Developement of high purity NaI(Tl) crystal for dark matter search

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Dark matter search is one of the most important subject in astrophysics, particle physics and nuclear physics. The most promising dark matter candidate is the group of weakly interacting massive particles (WIMPs). The event rate in a huge (1 ton) detector is expected to be less than a few events in a day [1, 2].

A NaI(Tl) crystal with low concentration of U chain and Th chain radioactivity was developed to investigate the WIMPs dark matter by elastic scattering. The radioactive impurities in NaI(Tl) crystal were reduced by selecting raw materials and controlling surrounding environment. The radioactive isotope ^{210}Pb was effectively reduced by chemical processing.

The densities of U chain and Th chain progeny were determined by pulse shape analysis [3]. The energy spectrum of alpha ray taken for the live time of 26.7 days×1.25 kg is shown in Fig.1.

Three prominent peaks were clearly observed in the energy spectrum. The three peaks were the alpha rays emitted by ^{226}Ra, ^{222}Rn and ^{218}Po. The calculated concentration of these isotopes were 105 ± 17 μBq/kg, 108 ± 17 μBq/kg and 100 ± 14 μBq/kg, respectively. These values agrees with the secular equilibrium in radioactivity. The concentration of Th chain was calculated by fitting the small peak around 6.8 MeV which is emitted by ^{216}Po. The concentrations of other progeny in Th chain were assumed to be in secular equilibrium. The concentration of other progeny in U chain were calculated by the yields of the continuum in the energy spectrum.

Figure 1: The energy spectrum of alpha ray observed by ingot 23.

A high purity NaI(Tl) crystal was developed by DAMA/LIBRA who reported a significant signal for WIMPs candidate[?]. The concentration of radioactive contamination on their NaI(Tl) are listed in Table 1[5]. The purity of present NaI(Tl) crystal is enough to search for WIMPs candidates. It should be remarked that the concentration of ^{210}Pb was sufficiently reduced to 58 μBq/kg.
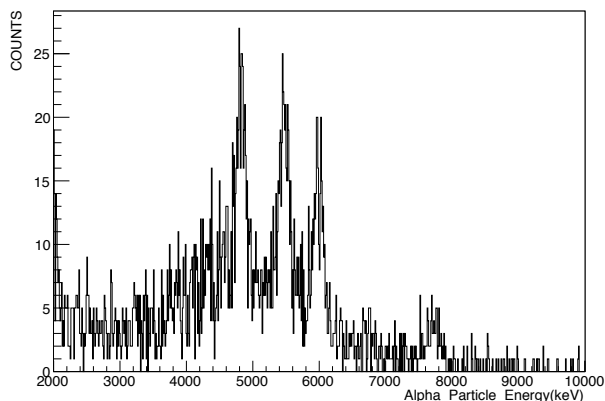
Table 1: The concentration of radioactive isotopes in a NaI(Tl) crystal for WIMPs search.

	DAMA/LIBRA	DM-ICE	This work
^{232}Th	0.5-0.7 ppt	2.5 ppt	3.3 ± 2.0 ppt
^{238}U	0.7-10 ppt	1.4 ppt	5.4 ± 0.9 ppt
^{210}Pb	5-30 μBq/kg	1470 μBq/kg	58 ± 26 μBq/kg

References

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