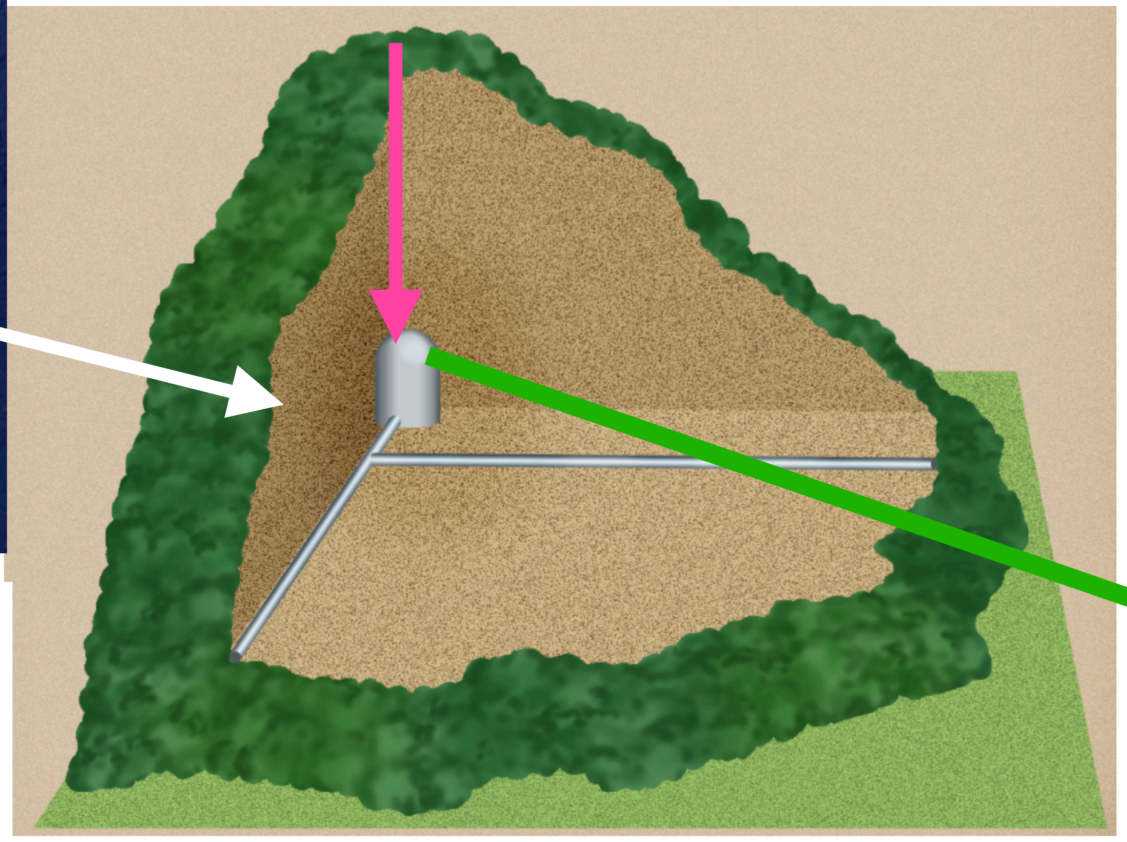
Status and future prospect of the Kamioka ultra-low BG facility

Contents:

- Introduction of the KamLAND and Kamioka Ultra-low BG facility
- Super-clean room and its application
- Experimental hall and its planned application
- Rn-free air and Ultra-pure water generation system

Low Radioactivity Techniques (LRT2024), 1-4 Oct. 2024 Krakow, Poland
K.Ichimura (RCNS, Tohoku Univ. ichimura@awa.tohoku.ac.jp)

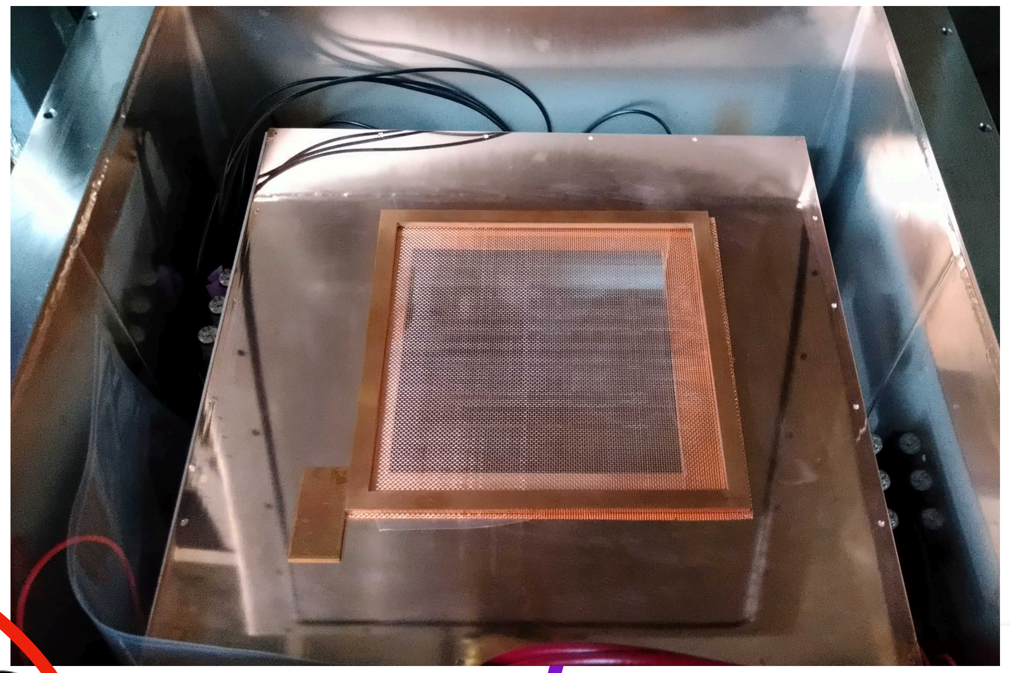
Kamioka Underground laboratory



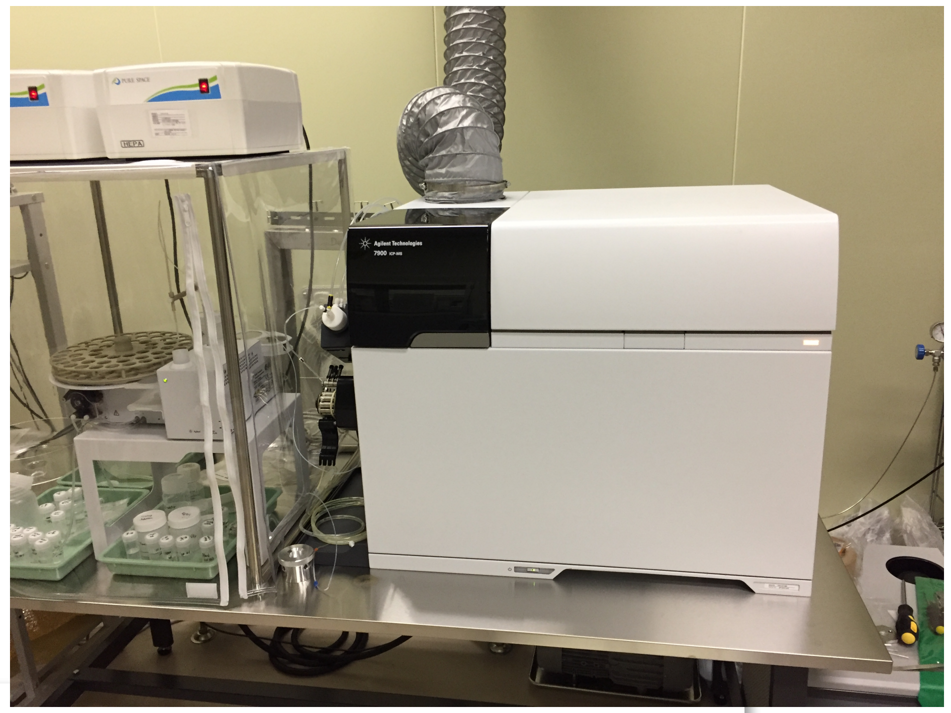
1000 m under the top of Mt. Ikenoyama

KamLAND（Tohoku Univ.）
details in later

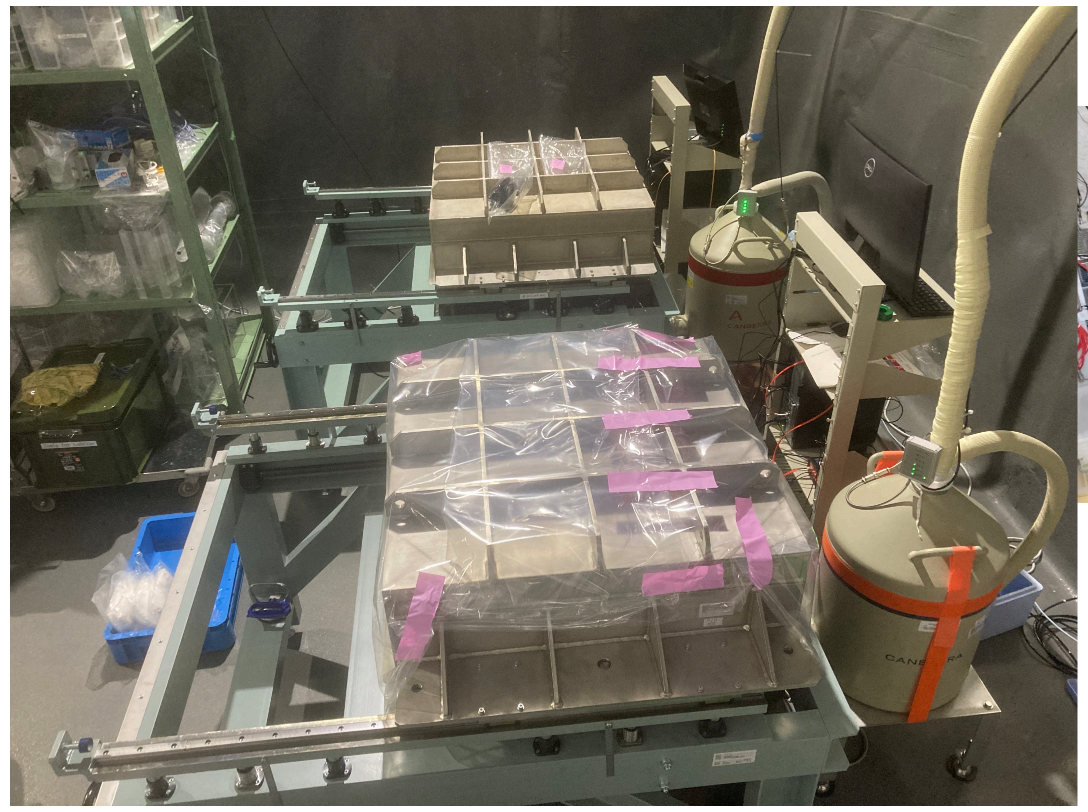
α imaging chamber (AICHAM) at Lab. A



ICP-MS at Clean room



ultra-low BG HPGe at Lab. C



low BG HPGe at Lab. D

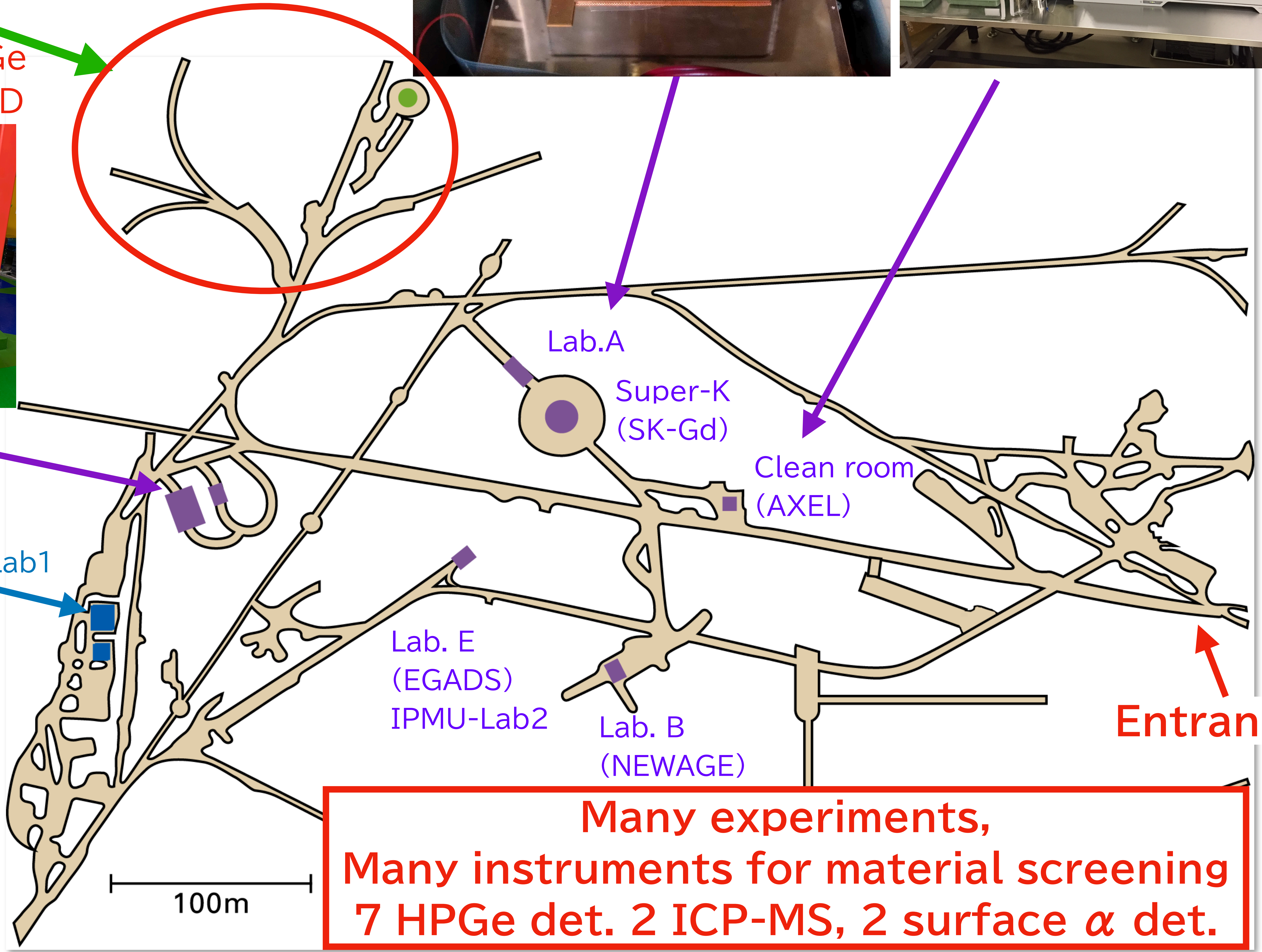
low BG HPGe at KamLAND

low BG HPGe at IPMU-Lab1

ICP-MS,
Ultralo-1800 surface α det.
at IPMU-Lab1 clean room

Lab. C (former XMASS)
Lab. D (CANDLES)

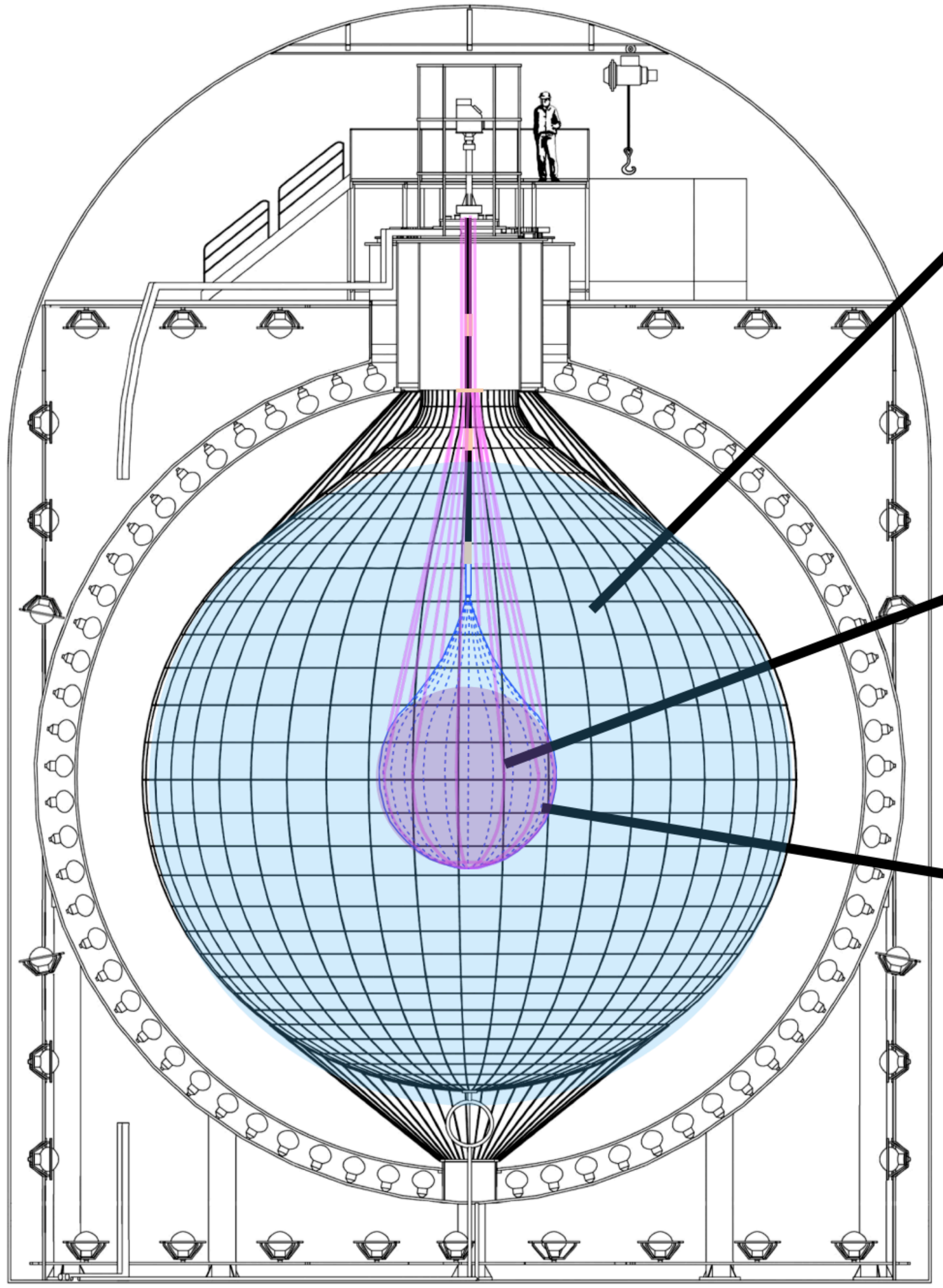
IPMU-Lab1



Entrance

Many experiments,
Many instruments for material screening
7 HPGe det. 2 ICP-MS, 2 surface α det.

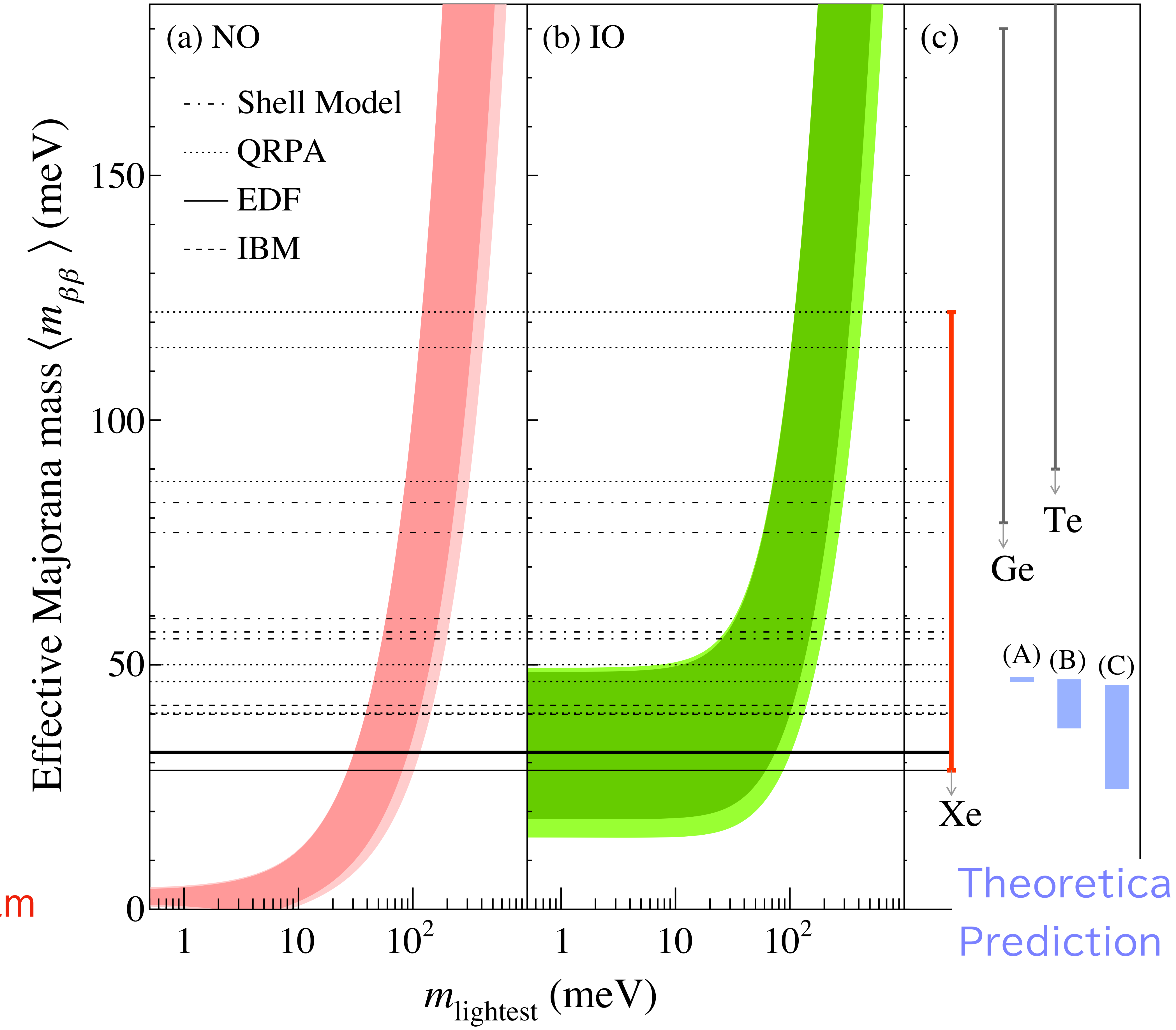
Status of the KamLAND (-Zen) experiment



Outer LS
~1000 ton pure liquid scintillator
^{238}U ~5.0×10^{-18} g/g
^{232}Th ~1.3×10^{-17} g/g

Xe-LS
745 kg Xe-loaded liquid scintillator
(91% ^{136}Xe enrichment)

ultra-clean nylon made inner balloon
^{238}U : $(3 \pm 1)\times10^{-12}$ g/g_{Film}
^{232}Th : $(3.8 \pm 0.2)\times10^{-11}$ g/g_{Film}



Latest result : arXiv:2406.11438

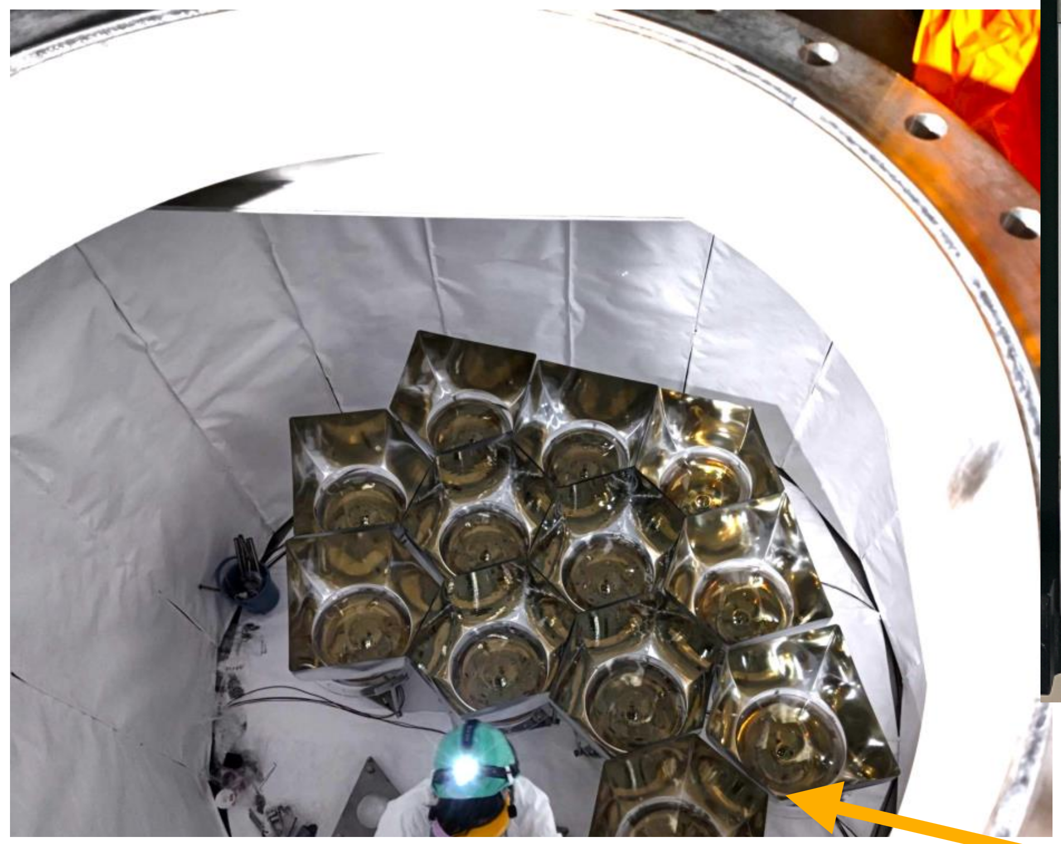
- Finished KamLAND-Zen data taking on Jan. 12, 2024
- The inner balloon was pulled out on May 31, 2024
  - Xe-LS was extracted from the inner balloon, and Xe gas is now stored in bottles.
- Finished KamLAND data taking on Aug. 27, 2024
  - We will start Outer LS extraction on Oct. 3 (just day after tomorrow)

➡ Upgrade to KamLAND2 (-Zen)

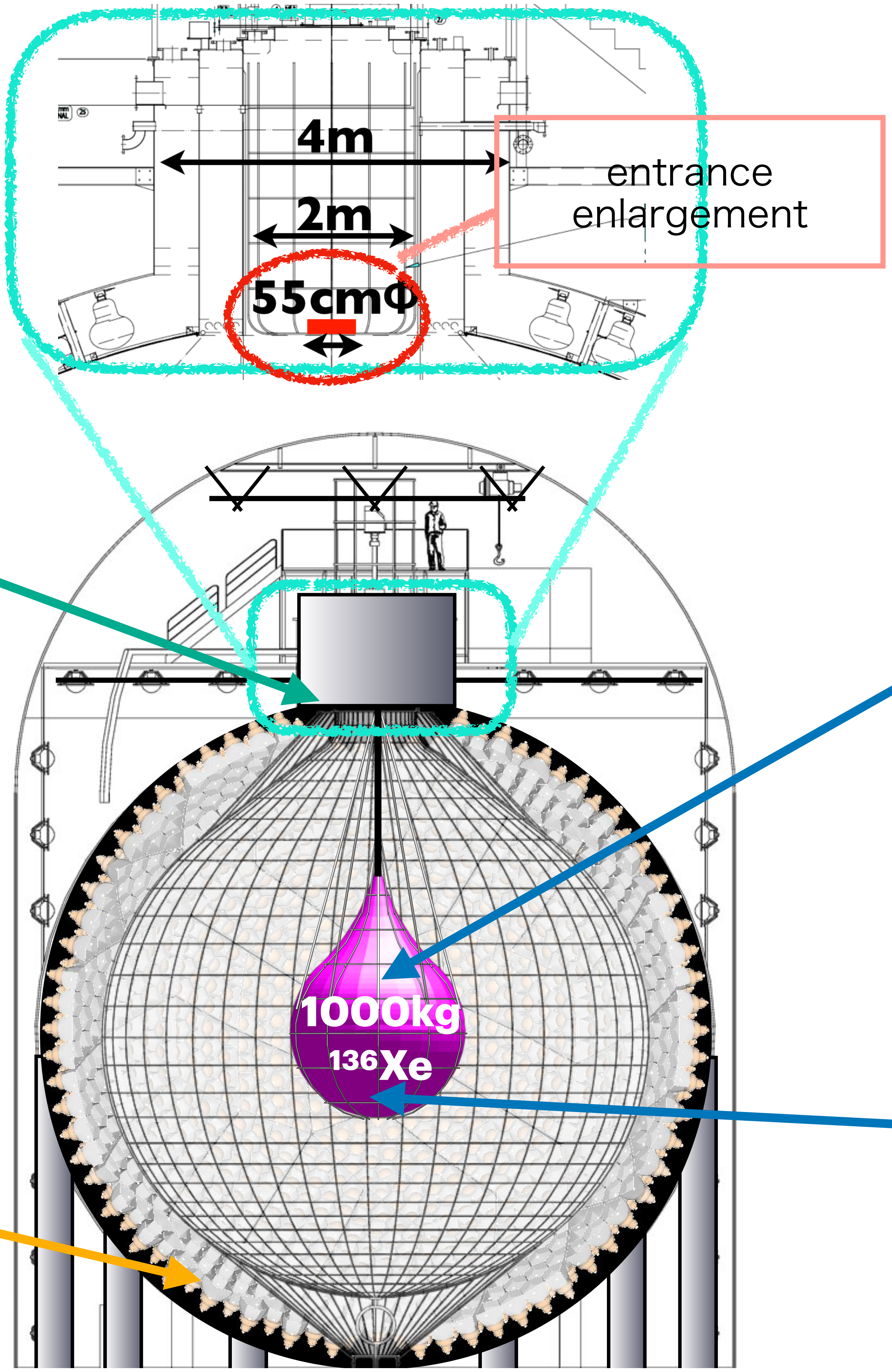
Toward KamLAND2 (-Zen) experiment

Scintillation fiber + SiPM

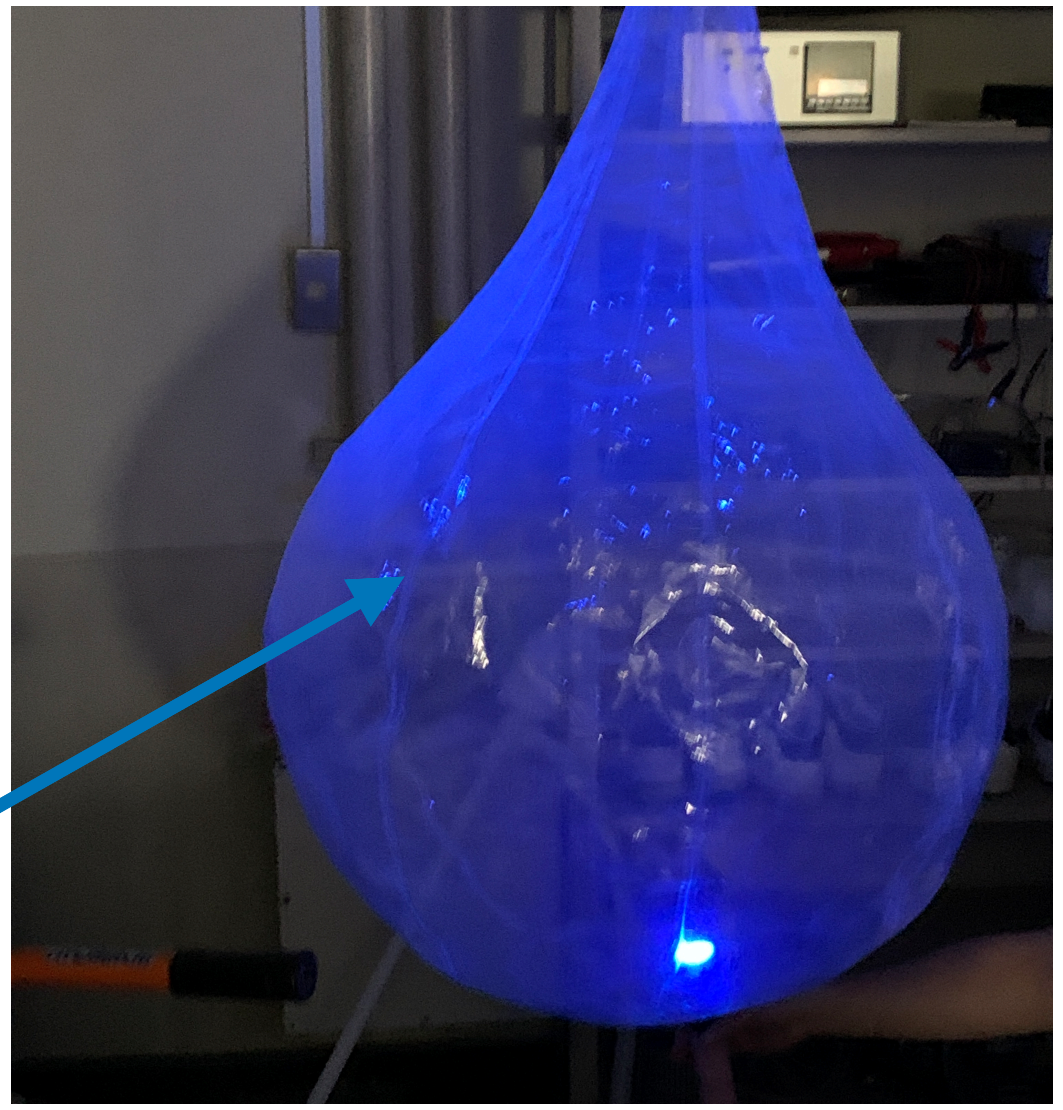
to collect photons at chimney region



High QE PMTs
+mirror (light collector)
to improve energy resolution



PEN (polyethylene-naphtalate made) inner-balloon



To eliminate BGs (^{214}Bi) originating from balloon

Wavelength-shifter

+new electronics
+increase ^{136}Xe
and more

Target sensitivity : <$m_{\beta\beta}$> ~20 meV / 5 years, start KamLAND2-Zen in FY 2027

need to assay & reduce RI in detector component with high sensitivity

need to keep items, and to develop detector component in a super-clean environment

