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October 28- November 1, 2019

Center for Applied Superconducting Accelerator
応用超伝導加速器センター

R&D Plan of Nb3Sn thin film SCRF gun at KEK

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KEK: HIGH ENERGY ACCELERATOR RESEARCH ORGANIZATION
ACCELERATOR LABORATORY-CASA

Outline

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    2. KEK SRF gun #1
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3. Plan of Nb3Sn SRF gun for UEM
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    2. Ultrafast Electron microscopy (UEM)
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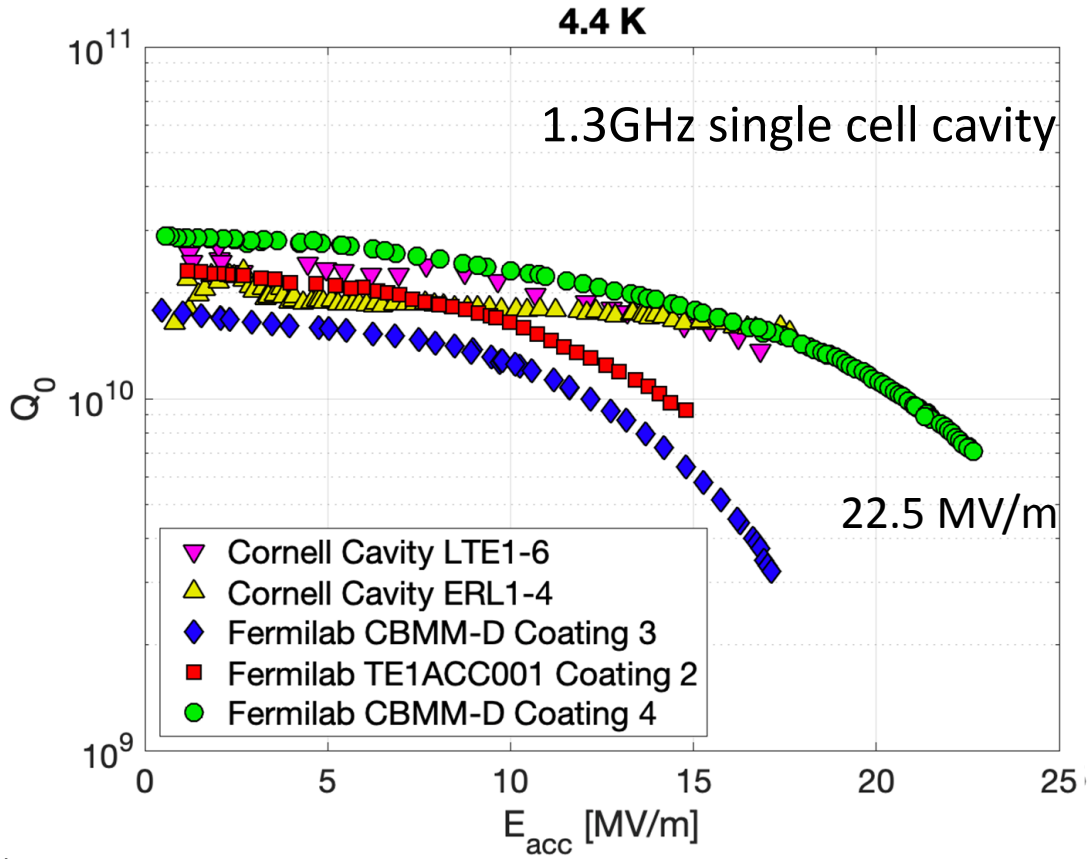
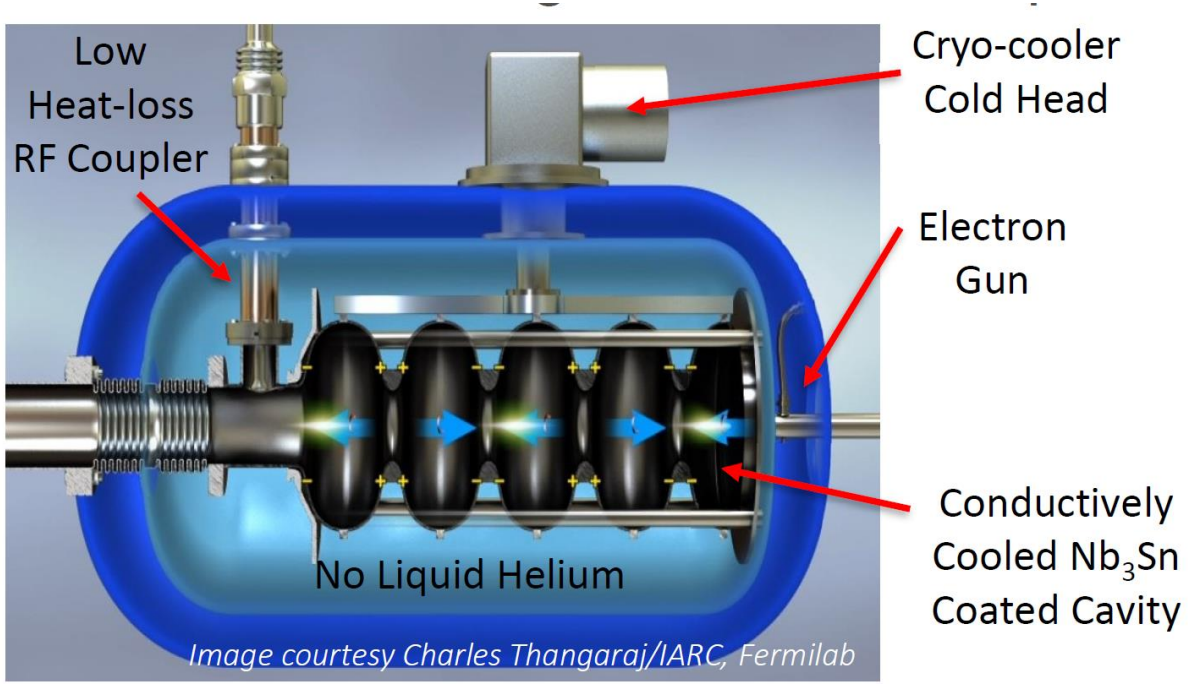
Design of the KEK Nb3Sn Furnace

Nb3Sn

- SRF cavity with Nb3Sn film can be operated at 4K, instead of 2K.
- Nb3Sn would reduce the power consumption of refrigerator drastically. SRF accelerator system becomes greener.
- It would provide an operator free system. It can be use in small accelerator lab and small hospital, airport.
- The performance of Nb3Sn is well demonstrated. KEK also want to apply Nb3Sn to accelerators.

