RAON Rare isotope Accelerator complex for ON-line experiments

Status of RAON Superconducting Linac at IBS

June. 26, 2023
SRF2023 Grand Rapids

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on behalf of IRIS(Institute for Rare Isotope Science)

ibs 기초과학연구원 Institute for Basic Science

RISP 중이온가속기건설구축사업단 Rare Isotope Science Project

Contents

Rare Isotope Science Project (RISP)

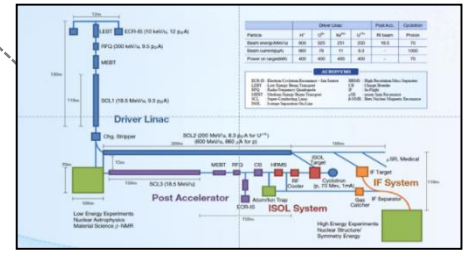
- **Goal:** To build **a heavy ion accelerator complex RAON,** for **rare isotope science** research in Korea.

  * RAON - Rare isotope Accelerator complex for ON-line experiments

- **Budget: KRW 1,518 billion (US$ 1.32 billion, 1$=1,146krw)**
  - 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)**
  2023.01 ~ (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



- **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**
  e.g., ^{132}Sn with up to 250 MeV/u,
  up to 10^9 particles per second

Facility Construction Project

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

※ Accelerator and experiment buildings, support facility, administrative buildings, and guest house, etc.

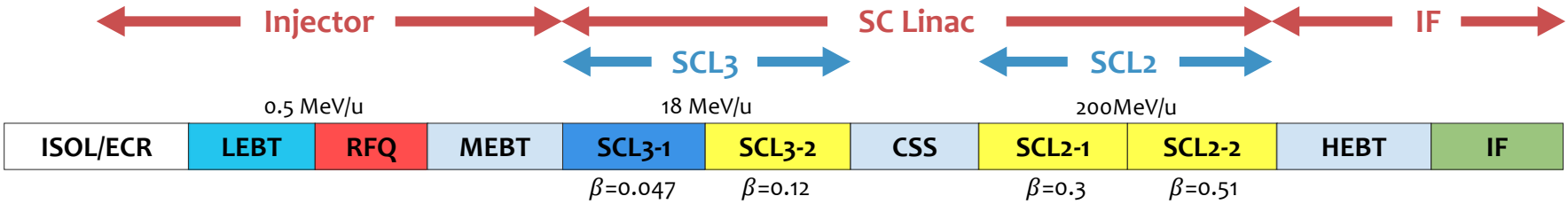
- **Providing More exotic RI beam production by combination of ISOL and IF**

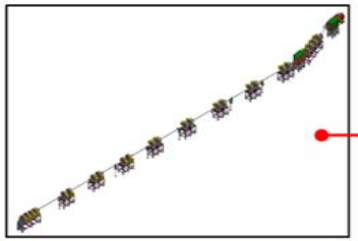
Campus Layout

RAON Layout

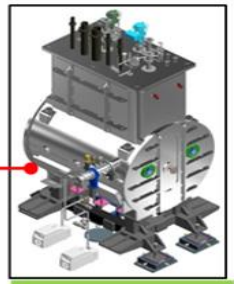
- SCL1 has been decided to postpone
  : SCL3 is going to be taking a role of SCL1 in the early operation

Accelerator Systems

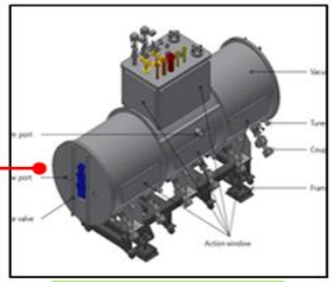




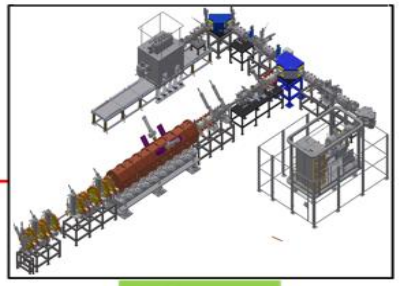
KoBRA Beam Line



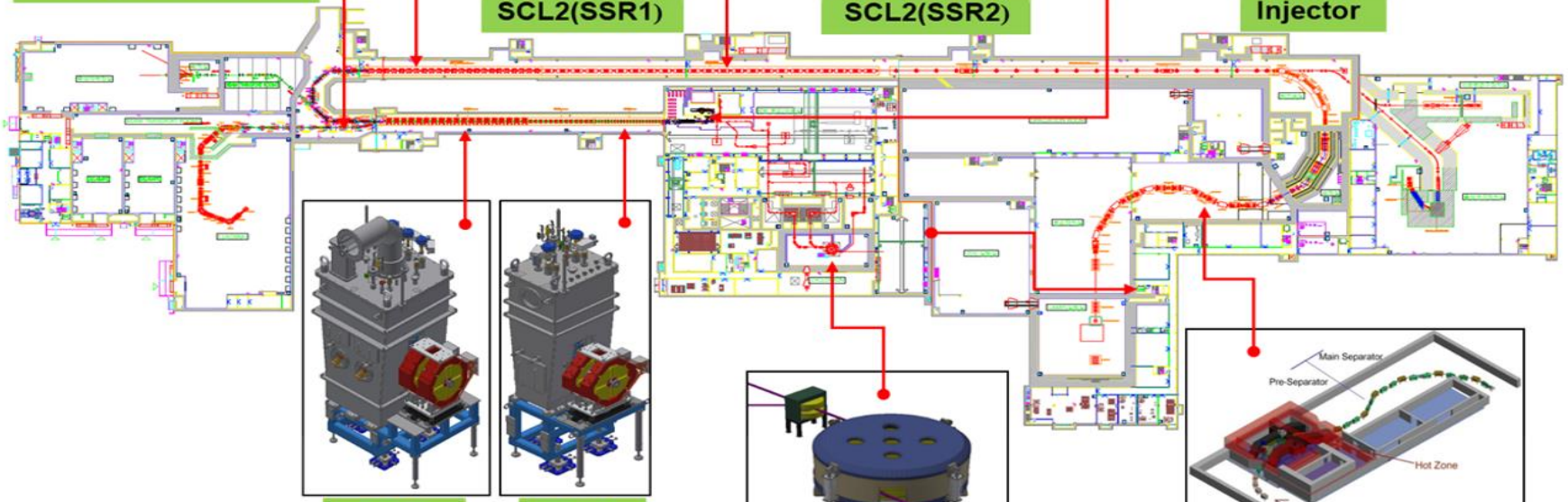
SCL2(SSR1)



SCL2(SSR2)



Injector



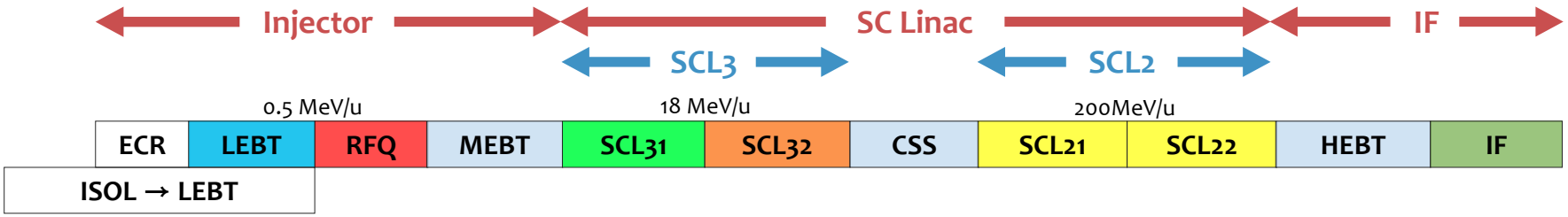
SCL3 (HWR)

SCL3 (QWR)

