# Low-radioactivity techniques for underground experiments

Yasuo Takeuchi
Kobe University

- A new cooperation among underground exp.
- Low-radioactivity R&Ds in Kamioka
  - 1. Radon assay
  - 2. Surface α assay
  - 3. Screening system
  - 4. Database

(Ikeno-yama, Kamioka)

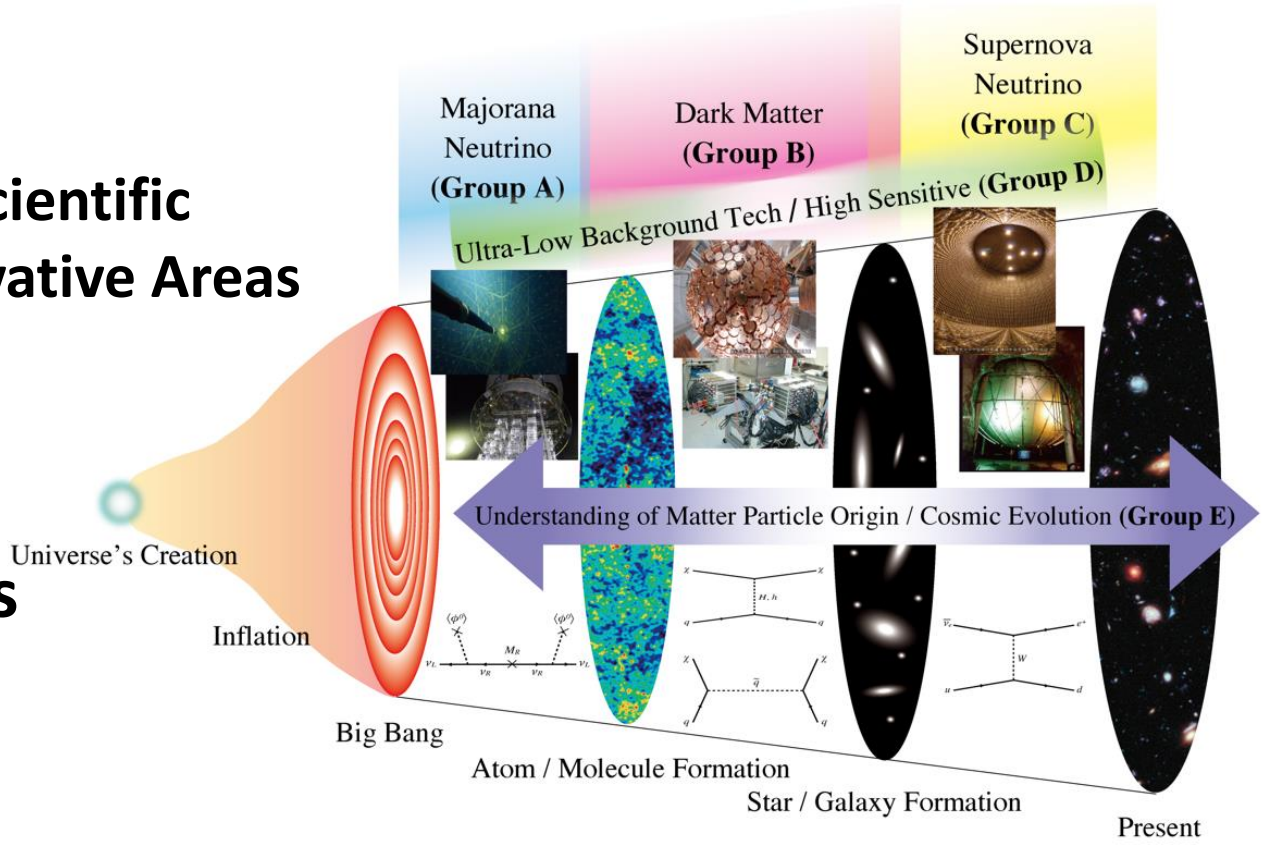
# “Revealing the history of the universe with underground particle and nuclear research”

科研費 KAKENHI

http://www.lowbg.org/ugnd/

**Cooperate among underground experiments, theorists, & low-BG researchers to achieve technical and scientific synergies.**

- **MEXT KAKENHI**
  - **Grant-in-Aid for Scientific Research on Innovative Areas**
- **JFY 2014 - 2018**
- **~10 million US$**
- **5 research groups**
- **~70 researchers**



