Investigation on 1, 3 and 9-cell SRF elliptical cavities made of large grain niobium

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KEK

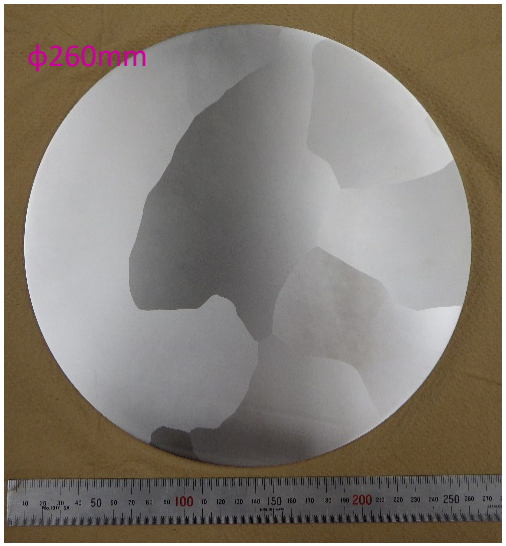
Introduction

Large grain (LG) Nb sheet; Directly sliced from Nb ingot

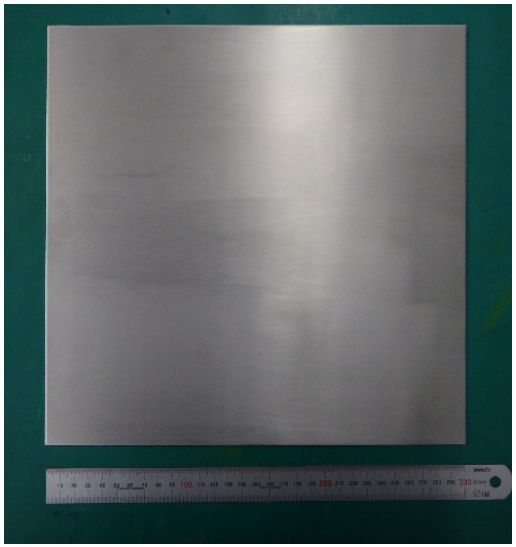
⇔ Fine grain (FG) Nb sheet

Advantage of using LG sheet

- Large material cost reduction
- High Q-value



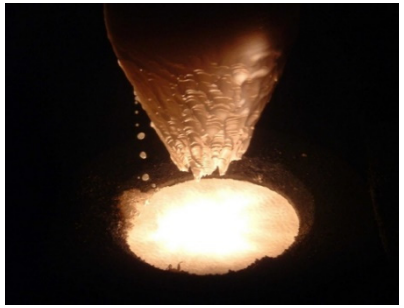
LG Nb
Crystal size
~200mm



FG Nb
Crystal size
~100μm

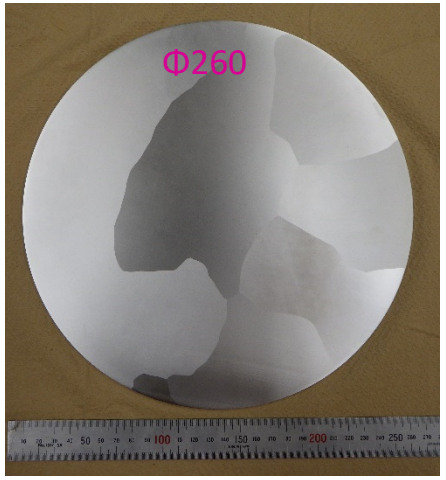
