Design of a new 18 GHz ECRIS for RIKEN RIBF

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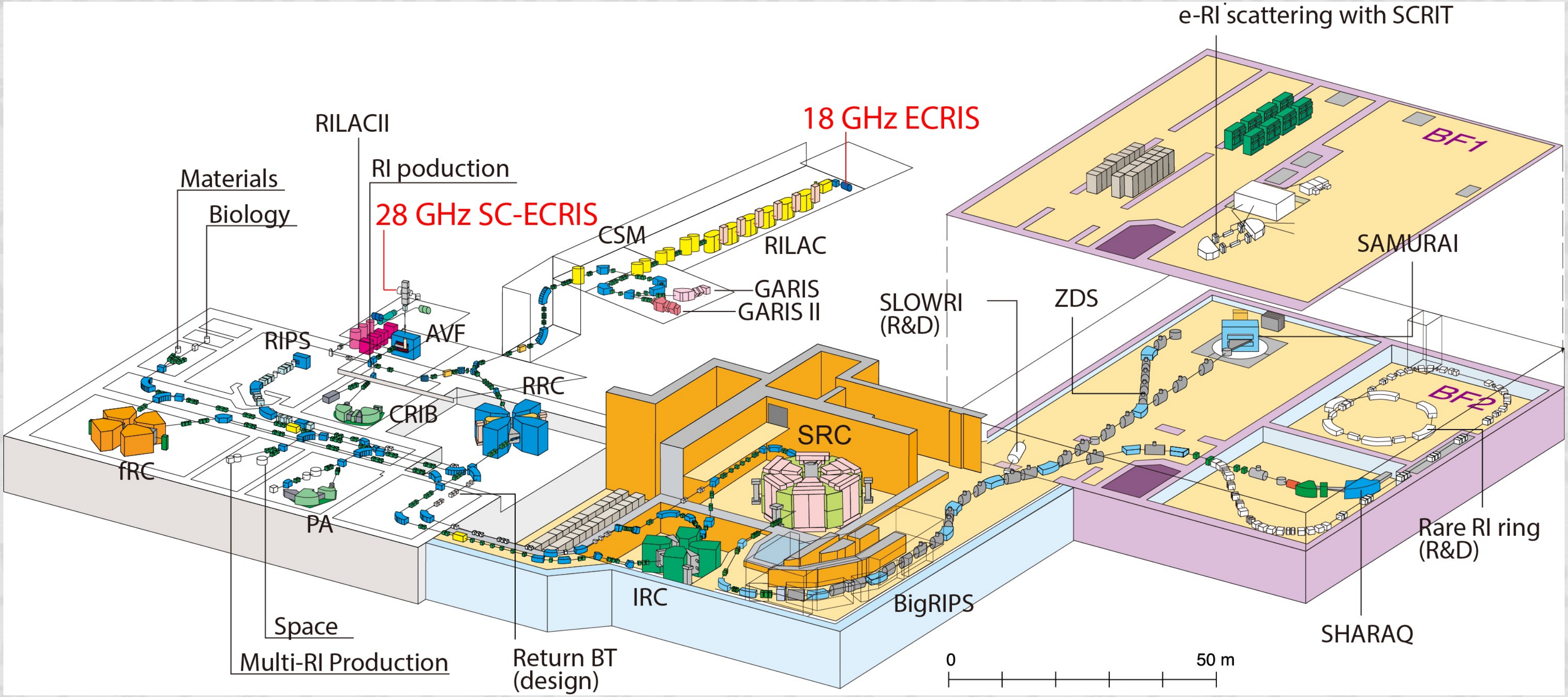
  - Plasma chamber
  - 18 GHz microwave generator
- Summary

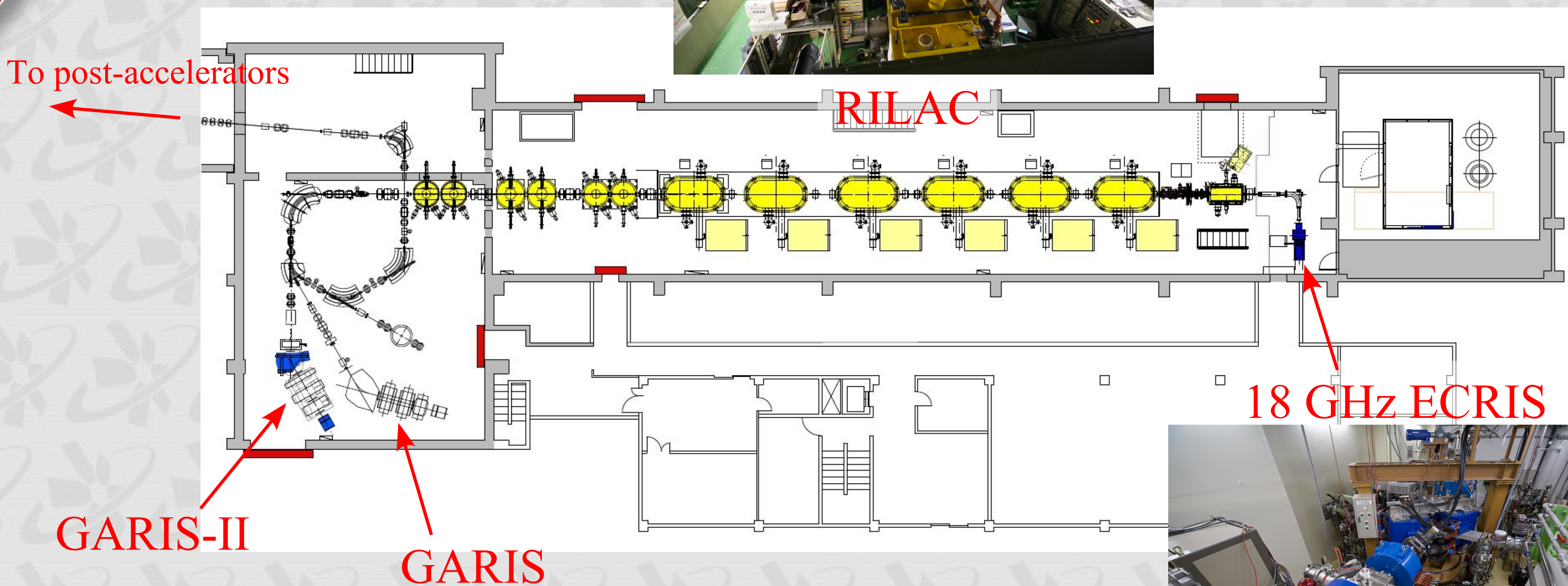
RIKEN Radio Isotope Beam Factory (RIBF)

