

# Report from ANPhA -Status of Nuclear Physics Facilities in Asia-

**Byungsik Hong** (Korea University)

Chair of Asian Nuclear Physics Association (ANPhA)

<https://asiannuclearphysic.wixsite.com/anpha>

IUPAP WG9/C12 Annual General Meeting 2025

IBS, Daejeon, Korea, 28 May 2025

## ■ Current management (2023-2025)

- Chair: Byungsik Hong (Korea)
- Vice Chairs: A. Thomas, G. Xiao, T. Uesaka
- Secretary: Yongsun Kim (Korea)

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- 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)
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- 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)
- Uzbekistan: Bakhadir Irgaziev (National University of Uzbekistan)
- Singapore: Andrew Anthony Bettiol (National University of Singapore)
- Thailand: Thawatchai Onjun (TINT)

## ■ Observers

- Weiping Liu, Kazuhiro Tanaka, Dong-Pil Min, Yanlin Ye, Hideyuki Sakai, Shoji Nagamiya, Tohru Motobayashi, Eberhard Widmann (NUPECC)



Chair



Secretary

- Uzbekistan & Singapore joined in 2023.
- Thailand joined in 2024.

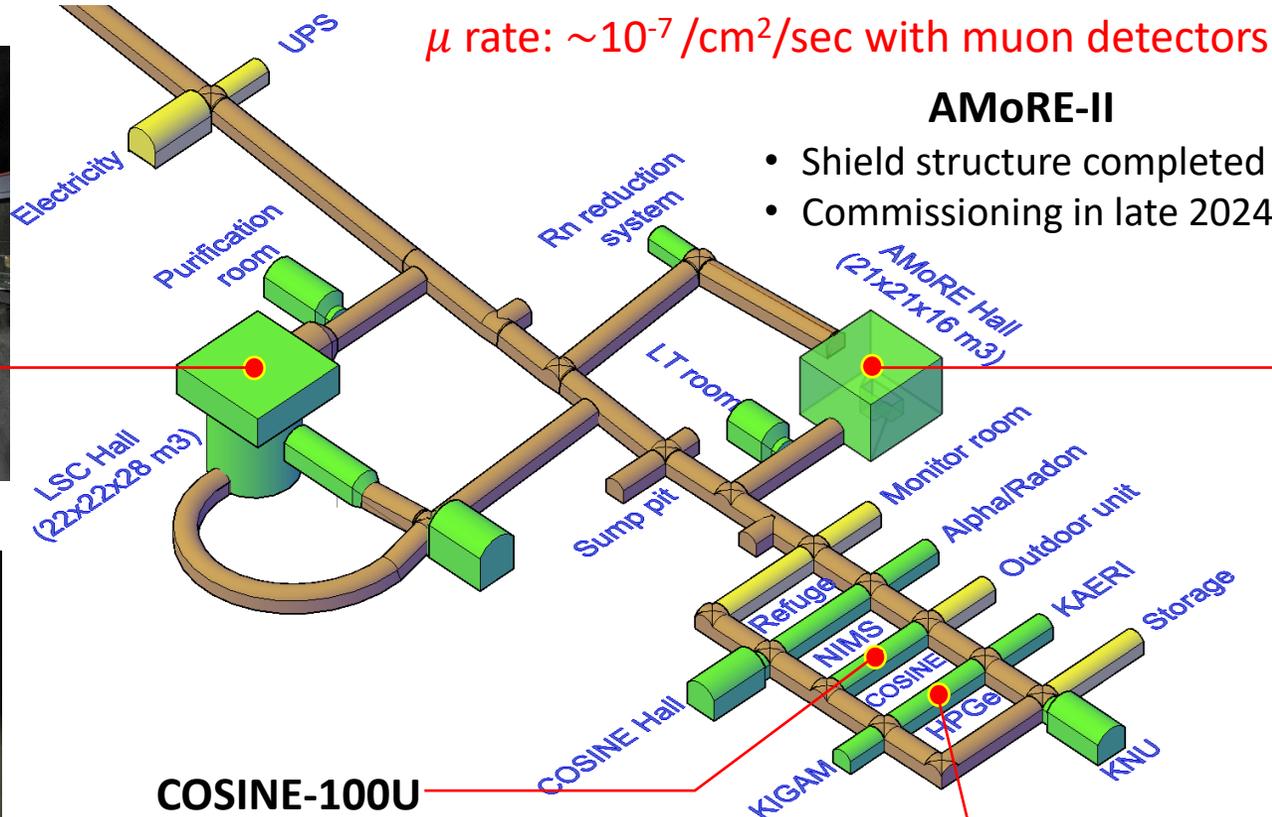
- Previous ANPhA Board Meeting & Symposium, SCNT, Huizhou City, China, 14-16 Nov. 2024



- Next meeting: Institute of Physics, Academia Sinica, Taipei, 27-29 Nov. 2025  
<https://indico.phys.sinica.edu.tw/event/228/>

## Yemilab: a new underground laboratory in Korea

- Y2L (700 m deep, 2003-2023): COSINE-100, AMoRE-I
- Yemilab (1,000 m deep, 2022-): COSINE-100U, AMoRE-II,  $\nu$ EYE, Cryogenic DM searches, etc.

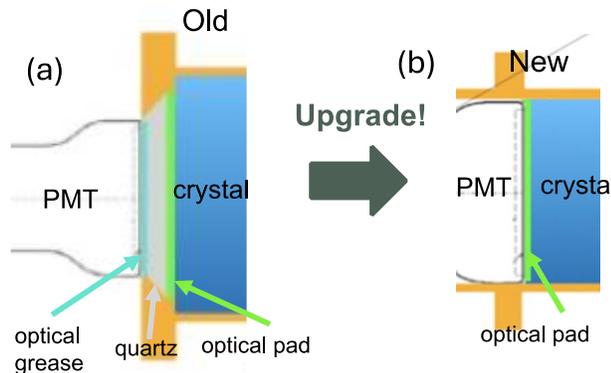
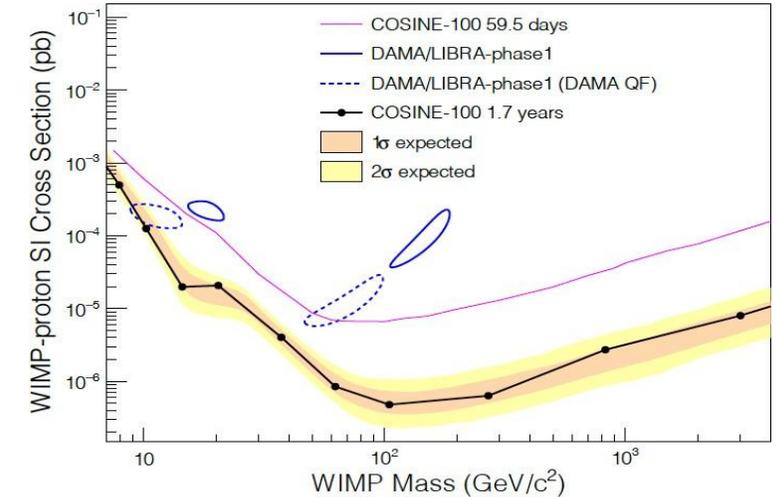


## Dark matter search

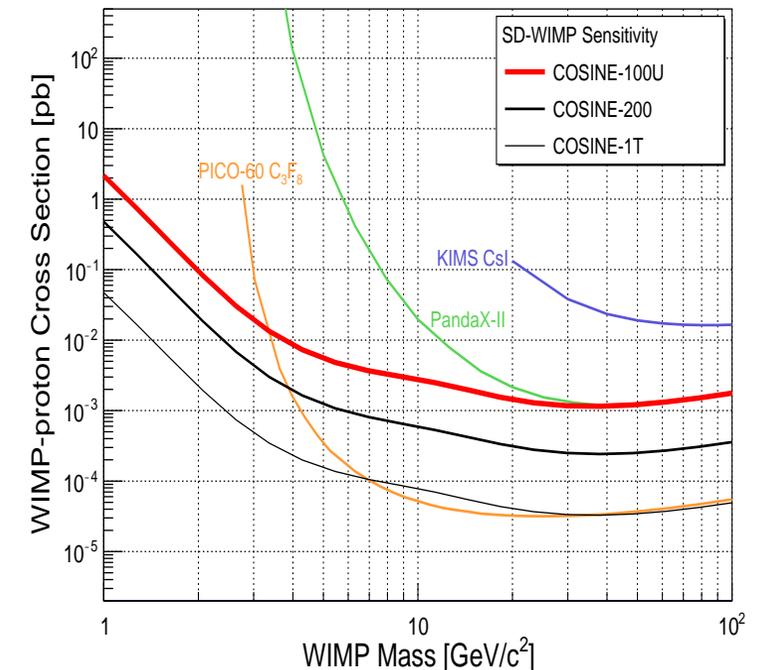
- COSINE-100 experiment @ Y2L
  - DAMA/LIBRA annual modulation of standard halo model was rejected.
- Relocation of COSINE-100: Y2L→Yemilab
- Upgrade COSINE-100 to COSINE-100U
  - Improving the light collection capability of NaI(Tl) by modifying the geometry and PMT attachment method: NIMA 981, 164556 (2020)
  - $21.6 \pm 0.6$  NPE/keV (30%  $\uparrow$ )
  - Commissioning in early 2024: Main experiment will begin in 2025



Sci. Adv. 7, 2699 (2021)



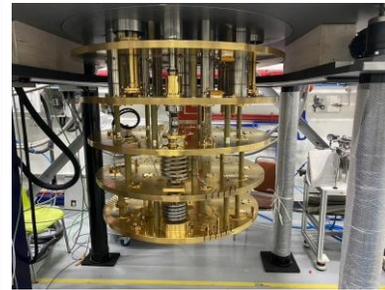
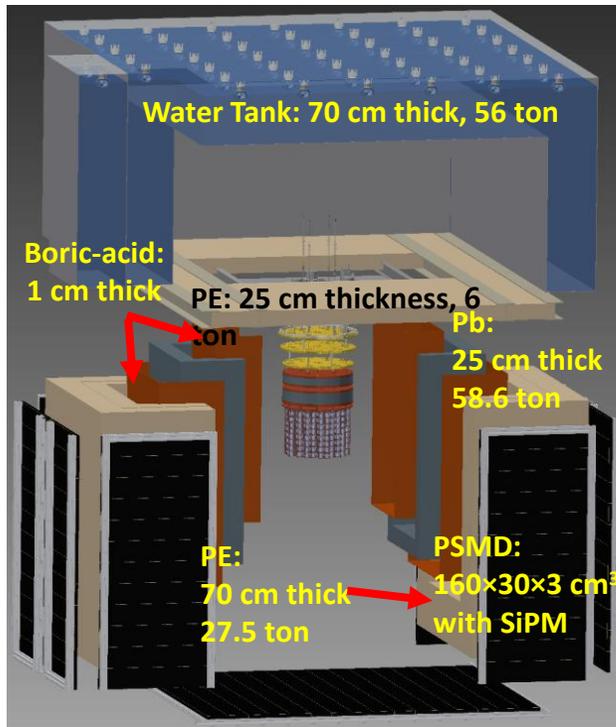
- Future experiment: COSINE-200
  - Development of **ultra-low background NaI crystals**
  - Aims a world best limit for low-mass WIMP-proton cross section



