Overview of underground and ion accelerator facilities for nuclear (& particle) physics in Asia

Byungsik Hong (Korea University)
Chair of Asian Nuclear Physics Association (ANPhA)
https://asiannuclearphysic.wixsite.com/anpha

52nd International Symposium on Multiparticle Dynamics (ISMD2023)
Károly Róbert Campus of MATE, Gyöngyös, Hungary, August 21-26, 2023

Introduction of ANPhA

- Short history
  - Three preparatory meetings in Tokyo (2008), Seoul (2009) and Beijing (2009)
  - Establishment of ANPhA in Beijing, July 18, 2009
  - Original member countries/region (8)
    - Australia, China, India, Japan, Korea, Mongolia, Taiwan, and Vietnam
  - Objectives
    - To strengthen the ***collaboration*** among Asian nuclear research scientists through the promotion of nuclear physics and its transdisciplinary and applications
    - To promote the ***education*** in Asian nuclear science through mutual exchange and coordination
    - To ***coordinate*** among Asian nuclear scientists by actively utilizing existing research facilities
    - To discuss ***future planning*** of nuclear science facilities and instrumentation in Asia

Introduction of ANPhA

- Regular activities
  - Annual board meeting together with either ANPhA Symposium or Conference

  - During the pandemic period ANPhA continued the online meetings and ANPhA Symposia
- Return to the offline face-to-face meeting in 2023
  - Date: Nov. 10-11, 2023
  - Venue: Institute for Basic Science (IBS), Daejeon City, South Korea

	Date	Location	Symposium	Comments
17th	Nov. 17, 2022	Beijing, China	13th ANPhA Symposium	Online
16th	Dec. 03, 2021	Beijing, China	12th ANPhA Symposium	Online
15th	Dec. 11, 2020	Hong Kong, China	11th ANPhA Symposium	Online
14th	Jun. 29, 2019	Jeju Island, Korea	10th ANPhA Symposium	
13th	Sep. 13, 2018	Beijing, China	9th ANPhA Symposium	
12th	Sep. 24, 2017	Halong City, Vietnam	ISPUN2017	
11th	Nov 24, 2016	Sendai, Japan	8th ANPhA Symposium	
10th	Oct. 24, 2015	Gyeongju, Korea	7th ANPhA Symposium	
9th	Nov. 07, 2014	Ho Chi Minh, Vietnam	ISPUN2014	
8th	Feb. 19, 2014	Kolkata, India	6th ANPhA Symposium	
7th	Apr. 27, 2013	Taipei, Taiwan	5th ANPhA Symposium	
6th	Aug. 04, 2012	Adelaide, Australia	4th ANPhA Symposium	
5th	Nov. 27, 2011	Hanoi, Vietnam	ISPUN2011	
4th	Apr. 30, 2011	Lanzhou, China	3rd ANPhA Symposium	
3rd	Oct. 02, 2010	Seoul, Korea	2nd ANPhA Symposium	
2nd	Jan. 17, 2010	Tokai, Japan	1st ANPhA Symposium	
1st	Jul. 18, 2009	Beijing, China		

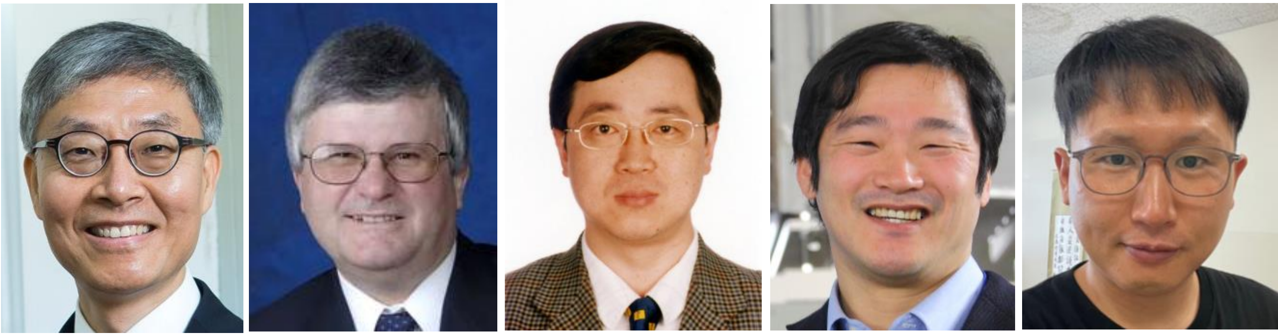
Introduction of ANPhA

- Establishment of the Division of Nuclear Physics (DNP) in Association of Asia-Pacific Physical Societies (AAPPS) in the 33rd Council meeting in Brisbane, Australia on Dec. 4, 2016

- Past Chairs
  ↓ Hideyuki Sakai, Japan (2009-2011)
  ↓ Yanlin Ye, China (2012-2014)
  ↓ Dong-Pil Min, Korea (2014-2016)
  ↓ Kazuhiro Tanaka, Japan (2017-2019)
  ↓ Weiping Liu, China (2020-2022)

Introduction of ANPhA

- **Current management (2023-2025)**
  - Chair: Byungsik Hong (Korea)
  - Vice Chairs: Anthony Thomas (Australia), Guoqing Xiao (China), Tomohiro Uesaka (Japan)
  - Secretary to Chair: Yongsun Kim (Korea)



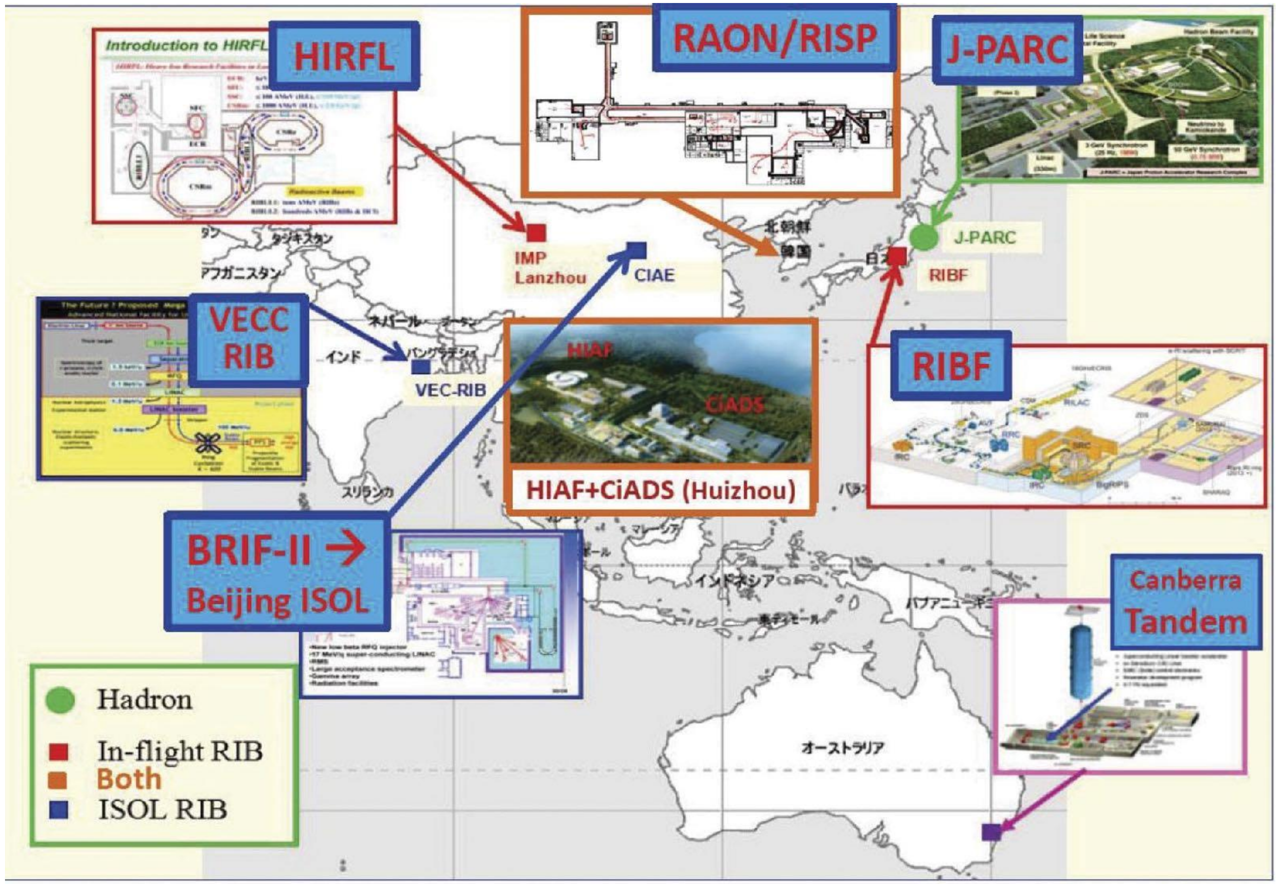
Chair | Vice Chairs | Secretary

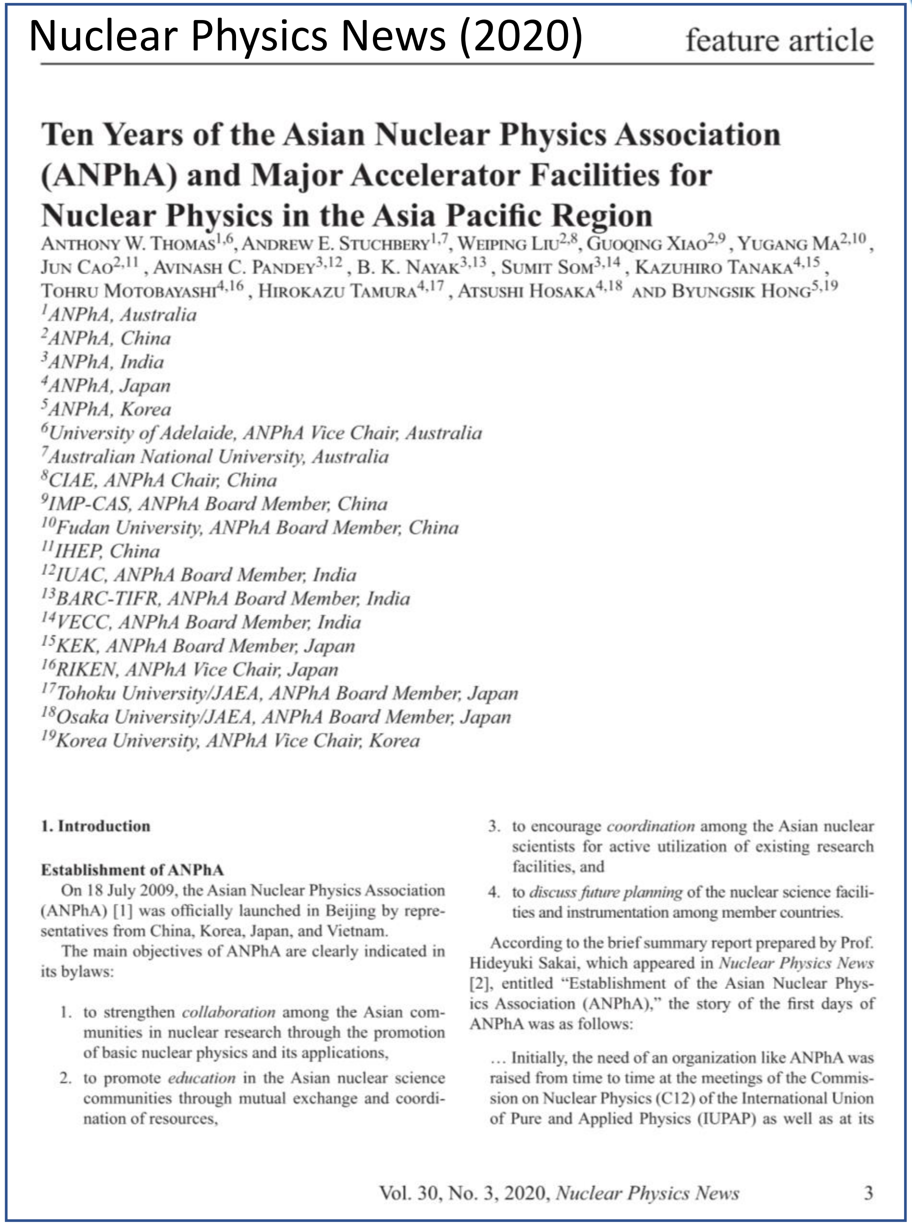
- **Board members (12 member countries/region)**
  - Australia: Anthony Thomas (Univ. of Adelaide)
  - China: Furong Xu (Peking Univ.), Guoqing Xiao (IMP), Yugang Ma (Fudan Univ.), Bing Guo (CIAE)
  - India: Avinash C. Pandey (IUAC), Sumit Som (VECC), Vandana Nanal (TIFR)
  - Japan: Kazuhiro Tanaka (KEK), Atsushi Hosaka (RCNP), Hirokazu Tamura (Tohoku Univ.), Tomohiro Uesaka (RIKEN)
  - Korea: Byungsik Hong (Korea Univ.), Jin-Hee Yoon (Inha Univ.), Eun-Joo Kim (Jeonbuk Nat. Univ.)
  - Taiwan: Wen-Chen Chang (Academia Sinica)
  - Vietnam: Phan Viet Cuong (VINAGAMMA)
  - Myanmar: Nyein Wink Lwin (Univ. of Mandalay)
  - Kazakhstan: Kairat A. Kuterbekov (Eurasian Nat. Univ.)
  - Hong Kong (China): Jenny Hui Ching Lee
  - Mongolia: To be determined
  - The Philippines: Denny Lane Sombillo (Univ. of the Philippines)

Introduction of ANPhA

ANPhA
Asian Nuclear Physics Association

- White paper of ANPhA
  - Catalog of existing and planned accelerator facilities for nuclear physics in Asia-Pacific region
  - https://kds.kek.jp/indico/category/1706/





Nuclear Physics News (2020)

feature article

Ten Years of the Asian Nuclear Physics Association (ANPhA) and Major Accelerator Facilities for Nuclear Physics in the Asia Pacific Region

Anthony W. Thomas[1,6], Andrew E. Stuchbery[1,7], Weiping Liu[2,8], Guoqing Xiao[2,9], Yugang Ma[2,10], Jun Cao[2,11], Avinash C. Pandey[3,12], B. K. Nayak[3,13], Sumit Som[3,14], Kazuhiro Tanaka[4,15], Tohru Motobayashi[4,16], Hirokazu Tamura[4,17], Atsushi Hosaka[4,18] and Byungsik Hong[5,19]

[1]ANPhA, Australia
[2]ANPhA, China
[3]ANPhA, India
[4]ANPhA, Japan
[5]ANPhA, Korea
[6]University of Adelaide, ANPhA Vice Chair, Australia
[7]Australian National University, Australia
[8]CIAE, ANPhA Chair, China
[9]IMP-CAS, ANPhA Board Member, China
[10]Fudan University, ANPhA Board Member, China
[11]IHEP, China
[12]IUAC, ANPhA Board Member, India
[13]BARC-TIFR, ANPhA Board Member, India
[14]VECC, ANPhA Board Member, India
[15]KEK, ANPhA Board Member, Japan
[16]RIKEN, ANPhA Vice Chair, Japan
[17]Tohoku University/JAEA, ANPhA Board Member, Japan
[18]Osaka University/JAEA, ANPhA Board Member, Japan
[19]Korea University, ANPhA Vice Chair, Korea

1. Introduction

Establishment of ANPhA

On 18 July 2009, the Asian Nuclear Physics Association (ANPhA) [1] was officially launched in Beijing by representatives from China, Korea, Japan, and Vietnam.

