ZEPLIN I—The UKDM Single Phase Xenon Experiment at Boulby

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I briefly review the ZEPLIN I liquid xenon detector of the UKDM collaboration.

1. ZEPLIN I Detector

The ZEPLIN I detector is a single phase, 3.6 kg fiducial mass, liquid xenon scintillation detector built by the UKDM Collaboration (RAL-Sheffield-ICSTM) and running at the Boulby underground site (see Figure 1). The target mass is housed in a Cu-101 copper vessel, shaped to maximise light collection, which provides a uniform temperature environment through the use of a cryo-liquid jacket. The fiducial volume of xenon is surrounded by a 5 mm PTFE reflector, giving diffuse scattering of the 175 nm scintillation photons to maximise light collection. This volume is viewed through 3 mm silica windows by three quartz windowed photomultipliers through optically isolated Œturrets[1] of liquid xenon. These act both as light guides and passive shielding for the X-ray emission from the photomultipliers. The novel use of the xenon turrets arose from experience with NaI detectors where solid high-grade silica is used for light guides and shields. However, the extensive use of such material for liquid xenon is precluded due to the absorption of the 175 nm photons. Scintillation light produced in the turret regions is seen predominantly by the nearest photomultiplier which allows the rejection of the photomultiplier X-ray events and the definition of a fiducial volume through a comparison of the light seen by each tube. Purification of the xenon is performed using Oxysorb ion exchange columns with additional purification by vacuum pumping on frozen xenon and subsequent fractionation of the xenon gas.

The liquid xenon target is enclosed by a multi-purpose, 1 tonne, liquid scintillator shield and an outer passive lead shield. The liquid scintillator shield acts as a Compton veto for low energy events produced by high energy gammas from the photomultipliers, an active shield for external gammas, a high purity inner passive shield and a neutron monitor. This shield comprises a stainless steel extended hemispherical container with aluminium reflectors on the internal surfaces viewed by ten 8-inch hemispherical photomultipliers.

The photomultiplier traces from ZEPLIN I are digitised at 1ns intervals using a LeCroy LC574 digital oscilloscope under the GPIB control of a Macintosh 266 G3, which also controls the automatic calibration source delivery mechanism and temperature logging. The Compton veto trigger is generated from a majority logic of three photomultipliers from all ten, with the coincident logic signal recorded onto the fourth channel of the LeCroy DSO to allow the state of the veto to be interrogated during analysis. Rejected events that show low energy deposition in the target and a veto trigger are used to cross check the liquid xenon gamma time constant distributions generated from manual Compton calibrations. Utilising the vetoed events in this way allows concurrent data sets to be produced for both the gamma calibration and signal searches.

2. ZEPLIN I characterisation

Extensive mechanical and characterisation tests have been conducted on the ZEPLIN I target and veto. Light yields, dependent on xenon purity, are found to be typically 0.9–1.4 pe/keV in the energy range around 100 keV. This exceeded the design specification of 1 pe/keV at the energy range of interest. The scintillation time constant for differing incident species was investigated

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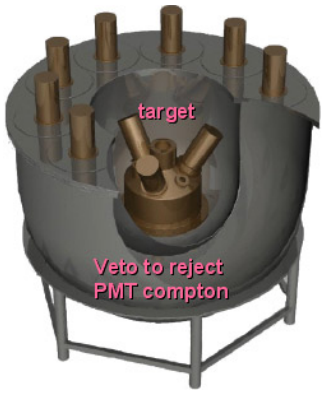

Figure 1: Schematic of ZEPLIN I detector and veto.

by irradiating the chamber with various gamma line sources and an Am/Be source. Scintillation pulses are analysed under the assumption of a single exponential time profile. Neutron calibrations at 10–30 keV observed energy show a clear discrimination between the neutron and gamma events with a preliminary 50% difference between the neutron and gamma time constants for high purity liquid xenon. Figure 2 shows an example event plot from the detector exposed to a ^{137}Cs source. Background events due to PMT x-rays occur in the prong regions away from the central fiducial volume.

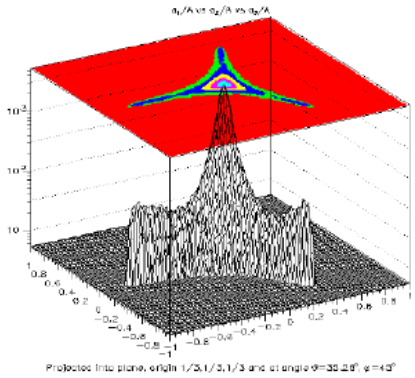

Figure 2: Events plot from ZEPLIN I exposed to a ^{137}Cs source.

Using the measured discrimination power from laboratory tests, and the measured light yield, threshold and underlying spectrum from underground runs an estimate of the sensitivity of the ZEPLIN I detector for WIMP searches can be made. This yields a sensitivity down to 10^{-6}pb for spin dependent interactions.