

N-infusion study at J-PARC and KEK new furnace

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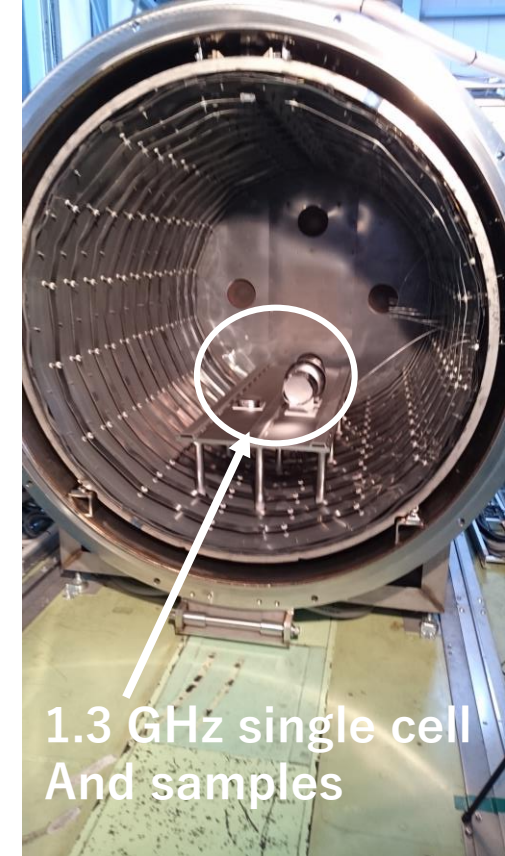
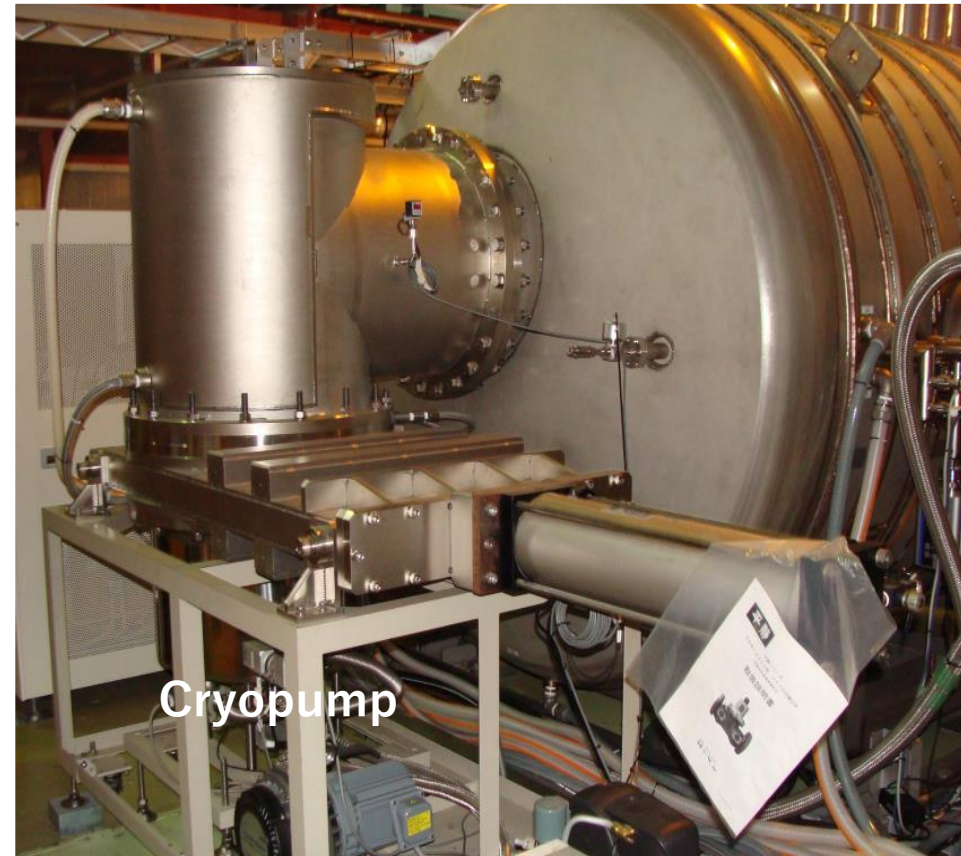
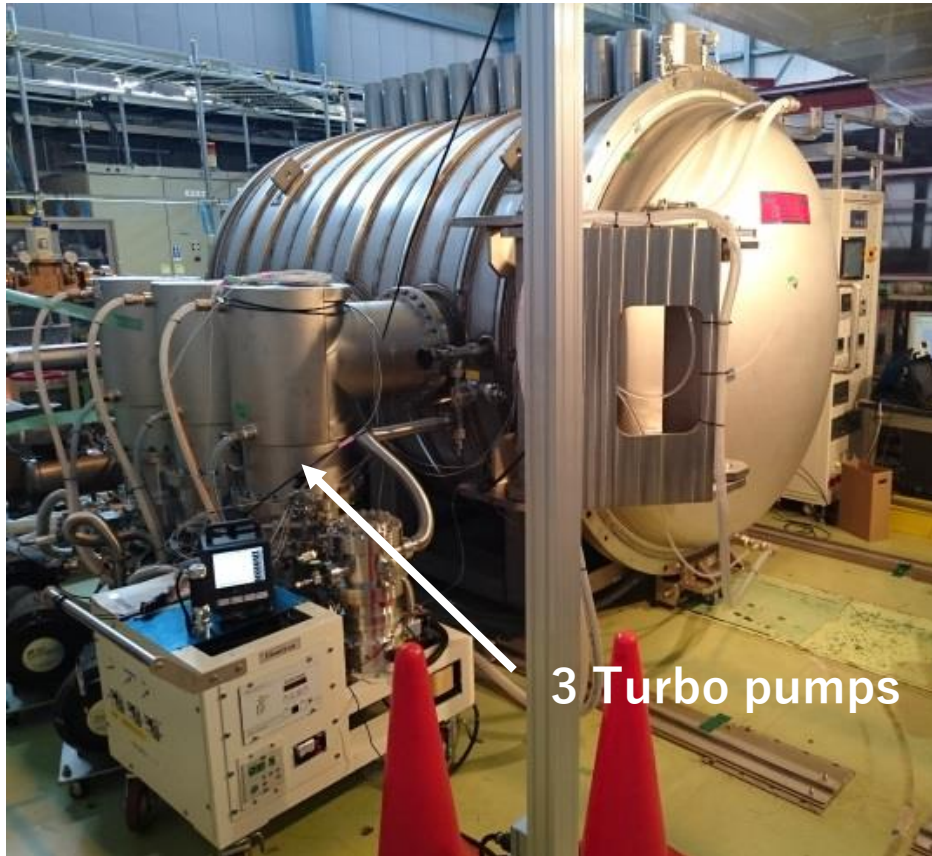
Outline

- **N-infusion at J-PARC furnace**
- **N-infusion results at J-PARC furnace**
 - **Successful results**
 - **Failed results**
 - **Results for LG and FG cavities**
- **KEK new furnace**
- **First N-infusion tryal at KEK furnace**
- **Summary**

J-PARC Furnace

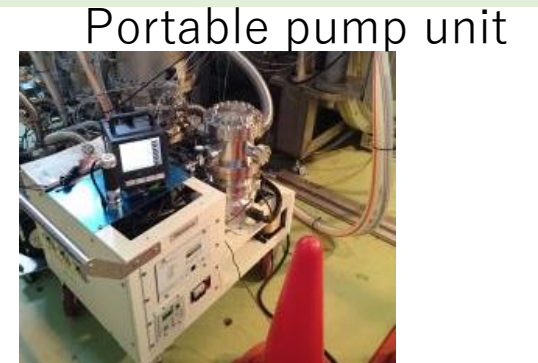
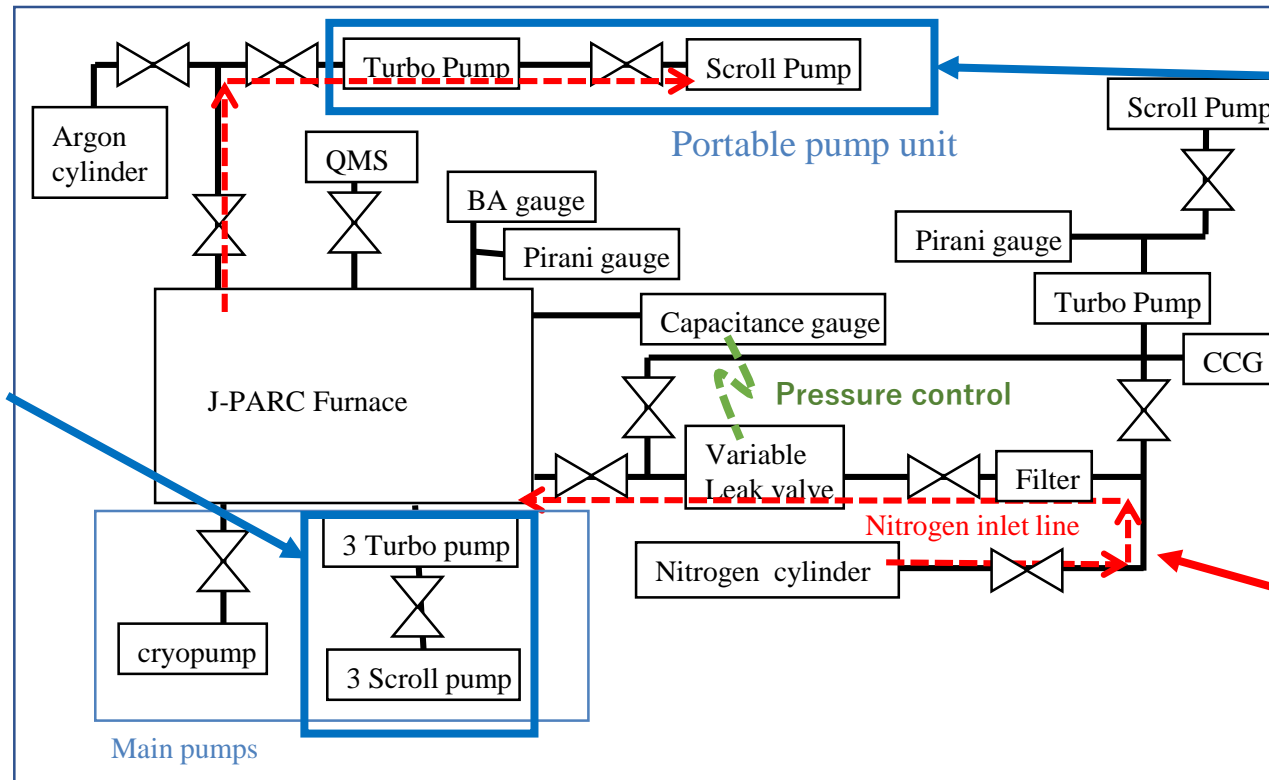
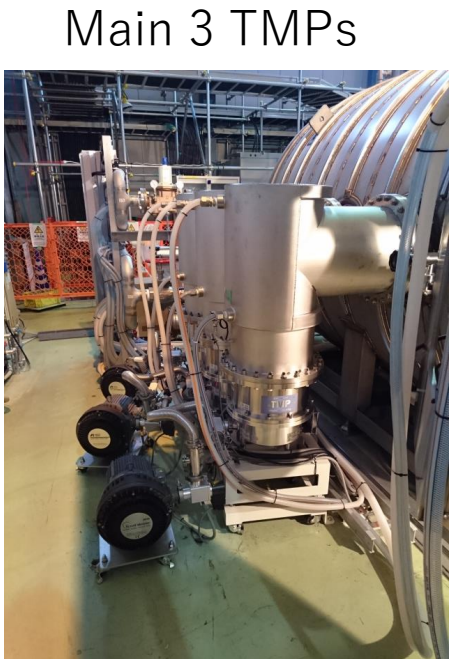
Clean furnace & clean procedure is essential

- Oil-free vacuum pump system.
 - Turbo pump 3units: SIMADZU TMP3202M (3000L/sec x3)
 - + Scroll pump 3units: ANEST IWATA ISP500 (500L/min x3)
 - Cryopump 1unit: ANELVA CAP220 (10000L/sec)
- J-PARC furnace has been used for SUS and Ti chambers degassing.
- Small samples for surface analysis were set beside with cavity.



