

# Status of N-infusion R&D at KEK furnace

2019/10/31

LCWS2019@Sendai, Japan

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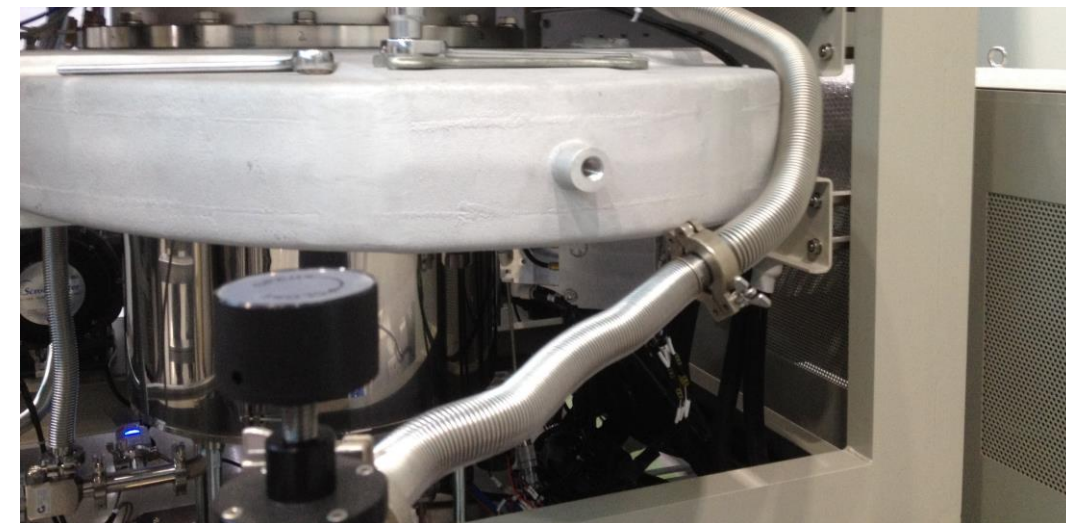
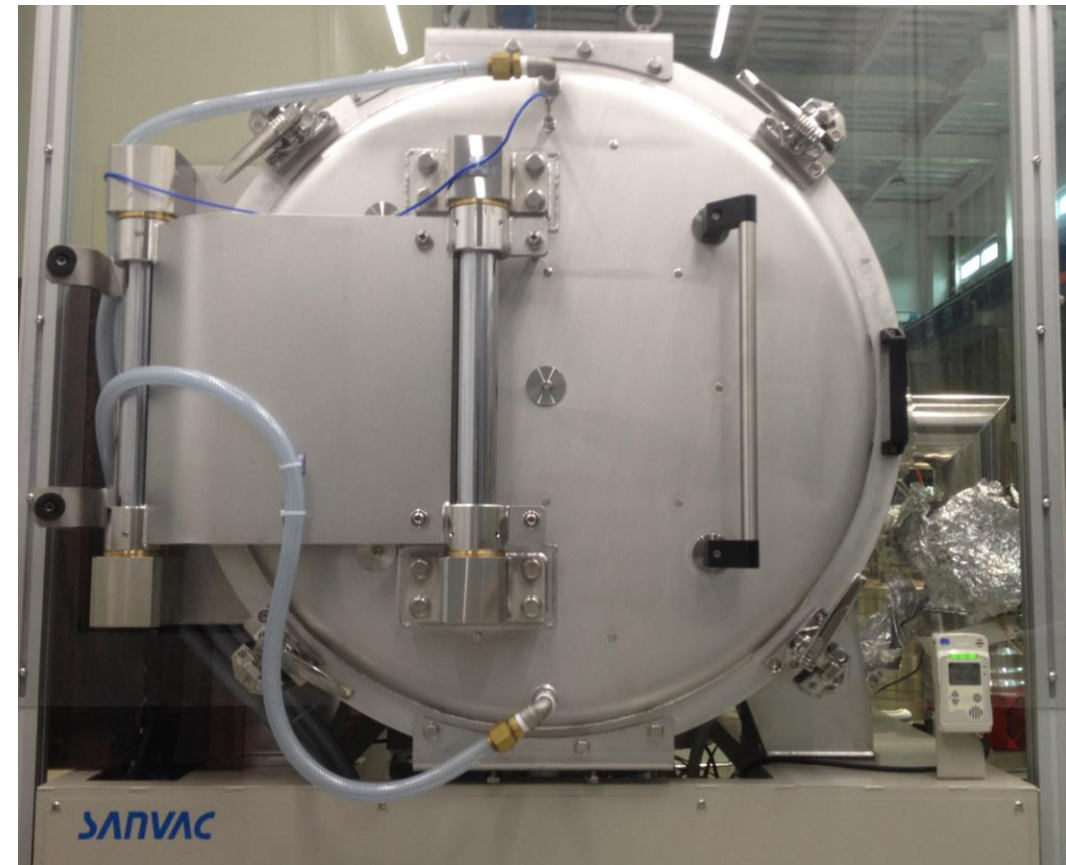
# Outline

- KEK furnace
- N-infusion summary table, carried out at KEK
- Some results of N-infusion.
- N-infusion procedure (800C + 800C + 120C)
- N-infusion results for a 9-cell cavity
- Summary

# Motivation of N-infusion R&D

- **N-infusion** technique was proposed by FNAL, to realize high-Q/high-G performance of SRF cavities.
- For the ILC, high-Q and high-Gradient performance of SRF cavities are beneficial for cost reduction.
  - **High-Gradient** → smaller number of cavities and cryomodules
  - **High-Q** → less cryogenic loss
- KEK has tried to obtain N-infusion technique for three years.

