

Surface Treatments in the RAON

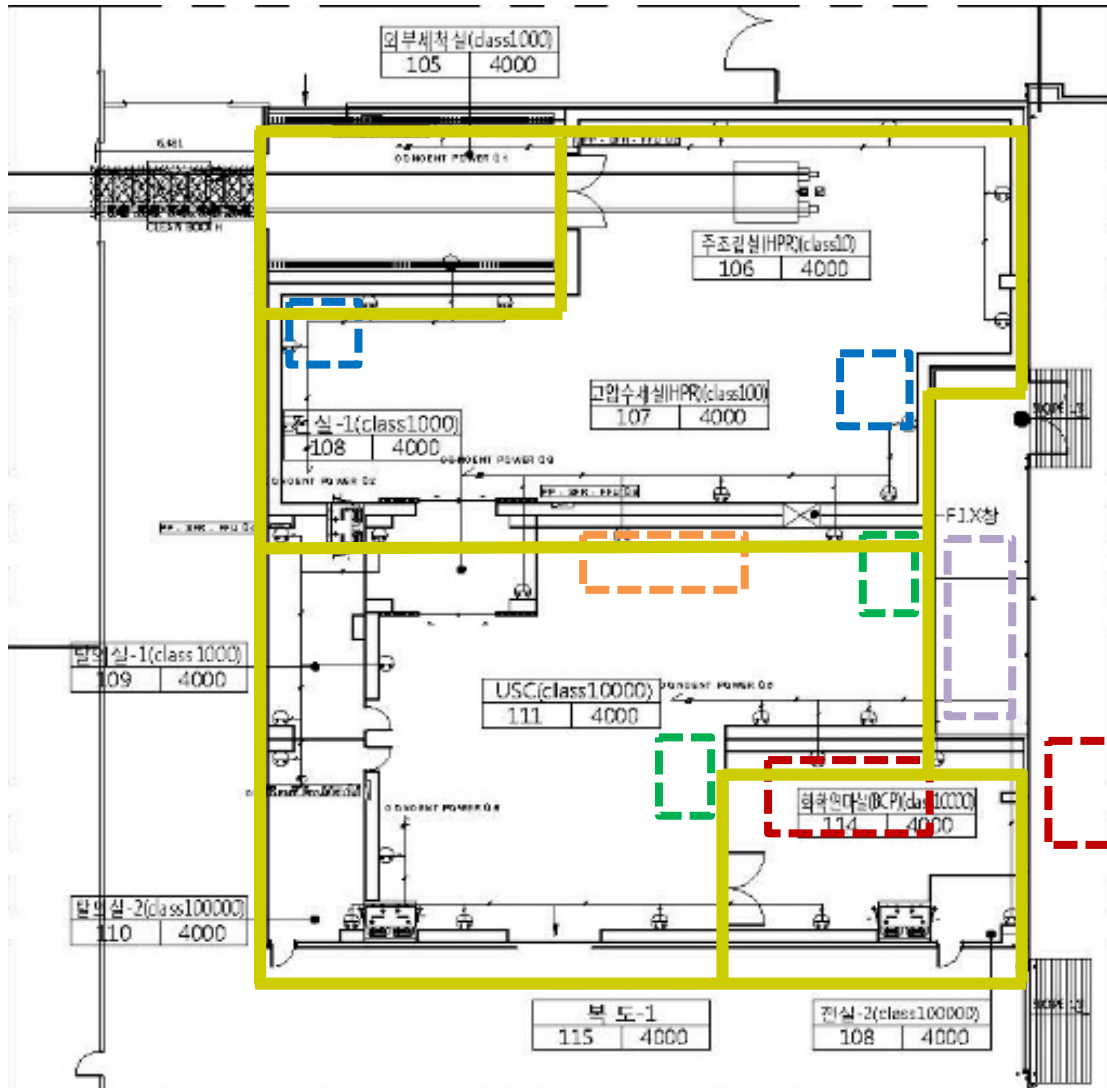
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Superconducting Linac Development Team



- **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°C	over 17.5MΩ
Particles	0.5μm, EA/mℓ	below 10~20EA/mℓ
Bacterial	EA/mℓ	below 0.01EA/mℓ
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

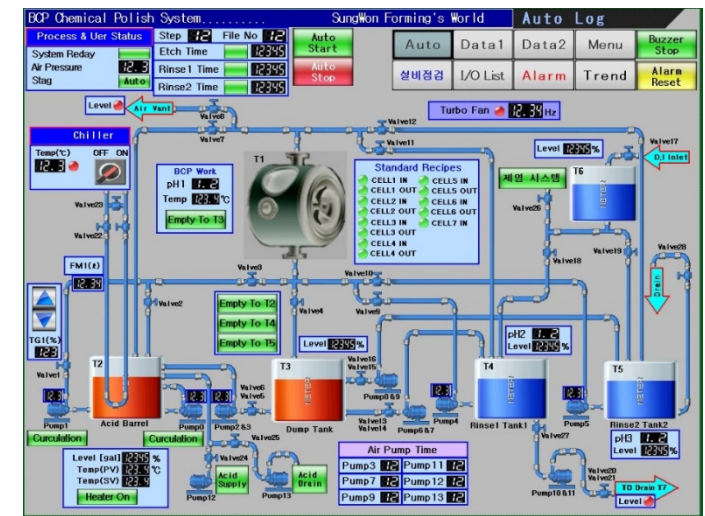
Ultrasonic Cleaning

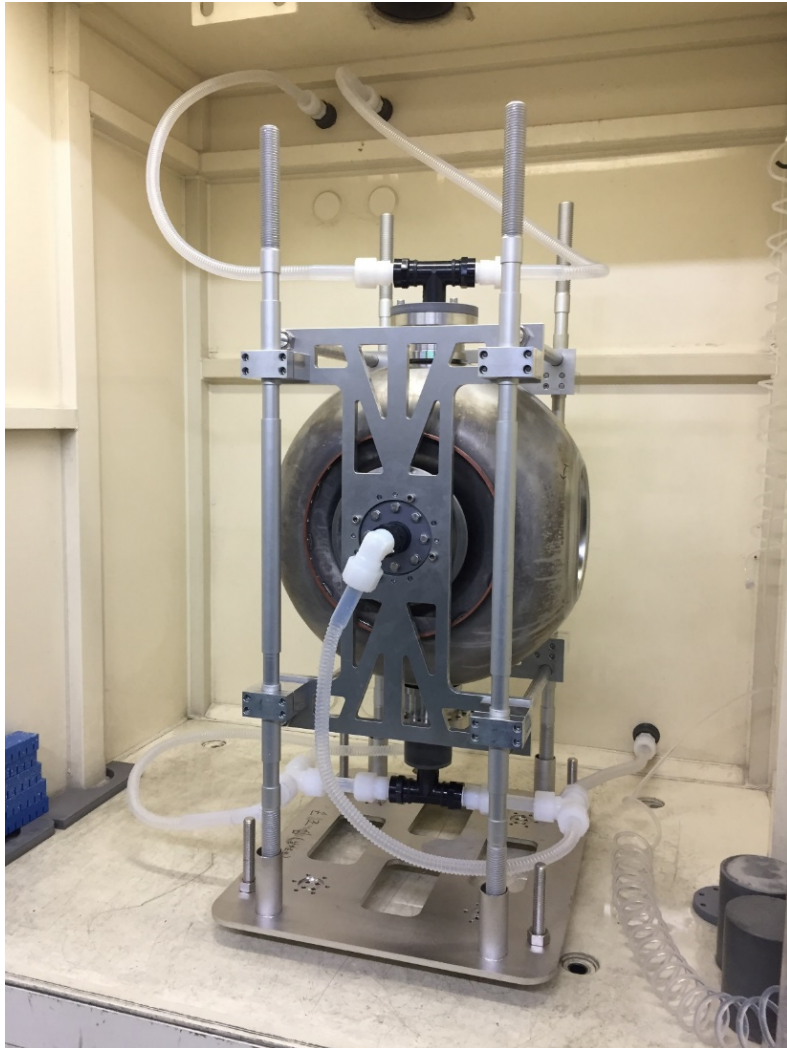
- Class1000 (ISO6) cleanroom
- Double bath type
 - 1st bath(degreasing) : 1% liquinox
 - 2nd bath(rinsing) : DI water
- Ultrasonic Power : 1.5kW
- Ultrasonic Frequency : 40kHz
- Heating up to 60°C ;140°F



Buffered Chemical Polishing

- Class10000 (ISO7) cleanroom
- Closed-loop chemical circulation type
- Acid storage tank : 350L ;92.5gal (HF, HNO₃, H₃PO₄ 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

