

KERNEL

URGP 2026

Investigation on the Origin and Evolution of Matter in the Universe by
Extremely Rare Events

September 28, 2026

Itaru Shimizu (Tohoku Univ.)

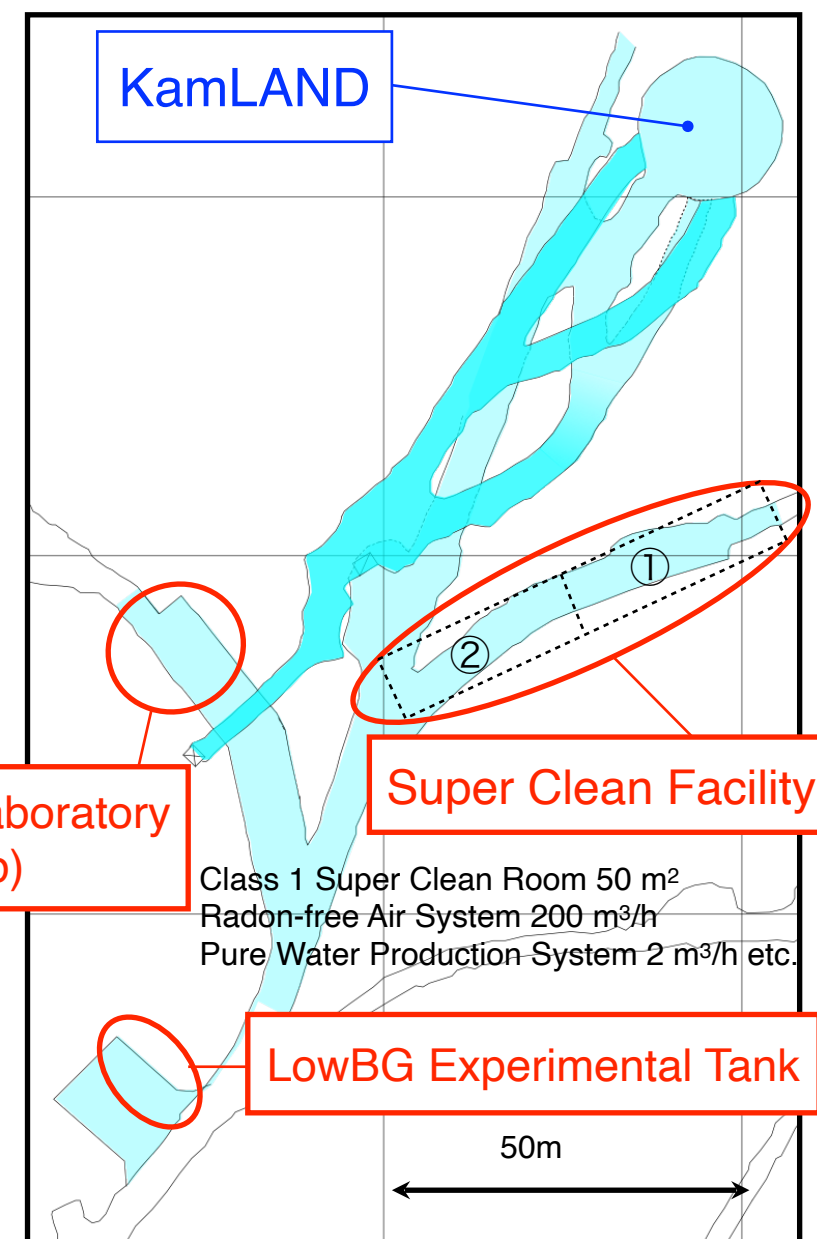
Kamioka Extremely Rare-phenomena and NEutrino-research Laboratory (KERNEL) as joint project between Tohoku and Osaka Universities launched since 2024

• The role of KERNEL

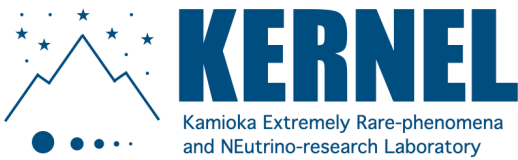
Promotion of **research** at the frontier of extremely rare phenomena
Inheritance and development of extremely low radioactivity **technology**
Leading the community of ultra-low-BG underground particle physics research through **joint usage and joint research**

• Facilities and equipment for joint usage / research inheriting also ongoing joint usage / research projects

- **Super Clean Facility** at KamLAND area
- **Clean Laboratory** that can conduct small-scale experiments
PICOLON (dark matter search) by Tokushima University and
PIKACHU (double-beta decay search) by Tsukuba University are in operation
- **CryoLab** (MoU 2023 for RCNS and KEK-QUP) provides ultra-low-temperature environments
 First user **TESSERACT (dark matter search)** is constructing experimental equipment
LOTUSS International Collaborative Research (superconducting sensor development) has been launched
- **LowBG Experimental Tank** capable of small experiments
- Existing low radioactivity measurement devices



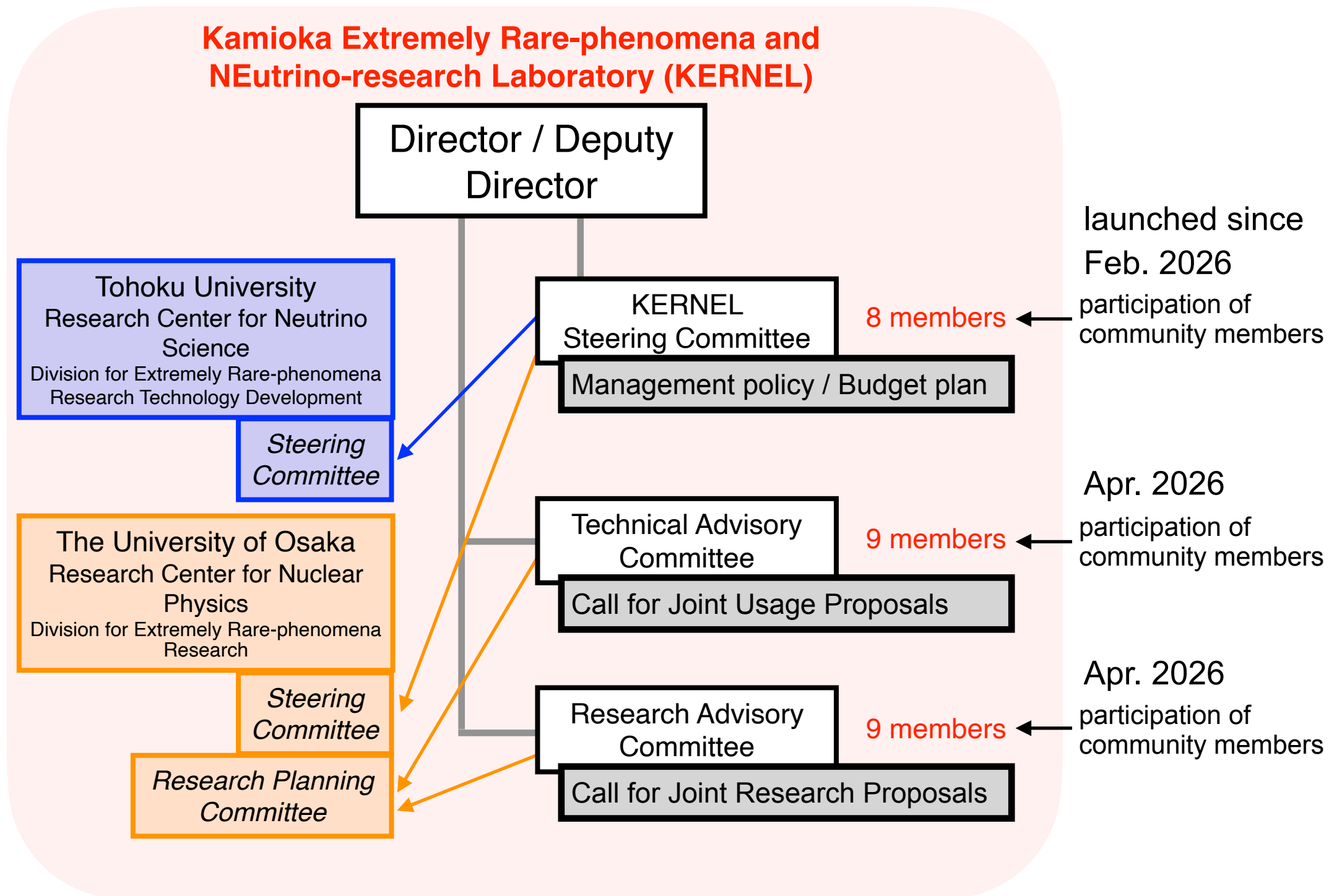
Management structure of KERNEL



15 members



Kamioka Extremely Rare-phenomena and NEutrino-research Laboratory (KERNEL)



Organically promote research and technology development across multiple communities, fields, and organizations through the formation of a new hub

