# Rn removal for ultra low background liquid xenon base detector

Masaki Yamashita
Kamioka Observatory, ICRR, the University of Tokyo

April/05/2017 XsSAT2017, Khon Kaen, Thailand

# Motivation

- Rn is one of the major background for ,especially, the future dark matter experiments.

# Motivation

- Rn is one of the major background for ,especially, the future dark matter experiments.
- Currently it has  X 10 or more than pp solar neutrino and the goal for  future experiments is to reduce 1/100 or more.  ~10 μBq/kg (=> ~1x$10^{-4}$ dru)

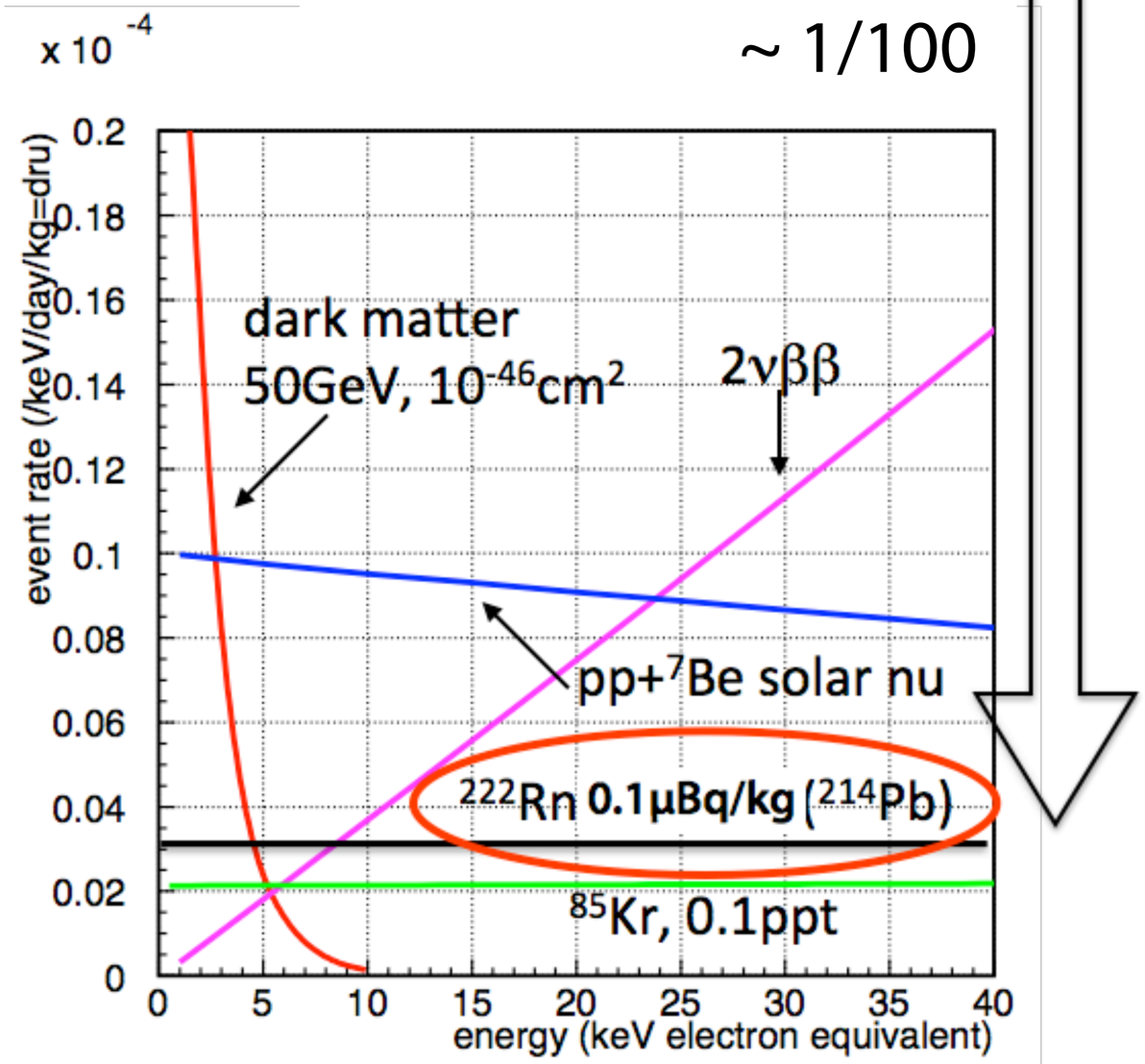
# Motivation

- Rn is one of the major background for ,especially, the future dark matter experiments.
- Currently it has  X 10 or more than pp solar neutrino and the goal for  future experiments is to reduce 1/100 or more.  ~10 μBq/kg (=> ~1x$10^{-4}$ dru)
- Dark matter detector can be used for not only WIMP search but also
  - neutrino physics such as pp/7Be, double electron capture, double beta decay
  - axion or axion like particle
  - model independent search by annual modulation and so on.
- It is very important to reduce Rn background in the future experiment.

# Background Budged for low background LXe detector

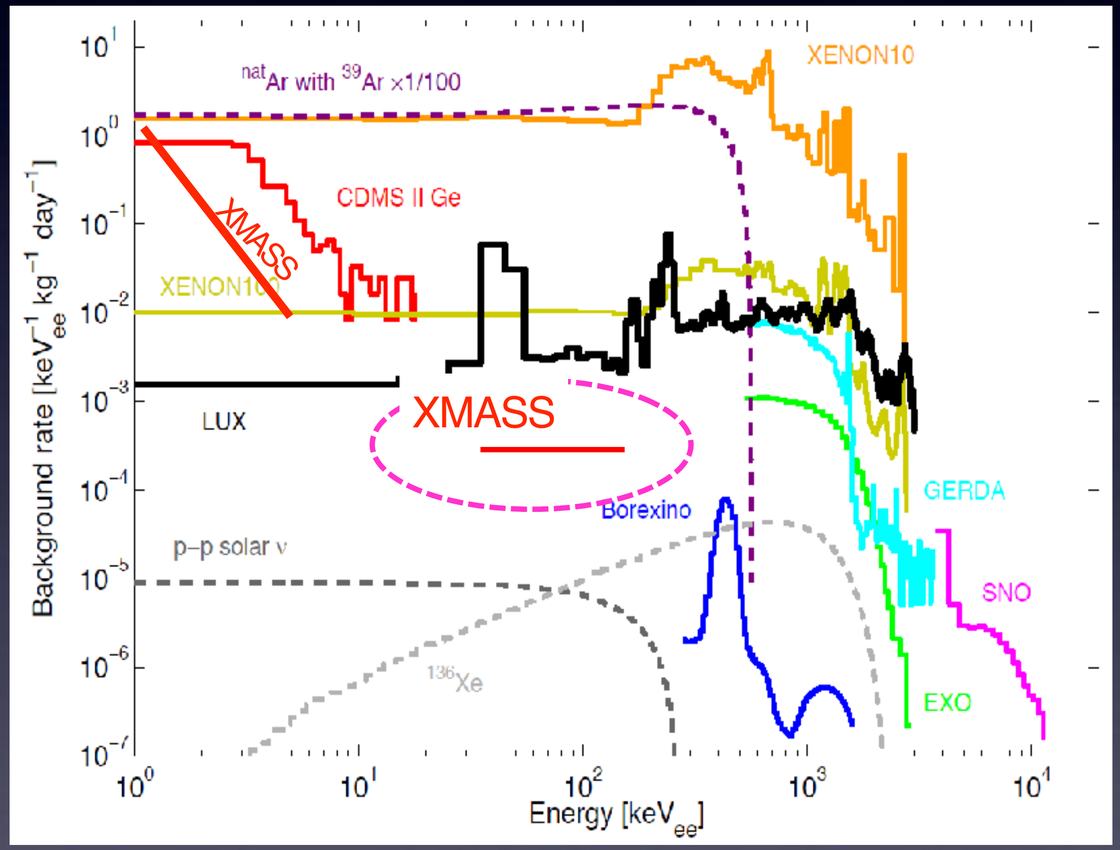
BG in the fiducial volume before any kind of PID