## Neutrinoless double beta decay ( $0\nu\beta\beta$ )

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

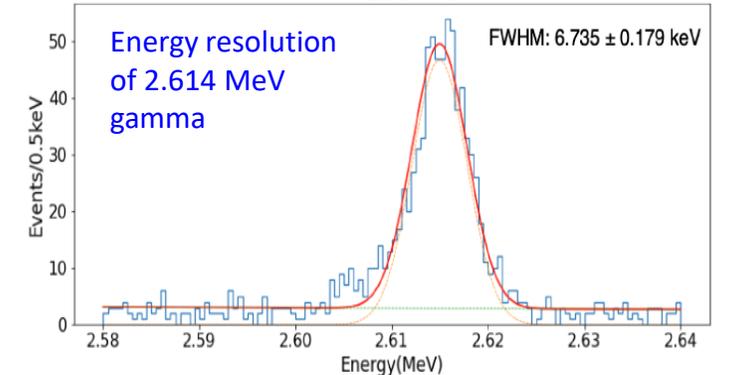
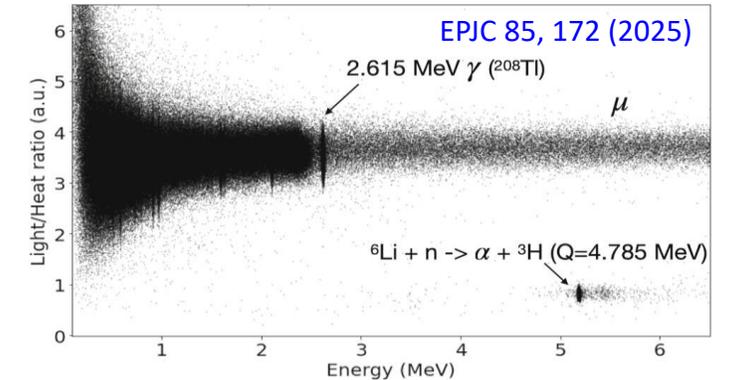
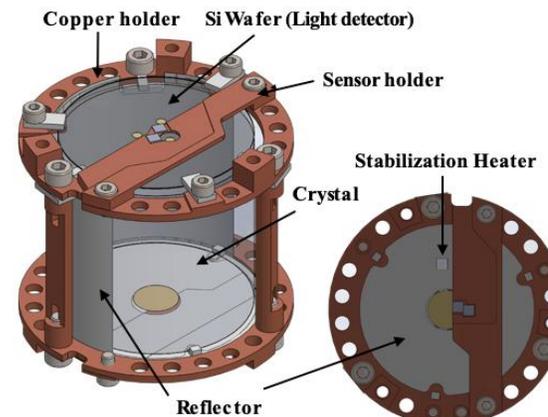
- Proves neutrinos are Majorana fermions & strengthen seesaw mechanism and leptogenesis.
- AMORE-II experiment @ Yemilab
  - 100 kg of  $^{100}\text{Mo}$  to reach  $T_{1/2}^{0\nu\beta\beta} > 4.5 \times 10^{26}$  years for 5 years: both phonons & photons measured by MMC+SQUID
  - So far 360 LMO( $\text{Li}_2^{100}\text{MoO}_4$ )+13 CMO( $^{40}\text{Ca}^{100}\text{MoO}_4$ ) cylindrical crystals (~85 kg of  $^{100}\text{Mo}$ ) were grown.
  - Stage-1 run with 90 crystals in 2025-2026  $\Rightarrow$  Stage-2 run with 360 crystals in 2026-2030



↑ Dilution refrigerator (DR)  
↓ Installed muon detectors



$\rightarrow$  Tests at ground showed satisfactory energy resolution and alpha rejection power.

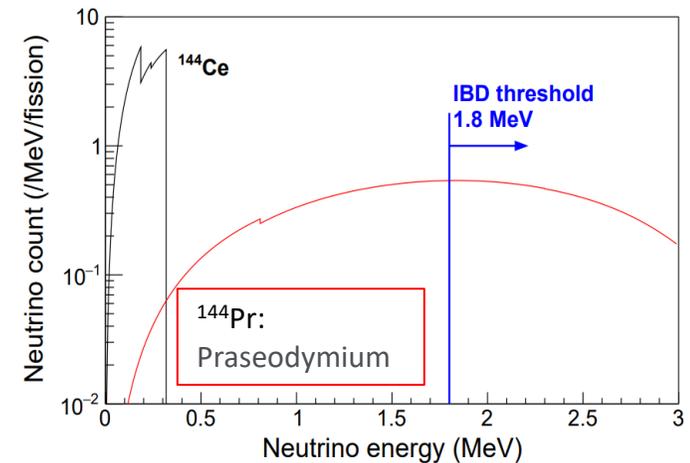


## Large Neutrino Detector: “Neutrino physics opportunities with the IsoDAR source at Yemilab”, (Future plan) <https://www.nevis.columbia.edu/daedalus/exp/isodar.html>, PRD 105, 052009 (2022)

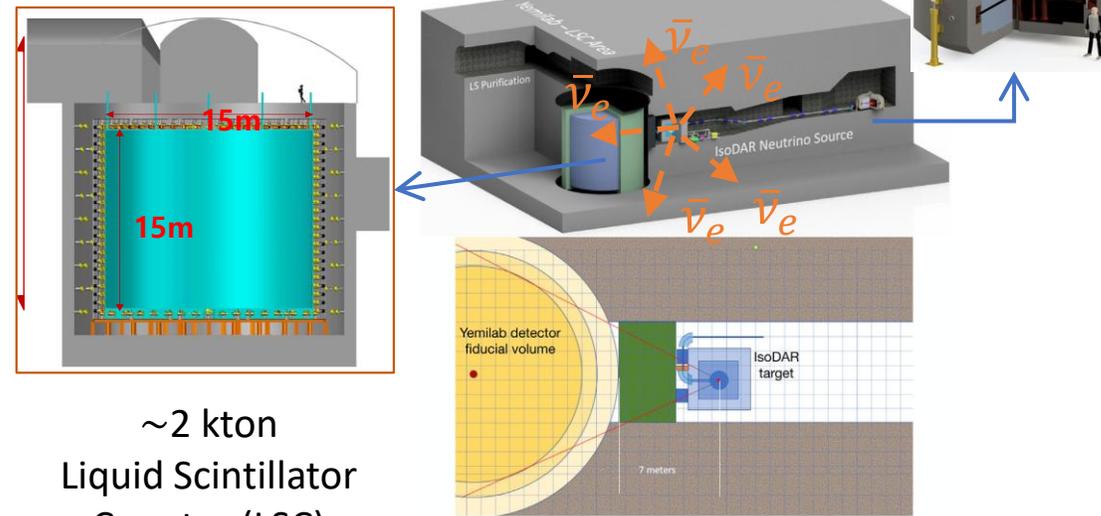
- IsoDAR@Yemilab plans to use  $\sim 10^{23}$   $\bar{\nu}_e$ s from decay of  ${}^8\text{Li}$ , bombarding  $p$  beams from cyclotron on Be target
  - Sterile neutrino search using the inverse beta decay (IBD)  $\bar{\nu}_e p \rightarrow e^+ n$
  - Nonstandard interaction search using elastic scattering off atomic electrons ( $\bar{\nu}_e e \rightarrow \bar{\nu}_e e$ )
  - Precision test of weak interaction (weak mixing angle) with very short baseline oscillation ( $\bar{\nu}_e \rightarrow \bar{\nu}_e$ )
  - Search for new particles such as a light  $X$  boson, etc.

Alternatively, 100 kCi  ${}^{144}\text{Ce}$  can be used:  ${}^{144}_{58}\text{Ce} \rightarrow {}^{144}_{59}\text{Pr} \rightarrow {}^{144}_{60}\text{Nd}$   
Decay processes emit  $\bar{\nu}_e$ s.

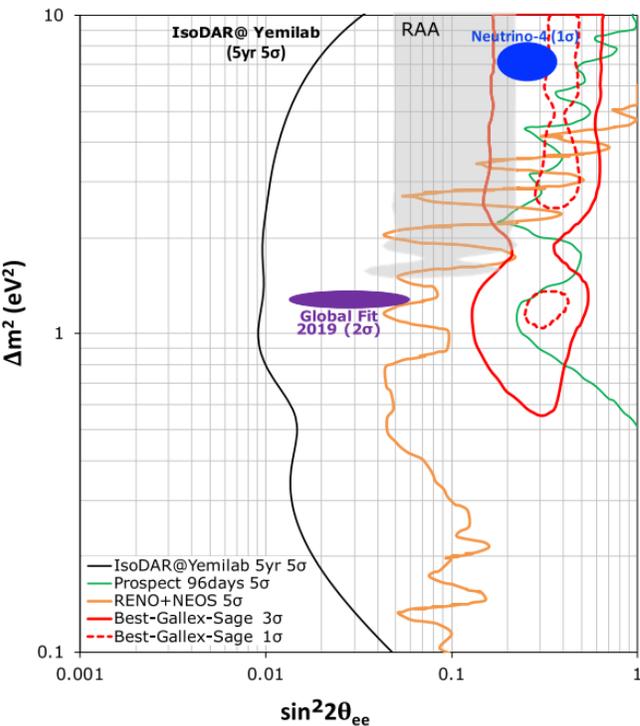
arXiv:2401.1321



Measurement of the energy ( $E$ ) and vertex ( $L$ ) of neutrinos for  $L/E$  for each event



$\sim 2$  kton  
Liquid Scintillator  
Counter (LSC)



## Kamioka Facility

ICRR, University of Tokyo <http://gwcenter.icrr.u-tokyo.ac.jp/wp-content/uploads/2011/02/LCGT.jpg>  
大型低温重力波望遠鏡KAGRAサイトから

KamLAND-Zen

$^{136}\text{Xe}$  double beta decay  
neutrino



CANDLES

$^{48}\text{Ca}$  double beta decay



Dark Matter search/R&D

NEWAGE

Direction sensitive  
dark matter search

Lab A

Low radioactivity detectors

Super-Kamiokande  
Super Nova Neutrino



**New : KERNEL**

Super clean room  
Clean air system  
Pure water system,  
etc.



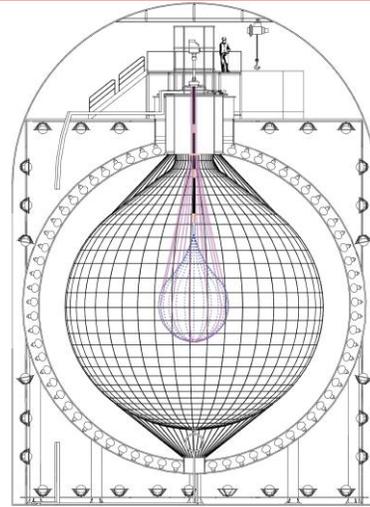
- Kamioka Observatory (ICRR)
- Kamioka Underground Laboratory (RCNS)
- **New Facility : Kamioka Extremely Rare phenomena and NEutrino research Laboratory (KERNEL) under construction**
  - Research Center for Neutrino Science(RCNS), Tohoku University
  - Research Center for Nuclear Physics(RCNP), Osaka University
  - Particularly low radiation environment for rare event search such as double beta decay of dark matter



## KERNEL related projects

KamLAND2-Zen: double beta decay under construction

DAQ was stopped for KamLAND upgrade (Aug. 2024)



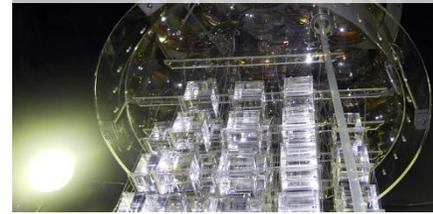
Removal of PMTs for outer detector (Feb. 2025)



