IRIS 중이온가속기연구소
Institute for Rare Isotope Science

Accelerator activities at IRIS, IBS, Korea

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On behalf of Institute for Rare Isotope Science

International Workshop on the High Energy Circular Electron Positron Collider (CEPC 2025)
November 7, 2025

PART 1

RAON
Overview

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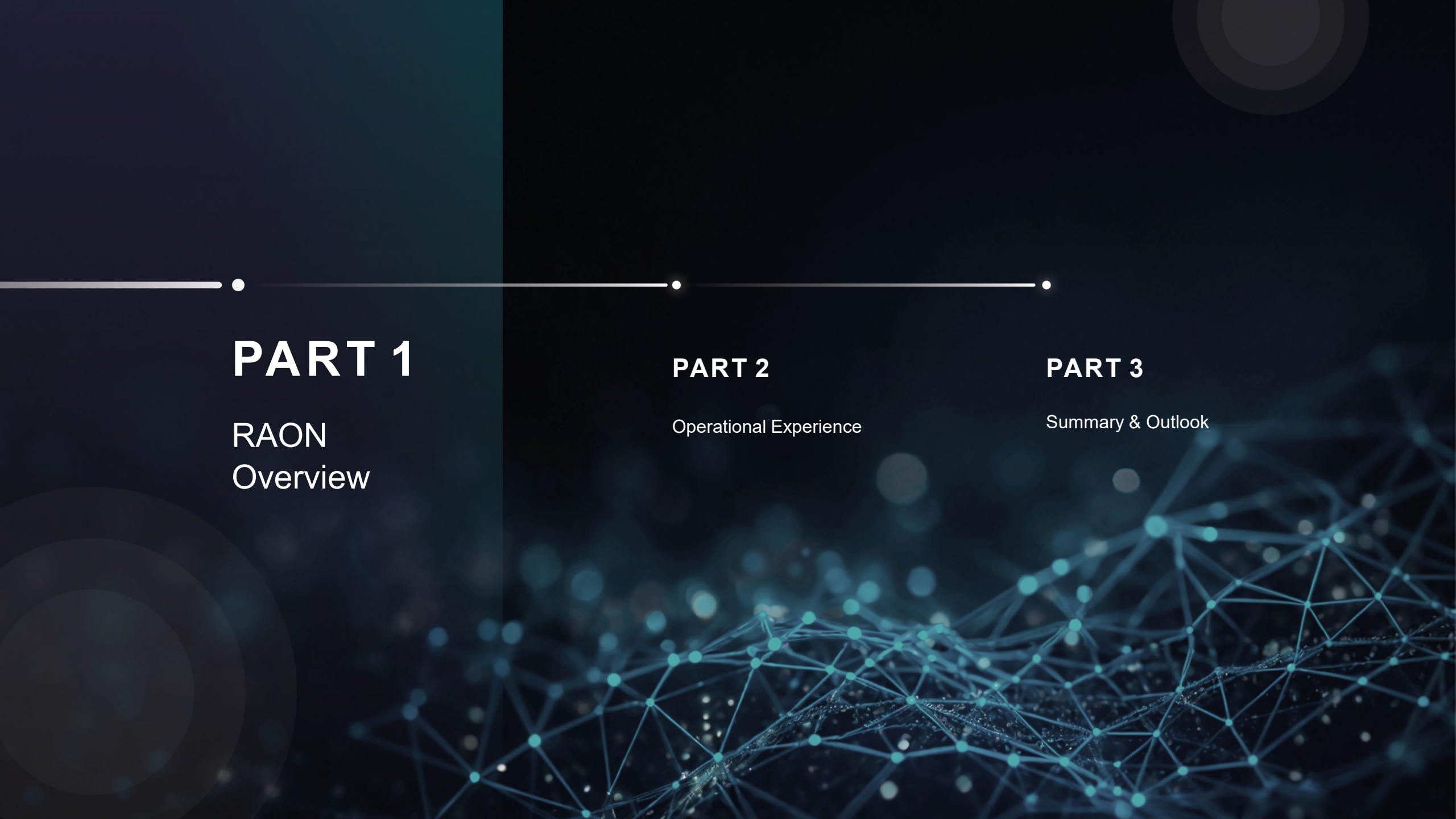
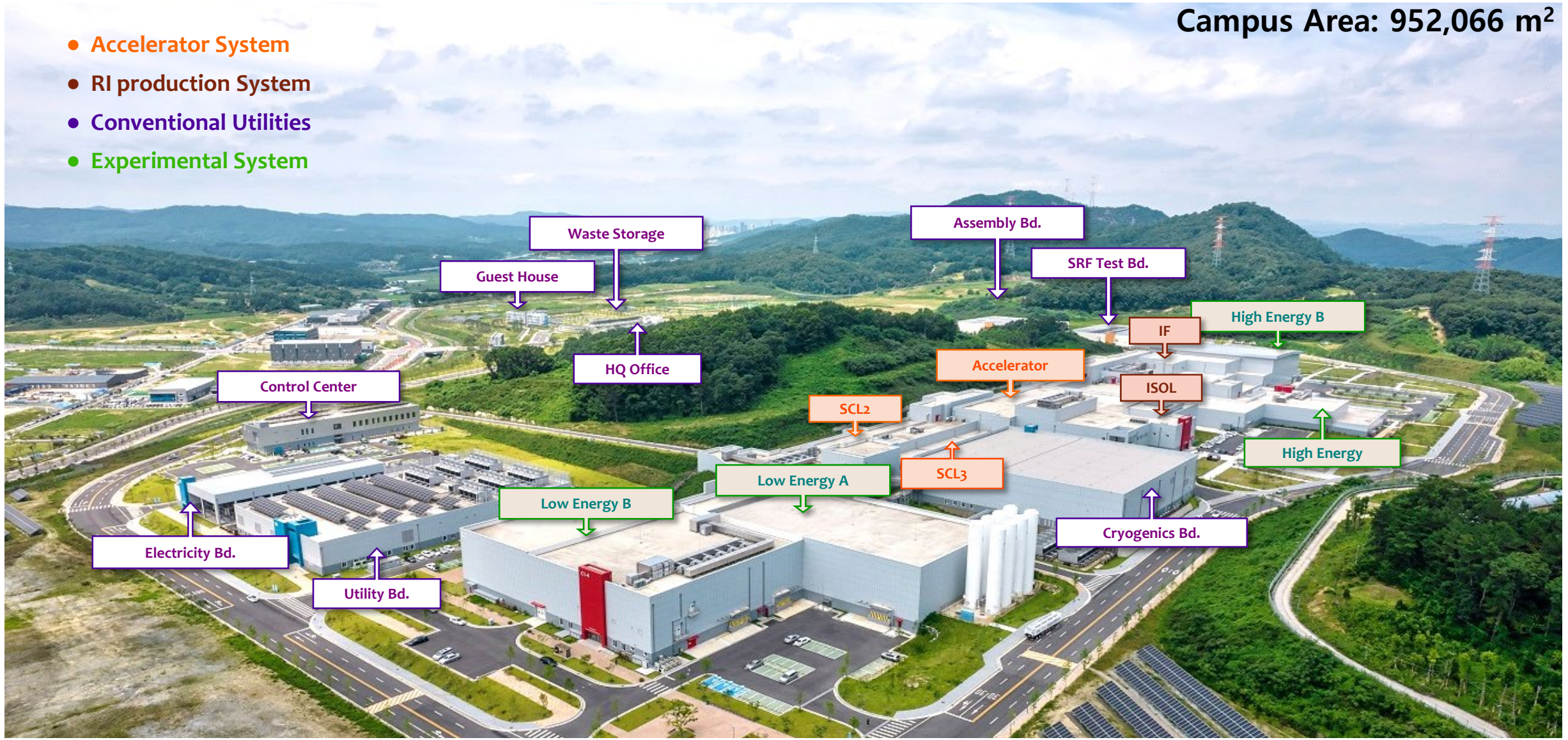
Summary & Outlook



