

Report of New-baking results for KEK cavities

~ Investigation of cavity fabrication / treatment?? ~

2018/10/4

TTC High (Q + G) WG Meeting

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FNAL-SRF team

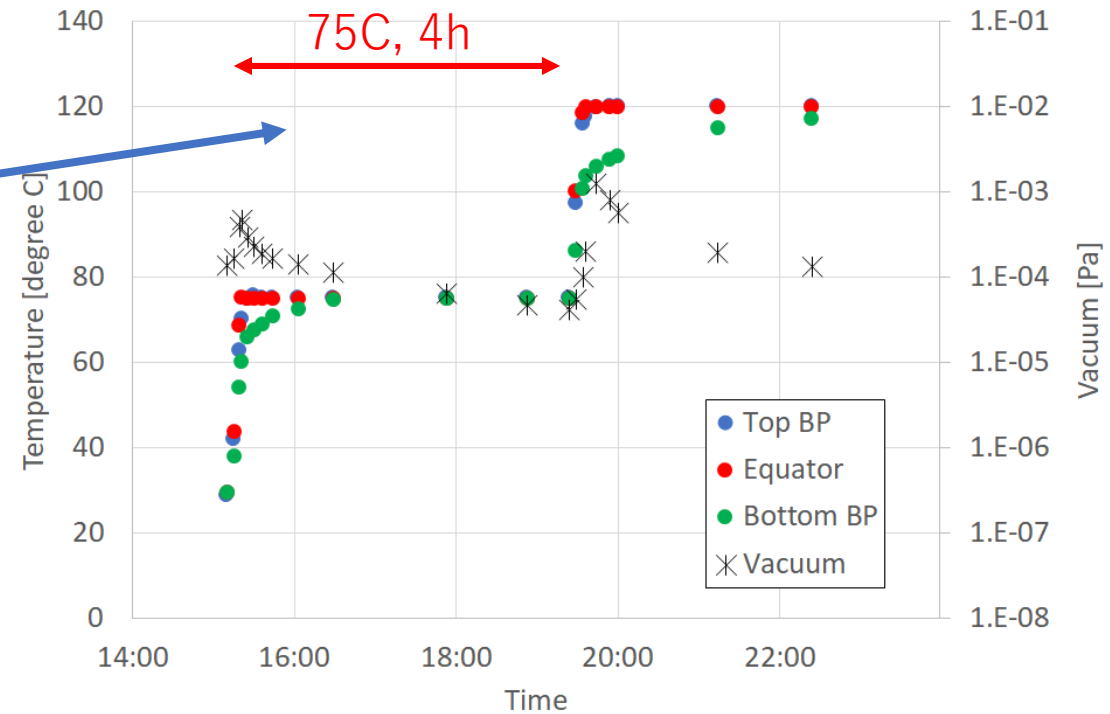
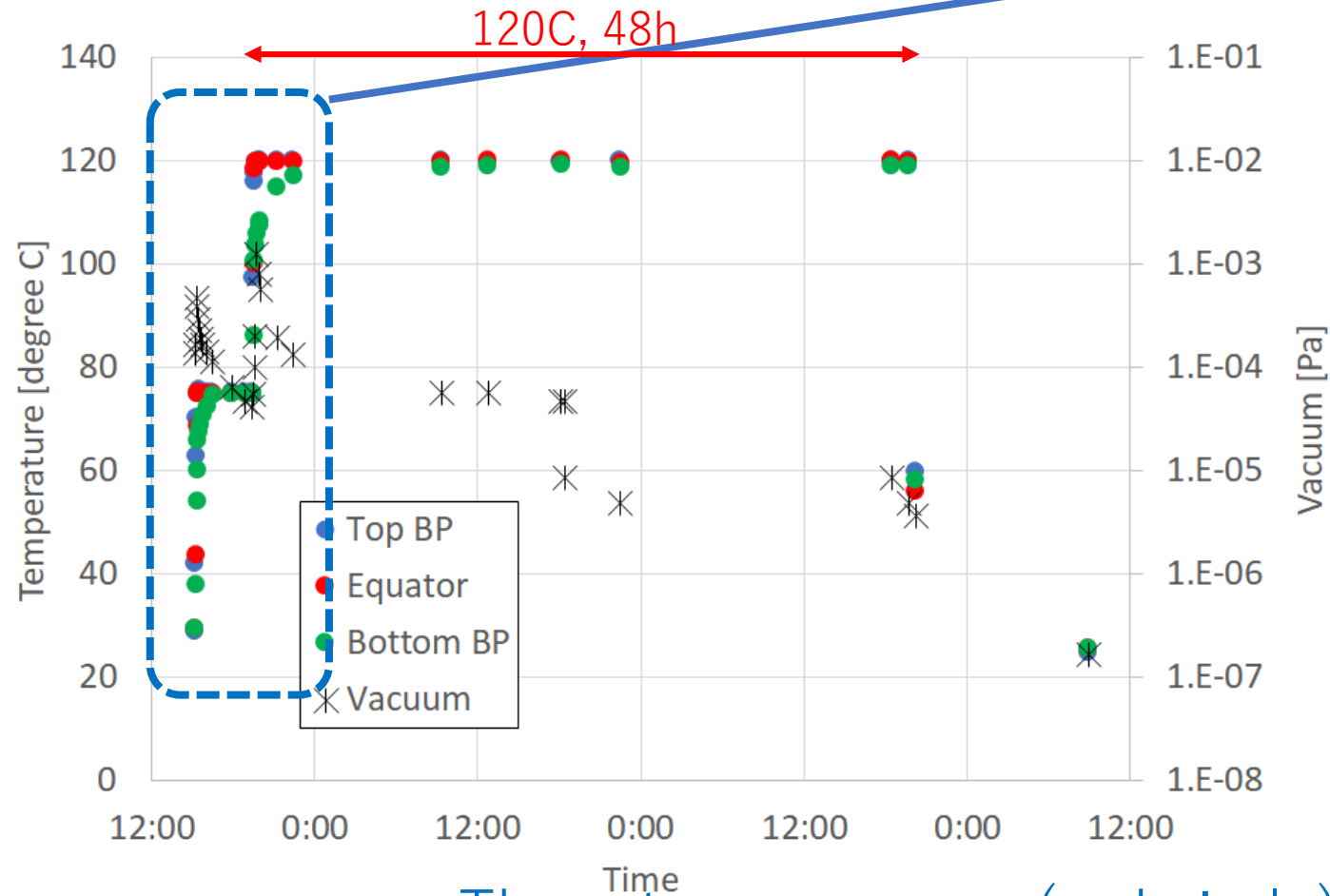
Introduction

- **New baking recipe, 75C4h+120C48h**, was applied to 4 KEK single-cell cavities.
 - TESLA-like(STF) end-cell type single cell cavities with TESLA flanges.
 - Made from Tokyo-Denkai FG sheet
 - Made by KEK-CFF & Mirapro(Japanese company)

	Lab for baking	Lab for VT
R-8 (KEK-3)	FNAL	FNAL
R-8b (KEK-2)	FNAL	FNAL
R-8c (KEK-4)	KEK	FNAL
R-9b	KEK	KEK

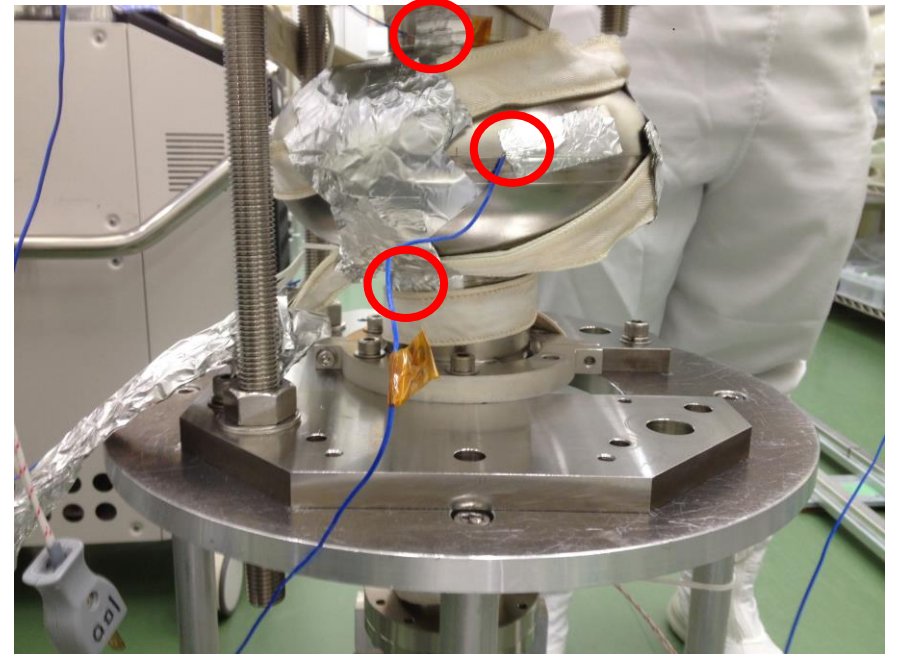
※ K. Umemori stayed FNAL at August for experiments