Liquid Scintillator Extraction

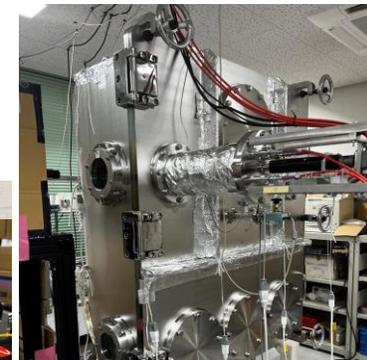
DAQ will be restarted in 2027

CANDLES-LT: double beta decay under development



CaF<sub>2</sub> scintillating bolometer

blue laser



LIS system for <sup>48</sup>Ca enrichment

Other Projects

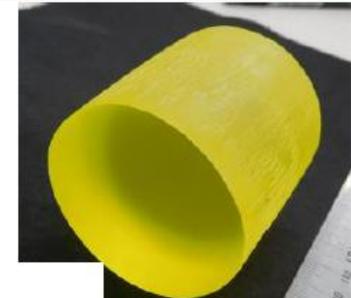


CryoLab dark matter search

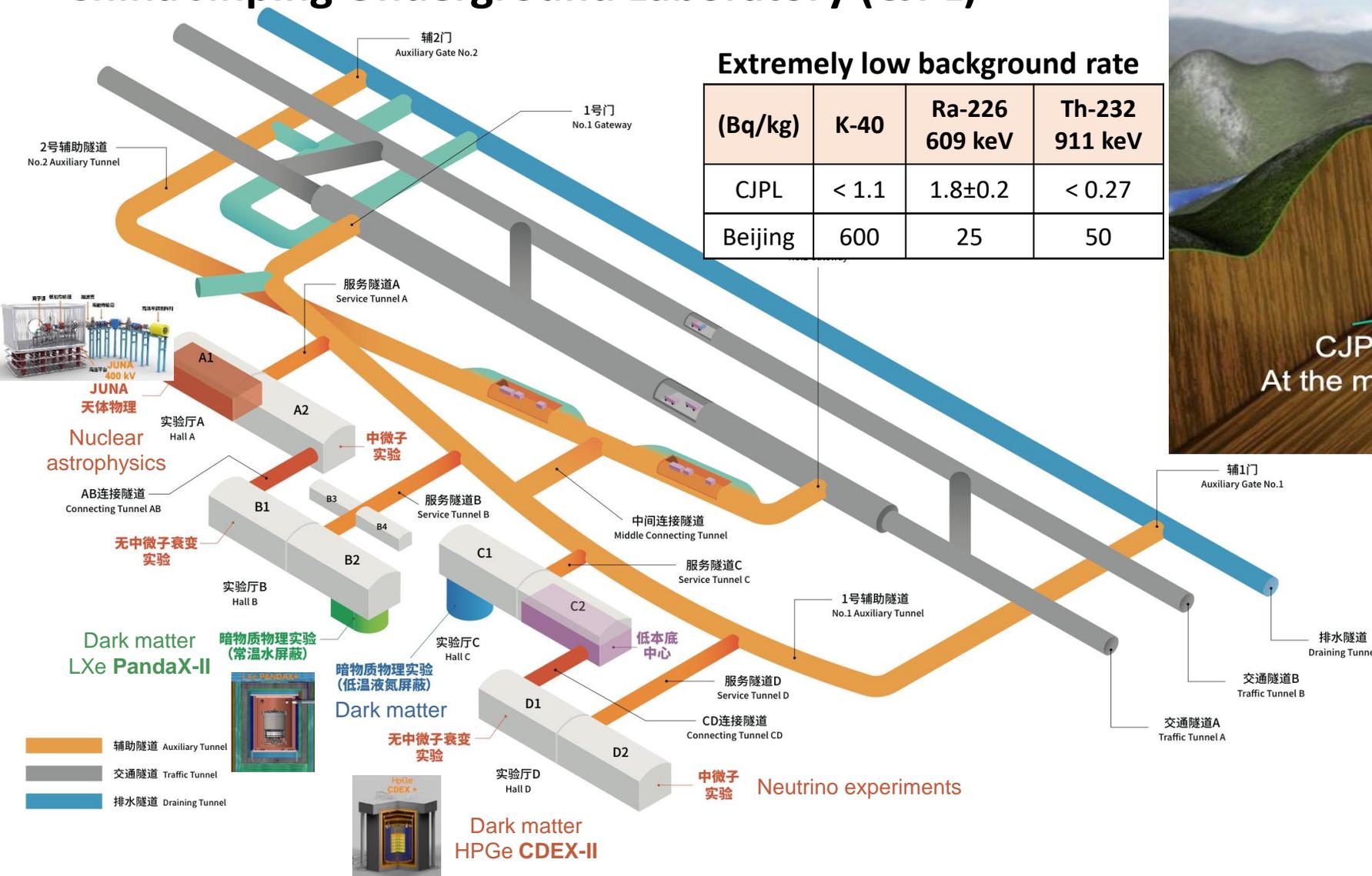


PICOLON dark matter search

PIKACHU double beta decay

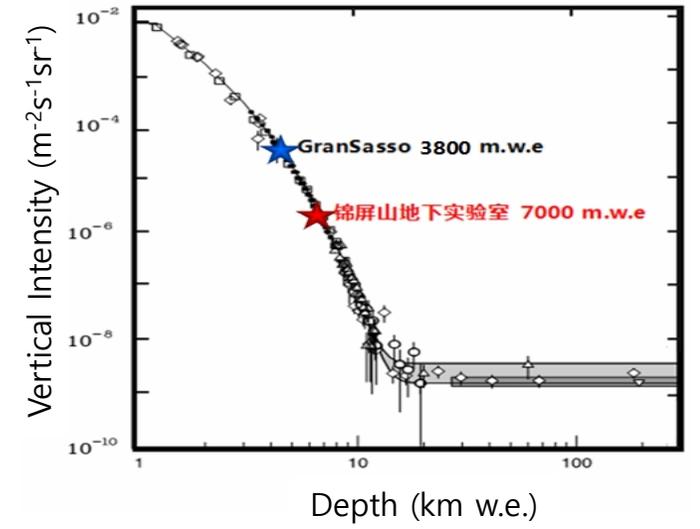
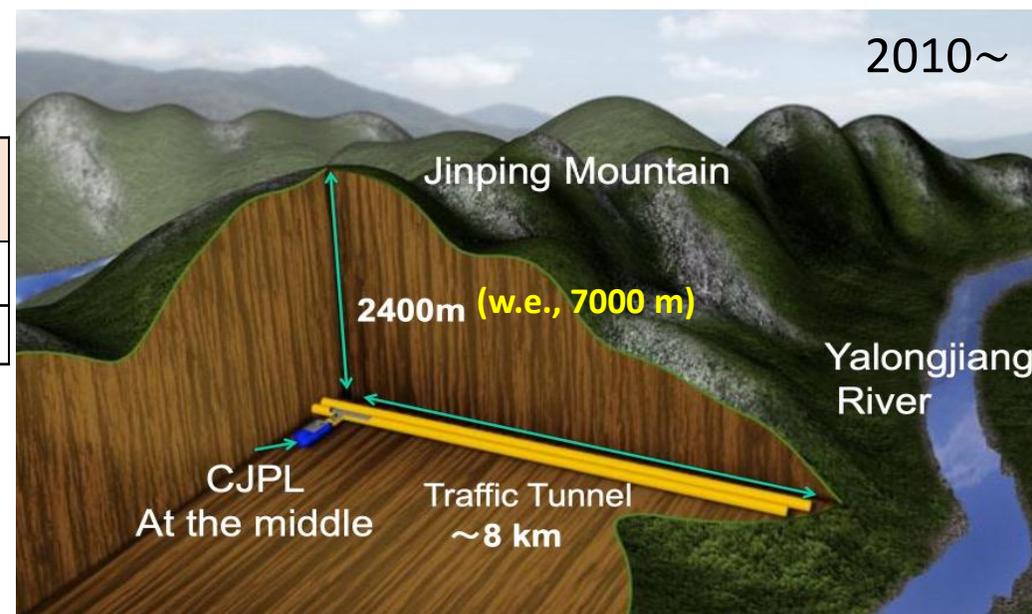


## China Jinping Underground Laboratory (CJPL)



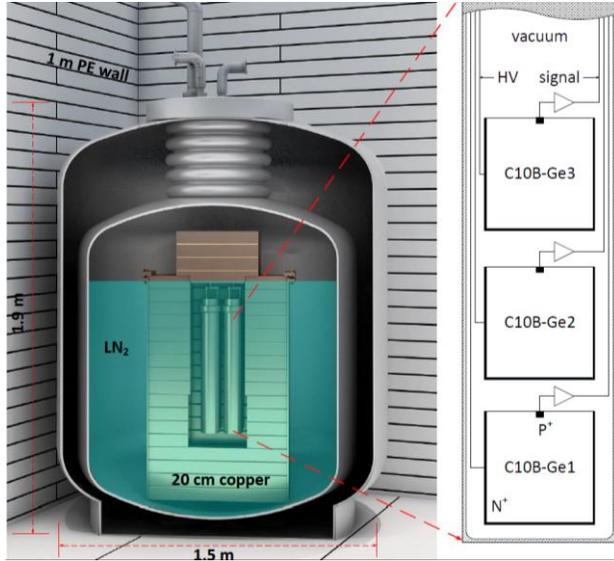
Extremely low background rate

(Bq/kg)	K-40	Ra-226 609 keV	Th-232 911 keV
CJPL	< 1.1	1.8±0.2	< 0.27
Beijing	600	25	50



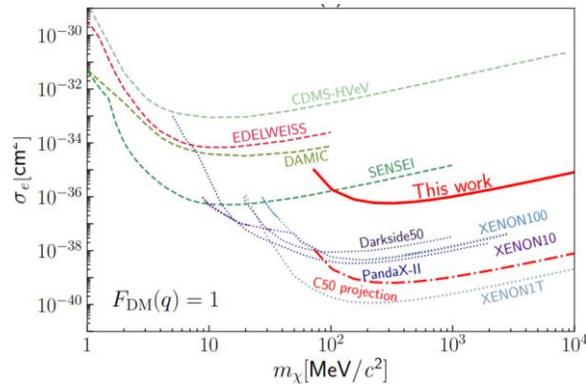
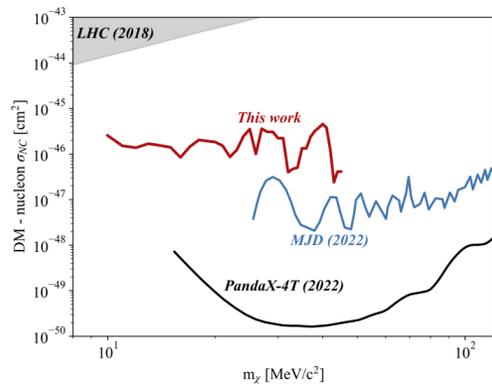
## China Dark Matter Experiment (CDEX)

**Ge** to search for light-WIMP: PRL 123, 221301 (2019)  
PRL 129, 221802 (2022), PRL 129, 221301 (2022)



- **CDEX-10 (2016):** 10-kg Point Contact Ge detectors immersed into liquid nitrogen
- CDEX-50 (in-preparation)
- CDEX-300 ( $\geq 2027$ )
- CDEX-1T

**Cf.) LEGEND-200  
LEGEND-1000**



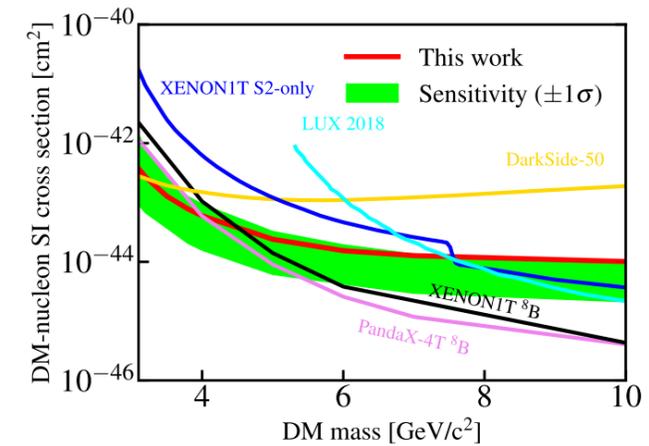
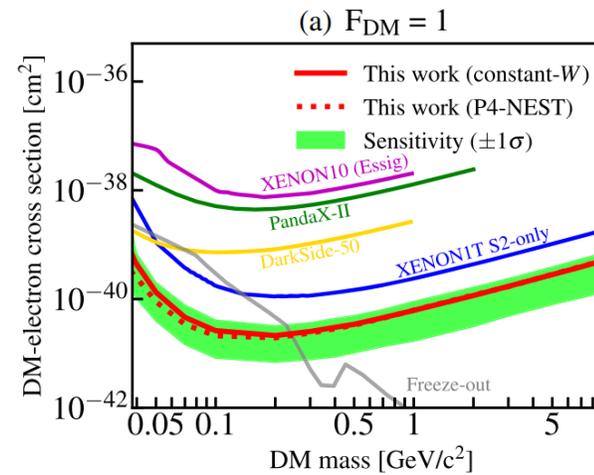
## Particle and Astrophysical Xenon Experiment (PandaX)

**Xe** to search for dark matter: Nature 618, 47 (2023),  
PRL 130, 261001 (2023), PRL 130, 021802 (2023)



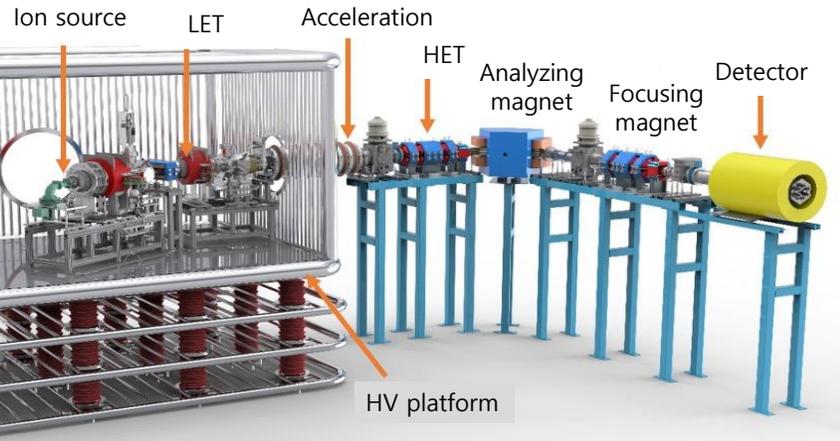
- PandaX-II (2014-2019): Dual-phase TPC with half-ton of ultra-high purity liquid  $^{136}\text{Xe}$   
**120 kg in 2014**  
**→ 580 kg in 2018**
- **PandaX-4T (2021-):** 5.75 tons of Xe

