A_RD_9
Effort Torwards Improving Large Scale Production for Superconducting (SC) Cavities

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France-Japan-Korea
Associated Laboratories
2016 International Anual Workshop

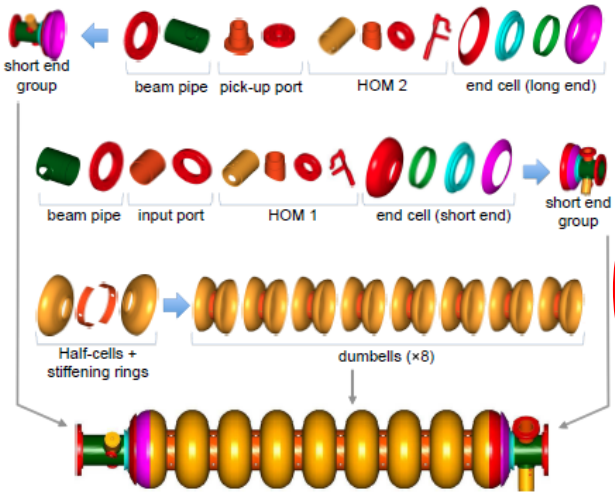
May 18th-20th 2016, Seoul

CONTEXT

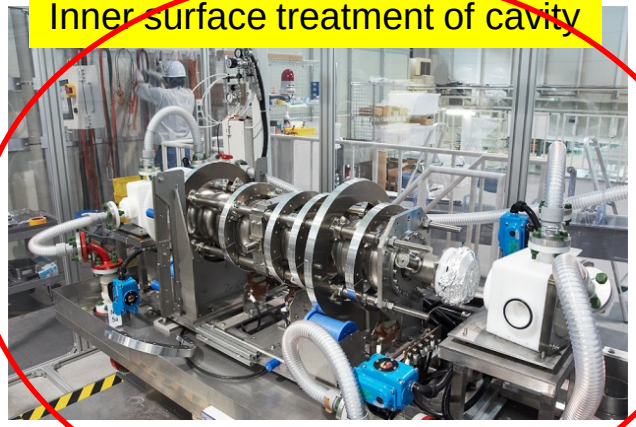
- **ILC: ~16000 Superconductive Niobium cavities > 31.5 MV/m**
  = cost driver
- **Challenging performance**
- **Requires a worldwide effort**

Table 2.1
The main goals and timeline for SCRF R&D established at the beginning of the Technical Design Phase

Year	2007	2008	2009	2010	2011	2012
S0: Cavity gradient at 35 MV/m in vertical test	→ yield 50%			→ yield 90%		
S1: Cavity string at average gradient of 31.5 MV/m in cryomodule		Global effort for string assembly and test				
S2: System test with beam acceleration including high- and low-level RF			FLASH at DESY, ASTA/NML at FNAL, STF2 at KEK			
Industrialisation: Study and preparation for industrial production of SCRF cavities and cryomodules				Production technology R&D		



Inner surface treatment of cavity



Horizontal EP set-up at KEK

Cleanroom Assembly at CEA/IRFU

Requires perfect knowledge of SRF technology from cavity fabrication to cleanroom assembly

In last year, we concentrated in the inner surface treatment of cavity.

GOAL OF A_RD_09

- Develop process for the large scale cavity production
- From Cavity Fabrication, inner surface treatments, to RF performance Test (Vertical Test: VT)
- Thanks to advanced facilities: CFF/STF/COI at KEK, Supratech at CEA Saclay

- Thanks to motivated teams:

FJPPL (TYL) application 2016-2017

Fiscal year April 1st 2016 – March 31st 2017

ID[1]:	Title: Effort towards improving large scale production of SC cavities					
	French Group			Japanese Group		
	Name	Title	Lab./Organis.[2]	Name	Title	Lab/Organis.[3]
Leader	F. Eozénou		Irfu	Takayuki Saeki		KEK
Members	C. Madec	Dr.	Irfu	Hitoshi Hayano		KEK
	C. Antoine	Dr.	Irfu	Shigeki Kato		KEK
	S. Berry	Dr.	Irfu	Masashi Yamanaka		KEK
	C. Servouin		Irfu	Motoaki Sawabe		KEK
				Hideaki Monjushiro		KEK
				Takayuki Kubo		KEK

In last year, we concentrated in the inner surface treatment of cavity.

OUTLINE

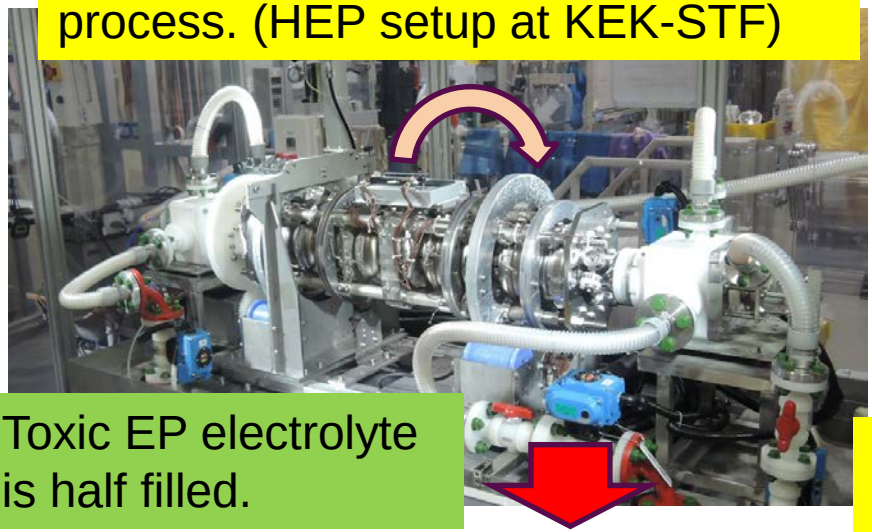
- INFRASTRUCTURE
- RECENT ACHIEVEMENTS
- PROPOSAL FOR 2016-2017

INFRASTRUCTURES

ELECTROPOLISHING (EP) AT KEK & MARUI

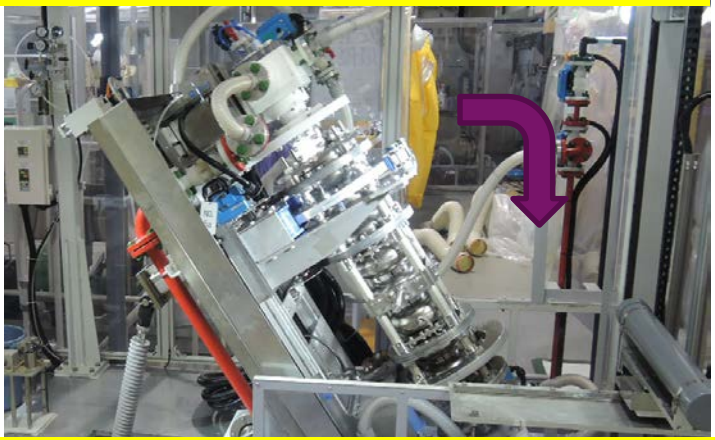
EP is the best method for inner surface treatment, but expensive.

Rotation of cavity in Horizontal EP process. (HEP setup at KEK-STF)



Toxic EP electrolyte is half filled.

