Surface Treatments in the RAON

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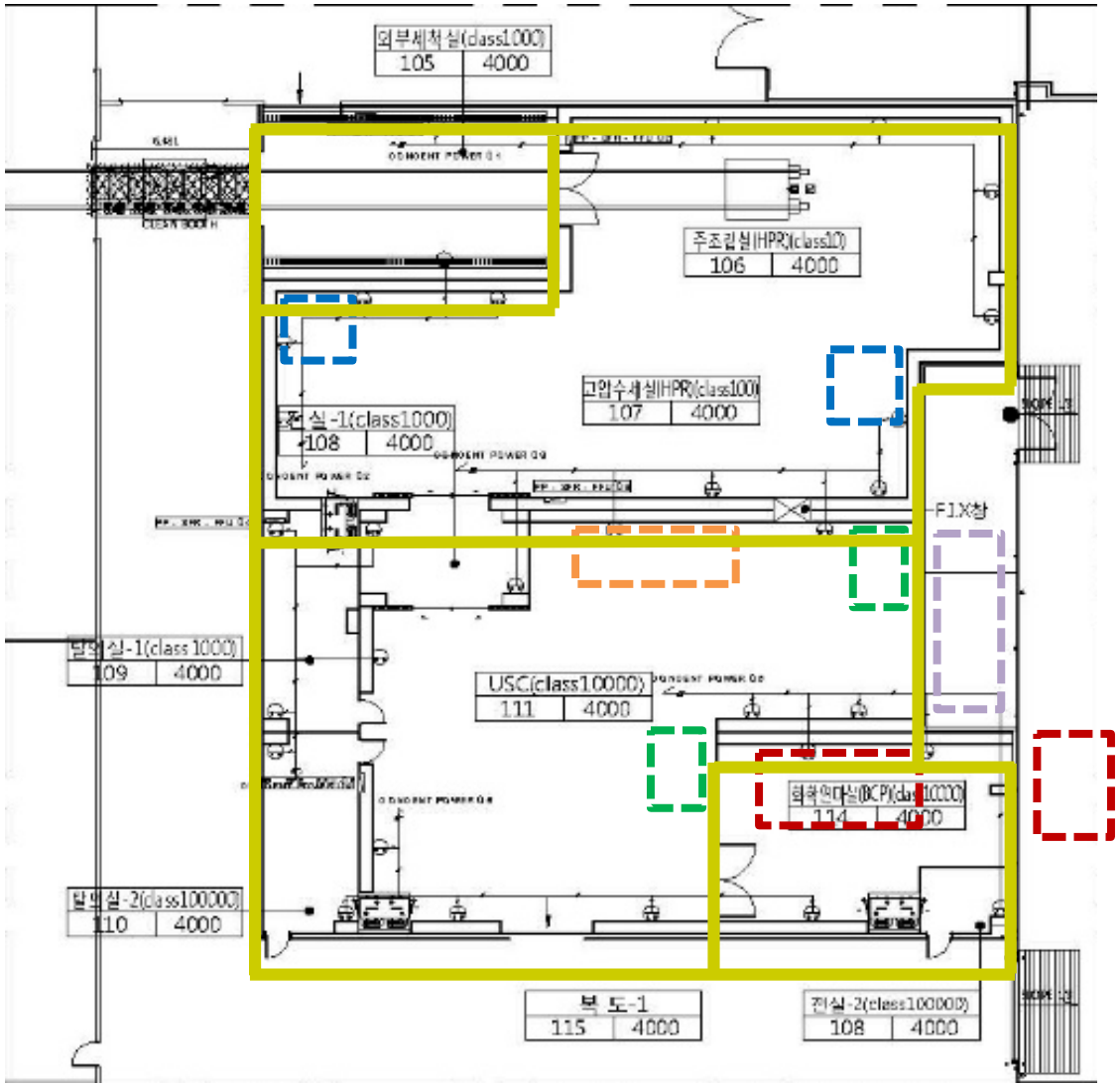
Superconducting Linac Development Team

RISP

Contents

- **Facilities** of Surface Treatments for RAON
- **Procedures** of Surface Treatments for RAON SCL2 cavities

Layout of surface treatments area



◆ **Cleanroom(30x34m)** ;98x112ft

- DI water Supplier
- Ultrasonic Cleaning
- Buffered Chemical Polishing
- High Pressure Rinsing
- High Temp. Vacuum Furnace

Quality of DI water for surface processing

- Requirements

	Unit	Target
Resistivity	MΩ/cm-25℃	over 17.5MΩ
Particles	0.5㎛, EA/㎖	below 10~20EA/㎖
Bacterial	EA/㎖	below 0.01EA/㎖
T.O.C.	ppb	below 10ppb
DO	ppb	below 50ppb
ION(Fe, Cu, Al, Na)	ppb	0.1~0.5ppb

- Measured (vendor)

↙ Improve Ion exchange resin

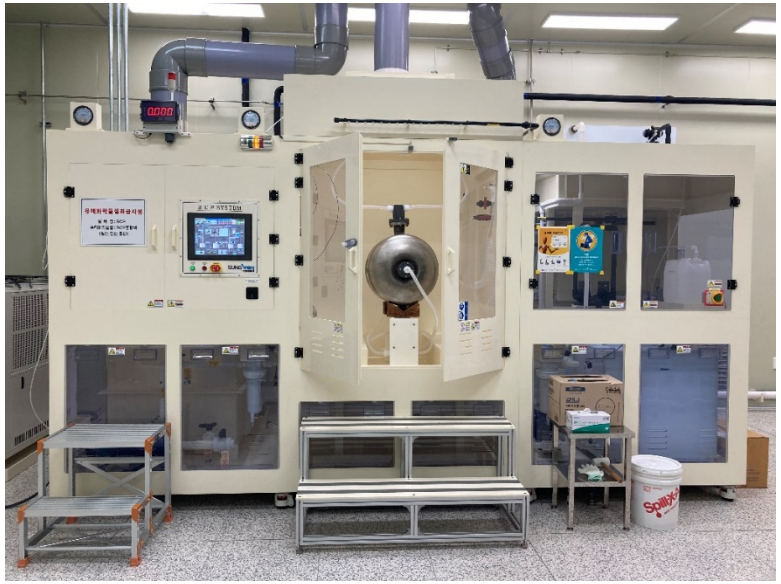
	2019-Sep.		2019-Dec.		2020-Mar.		2020-Aug.		2021-Jan.		2021-Jun.		2021-Jul.		2021-Aug	
	Supplier	HPR	Supplier	HPR	Supplier	HPR	Supplier	HPR	Supplier	HPR	Supplier	HPR	Supplier	HPR	Supplier	HPR
Resistivity	18.2	4.5	17.8	16.0	18.1	15.6	18.1	12.7	18.1	15.8	18.01	17.35	18.1	17.16	18.1	17.16
Particles	1	21	1	15	2	8	2	10	0	8	3	4	1	3	1	6
T.O.C.	54	66	32	34	29	34	51	56	17	17	14	14	15	17	14	15

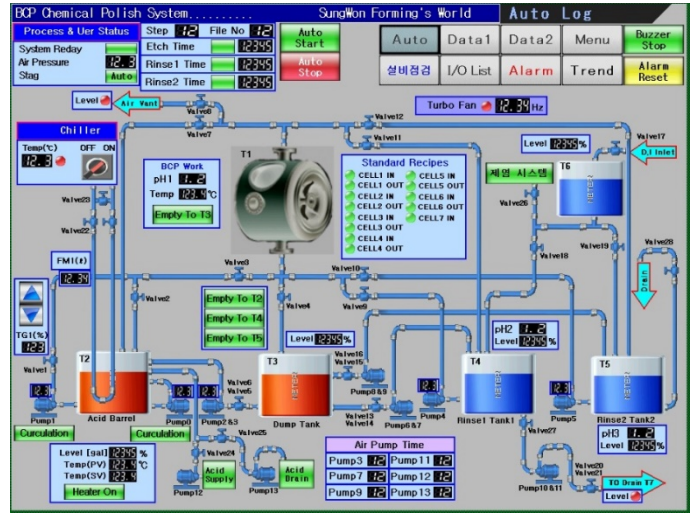
Ultrasonic Cleaning

- Class1000 (ISO6) cleanroom
- Double bath type
  - 1st bath(degreasing) : 1% liquinox
  - 2nd bath(rinsing) : DI water
- Ultrasonic Power : 1.5kW
- Ultrasonic Frequency : 40kHz
- Heating up to 60℃ ;140°F

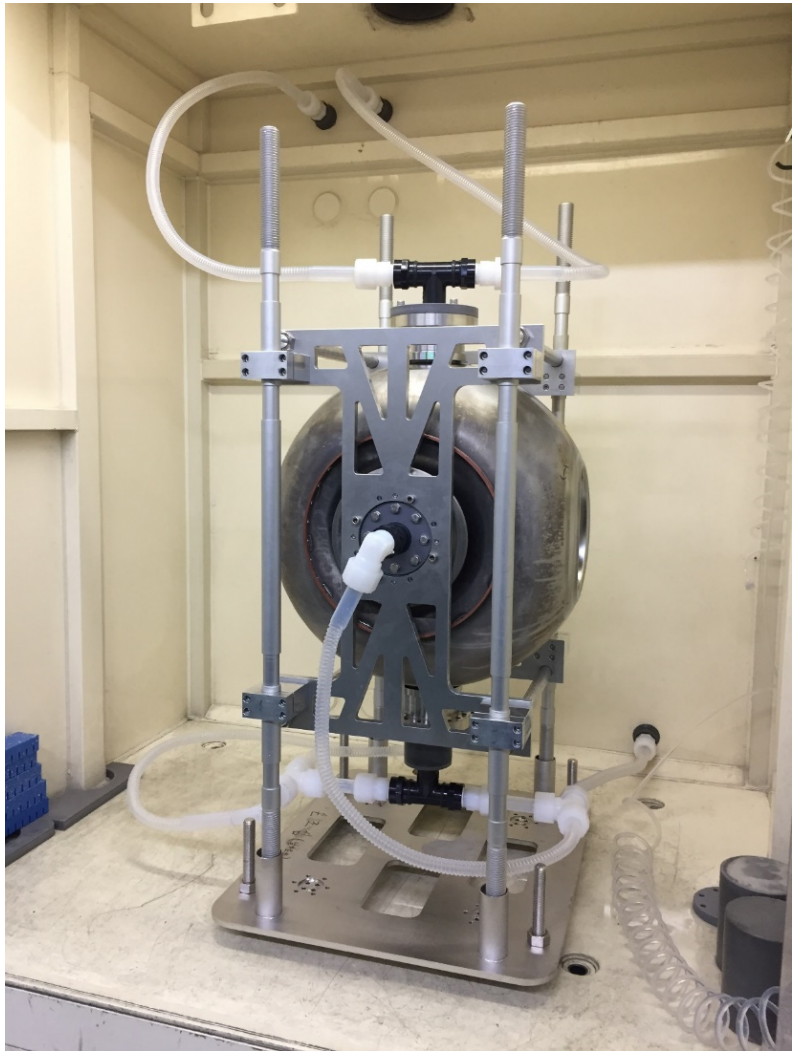
Buffered Chemical Polishing

- Class10000 (ISO7) cleanroom
- Closed-loop chemical circulation type
- Acid storage tank : 350L ;92.5gal (HF, HNO_3, H_3PO_4 mixtures)
  - Heat exchanger: 23kW chiller
- Acid dump tank
- Rinsing water tanks : 350L x 2ea (another 350L spare)
- Controlled by automatic system with PLC
- Exhaust gas scrubber(250CMM) ;8834CFM





