Cavity Fabrication Status in KEK/CFF

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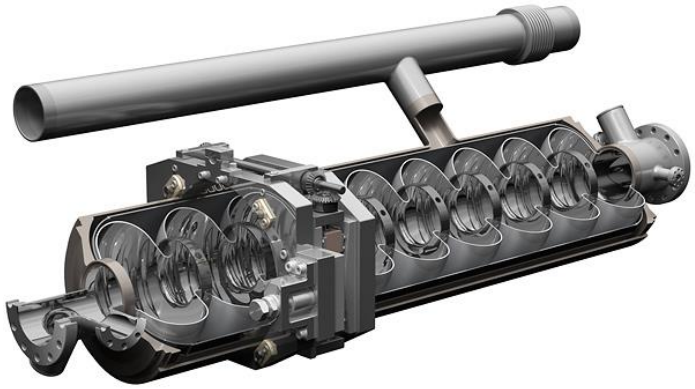
International Workshop on Future Linear Colliders (LCWS2018)

Current status of Cavity Fabrication Facility (CFF)

Cavity Fabrication Facility (CFF) is working for ILC project;

- Study for cost reduction in cavity fabrication
  - ✓Mass production techniques
  - ✓Try new materials (LINAC2018 THPO002)
- Pass the helium vessel code (high pressure gas safety act.)
  - ✓Buckling simulation
  - ✓Welding Procedure Specification



Main equipments in CFF

EB welding machine
（SST, Germany）
Max. beam voltage: 150 kV

Microscope
(Surface inspection)

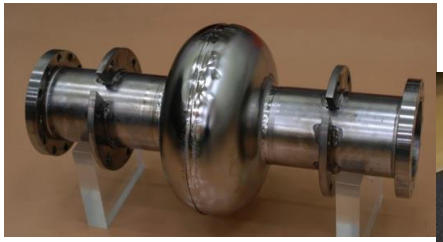
Servo press machine
(AMADA, Japan)
Max. applying force:
1500 kN

A cavity can be manufactured in KEK site combined with machine tools at MEC

Chemical polishiing

CNC vertival lathe
(Moriseiki, Japan)

History of CFF



3 × **9**-cell cavities, 5 × **3**-cell cavity, 10 × **1**-cell cavities
(& some seamless cavities)

Cost reduction study

Motivation in cavity fabrication facility (CFF)

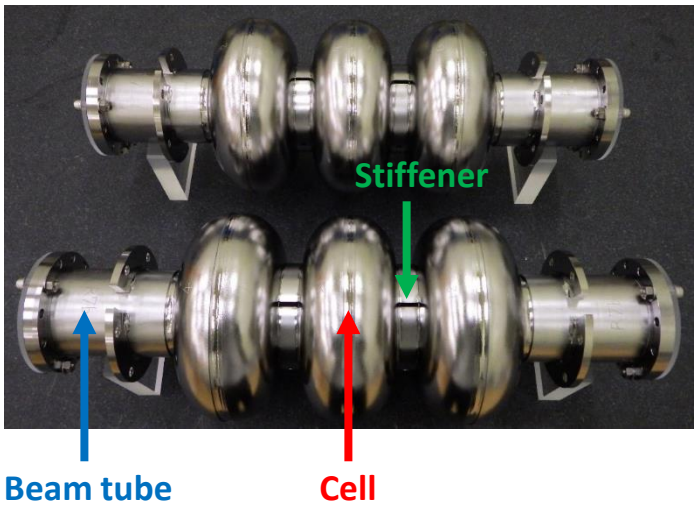
- To realize the ILC project, a cost reduction is imperative issue
- From view point of cavity fabrication:
  - ➢Establish mass production techniques.
  - ➢Reduce material cost w/ keeping performance.
    - ✓Low purity Nb (low RRR Nb)
    - ✓High Ta contained Nb:

      Low Ta contained Nb is expensive due to special chemical treatment
    - ✓Large grain Nb:

      Forge & rolling process is skipped

We tried two kind of Nb as the cavity material

Material 1: Low RRR, high Ta contained Nb



☆Start material: Nb ingot from CBMM

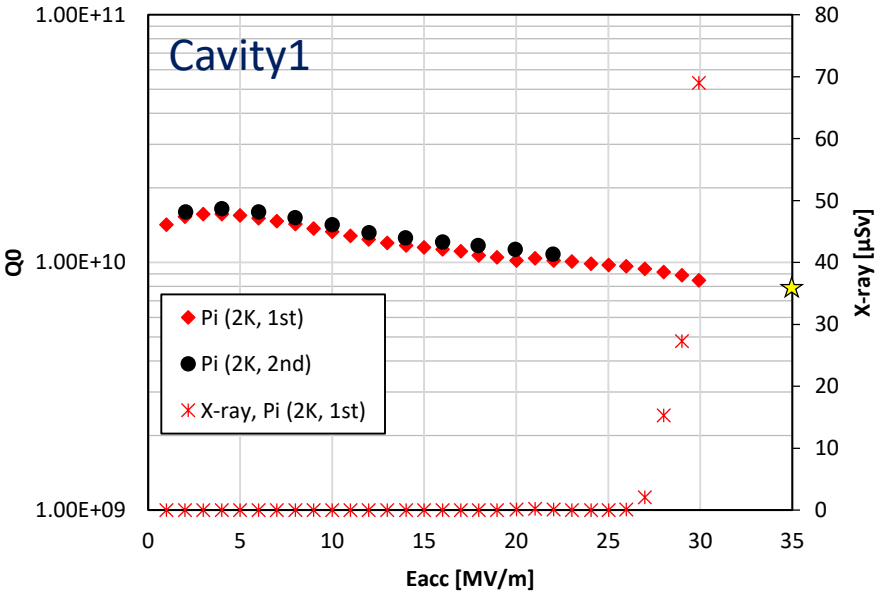
Beam tube: Forged into seamless tubes by ULVAC

