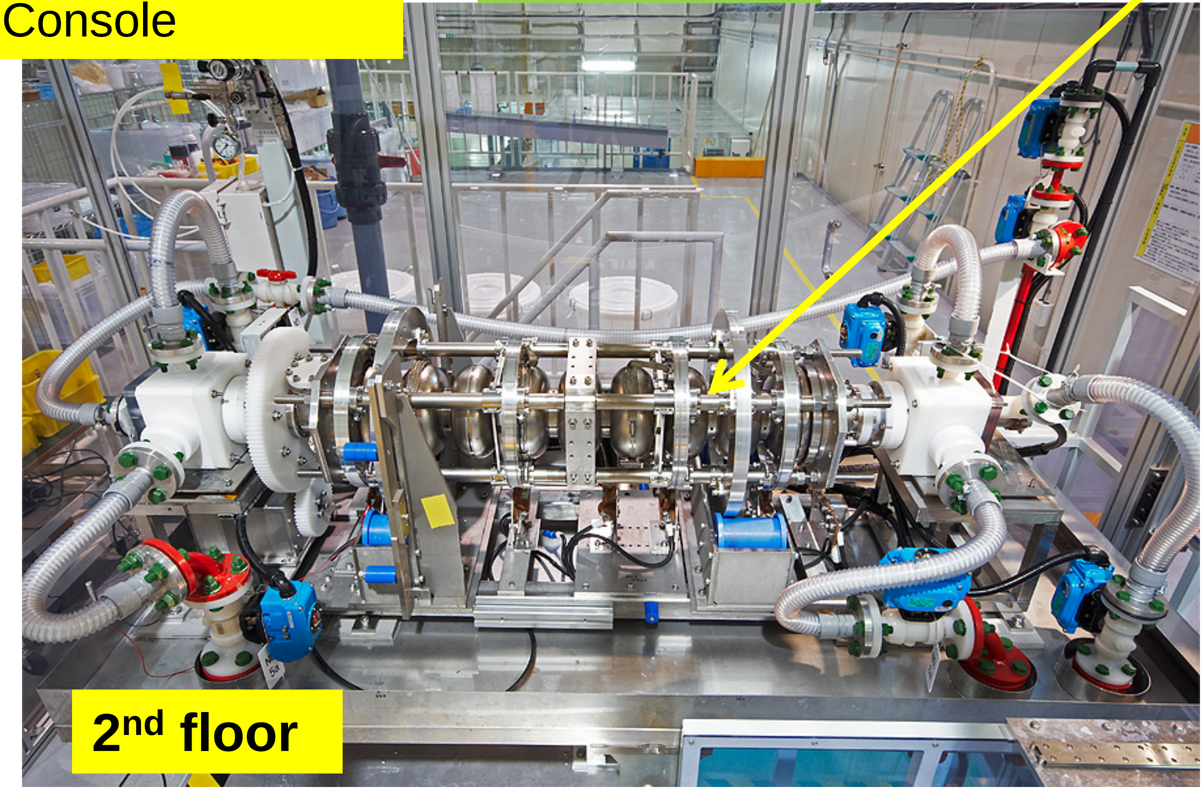


Electro-polishing facility at STF/KEK

Automatic Operation Console

EP bed

9-cell cavity



2[nd] floor

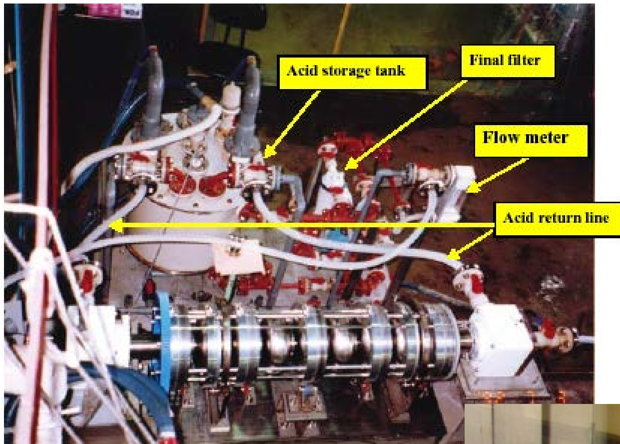
1[st] floor

EP solution reservoir tank

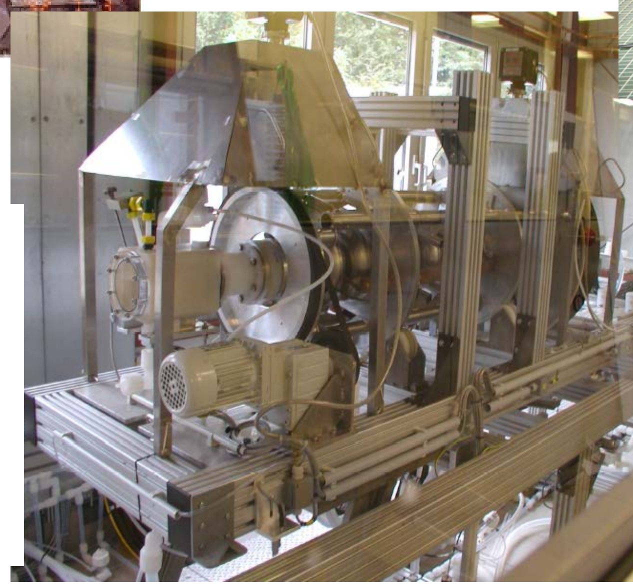
EP facility at KEK
EP acid: HF + H_2SO_4, Aluminum anode,
surface removal speed: 20μm/hour, V ~18V, I ~270A, T ~30degC (for 9-cell),
cavity rotation: 1 rpm.

Various EP systems in the world

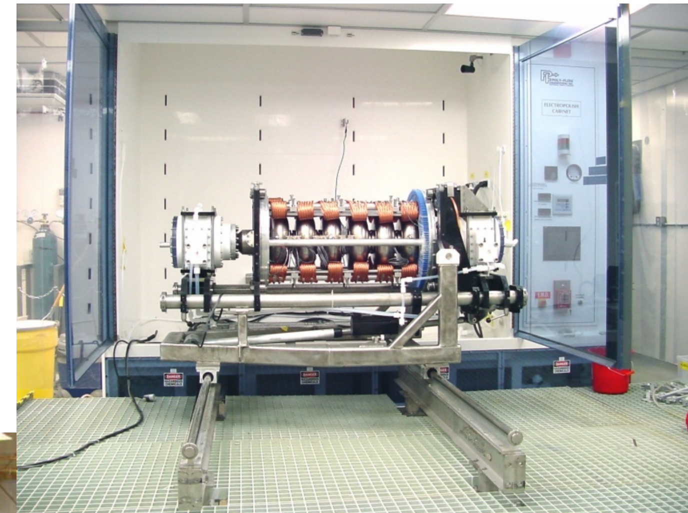
KEK/Nomura Plating



DESY

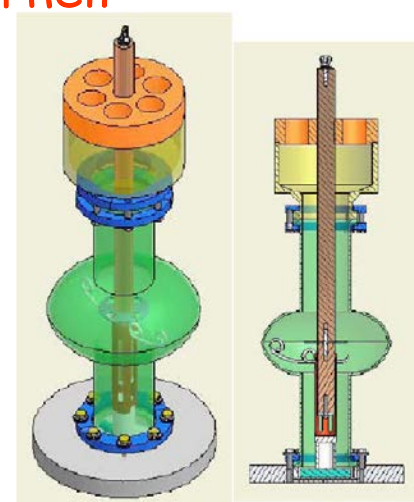


JLab



INFN

Cornell

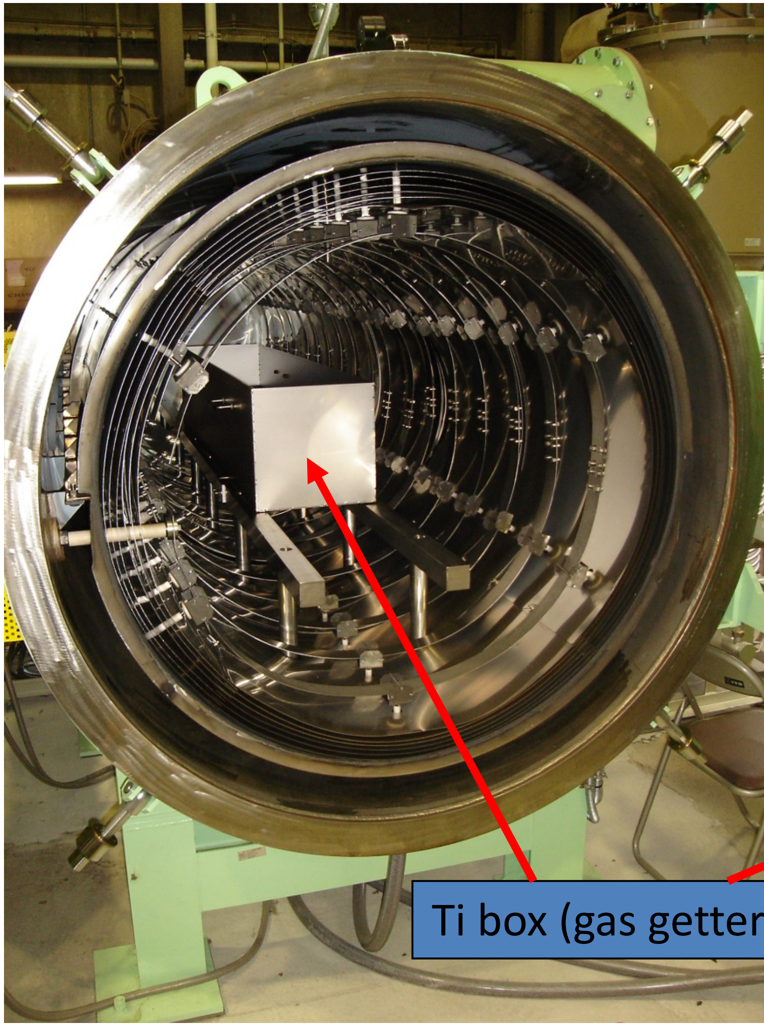


Annealing / Degassing

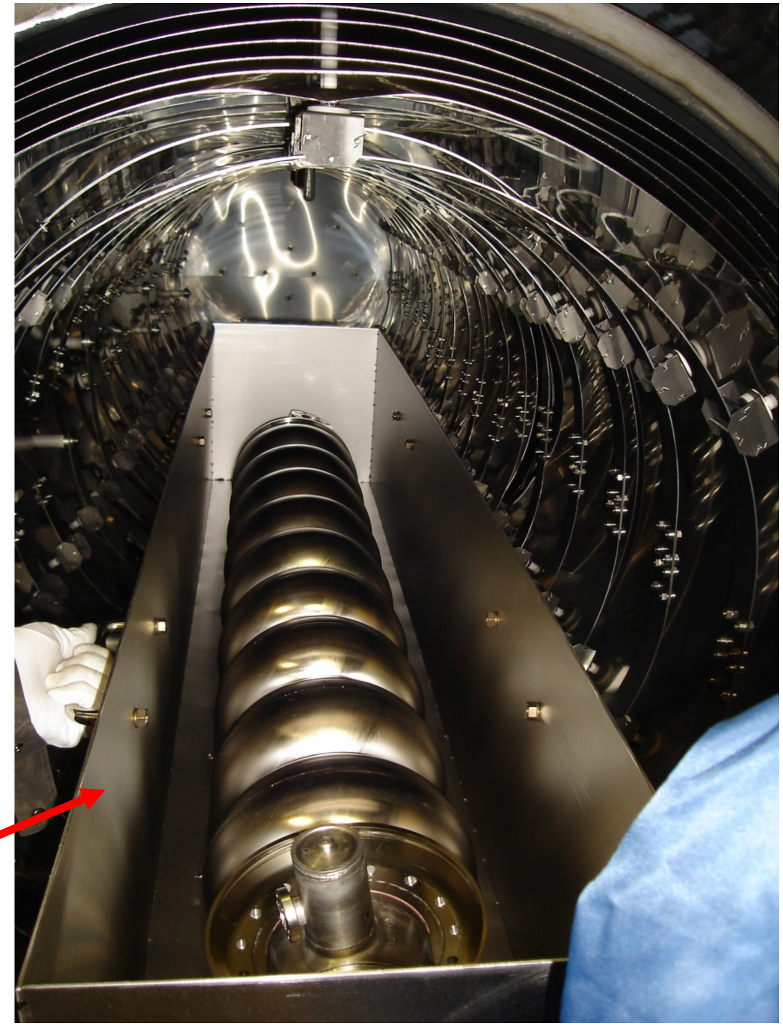
Annealing / degassing furnace at KEK：Two 9-cell cavity can be processed at once. Designed to consider about the supper-structure (Super-structure is consisting of two connected 9-cell cavities with one input-coupler).

Annealing / Degassing

Vacuum Furnce

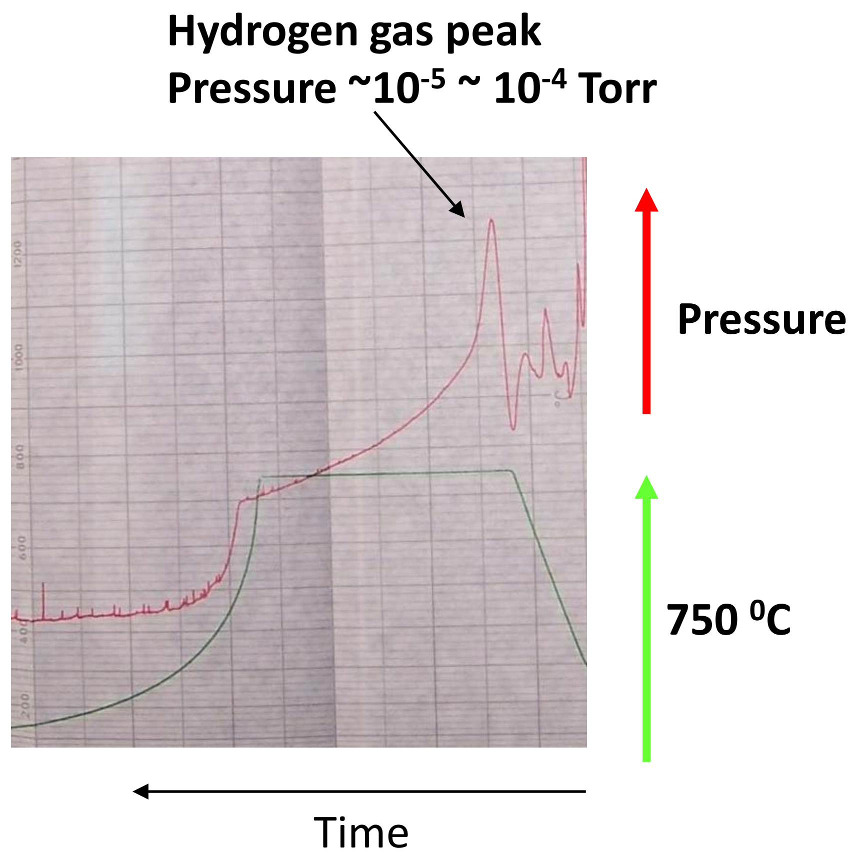


Cavity is set in a Ti box (gas getter)



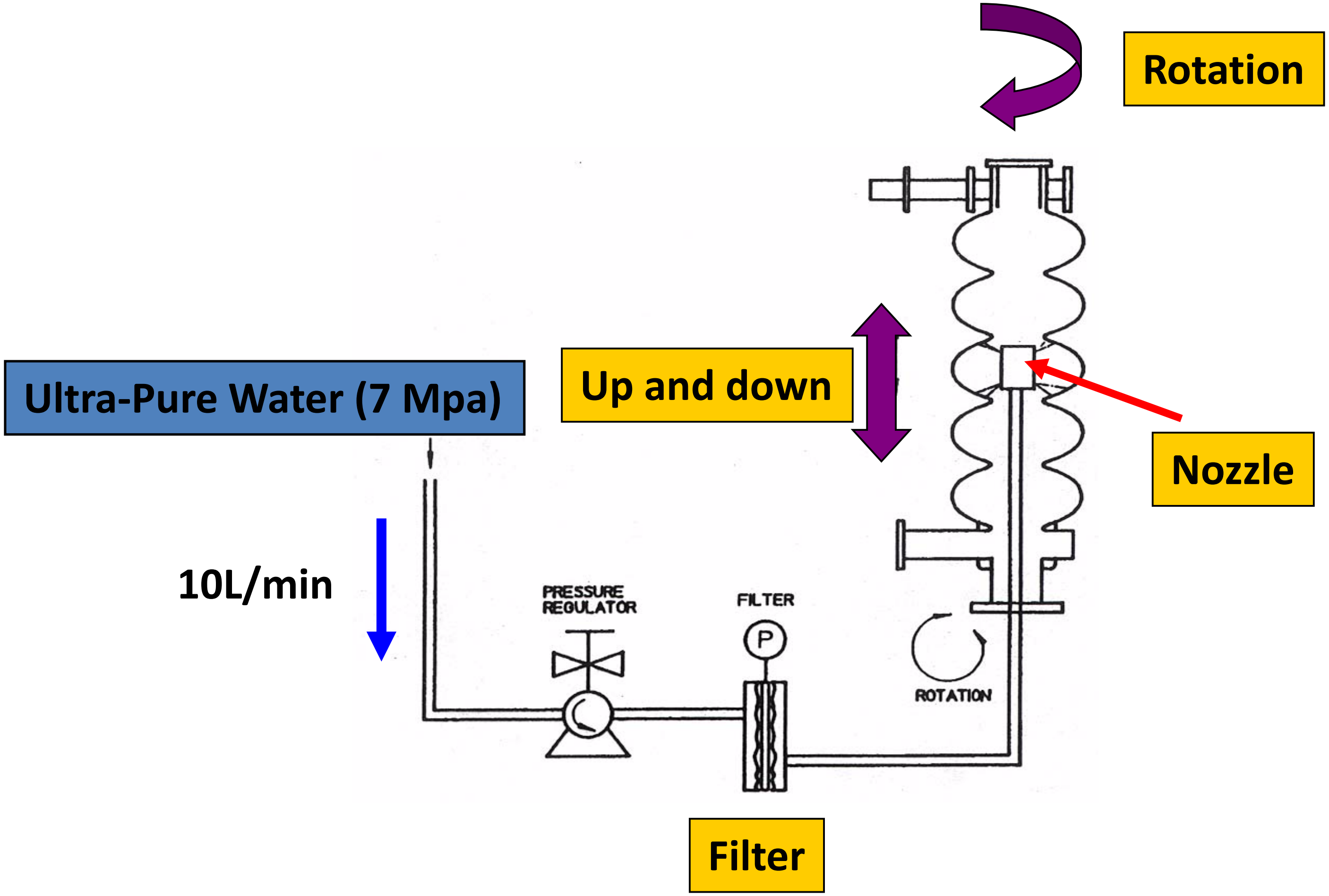
Ti box (gas getter)

Annealing / Degassing



KEK recipe : 750 ^{0}C, 3 hours.
Hydrogen gas can be degassed.
Hydrogen in the Nb material causes Q-disease that degrades the Q value.

High Pressure Rinse (HPR)



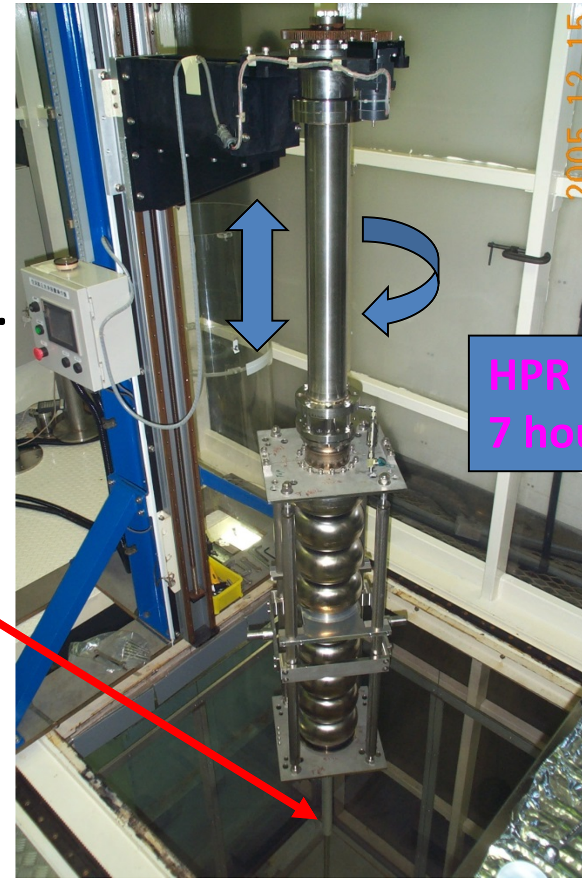
High Pressure Rinse (HPR)

Cavity

Pressure = 7 MPa

Flow rate = 10 L/min.

Nozzle



HPR
7 hours

Ultra Pure Water

Specific resistance = 18 M Ohm cm

TOC = 10 – 20 ppb

Bacteria = 0 – 3 count / mL

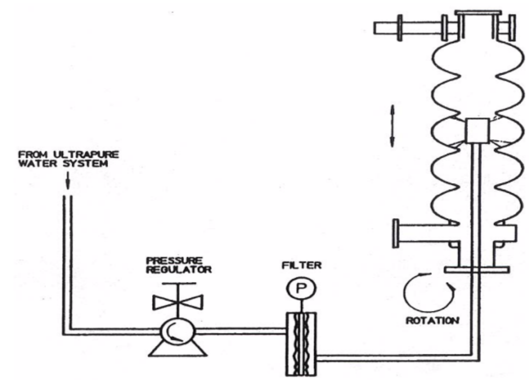
HPR is a strong tool to clean up the inside of cavity.

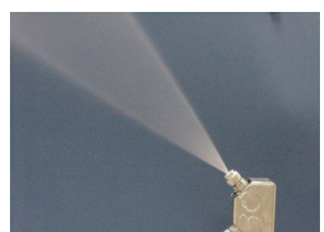
Various High Pressure Rinse (HPR) machines

DESY-System

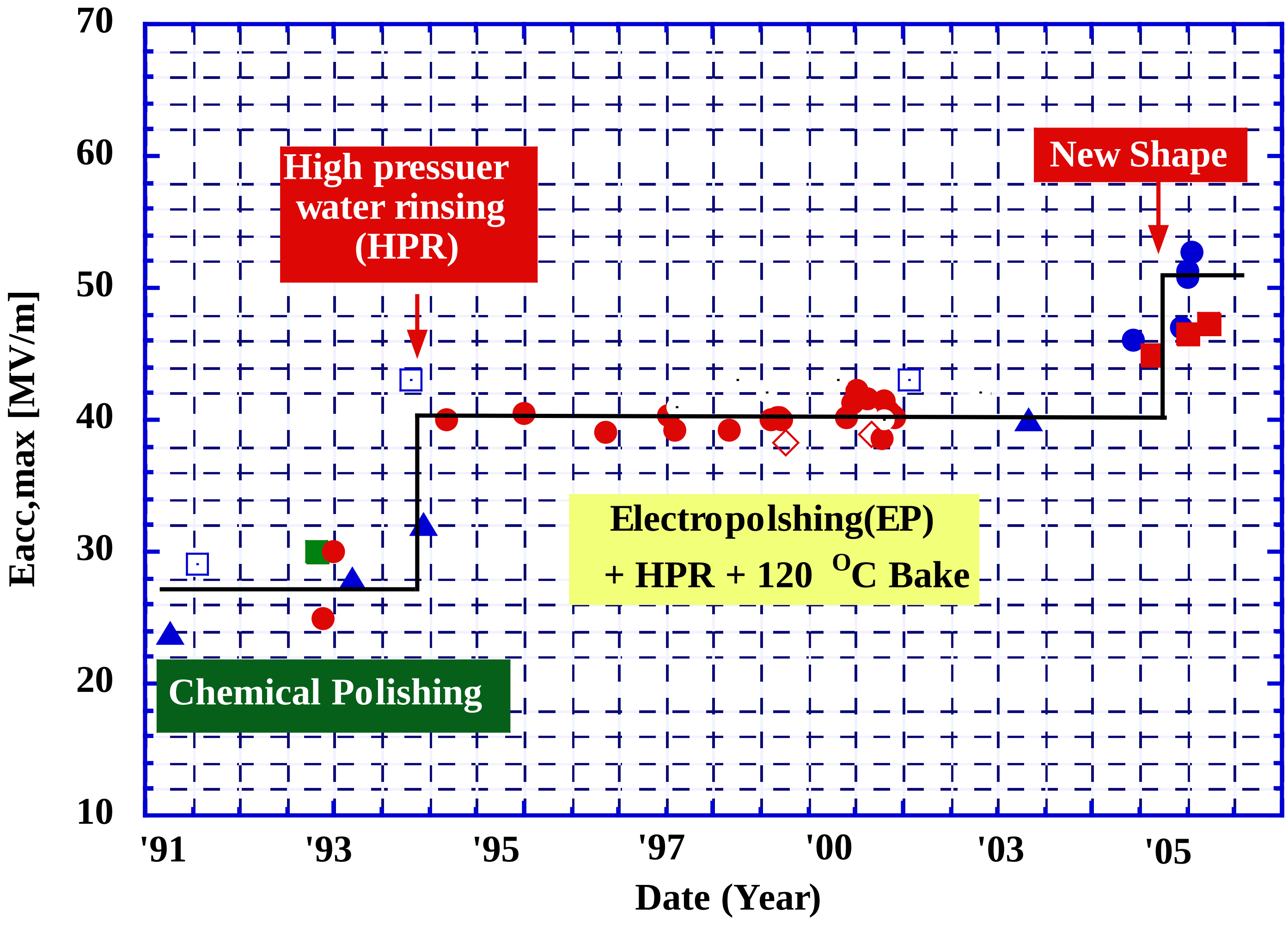
Jlab HPR Cabinet

KEK-System





Breakthrough by HPR



Assembly in Clean Room

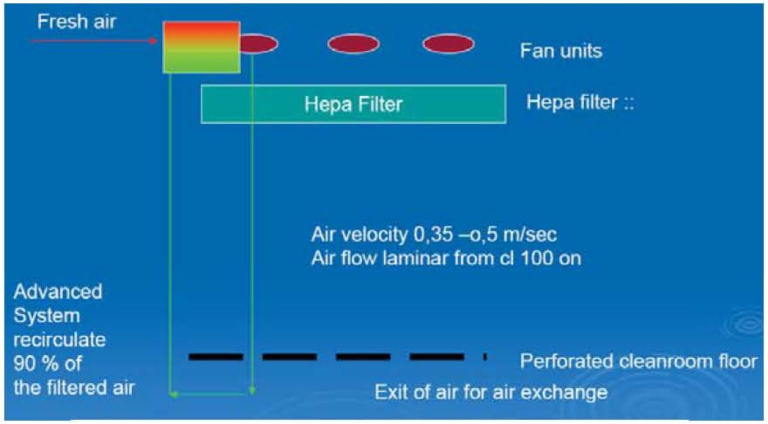
HEPA filter (class 100)

ULPA filter (class 10)

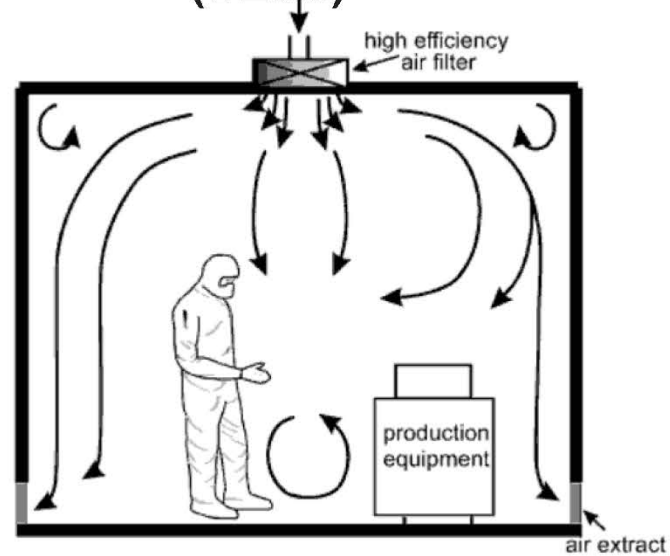
Clean-room

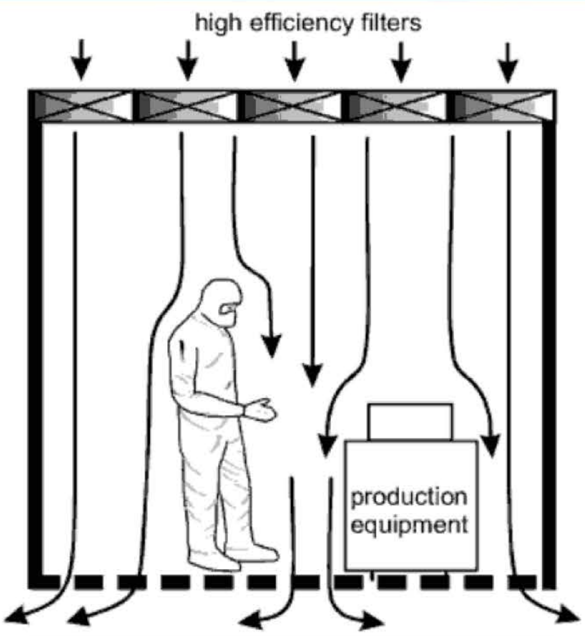
Class 10

Type of Cleanrooms



Non-Unidirectional airflow type (JLab)





Unidirectional airflow type (DESY)

Cleanroom Classification

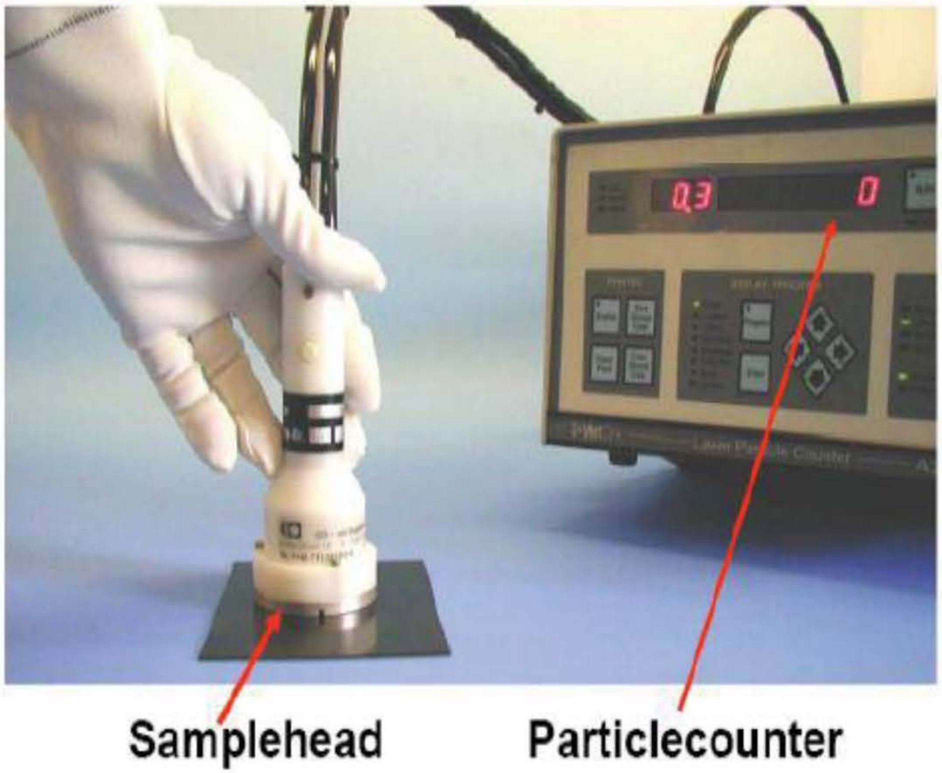
ISO Classification number	Maximum concentration limits (particles/m^3 of air) for particles equal to and larger than the considered sizes shown below					
	>=0.1µm	>=0.2µm	>=0.3µm	>=0.5µm	>=1µm	>=5.0µm
ISO Class 1	10	2				
ISO Class 2	100	24	10	4		
ISO Class 3	1 000	237	102	35	8	
ISO Class 4	10 000	2 370	1 020	352	83	
ISO Class 5	100 000	23 700	10 200	3 520	832	29
ISO Class 6	1 000 000	237 000	102 000	35 200	8 320	293
ISO Class 7				352 000	83 200	2 930
ISO Class 8				3 520 000	832 000	29 300
ISO Class 9				35 200 000	8 320 000	293 000

ISO 14644-1 Classes	Class 3	Class 4	Class 5	Class 6	Class 7	Class 8
FS 209 Classes	Class1	Class 10	Class 100	Class 1000	Class 10, 000	Class 100, 000

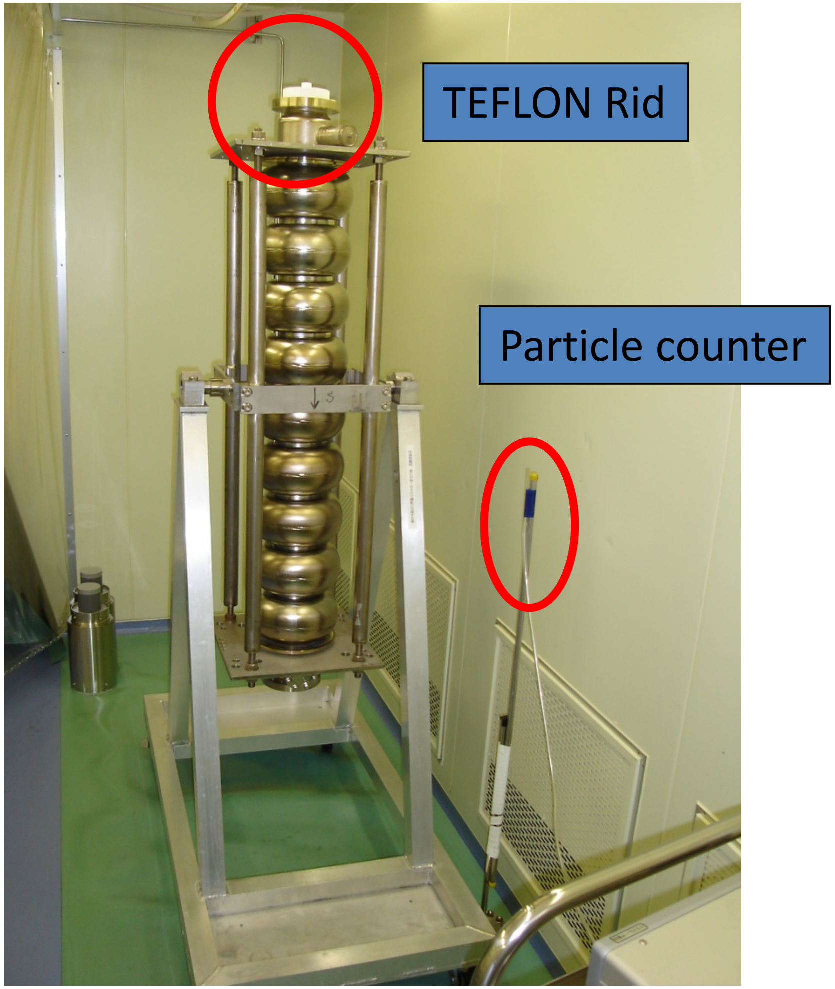
Cavity assembly (→ Class 10)

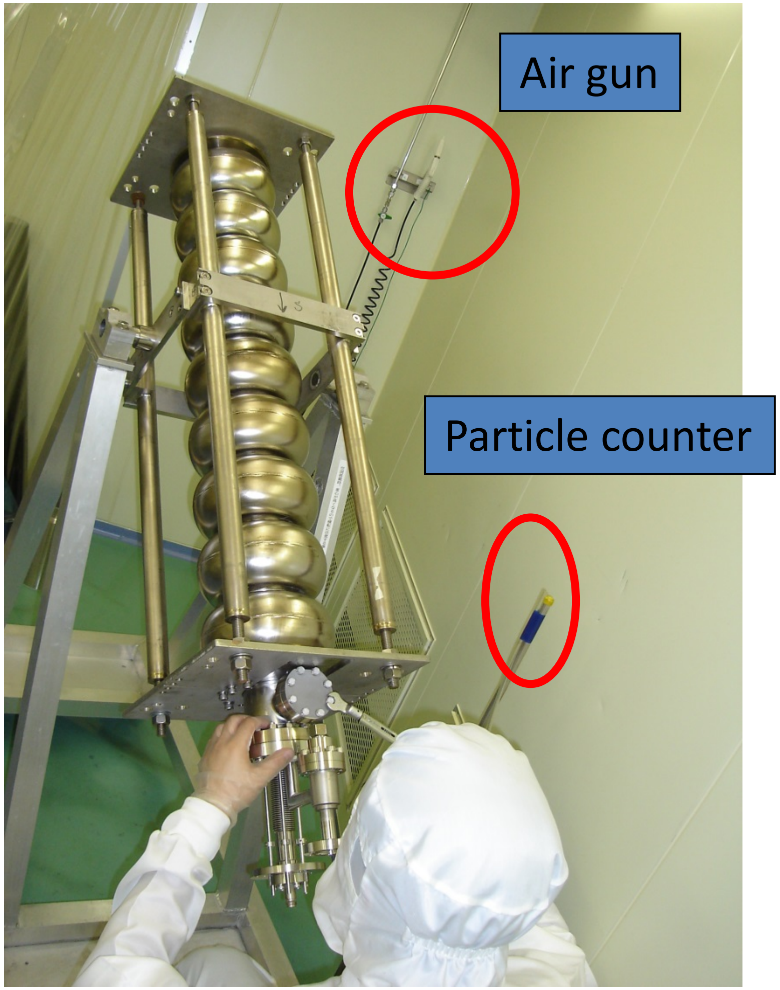
Cleanroom for SRF (→ Class 100)