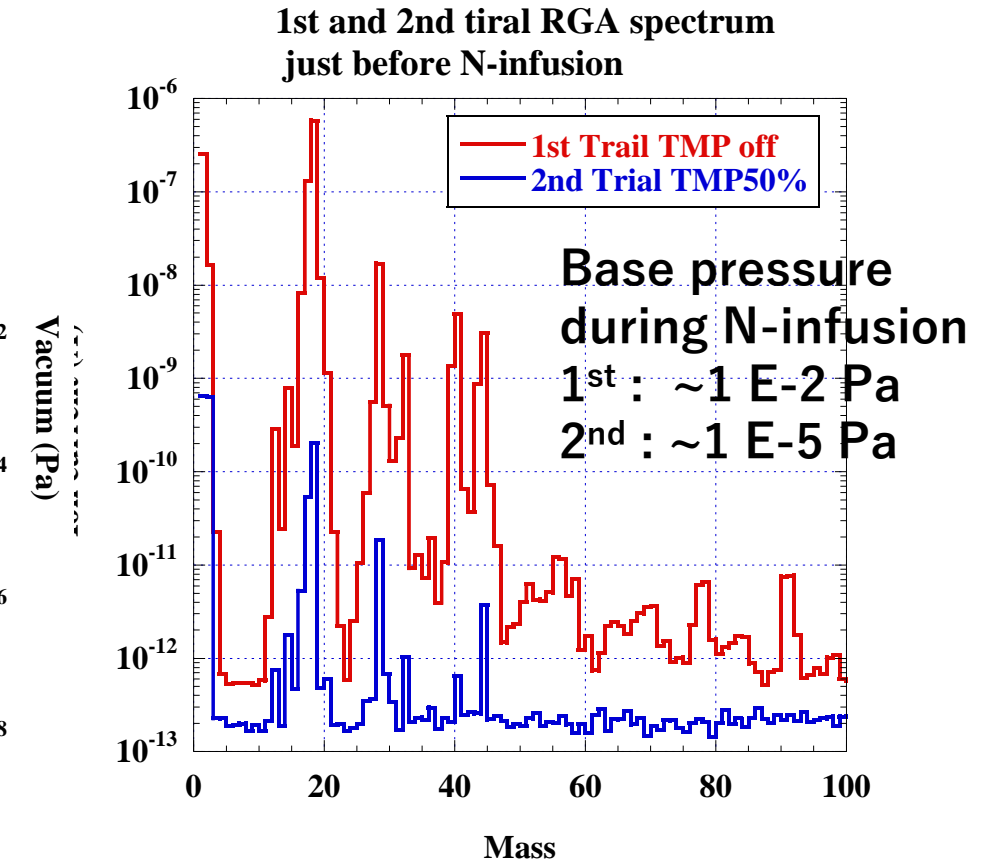
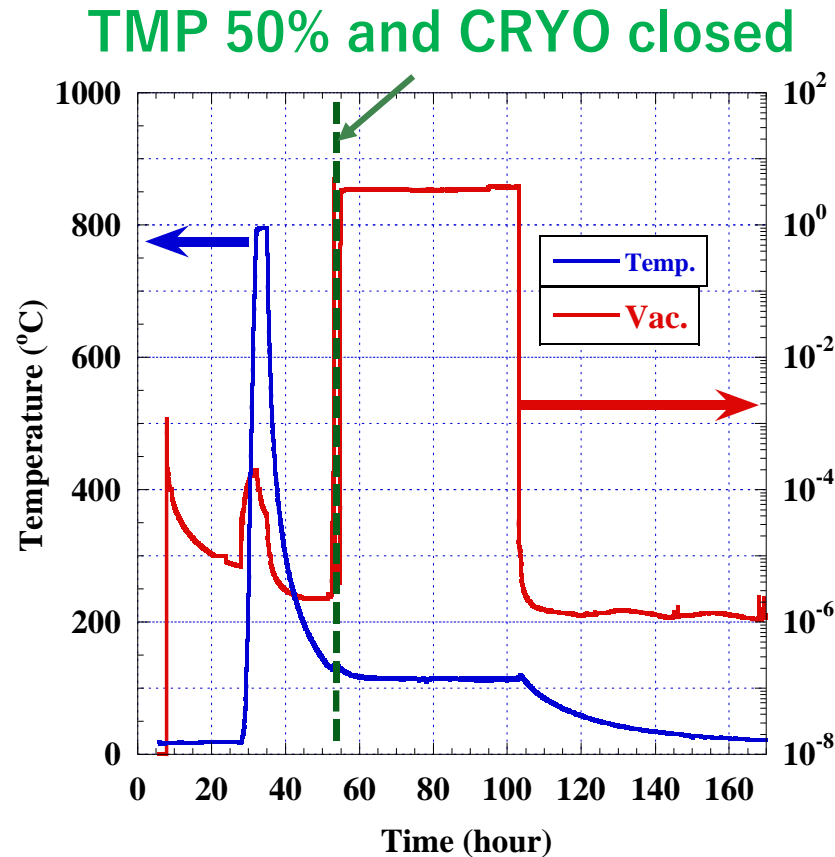
N-infusion system

- A nitrogen introduction line was added for nitrogen infusion.
- Pumping system during nitrogen infusion.
 - First, **portable pump** was used. → Poor background pressure
 - Later, three **TMPs** of the main pumps were used **with reduced speed**.
- The chamber pressure during N-infusion was monitored with a capacitance gauge and adjusted with a variable valve controller.



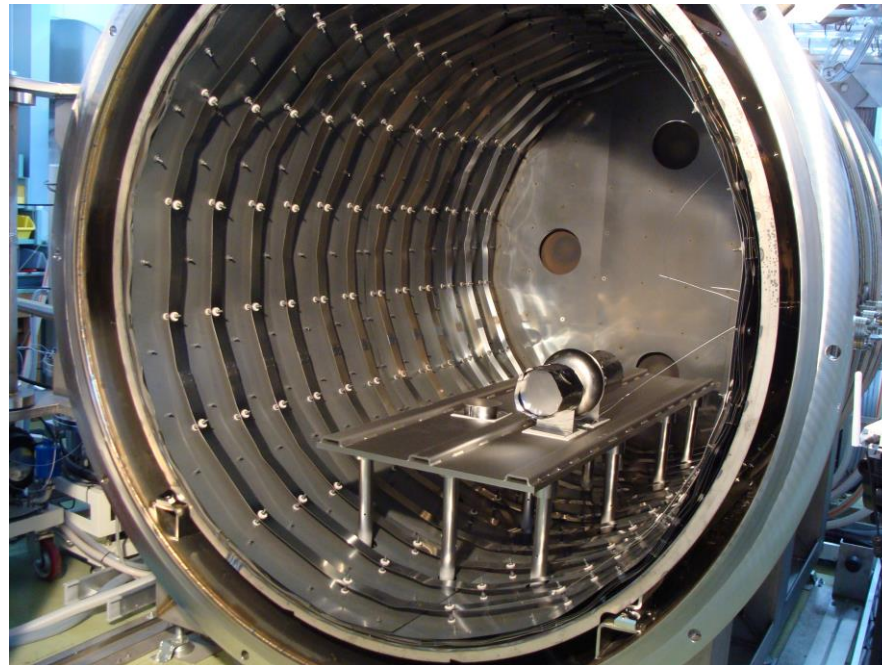
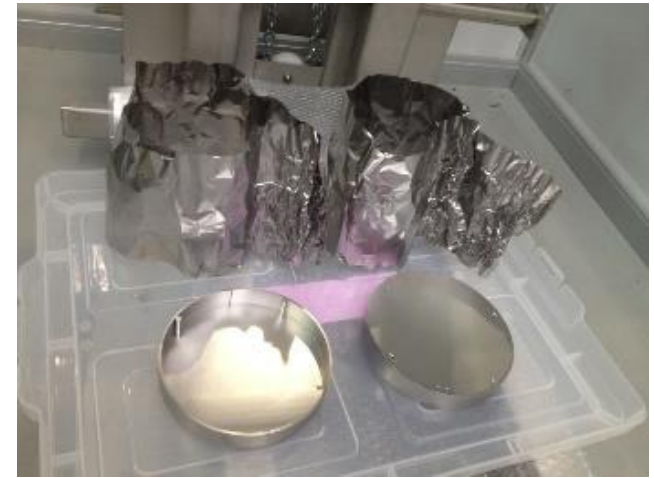
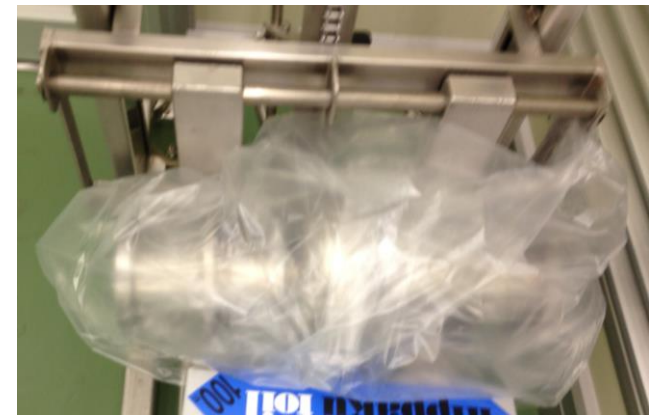
Typical N-infusion procedure

- Typical N-infusion parameters:
 - 800C, 8h + 120C, 48h (once tried 160C)
 - 3.3 Pa (~25mTorr) Nitrogen during 120 C
- From 2nd Trial, we used main 3 TMPs during N-infusion.



