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15min. talk

Development of High Intensity, High Brightness, CW SRF Gun in KEK

JURY 5TH , 2019

TARO KONOMI, YOSUKE HONDA, EIJI KAKO, YUKINORI KOBAYASHI, SHINICHIRO MICHIZONO, TSUKASA MIYAJIMA, HIROSHI SAKAI, KENSEI UMEMORI, SEIYA YAMAGUCHI (KEK)

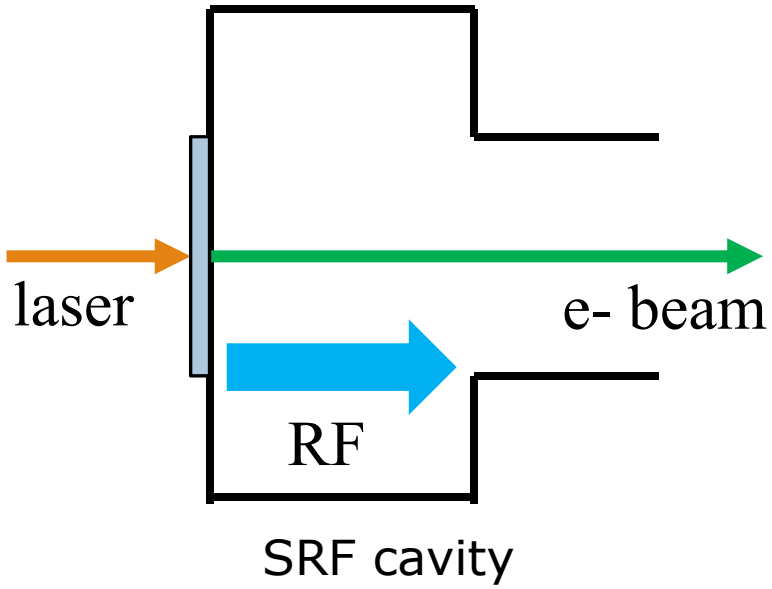
Outline

- KEK SRF gun design
- Performance of Prototype SRF gun (cavity #1)
- Progress of SRF gun cavity #2
- Future Plan
- Summary

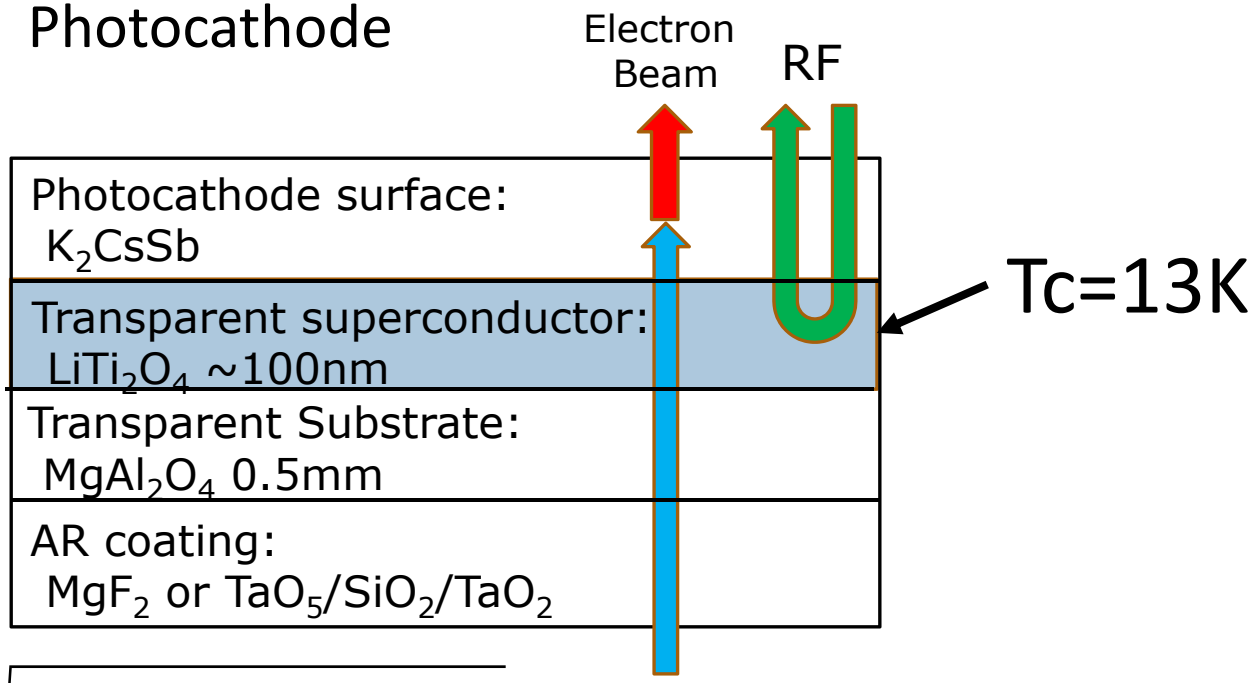
Concept of KEK SRF gun

- 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.

SRF gun cavity



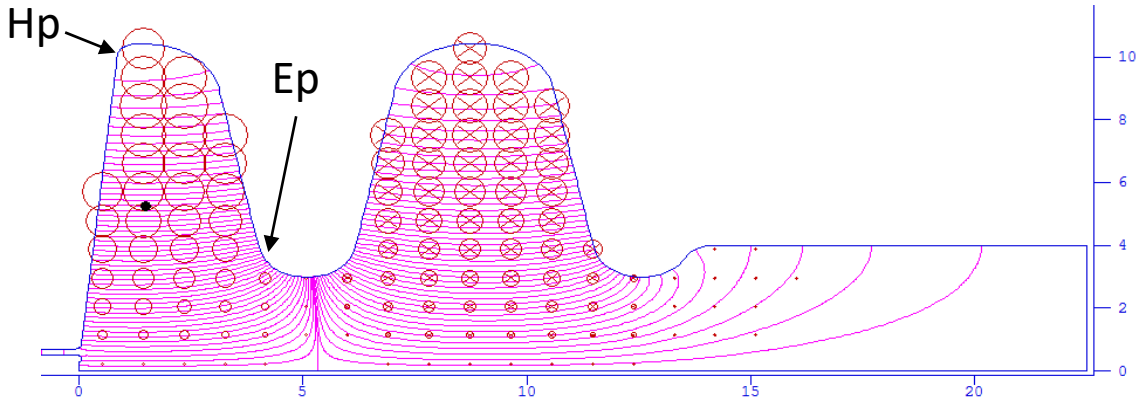
Photocathode

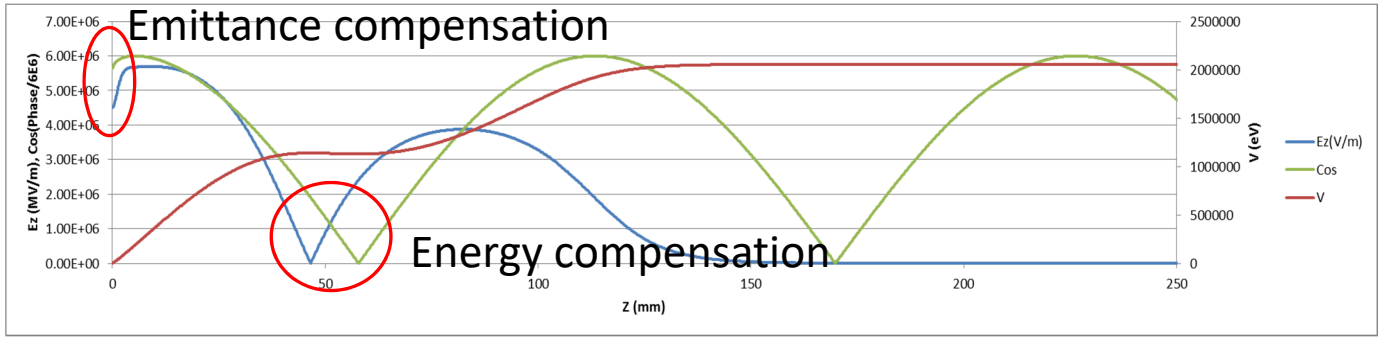


Thermal emittance: $\varepsilon_n = \frac{R}{2}\sqrt{\frac{2(\hbar\omega - E_0 + \phi_{sch})}{3mc^2} + \frac{2k_BT}{mc^2}}$

Gun cavity design

- Cell number is 1.5 cell because input power is 2 MeV x 100mA =200kW by using two input couplers.
- The cavity shape was designed with only gun cavity without booster cavities etc.
  - It is necessary to compensate emittance and energy spread at same time.
  - It will achieve better value with adding boosters and bunchers.