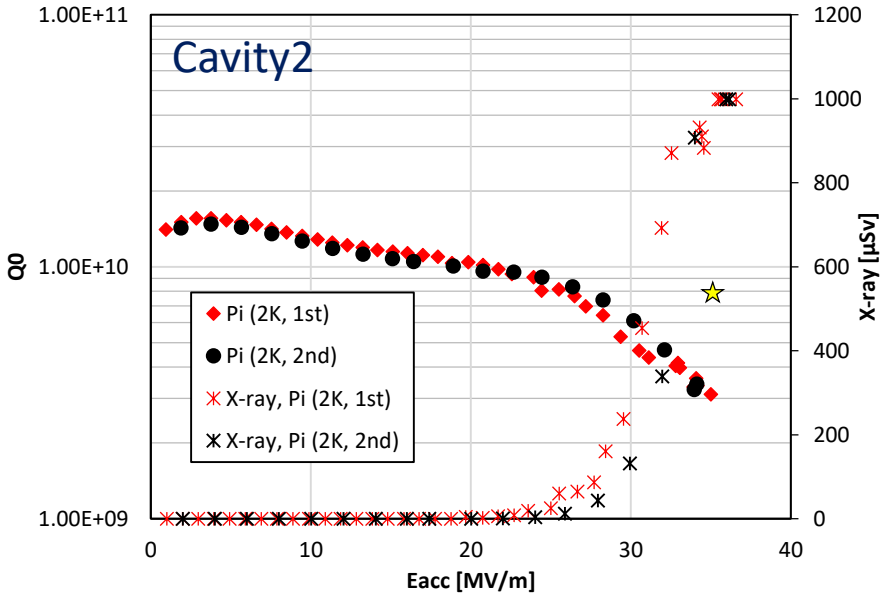
Stiffener rings: Forged and rolled into sheet by ULVAC

Cell: Melted 2 times (normally ~5 times), forged and rolled

	RRR
Start material	60~108
After 2 melting (ingot)	277~298
Nb sheet used for cell	293

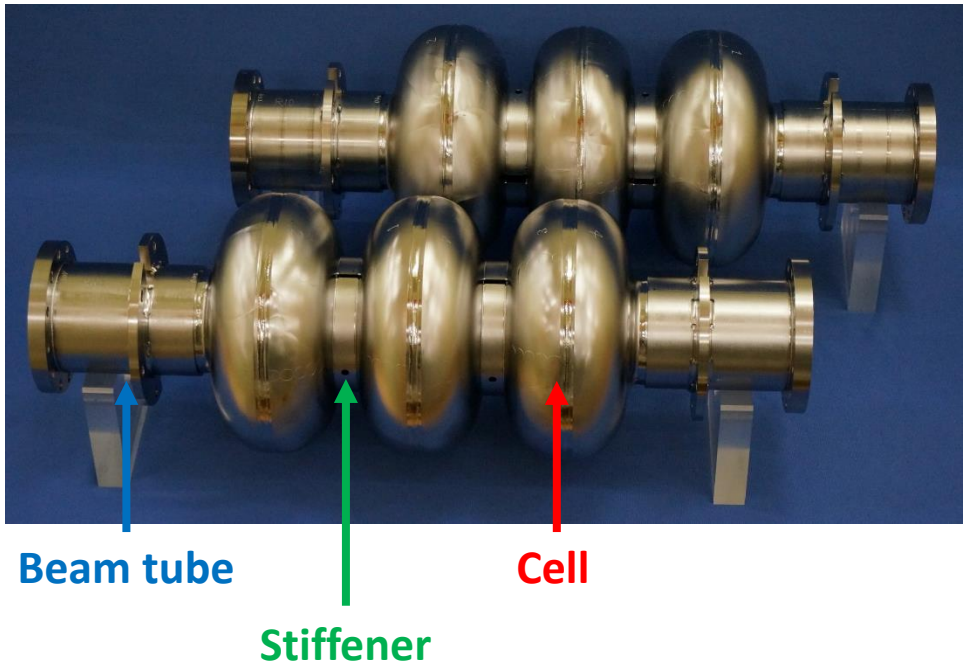
100μm EP ・ 750deg × 3hrs annealing
20-30μm EP ・ 120deg × 48hrs baking

