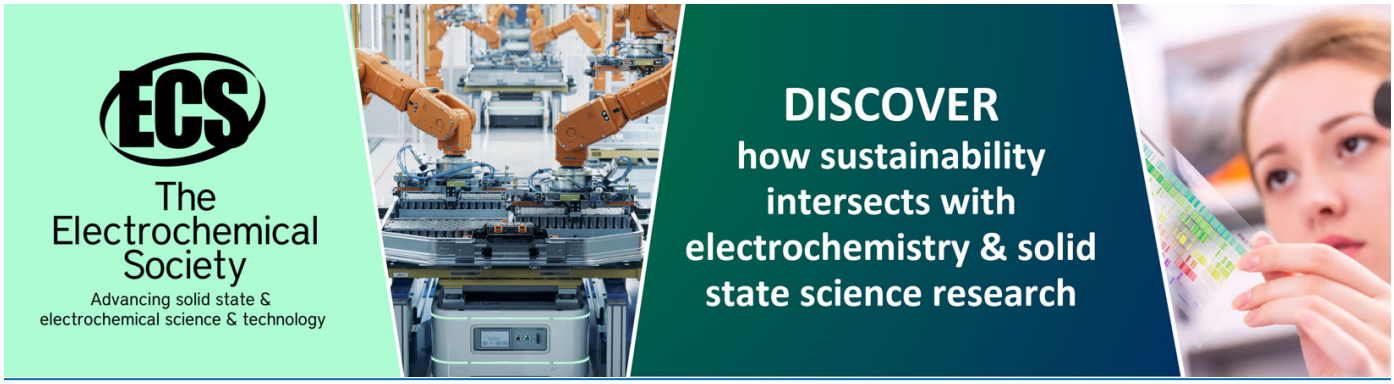
Dark matter search by means of segmented scintillator (PICO-LON)



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Dark matter search by means of segmented scintillator (PICO-LON)

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Abstract. Thin and wide area inorganic crystal was applied to search for WIMPs dark matter. A multilayer NaI(Tl) detector has great advantages for WIMPs dark matter search. The performance of the thin (5mm thickness) and wide area (18cm×18cm) was developed. The performance tests were performed and the results were good for dark matter search.

1. PICO-LON detector system

Dark matter (DM) problem is a current important subject in astroparticle physics. WIMPs (Weakly Interacting Massive Particles) is one of the most promising candidates for DM. Many projects proposed the highly sensitive detectors with various target nucleus. DAMA has reported for several years annual modulation of the WIMPs signal [1, 2]. On the other hand, the allowed region of the cross section and the mass of WIMPs by DAMA has been excluded by other experiments using another target nuclei [3, 4, 5, 6].

We propose a highly sensitive detector system to extract the WIMPs signal. The project PICO-LON (Planar Inorganic Crystal Observation for LOw-background Neutr(al)ino) has great advantage. PICO-LON system distinguishes the type of interaction of WIMPs [7]. ^{127}I has a low energy excited state (57.6keV) which is excited via spin-coupled scattering. The 57.6keV gamma ray is emitted in coincidence with the nuclear recoil. The gamma ray signal and the nuclear recoil signal is separately observed by neighboring module as shown in Fig.1. In the case of elastic scattering of WIMPs, only one plate of NaI(Tl) makes the signal (S1). In the case of inelastic excitation, emitted gamma ray escapes from the original crystal and detected in the other crystal as S2 in Fig.1. The interaction type is clearly distinguished by segmentation of the detector system.

PICO-LON test module has been developed by Horiba Ltd. The dimension of the NaI(Tl) crystal is 18cm×18cm×0.5cm. The crystal was encapsulated with thin aluminum sheet and quartz light guides to avoid the humidity. Scintillation photons are guided to the edge of the

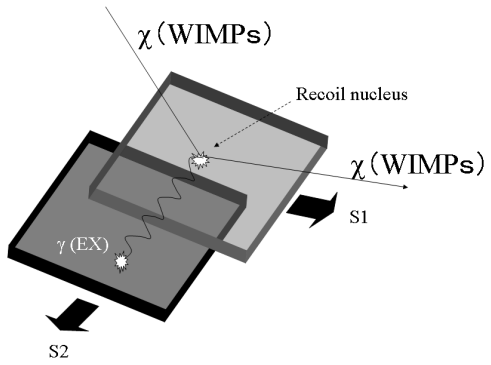

Figure 1. Multi NaI(Tl) plates system to distinguish the interaction type of WIMPs.