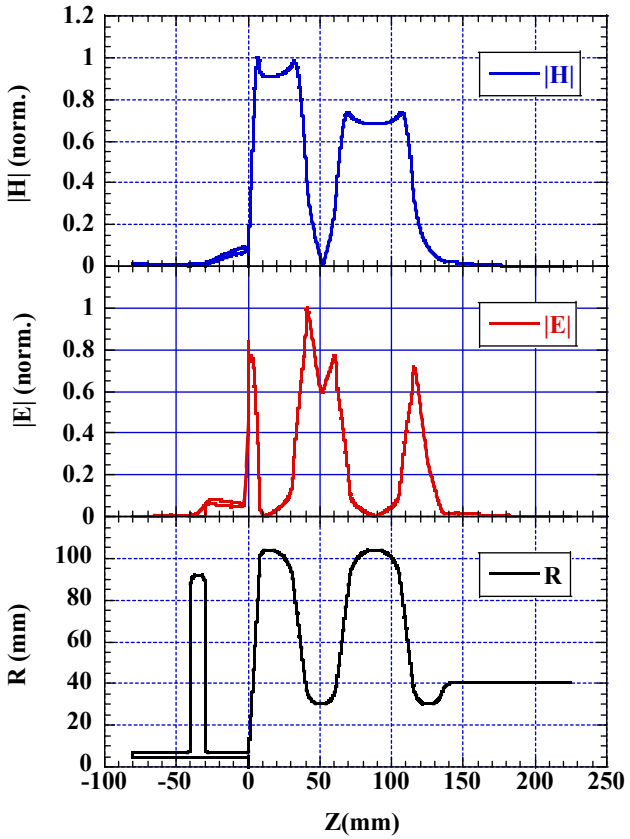


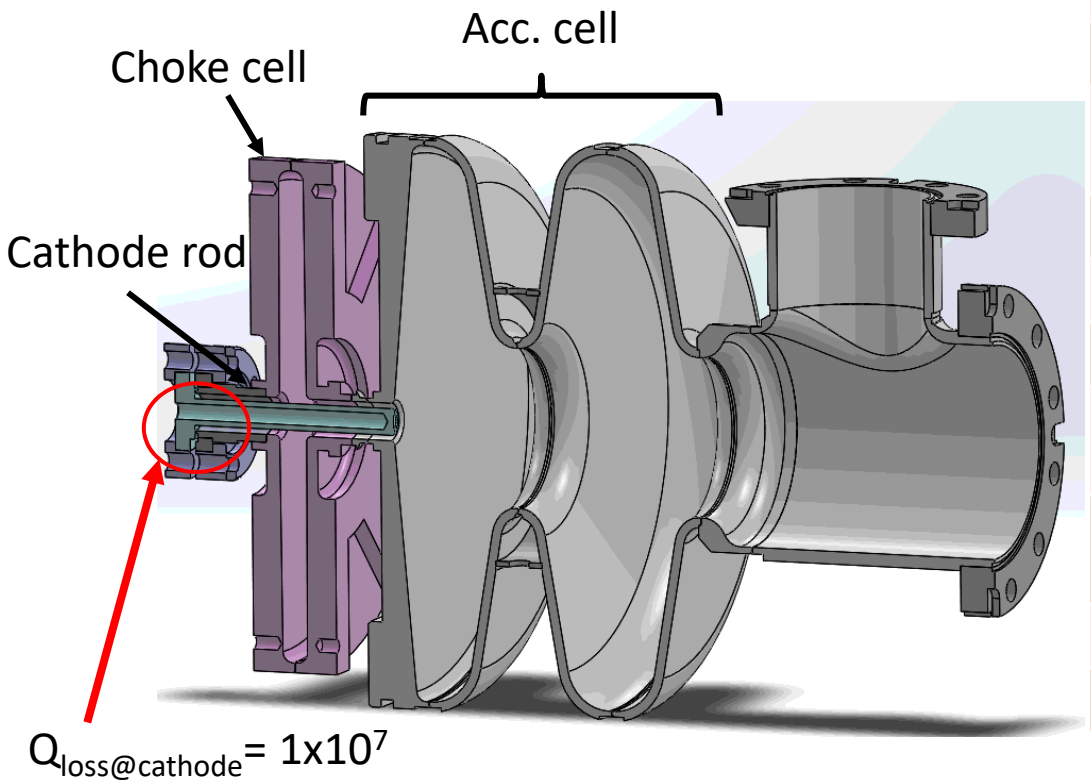


Parameter	Value Designed by MHI
Beam energy	2 MeV
Beam current	100mA
Bunch charge	80 pC
Laser length (uniform)	10ps
Projected emittance	0.6 mm.mrad
Projected energy spread	0.09%(1.84 keV)
Peak electric field	41.9 MV/m
Peak magnetic field	95.2 mT
RF phase	55°
Geometrical Factor	135.6 Ω (TESLA 270 Ω)
Target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

RF design

- Choke cell is the ¼ wave structure to reflect the RF leakage though the cathode rod.
- RF loss at cathode rod is $1x10^7$.
- The requirement of the attenuation is more than 30 dB.





