

Status of "RAON" Heavy Ion Accelerator

Yeonsei Chung

on behalf of IRIS (Institute for Rare Isotope Science)

April 17, 2024

EPICS Collaboration Meeting, Pohang

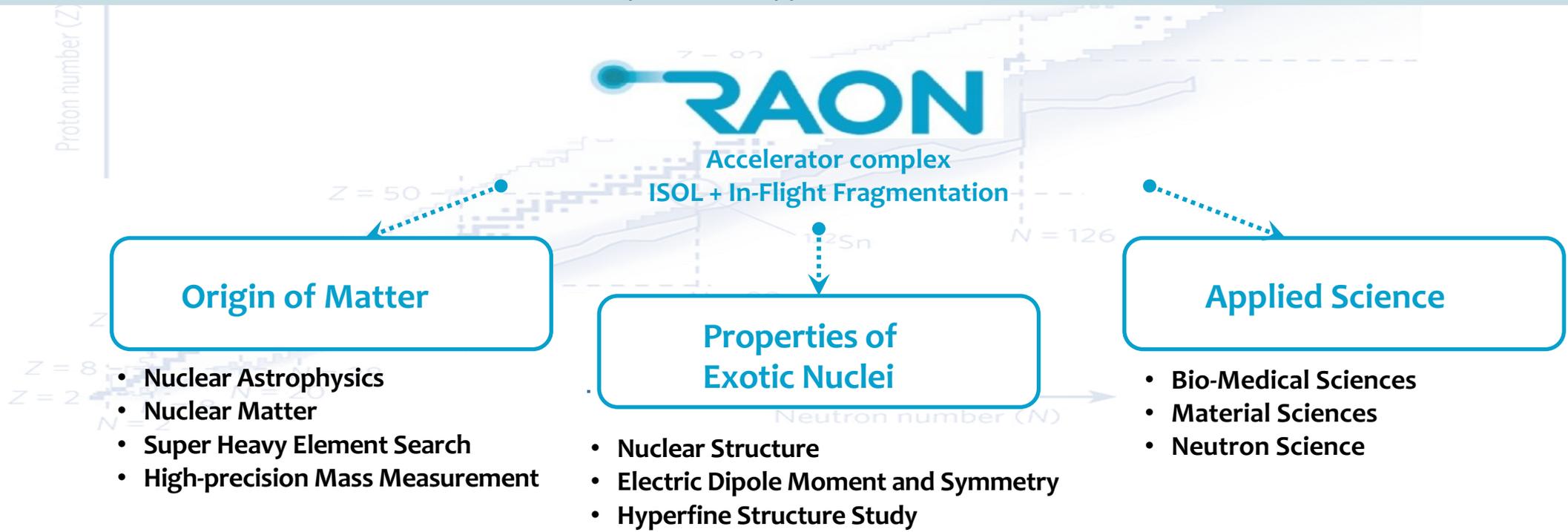


Contents

- 1) RAON Overview
- 2) Accelerator Systems
- 3) Rare Isotope & Experimental Systems
- 4) Summary

RAON (Rare isotope Accelerator complex for ON-line experiments)

Goal	To build a heavy ion accelerator complex, RAON, for rare isotope science research
Period	1 st Phase: 2011.12 - 2022.12 R&D for the 2 nd Phase: 2022.12 - 2025.12
Budget	~\$ 1.4 B (Facilities ~ \$ 0.5 B; Land, Bldgs & Utilities ~ \$ 0.9 B) * includes initial experimental apparatus



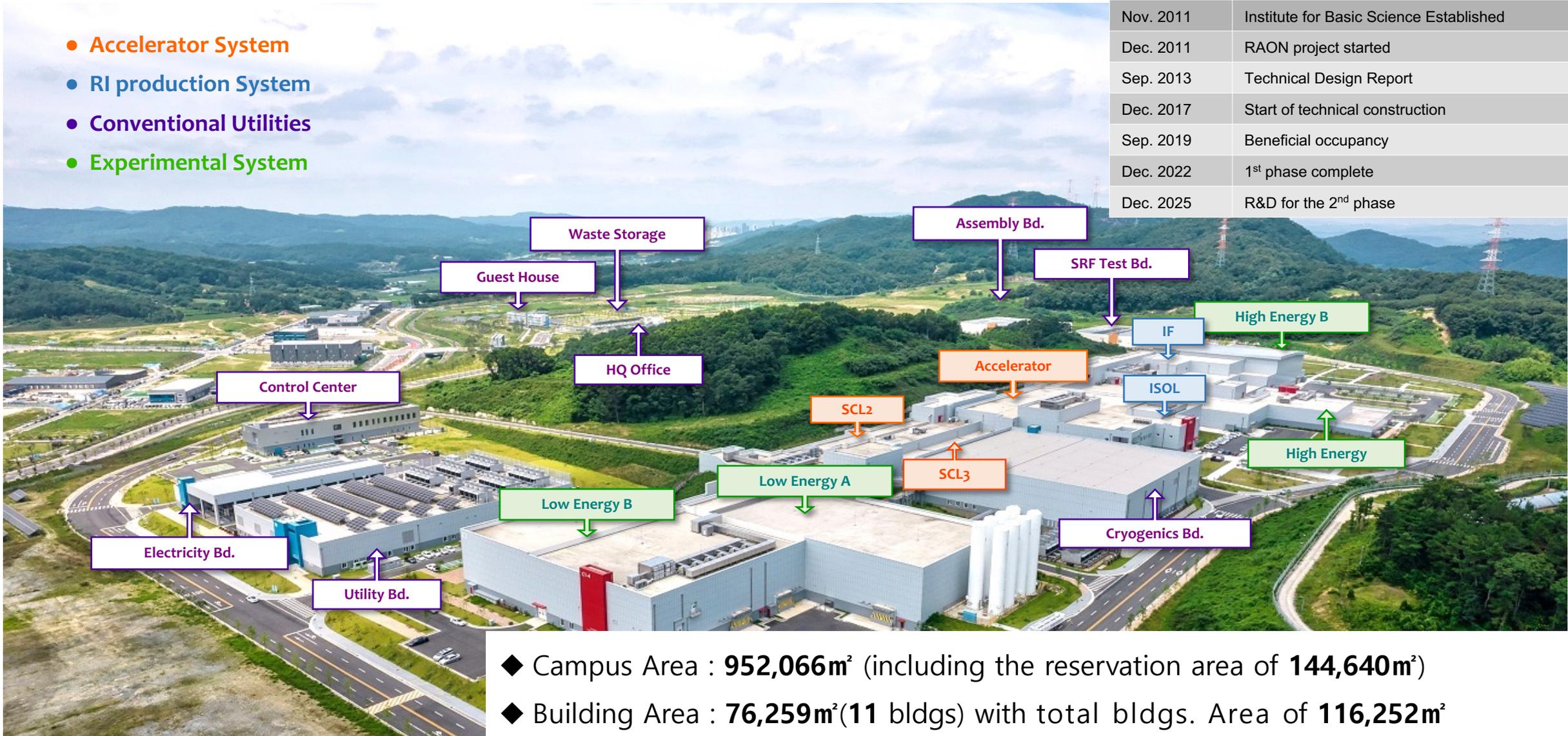
Where is RAON?



Bird's-eye view of RAON Campus

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

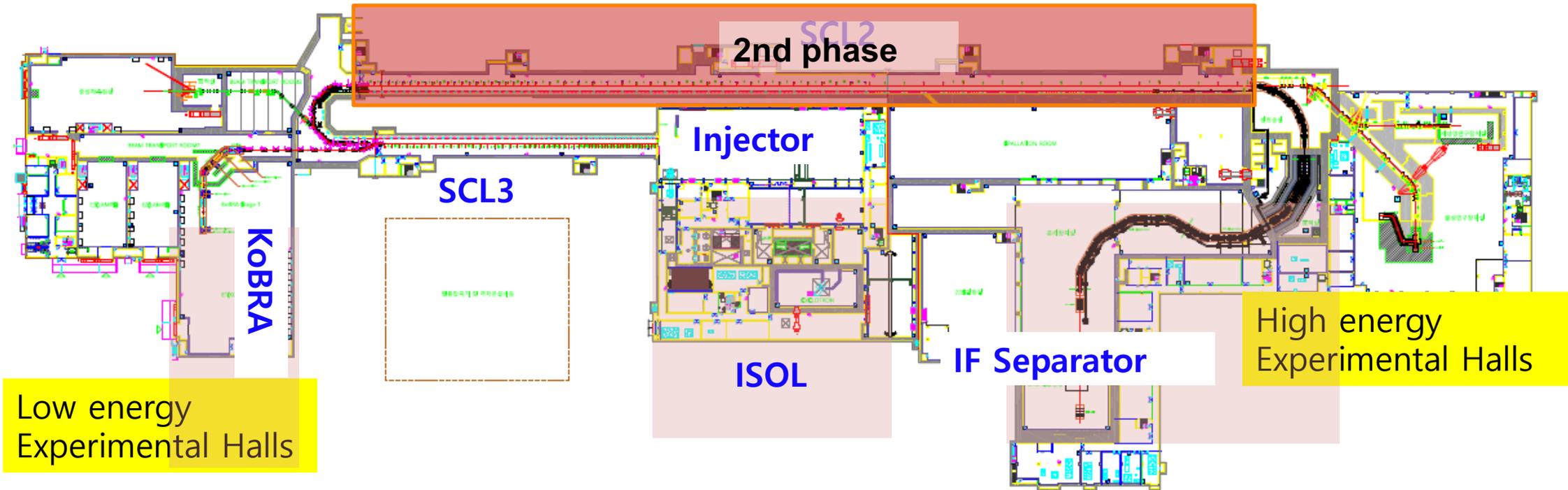
Nov. 2011	Institute for Basic Science Established
Dec. 2011	RAON project started
Sep. 2013	Technical Design Report
Dec. 2017	Start of technical construction
Sep. 2019	Beneficial occupancy
Dec. 2022	1 st phase complete
Dec. 2025	R&D for the 2 nd phase