Buffered Chemical Polishing

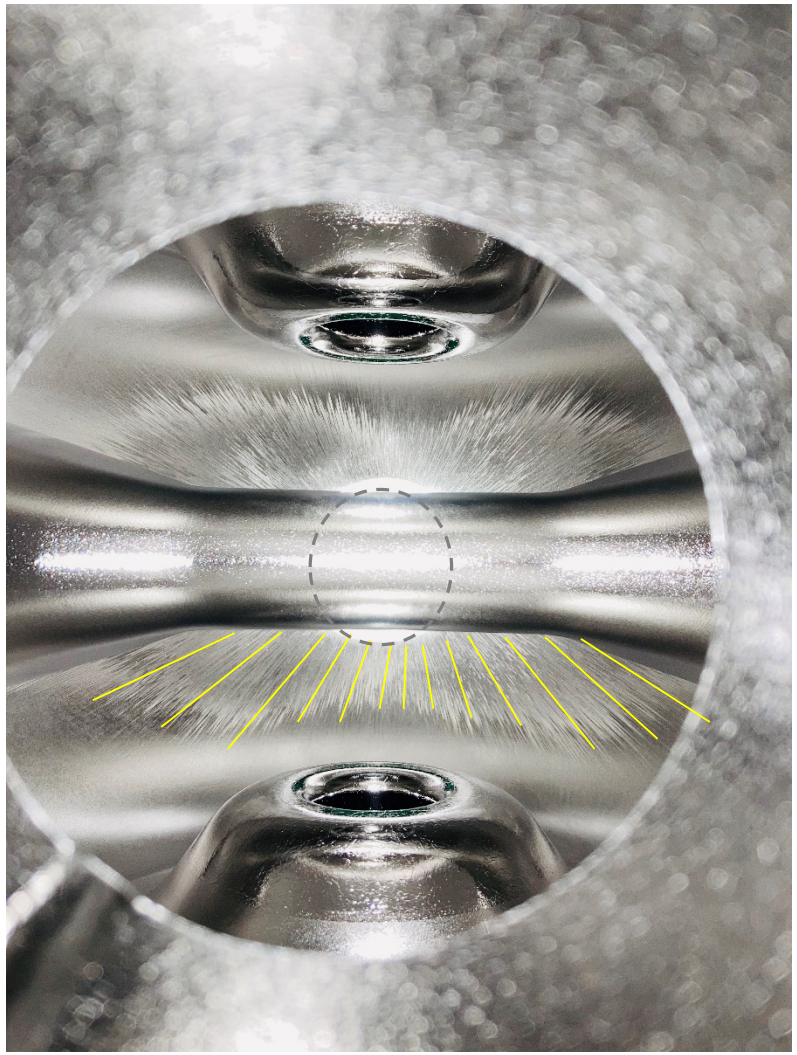


- 49%HF+69%HNO_3+85%H_3PO_4 (1:1:2)
- Keeping Nb concentration in acid below 15g/L.

- Acid flow rate : 2~10LPM
- Etch rate : 0.7~1㎛/min
- Target removal : 120~150㎛(Bulk BCP) + 15~20㎛(light BCP, bare) + 15~20㎛(light BCP, jacketed)
  - Cavity is etched in three 20㎛ steps, another three 20㎛ steps upside down. (to prevent air bubble trapped/ to correct for differential etching due to the acid filling and drain time)
  - For the rinse, it takes 1.5mins to refill the cavity with DI water after acid dumped.

- Temp. control : below 15℃ during the process
  - The acid is pre-cooled down to 5~9℃ in the acid storage tank. (cooling water temp. is just above the freezing level of chiller)

Bubble streak patterns

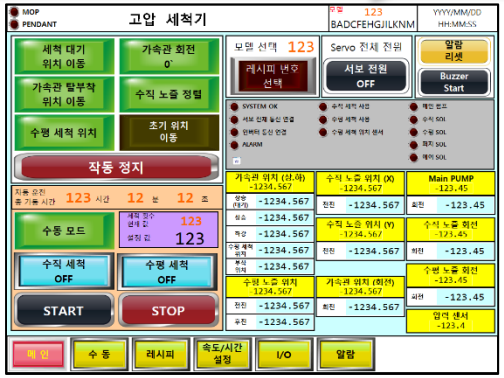


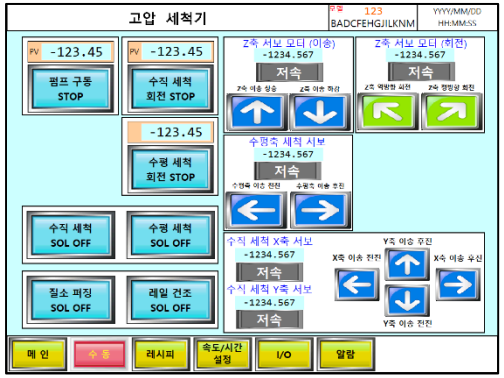
- Bubble streak pattern seems to be appearing in the upper RF port region after 60~80μm etched.

- Effects of bubble streaks on performance degradation of cavity?
  - All the QWRs and HWRs have been accepted to VT, even though some of them have similar patterns in the upper/lower end regions.)
  - In case of Fermilab and INFN, no Field Emission.
  - Not strong E-field region
- Other feasible alternatives to prevent bubble streaks?
  - Recipe of mixed acids? World wide used Standard.
  - Rotational BCP will be studied.

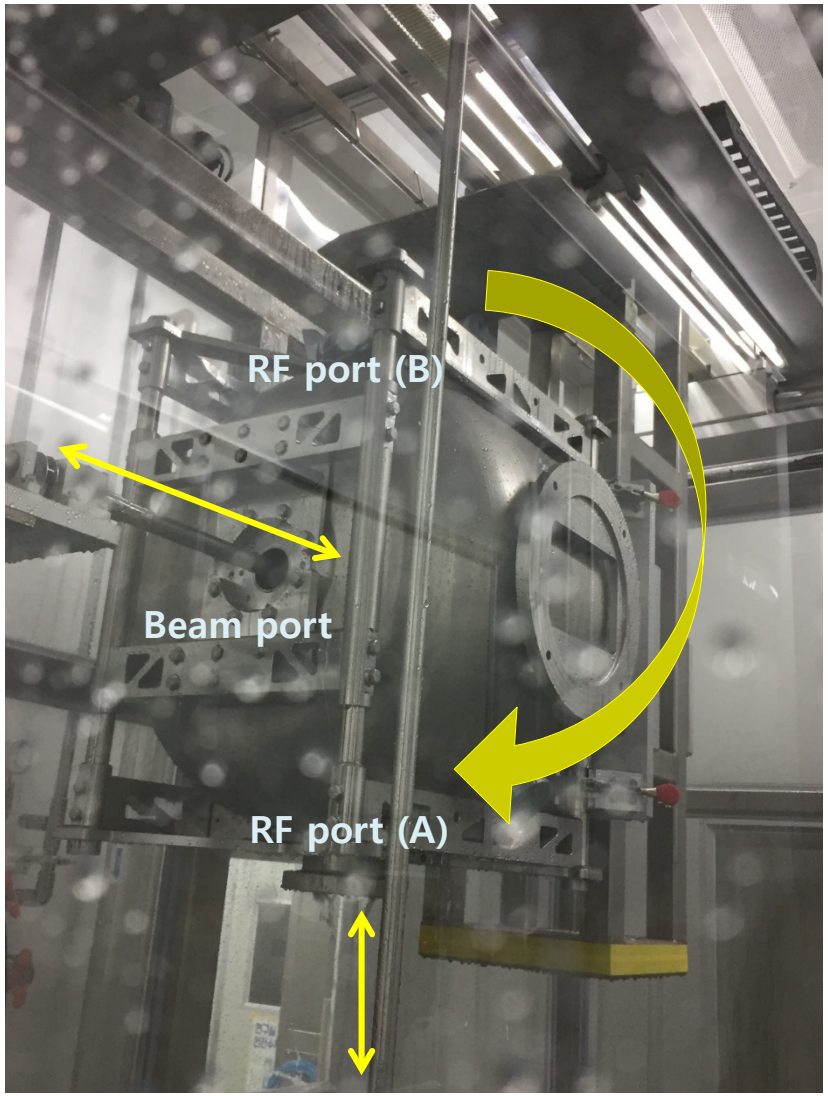
High Pressure Rinsing

- Class100 (ISO5) cleanroom
- Water flow : 20L/min.
- Water pressure : max. 250bar (adjustable)
- Two direction nozzle (vertical, horizontal)
- Water filter : 0.1, 0.3㎛ (low pressure) / 0.5㎛ (high pressure)
- Controlled by automatic system with PLC