Particle Counters

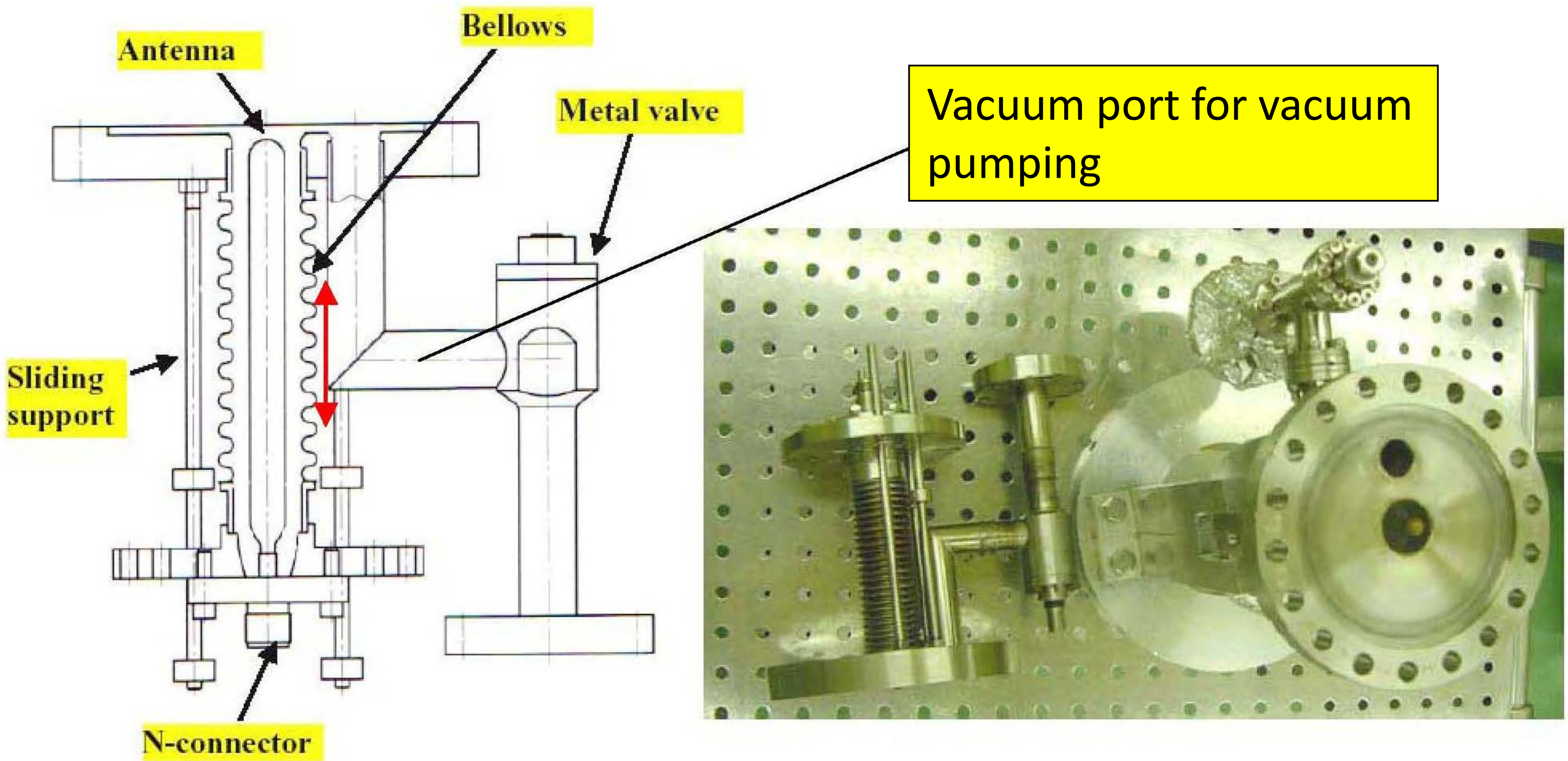


Assembly in Clean Room



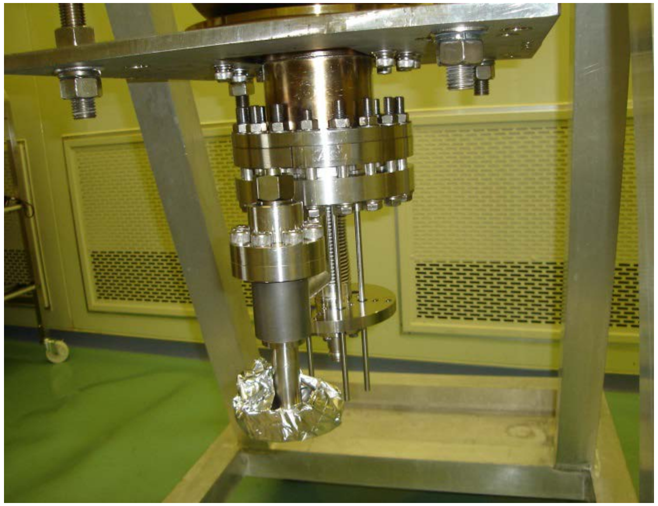


Input-coupler for RF vertical test

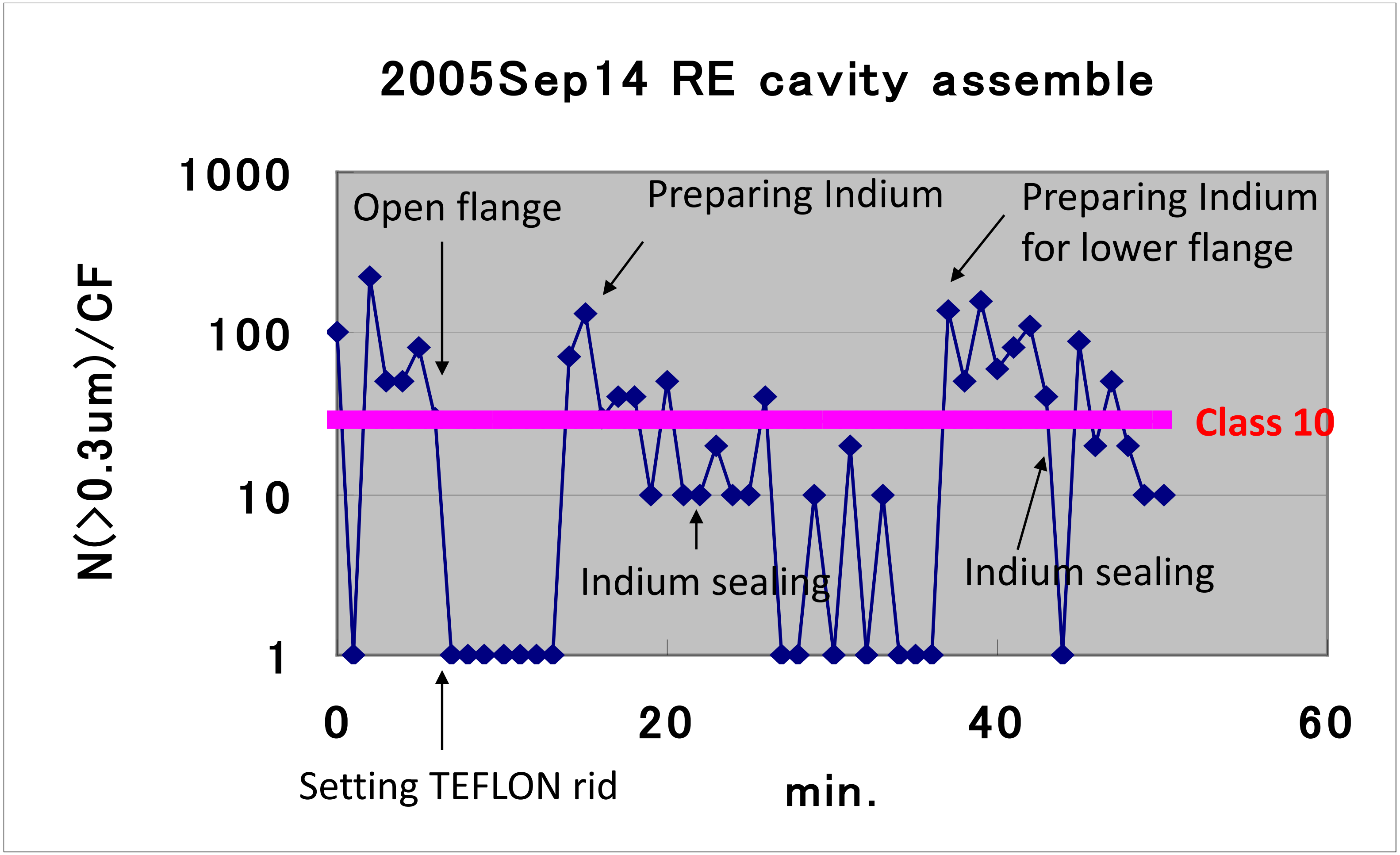


Variable input coupler for the vertical test in KEK

Assembly in Clean Room

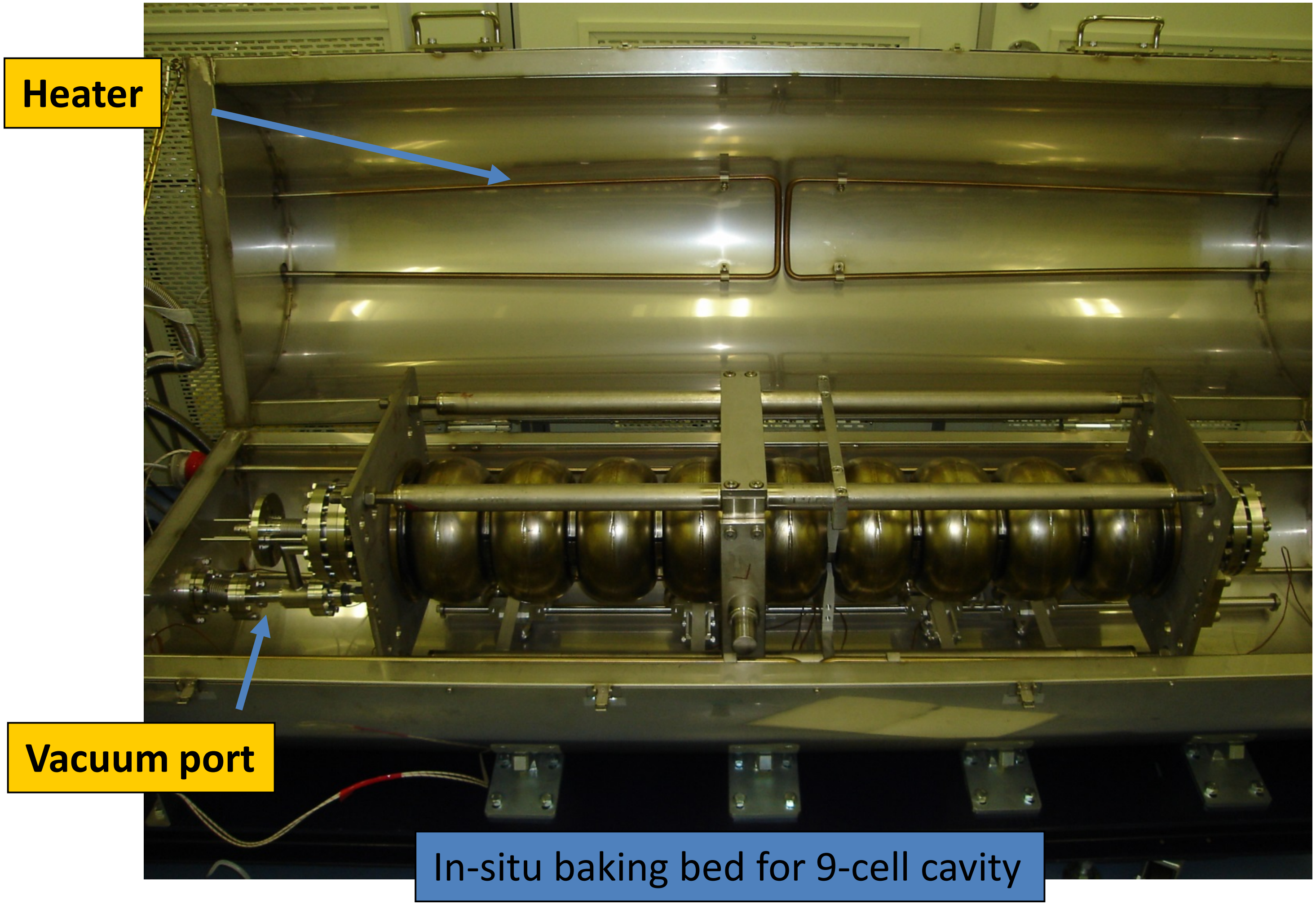


Assembly in Clean Room

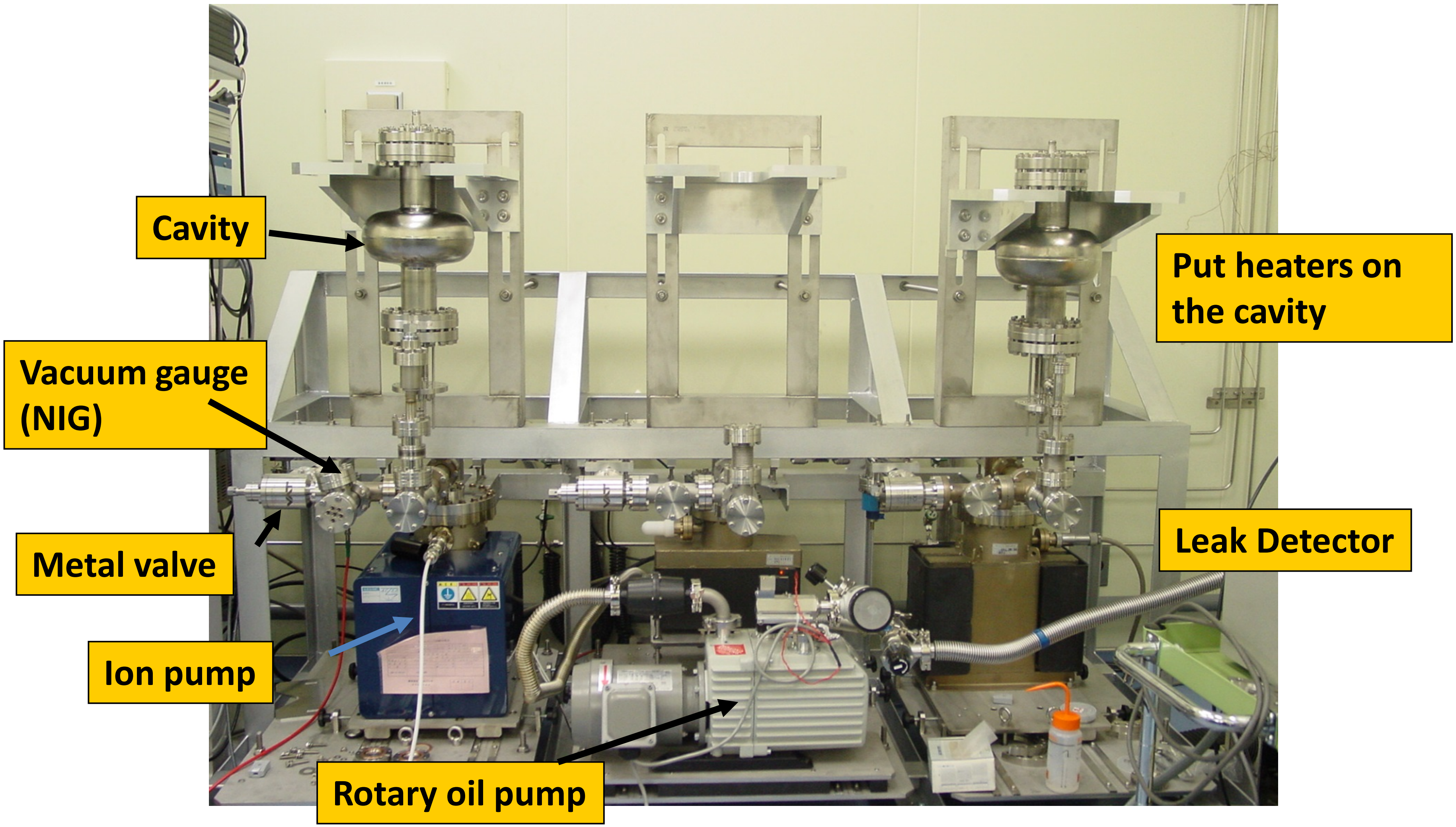


28 particles (>0.3um) / CF = class 10

In-situ Baking System for 9-cell Cavity



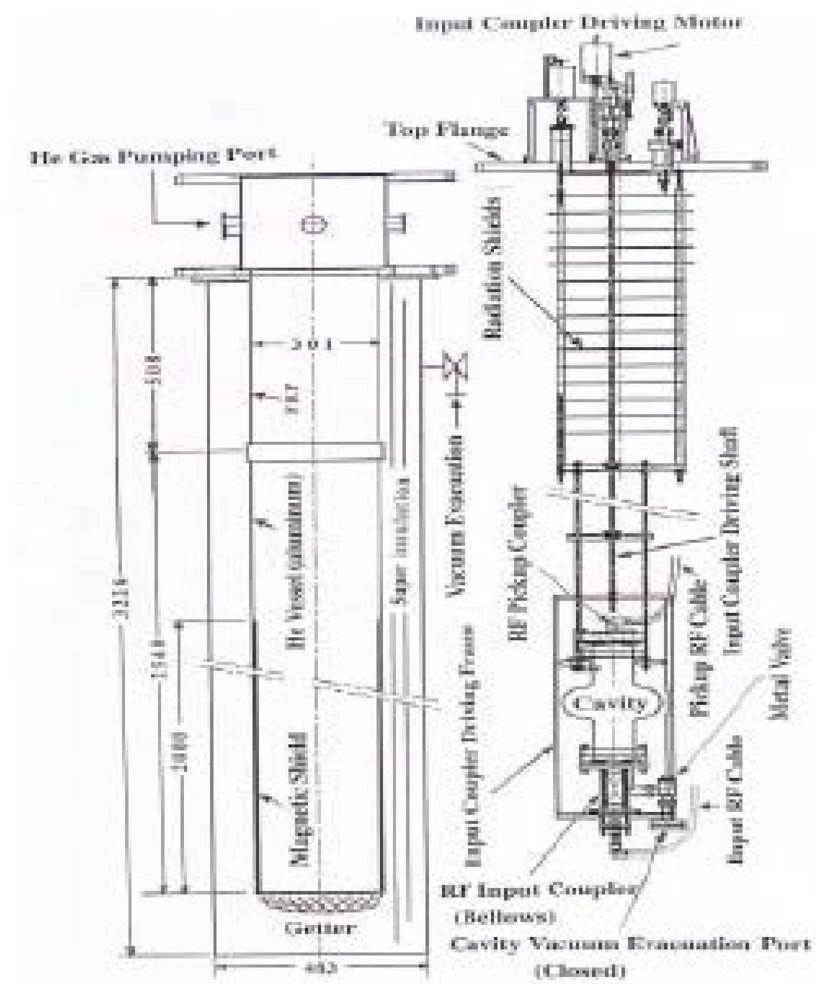
Vacuum System for In-situ Baking (120 – 140 deg. C)



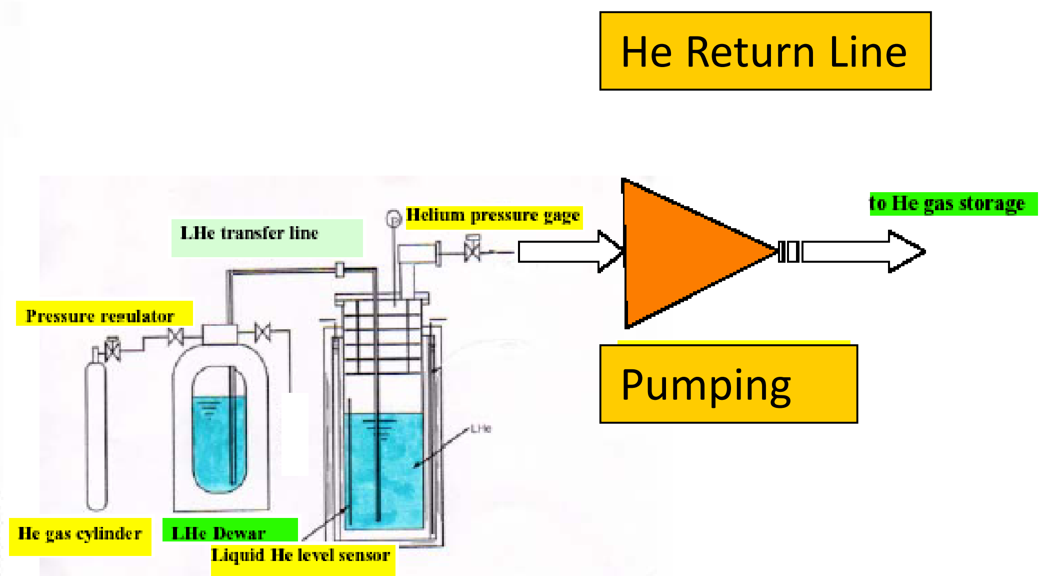
Lecture B2 and C3a: Superconductive RF

RF Test of Cavity

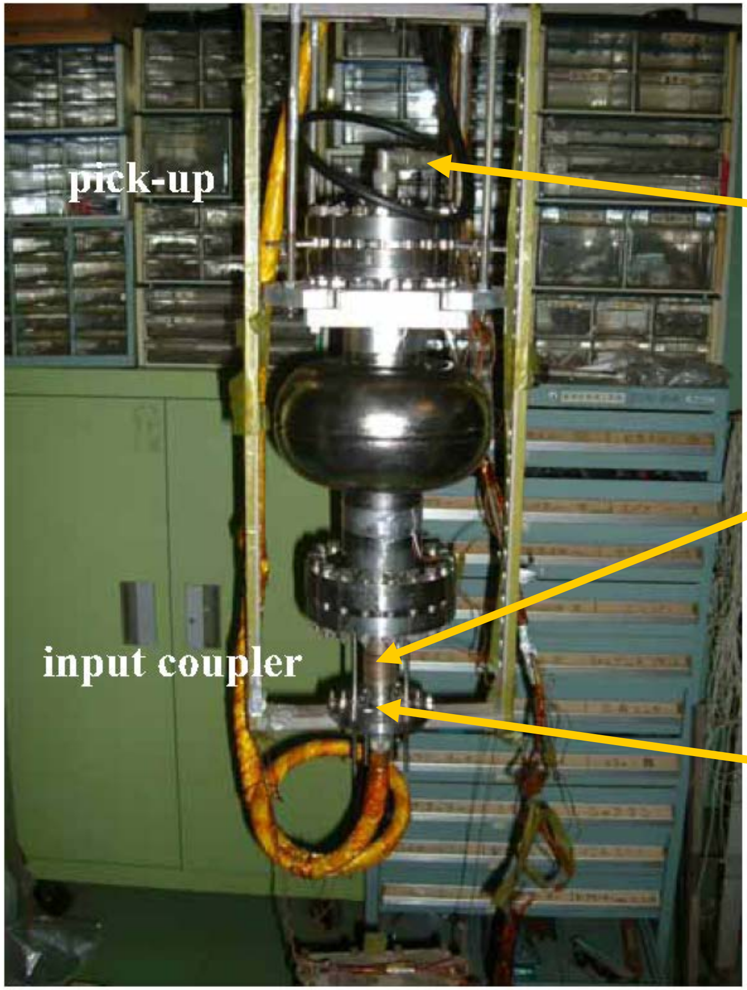
RF Test Cryostat (Vertical Test)



Vertical Cryostat   Vertical Test Stand



Cavity Preparation Stand

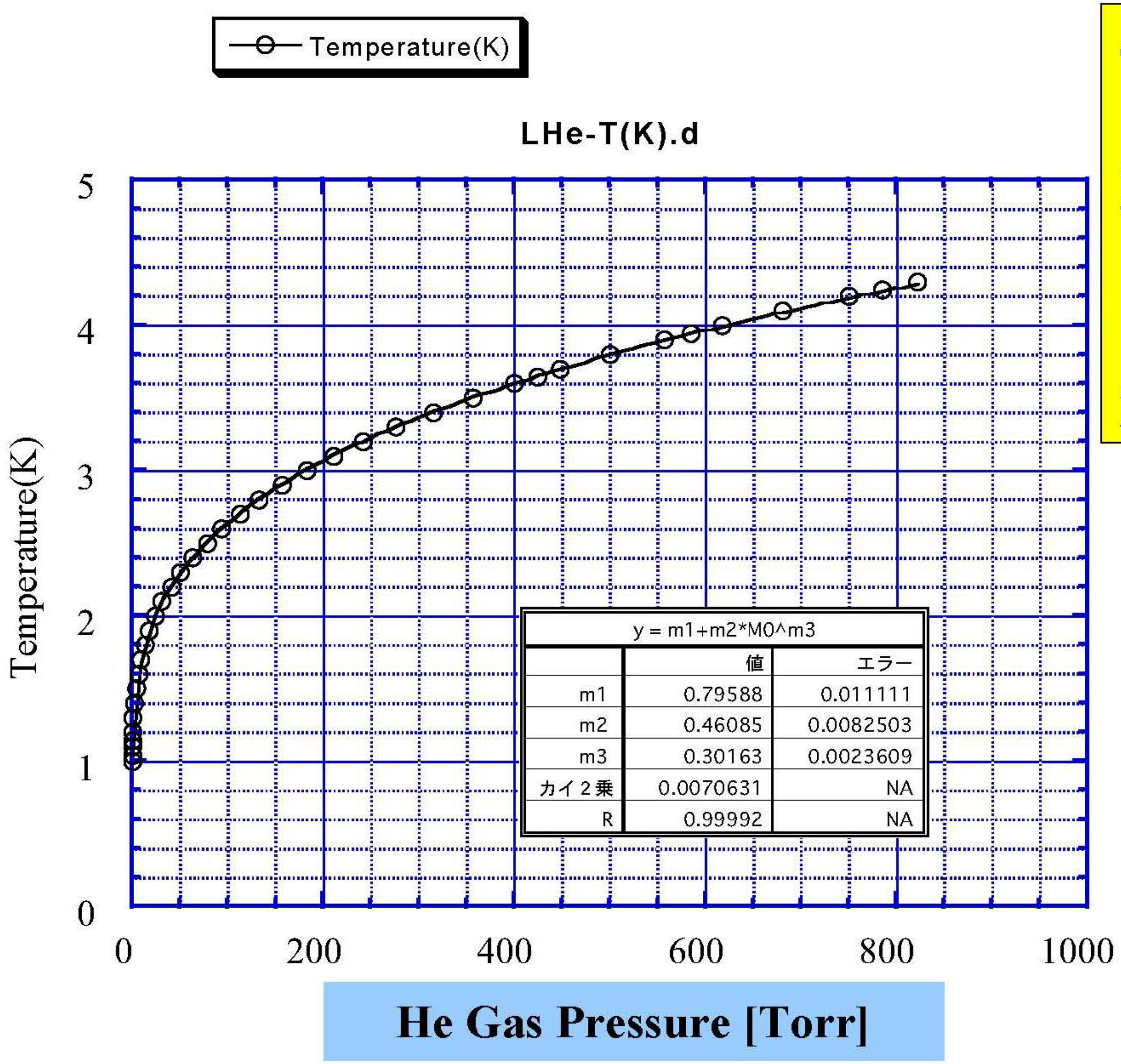


Pickup coupler

Input coupler

Metal valve for vacuum

Temperature of Liquid He (P vs. T)



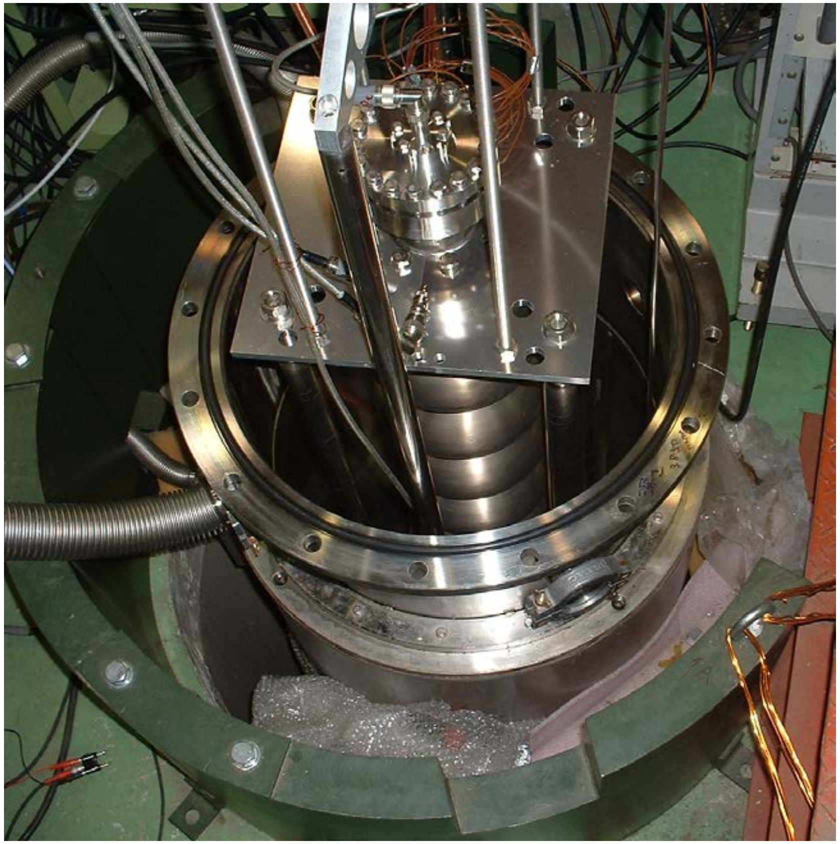
4.25 K = 760 Torr

λ-point :

2.1773K = 38.41 Torr

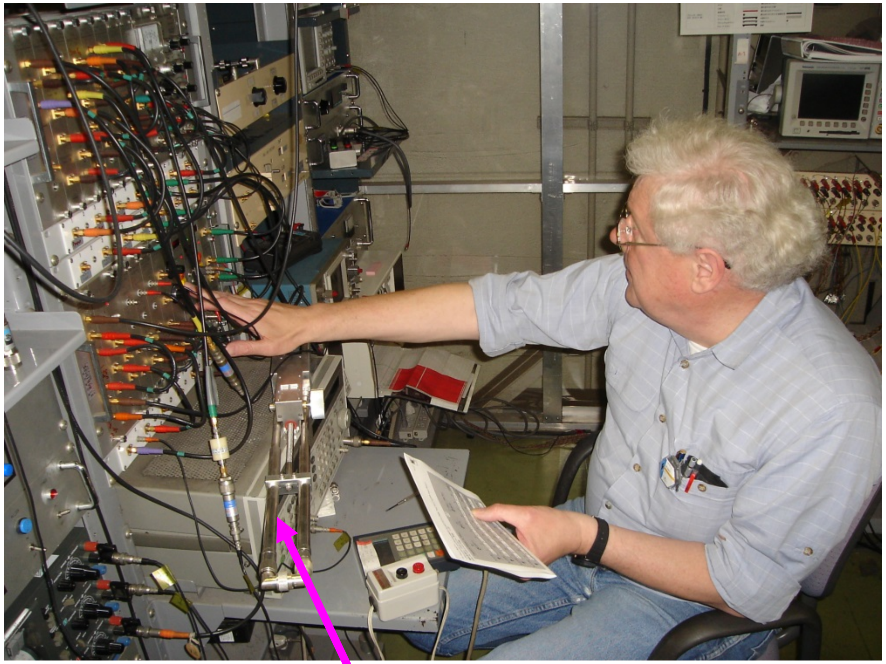
2K = 23.77 Torr

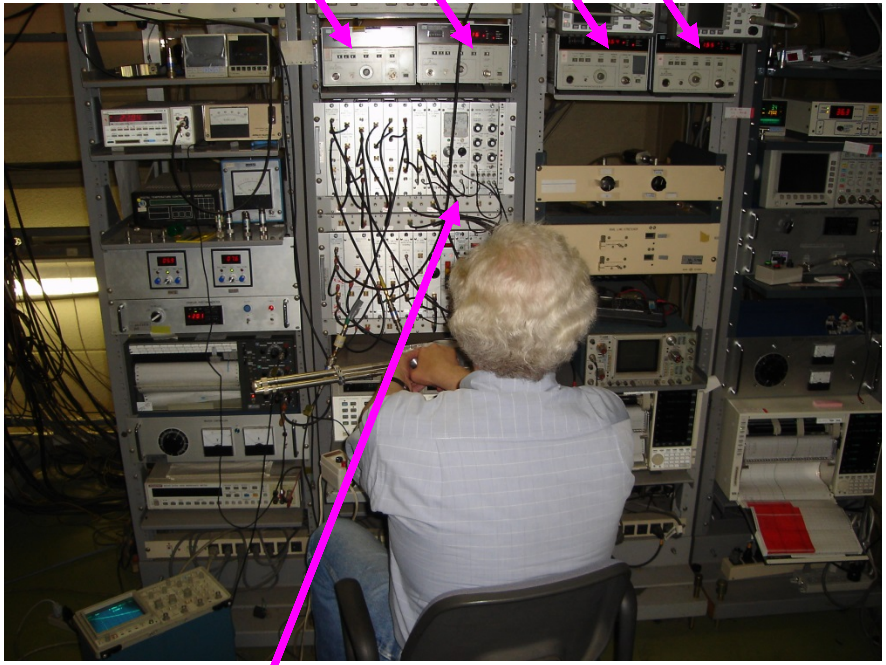
Cryostat for Vertical Test



Control Room of Vertical Test (VT)

Power-meter (Pin, Pr, Pt)

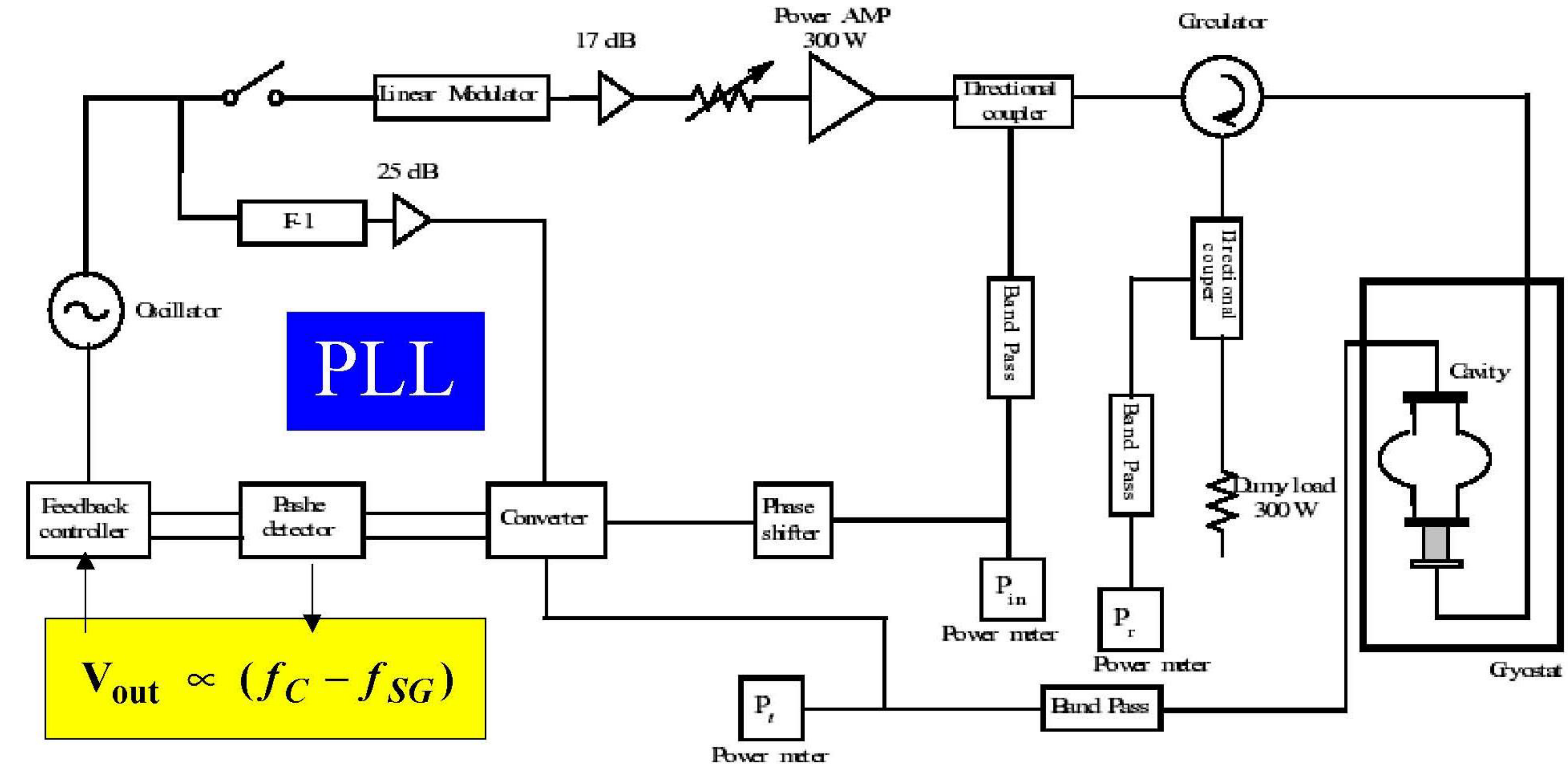


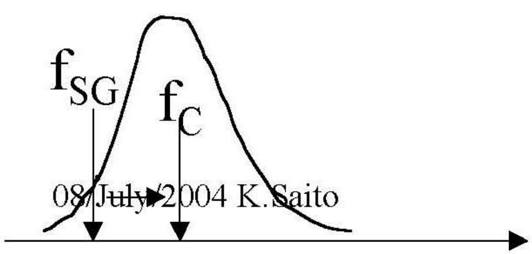


Signal Generator (SG)

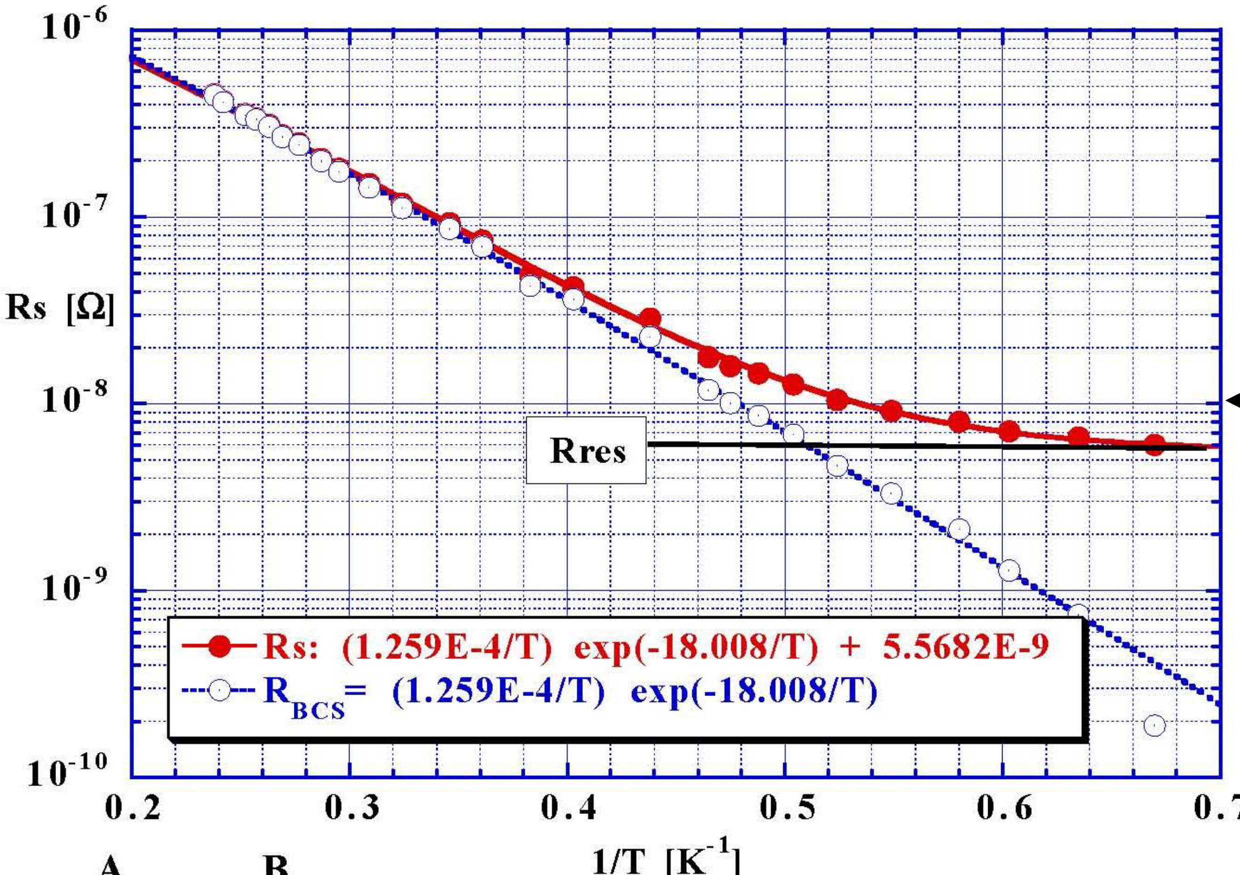
Feed-back system (PLL)

Feed Back System





Measurement of Surface Resistance (Dependence on T)

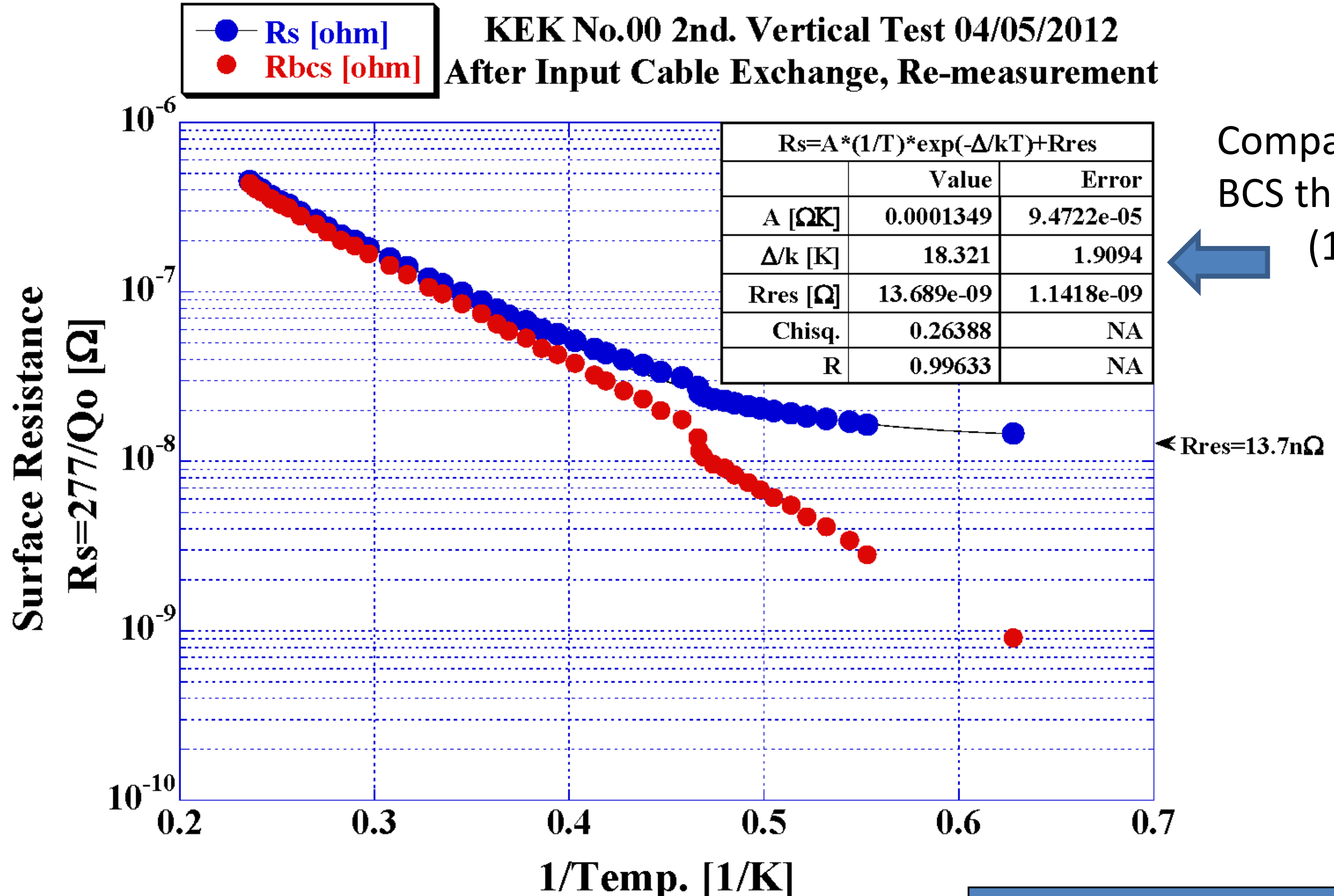


$$R_s - \text{fit}: R_s(T) = \frac{A}{T} \cdot \exp\left(-\frac{B}{T}\right) + R_{res}$$

$$B = \frac{\Delta}{k_B}$$ = 17.67 (BCS theory)

Rs = Γ/ Q0 is plotted

Measurement of Surface Resistance (Dependence on T)