# “Revealing the history of the universe with underground particle and nuclear research”

科研費 KAKENHI

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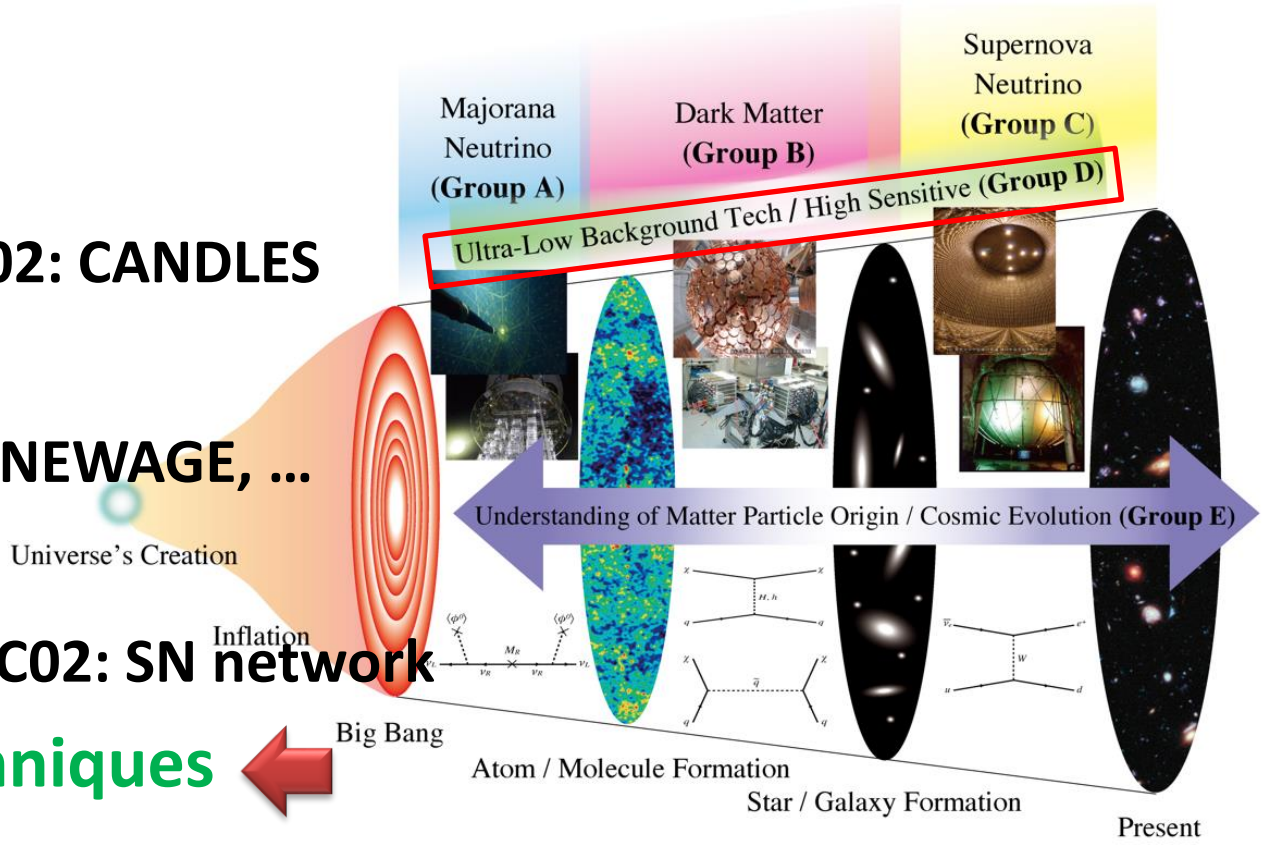
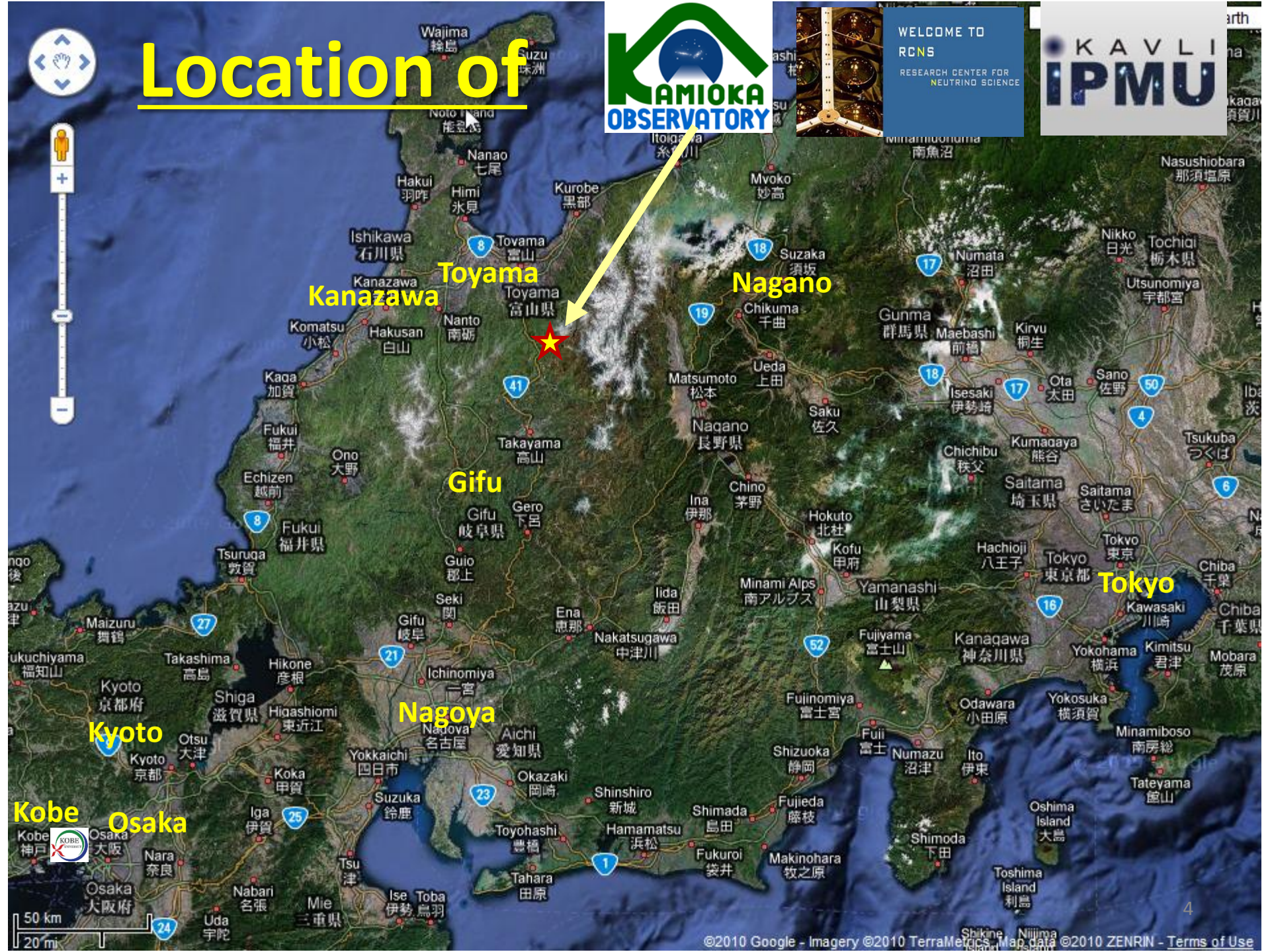
**Cooperate among underground experiments, theorists, & low-BG researchers to achieve technical and scientific synergies.**

