NEWAGE

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Abstract. The NEWAGE project (NEw generation WIMP search with an Advanced Gaseous tracking device Experiment) is a direction-sensitive dark matter search experiment, searching for WIMPs (Weakly Interacting Massive Particle) via nuclear recoil. We adopted µ-PIC (micro PIxel Chamber) to our detector. Then, we first obtained and updated the direction-sensitive exclusion limit. In this paper, we introduce NEWAGE experiment.

1. Direction sensitive dark matter search

Non-baryonic dark matter is widely believed to account for a large fraction of the mass in the universe. But the nature of this dark matter is still unknown. The Weakly Interacting Massive Particle (WIMP) is one dark matter candidate which is well motivated by cosmology and supersymmetry. Among the particles of the supersymmetric standard model, the lightest neutral supersymmetric particle, called the neutralino, is thought to be a good WIMP candidate. Direct detection of the dark matter is achieved via WIMP-nucleus elastic scattering. The expected event rate is very low because the cross section for a WIMP interacting with ordinal matter is very small. So, if we are to discriminate dark matter signals from background signals, an additional signal other than the simple energy spectrum is needed.

An annual modulation of the event rate is one of the well studied distinct signals. Dark matter is considered to be distributed throughout our milky-way galaxy, and since the earth goes around the sun, the relative velocity of the dark matter with respect to the earth would have an annual variation. In this scenario, the event rate is expected to show an annual modulation of a few %[1]. The DAMA group reported that they detected dark matter by observing such an annual modulation[2][3]. Recently, CoGeNT group also reported the observation of the annual modulation[4]. But some other groups have reported inconsistent results[5][6]. From these recent results, a new method is required to obtain more precise evidence.

A direction-sensitive method is capable of providing another distinct signal[7][8]. Owing to the motion of the solar system within the galaxy, the dark matter seems to come from one direction like a wind on the earth. The direction-sensitive method detects this incoming direction by measuring the recoil nuclear tracks. The recoil angle relative to the expected wind direction is expected to have a large asymmetry between the forward scattering and back scattering. We can
thus obtain a signal of a similar significance with 1000 times fewer statistics with this method compared to the conventional method.

2. NEWAGE experiment
We have been promoting the NEWAGE project (NEw generation WIMP search with an Advanced Gaseous tracking device experiment). We use a $\mu$-TPC (micro Time-Projection-Chamber)$[9]$ to detect three-dimensional nuclear tracks. We applied the $\mu$-PIC[10] for the readout of the $\mu$-TPC. Though the typical length of nuclear track scattered by dark matter is less than 1cm, an $\mu$-PIC with a 400$\mu$m pitch can detect these short tracks with a certain angular resolution. Additionally, such detailed track information can be used to discriminate from the gamma-ray background. The length of a nuclear event is much shorter than those of background electron tracks scattered by gamma-rays of the same observed energy. Thus, we can discriminate background electron tracks from nuclear tracks by the track length with a good discrimination factor ($< 1 \times 10^{-5}$).

2.1. Detector
A schematic drawing of $\mu$-TPC is shown in Figure 1. We have two large-size $\mu$-TPCs named NEWAGE-0.3a (at Kamioka underground laboratory) and NEWAGE-0.3b (at Kyoto surface laboratory). We use NEWAGE-0.3a as the dark matter search, on the other hand, NEWAGE-0.3b as R&Ds.

The $\mu$-PIC, the readout of the $\mu$-TPC, is made by PCB (Printed Circuit Board) technology. PCB technology is suitable to develop a large area detector at a low cost, and thus, the $\mu$-PIC can be a good tool for large-volume dark matter detectors. The largest available size is $30 \times 30$cm$^2$$[11]$. Figure 2 shows the structure of the $\mu$-PIC. Gas multiplication occurs around each anode electrode. The charge multiplied at each electrode is read out through orthogonally-formed anode strips and cathode strips. The size of the $\mu$-PIC is $30$cm $\times$ $30$cm, and the number of pixels is $768 \times 768$. We supply high voltage to the anode electrodes of the $\mu$-PIC.

