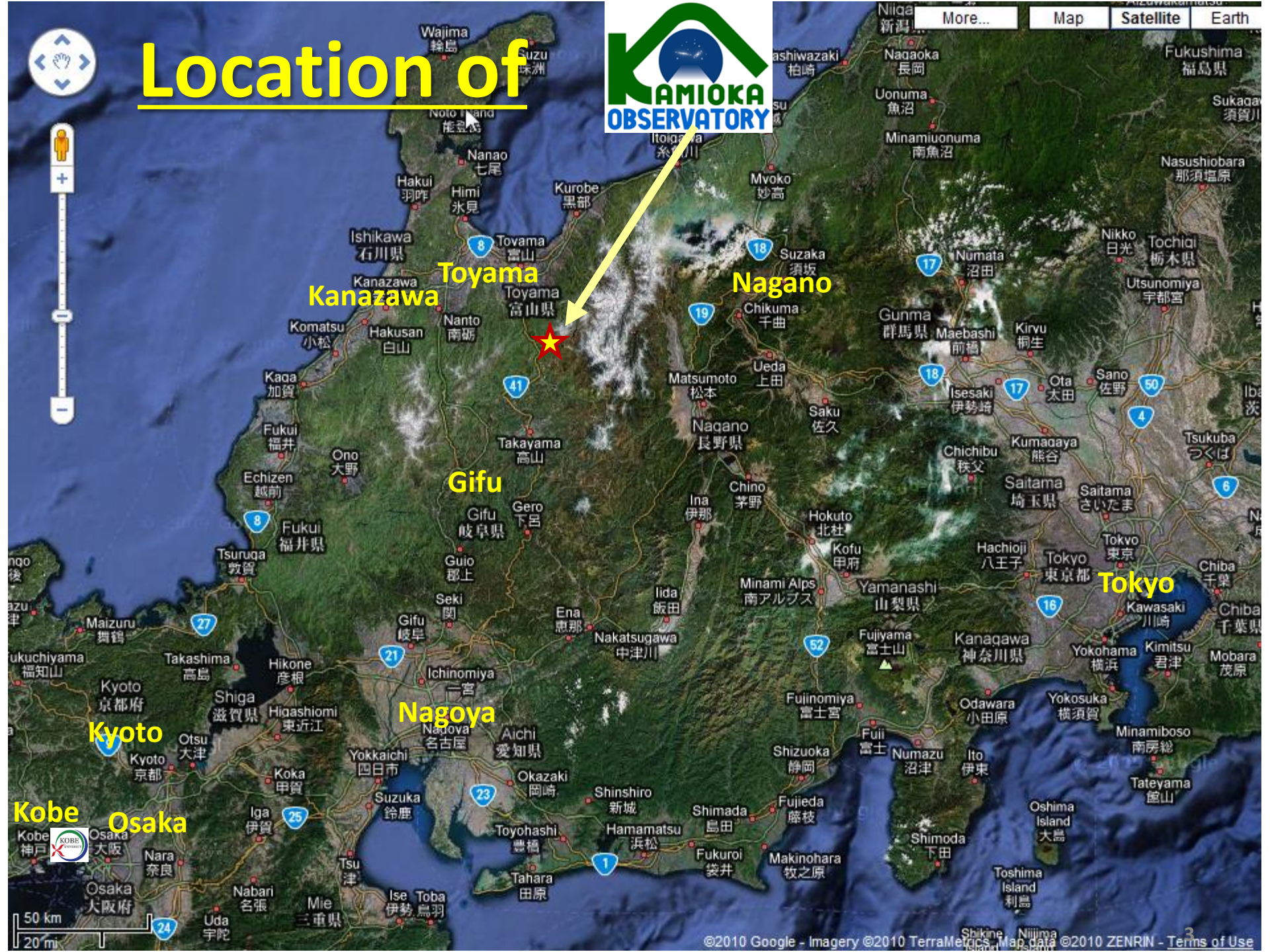
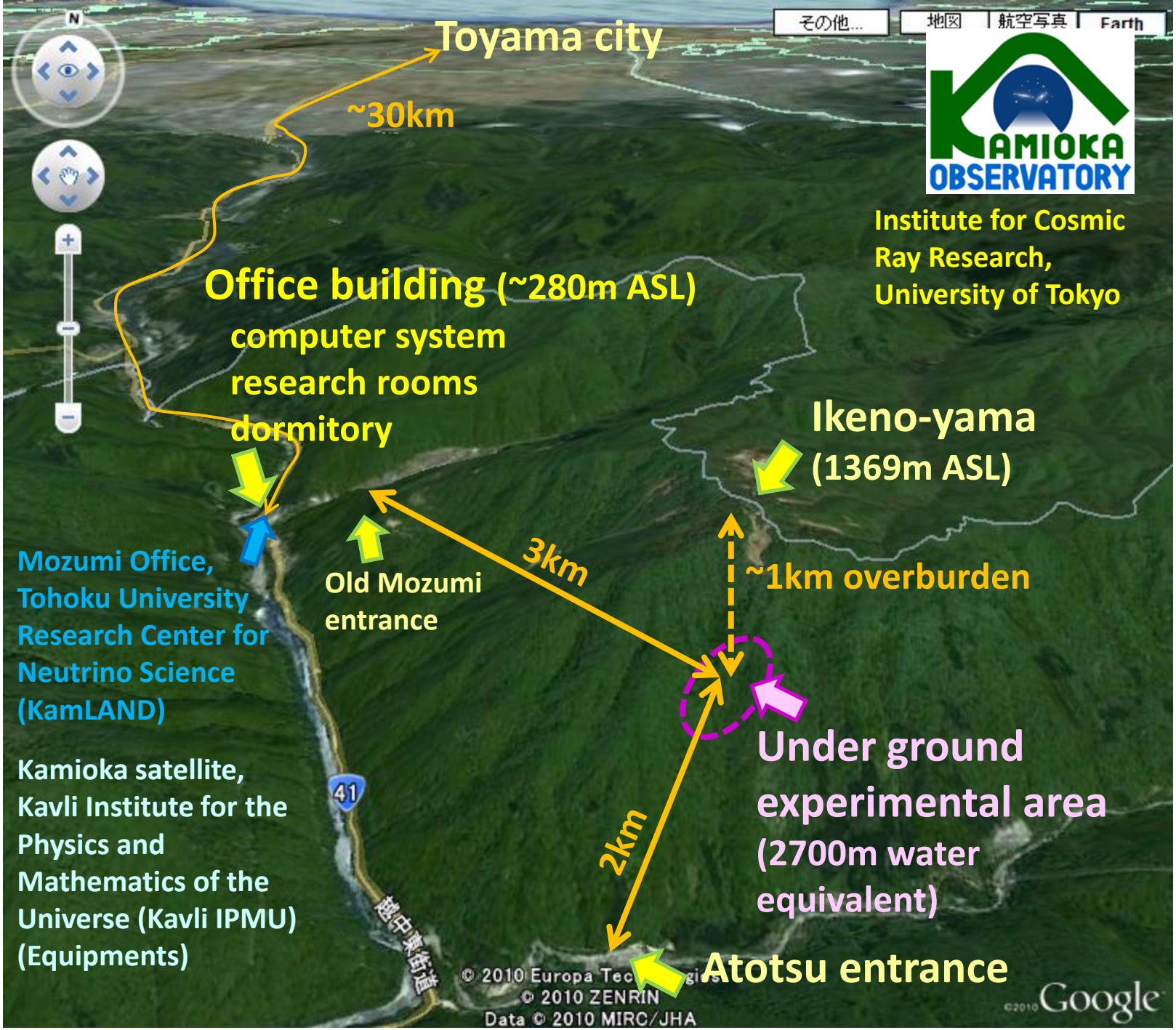
Neutrino group, Dark matter group

