

R & D STATUS OF THE NEWAGE EXPERIMENT *

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NEWAGE (NEw generation WIMP search with an Advanced Gaseous tracking dEvice) is an experiment seeking for the WIMPs with a gaseous micro time projection chamber(μ -TPC). We have developed a prototype μ -TPC with an original two-dimensional imaging detector, or the μ -PIC and investigated its performance as a WIMP detector.

1. Introduction

Direction-sensitive detection of the WIMPs (Weakly Interacting Massive Particles) is said to be a very convincing signature of the halo dark matter. There has been an intense effort for the directional detection with gaseous detector (DRIFT project¹). We have developed an advanced gaseous tracker, or the μ -TPC (micro time projection chamber) based on our original two-dimensional imaging detector, or the μ -PIC. The outstanding properties of our detector, which are 1) the μ -PIC is a fine pitch (400 μ m) device and 2) the μ -TPC can detect real three-dimensional tracks, would provide advantages over the DRIFT projects. We, therefore, started the studies on its application for the WIMP detection².

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2. μ -PIC and μ -TPC

We developed several μ -PICs of a practical size ($10 \times 10 \text{ cm}^2$)^{3,4}. The schematic structure of the μ -PIC is shown in the left panel of Figure 1. Orthogonal anode and cathode strips are formed with a pitch of $400 \mu\text{m}$ on the rear and front side of a thick ($100 \mu\text{m}$) polyimide substrate, respectively. Because μ -PIC is made by the print circuit board (PCB) technology, large area detectors ($> 30 \times 30 \text{ cm}^2$) are in principle made at a relatively low cost, which is an important feature for a WIMP detector. Another outstanding feature of the μ -PIC is that all structures for the multiplication and the readout are on one board and would provide a very stable and robust long term operation without the deformation. The gas multiplication occurs near an anode pillar and same amount of charges are read from corresponding anode and cathode strips. This is also important for a direction sensitive WIMP detector, because the three-dimensional recoil tracks would provide much more reliable and concrete results than the projected tracks do. Two-dimensional images as shown in the right panel of Figure 1 are detected by the μ -PIC. Two dimensional position resolution was measured to be $120 \mu\text{m}$ from the edge image.

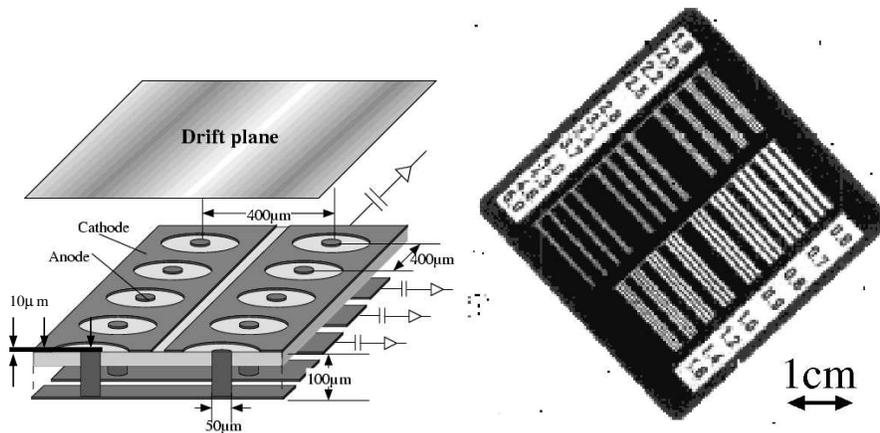


Figure 1. Schematic structure of the μ -PIC (left) and the a two-dimensional X-ray image detected by the μ -PIC (right).

One of the important, but often avoided, task we need to work on with any micro-structure detectors is the data acquisition of the many channels (more than 500 channels a for $10 \times 10 \text{ cm}^2$ detector). We developed a

FPGA-based fast data acquisition system. Anode and cathode signals are discriminated into the LVDS-level digital signals in the preamplifier chip⁵. Then the anode-cathode coincidence within an internal clock(50 MHz) of a FPGA are taken. The anode and cathode positions (X and Y) and the timing (Z) are recoded for each coincidence. A track of a charged particle is consequently recorded as successive points. The data size of each point is 32 bit. We also record the waveform of the summed analog signals with a 8 bit 100 MHz flash ADC (FADC). This summed waveform is used to measured the deposited energy and also to know the track sense because these summed signals basically carry the Bragg curve shapes.

