기초과학연구원
Institute for Basic Science

INSTITUTE for
RARE
ISOTOPE
SCIENCE

중이온가속기연구소

Prototyping of Single Spoke Resonators(SSRs) for RAON

- Hoechun Jung -

SSR cavities are on 2nd prototyping

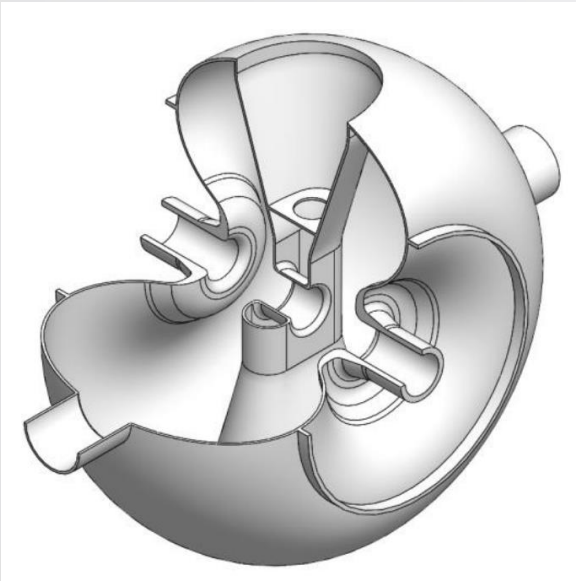
	QWR	HWR	SSR1	SSR2
Optimum β	0.047	0.12	0.3	0.51
$f\ [MHz]$	81.25	162.5	325	325
$L_{eff}(=\beta_o\lambda)[mm]$	173.5	221.5	276.9	470.8
$R/Q\ [\Omega]$	469	295	233	290
E_{peak}/E_{acc}	5.7	5.2	4.1	3.7
$B_{peak}/E_{acc}\ [mT/(MV/m)]$	10.4	9.0	6.9	7.7
Epeak	34.8	34.3	34.9	32.2
Bpeak	63.4	59.4	58.7	67.0
E_{acc} [MV/m]	**6.1**	**6.6**	**8.5**	**8.7**
V_{acc} [MV]	**1.06**	**1.46**	**2.35**	**4.1**
$Stored\ Energy\ [J]$	4.7	7.1	11.6	28.3
QRs	18.1	36.8	92.2	112.9

Installed in the SC linac already

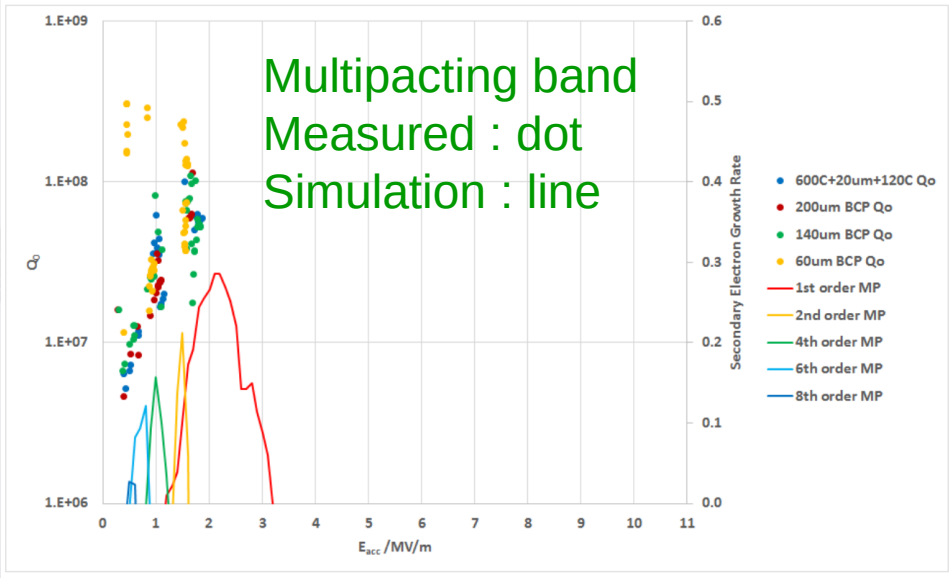
Test for 1st SSR cavities & 2nd prototyping is starting
→ Check & improve all designs & processes.

SSR Development with TRIUMF (Balloon Concept)

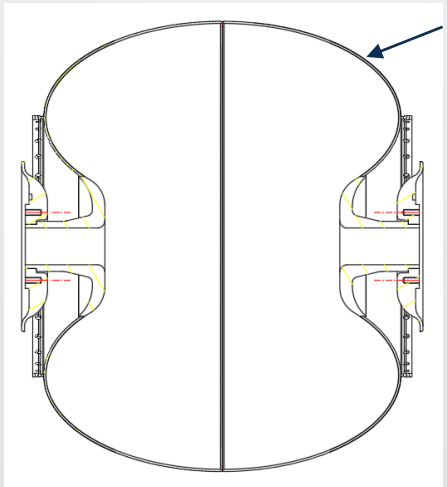
Design suggestion (2015. 07)



Test @ TRIUMF (Bare: 2018. 01, Jacketed: 2019.07)



- Cost effective design:
  Just 4 ports, minimized # of stiffeners,
  less fabrication process (forming, welding)
- Narrower multipacting band: < 4MV/m
- But deep drawing for half shell is not easy.
  → Plan B: Minimum straight + two shells