**Cf.) nEXO**



## JUNA nuclear astrophysics facility at CJPL

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



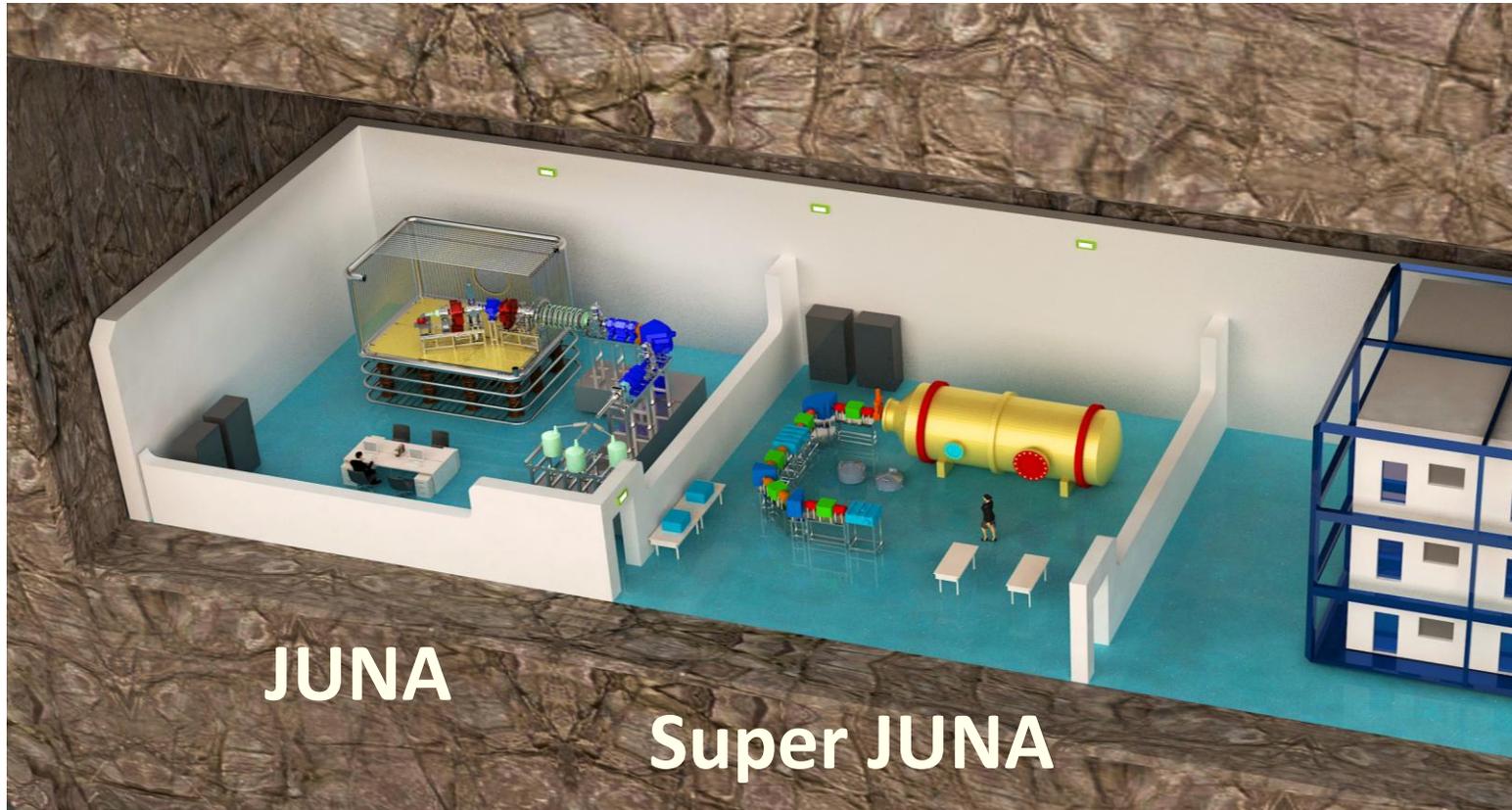
### Experimental conditions for JUNA

Cosmic muon Bkg. ( $\text{cm}^{-2}\text{s}^{-1}$ )	Beam energy (keV) / Maximum beam intensity (emA)			Energy stability
	H <sup>+</sup>	He <sup>+</sup>	He <sup>2+</sup>	
$2 \times 10^{-10}$	50-400 / 2-10	50-400 / 2-10	100-800 / 1-2	0.04%

### List of experiments from the first run (2020-2021)

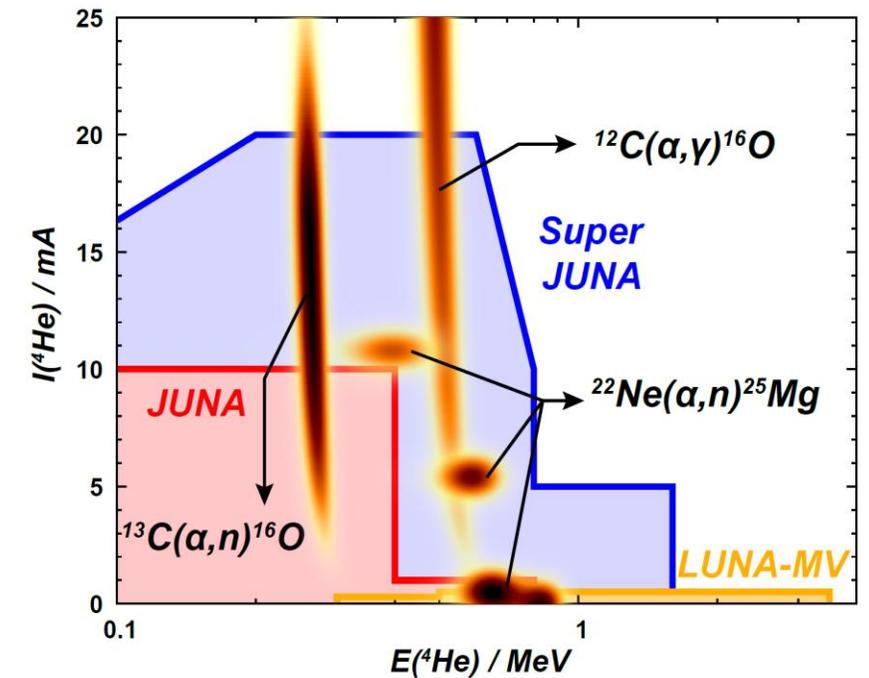
Reaction	Crucial parameters	Prior to JUNA	JUNA data	Publication
Holy grail $^{12}\text{C}(\alpha, \gamma)^{16}\text{O}$	Lowest energy (keV)	891	552	In preparation
	Cross section (b)	$10^{-11}$	$10^{-12}$	
Neutron source $^{13}\text{C}(\alpha, n)^{16}\text{O}$	Energy range (keV)	230-300	240-1900	PRL 129, 132701 (2022)
	s-process	50%	20%	
$^{26}\text{Al}$ abundance $^{25}\text{Mg}(p, \gamma)^{26}\text{Al}$	Uncertainty	21%	8%	Science Bulletin 67, 2 (2022) Cover paper
F abundance $^{19}\text{F}(p, \alpha\gamma)^{16}\text{O}$	Lowest energy (keV)	189	72	PRL 127, 152702 (2021)
	Uncertainty	80%	5%	Editor's suggestion
Ne isotope ratio $^{18}\text{O}(\alpha, \gamma)^{22}\text{Ne}$	Uncertainty	$472 \pm 18$ keV	$474.1 \pm 1.1$ keV	PRL 130, 092701 (2023)
CNO breakout $^{19}\text{F}(p, \gamma)^{20}\text{Ne}$	Lowest energy (keV)	300	200	Nature 610, 656 (2022)

## Plan for Super JUNA

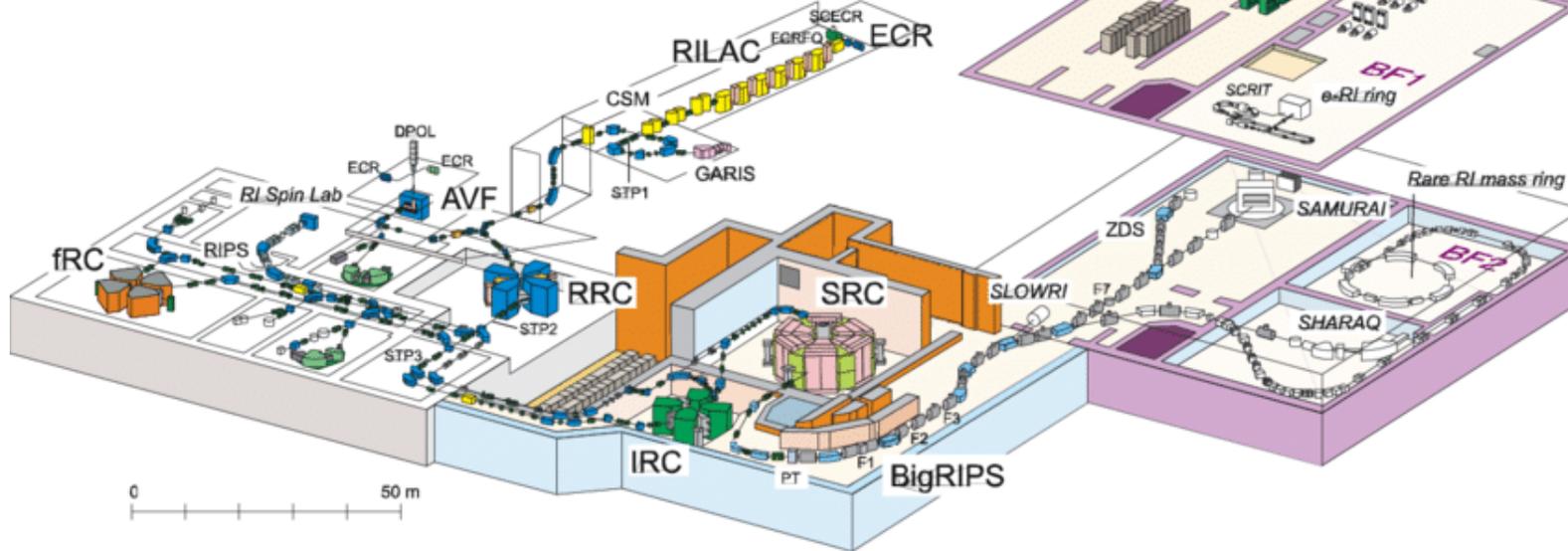


To cover various nuclear processes in He burning

- Higher intensity: 20 mA
- Higher energy: 800 keV



## Radioactive Ion Beam Factory (RIBF) @ RIKEN in Japan



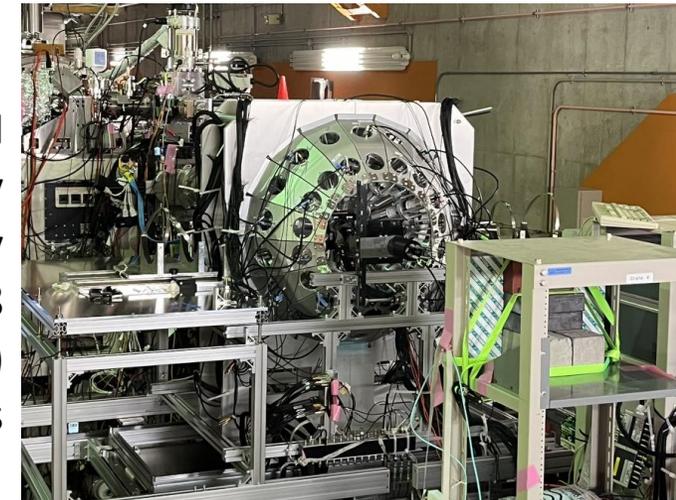
- **The beam is back to BigRIPS!**  
after a long break (Dec. 2022 – Mar. 2024)
- Supplied beams in 2024
  - $^{18}\text{O}$  (April),  $^{70}\text{Zn}$  (May),  $^{124}\text{Xe}$  (June)
  - $^{136}\text{Xe}$  (Nov.),  $^{238}\text{U}$  (Nov.-Dec.)

