# Electro-polishing experience at KEK

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KEKB RF

KEK

# EP of LHC crab cavities

LHC Crab cavitis for LH-LHC

- Compact and complicated cavity structure to meet space requirements
- High fields are required for sufficient bunch rotation
  - 3.4 MV per cavity at 400 MHz with $Q \sim 10^{10}$,T=2K
  - (KEKB crab: 1.4 MV at 509MHz with $Q=10^9$,T=4.4K)
- Surface treatment is one of important issues
  - CP(Chemical polishing) is used

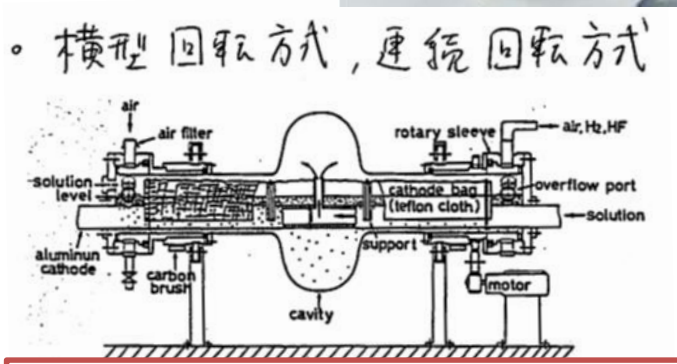
EP (Electro-polishing)

- First applied to TRISTAN SRF cavities at KEK
- Horizontally rotating technique developed
- Standard treatment method for high field cavities

VEP (Vertical EP)

- We proposed an R&D on application of EP to LHC crab cavities
- Horizontally rotating technique is difficult to apply
- Develop vertical EP at our EP station
- Applied VEP to BNL PoP DQW crab cavity

BNL DQW cavity




Horizontally rotating EP system developed for TRISTN SC cavities

Our EP apparatus for 500 MHz cavity

# Vertical EP results (PoP DQW CC) in 2017

TTC2018 at Riken

Sufficient surface polishing obtained

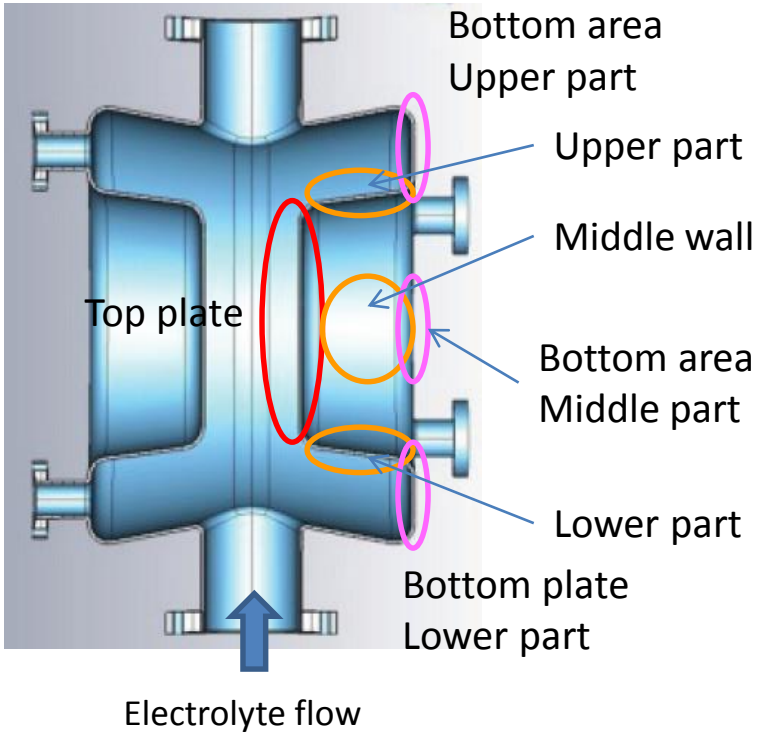
VEP results

Average polishing thickness: 35 μm (from I*T integral/surface area)

From thickness measurement;

1. Top plate: 44 μm
   - Almost uniform polishing
2. Bottom area: 22 μm on average
   - Slightly position-dependent
   - Upper part: 25 μm
   - Middle part: 19 μm
   - Lower part: 20 μm
3. Side area
   - Position-dependent
   - Upper part: 30 μm
   - Middle part : 29 μm
   - Lower part : 80 μm

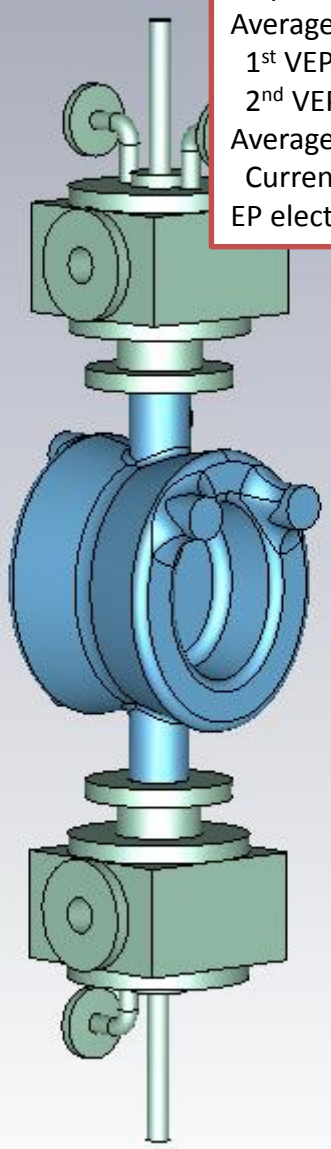
Large polishing.
Need to improve.