Cavity preparation for heat treatment

- HPR (flange open) 1.5 hours, drying one night
- Cavity was double-packed inside class-1000
- **Nb cap & foil** was cleaned by CP and ultrasonic cleaned with degreasing, drying inside class-10, packed inside class-1000
- Transport to J-PARC
- Setup into J-PARC furnace



History of N-infusion at J-PARC

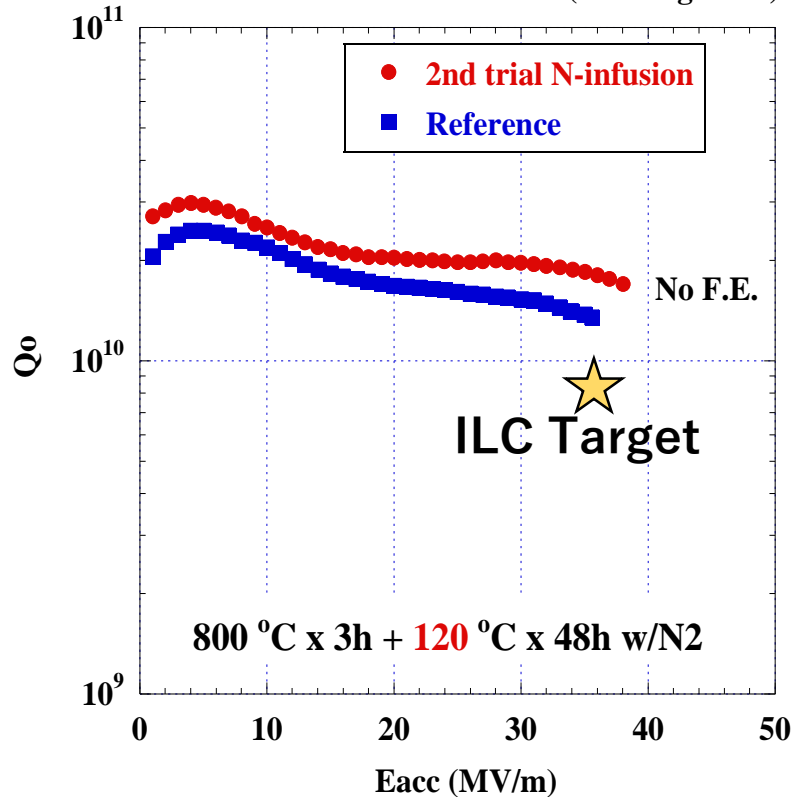
- After 1st N-infusion was failed, pumping unit during N-injection was improved.
- 6 times N-infusion was tried at J-PARC furnace to total of 8 cavities.

#	Month	Result	# of Cells	Series	Treatment	N2 pumping unit	Cavity material
0	2017.3	Success	Single	R-6	800C Anneal		FG (TD)
1	2017.4	Fail	Single	R-2	N-Infusion(800x3h+120x48h)	Portable pump unit	FG(TD)
1'	2017.6	Fail	Single	R-2	N-Infusion(800x3h+120x48h) w/o N2	Portable pump unit	FG(TD)
2	2017.1 1	Success	Single	R-8c	N-Infusion(800x3h+120x48h)	TMP50%	FG(TD)
First successful case! Q value and gradient were improved.							
3	2018.1	Success	Single	R-9b	N-Infusion(800x3h+125x48h)	TMP50%	FG(TD)
Q value was improved. Q value at high gradient was degraded by Field Emission.							
4	2018.2	Fail	Single	R-2	N-Infusion(800x3h+160x48h)	TMP50%	FG(TD)
5	2018.3	Fail	Single	R-9	N-Infusion(800x3h+120x48h)	TMP50%	FG(TD)
5	2018.3	Success	Three	R-10b			LG(CBMM)
First successful case of LG! Q value was improved. Q value at high gradient was degraded.							
6	2018.4	Fail	Single	R-2	N-Infusion(800x3h+120x48h)	TMP50%	FG(TD)
6	2018.4	Fail	Single	R-9b			FG(TD)

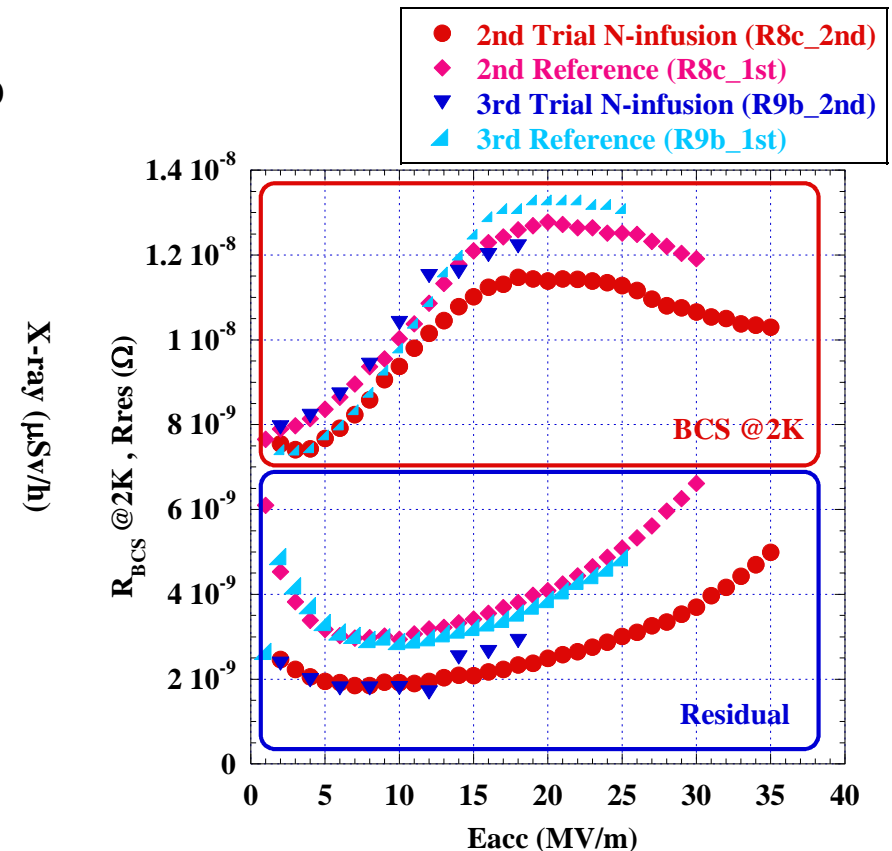
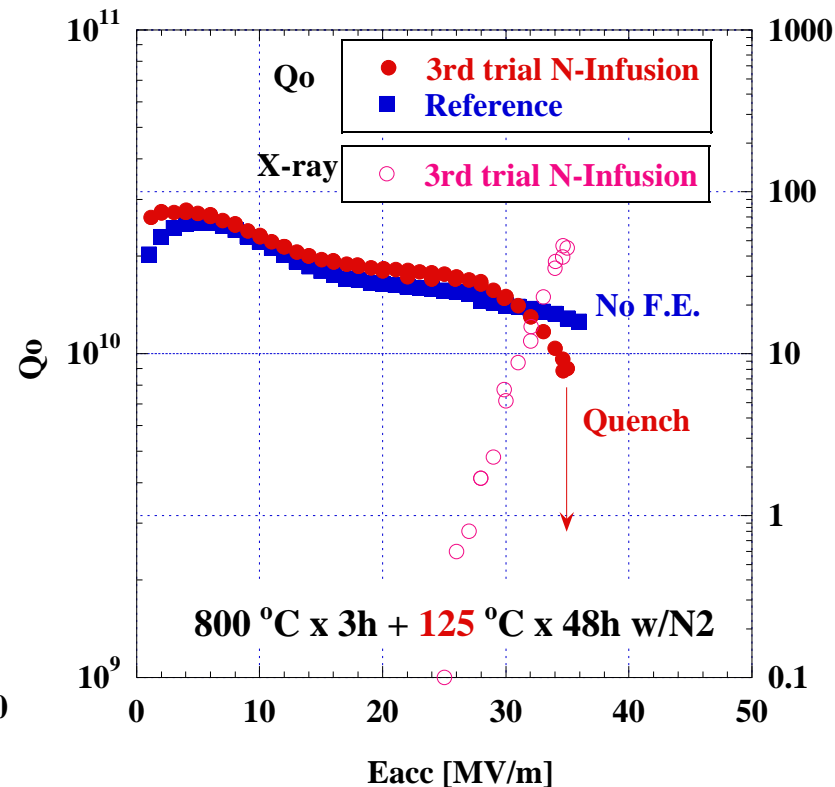
Successful examples of N-infusion

- Both 2nd and 3rd trial N-infusion was succeeded.
- **2nd trial (120 °C N-infusion):** Gradient was improved 5% and Q_0 was improved 30%.
- **3rd trial (125 °C N-infusion):** Unfortunately Q value at high gradient was degraded by field emission.
- Both residual resistance were lowered than reference and BCS resistance of 2nd trial was slightly lower than reference.

2nd Trial N-infusion @J-PARC (R8c single cell)



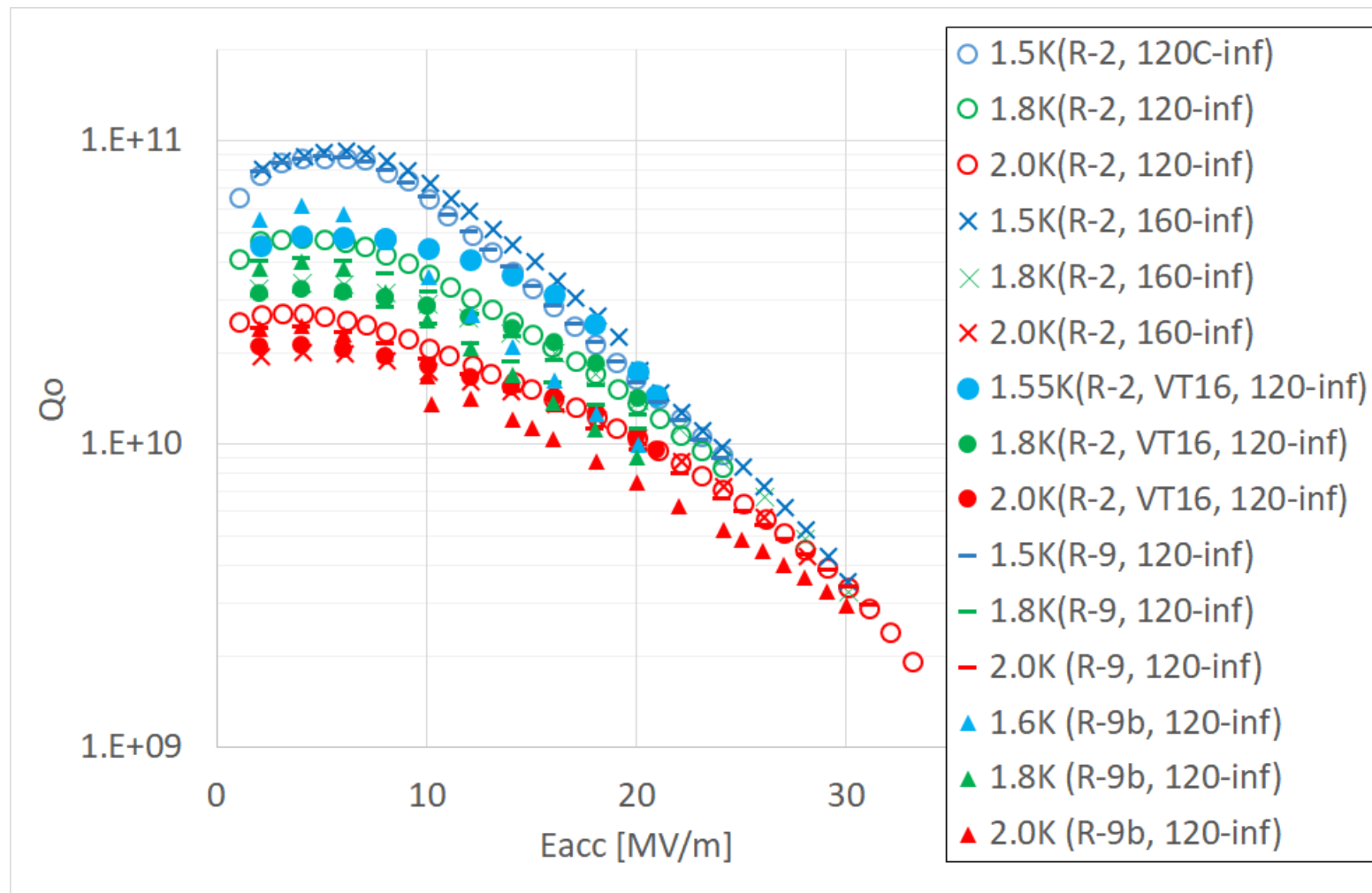
3rd Trial N-infusion @J-PARC (R9b single cell)