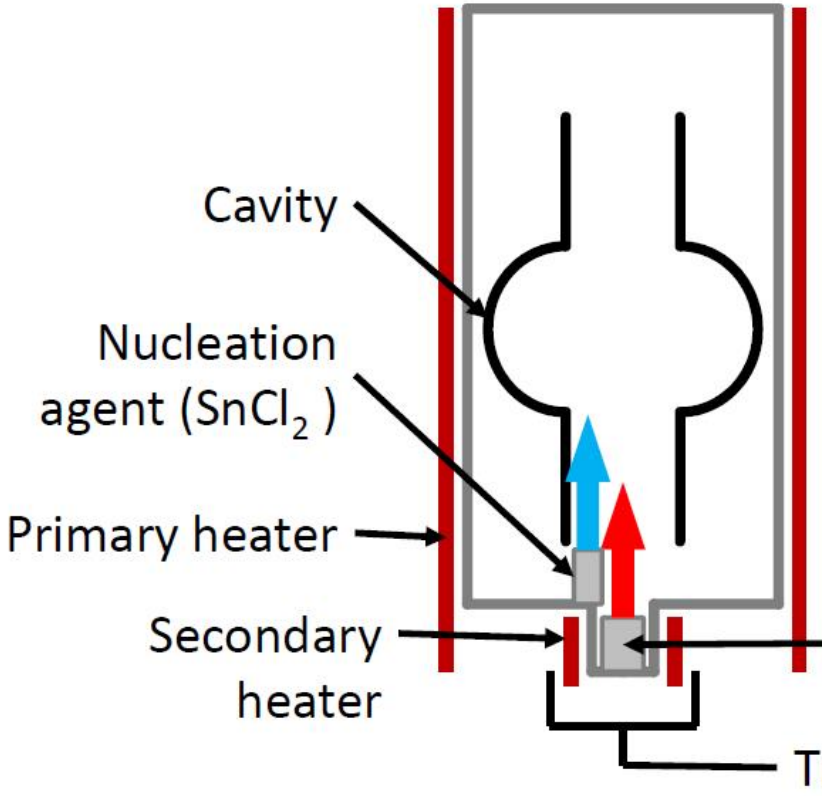


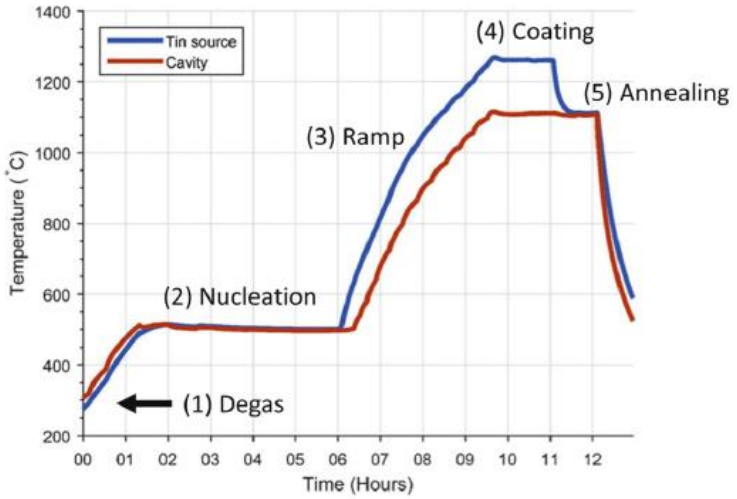


S.Posen, SRF2019, THFUB1

Cornell Nb3Sn Vapor Diffusion Furnace

- KEK selected vertical type Nb3Sn vaper diffusion furnace based on Cornell design.
- It is simple structure compared to horizontal type and well proved



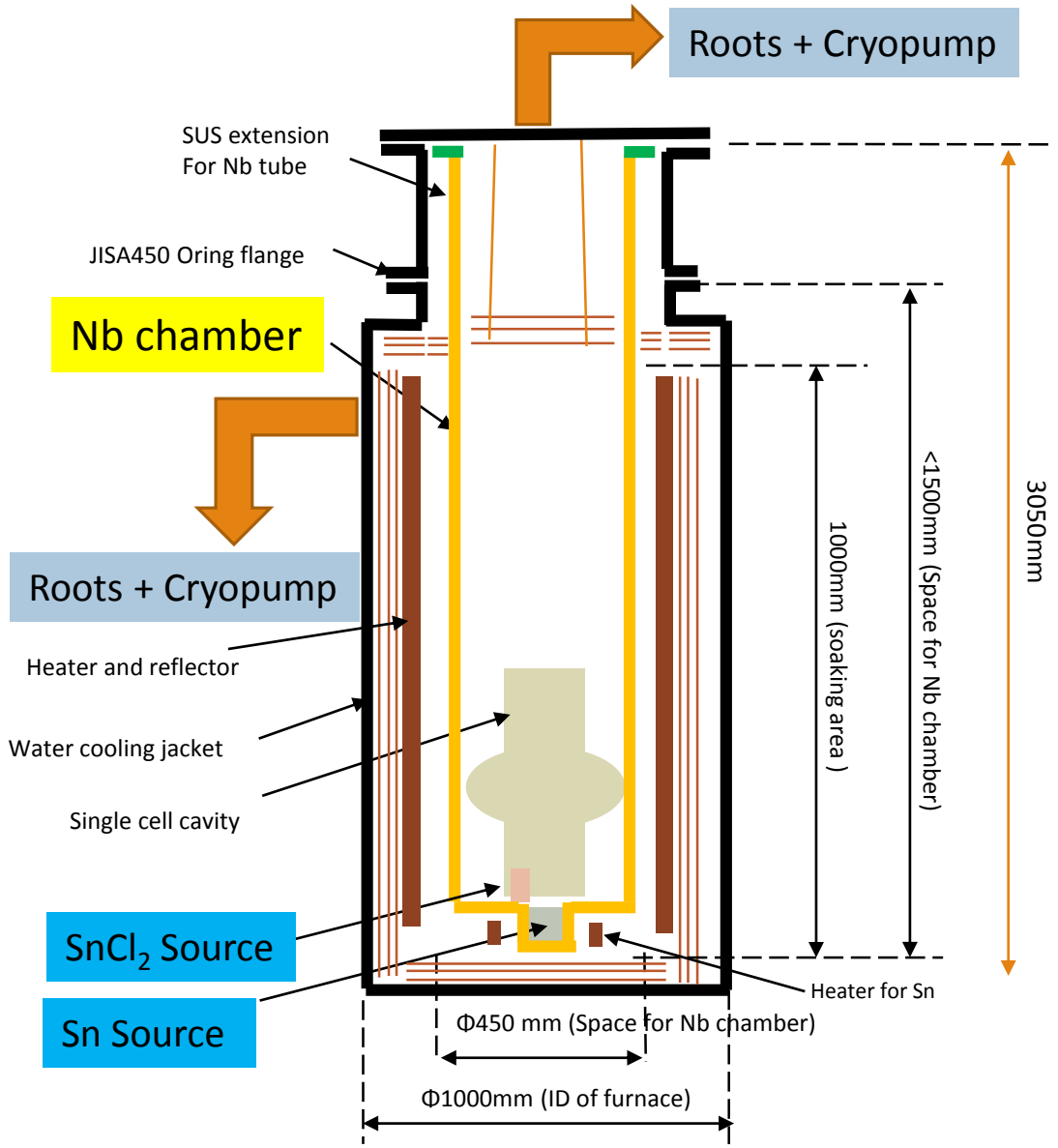


"Wuppertal" configuration, i.e., with secondary heater for the tin source
Optimized nucleation and temperature profile

S. Posen and M. Liepe, Phys. Rev. ST Accel. Beams 15, 112001 (2014).

Design concept of the KEK Nb3Sn furnace

- KEK furnace is designed based on Cornell one.
- The maximum operation temperature of the furnace is 1400 K
- Heater area and Nb3Sn vaper diffusion area are completely separated. Pumping system is also separated.
- Only Nb, Mo, W can be used for high temperature zone (>200°C) .
- The maximum cavity size is assumed 3 cell 1.3 GHz cavity.

