ECRIS2016
The 22nd International Workshop on ECR Ion Sources

KBSI 한국기초과학지원연구원
KOREA BASIC SCIENCE INSTITUTE

Development Status of 28 GHz Superconducting ECR Ion Source for the KBSI Accelerator

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Contents

Motivation

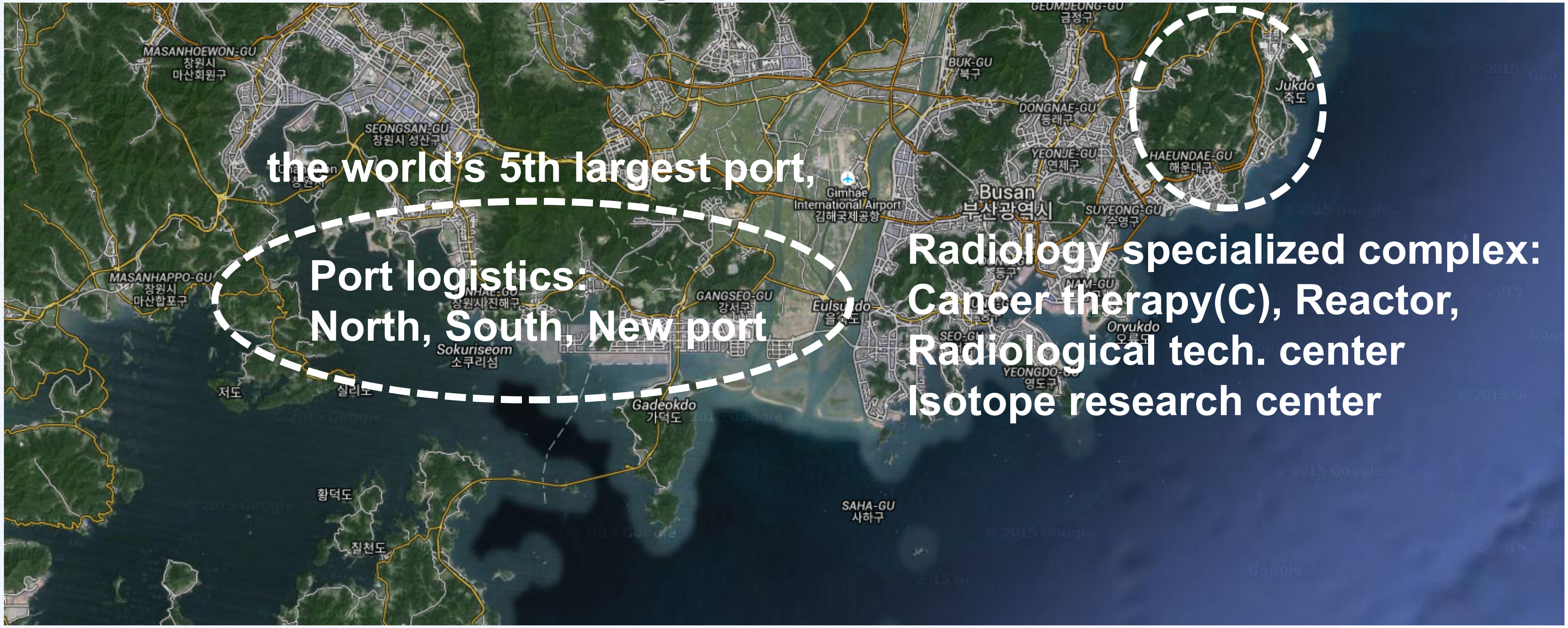
Busan metropolitan city

3.6 million population, the second biggest city in S. Korea

Images from google

Motivation

Busan metropolitan city



Images from google

Motivation

Research issues of KBSI (Busan center) specialized for Busan metropolitan city

Neutron Radiography based on accelerator

(Left) x-ray, (Right)Neutron imaging
Courtesy of Paul Scherrer Institute

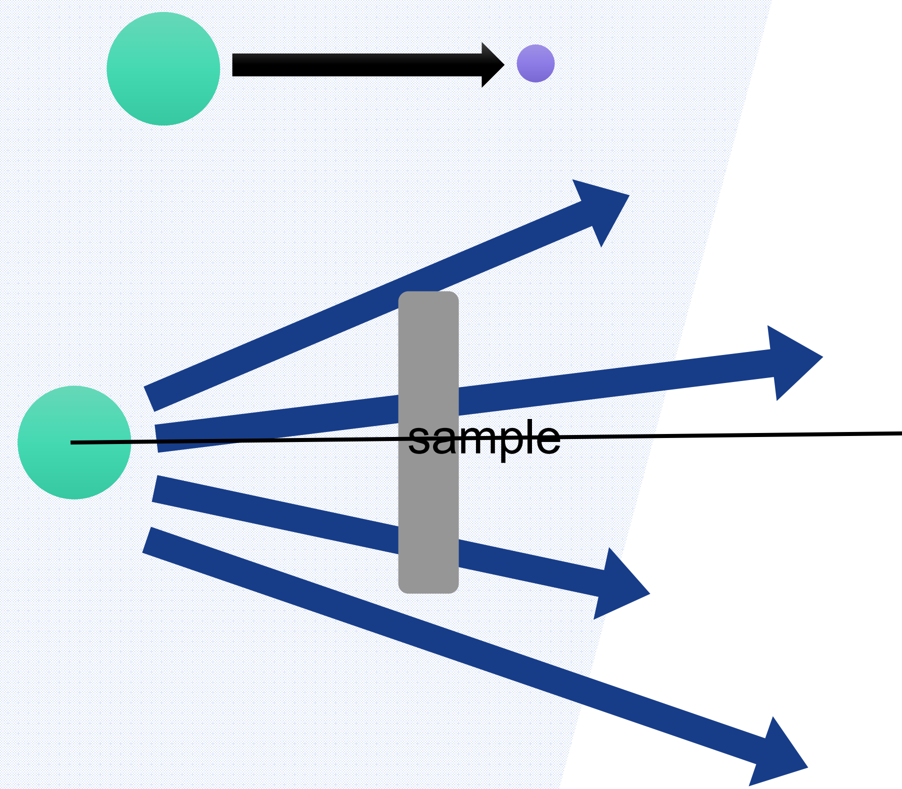
Cancer therapy based on accelerator

Particle cancer therapy using heavy ion (C)
Courtesy of nature.com(SIMENS)

Concept of neutron production: Inverse kinematics

Inverse kinematics for neutron generation

$$p(^{7}Li,n)^{7}Be$$



Inverse kinematics: the produced neutron will be go forward.
Production angle is limited about 30 degree and high intensity neutron beam.

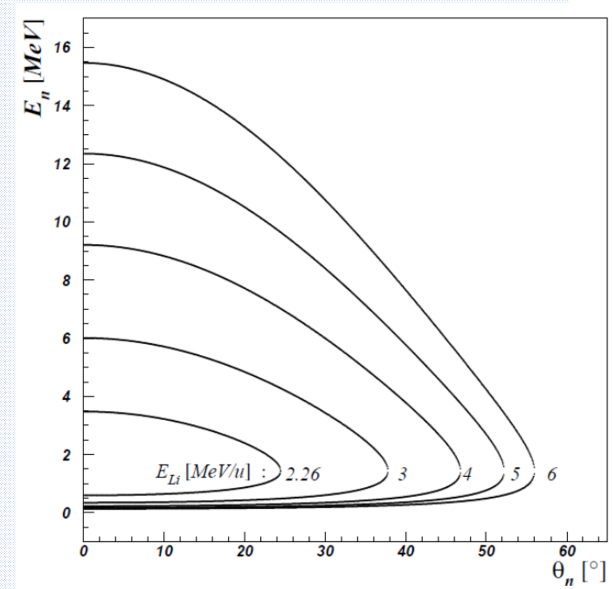
Concept of the neutron production for radiography employing heavy ion linear accelerator.

Most of neutrons are straight-forward
Proper to radiography

Neutron yield by inverse kinematics

Requirement for KBSI Neutron radiography facility

- → Higher than 1pmA of $Li^{2\sim3+}$ beam intensity
- → ~2.5 MeV/u (17.5 MeV) of beam energy
- → Lower neutron incident angle
- → High efficiency detector for fast neutron detection



Fast Neutron Yield

$$Y_n = F_{Li} \cdot \rho \frac{N_A}{Z} \cdot L \cdot \sigma$$

Y : Neutron yield

F_{Li} : Flux of lithium ion beam (2.1×10^{13})

ρ : Density of hydrogen

N_A : Avogadro constant

Z : Atomic number of hydrogen

L : Target length

σ : Cross-section of reaction

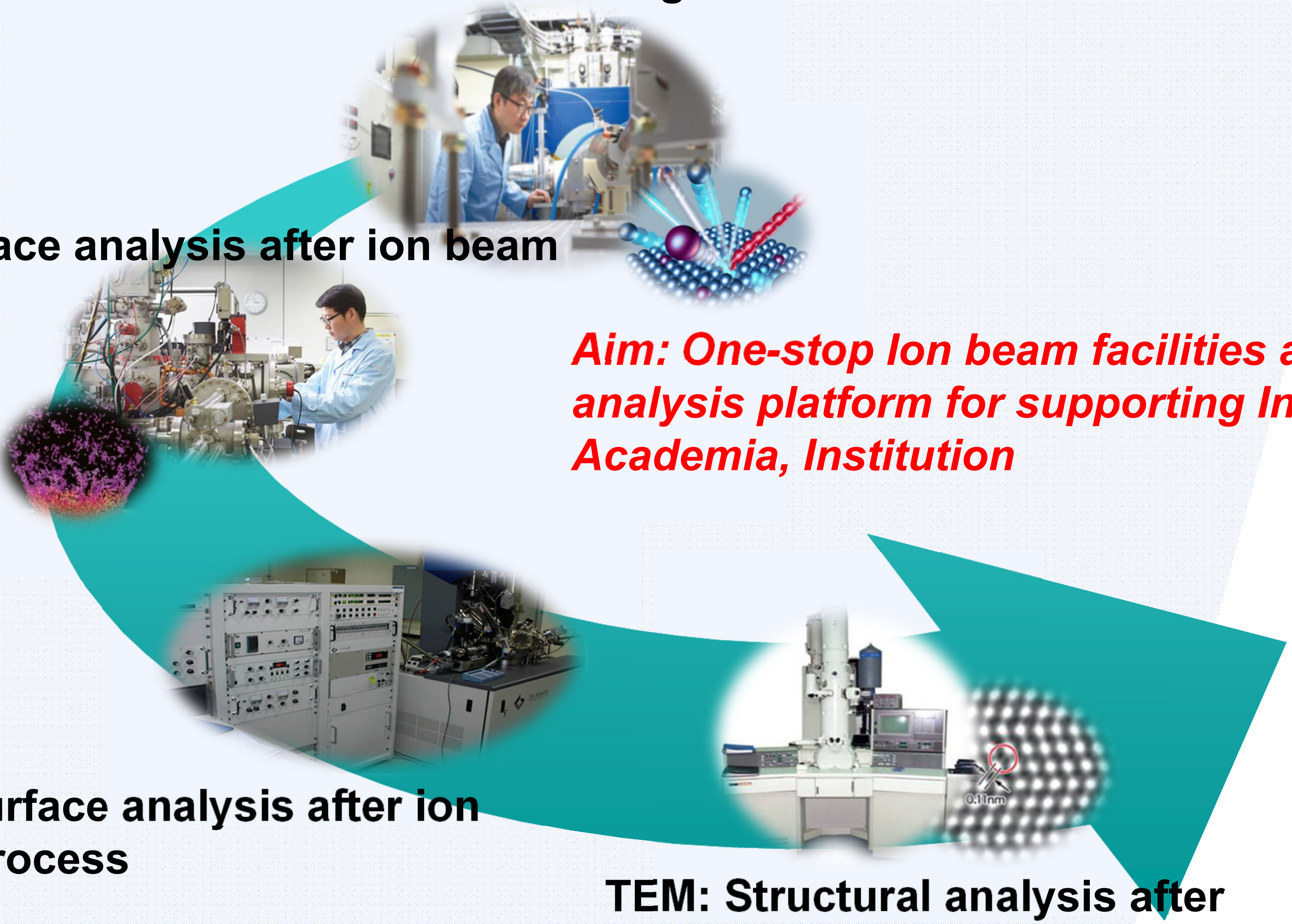
Li energy (MeV/u)	Max. angle (deg)	Cross-section (barn)	Neutron flux (n/cm^2 sec)	Max. neutron energy (MeV)
2.26	24.4	0.536	5.2×10^{13}	3.4

