Recent Activities of Cavity Fabrication Facility in KEK

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Our current motivation

- To realize the ILC project, a cost reduction is imperative issue
- From view point of cavity fabrication:
  - ➢Establish mass production techniques.
  - ➢Reduce material cost (←this talk).
    - ✓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

Main equipments in KEK-Cavity Fabrication Facility (CFF)

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

Microscope
(Surface inspection)

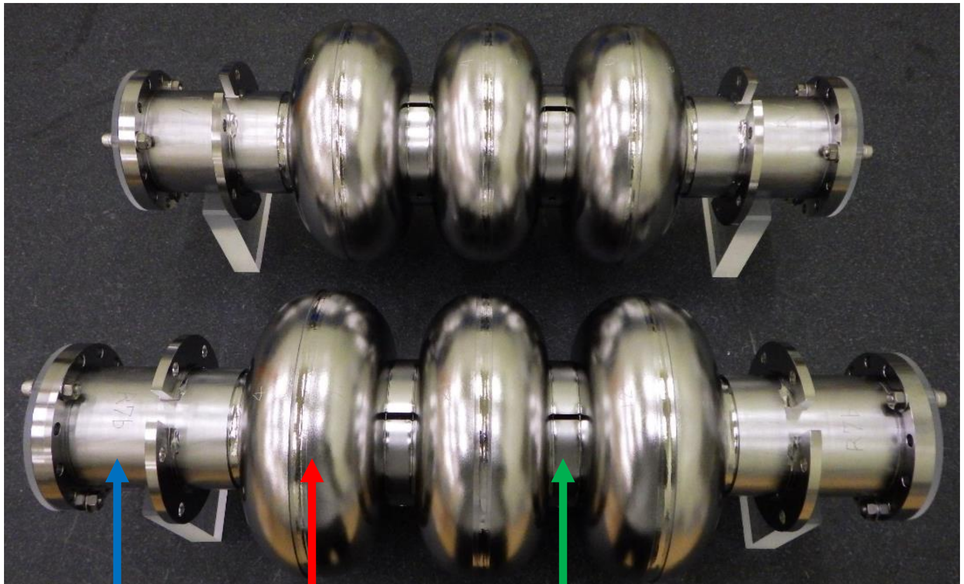
Servo press machine
(AMADA, Japan)
Max. applying force:
1500 kN

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

Chemical polishiing

CNC vertival lathe
(Moriseiki, Japan)

Material 1: Low RRR, high Ta contained Nb



RRR of used Nb

	RRR
Start material	60~103
After 2 melting (ingot)	277~298
Nb sheet used for cell	293

