First success of N-infusion at KEK/J-PARC

TTC High-Q Working Group Meeting

2018/Jan/11

Kensei Umemori(KEK)

on behalf of KEK SCRF group, JAEA vacuum group, MHI-MS

Outline

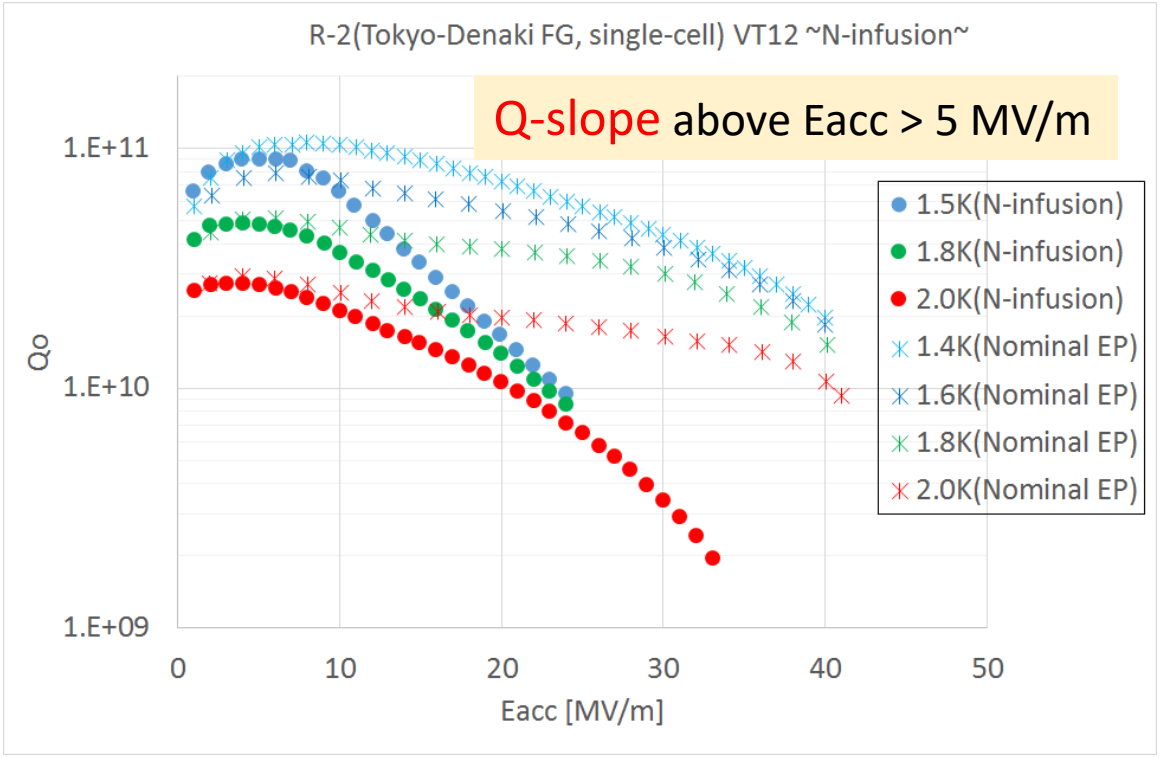
- Previous N-infusion results at J-PARC
- Improvement of vacuum system
- Latest results of N-infusion at J-PARC
- Summary

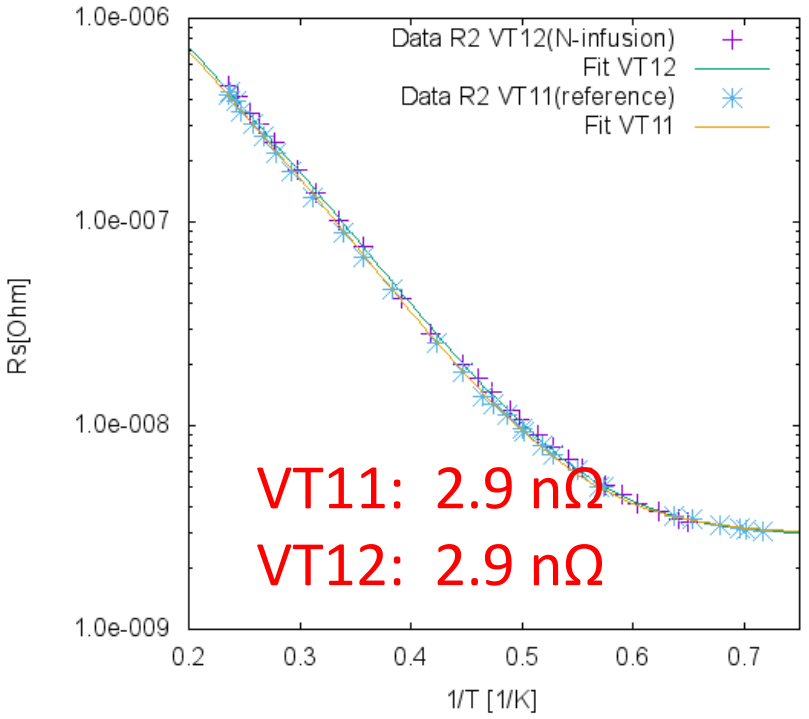
Previous results of N-infusion (Slides from 2017/Sep/8)

VT results for N-infusion

- Transfer to KEK
- HPR (No EP applied)
- Assembly

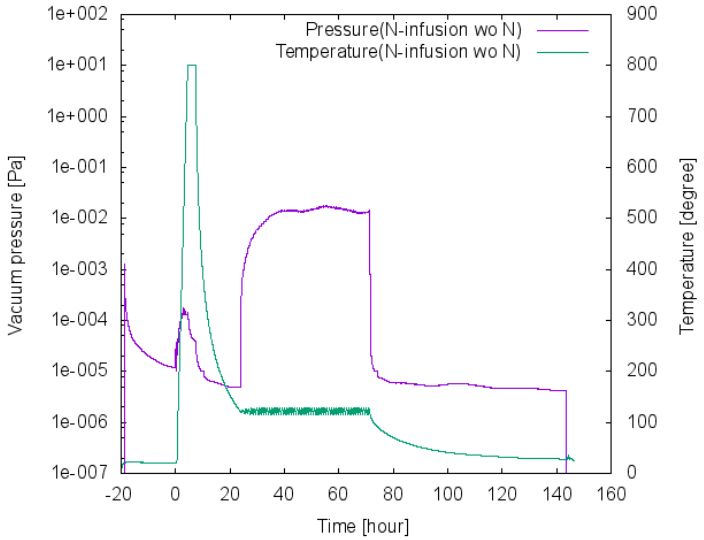
- Magnetic field canceled. (< 1mG)
- Cooled down with thermal gradient





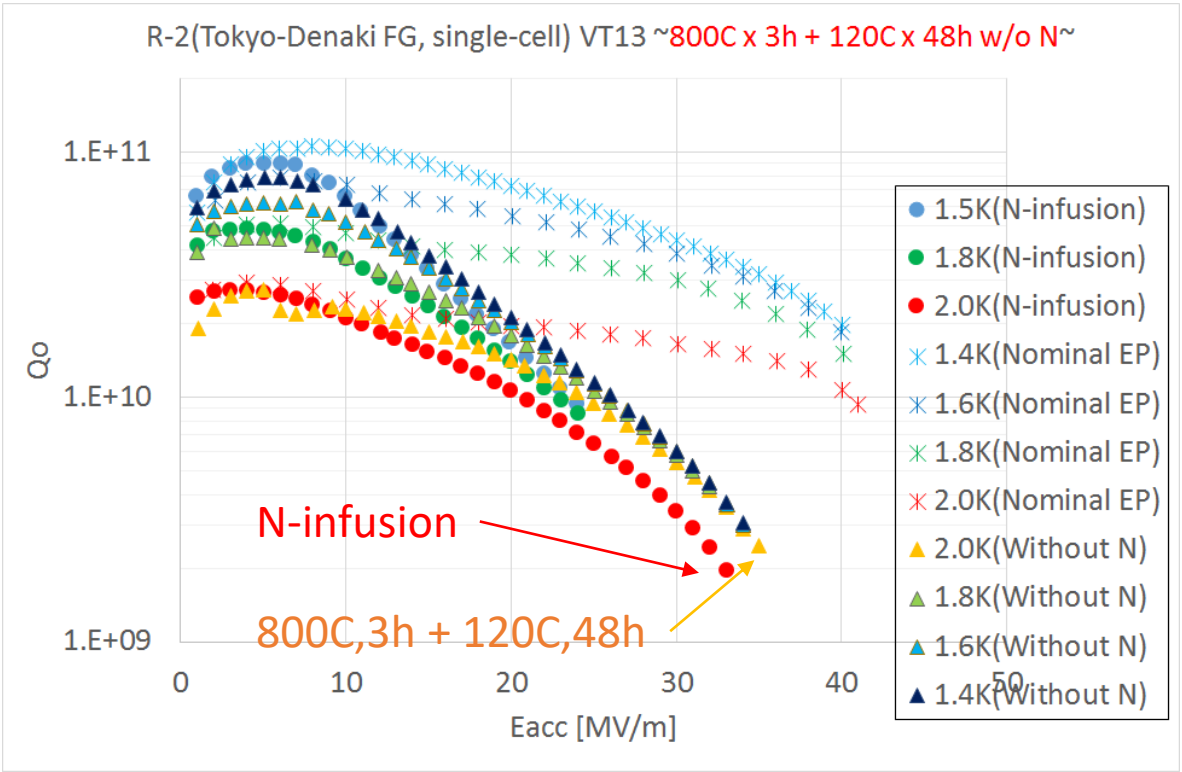
- Degradation was observed for > 5 MV/m
- Eacc was limited at 33MV/m by quench at 225 degree equator
- No field emission