- pp solar neutrino (ν+e -> ν+e )
- 2νββ 136Xe
  - it can be reduce if you have depleted Xe.
- $^{85}$Kr
  - The goal is less than 0.1 ppt.
  - Less than a few ppt Kr in Xe was achieved by some groups. (e.g. distillation)
- $^{222}$Rn background
  - $^{214}$Pb daughter beta decay
  - Currently, X 10 or more than pp Solar neutrino
- Ultimate background will be neutrino coherent scattering(solar atmospheric)



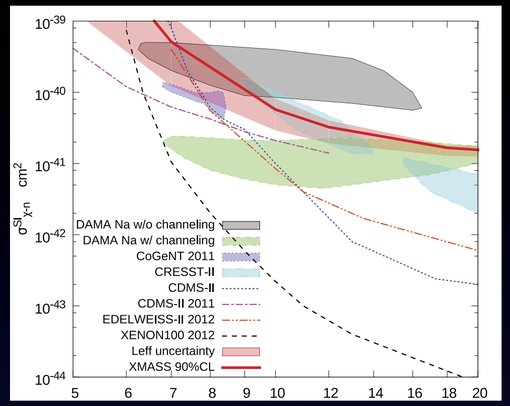
# Comparison of background rate

- Background rate in the fiducial volume before separation of nuclear recoils from e/γ.
- XMASS achieved O($10^{-4}$) event/ day/kg/keVee
  at a few 10's keV.
- Even modest background at low energy, XMASS has good sensitivity with a large mass (832 kg) and low energy threshold. (~ 1keVee) by annual modulation search.



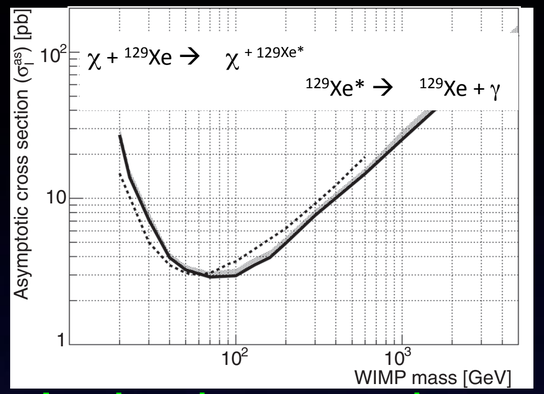

Added to D.C.Malling thesis (2014) Fig.

# Search by XMASS




## light mass WIMP

**Phys. Lett. B 719 (2013) 78**

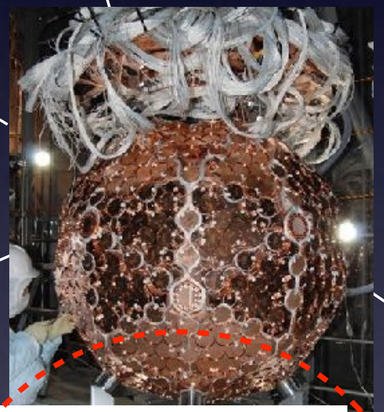


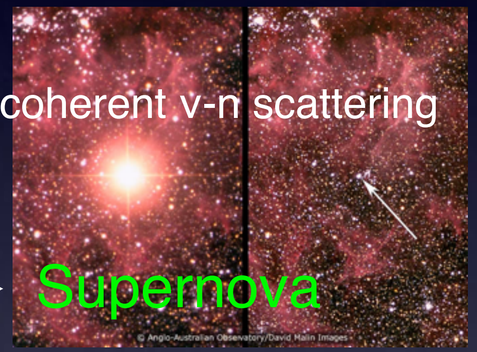

## Inelastic scattering

**PTEP 2014, 063C01**

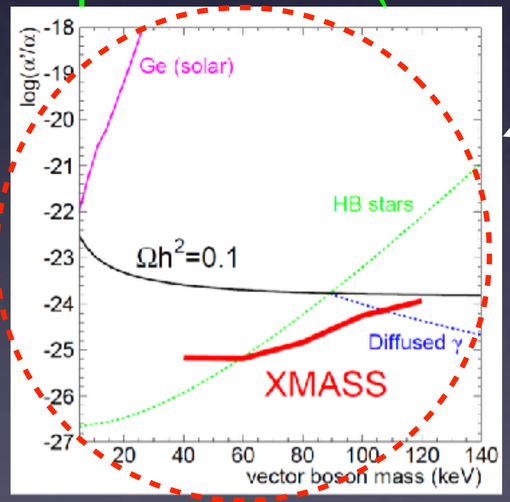
## Solar axion

**Phys. Lett. B 724 (2013) 46**

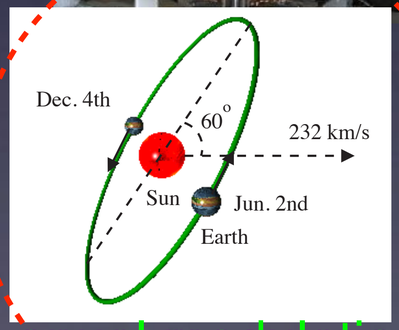





## super-WIMPs(ALPs)



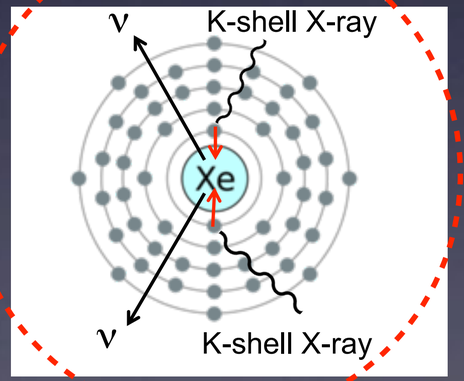

**Phys. Rev. Lett. 113 (2014) 121301**




## anual modulation

**arXiv:1511.04807v1**

## Rare decay search
## Double electron capture




**arXiv:1510.00754**

# Rn background in the dark matter community

| Experiment | LXe Mass[kg] | 222Rn[μBq/kg] |
|---|---|---|
| XMASS | 832 | 9.8±0.6 |
| XENON100 | 62 | 33.4±1.3 |
| LUX | 270 | 20 |
| PandaX-II | 500 | 8.6±4.6 |

XMASS: K. Abe et al. NIM A 716 (2013) 78

XENON100: E. Aprile et al. arXiv:1702.06942v1

LUX:arXiv: D. S. Akerib et al. PRL 112, 091303 (2014)

PandaX-II: A. Tan et al. PhysRevLett.117.121303 (2016)