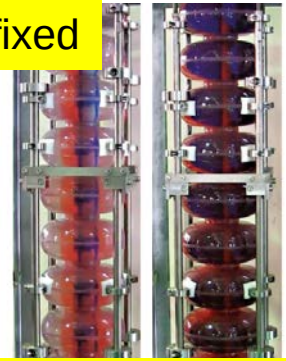
Turning the EP-bed for draining



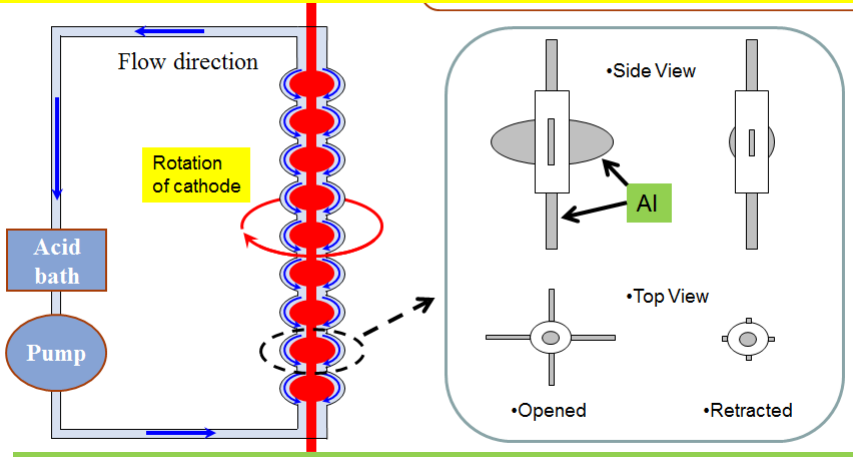
Massive and complicated system

Vertical EP (VEP) at Marui Galvanizing Co. Ltd. in collaboration with KEK

Cavity is fixed



Simple VEP is more cost-effective than HEP, but hydrogen-gas generation at cathode has a narrow way to escape at top and it is the main problem.



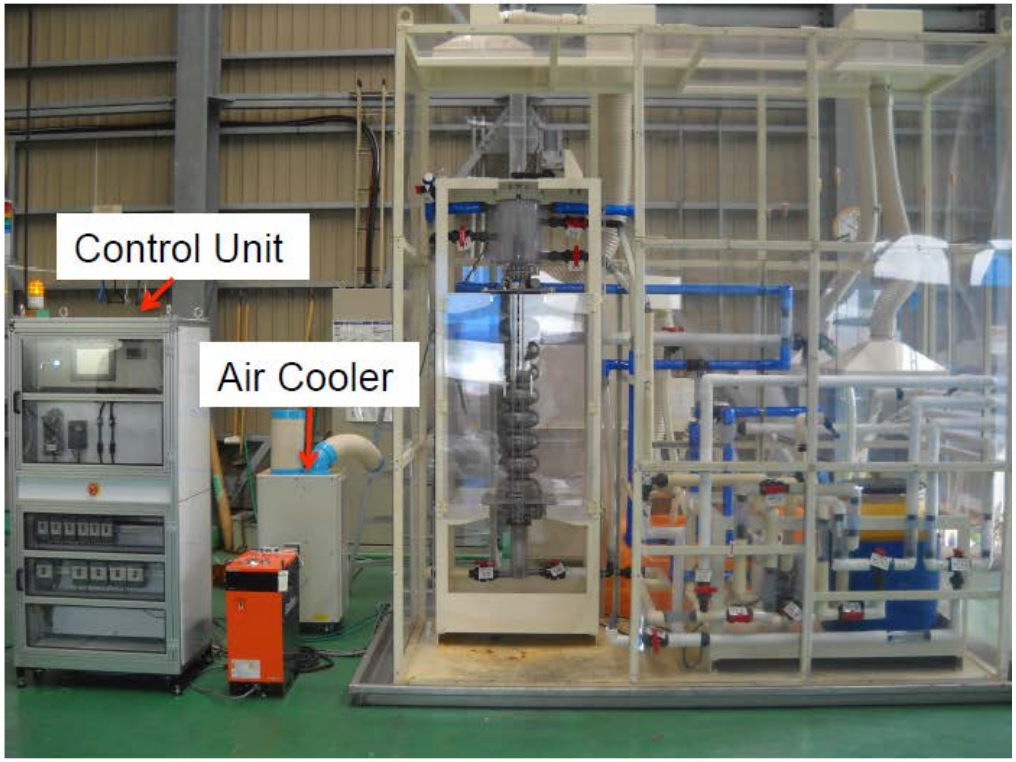
Special Ninja cathode by Marui Co. Ltd.

VEP SET-UPS AT MARUI

Simple VEP setups at Marui Co. Ltd.

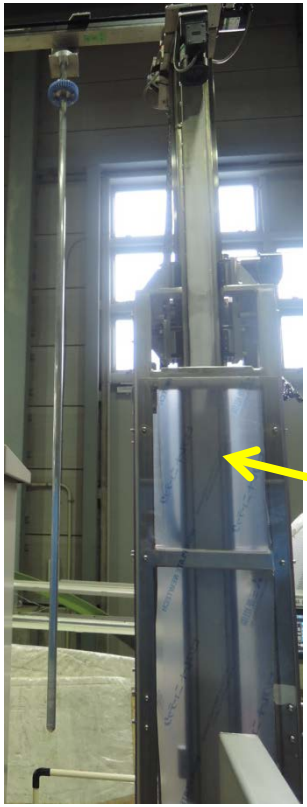
VEP Setup for 1-Cell

VEP Setup for 9-Cell



- We challenged to make the setups with PVC material for mass production and cost reduction.
- The 9-cell cavity VEP system can be used for VEP of 1-cell cavity also.
- System contains separate pipe lines and pumps for water and EP solution.

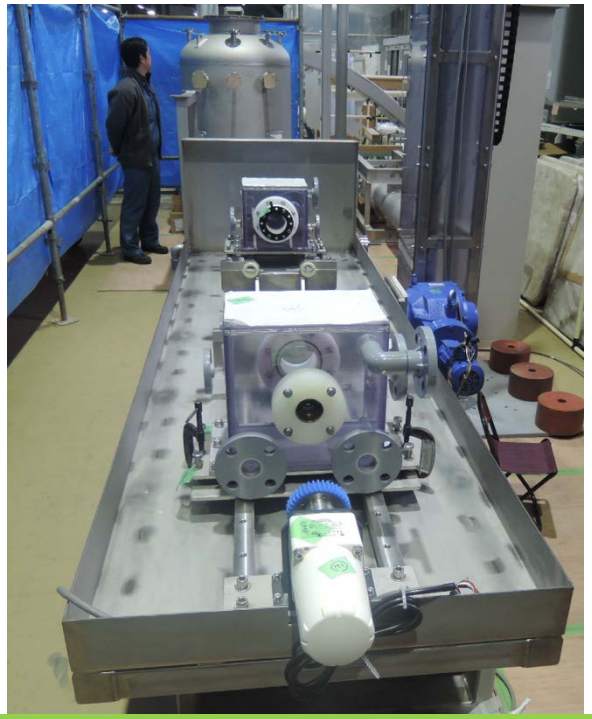
NEW EP SET-UP FOR COI BUILDING AT KEK (CENTER-OF-INNOVATION / COI)



Cathode insertion tool.

