Horizontal test of SRF gun #2 at KEK

October 5 (Wed), 2022

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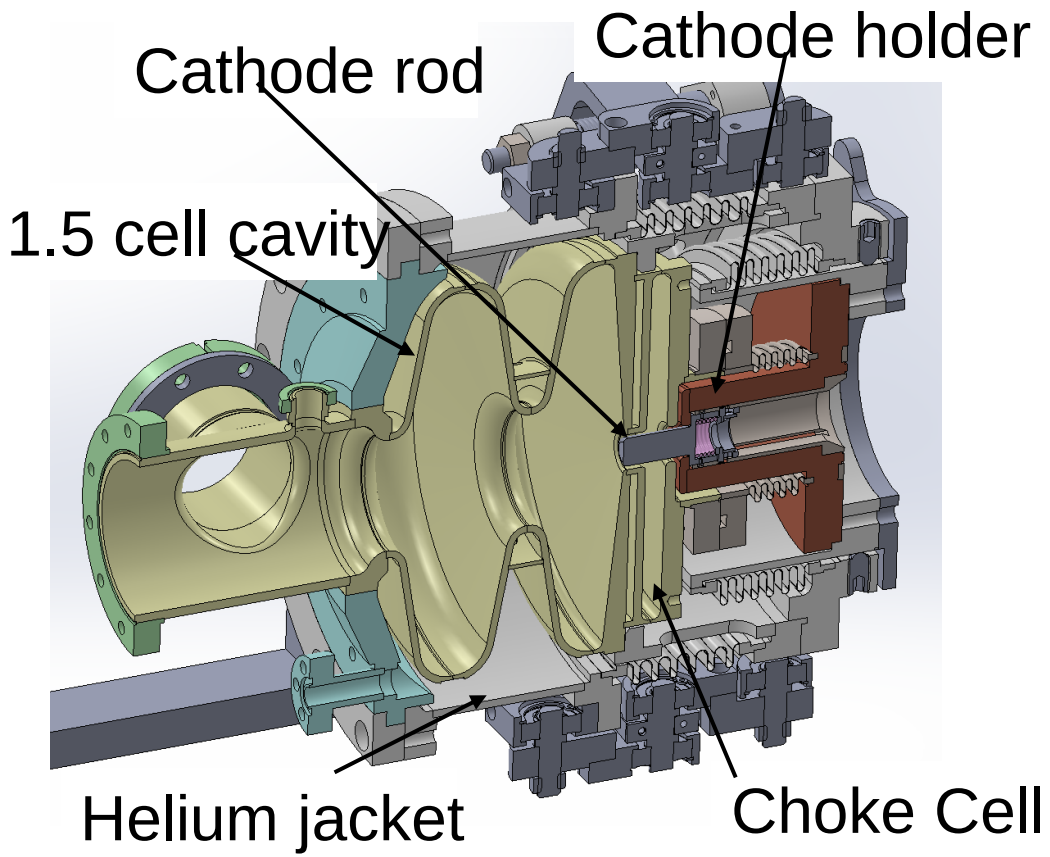
Outline

- Introduction
  - Cavity Structure
- Vertical test results
- Horizontal test
  - Preparation for Horizontal test setup
  - Horizontal test results
- Summary
- Future plan

Cavity Parameter

- KEK SRF gun was designed to demonstrate fundamental performance of SRF gun.
- ERL parameters are used to design KEK SRF gun.

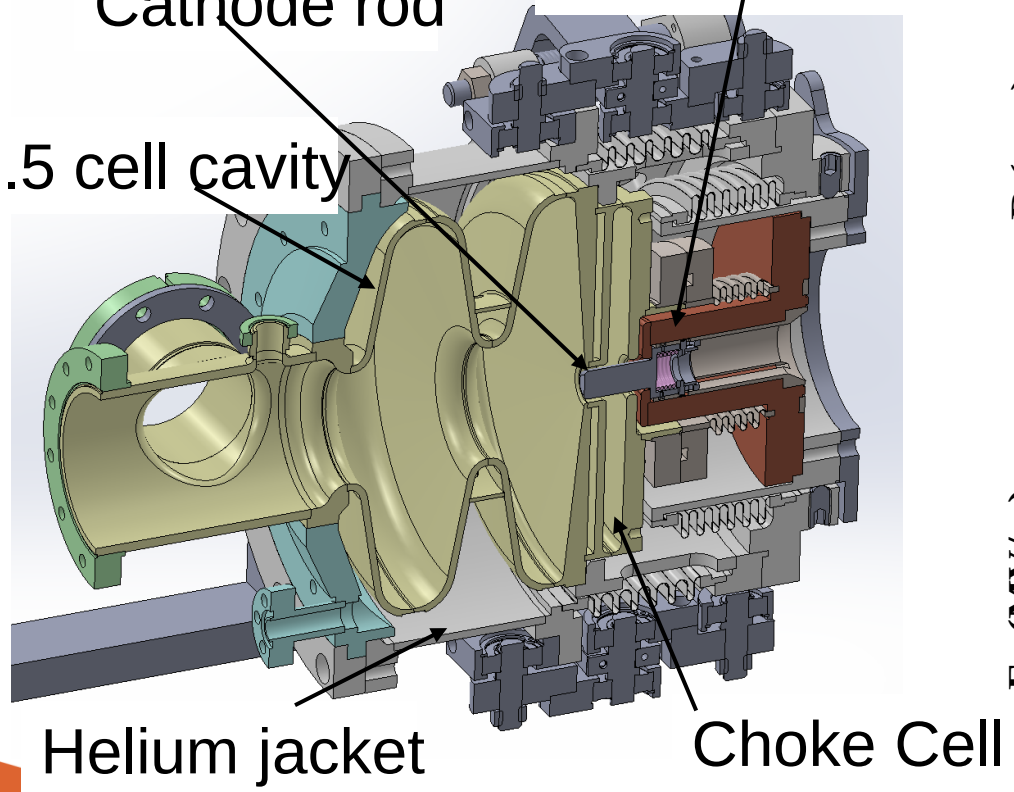


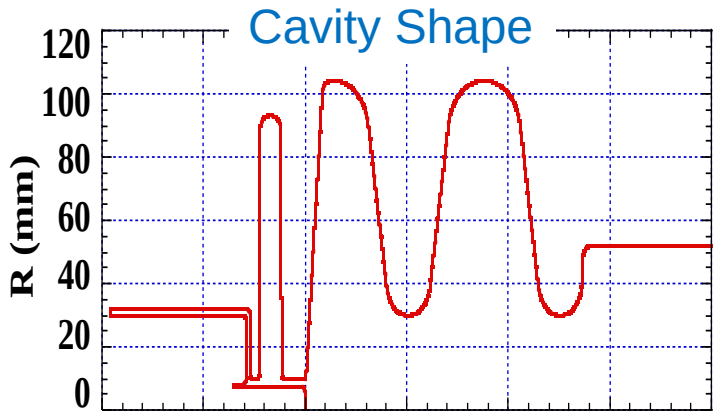
Parameter	Value
RF frequency	1.3 GHz
Accelerating Voltage (Vc)	2 MV
Geometrical Factor	133.1 W
Surface Peak Electric Field (E_{sp}) @Vc=2MV	**41.9 MV/m**
Surface Peak Magnetic Field (H_{sp}) @Vc=2MV	92.4 mT
H_{sp}/E_{sp}	2.2 mT/(MV/m)
Z_{ESP} *	241.3

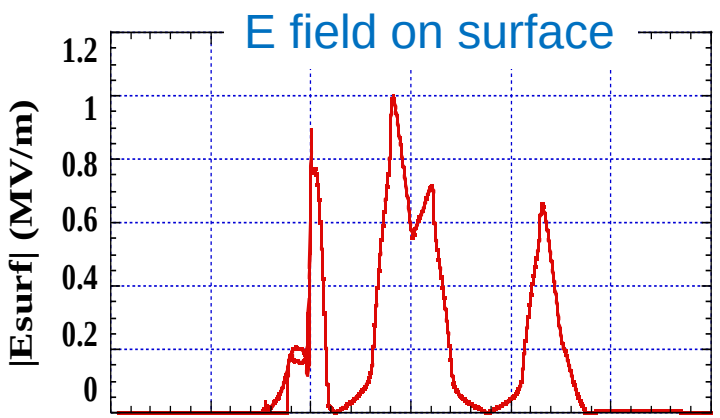
$$*E_{sp} = Z_{ESP}\sqrt{Q_0 P_{loss}}$$

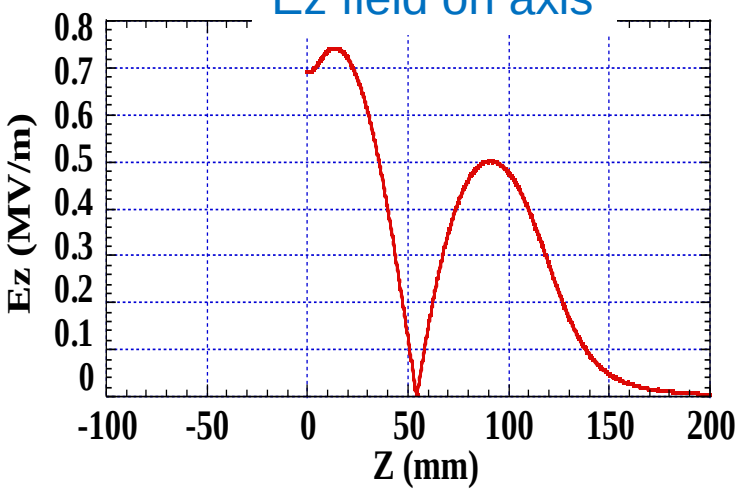
Cavity Field

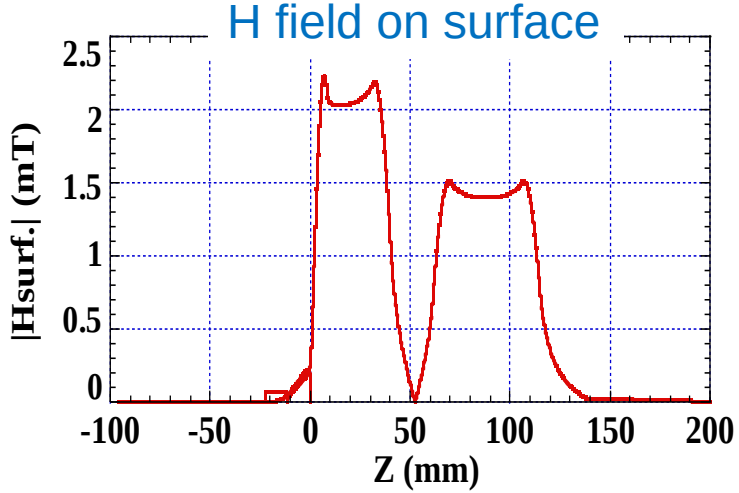
- Focusing field generate on cathode surface.
- 2nd cell length is shortened to prevent deceleration.
- 2nd cell field set lower to achieve an acceleration voltage of 2 MV.