Yasuo Takeuchi (Kobe University)

Underground experiments

- **Neutrino & dark matter: Event rates are very small.**
  - **Backgrounds should be reduced as much as possible.**
- **The cosmic-ray flux is very small in underground**
  - **Primary & secondary charged particles, muons, etc.**
  - **Radioisotopes generated by cosmic-rays (3H, 14C, etc.)**
- **In order to observe rate phenomena with high sensitivity, the experiments must be done in undergrounds.**


Location of
KAMIOKA OBSERVATORY
Toyama
Kanazawa
Nagano
Gifu
Nagoya
Kyoto
Kobe
Osaka
Tokyo
More...
Map
Satellite
Earth
50 km
20 mi
©2010 Google - Imagery ©2010 TerraMetrics, Map data ©2010 ZENRIN - Terms of Use


Toyama city
~30km
KAMIOKA OBSERVATORY
Institute for Cosmic Ray Research, University of Tokyo
Office building (~280m ASL)
computer system
research rooms
dormitory
Ikeno-yama
(1369m ASL)
Mozumi Office, Tohoku University Research Center for Neutrino Science (KamLAND)
Old Mozumi entrance
3km
~1km overburden
Kamioka satellite, Kavli Institute for the Physics and Mathematics of the Universe (Kavli IPMU) (Equipments)
Under ground experimental area
(2700m water equivalent)
2km
Atotsu entrance
© 2010 ZENRIN
Data © 2010 MIRC/JHA
Google

Kamioka Underground site

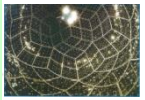
2700 m.w.e.

KAMIOKA OBSERVATORY

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

XMASS
(Mar. 2008~)

KamLAND
(Tohoku U.)



CANDLES
(Mar. 2008~)

Super-Kamiokande

40m

Experimental sites are increasing
(Gravitational wave experiment KAGRA is under construction)

IPMU
APIMS
GC
Ge det.
Rn det.
…
(Mar.08~)

Gadolinium project R&D
(March 2010~)

NEWAGE
Superconductive gravimeter

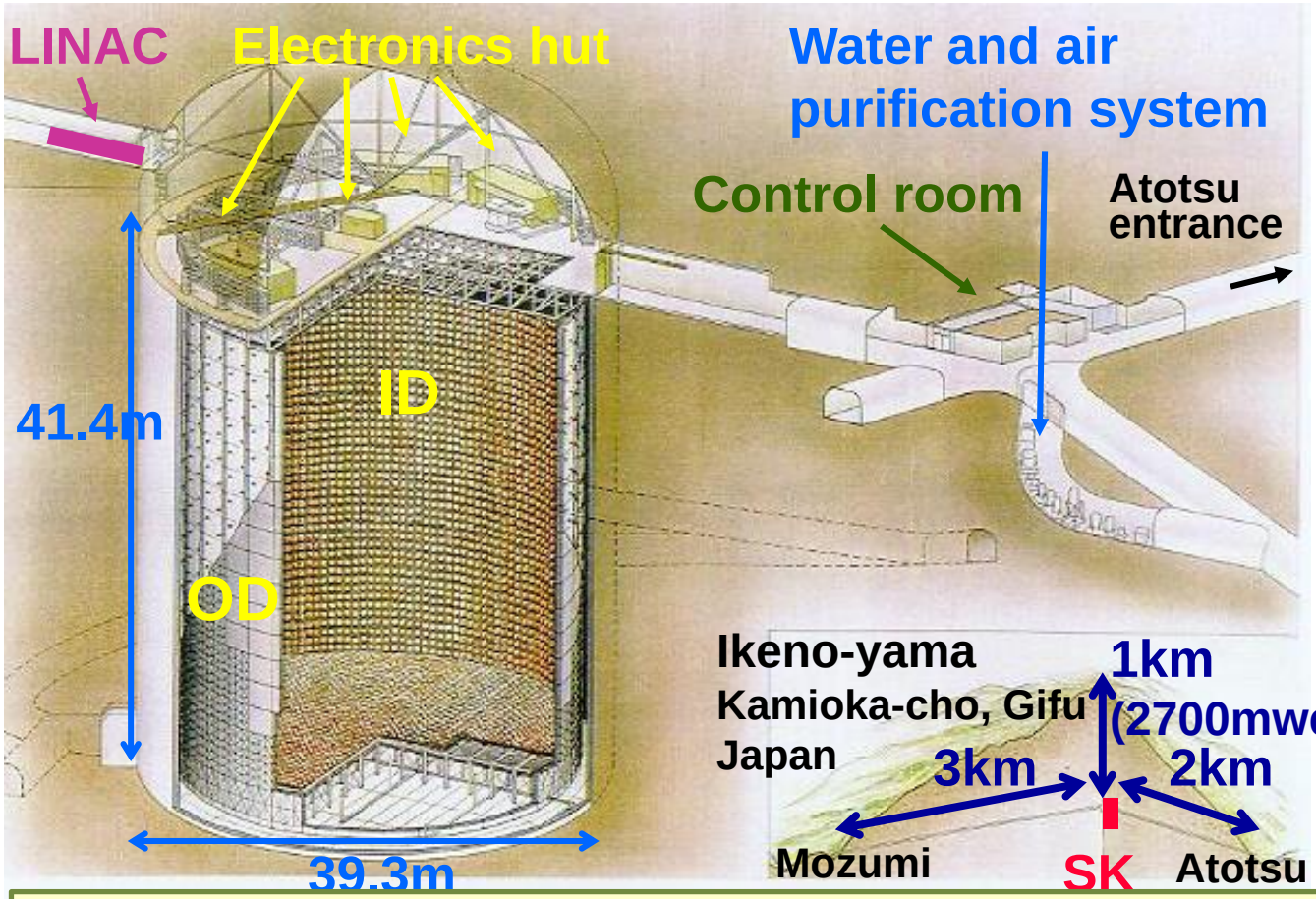
CLIO (Gravitational Wave)
Laser extensometer
(Geophysics)