1μBq/kg ~ pp solar

# Rn removal from gaseous xenon with activated charcoal

Nuclear Instruments and Methods in Physics Research A 661 (2012) 50–57

Contents lists available at SciVerse ScienceDirect

Nuclear Instruments and Methods in Physics Research A

journal homepage: www.elsevier.com/locate/nima

## Radon removal from gaseous xenon with activated charcoal

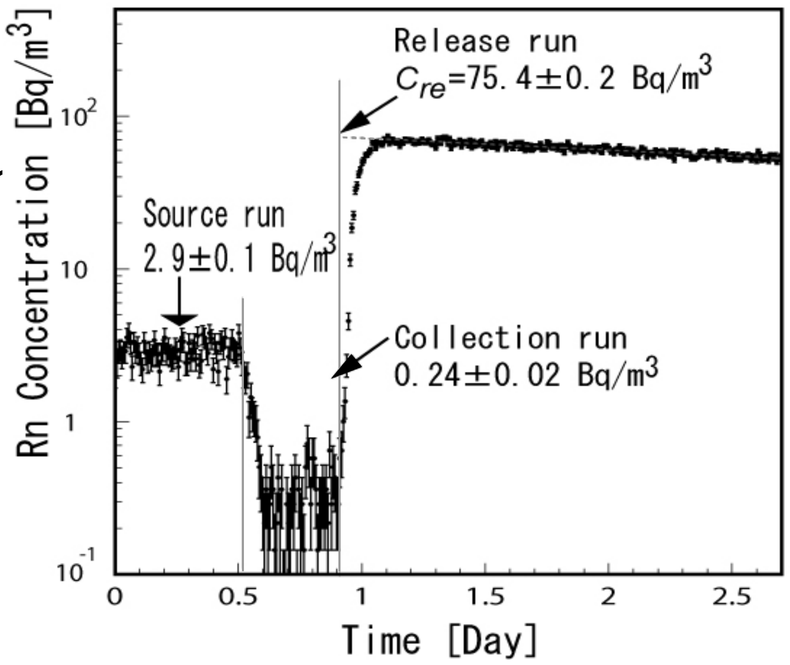
K. Abe [a], K. Hieda [a], K. Hiraide [a], S. Hirano [a], Y. Kishimoto [a], K. Kobayashi [a], Y. Koshio [a], J. Liu [b], K. Martens [b], S. Moriyama [a], M. Nakahata [a,b], H. Nishiie [a], H. Ogawa [a], H. Sekiya [a], A. Shinozaki [a], Y. Suzuki [a,b], O. Takachio [a], A. Takeda [a], K. Ueshima [a], D. Umemoto [a], M. Yamashita [a], K. Hosokawa [c], A. Murata [c], K. Otsuka [c], Y. Takeuchi [c], F. Kusaba [e], D. Motoki [d,*], K. Nishijima [e], S. Tasaka [f], K. Fujii [g], I. Murayama [g], S. Nakamura [g], Y. Fukuda [h], Y. Itow [i], K. Masuda [i], Y. Nishitani [i], H. Takiya [i], H. Uchida [i], Y.D. Kim [j], Y.H. Kim [k], K.B. Lee [k], M.K. Lee [k], J.S. Lee [k]

[a] *Kamioka Observatory, Institute for Cosmic Ray Research, The University of Tokyo, Kamioka, Hida, Gifu 506-1205, Japan*
[b] *Institute for the Physics and Mathematics of the Universe, The University of Tokyo, Kashiwa, Chiba 277-8582, Japan*
[c] *Department of Physics, Kobe University, Kobe, Hyogo 657-8501, Japan*
[d] *School of Science and Technology, Tokai University, Hiratsuka, Kanagawa 25 9-1292, Japan*
[e] *Department of Physics, Tokai University, Hiratsuka, Kanagawa 25 9-1292, Japan*
[f] *Department of Physics, Gifu University, Gifu, Gifu 501-1193, Japan*
[g] *Department of Physics, Faculty of Engineering, Yokohama National University, Yokohama, Kanagawa 240-8501, Japan*
[h] *Department of Physics, Miyagi University of Education, Sendai, Miyagi 980-0845, Japan*
[i] *Solar Terrestrial Environment Laboratory, Nagoya University, Nagoya, Aichi 464-8602, Japan*
[j] *Department of Physics, Sejong University, Seoul 143-747, South Korea*
[k] *Korea Research Institute of Standards and Science, Daejeon 305-340, South Korea*