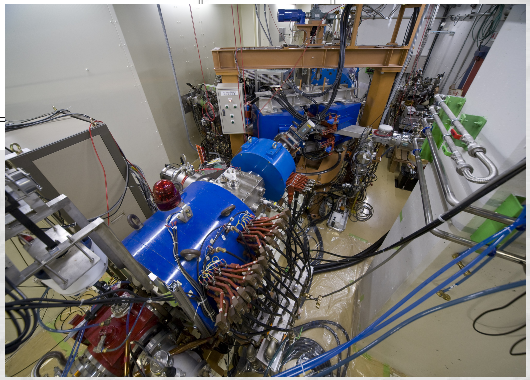
- Search for the new elements and isotopes
- Study of the nuclei far from stability line

Acceleration of the highly-charged intense beams of H~^{238}U



RIKEN Linear Accelerator (RILAC)

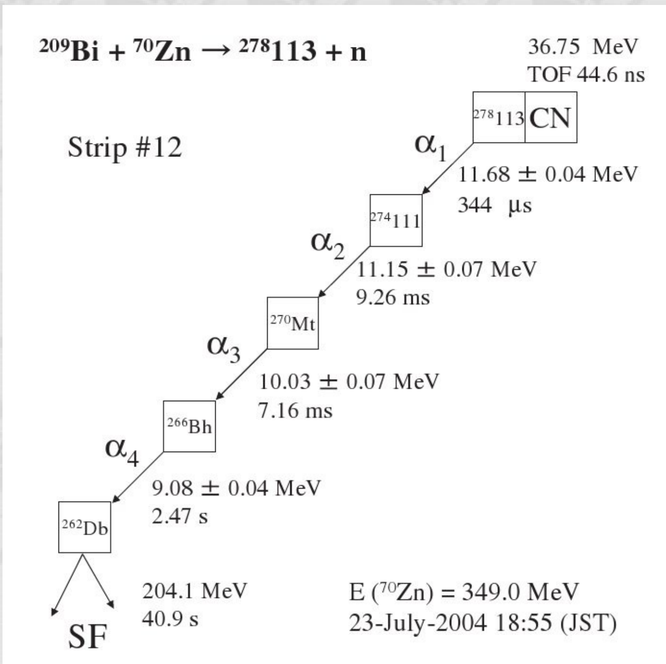




Search for the Super-heavy elements

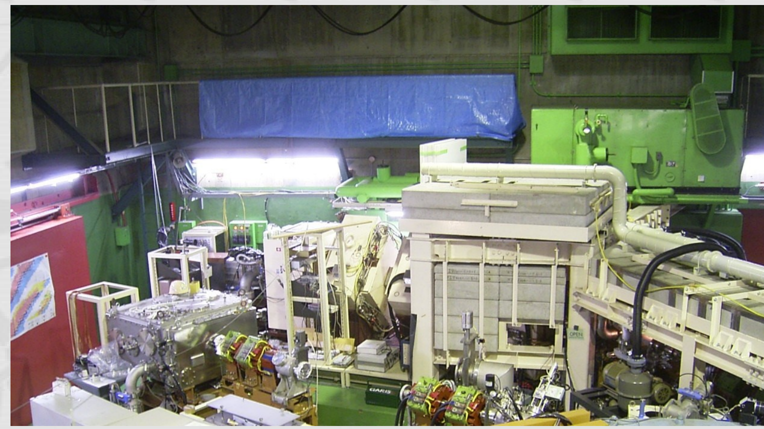
113^{th} element

Decay chain observed in irradiation of ^{209}Bi targets by ^{70}Zn projectiles



K. Morita et al., J. Phys. Soc. Jpn. 73 (2004) 2593

Gas-filled Recoil Ion Separator (GARIS)



