Nb_3Sn coating R&D at KEK

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On behalf of KEK Nb_3Sn group

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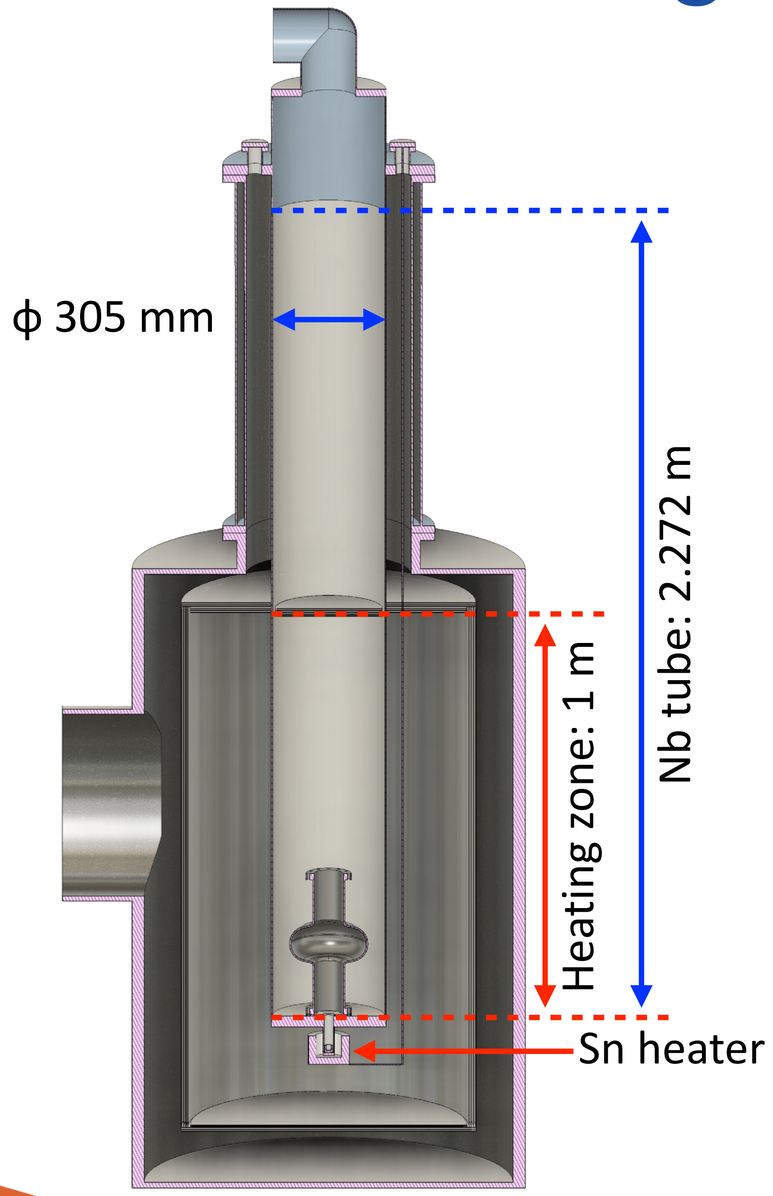
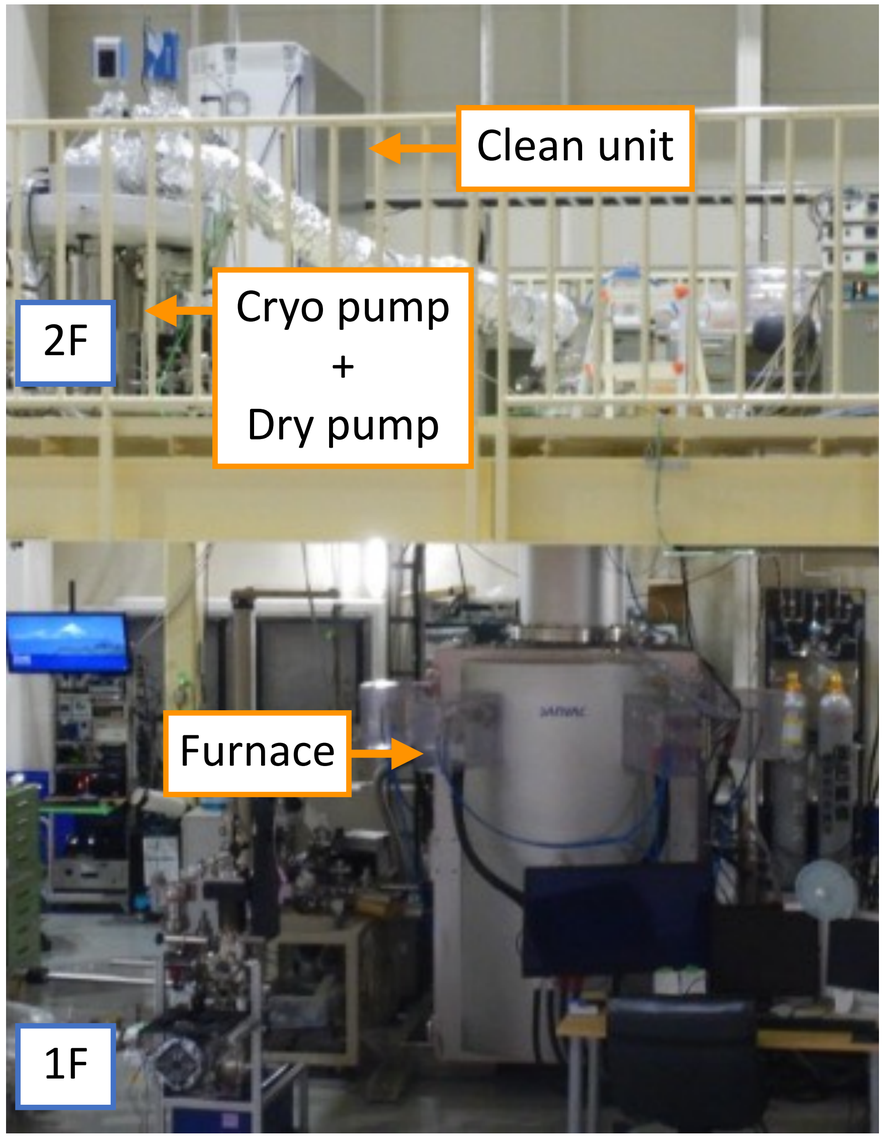
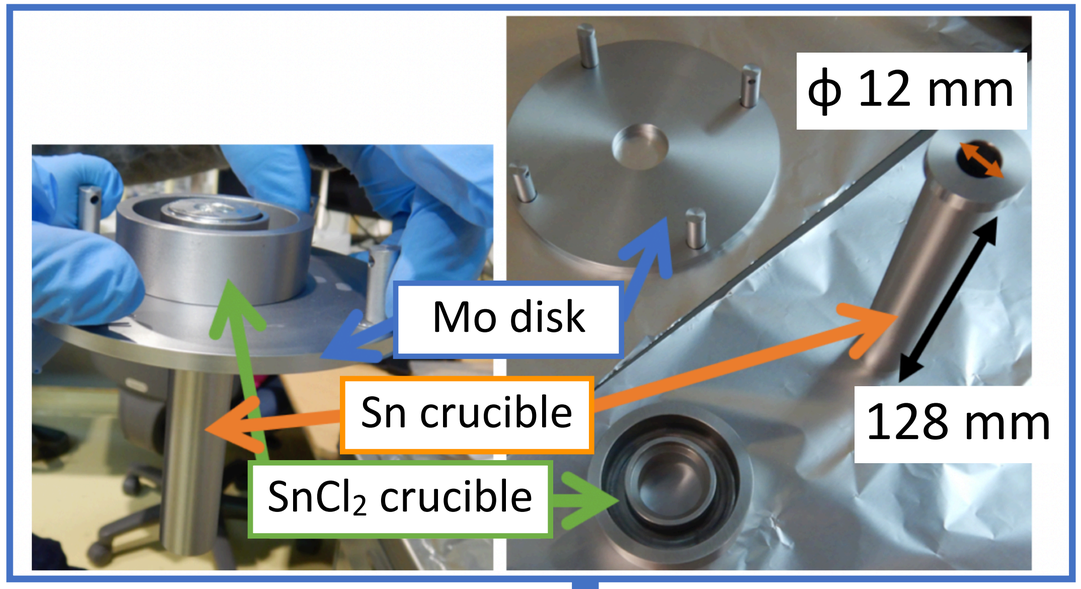
Nb_3Sn Coating Furnace at KEK



