

# Status of ULB HPGe at KERNEL

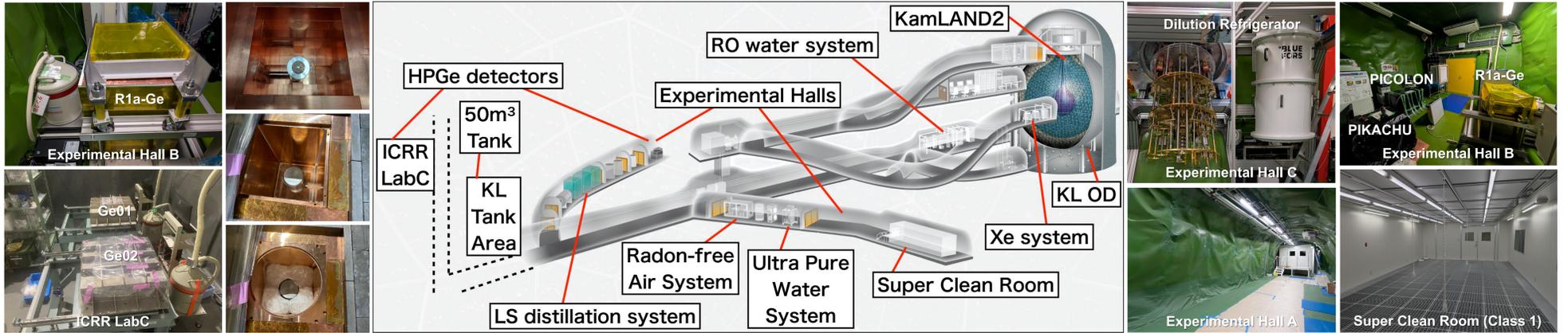
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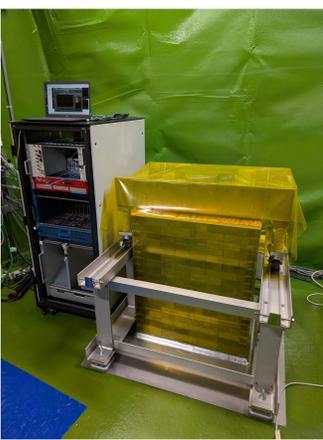
神岡極稀現象研究拠点  
 Kamioka Extremely Rare-phenomena and NEutrino-research Laboratory

## KERNEL

The Kamioka Extremely Rare-phenomena and NEutrino-research Laboratory (KERNEL) is located within the Kamioka Underground Laboratory at a depth of 2700 m.w.e. (~1000 m of rock overburden) and utilizes ultra-low-background (ULB) detectors and specialized facilities to perform rare-event searches for neutrinoless double beta decay and dark matter.