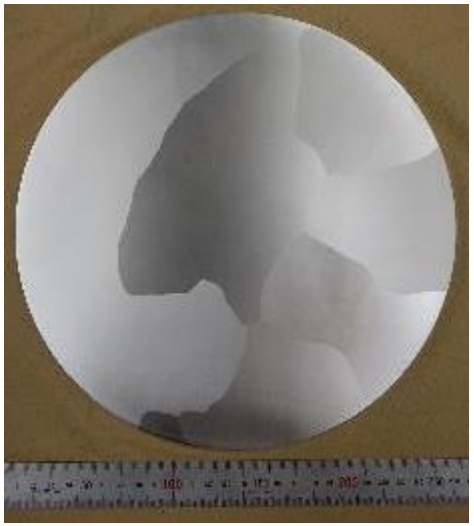




☆ ILC requirement

Material 2: Mid RRR, high Ta contained, LG



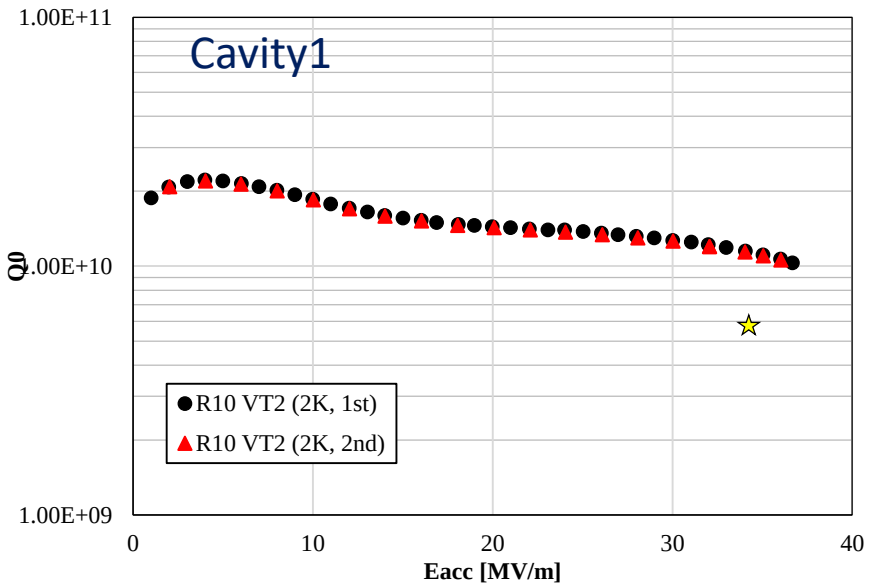


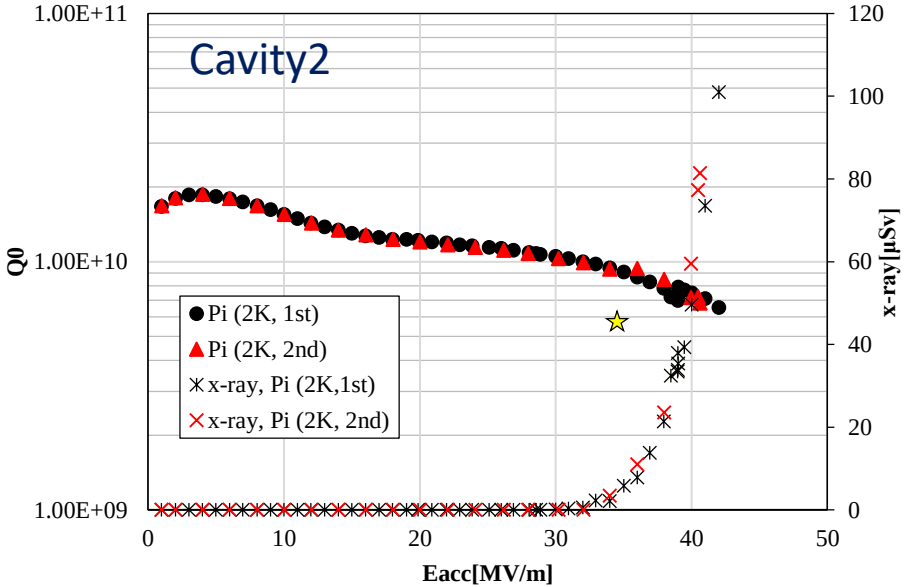
LG Nb (ϕ260)

- Beam tube: Low RRR (< 100), high Ta contained (same as previous cavity)
- Cell: Mid RRR, high Ta contained large grain (LG) Nb
  → Forge and rolling process were skipped (cost reduction)
  RRR=242~298
- Stiffener: Recycled Nb (melted, forged and rolled by ULVAC)

Two 3-cell cavities (Tesla-like shape) are fabricated using these materials

Material 2: Performance test results





☆ ILC requirement

100μm EP ・ 750deg × 3hrs annealing
20-30μm EP ・ 120deg × 48hrs baking

@2K, π-mode	$Q_{0,\,max}$	$E_{acc,\,max}$ [MV/m]	Rs [nΩ]	Mag. field* [mG]
Cavity1 (VT2)	2.22×10^{10}	36	4.19	-0.1 ~ 2.5**
Cavity2	1.87×10^{10}	42 (40 in final)	7.15	5.9 ~ 7.8

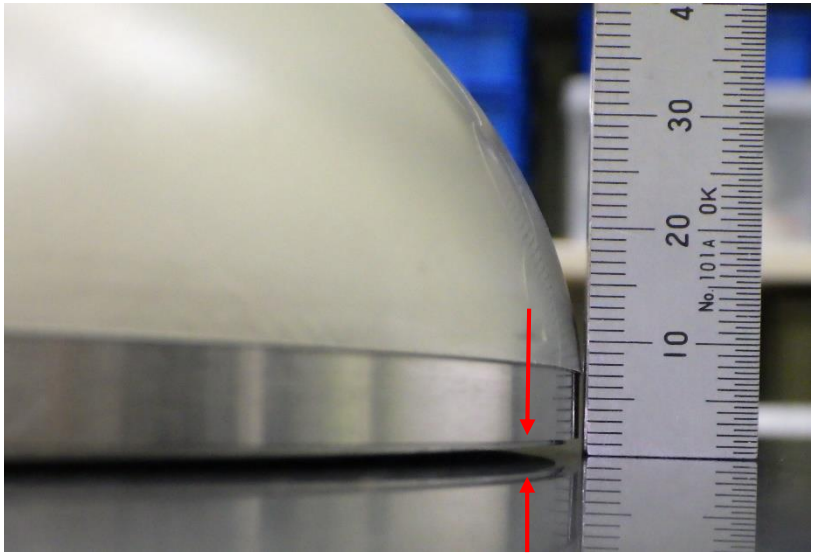
Cavity1: VT1 was limited at 25MV/m by quench. Defect was removed and VT2 was performed.

*Magnetic field measured by flux gate set at 2 cell during measurement. (after superconducting transition)
**Remaining mag. field was canceled by solenoid coil (< 1mG). ΔT (=temp. difference between top & bottom beam tube) ~ 30K was applied when superconducting transition.

Issues of LG cavity

- Different mechanical properties.
  - ✓ Problem in passing helium vessel code
- Large anisotropy and deformation;
  - ✓ Problem in welding due non-uniform thickness
  - ✓ Increase welding processes due to bad roundness at the equator
- RRR differs even in same ingot. (CBMM LG → 242~298)