Baking(75C,4h+120C,48h) at KEK

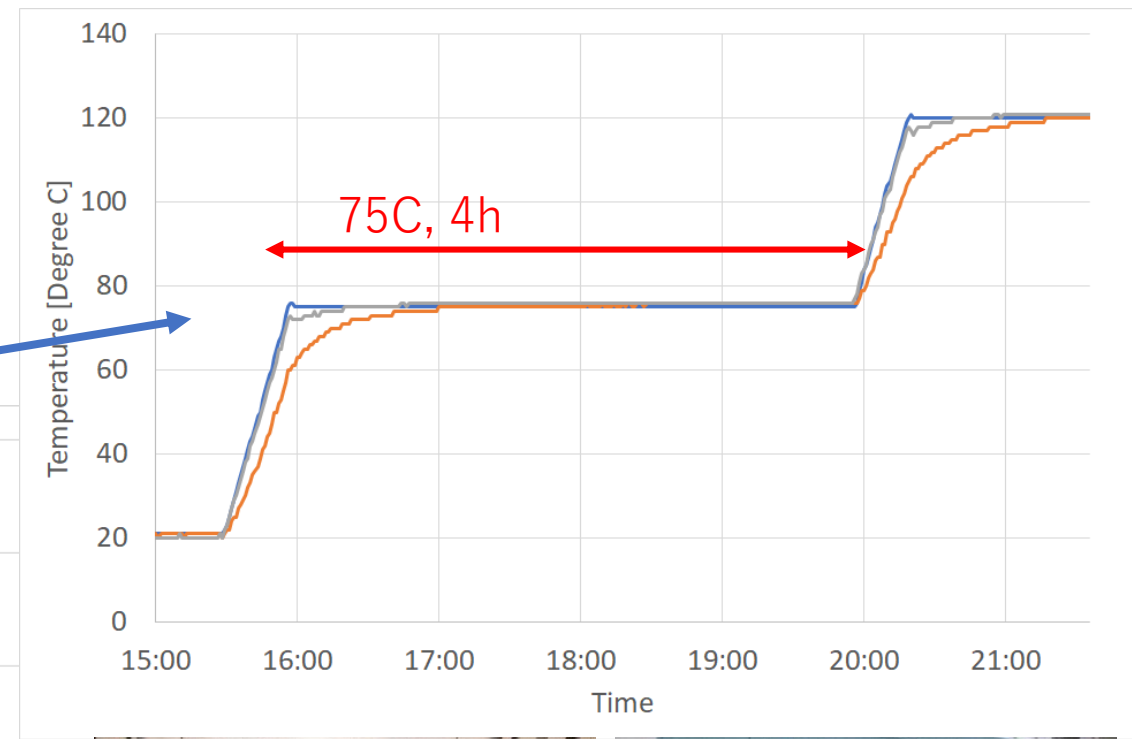
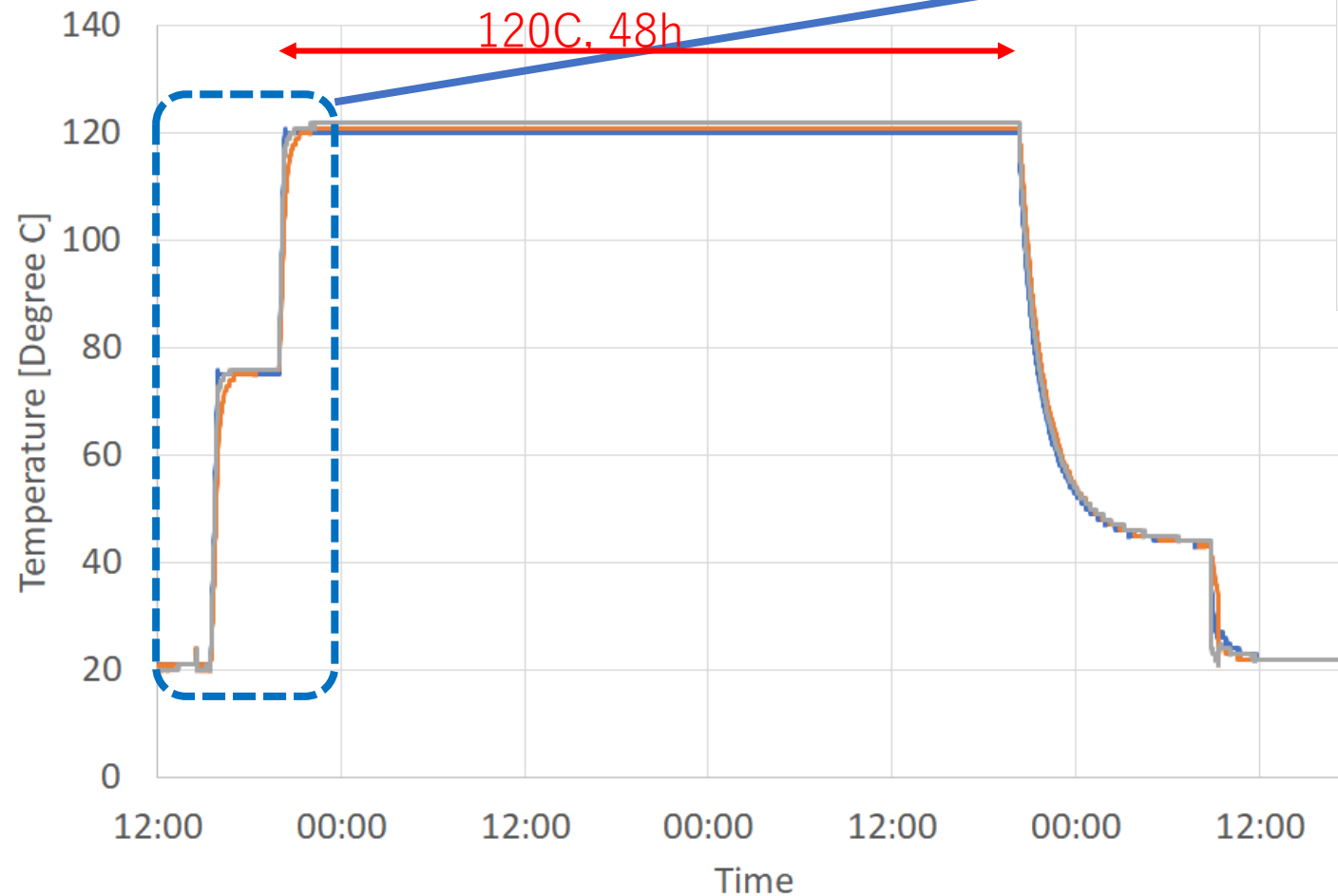


Three temp. sensors(red circle) at

- Equator
- Top and bottom irises

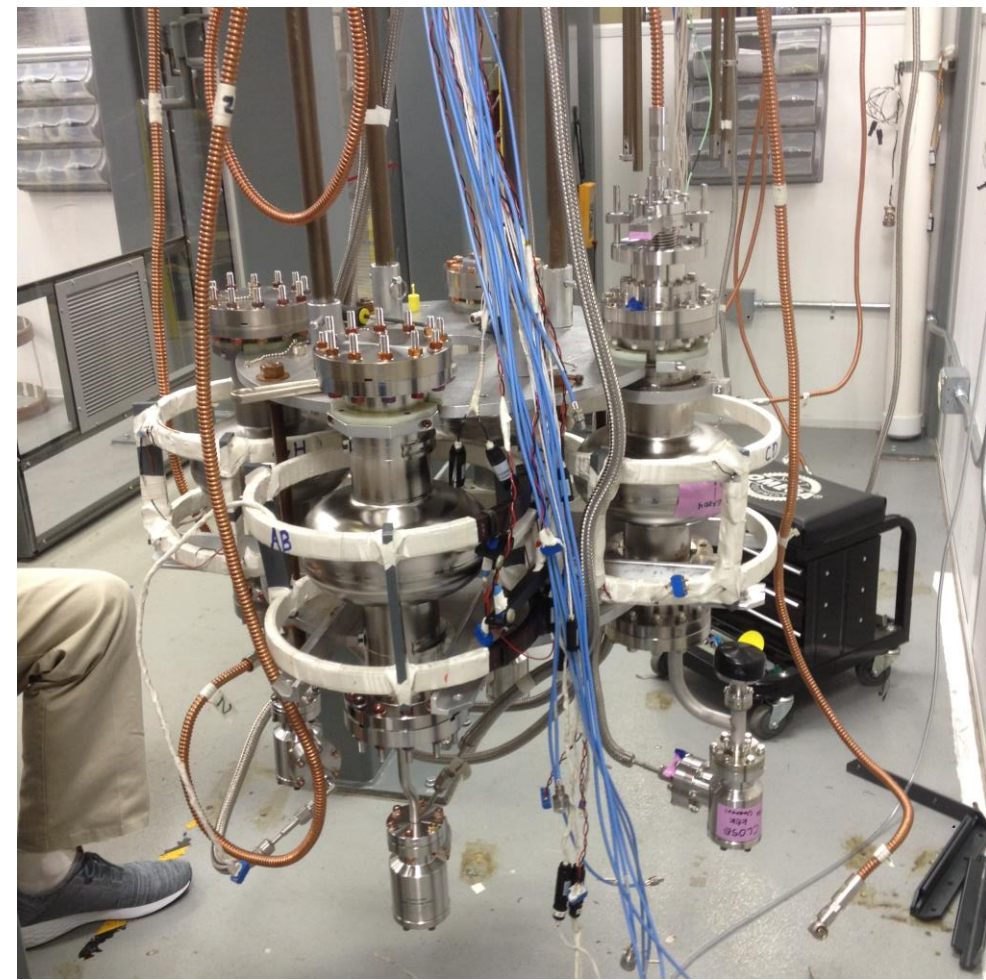


75C, 4h + 120C, 48h Baking at FNAL



KEK3(R-8)