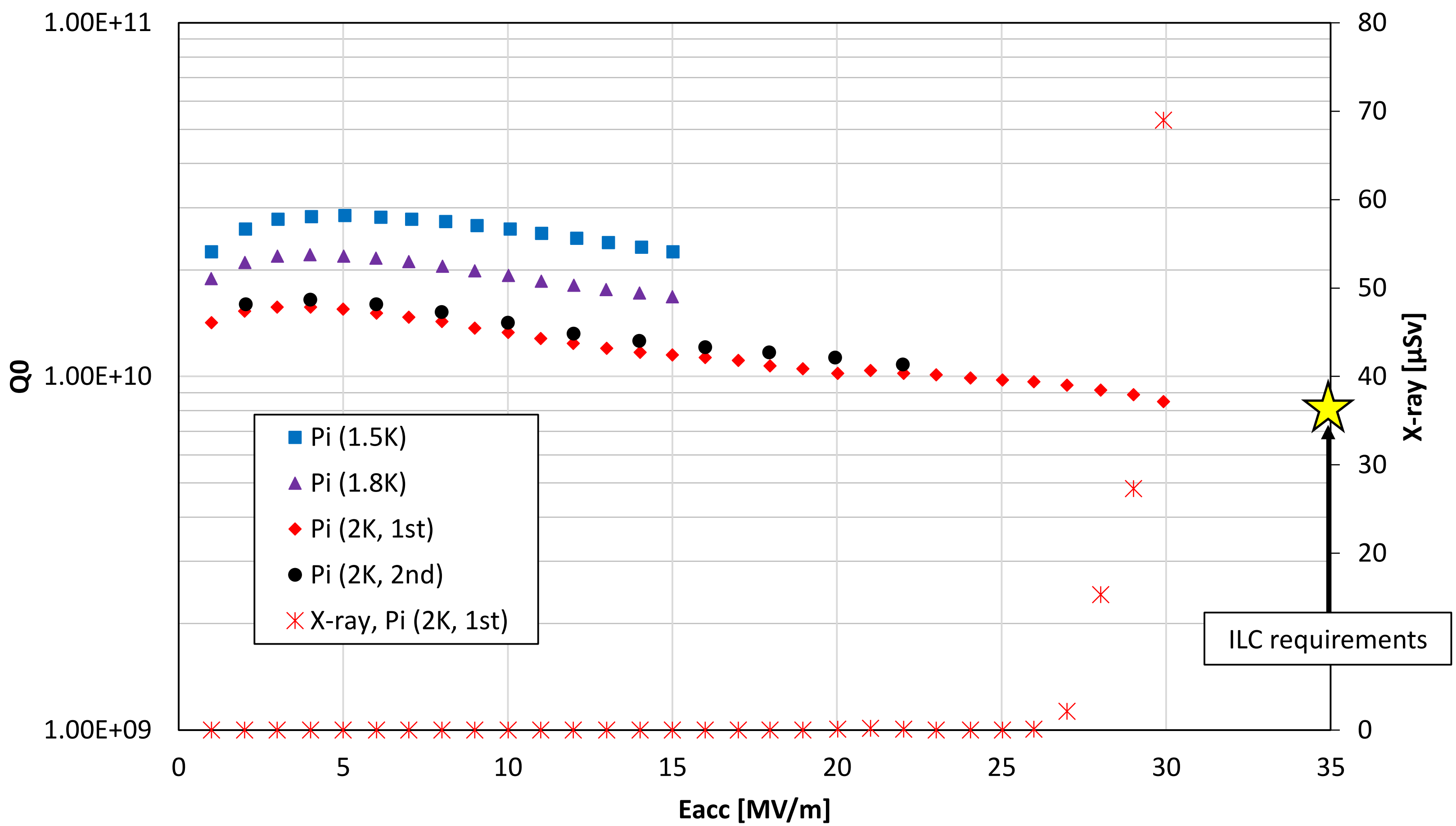
※ILC requirements RRR≧300

☆Start material: Nb ingot from CBMM, Commercial grade (Ta: 2000 ppm Max.)

- 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

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

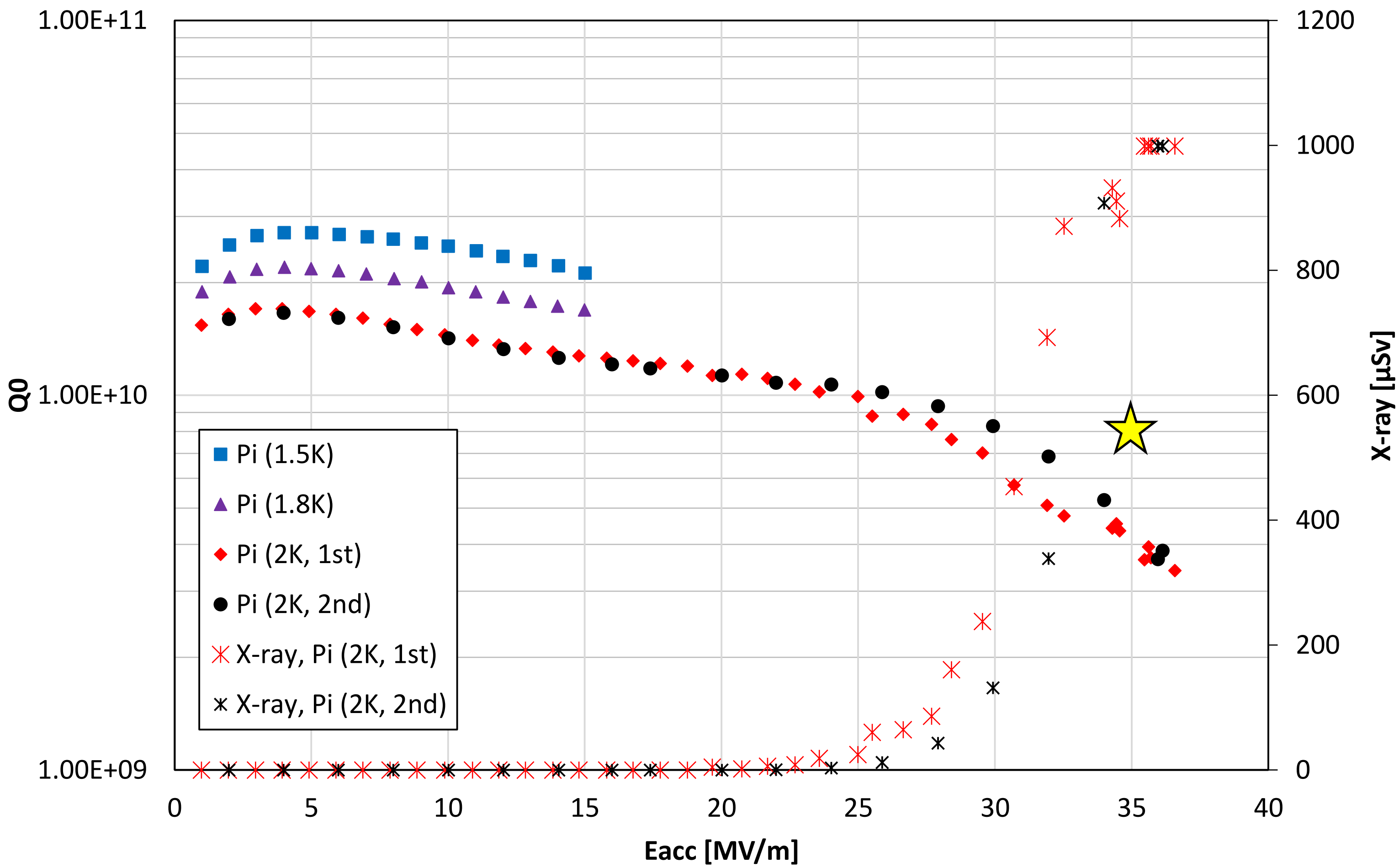
Material 1: Performance test results (cavity1)



