Current Status of Experimental Facilities at RAON

Young Jin Kim

Rare Isotope Science Project (RISP)

Institute for Basic Science (IBS)

EMIS XVIII

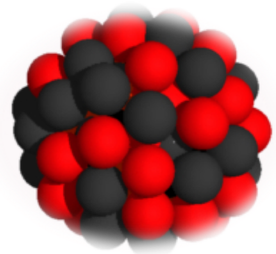
September 16-21, 2018

Contents

- Overview
  - Rare Isotope Science
  - RAON Accelerator and RI Production System
  - RAON Experimental Facilities
  - Development Plan
- Current status
  - KOBRA
  - LAMPS
  - HPMMS
  - CLS
  - NDPS
  - μSR
  - BIS
- Schedule
- Summary

Rare Isotope Science

Nuclear Physics

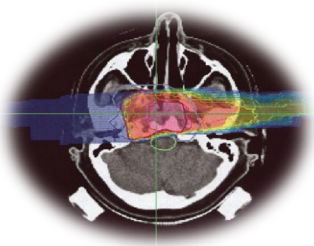


- Structure of exotic nuclei
- Properties of exotic nuclei: masses, radii, life-time etc.
- Search for super heavy elements
- Nuclear theory: nuclear force, nuclear model

Nuclear Astrophysics

- Stellar evolution
- Nucleosynthetic processes under stellar environments
- EoS of asymmetric nuclear matter such as neutron stars

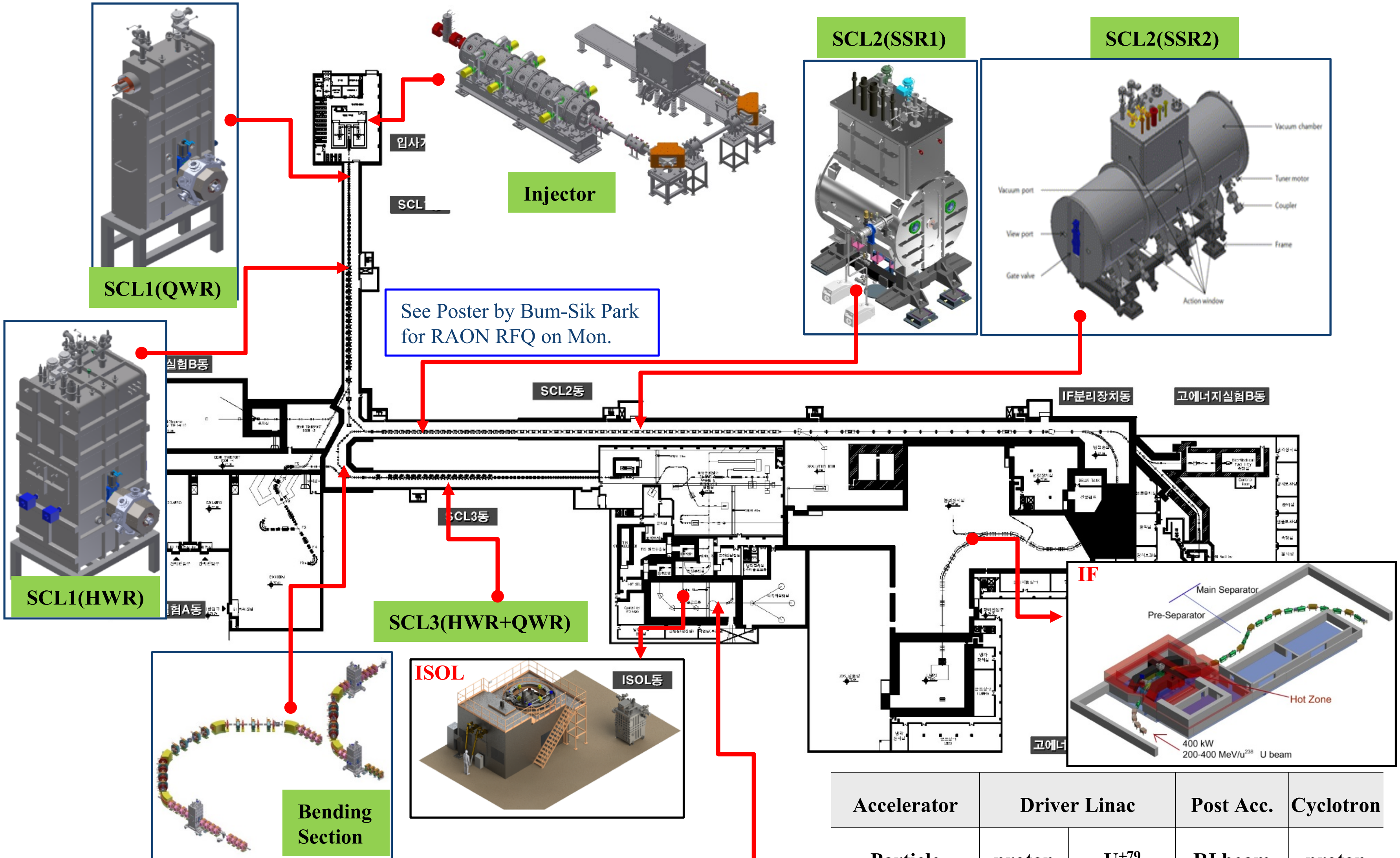
Applications



- Bio-medicine & Breeding
- Material sciences
- Nuclear data for next generation nuclear power plant
- National security

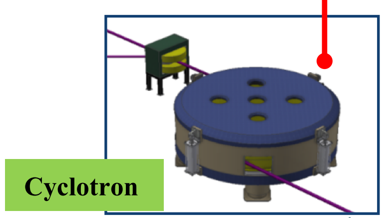
- **RISP = Rare Isotope Science Project (2011. December - 2021. December)**
  - Plan & build Rare Isotope accelerator and experimental facilities in Korea
- **RAON = Rare isotope Accelerator complex for ON-line experiments**
  - Provide that one could access to unexplored regions of the nuclear chart
    → More exotic, More intense, and More various Rare Isotope Beams (RIBs)