Atotsu Entrance
(~2km)


Super-Kamiokande
Inside of the SK detector during water filling (June 2006)
(c) 東京大学宇宙線研究所 神岡宇宙素粒子研究施設

Super-Kamiokande

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

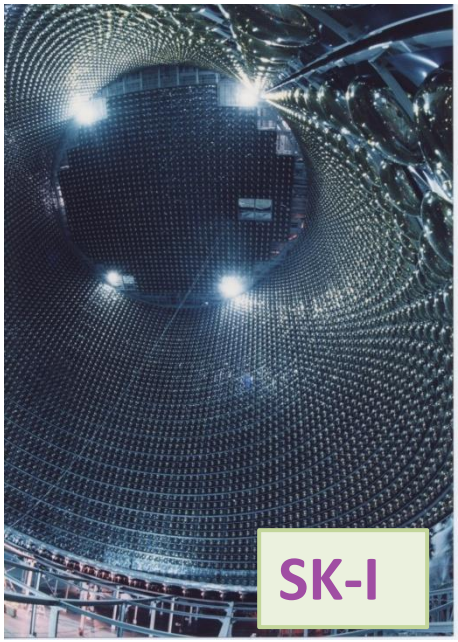


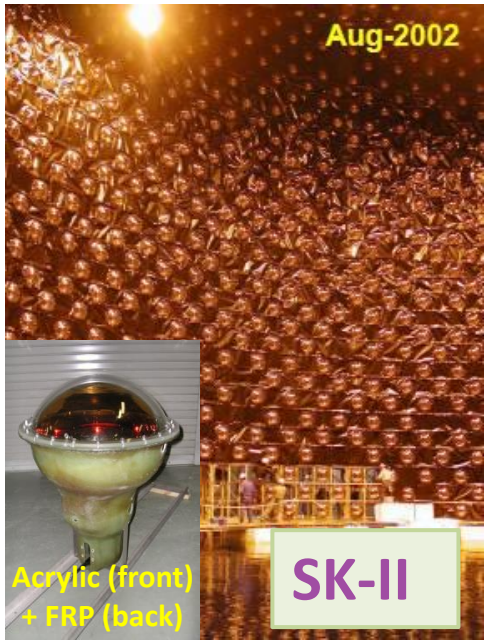
- 50 kton water
- 32 kt ID viewed by 20-inch PMTs
- ~2m OD viewed by 8-inch PMTs
- 22.5 kt fid. vol. (2 m from wall)
- E_{total}=~4.5 MeV energy threshold
- SK-I: April 1996~
- SK-IV is running

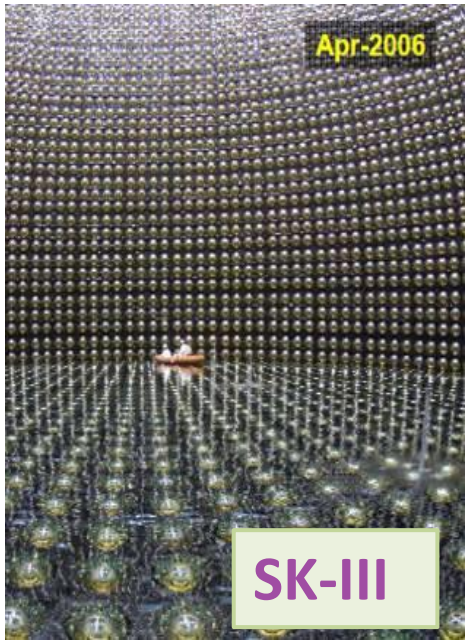
- SK is the largest neutrino detector with purified water.
- Kobe people are working on low-energy analysis (co-convener)), EGADS, off-line system (co-convener, and calibration system.

History of Super-Kamiokande

1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
SK-I							SK-II			SK-III		SK-IV		