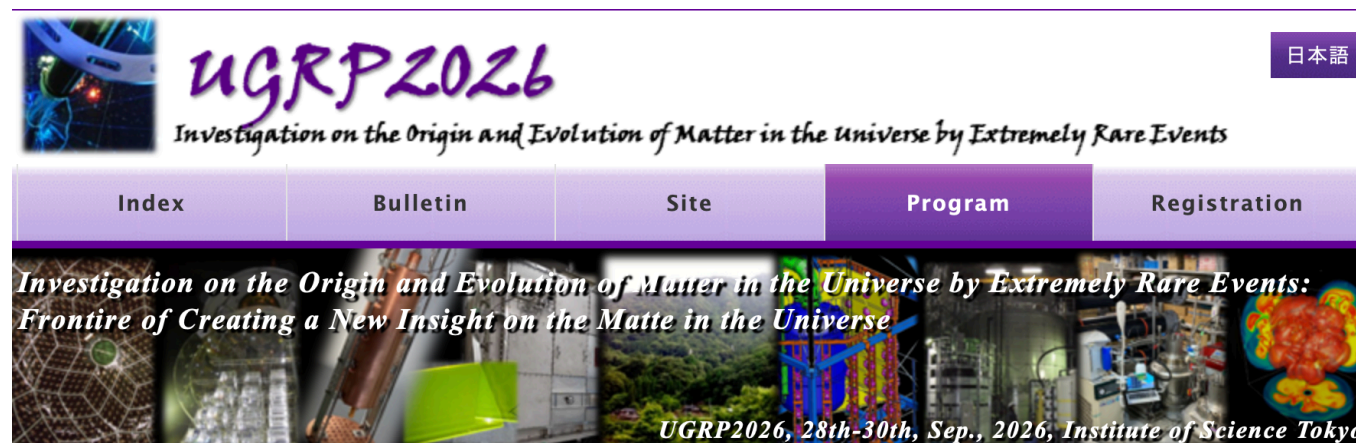
Call for Workshop Proposals

Applications are accepted for research workshops focusing on specific themes related to the development of **ultra-low radioactivity techniques** and **research in the Universe and elementary particle physics**

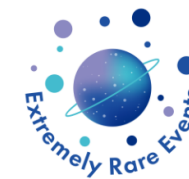
Call	Workshop period	Review results	# of accepted workshop
FY2026 Term 1	Aug. - Sep. 2026 or later	Jul. 10	2
FY2026 Term 2	Oct. - Dec. 2026 or later	Sep. 8	4

Research Advisory Committee will decide whether to accept or reject, taking into account factors such as academic significance and timing

If selected, please include **KERNEL** as one of the organizing bodies



Dept. of Phys.,
Sch. of Sci.,
Science Tokyo



After the workshop, organizers are requested to submit a report

Accepted Workshop

FY2026 Term 1

Workshop title	Co-sponsors, supporters, etc.	Workshop venue	Workshop dates
UGRP2026：学術変革領域研究(A)「極稀事象で探る宇宙物質の起源と進化」領域国際研究会	学術変革領域研究(A)「極稀事象で探る宇宙物質の起源と進化」東京科学大学 理学院 物理学系、東北大学ニュートリノ科学研究センター、大阪大学核物理研究センター	東京科学大学	2026年9月28日～9月30日
「NME 2026 二重β崩壊の核行列要素計算の現在と未来」	大阪大学RCNP	大阪大学RCNP (予定)	2026年12月～2027年1月 (調整中)

FY2026 Term 2

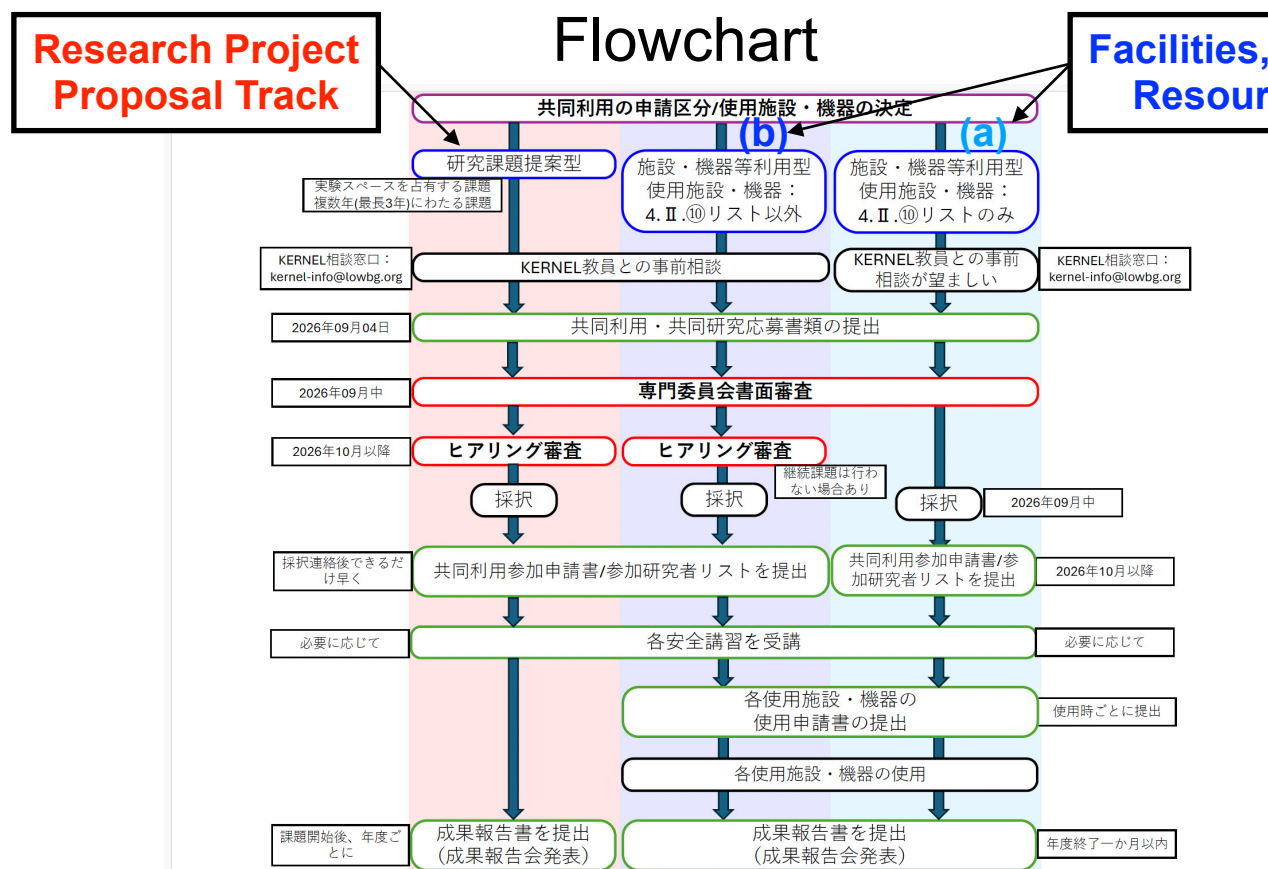
Workshop title	Co-sponsors, supporters, etc.	Workshop venue	Workshop dates
MPGD & Active媒質TPC 2026研究会	高エネルギー加速器研究機構	福井大学	2026年11月6日～11月7日 (予定日)
第12回「極低放射能技術」研究会	学術変革領域(A)「極稀事象で探る宇宙物質の起源と進化」計画研究D01「極低放射能技術の展開」	筑波大学未来社会デザイン棟	2027年3月10日～3月11日 (予定日)
第13回超新星ニュートリノ研究会	学術変革領域(A)「極稀事象で探る宇宙物質の起源と進化：新たな宇宙物質観創生のフロンティア」	東北大学片平キャンパス・知の館	2027年3月4日～3月5日 (予定日)
SK + KL 将来検討ワークショップ	学術変革領域(A)「極稀事象で探る宇宙物質の起源と進化：新たな宇宙物質観創生のフロンティア」	東北大学東京オフィス	2026年10月1日

Call for Joint Usage / Joint Research Proposals

Applicants may apply for **research conducted in the underground laboratory on rare phenomena**, or for **broader research related to rare phenomena**

Call	Research period	Review results	# of accepted projects
FY2026	Oct. 2026 - Mar. 2027	soon	-

Research / Technical Advisory Committee will review the projects, and decision will be made based on considerations such as academic significance and feasibility



Application Category

•Research Project Proposal Track

project to be **conducted jointly with KERNEL** or
project **using a dedicated underground laboratory area**

•Facilities, Equipment, and Resources Use Track

(a) only to use **Ge semiconductor detectors, underground network, underground vehicles, pure water and/or purified air**

(b) to use **others**

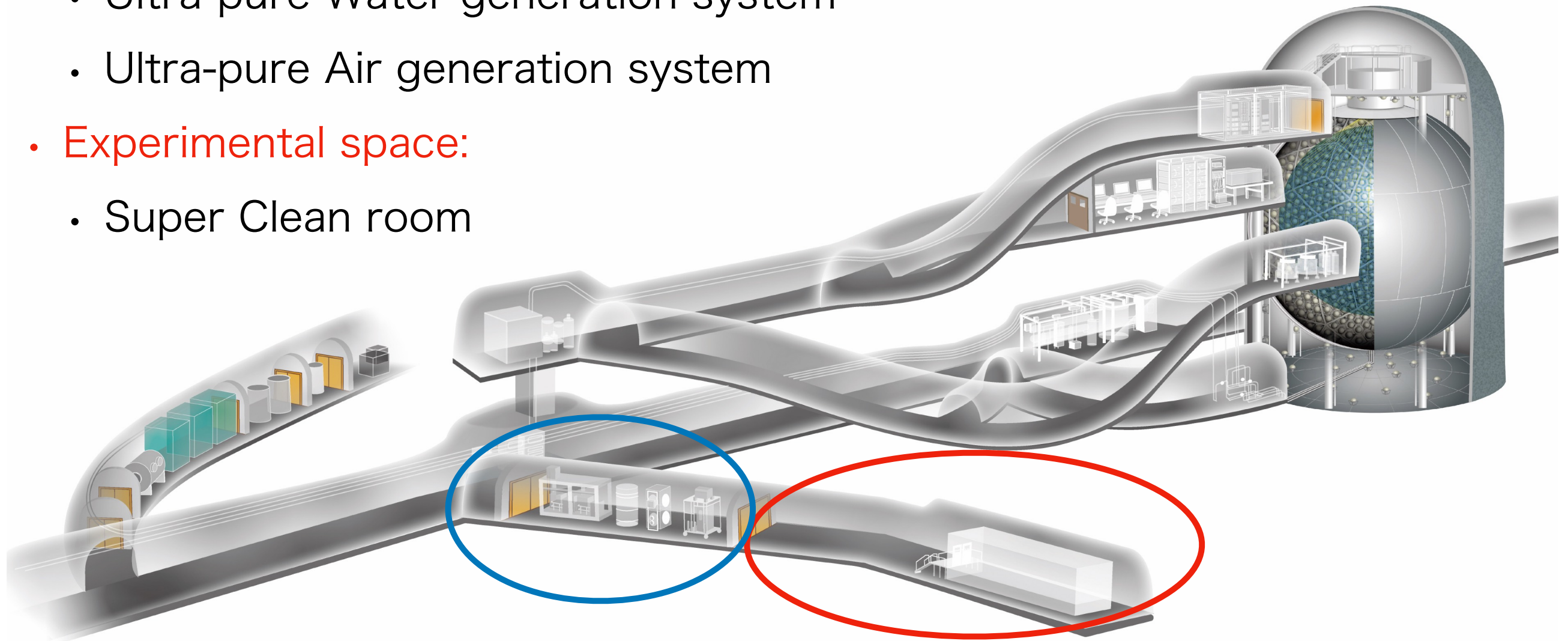
A report must be submitted after the end of the research period