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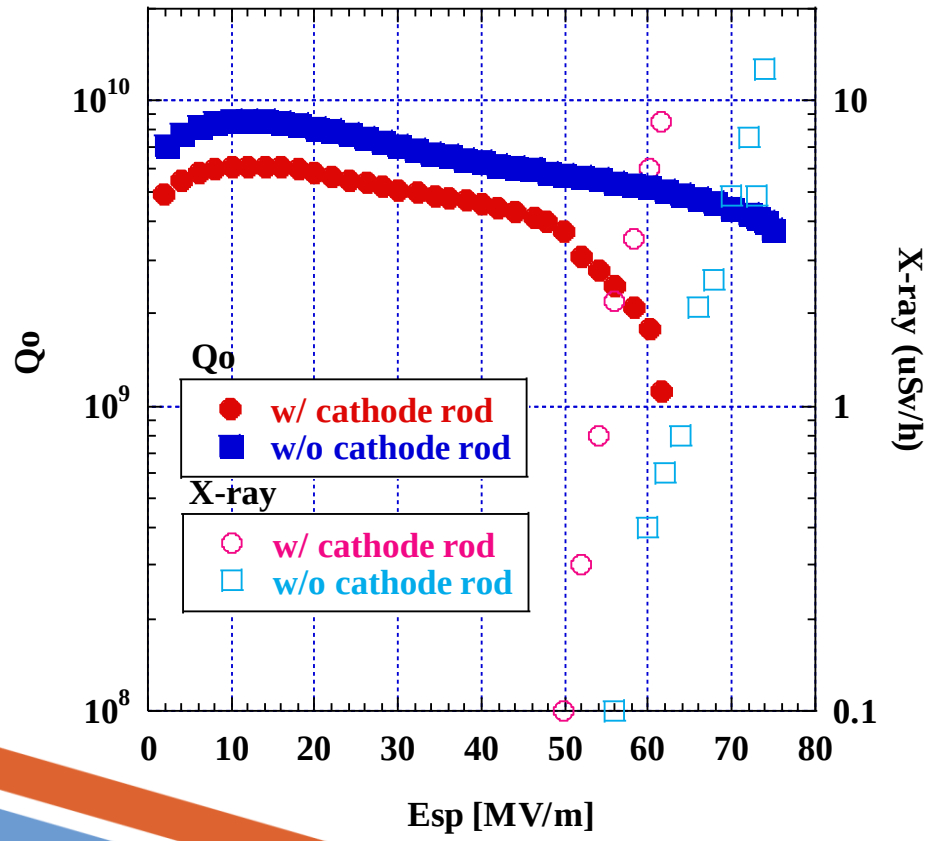
Vertical test results

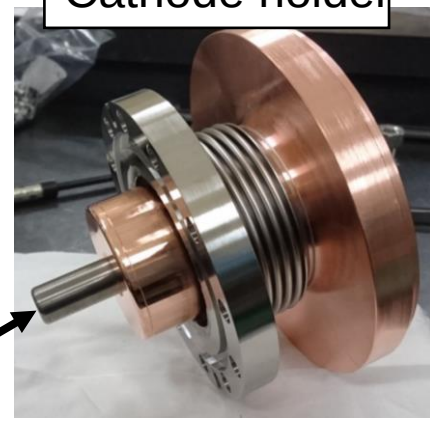
- Cavity polished by EP and applied HPR.
- w/o cathode rod: Esp = 76 MV/m. Hsp=167 mT.
- w/ cathode rod: Esp = 61.5 MV/m, Low Q_0 due to lack of choke tuning.

Bulk EP (100 μm) + Anneal (800ºCx3h)
+Field Tuning + USR + HPR



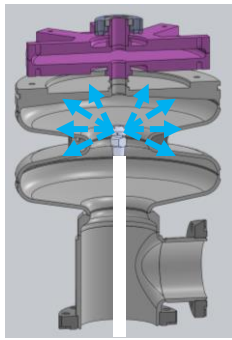
Cavity #2

Cathode holder

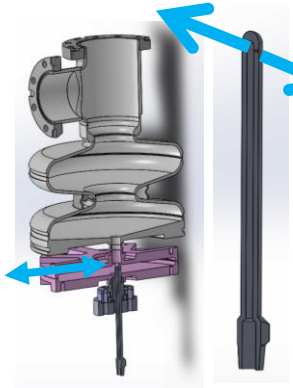


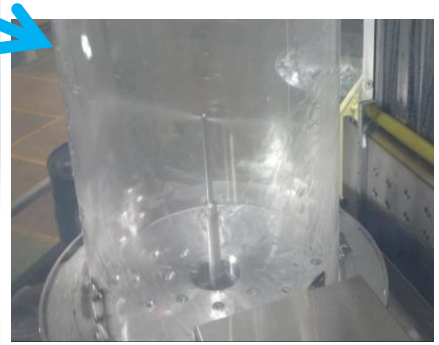
Cathode rod

HPR nozzle for Acc. cell



HPR nozzle for choke cell





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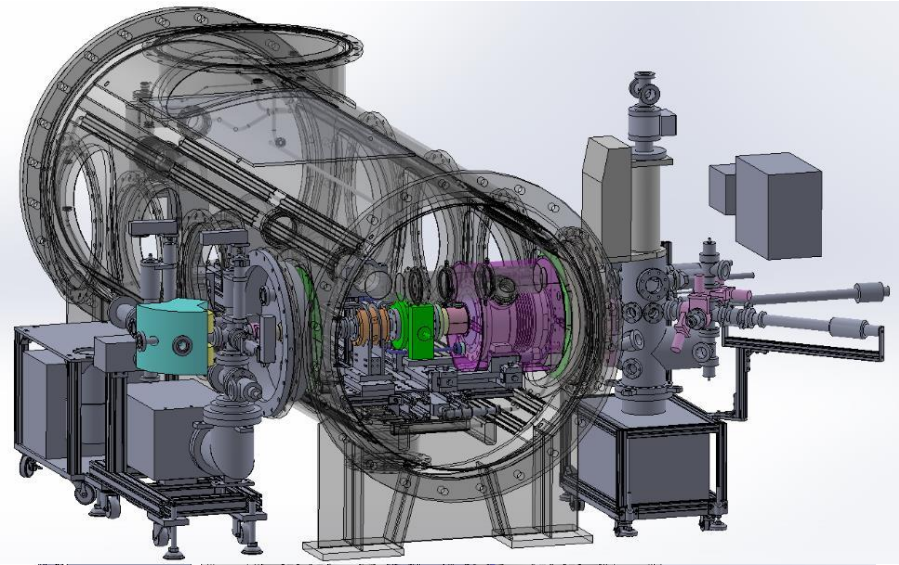
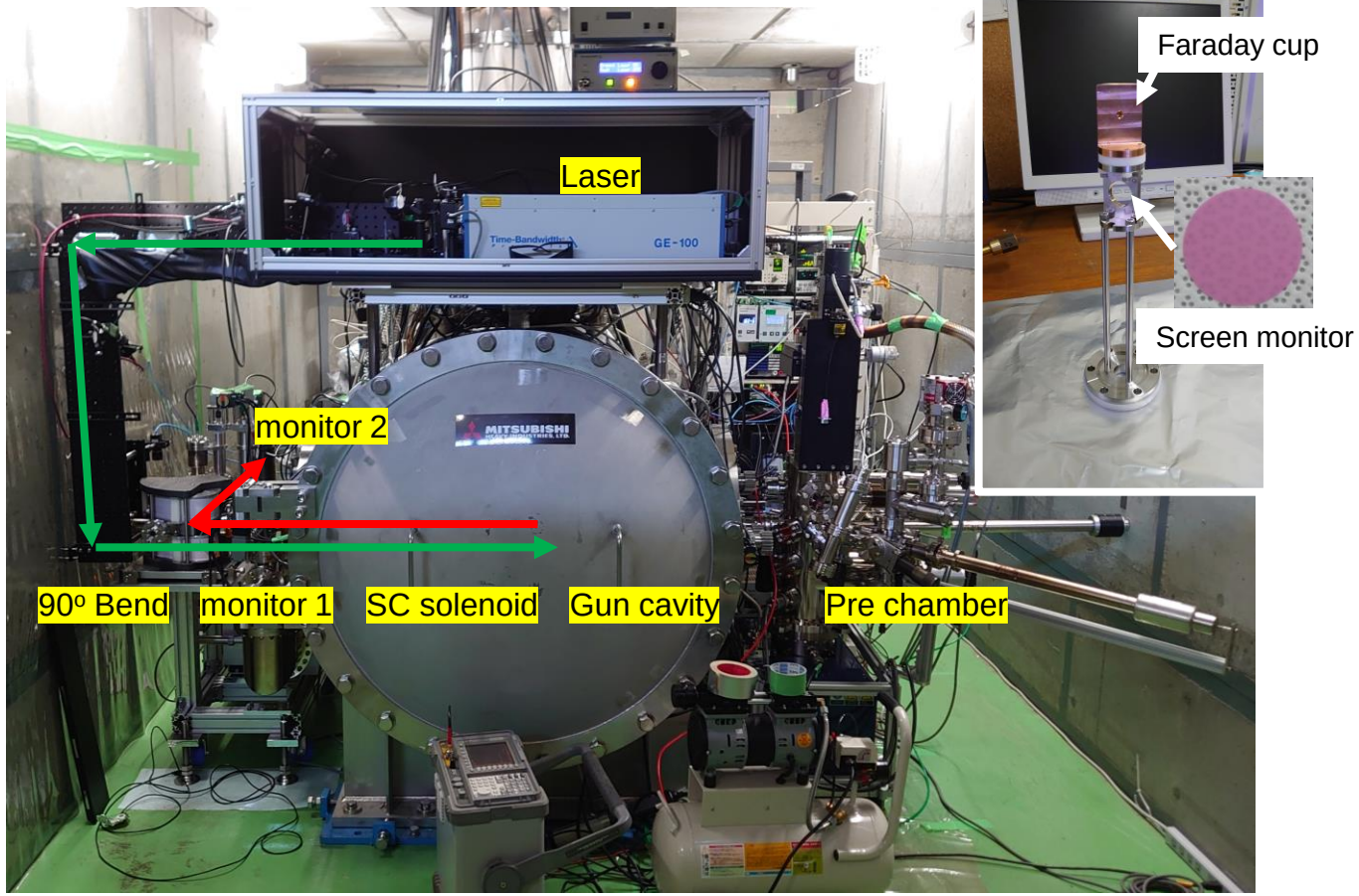
Horizontal test setup

- Use multi-purpose cryostat for Horizontal test and beam test.
- Gun cavity was cooled 6 times. High gradient performance was measured 4 times.
- Preparing components (SC magnet, 90deg. Bend, beam monitors) for beam test.