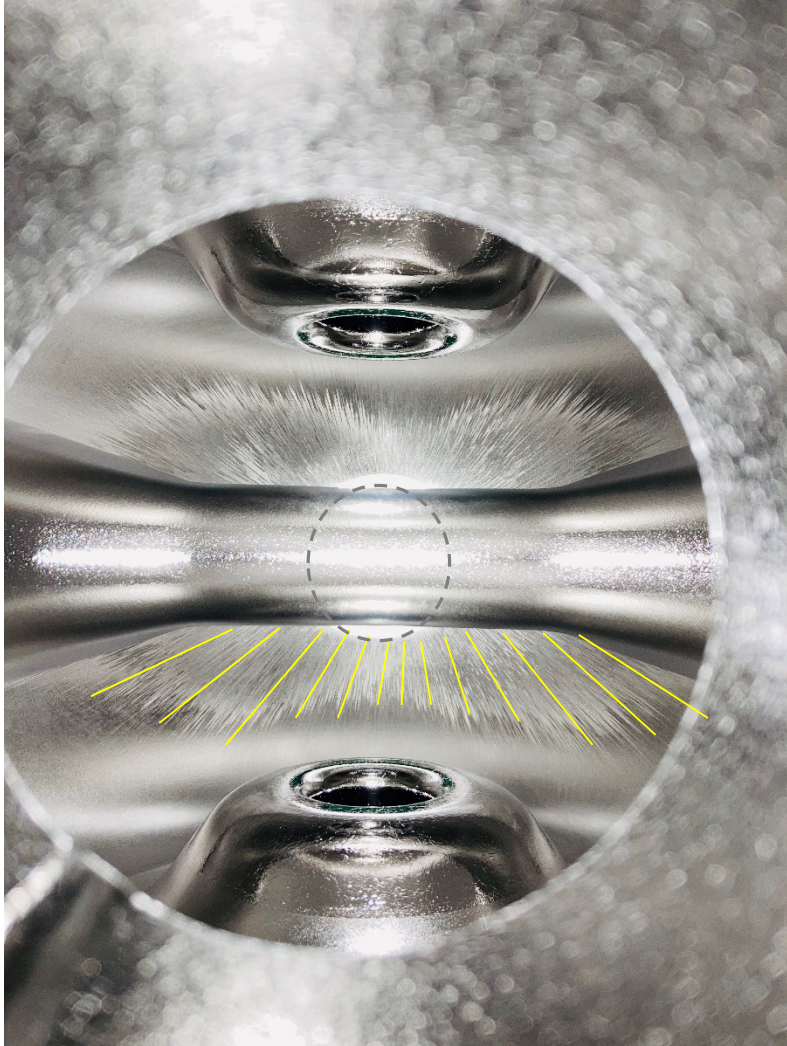




- 49%HF+69%HNO₃+85%H₃PO₄ (1:1:2)
- Keeping Nb concentration in acid below 15g/L.

- Acid flow rate : 2~10LPM
- Etch rate : 0.7~1 μ m/min
- Target removal : 120~150 μ m(Bulk BCP) + 15~20 μ m(light BCP, bare) + 15~20 μ m(light BCP, jacketed)
 - Cavity is etched in three 20 μ m steps, another three 20 μ m 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 $^{\circ}$ C during the process
 - The acid is pre-cooled down to 5~9 $^{\circ}$ C in the acid storage tank. (cooling water temp. is just above the freezing level of chiller)



- Bubble streak pattern seems to be appearing in the upper RF port region after 60~80 μm 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 μ m (low pressure) / 0.5 μ m (high pressure)
- Controlled by automatic system with PLC

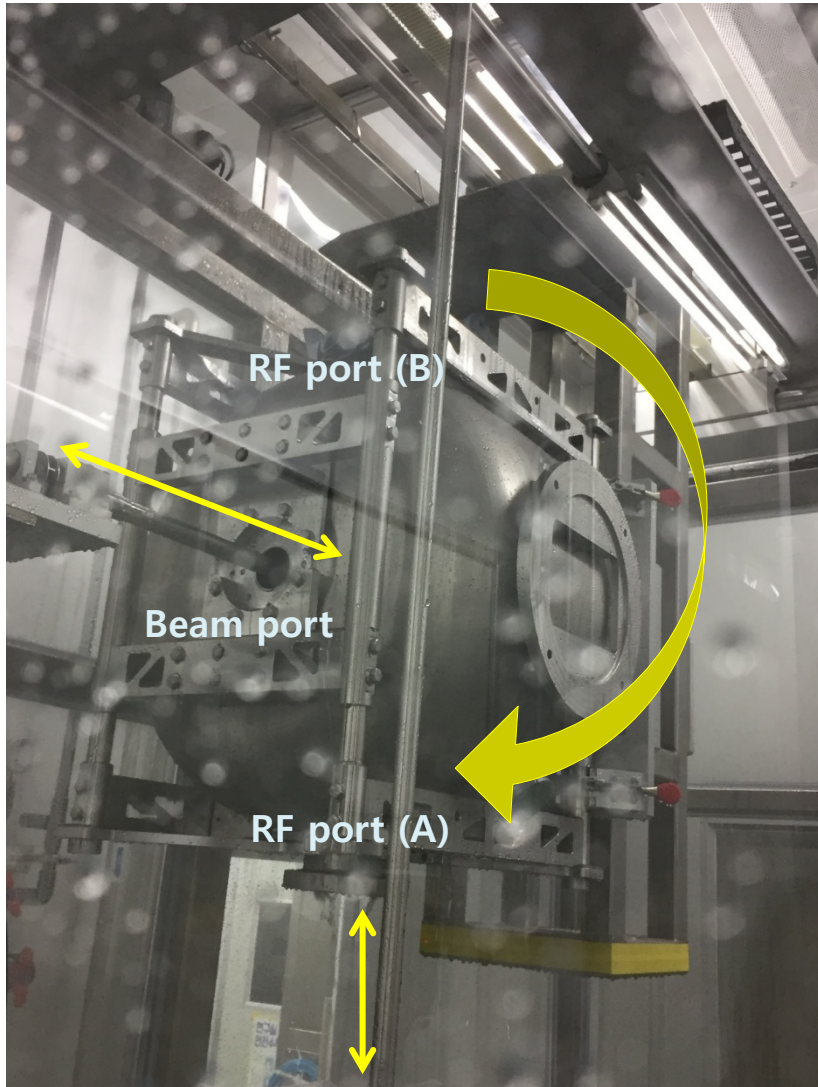


고압 세척기 (High Pressure Rinsing Machine) control panel screenshot. It displays various status indicators, buttons for 'START', 'STOP', '수동 세척 위치' (Manual Rinsing Position), and '작동 정지' (Stop Operation). It also shows a digital display for '123' and various sensor status indicators.

고압 세척기 (High Pressure Rinsing Machine) control panel screenshot showing movement controls. It includes buttons for 'Z축 서보 모드 (이송)' (Z-axis Servo Mode (Move)), 'Z축 서보 모드 (회전)' (Z-axis Servo Mode (Rotate)), and directional arrows for movement. It also shows '수평 세척 SOL OFF' (Horizontal Rinsing Solenoid Off) and '수직 세척 SOL OFF' (Vertical Rinsing Solenoid Off) buttons.

고압 세척기 (High Pressure Rinsing Machine) control panel screenshot showing a table of parameters. The table lists various positions and their corresponding velocity and speed values.

위치	123	ABCDEFHIJ
레시피 이름	위치 값 (mm)	속도 값 (mm/m)
Z축 이송 상승 위치	-1234.567	-12345.67
Z축 이송 하강 위치	-1234.567	-12345.67
X축 작업 위치	-1234.567	-12345.67
Y축 작업 위치	-1234.567	-12345.67
수평 축 전진 위치	-1234.567	-12345.67
수평 축 후진 위치	-1234.567	-12345.67
레시피 이름	위치 값 (Deg)	속도 값 (Deg/m)
Z축 회전 위치	-1234.567	-12345.67