RAON, Haevy-ion Accelerator Complex

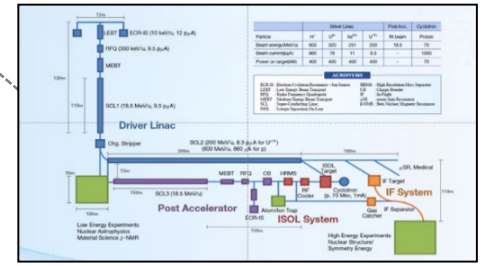


Rare Isotope Science Project (RISP)

- **Goal:** To build **a heavy ion accelerator complex RAON** for **rare isotope science** research in Korea
  - * **RAON** - Rare isotope Accelerator complex for ON-line experiments
- **Budget: KRW 1,518 billion (~ 1.3 billion USD)**
  - accelerators and experimental apparatus: 522.8 billion won
  - civil engineering & conventional facilities: 996 billion won (incl. site 357 billion won)
- **Period: 2011.12 ~ 2022.12 (1st Phase)**
  2022.12 ~ 2027.12 (SCL2 R&D for the 2nd Phase)

System Installation Project

Development, installation, and commissioning of the accelerator systems that provides high-energy (200MeV/u) and high-power (400kW) heavy-ion beam



Facility Construction Project

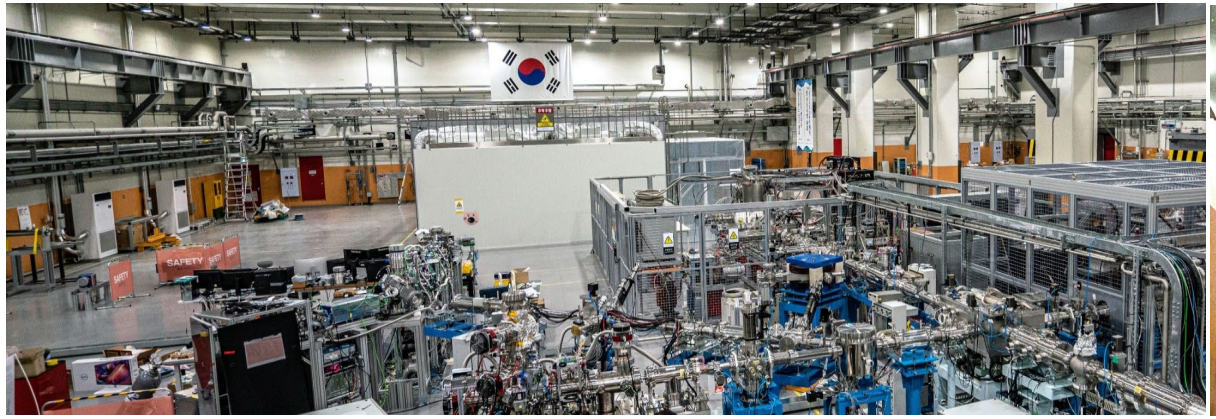
Construction of research and support facility to ensure the stable operation of the heavy-ion ac celerator, experiment systems, and to establish a comfortable research environment

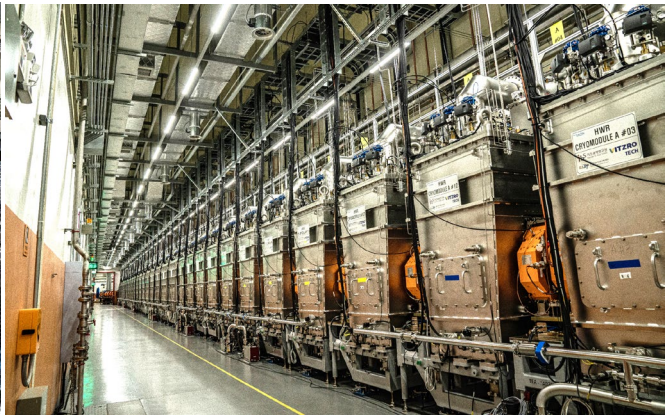
◆Providing high intensity RI beams by ISOL and IF
- ISOL: direct fission of ^{238}U by 70 MeV proton
- IF: 200 MeV/u ^{238}U (intensity: 8.3 pμA)

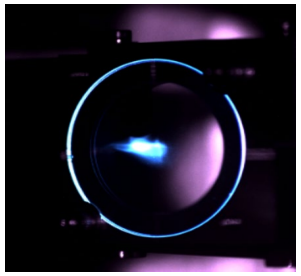
◆Providing high quality neutron-rich beams
- ^{132}Sn : up to 250 MeV/u & 10^9 particles per second

◆Providing More exotic RI beam production by combination of ISOL and IF

Brief History of RAON : RISP to IRIS







2011

- ‘10.02 Preliminary Design Study
- ‘11.02 Conceptual Design Study
- ‘11.11 IBS Established
- ‘11.12 Rare Isotope Science Project (RISP)
- ‘14.02 Purchasing the Land (RAON Site)
- ‘17.02 Civil Construction started

2015

2019

- ’19.04 RISP moved on RAON site
- ‘19.09 Installation Started
- ’20.09 QWR CM Installation
- ’21.12 HWR CM Installation
- ’22.07 Institute for Rare Isotope Science
- ’22.08 SCL3 Cryoplant commissioning
- ’22.12 1st Phase Completed

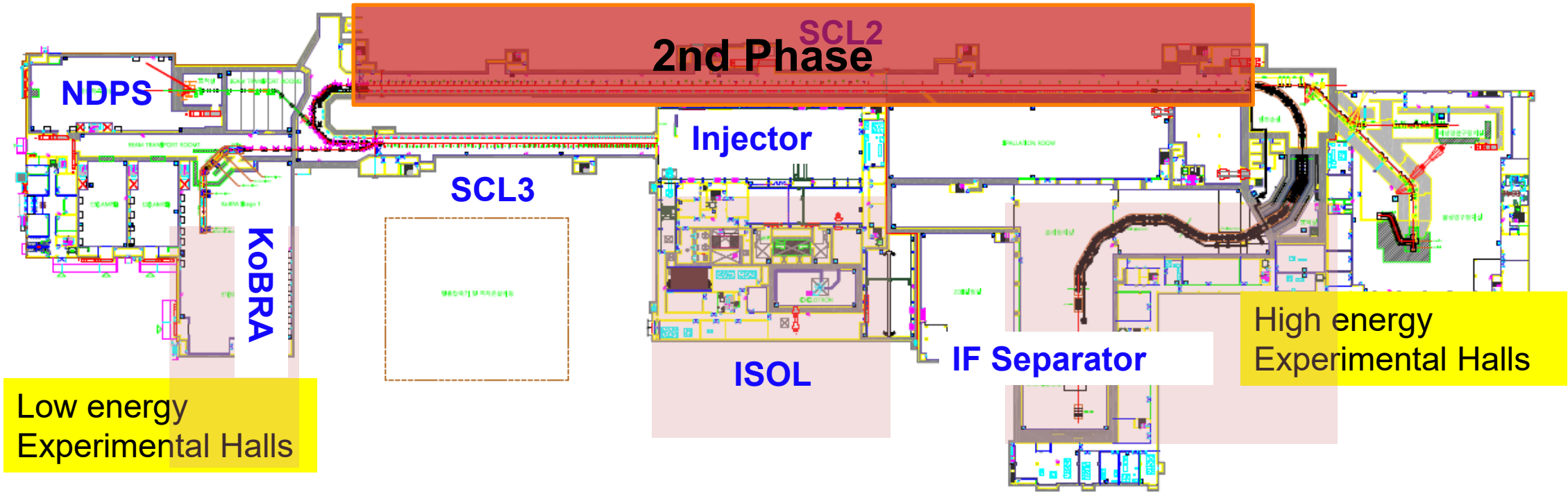
2023

- ’23.03 1st ISOL RIB Production
- ’23.05 SCL3 Beam commissioning
- ‘23.12 1st Call for Proposals
- ‘24.03 1st PAC meeting
- ‘24.07 User Beam Experiments started
- ‘25.01 2nd Call for Proposals
- ‘25.05 2nd PAC meeting