The XMASS Collaboration

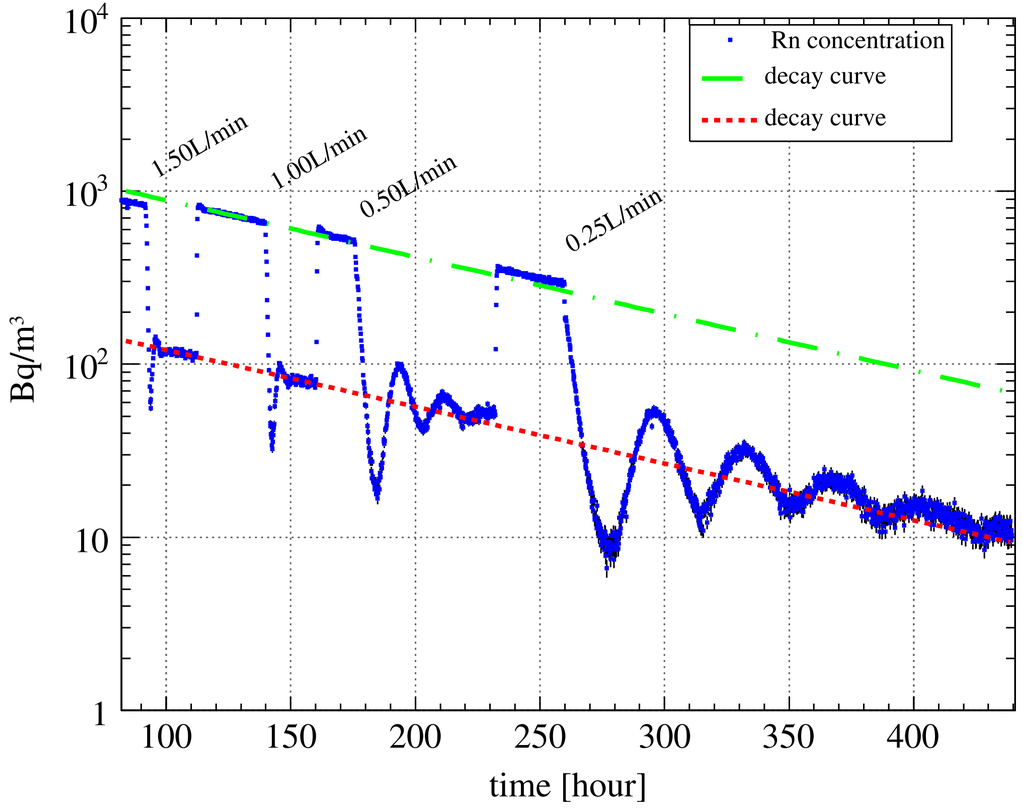
# Rn removal by charcoal

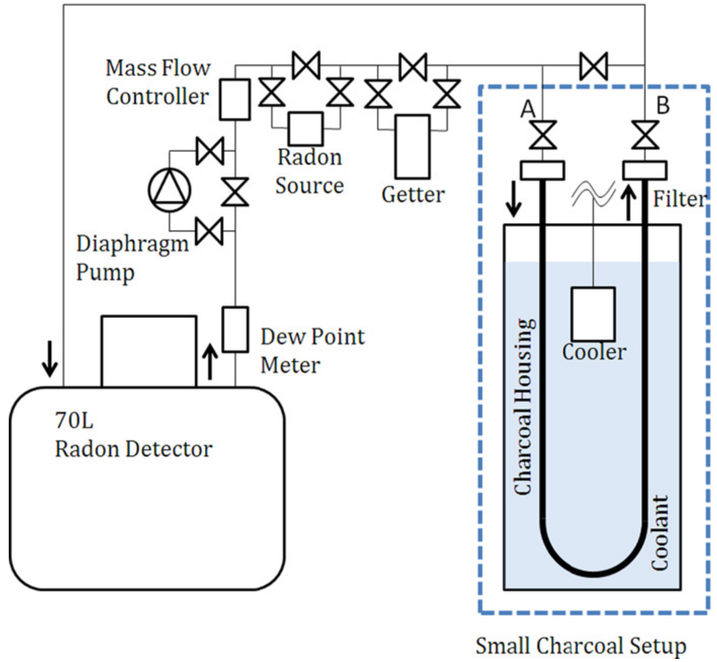
- It is well known that Rn in Air/Ar can be effectively removed by the activated charcoal. (e.g. RADIOISOTOPES,59, 29-36 (2010) )
- In 2009, for the first time, we reported about Rn removal in gaseous xenon with activated charcoal.
- Our finding was that Rn actually was not absorbed by the charcoal (Shirasagi G2X 4/6) but it only slow down the propagation speed in low temperature charcoal in gaseous xenon.
- From our measurements we infer a linear relationship between the mean propagation velocity vRn of radon and vXe of xenon in the trap with $V_{Rn}/V_{Xe} \sim 1/1000$ at -85℃.



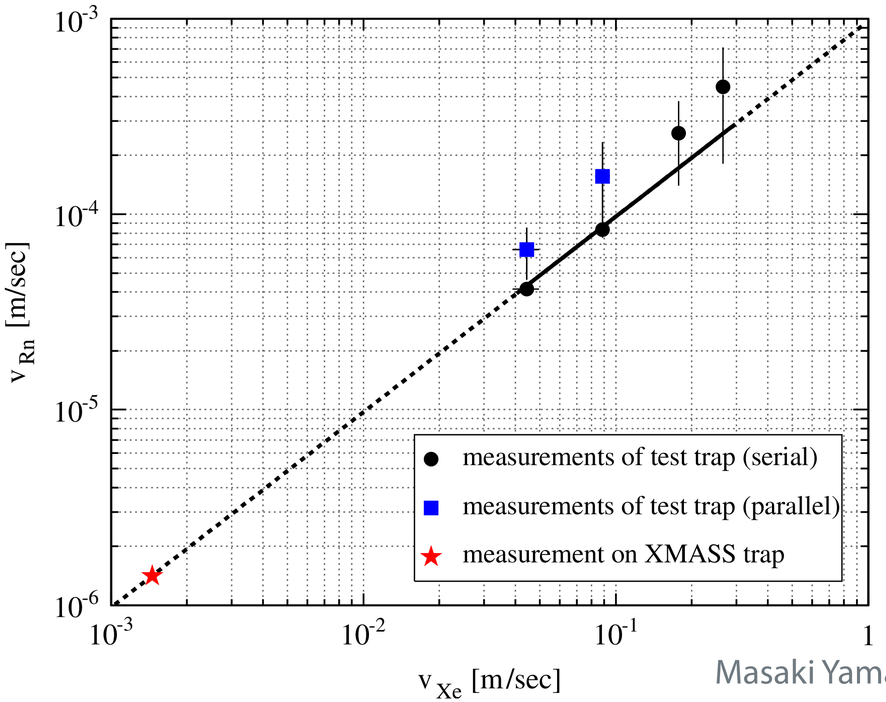
# Rn/Xe velocity in the charcoal

- Rn injected in the circulation system with Rn detector
- We observed 'oscillation' of Rn concentration and from arrival time information, we measured a velocity of Rn in the charcoal.