Cyclotron

IF System

Accelerator Systems

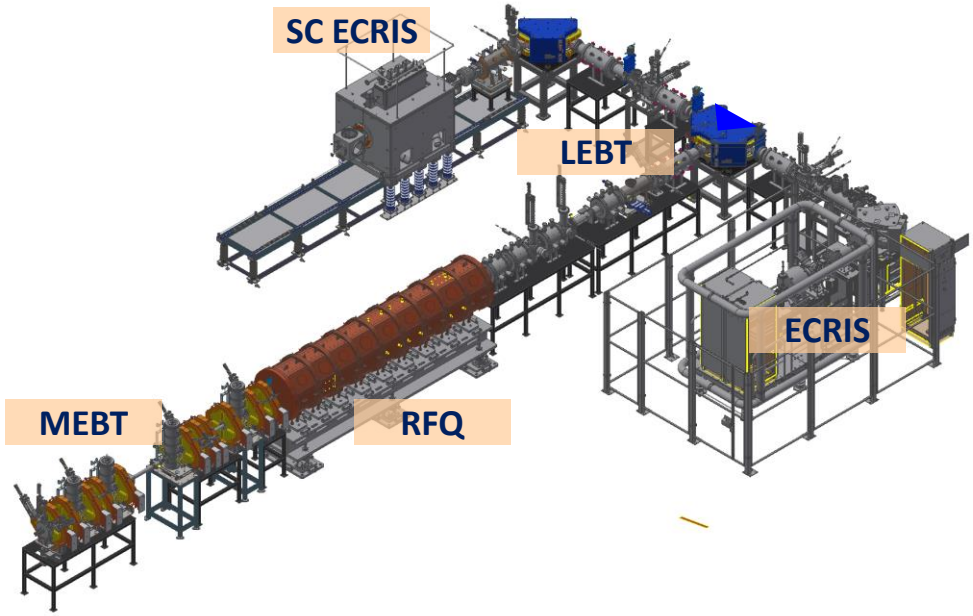


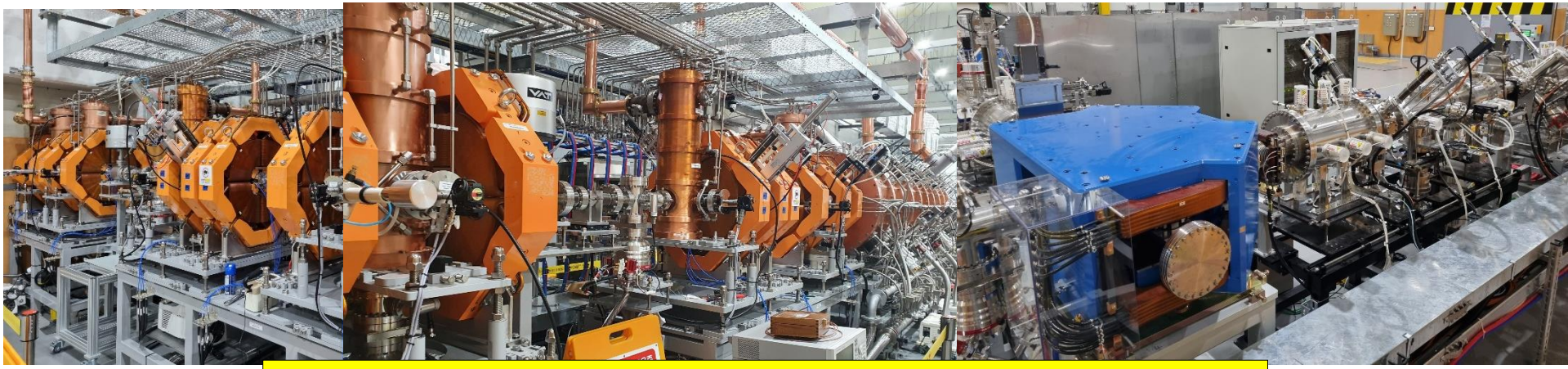
SCL3

SCL2

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, 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



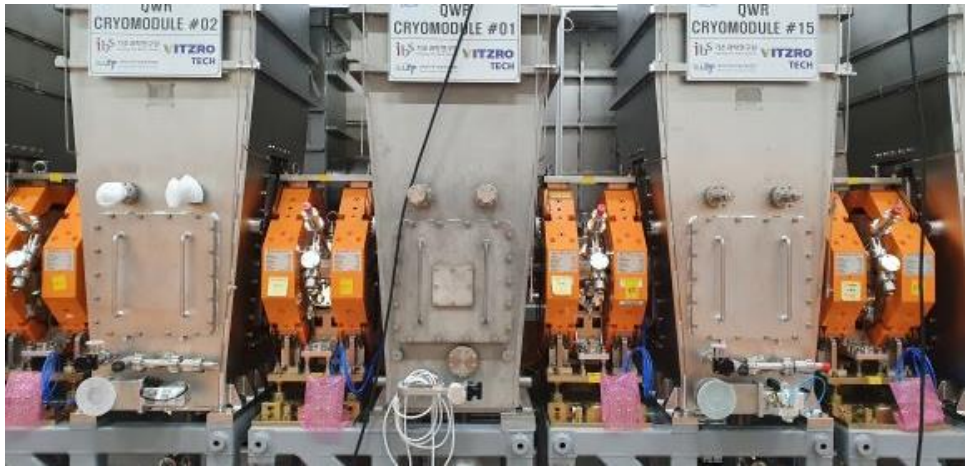


Installation completed and beam commissioning from October, 2020

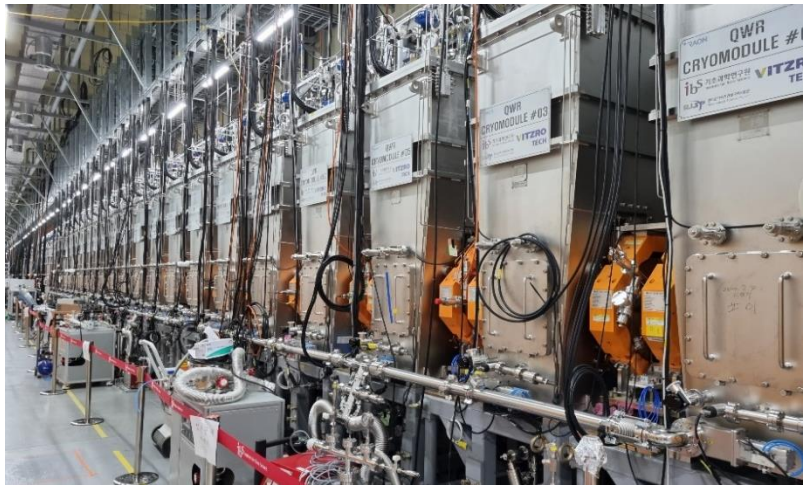
Clean Assembly @ Accelerator Tunnel

(Cryomodule + Warm section) + (Cryomodule + Warm section)

- Cryomodule & Warm section is clean assembled in the clean booth@tunnel
- Total Particle counts(size=0.5um above/10 mins) were less than 30 counts