2025

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



Accelerator Systems

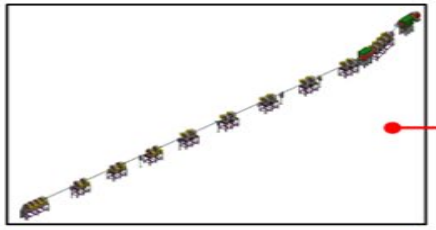
※ SCL1 is postponed

Injector — SC Linac — IF

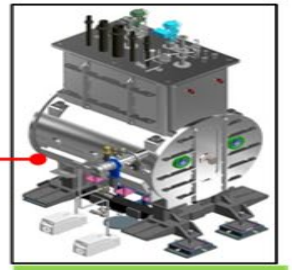
SCL3 — SCL2

0.5 MeV/u — 18 MeV/u — 200 MeV/u

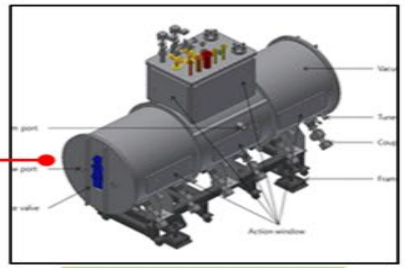
ISOL/ECR	LEBT	RFQ	MEBT	SCL3-1	SCL3-2	CSS	SCL2-1	SCL2-2	HEBT	IF
				β=0.049	β=0.13		β=0.32	β=0.51		



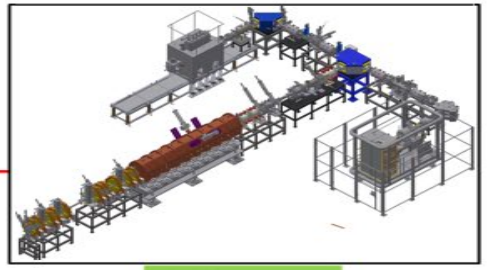
KoBRA Beam Line



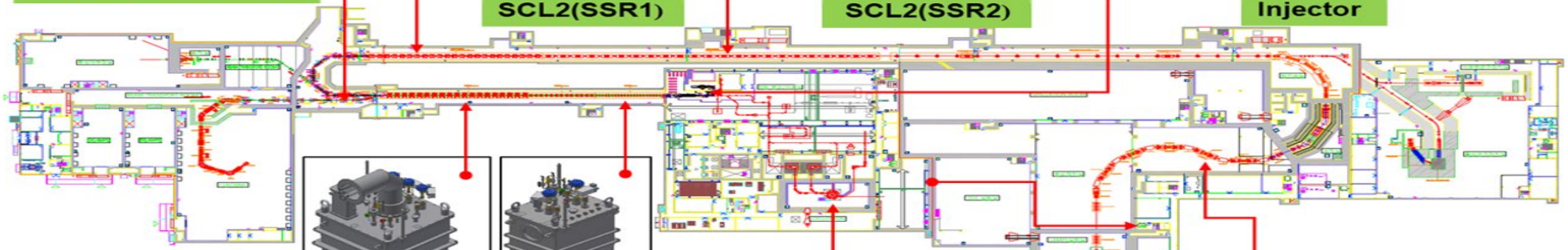
SCL2(SSR1)

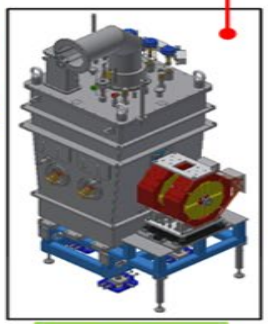


SCL2(SSR2)

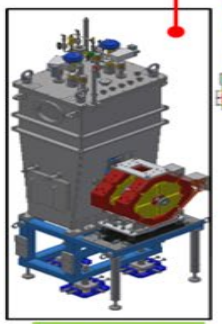


Injector

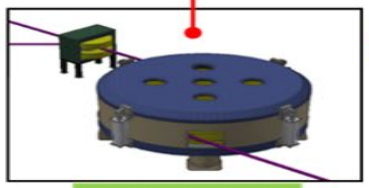




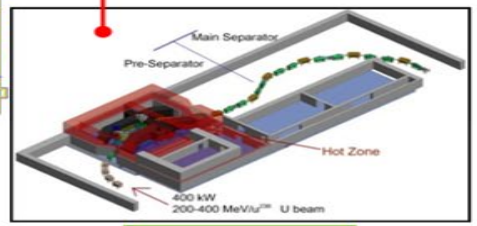
SCL3 (HWR)



SCL3 (QWR)