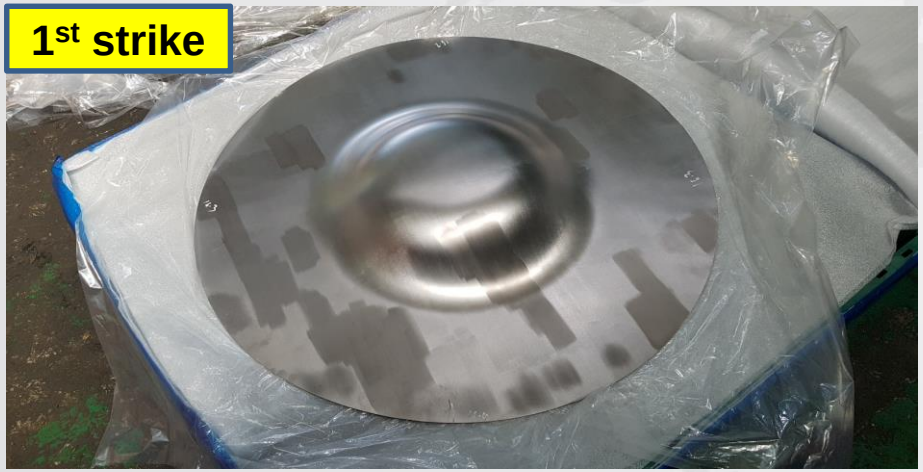
Deep Drawing Process for a Half Shell

Depth after pressing

[mm]	SSR1	SSR2
Depth	218	277

Half shell after machining

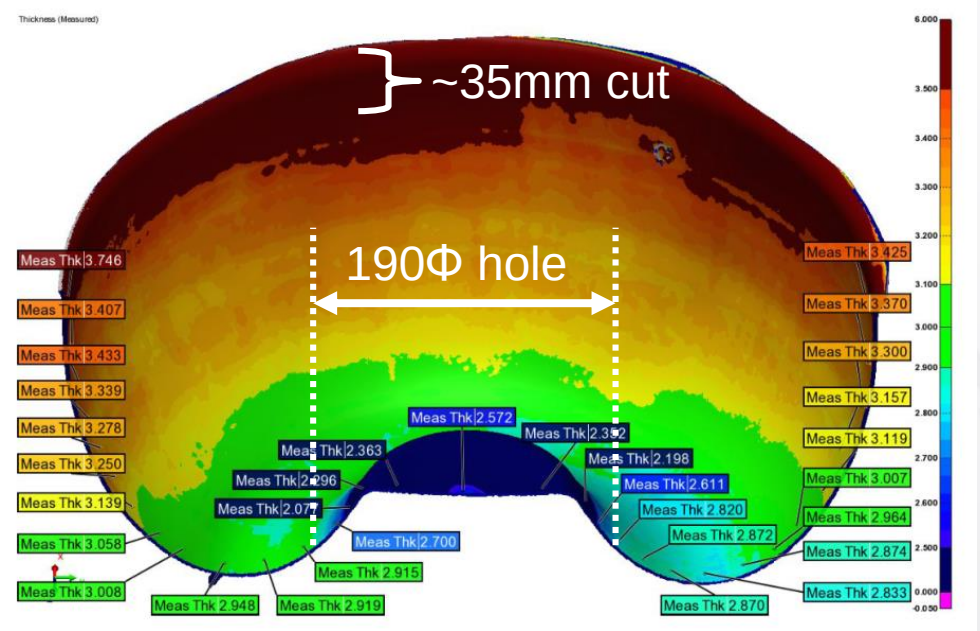
[mm]	SSR1	SSR2
height	173	243



Thickness of the Half Shell

Measuring using
3D laser scanner
(Hexagon 8535-7)

Measured thickness of a half shell

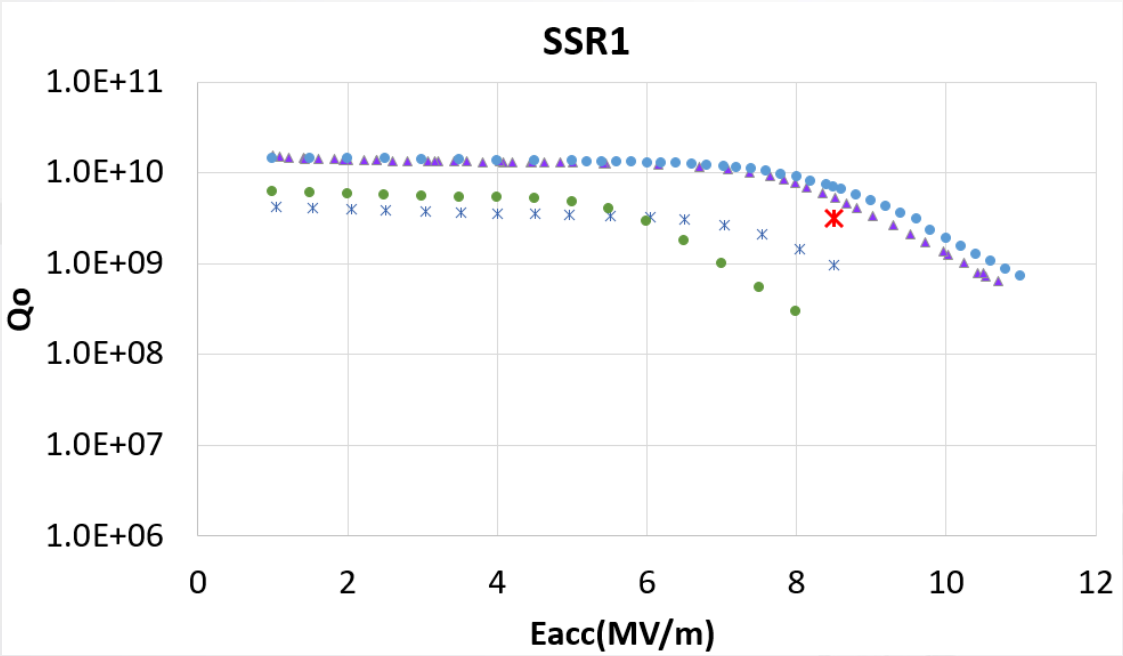


3.2T 900Φ plate
→ 2.9~3.4T(~10% changed) 500Φ half shell

➔ Press dies and drawing process are well optimized
➔ Make balloon shapes successfully