We developed a prototype μ -TPC (micro time projection chamber) with a detection volume of $10 \times 10 \times 10 \text{ cm}^3$. A picture of the μ -PIC(left) on the mother board and a picture of the prototype μ -TPC is shown in the left and right panel of the Figure 2, respectively. A field cage of 10 cm drift length which consists of a drift electrode, nine copper wires of 0.2mm diameter, and glass fiber reinforced plastics(GFRP) rods was set on the μ -PIC. The wires are set around the field area of $15 \times 15 \text{ cm}^2$ with 1cm pitch, which forms a uniform electric field in the detection volume. We set the μ -TPC in a 6mm-thick aluminum vessel of 20cm(height) \times 60cm(diameter) and measured its performance.

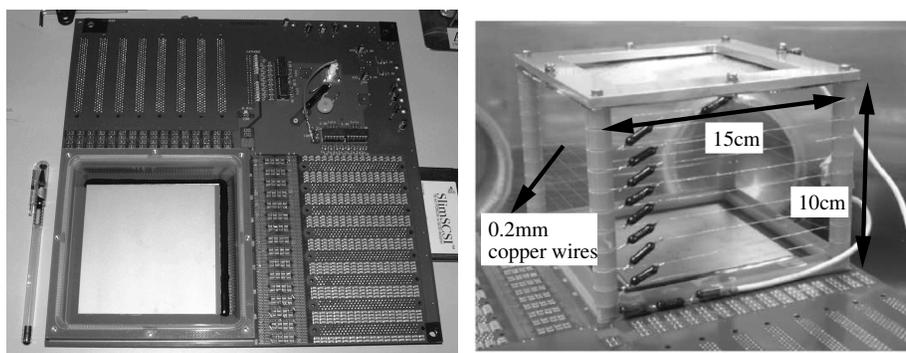


Figure 2. A picture of the μ -PIC(left) on the mother board(left) and a picture of the prototype μ -TPC(right)

3. Performance

Performance of the μ -TPC had been measured with a normal pressure gas flow in the most of the former development phase. Because the required

gas pressure for the WIMP search is 0.05 - 0.2 atm, we operated the μ -TPC with low-pressure chamber gas. As this is a first measurement with a low pressure gas, we put the whole mother board which has resistances and decoupling capacitances without any out-gas suppression. As expected, the out-gas made the μ -TPC unstable below 0.1 atm. We, therefore, performed the measurement with a gas mixture of Ar-C₂H₆(10%) at 0.2 atm. We are going to work on the out-gas suppression in the near future.

We operated the μ -PIC(TOSHIBA S/N 040223-2) with a gas gain of about 3000 and irradiated the μ -TPC with neutrons from ²⁵²Cf source. Typical recoil proton tracks with energies between 100 keV and 300 keV are shown in left panel of Figure 3, while one of the carbon track candidates is shown in the right panel of Figure 3. Track length known from the digital track data and the energy measured from the FADC waveform reconcile with SRIM2003⁷ calculations. We are going to analyze these data statistically in order to measure the energy resolution and tracking spatial resolution.

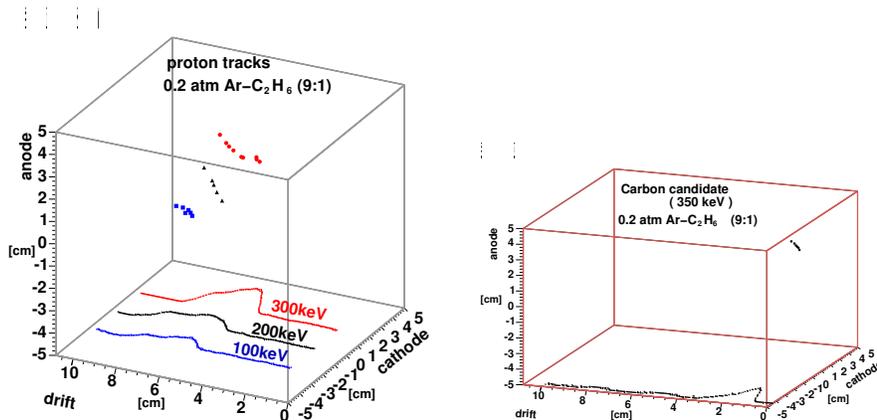


Figure 3. Detected proton(left) and carbon tracks. Proton tracks of 100 keV(square), 200 keV(triangle) and 300 keV(circle) are shown.