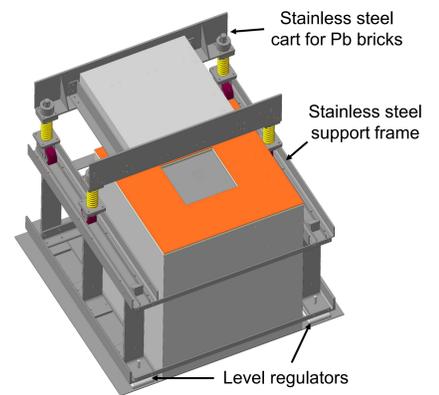


## ULB HPGe R1a-Ge setup

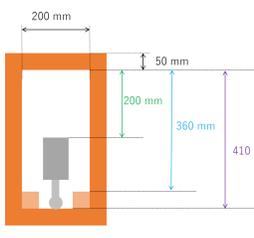


- ❖ HPGe detector: Canberra GC6520 (USA), coaxial p-type, 74% relative efficiency, ~1.4 kg crystal mass
- ❖ Operated inside an ultra-low-background shielding from 2016 to 2023; dismantled due to the establishment of the CryoLab at KERNEL
- ❖ Refurbished ULB HPGe setup reassembled at KERNEL in late 2025
- ❖ Passive shielding: 25–30 cm of lead and 5 cm of oxygen-free high-conductivity (OFHC) copper
- ❖ Lead shielding composed of “Chile”, “HP”, and “old US” lead bricks with varying  $^{210}\text{Pb}$  activity (~5 Bq/kg)
- ❖ All lead bricks cleaned in three consecutive nitric acid baths (12 bricks/day), followed by rinsing with ultra-pure water
- ❖ OFHC copper components cleaned according to the Majorana procedure (sulfuric acid → citric acid → ultra-pure water)
- ❖ Nitrogen gas is supplied to the inner copper shielding volume at the rate of 4 L/min
- ❖ Detector operated in a cleanroom environment (~800 particles/m<sup>3</sup> for particle size <0.3μm)
- ❖ Radon-reduced air supplied; radon concentration maintained below 100 Bq/m<sup>3</sup>

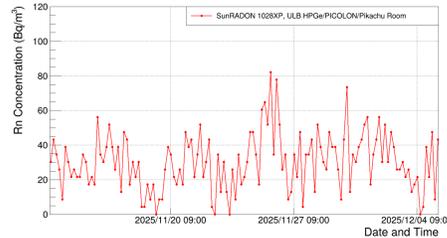
Novel idea to use springs as a passive lifting mechanism was implemented



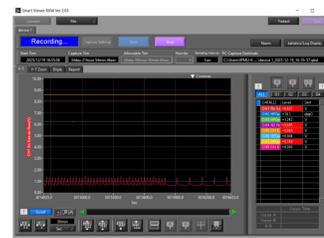
Dimensions of the inner Cu shielding allow to place relatively large samples, such as 1.3L Marinelli beakers, or 4” PMTs



Radon concentration is monitored using SunRADON 1028XP commercial detector



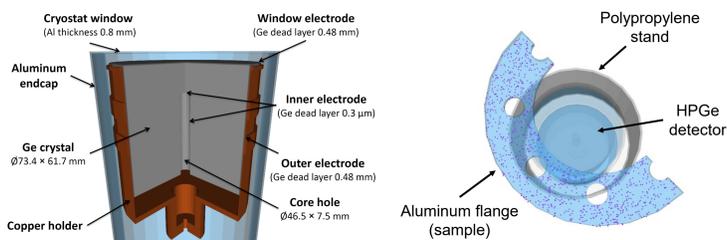
N<sub>2</sub> gas flow rate, Rn-reduced air velocity, room temperature are recorded via Omron Logger



- LN<sub>2</sub> consumption: ~1 kg/day; refilled weekly
- UPS#1 powers DAQ laptop, scales, and data logger
- UPS#2 dedicated to low-noise CAEN NIM crate (Canberra electronics)
- LN<sub>2</sub> level remotely monitored via scales and Canberra level control system



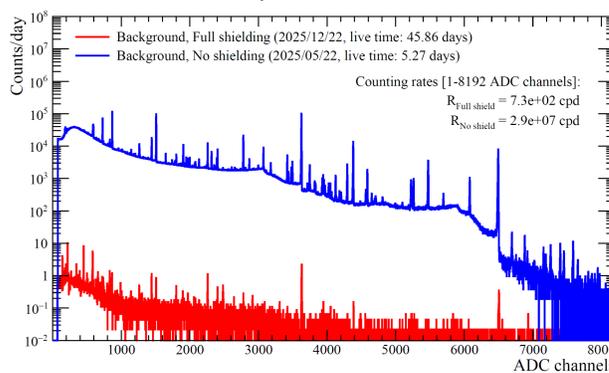
## Monte Carlo simulation



- ❖ We employed the Monte Carlo method to estimate the detection efficiency of the HPGe detector for gamma rays of various energies emitted by impurities in the analyzed samples
- ❖ A detailed GEANT4 model of the HPGe detector was developed based on technical drawings provided by Canberra
- ❖ For each measured sample, a dedicated GEANT4 model was constructed to reproduce its geometry and composition as accurately as possible

## Background

- ❖ Ultra-low-background shielding achieved a 40,000-fold background reduction
- ❖ Counting rates for multiple isotopes were determined using over 45 days of continuous data acquisition