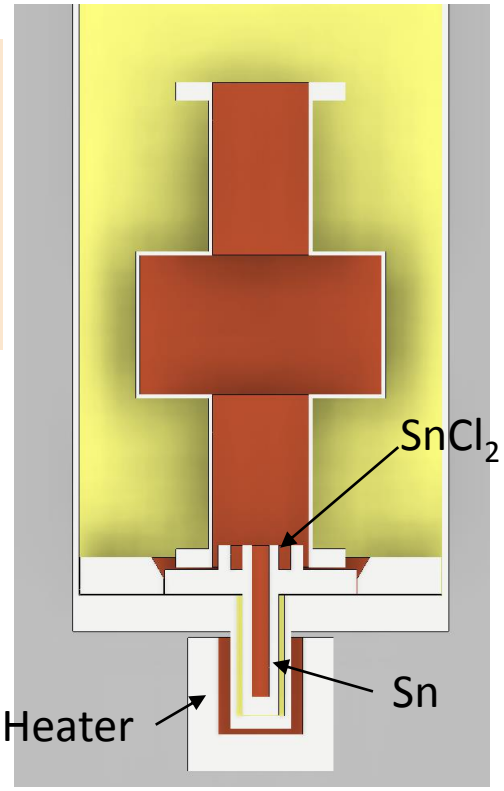


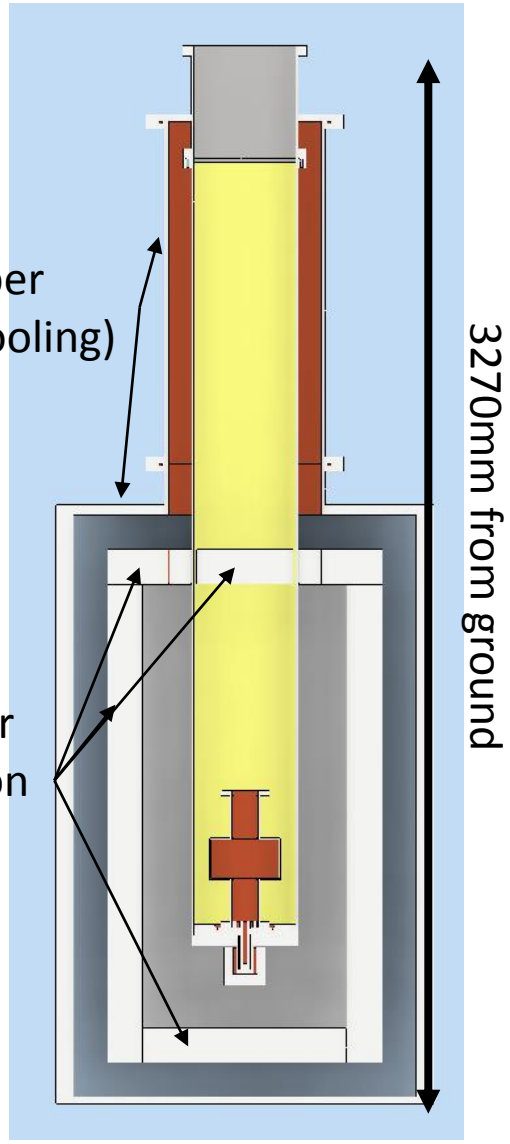
Design of the furnace

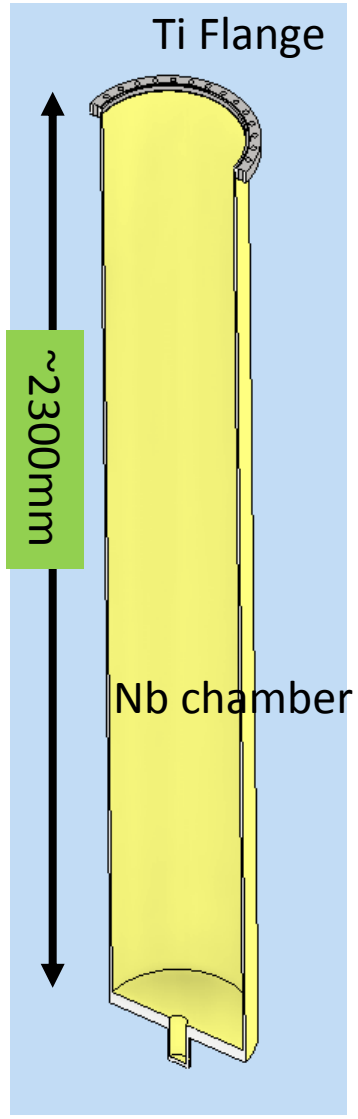
- Nb3Sn diffusion chamber is mainly made of Nb.
  - Ti is used for flange.
  - Cu is used for gasket.
  - Stainless steal is used for low temperature (<200℃) parts.

- We are designing the Sn heater now.
- Sn heater is 1 kW and covered by AlN.

- Cavity and Heater sources are connected each other and suspended at same time.