The main objectives of ANPhA are clearly indicated in its bylaws:

1. to strengthen *collaboration* among the Asian communities in nuclear research through the promotion of basic nuclear physics and its applications,
2. to promote *education* in the Asian nuclear science communities through mutual exchange and coordination of resources,
3. to encourage *coordination* among the Asian nuclear scientists for active utilization of existing research facilities, and
4. to *discuss future planning* of the nuclear science facilities and instrumentation among member countries.

According to the brief summary report prepared by Prof. Hideyuki Sakai, which appeared in *Nuclear Physics News* [2], entitled "Establishment of the Asian Nuclear Physics Association (ANPhA)," the story of the first days of ANPhA was as follows:

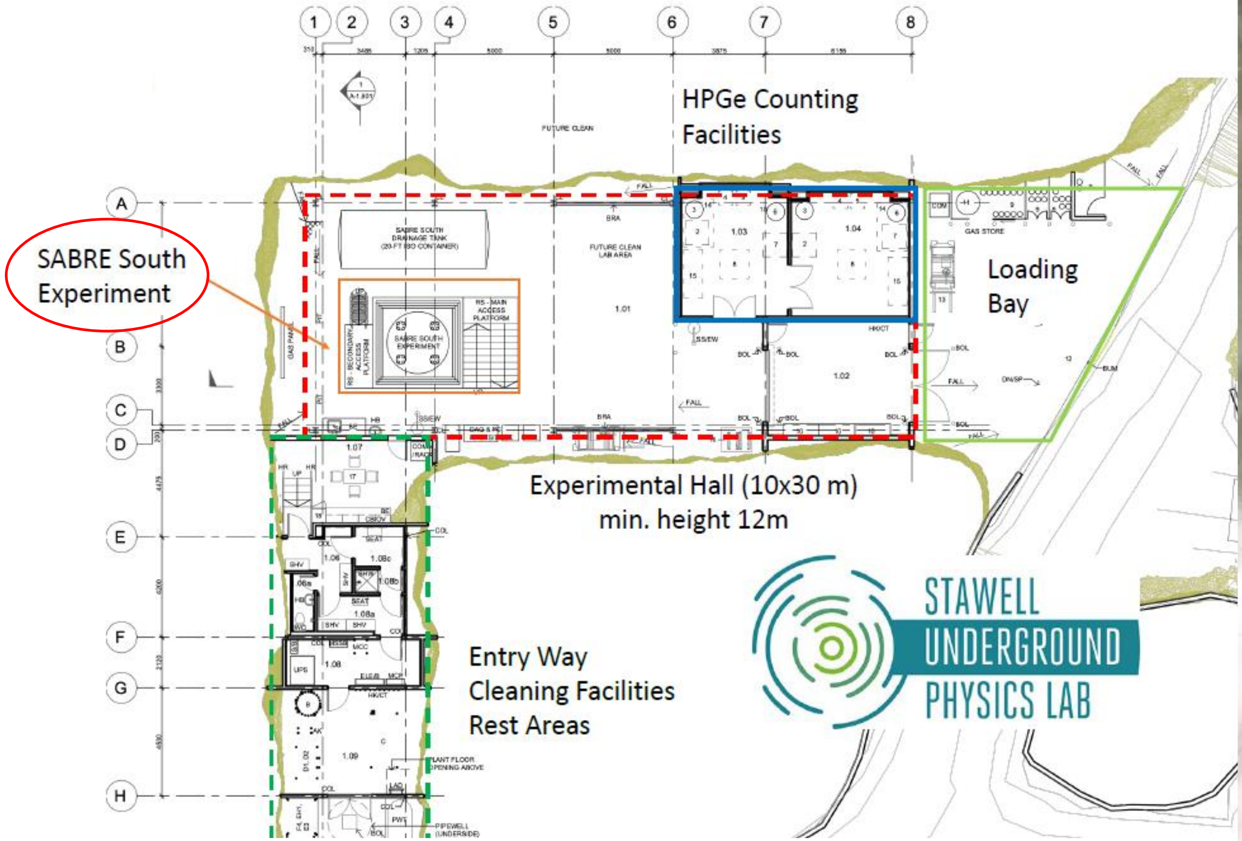
… Initially, the need of an organization like ANPhA was raised from time to time at the meetings of the Commission on Nuclear Physics (C12) of the International Union of Pure and Applied Physics (IUPAP) as well as at its

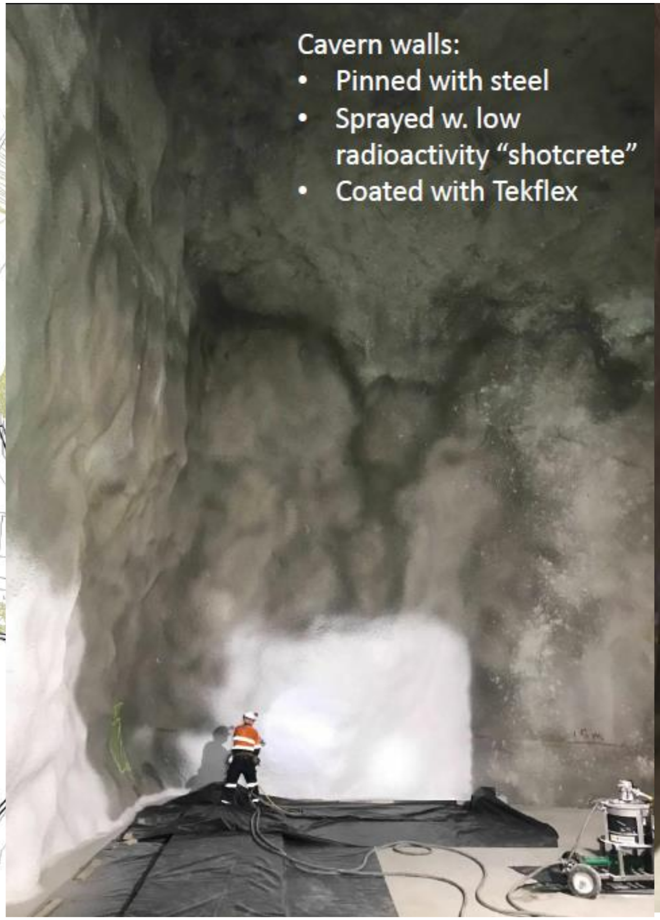
https://www.tandfonline.com/toc/gnpn20/30/3?nav=tocList

Underground Laboratory

Materials from Anthony Thomas

- Stawell Underground Physics Laboratory (SUPL)
  - Completed construction in 2022
  - Located in 240 km northwest of Melbourne (1,025 m deep)

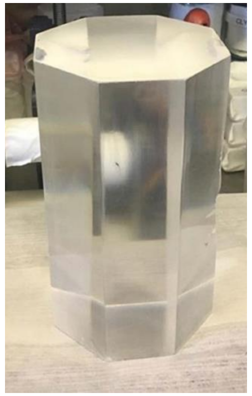




Underground Laboratory

ANPhA Asian Nuclear Physics Association

- SABRE South Collaboration
  - A new dark matter searching group (46 members across 5 institutions)
  - To measure the model independent modulation signal for dark matter caused by relative motion of the Earth through galactic halo
  - Expect to reach 5σ discovery sensitivity to a DAMA-like signal within two years



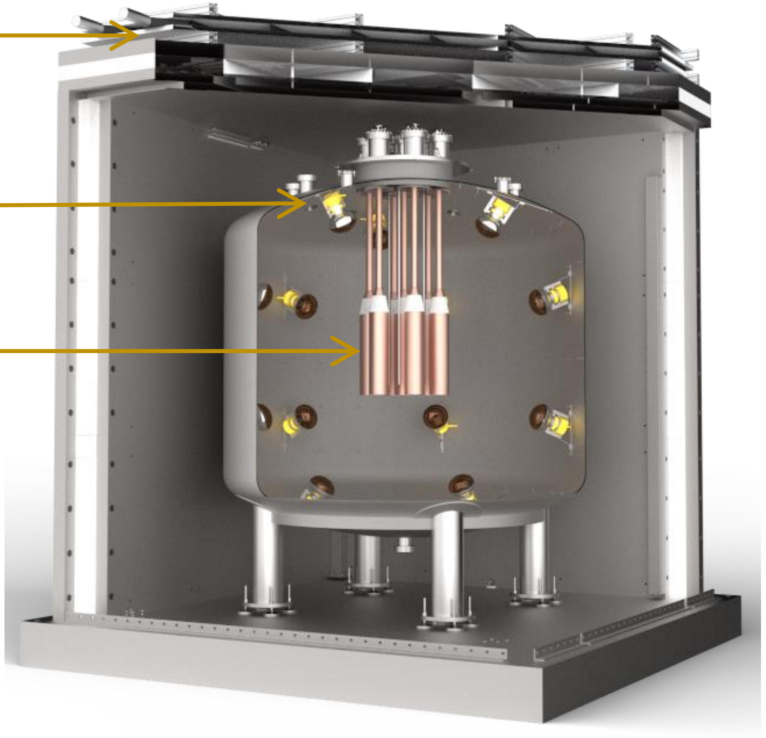
An engineering cutaway of the detector in its shield

ToF muon system
9.6 m2 × 5 cm EJ200
R13089 PMT × 16 @ 3.2 GS/s

Veto system
12k litres Linear Alkyl Benzene + PPO & Bias-MSB
Stainless steel, non-thoriated welds, lumirror coating
Oil-proof base R5912 PMT × 18 @ 500 MS/s

DM target detector
Low-activity NaI(Tl) crystals
R11065 low radioactivity PMT × ~14 @ 500 MS/s

Key requirement to understand modulation in background contributions: Particle ID, e.g., $\mu/\gamma/n$

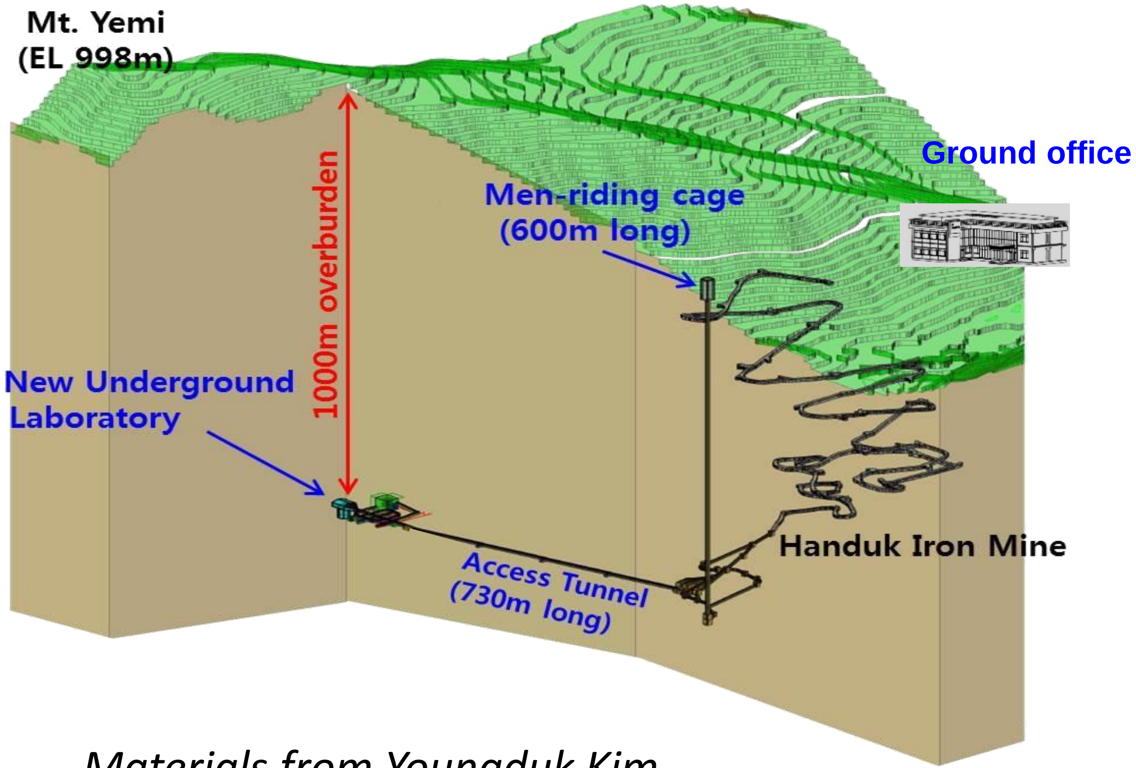


17,000 litres LAB scintillator base from Nanjing via JUNO/IHEP.

JUNO LS properties [6]
- Photon attenuation > 20 m
- $^{238}U/^{232}Th/^{40}K < 10^{-17}$ g/g

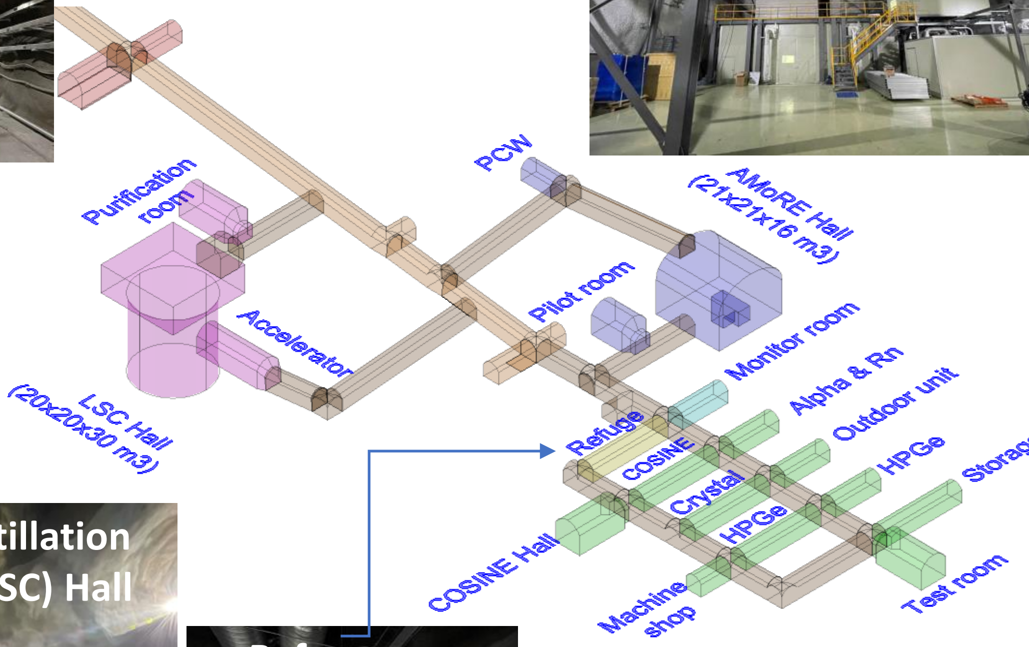
Underground Laboratory

- Yemilab: a new underground laboratory
  - Y2L (700 m deep) constructed in 2003 to house KIMS dark matter search experiment
  - Yemilab (1,000 m deep) constructed in 2022