## Research groups:

- **A: Majorana ν**
  - **A01: KamLAND, A02: CANDLES**
- **B: Dark matter**
  - **B01: XMASS, B02: NEWAGE, …**
- **C: Supernova ν**
  - **C01: GADZOOKS!, C02: SN network**
- **D01: Low BG techniques**
- **E01: Theory**




Location of
KAMIOKA OBSERVATORY
WELCOME TO
RCNS
RESEARCH CENTER FOR NEUTRINO SCIENCE
KAVLI IPMU
Toyama
Kanazawa
Nagano
Gifu
Nagoya
Kyoto
Kobe
Osaka
Tokyo
Wajima
Nanao
Hakui
Himi
Kurobe
Ishikawa
Toyama
Kanazawa
Nanto
Komatsu
Hakusan
Kaga
Fukui
Ono
Echizen
Tsuruga
Gifu
Gero
Takayama
Matsumoto
Ueda
Nagano
Chikuma
Suzaka
Myoko
Nasushiobara
Nikko
Tochigi
Numata
Utsunomiya
Gunma
Maebashi
Kiryu
Isesaki
Ota
Sano
Chichibu
Kumagaya
Tsukuba
Saitama
Hokuto
Kofu
Chino
Ina
Saku
Hachioji
Tokyo
Minami Alps
Yamanashi
Kawasaki
Chiba
Fujiyama
Kanagawa
Yokohama
Kimitsu
Mobara
Fujinomiya
Odawara
Yokosuka
Minamiboso
Tateyama
Shizuoka
Fuji
Numazu
Ito
Oshima Island
Shimoda
Toshima Island
Fujieda
Shimada
Shinshiro
Hamamatsu
Toyohashi
Fukuroi
Makinohara
Tahara
Okazaki
Aichi
Yokkaichi
Suzuka
Koka
Iga
Tsu
Ise
Toba
Nabari
Mie
Uda
Osaka
Nara
Kobe
Kyoto
Otsu
Shiga
Higashiomi
Hikone
Takashima
Maizuru
Fukui
Tsuruga
Seki
Gifu
Ena
Iida
Nakatsugawa
Ichinomiya
Osaka
Kobe
50 km
20 mi
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# Kamioka Underground site

2700 m.w.e.

http://www-sk.icrr.u-tokyo.ac.jp/

A01/C02: KamLAND

B01/C02: XMASS

D01: Low-radioactivity R&D (2014~ ?)

A02: CANDLES

C02: Super-Kamiokande

40m

C01: R&D of GADZOOKS!

IPMU
Rn det. (D01)
APIMS
GC
Ge det.
…

B02: NEWAGE
Superconductive gravimeter

CLIO (Gravitational wave exp.)
Laser extensometer
(Geophysics)

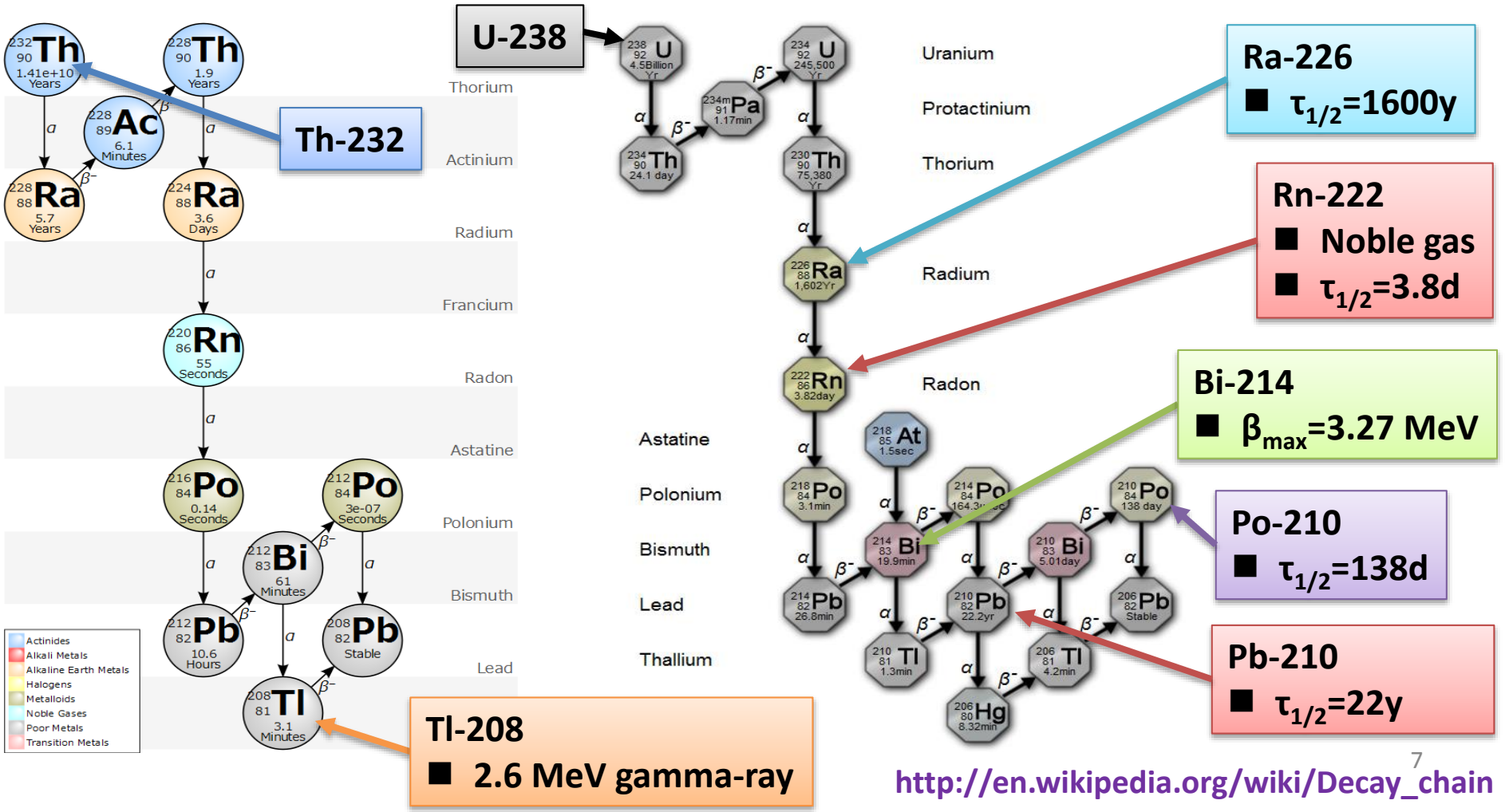
Atotsu Entrance (~2km)