## New instrumentation

**NEBULA-PLUS**  
Neutron  
detection  
capability  
doubled



**IDATEN**  
Fast  $\gamma$ -ray  
spectroscopy  
with 48  
 $\text{LaBr}_3(\text{Ce})$   
detectors



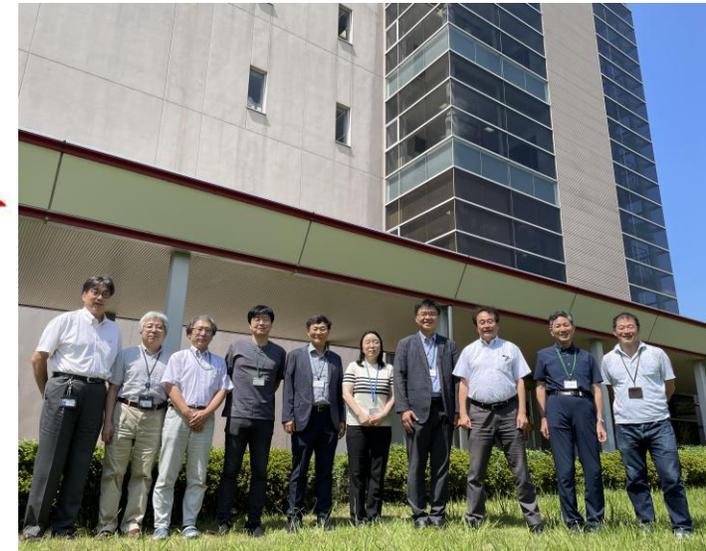
2024  
**IRIS**  
Rare Isotope

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

**ibs** 기초과학연구원  
Institute for Basic Science



 Dr. Taeksu Shin		기초과학연구원 Institute for Basic Science	서울대학교 SEOUL NATIONAL UNIVERSITY Prof Seonho Choi	고려대학교 KOREA UNIVERSITY Prof. Jung Keun Ahn	한국원자력연구원 Korea Atomic Energy Research Institute Dr. Do Heon Kim
			Center for Nuclear Study The University of Tokyo Director Y. Sakemi	WNSC KEK Wako Nuclear Science Center Director Y. Watanabe	



## Research Center for Nuclear Physics (RCNP) @ Osaka Univ. in Japan

### Grand Raiden

Precision nuclear physics  
International collaborative research

### K400 Ring cyclotron

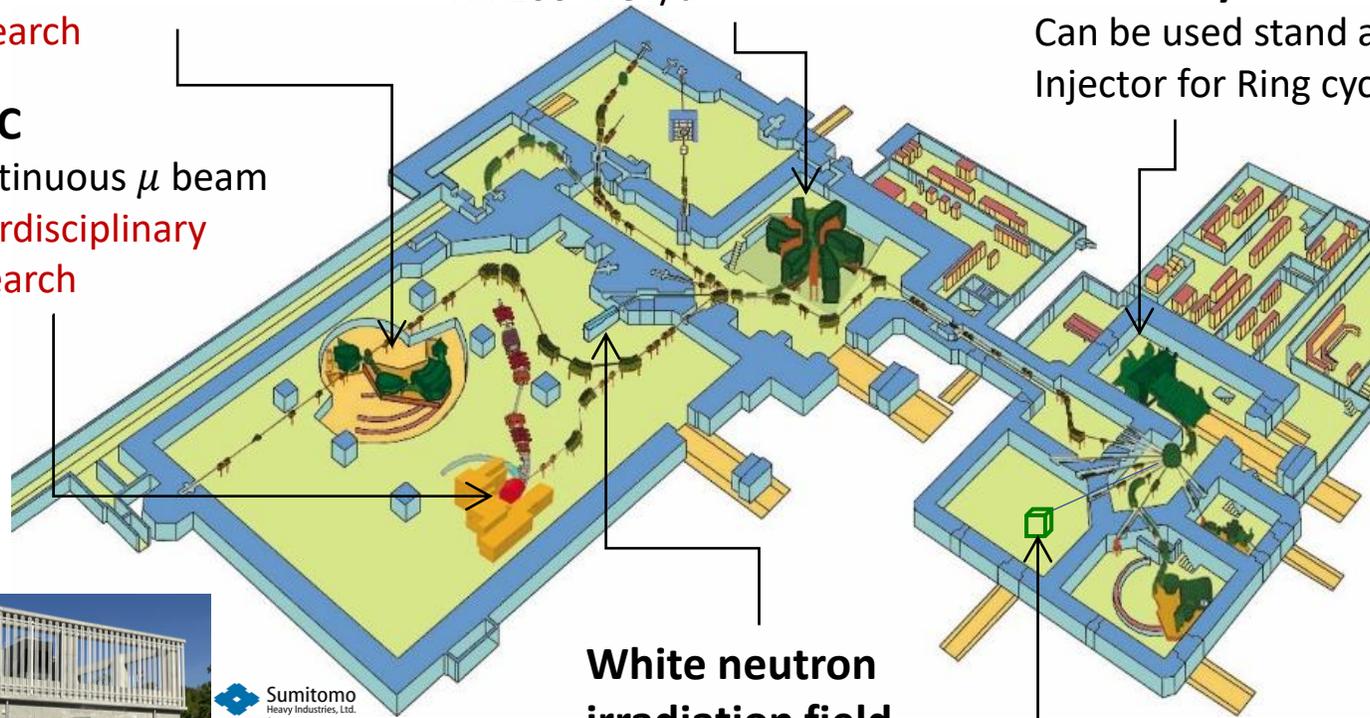
p: 400 MeV, 10  $\mu$ A,  $\Delta E/E \sim 10^{-4}$   
HI: 100 MeV/u

### K140 AVF cyclotron

Can be used stand alone  
Injector for Ring cyclotron

### MuSIC

Continuous  $\mu$  beam  
Interdisciplinary research



### White neutron irradiation field

Semiconductor software error evaluation

### Short half-life radio-isotope production

Targeted alpha therapy

- Completion of the upgrade of AVF (Azimuthally-Varying Field) cyclotron
  - Upgrade for 10× larger beam intensity in 2022 (several 10s to 100  $\mu$ A)
- Independent use of AVF
  - p & d beam: Mass production of short-lived radio isotopes
  - He beam: Production of  $^{211}\text{At}$  (Astatine) for targeted alpha therapy (TAT)
- AVF + Ring cyclotron
  - p beams for MuSIC and white neutron Exp.
  - MuSIC: Muons @ 28-100 MeV/c
    - $\mu^+/\mu^- \sim 10^5/10^4$  cps @ 60 MeV/c
  - Grand Raiden
    - Ultra high-resolution NP experiments
    - $\alpha$  cluster search



Sumitomo Heavy Industries, Ltd.  
Alpha Fusion Inc.  
**TOSHIBA**

TAT cyclotron facility will start a large and stable supply of  $^{211}\text{At}$  in 2027.

## RARiS: Research center for Accelerator science & Radiolotope Science @ Tohoku Univ. in Japan

### RARiS-Mikamine

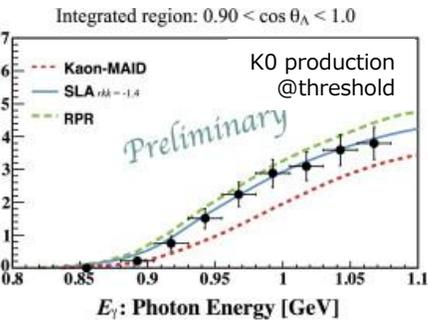
Previously **ELPH**

Two photon beam lines for nuclear physics

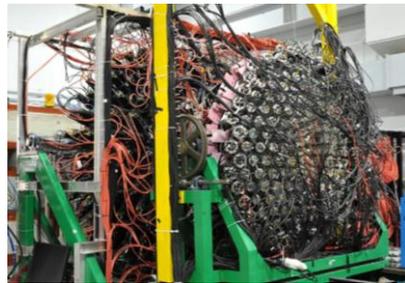
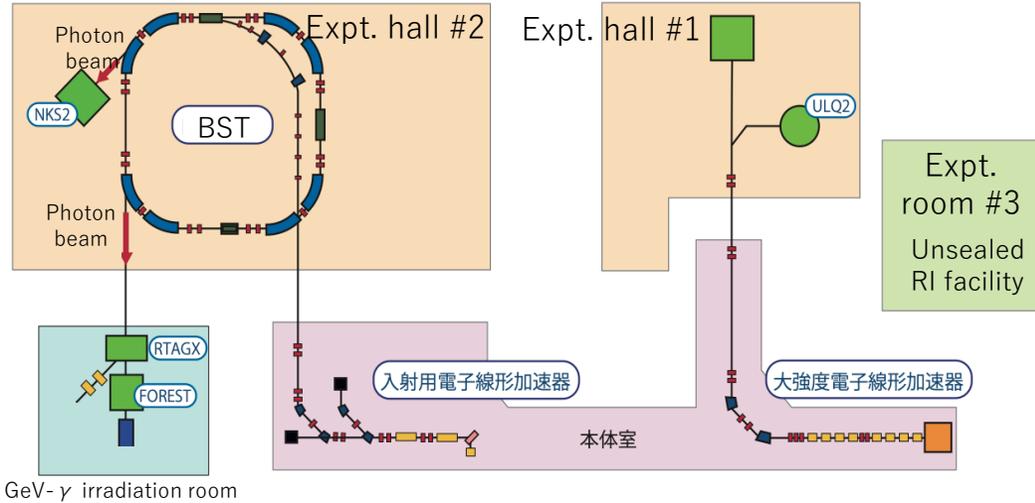
1.3 GeV synchrotron



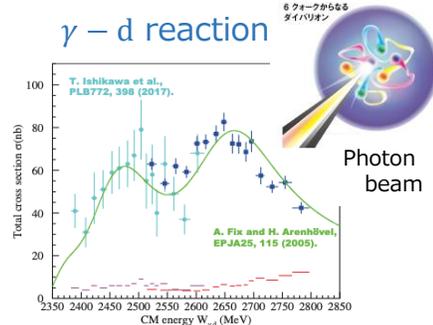
NKS2: Neutral kaon Spec. II



28 May 2025



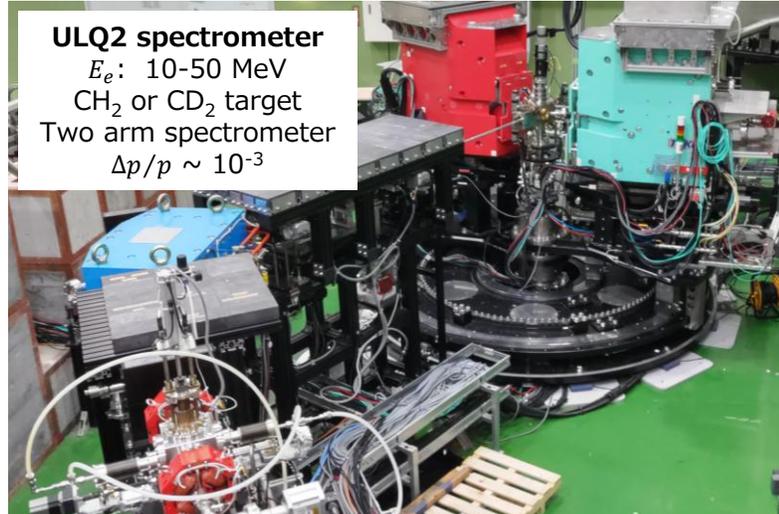
FOREST: Multi- $\gamma$  spectrometer



### Low-energy $e$ scattering

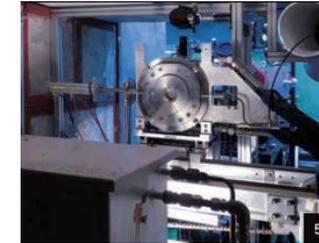
ULQ2 (Ultra-Low Q2) for p charge radius

**ULQ2 spectrometer**  
 $E_e$ : 10-50 MeV  
 $\text{CH}_2$  or  $\text{CD}_2$  target  
Two arm spectrometer  
 $\Delta p/p \sim 10^{-3}$



### Radioisotope production

**High power linac**  
10 - 50 MeV, 300 Hz  
 $I_{\text{peak}} \sim 130 \text{ mA} (@50 \text{ MeV})$   
 $I_{\text{average}} \sim 120 \mu\text{A} (@50 \text{ MeV})$

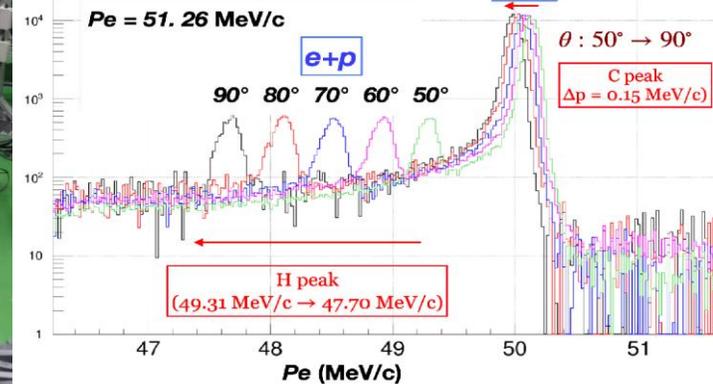


RI Production Station

### Deliverable RIs

- $^{42/43}\text{K}$ ,  $^{46/47/48}\text{Sc}$ ,  $^{64/67}\text{Cu}$ ,  $^{225}\text{Ac}$  for theranostics
- $^{83/84/86}\text{Rb}$ ,  $^{132/136}\text{Cs}$  for plant imaging