$Q_{0,\ max}$: 1.65 × 10^{11} @ 2K, π-mode

$E_{acc,\ max}$: 30 MV/m @ 2K, π-mode **(23 MV/m final)**

Material 1: Performance test results (cavity2)



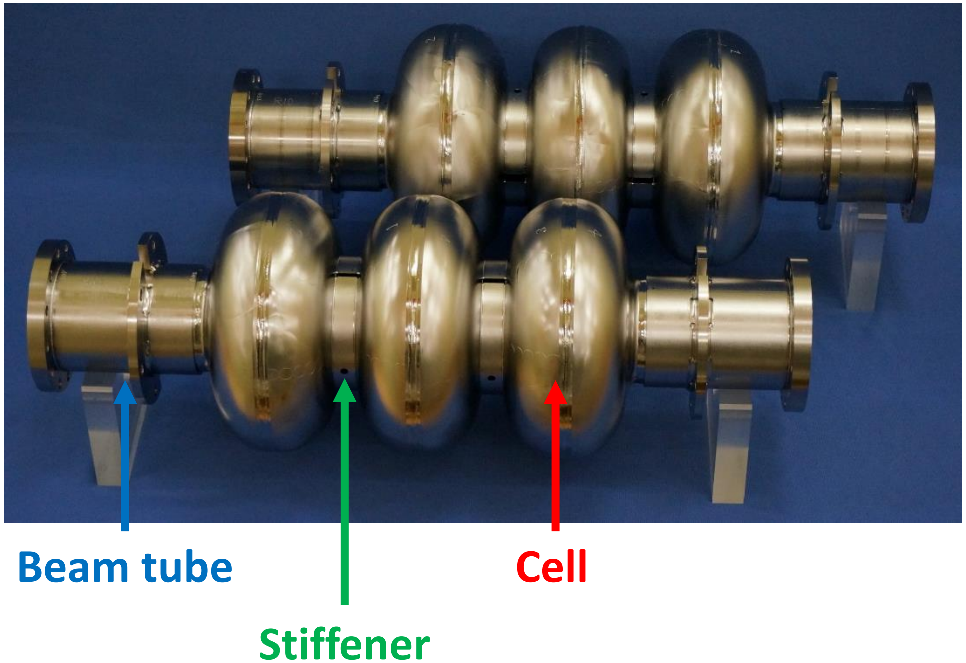
$Q_{0,\ max}$: 1.70×10^{11} @ 2K, π-mode

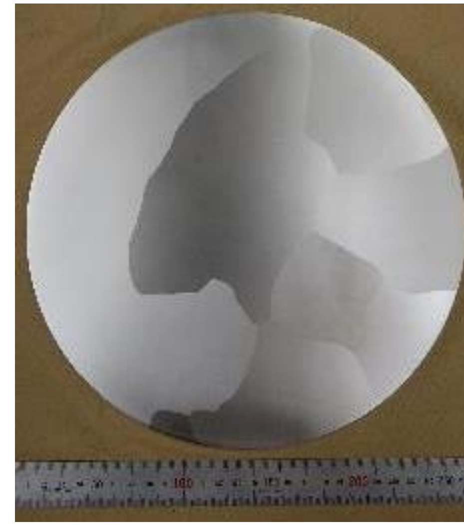
$E_{acc,\ max}$: 36 MV/m @ 2K, π-mode

Summary of material 1

- CBMM commercial grade (RRR: 60~103, high-Ta) niobium ingot was used for a start material.
- Forge and rolling process for Nb sheets were done by ULVAC. (for stiffener rings)
- Seamless beam tubes were produced by ULVAC.
- The RRR was improved to 278~298 after two times melting by ULVAC. This Nb was used for cavity cells.
- Two 3-cell test cavities were successfully fabricated by KEK-CFF.
- The max. E_{acc} were 30 and 36 MV/m, respectively.
- 50% cost reduction was not accomplished.