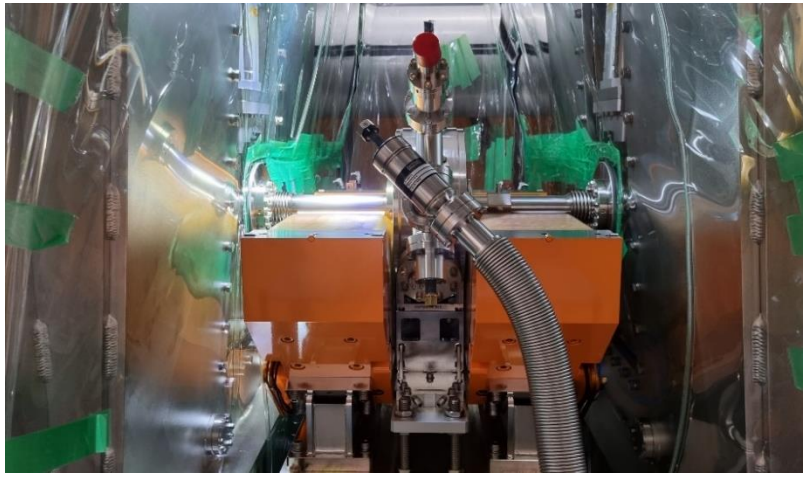


Superconducting Linac, SCL3 Tunnel and Gallery



QWR & HWR Cryomodule

Cryogenic Distribution to Cryomodule



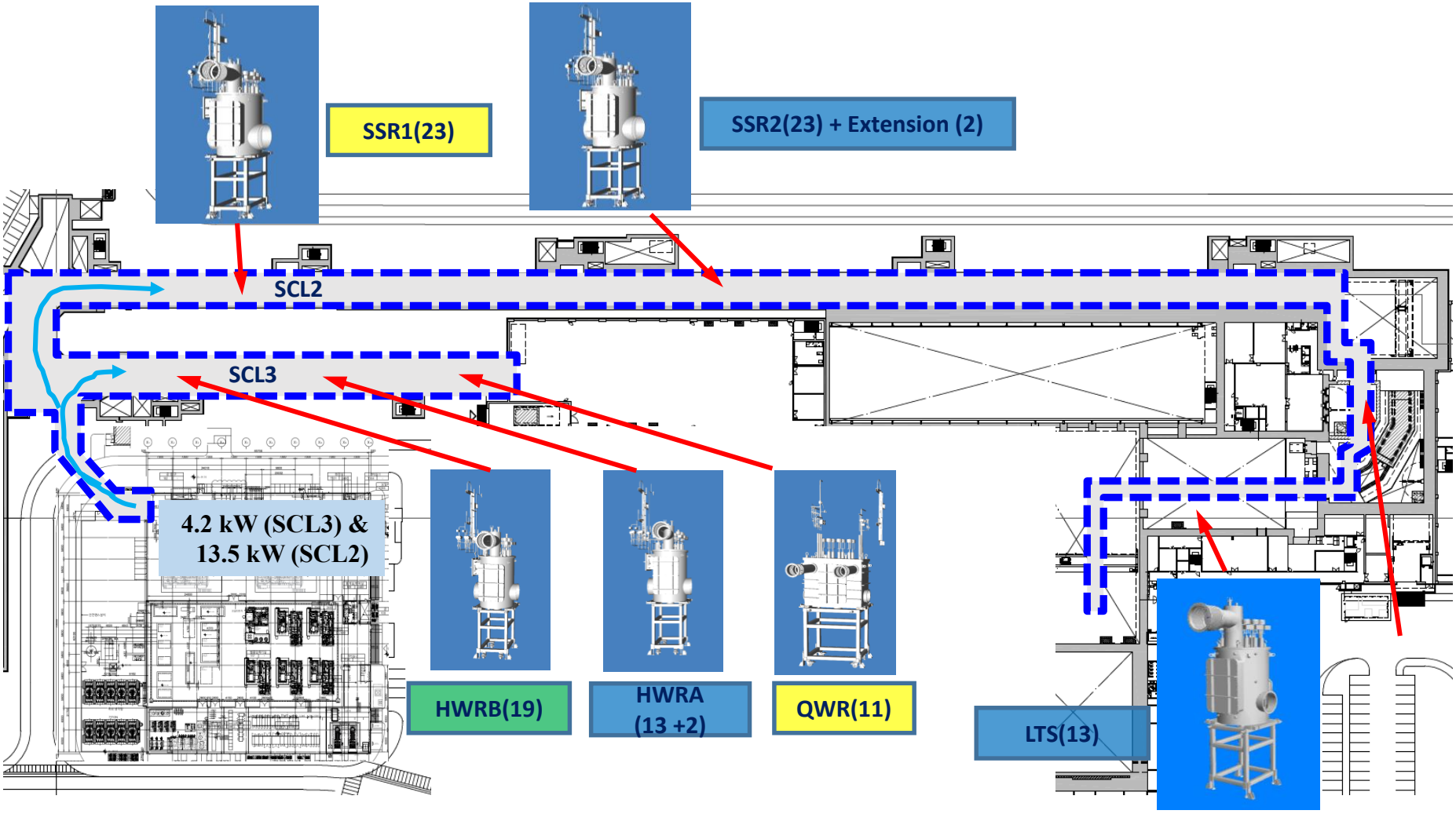
Clean beam line assembly

CM/Cryogenic Control Rack and SSPA

Installation completion and ready for beam commissioning in 2021

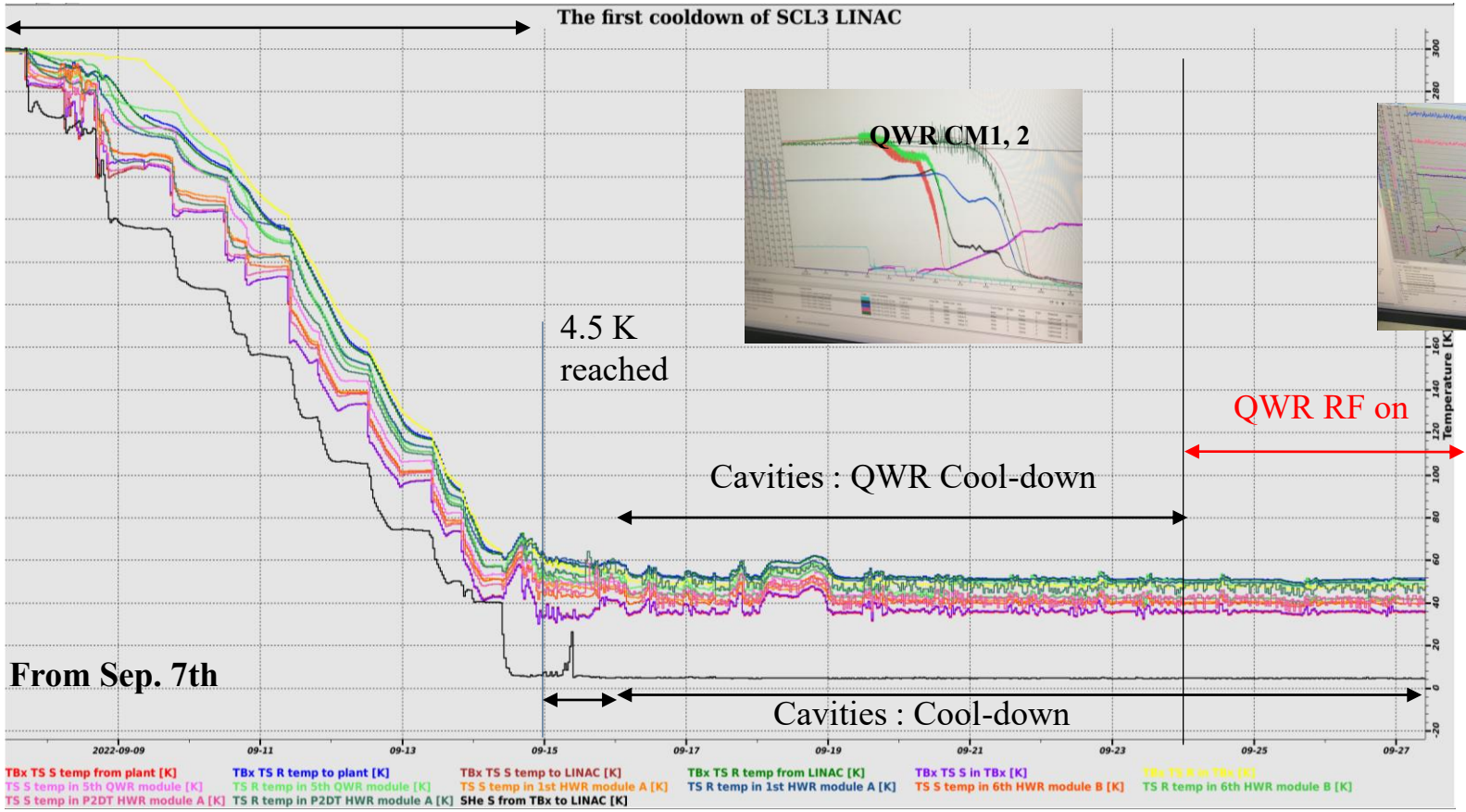
Cryogenic Distribution Systems

- Layout of cryogenic distribution system @ SCL3 and SCL2



The First Cool-Down Curve of SCL3

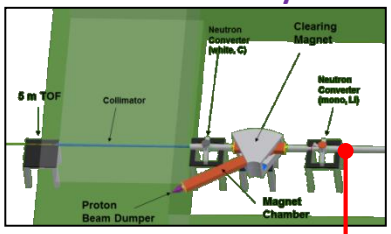
Cooled down cryogenic distribution system & thermal shields of all CM, simultaneously