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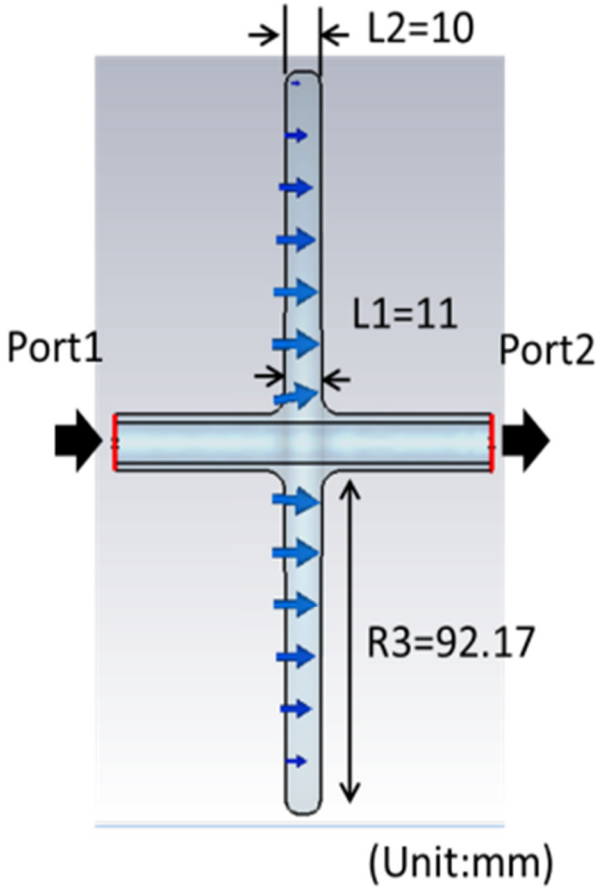
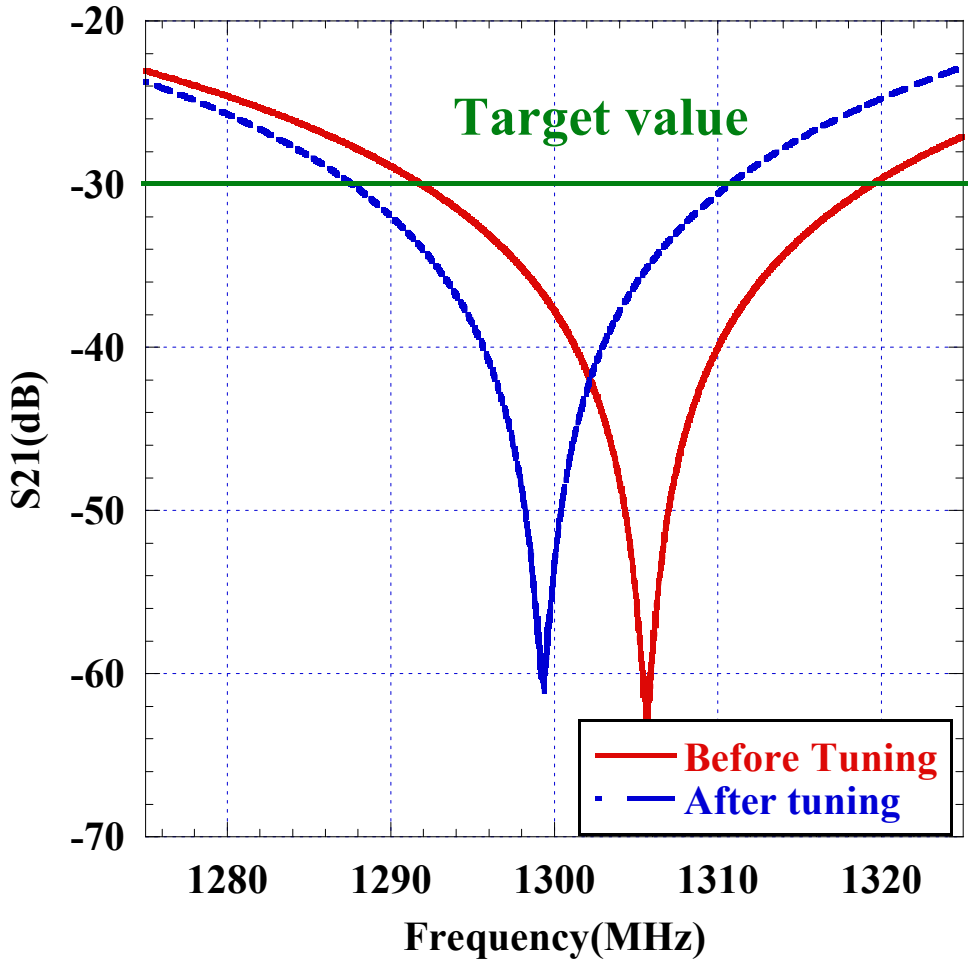
Geometrical Factor	135.6 Ω (TESLA 270 Ω)
Target surface resistance	30 nΩ (ILC target)
Target Q value	4.5×10^9
Target cavity loss	8 W

Choke design

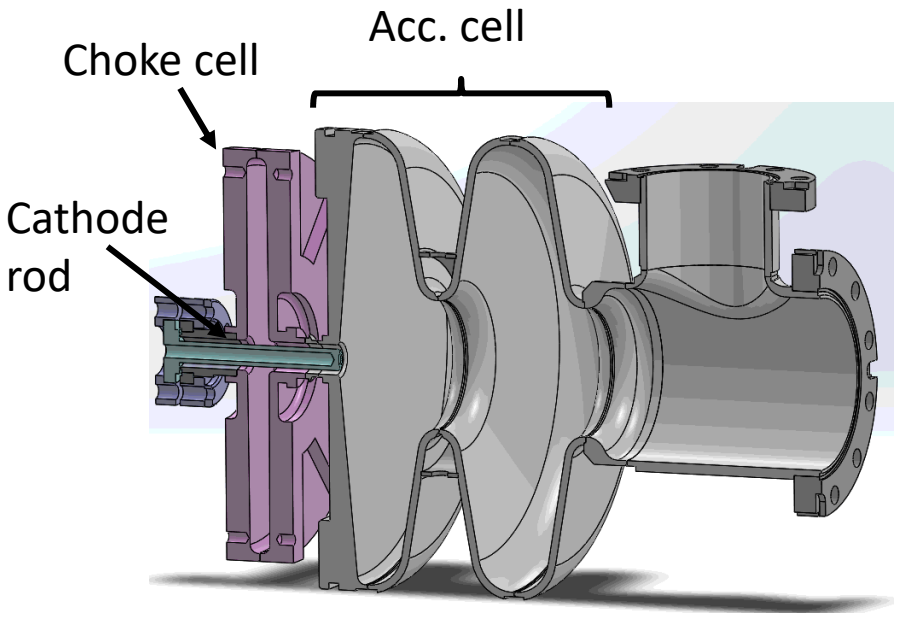
- The choke is a simple parallel shape. The parallel two face has slight taper for cleaning easily.
- Choke was machined from large grain ingot Nb, and has high stiffness.
- The tuning range is wide enough to accept the target attenuation (-30dB)



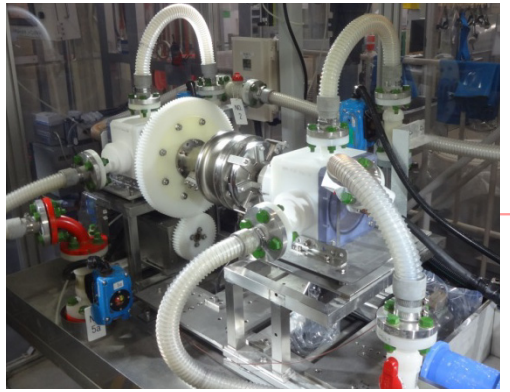


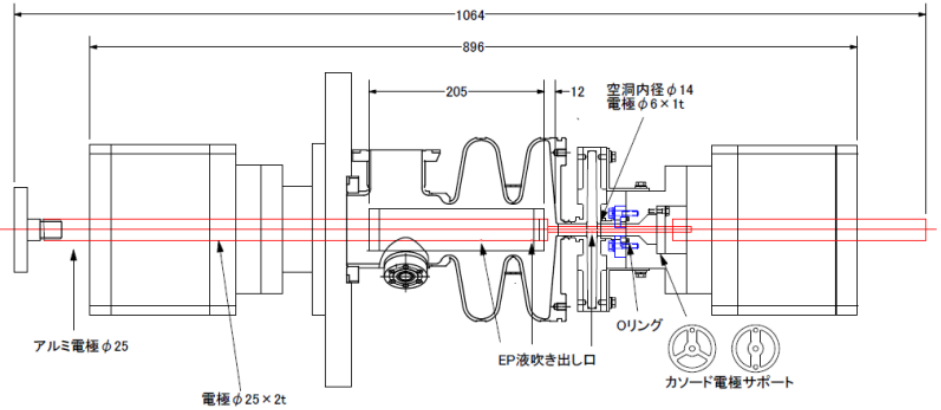
Prototype gun cavity #1

- We understand the good cavity treatment procedure by using cavity #1.
- Choke cell is parallel shape to make HPR easily.
- EP rod and HPR nozzles were modified for KEK SRF gun cavity.