Special jig for equator EBW



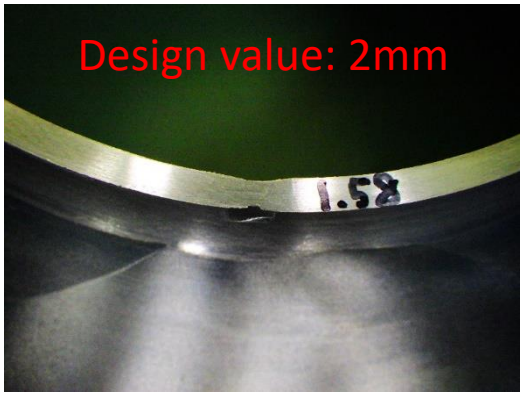
Non-flat equator edge after trimming

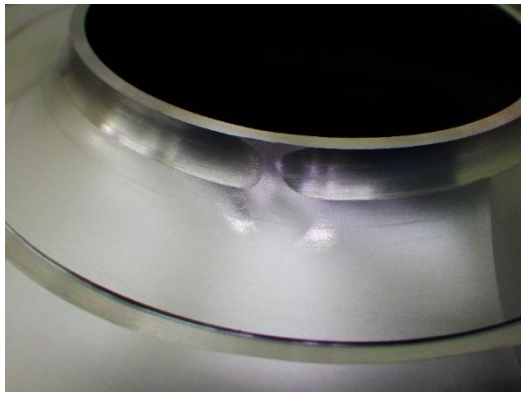
Current status in CFF

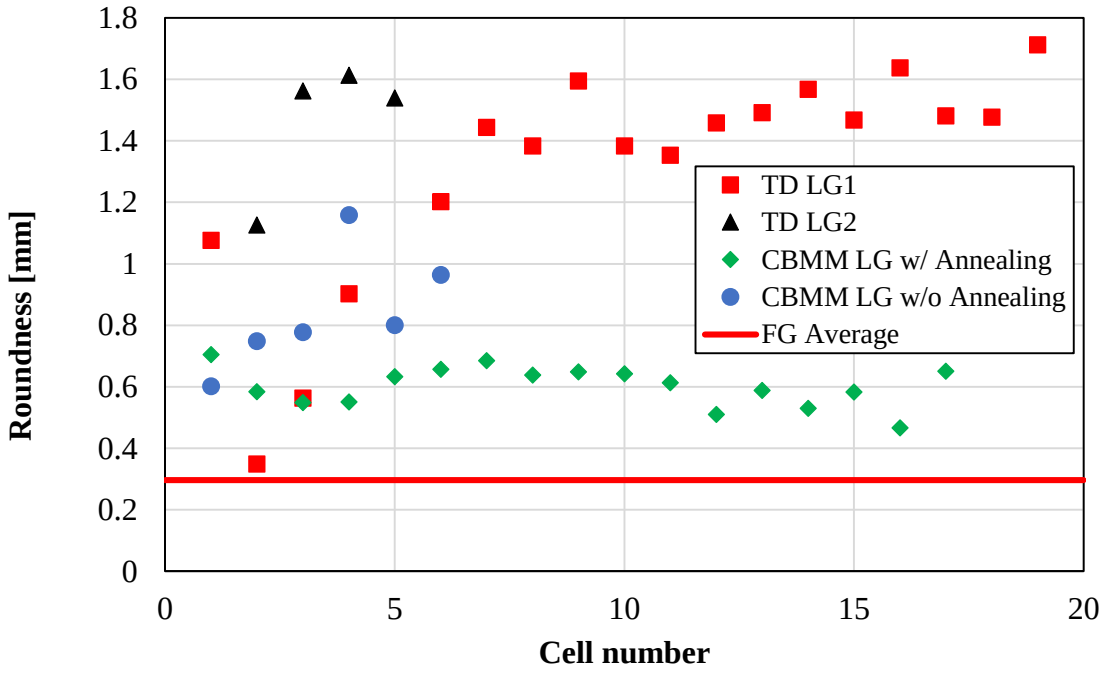
On going fabrication in 2018

Fabrication of 9-cell Tesla shape cavity made by LG Nb (material 2) is on going now.

Still some difficulties for fabrication.







Fabricated dumbbells for 9-cell cavity

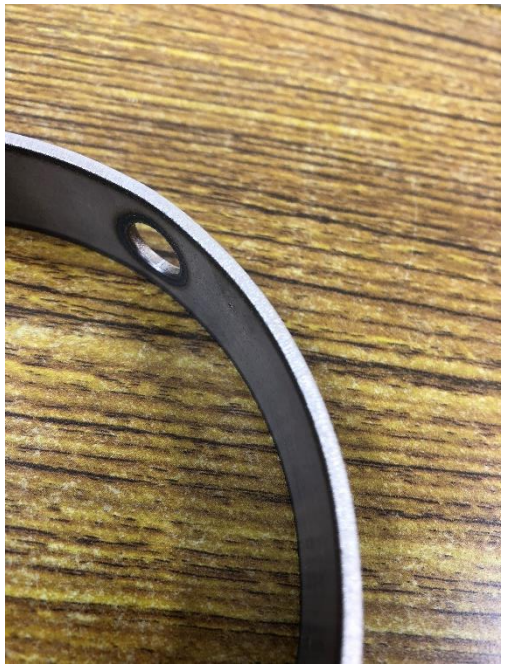
Roundness = radius difference between two concentric circle of internally and externally tangent.