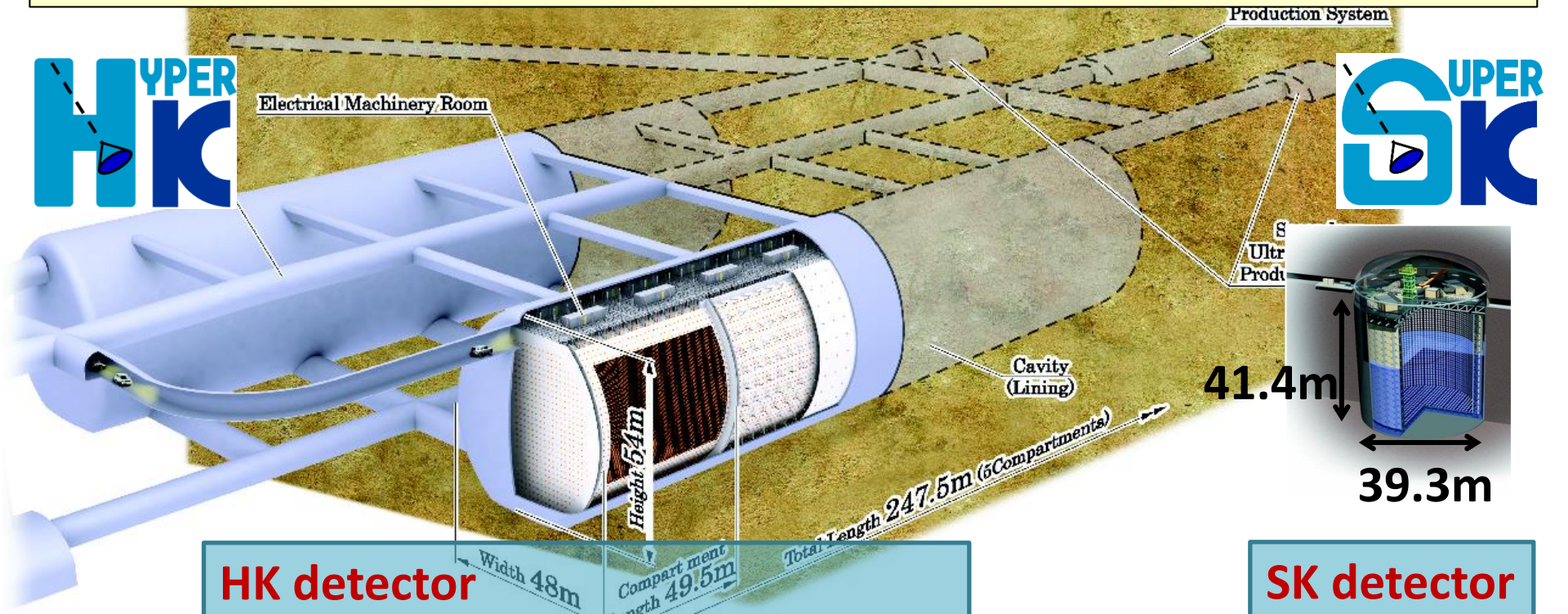
	SK-I	SK-II	SK-III	SK-IV
	11146 ID PMTs (40% coverage)	5182 ID PMTs (19% coverage)	11129 ID PMTs (40% coverage)	Electronics Upgrade
Energy Threshold	5.0 MeV	7.0 MeV	5.0 MeV	~4.5 MeV < 4.0 MeV
(Total energy)	~4.5 MeV	~6.5 MeV	~4.5 MeV	~4.0 MeV <~3.5 MeV
(Kinetic energy)				Current Target

Physics targets at SK

- **Nucleon decay search**
  - KAMIOKANDE (= KAMIOKA Nucleon Decay Experiment)
  - Not observed yet. (on going with world best limits)
- **Cosmic neutrinos**
  - Atmospheric neutrino oscillation
  - Solar neutrino oscillation
  - Supernova neutrinos (burst, past)
- **Long baseline neutrino oscillation**
  - J-PARC to Kamioka (T2K)
- **Astrophysics**
  - Indirect WIMPs search
  - Monopole search
  - Search for neutrinos from GRB

Hyper-Kamiokande project

Study grand unification view of the elementary particles and origin of the matter-dominant Universe with a large detector in the next generation.



HK detector

Fiducial volume : 0.56 Mega ton

Photo coverage : 20 %

Overburden (water eq.) : 1780 m

SK detector

22.5 kton

40 %

2750 m

Recent news

- For the neutrino experiments related to Japan (T2K, Double Chooz, SK/HK, IceCube, etc.), Grant-in-Aid for Scientific Research on Innovative Areas (2013-17) is approved.
- For the under ground experiments in Kamioka (KamLAND, CANDLES, XMASS, NEWAGE, GADZOOKS!, Low-background techniques R&D, etc.), Grant-in-Aid for Scientific Research on Innovative Areas (2014-18) is approved.
- For the GADZOOKS!, Grant-in-Aid for Specially Promoted Research (2014-18) is approved.

Direct dark matter searches: XMASS / NEWAGE

Inside of the XMASS detector
during construction (Feb. 2010)

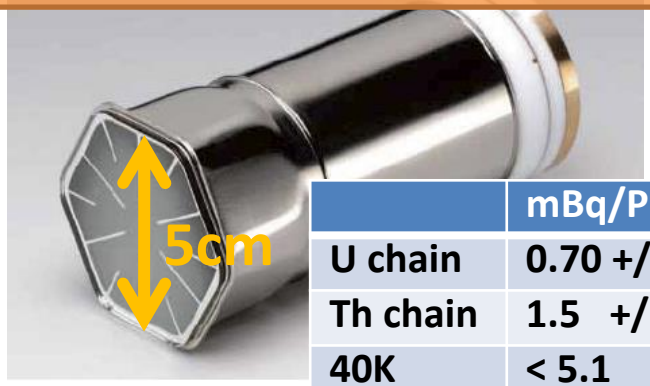
Strategy of Kobe group

- XMASS: Search DM signal with large mass & low BG liquid Xe.
  - Current: total 1 ton in XMASS-I
  - Next: total 5 ton XMASS-1.5 (under budget requesting)
- NEWAGE: Provide a strong evidence of DM signal with direction-sensitive detector, then try to reveal the DM properties.
  - Current: NEWAGE-0.3b' detector
  - Provide the current best direction-sensitive limit.
- Strategy: At first, detect DM signal with XMASS, then obtain secure evidences of DM with NEWAGE.

