PROCEEDINGS OF SCIENCE

# Direct Dark Matter Searches - DRIFT and ZEPLIN

**Timothy Sumner**[*†]

*Imperial College London, UK*

*E-mail:* `t.sumner@imperial.ac.uk`

Three new direct dark matter detection experiments are nearing operations within our collaboration. DRIFT II is a next generation modular gas time projection chamber designed to demonstrate directionality with a scalable technology. The first module of this is operational in our underground laboratory at Boulby. ZEPLINs II and III are next generation liquid time projection chambers offering simultaneous measurement of scintillation and charge from liquid xenon. These two instruments will provide sensitivities into the $10^{-8}$ pb range. ZEPLIN II is just beginning science operations underground at Boulby. ZEPLIN III is in a final assembly in a surface laboratory. Our programme status will be presented.

*International Europhysics Conference on High Energy Physics*
*July 21st - 27th 2005*
*Lisboa, Portugal*

[*]Speaker.

[†]This presentation is on behalf of a collaboration including the UKDMC (Edinburgh University, Imperial College, Rutherford Appleton Laboratory and Sheffield University), Boston University, ITEP, LIP-Coimbra, New Mexico University, Occidental College, Rochester University, Temple University, Texas A&M and UCLA.

 

PoS(HEP2005)003

## 1. Introduction

Understanding the nature of dark matter is one of the most pressing questions in physics and cosmology today. The Universe appears to be almost entirely composed of unknown quantities referred to as dark energy and dark matter. What we do know about in detail seems to be only a few percent of the Universe. In the case of dark matter, a couple of plausible explanations invoke new particle species that have yet to be detected. The most compelling of these elegantly connects two major strands of physics; the quest for quantum gravity and unification through supersymmetry (SUSY) and a solution to the dark matter. SUSY predicts the existence of new particle species, with properties such that one of them could survive as stable relics from the big bang, in sufficient quantities for them to be the dark matter. Hence the direct detection of Galactic dark matter would be of profound significance for fundamental physics as well as cosmology. The first convincing detection would be a discovery of enormous importance in itself. However the continuing study of the particles' properties would require combining complementary information from experiments capable of probing different ranges of the new particles' characteristics. Measurement of the local dark matter particle velocity distribution would help understand galactic dynamics and galaxy formation. The current preoccupation is with discovery and to that end there are many collaborations world wide developing more and more sensitive experiments. To first approximation sensitivity is improved with larger target masses, lower backgrounds and better particle discrimination. Our ZEPLIN project, based on high density xenon targets, is this class of experiment. DRIFT on the other hand uses a low density gas target to increase the recoil range of events so that their direction can be measured. This technology will enable the study of dark matter velocity distributions.

## 2. Detection Principles

The dark matter particles predicted by SUSY are weakly interacting massive particles (WIMPs). The main interactions with normal matter are elastic nuclear recoils. For Galactic dark matter with a virialised velocity distribution these deposit $< 100\,\mathrm{keV}$ of energy at a rate $10^{-5}$ to 1 event/day/kg. In general the energy deposited can give rise to phonons, photons and/or charge whose relative proportions and/or characteristics depend on rate of energy loss, dE/dx, and hence particle type.

### 2.1 DRIFT II

DRIFT II is a negative ion time projection chamber using $CS_2$ gas. A nuclear recoil interaction produces charge distributed along the length of the nuclear recoil track. The charges immediately attach to nearby gas molecules ($CS_2$). These heavy ions are then drifted in an electric field into a high-field multi-wire chamber with crossed grids where the electrons are stripped away from the molecules and avalanche amplification occurs. The avalanche electrons are read out using multi-wire proportional counters consisting of two perpendicular arrays of 512 wires (2 mm pitch). The distribution of charge seen on the wire array provides a two-dimensional image of the track, and may be combined with the relative drift time to provide full 3-D track reconstruction. This is only possible through the reduced diffusion incurred by the drifted track through the use of negative ion drift techniques. The length of the track depends on $dE/dx$ which provides a very efficient means of discrimination against the main background which comes from $\gamma-$rays.



PoS(HEP2005)003

### 2.2 ZEPLIN

The ZEPLIN experiments use liquid xenon as the target medium. A nuclear recoil interaction produces an immediate scintillation. Free charge is also released at the site of the interaction and this is drifted in an applied electric field to the surface of the liquid. At the surface there is a sufficient field to extract the electrons into the gas phase in which they continue to drift and cause electroluminescence. Photomultipliers are used to detect both the primary scintillation and the delayed secondary electroluminescence. The ratio of primary to secondary signal is dependent on the track $dE/dX$ and this enables a high level of discrimination from two-phase xenon instruments.

