Status of an Electron Beam Ion Source for Charge Breeding for RISP

Young-Ho Park, Hyock-Jun Son, Jun-Young Moon,
Seongjin Heo, Haolin Liu, Ramzi Boussaid, Jongwon Kim

RI Experimental Systems Team,
Rare Isotope Science Project,
Institute for Basic Science (IBS)

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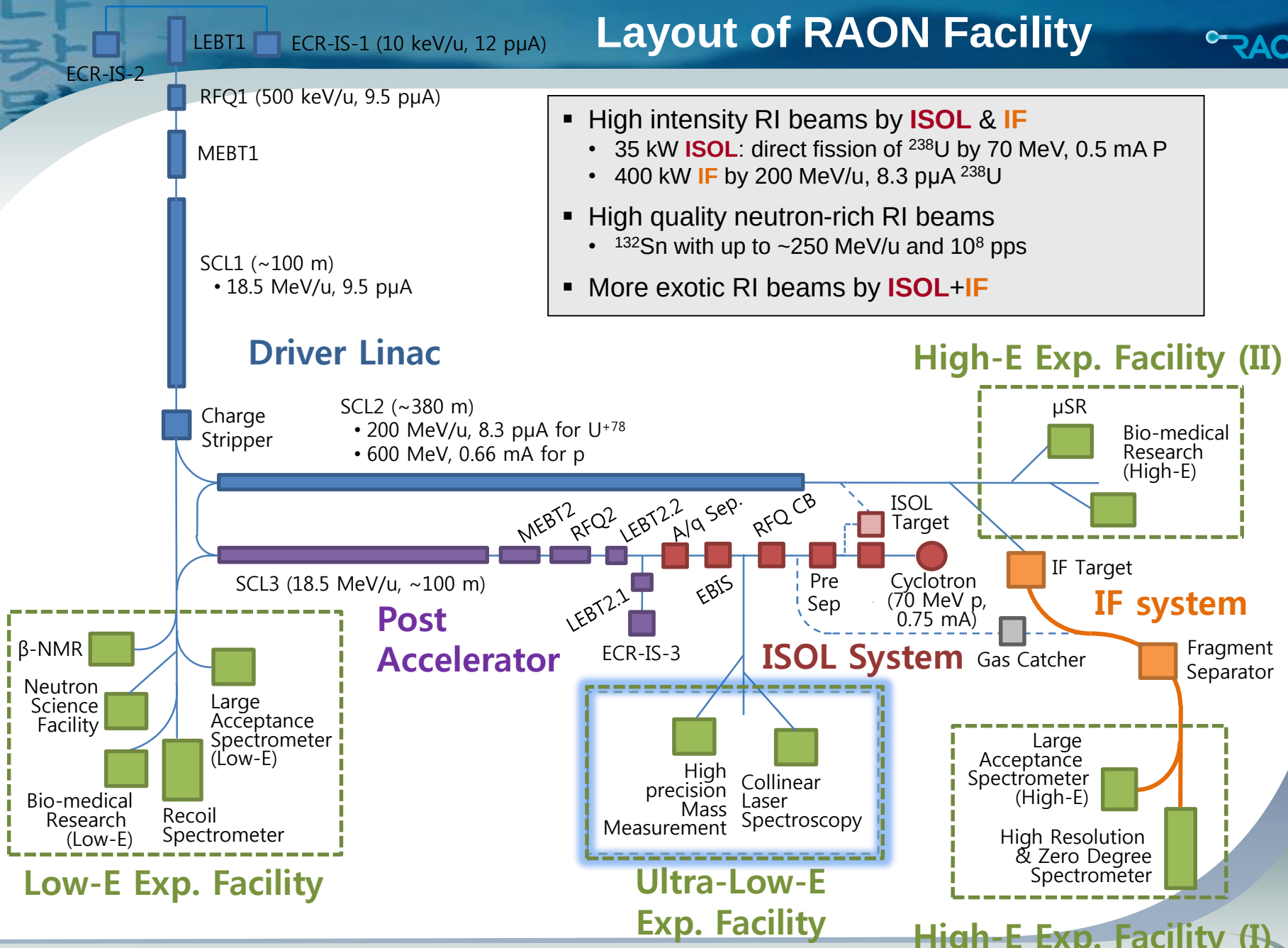
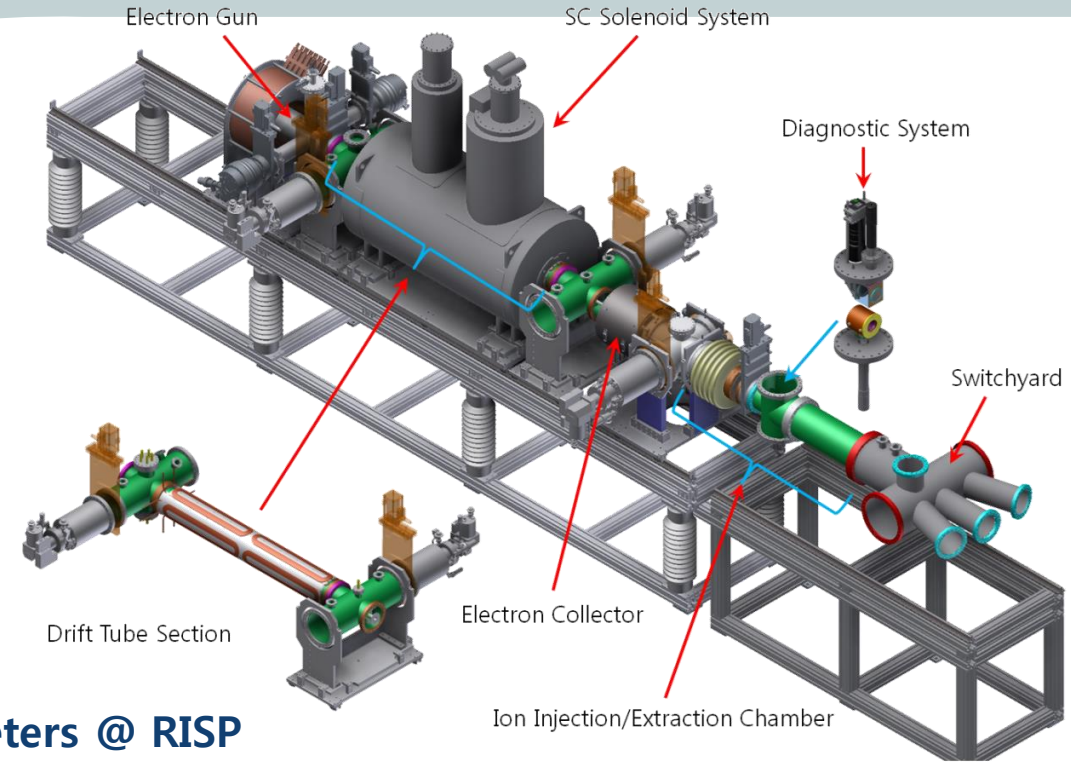
- Design parameter of EBIS at RAON
- Operation principle
- E-beam Simulation
- Electron Collector Design
- Electron gun Test
- Superconductor Magnet
- Vacuum system for EBIS Charge Breeder
- Works to be done this year

Layout of RAON Facility



- High intensity RI beams by **ISOL** & **IF**
  - 35 kW **ISOL**: direct fission of ^{238}U by 70 MeV, 0.5 mA P
  - 400 kW **IF** by 200 MeV/u, 8.3 pμA ^{238}U
- High quality neutron-rich RI beams
  - ^{132}Sn with up to ~250 MeV/u and 10^8 pps
- More exotic RI beams by **ISOL**+**IF**

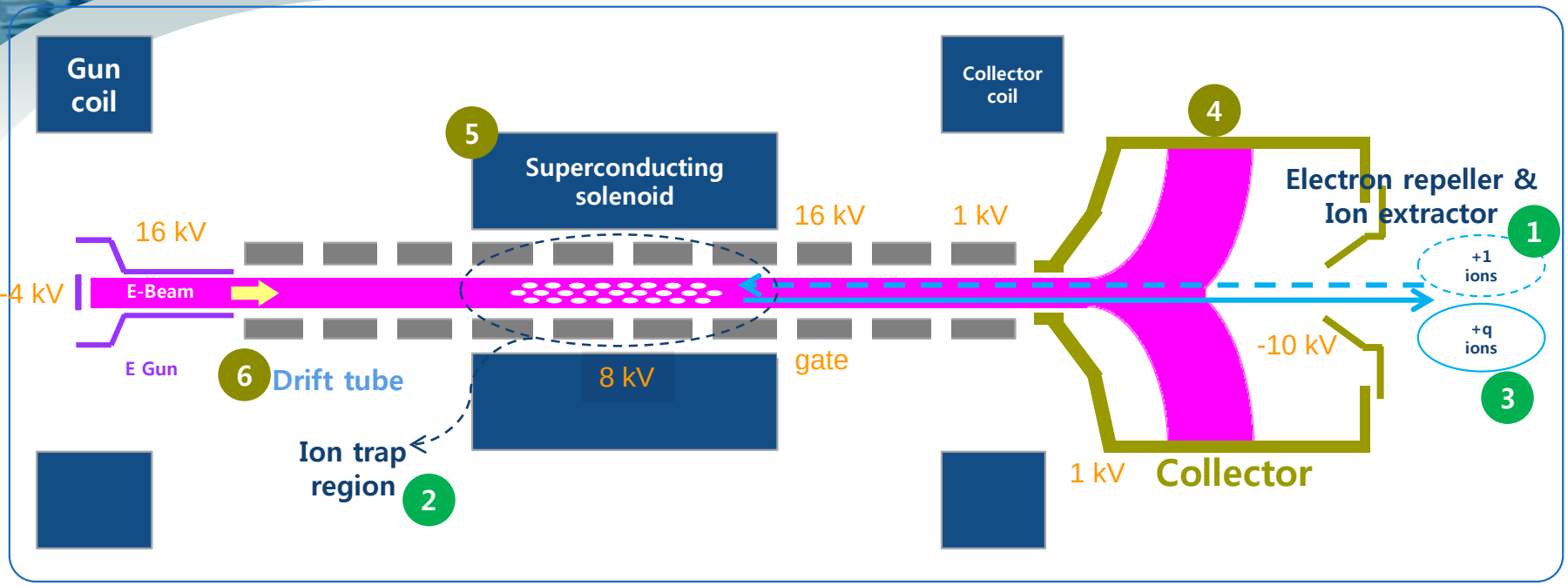
EBIS: Design Parameter

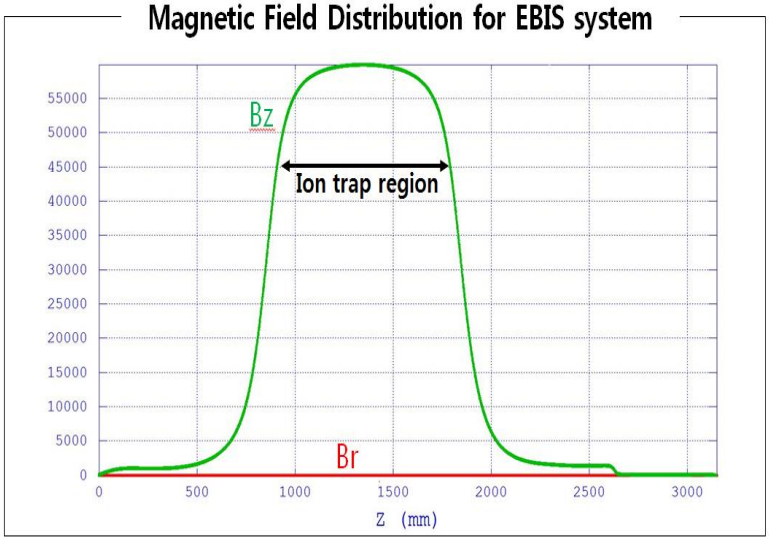


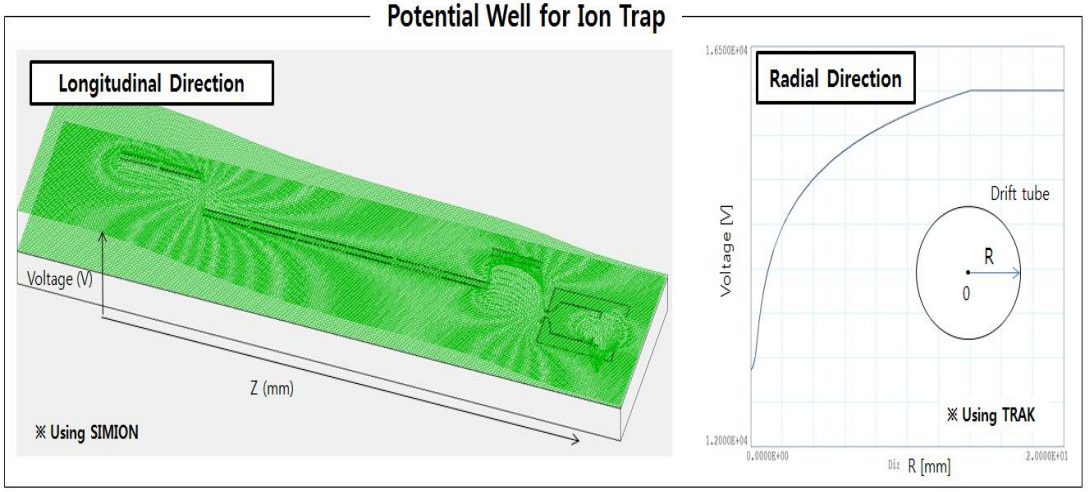
Design parameters @ RISP

Electron beam current	Electron beam current density	Extraction beam energy	B-field in Trap region
0 ~ 3 A	500 A/cm^2	10 keV/u	6 T
A/q	Capacity	Breeding time	Breeding efficiency
< 6	~ 10^8 ions/bunch	50 ~ 100 ms	15 % for $^{133}Cs^{27+}$
Repetition rate	Pulse width		
~ 10 Hz	10 ~ 20 μs		