Material 2: Mid RRR, high Ta contained, LG



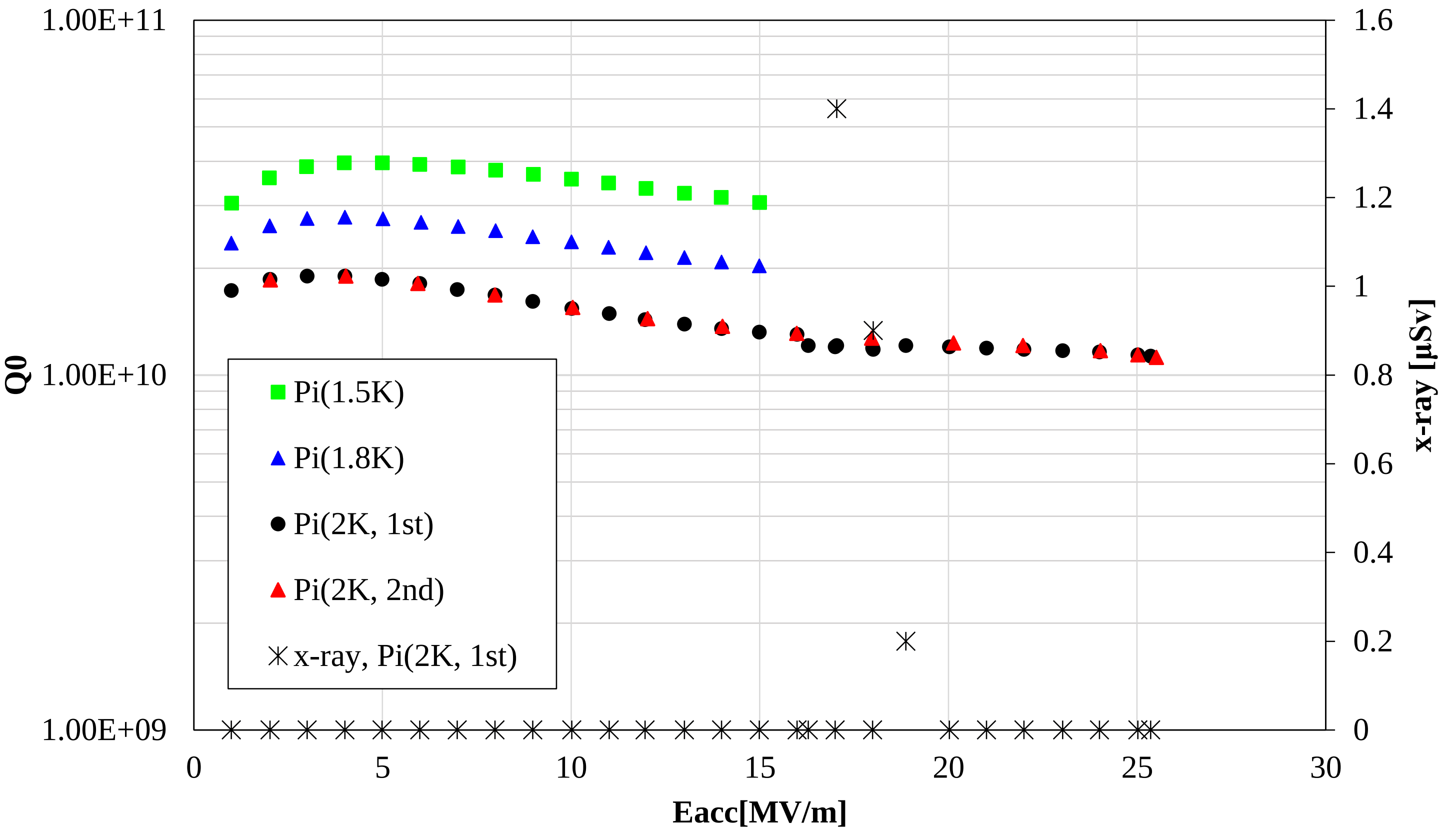


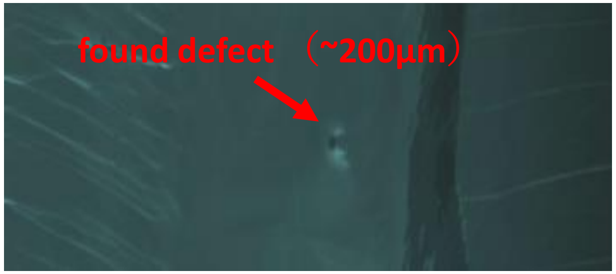
LG Nb (ϕ260)