### $\text{CH}_2(e, e')$ $E_e = 51.26 \text{ MeV}$ **e+C**



## RARiS: Research center for Accelerator science & Radiolotope Science @ Tohoku Univ. in Japan

### RARiS-Aobayama

Previously CYRIC

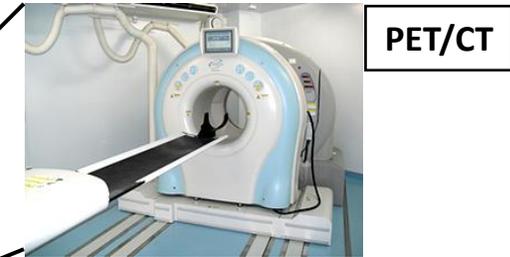
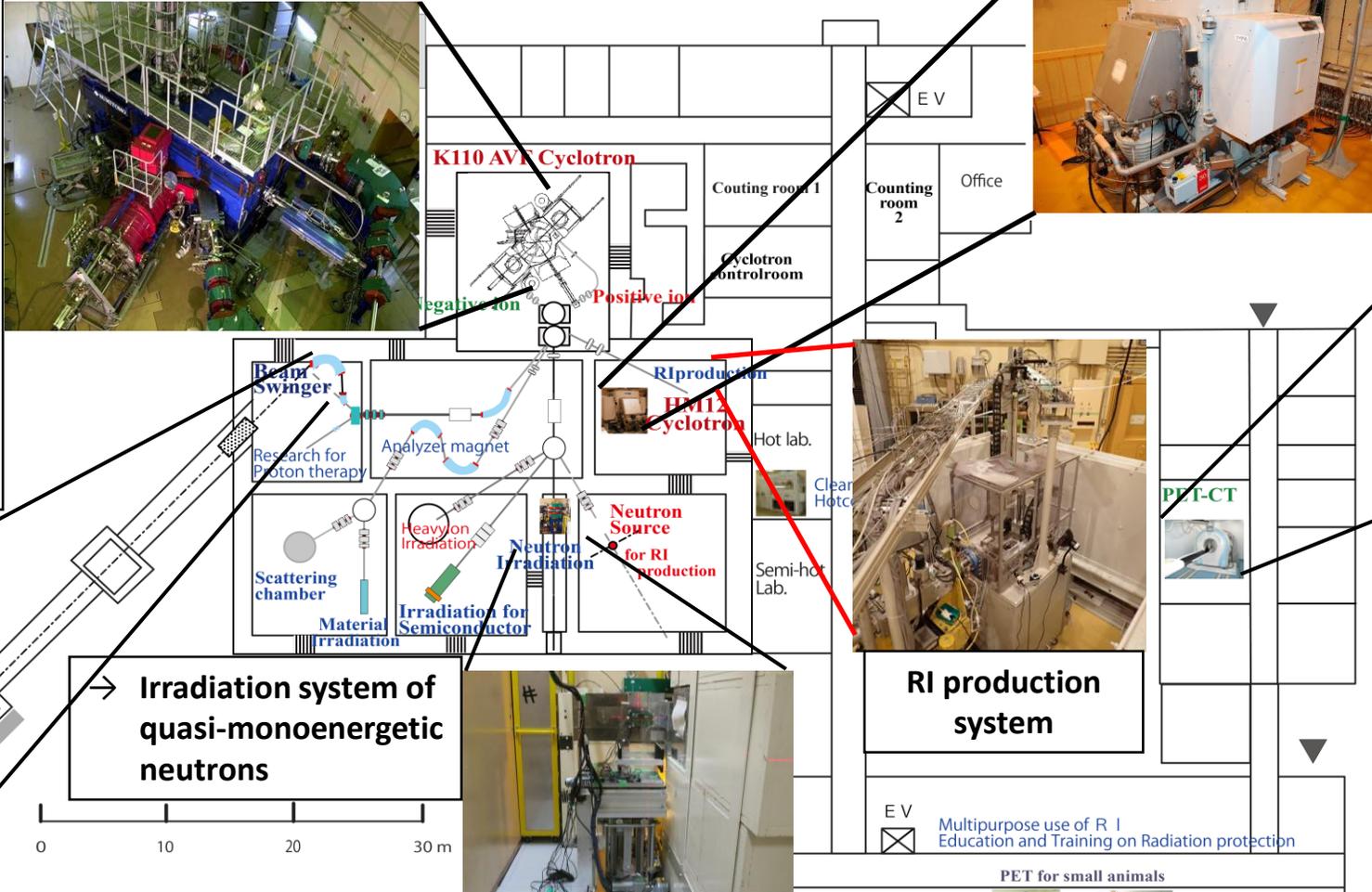
#### 930 AVF cyclotron

- K number: 110 MeV
- Magnet
  - Weight: 200 t
  - Max Field: 19.6 kG
  - Max power: 230 kW
- RF
  - D-electrode: 2
  - Frequency: 11-22 MHz
  - Max voltage: 50 kV
  - Max power: 70 kW×2



#### HM12 cyclotron

- Proton: 12 MeV, 60  $\mu$ A
- Deuteron: 6 MeV, 30  $\mu$ A
- Ion-source: PIG internal ion-source
- Beam port: 2



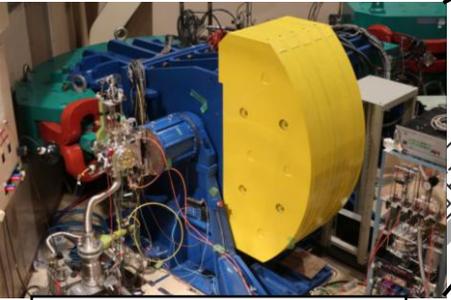
PET/CT



RI production system



<https://www.cyric.tohoku.ac.jp/en/>



Beam swinger system

Irradiation system of quasi-monoenergetic neutrons

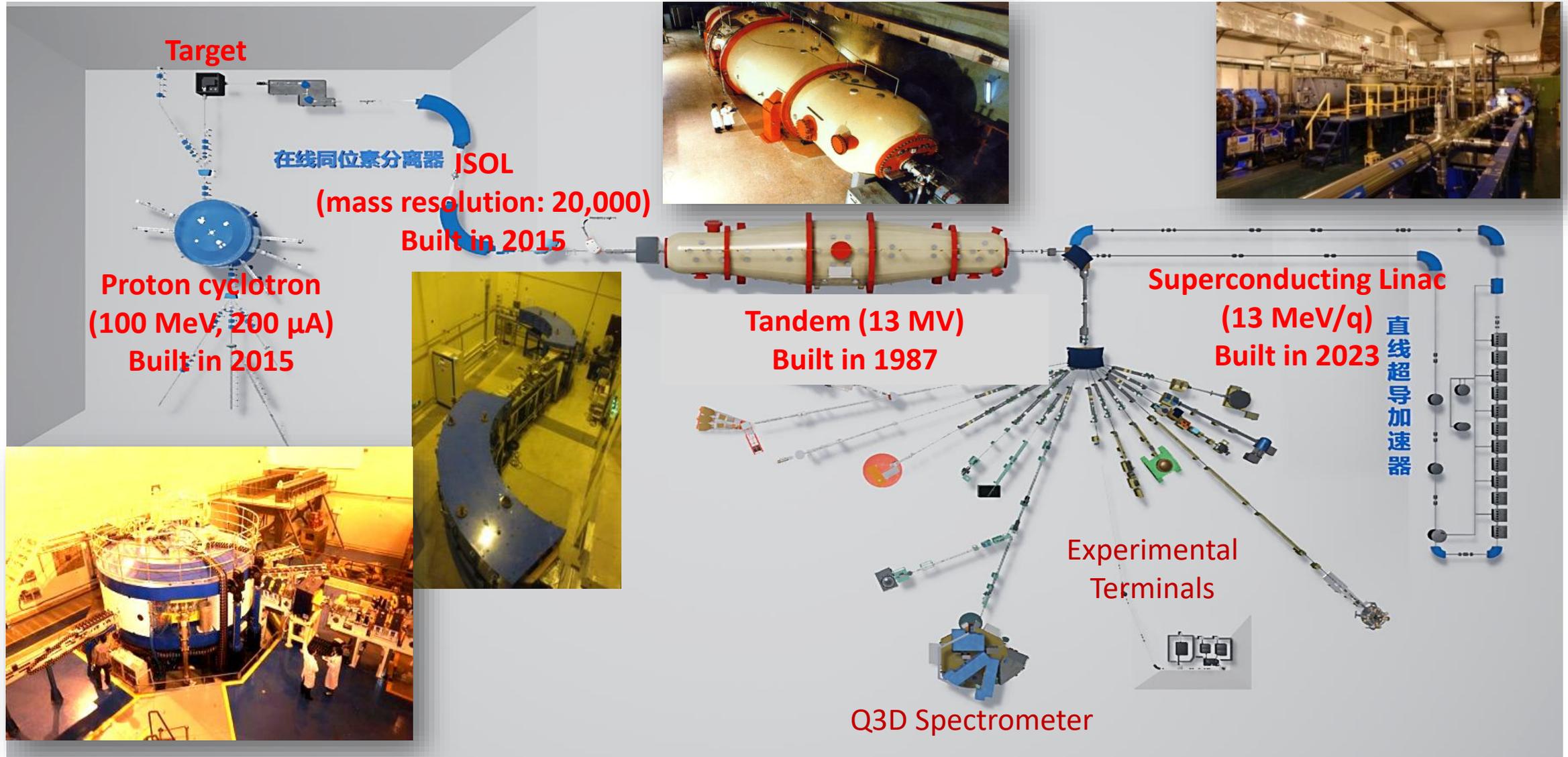
EV Multipurpose use of R I Education and Training on Radiation protection

PET for small animals

(Fine PET) Clairvivo-PET Clairvivo-CT

## Beijing Radioactive Ion beam Facility (BRIF) @ CIAE in China

W. Nan, B. Guo\*, J. Chen *et al.*  
arXiv:2503.17384 (2025), Submitted to PPNP



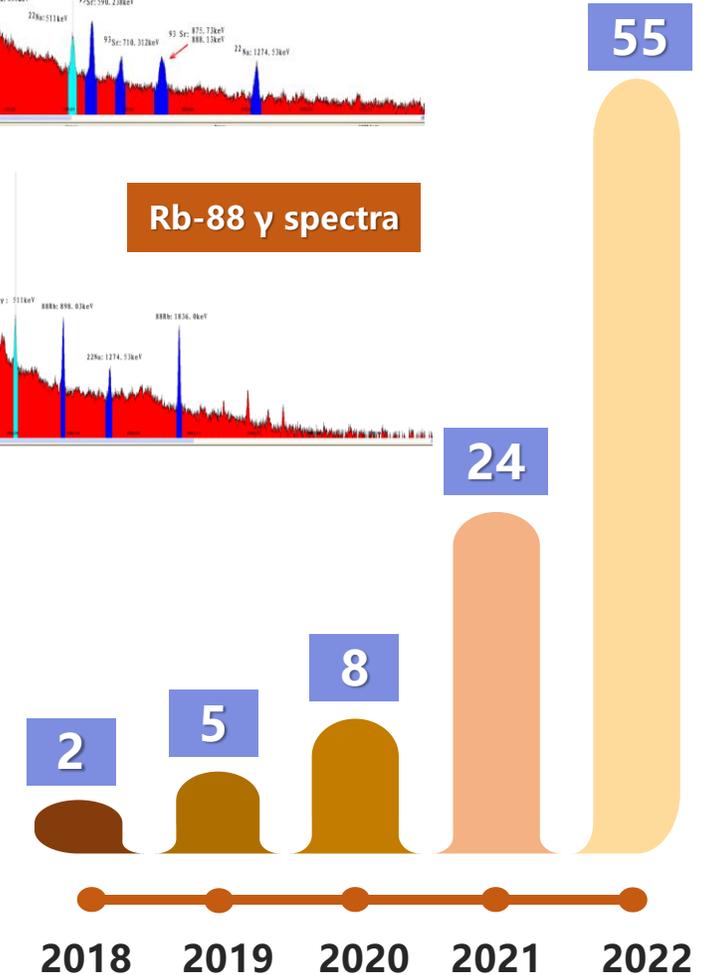
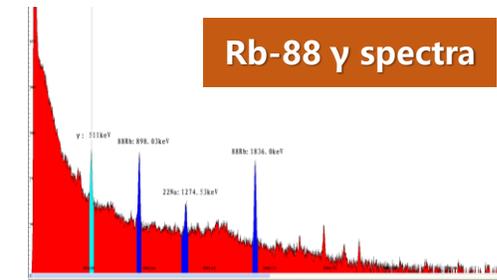
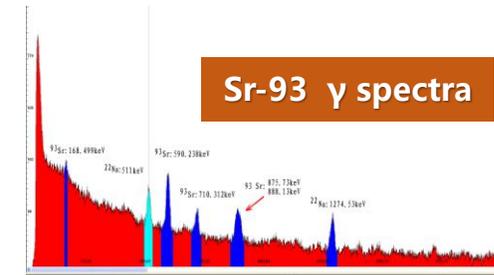
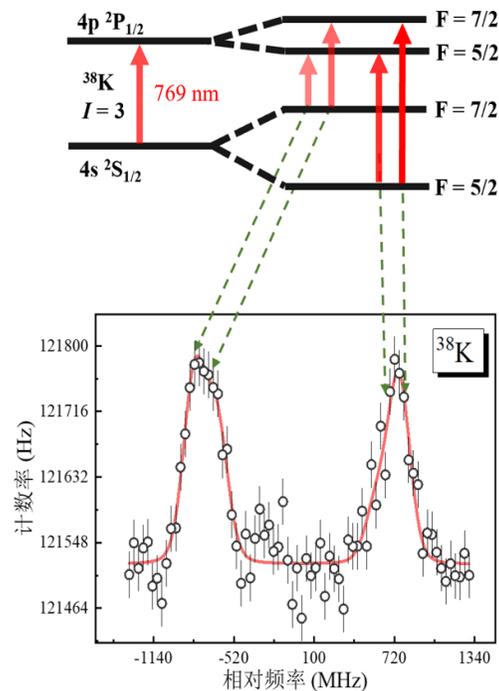
## Beijing Radioactive Ion beam Facility (BRIF) @ CIAE in China