## 3. Experiment Status

The collaboration has been developing and deploying dark matter detectors since the early 1990s. Results from early generations of detectors have already been published and these include NaI single crystals [1], the NAIAD array of NaI crystals [2] and first generations of DRIFT [3] and ZEPLIN [4].

### 3.1 DRIFT

DRIFT I was a technology demonstrator which successfully proved discrimination against gamma and alpha backgrounds and directionality capability (at high energy). A number of technical problems were identified and resolved and the detector achieved safe and stable operations underground [3]. With it we were able to study the ambient neutron background in Boulby. DRIFT II has a more robust modular design, a streamlined coded data acquisition system, a full 3-D readout (compared with 2-D for DRIFT I), a higher drift field and a lower trigger threshold. The first $1m^3$ module, DRIFT IIa [5], is operational in the Boulby laboratory and is undergoing commissioning and calibration prior to starting a first science data taking run.

### 3.2 ZEPLIN

Our ZEPLIN programme has two ongoing experiments called ZEPLIN II [6] and ZEPLIN III [7]. Both are two-phase targets measuring both scintillation and ionisation. ZEPLIN I was a single phase target using pulse shape discrimination on the scintillation signal. ZEPLIN II is a large mass target ($\sim$ 40 kg) with seven large area PMTs in the gas phase which view both the scintillation signal from the liquid phase and the gas-phase electroluminescence from the charge. The whole system is completed and two surface test runs in which the full 40 kg of xenon were liquefied into the target have been completed. Two-phase operation was obtained. It has now been installed underground and the very first underground tests are started. ZEPLIN III has a number of enhancements including a large array of smaller PMTs immersed in a thin liquid layer giving $\sim 4$ times better light collection for the primary scintillation, much higher electric fields ($\sim$ 8 kV/cm), better discrimination ($\sim 10^5$ at threshold), and $<$cm 3-d position reconstruction from gas phase electroluminescence, even for 1 electron escaping, which leads to a well defined fiducial volume. ZEPLIN III is now assembled in a surface laboratory and awaiting is first cooldown tests. Critical achievements during the manufacturing and assembly were PMTs characterised at low temperature, e-beam welding used throughout, individual leak tests on all welds/seams to $10^{-10}$ mbar.l.s$^{-1}$,

**Figure 1:** DRIFT IIa and ZII in the underground laboratory (left and centre). ZIII in the surface laboratory.



pressure testing for safety certification, specialised cleanroom facility with customised cleaning procedures. 50 kg of low krypton (pre bomb-test) xenon has been provided from ITEP.

## 4. Summary

The UKDMC and its collaborators now has a unique and very strong world position, and is poised for rapid advances. We have:-

- A dedicated world-class well-equipped low-background underground laboratory.
- Competitive world limits already demonstrated.
- A new generation of competitive and scalable high-sensitivity instruments (ZII and ZIII) about to be deployed with limiting sensitivities $10^{-7}$ to $10^{-8}$ pb.
- Upgrade paths for these instruments to extend the sensitivity to $10^{-9}$ pb.
- A unique and scalable directional technology promising significant galactic astrophysics.
- Multiple target options for confirmation and constraining SUSY parameter space.
- Mature plans for achieving tonne-scale targets.

## References


[1] P.F. Smith *et al.*, *Improved dark matter limits from pulse shape discrimination in a low background sodium iodide detector at the Boulby mine*, *Phys. Letts. B*, **379** (1996) 299-308.

[2] G.J. Alner *et al.*, *Limits on WIMP cross-sections from the NAIAD experiment at the Boulby Underground Laboratory*, *Phys. Letts B* **616** (2005) 17-24.

[3] G.J. Alner *et al.*, *The DRIFT-I dark matter detector at Boulby: design, installation and operation*, *Nucl.Instrum. Meths. Res Phys.* **A535** (2004) 644-655.

[4] G.J. Alner *et al.*, *First limits on nuclear recoil events from the ZEPLIN I Galactic Dark Matter Detector Astropart. Phys.* **23** (2005) 444-462.

[5] G.J. Alner *et al.*, *The DRIFT-II Dark Matter Detector: Design and Commissioning*, *Nucl.Instrum. Meths. Res Phys. A*, in press

[6] G.J. Alner *et al.*, *Status of the ZEPLIN II experiment*, *New Astr. Revs.* **49** (2005) 259-263.

[7] T.J. Sumner *et al.*, *The ZEPLIN III dark matter project*, *New Astr. Revs.* **49** (2005) 277-281.