Low background measurement with highly pure NaI(Tl)

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Discovering the nature of the dark matter of the universe is one of the big challenges in cosmology, astrophysics, and particle physics. Recently two experiments[1, 2], both using cryogenic heat-and-ionization germanium detectors, have reported to exclude at more than 90%CL the central value deduced by DAMA from its annual modulation signal for the WIMP mass and its nucleon scattering cross-section (M_W = 52 GeV/c^2 and $\sigma_n = 7.2 \times 10^{-6}$ pb, respectively)[3]. However germanium detectors are sensitive to only spin-independent interaction. So dark matter search with same target(NaI) of DAMA has become recently of even greater importance.

Tokushima Univ. and Osaka Univ. collaboration has been developed highly sensitive detector for dark matter search which has been applied NaI(Tl). We will study regions of WIMP parameter space favored by the DAMA positive signal. The our goal is to perform selective measurement of inelastic scattering of nuclei. The expected signals are very low energy recoils (of the order of tens of keV) at event rates depending on model parameters, for example, in most of the models below 1/day/kg. Therefore, in addition to low threshold detection energies, low radioactive background detectors and environment are required. We successfully produced the highly pure NaI(Tl) detector. The purity of it correspond to that of DAMA. This paper described the low back ground measurement with this detector.

A highly pure NaI(Tl) scintillator has been developed in collaboration with Horiba Ltd. The dimension of crystal is 50.8mm $\times$ 50.8mmϕ (0.38kg). The amount of ^{214}Po in the scintillator has been measured by means of delayed coincidence method. The measured activity concentration of ^{214}Po was 12.7$\pm$3.4μBq/kg. The α-ray spectrum was extracted by pulse shape discrimination (PSD)[4]. The peak yields of α-rays was as large as 11.27$\pm$0.10mBq/kg, which may be mostly due to the ^{210}Po in the NaI(Tl) detector. The impurity in the scintillator was stadyed by measuring α spectrum.[5]

Not only nucleus belong to U-chain but also ^{40}K seriously affects the sensitivity of a detector for dark matter search. In particular, to determine the potassium content measurements have been performed because it is difficult to distinguish radiation due to internal ^{40}K from external radiation. The experiment is located in the Oto Cosmo Observatory, which belongs to RCNP Osaka Univ. under a 470m(1400m.w.e.) rock overburden. The new scintillator was installed into ELEGANT V shield, which was placed into air tight box and was shielded from radioactive environment by 10cm thick OFHC (Oxygen Free High Conductivity) copper and 15cm thick low background lead. Pure nitrogen gas was circulated in order to purge radon gas in the box. The radon concentration in the air tight box was around 8mBq/m^3. External γ rays from environment are reduced by three orders of magnitude by using the ELEGANT

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V shield. The new NaI(Tl) scintillator was viewed by a photomultiplier tube (PMT) through a 20cm light guide.

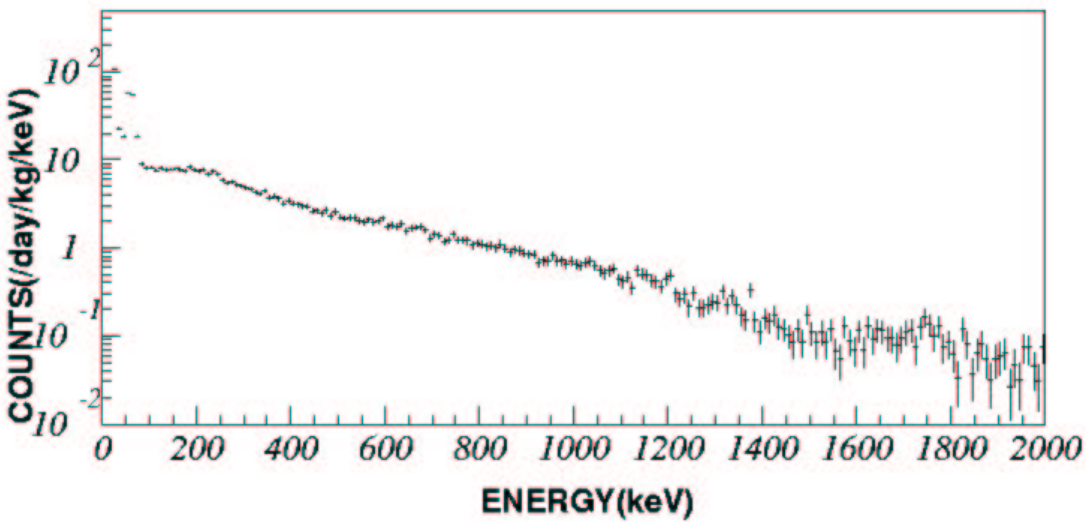

Figure 1: The energy spectrum observed with the highly pure NaI(Tl) scintillator.

The ^{40}K concentration has been then derived by staudying the presence of the γ peak at 1460keV. In Fig.1 the energy distribution measured at ELEGANT-V shield for the live time of 10.8kg·day is shown. The fitted value of the peak yield of 1461keV gamma ray was -80 ± 191 events. An upper limit at 68% C.L. was derived: ^{nat}K$<$ 48 ppb folloing the procedure recommended by Particle Data Group.[6]

The large peak around 50keV in the spectrum due to the ^{210}Pb contamination. The radioactivity of ^{210}Pb, 12.9$\pm$0.1mBq/kg was obtained from the yield of the ^{210}Pb events. The radioactivity of ^{210}Pb correspond to the that of ^{210}Po which was determined from α spectrum [5]. Each RI's of ^{226}Ra$\longrightarrow^{214}$Po in U-chain reach a state of secular equilibrium and are the same radioactivity. This result consistent with the conclusion that the peak yield of α spectrum extracted by PSD was due to the ^{210}Po.

The gamma spectraum was stadied to estimate the effect of radioactivity in the highly pure NaI(Tl) scintillator. The detecor was installed inside the shield of ELEGANT-V. The requirement of ^{40}K content was archived. The radioactivty of ^{210}Pb obtained from the peak yield of 46.5keV γ-ray was consistent with the one of α supectrum. We started investigating manufacture process to reduce the lead in the detector. In near future the sensitivity to nucleon-neutralino inelastic scattering will be improved.

References

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