- EP 40μm, HPR
- Assembly
- Baking(75C, 4h + 120C, 48h)
- VT
- Inspection



※ Surface treatment and VT were carried out at FNAL

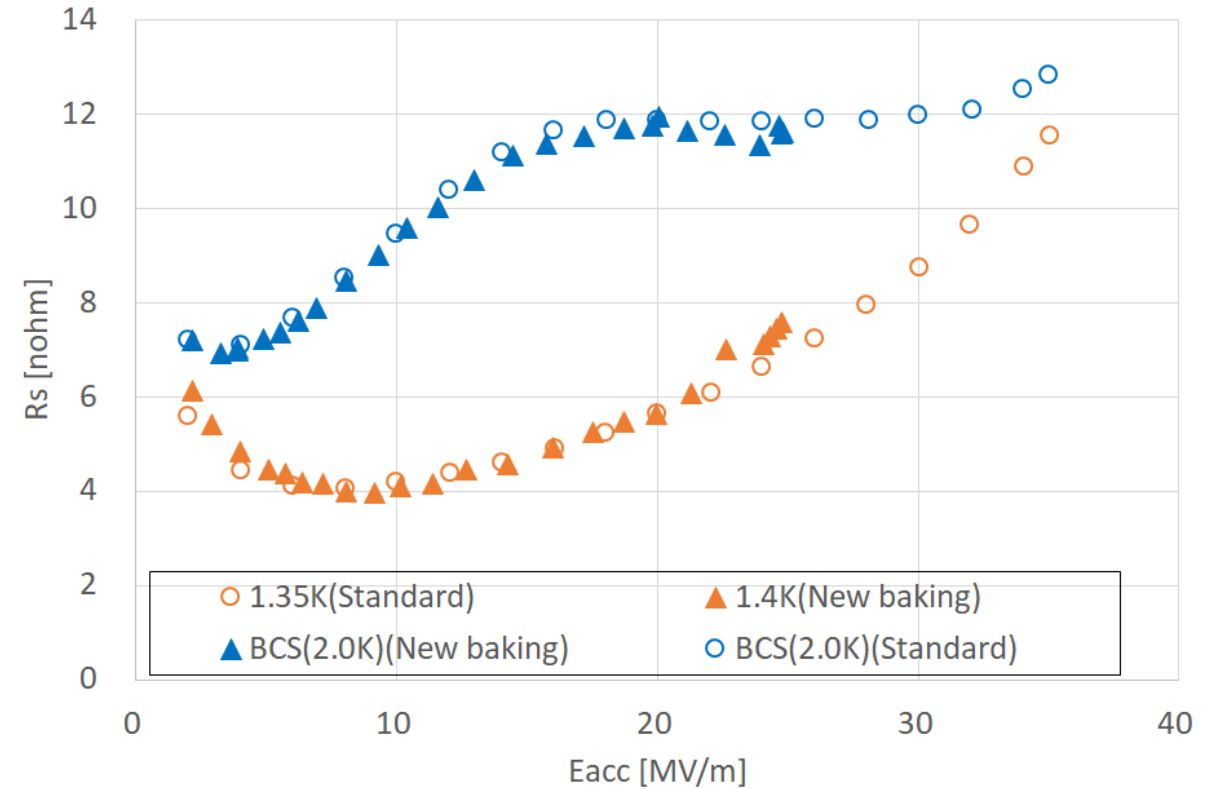
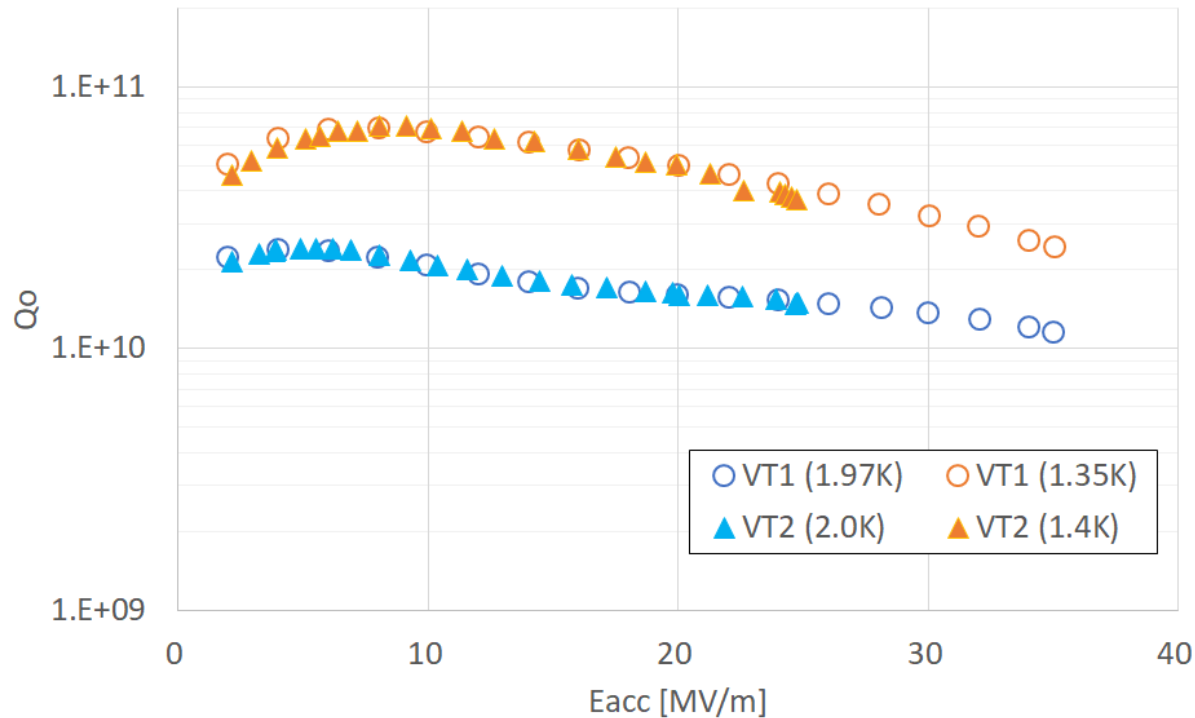
Results for KEK-3

$$Q_{in} = 5.24e9$$

$$Q_t = 1.68e11$$

Mag. Field cancelled $\sim 0.3\text{mG}$

KEK-3 VT1: standard recipe, VT2: new baking recipe



- No change observed.
- Just E_{acc} decreased to $25\text{MV/m}??$
- No X-rays.

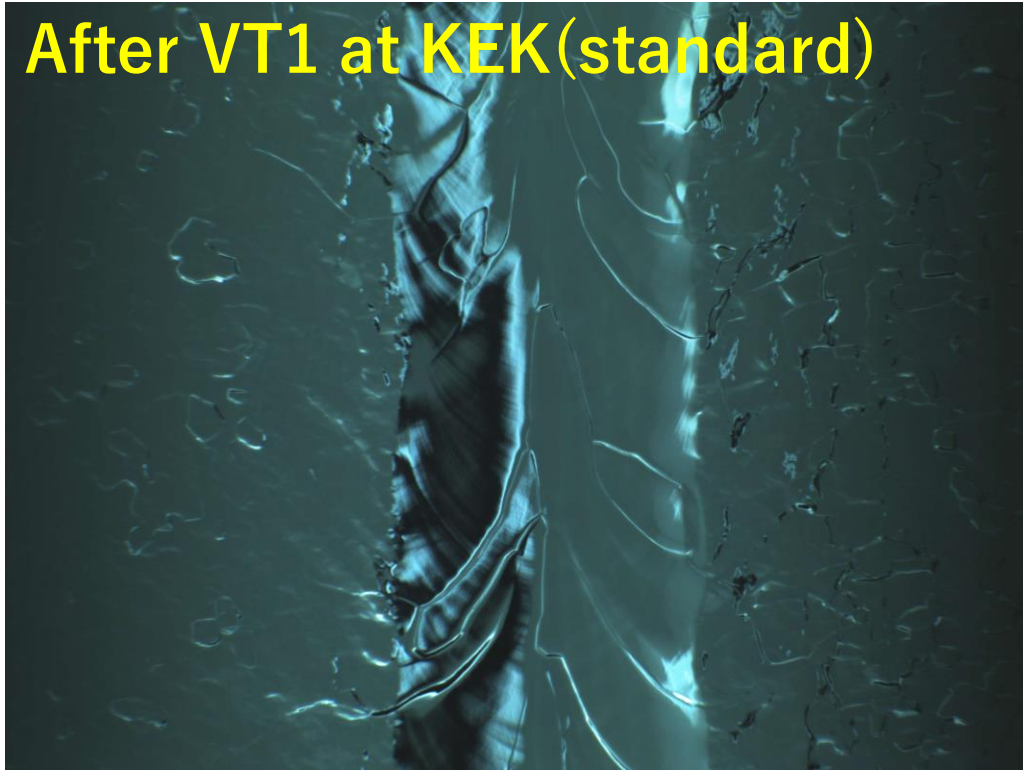
- No change on R_{BCS} and R_{res} , since no change on Q - E curve.

BCS resistance is estimated by subtraction of low-T data from 2.0K data (for all data in these slides).

Inspection after VT (at FNAL camera)