1^{st} event	23-Jul-2004
2^{nd} event	2-Apr-2005

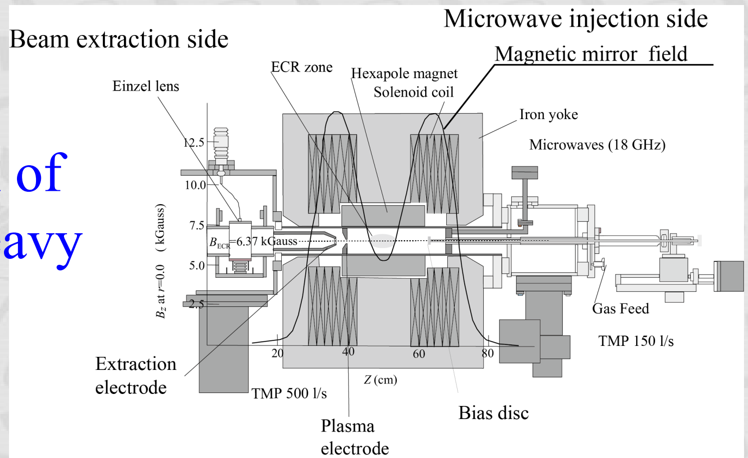
Experiment still continues...

Supply of the $^{70}Zn^{15+}$ beam over a long period

RIKEN 18 GHz ECRIS

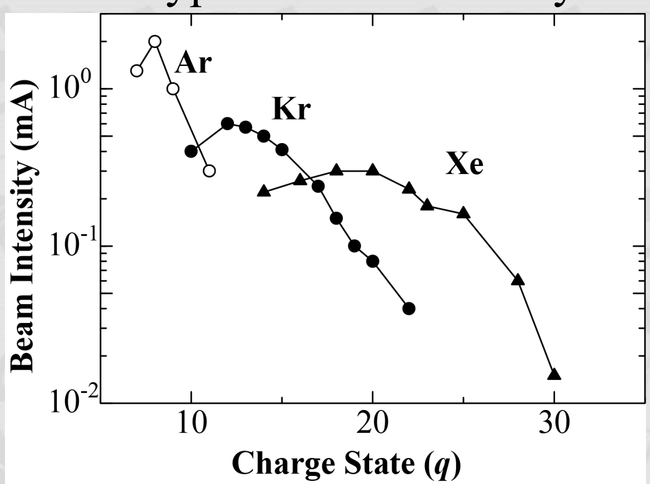
External ion source for the RILAC

Production of medium-heavy ions



$^{40}Ar^{8+}$	2 emA
$^{40}Ar^{9+}$	1 emA
$^{84}Kr^{13+}$	0.6 emA
$^{48}Ca^{10+}$	40 eμA
$^{70}Zn^{15+}$	30 eμA

Typical beam intensity



T. Nakagawa et al., Nucl. Instr. and Meth. B 226 (2004) 392

Main parameters of the ion source

Mirror coils	
Maximum current	800 A
Maximum field on axis	1.4 T
Mirror ratio	3
Hexapole magnet	
Inner diameter	80 mm
Outer diameter	170 mm
Length	200 mm
Material	Nd-B-Fe
Field strength on surface	1.4 T
Microwave	
Frequency	18 GHz
Maximum power	1.5 kW
Extraction	
Maximum voltage	20 kV

Development of the low-temperature oven

Low-temperature oven for
- stable supply of the ^{48}Ca ion beam
- development of other metallic beams