Cathode motor

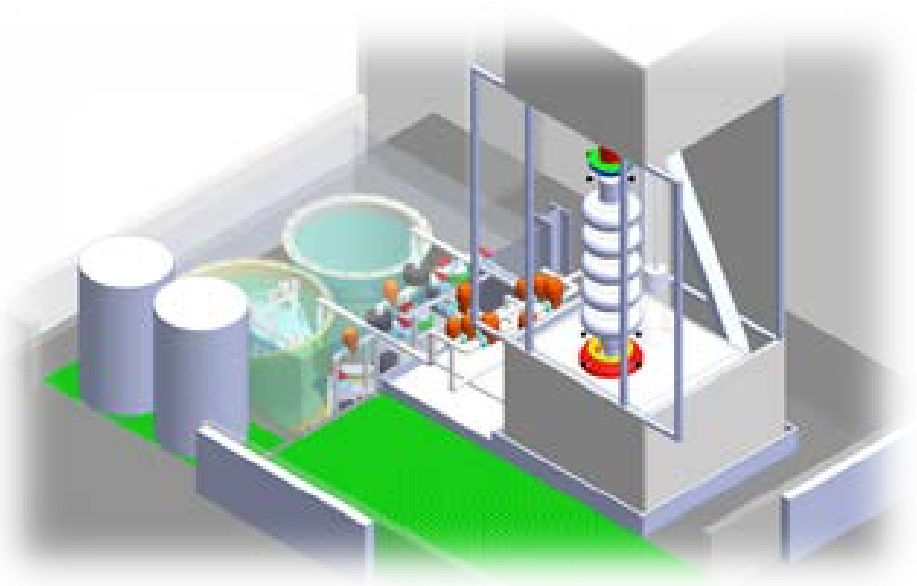
EP bed



EP bed is used both for HEP and VEP (2 ways). This enables the direct comparison of HEP and VEP processes.

Manufacturer is MHI

VEP SET-UP AT CEA SACLAY



- Designed for large cavities
- Circulating acid
- Injected from bottom
- 300L acid capacity
- Cooling system (heat exchanger in acid tank)
- Emptying/draining by gravity
- Nitrogen blowing in top of cavity/acid tank
- Cathode inserted in horizontal position

SPL Cavity insertion in the cabinet

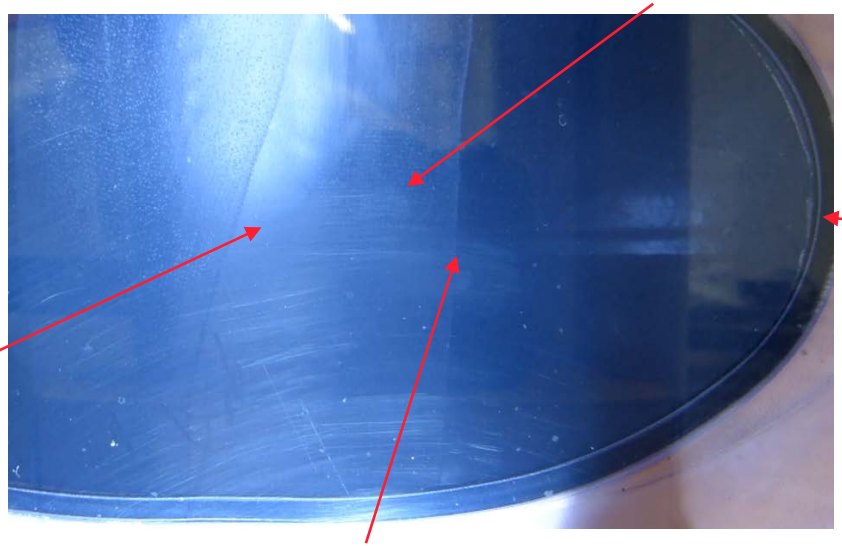
Cathode's insertion in horizontal position

A simple rod-cathode is used. Low-voltage recipe to reduce hydrogen gas.

RECENT ACHIEVEMENTS

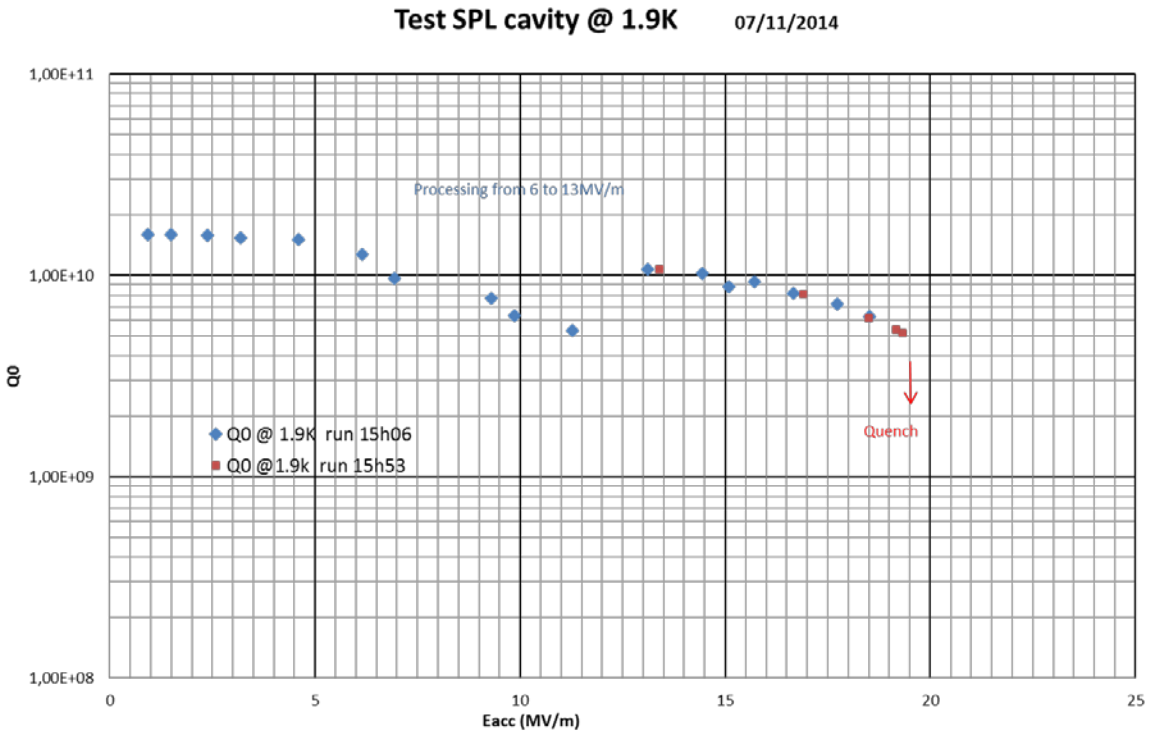
OBSERVATION OF H_2 IN CAVITY DURING VEP

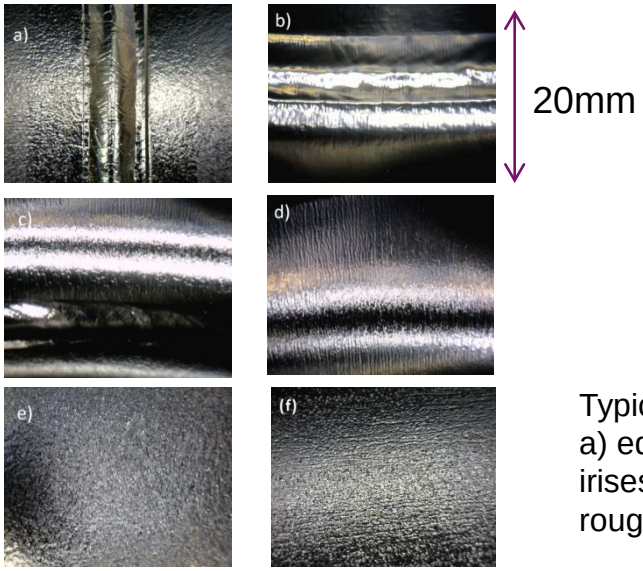
- Improved set up to observe the inside of a 1cell cavity during VEP
- Videos have been made with and w/o the use of a teflon net around the cathode to trap hydrogen gas.
- Teflon net efficient to guide the H_2 –gas generated during process, but bubbles already existing in the mixture (previous VEP) may reach the cavity surface
- Acid circulation without current prior to the process makes it possible to reduce the quantity of hydrogen bubbles