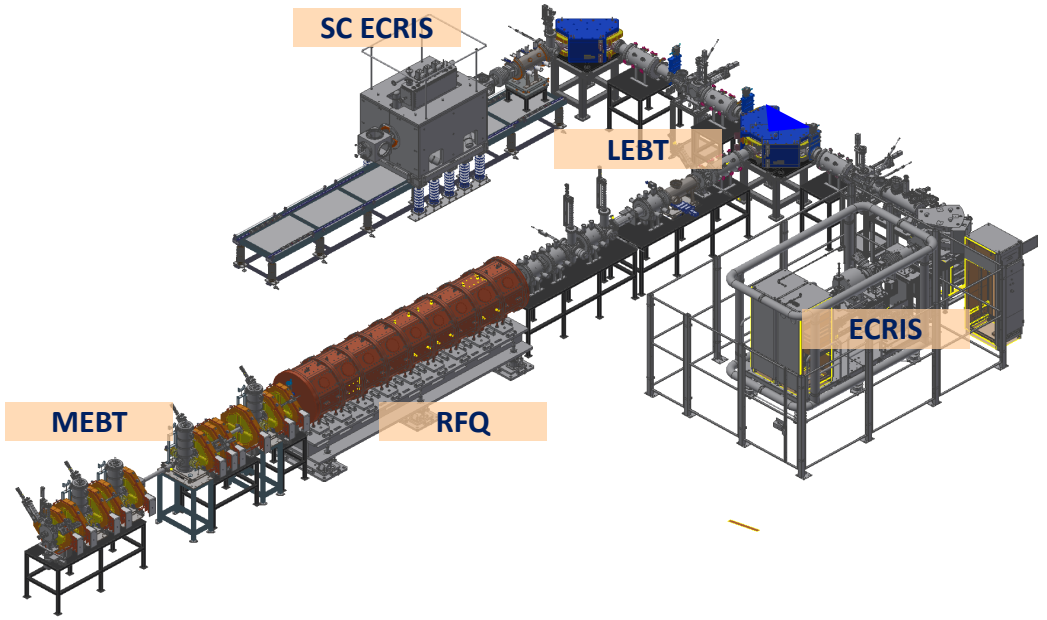
Cyclotron

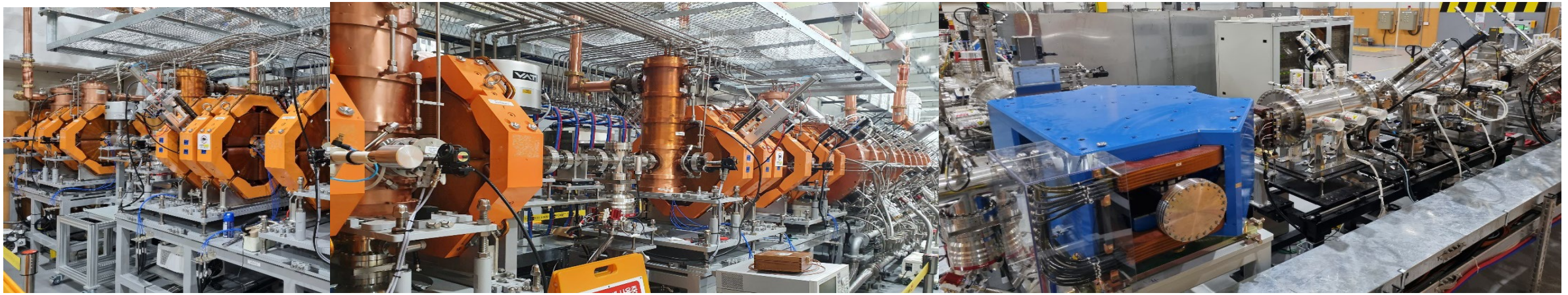


IF System

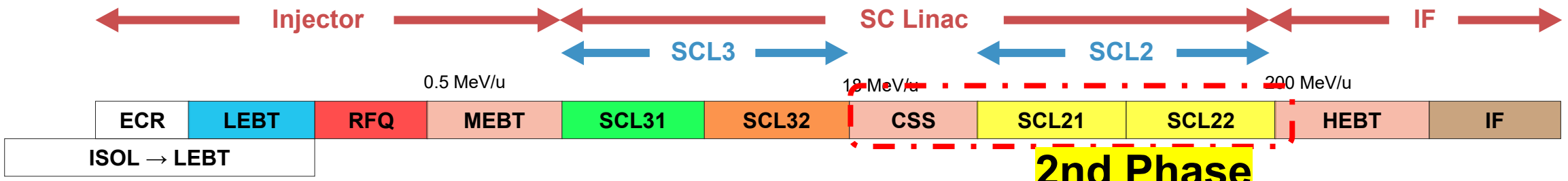
Injector System

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





Superconducting Linear Accelerator



2nd Phase

Superconducting Linac 3(Low-energy section)

Superconducting Cavity (QWR/HWR)

Total (124 cavities)

Superconducting Linac 2(High-energy section)

Superconducting Cavity (SSR1, SSR2)

Total (219 cavities)

Cryogenic System

SCL3 Cryoplant (4.2 kW @ 4.5 K eq.)

Compressor (HP+LP) & Oil Removal System
(Warm Compressor Section)

Cold Box & Dewar

PVPS (for 2K)
(Process Vacuum Pumps System)

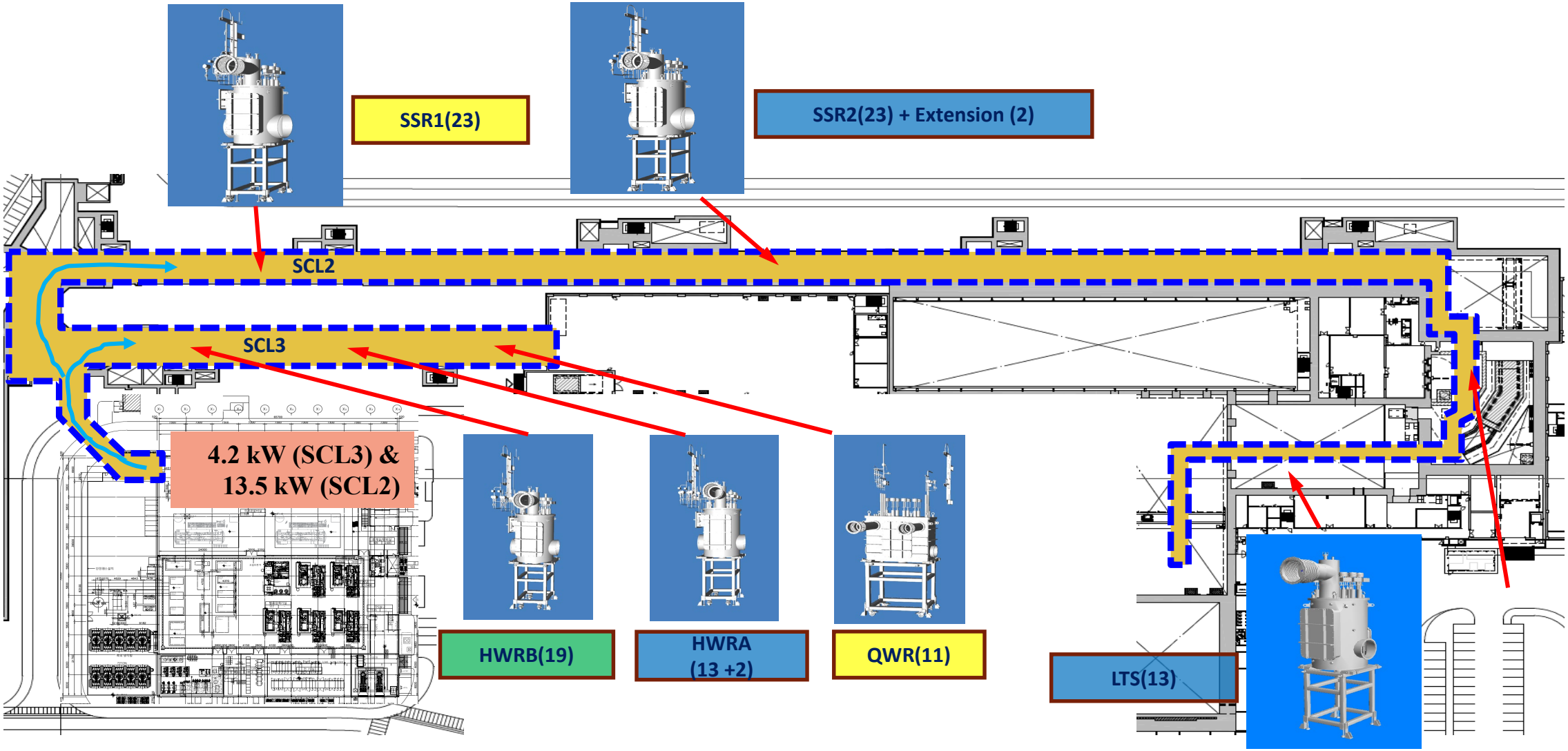
SCL2 Cryoplant (13.5 kW @ 4.5 K eq.)

HP/LP Compressor & Oil Removal System
(Warm Compressor Section)