- Production of fission fragment RIBs (Rb, Sr, etc.)
- Number of RIB types: 24 (2021) → 55 (2022)
- The shortest half-life of RIB with ISOL: 0.45 sec → 0.17 sec
- Beam intensity:  $10^3 \sim 10^{10}$  pps

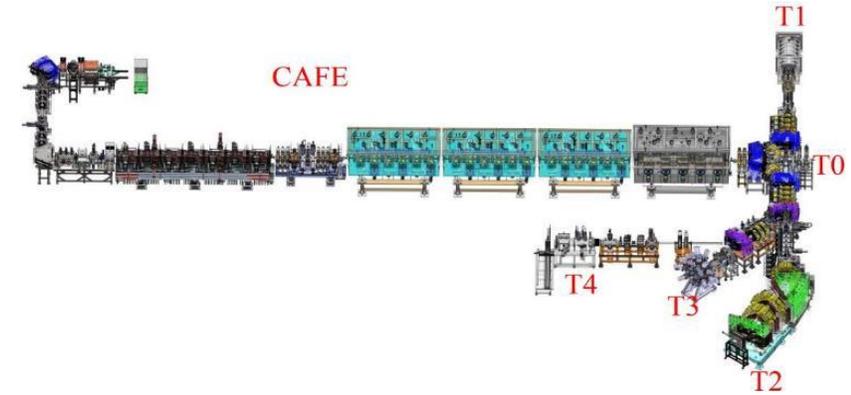
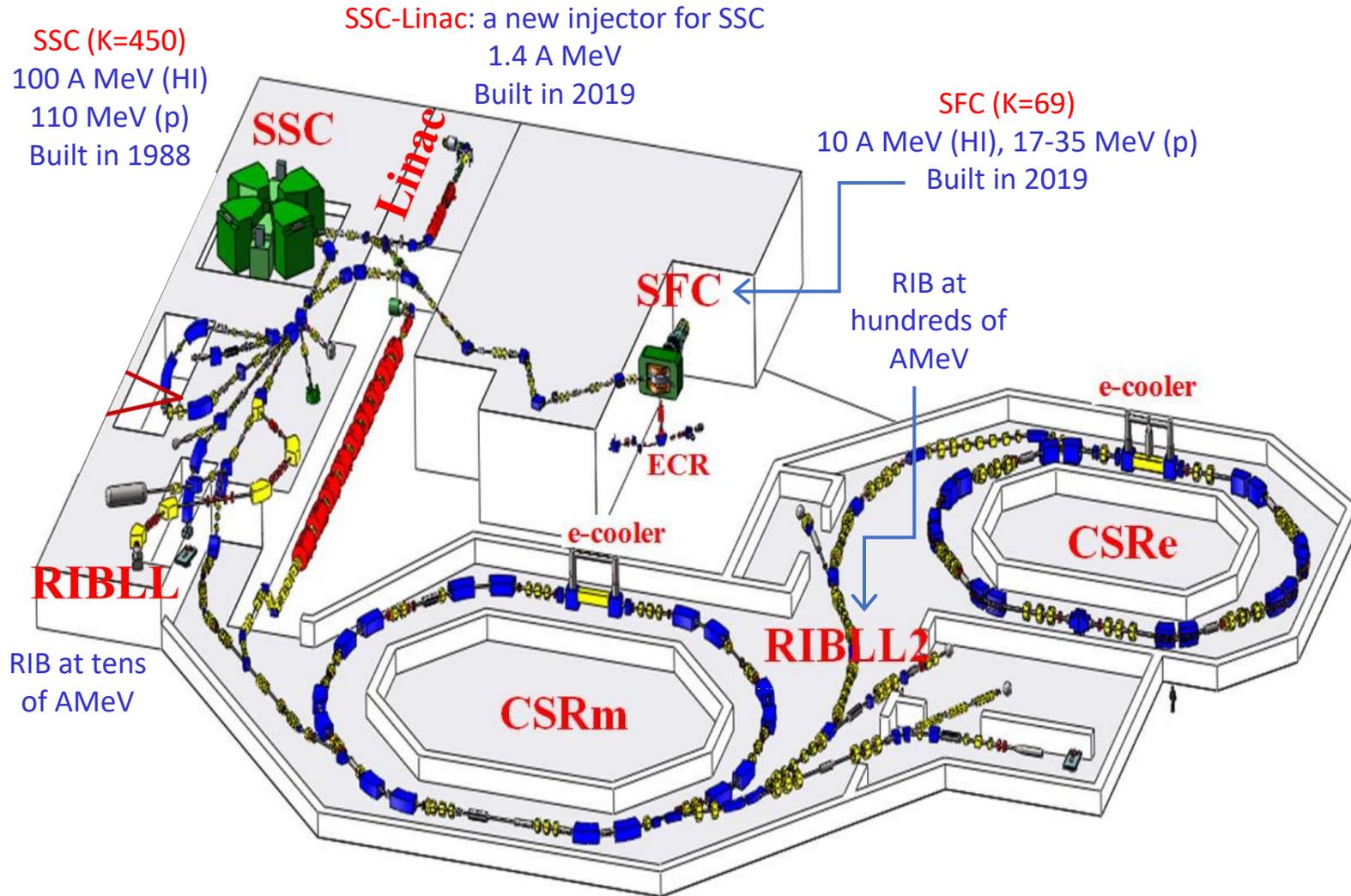
### Recent achievements

- First RIB experiment: 3  $\beta$ - $\gamma$ - $\alpha$  exotic decays in  $^{20}\text{Na}$  [PRC103, L011301 (2021)]
- Elastic scattering of the post-accelerated  $^{21-23}\text{Na}$  beams on  $^{40}\text{Ca}$  target [NST32, 53 (2021)]
- Total Absorption Gamma-ray Spectroscopy (TAGS) for  $^{88,90}\text{Rb}$  and  $^{140,142}\text{Cs}$  using Large Module BGO Detector Array (LAMBDA)
- First CLS experiment [NIMA1032, 166622 (2022)]

HFS of  $^{38}\text{K}$  by CLS



## Heavy Ion Research Facility in Lanzhou (HIRFL) @ IMP in China



China Accelerator Facility for Superheavy Elements (CAFÉ2) is based on the ADS demo project, operating for the discoveries of new isotopes

### CAFÉ2 parameters

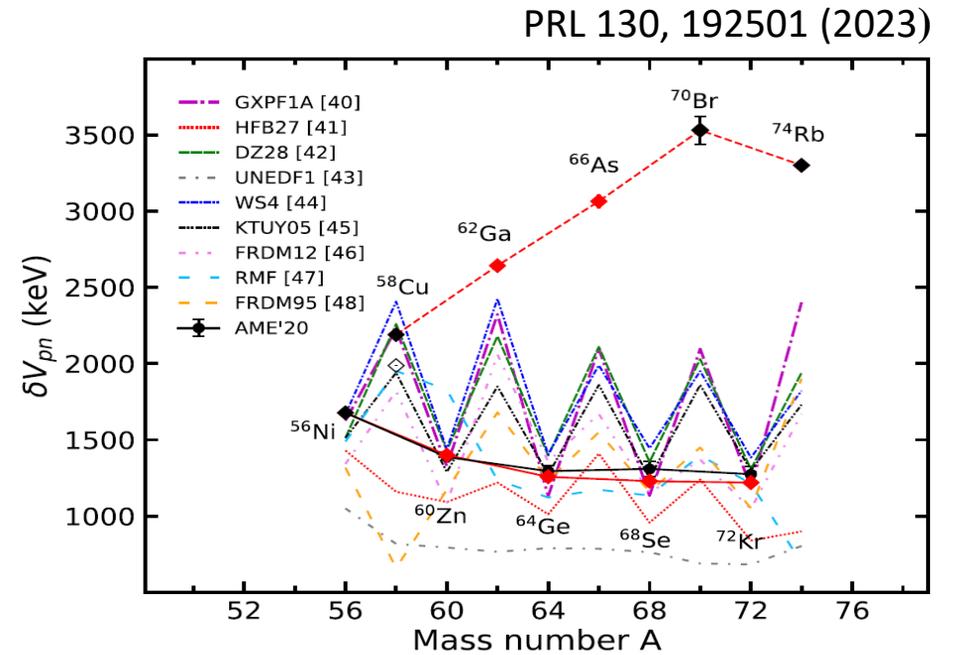
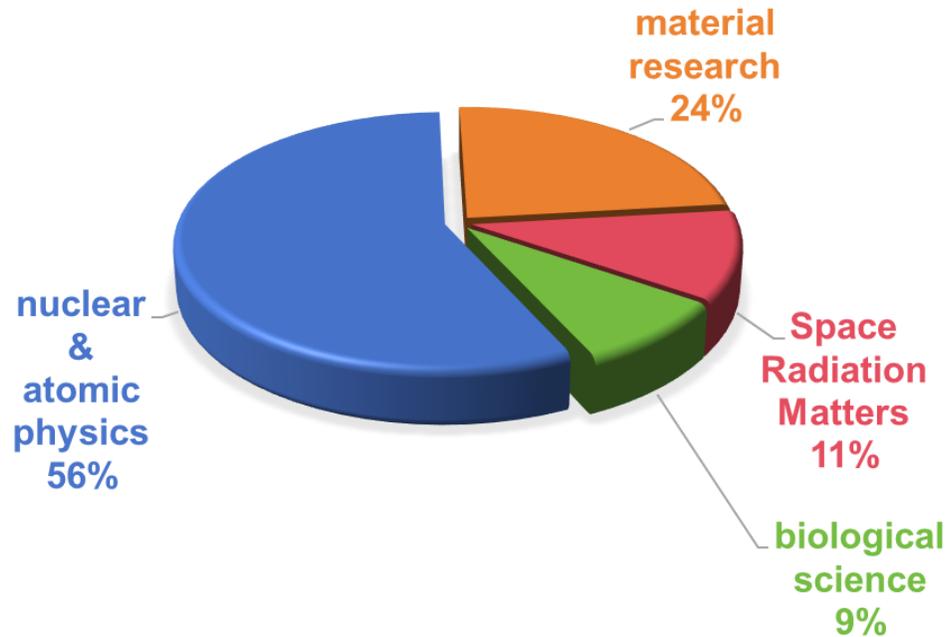
Ion species	Ca ~ Zn
Q/A	1/3
Energy	5 ~ 7 MeV/u
Current	3 ~ 10 $\mu$ A
Modes	CW

## Heavy Ion Research Facility in Lanzhou (HIRFL) @ IMP in China

- Beam time on target was about **5,500 hours** in 2023, providing 28 ion species including  $U^{74+}$  up to 500 MeV/u.