# Low-radioactivity techniques

- **To observe rate phenomena, low-background environment is necessary.**
  - **Neutrino double beta decay measurements, direct dark matter searches, supernova neutrinos, …**
- **Cosmic-ray flux is reduced in underground sites**
  - **Charged particles (like muons) will be stopped in ground**
  - **In Kamioka, cosmic-ray muons are reduced by 1/100000**
- **Other radio activities should be reduced**
  - **Natural radioactivity (U/Th series, etc.), …**
- **Low-radioactivity techniques are essential to improve experimental sensitivities.**

# U-series, Th-series

- In nature: 1～10 ppm($10^{-6}$)
  → In experiments: ppb($10^{-9}$), ppt($10^{-12}$), ppq($10^{-15}$),,,



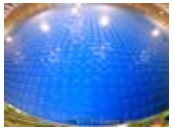

http://en.wikipedia.org/wiki/Decay_chain

# Goals of impurities

- **KamLAND, KamLAND-Zen (A01)**
  - **U: ~1x10$^{-12}$ g/g, Th: ~1x10$^{-12}$ g/g (mini-balloon)**
  - **U: ~2x10$^{-19}$ g/g, Th: ~2x10$^{-17}$ g/g, $^{210}$Po: ~1 mBq/m$^3$ (in LS)**
- **CANDLES (A02)**
  - **U: ~10 μBq/kg, Th: ~1 μBq/kg**
- **XMASS (B01)**
  - **U: ~1x10$^{-14}$ g/g, Th: ~2x10$^{-14}$ g/g, Kr: ~1 ppt (vol.), $^{222}$Rn: ~7 μBq/m$^3$ (in gas Xe)**
- **NEWAGE (B02)**
  - **U: ~5 ppb, Th: ~20 ppb**
- **Super-Kamiokande (C02), GADZOOOKS! (C01)**
  - **$^{222}$Rn: ~0.1mBq/m$^3$ (in water)**
- **KamLAND-PICO, PICO-LON (D01)**
  - **U: ~10 μBq/kg, Th: ~4 μBq/kg, $^{210}$Pb: ~5 μBq/kg**

# Major common BG sources (in Kamioka)

## Purified water



- C02(SK): target
- A01, A02, B01: shield
- A01, A02: LS purification
- Cooperation: experiences in C02(SK) (SK is largest detector with purified water)

## Radon


- All: Reduction!
- In detector, In environment
- Cooperation: experiences in D01(Rn detector) (provided info. To LSM(France), SDSMT(US), etc.)

## RI in material


- All: Reduction!
- A02, B02, C01: essential
- Cooperation: experiences in D01(PICO-LON) (highly radio pure NaI(Tl), next talk by K. Fushimi)

## Surface RI

- A01: balloon
- B01: Cu, PMT
- Cooperation: Try to apply B02 to measure surface α