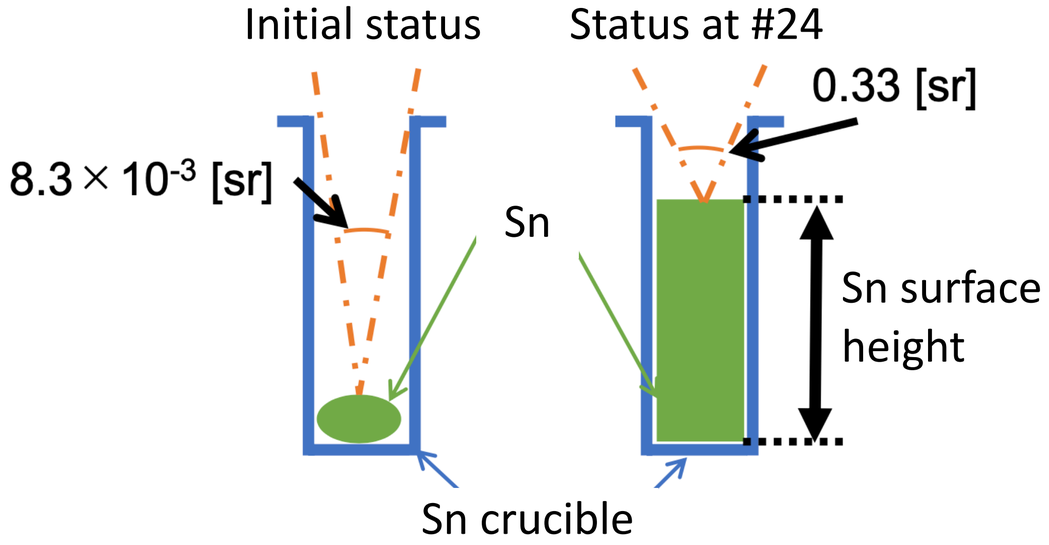


- Two independent vacuum systems
- Heaters
  - Furnace: Max 1200°C
  - Sn crucible: Max 1500°C
- Nb tube is evacuated during coating

1st Cavity Coating _ #24



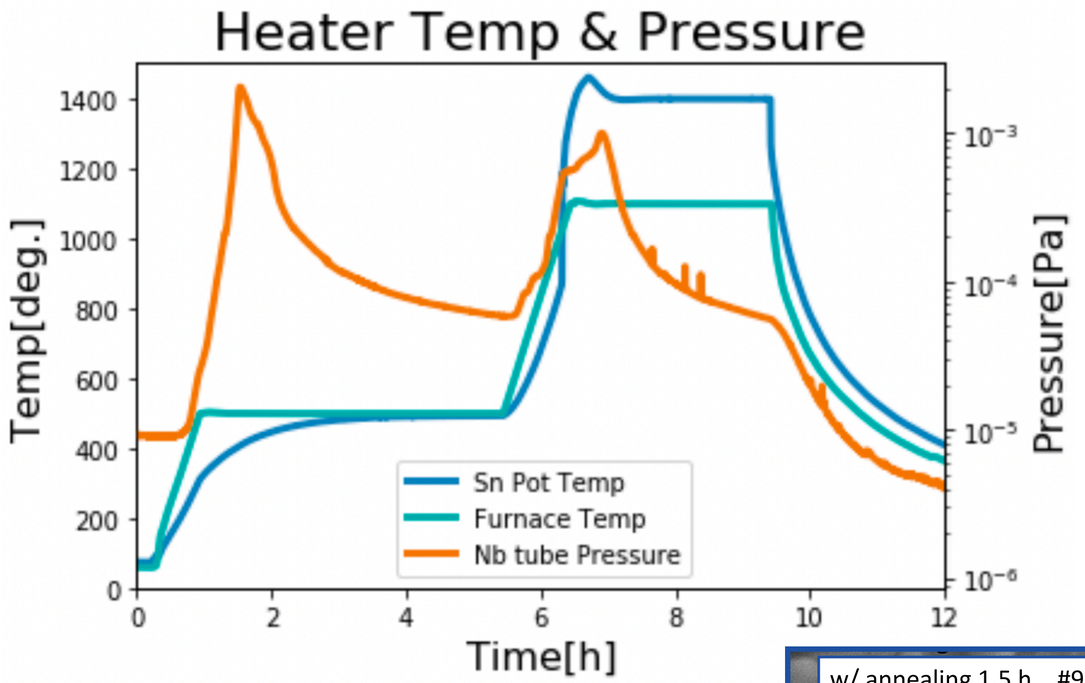
- The top flange open
- Witness samples inside



- Small solid angle significantly limits the Sn evaporation
  - 0.17 g for a coating time of 1.5 h at Run #1
- To gain a solid angle, we put a lot of Sn into the Sn crucible
  - Up to 2.33 g of Sn evaporated
- The amount of evaporation was uncontrollable

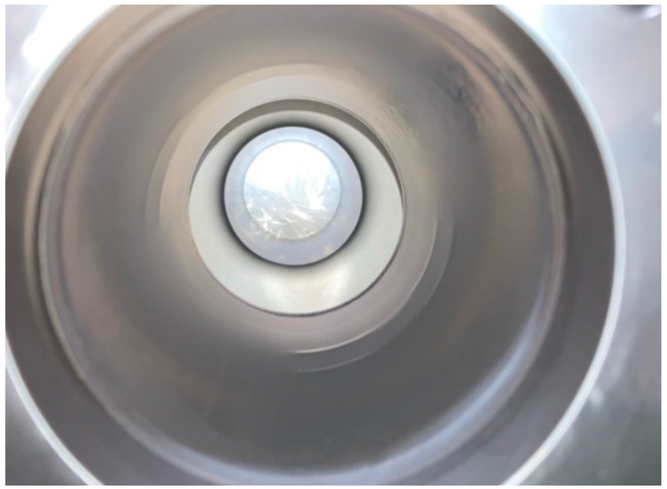
  -> we made a new Sn crucible for 2nd cavity coating