LG slice production

Melting



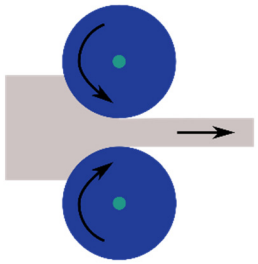
Nb ingot

LG Nb

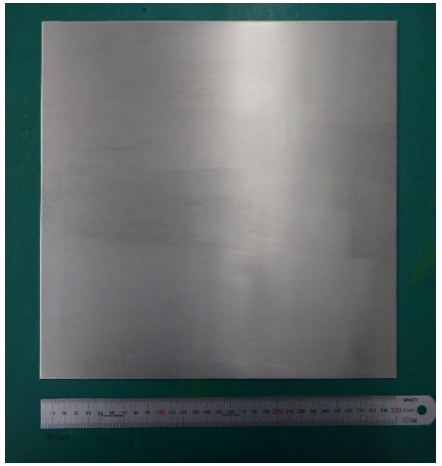


Forging

Rolling

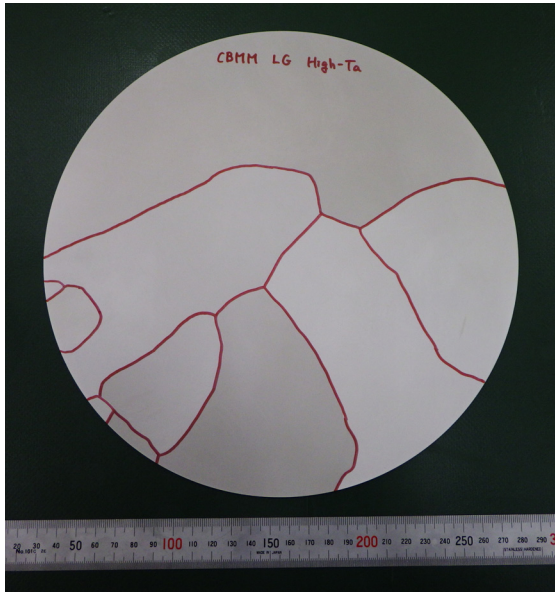


FG Nb



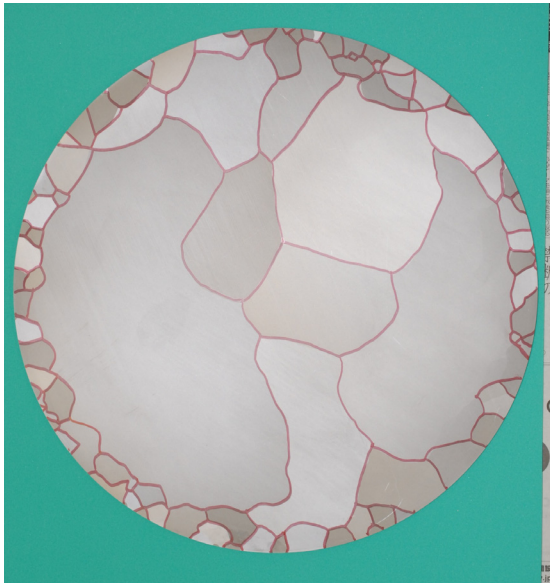
Various Crystal Location

CBMM ϕ260



CBMM ϕ260

Tokyo Denkai ϕ290



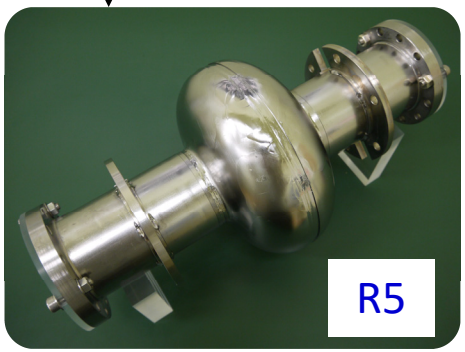
- ✓ **Crystal arrangement, size and orientation** are different between each ingot.
  →Largely affects to fabrication process
- ✓ Crystal size depends on cooling speed, purity and etc.
  →Not controllable