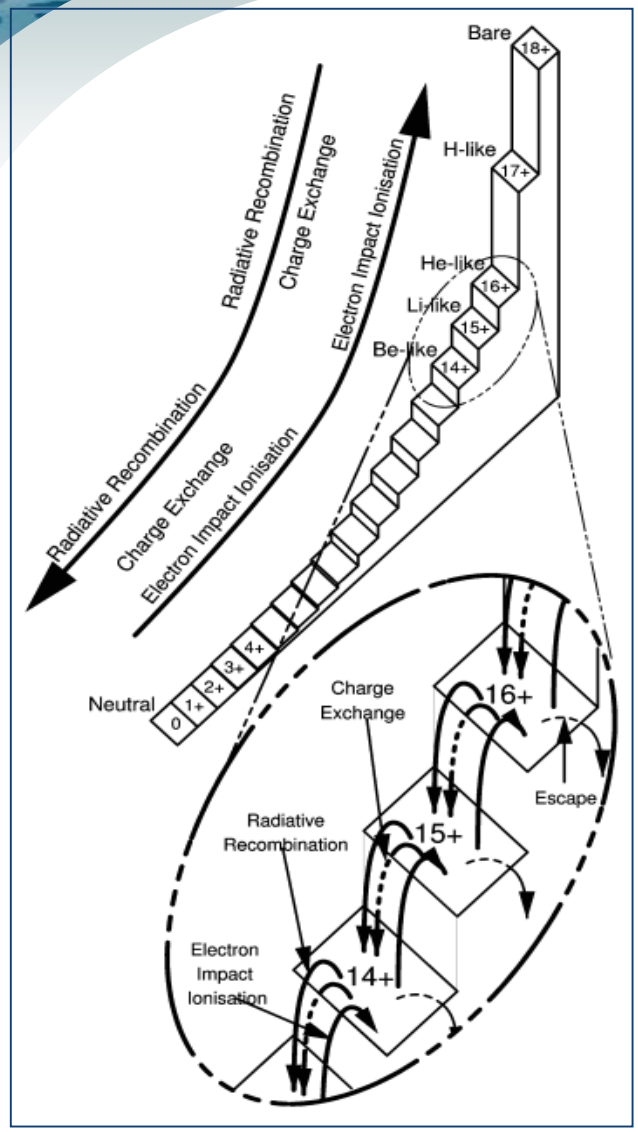
EBIS: Structure and Principle







EBIS: Charge Breeding Process



Overlap Factor: 0~1

$$\frac{dN_i}{dt} = \frac{J_e}{e}\left(N_{i-1}\sigma_{i-1}{}^{EI} f_{e,i-1} - N_i\sigma_i{}^{EI} f_{e,i}\right)$$ Electron Impact ionization

$$+\frac{J_e}{e}\left(N_{i+1}\sigma_{i+1}{}^{RR} f_{e,i+1} - N_i\sigma_i{}^{RR} f_{e,i}\right)$$ Radiative Recombination

$$+n_0\left(N_{i+1}\langle v\sigma_{i+1}{}^{CX}\rangle - N_i\langle v\sigma_i{}^{CX}\rangle\right)$$ Charge Exchange

$$-N_i R_i{}^{Esc}$$ Escape

Main parameters for charge evolution

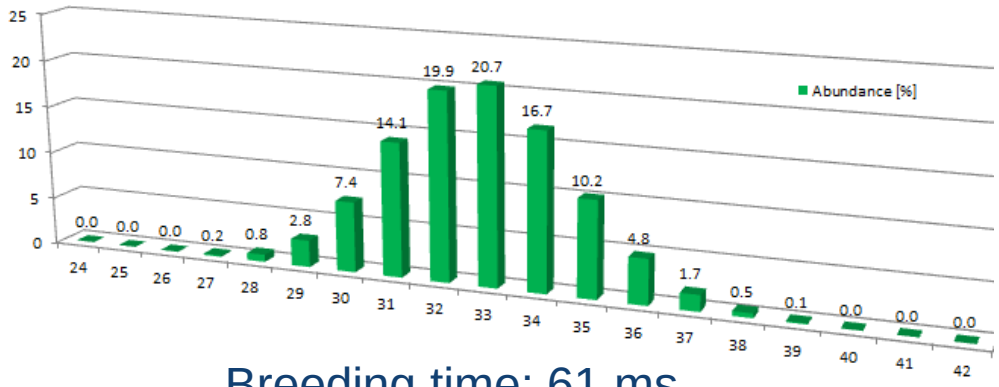
- Electron beam **energy**
- Electron beam **current density**

EBIS: Charge Breeding Simulation (CBSIM)

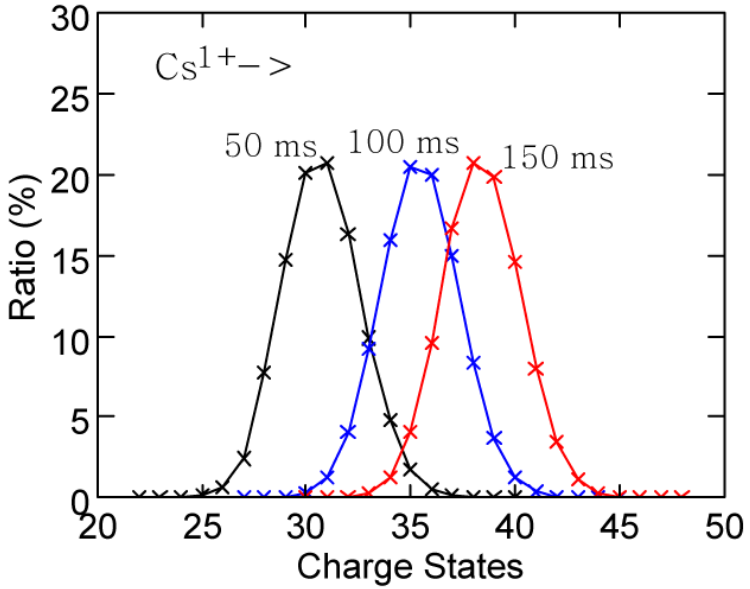
Electron Beam Energy : 20 KeV
E-Beam Current : 3 A
E-beam Current Density : 493.5 A/cm²

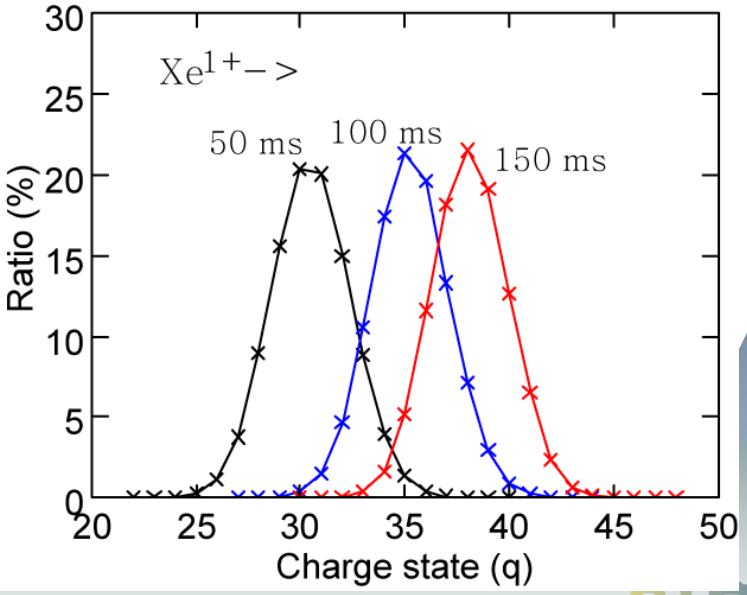
Isotopes of interest	Emittance	
	with rfq cooler	without rfq cooler
^{132}Sn, ^{142}Xe, ^{95}Sr, ^{15}O, ^{126}Al	3 π mm mrad	30 π mm mrad

Sn^{1+} ➔

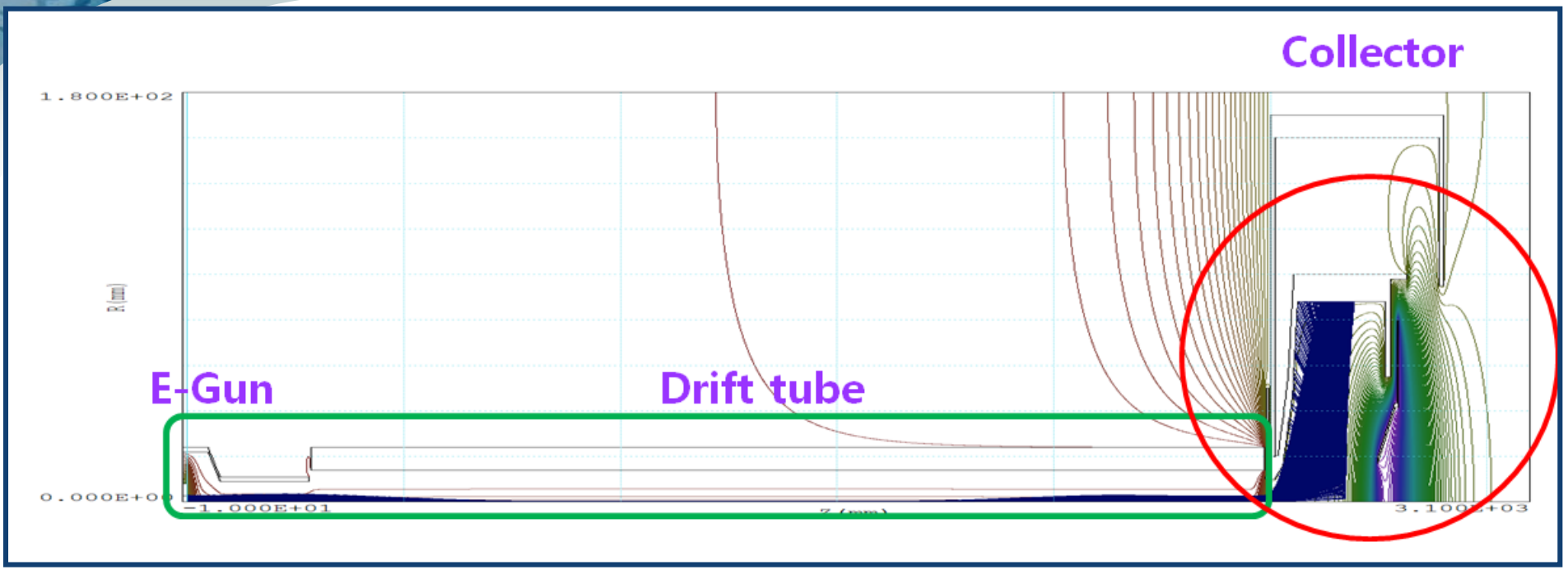


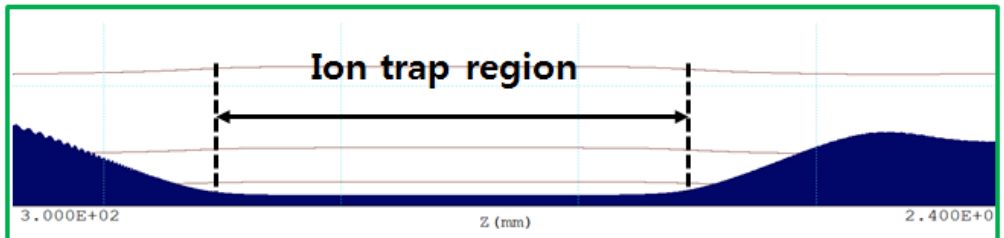
Breeding time: 61 ms



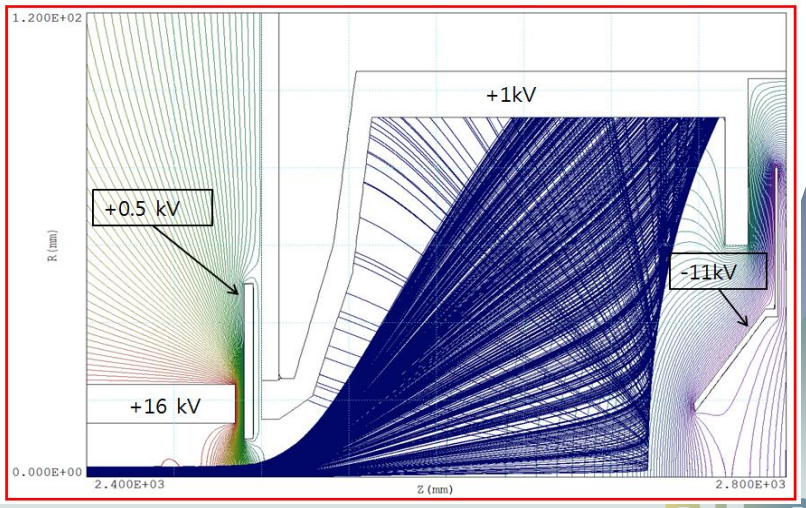


EBIS: Electron Beam Simulation (TRAK)



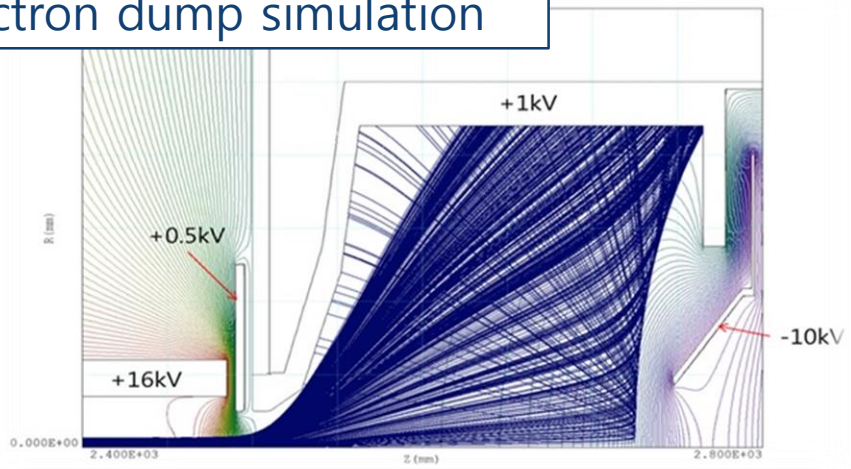


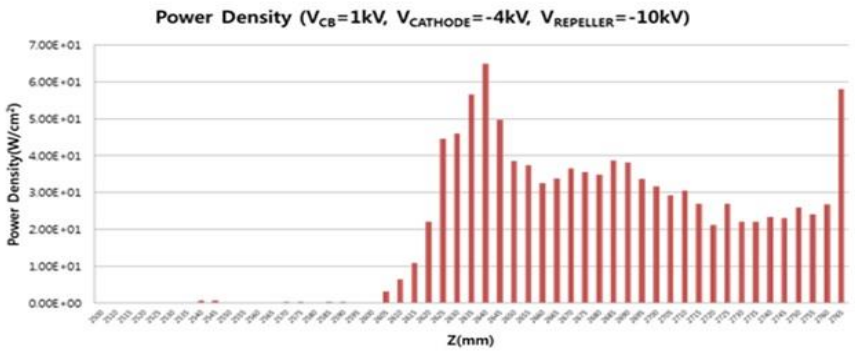
Within ion trap region
- Electron beam radius : 0.45 mm
- Electron beam current density : 500 A/cm^2
- Longitudinal B-field : 6T