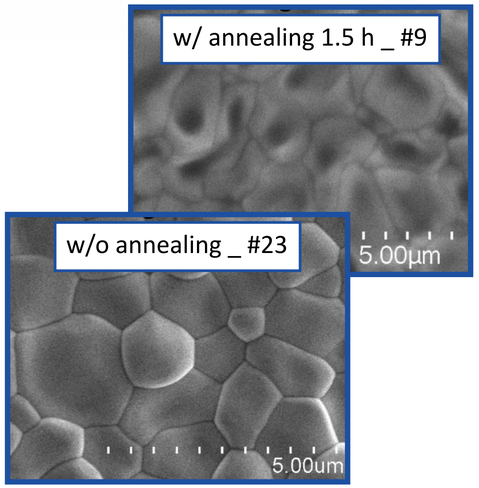
1st Cavity Coating _ #24



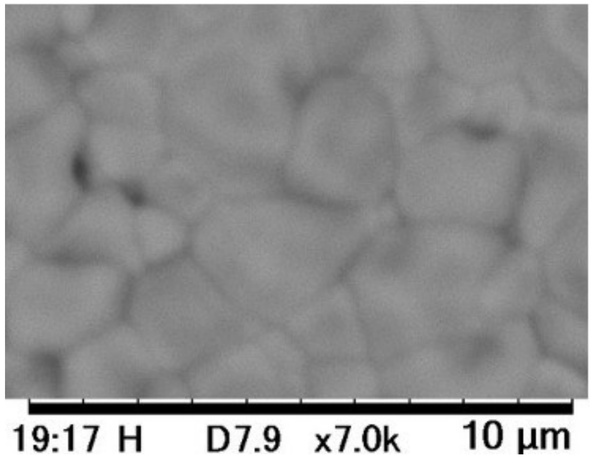
Before coating

After coating





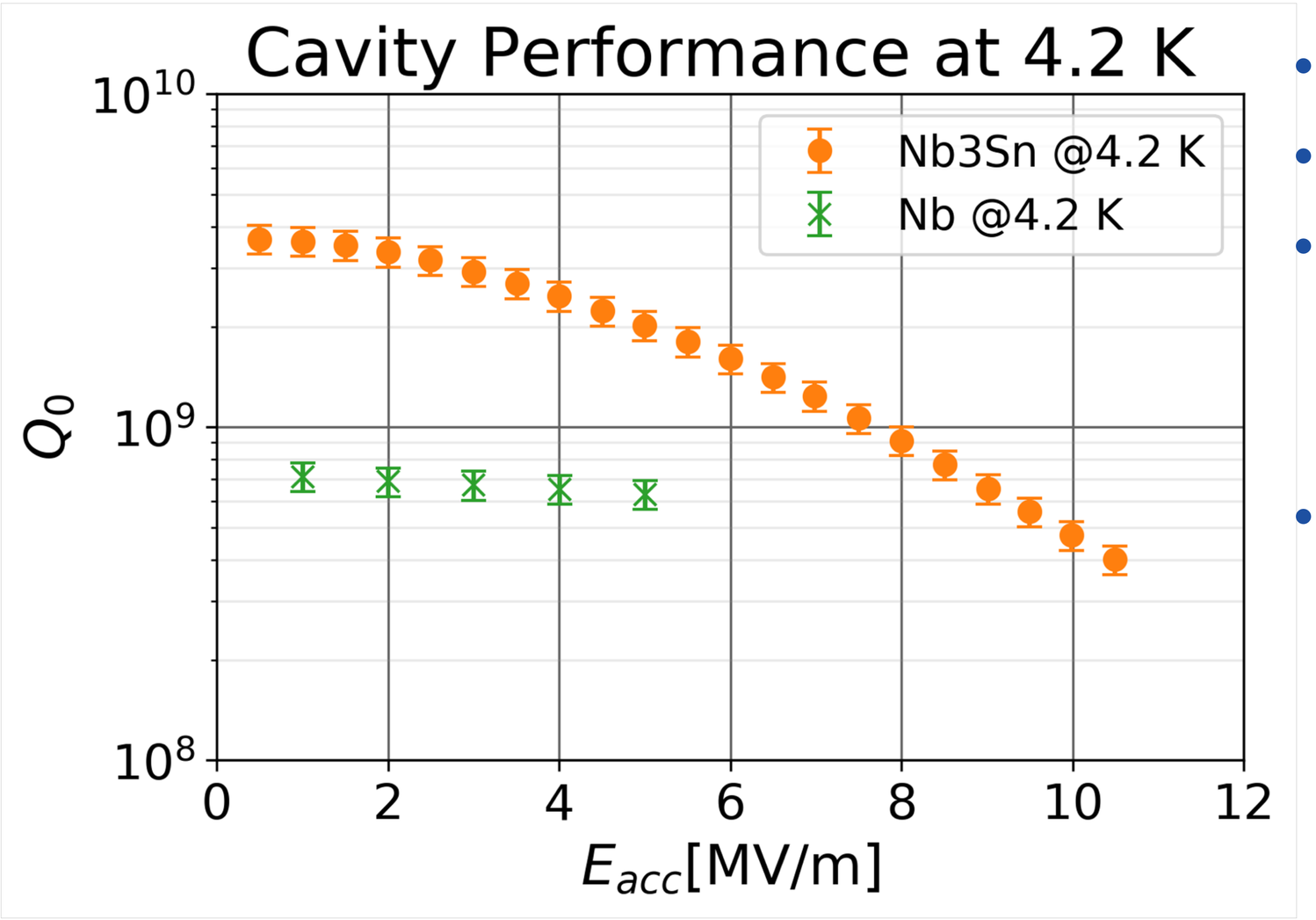
Witness sample _ #24



- Coating process
  - Nucleation: 500°C 4.5 h
  - Coating : 1100°C 3 h (Furnace)
    1400°C 3 h (Sn crucible)
- Annealing : 0 h

- Sample inspection
  - Grain size: 1~3 um
  - Thickness: 1.7±0.4 um
  - Atomic Sn content: 23.1±0.4 %

VT Result



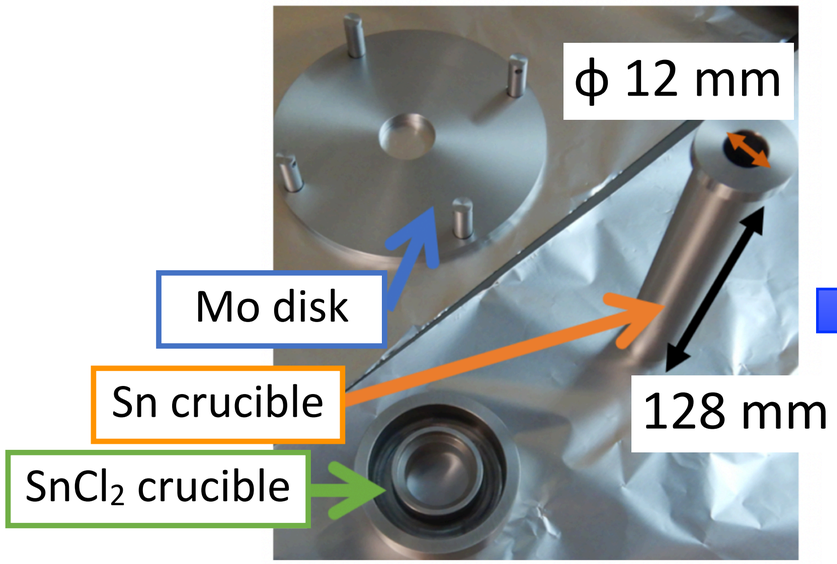
- Max E_{acc}: 10.8 MV/m
- Thermal quench
- Max Q_0: 3.7E9 at 1 MV/m
  <- 5 times higher than the Nb cavity

- To reach more higher performance:
  1. making a new Sn crucible
  2. Installation of clean booths
  3. using a cap for the top flange

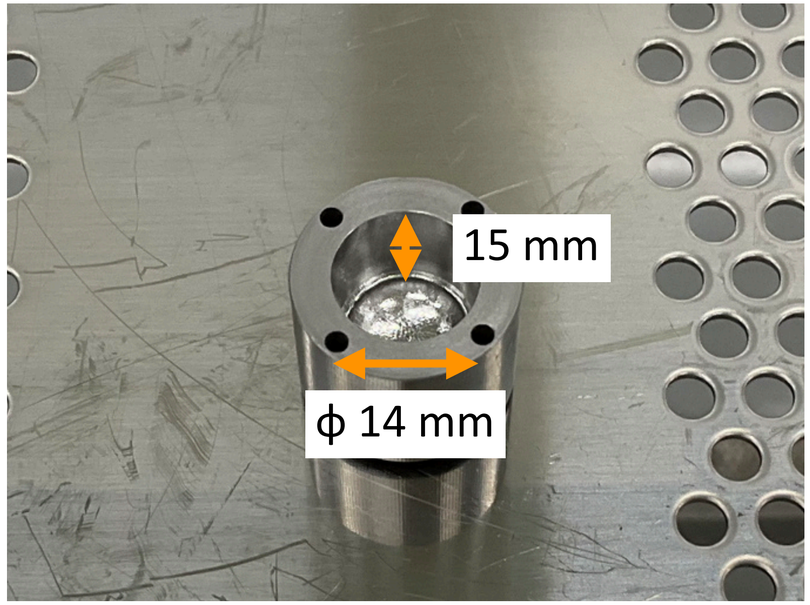
Modification 1

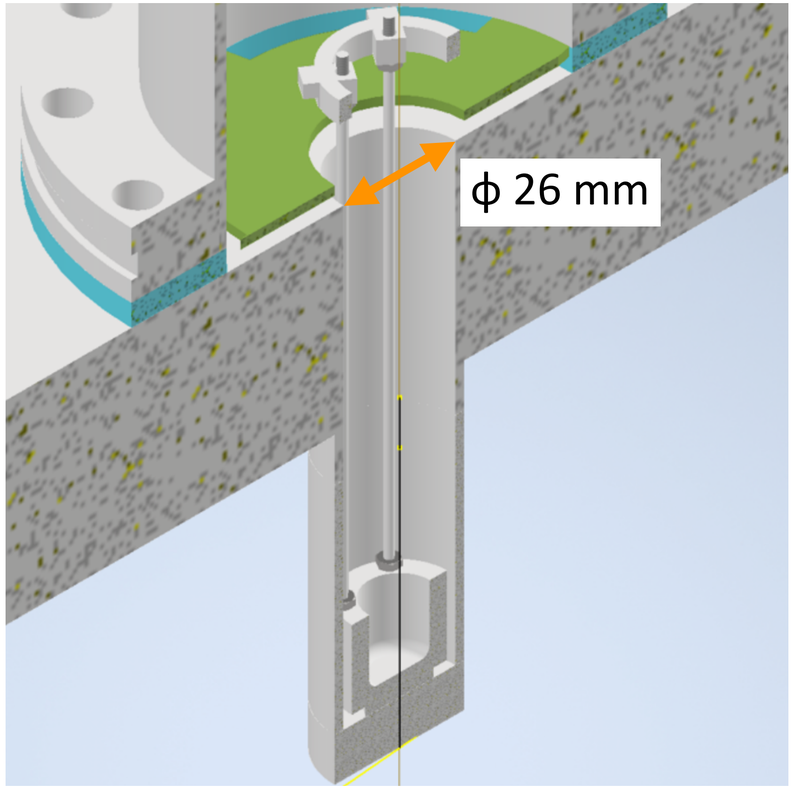
- We made a new Sn crucible to get a enough Sn evaporation

