Background analysis of NaI(Tl) crystals for the PICOLON detector.

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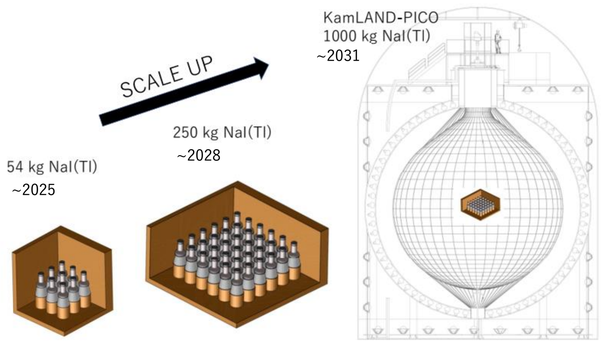
PICOLON Project

PICOLON Project
(Pure Inorganic Crystal Observatory for Low-energy Neut(ra)lino)

We search for dark matter(WIMP) using high-purity NaI(Tl) detector and verify the annual modulation reported by the DAMA/LIBRA group. [1]



Status

Ingot # 85 (2021) crystal was purified by optimized method. [2]

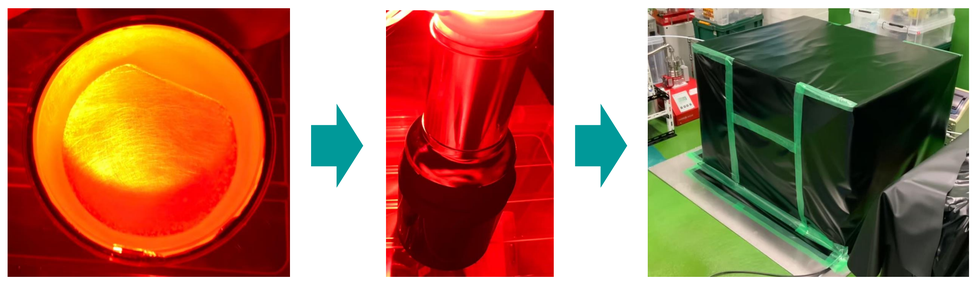
⇩

We verified the purification method.
→Ingot #94 was produced!

Reference
[1] NUCL. PHYS. AT. ENERGY **19** (2018) 307-325
[2] K.Fushimi et al. PTEP 2021 043F01

Experimental Setup

Ingot#85 & Ingot#94 →These detectors were installed each shield.



Ingot#94 (crystal) Detector(#94) Shield (# 94)

Both signals of two detectors make a DAQ trigger.

Shield (# 85)

Data Analysis

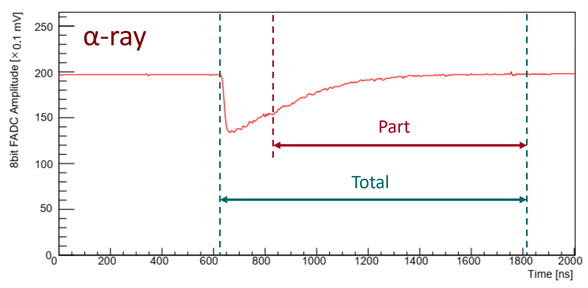
α -ray concentration:
Pulse Shape Discrimination (PSD)
α -ray & β , γ -rays events:
$\tau_\alpha \sim 190$ ns, $\tau_{\beta,\gamma} \sim 230$ ns

PSD Ratio: R_{PSD}

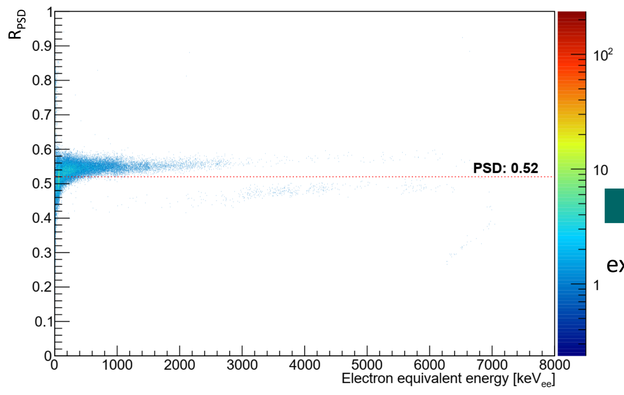
$$R_{\mathrm{PSD}} = \frac{Q_{Part}}{Q_{Total}} = \frac{\int_{0.2\mu s}^{1.2\mu s} I(t)\,dt}{\int_{0.0\mu s}^{1.2\mu s} I(t)dt}$$

⇨ α -ray events were extracted to calculate the concentration.