RAON Accelerator & RI Production



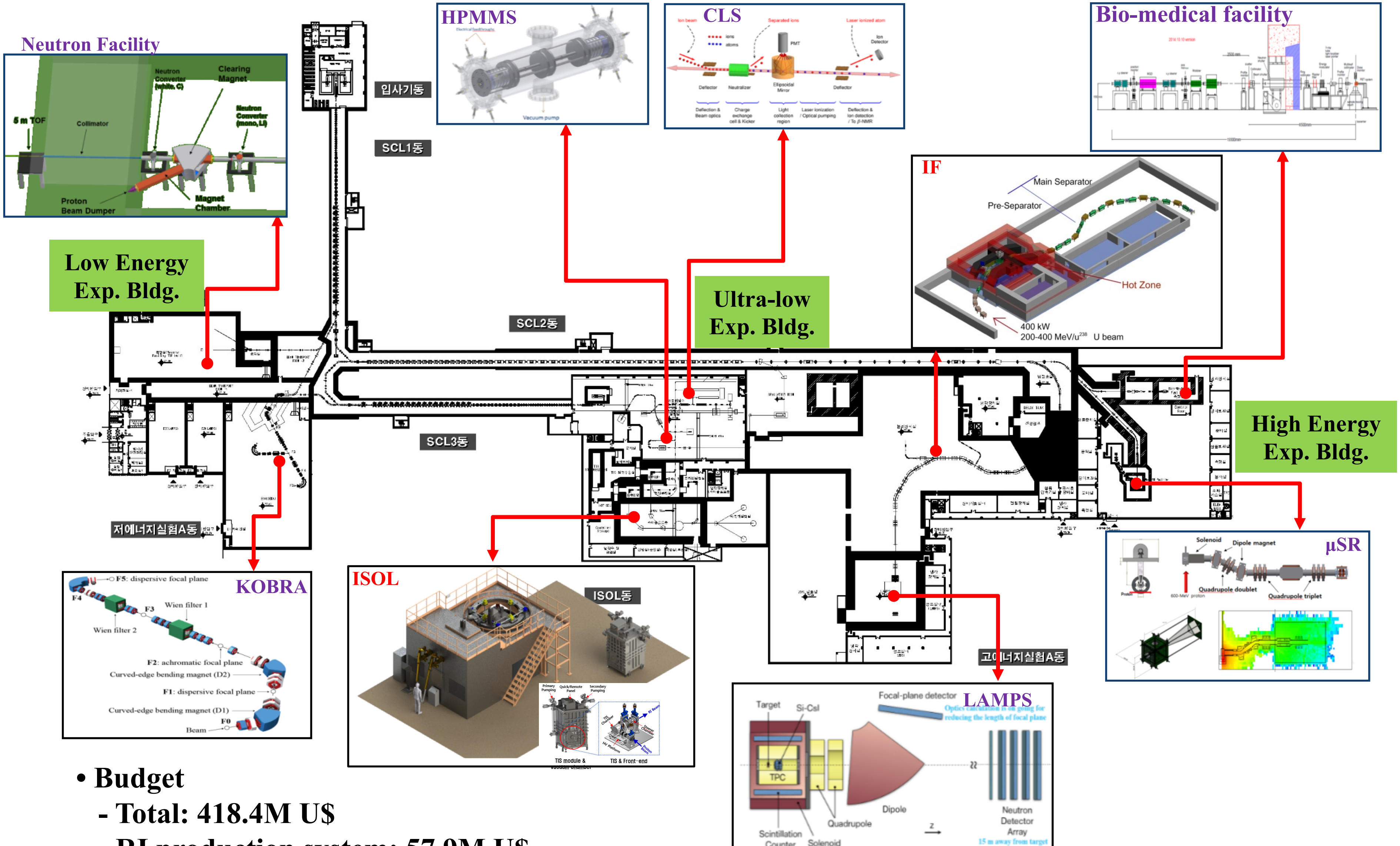
See Poster by Bum-Sik Park for RAON RFQ on Mon.

- See Poster by Taeksu Shin for the status of RISP on Mon.
- See Talk By Byoung Hwi Kang for RAON ISOL on Fri.



Accelerator	Driver Linac		Post Acc.	Cyclotron
Particle	proton	U^{+79}	RI beam	proton
Beam energy	600 MeV	200 MeV/u	18.5 MeV/u	70 MeV
Beam current	660 μA	8.3 pμA	-	1 mA
Power on target	400 kW	400 kW	-	70 kW

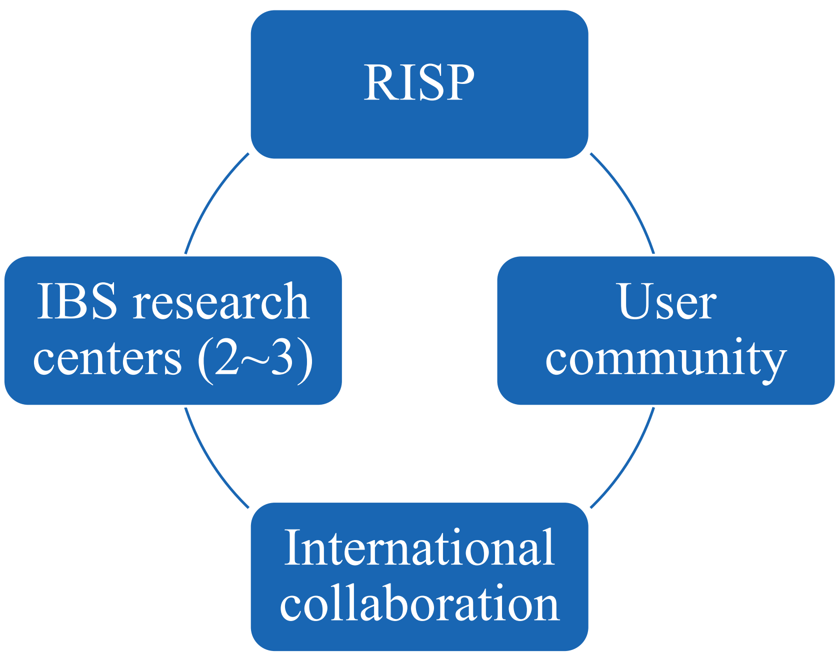
RAON Experimental Facilities



- **Budget**
  - **Total: 418.4M U$**
  - **RI production system: 57.9M U$**
  - **Experimental system: 22.4M U$**

Plan for Development of Experimental Systems

~ 2016	2017	2018	2019	2020	2021	2022	2023
Stage1 : ISOL, IF, KOBRA, LAMPS, HPMMS (MR-TOF)							
			Stage2 : CLS, μSR, Bio-medical, Nuclear Data				
Staged Approach						Stage 3: upgrade, new facilities	