Materials from Youngduk Kim

- Experimental area of Yemilab
  - Run by Center for Underground Physics (CUP) of IBS
  - Lab. space > 3,000 m^2 with 2.5 MW electricity

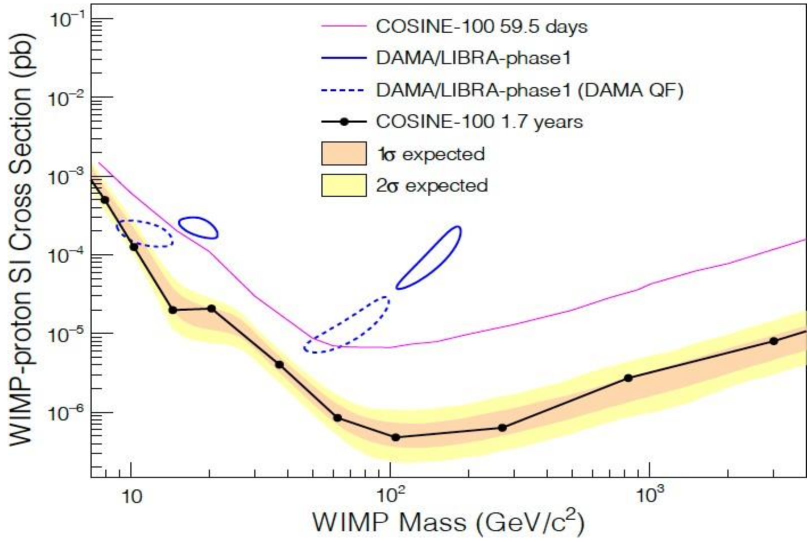


Underground Laboratory

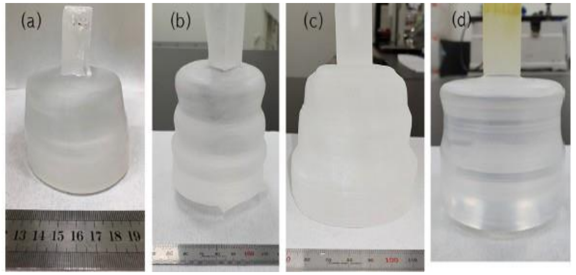
Dark matter search

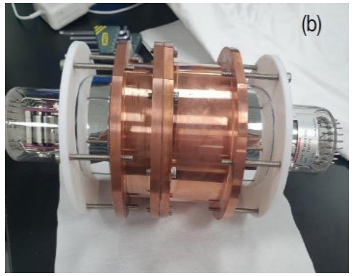
- COSINE-100 experiment @ Y2L
  - Collaboration : Yale, CUP, Sheffield, San Paulo
  - DAMA/LIBRA annual modulation of standard halo model is rejected.

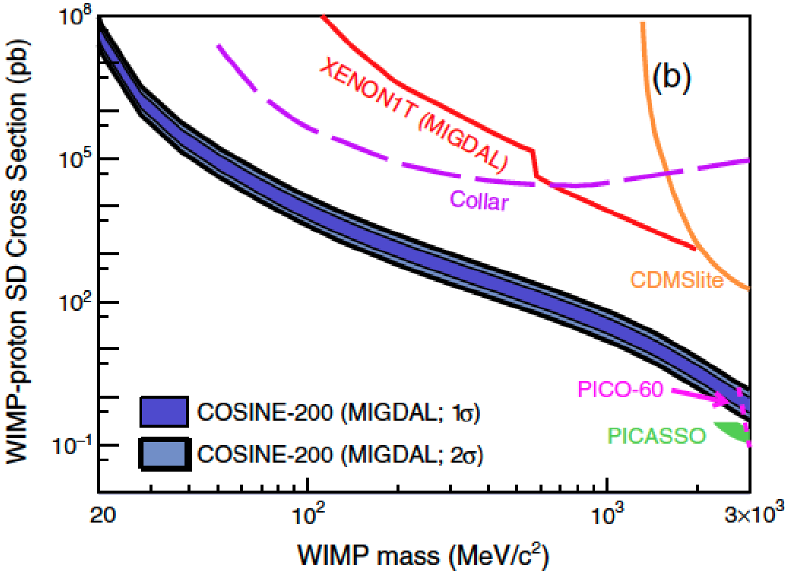
Sci. Adv. 7, 2699 (2021)



- COSINE-200 experiment @ Yemilab
  - Ultra-low background NaI crystals developed
  - Aims a world best limit for low-mass WIMP-proton spin-dependent interaction
  - Expect to begin the data taking run in 2025





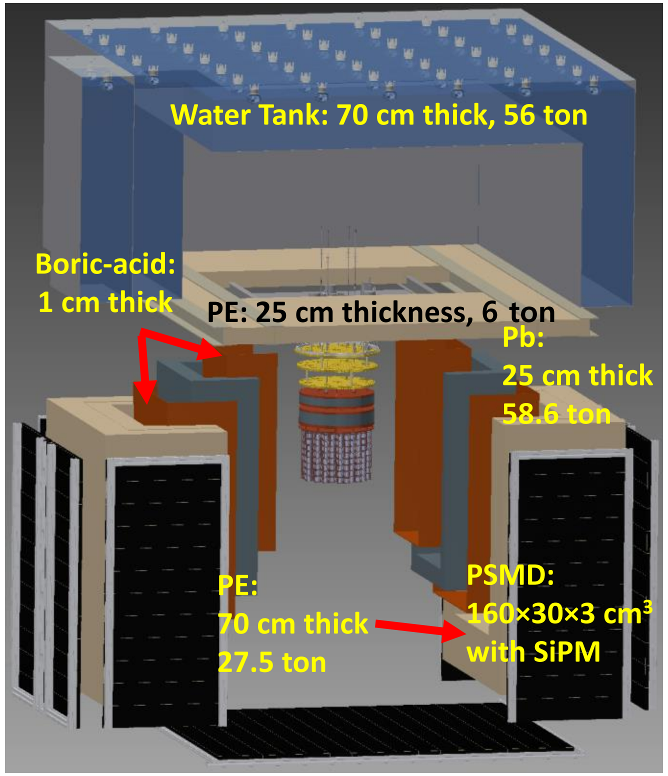


Underground Laboratory

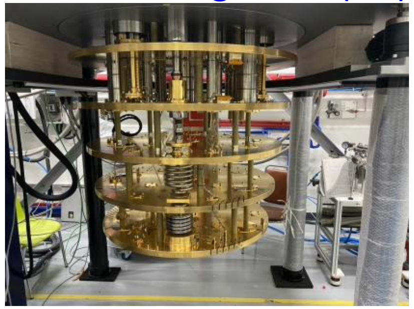
Neutrinoless double beta decay

Cf.) CUPID @ LNGS with 240 kg of ^{100}Mo

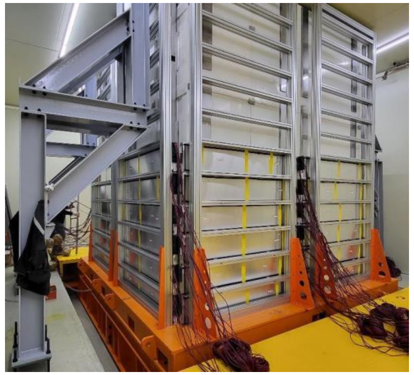
- AMORE-II experiment @ Yemilab
  - 100 kg of ^{100}Mo for 5 years to reach $T_{1/2}^{0\nu} > 4.5 \times 10^{26}$ years
  - Both phonons and photons measured by MMC+SQUID sensors
  - 90-crystal run from 2023: Full scale (100 kg of ^{100}Mo) run from early 2025
  - $Li_2{}^{100}MoO_4$ crystals in 5 and 6 cm cylinder (~400 crystals)
  - DR inside shielding of 25cm Pb + 70cm of PE and water

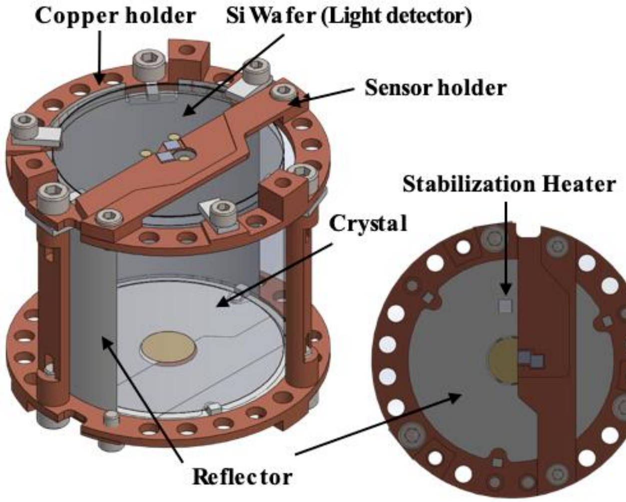


Dilution refrigerator (DR)

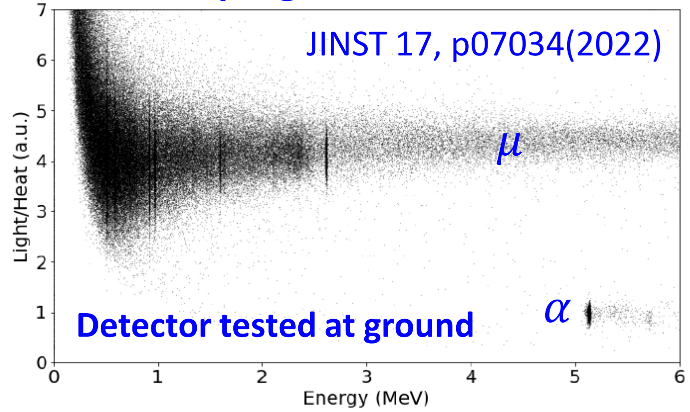


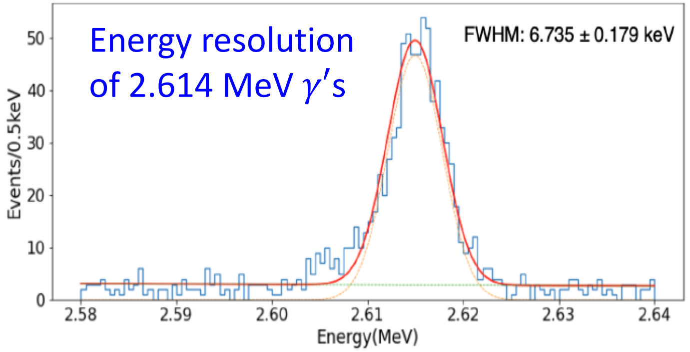
Installed muon detectors





Recent progress in detector R&D



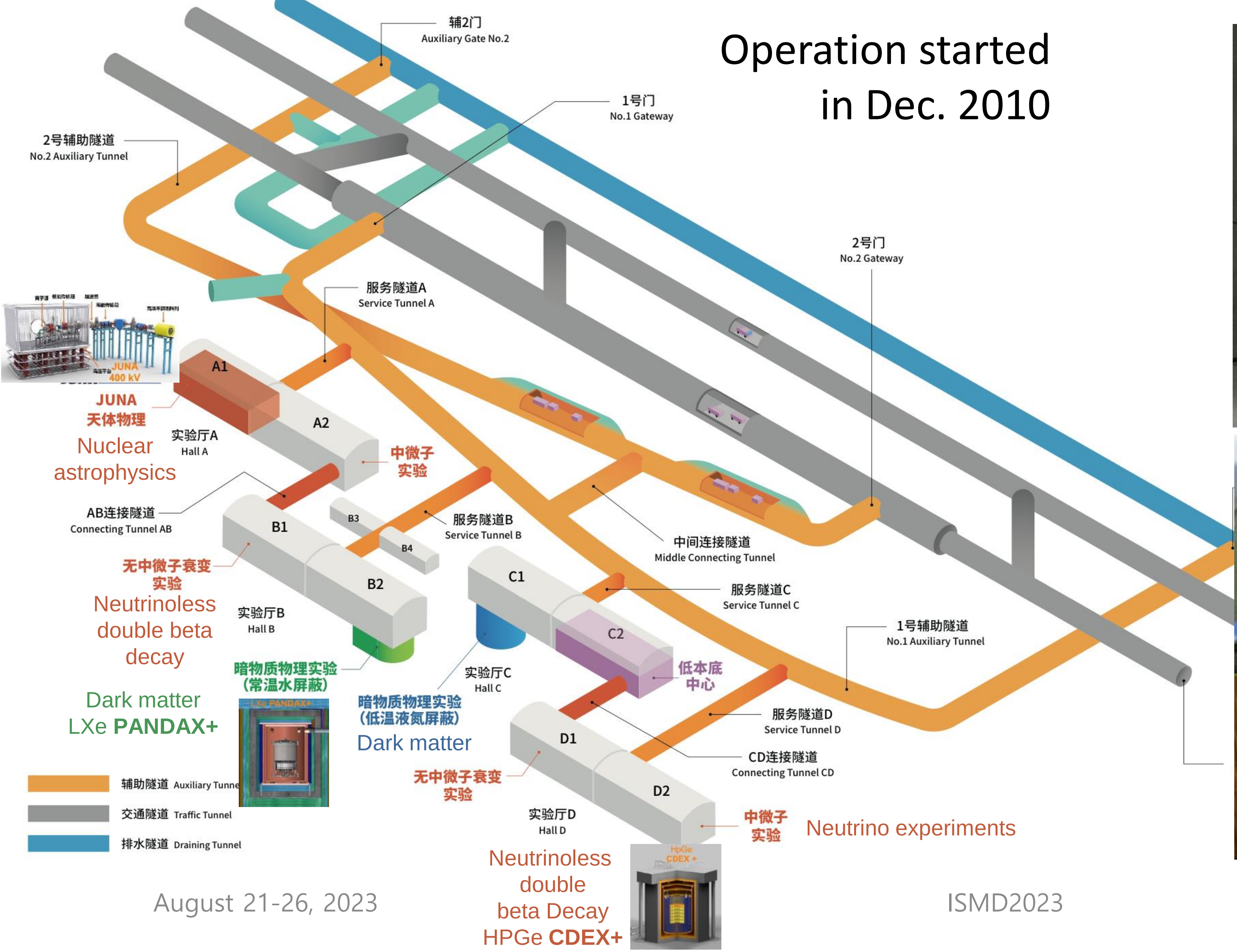


Underground Laboratory

Materials from Weiping Liu

China Jinping Underground Laboratory (CJPL)-II

Operation started in Dec. 2010

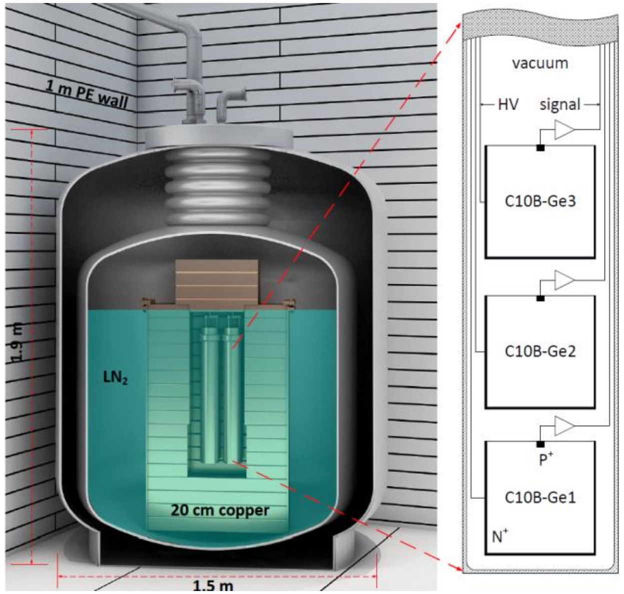


Underground Laboratory

China Dark Matter Experiment (CDEX)

Ge to search for light-WIMP: PRL 123, 221301 (2019)

Dark photon: PRL 124, 111301 (2020)

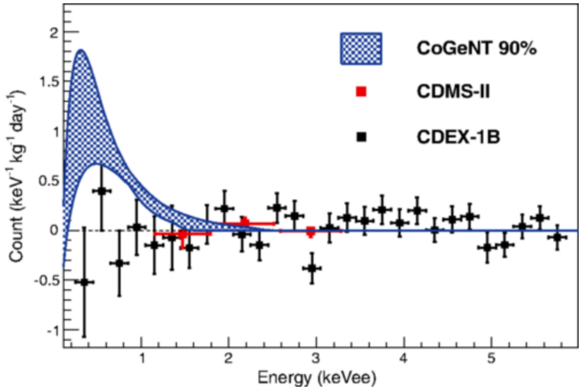


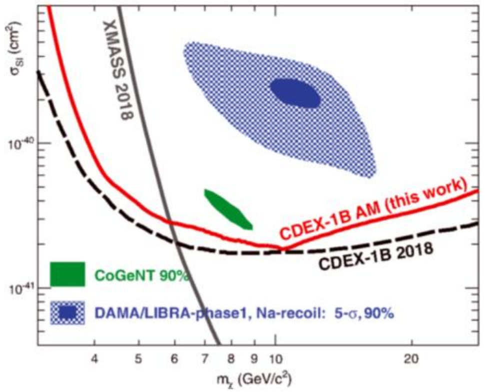
- CDEX-10 (2016): 10-kg Point Contact Ge detectors immersed into liquid nitrogen

→ CDEX-300 (2027)

→ CDEX-1T (????)