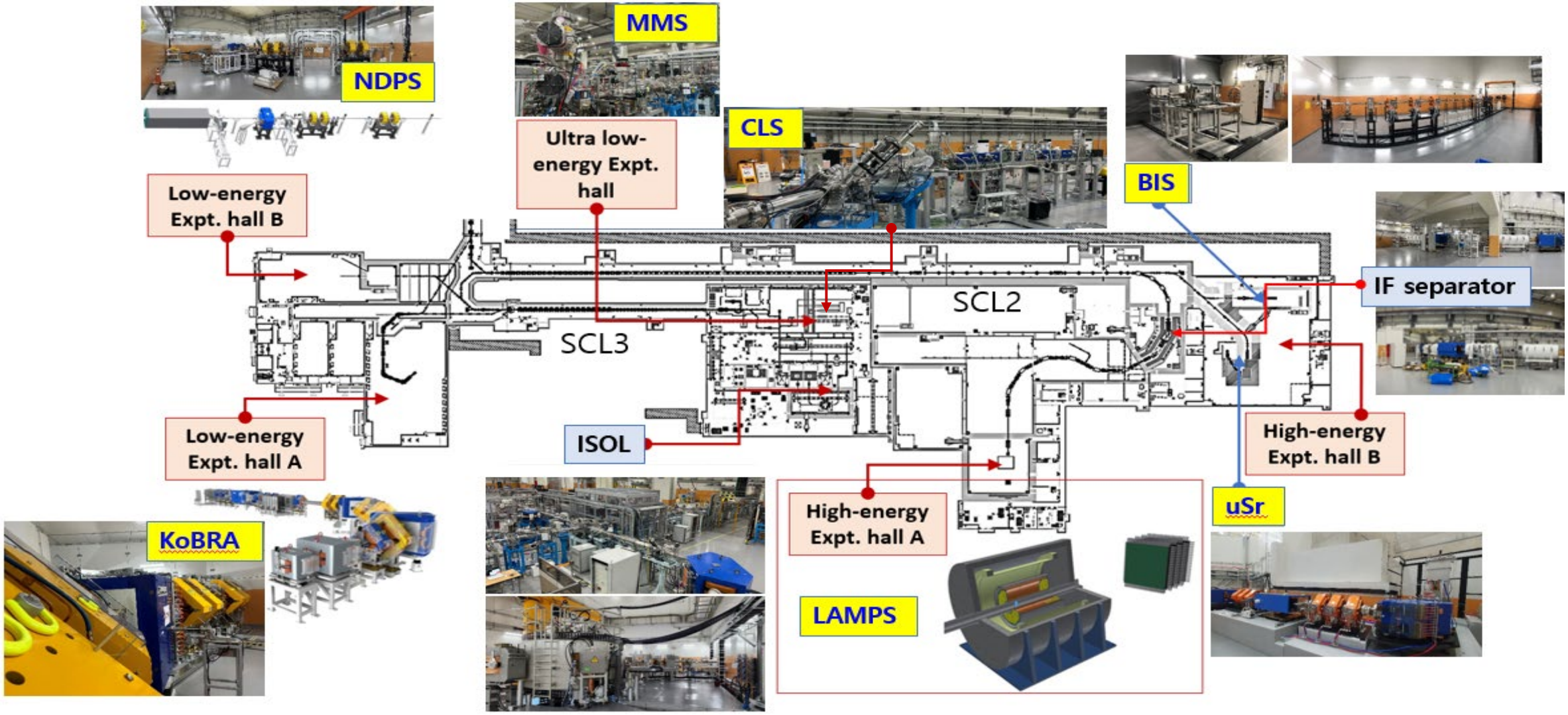
Cold Box & Dewar

VLP Compressor (for 2K)
(Very Low Pressure)

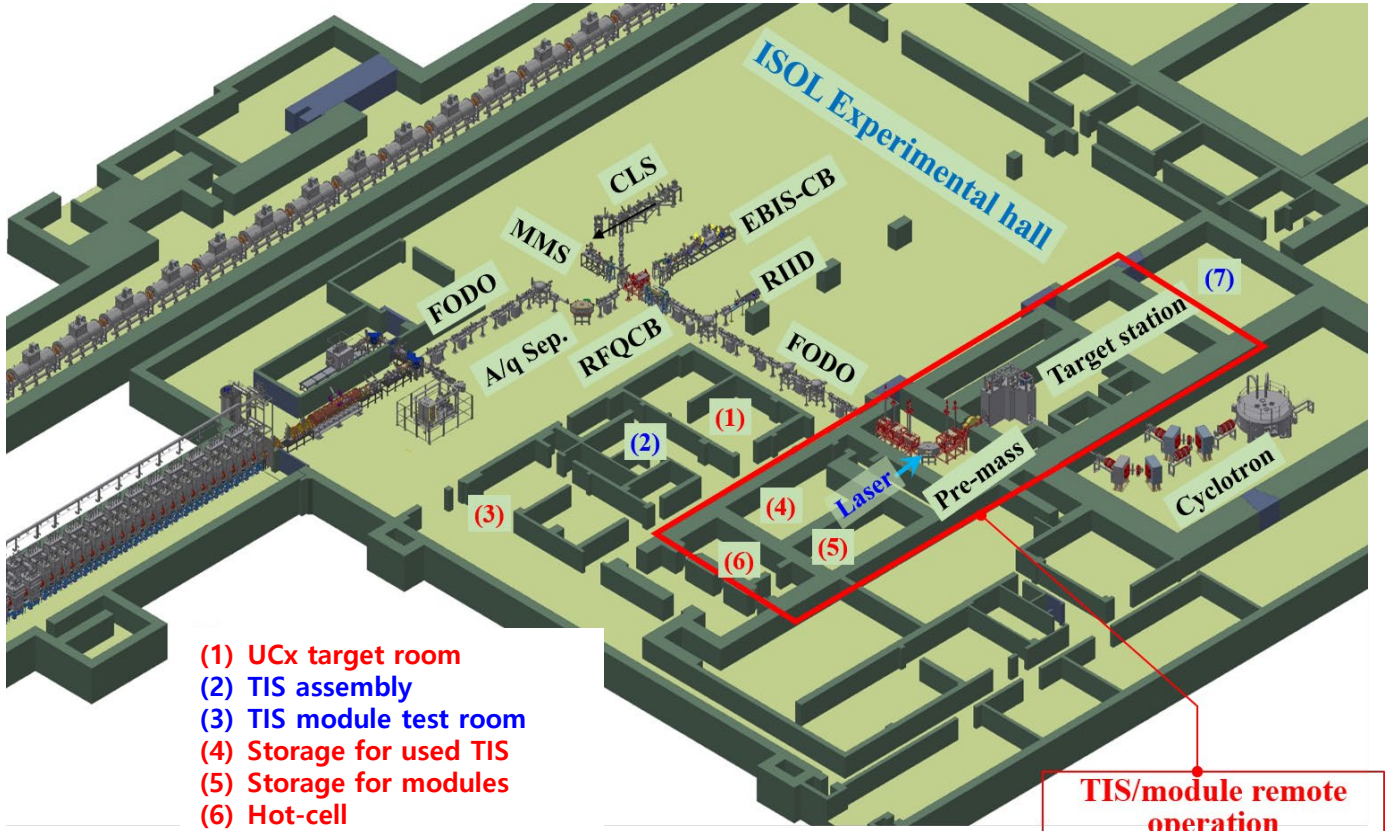
Layout of Cryogenic Distribution Systems



RI Production & Experimental Systems

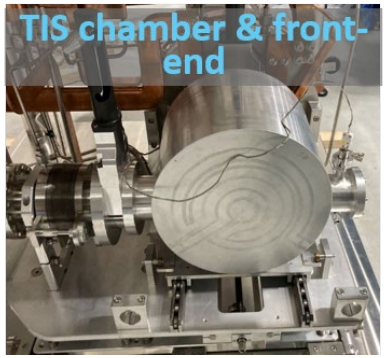


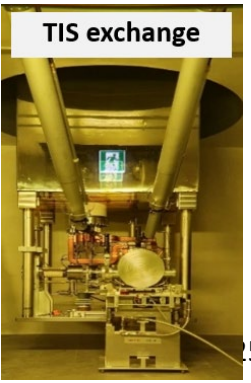
ISOL System

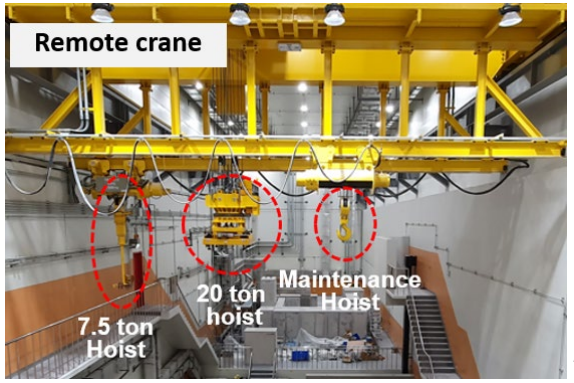


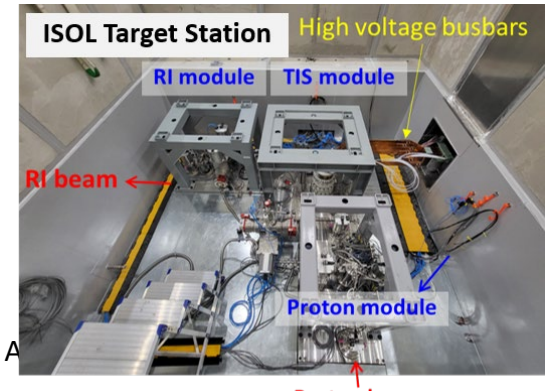
- **Proton cyclotron of 70 MeV and 50 kW (tested)**
  (35 MeV < E < 70 MeV)

Year	2024	2025	2026
Beam power	1 kW	2 kW	3 kW
Target	SiC, LaC_2	TiC	ThC_x, UC_x
Ion source	SIS	RILIS, FEBIAD	RILIS, FEBIAD