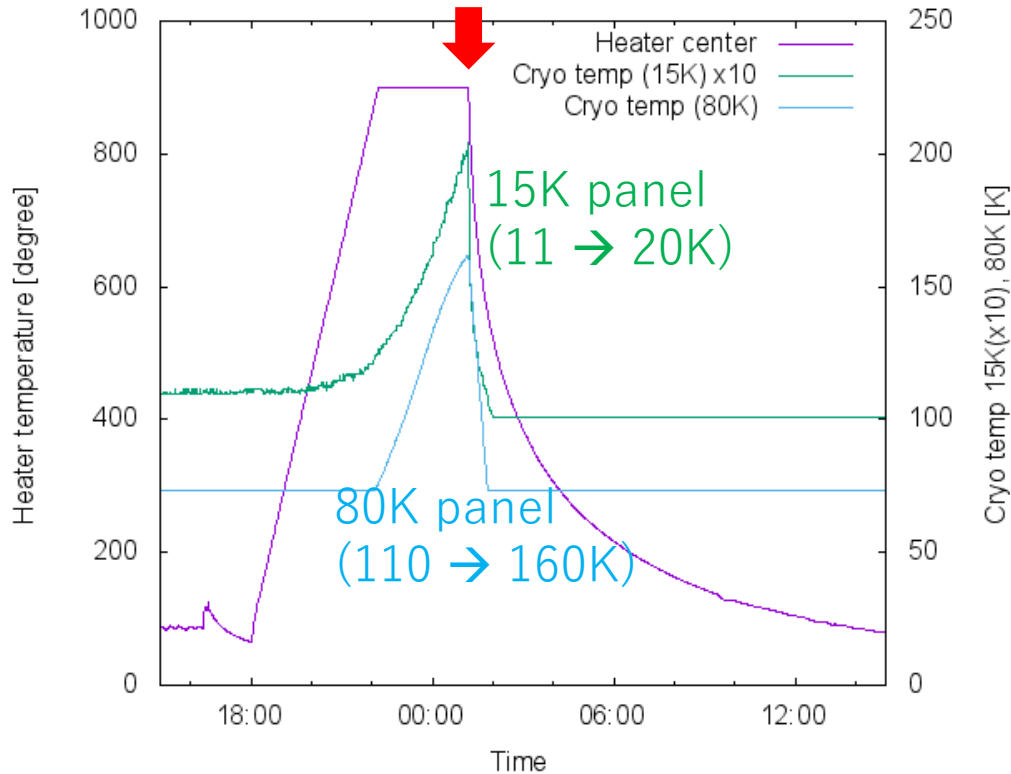
# KEK furnace(located at COI)



- Completed at the end of FY2017
- Cryopump for main pump, oil-free pumping system.
- Molybdenum is used for heater, reflector, table etc.
- TMP is used during N-injection, can reach  $\sim 2\text{e-}5\text{Pa}$ .
- Clean-booth surround entrance door.

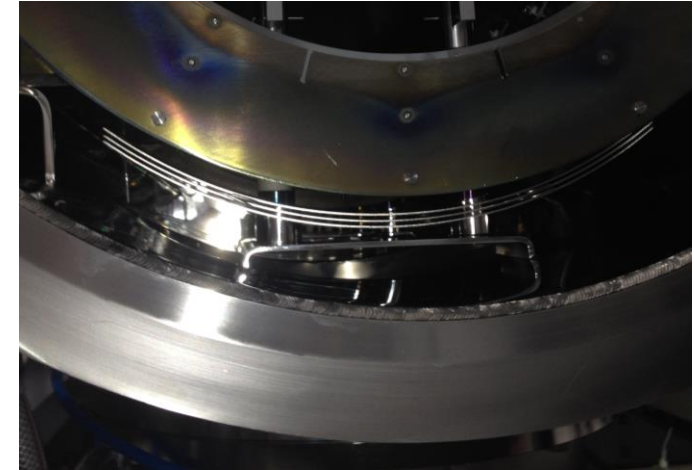
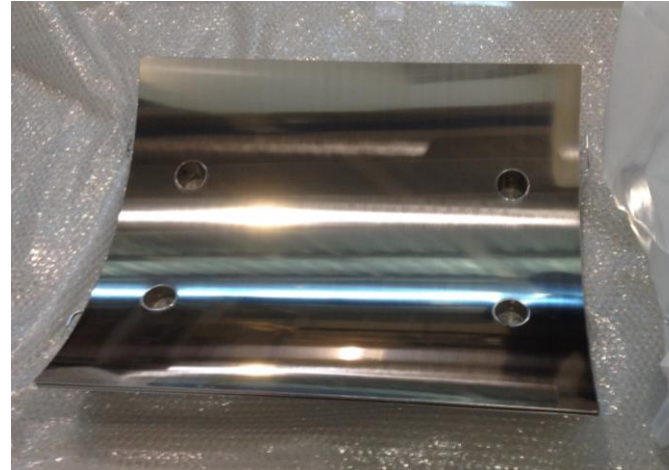
# Problem of temperature rise on cryo-pump

Cryo-pump down after 900C, 3h operation

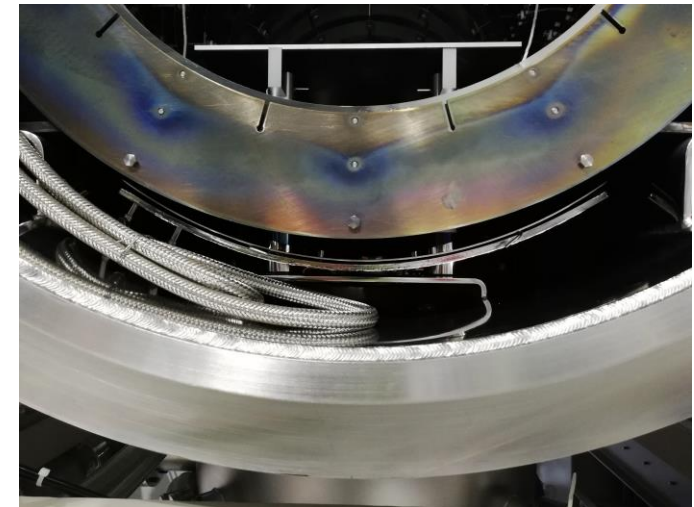


- Temperature rise was observed for 15K/80K panel of the cryo-pump.
- High temperature operation was difficult.