Cf.) LEGEND-200
LEGEND-1000





Particle and Astrophysical Xenon Experiment (PandaX)

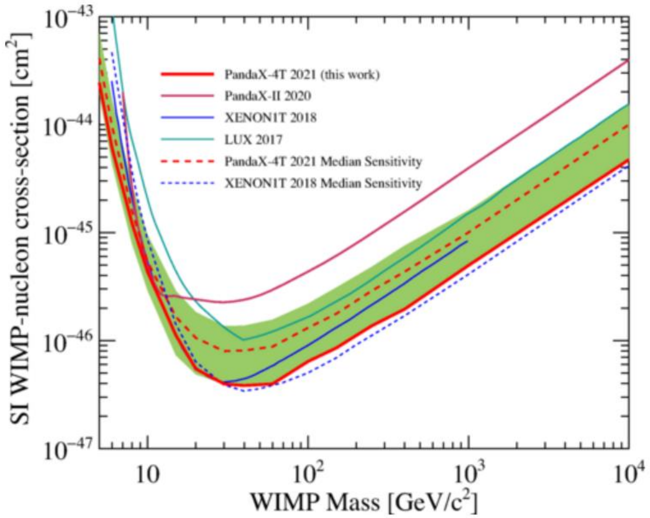
Xe to search for dark matter: Nature 618, 47 (2023), PRL 129, 161803 (2022), PRL 127, 261802 (2021)

- Panda-II (2014): Dual-phase Time Projection Chamber (TPC) with half-ton of ultra-high purity liquid Xe

→ PandaX-4T (2021): 5.75 tons of Xe

→ Panda-III (????): 200 kg to one ton of 90% enriched high-pressure gaseous ^{136}Xe in TPC

Cf.) nEXO

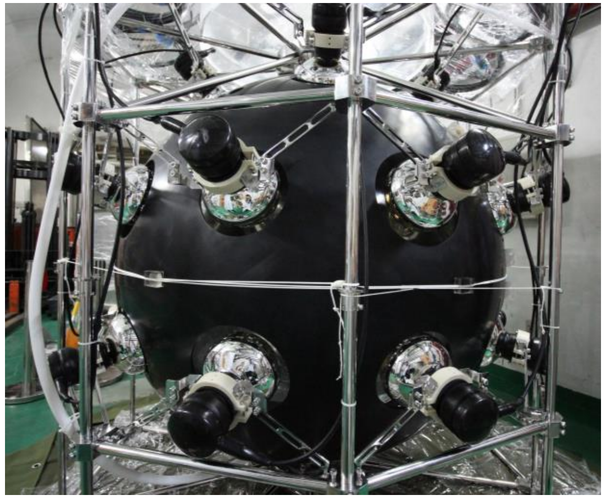


SD WIMP-nucleon elastic cross section
PRL 127, 261802 (2021)

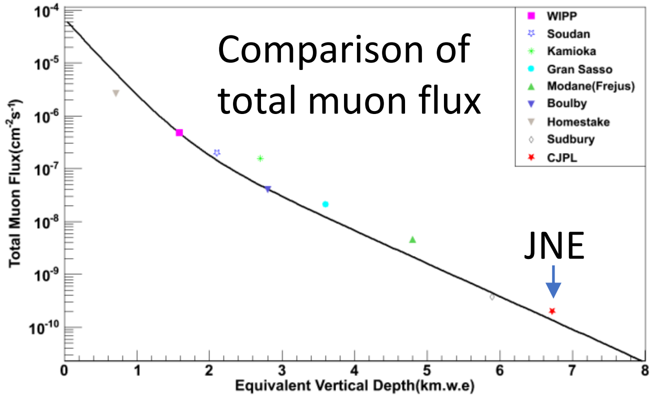
Underground Laboratory

Jinping Neutrino Experiment (JNE)

Solar, geo-, and supernova neutrinos

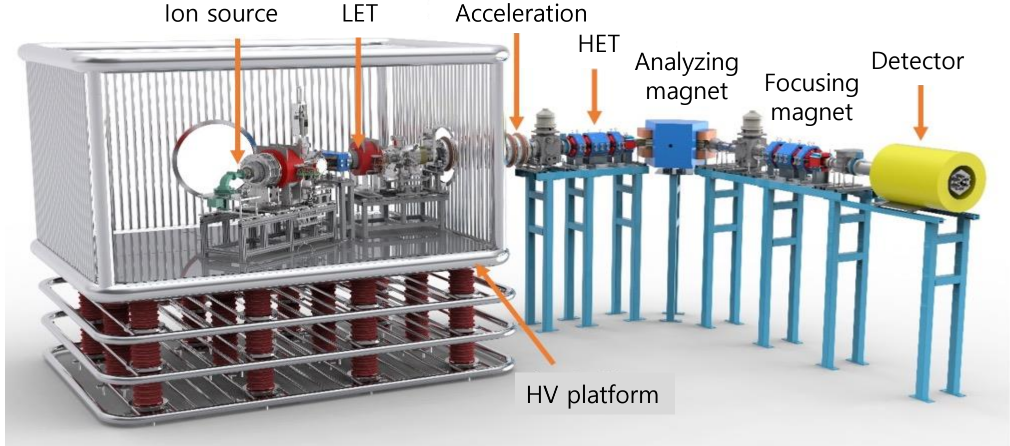


Prototype detector with 1-ton liquid scintillator (2017), arXiv:2212.13158



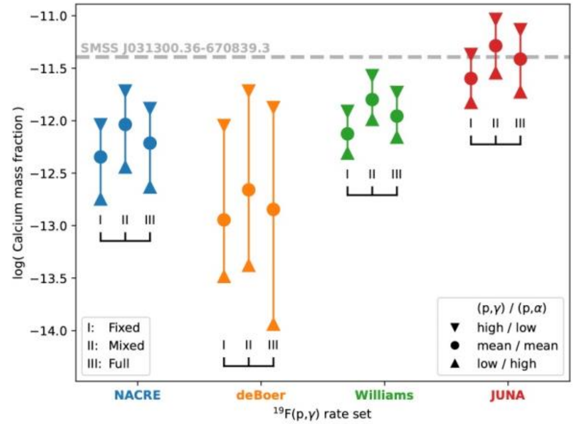
JUNA for nuclear astrophysics

W.P. Liu, et al., Sci. China 59, 5785 (2016)

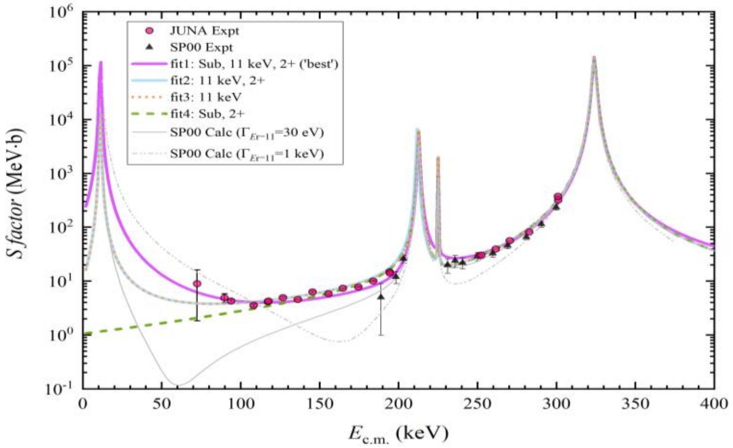


$^{19}F(p,\gamma)^{20}Ne$: Nature 610, 656 (2022)

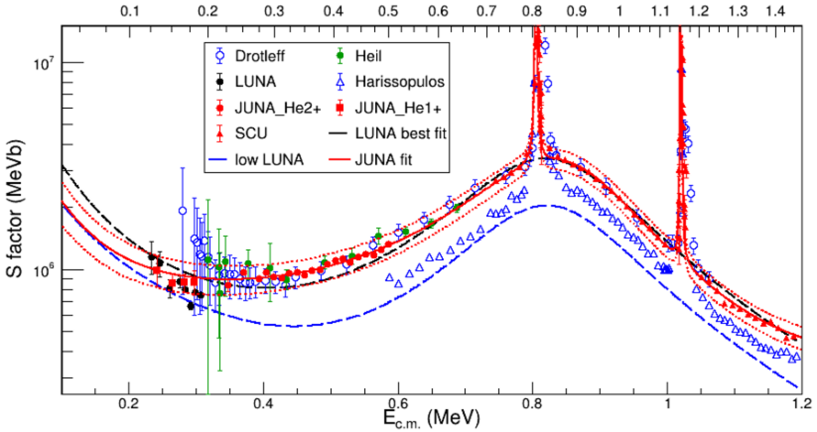
Explain Ca in the oldest star!



$^{19}F(p,\alpha\gamma)^{16}O$: PRL 127, 152702 (2021)



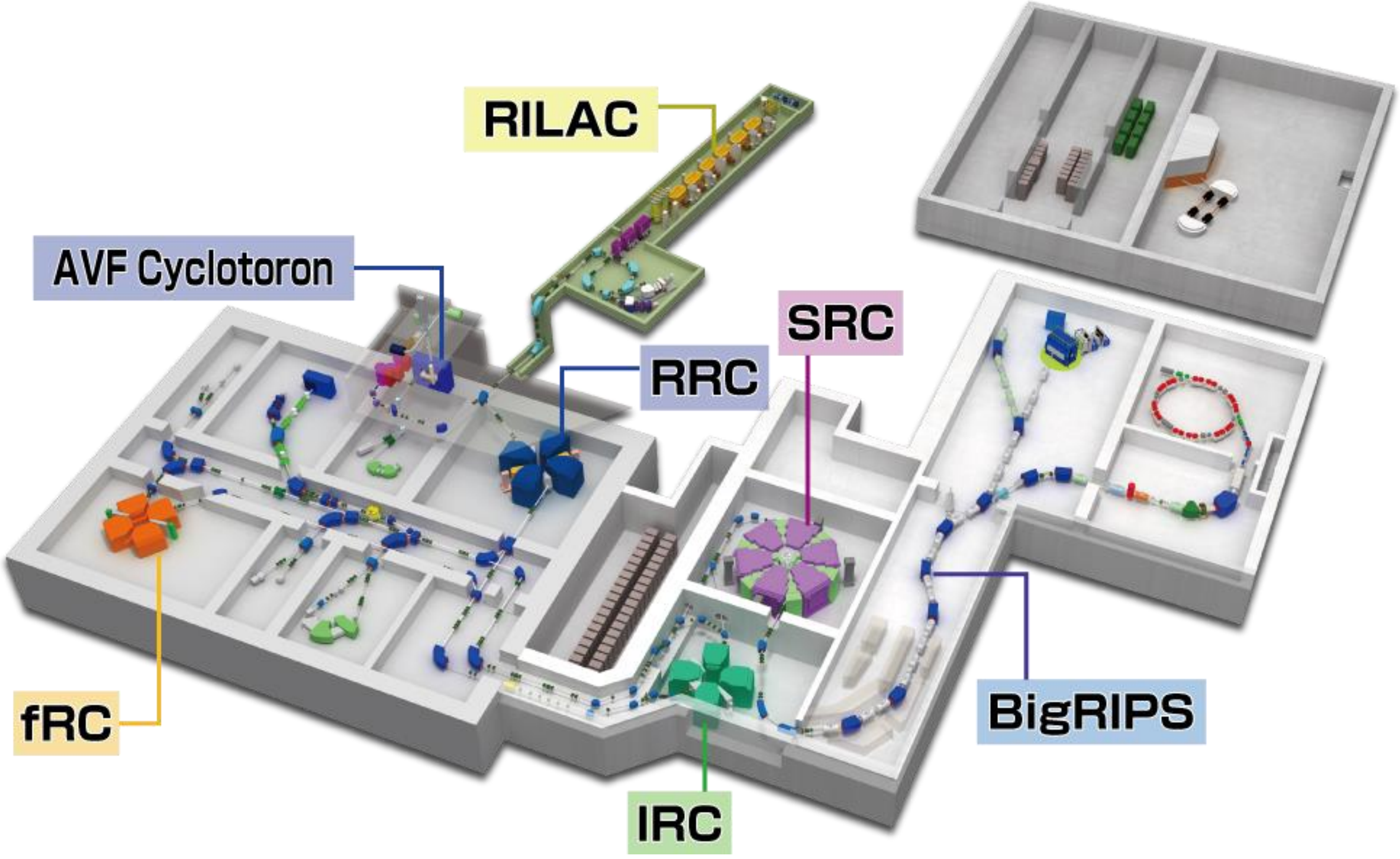
$^{13}C(\alpha,n)^{16}O$: PRL 129, 132701 (2022)