EBIS: Electron Collector Design

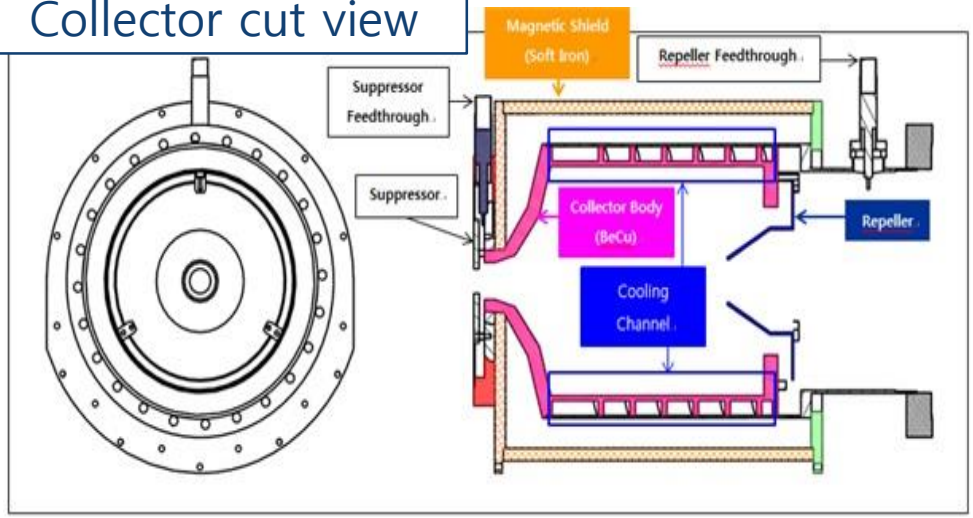
Electron dump simulation





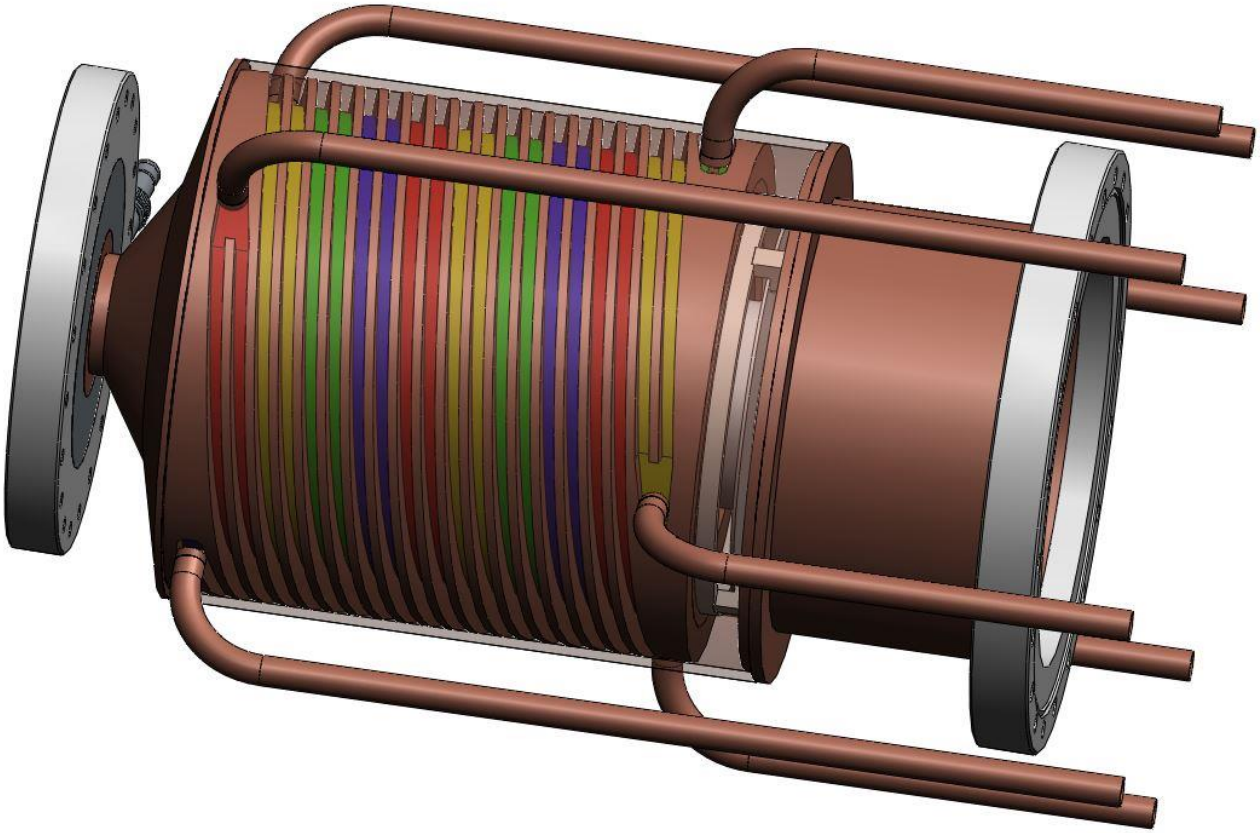
Dissipated Power	Flow Rate (kg/s)	Flow Rate (liter/min)	Temperature Rise (℃)
15 kW	1.0	60	3.6
	0.8	48	4.5
	0.6	36	6.0
	0.4	24	9.0

Collector cut view

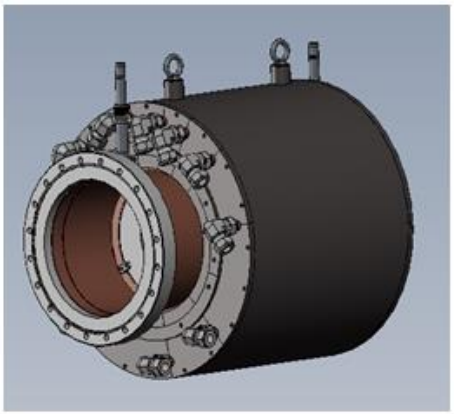


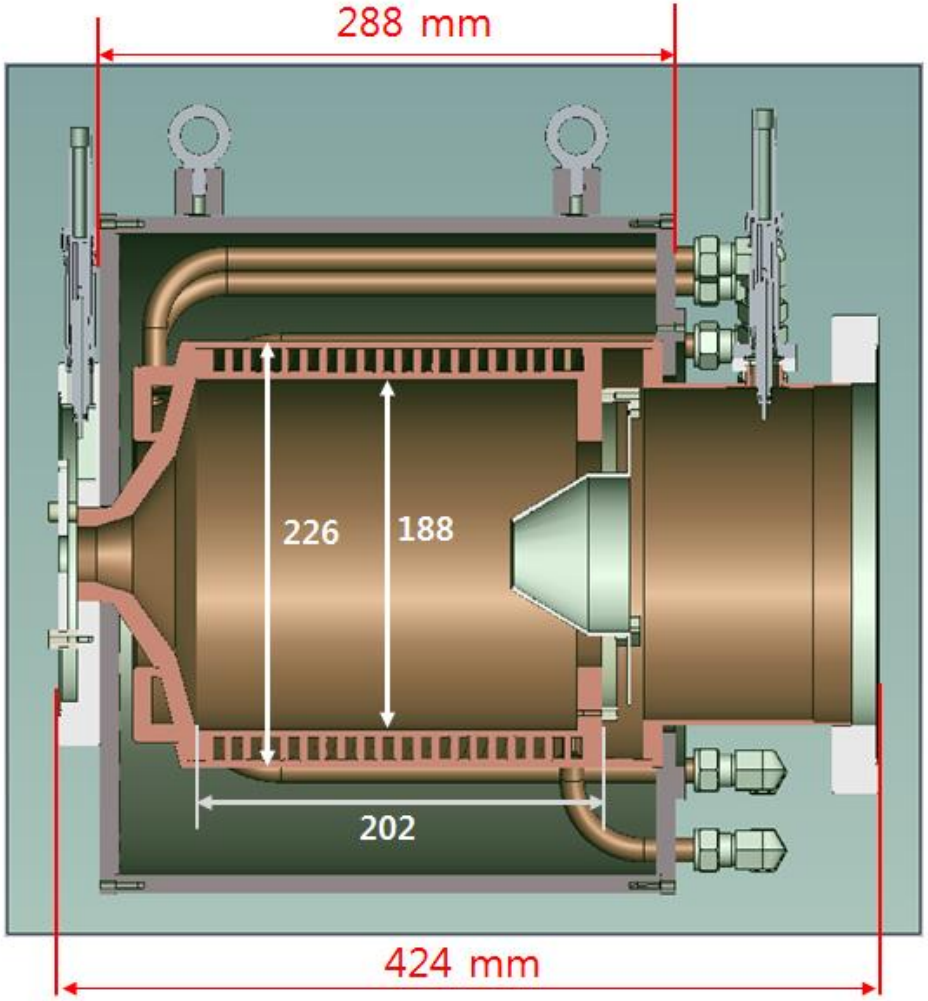
- ✓ E-beam simulation was performed with TRAK code.
- ✓ Colletor design was verified based on the simulation.
- ✓ Distribution of the power deposit on the inner surface of collector was calculated.
- ✓ Collector dimension, the repeller position, and the repeller voltage were tuned to achieve as small power density on the surface as possible.

EBIS: Electron Dump (Collector) Water line



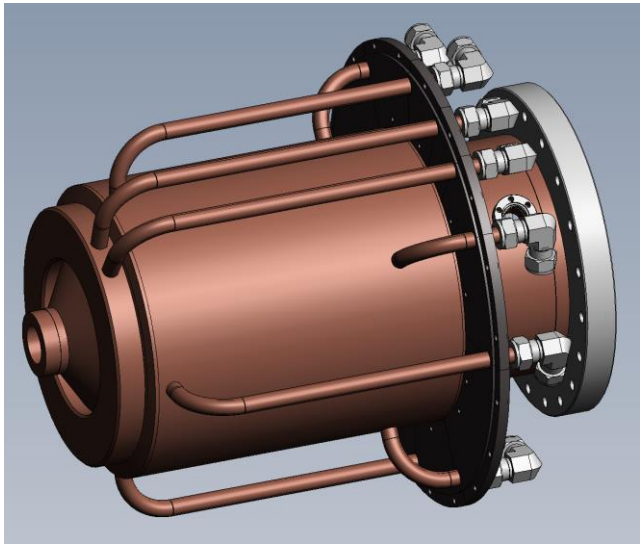
EBIS: Electron Dump (Collector) Magnetic shield

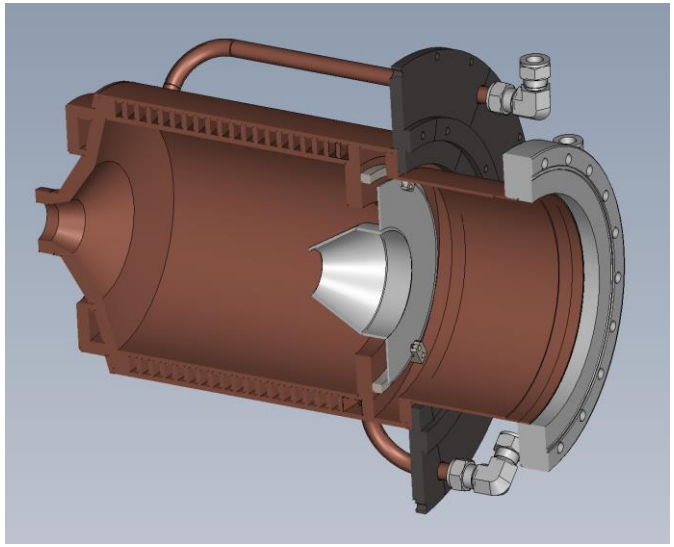




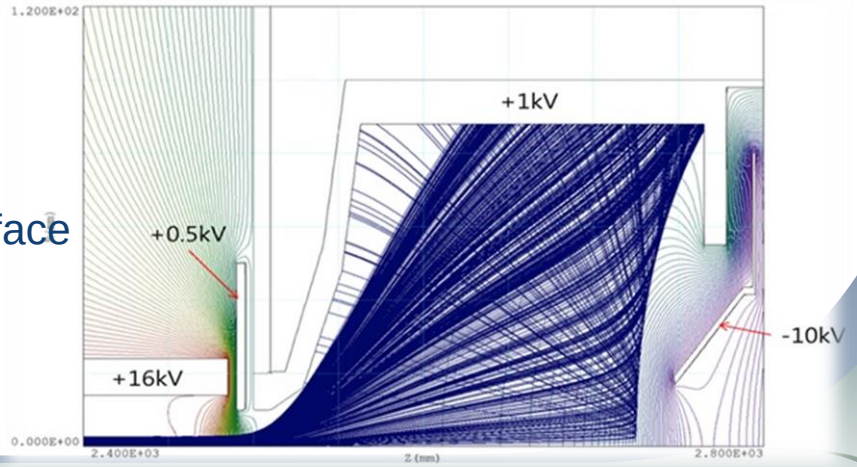
- Materials : OFHC, Stainless Steel **(STS 316L)**, Soft iron
- Connection method : All vacuum brazing

EBIS: Electron Dump (Collector) Cooling water

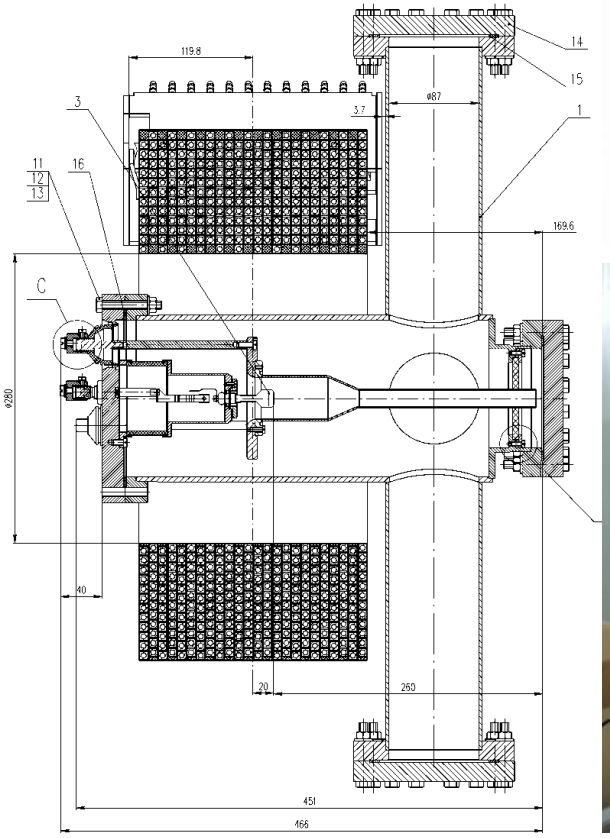




- Cooling Power: >15 kW
- Flow rate: ~ 25 L/min
- Parallel four water lines at the cylinder surface
- One water line at the front
- Cross section of water line: 6X12 mm^2
- Material: OFHC