Achieve ultra low-radioactivity quickly with cooperation

# LOW-RADIOACTIVITY R&DS IN KAMIOKA

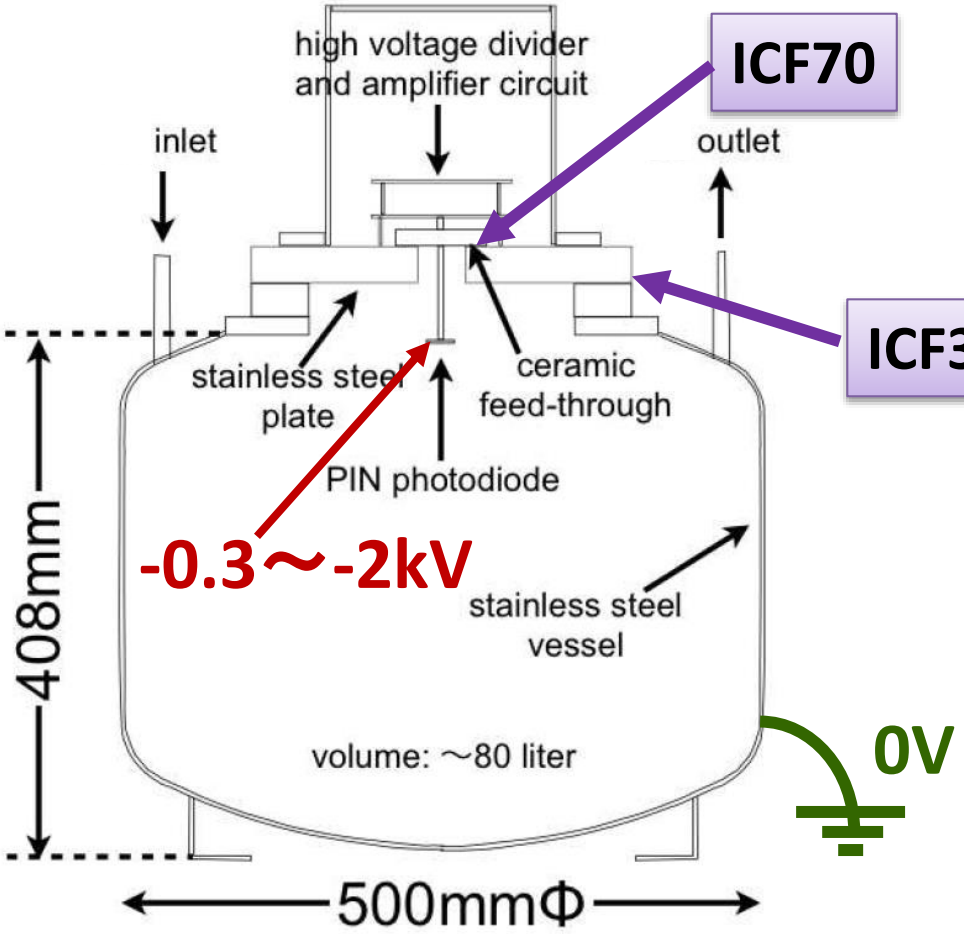
# 1. Improvement of Rn assay

- **Radon is a major BG source in many UG exp.**
- **Precise measurements are needed**
  - **Rn emanation from materials → Screening system**
  - **During construction → Reduce Rn daughters in air**
  - **Prevent mixture from environment**
- **Our group has developed Rn detectors in air, in water, in gas argon**
  - **NIM A421 (1999) 334, NIM A497 (2003) 414, RADIOISOTOPES 59 (2010) 29**
- **Goal: Reduction of BG revel of the Rn detectors, Rn measurement in purified Xe, etc.**
  - **Try to apply nano-material to trap Rn in Xe.**