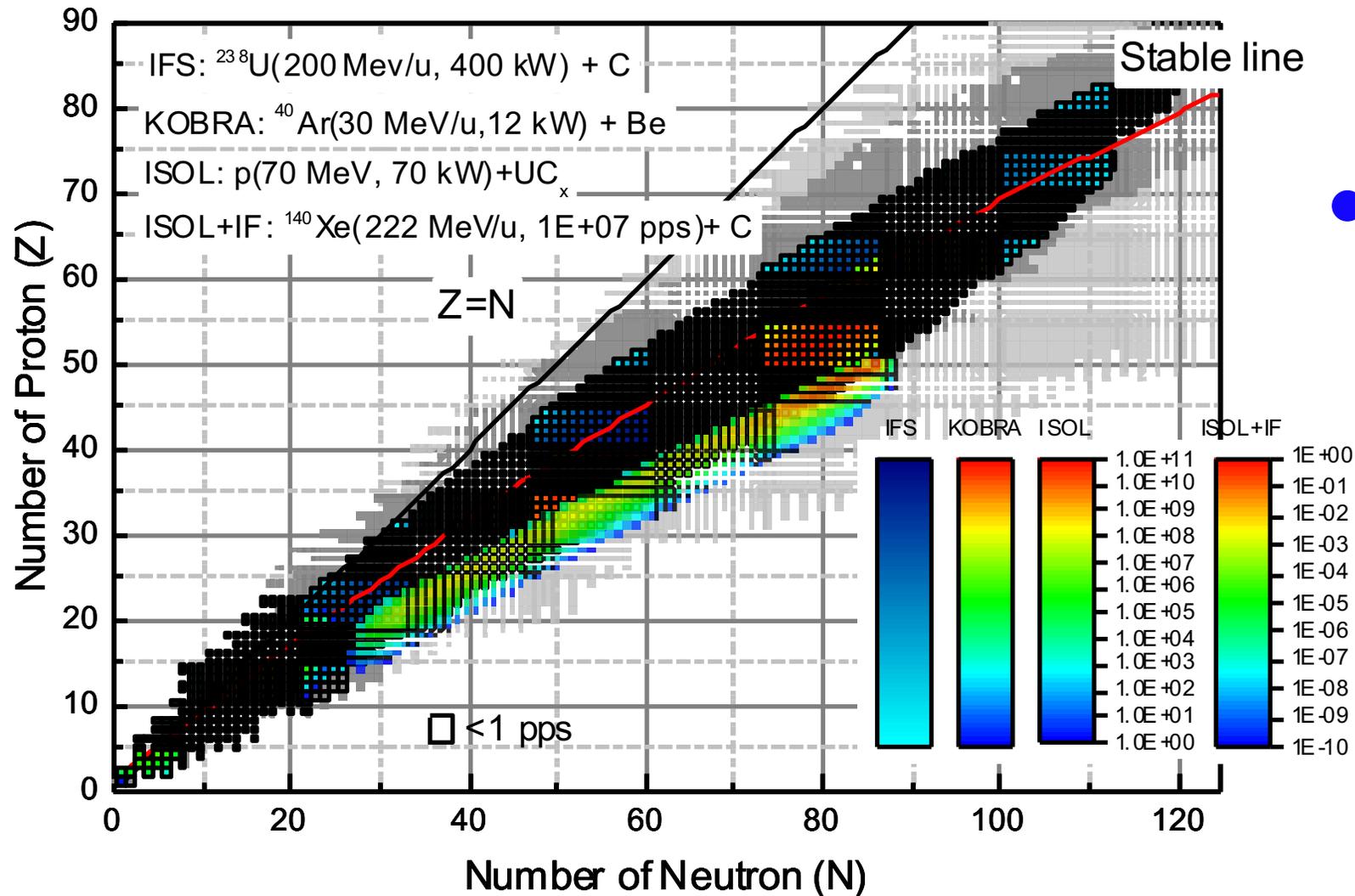
- ◆ Campus Area : **952,066m²** (including the reservation area of **144,640m²**)
- ◆ Building Area : **76,259m²**(11 bldgs) with total bldgs. Area of **116,252m²**

Production of Rare Isotope Beams at RAON

Driver Accelerator	SCL3 (ECR/ISOL)	Cyclotron	SCL3 + SCL2
Primary Beam Energy	80 MeV (p), 18 MeV/u (U)	< 70 MeV (p)	600 MeV (p), 200 MeV/u (U)
Experiment Facility	KoBRA, NDPS	ISOL	In-flight Fragment Muon facility
RIB Energy	< tens of MeV/u	> a few keV/u	< hundreds of MeV/u