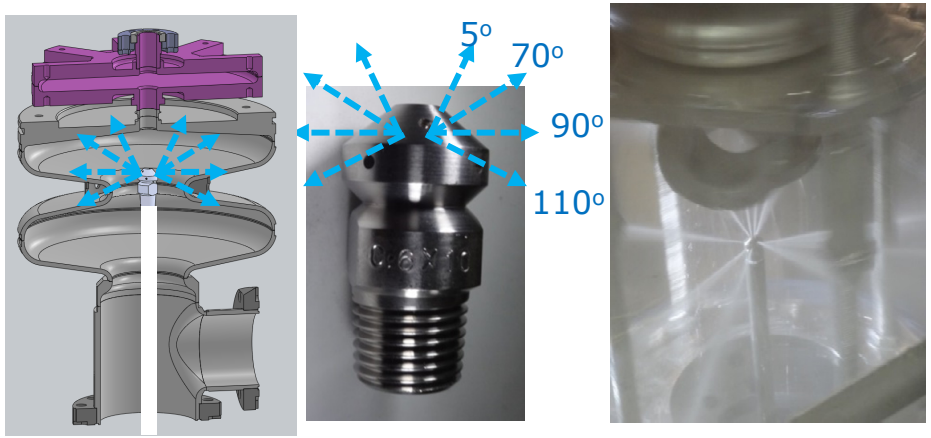


EP





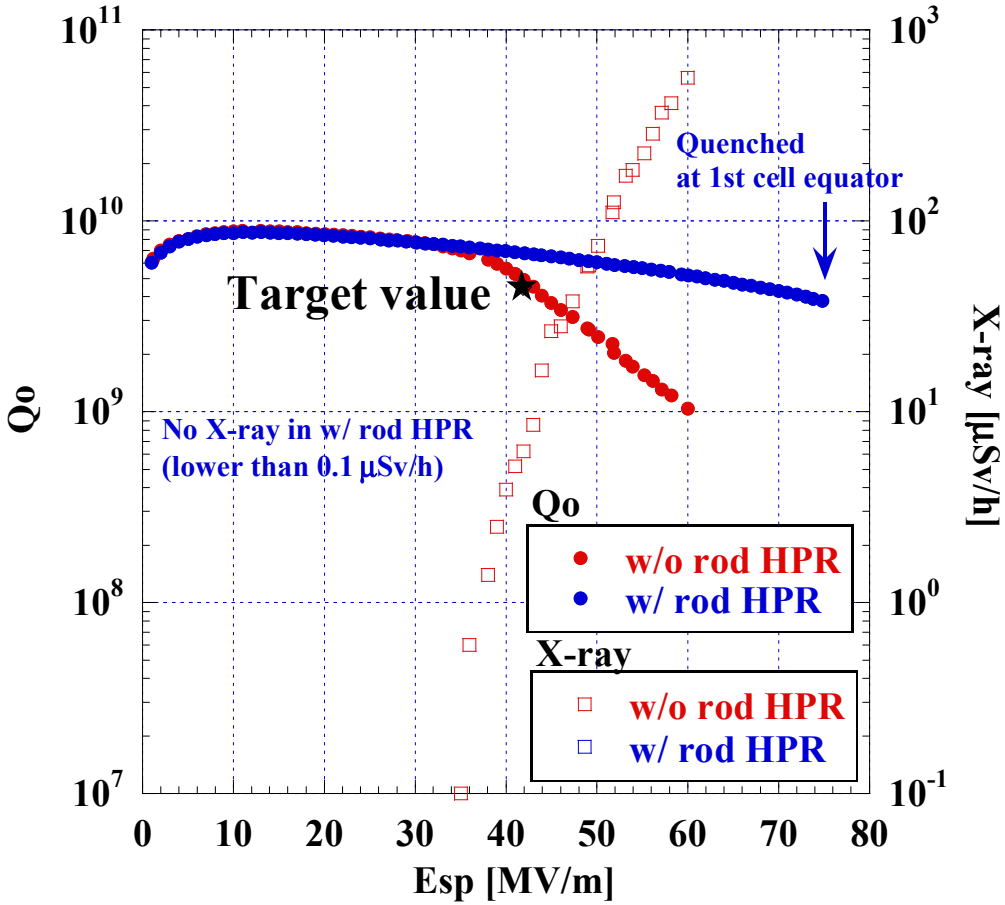
HPR nozzle for Acc. cell

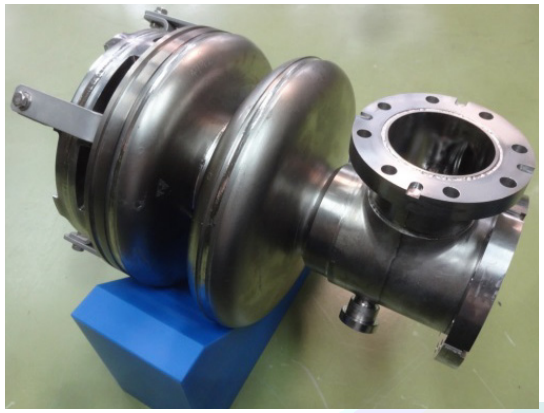


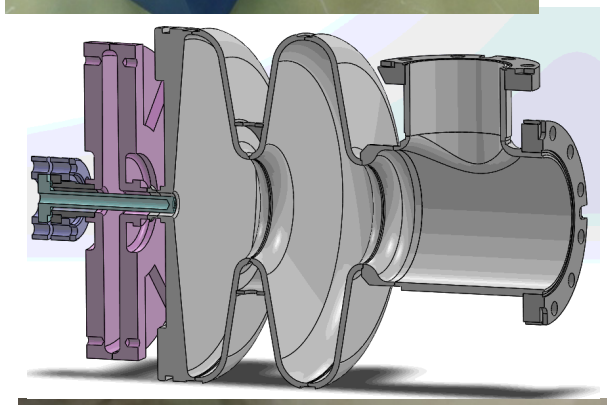
HPR nozzle for choke cell

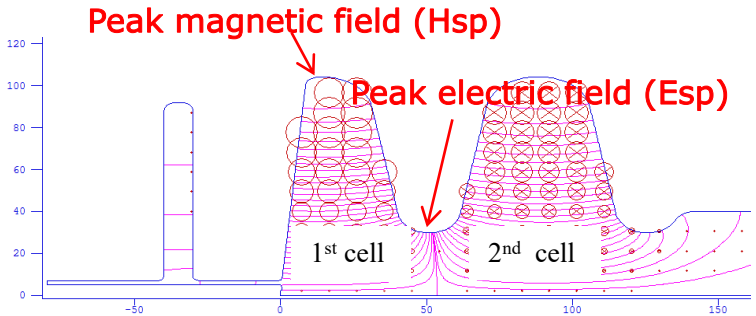
Performance of prototype #1 cavity

- It is important to apply HPR to the cathode rod.



