Status of RFQ Cooler Buncher for rare isotope experiments with Isotope Separation On-Line system

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Contents

01 RAON Facility & ISOL System

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RAON Rare isotope Accelerator complex for ON-line experiments

Rare Isotope accelerator complex:

1. Cyclotron for ISOL
2. Superconducting Linac for Post-acceleration of RIB and In-Flight Fragmentation

RAON

Accelerator complex
ISOL + In-Flight Fragmentation

Origin of Matter

- Nuclear Astrophysics
- Nuclear Matter
- Super Heavy Element Search
- High-precision Mass Measurement

Properties of Exotic Nuclei

- Nuclear Structure
- Electric Dipole Moment and Symmetry
- Hyperfine Structure Study

Applied Sciences

- Bio-Medical Sciences
- Material Sciences
- Neutron Science

Status

Rare Isotope Science Project (RISP) : Dec. 2011 – Dec. 2022

RISP is changed to “IRIS” as of July 1, 2022. (From project to operation)

R&D for the 2nd Phase for high energy linac : 2022.12 - 2025.12

Budget

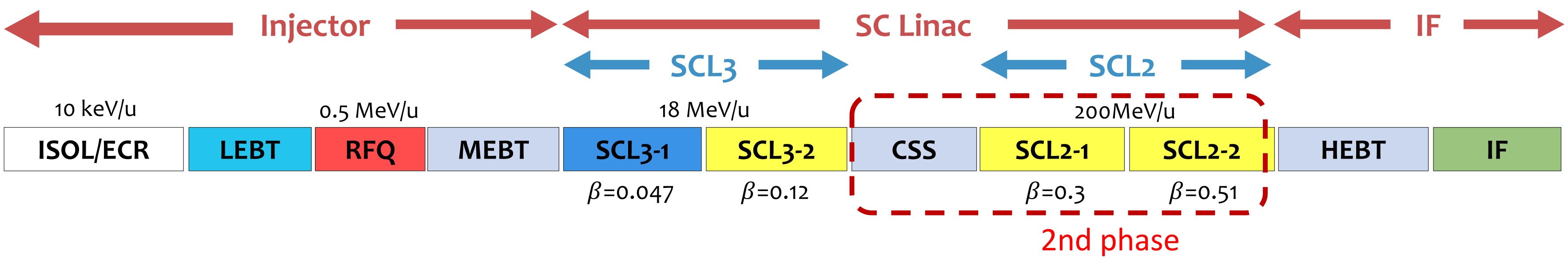
~$ 1.4 B (Facilities ~ $ 0.5 B, Land, Bldgs & Utilities ~ $ 0.9 B)

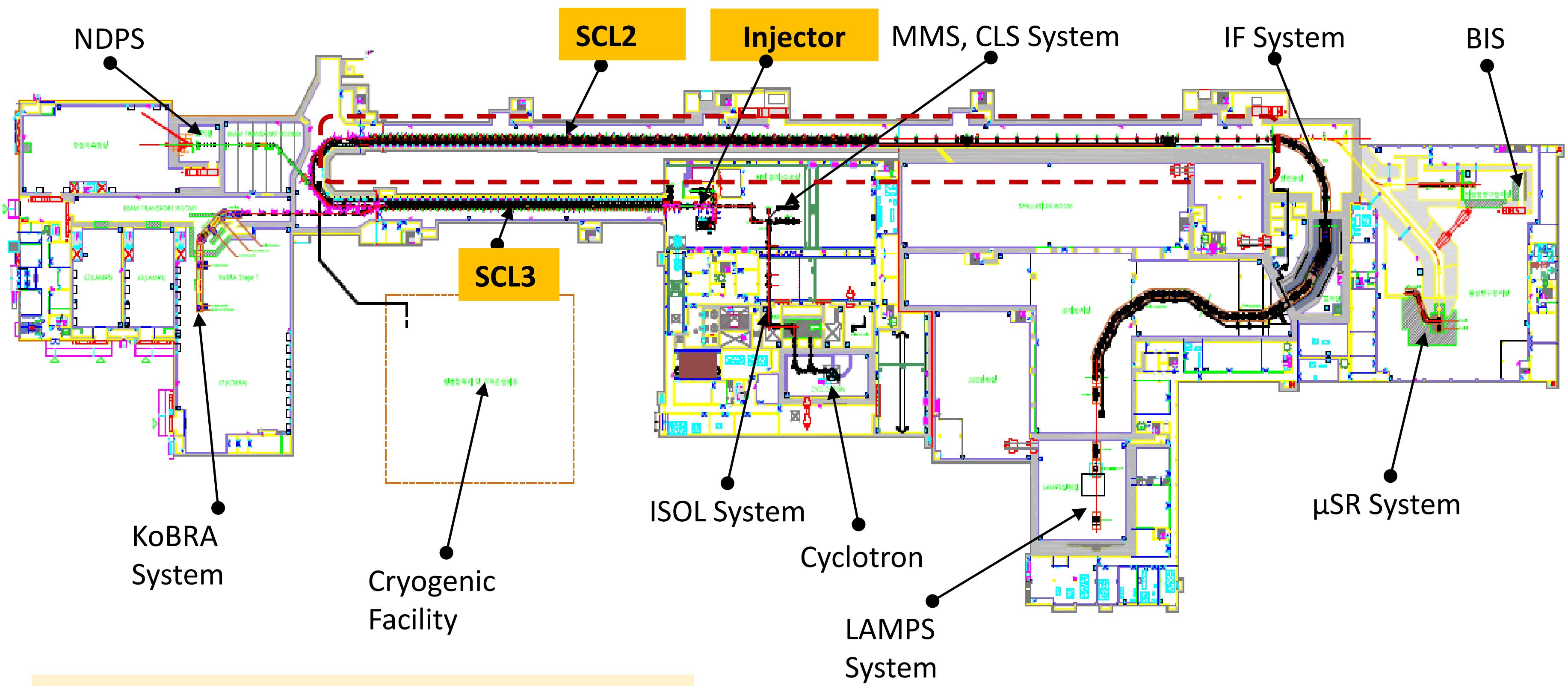
Facilities include experimental apparatus

Bird's-eye-view of RAON

- Accelerator System
- RI production System
- Conventional Utilities
- Experimental System

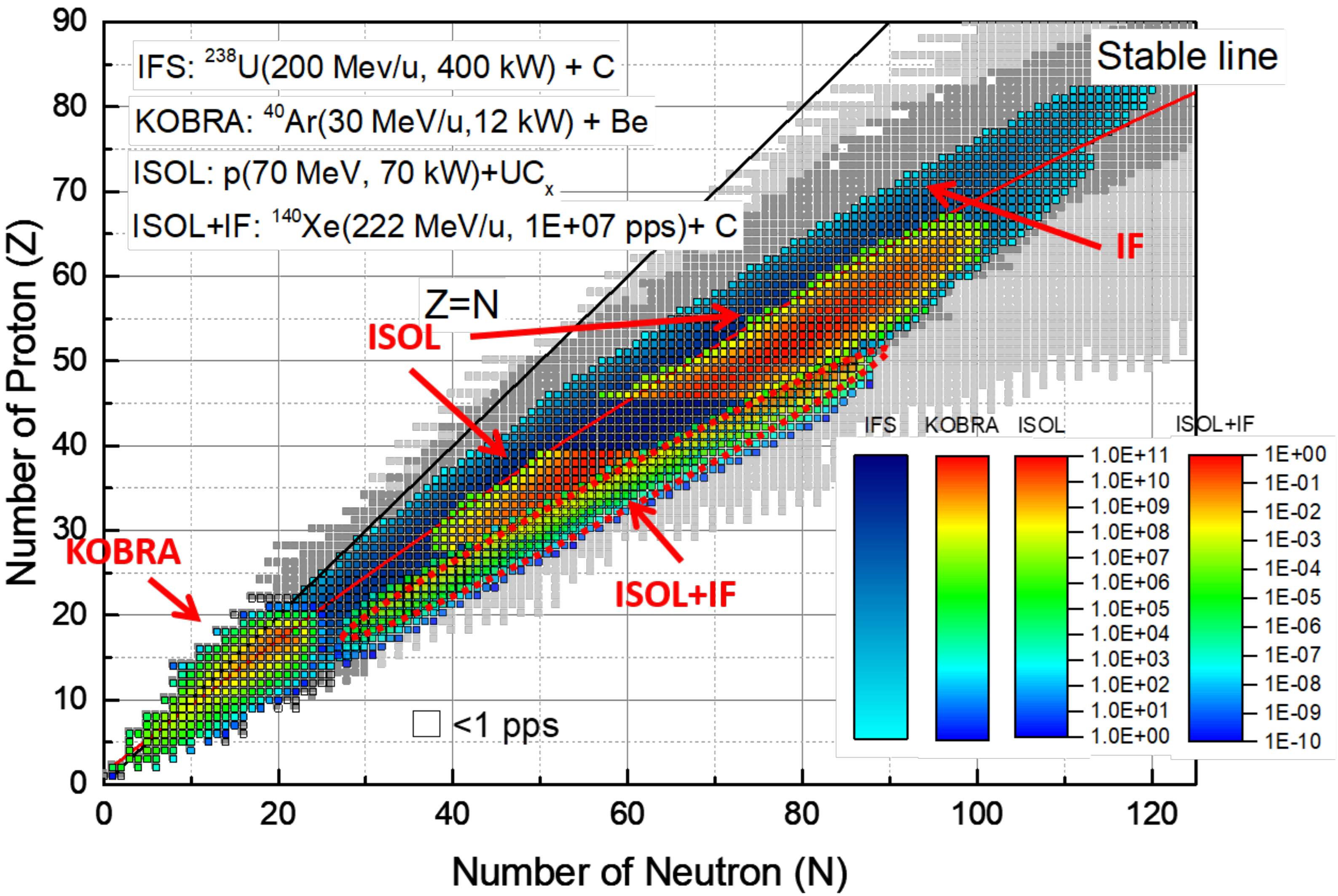
Accelerator System





※ SCL1 is postponed and is not shown here.

Experimental Systems

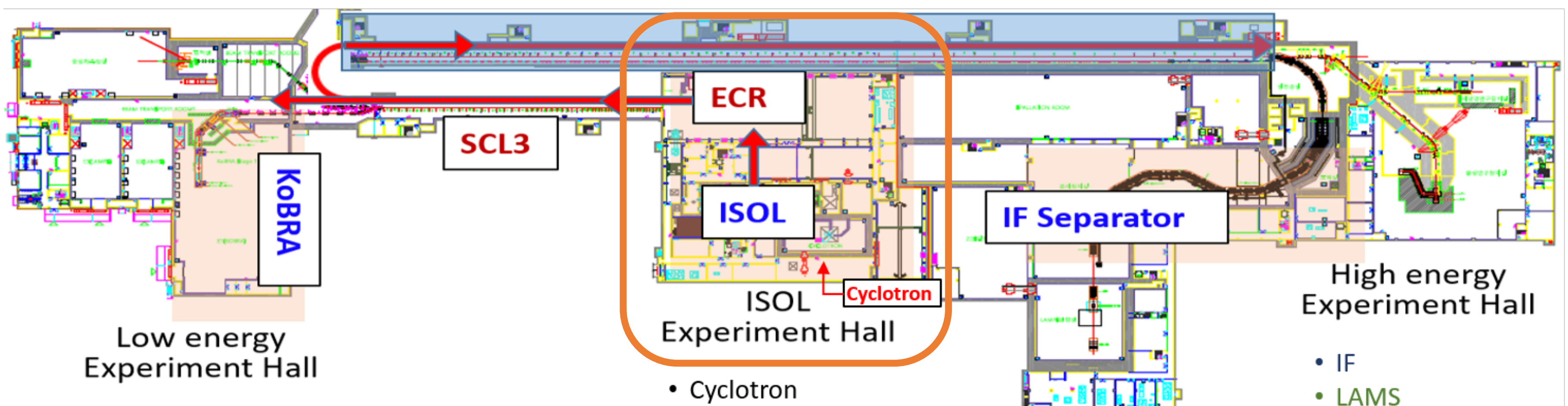


- RAON is going to eventually combine ISOL and IF to provide more exotic RIBs.
- RAON is expected to access to more neutron-rich regions of the nuclear chart.

RIB Production at RAON

	KoBRA	ISOL	IF Separator
RIB production & acceleration mode	ECR (SIB) → SCL3 → KoBRA Prod. Target	Cyclotron (p) → ISOL (RIB) → SCL3	ECR (SIB) or ISOL (RIB) → SCL3 → SCL2 → IF (RIB)
Production Mechanism	Direct reactions Multi Nucleon Transfer	p induced U fission	Projectile Fragmentation (U fission)
RIB Energy	< a few tens of MeV/u	> a few of keV/u	< a hundreds of MeV/u

KoBRA : Korea Board acceptance Recoil spectrometer & Apparatus
ISOL : Isotope-Separator Om-Line
IF : In-flight Fragmentation separator
SCL 3: (Low-energy) Super Conduction Linac 3
SCL2 : (High-energy) Super Conduction Linac 2

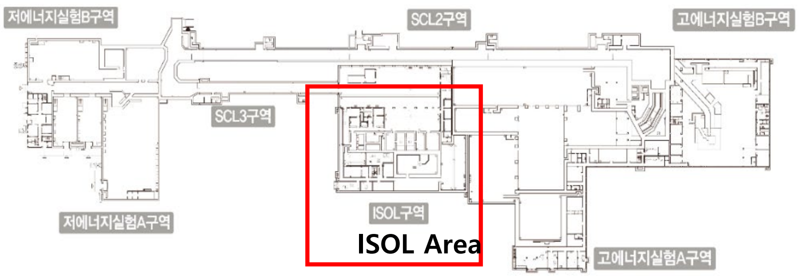


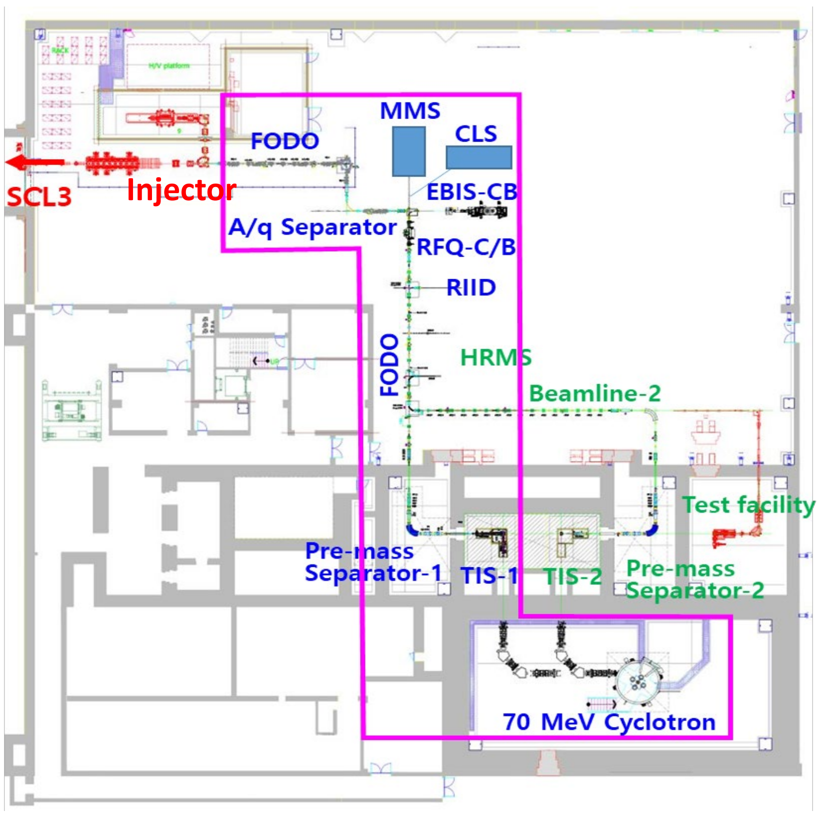
Low energy Experiment Hall
- KoBRA
- NDPS