PART 2

Operational Experience

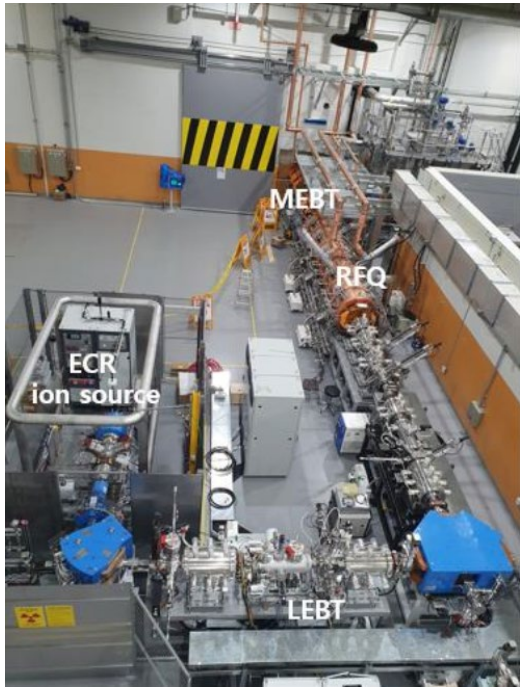
PART 3

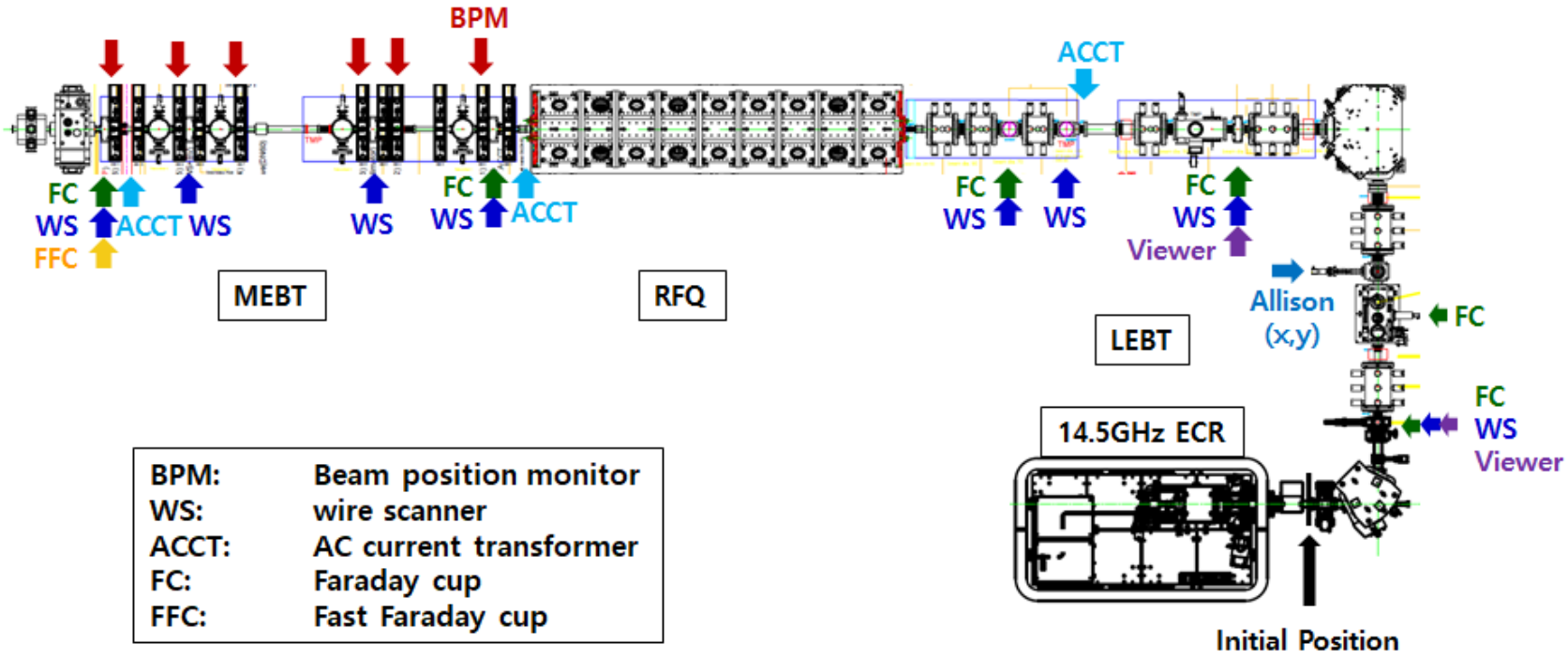
Plan & Summary

Injector beam commissioning

- Beam commissioning since October 2020

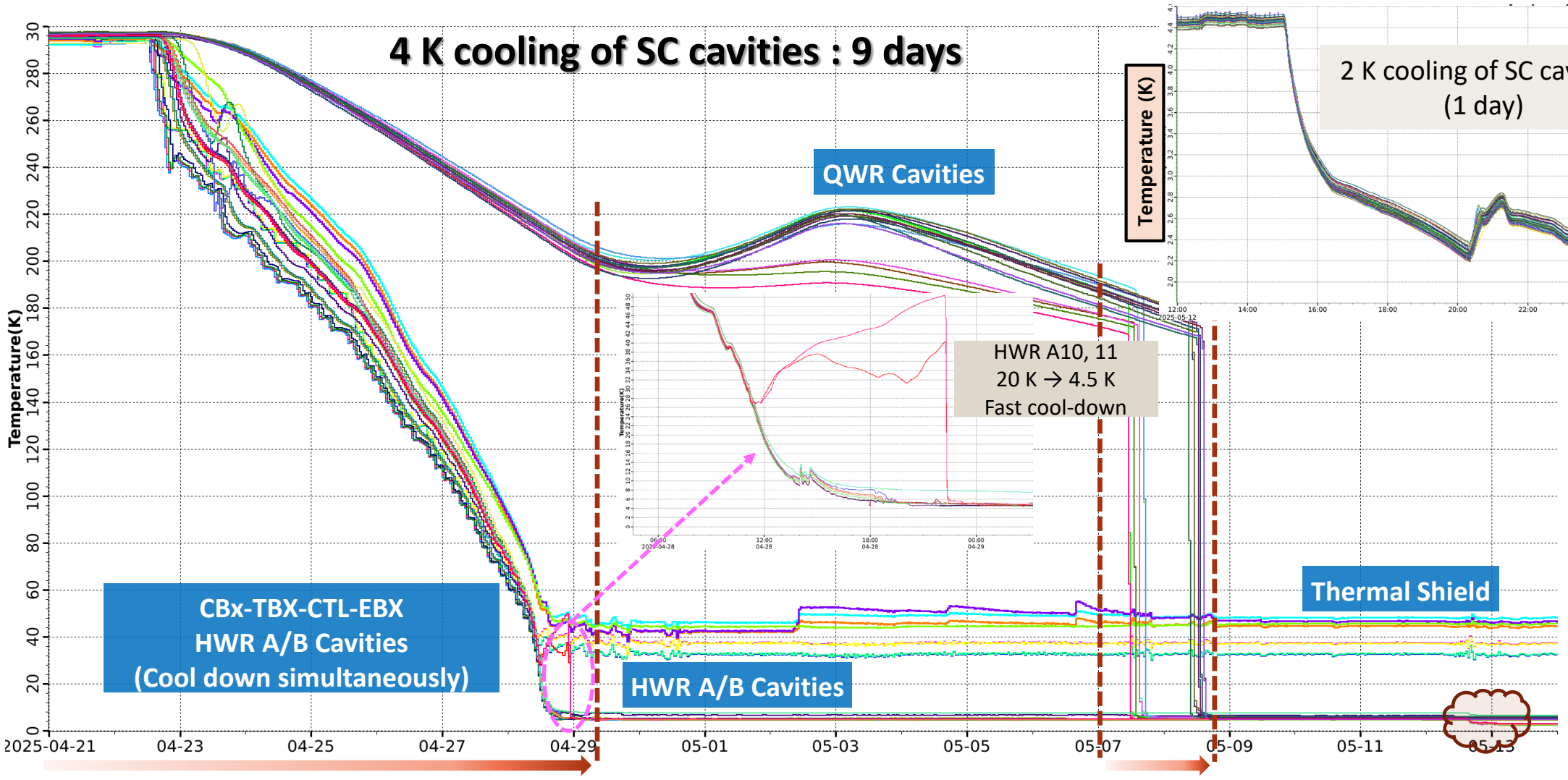
Ion	Argon	Neon	Oxygen	Helium	proton
Period	Aug. 2020 ~	Sep. 2023 ~	-	-	Apr. 2025~
A (Q+)	40 (8, 9, 11)	20 (4)	16 (6)	4 (2)	1 (1)
Current	~ 40 μA	~ 60 μA	~ 40 μA	~ 50 μA	> 100 μA





