A_RD_9
R&D on innovative treatments and characterization of SRF surface for future accelerators.

T. Kubo, T. Proslier

France-Japan-Korea
Associated Laboratories
2017 International Annual Workshop

May 11th, Strasbourg

CONTEXT

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

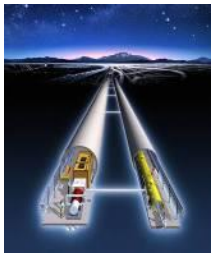
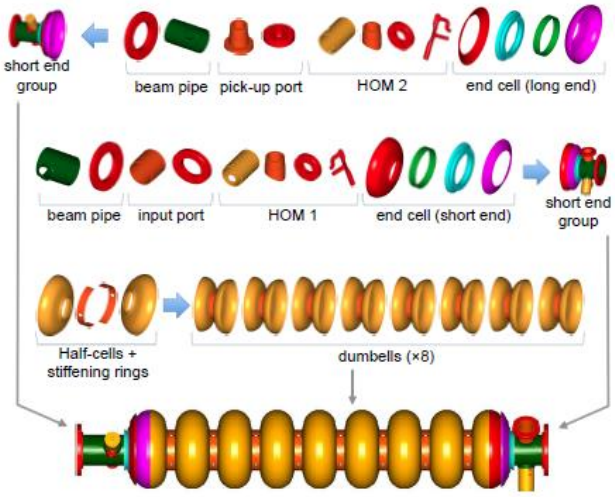
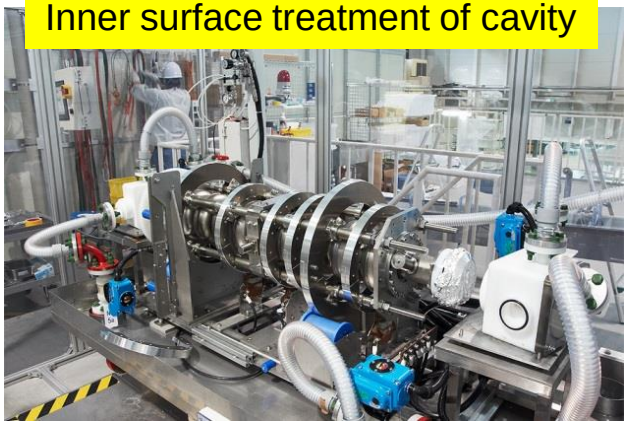


Table 2.1
The main goals and timeline for SCRF R&D established at the beginning of the Technical Design Phase

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

- Decrease the cost:
  - Multilayer: increase the performances (Emax and Q)
  - Vertical Electro-Polishing

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:

ID[1]:	Title: R&D on innovative treatments and characterization of SRF surface for future accelerators.					
	French Group			Japanese Group		
	Name	Title	Lab./Organis.[2]	Name	Title	Lab/Organis.[3]
Leader	T. Proslier	Dr.	Irfu	Takayuki Kubo	Dr.	KEK
Members	C. Madec	Dr.	Irfu	Hitoshi Hayano	Dr.	KEK
	C. Antoine	Dr.	Irfu	Shigeki Kato	Dr.	KEK
	S. Berry	Dr.	Irfu	Motoaki Sawabe		KEK
	C. Servouin		Irfu	Hideaki Monjushiro	Dr.	KEK
	F. Eozénou		Irfu	Takayuki Saeki	Dr.	KEK
	A. Four		Irfu			

OUTLINE

Vertical Electro-Polishing and multilayers:

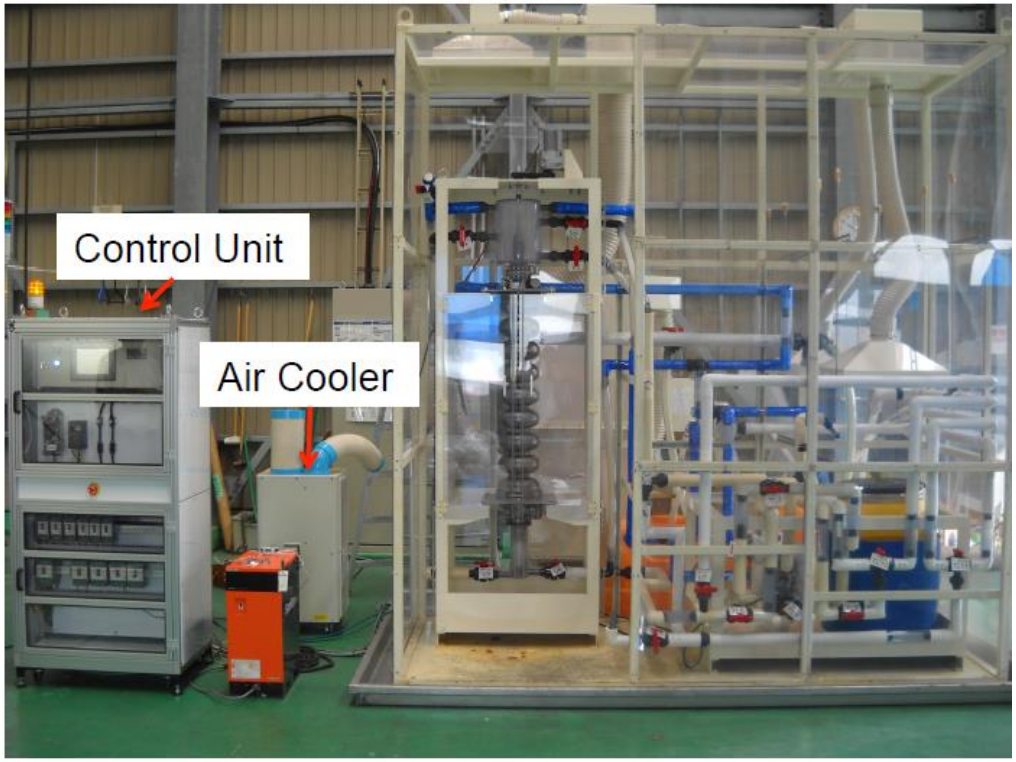
- INFRASTRUCTURE
- RECENT ACHIEVEMENTS
- PROPOSAL FOR 2017-2018

INFRA: VEP SET-UPS AT MARUI

Simple VEP setups at Marui Co. Ltd.