- 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 (cavity1)

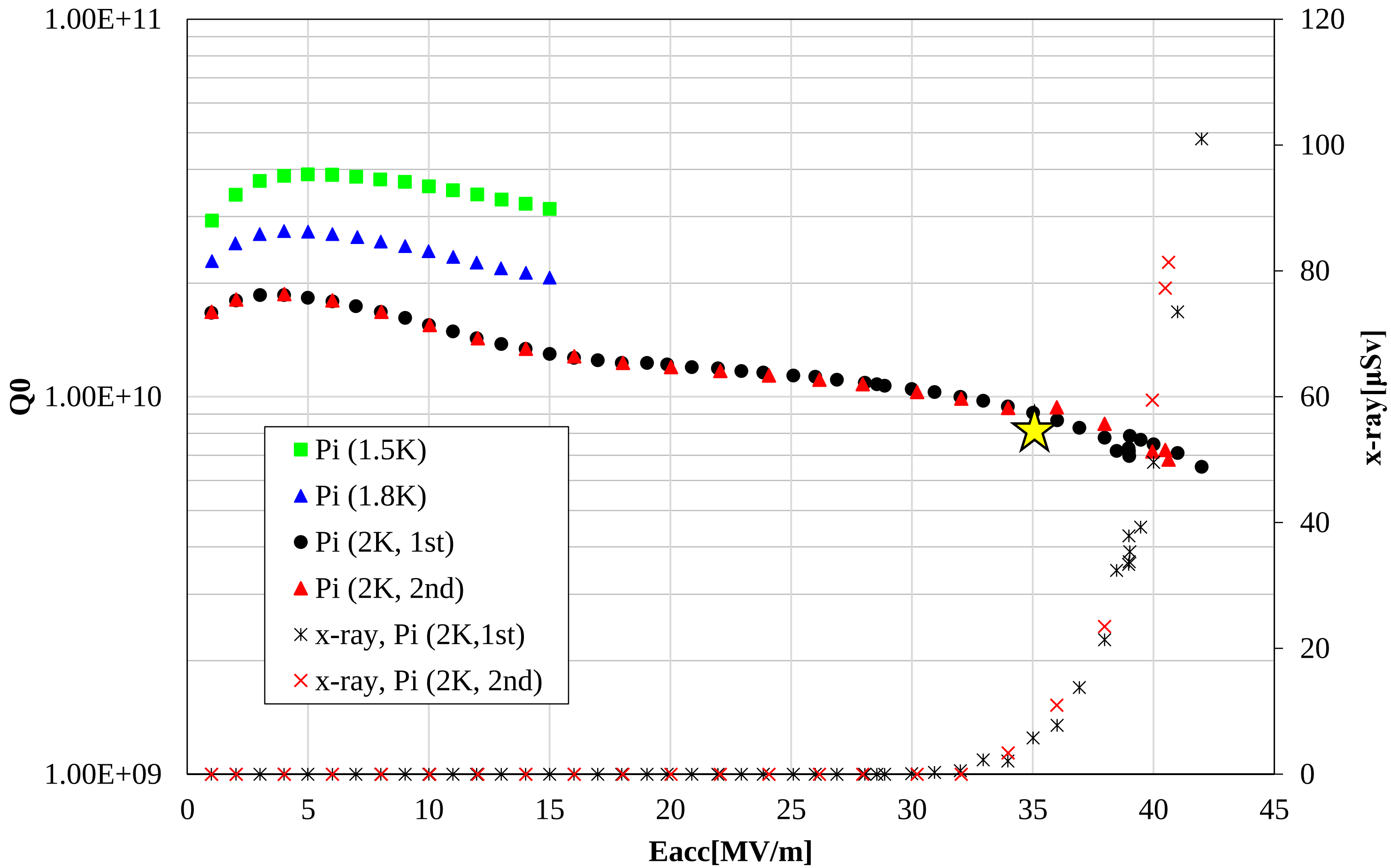




$Q_{0,\ max}$: 1.9 × 10^{11} @ 2K, π-mode

$E_{acc,\ max}$: 25 MV/m @ 2K, π-mode (quench)

Material 2: Performance test results (cavity2)

