IRIS 중이온가속기연구소
Institute for Rare Isotope Science

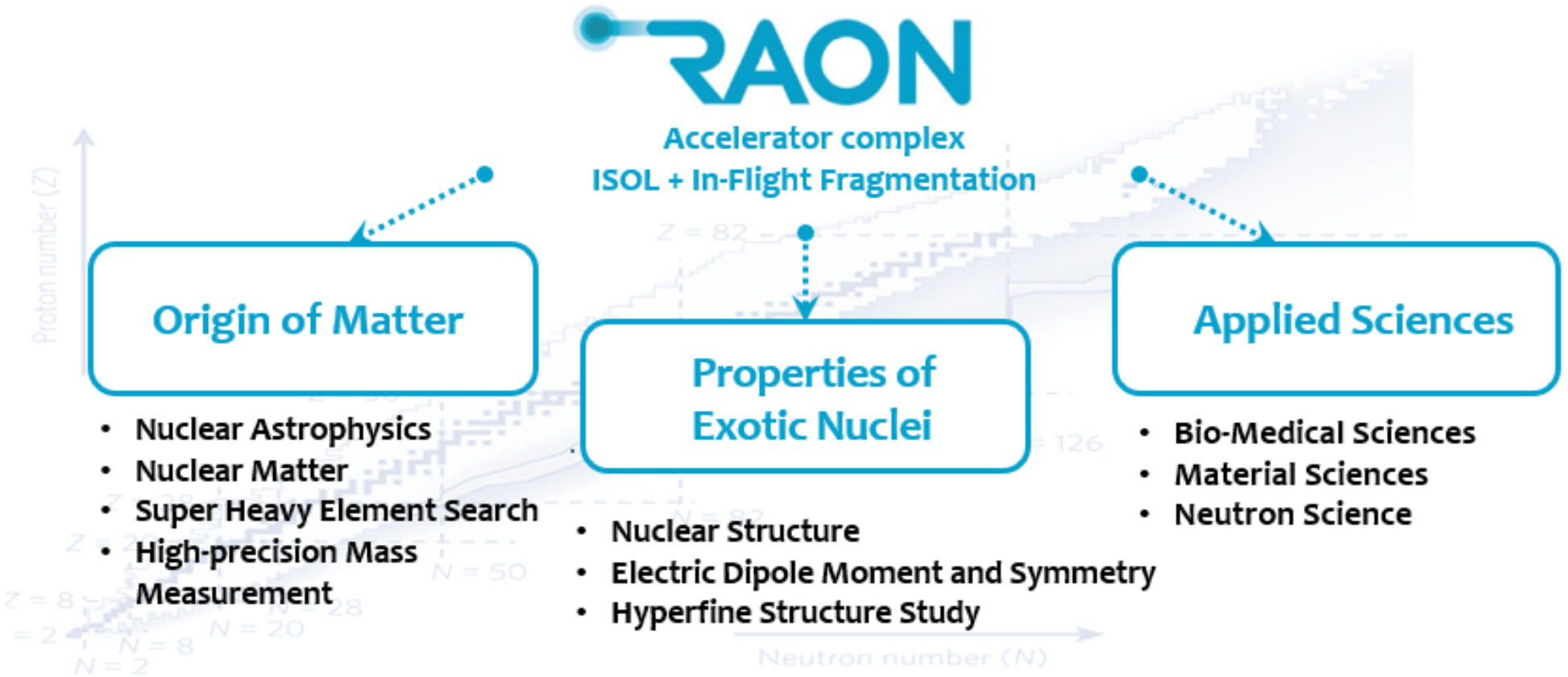
Status of RAON

Seung-Woo Hong
Institute for Rare Isotope Science, IBS

Nov. 16, 2024, ANPhA Symposium

Rare Isotope Science Project (RISP) : 2011-2021

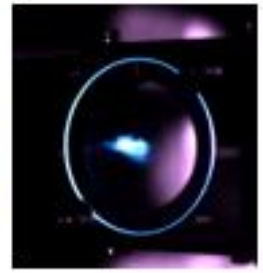
"라온" → RAON → (Rare isotope Accelerator complex for ON-line experiments)



Two accelerator drivers
1. Cyclotron for ISOL
2. Superconducting Linac (for post-acceleration of RIB and In-Flight Fragmentation)

From Project to Operation : From RISP to IRIS

2011~
2023



2011

- '11.02 Conceptual Design Report(CDR)
- **'11.12 Rare Isotope Science Project(RISP) Launched**
- '13.09 Technical Design Report (TDR)
- '14.02 Contract of Purchasing Land, Shindong

2015

- '16.12 RFQ Ion Bean Extracted
- '17.02 Civil Construction Project Started
- '17.06 Ground Breaking Eng. Completed
- '19.04 Move RISP office in Shindong Site
- '19.09 1st SRC Cryomodule Installed(QWR)

2019

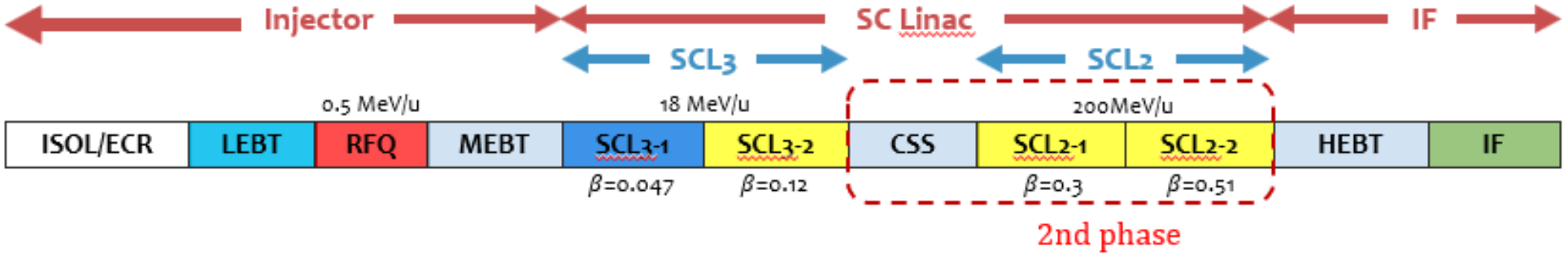
- '20.09 Completed QWR Installation
- '21.06 RAD Safety Permission Acquired
- **'22.07 Institute for Rare Isotope Science(IRIS) begin**
- '22.12 Completed Stage-1 of RISP
- **'23.05 Commission of SCL3 Accelerator**
- '23.12 Call for Proposals

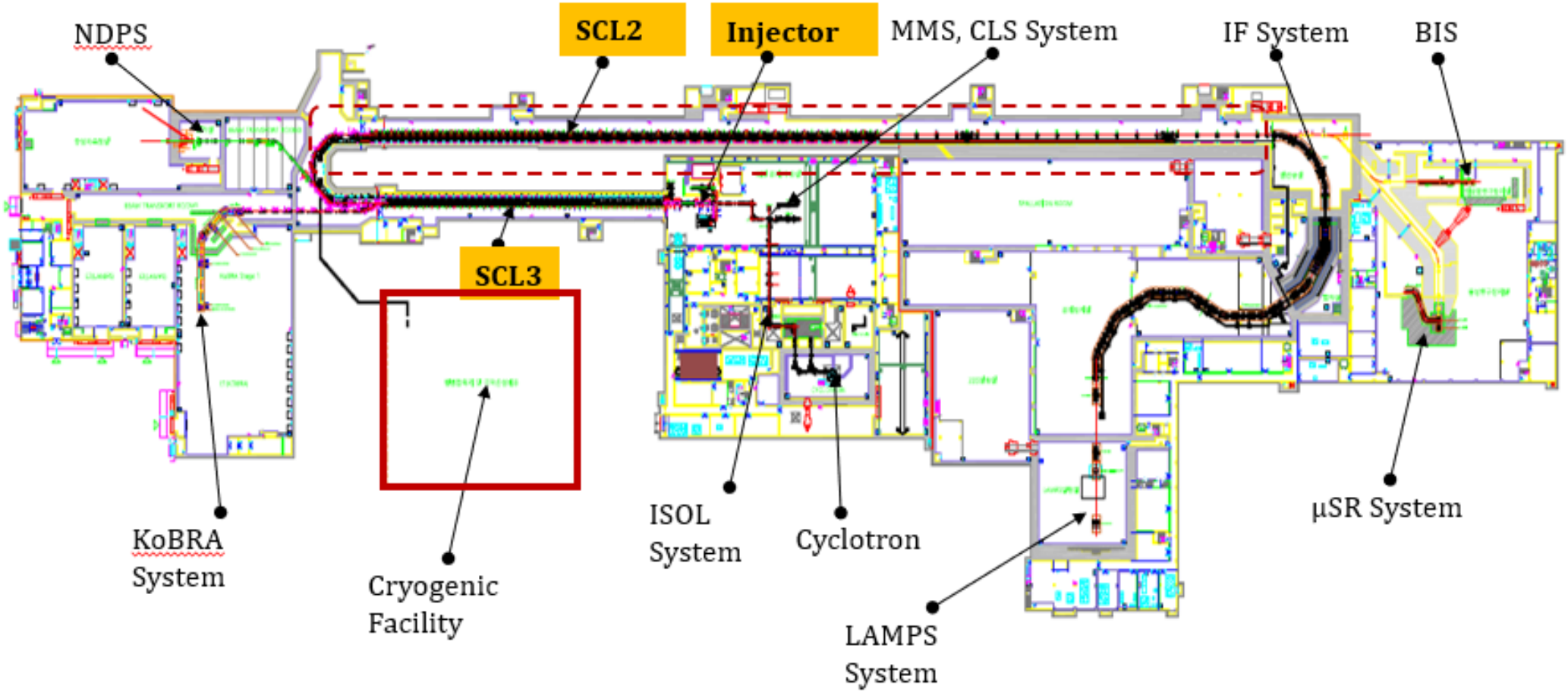
2023

IRIS Campus

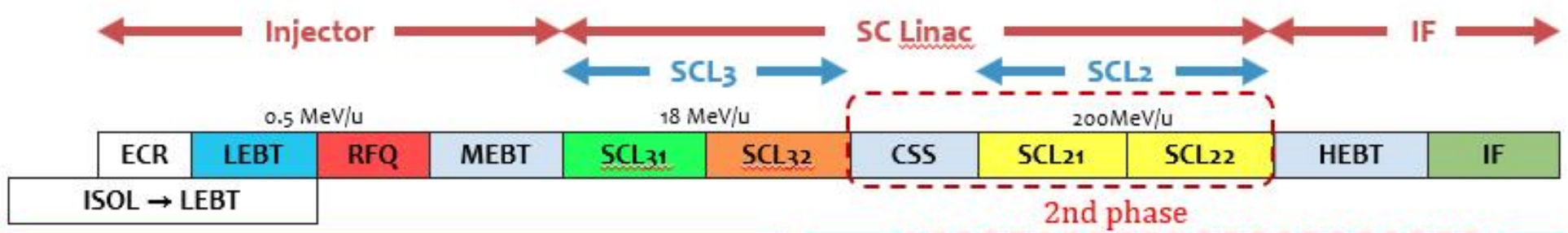
1M m^2

Accelerator systems

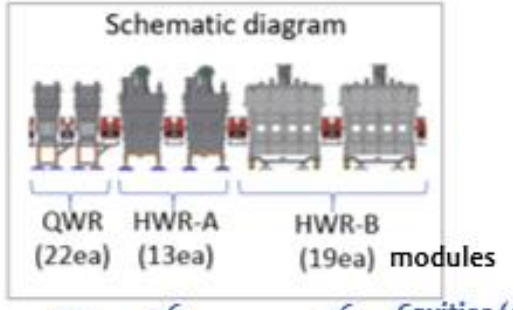




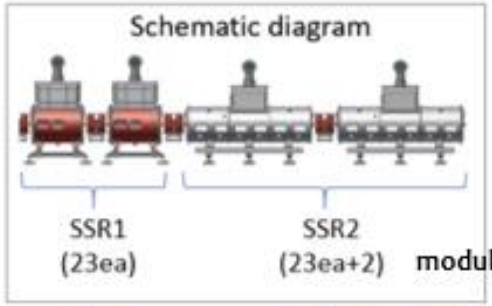
Superconducting Linac (SCL3 & SCL2)



