Recent results from the UK dark matter search at Boulby mine.

N J T Smith[1]
on behalf of the UK dark Matter Collaboration

[1] Particle Physics Department, Rutherford Appleton Laboratory,
Chilton, Didcot, Oxon, OX11 0QX, UK
E-mail: n.j.t.smith@rl.ac.uk

Abstract

The UK Dark Matter Collaboration is currently running a series of scintillation devices at the Boulby mine in North Yorkshire to search for the neutralino, the hypothetical WIMP solution to the dark matter problem. Results of the current NaI detector array utilising crystals ranging in size from 0.3kg to 8.5kg illustrate a population of events of unknown origin, of faster scintillation light decay time constant than that expected from gamma and neutron calibrations. Diagnostic tests performed to investigate the origin of these anomalous events have excluded neutrons, beta , x-ray, high energy alpha and low energy stopping alphas.

1. The UKDMC NaI Programme

The UK Dark Matter Collaboration (Imperial College, Rutherford Appleton Laboratory and the University of Sheffield) operate a series of NaI scintillation detectors to search for the rare, keV energy, coherent scattering events due to Weakly Interacting Massive Particles (WIMPs) that have been postulated as a solution to the dark matter problem. The use of NaI and, in development, liquid Xenon targets is to match the expected mass range for the MSSM neutralino and to allow discrimination between the nuclear recoil signal events and the background gamma initiated electron recoil events [1]. This discrimination is performed through comparison of scintillation pulse shapes, different incident species yielding scintillation signals with differing decay time constants (Figure 1).

In the NaI systems scintillation light is observed by two photomultiplier tubes coupled to the crystal by silica light guides. These shield the crystal from X-radiation due to impurities in the photomultiplier glass. Detector components are selected for low radio-isotopic impurities. The detectors are operated at a depth of 1100m at the Boulby Mine in North Yorkshire, England, which provides an attenuation of 10^6 in the cosmic ray muon flux. They are shielded from local gamma activity in cavern walls by either a 6m tank of high purity water, or high purity lead and copper castles. Time constant calibrations of the detector systems are performed with gamma and neutron sources, the neutrons being used to simulate a WIMP recoil.

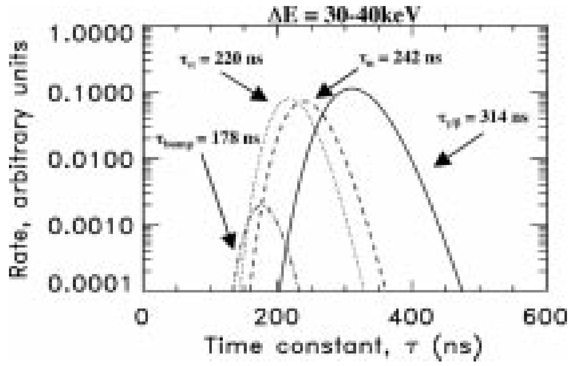

Figure 1. Scintillation light decay time constant distributions for several incident species, illustrating the anomalous event distribution and several characterisation tests. A single energy band is shown

2. Anomalous events

Improvements in the resolution, light collection and temperature stability of the NaI systems had, by 1998, given an order of magnitude improvement in the sensitivity to WIMP signals over previously published results [2]. However an emergent population of events with faster time constants than the gamma calibrations, yet faster still than the neutron calibrations, prevents this improvement from yielding improved dark matter signal limits (Figure 2)[3].