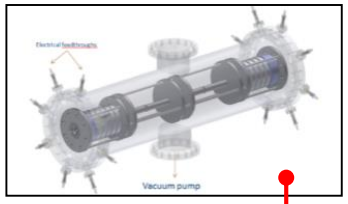
※ 1st cool-down of SCL3 : more conservative way – step cooling ! + manually checking dT @ cryogenic distribution system

RI & Experimental System

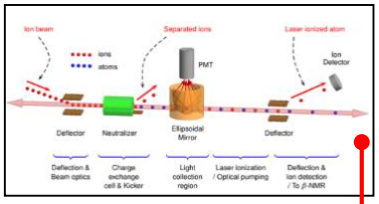
Neutron Facility



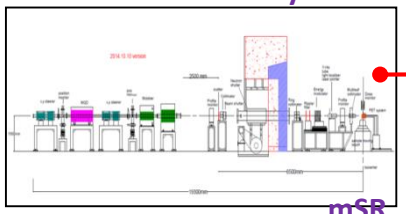
HPMMS



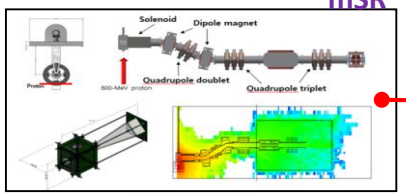
CLS



Bio-medical facility

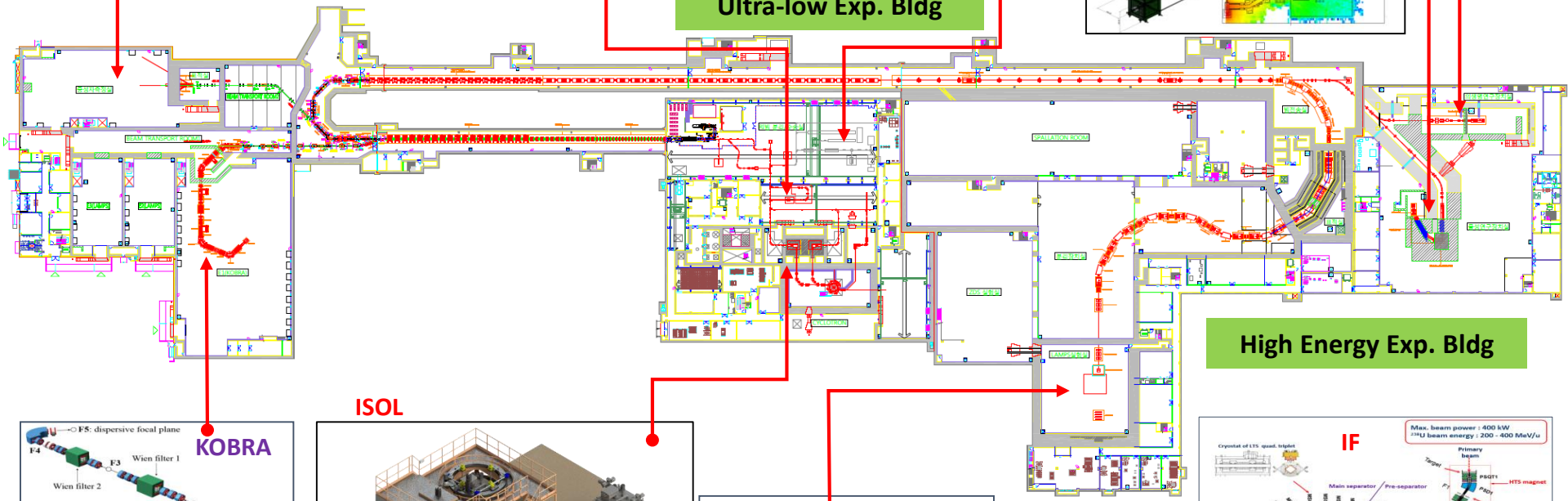


mSR



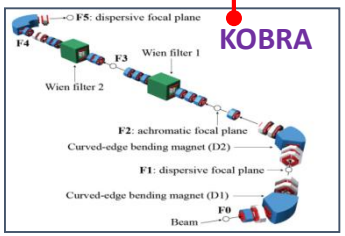
Low Energy Exp. Bldg

Ultra-low Exp. Bldg

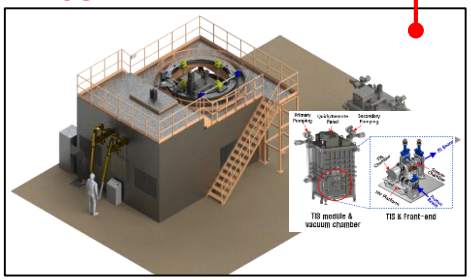


High Energy Exp. Bldg

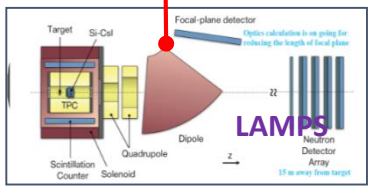
KOBRA



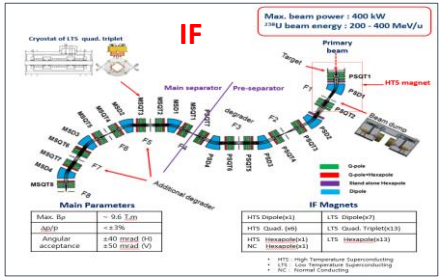
ISOL



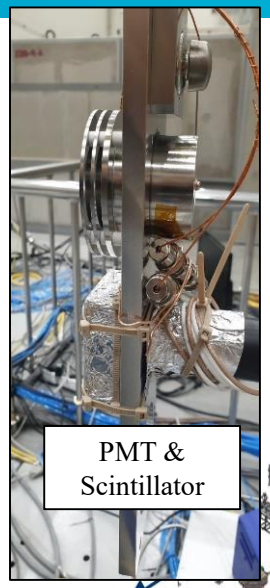
LAMPS

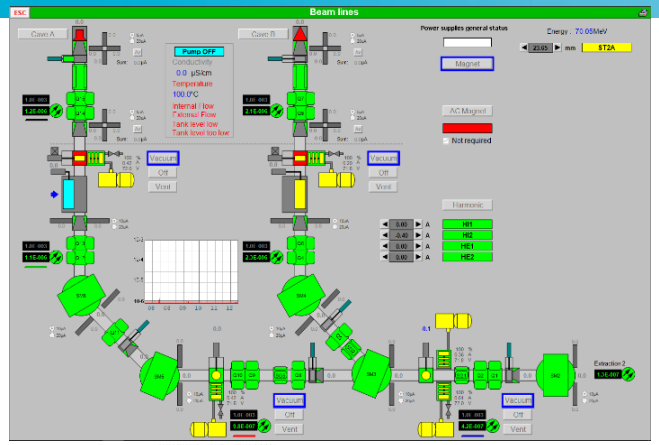


IF



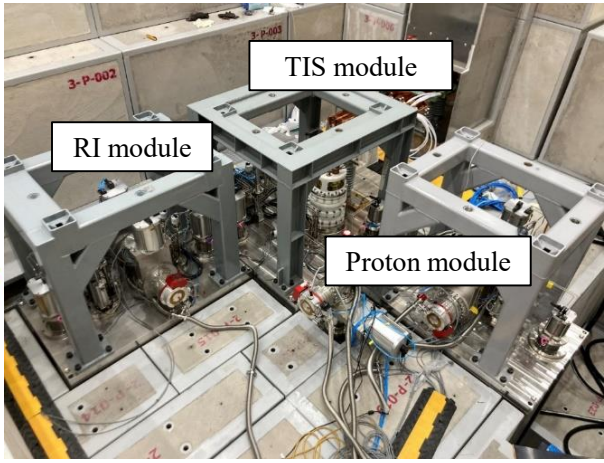
ISOL Beam Commissioning with RIB ($^{21, 22, 24, 25}$Na)