SCL3

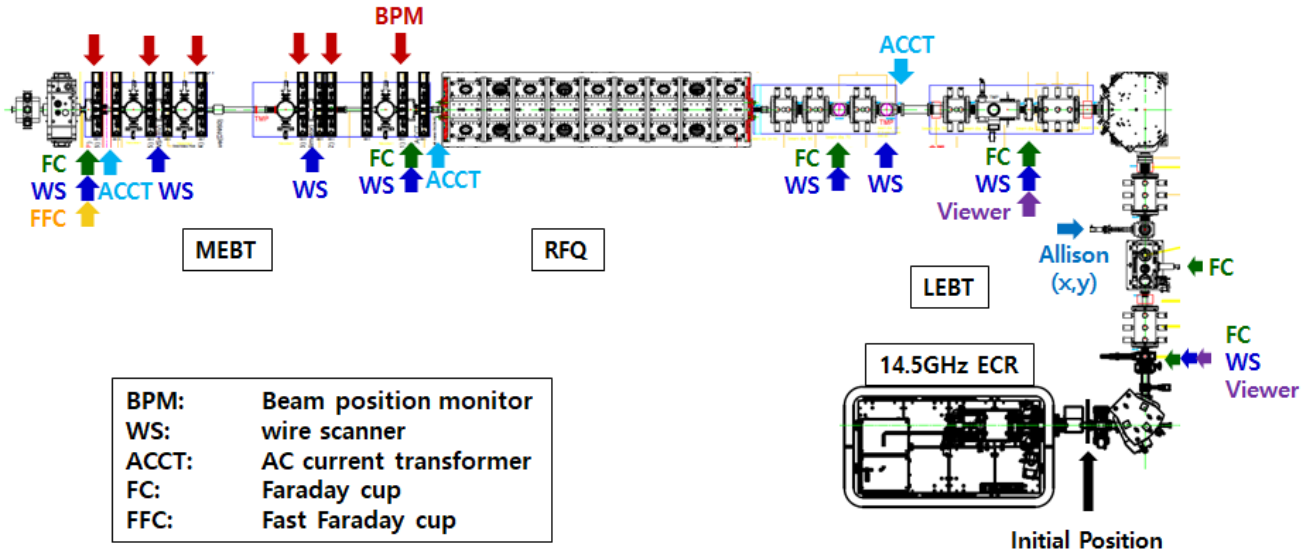


SCL2

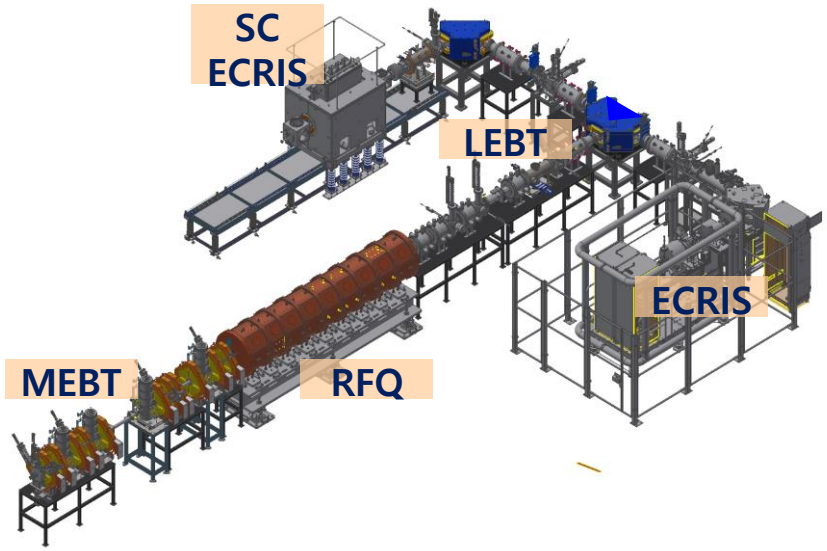


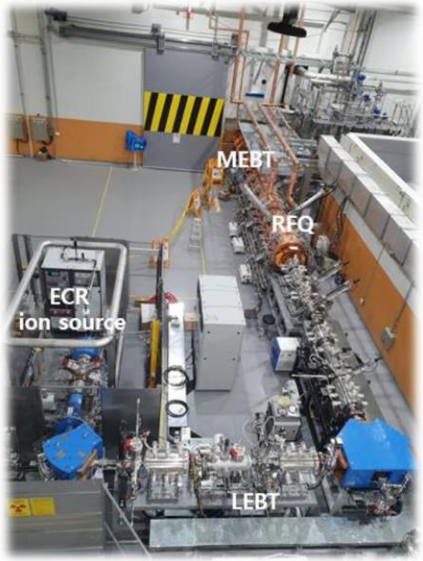
Accelerator: Injector

- **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, 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)
  - Simple quadrupole magnets, Instrumentation



[Beam Diagnostics in injector]





Ion	Argon	Neon	Oxygen	Helium	Proton
A (Q)	40 (8, 9, 11)	20 (4)	16 (6)	4 (2)	1(1)
Current [μA]	50, 30, 50	40	40	50	50 ~ 160

- Injector: 14.5 GHz ECR (10keV/u),
  LEBT (charge selection, matching),
  RFQ (507 keV/u, 98% transmission),
  MEBT (matching)
- Injector beam commissioning:

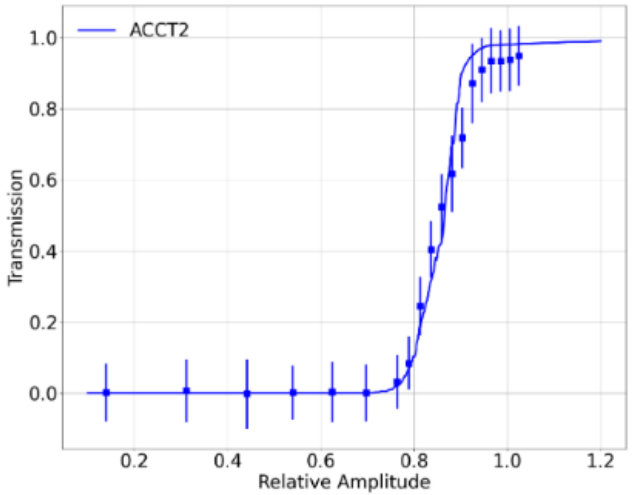
Accelerator: RFQ

- RFQ set point: beam transmission measured by ACCT in LEBT and MEBT.
  - Low RFQ transmission for Ne beams ⇒ main issue in injector beam commissioning with Ne beams
  - Different set values for the same A/Q (Ar8+, Ne4+): Need more study

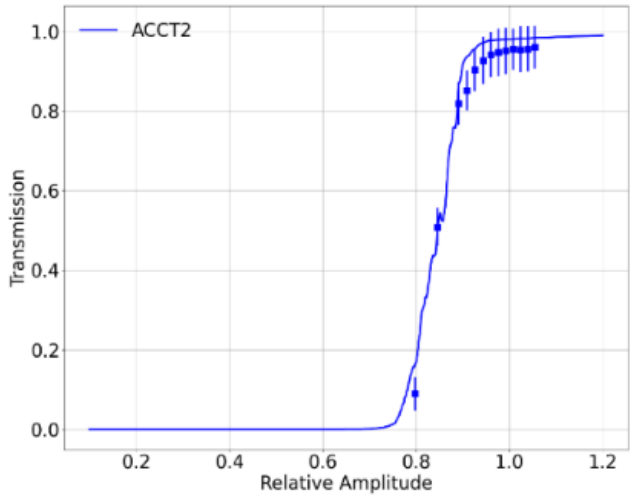
[Installed RFQ and MEBT]

	Ar(Q=9)	Ar(Q=8)	Ne(Q=4)
Transmission	93.4%	95.4%	85.7%
RF set value	51.5 kW	62.9 kW	67.4 kW

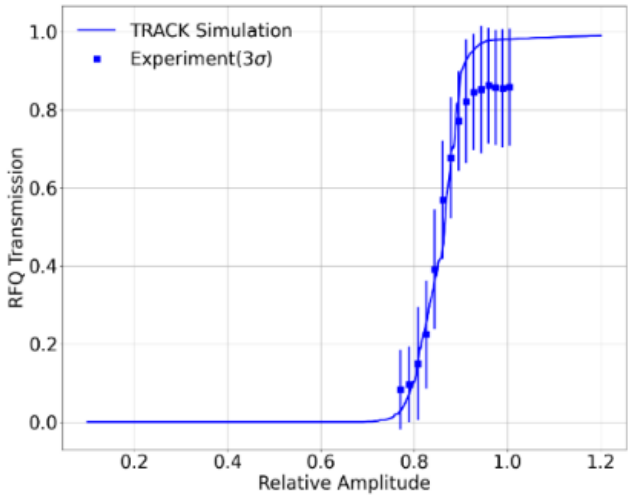
[RFQ set-point for Ar (9+)]



[RFQ set-point for Ar (8+)]



[RFQ set-point for Ne (4+)]



Cryoplants

- SCL3 cryoplant (4.2 kW @ 4.5 K)

Compressors and Oil Removal System (WCS)

Cold Box(CB)

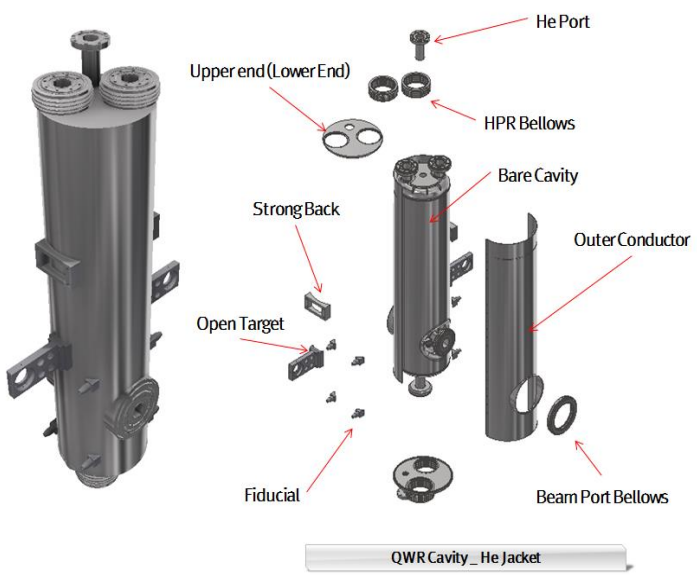
- SCL2 cryoplant (13.5 kW @ 4.5 K)

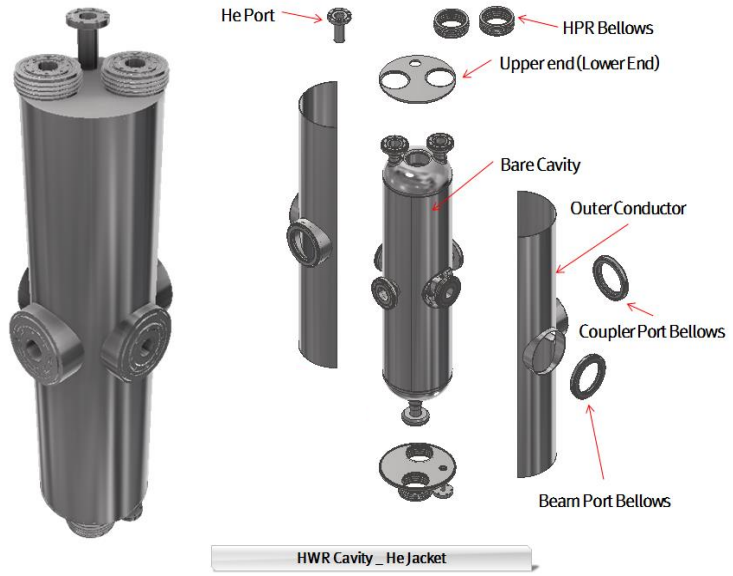
Compressors and Oil Removal System (WCS)

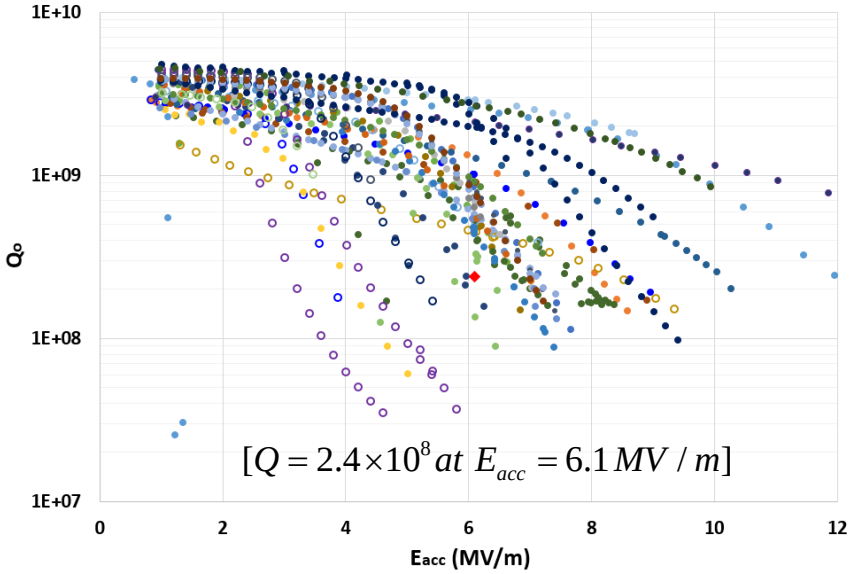
Cold Box (CB)

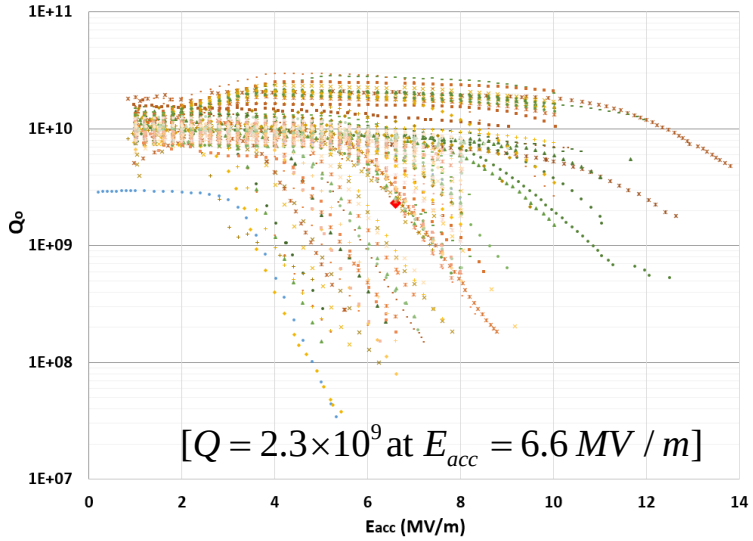
(Left warm side, right – cold side)