1<sup>st</sup> trial; install multi-layer shield



2<sup>nd</sup> trial; install water-cooled shield



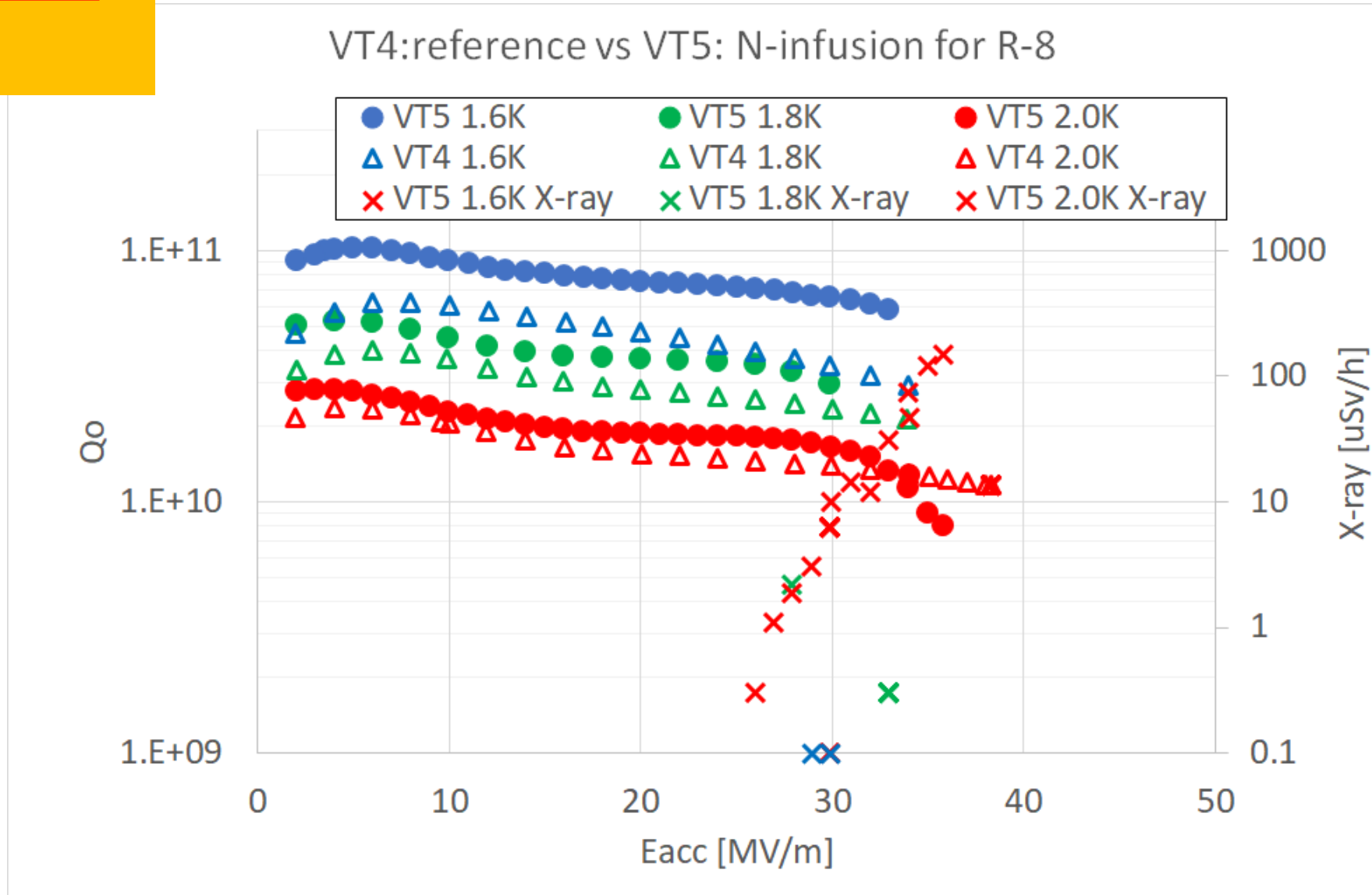
Not perfect, but became much better

#	Day (N-inf / VT)	Cavity name	# of cell	Nb	Treatment	Results	Eacc (MV/m)	Comment
1	2018/Jun	R-6	1	FG	800C, 3h + <b>120C</b> , 48h, 3.3Pa N2	No Q-degradation	35	
2	2018/Jun, Jul	R-9b	1	FG	800C, 3h + <b>120C</b> , 48h, 3.3Pa N2	No Q-degradation	26	Defect limited
3	2018/Jun, Jul	R-10	3	LG	800C, 3h + <b>120C</b> , 48h, 3.3Pa N2	No Q-degradation	27	F.E. limited
Summer shutdown								
4	2018/Sep, Oct	R-2	1	FG	800C, 3h + <b>160C</b> , 48h, 3.3Pa N2	Q-degradation	19	No defects found
5	2018/Oct	R-6	1	FG	800C, 3h + <b>120C</b> , 48h (without N2)	Q-degradation	32	
Apply dedicated burning run after this period								
6	2018/Nov, Dec	R-8	1	FG	800C, 3h + 800C, 2h + <b>120C</b> , 48h, 3.3Pa N2	Better Q than reference	36	
Improve cooling of cryo-pump by adding cooling-water type shielding plate								
7	2018/Dec 2019/Jan	R-9b	1	FG	800C, 3h + 800C, 2h + <b>160C</b> , 48h, 3.3Pa N2	Q-degradation	24	Defect limited
8	2019/Jan, Feb	AES18	1	FG	800C, 3h + 800C, 2h + <b>120C</b> , 48h, 3.3Pa N2	No Q-degradation	38	
Modify N2 injection line								
9	2019/Apr	R-4	1	FG	800C, 3h + <b>120C</b> , 48h, 3.3Pa N2	Q-degradation	39	
10	2019/May	AES18	1	FG	800C, 3h + <b>120C</b> , 48h, 3.3Pa N2	Q-degradation	31	
Remove cooling-water type shielding plate due to water leak trouble								
11	2019/Jun, Jul	MHI31	9	FG	800C, 3h + 800C, 2h + <b>120C</b> , 48h, 3.3Pa N2	Better Q than reference	37	
12	2019/Sep	R-4	1	FG	800C, 3h + 800C, 2h + <b>120C</b> , 48h, 3.3Pa N2	No Q-degradation?	26	F.E. limited