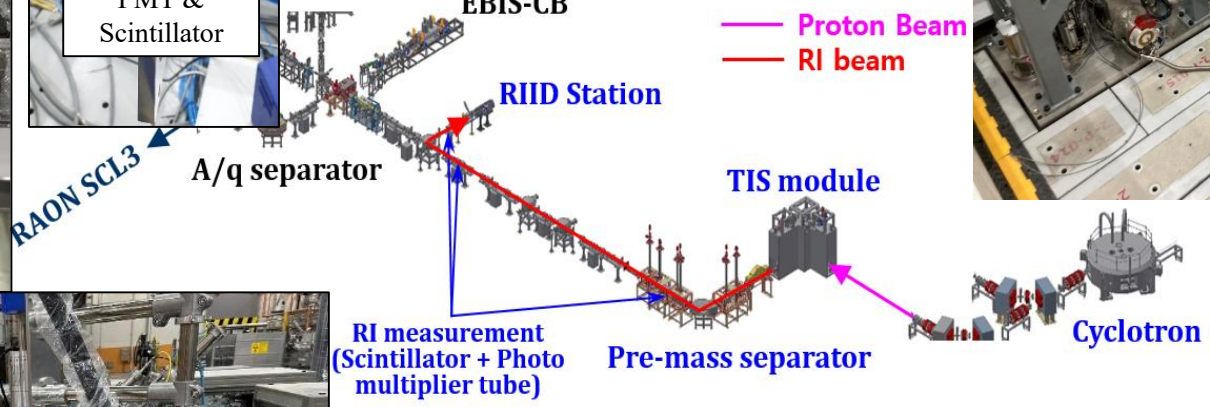


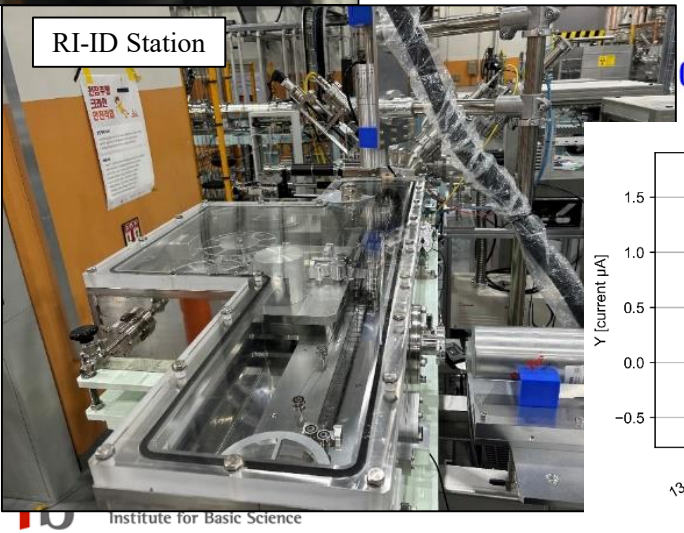


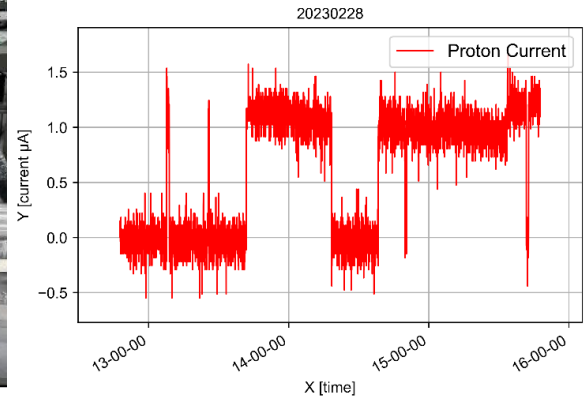
EBIS-CB

Cyclotron proton beam
(70 MeV/1μA)
on SiC target inside TIS



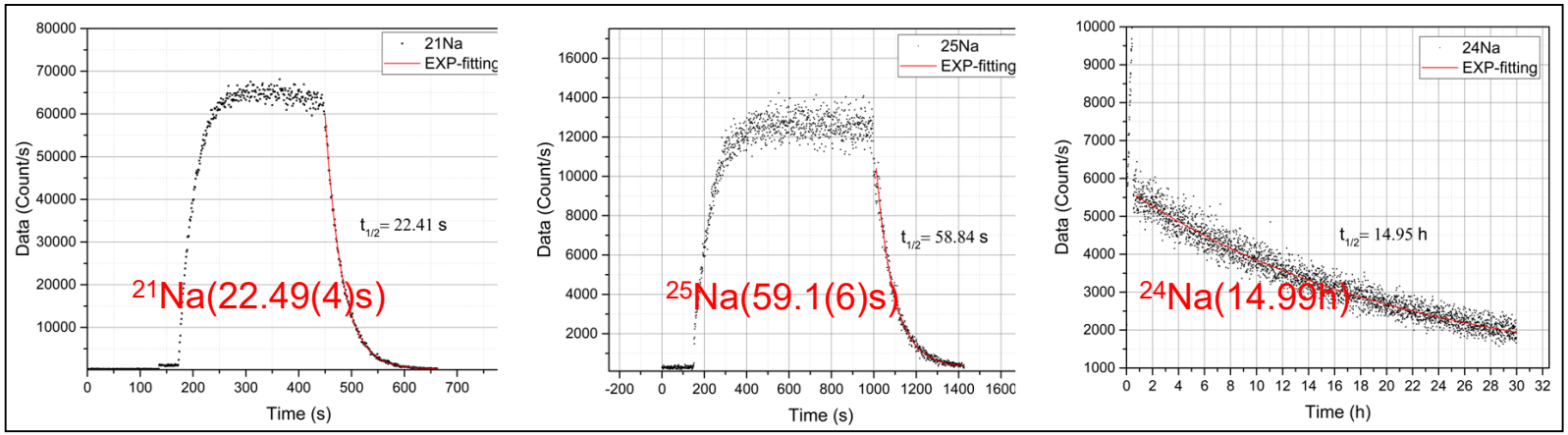




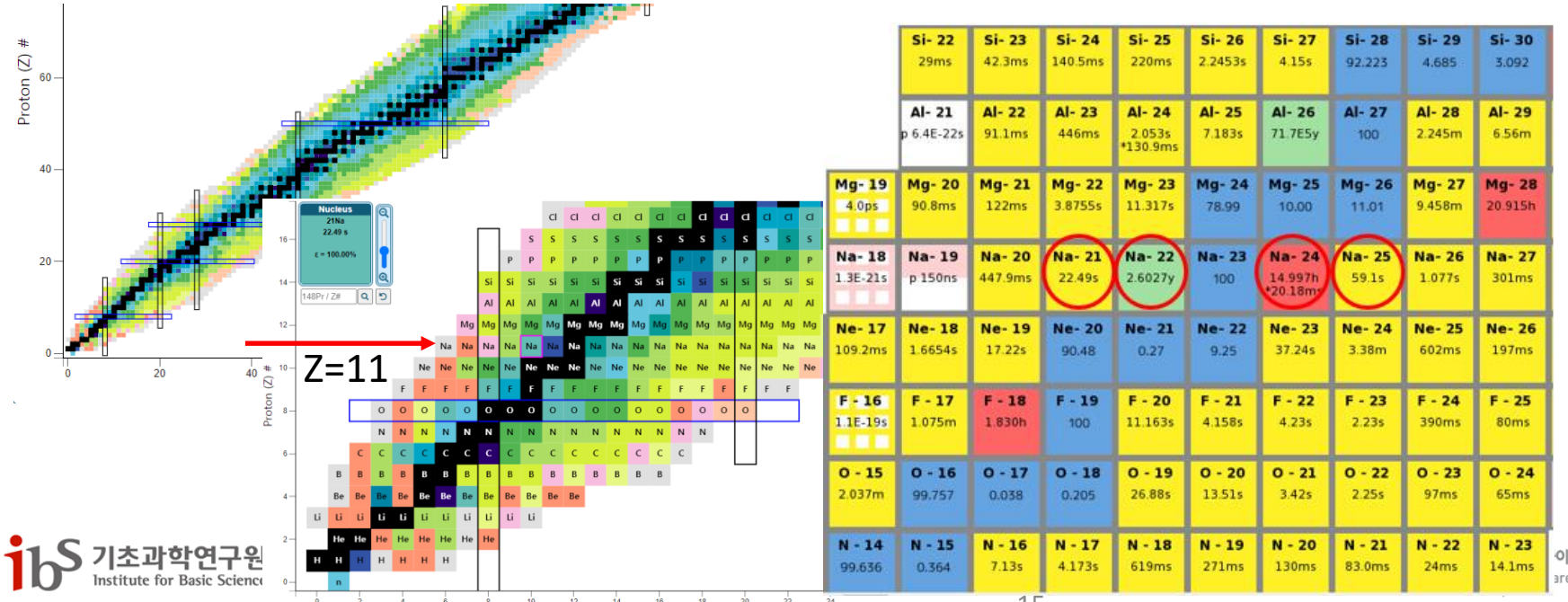


ISOL Beam Commissioning with RIB ($^{21, 22, 24, 25}$Na)

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

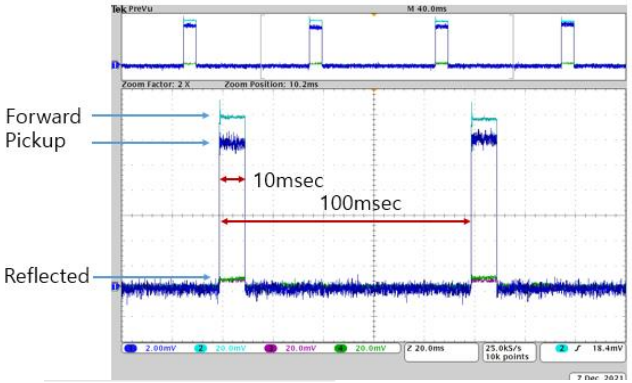


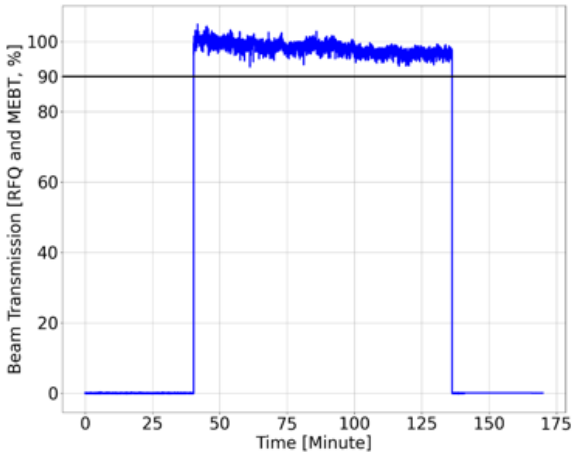
The measured half-lives of Na isotopes by using PMT & Scintillators