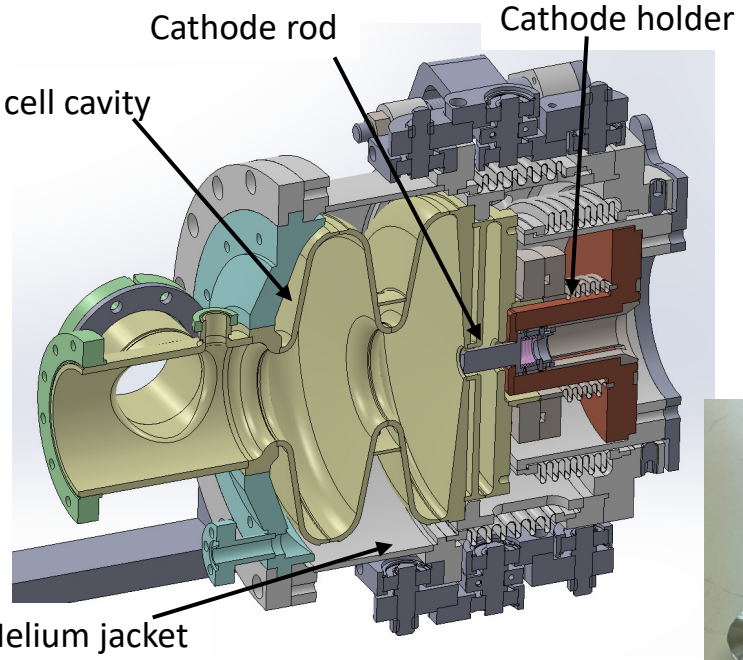


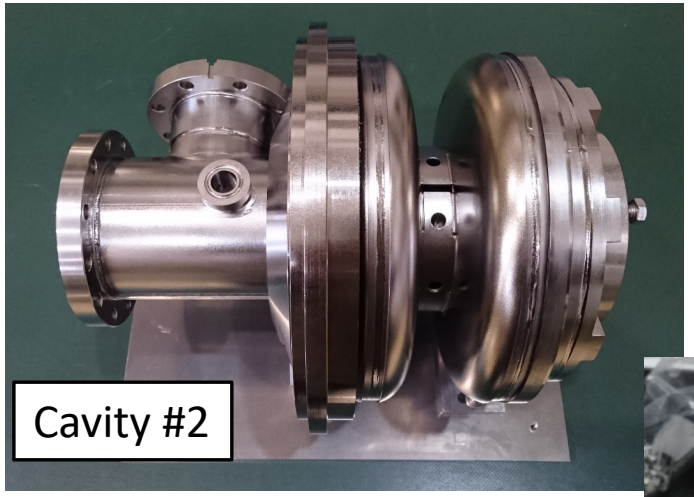




Fabrication of Gun cavity #2

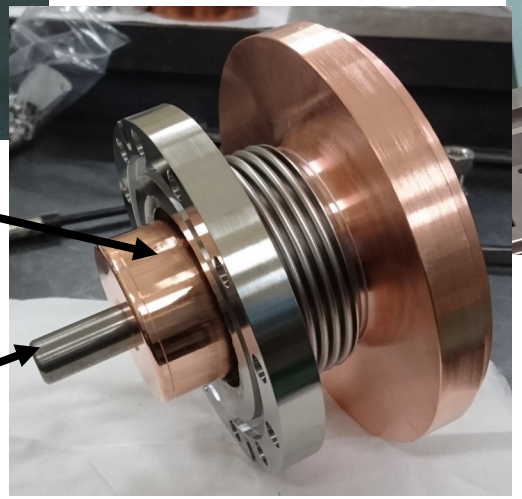
- #2 cavity is modified from #1 to add the helium jacket for beam test.
- The cathode rod can be remove from the cavity.

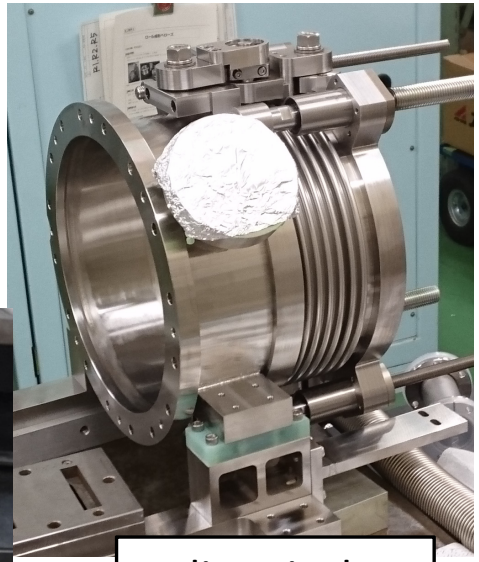




Cathode holder

Cathode rod

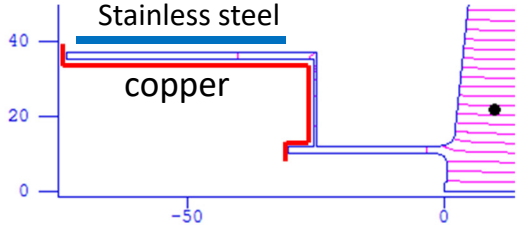


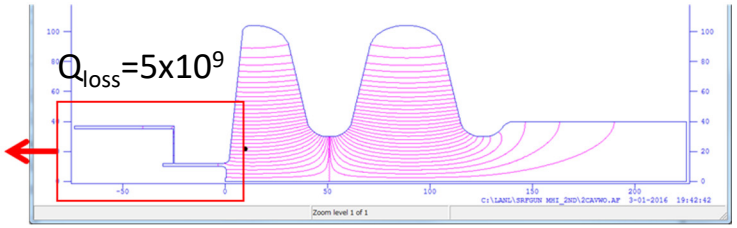


Preparation for vertical test

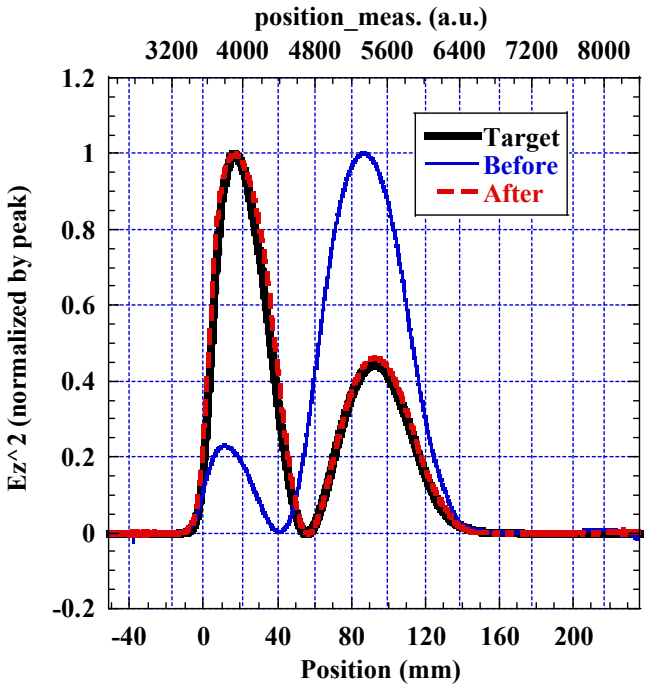
- The surface treatment was followed with the experience of the gun cavity # 1.
  - EBW in KEK
  - EP 100 um
  - Anneal 800Cx3h
  - Field tuning
  - Final EP 20um
  - USR, HPR
  - Assembly

- Loss Q at cathode rod and holder is 5×10^9 if there is no choke filter.
- Target attenuation of choke filter is 30dB for 1% loss.
- The adjusted choke attenuation is 10 times higher than the target.
  - 10% (0.8W) is acceptable for the cooling ability for the cathode holder.