J. Park and J. Ahn, Sae-Mulli, 54, pp.171, 2007

Ion beam application platform at Busan center, KBSI

ECR IS: Wide ragne of Ion beam irradiation

SIMS: Surface analysis after ion beam process



Aim: One-stop Ion beam facilities and analysis platform for supporting Industry, Academia, Institution

XPS: Surface analysis after ion beam process

TEM: Structural analysis after ion beam process

Overview of KBSI Accelerator Project

Motivation

- Fast neutron radiography facility
- Achievement: High-yield neutron flux
- Implementation: Inverse kinematics
- Requirements: Li ion beam + hydrogen target
- Pros.: effective and compact

28 GHz SC ECR ion source

- 3solenoids+1 Hexapole SC magnet
- LHe re-condensing cryostat
- 28 GHz-10 kW gyrotron
- Large bore plasma chamber
- Output beam: 84 keV (12keV/u)

KBSI Accelerator Systems

LEBT System

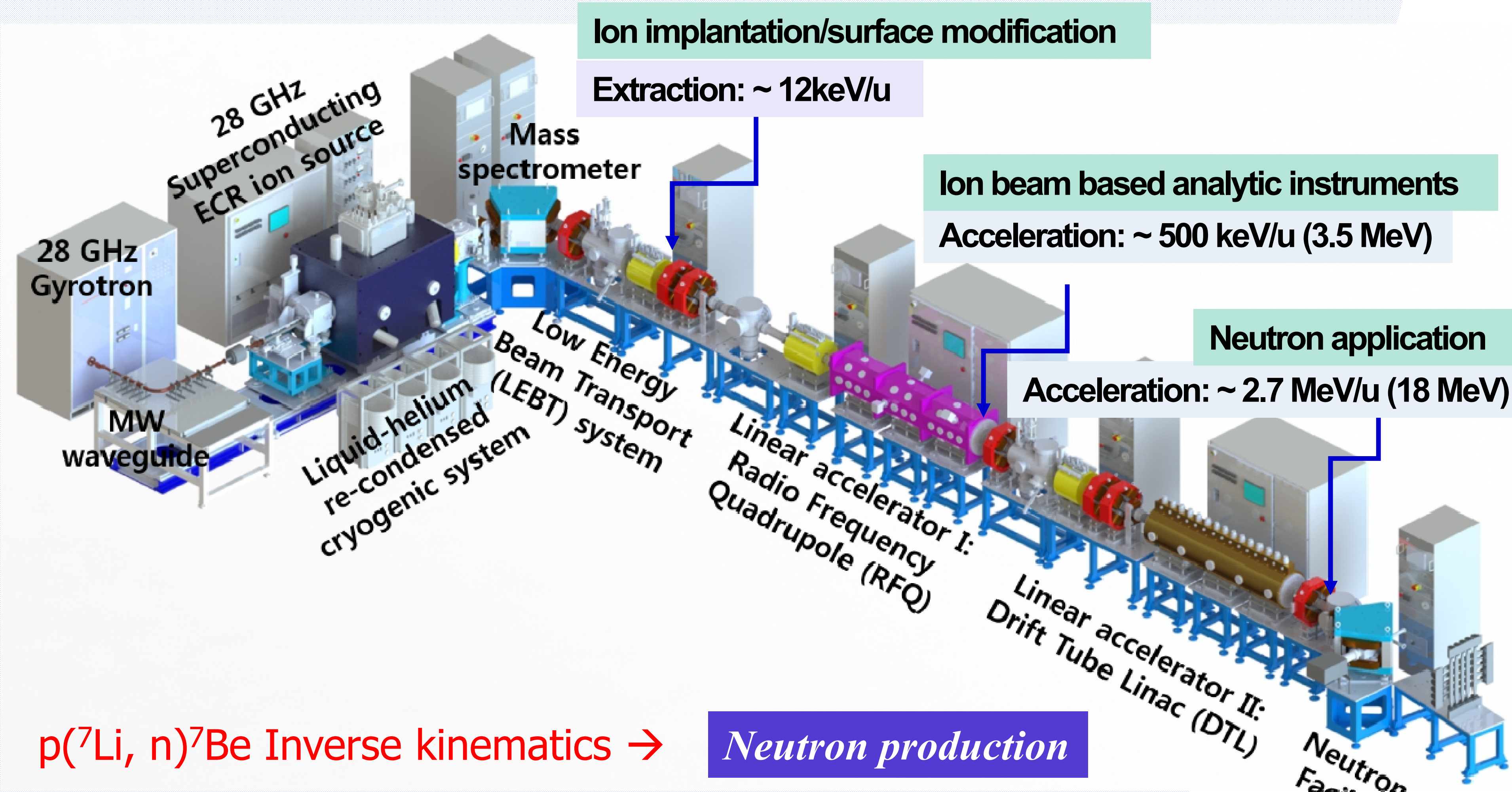
- enable to separate the ions from IS
- satisfy the RFQ input condition: beam acceptance, current, size and etc.
- 1dipole+3solenoids+2quadrupoles
- 2 diagnostic chambers

Linear Accelerator

- Reference particle: Li^{3+}
- Freq.=165 MHz
- Output beam :
  ~ 3.5 MeV@RFQ
  ~ 18 MeV@DTL

KBSI Accelerator System Layout

Heavy ion accelerator employing 28 GHz superconducting ECR ion source



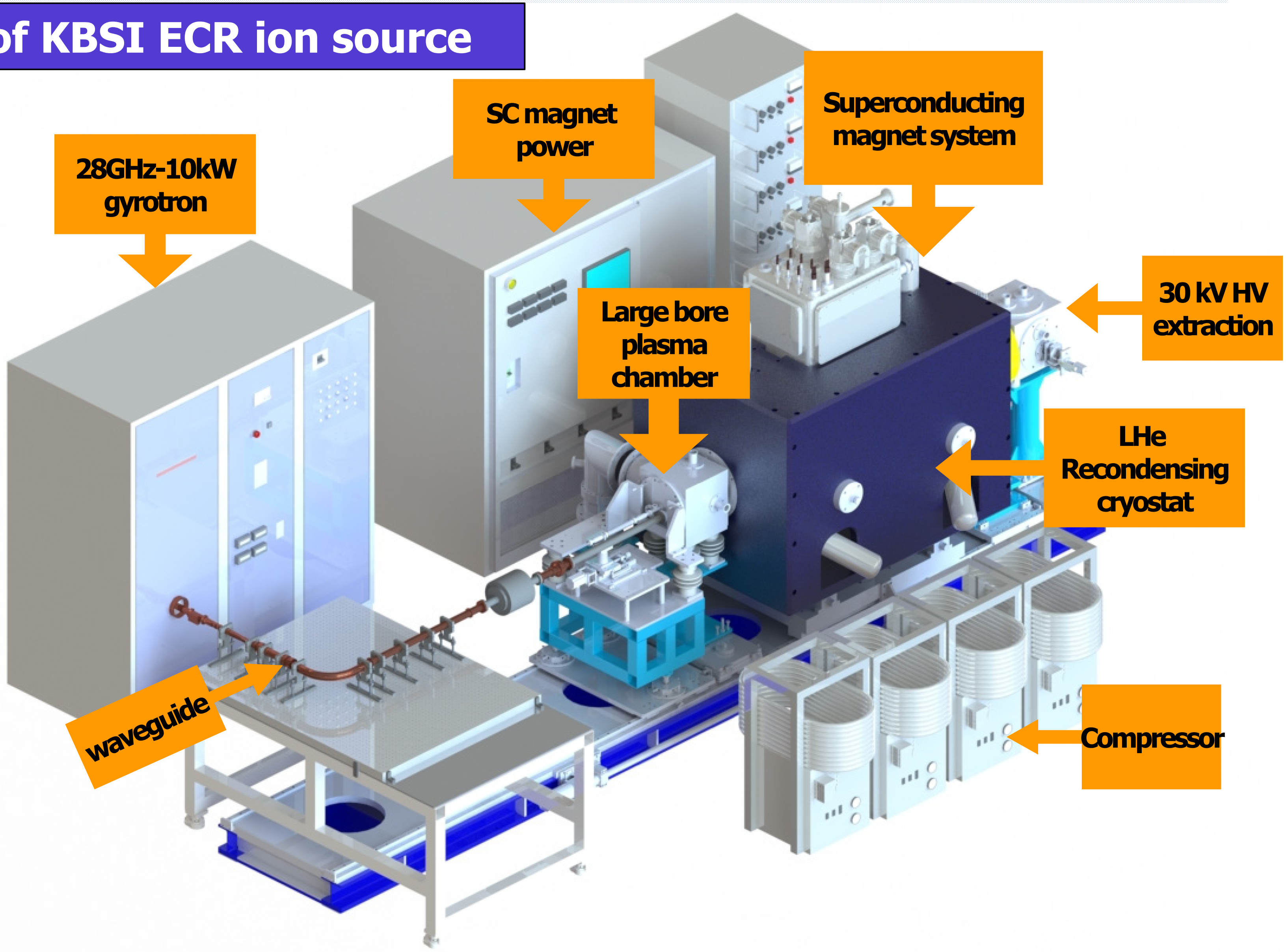
p(^{7}Li, n)^{7}Be Inverse kinematics → ***Neutron production***