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

1st step : beam port for 2hrs

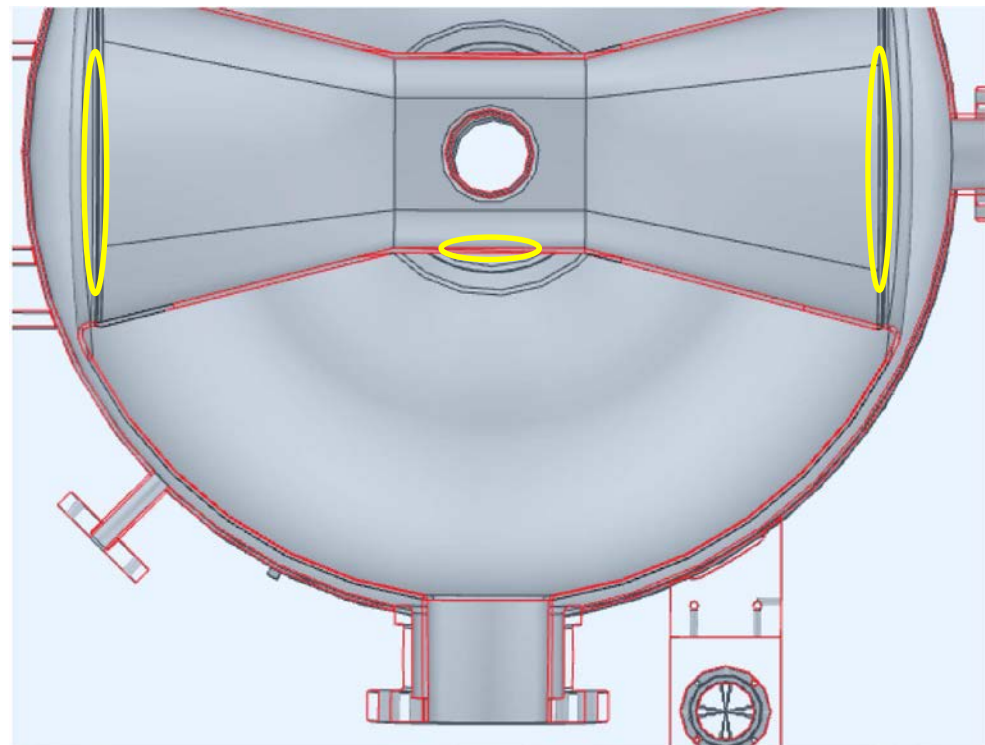
2nd step : RF port A for 3hrs

* turn the RF port upside down

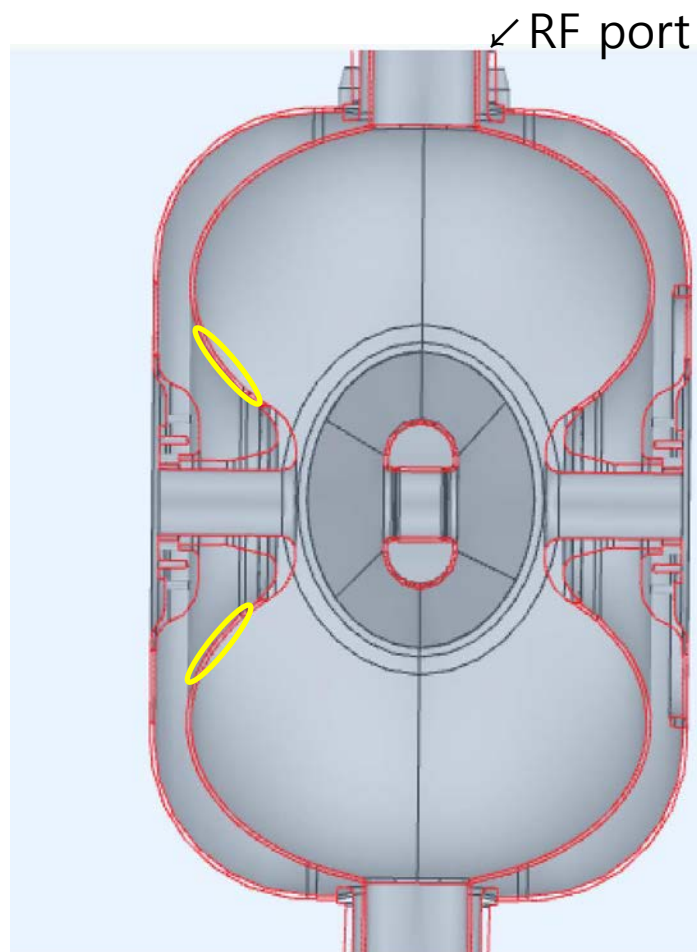
3rd step : RF port B for 3hrs

4th step : beam port for 2hrs

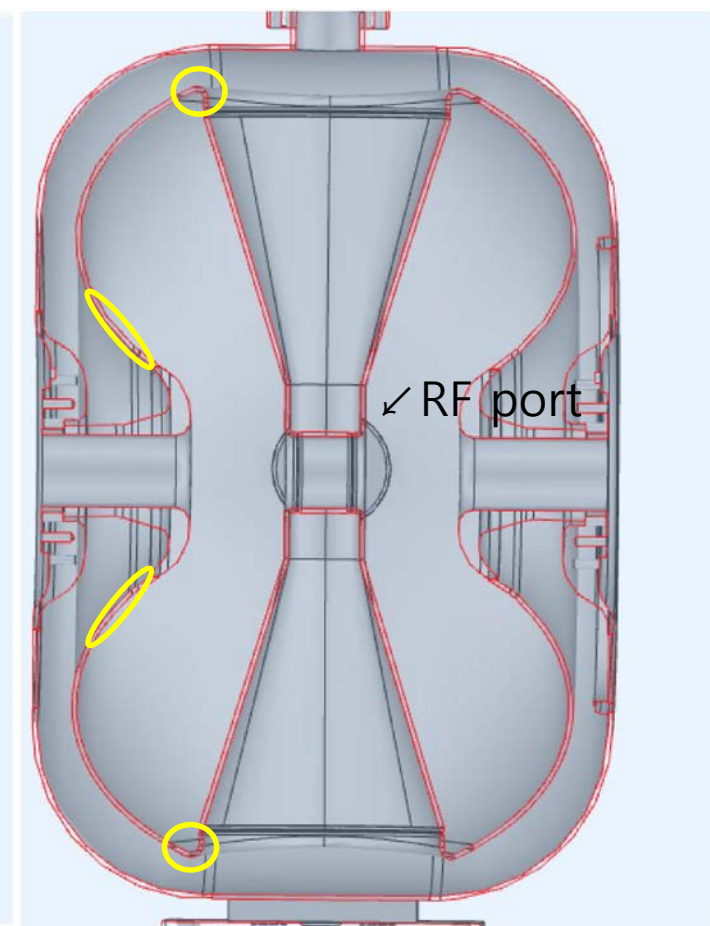
Grey zone of SSR1



Front view

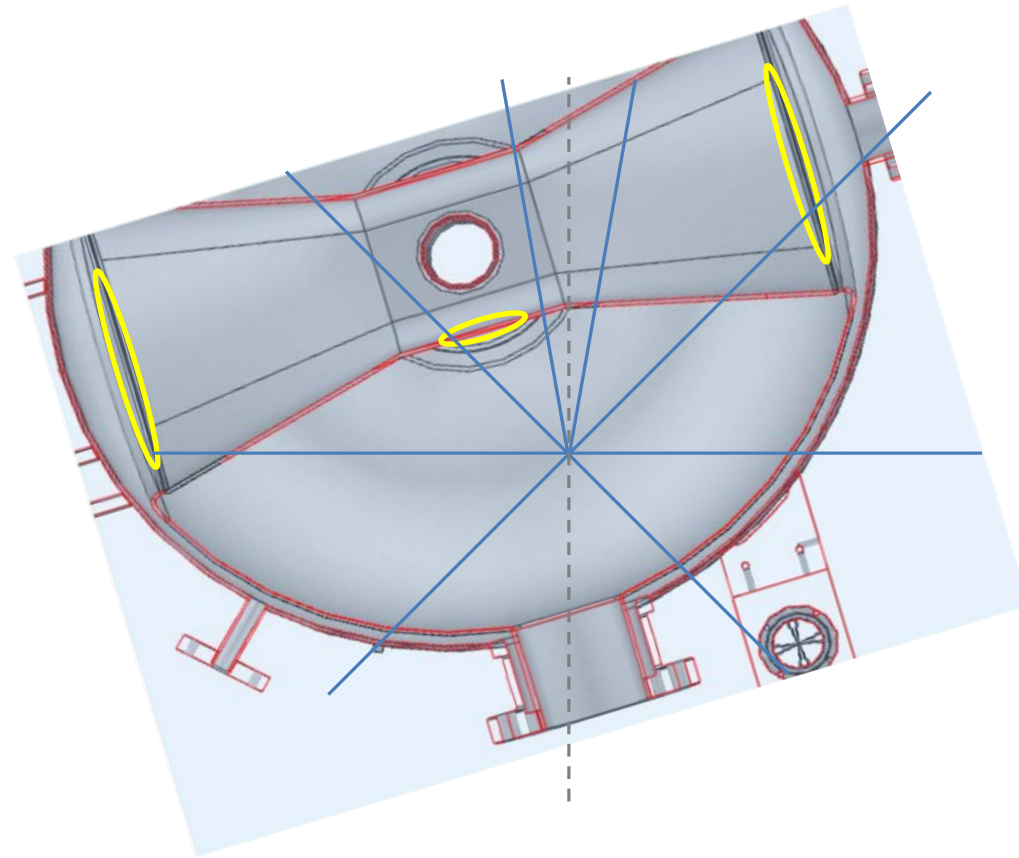


Side view

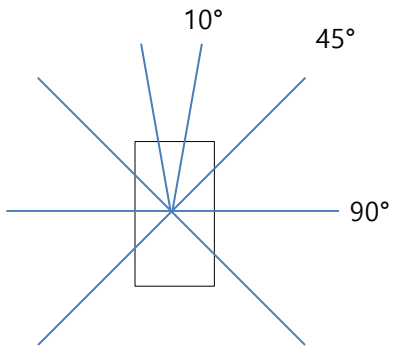
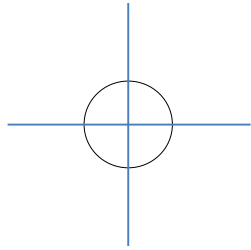
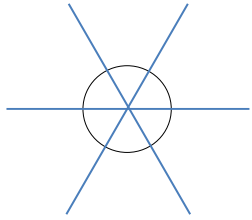


Top view

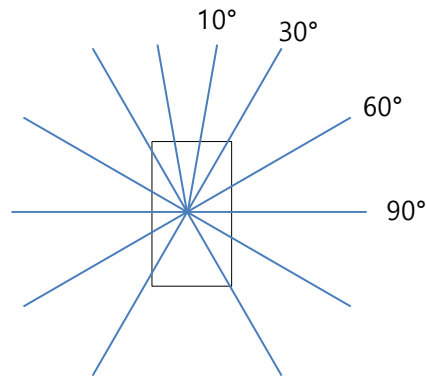
Reduce grey zone – cavity tilted $\pm 20^\circ$



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

Technical drawing showing a nozzle assembly with dimensions and hole specifications. The drawing includes a side view, a cross-section (A-A), and a cross-section (B-B). Dimensions include diameters of 17.3, 13, and 16.3, and lengths of 56, 35, 22, 50, and 7.5. Hole specifications include 4-φ0.5 holes at 90° and 180°, and 2-φ0.5 holes at 180°. Section A-A shows a 15° angle, and section B-B shows a 60° angle. A note specifies 1/4" PT thread.