Motivation for the new 18 GHz ECRIS

Existing operational difficulty

· Requirements for the new beam
→ Developments of the new beam

↕ Difficult to satisfy both tasks

· Long irradiation time (> 1 month)
and high operation rate throughout the year

By equipping another ECRIS for the RILAC,

Development of the new beam
Beam supply for the experiments
} Compatible

\+

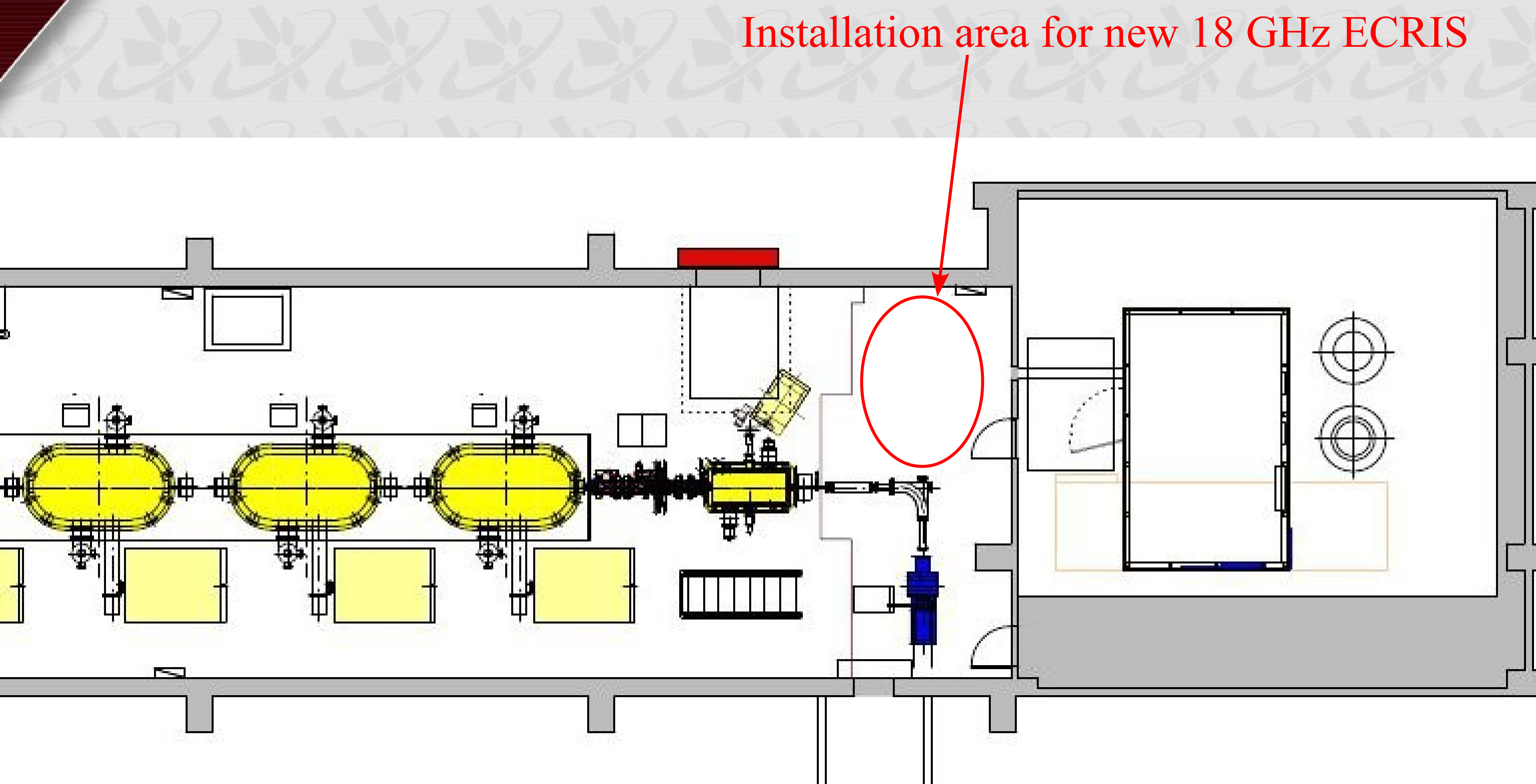
Flexible operation of the ion sources

- Compliment or exchange of the material
- Maintenance
- Trouble !