ISOL Experiment Hall
- Cyclotron
- ISOL
- MMS
- CLS

High energy Experiment Hall
- IF
- LAMS
- BIS
- μSr

ISOL system





- Driver beam : proton 35~70 MeV, up to 0.75 mA
- Target : SiC, LaC_2, Ta, TiC, CaO / UCx, ThC_2 (2026)
- Ion source : SIS, RILIS, FEBIAD (2025)

  * Plasma ion source is being tested using an offline test facility
- Pre-mass separator (Rm ~400), A/q separator ($R_{A/q}$ ~250)
- RIB (using 10 kW UCx target): 6< A< 160, 10< K< 60 keV, 10^8 pps(Sn), > 90% purity @Exp.
- Charge breeding : (RFQ cooler/buncher and EBIS)

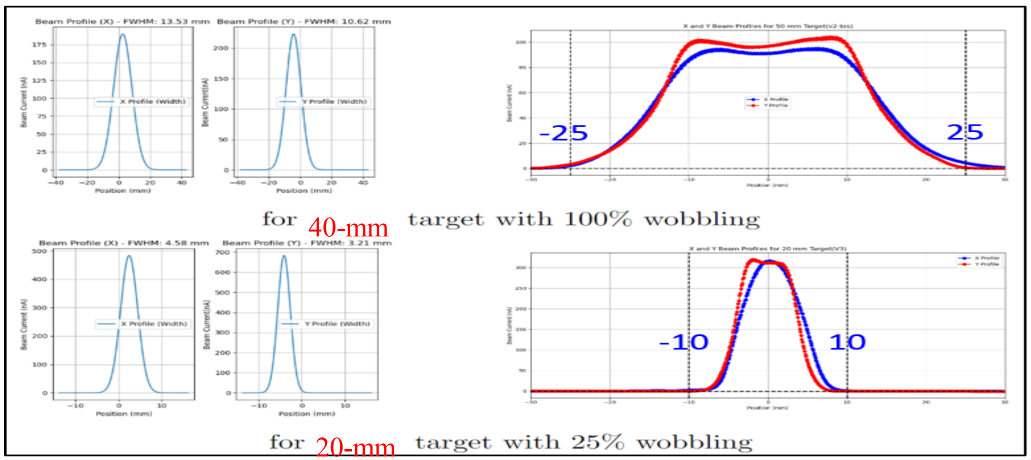
  → incident to RFQ at 10 keV/u for post acceleration
- Remote-handling system for TIS/module

- 2022.12, ISOL system integration and SIB commissioning
- 2022.10, SAT of 70 MeV Cyclotron
- **2023.03, First production of RI (Na isotopes) w/SiC target**
- 2023.05, Na isotopes to RIID, RFQCB-EBIS
- 2024.03, production of Al isotopes (using a surface IS)
- 2024.05, Mass measurement of Na, Al isotopes at MMS
- 2024.06, Cs & Ba RIs production w/LaC2 target
- **2024.08, Acceleration of $^{25}Na^{5+}$ beam by SCL3 and transport to KoBRA**
- 2024.11~, RI-beam commissioning of CLS

ISOL beam driver

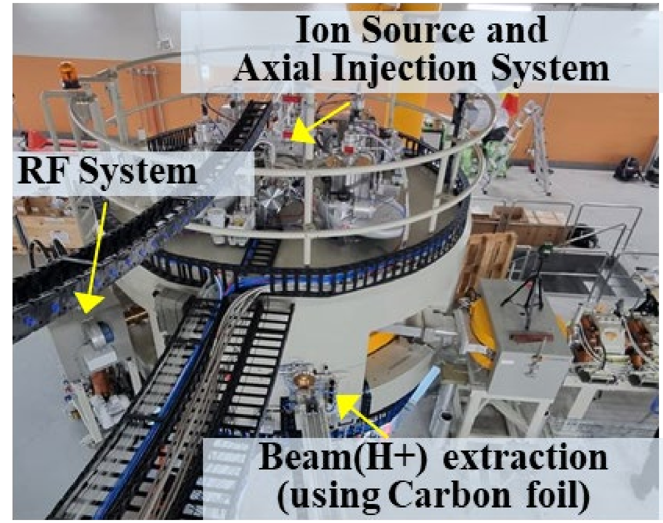
- Specifications of 70 MeV Cyclotron (SAT in Oct, 2022)

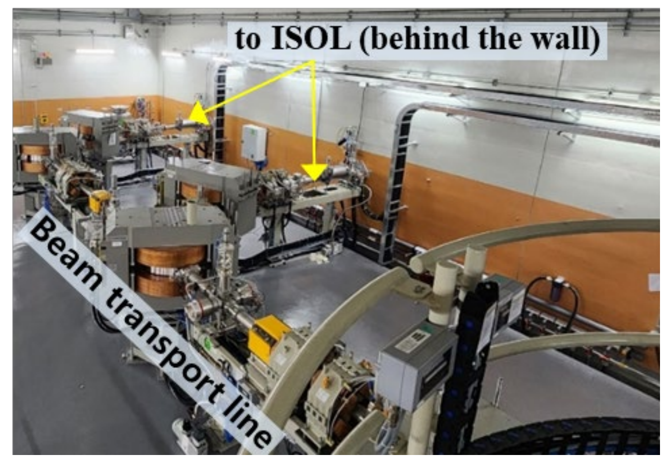
Energy	35 ~ 70 MeV
Injected H- current	10 mA (H-), Multicusp IS
Maximum Current	750 μA(upgradable to 1 mA) stability >95%
Hill field	1.6 Tesla
Acceleration Efficiency	97.5% with radial probe
Harmonic mode	4
Cyclotron dia.	3.8 m
Frequency (fixed)	61 MHz
Total weight	140 tons
Beam Line Transmission	97%@Cave A, 100%@Cave B



< Configuration of reference beam sizes with respect to the target size >

- 35~70 MeV proton, 0.75mA max with two beams to ISOL target module





< Cyclotron & beam transport line >

ISOL commissioning target

- ISOL Target Ion Source (TIS)

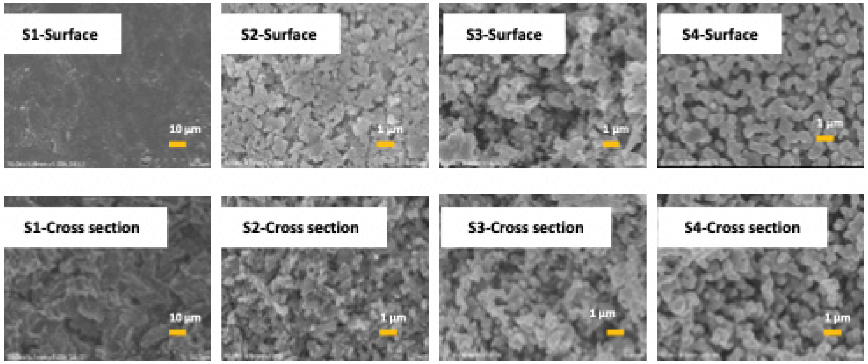
○ Non-actinide target preparation (1 kW)

- **SiC, BN, MgO, LaC2 ….**
- SiC target for RI beam commissioning

selected for RIB commissioning (S-3)

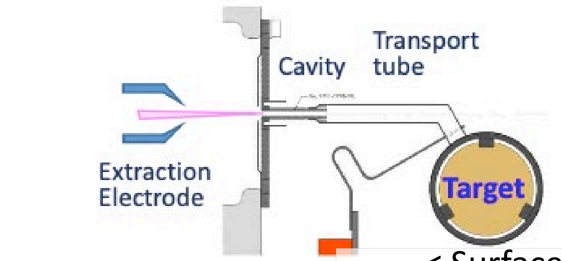
Item		S-1	S-2	S-3	S-4
Density (g/cm^3)		~3.0	~1.9	~ 1.8	~1.9
Grain size (um)		> 10	~ 1	0.1-1.4	0.2-0.8
Emissivity (@1,563 °C)		0.79	-	0.85	0.85
Thermal shock test	SEM (surface)	-	-	Crack-free	Crack-free
	SEM (cross section)	-	-	Crack-free	Crack-free
Specific surface	Langmuir model (m^2/g)	-	-	2.11	8.39
Thermal diffusivity (mm^2/s, 1200 °C)		-	4.0	3.1	2.5

- *S-1 : commercial, S-2 ~ S-4 : self-made*



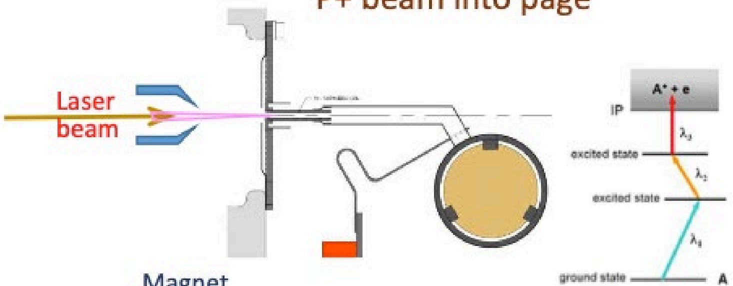
< SEM images for SiC targets >

○ Ion source for on-line application

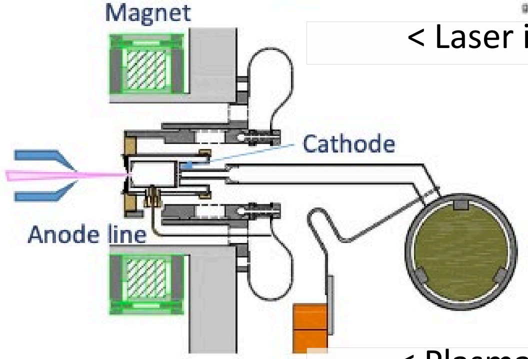


< Surface ion source>

P+ beam into page



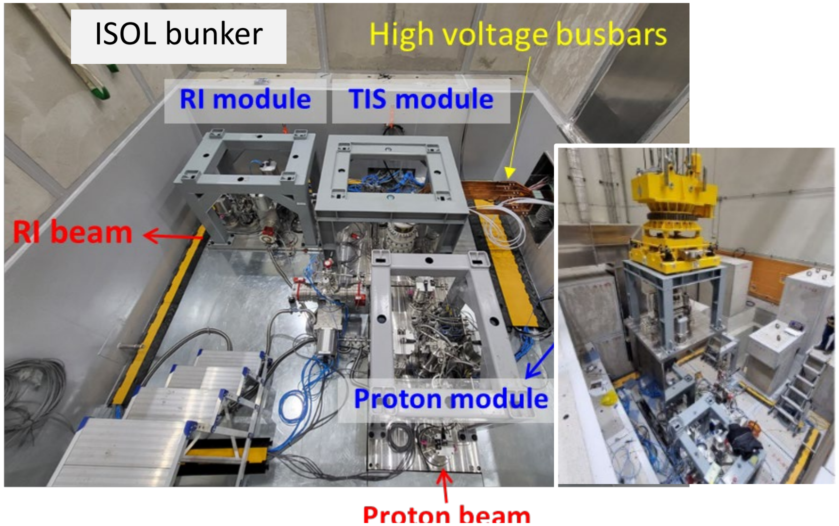
< Laser ion source >

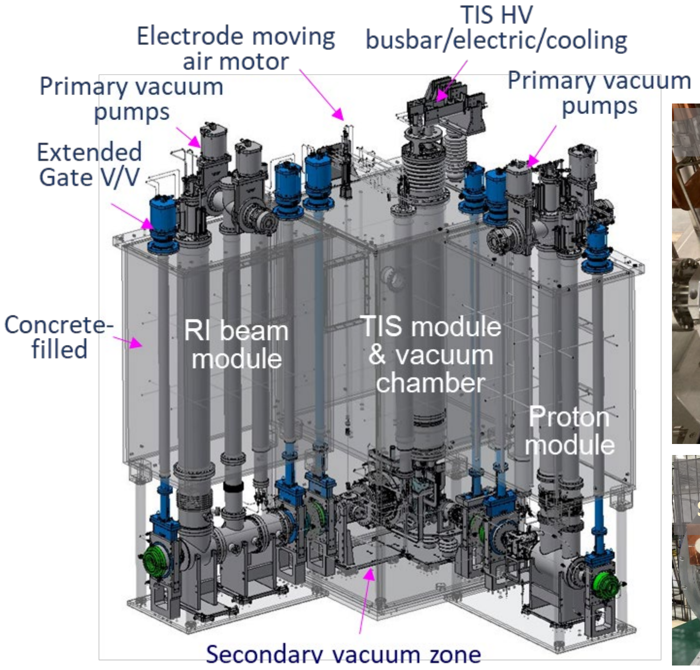


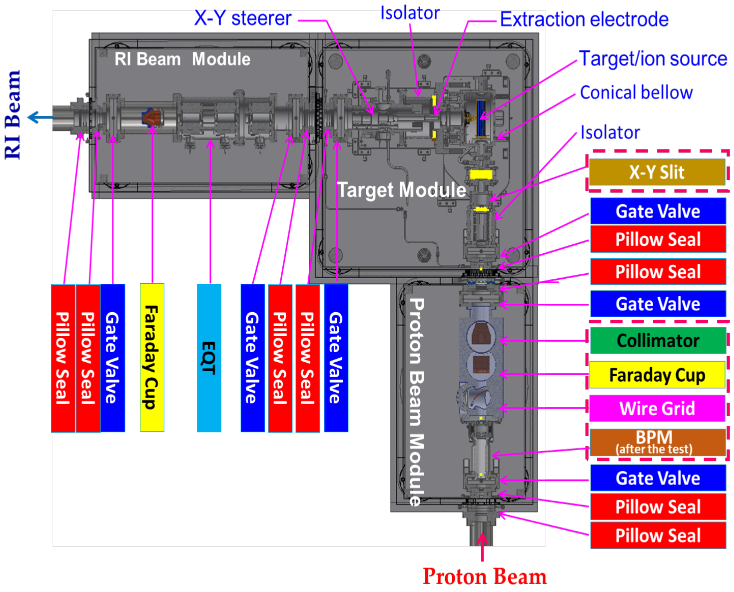
< Plasma ion source>

RI production module in ISOL bunker

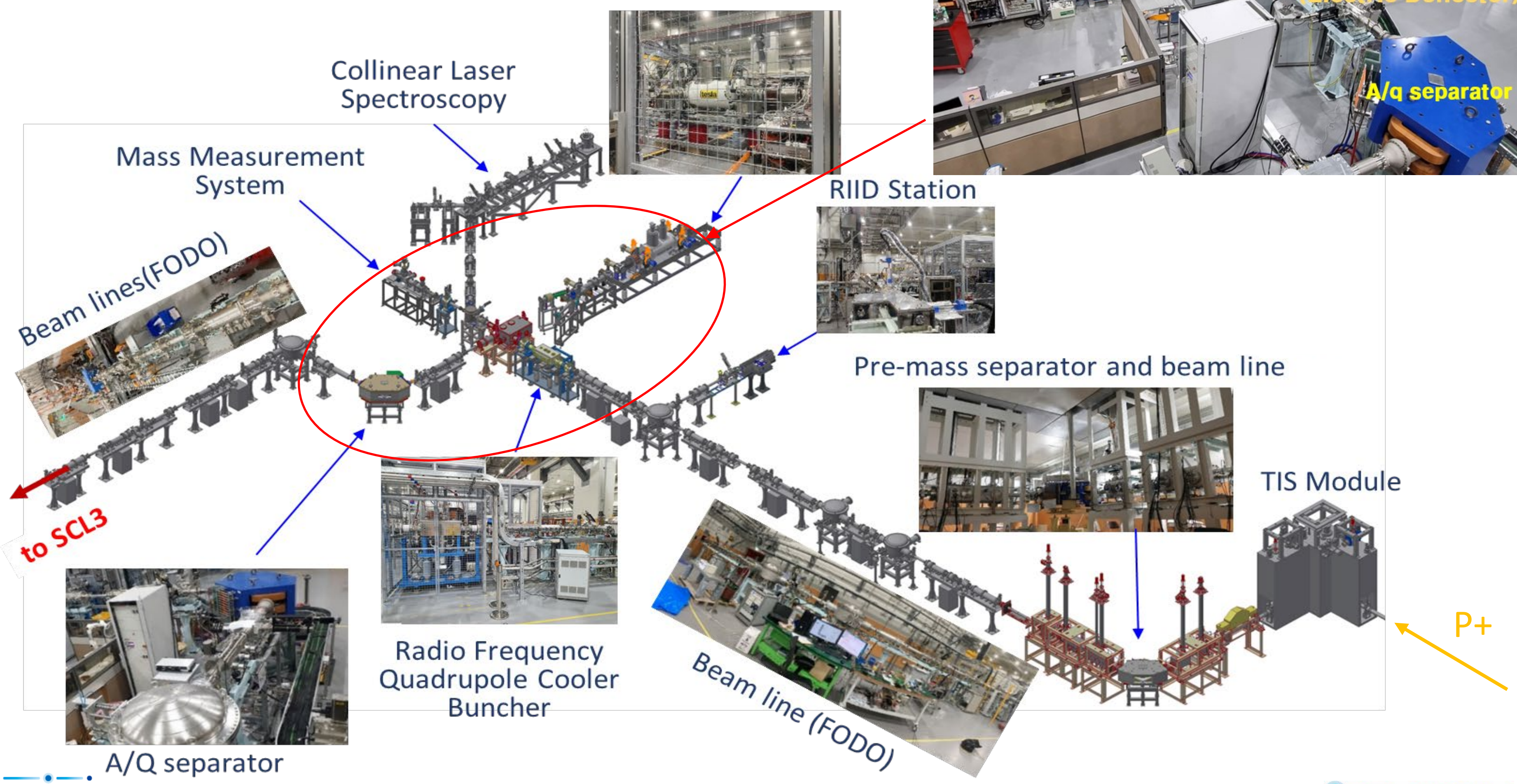
- TIS module, Proton beam module, RI beam module
  - connected & disconnected by pillow seals
  - movable concrete blocks filled up around the modules
  - TIS is located on 60 kV platform
  - operated/maintained by a remote handling system
- Radiation safety
  - radio-activated vacuum exhaust gas treatment system
  - negative pressure in service area
  - quick line connection & disconnection in services zone