NO	DESCRIPTION	MATERIAL	QTY	INS. NO	FORM	DATE

NOTE

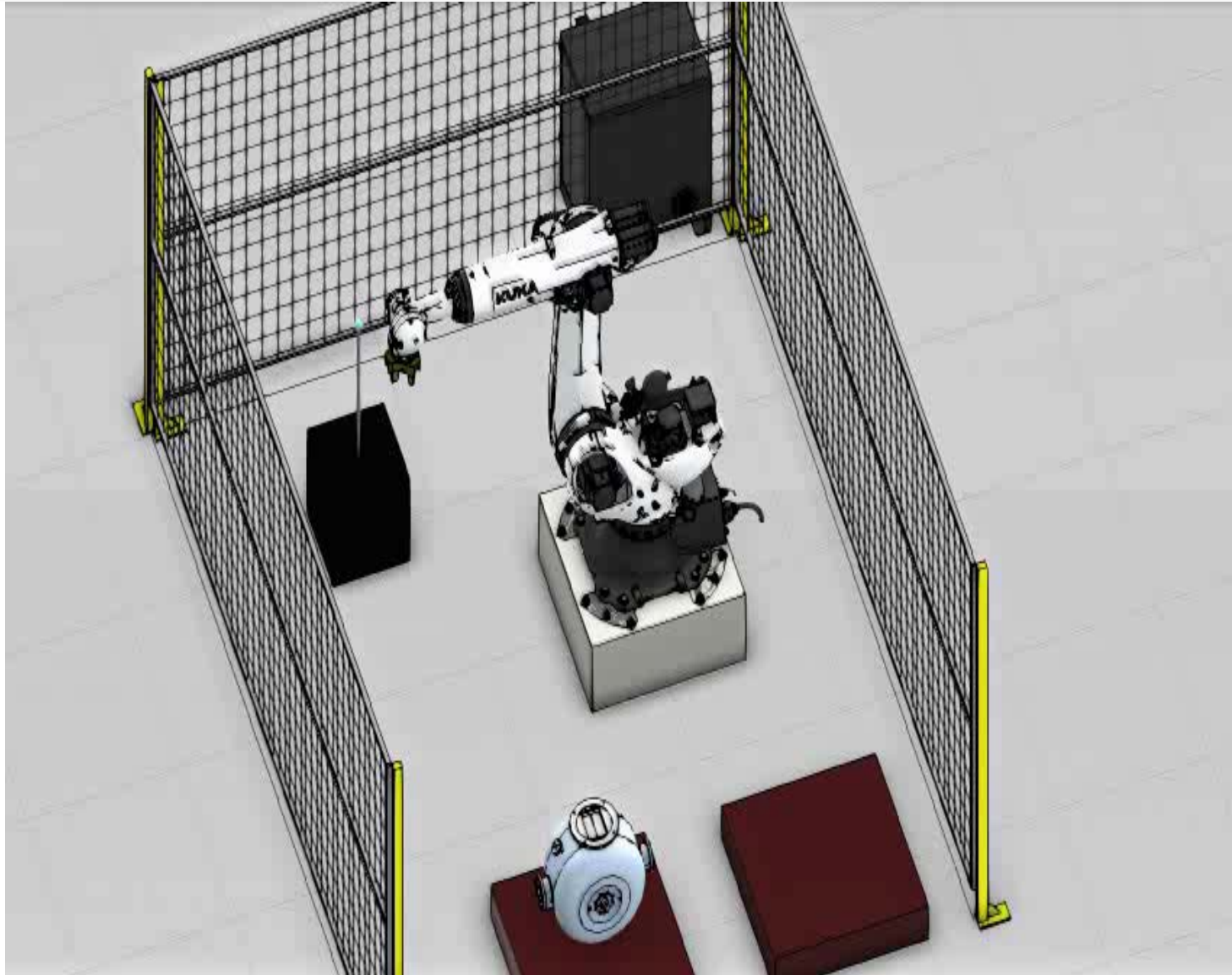
1. 재질: STS316L
2. 표면처리: 전해연마
3. 날카로운 모서리는 제거 할 것
4. 수량: 4ea
5. 비고 : 노즐구멍 (φ0.5mm) 의 각도에 유의할것
필요시 가공용 지그 제작 후 가공
6. 노즐 구멍
 - 10° - 2개소 (시작각 0°, 180° 등각)
 - 30° - 4개소 (시작각 0°, 90° 등각)
 - 60° - 4개소 (시작각 45°, 90° 등각)
 - 90° - 4개소 (시작각 0°, 90° 등각)
 - 120° - 4개소 (시작각 45°, 90° 등각)
 - 150° - 4개소 (시작각 0°, 90° 등각)

REV	DATE	DESCRIPTION	DRAWN	CHECK	APPROVAL

FILE: HPR 노즐

DRAWING: --

SHEET: --



- Assist in
 - HPR process
 - Drying after HPR
 - Cavity assembly
- Improvements
 - reduce manpower
 - prevent particle contaminations

- 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 $\pm 20^\circ$
 - ✓ Nozzle shape modified
 - ✓ RISP is looking into automatic robot arm system for HPR and cavity assembly.

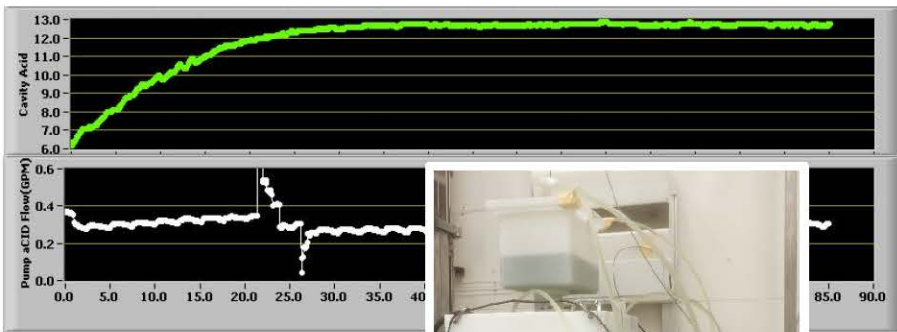
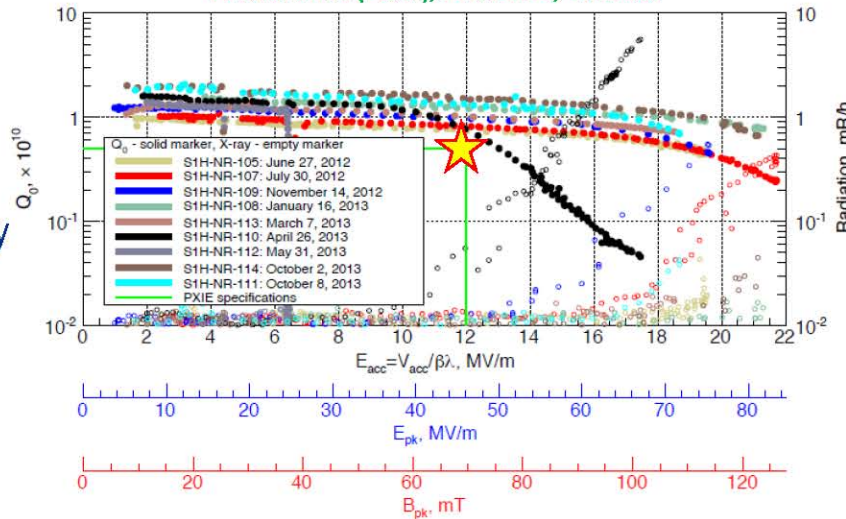
Back up