② 800℃, 3hours + 120℃, 48 hours w/o Nitrogen



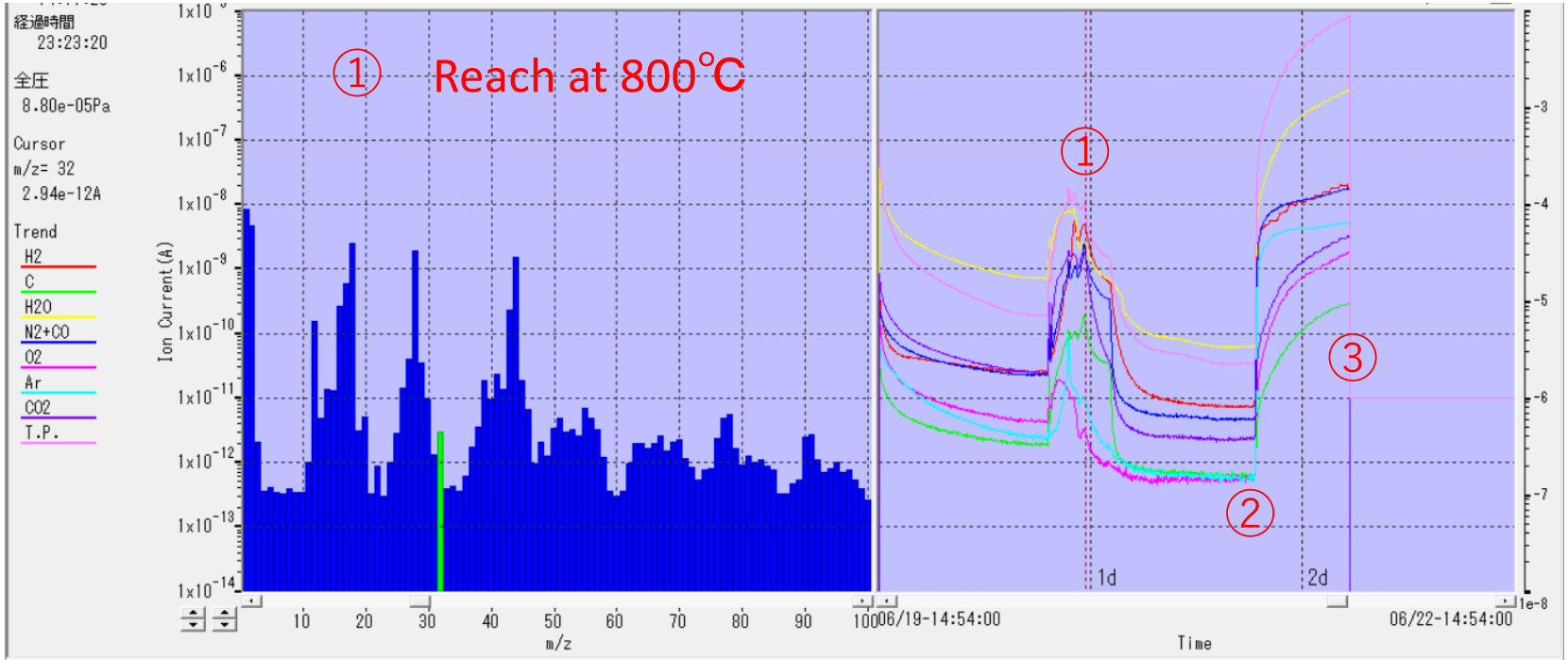
[Vacuum condition during 120 degree]

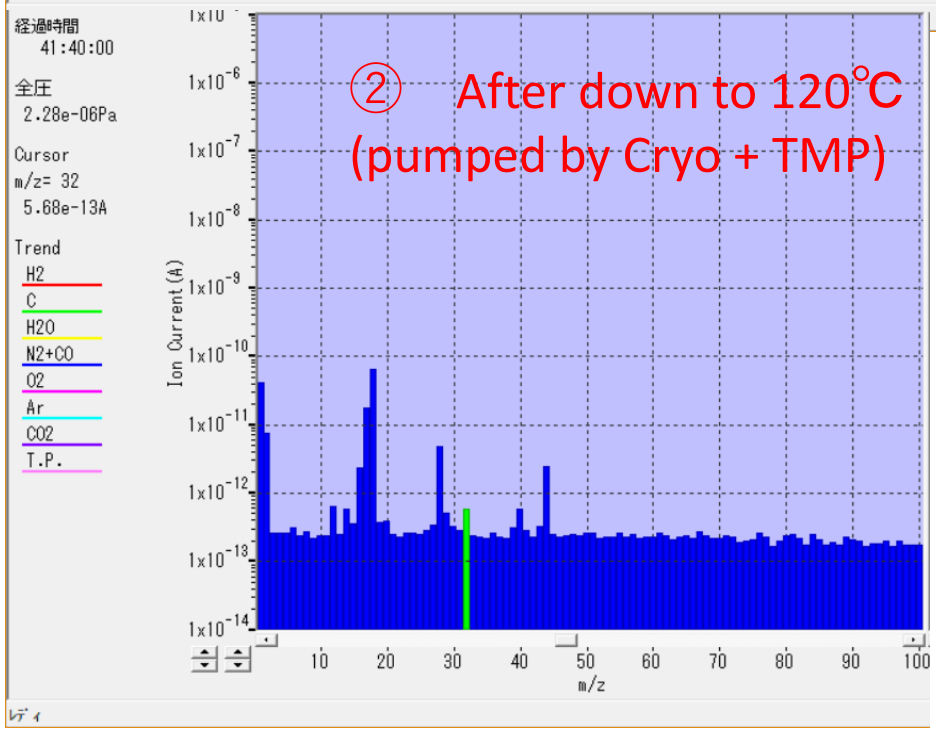
- Valve of cryopump was closed
- TMP OFF
- Vacuum pumping by small pumping system(TMP and scroll)
- Vacuum level worthened to 1.7e-2 Pa (Around 0.5% of Nitrogen level)

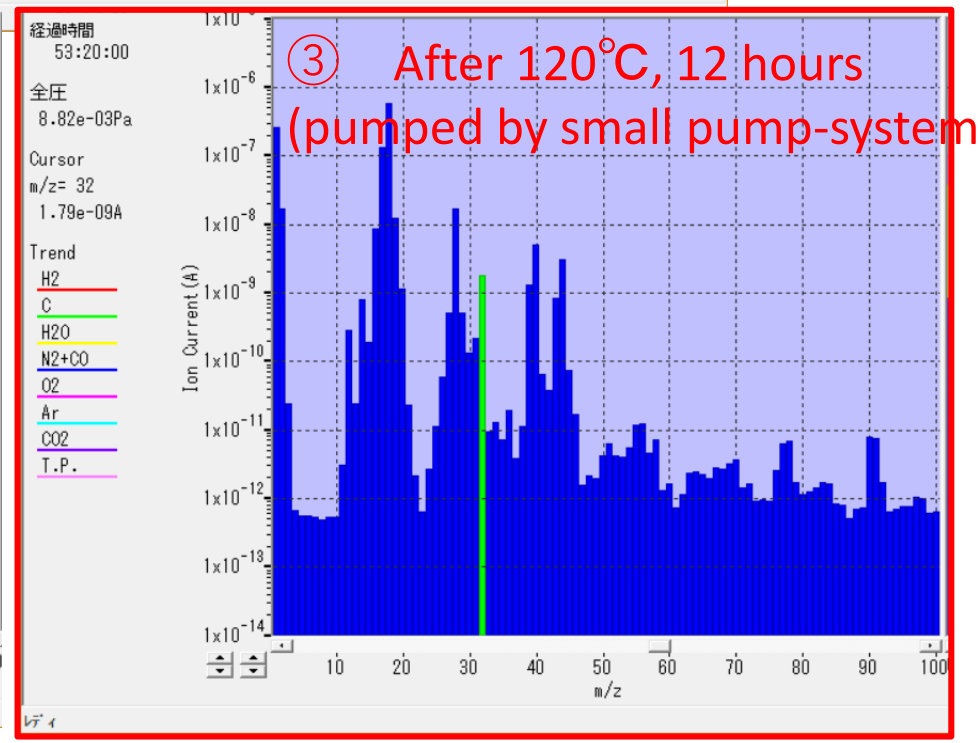


- Refresh surface by 10um EP after N-infusion
- 800C, 3h + 120C, 48h (No Nitrogen)
- HPR and assembly (No EP, No baking)
- Vertical test

- Q-slope above Eacc > 5 MV/m
- Almost same performance with N-infusion


経過時間
23:23:20
全圧
8.80e-05Pa
Cursor
m/z= 32
2.94e-12A
Trend
H2
C
H2O
N2+CO
O2
Ar
CO2
T.P.
① Reach at 800℃
Ion Current(A)
m/z
Time
1d
2d
06/19-14:54:00
06/22-14:54:00


経過時間
41:40:00
全圧
2.28e-06Pa
Cursor
m/z= 32
5.68e-13A
Trend
H2
C
H2O
N2+CO
O2
Ar
CO2
T.P.
② After down to 120℃
(pumped by Cryo + TMP)
Ion Current(A)
m/z


経過時間
53:20:00
全圧
8.82e-03Pa
Cursor
m/z= 32
1.79e-09A
Trend
H2
C
H2O
N2+CO
O2
Ar
CO2
T.P.
③ After 120℃, 12 hours
(pumped by small pump-system)
Ion Current(A)
m/z

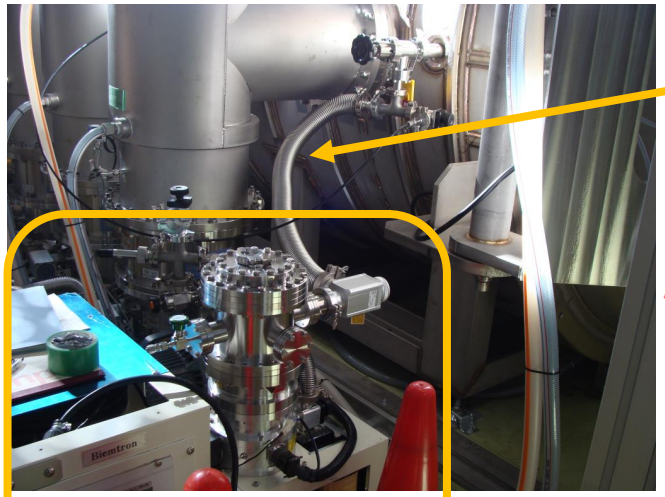
Latest results of N-infusion with improved vacuum condition

History of R-8c cavity

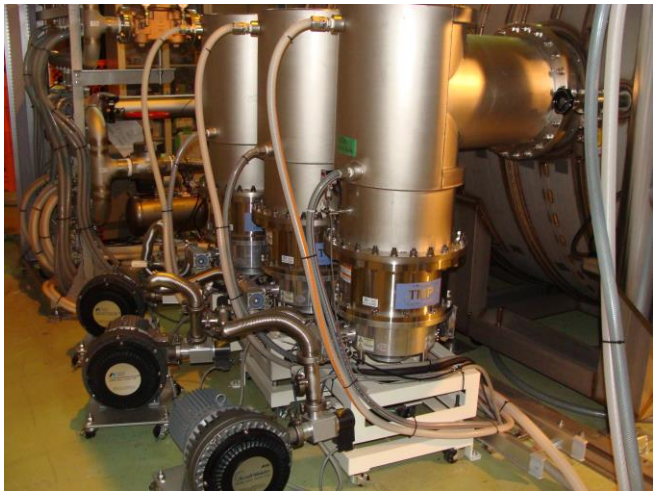
- TESLA-like single cell cavity made of Tokyo Denkai FG Nb sheet.