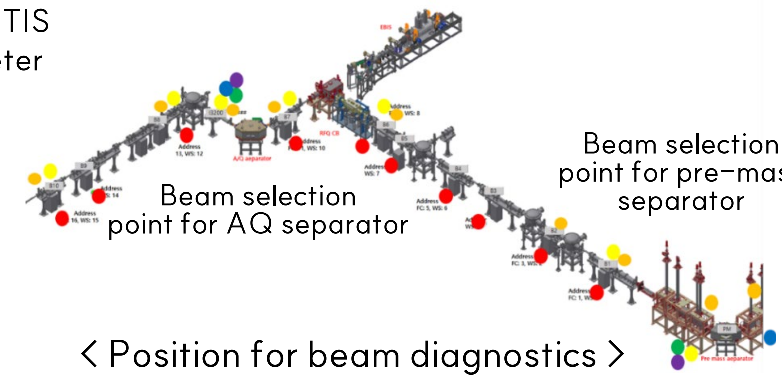
- ISOL Beamline System



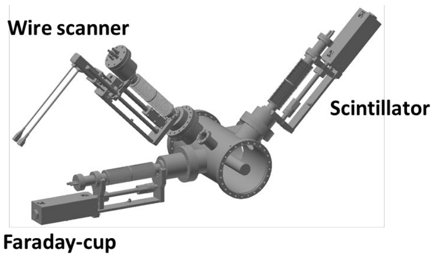
Stable beam commissioning

- ISOL Beamline System – Diagnostics

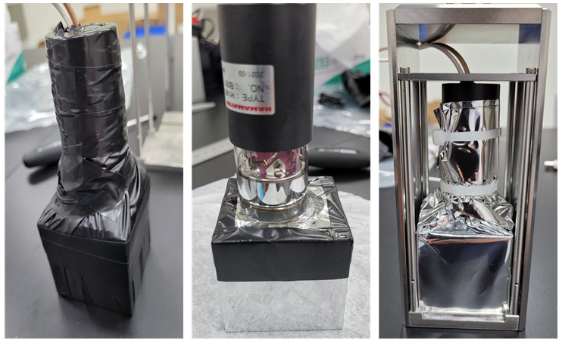
1. Tuning using stable beam, such as Cs, K Na, extracted from TIS
   - FC, Wire scanner, Wire Grid, Beam viewer, Emittance meter
2. Changing magnetic field of MD
3. Tuning for RIB
   - plastic scintillator(50x50x50 mm^3) covered by thick aluminum
   - low intensity beam monitor of MCP (max. 10^6 pps)



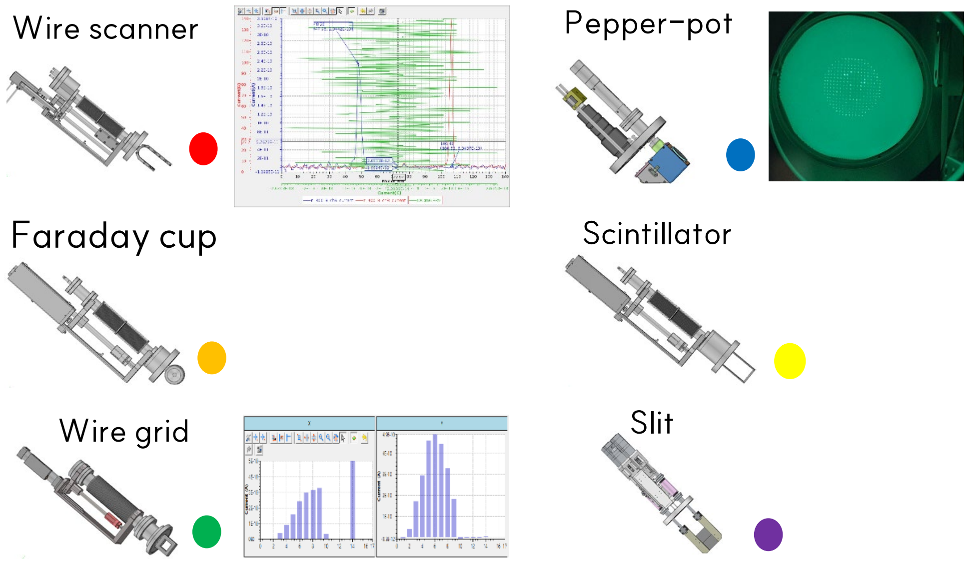
< Position for beam diagnostics >



< Typical diagnostic chamber >



< Plastic Scintillator + Aluminum layer + PMT >

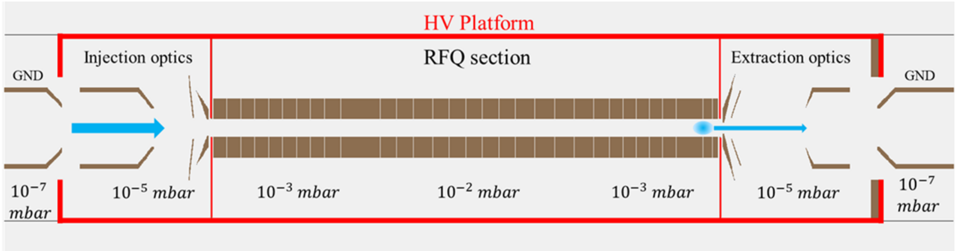


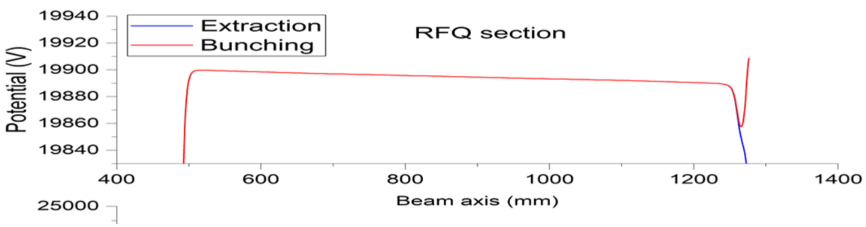
02 RAON RFQ Cooler Buncher & EBIS Charge Breeder

Institute for Rare Isotope Science

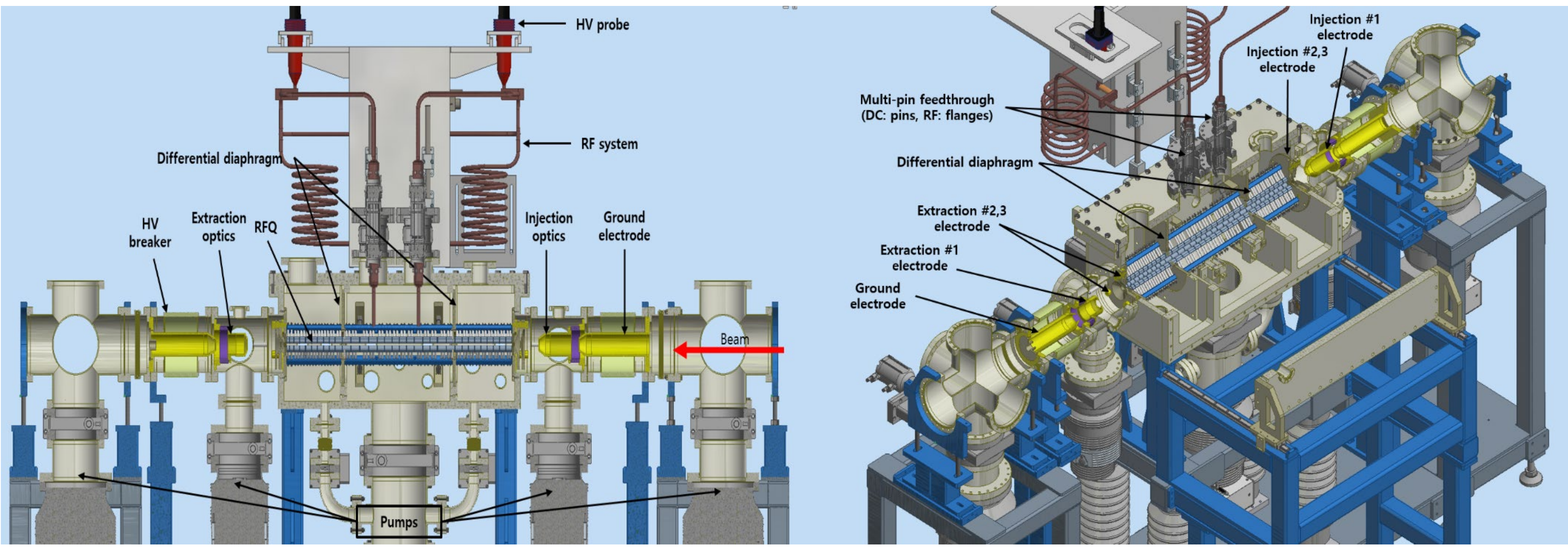
RAON

RFQ Cooler and Buncher



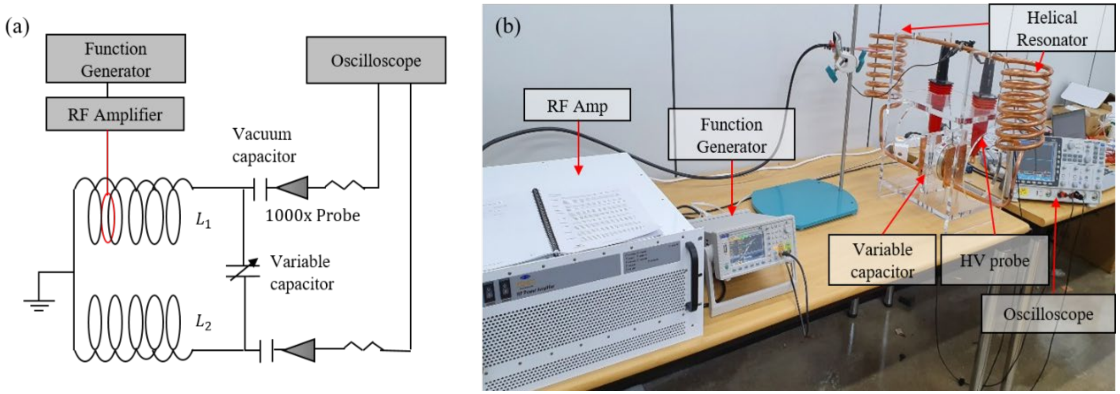


Beam parameter	Performances for EBIS
Beam current	10^8 *ion per bunch*
Transverse Emittance	$< 10\ \pi\ mm\ mrad$
Energy Spread	< 10 eV
Bunch width	$< 100\ \mu s$
Cooling time	~ 100 ms
Transmission Efficiency	> 80 %



Cross-section view of RFQ CB design

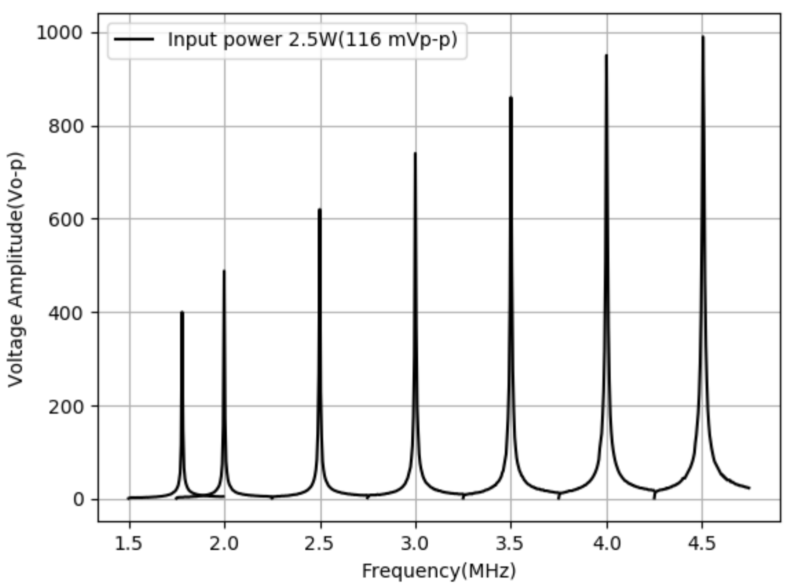
RFQ Cooler and Buncher



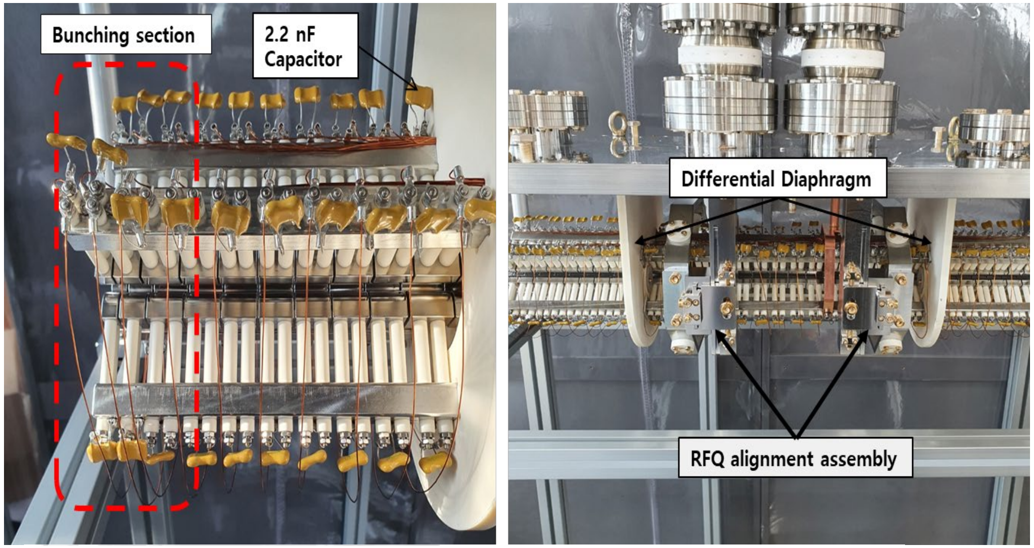
High voltage RF system

Parameter	Symbol	Value
Coil inductance	L_1, L_2	4.5 μH
Capacitance range	C_{tot}	120-1120 pF
Resonance frequency range	f_0	1.6 MHz–4.8 MHz
Capacitance of the vacuum capacitor	C_{vacuum}	0.7 pF
Input capacitance of the HV probe	C_{probe}	2.0 pF

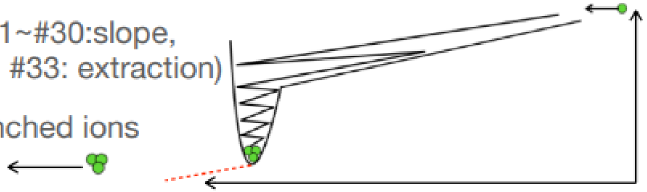
Scheme of the prototype RF system (a) and the photograph of its actual setup (b)



RF voltage amplitude of the prototype RF system with 2.5-W RF input power.