(researchers may also be asked to give a presentation at an outcome reporting meeting or similar event)

Facilities

KERNEL infrastructure (machine room, experimental space)

- Machine room:
 - Ultra-pure Water generation system
 - Ultra-pure Air generation system
- Experimental space:
 - Super Clean room



Facilities

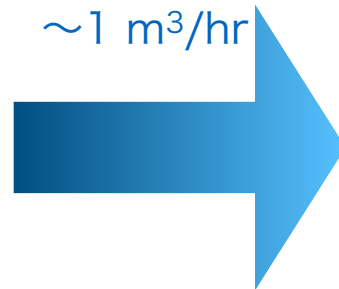
Ultra-pure water (UPW) generation system

- Capable of generating ultra-pure water ($> 18.2 \text{ M}\Omega \cdot \text{cm}$) at a rate of $1 \text{ m}^3/\text{hr}$
 - CO_2 degasifier, Capacitive deionization (CDI[®]), Cartridge polished, Rn degasifier
 - 2m^3 buffer tank : at most $2 \text{ m}^3/\text{hr}$ UPW can be supplied to Super-clean room, KamLAND Buffer-oil water-extraction system (to be developed) etc.
- ➡ can be used for making solution for ICP-MS, cleaning materials etc.

Pure-water generation system



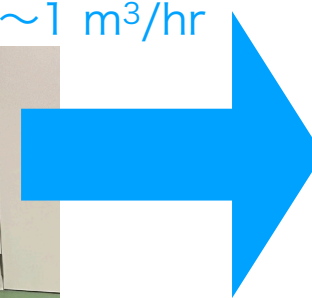
RO Water
 $\sim 5 \text{ M}\Omega \cdot \text{cm}$
 $\sim 1 \text{ m}^3/\text{hr}$



UPW generation system



UPW Water
 $> 18.2 \text{ M}\Omega \cdot \text{cm}$
 $\sim 1 \text{ m}^3/\text{hr}$



Super clean room



Facilities

Ultra-pure Air (UPA) generation system

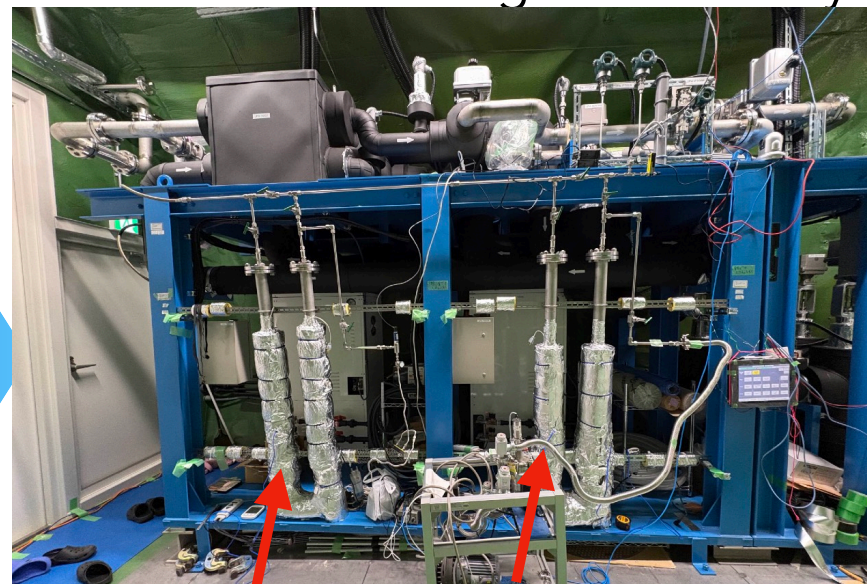
- Rn-less air ($> 200 \text{ m}^3/\text{hr}$, dew point $< -70^\circ\text{C}$, ^{222}Rn : $\sim 30 \text{ Bq/m}^3$) passes through charcoal tower and supplied to super-clean room and KamLAND dome area
- ➔ Need to improve Rn reduction performance
 - Collaborating with Group D01 on Ag-zeolite to improve radon removal performance
 - Designing a parallel system utilizing 80A U-shaped tubes
 - First 80A U-shaped tube delivered this month

Compressor, Dehumidifier



Air flow : $> 200 \text{ m}^3/\text{hr}$
Dew point : $< -70^\circ\text{C}$

UPA generation system



U-shaped tubes (50A for test)
filled with Zeolite & Ag-Zeolite

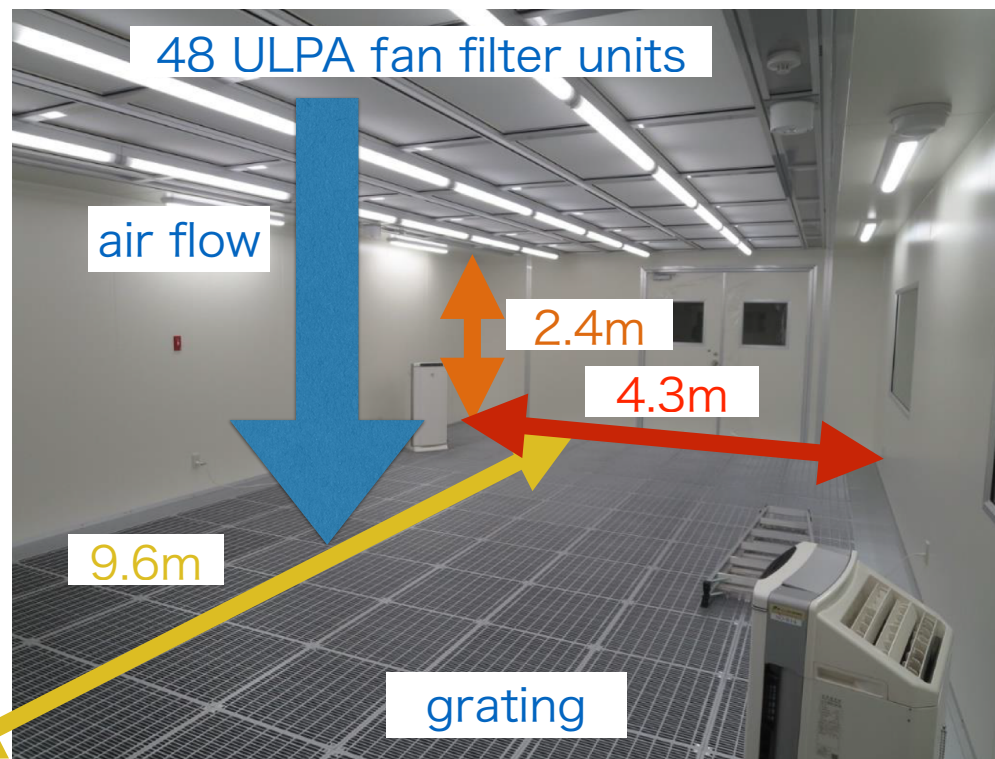


Charcoal tower
~250 kg
currently room temp.

