

PICO-LON dark matter search

K.Fushimi for PICO-LON collaboration

1. Outline of PICO-LON
2. Purification of NaI(Tl) crystal
3. Experimental setup (4" ϕ X 3" NaI(Tl))
4. Performance test
5. Preliminary BG measurement
6. Summary and prospect

PICO-LON for WIMPs search

- **P**ure
 - **I**norganic
 - **C**rystal
 - **O**bservatory for
 - **L**ow-energy
 - **N**eutr(al)ino
- High selectivity
 - Background reduction
 - NaI(Tl) scintillator
 - Sensitive to
 - Elastic scattering (SI+SD)
 - Inelastic scattering (SD)
 - Study the interaction type of WIMPs

K.Fushimi, et al.,: “WIMPS Search by Exclusive Measurements with Thin Multilayer NaI(Tl) Scintillators (PICO-LON)” , Proceedings of Sixth International Workshop “Identification of Dark Matter”, pp.296–301, 2007.

K.Fushimiet al., “Dark matter search project PICO-LON”, J. of Phys.: Conf. Ser., 718, p.042022, 2016.

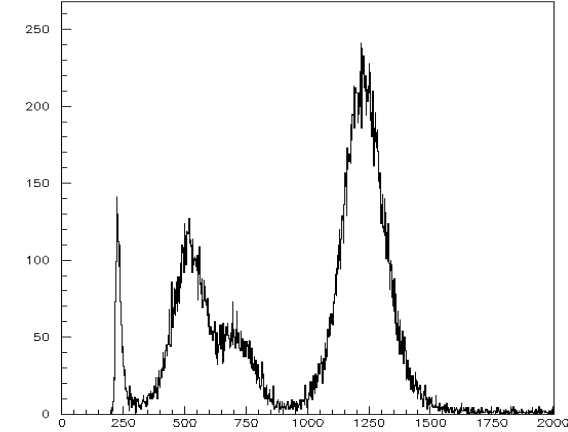
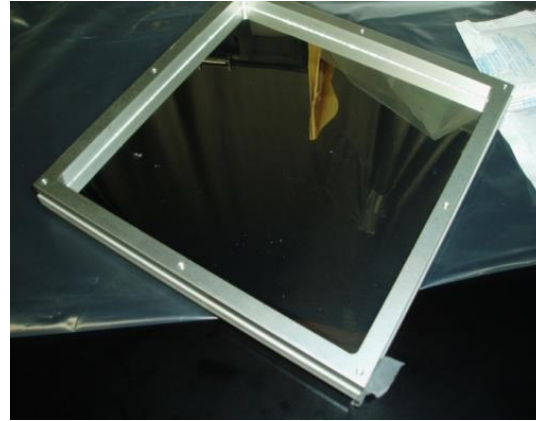
PICO-LON Collaboration

- Tokushima University
 - K.Fushimi, R.Orito, G.Kanzaki, S.Hirata
- I.S.C. Lab.
 - K.Imagawa, K.Yasuda
- Kavli IPMU Tokyo University (WPI)
 - A.Kozlov, D.Chernyak
- Osaka University
 - Y.Takemoto, H.Ejiri, T.Shima, S.Umehara, S.Yoshida
- Osaka Sangyo University
 - R.Hazama
- Tohoku University
 - K.Inoue, H.Ikeda, Y.Teraoka

PICO-LON dark matter search by using NaI(Tl)

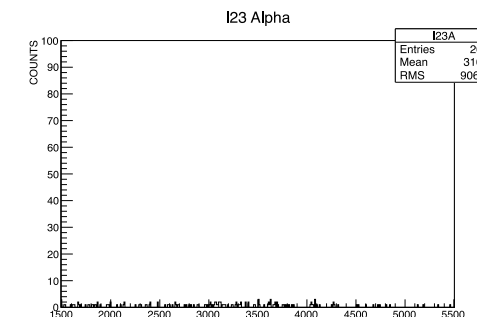
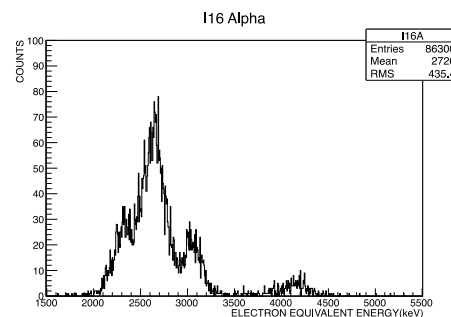
- 2006-2012 : Thin layer NaI(Tl) array to search for dark matter search

- Thin \rightarrow 0.5 cm
- Wide area \rightarrow 15 cmX15cm
- High performance was established
- Energy threshold = 1 keV_{ee}
- Resolution = 24% FWHM at 60 keV



- 2012- : Highly radiopure NaI(Tl) detector for dark matter search

- Reduction of radioactive impurities step by step.
- Highly radiopure NaI(Tl) crystal was developed with the same level of purity reported by DAMA/LIBRA.