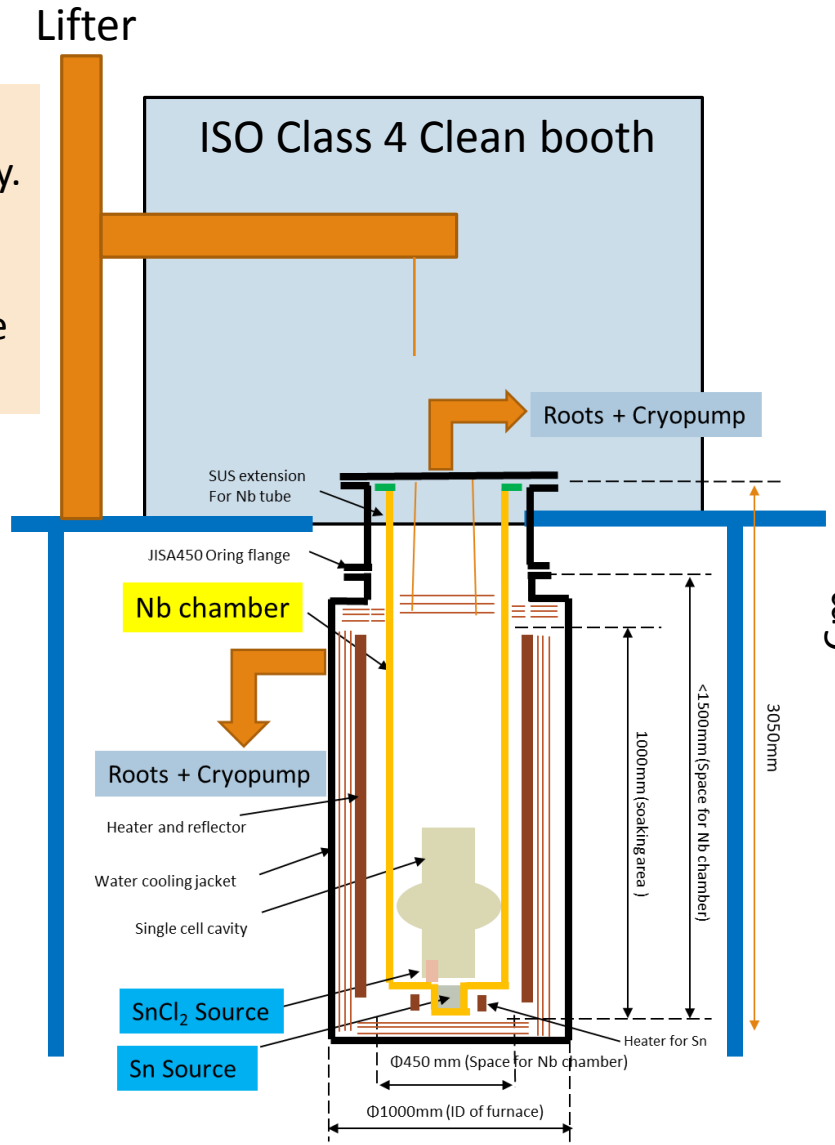


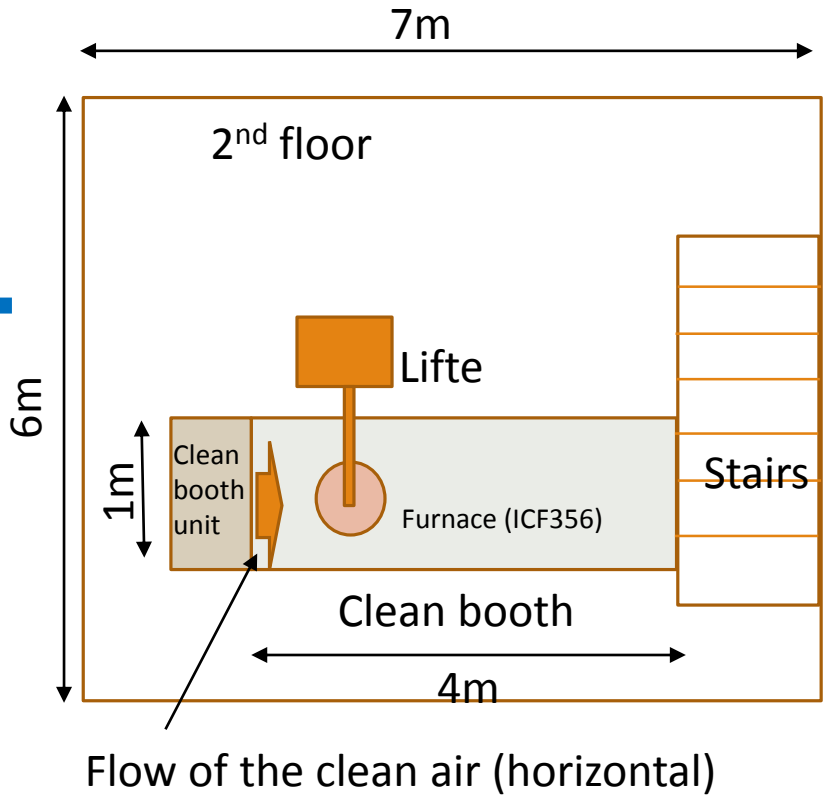




Experiment area

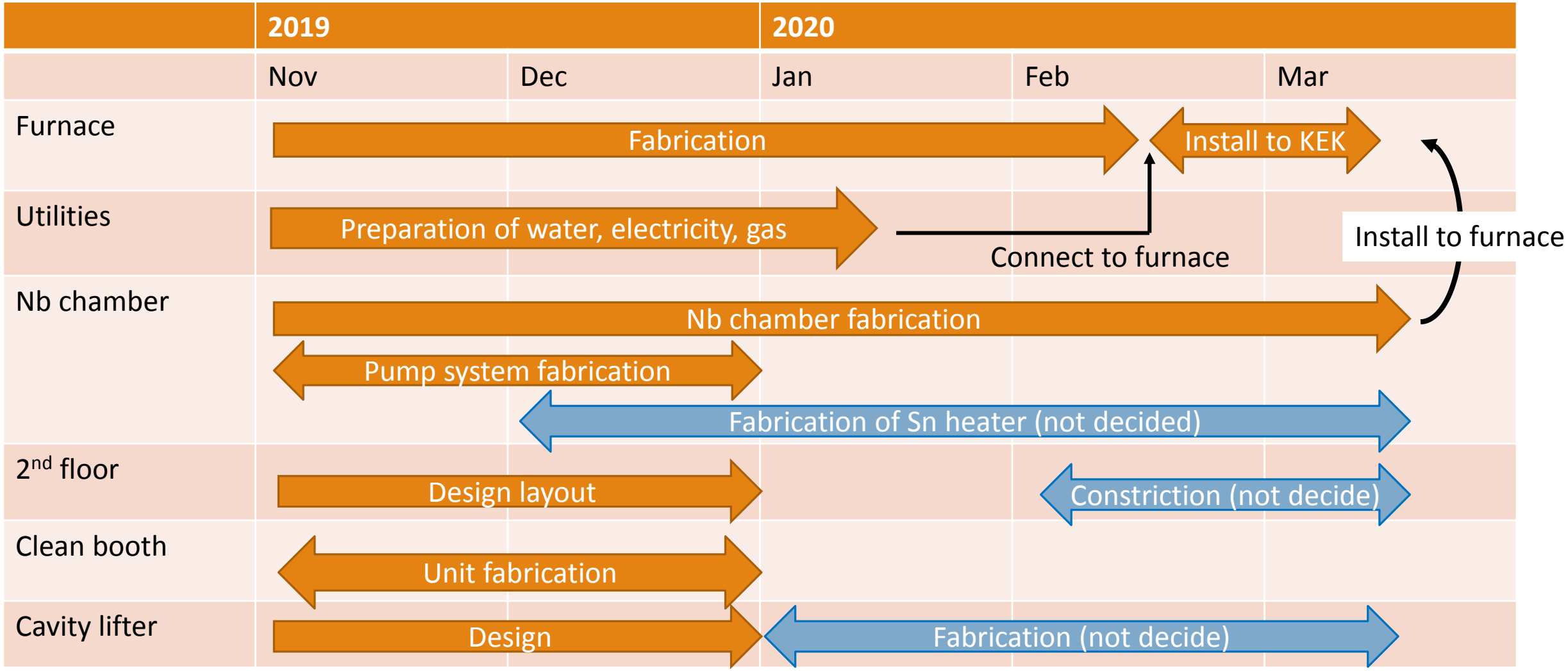
- We will build Nb3Sn furnace in COI building.
- 2nd floor will be construct to install the cavity.
- 2nd floor is covered by clean booth.
  - Clean booth unit is Horizontal type to avoid the contamination come into the furnace.





Schedule

- We want to finish building all of Nb3Sn furnace until end of March 2020.

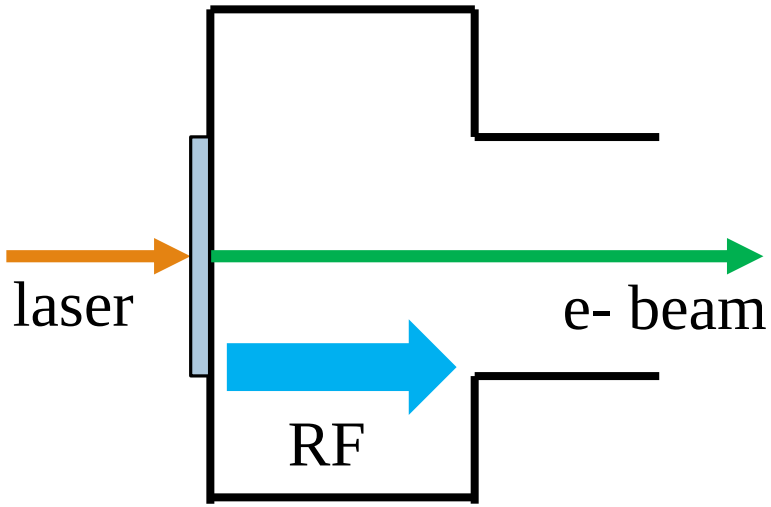


Development of the pure Nb SRF GUN

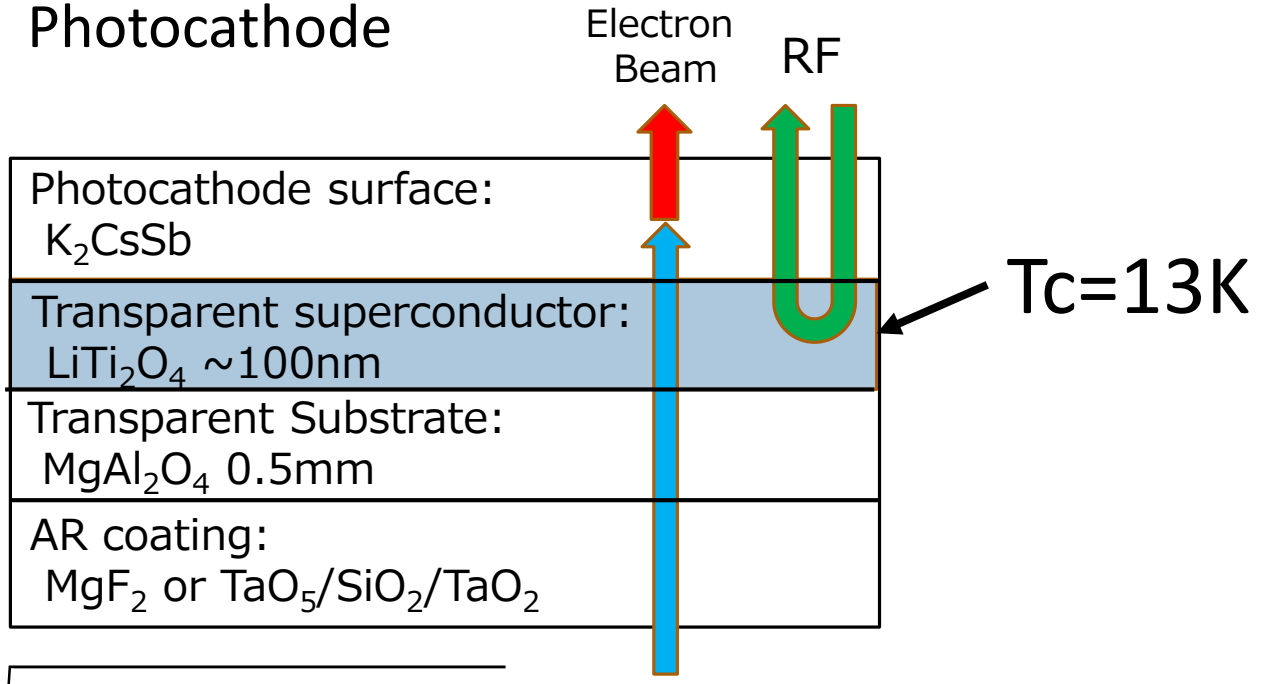
Design of the pure Nb gun

- We are developing the SRF gun for KEK ERL project.
  - The feature is transparent photocathode for simple transport line and easy laser spot control.
  - Cathode rod should be kept around 2K because transit temperature of the transparent superconductor is 13 K.
- Transparent photocathode can realize very small laser spot (~ϕ1um) for small emittance.