28 GHz Superconducting ECRIS

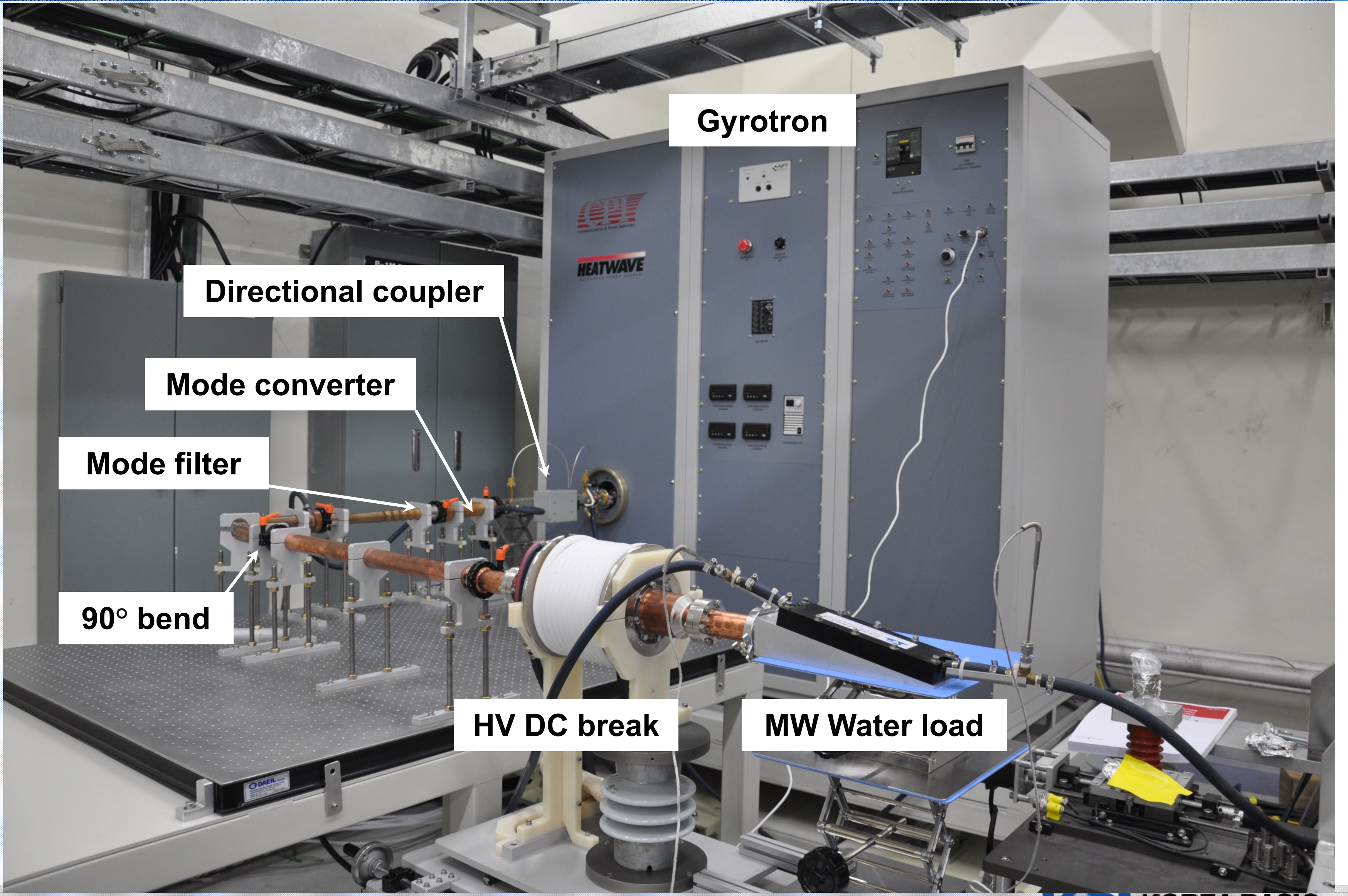
Status of
28 GHz Superconducting ECR ion source

28 GHz Superconducting ECR ion source

Layout of KBSI ECR ion source



28 GHz Microwave system



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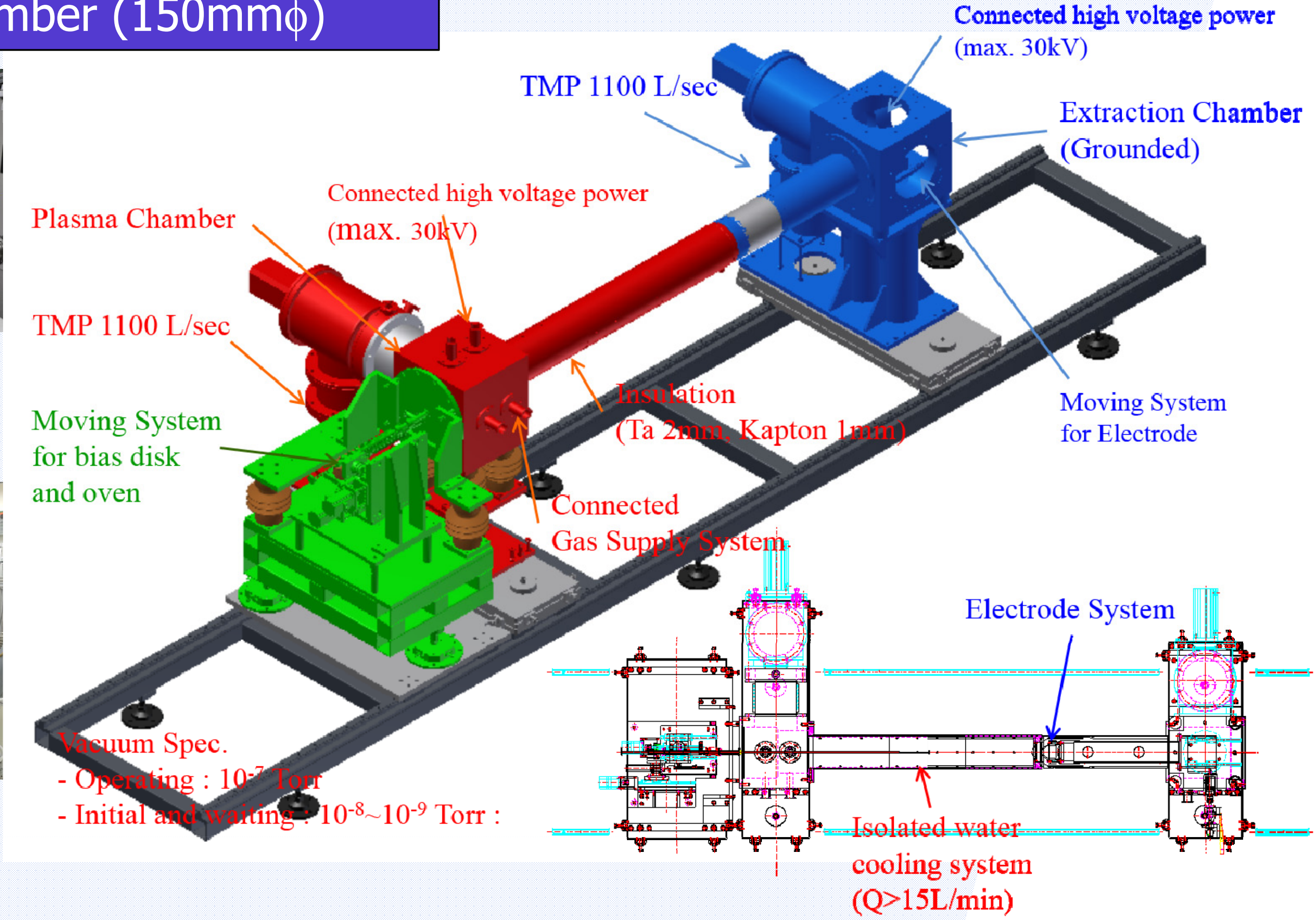
Plasma Chamber & Extraction System

Plasma chamber (150mmϕ)

Assembly



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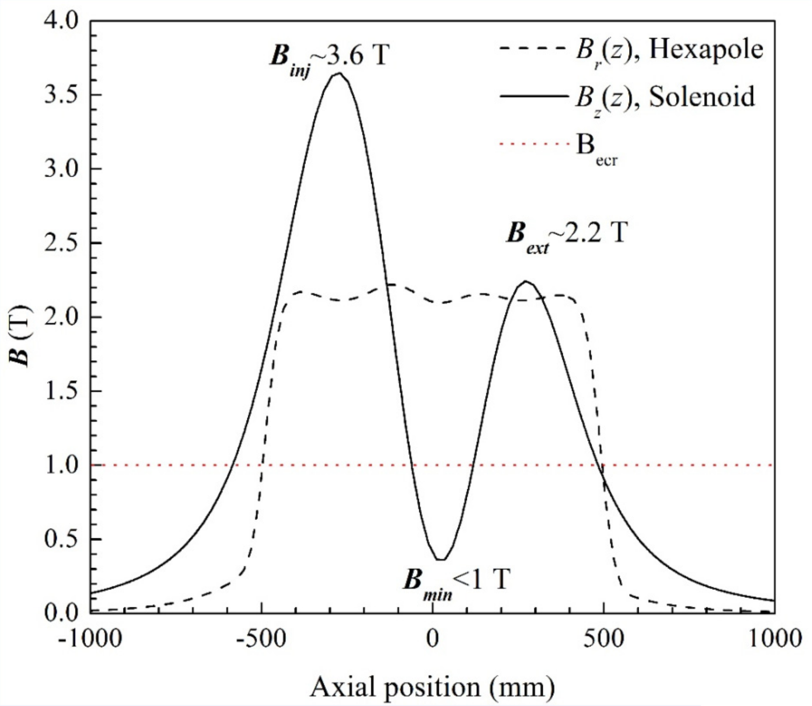
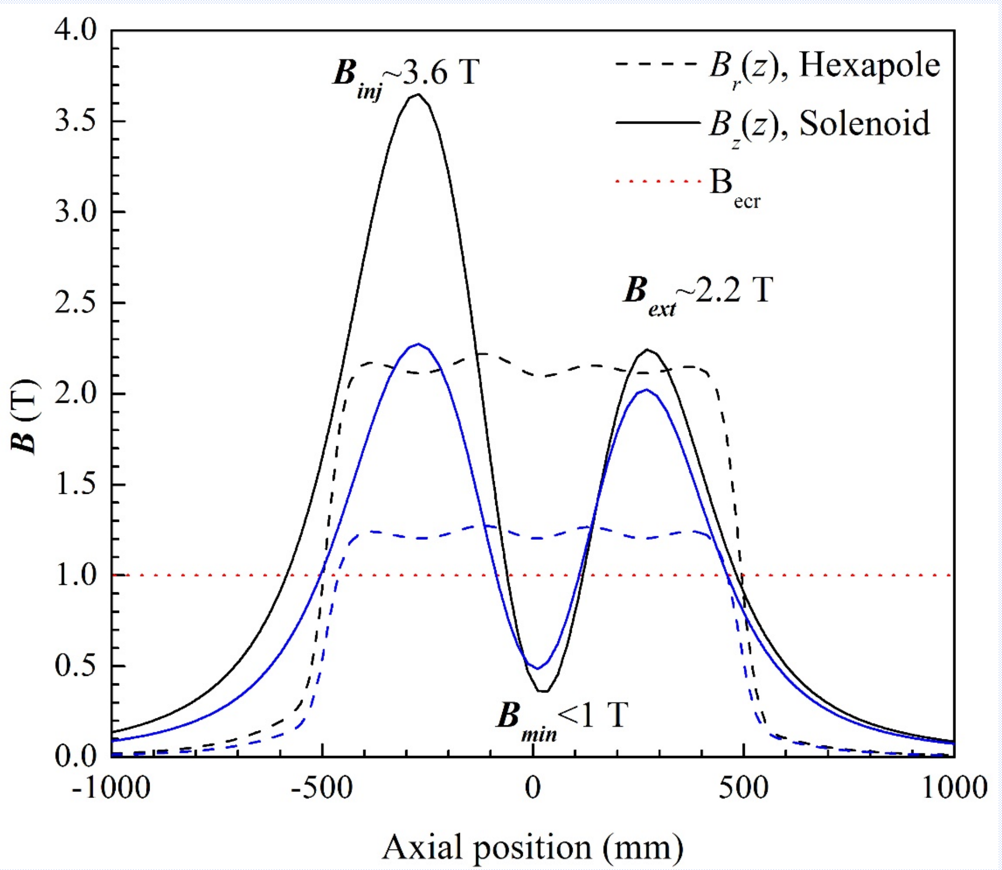
Superconducting magnet system