LG cavities fabricated in KEK

f = 1.3GHz

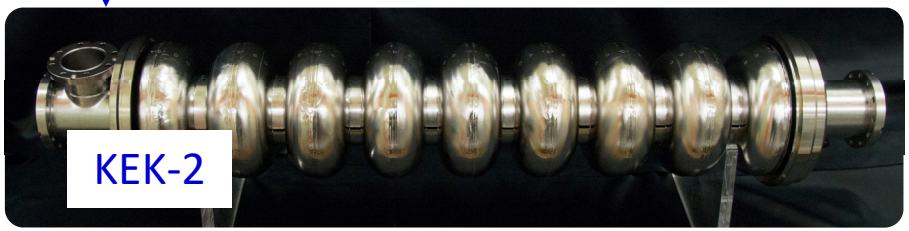
Tokyo Denkai; high-RRR

CBMM; low-RRR



Extend to 9-cell

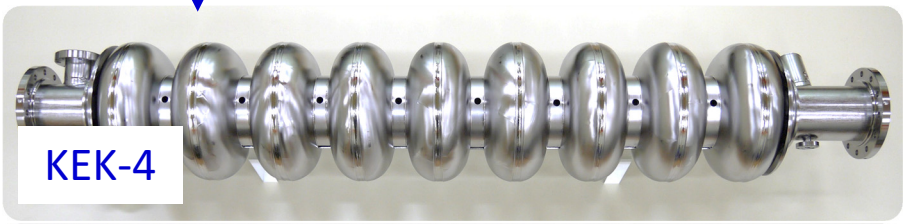
Tokyo Denkai; high-RRR

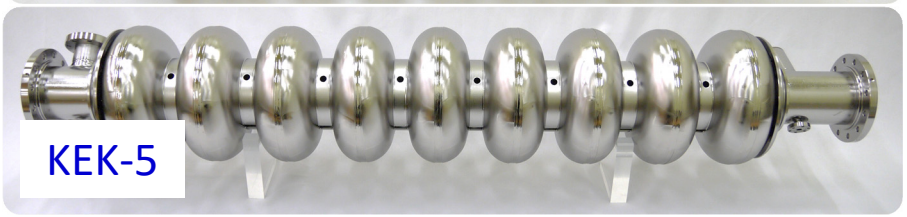


Aiming at cost reduction

CBMM; mid-RRR, high-Ta

Extend to 9-cell





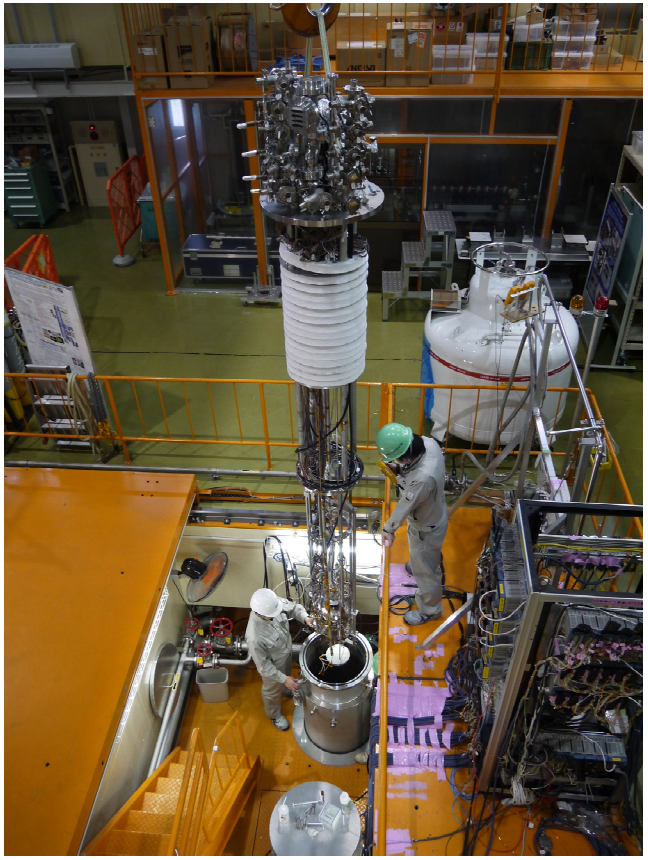
Performance test

Surface treatment (before test)

1. EP1 (100μm)
2. Annealing (750deg × 3hrs)
3. Tuning
4. EP2 (20～30μm)
5. Assembly
6. Baking (120deg × 48hrs)

Measurement environment

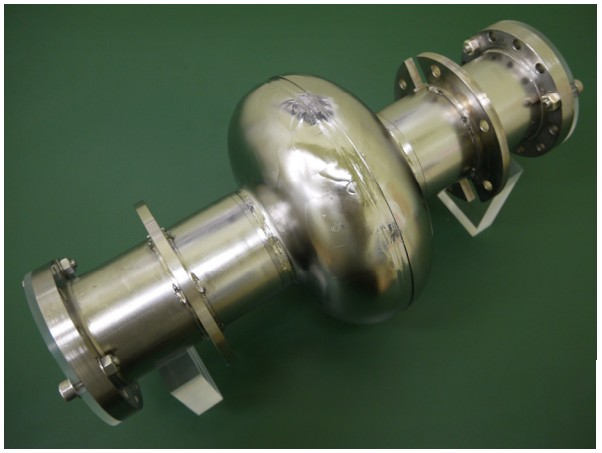
- ✓ Vertical cryostat filled with liquid He
- ✓ Remaining magnetic field：5～10mG
- ✓ No magnetic cancelation. (except R10)