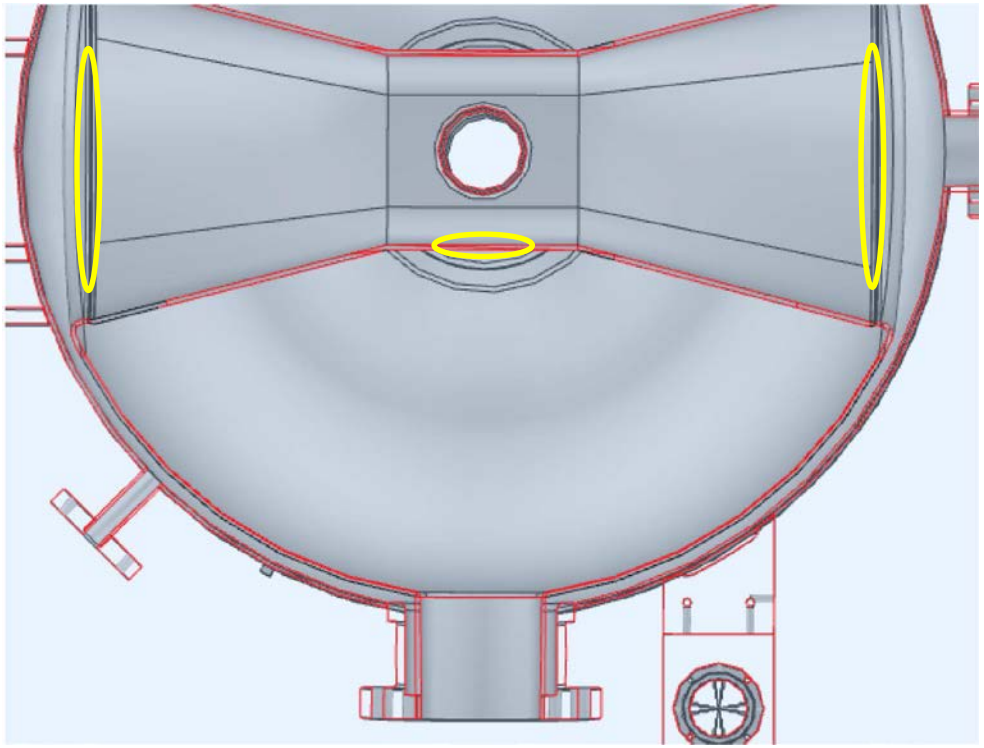
High Pressure Rinsing



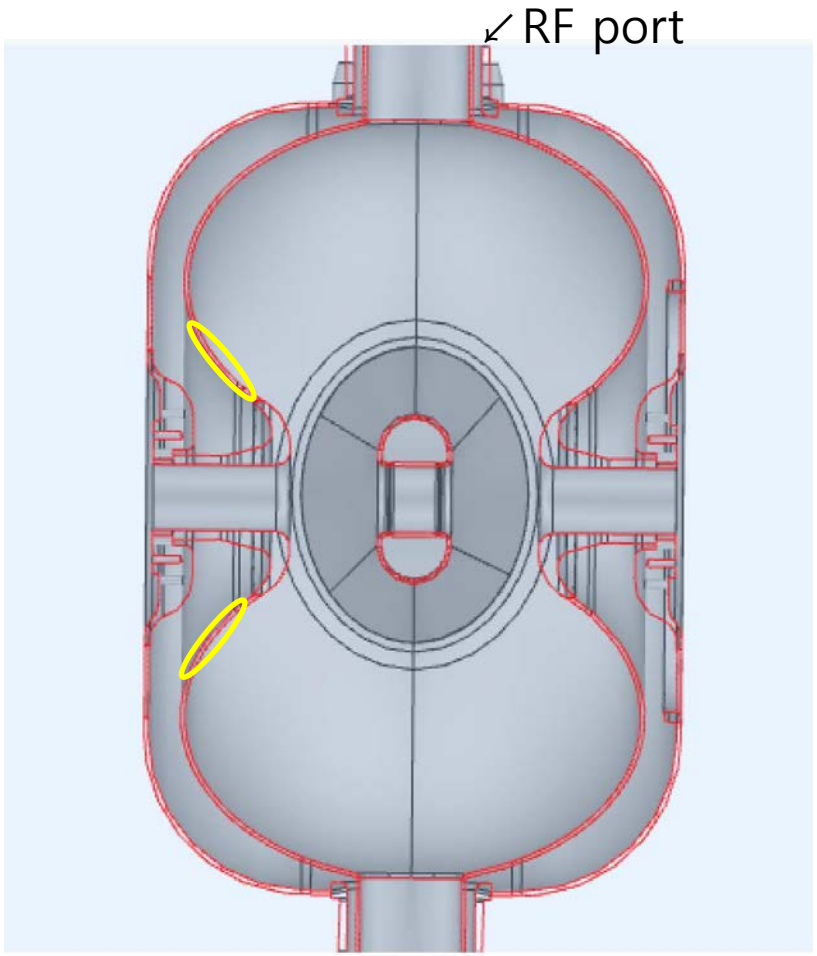
- DI water
- Water pressure : 60~100bar
- Nozzle rotating speed : 20rpm
- Nozzle/Cavity moving speed : 5cm/min

1st step : beam port for 2hrs
2nd step : RF port A for 3hrs
  * turn the RF port upside down
3rd step : RF port B for 3hrs
4th step : beam port for 2hrs