Purity of NaI(Tl)

	DAMA	DM-Ice	Ingots 26~37 (2016)	Goal of PICO-LON	
^{nat}K (ppb)	<20	660	< 1	<20	😊
^{232}Th (ppt)	0.5-0.7	2.5	0.3 ± 0.5	<4	😊
^{238}U (ppt)	0.7-10	1.4	4.7 ± 0.3	<10	😊
^{210}Pb ($\mu\text{Bq/kg}$)	5-30	1470	29.4 ± 6.6	< 5	😊

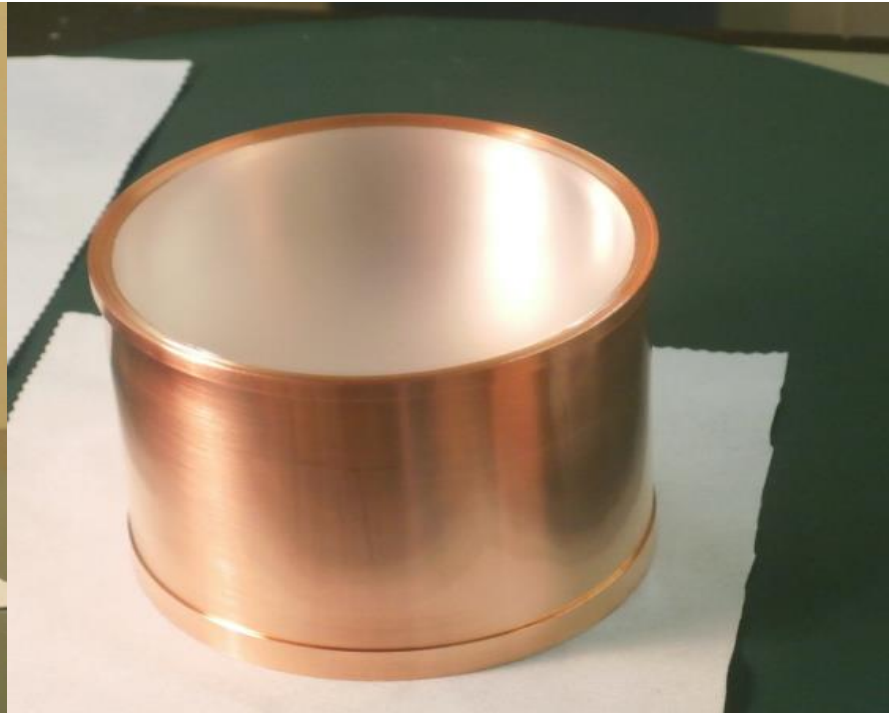
- U-chain: 1ppt= 12.3 $\mu\text{Bq/kg}$
- Th-chain: 1ppt= 4.0 $\mu\text{Bq/kg}$
- ^{210}Pb : 1ppt=2.5kBq/kg

DAMA: NIM A592 (2008) 297.

DM-ICE: Phys. Rev. D90 (2014) 092005.

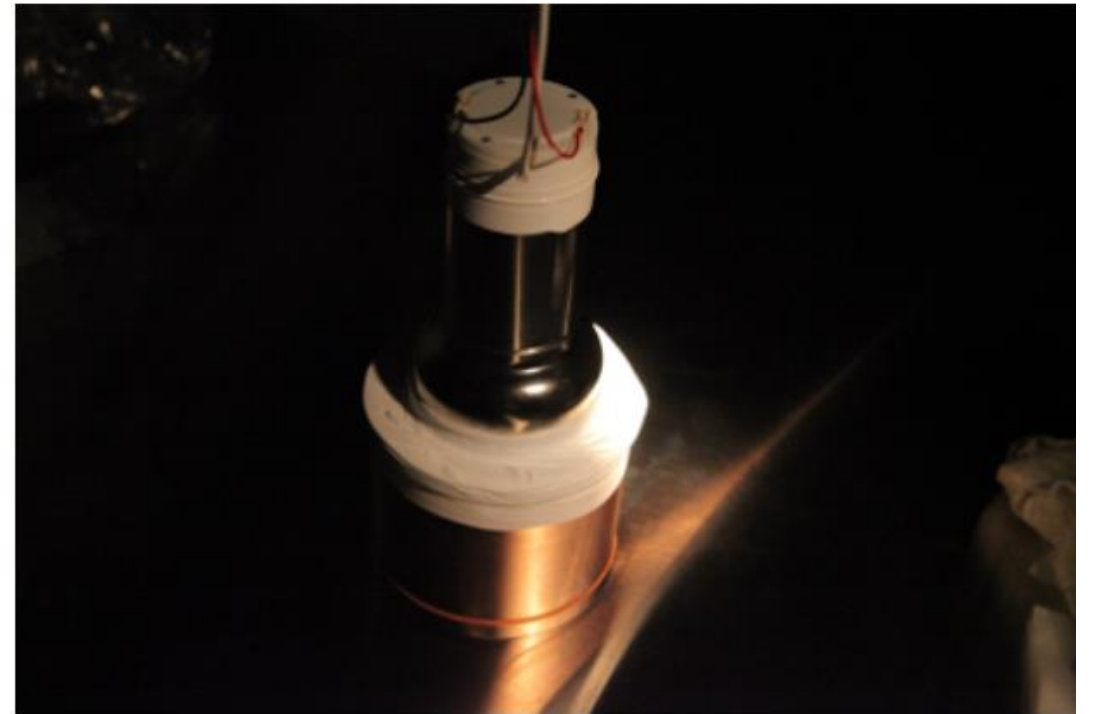
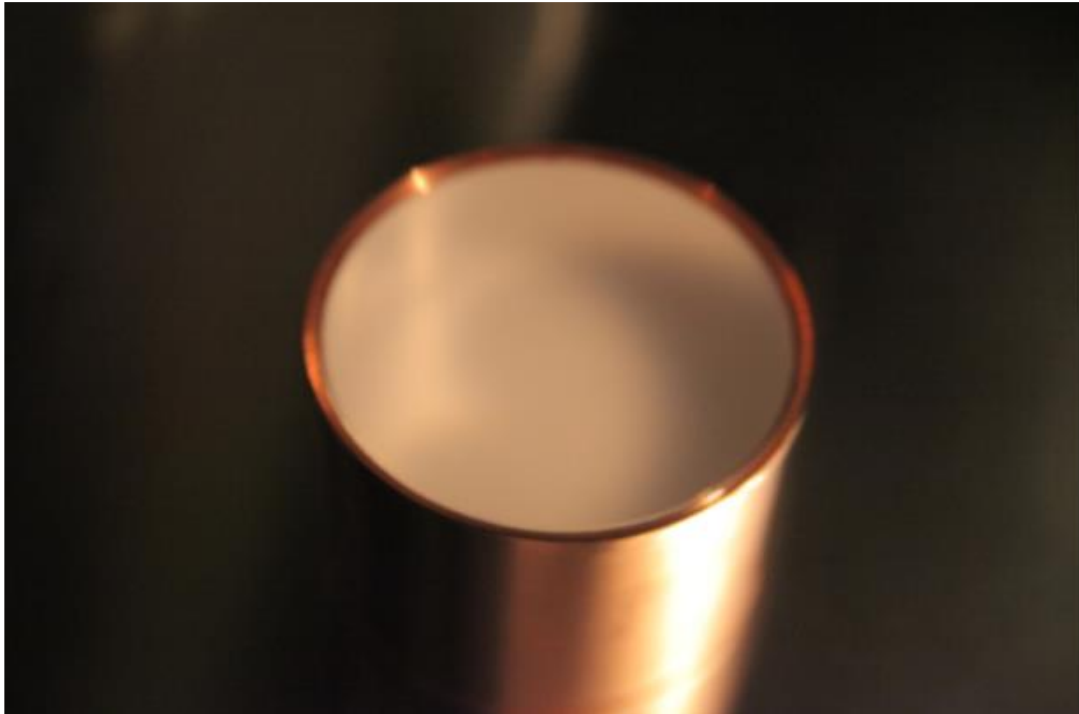
Potassium reduction in NaI(Tl)

