Development of Ge detector for purification of CaF_2 crystals

Yumiko Kishida[A], Saori Umehara[D],Shunsuke Kurosawa[B,C,E] , Rikito Murakami[B], Yuji Ohashi[E,B],Akitoshi Sakaue[A],
Tomomi Yoshida[D],Kyoshiro Imagawa[F],Kensuke Yasuda[F], Ken-ichi Fushimi[A], Akihiro Yamaji[E, B]

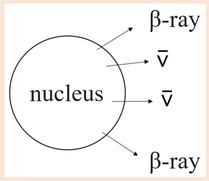
Tokushima Univ. [A], IMR Tohoku Univ. [B], ILE Osaka Univ. [C],
RCNP Osaka Univ.[D],NICHe Tohoku Univ.[E], I.S.C.Lab.[F]

1. Observation of double beta decay by ^{48}Ca[1]

Double beta decay

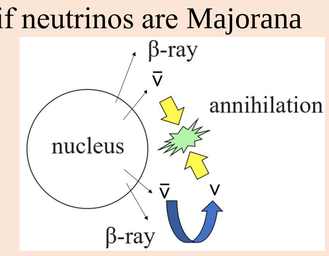
・Two neutrino double-beta decay (2νββ) is allowed within the standard model of particle physics and has been observed in several isotopes.

$$(A,Z) \rightarrow (A,Z+2) + 2e^- + 2\nu_e$$



・Neutrino-less double-beta decay (0νββ) , which can occur only if neutrinos are Majorana particles.

$$(A,Z) \rightarrow (A,Z+2) + 2e^-$$



CANDLES-Group

We search for neutrino-less double beta decay (0νββ) of ^{48}Ca.

・Why ^{48}Ca ? : $Q_{\beta\beta}$ value(4.27 MeV) is higher than background(BG)

E_{max}=2.6 MeV(^{208}Tl, γ-ray) , 3.3 MeV(^{214}Bi,β-ray)

・Low background and energy resolution is important :
to distinguish between 0νββ and background events.

☺ At Kamioka underground lab :
Shielding system for background reduction

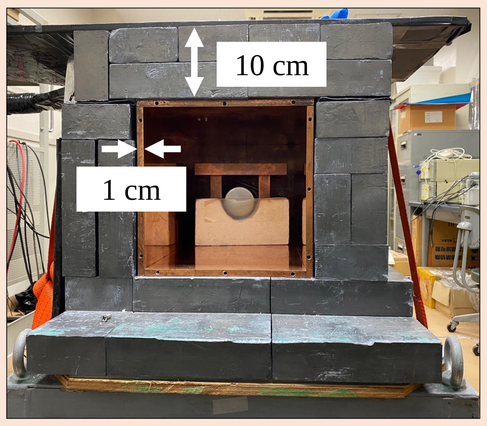
☹ Small natural abundance 0.19% (Condensation in R&D)

2. Measurement

Ge semiconductor detector

・A detector with good energy resolution
when used for gamma-ray (X-ray) spectral measurements.

・The resolution ：0.333%(4.4 keV, FWHM @ ^{60}Co 1333 keV)