RIB Accelerator Facility

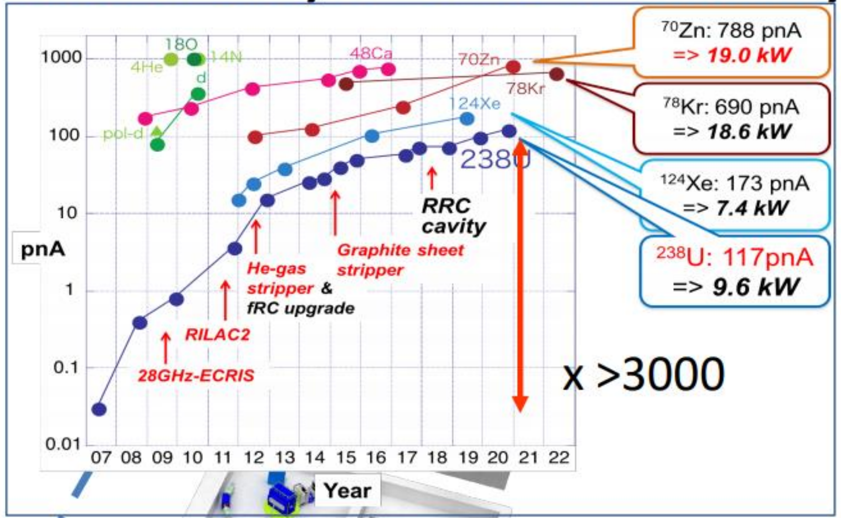
Slides from Hiroyoshi Sakurai

Radioactive Ion Beam Factory (RIBF)

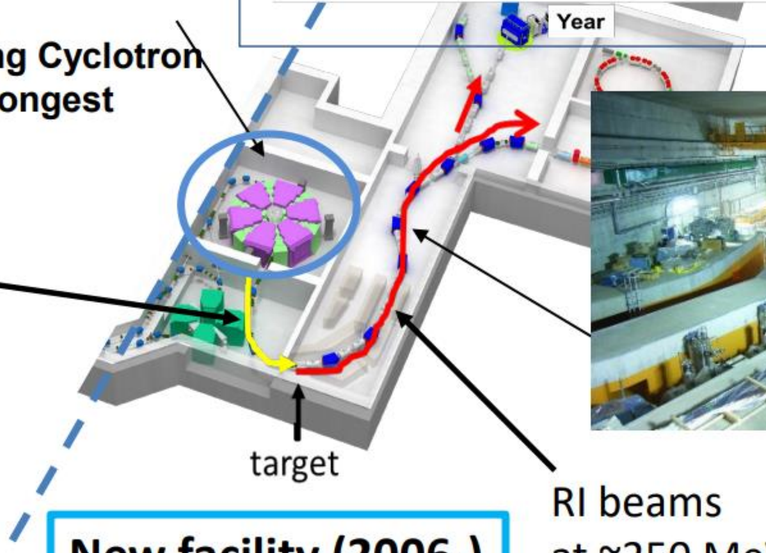


RIB Accelerator Facility

Beam Intensity of SRC as a function of year



SRC:
Superconducting Ring Cyclotron
World's First and Strongest
K2600MeV



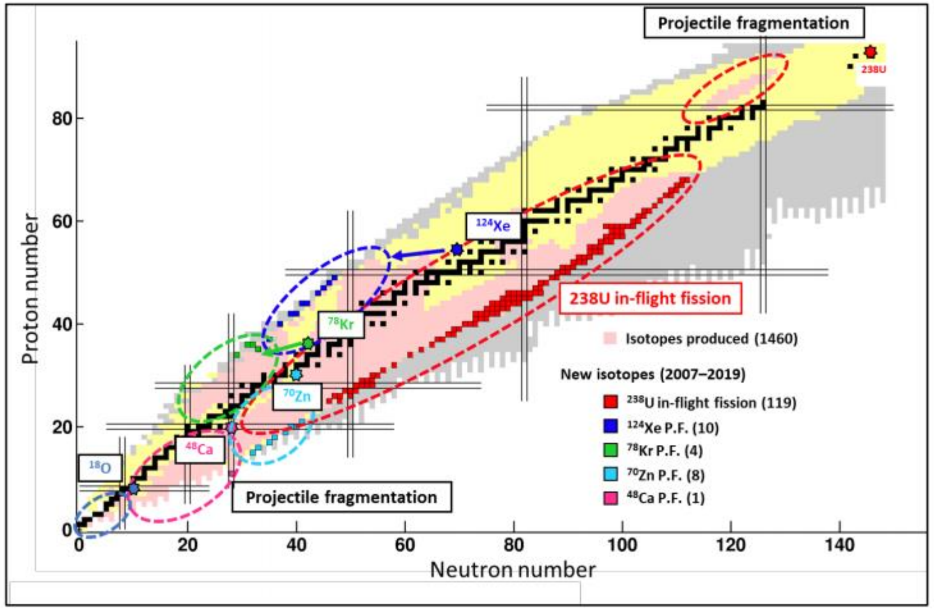
primary beams
at 350 MeV/u

target

RI beams
at ~250 MeV/u

New facility (2006-)

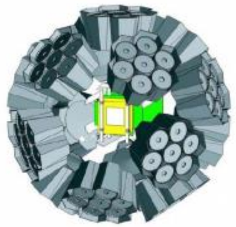
159 new isotopes created since 2007



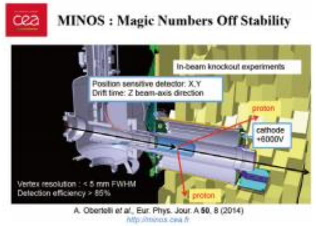
BigRIPS:
Superconducting RI beam Separator
In-flight separator
World's Largest Acceptance
High magnetic rigidity 9 Tm

RIB Accelerator Facility

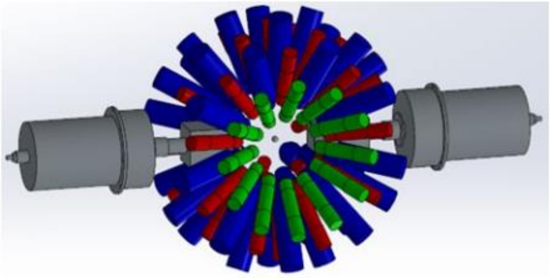
EURICA (2011-2016):
EUroball-RIKEN Cluster Array



SEASTAR (2014-2017):
thick liq. H_2 +TPC+NaI
for in-beam gamma
spectroscopy



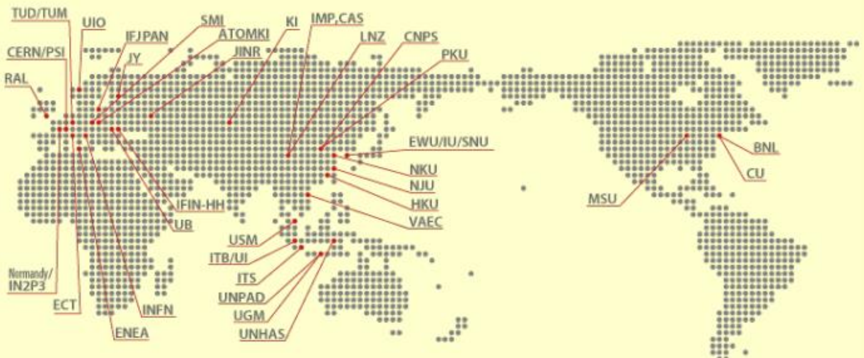
IDATEN (2021-):
84 $LaBr_3$ (Ce) + 2 Cover Ge detectors
to measure lifetime of excited states



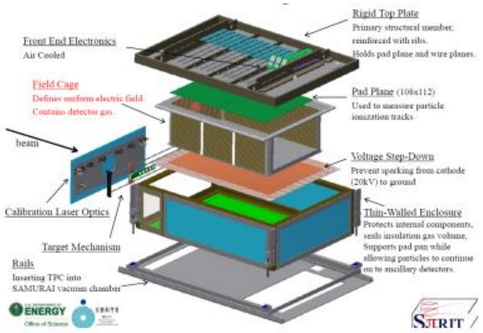
BRIKEN(2017-2021):
He-3 detector array for
beta-delayed neutron

HiCARI (2019-2020):
Tracking Ge detectors
for in-beam gamma
spectroscopy

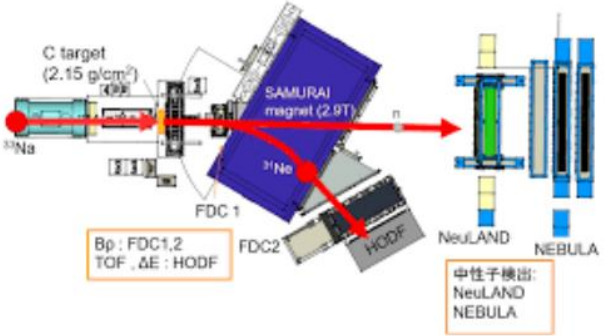
MoU with
41 institutions and universities in 19 countries



SpiRIT TPC (2015-):
heavy-ion collision program for EOS



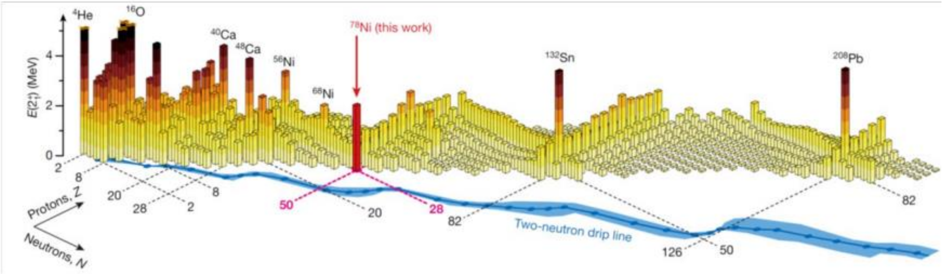
SAMURAI (2012-):
neutron detectors + CsI+…
for neutron correlation



RIB Accelerator Facility

Shell-evolution: magicity loss and new magicity

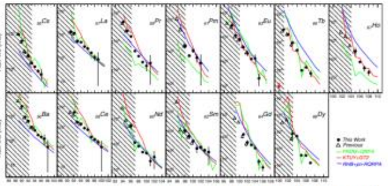
^{78}Ni revealed as a doubly magic stronghold against nuclear deformation



Taniuchi, Nature 569, 53 (2019)

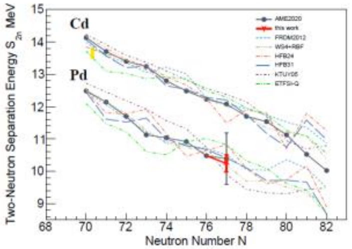
r-process path : nucleo-synthesis up to U

T1/2



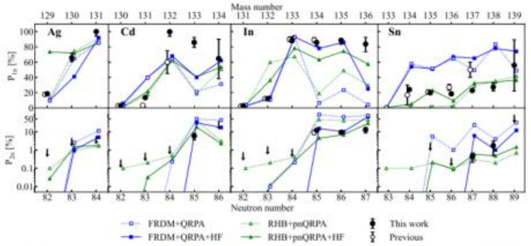
Wu, PRL 118, 072701 (2018)

Mass



Li, PRL 128, 152701(2022)

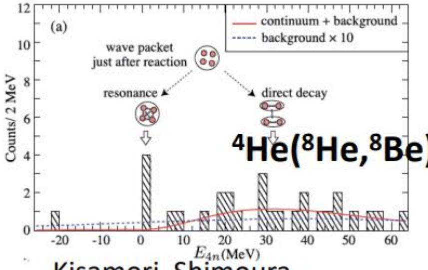
Pn



Phong,
PRL 129, 172701 (2022)

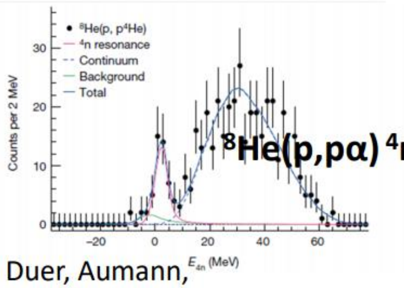
Neutron-neutron correlation in the vicinity of the dripline

Tetra-neutron system



^{4}He(^{8}He,^{8}Be) ^{4}n

Kisamori, Shimoura,
PRL 116, 052501 (2016)

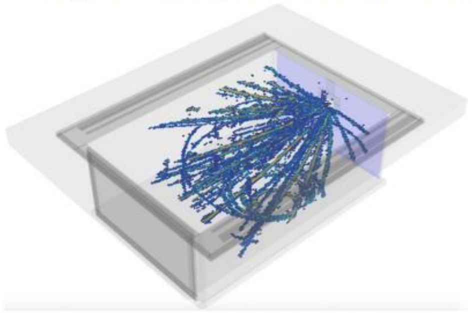


^{8}He(p,pα) ^{4}n

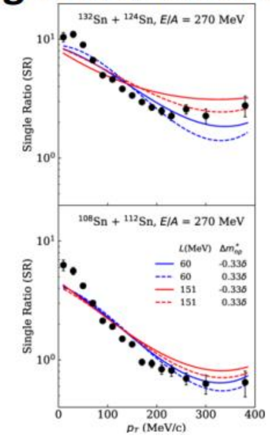
Duer, Aumann,
Nature 606, 678 (2022)

Equation-of-State in asymmetric nuclear matter

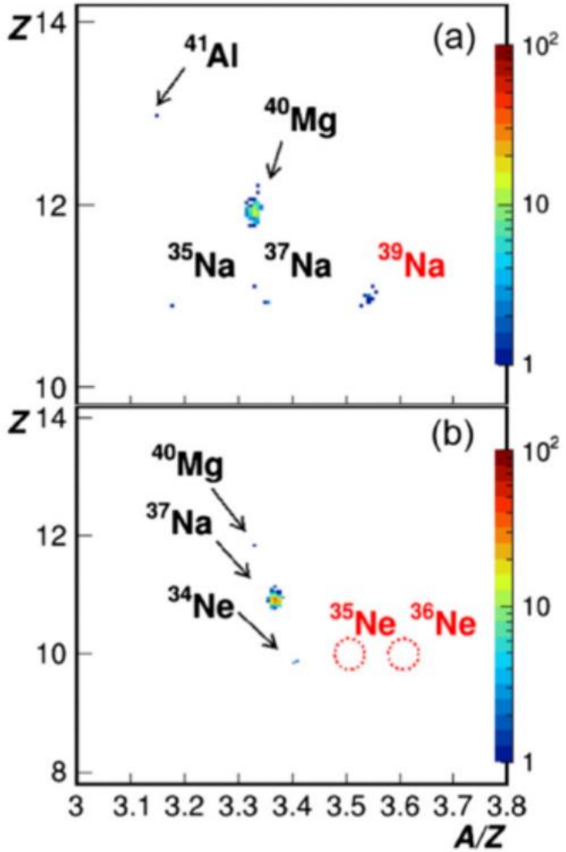
SN explosion, neutron-star, gravitational wave



Estee, PRL 126, 162701 (2021)



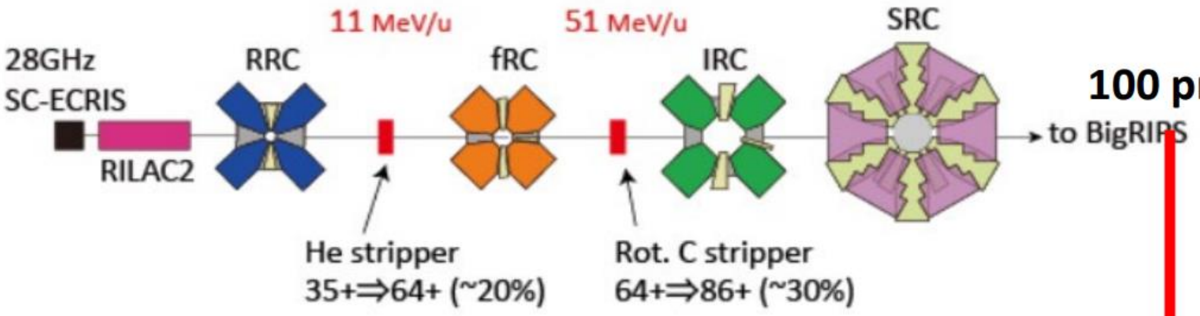
Discovery of ^{39}Na
Ahn et al.,
PRL129, 212502 (2022)