RADIOACTIVITY MEASUREMENTS

Background reduction in XMASS

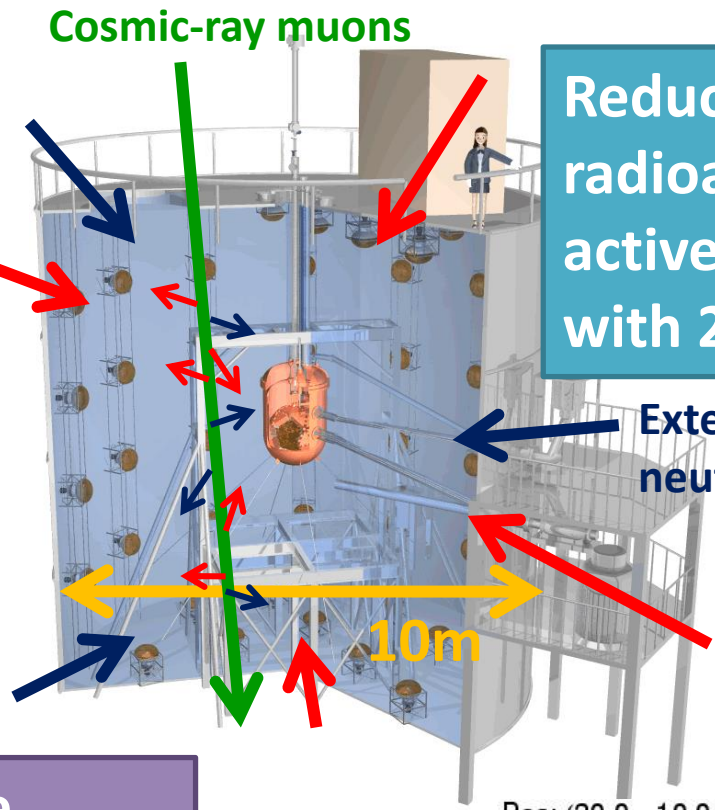
Developed 2-inch very low radioactivity PMT (R10789)



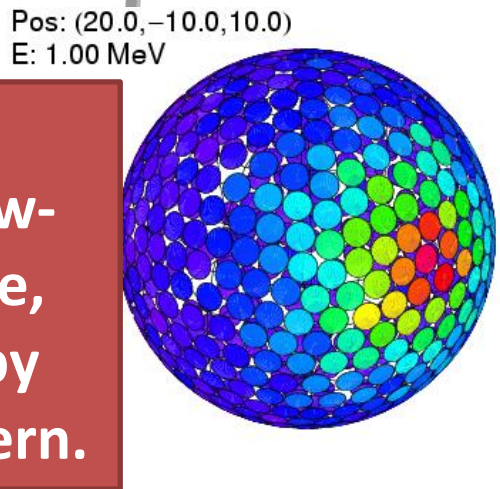
	mBq/PMT
U chain	0.70 +/- 0.28
Th chain	1.5 +/- 0.31
40K	< 5.1
60Co	2.9 +/- 0.16

Remove Kr by distillation

Low radioactivity materials are selected by Ge/ICP-MS/Rn detectors



Reduce external radioactivity by active water shield with 20-inch PMTs



Use only central low-BG volume, selected by light pattern.

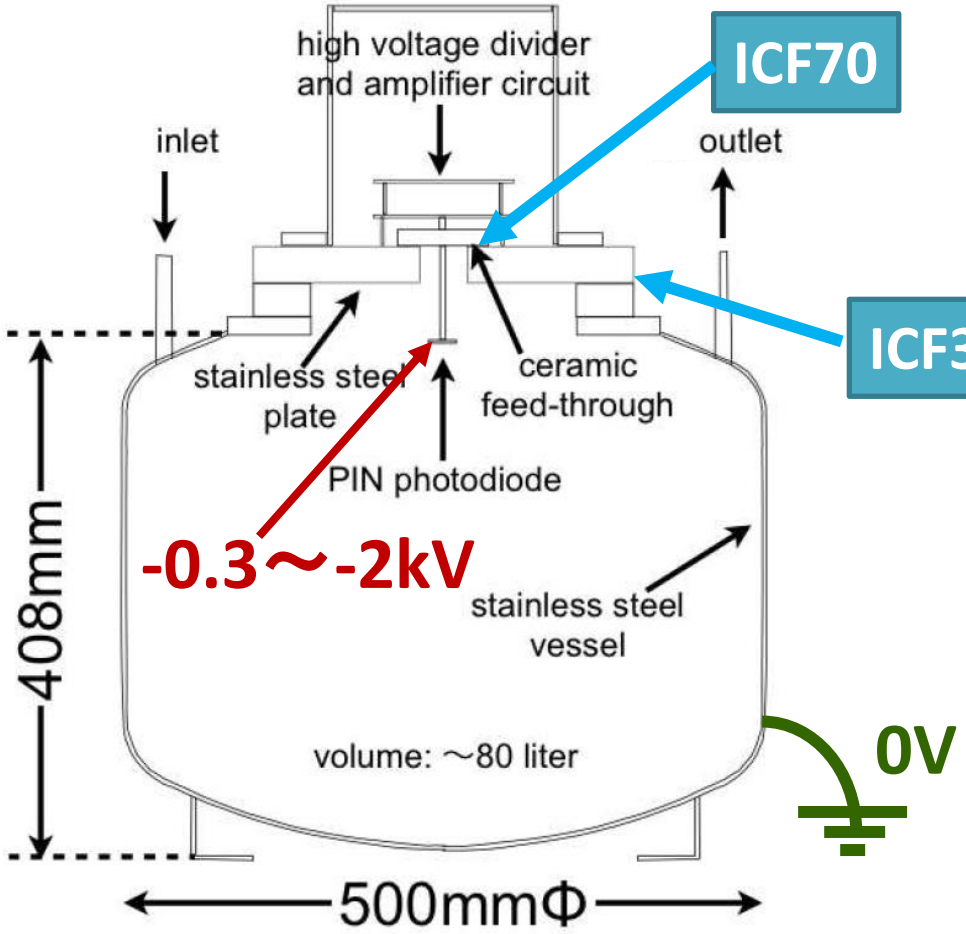
Development of the high-sensitive radon detector at Kobe U.