4. Neutron background to the gaseous detectors

Neutron background is known to be a serious problem in the next generation WIMP search experiment. In fact, the comparison of the simulation codes for the neutron background calculation was intensely discussed in

this conference⁸. Gaseous detectors have an advantage for the neutron background measurement and monitoring because the neutron flux inside of the shield is easily monitored by a same type detector (μ -TPC) with an addition of neutron targets to a WIMP target gas: *i.e.* hydrocarbon for the fast neutron and ^3He for the thermal neutron. We estimated the fast neutron background at Kamioka Observatory with the WIMP and the neutron target gas (CF_4 and C_2H_6 , respectively). As we need to demonstrate the performance of this new device before developing a large volume ($\sim 1\text{m}^3$) WIMP detector, we are going to measure the neutron background at Kamioka Observatory with a small-size ($30\times 30\times 30\text{cm}^3$) prototype. We, therefore, simulated the response of a μ -TPC with a detection volume of $30\times 30\times 30\text{cm}^3$ filled with 0.3 atm gas without any shield at Kamioka Observatory. We assumed an exponential neutron spectrum above 0.5 eV scaled to the measured flux of $1.15 \times 10^{-5}\text{nn} \cdot \text{cm}^{-2} \cdot \text{s}^{-1}$ and used the neutron scattering cross section data of the ENDF/B-VI⁹. We found that the neutron background can be measured with a short running time (~ 100 days) with a prototype detector.

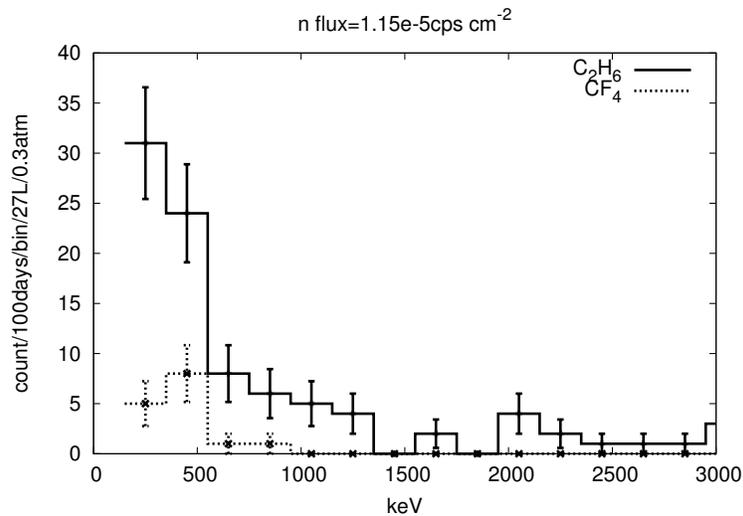


Figure 4. Expected neutron background without any shield at the Kamioka Observatory. The solid and the dotted lines represent the spectra with C_2H_6 and CF_4 target gas, respectively.

5. Prospects

A larger area ($30 \times 30 \text{ cm}^2$) μ -PIC is now being manufactured and is expected to be ready at the end of 2004. We are going to develop a prototype μ -TPC with a volume of $30 \times 30 \times 30 \text{ cm}^3$ and measure its performance. We are going to measure the gamma-ray rejection power, energy and tracking resolution, and absolute efficiency by the end of 2005 and we hope to start the underground run with a neutron background measurement in 2006.

6. Summary

We started investigating the performance of the μ -TPC for the direction sensitive WIMP search. We operated the μ -TPC with low pressure (0.2 atm) chamber gas and detected low energy proton and carbon recoil tracks. We hope to start the underground run in 2006 after a development and performance study of a 30 cm size μ -TPC.

References

1. N. Spooner et al., these proceedings and the references therein.
2. T. Tanimori, et al., Phys. Lett. B 578 (2004) 241
3. T. Nagayoshi, et al., Nucl. Instr. Meth. A 513(2003)277,
4. T. Nagayoshi, et al., Nucl. Instr. Meth. A 525(2004)20, A. Takeda, et al., IEEE Trans. Nucl. Sci, in press.
5. R. Orito, et al. IEEE Trans. Nucl. Sci., 51 (2004) 1337
6. K. Miuchi, et al., IEEE Trans. Nucl. Sci., 50 (2003) 825, K. Miuchi, et al., Nucl. Instr. Meth. A in press.
7. J. F. Ziegler, J. P. Biersack and U. Littmark, SRIM - The Stopping and Range of Ions in Matter, Pergamon Press, New York, 1985.
8. V. Kudryavtsev, et al.
9. ENDF/B-VI the Evaluated Nuclear Data File/Version B, the U.S. national nuclear data file.
10. K. Miuchi, et al. Nucl. Instr. Meth. A 517(2004)219, T. Tanimori, et al. Nucl. Instr. Meth.