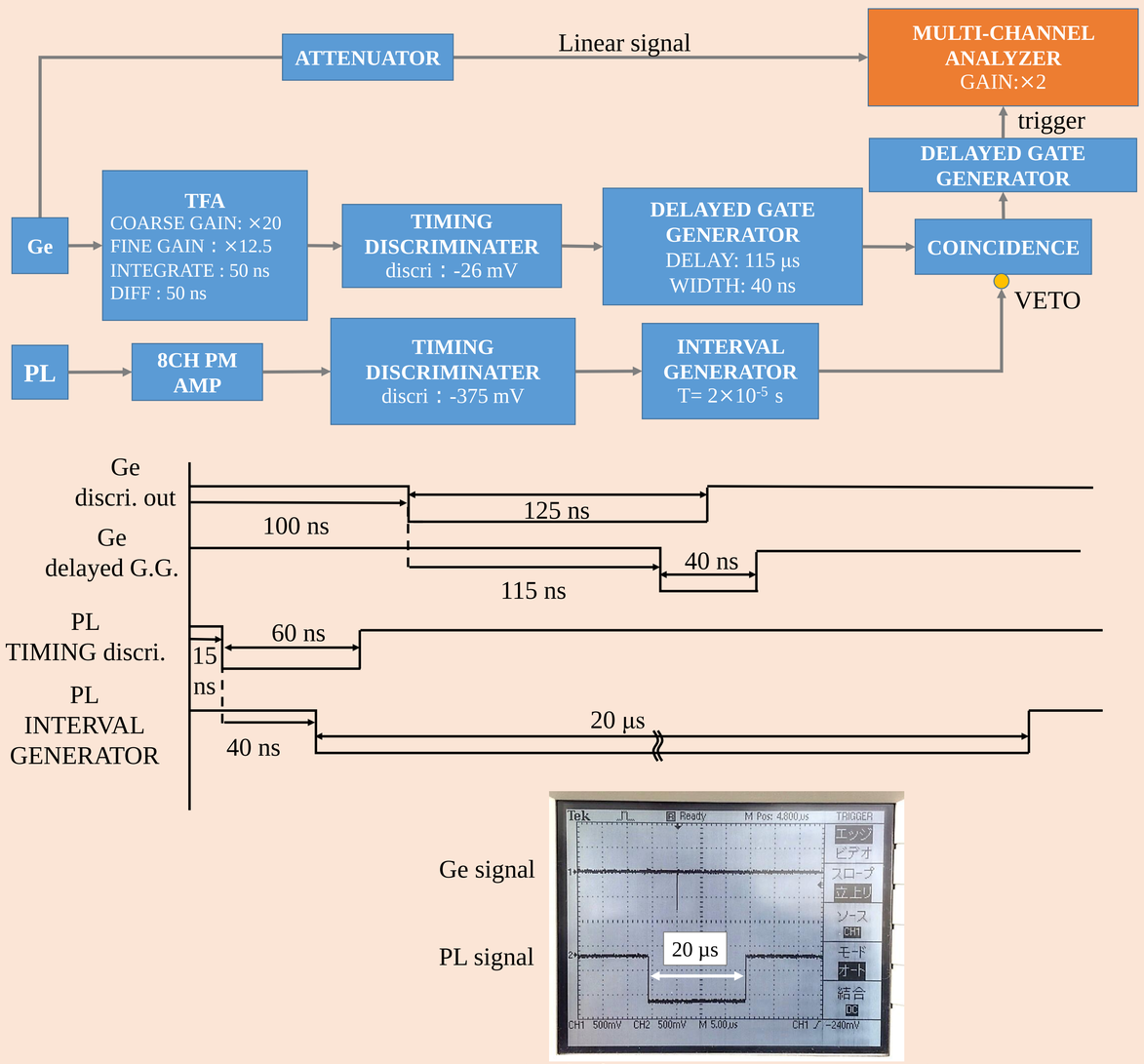


Shielding system

・Pb blocks (10 cm in thickness)
around the Ge detector.
➡ reduction of γ-ray BG from (n,γ) reaction
➡ 99.9% reduction

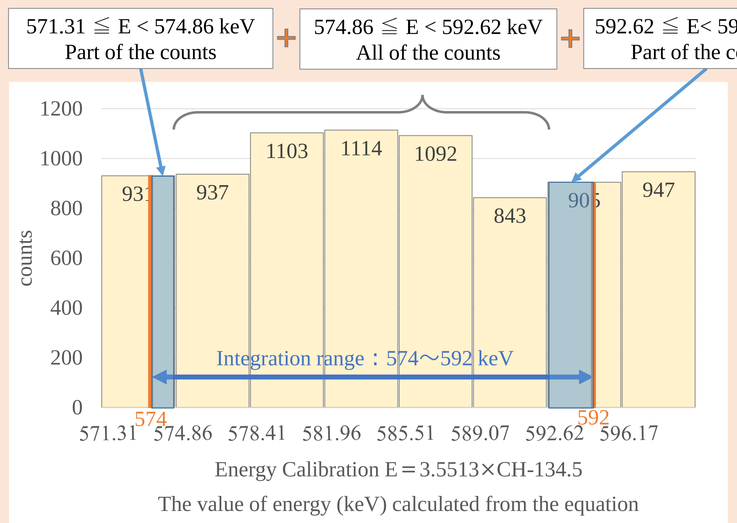
・Install Cu plates(1 cm in thickness)
inside the Pb block.
➡to reduce characteristic X-ray of Pb