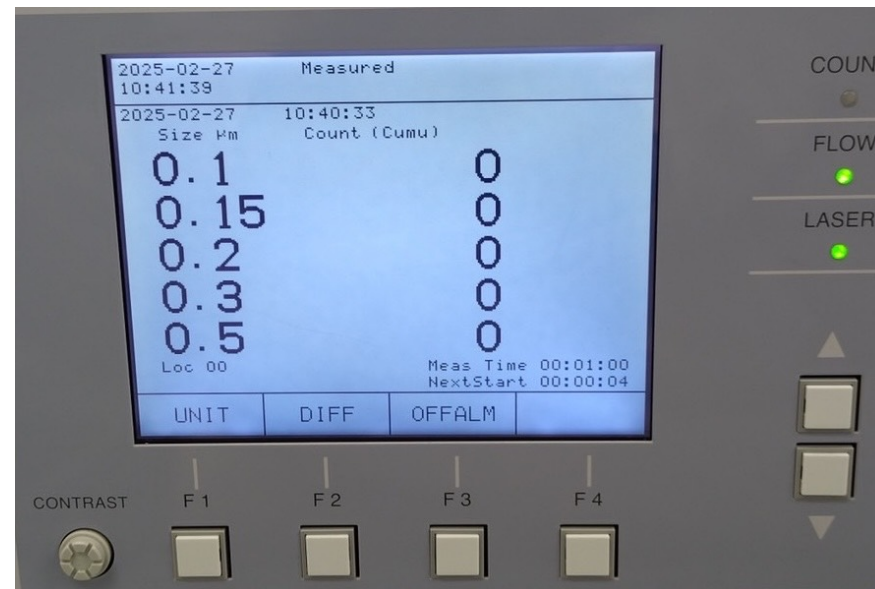
Facilities

Super Clean room

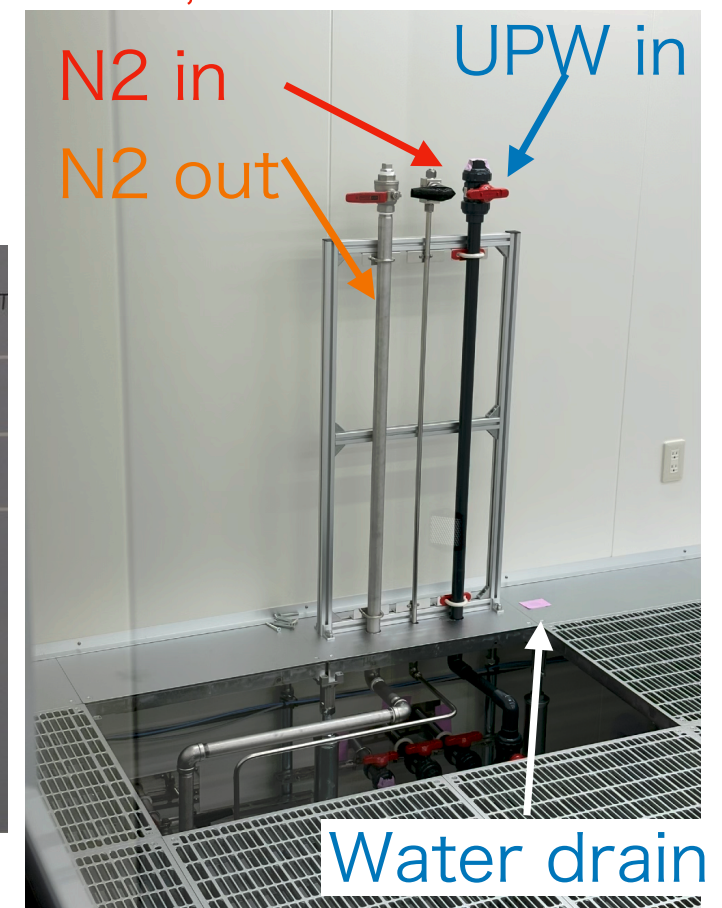
- ISO 14644-1 Class 1 (the cleanest) super cleanroom
 - No particles observed: World's cleanest level
 - Large size : capable of fabricating a mini-balloon
 - N2 supply/exhaust and ultra-pure water supply/drain ports are now available
- ➔ Developing technologies for next-generation experiments (crystallization, detector preparation, etc.)



of particle (any size) is 0



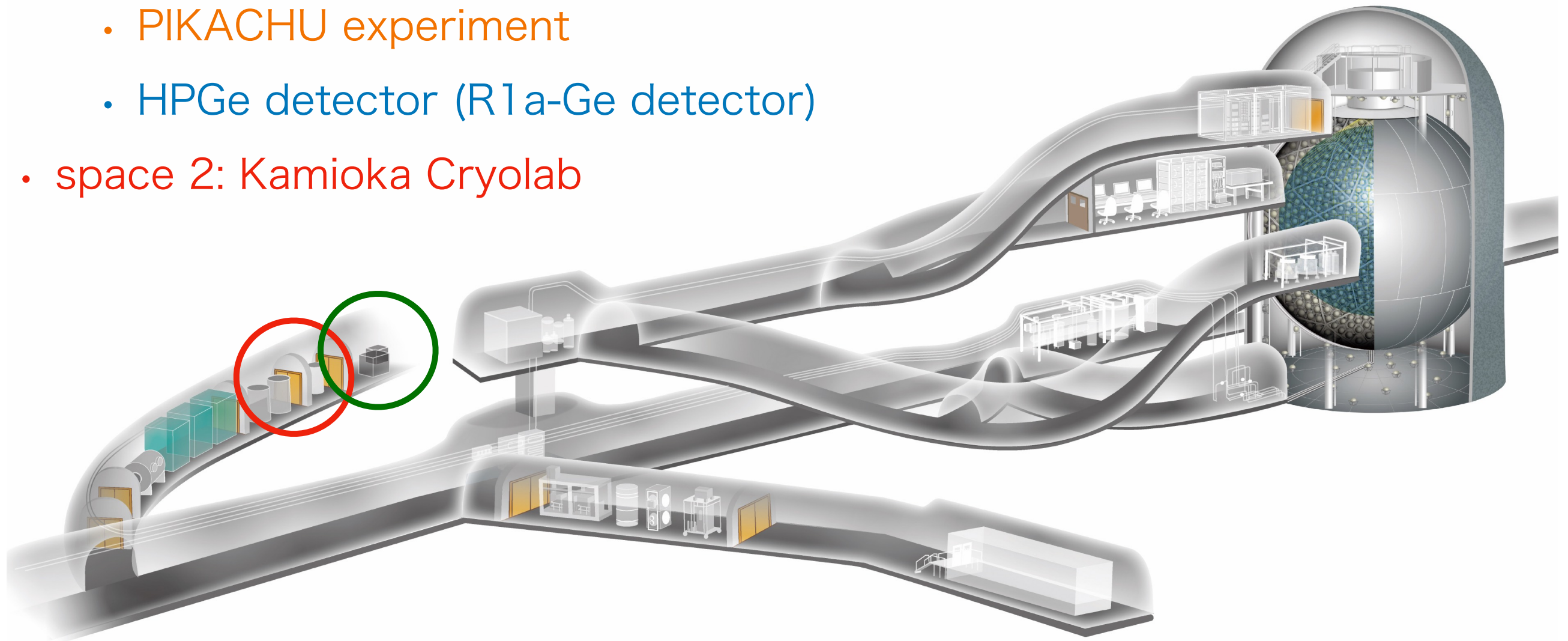
World's highest cleanliness



Facilities

Activities in the Clean experimental space1 and space2

- space 1:
 - PICOLON experiment
 - PIKACHU experiment
 - HPGe detector (R1 a-Ge detector)
- space 2: Kamioka Cryolab



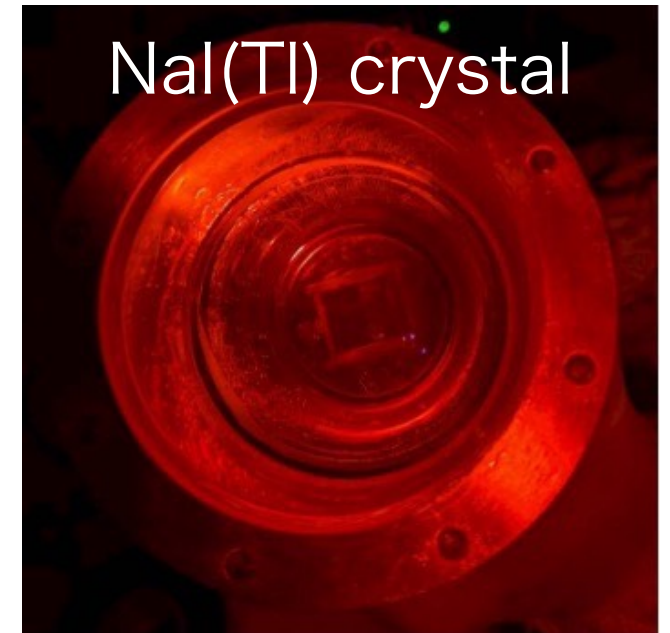
Ongoing Research Projects

PICOLON experiment

- Pure Inorganic Crystal Observatory for LOw-energy Neutr(al)ino
- Dark matter experiment using ultra-pure NaI (TI) crystal
- a PICOLON NaI(Tl) crystal (Ingot#85) reached **the same purity level as DAMA/LIBRA crystals**. (PTEP 2021, 043F01)
- BG stability of purity in the Ingot#94 (same purification method with Ingot#85) is reported in PTEP 2025, 123F01
- Achieved 0.4 keV_{ee} threshold (LBGT workshop 2026)
 - Lower than that of COSINE experiment

➔Next target : To demonstrate ultra-low energy electron recoil observation

RIs	DAMA/LIBRA [13]	COSINE [14]	ANAIS-112 [9,15]	SABRE [16,17]	Ingot#85 [11]	Ingot#94 (30 d) [12]	Our goal
⁴⁰ K [μ Bq/kg]	< 600	< 1060	545–1200	120	—	—	600
²³² Th [μ Bq/kg]	2–31	2.5–35	4	0.8	1.2 ± 1.4	4.6 ± 1.2	10
²²⁶ Ra [μ Bq/kg]	8.7–124	11–451	10	5	13 ± 4	7.9 ± 4.4	10
²¹⁰ Pb [μ Bq/kg]	5–30	10–3000	740–3150	360	<5.7	19 ± 6	50
BG rate (dru)	1	3	3.605 ± 0.003	1.39 ± 0.02	—	—	1



NaI(Tl) crystal

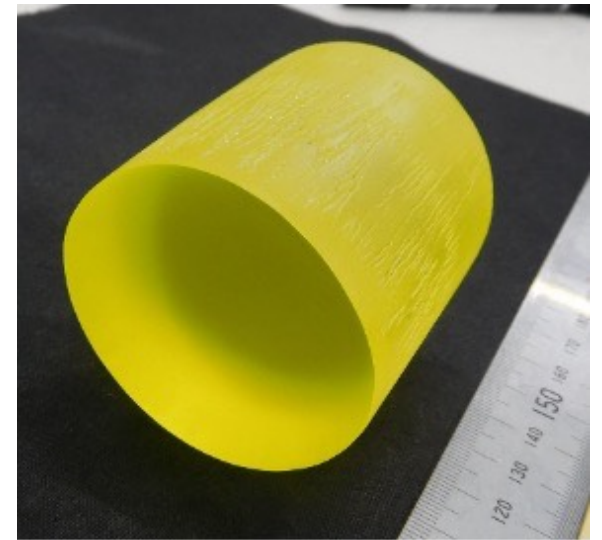


Shield(Pb + Cu)