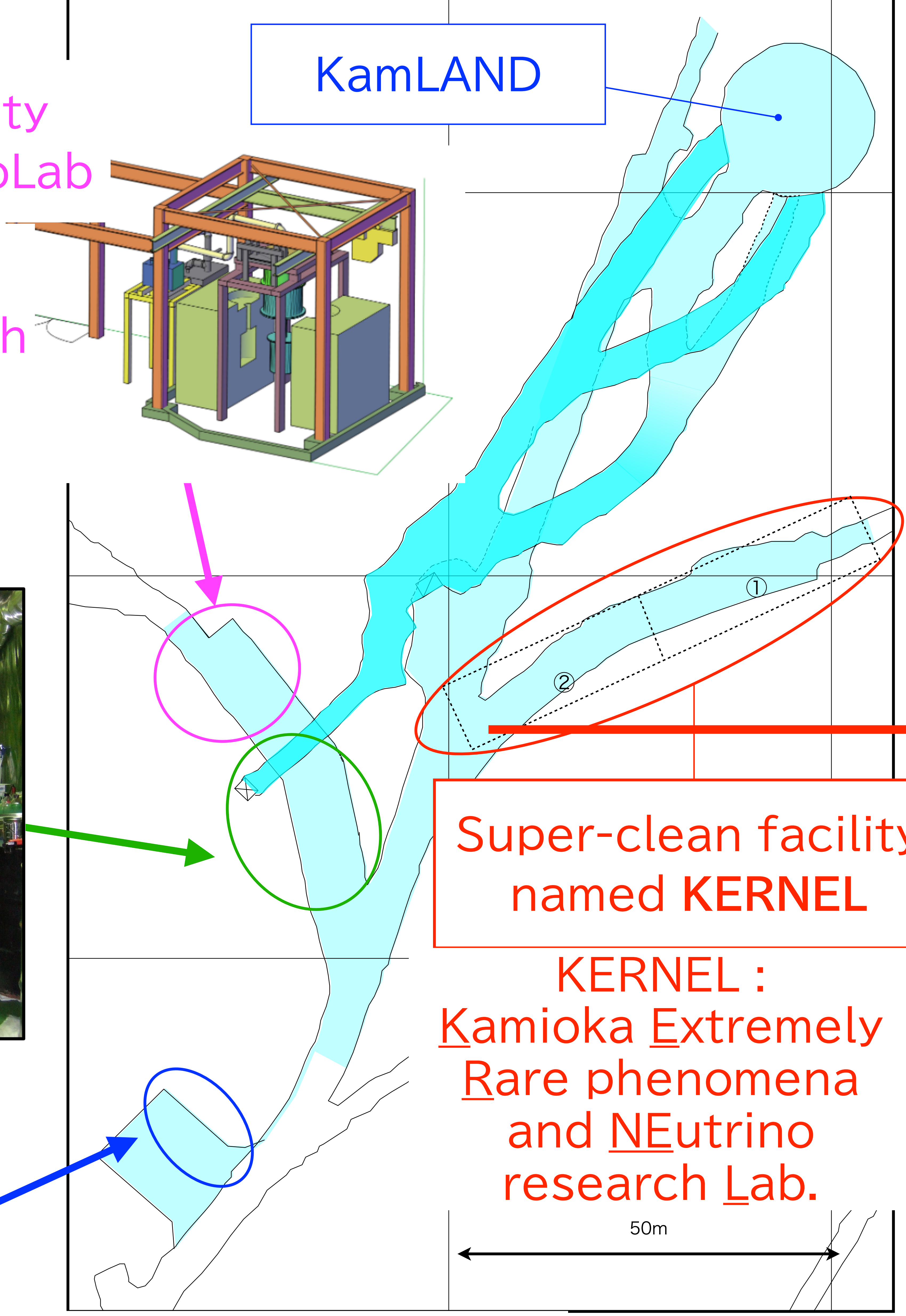
→We need a super-clean facility : KERNEL

KamLAND and related facilities

Clean facility
Kamioka CryoLab

Low BG Pb shield
Low BG cryostat
→ Low mass DM search
(1 — 100 MeV/c^2)

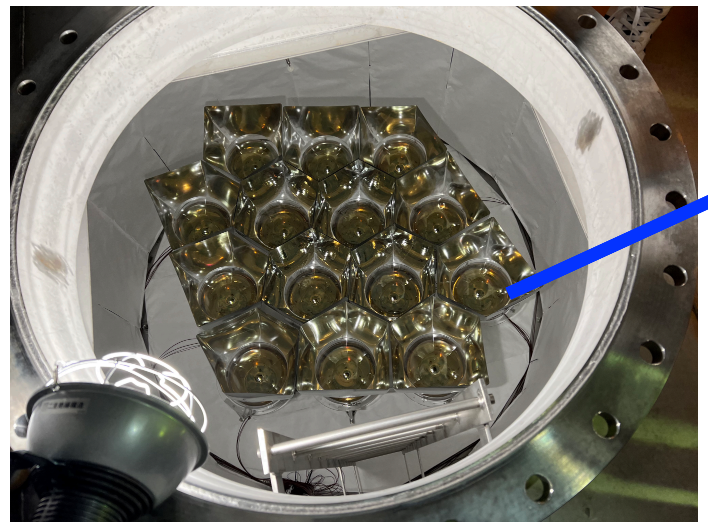
LS purification area
by distillation



Super-clean facility
named **KERNEL**

KERNEL :
Kamioka Extremely Rare phenomena and NEutrino research Lab.

This area
(past LS purification area by water extraction)
will become a super clean-facility in this FY



lowBG test bench
PMT and light guide
performance test

Purpose of KERNEL :

KERNEL is not only a facility for the success of KamLAND2, but also for the growth of the entire LowBG community (innovation, development of new technologies, development of young talent)

Photos of KERNEL site (Sep. 2024)

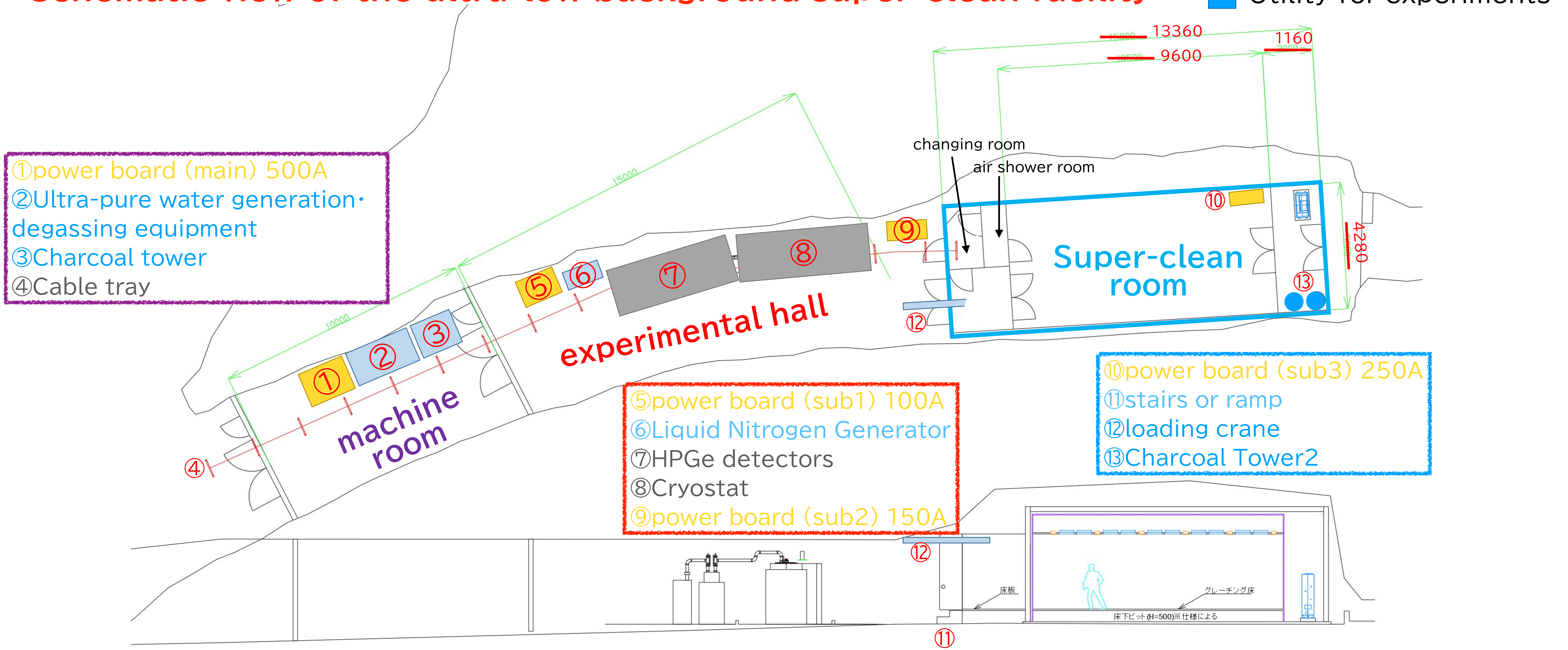
Current Status :
Mine-guard painting work has been completed

Cable-tray installation work has been completed

→ Start of construction of Class 1 Super Clean Room

KERNEL (Kamioka Extremely Rare phenomena and NEutrino research Laboratory)

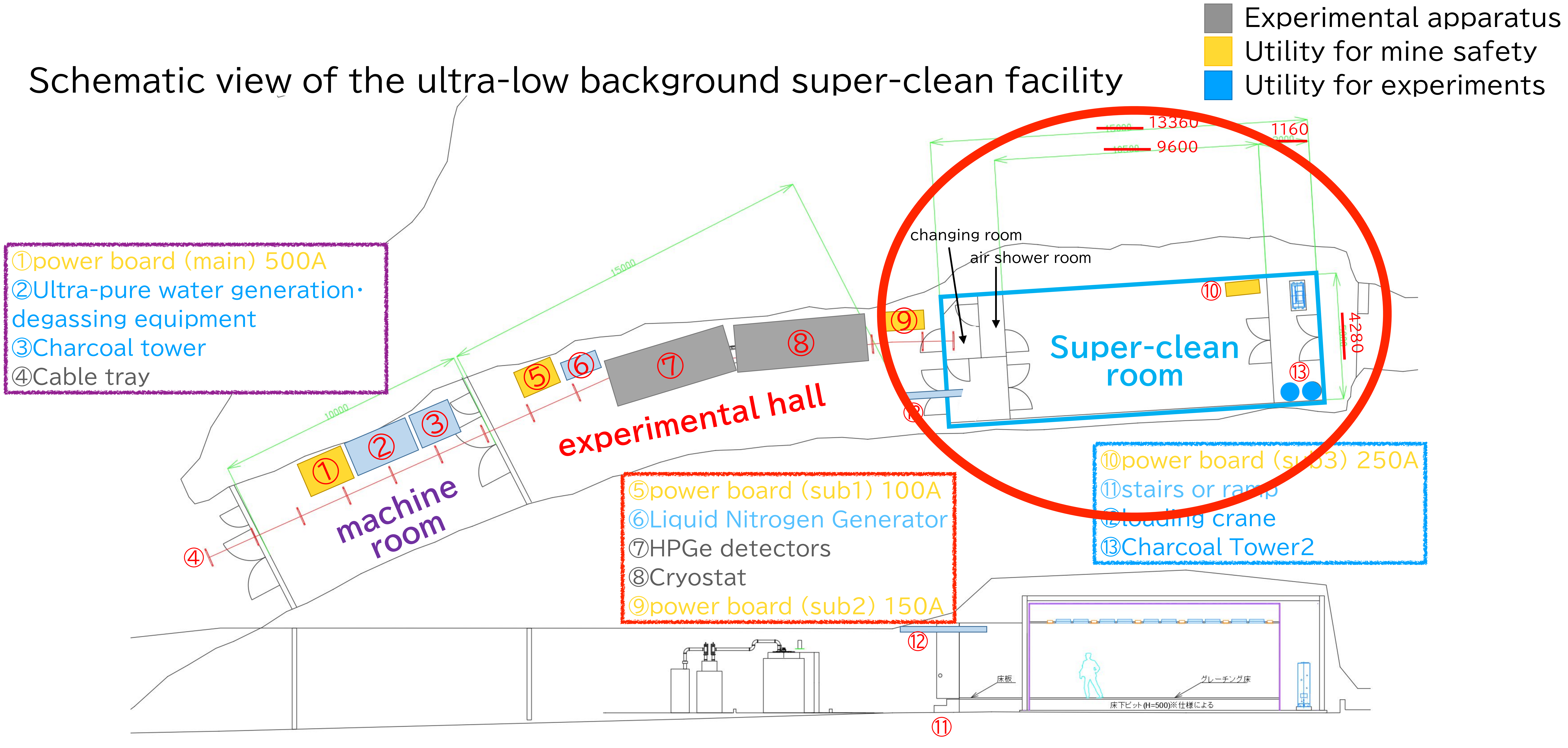
Schematic view of the ultra-low background super-clean facility



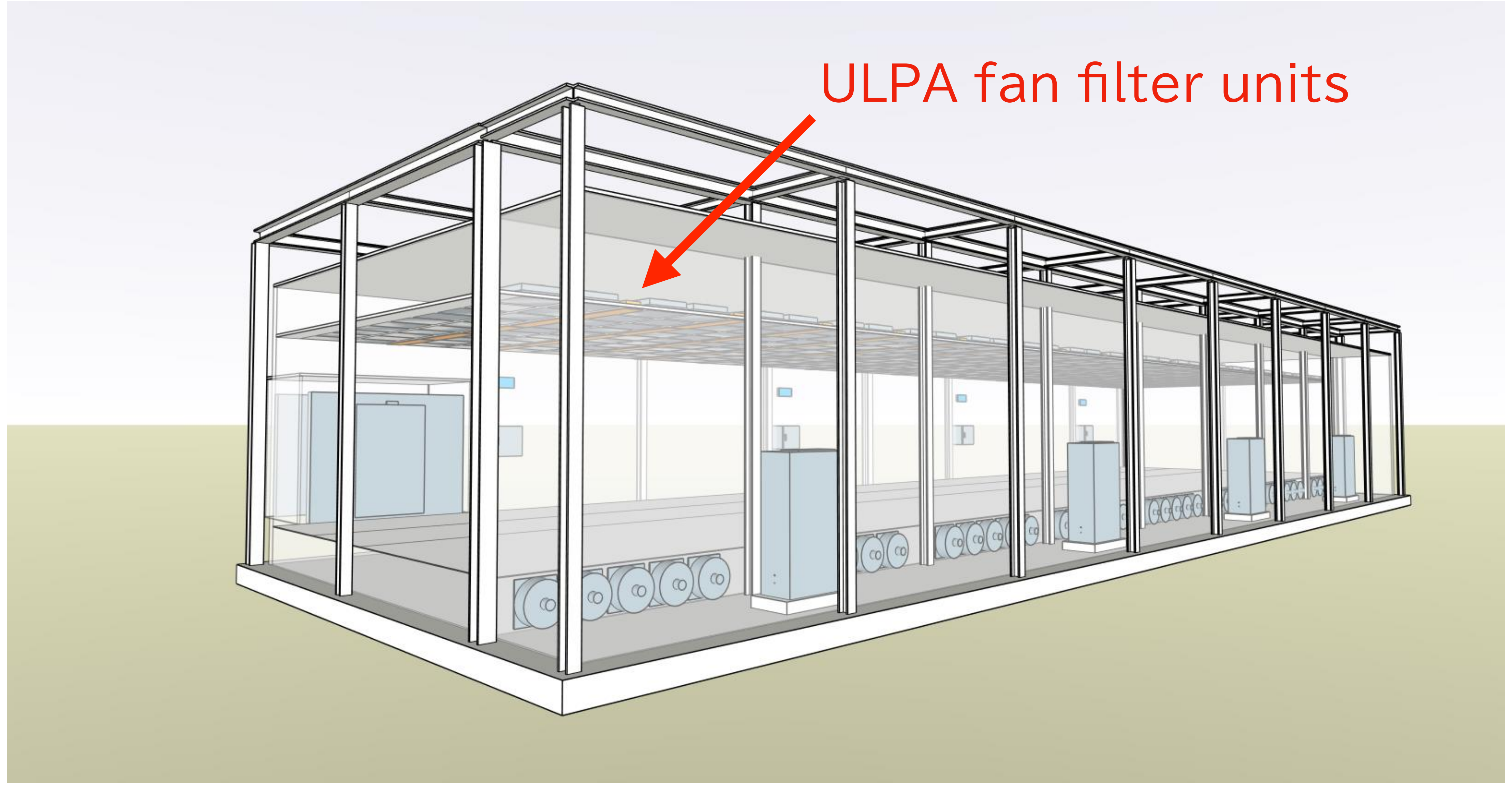
We began to organize an inter-university laboratory to search for extremely rare phenomena "KERNEL" in the Kamioka underground in this year

Class-1 Super-clean room and application

Schematic view of the ultra-low background super-clean facility



Capability of the super-clean room



- Floor space : 9.6 m × 4.3 m, 2.4 m height
- **54** Ultra Low Penetration Air (ULPA) fan filter units to keep ISO 14644-1 class1 cleanness
  - < 10 particles (size : 0.1 μm) / m^3
  - Same specification as Micro System Integration Center (μSIC) at Tohoku University in Sendai
  - http://www.mu-sic.tohoku.ac.jp/index e.html
- Air flow : ~2m/s down-flow (360,000 m^3/hr)
  - Internal circulation
- Air conditioner : control temperature & humidity
  - For example, humidity should keep > 50% to make KamLAND-Zen balloon

μSIC, Tohoku Univ., Sendai

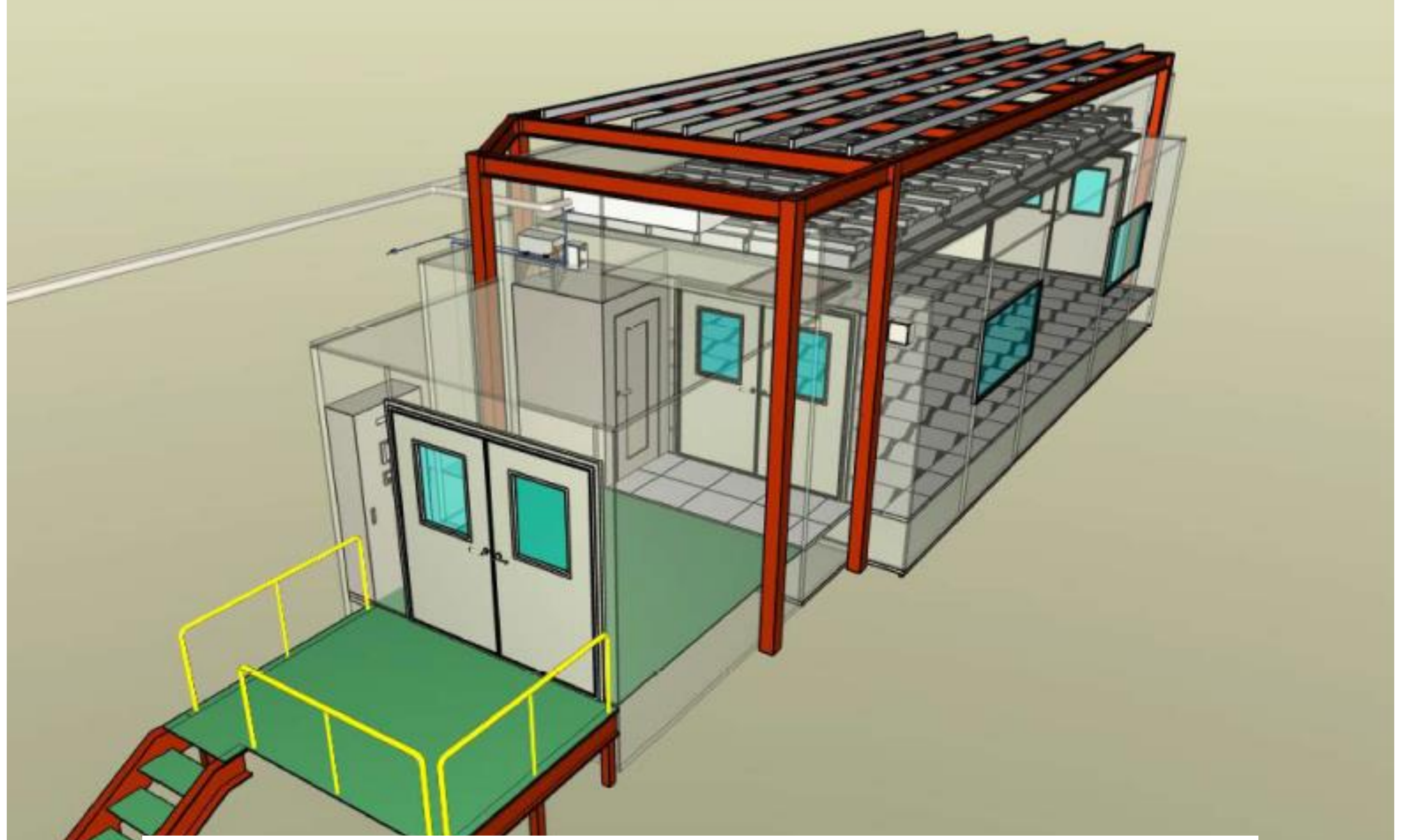


Image of the super clean room

Super-clean room application(1) inner-balloon fabrication

①Film washing

②Seam welding

- All fabrication work were done in class 1 clean room at μSIC in Sendai, Japan for KamLAND-Zen 800
  - ^{238}U : $(3 \pm 1)\times10^{-12}$ g/g$_{Film}$
  - ^{232}Th :$(3.8 \pm 0.2)\times10^{-11}$ g/g$_{Film}$
- Such things could be done in new class1 clean room in the mine for KamLAND2-Zen

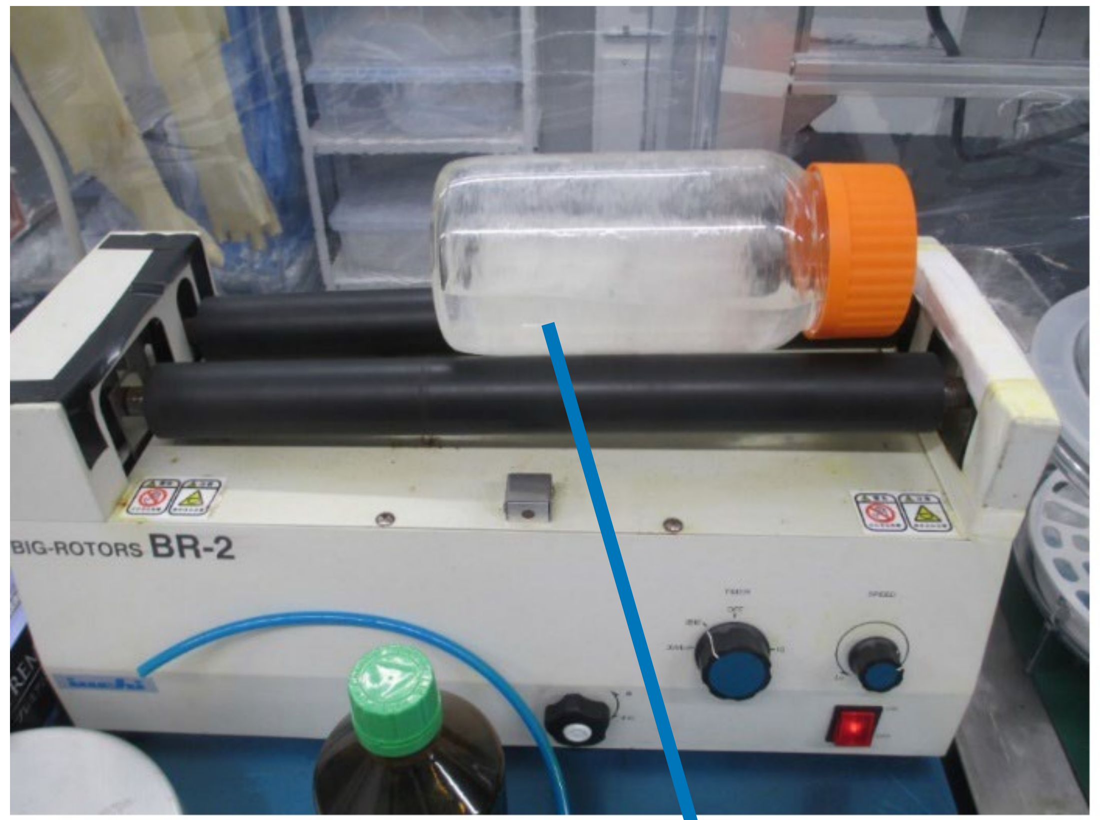
③He leak test+repair

④Folding

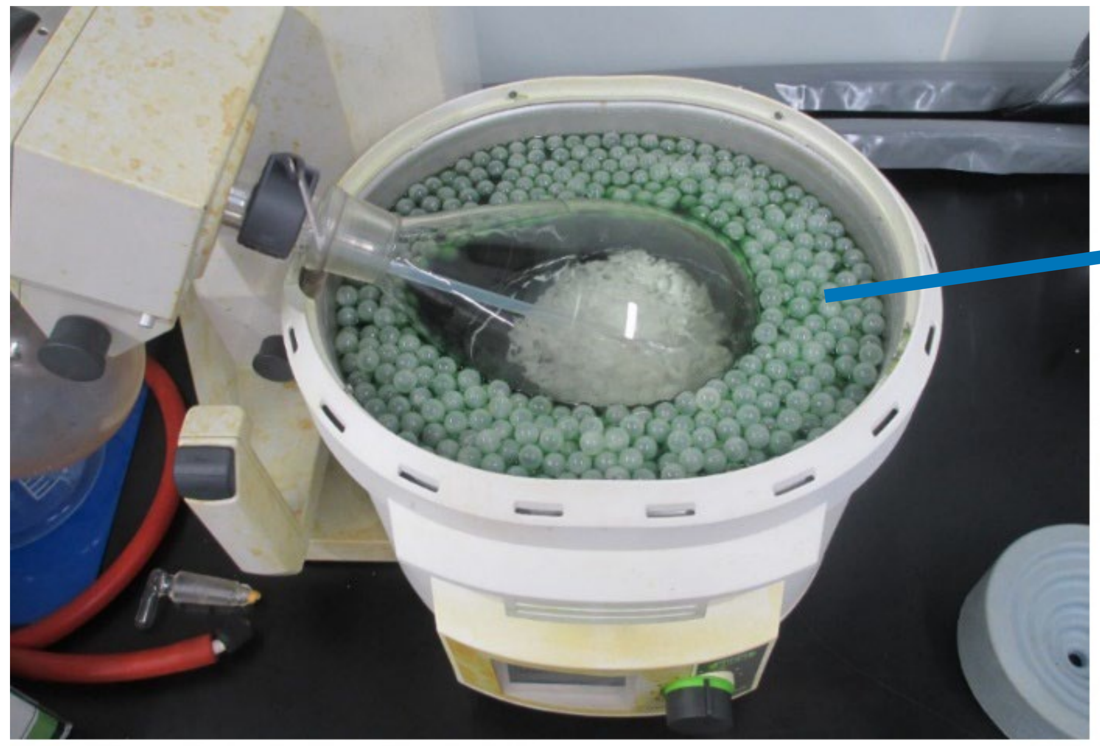
⑤Packaging

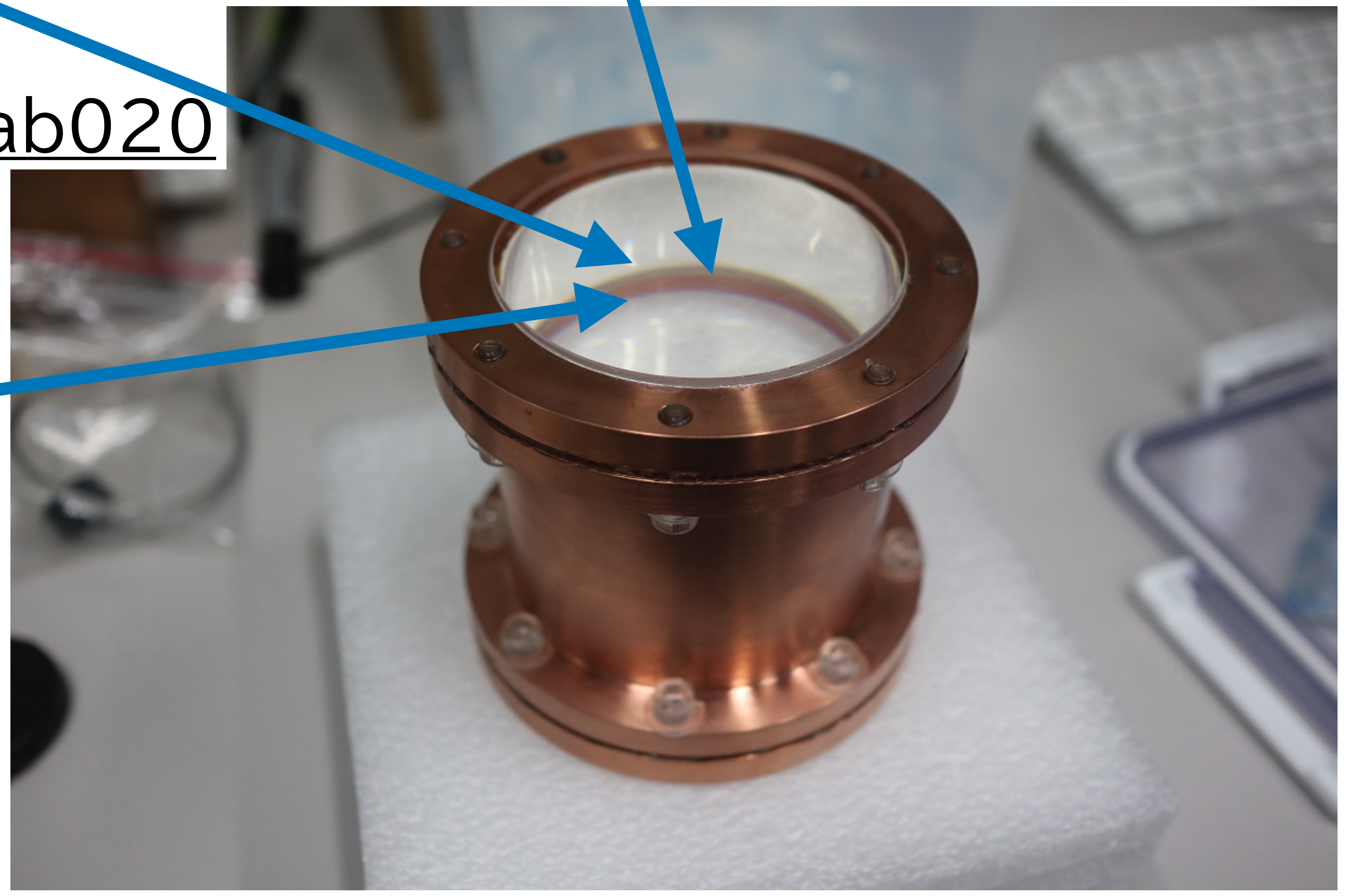
More details can be found : JINST 16, P08023 (2021)

Super-clean room application(2) crystallization, detector construction etc.