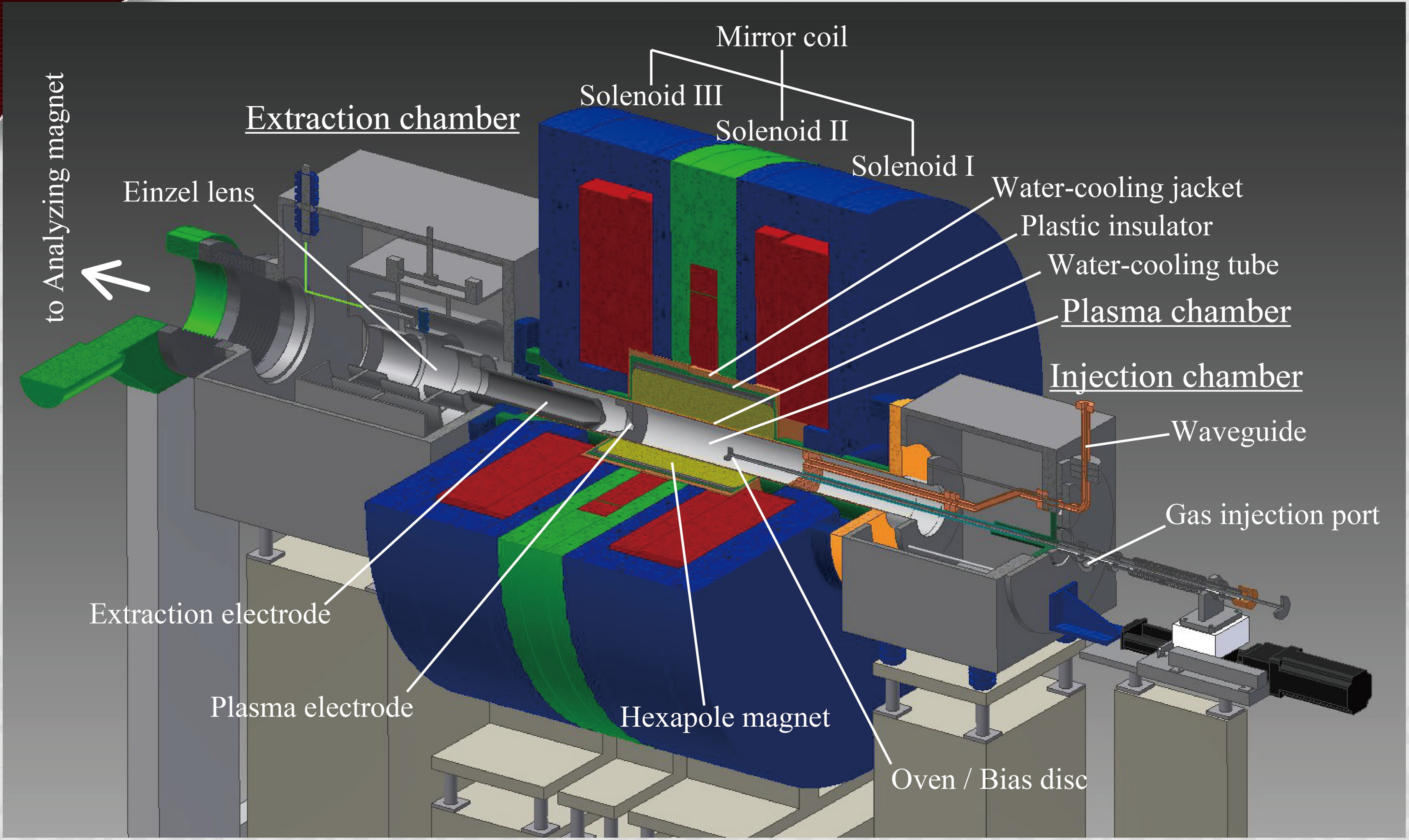
⋮

(Microwave of 18 GHz is sufficient to produce required intensity of medium-heavy ion beam)

Installation of the new 18 GHz ECRIS



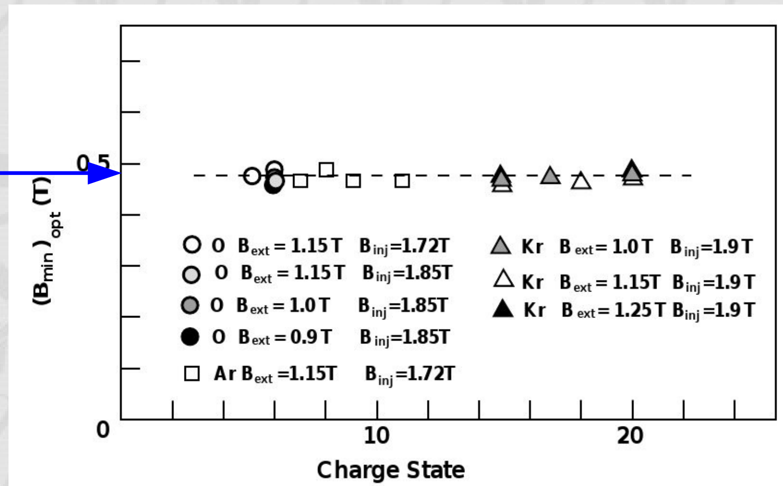
Overview of the new 18 GHz ECRIS



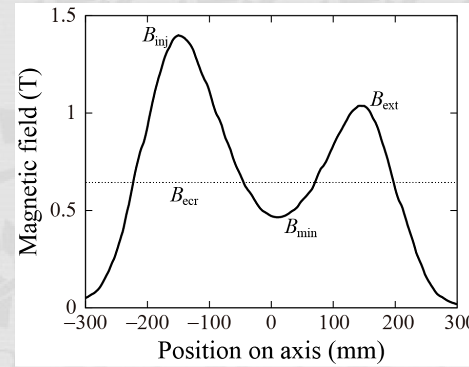
Mirror coil (1)

The optimum B_{min} for various charge state of heavy ions

$0.7 \sim 0.8 \times B_{ecr}$



H. Arai et al., Nucl. Instr. Meth. A 491 (2002) 9



Typical magnetic field distribution along the axis

B_{min} ←——→ beam intensity

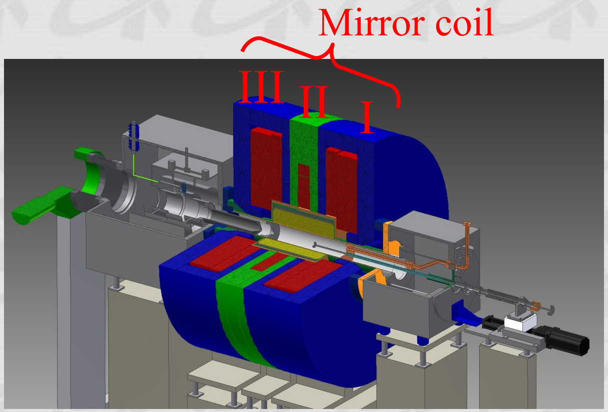
Strong correlation: B_{min} should be kept constant

Requirements

Mirror ratio ←——→ charge state

Correlation via confinement time of the plasma: Mirror ratio should be variable for maximizing the beam intensity of required charge state

Mirror coil (2)