II. Experience with SSR1 BCP

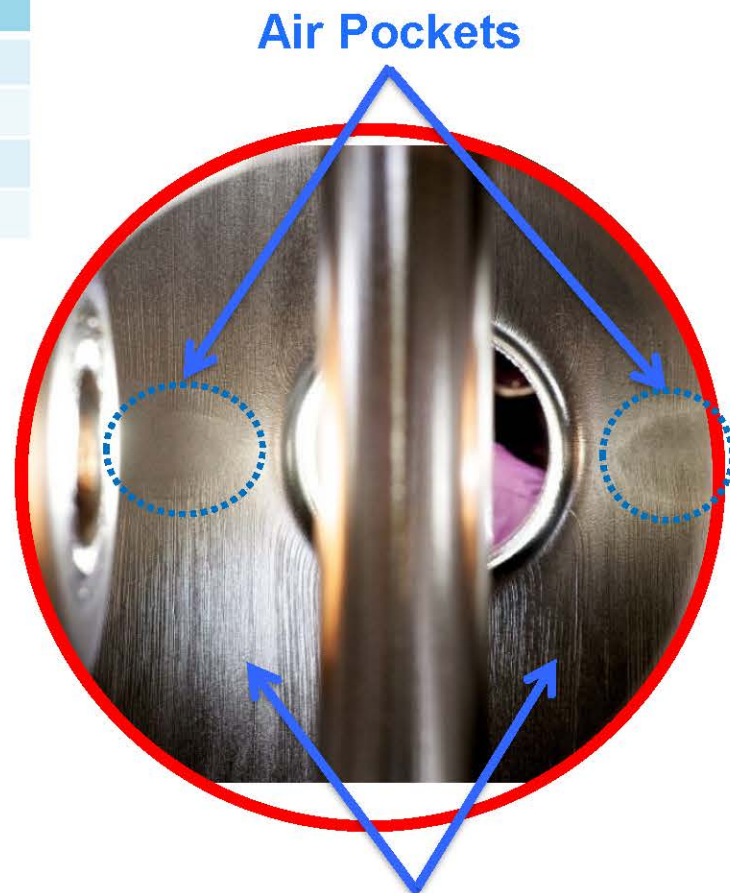
- New facility, same procedure as HINS cavity BCP
 - Additional mixing to prevent stagnant areas
- Standard 1:1:2 BCP mix
 - Pre-chill overnight (2-7° C)

	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	

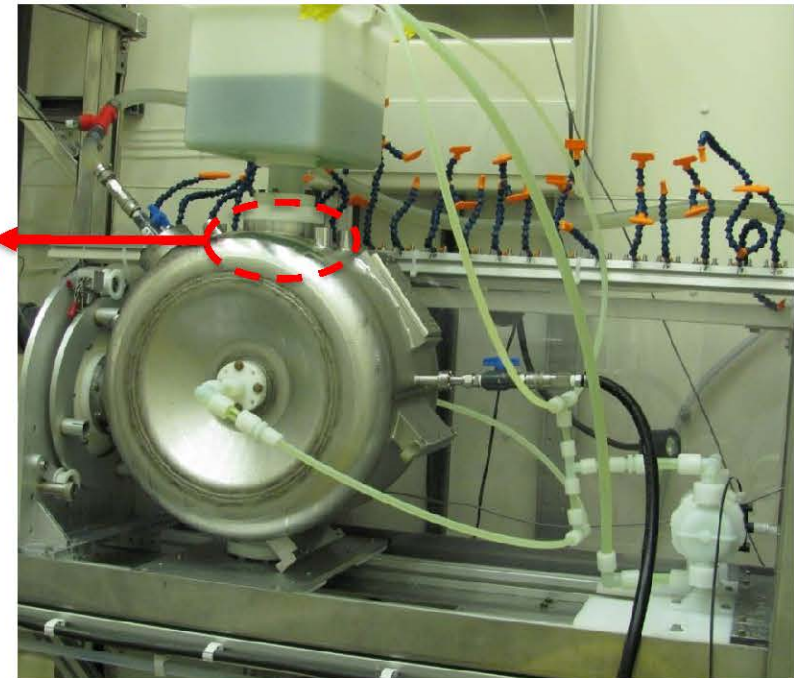
- Fixed cavity BCP results in unwanted surface features
- Cavity performance pretty good (lots of multipacting, not sure if any relation to chemistry)
- But room for improvement



Bulk BCP of bare cavity



Bubble Streaks

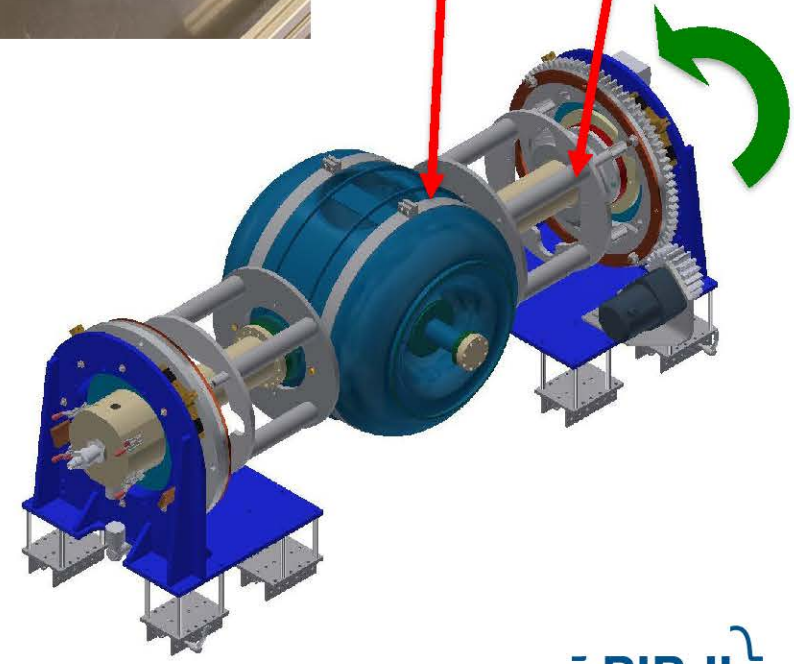
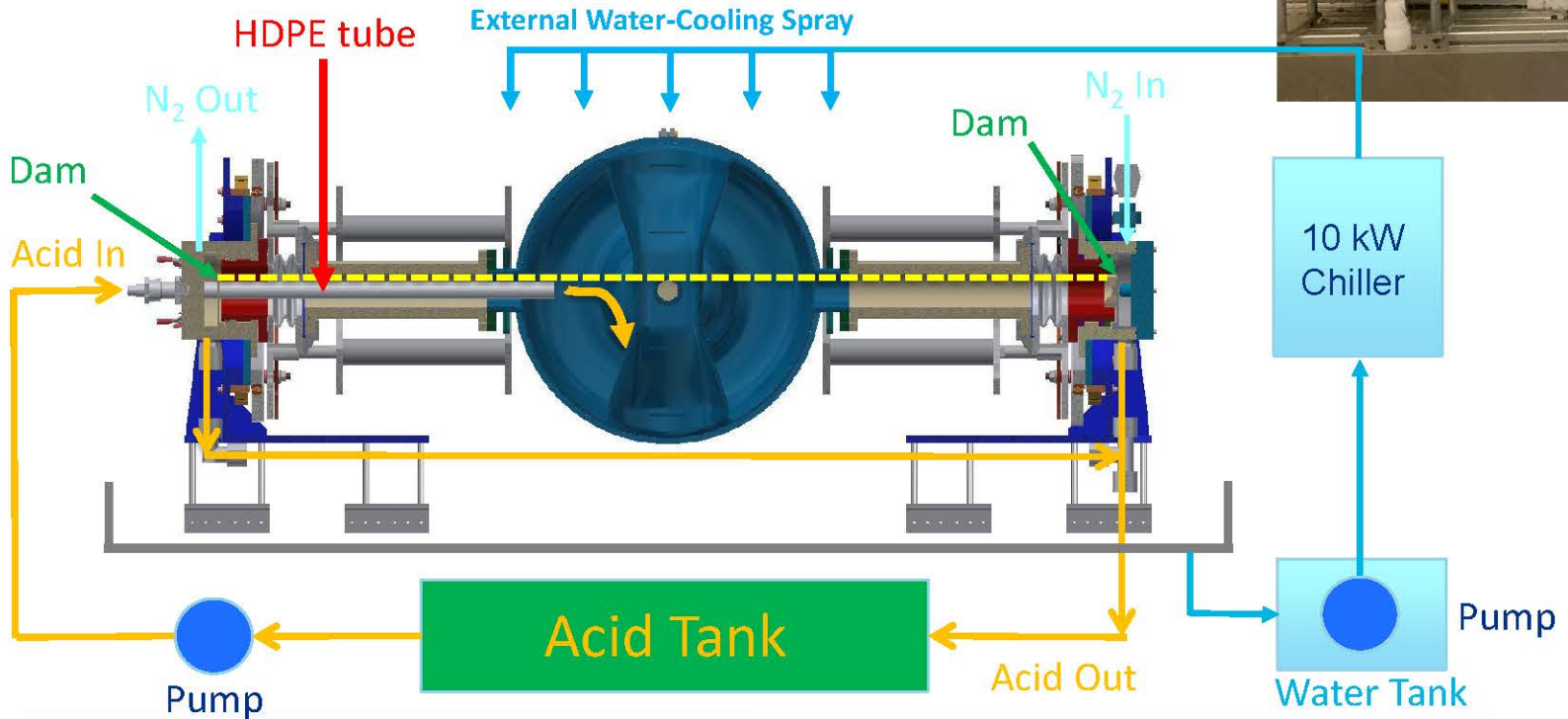
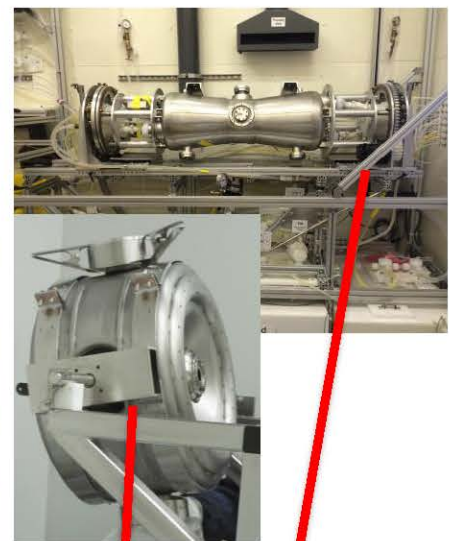