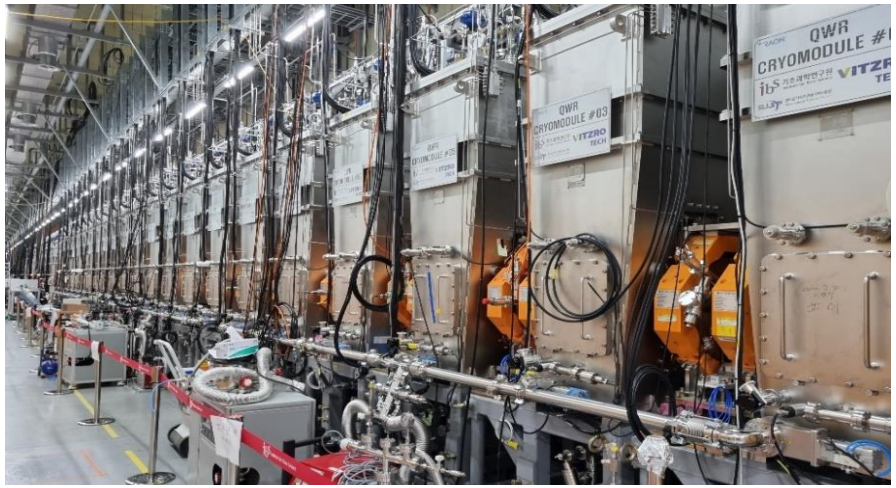
Superconducting linac: QWR & HWR for SCL3





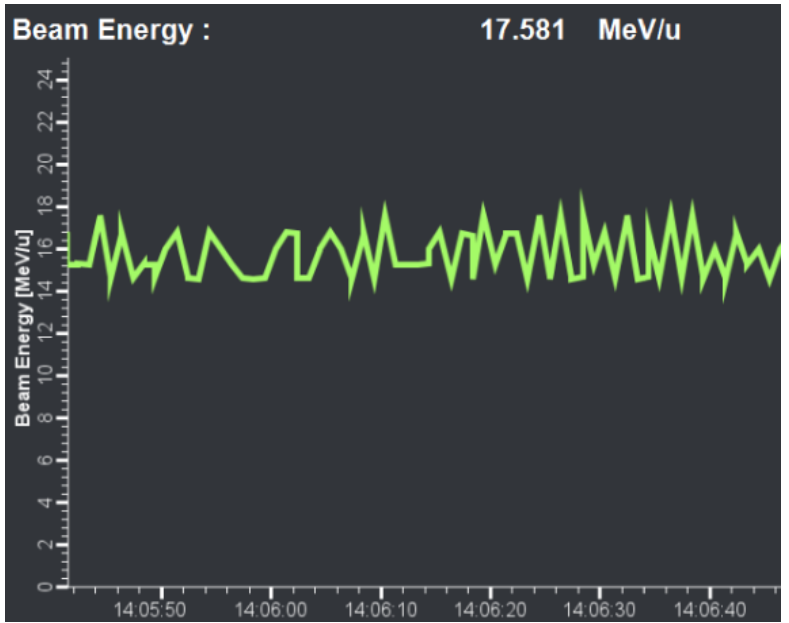




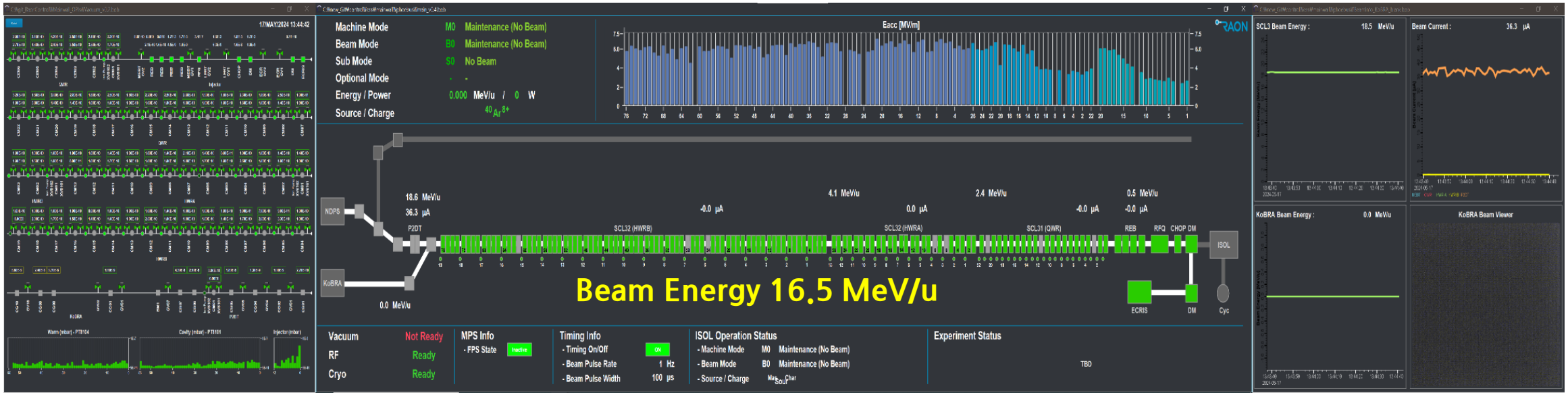


1st SCL3 Beam Commissioning in 2023

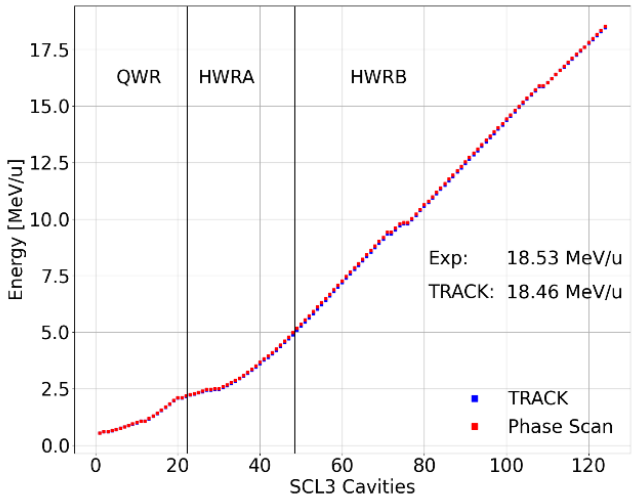
Ar^{9+} beams accelerated by entire SCL3(QWR/HWR) on May 23, 2023



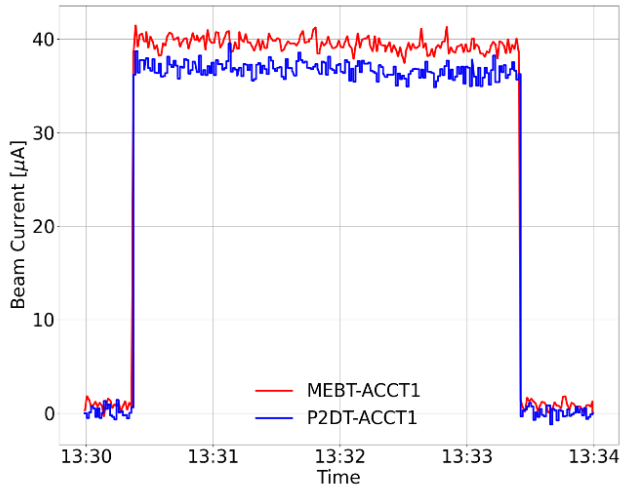
SCL3 Beam Operation in 2024



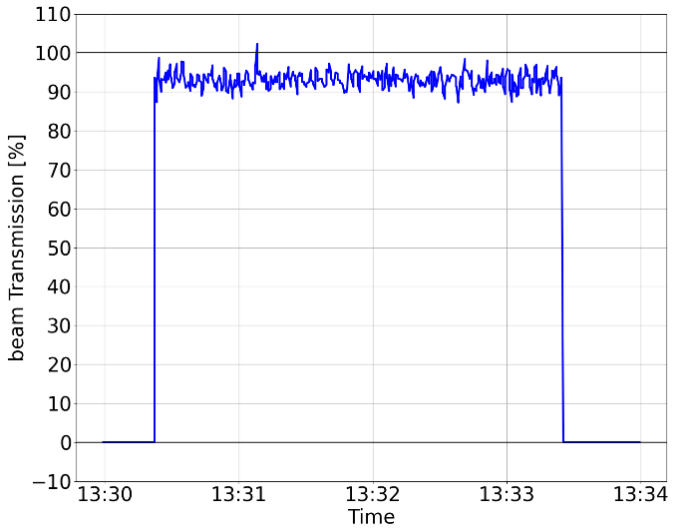
$^{40}Ar^{8+}$ beam accelerated by the entire SCL3(QWR/HWR) on May 17, 2024



[Energy in SCL cavities]



[Beam current measured by ACCT in MEBT and P2DT]



[Beam transmission through SCL3]