SRF gun cavity



Photocathode



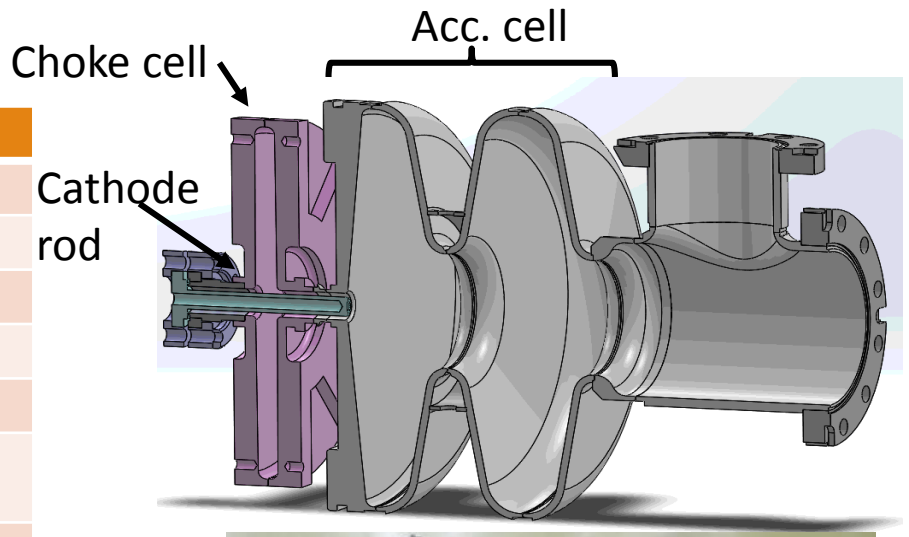
Thermal emittance: $\varepsilon_n = \frac{R}{2}\sqrt{\frac{2(\hbar\omega - E_0 + \phi_{sch})}{3mc^2} + \frac{2k_BT}{mc^2}}$

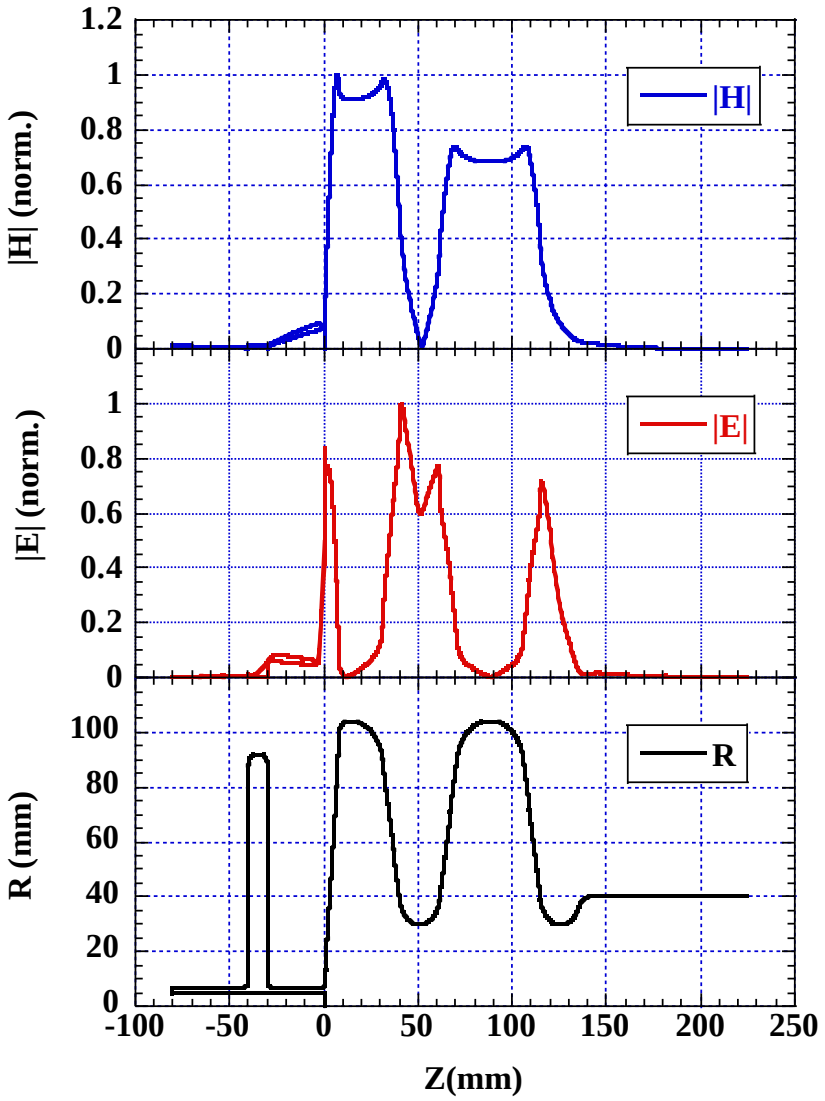
Design of the KEK SRF gun #1

- KEK SRF gun #1 was developed to check the RF performance.
- Cathode can be cooled directly by LHe.

KEK SRF gun @2K

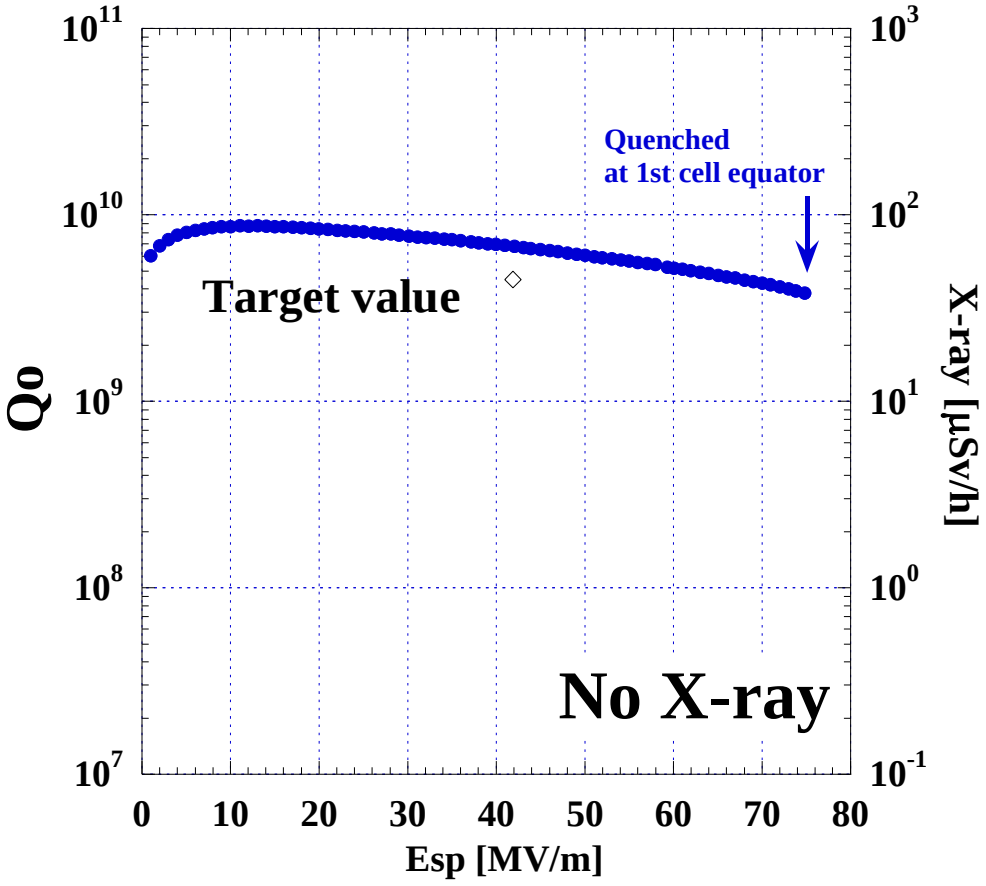
Parameter	Value
Beam energy	2 MeV
Beam current	100mA
Bunch charge	80 pC
Laser length (uniform)	10ps
Projected emittance	0.6 mm.mrad
Projected energy spread	0.09% (1.84 keV)
Peak electric field	41.9 MV/m
Peak magnetic field	95.2 mT
RF phase	55°
Geometrical Factor	**135.6 Ω (TESLA 270 Ω)**
Target surface resistance	30 nΩ (ILC target)
Target Q value	**4.5×10^9**
Target cavity loss	8 W