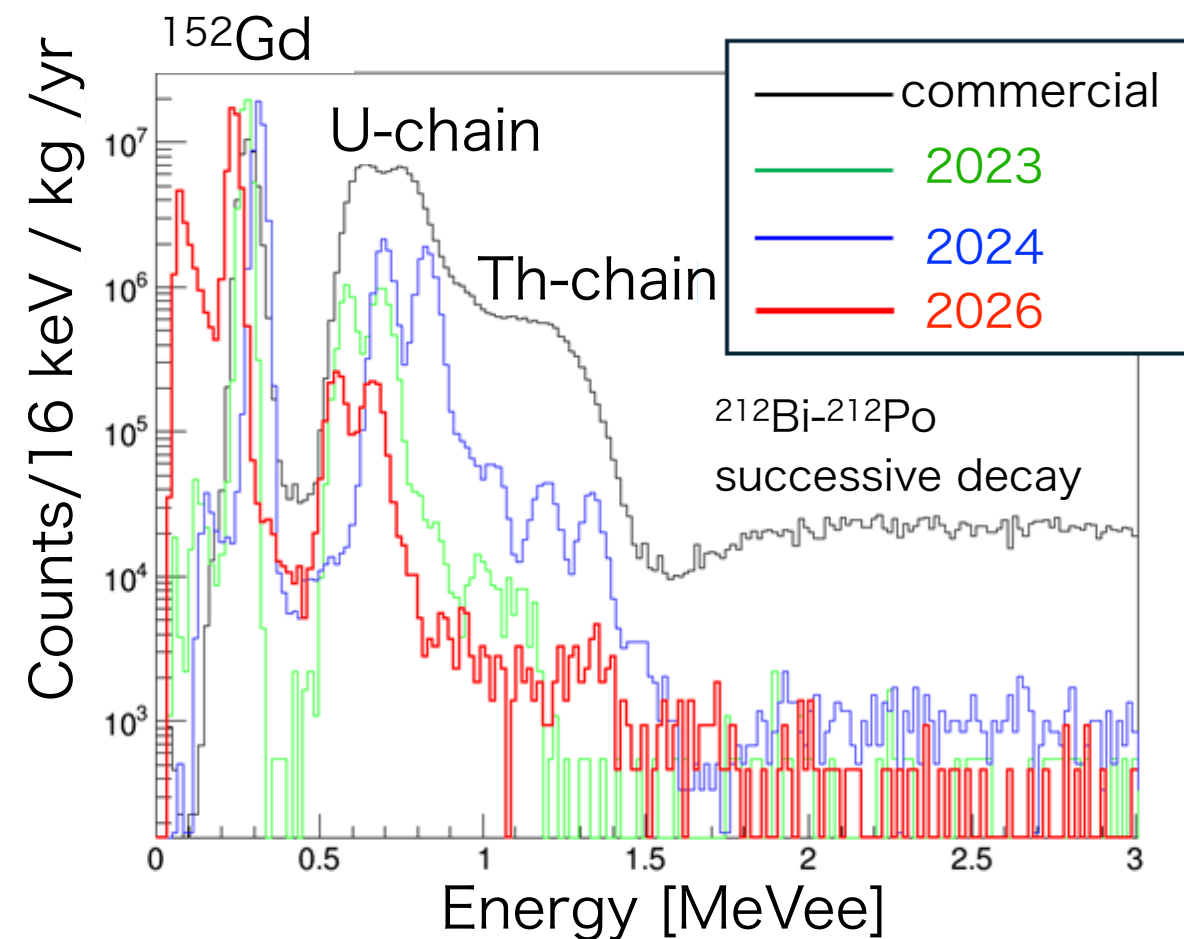
Ongoing Research Projects



PIKACHU experiment



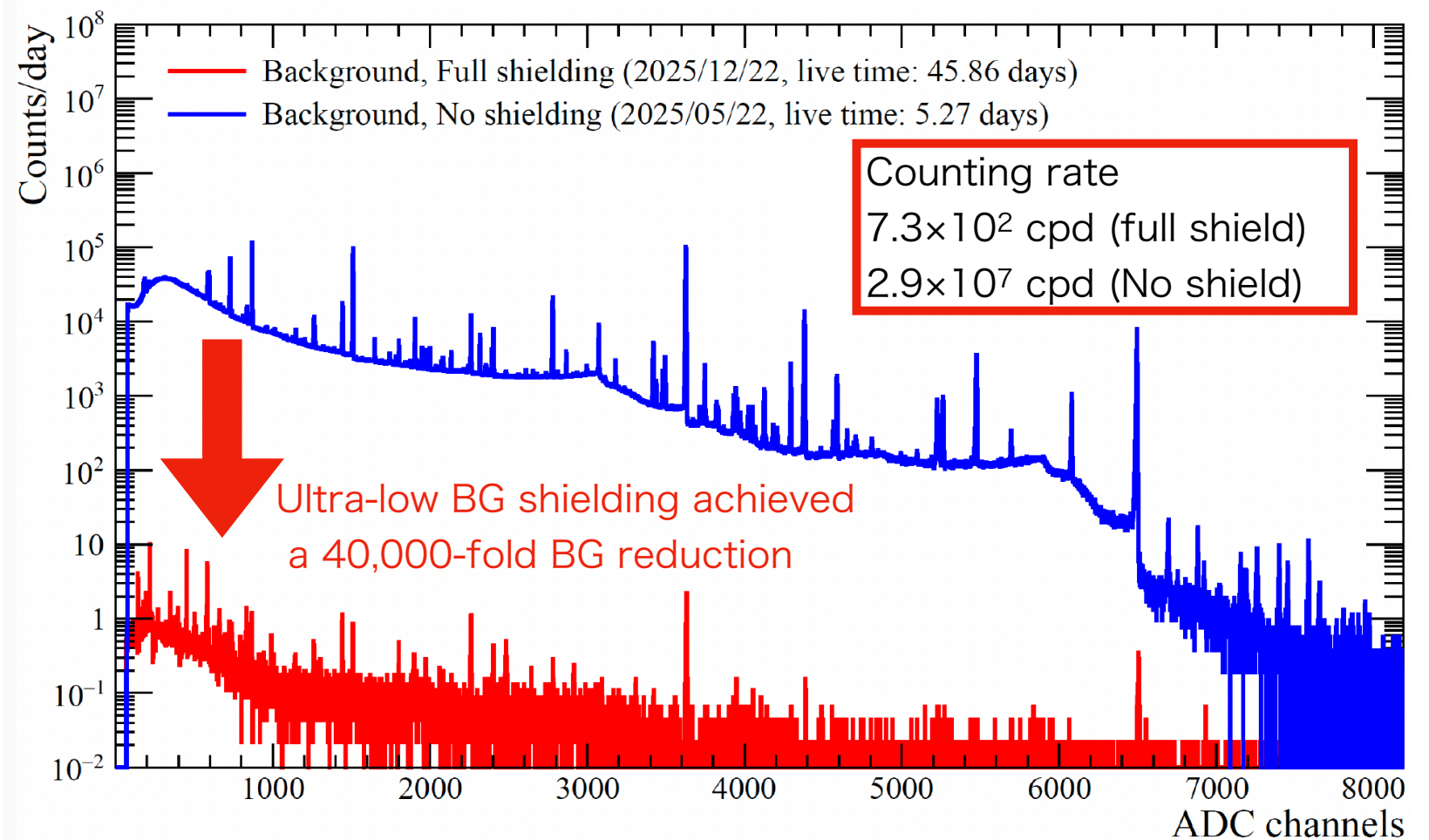
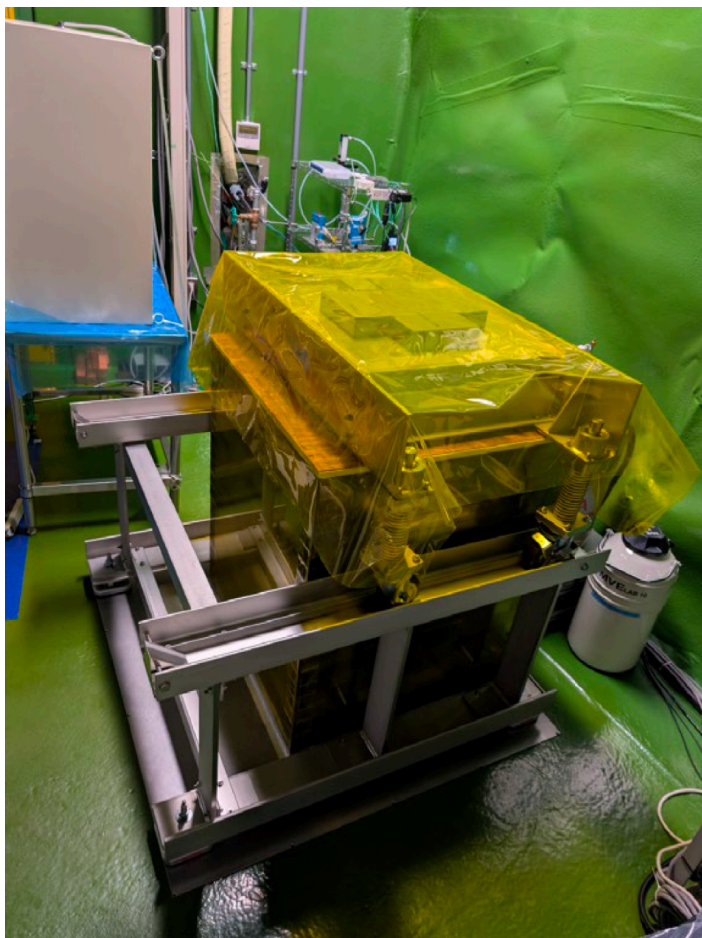
- Pure Inorganic scintillator experiment in KAmioka for CHallenging Underground Science
- Double beta decay experiment using GAGG crystal (^{160}Gd , $Q_{\beta\beta} = 1730$ keV, n.a. = 21.8%)
- Phase1 (2024~) : Aiming to demonstrate higher sensitivity than previous studies
- Developed ultra-pure GAGG :
 - (PTEP 2024, 033D01)
 - 2026 crystal: Achieved further purification by a factor of 3 to 4
- Sensitivity analysis of double beta decay :
 - NIM-A, Vol.1082, Part 2, (2026), 171023
- More details can be found in Poster P27 and P51 in this UGRP 2026 workshop



