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ZEPLIN III: Position Sensitivity

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ZEPLIN III is a xenon detector for direct dark matter searches soon to be deployed underground at the Boulby mine (North Yorkshire, UK). This two-phase (liquid/gas) system will look for the rare nuclear recoils that should be produced by elastic scattering of Weakly Interacting Massive Particles (WIMPs) off xenon atoms.
Neutron interactions can also cause nuclear recoils and therefore constitute an irreducible background in this type of detector. This is mitigated by the use of radio-pure construction materials, by surrounding the detector with extensive hydrocarbon shielding and by deploying the system deep underground, where a large rock overburden protects it from the effects of cosmic rays. Another key challenge is to identify the very rare nuclear recoil events due to WIMPs or neutrons in a background of beta and gamma-rays from residual internal and external radioactivity. These electron-recoil events are some ˜106 times more abundant and must be effectively discriminated from nuclear recoils.
ZEPLIN III measures both the scintillation and ionisation signals produced in liquid xenon by the interacting particle. The prompt scintillation is measured by an array of 31 photomultipliers immersed in the liquid xenon. A strong electric field also extracts the ionisation from the interaction site, which drifts up to the liquid surface and is extracted into the gas phase. A large number of electroluminescence photons is produced in the gas and detected by same photomultiplier array. A sensitivity down to one electron extracted from the liquid is thus easily achieved. The ratio of the two response channels is different for electron and nuclear recoils, allowing effective discrimination between the two types of interaction down to ˜keV deposited energies (electron-equivalent).
In order to achieve the excellent discrimination ability required to fully separate the electron and nuclear-recoil populations, a very uniform response is necessary for both channels across the active volume. In most detectors, this fiducialisation is achieved by physically delimiting the active region. In ZEPLIN III, this is accomplished by reconstructing the 3-dimensional interaction point and rejecting events occurring in out-lying regions, where the light collection and the electric field may not be uniform. We will describe the position reconstruction methods to be used in ZEPLIN III and how we hope to achieve a positional accuracy of a few millimetres in the horizontal plane and sub-millimetre in the vertical coordinate.

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