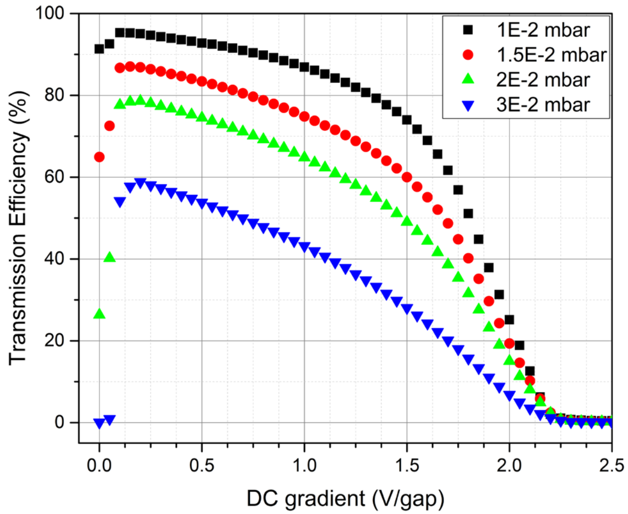


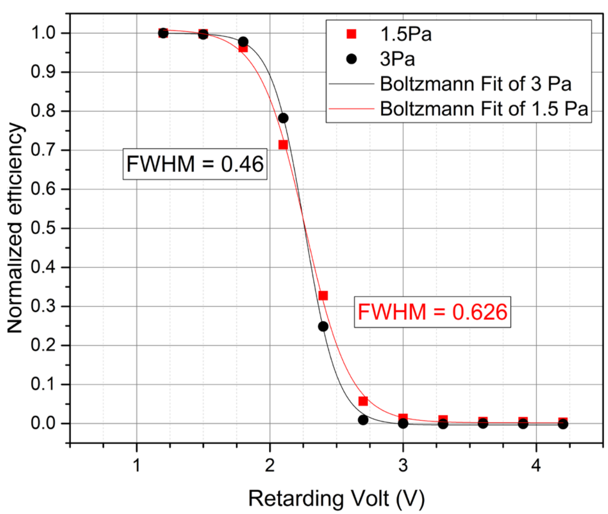
33 electrodes (#1~#30:slope, #31,#32: bunch, #33: extraction)

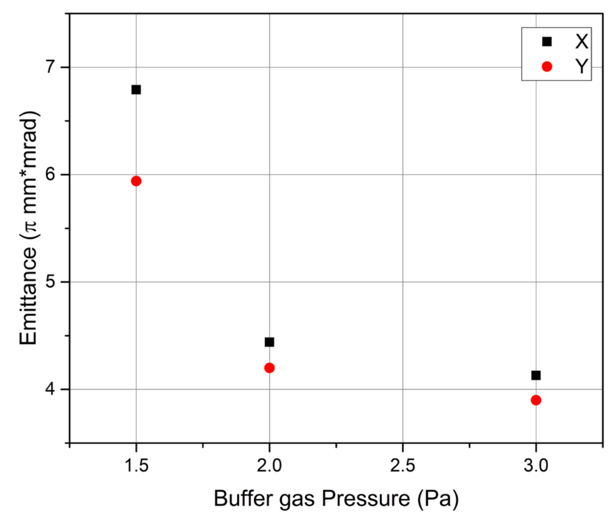


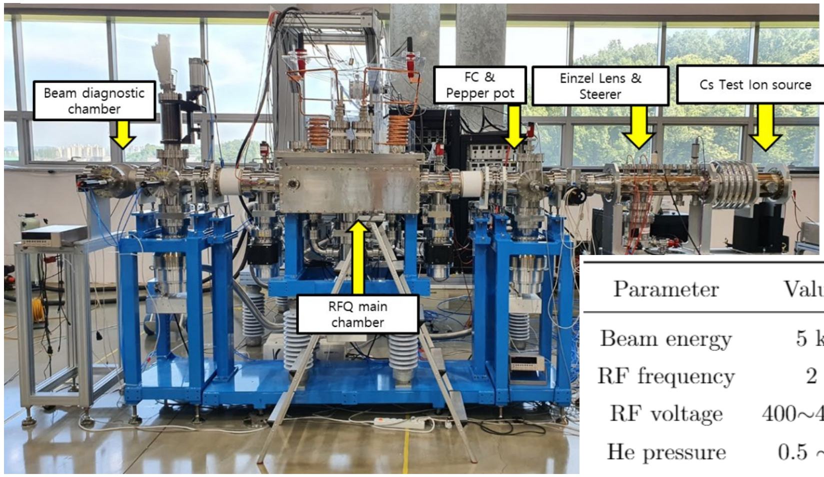
RFQ Cooler and Buncher

- Off-line test result (DC mode)



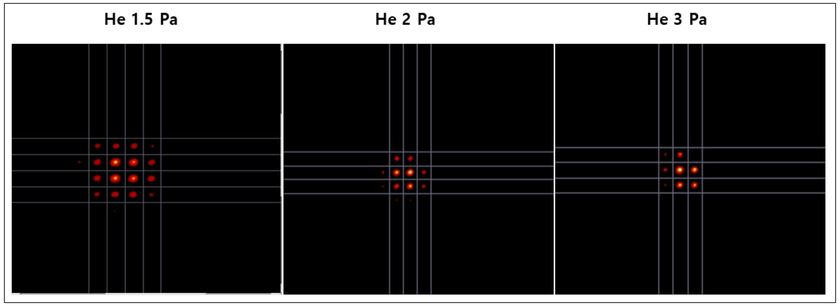






Setup for off-line test bench

Parameter	Value	unit
Beam energy	5 k	eV
RF frequency	2	MHz
RF voltage	400∼4800	V_{p-p}
He pressure	0.5 ∼2	Pa
Beam current	1∼40	nA
DC gradient	0.1∼2	V/gap
DC gap	32	gap

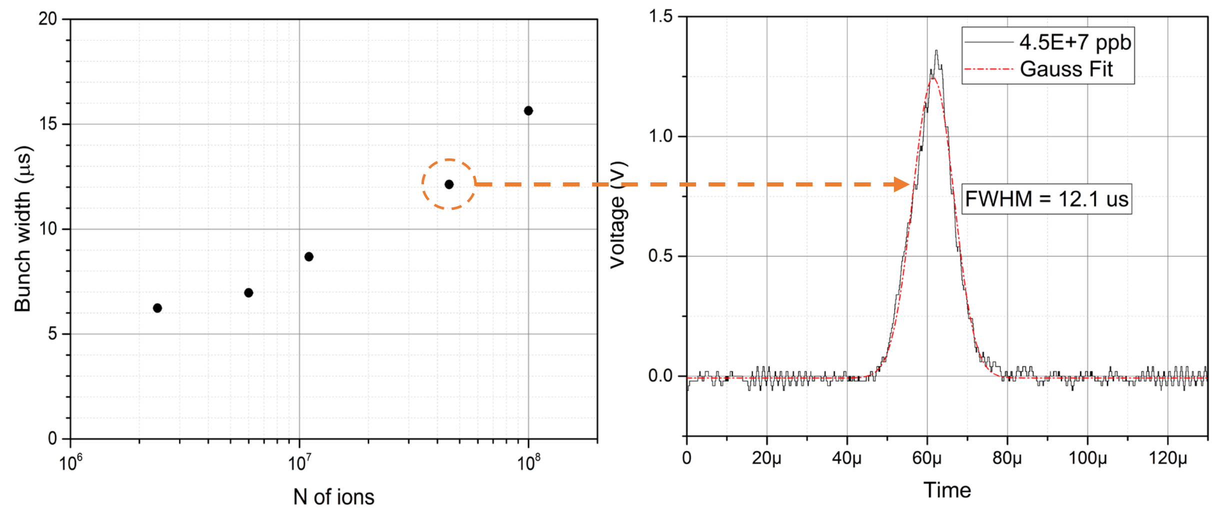


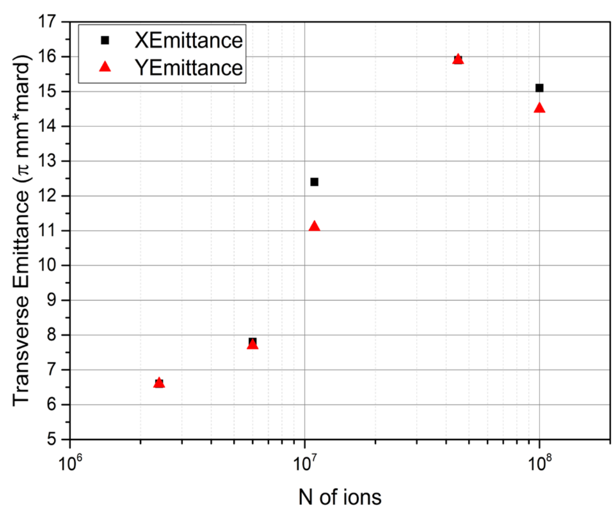
Higher buffer gas pressure is beneficial for cooling ions, resulting in better emittance, but makes worse transmission.

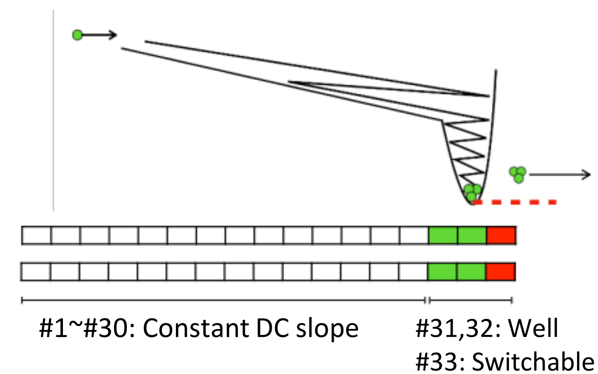
RFQ Cooler and Buncher

- Off-line test result (Bunch mode)

Parameter	Value	unit
High Voltage platform	4834	V
RFQ input energy	100	eV
RF frequency	2	MHz
RF voltage	1100	Vp-p
He pressure	2	Pa
Cooling time	99.95	ms
Repetition rate	10	Hz
Extraction time	46	us
DC electrode 1 Bias	66	V
DC electrode 30 Bias	56	V
Bunching electrode 31 Bias	55	V
Bunching electrode 32 Bias	20	V
Switching electrode 33 Bias	200	V
Extracting electrode 33 Bias	0	V
Bunch capacity	10^6 - 10^8	ppb
Injection electrode 1	3600	V
Injection electrode 2	4800	V
Injection electrode 3	3000	V
Extraction electrode 1	1500	V
Extraction electrode 2	4800	V
Extraction electrode 3	2000	V





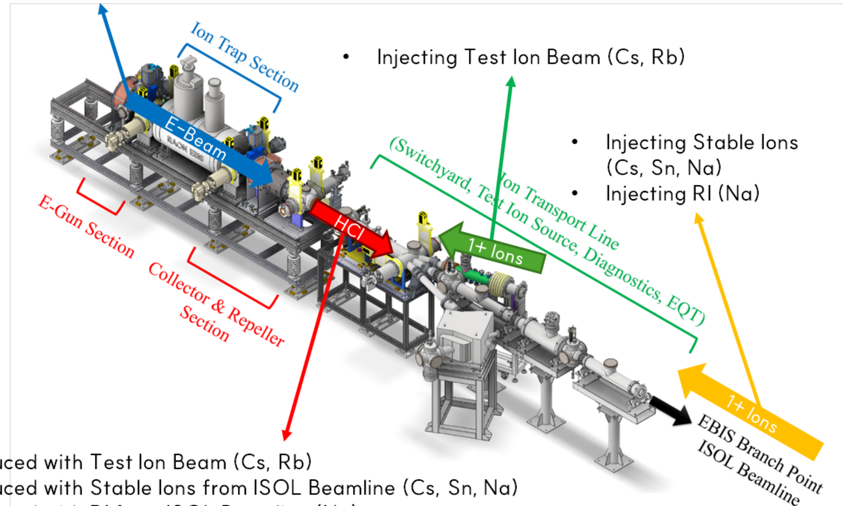


- Higher ions per bunch causes worse transverse emittance and wider bunch width due to space charge effect.

EBIS Charge breeder

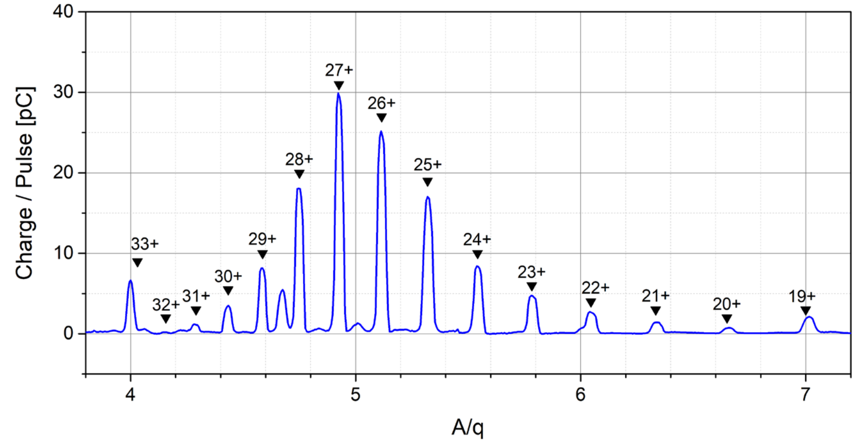
Off-line test result

- Electron Beam Transmission



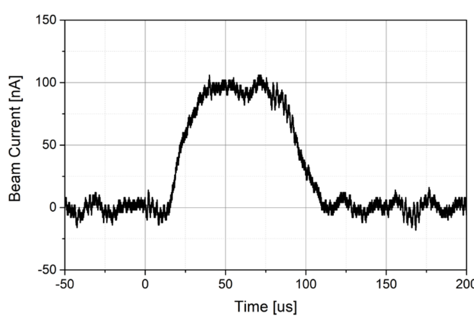
- HCI produced with Test Ion Beam (Cs, Rb)
- HCI produced with Stable Ions from ISOL Beamline (Cs, Sn, Na)
- HCI produced with RI from ISOL Beamline (Na)