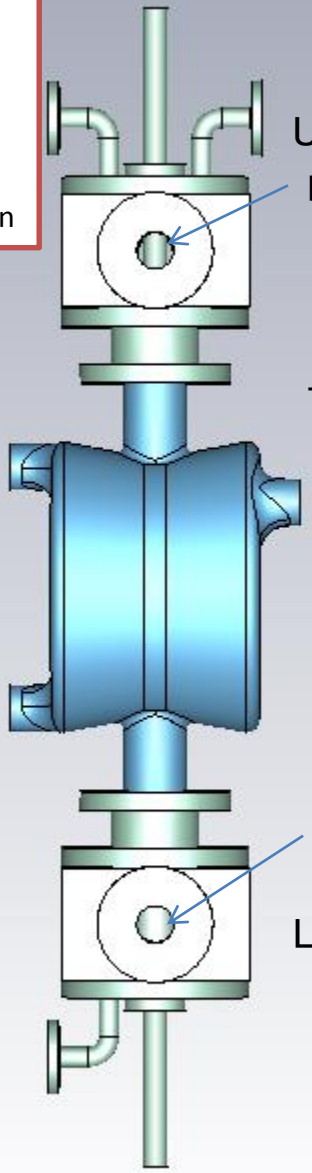


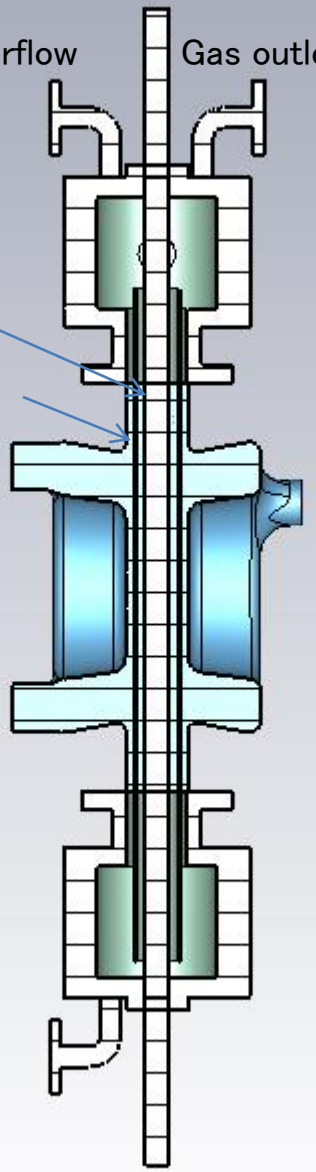

VEP with position flipping

# Vertical EP apparatus and SPS DQW CC

EP parameters
Average polishing: 30 μm
1st VEP: 15 μm
2nd VEP: 15 μm
Average current: 108 A at 16V
Current density: 16 mA/cm$^2$
EP electrolyte flow rate: 15 L/min