VT1 (Standard) : 36 MV/m
⇒ VT2 (New baking) : 25 MV/m



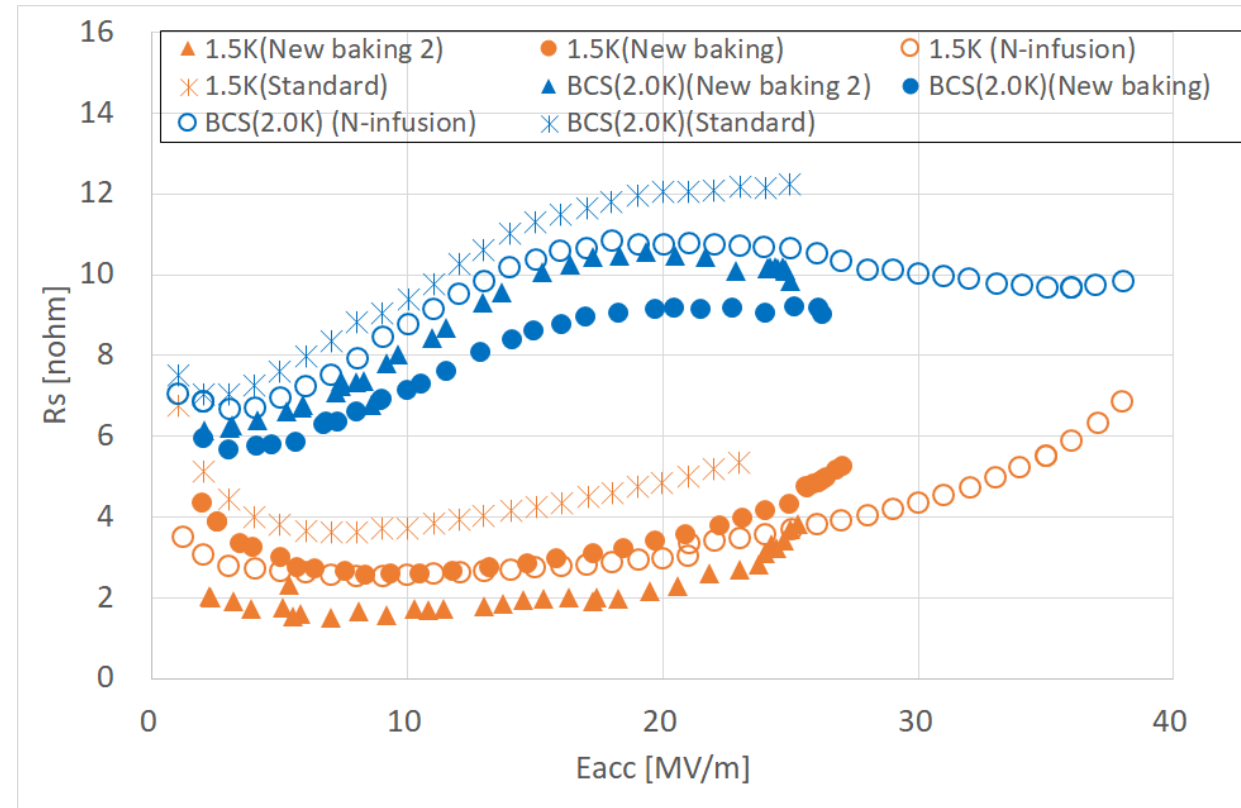
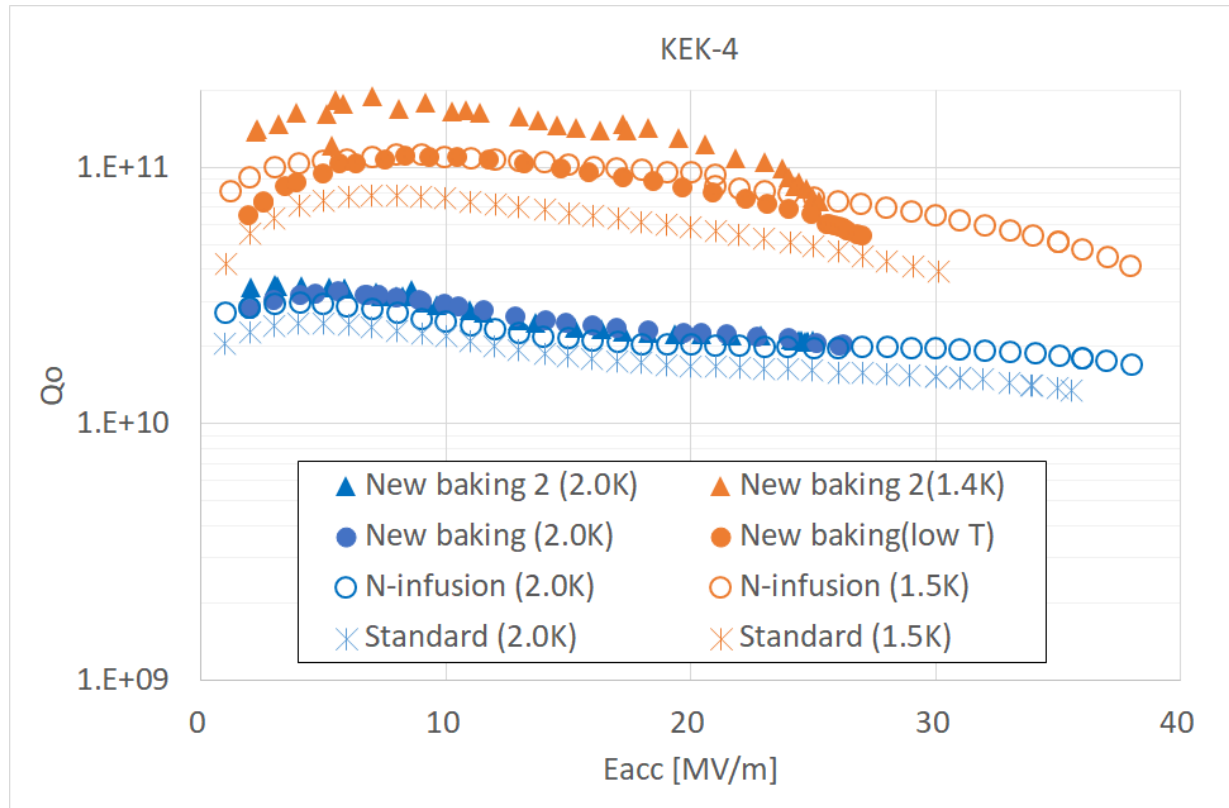
- Suspicious defects are found just side of welding bead, around 190 degree.
- Did the defect appear after EP (40um)?

KEK4(R-8c)

- EP 20um, HPR at KEK
- Assembly at KEK
- Baking(75C,4h + 120C, 48h) at KEK
- Transfer to FNAL
- VT at FNAL
- HPR & Assembly at ANL
- VT at FNAL
- Inspection at FNAL



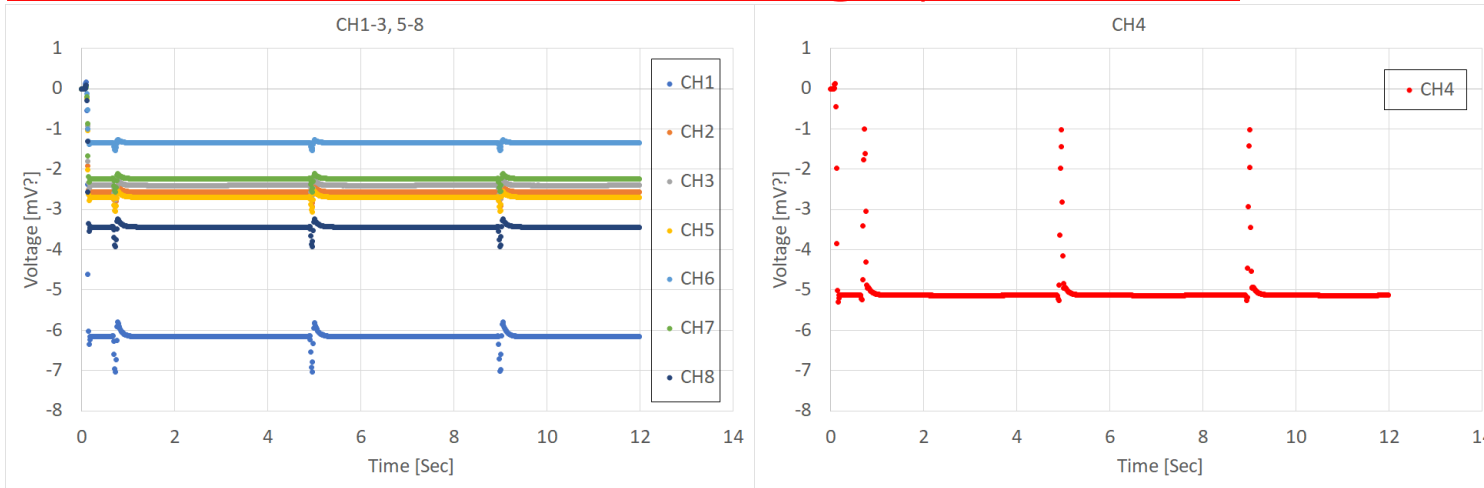
Results for KEK-4 at VT(Aug/14 and 24)



- Little bit better Q_0 at 2.0K than N-infusion.
- Q_0 at low-Temp is very good.
- **Quench at 27 / 25 MV/m**
- No X-rays. (Just spike at 22 MV/m)

- BCS resistance is lower than standard recipe, little bit better than N-infusion.
- R_{res} is low.

Reaction of RTD during quenches



CH4(135degree) shows clear signal of temperature rise.

⇒ Unstable welding bead
Is this a reason of quench?

VT1 (Standard) : 36 MV/m
VT2&3 (N-infusion) : 38 MV/m
⇒ **VT5&6 (New baking) : 25~27 MV/m**

After VT6 at FNAL(new baking)



After VT1 at KEK(standard)

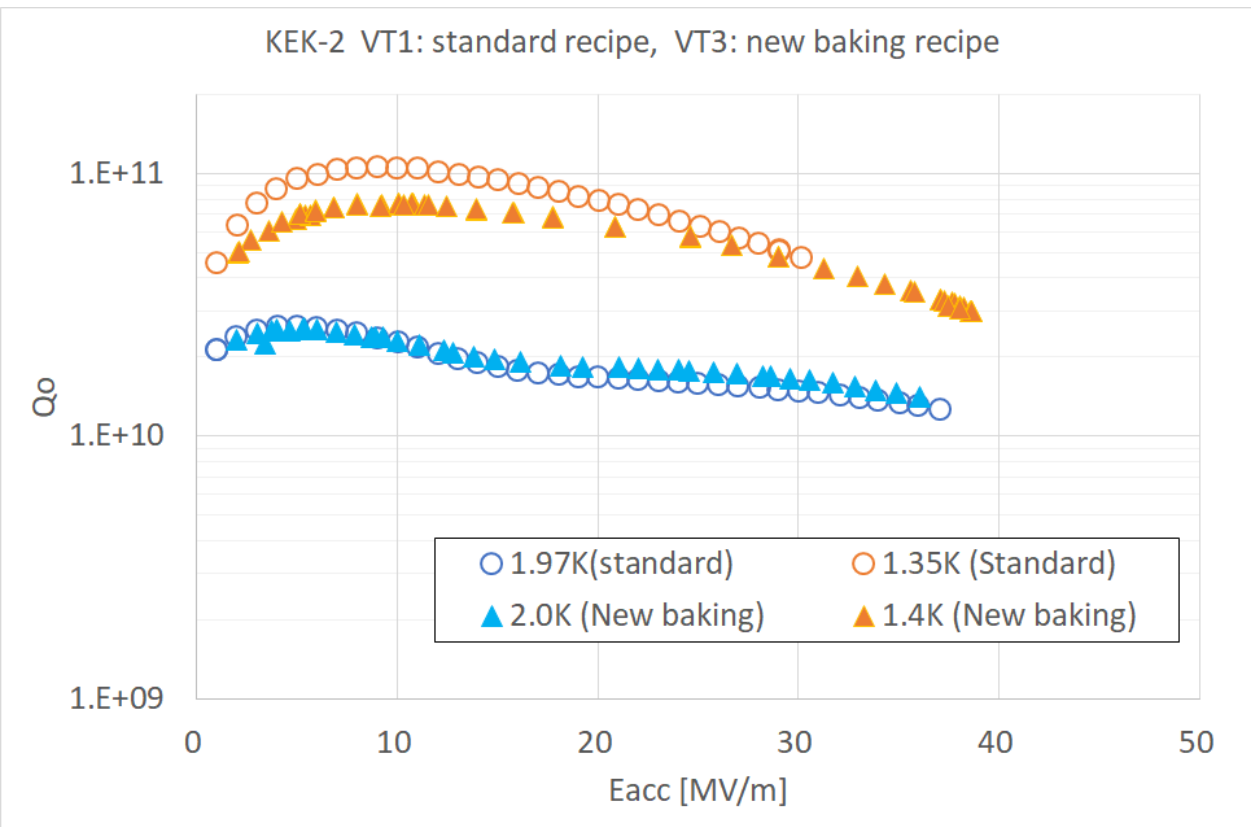


KEK2(R-8b)