- KOBRA Collaboration
- LAMPS Collaboration
- MR-ToF-MS, Gamma Array (KEK)
- Detectors & DAQ (GET Collaboration, TRIUMF, etc.)
- UC_x target (KNF, ISOLDE)
- ISOL RH (TRIUMF & J-PARC)
- ISOL TIS (TRIUMF, ISOLDE)
- EBIS (BNL)
- IF target test (BINP)
- IF magnet (KERI)
- and more

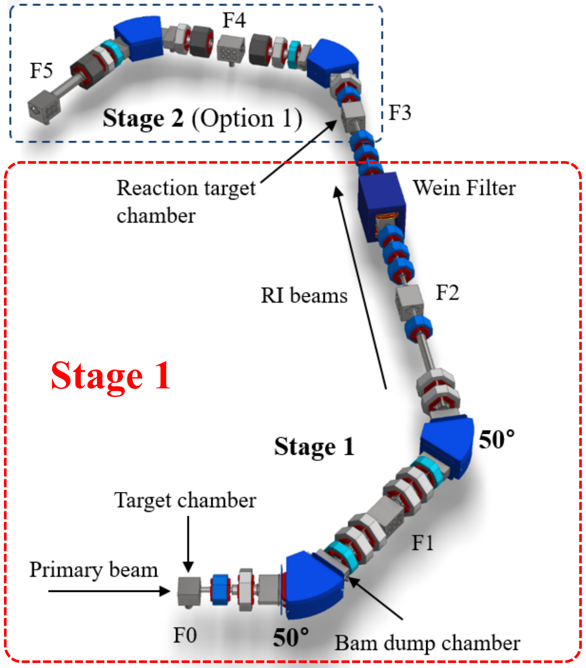
• Established
- RAON User Liaison Center
- RAON Users Association

➔ They cooperate with RISP to develop experimental system, training students, looking for international collaborations

KOBRA (KOrea Broad acceptance Recoil spectrometer and Apparatus)

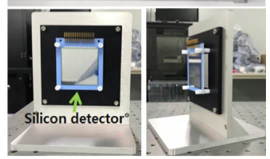
RAON

Conceptual design	Prototype & Test	**Manufacturing**	Installation & Commissioning	Operation
2011 ~ 2012	~ 2017.9	**~ 2019.4**	~ 2020.12	2021.1 ~



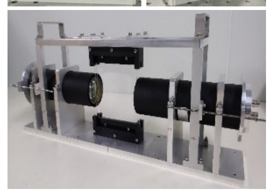
PPAC

- We have two 10 x 10 cm^2, two 20 x 20 cm^2, one 40 x 20 cm^2 active area PPACs
- Position resolution: < about 0.7 mm in FWHM, (C_4H_{10} gas, ^{241}Am)
- Four 10 x 10 cm^2 and one 40 x 20 cm^2 PPACs will be produced



SSD

- We have two 5 x 5 cm^2 active area, 50 μm-thick, 16 channel SSD
- Energy resolution ~ 0.7%, S/N ~ 272 for 5.486 MeV α in vacuum



Plastic scintillator detectors

- We have one 10 x 10 cm^2 active area, 100 μm thick both side readout plastic detector
- Time resolution < 42 ps for 5.486 MeV α in vacuum
- One 10 x 10 cm^2 active area, 100 μm thick one side readout plastic will be produced

HPGe gamma ray detectors

- 32 segmented HPGe detectors (6set)
- Compton suppressor BGO crystals (6set)
- Complete set of TIGRESS electronics

- **Multi-purpose experimental instrument using stable or rare isotope (RI) beams for nuclear structure and nuclear astrophysics Studies**
  - RI beam productions using stable or rare isotope (RI) beams
  - Recoil mass separator
  - High-resolution spectrometer, and so on

- **The first part of stage 1 (stage 1 part 1) has been contracted with foreign and domestic companies in April 2018, and production is ongoing**
- **The present design of the second part of stage 1 (stage 1 part 2) was finally decided among the various design options in June 2018 by consultation with domestic potential users, and now biding is ongoing**
- **Stage 1 will be installed in Low Energy Experimental room (E1) until the end of June 2020**
- **The commissioning of Stage 1 will be started from beginning of 2021 with stable ion beam**

ibs 기초과학연 Institute for Basic S

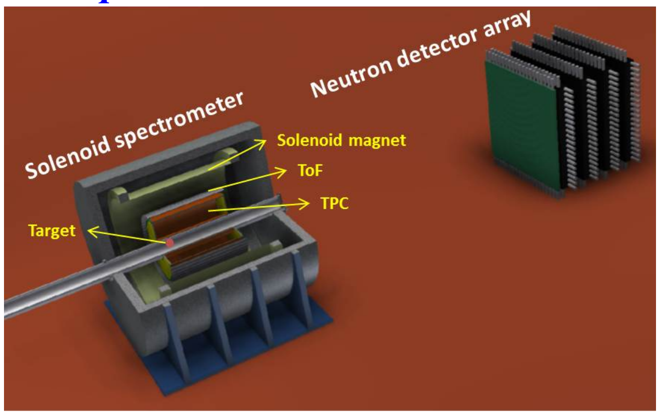
RISP Rare Isotope Science Project

LAMPS (Large Acceptance Multi-Purpose Spectrometer)

Conceptual design	Prototype & Test	Manufacturing	Installation	Commissioning	Operation
2011 ~ 2012	~ 2018.12	~ 2020.12	~ 2021.7	~ 2021.12	2022 ~

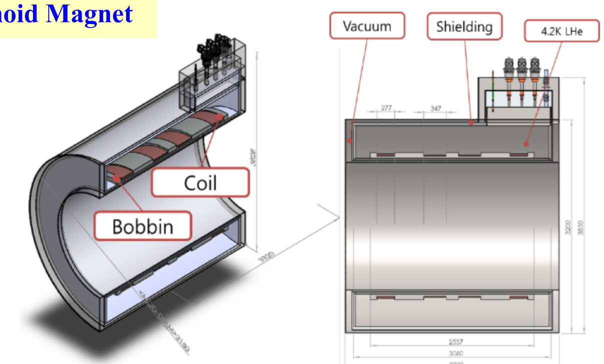
- **Nuclear matter and nuclear reaction studies with intermediate energy stable and rare isotope beams, especially nuclear symmetry energy at supra-saturation density via heavy-ion collision**

(e.g. measure *n/p* ratio & collective flow at the same time in the combination of ^{106,112,124,130,132}Sn + ^{112,118,124}Sn)