Ongoing Research Projects

HPGe detector (R1a-Ge detector)

- Canberra GC6520 (USA), coaxial p-type, 74% relative eff.
- The HPGe R1a-Ge setup reassembled in late 2025
- Detailed Geometry can be found in Dima's presentation in LBGT 2026 ([Link](#))
- The R1a-Ge detector is currently used for radioassay of KamLAND2 material
- If you want to measure some samples with this detector, please contact Dima



Ongoing Research Projects

Kamioka Cryolab

- A low-BG dilution refrigerator at Kamioka enables quantum-sensor payloads for extremely rare-event searches
- Based on MoU between Tohoku Univ. RCNS and KEK QUP
- Project was started with a US-Japan proposal in 2022

Quantum sensing

Cryogenic system

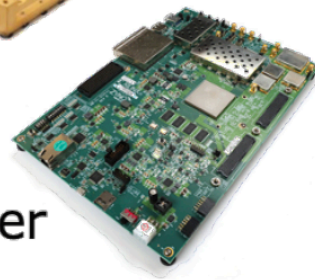
- ~ 0.1 K with refrigerator

Superconducting device

- MKID, TES, ...
- Fabrications
- Chain tests

RF/readout electronics

- 5G/6G technologies
- Quantum limited amplifier

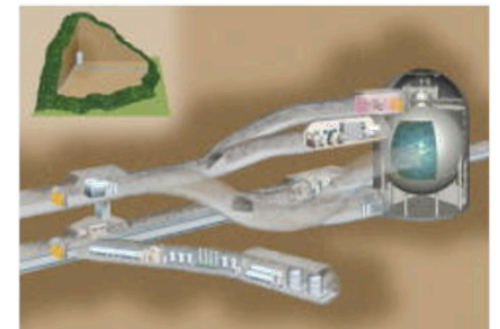


meets
X

Low background

Underground facility at the Kamioka mine

- Protecting system from cosmic-ray

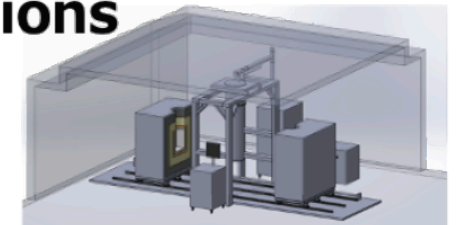


Low environmental radiation

- Understanding impacts of radio activities
- Low radio activities in materials
- Shielding system from radio activities

Low systematic fluctuations

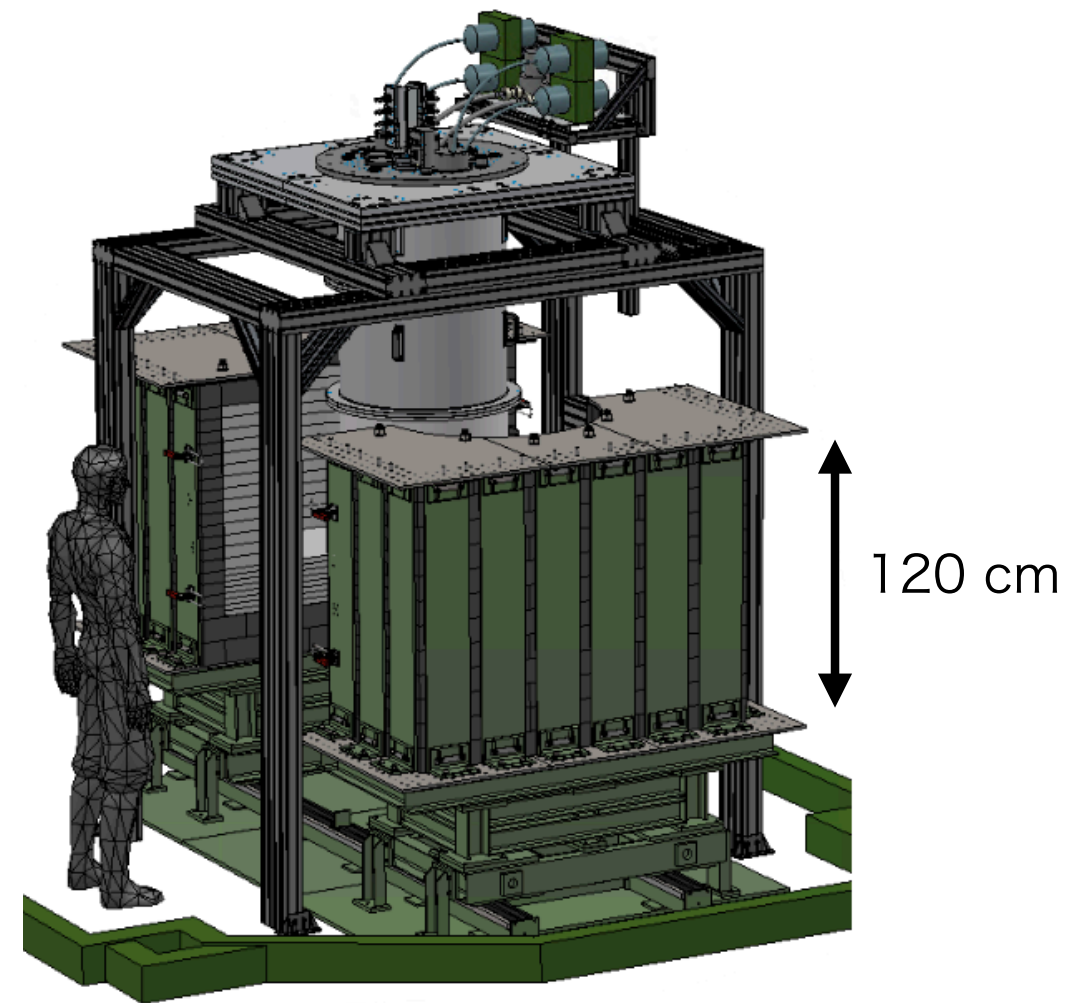
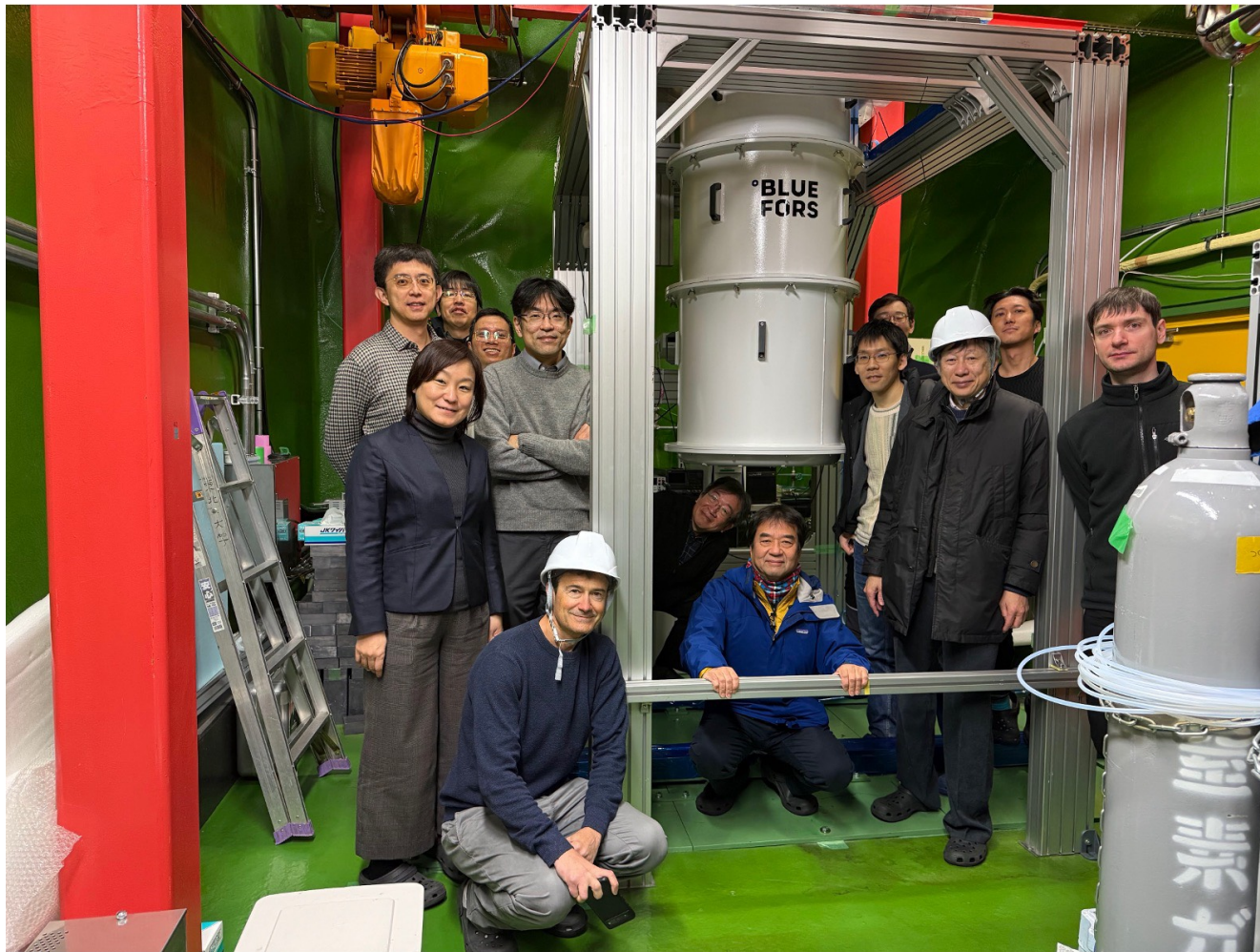
- Low thermal noise
- Low vibration