Charge Breeding Results

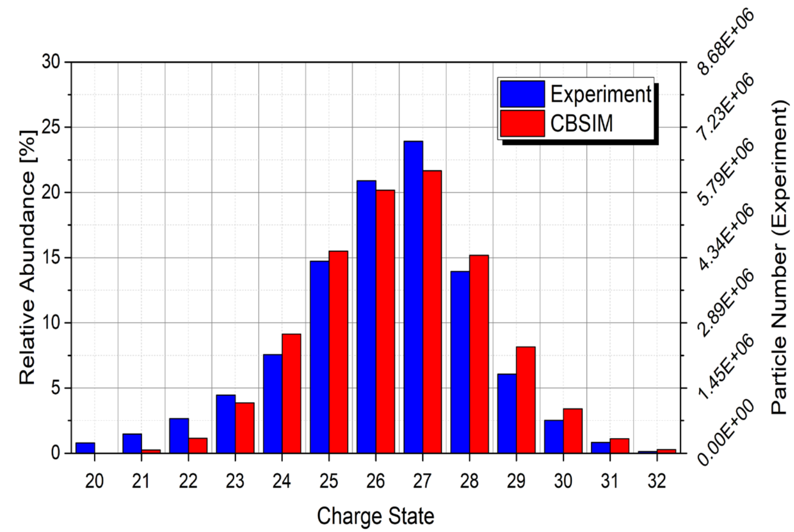


Ion Beam Energy	10 keV/u
A/q	< 6
Electron Beam Current	3 A
Magnetic Field in Breeding Region	6 T
Trap Capacity	< 10^8 ions/bunch
Breeding Time	< 100 ms
Breeding Efficiency	> 15 % for $^{133}Cs^{27+}$
Vacuum Condition in Breeding Region	~ 10^{-11} torr

- Ion Beam Energy : 20 keV
- Pulse Length : 100 μs (end-to-end)
- Injected Ion Numbers : 4.28E+7



Injected Cs Ions



03 Stable Beam Charge Breeding with ISOL Beamline

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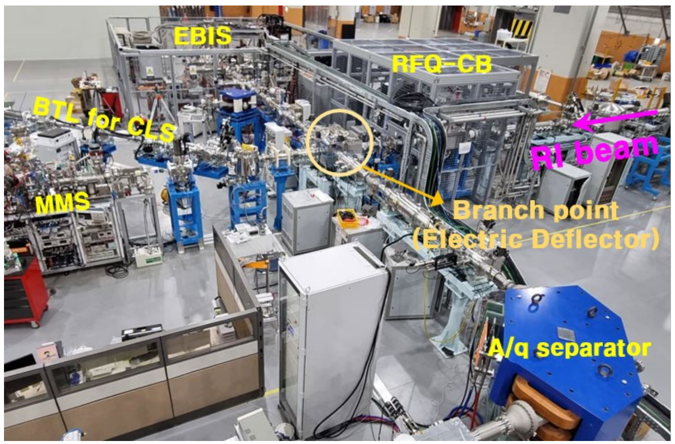
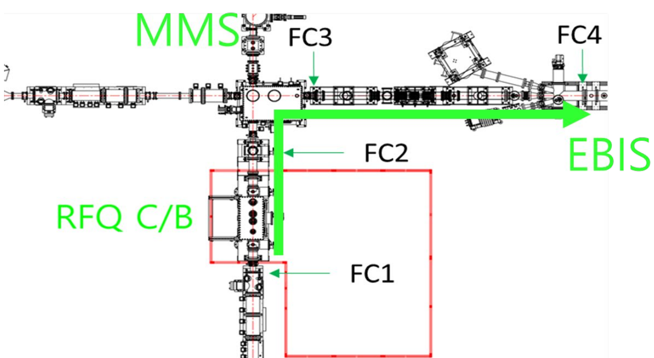
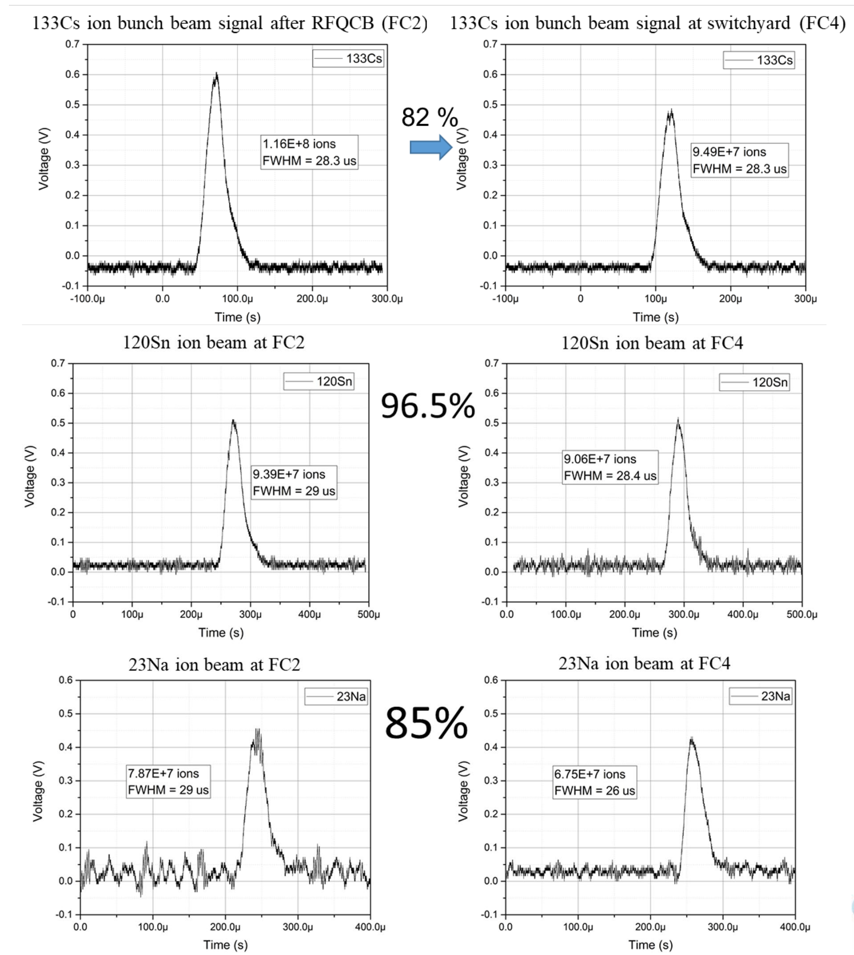
Stable beam commissioning

- RFQ CB -> EBIS transmission (133Cs, 120Sn and 23Na)

Beam species	I (ppb)@F2	I (ppb)@F4	Transmission (F4/F2)
^{133}Cs	9.49E+07	1.16E+08	82%
^{120}Sn	9.39E+07	9.06E+07	96.5%
^{23}Na	7.87E+07	6.75E+07	85%

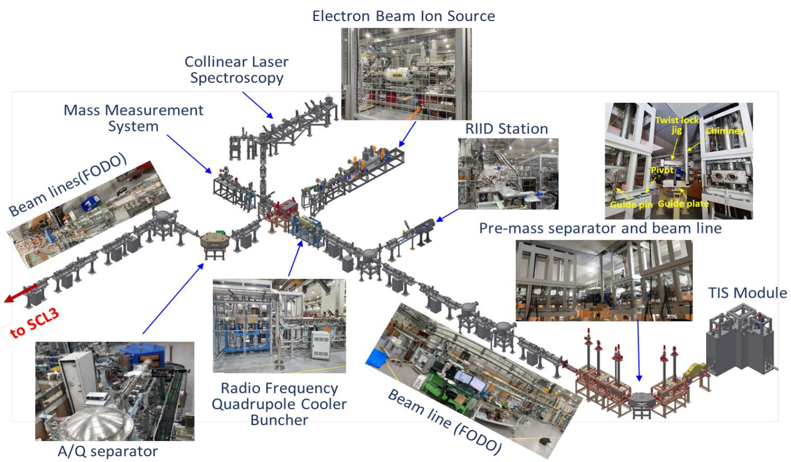




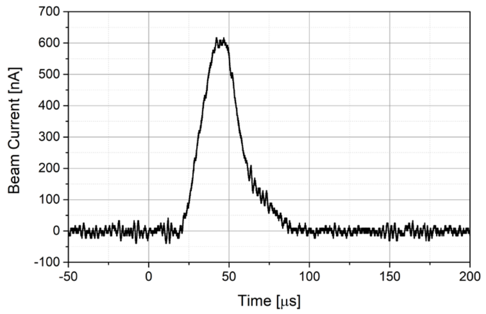


Stable beam commissioning

- EBIS -> ISOL end point transmission (120Sn)

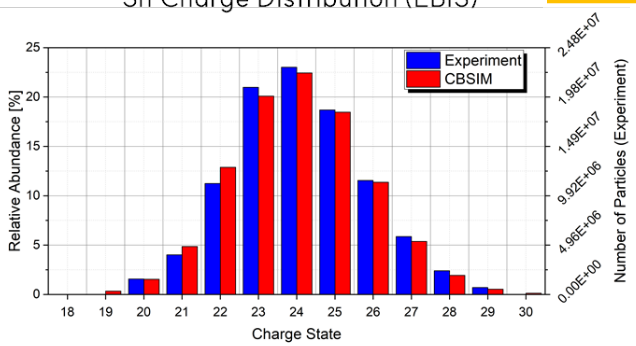


Injected Sn Ions

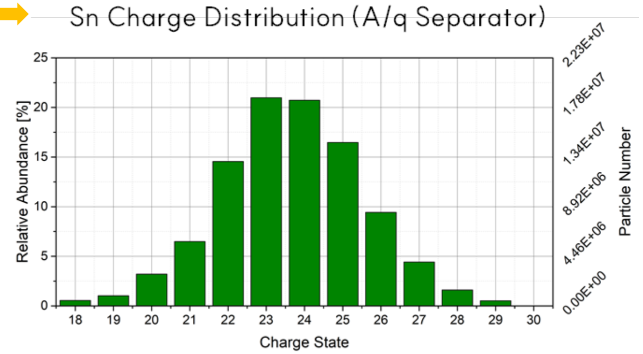


- Ion Beam Energy : 20 keV
- Pulse Length : 150 µs (end-to-end)
- Ion Numbers : 1.14E+8
- Extracted Ion Beam Energy : 49.3 keV/q

Sn Charge Distribution (EBIS)



Sn Charge Distribution (A/q Separator)

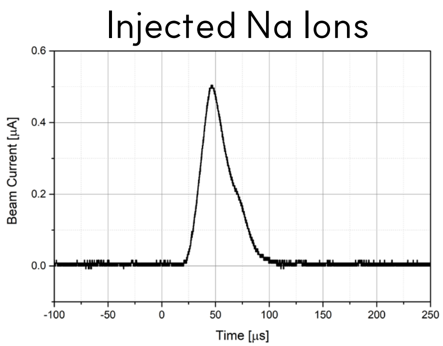


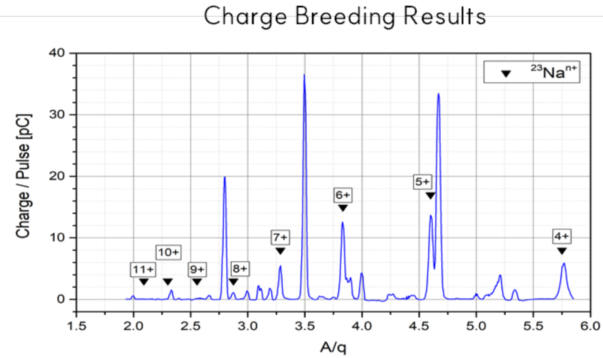
- Total Ejected Sn Numbers in EBIS : 9.92E+7
- EBIS Efficiency : 89.1 %
- $^{120}Sn^{24+}$ Numbers in EBIS : 2.28E+7
- $^{120}Sn^{24+}$ Efficiency in EBIS : 20.5 %
- Total Bred Sn Numbers in A/q Separator : 8.92E+7
- Transmission Efficiency : 89.9 %

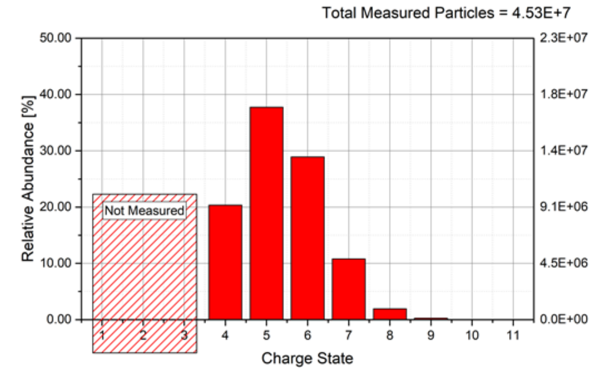
Injected Number	Total Bred Number in EBIS	EBIS Efficiency	Total Bred Number in A/q Separator	Transmission Efficiency
1.11×10^8	9.92×10^7	89.1 %	8.92×10^7	89.9 %

Stable beam commissioning

▪ EBIS -> ISOL end point transmission (23Na)







- Ion Beam Energy : 20 keV
- Pulse Length : 150 μs (end-to-end)
- Ion Numbers : 1.14E+8
- Extracted Ion Beam Energy : 49.3 keV/q

- Total Ejected Na Numbers : 4.53E+7
- Efficiency for total charge state : 45.5 %
- $^{23}Na^{7+}$ Numbers : 1.71E+7
- $^{23}Na^{7+}$ Efficiency : 17.2 %
- Extracted Ion Beam Energy : 50.0 keV/q

▪ Transportation of $^{23}Na^{5+}$ to ISOL Beamline

Measurement Point	Beam Current ($^{23}Na^{5+}$)	Number of Particles	Transmission from before point	Transmission from EBIS
EBIS Dipole	9.25 nA	1.93E+7	-	-
A/q Separator	8.30 nA	1.73E+7	89.7 %	89.7 %
End of ISOL Beamline	5.30 nA	1.10E+7	63.9 %	57.3 %

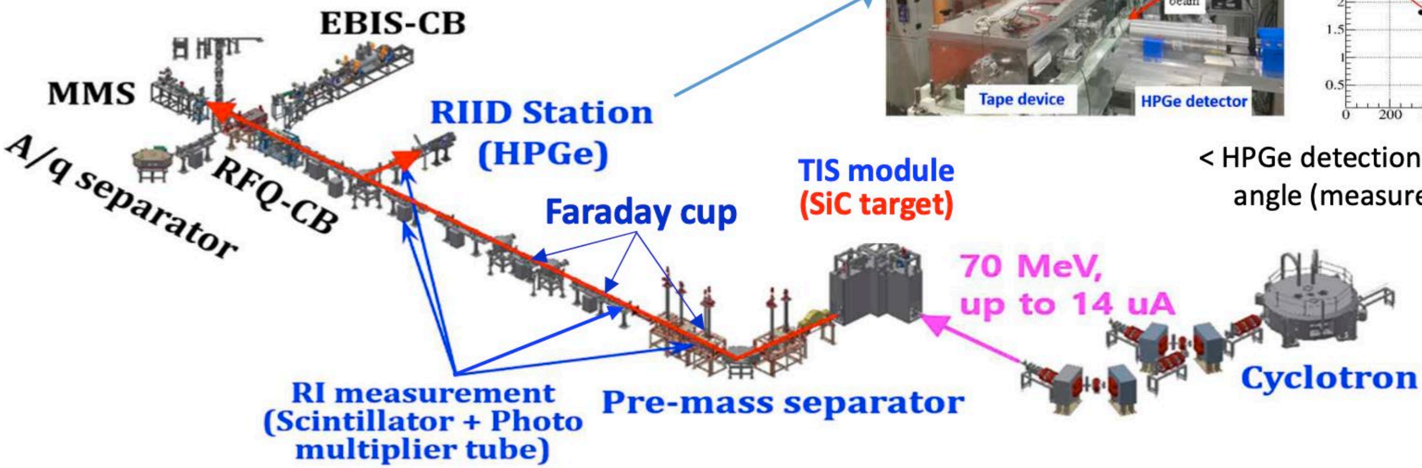
04 RI Beam Experiment

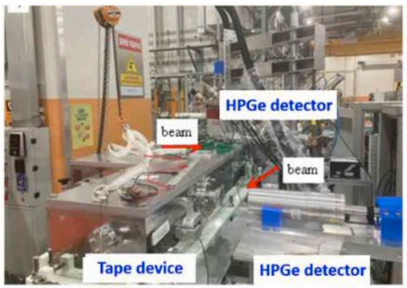
Institute for Rare Isotope Science

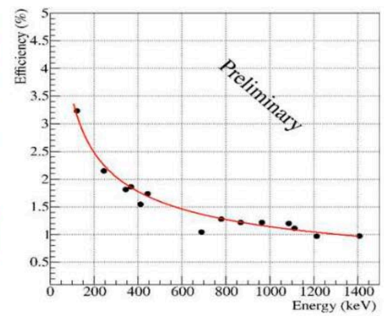
RI beam commissioning

- ISOL RI Beam Commissioning

  - March 2023 ~
  - Stable beam tuning using $^{39}K^{1+}$ with energy of 20 keV before RI beam experiment
  - Low density SiC target (density 1.8 g/cm3) / Surface ion source
  - Proton beam : 70 MeV, up to 14 μ A, non-wobbling (beam profile at Proton module X 35 mm, Y 30 mm)
  - TIS temperature : target < 1,600 ˚C (prevent for Si evaporation), Ion source 1.500 ~ 1,800 ˚C
    - Joule heating of the target heater was controlled according to the proton beam current
  - Targeted isotopes : Na, Al and Li...
  - RI confirm (in RIID) and evaluation of beam transmission efficiency