## Typical good results

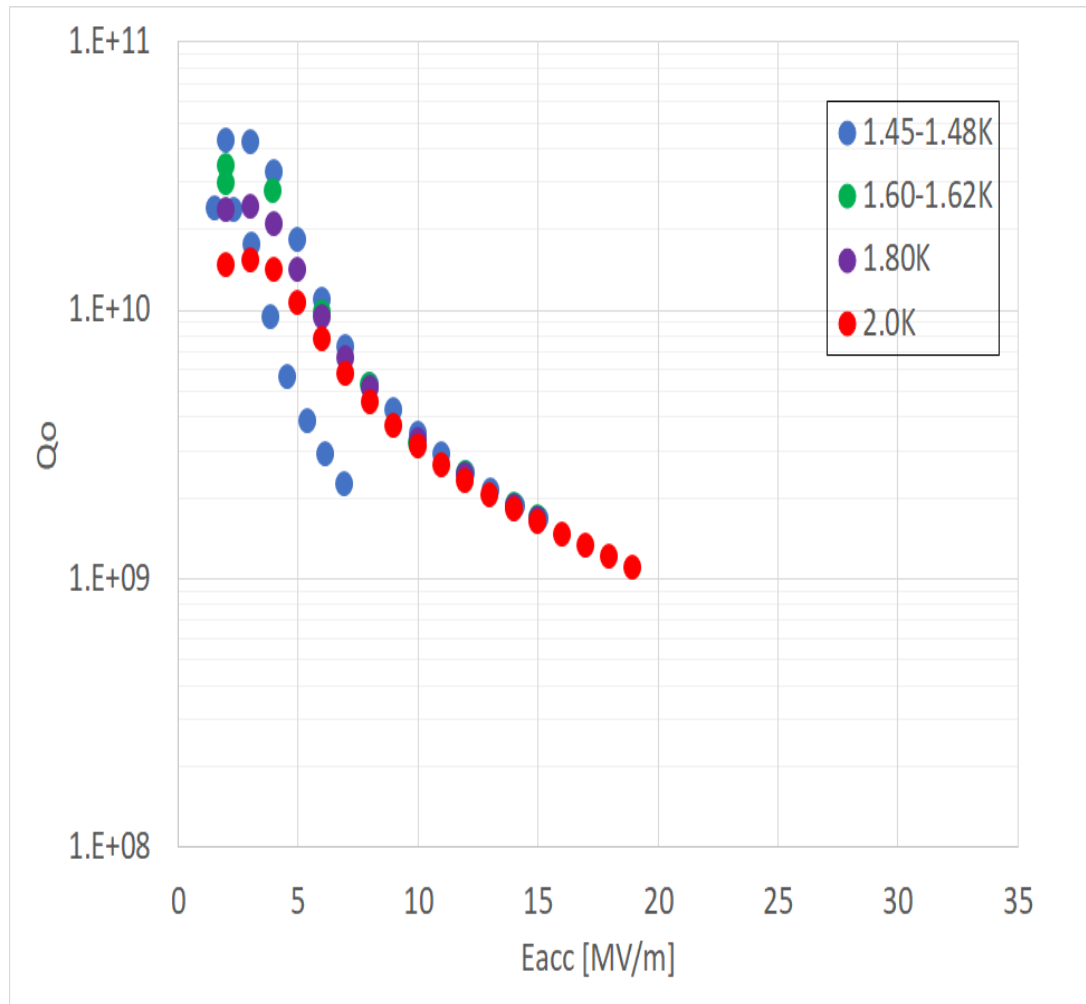
### ⑥ R-8 cavity

- 0mG cancelled by the coil.
- Very high- $Q$  was achieved.
- Good  $Q$  for medium to high field too.  
⇒ Feature of N-infusion
- Eacc degraded from 39 to 35 MV/m.
- F.E. started from 25 MV/m.