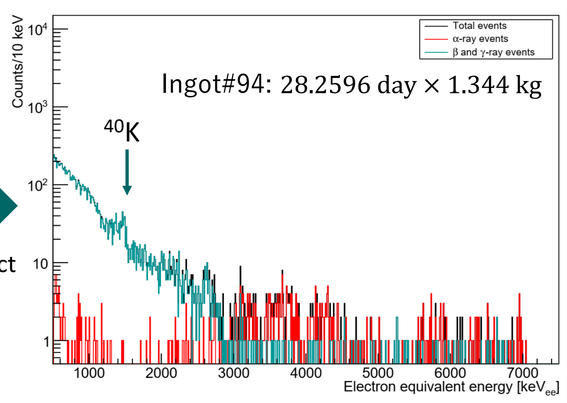
Waveform (α and β,γ event)



PSD Ratio for Electron equivalent energy.



Energy spectrum after PSD.

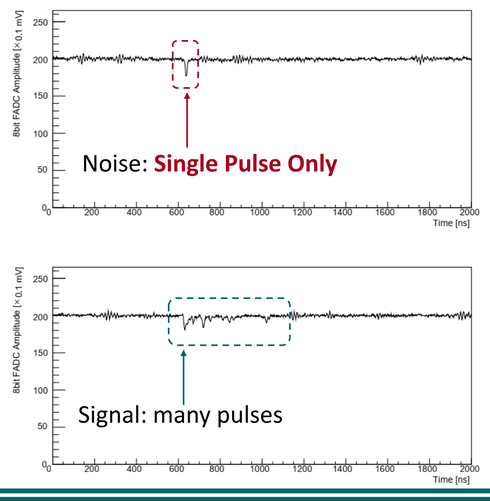


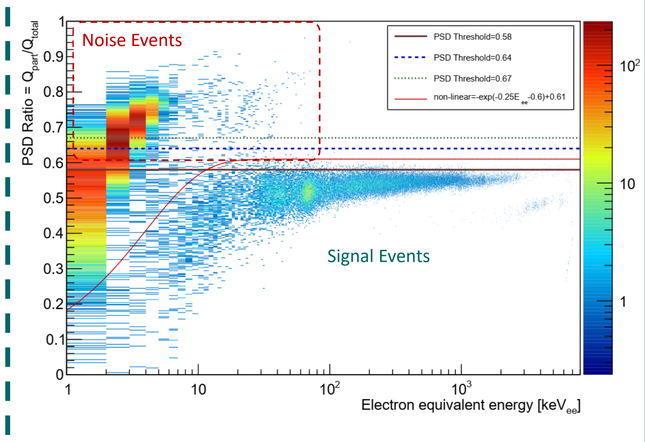
extract

Background in the low energy region:

We used two noise reduction methods.

1. Single pulse noise reduction.
2. PSD noise reduction.





Result

α -ray result

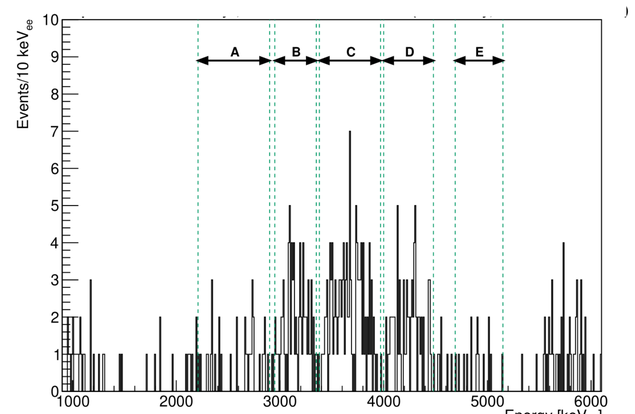
- Faint but clear 5 peaks.