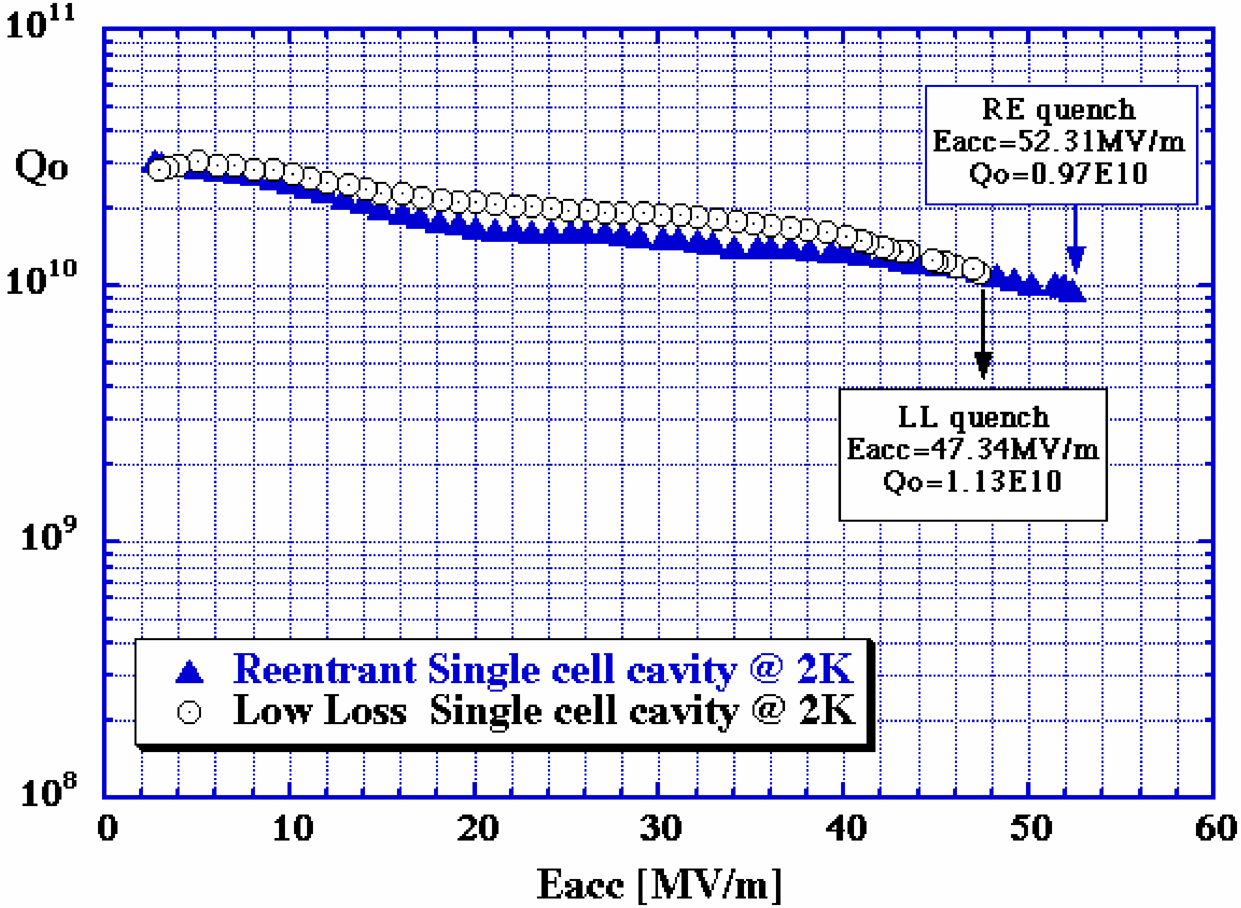


Compare with BCS theory (17.67)

Rs = Γ/ Q0 is plotted

Qo vs Eacc

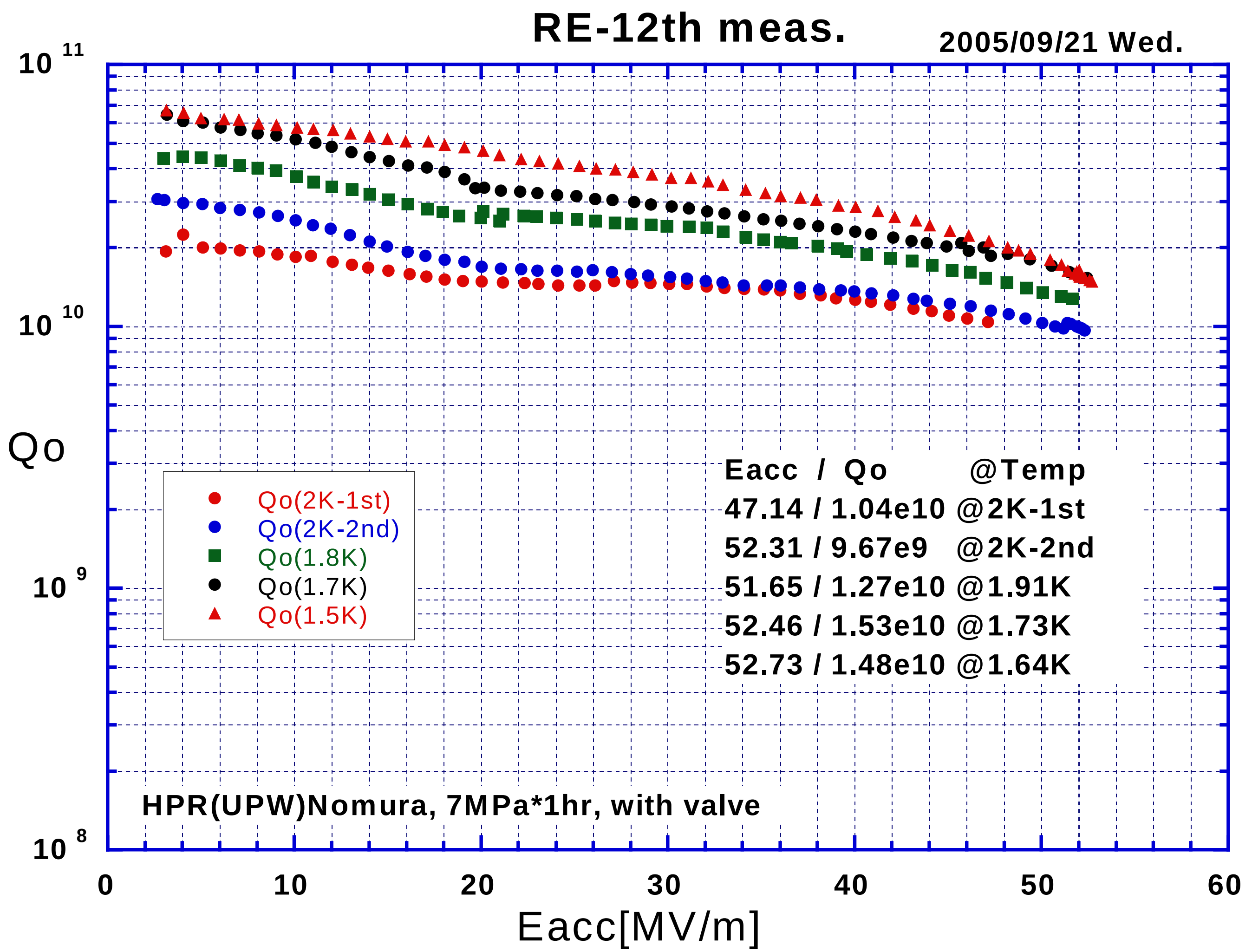
Eacc > 45 MV/m with new-shape at KEK



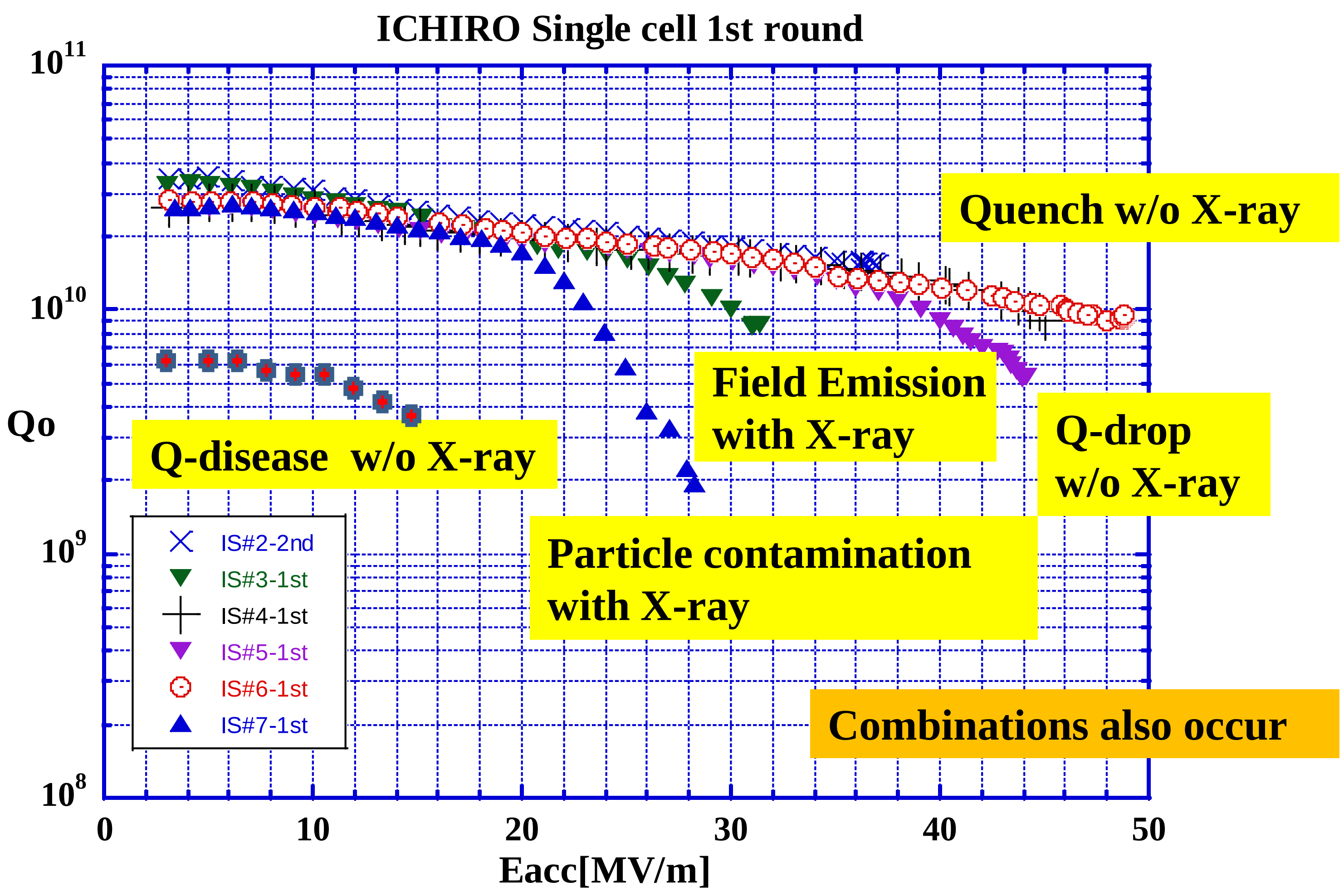
Eacc = Z sqrt(Qt･Pt) , Q0 = Qt ･ Pt / Ploss

Q0 vs Eacc（T dependence）

Temperature dependence (RE cavity)

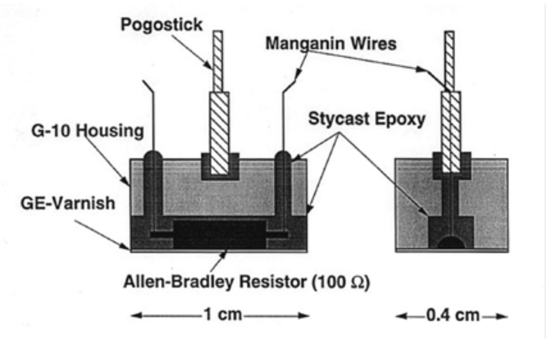


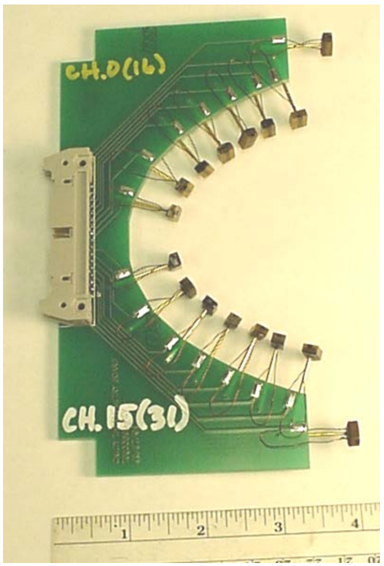
Q0 vs Eacc（Limitation）



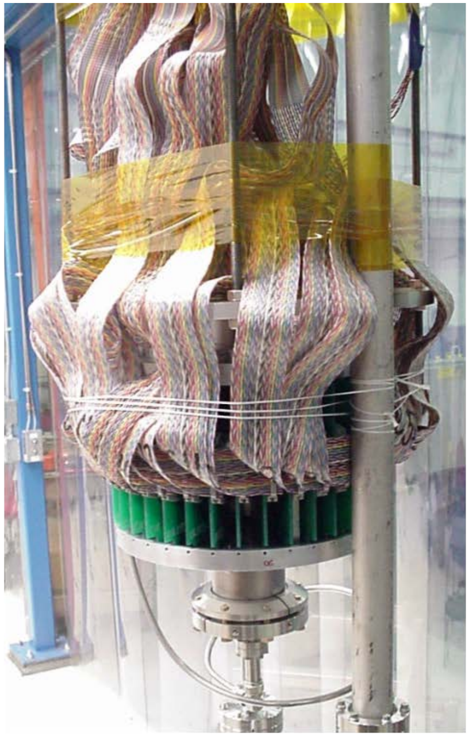
T-Mapping (1)

T-mapping system: ~600 Allen-Bradley C-resistors

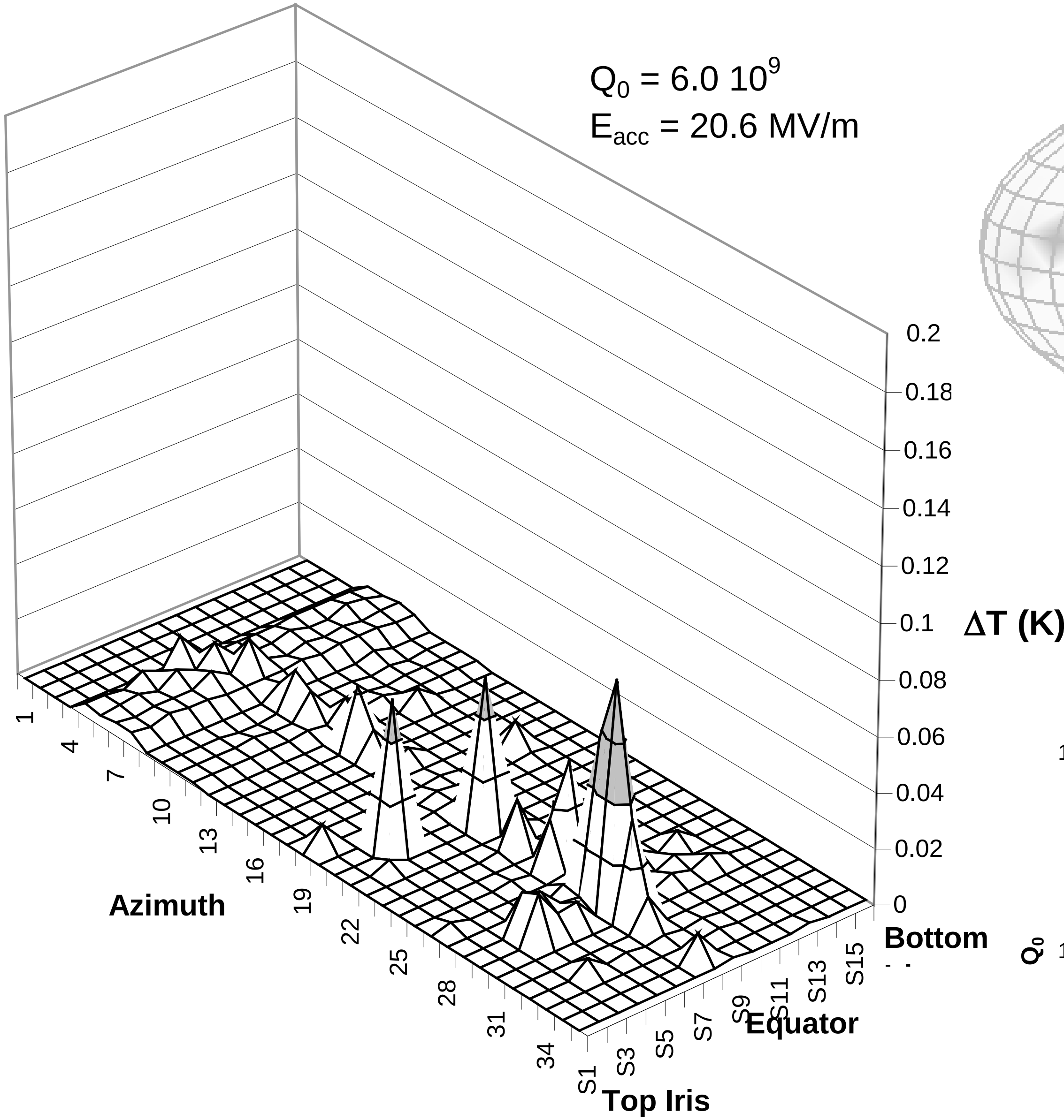




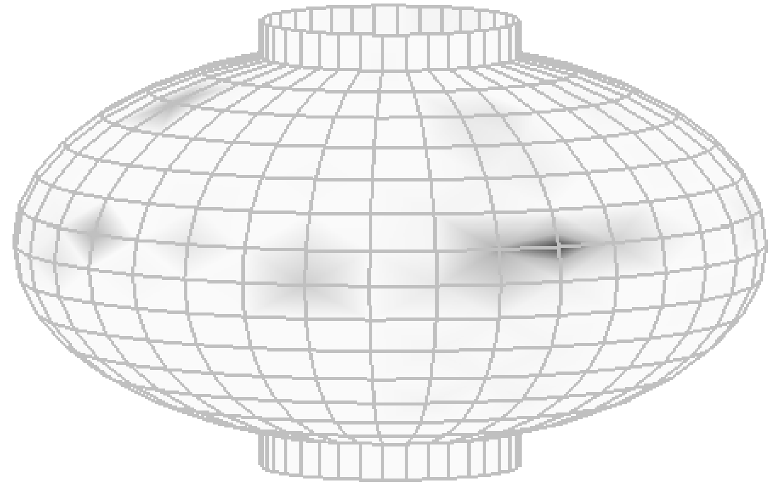
a)

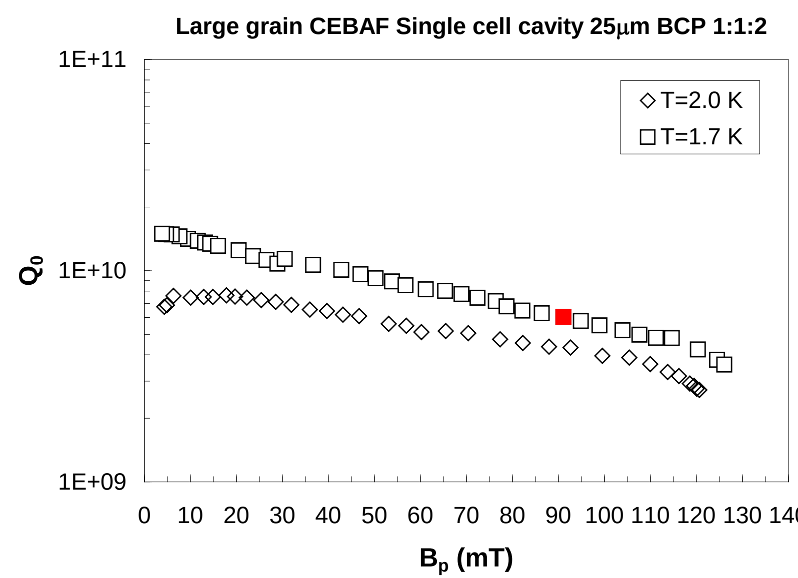


b
)



Q_0 = 6.0 10^9
E_{acc} = 20.6 MV/m
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
ΔT (K)
1
4
7
10
13
16
19
22
25
28
31
34
Azimuth
S1
S3
S5
S7
S9
S11
S13
S15
Top Iris
Equator
Bottom



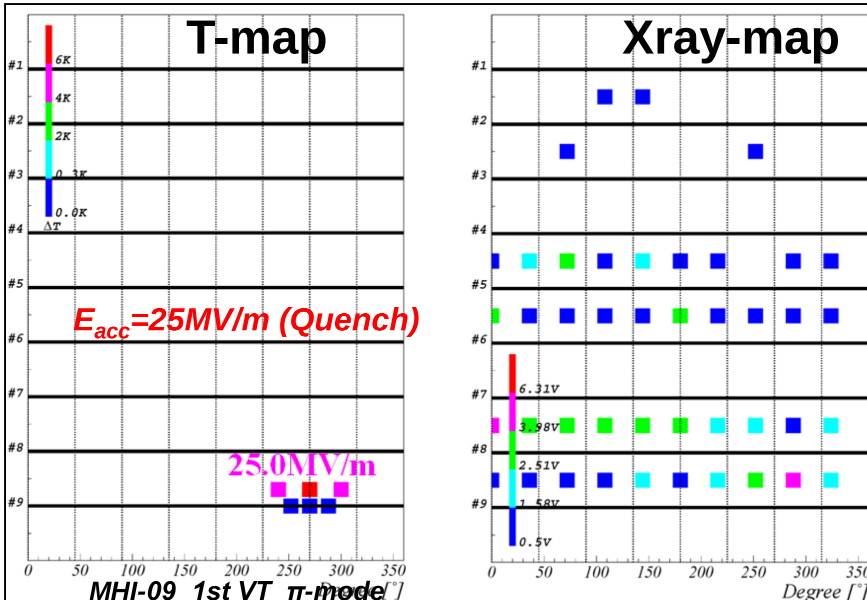


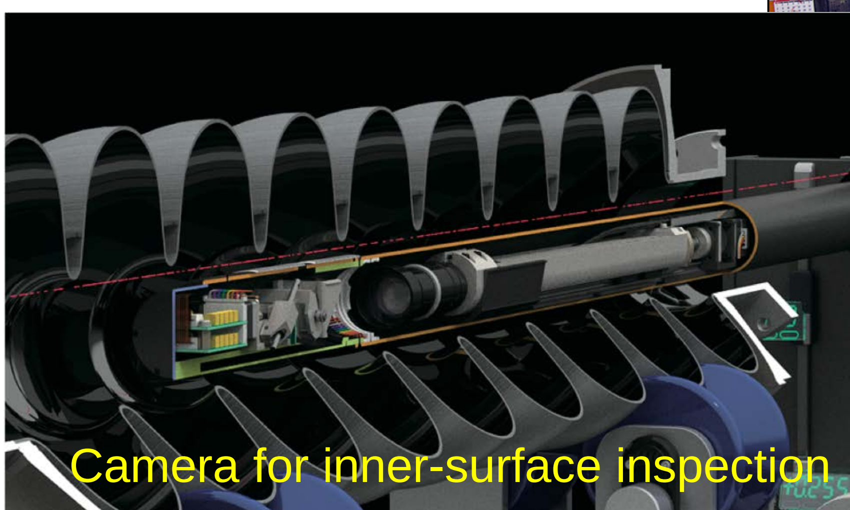
Large grain CEBAF Single cell cavity 25µm BCP 1:1:2
1E+11
1E+10
1E+09
Q_0
T=2.0 K
T=1.7 K
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
B_p (mT)

Acceptance test of cavity

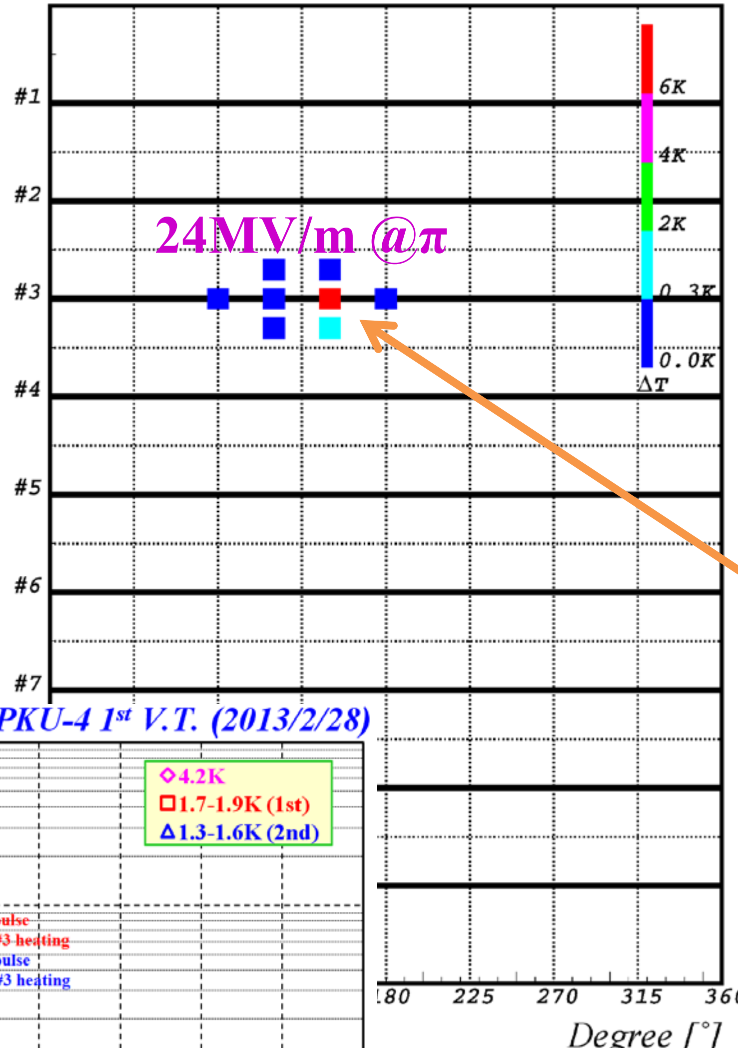
Temperature and X-ray maps of cavity are obtained during each test.

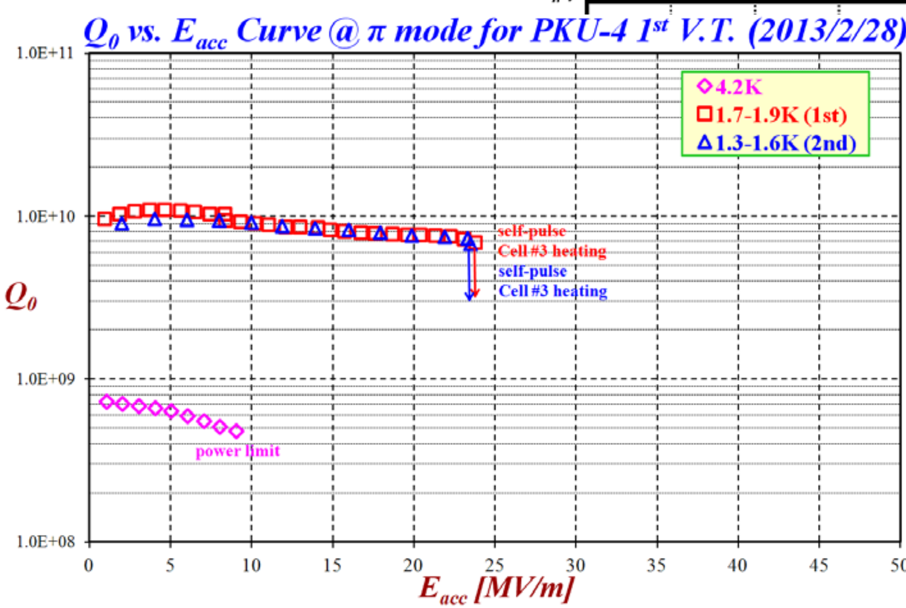
T-map & Xray-map,
together with pass-band
mode measurement,
location of quench is identified.
Inspection camera visualize
what's happen inside.

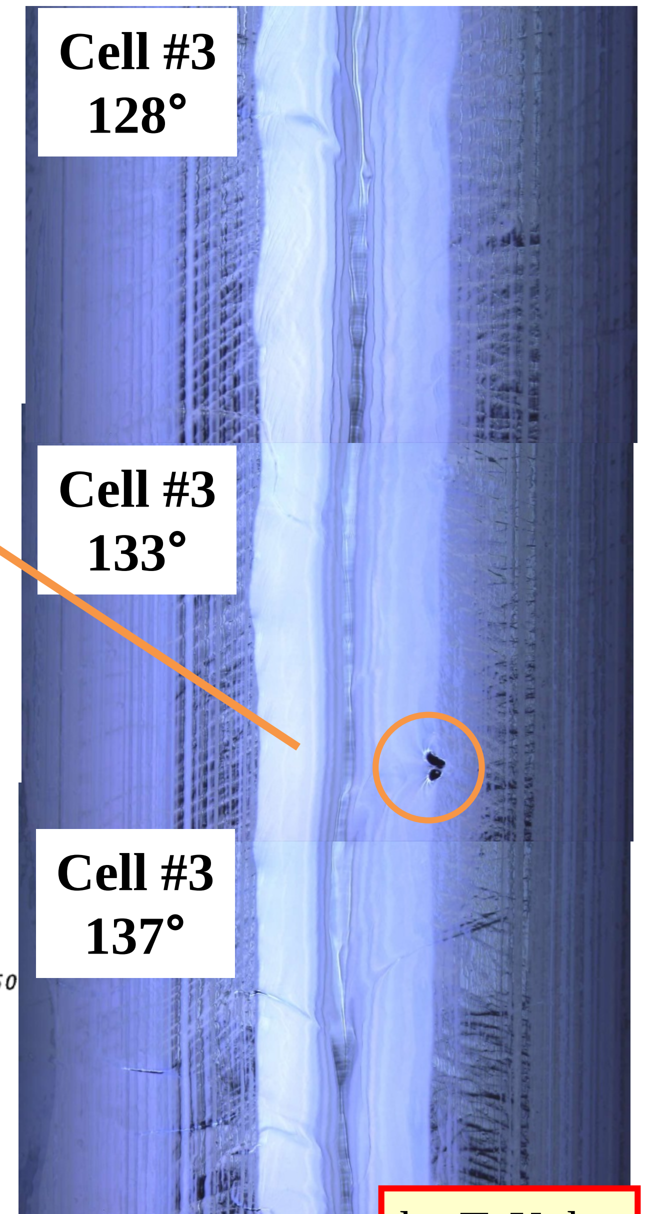




PKU-04 cavity

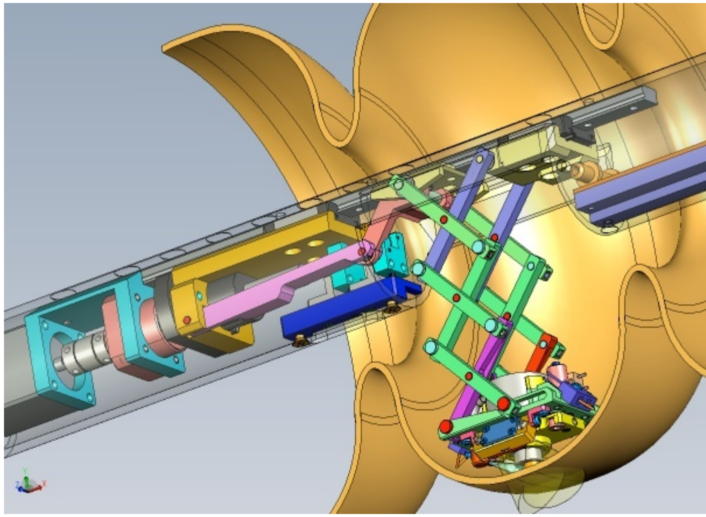
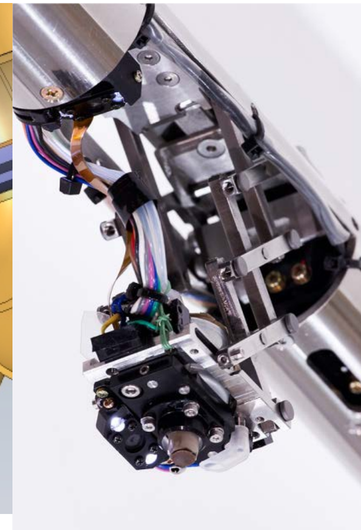
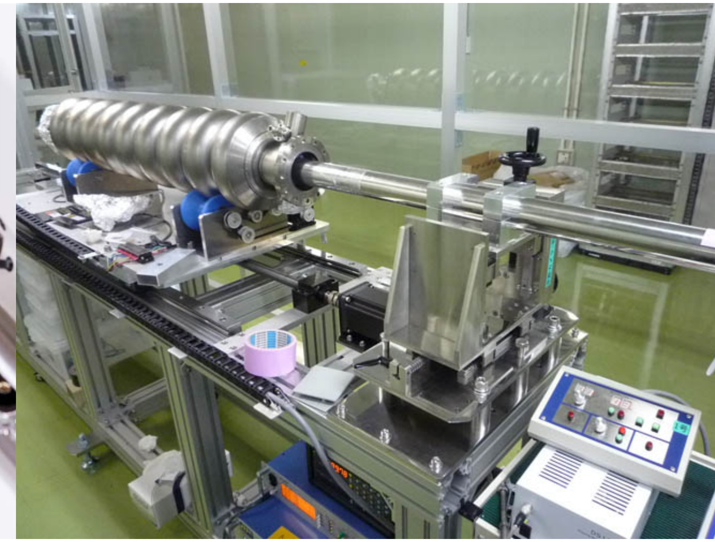






by T. Kubo

Local grinding at KEK

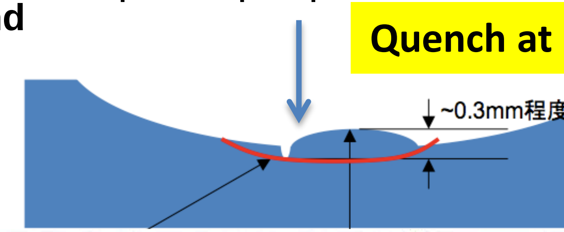




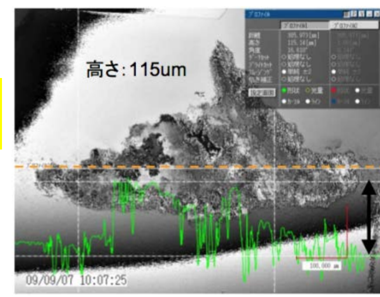
Grinding only for pit, without touching other surface

diamond powder compound with water in between were used.

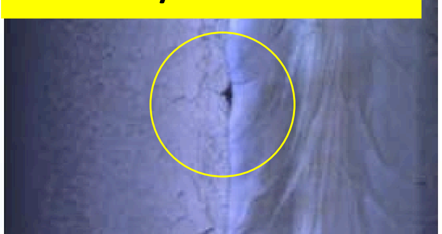
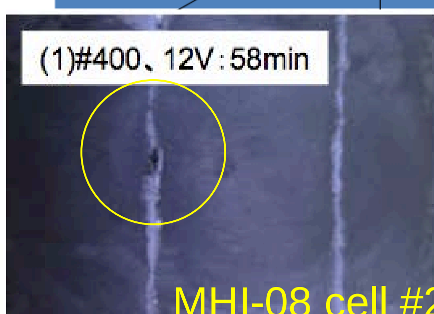
~115μm depth pit in MHI-08 cavity

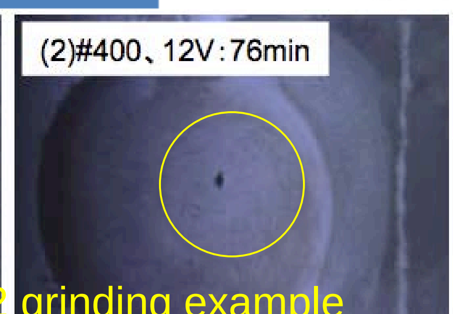
Quench at 16 MV/m

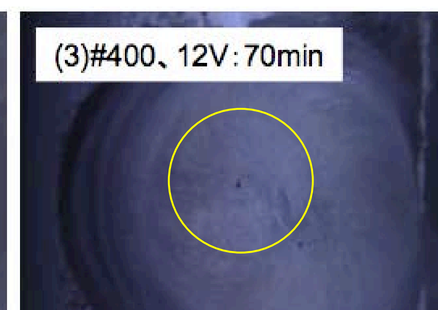




This pit caused quench at 16 MV/m





MHI-08 cell #2 grinding example

Q-drop and In-situ Baking

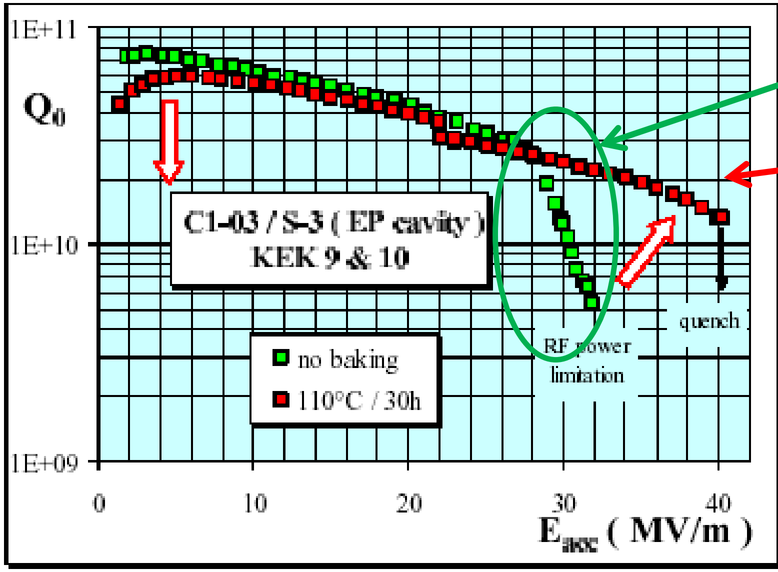


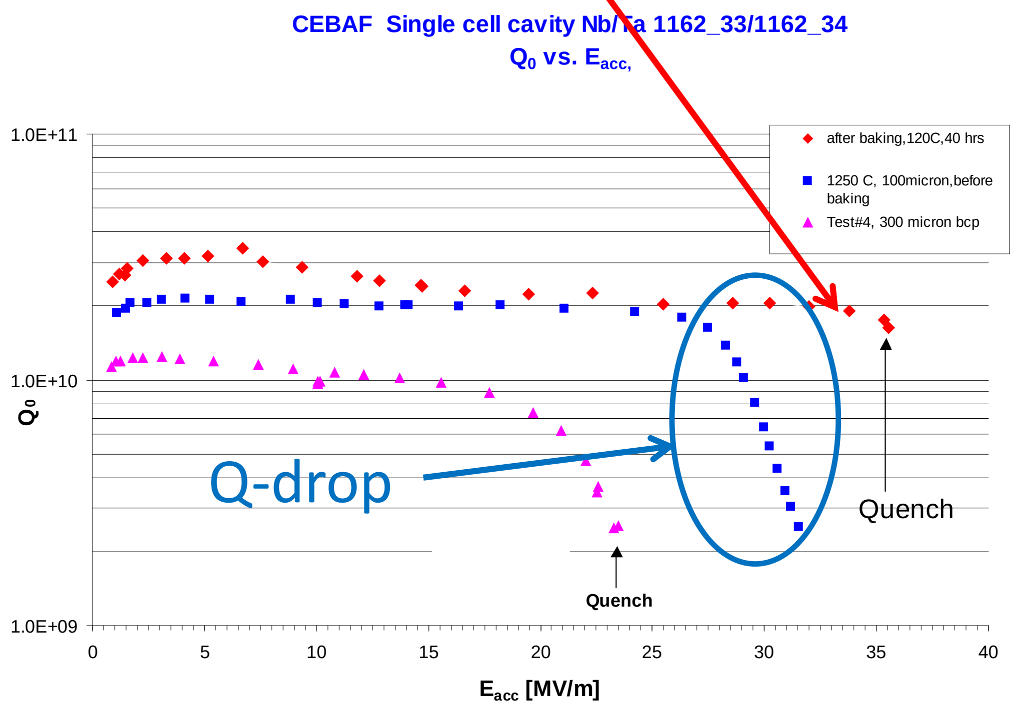
Figure 4: Baking effect on C1-03 Saclay cavity (electropolished and tested at KEK) [9].