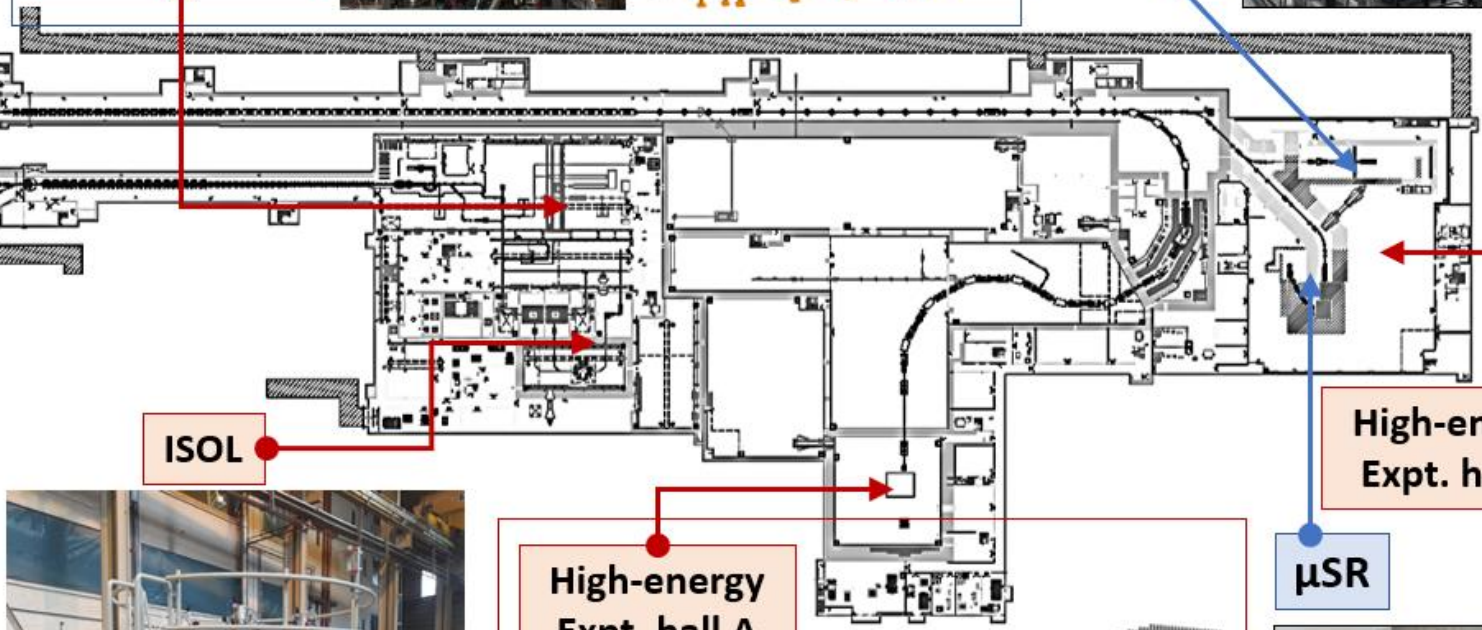
Experimental Systems

Low-energy Expt. hall B

nDPS

Ultra low-energy Expt. hall

BIS



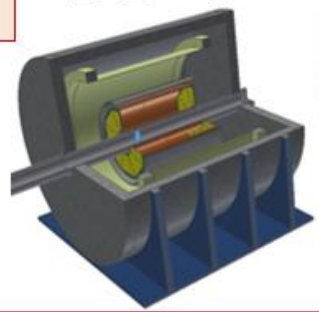
Low-energy Expt. hall A

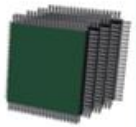
KoBRA

ISOL

High-energy Expt. hall A

LAMPS

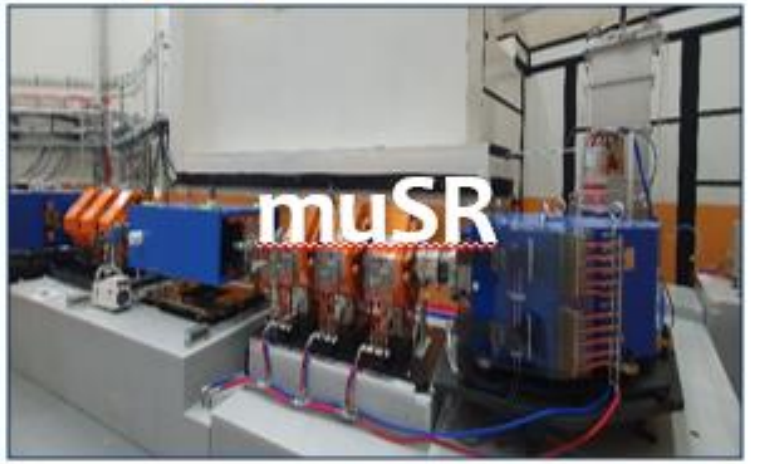


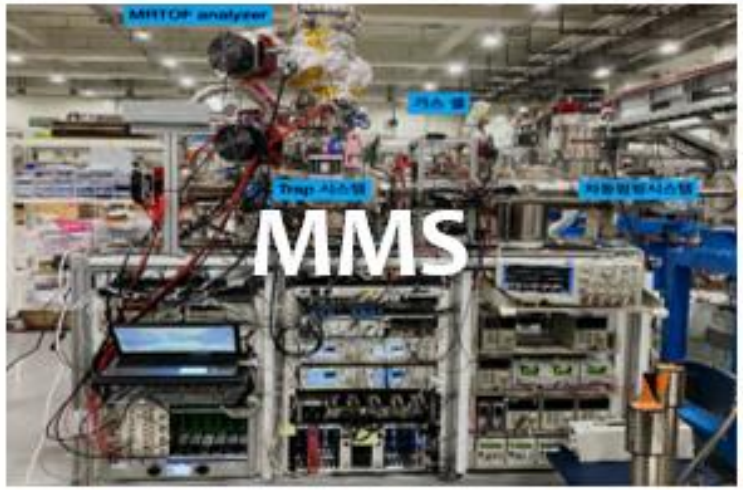


High-energy Expt. hall B

µSR

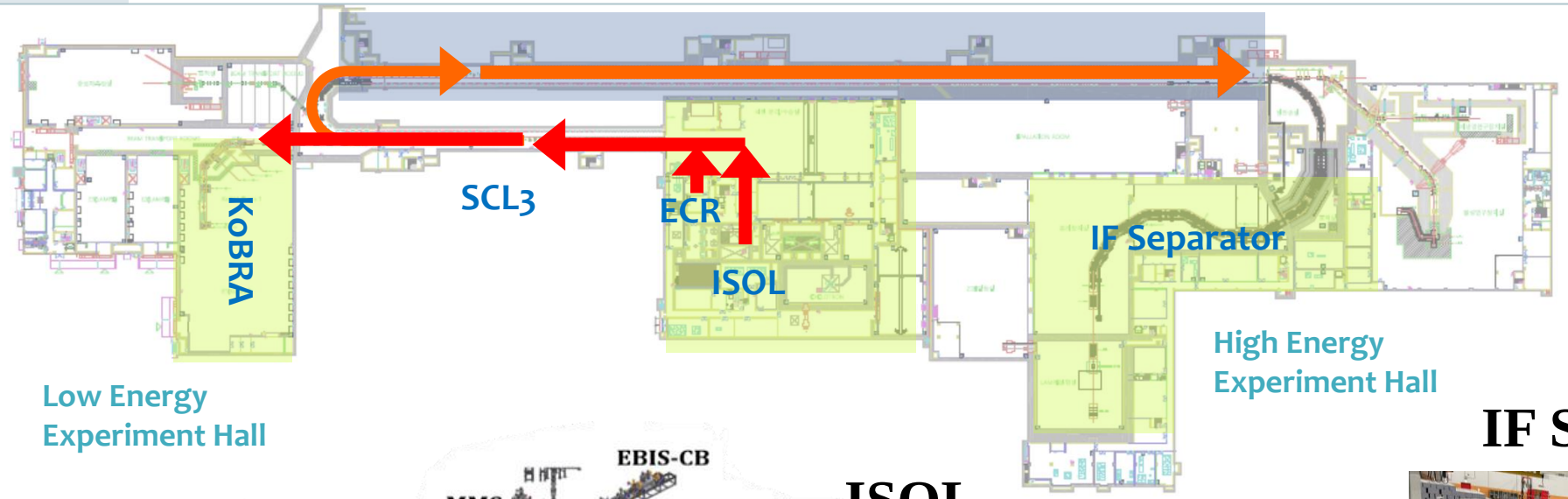
Experimental Systems

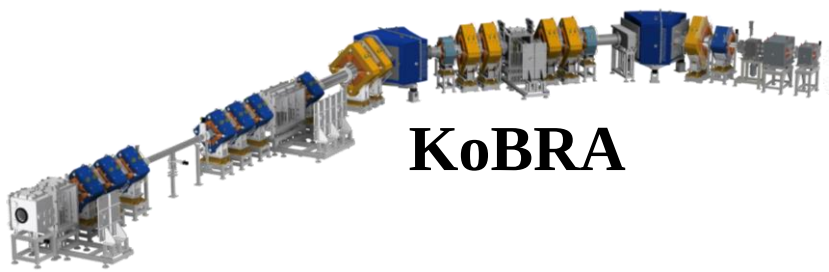




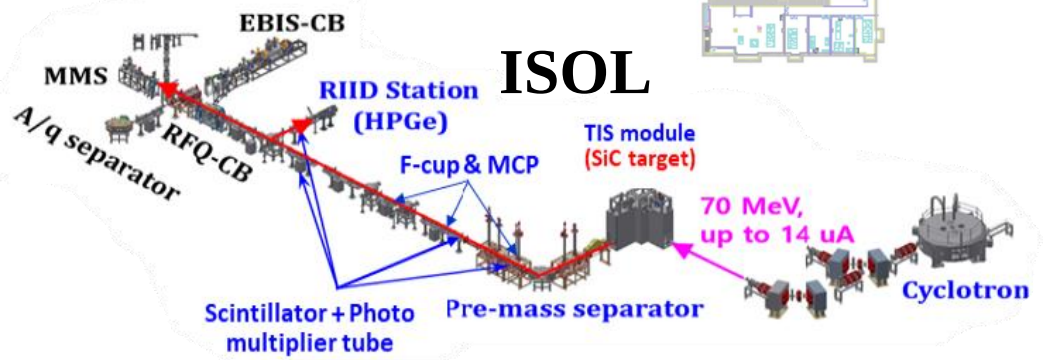
RIB Production

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





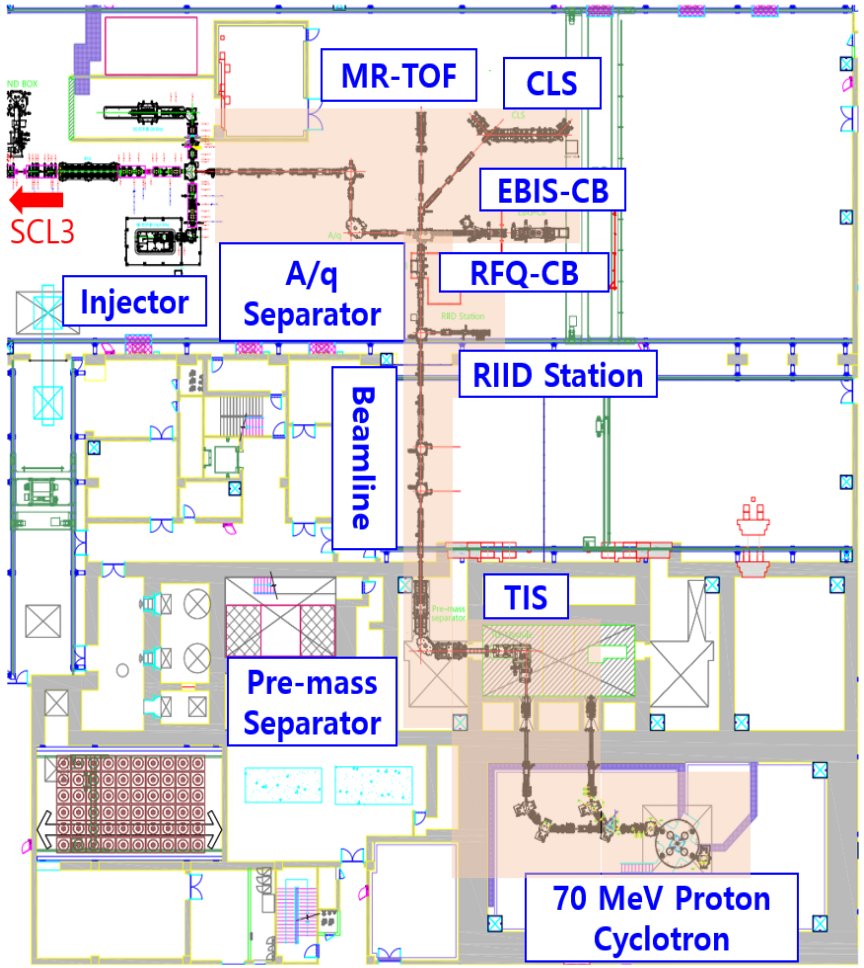
KoBRA



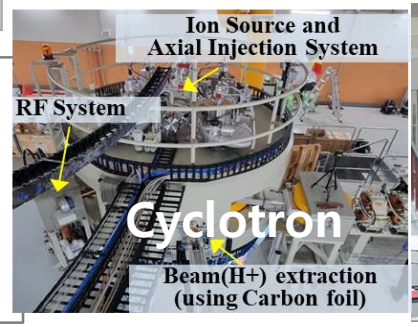
ISOL

IF Separator

ISOL System



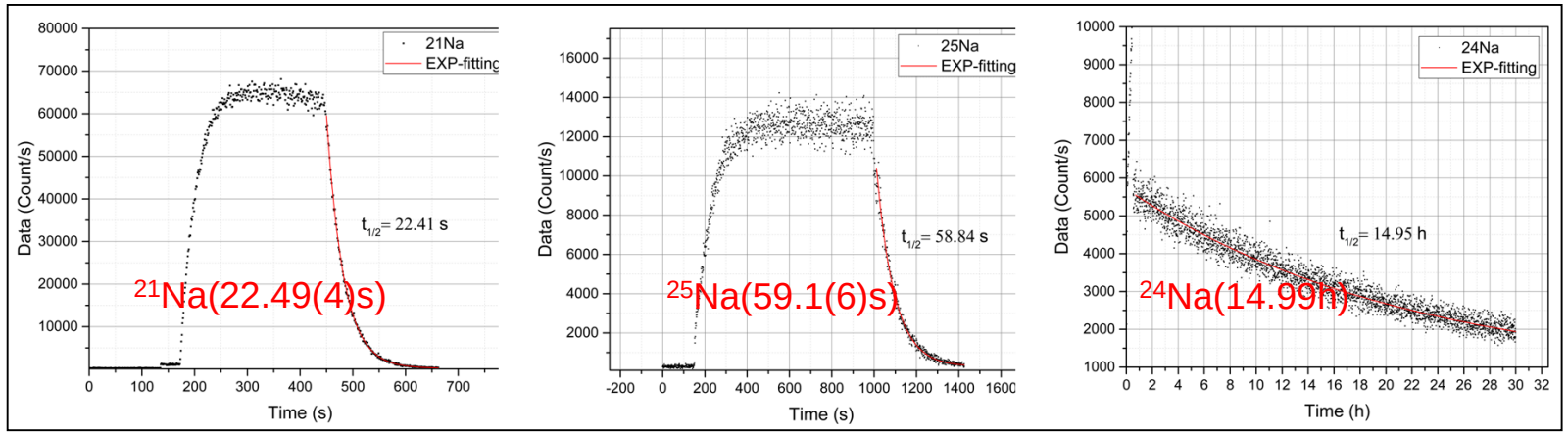
- U fission target for **80 < A < 160** neutron-rich isotope production and delivery
- Driver using Cyclotron : proton 40<K<70 MeV, up to 0.75 mA
- Target: UCx & non-fissile target (SiC, BN, MgO, LaC_2, TiC, CaO etc)
- Ion source : SIS, RILIS, FEBIAD
- Pre-mass separator, Rm ~400
- RIB: 10< K< 60 keV, up to 40 pi mm mrad, 10^8 pps(Sn), > 90% purity @Exp.
- RFQ-Cooler/buncher + EBIS charge breeder
- A/q separator, $R_{A/q}$ ~250
- 10 keV/u, A/q<6 to RFQ of post accelerator (SCL3) for RIB acceleration
- Remote handling system for TIS/module