VT OF SPL CAVITY AT HIGHER POWER

- 200 µm average removal by VEP
- Test stopped because of radiation level
- Test carried out at higher power until reaching quench at 20 MV/m



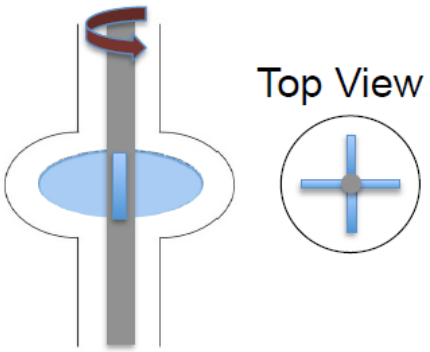


Typical surface morphologies after >100µm VEP at different locations. The weldings at a) equators, and b) irises are smooth. Bubbles stripes are observed at the proximity of irises c) and d). In the areas between equators and irises e) and f), the surface is rougher. Some pitting due to the uncontrolled EP sequence

NINJA CATHODE AND 1CELL COUPON CAVITY

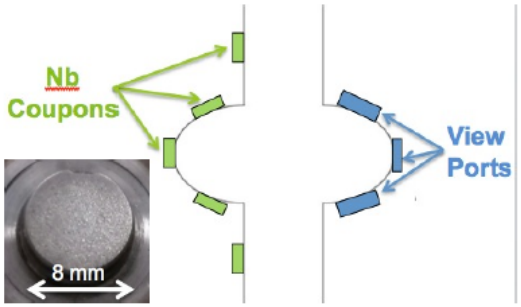
Ninja Cathode

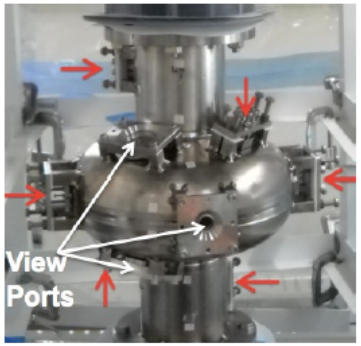
- There are a couple of advantages in VEP.
- However inhomogeneous removal along with cavity length is usually found and this is a primary issue in VEP.
- Marui Galvanizing developed a unique cathode called Ninja cathode for VEP with 4 retractable Al wings for agitation and uniform EP over the cavity.



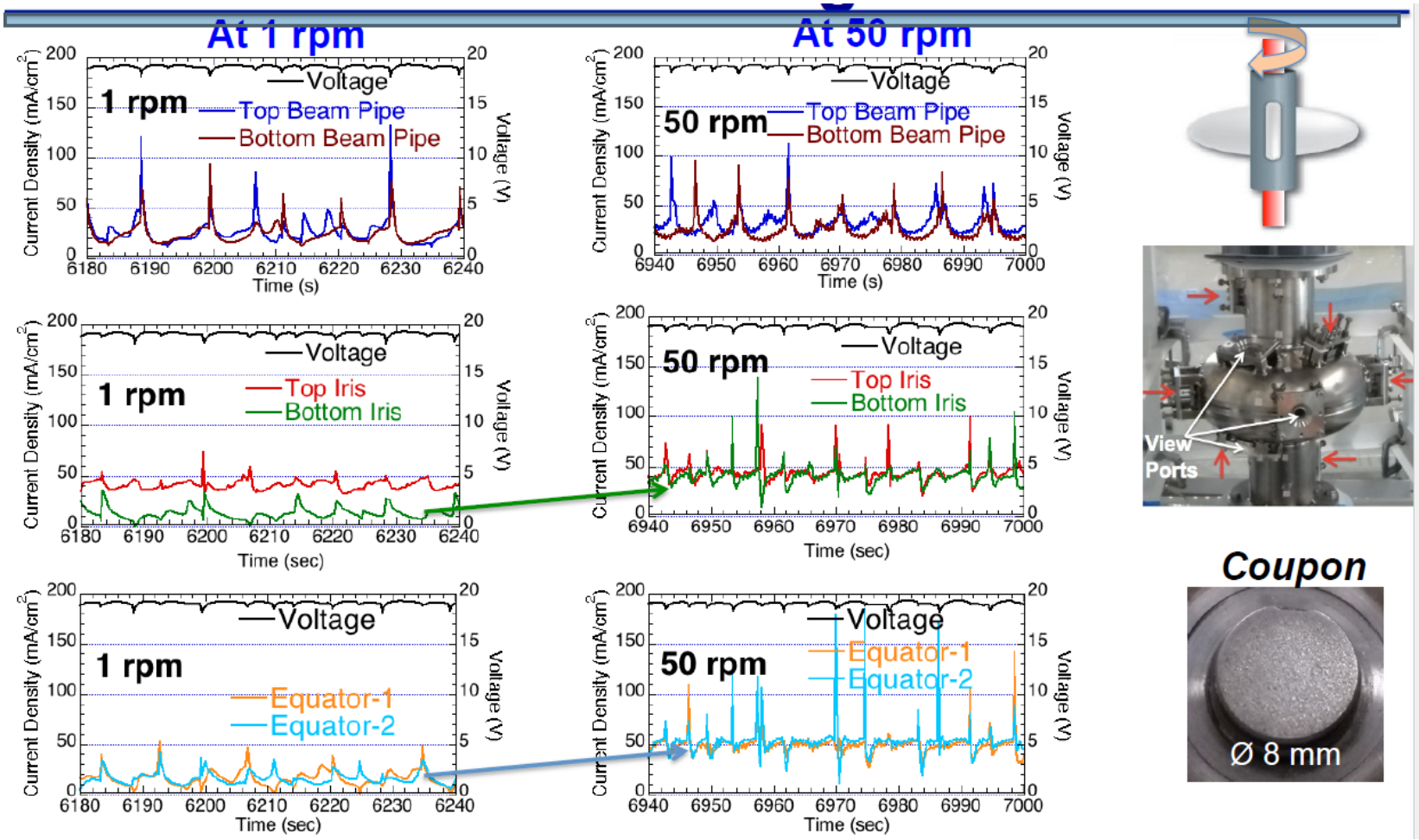
Coupon Cavity

- A KEK coupon cavity was used in order to investigate VEP with Ninja.
- 6 Nb disk type coupons can be set at beam pipes, irises and equator of a single cell cavity.
- The individual coupon EP current is measurable.
- The cavity has also 4 view ports at the top iris, bottom iris and equator for in-situ observation of wings and H_2 bubbles.