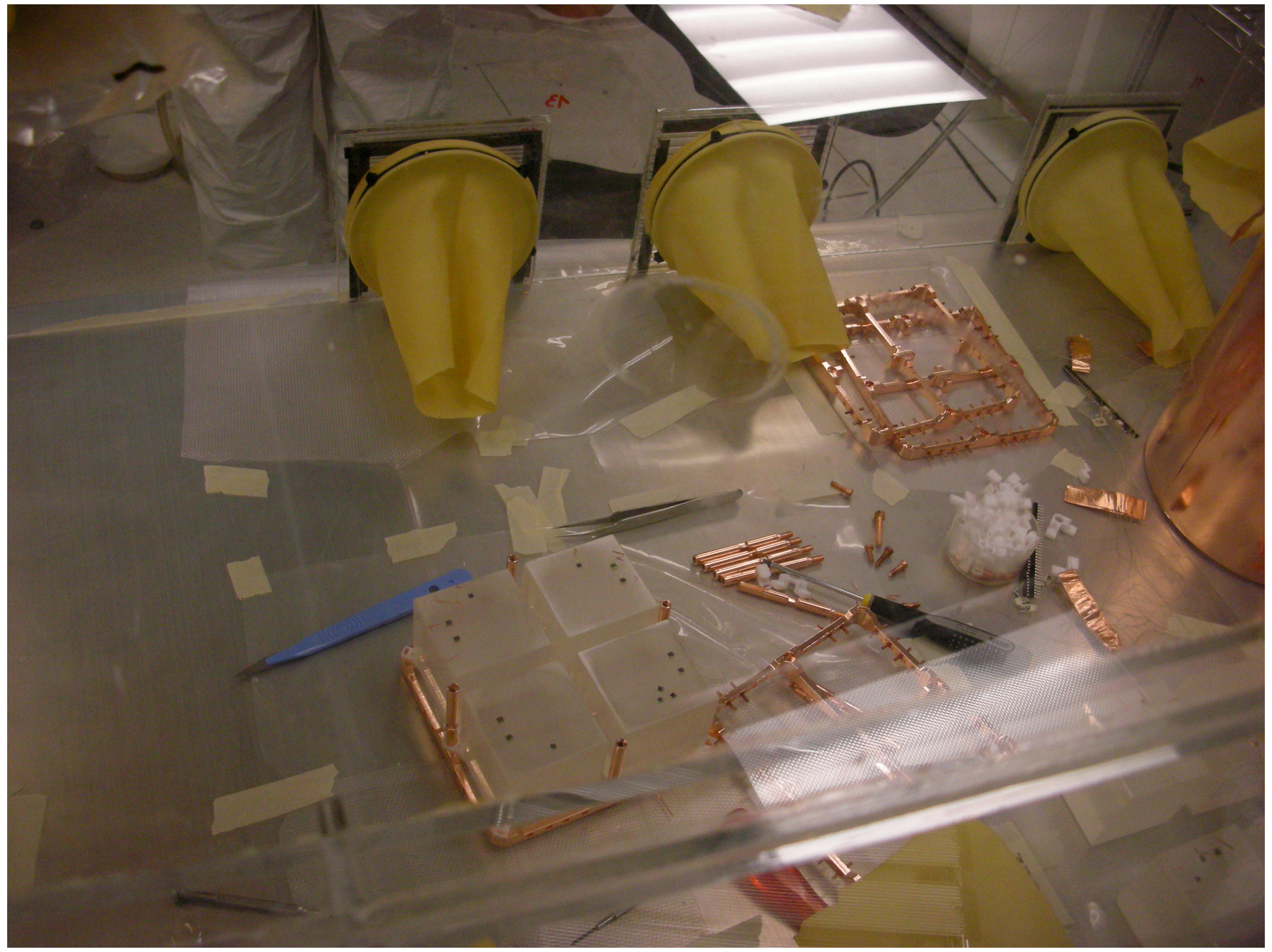


NaI purification
https://doi.org/10.1093/ptep/ptab020





Large detector can be assembled in the large super-clean room, not in the glove box



- Sample preparation for HPGe, ICP-MS measurement (details are in the later slides)
- Crystallization (NaI, SrI_2, $ZnWO_4$ etc. for DM and rare decay searches)
  - Purification of crystal materials
- Large detector assembly
- Production of PEN component from raw materials like LEGEND, Ultra-pure Cu electroforming like Sanford etc.
- Collaborative researches are very welcome

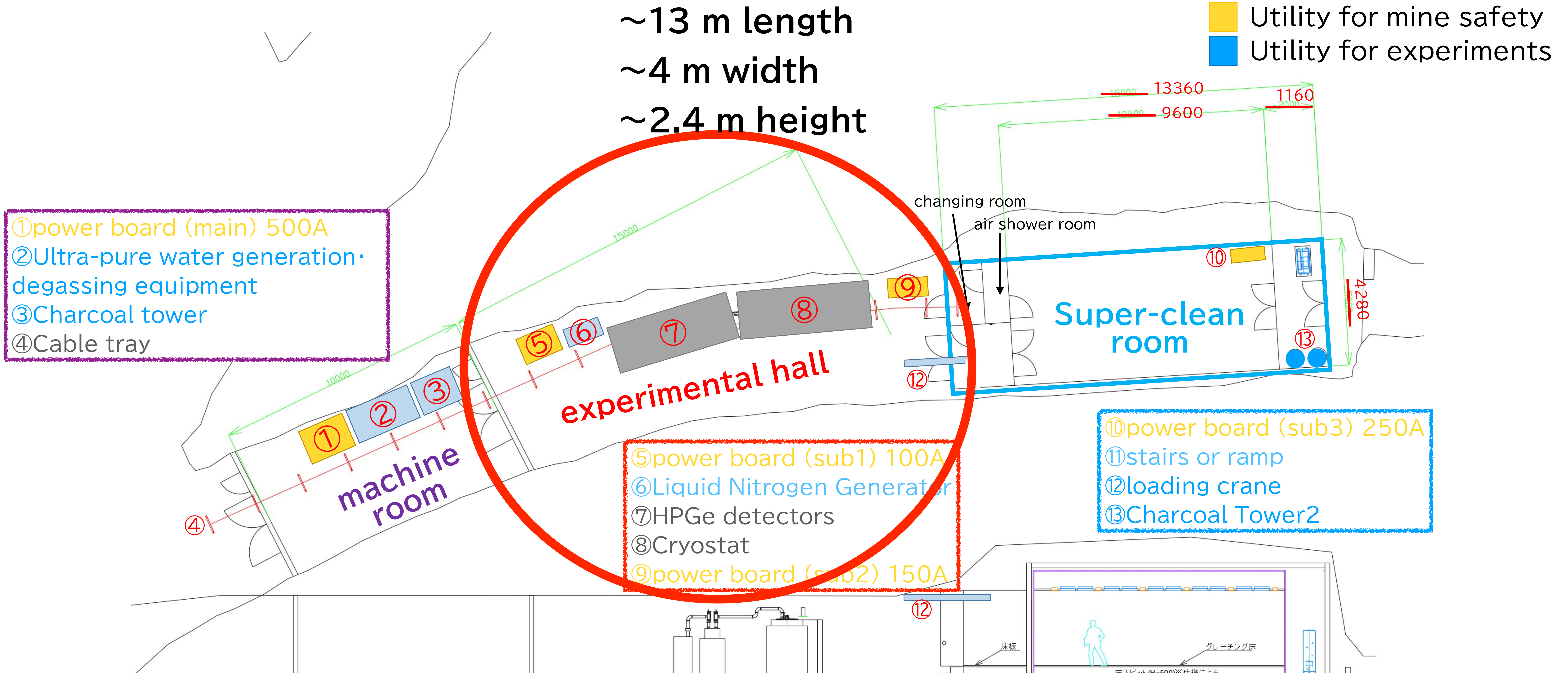
Photos of Super-clean room construction(Sep. 2024)

The framework of the Super-clean room is in place

Construction of the Super-clean room will be finished in Mar. 2025

Experimental hall and application

Schematic view of the ultra-low background super-clean facility

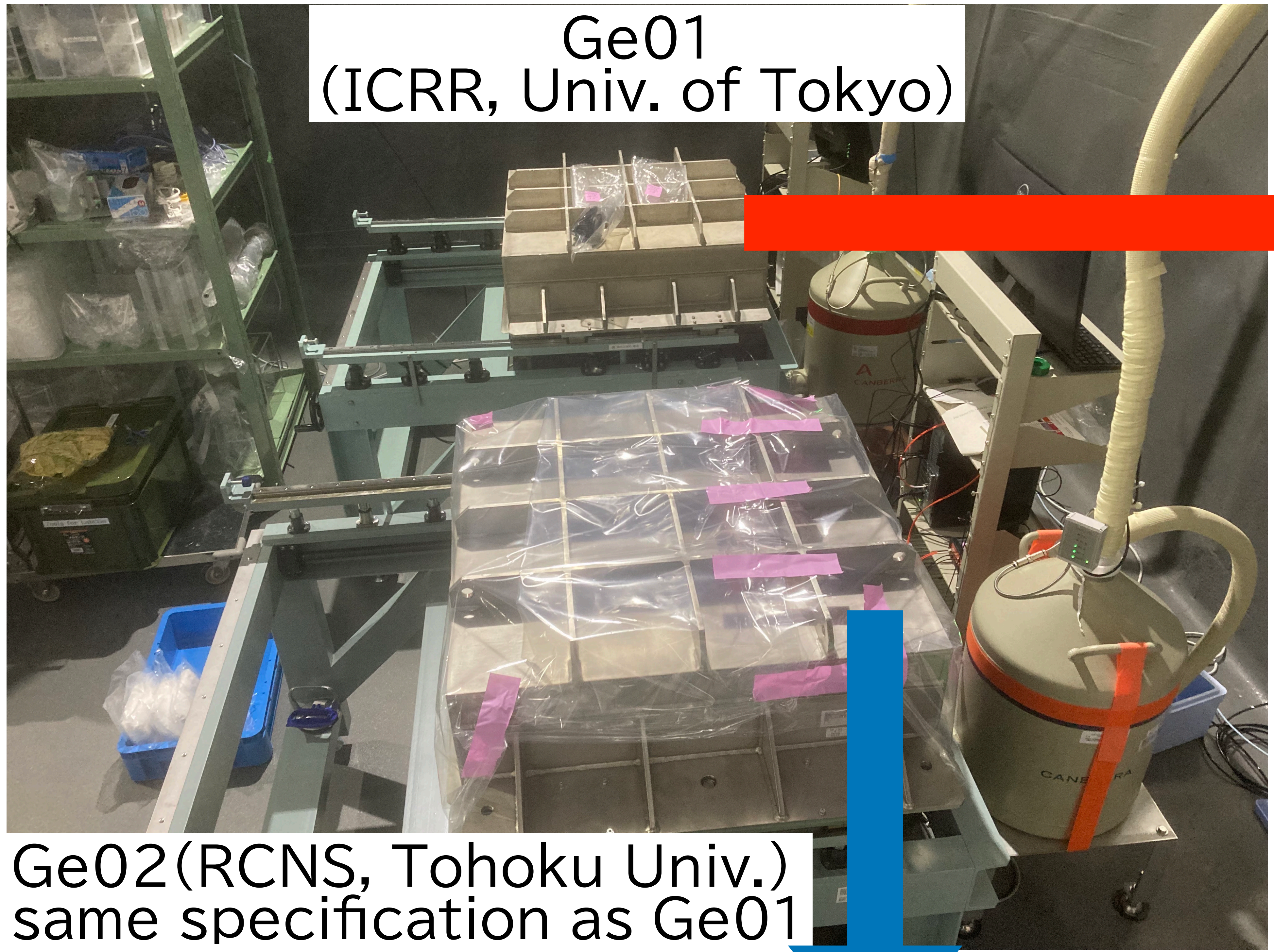


This hall is planned to use material screening and some R&D experiments

Followings are ideas to use this hall. There is no fixed project so far.

Collaborative researches are very welcome

Idea to use the experimental hall (1) HPGe



ultra-low BG HPGe
coaxial p-type relative efficiency = 80%
used to assay RI in $Gd_2(SO_4)_3 \cdot 8H_2O$ for SK-Gd
with LSC and Boulby
(https://doi.org/10.1093/ptep/ptac170)

Lab	Detector	Mass (kg)	FWHM@ 1332 keV (keV)	Counts (/kg/day) Integral 60–2700 keV	^{208}Tl, 2614 keV	^{214}Bi, 609 keV	^{60}Co, 1332 keV	^{40}K, 1461 keV	SK-Gd total samples
BUGS	Belmont	3.2	1.92	90.0	0.12	0.67	0.47	0.58	8
BUGS	Merrybent	2.0	1.87	145.0	0.23	2.15	0.47	1.16	5
LSC	GeOroel	2.31	2.22	128.7	0.53	0.89	0.06	0.46	3
LSC	Asterix	2.13	1.92	171.3	0.11	1.10	0.28	0.61	13
LSC	GeAnayet	2.26	1.99	461.2	3.68	0.71	0.16	0.74	2
Kamioka	Lab-C Ge	1.68	2.39	104.5	0.08	0.39	0.41	0.44	23

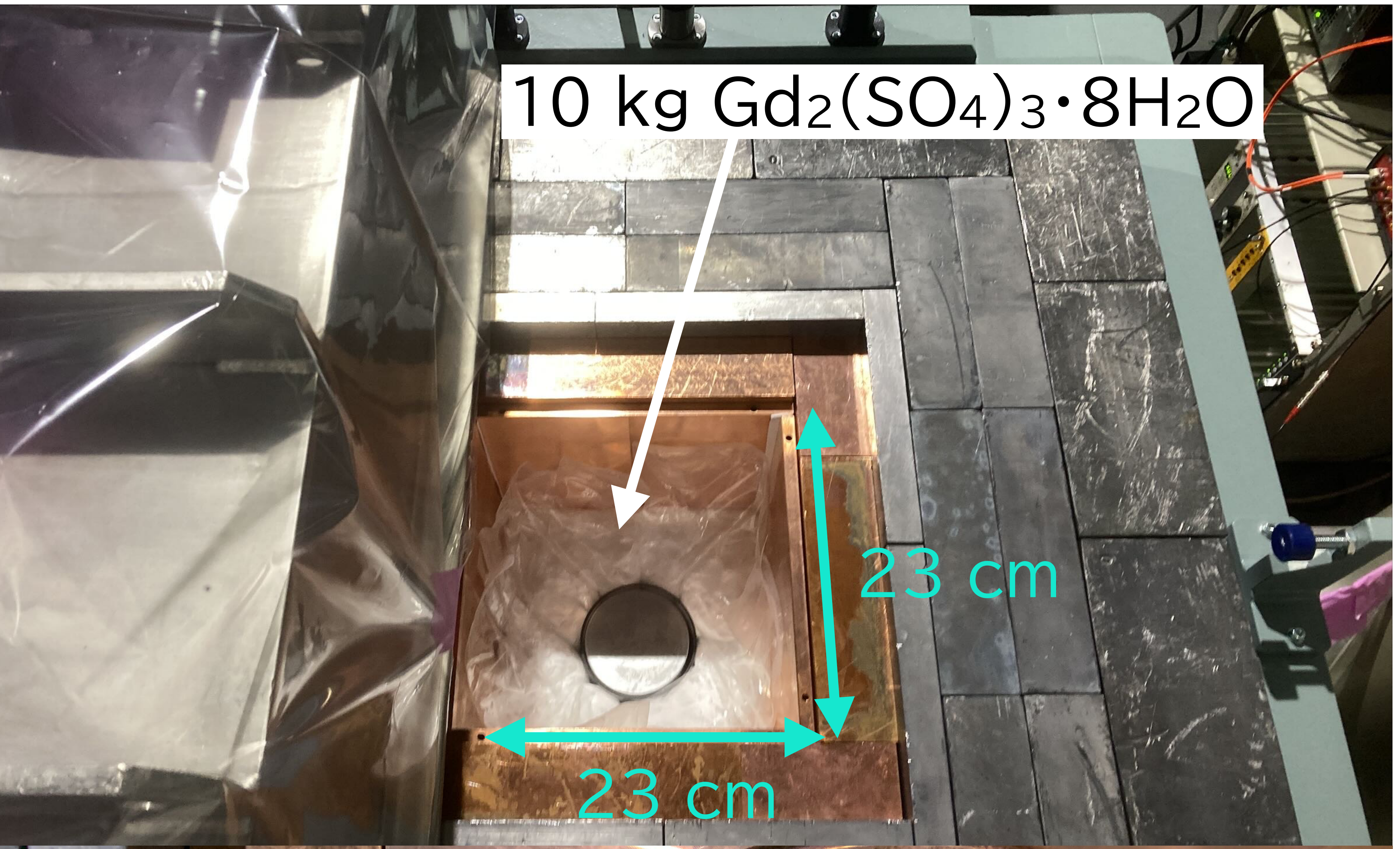
Careful shield surface cleaning, noise reduction
→ lower ^{210}Pb, ^{137}Cs, continuum BG

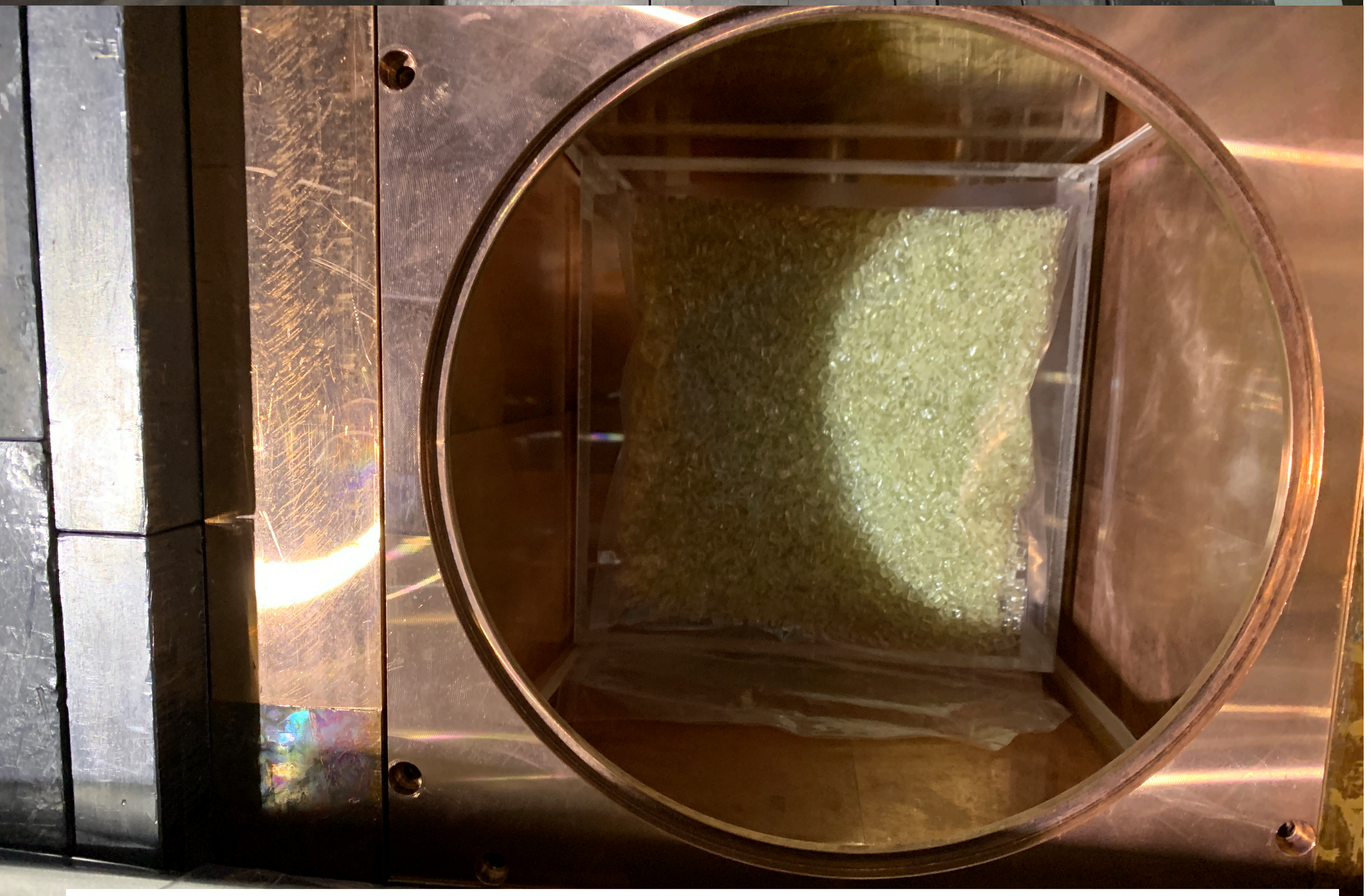
Detector	Ge01	Ge02		
Date	Dec. 2019	Dec. 2021	Jul. 2022	Apr. 2023
Measurement time (d)	23.0	19.0	47.2	86.2
	Count rate (kg_{Ge}^{-1} d^{-1})			
Integral 40–2700 keV	112.6	140.2	100.0	84.3
^{208}Tl, 2614 keV	0.08±0.04	0.25±0.09	0.16±0.05	0.13±0.03
^{214}Bi, 609 keV	0.39±0.10	0.25±0.09	0.38±0.07	0.23±0.04
^{60}Co, 1333 keV	0.41±0.10	0.66±0.14	0.48±0.08	0.68±0.07
^{40}K, 1461 keV	0.44±0.11	0.31±0.10	0.44±0.07	0.42±0.05
^{137}Cs, 662 keV	1.29±0.18	0.53±0.13	0.38±0.07	0.32±0.05
^{210}Pb, 46.5 keV	3.24±0.29	0.69±0.14	0.64±0.09	0.59±0.06

- In the Kamioka mine, there are :
  - 2 ultra-low BG HPGe det.
    - manufactured by Mirion France
    - both co-axial p-type, 80% relative eff.
    - Details can be found in : PTEP 123H01 (2023)
  - 5 low BG HPGe det.
    - manufactured by Mirion US
    - 4 co-axial p-type (120%, 100%, 74%, 50% rel. eff.)
    - 1 co-axial n-type (100% rel. eff.)
- Published many screening results : KamLAND PEN, SK-Gd $Gd_2(SO_4)_3$, NEWAGE μ-PIC, XMASS PMT etc.

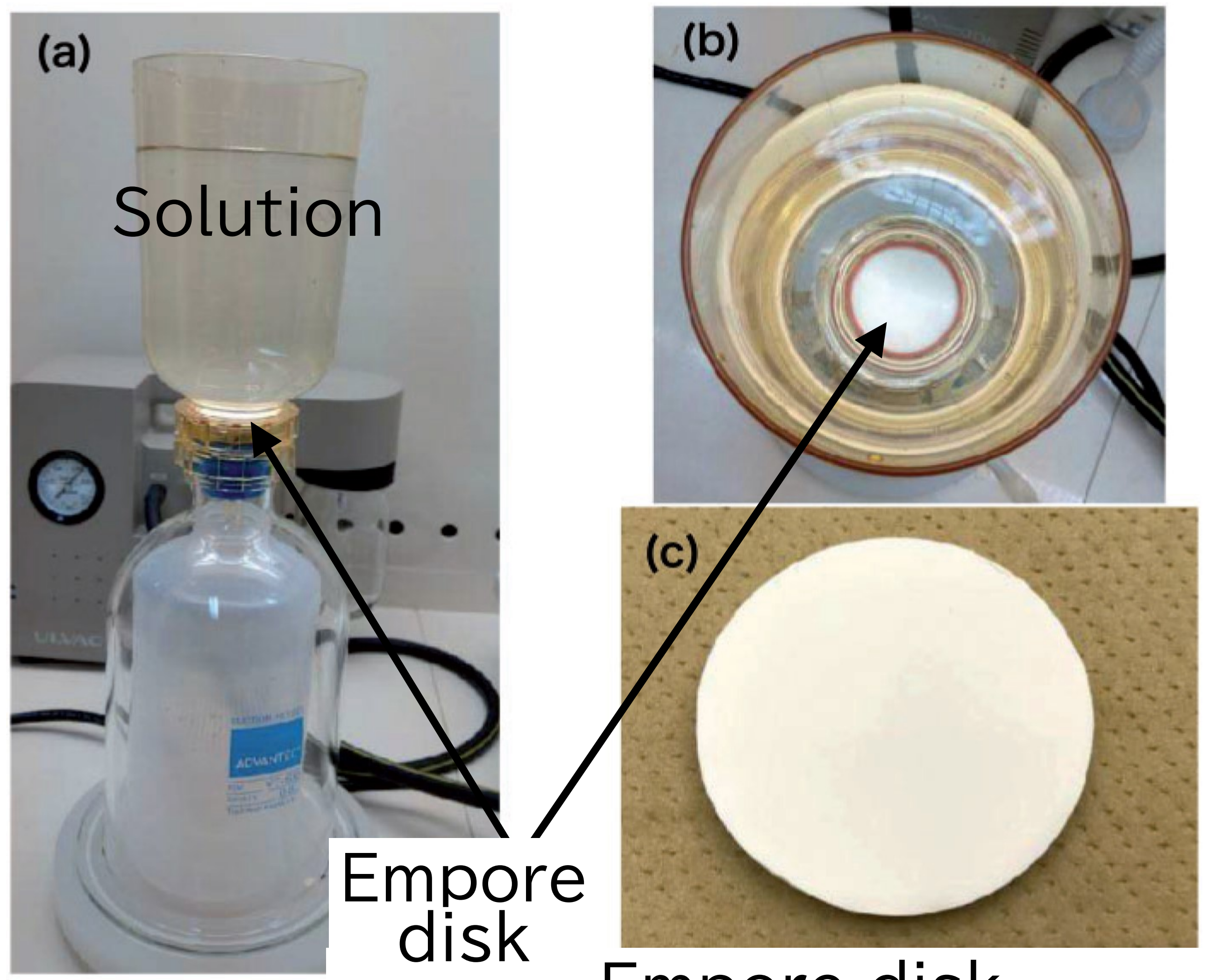
Idea to use the experimental hall (1) HPGe

example of material screenings

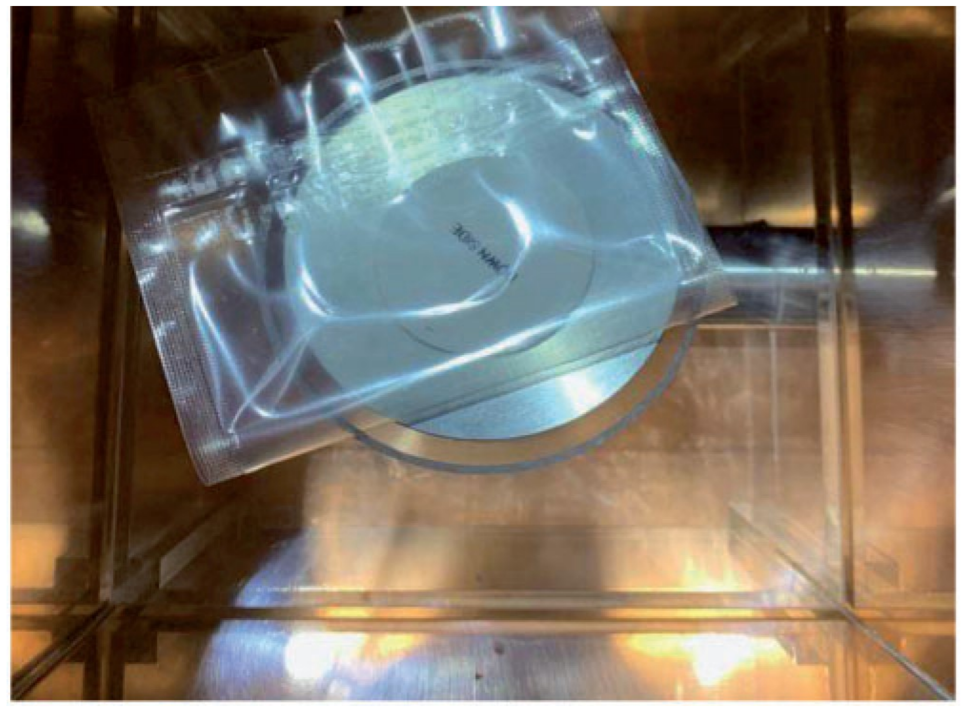




polyethylene naphthalate (PEN) pellet
on the acryl stage



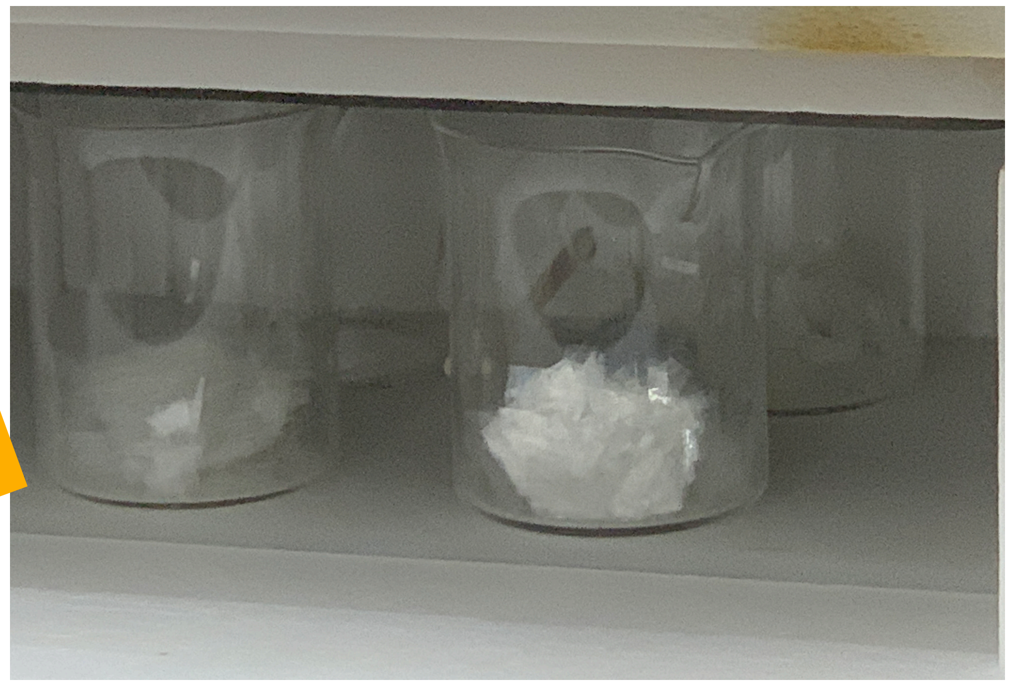
Empore disk
on the HPGe Endcap



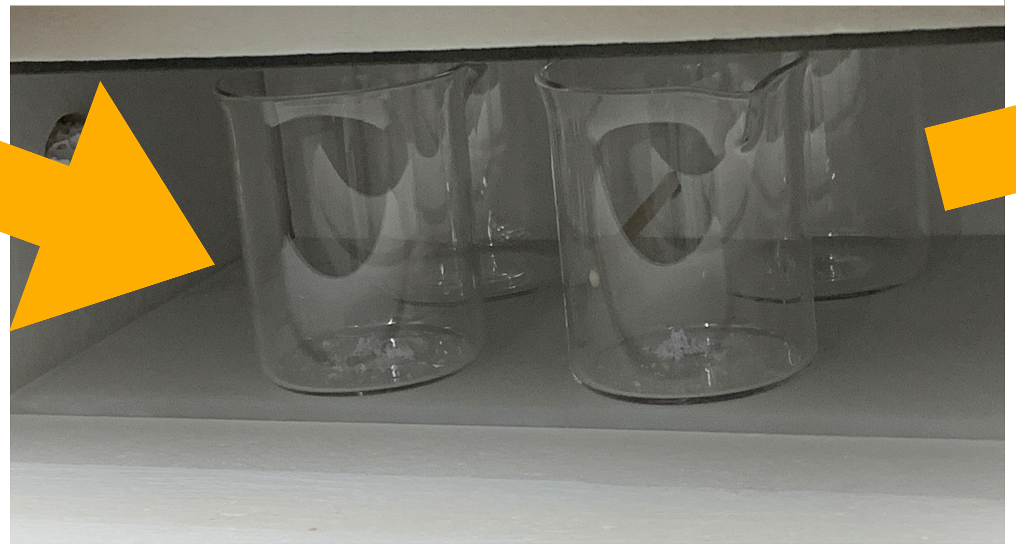
- We can measure large sample
  - $(23 \times 23 \times 19\ cm^3)$ on the acryl stage
  - $(23 \times 23 \times 15\ cm^3$ - Ge detector volume) for side region
- High sensitive ^{226}Ra measurement with molecular recognition resin
  - https://doi.org/10.1093/ptep/ptaa105
- O(0.1 mBq/kg) ^{226}Ra measurement can be done within 10 days
  - https://doi.org/10.1093/ptep/ptac170