Ongoing Research Projects

Kamioka Cryolab

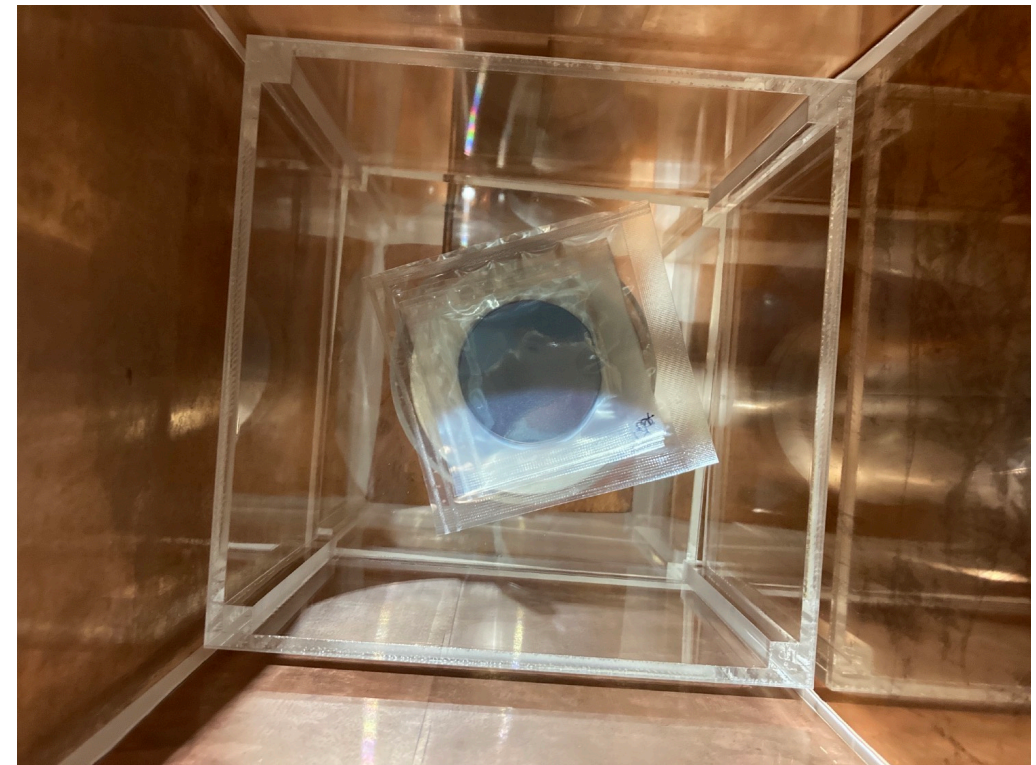
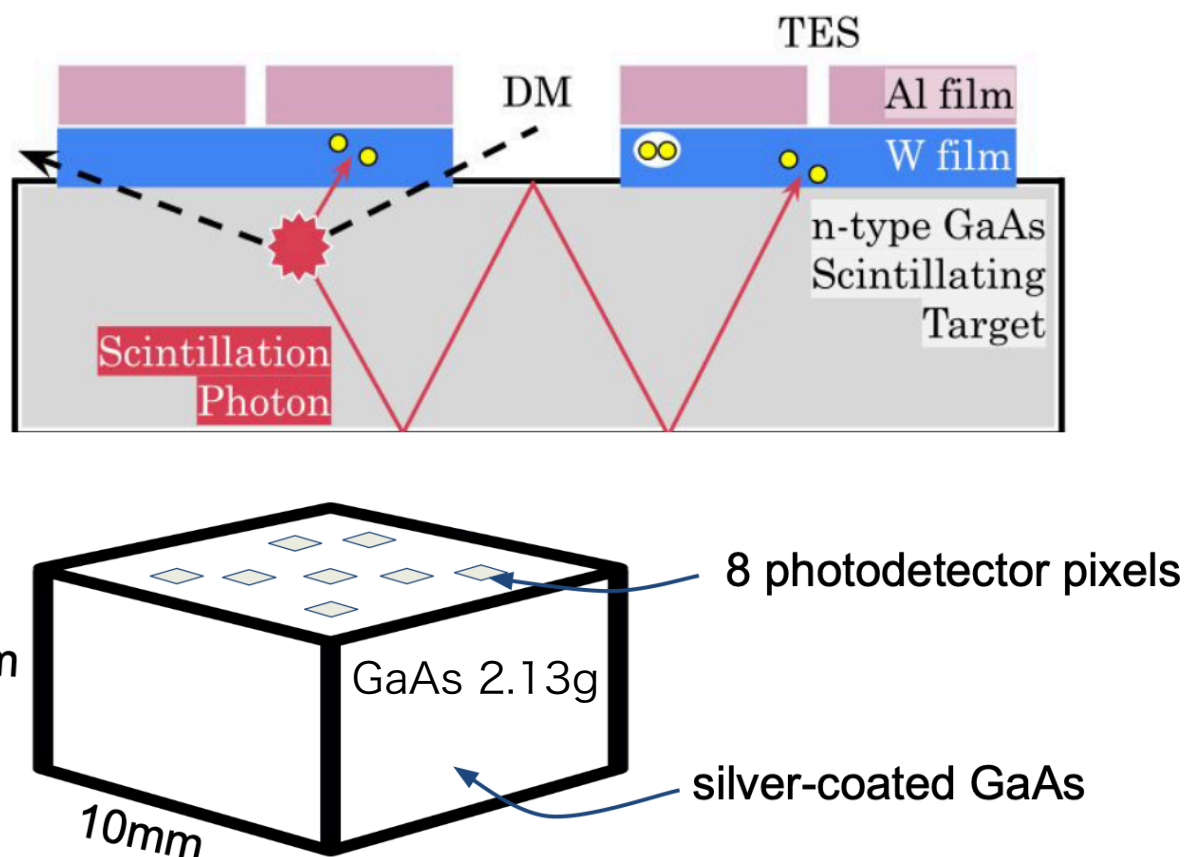
- XLD400 cryostat was moved from KEK to Kamioka in Nov. 2024
- Commissioning of full setup with shielding, readout electronics, etc. in progress
- Evaluation of lead shielding performance & optimization of shield design are ongoing



Ongoing Research Projects

First experiment : light DM search with GaAs

- Based on US-JP joint research program
- GaAs : bright scintillating crystal
 - Scintillation photon is absorbed by W-Al bilayer coupled to TES. → photon counting
- **First science run will be conducted in this fiscal year.**
 - **Now performance test is ongoing.**