Failed example of N-infusion

- Failed 5 cavity tests are shown as right figure.
- Even for different parameters, different cavities, **degraded Q-slope is very well reproduced.**
- Most probably, **contamination(carbon?) caused by the furnace.**

Q-E curves for failed 5 cavities



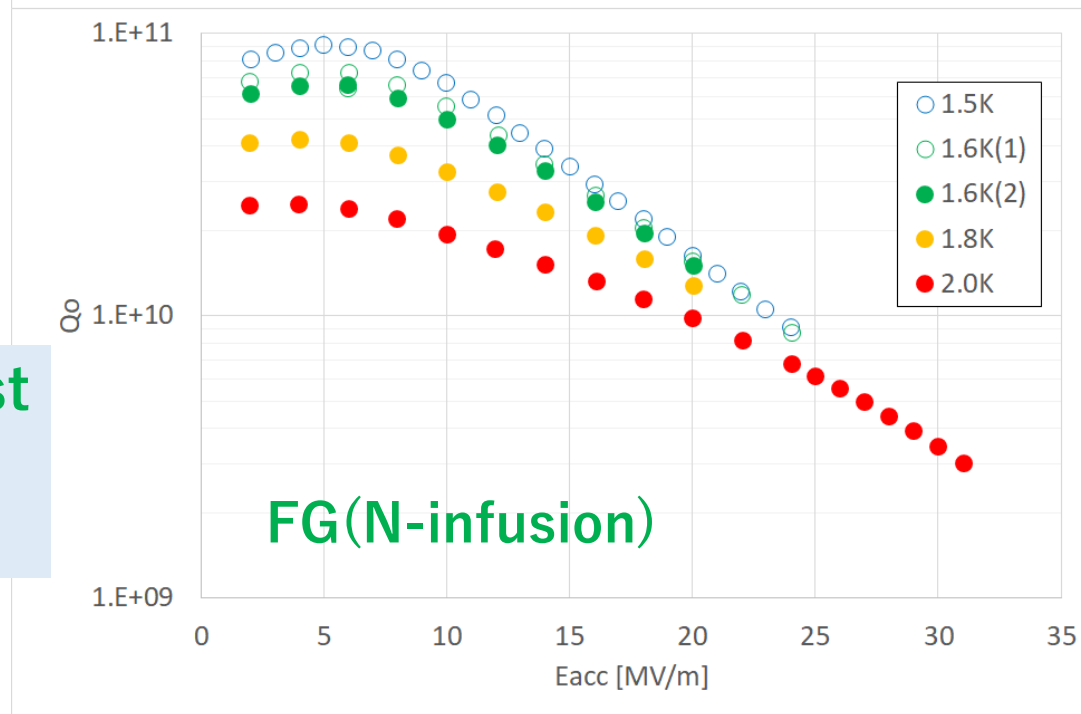
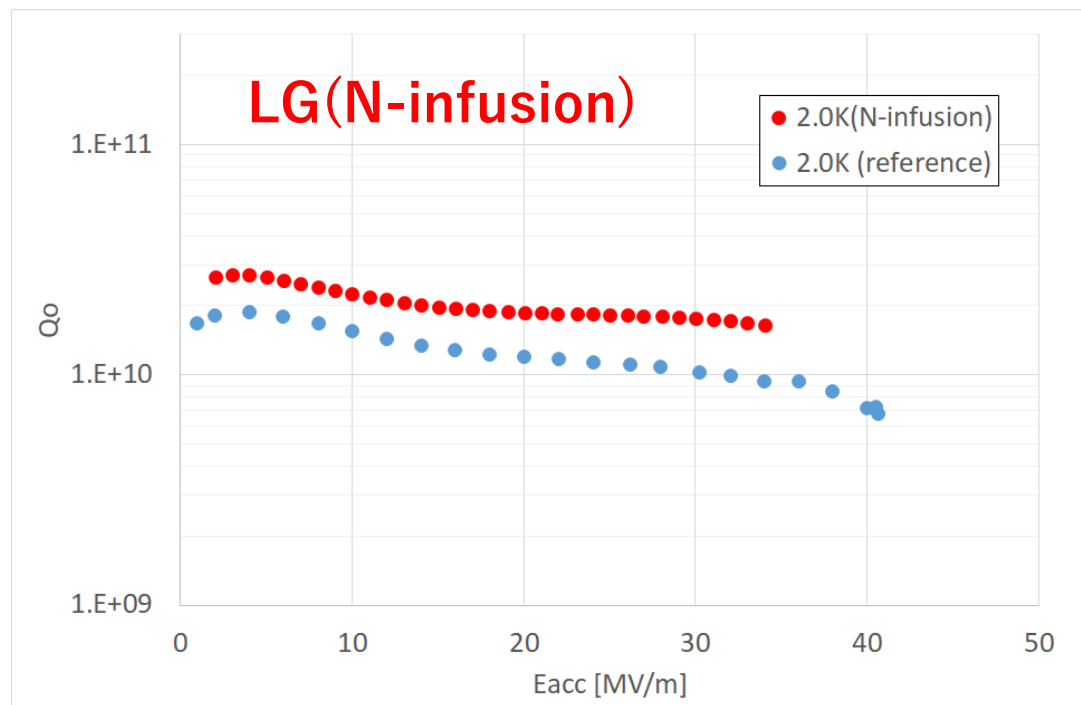
Why always very similar degradation curve?

N-infusion applied to LG cavity

- N-infusion was applied to LG 3-cell and FG single-cell cavities, at the same time.
- N-infusion for **LG** was **successful**.
- N-infusion for **FG** was **failed with degradation**.



LG is strong against contamination??
Other reasons??



KEK new furnace

Requirement for furnace

What is “clean furnace”?

⇒ **Excellent reachable vacuum pressure**

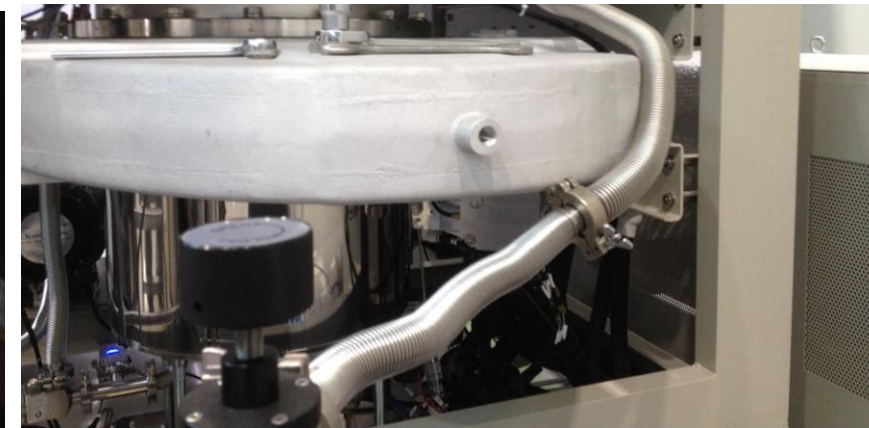
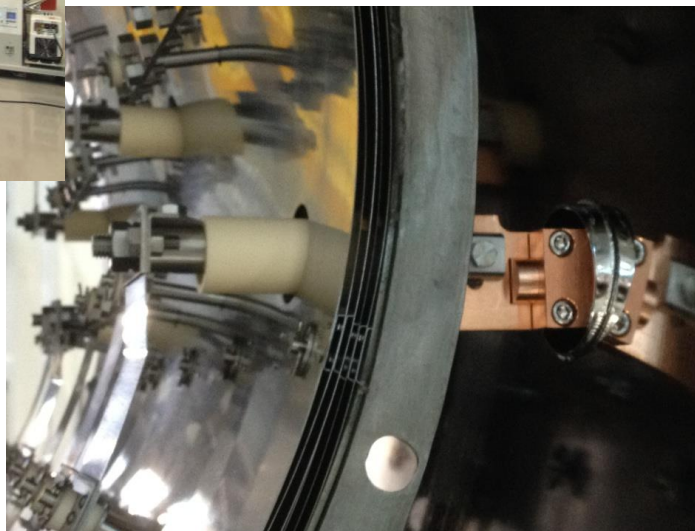
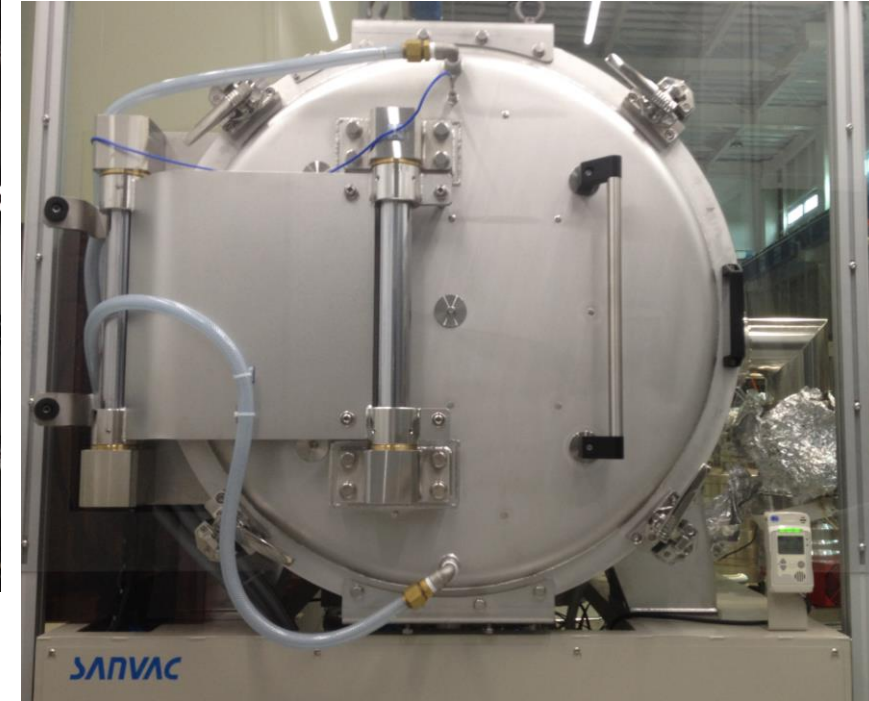
Cryopump, oil-free pumping system, TMP for N-injection