NaI(Tl) crystal by total reflection and a reflector with good reflective efficiency. The 12 modules of photomultiplier tubes (PMT) are contacted at the edge of quartz light guides by silicon oil. Each current pulses from the PMTs are individually integrated by analog-to-digital converter (ADC).

2. Performance of thin and large area NaI(Tl) scintillator

The most important performance for WIMPs detector is its low energy threshold and good energy resolution. Since the recoil energy due to WIMPs-nuclear interaction is less than several tens keV and the scintillation output response for nuclear recoil is factor 0.05 of the response of electron, the energy threshold must be less than 5keV electron equivalent energy.

In order to clearly distinguish the peak of 57.6keV gamma ray from the most serious background peak due to 46.5keV gamma ray from ^{210}Pb, the energy resolution around 60keV is needed to be less than 20% in FWHM.

The energy threshold and the energy resolution were measured by irradiating the gamma ray from ^{241}Am and ^{133}Ba sources. The scintillation light output spectrum are shown in Fig.2(A) and (B).

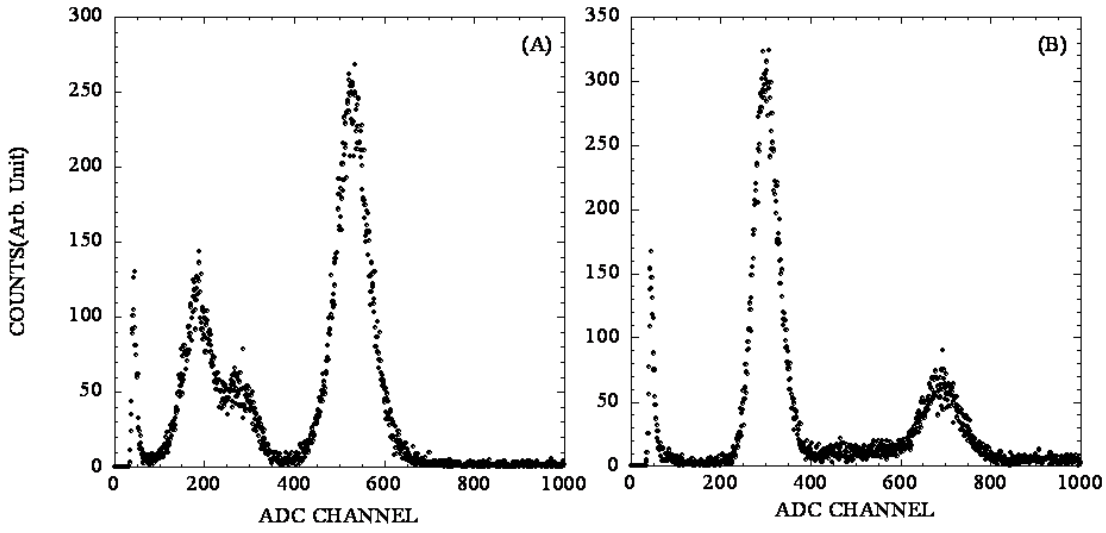

Figure 2. The energy spectra of thin NaI(Tl) plate with (A)^{241}Am. and (B)^{133}Ba.

Table 1. Energy resolution of prominent peaks of gamma rays and X ray.

Energy(keV)	$\Delta E/E(\%)$
31	17
59.5	14
81.0	10

The energy resolution was calculated by gauss fitting. In the Fig.2(A), 59.5keV gamma ray, 17keV X-ray and 31keV escape peak were clearly observed. The obtained energy resolutions of each peaks are listed in Table 1. It has been shown that the energy resolution is enough for observing the inelastic excitation.

The energy threshold was measured without any radioactive sources. The electric noise was reduced down to about 3keV, which was enough for observing the nuclear recoil.

3. Future prospect

The thin and wide area NaI(Tl) crystal was developed for studying nuclear rare processes. The PICO-LON detector system has the great advantages for dark matter search; selection power of the events, good energy resolution and low energy threshold. The purification of NaI crystal and selection of surrounding materials are now undergoing.

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References

[1] R.Bernabei et al., Nucl. Instr. and Meth. in Phys. Res.**A592** (2008) 297-315.
[2] P.Belli et al., Paper in this proceedings.
[3] Z.Ahmed et al., Phys. Rev. Lett. **102** (2009) 011301.
[4] J.Angle et al., Phys. Rev. Lett. **100** (2008) 021303.
[5] K.Abe et al., Jour. of Phys.: Conf. Ser.**120** (2008) 042022.
[6] J.Gascon, arXiv:0906.4232v1[astro-ph.HE].
[7] K.Fushimi et al., Jour. of the Phys. Soc. Japan **74** (2005) 3117-3121.