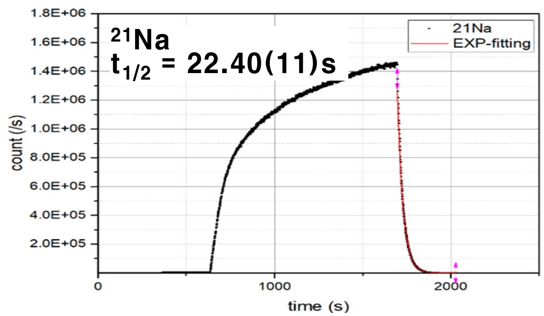


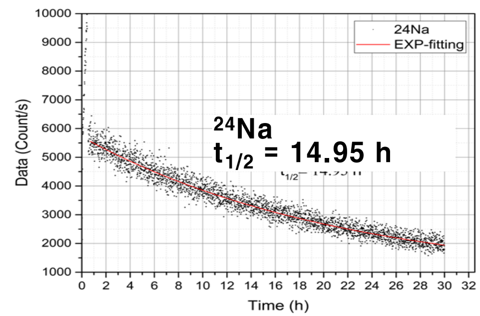


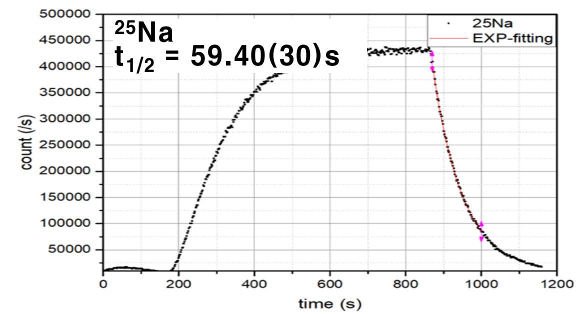
< HPGe detection efficiency including the solid angle (measured using a 152Eu source) >

RI beam commissioning

- **The first RI production and transport (March 3, 2023)**
  - **High density SiC target** (density > 3.0 g/cm^3) & SIS / Proton beam : 70 MeV, 1.2 μ A





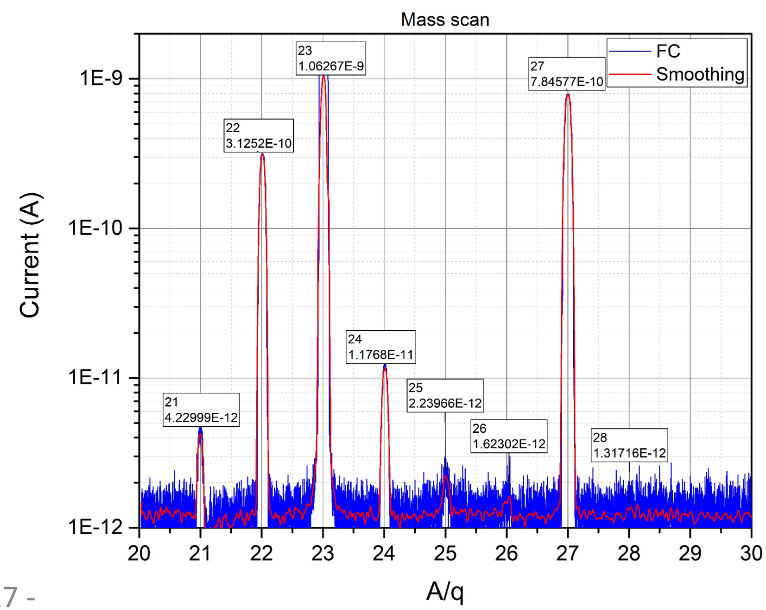


< The measured half-lives of Na isotopes using PMT & Scintillator >

- **RI beam commissioning using low density (~1.8 g/cm^3) SiC target (2023, May~)**
  - **Identified rare isotopes of Li, Na, and Al** that can be confirmed **by SIS** using a **low-density SiC target**

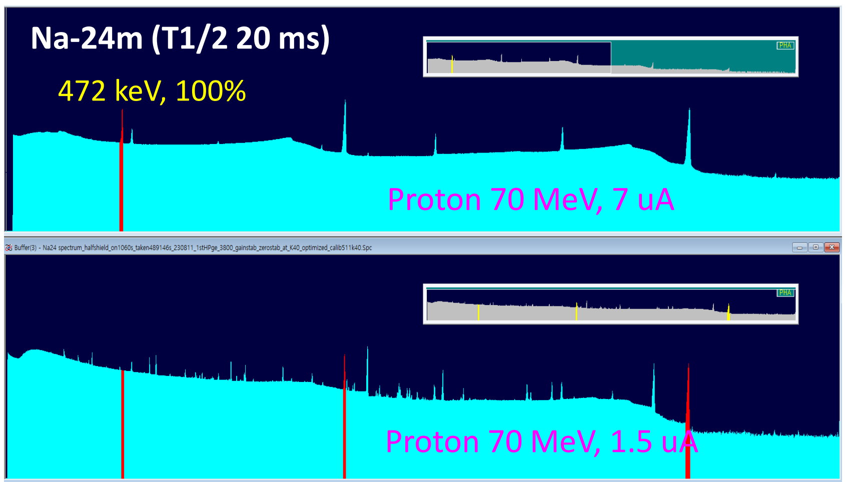
Si- 22 29ms	Si- 23 42.3ms	Si- 24 140.5ms	Si- 25 220ms	Si- 26 2.2453s	Si- 27 4.15s	Si- 28 92.223	Si- 29 4.685	Si- 30 3.092
Al- 21 p 6.4E-22s	Al- 22 91.1ms	Al- 23 446ms	Al- 24 2.053s *130.9ms	Al- 25 7.183s	Al- 26 71.7E5y	Al- 27 100	Al- 28 2.245m	Al- 29 6.56m
Mg- 20 90.8ms	Mg- 21 122ms	Mg- 22 3.8755s	Mg- 23 11.317s	Mg- 24 78.99	Mg- 25 10.00	Mg- 26 11.01	Mg- 27 9.458m	Mg- 28 20.915h
Na- 19 p 150ns	Na- 20 447.9ms	Na- 21 22.49s	Na- 22 2.6027y	Na- 23 100	Na- 24 14.997h *20.18ms	Na- 25 59.1s	Na- 26 1.077s	Na- 27 301ms
Ne- 18 1.6654s	Ne- 19 17.22s	Ne- 20 90.48	Ne- 21 0.27	Ne- 22 9.25	Ne- 23 37.24s	Ne- 24 3.38m	Ne- 25 602ms	Ne- 26 197ms
F - 17 1.075m	F - 18 1.830h	F - 19 100	F - 20 11.163s	F - 21 4.158s	F - 22 4.23s	F - 23 2.23s	F - 24 390ms	F - 25 80ms

< Na and Al Ris observed using HPGe at RIID >

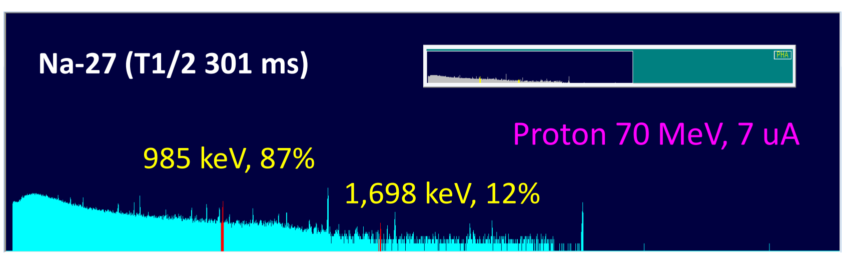


RI beam commissioning

- **Measurement of short-lived Na beams**
  - Proton beam : 70 MeV, 7 μ A
  - Na-24m ($T_{1/2}$ 20 ms) & Na-27 ($T_{1/2}$ 301 ms) detected at RIID ← fast diffusion rate of Na isotopes & small particle size of target material

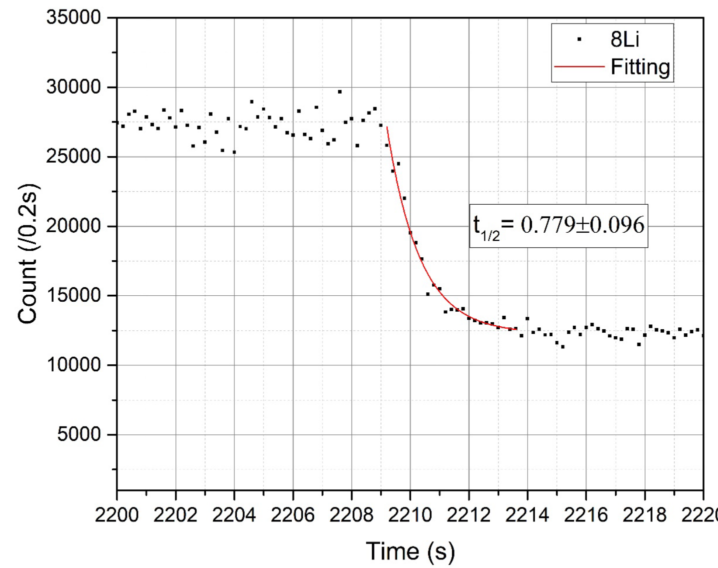


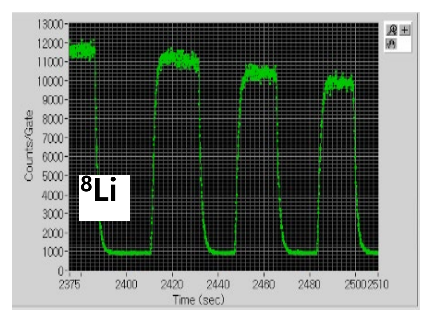
< Gamma spectrum of Na-24 measured by HPGe >
Proton 7 uA (upper) & 1.5 uA (lower)

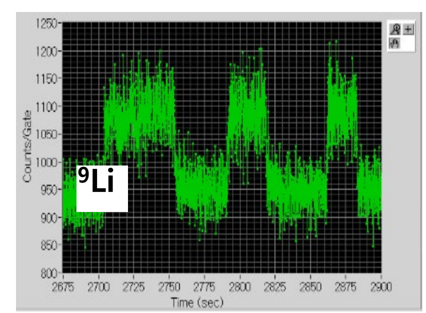


< Gamma spectrum of Na-27 measured by HPGe >

- **Measurement of ^{8,9}Li beams**
  - Proton beam : 70 MeV, 10 μ A
  - measured by Scintillator (Li does not occur gamma decay)
  - ^{8}Li($T_{1/2}$ = 838 ms), ^{9}Li($T_{1/2}$ = 178 ms)
  - ^{11}Li($T_{1/2}$ = 8.5 ms) was not observed (slow diffusion rate of Li isotopes in SiC)



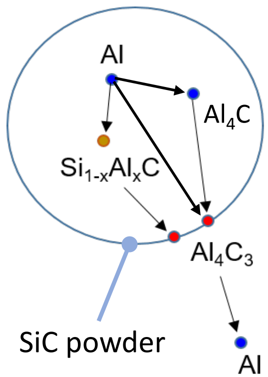




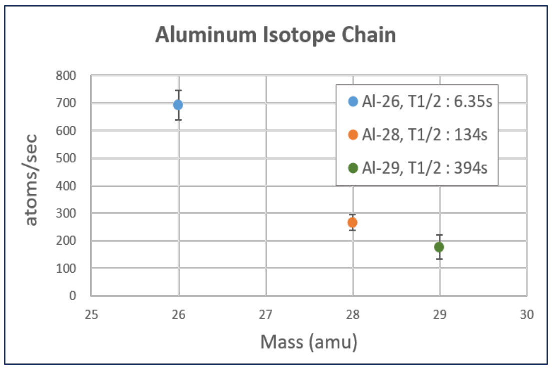
RI beam commissioning

▪ Production of Aluminum RI beams

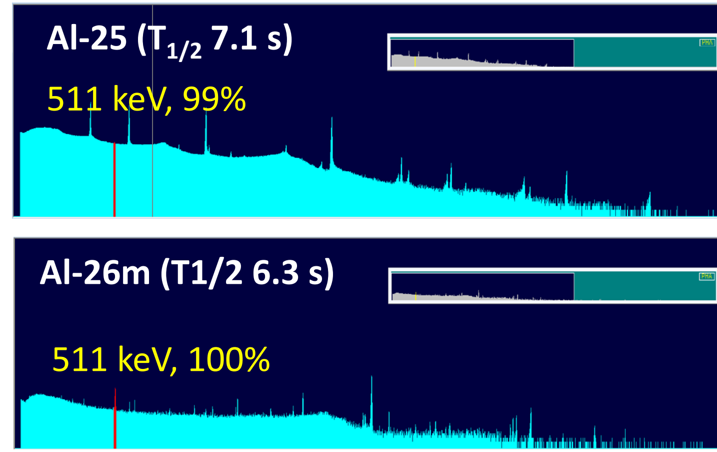
- Very slow release of Al isotopes from SiC material
- Al yield was about 6 order lower than the calculated value
- Al forms $Si_{1-x}Al_xC$ or Al_4C in SiC powder and Al_4C_3 in surface regions