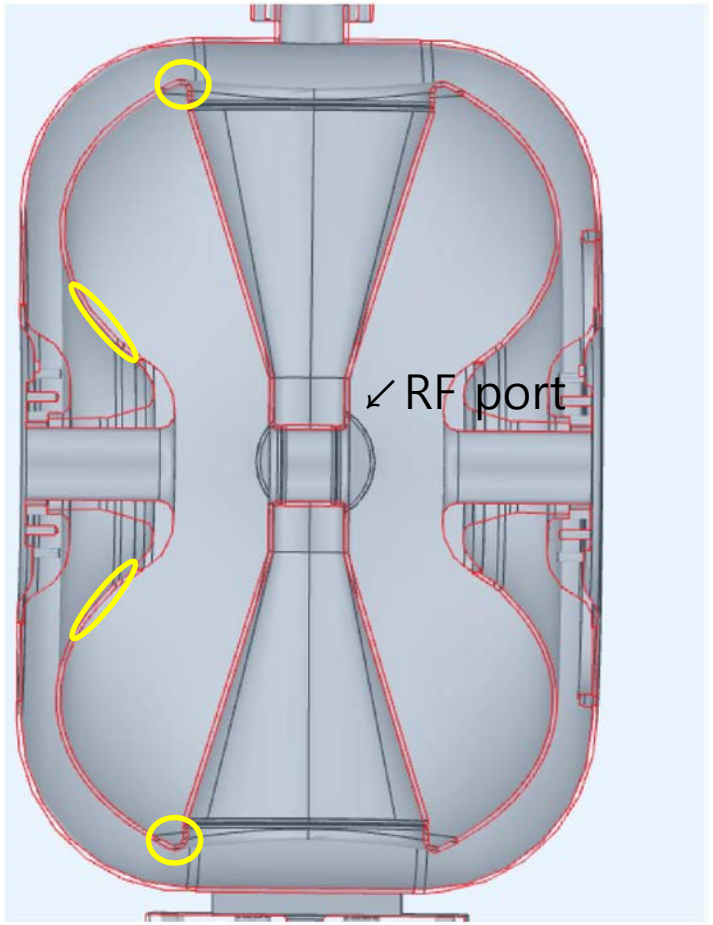
Grey zone of SSR1



Front view

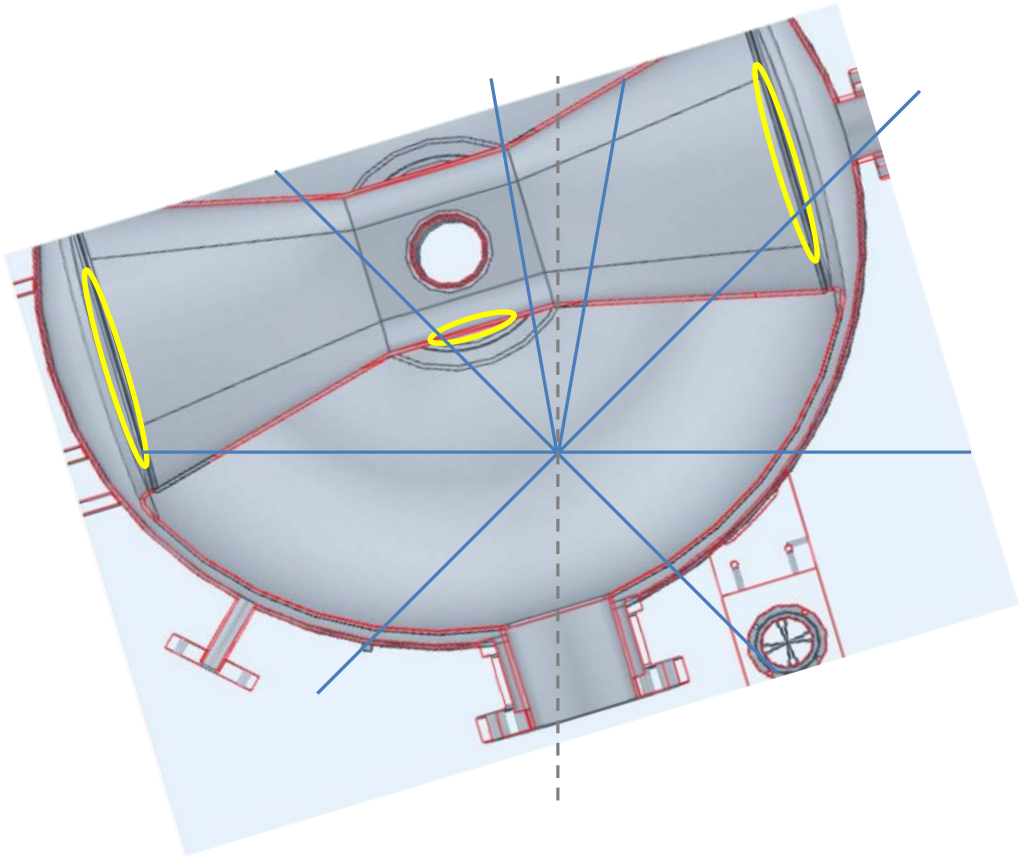


Side view

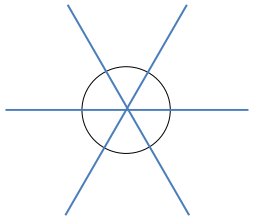


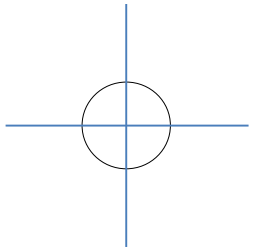
Top view

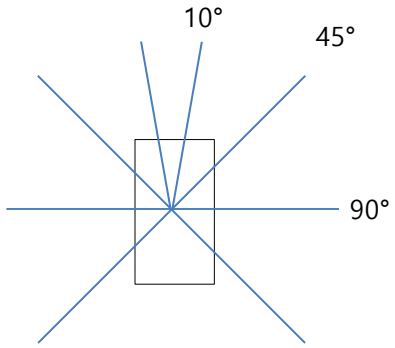
Reduce grey zone – cavity tilted ±20°

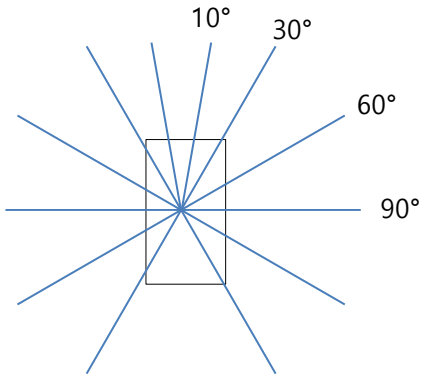


Reduce grey zone – improve nozzle shape



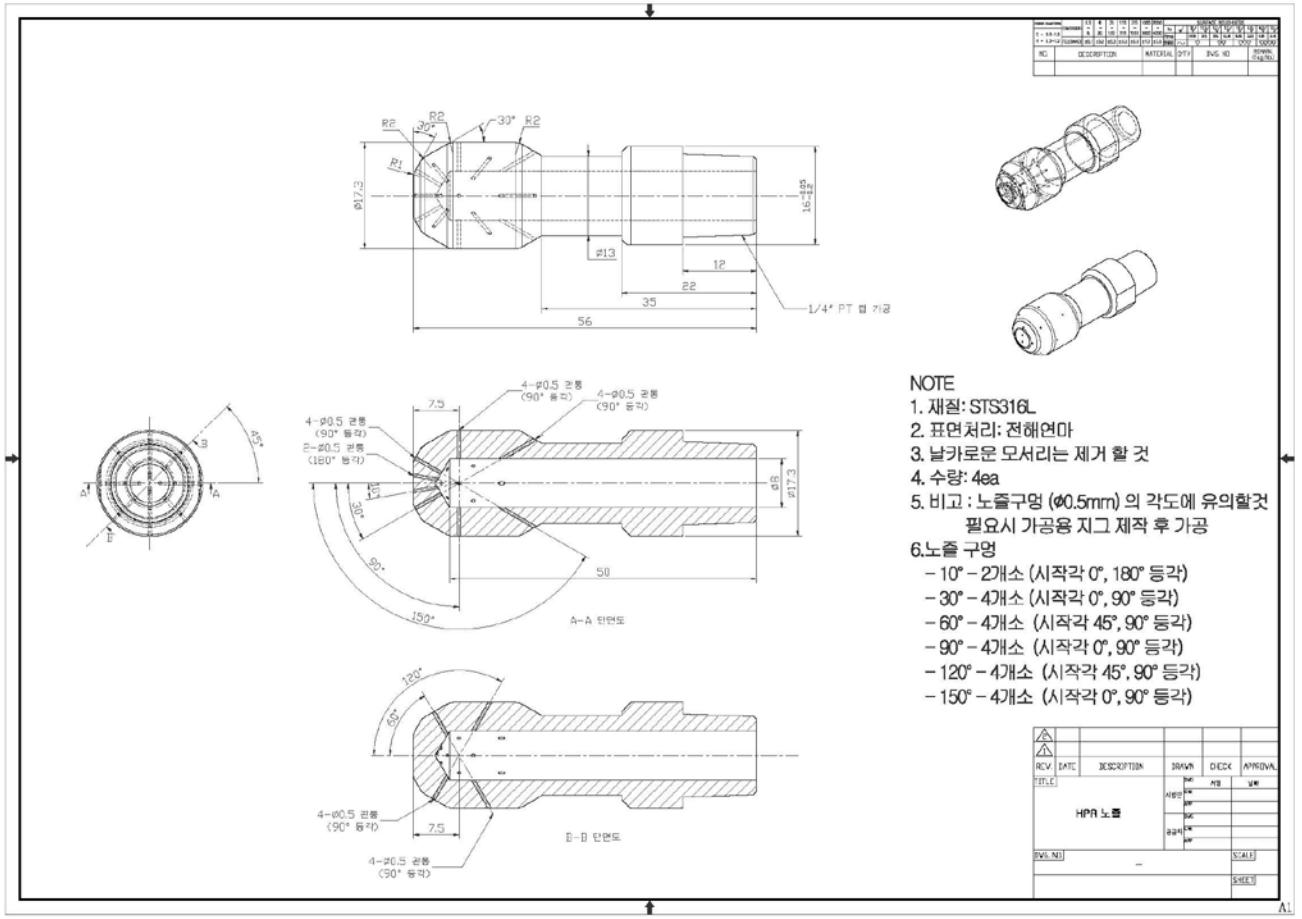




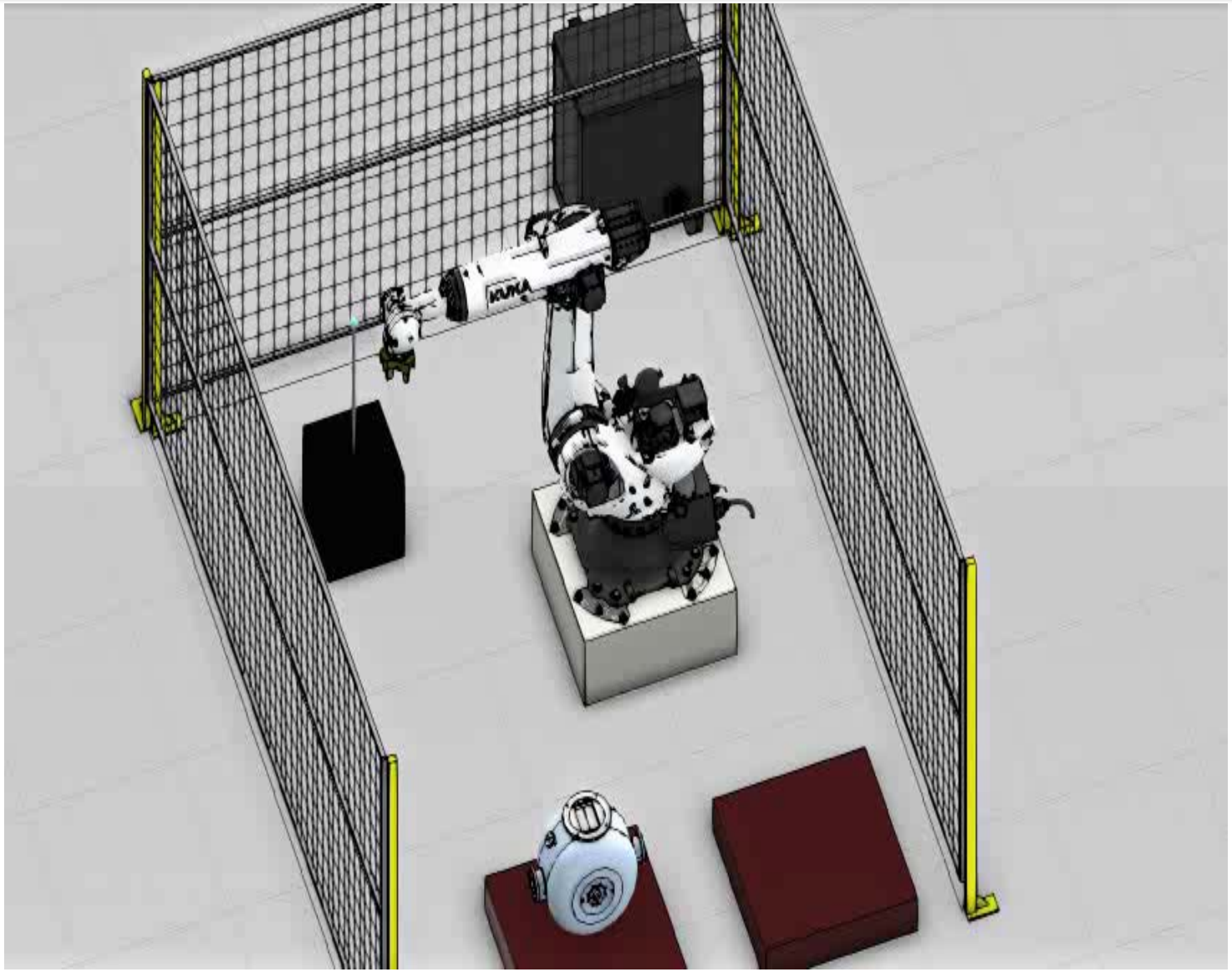


2(10°)+6(45°)+6(90°)
+6(-45°) holes

2(10°)+4(30°)+4(60°)+4(90°)
+4(-30°)+4(-60°) holes



Automatic Robot arm system



- Assist in
  - HPR process
  - Drying after HPR
  - Cavity assembly

- Improvements
  - reduce manpower
  - prevent particle contaminations

Summary

- Facilities and Procedures of Surface Treatments are shown.

- Issue for BCP – Bubble Streak
  - ✓ Effect on performance degradation of cavity?
  - ✓ Rotational BCP will be studied.