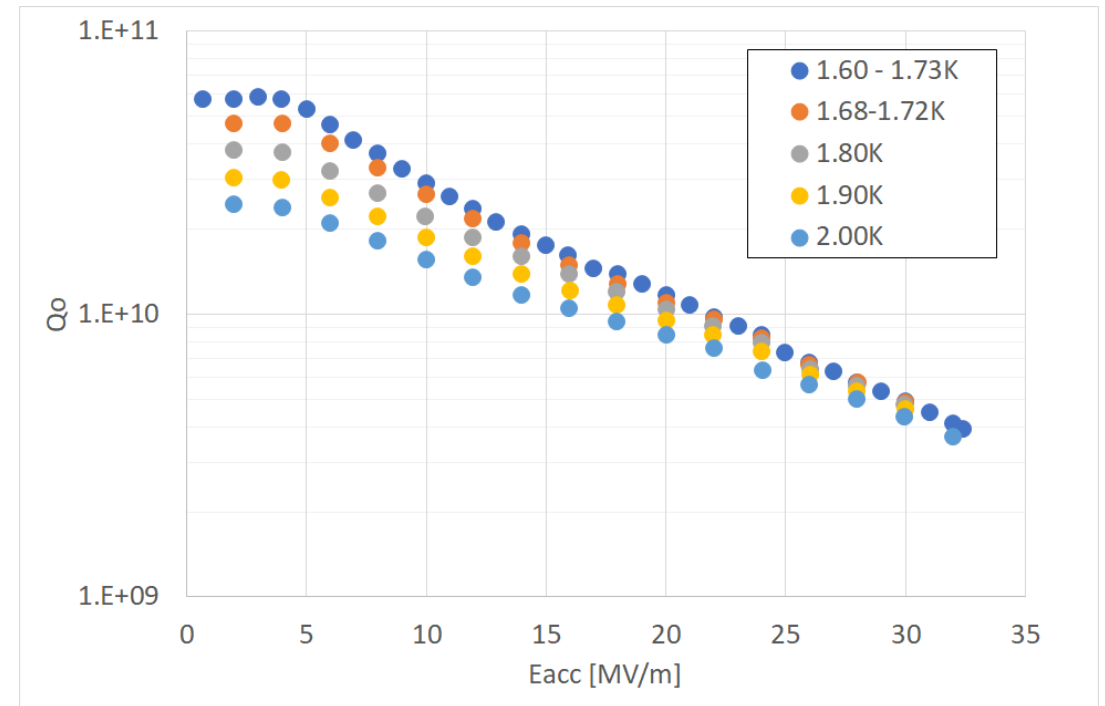


# Bad results of N-infusion

## ④ Results for 4th N-infusion (160C) at COI, R-2 cavity



## ⑤ Results for 5th N-infusion(120C, w/o N2) at COI, R-6 cavity

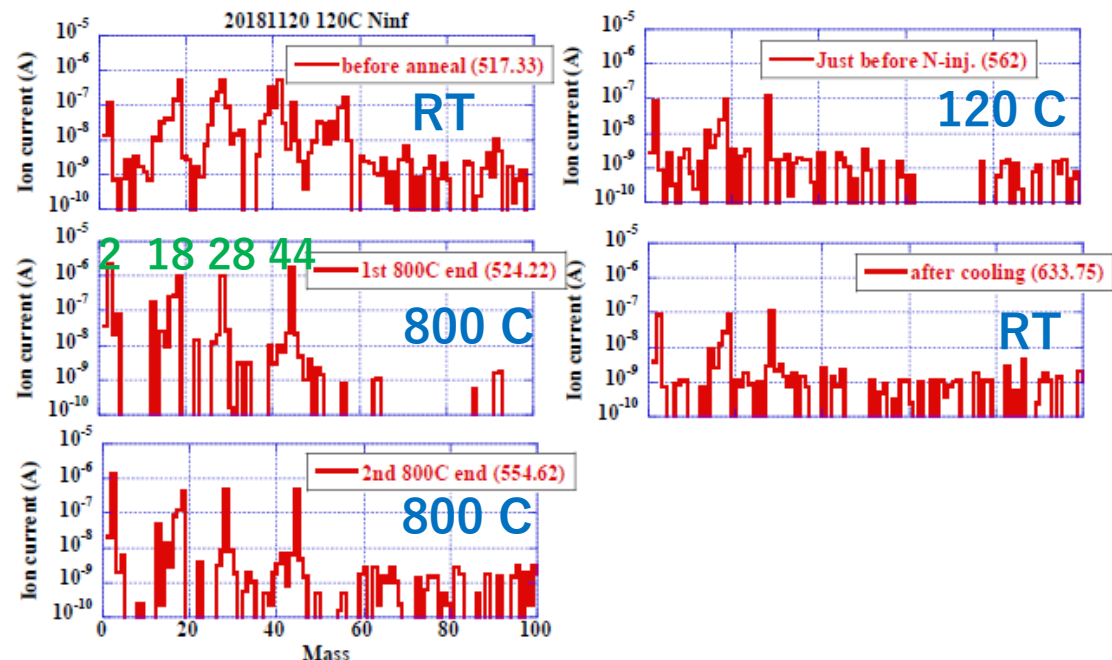
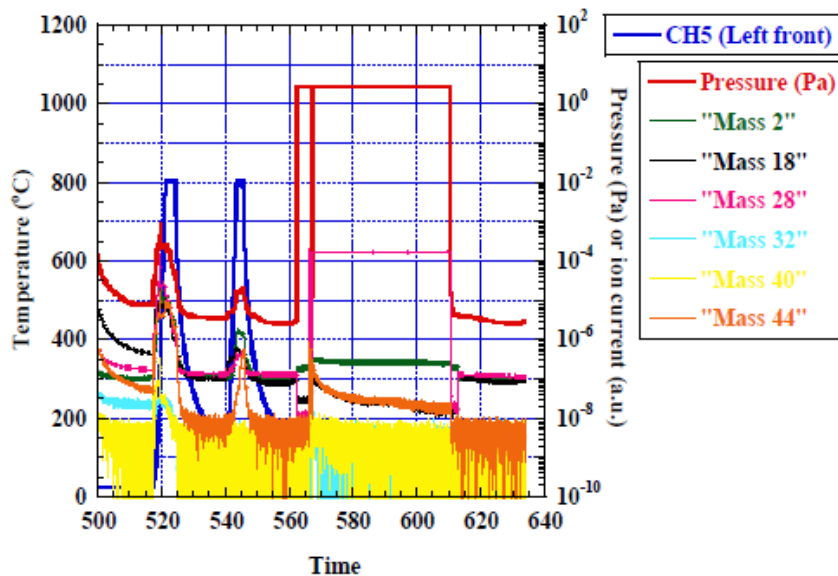


- Q-degradation occurred even at KEK New furnace.
- What's reason of degradation??
- Lack of burning run after summer?

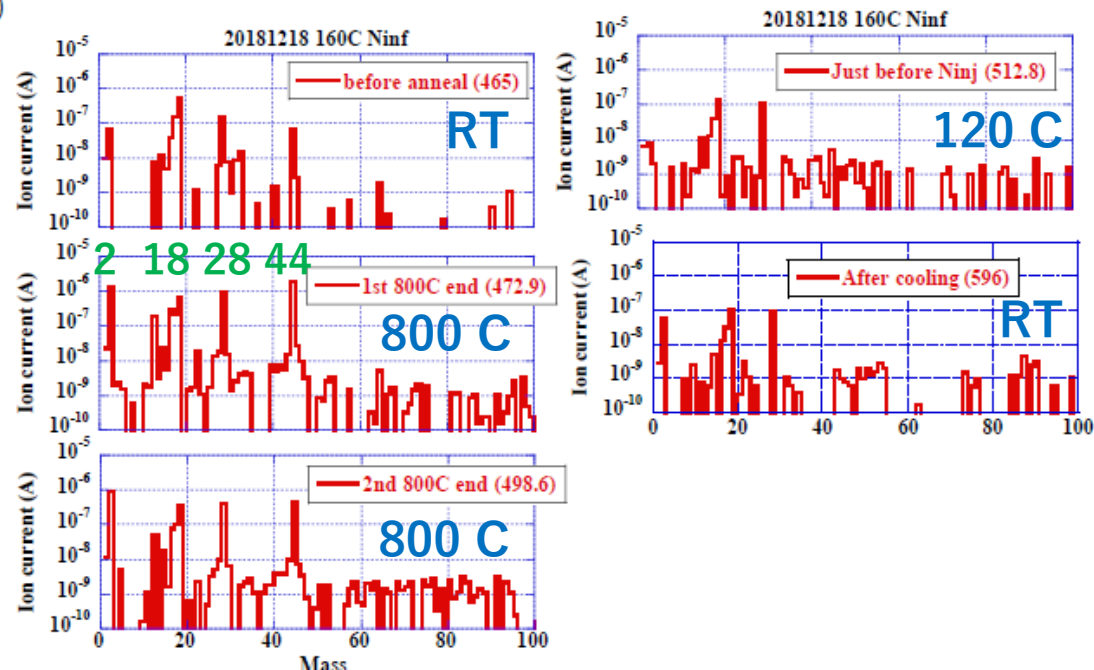
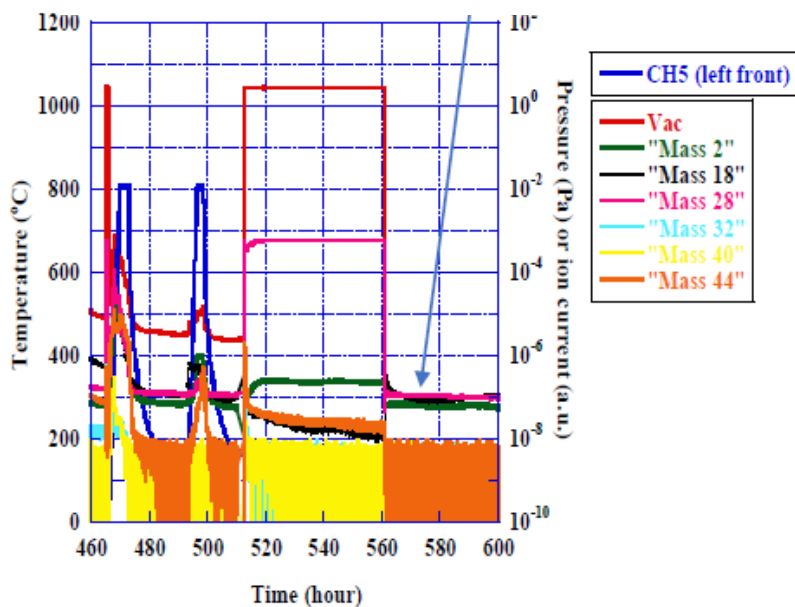
# Typical RGA spectrum