Light BCP of jacketed cavity

III. Plan for SSR2 BCP

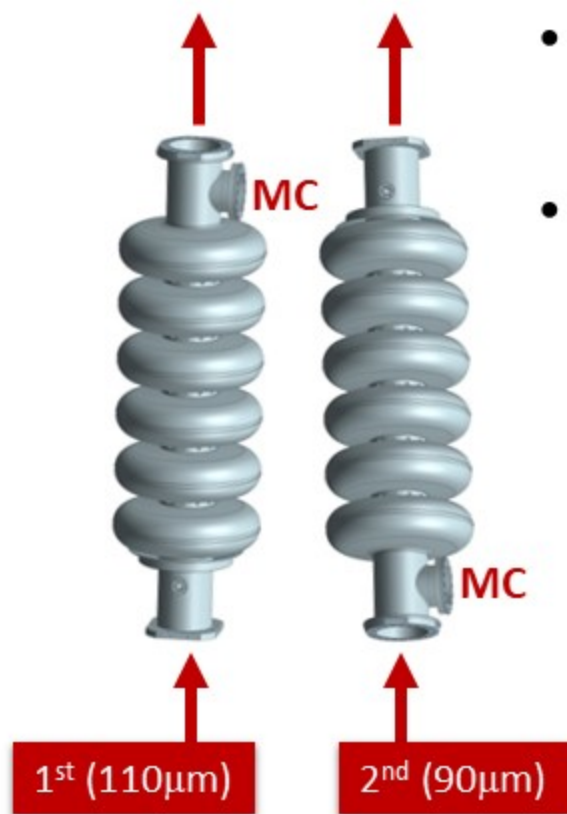
- Apply horizontal rotational BCP to eliminate unwanted surface features inherent to fixed cavity BCP as seen in SSR1s
- Only needed hardware is a cavity support structure and flange adapters
 - Based on SSR1 HPR cage and 162 MHz HWR processing cage

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



Bulk BCP new cycle: BCP grooves on MC tube

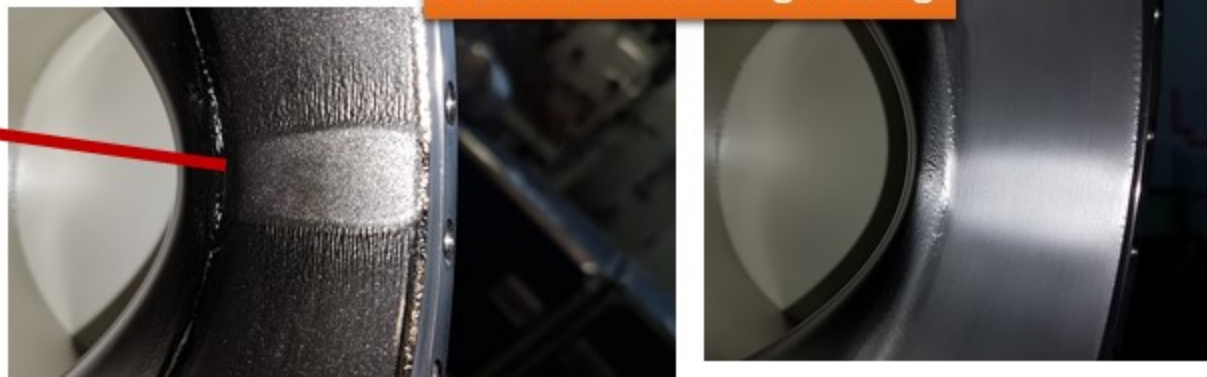
- Grooves on the MC tubes after Bulk BCP (done in two steps)
- Reason: BCP acid stagnant and possible air bubble when the cavity is in vertical position with the MC on the top
- How we recovered:



- 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

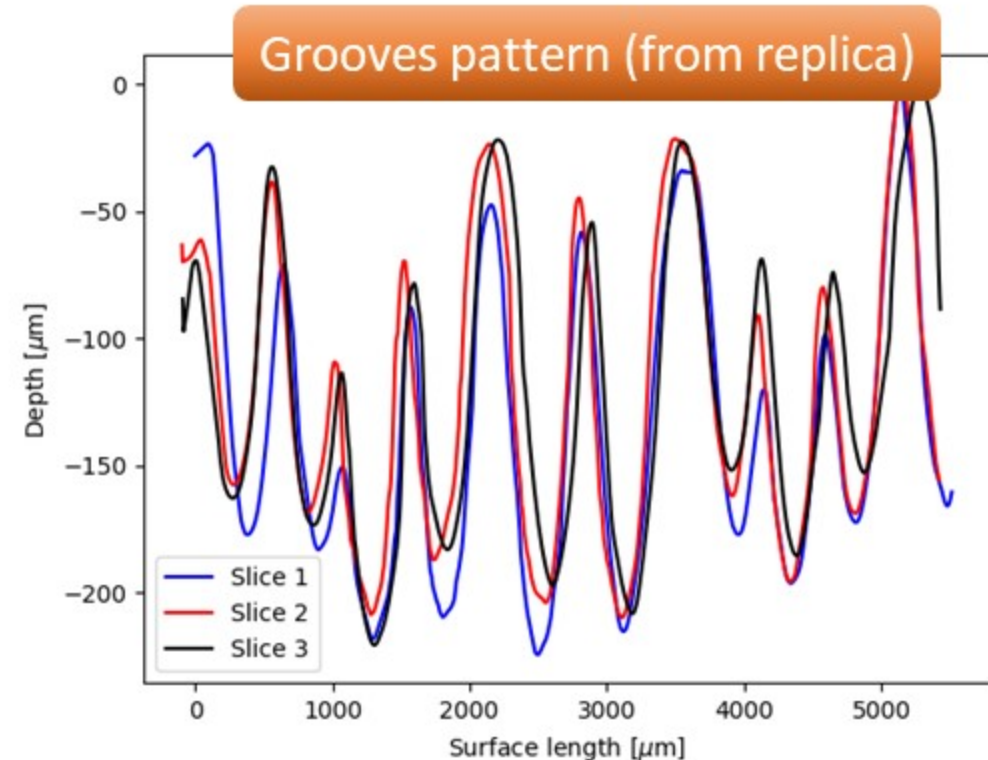
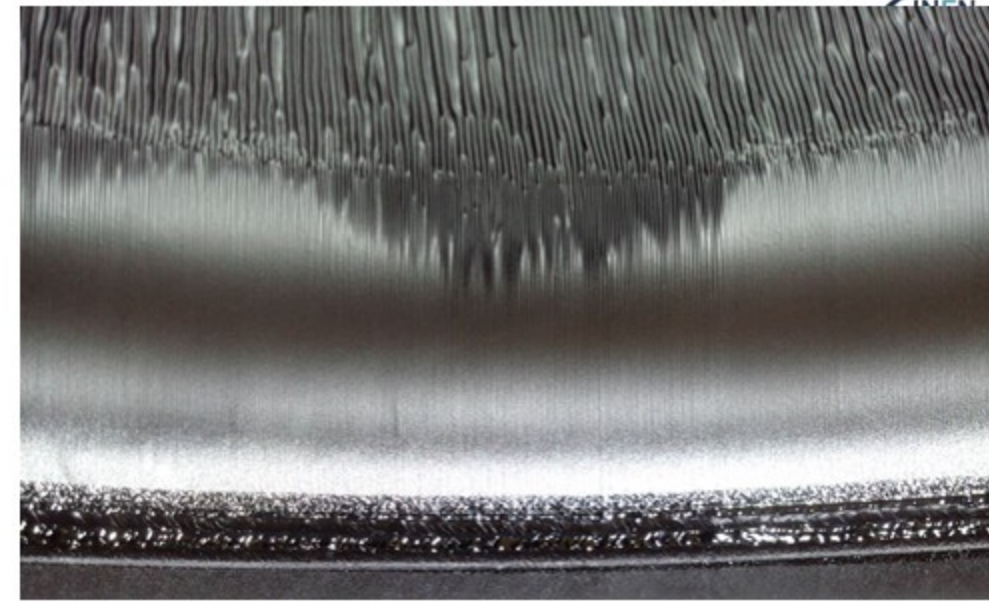


Before and after grinding



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 cleanliness.