3 Solenoid + 1 hexapole magnet (step-type coils)

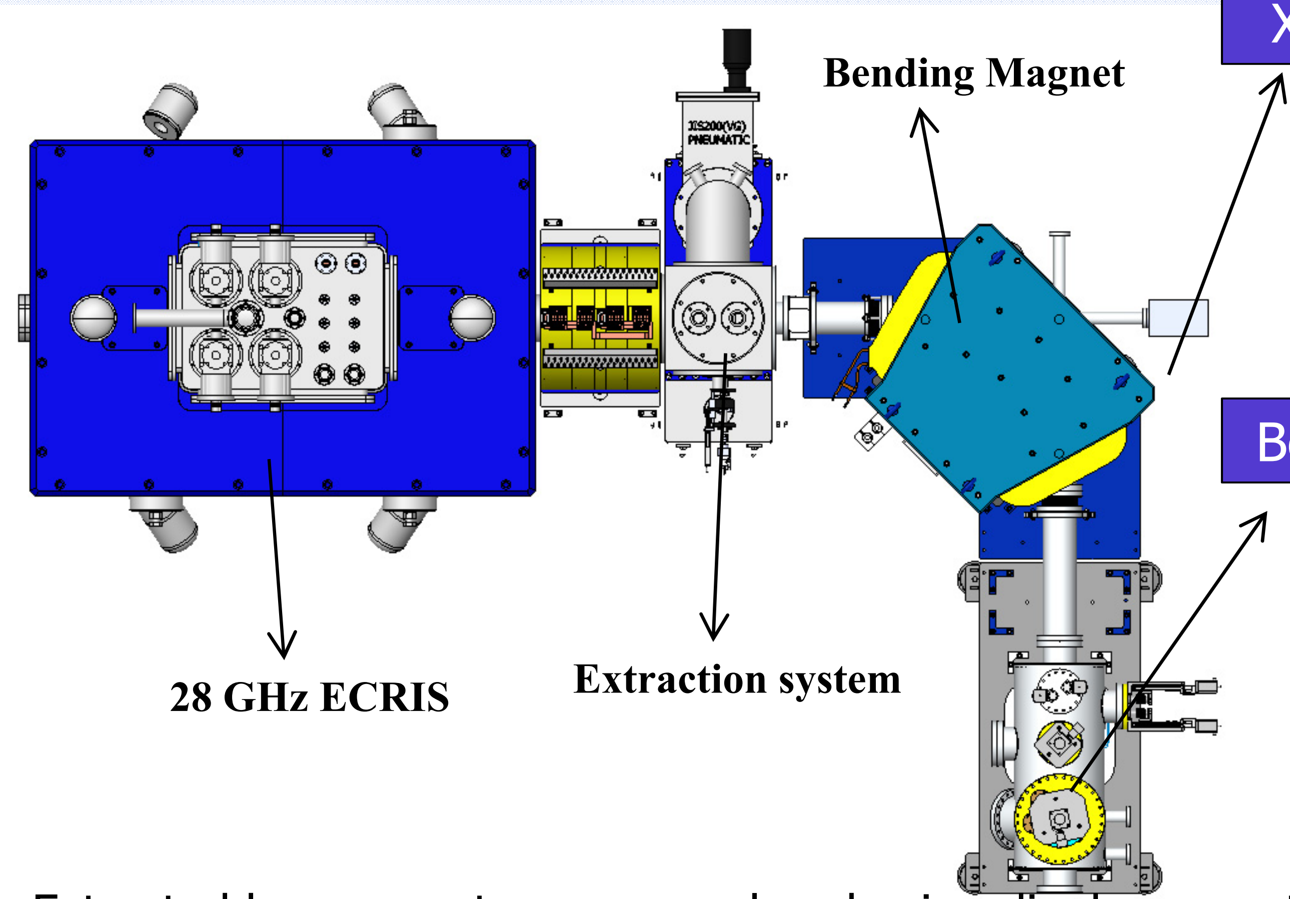
- The axial field: 3.6 T at injection, 2.2 T at extraction.
- The minimum axial field : 0.4 ~ 0.8 T.
- The radial field on the plasma chamber wall: 2.1 T

Superconducting magnet condition

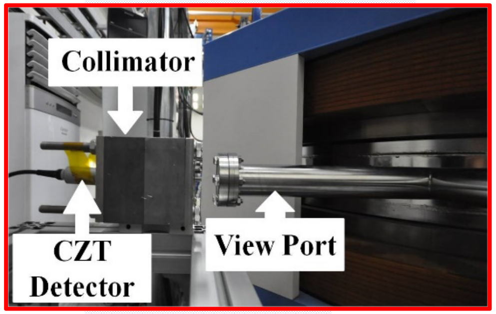


Location	Design values	Plasma ignition condition
B_{inj} (T)	3.65	2.3
B_{min}(T)	variable	0.45
B_{ext}(T)	2.24	2.02
B_r(T)	2.2	1.3

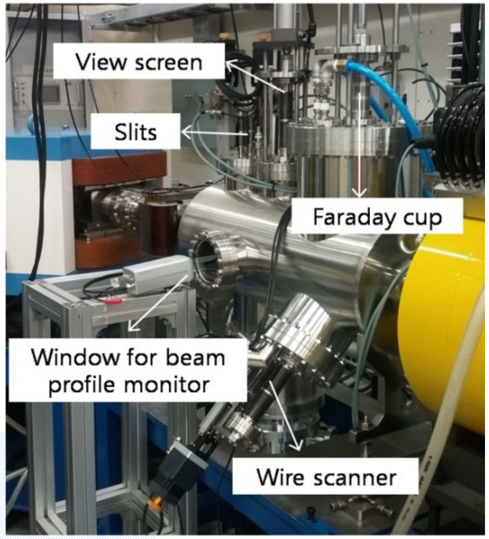
Beam measurement system in LEBT



X-ray detection system



Beam diagnostic system



- Extracted beam spectrum are analyzed using dipole magnet
- Also, x-ray from plasma chamber are measured with x-ray detection system
- Diagnostic tools are ready to evaluate the ion beam quality.

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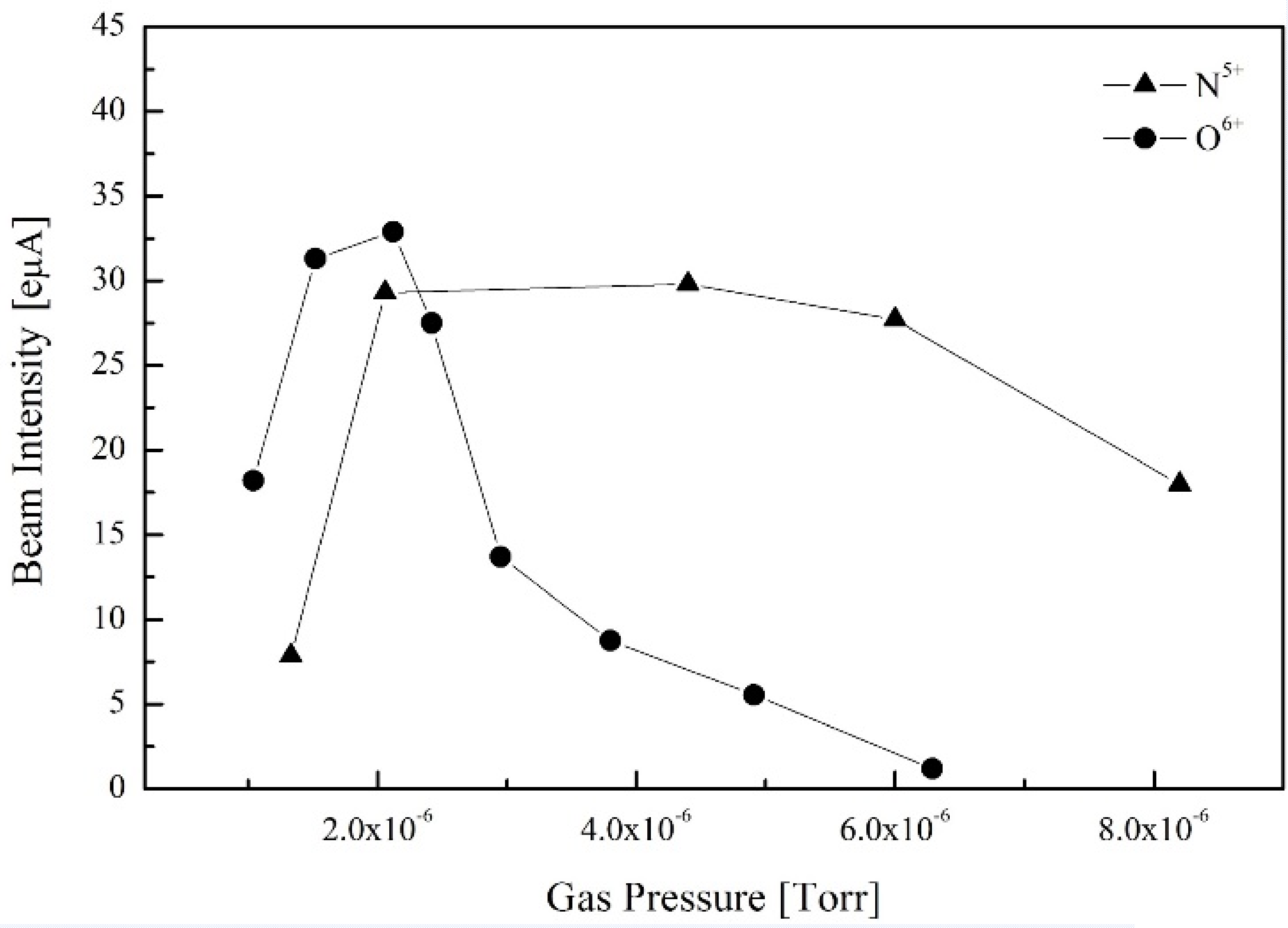
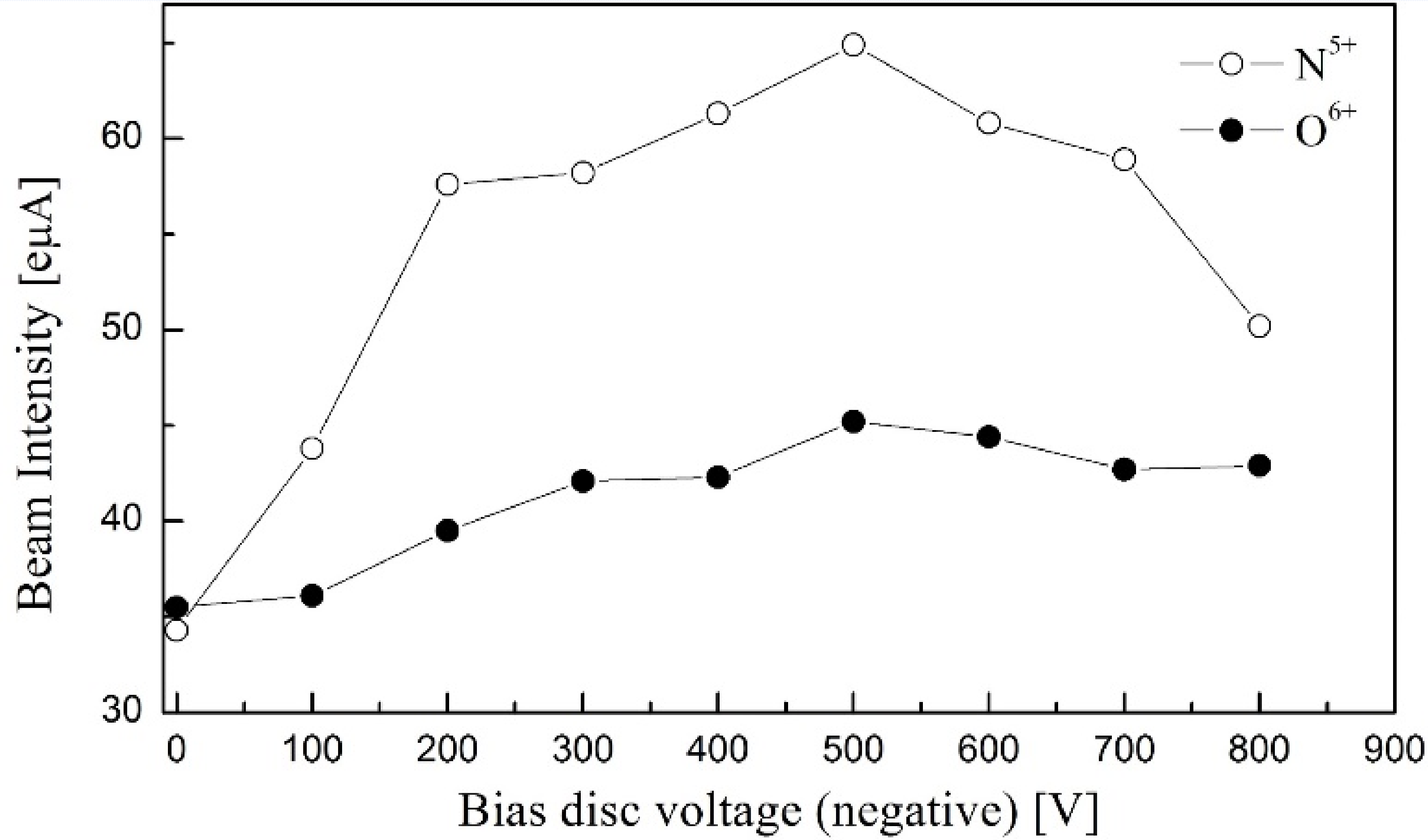
Commissioning of ECR ion source