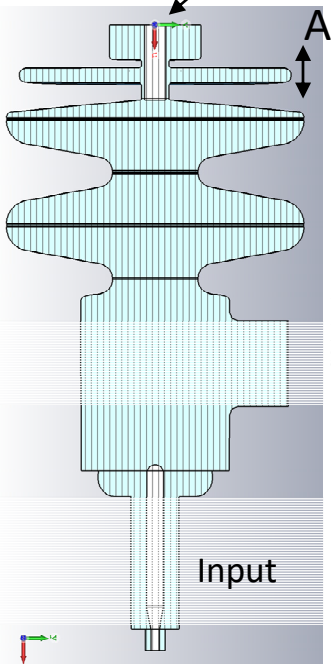
Acc. cell tuning

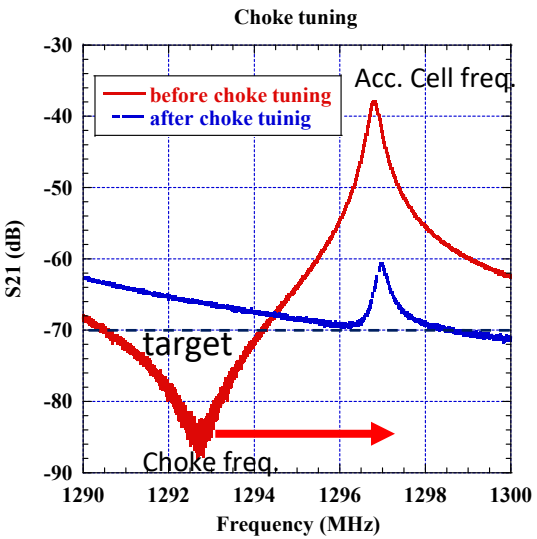


Choke cell tuning

Dummy rod for pick up

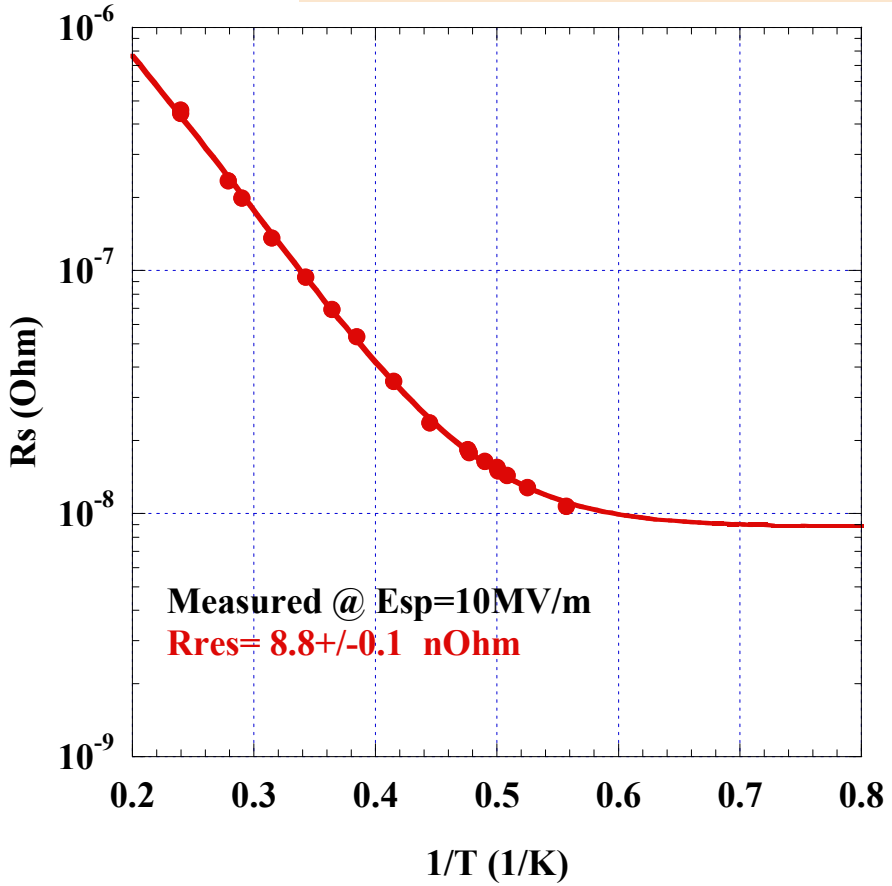
Adjust this length

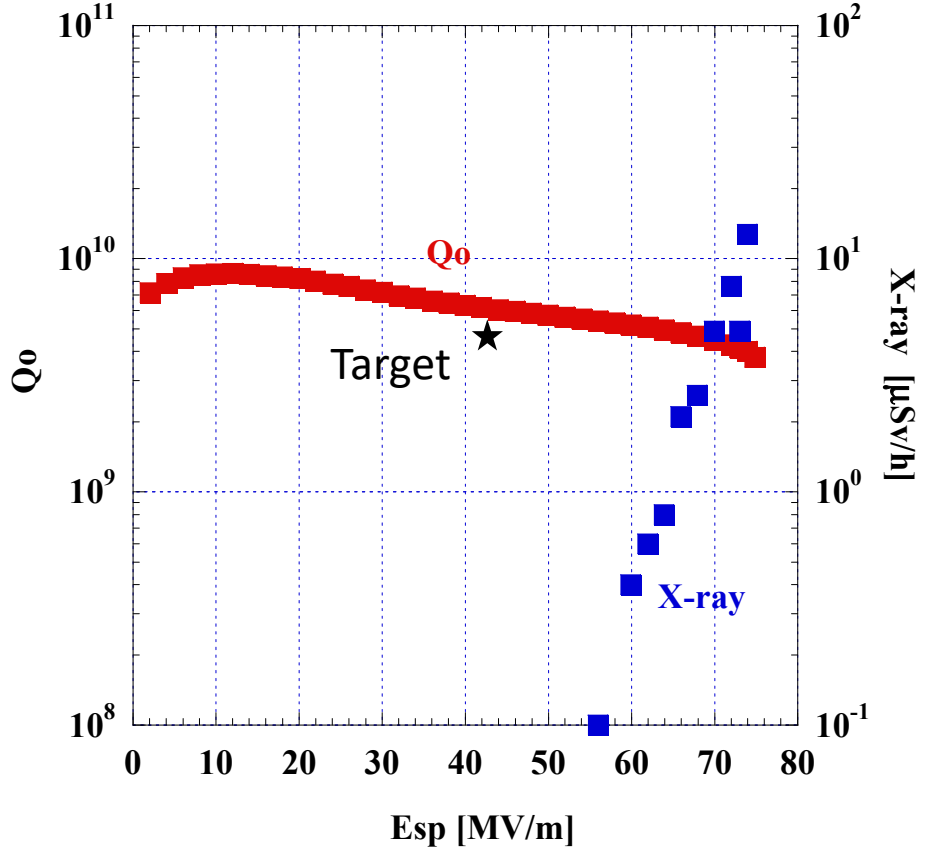




Vertical test of the 1.5 cell type SRF gun

- The maximum gradient without cathode rod reached to target value.