RIB Accelerator Facility

RIBF upgrade plan for more intense U beams

Present Acceleration Scheme



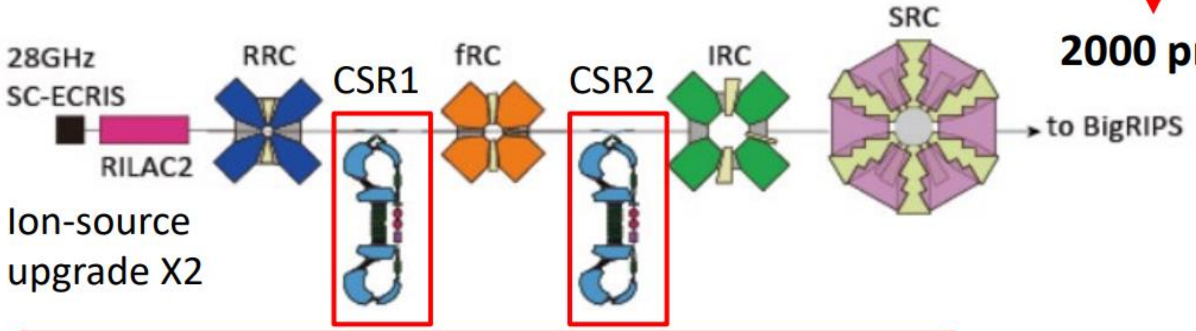
100 pnA

x20

2000 pnA

Large loss at the strippers : transmission efficiency is about 6%

Upgrade plan

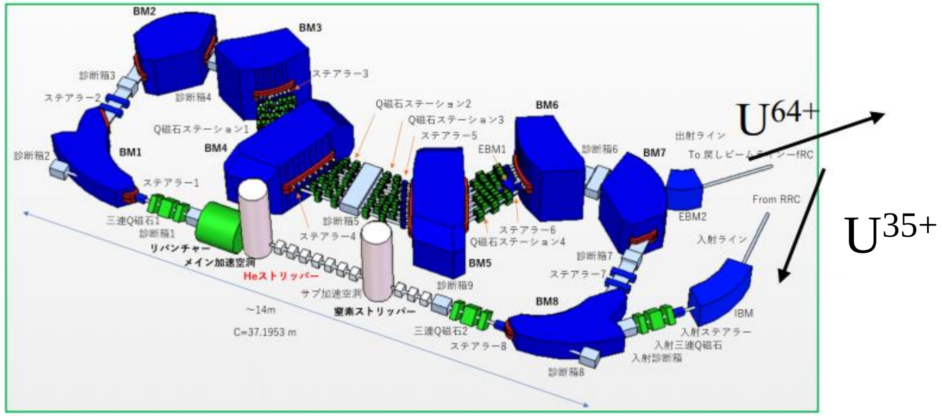


Ion-source upgrade X2

Charge Stripper Rings : beam recycling technology to increase transmission efficiency by a factor of 10

Requesting the construction budget now

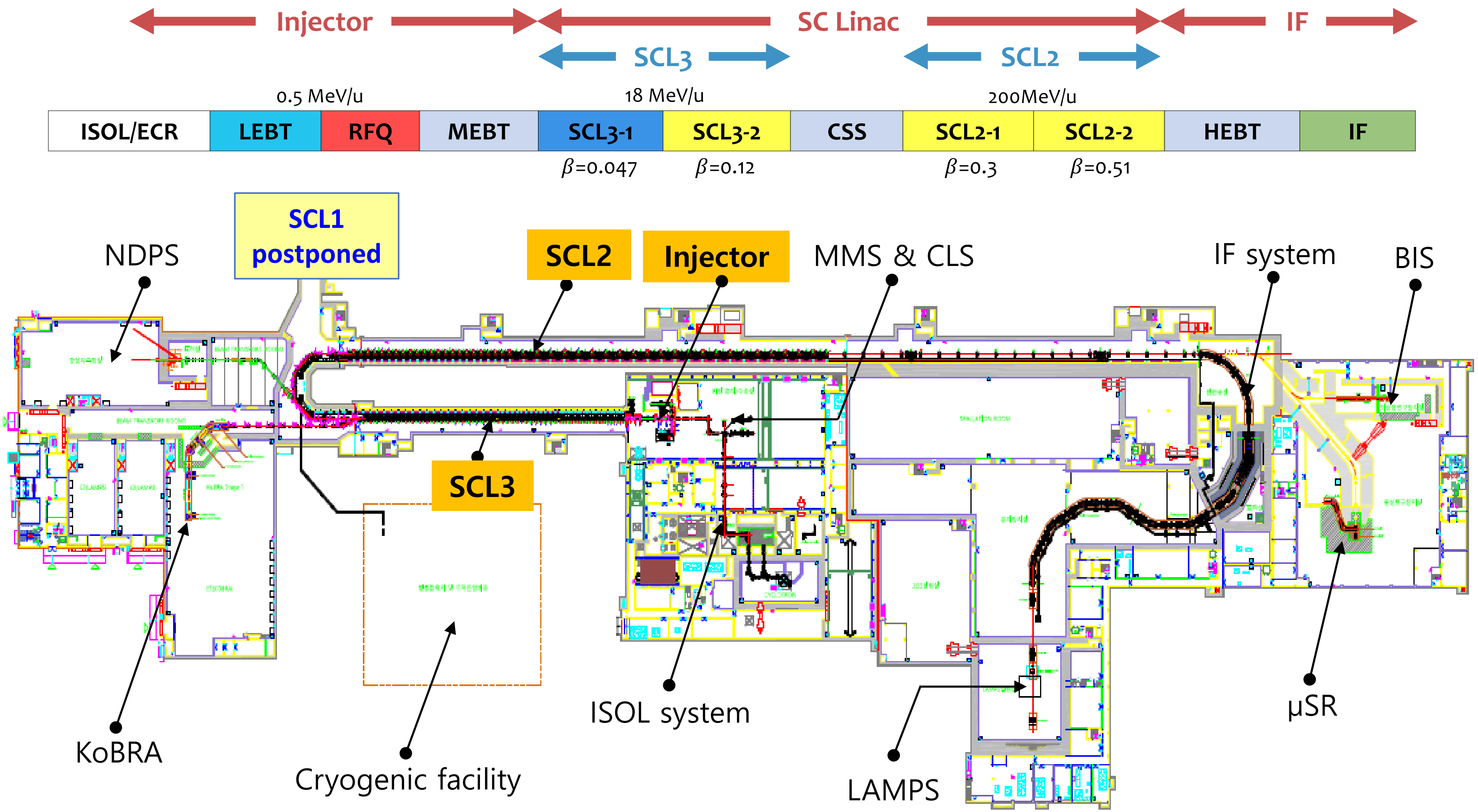
CSR1



RIB Accelerator Facility

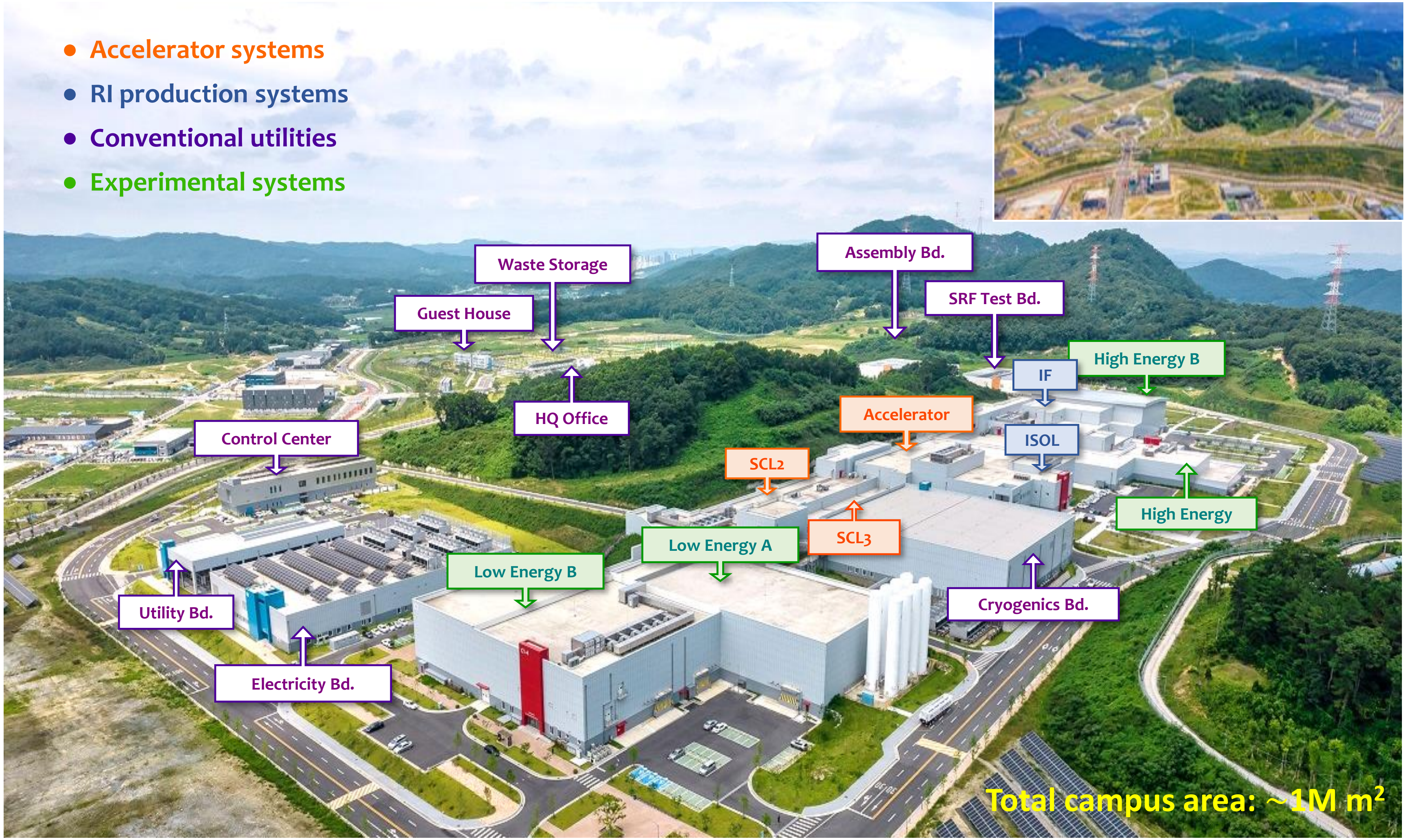
Rare isotope Accelerator complex for ON-line experiments (RAON)

Materials from Seung-Woo Hong



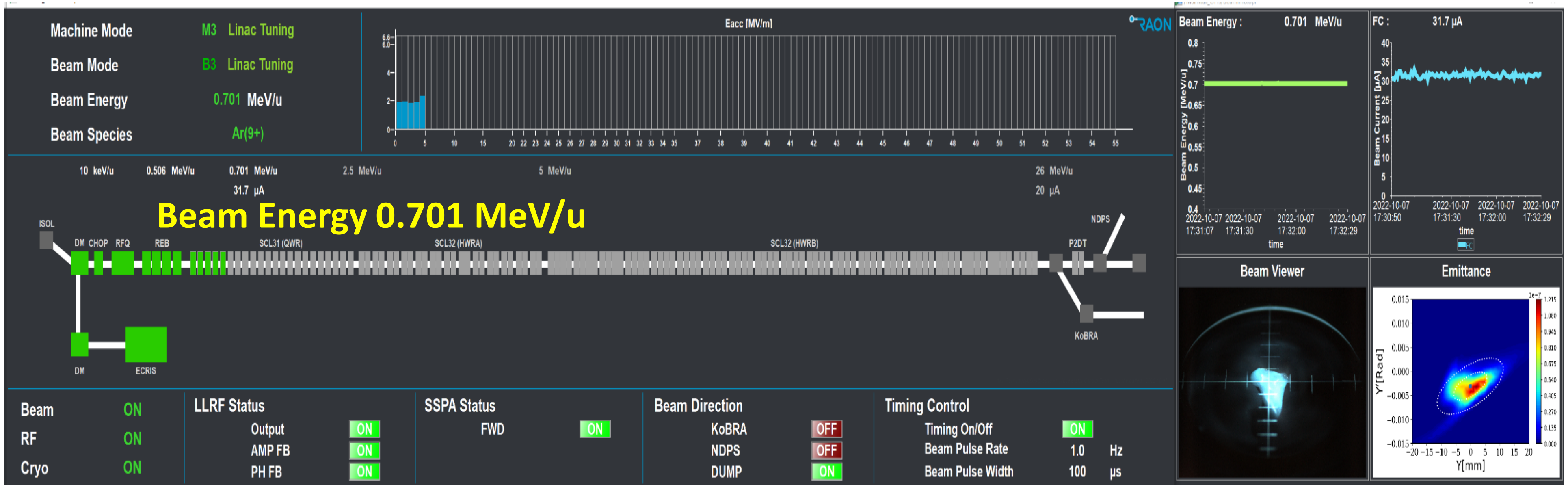
- Construction plan
  - Phase I [2011~2022]: Injector + ISOL + SCL3 + IF + Expt. Systems
  - R&D [2023~2025]: SCL2 cavities & modules
  - Phase II [Period to be determined ~2030 (?)]: Construction of SCL2

RIB Accelerator Facility

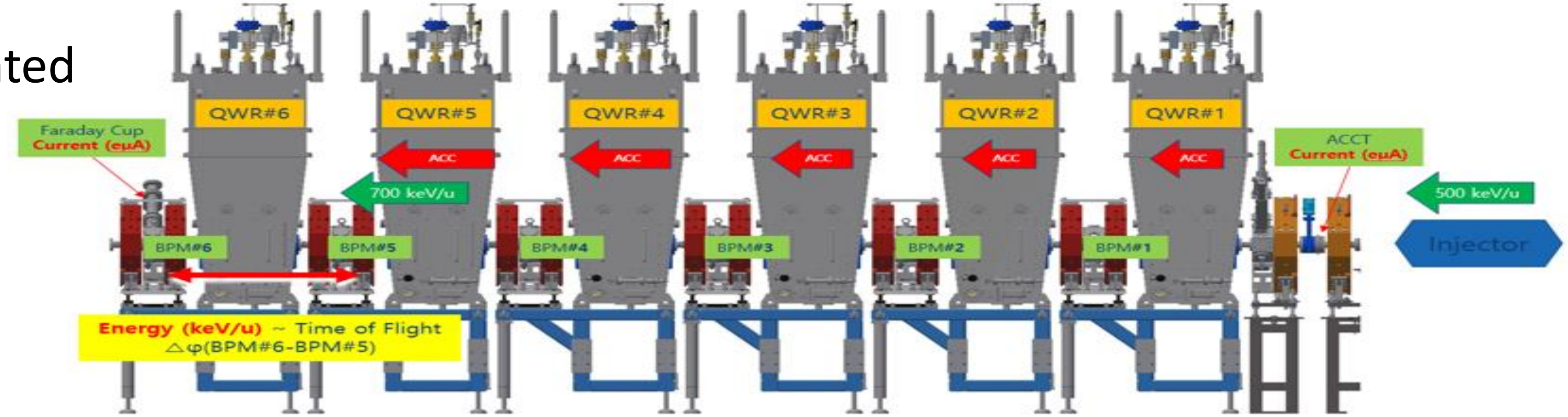


RIB Accelerator Facility

The 1st SCL3 beam commissioning (Oct. 7, 2022)