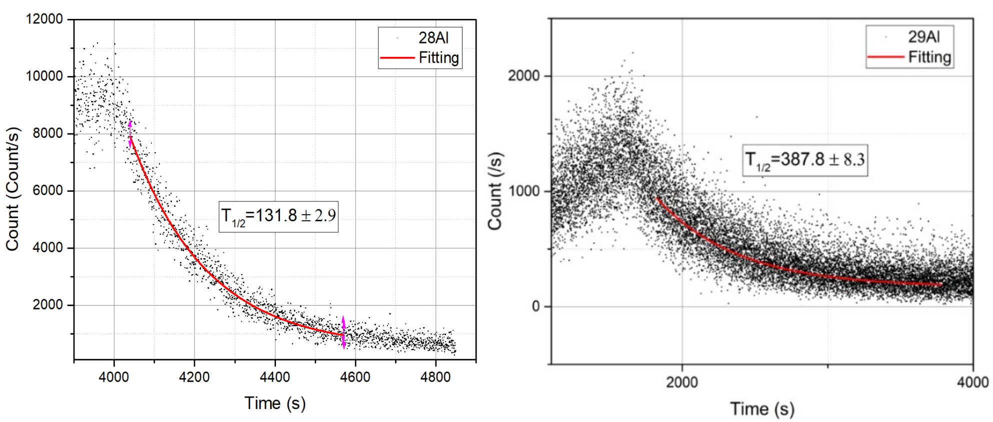
< Diffusion of Al isotopes >



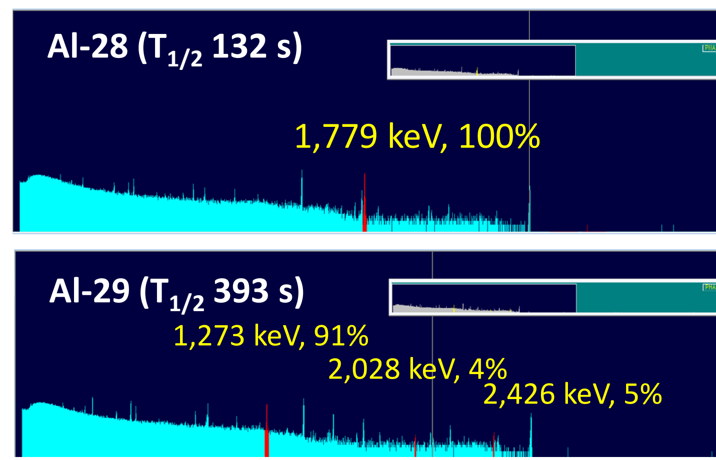
< Yields of Al RIs in P+ 7 uA >



< Gamma spectrum of Al-25(upper) & Al-26m(lower) >



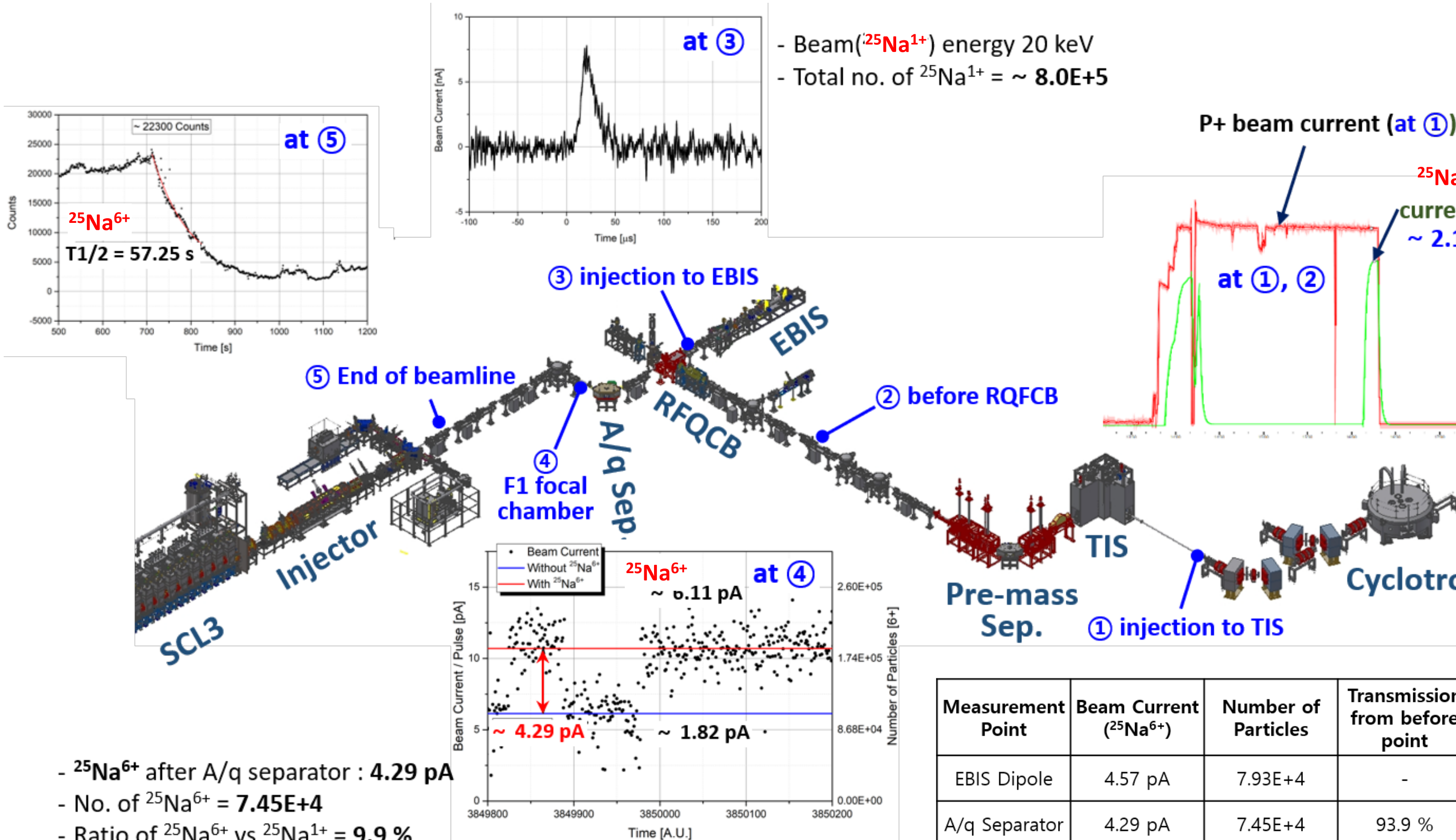
< Al-28(L) &29(R) measurement using Scintillator >



< Gamma spectrum of Al-28(upper) & Al-29(lower) >

Post-acceleration of ISOL RIB

- August 19 ~ 21, 2024
- Targeted isotopes : $^{25}Na^{5+}$ (10 keV/u, A/q 5) / pre-test using $^{25}Na^{6+}$ (August 8, 2024)
  - **Charge breeding and beam transportation of $^{25}Na^{6+}$**



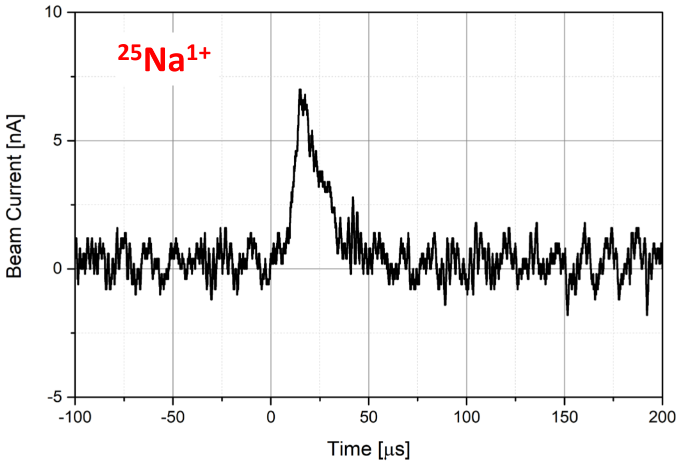
- $^{25}Na^{6+}$ after A/q separator : **4.29 pA**
- No. of $^{25}Na^{6+}$ = **7.45E+4**
- Ratio of $^{25}Na^{6+}$ vs $^{25}Na^{1+}$ = **9.9 %**

Measurement Point	Beam Current ($^{25}Na^{6+}$)	Number of Particles	Transmission from before point	Transmission from EBIS
EBIS Dipole	4.57 pA	7.93E+4	-	-
A/q Separator	4.29 pA	7.45E+4	93.9 %	93.9 %
End of ISOL Beamline	-	~ 4.46E+4	~ 59.8 %	-

Post-acceleration of ISOL RIB ($^{25}Na^{5+}$)

- **Transportation of $^{25}Na^{5+}$ ion beam to SCL3**

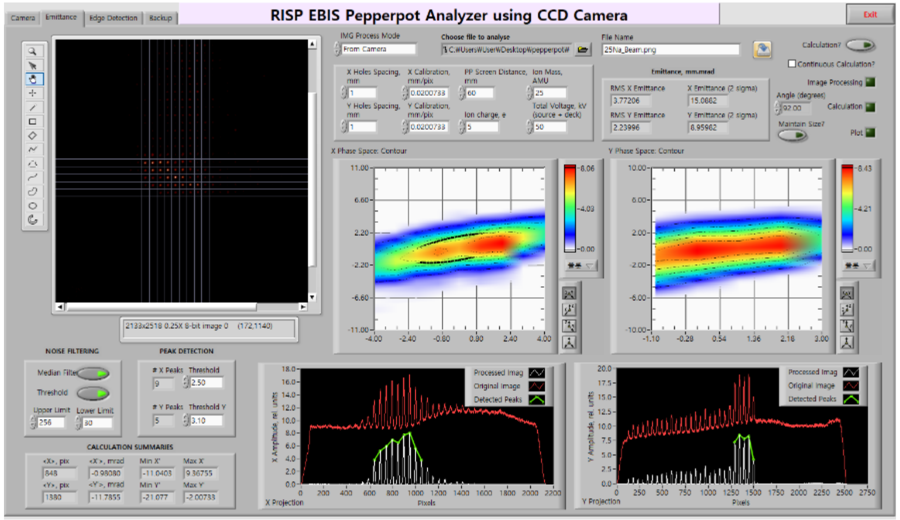
  - Injection to EBIS



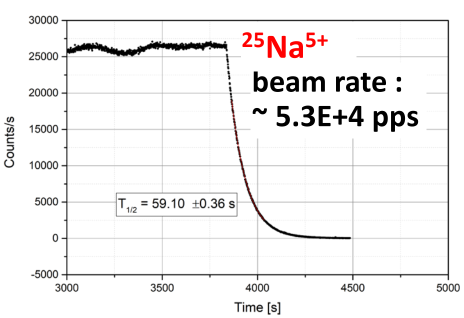
    - Pulse Length : **40 µs** (end-to-end)
    - Total particles of $^{25}Na^{1+}$ = **~ 7.32E+5**
    - Bunch repetition rate : **1 Hz**

  - EBIS experimental condition
    - SC Magnet : 6 T
    - E-Beam Energy : 13 keV
    - Breeding Time : 10 ms
    - Cathode Current (DC-CT) : 0.68 A
    - Collector Current (DC-CT) : 0.68 A
    - Extracted ion Beam Energy : **10 keV/u ($^{25}Na^{5+}$)**

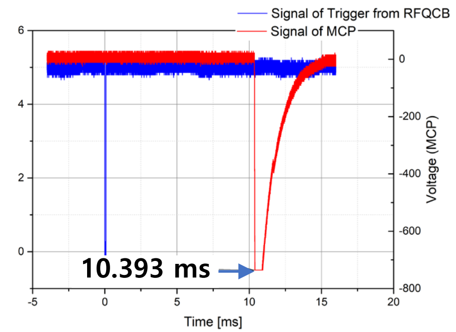
  - Beam Emittance (2σ) of $^{25}Na^{5+}$ (Horizontal: 15.09 πmm・mrad, Vertical: 8.69 πmm・mrad)



  - Counts at end of ISOL beamline (before injector)



  - Delay time of $^{25}Na^{5+}$ (from RFQCB to end of beamline)



Post-acceleration of $^{25}Na^{5+}$ to KoBRA

- **Screen shot of the monitor showing the operation status on Aug. 21, 2024**

Display

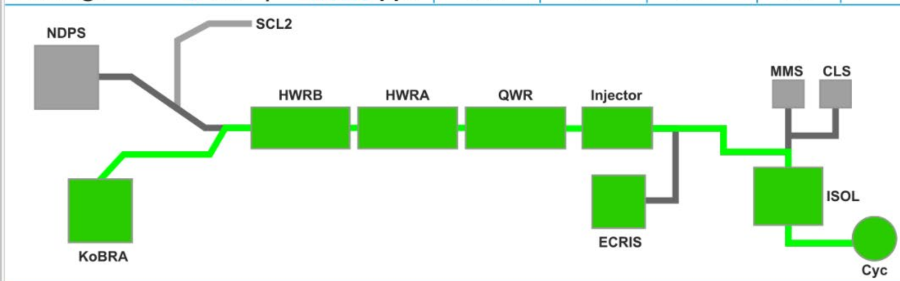
RAON Operation Status
21/AUG/2024 17:53:56 IRIS

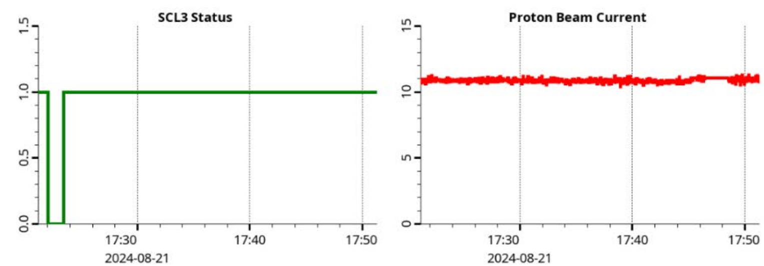
Machine · Beam Mode (SCL3)	Machine · Beam Mode (ISOL)	Timing (Chopper)	Exp. Hall Access
M4 User Operation (KoBRA)		Pulse Rate : 1 Hz	KoBRA
B3 Normal Pulse Mode		Pulse Width : 1000 μs	NDPS

○ Experiment Parameters

SCL3					RI		PROTON		
Beam	RF	Source · Charge	Energy	Power	Energy	Source · Charge	Beam	Energy	Current
ON	OFF		16.500 MeV/u	-0.10 W	10 keV/u	$^{25}Na^{5+}$	ON	70.0 MeV	11.0 uA

	Current	Intensity	Attenuator LEBT1	LEBT2	MEBT	ATT	OTHER INFO.
Peak	0 uA	-1.0E12 pps	OFF	OFF	OFF	OFF	
Average	0 uA	-1.0E9 pps					





○ Experiment schedule

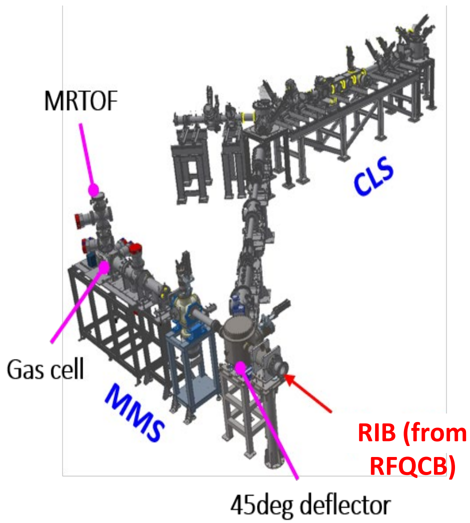
Date	Spokesperson	Exp. Keyword	Beam Types	Exp. Hall	Beam Time Unit (*1BTU = 8h)
8. 9	IRIS	Beam Tuning	40-Ar	KoBRA	1
8. 12 - 8. 14	Deuk Soon Ahn (CENS)	Cross section, Momentum distribution, RIs	40-Ar	KoBRA	3
8. 19 - 8. 21	IRIS	ISOL RI Beam Machine Study	20~25-Na	KoBRA	3
8. 22 - 8. 23	Deuk Soon Ahn (CENS)	Cross section, Momentum distribution, RIs	40-Ar	KoBRA	2
9. 2 - 9. 6	IRIS	Accelerator & NDPS Machine Study	40-Ar	NDPS	5

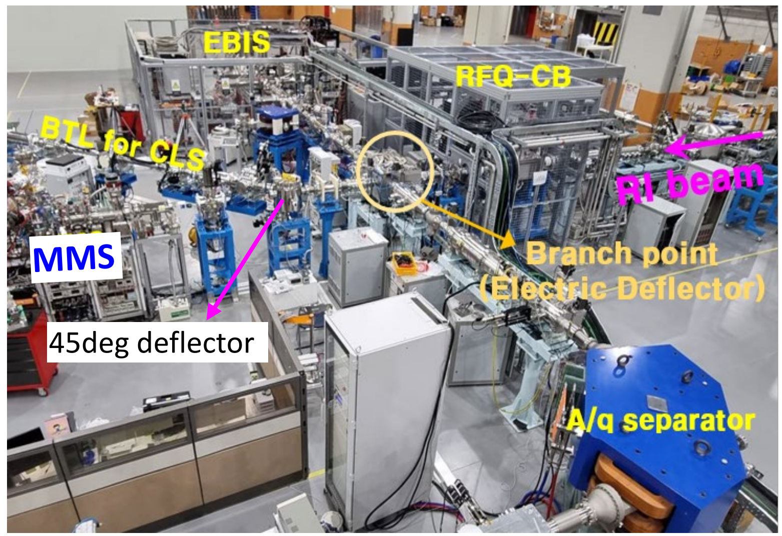
* Accelerator Control Team, *Last modified : 2024/ 08/ 26