The masses of  $^{62}\text{Ge}$ ,  $^{64}\text{As}$ ,  $^{66}\text{Se}$ ,  $^{70}\text{Kr}$  were determined for the first time, using the newly-developed “B $\rho$ -defined Isochronous Mass Spectrometry”

### BEAM TIME STRUCTURE 2023



## ■ Major facilities in India

### • **BARC- TIFR Pelletron Linac Facility @ Mumbai**

- 14 MV Pelletron +SC Linac
- Upgrade
  - Installation of higher gradient accelerating tubes for the pelletron
  - Installation of low  $\beta$  Nb RF cavities in place of the existing Pb-based cavities in the first linac module module
  - Expected to be completed in the next 2-3 years

### • **Inter University Accelerator Centre (IUAC) @ New Delhi**

- 15 MV Pelletron + SC linac, High current Injector
- Upgrade: High current injector (HCI) for the superconducting linear accelerator (LINAC)

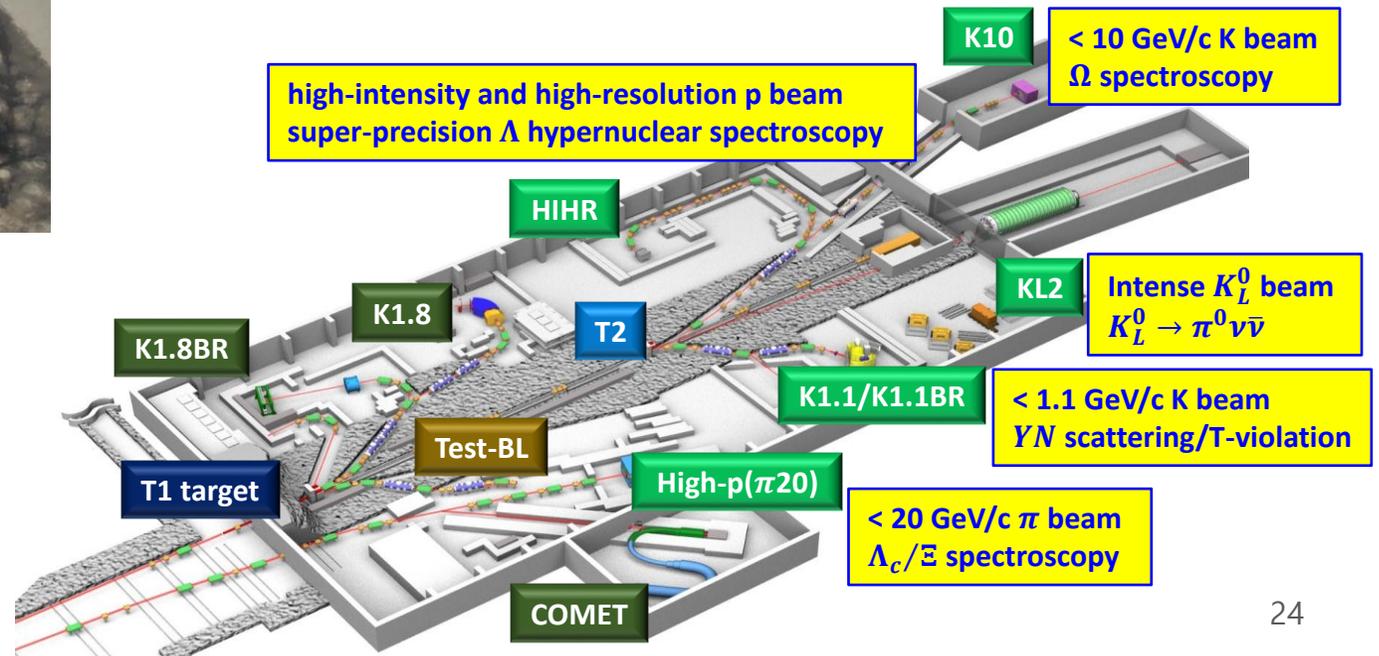
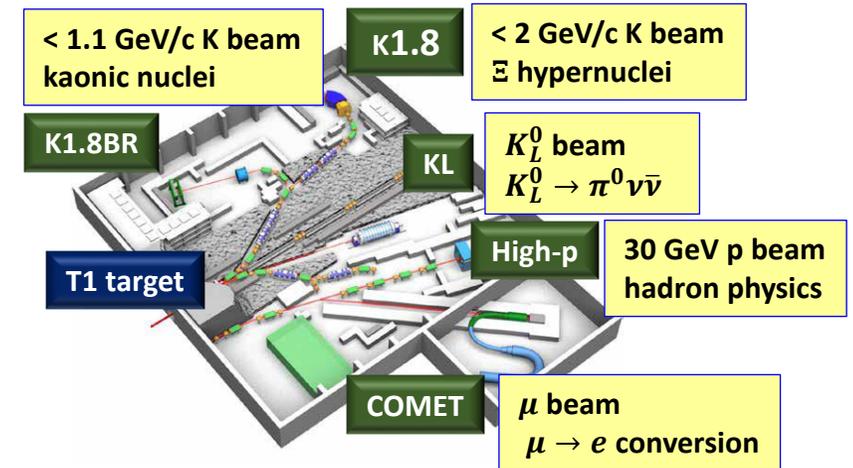
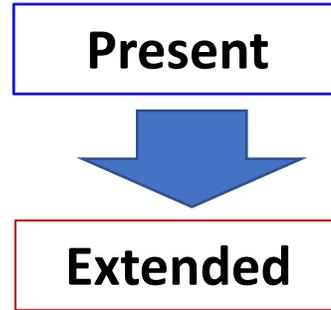
### • **VECC @ Kolkata**

- K = 130 cyclotron
- K = 500 Superconducting cyclotron (India's largest superconducting magnet that produces a maximum field of 5 T) is now available.
- Upgrade: ANURIB - Radioactive ion beam facility

### • **FRENA@SINP, Kolkata**

- Tandetron for  $^1\text{H}$ ,  $^4\text{He}$ , and heavy ion beams at  $\sim 0.2\text{--}3$  MeV with  $50\text{--}300$   $\mu\text{A}$

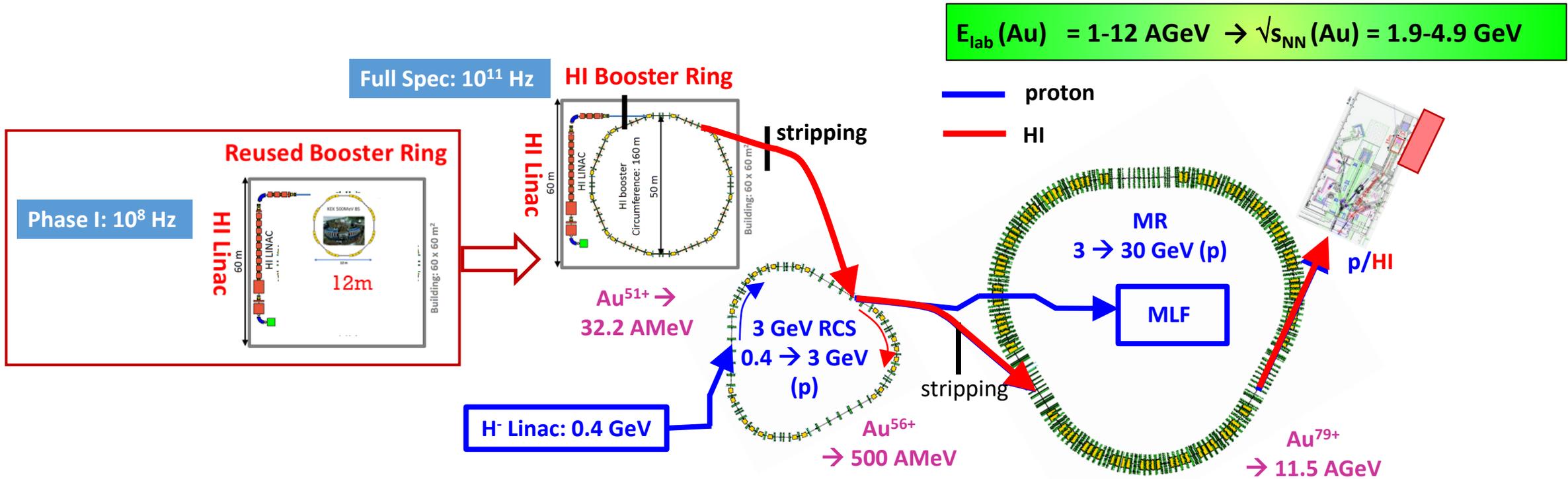
## Japan Proton Accelerator Research Complex (J-PARC)



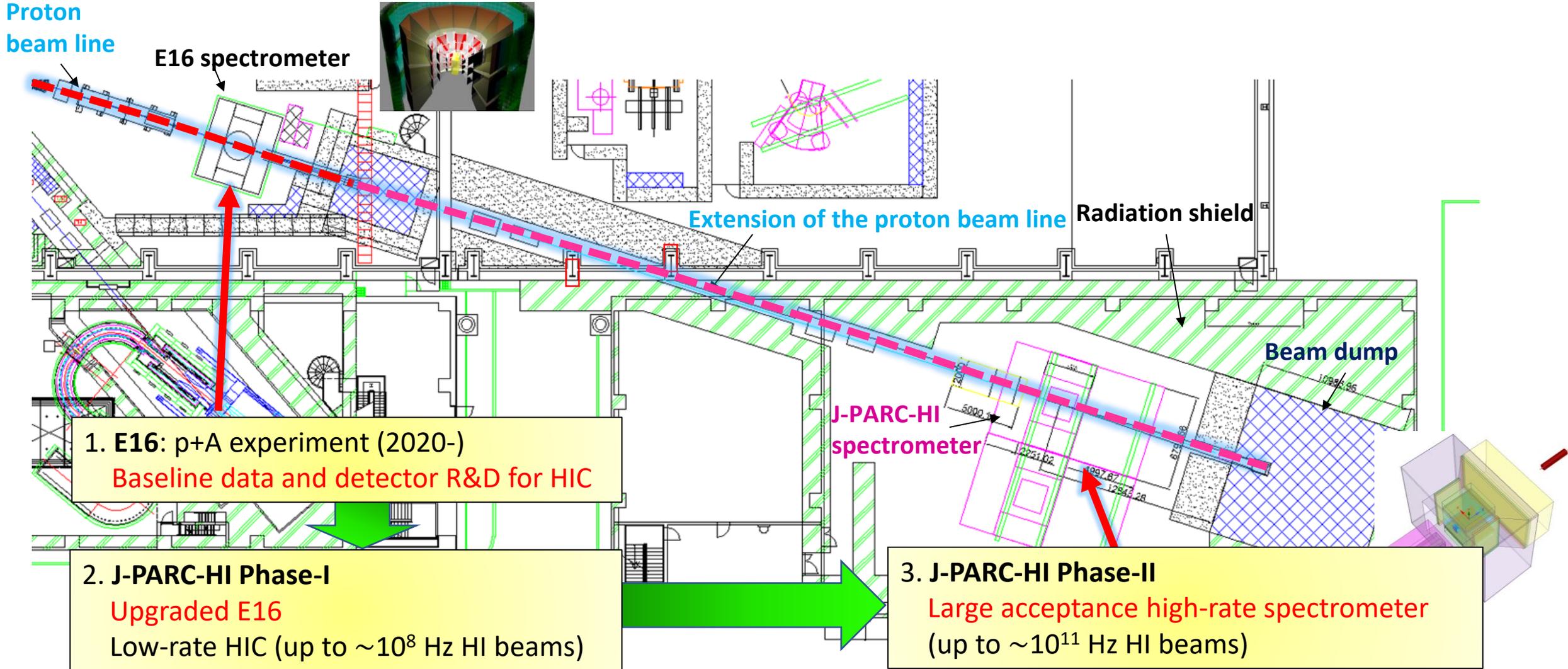
### Hadron experimental facility extension

- Additional production target (T2)
- Four more new beamlines (HIHR, K1.1/K1.1BR, KL2, K10)
- Upgrade beamlines: High-p( $\pi 20$ ), Test-BL

- Upgrade plan of J-PARC for heavy-ion beams
  - New heavy-ion injector (LINAC and BOOSTER), new experimental area and spectrometers
- Staging plan
  - Phase I: New LINAC & **reuse of KEK-PS 500 MeV** booster, Upgrades of the existing spectrometer ( $10^8$  Hz for Au)
  - Phase II: New booster and new spectrometer ( $10^{11}$  Hz for Au)



## J-PARC-HI staging strategy (Experiments)



- Several nuclear physics facilities in Asia are in the construction, commissioning, operational or upgrade stage:
  - Underground facilities: Yemilab (Korea), Kamioka (Japan), CJPL-II (China), SUPL (Australia)
  - RIB accelerators: BRIF, JUNA/CJPL, HIRFL, HIAF (China), RIBF, RCNP, RARIS (Japan), RAON (Korea), Several small scale facilities (India)
  - Hadron accelerators: HIAF (China), J-PARC (Japan)
  - Photon & electron accelerators: Spring-8, RARIS (Japan), SLEGS (China)
  
- More information
  - RAON (→ Seung-Woo Hong)
  - HIAF (→ Wenlong Zhan)
  - RIBF (→ Hiroyoshi Sakurai)
  - JUNA (→ Weiping Liu)
  
- *The nuclear physics facilities in Europe, U.S.A., and Asia are complimentary.*
- *The closer collaborations will be necessary even more in the future!*