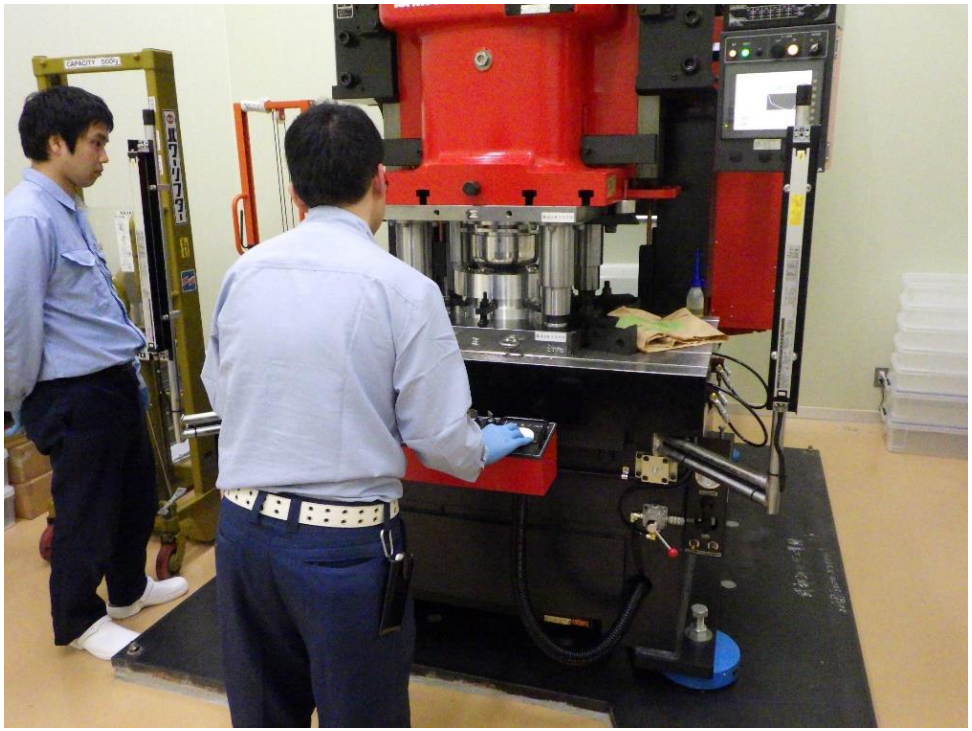
Training of new industrial company

- Collaborating and training new company for cavity fabrication.
- “MIRAPURO” is fabricating 9-cell cavity following CFF cavity fabrication.
- Innovates new techniques into cavity fabrication from their industrial field. (laser cutting etc.)

MPC
MIRAPURO

Stiffener rings cut by a laser beam





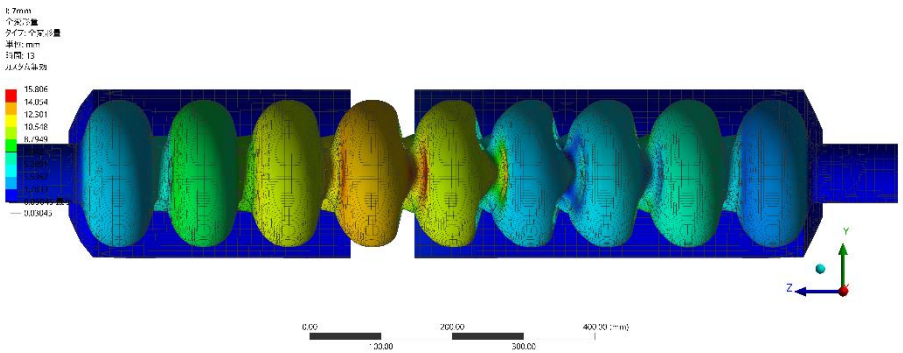
Helium vessel code

Aiming to pass the high pressure gas safety act. by KEK.

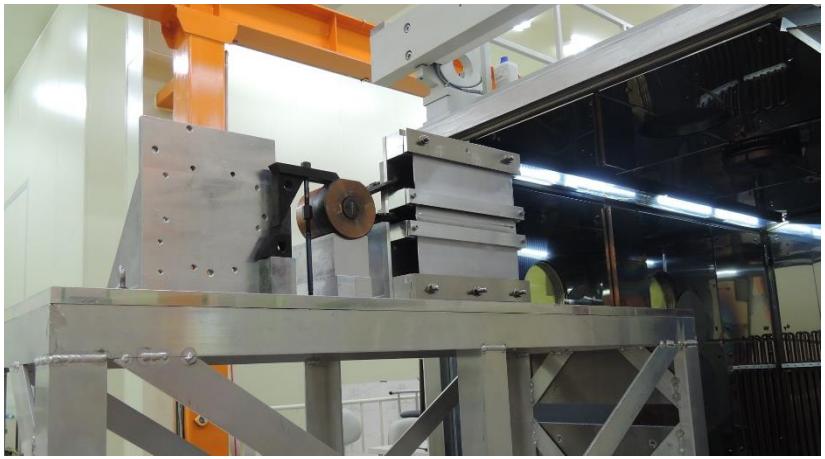
Several items are necessary;

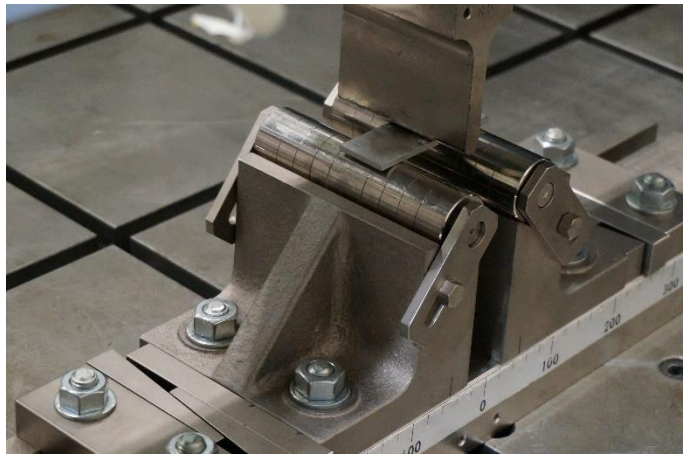
- Buckling simulation
- Mechanical properties of materials
- Thickness check after welding
- Welding procedure specification

etc.