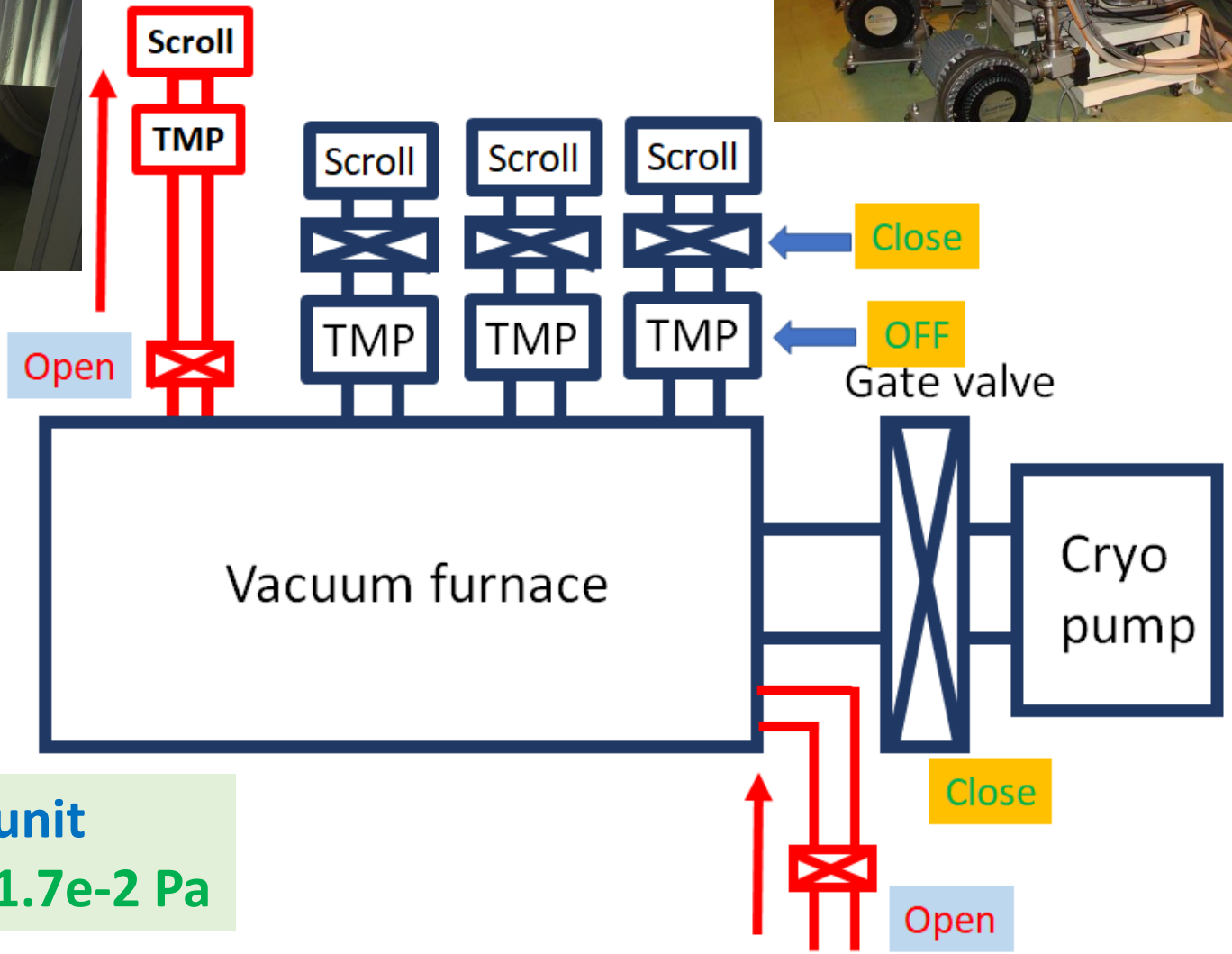
Date	Procudures
Jul/11, 12	Pre-EP (5um) & EP-1 (100um)
Sep/12	Heat treatment (800 C x 3hours)
Sep/21	EP-2 (20um)
Sep/22	HPR (3 hours), Assembly, Baking (120 C x 48 hours)
Sep/27, 28	1st vertical test (Reference VT)
Nov/7-10	N-infusion at J-PARC (800C x 3h + 120C x 48h, 3Pa N2)
Nov/15	HPR (3 hours), Assembly
Nov/21, 22	2nd vertical test (N-infusion)

Pumping system during 120 C N-injection (before)



Bellows limit conductance
~10 litter/sec

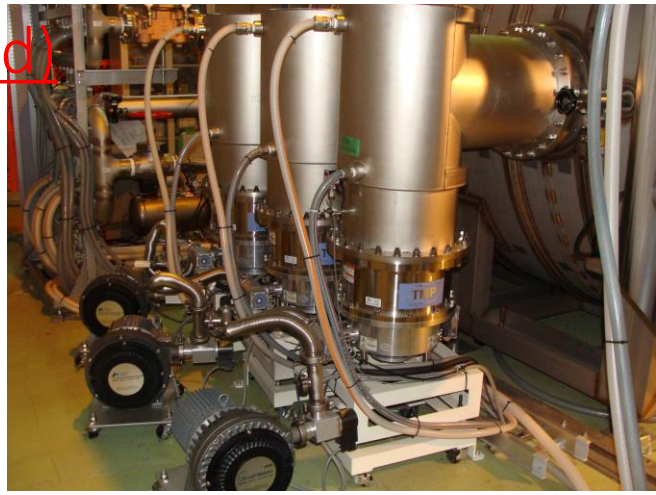


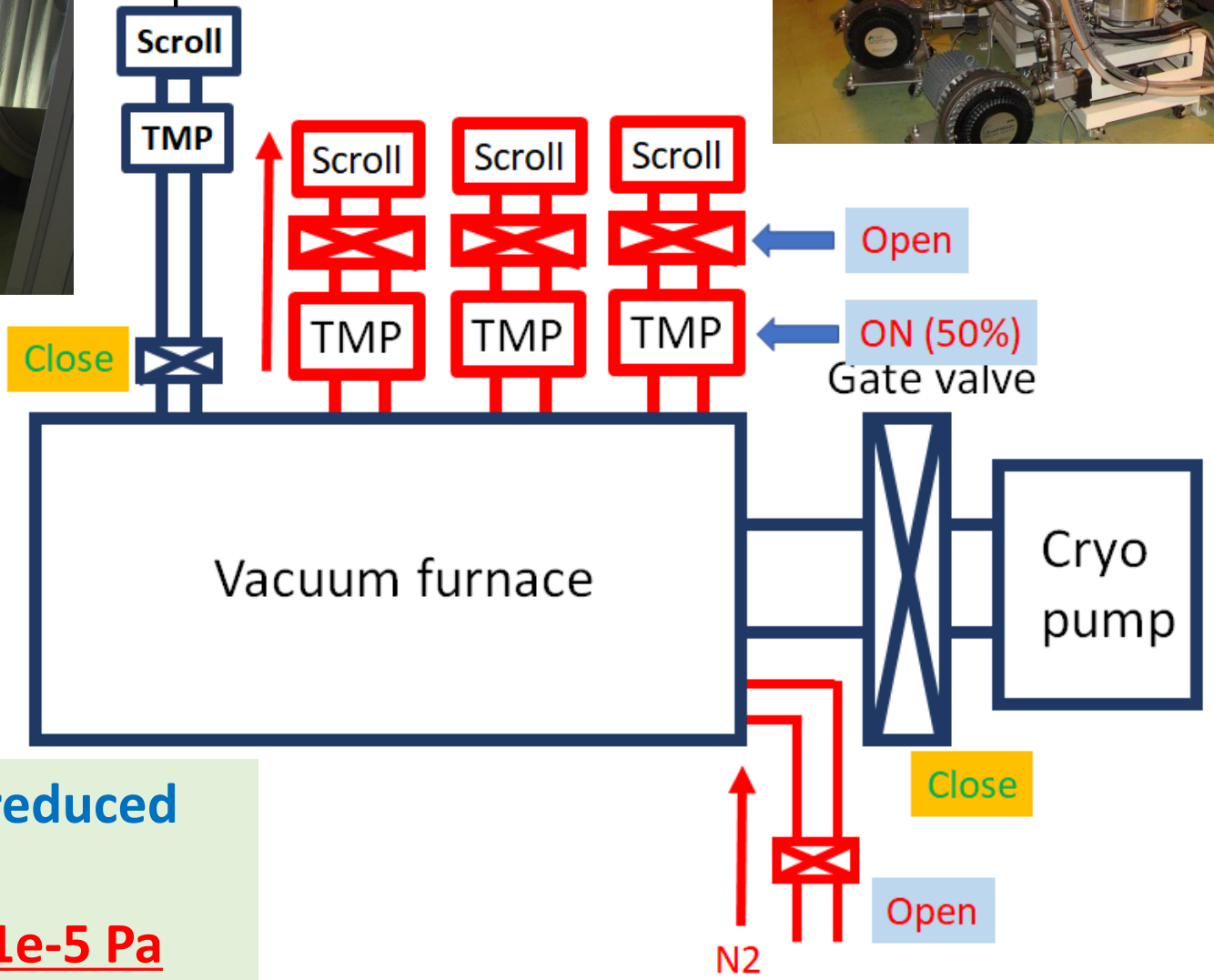


Use **small pumping unit**
Background level **~ 1.7e-2 Pa**

Pumping system during 120 C N-injection (improved)

- Use TMP with reduced rotation speed.
- Scroll pumps limit rotation speed.





Background vacuum was improved three orders.

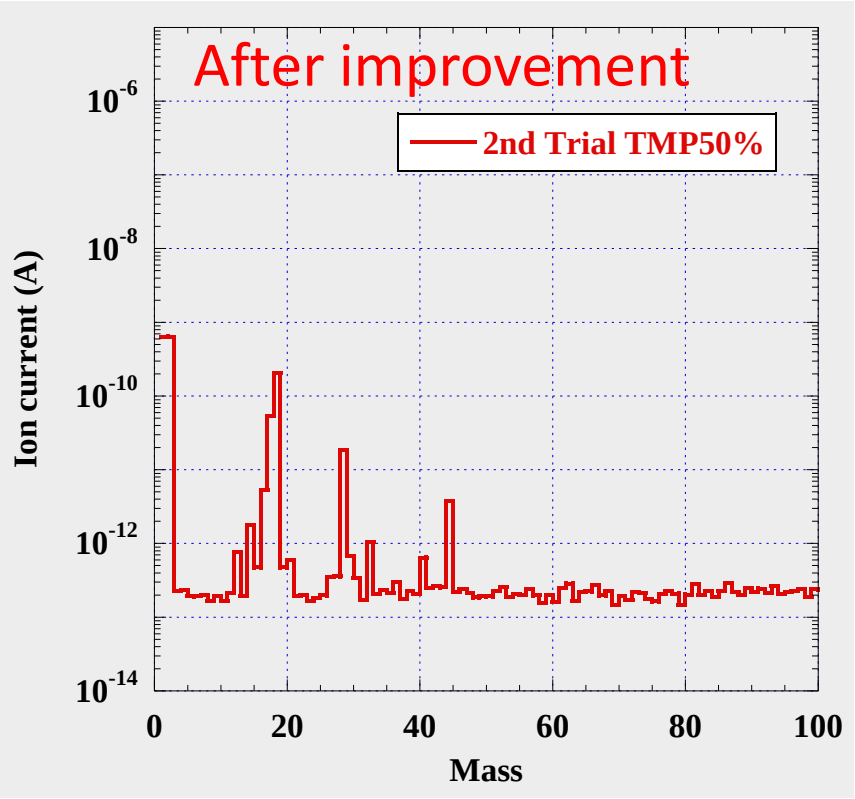
Use **large TMP with reduced rotation speed**