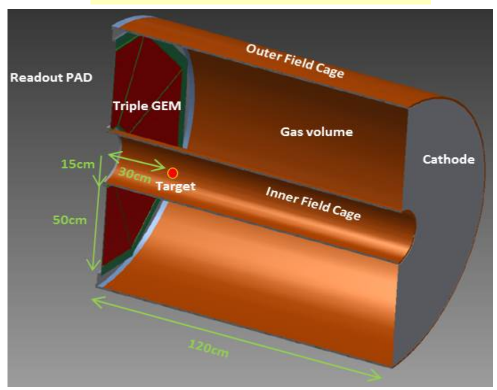
- **Beam Energy: up to 250 MeV/u for ^{132}Sn ($\leq 10^8$ pps)**
- **Solenoid Spectrometer**
  - Max. 1T solenoid magnet
  - TPC (~ 3π sr acceptance, charged particle tracking)
  - Scintillation counter (trigger & ToF)
- **Neutron Wall (neutron tracking)**
- **All of LAMPS system will be ready by 2020**
- **Start installation from 2021 then standalone commissioning during 2021**

Solenoid Magnet



- **Almost completed design of cylindrical superconducting magnet**
  - 3200 mm (D) x 3320 (L)
  - Coil-turn starts from 850 mm in radius
  - Max. B-filed ~ 1 T, Operation B-filed = 0.5 T
  - ΔB/B ~ 1.87%, current 131.2 A
- **Procurement will be started next year**

Time Projection Chamber



- **Test with prototype of TPC completed**
  - Fulfill the requirement of TPC
- **Based on test results, change TPC design**
  - Both side readout → one side readout
  - P-10 gas → P-20 gas
- **Construction and tested from 2019 to 2020**

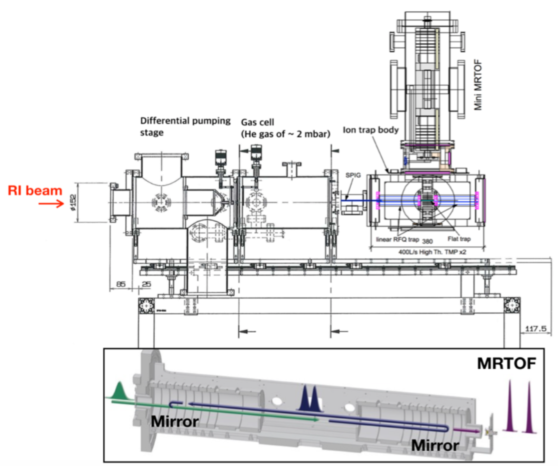
Forward Neutron Detector Array

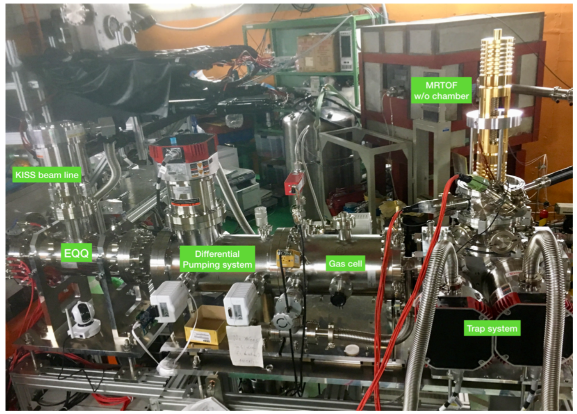
- **Completed all R&D processes**
- **Detector production in progress**
  - 2 veto detectors (total: 20)
  - 148 neutron detectors (total: 160)
- **Array frames are in house**
- **Finish integration & test by the middle of 2019**

High Precision Mass Measurement System (MR-ToF)

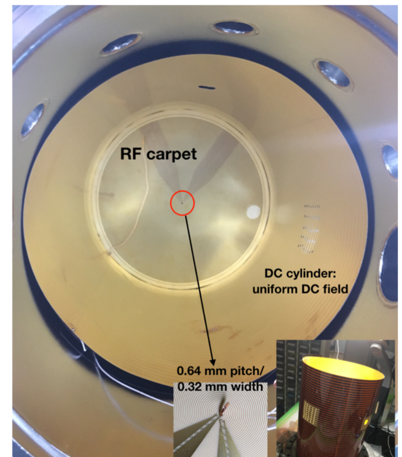
Conceptual design	**Manufacturing & Test**	Installation	Commissioning	Operation
2011 ~ 2012	**~ 2019.12**	~ 2020.12	~ 2021.12	2022 ~

- **Multiple Reflection ToF Mass spectrograph, chosen for mass measurement of unstable nuclei with short life time of < 100 ms and with sufficient precision of better than 10^{-6}**

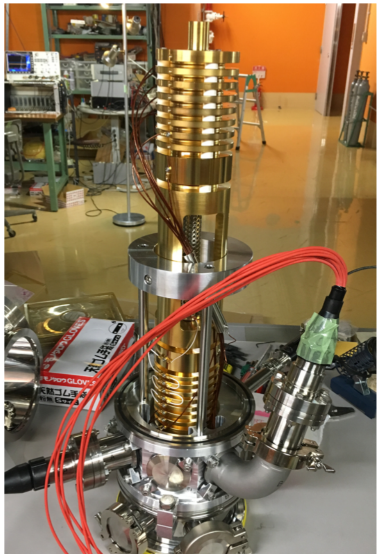




A picture of MR-ToF-MS system and others at RISP-KEK/WNSC

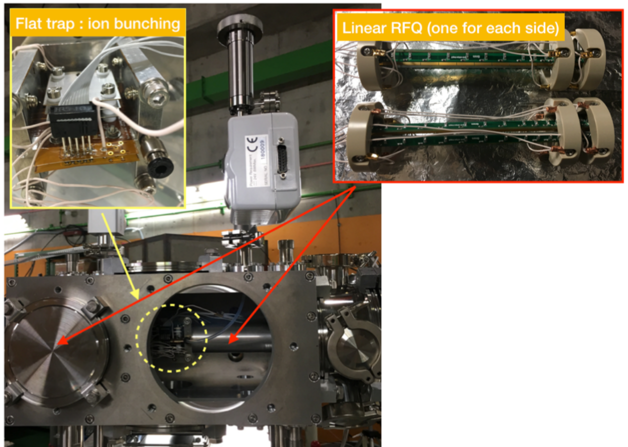


Gas cell (catcher)



MR-ToF (analyzer)