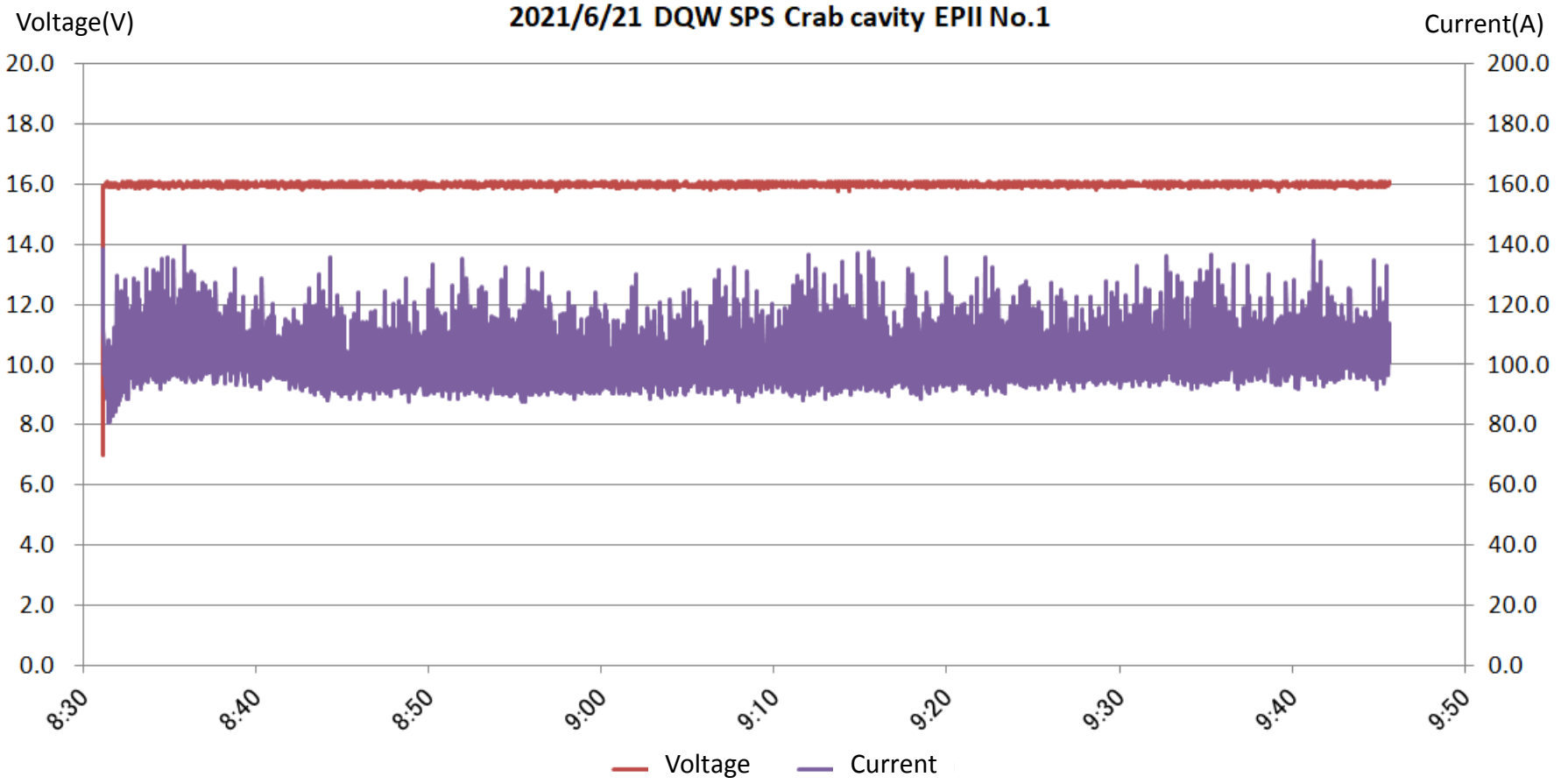


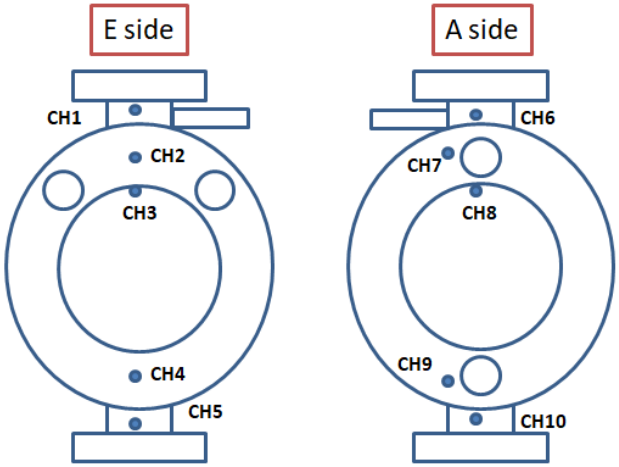
# Setup for the 1st VEP

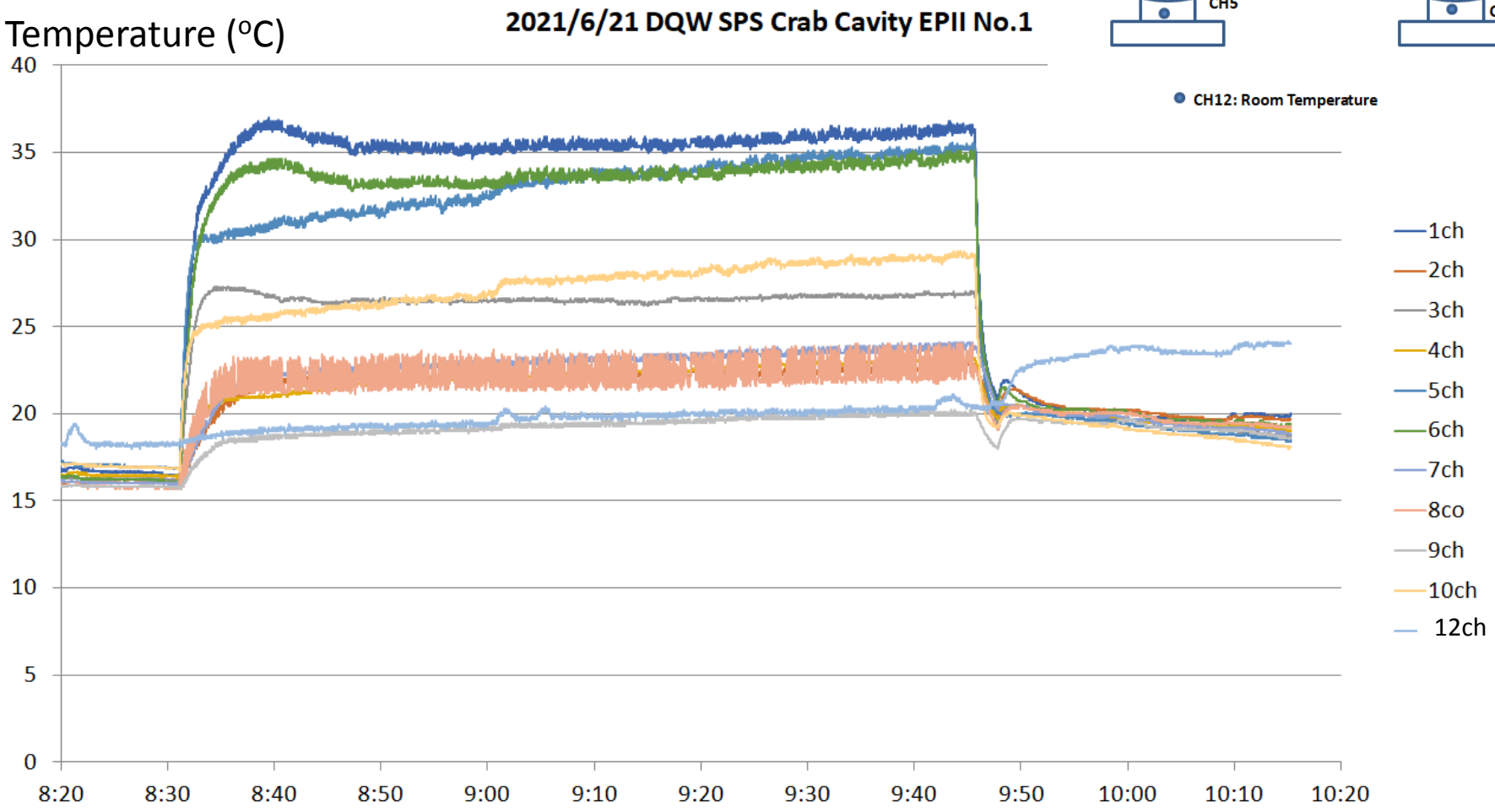
# Current and voltage during 1st VEP

Voltage : 16V
Average current: 108 A
Current density: 16 mA/cm$^2$
Average polishing: 15 μm