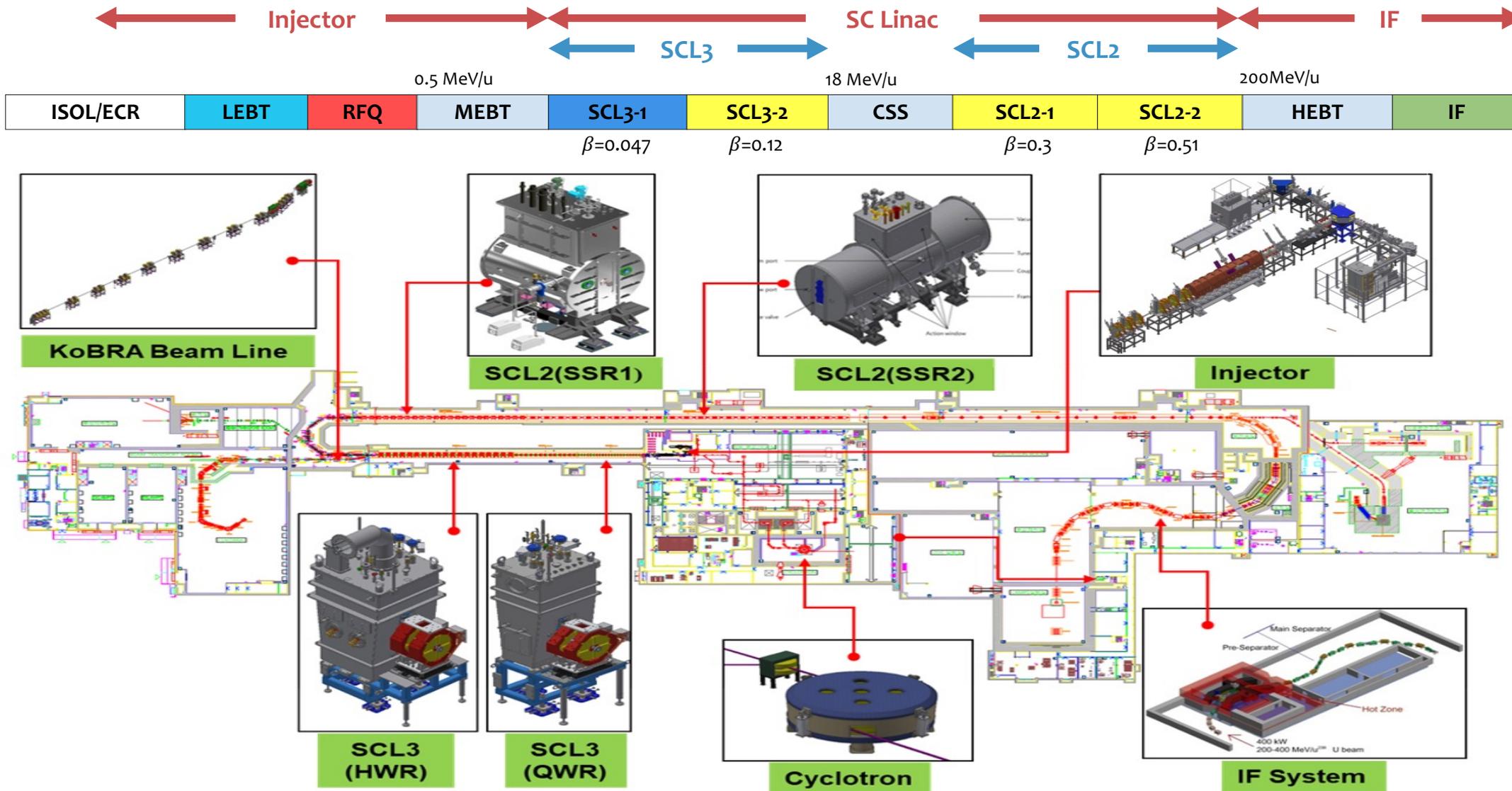


RIBs (Rare Isotope Beams) at RAON



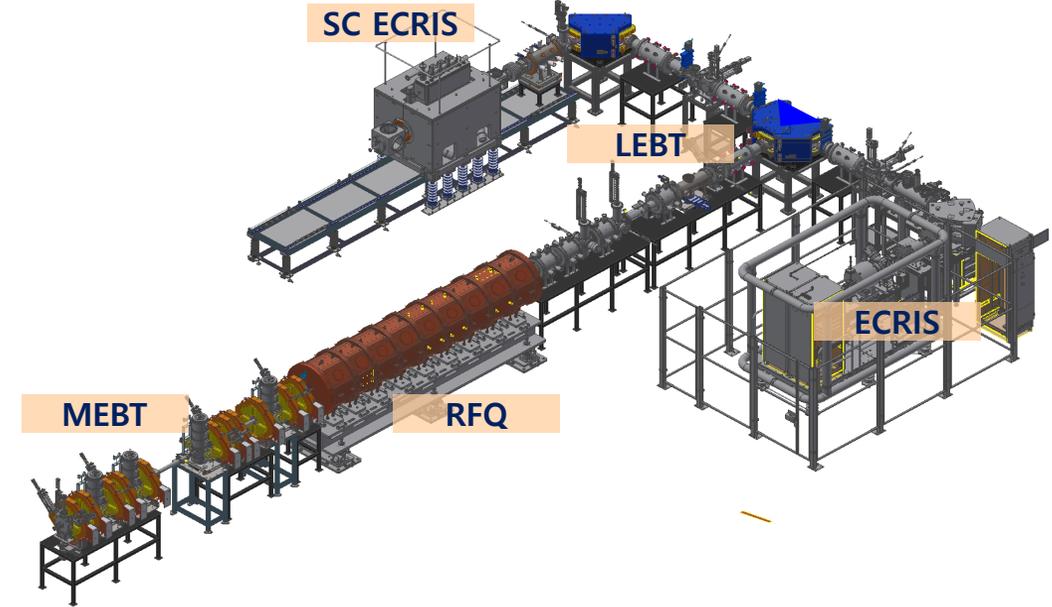
- RAON will provide access to unexplored regions of the nuclear chart

Accelerator Systems



Injector System

- **Two ECR-IS on high voltage platforms**
 - 14.5 GHz ECR ion source
 - 28 GHz superconducting ECR ion source
- **LEBT ($E = 10 \text{ keV/u}$)**
 - 10 keV/u, Dual bending magnet
 - Chopper & Electrostatic quads, Beam instrumentation
- **RFQ ($E = 500 \text{ keV/u}$)**
 - 81.25 MHz, Transmission Eff. $\sim 98\%$
 - CW RF Power 94 kW (SSPA: 150 kW)
- **MEBT ($E = 500 \text{ keV/u}$)**
 - Four RF bunchers (SSPA: 20, 15, $2 \times 4 \text{ kW}$)
 - Eleven quadrupole magnets, Beam instrumentation

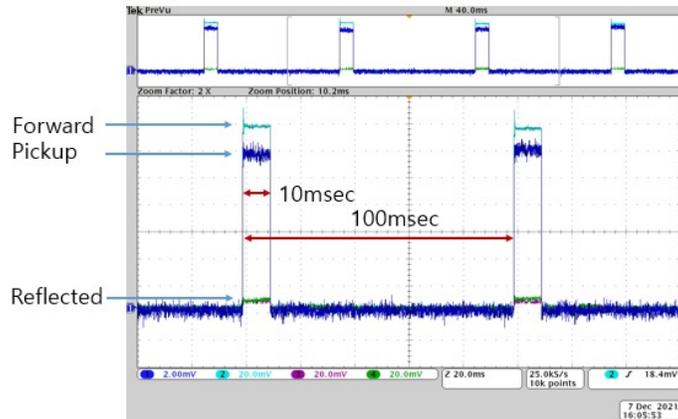


- Installation completed and beam commissioning from October, 2020

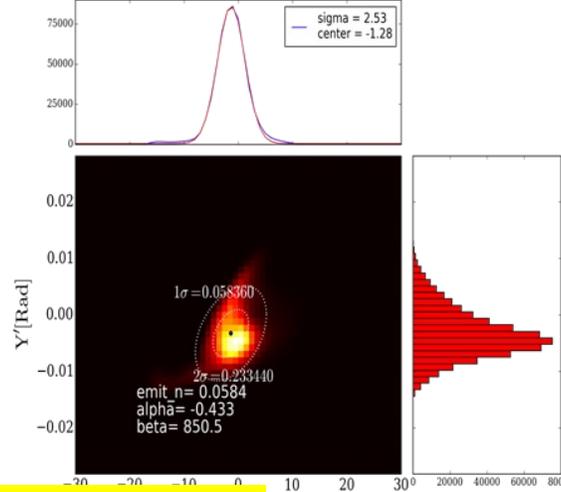
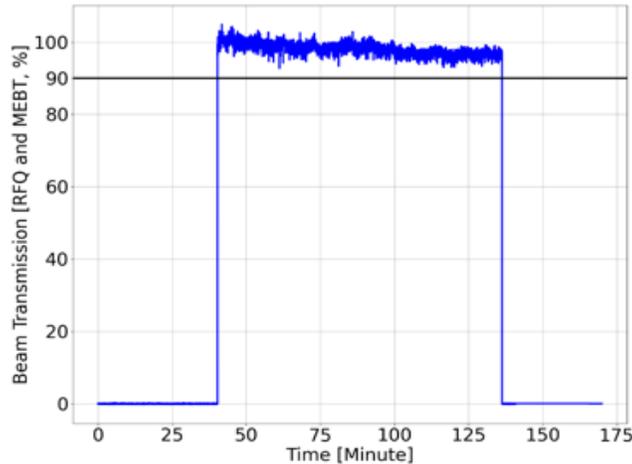
Injector beam commissioning

- 10% beam duty operation: 96 minutes, 10Hz, 10msec (2021.12.07.)

* Injector transmission > 94%

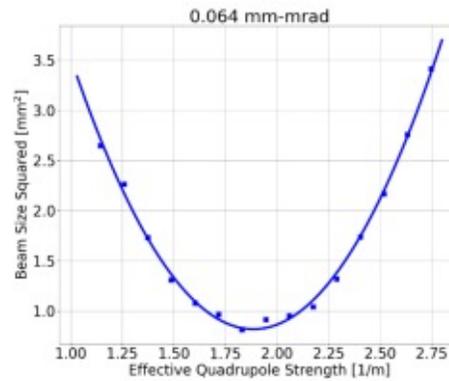


Injector beam transmission



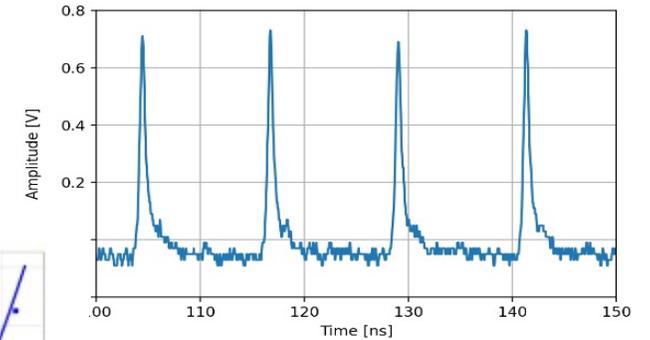
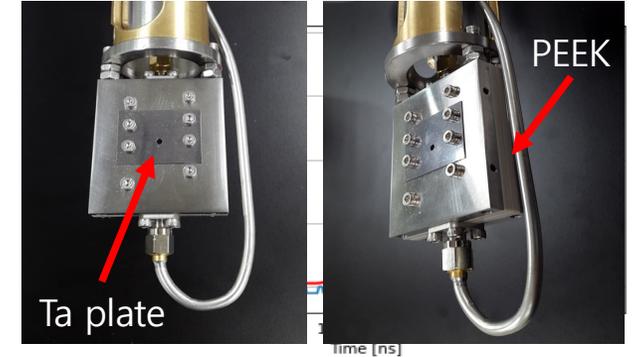
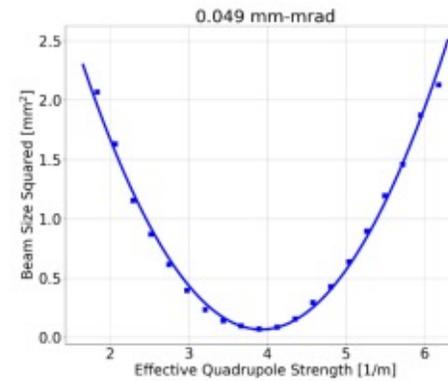
LEBT emittance (Allison scanner)

$$\begin{aligned} \epsilon_x &= 0.048 \text{ mm-mrad} \\ \epsilon_y &= 0.067 \text{ mm-mrad} \end{aligned}$$



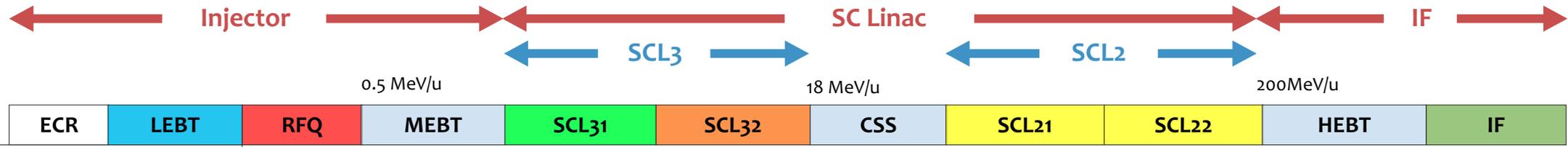
MEBT emittance (quad scan)

$$\begin{aligned} \epsilon_x &= 0.064 \text{ mm-mrad} \\ \epsilon_y &= 0.049 \text{ mm-mrad} \end{aligned}$$

