

NITPC technical work in progress and sketch for a WIMP observatory

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Abstract. Direction-sensitive WIMP detection is important for conclusively identifying a halo-WIMP signal. It would also make possible the study of galactic halo dynamics through WIMP astronomy. A large low-pressure Negative Ion TPC (NITPC) is the only technique presently known which is capable of direction sensitive WIMP detection. Several advances in NITPC technology reported here. A new capture agent (CH_3NO_3) with several advantages over the standard CS_2 is identified. Simulations with GARFIELD show that tracks completely contained within a single drift cell can be measured using the “radial drift chamber” structure proposed by Nygren. DRIFT I neutron source calibration data is shown in which the “head-tail” orientation of tracks is able to be determined. (Supported by the U.S. NSF under NSF-PHY-0300766.)

Introduction

The power of direction-sensitive detection for identifying and studying galactic halo WIMPS was recognized long ago[1, 2]. The 2003 NUSEL Science Book stated: “Because WIMPS should have a strong directional asymmetry due to the movement of the Sun with respect to the galaxy frame, the directional information can confirm that the events are due to WIMPs.” [3] The negative ion TPC was conceived to allow the direction of nuclear recoils from WIMP scattering to be measured, along with the deposited energy[4].

New Electron Capture Agent

Up to now, NITPC have relied on the toxic, explosive CS_2 as an electron capture agent. The safety aspects of using this material are by no means insurmountable, as the years of accident-free DRIFT underground operations demonstrated. However, a more benign agent would be desireable. Research at Temple has identified the compound nitromethane as a promising candidate. The flammability and toxicity of this compound are markedly lower than those of CS_2 .

Drift velocity (Figure 1) is shown here for gas mixtures containing nitromethane. Its properties so far are comparable to CS_2 . The longitudinal diffusion has also been measured and remain thermal up to at least 5 V/cmTorr.

Research on this compound is continuing, with a particular additional interest being its low-Z composition. This allows a high polarization analyzing power for low energy x-rays of interest for space-based astronomical x-ray polarimetry.

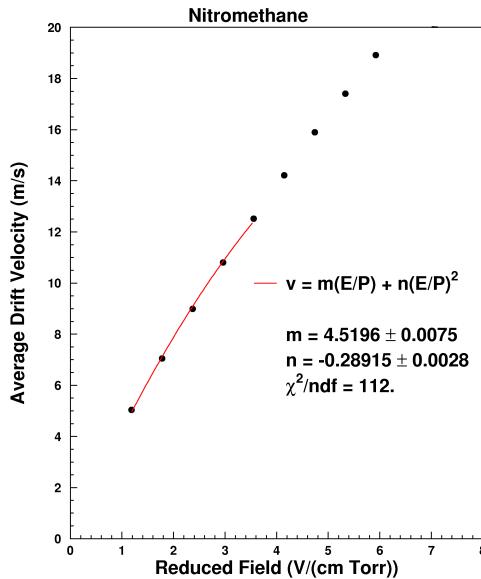


Figure 1. Nitromethane ion drift velocity

High Resolution with Low Channel Count

To have an “interesting” level of sensitivity compared to existing and planned non-directional detectors, the next NITPC will have to be large, of the order of 50-100 m³. Such a large device would be prohibitively expensive if the brute force solution of a pixel readout were used to measure the millimeter-scale recoil tracks. Research at Temple has therefore been undertaken to find a way to decouple the readout cell size from the minimum measureable track length.

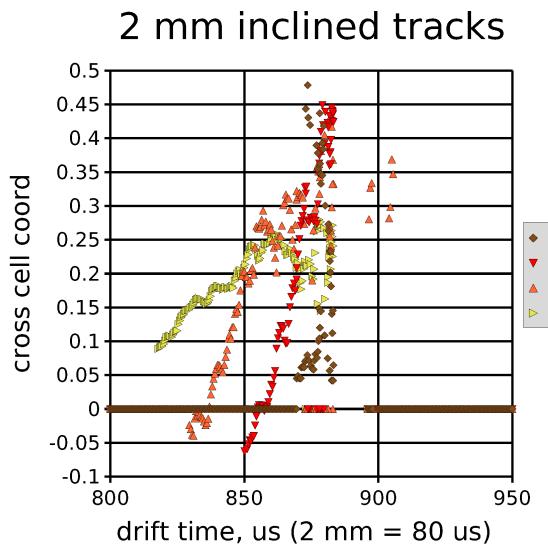


Figure 2. GARFIELD study of reconstructing inclined tracks within one cell of a NITPC with “radial drift chamber” readout scheme of Nygren, 1985. The slow ion drift speed allows many points to be reconstructed within a cell, even with relatively slow electronics.