# Temperatures on the cavity, 1st VEP

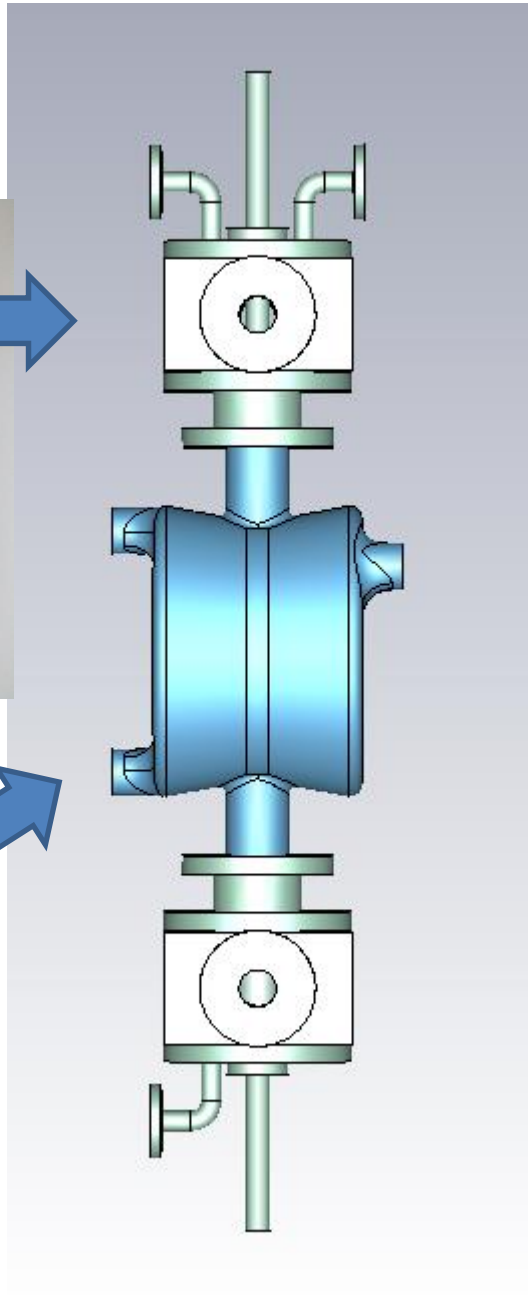


# H2 separation and chemical compound found in VEP

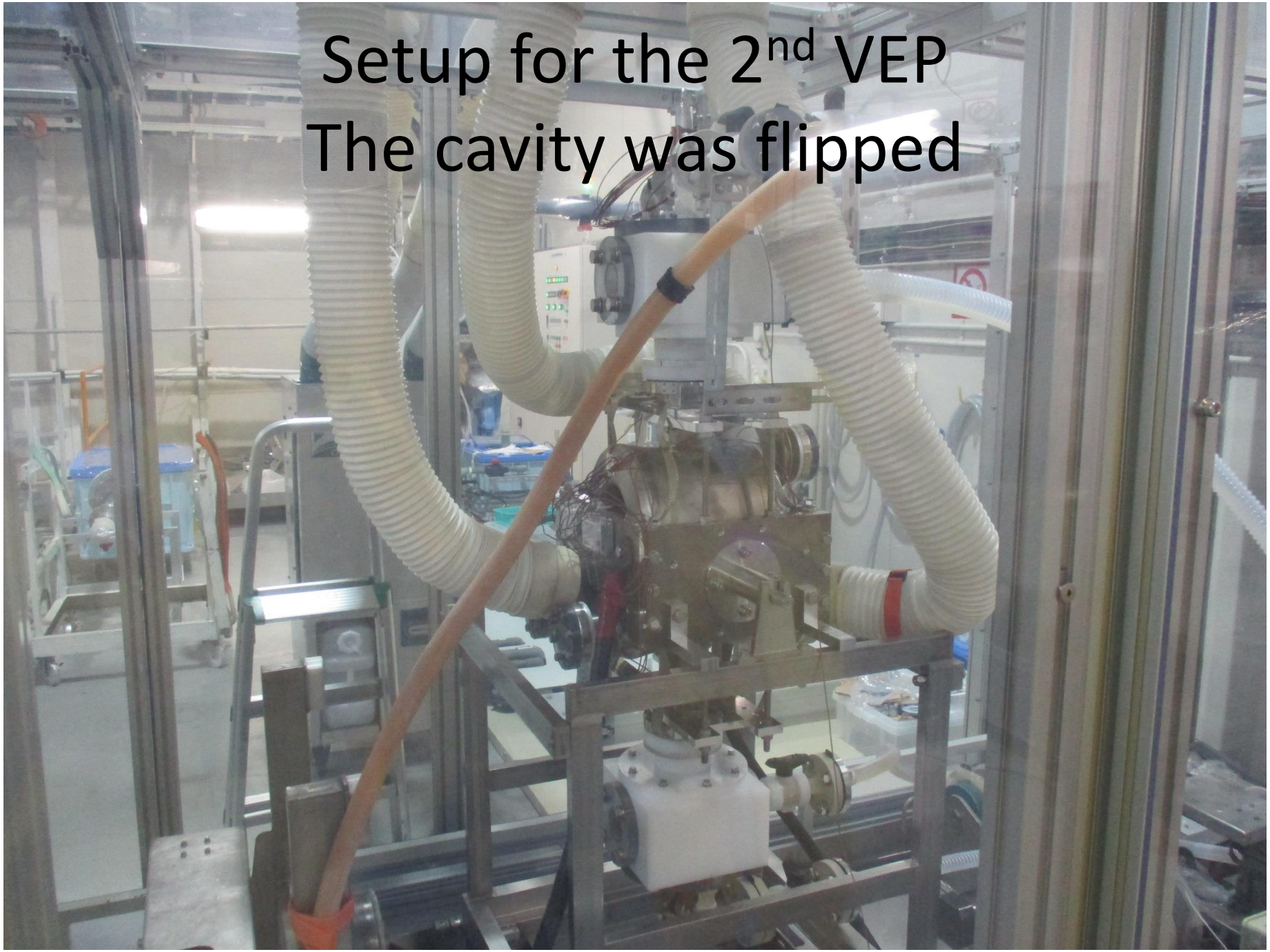
Inspection and swing

Hydrogen gas separation



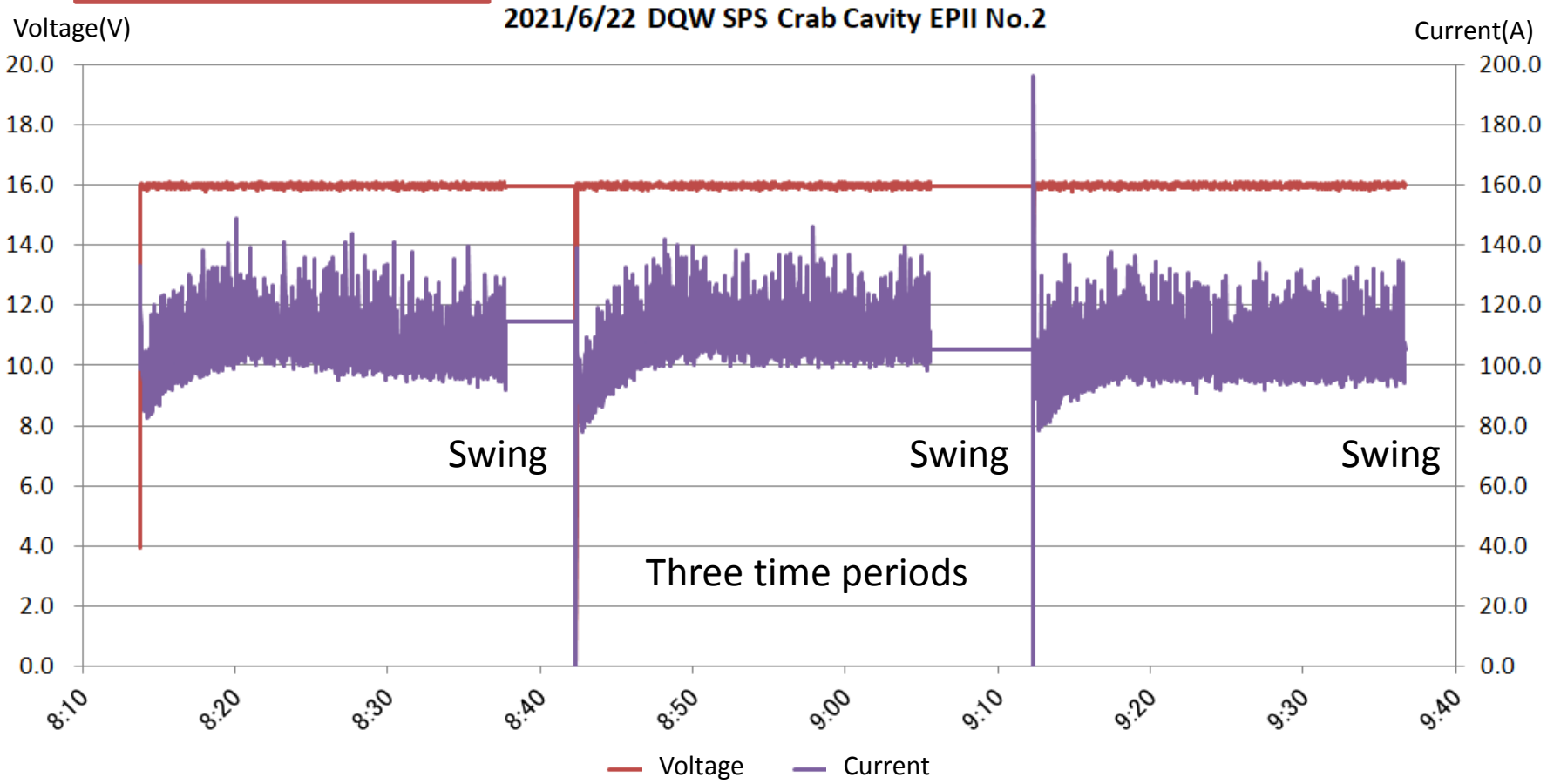
Sampling for X-ray fluorescence analysis
=> Niobium Oxide