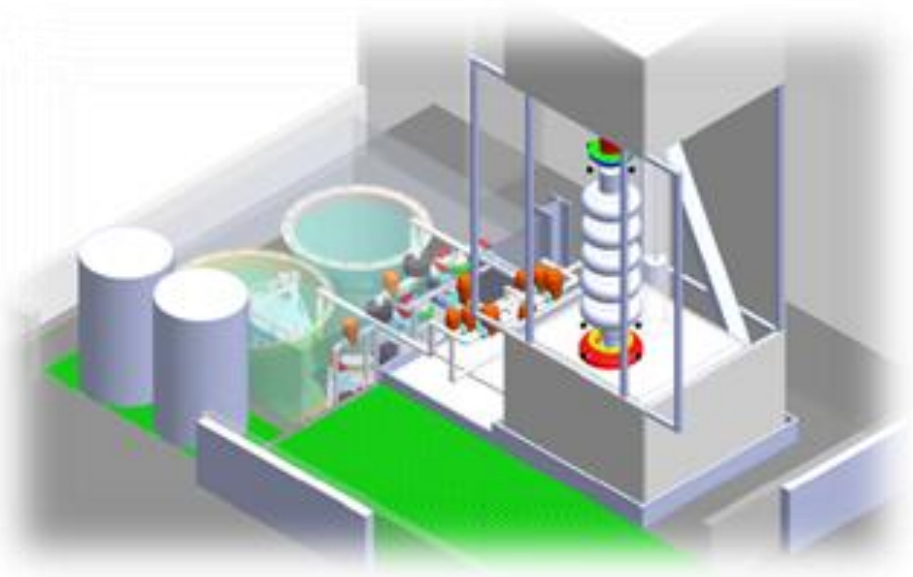
VEP Setup for 1-Cell

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.

INFRA 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

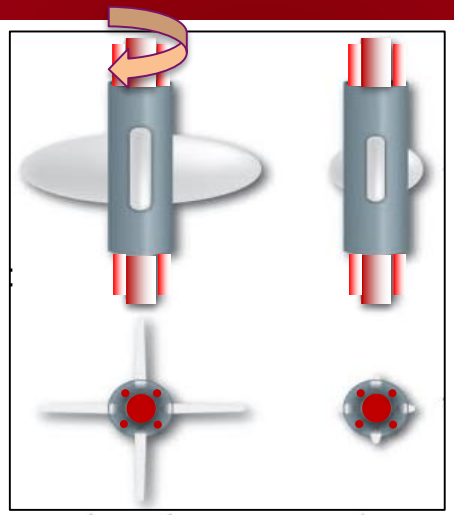
Cathode's insertion in horizontal position

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

ACHIEVEMENTS: NINJA CATHODE 1CELL CAVITY

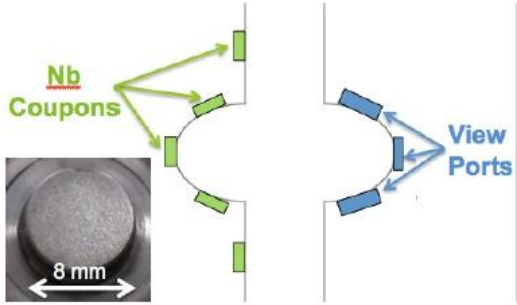
Ninja Cathode

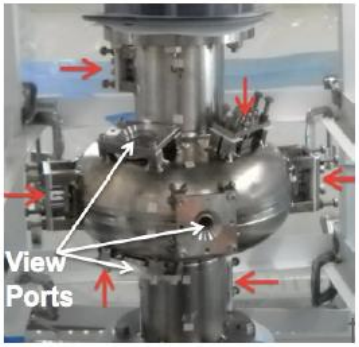
- There are a couple of advantages in VEP.
- However inhomogeneous removal along with cavity length is usually found and this is a primary issue in VEP.
- Marui Galvanizing developed a unique cathode called Ninja cathode for VEP with 4 retractable wings for agitation and uniform EP over the cavity.



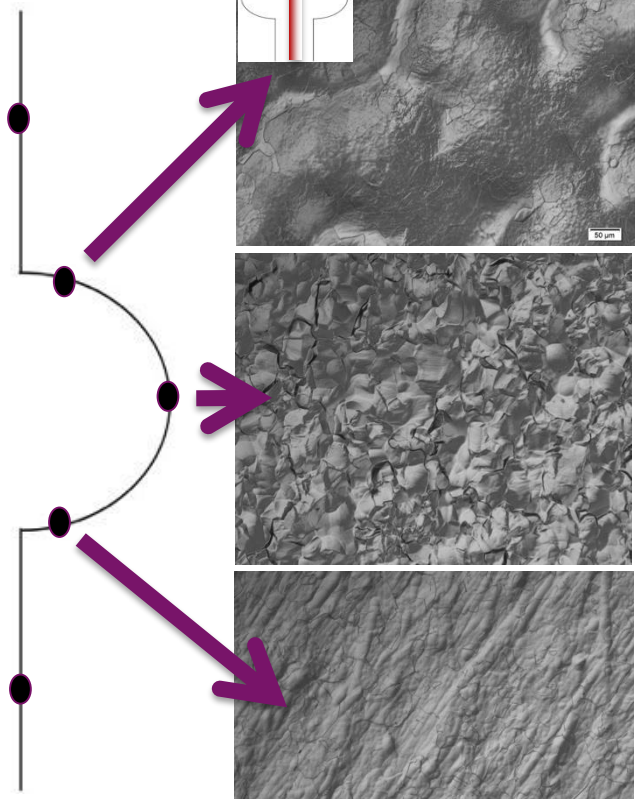
Coupon Cavity

- A 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.