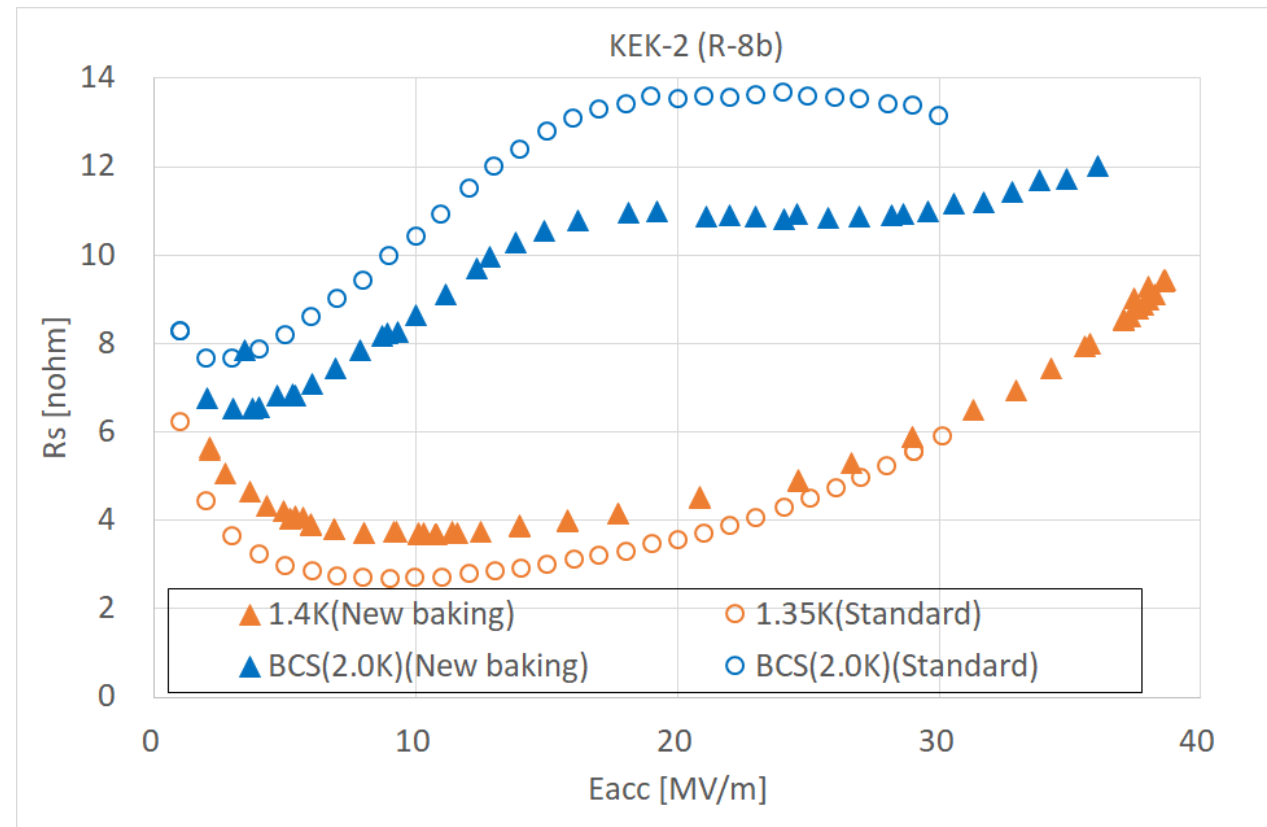
- 800 C x 3h
- HPR, Assembly
- Baking(75C,4h + 120C, 48h)
- VT
- EP (40um)
- HPR & Assembly
- Baking(75C,4h + 120C, 48h)
- VT
- Inspection

※ Above all works were done at FNAL

Results for KEK-2 (VT at July/26)

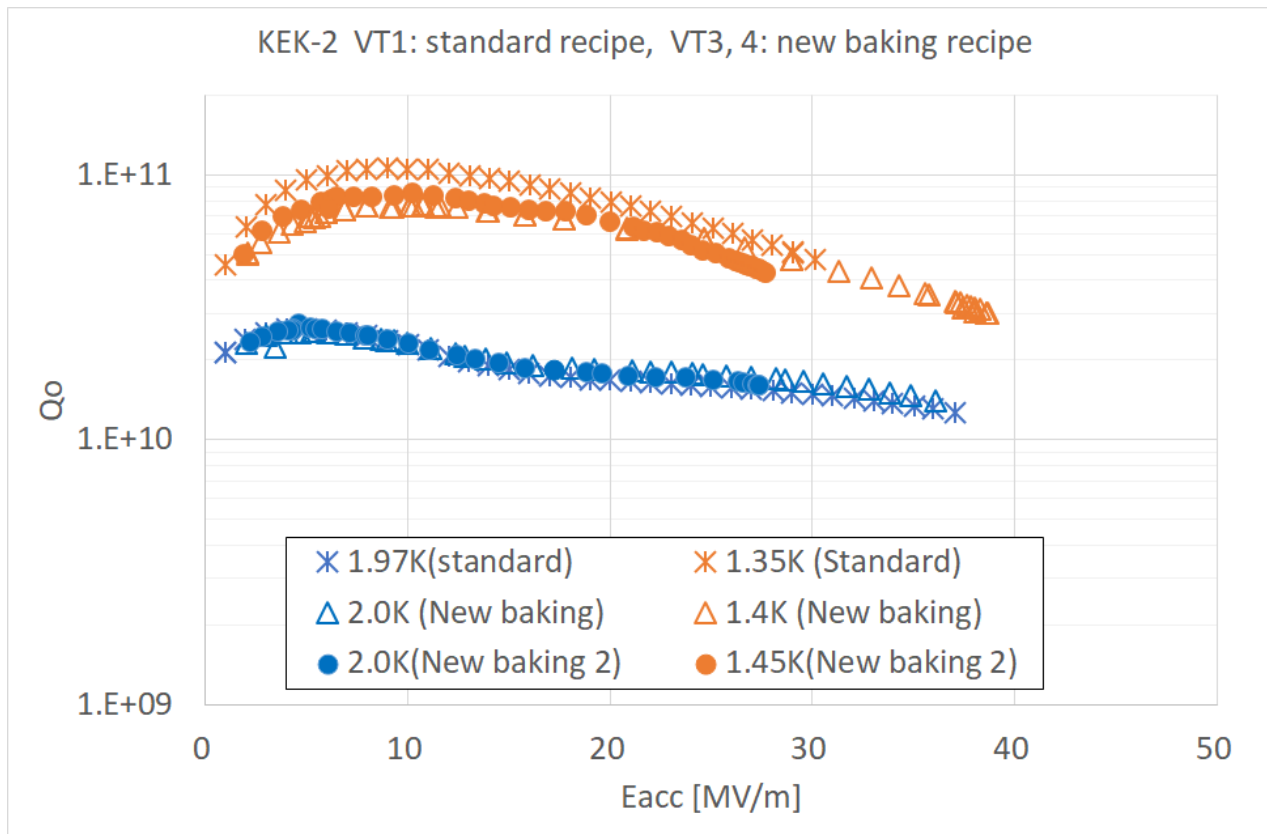


- Not much change on Eacc.
- Reached to 36 / 39 MV/m @ 2.0K / 1.5K
- But quench due to F.E.? Heating at beam-pipe.
- X-ray from 32 MV/m.
- Q_0 at low-middle field is rather low for low-T.



- BCS is smaller for new recipe
- R_{res} is larger

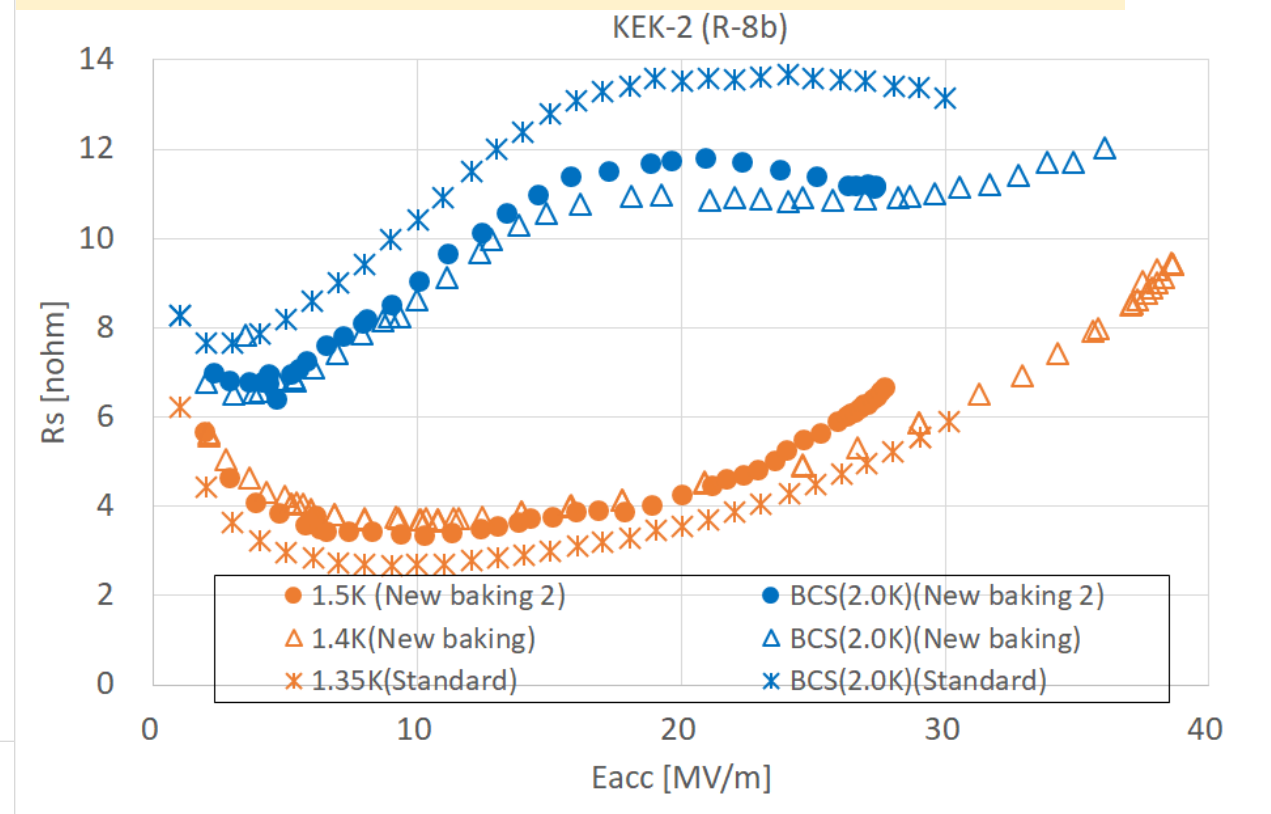
Results for KEK-2 (VT at Aug/21)