- Chemical process of raw NaI powder
 - Cation exchange resin for potassium and radium ion.
- Pure and good graphite crucible
 - NaI(Tl) do not interact with crucible.
- Clear and pure NaI(Tl) was produced successfully.



Performance test

- Ingot #37 (Chemical processed to remove radioactive impurities)
- 101.6 mm ϕ X76.2 mm: 2.27 kg
- OFHC housing: Electrolytic polished.
- PMT: R11065-20 mod low BG PMT by Hamamatsu



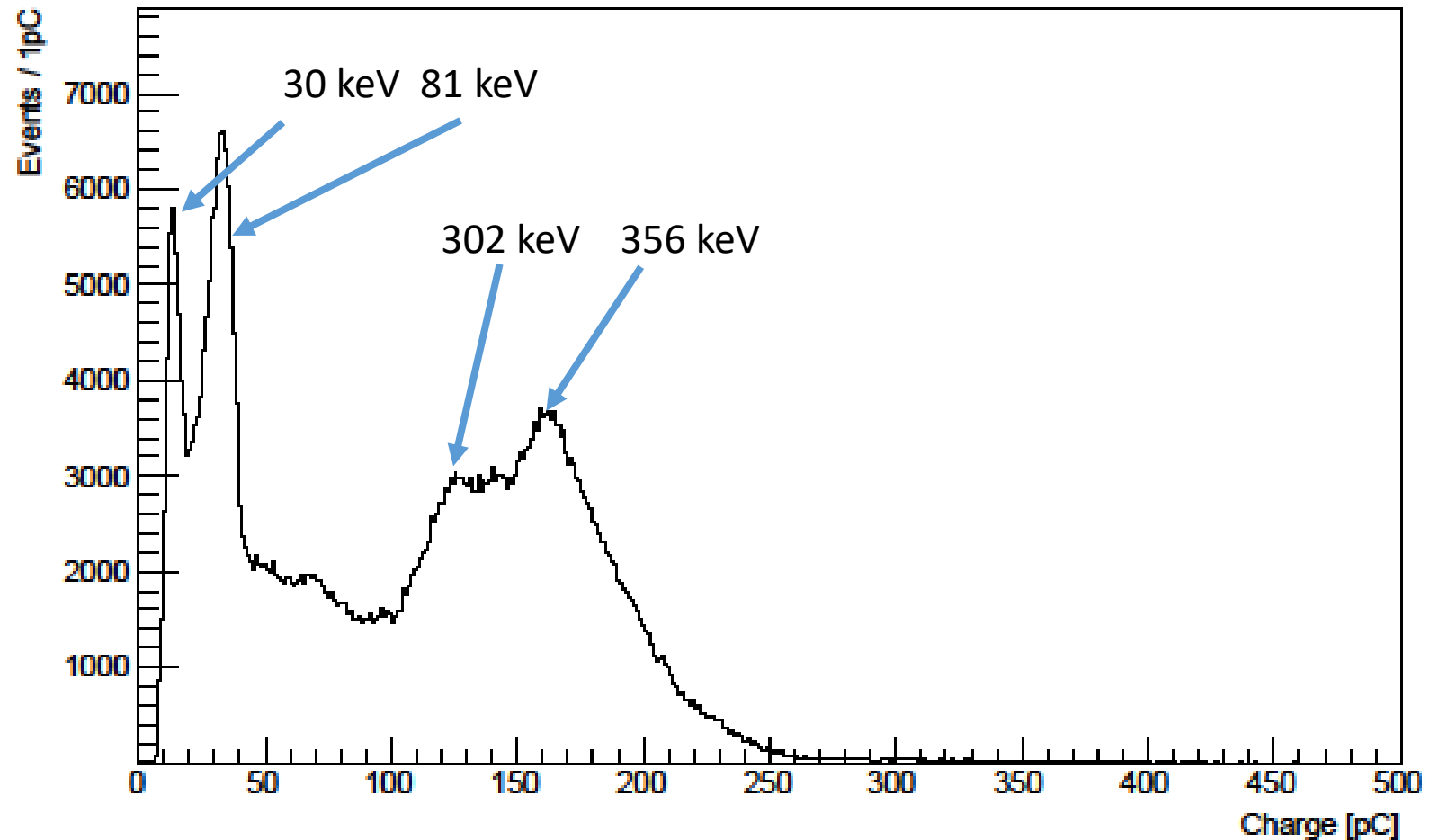
Performance test

- Energy calibration by ^{133}Ba .
- Poor energy resolution relative to previous ingots.



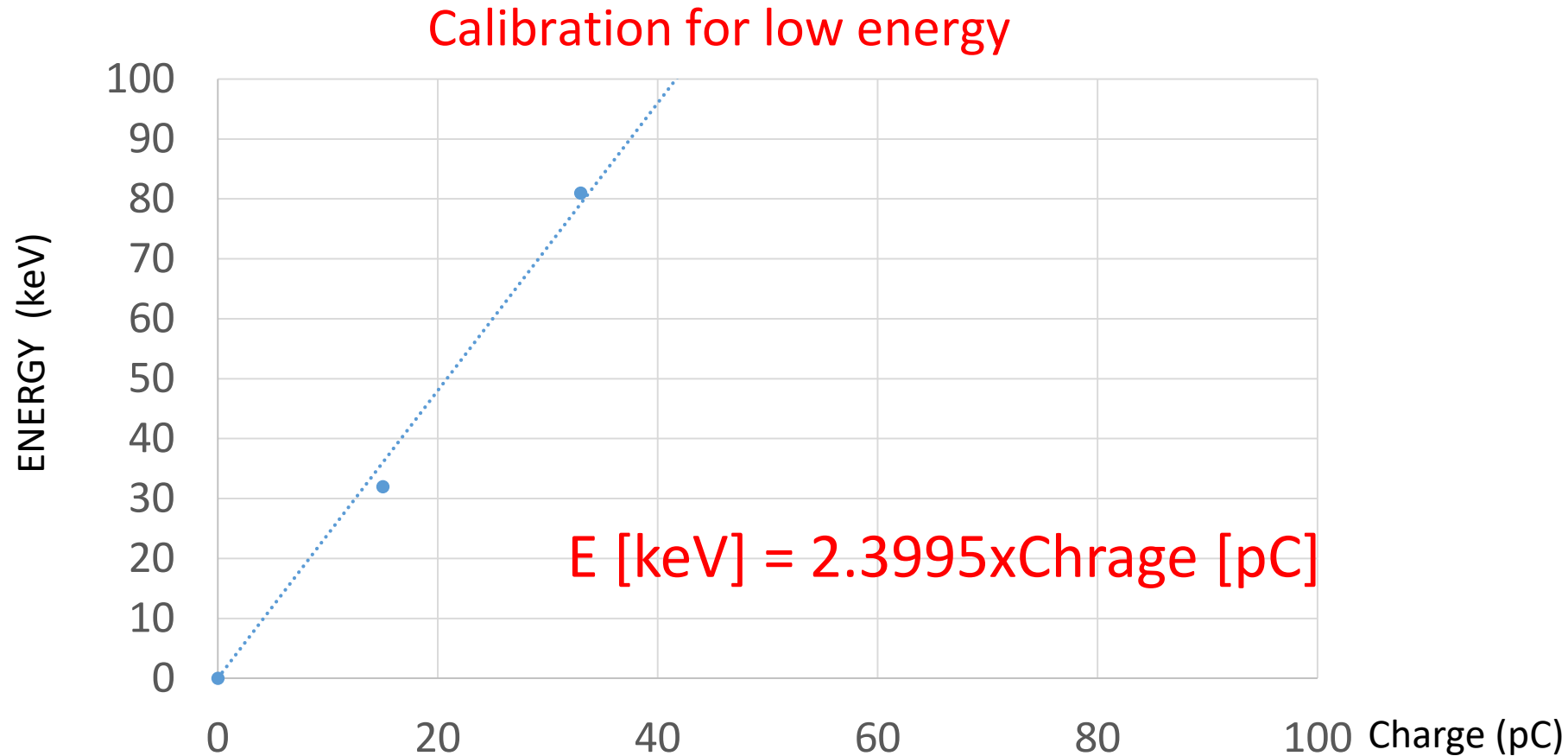
Small concentration of Tl

Charge Distribution (PSD w/ Width)