Injector Beam commissioning(Aug. 2021~)

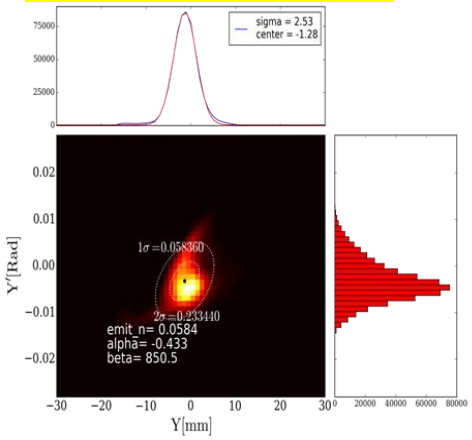
- 10% beam duty operation: 96 minutes, 10Hz, 10msec (2021.12.07.)
  * Injector transmission > 94%
- MEBT beam emittance measurement based on quad scan





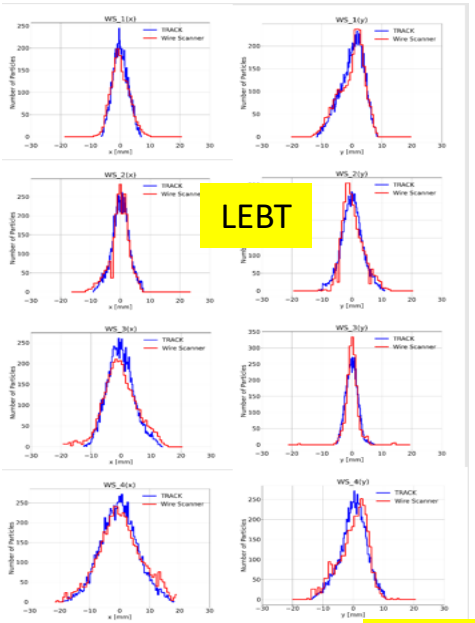
Injector beam transmission

Beam emittance (Allison scanner)



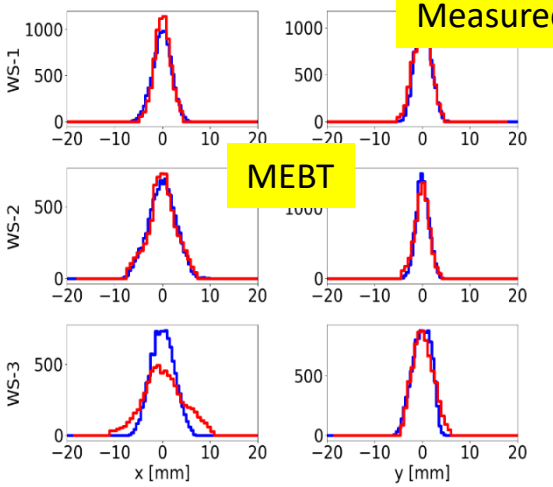
emittance comparison

	X	Y
Allison	0.048	0.067
Quad Scan	0.041	0.038



LEBT

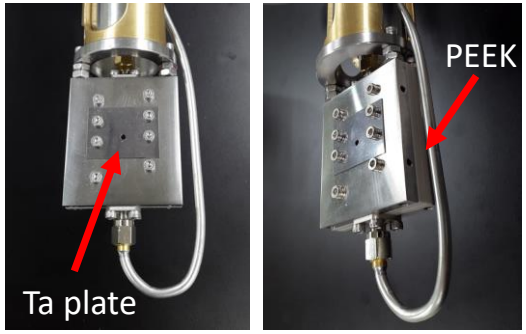
TRACK (blue)
Measured(red)