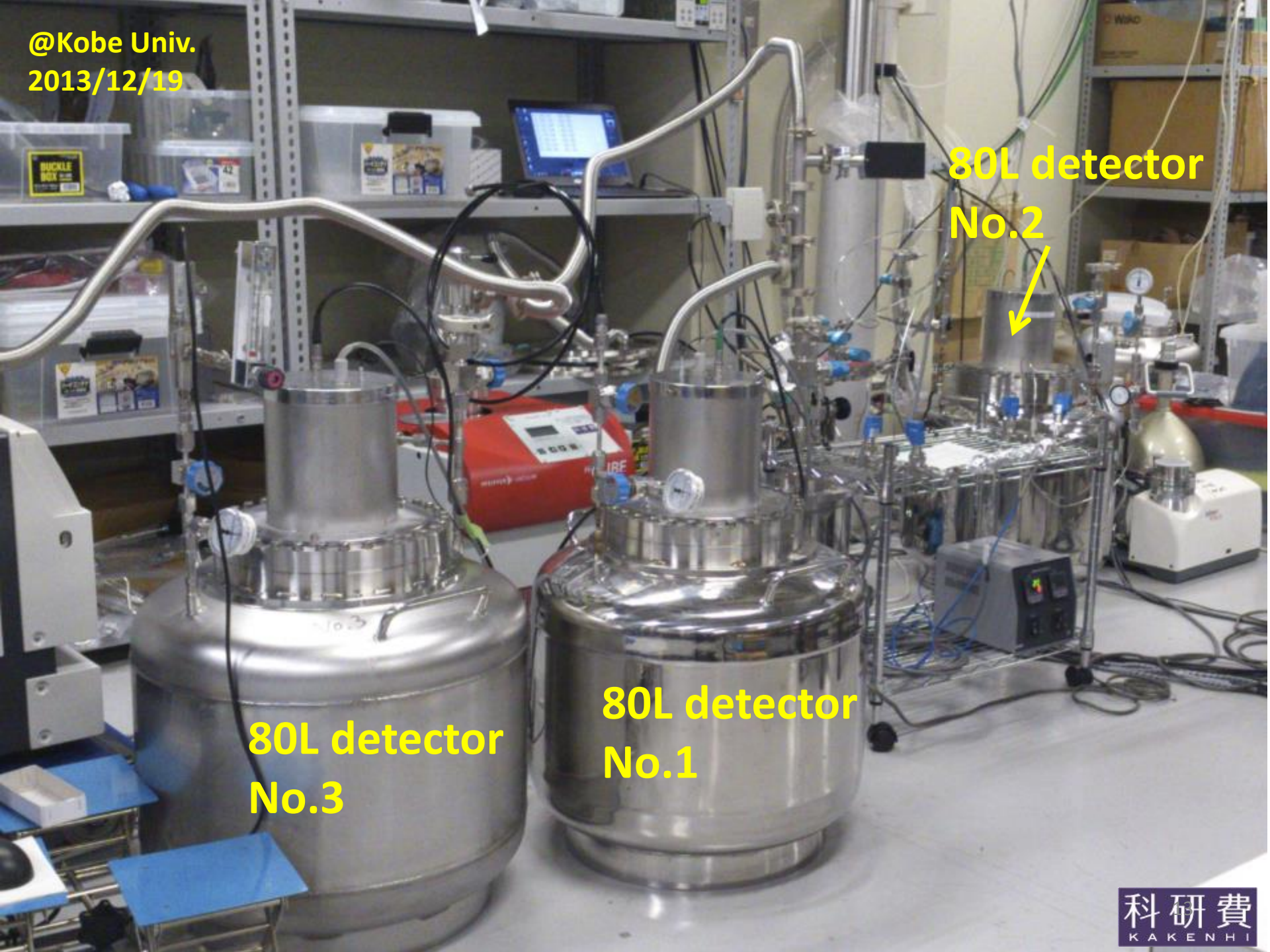
# 80L Radon detector

Cf. 70L Rn detector
NIM A421 (1999) 334

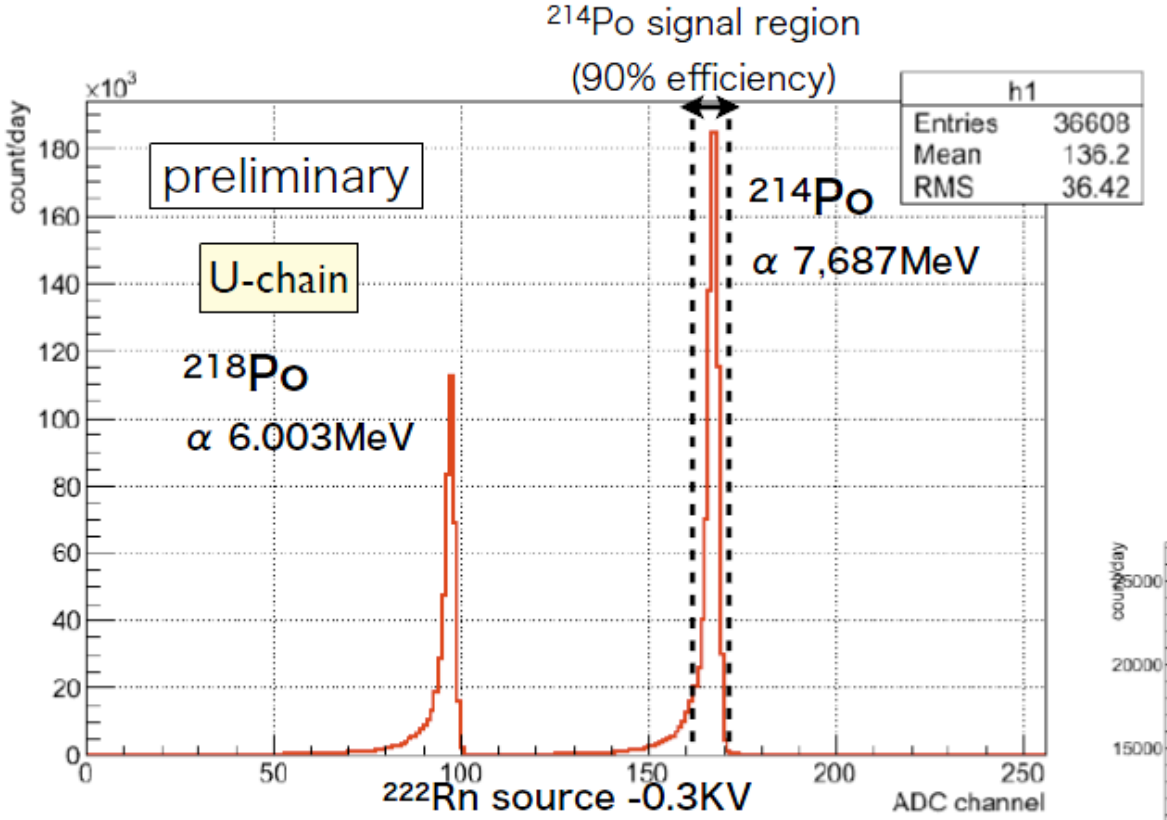
**Method = PIN photodiode + Electrostatic collection**




- Collect positively charged Rn daughters on PIN photodiode
- Measure the energy of α-decays, then count it


@Kobe Univ.
2013/12/19
80L detector
No.2
80L detector
No.1
80L detector
No.3
科研費
KAKENHI