BPM:	Beam position monitor
WS:	wire scanner
ACCT:	AC current transformer
FC:	Faraday cup
FFC:	Fast Faraday cup

Cool-down (3rd) of SCL3 in 2025

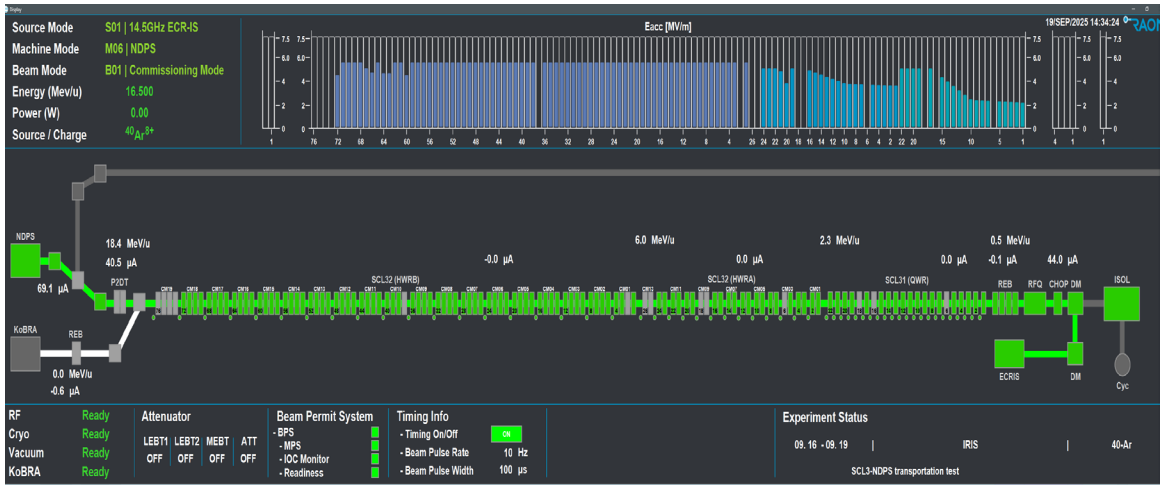


CBx-TBx-CTL-EBx and HWR A/B 4.5K Cool-down
Thermal Shield 40 K Cool-down(7 days)

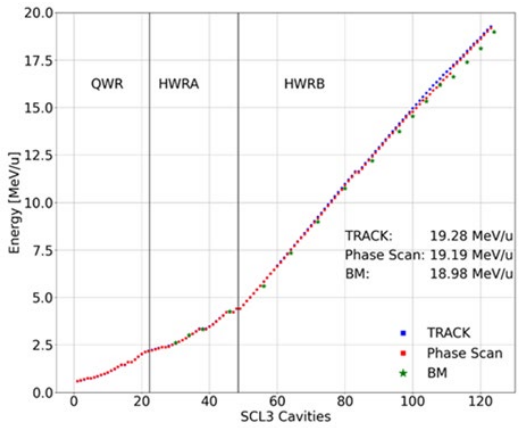
QWR 4.5K
Cool-down(2 days)

HWR A/B 2K
Cool-down(1 day)

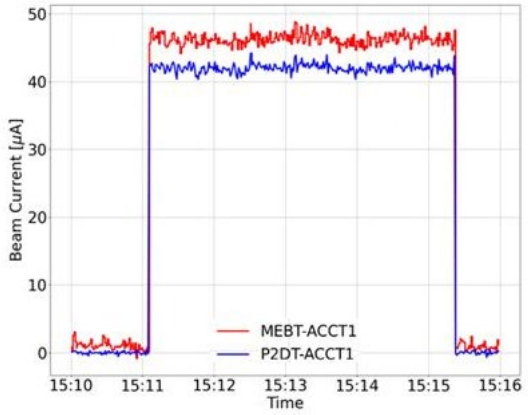
SCL3 Beam Operation (2024~2025)



$^{40}Ar^{8+}$beams (18.5 MeV/u) to NDPS experimental hall



[Energy in SCL cavities]



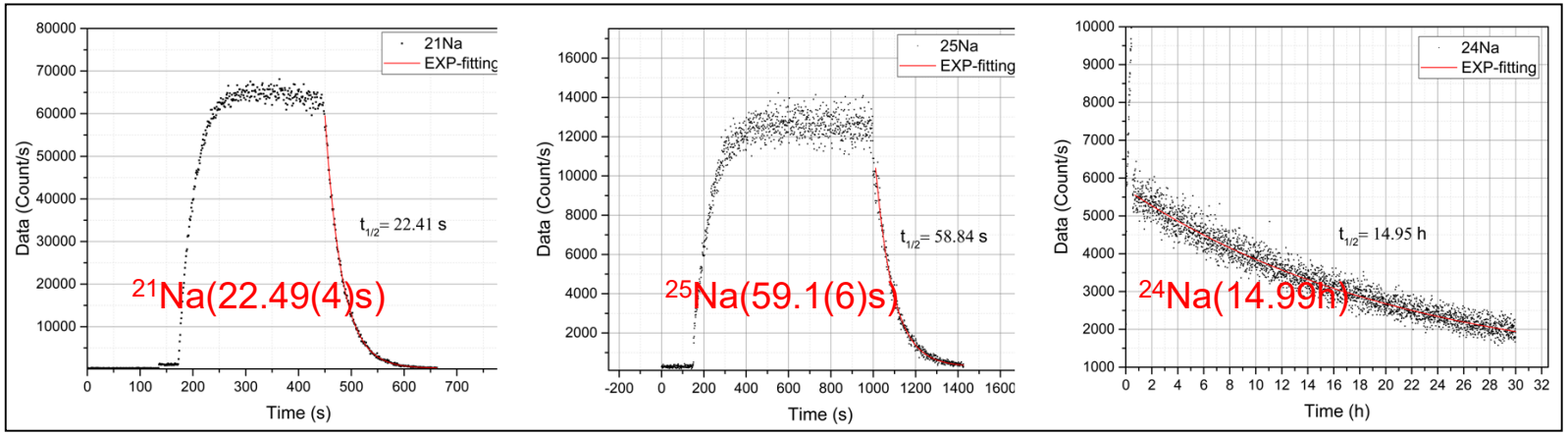
[Beam current measured by ACCTs]

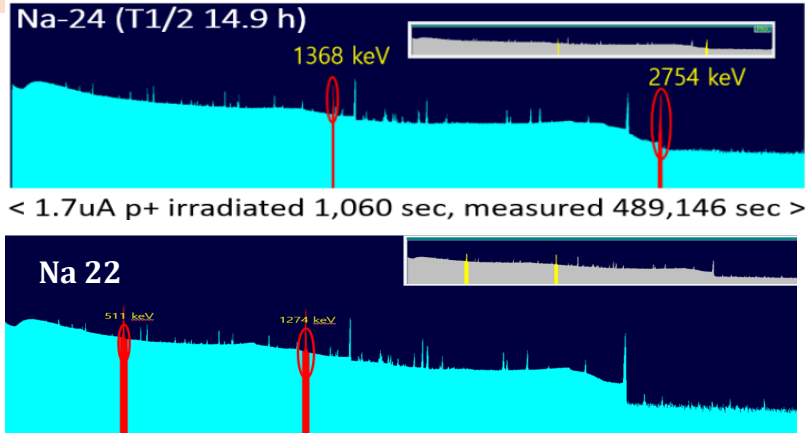
	2024	2025
Particle	$^{40}Ar^{8+}$	$^{40}Ar^{8+}$
Current (MEBT, μA)	42.4	46
QWR Field(MV/m)	5.0	5.0
HWR Field (MV/m)	5.0	5.5
RF amplitude, phase	(<±1%, <±1°)	(<±1%, <±1°)
QWR (Unused cavities)	19 (3, 12, 21)	19 (6, 16, 18)
HWRA (Unused cavities)	24 (6, 8)	21 (6, 17&18, 25&26)
HWRB (Unused cavities)	71 (24, 28, 61)	72 (2, 37)
SCL3 energy (MeV/u)	16.4	19.2
Transmission	91~93%	~91%