Idea to use the experimental hall (2) ICP-MS

PEN film before ashing



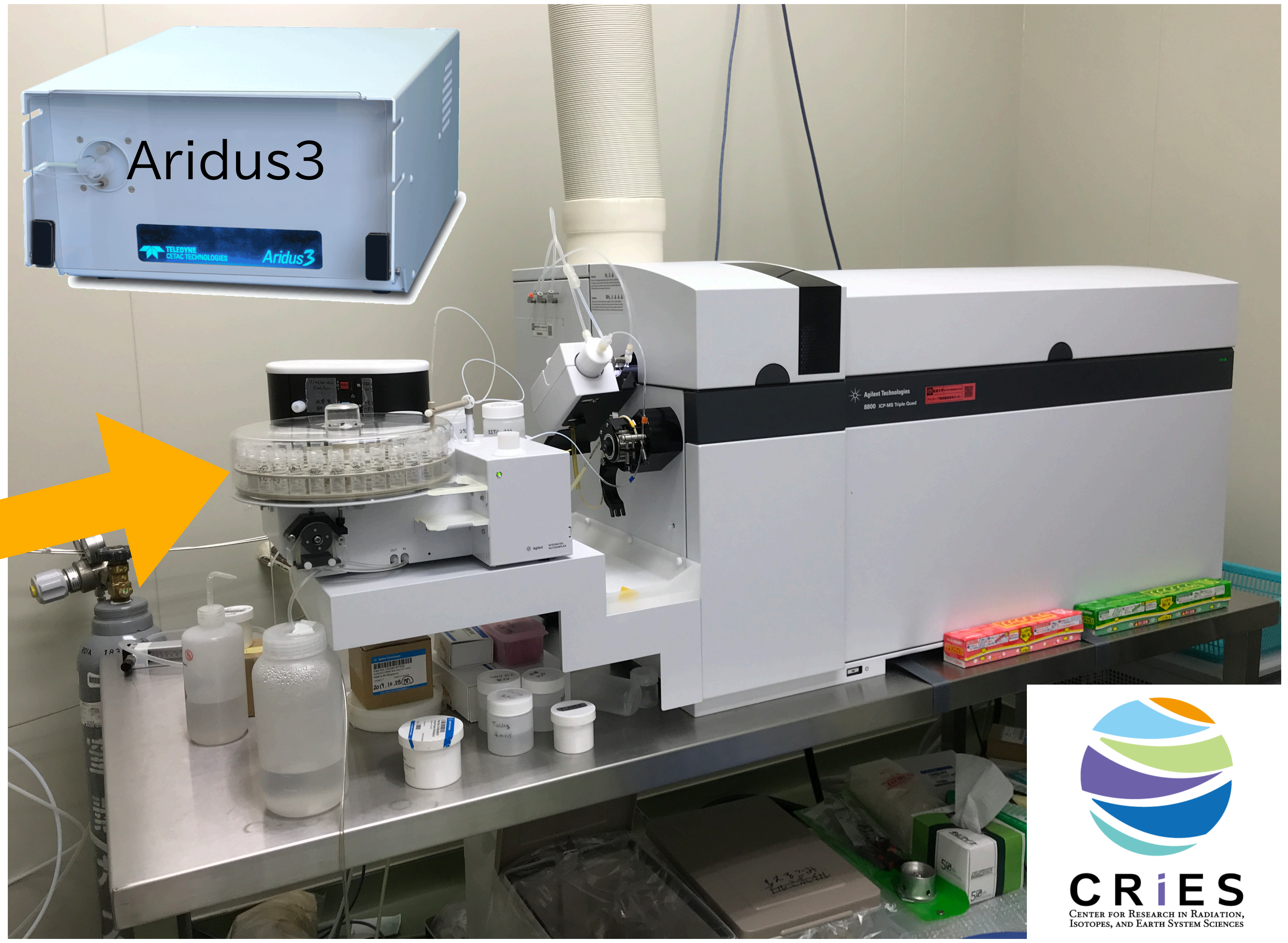
PEN film after ashing



PYRO microwave ashing system

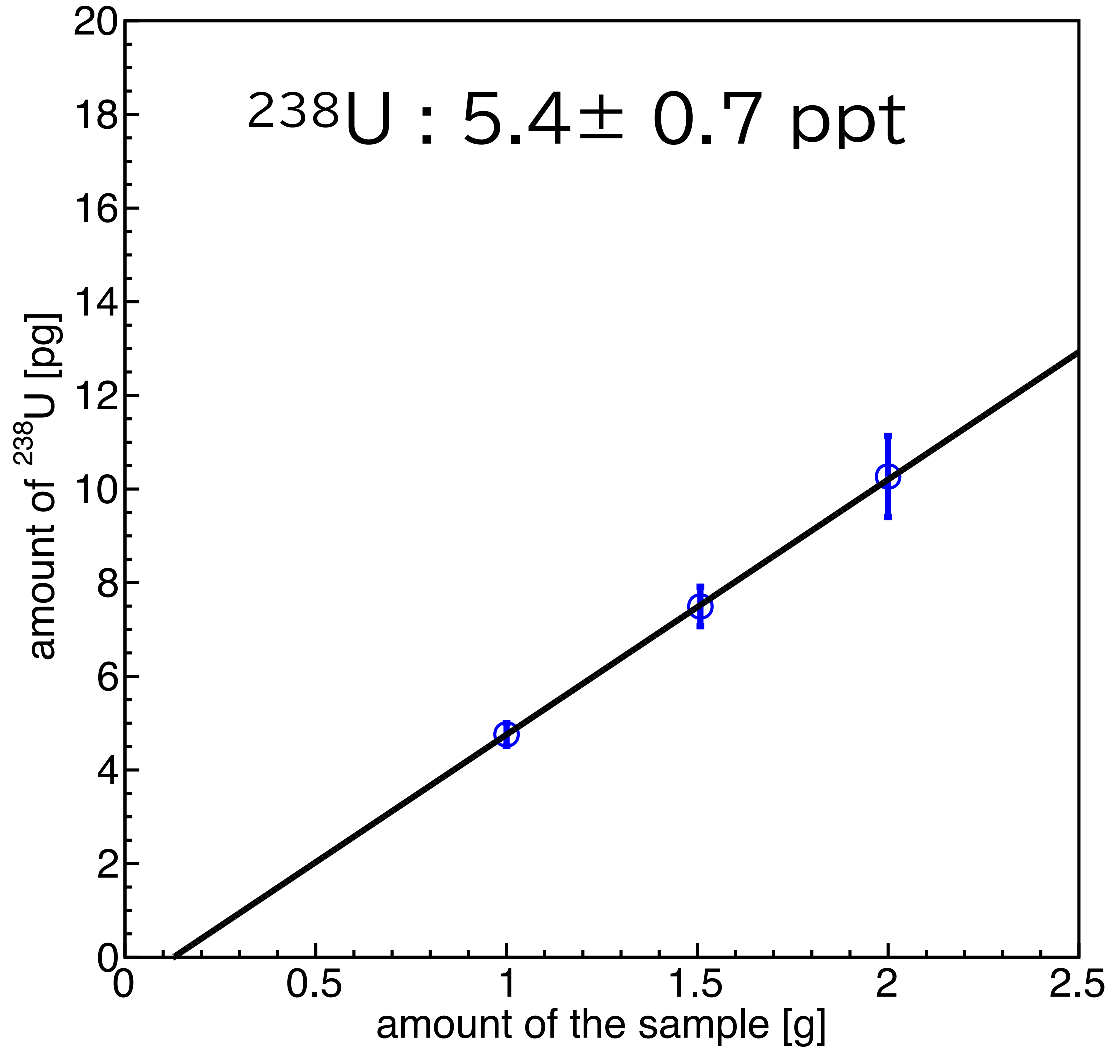
solution (ultrapure HNO_3)

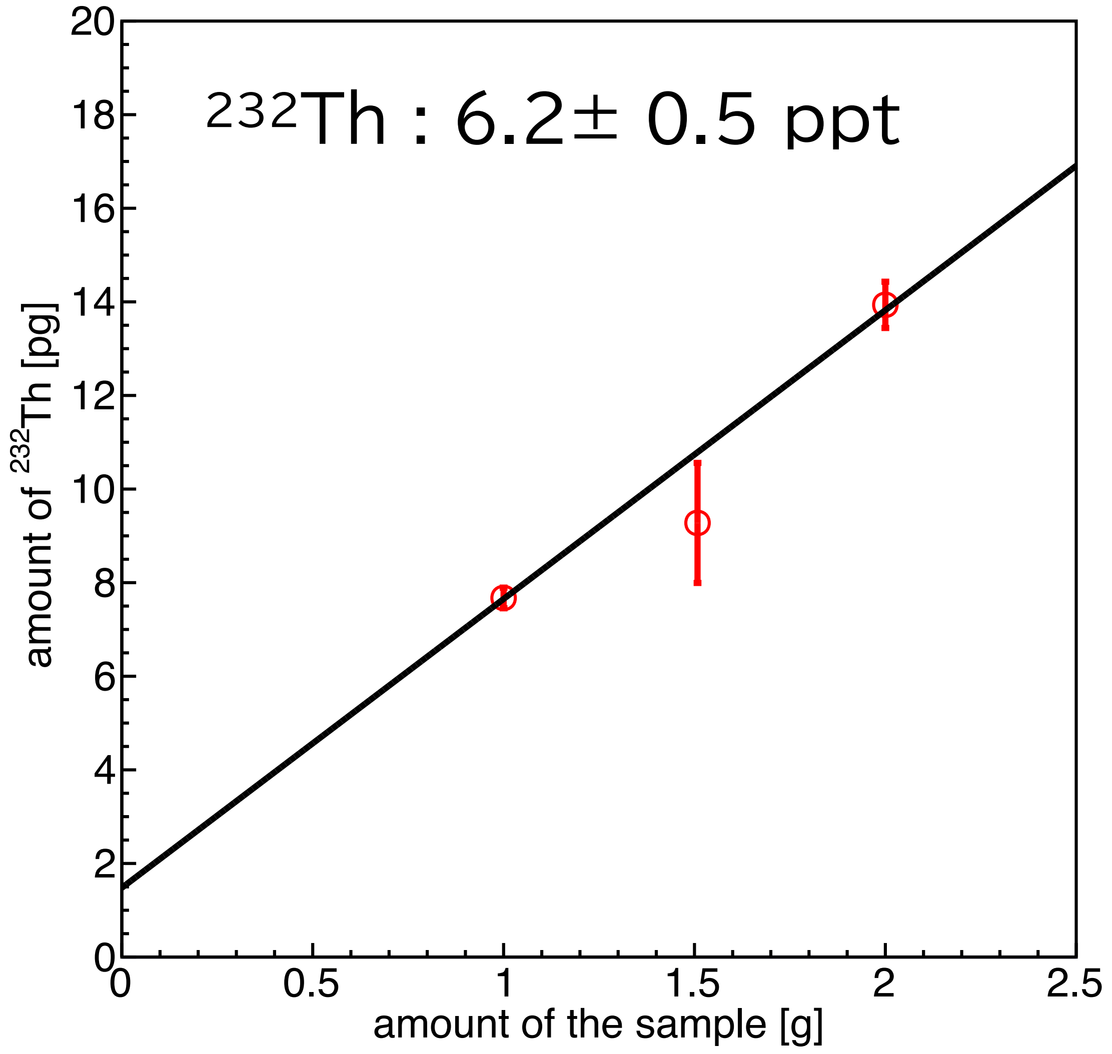
Agilent 8800 (CRiES, Univ. of Tsukuba)



CRiES

PEN film sample measurement





- Collaborative research with Univ. of Tsukuba
- Microwave ashing machine (PYRO)
  - O(a few g) organic materials can be ashed
- Agilent 8800 with Aridus3 desolvating nebulizer system
  - special tune (s-lens etc.) for ^{238}U, ^{232}Th measurement
- O(ppt) level ^{238}U, ^{232}Th measurement is achieved so far
  - https://doi.org/10.1093/ptep/ptae071
- This ICP-MS was also used for rapid ^{226}Ra analysis in $Gd_2(SO_4)_3 \cdot 8H_2O$ for SK-Gd (K.Hosokawa's poster)
  - https://doi.org/10.1093/ptep/ptad117

Idea to use the experimental hall (3)
Cryostat, Alpha Imaging Chamber

Low-BG cryostat（Sendai, Tohoku Univ.)

Low-BG cryostat for development of superconducting sensors (KID, TES, etc.) and absorbers for future DM and rare decay search

For example :
KID + CaF_2 : https://doi.org/10.1093/ptep/ptad124
TES + Sn : https://pos.sissa.it/441/267/pdf

AICHAM : Alpha Imaging Chamber

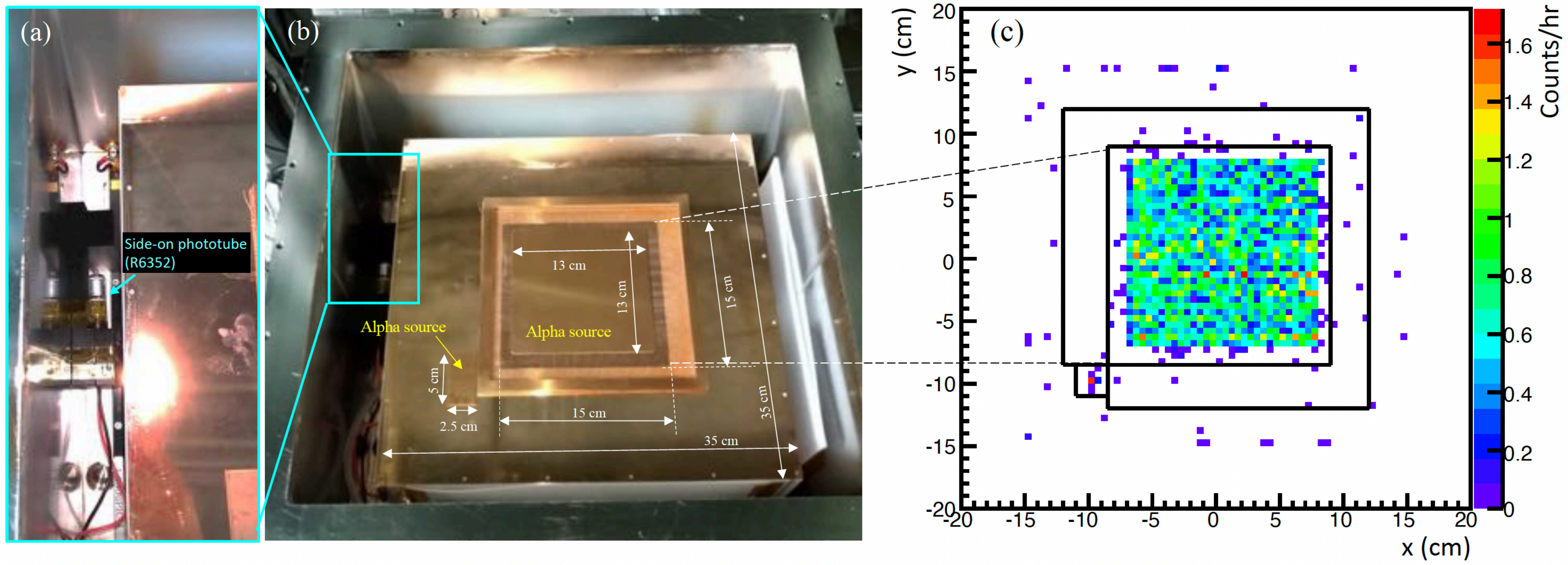


Fig. 1: Graphical top view of AICHAM (b) and focusing PMT between the vessel and TPC (a). Alpha emissivity imaging for alpha sources (c).

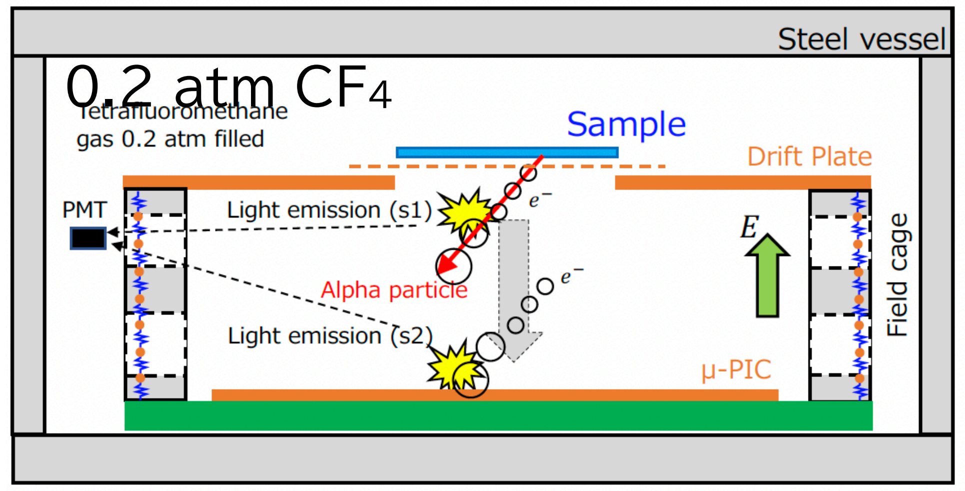


Fig. 2: Schematic view.

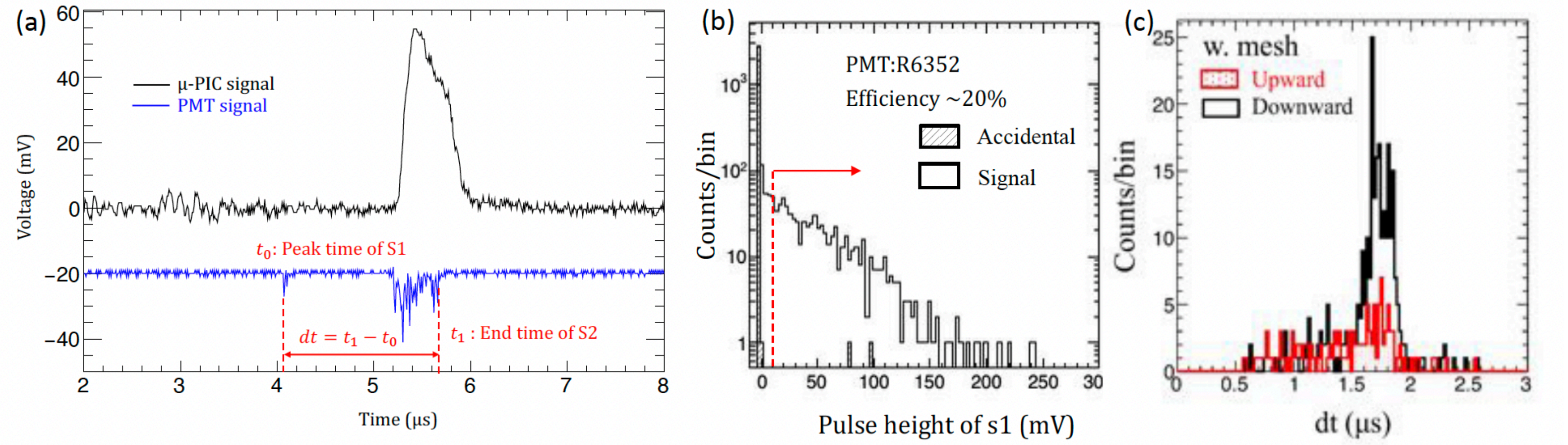


Fig. 3: Typical signal waveforms (a). S1 pulse height distribution (b). Distribution of time interval betwee S1 and S2 for mesh sample (c).

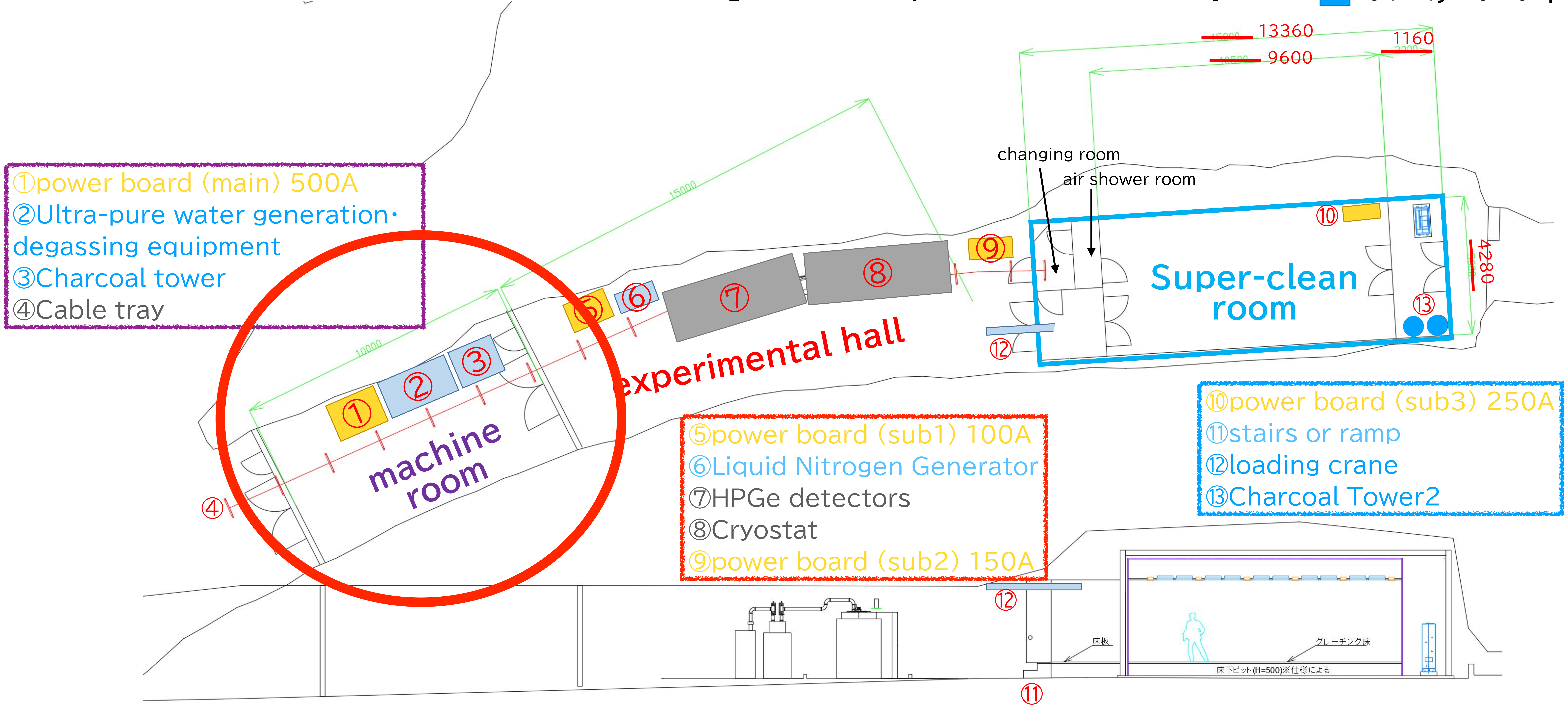
can measure surface contamination like
Ultralo-1800 https://xia.com/products/ultralo-1800/

PEN Film measurement : < 3.7×10^{-3} $\alpha/cm^2/hr$ (90% C.L.)
To improve the sensitivity, install small-size PMT to detect S1/S2 photons（H. Ito, ICRC 2023 poster presentation)
https://pos.sissa.it/444/1374/pdf

Performance of machine room

Schematic view of the ultra-low background super-clean facility

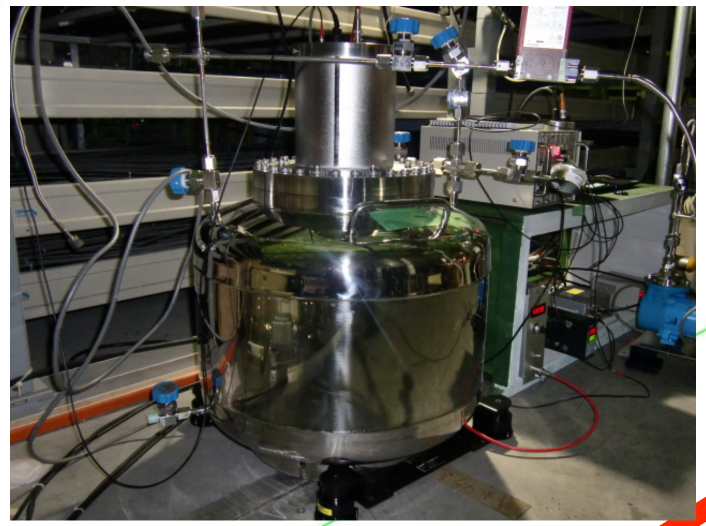
- Experimental apparatus
- Utility for mine safety
- Utility for experiments

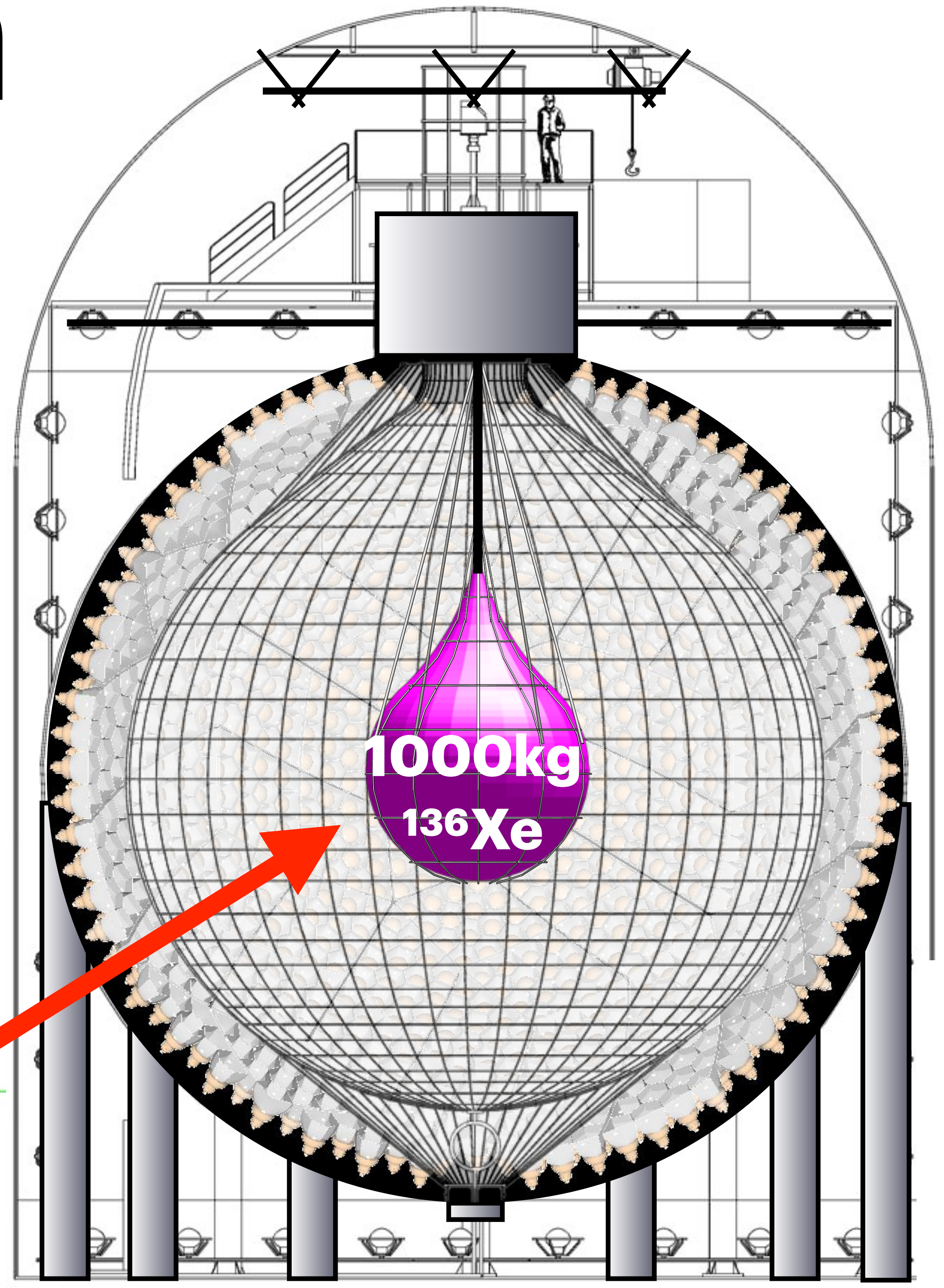


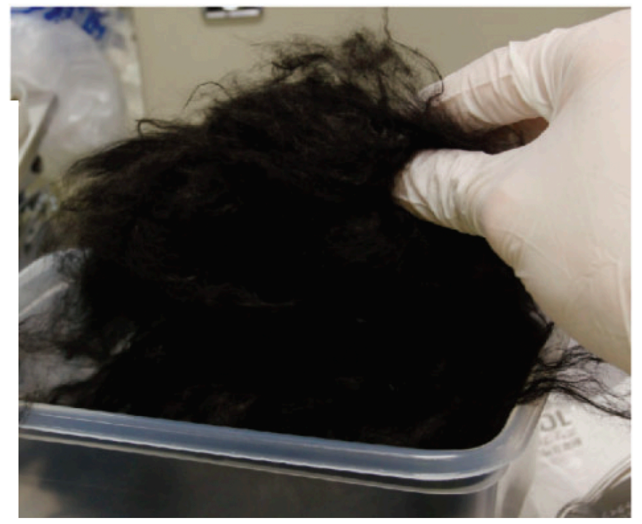
Rn-free air generation system

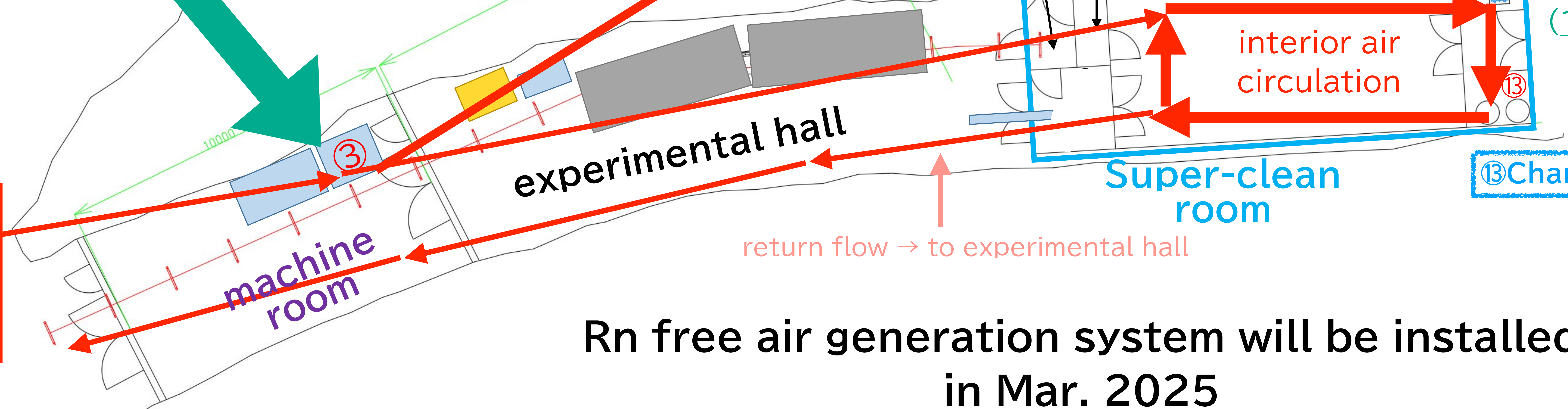
Image of the
Chilled activated charcoal system
(Ref : R. Hodak et al)

Similar to LSC :
- Chilled charcoal tower (~250 kg)
- input air : outside air, O(30 Bq/m^3)
  - 200 m^3/hr
  - humidity and CO_2 are removed
  - Cooled to ~ -65℃
- Supply to :
  - Super-clean room
  - Experimental hall
  - KamLAND2-Zen detector(installation work)
- Rn activity will be measured by 80L Rn det.