Tests for 1st Prototypes

SSR jacketed cavity

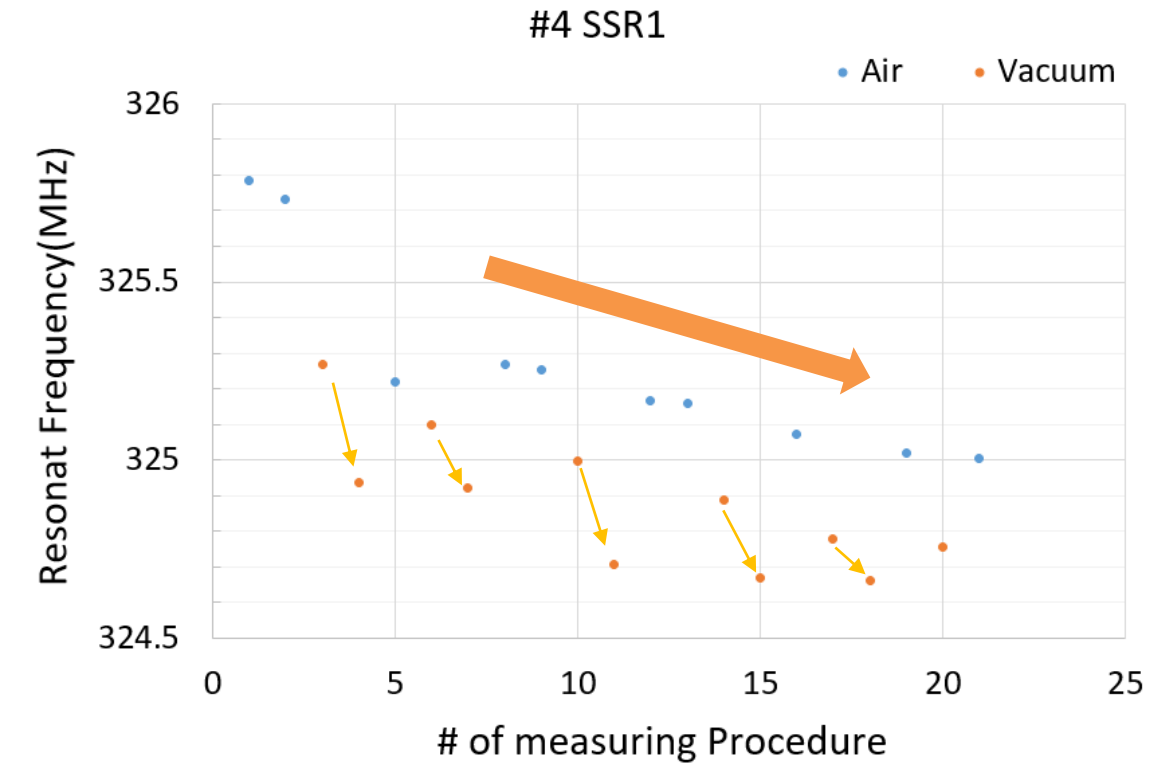


◆ 2 of 4 SSR1 cavities passed the qualification
One SSR1 cavity is failed with strong field emission
Another one is failed with thermal quench
➔ Will be tested in a cryomodule

◆ 6 SSR2 cavities are fabricated
Stocked about 1~2 years in air, cleanroom after HT baking
2 of 6 are tested without additional HT baking & will test again with additional HT baking
4 of 6 are tested with additional HT baking
➔ Check the process & contamination (foreign materials, particles, gas)

Checking Frequency: Plastic Deformation during Vacuum

	#4		
	air	vacuum	
1	325.7853		Jacketing
2	325.7329		light BCP
3		325.2665	Cleanroom assembling
4		324.935	After VT
5	325.218		
6		325.1	Cleanroom assembling
7		324.92	After VT
8	325.2678		HT baking
9	325.2547		light BCP
10		324.9955	Cleanroom assembling
11		324.7051	After VT
12	325.1656		HT baking
13	325.1581		light BCP
14		324.8891	Cleanroom assembling
15		324.6696	After VT
16	325.0727		light BCP
17		324.7792	Cleanroom assembling
18		324.6611	After VT
19	325.0199		light BCP
20		324.7557	Cleanroom assembling
21	325.0042		light BCP



Resonant frequencies of 1st prototypes are continually decreased
: Mistake of making vacuum without fixing the beamports

Holding Jig for Vacuum

Table 10: Stress on cavity and jacket with various conditions at or near room temperature

RF, He, Iso Pressure (bar)	CM situations	Cryostat situations	Lab test situations	Beam Pipe Fixed (MPa)		Beam pipe Free (MPa)	
				Niobium	SS316L	Niobium	SS316L
0, 2, 0	Cavity cooldown	Cavity cooldown		36.9	64.5	34.9	65.7
0, 1, 0	He purge	He purge		18.5	32.2	17.4	32.9
1, 2, 1			pressure test	18.5	32.2	17.4	32.9
1, 0, 1	He - pump			18.5	32.2	17.4	32.9
			He leak chk				
0, 1, 1		RF pump		18.3	negligible	44.8	37.5
			RF leak chk				
1, 1, 0	Isolate leak chk			9.7	33.9	33.1	34.1
0, 0, 1		He, RF-pump		9.7	33.9	33.1	34.1
			RF,He leak chk				

Handling Jig
for cleaning process
in the vender

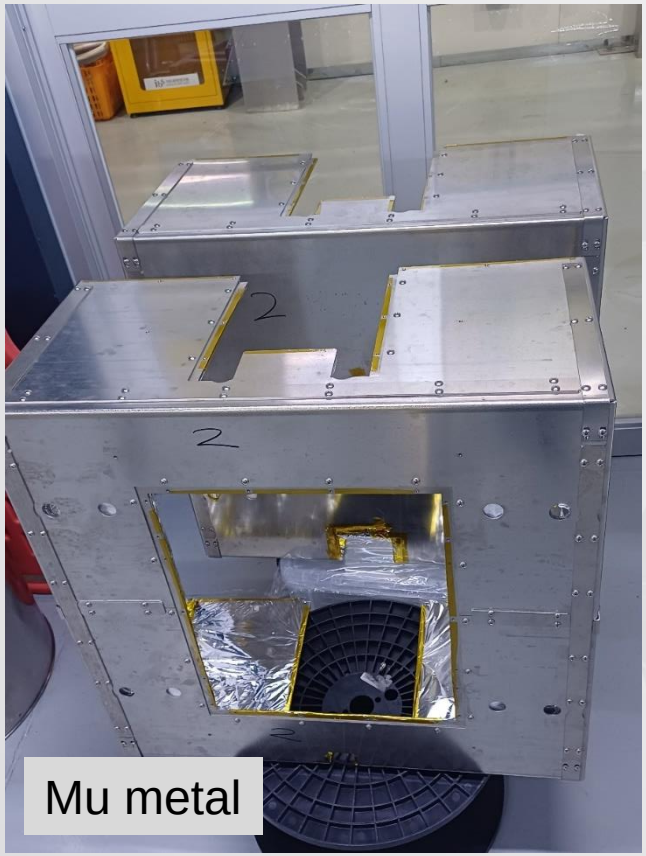
Fixing Jig
for vacuum !
Not only for cavity cold Test