- **Radon** is one of **major background** sources in the underground experiments.
  - Radioactive rare gas, many daughter nucleus, …
- **Precise measurements** of Rn are important.
- **High sensitive detectors are developed.**
  - Rn in air, in water, in Ar gas
  - RADIOISOTOPES 59 (2010) 29, NIMA 497 (2003) 414, NIMA 421 (1999) 334
- **We have provided our techniques to other groups.**
  - KamLAND, NEMO, LSM (France), SDSMT (US), …

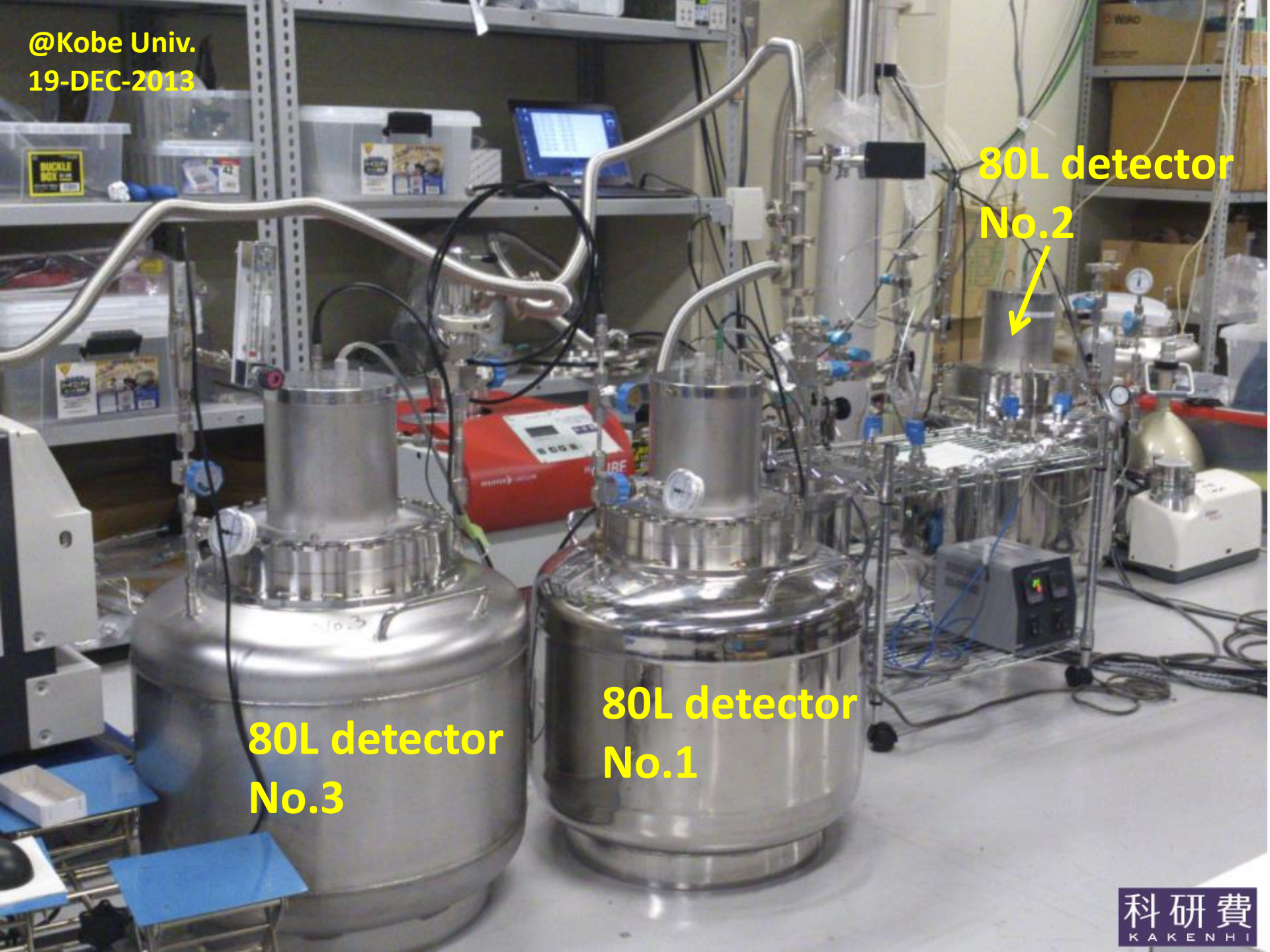
80L Radon detector

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

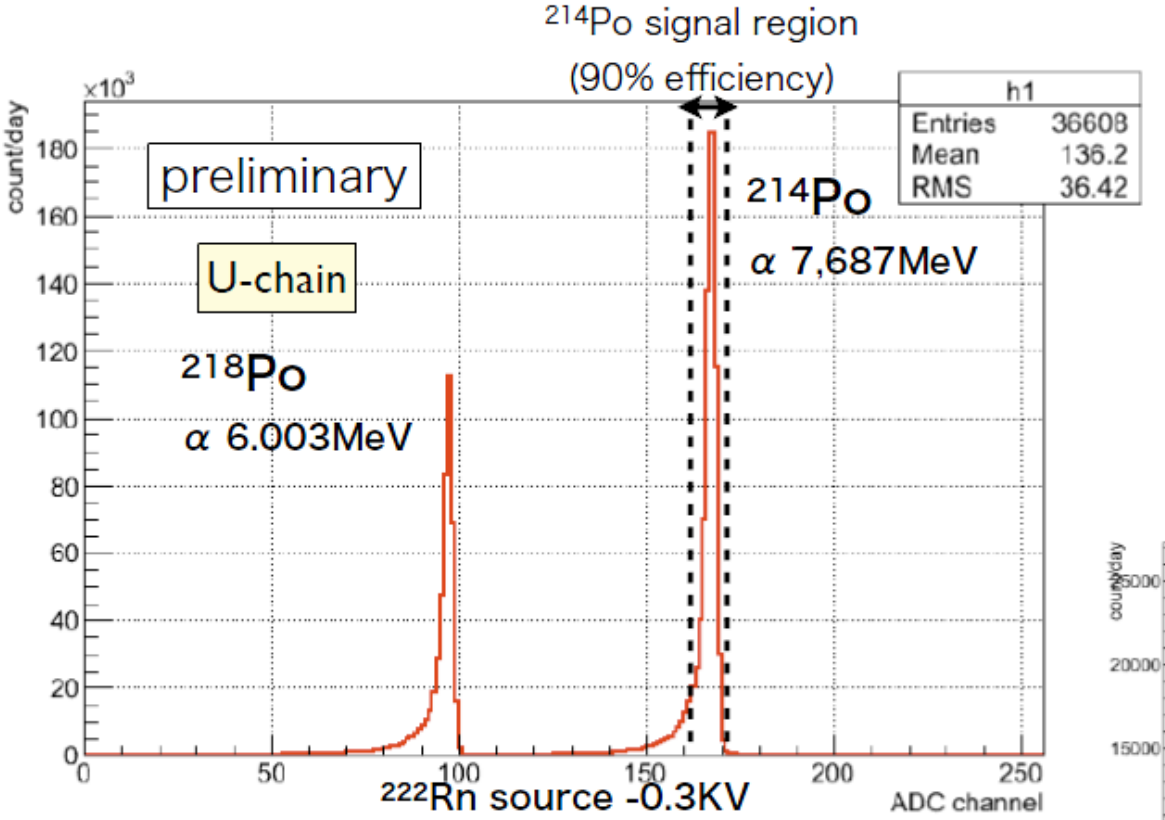
Method = PIN photodiode + Electrostatic collection