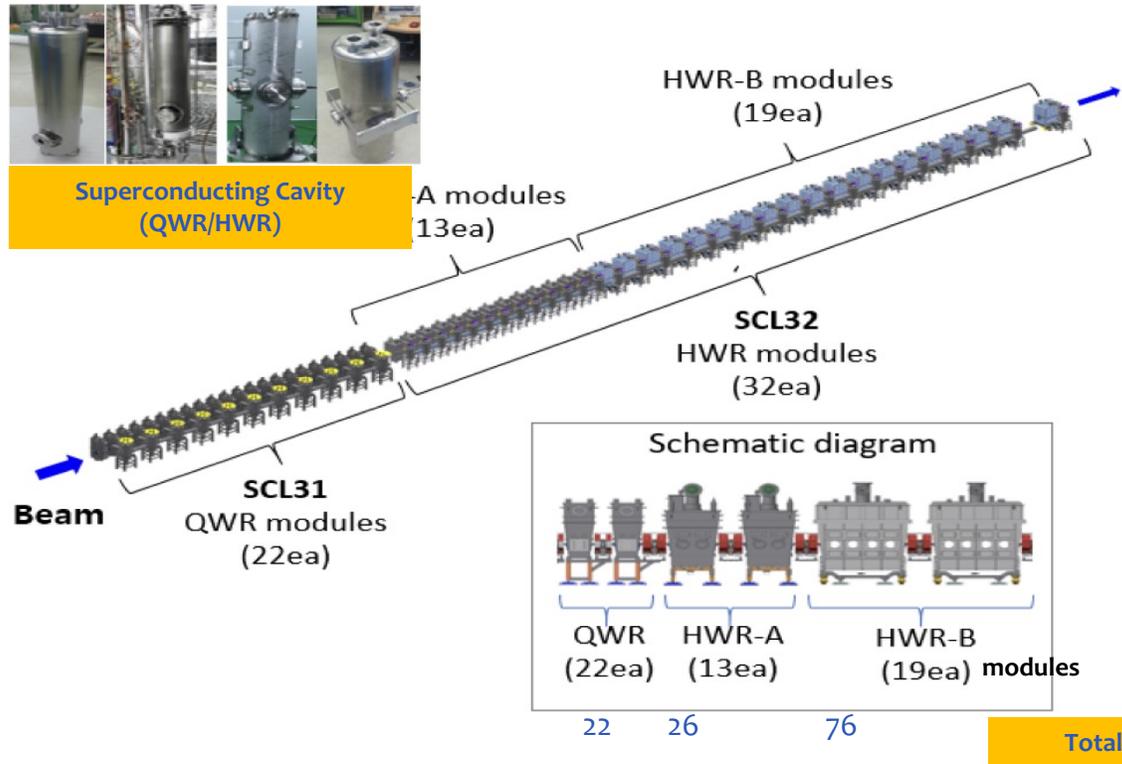


- bunch length using FFC
- length ~ 0.297 ns (1σ)

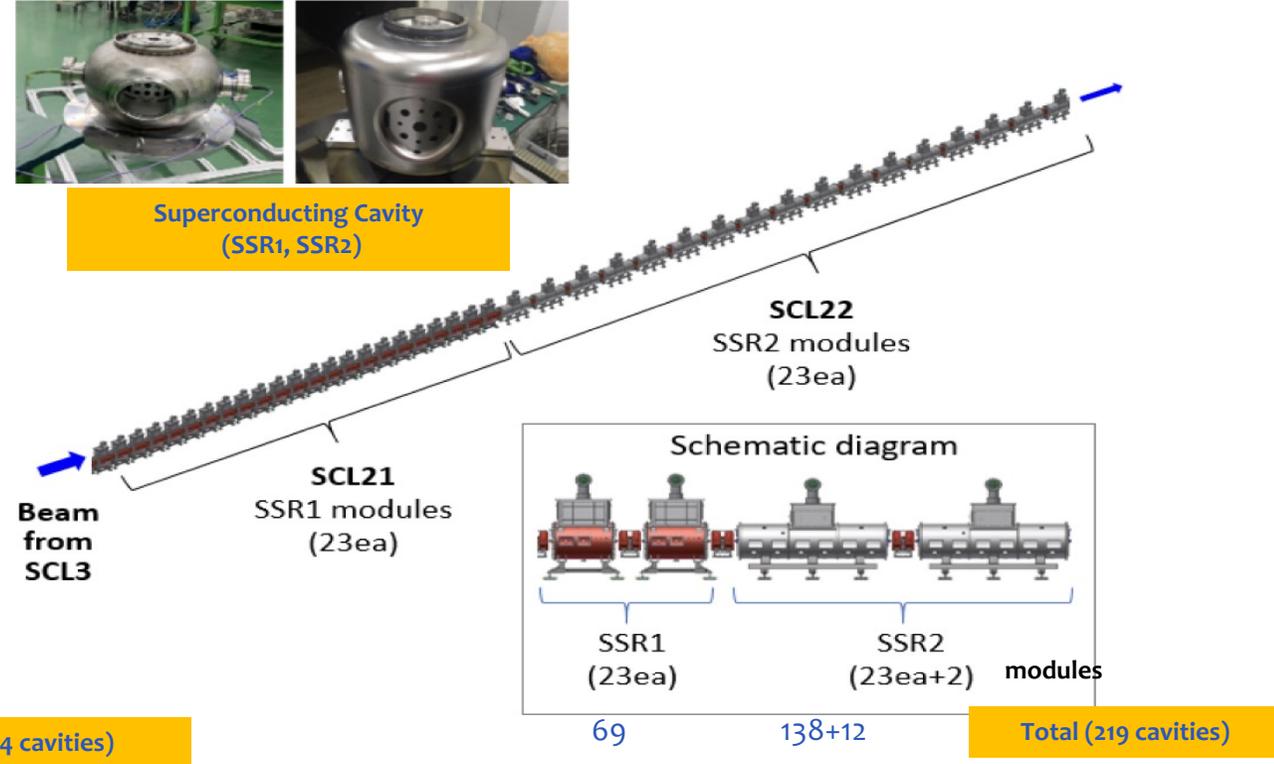
Superconducting Linear Accelerator



Superconducting Linac 3 (Low-energy section)



Superconducting Linac 2 (High-energy section)



SCL3 QWR/HWR CM Installation

- QWR(22EA) 1st CM Installation(20.4.20)



- HWR-B(19EA) 1st CM Installation(21.06.09)



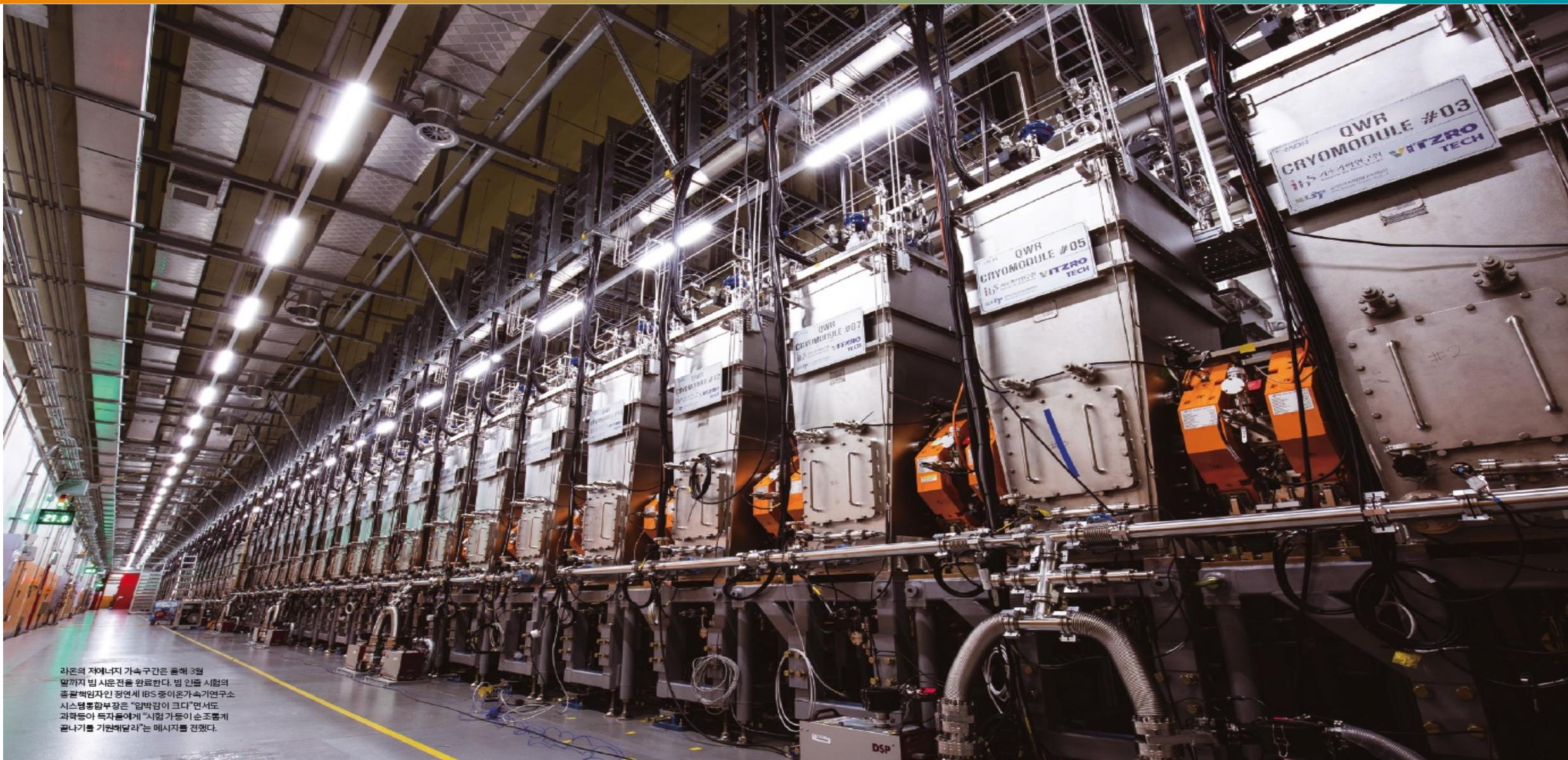
- HWR-A(13EA) 1st CM Installation(21.03.24)