- The first ECR plasma ignition was performed in August 2014
- The first ion beam was extracted from the ECR ion source in Feb. 2015
- Beam extraction with various conditions:
  - Superconducting magnet: B_{inj}=2.3T, B_{min}=0.48, B_{ext}=2.02T, B_r=1.3T
  - Plasma chamber pressure: ~ 10^{-8} Torr, ~10^{-6} Torr(after gas flowing)
  - MW power: 1kW
  - Extraction: Plasma electrode 13/30kV, Negative electrode 0/-10kV, Ground
- Modification:
  - Inner yoke installation for superconducting magnet
  - Electrode modification for enhancing emittance and insulation
  - Cooling system in the bias disc

Gas pressure effect on beam intensity



Bias disc effect on beam intensity



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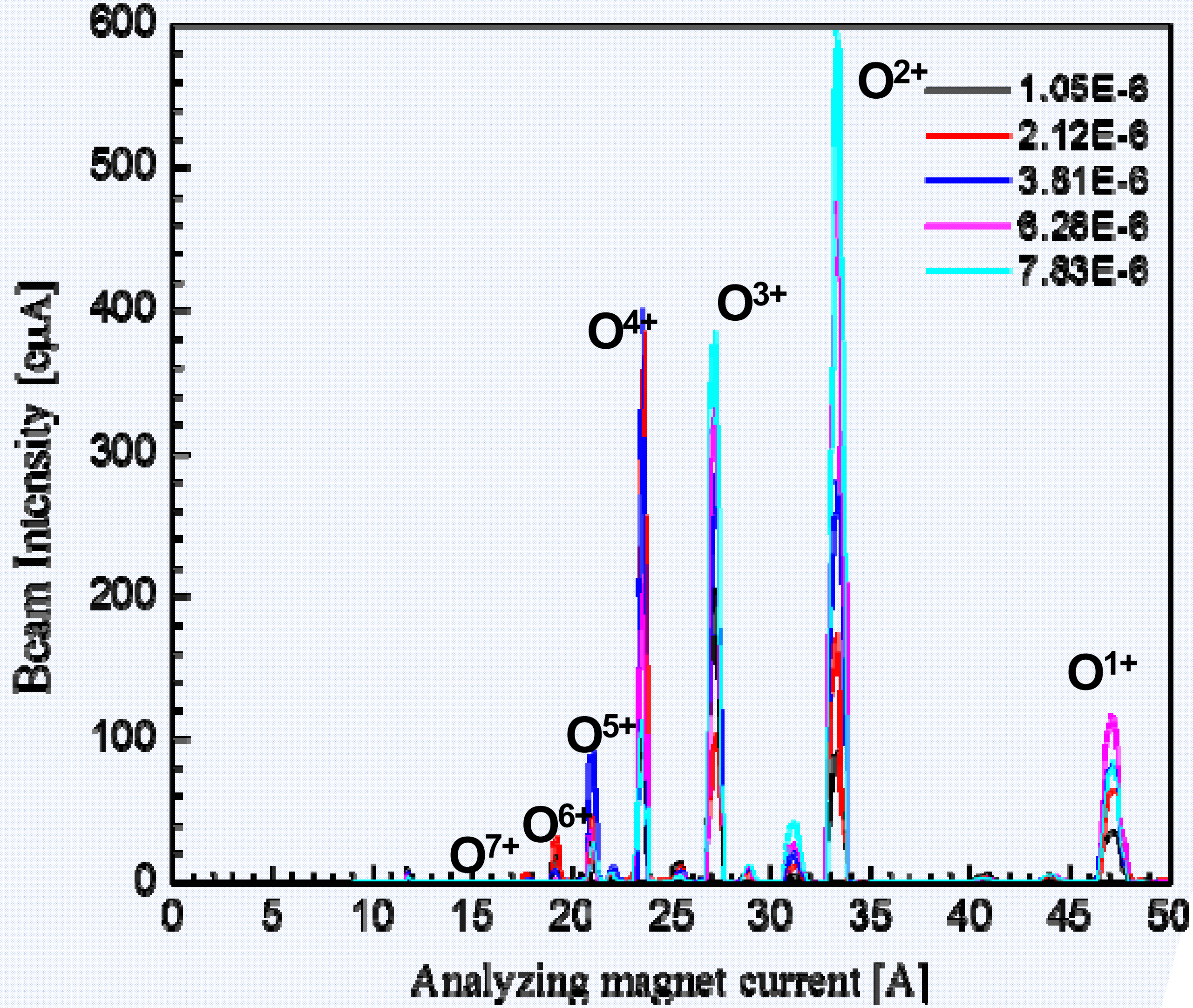
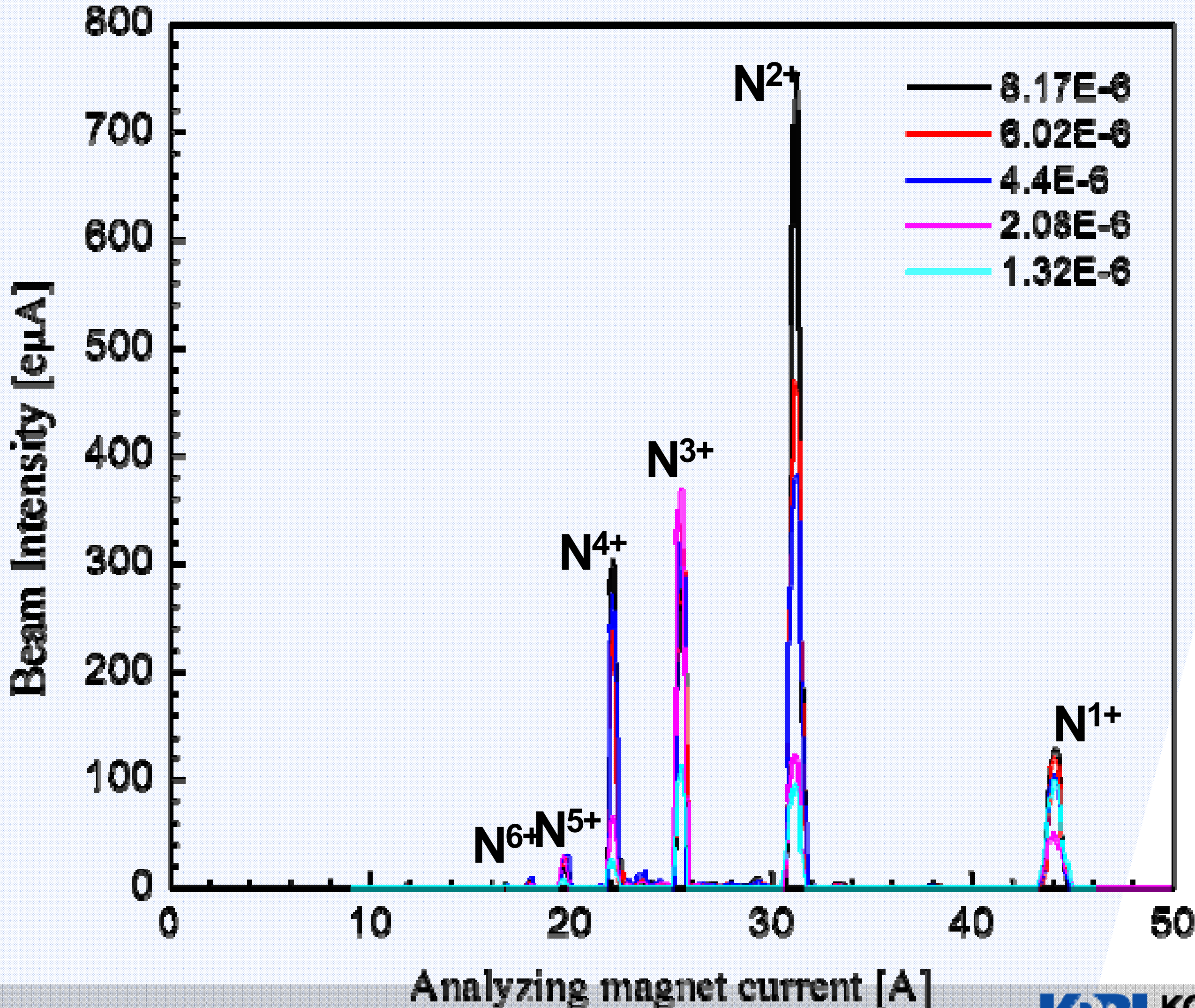
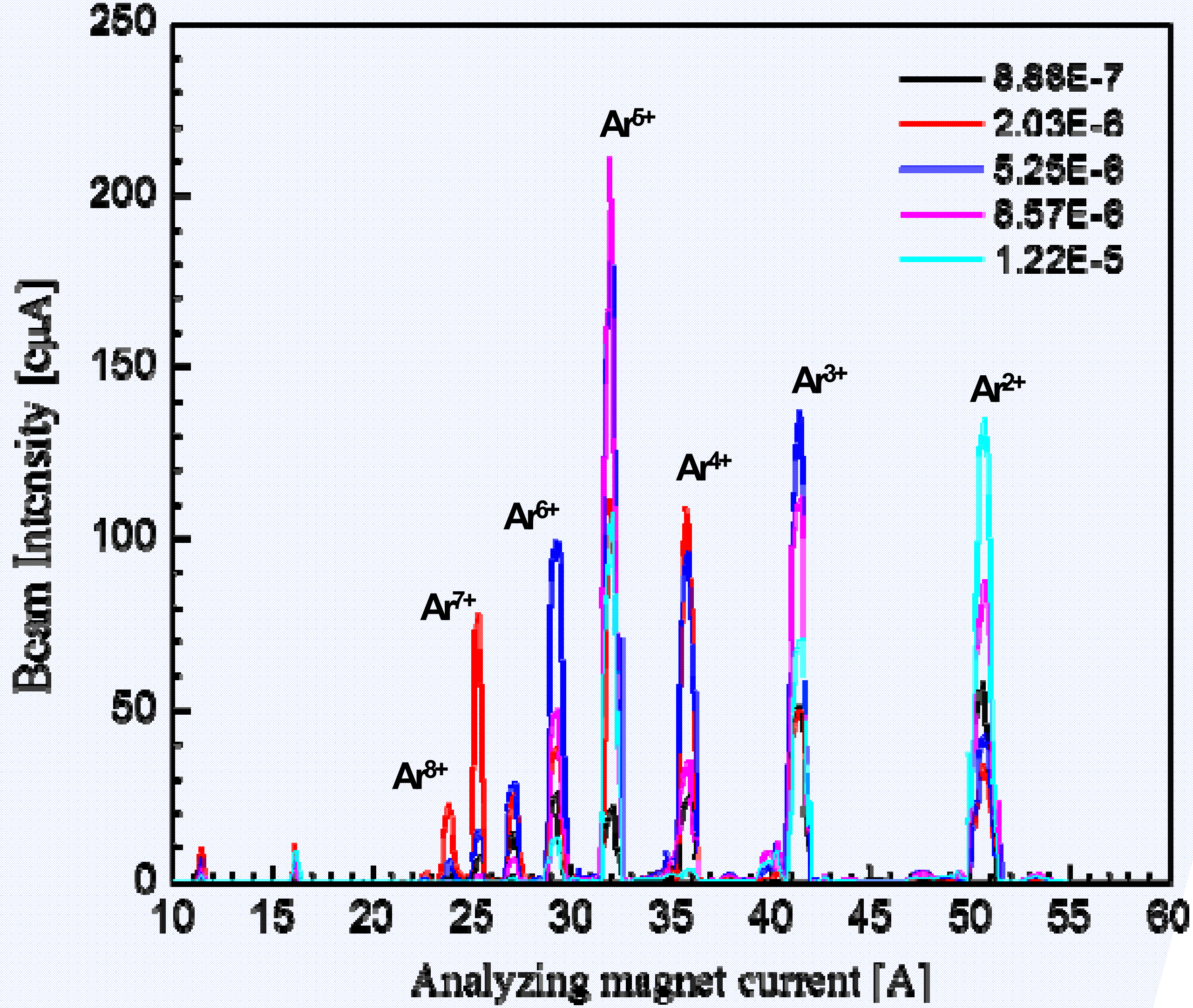
Oxygen: gas pressure