Air flow

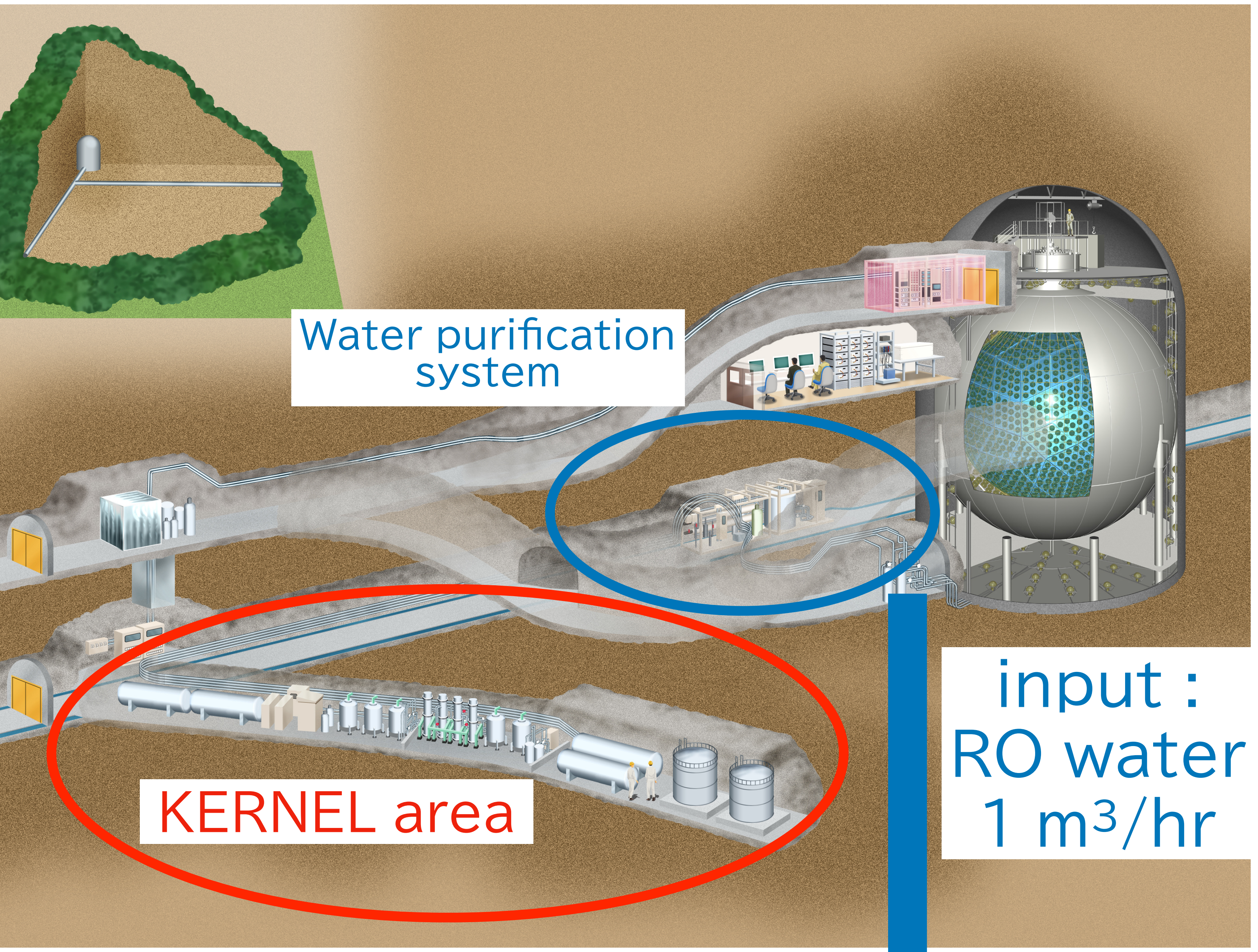
outside air from outside of the mine O(30 Bq/m^3)

Plan to use active charcoal fiber (10.1093/ptep/ptaa119) in the Super-clean room

⑬Charcoal Tower2

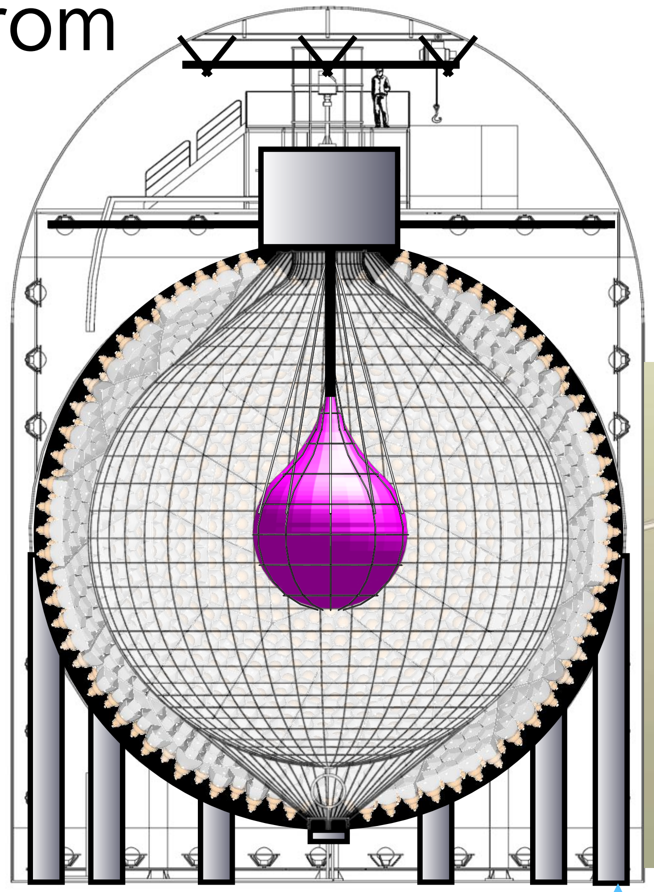
Rn free air generation system will be installed in Mar. 2025

Ultra-pure water generation system



- Requirement : 1 ~ 2 m^3/hr ultra-pure water (18.2 MΩ·cm) for KamLAND2-Zen inner balloon fabrication
- Input : 1 m^3/hr RO (Reverse Osmosis) water from KamLAND water purification system
- 2 m^3 buffer tank with UV sterilizer

Supply to :
- Super-clean room
- Experimental hall
- KamLAND2-Zen detector



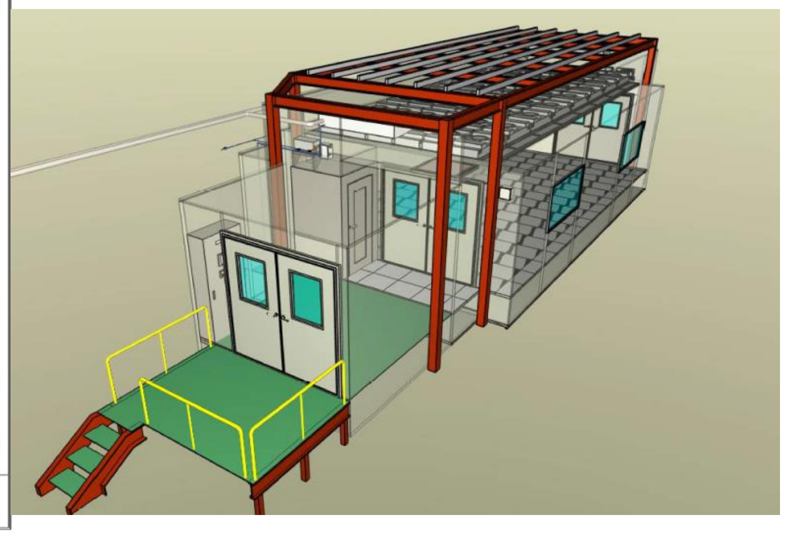
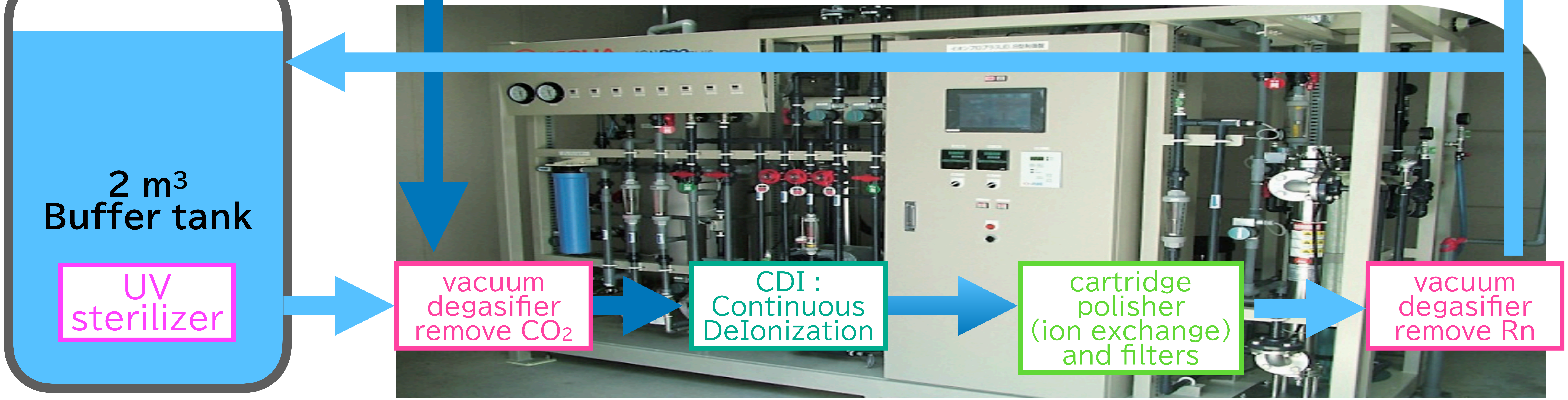
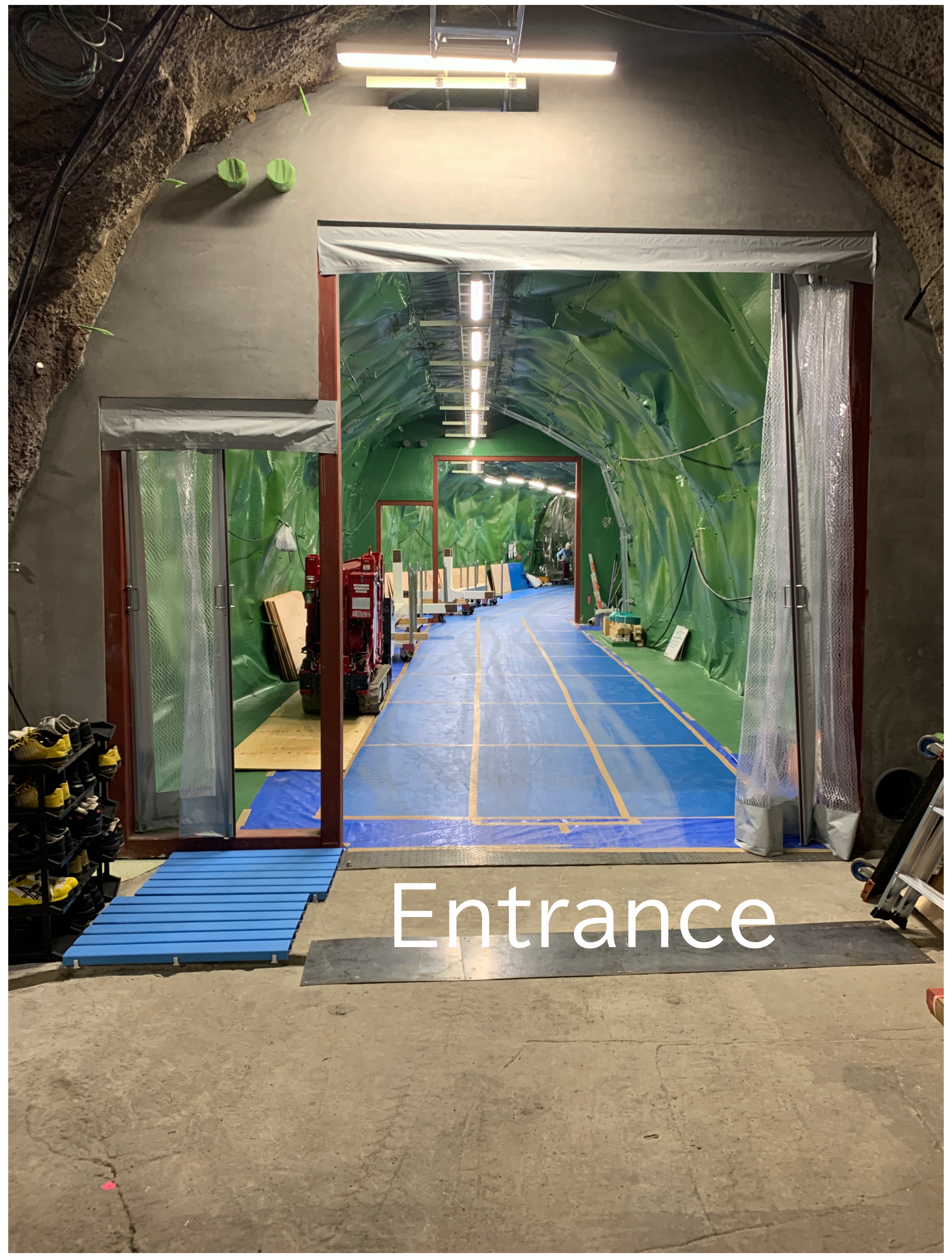


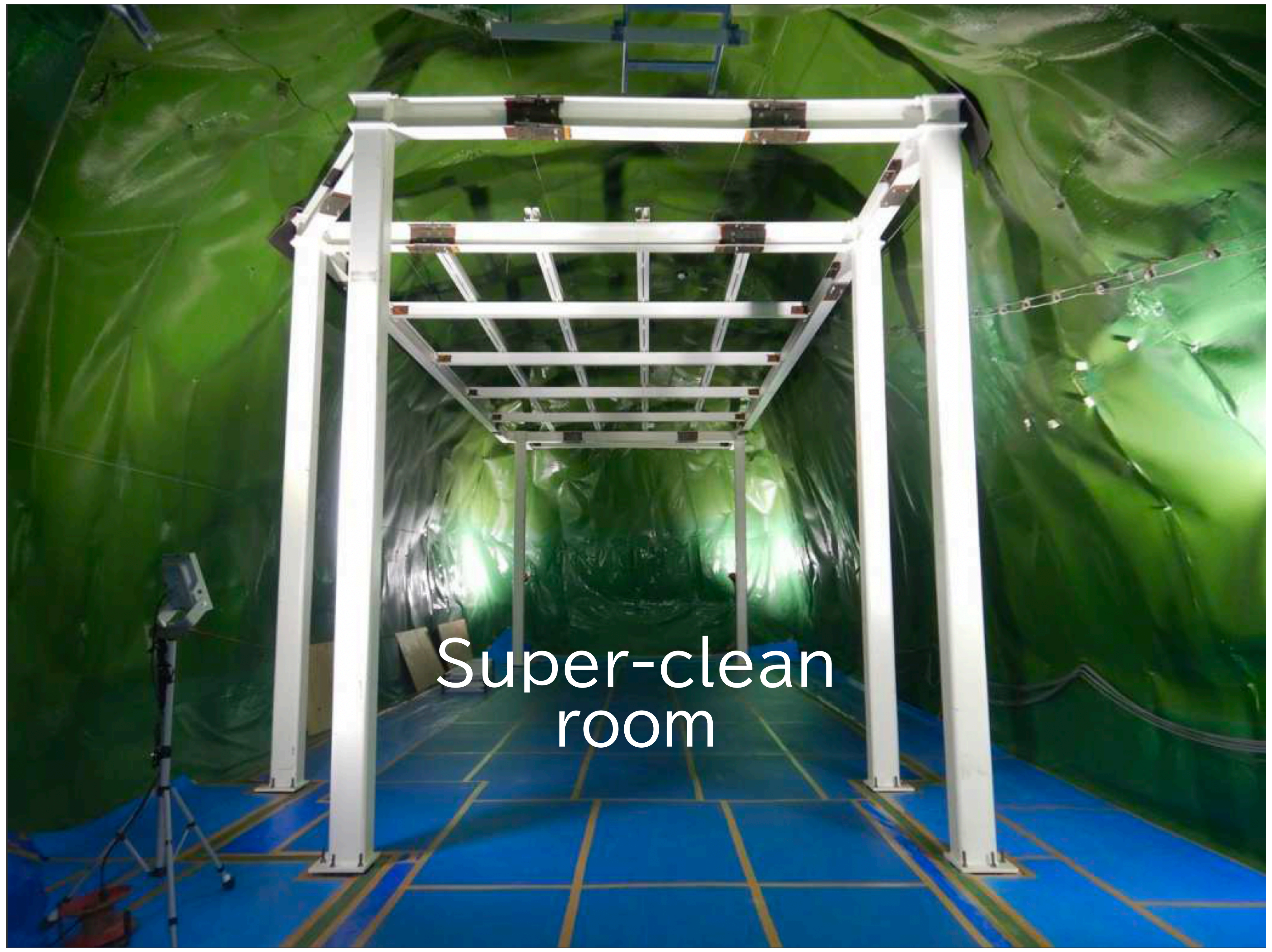
Image of the ultra-pure water generation system



Ultra-pure water generation system will also be installed in Mar. 2025

Summary



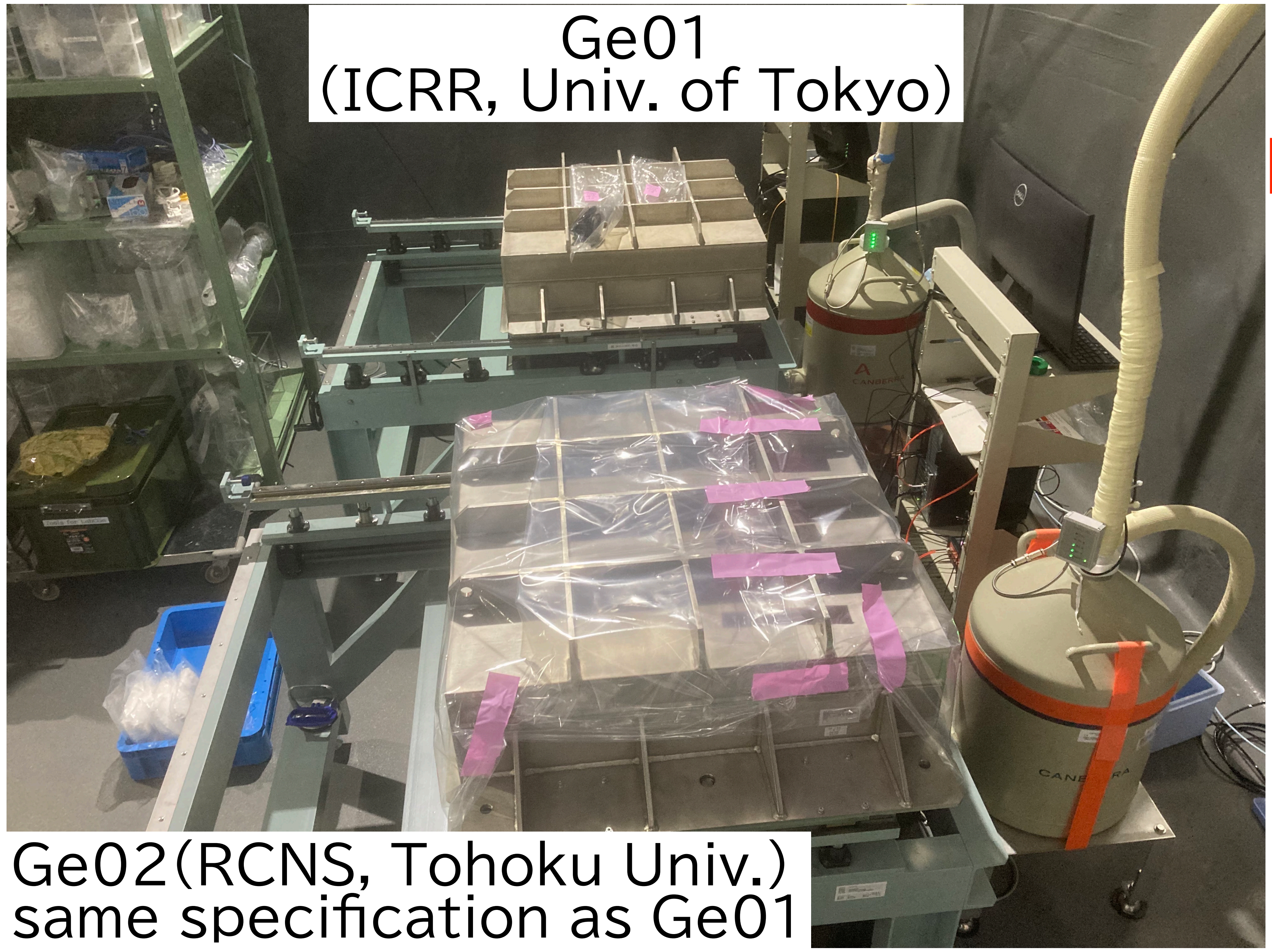


- We began to organize the ultra-low BG facility for extremely rare events in the Kamioka underground
- Super-clean room : ultra-low BG balloon fabrication, crystallization, etc. : available in Mar. 2025
- Experimental hall : high sensitive material screening, R&D for further experiments
- Environment : Rn-free air, ultra-pure water generation system : available in Mar. 2025

Collaborative researches are very welcome

Backup

Activity of material screening (1): HPGe



Ge01
(ICRR, Univ. of Tokyo)

Ge02(RCNS, Tohoku Univ.)
same specification as Ge01

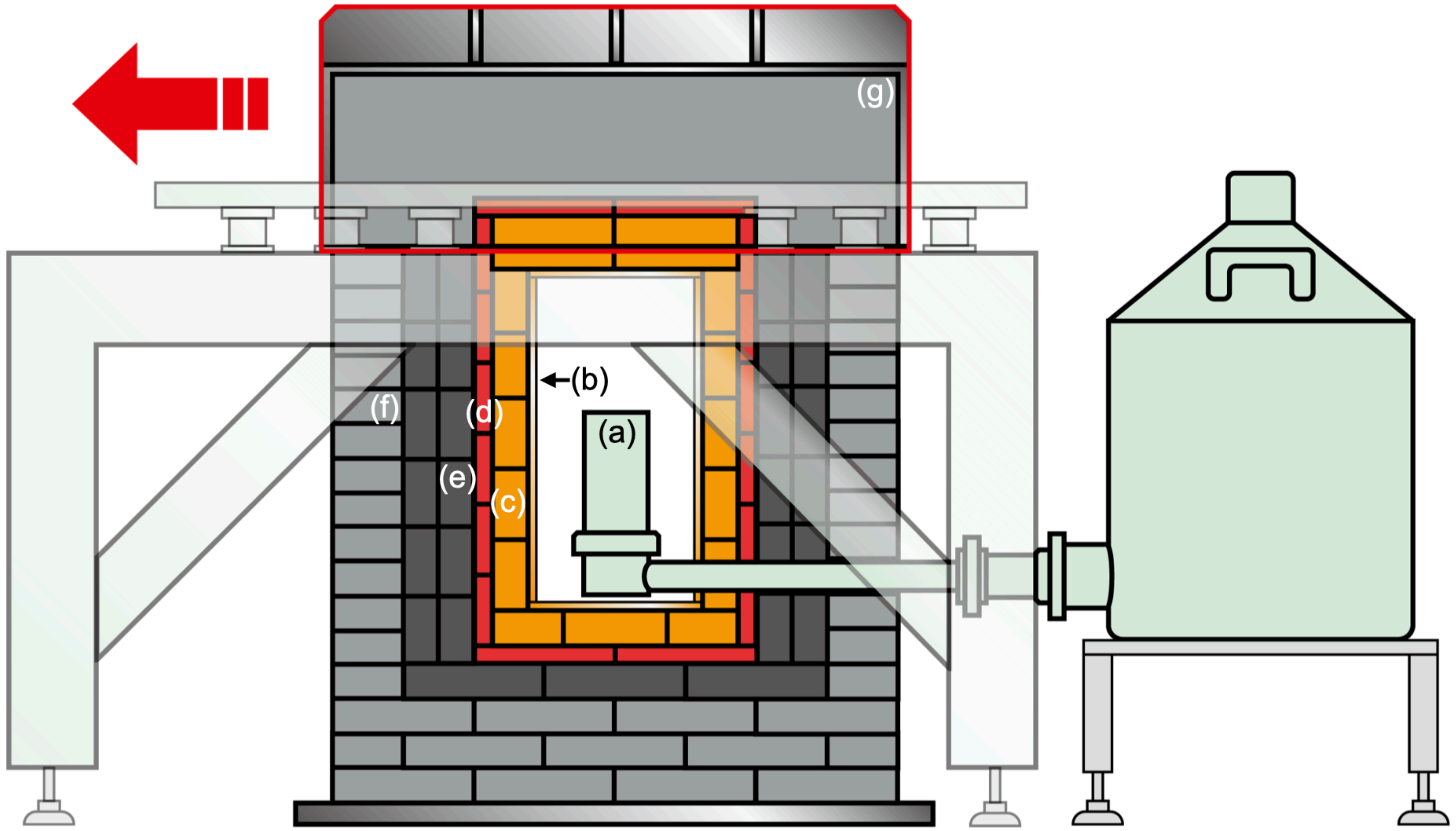
ultra-low BG HPGe
coaxial p-type relative efficiency = 80%
used to assay RI in $Gd_2(SO_4)_3 \cdot 8H_2O$ for SK-Gd
with LSC and Boulby
(https://doi.org/10.1093/ptep/ptac170)

Lab	Detector	Mass (kg)	FWHM@ 1332 keV (keV)	Counts (/kg/day) Integral 60–2700 keV	^{208}Tl, 2614 keV	^{214}Bi, 609 keV	^{60}Co, 1332 keV	^{40}K, 1461 keV	SK-Gd total samples
BUGS	Belmont	3.2	1.92	90.0	0.12	0.67	0.47	0.58	8
BUGS	Merrybent	2.0	1.87	145.0	0.23	2.15	0.47	1.16	5
LSC	GeOroel	2.31	2.22	128.7	0.53	0.89	0.06	0.46	3
LSC	Asterix	2.13	1.92	171.3	0.11	1.10	0.28	0.61	13
LSC	GeAnayet	2.26	1.99	461.2	3.68	0.71	0.16	0.74	2
Kamioka	Lab-C Ge	1.68	2.39	104.5	0.08	0.39	0.41	0.44	23

low BG HPGe
coaxial p-type
relative eff. 74%

- Used to assay radioisotopes (^{226}Ra, ^{40}K etc.)
- In the Kamioka mine, there are 2 ultra-low BG HPGe detectors manufactured by Mirion France
  - \+ 5 low BG HPGe detectors manufactured by Mirion US
- RCNS has 1 ultra-low BG HPGe and 1 low BG HPGe detectors

Activity of material screening (2): HPGe



a) Ge detector (Al endcap)
b) 1 cm 6N purity (99.9999%) Cu (Mitsubishi Material Company)
c) 5 cm OFHC Cu
d) 2.5 cm (5±3) Bq/kg ^{210}Pb Lead brick : Kolga
e) 10 cm (for side) (35±4) Bq/kg ^{210}Pb Lead brick
f) 10 cm O(100) Bq/kg ^{210}Pb Lead brick
g) 17.5 cm O(500) Bq/kg ^{210}Pb Lead brick

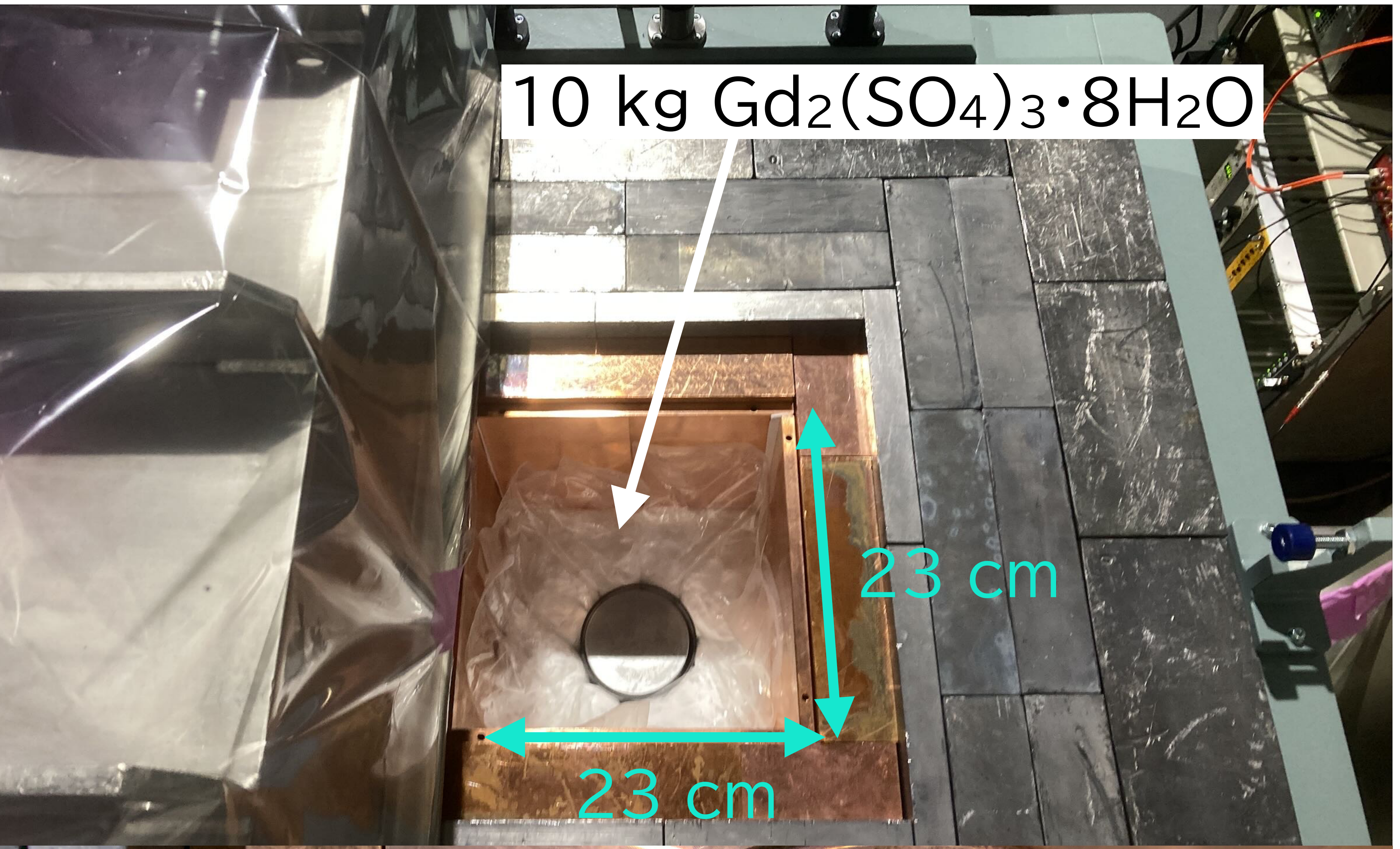
Lab	Detector	Mass (kg)	FWHM@ 1332 keV (keV)	Counts (/kg/day) Integral 60–2700 keV	^{208}Tl, 2614 keV	^{214}Bi, 609 keV	^{60}Co, 1332 keV	^{40}K, 1461 keV	SK-Gd total samples
BUGS	Belmont	3.2	1.92	90.0	0.12	0.67	0.47	0.58	8
BUGS	Merrybent	2.0	1.87	145.0	0.23	2.15	0.47	1.16	5
LSC	GeOroel	2.31	2.22	128.7	0.53	0.89	0.06	0.46	3
LSC	Asterix	2.13	1.92	171.3	0.11	1.10	0.28	0.61	13
LSC	GeAnayet	2.26	1.99	461.2	3.68	0.71	0.16	0.74	2
Kamioka	Ge01	1.68	2.39	104.5	0.08	0.39	0.41	0.44	23
	Ge02	1.68	1.82	81.3	0.13	0.23	0.68	0.42	