- Collect positively charged Rn daughter nucleus with the electric field.
- Measure the energy of α-decay with a PIN photo diode, then count it.


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

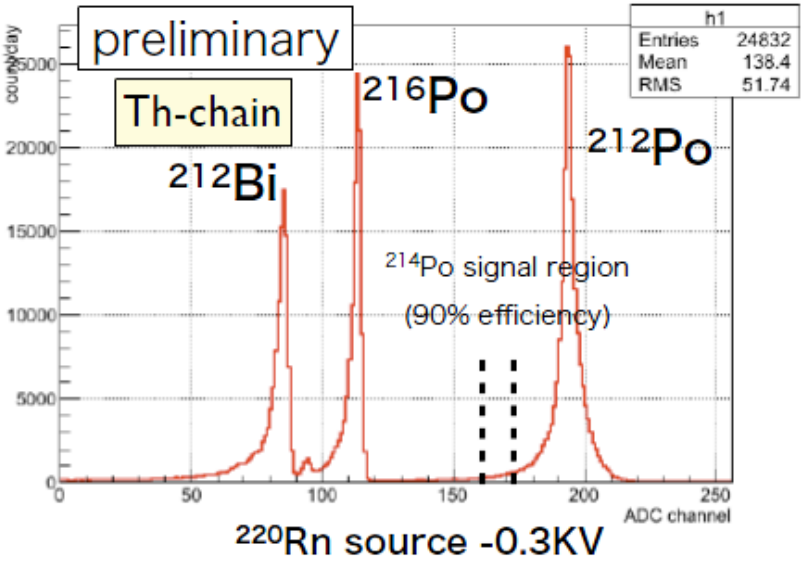
Energy spectrum



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.

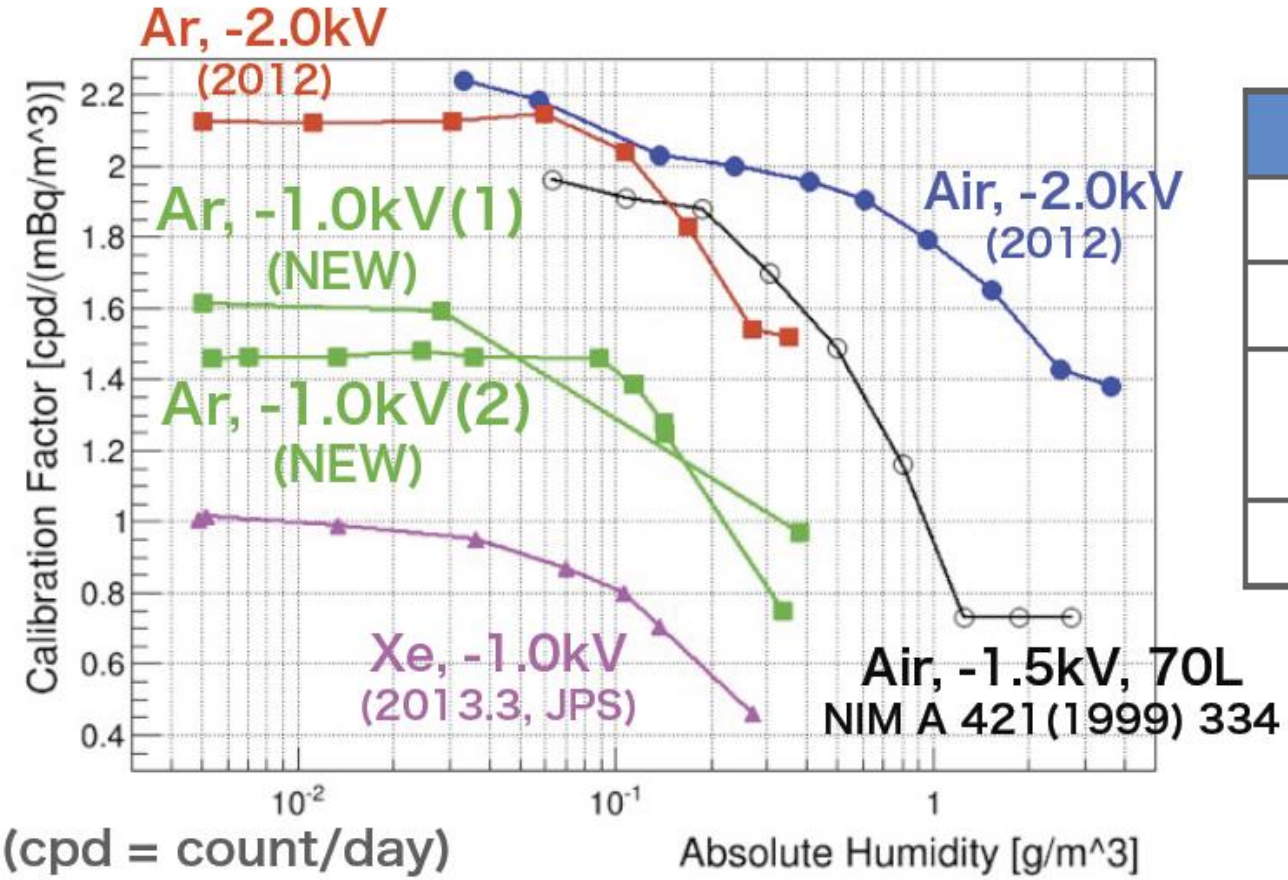
- **Higher efficiency** than ^{218}Po.
- **Lower ^{232}Th-Chain BG** in signal region.
  - 218Po signals overlap 212Bi signal.