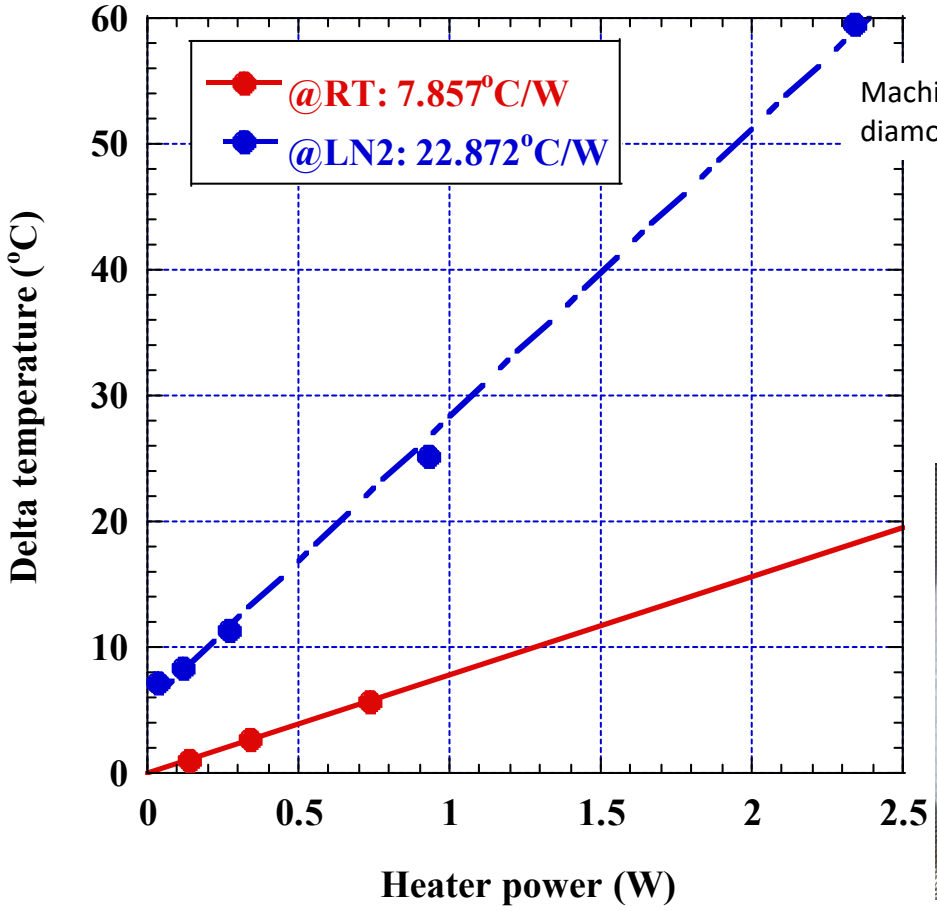


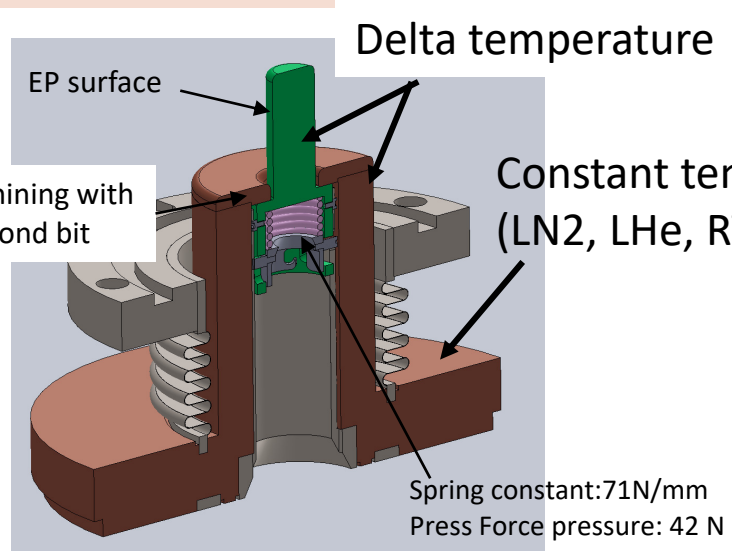


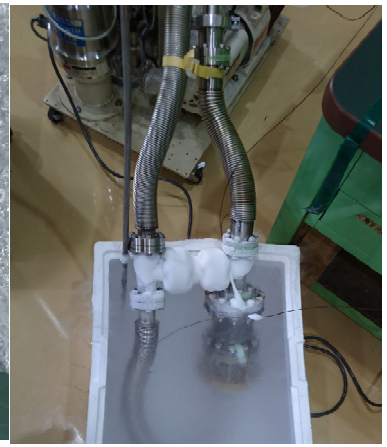
We can shift the main target to cathode rod and holder development
- Effective cooling structure to keep the cathode rod around 2K.
- Particle free cathode transport method.

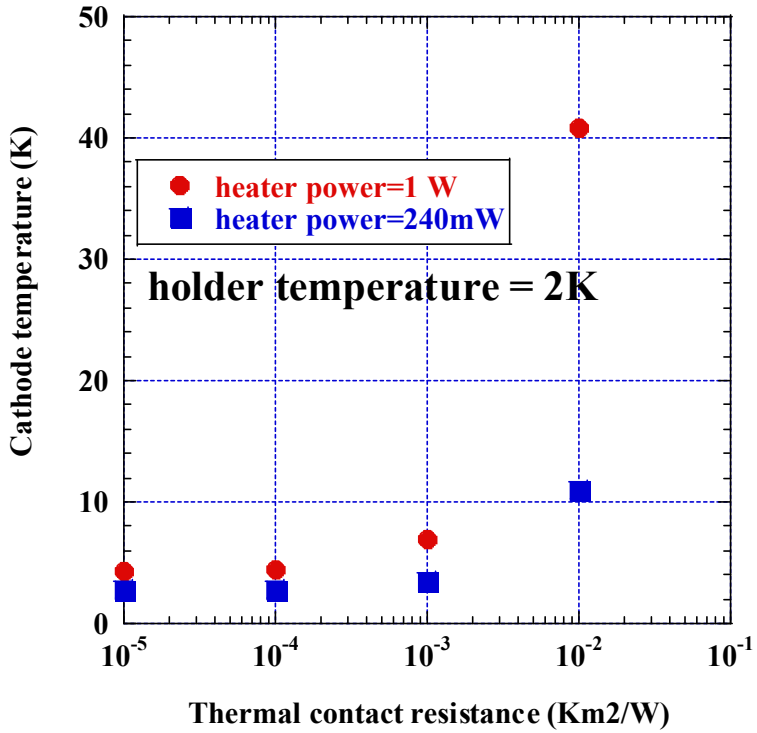
Thermal contact resistance measurement

- The thermal contact resistance is 21.7E-4 [m^2K/W] and 63.2E-4[m^2K/W] at RT and LN2 respectively .
- The target resistance is 1E-4 [m^2L/W]. It is 10~100 times higher than the target.
- We will apply mirror polish (target Ra ~1nm) to contact surface.









240mW is ideal RF loss in the case the rod keep at 2K.

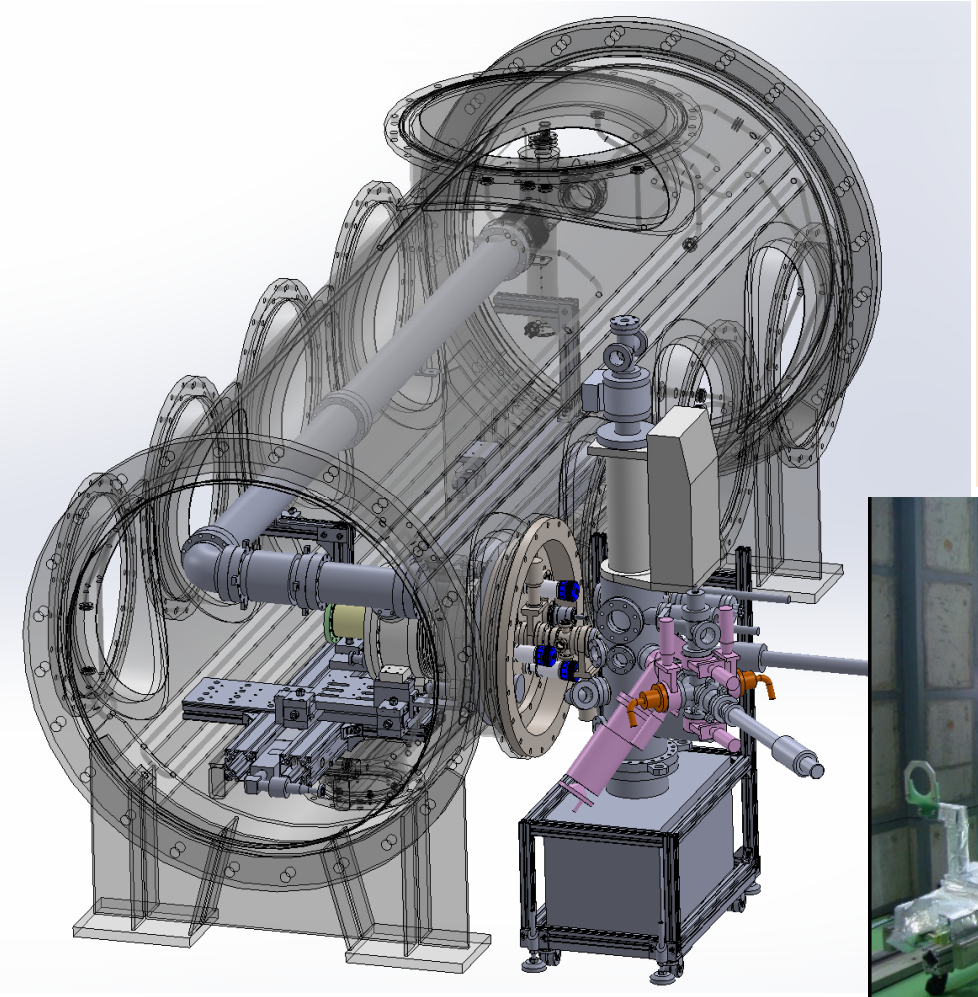
Future plan

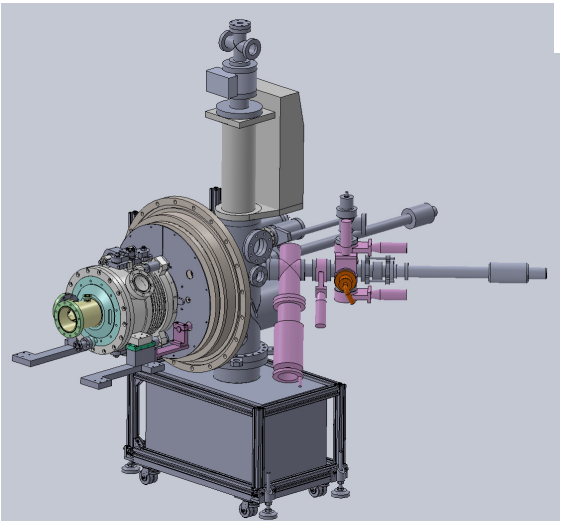
- We are planning beam test with small current in the horizontal test cryostat.
- Support Jigs to install cavity are under fabrication.
- Short diagnostic (beam energy and emittance) line will be designed.