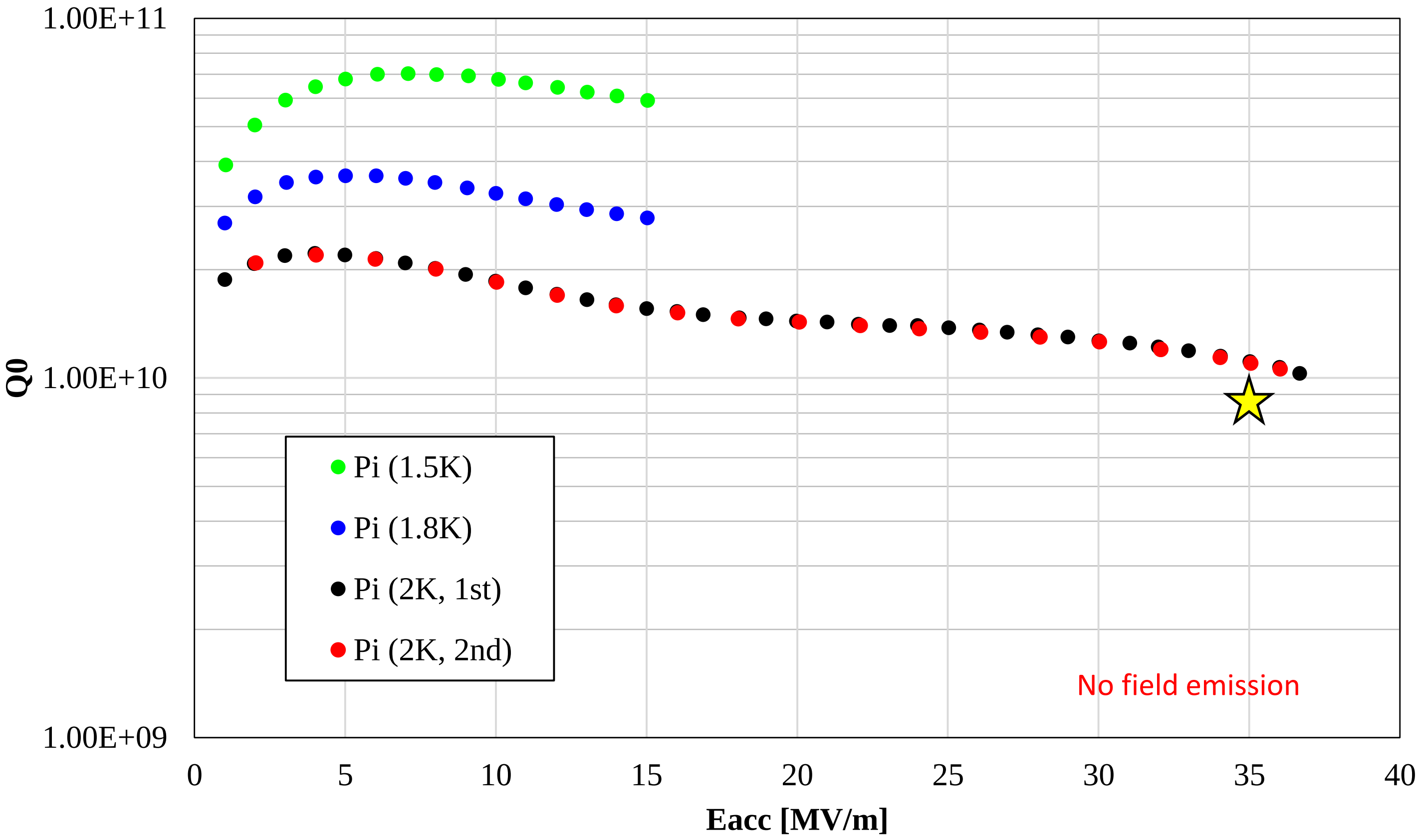


$Q_{0,\ max}$: 1.9 × 10^{11} @ 2K, π-mode

$E_{acc,\ max}$: 42 MV/m @ 2K, π-mode （40MV/m final）

Material 2: Performance test results2 (cavity1)

Defect which caused quench was removed, and measured again



$Q_{0,\ max}$: 2.2×10^{11} @ 2K, π-mode
$E_{acc,\ max}$: 36 MV/m @ 2K, π-mode

IMPORTANT NOTE

LG Nb has large crystal→strong anisotropy

LG by T.D.

LG by CBMM

- Deformation after press forming

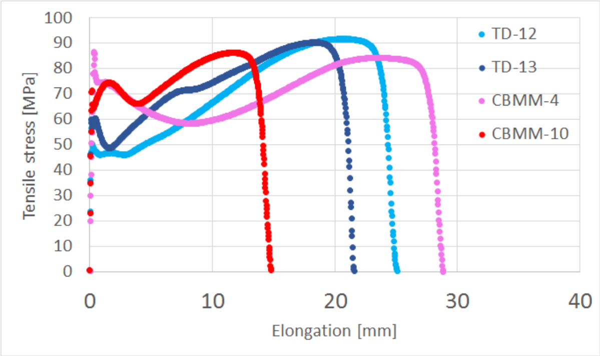
  →increase fabrication process

  →more difficulties of fabrication

- Different mechanical properties by sheet & ingot

  →difficult quality control

Results of tensile test: LG Nb (normal temperature)