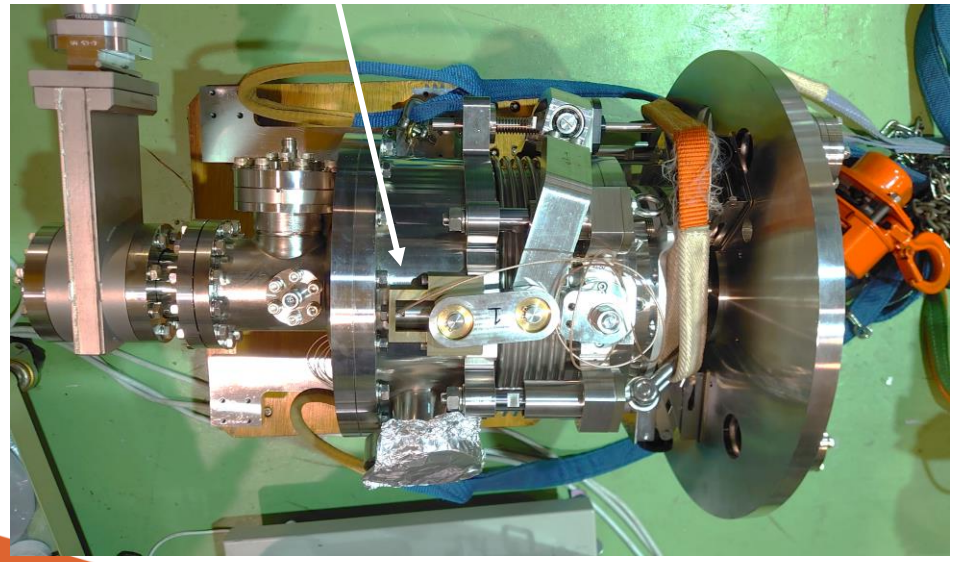




Helium jacket with frequency tuner

- Mechanical tuner was designed compact to fit multi-purpose cryostat, and the tuning range is 450 kHz.
- 2 Piezo tuner is installed, and the tuning range is 200 Hz.

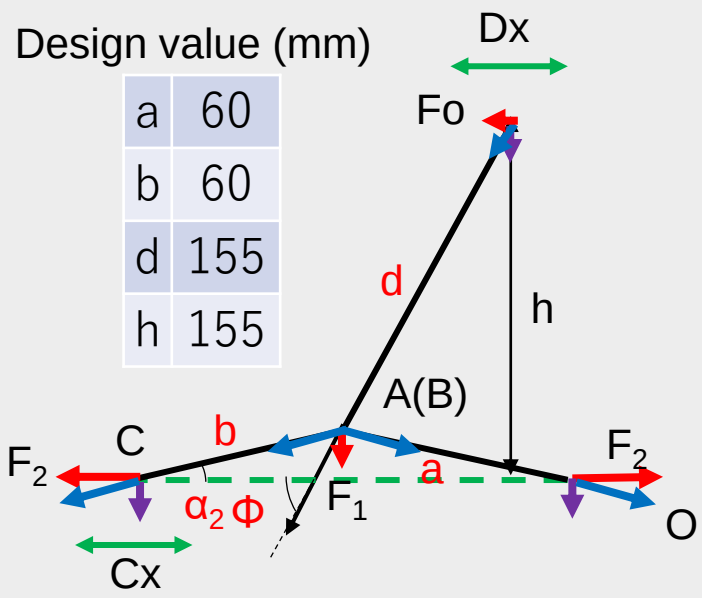
Piezo

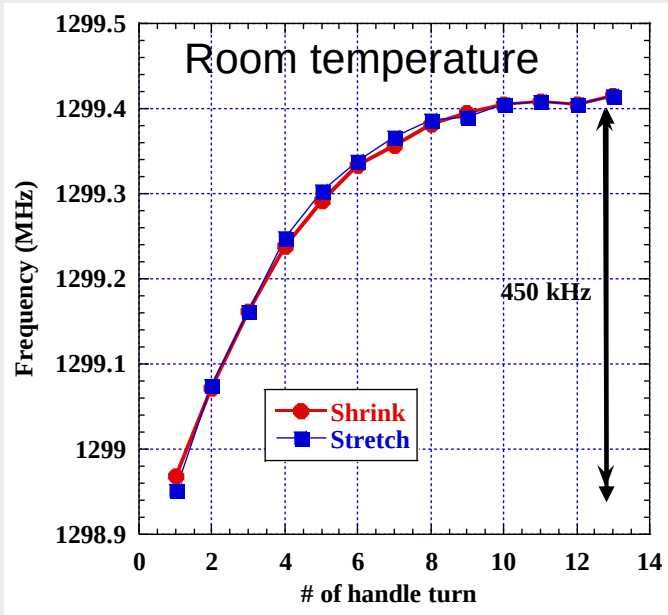


Mechanical tuner

Design value (mm)

a	60
b	60
d	155
h	155





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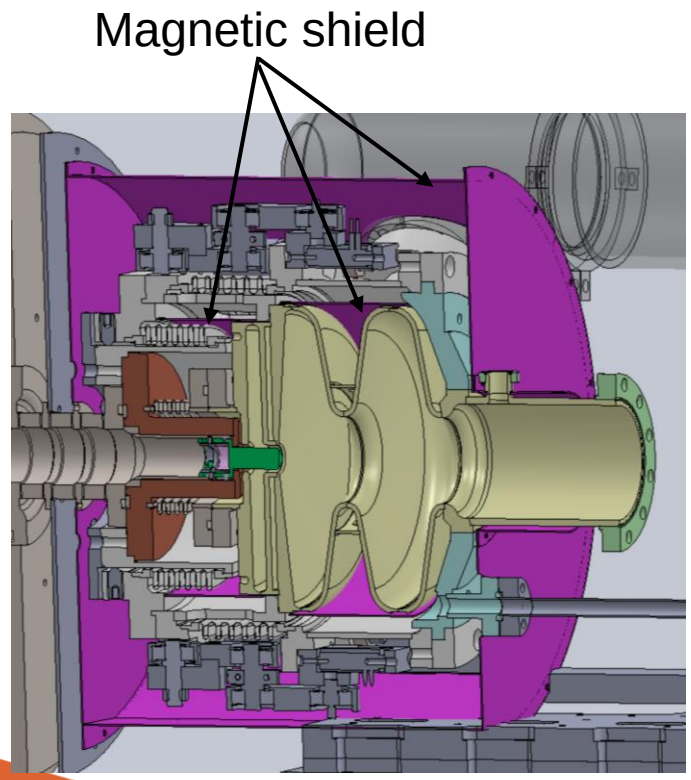
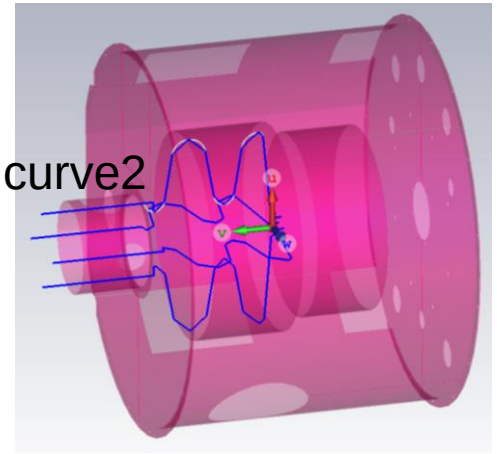
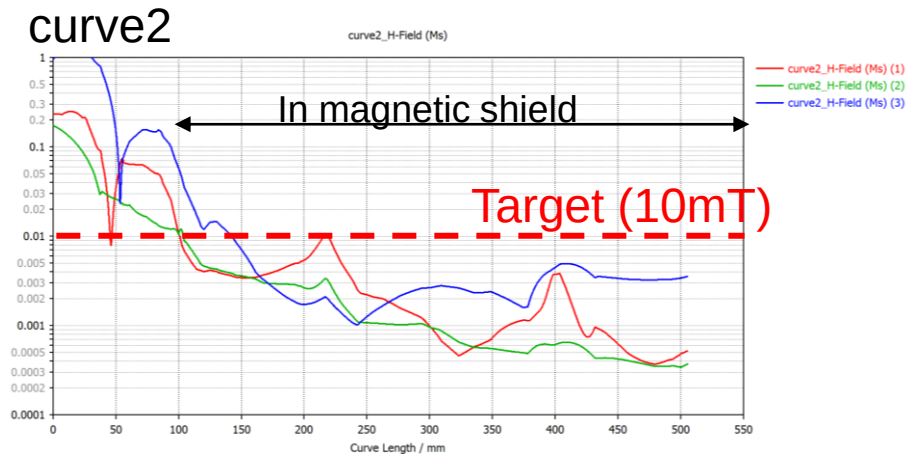
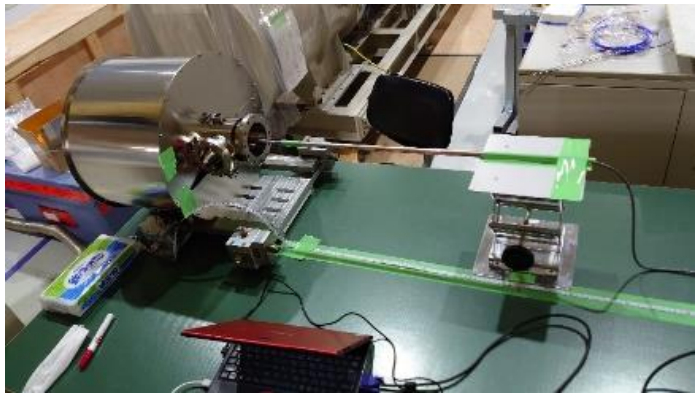
Magnetic shield

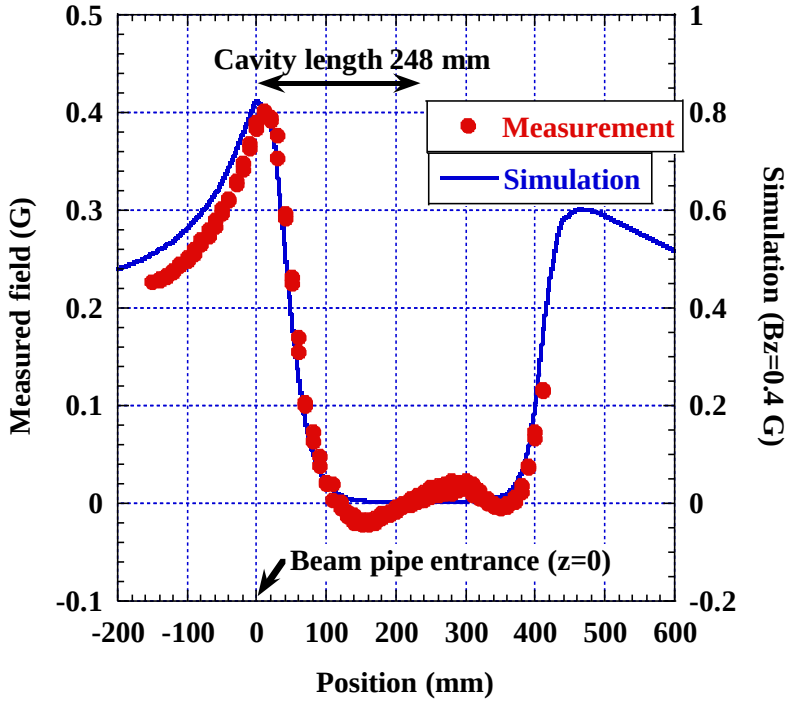
- 2 layer of magnetic shield (Ota's Permalloy PC) reduce the geo magnetic field to 10 mT.
- Experimental result shows good agreement with simulation.