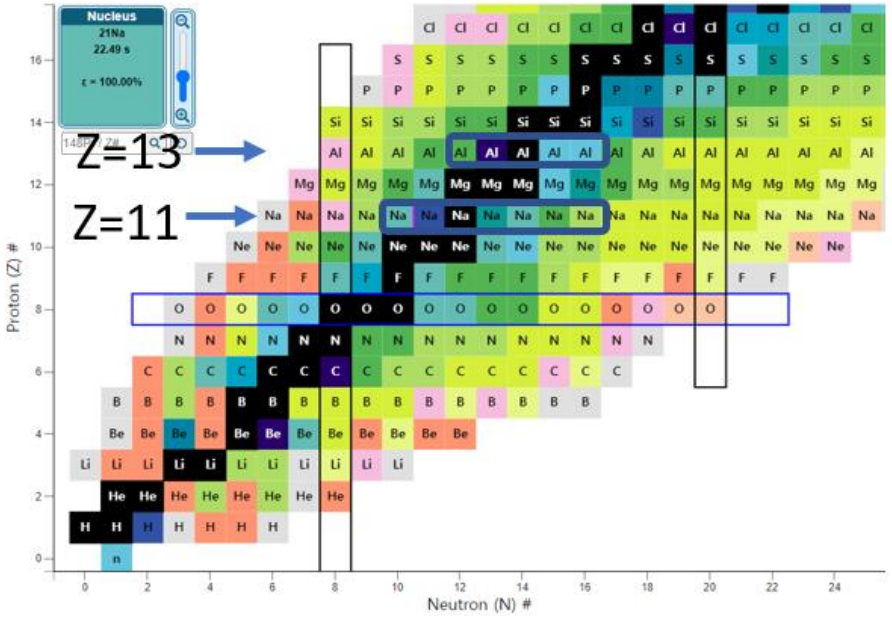
- ~ 2021.05, ISOL system installation and performance tests using a test ion source
- ~ 2022.12, ISOL system integration and stable beam commissioning
- 2022.10, 70 MeV Cyclotron SAT
- 2023.03, Initial RI beam (Na) commissioning using a SiC target
- 2023.06, RI beam (Na) transport to ISOL beamline, RIID, RFQ-CB, EBIS charge breeder and MMS

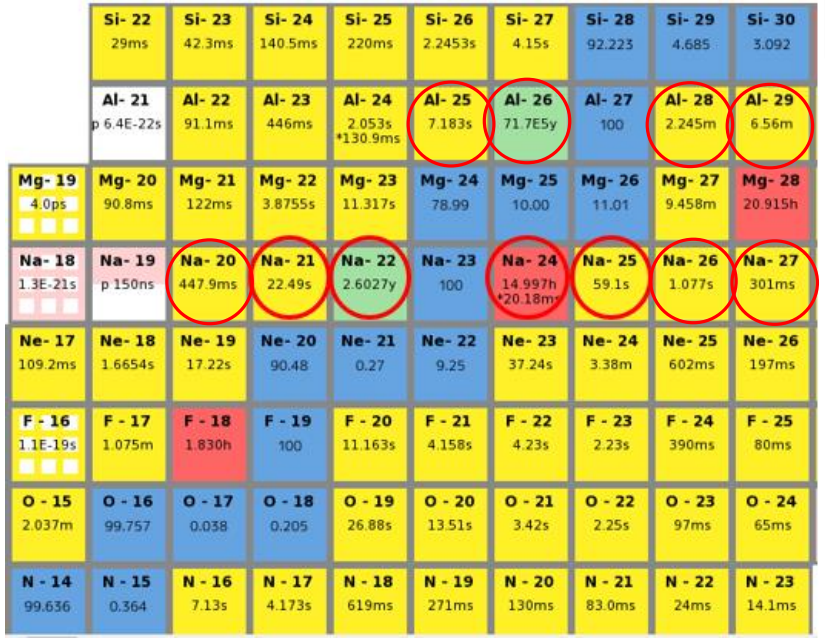
1st production of rare isotopes from ISOL in 2023

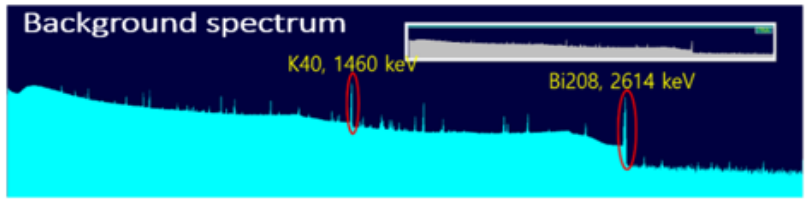
The first RI production and transport at ISOL on March 3, 2023



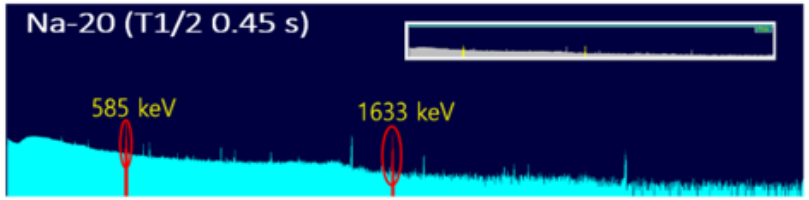
Half-lives of Na isotopes measured by using scintillators & PMT



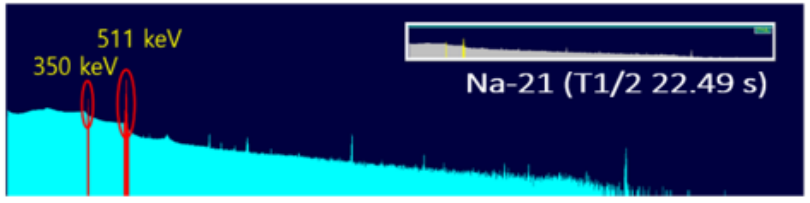




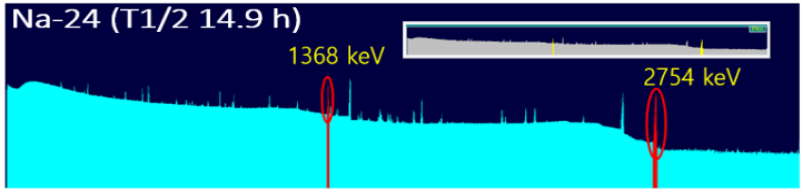
< Measurement of 534,632 sec >



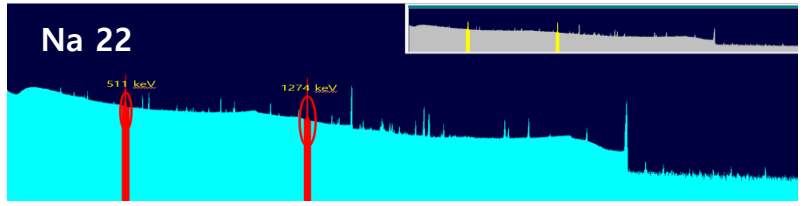
< 2uA p+ irradiated 3,180 sec, measured 3,260 sec >



< 1.71uA p+ irradiated 1,000 sec, measured 1300 sec >

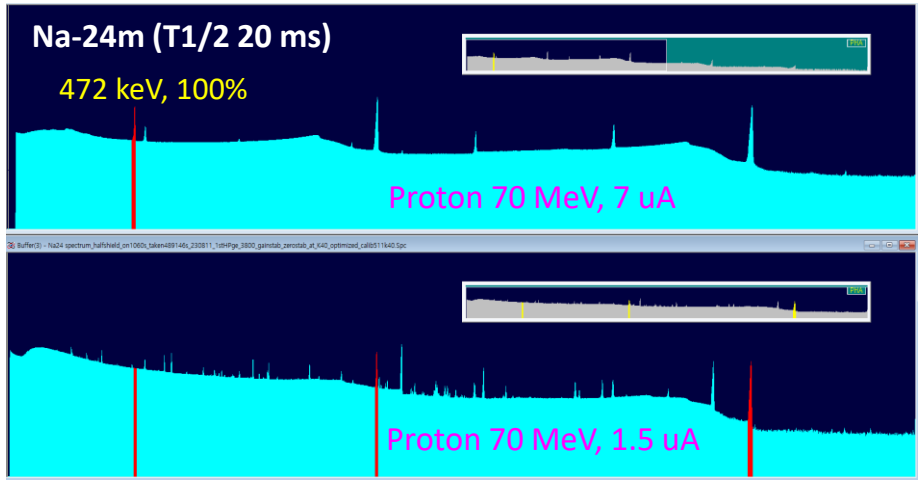


< 1.7uA p+ irradiated 1,060 sec, measured 489,146 sec >

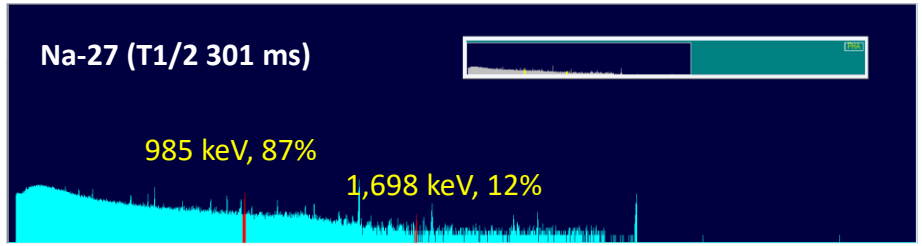


Production of rare isotopes from ISOL in 2024

- **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**
  - RIs with very short half-lives can be produced and transported

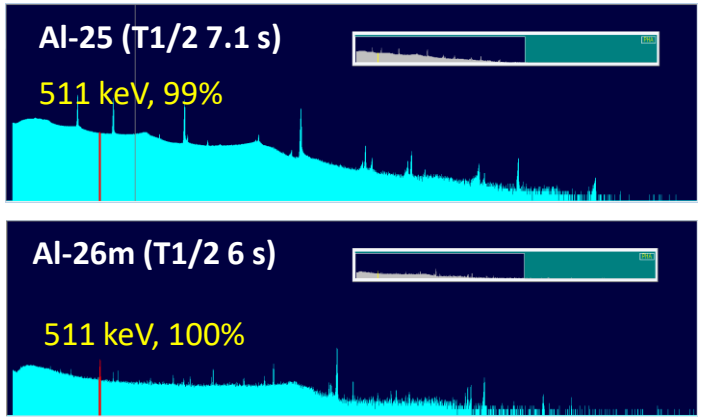


< Gamma spectrum of Na-24 measured by HPGe >
Proton 7 uA (upper) & 1.5 uA (lower)

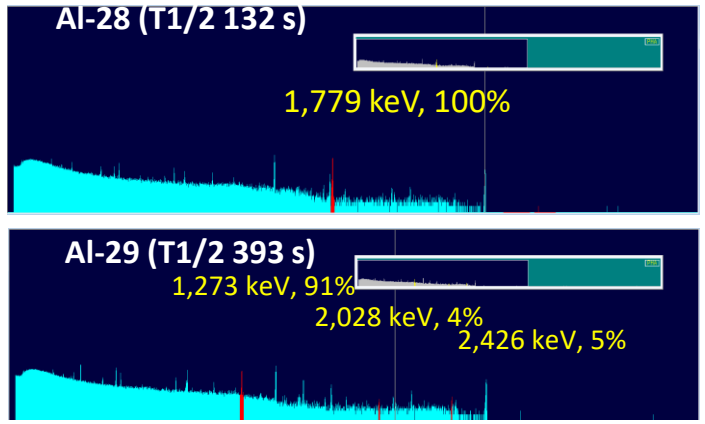


< Gamma spectrum of Na-27 measured by HPGe >

- **Aluminum isotopes**
  - Release of Al isotopes is very slow
  - Low ionization efficiency with a surface ion source
  - Al yield is low (in SiC target)

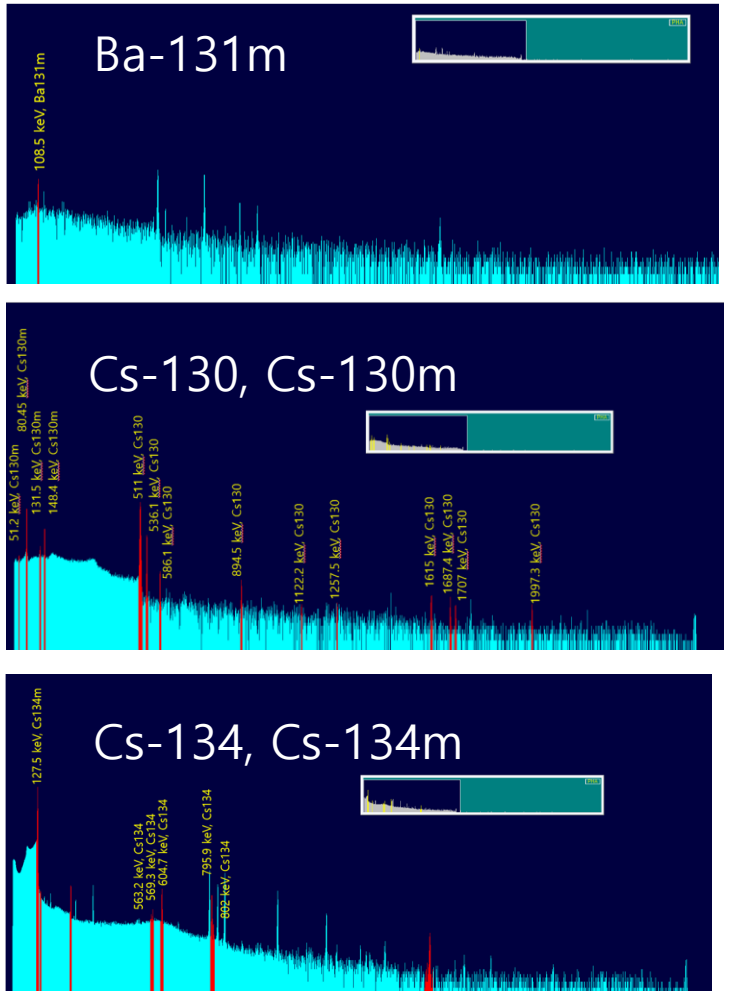


< Gamma spectrum of Al-25(upper) & Al-26m(lower) >



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

- **LaC_2 target in ISOL TIS**
- Cs130, Cs130m, Ba131m, Ba133, Ba133m, Cs134, Cs134m, Cs135m, Ba135m, Cs136, Ba137m, Cs138, Cs138m observed