INFLUENCE OF STIRRING



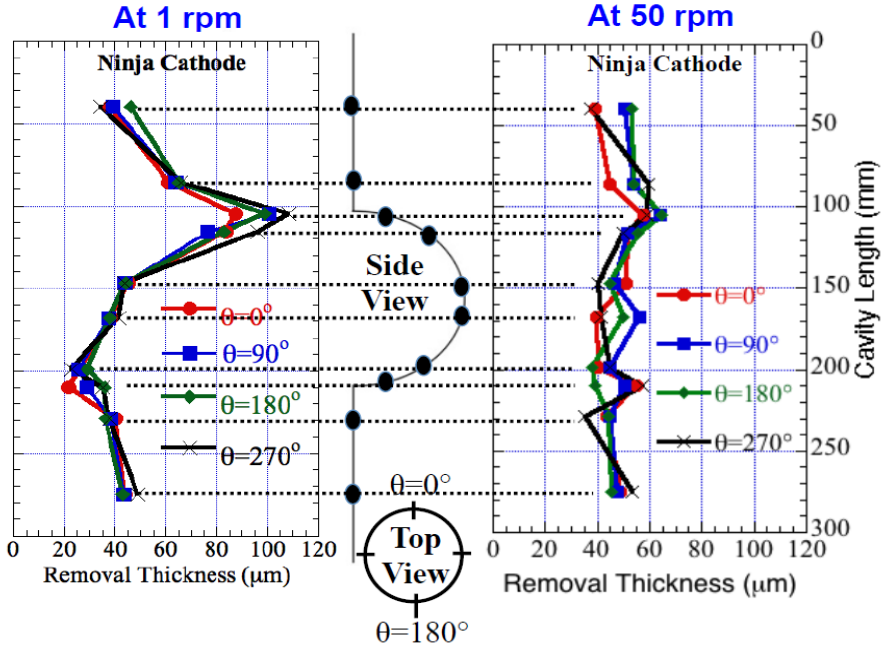
Increasing the stirring speed makes it possible :

- to increase the current in lower half cell
- to achieve similar curent in both half cells : symmetric removal expected

- First test carried out on 1cell cavity carried out at 1rpm
- New experiment at 50 rpm

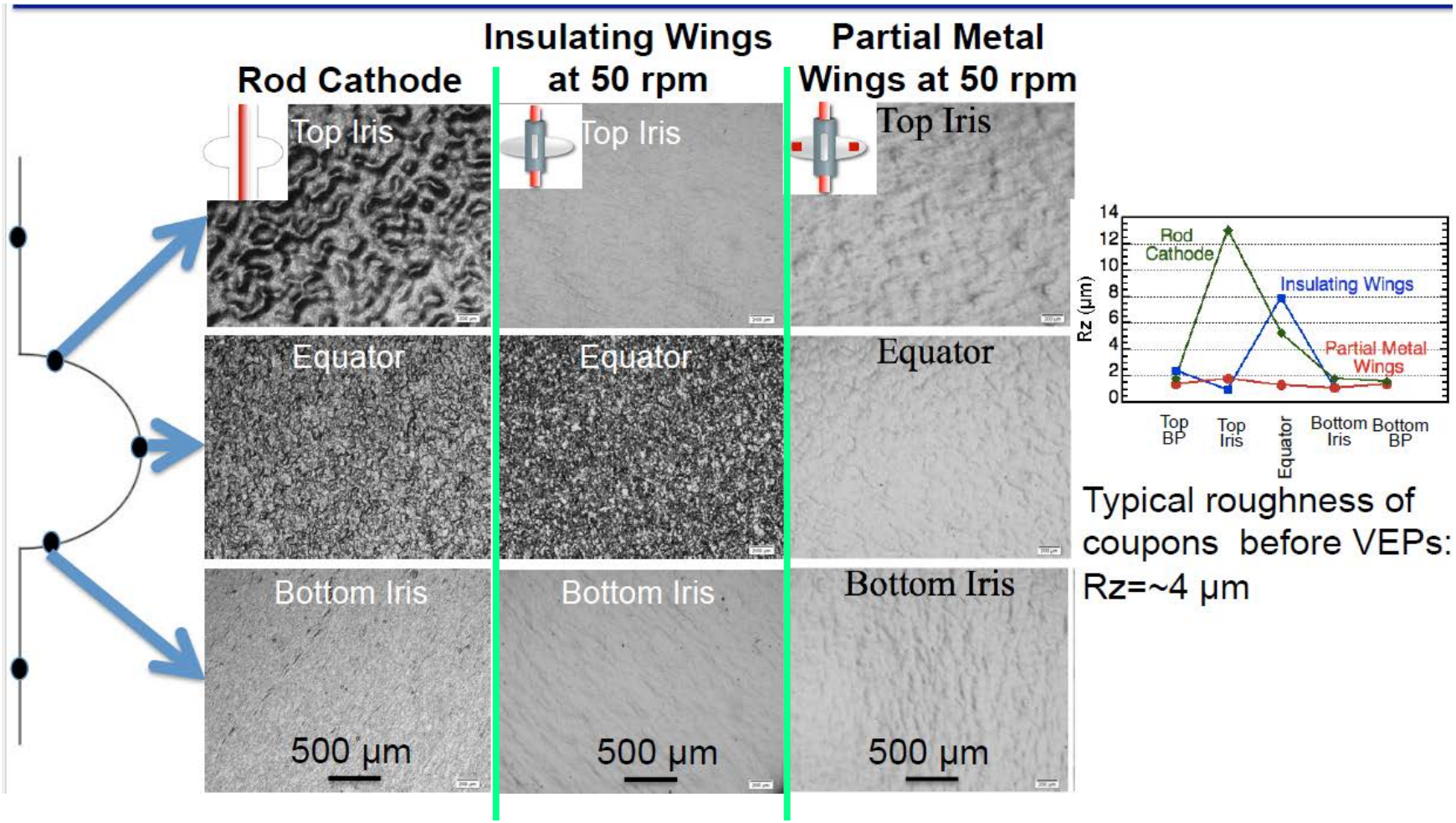
Removal Thickness of the Cavity

- Average cavity removal thickness (from cavity weight loss) = 55 µm



- The removal thickness was almost homogeneous on entire cavity including the top and the bottom irises.
- The high rotation speed might generate uniform viscous layer on the surface of cavity cell since the high flow of EP solution remove H_2 bubbles form the top iris.