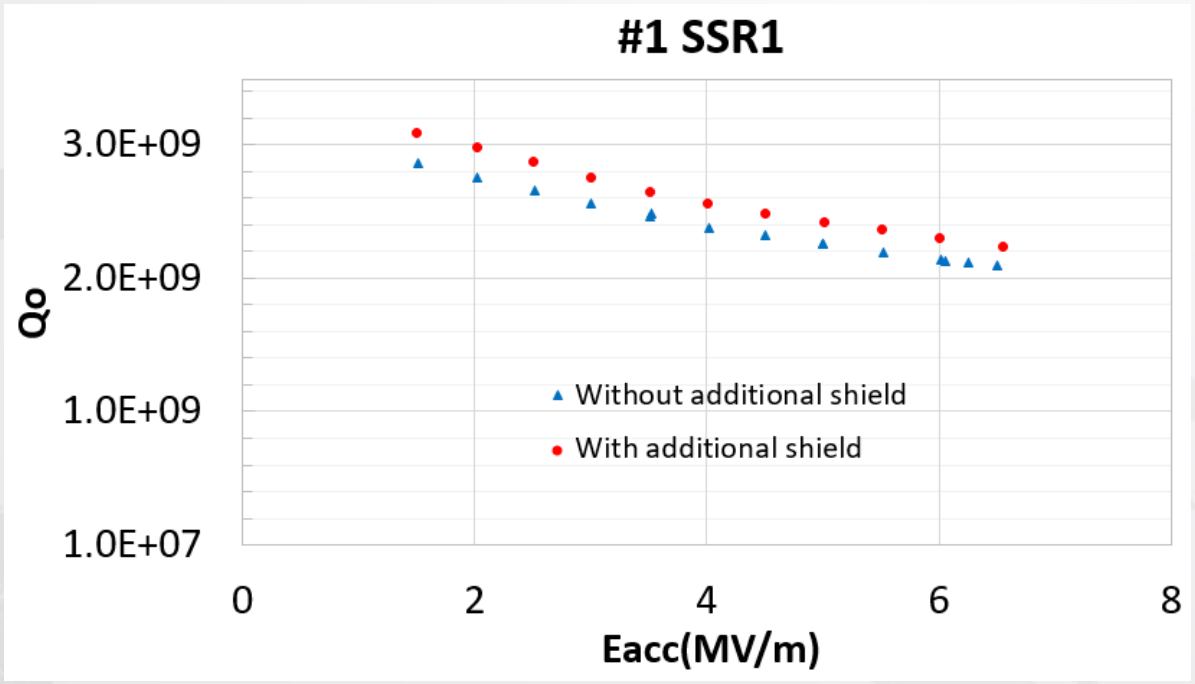
→ Send this jig to the vender

→ Fix beamports for leak test, clean assembly in the vender

Improved Q Factor with Additional Magnetic Shield

Additional magnetic shield





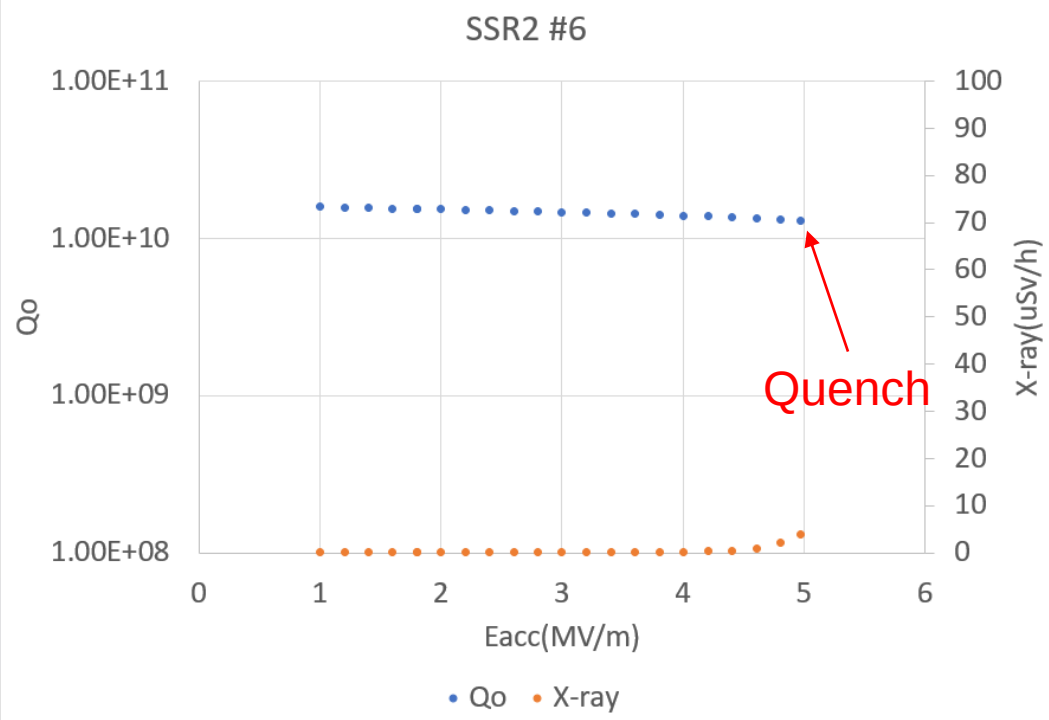
Q factor of some SSR cavities at the low gradient is lower than the expectation

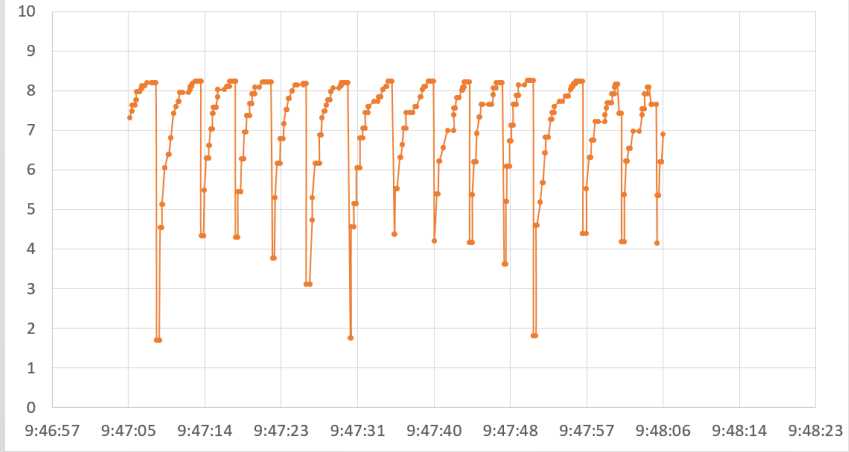
→ Checked the geomagnetic field in the cryostat(13.6 ~105.6 mG)

➔ Reduced the geomagnetic field with the additional shield(2.1~ 9.8 mG)