	RIs	Energy Range [keV_{ee}]	Events
A	^{238}U(U) + ^{232}Th(Th)	2210-2900	33 ± 6
B	^{234}U(U) + ^{230}Th(Th) + ^{226}Ra(U)	2950-3350	72 ± 9
C	^{228}Th(Th) + ^{224}Rn*(U) + ^{210}Po(U)	3380-3970	118 ± 11
D	^{218}Po(U) + ^{212}Bi(Th) + ^{224}Rn*(U) + ^{220}Rn(Th)	4000-4480	71 ± 9
E	^{216}Po(Th)	4690-5150	15 ± 4

$$\text{Concentration} = \frac{\text{Counts}}{\text{LiveTime} \times \text{IngotMass}}$$

RI	Concentration [μBq/kg]	Goal
Th-chain (^{232}Th)	4.6 ± 1.2	<10
^{226}Ra	8.7 ± 1.5	<10
^{210}Po	28 ± 5	<50

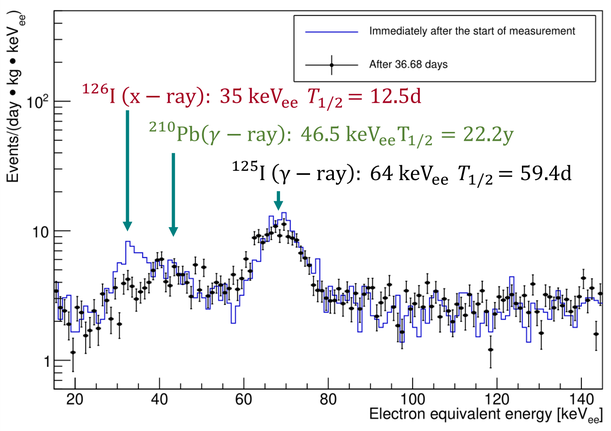
Achieved out goals!!



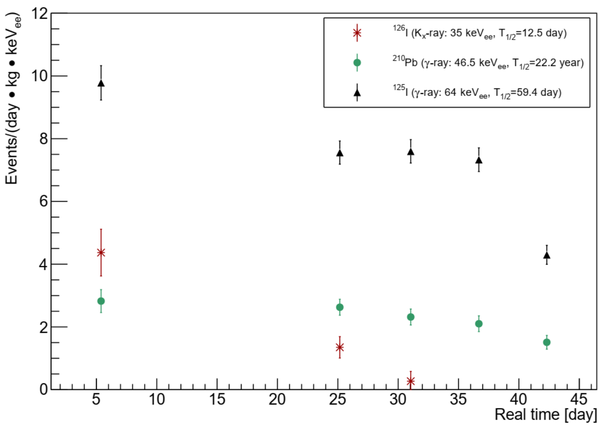
Low energy region

- 3 peaks (^{125}I、 ^{126}I、 ^{210}Pb):
  - ^{125}I, ^{126}I: We confirmed these the peaks decreased over time.

Spectral comparison



Time variation of RI concentration



Discussion

We have achieved our goal of high purity NaI(Tl).
⇨We have confirmed the reproducibility of the purification method.

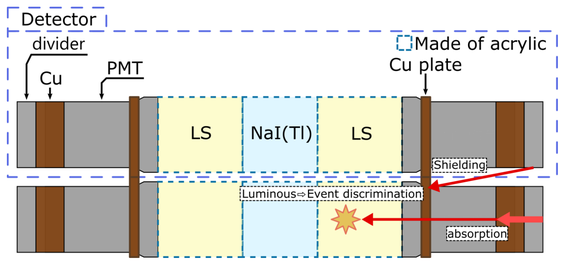
	DAMA/LIBRA (NIM A592 (2008) 297.)	Ingot #85 (2020)	Ingot #94 (This work)
Crystal size	$10.2 \times 10.2 \times 25.4$ cm^3	$7.62\phi \times 7.62$ cm^3	
^{232}Th [μBq/kg]	2~31	0.3 ± 0.5	4.6 ± 1.2
^{226}Ra [μBq/kg]	8.7~124	1.0 ± 0.4	8.7 ± 1.5
^{210}Po [μBq/kg]	5~30	< 5.7	28 ± 5

BG Rate: ~2 Events/(day・kg・keV_{ee}).

Prospect

Further reduction of backgrounds !!

- Need to remove noise below 3 keV_{ee}
  - Noise reduction using machine learning. (Most likely an event from PMT).



- Background events are reduced by active shields with detector.