[B.Visentin,SRF2003]

electropolished

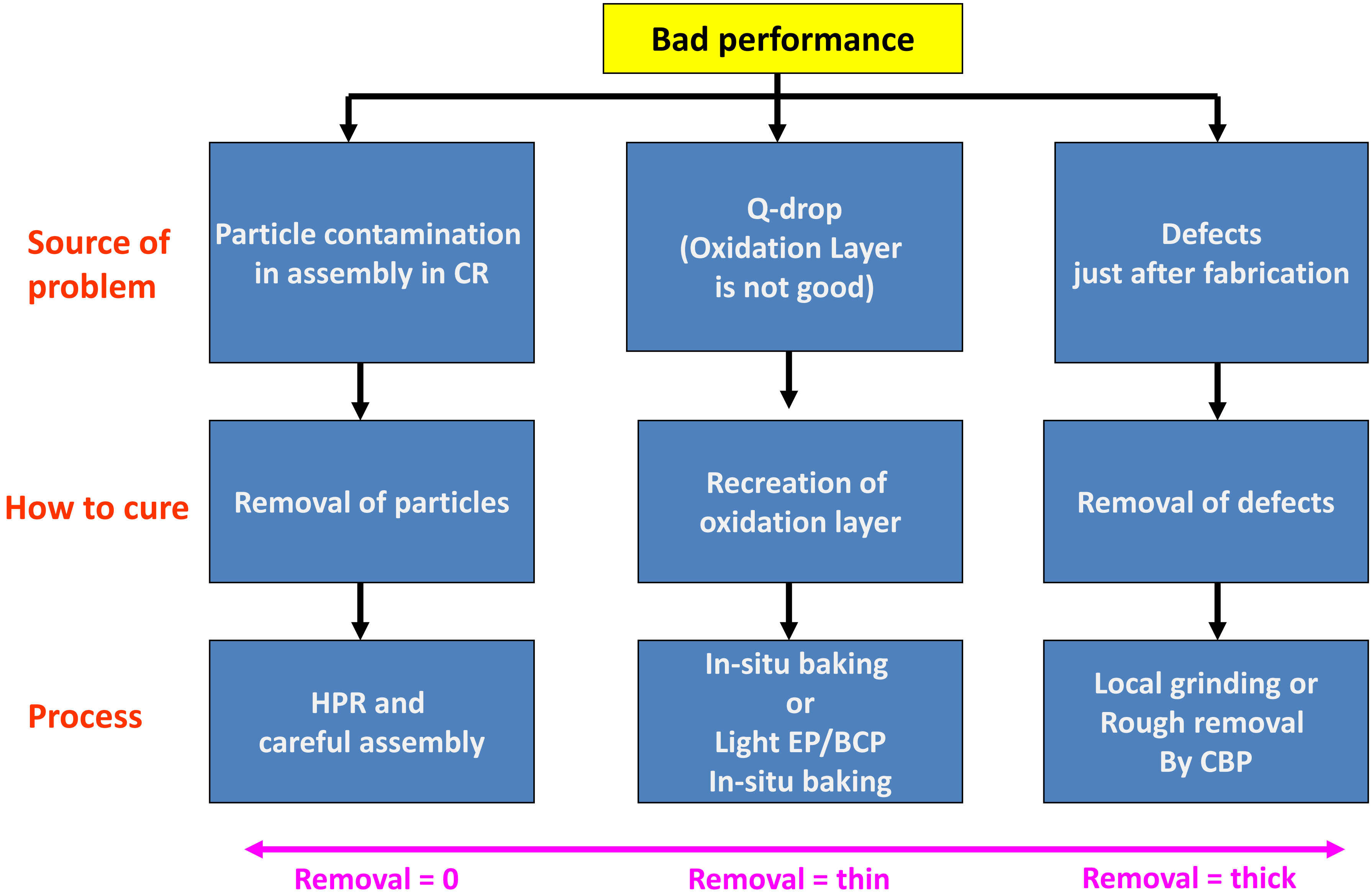
Q-drop

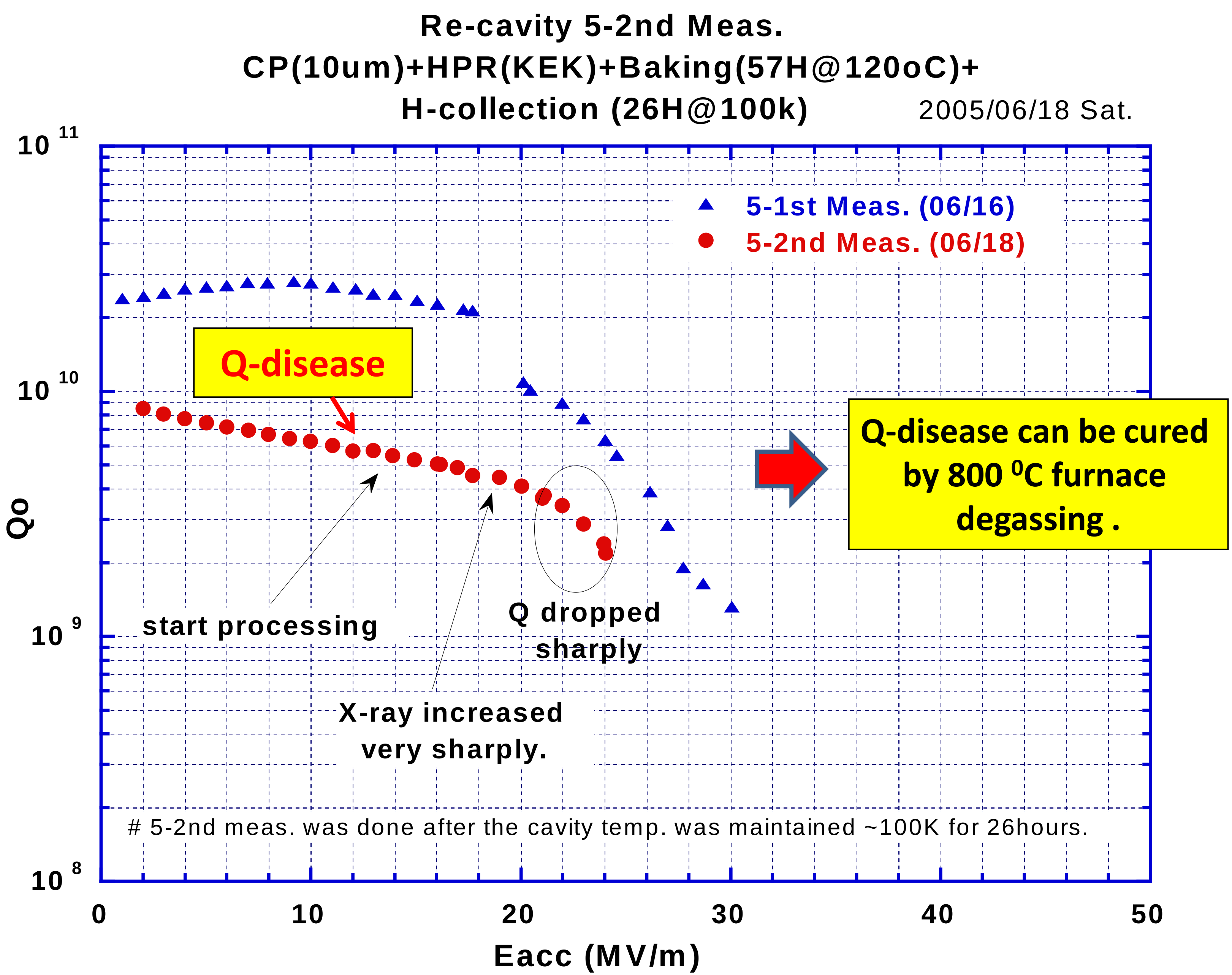
Q-drop was recovered by in-situ baking



Buffered Chemical Polished(1:1:1)

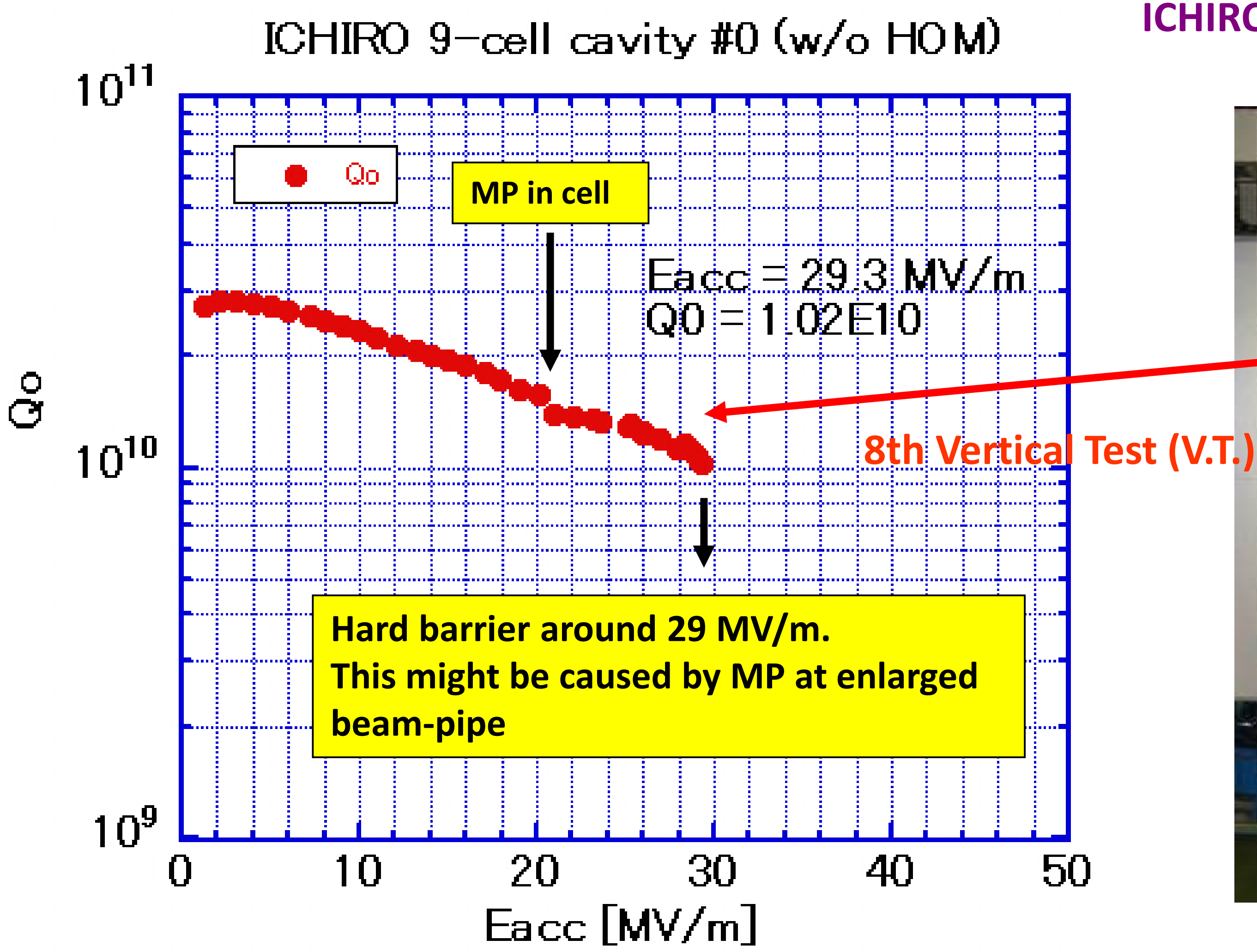
How to cure bad cavities (1/2)



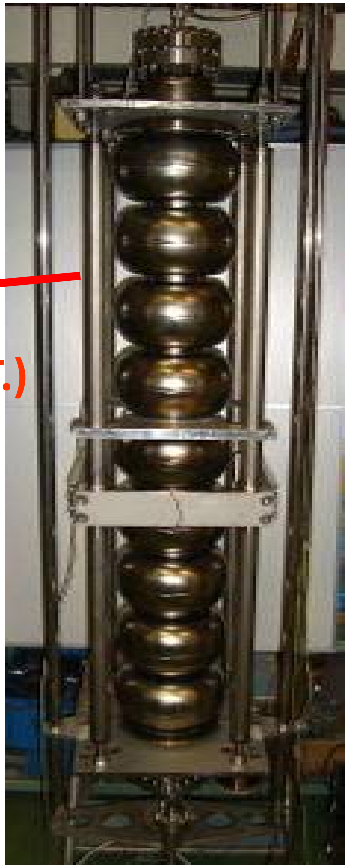


Re-cavity 5-2nd Meas.
CP(10um)+HPR(KEK)+Baking(57H@120oC)+
H-collection (26H@100k)
2005/06/18 Sat.
5-1st Meas. (06/16)
5-2nd Meas. (06/18)
Q-disease
Q-disease can be cured by 800 ⁰C furnace degassing .
start processing
Q dropped sharply
X-ray increased very sharply.
5-2nd meas. was done after the cavity temp. was maintained ~100K for 26hours.
Qo
Eacc (MV/m)
10 11
10 10
10 9
10 8
0
10
20
30
40
50

ICHIRO 9-cell 1st cavity (#0) w/o HOM



ICHIRO 9-cell 1st Cavity #0 w/o HOM

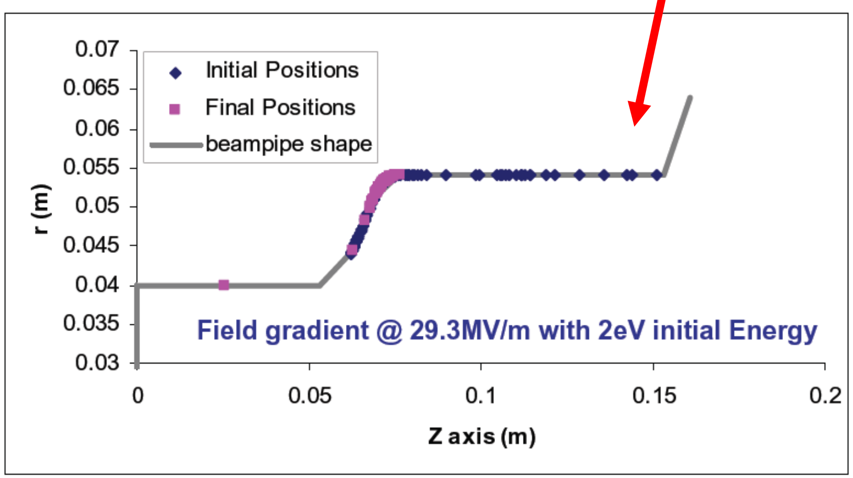


No Q-disease was found.

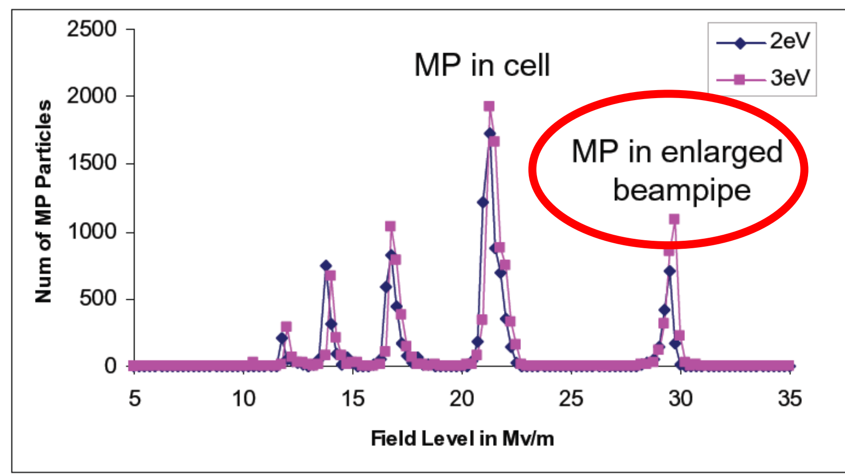
Multi-pacting simulations by L. Ge at SLAC

Multi-pacting points were found at the taper part of enlarged beam-pipe from simulation.

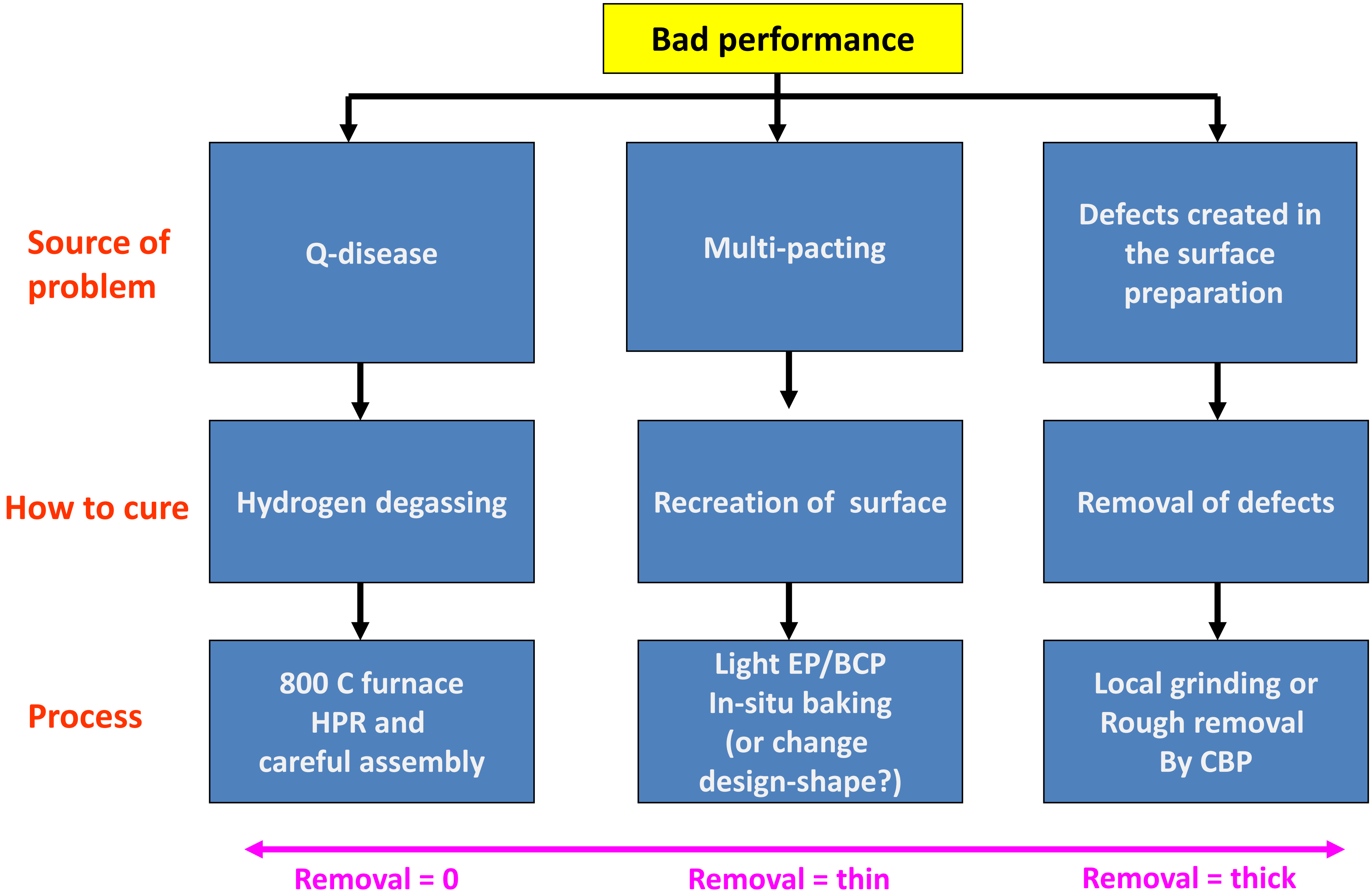
- MP Particles Distribution (surviving 50 impacts)



- MP in end-group of ICHIRO Cavity with enlarged beam-pipe



How to cure bad cavities (2/2)



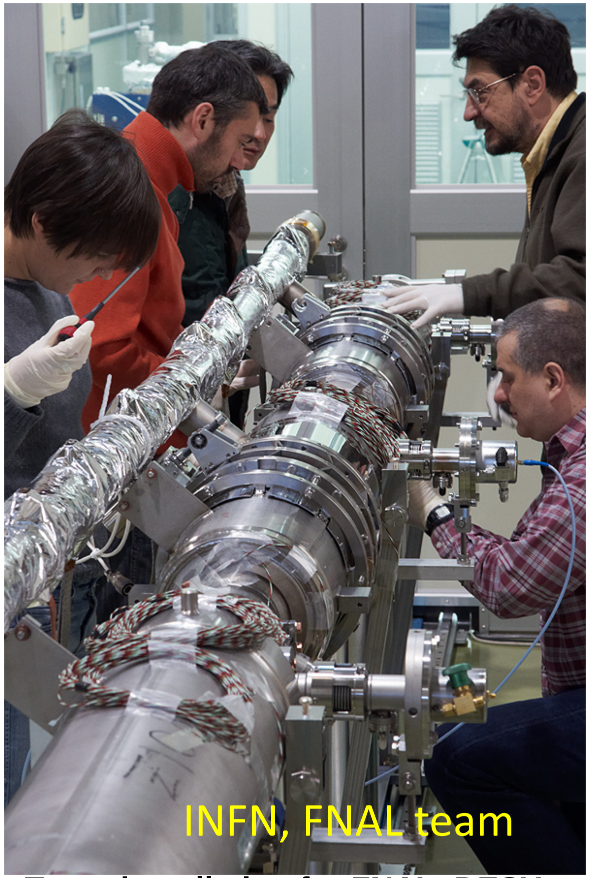
Cavities assembly for Cryomodule C

Two cavities from FNAL, two cavities from DESY,

FNAL, DESY team assembled 4 cavities, INFN, FNAL team installed blade tuners and Saclay tuners.

Tug Arkan
Brian Smith
Marco Battistoni
Manuela Schmoekel
Patrick Schilling

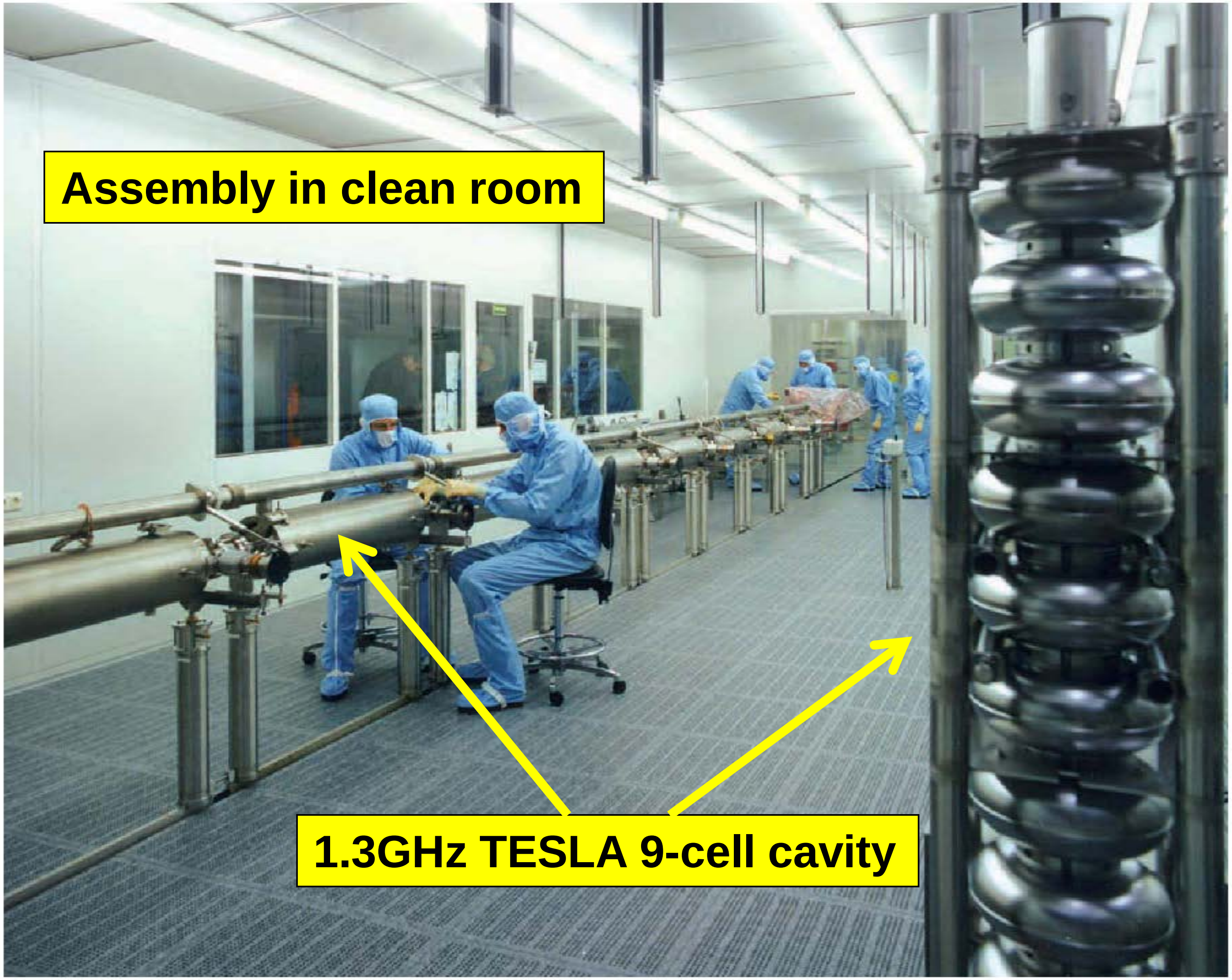
cavity connection in clean room for module installation



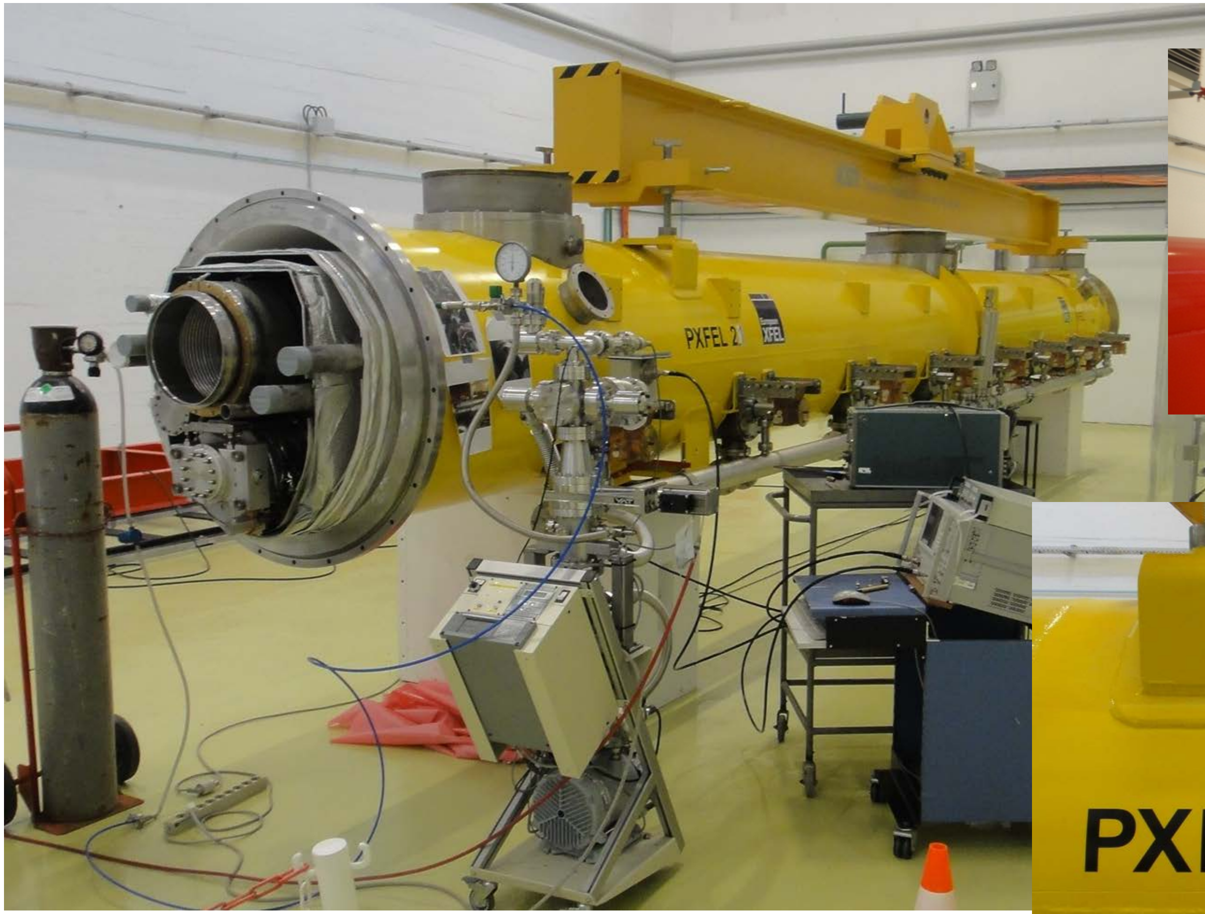
Tuner installation for FNAL, DESY cavities at outside of clean room

Carlo Pagani
Angelo Bosoti
Rocco Pararella
Serena Barbanotti

Cavity-String Assembly in Clean Room (DESY)



Saclay (March 2011)

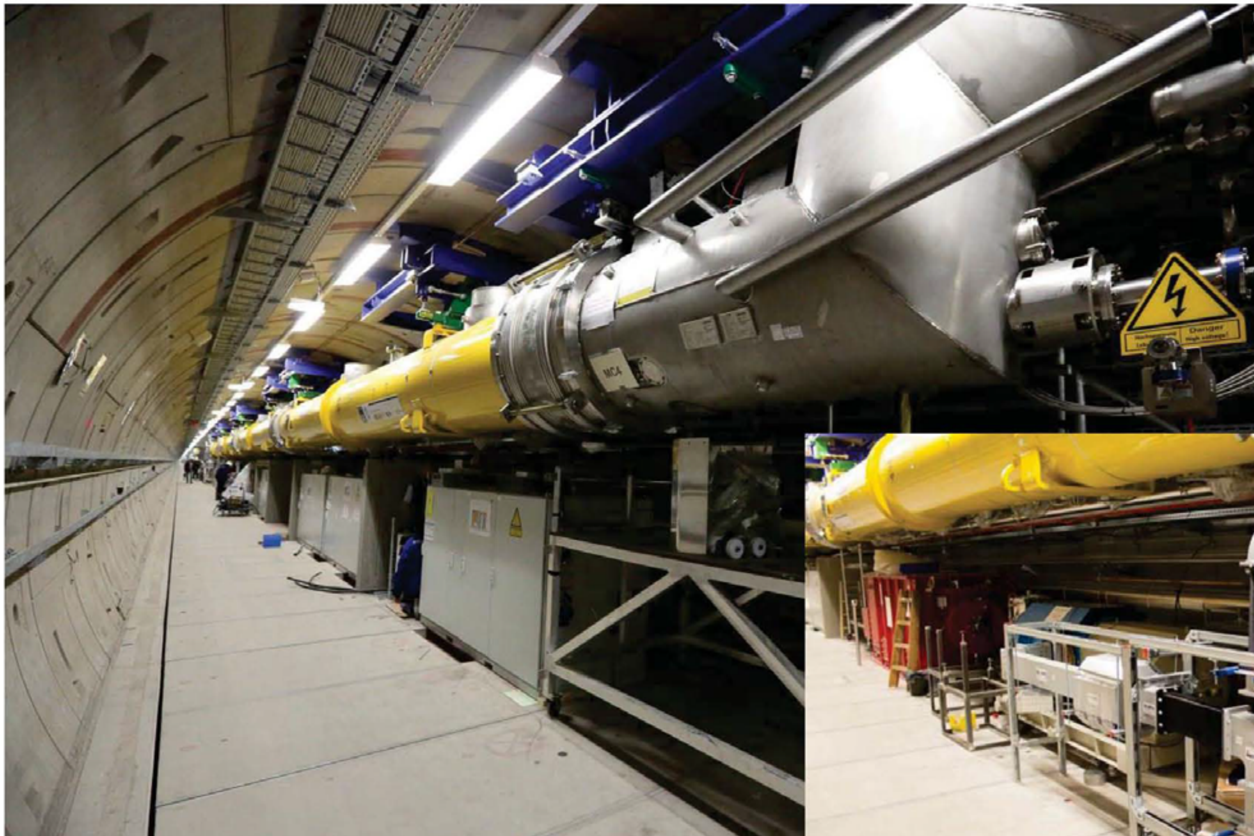


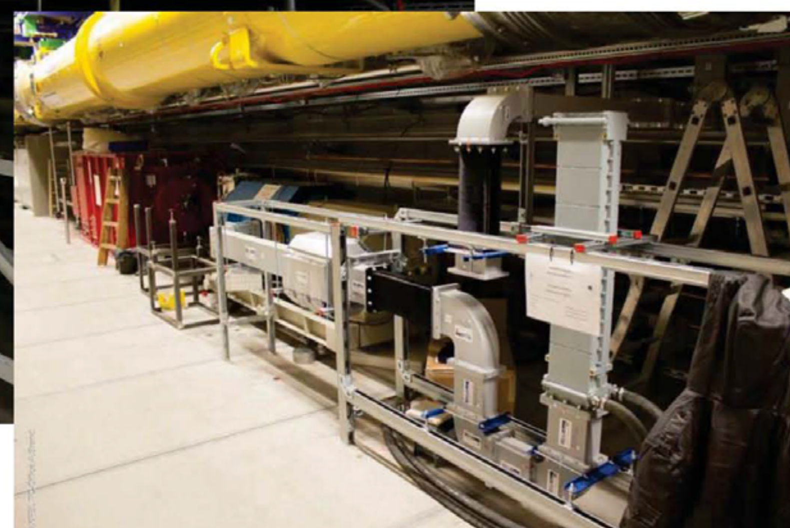
7 March 2011 at Saclay

PXFEL 2.1 (DESY >>> Saclay >>> transportation to DESY within a few weeks)

European XFEL

The finished L1 section

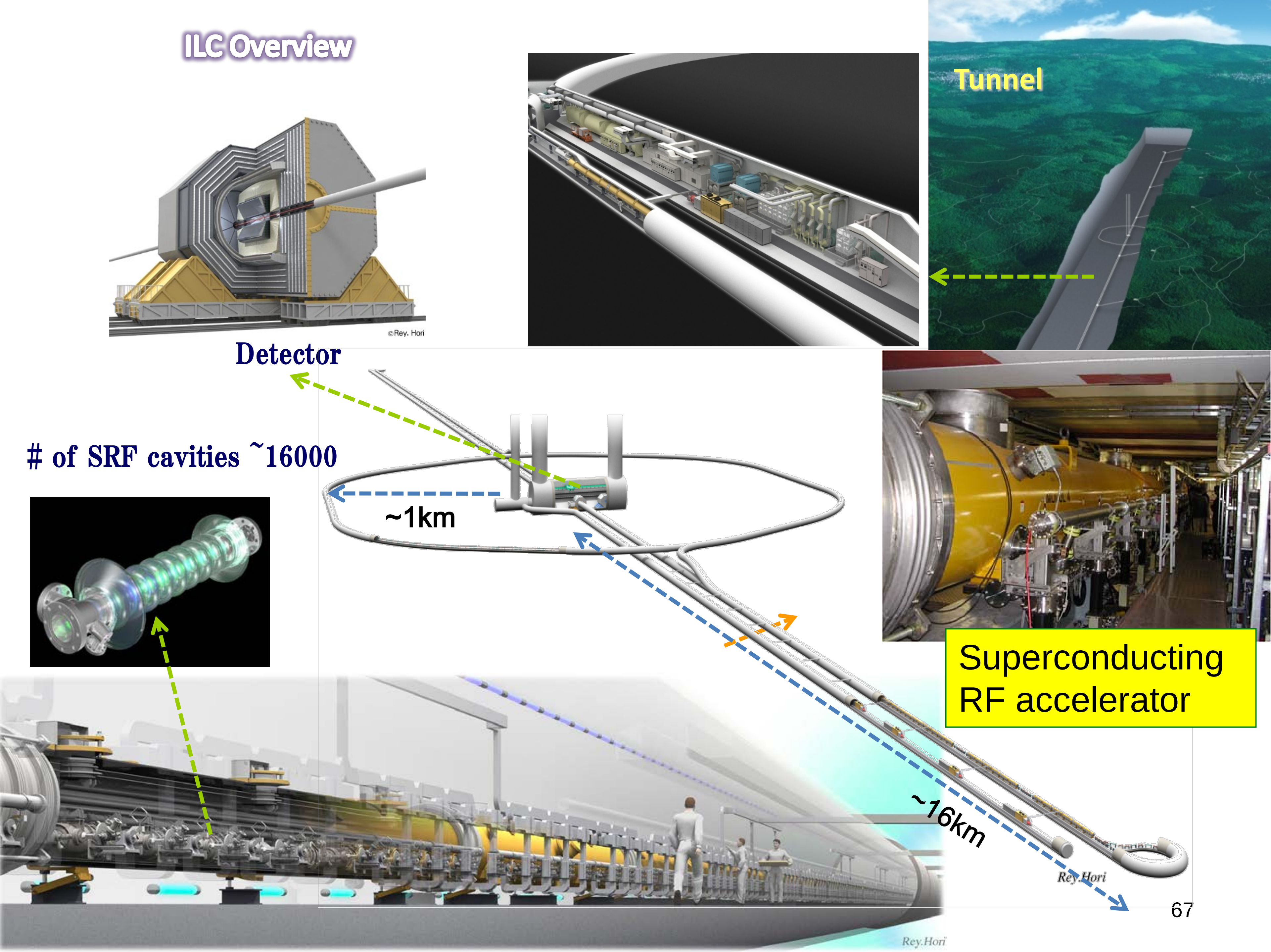




Lecture B2 and C3a: Superconductive RF

Industrialization and Challenges

ILC Overview



ILC Cost Breakdown (RDR)

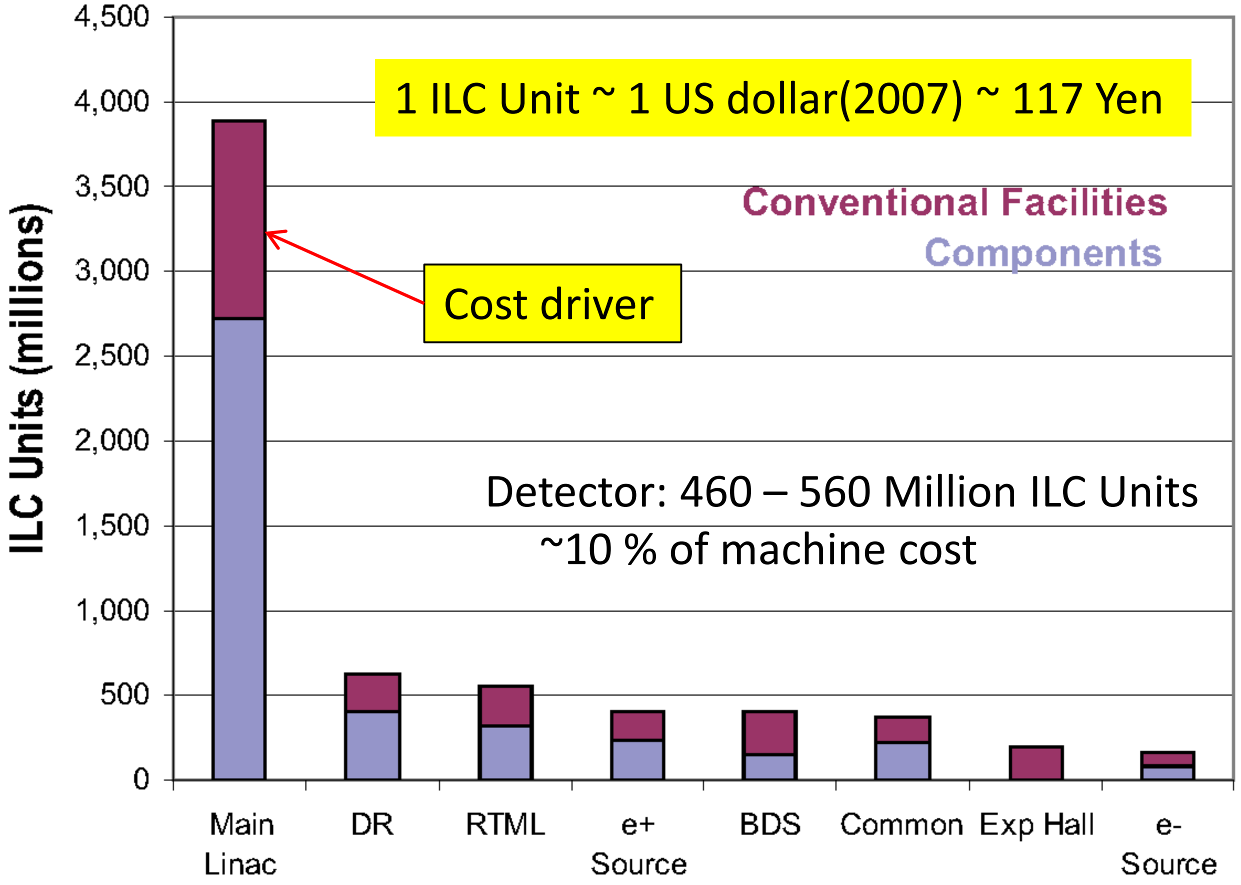
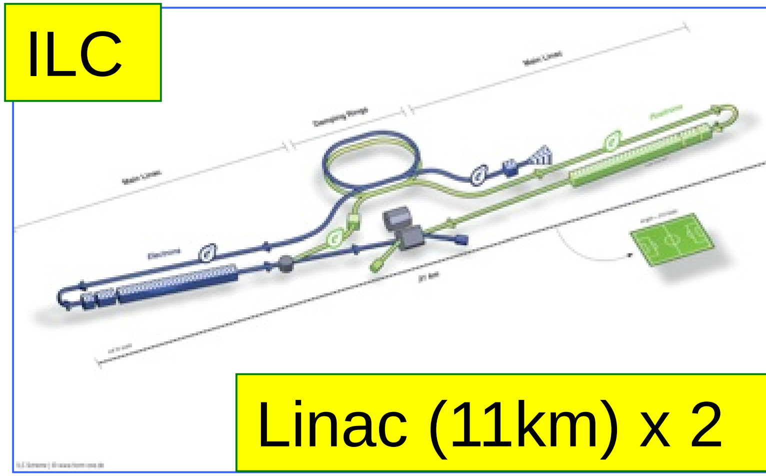


FIGURE 6.2-1. Distribution of the ILC value estimate by area system and common infrastructure, in ILC Units. The estimate for the experimental detectors for particle physics is not included. (The Conventional Facilities estimates have been averaged over the three regional site estimates.)