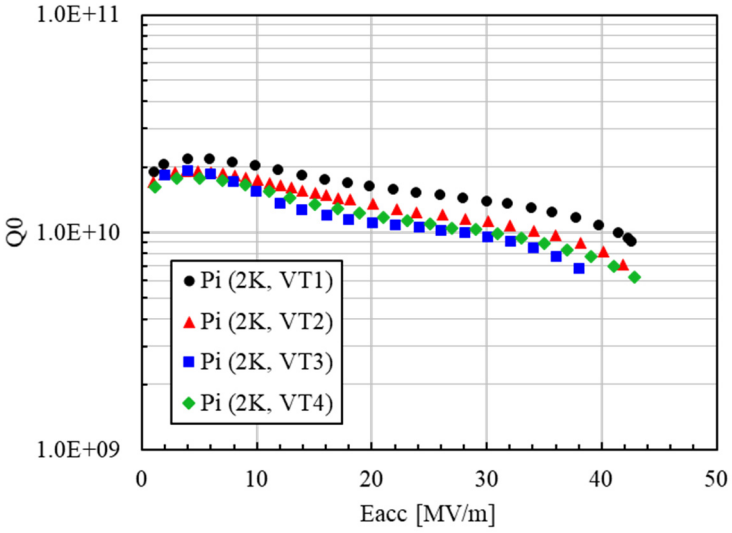


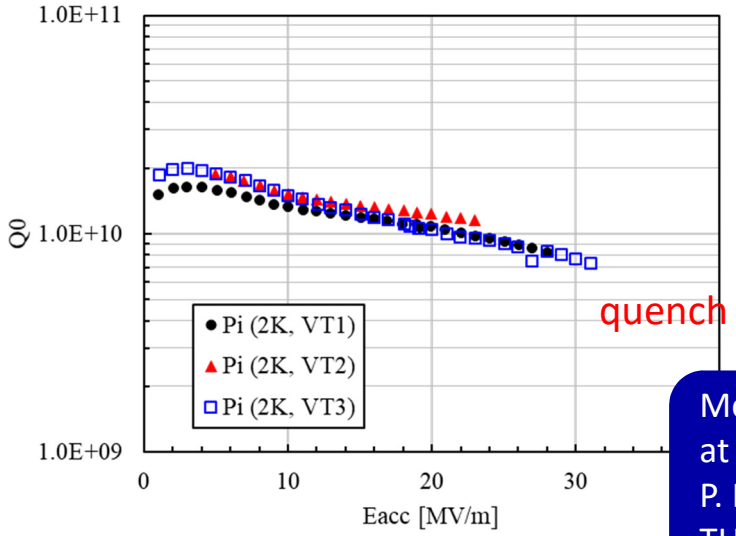
Different RRR LG slices

Tokyo Denkai: RRR = 496

CBMM: RRR = 107







Measured again at Jlab
P. Dhakal
TUP012

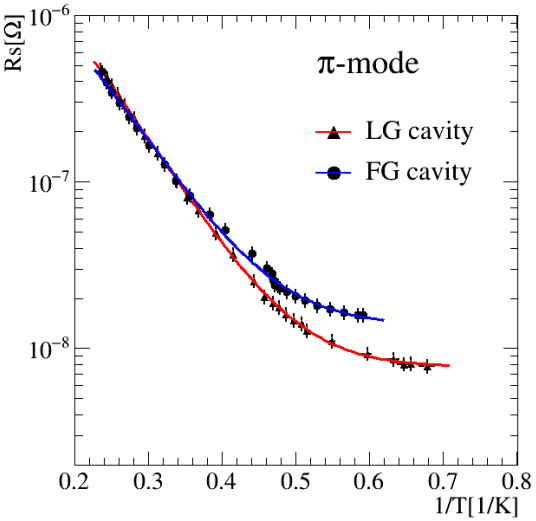
Achieved to high gradient with hi-RRR LG, but not with lo-RRR