➔ Decrease of surface resistance is checked with the magnetic shield by 3nΩ

Thermal Quench





Thermal Quench with no or low x-ray

→ Metallic foreign material
or metallic particles
or poor welding

→ Visual inspection inside the cavity
: no evidence of foreign materials
or poor welding
but particles from the test coupler

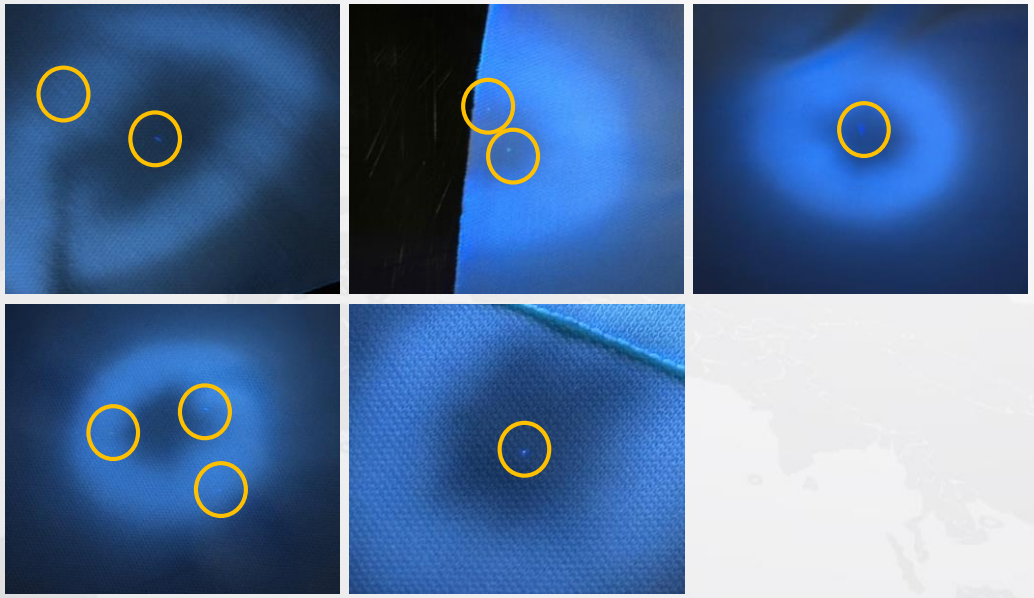
➔ Will be tested again after
light BCP + HPR

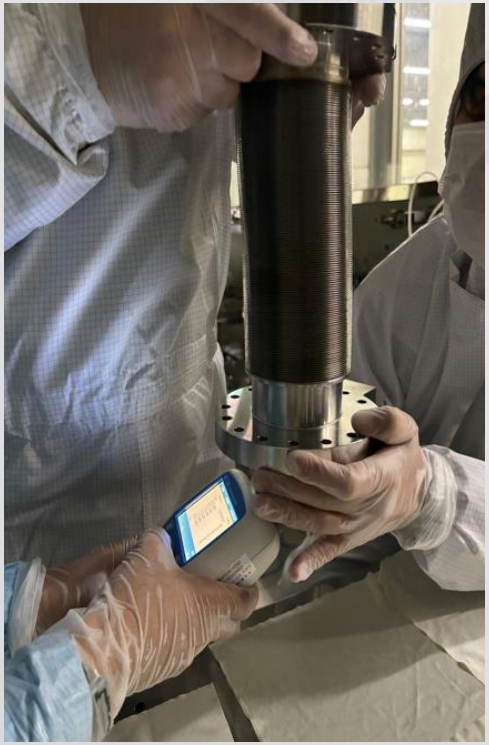
But still worry about foreign materials

➔ Heavy BCP+ HT baking
if there is no improvement

RF level: Slow rising & Fast falling with amplitude locking

Contamination: Particle (test coupler)





Thermal quench

→ Visual inspection of cavity & test coupler

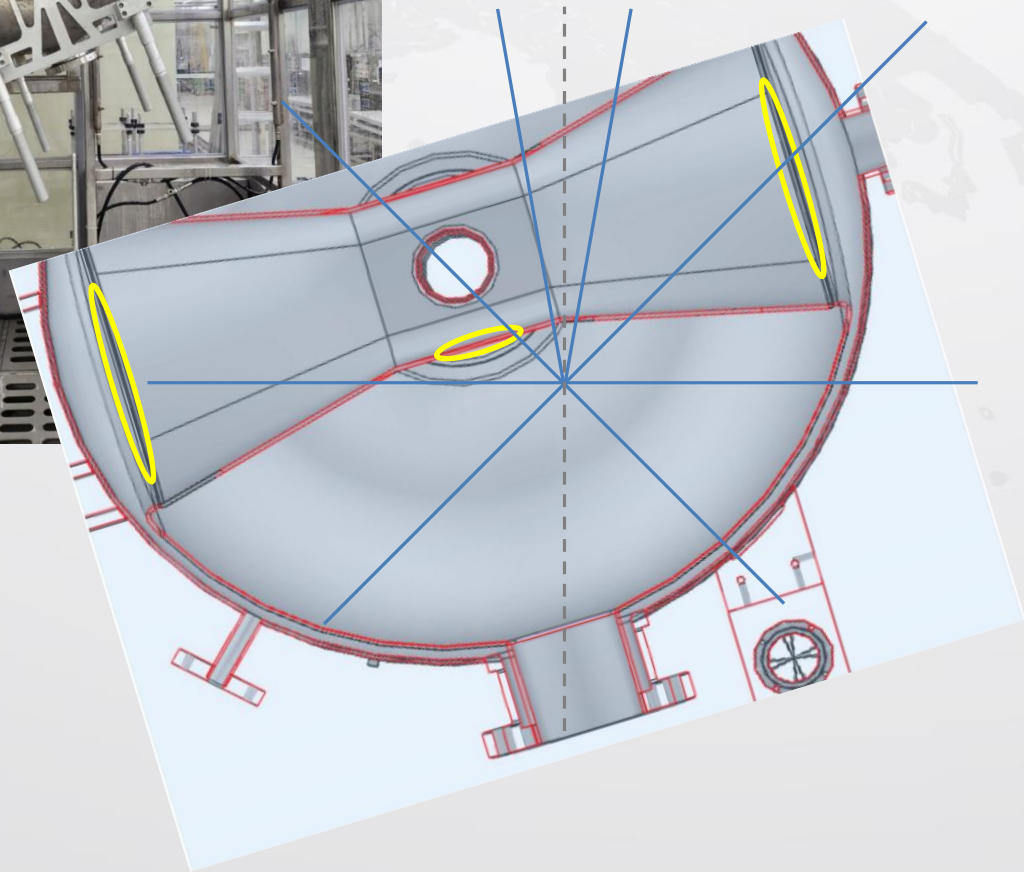
→ blowing & check particles

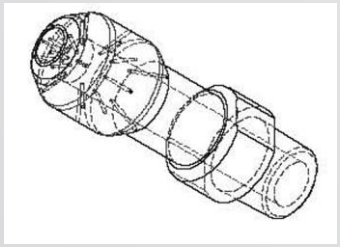
→ Assembling with cavity when no more particle