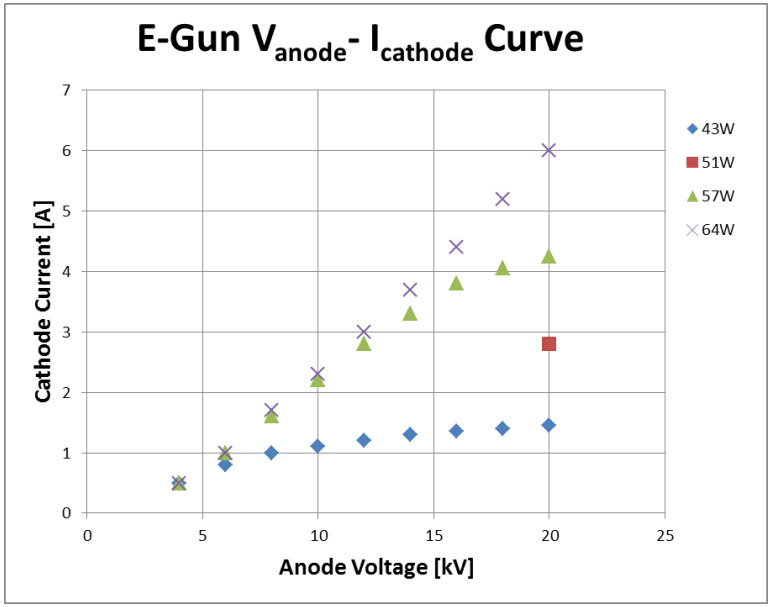


Electron Gun

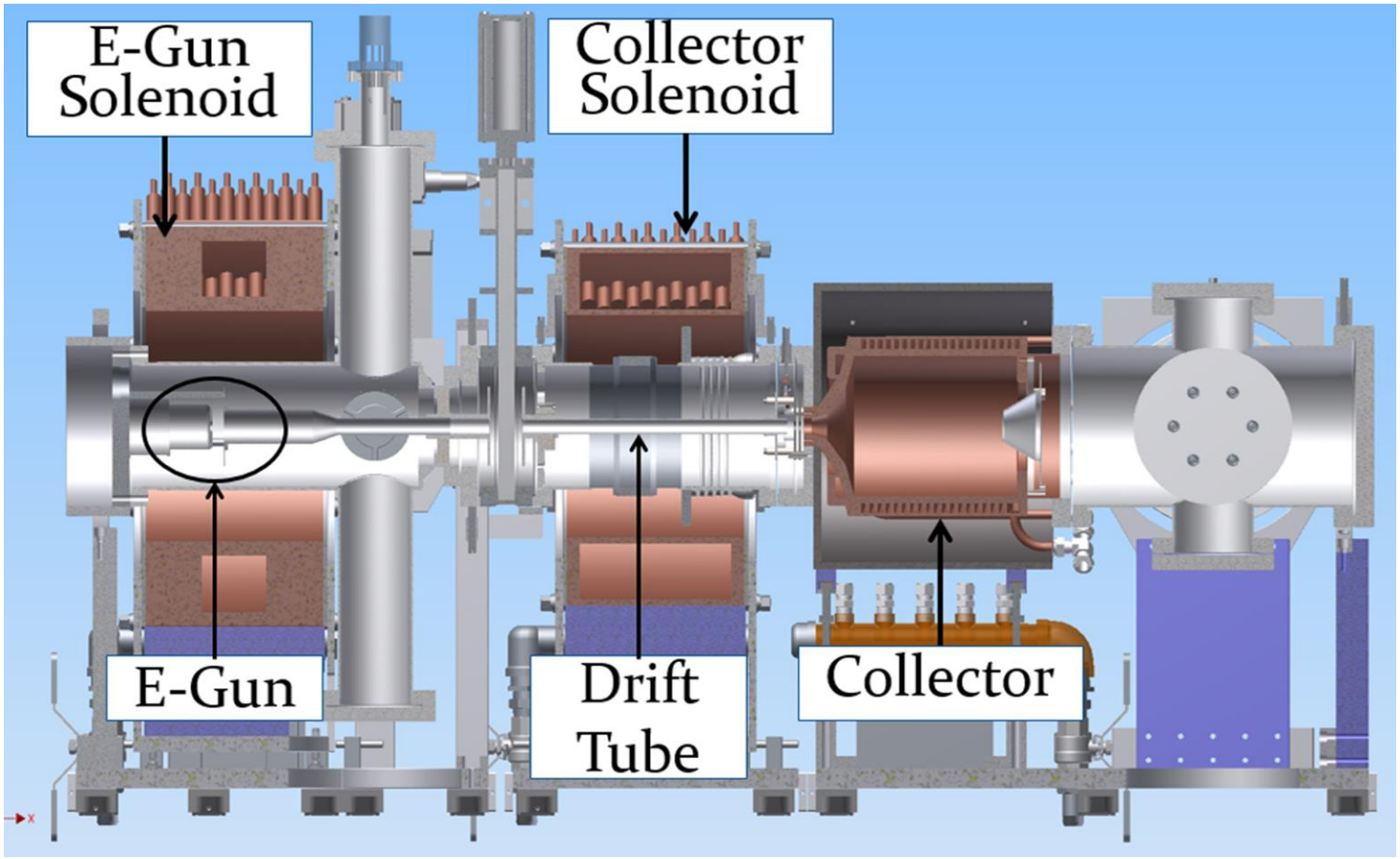


Manufacturer: BINP (Russia)

E-Gun Cathod Diameter: 5.6 mm
Cathod Material: IrCe
E-Beam Current: 3 A
Current Density at Cathod: 12 A/cm^2
Magnetic Filed at Cathod surface : 0.2 T



EBIS: Electron Gun Test



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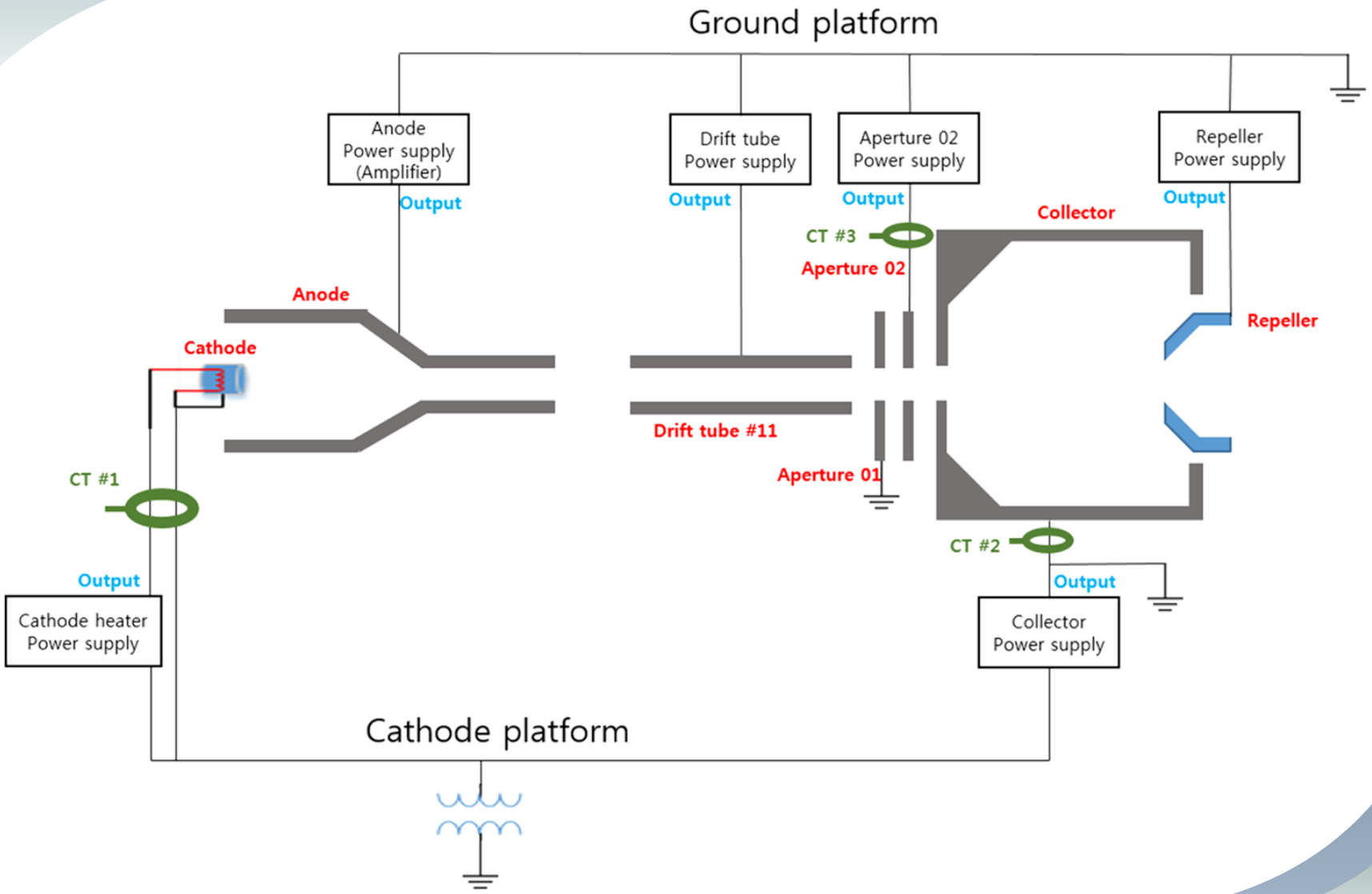

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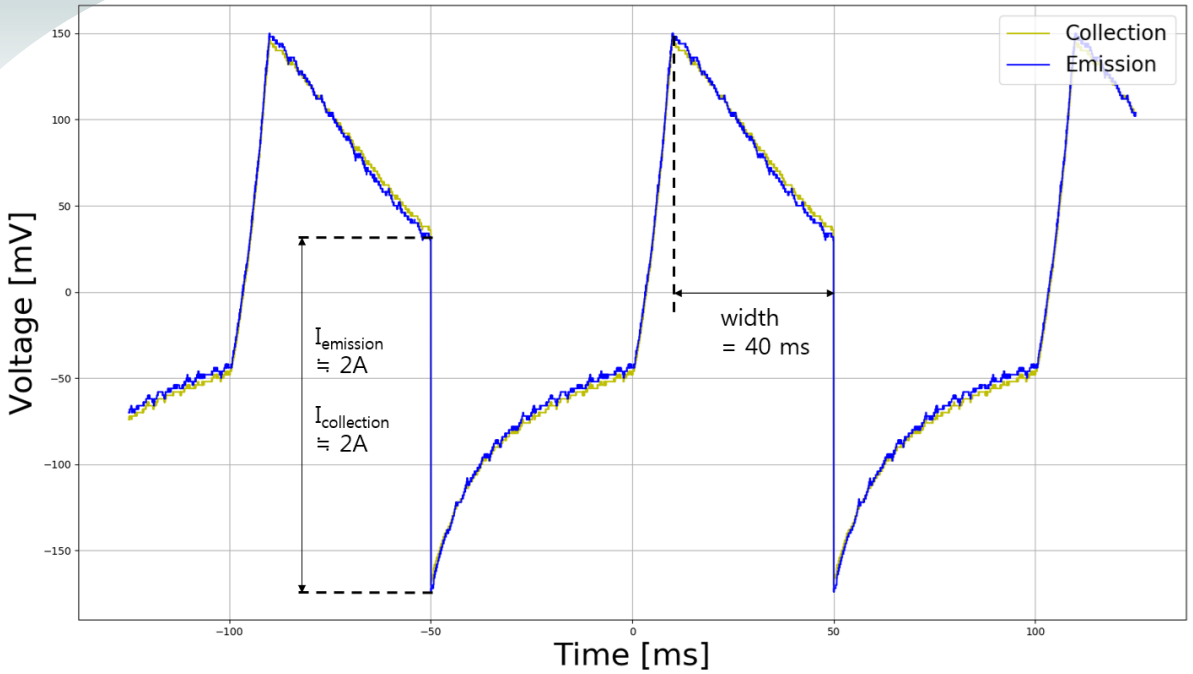
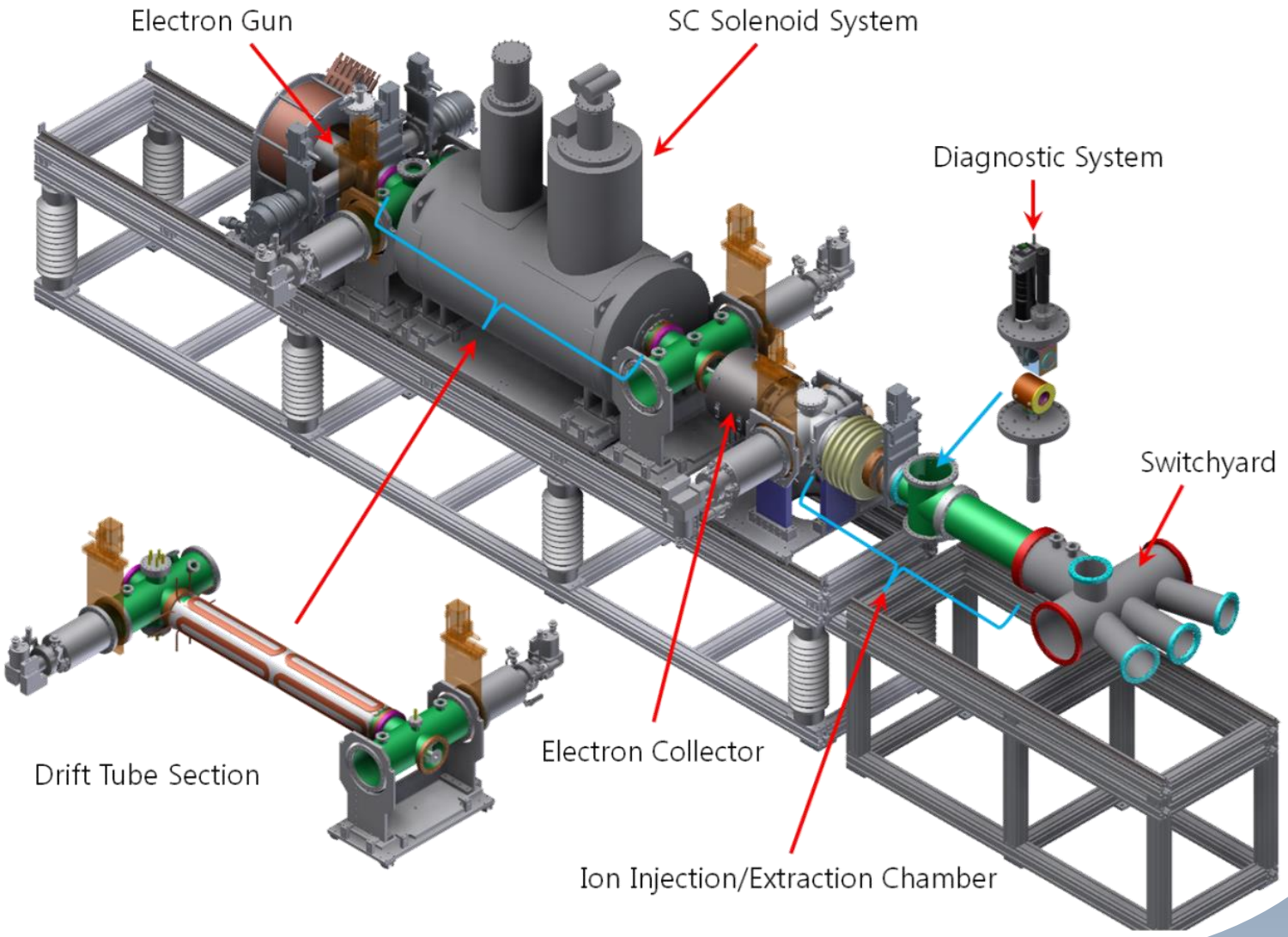


	$I_{emission}$	$I_{collection}$	Pulse width	Duty cycle	V_{anode}	I_{anode}
5.6 mm cathode	2 A	2 A	40 ms	40 %	12.5 kV	15~60 mA
4.2 mm cathode	3 A	3 A	Sawtooth mode		14 kV	2 mA
	2.3 A	2.3 A	50 ms	25 %	13 kV	< 2 mA