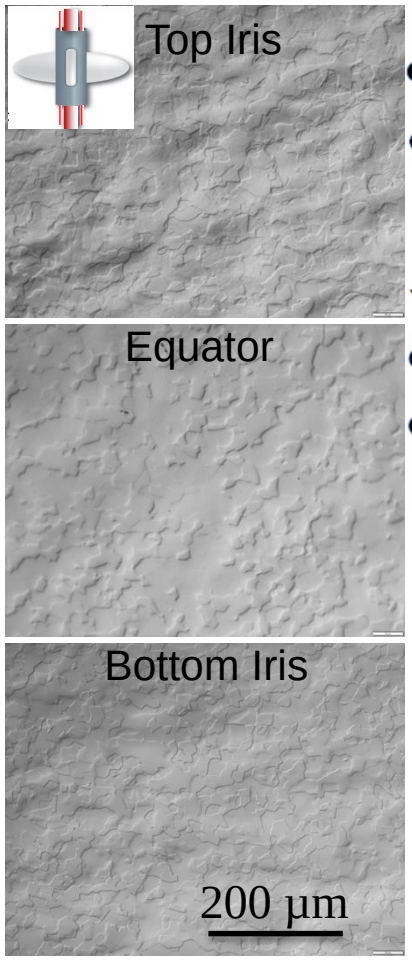


ACHIEVEMENTS: STIRRING AND ROUGHNESS

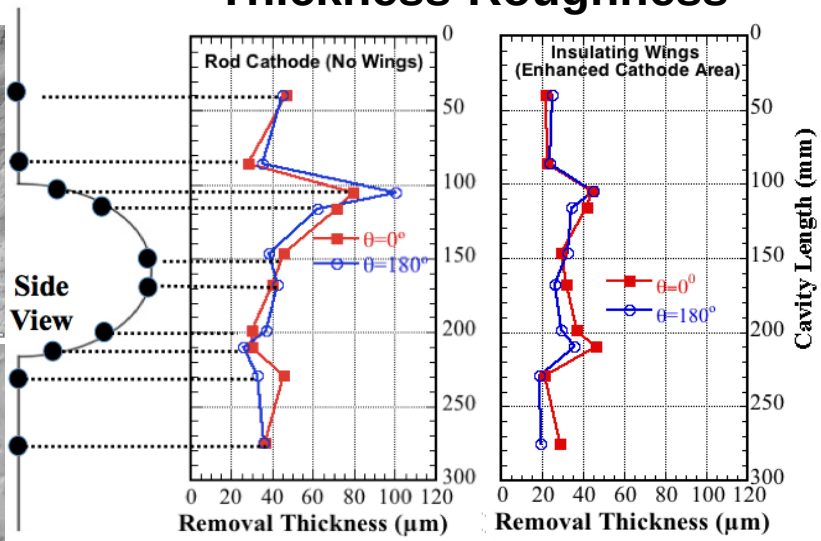


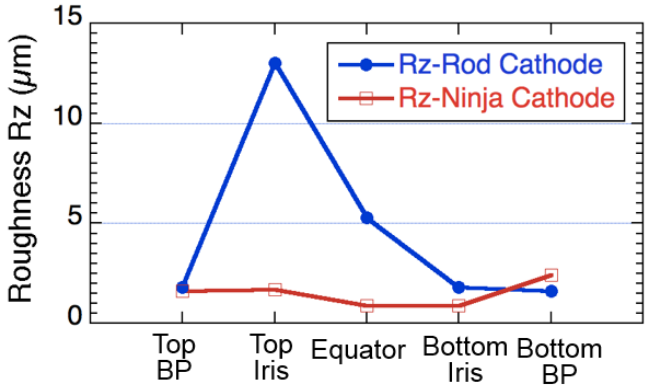
Rod Cathode

Ninja Cathode



Thickness-Roughness





- Almost symmetric removal
- entire surface smooth and shiny

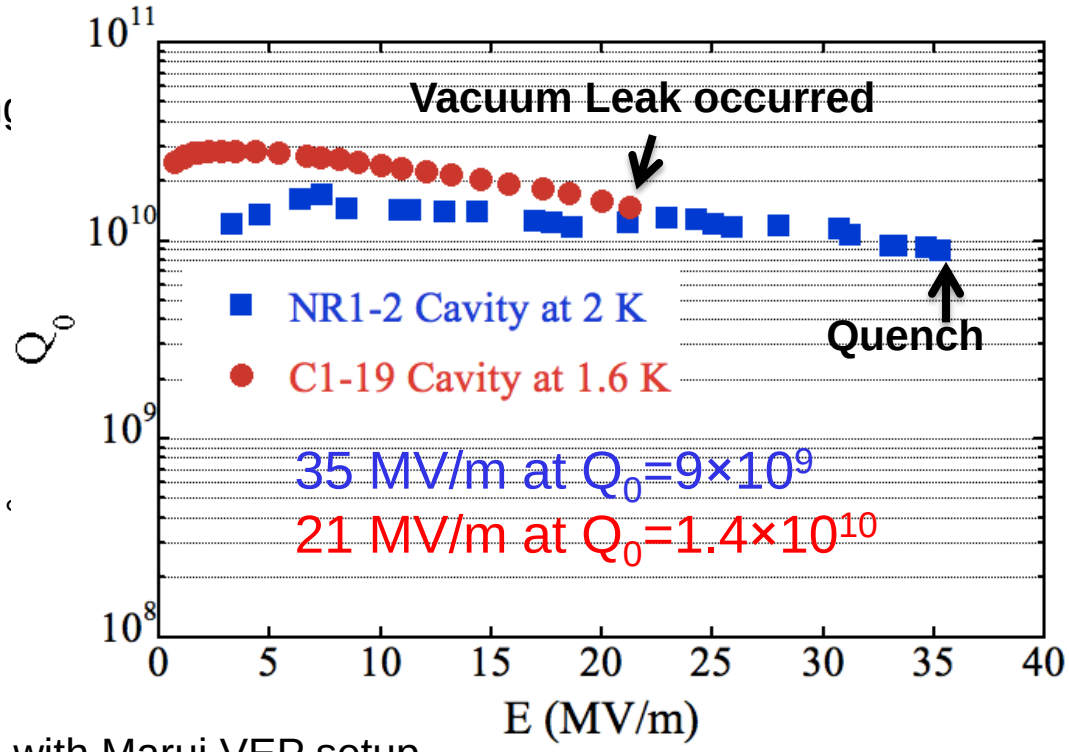
Successful results on Monocellule Nb cavities -> promising for 9 cells