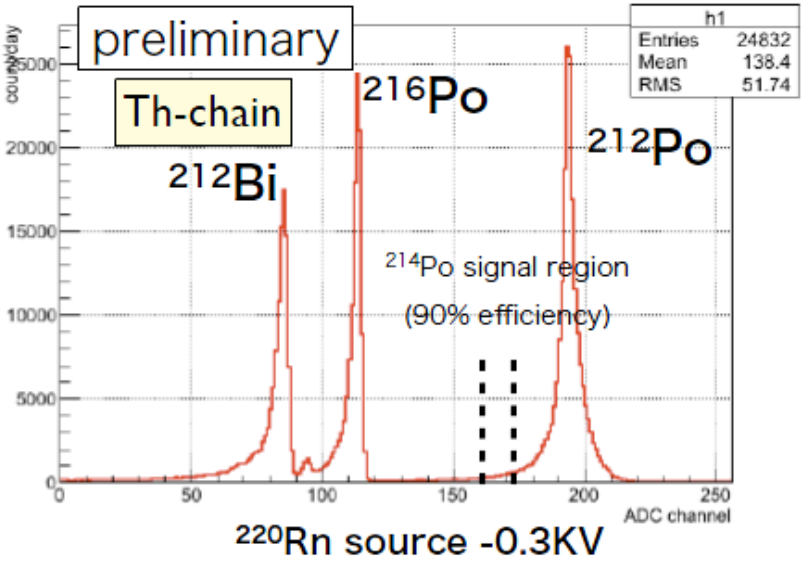
# Energy spectrum




purified Ar 1atm

$^{222}$Rn source (U-Chain)
: PYLON RNC $^{226}$Ra

$^{220}$Rn source (Th-Chain)
: Lantern mantle



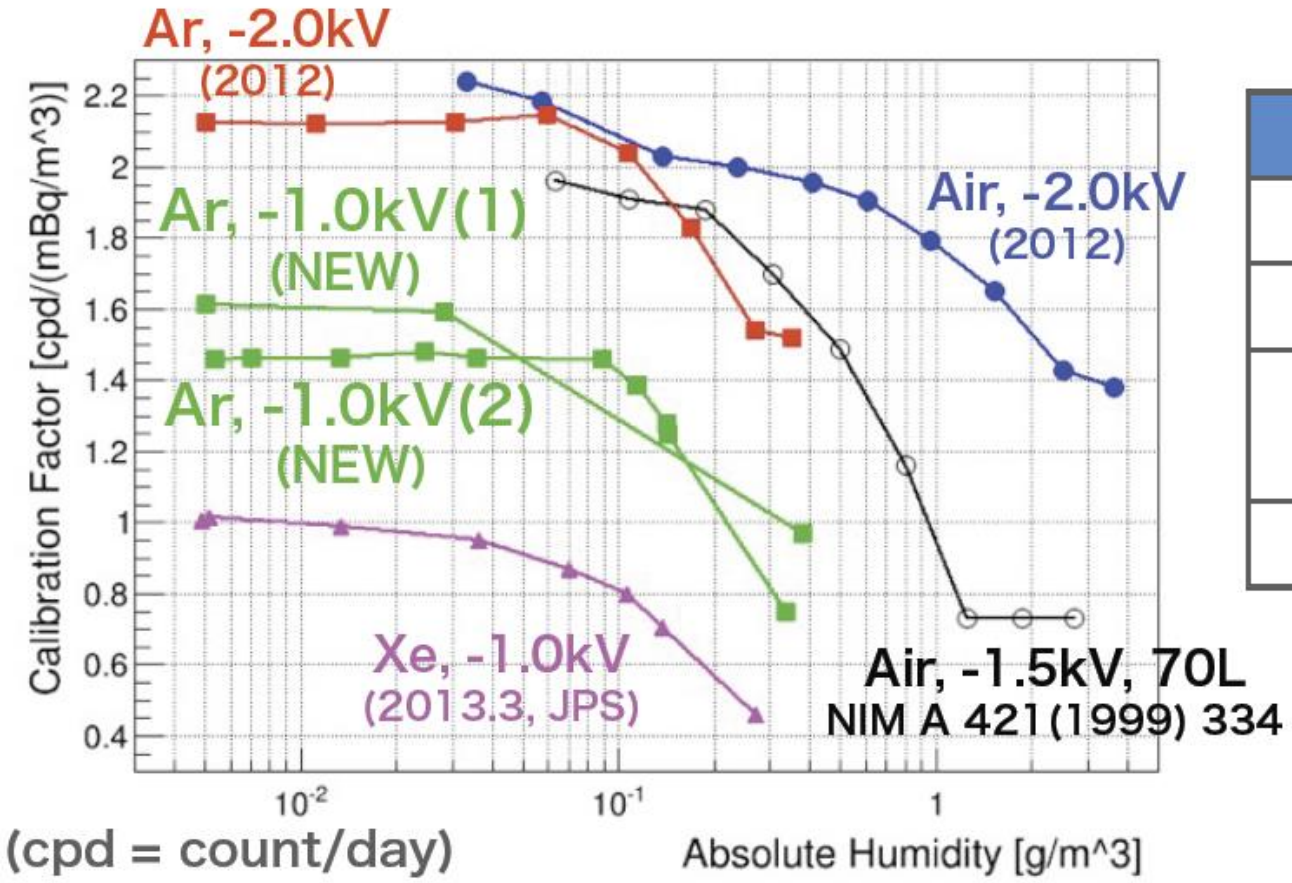

✓ Only $^{214}$Po signal region is used.

- **Higher efficiency** than $^{218}$Po.
- **Lower $^{232}$Th-Chain BG** in signal region.
  - 218Po signals overlap 212Bi signal.