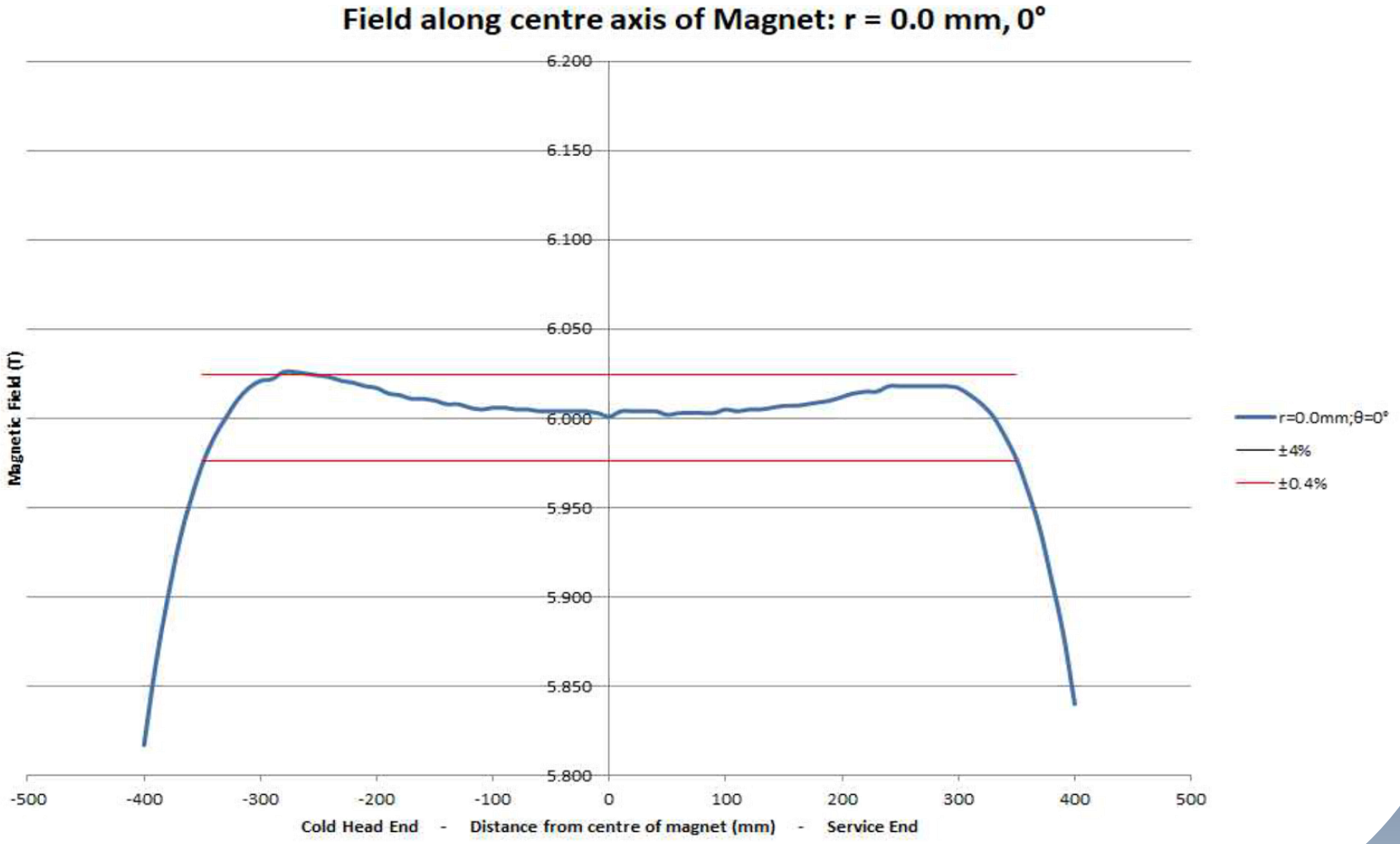
EBIS Charge Breeder



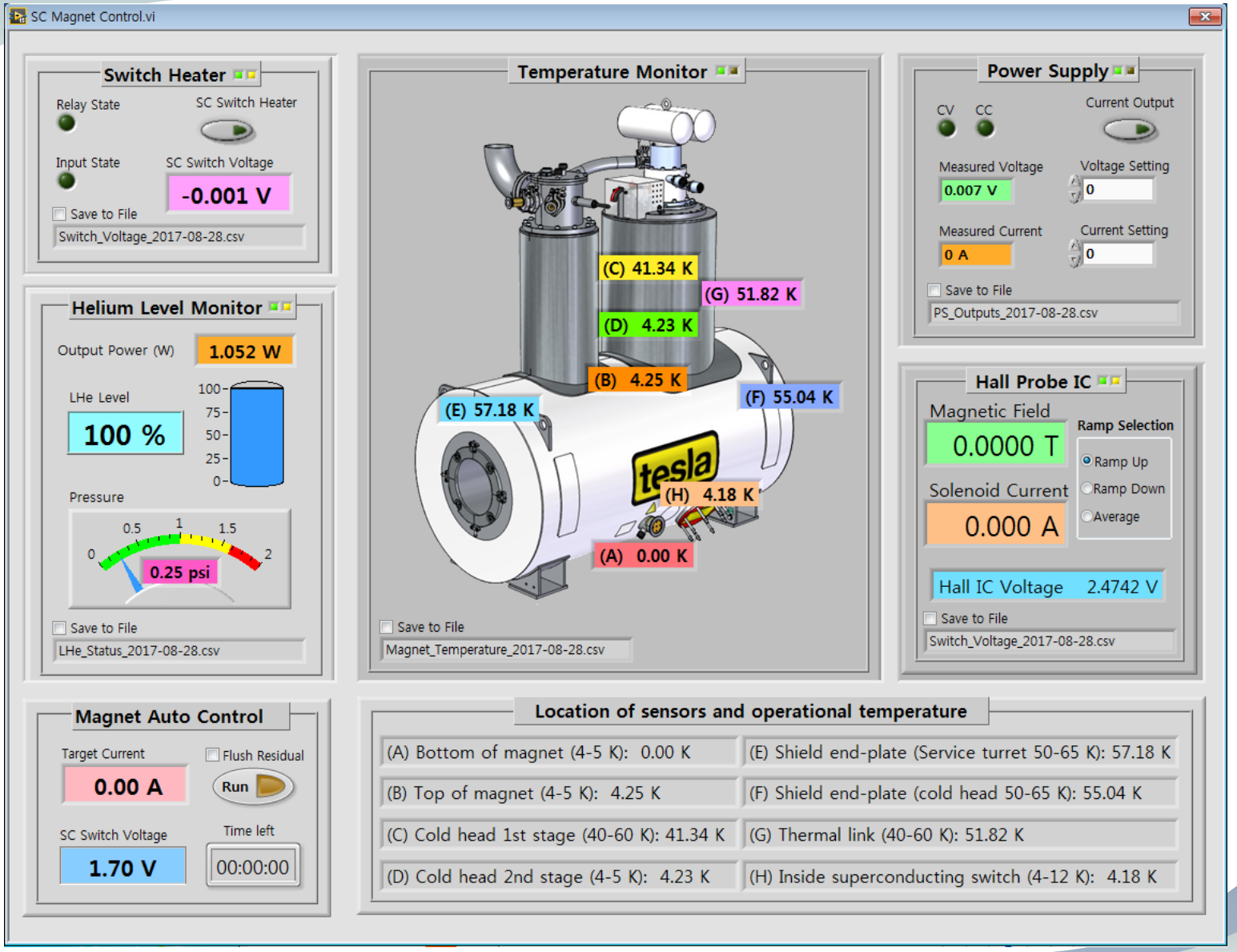
Superconductor Magnet

- Magnetic Field: 6T
- Warm Bore : 8”
- Cyrocooler: 1.5W
- Currnt: 96.3 A
- Homogeneity: 0.4%