Chemical compound found in the lowest HOM port

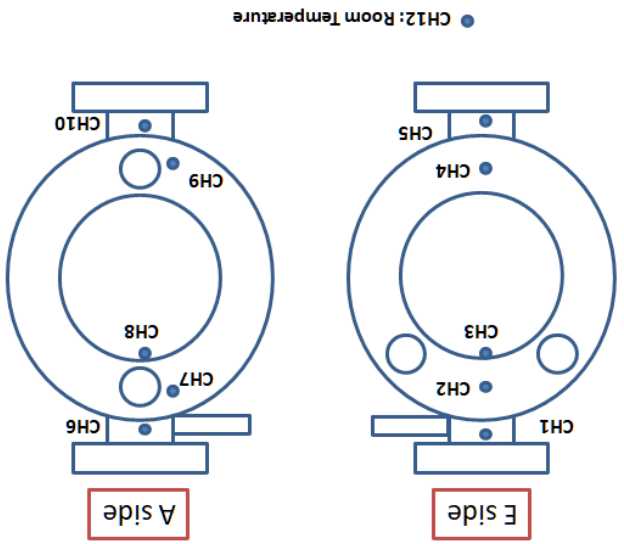

Setup for the 2nd VEP
The cavity was flipped

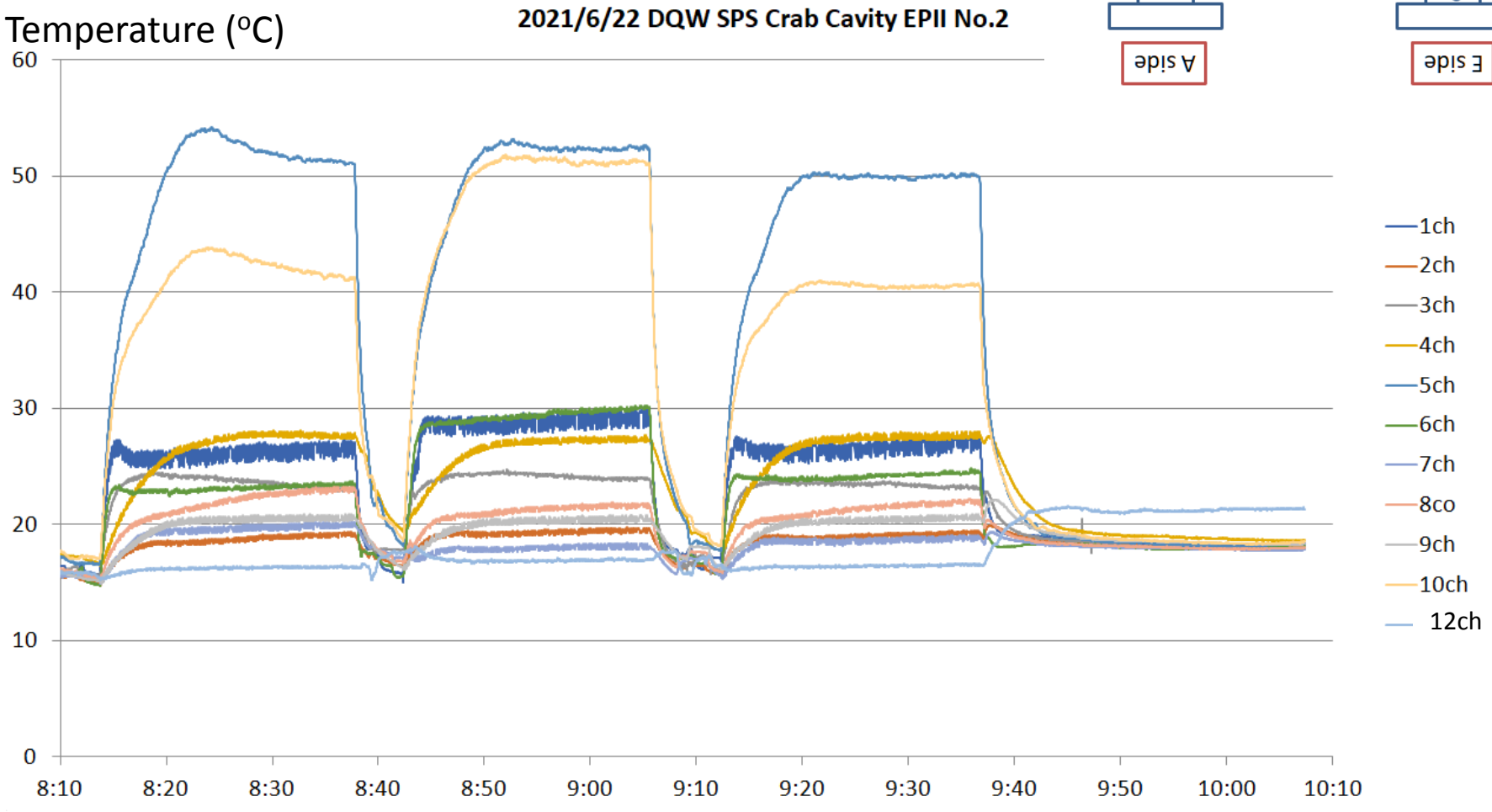
# Current and voltage during 2nd VEP

Voltage : 16V
Average current: 108 A
Current density: 16 mA/cm$^2$
Average polishing: 15 μm