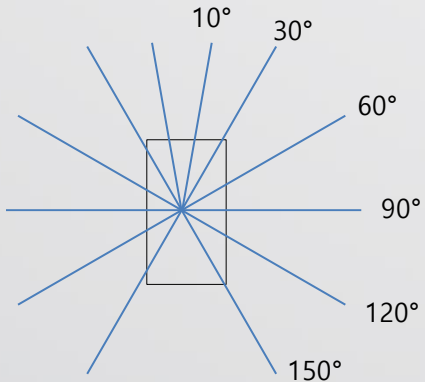
Particles with N2 blowing in Class 10 cleanroom

	0.3um	0.5um	1um
1st blowing	5	3	0
After 3 times	0	0	0

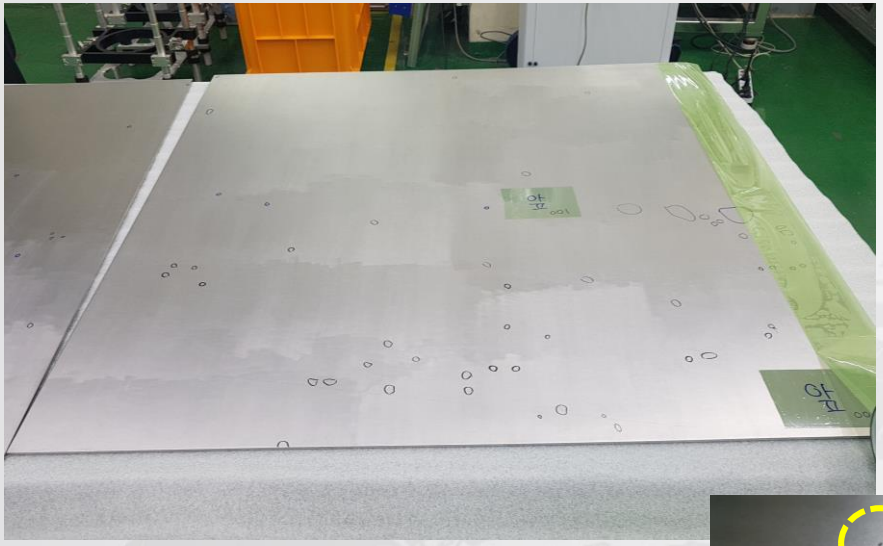
Reduce grey zone: cavity tilted ±20° & Nozzles Optimization







Contamination : Foreign Material

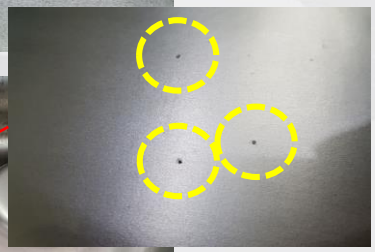


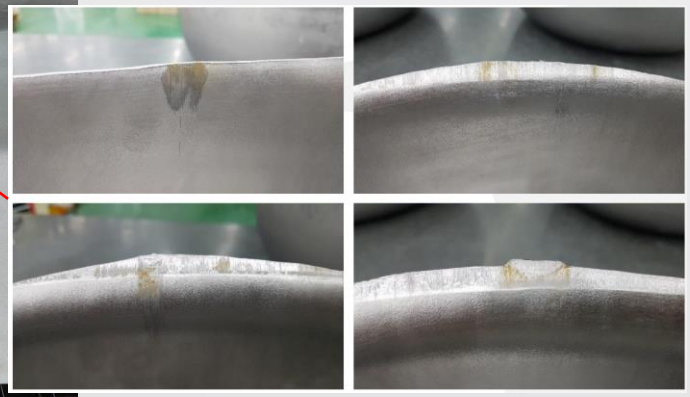
Nb Plates & Half shells : Dozens dents and dusts are founded after soaking