ACHIEVEMENTS: RF TESTS RESULTS

Two single-cell cavities (NR1-2 and C1-19) were VEPed with the Ninja cathodes and tested in vertical cryostats.

NR1-2 Cavity (Cornell Cavity)

- **Pre-treatment**: Tumbling, BCP, degassing at 800 °C
- **Cathode**: Ninja cathodes (partial metal wings and enhance area) with the VEP setup of Cornell University
- **VEP**: VEP with each cathode (20+20 µm removal)
- **Ninja rotation speed**: 50 rpm
- **VT**: Performed at 2K at Cornell after 120 ° baking



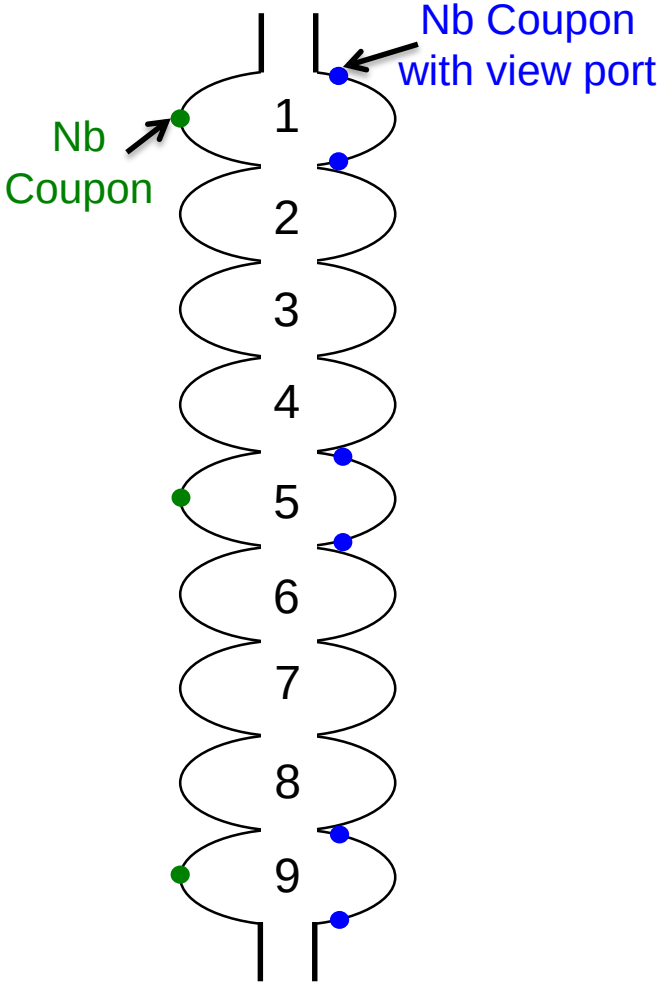
C1-19 Cavity (Saclay Cavity)

- **Pre-treatment**: BCP
- **Cathode**: Ninja cathode (enhanced area) with Marui VEP setup
- **VEP**: Two VEP for 31 and 55 µm removal, degassing at 750°C and final VEP for 11 µm removal
- **Ninja rotation speed**: 30 rpm
- **VT**: Performed at 1.6K at Saclay

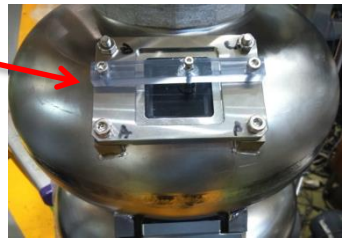
The both cavities showed good performance in the vertical tests.

FUTURE WORK VEP

- Tests of Ninja cathode VEP of 9-cell cavities.
- A coupon cavity was fabricated for VEP parameter optimization.