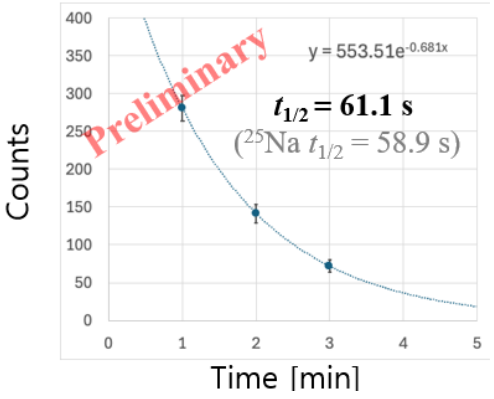


SiC Target

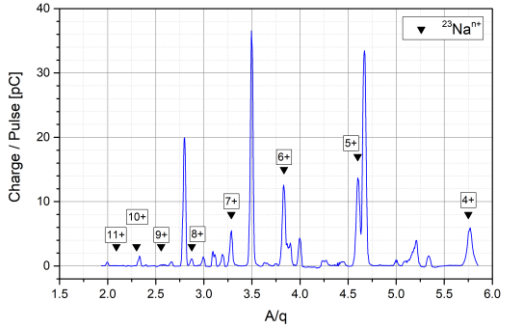
JH Lee of IRIS

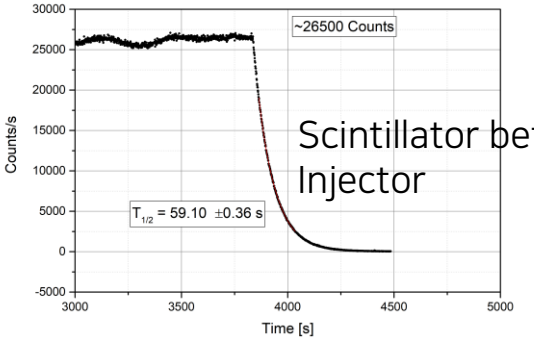
LaC2 Target

First acceleration of ISOL RIB ($^{25}Na^{5+}$) to KoBRA



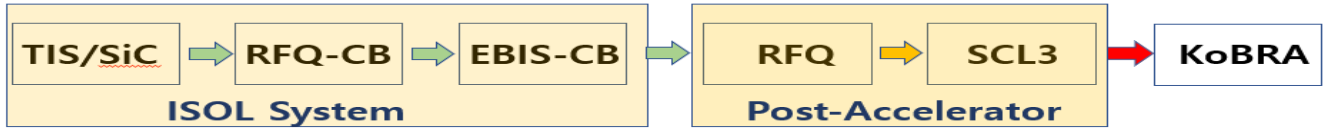
Charge Breeding

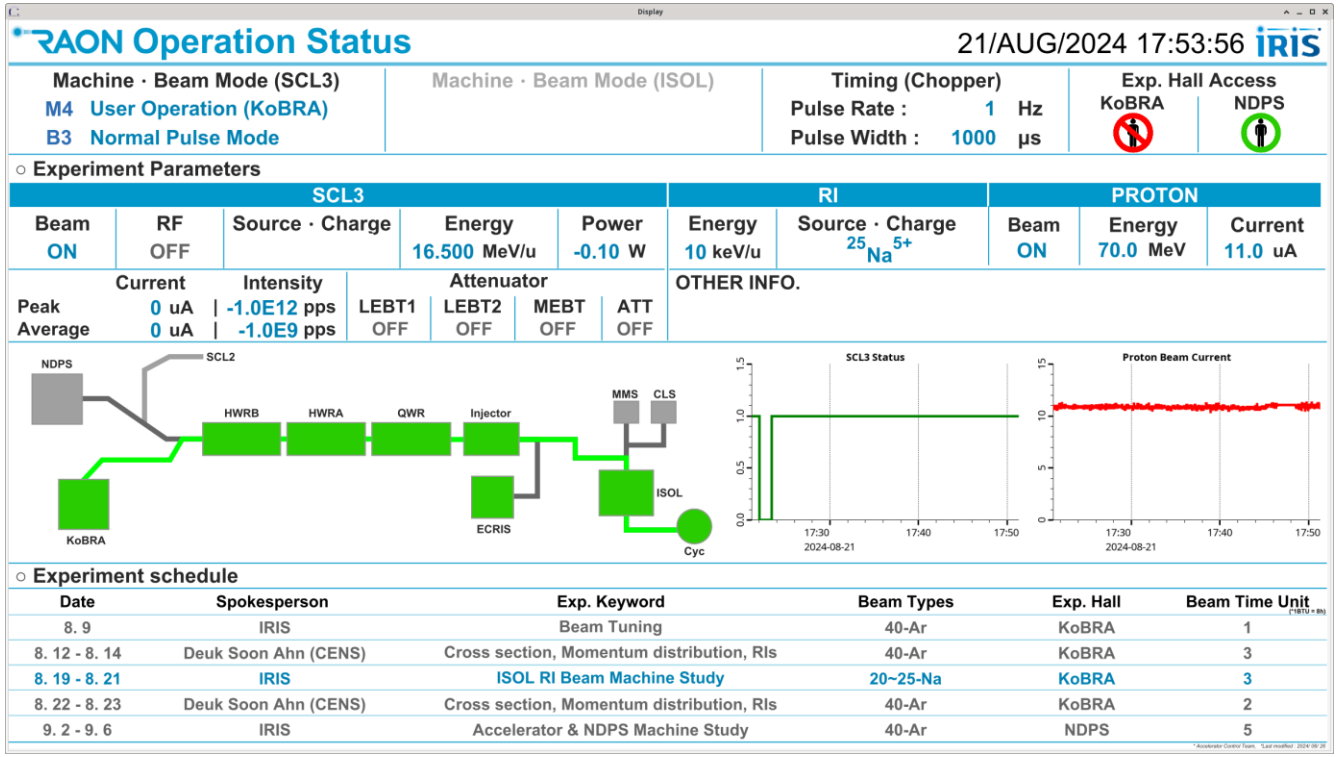




Scintillator before Injector

By KH Yoo of IRIS

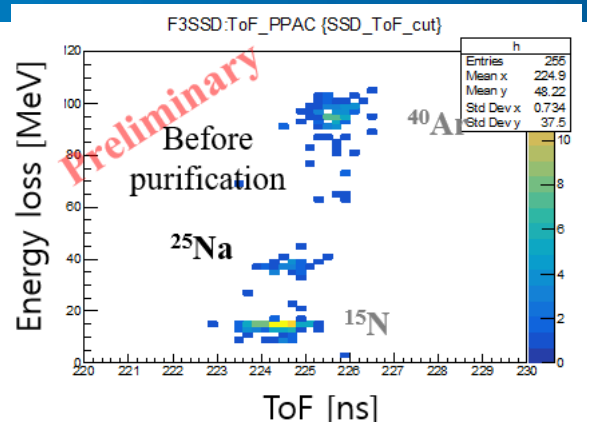


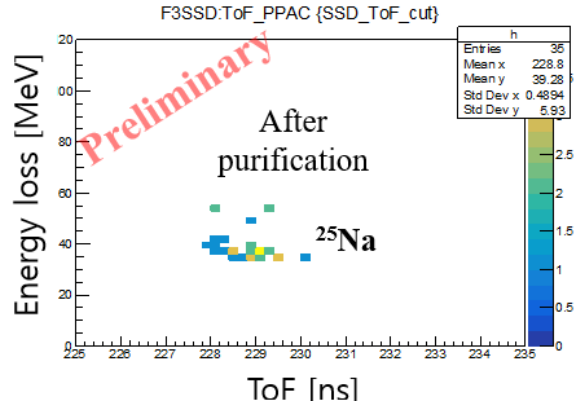


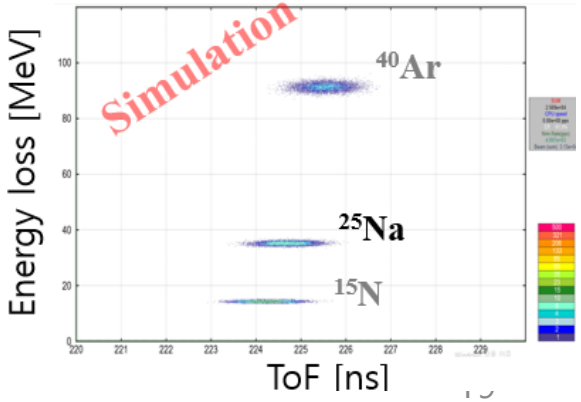
Date	Spokesperson	Exp. Keyword	Beam Types	Exp. Hall	Beam Time Unit
8. 9	IRIS	Beam Tuning	40-Ar	KoBRA	1
8. 12 - 8. 14	Deuk Soon Ahn (CENS)	Cross section, Momentum distribution, RIs	40-Ar	KoBRA	3
8. 19 - 8. 21	IRIS	ISOL RI Beam Machine Study	20~25-Na	KoBRA	3
8. 22 - 8. 23	Deuk Soon Ahn (CENS)	Cross section,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

ISOL $^{25}Na^{5+}$ beam post-accelerated on Aug. 2024

- Beam Energy after SCL3: ~16.5 MeV/u
- ^{25}Na, ^{40}Ar, ^{15}N were identified in KoBRA
- ^{25}Na was purified by using energy degrader at KoBRA
- Decay curve of beta ray was measured





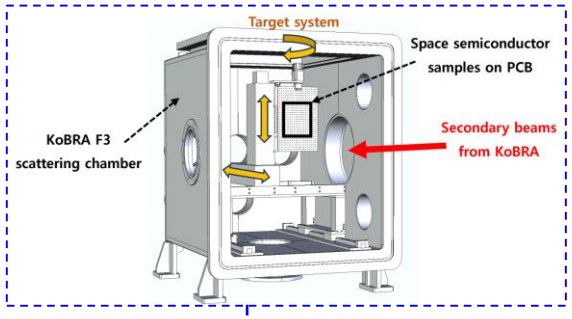


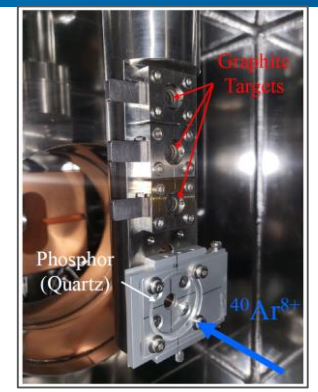
By MS Kwak of IRIS

KoBRA : Korea Broad acceptance Recoil spectrometer and Apparatus

KoBRA Experimental Setup

- 2 × Large Area PPACs (Bρ, Position)
- 1 × Homogeneous Degrader (RI Separation)
- 1 × Plastic (Intensity)
- 1 × Phosphor (Beam Centering)





Target Ladder

- 2 × PPACs (ToF, Position)
- 1 × Plastic (ToF, Position)

F2 chamber

F1 chamber

Low power solid target chamber

Water cooled collimator

Wien filter space

Scattering chamber

Q9 Q10 Q11 Q12 Q13 Q14 Q15 Q8 Q7 D2 H2 Q6 Q5 Q4 Q3 H1 D1 Q2 Q1

- 2 × PPACs (ToF, Position)
- 1 × Plastic (ToF, Position)

F3 chamber

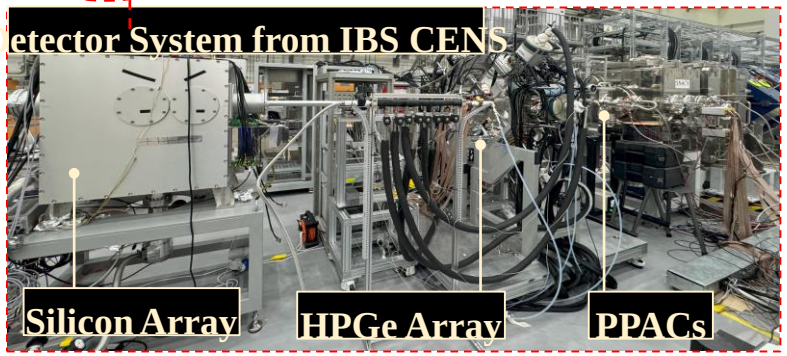
Water cooled beam dump

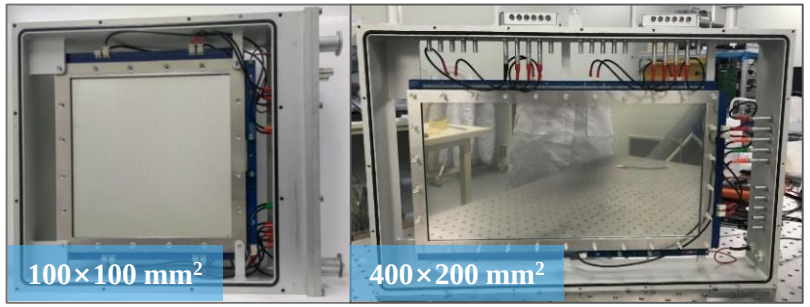
Beam Swinger

$^{40}Ar^{8+}$
from SCL3
E = 16.5 MeV/u
I = 5 pnA

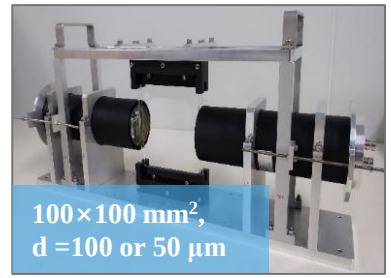
By DG Kim, K Tshoo , M Kwak of IRIS

CENS STARK

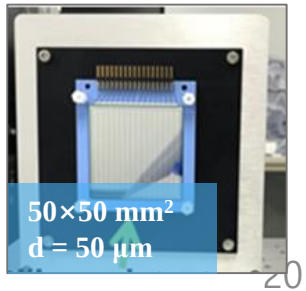




Parallel-Plate Avalanche Chambers (PPACs)