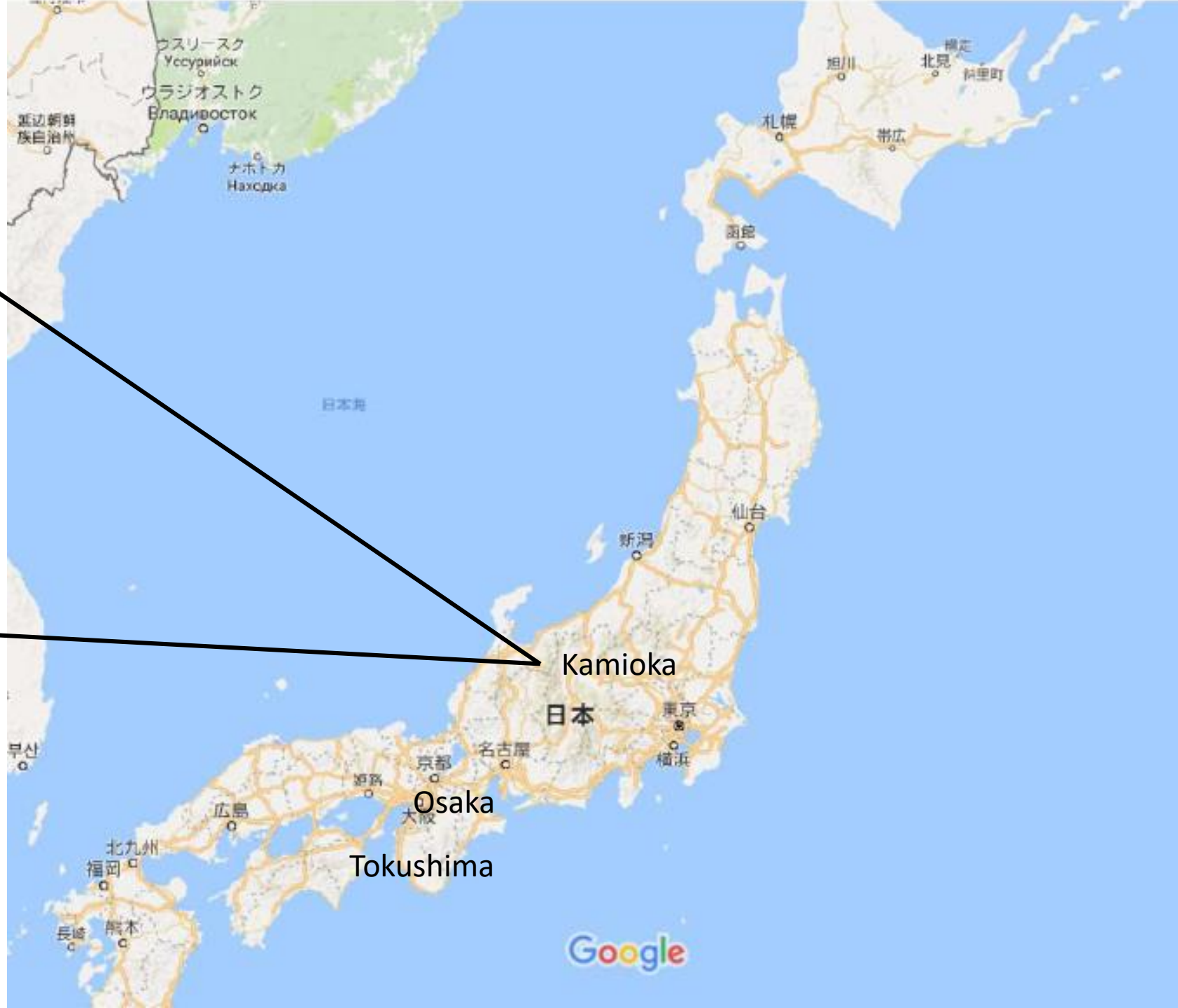
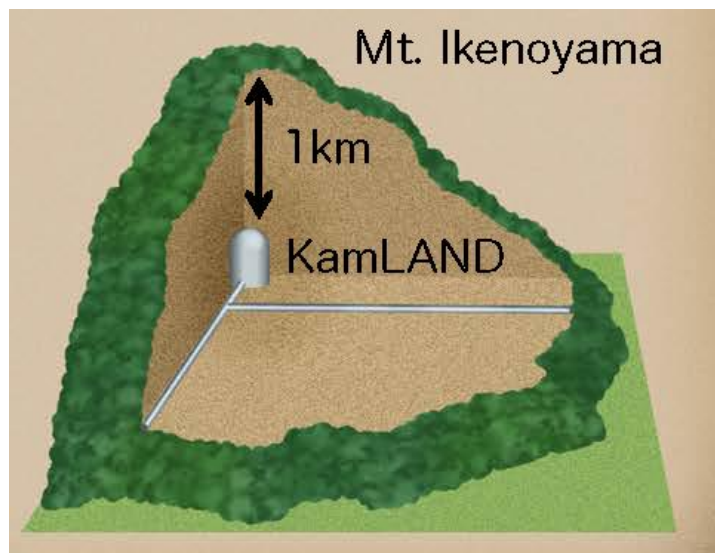


Energy calibration in low energy region

- Good linearity in low energy region.