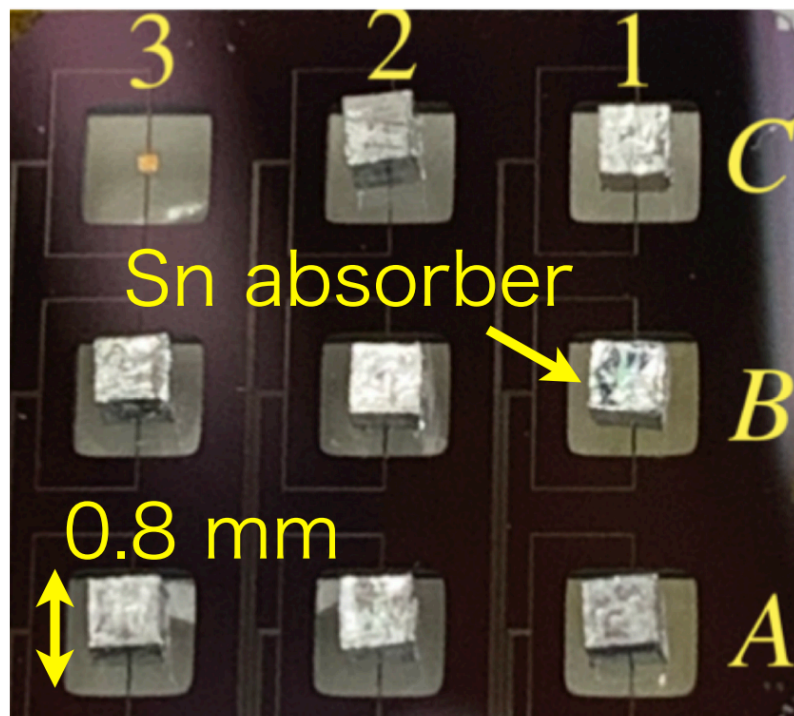
GaAs wafer measurement

Ongoing Research Projects

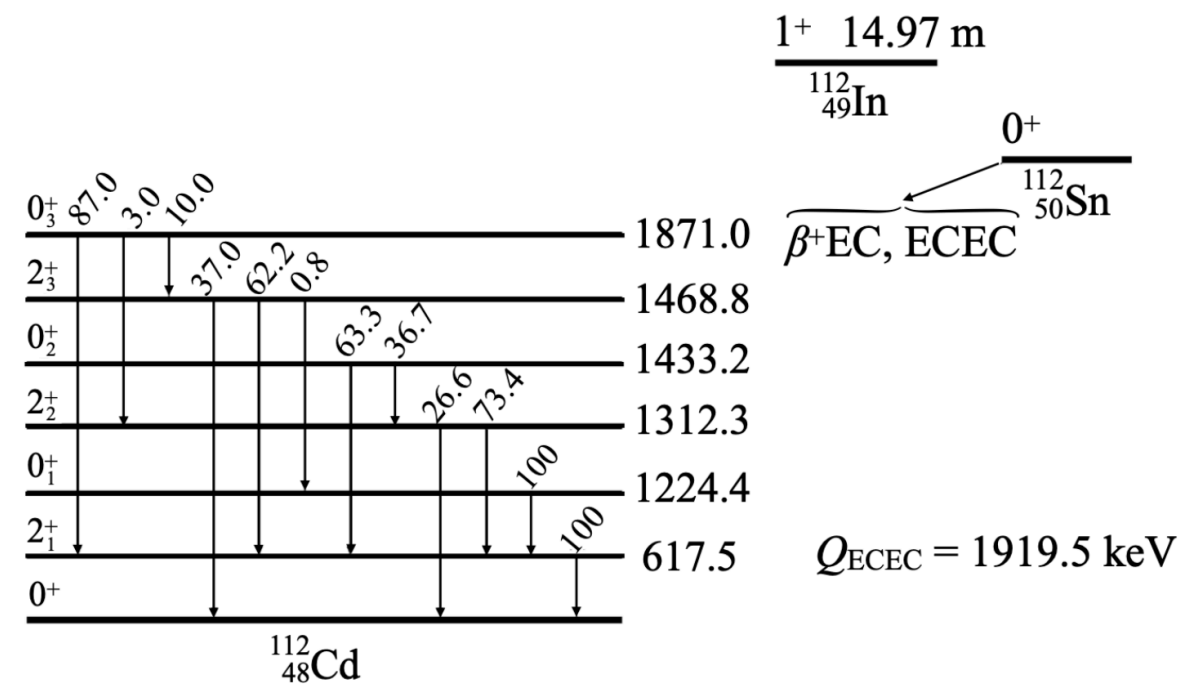
Example of Rare Event Search(1) ^{112}Sn rare decay

- ^{112}Sn (n. a. = 0.97%) decays to ^{112}Cd with ECEC or $\beta^+\text{EC}$ ($Q = 1.92$ MeV)
- γ -TES (collaborative research with AIST : **source = detector (for 2ν ECEC search)**)
 - **high detection efficiency (X-ray, Auger electron), high energy resolution (< 0.1% FWHM)**
- can detect X-ray or Auger electron from ECEC (~53 keV energy deposit) or $\beta^+\text{EC}$
- Sensitivity study for 2ν ECEC mode is ongoing (A. Takeuchi, TAUP2025), **paper in preparation**

8 Sn absorbers
(0.8 x 0.8 x 0.8 mm³)



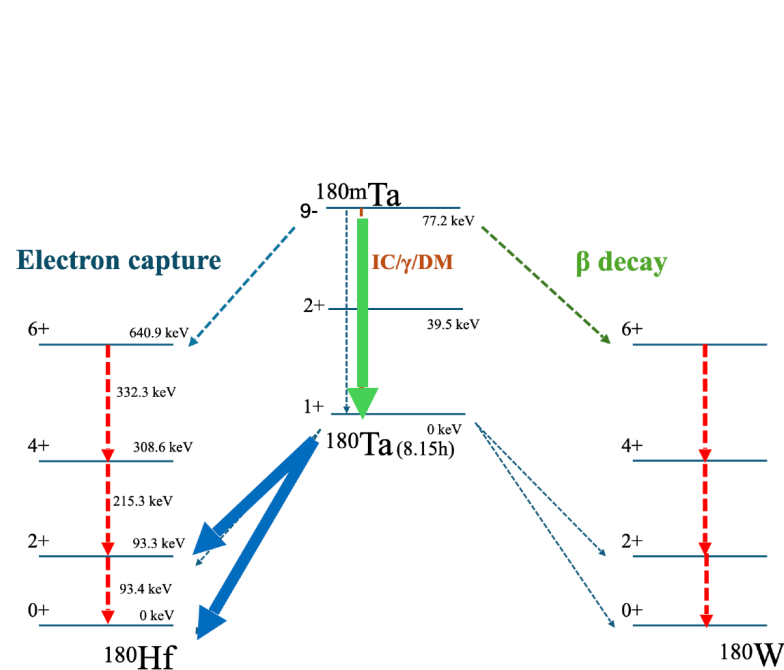
IEEE TRANSACTIONS ON APPLIED SUPERCONDUCTIVITY
VOL. 35, NO. 5, (2025) 2100104



Ongoing Research Projects

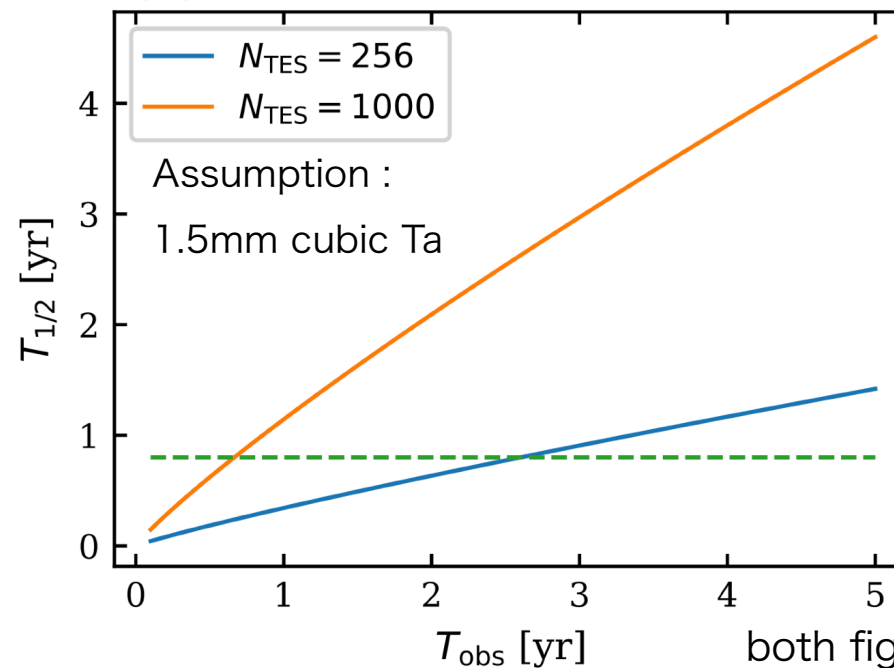
Example(2) $^{180\text{m}}\text{Ta}$ rare decay & DM search

- $^{180\text{m}}\text{Ta}$: The only nuclear isomer with no observed decay
- Deexcitation via interaction with dark matter is suggested ([PRC 95, 044306 \(2017\)](#))
 - $\chi + ^{180\text{m}}\text{Ta} \rightarrow \chi^* + ^{180(\text{m})}\text{Ta}$, $^{180}\text{Ta} \rightarrow ^{180}\text{Hf}$ via EC or ^{180}W via β^-
- Superconducting sensor (TES, MKID) can detect clear EC signal (X-ray, Auger electron)
 - Sensitivity study is published ([PRD 113, 052007 \(2026\)](#))
- **Other ideas with utilizing Cryogenics are very welcome**

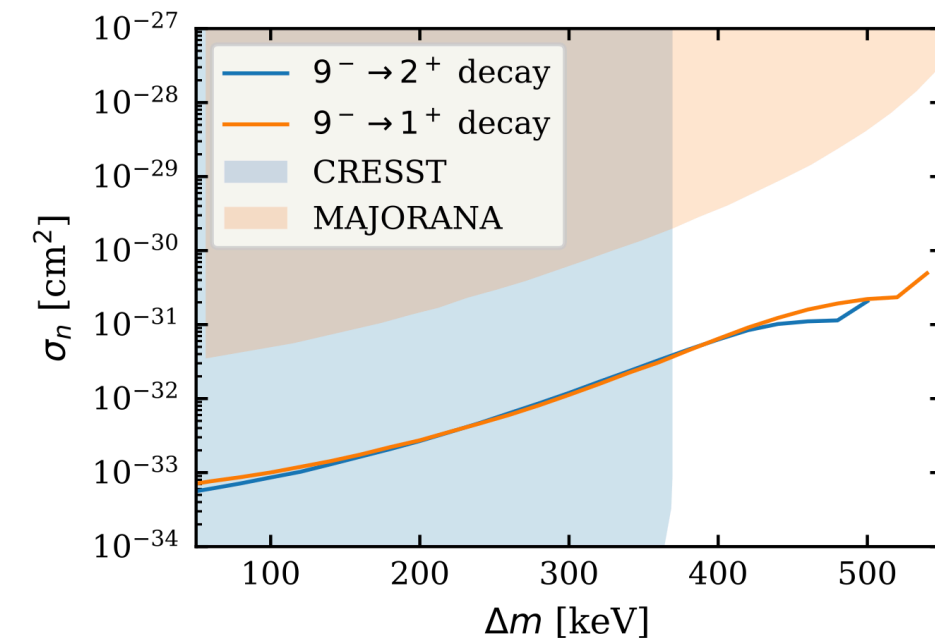


$^{180\text{m}}\text{Ta}$ Internal Conversion decay mode

Theoretical half life : 8×10^{18} yr
 1×10^{19}



$N_{\text{TES}} = 10,000$, 5 year exposure
 $m_\chi = 1$ TeV, Δm = mass splitting



both figure : 3σ discovery level

Summary

- We have launched a **Steering Committee** and **Technical / Research Advisory committees** to steadily advance researches and ultra-low radioactivity technologies.
- We are developing Super Clean Facilities to enhance the KERNEL activities.
 - Essential for the **upgrade plan of KamLAND (KamLAND2)**
 - Strong supports for **next-generation technology development and small-scale experiments** for extremely rare phenomena research
- We welcome the use of KERNEL facilities by **many researchers from Japan and abroad**, as well as by **young researchers** who will lead the next generation.

New proposals are welcome !!