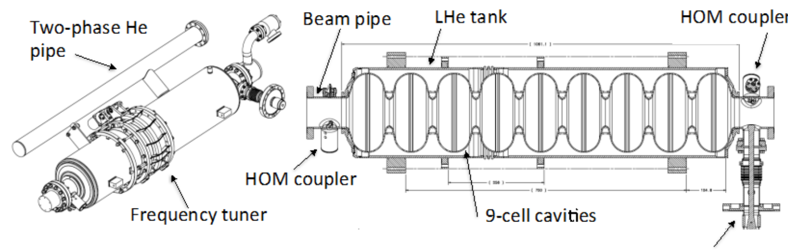
SCRF Industrialization required for ILC

Parameters	Value
C.M. Energy	500 GeV
Peak luminosity	1.5 x10^{34} $cm^{-2}s^{-1}$
Beam Rep. rate	5 Hz
Pulse duration	0.73 ms
Average current	5.8 mA (in pulse)
Av. field gradient	31.5 MV/m +/-20% Q_0 = 1E10
# 9-cell cavity	16,024 (x 1.1)
# cryomodule	1,855
# Klystron	~400

ILC



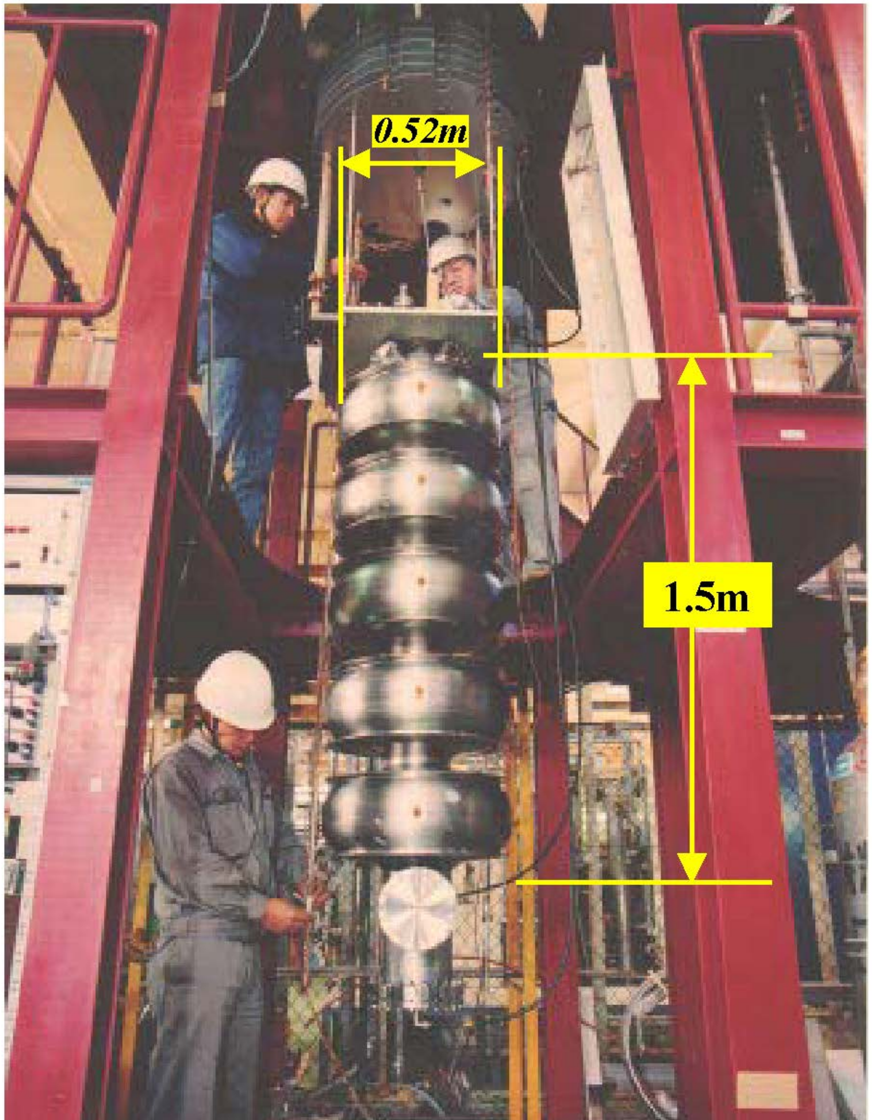
Linac (11km) x 2



High quality

16024 x 1.1(Yield = 90%)
~ 17600 cavities of mass-production

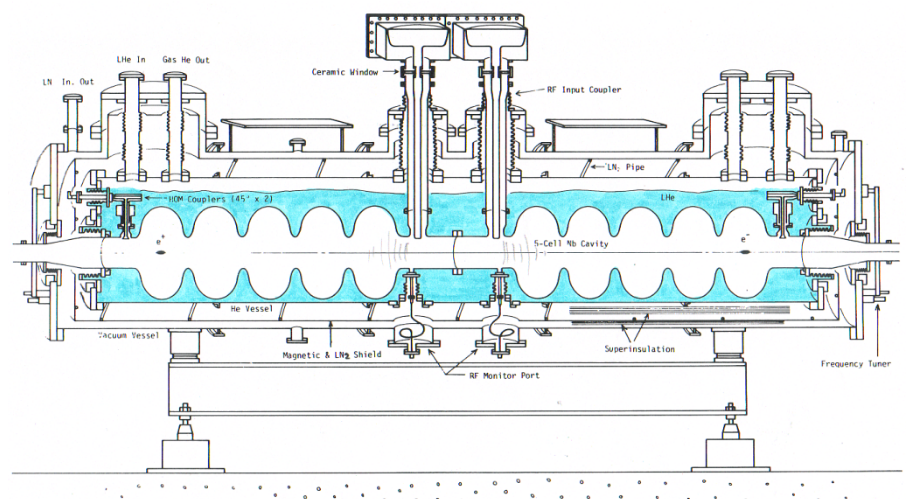
History of SRF Cavity
TRISTAN @ KEK (1988 – 1995)



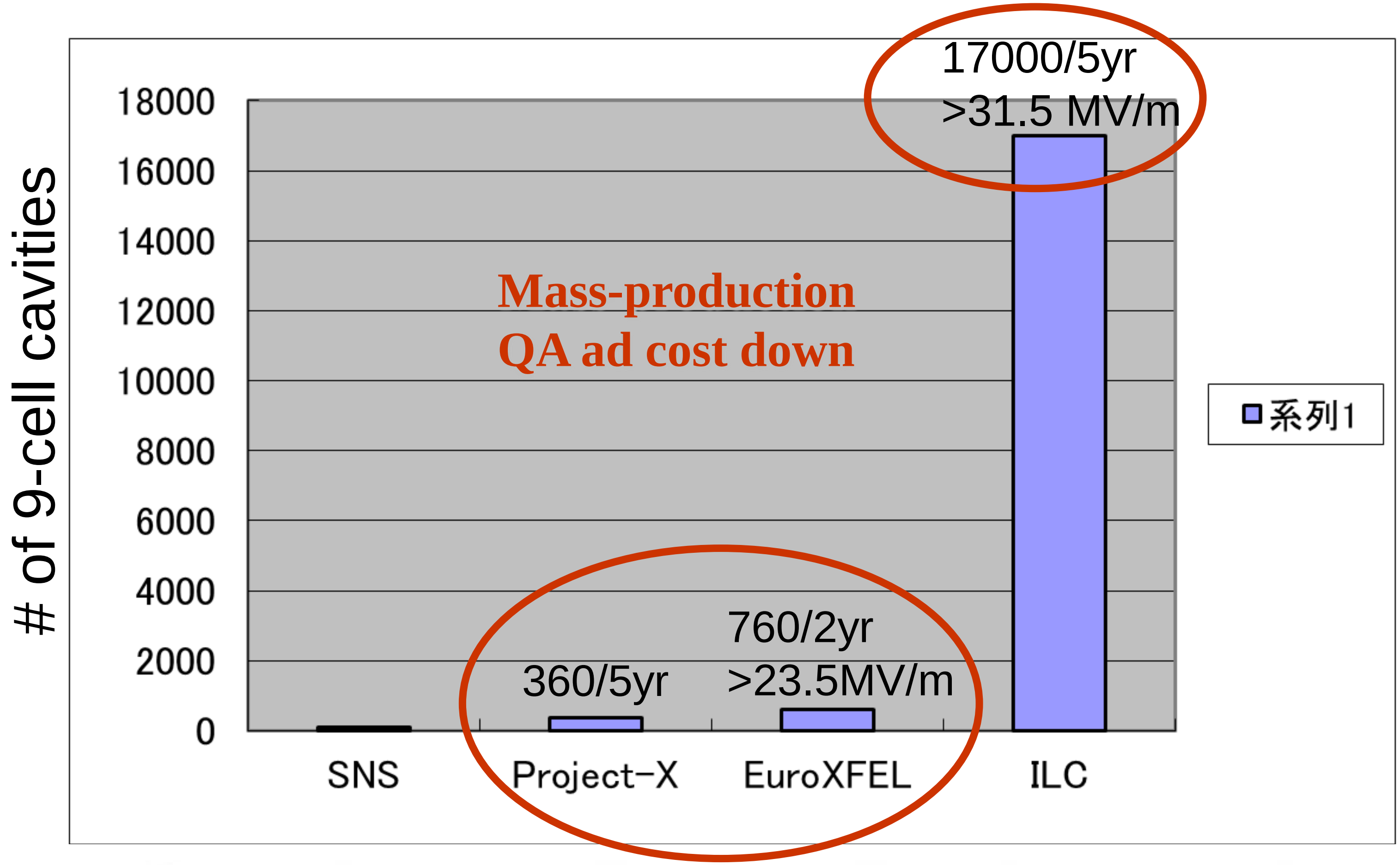
History of SRF cavity at KEK

SRF Cavity in TRISTAN
Bulk-Nb 508MHz 5-Cell Cavity

The first mass-production of SRF Cavities in the world.
32 SRF cavities were fabricated and operated in TRISTAN.



Fabrication of cavities in ILC

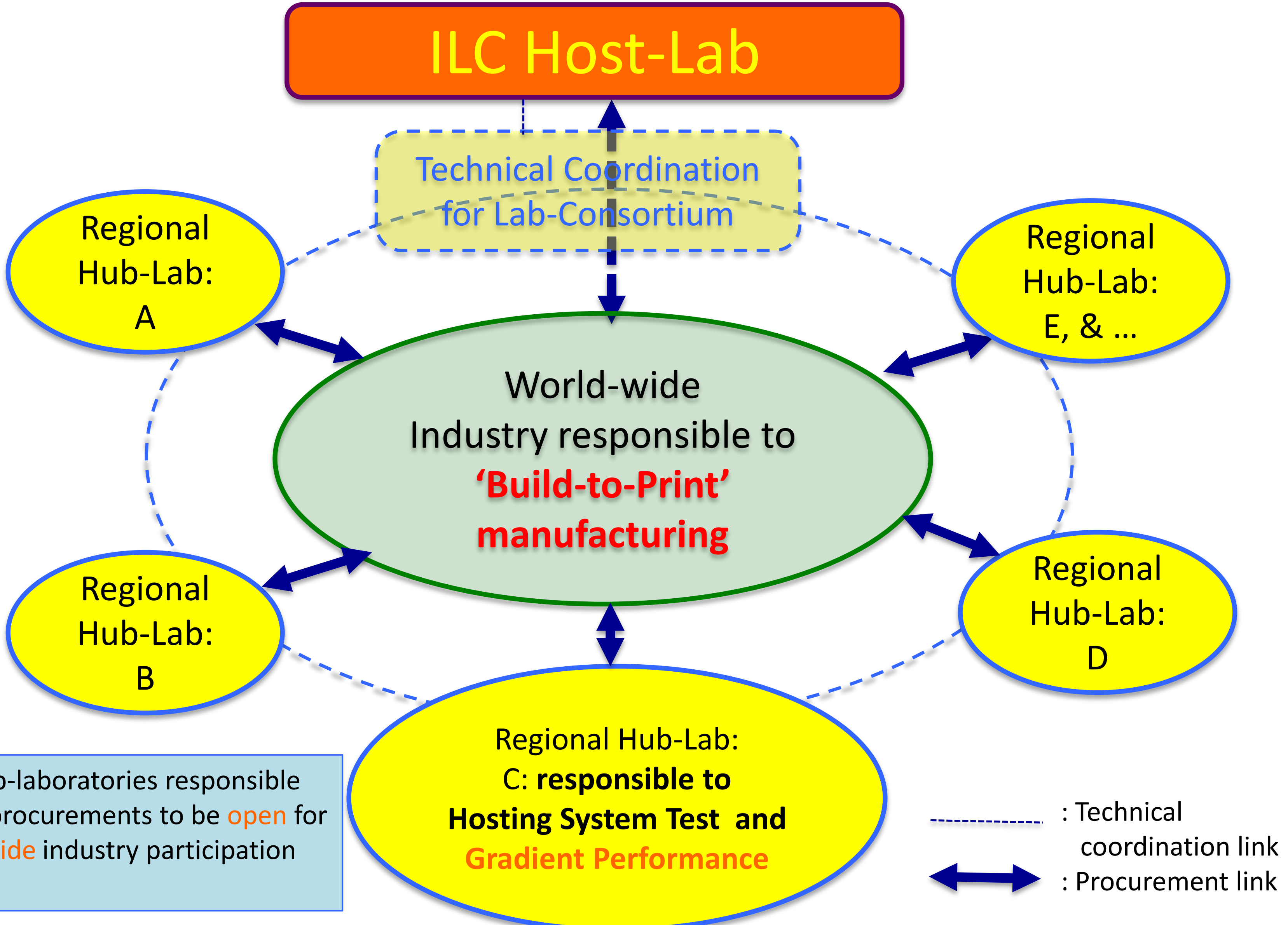


Toward Industrialization

- Global status of Industries
  - Research Instruments (ACCEL) and Zanon in Europe
  - AES, Niowave, Roak, PAVAC in Americas
  - MHI, Hitachi, Toshib, and others in Asia

Project Scope	# of Cav.		Assuming 200 work-days/yr
SNS	~ 110	3years	< ~ 1 cavity / week
XFEL → ÷ 2 vendors	~760	2 years	380/yr : ~ 1.9 cavity/day → 0.95 /day/vendor
Project X	~360	4-5 years	72/yr : 1.8 cavity / week
ILC			
Single vendor model	~15,500 + spare	5 years	~3100/yr → 16/day ~3400/yr → 17/day
6 vender model (3 regions x 2)	same	same	→ ~ 570/yr → 2.8/day/vendor

SCRF Procurement/Manufacturing Model



Regional hub-laboratories responsible to regional procurements to be open for any world-wide industry participation

Slide by A. Yamamoto

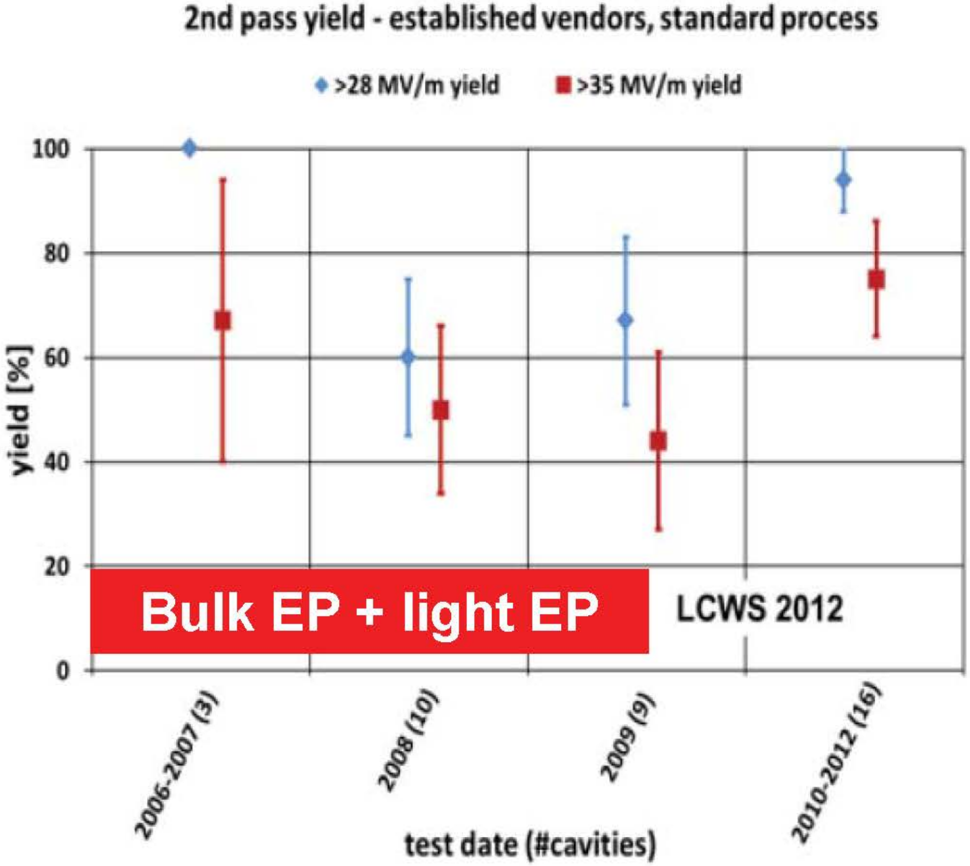
Visiting Companies in Progress

(and further plan)

	Date	Company	Place	Technical sbject
1	2/8	**Hitachi**	Tokyo (JP)	Cavity/Cryomodule
2	2/8	**Toshiba**	Yokohana (JP)	Cavity/Cryomodule, Magnet
3	2/9	**MHI**	Kobe (JP)	Cavity / (Cryomodule)
4	2/9	**Tokyo-Denkai**	Tokyo (JP)	Material (Nb)
5	2/18	**OTIC**	NingXia (CN)	Material (Nb, NbTi, Ti)
6	3/3	**(Zanon) mtg at INFN**	Verona (IT)	Cavity/(Cryomodule)
7	3/4	**RI**	Koeln (DE)	Cavity (Cryomodule)
8	3/14, (4/8)	**AES**	Medford, NY (US)	Cavity (Cryomodule)
9	3/15, (4/7)	**Niowave**	Lansing, MI (US)	Cavity/ (Cryomodule)
10	4/6	**PAVAC**	Vancouver (CA)	Cavity, EBW-machine
11	4/25	**ATI Wah-Chang**	Albany, OR (US)	Material (Nb, Nb-Ti, Ti)
12	4/27	**Plansee**	Ruette (AS)	Material (Nb, Nb-Ti, Ti)
13	5/24	**SDMS**	Sr. Romans (FR)	Cavity, Vessel, joint
14	7/6	**Heraeus**	Hanau (DE)	Material (Nb, Nb-Ti, Ti)
15	9/14	**Zanon**	Verona (IT)	Cryomodule
16	11/16	**SST**	Munchen (DE)	EBW-machine

Slide by A. Yamamoto

Progress in SCRF Cavity Gradient



Production yield:
94 % at > 28 MV/m,

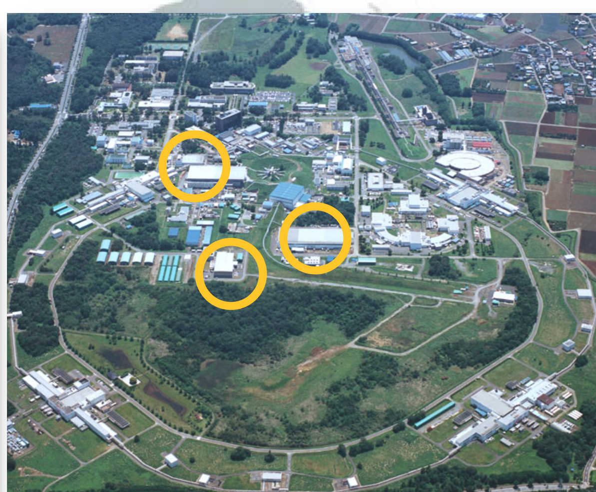
Average gradient:
37.1 MV/m

reached (2012)

Presented by A. Yamamoto, IPAC13

Main Laboratories for ILC R&D in the world

FLASH@DESY



STF@KEK

ILCTA@FNAL

Accelerator technology - collaborative effort

Industrial study module assembly (M6 done, M8 autumn 2007)

2 more cryostats (TTF3/INFN) delivered

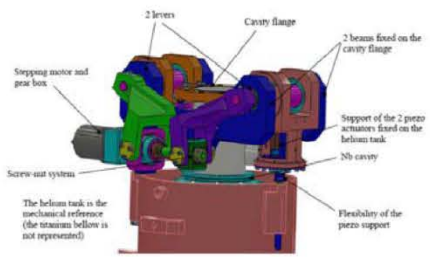
Superferric magnet (CIEMAT)

BPM (Saclay)

Integrated HOM absorber

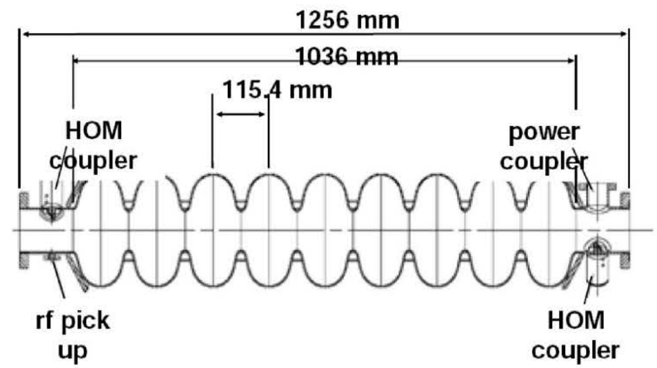
# of 9-cell cavities = 760

Length quantized n·λ/2 (possibility of ERL)

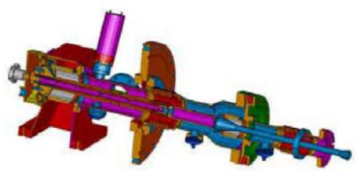


Tuner w/piezo (Saclay)

Industrialization in preparation



LLRF development (collab. Warsaw/Lodz)



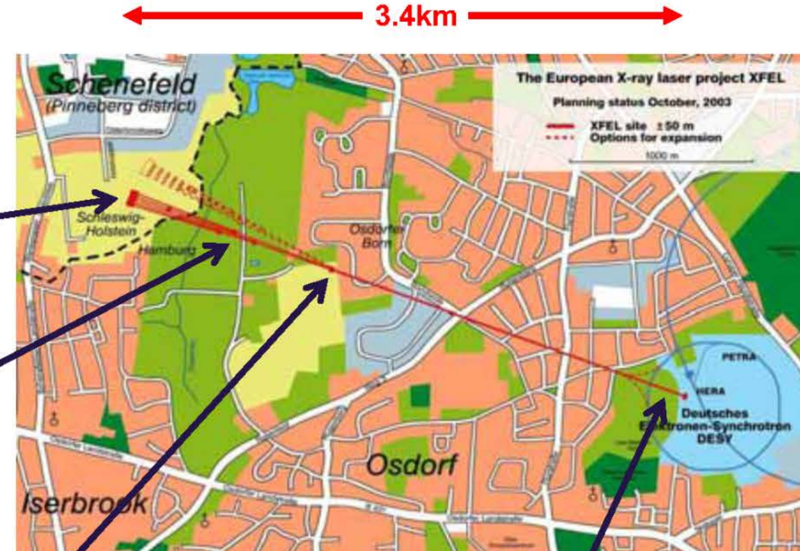
TTF3-type coupler

Industrialization launched (Orsay)

Almost the same technology as ILC

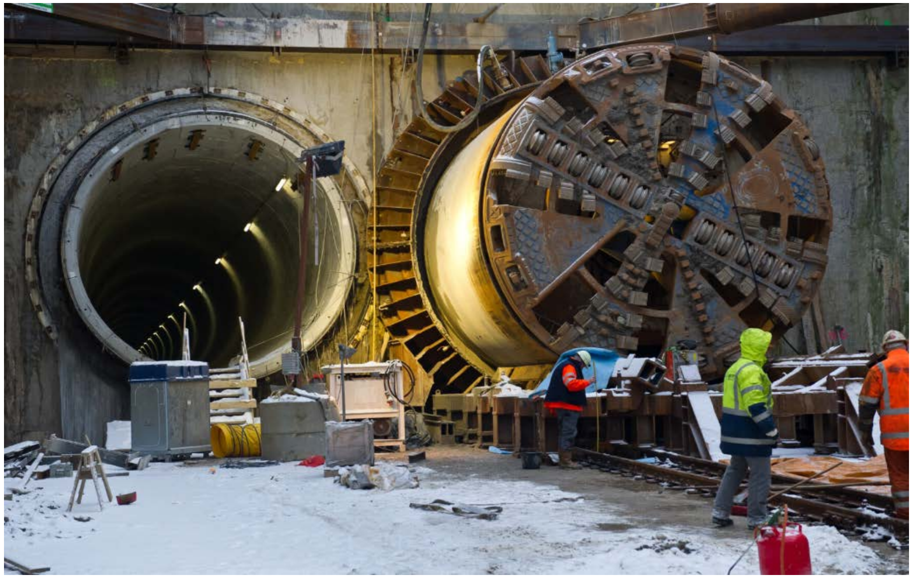
European XFEL

Civil Construction for the European XFEL

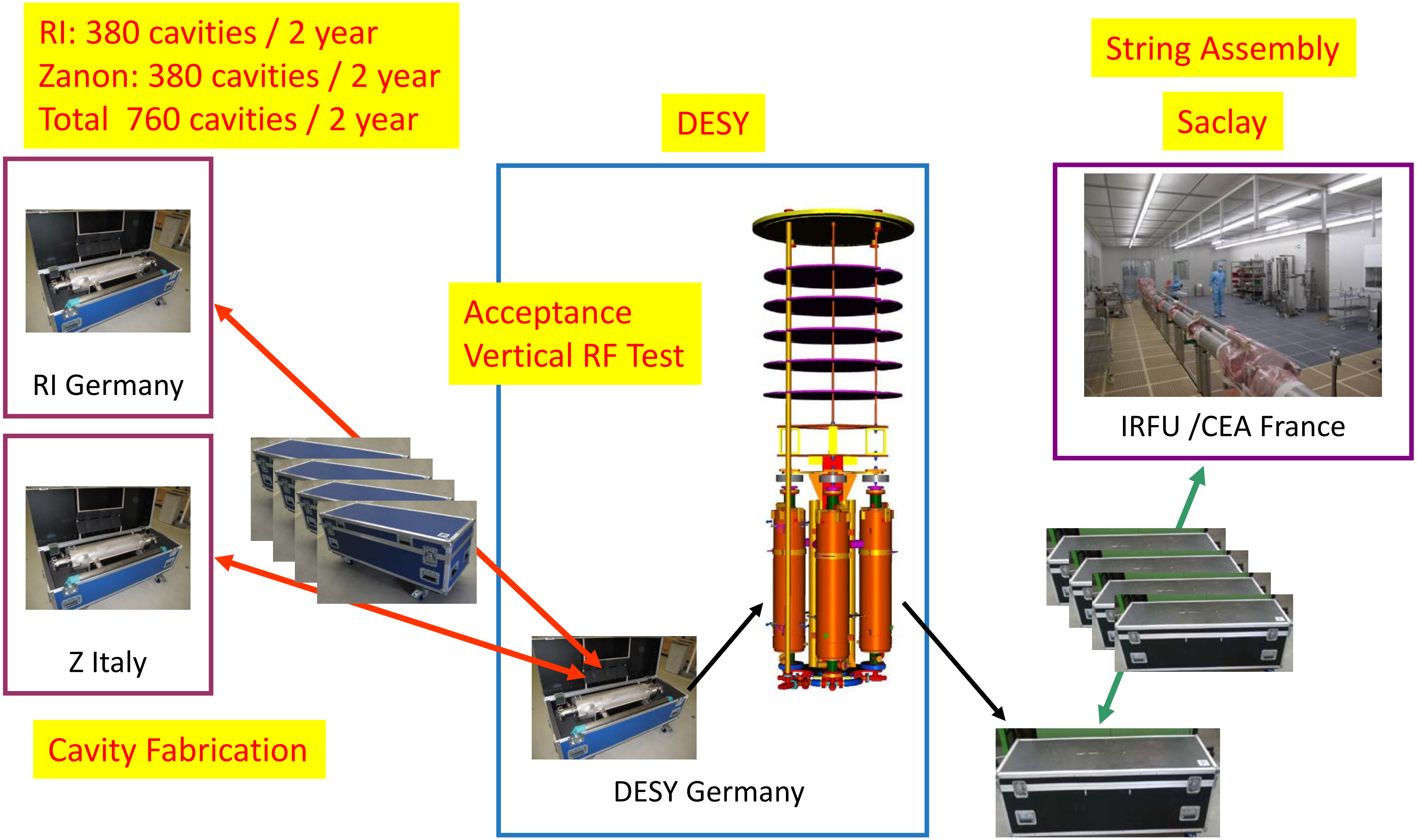


Slide by H. Weise

Civil Construction



Slide by H. Weise



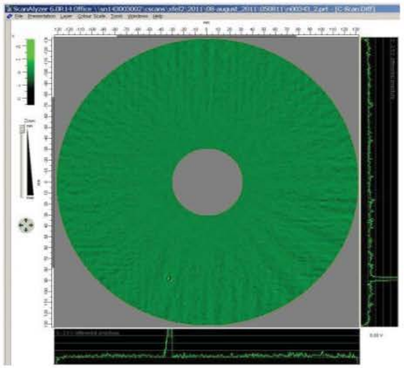
DESY takes care of installation / dismounting of cavities into / from test insert
Transport to CEA in transport boxes as well

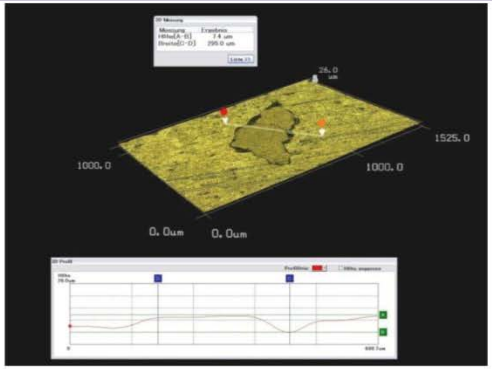
Slide by H. Weise

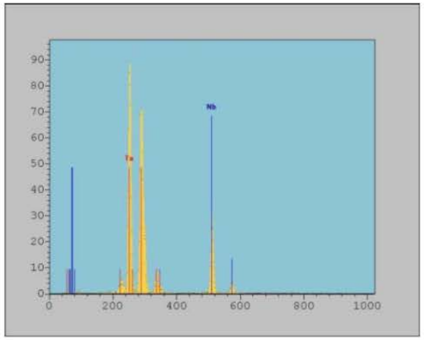
Status of Euro-XFEL (E.U.)

European XFEL

One example of foreign material inclusion (Ta) in the Nb sheets. For details see MOP050, MOP032

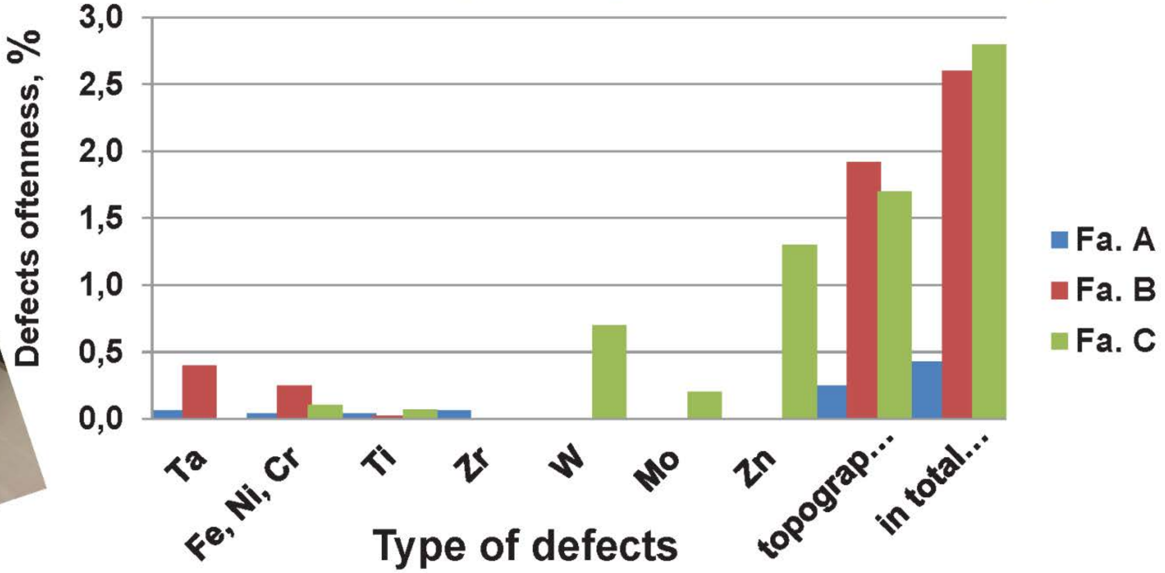






Example: Eddy-Current scan, 3D -Microscope image and element analysis

Statistic:
Comparison of detected defects in Nb-sheets for different suppliers



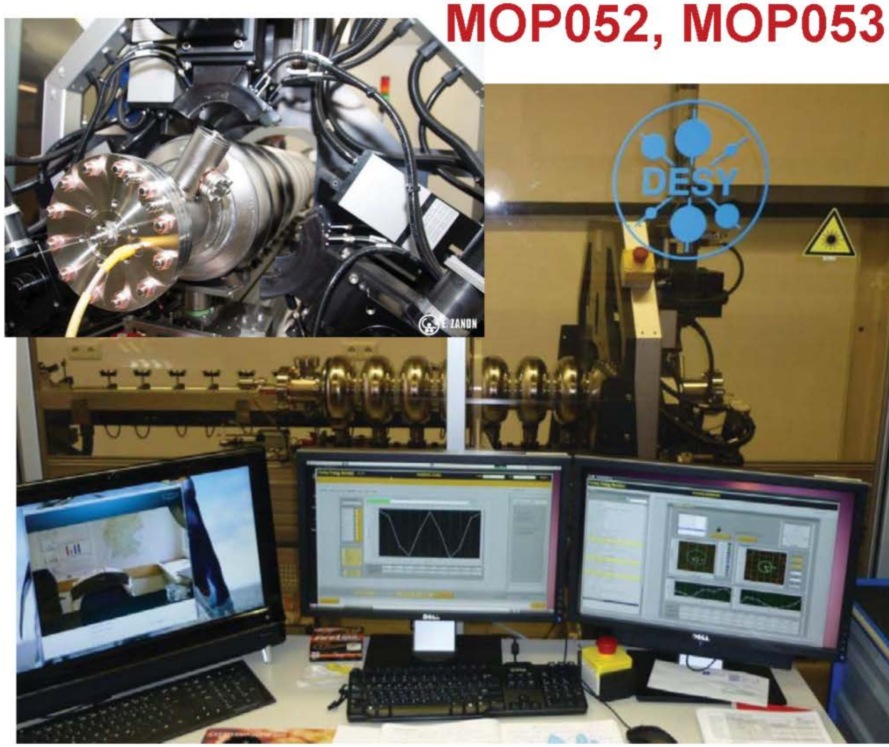
Slide by W. Singer / DESY

Status of Euro-XFEL (E.U.)

European XFEL

DESY developed, build and installed at both companies the Cavity Tuning Machine CTM and Equipment for RF measurement of half-cells, dumb-bells and end-groups HAZEMEMA

Service is in DESY responsibility. Equipment has to be robust, required trained personal that has special background. **MOP051, MOP052, MOP053 A. Sulimov et al**



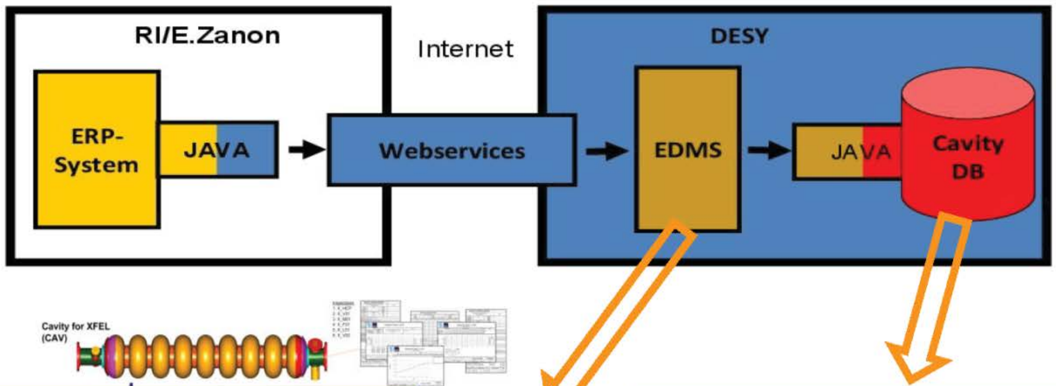
Cavity Tuning Machine CTM installed at RI

HAZEMEMA installed at EZ

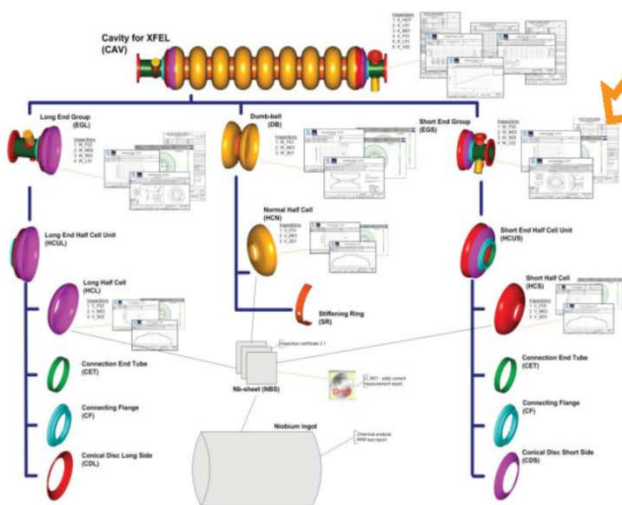
Status of Euro-XFEL (E.U.)

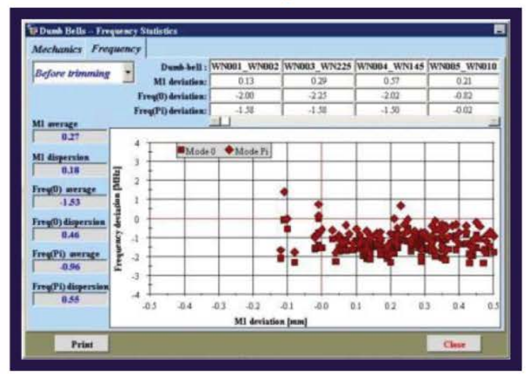
European XFEL

QM and Documentation : EDMS, Data Bank for statistic.
Automated transfer of documents/data from System to System.
Paperless documentation



EDMS product breakdown structure for XFEL cavity





XFEL Cavity Data Bank for statistical analysis

All XFEL SC cavity documents (specifications, protocols, PED data etc.) recorded in EDMS. RI and E. Zanon have an access (to relevant data only).
For more see poster MOP035, J. Iversen et al.

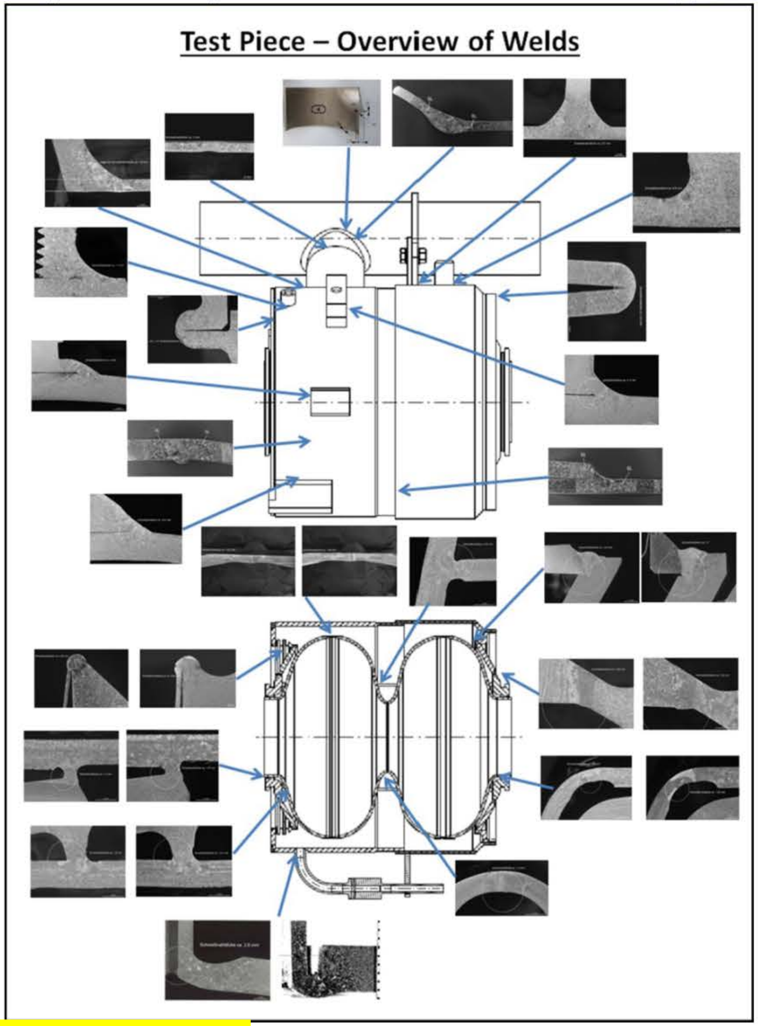
Slide by W. Singer / DESY

Status of Euro-XFEL (E.U.)