Fabricate 9-cell cavity with certification in FY 2018
→load into STF





Additional investigation

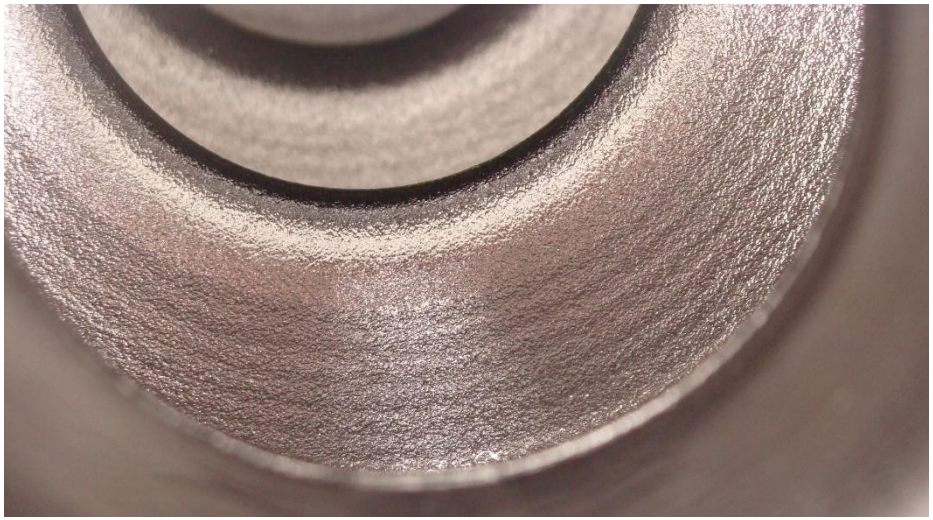
Hydroforming cavity fabrication

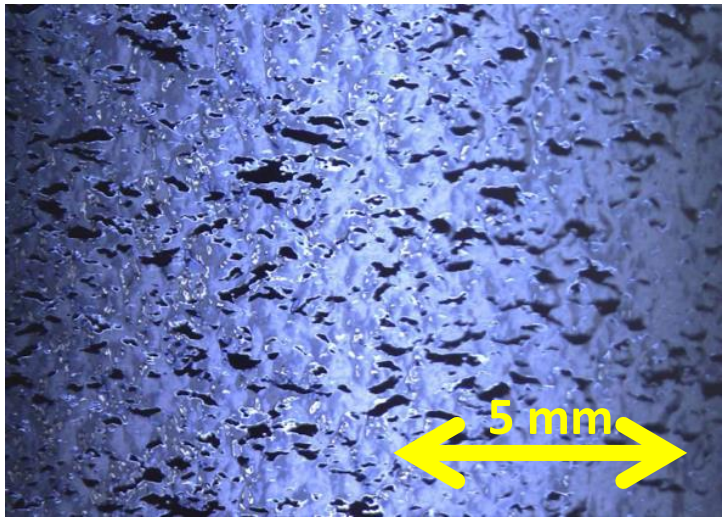
KEK is still investigating hydroforming cavities.
Currently two 3-cell cavities were fabricated.

Materials and inner surface

Cavity		W3	U6
Nb tube	Supplier	ATI Wah Chang Allegheny Technologies	ULVAC
	Size	OD130 x ID123 (t3.5) x 800L	OD138 x ID131 (t3.5) x 830L
	RRR	387	353
Average roughness after EP2		Ra 8.6µm	Ra 10.6µm

Inner surface after EP1 (100µm) + EP2 (30µm)

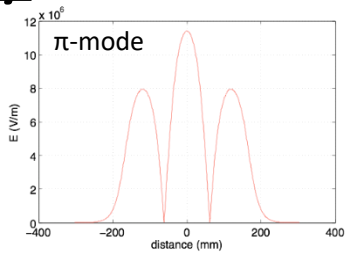




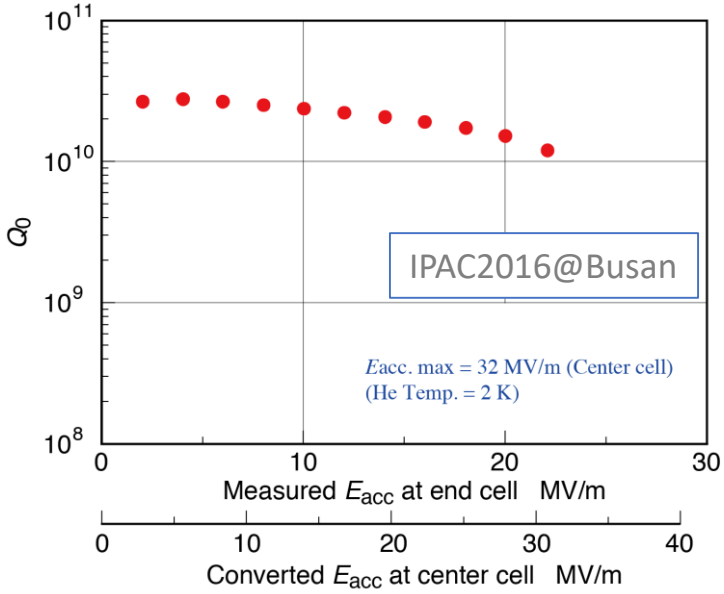
Barrel polishing was skipped before VT.

Summary of two 3-cell hydroforming cavity

Note: All cells are center-cell shape → Not a flat field

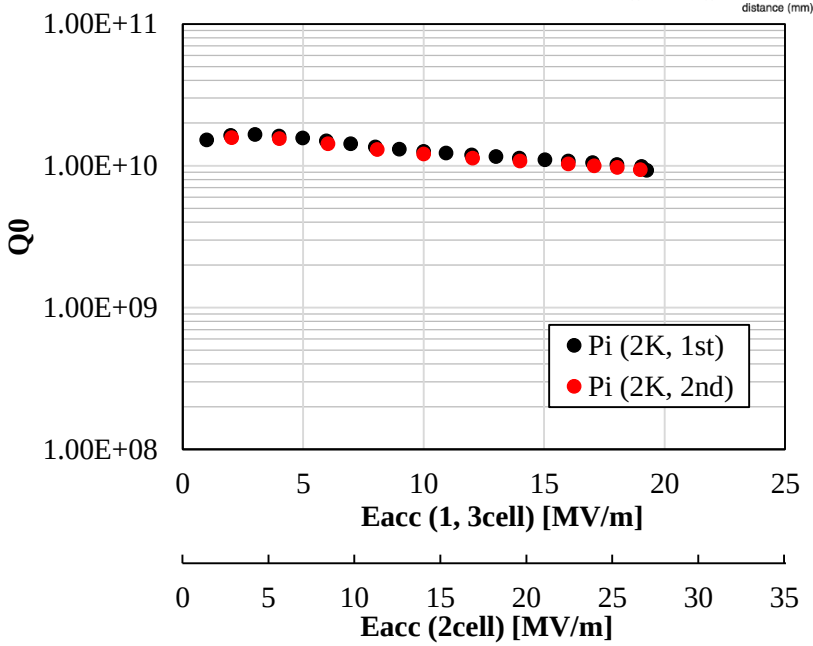


KEK-W3



Cell #1	Cell #2	Cell #3
> 26.4 MV/m	36.1 MV/m (initial) 31.7 MV/m (final)	26.4 MV/m