Simulations show that the “radial drift chamber” (RDC) scheme of Huth and Nygren[5] holds promise for this goal. The RDC uses a plane of wires consisting of anodes closely flanked by pickup wires, plus additional field shaping wires in the plane to spread out the field lines. A time-resolved signal is formed from the difference in induced signals on the left and right side pickup wires. This gives high resolution information on the origin of charge arriving at the anode in the direction transverse to the wires and parallel to the wire plane. Figure 2 shows the result of a GARFIELD simulation in which tracks just half as long as the width of a readout cell were projected at varying angles to the readout plane, and then reconstructed using the RDC principle. The extension of the tracks in the drift direction and transverse to the wire are well reconstructed. Combining this with time resolved centroid fitting from cathode pads will allow all three components of tracks to be measured with resolution much smaller than the anode pitch. The next stage is to build a small chamber to test this development using neutron recoils.

Head-Tail Discrimination

Theoretical studies[6] have shown the importance of determining which end of a recoil track is the beginning and which is the end, in addition to finding the direction of the track axis, This has come to be called “head-tail discrimination”. For nuclear recoil tracks in the energy range of interest (far below the Bragg peak in the energy loss rate), the *rise* in dE/dx with *rising* energy gives a potential head-tail signature. For a detector like DRIFT I, with only the 2 mm pitch anode wires instrumented, Monte Carlo studies show that a track must hit at least *six* wires for head-tail discrimination to be achievable. For tracks shorter than this, the fluctuations due to random track starting and stopping points within a readout cell, plus diffusion, conspire to wash out the effect. Six wires corresponds to a minimum energy of ~ 200 keV for Carbon recoils.

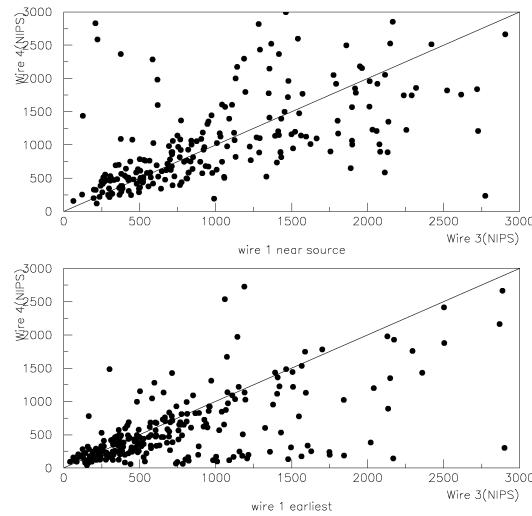


Figure 3. DRIFT I data showing “head-tail” discrimination with ^{252}Cf neutron-source events spanning six wires. See text for explanation.

Figure 3 shows head-tail discrimination of the expected size for DRIFT I data. Six wire events were selected from data taken with a ^{252}Cf neutron source placed outside the vessel. The top panel is a scatterplot of pulse height on the “third” wire of each event vs that on the “fourth” wire, where the assignment of “first” vs “sixth” wire was made randomly. In the bottom panel

the same events are plotted with the first wire correctly assigned as the one nearest the neutron source. A clear preference for more pulse height on the third wire is evident, as expected from Monte Carlo. Further refinements in analysis such as channel-to-channel gas gain matching are expected to improve the result.

These events are rather higher in energy than expected from most halo WIMP models. However this analysis shows that the dE/dx effect is useable, and points up the importance of having as many resolution elements as possible within a track.

Conclusion

Advances in the capabilities of NITPC are directed at enabling a very large detector to be built affordably. Schematic designs for a modular 100 kg array have been described[7], which could enable the positive detection and identification of a WIMP signal, and usher in the era of WIMP astronomy.

References

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