Background level **~ 1e-5 Pa**

RGA spectrum

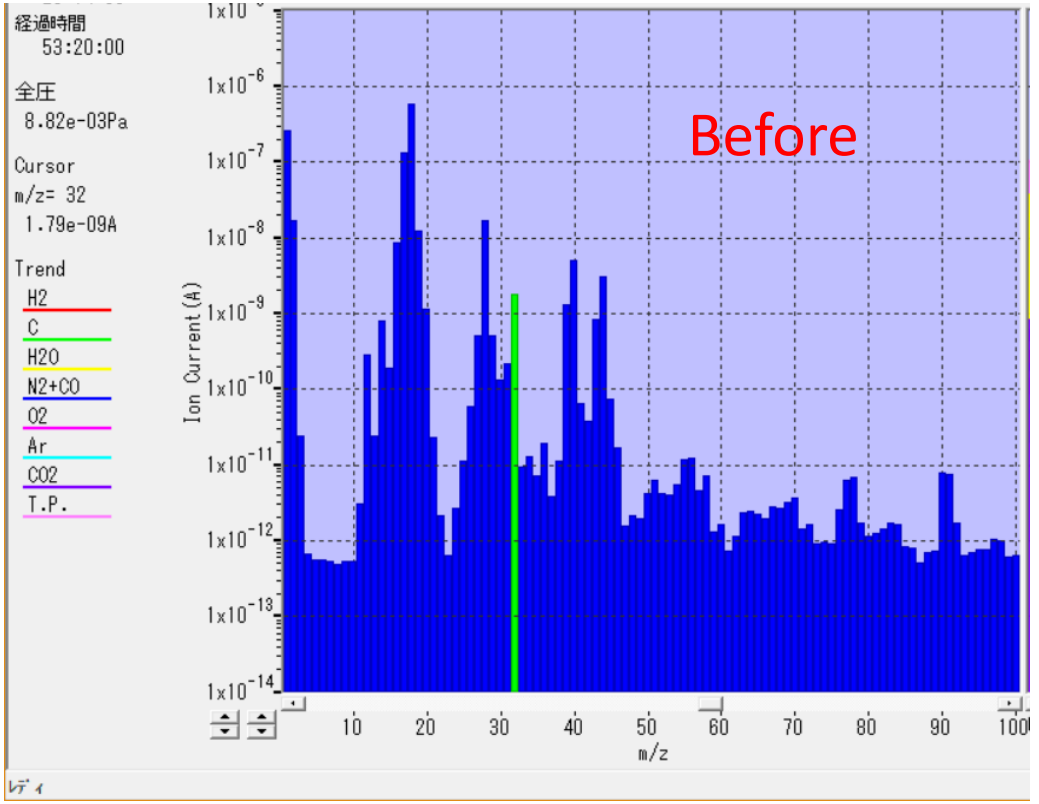
Use **large TMP with reduced rotation speed**

Background level **~ 1e-5 Pa**



Use **small pumping unit**

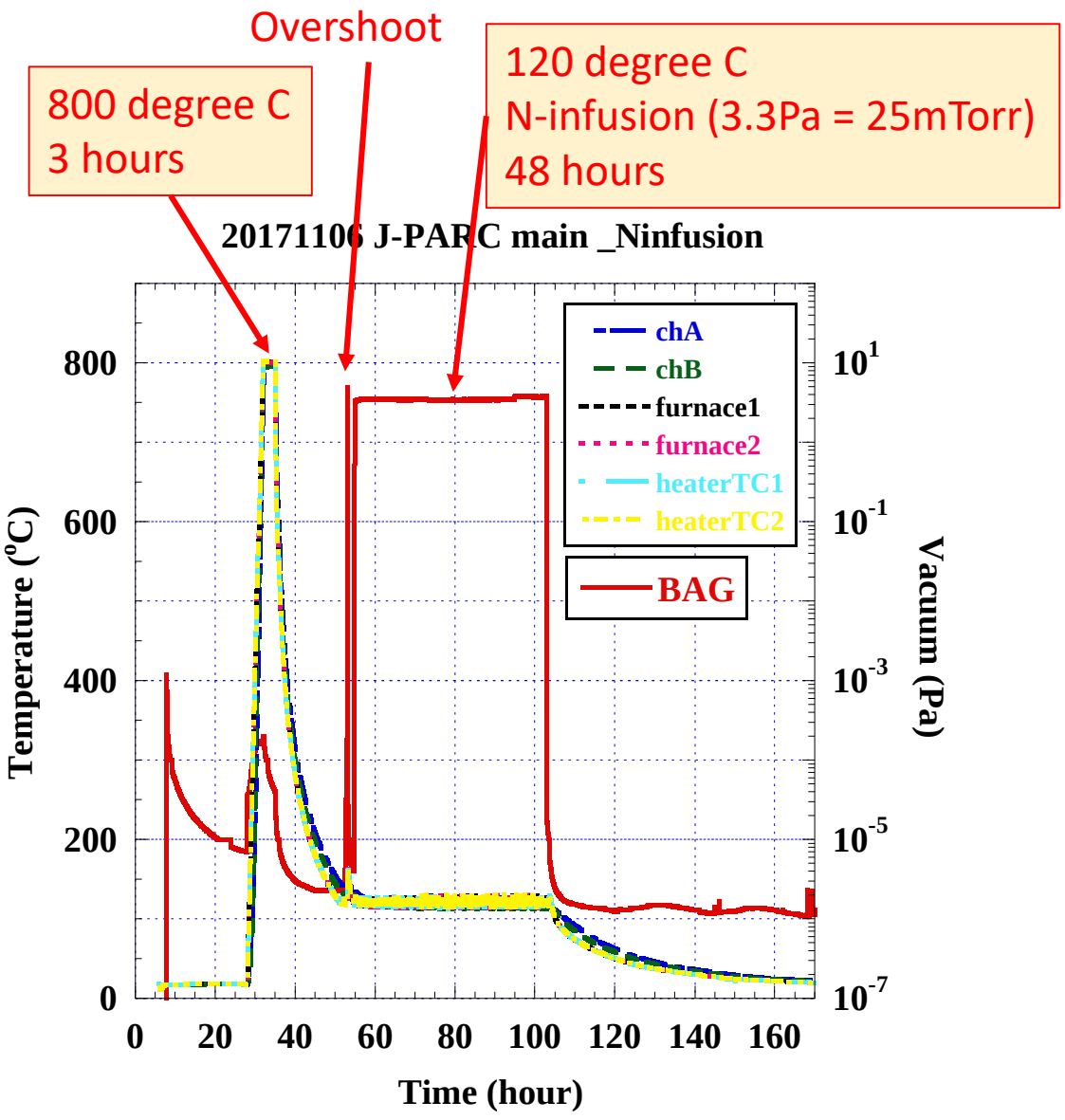
Background level **~ 1.7e-2 Pa**

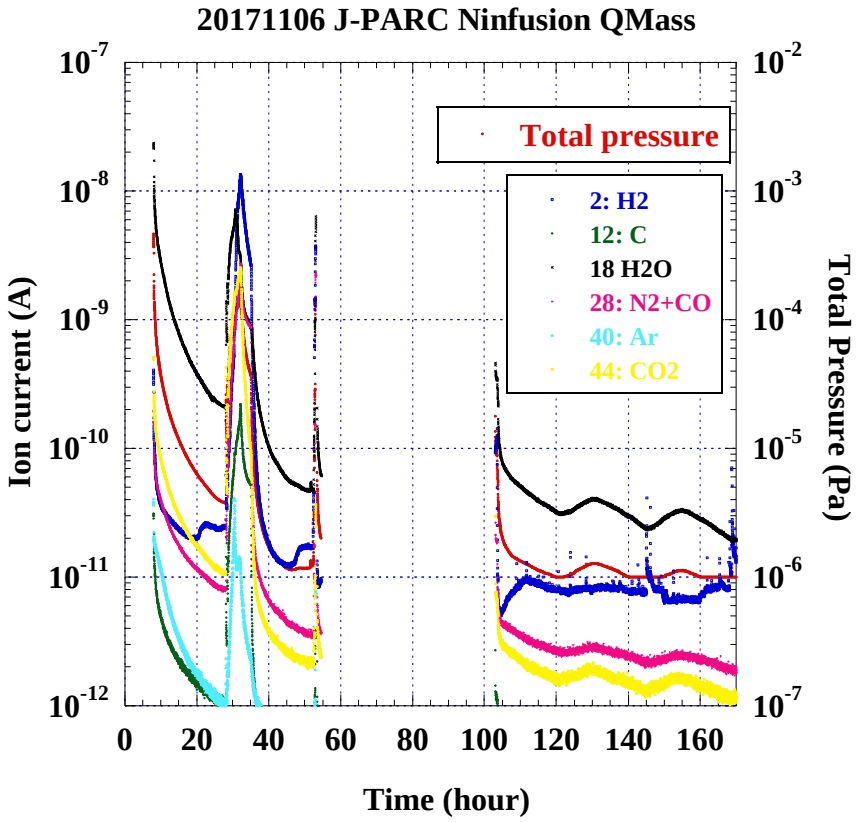


Vacuum background level improved much and showed relatively clean RGA spectrum.

N-infusion at J-PARC furnace

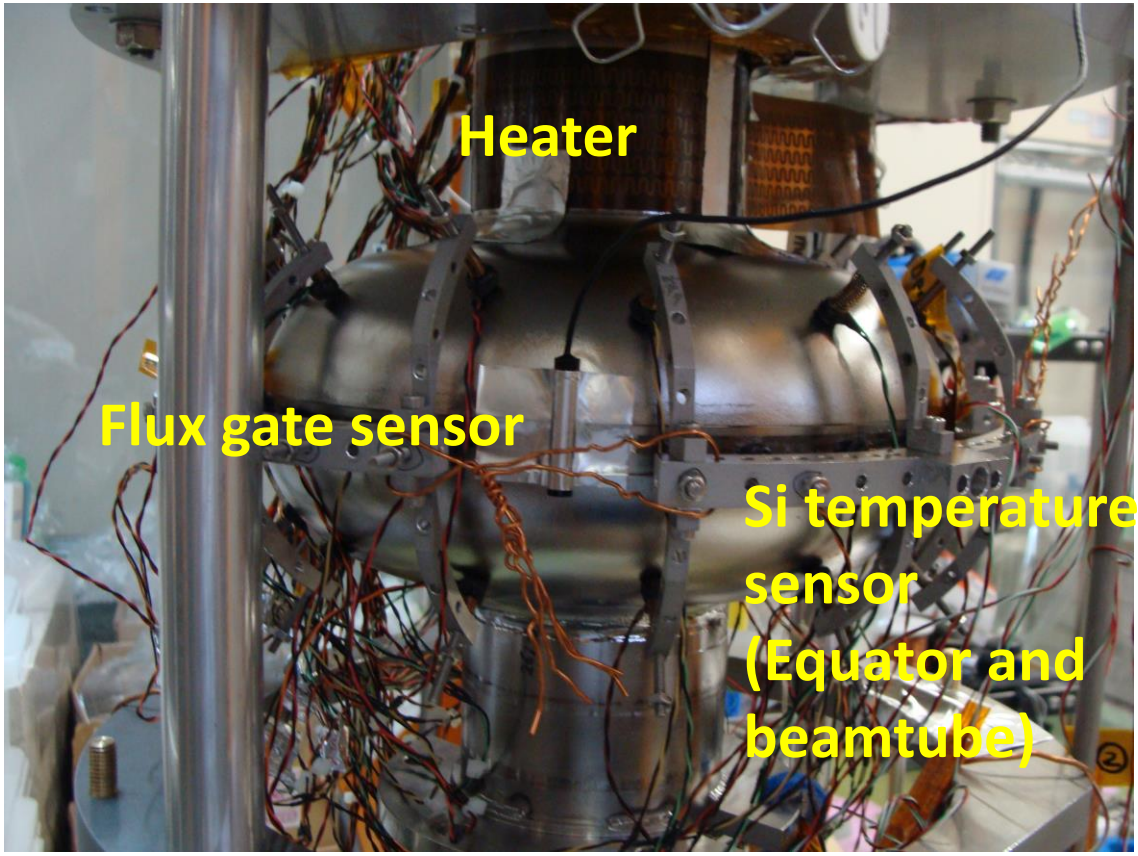
- Followed FNAL N-infusion parameter.
- Temperature of cavity might be little bit lower(~5deg) than furnace temperature.
- Total of 3 hour HPR, followed by dry assembly. (No 120C baking)