RGA does not  
show difference  
between good  
and bad  
examples.

## Good ⑥ 120C N-infusion



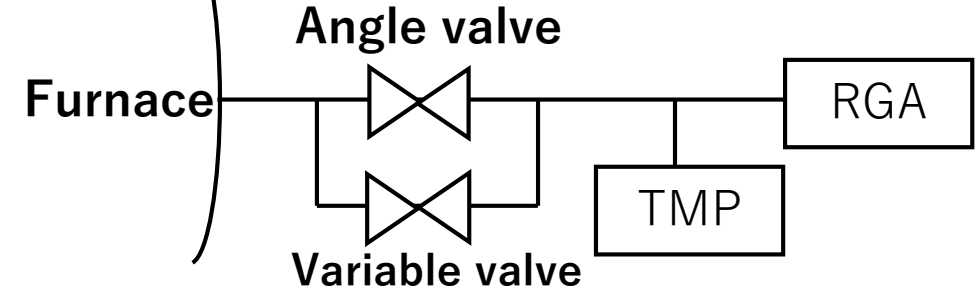
## Bad ⑦ 160C N-infusion (uge not fired)



# RGA spectrum during N-injection

RGA line

-- Direct line & Bypass line

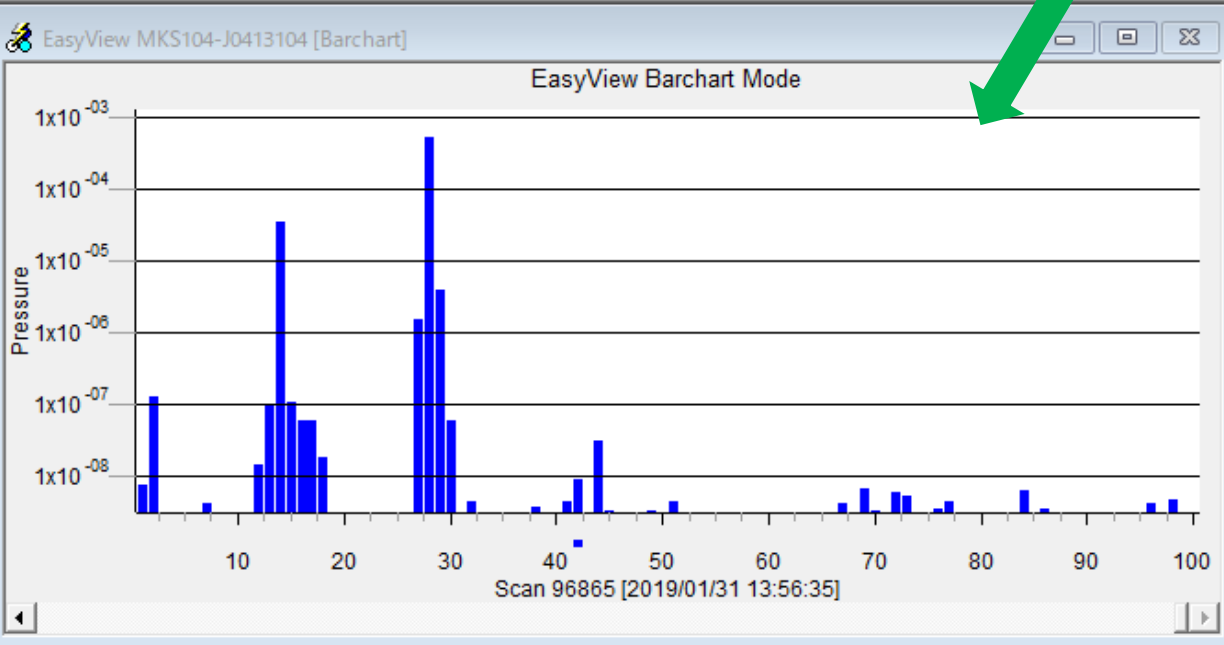
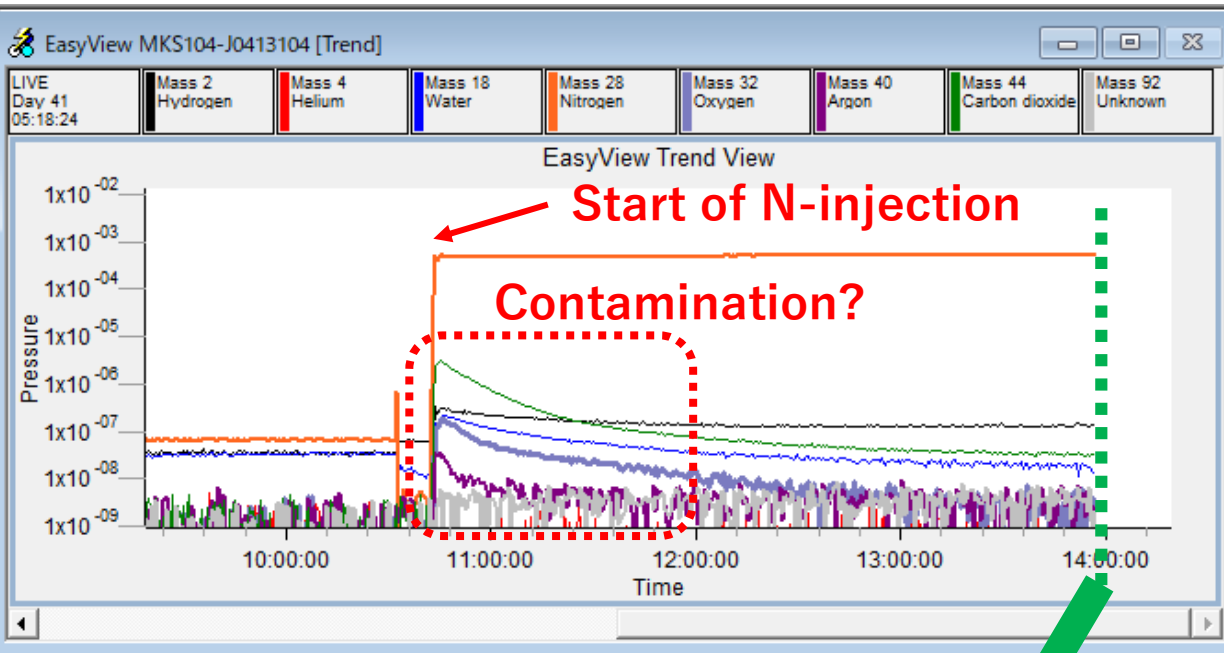