European XFEL

Test piece represents all pressure bearing parts: Destructive notified body analysis. MOP048

- Test piece (TP) is composed by 2 cell with helium vessel, representing all pressure bearing parts and welding seams.
- It is built using the same welding parameters that will be used in the series production.
- Two EBW machines/company. Consequently two test pieces had been built per company and destructively tested by TUEV NORD.
- Previously DESY has done similar tests on real cavities and gave the feed back to companies



Slide by W. Singer / DESY

Status of Euro-XFEL (E.U.)

European XFEL

Treatment: European XFEL treatment recipe was worked out on prototype cavities

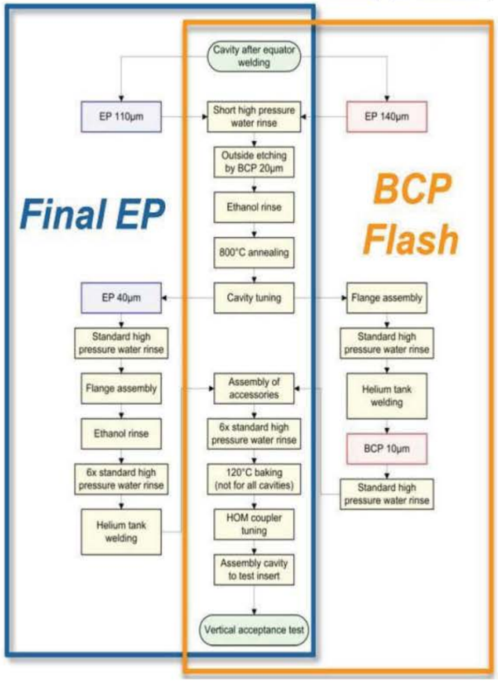
19

Prior surface treatment.

EP 110-140 μm (main EP), outside BCP, ethanol rinse, 800° C annealing, tuning

Final surface treatment - two alternative options

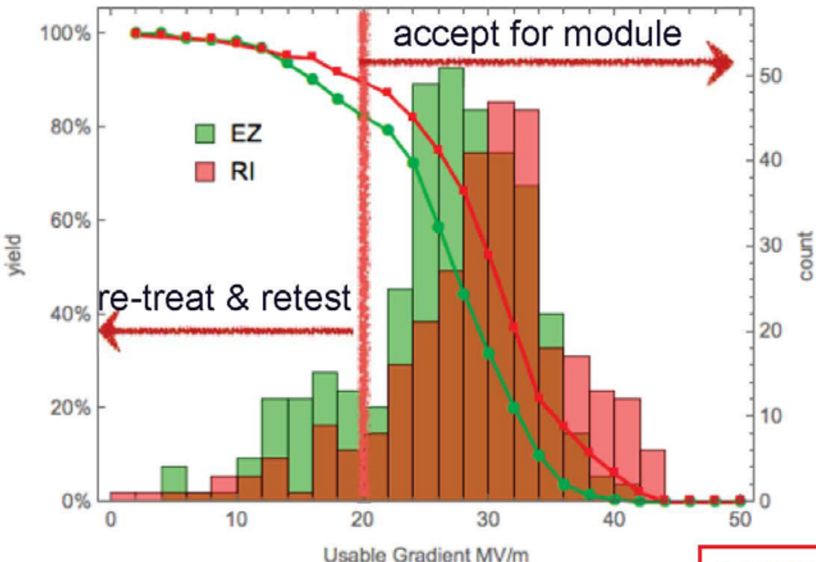
1. Final EP of 40 μm, ethanol rinse, high pressure water rinsing (HPR) and 120° C bake
2. Final BCP of 10 μm (BCP Flash), HPR and 120° C bake.



Integration of the helium tank, assembly of HOM, pick up and high Q antennas and shipment to DESY for 2K RF acceptance test

Slide by W. Singer / DESY

Results: Usable Gradient “As received”



	RI	EZ	Total
Tests	303	358	661
G_{AVG} (MV/m)	29.4	26.3	27.7
G_{RMS} (MV/m)	7.4	6.8	7.2
yield @ 20MV/m	90%	82%	86%
yield @ 26MV/m	75%	59%	66%
yield @ 28MV/m	66%	44%	54%

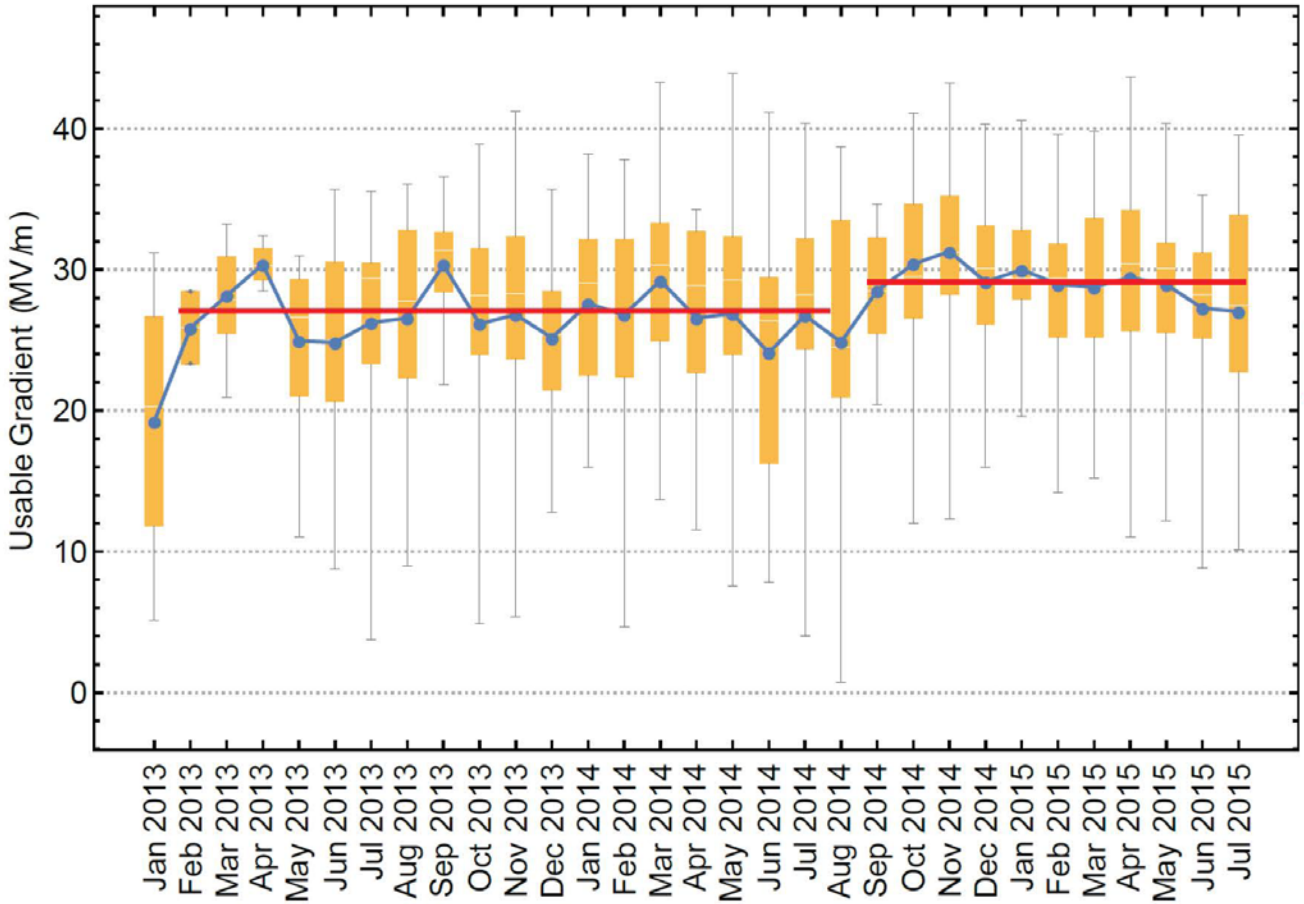
MOPB086

- Both vendors well above Spec
- RI shows ~ 3MV/m in average more than EZ:
  a) final EP
  b) low gradient quenches at EZ
- In general, first re-treatment is a standard High-Pressure Rinse (or “special” handling at vendor)
- Several cavities with < 20 MV/m accepted, especially if
  a) limitation = “bd“ +
  b) no FE

- “Missing” 75 cavities?
  Not included in “as received”, because “retreatment at vendor” necessary before first RF test

Slide by D. Reschke / DESY (E.U.)

SRF2015: Trend of Usable Gradient "As received"



YES!

Increased Usable Gradient

MOPB086

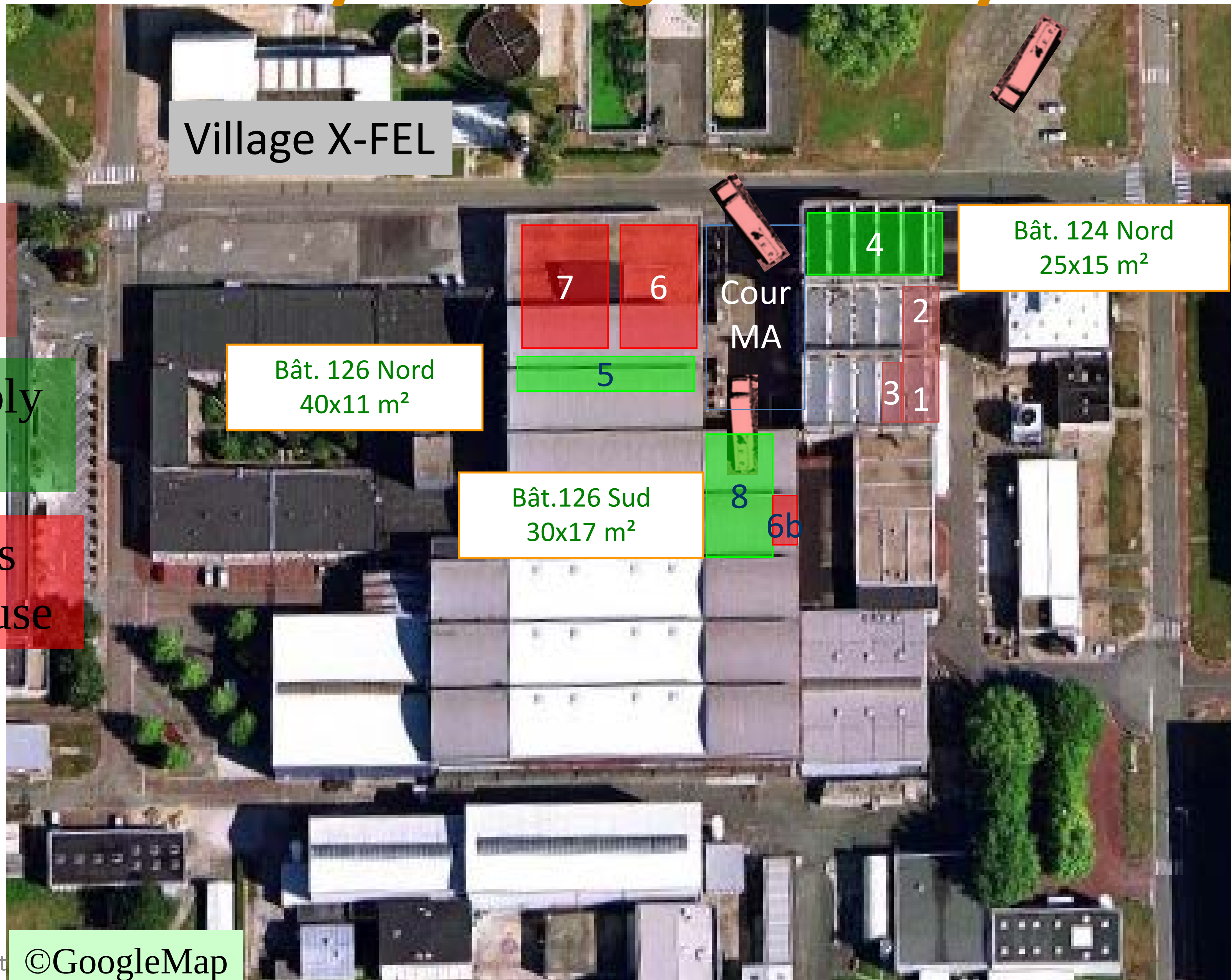
Slide by D. Reschke / DESY (E.U.)

Assembly Buildings at Saclay

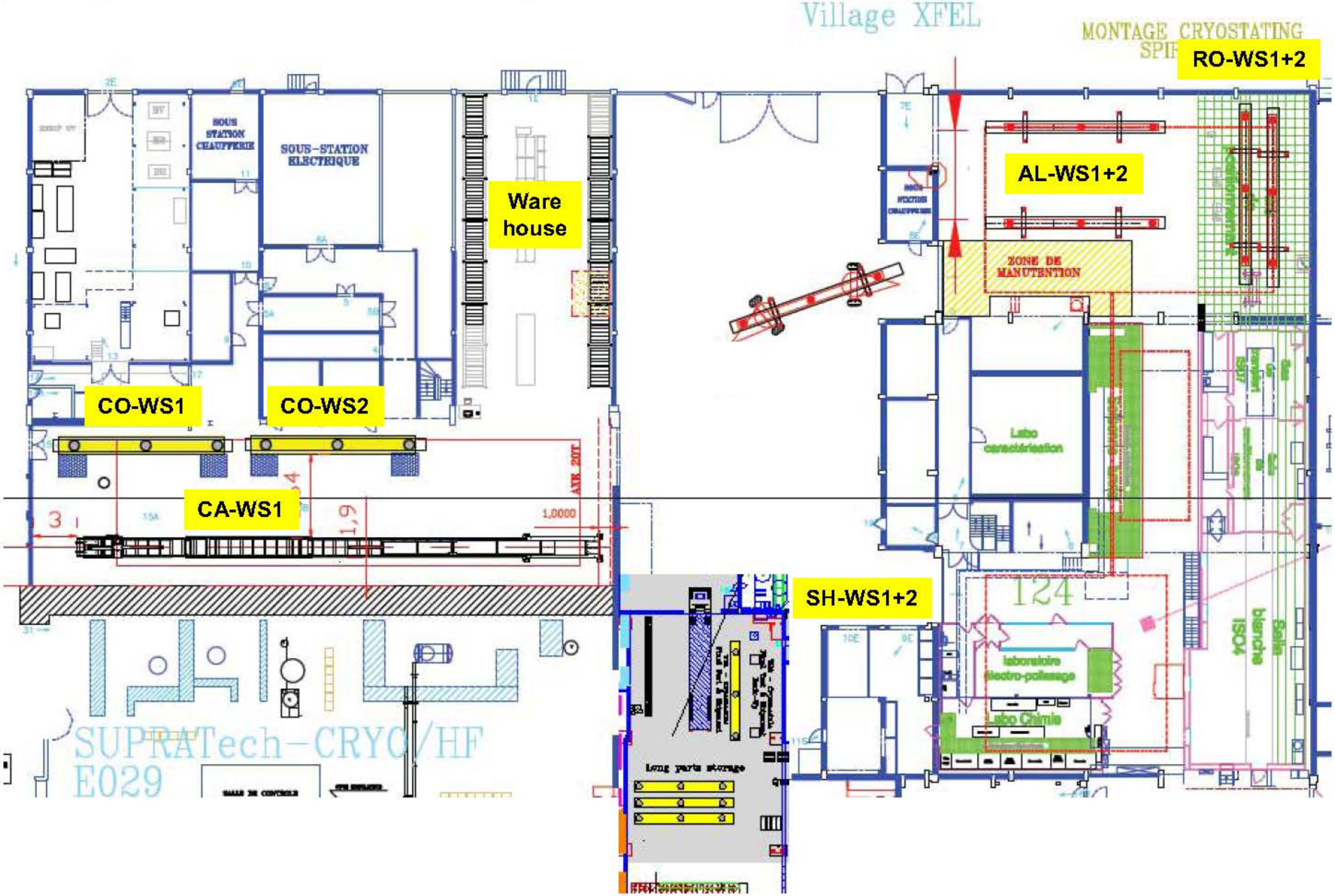
Clean Romm

Assembly Halls

Offices Warehouse



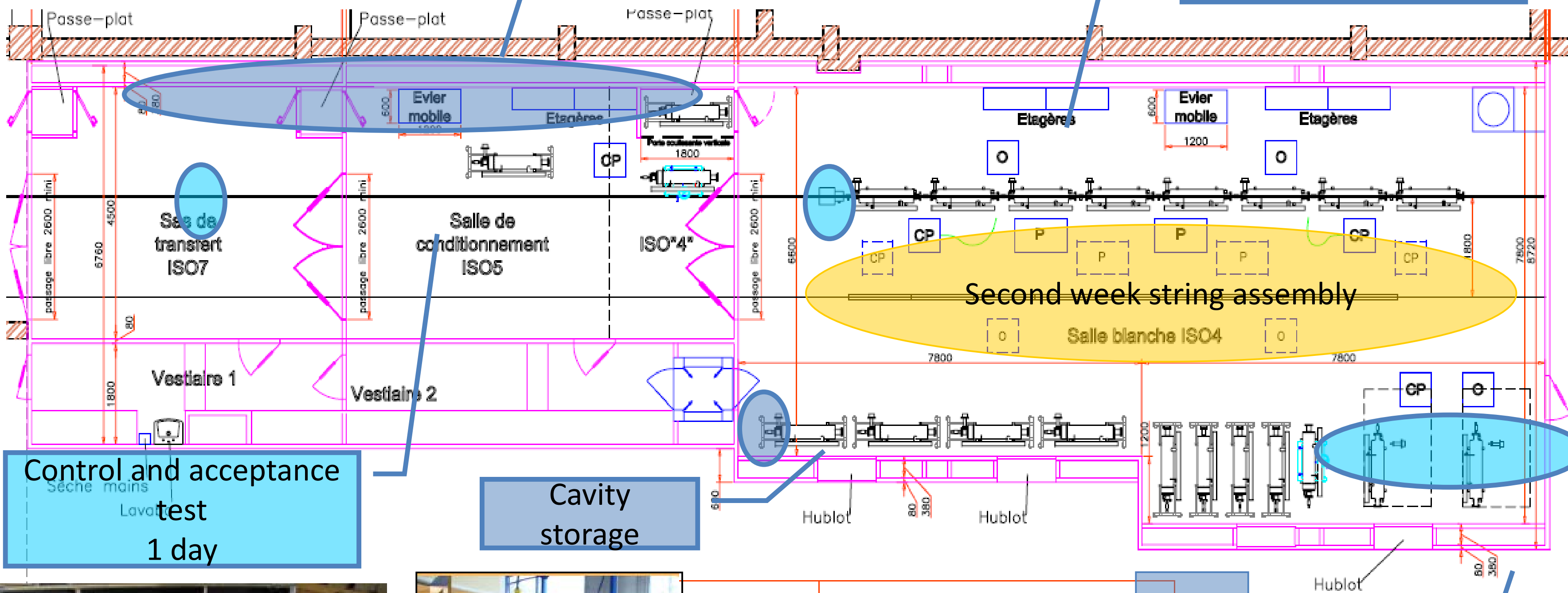
Assembly Hall : Workstations



Clean Room Workstations at Saclay

Unpacking / packing and cleaning pieces

Cavity string assembly (1 string / week)

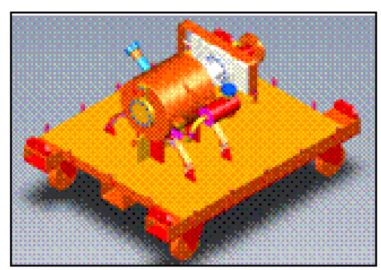


Control and acceptance test
1 day

Cavity storage

Cavity washer

Coupler cold part assembly
(8 cavities / week)



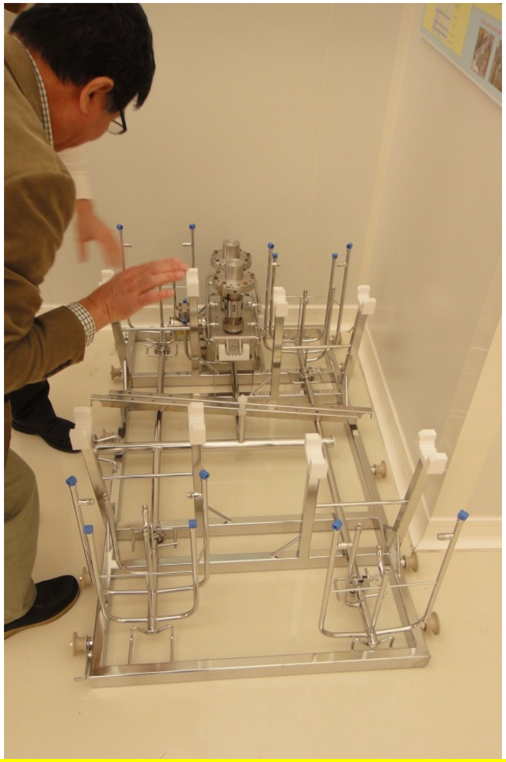
Clean Room constructed (Sept'09)

Saclay

5 Mar. 2012

Saclay(March 2011)

Clean room and low-pressure rinsing system



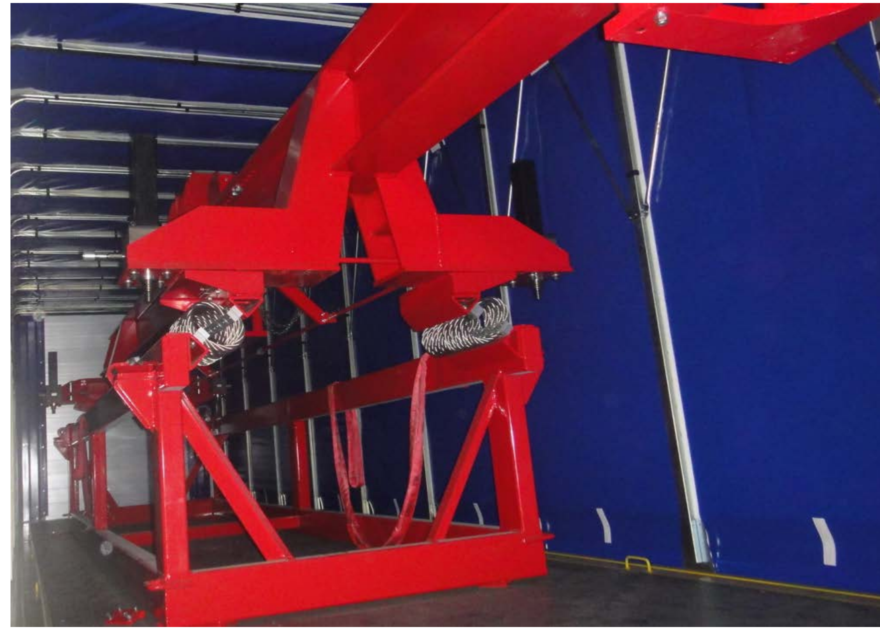
Platform with many nozzles for
Low-pressure rinsing system

High-pressure rinsing system for Spiral-2 cavity

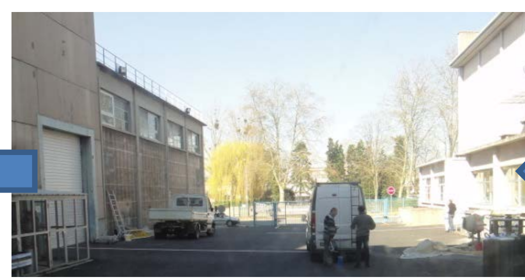
Saclay

5 Mar. 2012

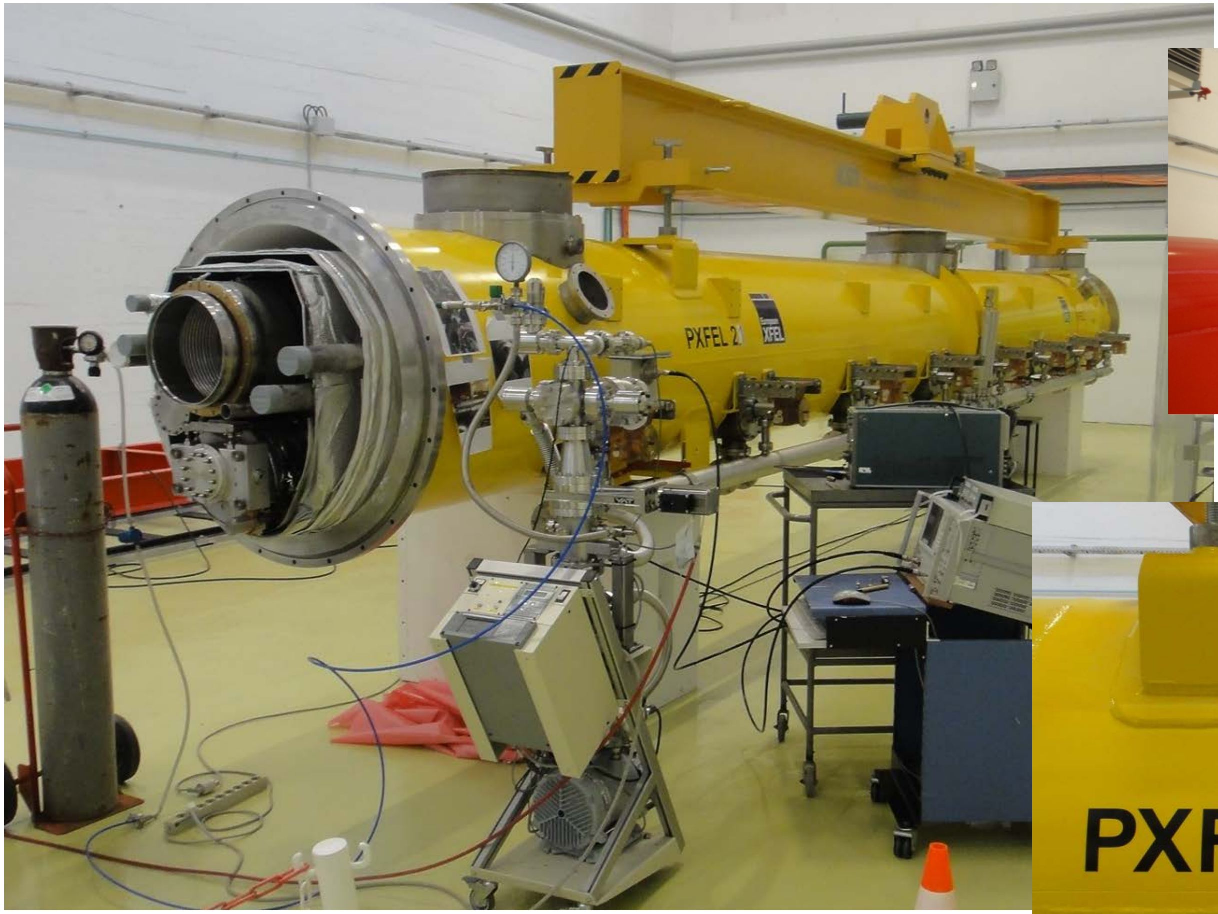
Saclay(March 2011)



Cold-mass carrier with electric motor with wireless-controller



Saclay (March 2011)



7 March 2011 at Saclay

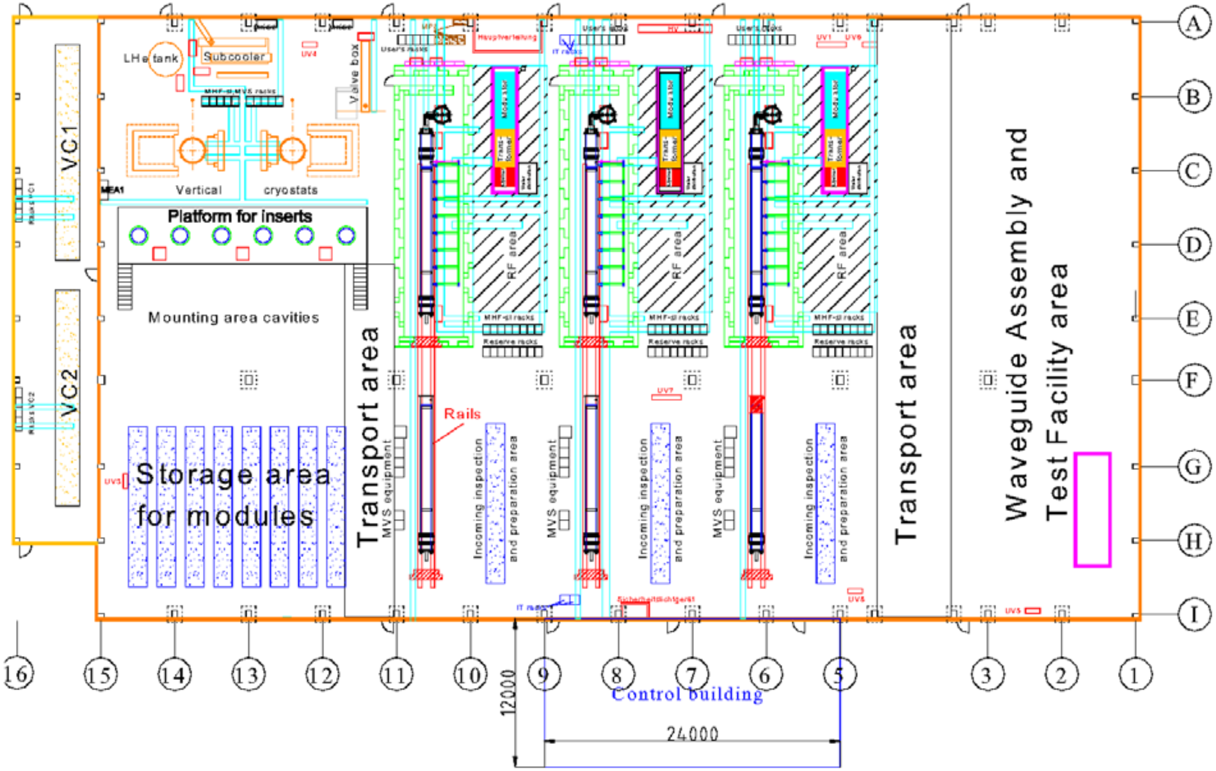
PXFEL 2.1 (DESY >>> Saclay >>> transportation to DESY within a few weeks)

DESY (March 2011)

Construction of Accelerator Module Test Facility (AMTF) hall is on going.

Three cryomodule test stands.

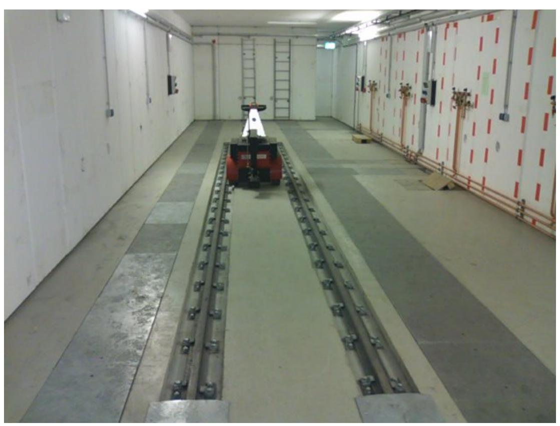
Accelerator Module Test Facility (AMTF) Including Single Cavity Tests



- Warm cryogenic piping 10/2010
- ISO- and UH Vacuum equipment 10/2010
- Vacuum compressors commissioning 11/2010
- cryo components (LHe sub cooler & He storage tank main transfer line & vertical cryostats) **are late** – fall 2011

- **Commissioning**
  - **- vertical tests late fall 2011**
  - **- horizontal tests end 2011**

DESY(March 2011)



Construction of Accelerator Module Test Facility (AMTF) hall is on going.

DESY (March 2011)

Construction of Injector hall is ongoing.

He tanks

Spring 2011

DESY (March 2012)

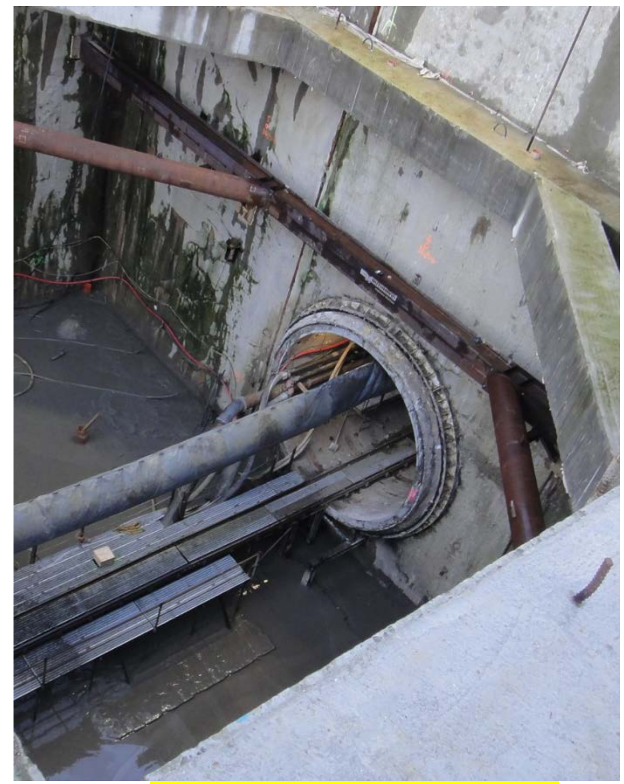
He tanks

Spring 2012

Construction of Injector hall is ongoing.

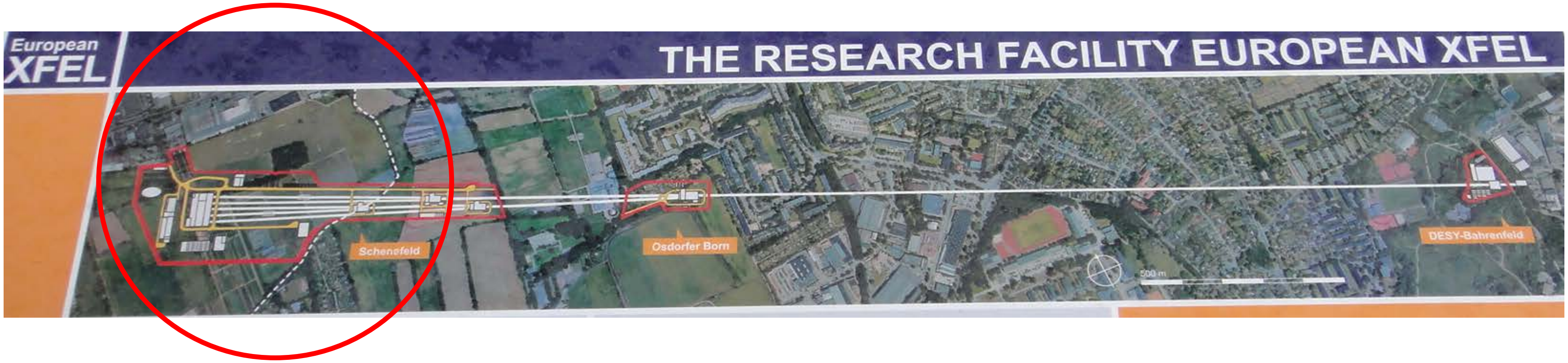
DESY (March 2011)

End of SRF linac. Entrance of tunnel bawling machines.



End of SRF linac

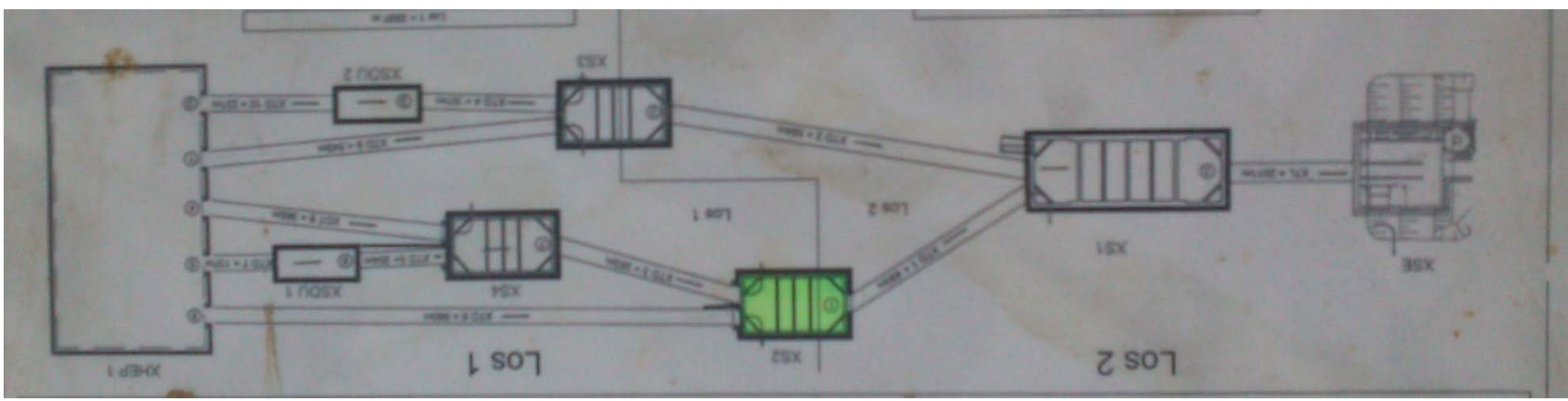
DESY (March 2011)



DESY is in this direction

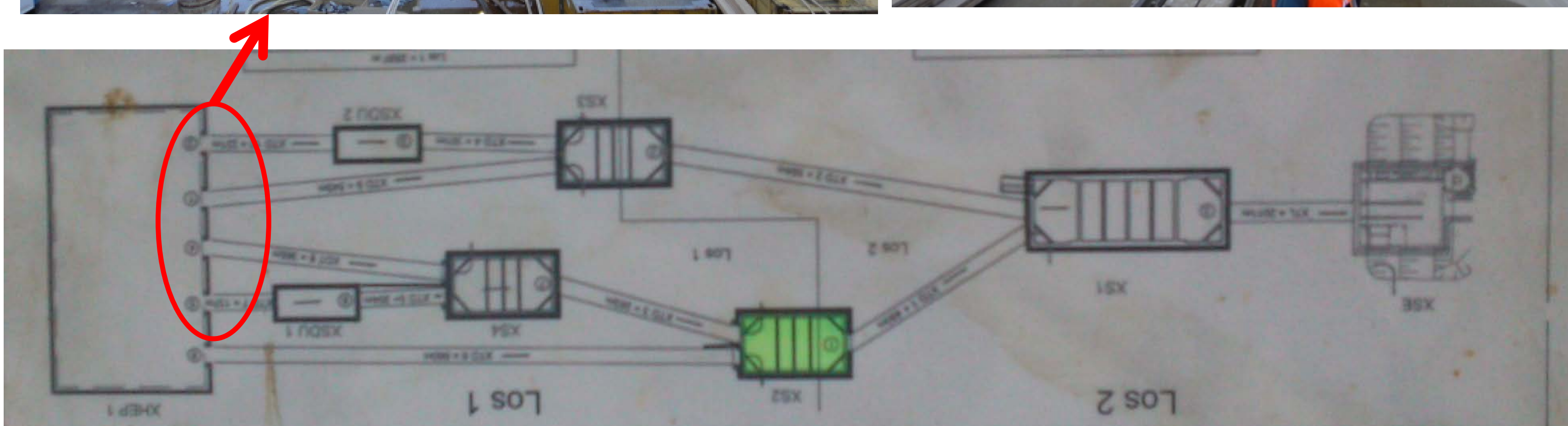
Construction of experimental halls is ongoing.

