R&D and physics with a $9m^3$ gaseous Time Projection Chamber

A broad R&D program is proposed jointly by Temple University and Wayne State University, to study the performance and optimization of underground gaseous TPC. Background rejection capabilities, energy and angular resolution in particular will be quantified. The proposal is based on numerous papers over the last 13 years[1 − 11], as well as unpublished simulation results.

TPCs recover the most information about the low energy events that form the bulk of the underground physics program. They can disentangle single from double events with extreme precision, and distinguish neutron from electromagnetic events down to very low energies. Unpublished simulations by Alexander Schreiner also suggest that the energy and charge of particles in the MeV range can be measured with high precision, leading to the possibility of a sensitive search for neutrinoless double beta decay with a fill containing Xenon. In particular the energy resolution in a low pressure Xenon chamber at 2.5 MeV can be of order 0.3%.

Most important of all, the TPC can provide directionality information. Because dark matter events (and solar neutrino events) are expected to be directional, even a modest directionality measurement provides dramatic background reduction and minimal uncertainty in the determination of the background error.

An underground TPC would also allow a sensitive search for axion-like particles produced in the Sun and decaying within an underground detection volume. Such particles been proposed as an explanation for a number of anomalies in x-ray astronomy. While most of the anomalies also have alternative explanations, one in particular (the x-ray activity of the magnetically quiet Sun) is explained only by the axion hypothesis. Relevant papers and presentations about this topic are Refs. [12 − 13].

We propose to build a $1.5 \times 1.5 \times 4$ m^3 TPC, inside a pressure vessel and with some inner shielding (of order 0.3 mwe), and variable shielding outside the TPC, both to be provided by water-filled polyethylene tanks. The TPC barrel, in view of a simplified large scale version, is to be made of polyethylene with deposited copper strips acting as field degraders. The electronics to be used (2000 channels) is to be the Icarus electronics [14 − 15] sampling every 400 nsec. The trigger electronics is likewise part of the Icarus electronics system. There will be one gas recirculation system, which simplifies further when the TPC is not operated in Negative Ion mode.

With this baseline structure, the TPC will be tested in Negative Ion mode (He/CS_2 at atmospheric pressure, and 3.4 m^3 of the TPC in use), double beta decay mode (Xe/CH_4 at low pressure and low temperature, all $9m^3$ in use), and solar neutrino mode (He/CH_4 at high pressure and low temperature, $9m^3$ in use). The solar axion experiment (which could be completed with two months data taking) can be performed either in NITPC mode or solar neutrino mode at atmospheric pressure. Readout panels to be tested include checkerboard strips against either traditional wire/grid structures or, over a smaller area, against Micromegas structures. The latter have been proven to provide a large gain with He/CS_2 at atmospheric pressure [9].

The whole structure fits inside a standard underground container, plus three racks for the gas system and electronics, plus gas bottles as needed. Initially, an experimental area at roughly 2000 mwe depth is preferred so that cosmic ray calibration can be performed efficiently. Safety requirements are dominated by the He/CS_2 mixture, which is toxic. However, the total CS_2 content of the chamber is less than 700 grams so that modest ventilation systems should suffice. A CS_2 circulation and recovery system was successfully operated in the Boulby mine for several years by members of this group[16]. The other two mixtures are non-toxic and non-flammable. As with all other experiments, Internet connection to the outside world is strongly preferred. These are rugged detectors which have been shown to be able to run unattended for long periods of time.

References

[1] T. Ohnuki, D. P. Snowden-Ifft and C.J. Martoff, Nucl. Instrum. Meth. A463, (2001) 142.

[2] D.P. Snowden-Ifft *et al.*, Nucl. Instrum. Meth. A498, (2003) 164.

[3] J.K. Black *et al.*, physics/0303114

[4] J. Miyamoto *et al.*, Nucl.Instrum.Meth.A526:409-412,2004

[5] C.J. Martoff *et al.*, Nucl.Instrum.Meth.A555:55-58,2005

[6] J. Miyamoto *et al.*, physics/0310124

[7] F. Arzarello *et al.*, LPC-94-28.

[8] G. Bonvicini, N. Harris, V. Paolone, hep-ex/0308025

[9] G. Bonvicini *et al.*, Contributed to APS / DPF / DPB Summer Study on the Future of Particle Physics (Snowmass 2001), Snowmass, Colorado, 30 Jun - 21 Jul 2001. e-Print Archive: hep-ph/0109199

[10] G. Bonvicini, D. Naples, V. Paolone, Nucl.Instrum.Meth.A491:402-418,2002

[11] G. Bonvicini, A. Schreiner, Nucl.Instrum.Meth.A493:90-98,2002

[12] L. Di Lella and K. Zioutas, Astroparticle Physics 19, (2003) 145.

[13] D. Naples *et al.*, Nucl.Phys.Proc.Suppl.134:130-132,2004

[14] F. Arneodo *et al.*, (ICARUS Collaboration), Nucl. Instrum. Meth. A498 (2003), 292.

[15] http://www.caen.it/

[16] G.J. Alner, *et al.*, (DRIFT I Collaboration),. Nucl. Inst. Meth. A535, (2004) 644-655.