**Bypass line** was developed to monitor purity of N<sub>2</sub>.

**Some gas(44, 32) components** are observed and show **higher value at beginning**.  
→ Source of bad results?

First N-injection line was suspected.  
→ Add gas purifier → No change on results

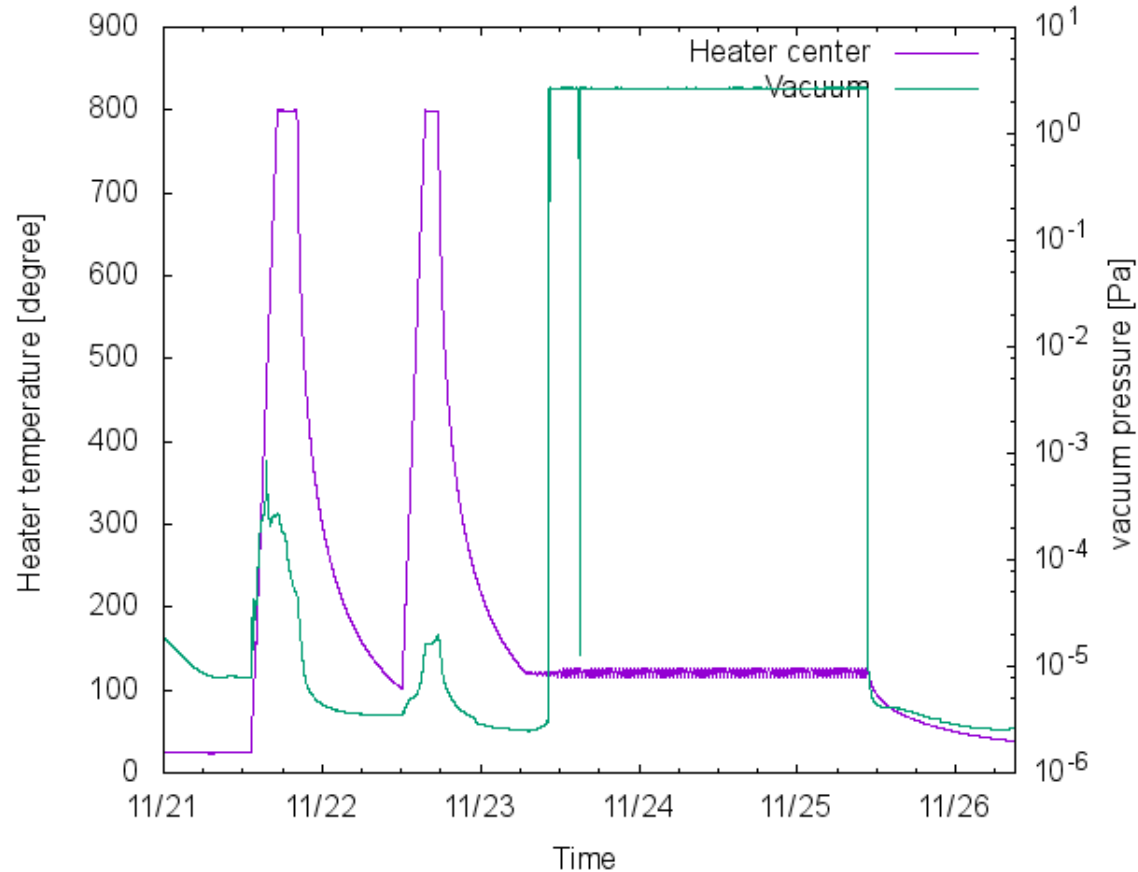
Later it was found that **contamination** come from **combination of “Open to air + heating furnace + flushing by N-injection”**. Difficult to remove