Experimental cite



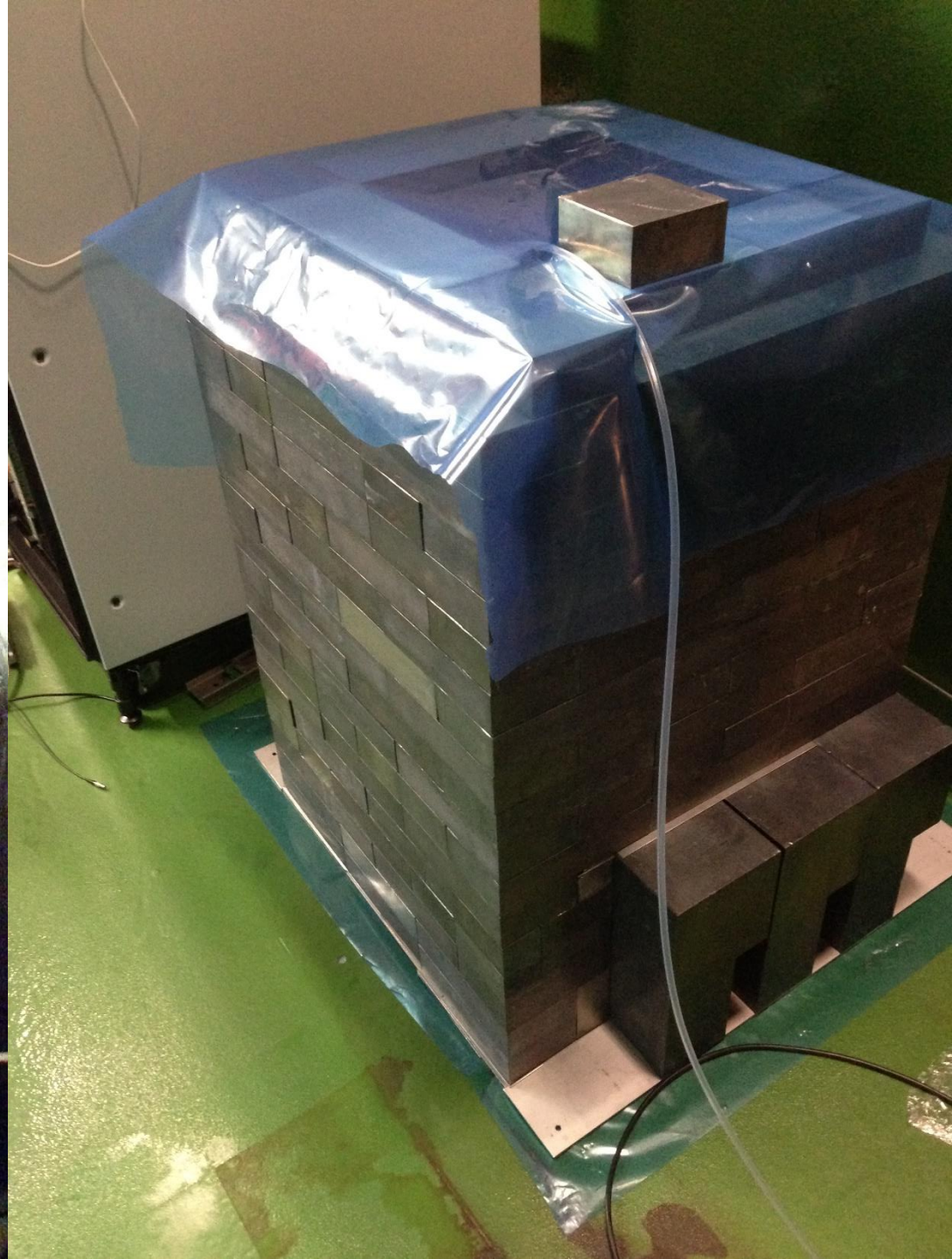
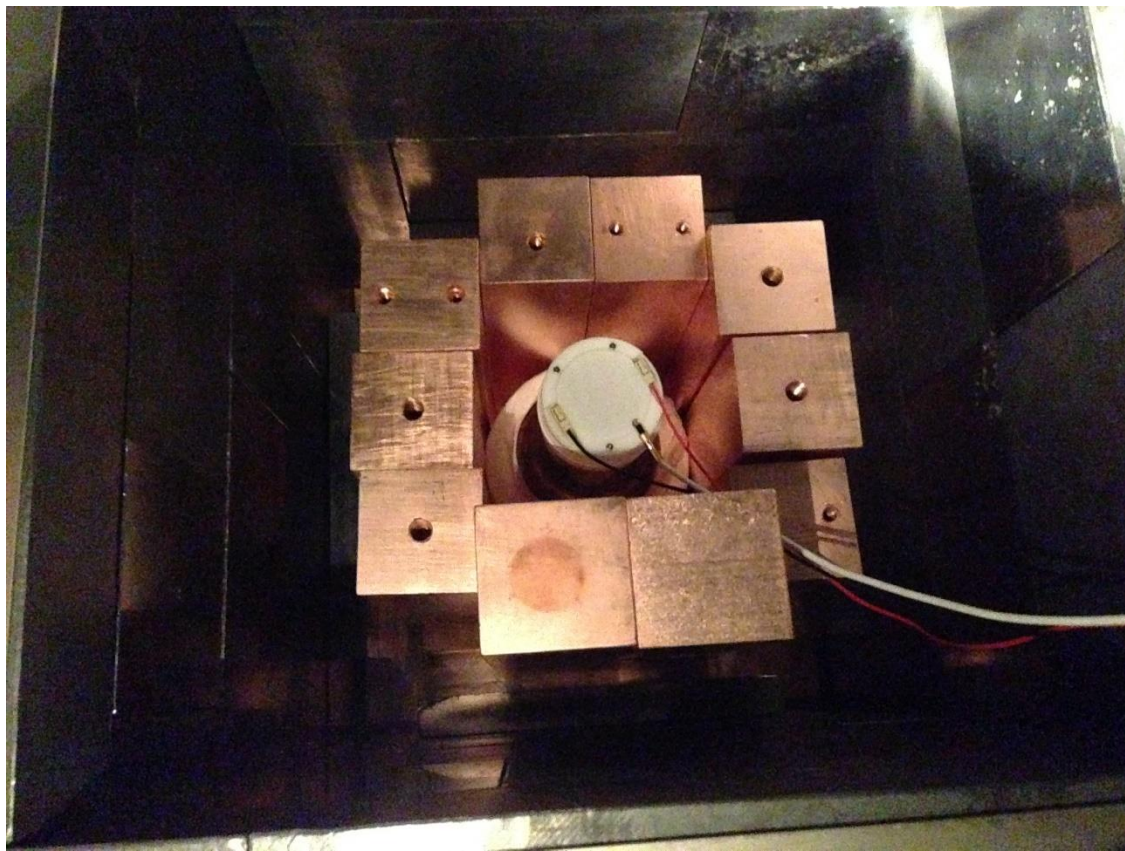
Shield construction