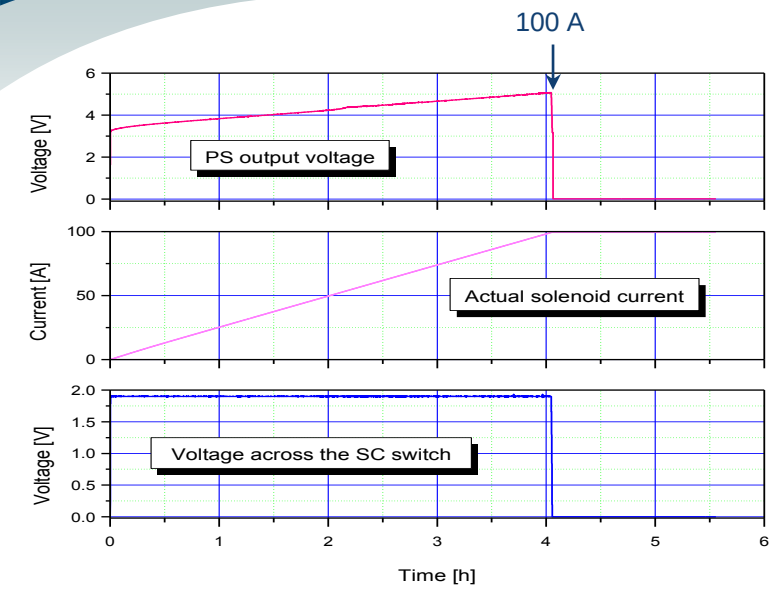
Superconductor Magnet : Inhomogeneity

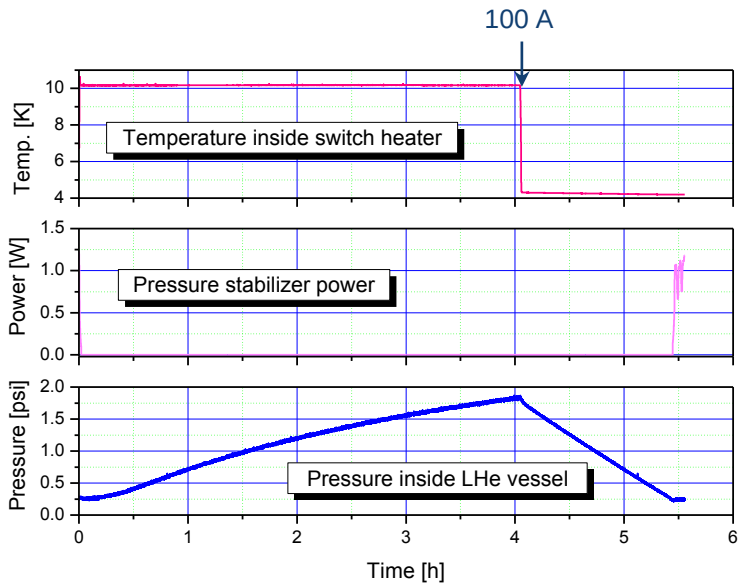


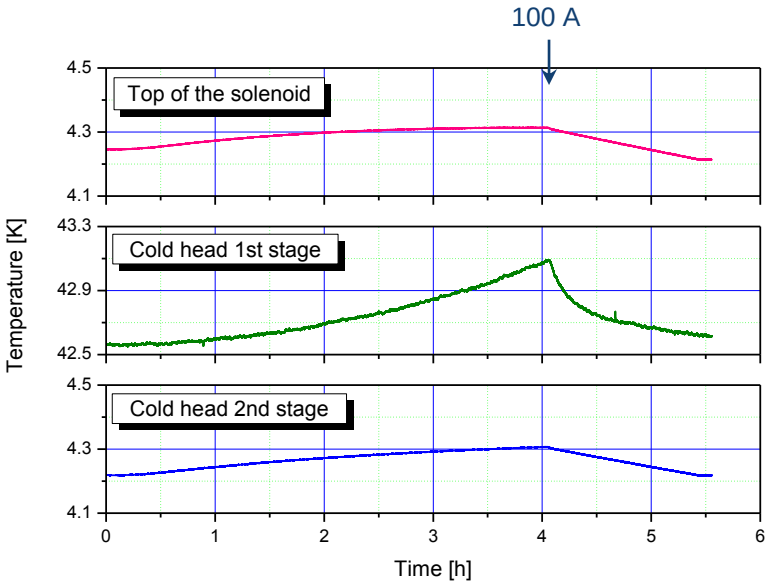
Superconductor Magnet Control Program

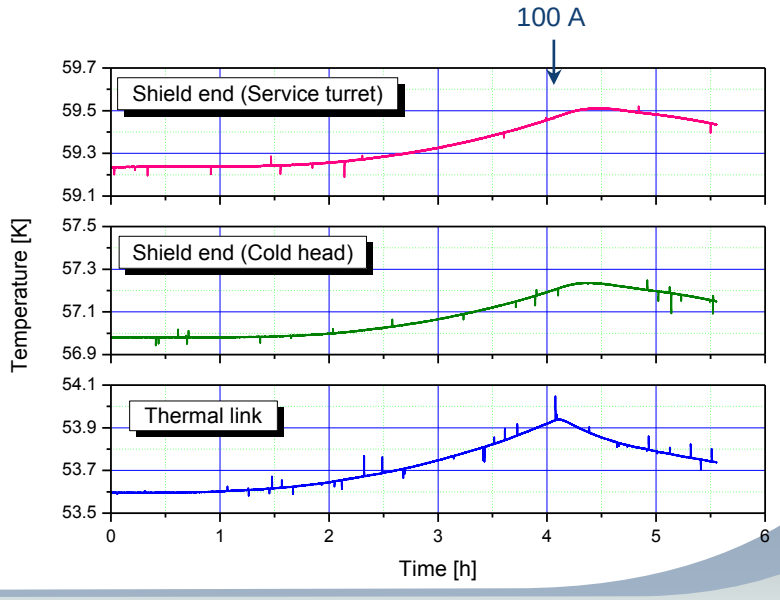


Superconductor Magnet : Energizing









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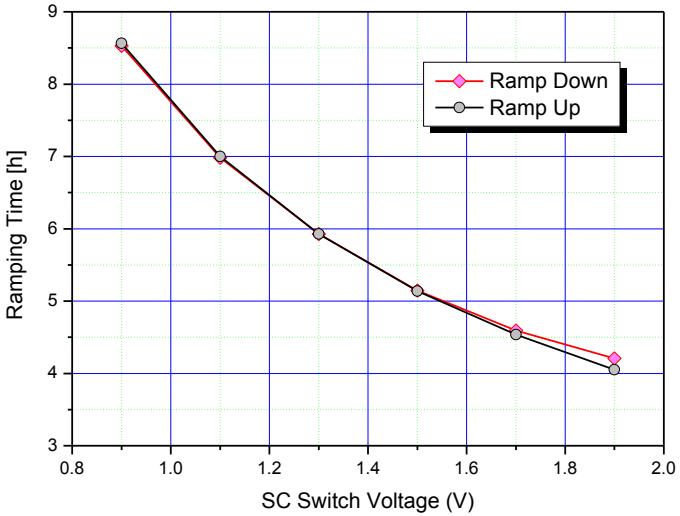
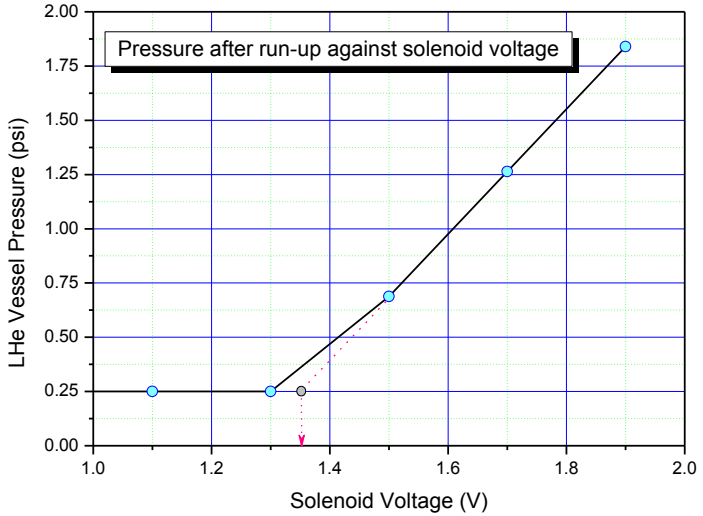
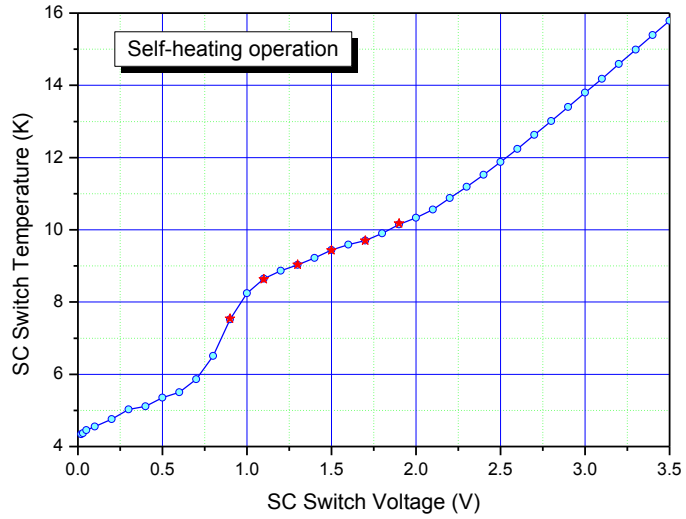
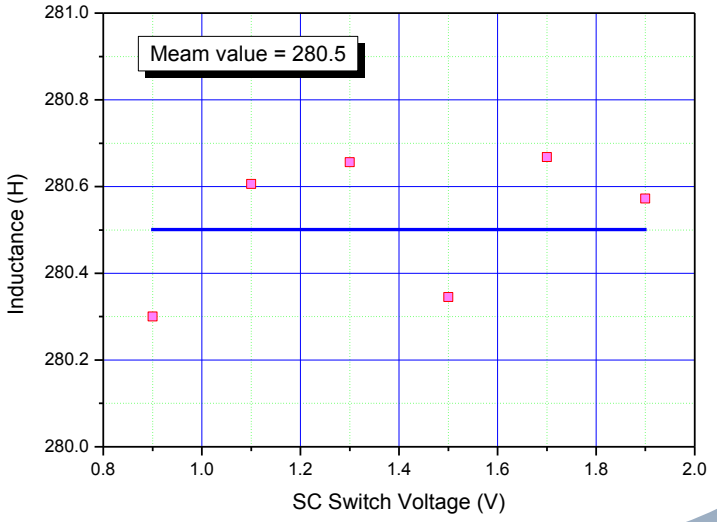
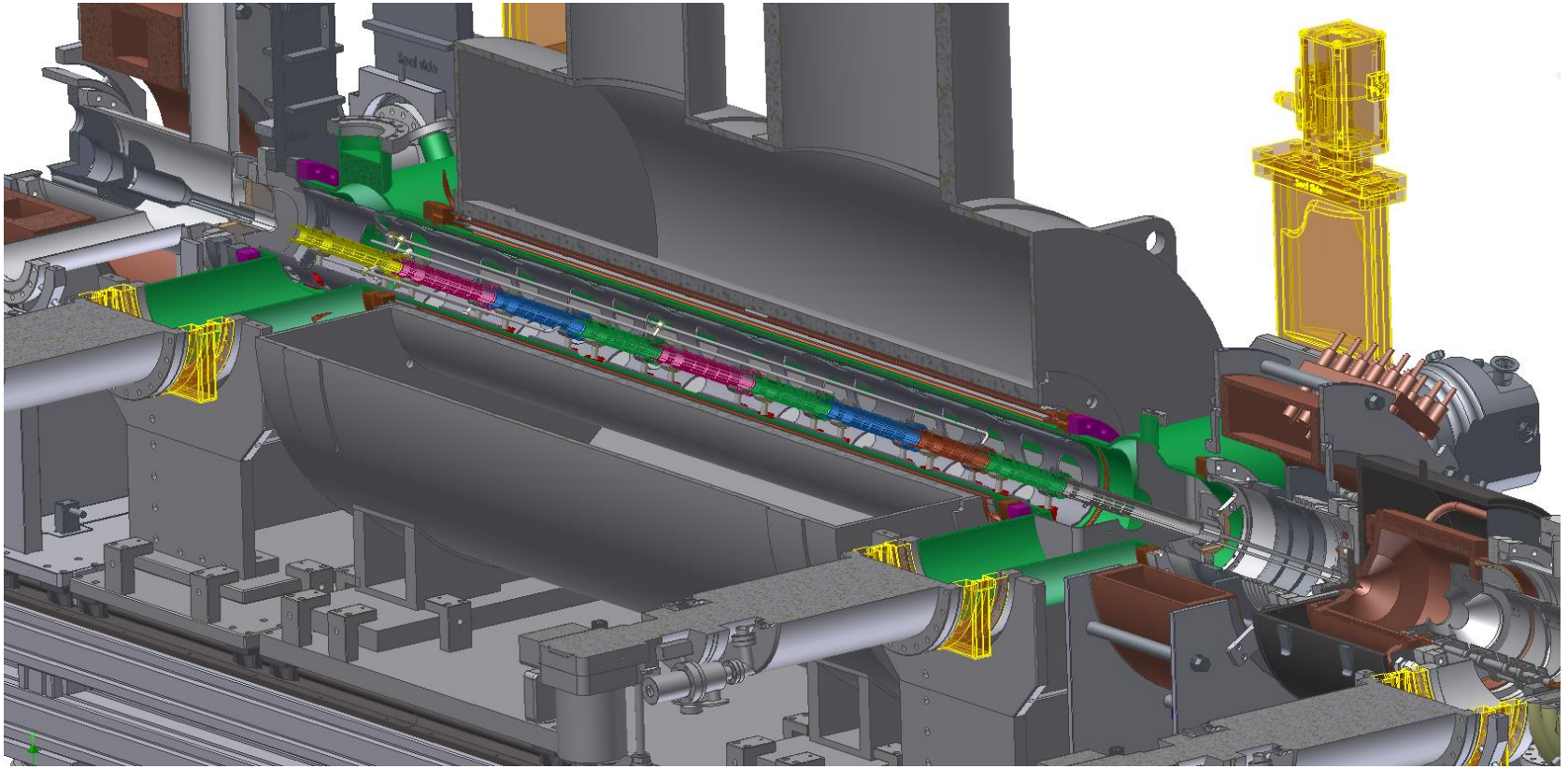