Nitrogen: gas pressure



Argon: gas pressure



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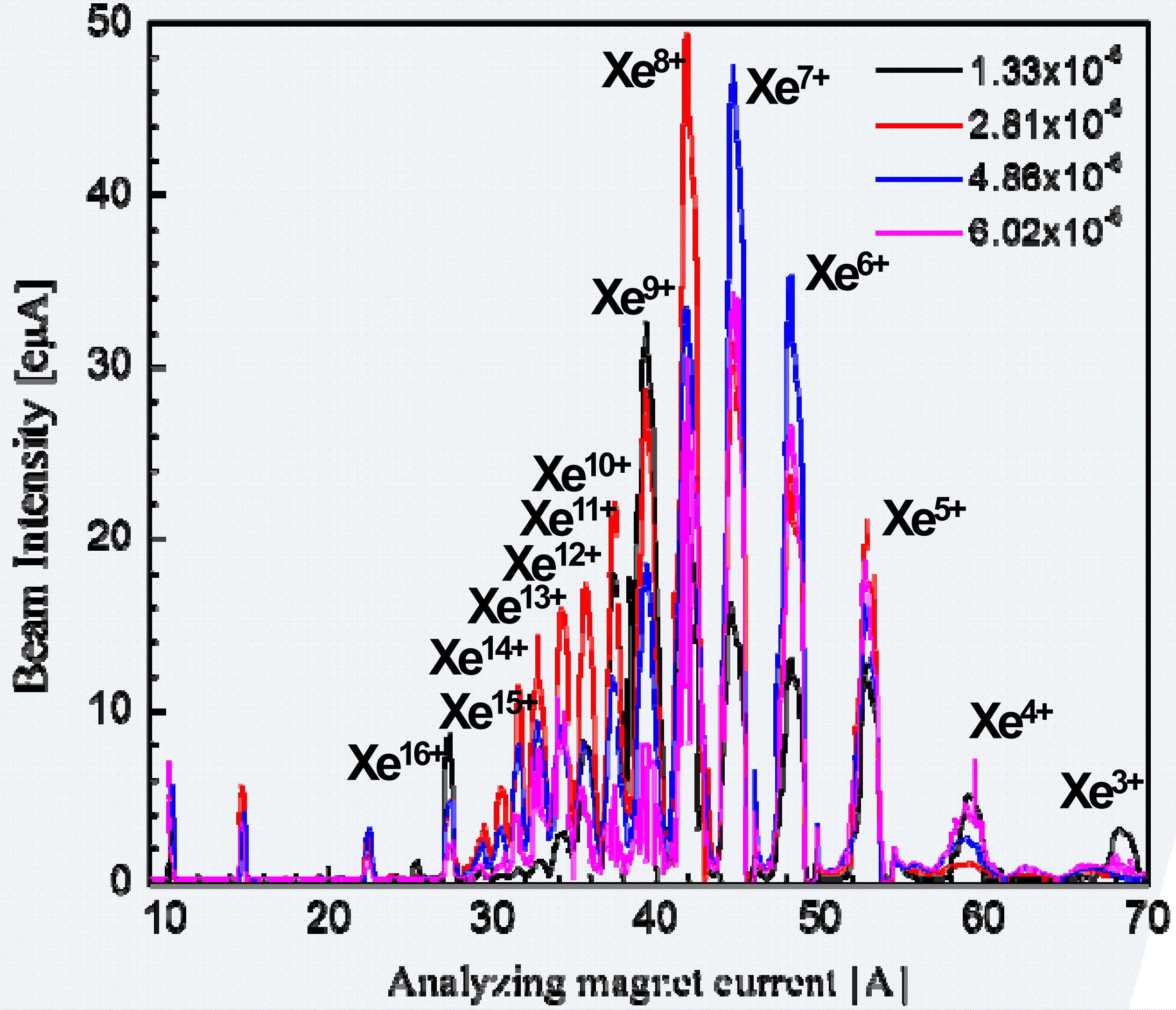
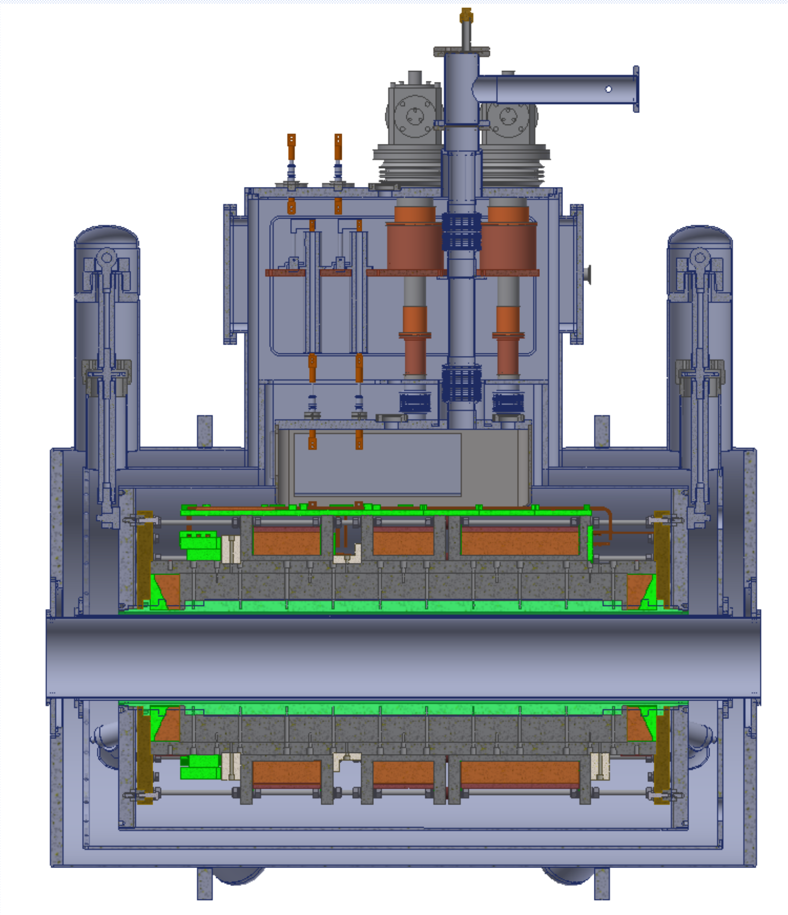
Xenon: gas pressure

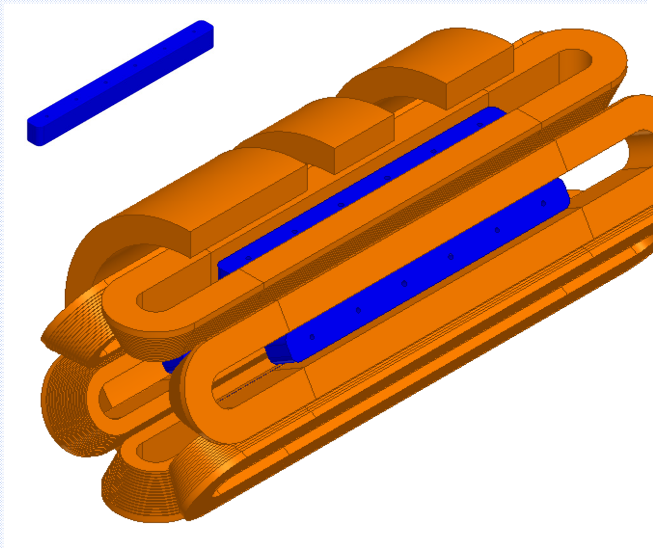


Some modification
further enhancement

Superconducting magnet modification

- Inner yoke installed to increase the B_r at same operating current
- Some improvements have been made in LHe recondensing device





WEPP20, J. G. Hong et.al.