Ver.1



Sn crucible ver.2





- Effective aperture is twice bigger than Ver.1 (ϕ 12 mm to ϕ 26 mm)
- All Sn in the Sn crucible evaporates now, allowing control of the amount of Sn evaporation

Modification 2

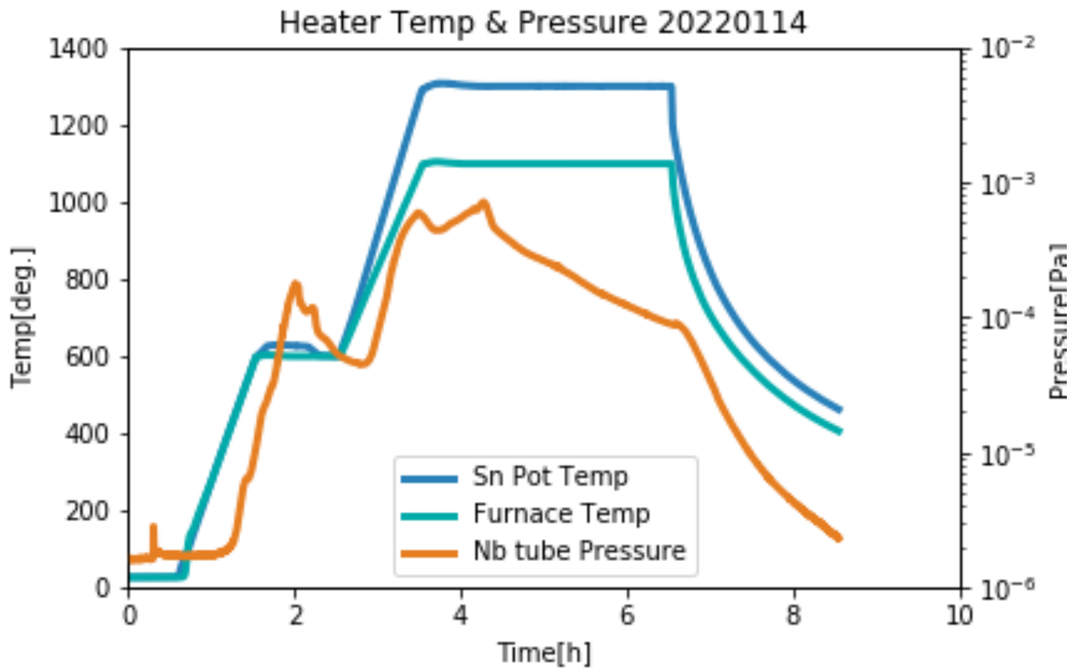
Modification 3

1st cavity coating

2nd cavity coating

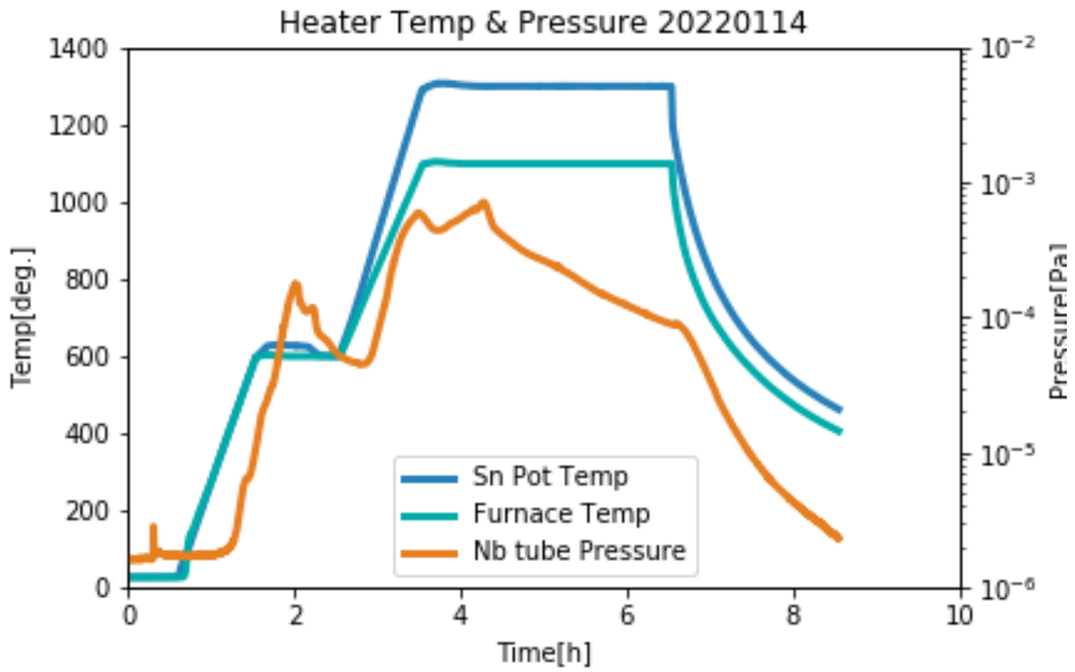
- We close the top flange with Nb foil
- Aims:
  - Increasing Sn vapor pressure
  - Prevent dust from entering the cavity

2nd Cavity Coating _ #43



- Coating process
  - Nucleation: 600°C 1 h
  - Coating : 1100°C 3 h (Furnace)
    1300°C 3 h (Sn crucible)
- Annealing : 0 h