- Eacc decreased to 27 MV/m!
- No F.E.
- Q_0 at low-T is little bit better than previous test.
- Q_0 at 2.0K is very similar.

No defects found at inspection after VT

VT1 (Standard) : 37 MV/m
VT3 (New baking 1) : 36-39 MV/m
VT4 (New baking 2) : 27 MV/m



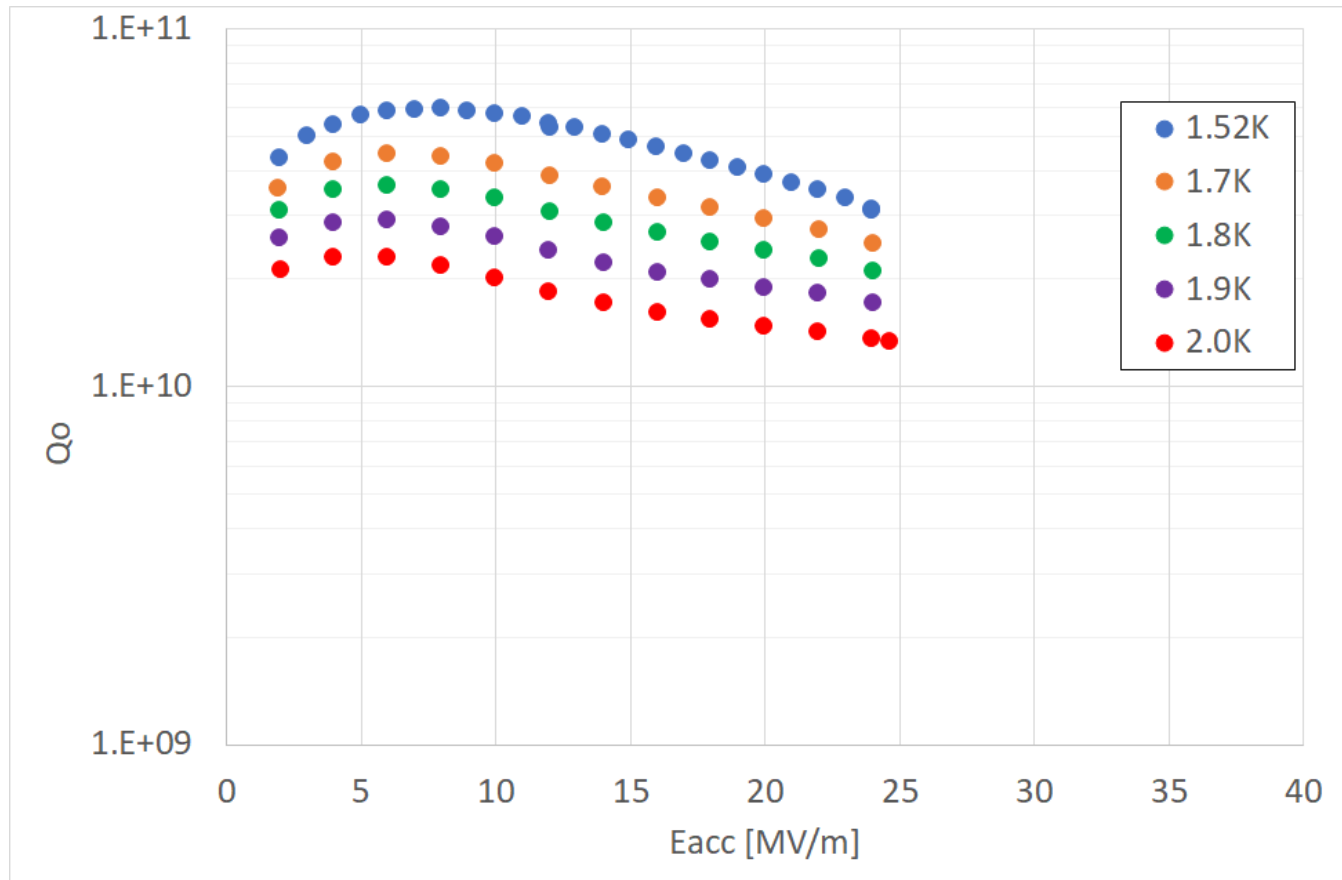
- BCS and R_{res} are similar with previous test.
- BCS little bit larger at middle field and R_{rest} tend to be higher to higher field

R-9b

- ☐ EP (20um)
- ☐ HPR & Assembly
- ☐ Baking(75C,4h + 120C, 48h)
- ☐ VT
- ☐ (Inspection, this week)

※ Surface treatment and VT were carried out at KEK

Q-E curve



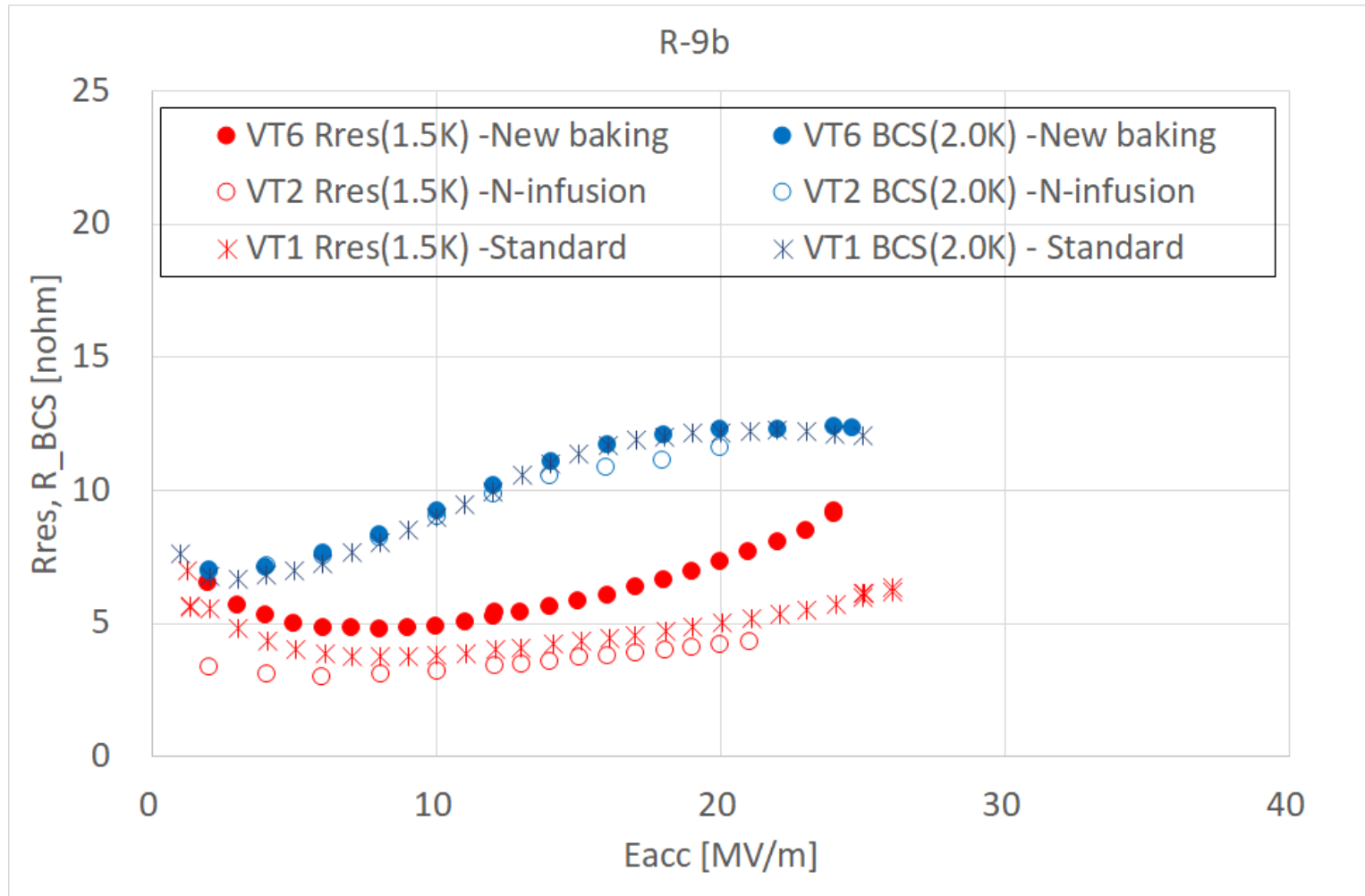
- E_{acc} was limited at 25 MV/m.
- Quench location: ~ 105 degree, equator
- No field emission.
- Q_0 is not good for low temperature, due to bad R_{res} .

VT1 (Standard) : 36 MV/m

VT5 (N-infusion) : 26 MV/m \leftarrow Something wrong?