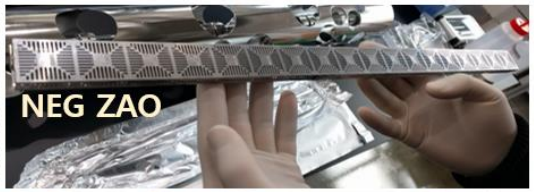


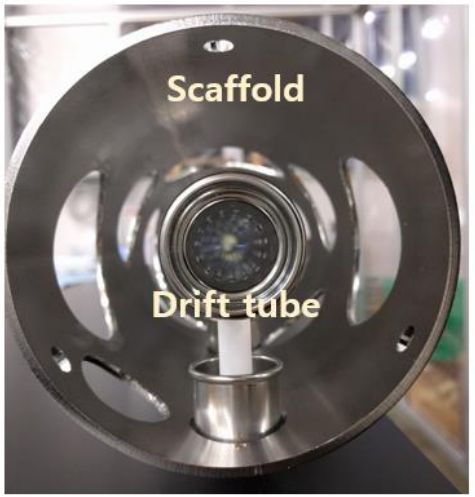
Ion Trap Section

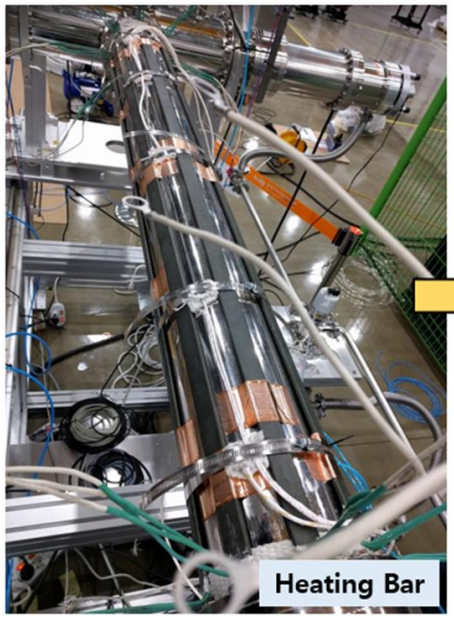


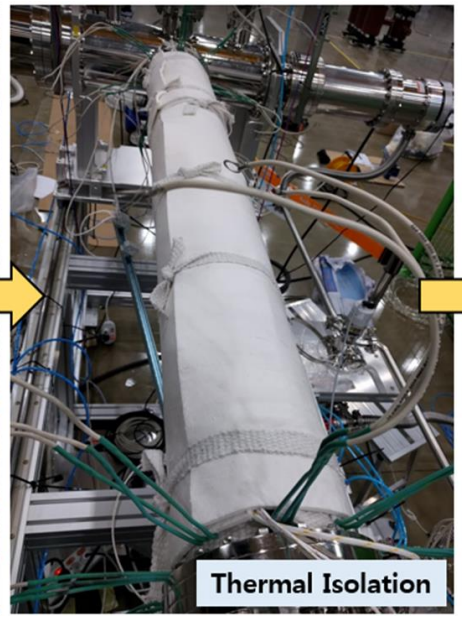
- Alignment, High vacuum, High voltage

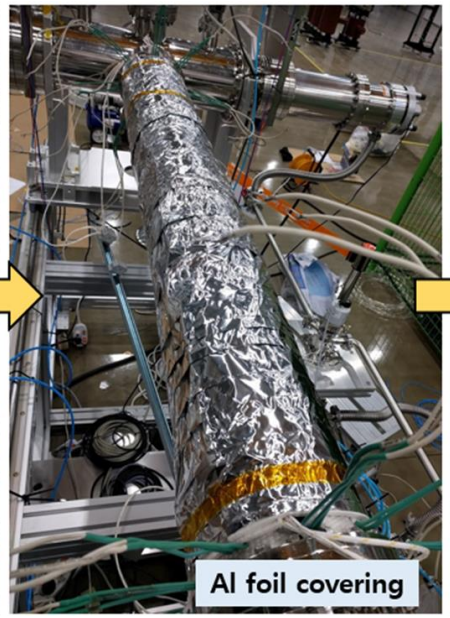
Ion Trap Section: Chamber Baking

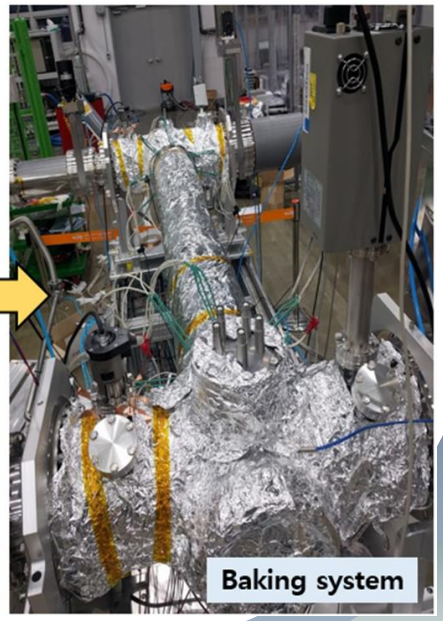






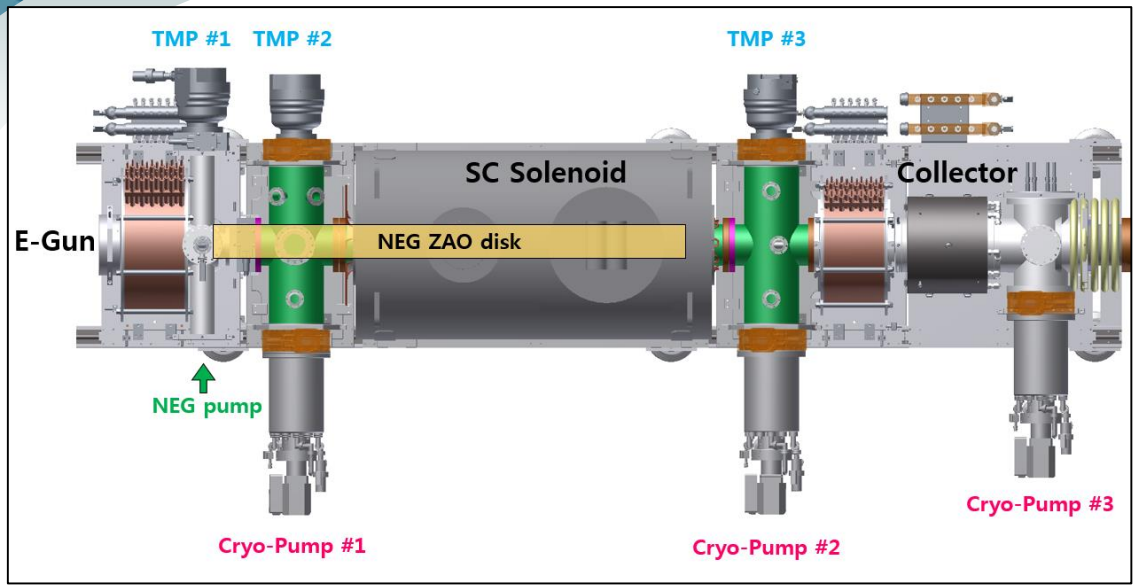


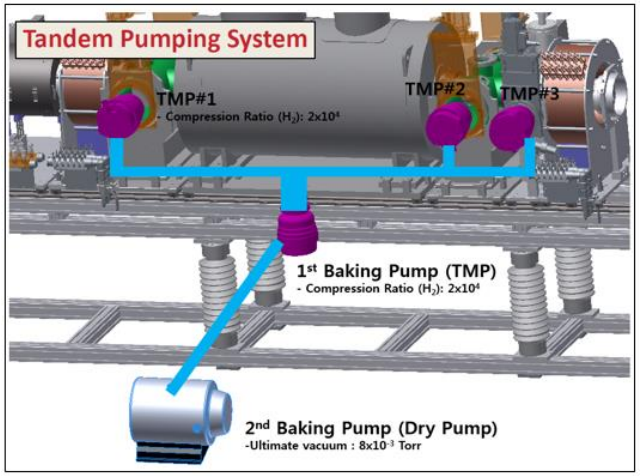




Ion Trap Section: Chamber Baking

Vacuum System

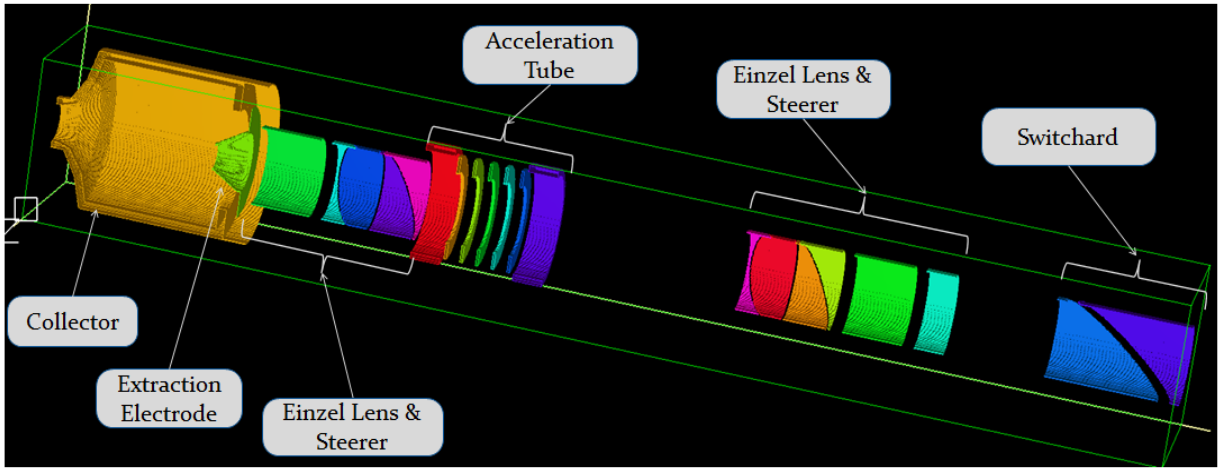


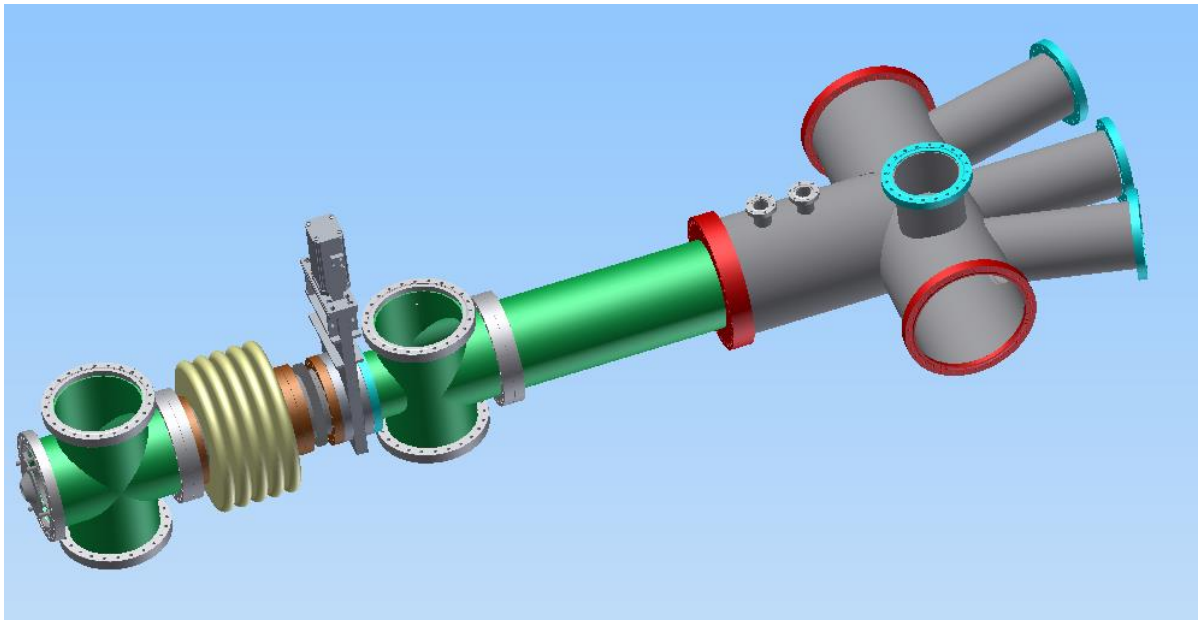


Vacuum System : Ultimate pressure

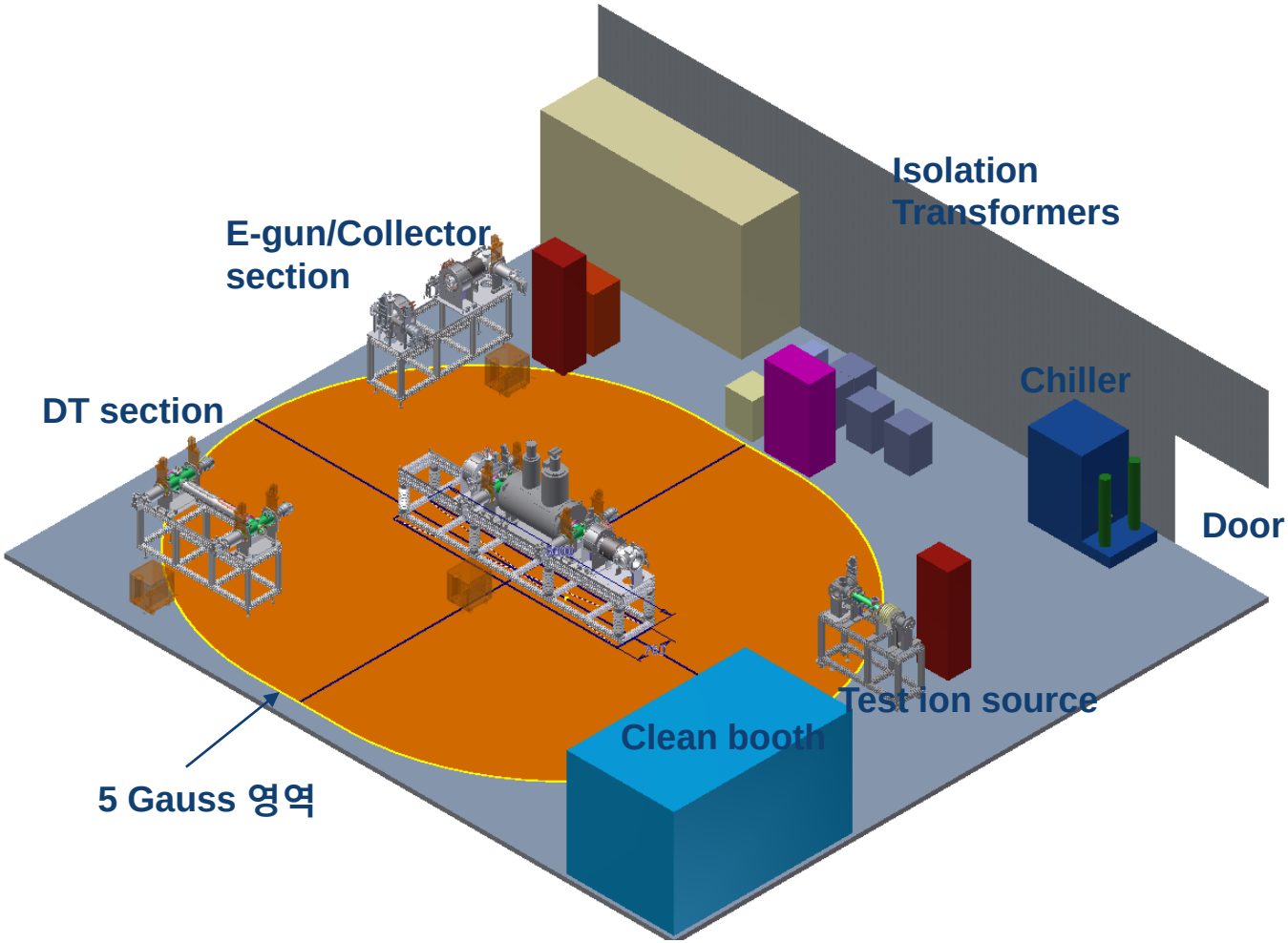
Staged vacuum test		Final pressure (Gauge 01 / 02)	Remarks
1st stage	TMP only	1.42E-09 / 1.84E-09 torr	150℃, 72hBaking
	Tandem TMP system & Cryopump	1.21E-09 / 9.96E-10 torr	
	Chamber Baking	3.66E-10 / 6.72E-10 torr	150℃, 72h Baking
2nd stage	After 1st Baking (450℃)	8.89E-11 / 1.45E-10 torr	450℃, 78h Baking
	Afte 2nd Baking (550℃)	**3.60E-11 / 2.08E-11 torr**	550℃, 143h Baking