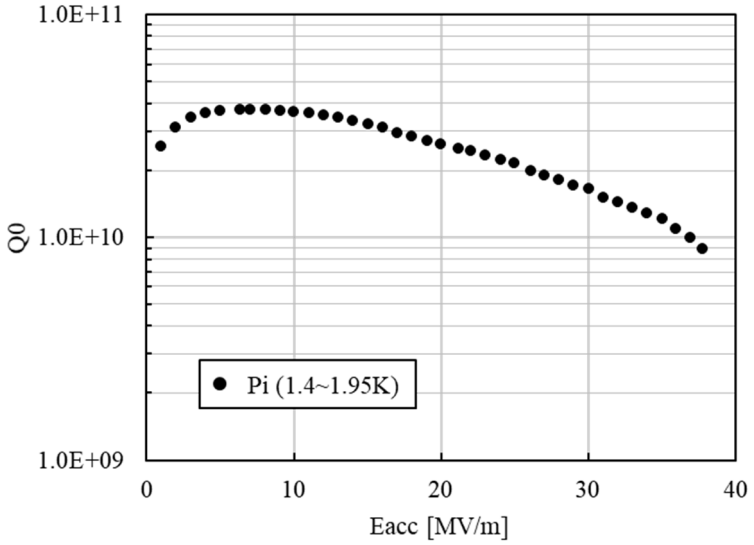
"Fabrication and evaluation of superconducting single-cell cavities manufactured using different materials and methods", Hirotaka Shimizu *et al.*, 2017

9-cell cavity made by high-RRR LG slices

Tokyo Denkai: RRR = 496

Rs vs 1/T





- Achieved high gradient
  →more than 40MV/m at most of cells
- Residual resistance is lower than FG
  →higher Q-value is expected
  →further study necessary with good magnetic environment

Maximum gradients at each cell

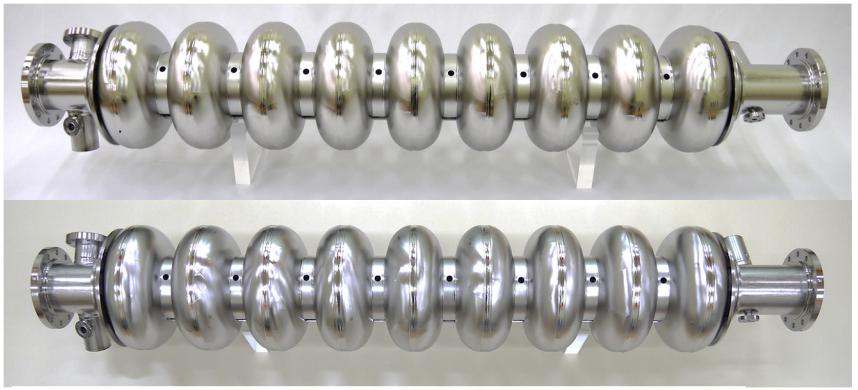
Cell#	1	2	3	4	5	6	7	8	9
E_{acc}	>45	40.4	39.6	>44.7	>42.7	>44.7	>39.6	>40.4	>45

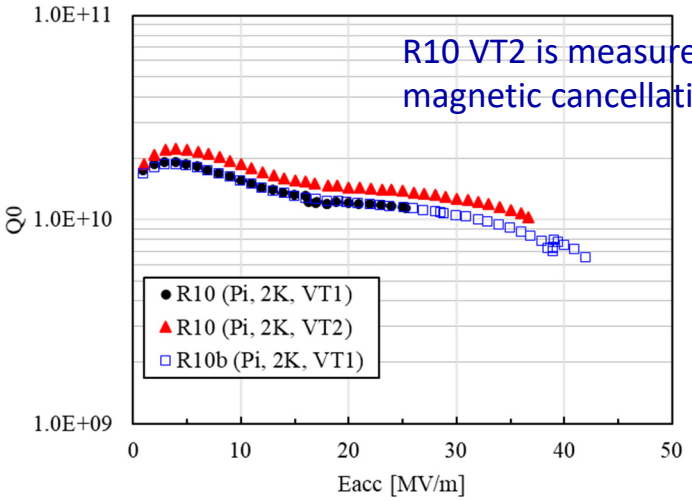
"Investigation of in-house superconducting radio-frequency 9-cell cavity made of large grain niobium at KEK", Takeshi Dohmae *et al.*, 2017