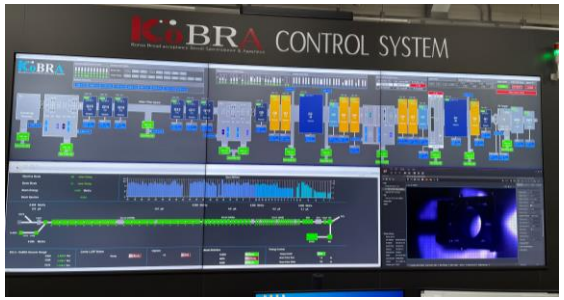
Plastic Scintillator

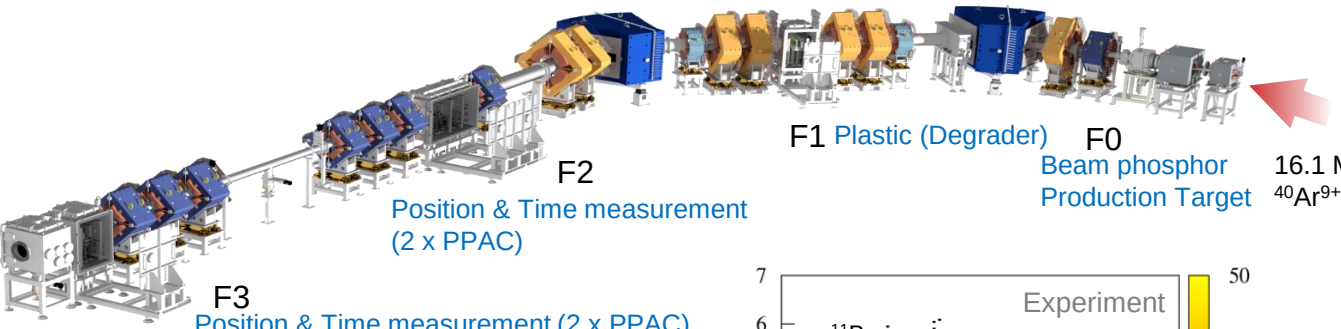


Silicon Strip Detector

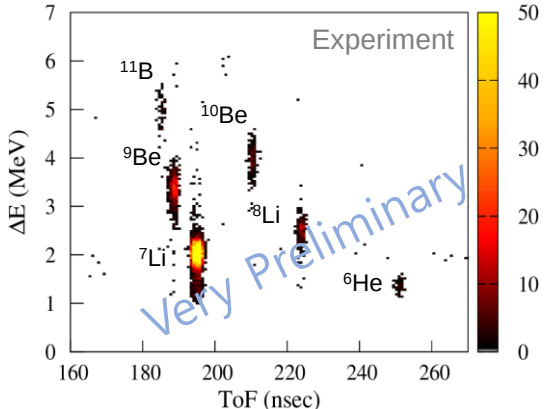
Commissioning of KoBRA (2023, 2024)

First $^{40}Ar^{9+}$ beam commissioning of KoBRA (2023.5.31~6.2)

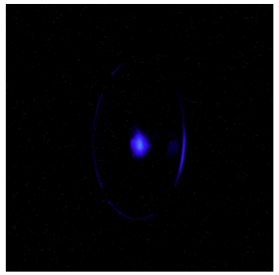


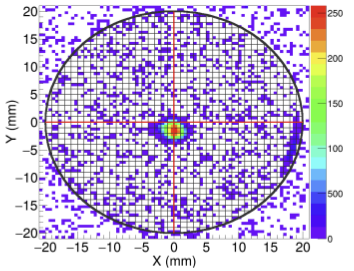


IRIS Experimental system team
(K. Tshoo, D. G. Kim *et al.*)



$^{40}Ar^{8+}$ beam commissioning of KoBRA (2024. July ~ August)



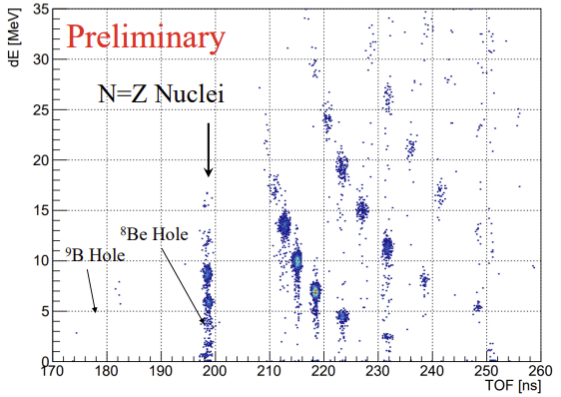


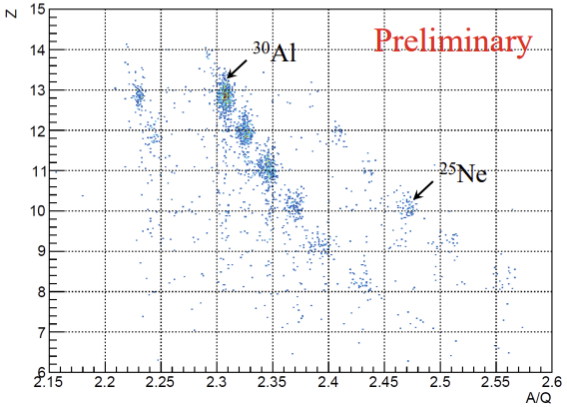
$^{40}Ar^{8+}$ Primary Beam

$\sigma_x = 0.99 \pm 0.01$ mm
$\sigma_y = 0.90 \pm 0.01$ mm
E = 16.44 ± 0.01 MeV/u
I_p = 5 pnA

Phosphor Screen Images

Particle Identification in ΔE−ToF & Bρ−ΔE−ToF plots



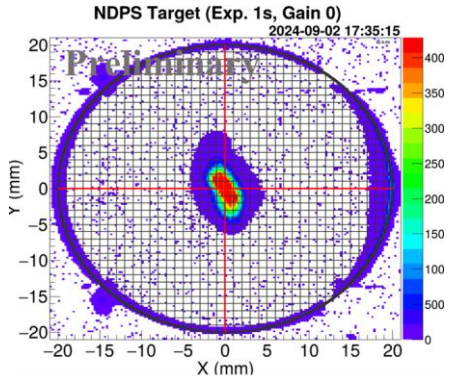


IRIS Experimental system team
(K. Tshoo, D. G. Kim *et al.*)

Collaboration with CENS/IBS

NDPS (Nuclear Data Production System)

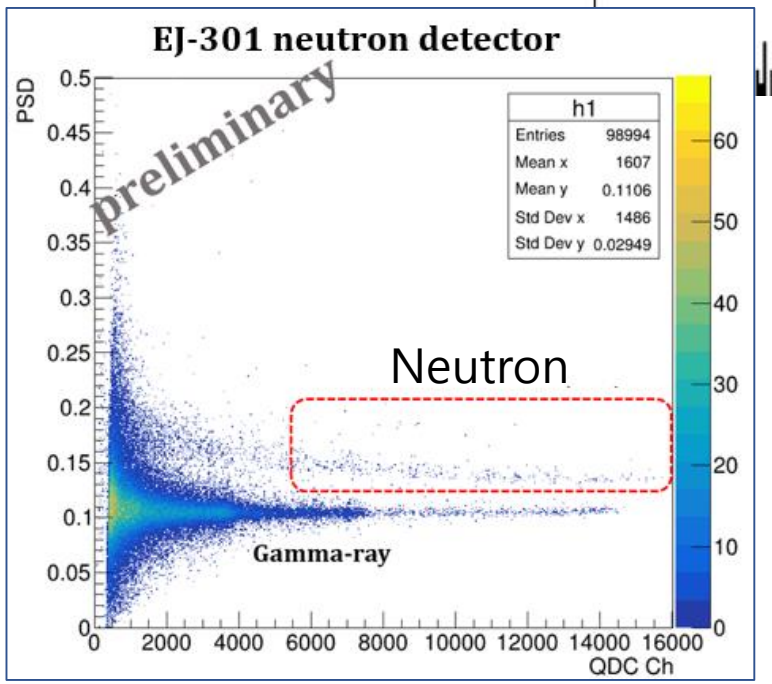
- ❖White neutrons produced by 50 MeV/u deuteron beams from SCL3
- ❖Monoenergetic neutrons, by using proton beams of 20-80 MeV/u from SCL3

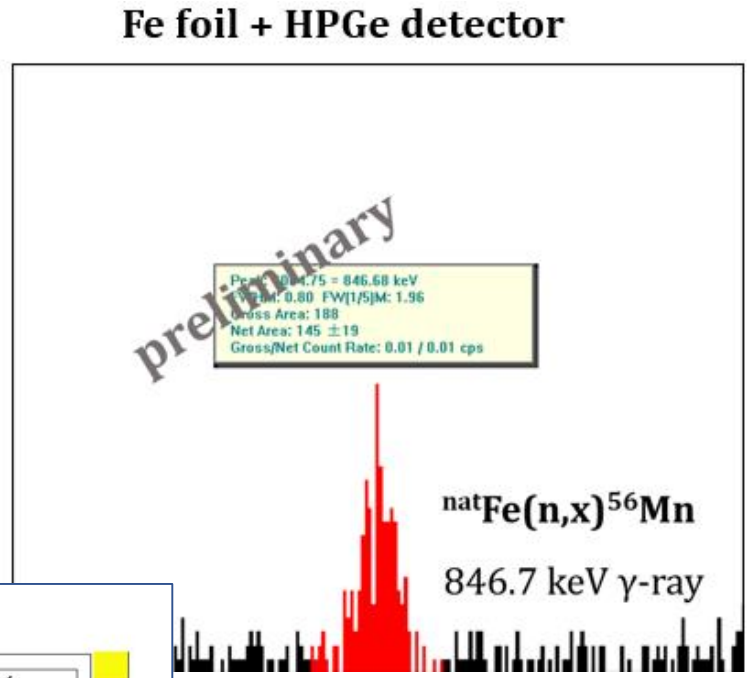


NDPS
Nuclear Data Production System

By CM Ham, G Oh of IRIS

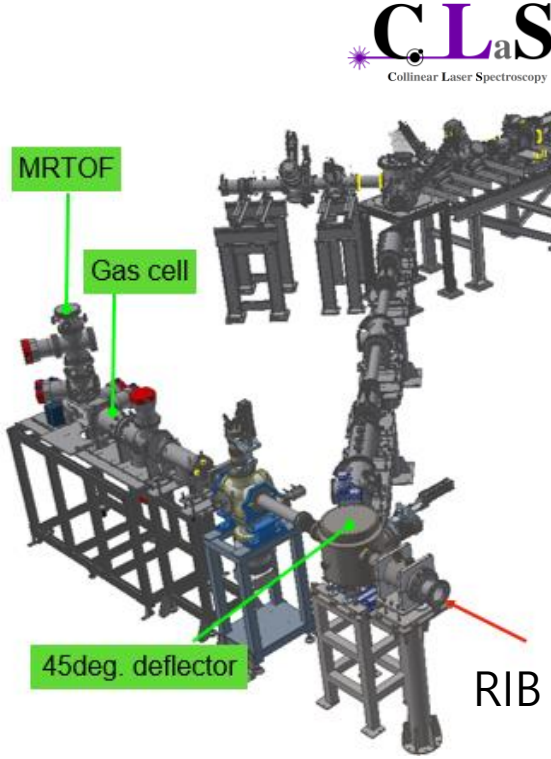
Part of radiation safety examination by KINS