Typical vertical test setup

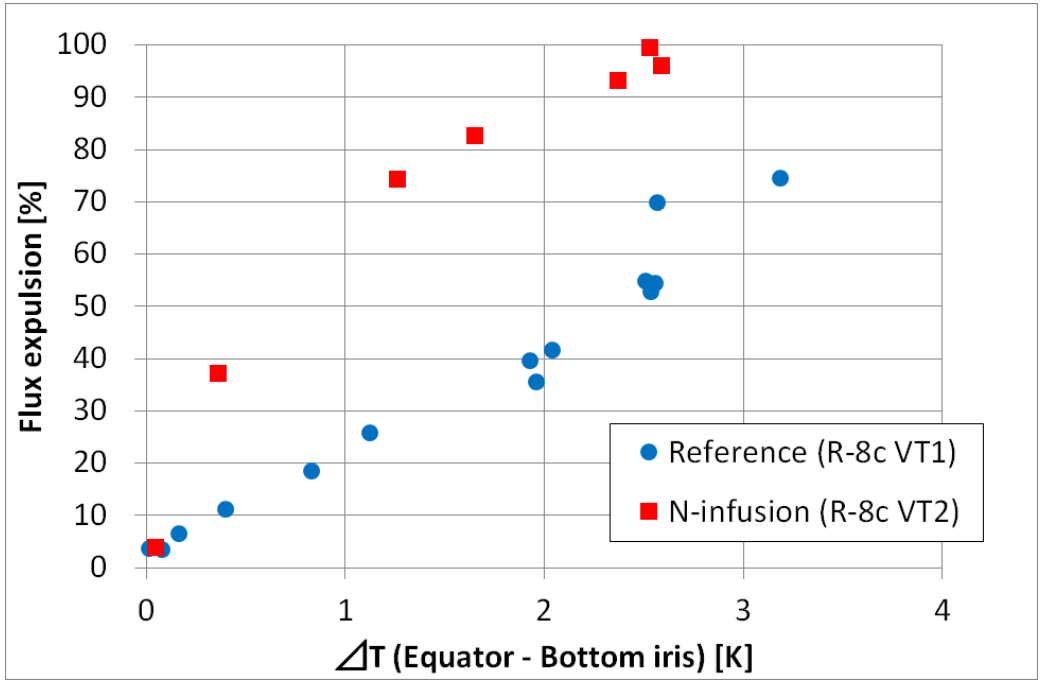
※ Pictures are for different measurement.
※ But setup of sensors and coil are same.

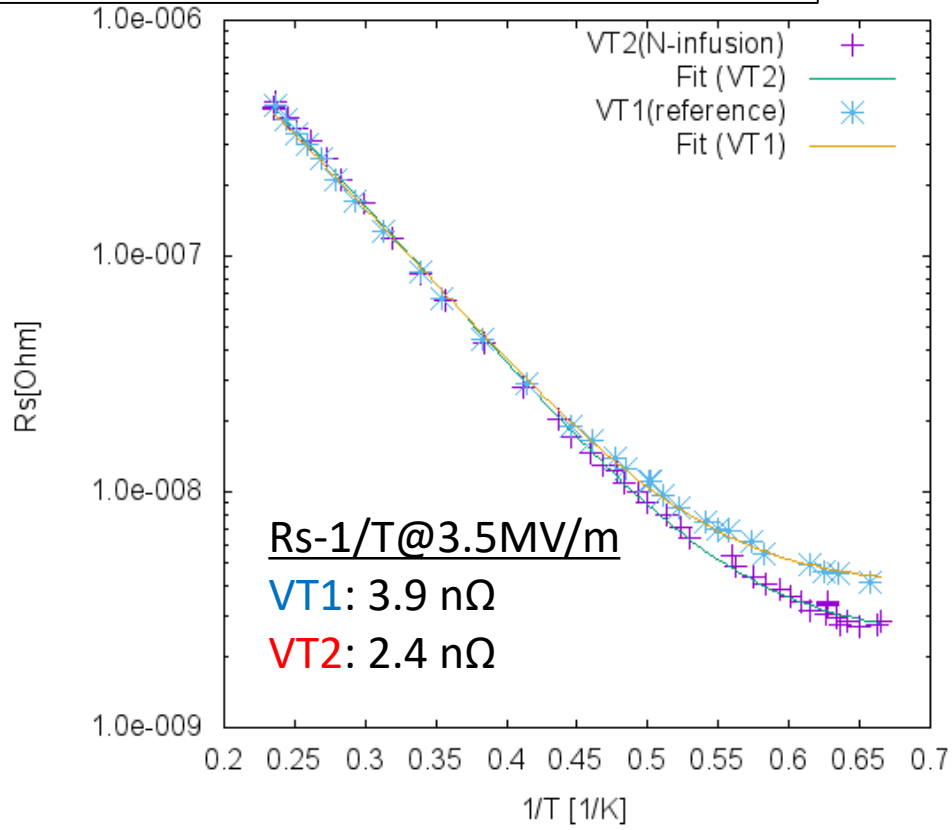


Flux gate sensor, Si temperature sensor, heater and solenoid coil were used.

Flux expulsion & Rs-1/T

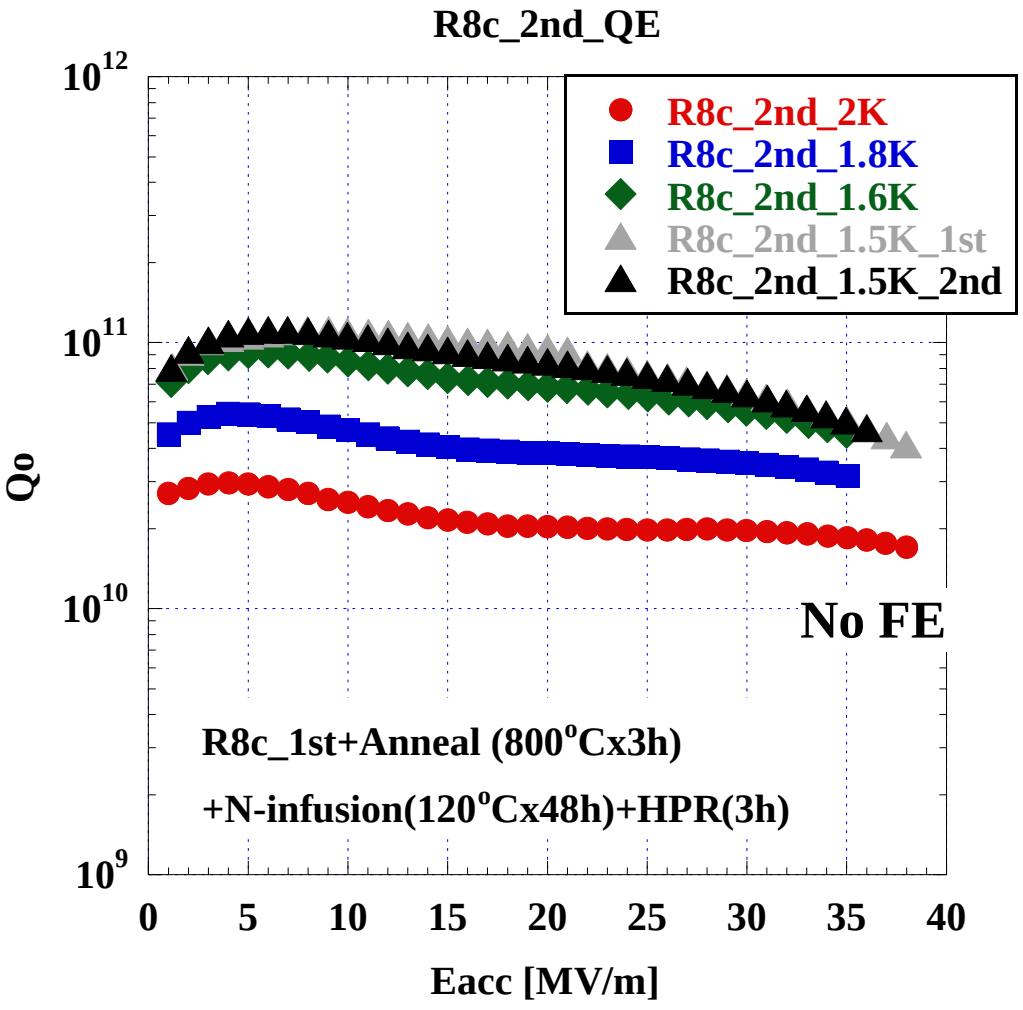
VT1: 800C x 3h heat treatment, EP2, 120C x 48h baking
VT2: 800C x 3h heat treatment, EP2, 120C x 48h baking + N-infusion (800C x 3h + 120 C x 48h, N2)