KEK-U6



Cell #1	Cell #2	Cell #3
> 27.9 MV/m	26.7 MV/m	28.4 MV/m

Over 25 MV/m was achieved with basic surface treatment.
(w/o any special surface treatment such as barrel-polishing, local grinding)

Summary

- Cost reduction study
  - ✓3-cell cavities were fabricated with different materials.
  - ✓Cavities made of mid-RRR, high-Ta LG meet ILC requirement.
- Current status in CFF
  - ✓Cavity fabrication:
    - Fabricating 9-cell cavity with LG.
    - Collaborate and training with new company.
  - ✓Helium vessel code
    - Aiming to pass through the helium vessel code by KEK.
    - Fabricate 9-cell cavity with certification.→into STF
- Hydroforming cavity

  Over 25MV/m was achieved with standard surface treatment recipe.

Backup slides

Material1: Chemical components

unit: wt ppm

	C	N	O	H	Zr	Ta	Fe	Si	W	Ni	Mo	Hf	Ti	S
Spec. ASTM B393*1	100	100	250	15	200	3000	100	50	500	50	200	200	300	N/A
Spec. CBMM	50	100	250			2000	50							10
Ingot*2	<30	33	26	<2	<1	1194	3	<20	<5	<1	<1	<2	7	<10
Sheet*3	<10	30	<10	1	<10	1210	<10	<10	<10	10	<10		<5	
Ingot*4	**<10**	**<10**	**<10**	**<1**	**<10**	**1430**	**<10**	**<10**	**<10**	**10**	**<10**		**<5**	

*1 R04210-Type 2, Commercial grade unalloyed niobium

*2 Start material, measured by CBMM

*3 Low RRR, after 2nd process, measured by ULVAC

*4 Medium RRR, **after 2-time EB melting, measured by ULVAC**

Material2: Chemical components

unit: wt ppm

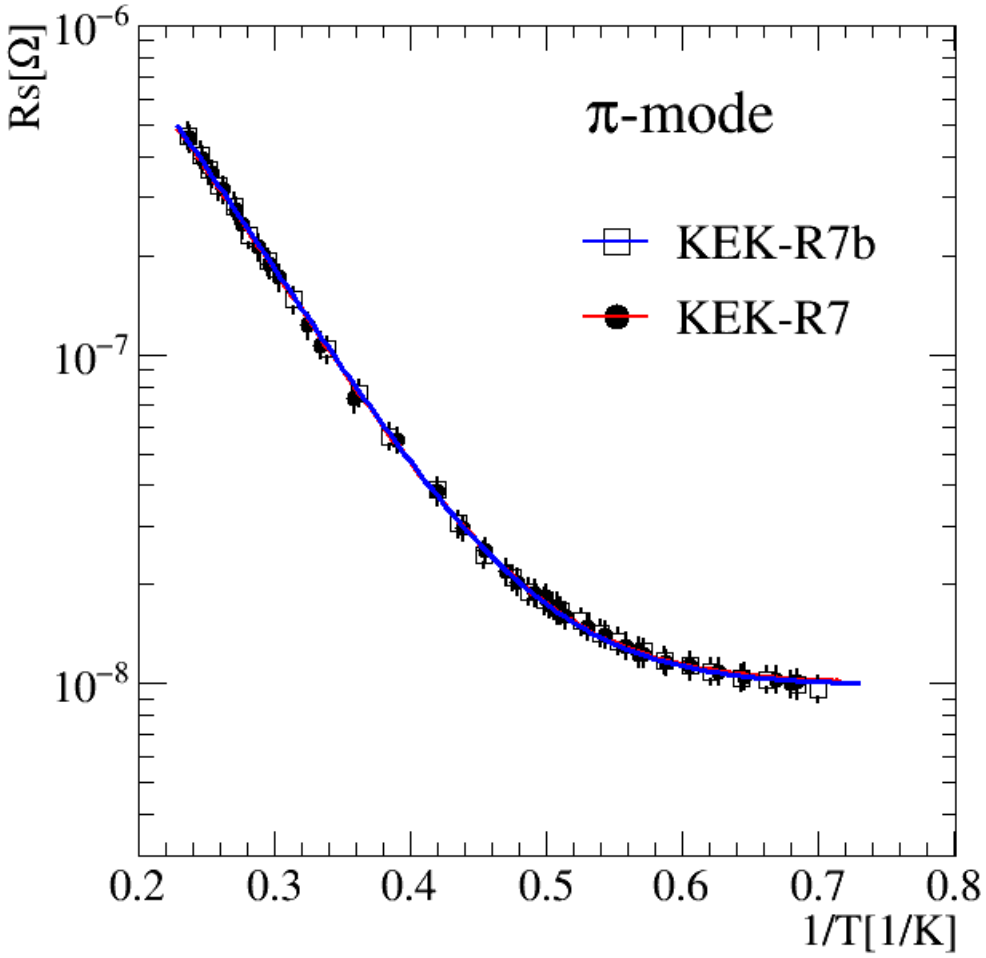
	C	N	O	H	Zr	Ta	Fe	Si	W	Ni	Mo	Hf	Ti	S
Spec. ASTM B393[*1]	30	30	40	5	100	1000	50	50	70	30	50	50	50	N/A
Ingot[*2]	**<30**	**6**	**5**	**<2**		**1191[*3]**	**<3**		**<5**		**1**			**<10**