- HWR-B 19th Installation(21.12.07)



Superconducting linear accelerator (SCL3) in the tunnel



라온의 저에너지 가속구간은 올해 3월 말까지 빔 시운전을 완료한다. 빔 인출 시험의 총괄책임자인 정연세 IBS 중이온가속기연구소 시스템총괄부장은 "입막임이 크다"면서도 과학자들이 독자롭게 "시험 가동이 순조롭게 끝나기를 기원해달라"는 메시지를 전했다.

Cryogenic System

Helium Storage (8 x 250 m³)



Distribution Box(TBx)



SCL2 coldbox



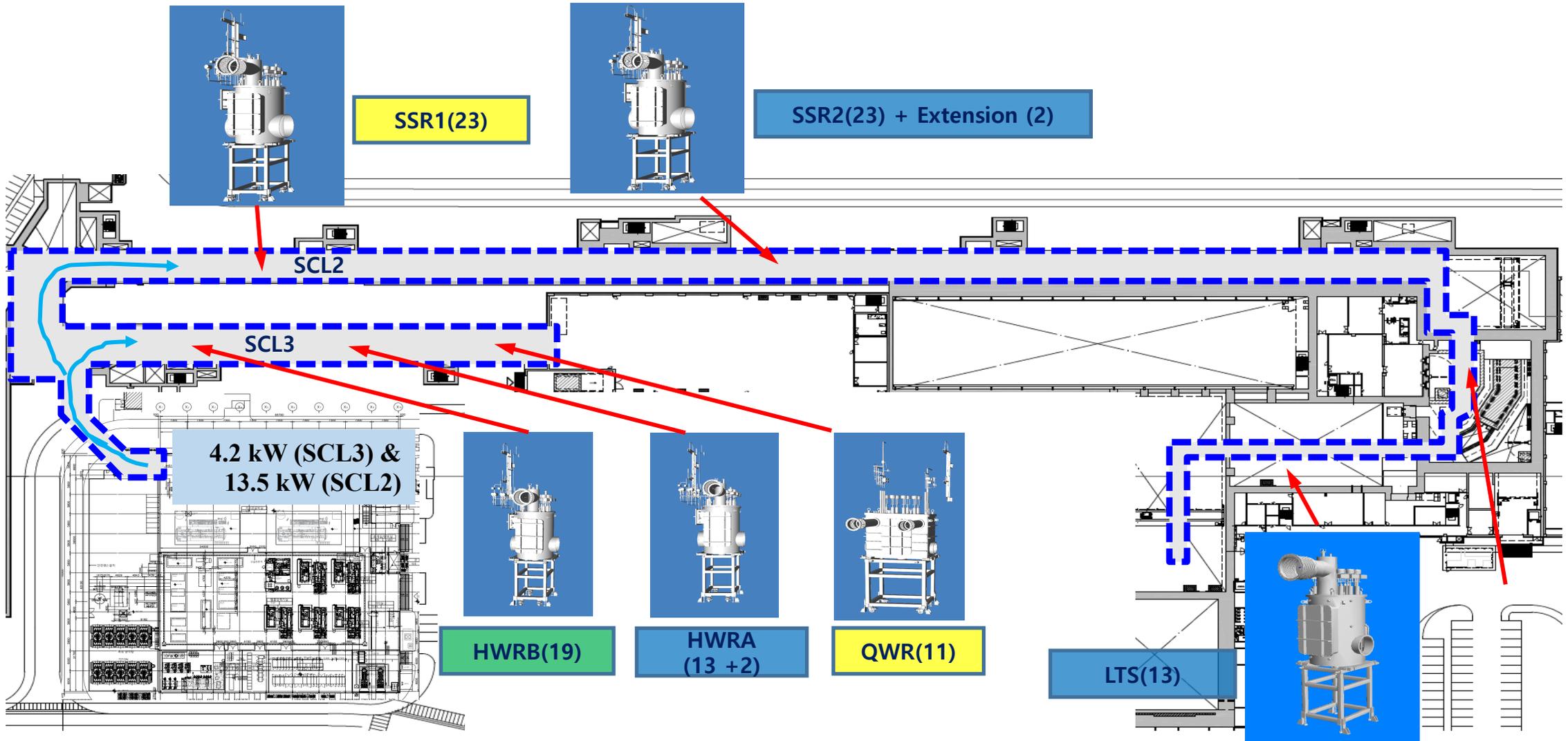
SCL3/SCL2 Compressors



Completion of SCL3 4.5 K cool-down('22.10)



Layout of Cryogenic Distribution Systems

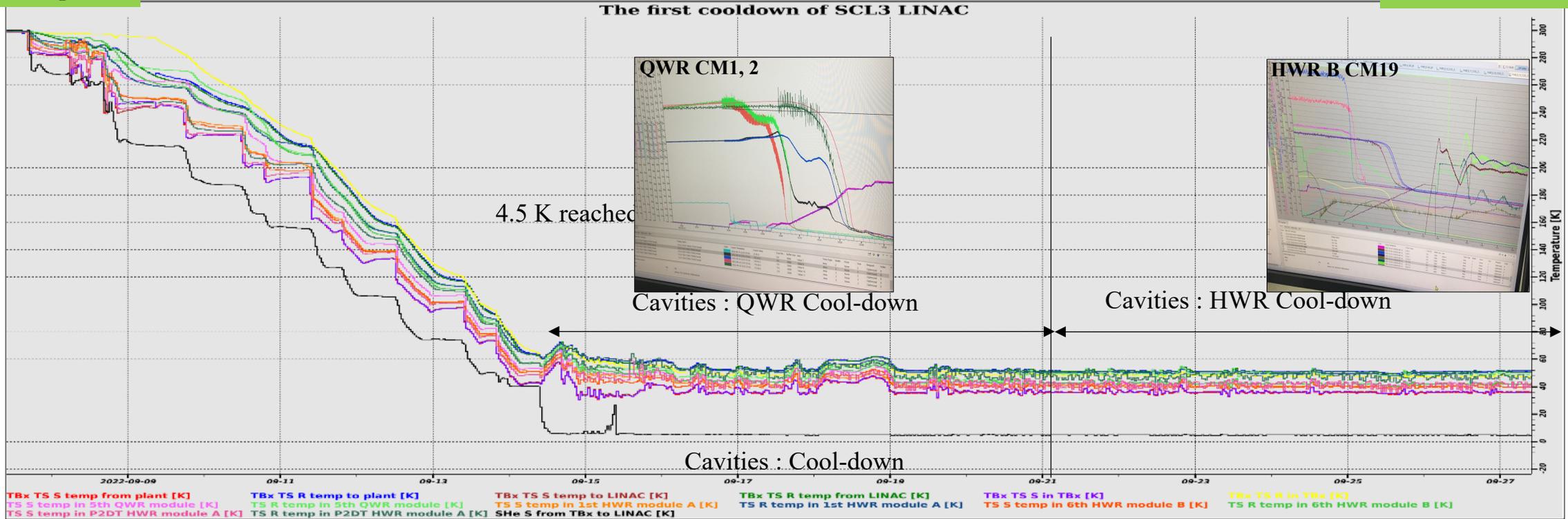


The 1st Cool-down of SCL3

Cooled-down CDS & thermal shields of all CM, simultaneously

From Sep. 7th

End Oct. 26th



- SCL3 1st cooled-down to 4.5 K('22.10) and 2 K('23.1) successfully
- Operated until June 2023, about 9 months without a major issue
- SCL3 was warmed up to room temperature('23.6); **2nd cool-down('24.2~3)**