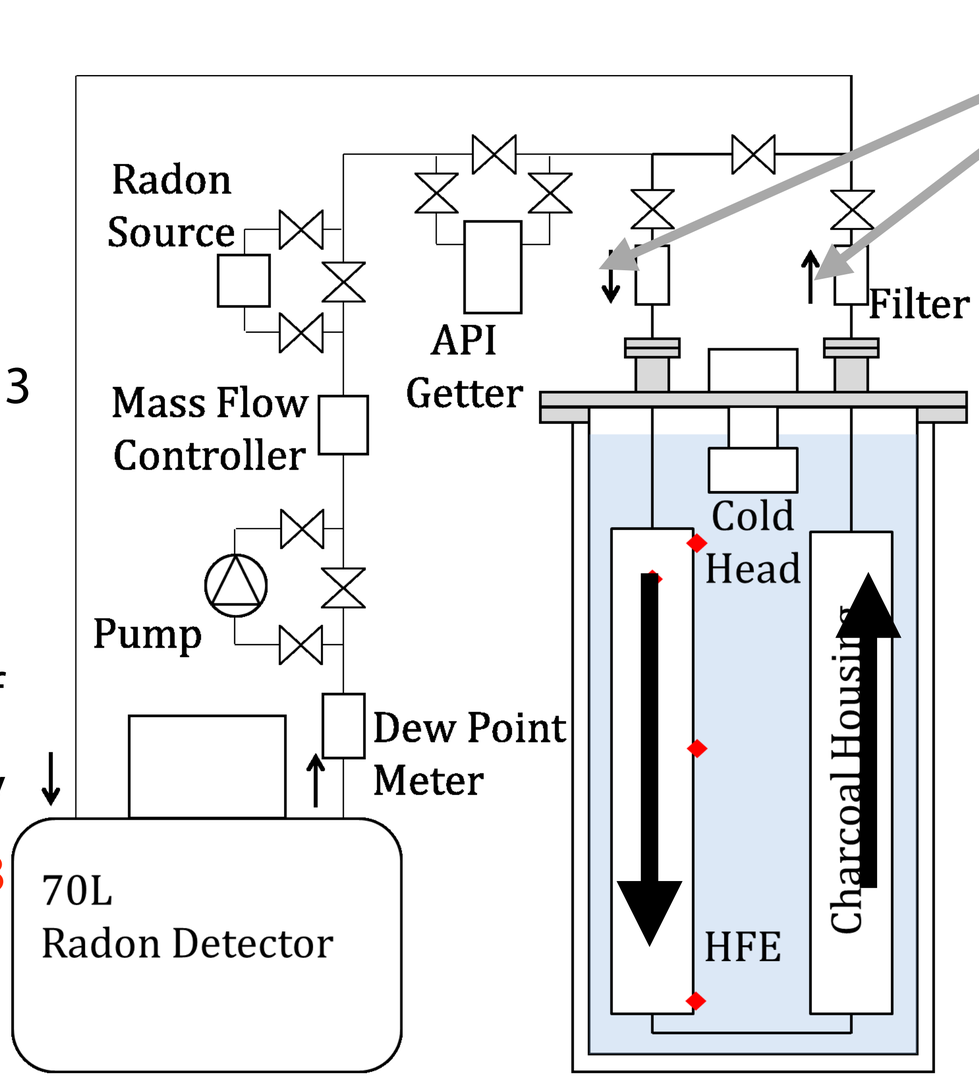



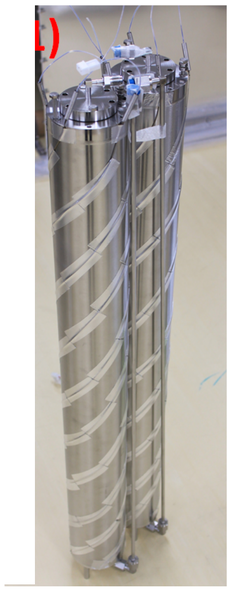

Small Charcoal Setup

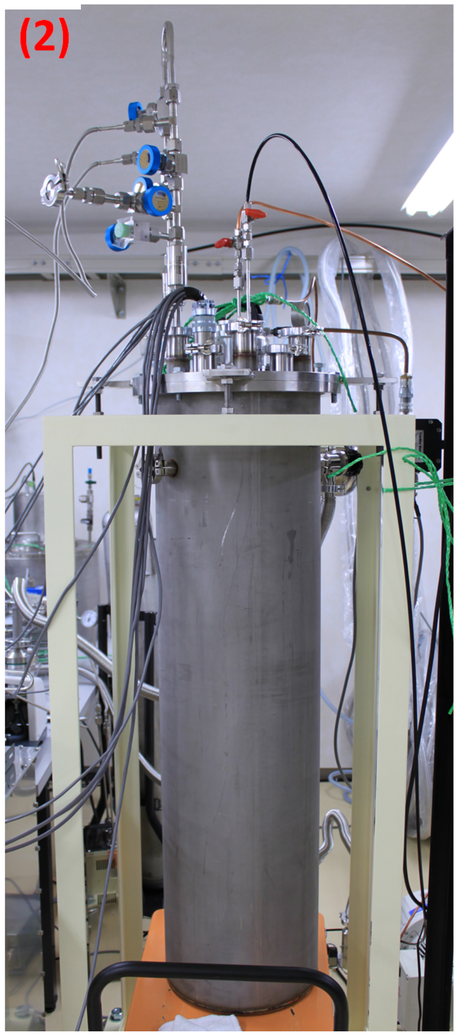


# Set up (Abe et al. NIM A 661(2012) 50)

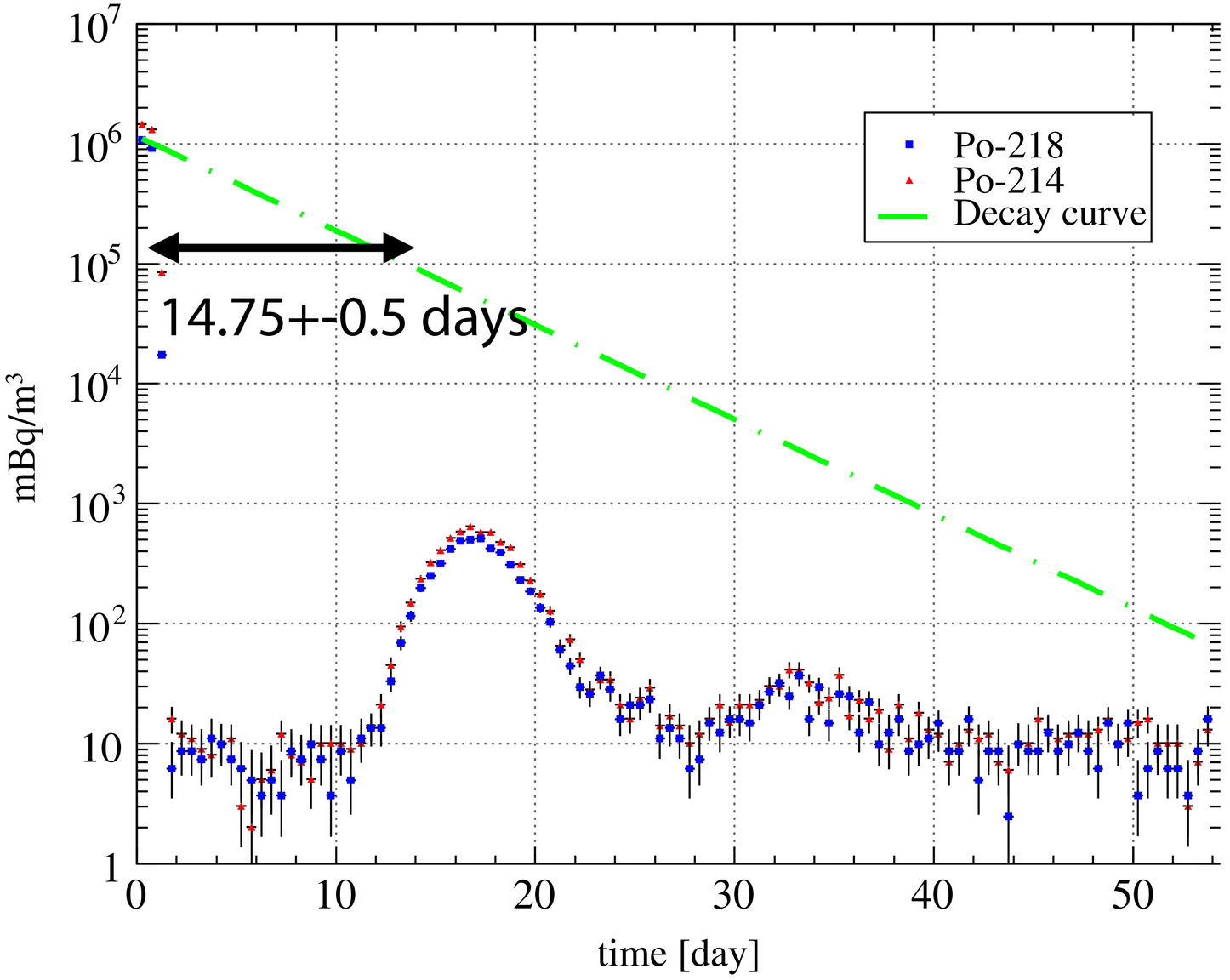
- Based on that study , we built a removal system with 5.5 kg (Shirasagi G2X 4/6) .
- Xe 1 L/min with $V_{Rn}$ will be 1.47x10 3 m/s in the charcoal housings
- $T_{Rn}$ becomes about 14.7 days.
- This corresponds to 3.8 half-lives of 222Rn or an expected reduction by a factor of 1 - (1/2)^(14.7/3.8) ~0.93