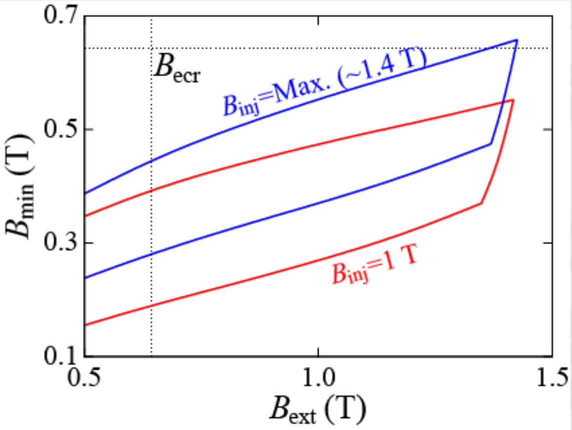
Three solenoid coils

↓

Mirror ratio, B_{min} } Settable independently

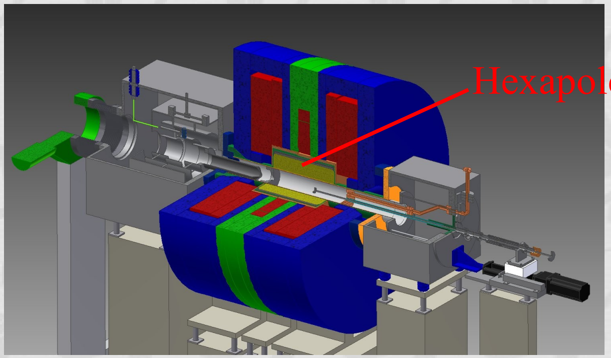
Specifications of the Mirror coil

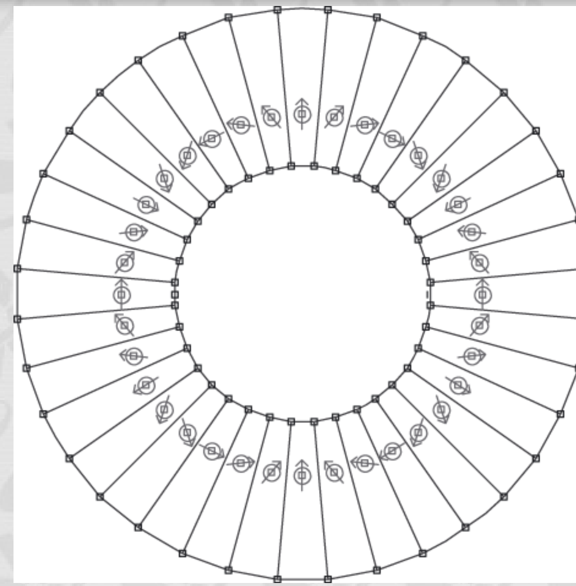
	Solenoids I & III	Solenoid II
Number of turns	296	60
Maximum current	660 A	300 A
Maximum voltage	105 V	10 V
Maximum intensity of the magnetic field		>1.3 T
Minimum intensity of the magnetic field		<0.5 T



Possible combination of B_{ext} and B_{min}

Hexapole magnet





Schematic drawing of the hexapole magnet.
Arrows indicate the direction of magnetization

Specifications of the Hexapole magnet

Inner diameter	85 mm
Outer diameter	186 mm (magnet only)
	210 mm (including holding jacket)
Length	250 mm
Material	Nd-B-Fe
Number of divisions	36
Magnetic field intensity	~1.3 T at the inner surface of the plasma chamber (79 mmϕ)

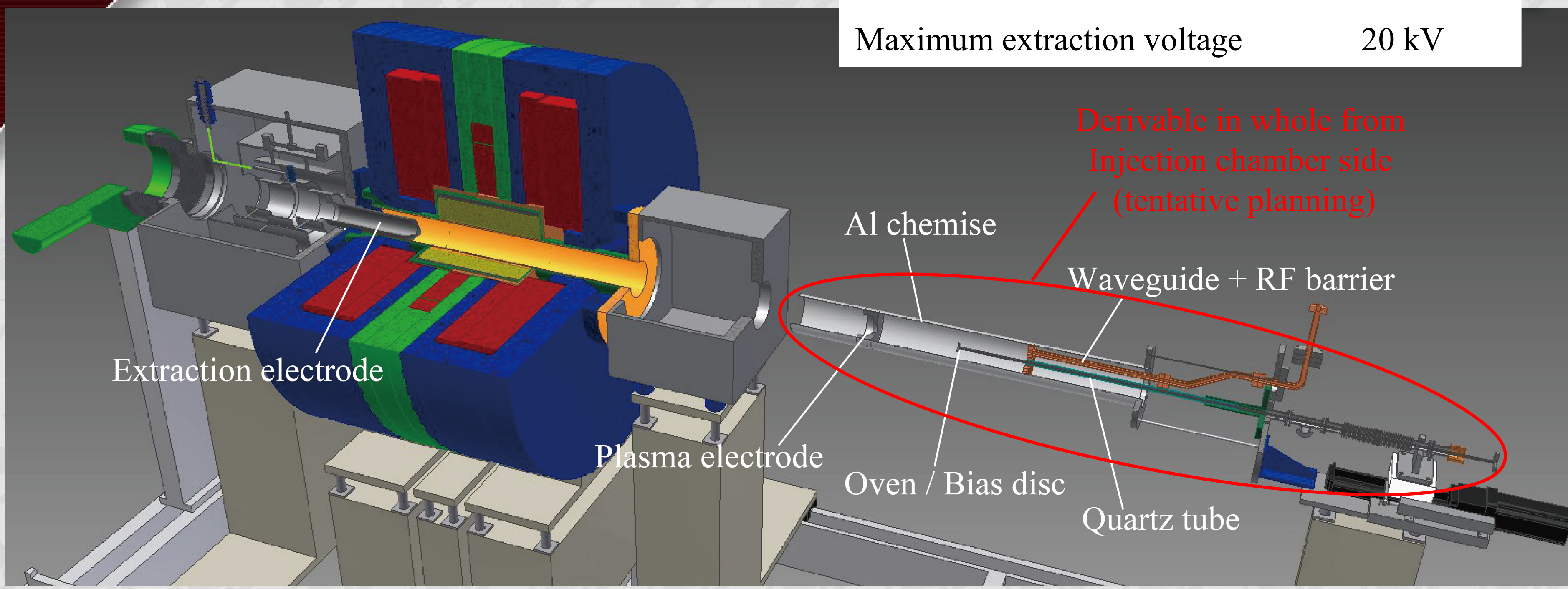
Nd-B-Fe ← Countermeasure against demagnetization