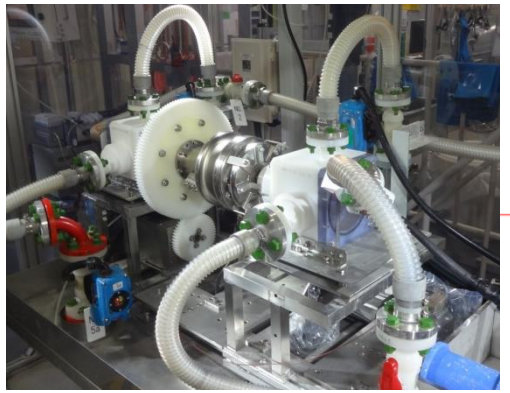


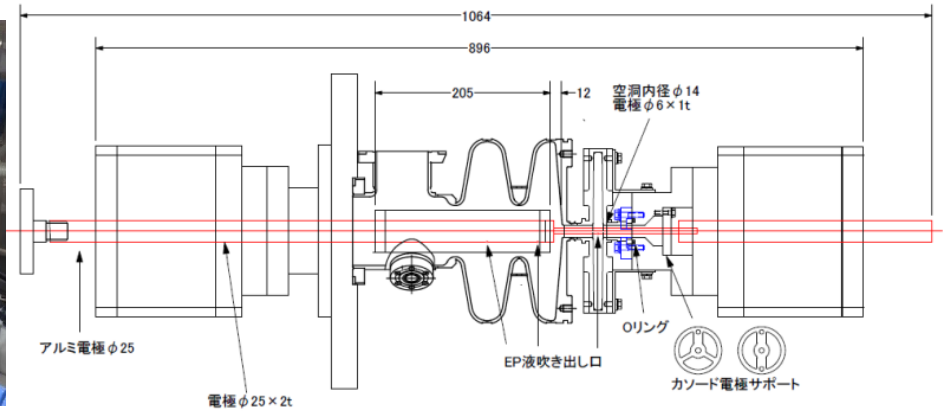
Vertical test result of the KEK SRF gun #1

- We already has the EP and HPR technique to achieve high gradient without field emission.

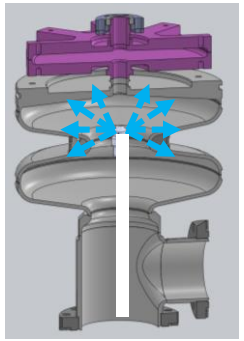


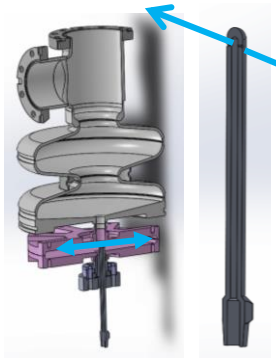
EP

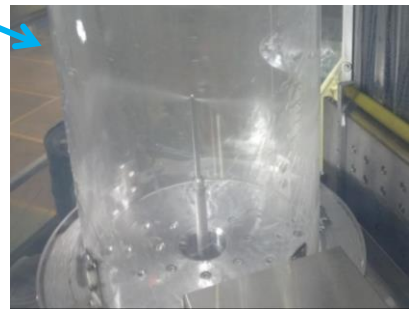




HPR

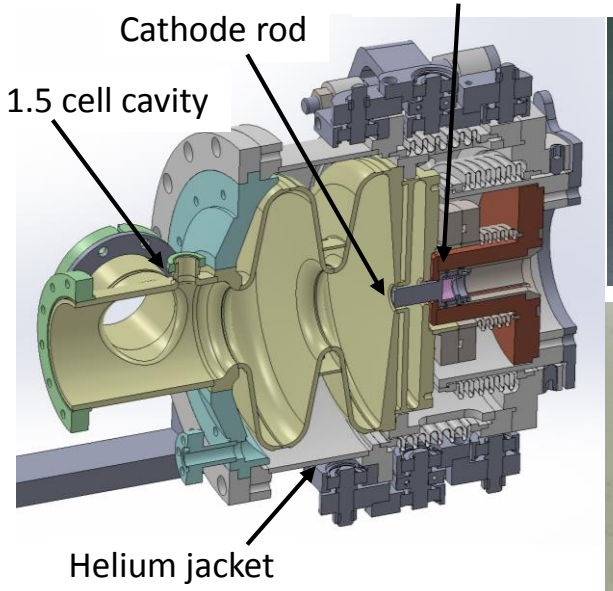


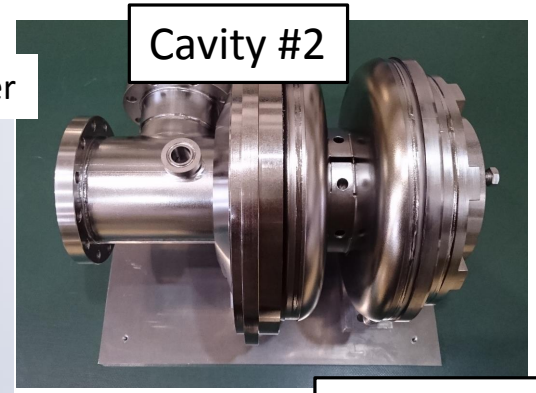


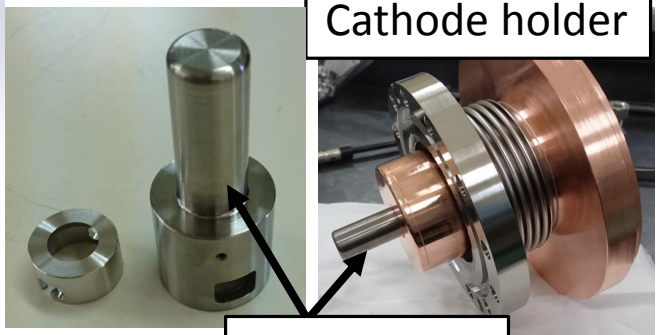


Design of the KEK SRF gun #2

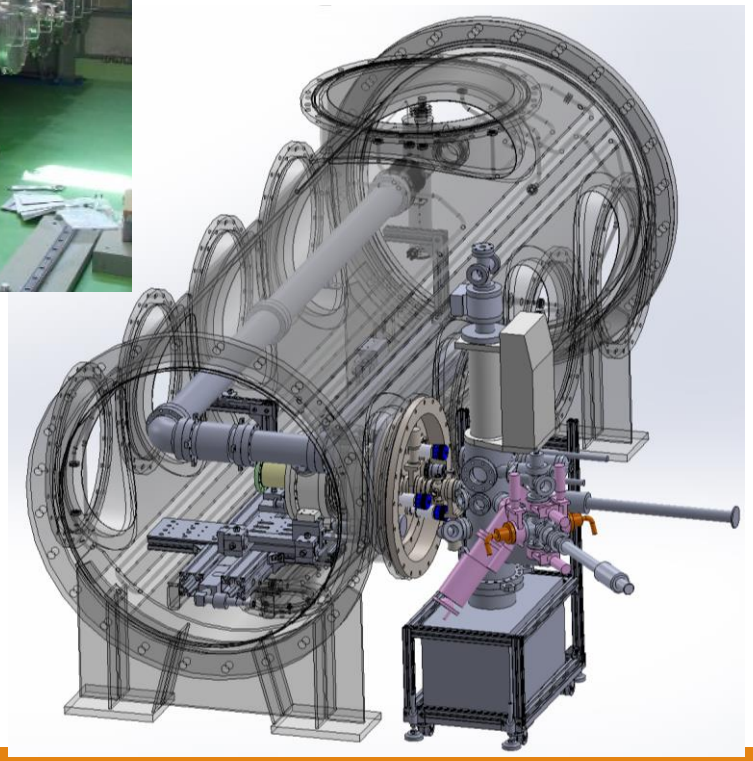
- We fabricating the KEK gun #2 for testing the demountable photocathode to test the K2CsSb photocathode.
- It will be tested in Horizontal cryostat.