Other problem

- Different RRR: even in a same ingot (this time: 242 – 298)

  →difficult quality control

We should carefully discuss about this material

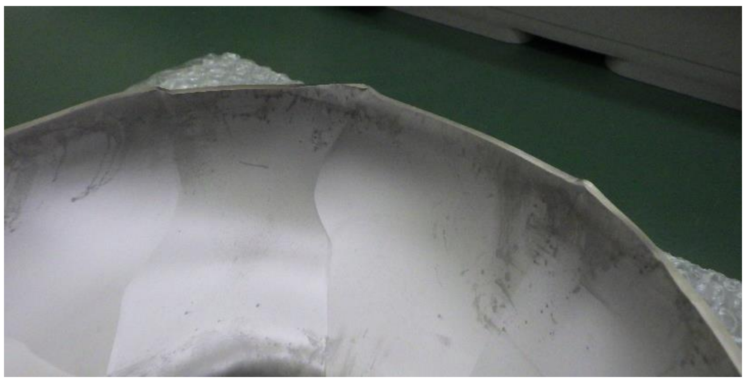
Processing characteristics 1

Large deformation after press forming

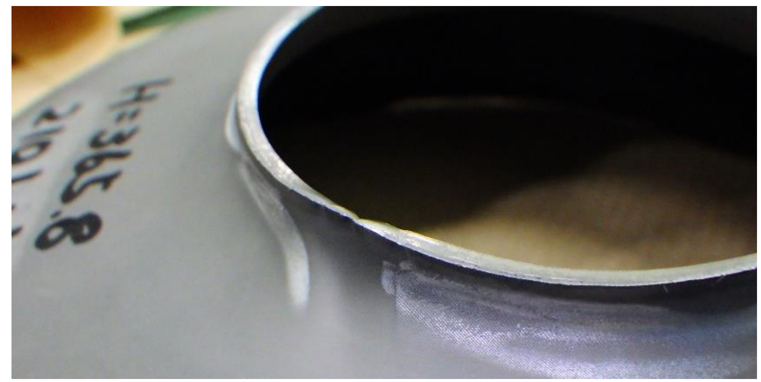
- Difficulties in trimming due to unleveled edges
- Difficulties in welding due non-uniform thickness
- Increase welding processes due to bad roundness at the equator

→Nb discs were annealed before press forming

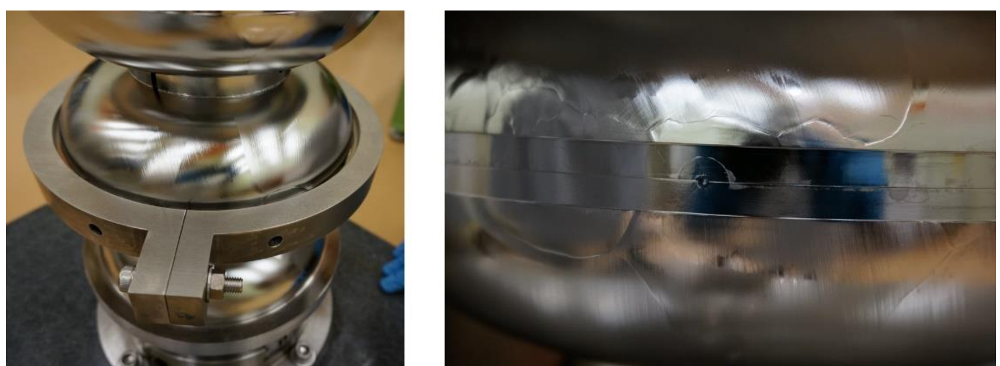
Unleveled edges



Non-uniform thickness



Special jig for equator EBW



Summary of material 2

- CBMM LG (RRR=242~298, high-Ta) sheets were used for cells.
- The max. E_{acc} were 36 and 42 MV/m, respectively.
- There were lots of difficulties for fabrication due to its strong anisotropy.
- Low RRR and high-Ta Nb was used for beam tubes, and it did not affect cavity performance.

  (→Need further observations)
- 50% cost reduction could be possible with this material.

Summary

- Current issue for cavity fabrication is cost reduction to realize ILC.
- KEK-CFF focus on cavity materials.
  - ✓Material 1: Low RRR, high-Ta contained Nb (FG)
  - ✓Material 2: Mid RRR, high-Ta contained LG Nb
- Acceptable results were measured with cavities made by material 2. But lots of difficulties in fabrication.
- Two 9-cells will be fabricated using material 2 in FY2018.