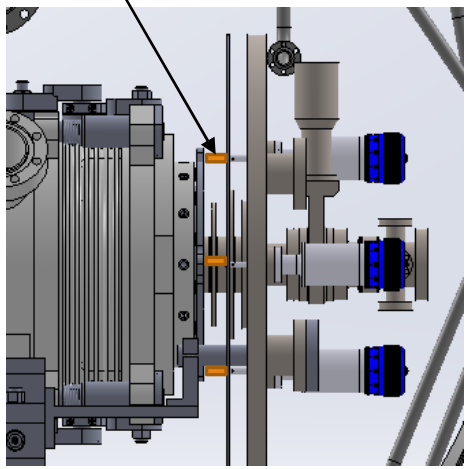
Cooling test
- Heat loss of cathode rod adjuster.

High voltage test
- Particle free cathode rod transportation.
- Q-E curve with cathode rod.

Small current beam test
- Dark (and beam) lifetime of the photocathode.
- Measure the RF field distribution error.





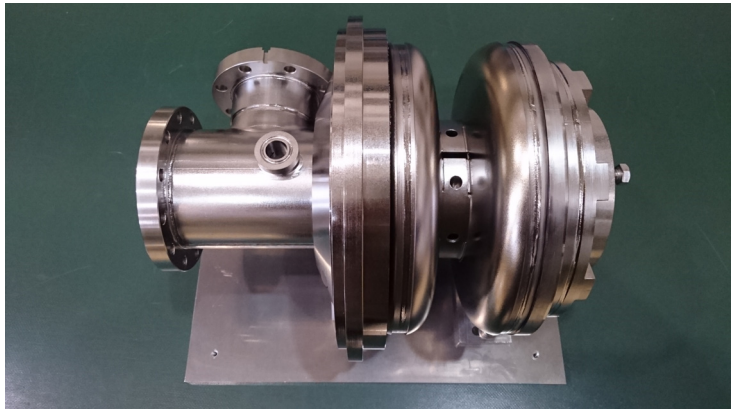


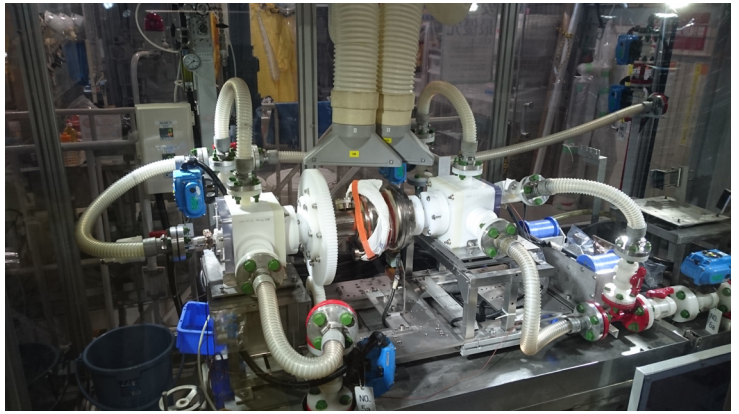
Summary

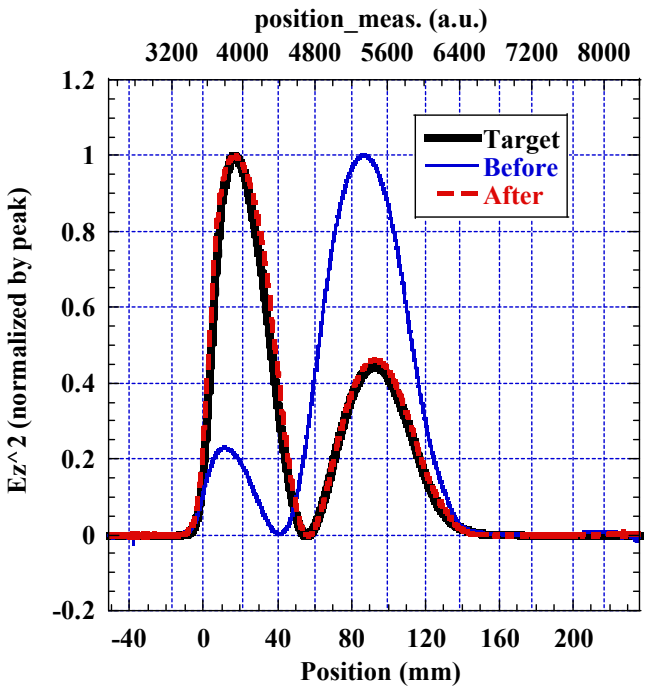
- KEK SRF Gun cavity #1 reached to Esp=75 MV/m with cathode rod.
- KEK SRF Gun cavity #2 itself reached to Esp=75 MV/m with FE.
  - Gun cavity #1 and #2 are same RF design.
  - Gun cavity #2 can be connect to helium jacket.
- We are preparing for horizontal test.

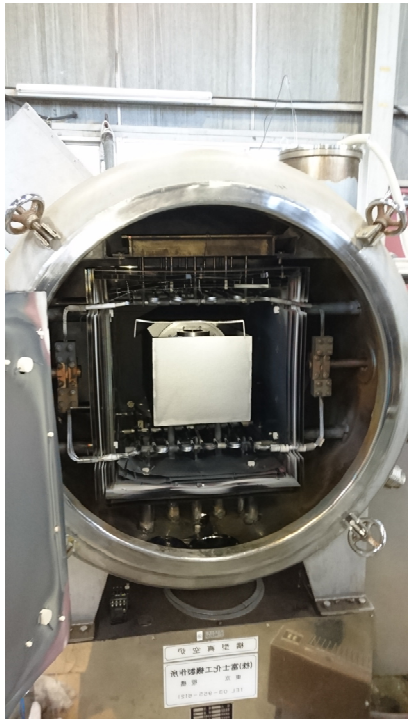
Preparation for vertical test

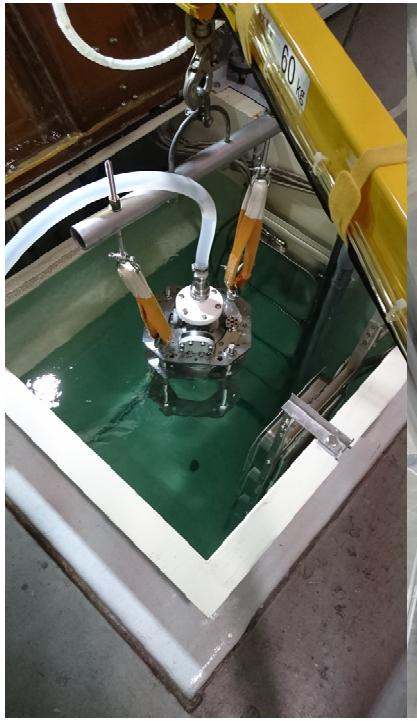
- EBW at KEK
- EP 100 um
- Annealed 800Cx3h
- Field tuning
- Final EP 20um
- USR, HPR
- Assembly

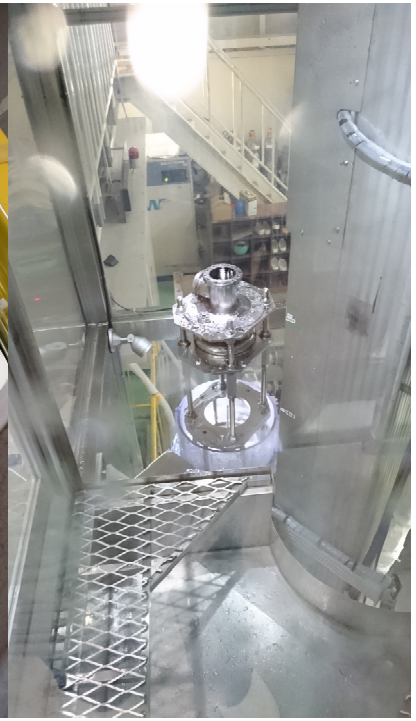












Vertical test of the 1.5 cell type SRF gun

- The maximum gradient without cathode rod reached to target value.
- However the Q value is dropped at 15 MV/m with cathode rod.
  - We suspect it is because the thermal contact resistance between cathode rod and holder is higher than expected.