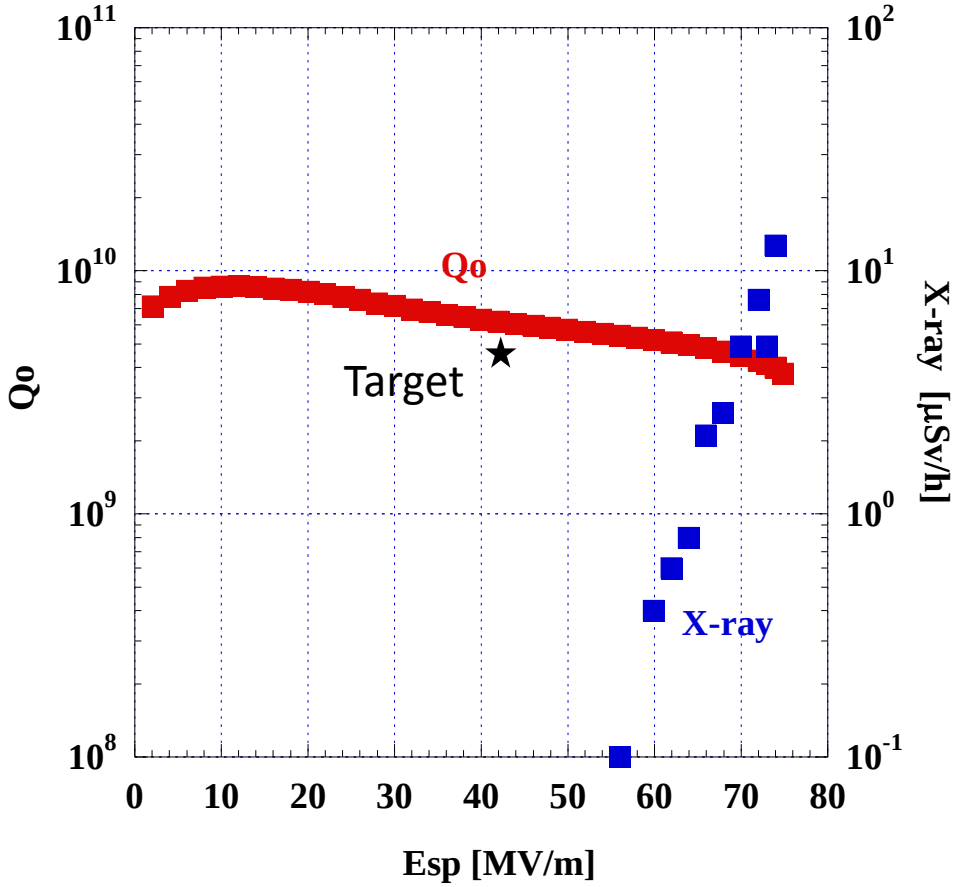


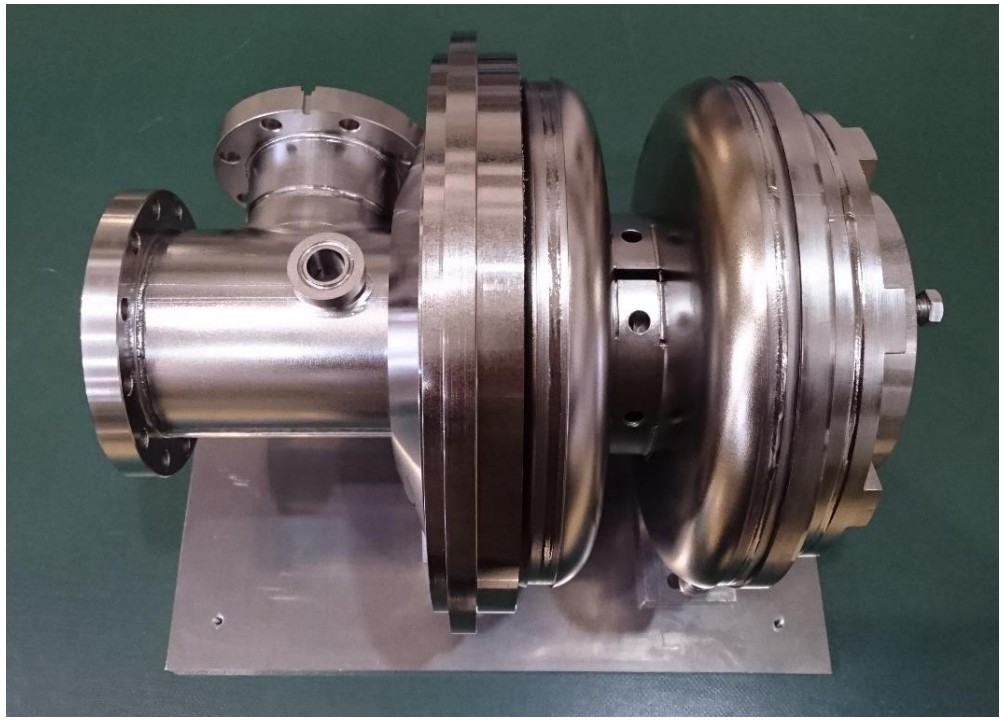
Horizontal cryostat



Vertical test results of the KEK SRF gun #2

- The maximum gradient without cathode rod reached to target value.
- We can shift the main target to cathode rod and holder development
  - Effective cooling structure to keep the cathode rod around 2K.
  - Particle free cathode transport method.