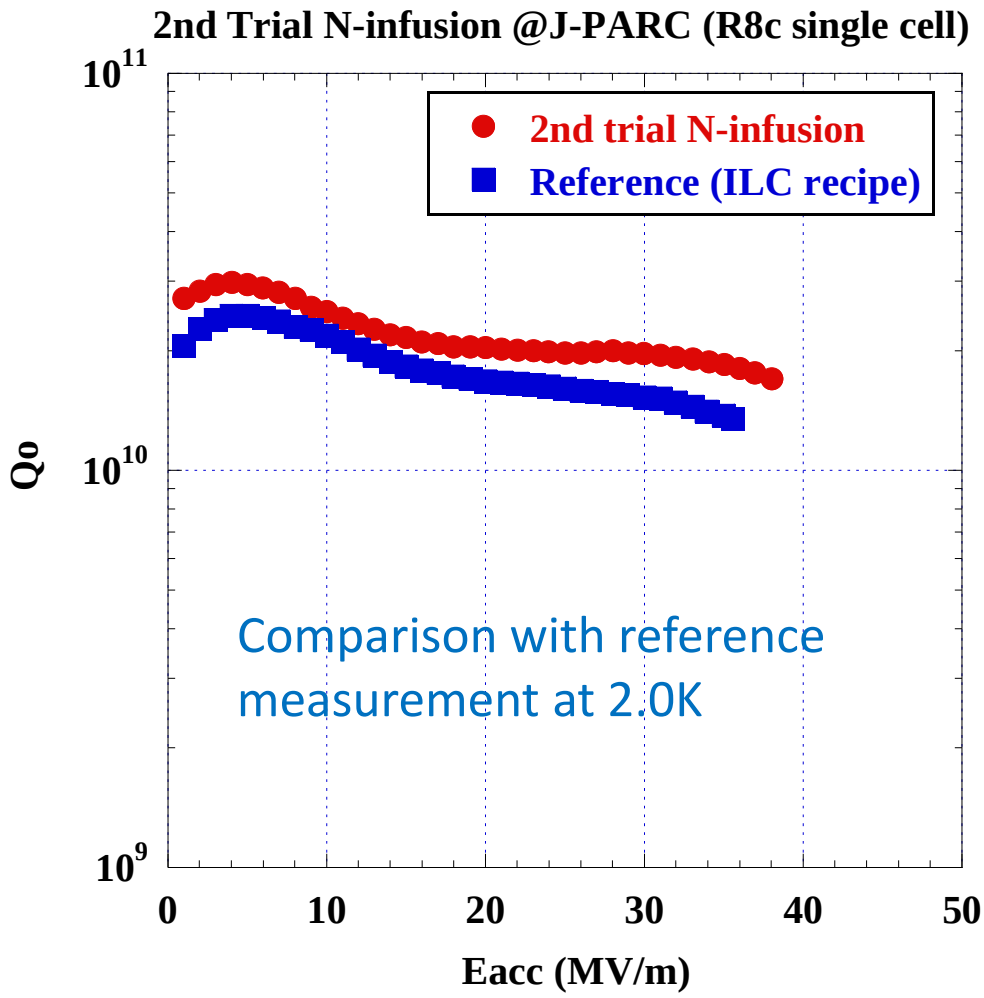




- Additional N-infusion process improved flux expulsion much.
- Residual resistance (@3.5MV/m) is also reduced.

Q-Eacc measurement



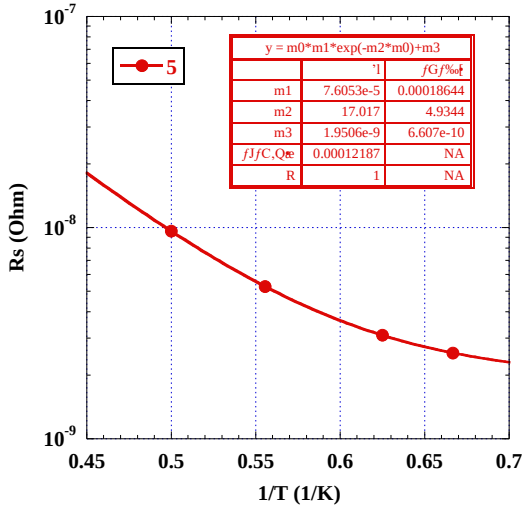


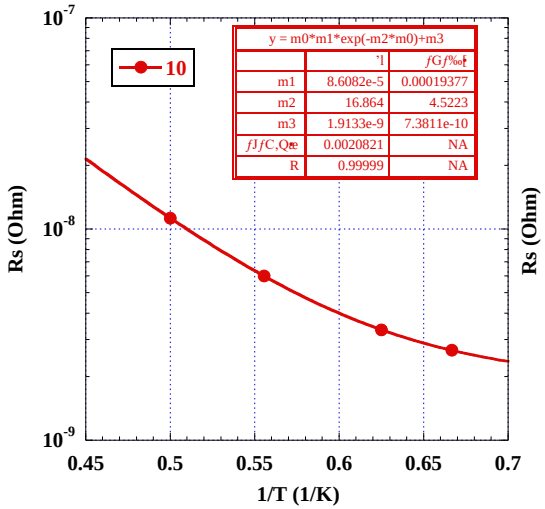
- Q-value improved for all Eacc region.
- Eacc is also improved from 36 to 38 MV/m

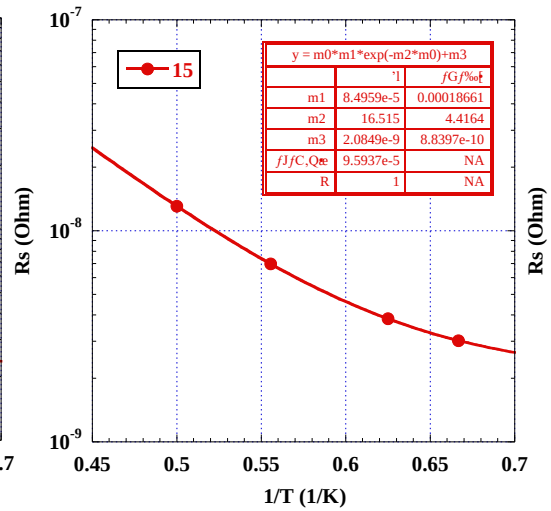
Deconvolution of R(BCS) & R_res

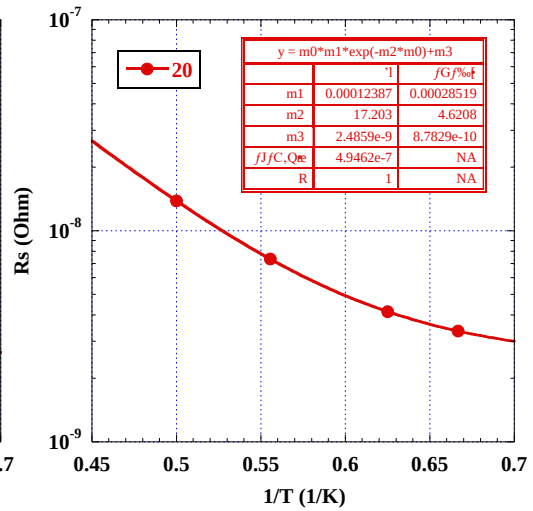
- Rs-1/T curve from each Eacc were fitted by using 2.0, 1.8, 1.6, 1.5 K data points.
- Around 10% error is assumed.

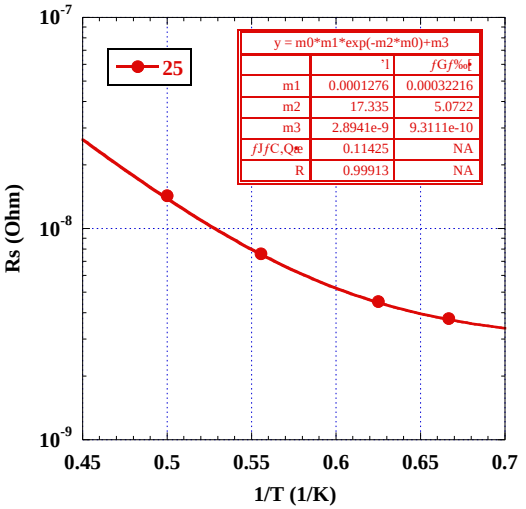
$$R_s = R_{BCS} + R_{res} = \frac{A}{T}\exp\left(-\frac{B}{T}\right) + R_{res}$$