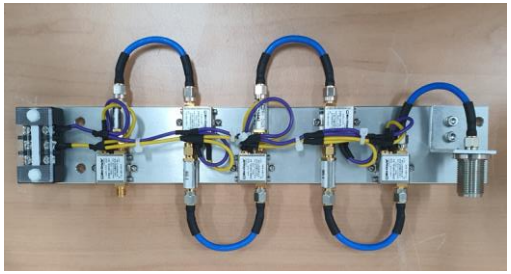
MEBT

Bunch Length Measurement, Fast-FC

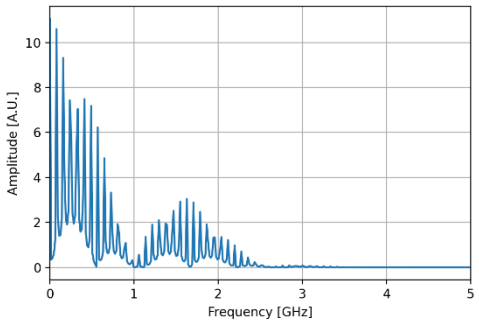
- Fabrication of Stripline type Fast Faraday Cup



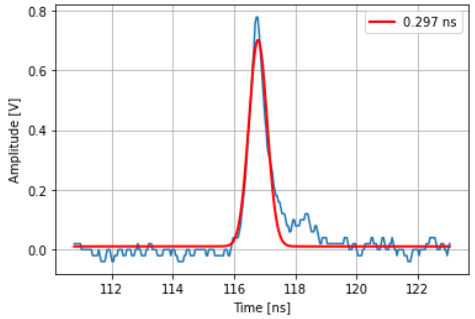
- Semi-rigid SMA cable in vacuum
- PEEK insulator
- Ta plate in front of FFC
- Bolting at irregular position

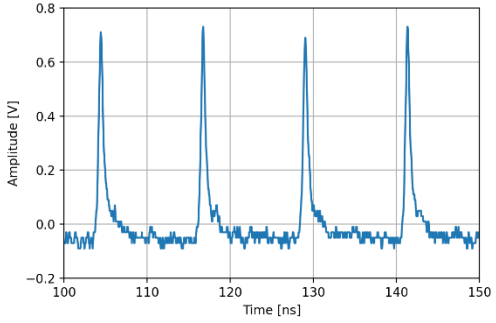


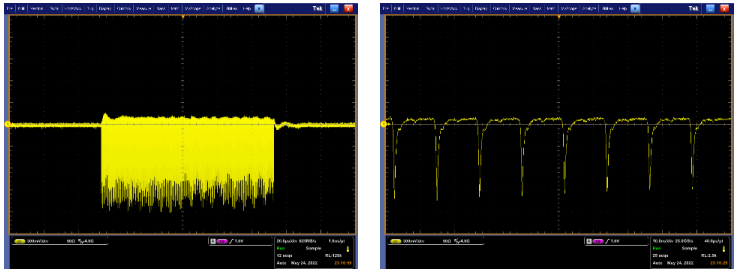
Amplifier (43 dB Gain)
Bandwidth 300 kHz ~ 14 GHz



Frequency component < 3 GHz
With 0.13 ns bunch length





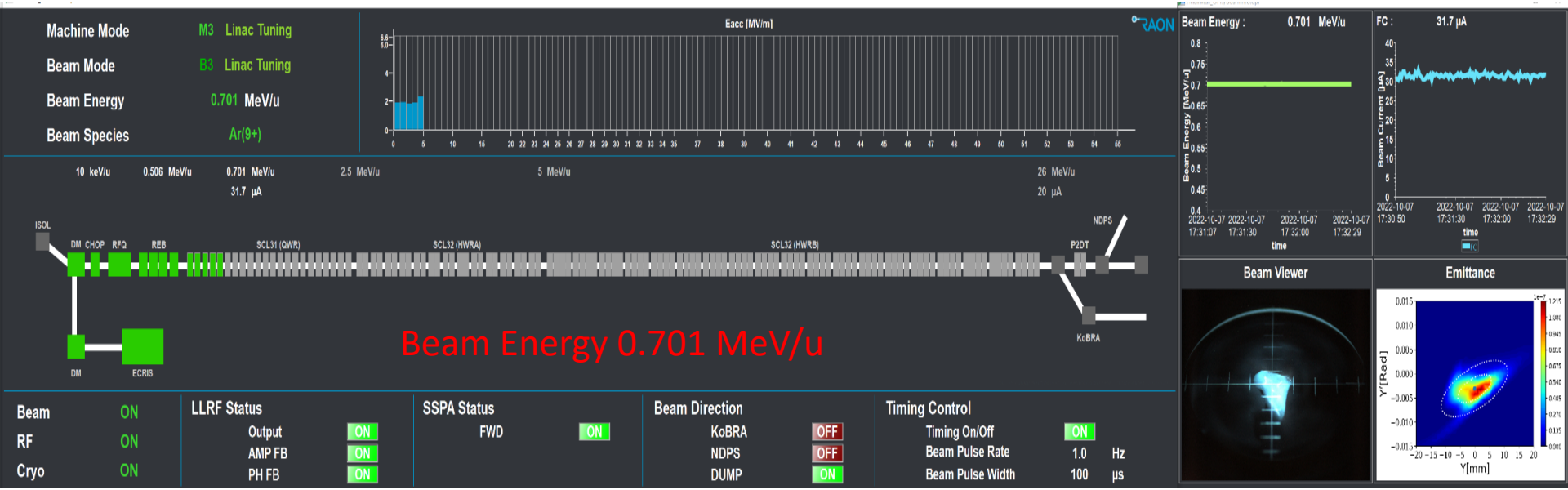


Oscilloscope (4 GHz, 25 GSPS)

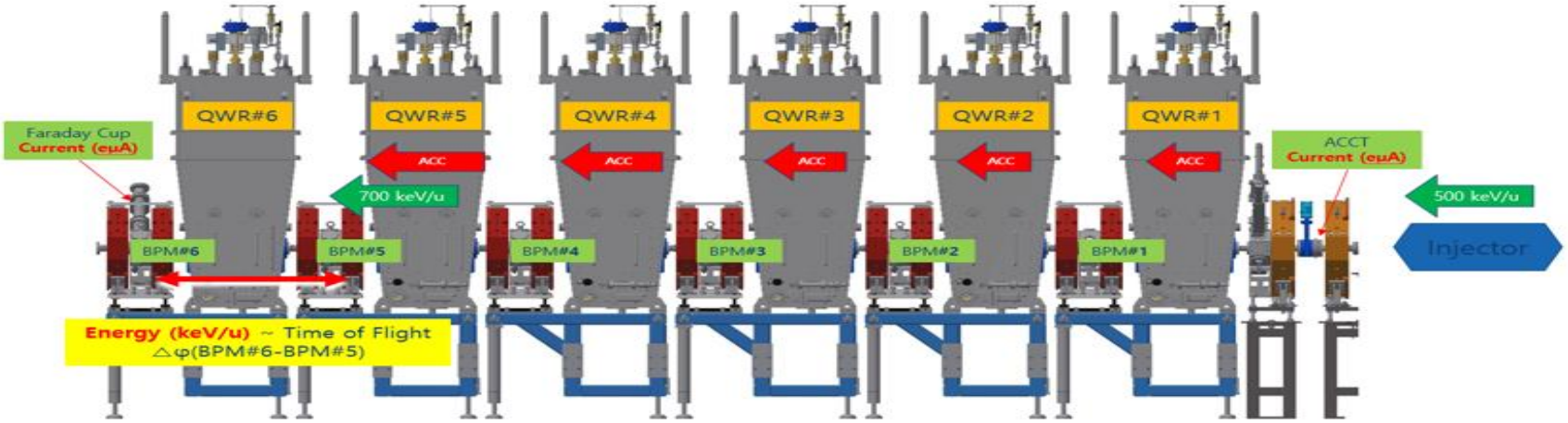
- Ar 8+, 50 uA, at the end of MEBT (4 bunchers)
- 100 μs macro pulse commissioning beam