2nd Cavity Coating _ #43



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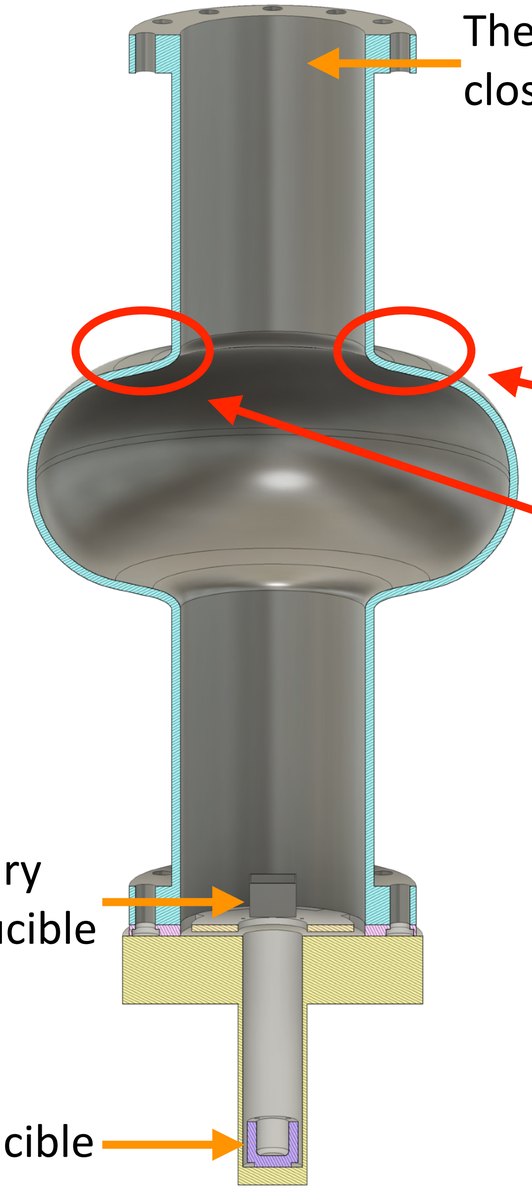
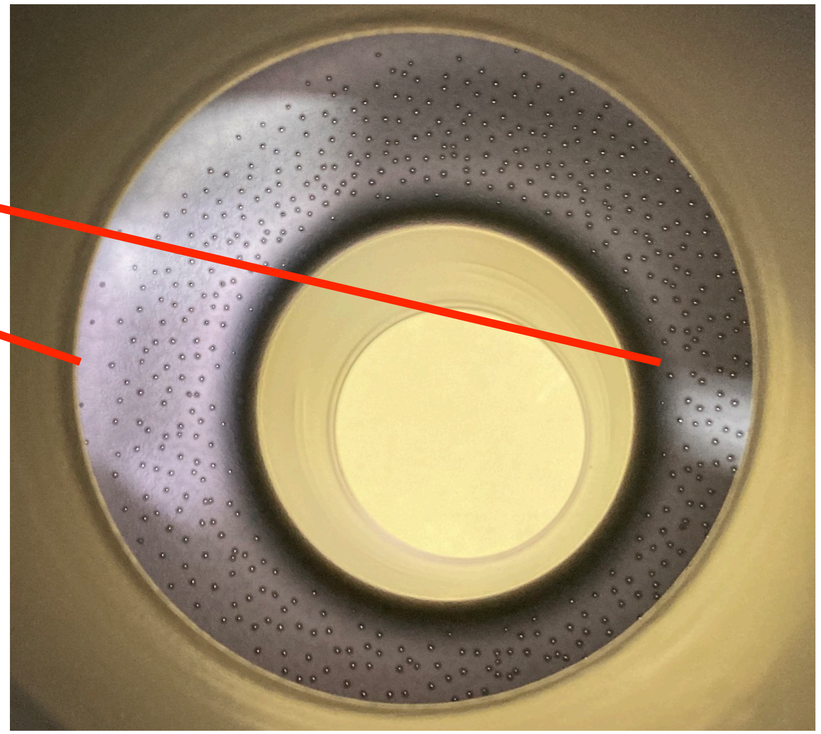
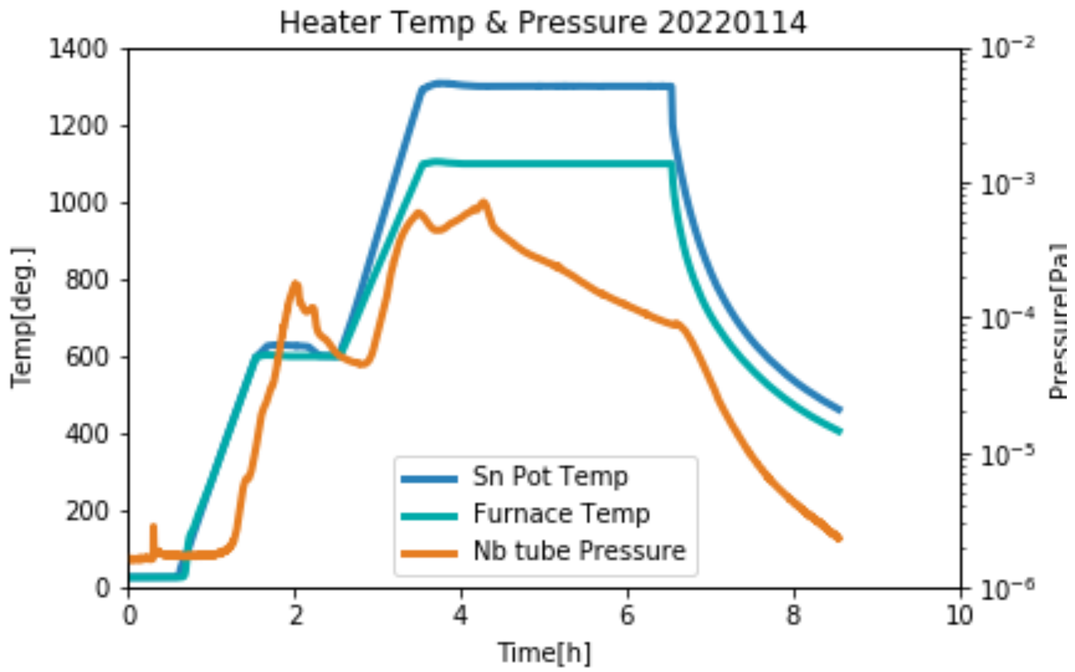