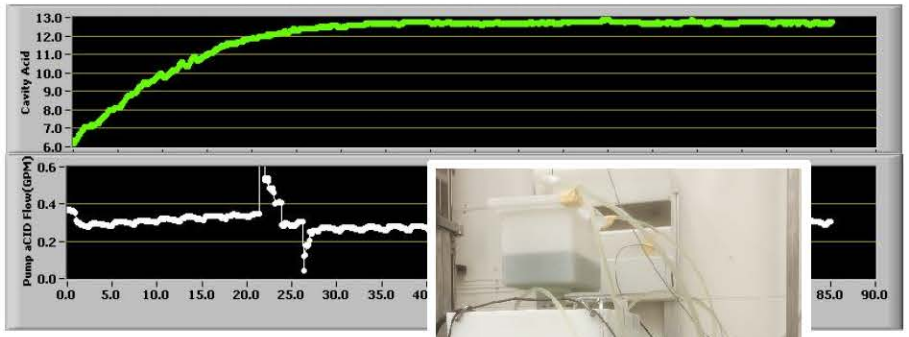
- Issue for HPR – Grey Zone
  - ✓ Cavity tilted ± 20°
  - ✓ Nozzle shape modified
  - ✓ RISP is looking into automatic robot arm system for HPR and cavity assembly.

Back up

II. Experience with SSR1 BCP

- New facility, same procedure as HINS cavity BCP
  - Additional mixing to prevent stagnant areas
- Standard 1:1:2 BCP mix
  - Pre-chill overnight (2-7° C)

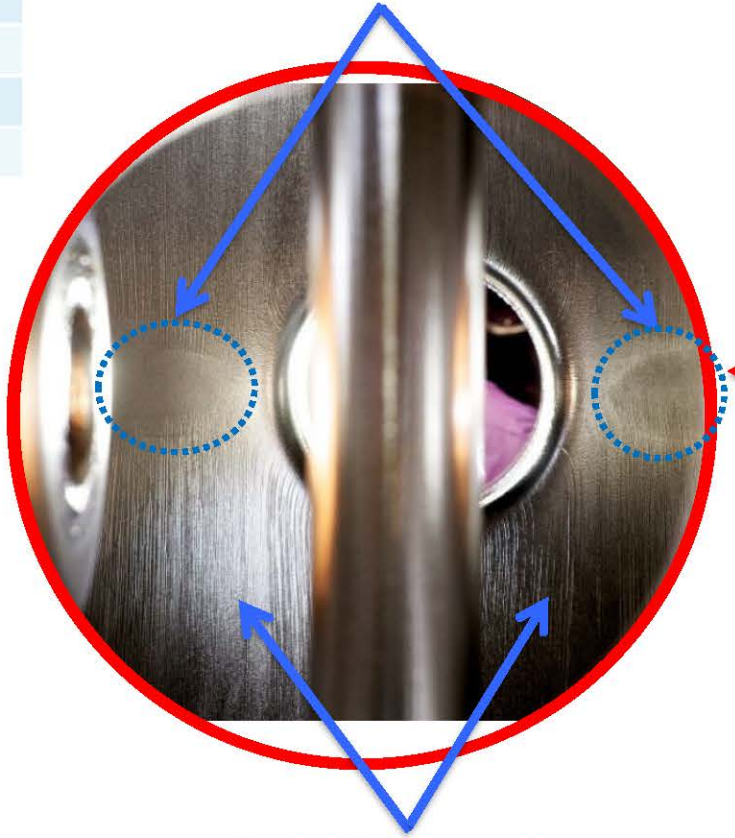
	Bulk BCP (bare)	Light BCP (bare)	Light BCP (jacketed)
Target Removal (μm)	120-150	20-30	20
Acid Temperature (°C)	<15		
Cavity Cooling	External Water Bath		Helium Jacket
Flow Rate (gpm)	~0.5		



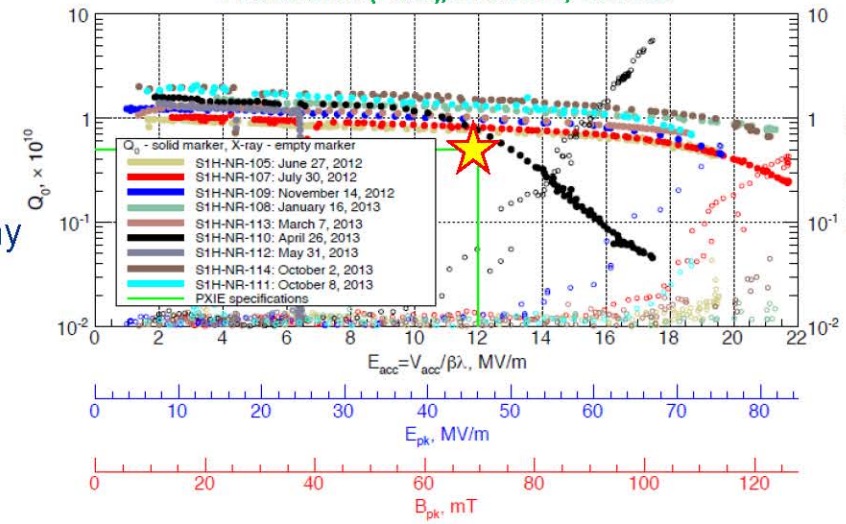
Max acid temp: 13°C
Run Time: 90 min

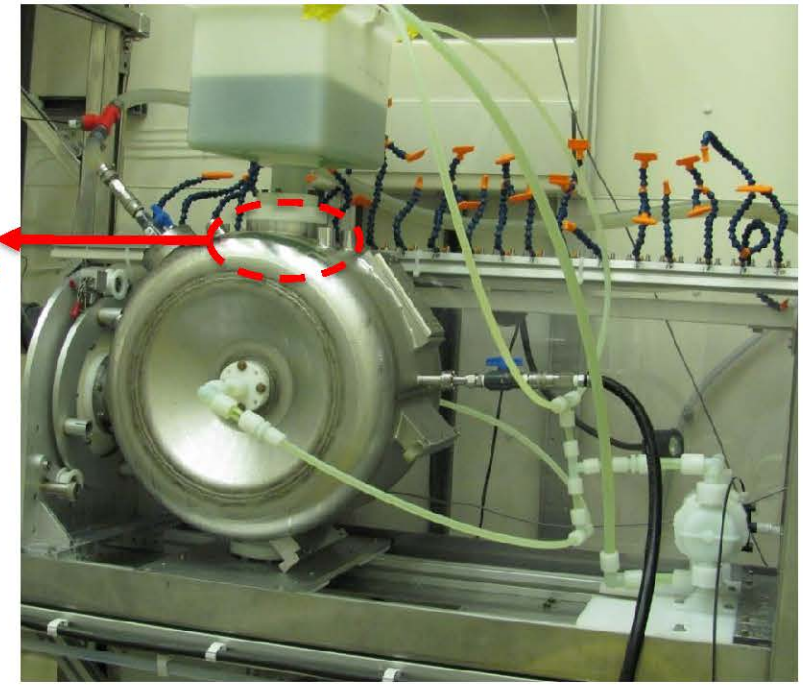
Bulk BCP of bare cavity

- Fixed cavity BCP results in unwanted surface features
- Cavity performance pretty good (lots of multipacting, not sure if any relation to chemistry)
- But room for improvement



