Search for the Annual Modulation of WIMPs by means of ELEGANT V

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Experimental and theoretical studies for the universe indicate that at least 90% of the mass in the universe is composed mostly of invisible matters (DM) [1]. The cold dark matter (CDM) particles, such as Weakly Interacting Massive Particles(WIMPs), is of current interest from the view points of astroparticle and nuclear physics. WIMPs could be detected in the laboratory through the nuclear recoil produced by their elastic and inelastic scattering with target nuclei in the detector [2]. Investigating the annual modulation is one of the most convincing evidence for WIMPs signals [3]. The NaI scintillator has the following merits; a large volume crystal with extremely high purity can be made, easy to handle, 100% isotopic contents on odd-A isotopes, and large light output (low energy threshold).

The ultra-low-background high sensitivity detector ELEGANT V (ELEctron GAmma ray Neutrino Telescope) has been applied for this study. Details of this system are given in ref [4].

The data considered here have been collected with 6 modules of NaI(Tl) detectors, partly of the 20 modules of NaI(Tl) of ELEGANT V, at the Oto Cosmo Observatory. A statistics of 30848kg×day is available for the annual modulation study, corresponding to about 141days. It has been collected roughly from the end of May to the middle of January.

To search for the existence of the annual modulation in the data, one could simply look for the difference between the event rates of June and that of December [3]. The expected energy spectrum of recoil nuclei in the target detector is given in ref. [2],

The observed energy spectra at the low energy region were summed over about a month around the maximum(June 2nd) and the minimum(December 4th) of the modulation, as shown in Fig. 1. The live times of each data are 5531kg×day at June and 5304kg×day at December, respectively.

The difference of the peak yield between energy spectra in Fig. 1 could be explained by the contribution of ^{210}Pb contamination in NaI detectors, and its contribution to subtracted spectrum at low energy region was estimated by the Monte Carlo simulation. The final energy spectrum was obtained by subtracting the energy spectrum in December and the contribution of ^{210}Pb from the energy spectrum in June, as shown in Fig. 2

No significant deviation above statistical fluctuation was also found in the present work. The obtained upper limit on the modulation amplitude $S_{limit} \leq 0.12$/day/kg (90%C.L.) was derived from the analyzing energy interval between 8.8keV and 15.8keV.

One can convert S_m to the limit on the equivalent cross section for a single proton by the formulae given in ref [2], The converted exclusion plots on the spin-independent and spin-dependent WIMPs are shown in Fig. 3. The most stringent limit of 4.0×10^{-4}nb was obtained for the light WIMPs with the mass around 20GeV for spin dependent interaction. The obtained limit was improved by a factor of around 6 compared with the limit previously derived at the Kamioka Underground Laboratory [5].

The DAMA collaboration reported preliminary result [10] suggesting that the effect of the annual modulation might be present in their data. The data considered in the present work were not sensitive enough to neither exclude nor prove the claimed candidate, with a cross section $\sigma_{p-\chi} \simeq 1.0 \times 10^{-5}$pb for 50GeV WIMPs mass. After improvement of the energy threshold of NaI(Tl) detectors, the experiment is now running for further investigation of

the annual modulation of WIMPs, and will be explored the allowed region from DAMA/NaI data.

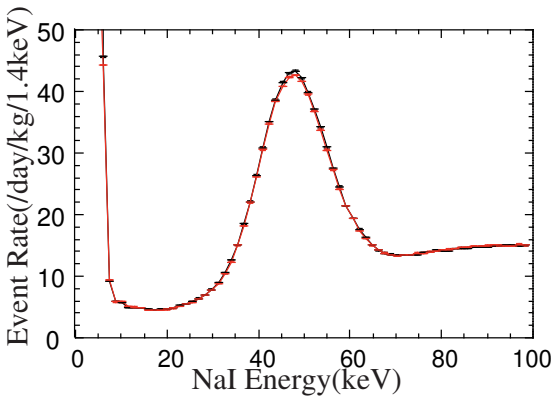

Figure 1: The energy spectra in the region of interest from 6 NaI(Tl) modules. The difference between two energy spectra was explained by the ^{210}Pb contamination inside NaI(Tl).

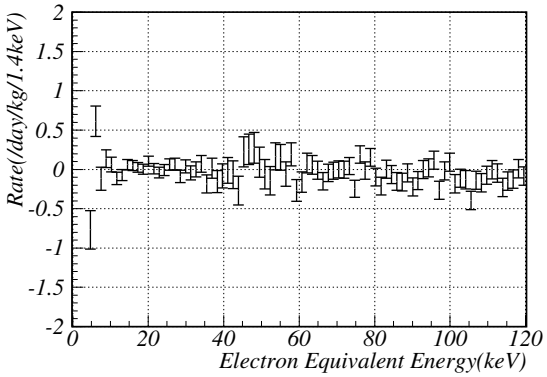

Figure 2: The difference between the data taken at June and December. The contribution from ^{210}Pb intrinsic contamination in NaI was also subtracted.

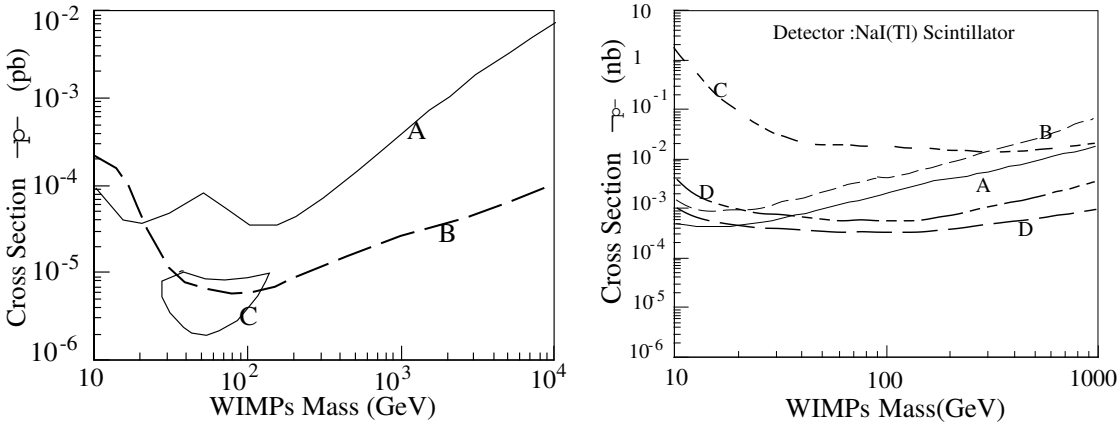

Figure 3: Left: The exclusion plot on $\sigma_{p-\chi}$ for spin dependent interaction. A: The present work; B: ELE-V at Kamioka [5]; C: Canfranc NaI [7]; D: UK NaI [8]; E: DAMA/NaI [9]. Right:The exclusion plot on $\sigma_{p-\chi}$ for spin independent interaction. A: The present work; B: DAMA/NaI [9]; C: DAMA/NaI [10].

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