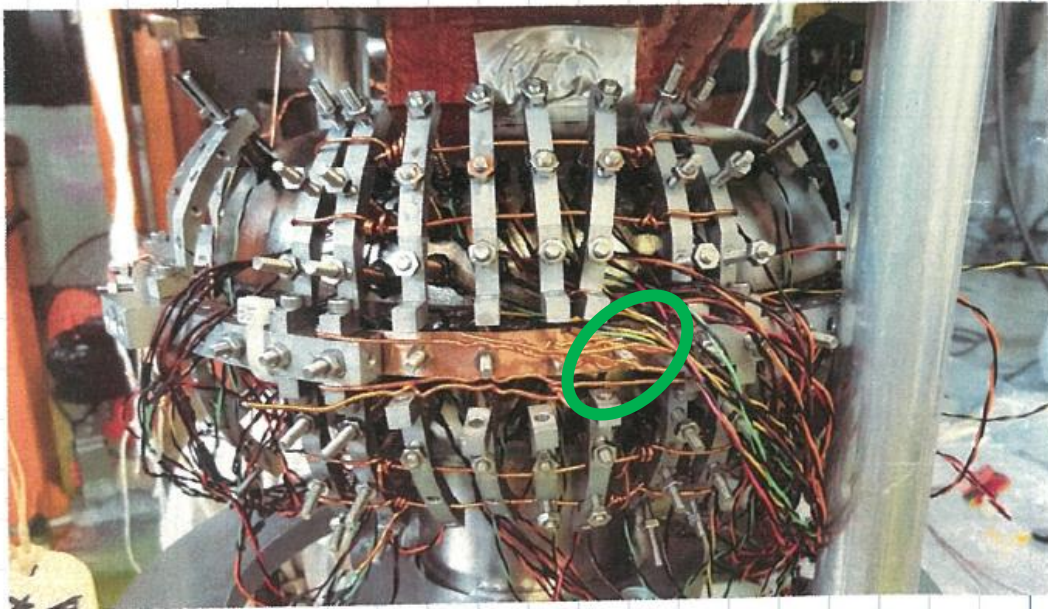
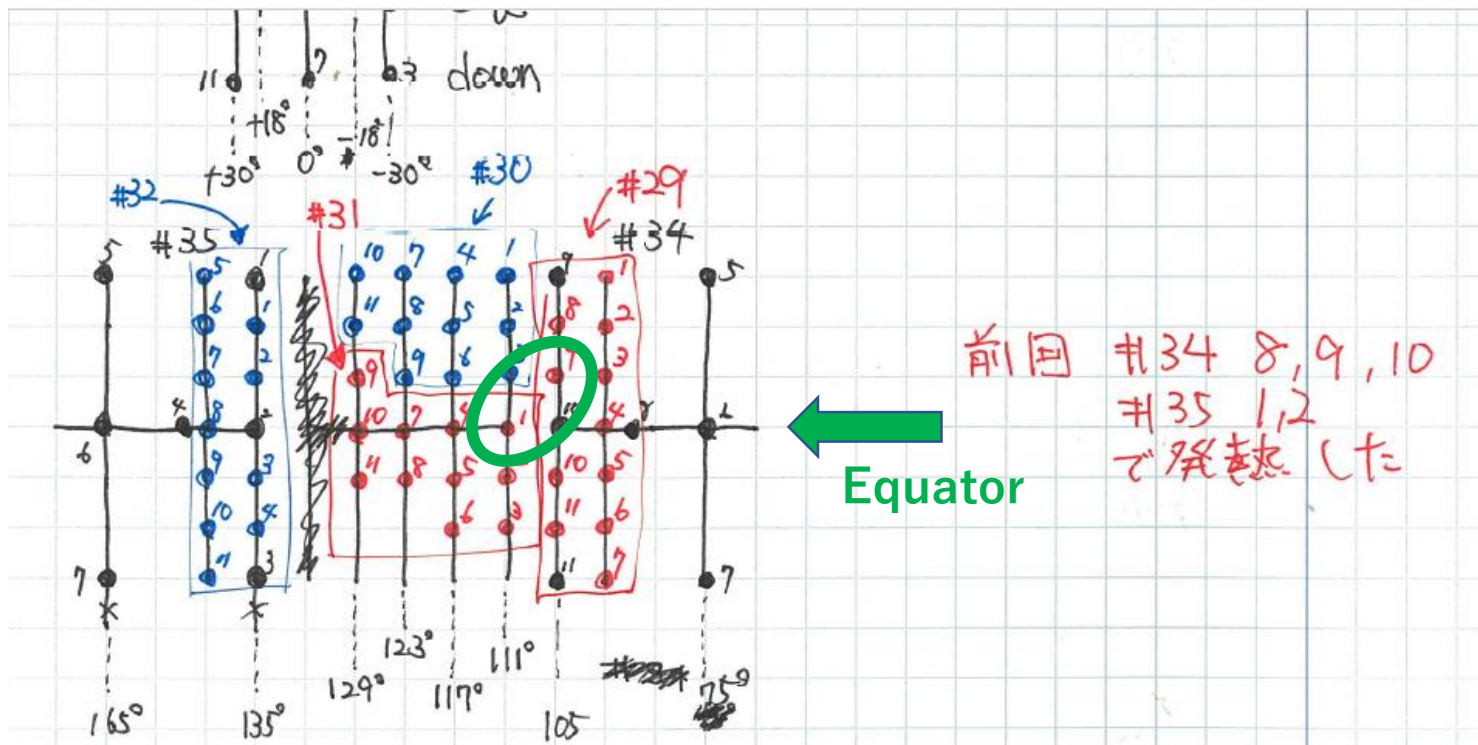
VT6 (New baking) : 25MV/m \leftarrow Same heating location with VT5

Deconvolution of R_{BCS} & R_{res}



- R_{BCS} is very similar to Standard treatment (VT1) and N-infusion at J-PARC (VT2)
- R_{res} (=R_s(1,5K)) is larger compared with standard treatment and N-infusion.

R_{BCS}(2.0K) is estimated by subtracting R_{res}=R_s(1.5K)

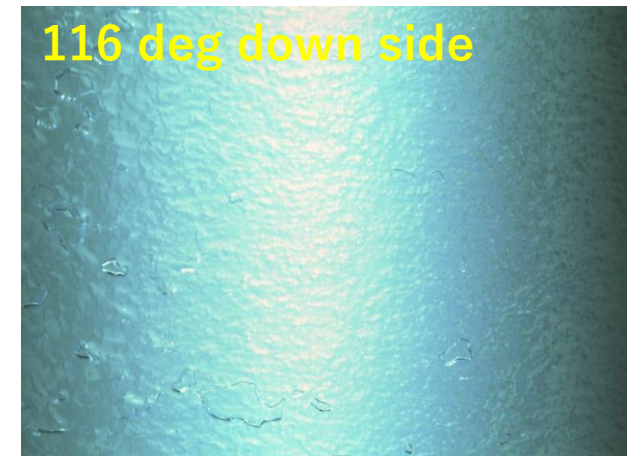
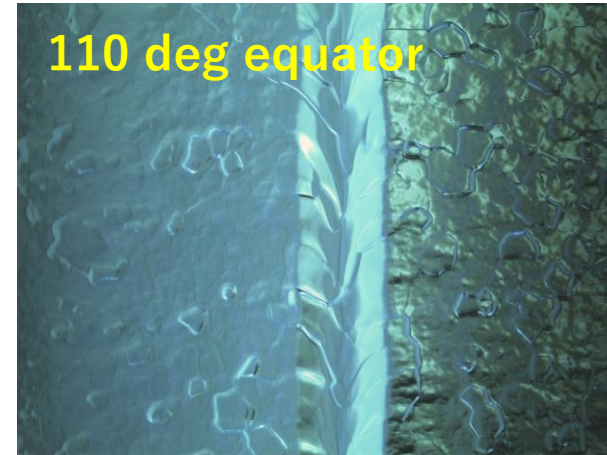
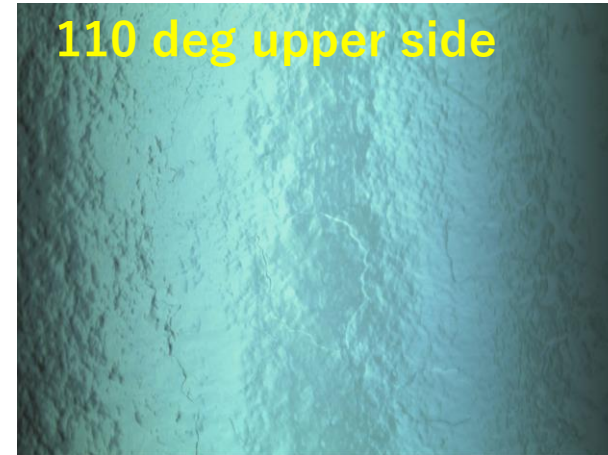
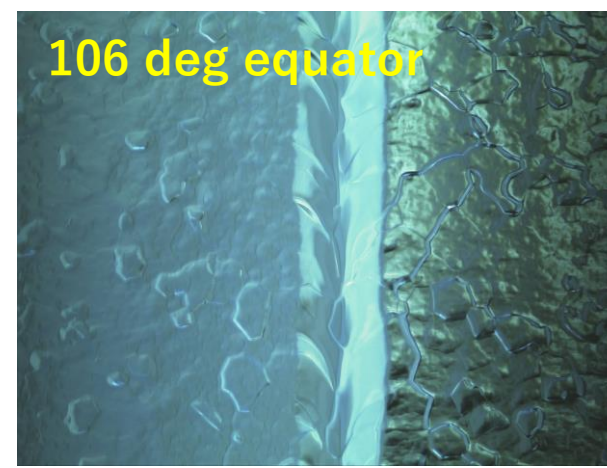
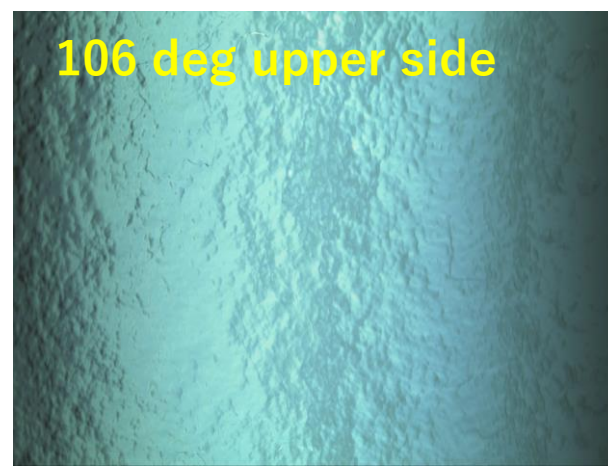


Dedicated carbon sensors are mounted on the cavity, to identify quench location.