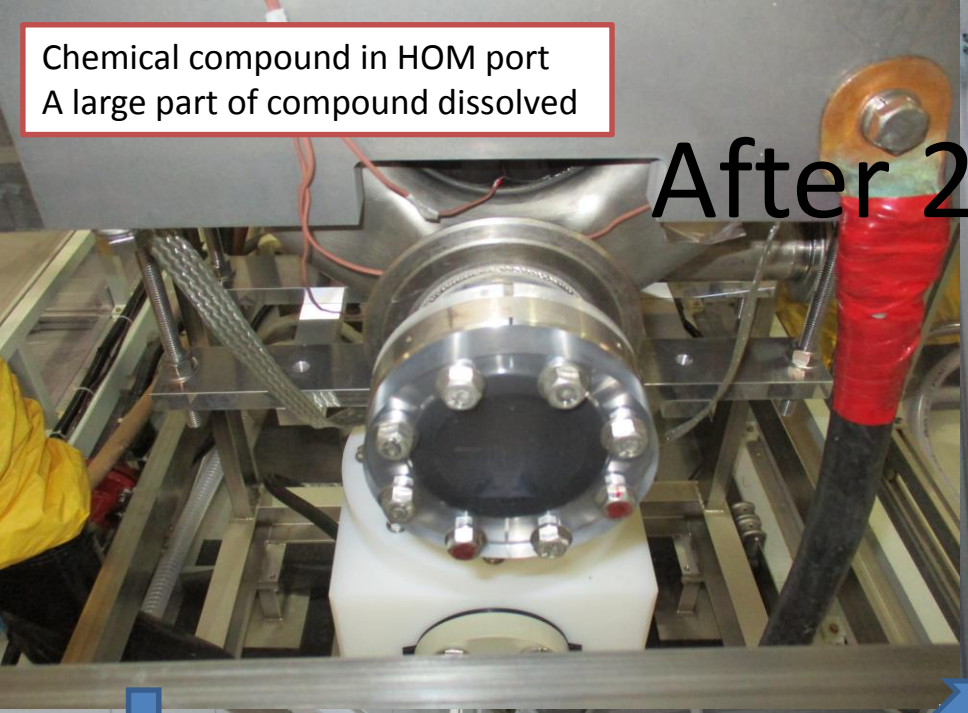


# Temperatures on the cavity, 2nd VEP



# After 2nd VEP



Chemical compound in HOM port
A large part of compound dissolved

Remove Teflon boxes

Central cathode with cathode bag

Pure water rinsing

# Rinsing after VEP
# O3 water rinsing
# Ultrasonic rinsing

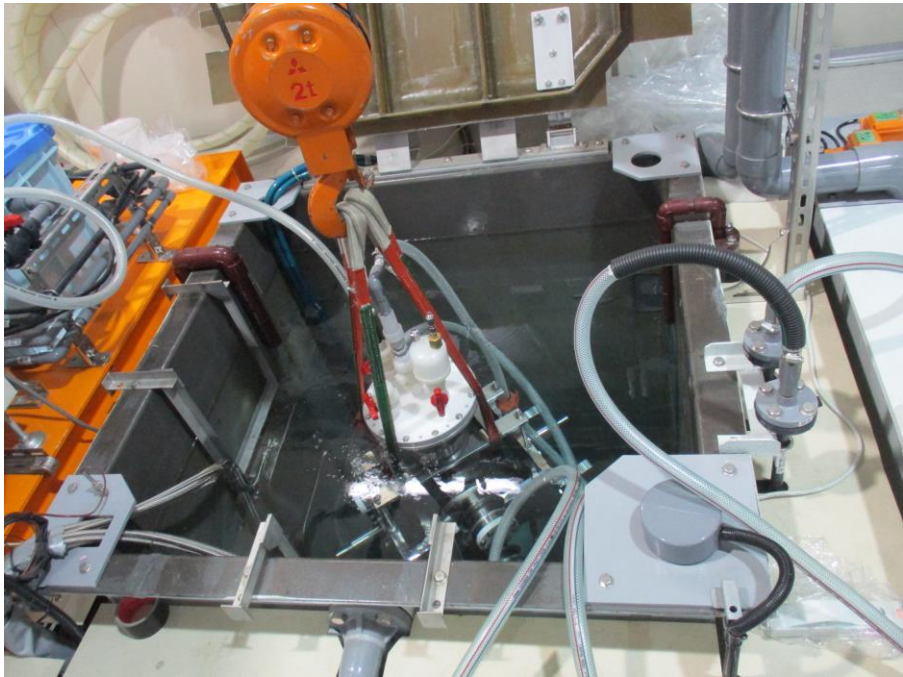
Ozonized water rinsing
Ozonized water: 3.3 ppm
Overflowing for 10 min.

↓

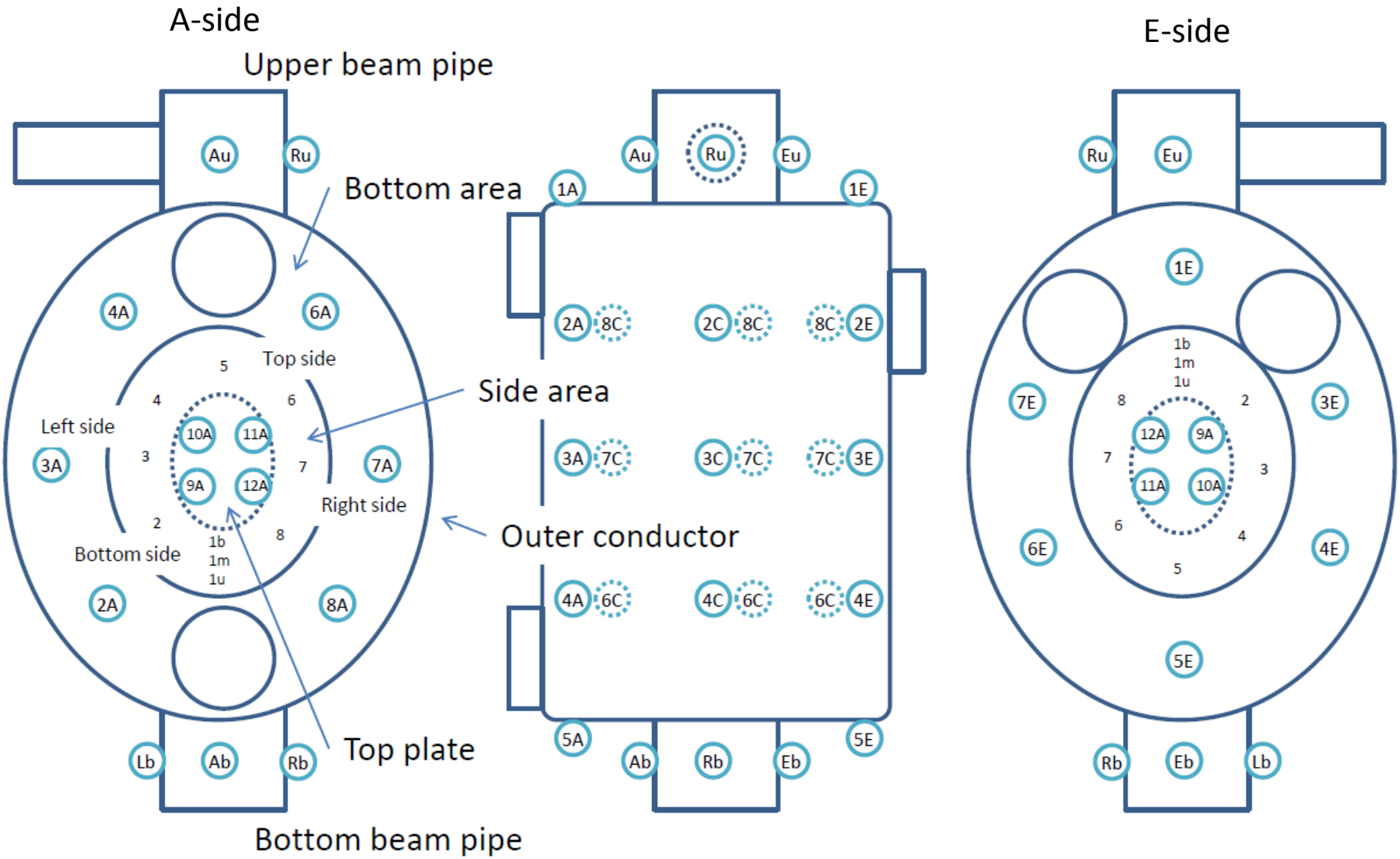
Ultrasonic rinsing
Ultrapure water
Overflowing for 1 hour
Ultrasonic: 40 kHz
Hot bath temperature: 50 °C