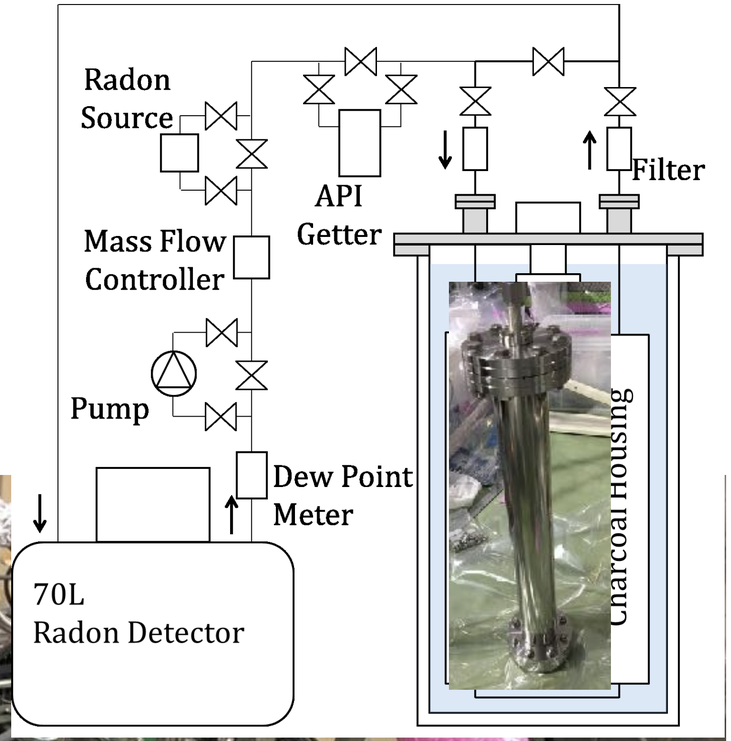
# 5.5 kg charcoal test

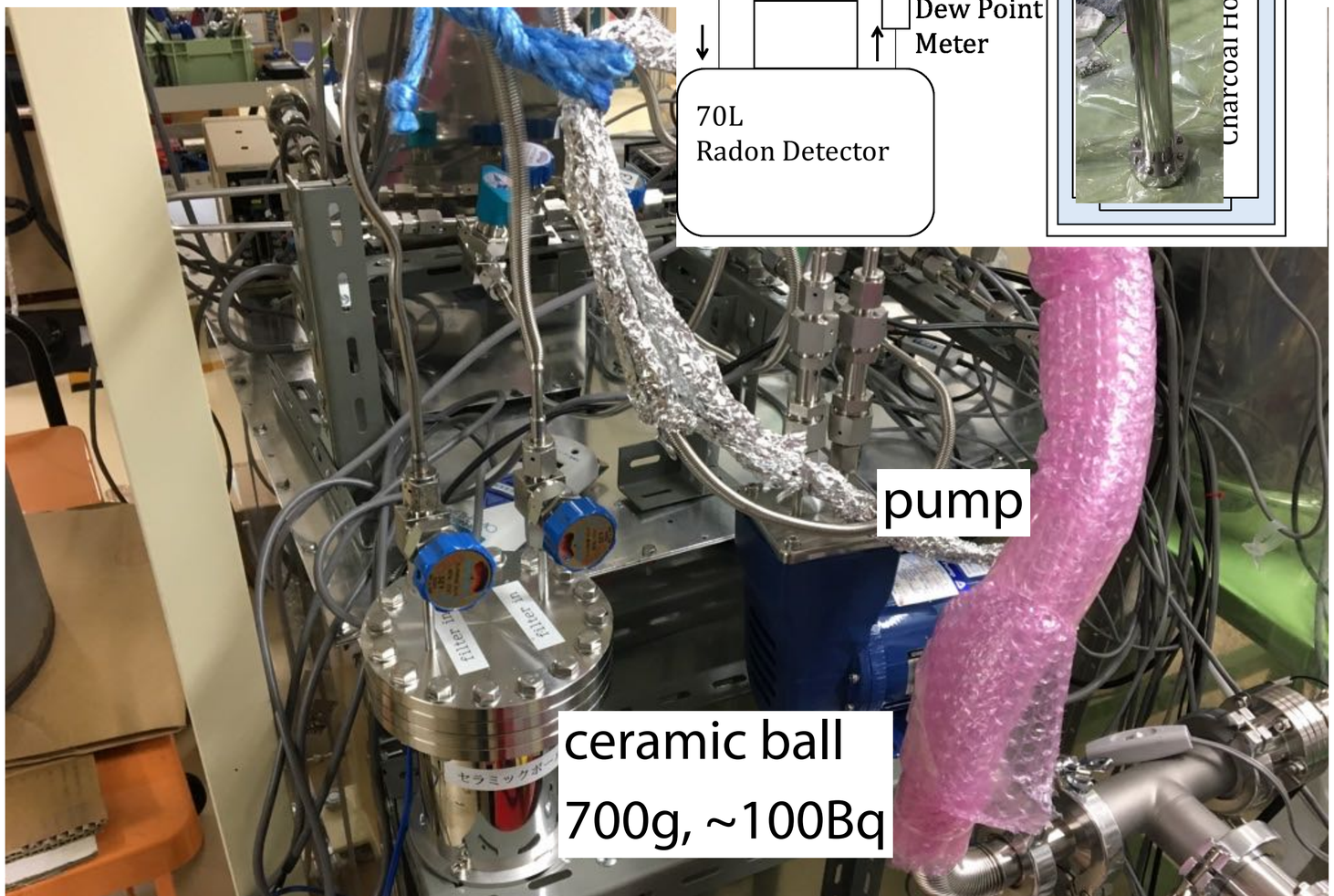



estimated emanation <3.1mBq

estimated from 120℃ temperature.

# Rn source



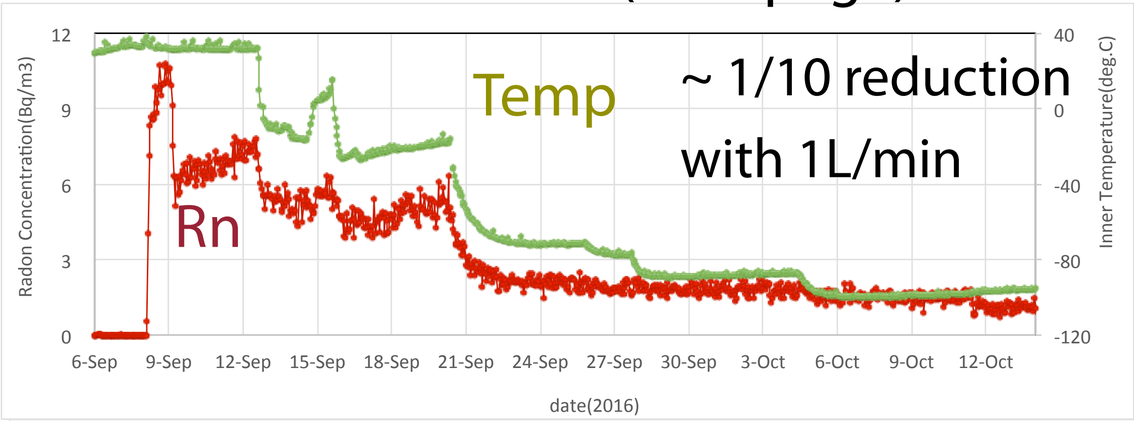

- Rn source current set up
- It is called 'radium ceramic ball' to have Onsen(hot spring ) at home !!
- buy at Amazon

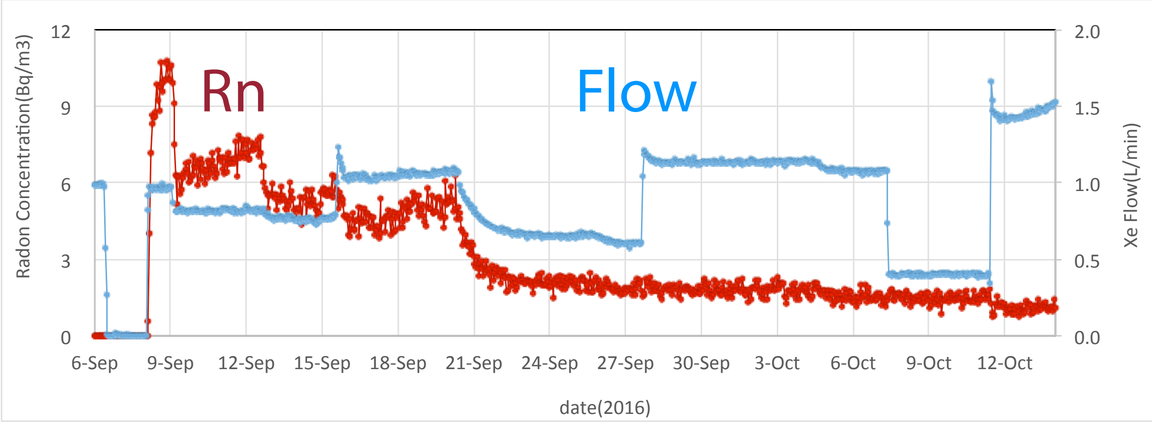
# Charcoal A

At same time we are looking for new material as well.
HPGe couing (U-chain)