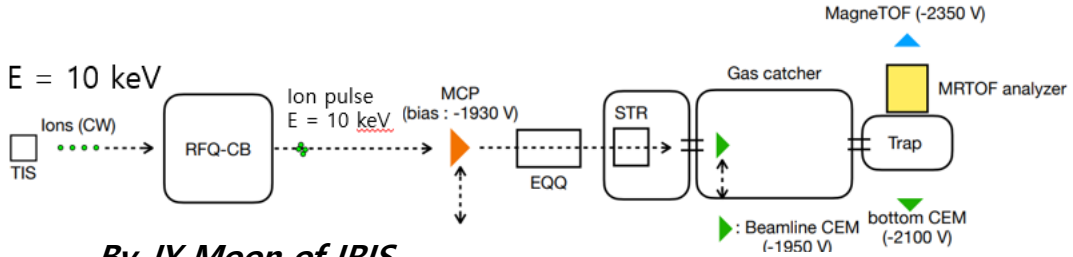


ISOL Beam to MR-TOF

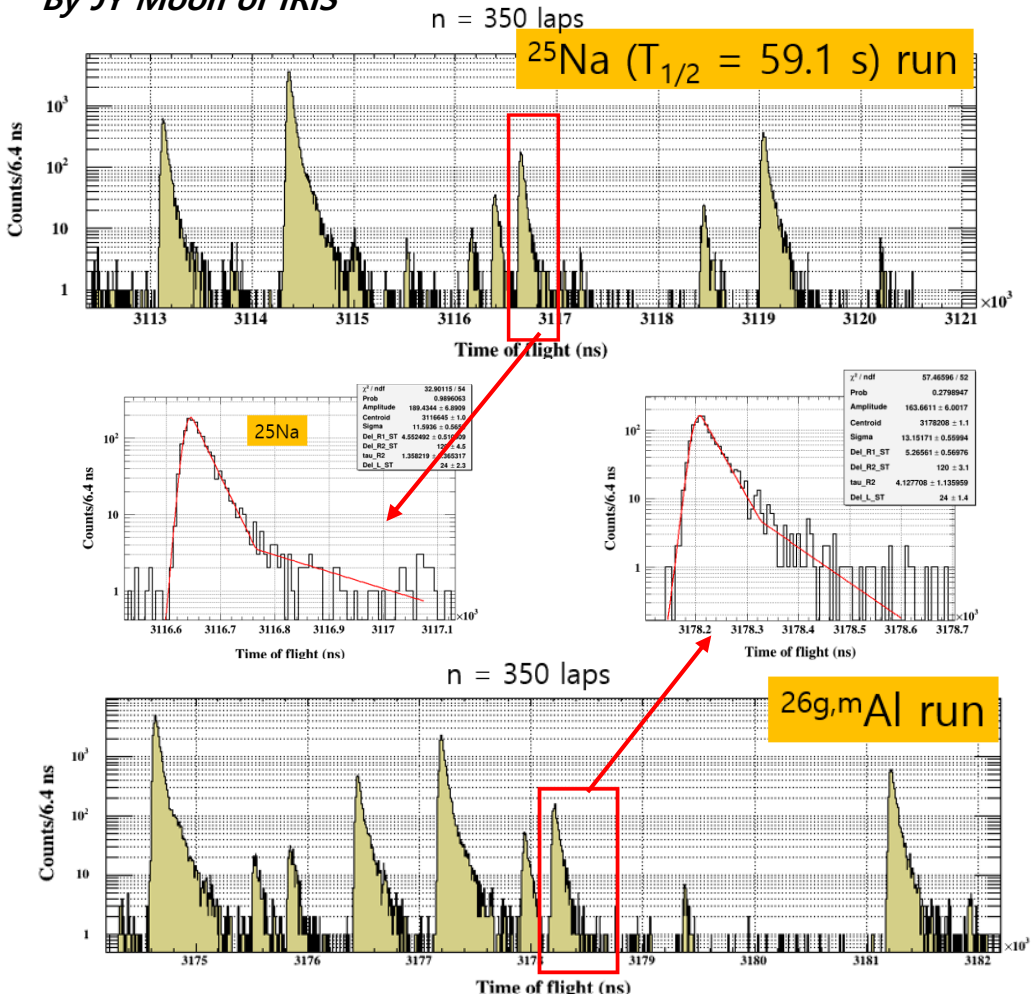
MR-TOF consists of
- Gas cell (or catcher), Trap system: Buffer-gas collision, ion thermalization
- MRTOF analyzer : Multi-reflection, mass measurement



MRTOF-MS



By JY Moon of IRIS



First call for proposals

2024 Call for Proposals of Low-Energy Beam at RAON

December 12, 2023 to January 19, 2024
Institute for Rare Isotope Science
Asia/Seoul timezone

Enter your search term

- Overview
- Registration
- Call for Proposals
- Facility Information
  - KoBRA
  - MRTOF-MS
  - Cyclotron
  - CLS
- Important Dates
- Program Advisory Committee (PAC)
- IRIS Homepage
- RAON Users Association Homepage

User Support Office
user_support@ibs.re.kr
+42 878 8746

CALL FOR PROPOSALS

The Institute for Rare Isotope Science (IRIS) invites proposals for beam times extended to domestic users in Korea. The primary beams to be provided in 2024 will be Ne-20 and Ar-40 accelerated by the superconducting linac SCL3 at the energies of ~20 MeV/u or less with a maximum current of ~40 μA. Proton beams of 40 and 70 MeV can be provided by a cyclotron up to 10 kW or less.

The beam times will be provided for non-proprietary experiments based on the scientific merits through the review of proposals by the PAC members. There will be no beam time charge for non-proprietary experiments as long as the results are expected to be published.

The experimental systems such as KoBRA, MMS, and CLS can be used for experiments. Details of the experimental conditions can be discussed with the contact person of each experimental system.

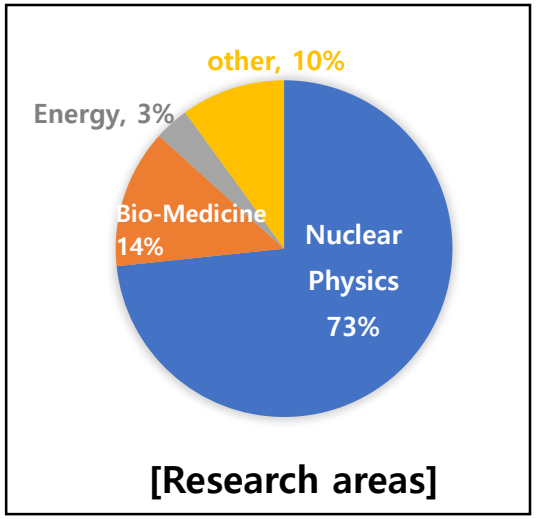
The proposals need to be submitted by January 19, 2024 to allow for scientific and technical reviews of the proposals prior to the PAC meeting, which will take place in early March, 2024.

Important dates

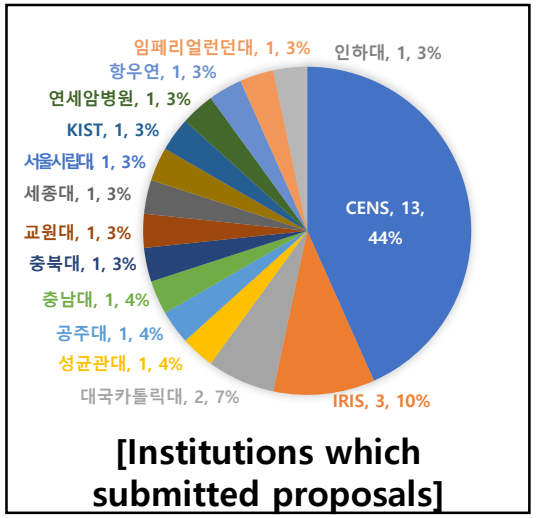
- 12 December, 2023: Call for proposals
- 19 January, 2024: Deadline for submission of proposals
- Early March, 2024: First PAC Meeting
- Middle of March, 2024: Notification of approved experiments
- May ~ June, 2024: Ne-20 and Ar-40 beams provided from the SCL3
- Beam times for proton beams/ISOL can be discussed and fixed individually

- From Dec. 12, 2023 ~ Jan. 19, 2024 (6 weeks)

- For domestic users
- 30 proposals
- 313 participants



[Research areas]



[Institutions which submitted proposals]

International collaboration

MOUs with 17 International Institutes

TOP-Tier platform In Extreme Rare isotope science (TOPTIER)

International Research Collaboration

Exchange of researcher

Sharing information and know-how

Collaboration Platform

World-class Research Results

Establishment of International Collaboration Center

RAON
극한 희귀동위원소 국제협력 사업단

RIKEN NISHINA CENTER
RIKEN 니시나센터 협력 사업팀

Top-tier Level New Researcher

Differentiated and Challenging Research Topics

Director
Taeksu Shin

기초과학연구원 Institute for Basic Science

IRIS 한국형 CENS CENTER FOR EXOTIC NUCLEAR STUDIES

서울대학교 SEOUL NATIONAL UNIVERSITY

Prof Seonho Choi

고려대학교 KOREA UNIVERSITY

Prof. Jung Keun Ahn

KAERI 한국원자력연구원 Korea Atomic Energy Research Institute

Dr. Do Heon Kim

RIKEN NISHINA CENTER

Center for Nuclear Study The University of Tokyo

Director Y. Sakemi

WNSC KEK Wako Nuclear Science Center

Director Y. Watanabe

Director
Hiroyoshi Sakurai

RAON will provide various rare isotopes and can be important for nuclear reactions, nuclear structures, and nuclear astrophysics but also for developing new techniques in various fields. RAON has great opportunities for rare isotope studies.

Slide from D.S. Ahn

International workshop on nuclear physics related to HIAF

2024.04.16-19, Huizhou Research Department, Institute of Modern Physics.Chinese Academy of Science

HIAF under construction 7 months ago

HIAF + CiADS

Summary

- Commissioning of SC Linac (SCL3) is done. (2023 & 2024)

- Commissioning of ISOL system is done with SiC (2023) & LaC_2 (2024)
- UCx target is expected to be tested for ISOL in 2026

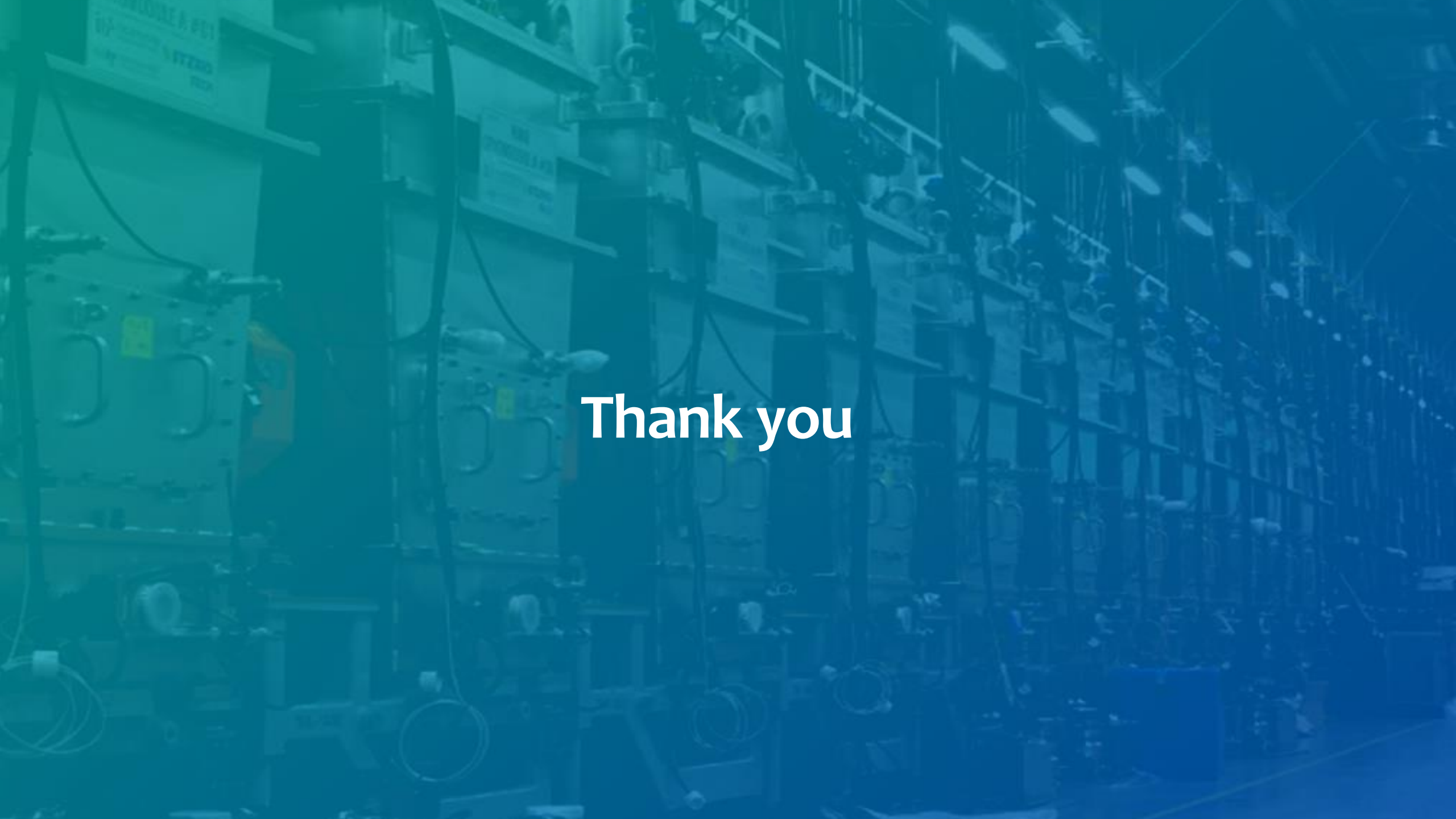
- Commissioning of KoBRA spectrometer is done in 2023 and 2024
- KoBRA produced and identified secondary isotopes in low-mass regions

- ISOL RIB ($^{25}Na^{5+}$) was accelerated by SCL3 and transported to KoBRA at 16.4 MeV/u

- MRTOF is under commissioning with RI beams from ISOL
- CLS is under commissioning with RI beams using laser spectroscopy

- The first call for proposals was announced in Dec 2023 for domestic users (as recommended by Int Science Advisory Committee)
- The first PAC was held in March, 2024 (Ar and Ne beams)
- Three experiments were performed for user services using KoBRA, from July to August
- Cryoplant is under maintenance

- Hope to provide beams to international users soon.


Thank you