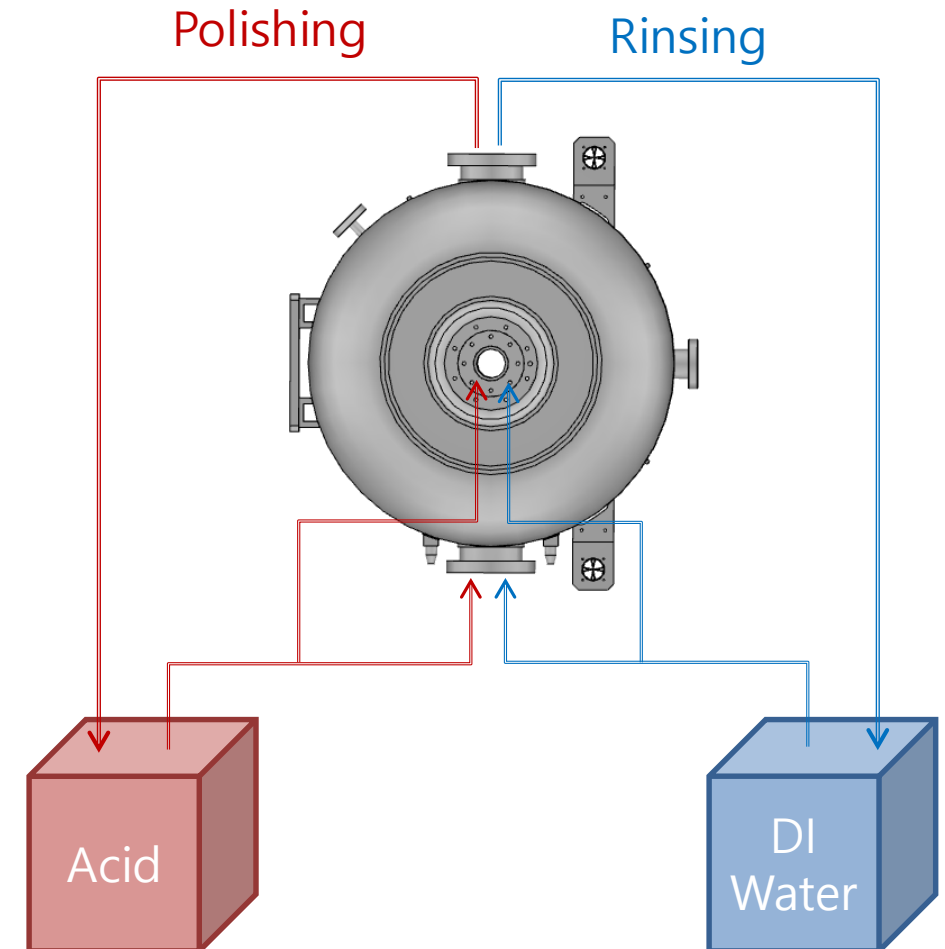
➤ RISP

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

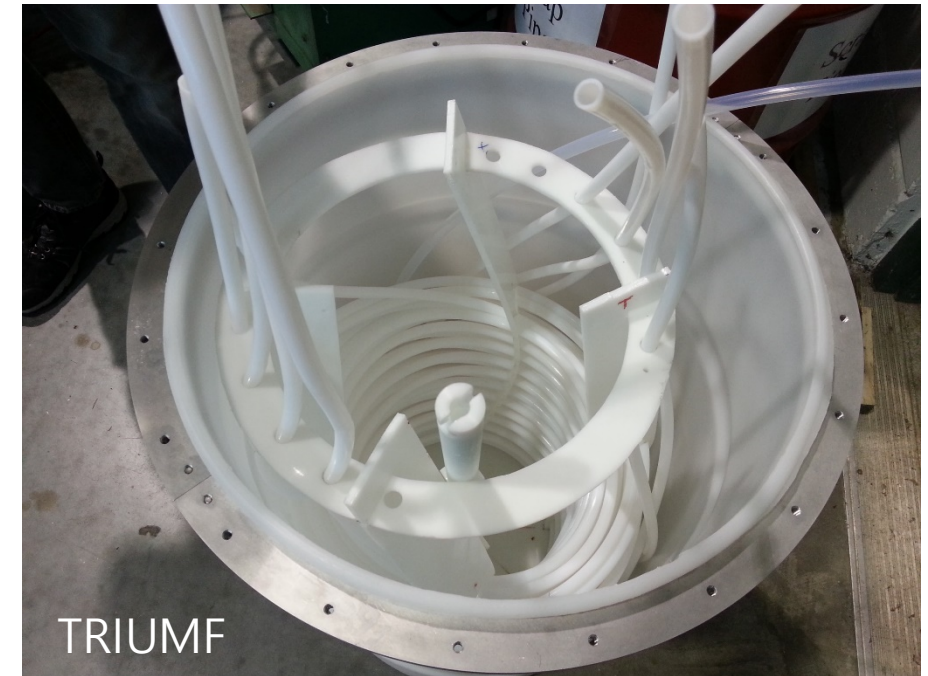
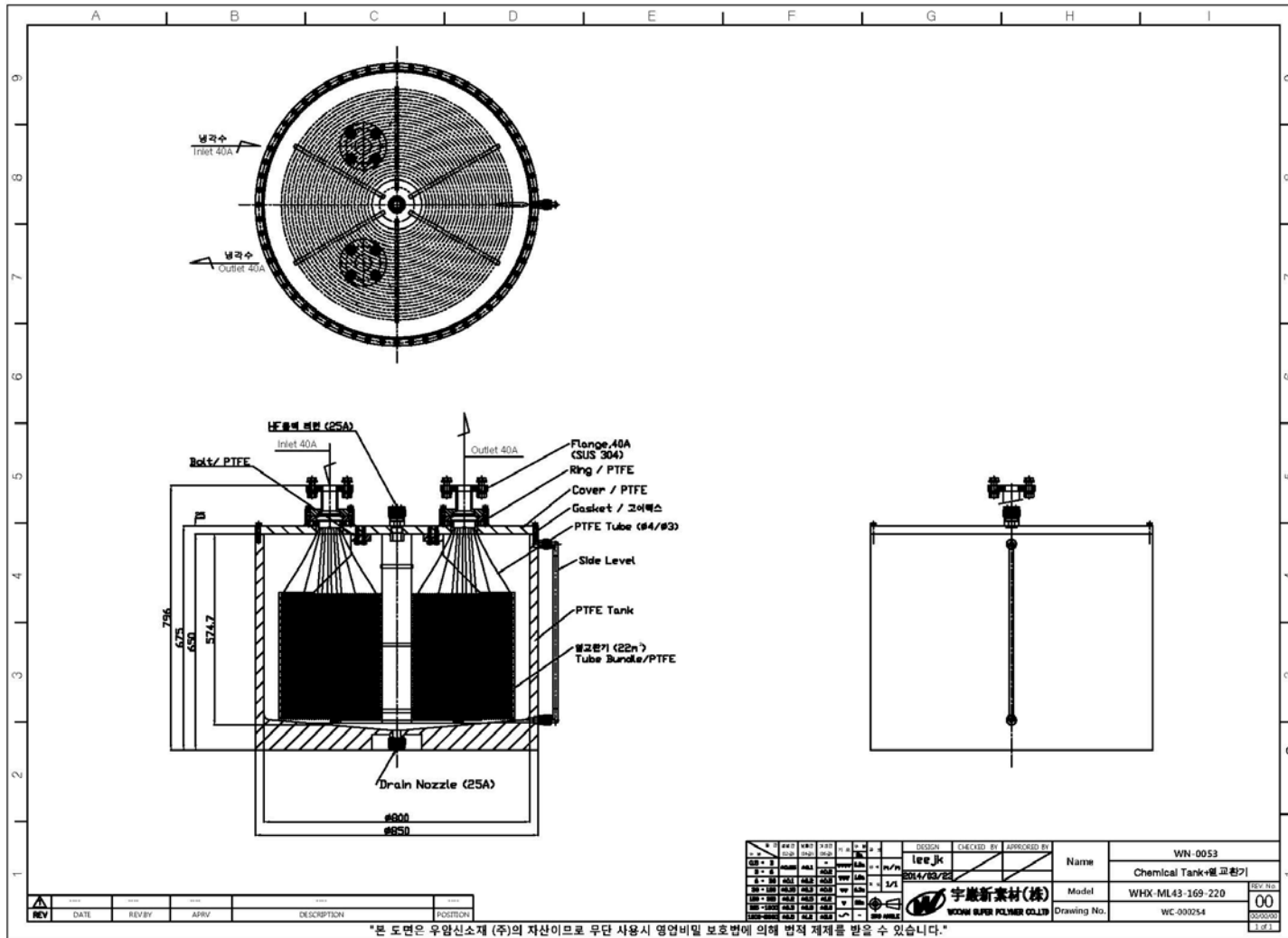
➤ Other labs