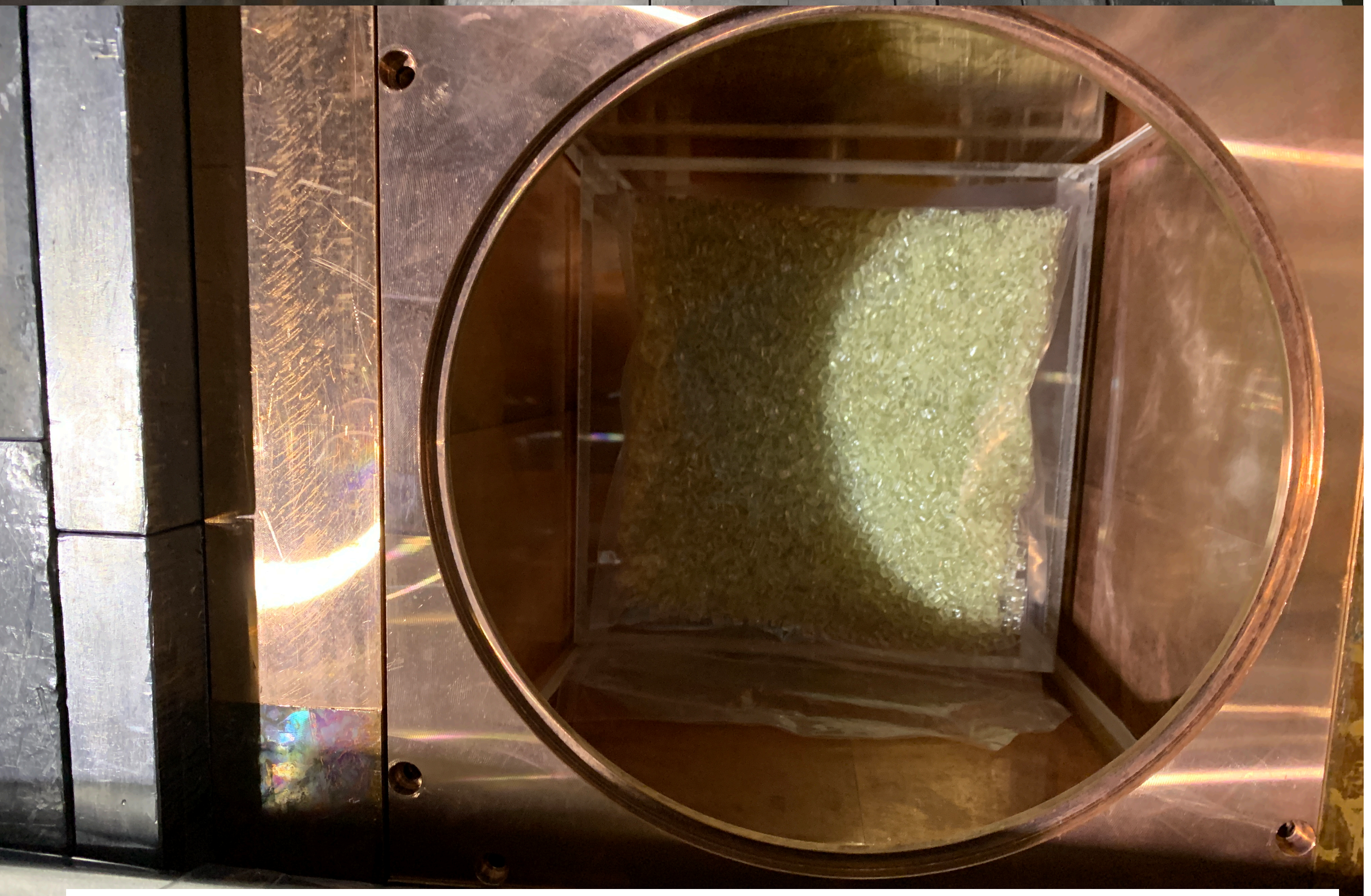
Detector	Ge01		Ge02	
Date	Dec. 2019	Dec. 2021	Jul. 2022	Apr. 2023
Measurement time (d)	23.0	19.0	47.2	86.2
Count rate (kg_{Ge}^{-1} d^{-1})				
Integral 40–2700 keV	112.6	140.2	100.0	84.3
^{208}Tl, 2614 keV	0.08±0.04	0.25±0.09	0.16±0.05	0.13±0.03
^{214}Bi, 609 keV	0.39±0.10	0.25±0.09	0.38±0.07	0.23±0.04
^{60}Co, 1333 keV	0.41±0.10	0.66±0.14	0.48±0.08	0.68±0.07
^{40}K, 1461 keV	0.44±0.11	0.31±0.10	0.44±0.07	0.42±0.05
^{137}Cs, 662 keV	1.29±0.18	0.53±0.13	0.38±0.07	0.32±0.05
^{210}Pb, 46.5 keV	3.24±0.29	0.69±0.14	0.64±0.09	0.59±0.06

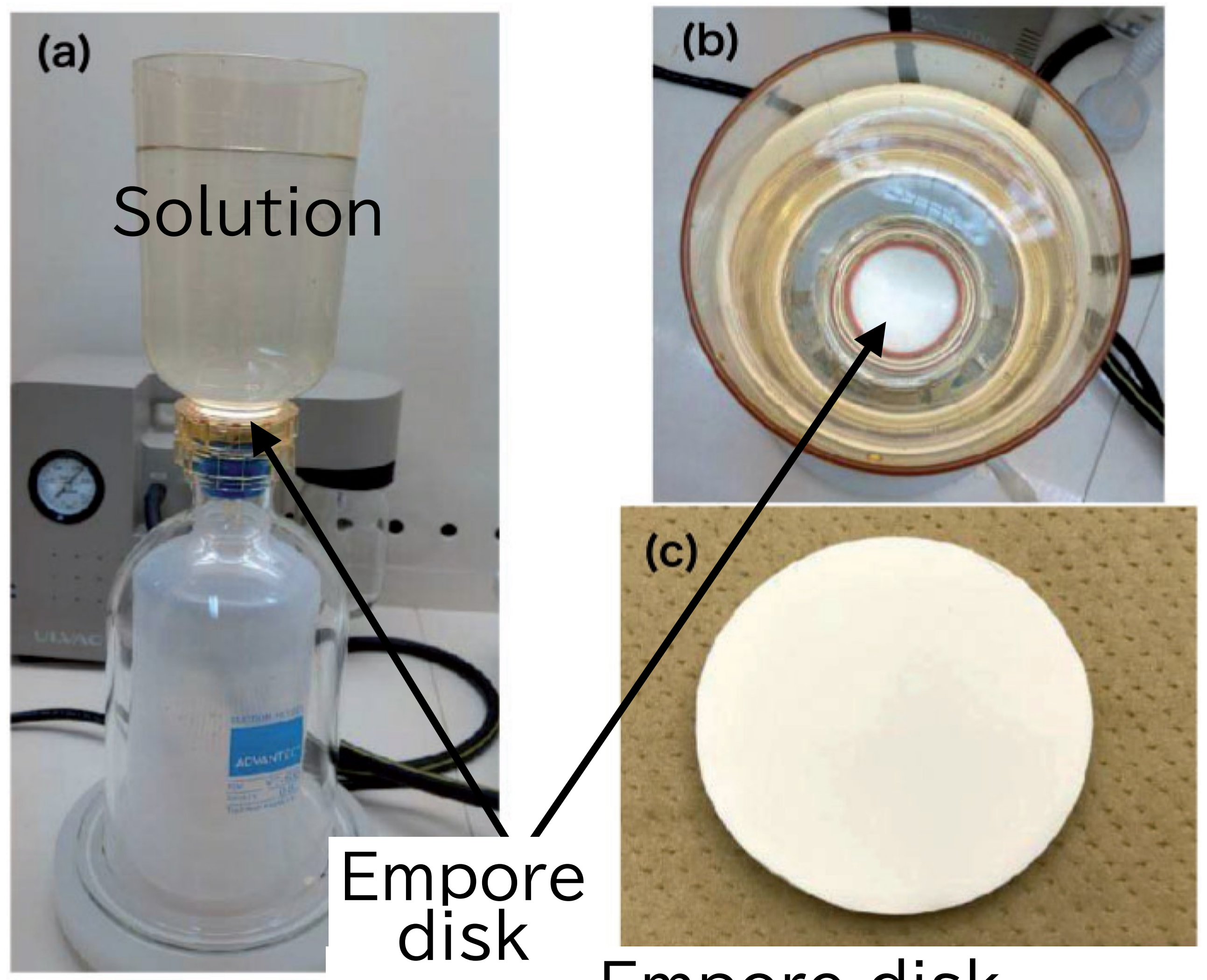
Careful shield surface cleaning, noise reduction
→ low ^{210}Pb, ^{137}Cs, continuum BG, 10 keV energy threshold
More details can be found in https://doi.org/10.1093/ptep/ptad136

Activity of material screening (3): HPGe

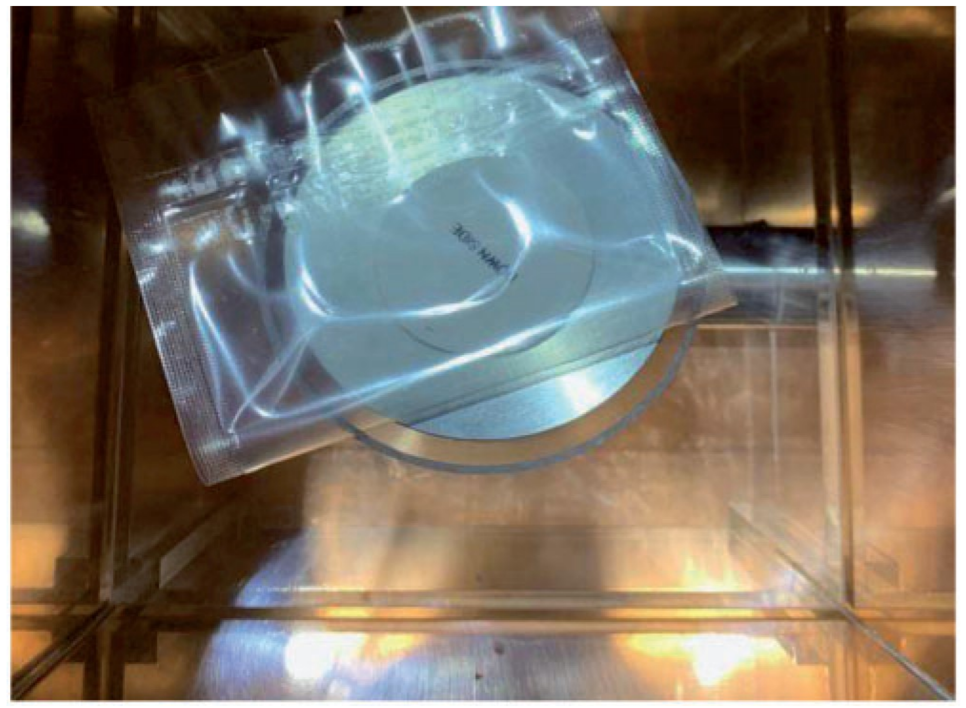
example of material screenings




polyethylene naphthalate (PEN) pellet
on the acryl stage



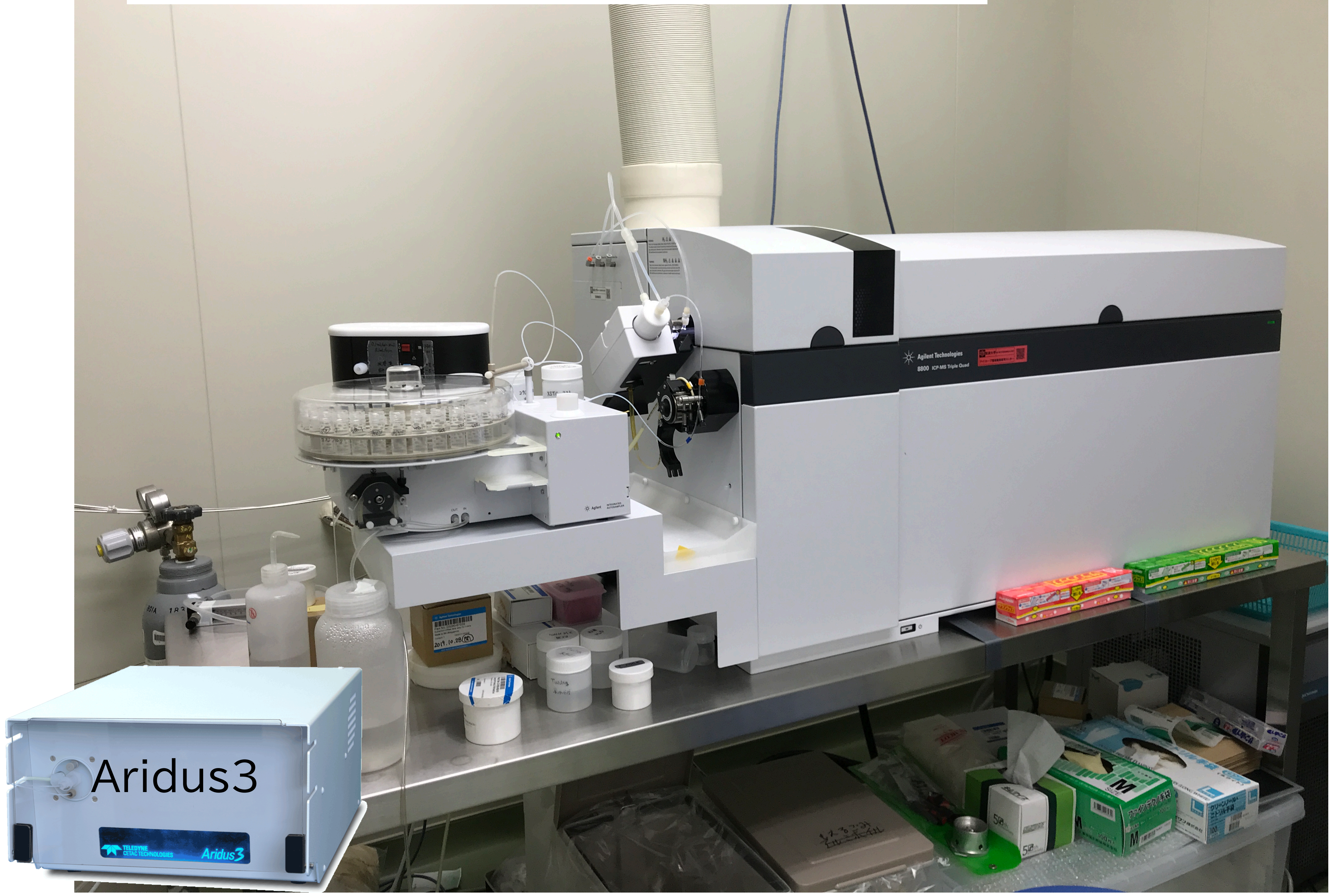
Empore disk
on the HPGe Endcap



- We can measure large sample
  - ($23 \times 23 \times 19$ cm^{3}) on the acryl stage
  - ($23 \times 23 \times 15$ cm^3 - Ge detector volume) for side region
- High sensitive ^{226}Ra measurement with molecular recognition resin
  - https://doi.org/10.1093/ptep/ptaa105
- O(0.1 mBq/kg) ^{226}Ra measurement can be done within 10 days

ICP-MS (1)

Agilent 8800 (Univ. of Tsukuba)



Agilent 7900 (ICRR, Univ. of Tokyo, in the mine)

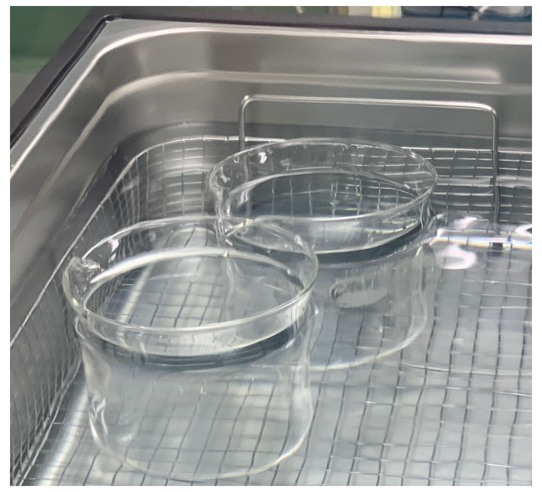
- 2 ICP-MS in the mine (Both ICRR, Univ. of Tokyo) to measure ^{238}U, ^{232}Th, ^{144}Ce in $Gd_2(SO_4)_3 \cdot 8H_2O$ and Gd in the water
- Not in the mine, but for KamLAND material screening with ICP-MS :
  - collaborative research with Univ. of Tsukuba
  - Agilent 8800 ICP-MS & Aridus3 desolvating nebulizer system
  - Sensitive to ^{238}U and ^{232}Th in organic materials (ppt to sub-ppt range)
    - (PEN film : Scintillation film, Bis-MSB : Wavelength shifter etc.)

ICP-MS (2)

①Sample preparation

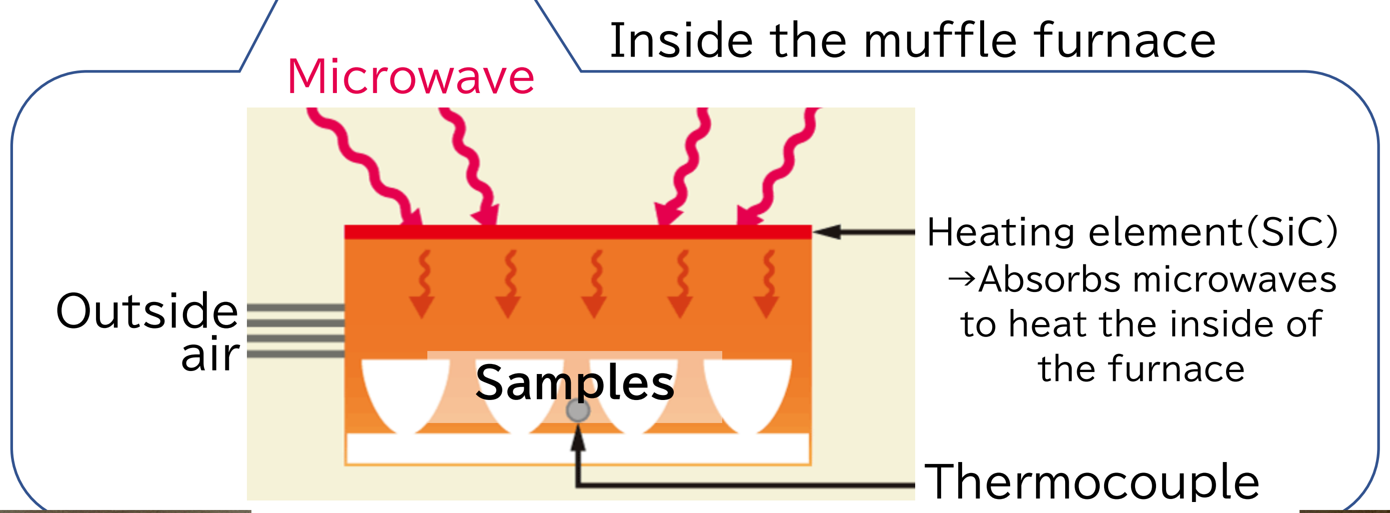
Tohoku Univ.
ISO class 5 clean room

Bis-MSB

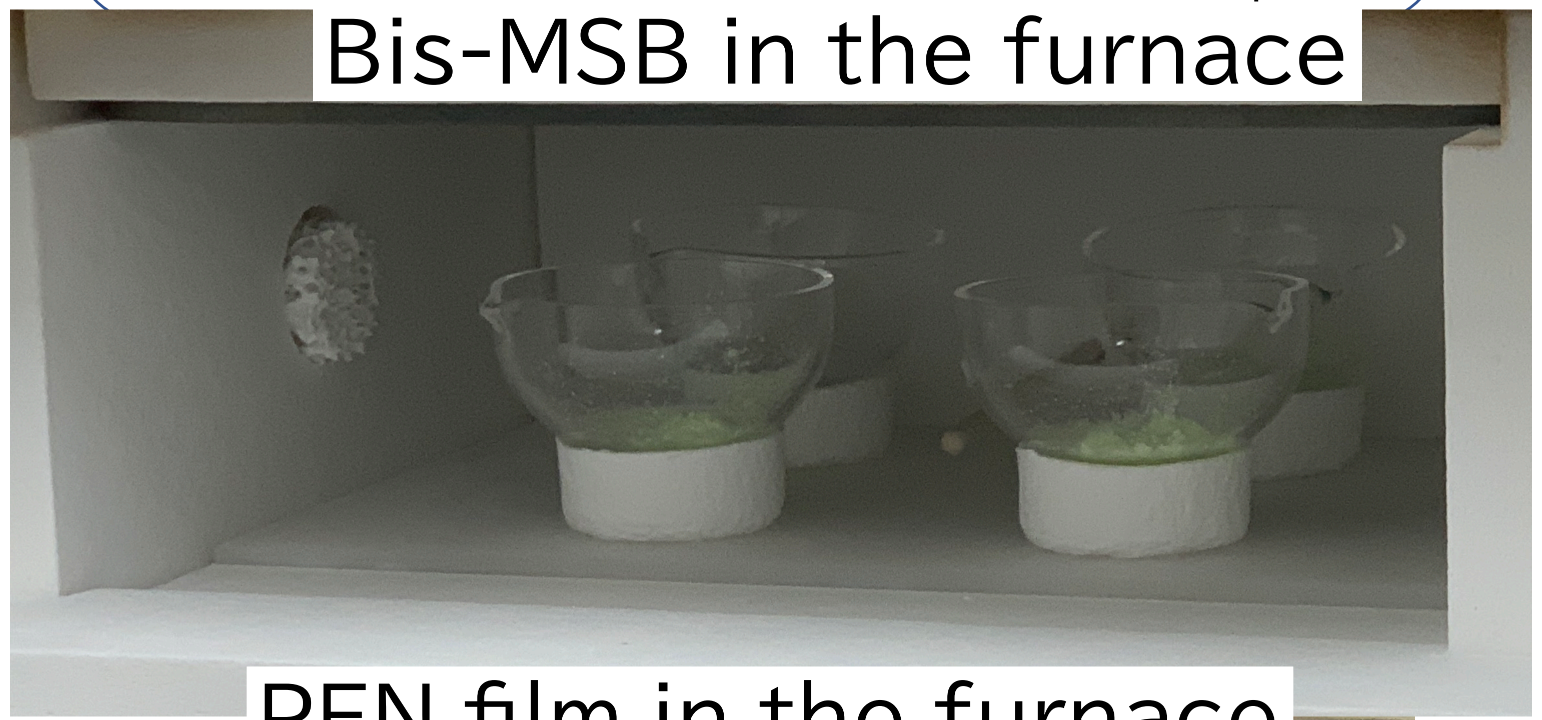


PEN Film
ultrasonic cleaning
with ultra pure water

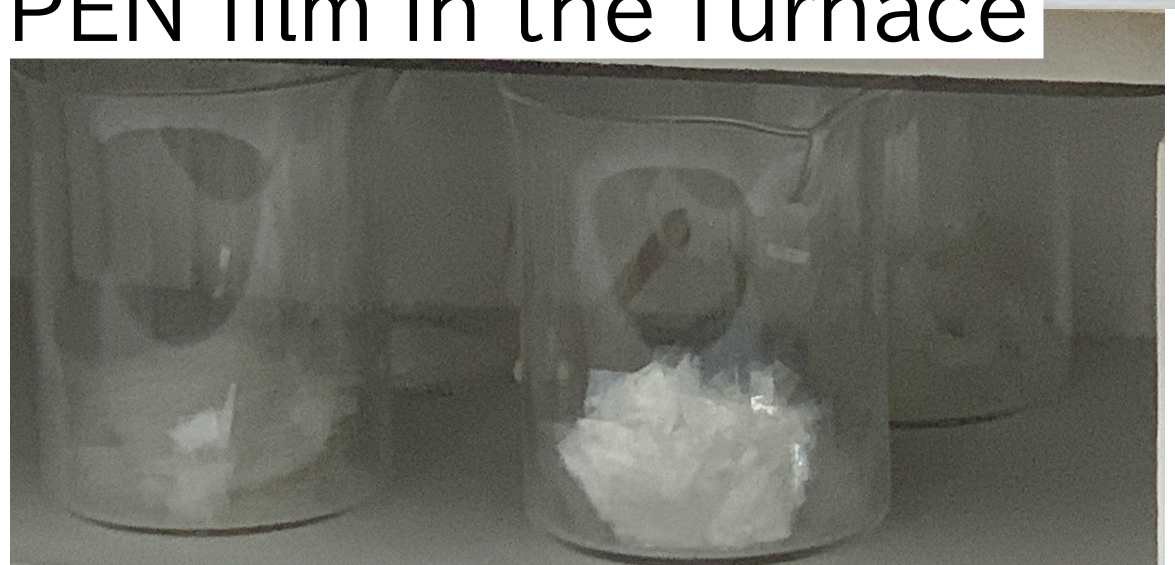
②Ashing (Univ. of Tsukuba)