**Figure 1.** Schematic drawing of NEWAGE-0.3b detector. The size of the $\mu$-PIC is $30$cm $\times$ $30$cm, the size of the GEM is $28$cm $\times$ $23$cm, and drift length is $30$cm (at Kamioka underground laboratory) or $50$cm (Kyoto surface laboratory). Induction gap, the length between $\mu$-PIC and GEM, is $5$mm.

**Figure 2.** Left figure is the photograph of the $\mu$-PIC (30cm $\times$ 30cm). Right figure is the enlarged schematic drawing of the $\mu$-PIC. Anode electrodes with a diameter of 50$\mu$m are formed with a pitch of 400$\mu$m.
Also, we put a GEM (Gas Electron Multiplier) [12], consisting of a 50μm-thick polyimide insulator sandwiched between 5μm-thick copper electrodes, 5mm above the μ-PIC to obtain sufficient gain. The size of the GEM is 23cm × 28cm, and this GEM is segmented into 8 parts to reduce the damage by discharges. We supply negative high voltages at the top and bottom of the GEM.

The drift length is 30cm (NEWAGE-0.3a) or 50cm (NEWAGE-0.3b). The detection volume is surrounded by a drift cage to form the electric field. Copper electrodes are formed on the inner surface of the drift cage by every 1cm. We supply high voltage to the drift plane. These detector components are set in a chamber made of SUS304 stainless steel. The inner surface of the chamber was electrolyically-polished to reduce out-gassing. We use CF4 as the μ-TPC gas because fluorine has a relatively large spin-dependent cross section for the neutralino. The gas pressure is 152torr (NEWAGE-0.3a : dark matter search up to 2011) or 76torr (NEWAGE-0.3b : low pressure R&D).

A dedicated electronics system was used for the measurement. Details of the electronics are described in [13] and the references therein. Three-dimensional tracks were detected by the discriminated "hit" signals of 768 anode strips and 768 cathode strips and the anode-cathode coincidence-timing. Energy of each track was determined by the summed waveform.

2.2. Current status
We performed our first underground dark matter search in 2010 at the Kamioka underground laboratory, at a depth of 2700 m water equivalent. [13]. The exposure was 0.524kg · days. The gas pressure was 152torr, and the energy threshold was 100keV. Figure 3 shows the direction-sensitive exclusion limit obtained by measuring the directions of nuclear tracks. We set a limit of 5600pb for 150GeV WIMPs.

Now, we aim to reach the DAMA-region[3] as the next milestone. To do this, we need to improve the sensitivity by 3 orders of magnitude (Figure 3). We plan to reach this sensitivity through the following improvements.

- Lowering the energy threshold by using a lower pressure gas. By reducing the energy threshold by one-half, the sensitivity is expected to improve by 1 order of magnitude. To check the performance of lower pressure gas, we measured the angular resolution with 76torr gas. The result is shown in Figure 4. The results with 76torr gas is shown by the red histogram, while our previous work with 152torr gas is shown by the blue histogram for comparison. By using the lower pressure gas, we were able to measure the angular

![Figure 3](image-url)  
**Figure 3.** Exclusion limits and expected sensitivities. Horizontal axis is the WIMP mass, and vertical axis is the spin-dependent WIMP-proton cross section. Thick black line represents the limit set by NEWAGE in [13]. Thin black line represents allowed region by DAMA[3]. Blue line represents expected limit when we decrease the energy threshold by one half. Red line represents expected limit when we additionally decrease the background to 1/50.
resolution in the 50-100keV energy range in addition to other energy ranges. We are working on understanding the observed energy dependence.

- Lowering background by using a radon elimination system and replacing the detector components. We plan to reduce the background by at least 1 order of magnitude.
- Recognizing the sense of the nuclear tracks (i.e., head-tail recognition). With this recognition, the sensitivity is expected to improve by several factors.
- Taking higher statistics data by constructing a large size detector. We plan to construct a detector with 10-times larger volume.

3. Conclusions

Direction sensitive method is strong tool to reveal the dark matter problem. NEWAGE is the direction sensitive dark matter search experiment using a μ-PIC. We performed our first underground direction-sensitive dark matter search in 2010 at the Kamioka underground laboratory, and obtained 5600pb limit for 150GeV WIMPs. To reach DAMA region, we now improve the detector on lowering the energy threshold, lowering background, head-tail recognition and large size detector.

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