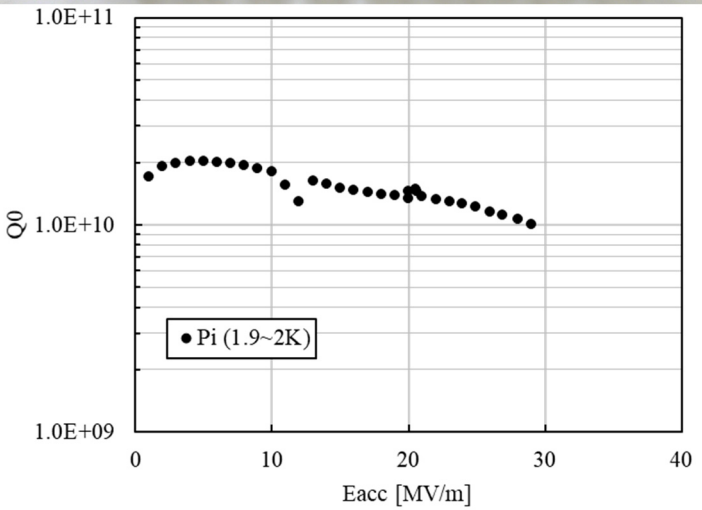
Aiming cost reduction

CBMM: RRR = 242-298, High-Ta contained (1034ppm)

※High-Ta contained Nb is cheaper than low-Ta contained Nb







Acceptable results!

Cell#	1	2	3	4	5	6	7	8	9
E_{acc}	40	41	>30	>31	>41	31	30	>41	>40

→ To be measured again

Summary of each cavities

	KEK-R1	KEK-R5	KEK-2	KEK-R10/R10b	KEK-4
Supplier	Tokyo Denkai	CBMM	Tokyo Denkai	CBMM	CBMM
# of cells	Single	Single	9-cells	3-cells	9-cells
RRR	496	107 (hi-Ta)	496	242 – 298 (hi-Ta)	242 – 298 (hi-Ta)
Results (π-mode)	41.8 MV/m	31 MV/m	38MV/m	38/42 MV/m	29MV/m

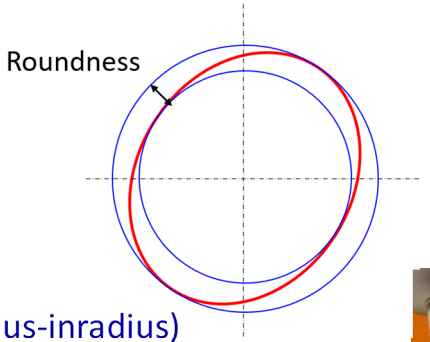
- High E_{acc} is achieved with LG Nb which RRR > 240
- No dependency on supplier
- Composition of Ta does not affect to the E_{acc}