- **MR-ToF-MS construction under the collaboration**
  - R&D work, led by WNSC MR-ToF group (Leader : Prof. Wada)
  - Additional beam line to the MR-ToF-MS, already constructed (2017)
  - Differential pumping system, gas cell (or catcher), Trap system, and MR-ToF analyzer have been assembled, waiting for offline ion source test
  - Test of the differential pumping system with the gas cell filled with 1 mbar helium gas, performed : $3.4x10^{-4}$ Pa upstream side
  - Optimizing the beam transmission through the φ 2-mm gas cell hole, performed : 72% efficiency, but will be improved by additional beam steerer

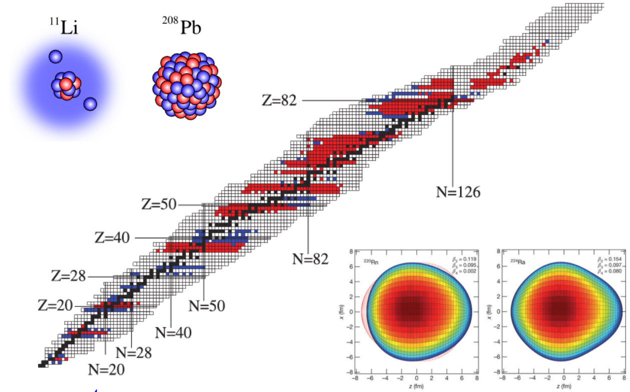


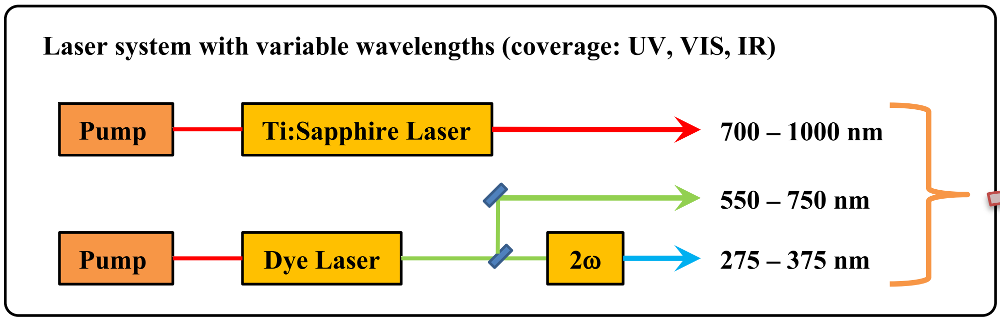
Trap system

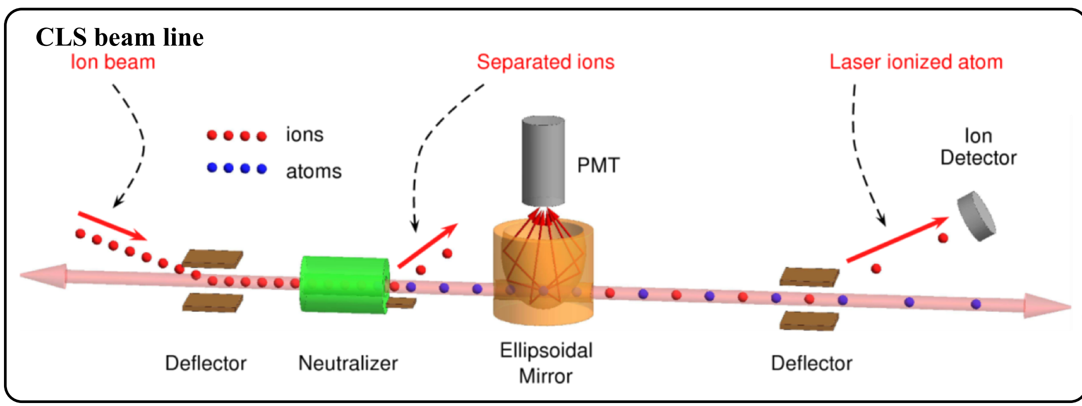
CLS (Collinear Laser Spectroscopy)

Conceptual design	Procurement & Test	Installation	Commissioning	Operation
2011 ~ 2012	~ 2018.12	~ 2020.12	~ 2021.12	2022 ~

- **Measurement of the electron energy levels of rare isotopes produced in RAON**
  - Tool to acquire information on nuclear charge distribution, nuclear spins, nuclear shape, etc.
  - Study the nuclear structure or verify the accuracy of nuclear models







- **Components**
  - Optical sources and spectroscopy system
  - CLS beam line: Deflector, Neutralizer, Fluorescence detector

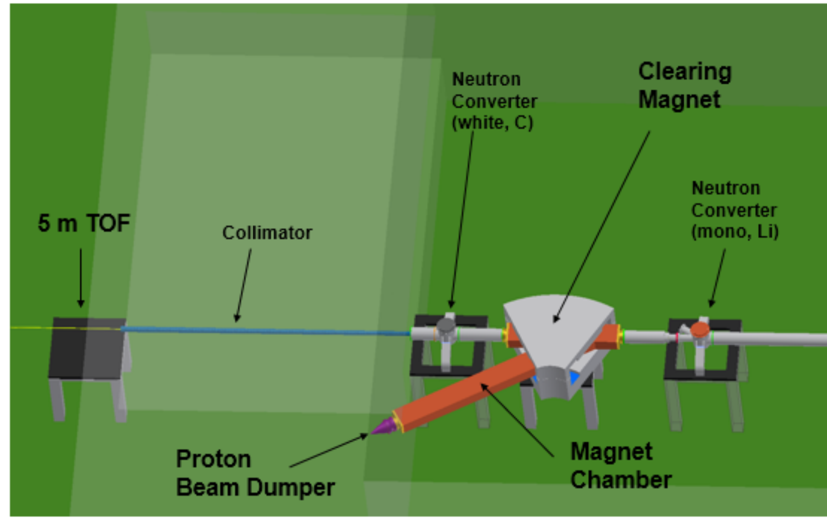
- **Main Specifications**
  - Resolution: ~ 10MHz @ E=40keV and ΔE=1 eV
  - Wavelength range: UV, VIS, IR
  - CLS beam line including 10º-deflector, neutralizer, and reionizer etc.