After coating



2nd Cavity Coating _ #43



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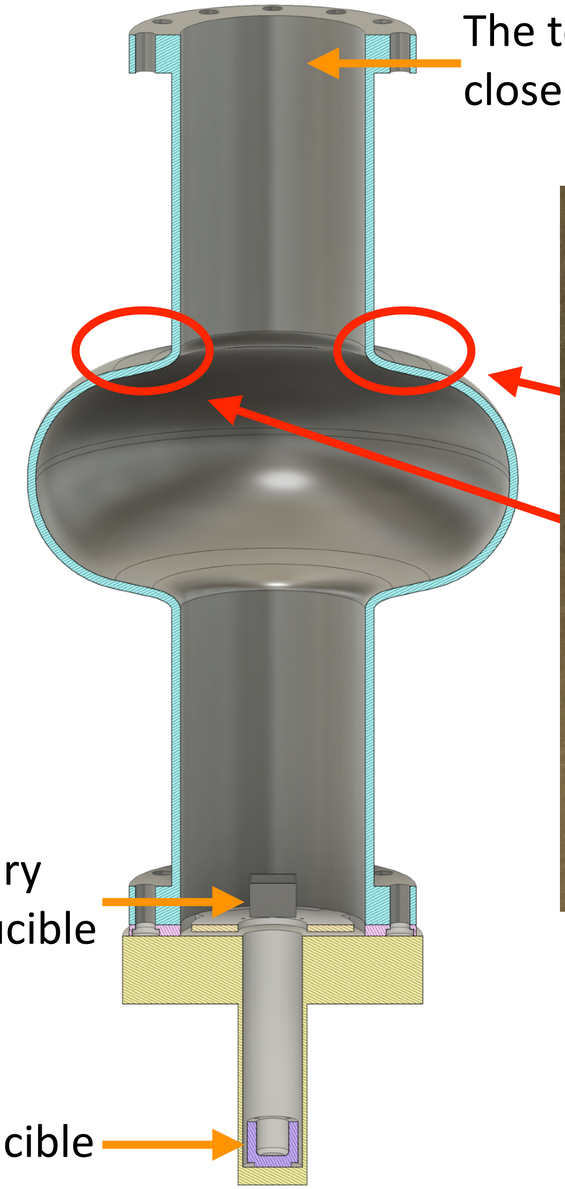
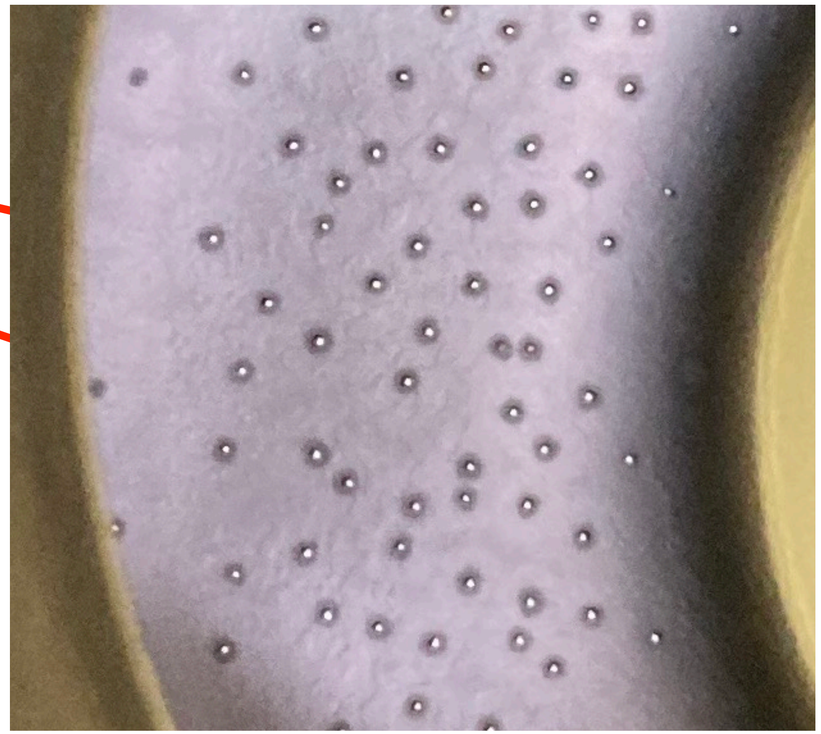
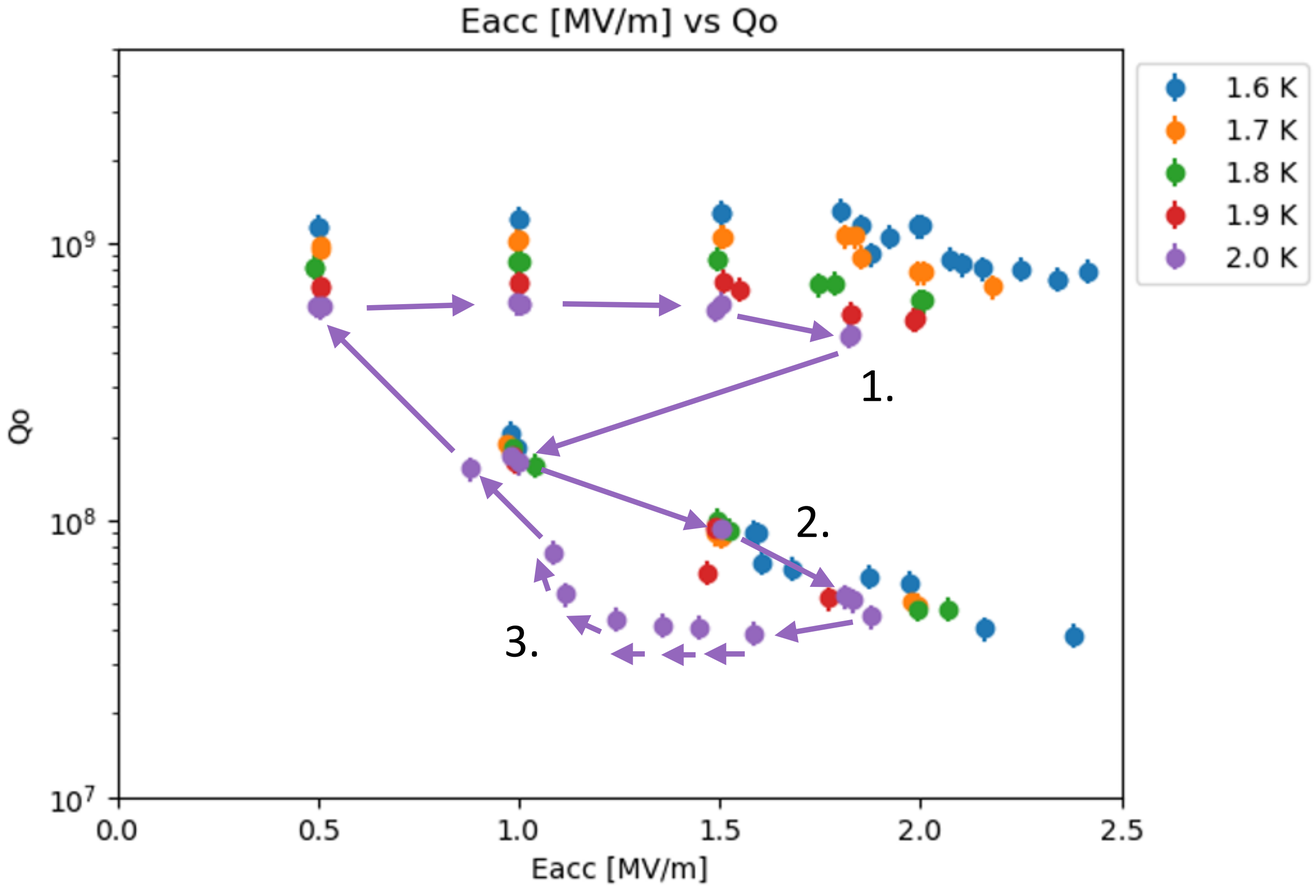


After coating



Many Sn droplets formed at the top of the cell.

VT Result



- Max E_{acc}: 1.8 MV/m at 2 K
- Power limit
- Max Q_0: ~ 5E8 at 2 K

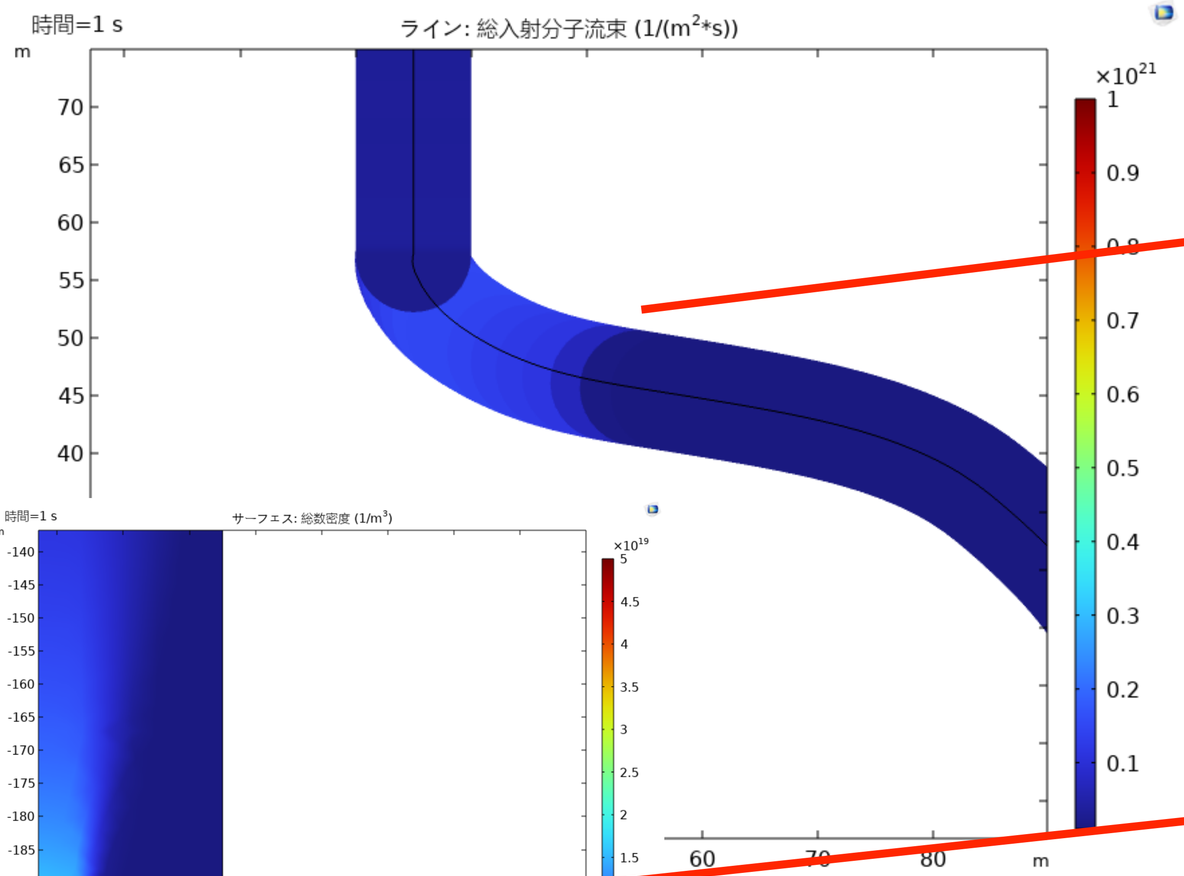
1. Top of the cell was heated up
2. Q_0 was decreased
3. As E_{acc} was decreasing, Q_0 recovered to Initial value