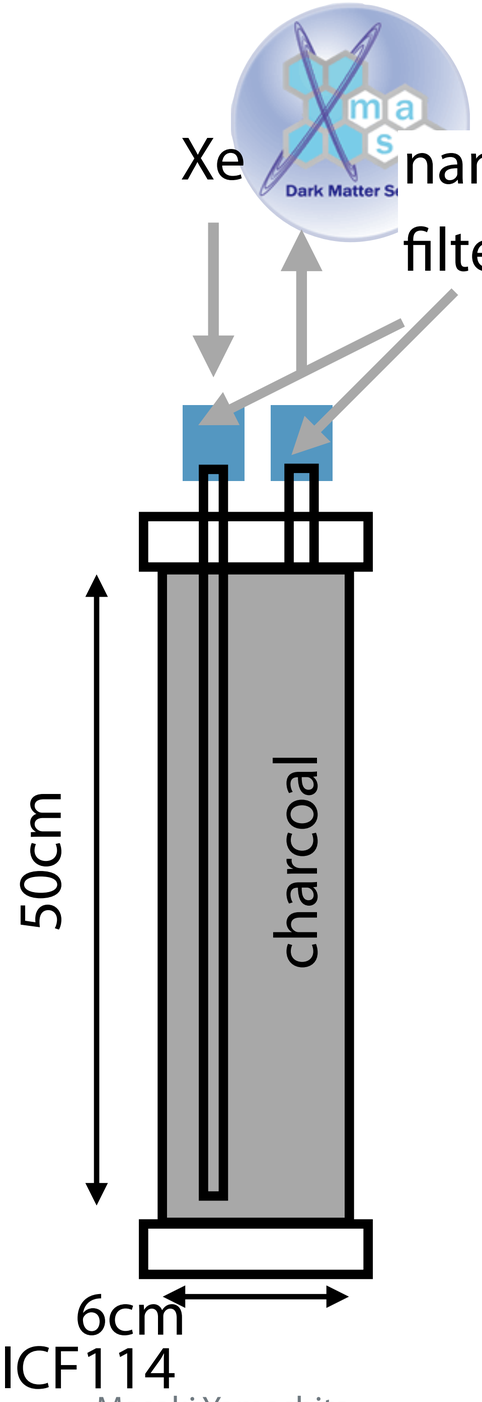
NIM(2011) Shirasagi 67+/-15 mBq/kg
Charcoal A < 11.9 mBq/kg (90%CL)

Tested with Rn source. (next page)