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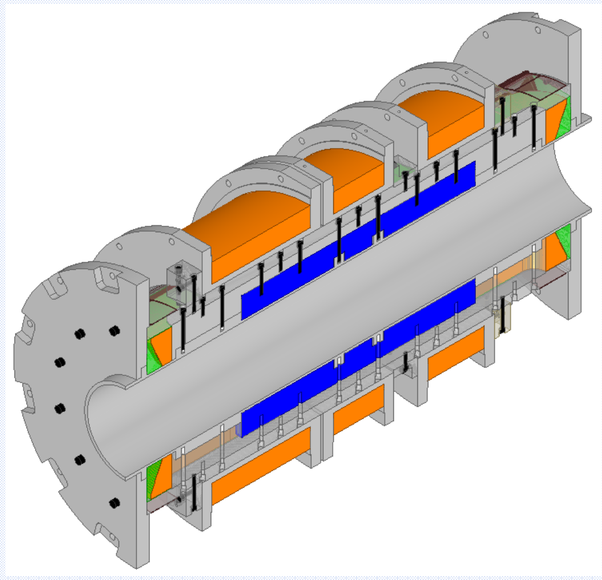
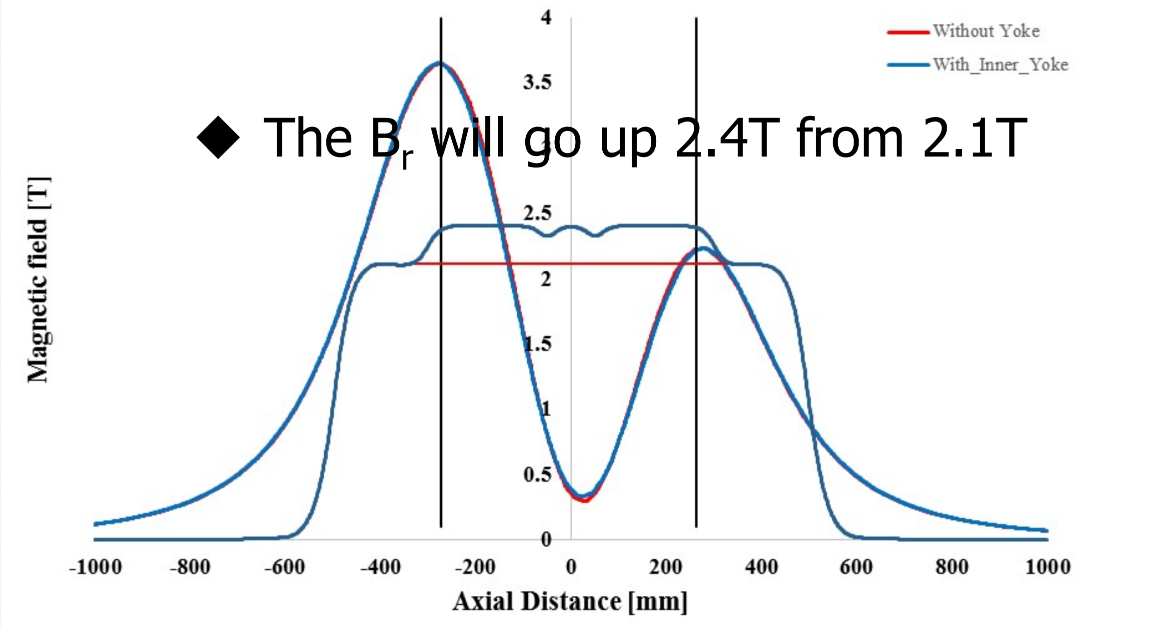
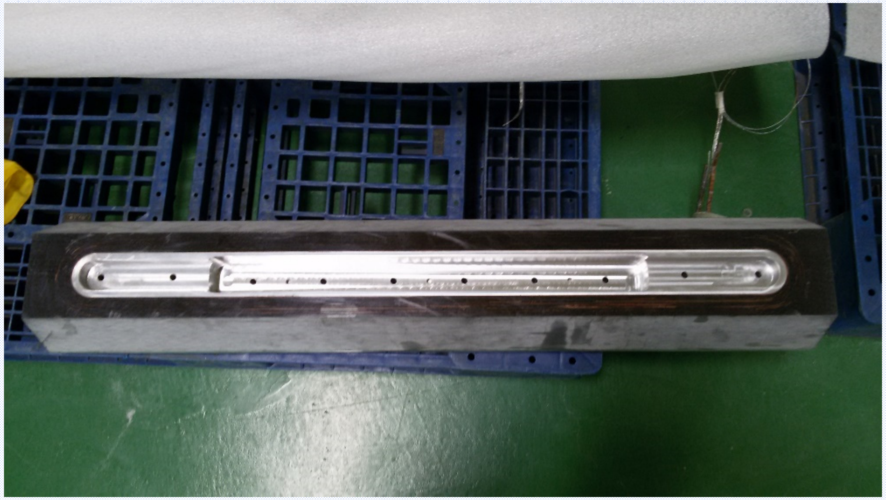
Superconducting magnet modification