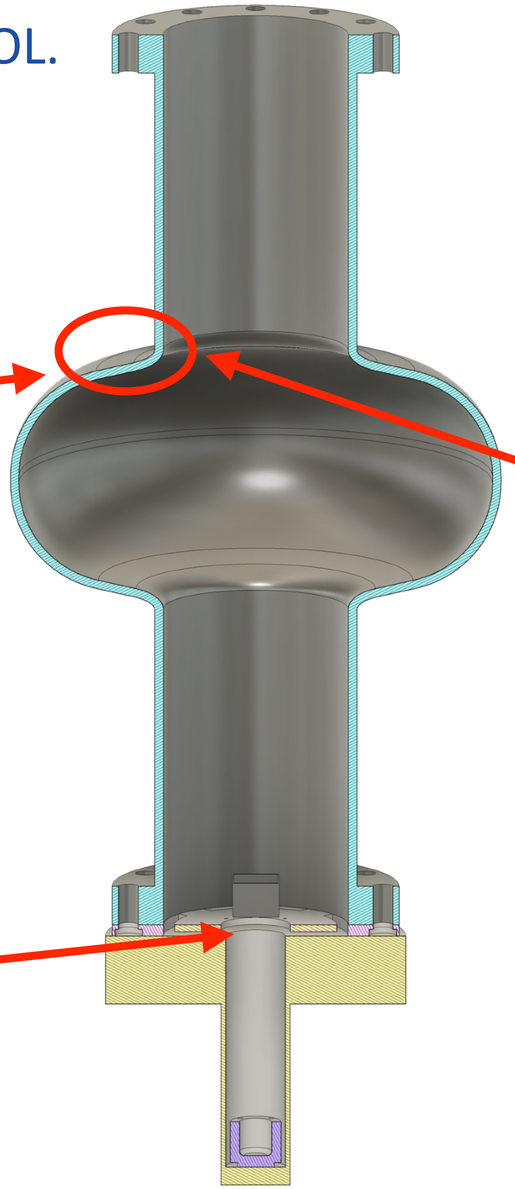
- Measurement points take an irreversible path
- Transition of Sn droplets on the inner surface of the cavity might occurred
- Tc of Sn: 3.72 K

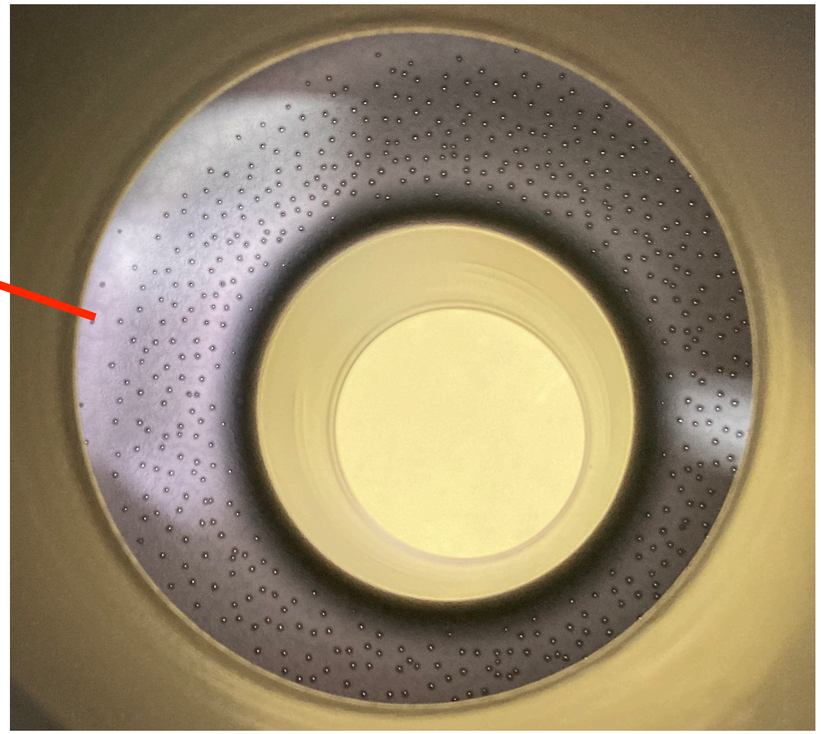
- We have to avoid formation of Sn droplets

For Next Cavity Coating

- We performed a simple verification using COMSOL.