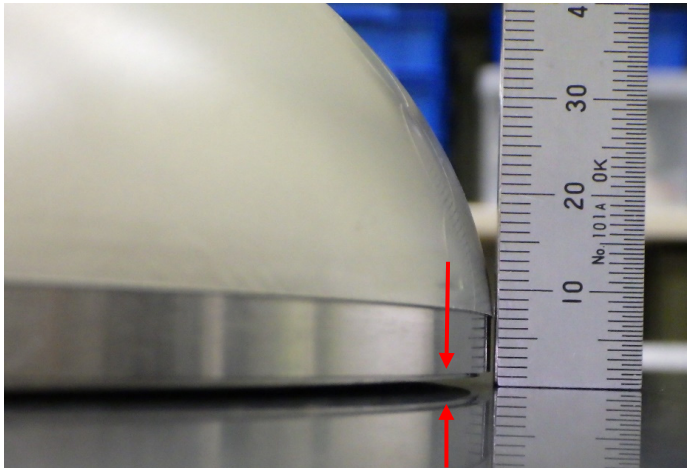
Technical issues

Large anisotropy

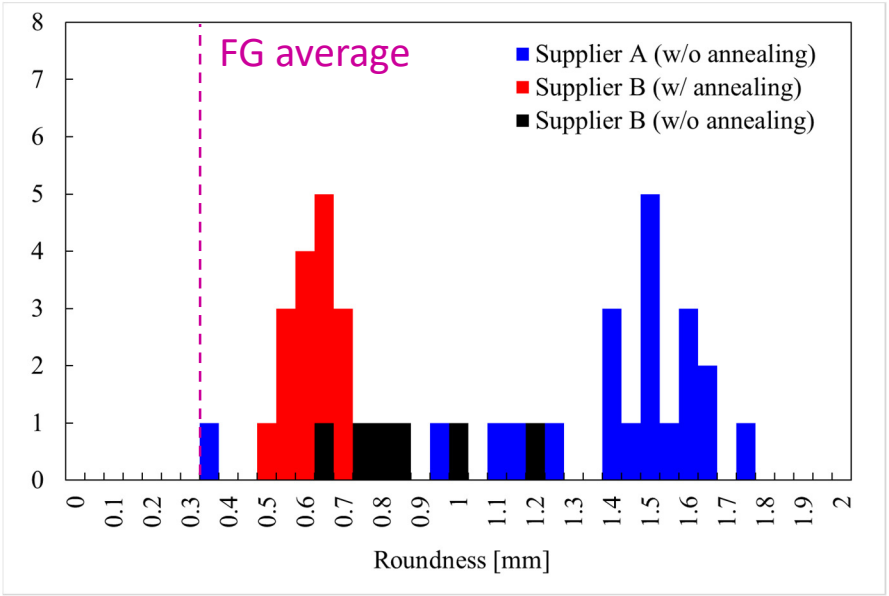
LG has strong anisotropy (due to large crystal size)

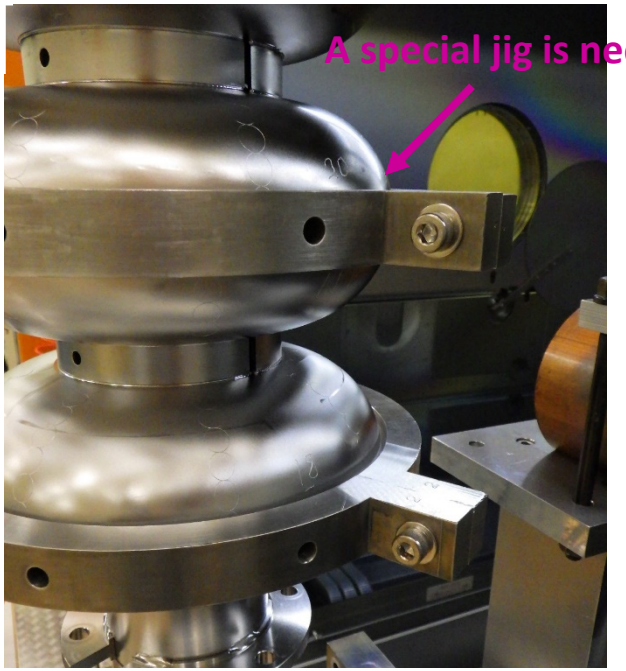
Large deformation is observed after press forming
→Difficulties in fabrication
→Difficulties in alignment





Roundness at equator (circumradius-inradius)





Mechanical strength

- Not always same mechanical strength
- Depends on crystal orientation

How to guarantee material quality?

→How to pass high pressure gas safety act. (Japanese law)?

(Pressure Equipment Directive)

Three samples which have same crystal position

- ✓ Broke at the different position
- ✓ Different results were observed

Under investigation (need more study)

Summary

- KEK has been investigating 1.3GHz elliptical cavity made of LG Nb.
  - Several single-cell, 3-cell and 9-cell cavities were fabricated by several kinds of LG sheets.
  - ✓Single-cell and 9-cell cavity with high RRR LG
    - →Achieved > 35MV/m
  - ✓3-cell and 9-cell cavities with mid RRR & high Ta contained LG
    - →Achieved > 35 MV/m
  - Acceptable results are obtained with LG of RRR>240
- Strong anisotropy
  - Large deformation → Fabrication difficulties
- Different mechanical strength
  - How to guarantee material quality? → Next issue