↓

Purging with nitrogen gas

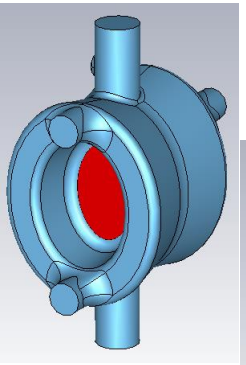


# Polishing thickness, measured points

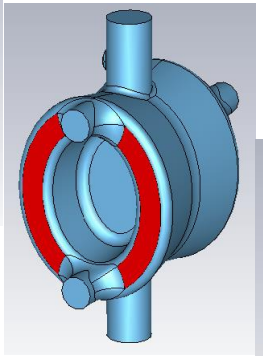


# Polishing thickness

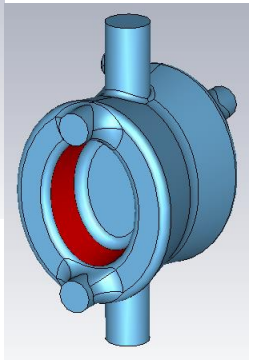
Top plate area



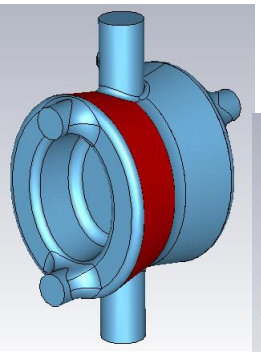
Bottom area



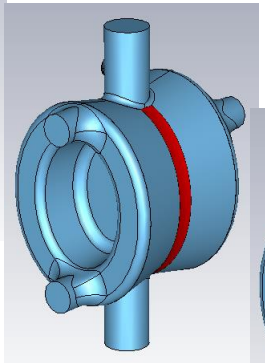
Side area



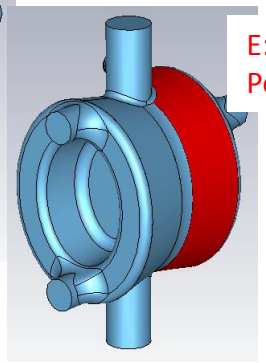
Outer conductor



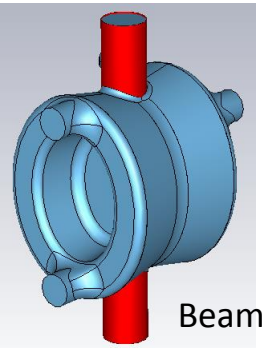
A side



C area



E side



Beam pipe

| Component | Area | | Polishing thickness (mm) |
|---|---|---|---|
| Inner conductor A,E | Top plate | A side | 0.025 |
| | | E side | 0.024 |
| | Bottom area | A side | 0.018 |
| | | E side | 0.017 |
| Inner conductor A | Side area | Upper part | 0.022 |
| | | Right part | 0.042 |
| | | Left part | 0.007 |
| | | Lower part | 0.031 |
| Outer conductor | | A side | 0.029 |
| | | E area | 0.031 |
| | | C side | 0.024 |
| Beam pipe | Upper | | 0.075 |
| | Lower | | 0.092 |

E: not clear(not accurate measurement)
Polished more than other parts

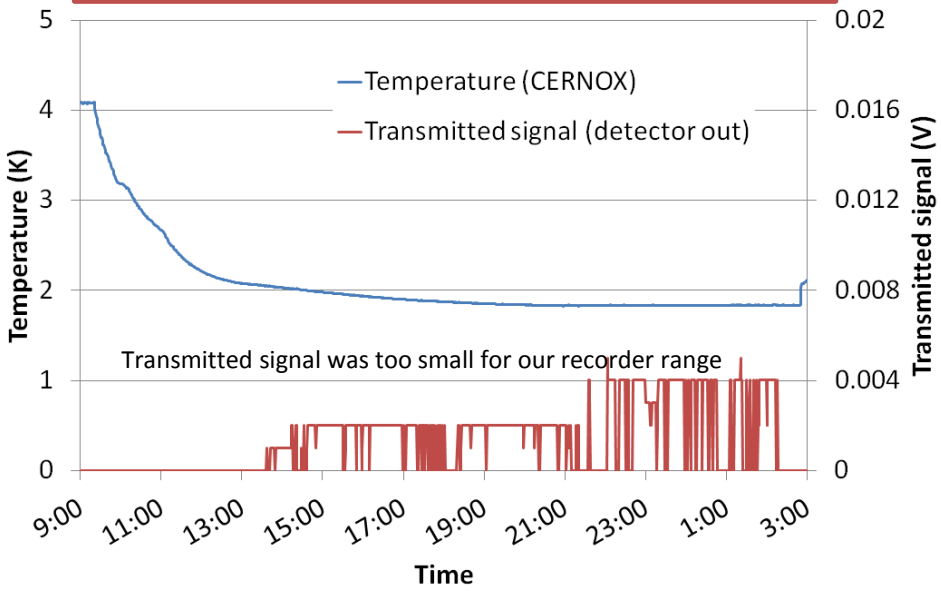
Large polishing
Better to suppress but acceptable?

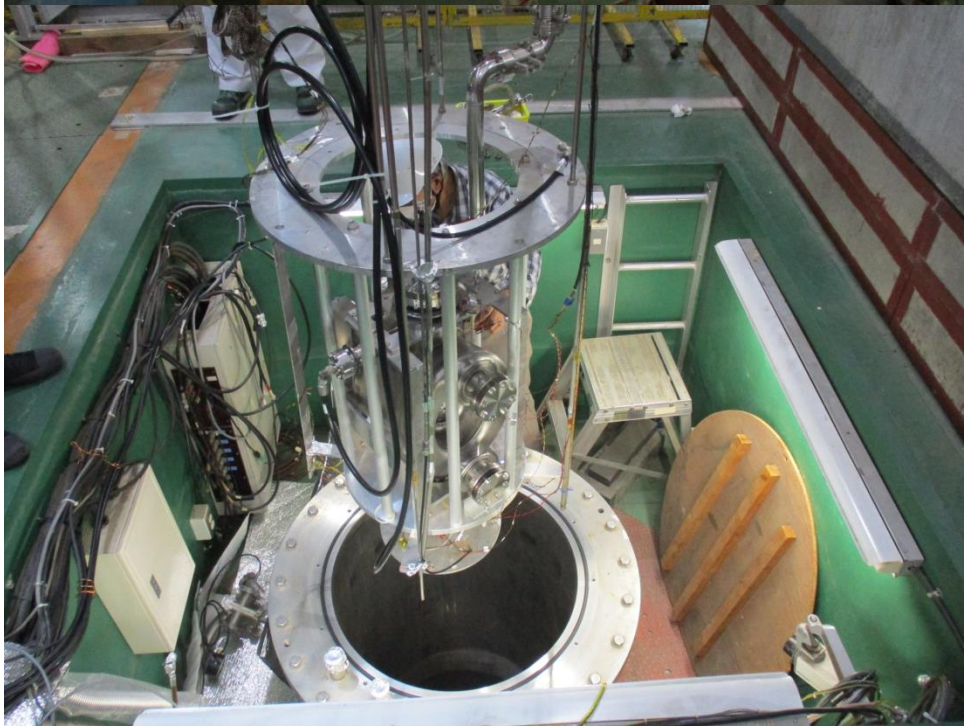
# Cold test

Set up and baking (120 oC x 48 Hours)