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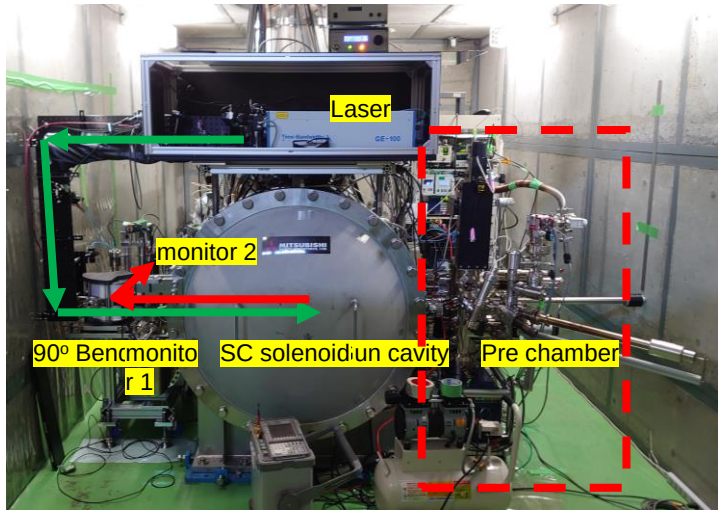
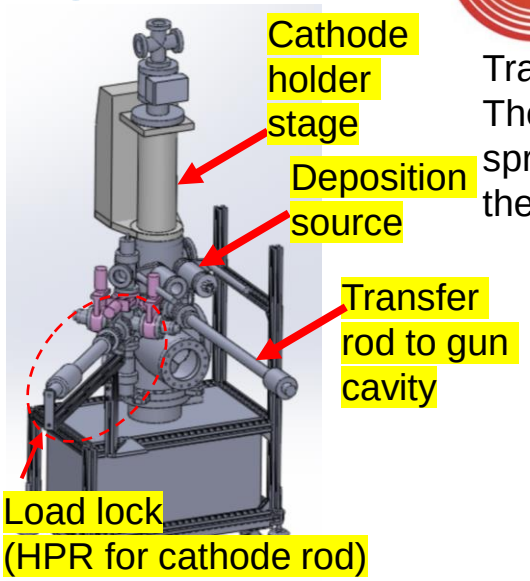
Photocathode preparation

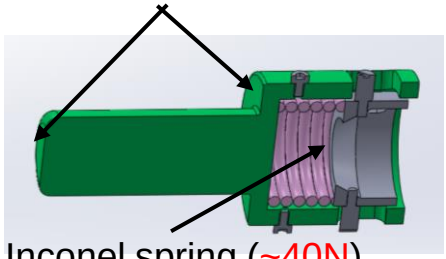
- K2CsSb coated on mirror polished Nb plug.
- But dark lifetime is too short.
- And too many trouble in load lock system.



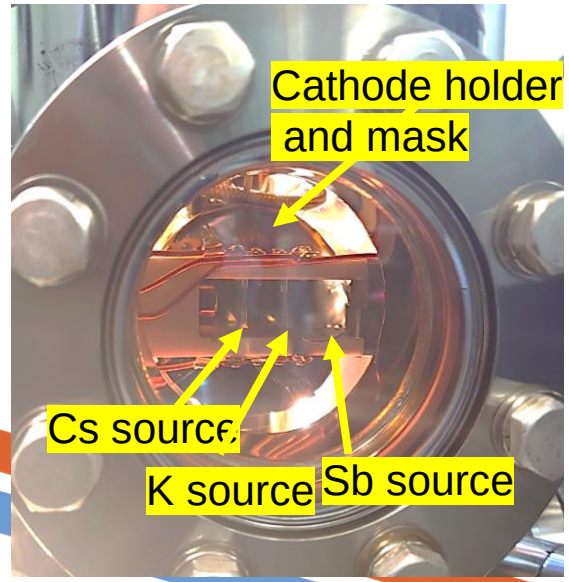


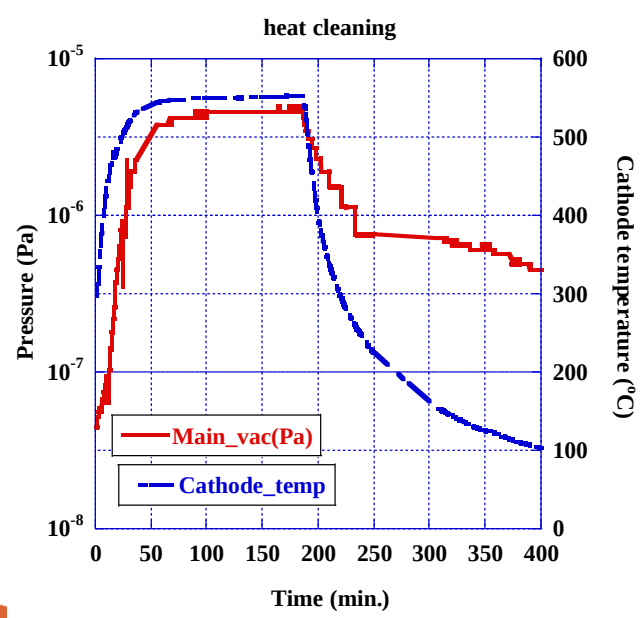
Transfer rod design is not good:
The transfer system has to withstand a spring force of 40N to lower the contact thermal resistance.

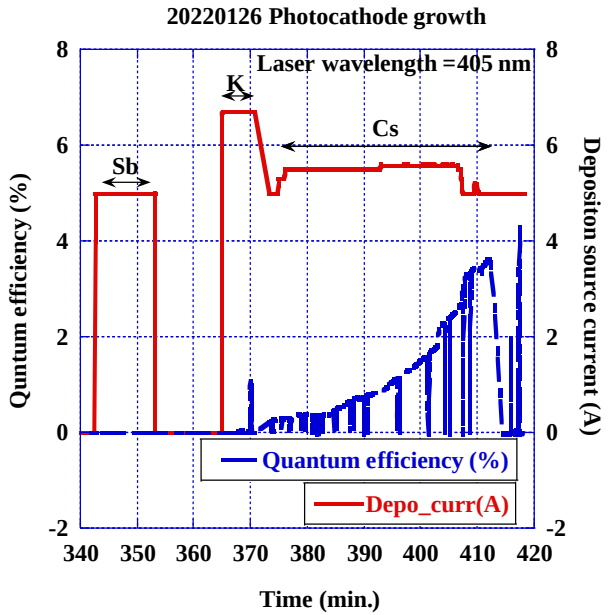
Mirror polished (Ra ~0.4nm)

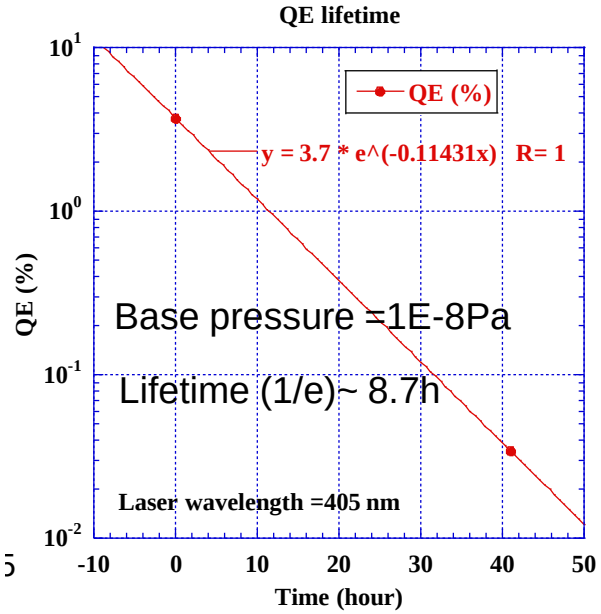


Typical K2CsSb photocathode coating procedure.



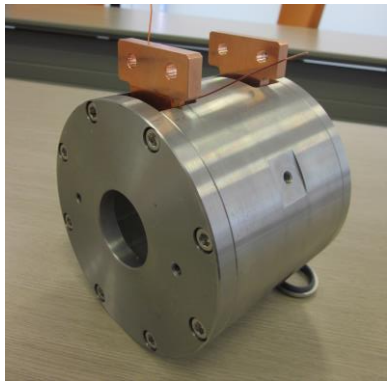






SC solenoid

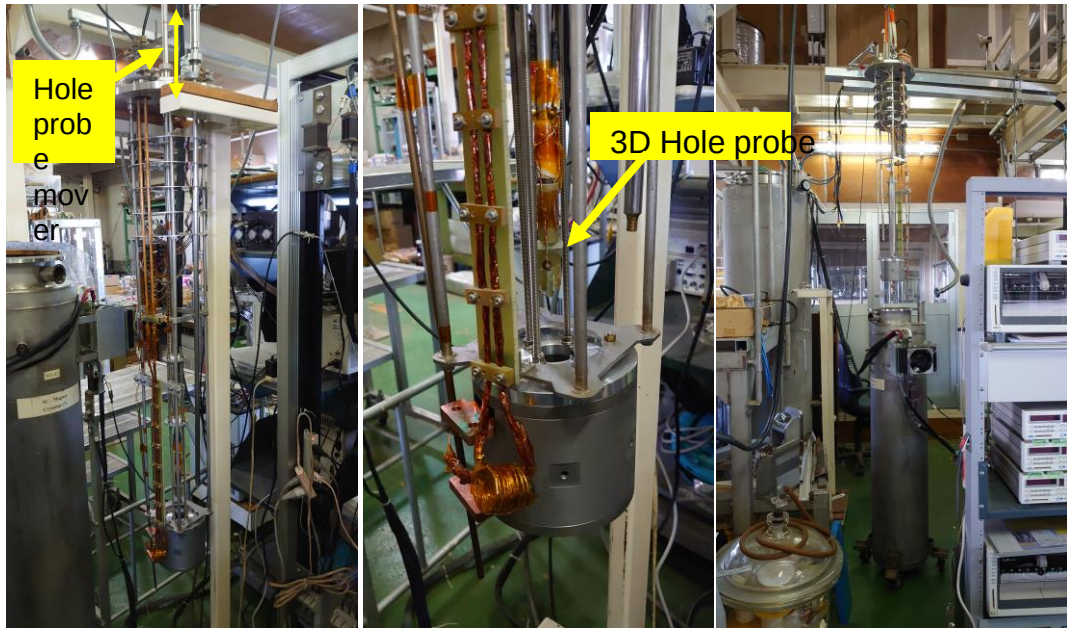
- SC solenoid was designed for emittance measurement.
- The focal length is 100 mm for 2MeV beam.
- Coil is cooled by conduction cooling from 2-Phase line.