Control System

Control Center



Main Control Room



Data Storage System

Integrated Control System



Timing System



Machine Protection System

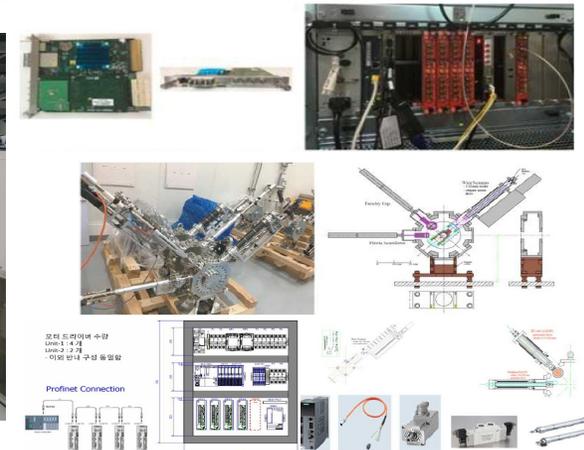
Local Control System



EPICS IOC Controllers

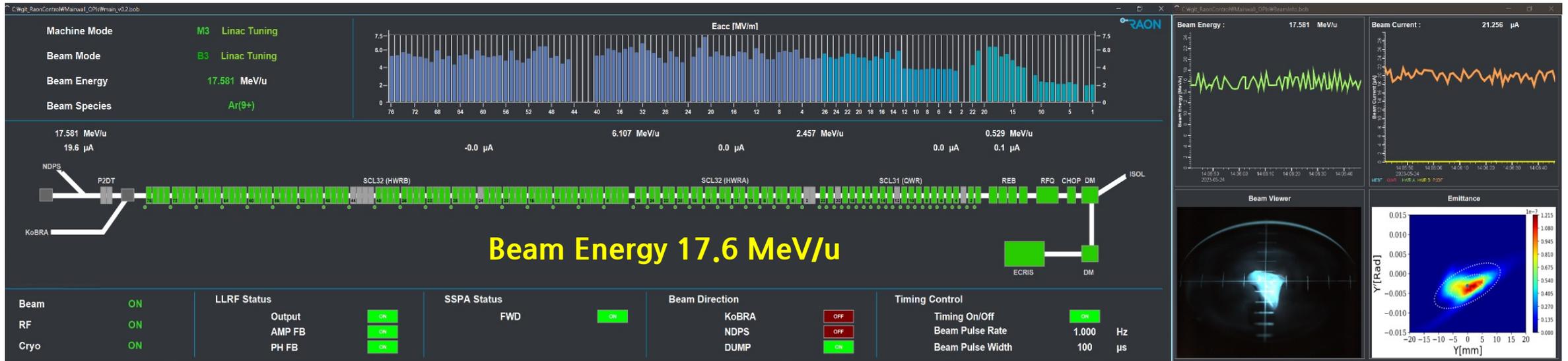


SCL3 Control System(43)



Beam Diagnostics Control System

SCL3 Beam Commissioning (May 23, 2023)



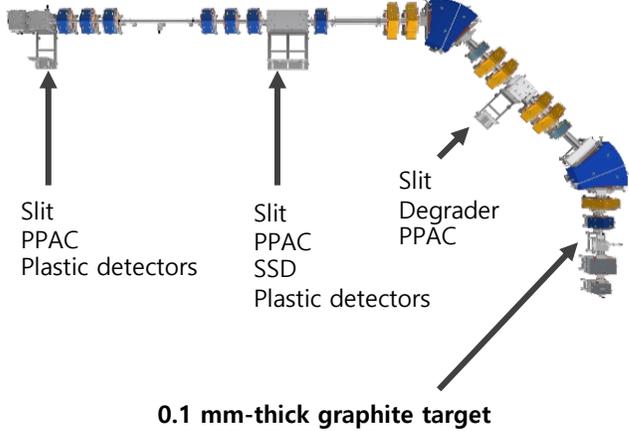
Ar⁹⁺ beams accelerated by entire SCL3(QWR/HWR) on May 23, 2023



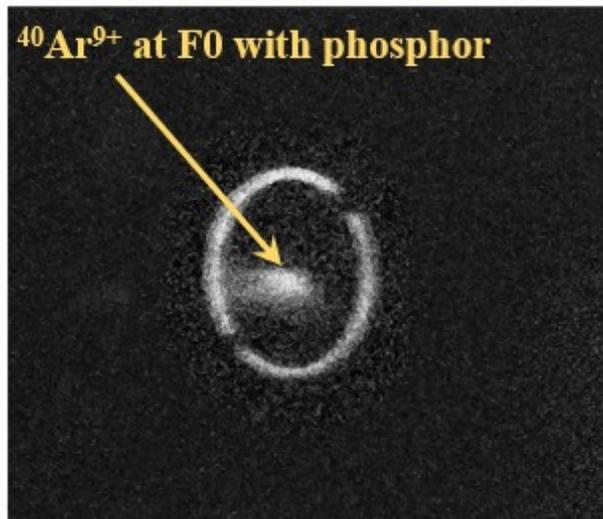
- Total 10 cavities (out of 124) excluded
 - QWR#3: control issue
 - QWR#20: out of tuner control range
 - HWR-A CM#1(2 cavities): cold-leak
 - HWR-B CM#11(4 cavities): cold-leak
 - HWR-B#24: control issue
- Delivered beams to KoBRA (5/30~6/2)
 - ⁴⁰Ar⁹⁺, 16.5 MeV/u, 100 μsec, 1 Hz



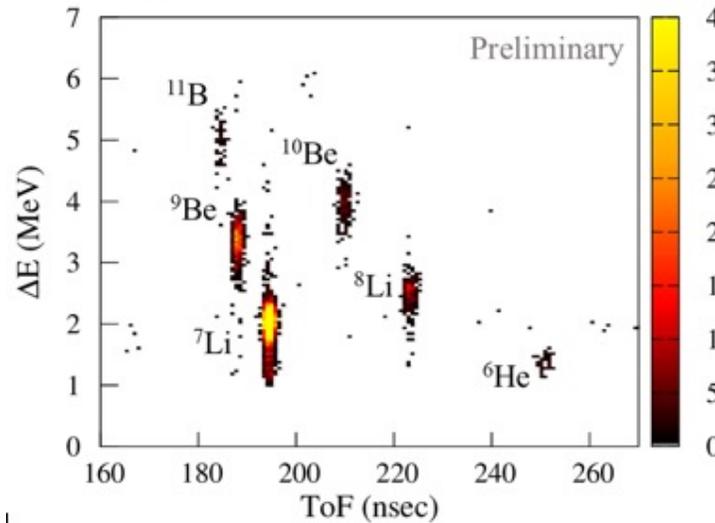
The First production of RIs at F3 of KoBRA (Ar + C)



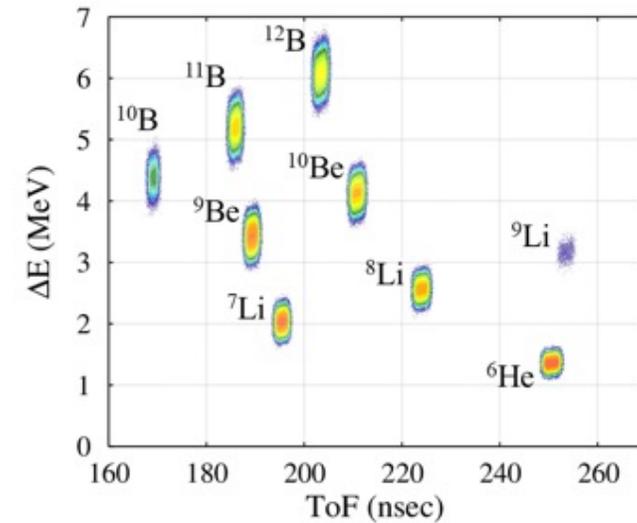
16.5 MeV/u ^{40}Ar beam
(about 0.2 W)



Experimental data



LISE++ Simulation



Superconducting Linac, SCL2



◆ Plan for SCL2 Linac construction

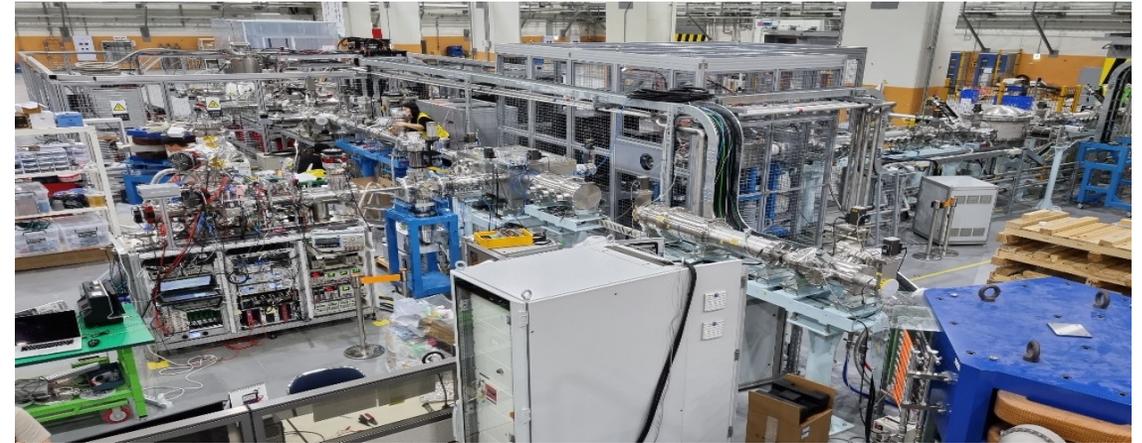
- CM(SSR1, SSR2) R&D project : 2022.12~2025.12
- SCL2 construction is expected to start in 2026