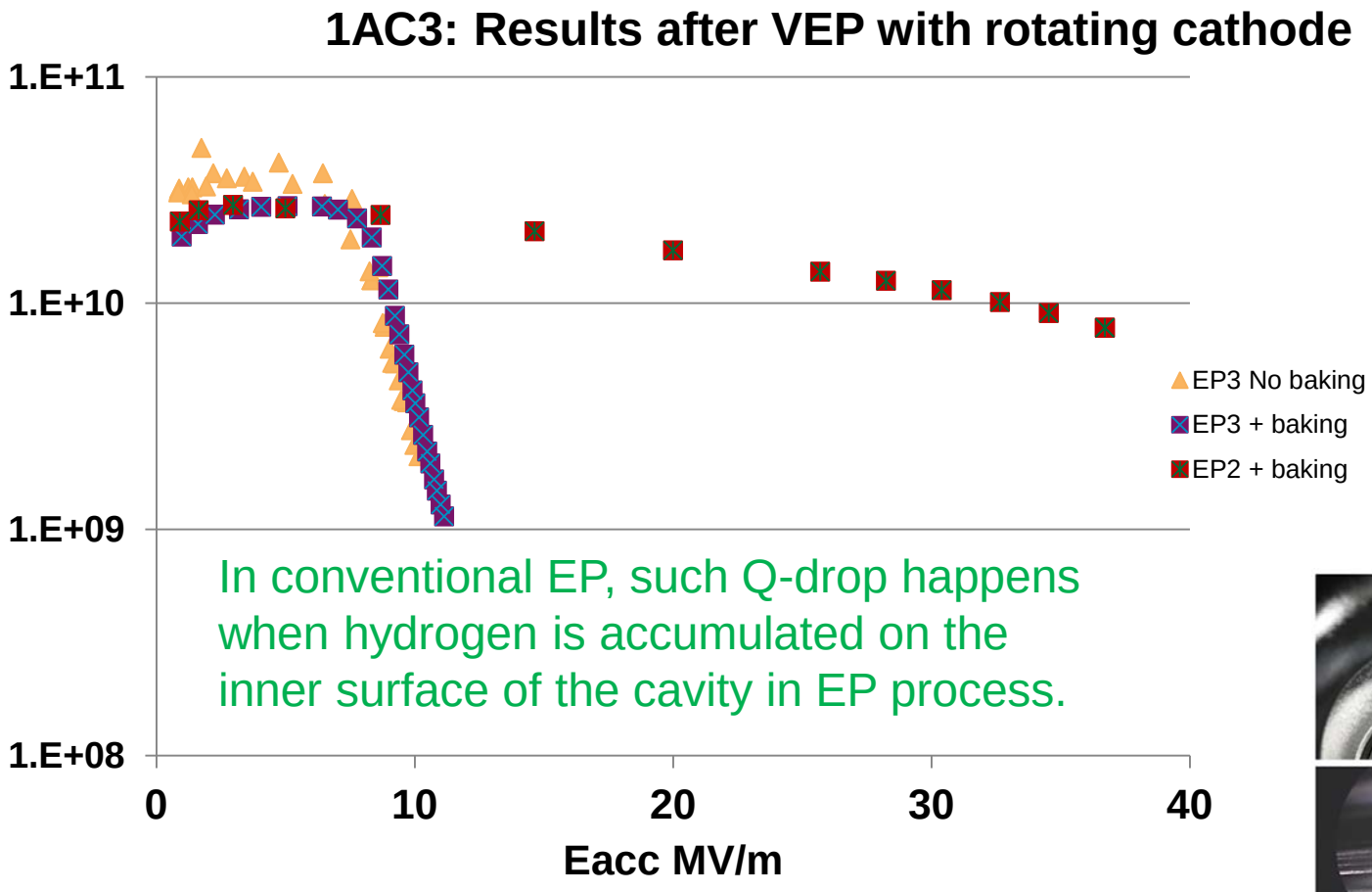
STIRRING AND ROUGHNESS



Typical roughness of coupons before VEPs: Rz=~4 µm

Continuous improvement of Ninja cathode concept makes it possible to improve the surface along the cavity surface

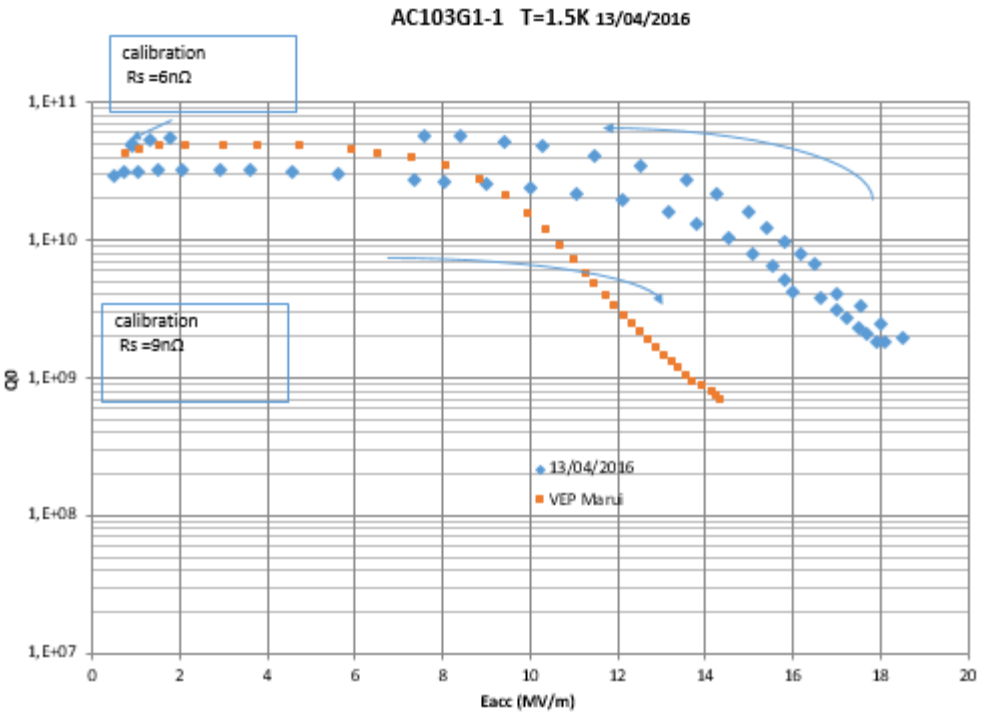
TESTS RESULTS AFTER VEP WITH ROTATING CATHODE (1RPM)



Surface improvement of 1AC3 after VEP with rotating cathode

- 1AC3 cavity was VEP'ed at KEK after previous VEP at CEA
- The inner surface has been smoothened
- However, the cavity is limited by Q-slope
- The Q deterioration is not cured by baking (120 C).

TESTS RESULTS AFTER 2D VEP WITH ROTATING CATHODE (50 RPM)



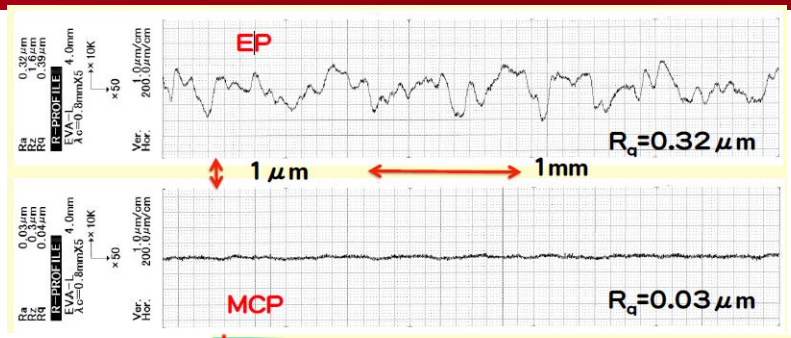
Baking (800 C) should degas/ release the hydrogen from the cavity.

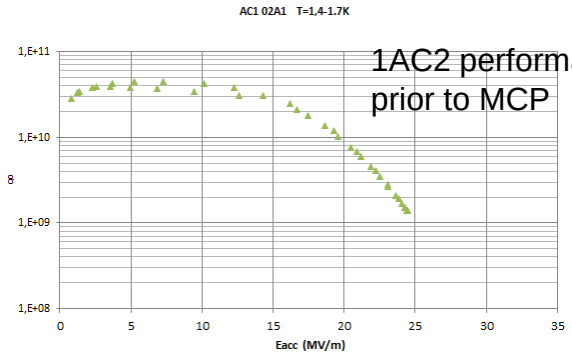
- 1AC3 cavity was baked at KEK (800°C) and VEP'ed with new VEP parameters to reduce hydrogen generation.
- The cavity was sent back to Saclay for VT
- Performance is limited by similar Q-slope
- Q_0 at low field is high
- Additional 10µm standard VEP at Saclay: Performance is improved

Ninja cathode is being modified to trap hydrogen gas in Teflon-mesh net. (Smoothness and uniformity is OK, but hydrogen gas is still problem.)