Cool-down to 4K with Liq.He of 1700L
Cool-down to 2K by pumping

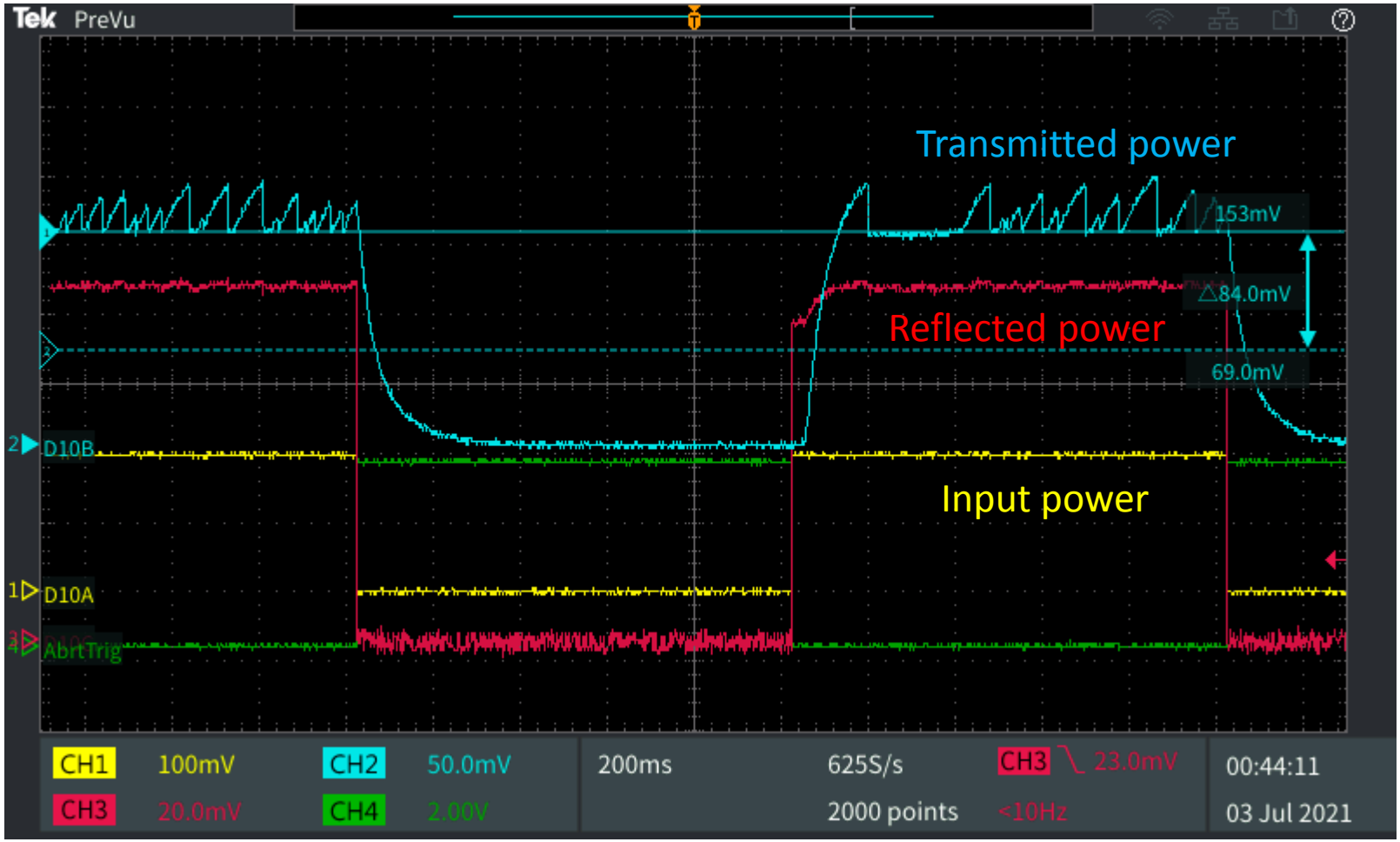
Frequency search and phase lock
Frequency shift after VEP: 2.3MHz
(Too large, shape deformation?)
Multipacting processing at around 0.1MV
Could not process MP within 12 hours



# Multipacting at low fields

Used pulsing to process multipacting.
Input RF power: 5~8W
Transmitted power: ~2.5 microW
Corresponding Vc: ~0.1MV
This multipacting level was quite hard.
Could not process this barrier.

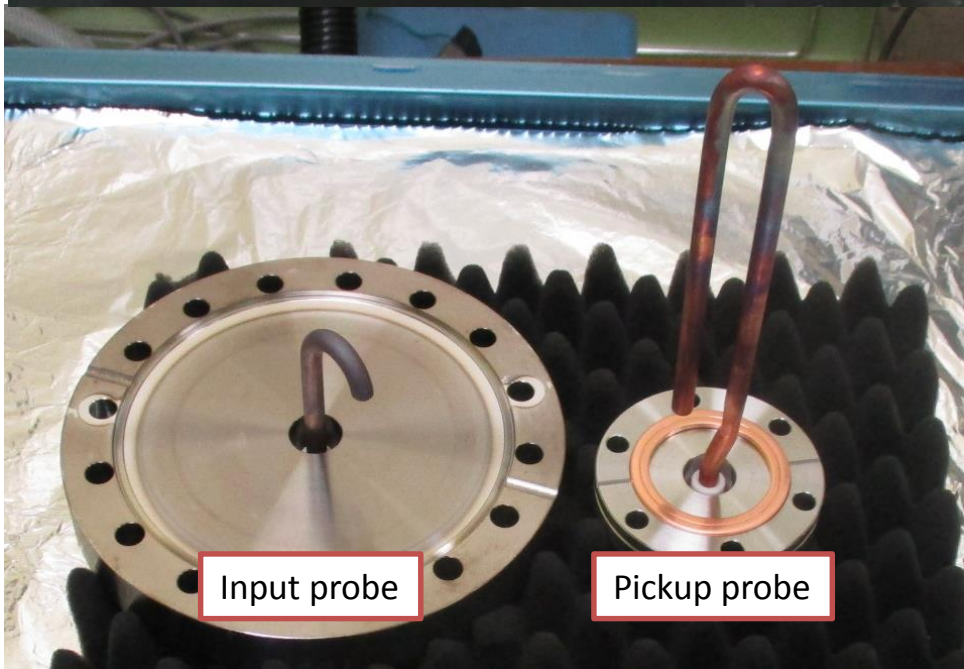


# Inspections after cold test

- Frequency at room temperature
  - 404.385 MHz
  - +2.3MHz after VEP
  - Shape deformation?
- Inspection of inner area
  - White Niobium oxide layer found
  - Nibium oxide not well dissolved
- Input and pickup probes
  - Change of color found
  - Multipacting occurred on the probes

| | Room temp. | 4K | 2K |
|---|---|---|---|
| Before EP (MHz) | 402.087 | | 402.777 |
| After EP (MHz) | 404.385 | 403.906 | 405.083 |

Cavity frequency before and after VEP

# summary

- Vertical electro-polishing with position flipping
  - Polished 30 microns
  - Uniformity
    - Better than previous VEP (PoP QWRCC in 2017)
      - Large polishing on the side area not observed
    - Large polishing on beam pipes (not measured for PoP DQWCC)
      - Better to suppress but acceptable?
  - Niobium oxide
    - Niobium oxide not well dissolved in EP solution
    - Check fluoric acid fraction
  - Frequency shift after VEP
    - Shape deformation during cold test?
- Cavity performance after VEP
  - Not tested
    - Fail to process MP
    - MP on probes
      - HPR improves MP processing