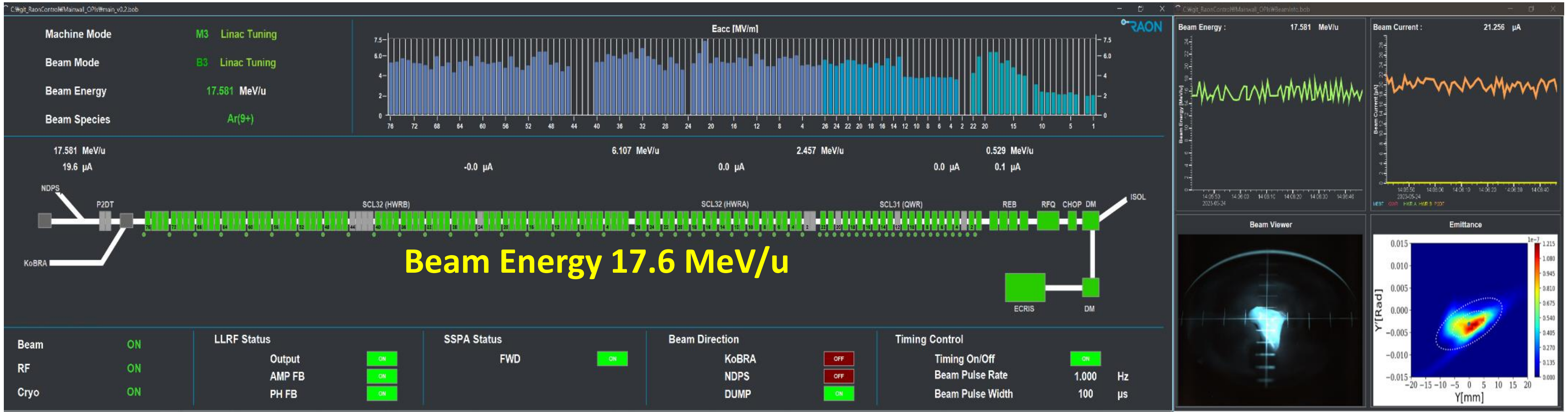


Ar^{9+} beams accelerated by QWR #1~#5

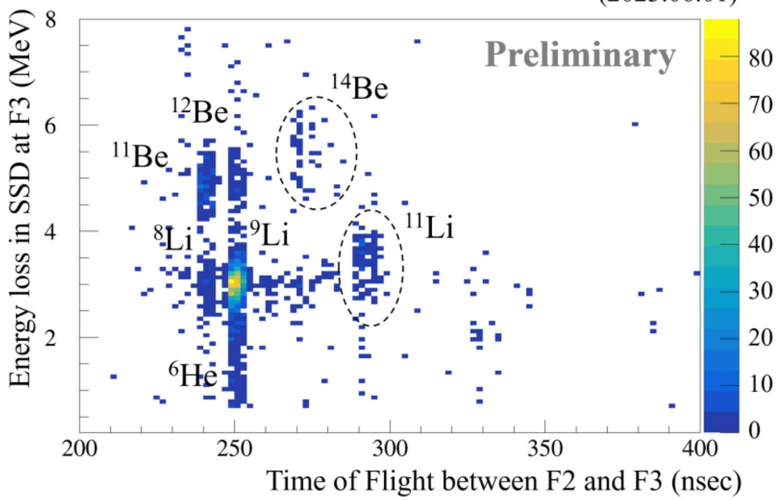


RIB Accelerator Facility

The 3rd SCL3 beam commissioning (May 23, 2023)

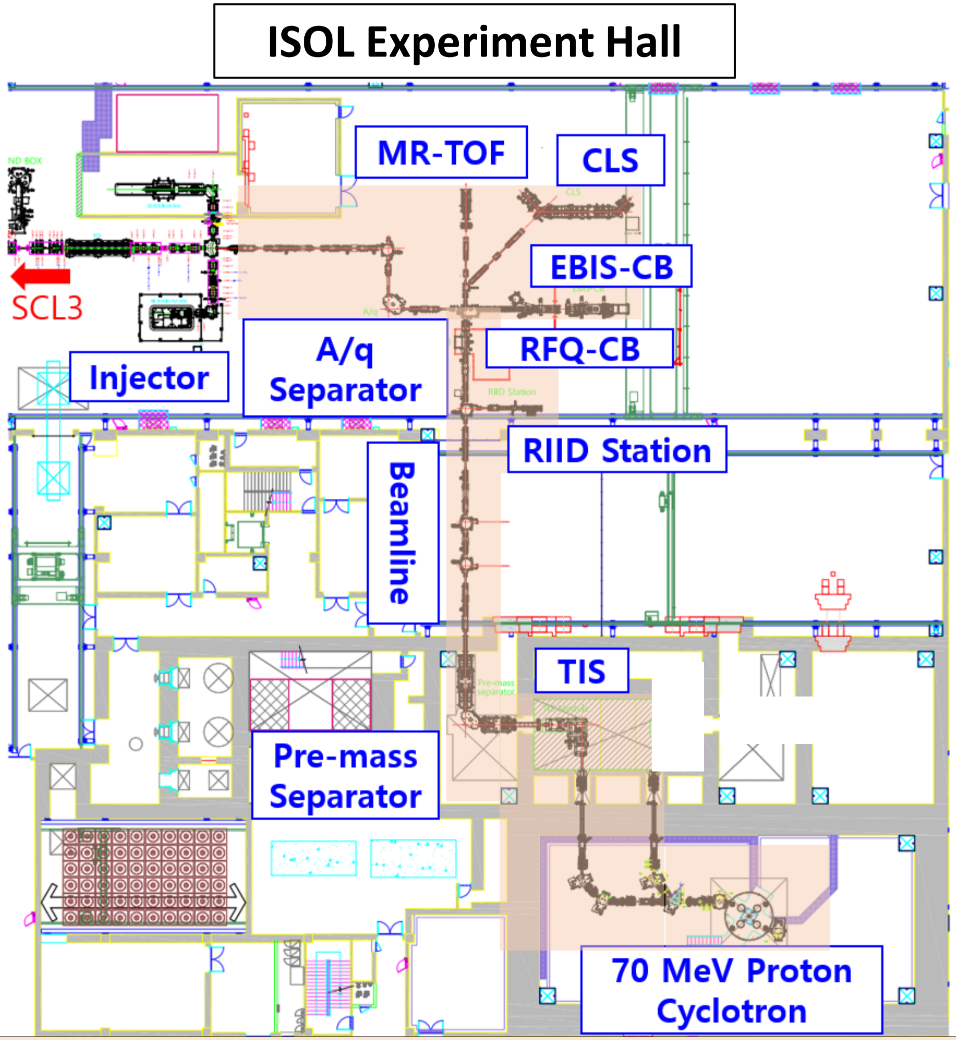


Particle identification with the first KoBRA beam commissioning (2023.06.01)



- Ar^{9+} beams accelerated by entire SCL3(QWR/HWR) on May 23
- Ar^{9+} beams delivered to the KoBRA target on May 31
  → **First RI production in F3 of KoBRA by Ar+C**
- SCL3 warm up and maintenance started from June.
- The beams plan to be delivered to KoBRA for experiments in early 2024.

RIB Accelerator Facility

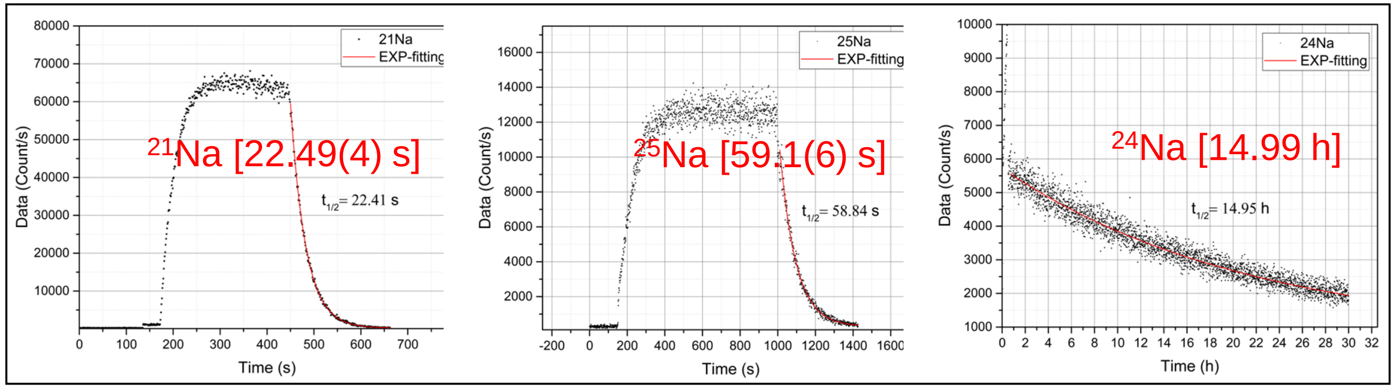


- ISOL beam lines including sub-systems commissioned with a Cs ion source in Dec. 2021
- **RI beam commissioning using SiC target in Mar. 2023)**

- Driver beam: 35∼70 MeV proton beams up to 70 kW
- Target: **SiC**, BN, MgO, LaC_2, UCx, CaO, BeO, etc.
- Ion Source: **Surface, RILIS**, Plasma
- RIB : 6 < A < 160, 10 < K < 80 keV, 10^8 pps (Sn), > 90% purity for experiments
  - Incident on RFQ of the post accelerator with 10 keV/u
  - Full remote maintenance system with TIS modularization

ISOL beam commissioning with ISOL

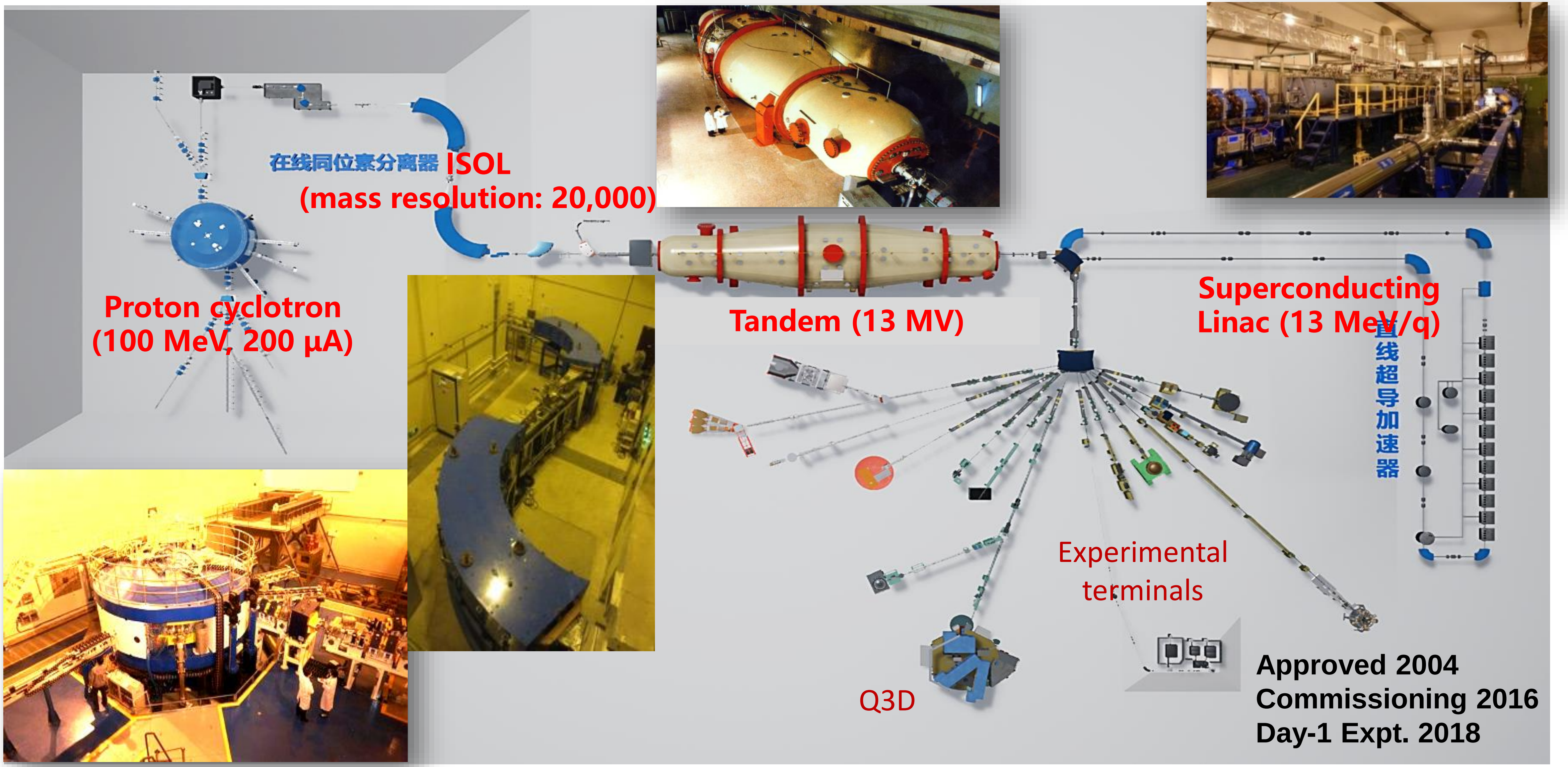
- ^{21,22,24,25}Na on March 3
- ^{26m}Al and ^{20}Na on May 23
  - Proton beam: 70 MeV, 1.2 μ A
  - SiC target temperature: ∼1,400℃ (Ta heater ohmic heating 1.8 kW)



RIB Accelerator Facility

Materials from Bing Guo

Beijing Radioactive Ion beam Facility (BRIF) @ CIAE



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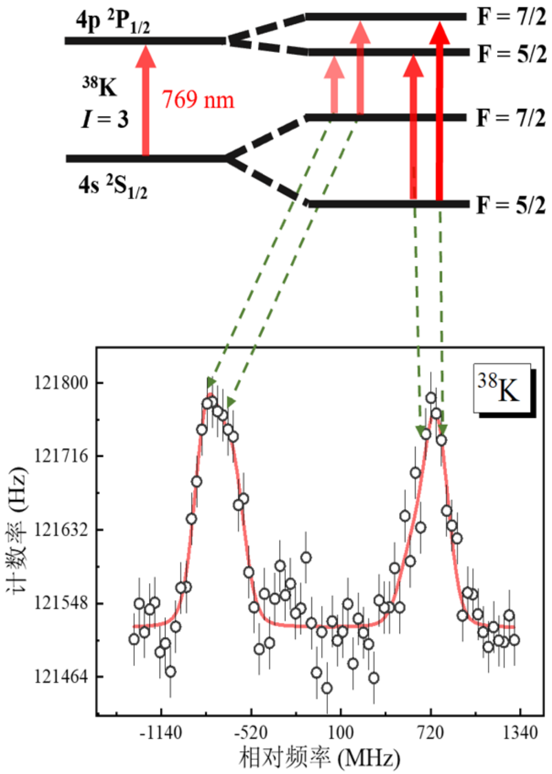
RIB Accelerator Facility

