Natural Radioactivities in Materials measured with HP-Ge Detector for Low Background Detectors

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The new NaI(Tl) detector, which was a component of ELEGANT V system, is under development in order to improve the sensitivity for WIMPs search[1]. The WIMPs signals, which induced by the elastic scattering with nuclei in the detector, is a extremely rare with the order of 1 cpd/kg/keV. Thus the measurement with low background condition is required for WIMPs search.

The natural radioactivities in materials used for the detectors might be a main source of background. The detector consutructing materials should be carefully selected by the measurement of residual radioactivities.

A low-background γ -ray and X-ray detector system, ELEGANT III [2], which consists of a High Purity Ge detector, was used to measure radioactivities in various kind of materials.

The Ge detector is surround by 10 cm thick OFHC(Oxygen Free High Conductive Copper) and 10 cm thick lead shield. The OFHC is known to be quite free from radioactive contamination, namely below the observable limit of 0.2 ppb. In order to avoid backgrounds from daughters of ^{222}Rn in the air, the Ge detector and the OFHC shields are covered with the air tight container, which is filled with nitrogen gas. The whole system is covered with 15mm thick plastic scintillators which are used as veto counters agaianst cosmic-rays.

The system has been installed in the laboratory at sea-level of the RIRC (Osaka University Radio Isotope Reseach Center). A sample material has been set in front of the Ge cap. Radioactivities in a sample material are identified from the energy spectrum after subtracting that of background.

The radioactivities concerned are ^{214}Bi and ^{214}Pb, in U chain, ^{208}Tl,^{212}Pb and ^{228}Ac in Th chain, ^{40}K, ^{137}Cs, ^{60}Co. The absolute efficiency is obtained by the Monte Carlo calcuration and are consistent with the experiment by using of standard γ sources with known intensities [1, 3]. Many kinds of material have been measured. The obtained data of sample materials are listed in Table 1.

From the measured radioactivities in materials by ELEGANT III, the background rates from materials used for the renewal NaI(Tl) detector[1] can be estimated by Monte Carlo simulation as listed in Table 2. The expected background rate is less than 3.1cpd/kg/keV on the average at the energy region between 1 and 5keV. Some materials, such as Teflon reflector, OFHC Cu and so on, should have lower limits of radioactivities, and therefore their activities were checked by the ICP-MS measurement[1]. From the measured contents by ICP-MS, the total rate is estimated to be less than 0.87cpd/kg/keV assuming the radiative equilibrium in U chain. Hence the estimated background rate in the renewal NaI(Tl) detector from surrounding materials is small enough to satisfy the required condition.

References

[1] S.Yoshida, Doctral Thesis(2002), Osaka University
[2] N.Kamikubota *et al*, Nucl. Instr. and Meth.**A 245** (1986) 379.
[3] S.Shiomi, Master Thesis at Osaka university (1999)

Table 1: Measured radioactive contaminations in materials.

Material	Contamination [Bq/kg]				
	U-chain	Th-chain	^{40}K	^{137}Cs	^{60}Co
*Teflon A($200\mu m^t$)	0.12	0.06	0.55	0.05	0.03
Teflon G($85\mu m^t$)	0.10	0.08	0.84	0.05	0.05
*Al Mylar	0.07	0.06	0.37	0.04	0.06
*Quartz B	0.05	0.02	0.04	NA	0.01
*Silicon Gel	0.08	0.05	0.22	0.02	0.02
*Alumina B	0.03±0.02	0.07±0.03	0.18	0.01	0.01
*Clothes A	0.94	0.91	4.40	0.24	0.28
*Silicon Oil	0.17	0.10	0.78	0.24	0.02
Optical Greese A	0.11	0.12	0.76	—	0.03
Optical Greese B	0.07±0.05	0.08	0.33	0.05	0.03
*OFHC Cu A($1mm^t$)	0.12	0.19	0.23	0.09	0.06
*OFHC Cu C($20mm^t$)	0.04	0.05	0.07	NA	0.01
*OFHC Cu D($0.1mm^t$)	0.03	0.06	0.15	0.02	0.01
*OFHC Cu E	0.07	0.07	0.21	0.03	0.05
*Aluminum A	0.16	0.38±0.06	0.78	0.04	0.07
Aluminum B	0.28±0.16	0.30±0.10	1.29	0.02	0.09
*Glue B(Epoxy)	0.10	0.08	0.56	0.04	0.02
Glue D(ECOBOND-45)	3.74±0.24	5.94±0.20	117.±4.	0.64	0.48
*Glue E	0.37±0.18	0.22	1.26	0.05	0.07
*SUS A	0.09	0.04	0.36	0.02	0.02
*Tape Sample A	0.10±0.04	0.11	3.16±0.41	0.03	0.06
Tape Sample B	0.22±0.04	0.28±0.04	0.64±0.24	0.06	0.03
	Contamination [Bq/module]				
PMT(B89B01-2)	0.17±0.02	0.11±0.01	2.97±0.14	0.02	0.01
*PMT(B89B01-L)	0.16±0.02	0.14±0.01	2.76±0.13	0.02	0.01
PMT(EMI9307KB)	0.21±0.01	0.11±0.01	0.98±0.09	0.02	0.01

Table 2: Estimated background rate at the low energy region of the renewal NaI(Tl) detector. The values in parentheses are estimated by ICP-MS analyses.

Material	Background Rate [cpd/kg/keV]					
	U-chain	Th-chain	^{40}K	^{137}Cs	^{60}Co	Total
Teflon	0.33(—)	0.15(—)	0.35	0.02	0.03	0.87(0.40)
Al Mylar	0.001	0.001	0.002	—	—	0.004
OFHC Cu	0.49(—)	0.95(—)	0.10	0.14	0.10	1.77(0.34)
Quartz	0.16(—)	0.09(—)	0.009	—	0.01	0.28(0.02)
Optical Gel	0.005(—)	0.003(—)	0.005	—	—	0.01(0.01)
Glue	0.001	0.001	0.001	—	—	0.003
PMT	0.027±0.003	0.048±0.003	0.025±0.001	0.004	0.002	0.10±0.01
Total						3.06(0.87)