⇒ **Less contamination, especially from Carbon**

Mo is used for high temp., prepare clean booth

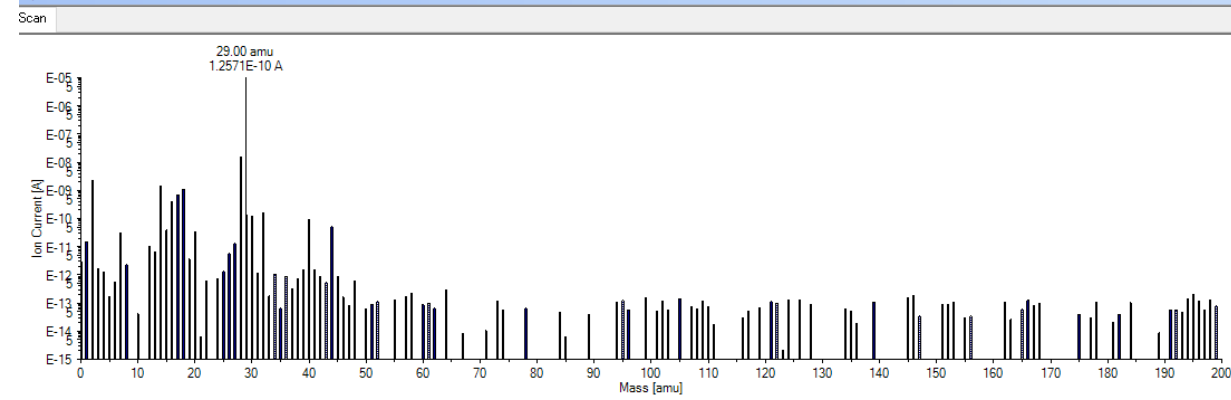
Parameters	Design value
Inner size of chamber	Φ 950 x 2080mm
Effective heating zone	370 x 370 x 1500 mm
Operation (max.) temperature	~1100 (1150) degrees
Cryopump (CRYO-U-20H)	10000 L/sec (N2)
Heater	Mo
Reflector	6 layers of Mo reflector
Target vacuum pressure	RT: 1e-6 Pa 600 degrees: 1e-5 Pa 1000 degrees: 1e-4 Pa

Construction of new furnace

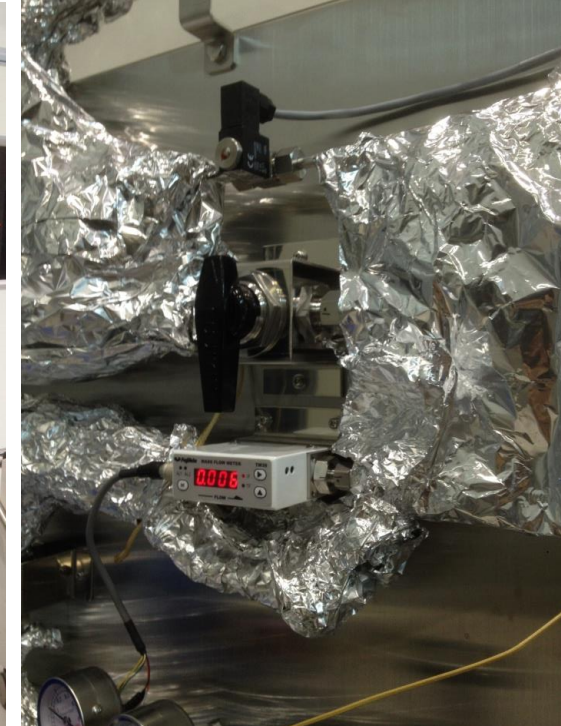


Completed at the end
of last fiscal year

N-injection line

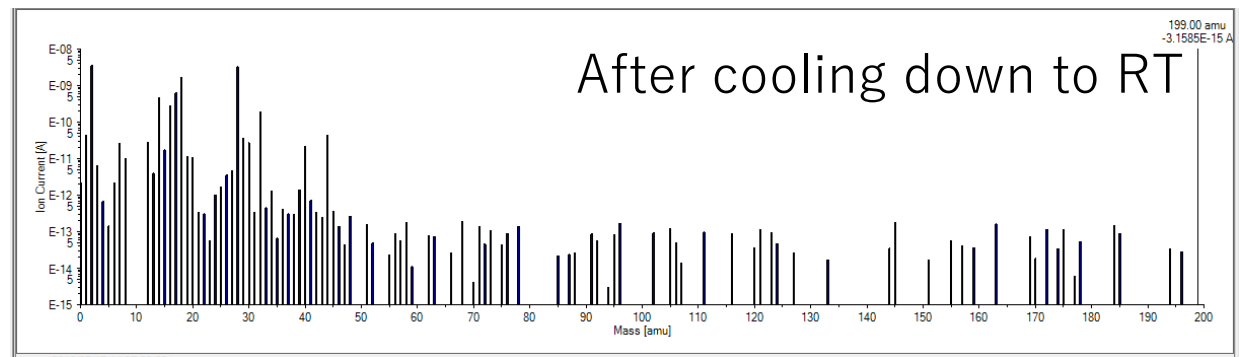
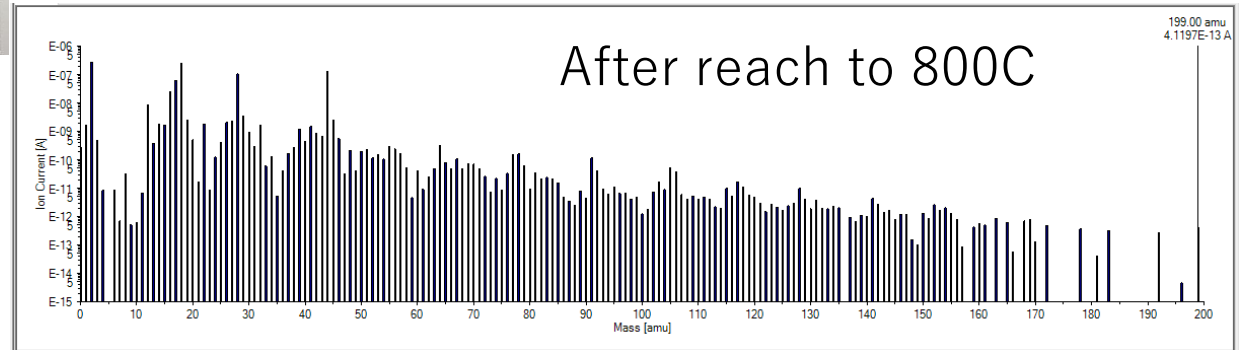
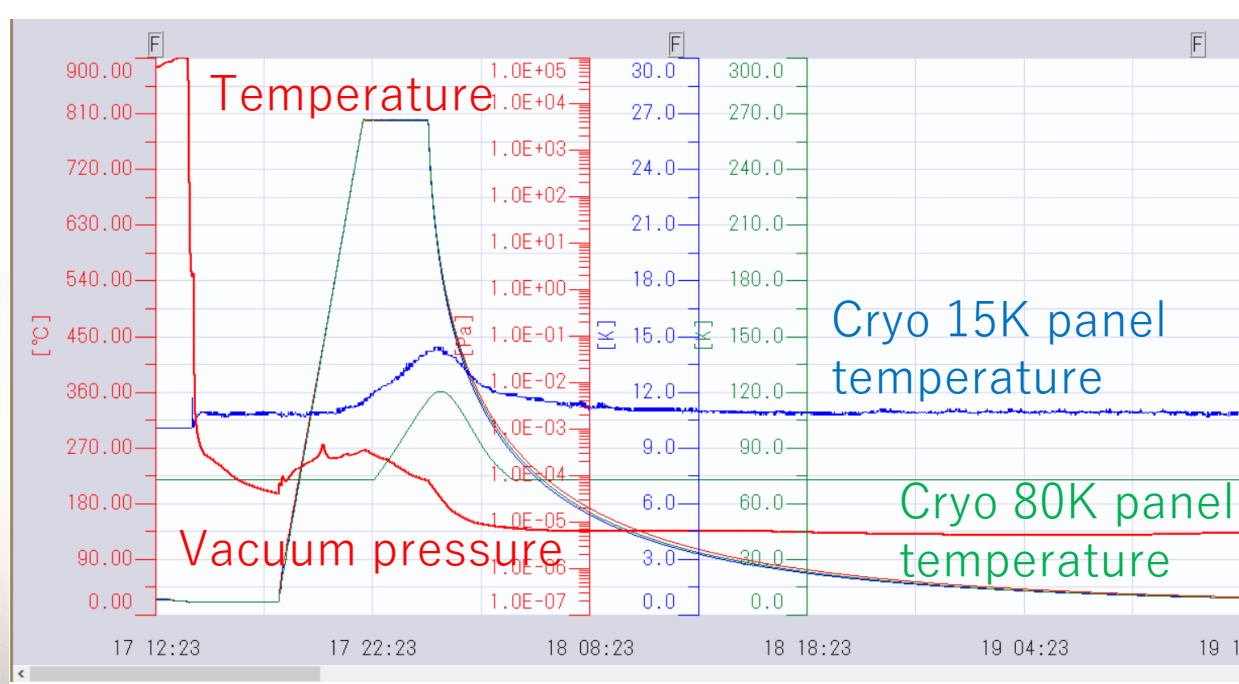
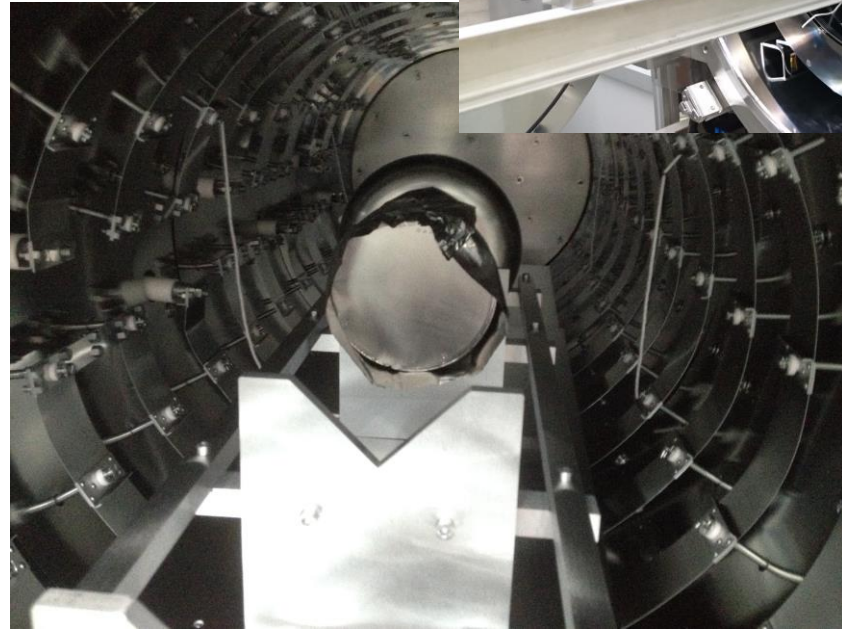
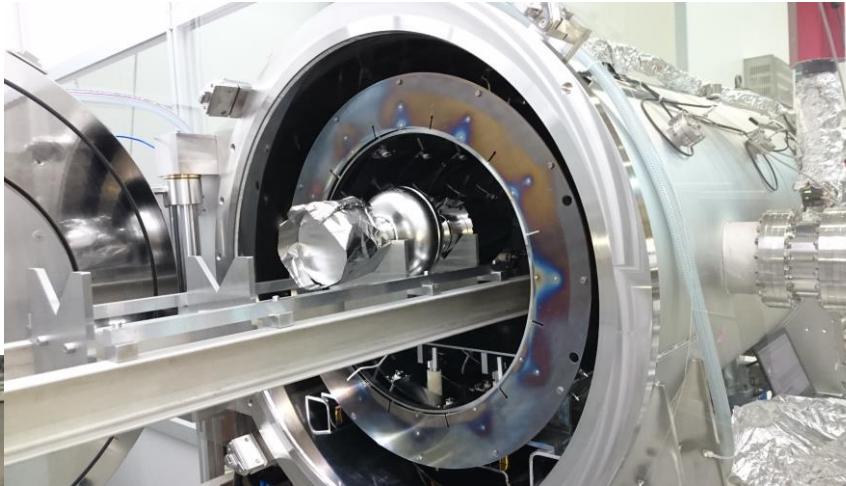