A. Sukhanov (FNAL), Linac2014, THPP057



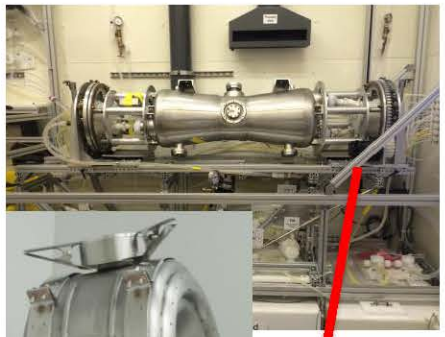


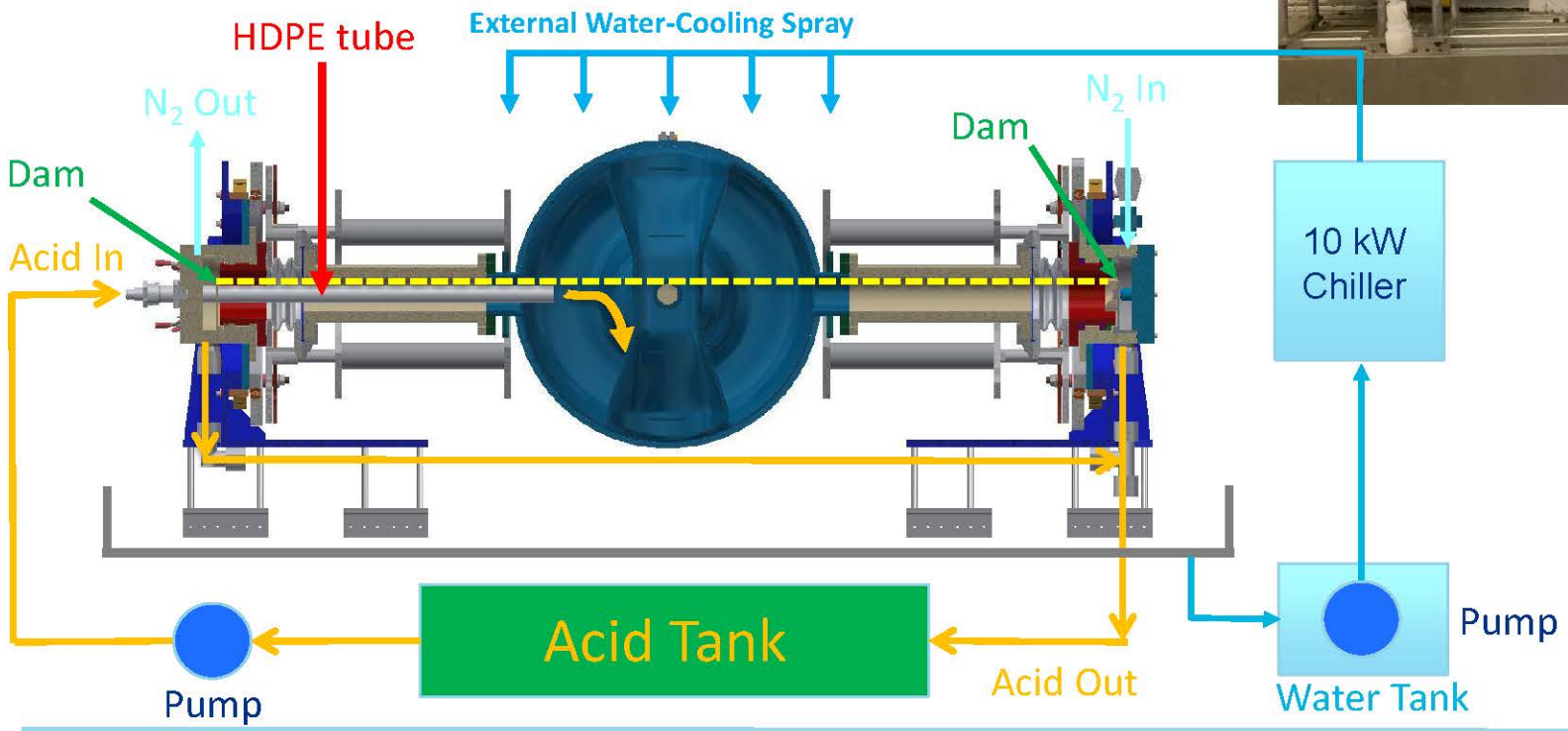
Light BCP of jacketed cavity

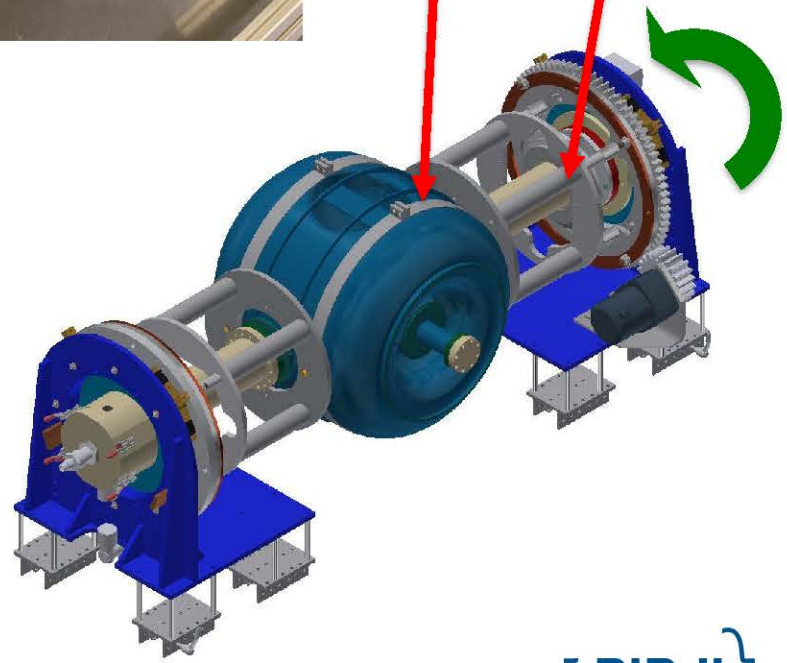
III. Plan for SSR2 BCP

- Apply horizontal rotational BCP to eliminate unwanted surface features inherent to fixed cavity BCP as seen in SSR1s
- Only needed hardware is a cavity support structure and flange adapters
  - Based on SSR1 HPR cage and 162 MHz HWR processing cage

	Bulk BCP (bare)	Light BCP (bare)
Target Removal (μm)	120-180	20-30
Acid Temperature (°C)	<15	
Flow Rate (gpm)	~0.5	
Rotation Speed (rpm)	1	
Cavity Cooling	External Water Spray	

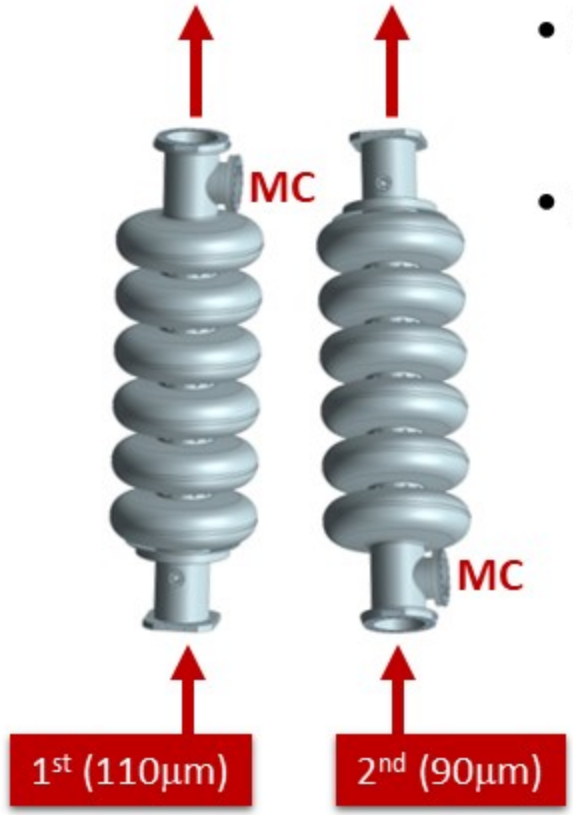






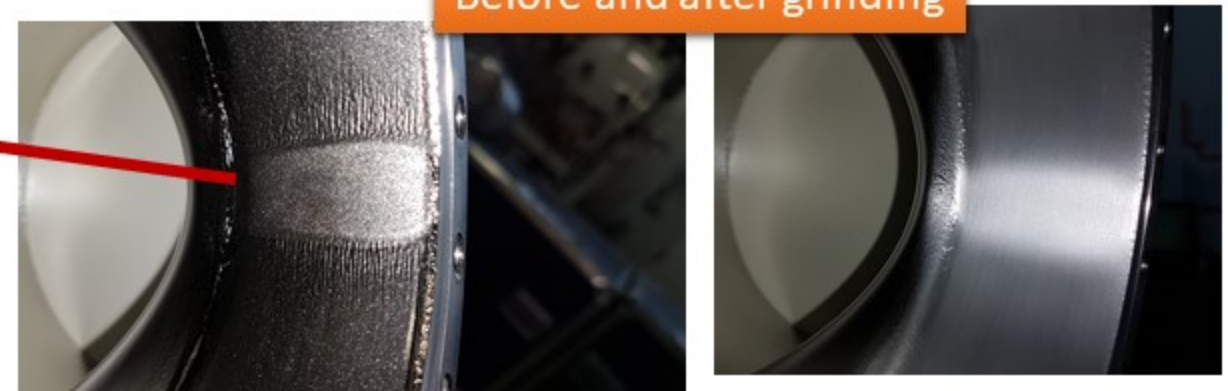
Bulk BCP new cycle: BCP grooves on MC tube

- Grooves on the MC tubes after Bulk BCP (done in two steps)
- Reason: BCP acid stagnant and possible air bubble when the cavity is in vertical position with the MC on the top
- How we recovered:



- Cavities already treated with Bulk BCP:
  - Local grinding at the MC tube and 50µm BCP
- Cavities still to be treated with Bulk BCP:
  - Reversing of the two main steps (starting with MC up)
  - if grooves visible -> grinding and then 2nd BCP step

Before and after grinding



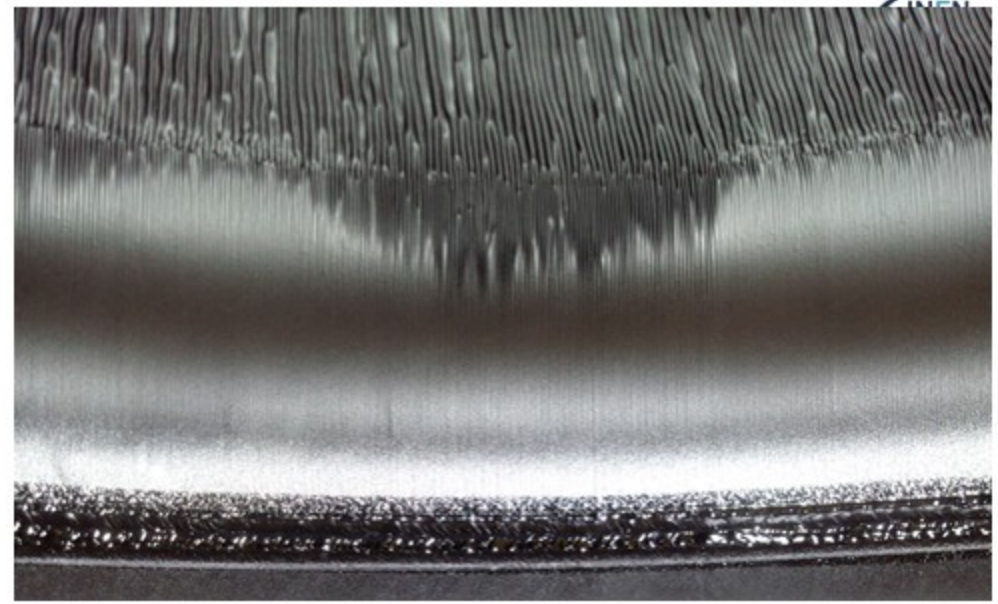
Production «review»

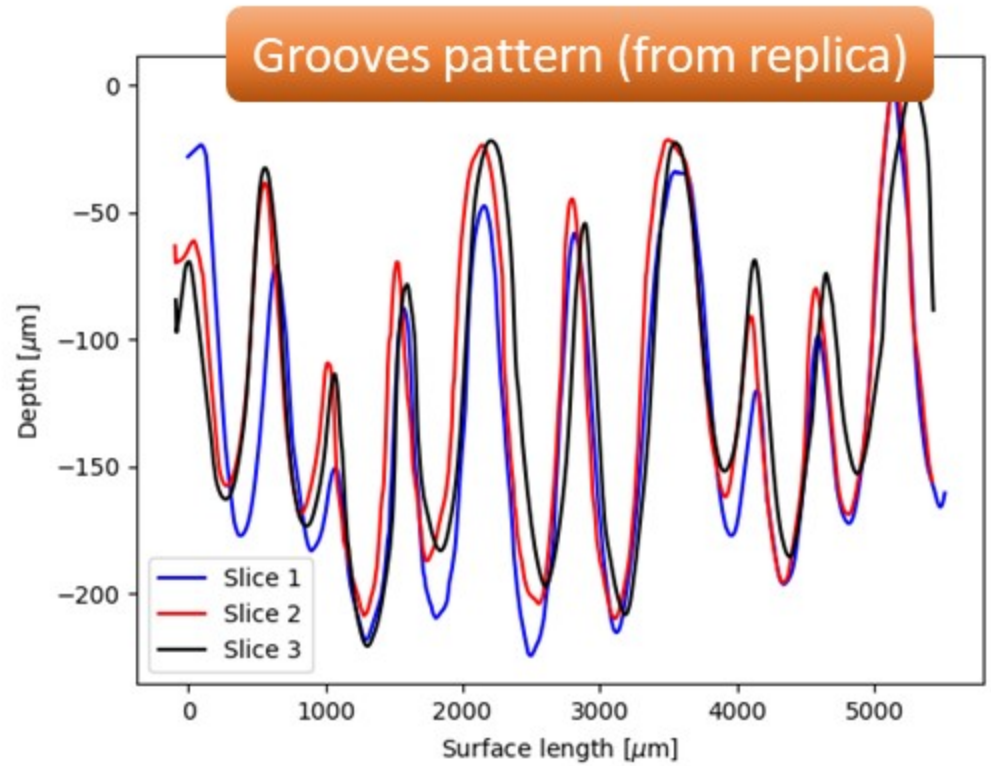
- Buffered Chemical Polishing (**BCP**) on MB Cavities is **critical** due to the large cell radius and steep wall angle