- 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

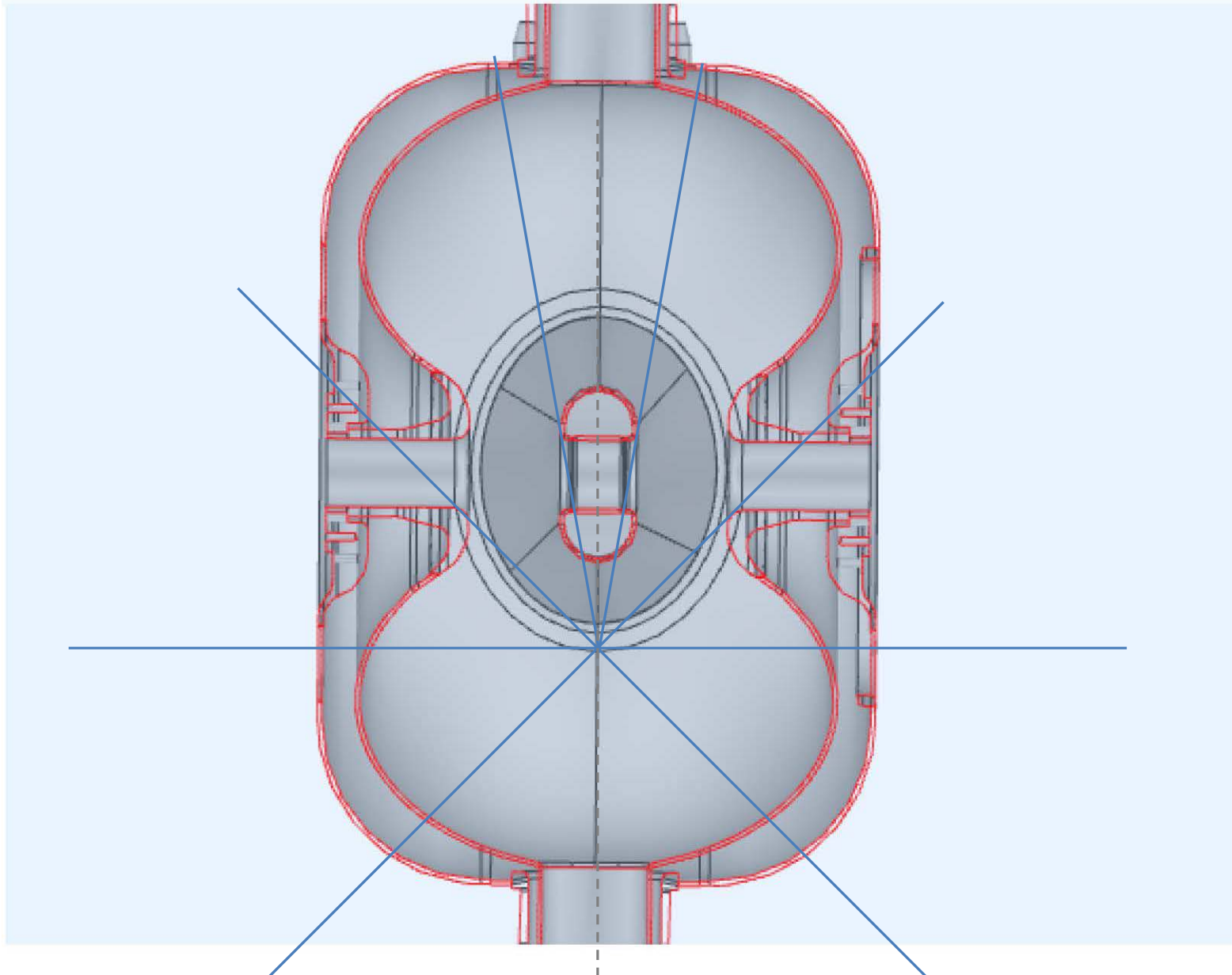


Heat exchanger of acid tank

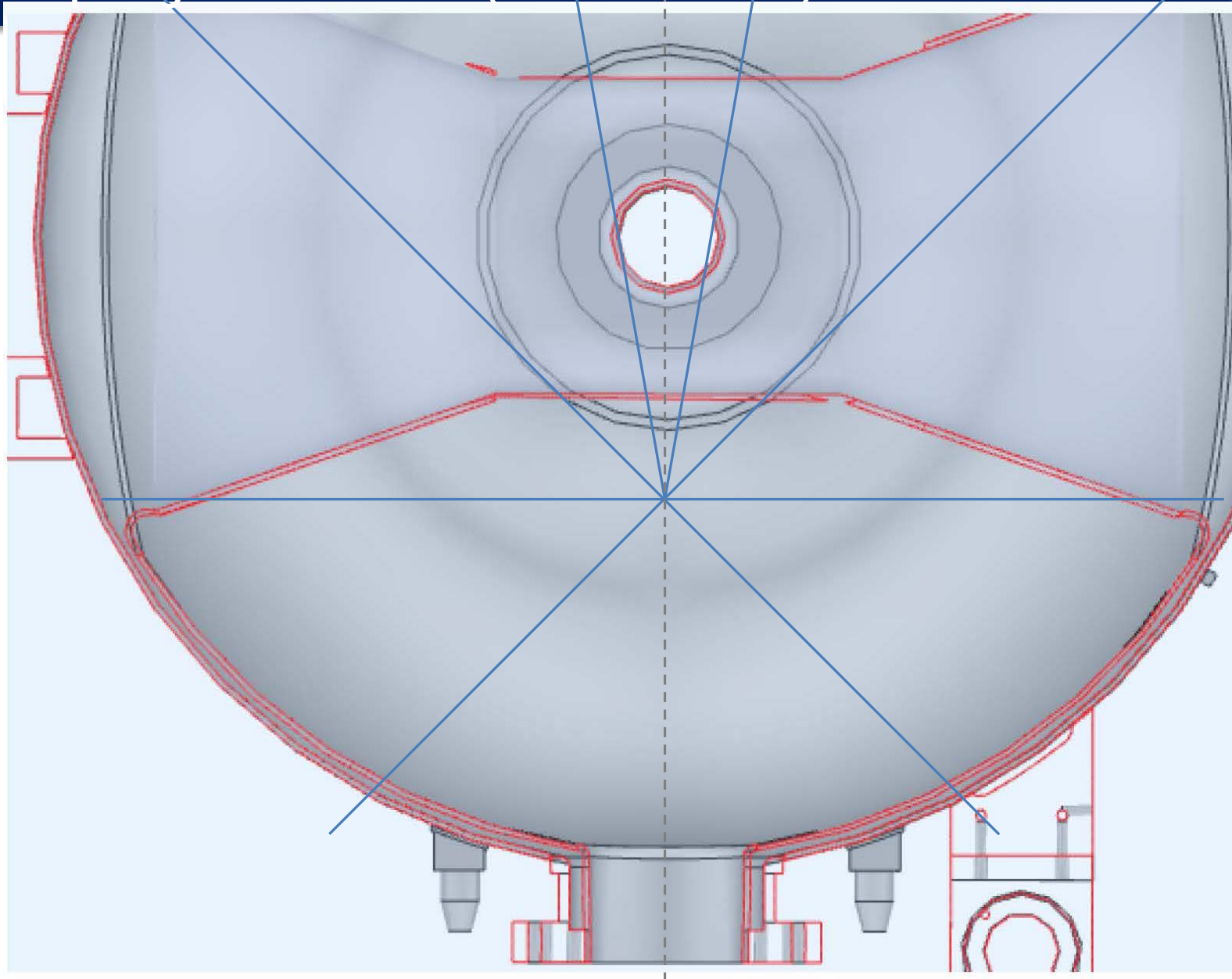


TRIUMF

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



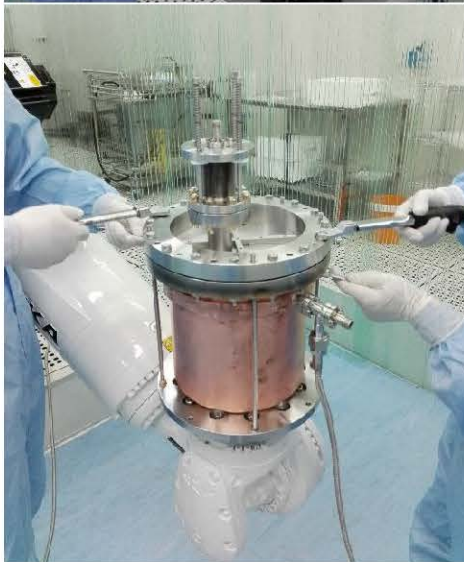
HPR for 1.3GHz Elliptical cavities

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.