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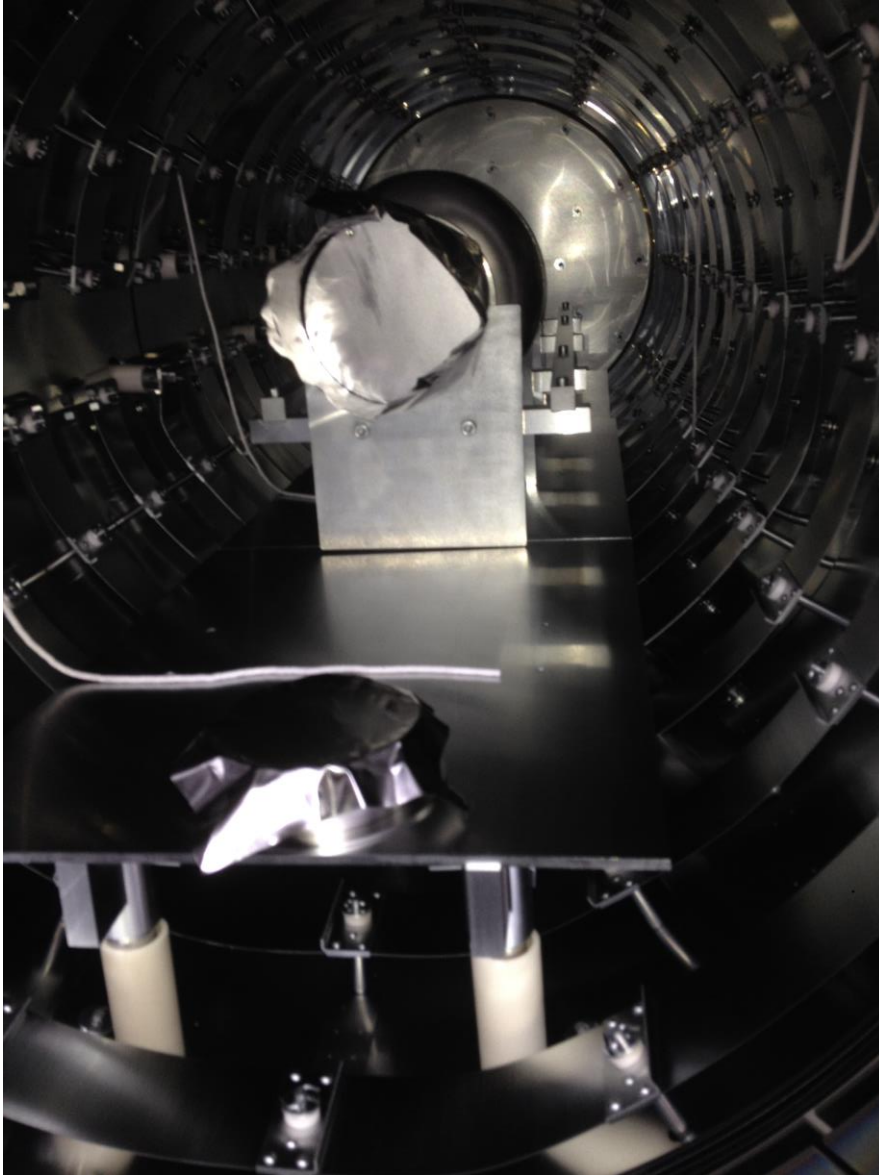
- **TMP(700 litter/sec)** is used during N-injection.
- **2~3e-5 Pa** can be reached.
⇒ Background during N-injection
- **N2 pressure is controlled by mass-flow controller.**
- **~3Pa can be kept** by this N-injection system.

Typical 800C heat treatment t

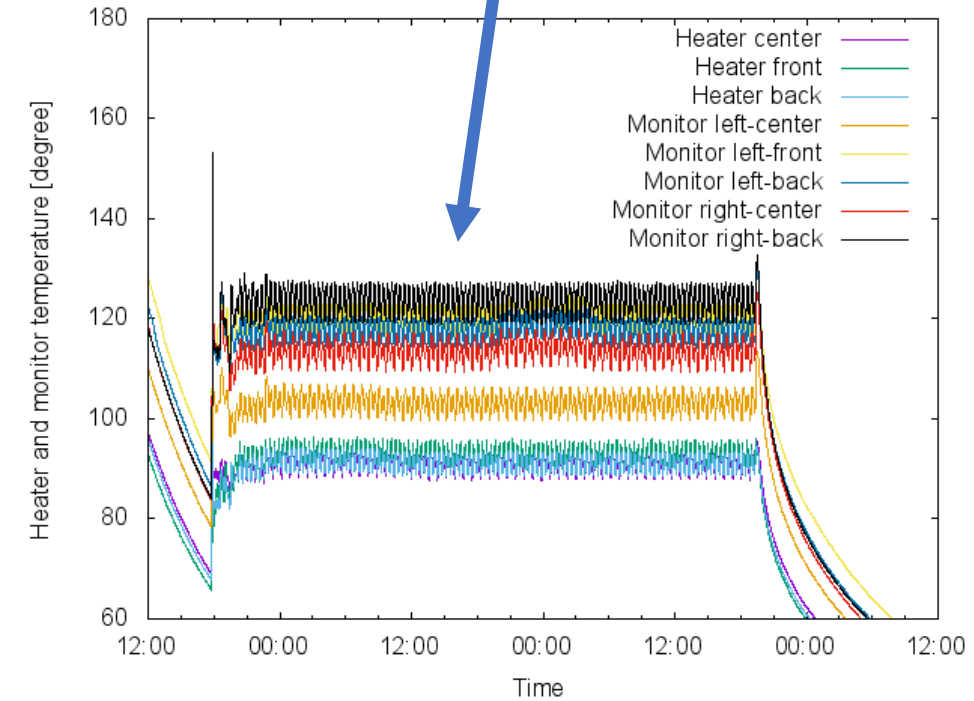
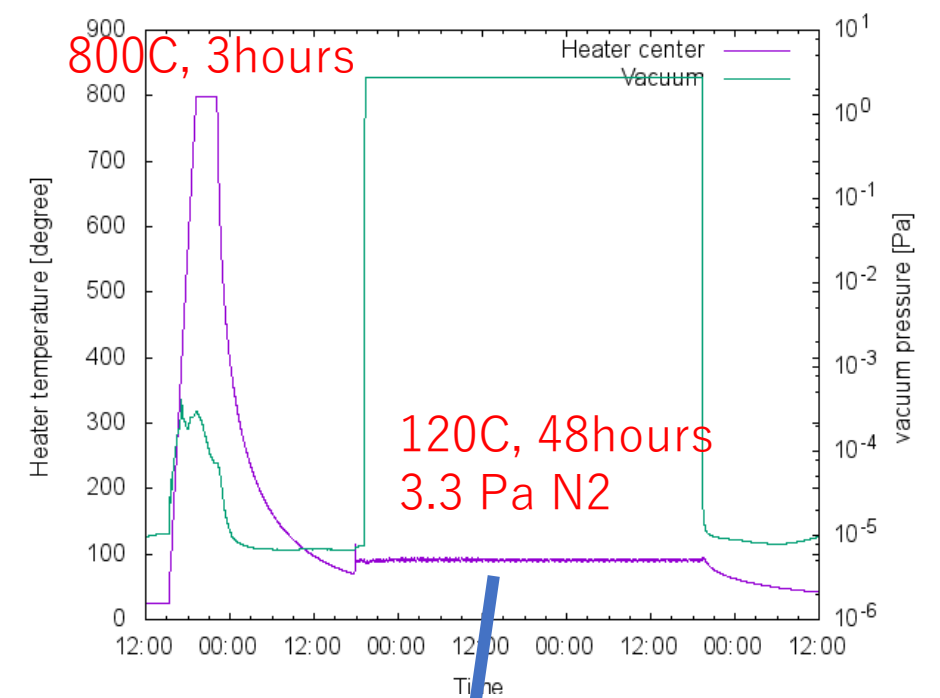


First N-infusion trial at KEK furnace

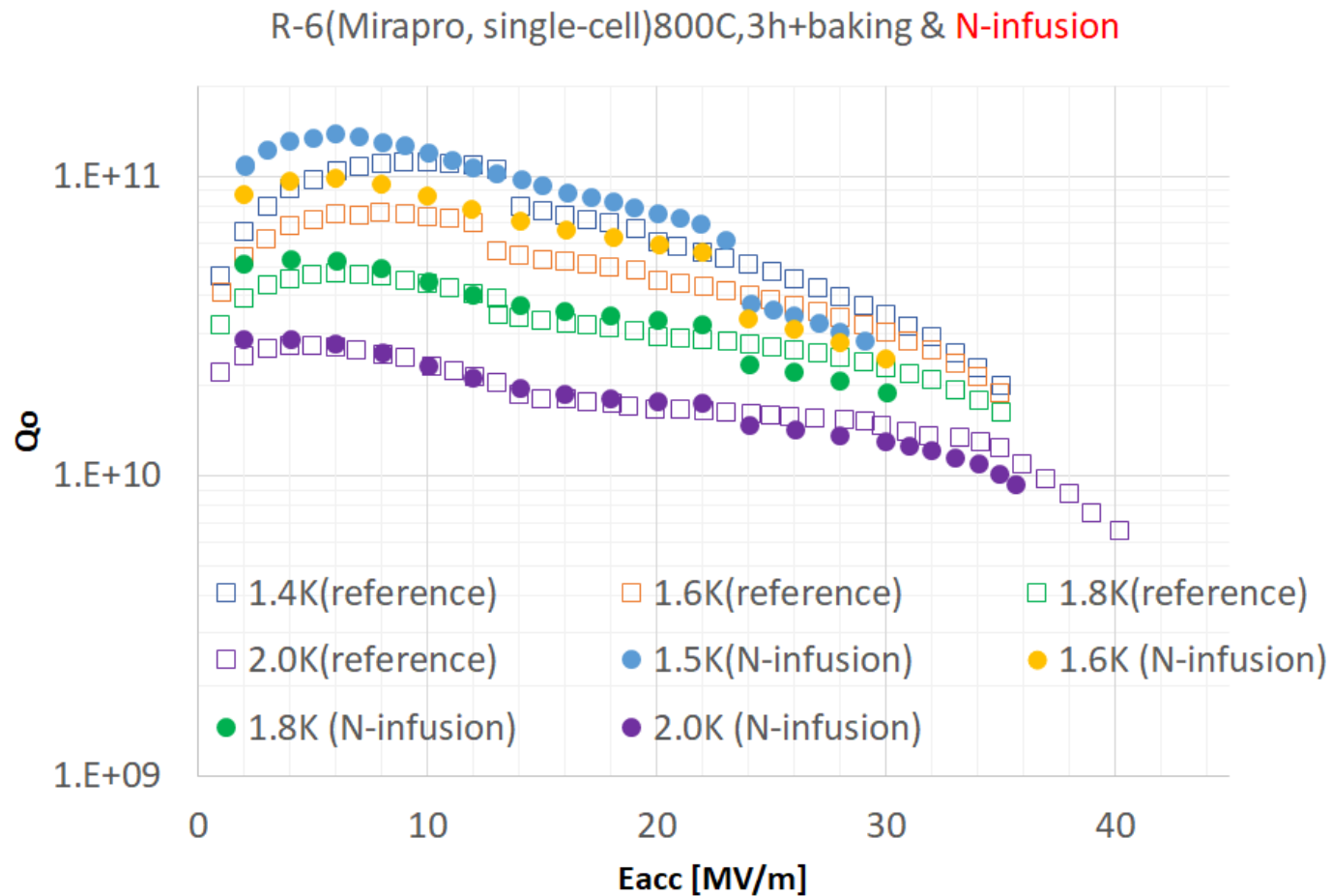
First N-infusion at KEK new furnace



- HPR
- Packing
- Install into furnace
- **N-infusion**
 - **800C, 3h + 120C, 48h with 3.3Pa N2**
- Uninstall from furnace
- Packing
- HPR
- Assembly
- VT