Plasma chamber (1)

Two TMPs of ~500 L/s

Specifications of the Plasma chamber

Inner diameter	79 mm
Vacuum	$<1.0\times10^{-7}$ Torr
Maximum extraction voltage	20 kV



Position of { Extraction electrode / Oven / Bias disc }

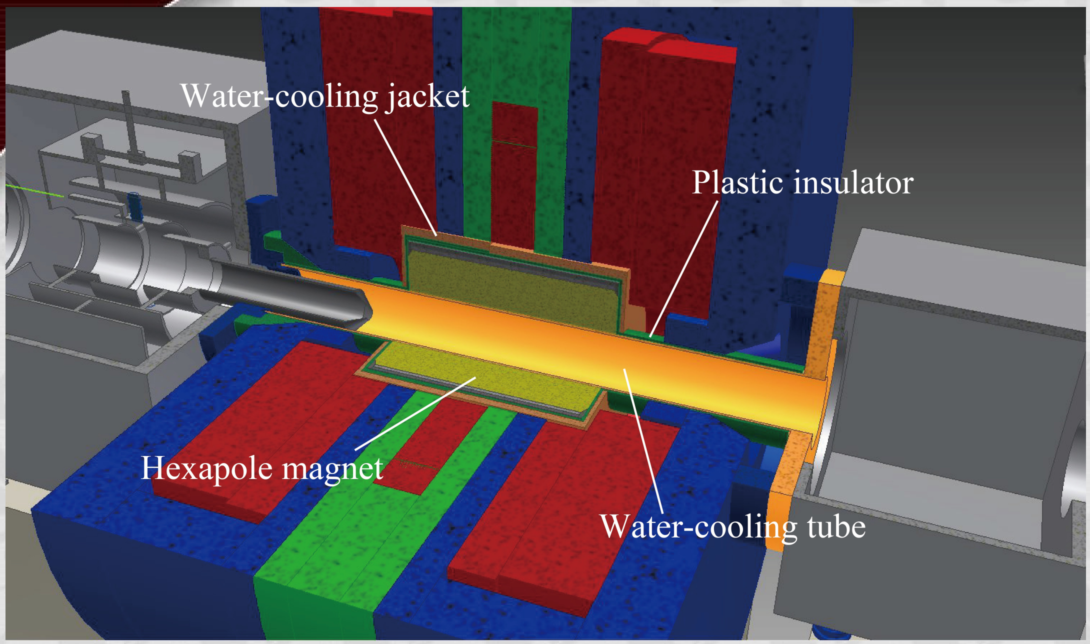
Negative voltage of the Bias disc

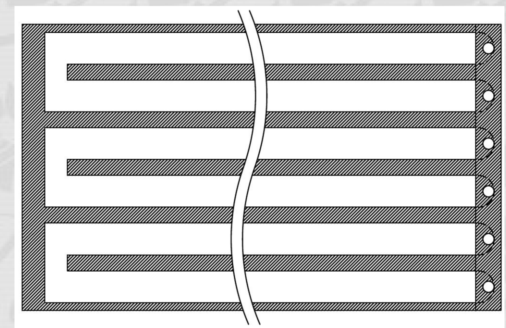
} Controlled remotely

Re-evaporation of atoms attached to the inner wall

Plasma chamber (2)

Prevention of the demagnetization of the hexapole magnet





Water channel of the Water-cooling tube (developed figure)