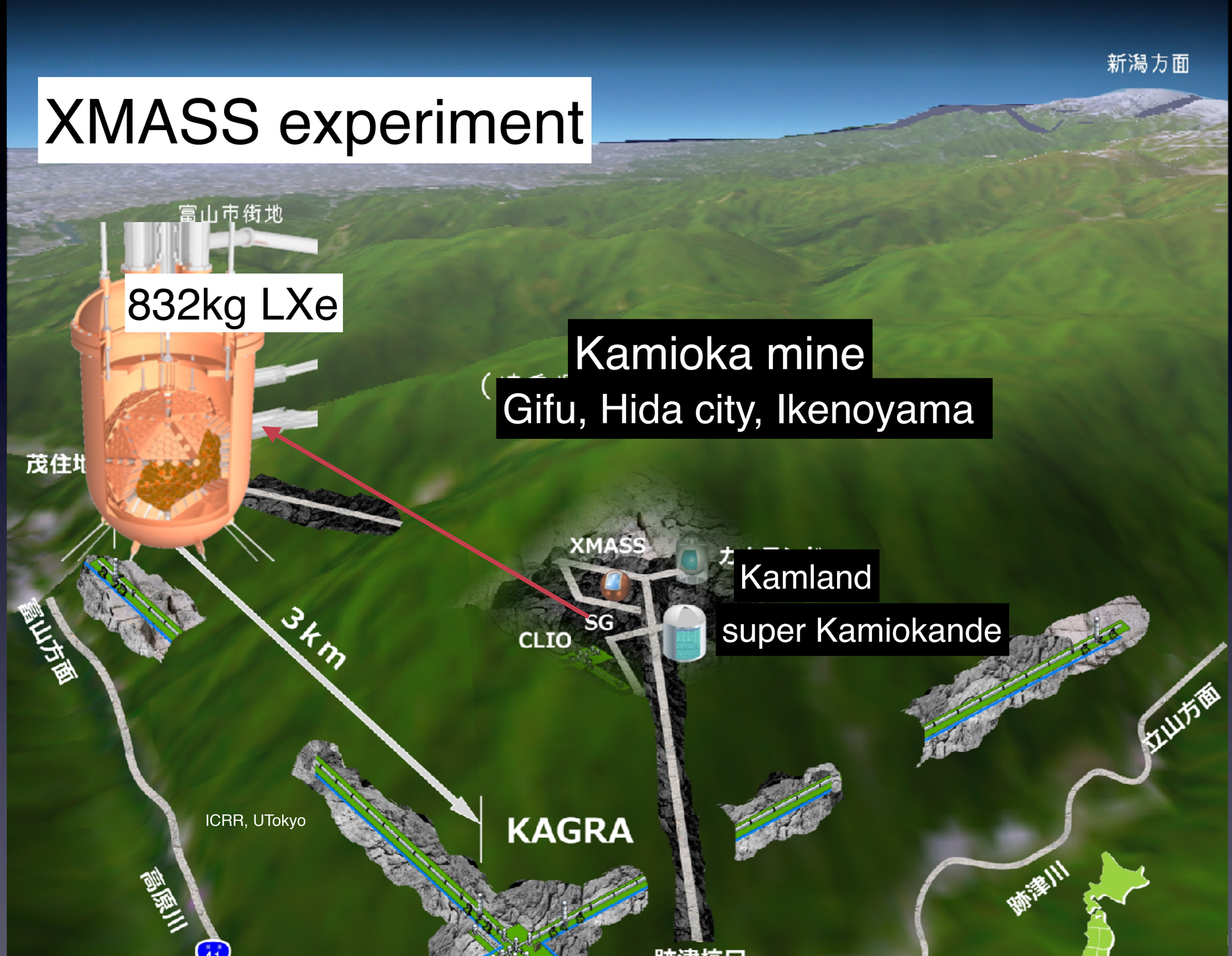


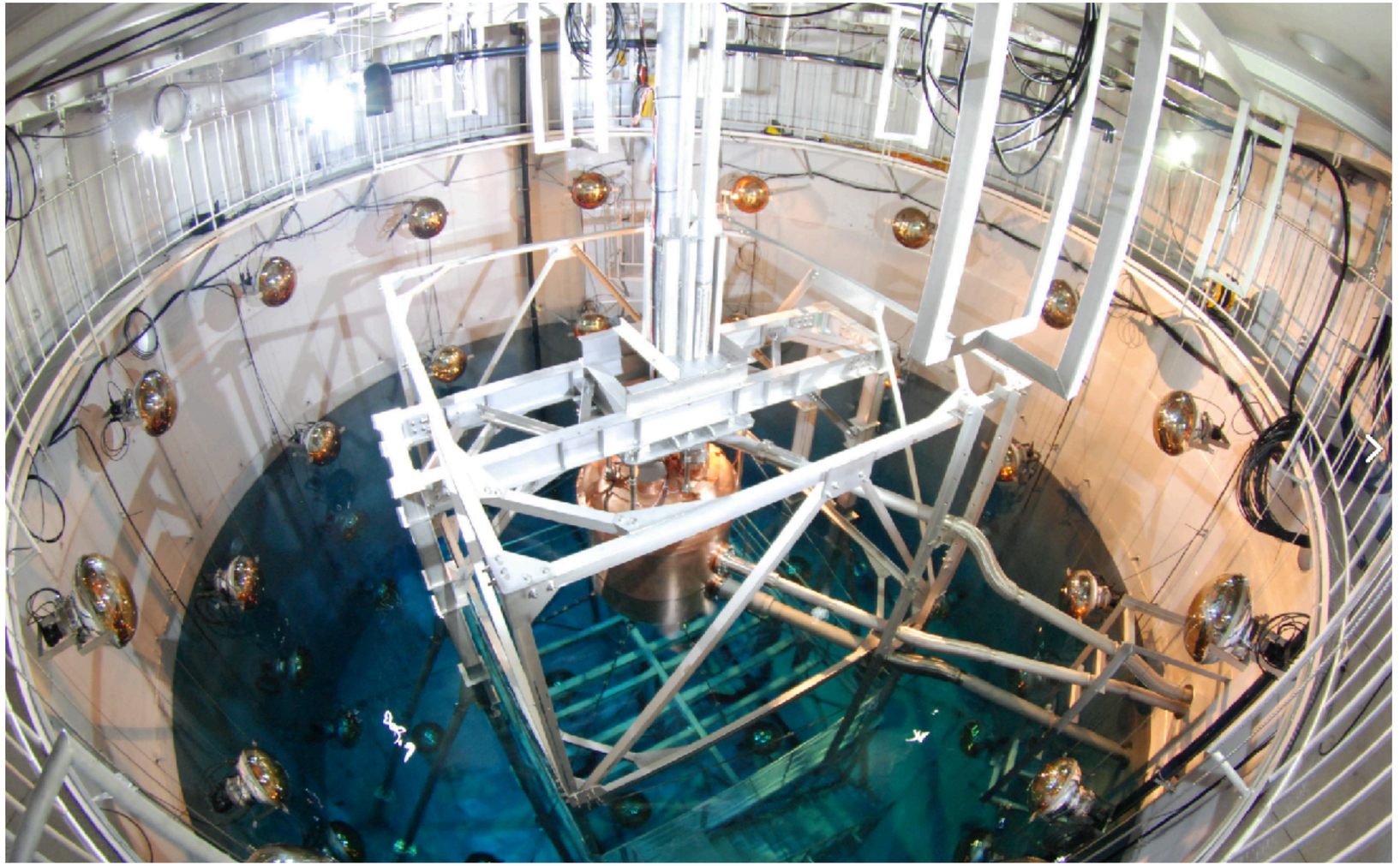




140g



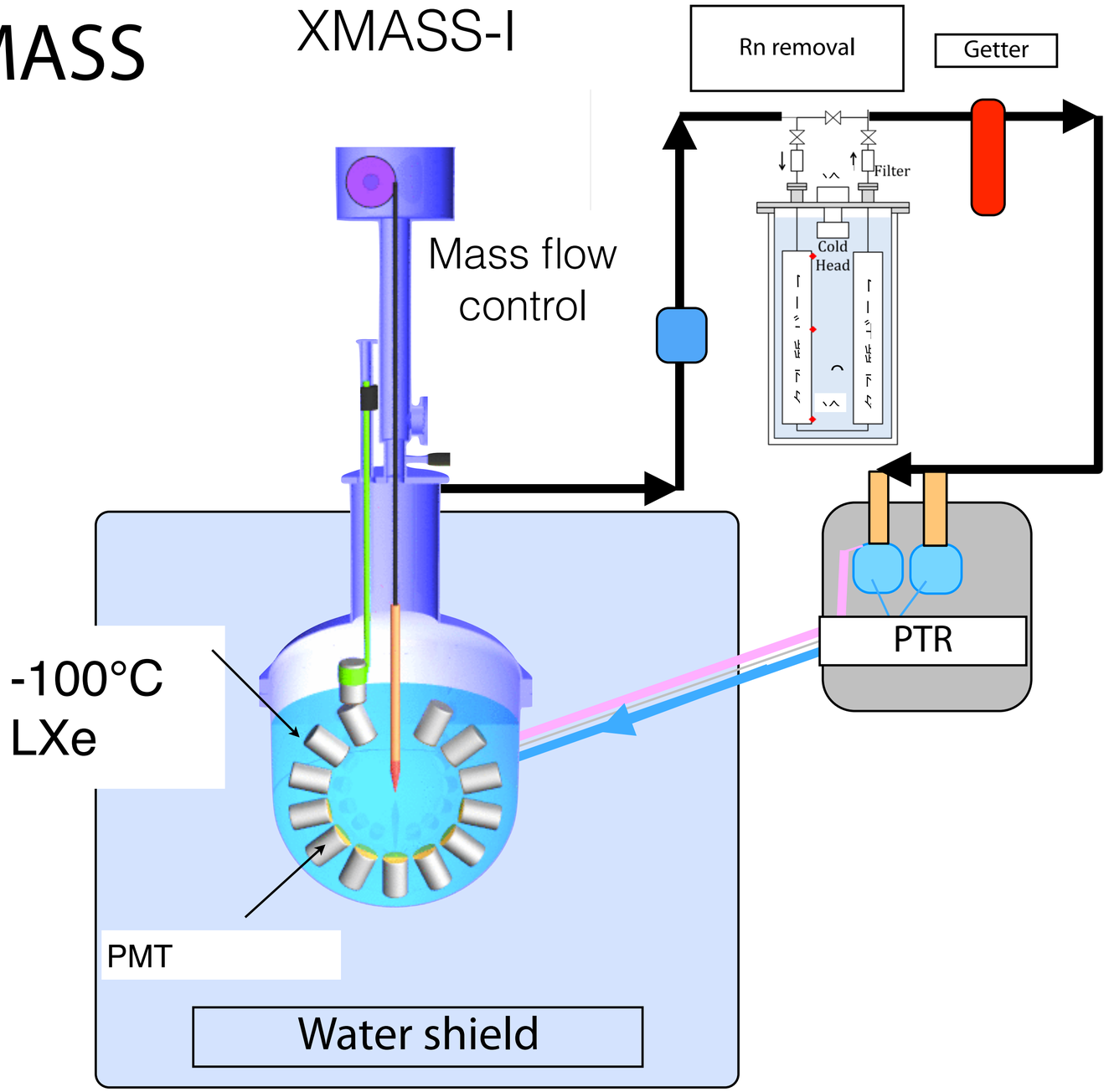
# Plan for Testing in XMASS


XMASS experiment
新潟方面
富山市街地
832kg LXe
Kamioka mine
Gifu, Hida city, Ikenoyama
茂住地
XMASS
Kamland
super Kamiokande
SG
CLIO
3km
富山方面
立山方面
ICRR, UTokyo
KAGRA
高原川
跡津川



-φ10m x 10m ultra pure water shield with 20 inch x 70 PMTs for muon veto

# Plan for XMASS




# Summary

- Rn will be the one of the main background for future dark matter experiment with liquid xenon.
- The activated charcoal was tested for this purpose and we found that Rn atom moves more slower than Xe atom in the cold charcoal.
- Prototype Rn removal test show ~1/10 reduction @1L/min and will be test in XMASS detector.