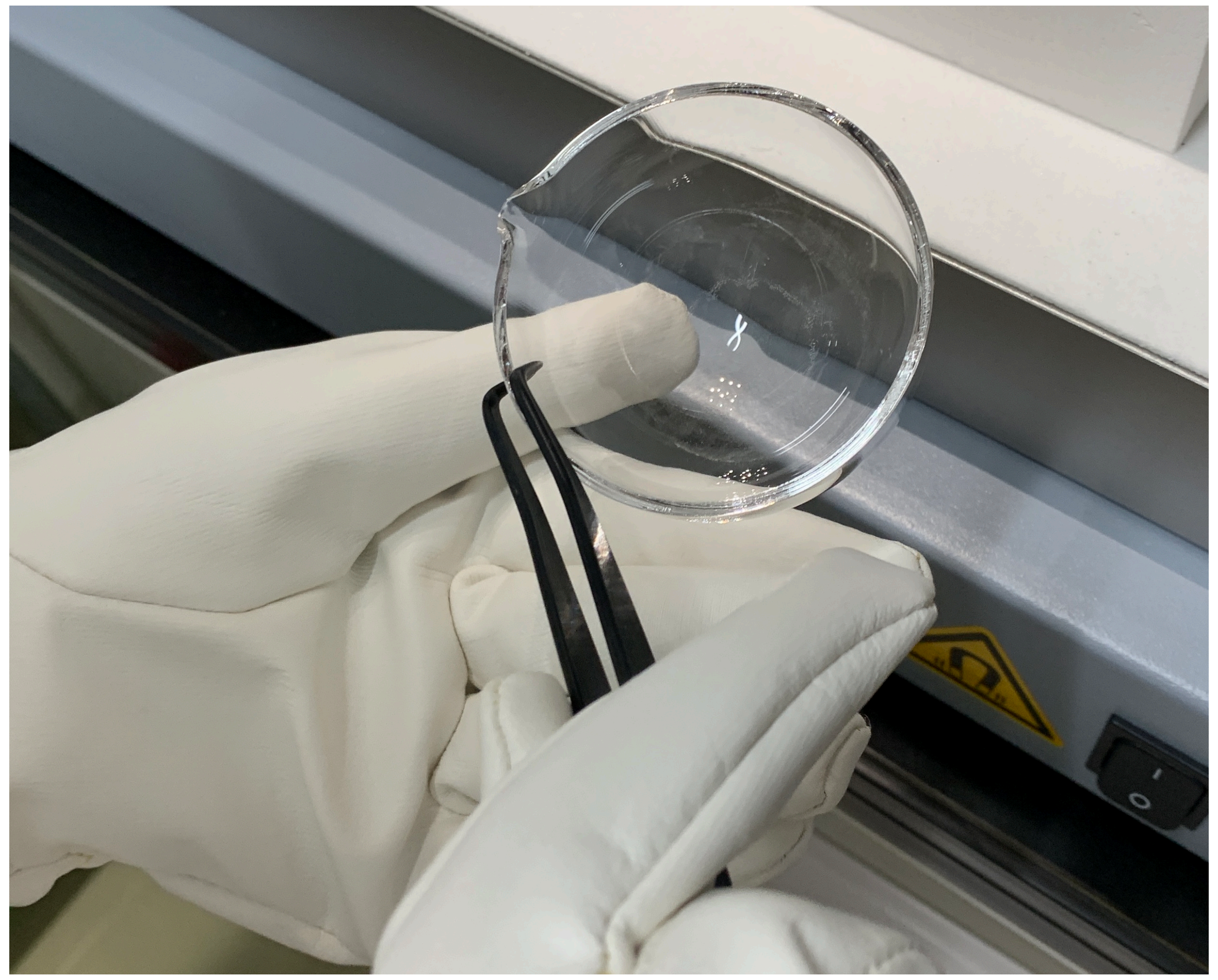
Bis-MSB in the furnace



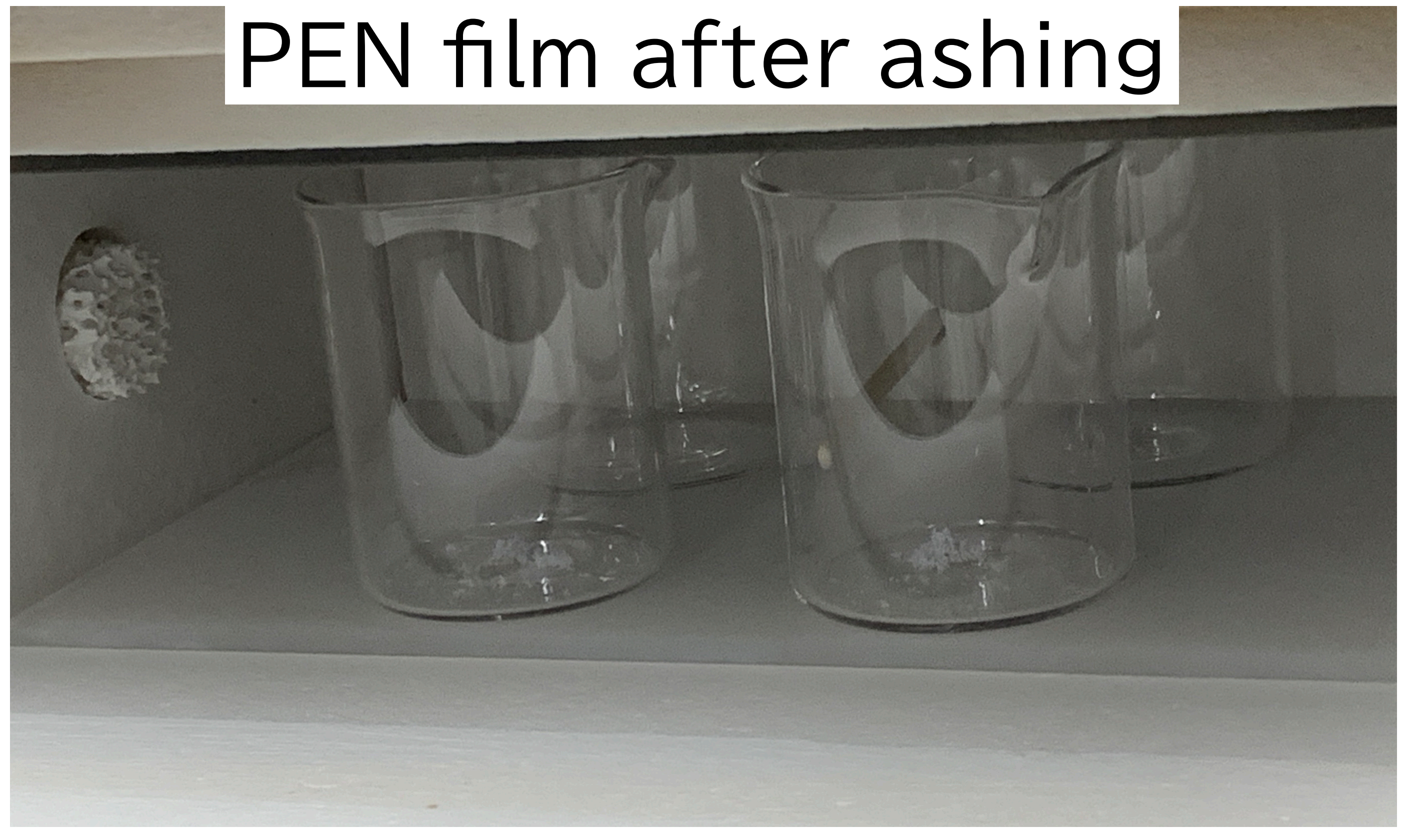
PEN film in the furnace



Bis-MSB after ashing



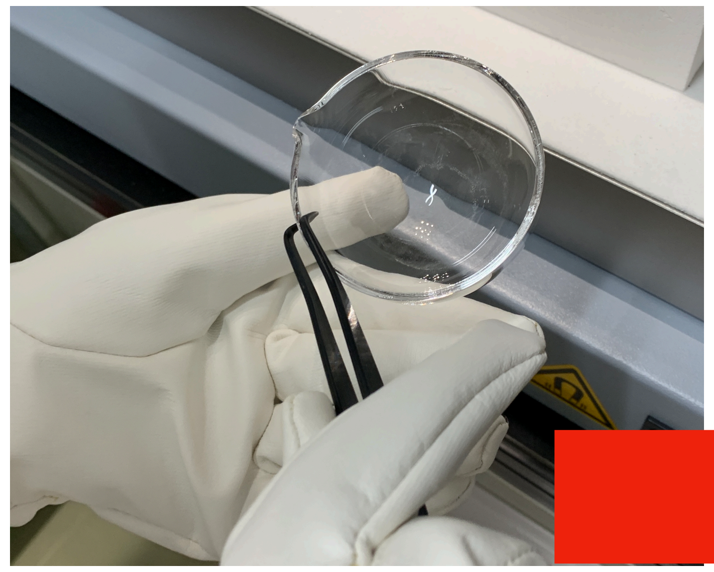
PEN film after ashing



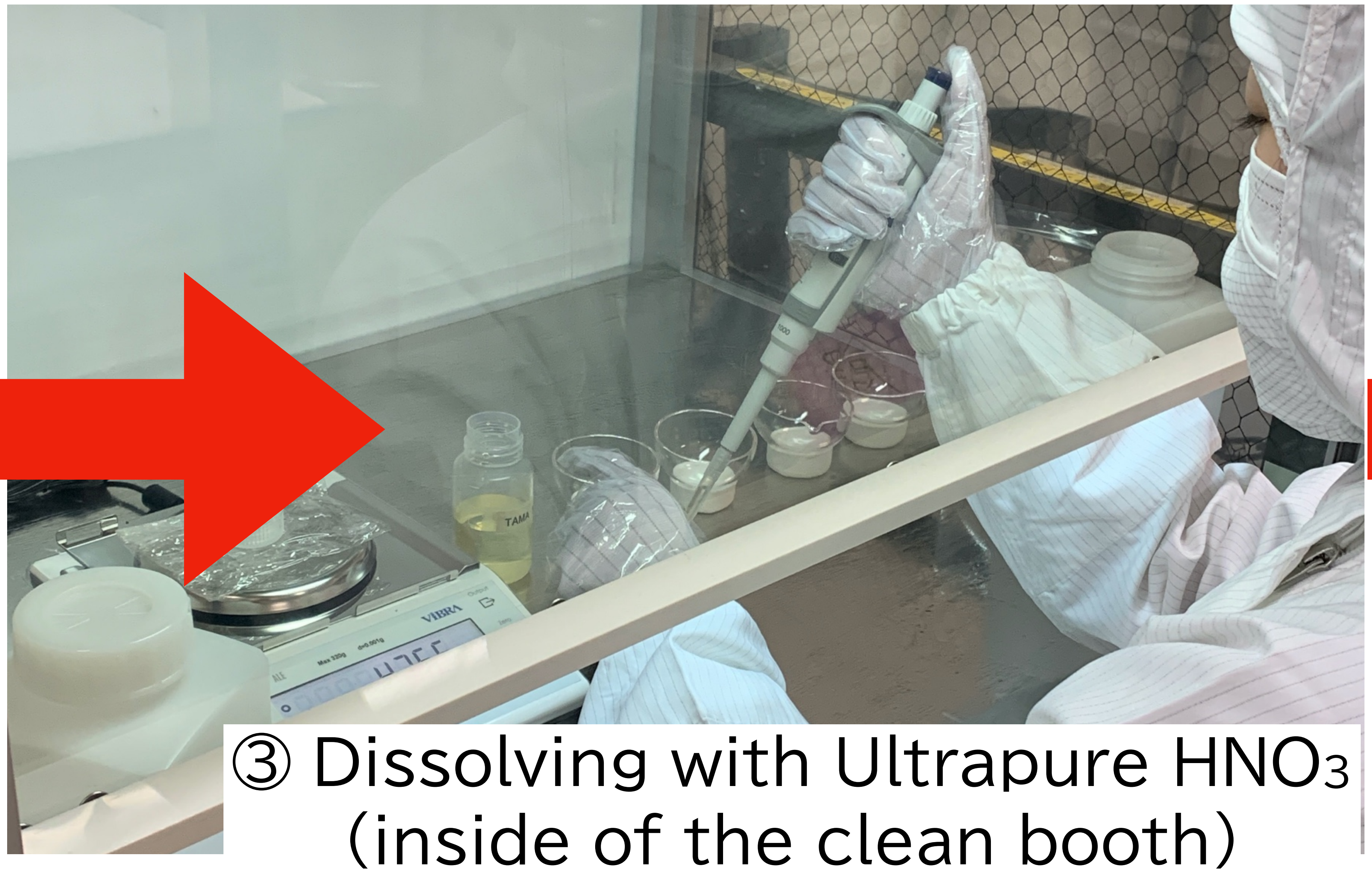
O (1～10 g) organic materials
can be ashed.

ICP-MS (3)

Bis-MSB after ashing

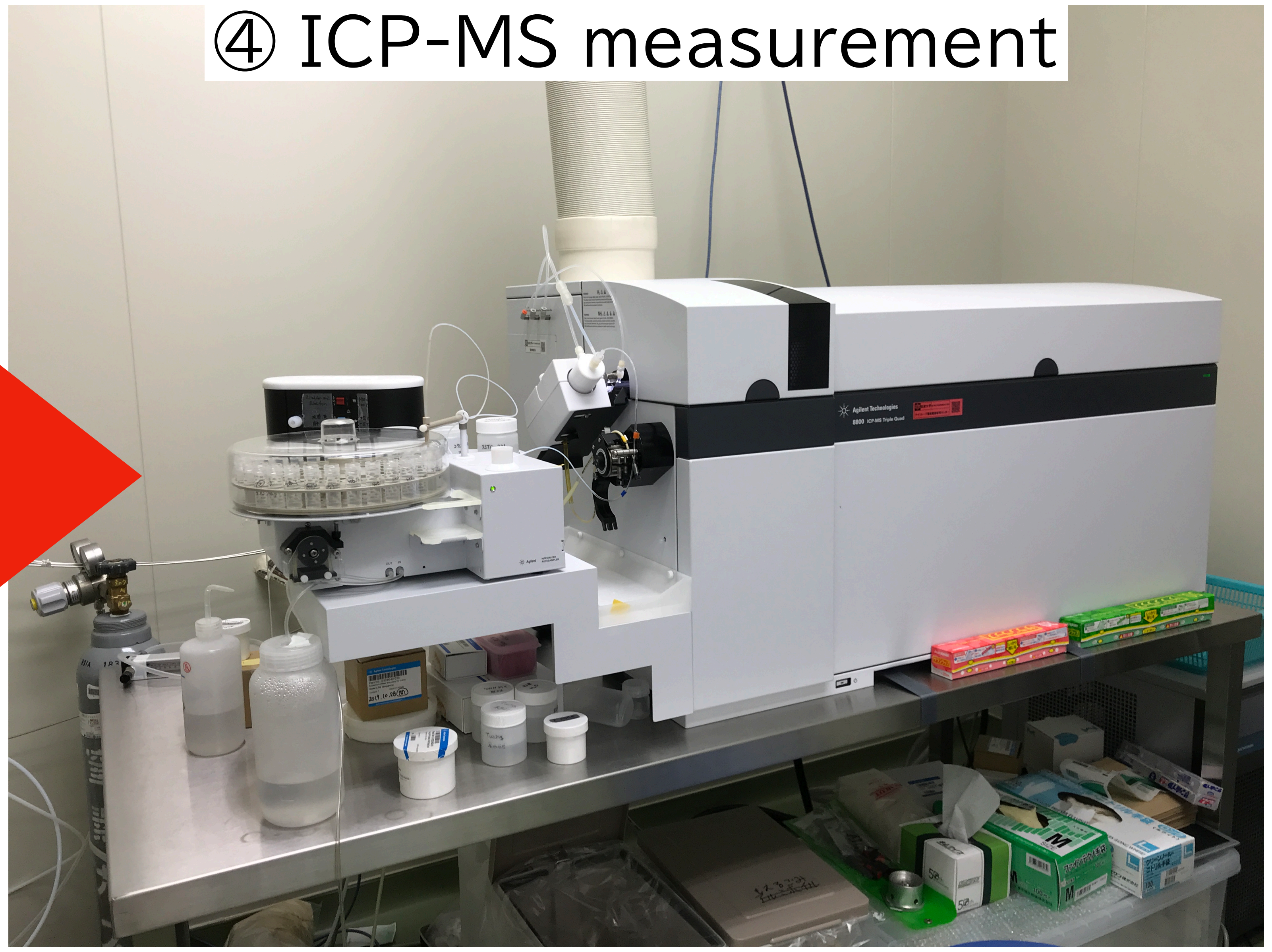


PEN film after ashing



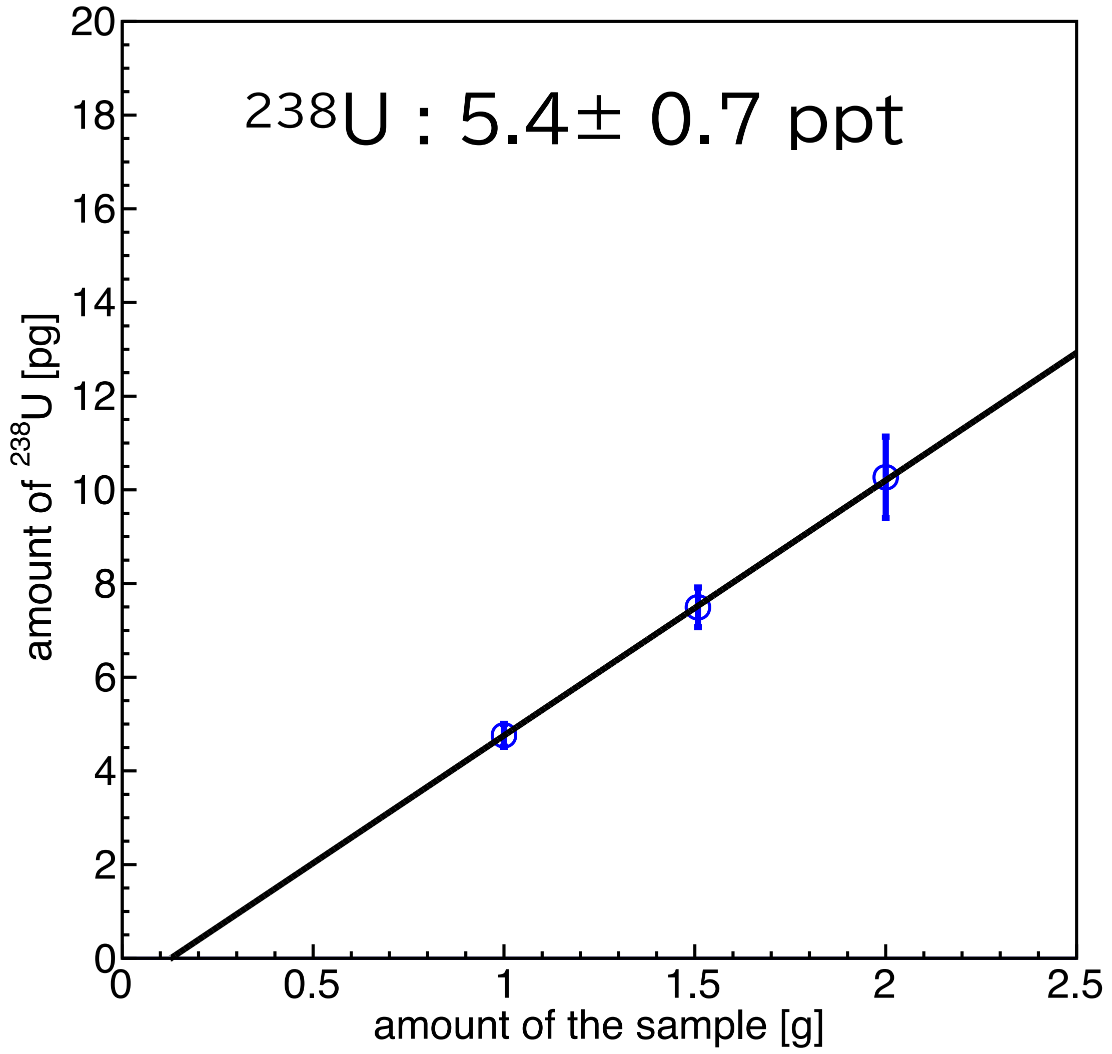
③ Dissolving with Ultrapure HNO_3
(inside of the clean booth)

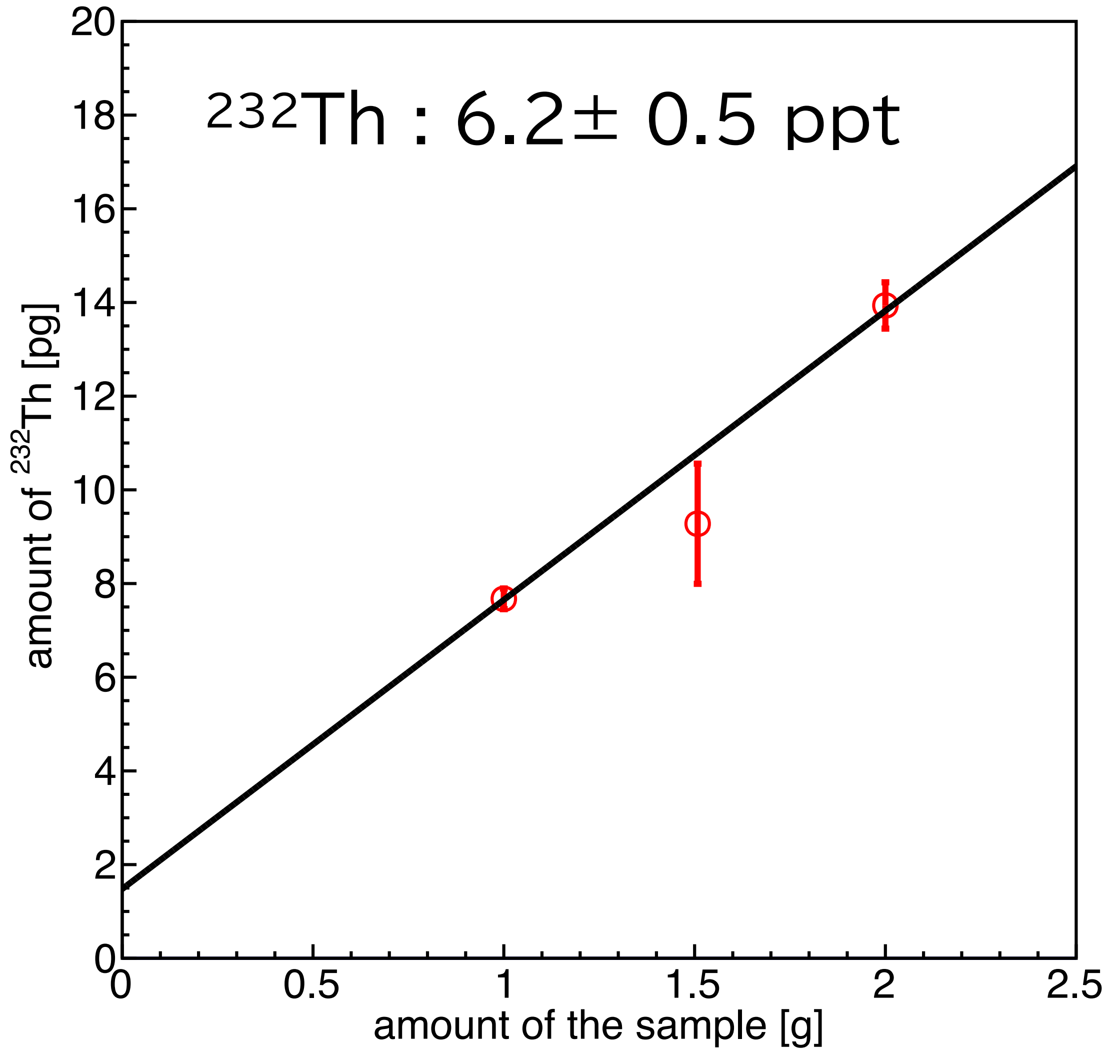
solution



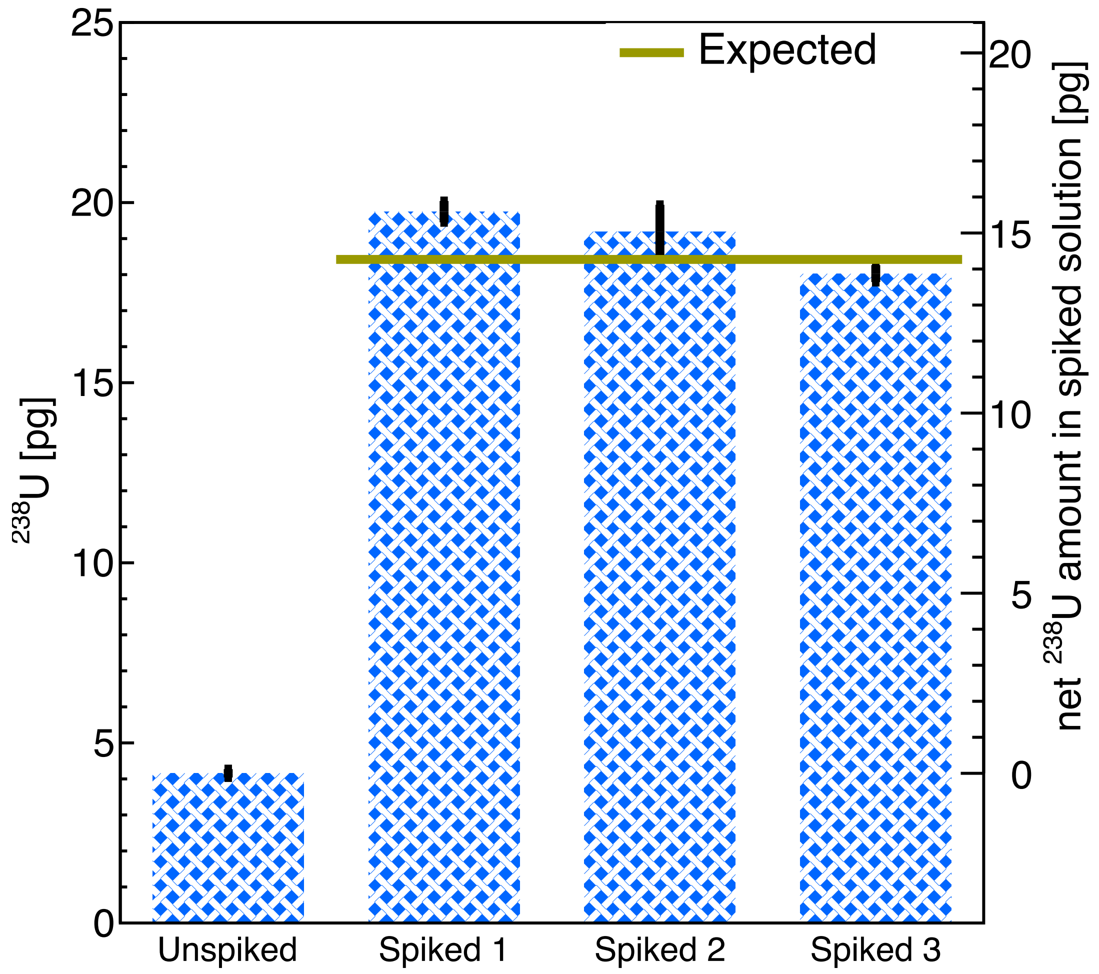
④ ICP-MS measurement

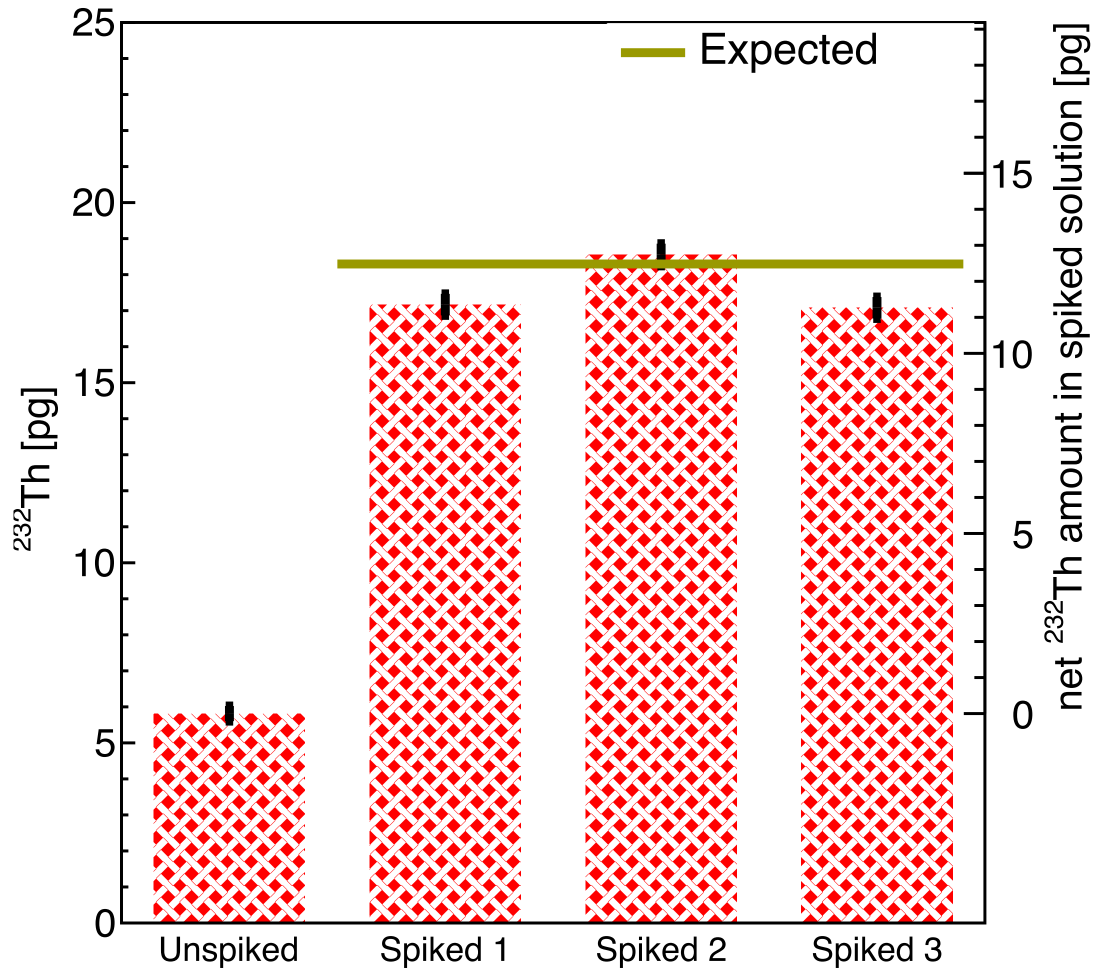
PEN film sample measurement





recovery rate measurement (PEN film sample)





Can be measure O(1 ppt) ^{238}U, ^{232}Th by ashing O(1 g) sample with almost 100% recovery rate
By increasing the amount of sample, sensitivity is getting better

PTEP

Prog. Theor. Exp. Phys. **2020**, 113H01 (15 pag
DOI: 10.1093/ptep/ptaa

Evaluation of radon adsorption efficiency values in xenon with activated carbon fibers

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The radioactive noble gas radon-222 (^{222}Rn) produced in the uranium series is a crucial background source in many underground experiments. We have estimated the adsorption property of Rn with activated carbon fibers (ACFs) in air, argon, and xenon gas. We evaluated six ACFs, named A-7, A-10, A-15, A-20, A-25, and S-25, provided by Unitika Ltd. We measured the intrinsic radioactivity of these ACF samples, and found A-20's radioactivity of the uranium series to be < 5.5 mBq/kg with 90% confidence level. In air and Ar gas, we found that ACF A-15 has an adsorption efficiency of 1/10000 reduction at maximum before saturation of Rn adsorption, and more than 97% adsorption efficiency after the saturation. In Xe gas, we found that ACF A-20 has the best Rn adsorption ability among the tested ACFs. We also found that S-25, A-25, and A-15 have similar Rn adsorption performance.

Subject Index H20

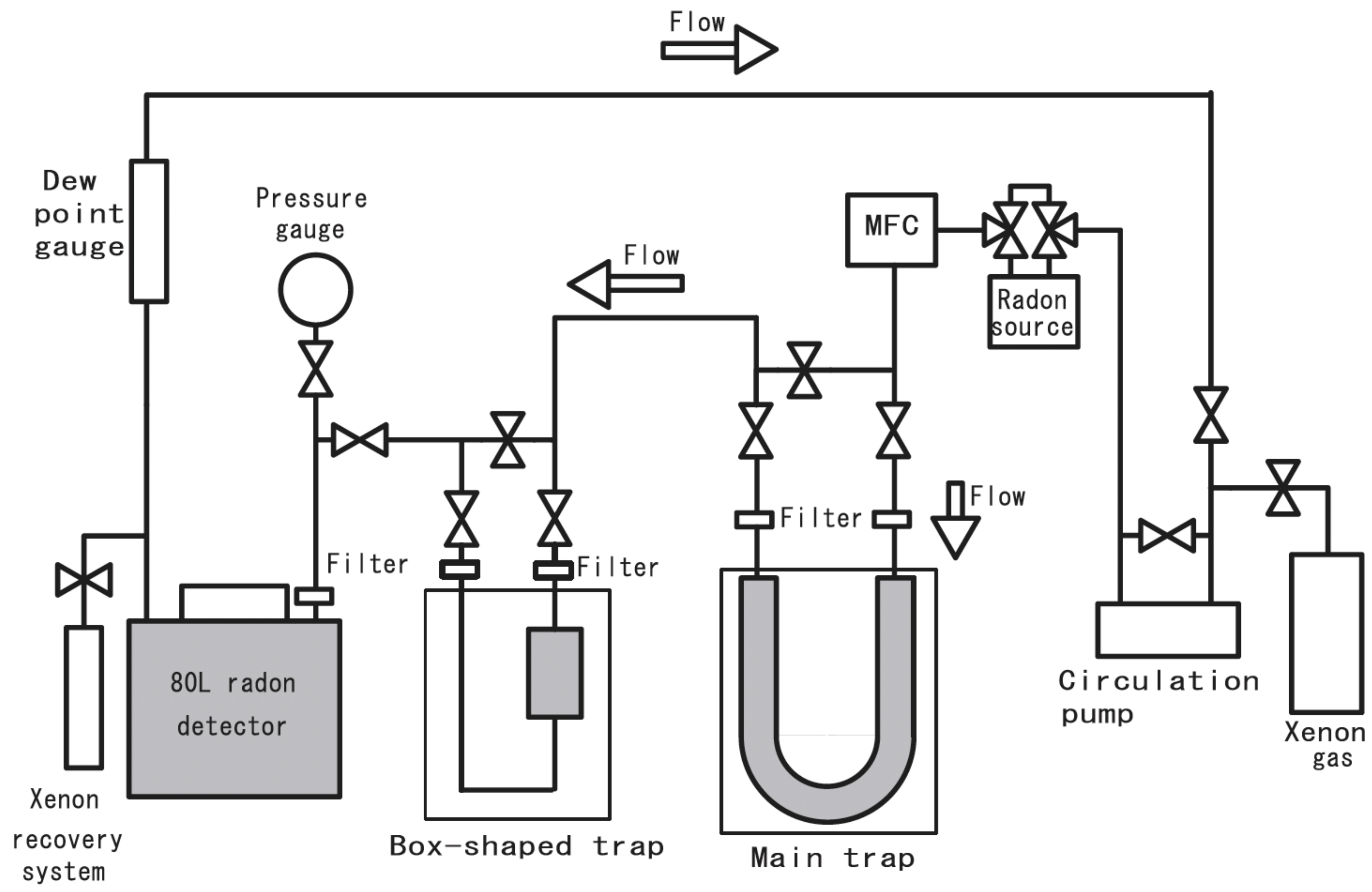


Fig. 3. Experimental setup of the full test bench. The Rn detector was upgraded to an 80-L detector from the system in Ref. [27]. Then, a new refrigerator and a new larger cold trap (main trap) were newly added for the measurements with Xe gas. The arrows show the direction of the circulation gas flow.

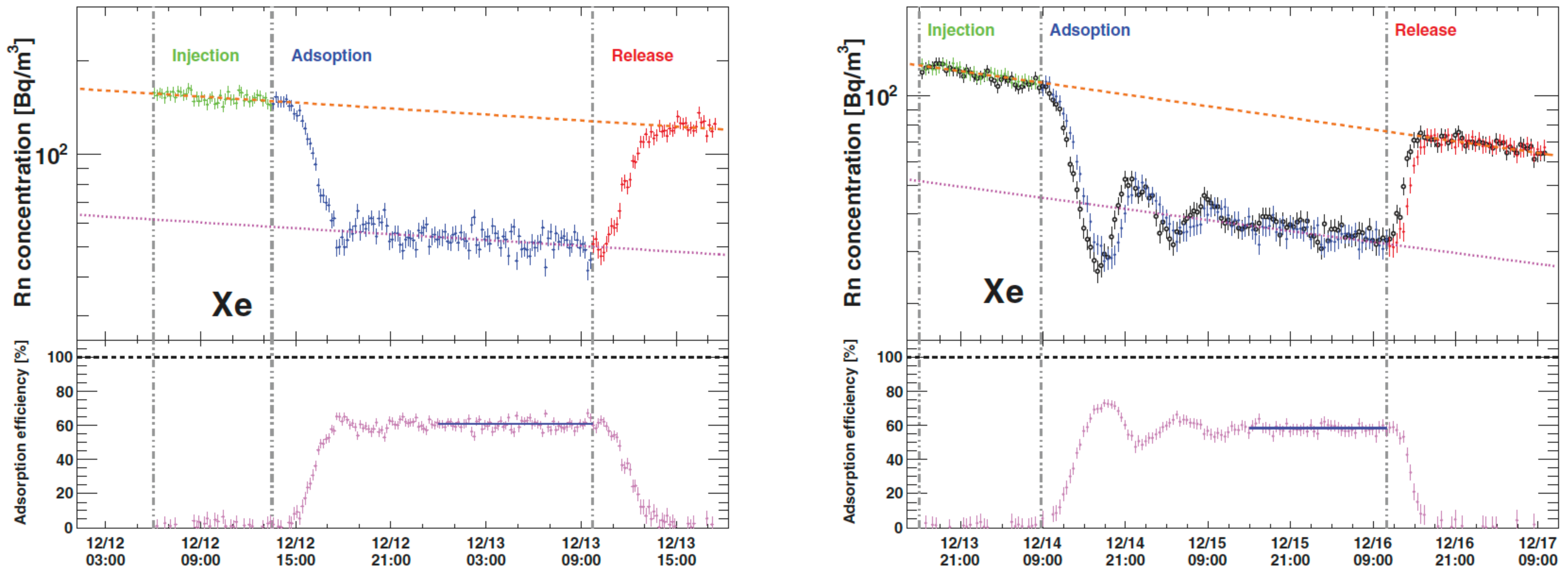


Fig. 5. An example of the measurements with Xe gas with ACF A-25. The Xe gas pressure before the adsorption phase, Xe gas pressure before the release phase, and flow rate in left (right) are −0.071 MPa (−0.071 MPa), −0.076 MPa (−0.075 MPa), and 0.41 SLM (0.14 SLM), respectively. The plot and color definitions are the same as Fig. 2. The black open circles in the upper right plot are the Rn concentration obtained from ^{218}Po counts.