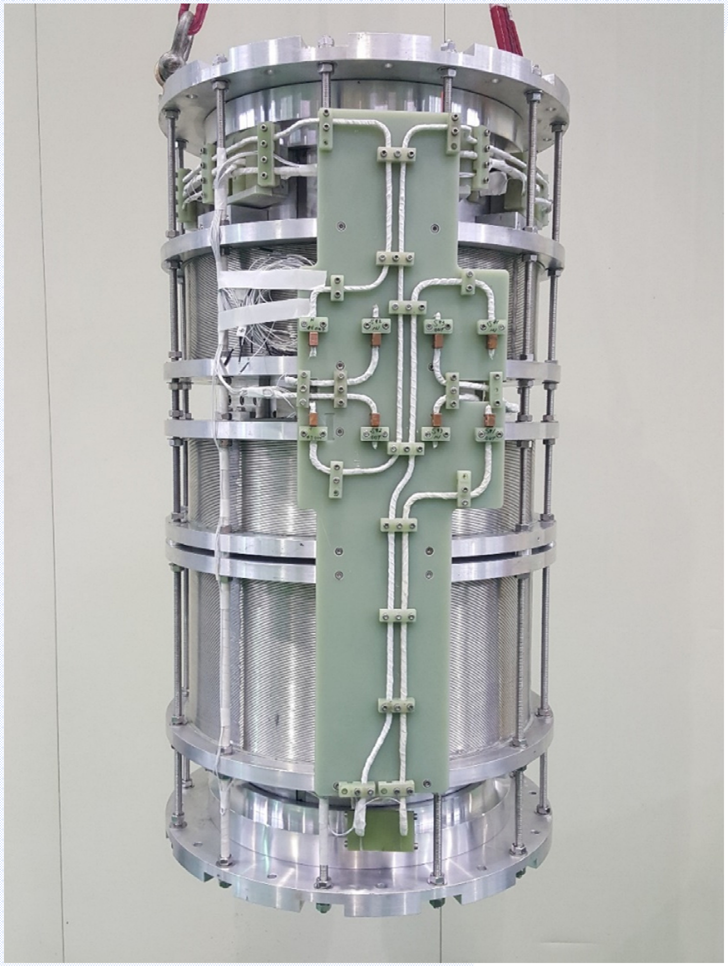




- The B_r will go up 2.4T from 2.1T

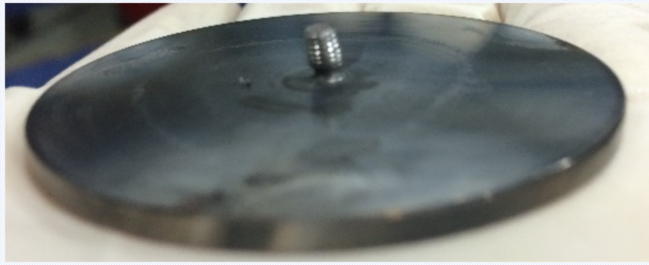
Superconducting magnet modification

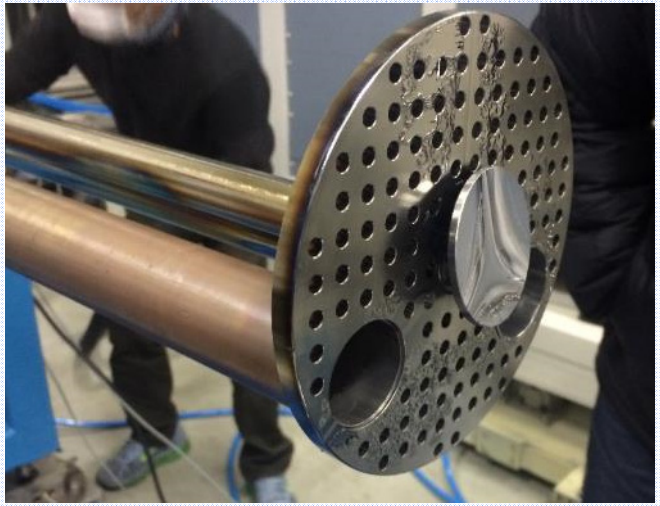


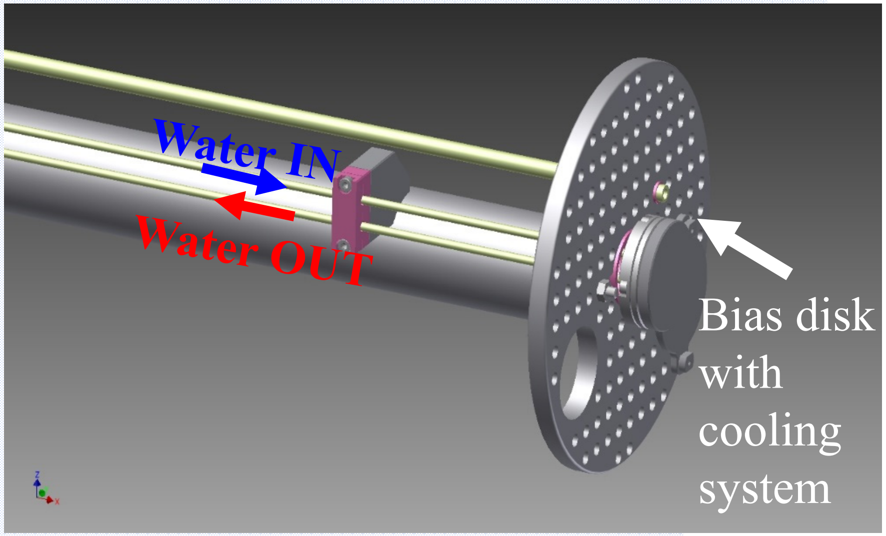


Launcher and Bias disc modification

◆ Bias disc has been improved with cooling system

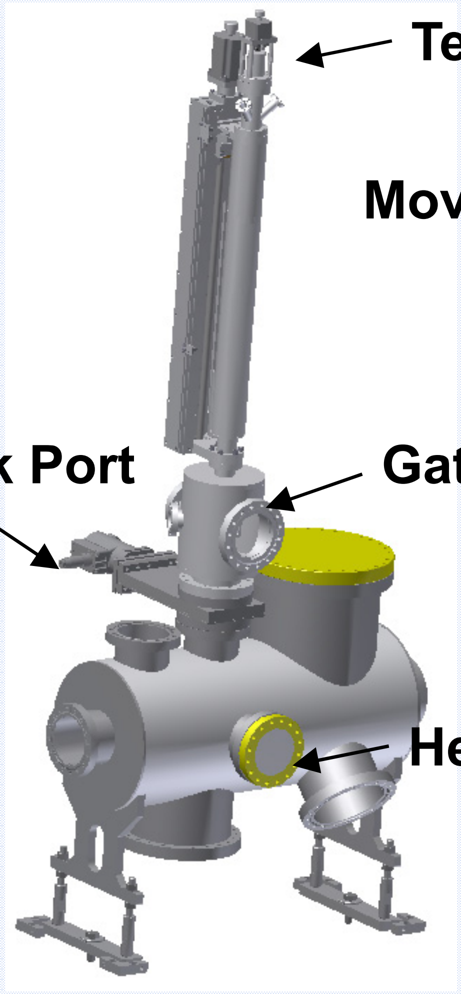






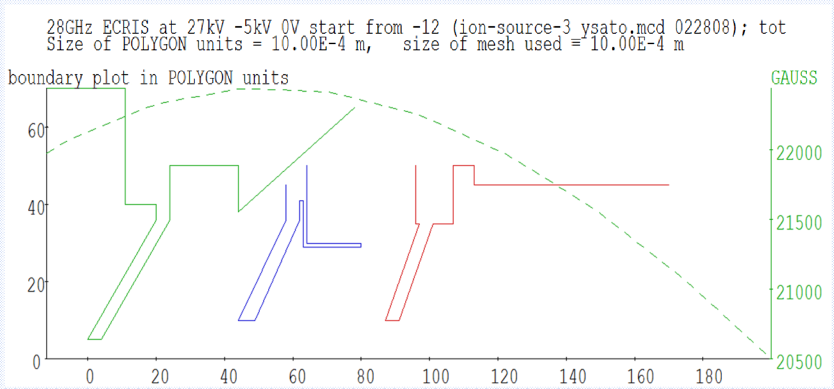
Ion beam process chamber

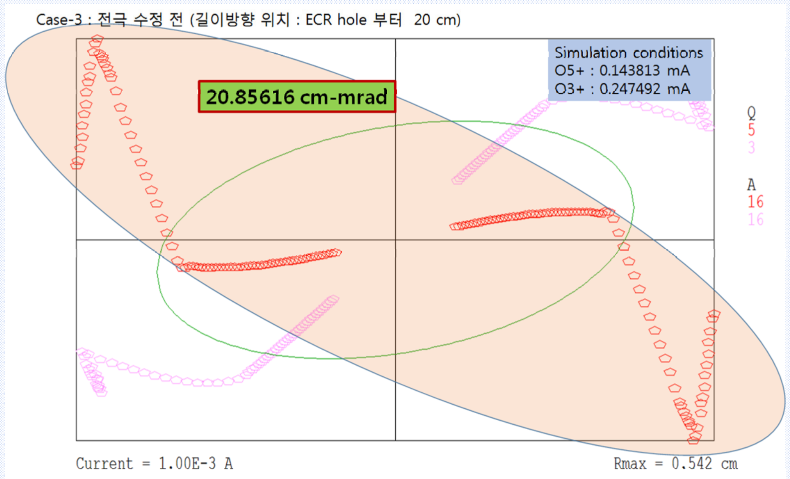
- Ion beam process chamber and device are ready for user



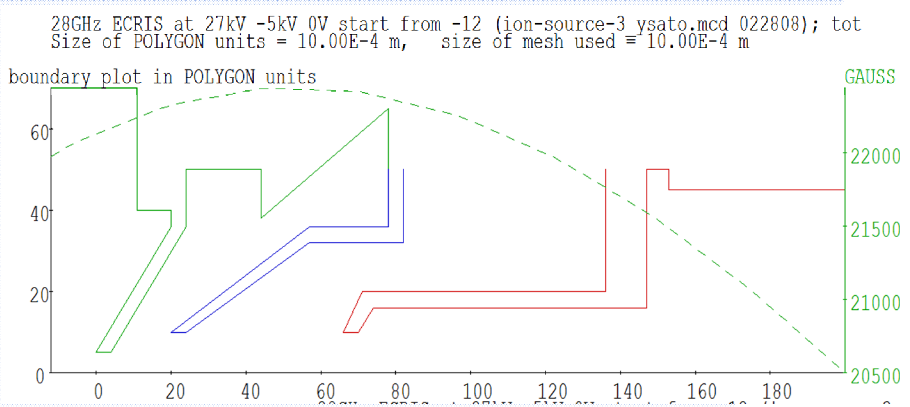
Electrode modification

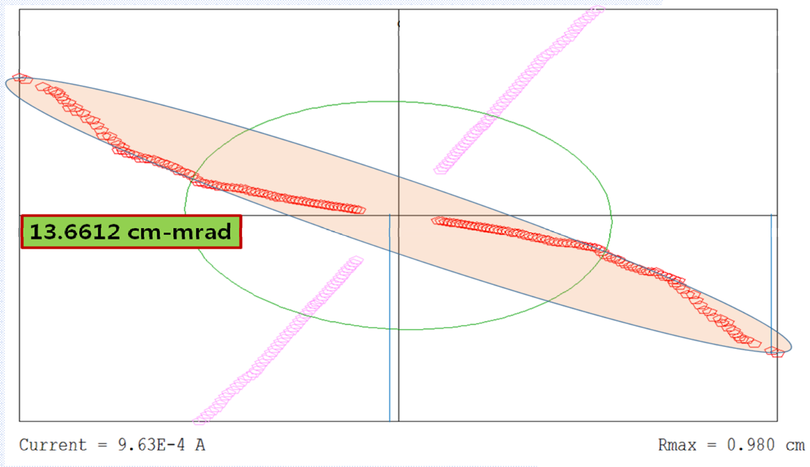
before





After





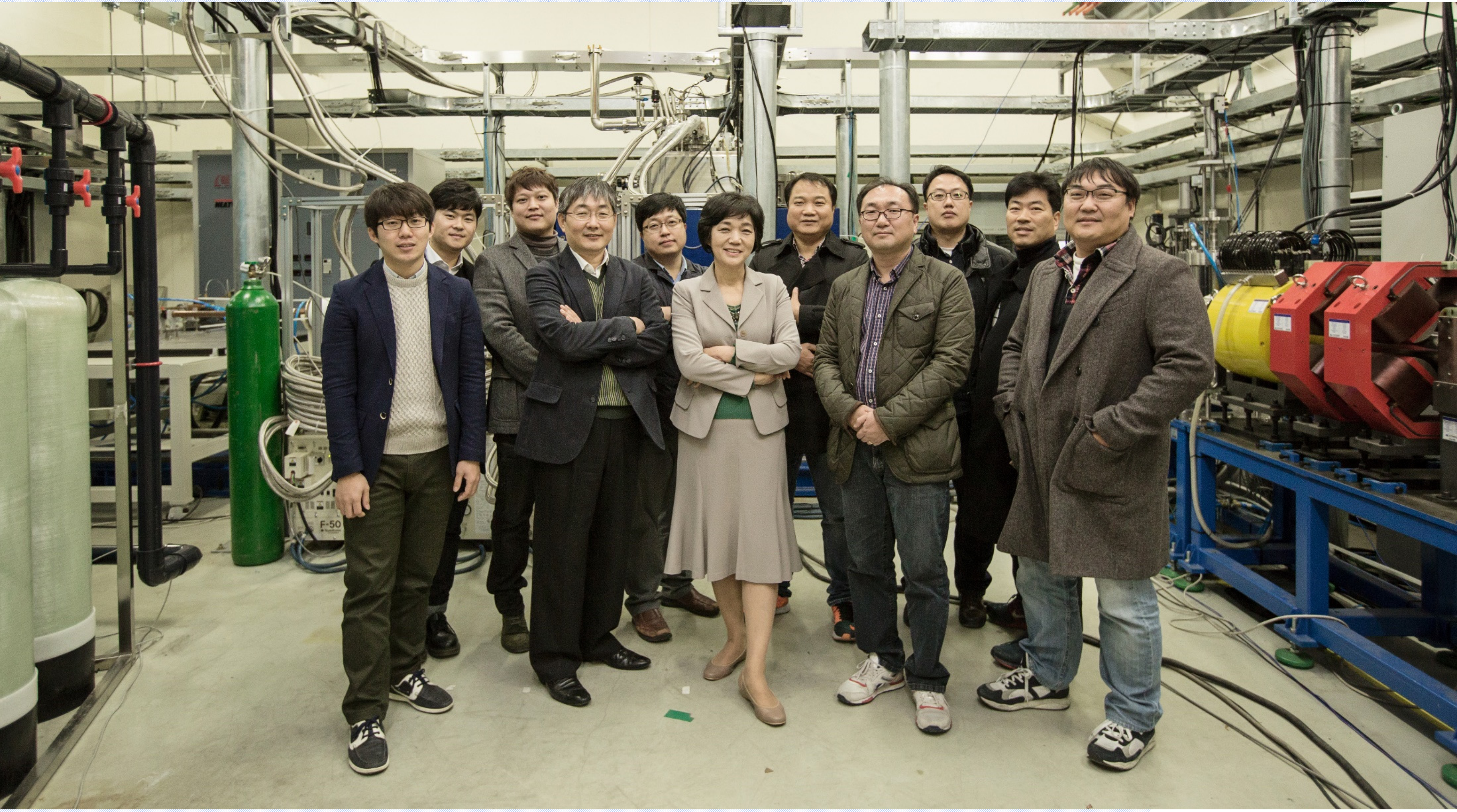
Future plan

- Superconducting magnet training and cryogen recondensing
- Beam diagnosis under full operation of LEBT
- RFQ tunning
- Further optimization of ECR ion source operational condition
- Ion beam service for applicable user group

Future plan: Ion beam utilization building

- Construction: 2015-2017 (2018)
- 1 beam utilization building, 1 supporting building, 4,099m^2

Members of ion beam application research team



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