Water-cooling jacket

Water-cooling tube

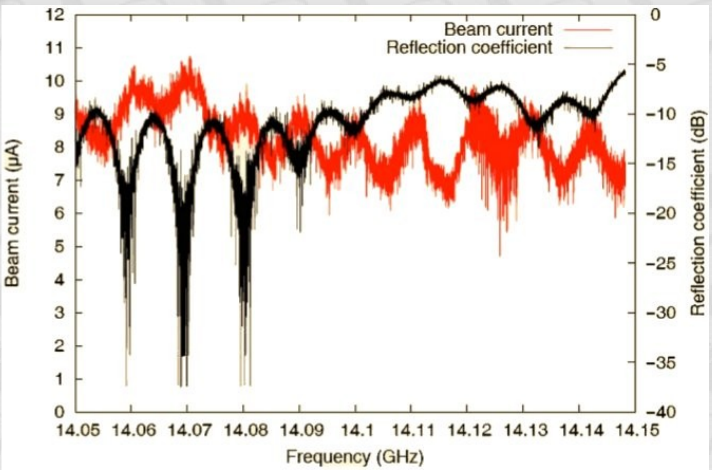
20°C, ~6 L/min

Solenoid coils → ~~Heat load~~ → Hexaple magnet ← ~~Heat load~~ ← ECR plasma

18 GHz microwave generator (1)

"Frequency tuning" is effective to enhance the beam intensity

L. Celona et al., Rev. Sci. Instrum. 81, 02A333 (2010)



Electric field distribution
on the resonance surface

→ { ECR heating
Ionization process

Microwave frequency ⟷ Geometry of the plasma chamber and ECR zone	match	mismatch
Isodensity surface of the plasma	smooth	corrugated
Charge state	high	low
Brightness	high	low

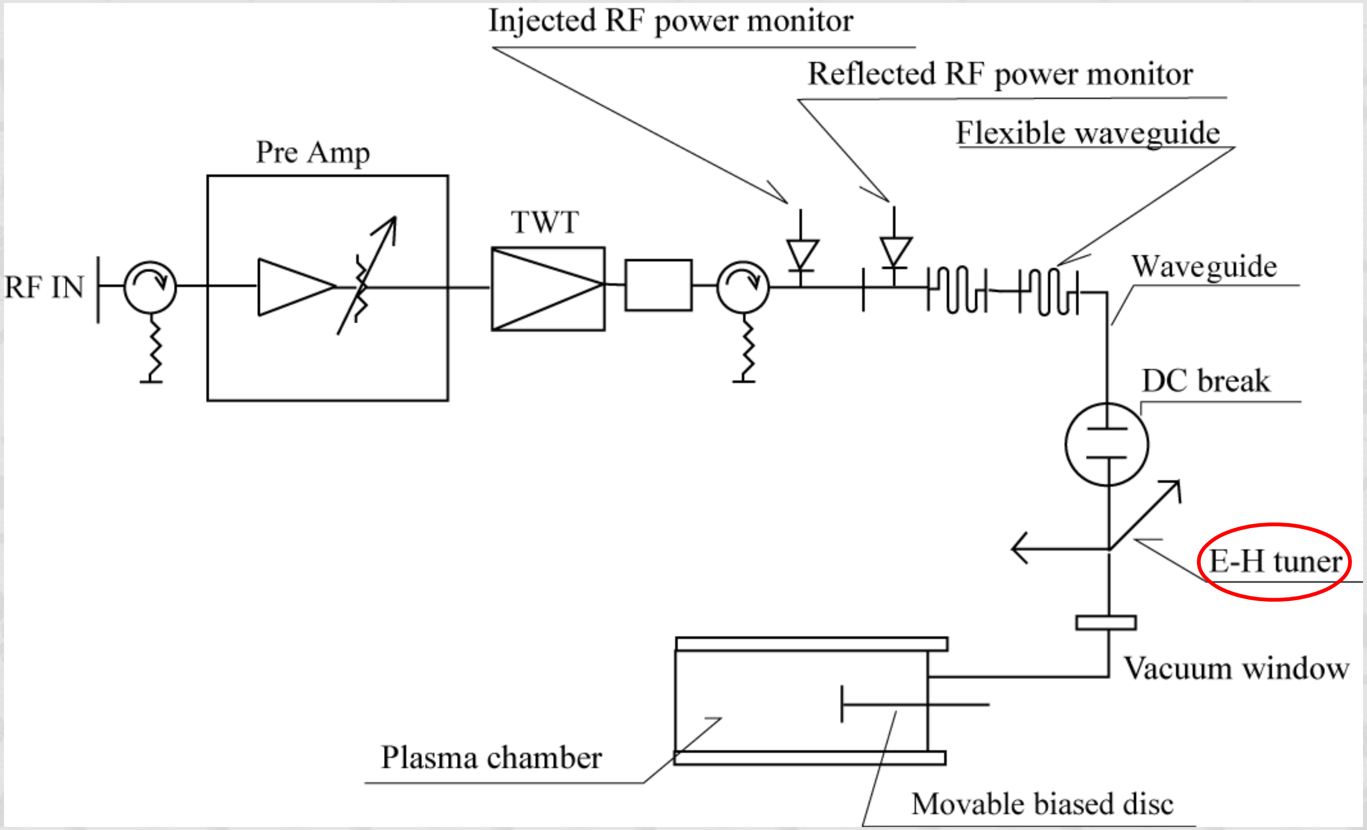
Use of the TWT amplifier

Specifications of the TWT amplifier

Frequency range	17.2~18.4 GHz
Maximum power	~700 W

18 GHz microwave generator (2)

RF power line from the TWT amplifier to the plasma chamber



Summary

- We plan to install a new 18 GHz ECRIS for the RILAC.
  - The mirror coil consists of three solenoid coils to set the magnetic mirror ratio and B_{min} independently.
  - We use the variable frequency microwave generator for further enhancement of the beam intensity.
- Progress status
  - Mirror coil, hexapole magnet, microwave generator → already prepared
  - Chambers, Electric power supply, … → under negotiation to acquire the budgets
- The low-temperature oven is under development in parallel