Ion Injection/Extraction Line

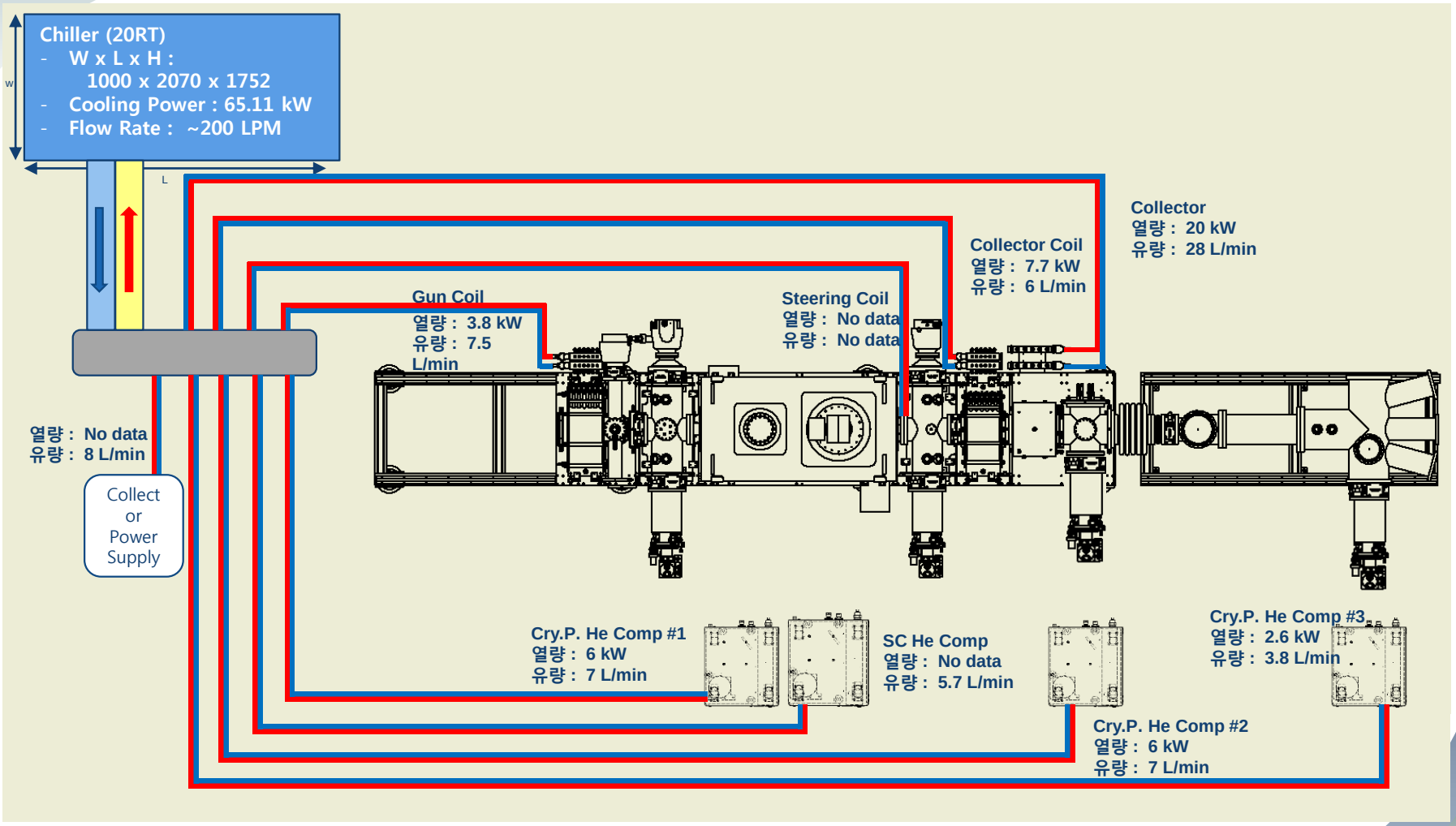




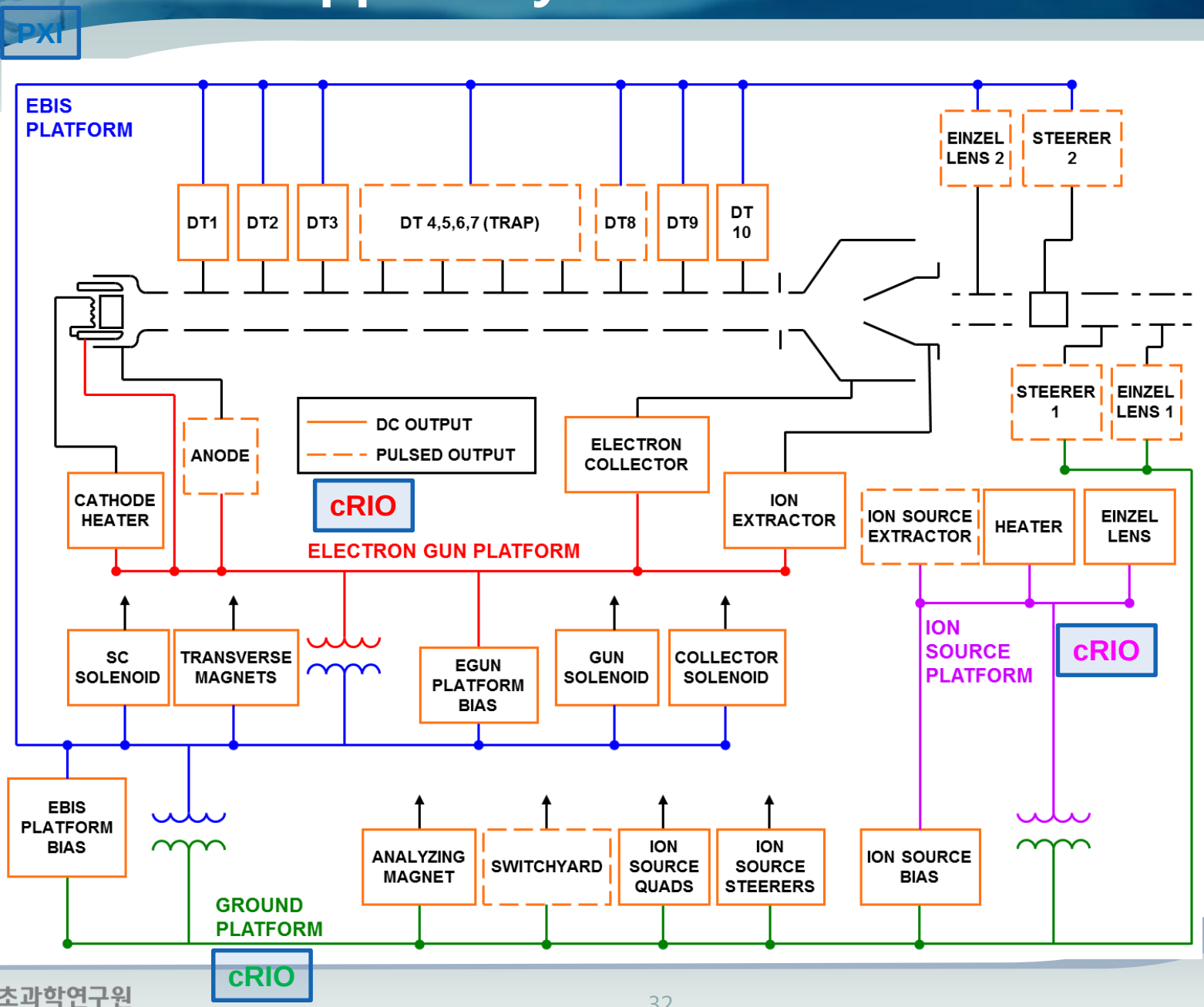
EBIS Floor plan at Korea University



Cooling Water



EBIS: Power Supplies System

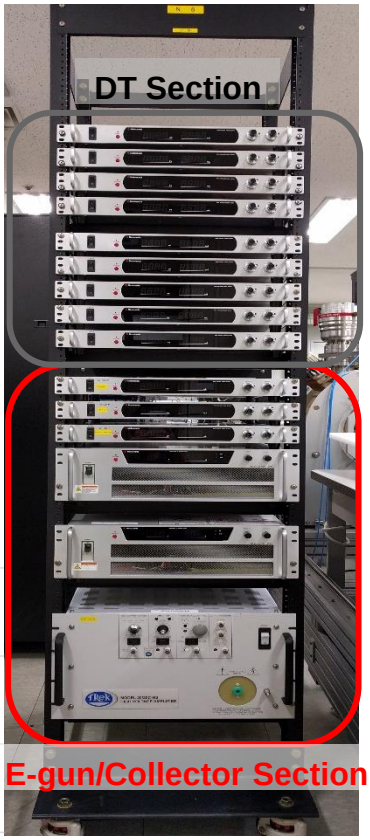


Power Supply System

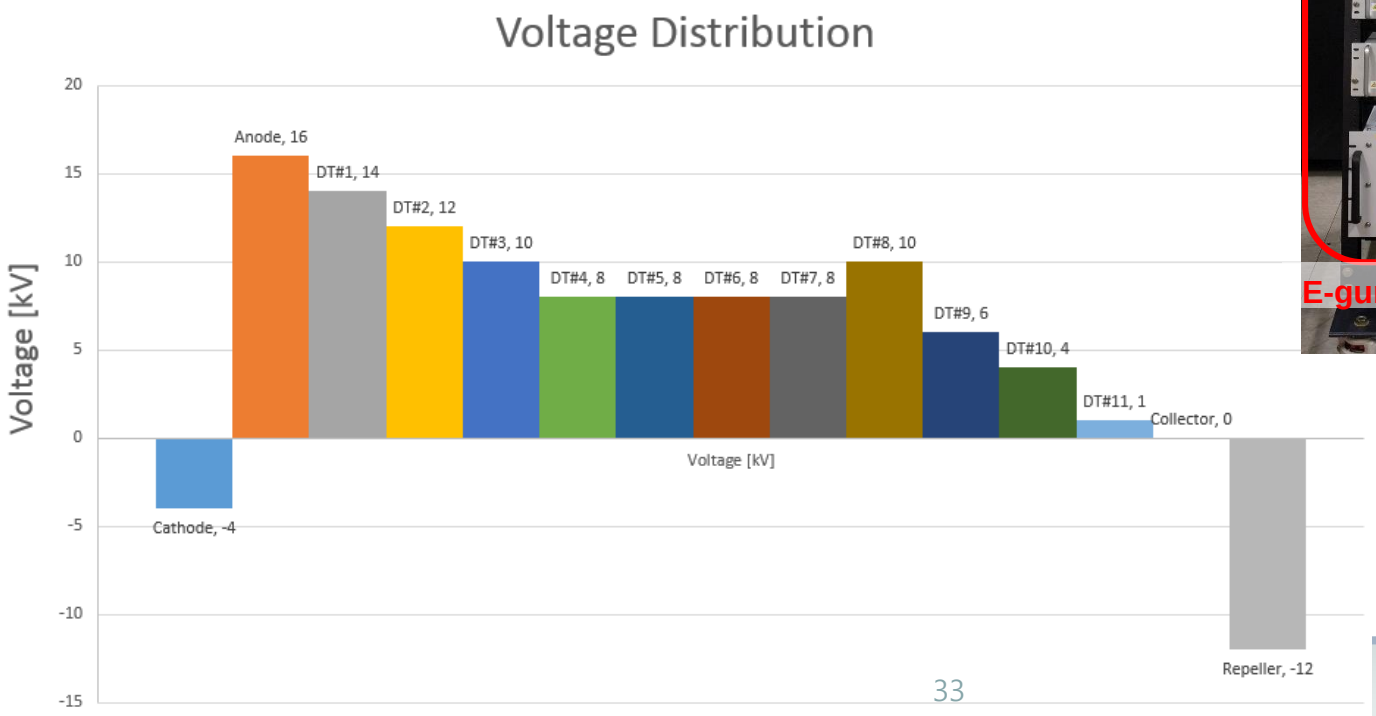
- Power Supplies #1
  - E-gun & Collector section
  - DT section

Control Units

Collector PS

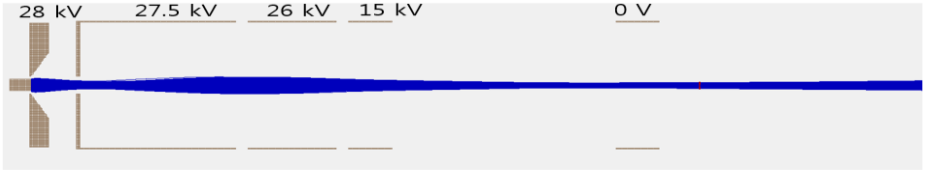


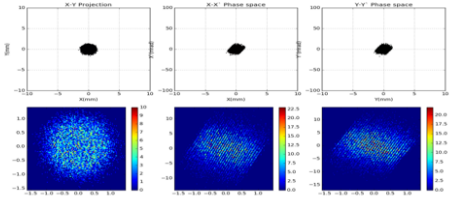
E-gun/Collector Section



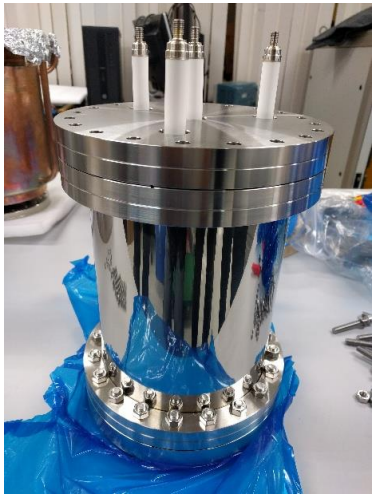
Test Ion Source

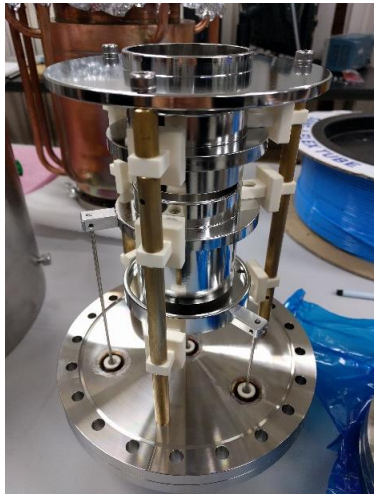
- Test ion source
  - Cs+1 이온 소스
  - 제작 완료



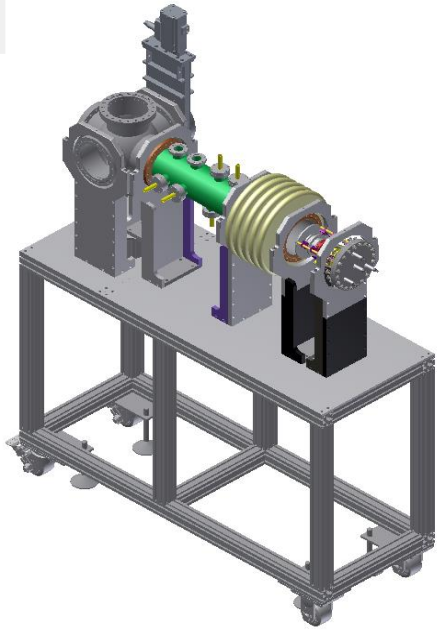


- Emittance (RMS)
  $8.5\ \pi\ mrad \cdot mm$
- Emittance (Normalized)
  XX' : $0.00876\ \pi\ mrad \cdot mm$
- Average Energy : 26.84 [keV]



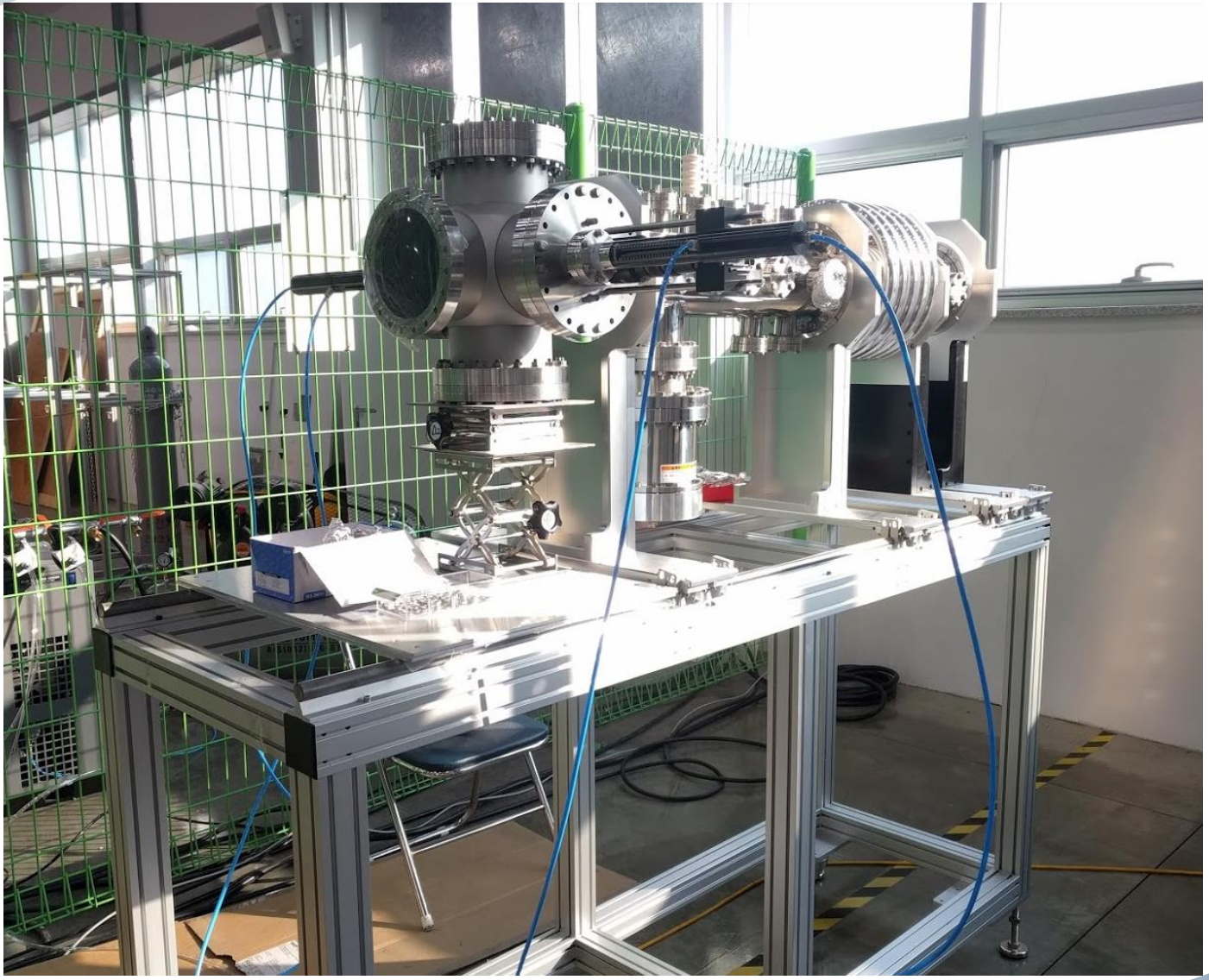


- Power Supplies - Test ion beam line part #1



Test Ion Source

Test Ion Source

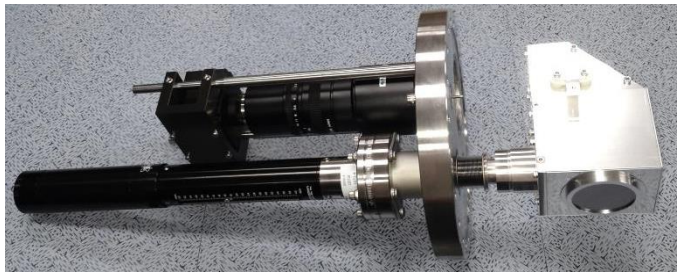


Beam Diagnostics

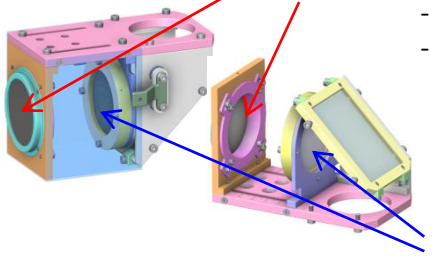
Pepperpot Assy

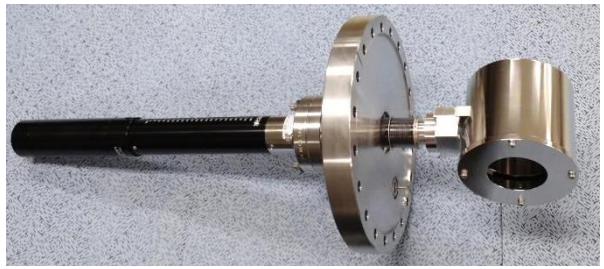
CCD Camera
-CCD Size : 2/3”
-Resolution : 2448X2048
-Pixel Size : 3.45X3.45um^2

Zoom Lens (1X)



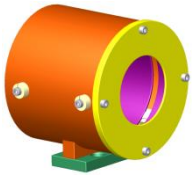
Mask
- Aperture size : 40 mm
- Hole sep/size : 1 mm / 20 um
- Tantalum

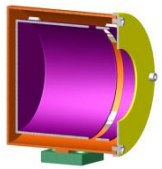




MCP Active Area : 40 mm
Mask-MCP Sep : 17-60 mm

FC Assy





Faraday Cup

- Aperture size : 47mm

Summary

- Detailed design of EBIS CB was finished.
- Superconductor Magnet was procured.
- Test ion source is being built.
- Beam diagnostics (pepperpot, FC) were manufactured.
- Vacuum conditioning of DT chamber was performed.
- Electron beam extraction test was performed. The anode structure will be improved.
- Injection/extraction beam line and ToF charge state analyzer will be manufactured soon.
- Hope we will be able to perform the 1st charge breeding experiment at the end of this year.

Thank You!