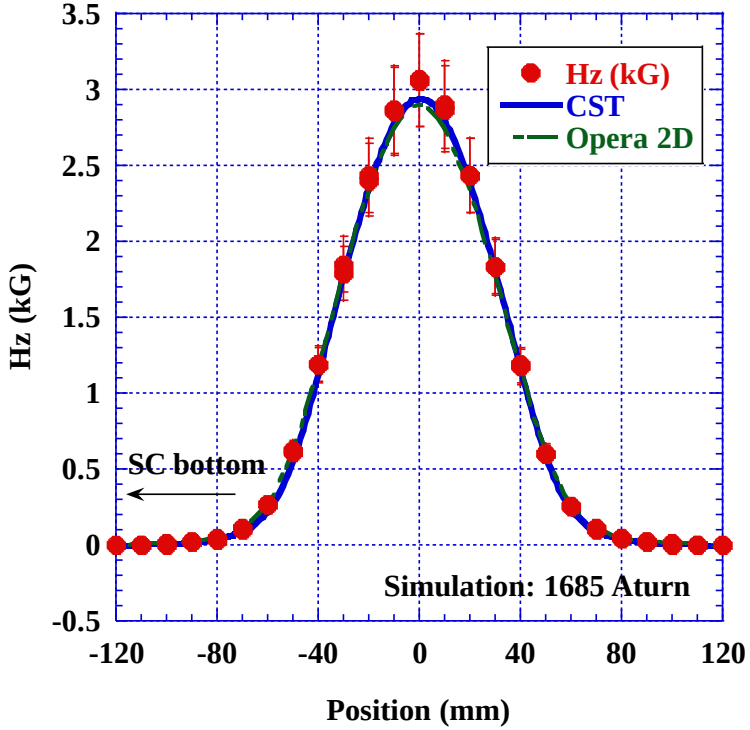


Peak Hz =3.06±0.31 kG
(CST＝ 2.95 kG, Opera2D=2.90 kG)

Wire	Design value
Material	NbTi/Cu
Manufacturer	Furukawa F54/4.2/65
Resistance of unit length @RT	0.597 (mOhm/cm)
Resistance of unit length @20K	2.84 (uOhm/cm)
Number of turns	**1685**
Operation current	~ 10.3 A
Max field on wire	~ 0.35 T
Load line ratio	~20 % @8K

Offline measurement with 4K helium bath





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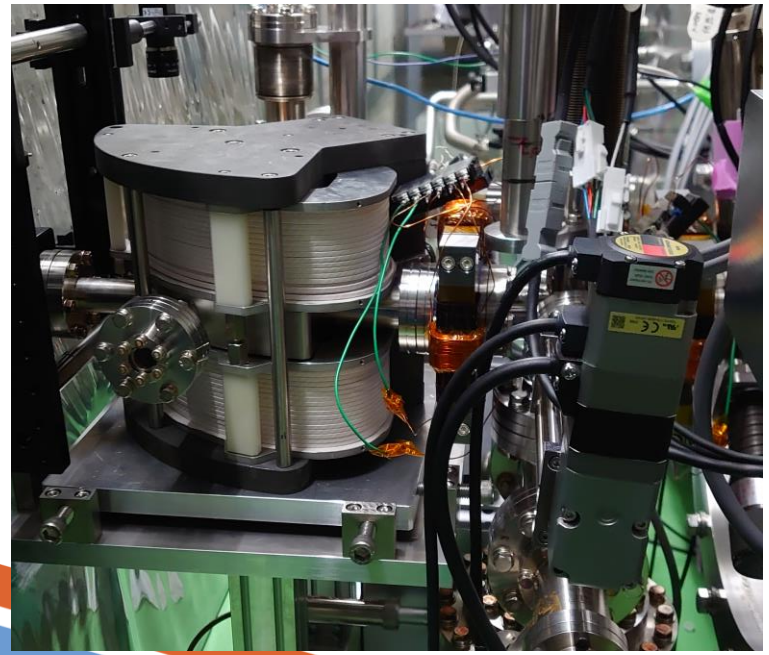
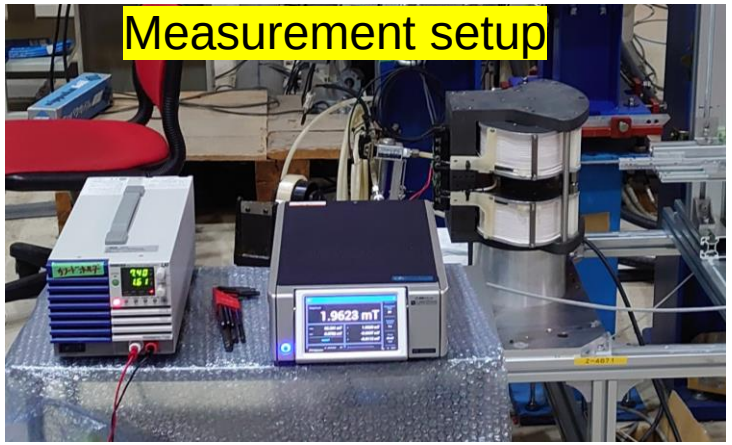
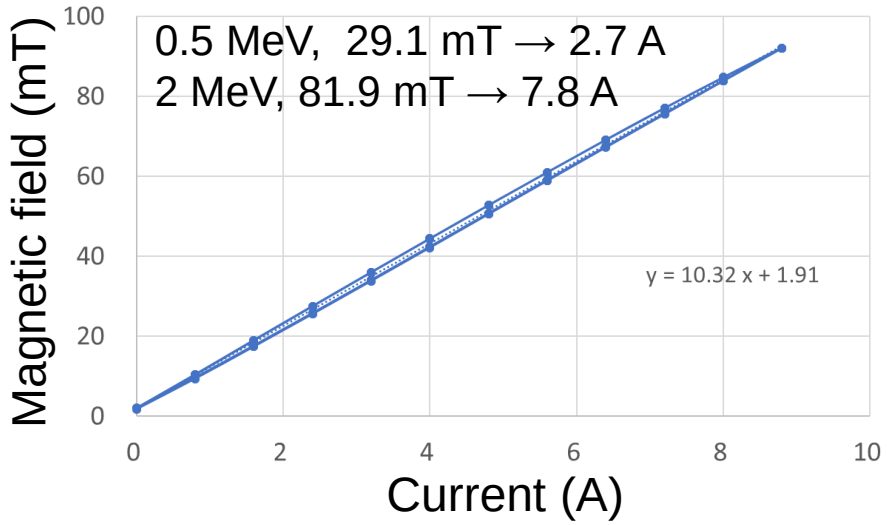
90 deg. Bending magnet

- 90 deg. Bending magnet was designed for 2 MeV beam energy evaluation.
- The hysteresis curve was measured.