Rn detector

https://doi.org/10.1016/j.nima.2017.04.037

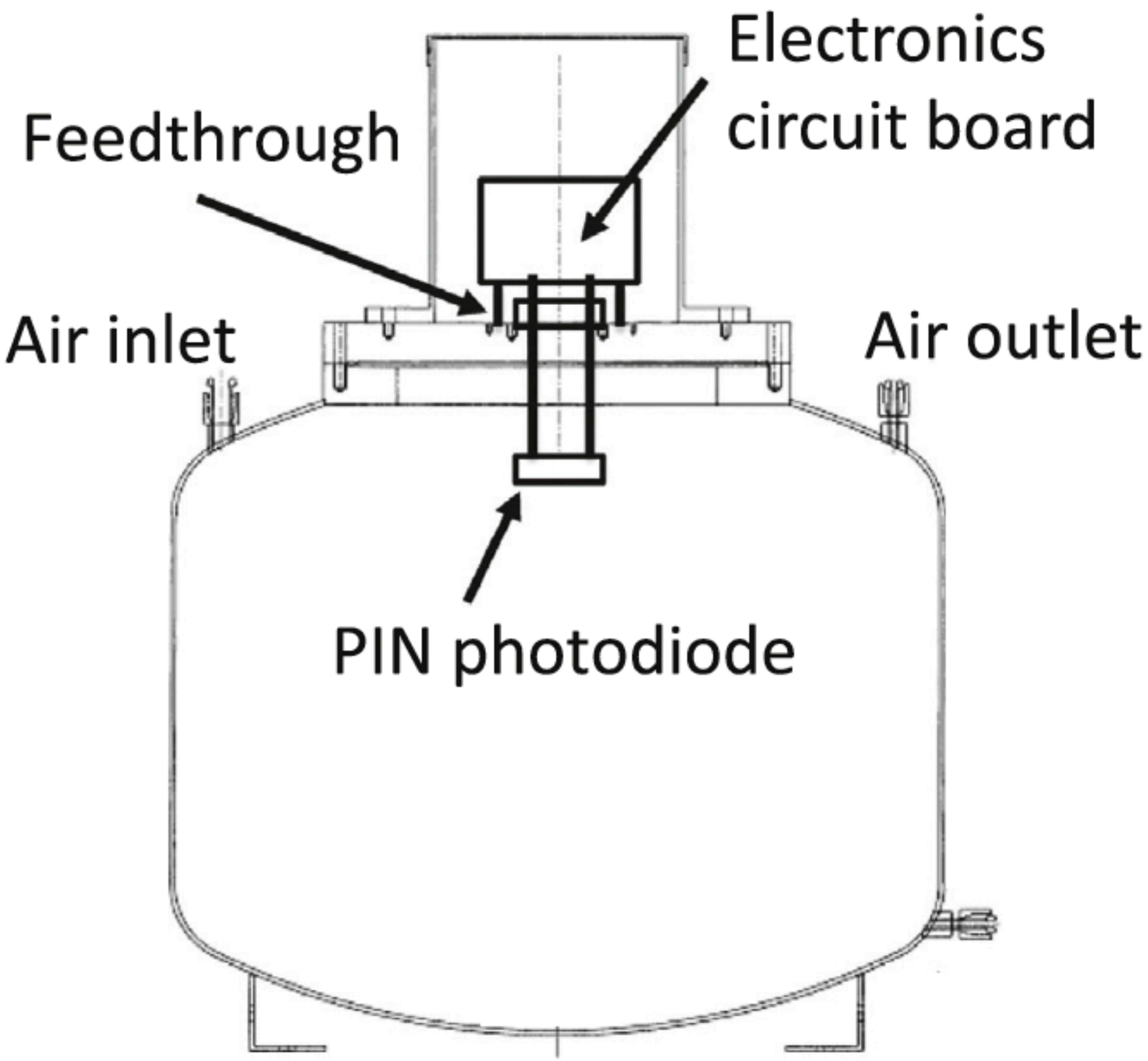


Fig. 1. The structure of the 80 L Rn detector.

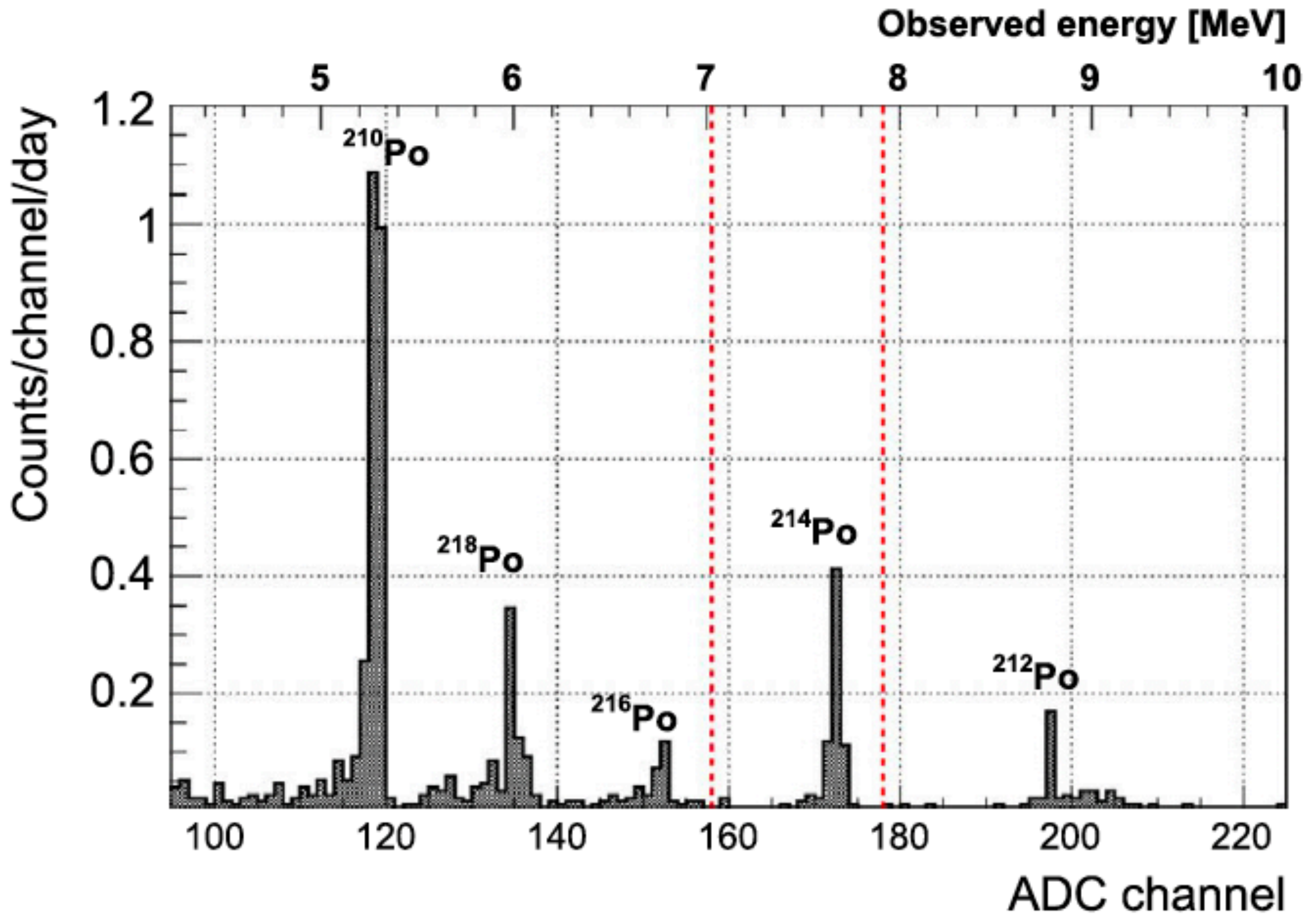
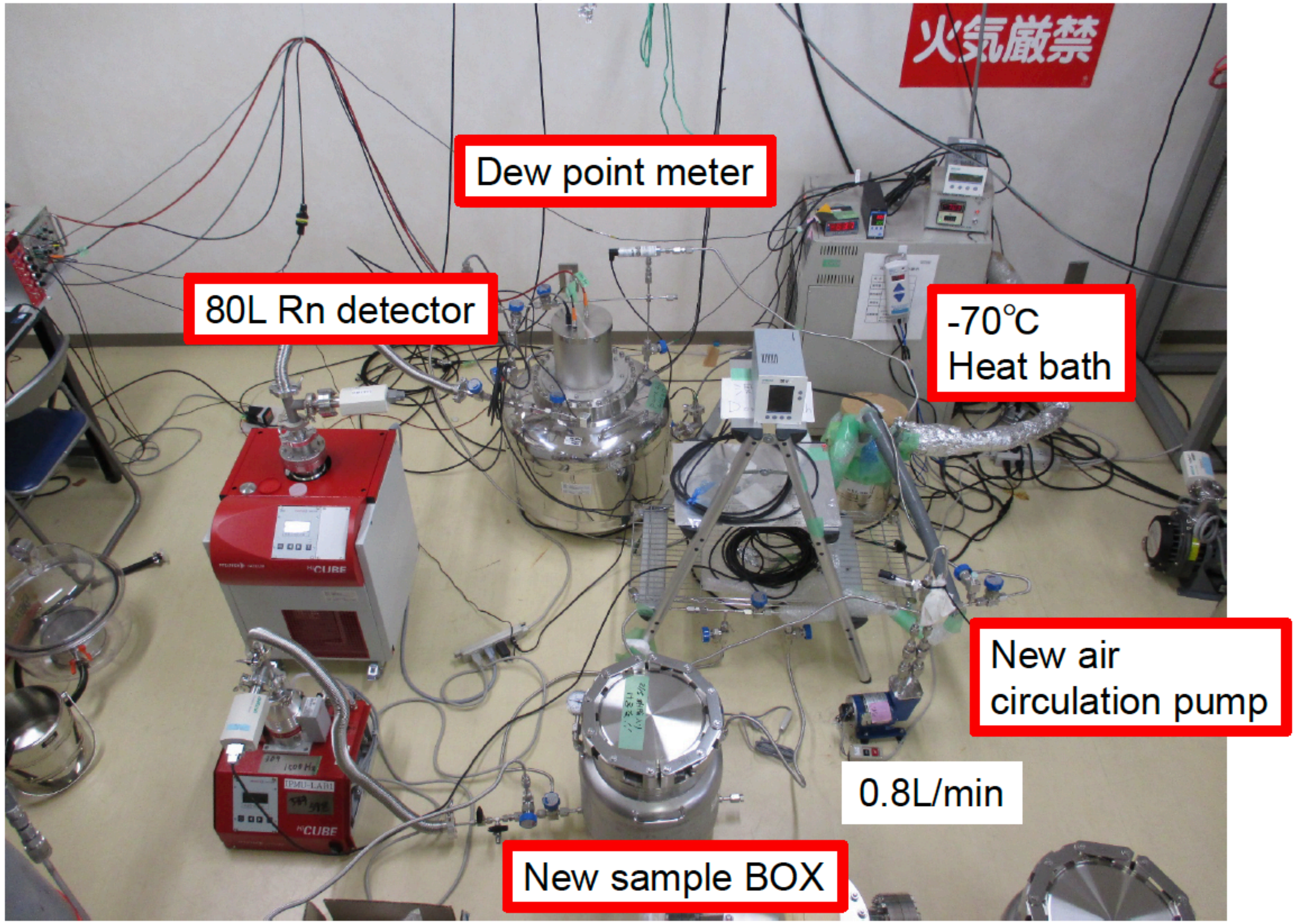


Fig. 2. Typical energy spectrum from ^{222}Rn and ^{220}Rn daughters. The region between ADC channels 158–178 and shown by the red dashed lines defines the ^{214}Po signal region used to calculate the ^{222}Rn concentrations for this particular detector. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

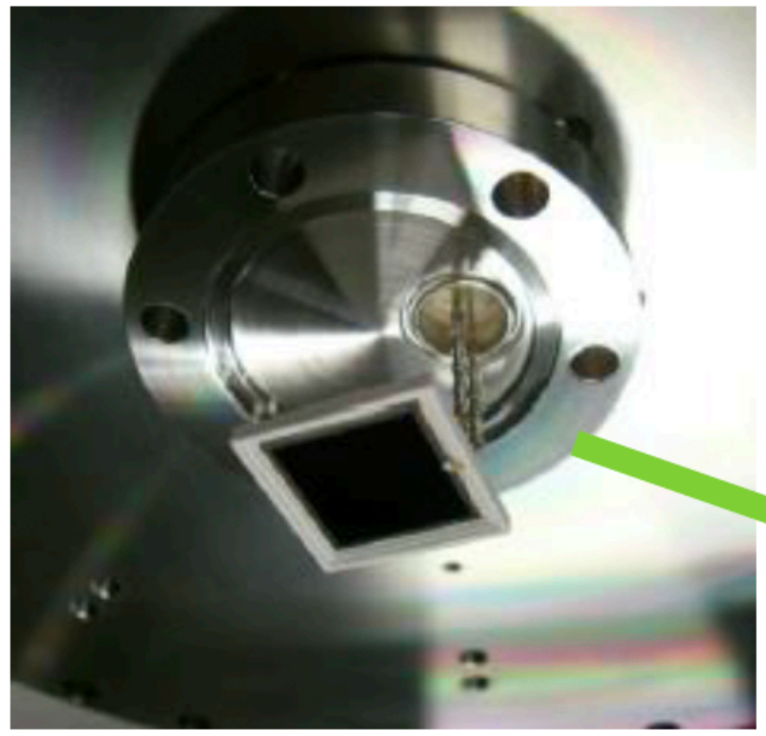
Rn detector

Rn emanation Setup



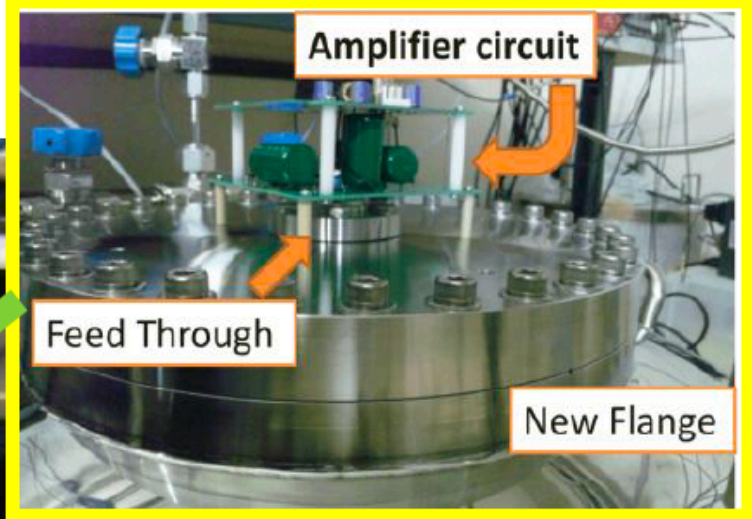
Rn detector

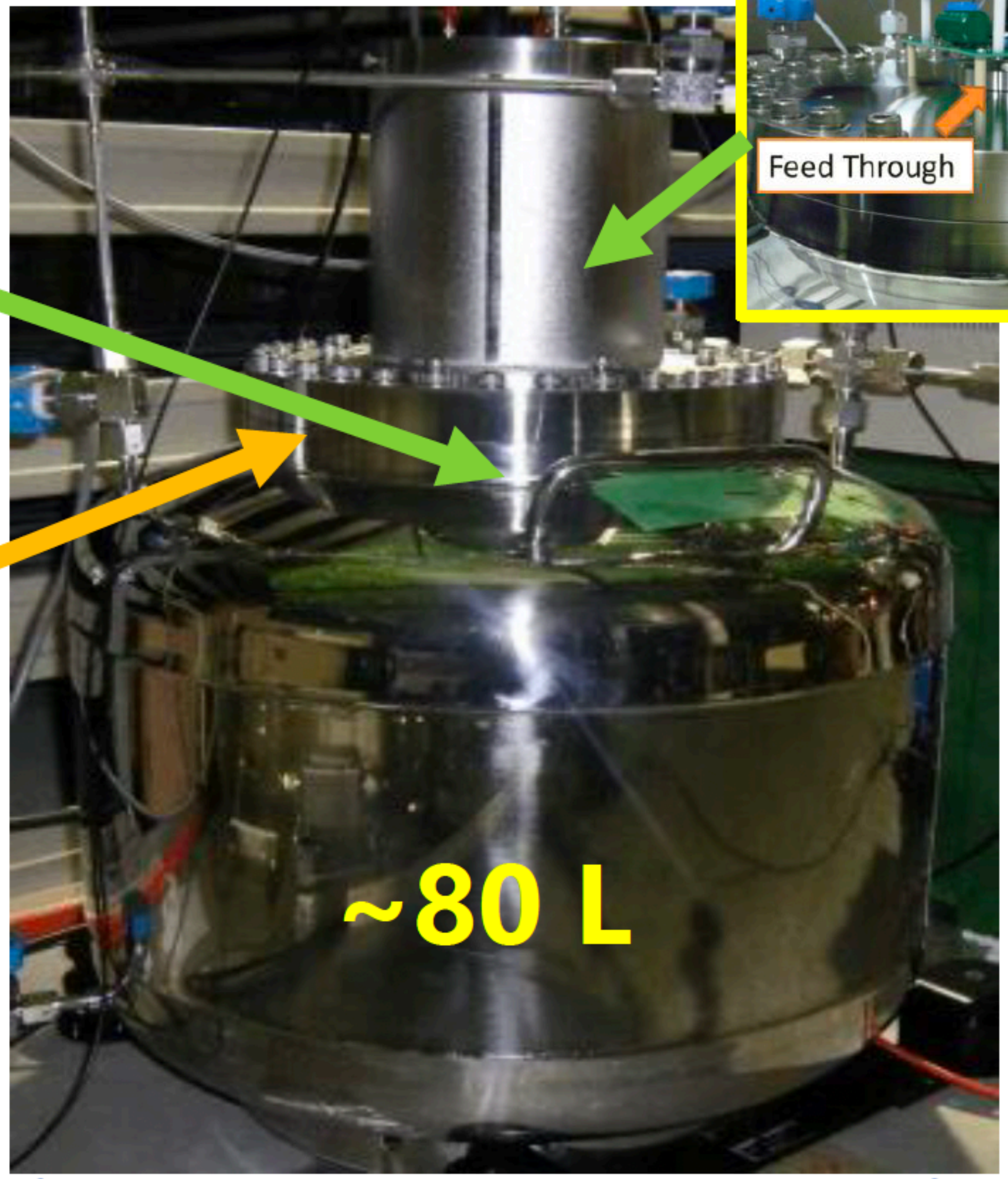
Design of high sensitivity Rn detector



18×18 mm^2 PIN photodiode.
Connected with feed through.

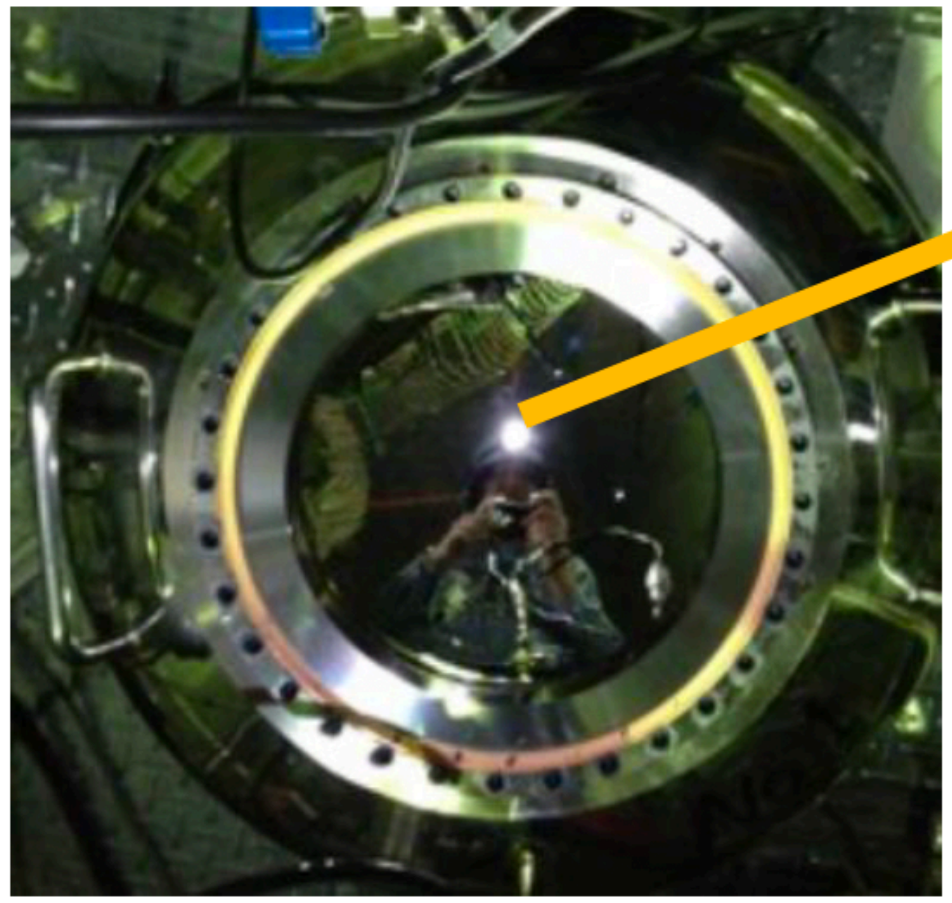
Amplifier circuit
on the detector.





40.8 cm

50.0 cm

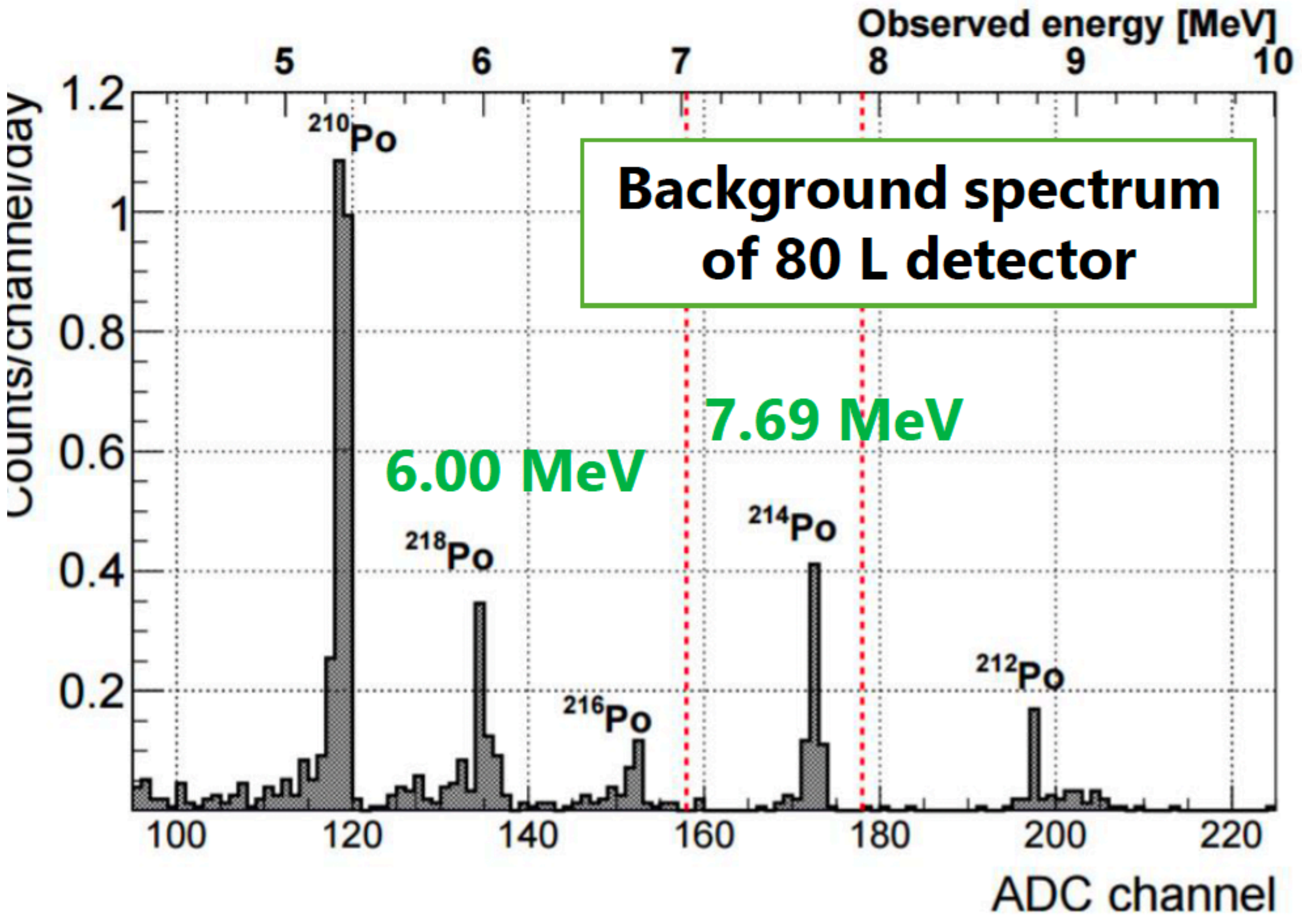


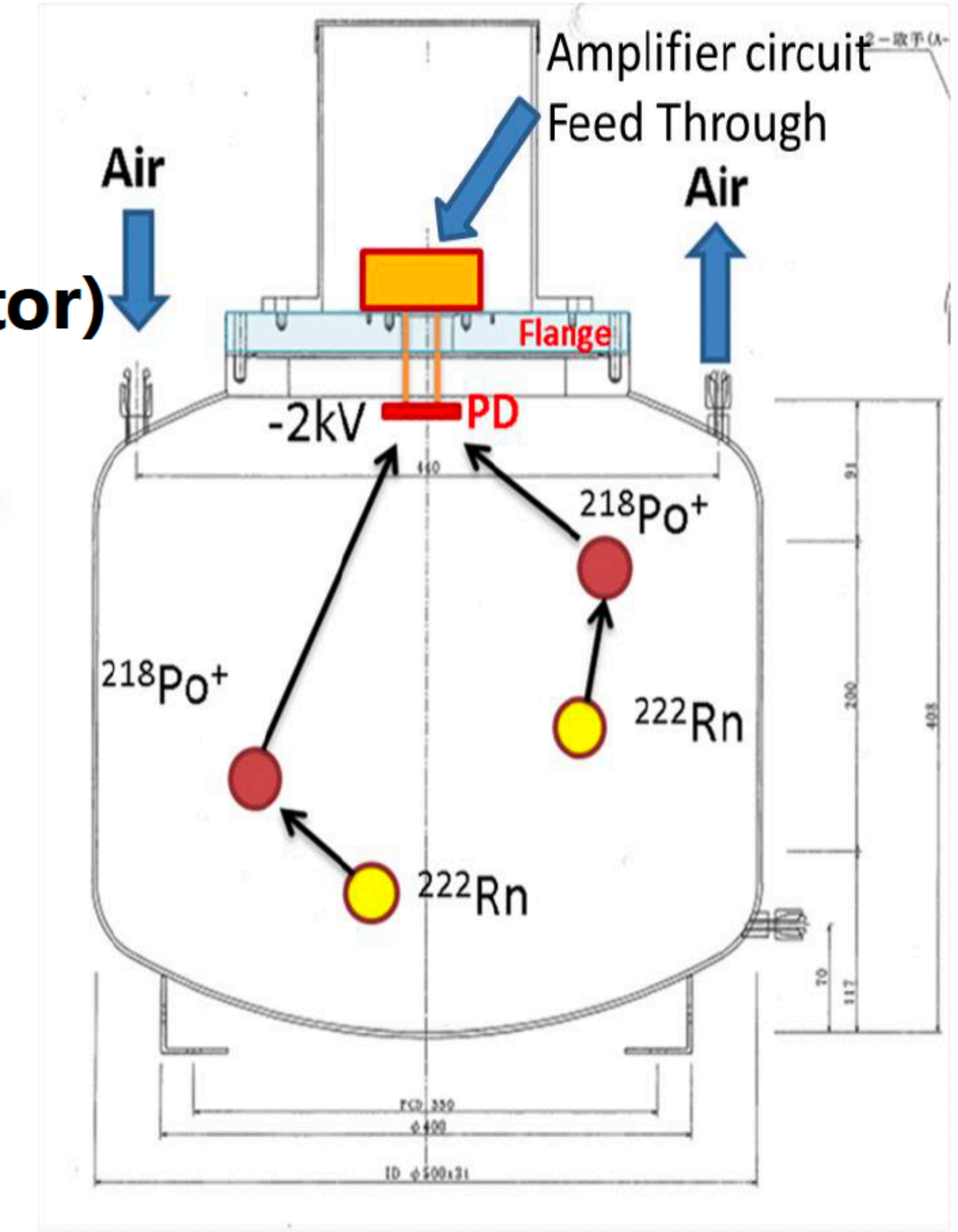
For vacuum: ICF copper gasket
For low BG: Electropolished.

Rn detector

How to measure

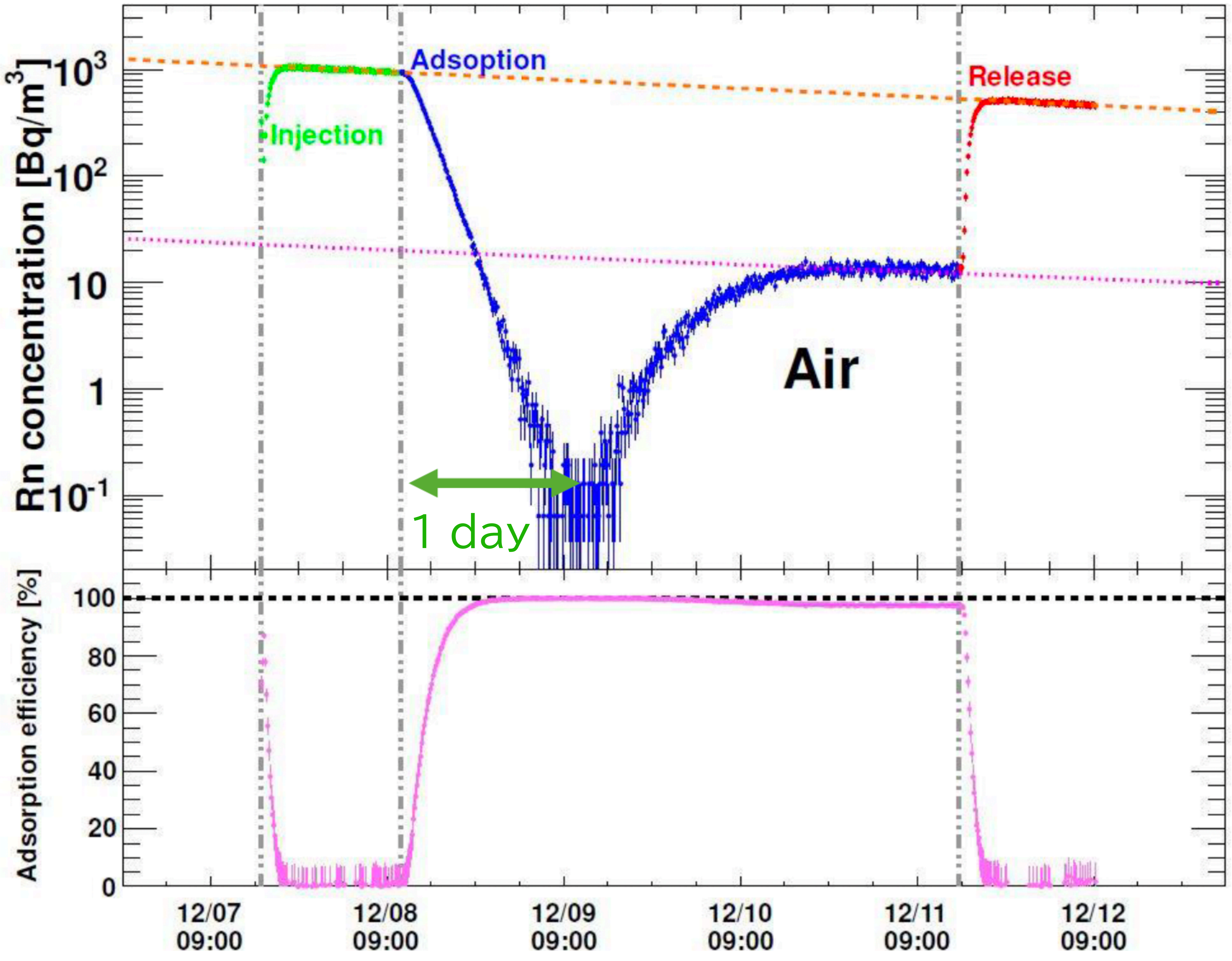
- **Electrostatic collection**
  - Positive ions from ^{222}Rn decay.
    $^{218}Po^+$, $^{214}Po^+$, $^{210}Po^+$
  - Collect ions on PIN photo-diode.
    (Form an electrical field inside detector)
    → Measure energy of α particle.





Nucl. Instrum. Meth A
867 (2017) 108-114.

Rn detector



Rn concentration [Bq/m³]
Adsoption
Release
Injection
Air
1 day
Adsorption efficiency [%]
12/07 09:00
12/08 09:00
12/09 09:00
12/10 09:00
12/11 09:00
12/12 09:00