- **Laser system is already procured**
- **Conceptual design of the CLS beam line is finished**
- **Resume development works from 2019**

NDPS (Nuclear Data Production System)

Conceptual design	R&D Pause	R&D, Manufacturing	Installation	Commissioning	Operation
2011 ~ 2012	~ 2018.12	~ 2020.12	~ 2021.12	2022.1 ~	After Commissioning

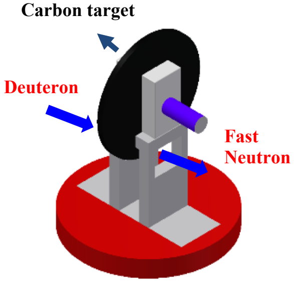
- **Fast neutron nuclear data production system for developing next-generation nuclear power plant**
  - fast neutron production system
  - fast neutron ToF and Fission cross-section detection system

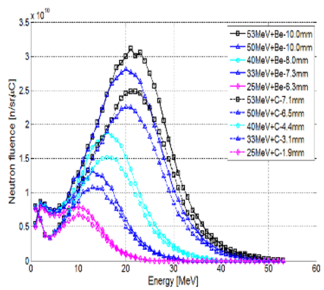


• Main Specification

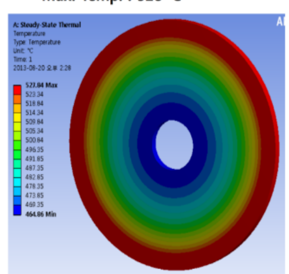
- n-ToF system: 5 m and 20 m (Extendable ~ 70 m)
- Neutron beam: ≤ 53 MeV pulsed beam (white)
- Repetition rate: 300 kHz ~ 1 MHz
- Beam intensity: 2 × 10^{12} neutron/sr/μC
- Beam width: 1 ~ 2 ns (need single bunch selector)
- Beam line for deuteron & neutron
- Collimator and dump
- Fission cross-section uncertainty: < 10%

Target System for White Neutron Production

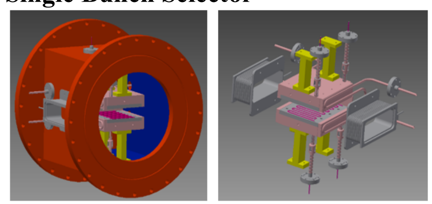




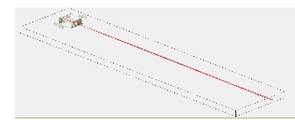
1 MHz, 12.3 μA
Max. Temp. : 528 ℃



Single Bunch Selector

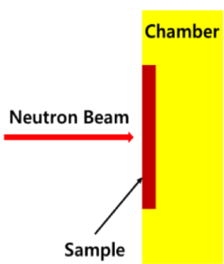


Length : 35 cm , OD : 47 cm, ID : 26cm

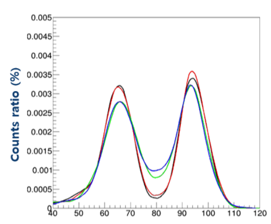


- Emittance : 0.3 π mm mrad,
- d energy : 1 MeV
- Radius : 2 mm , angle : 0.027°
- Total length for SBS : 2.1 m
- RF field : 1550V, magnetic field: 45 gauss

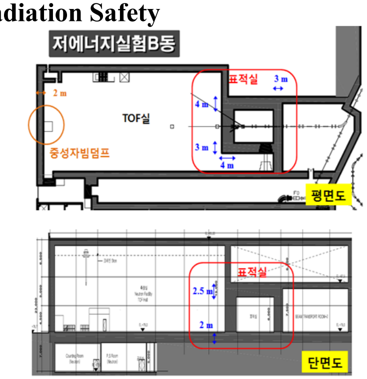
Nuclear Data Measurement (FIC for fission CX)



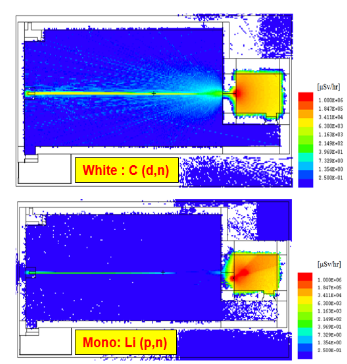
Chamber dimension	10 cm x 10 cm x gap
Gap	variable
Gas composition	Ar (90%) + CF_4 (10%)
Gas pressure	variable
Sample	U235
Sample dimension	1 cm x 1 cm x thick.
Sample thickness	variable
Source	variable



Radiation Safety



Building design of NDPS



Dose map due to prompt neutrons

μSR (Muon Spin Rotation/Relaxation/Resonance)

Conceptual design	R&D Pause	R&D, Manufacturing	Installation	Commissioning	Operation
2011 ~ 2012	~ 2018.12	~ 2020.12	~ 2021.12	2021.12 ~	After Commissioning

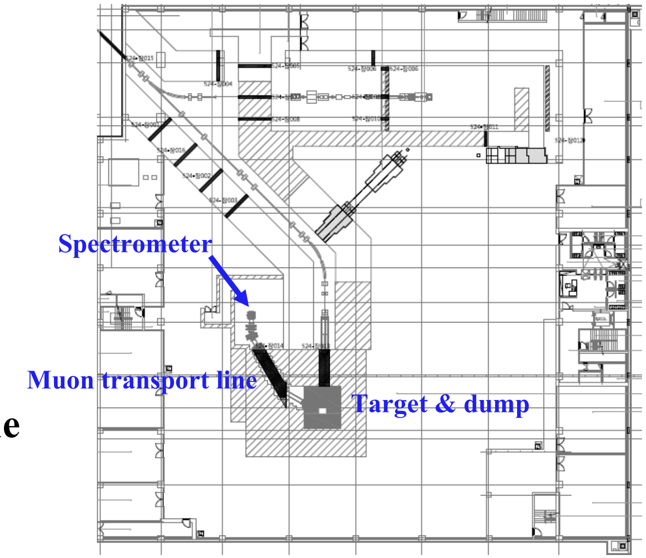
- **Facility for studying characteristics of new materials (e.g. high temperature SC, semiconductor, etc.)**
  - production of polarized moun beams
  - high sensitive X & γ ray detections

  - **Main Specification**

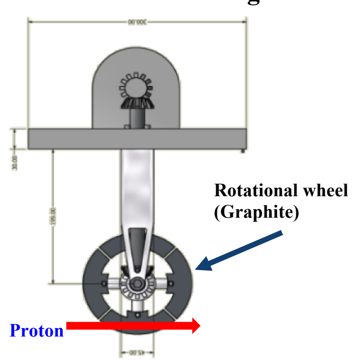
    μ^+ (surface muon, >10^5 pps, CW)