Heating spot is 111 degree on equator

Inspection

No defects
found around
heating location.

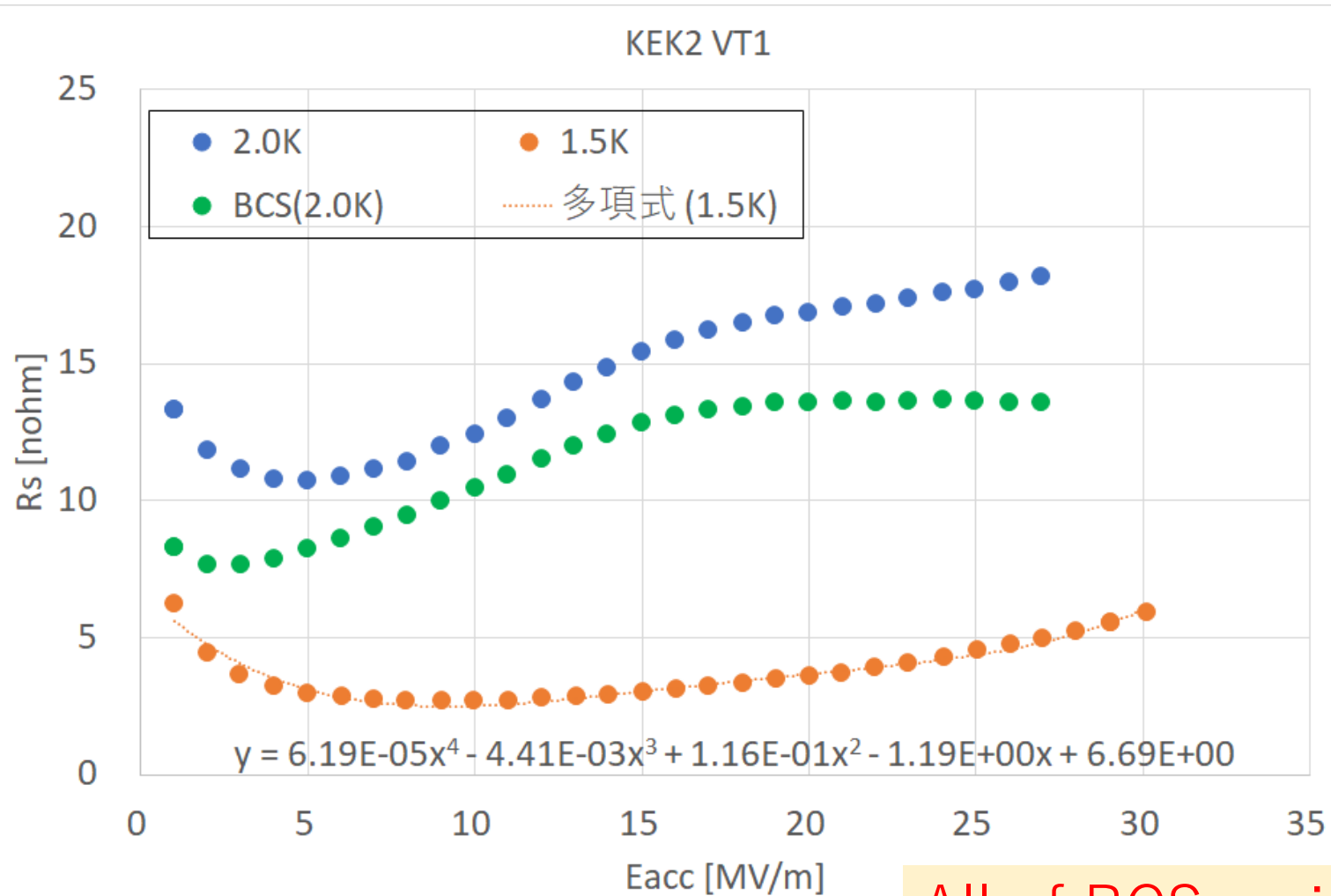


Summary

- New baking recipe “75C,4h + 120C,48h” was applied to four KEK single-cell cavities.
- Two of them, R-8 and R-8b (KEK3 and 2), were applied at FNAL and other two, R-8c(KEK4) and R-9b were at KEK.
- Once, results for R-8b(KEK2) show slight improvement.(No EP was applied just before new baking recipe).
- But, finally all of four KEK cavities were limited to 25 – 27 MV/m.
- What is reason of degraded performance?
 - All of them were once cleared > 35 MV/m
 - Cavity surface became bad? (One shows small defect, another shows unstable welding bead)
 - Effect of new baking ???
- We will recheck performance for standard recipe, EP + 120C baking, then re-try again!

Backup slide
(History of each cavity)

How to estimate R_{BCS}?



- Rs of lowest temperature data was fitted by polynomial curve.
- Fitted curve is assumed to be “R_{res}”.
 - Note: R_{BCS}(@low T) is included in R_{res}, as an error source. ~0.5nΩ?
- R_{BCS}(@2.0K) is estimated by following equation.
- R_{BCS}(2.0K) = Rs(2.0K) – fitted R_{res}
- Total of around 1nΩ error is expected.

All of BCS resistance in this slide is obtained by subtraction of low-T data from 2.0K data.

History of KEK-3(R-8)

2017/Jul/19	EP-1 (100um)	
2017/Aug/23	Heat treatment (750C, 3h)	
2017/Aug/29	EP-2 (20um), HPR	
2017/Aug/30	Assembly, Baking (120C, 48h)	Standard recipe
2017/Sep/8	VT1	Eacc = 35 MV/m
	Disassembly	
2018/Jan/22	N-infusion at FNAL	No VT after N-infusion
2018/Aug/7	EP (40um)	
2018/Aug/7	HPR, Assembly	
2018/Aug/10	Baking (75C,4h+120C,48h)	
2018/Aug/14	VT2 at FNAL	Eacc = 25MV/m

History of KEK-2 (R-8b)

Date	Procedure	Comment
2017/Jul/5	EP-1 (100um)	
2017/Aug/29	Heat treatment (900C, 3h)	
2017/Sep/5	EP-2 (20um), HPR	
2017/Sep/6	Assembly, Baking (120C, 48h)	Standard recipe
2017/Sep/14	VT1	Eacc = 37MV/m
	Disassembly	
	Transport to FNAL	
2017/Dec/1?	N-infusion at FNAL	
2018/Jan/4	VT2 at FNAL	Eacc = 38 MV/m
	Heat treatment (800C, 3h) at FNAL	
2018/Jul	HPR, Assembly	
2018/Jul/18	Baking (75C, 4h + 120C, 48h) at FNAL	
2018/Jul/26	VT3 at FNAL	Eacc=36/39MV/m(2.0/1.5K)
2018/Aug/9	EP (40um)	
2018/Aug/16	HPR, Assembly	
2018/Aug/17	Baking (75C, 4h + 120C, 48h) at FNAL	
2018/Aug/21	VT4 at FNAL	Eacc=27MV/m

History of KEK-4(R-8c)

2017/Jul/14?	EP-1 (100um)	
2017/Sep/12?	Heat treatment (800C, 3h)	
2017/Sep/20	EP-2 (20um), HPR	
2017/Sep/21	Assembly, Baking (120C, 48h)	
2017/Sep/28?	VT1	$E_{acc} = 36 \text{ MV/m}$
2017/Nov/7	N-infusion at J-PARC	800C,3h + 120C, 48h with N
2017/Nov/15?	HPR, Assembly	
2017/Nov/22	VT2	$E_{acc} = 38 \text{ MV/m}$, First success of N-infusion
2018/Jan/23	VT3 with mag. field	Cavity had been kept vacuum after VT1
	Heat treatment (800C, 3h)	Test of KEK new furnace
2018/May/31	VT4	HFQS > 25MV/m, $E_{acc} = 32 \text{ MV/m}$
2018/Jul/23	EP-2 (20um), HPR	
	Assembly, Baking (75C,4h+120C,48h) at KEK	
	Send to FNAL	
2018/Aug/14	VT5 at FNAL	New baking, $E_{acc} = 27 \text{ MV/m}$

History of KEK-4(R-8c)

2018/Aug/20	Disassembly and send to ANL	
2018/Aug/21	HPR at ANL	
2018/Aug/22	Assembly at ANL	
2018/Aug/23	Send to FNAL and preparation	
2018/Aug/24	VT6	Eacc = 25 MV/m

History of R-9b

R-9b cavity: TESLA-type single cell made by Mirapro, from TD FG sheet.

- ❑ Standard treatment (EP 100um + 850C, 3h Anneal + 20um EP + Assembly + Baking 120C, 48h)
- ❑ VT1(2017/10): Reference VT, $E_{acc}=36$ MV/m
- ❑ N-infusion@J-PARC(success); 800C, 3h+120C, 48h w/ 3.3Pa N₂
- ❑ VT2(2018/2): $E_{acc}=35$ MV/m
- ❑ Additional baking (without disassembly), 120C, 19h
- ❑ VT3(2018/2): $E_{acc}=38$ MV/m
- ❑ N-infusion@J-PARC(fail); 800C, 3h+120C, 48h w/ 3.3Pa N₂
- ❑ VT4(2018/5): $E_{acc}=30$ MV/m ← Due to degradation of Q??
- ❑ Refresh EP 20um(2018/6), N-infusion@KEK furnace(2018/6/12)
- ❑ VT5(2018/7): $E_{acc}=26$ MV/m
- ❑ Refresh EP 20um(2018/8), **Assembly + Baking 75C, 4h + 120C, 48h**
- ❑ VT6(2018/9): **$E_{acc} = 25$ MV/m**