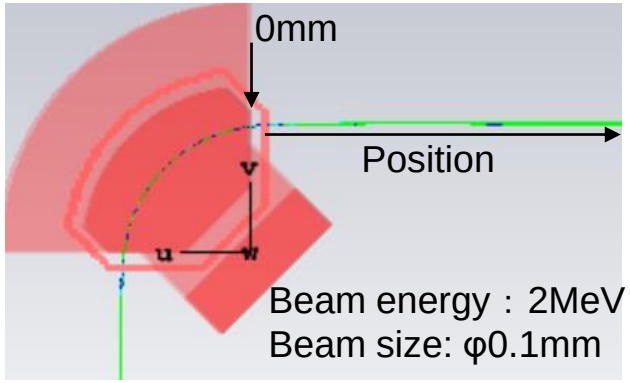


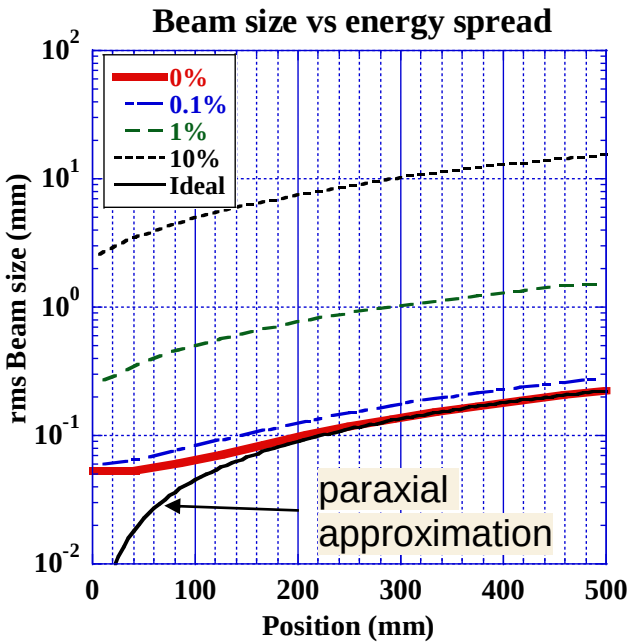
Hysteresis measurement at center magnet





Estimation of beam size





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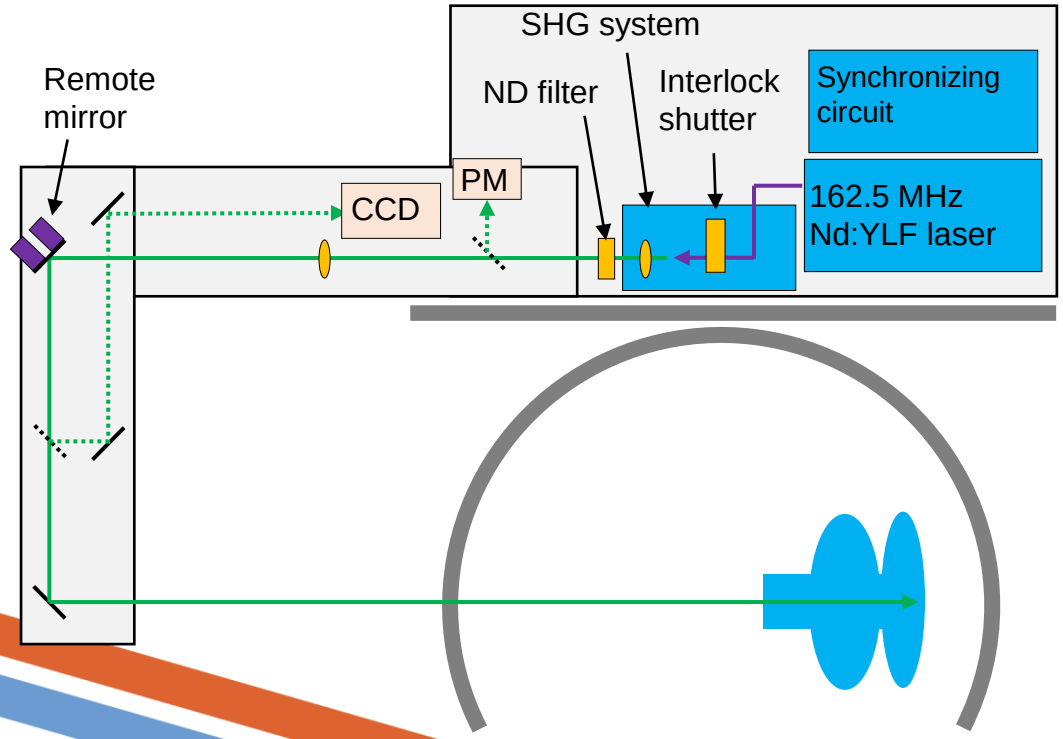
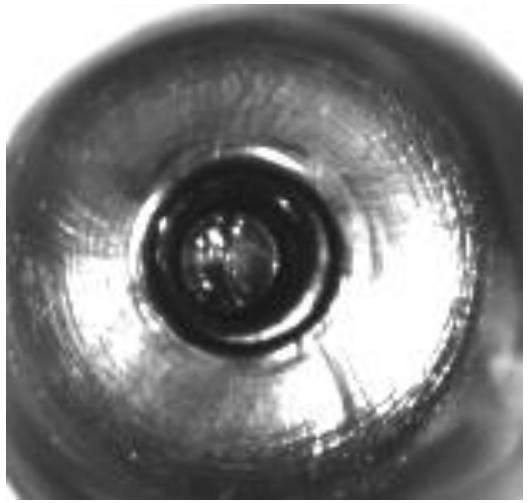
Laser system

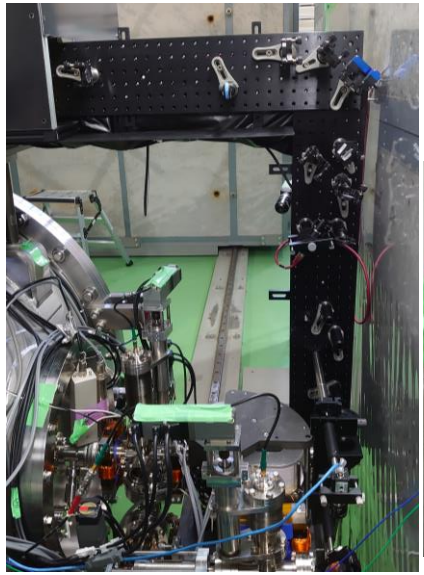
- Synchronization signal is 162.5 MHz.
  - Borrowed laser system from cERL and STF.
- Laser position is aligned by using double slit and CCD camera.

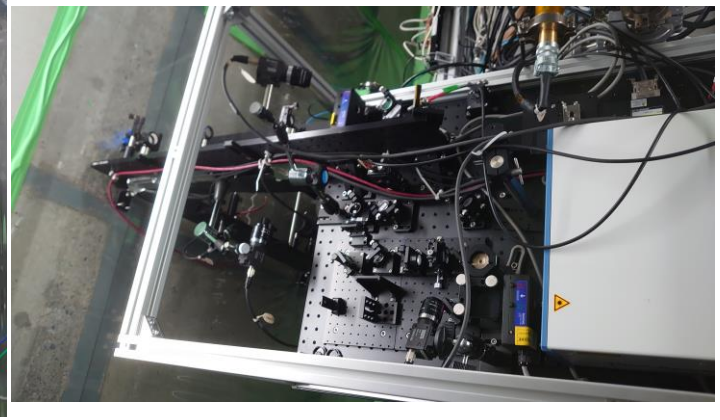
Reference signal, 1300 MHz from cavity pick up.
Synchronization signal 162.5 MHz



Photocathode image

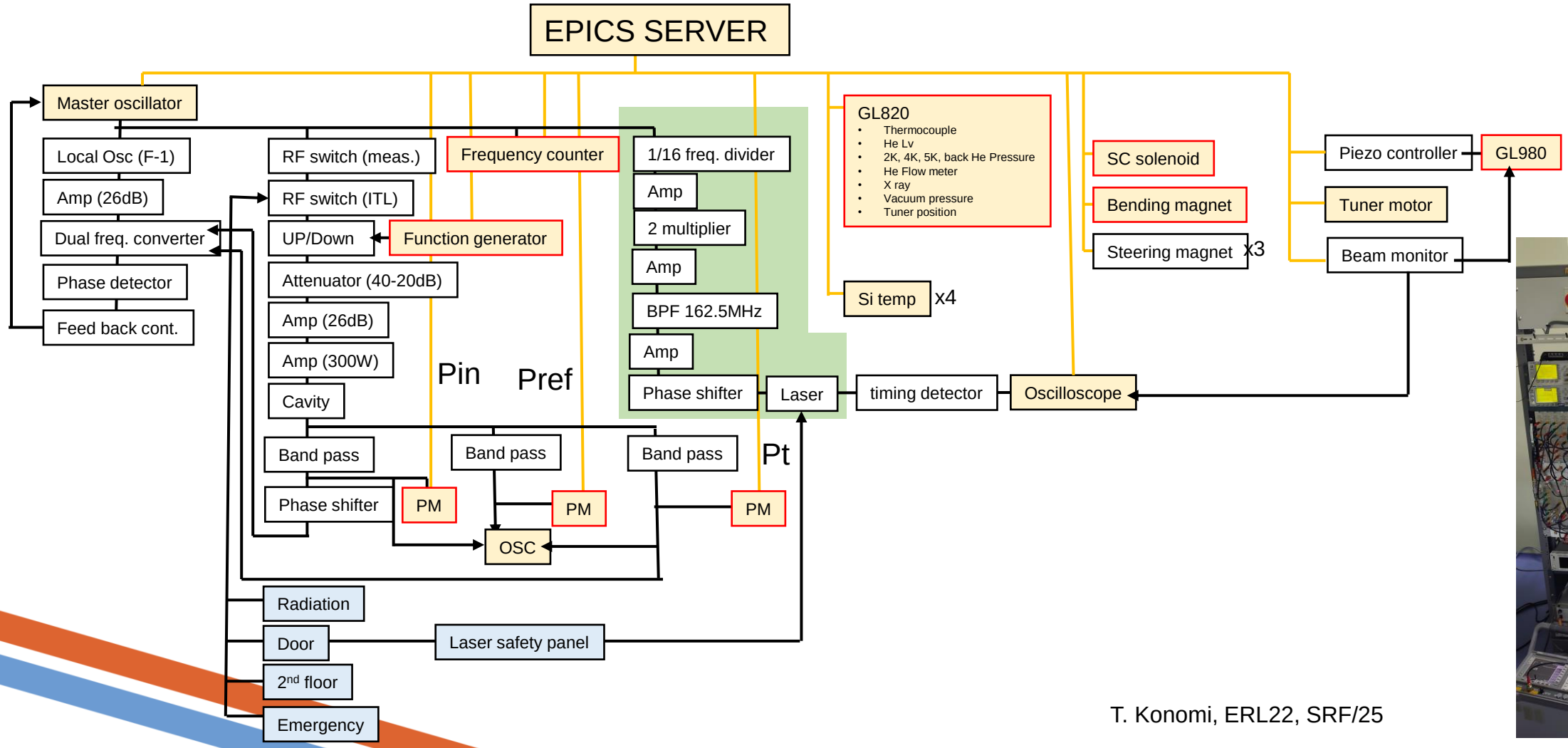


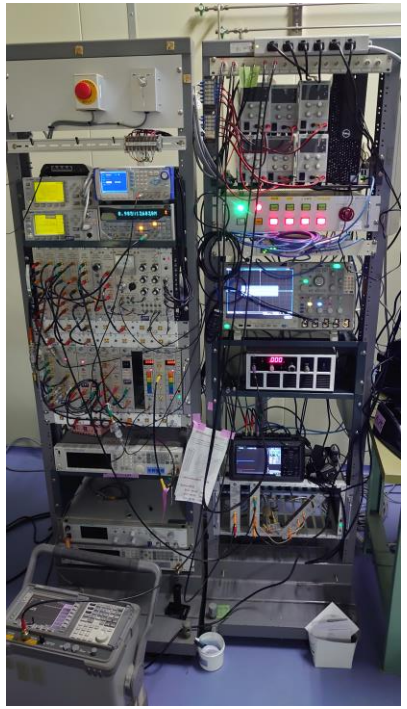




LLRF and Data taking

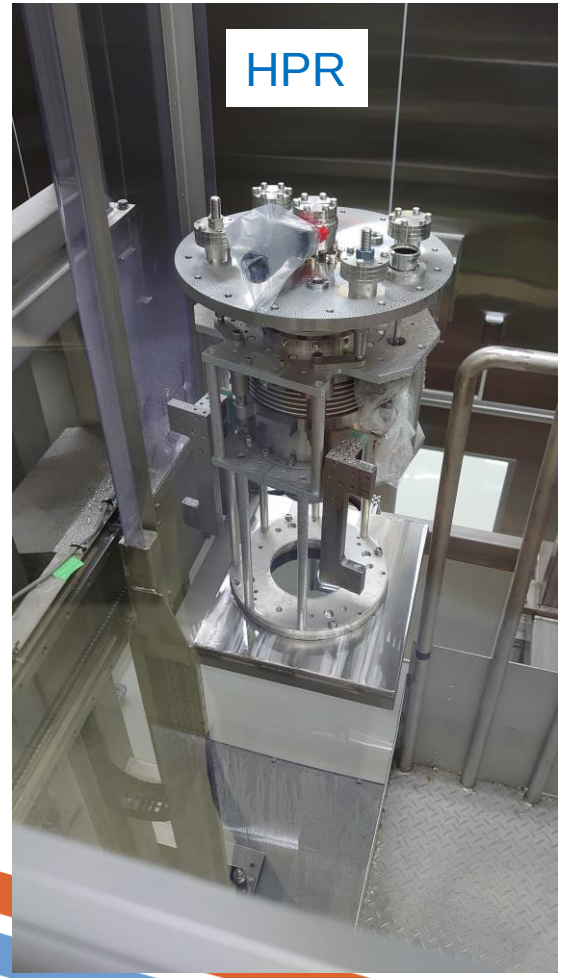
- A laser synchronization circuit was added to the existing LLRF.
- The laser frequency follows the cavity frequency.
- Data taking system was updated to EPICS server and CS-studio.