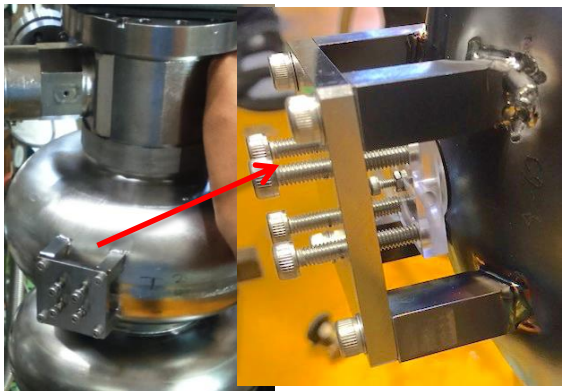


Coupon with View Port near Iris



6 coupons near iris positions

Equator Coupon



3 coupons at Equator positions

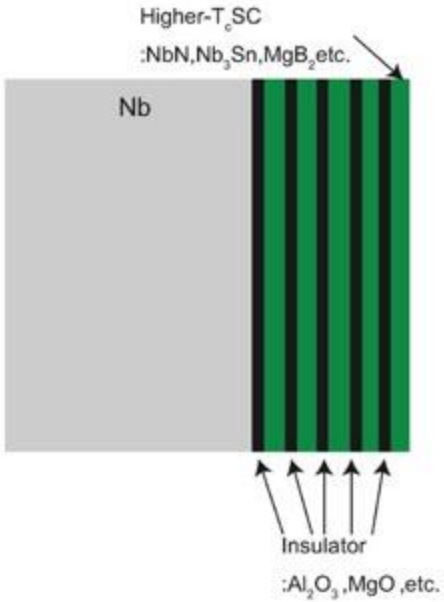
FUTURE WORK VEP

- The 9-cell VEP facility is being improved for better control of VEP condition.
- VEP parameter study for a 9-cell cavity is being carried out using the 9-cell coupon cavity and the Ninja cathode.
- Optimized VEP parameters will be applied to a 9-cell cavity at Marui and the cavity will be tested in a vertical cryostat at KEK.
- Additionally, VEP set up for monocell cavity installed at Saclay (October 2017)
- Single cell cavities will be vertically electropolished and tested for evaluation of RF performance at Saclay

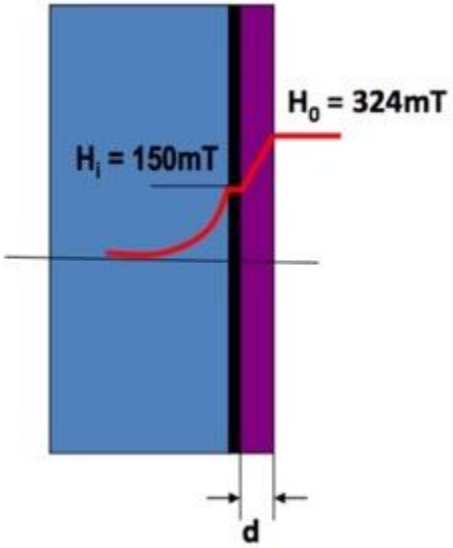
MULTILAYER-SC

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

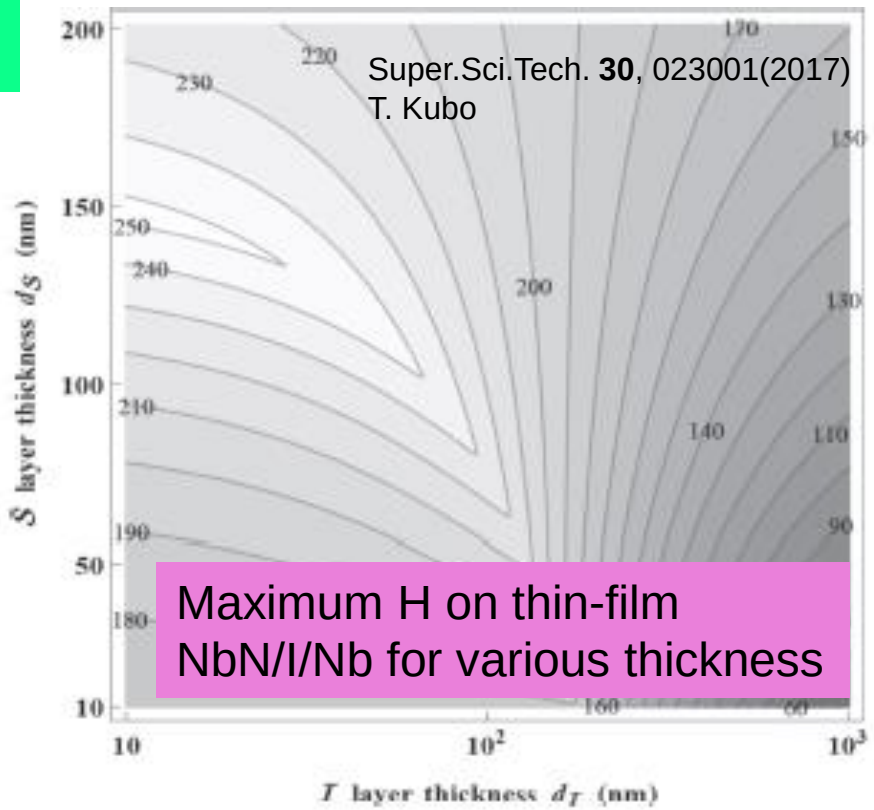
Very big impact on ILC.



Multi-layer-thin-film



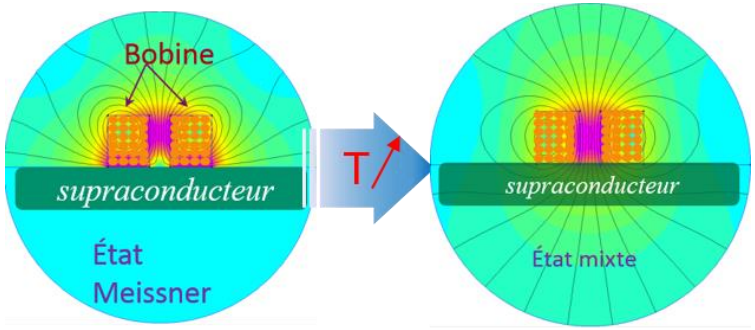
Single-layer-thin-film

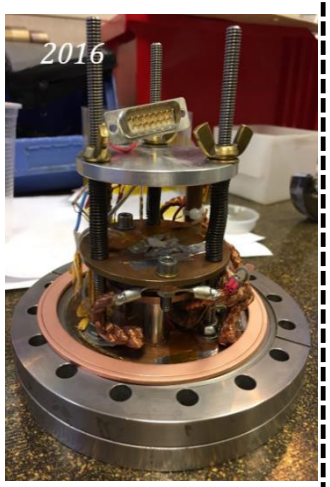


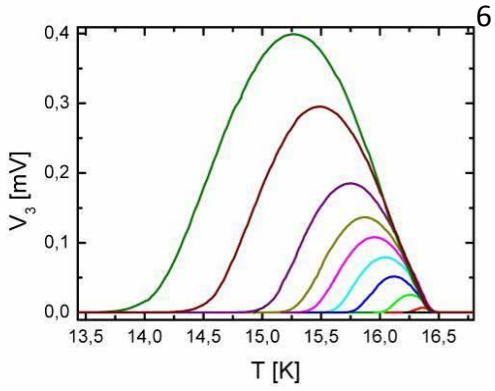
Maximum H on thin-film
NbN/I/Nb for various thickness