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「800C, 3h + 800C, 2h + 120C, 48h with N2」 seems to be better.								
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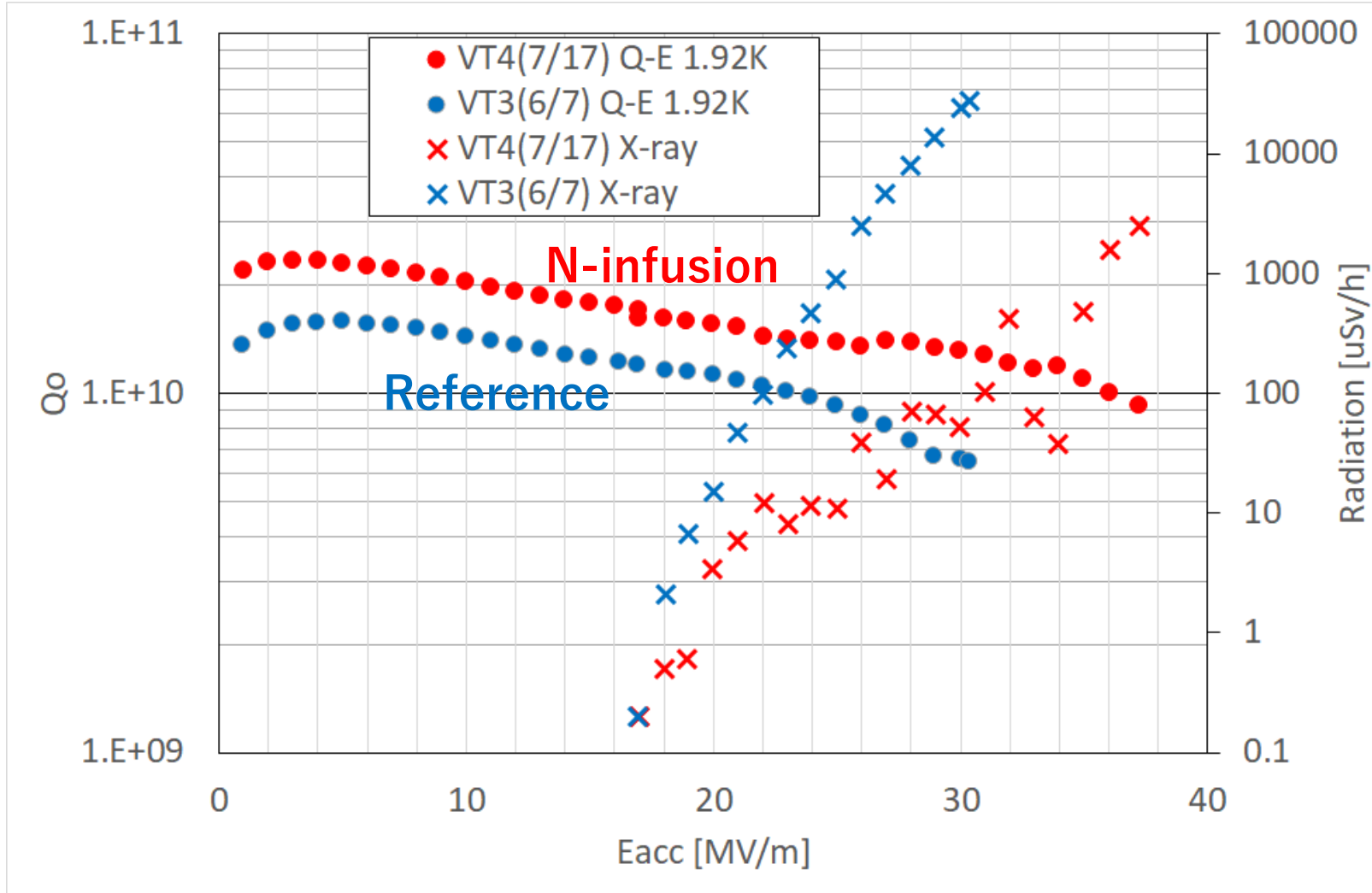
# Process, “800C, 3h + 800C, 2h + 120C, 48h, N2”



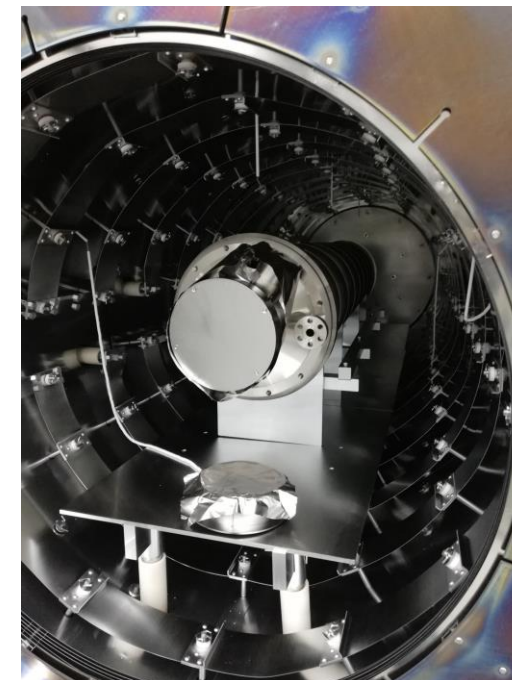
- 1<sup>st</sup> 800C heat treatment
  - De-gassing of cavity
  - One important target is Hydrogen
- 2<sup>nd</sup> 800C heat treatment
  - Much better vacuum condition
  - Less absorption on cavity surface
  - “H” start to rise after 2 hours, due to temperature rise of cryo-pump.
- 120C, N-infusion
  - Normal N-injection procedure
  - 3.3Pa N2 injection for 48 hours.

- “Better vacuum” or “less hydrogen” might be necessary condition for N-infusion.
- Is Hydrogen key components?

# First N-infusion for 9-cell cavity



※ Eacc for reference measurement was limited by F.E.



- **Max Eacc = 37MV/m**
- **Quench : 1-cell, 120deg.**
- **Final field emission onset Eacc = 20-21MV/m**
- **Improvement of Qo ?**
- **Magnetic field inside VT dewar was not controlled for 9-cell cavities.**

## Summary

- KEK has carried out N-infusion study for realize high-Q/high-Gradient performance of SRF cavities.
- New clean furnace was constructed at KEK. It has been used for N-infusion studies.
- Roughly half of N-infused cavities show degradation of Q.
- “Two step 800C + 120C N-infusion” may help to realized successful N-infusion.
- First trial for 9-cell cavity showed good results.
- We will continue study to find more stable condition and more reliable SRF performance.