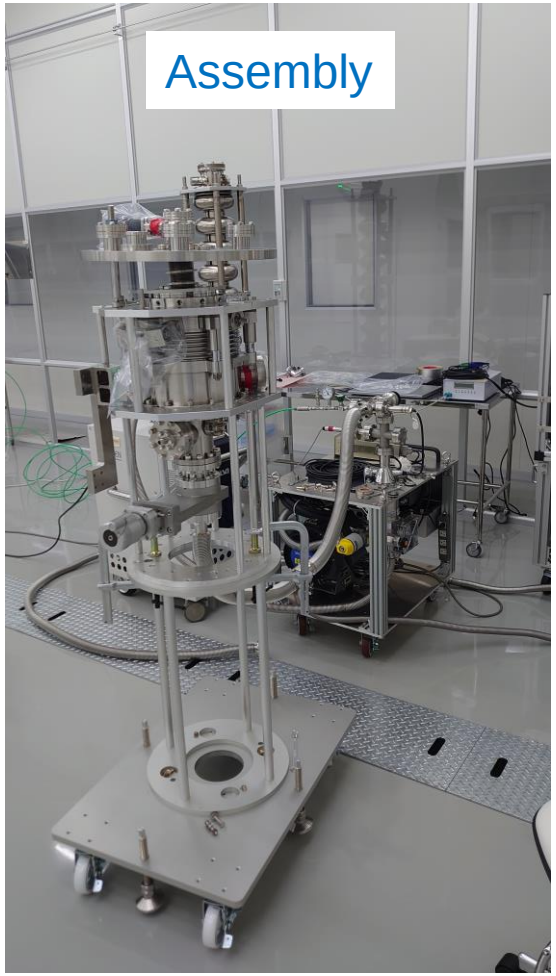




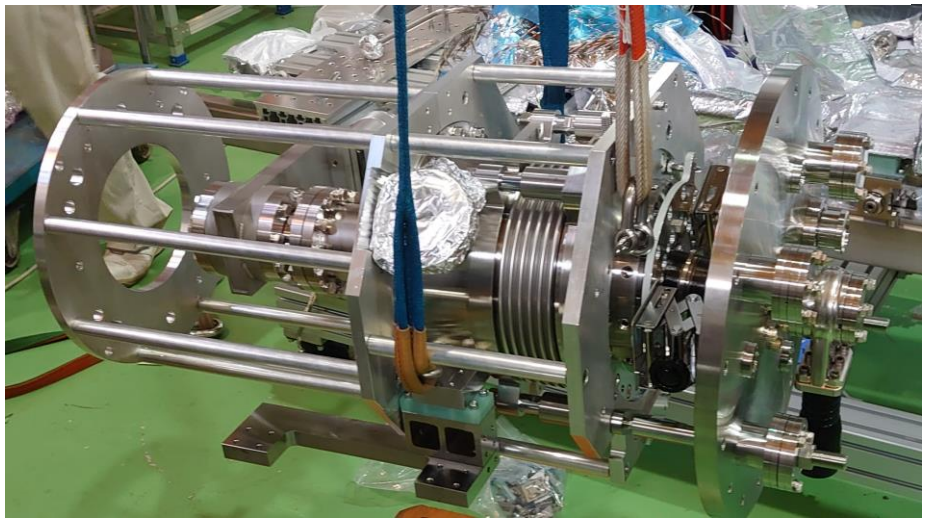
Assembly procedure

- Apply HPR to cavity with jacket.
- Assembled in clean room.
- Baking at out of clean room





Transport to horizontal test cryostat area



Assembly procedure

- All vacuum components are assembled in local clean booth.
  - The connection process was performed in different locations for 6-7 times.
- Pumped with slow pumping unit (pumping speed is 0.6 L/min, purge speed is 0.2 L/min)

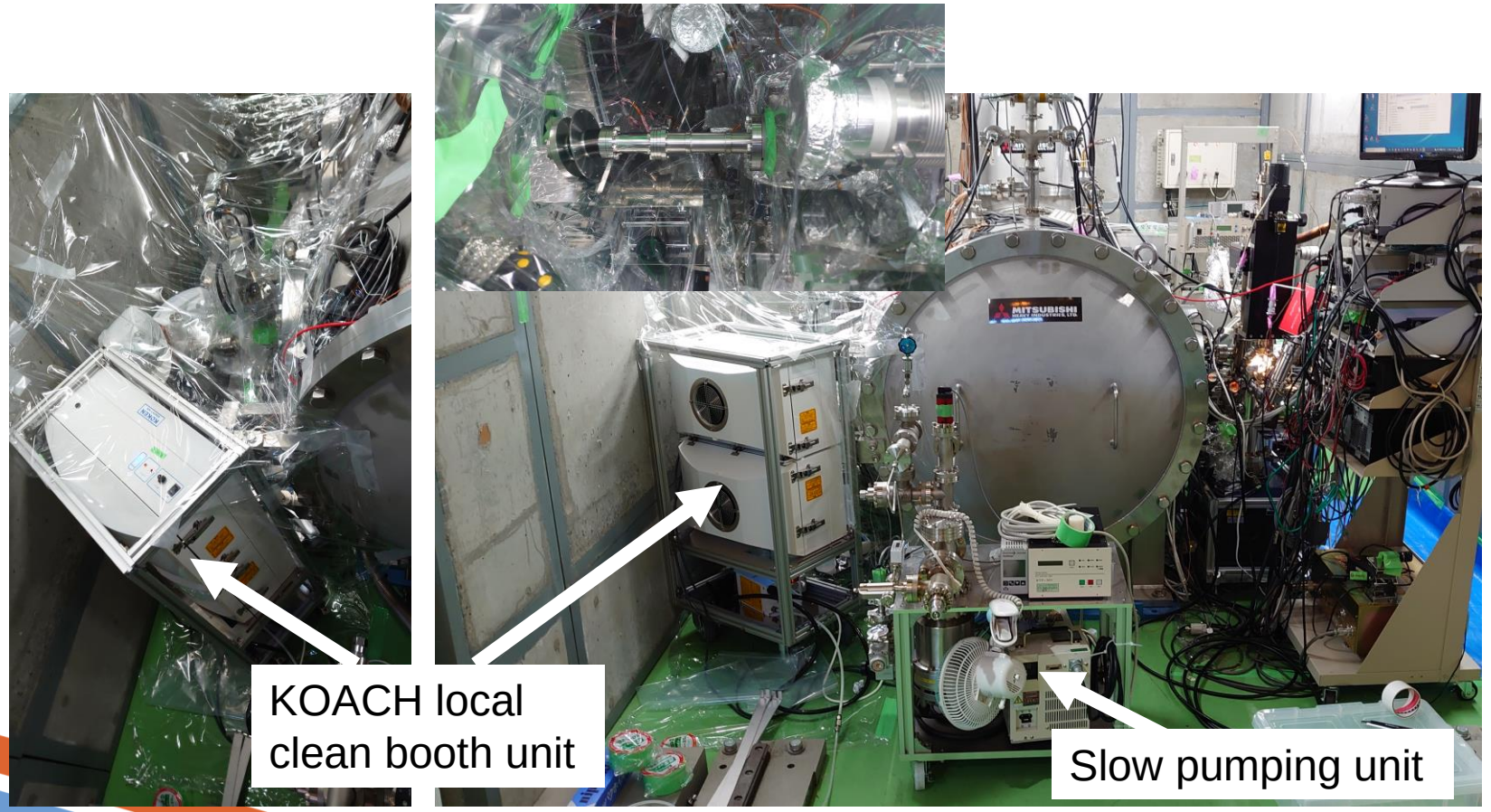
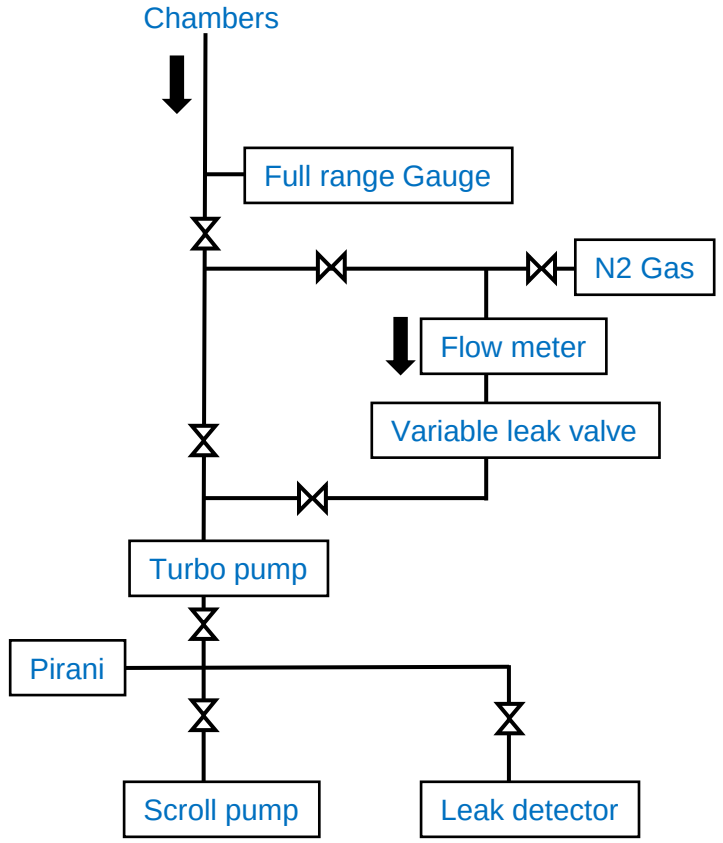