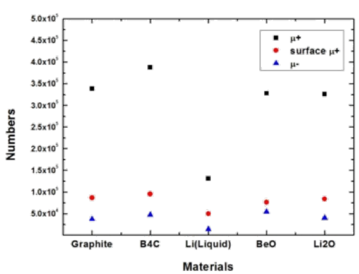
    600 MeV proton with an intensity up to 400 μA

- **Conceptual design of μSR is finished**
- **Some of R&D for target, spectrometer, muon transport line completed**
- **Resume development works from 2019**

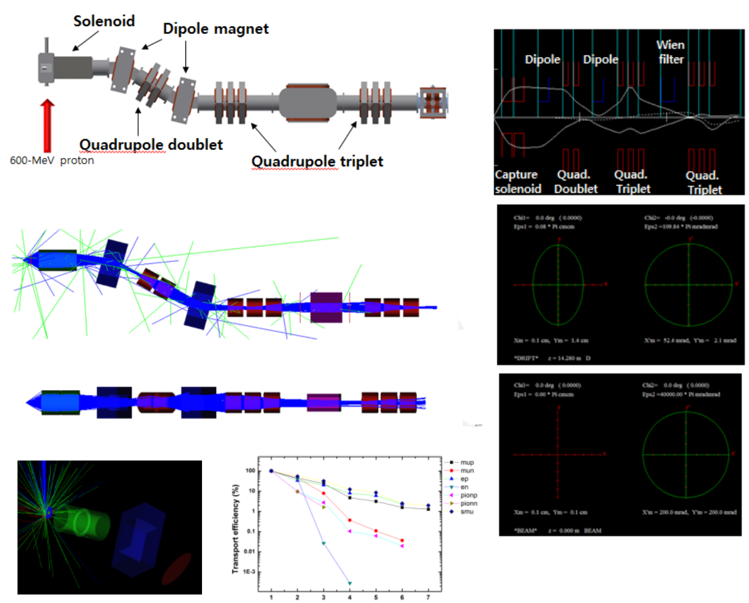


Muon Production Target

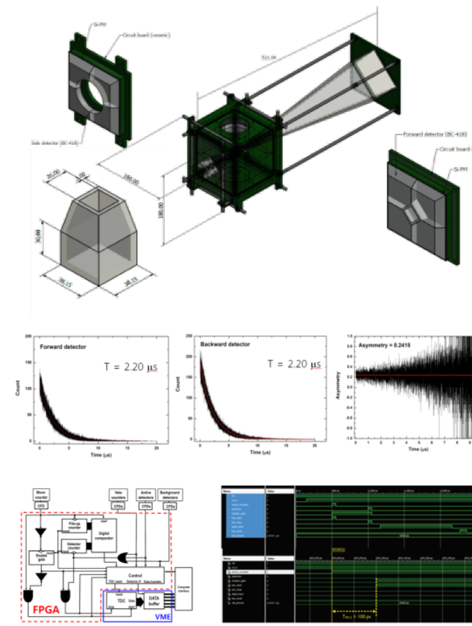




Surface μ+ transport beam line



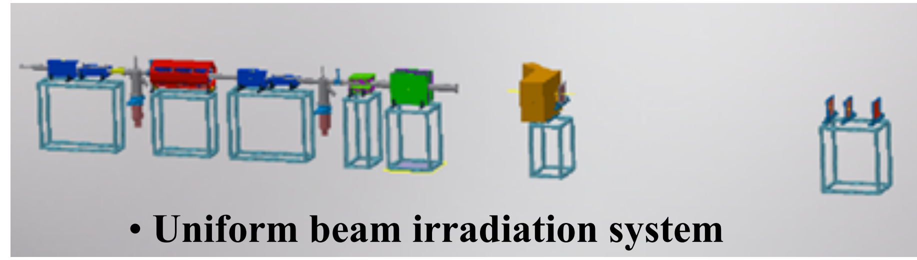
Spectrometer



BIS (Beam Irradiation System)

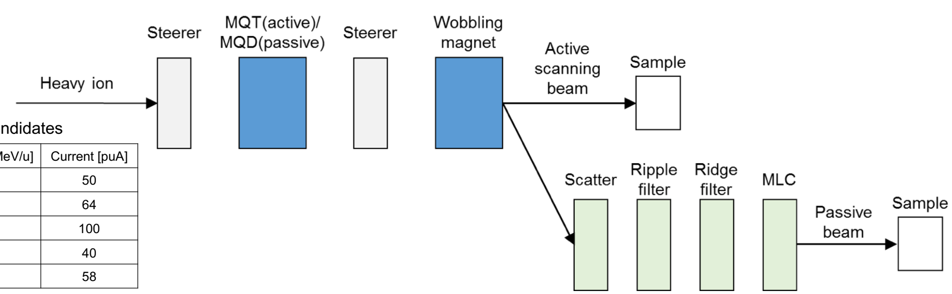
Conceptual design	R&D Pause	R&D, Manufacturing	Installation	Commissioning	Operation
2011 ~ 2012	~ 2018.12	~ 2020.12	~ 2021.12	2021.12 ~	After Commissioning

- **Bio-medical beam irradiation system for biomedical R&D**
  - Passive scanning system including magnet and magnet power supply can be enabled in active scanning system
  - Uniform irradiation system with large area
    - ➔ Studies of the response of cancer cell and normal cell to various heavy ions including RIBs
    - ➔ Studies of useful genetic resources using high LET heavy ion beams and developments of new variety



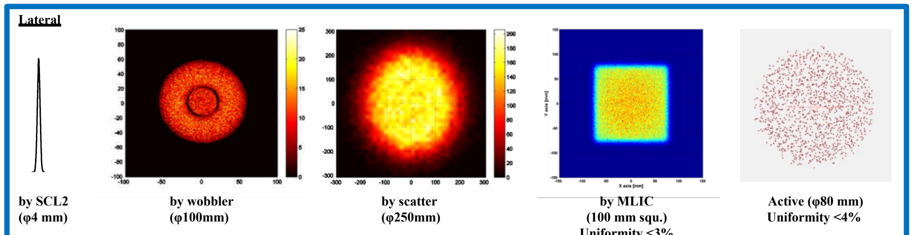
- **Uniform beam irradiation system**
  - Wobbling magnet, W scatter, ripple and ridge filter, MLC
  - Use of both passive (φ < 200 mm) and active beam (φ < 80 mm)