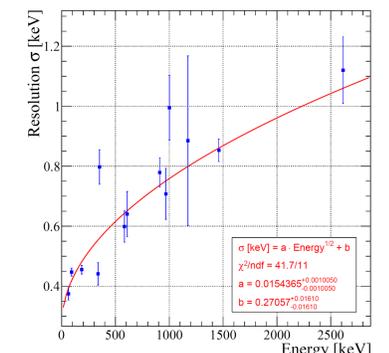
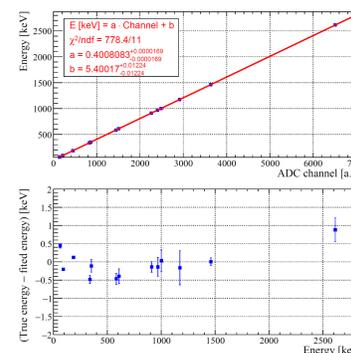
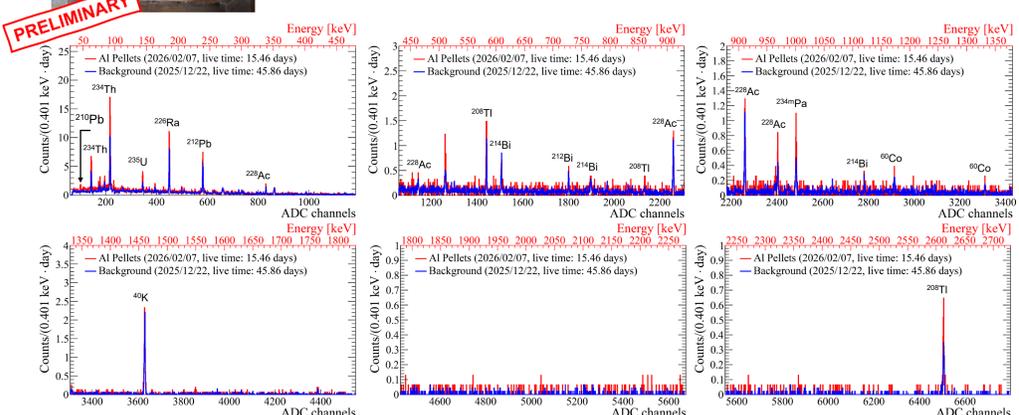


Isotope	Energy [keV]	Rate [cpd]
$^{234}\text{Th}$	63.3	$8.9 \pm 0.5$
$^{234}\text{Th}$	92.4	$28.3 \pm 0.9$
$^{235}\text{U}/^{226}\text{Ra}$	185.7+186.2	$22.4 \pm 0.8$
$^{228}\text{Ac}$	338.3	$3.5 \pm 0.3$
$^{214}\text{Pb}/^{214}\text{Bi}$	351.9+351.1	$5.2 \pm 0.4$
$^{208}\text{Tl}$	583.2	$3.4 \pm 0.3$
$^{214}\text{Bi}$	609.3	$2.3 \pm 0.3$
$^{228}\text{Ac}$	911.2	$5.2 \pm 0.4$
$^{228}\text{Ac}$	969.0	$1.8 \pm 0.2$
$^{234m}\text{Pa}$	1001.0	$2.4 \pm 0.3$
$^{60}\text{Co}$	1173.2	$1.0 \pm 0.2$
$^{40}\text{K}$	1460.8	$9.9 \pm 0.5$
$^{208}\text{Tl}$	2614.5	$2.0 \pm 0.2$

## Radioassay



- ❖ Quantification of trace radioactivity in materials (U/Th chains,  $^{40}\text{K}$ ,  $^{60}\text{Co}$ ,  $^{137}\text{Cs}$ , etc.)
- ❖ High energy resolution for precise isotope identification
- ❖ Activity determination via efficiency-calibrated spectral analysis
- ❖ Sensitivity down to mBq/kg level (depending on sample and counting time)



## Summary

- ❖ KERNEL is under construction at the Kamioka Underground Laboratory
- ❖ The ULB HPGe R1a-Ge setup reassembled at KERNEL in late 2025
- ❖ Demonstrated high energy resolution and sensitivity at the mBq/kg level
- ❖ The R1a-Ge detector is currently used for radioassay of KamLAND2 materials