Diagram of Slow pumping unit



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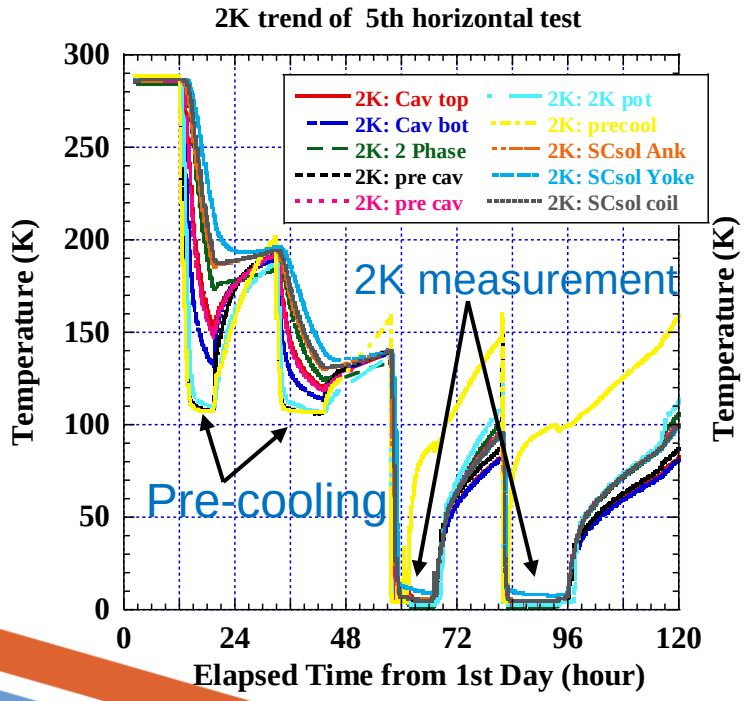
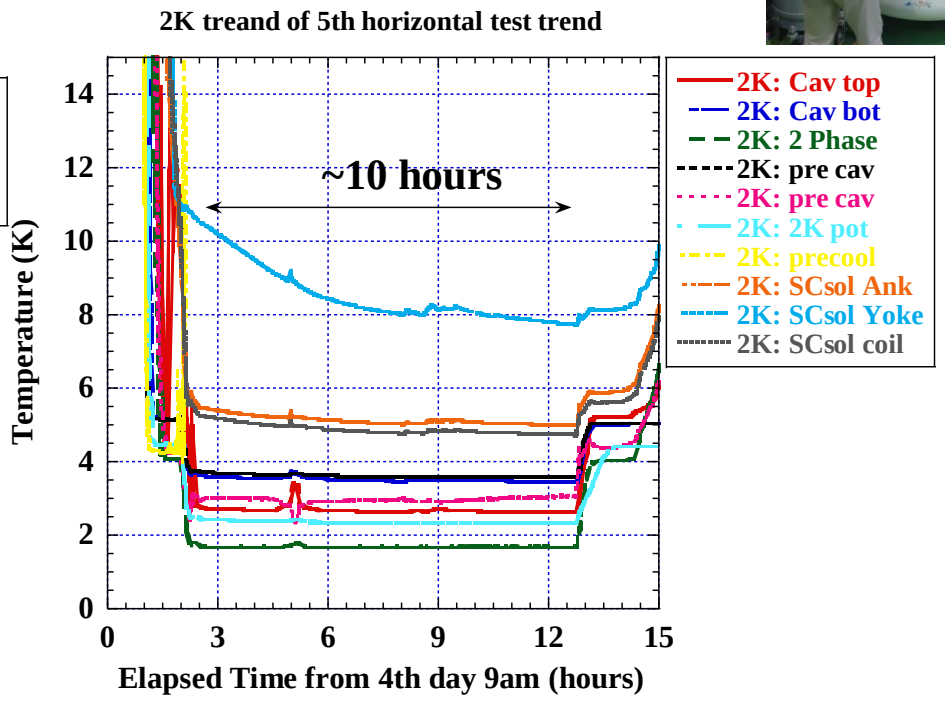
Cooling procedure

- Pre-cooling by He gas heat exchanged with LN2 for 2 days.
- 2K measurement used LHe 1000 L /day.
  - Measurable time depends on precooling.
    - 1st day of 2K measurement is 8 hours
    - 2nd day of 2K measurement is more than 10 hours

1000L LHe dewar





Test # and condition	
HPR	
2nd HT	w/o cathode rod
HPR+beamline+pre	
3rd HT	w/o cathode rod
4th HT	w/ cathode rod
HPR+beamline+SCsol+pre	
6th HT	w/ cathode rod

1st HT is cooling only.
5th HT is failed by RF cable trouble

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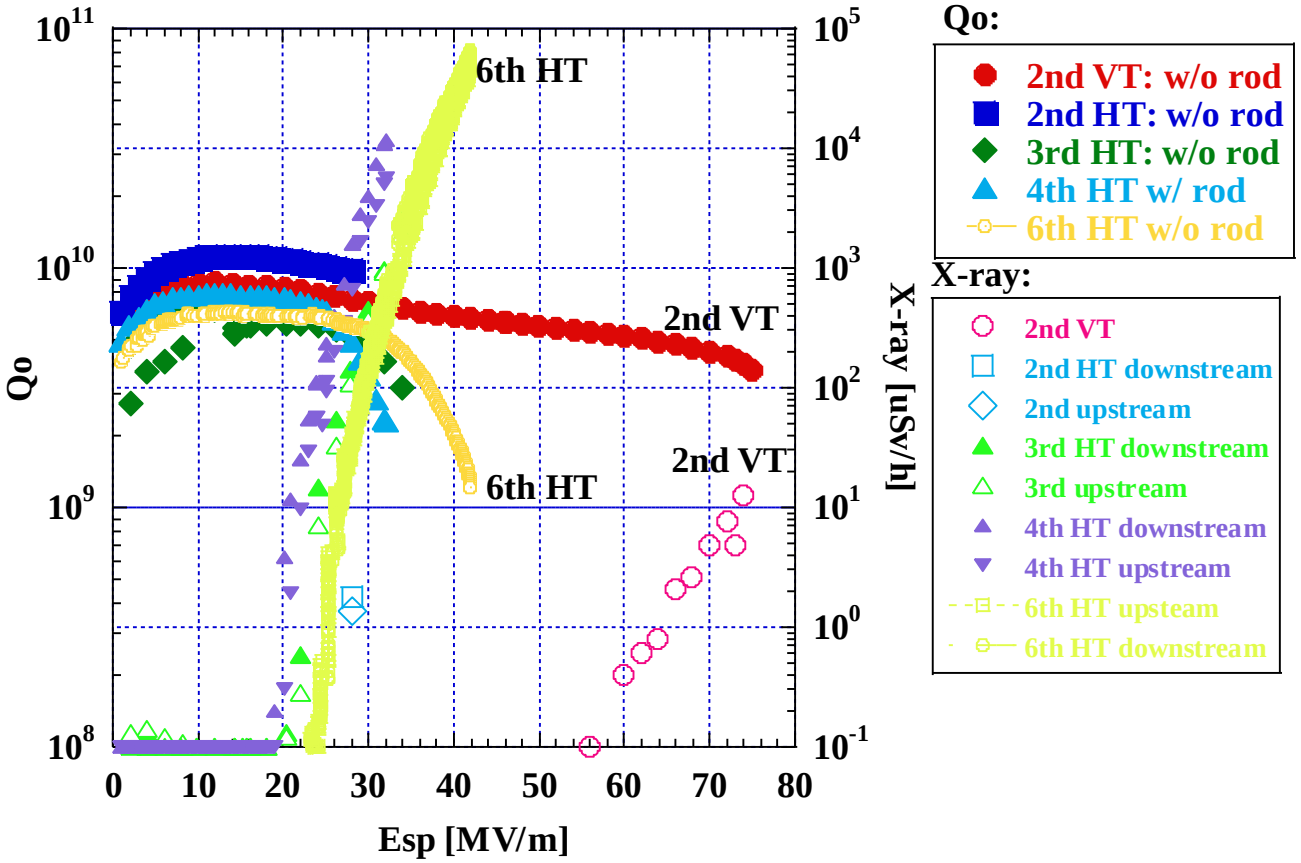
Horizontal test result

- The maximum Esp was limited around 20-30MV/m by FE or by quench.
- Although the cavity was completely disassembled and applied HPR, FE could not remove.
- We suspect the FE source come into the cavity in complicated local clean booth work.
- We tried a beam test following 6th HT. But cathode transfer trouble was happened, and cathode lifetime was too short. Unfortunately, we could not observe beam.



Test # and condition	
HPR	
2nd HT	w/o cathode rod
HPR+beamline+pre	
3rd HT	w/o cathode rod
4th HT	w/ cathode rod
HPR+beamline+SCsol+pre	
6th HT	w/ cathode rod

1st HT is cooling only.
5th HT is failed by RF cable trouble

T. Konomi, ERL22, SRF/25

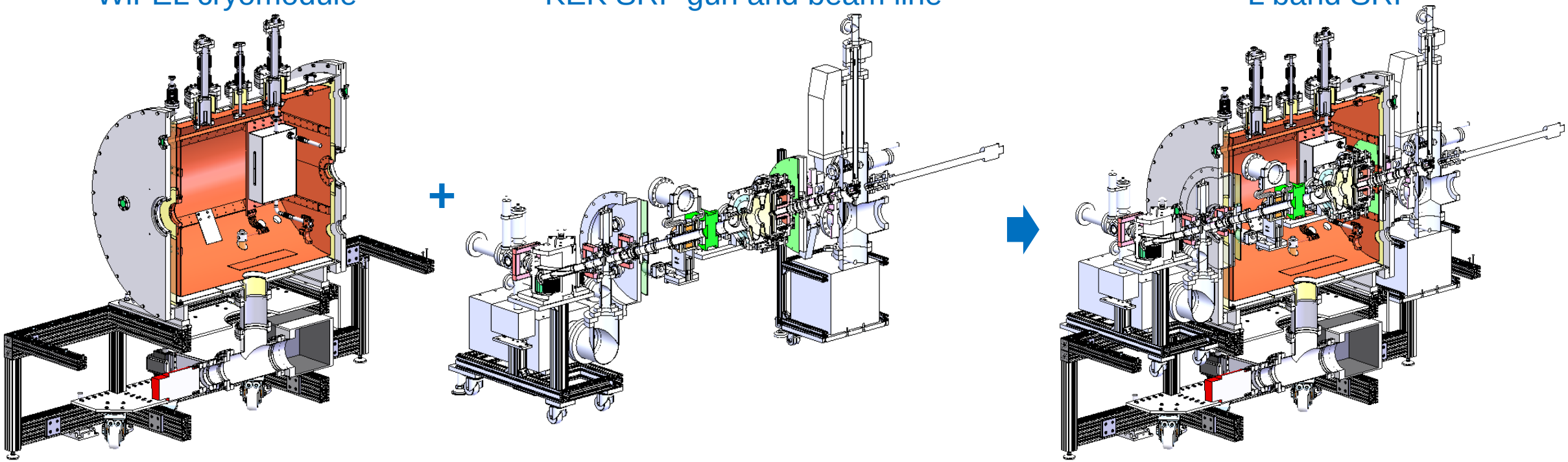
Plan for deliver the cavity to MSU/FRIB

- We shipped the cavity and beam test system except cryomodule, laser, and LLRF.
- We will combine KEK SRF gun and WiFEL cryomodule and continue L band SRF gun study.

WiFEL cryomodule

KEK SRF gun and beam line

L band SRF



Summary

- KEK SRF gun was built to evaluate the fundamental performance of the SRF gun.
- Esp reach the target value by applying EP and HPR in VT because assembly procedure is well established.
  - Esp= 76 MV/m w/o cathode, Esp=61.5 MV/m w/ cathode (target Esp=41.9 MV/m)
- The gradient was significantly lower in HT. This was due to the complicated procedure.
  - Esp=42 MV/m (6^{th} HT)
- We made a beam test components to evaluate gun cavity. Each components were evaluated in offline.
  - The photocathode chamber has a lot of issues, load lock system and short lifetime.
- We shipped the cavity and beam test system except cryomodule, laser, and LLRF. And combine KEK SRF gun and WiFEL cryomodule and continue the SRF gun study.