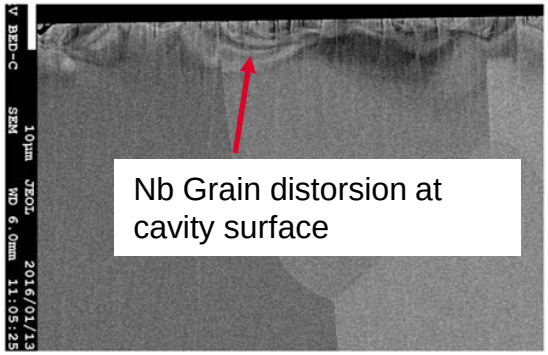
CAVITY EXCHANGE PROGRAM
1AC2 / MCP: MECANOCHEMICAL POLISHING

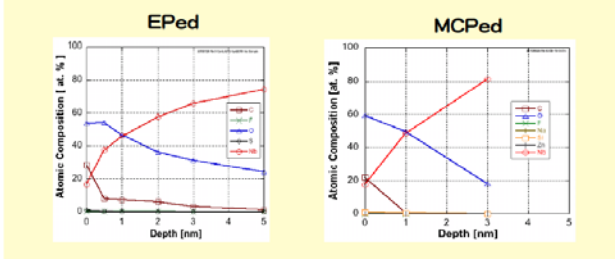
- In the program ECB (electro-chemical buffing) was replaced by MCP.
- MCP is cost effective compared to ECB
- Makes it possible to reach low Ra
- Polishing into 2 steps:
  - MCP with SiO_2 (65 nm)
  - MCP w/o SiO_2





1AC2 performance prior to MCP





1AC2 cavity after MCP

- Cavity exchange program with 1AC2
- Performance of 1AC2 limited by Q-Slope after VEP
- MCP at KEK: Very smooth surface, removal of defects (pits)
- Very high Rs found at 4K.
  Probably due to grain distorsion at Niobium surface
- +10 µm Standard VEP at Saclay: Decrease in Rs, but still high.

The cause of the bad RF performance is investigated by sample test.
(Also more VEP removal of 1AC2 is planned to check the depth of bad surface.)

PROPOSAL FOR FY 2016-2017

ONGOING VEP EXPERIMENTS: TESTS WITH C1-19 CAVITY

Repeat VEP (w/ modified Ninja cathode) and VT by a new single-cell cavity: C1-19.

C1-19: Single Cell Nb cavity treated by standard Chemical Polishing (BCP) at Saclay

C1-19 will be tested for ultimate VEP recipe (w/ Ninja cathode) developped by KEK:

- Bulk VEP (50 µm+ 50 µm after flipping the cavity; total 100µm)
- Baking at 800 °C
- Fine VEP (5-10µm) With 'Ninja2' cathode
- HPR at KEK
- Cavity shipped to Saclay for VT

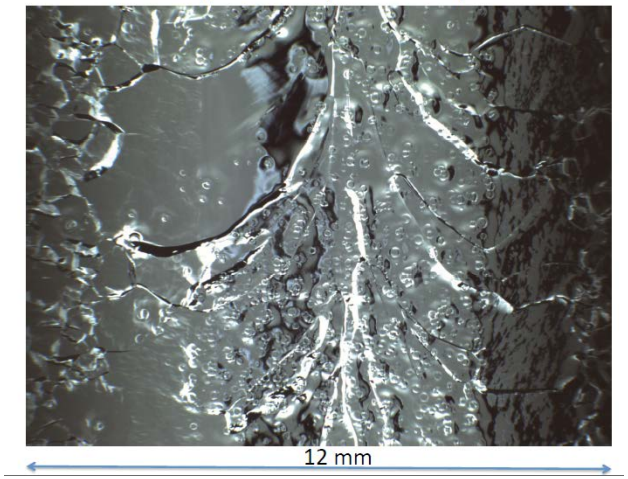
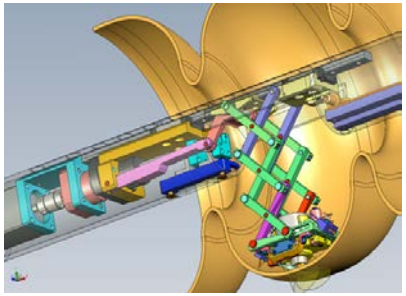
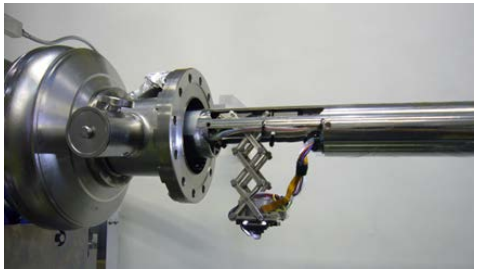


Image of cavity surface at equator welding after BCP ('Kyoto Camera').
The cavity will be mechanically polished by local grinding prior to VEP treatment.