No.2 detector

Humidity dependence

Y. 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

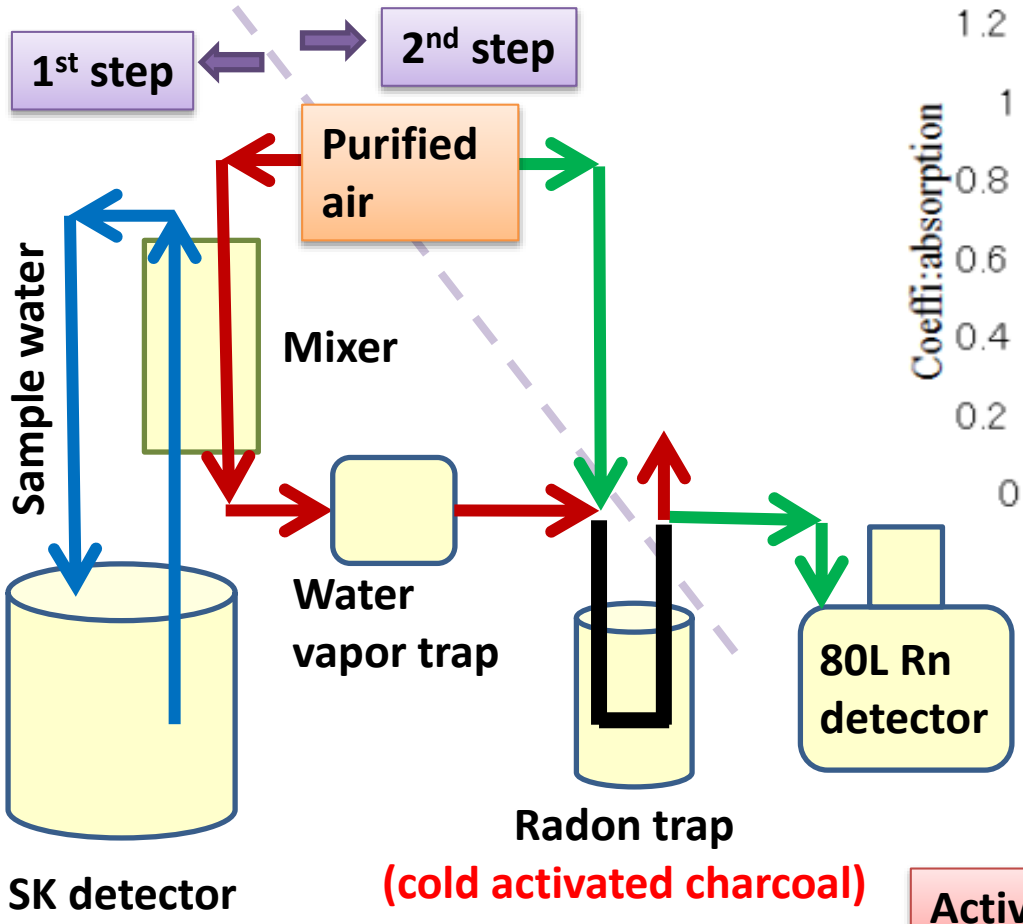
- A paper is under preparation
- More improvements will be done

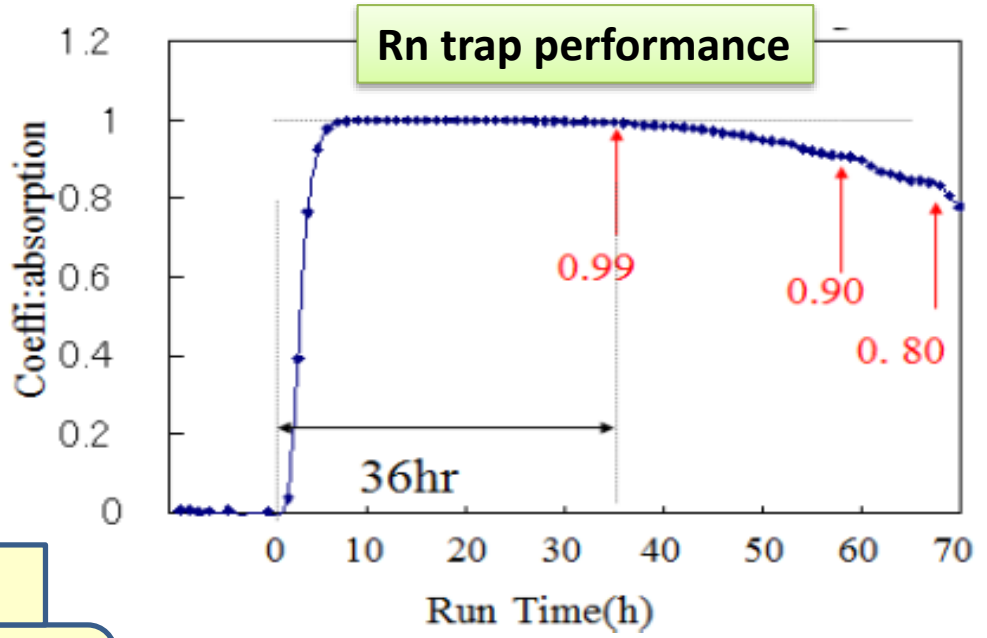
Rn measurement in SK water

科研費 KAKENHI

1. Radon in sample water is extracted by the Mixer into air. The air go through the Radon trap. Radon in air will be trapped.
2. Extract radon by baking the radon trap, then the radon will be supplied into Rn detector by air.

Developed by S. Tasaka et al.





- 24 g activated charcoal
- 100 Bq/m³ Rn
- 2 L/min flow rate

Activated charcoal trap works well for Rn in air

Summary

- Neutrino group & Dark matter group at Kobe U.
  - SK, T2K, Double-Chooz
  - XMASS, NEWAGE
- Dark matter group at Kobe was started in 2010.
  - Underground experiment group at Kobe was reinforced.
- R&D of Low-background techniques is one of major topics at Kobe U.
  - Development of high-sensitive Rn detector
  - Possible collaborative development is very welcome