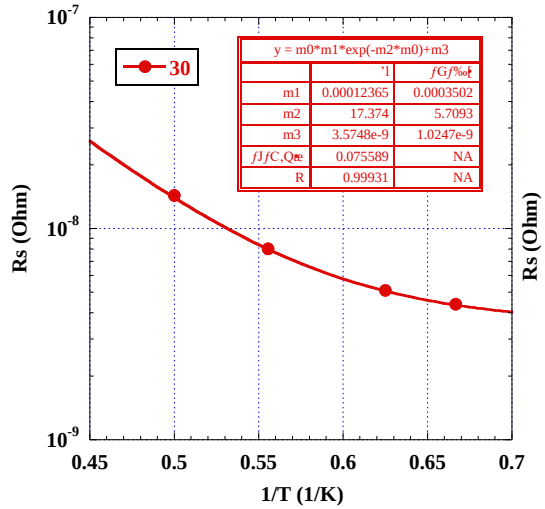


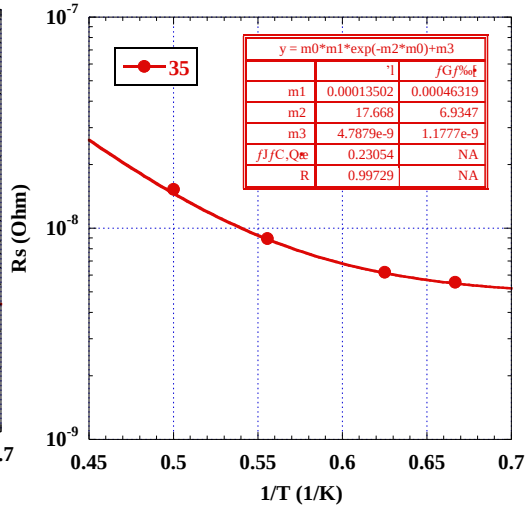




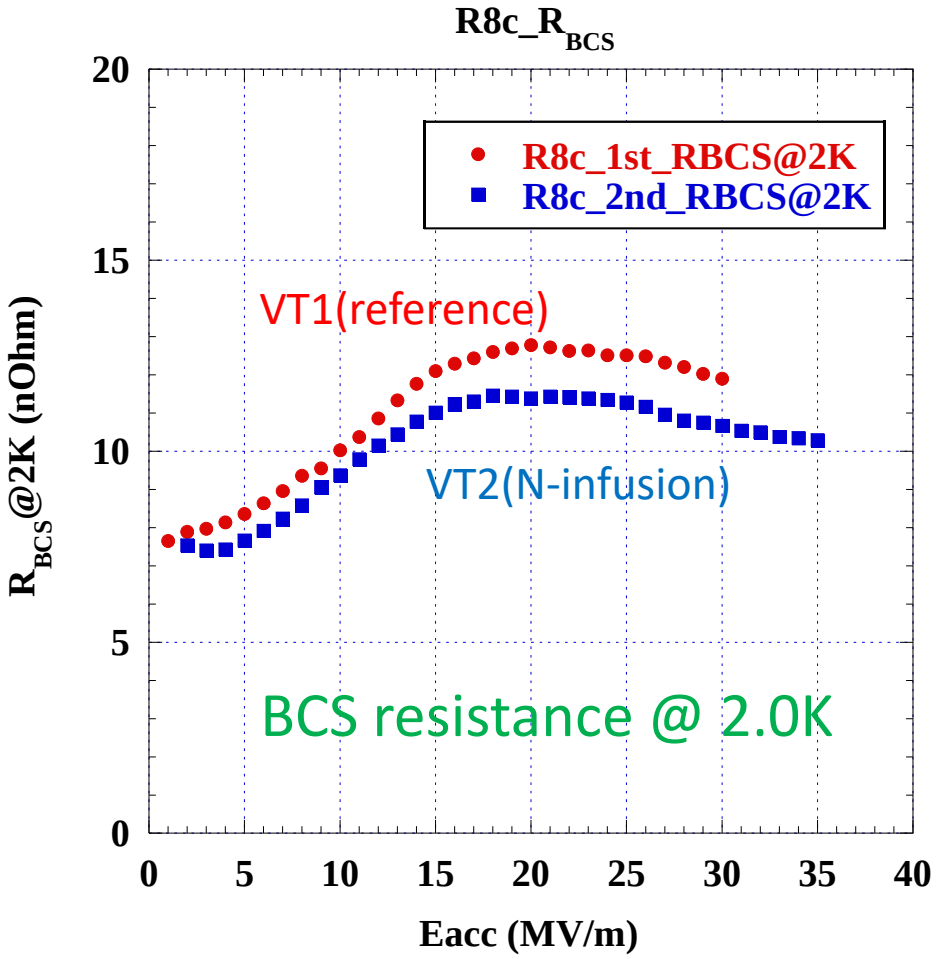


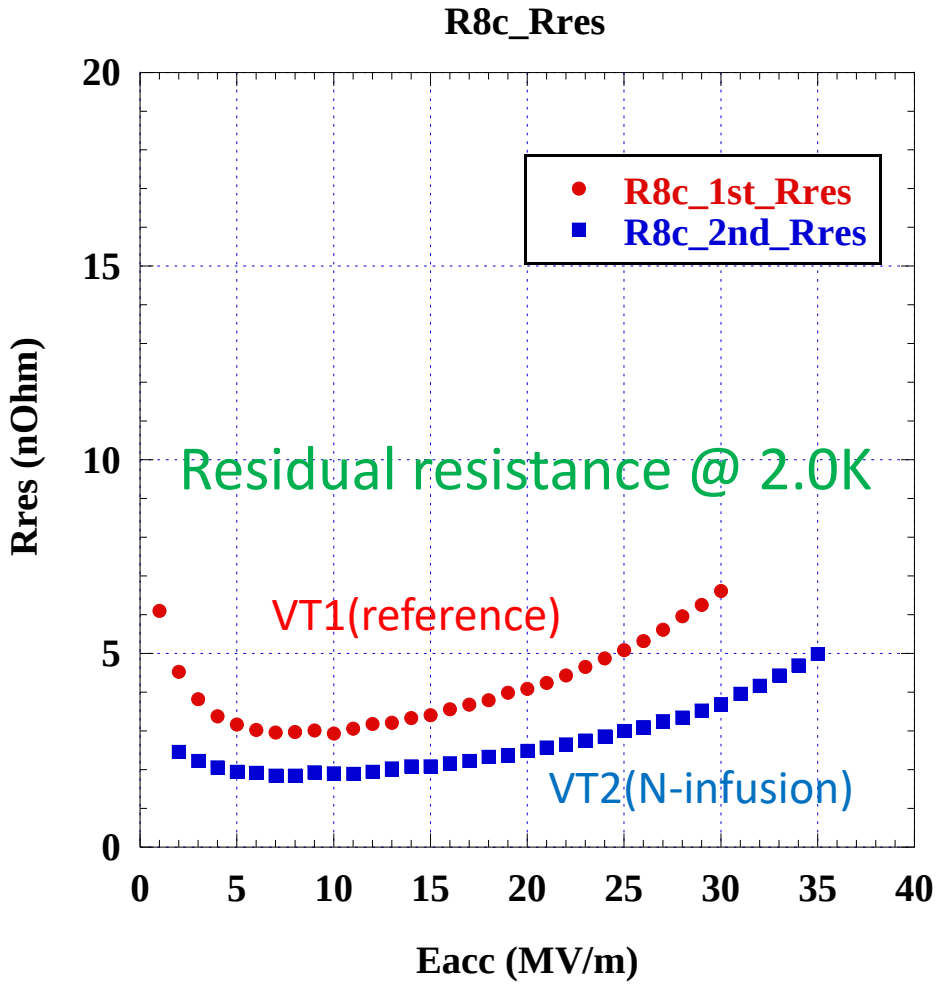






Deconvolution of R(BCS) & R_res





- BCS resistance tends to be reduced for N-infusion.
- Residual resistance was reduced to roughly half.

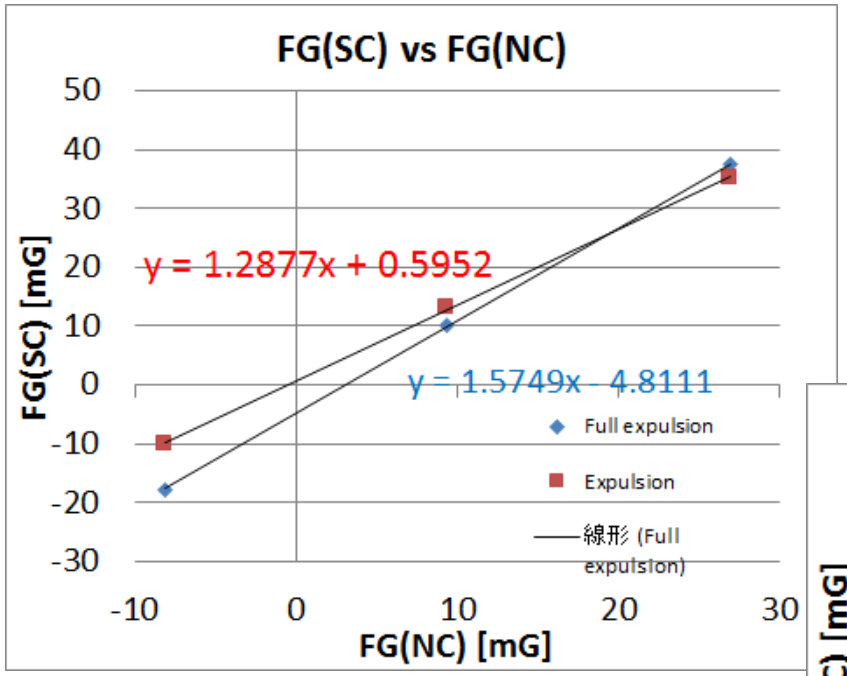
Summary

- KEK continue N-infusion study.
- We tried N-infusion with improved vacuum background condition for 120 C N-injection process.
- Results shows successful N-infusion performance of cavity. (At lease, high field Q-slope can not seen.)
- Even in the case furnaces have some contaminations, better vacuum pumping system can cure cavity degradation.

Backup slide

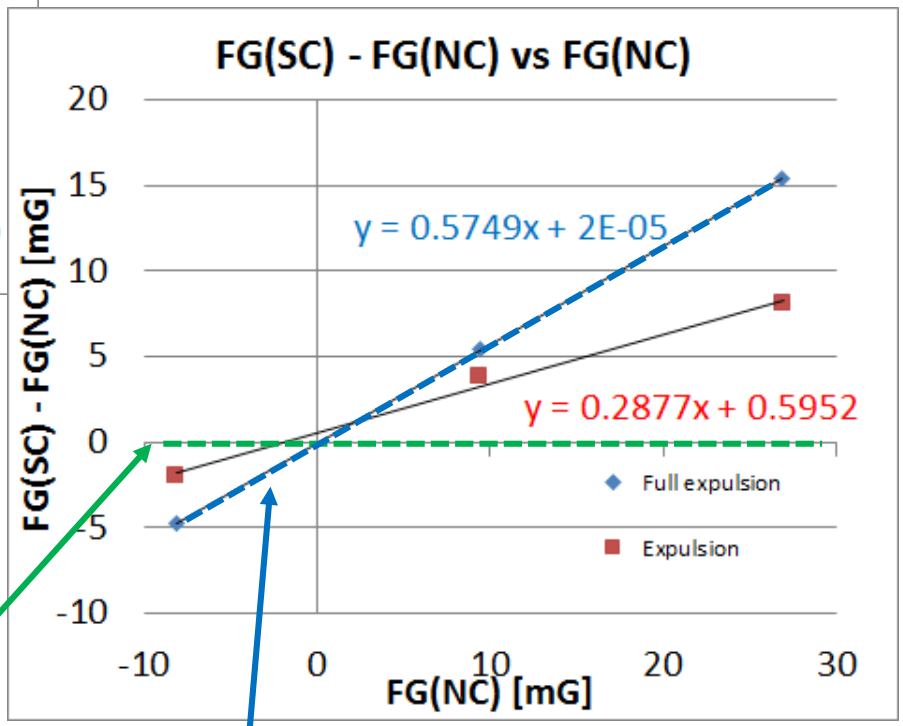
Example of flux expulsion measurement

Full expulsion
Add external field after cooling down.