Results of vertical test for first N-infusion at KEK

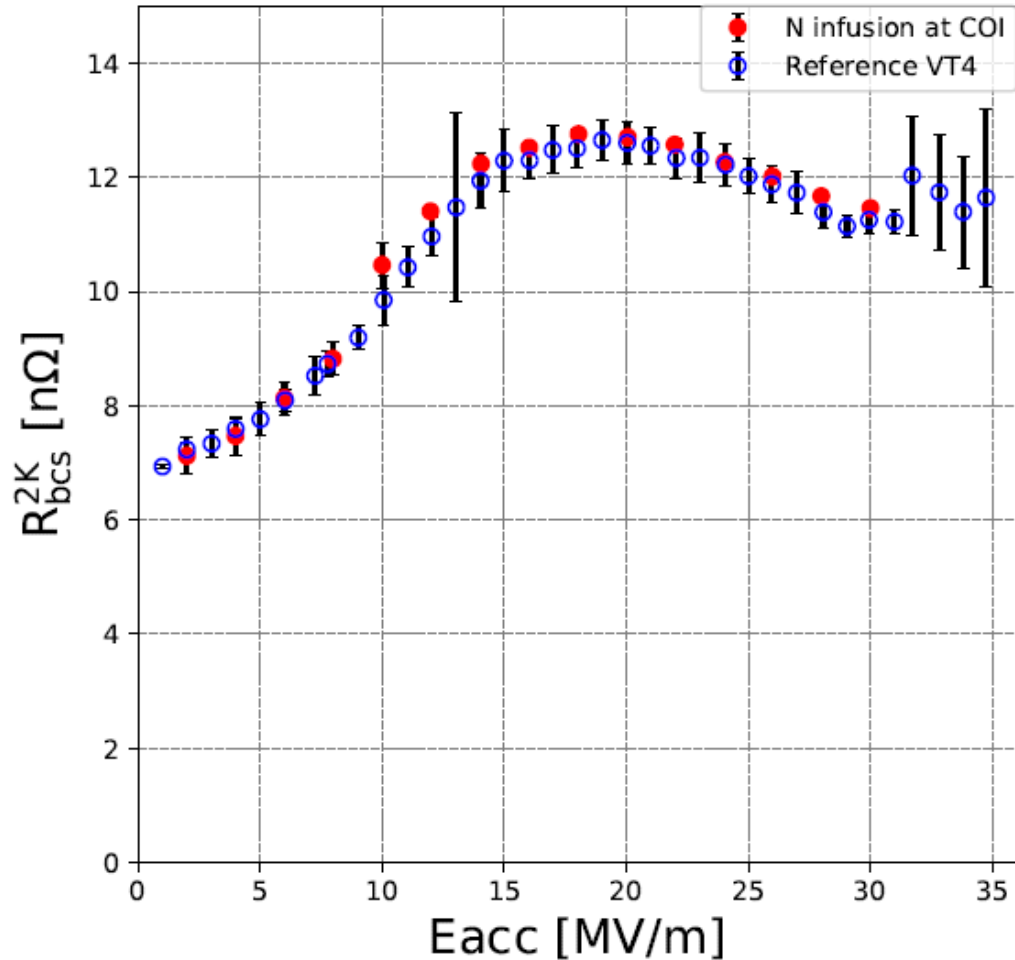


- Slight Q improvement at low field
- Q -values at >10 MV/m are slightly lower?
- Direct comparison is little bit difficult due to Q -gap(due to this cavity's defect).
- **Almost no change at 2.0K(E_{acc} decreased from 40 to 35 MV/m)**

- Cavity performance as N-infused cavity is not so good. However, **at least no clear degradation can be seen.** \Rightarrow Furnace cleanness is O.K.
- Systematic study of N-infusion, including optimum parameter search, will be carried out.

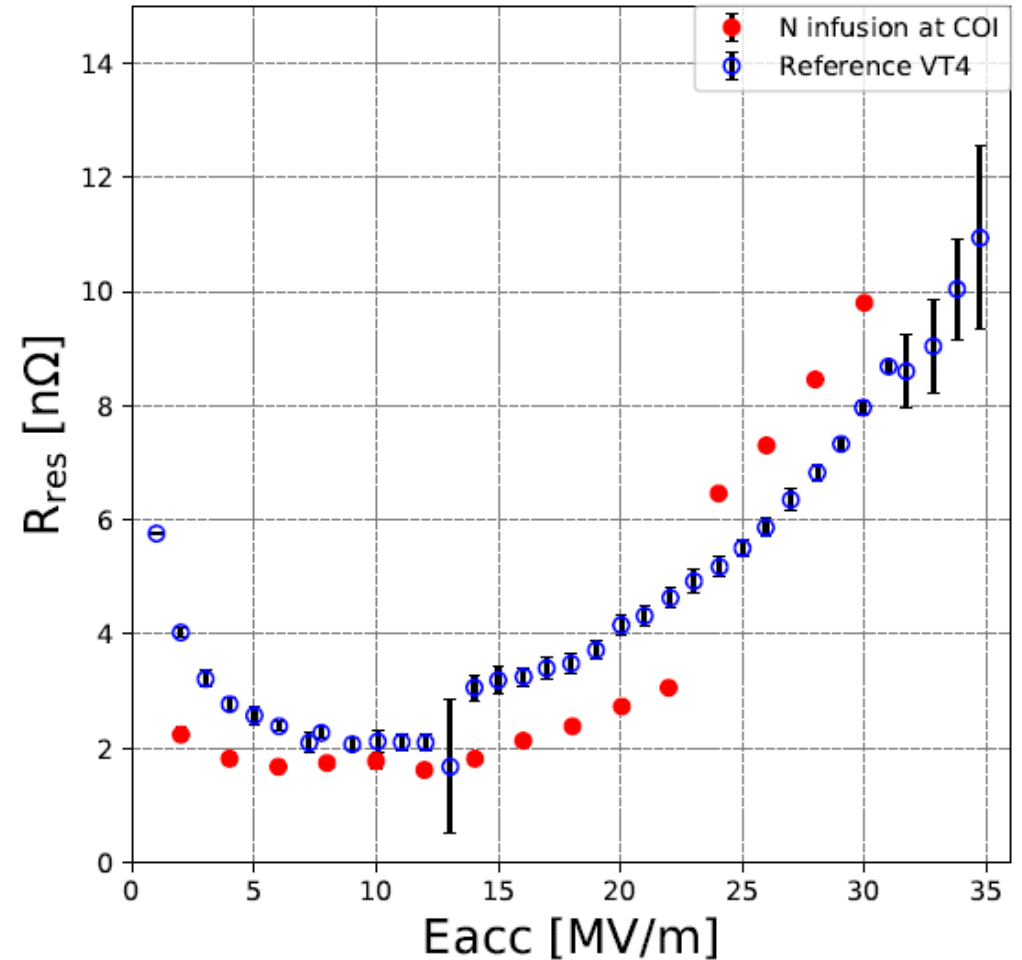
BCS & residual resistance (@2.0K) ---by T. Okada

BCS Resistance at 2 K
R-6 VT7



No change on BCS resistance.

Residual Resistance
R-6 VT7



Residual resistance tend to be lower, at least below Q-gap.

Summary

【N-infusion at J-PARC furnace】

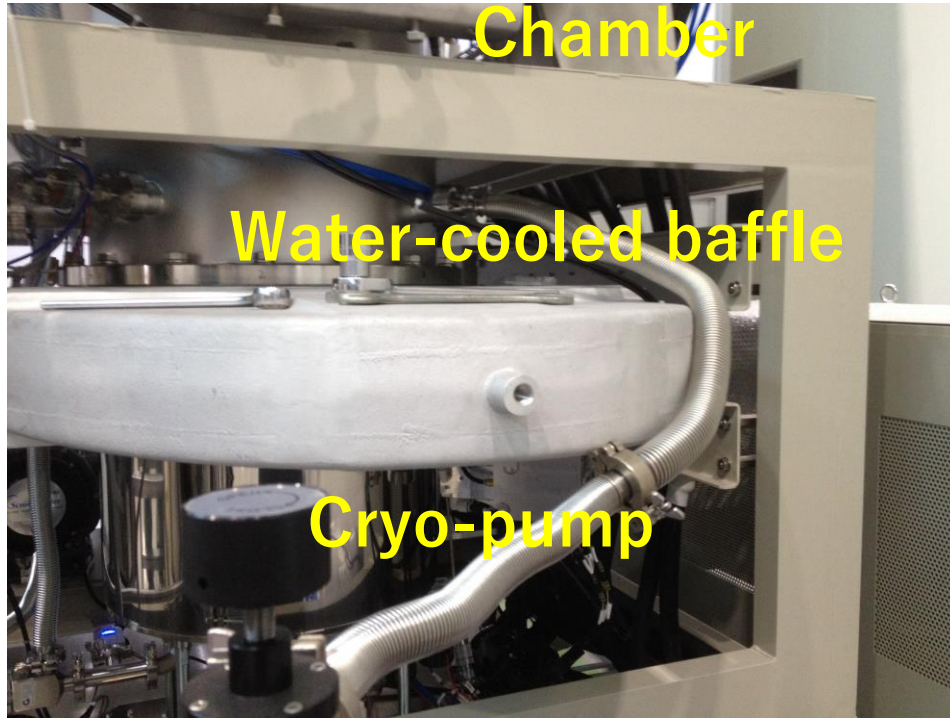
- KEK carried out 6 times N-infusion studies for total of 8 L-band cavities.
- There were some successful results. But not reproducible.
- Q-degradations were observed for some trials.
- LG cavity shows different results compared with FG. (But only 1 results ...)