- We have observed **grooves**, deep and with **high spatial frequency**, on the cavity walls in some of the cavities not yet qualified. These might be the cause of **not proper final cleaning** or a **source of dissipation**

- **No field emission** has been observed on these cavities

- The new treatment approaches aims to improve final surface finishing to improve smoothness and/or cleaness.

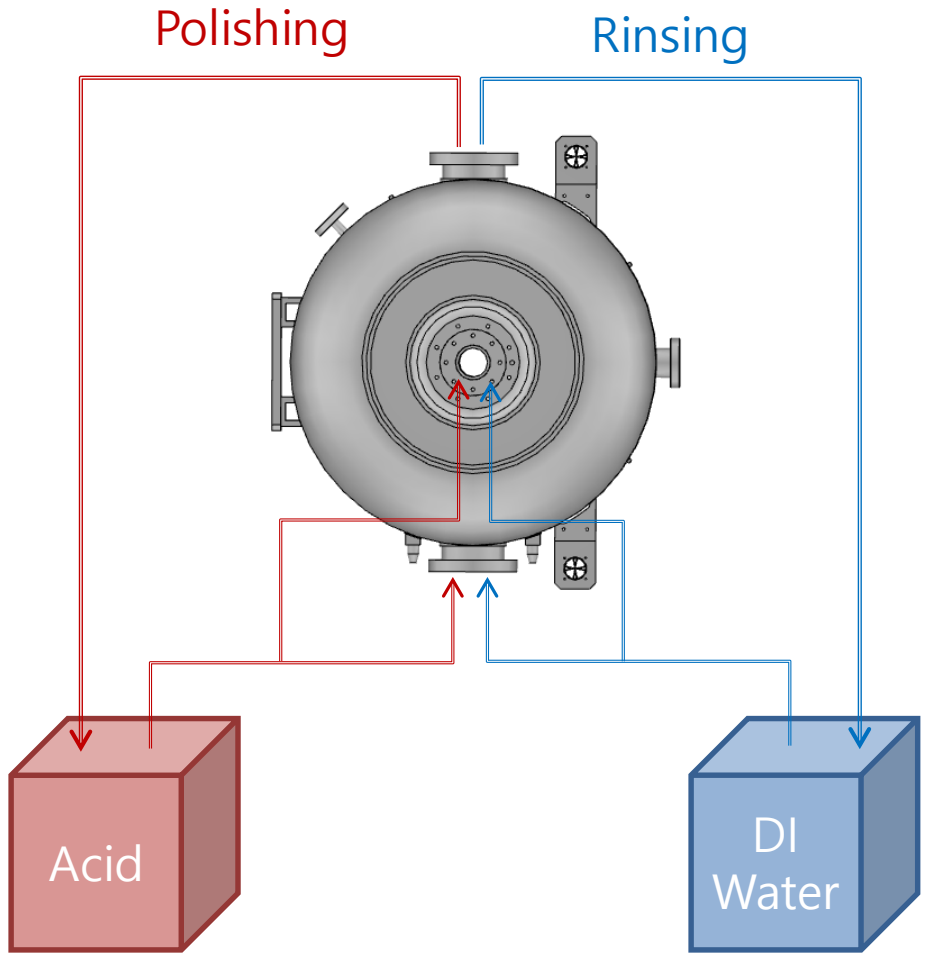




Recipes of etchant

➢ **RISP**

- 49%HF + 69%HNO3 + 85%H3PO4 (1:1:2, vol. fraction)

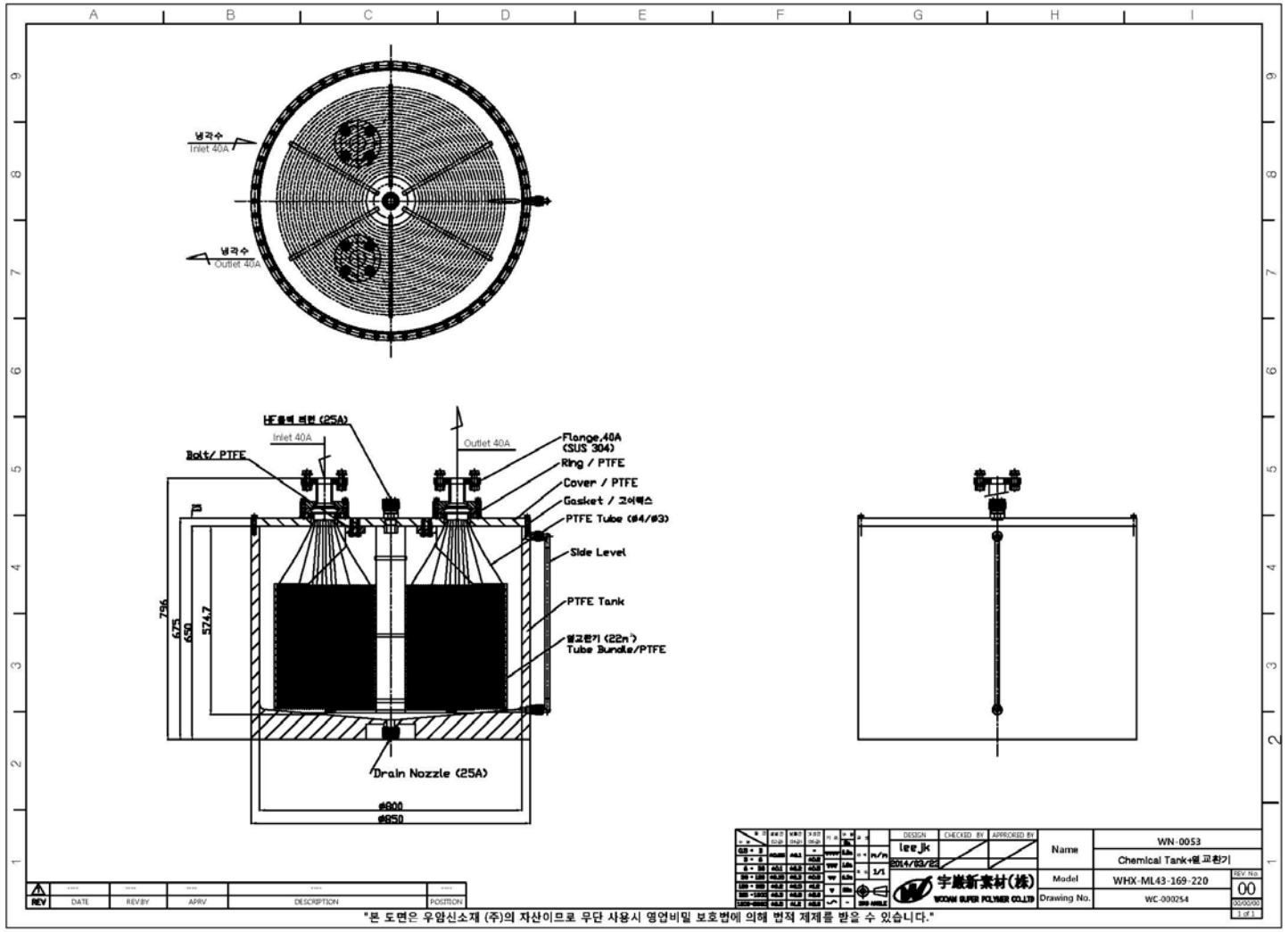


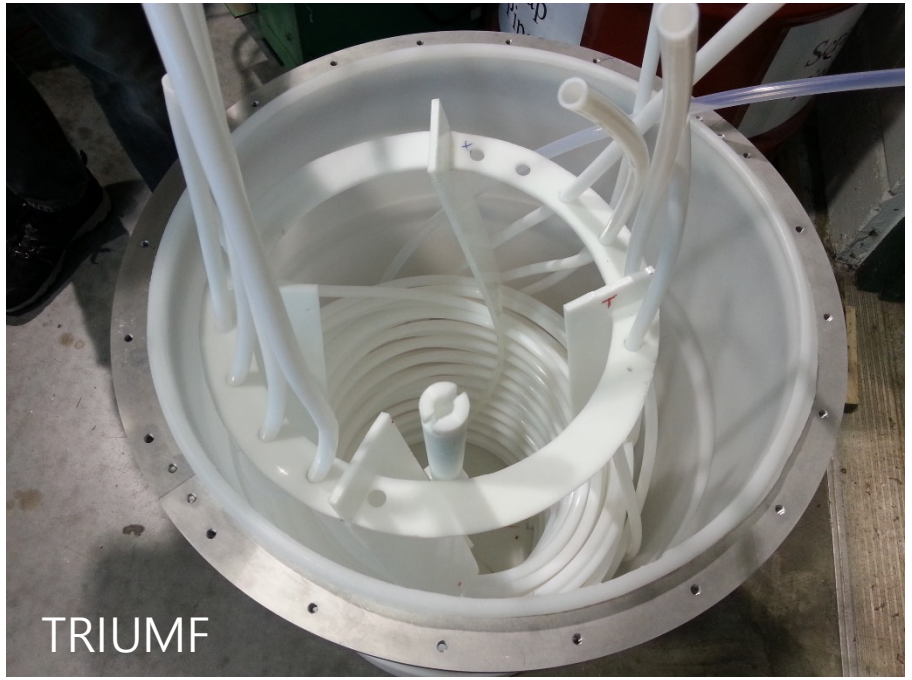
➢ **Other labs**

- HF+HNO3+H3PO4 (1:1:2, standard recipe for BCP)
- TRIUMF : 48%HF+68~70%HNO3+85%H3PO4
- FRIB : 49%HF+70%HNO3+85%H3PO4
- ANL : 48%HF+69~70%HNO3+85%H3PO4,
- DESY : 49%HF+69.5%HNO3+85%H3PO4
- JLAB : 49%HF+69%HNO3+85%H3PO4
- CEA : 40%HF+65%HNO3+85%H3PO4
- ESS : 40%HF+65%HNO3+85%H3PO4