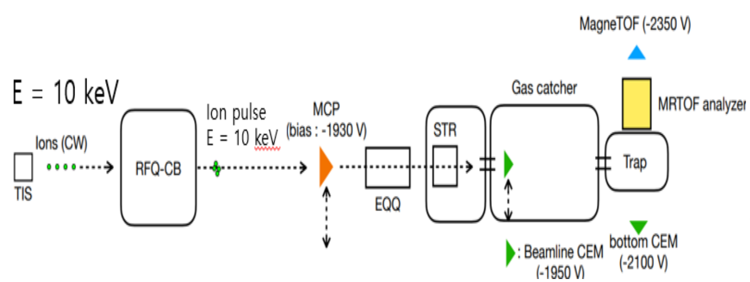
Mass measurement of ISOL RIB

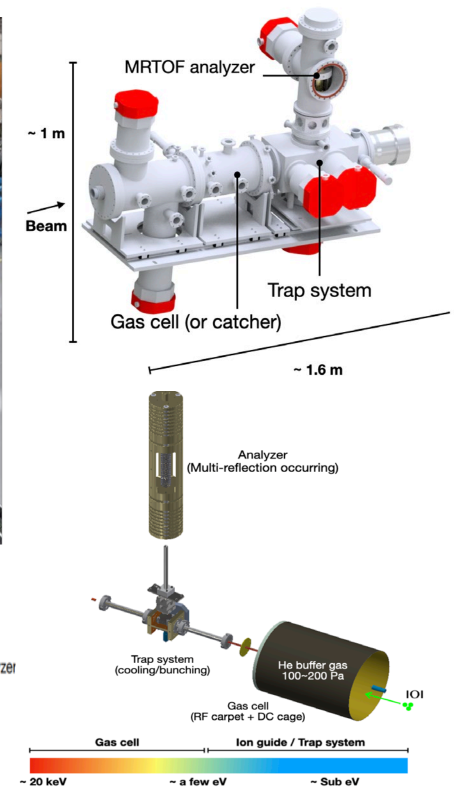
Joonyoung Moon of IRIS

- Mass measurement using MRTOF-MS (Multi-reflection time-of-flight mass spectrograph)
  - Gas cell : He buffer collision (stopping the ion beam of < 10 keV), RF carpet for quick extraction
  - Trap system: three linear RFQ PAUL traps (cooling and bunching)
  - MRTOF analyzer: ~ 0.5 m, mirror electrodes, multiple reflections for high MRP





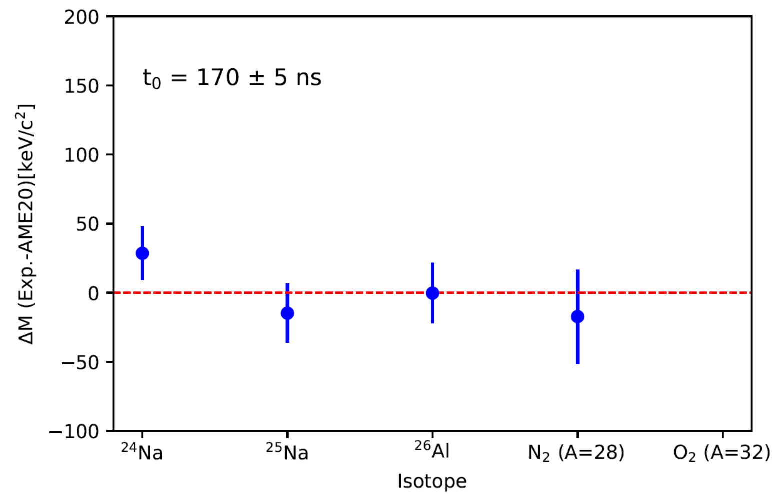


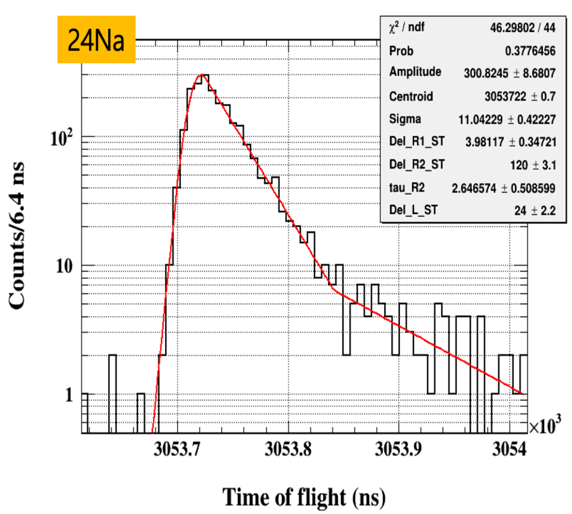


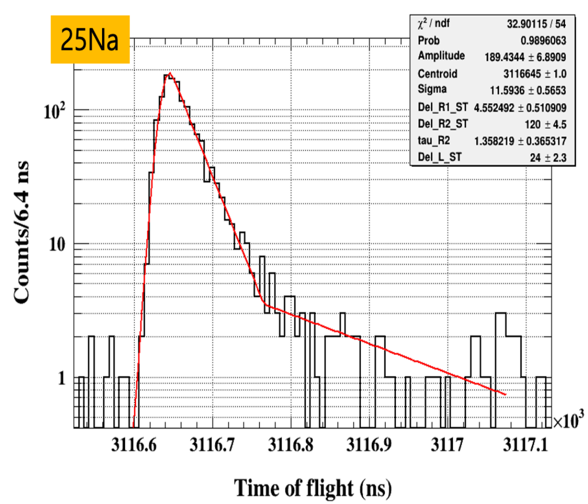
< MRTOF-MS >

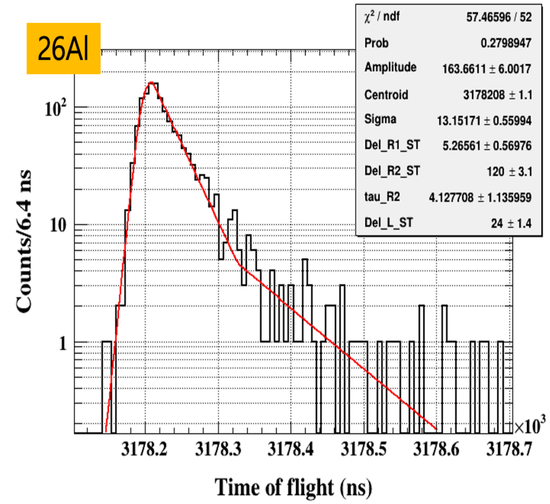
Mass measurement of RI at MRTOF-MS

- RI beam commissioning (May, 2024)
  - ^{24}Na ($T_{1/2}$=14.9 h), ^{25}Na ($T_{1/2}$=59.1 s), ^{26}Al of E ~ 10 keV
  - Gas cell buffer gas pressure: P_{He} < 100 Pa
  - ^{39}K alkali ion source as a reference
  - Their masses have been confirmed within ppm accuracy
  - Note that ^{26g,m}Al could not be separated due to low MRP, so should be remeasured with higher MRP of 120,000



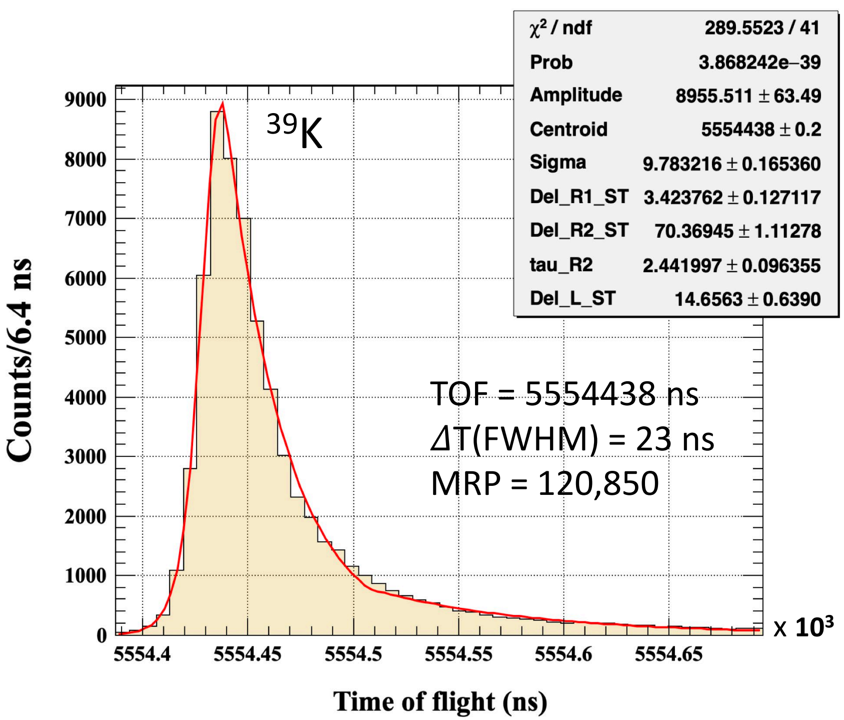


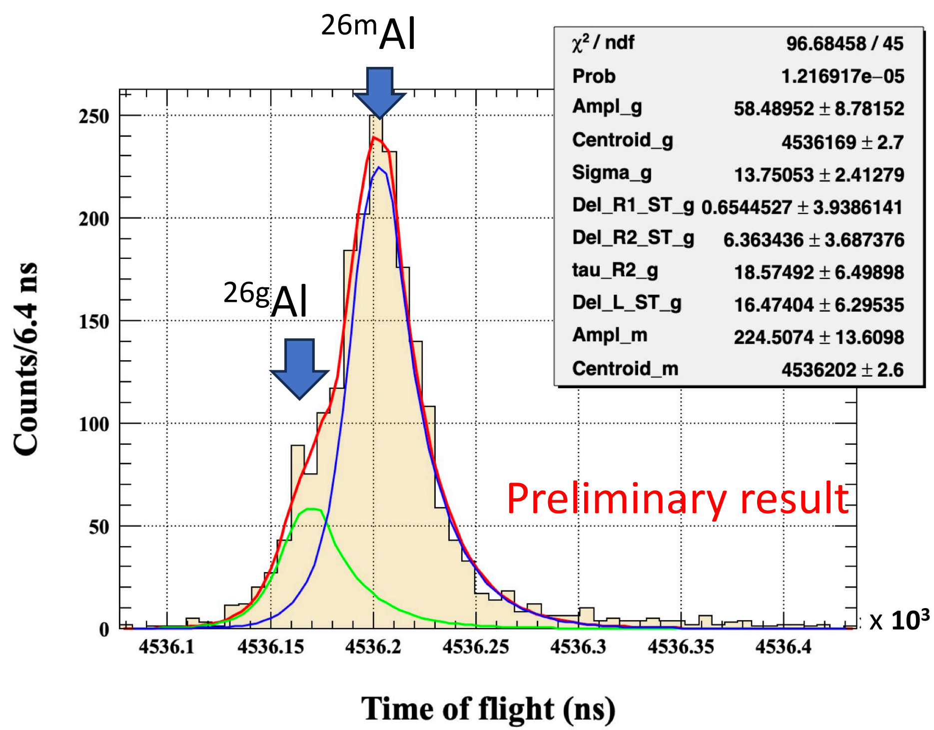




Mass measurement of RI at MRTOF-MS

- RI beam commissioning (^{26m}Al isomer measurement, September 2024)
  - Recent improvement of the mass resolving power: ~ 120,000 for ^{39}K
  - The isomer state (Ex = 228 keV) of ^{26}Al could be measured
  - Bump structure, probably due to mixture of ^{26g}Al and ^{26m}Al ions, observed
  - However, the separation is not complete because of poor resolution for the ^{26}Al ion



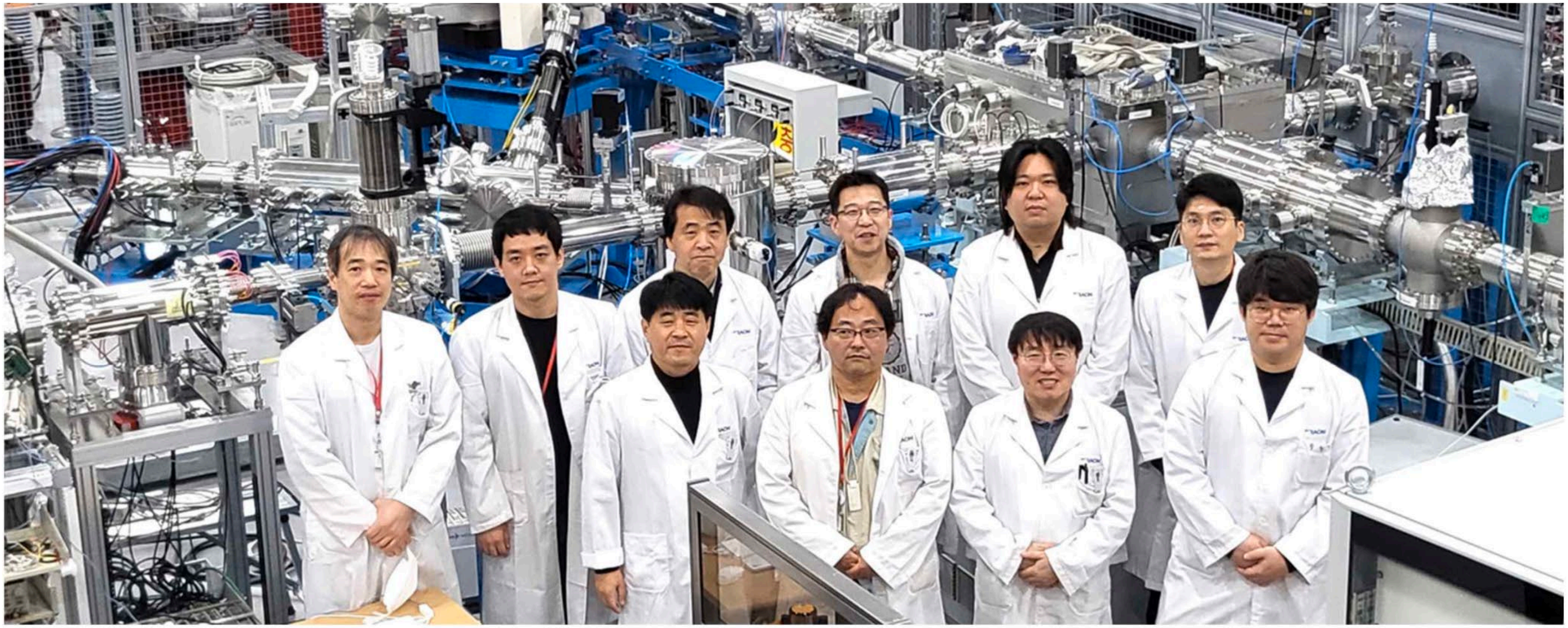


Summary

- RFQ Cooler Buncher was performed the cooling and bunching of the stable ions and RI from ISOL.
- ISOL RI beams (Li, Na, Al, Cs, Ba) were produced from SiC & LaC_2 using a surface ion source in 2024
- For the first time in RAON, ISOL RI beam ($^{25}Na^{5+}$) was accelerated by SCL3 and transported to KoBRA with energies of 16.4 MeV/u
- Commissioning of MMS using ISOL RI beams is in progress, and the masses of ^{24}Na, ^{25}Na and ^{26g}Al have been measured (^{26m}Al is under analysis)
- The ISOL system is currently providing beams for the CLS experiment.

Thank you for your attention

Hee-Joong Yim, Seongjin Heo, Shinwoo Nam, Jun Young Moon, Kyounghun Yoo, Yeong-Heum Yeon,
Jinho Lee, Takashi Hashimoto, Dong-joon Park, Wonjoo Hwang,
(Jae-Won Jeong, Jongwon Kim, Ha-Na Kim, Jae Han Hwan(PhD Student))



Acknowledgement Hyung Joo Woo, Young Seok Kim, Sang Ho Na

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