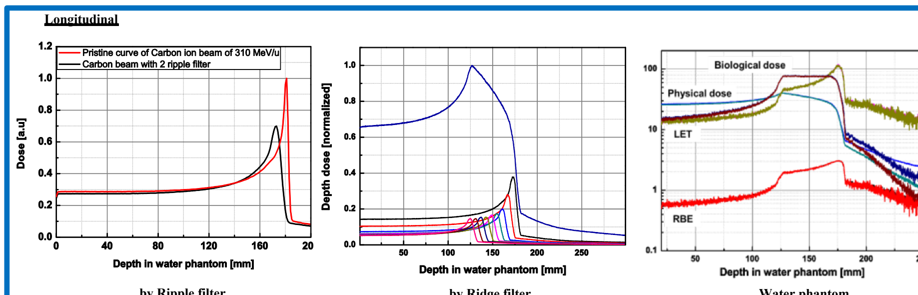
- **Main Specification**
  - E_{beam} = 310 Mev/u with > 50 ppA for ^{12}C
  - Irradiation rate: > 2 Gy/min
  - Irradiation area: > the diameter of 20 cm
  - Non-uniformity: < 5%
  - SOBP: < 4 cm because of the limited acceleration energy
  - Available LET: ~ 10 keV/mm



Heavy ion candidates

Ion	Energy [MeV/u]	Current [puA]
^{12}C	310	50
^{14}N	300	64
^{16}O	305	100
^{20}Ne	303	40
^{40}Ar	270	58

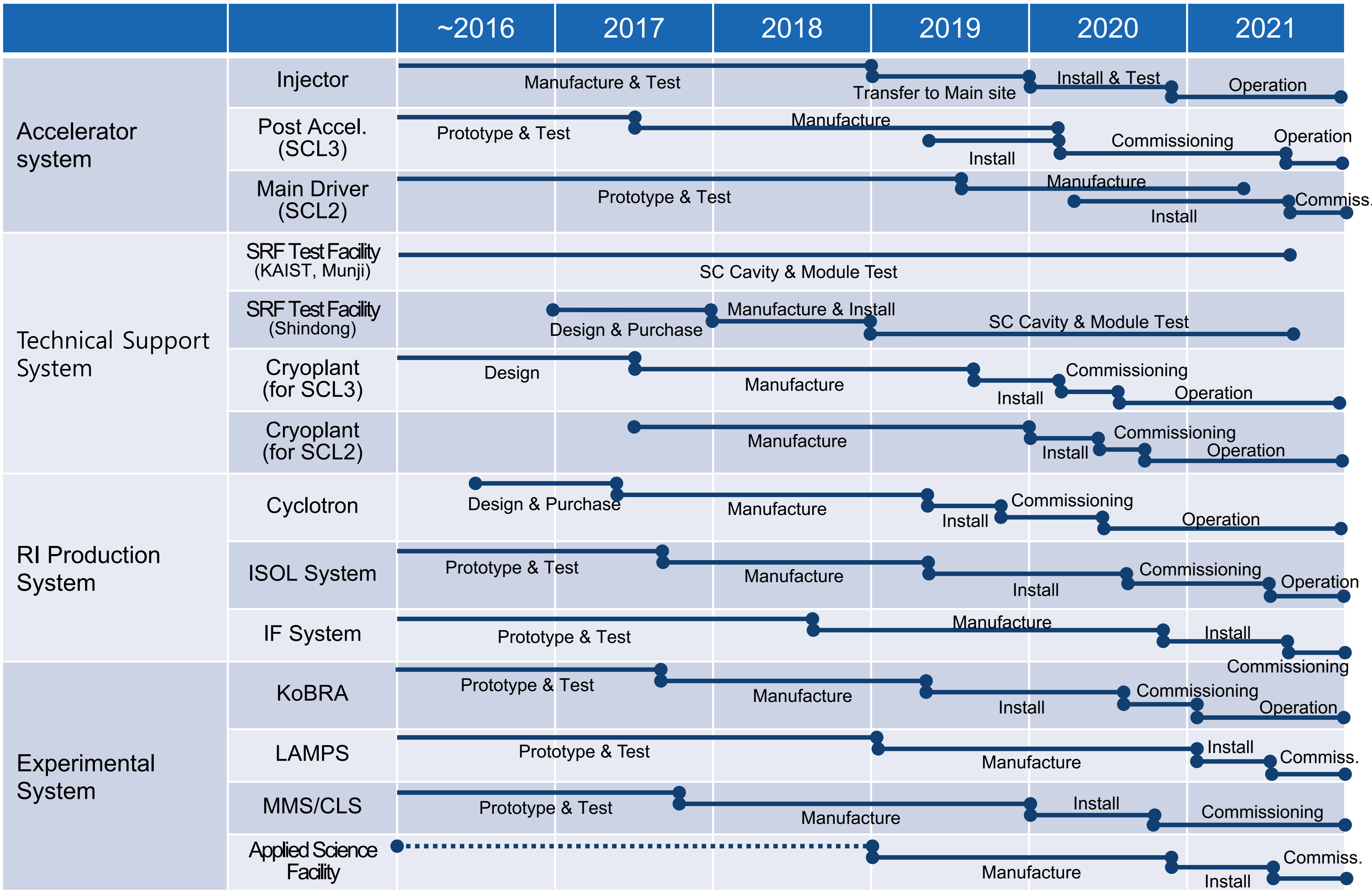




- **Biological dose: 5.022 Gy/min @ 0.1 nA C beam**
- **LET (keV/mm): 12@entrance to 130@peak, 2.5% for 4 cm SOBP**
- **Neutron dose distribution : 4~5x10^{-4} /beam paths of C and N**

- **Conceptual design of the BIS beam line is finished**
- **Resume development works from 2019**

RAON Schedule



Summary

- RAON is Rare Isotope Beam Accelerator and Experimental Facilities in Korea
- Staged approach for development of experimental facilities
  - HPMMS, KOBRA, and LAMPS are being developed with priority
  - R&D and production of other experimental facilities will be resumed from next year
  - Installation start from 2019 year, experiment start on 2021

- Status
  - KOBRA: Manufacturing of Stage 1 is ongoing, Stage 2 will be developed by user community
    Installation will be started from the middle of 2019
  - LAMPS: Manufacturing of solenoid R&D magnet and TPC from 2019
    Complete integration & test of forward neutron array by the middle of 2019
  - MR-ToF-MS: Under development with KEK-KISS group as HPMMS
  - CLS, NDPS, μSR, BIS: Detailed design is under discussion with RAON User Liaison Center and user community

Thanks for your attention !