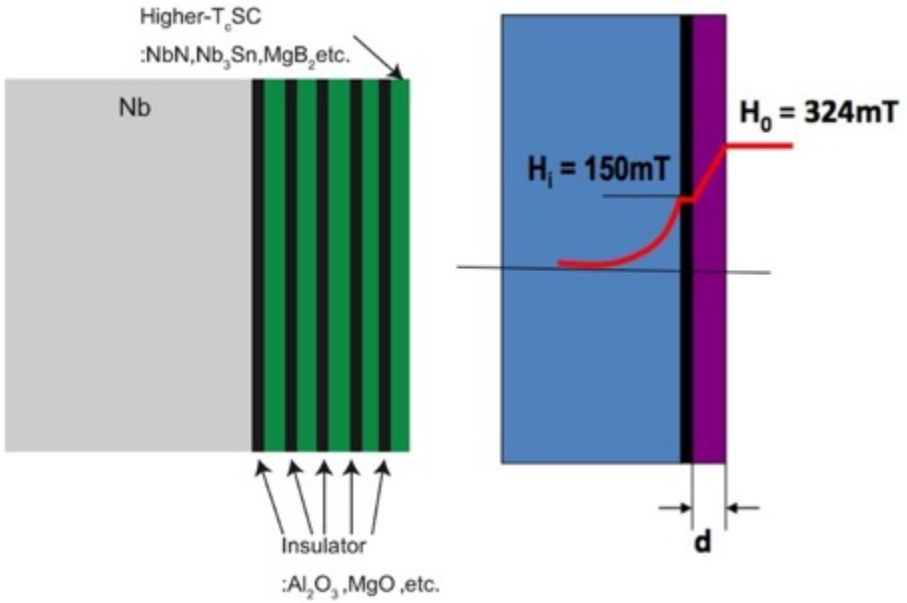




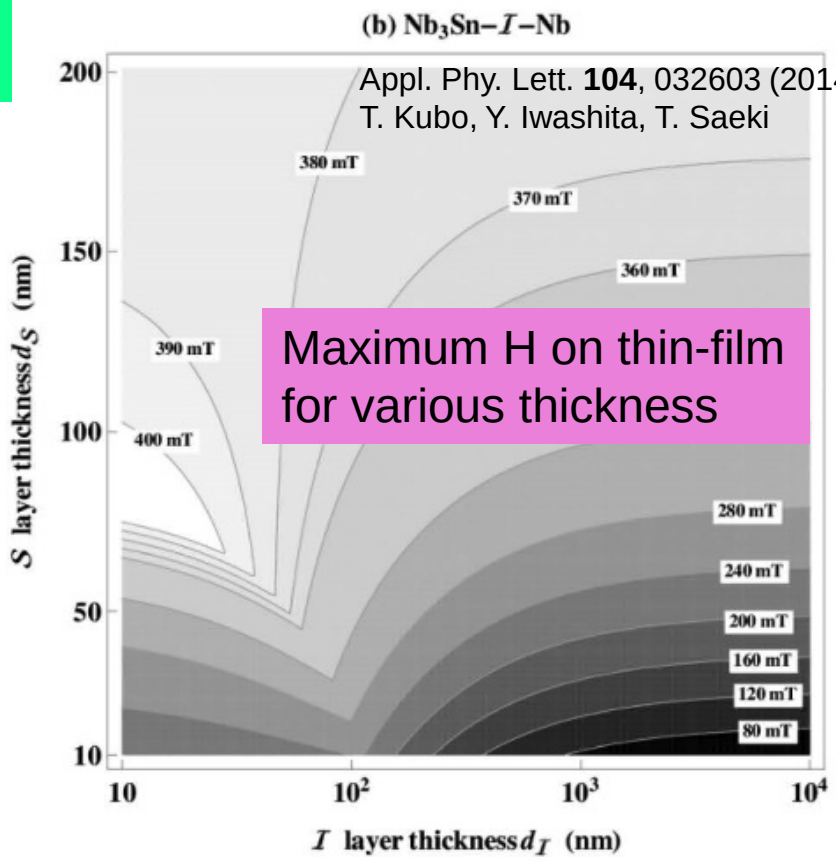
STUDIES OF MULTILAYER-SC

Higher Hc of thin-film on Nb → Higher quench field
(Cavity of higher gradient)

Very big impact on ILC.



Multi-layer-thin-film Single-layer-thin-film

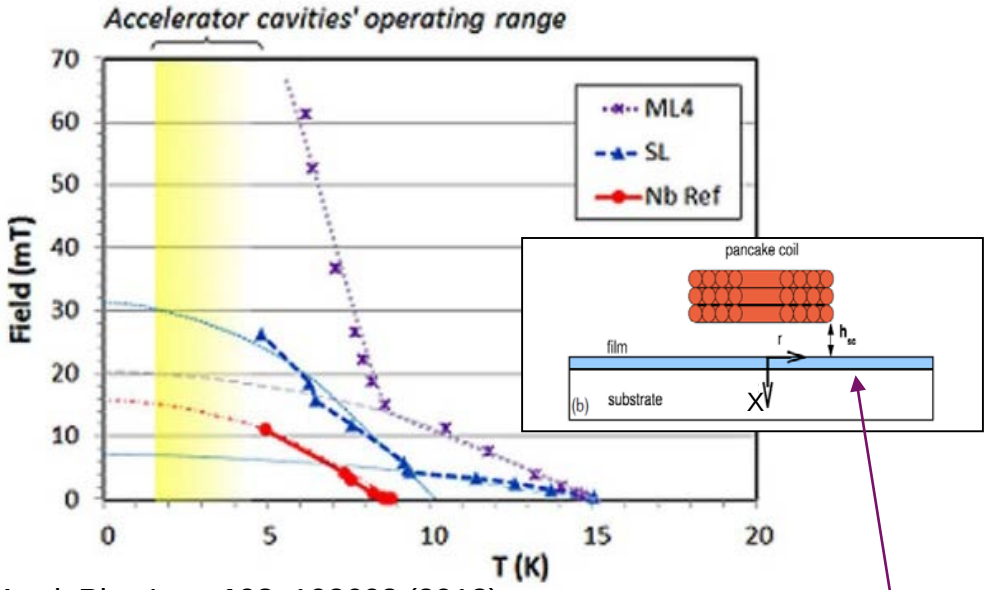


Appl. Phy. Lett. **104**, 032603 (2014)
T. Kubo, Y. Iwashita, T. Saeki

Maximum H on thin-film for various thickness

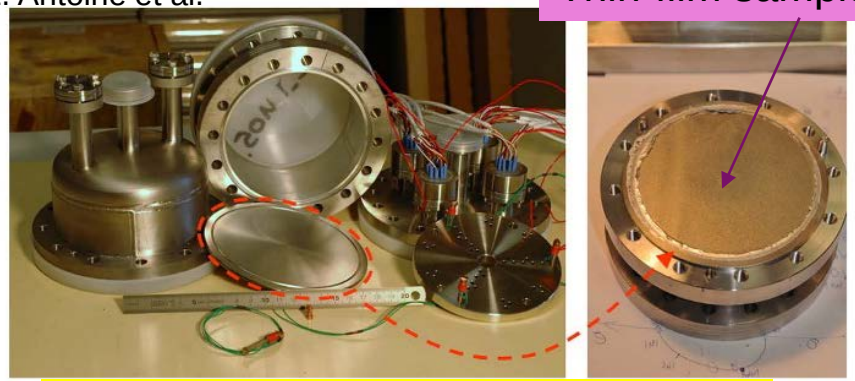
Optimized thicknesses of SC and Insulator layers are calculated.
T. Kubo. et al. (KEK)

STUDIES OF MULTILAYER-SC



Appl. Phy. Lett. **102**, 102603 (2013)
C. Z. Antoine et al.

Thin-film samples

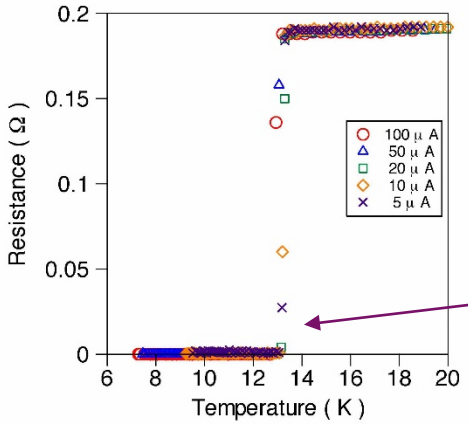


CEA/Saclay has lots of experiences for experiments of thin-film samples.

Proc. of IPAC2016
T. Saeki et al.
ID = WEPMB021

KEK just started experiments for thin-film samples.

Thin-film sample NbN (200 nm)



(Tc of NbN = 16.2 K)

Measured Tc = 13.3K

Collaboration for thin-film subjects

SUMMARY

Funding Request from France				
Description	**€/unit**	**Nb of units**	**Total (€)**	**Requested to[4]:**
Travel to Japan	1000	1	1000	Irfu
Visit to Japan	150/day	4	600	Irfu
Shipping of cavity	1300	1	1300	Irfu
Tests of cavity	2500	4	10000	Irfu
Total			12900	Irfu
Funding Request from KEK				
Description	**k¥/Unit**	**Nb of units**	**Total (k¥)**	**Requested to:**
Travel	250	2 travels	500	KEK
Visit to France	20/day	20	400	
Total			900	

THANK YOU FOR YOUR ATTENTION