- Expected peak amplitude was ~ 4 mV
- RF amplifier and oscilloscope prepared, considering frequency component

The 1st SCL3 Beam Commissioning (Oct. 7, 2022)

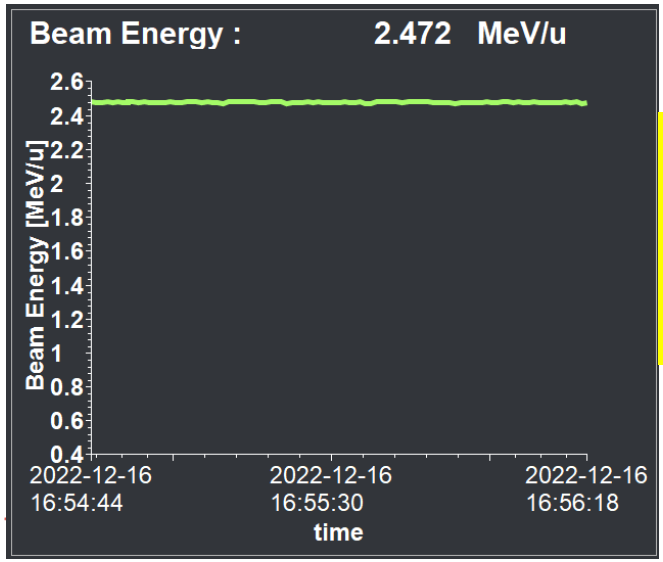


Ar^{9+} beams accelerated by QWR #1~#5 on the 7th of Oct, 2022



The 2nd SCL3 Beam Commissioning (Dec. 16, 2022)

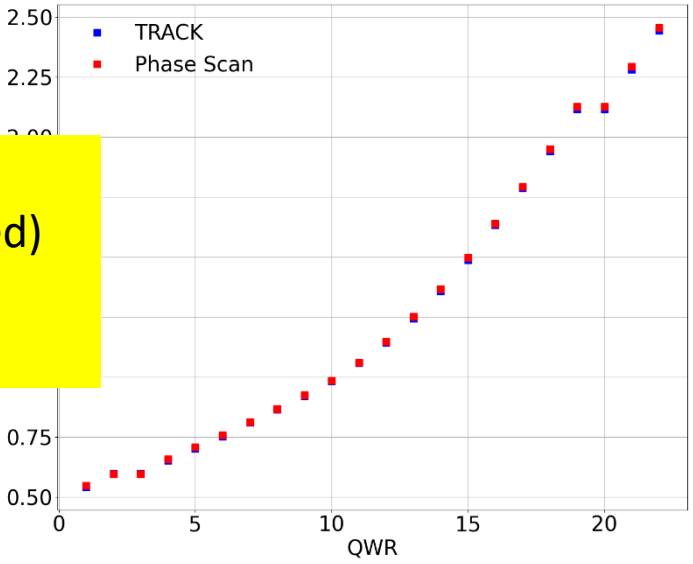
Ar^{9+} beams accelerated by QWR #1~#22 on the 16th of Dec, 2022



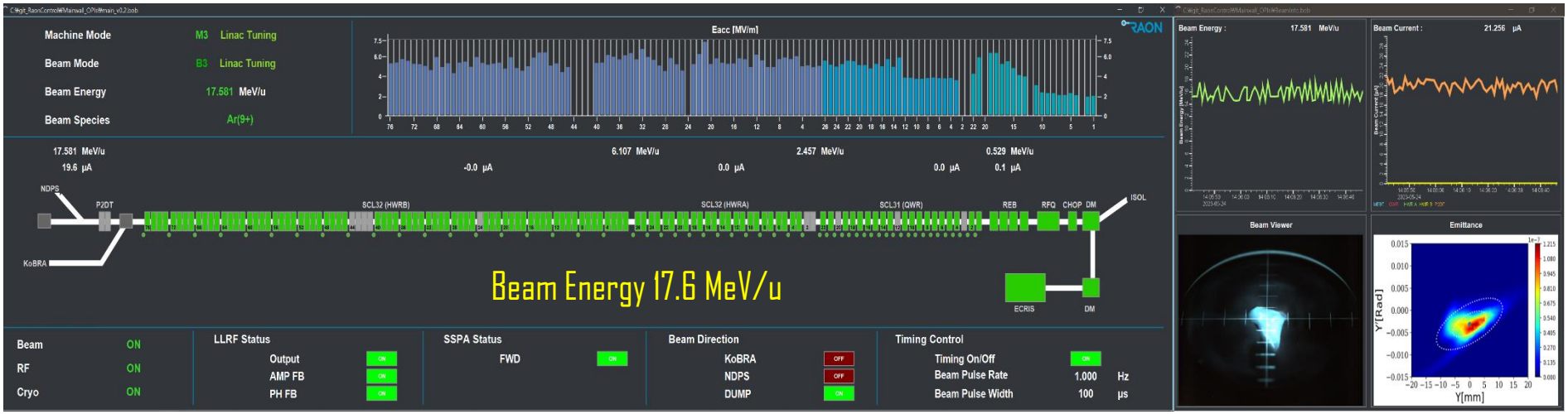
Final Results :

- 2.457 MeV/u (Measured)
- 2.444 MeV/u (TRACK)

QWR#3, #20 excluded



SCL3 Beam Commissioning (May. 23, 2022)



- ❖ Total 10 cavities (out of 124) excluded
  - QWR : #3&#12(Phase lock), #20(Tuner range)
  - HWR-A CM#1(2 cavities) : cold-leak
  - HWR-B CM#11(4 cavities) : cold-leak
  - HWR-B : #24 (Phase lock)

- ❖ Delivered beams to KoBRA during (5/30~6/2)
  - ➢ Ar(9+), 16.5 MeV/u, 100 μsec, 1 Hz

Issues found 1st cool down through beam commissioning

- **3 CMs during cool-down**
  - QWR#20, out of tuner control range : upgrade a tuner bracket at the tunnel
  - HWR-A#1 & HWR-B#11, cold –leak : will be fixed during 2023 shutdown
  - 2 K control valves (@HWR VBx) TAO@4 K : need stem with convection brakes
- **Frequency shift during applying RF power**
  - Temperature rises at the input coupler, then frequency shift (by deformation of the cavity) and varied as the power change
  - No Cu plating on the outer conductors(SUS316L) of input coupler
  - Cooling fans installed to the RF coaxial line just outside of CM
  - Consider to replace current SUS RF coaxial line with copper & more effective cooling
  - Requires frequency tracking with slow tuner(stepper motor); no fast tuner installed
- **Vacuum Pressure rises in several QWRs**
  - Not observed in Dec. 2022 beam commissioning, but appeared in March, 2023
  - Multipacting combined with coupler temperature rises ?
- **Others**
  - Noise/grounding problems in temp/pressure sensors, beam diagnostics (BPM, BLM, ACCT)
  - Beam Phase changed(2 times) during HWR commissioning

Summary & Outlook

- **Injector beam commissioning was carried out, achieving machine setting and key measurements :**
  - measured beam parameters (energy, emittance, Twiss parameters, beam sizes etc)
  - capable of controlling LEBT and MEBT beam optics freely as needed
  - achieved beam transmission of 95% max (routinely > 90%)
  - machine verification including diagnostics devices
- **Linac(SCL3) beam commissioning**
  - 1st/2nd beam commissioning using 22 QWRs were successfully done
  - beam commissioning of HWR section was done in May 2023
  - delivered Ar(9+) beams to KoBRA target, then RI beams produced
- **Plan for SIB/RIB experiments**
  - RIBs from ISOL will be injected into SCL3/Injector in Q4 of 2023
  - SIB experiments(ECR→SCL3 → KoBRA/NDPS) is planned in 2024
- **Plan for SCL2 linac construction**
  - CM(SSR1, SSR2) R&D project : 2022.12~2025.12
  - SCL2 construction is expected to begin in 2026

감사합니다.

Thank you