Backup

Material 1: Chemical compositions

unit: wt ppm

	C	N	O	H	Zr	Ta	Fe	Si	W	Ni	Mo	Hf	Ti	S
Spec. ASTM B391[*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

Material 2: Chemical compositions and RRR

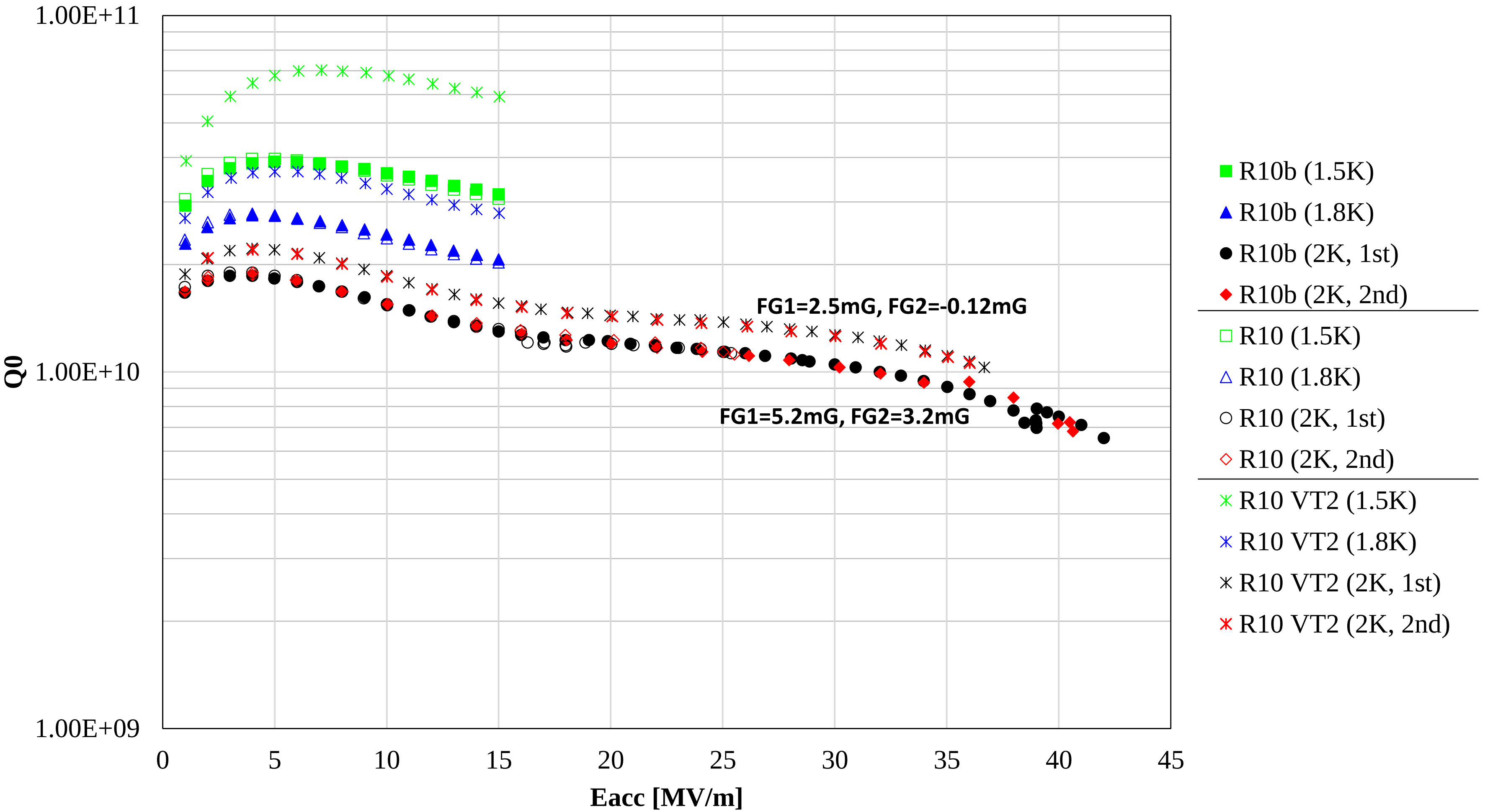
unit: wt ppm

	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.

Measured RRR at KEK
242~298 (Sliced ingot) Spec. >200

Summary



1.00E+11
1.00E+10
1.00E+09
Q0
0
5
10
15
20
25
30
35
40
45
Eacc [MV/m]
FG1=2.5mG, FG2=-0.12mG
FG1=5.2mG, FG2=3.2mG
R10b (1.5K)
R10b (1.8K)
R10b (2K, 1st)
R10b (2K, 2nd)
R10 (1.5K)
R10 (1.8K)
R10 (2K, 1st)
R10 (2K, 2nd)
R10 VT2 (1.5K)
R10 VT2 (1.8K)
R10 VT2 (2K, 1st)
R10 VT2 (2K, 2nd)