- ❖ 8 cavities(2024), 10 cavities(2025) were not used
  - ➢ due to no spare SSPA's; spare parts fabricating(2024~)
  - ➢ 2 HWR CMs (HWR-A #09, #13) were dismounted from the SCL3 tunnel
- ✓ To test new couplers and improve slow tuner

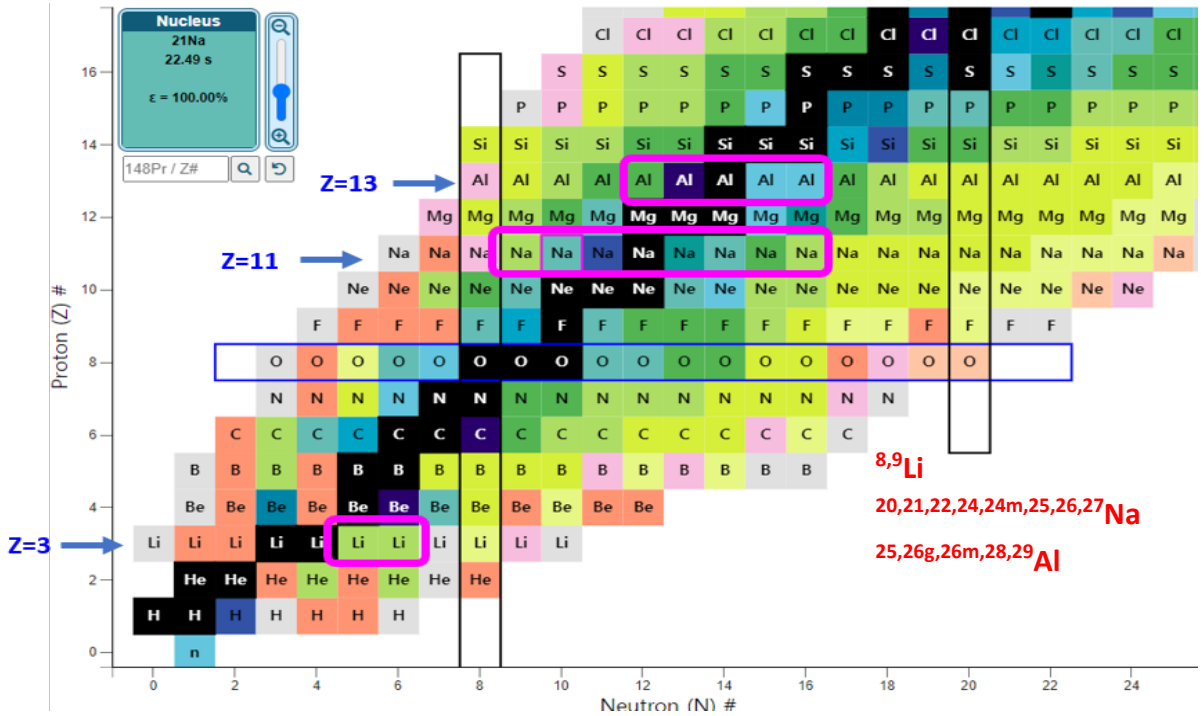
RIB Commissioning of ISOL System

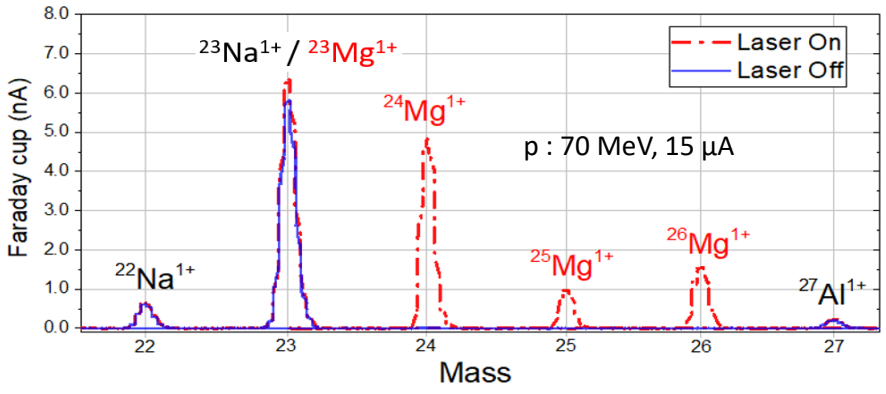
The first RI produced from ISOL system on March 3, 2023





Half-lives of Na isotopes measured using scintillators





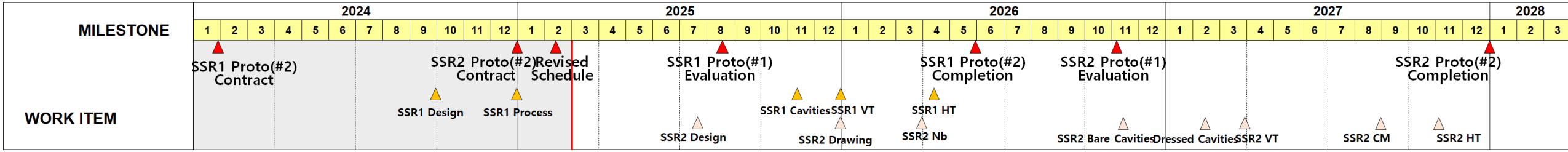
- **RIB production in 2024: proton on SiC target**
  - **Li, $^{20\sim27}$Na, and Al beams** using Surface ion source
  - **^{22,23,27,28}Mg beams** using laser ion source

PART 3

Summary & Outlook

SCL2 R&D Update

SCL2 R&D Project ● CM(SSR1, SSR2) R&D project : 2022.12~2027.12



◆ Status of prototype (#1)

Cavity Type	Manufacturer	Cavity Production	Cryomodule Assembly	Vertical Test(VT)	Horizontal Test(HT)
β=0.32 SSR1	Domestic	Completed	Completed	**2/3 Passed**	**On going**
β=0.51 SSR2	IHEP(China)	Completed	Completed	**6/6 Passed**	**On going**

- ◆ **(SSR1 Balloon-type)** Design and engineering are led by IRIS, while the manufacturing process development is carried out by a domestic company (‘24.1, VITZRO Tech)
  - Jacket material of SSR1 cavity has been changed from STS (prototype #1) to Titanium (prototype #2)
- ◆ **(SSR2 Cylinder-type)** Considering the high technical complexity, we maximally utilize the use of external resources (KAT & IHEP) from engineering design to manufacturing

Summary & Outlook

◆Beam Commissioning and operation of the low-energy Linac and ISOL have been carried out since 2023

- SI beams; 2023: 40Ar9+, 2024: 40Ar8+, 2025: 40Ar8+, 20Ne4+
- ISOL produced RI beams and successfully post-accelerated 25Na5+ via SCL3.
- Ion sources such as RILIS and FEBIAD are under development to expand RI beam capabilities.
- The first user experiments were conducted in 2024 at KoBRA and CLS

◆Operation and Improvement plans

- SCL3 was cooled to 4K/2K; beam delivery to users started in September 2025.
- ISOL operations and improvements continue, including high-power target development.
- SCL2 R&D is in progress, with the SSR1/SSR2 CM prototype scheduled for completion by 2027