→ mechanical & chemical polishing

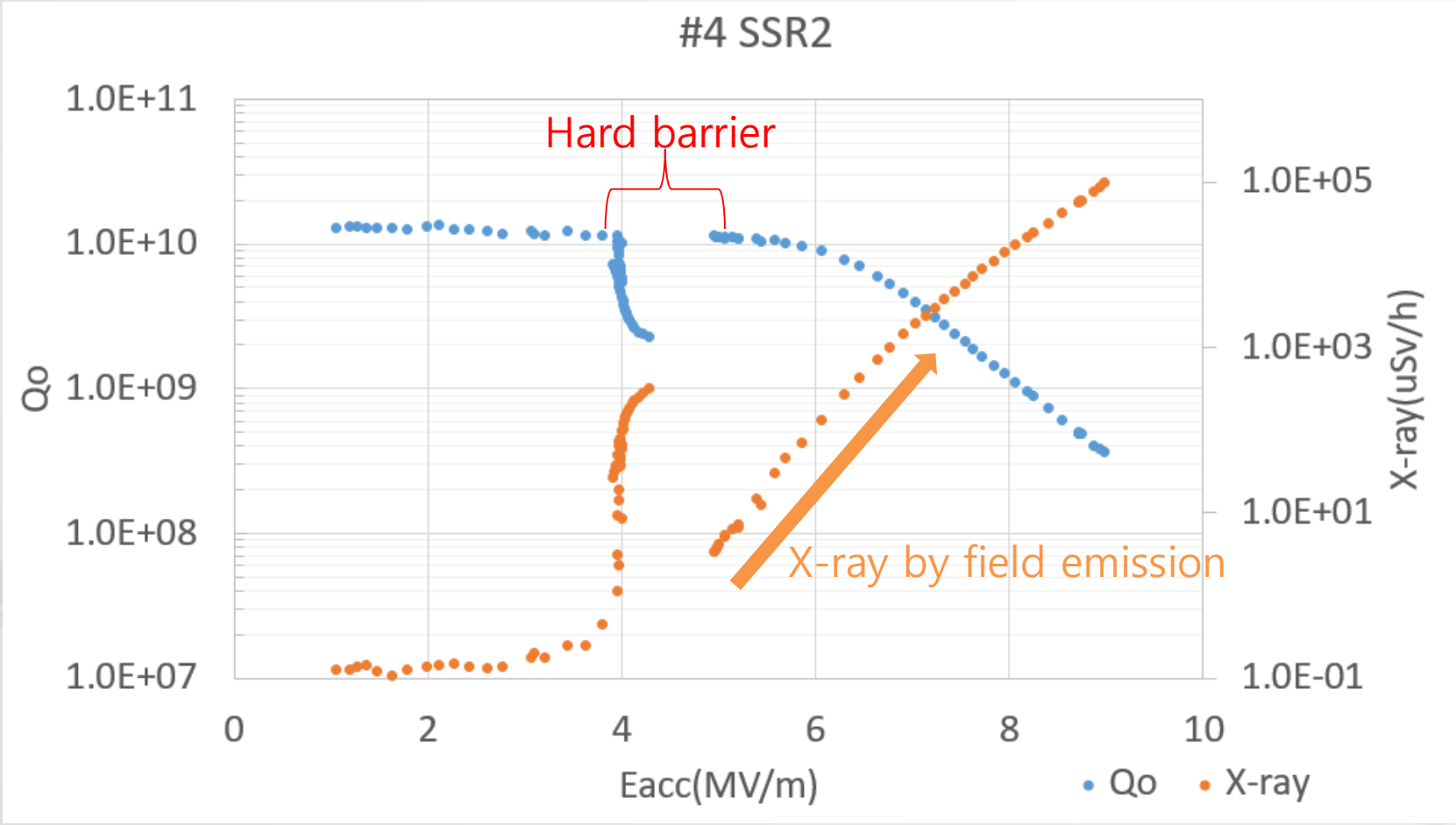
→ Could not be removed perfectly

➔ Need more cleaning before & during the process
in the vender & sub-vender





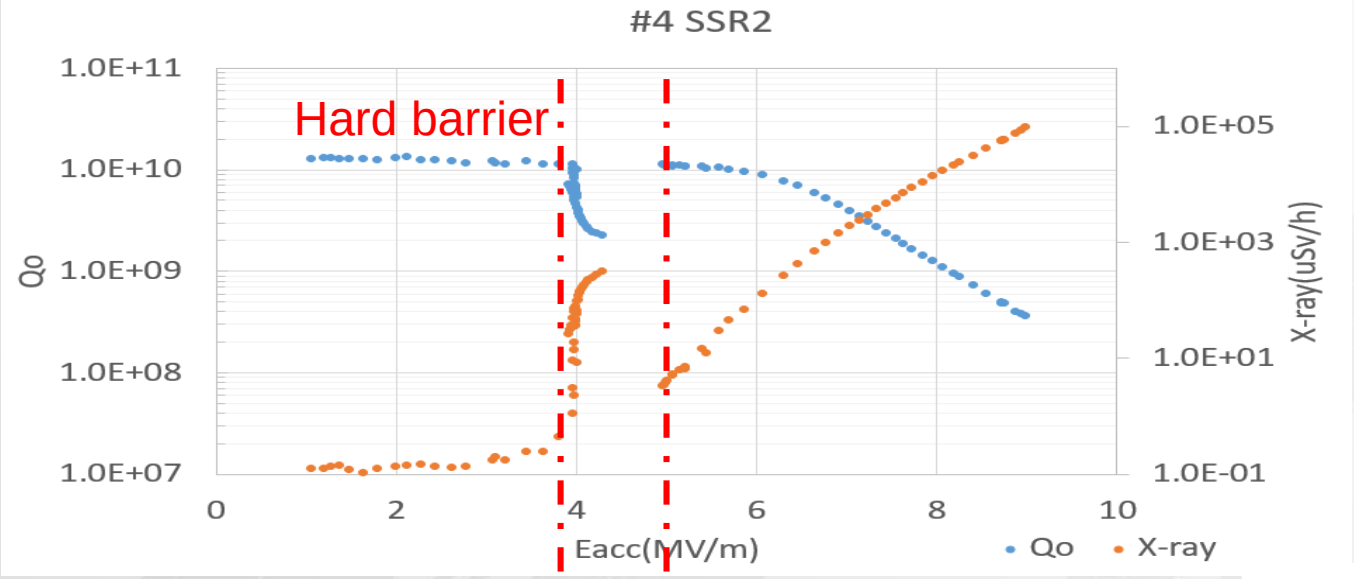
Hard Barrier: Multipaction at High Gradient

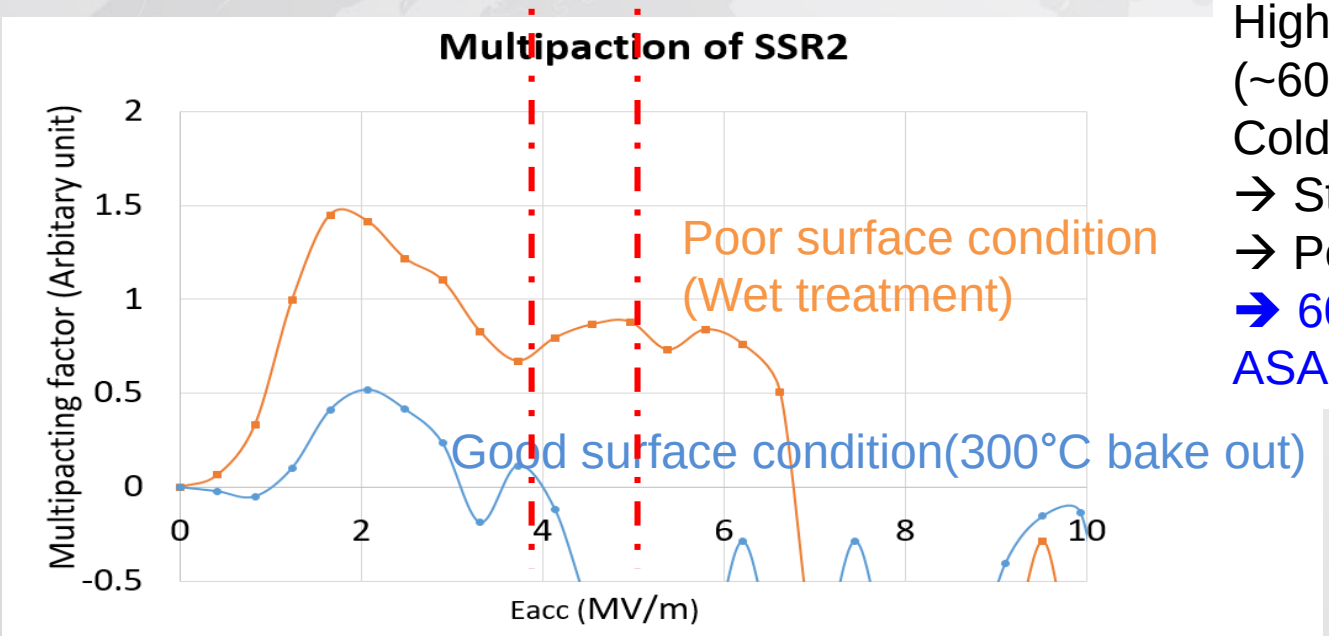


Multipaction → acceleration → impact → x-ray & secondary electrons

?