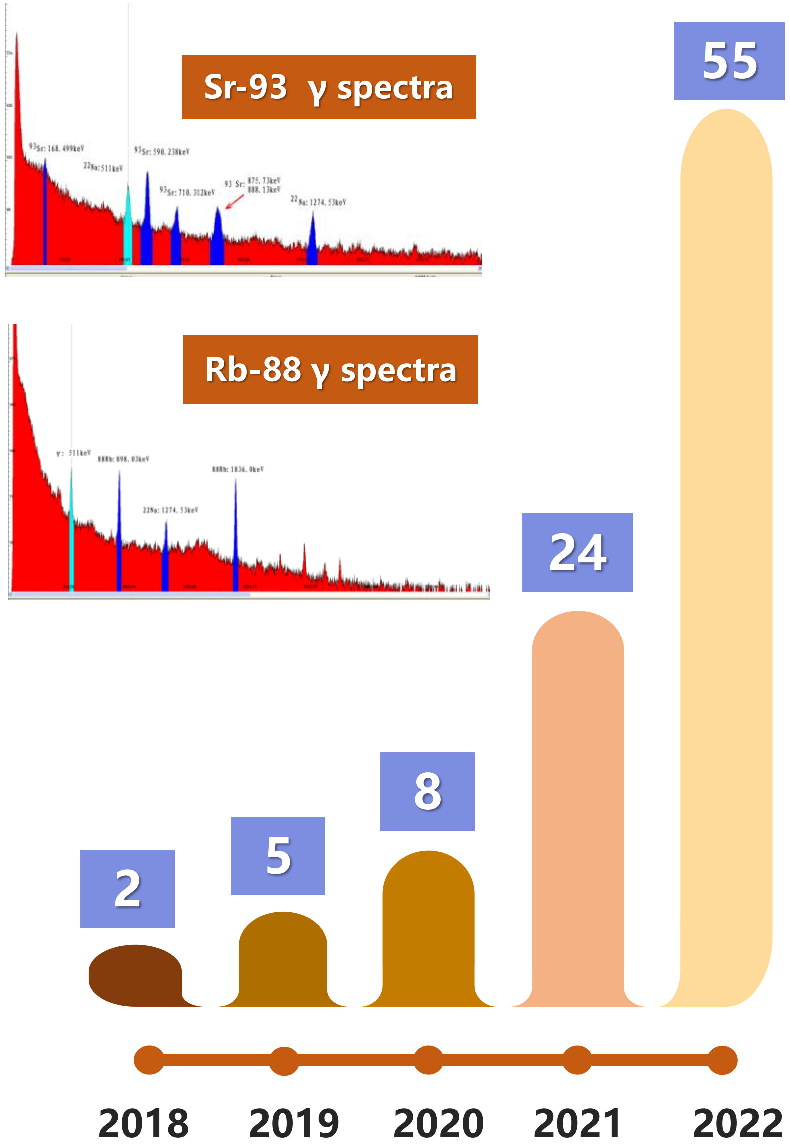
Beijing Radioactive Ion beam Facility (BRIF) @ CIAE

- Production of fission fragment RIBs (Rb, Sr, etc.)
- Number of produced RIB types: 24 → 55
- The shortest half-life of RIB with ISOL: 0.45 sec → 0.17 sec
- Beam intensity: $10^3 \sim 10^{10}$ pps

- First RIB Expt.: 3 $\beta - \gamma - \alpha$ exotic decays in ^{20}Na [PRC103, L011301 (2021)]
- First Expt. with the post-accelerated Na beams on ^{40}Ca target [NST32, 53 (2021)]
- First CLS Expt. [NIMA1032, 166622 (2022)]

HFS spectra of unstable ^{38}K by CLS





RIB Accelerator Facility

Materials from Wenlong Zhan

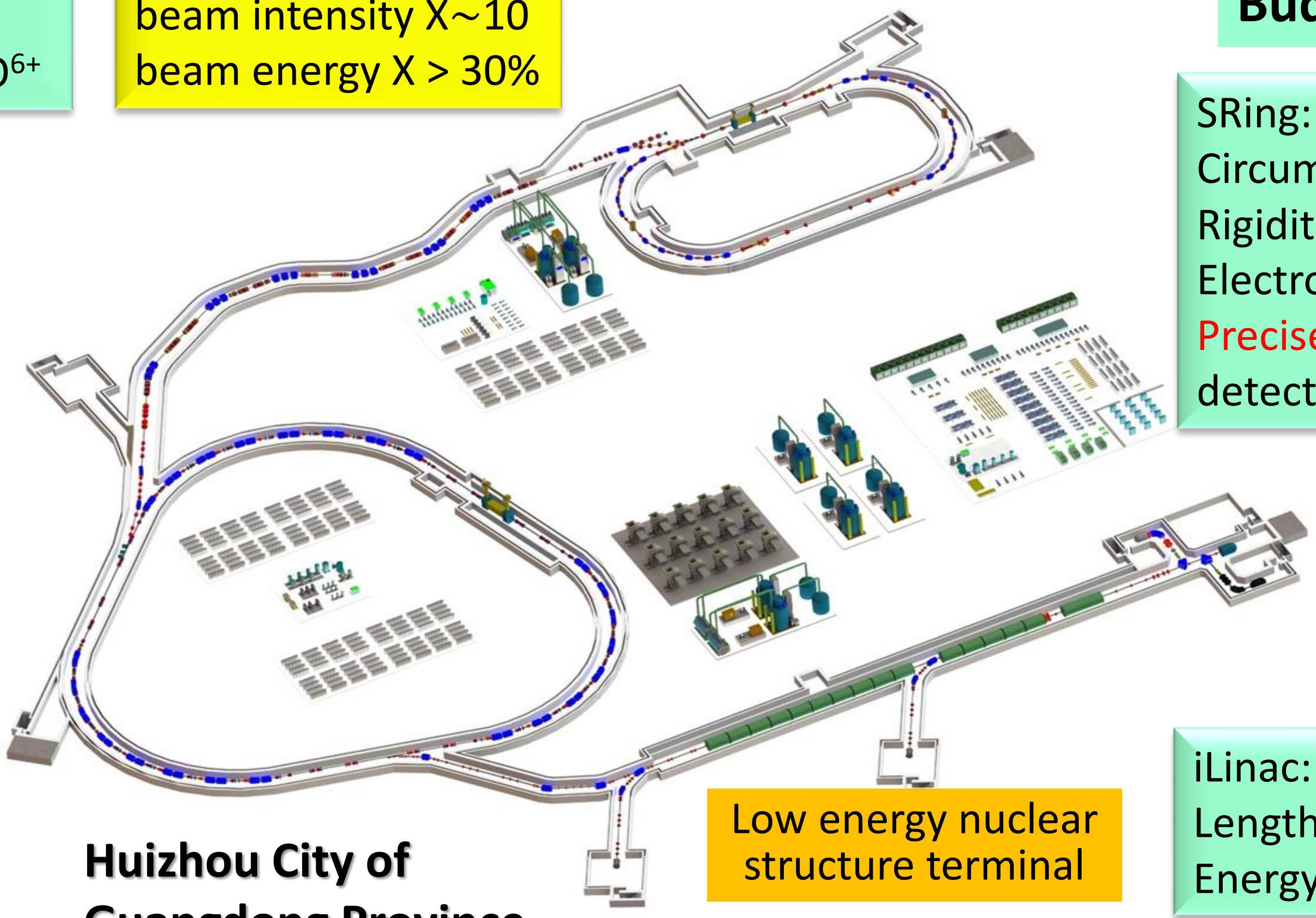
Heavy Ion Accelerator Facility (HIAF): 1st Phase

E_{B1}: 0.8 AGeV, 3×10^{10}ppp $^{238}U^{35+}$
1.75 AGeV, 7.5×10^{10}ppp $^{78}Kr^{19+}$
2.6~3.0 AGeV, 1.0×10^{11}ppp $^{16}O^{6+}$

After optimization,
beam intensity X~10
beam energy X > 30%

HIAF-I: 2018-2025
Budget: 1.6+1.2B CNY

External target station
High Energy Density Physics (HEDP)
Nuclear matter study - CEE
Hypernuclear physics
High energy irradiation



SRing: Spectrometer Ring
Circumference: 273 m
Rigidity: 15 → 20 Tm
Electron/Stochastic cooling
Precise measurement by two TOF detectors, four operation modes

SECRAL and FECR
28-45GHz,1.0emA (U^{35+})

BRing1: Booster Ring 1
Circumference: 600 m
Rigidity: 34 → 40 Tm
Large acceptance (200/100)
Two planes painting injection
Fast ramping rate (3-10 Hz)

Huizhou City of Guangdong Province

Low energy nuclear structure terminal

iLinac: Superconducting linac
Length: 100 m
Energy: 17~22 MeV/u ($U^{35+\sim46+}$)

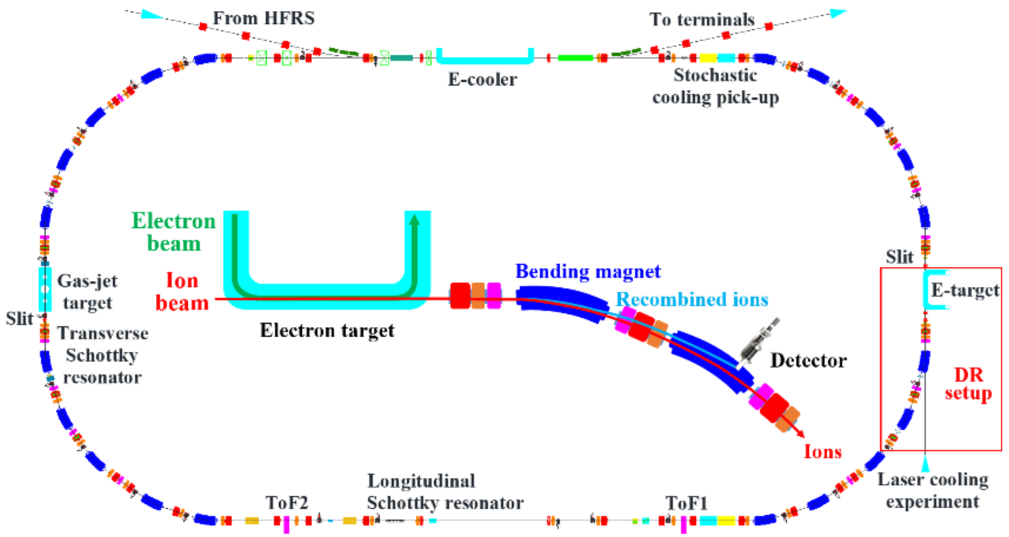
ANPhA Asian Nuclear Physics Association

RIB Accelerator Facility

Heavy Ion Accelerator Facility (HIAF)

- Beam physics study
  - Highest pulse beam
- ECR ion source
  - 45 GHz 12 T Nb_3Sn SECRIS under assembling
- Key technology development for HI synchrotron
  - 0.3 mm chamber for high vacuum
  - High-gradient magnetic alloy RF for fast injection, etc.
  - Active power source for high repetition rate
  - Results
    - Beam Intensity → X100
    - Repetition rate → ~10 Hz
    - Assembly time: years → months
    - Tunning time: months → days
- HFRS for in-flight fragmentation of projectiles
- High Accuracy Spectrometer at SRing
- CEE R&D and fabrications

Laboratory	Facility	Design Intensity	Heavy Ion
BNL	AGS Booster		Au^{32+}
JINR	NICA Booster	4×10^{9}	Au^{32+}
GSI	SIS18	1.0×10^{11}	U^{28+}
FAIR	SIS100	4.0×10^{11}	U^{28+}
IMP	HIAF-SRing	$5/20\times10^{11}$	U/Bi $^{(35\text{-}45)+}$
IMP	HIAF-BRing-SRing	$1/5\times10^{12}$ $2/12\times10^{12}$	U/Bi $^{(35\text{-}45)+}$

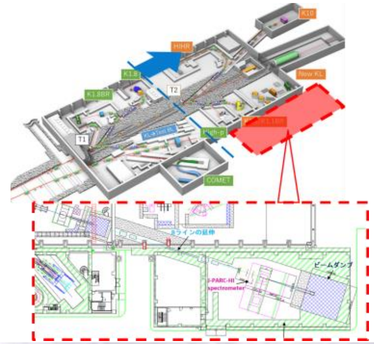


RIB Accelerator Facility

Hadron Accelerator Facility

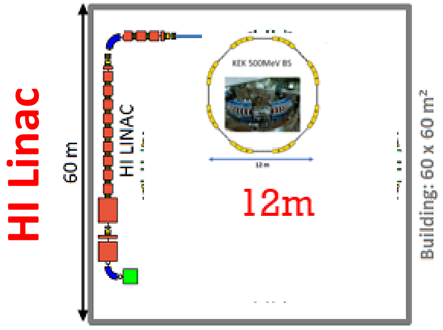
Materials from Kazuhiro Tanaka

- Upgrade of J-PARC for heavy-ion beams
  - New heavy-ion injector (LINAC and BOOSTER)
  - New experimental area and spectrometers
- Staging plan
  - On-going
    - pA collisions using existing beamline and spectrometer (Vector meson production in e^+e^- decay modes)
    - Upgrade of the spectrometer for hadron measurements
  - Phase I
    - New LINAC and **reuse of KEK-PS 500 MeV** booster
    - Upgrades of the existing spectrometer
    - Beam Intensity: 10^8 Hz for Au
  - Phase II
    - New booster and new spectrometer
    - Final configuration



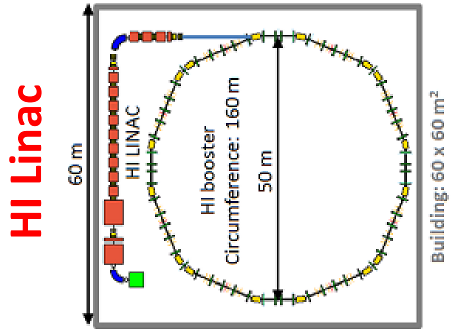
Phase I

Reused Booster Ring



Phase II

HI Booster Ring



Summary

- Nuclear physics facilities in Asia in the construction, commissioning, upgrade, or operational stage:
  - Underground facilities: SUPL (Australia), CJPL-II (China), Yemi Lab. (Korea)
  - RIB accelerators: BRIF, JUNA, HIRFL, HIAF (China), RIBF, RCNP (Japan), RAON (Korea)
  - Hadron accelerators: HIAF (China), J-PARC (Japan)
  - Photon & electron accelerators: Spring-8, ELPH (Japan)

- The facilities in Asia, Europe, and U.S.A. are overlapped or complimentary. For example,
  - INFN Gran Sasso National Laboratory (LNGS) in Europe
  - The Isotope mass Separator On-Line facility (ISOLDE) at CERN in Europe
  - Facility for Rare Isotope Beams (FRIB) in Michigan State University in U.S.A.
  - Electron-Ion Collider (EIC) at BNL in U.S.A.

- *The collaboration among different continents must be greatly beneficial to all of us!*