KamLAND area

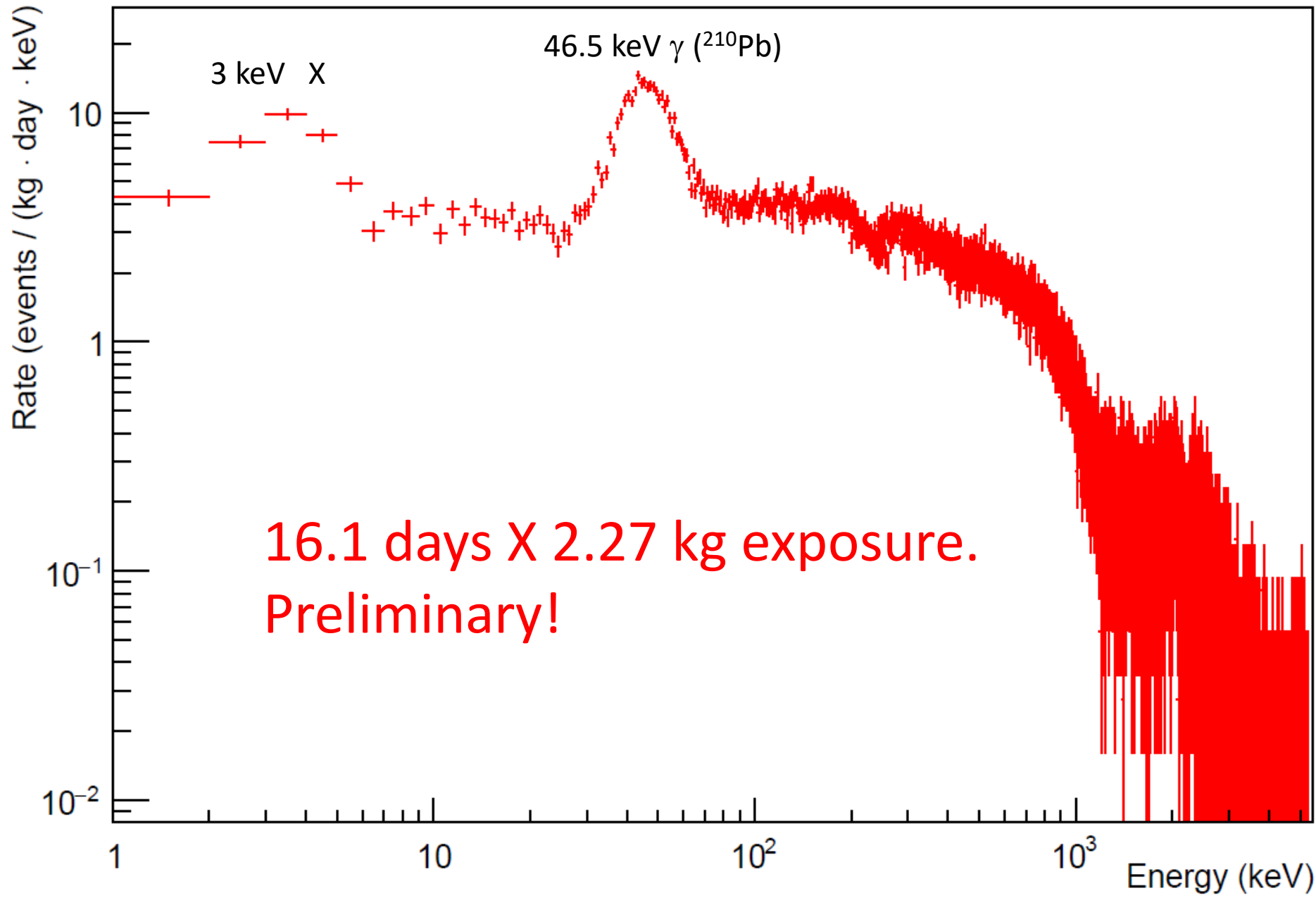
OFHC 5 cm

Old lead 20 cm

N_2 flow \rightarrow ^{222}Rn was reduced



Ingot37-mod1 & R11065-20-mod2

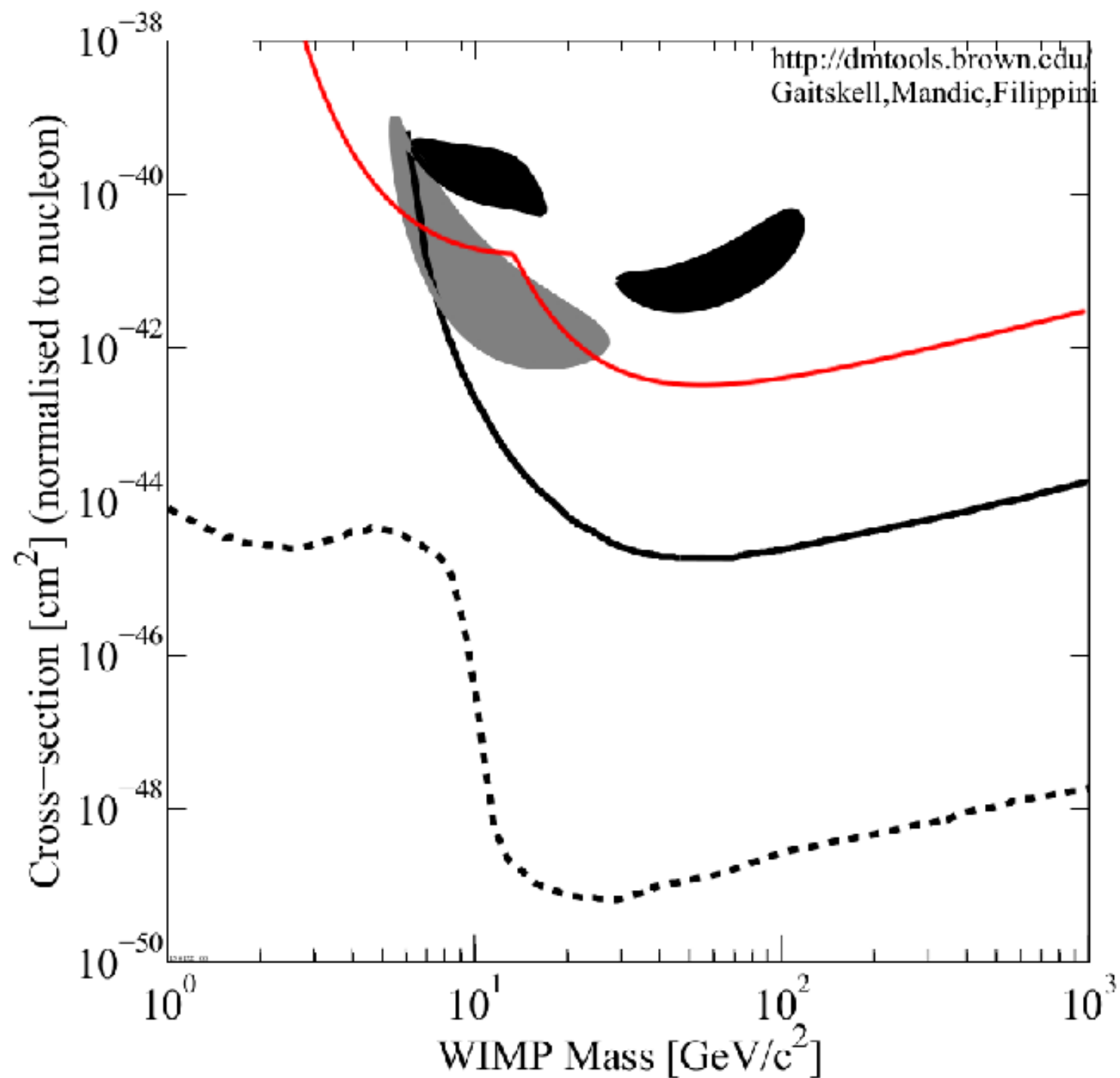


Setting a sensitivity plot

- Energy threshold = 1.5 keVee
- Event rate = 4.3 ± 0.6 /kg/day/keV (1-sigma Statistic only)
- Upper limit of the fluctuation = 0.8 /day/keV/kg (90% C.L.)

- Velocity of WIMPs = 230 km/sec
- Density of WIMPs = $0.5 \text{ GeV}/c^2/\text{cm}^3$
- Quenching factors $\begin{cases} f_I = 0.05 \\ f_{Na} = 0.4 \end{cases}$

- Low BG enough to explore DAMA region.
- More mass is needed to search for annual modulating signal.



Summary and future prospect

- Ultra radiopure NaI(Tl) is developing.
- The same level of the NaI(Tl) of DAMA/LIBRA.
 - Small activity of ^{210}Pb : $\sim 30 \mu\text{Bq/kg}$
- Low background measurement in Kamioka.
 - $101.6 \text{ mm}\phi \times 76.2 \text{ mm}$: 2.27 kg crystal.
 - 16.1 days \times 2.27 kg exposure.
 - $4.3 \pm 0.6 \text{ /kg/day/keV}$
 - Monte Carlo simulation is now running.
- Prospect
 - Further reduction of BG
 - Selecting surrounding materials: reflector, housing and light guide.
 - WIMPs search by 56 kg will be started in 2017~2018.
 - Finally 1 ton NaI(Tl) will be installed in KamLAND.

Scale up

54 kg
~2020

250 kg
~2025



KamLAND-PICO: 1ton

DAMA/LIBRAは250kg

NaI 1トン