[*1] R04220-Type 5, RRR Superconducting Grade Pure Niobium

[*2] Start material, measured by CBMM

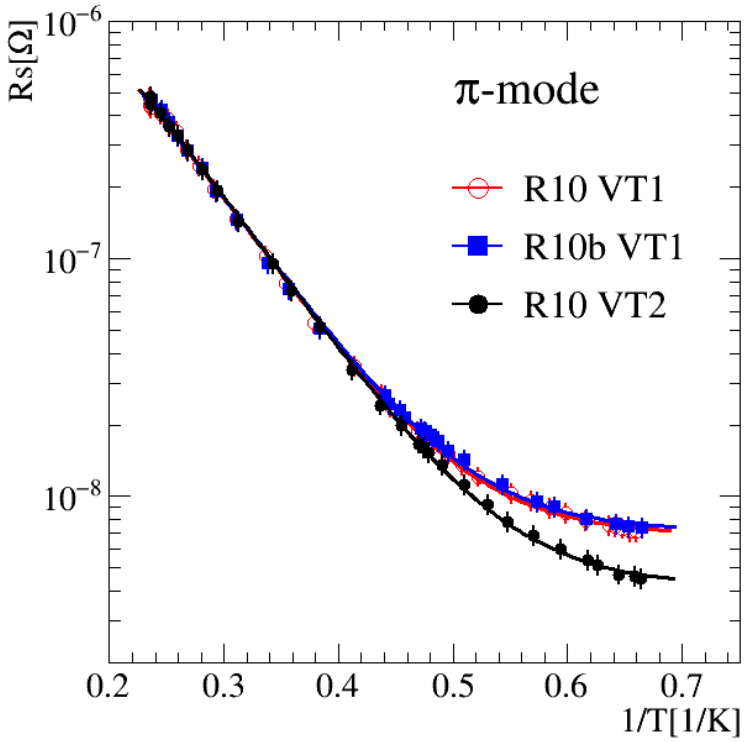
[*3] Ta content is allowed up to 1300 in spec.

Material1: 1/T vs R



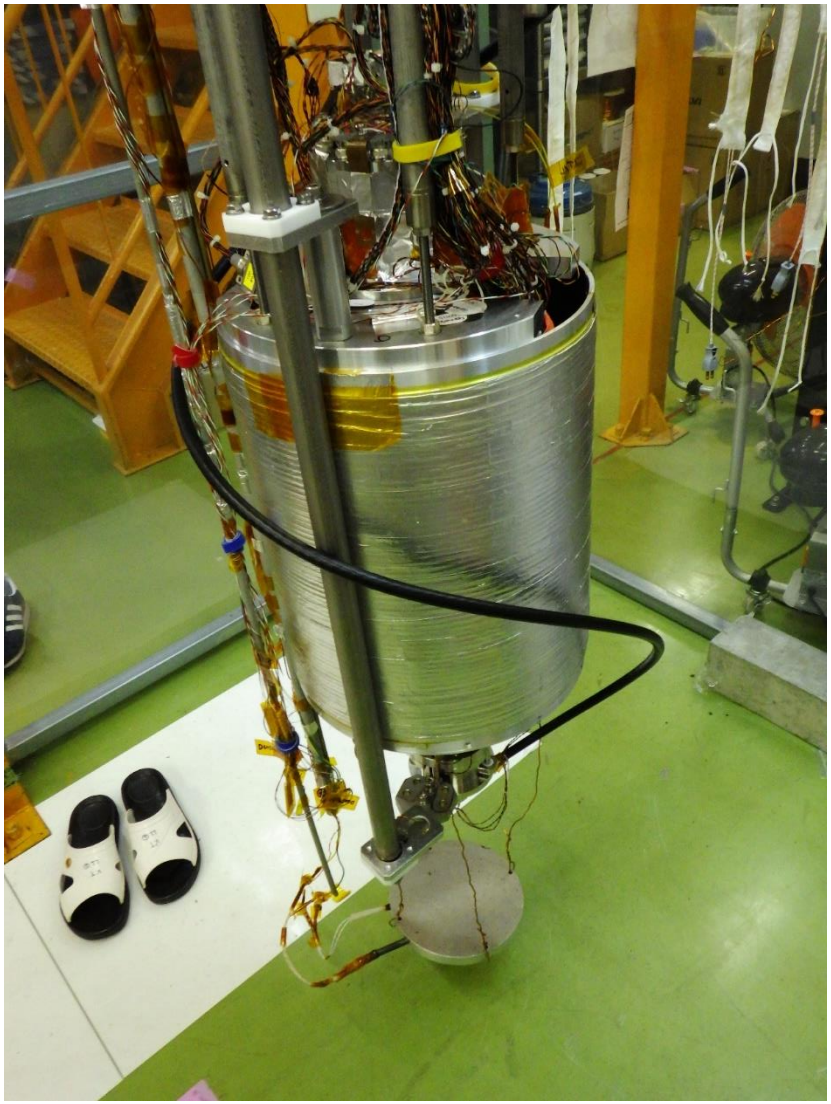
	Rs [nΩ]
cavity 1	10.0 ± 0.4
cavity 2	9.9 ± 0.4

Material2: 1/T vs R



R10 (VT1)	6.88 ± 0.28 nΩ	FG1=5.2mG, FG2=3.2mG @1.8K
R10b (VT1)	7.15 ± 0.38 nΩ	FG1=7.33, FG2=6.7mG @ 4K
R10 (VT2)	**4.19 ± 0.24 nΩ**	**FG1=2.5mG, FG2=-0.12mG @4K**

VT setup with solenoid coil



	Date	Magnetic field
R7	2017/6/14	2.3, 1.0 mG @ 290K 8.3, 6.8 mG @ 4K Tc; 6/14 12:40 ~ 12:50
R7b	2017/6/28	2.0, 1.5 mG @ 290K 7.7, 7.4 mG @ 4K Tc; 6/28 12:00 ~ 12:10
R10 (VT1)	2017/12/21	3.8, 2.5 mG @ 290K 3.0, 5.0 mG @ 4K Tc; 12/21 11:35 ~ 11:45
R10b	2018/2/22	6.3, 6.7 mG @ 290K 7.3, 5.9 mG @ 4K Tc; 2/22 11:20 ~ 11:30
R10 (VT2)	2018/4/19	5.2, 5.1 mG @ 290K 2.5, -0.1 mG @ 4K Tc; 4/19 9:35 ~ 9:45

Thickness distribution

Measured by ultrasonic measurement device
Measured after VT1