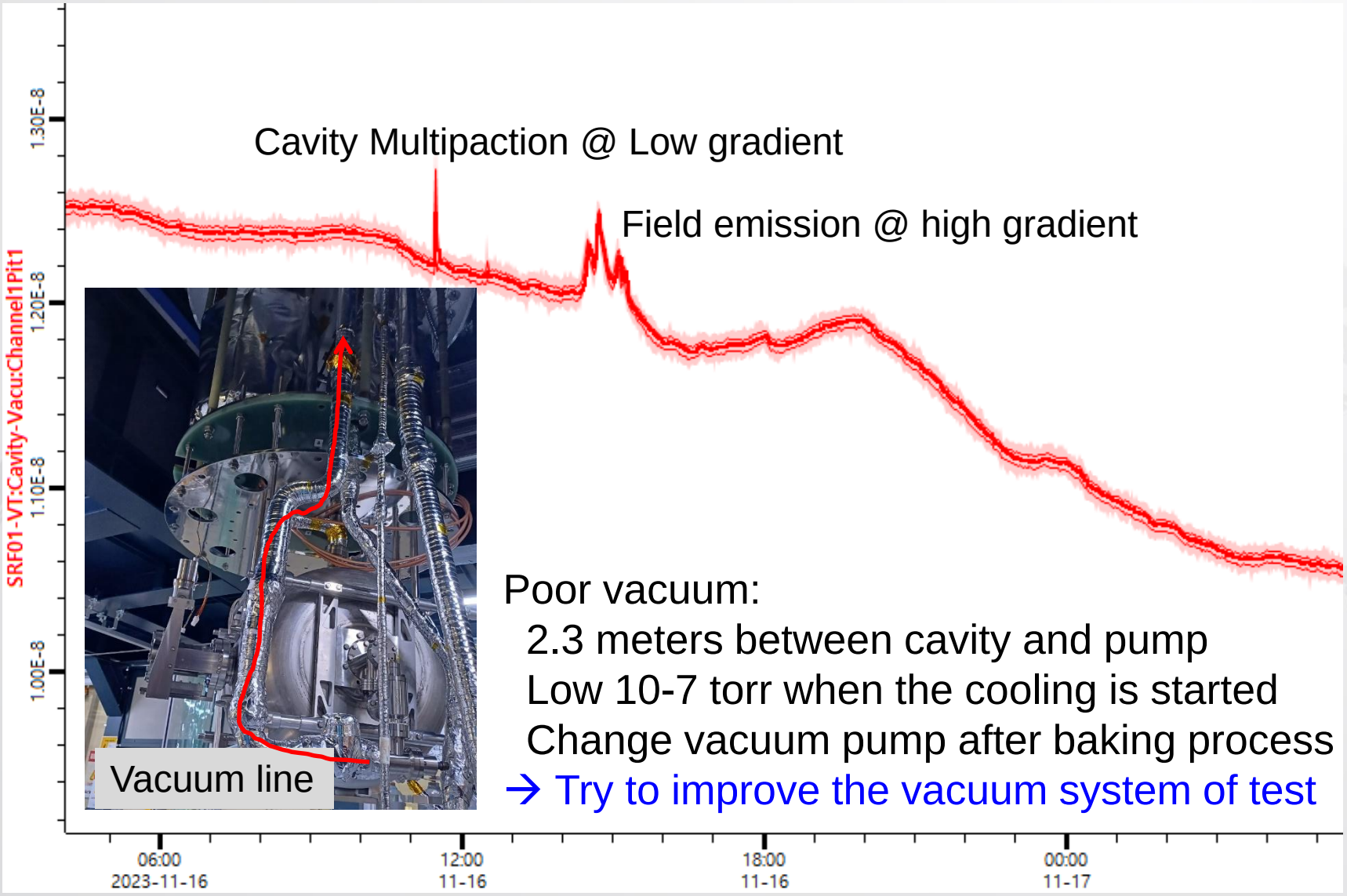
Hard Barrier due to Poor Surface Condition?





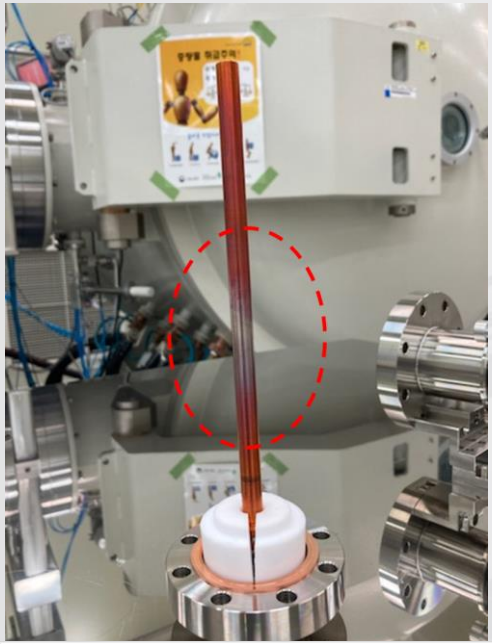
High Temperature baking (~600°C) : November, 2021
Cold Test : September, 2023
→ Stocked in air, cleanroom
→ Poor surface condition ?
➔ 600°C baking & test again ASAP

Contamination: Gas, Vacuum Spike



Thank you
for your attention

Test Failure due to Test Coupler Problem for HWR Mass Production



High failure rate of HWRs qualifying test in early stage
- More than 60% failure
- Damaged surface of test couplers is checked
- After additional rinsing and higher temperature baking failure rate is reduced to around 20%
- Total pass rate with 30mm couplers is less than 70%

More than 90% pass rate with new test couplers
- 12 new test couplers(40mm) are fabricated
- 51 successful cases among 56
- Pass rate is obviously increased.
- There is no evidence for surface damages