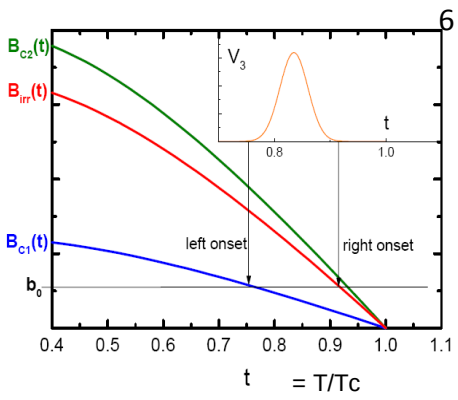
-Optimized thicknesses of SC and Insulator layers are calculated. T. Kubo. (KEK).
- Numerical simulation TDGL

magnetometry









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

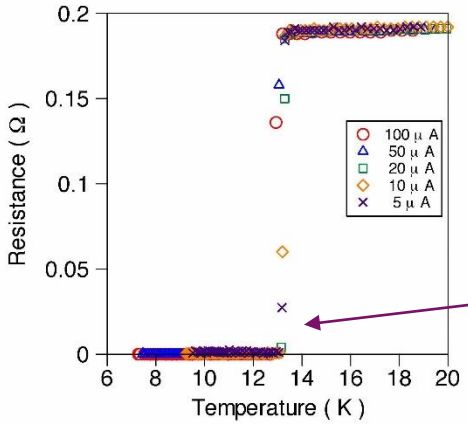
Thin-film samples

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)



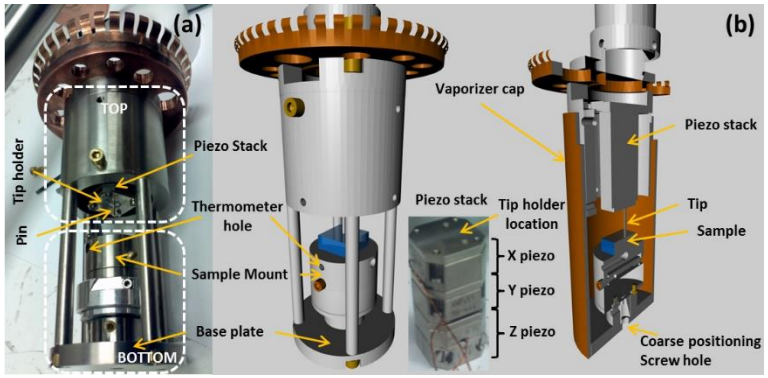
(Tc of NbN = 16.2 K)

Measured Tc = 13.3K

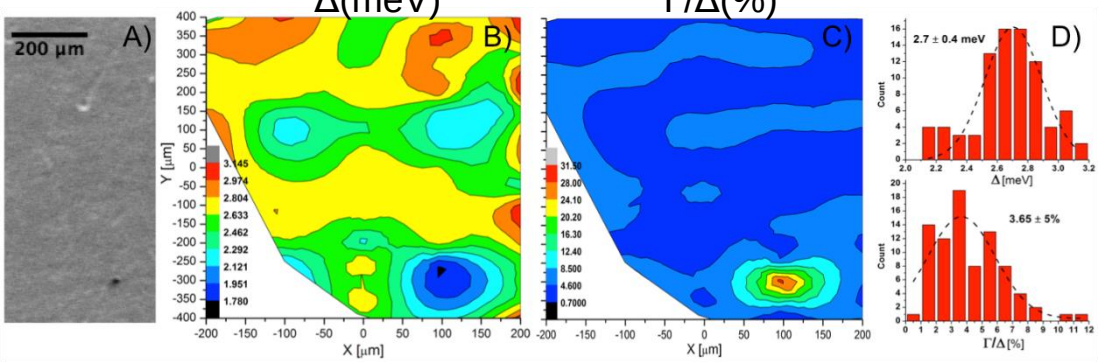
Collaboration for thin-film subjects

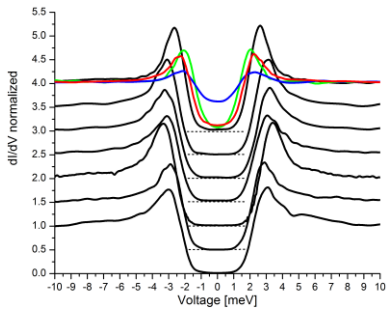
INFRA MULTILAYER-SC

Tunneling spectroscopy



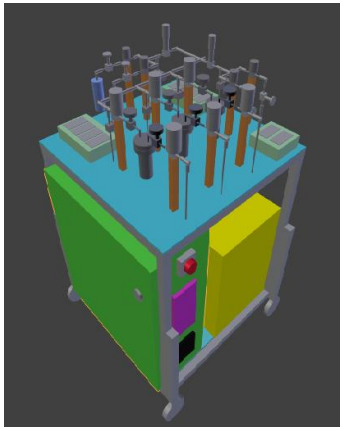
Nb_3Sn/Nb

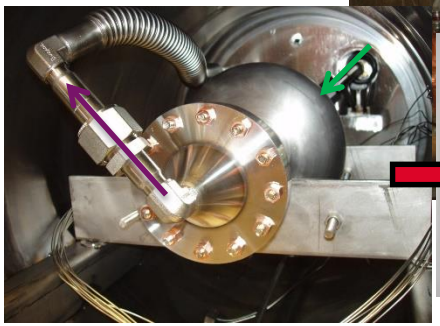




- Maps of superconducting properties (Δ, Tc, ξ) of alloys and structures
- Large sampling area: up to 1x1 mm^2
- Future: visualise vortices.