【KEK-furnace】

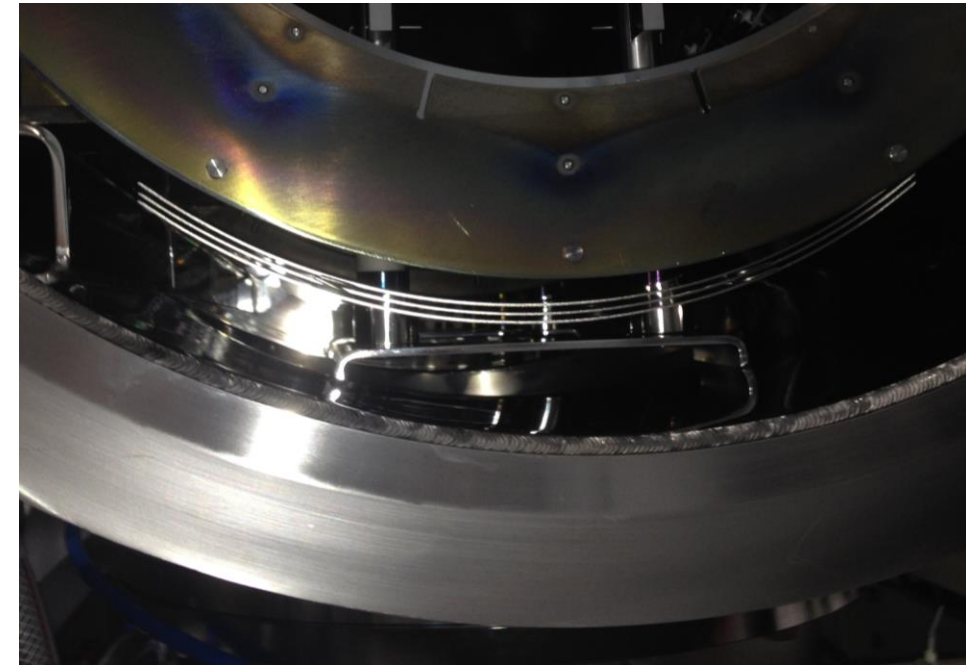
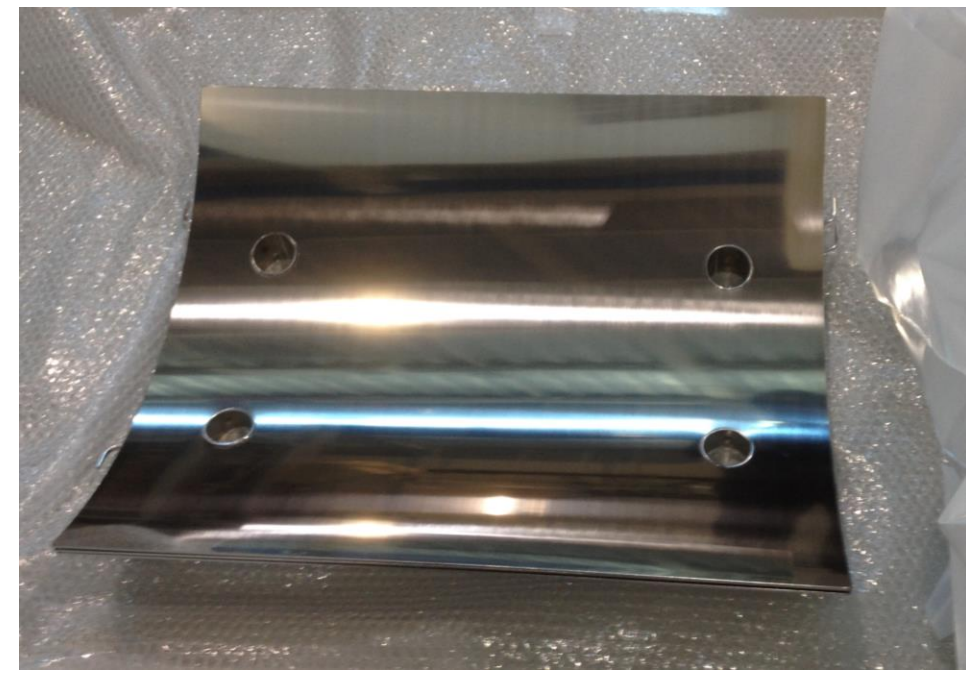
- New clean furnace was constructed at KEK
- Construction and commissioning was finished.
- First N-infusion results was showed. No Q-degradation observed. Cleanness seems to be fine.
- Systematic N-infusion study will be carried out to realize high SRF cavity performance.

Thank you very much
for your attention !

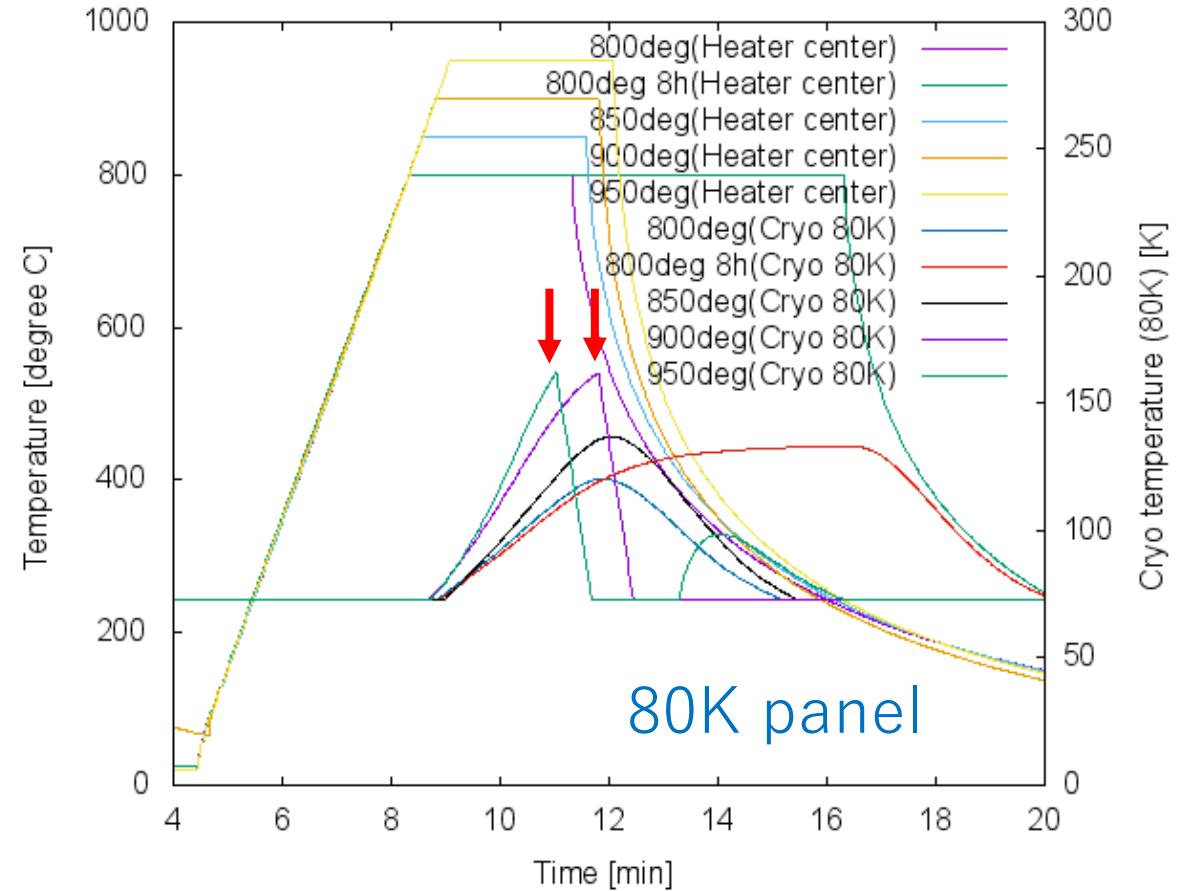
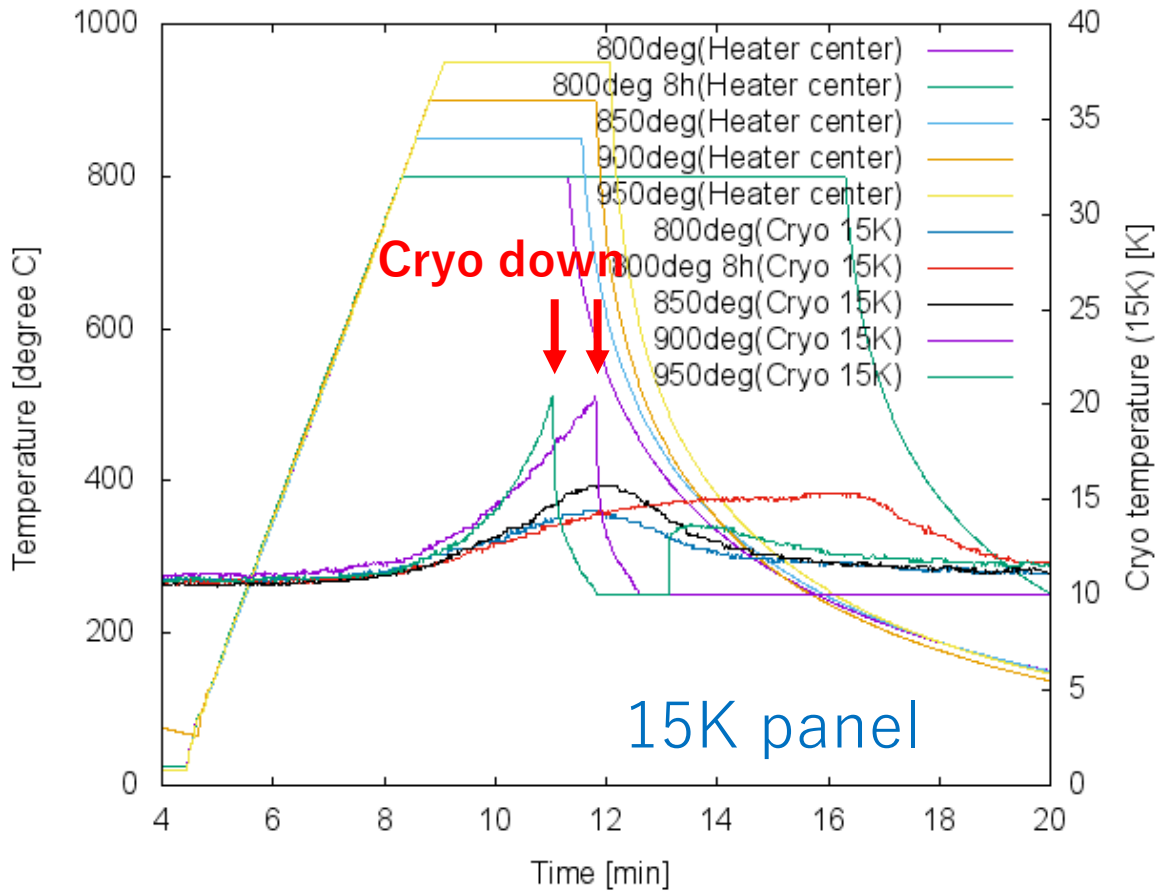
Problem and modification



- Cryo-pump sits just bottom of vacuum chamber.
⇒ save space, material, cost...
 - **Temperature rise of cryo-pump** during heat treatment.
- ↓
- **Added 3 layers of additional local reflector.**
⇒ Now 800C operation is possible.



Temperature on cryopump (15K and 80K panel) ~after adding SUS reflectors~



- 800 degrees & 850 degrees x 3 hours runs were successful.
- However, could not keep > 900 degree.