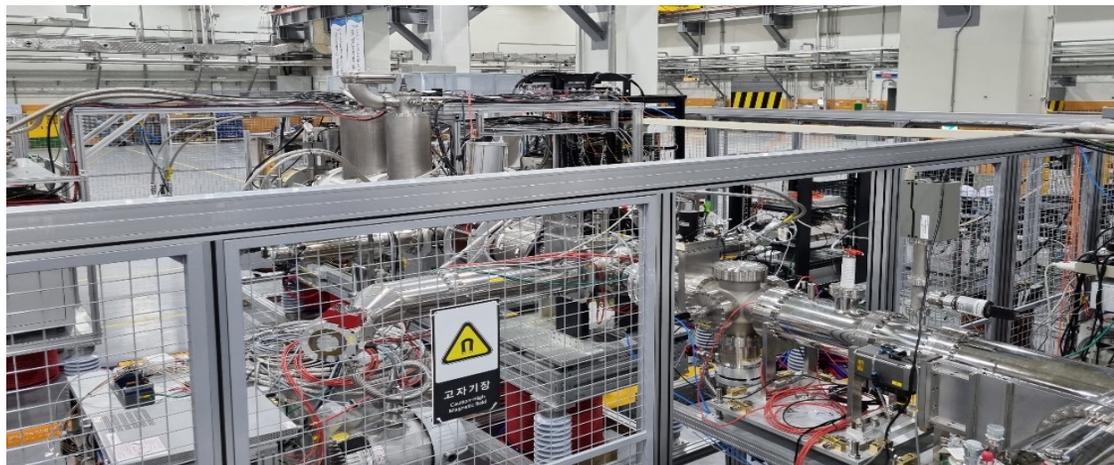
ISOL System



ISOL Target Room



ISOL Beam Line



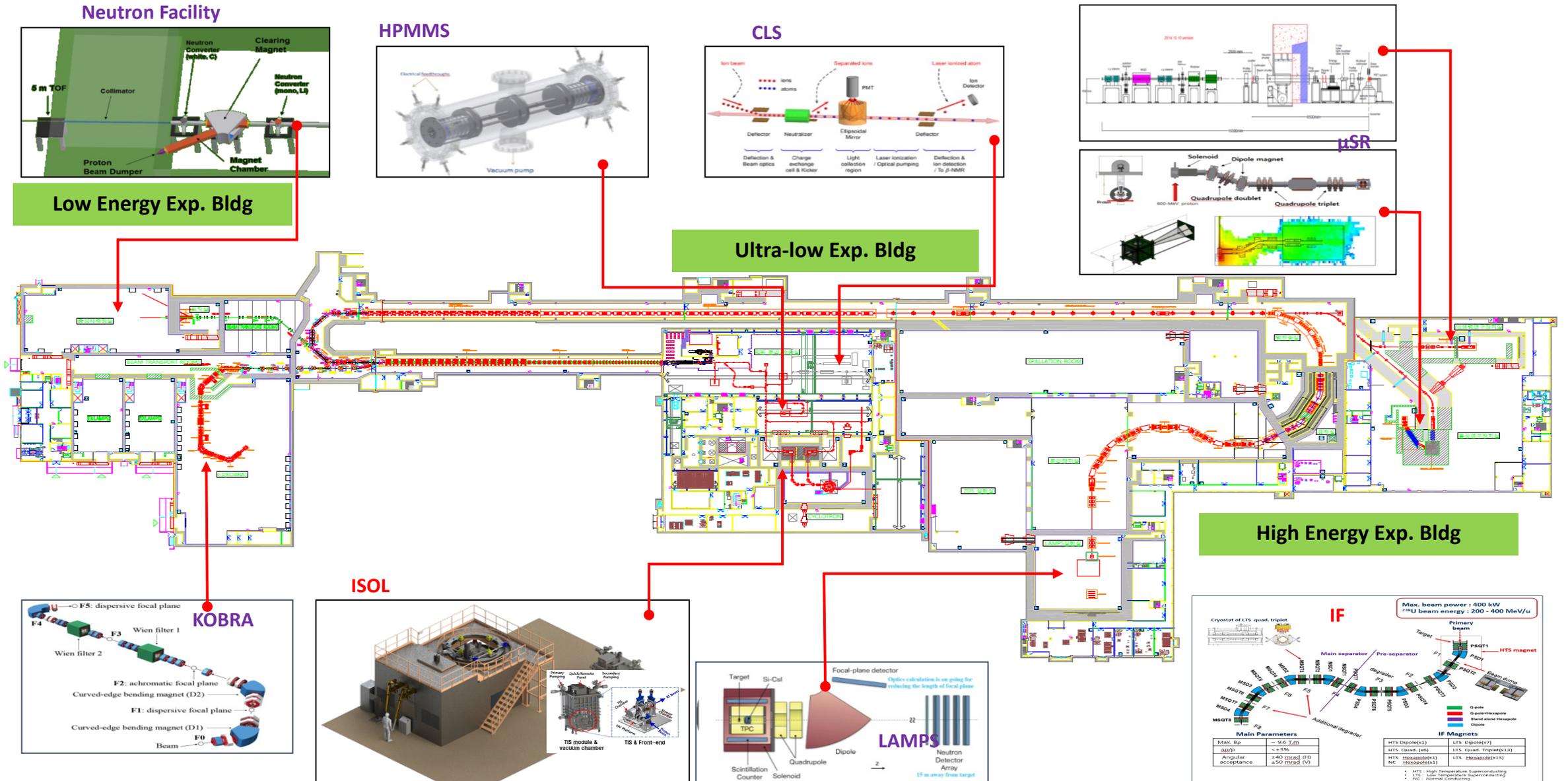
EBIS Charge Breeder



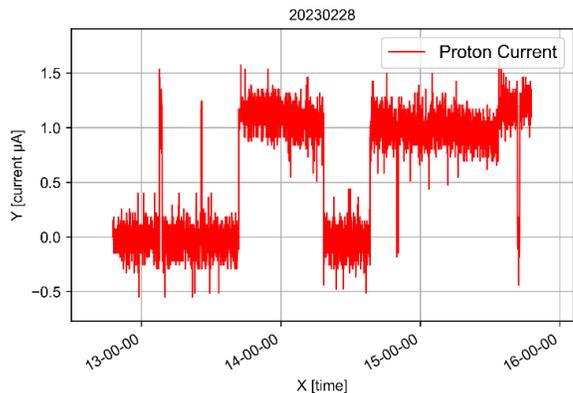
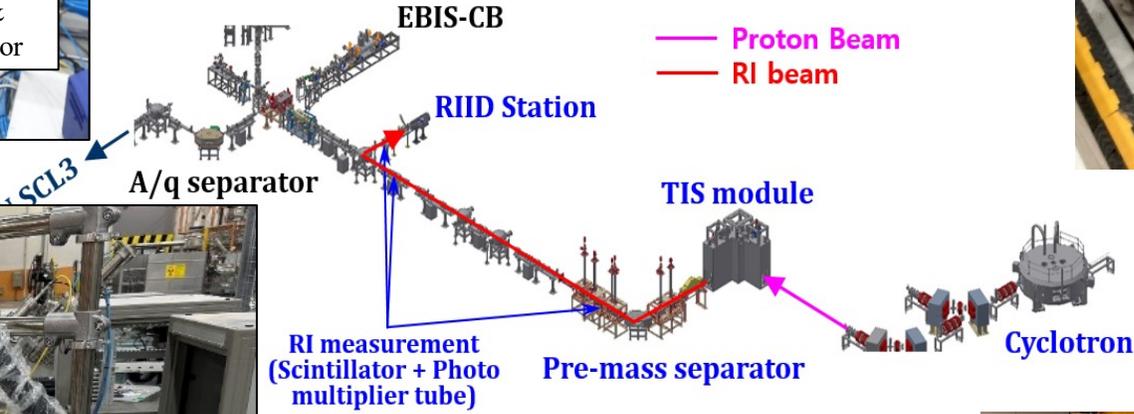
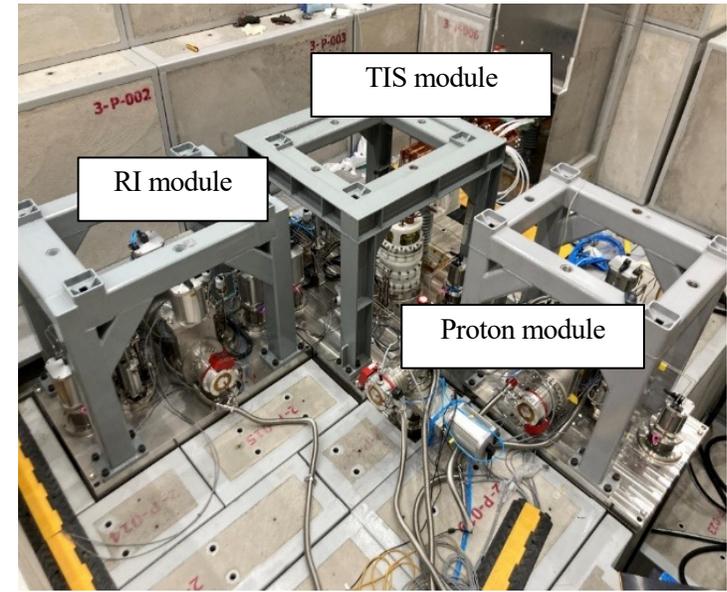
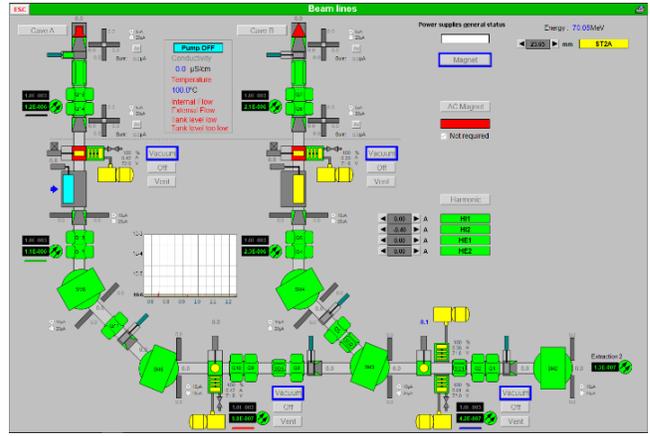
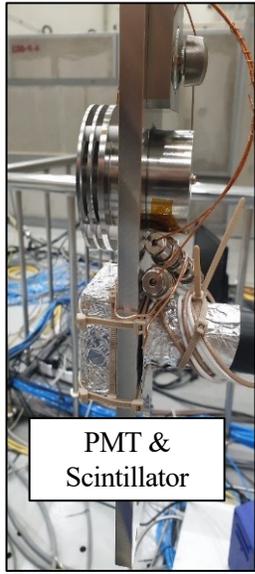
MMS/MR-TOF