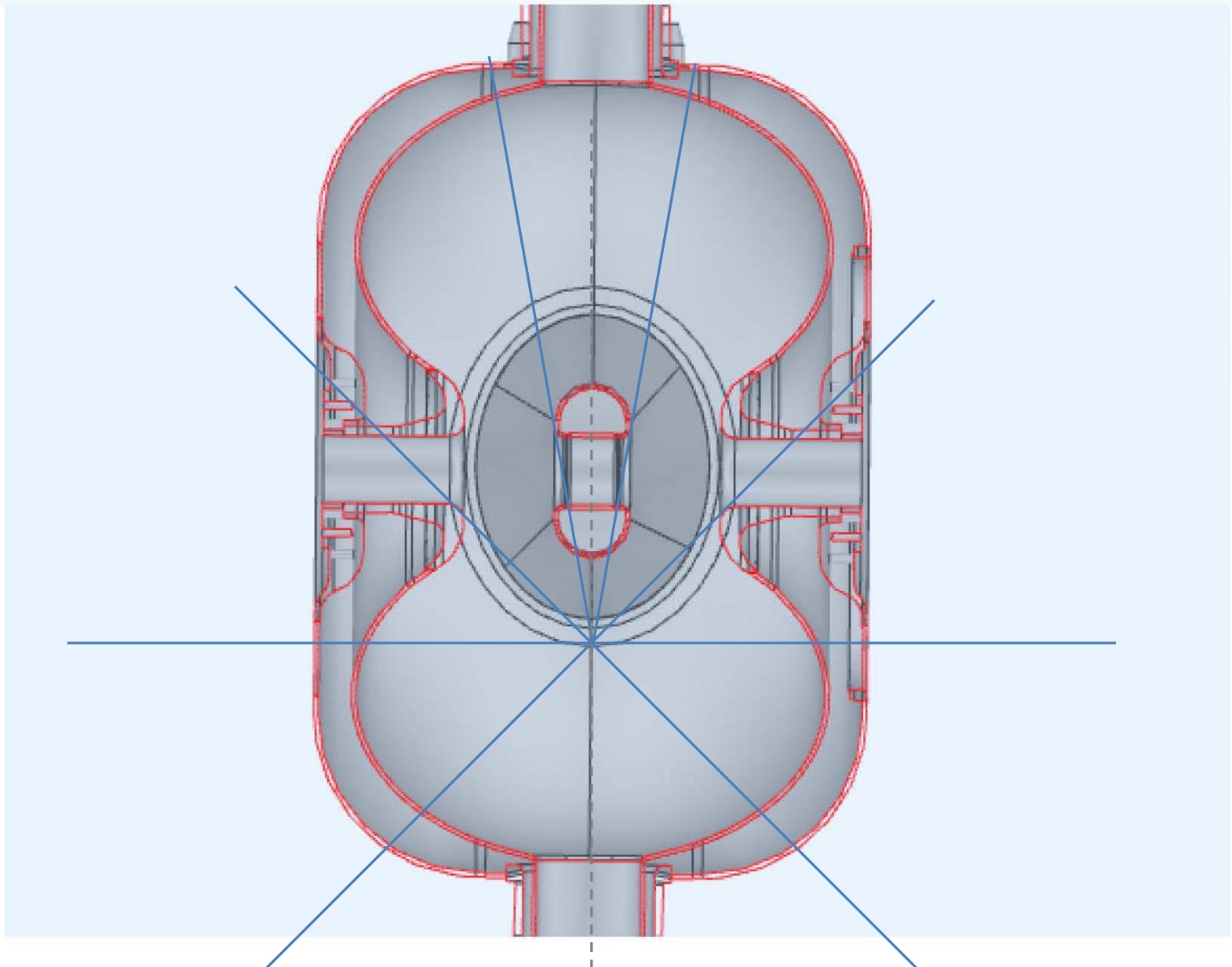
* various papers

Heat exchanger of acid tank

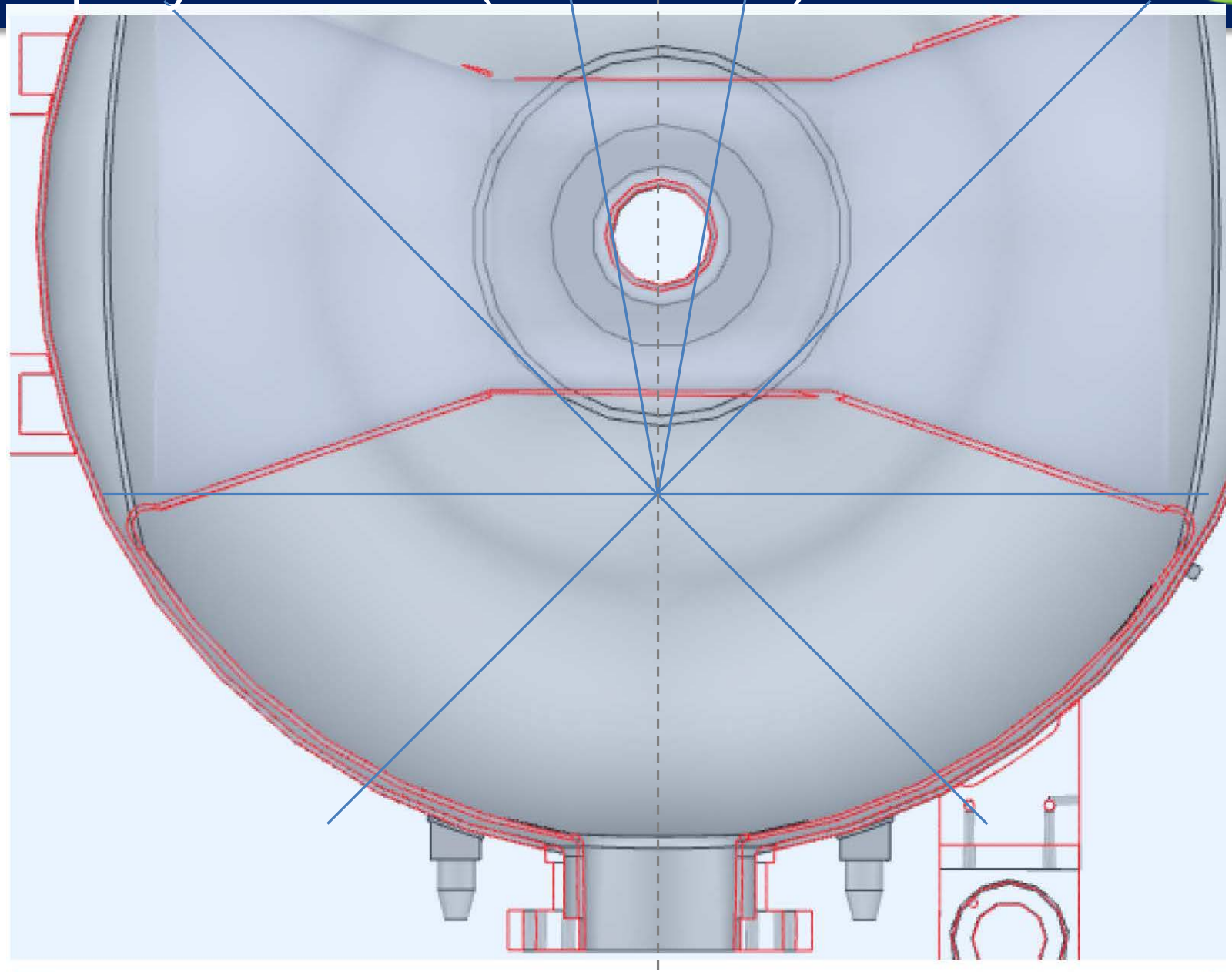




Water spray of SSR1 (side view)



Water spray of SSR1 (front view)



Robot assisting on HPR process

Horizontal HPR for HWR-015 cavities

15 times

Vertical HPR for HWR-015 cavities

15 times

HPR for 325MHz QWR Nb/Cu cavities

3 times

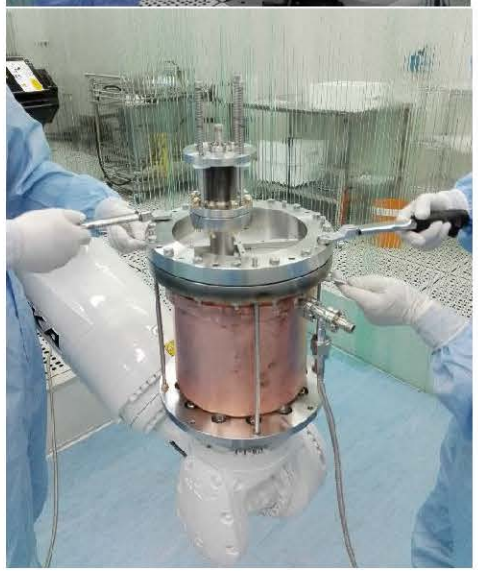
HPR for 1.3GHz Elliptical cavities

5 times

Process	Operators (nomal)	Hours (nomal)	Operators (with robot)	Hours (with robot)	Hours saved
HWR-015 cavities HPR	3	8	1	8	16

Robot assisting on cavity assembly






Cavity	Ports number
HWR-010	8
HWR-015	8
QWR Nb/Cu	3
elliptic cavities	2

- Cavity held by robot which has 6 degrees of freedom is easier to be assembled.