Atomic Layer Deposition

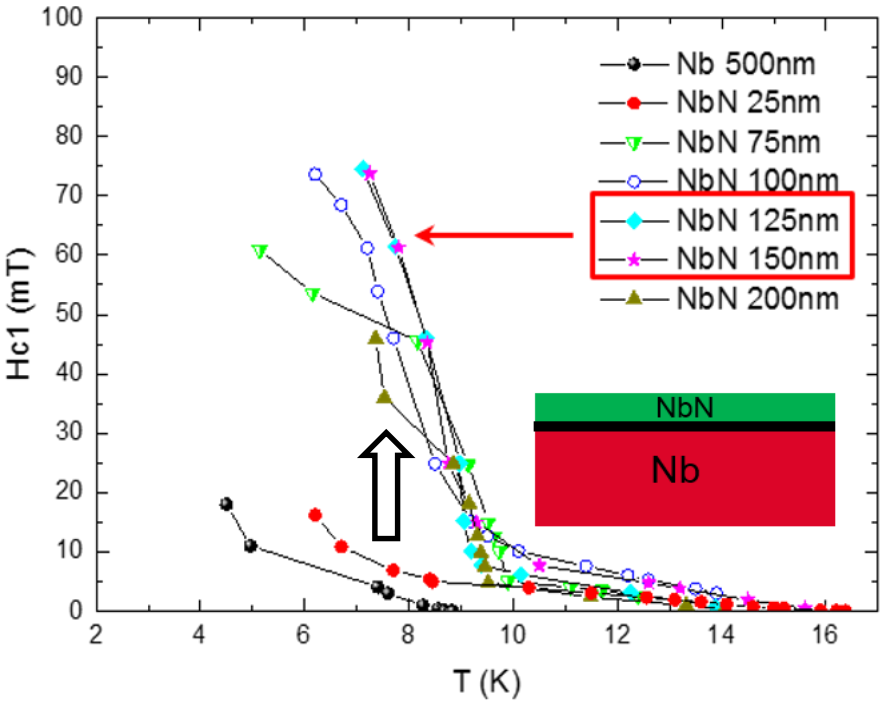


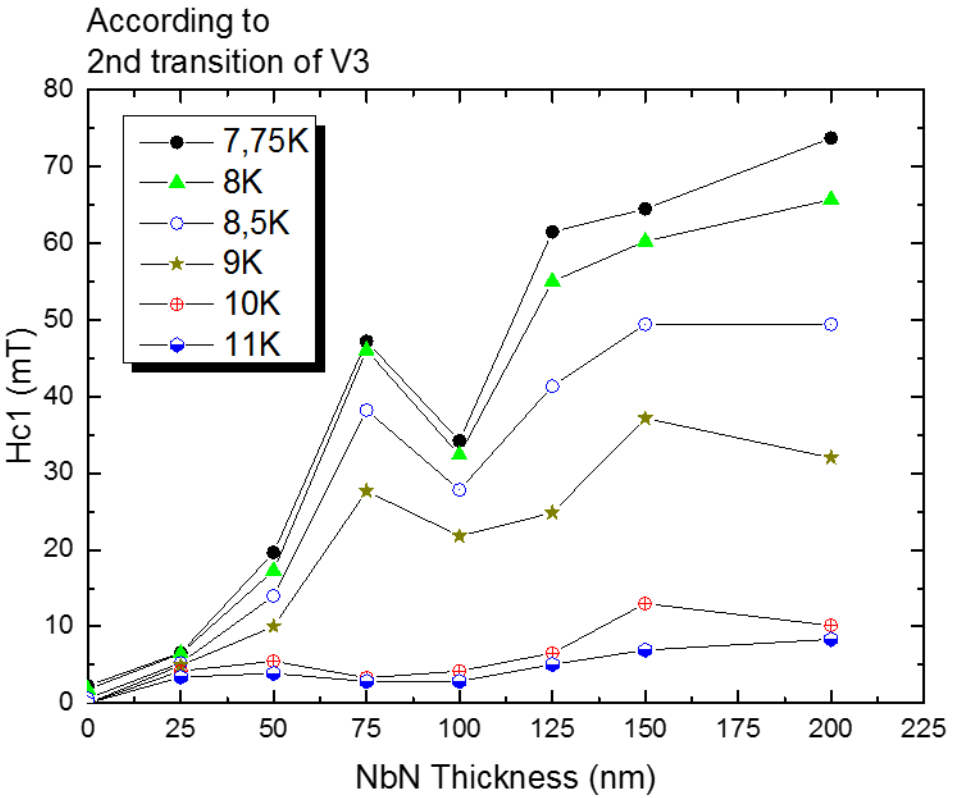


- AlN/MoN and AlN/NbTiN by ALD on Nb already optimized.
- Coupons -> cavities is trivial
- Future: Integrate oven to existing set up.