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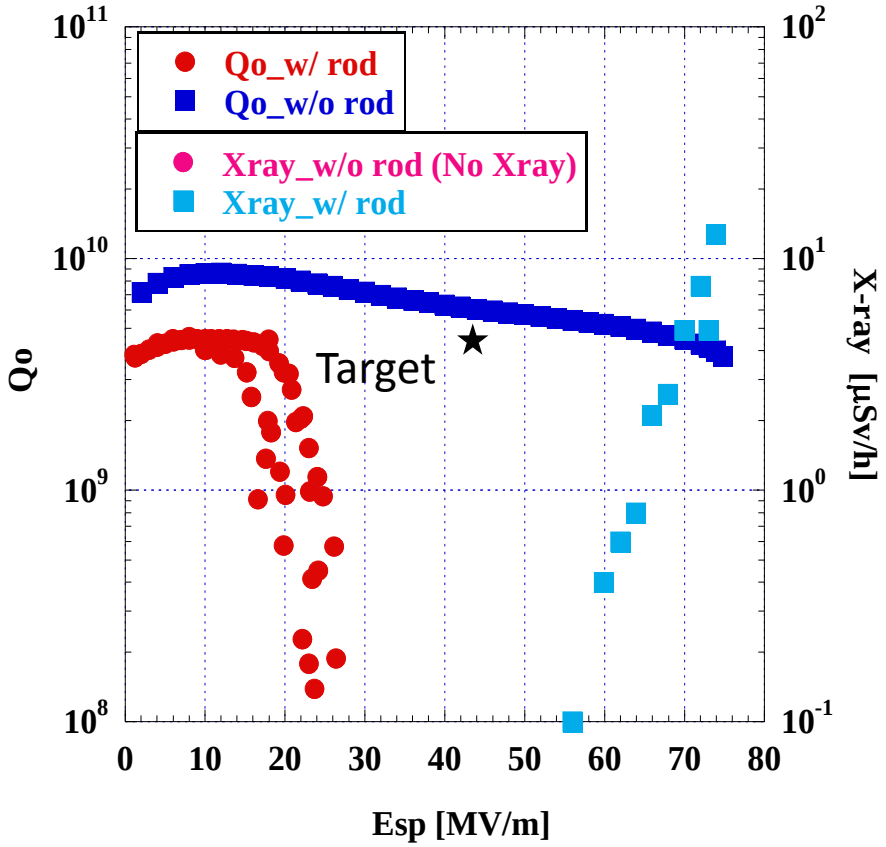
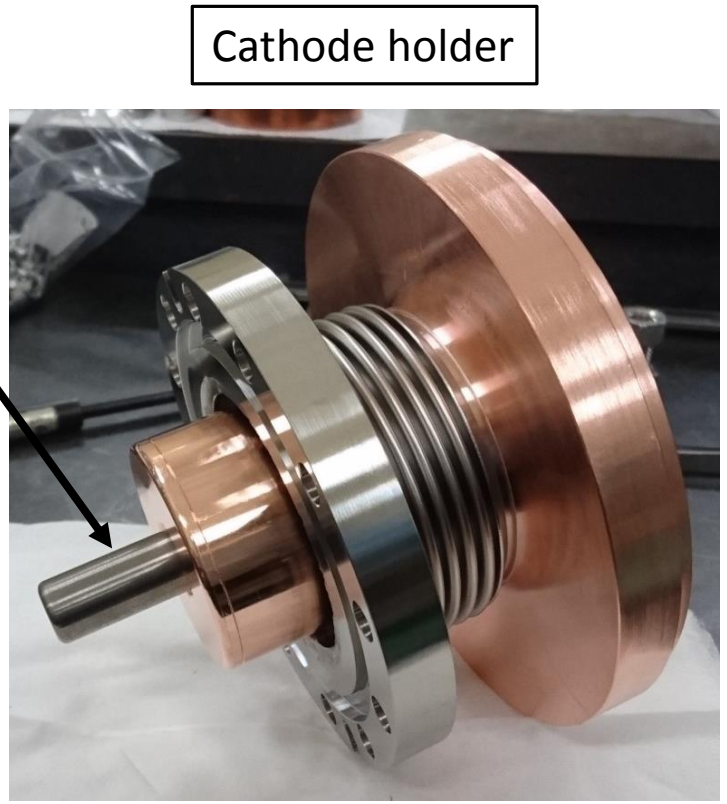
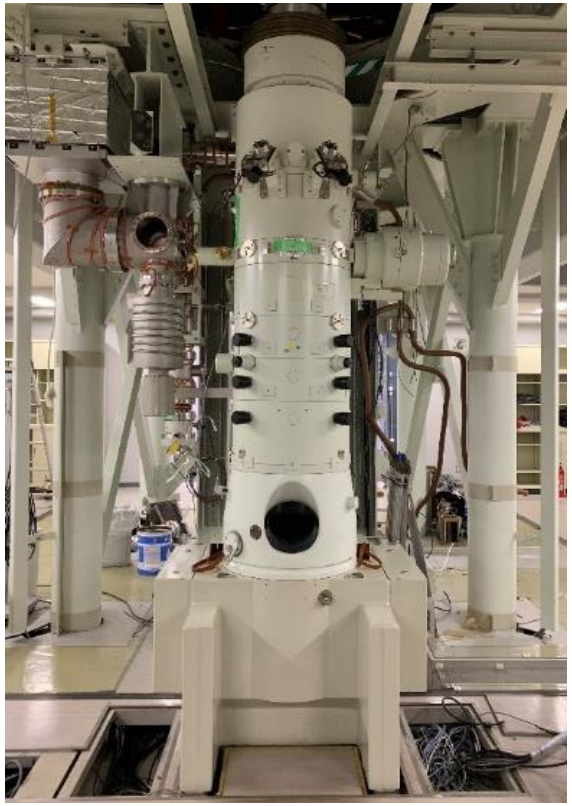




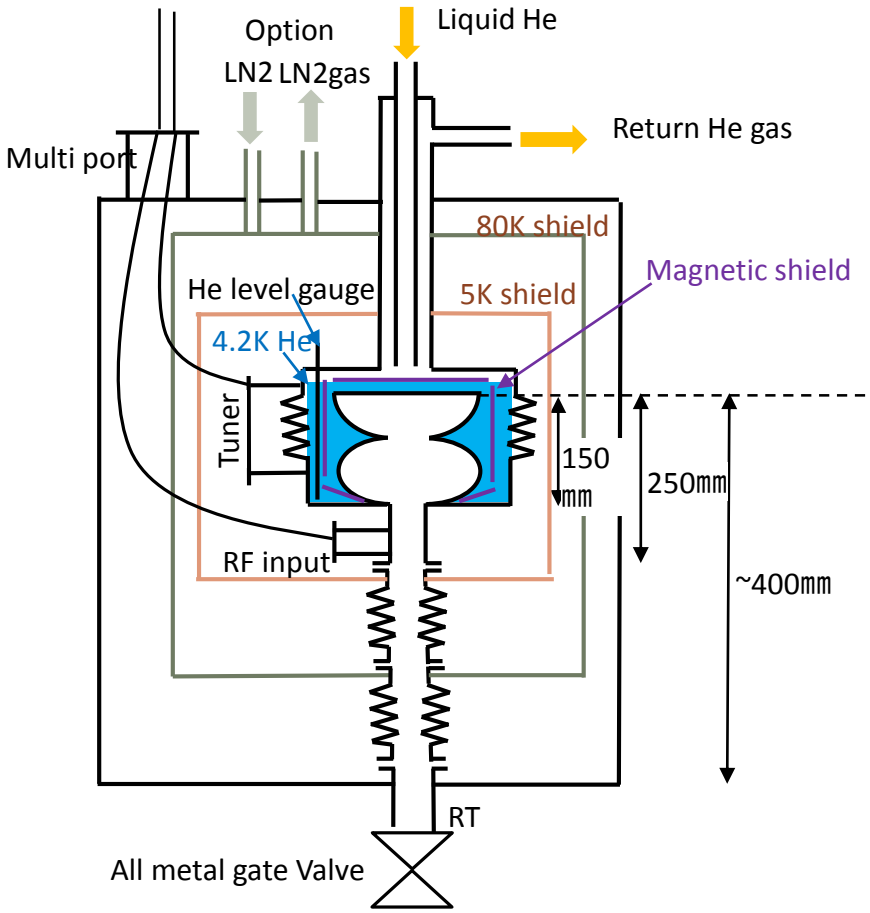
Plan of Nb3Sn SRF gun for UEM

SRF gun for Microscopy

- There are many applications using Nb3Sn can be considered. Light source, Water purification.
- Nb3Sn technology enables operation in small facilities which don't have a large refrigerator system.
- We start designing of the SRF gun for microscopy in collaboration with Osaka university.
  - RF power is low (RF cable can be use).
  - Beam current is low (Metal (Nb) cathode can be use)



1.3MV TEM@Osaka Univ. ISIR



Ultrafast Electron Microscopy (UEM)

- The RF design of the gun cavity is same as KEK SRF gun #1.
  - KEK SRF gun #1 is already achieved high gradient without filed emission.
  - The photocathode is metal Nb cathode.
- We will try to coat the Nb3Sn on the KEK SRF gun #1

Required parameters for Nb3Sn gun

Paramter	Value
Operation temperature	4.2 K
Beam energy	1~2 MeV
Pulse width	10 fs
Charge	10 fC
Pulse repetition	**100 MHz**
Current	~ 1μA
Norm. Emittance	20 nm-rad
Energy spread	10^{-5}
RF loss	**8W** @Qo=4.5x10^{10}

Nb SRF gun ⇒ Nb3Sn SRF gun

1.3GHz KEK SRF gun #1

Summary

1. Nb3Sn furnace
   - KEK start designing Nb3Sn furnace based on Cornell.
   - We want to finish construction until end of March 2020.
2. Nb SRF gun
   - KEK SRF gun #1 (metal cathode) was reached Esp=75MV/m.
   - KEK SRF gun #2 K2CsSb photocathode will be tested by using horizontal cryostat.
3. Nb3Sn SRF gun for UEM
   - We consider to apply Nb3Sn for Ultrafast Electron Microscopy (UEM).