DESY (March 2012)

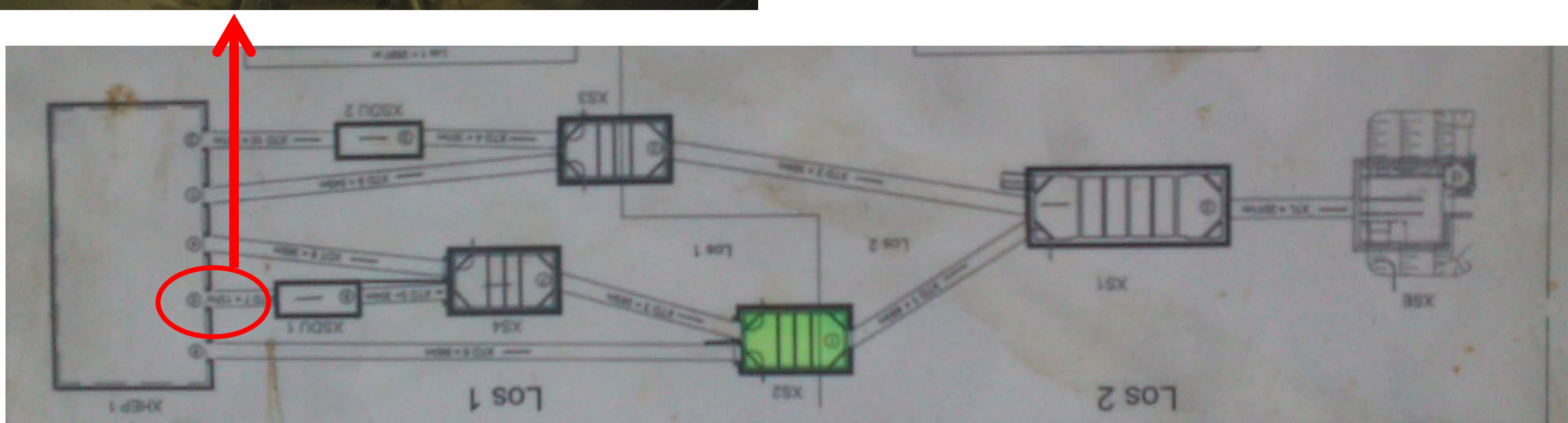


DESY (March 2012)

8 Mar. 2012

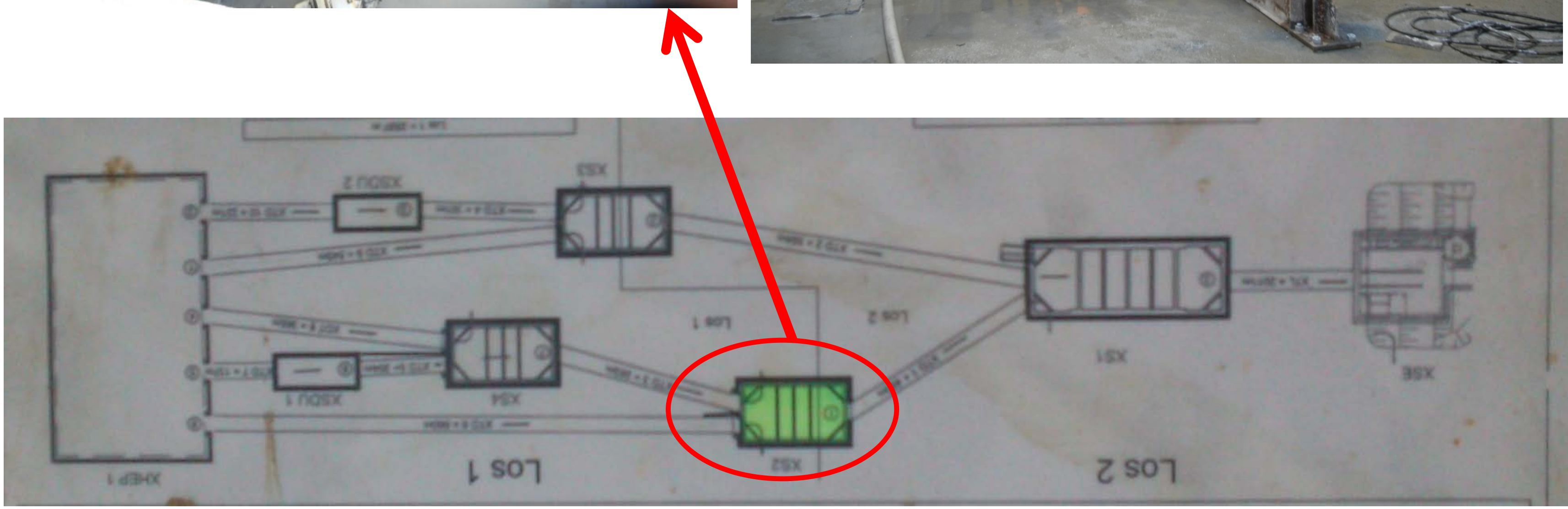


DESY (March 2012)

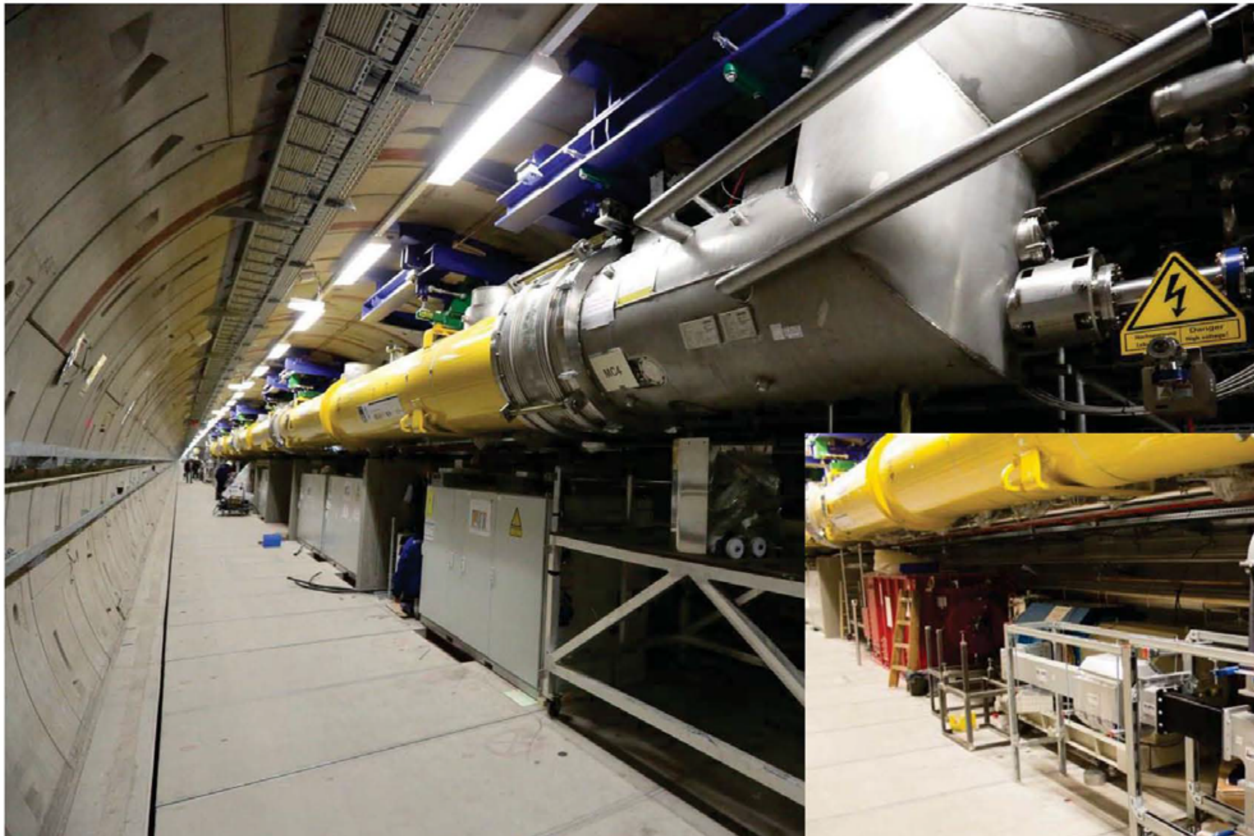


DESY (March 2012)

8 Mar. 2012



The finished L1 section



European XFEL

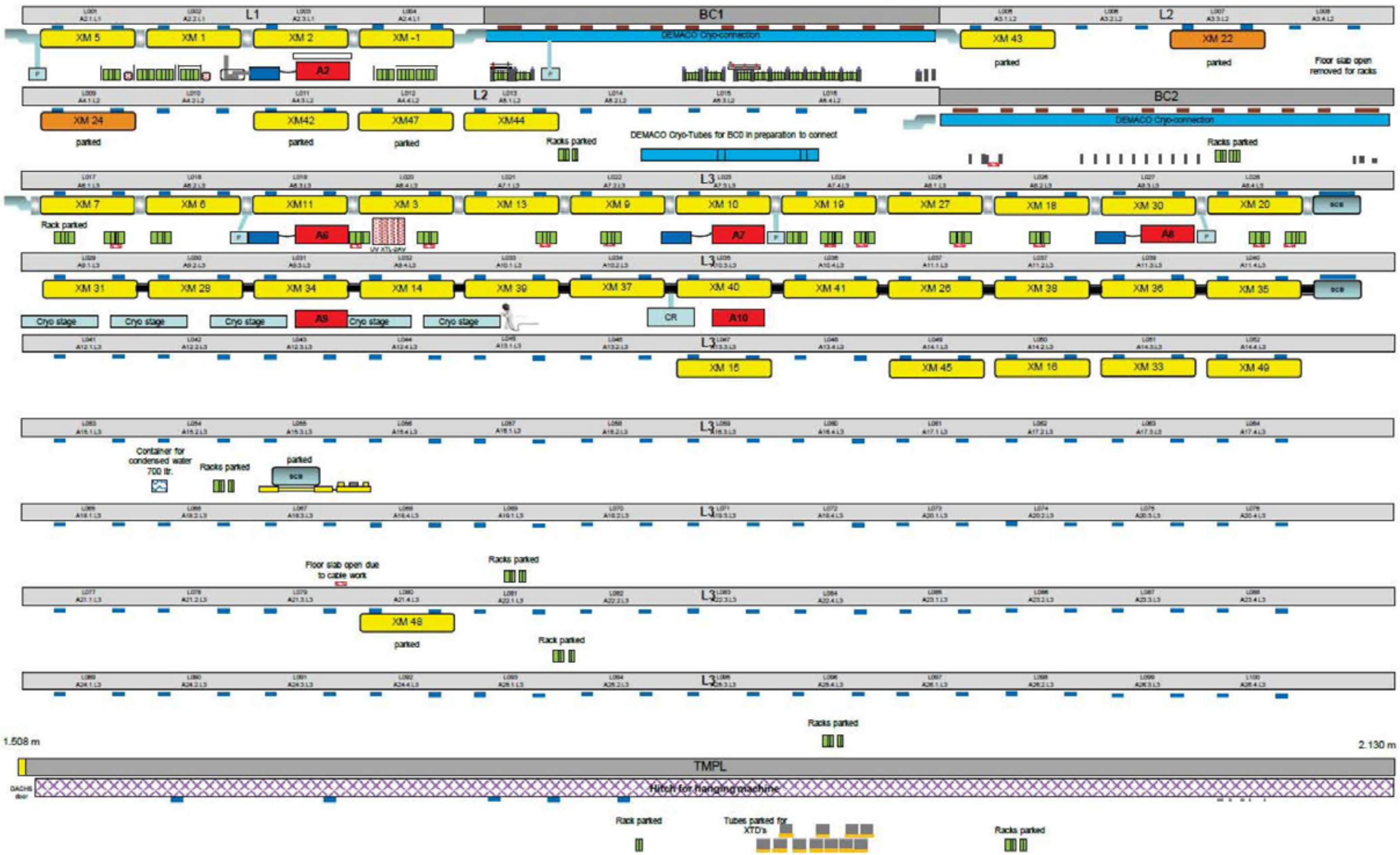
Installation Progress XTL

34 Modules installed
6 Modules parked

1 RF-Station ready
5 RF-Station in preperation

Status: 04.09.2015

1



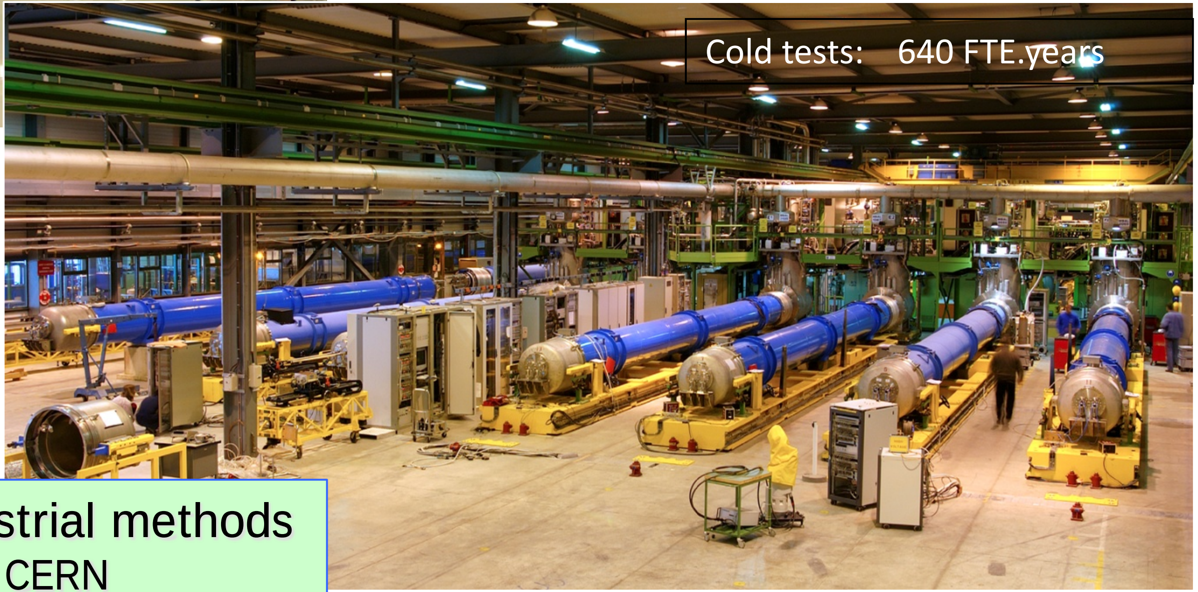
Armin Brand
XFEL TC - Office

HELMHOLTZ ASSOCIATION

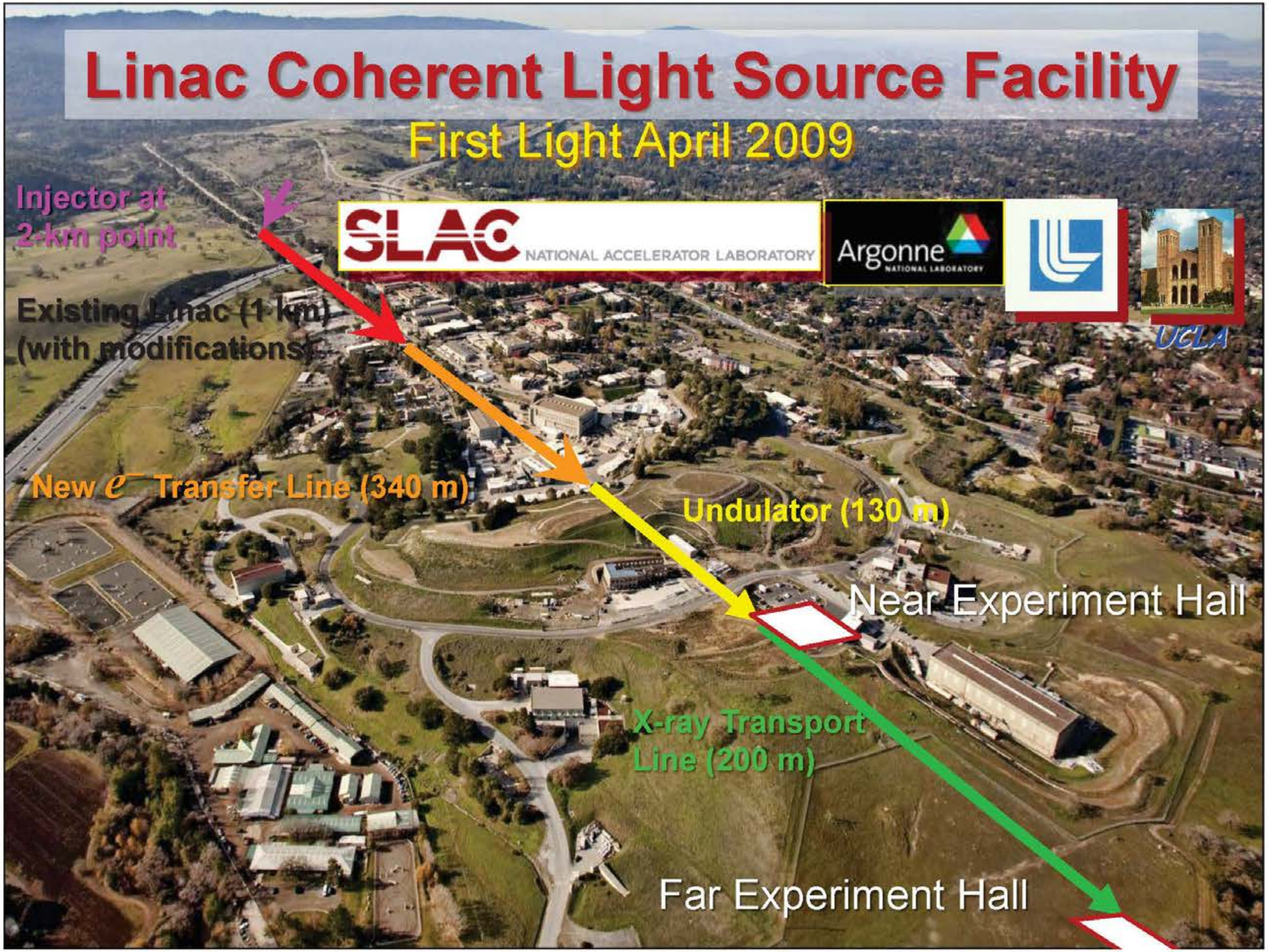
Courtesy: P. Lubrun (CERN), 1st WS, 2010

CERN's Experience from LHC Cryostating and Test

Bringing industry to the laboratory
Cryostat assembly by industry on CERN site



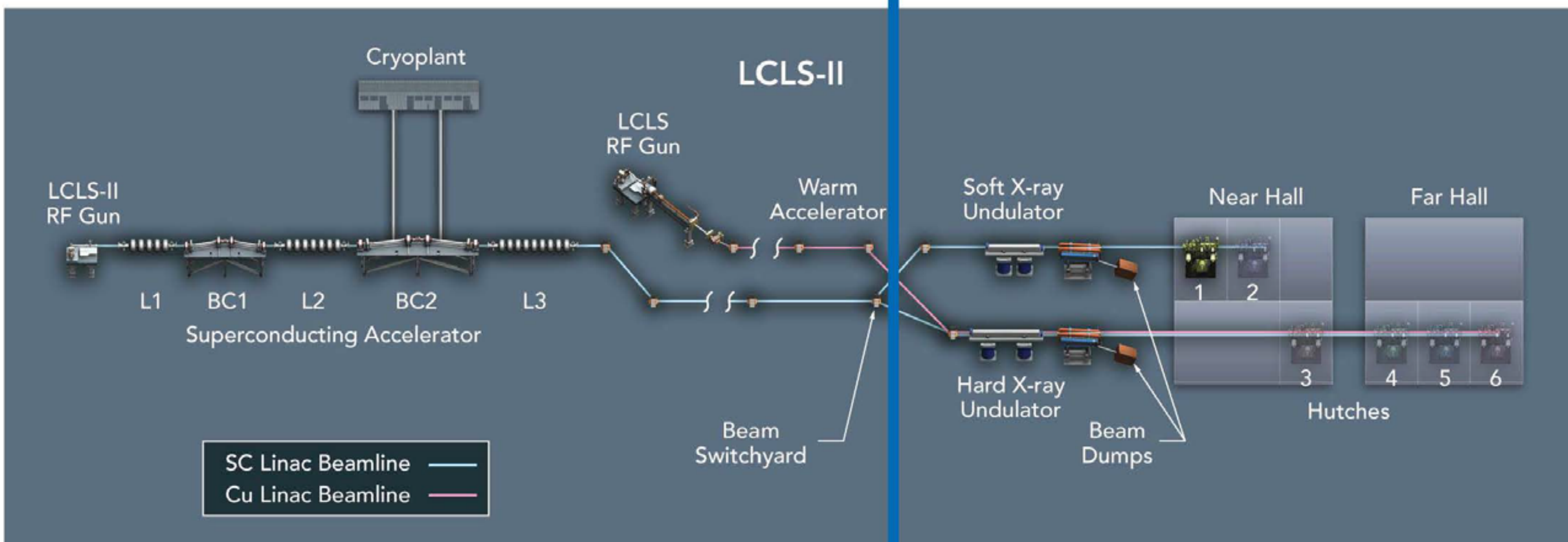
Producing in-house with industrial methods
Cryogenic magnet test station at CERN



Linac Coherent Light Source Facility
First Light April 2009
Injector at
2-km point
SLAC NATIONAL ACCELERATOR LABORATORY
Argonne NATIONAL LABORATORY
UCLA
Existing Linac (1 km)
(with modifications)
New e^- Transfer Line (340 m)
Undulator (130 m)
Near Experiment Hall
X-ray Transport
Line (200 m)
Far Experiment Hall

LCLS-II Hybrid Free Electron Laser at SLAC:

SLAC



LCLS-II SRF Linac

Closely based on the ***European XFEL / ILC / TESLA*** Design

- Under development ~ 20 years with ***> 1000 cavities*** by 2016

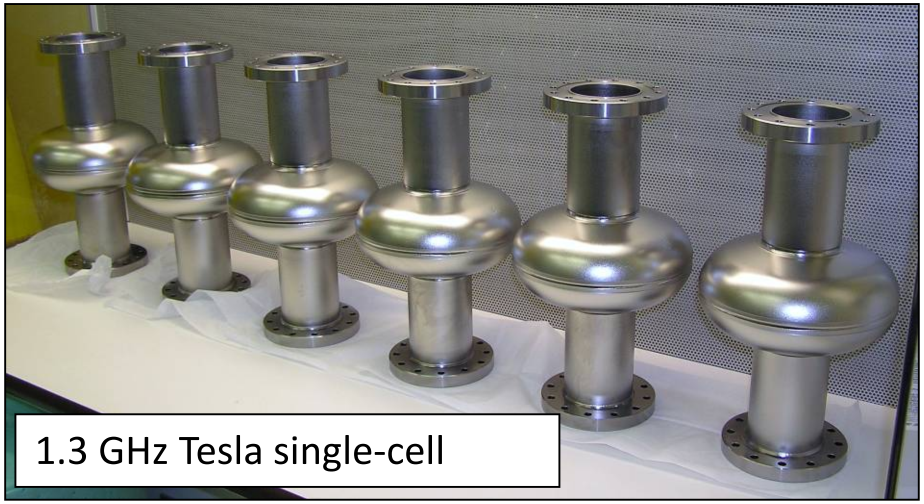
Uses ***CEBAF-12 GeV Upgrade Cryoplant*** Design

LCLS-II Linac consists of:

Component	Count	Parameters
Linac	4 cold - segments	35 each 8 cavity Cryomodules (1.3 GHz) 2 each 8 cavity Cryomodules (3.9 GHz)
1.3 GHz Cryomodule	8 cavities/CM	13 m long. Cavities + SC Magnet package + BPM
1.3 GHz 9-cell cavity	280 each	16 MV/m; Q_0 ~ 2.7e10 (avg); 2 deg. K; bulk niobium sheet - metal
Cavity Auxiliary	per each cavity	Coaxial Input Coupler; 2 each HOM extraction coupler; lever-type tuner
Cryoplant	2 each	4.5 K / 2.0 K cold box system; 18 kW @ 4.5 K equivalent (x two)

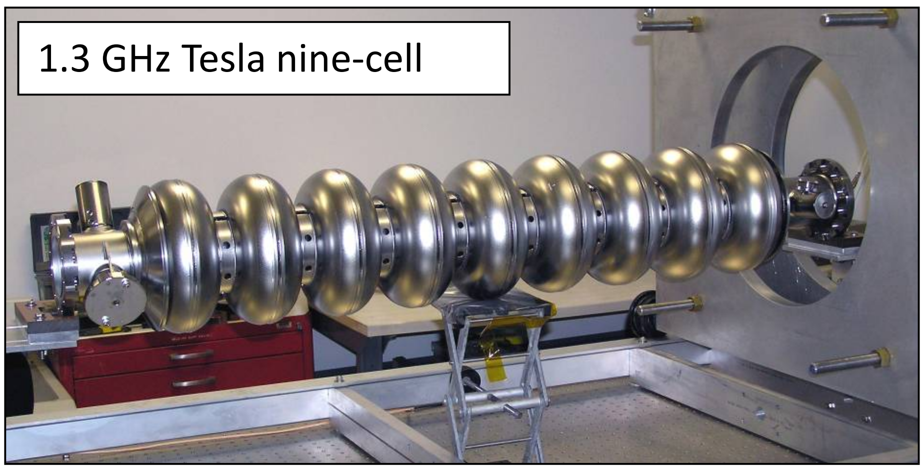

Nick Walker
XFEL
X-Ray Free-Electron Laser
Largest deployment of this technology to date
- 100 cryomodules
- 800 cavities
- 17.5 GeV (pulsed)
Kitakami proposed ILC site
FNAL/ANL
SLAC
Cornell
JLab
LCLS-II
LAL/ Saclay
DESY
INFN Milan
IHEP
KEK
US infrastructure for
- 35 cryomodules
- 280 cavities
- 4 GeV (CW)
International Partner Labs lend their expertise

AES (Cavity industry in USA)

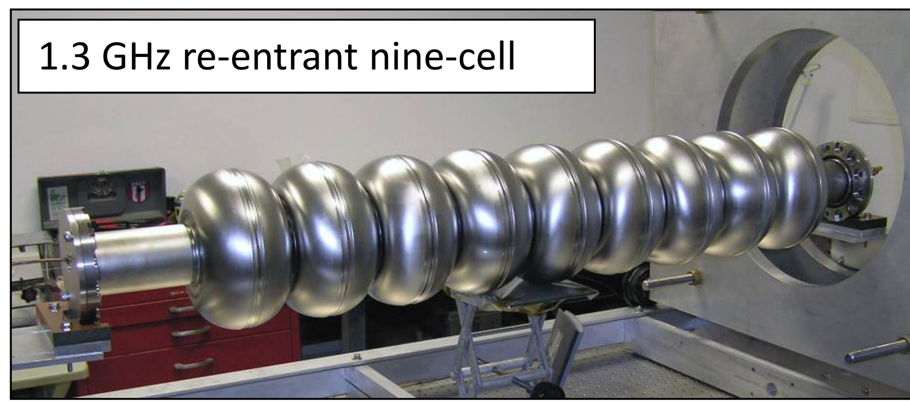


1.3 GHz Tesla single-cell

Electron-beam welding facility



1.3 GHz Tesla nine-cell



1.3 GHz re-entrant nine-cell

Cryomodule activities at FNAL

CM1 String Assembly

MP9 Clean Room

Final Assembly

CM1

Move to NML

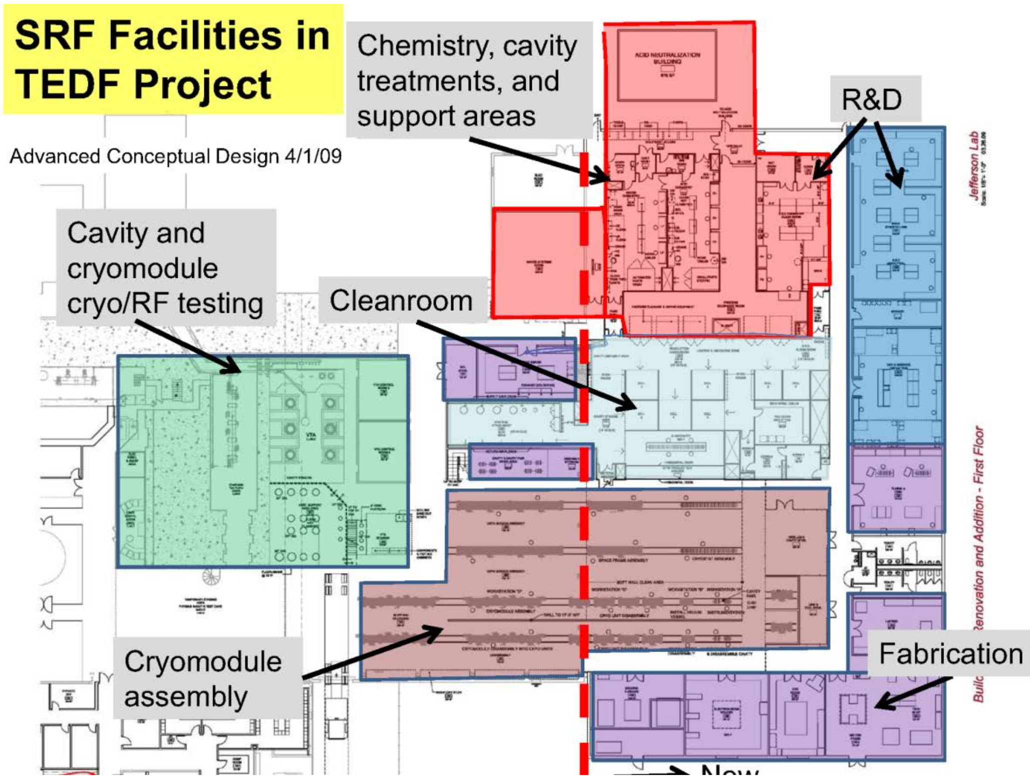
CM1 installed

Dressing cavities for CM2

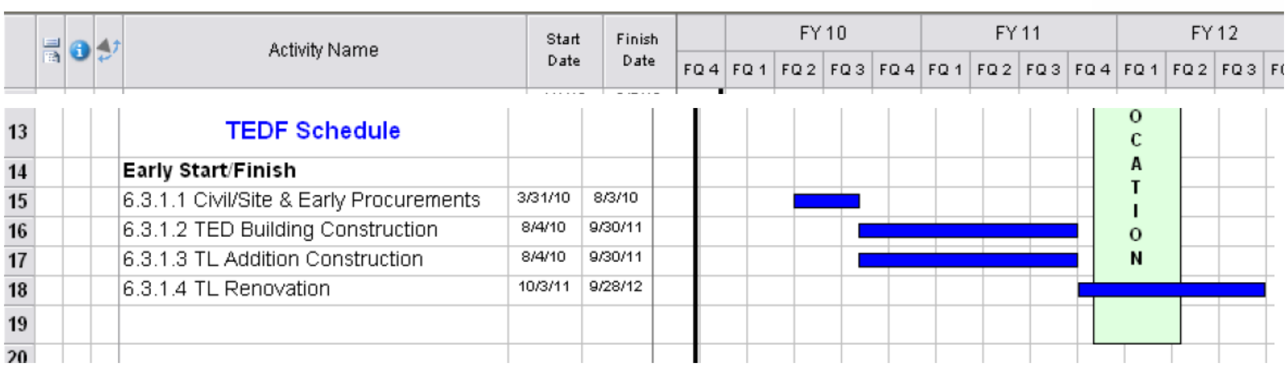
FNAL S1 global
Cavities @ KEK

Jefferson Lab Technology and Engineering Development Facility Project (TEDF)

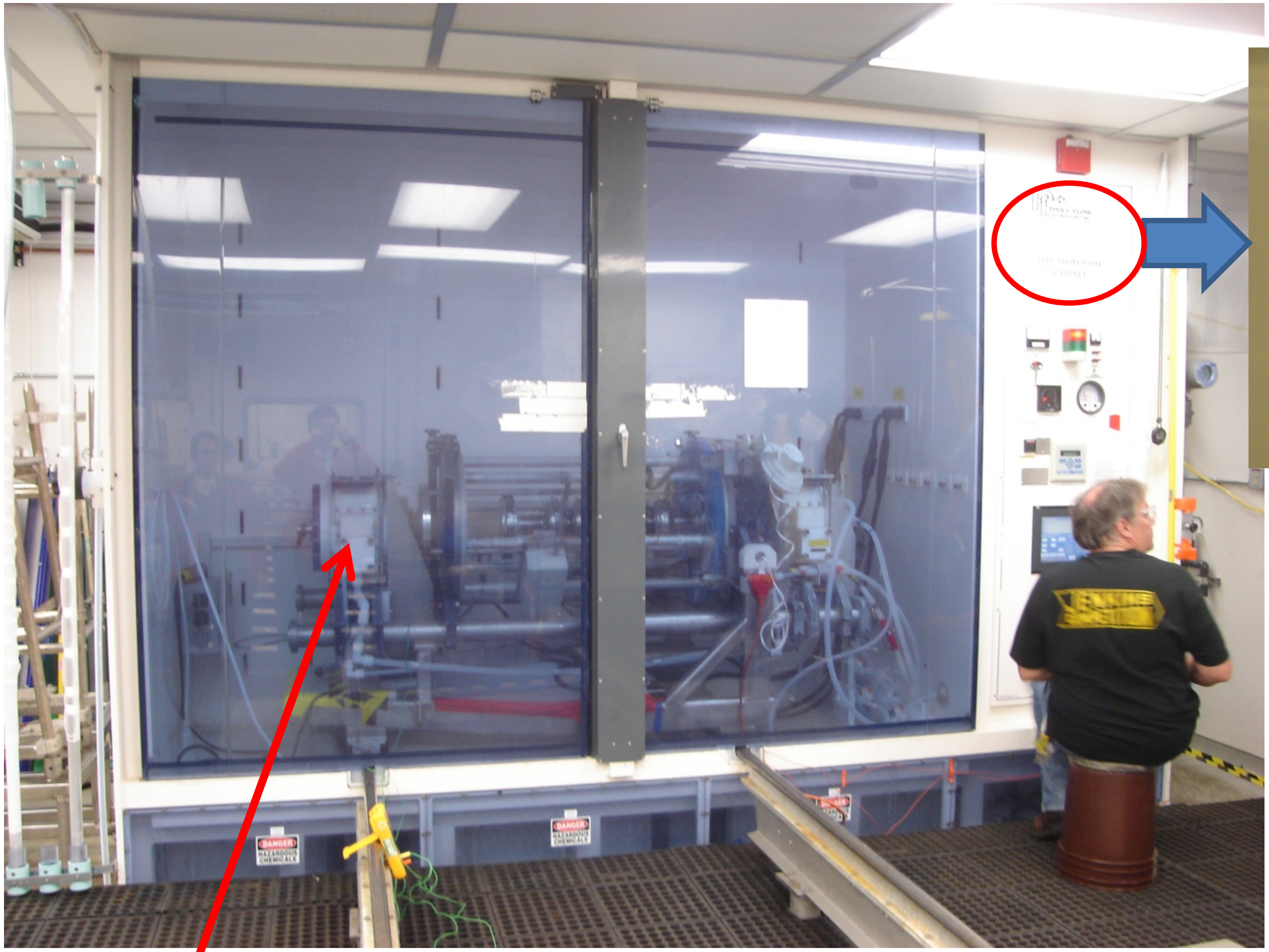
Presented by C. Reece at TTC(March 2011)



Only the VTA and Cryo-module Test Facility will be unchanged!

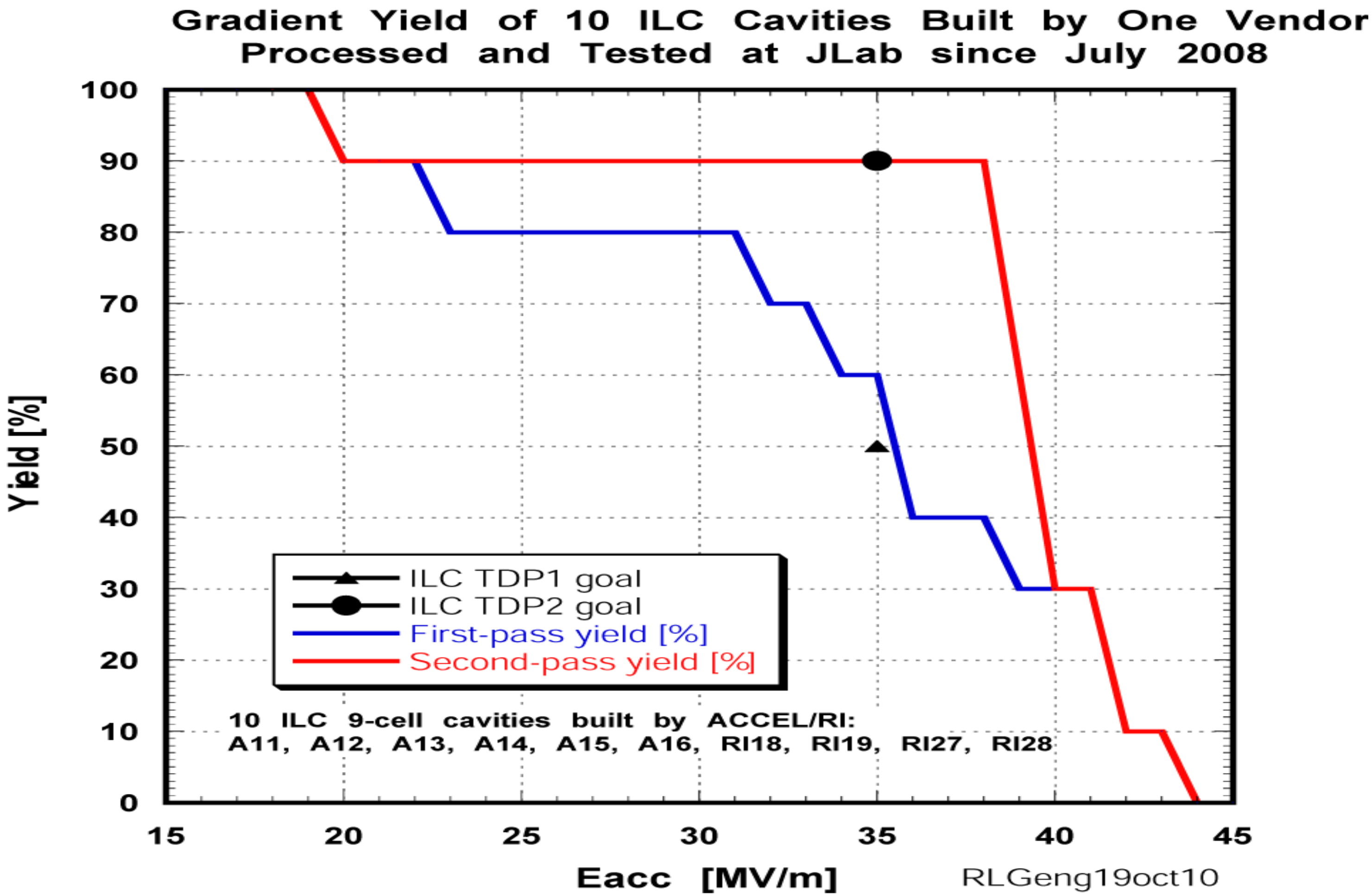


EP facility at JLab



Sleeve design
Nomura plating

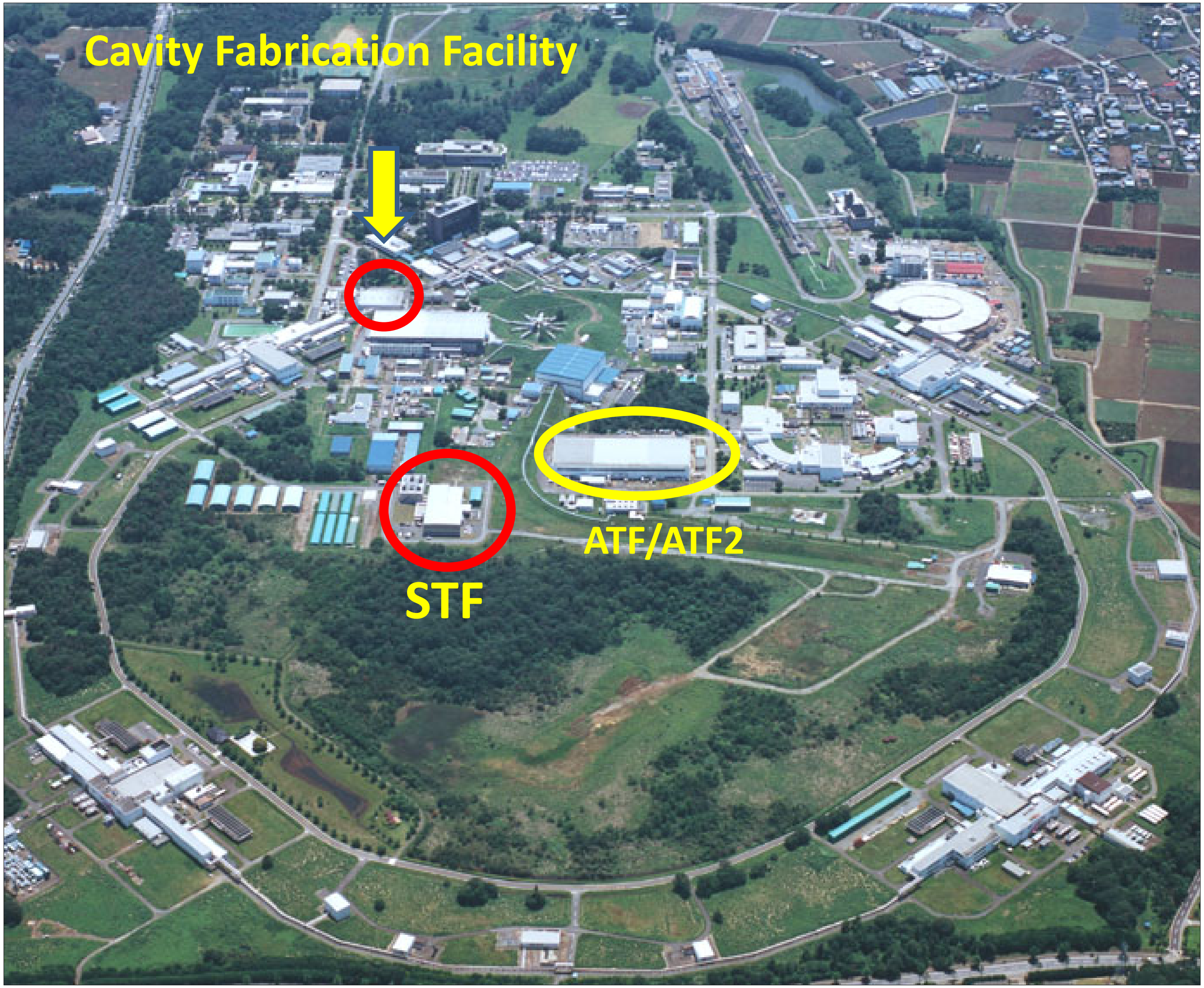
System design
J. Mammosser and Poly Flow Engineering