Subtract FG(NC) to see expulsion signal clearer

Slope
Full expulsion: 0.57
Measurement: 0.29

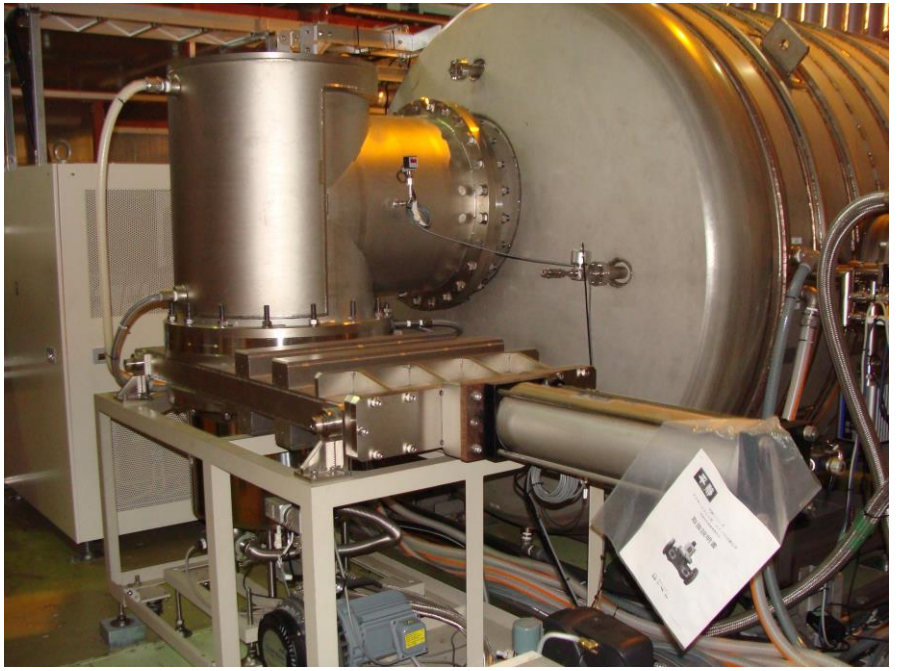


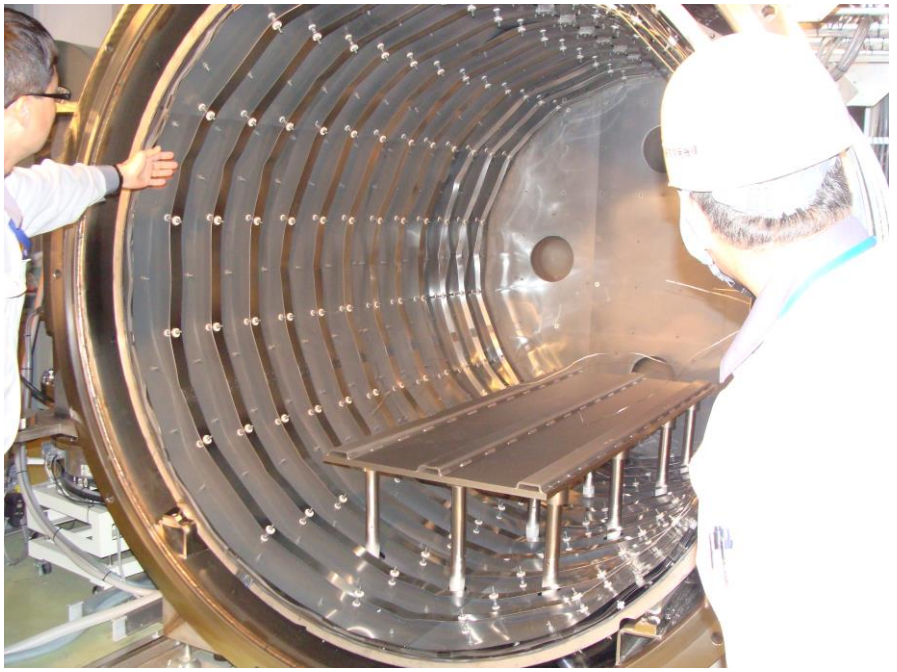
Slope
Full expulsion: 1.57
Measurement: 1.29
※ ”1.57” agree well with simulation for our cavity

Zero slope = No expulsion

Slope of “0.57” = 100% expulsion

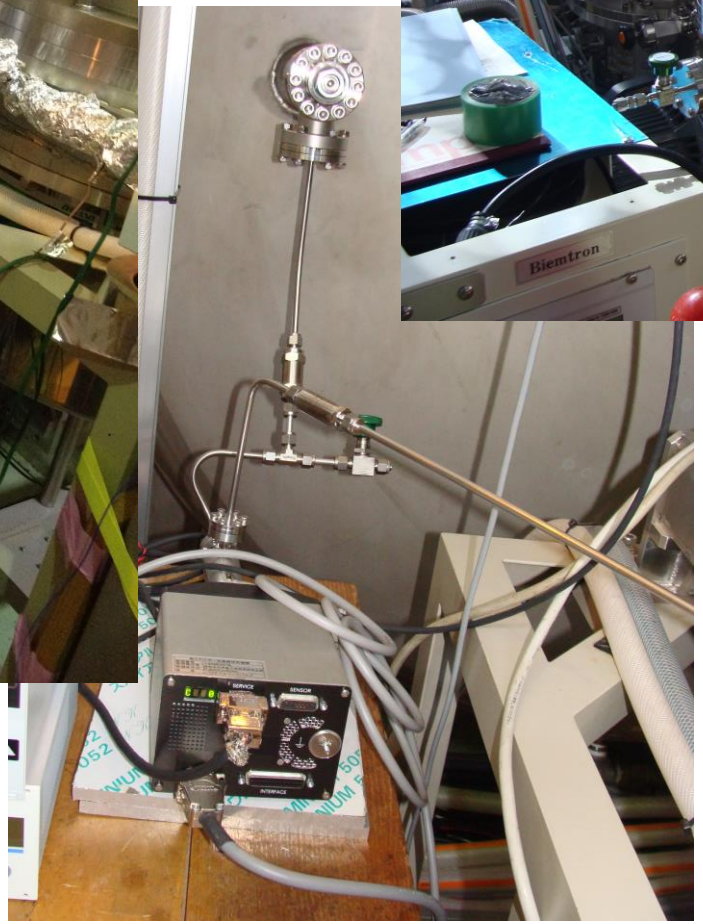
N-dope/N-infusion trial using J-PARC furnace





- J-PARC has oil-free furnace with cryo-pump(10,000 litter/sec) and three TMPs(3,000 litter/sec x 3).
- Vacuum level reached to ~1e-6 Pa.
- Normally used for degassing of beam-duct and components.

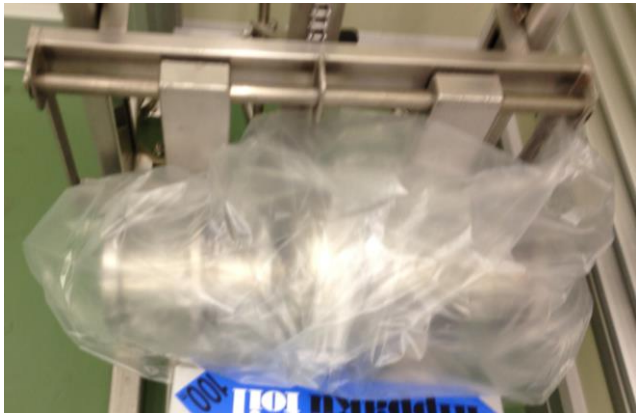
N-injection system

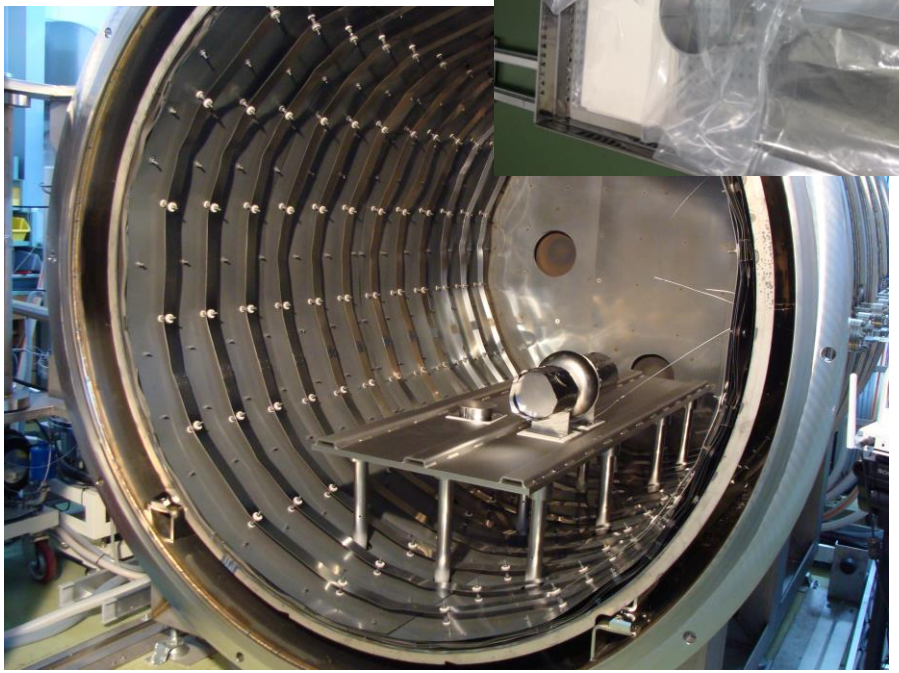


- Nitrogen pressure is controlled by variable leak valve
- Cryo-pump is closed and TMPs are off during N-injection. Small pump set, TMP and scroll, pump the furnace.

Cavity preparation for heat treatment

- HPR (flange open) 2 hours, drying one night
- Cavity was double-packed inside class-1000
- Nb cap & foil was ultrasonic cleaned with degreasing, drying inside class-10, packed inside class-1000
- Transport to J-PARC
- Setup into J-PARC furnace

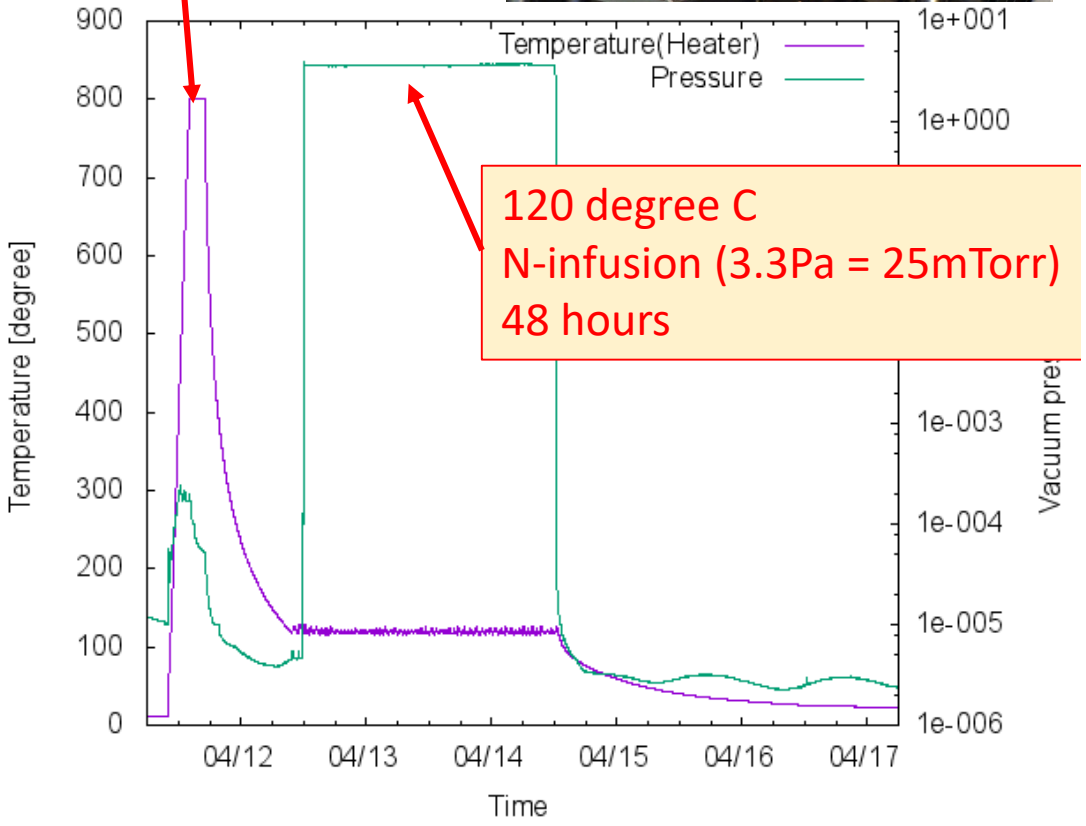




1st N-infusion(FNAL parameter)

800 degree C
3 hours

120 degree C
N-infusion (3.3Pa = 25mTorr)
48 hours



- Pressure is stabilized less than 0.1Pa
- Different vacuum gauges at different positions show around 0.3 Pa offset.
- Temperature is stabilized with +/- 5 degree.
- Temp. offset ~ 5 degree between furnace and jigs.