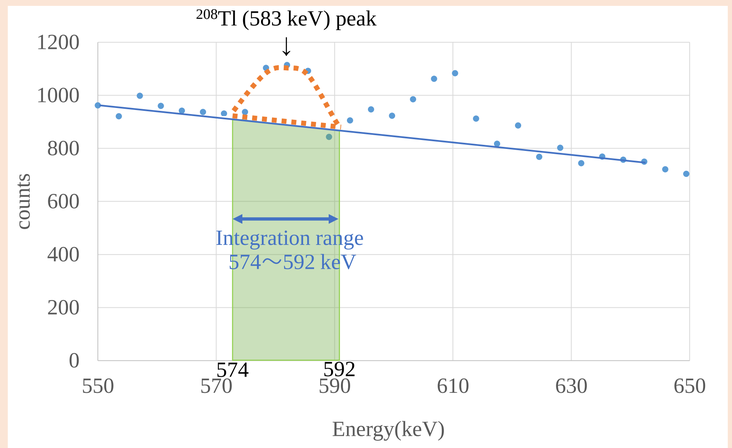
3. Circuit configuration



Timing before entering COINCIDENCE

4. Analysis





ex; ^{208}Tl (583 keV) peak

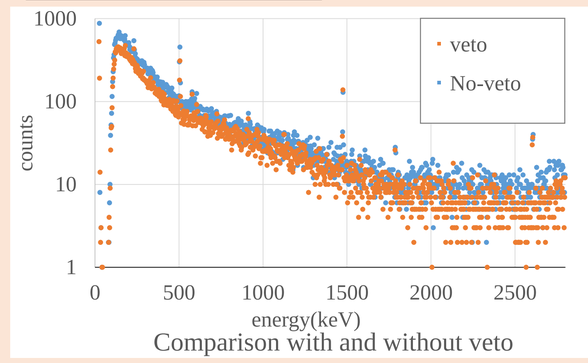
(1) Suppose that the integration range is determined to be 574 ~ 592 keV.

(2) Accumulate the counts in the range corresponding to 574 ~ 592 keV.

(3) 2 points (Energy , counts) make a linear function to subtract the count number of the green part (BG), and we get the count number of only the total absorption peak part.

5. Result [2],[3]

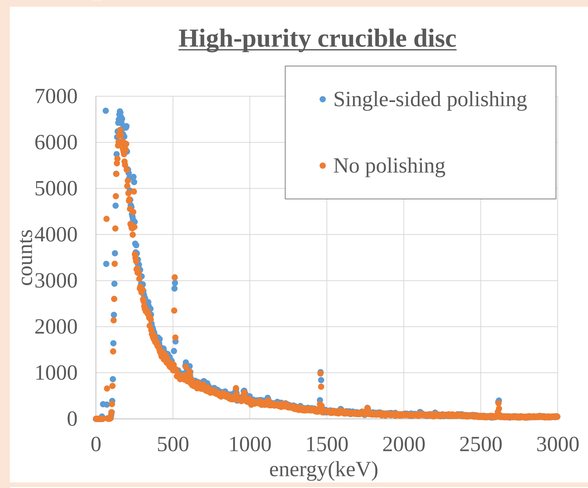
The effect of veto

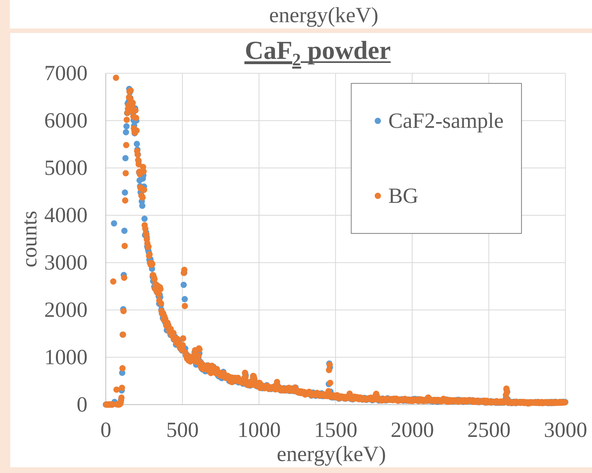


Comparison with and without veto

Discriminator value of PL	nuclide	veto or No veto	Peak counts	
-375mV	511 keV (^{208}Tl)	No	654	×0.57
		Yes	374	
	1461 keV (^{40}K)	No	171	
		Yes	167	
	2614 keV (^{208}Tl)	No	46	
		Yes	70	

Sample measurement





chain	nuclide	Nuclide energy [keV]	Polished or No polishing	radioactivity dN/dt ± $\sigma_{dN/dt}$ [mBq/kg]
Th	^{208}Tl	583	Yes	-20±10
			No	-84±9
		2615	Yes	55±38
			No	-64±36
U	^{214}Pb	352	Yes	-188±14
			No	-266±12
	^{214}Bi	609	Yes	-63±23
			No	-200±22
		1120	Yes	-592±63
			No	-681±61
		1765	Yes	-424±96
			No	-593±91
Impurities	^{40}K	1461	Yes	1072±304
			No	311±296

chain	nuclide	Nuclide energy [keV]	radioactivity dN/dt ± $\sigma_{dN/dt}$ [mBq/kg]
Th	^{208}Tl	583	-59±8
		2615	-70±29
U	^{214}Pb	352	-132±11
	^{214}Bi	609	-142±18
		1120	-238±55
		1765	-353±76
Impurities	^{40}K	1461	206±236

6. Summary and future outlook on research

・Resulting sample measurements were less than the detection limit.
・CaF_2 powder will be used as a shielding material for Ge detectors .
・Improve the sensitivity of the Ge detector 10～100mBq/kg in the surface laboratory.

7. References

[1] S. Ajimura *et al.*, PHYSICAL REVIEW D 103 , 092008(2021)
[2] 公益社団法人 日本アイソトープ協会 アイソトープ手帳 11版 机上版
[3] マルセル・ボル著 弥永 昌吉、矢野健太郎共訳　改訂増補　万能数値表