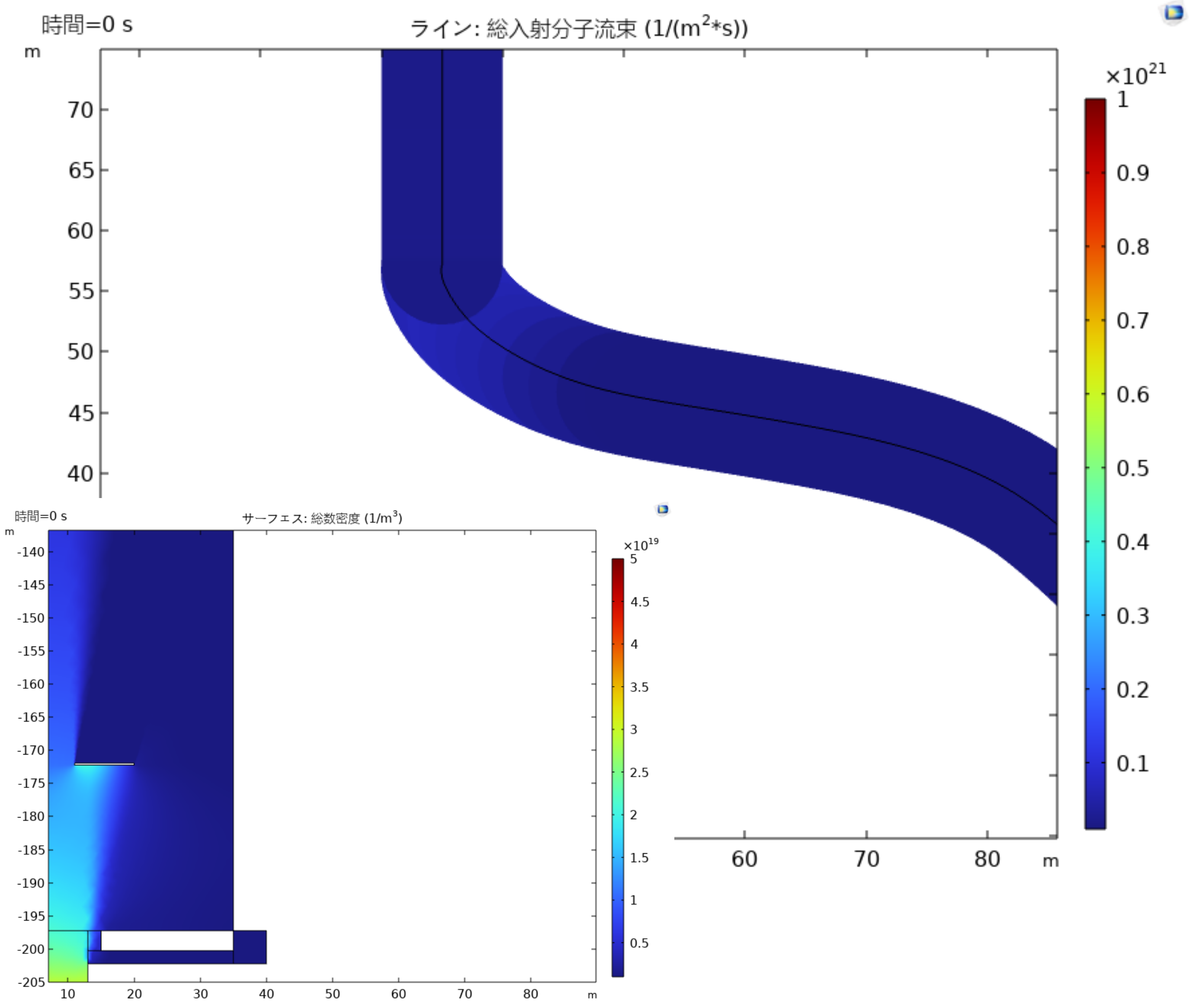


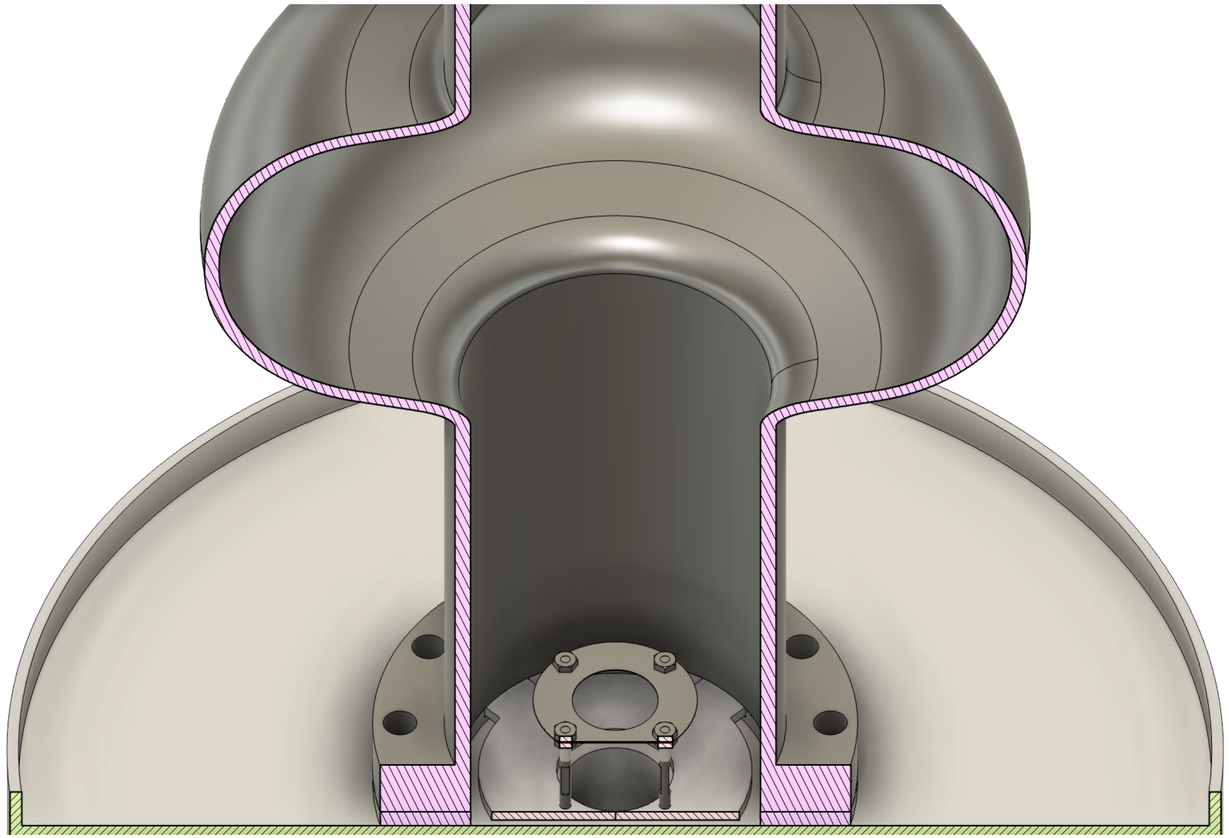




For Next Cavity Coating

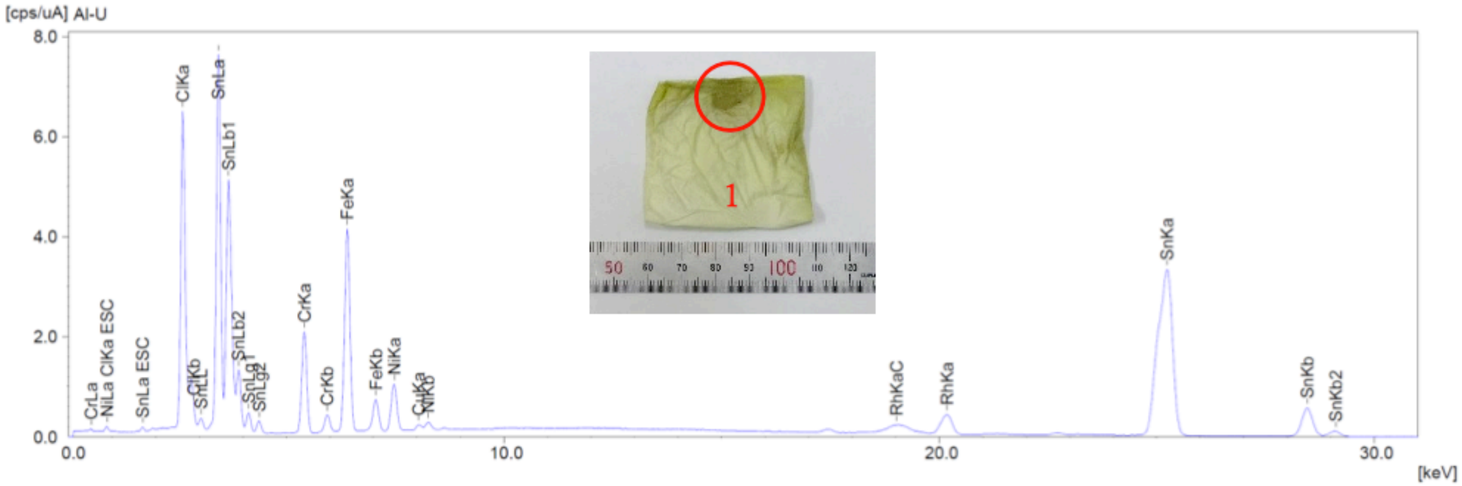
- Simple shader would work well.

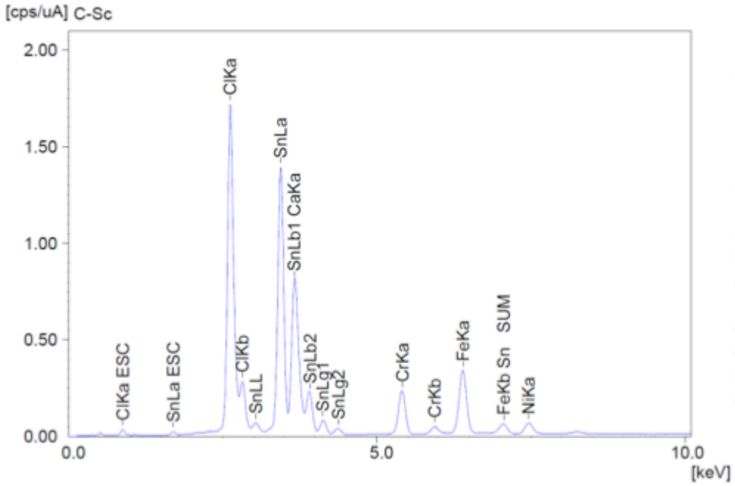




For Next Cavity Coating

- $SnCl_2$ contamination inside the tube





定性分析結果

元素：Cr, Ni, Cl, Sn, Fe, Cu, Rh, Ca

定量分析結果

分析対象	分析結果	[3σ] 処理-計算	分析線	強度(cps/uA)
Sn	47.860 %	[0.151] 定量-FP	SnKa	65.7519
Cl	31.909 %	[0.077] 定量-FP	ClKa	19.0353
Fe	8.397 %	[0.039] 定量-FP	FeKa	29.5299
Cr	6.720 %	[0.045] 定量-FP	CrKa	14.2580
Ca	3.505 %	[0.097] 定量-FP	CaKa	1.3233
Ni	1.480 %	[0.013] 定量-FP	NiKa	7.2615
Cu	0.130 %	[0.008] 定量-FP	CuKa	0.7710

- Most of the components were derived from $SnCl_2$, but components derived from SUS were also detected
- $SnCl_2$ adhering to the inside of the tube corroded the SUS
- It has to be removed because it causes contamination

Summary

- Nb_3Sn cavity study using a vapor diffusion method has been conducted at KEK
- Nb_3Sn coating for the single cell cavity has been performed twice with various improvement
  - Creating a clean environment around the furnace
  - Crucible design to ensure sufficient evaporation of Sn vapor
  - Nb_3Sn coating with high Sn vapor pressure
- -> Sn droplets formed inside the cavity in 2nd coating test

- For next cavity coating
  - We will install the shading to suppress the Sn droplets formation

    <- Is a simple shading sufficient? Or do we need something like a diffuser?
  - We have to remove the $SnCl_2$ contamination inside the tube

    <- Is this kind of experience only KEK? How can we remove it?