Background Measurement of Improved NaI(Tl) Scintillator

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The measurement of the detector performance and background event rate with the improved NaI(Tl) detector were carried out at the Oto Cosmo Observatory. The detector was re-polished and encapsulated by the Horiba Co. Ltd..

The improved NaI(Tl) detector was installed in the passive shield of the ELE-V. The ELE-V/NaI(Tl) detectors themselves act as not only the active shield, but also the effective passive shield against the surrounding materials. The improved NaI(Tl) detector was placed at the center of the bottom row(labeled NaI03) in the simple setup of the ELE-V[1].

The radioactive contaminations in the NaI(Tl) detector can be evaluated with PSD of α particles and the delayed coincidence technique. The strategies used for the evaluations of contaminations in the improved NaI(Tl) detector are as follows. (i) Total α amounts in NaI(Tl) were estimated by measuring high energy α particles with α/e PSD method[1]. (ii) The amount of ^{210}Pb in NaI(Tl) was evaluated from the energy spectrum around 50keV by fitting with the response function[1], (iii) U chain contamination was measured by tagging of elayed α event(^{214}Bi$\rightarrow^{214}$Po$\rightarrow^{210}$Pb) with the half life of 164μsec. (iv) As for Th chain contamination, sequential decay event with the half life of 297nsec
(^{212}Bi$\rightarrow^{212}$Po$\rightarrow^{208}$Pb) was detected by using the pulse shape of the signal during 1μsec. The evaluated values of contaminations in the improved NaI(Tl) detector are summarized in Table 1, together with the expected background event rate from each contamination.

Table 1: The contribution to the event rate from each activities in NaI(Tl) and materials used for the re-polished NaI(Tl) detector in the energy region between 5 and 15keV.

Components	Amount	Event Rate(cpd/kg/keV)
^{210}Pb	6.91±0.20mBq/kg	2.10±0.39
U Chain(^{226}Ra$\rightarrow^{210}$Pb)	281±6μBq/kg	0.20±0.03
Th Chain	23.0±1.1μBq/kg	0.04±0.01
Materials		< 0.87(0.10±0.01 for PMT)
Observed RateResidual		1.06±0.40(0.29±0.40)

The observed low energy spectrum after the correction with the evaluated efficiencies is shown in Fig.1, together with the raw spectrum and the cut spectrum with noise rejection[1]. From the obtained low energy spectrum, the energy threshold after the software analyses is 2keV, which is satisfied with the required condition[1]. It seems that the energy bin of 1-2keV is available to the analysis for WIMPs search. However, the event rate at this energy bin is unstable in time as shown in Fig.2(A), since the possible noise events may remain. In order to search for WIMPs, the analysis of the annual modulation was take into consideration, prospectively. Thus the energy bin of 1-2keV cannot be available to search for WIMPs. At higher energy bins, the event rate is stable as shown in Figs.2(B),(C). The RMS value of variations is consistent with the error bar for one day measurement.

The event rate at the lowest energy(2-3keV bin) is 4.06±0.16cpd/kg/keV with the statistic of 753.6kg×day. It is corresponding to 4.06±1.07cpd/kg/keV for one day measurement. The average event rate within the energy interval between 5 and 15 keV is 3.50±0.03 cpd/kg/keV. The background from ^{210}Pb can be estimated to be 2.10±0.39cpd/kg/keV. Thus around 60% of the total event is due to the residual ^{210}Pb activity in the improved NaI(Tl) detector.

If the background from the materials except for the photomultipliers would be maximumly affected, the residual background rate is turned out to be 0.29±0.40cpd/kg/keV. Hence most of the background could be identified and the reason why the event rate can not be achieved to the level of 2cpd/kg/keV(required BG level[1]) is due to the residual ^{210}Pb contamination in the NaI(Tl) detector, which can not be reduced by shaving off and re-polishing the surface of the NaI(Tl) detector[2].

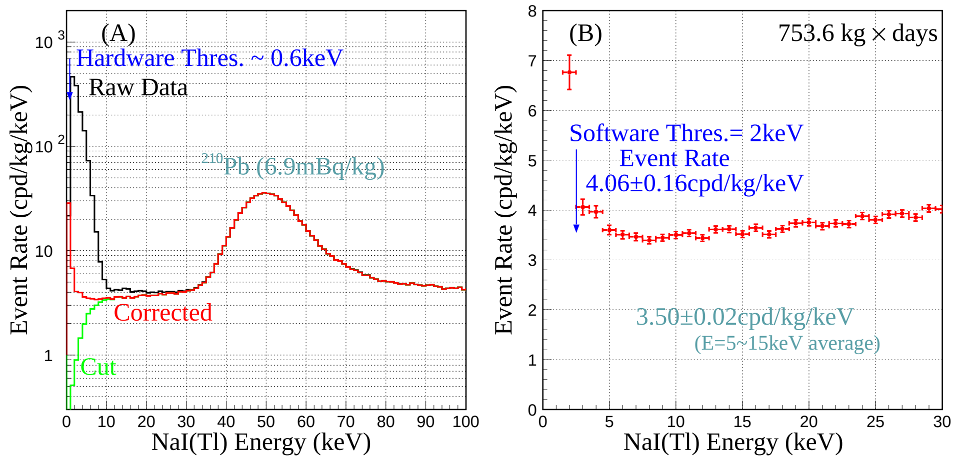

Figure 1: The energy spectrum observed with the improved NaI(Tl) detector at the low energy region. (A)The energy spectra of raw data collected at the Oto Cosmo Observatory, and of survived events after cut for the rejection of the noise events and the corrected energy spectrum by the measured efficiency. (B)The energy spectrum below 30keV, together with the statistical errors.

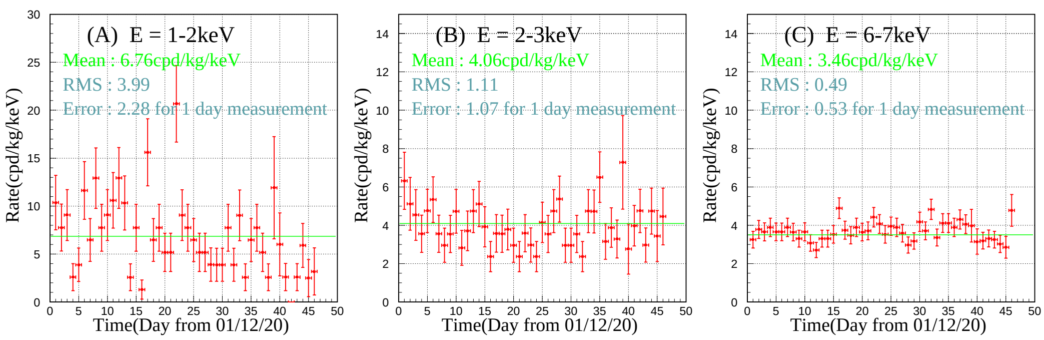

Figure 2: Observed variations of event rates with in a day at energy bins of (A)1-2keV, (B)2-3keV and (C)6-7keV.

References

[1] S.Yoshida, Doctral Thesis(2002), Osaka University.
[2] S.Yoshida *et al.*,RCNP Annual Report(2001).