Collaboration for thin-film subjects

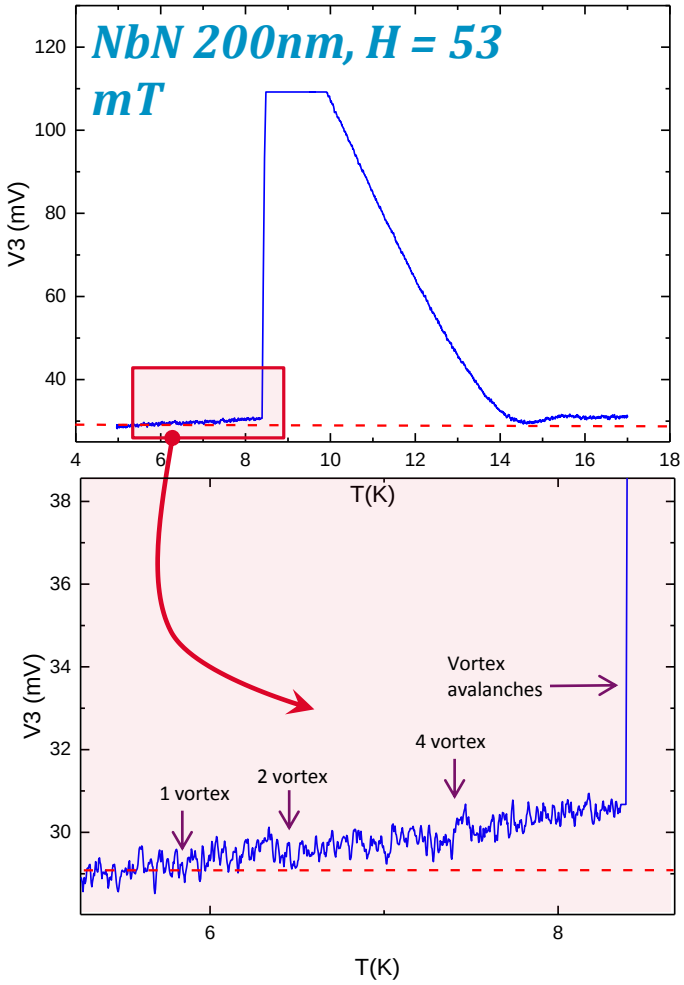
ACHIEVEMENT
MULTILAYERS-SC MAGNETMETRY

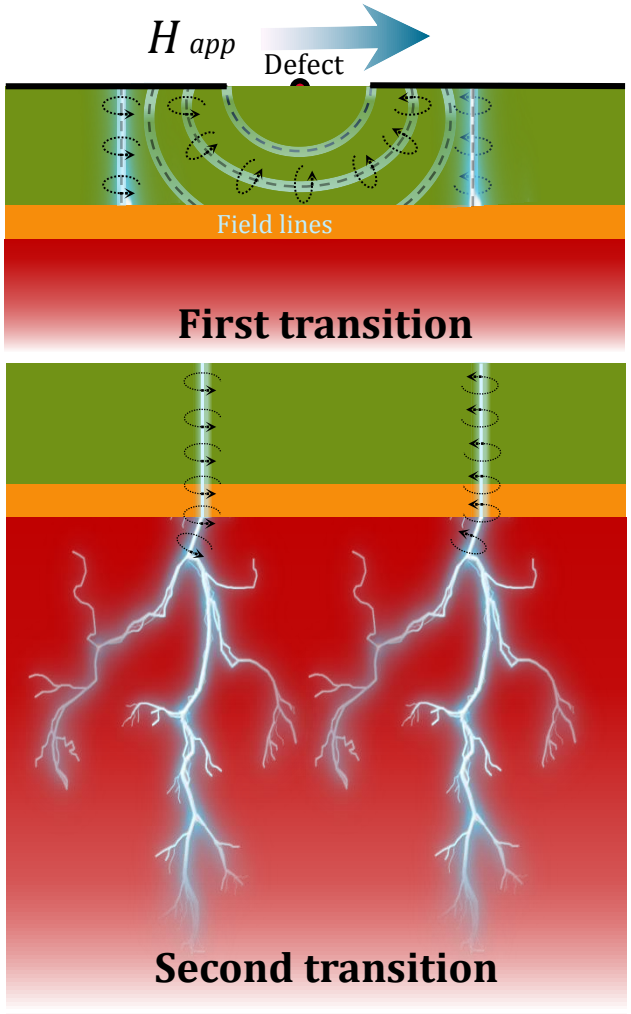




- Saturation of H_{C1} for NbN > 150 nm. Try thicker films (prediction optimal ~ 150 nm)
- Understanding of vortices transition measured by magnetometry

Why we have two transitions ?



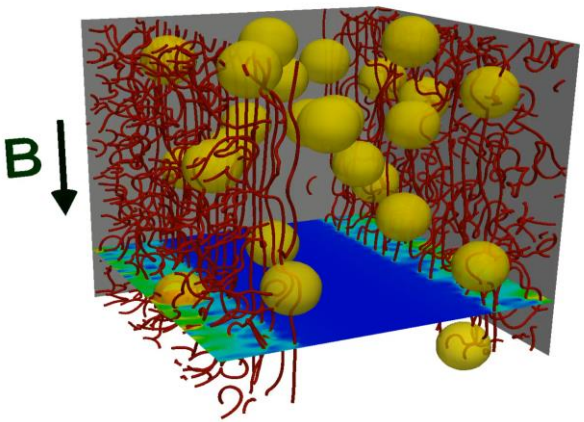


- Thin SC layer NbN
- Insulator MgO
- Thick SC layer Nb

- *H* // surface => surface barrier[7]
- A defect locally weakens the surface barrier
- **1st transition**, vortex blocked by the insulator ~100 nm => low dissipation.
- **2nd transition**, propagation of vortex avalanches (~100 µm) => high dissipation.

FUTURE WORK MULTILAYERS

- Continue measuring penetration fields of various multilayers alloys.
- Correlation with Tunneling spectroscopy.
- Deposition of MoN and NbTiN multilayers by ALD on Nb coupons
- Upgrade the magnetometer (coil and thermal design) to reach higher external fields
- Numerical simulation using TDGL equations to visualize vortex dynamic



FUNDING

Funding Request from France				
Description	€/unit	Nb of units	Total (€)	Requested to[4]:
Travel to Japan	1000	3	3000	Irfu
Visit to Japan	150/day	12	1800	Irfu
Shipping of cavity and samples	1300	3	3900	Irfu
Total			8700	

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	10 days	200	
Total			700	

THANK YOU FOR YOUR ATTENTION