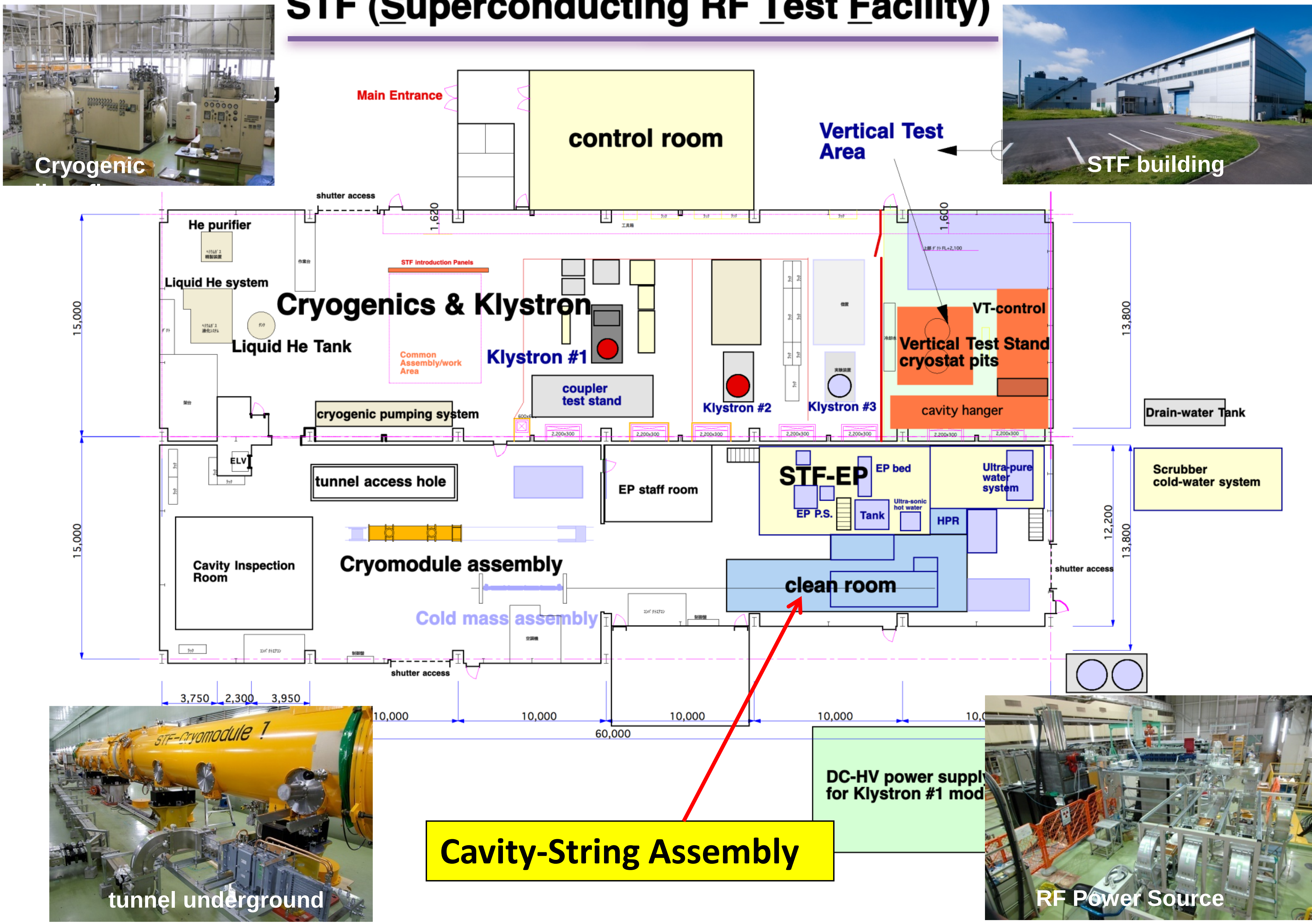
Gradient data of 9-cell cavities processed by using JLab standard ILC electropolishing procedure suggest 90% gradient yield at > 38 MV/m is within reach as long as cavities are free from genetic defects due to fabrication or material

Slide by R. Geng

ILC Test Facilities at KEK



STF (Superconducting RF Test Facility)



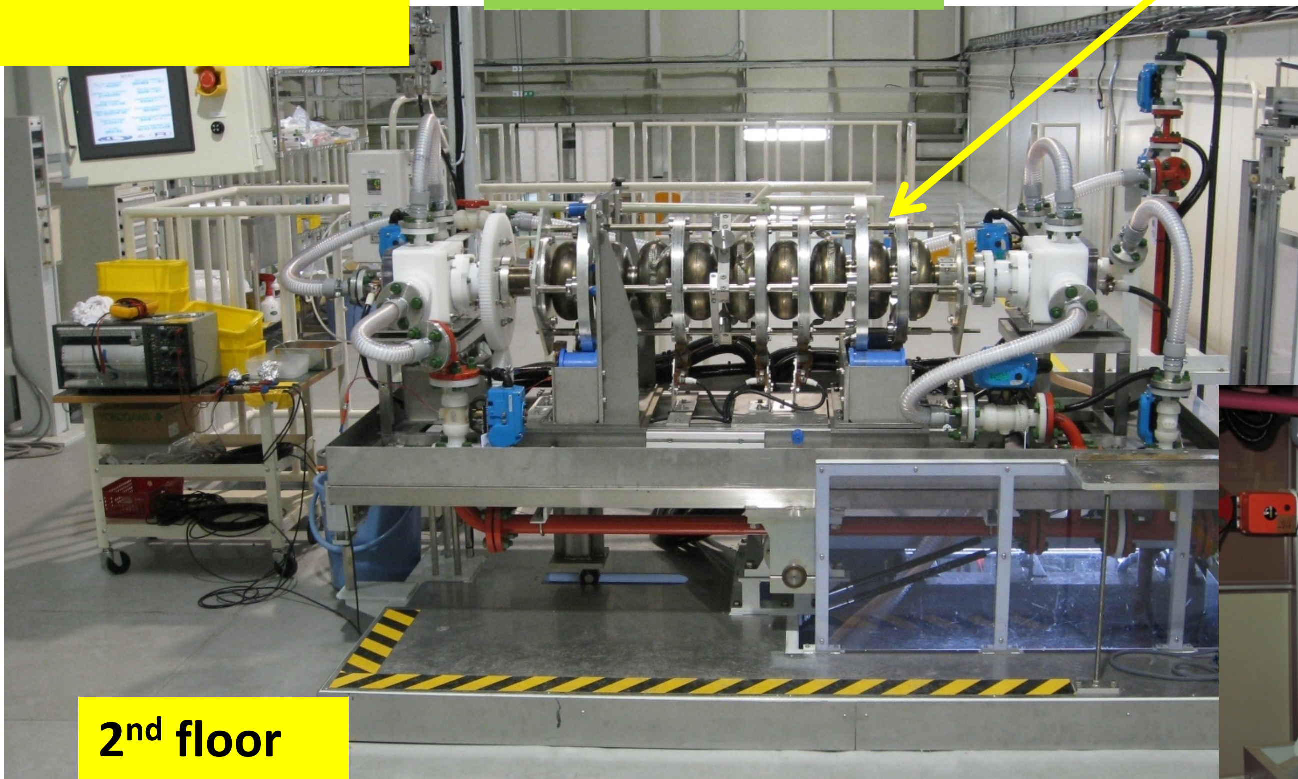
EP facility at STF/KEK

Automatic Operation Console

1st EP bed

9-cell cavity

EP acid: HF + H_2SO_4
Aluminum anode,
surface removal speed: 20µm/hour,
~18V ~270A ~30degC (for 9-cell)
cavity rotation: 1 rpm



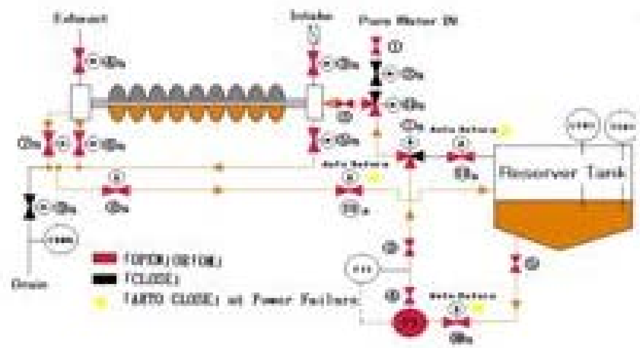
2nd floor

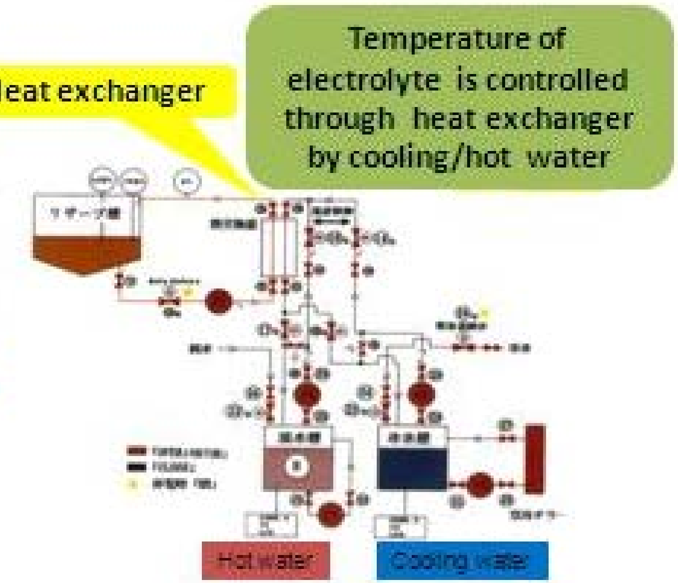
1st floor

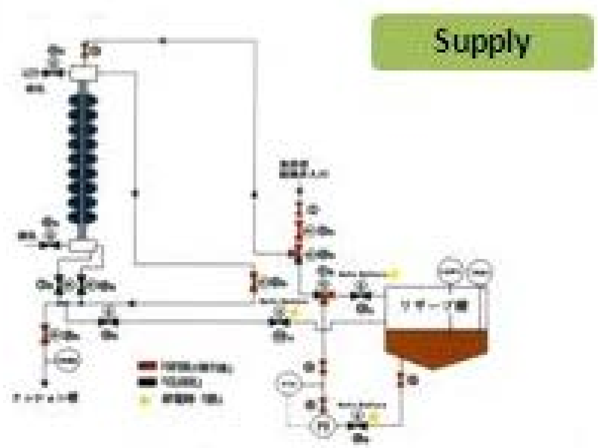
EP solution reservoir tank

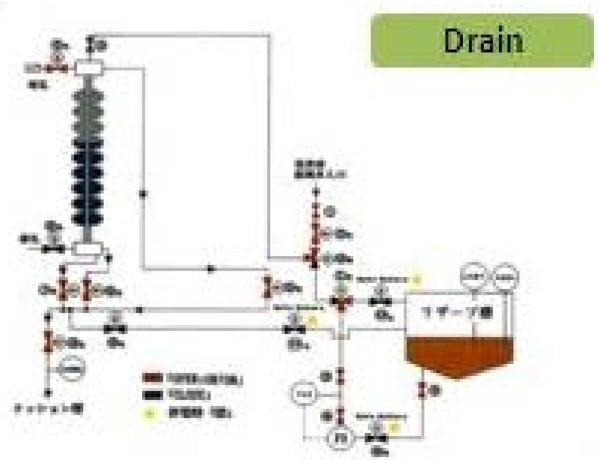
New EP facility at KEK was constructed in 2008, instead of old Nomura EP facility.

EP process at STF-KEK

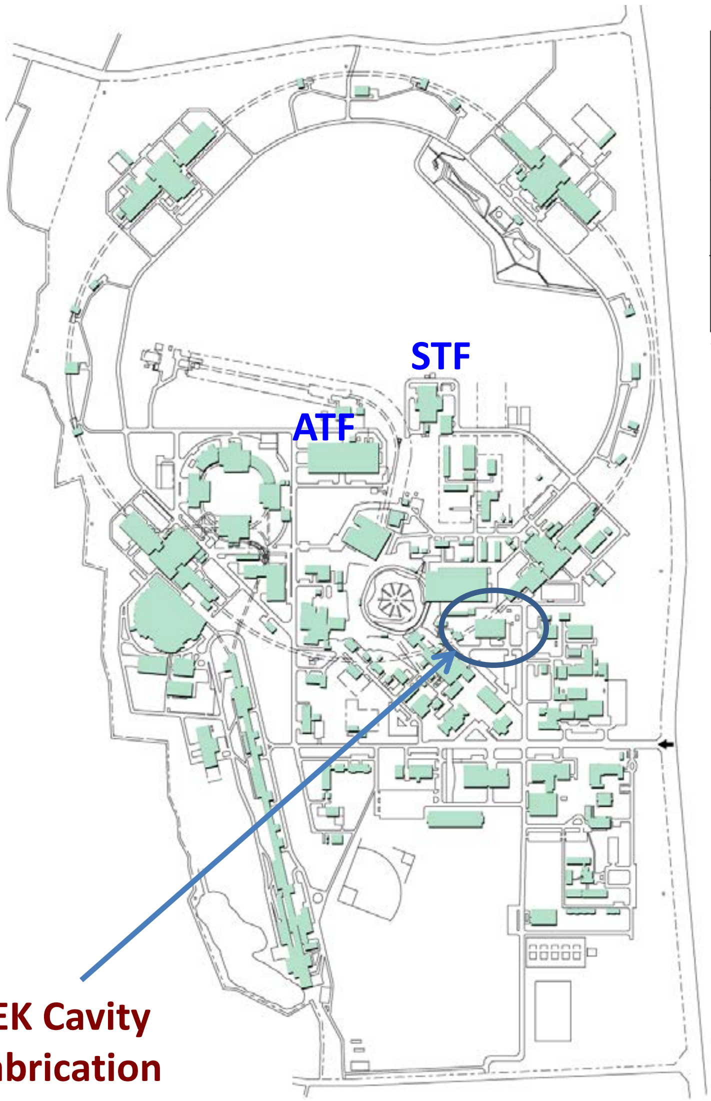








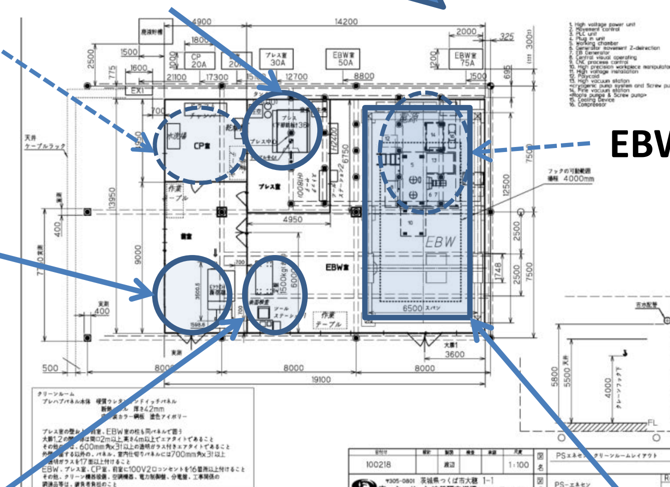
KEK Cavity Fabrication Facility



KEK Cavity Fabrication Facility

19m x 14m clean room

Building inside



Press Machine

Chemical Room

EBW

Trimming Machine

Inspection area

Plant clean room

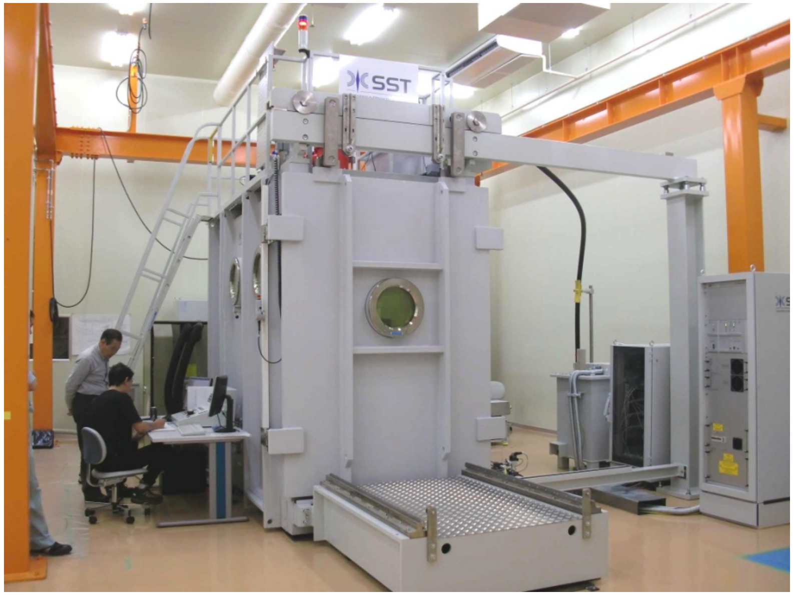
Crane range

Slide by Hayano

Slide by Hayano

Main Machines in the facility

EBW



SST EBOCAM KS-110 – G150KM
Chamber (Stainless Steel chamber)

Press

AMADA digital-survo-press SDE1522
150t, 50stroke/min, 225mmstroke

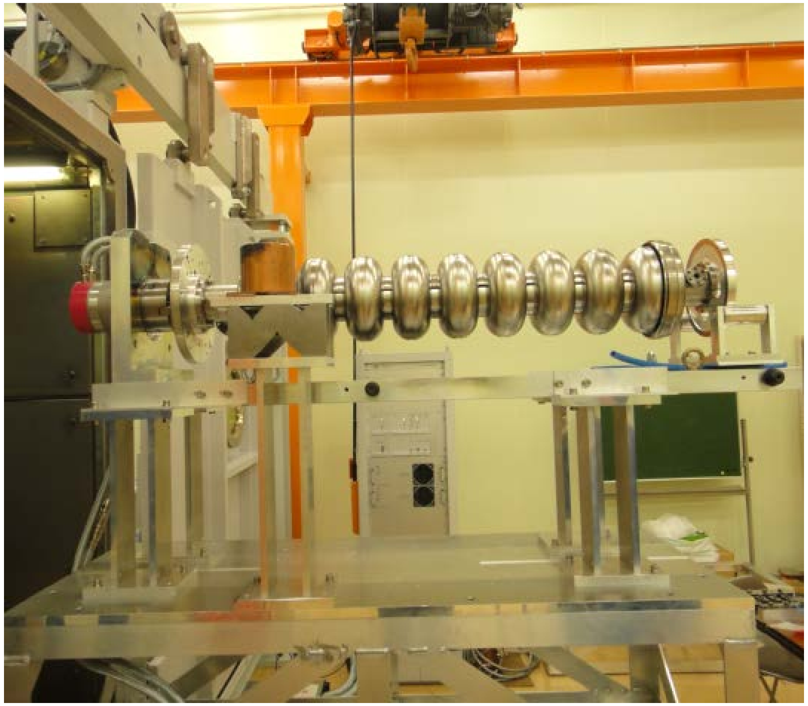
Trim

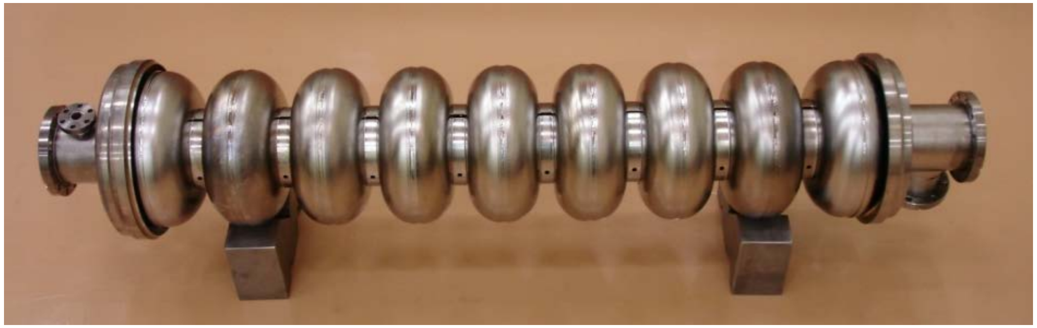
MORI VKL-253
Vertical CNC lathe

Tape-cut Ceremony on
July 13,2011
for
EBW operation start.

Chemi-room

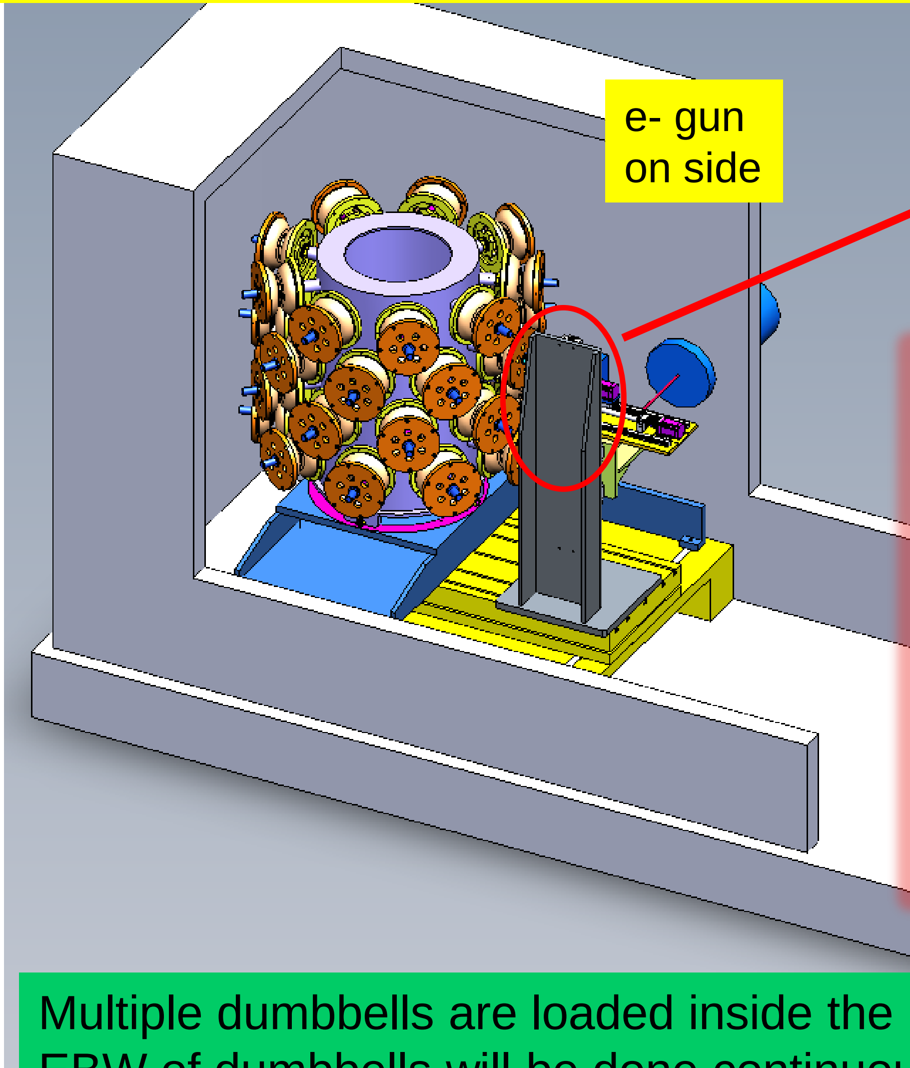
EBW assembly in CFF/KEK

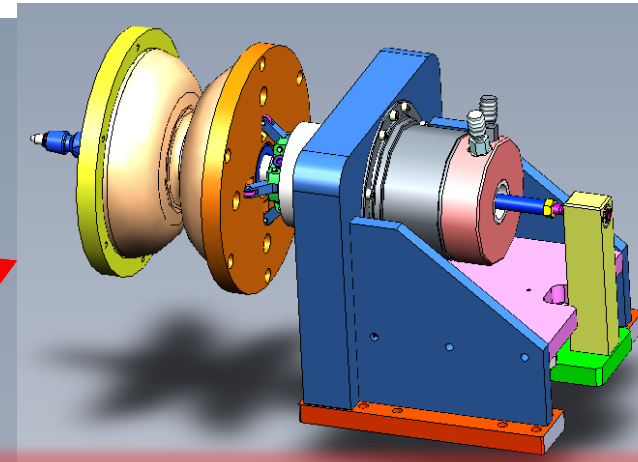




Design of loader for multiple dumb-bells

Pumping time (~30 min.) and cooling time (~30 min.) are duplicated in EBW processes.

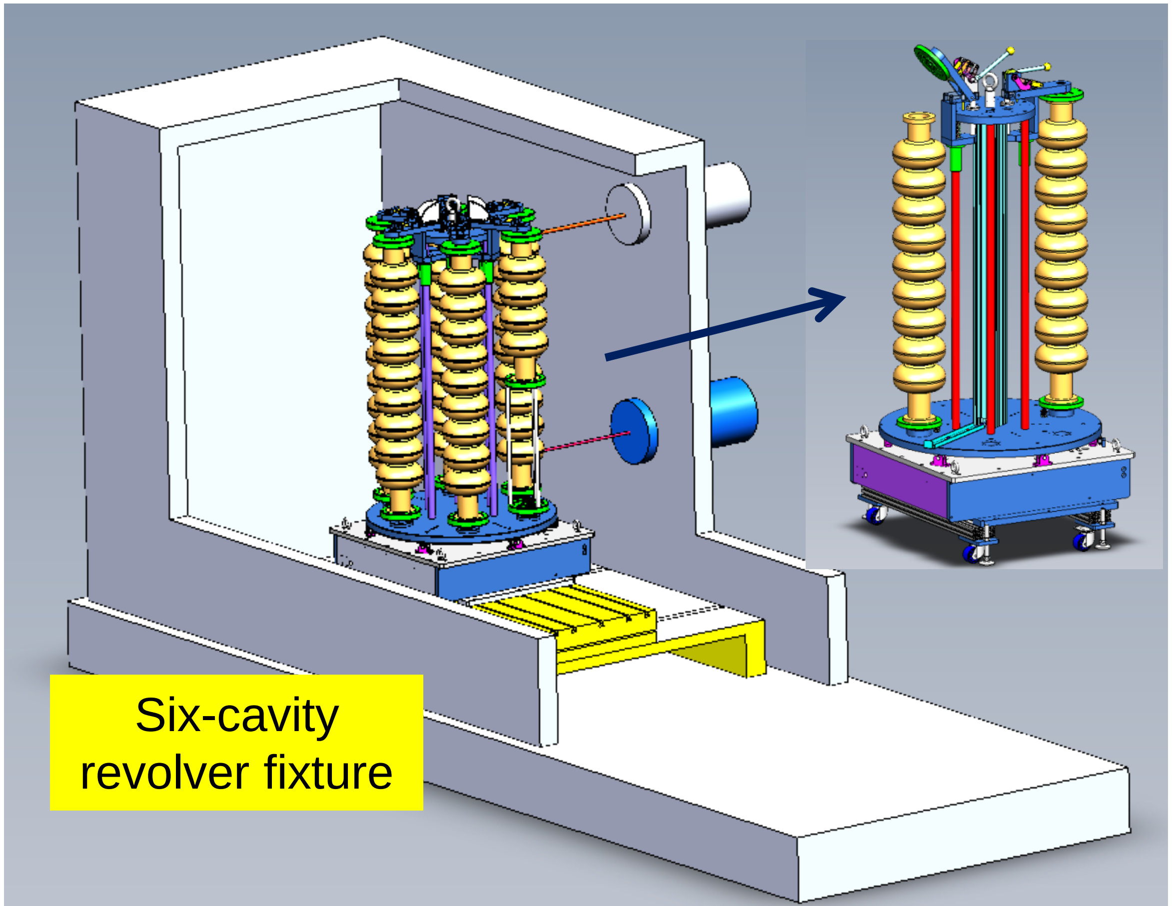




Proto-type of four-dumbbell loader

Multiple dumbbells are loaded inside the EBW chamber at once and the EBW of dumbbells will be done continuously after pumping down.

Design of 9-cell cavity fixture for EBW machine

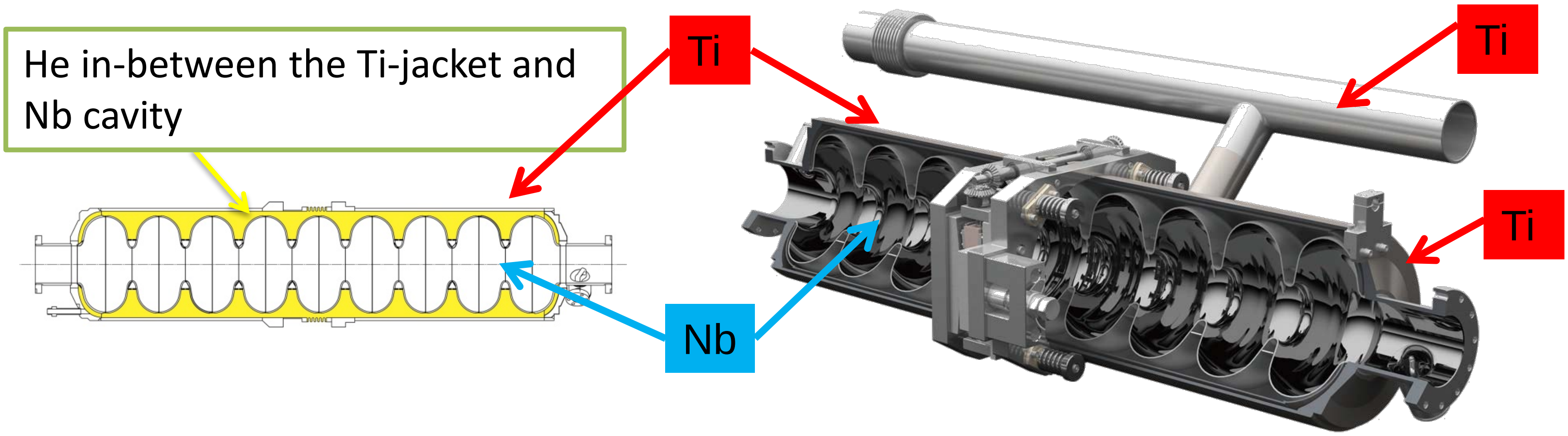


Six-cavity revolver fixture

Proto-type of revolver fixture

Pumping time (~30 min.) and cooling time (~30 min.) are duplicated in EBW process. The time is reduced if multiple-seams are welded in one pumping cycle.

Japanese High-Pressure Gas safety act



One must fabricate cavities complying with Japanese High-Pressure Gas (J-HPG) safety act if we use the cavities in accelerators.

For cavities by venders,
Manufacturer: KEK
Applicant: venders

→

For cavity KEK-03 in CFF,
Manufacturer: KEK
Applicant: KEK/CFF

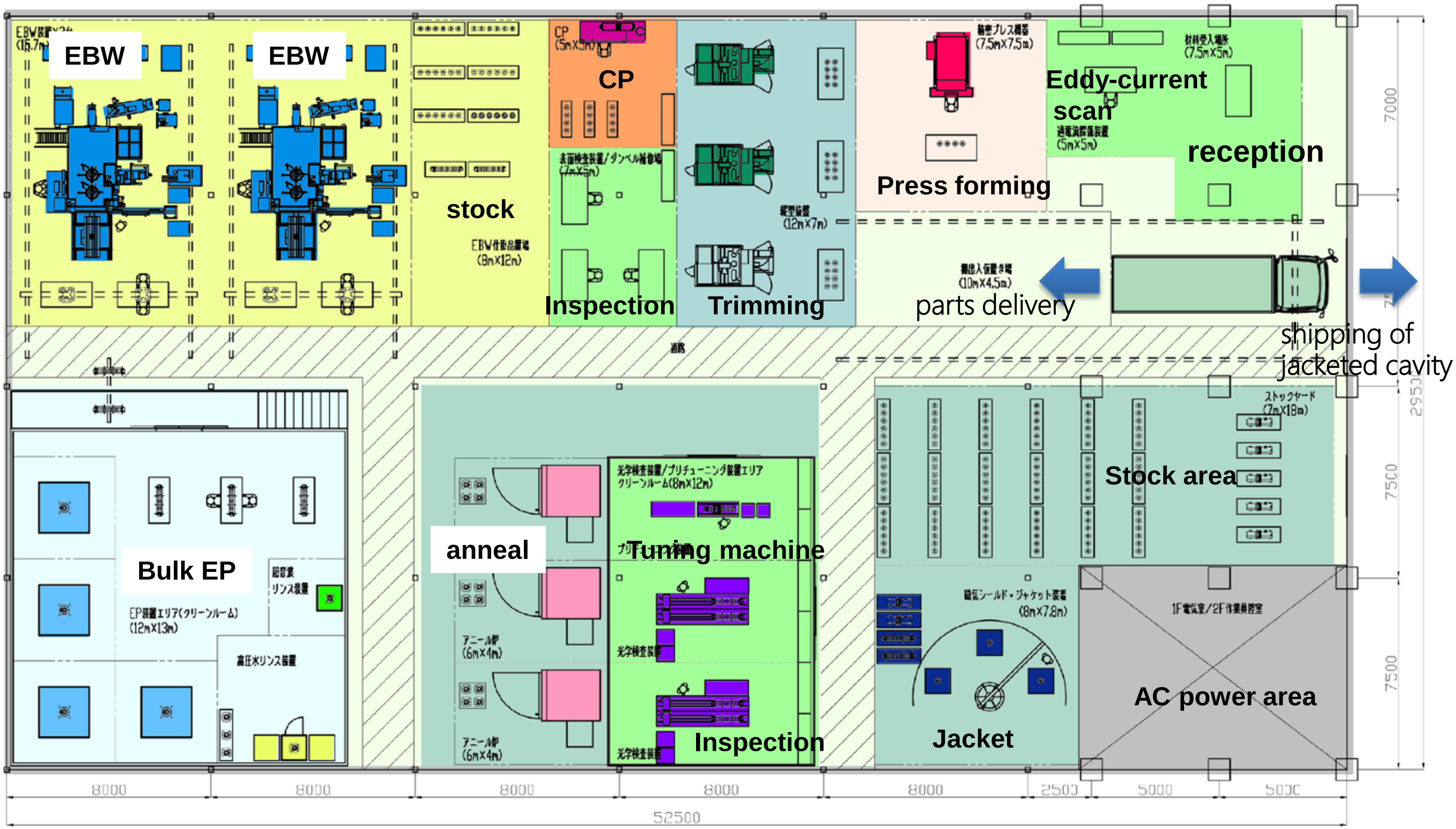
In case of ILC in Japan, a significant fraction of cavities might be imported from foreign vendors. KEK/CFF can guide them for the procedures of J-HPG safety act.

Estimation of cavity production plant

Slide by Hayano

KEK-MHI

Plant Simulation study using CFF housing area (53m x 30m)



Assuming Nb plates for cell, fabricated end-group parts are input,
200 working days/year, 2 shifts/day with 30 people times 2 shifts

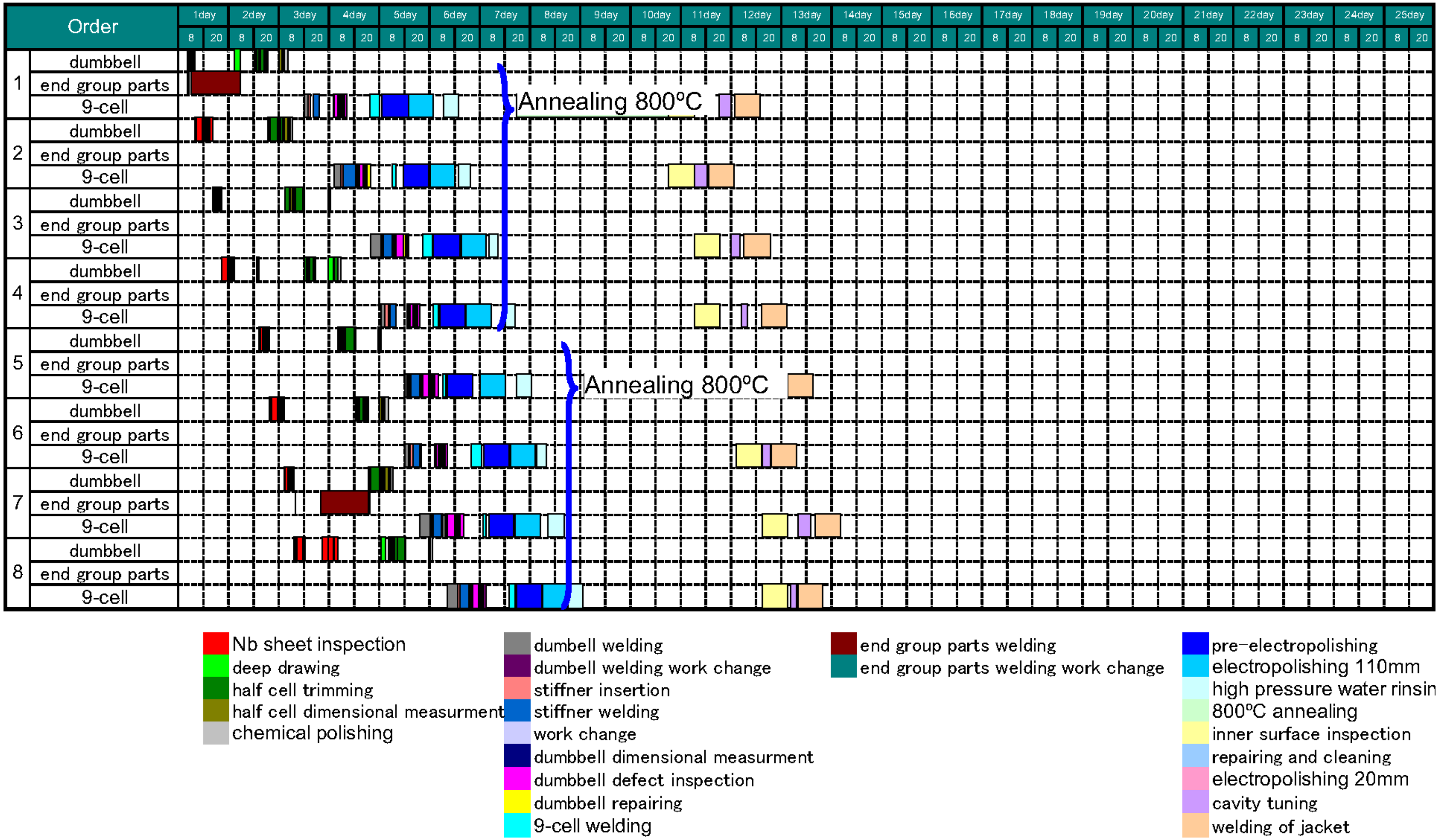
Max. production rate will be ~530 cavities/year, ~2650 cavities for 5years.

Assuming that final treatment and vertical test will be done in other place.

Cavity production Gantt chart

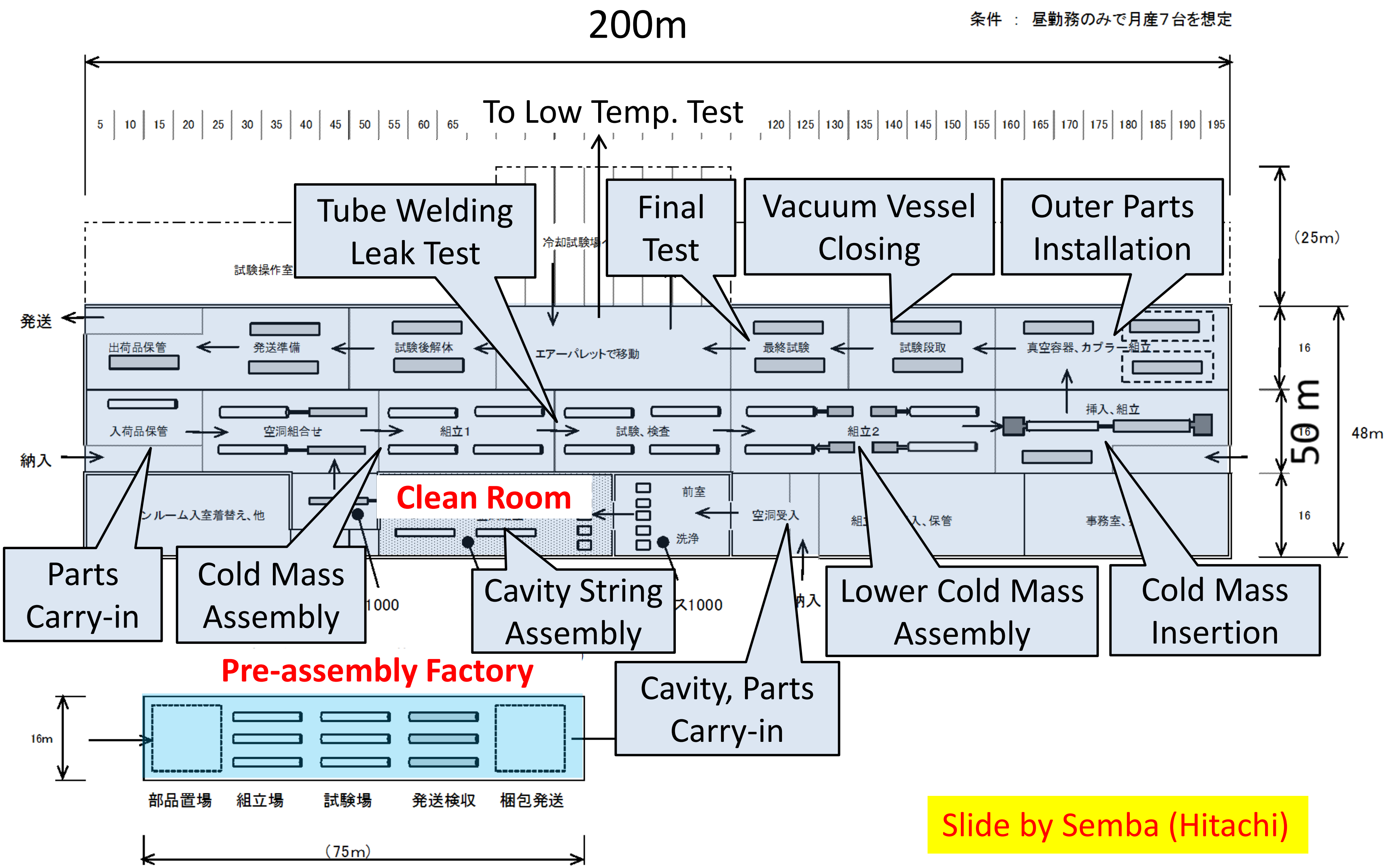
Slide by Ishii (MHI)

MITSUBISHI HEAVY INDUSTRIES, LTD.
TECHNOLOGY & INNOVATION HEADQUARTERS



5-3 New Assembly Building

Day shift only



Slide by Semba (Hitachi)