- ISOL beam lines including sub-systems are commissioned in 2021

RI & Experimental System



ISOL Beam Commissioning with RIB (21, 22, 24, 25Na)

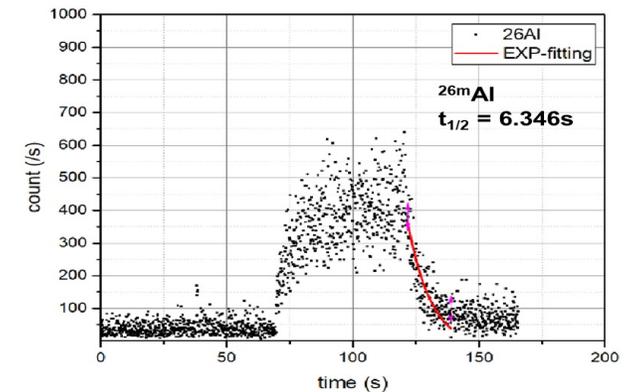
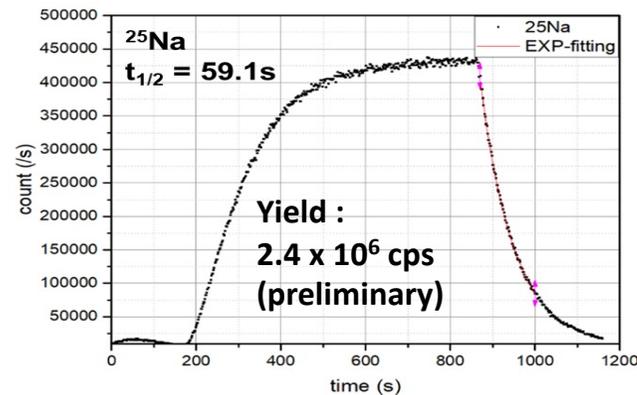
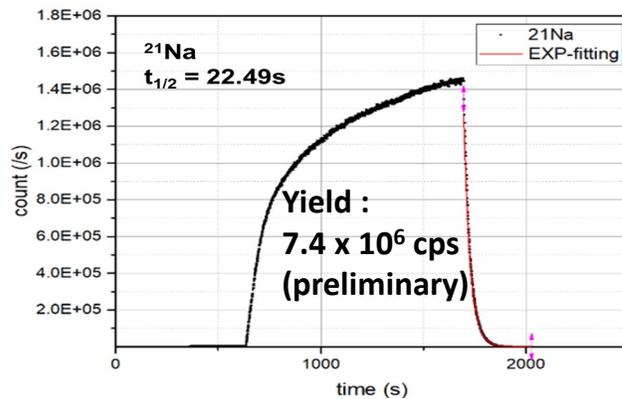
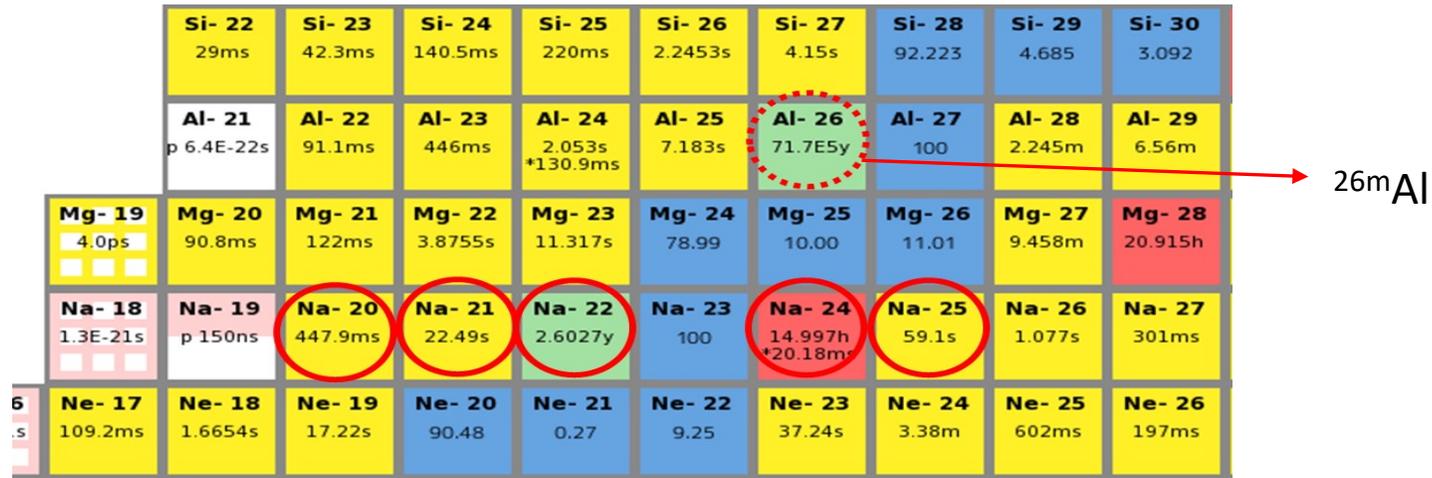


ISOL Beam Commissioning with RIB (3/3/2023~)

● Experimental results

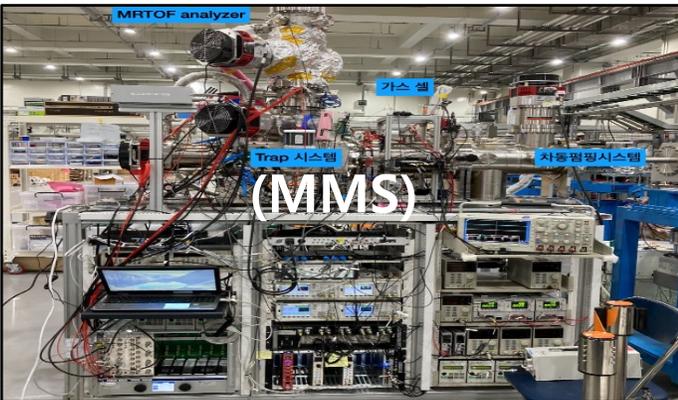
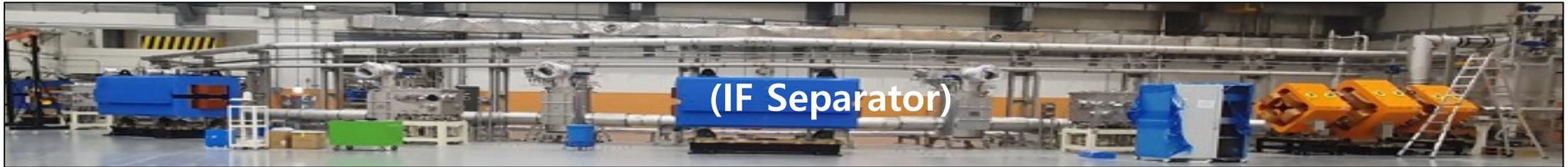
- Proton beam 70 MeV, 1.2 μ A
- SiC target temperature $\sim 1,400^\circ\text{C}$ (Ta heater ohmic heating 1.8 kW)

The RI Production on May 23, 2023



< Measurements using scintillator + PMT >

Other Experimental Systems



- All experimental systems are installed and machine-commissioned

Summary

- ❖ The beam commissioning of accelerator systems is done
- ❖ Initial beam commissioning of the KoBRA spectrometer is done
- ❖ NDPS is expected to be prepared for use in 2024
- ❖ 30 Proposals for early stage experiments are received, reviewed (PAC)
- ❖ Beams will be provided to selected/outstanding proposals in June/July 2024
- ❖ RAON will provide new opportunities not only in nuclear physics, but also in nuclear data and other applications
- ❖ International collaboration has been essential
- ❖ Hope to provide beams to the international users soon



Thank you ~ ~ ~