# Humidity dependence of Rn detector

Onishi
@JPS2013.09.21

$$\text{Calibration Factor } [(\text{count/day})(\text{mBq/m}^3)] = \frac{\text{214Po count rate [count/day]}}{\text{222Rn concentration [mBq/m}^3]}$$



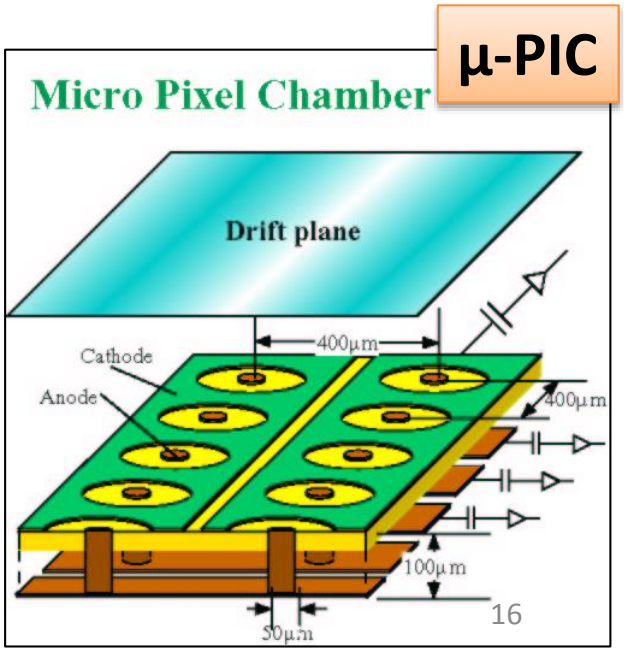

| | CF |
|---|---|
| Air, -2.0kV | ~2.2 |
| Ar, -2.0kV | ~2.2 |
| Ar, -1.0kV (NEW) | ~1.5 |
| Xe, -1.0kV | ~0.9 |

Absolute Humidity
= 0.06g/m3

- Summarizing results
- Try to improve more

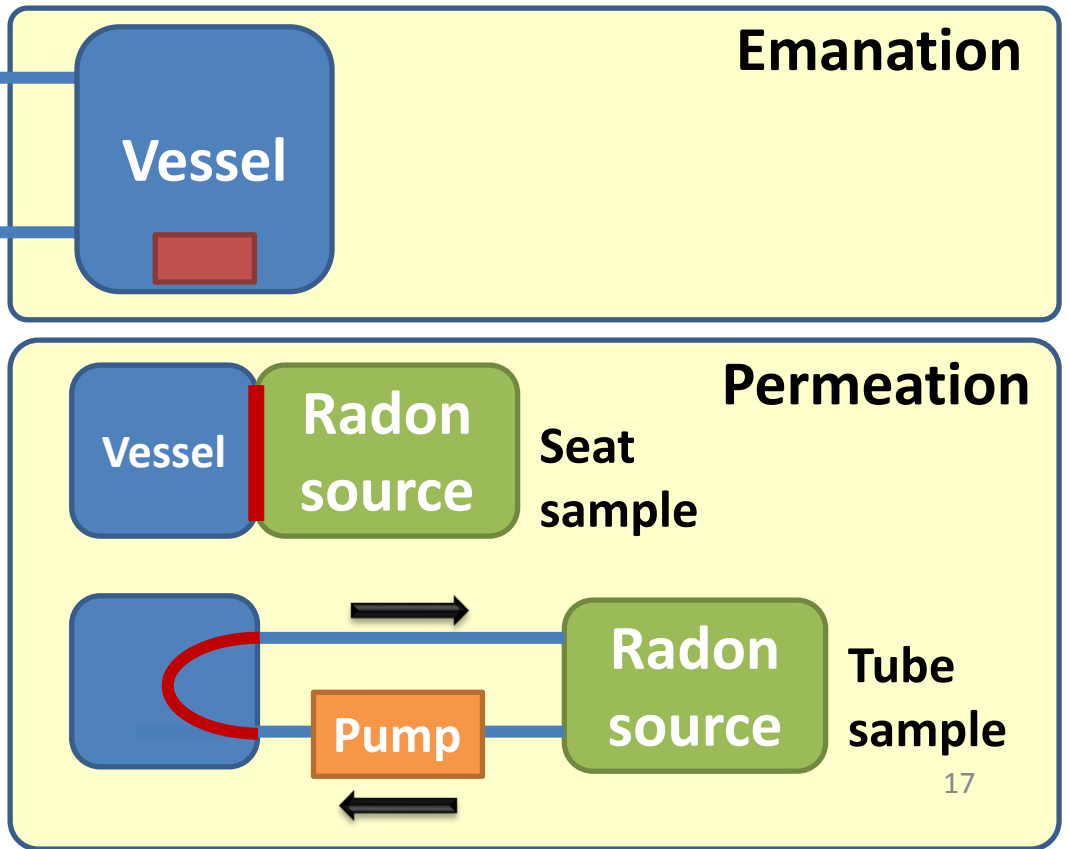
# 2. Surface α assay

- Reduce α decays on the detector surface
  - Film for mini-balloon (KamLAND), Copper (XMASS)
- High-sensitivity assay is needed
- Try to apply NEWAGE-0.3a (B02) detector
  - A prototype detector of NEWAGE
  - Gas imaging detector with μ-PIC
  - Tentative goal: < ~0.0001 α/cm²/hr

# 3. Screening system

- **Build a common screening system in Kamioka**
  - **Surface α assay**
  - **Radon emanation (& permeation) assay**
    - **Tentative goal: < ~100 μBq/day (Rn emanation/sample)**

# 4. Database

- **Gather various radioactivity assay data under this KAKENHI project.**
  - **HPGe detector, Rn detector, ICP-MS, API-MS, GC**

- **Prepare a database system on web**
  - **A design of the system is underway.**

# Summary

- **A new cooperation among underground experiments in Kamioka has been started in JFY2014.**
  - **Supported by MEXT KAKENHI, for 5 years**
  - **URL: http://www.lowbg.org/ugnd/**

- **A cooperative R&Ds on Low-radioactivity techniques are on going.**
  - **Radon assay, surface α assay, screening system, database, …**