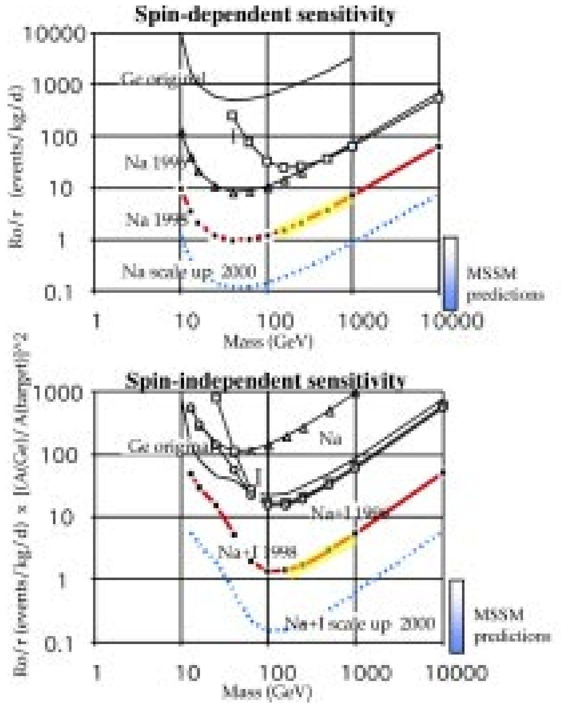

Figure 2. Achieved Dark Matter limits, current and projected sensitivity. Shaded area represents the region of the observed anomaly.

These anomalous events have been observed in all detector systems with sufficient resolution (Figure 3). Similar events have been independently observed by a French collaboration operating NaI crystals at the Modane site [4], ruling out crystal supplier, DAQ and analysis as potential sources of these events. Neutron initiated recoils are ruled out due to the hydrogenous shielding on some systems and the low muon flux. Direct calibrations with neutron sources also exclude this origin. Pulses due to alpha particles from U or Th decays within the bulk of the crystal will be too energetic.

A series of studies to characterise the decay time constant of the scintillation light from different incident species has been performed, to evaluate if external contamination may be the source of the anomalous population (Figure 1). Events due to X-rays incident on the surface of a bare NaI crystal were found to be similar to gamma initiated events [5]. Additionally, pulses due to betas were also found to be similar to gamma events [6]. Those events produced by alpha particles, degraded in energy from an external MeV source,incident on the surface were found to be faster than gamma events, yet insufficiently fast to account for the anomalous population.

A potential origin of these events, not yet excluded, is alpha particles emitted from a thin

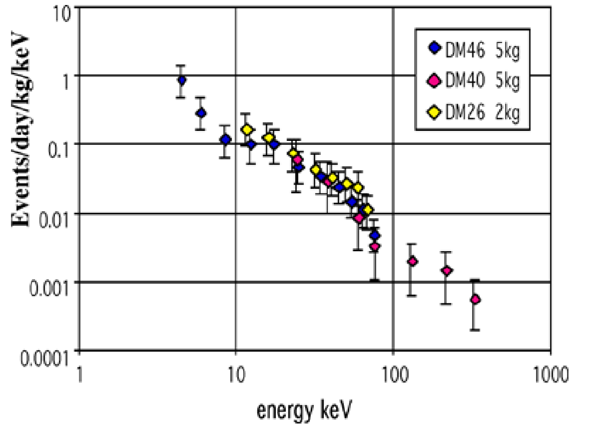

Figure 3. Energy spectrum of the anamolous events from several different NaI crystals

surface layer (0.1-0.2 μm) which yields the observed energy spectrum. Such a layer may arise from U/Th contamination during the manufacturing process or though an ion-implantation process from atmospheric radon [7]. However, such a scenario requires a rather high level of contamination ($\sim$ 0.1ppm U/Th or $\sim 10^{-2}$ decay sec^{-1} g^{-1} of Rn).

3. Future studies

To assess the thin surface layer of alpha emitting contaminant as the origin of these anomalous events a bare crystal will be exposed to high levels of radon to allow the ion-implantation mechanism to occur [8]. If this is indeed the origin then a population of anomalous events will emerge with the half life of the ^{210}Po daughter.

A liquid Xe scintillation detector is in the final stages of commissioning which will have similar sensitivity to WIMP signals as a large 100kg NaI array currently under development, testing the presence of the anomalous population in a different target material.

References

[1] R. B. Owen Nucleonics 17 (1959) 92.
[2] P. F. Smith *et al Phys. Lett. B (1996)* **379** 299.
[3] P. F. Smith *et al Phys Reports (1998)* **307** 275.
[4] G. Gerbier *et al* Astroparticle Physics (1999) 11 287.
[5] V. A. Kudryavtsev *et al Phys. Lett. B (1999)* **452** 167.
[6] N. J. T. Smith *et al Phys. Lett. B (1999)* **467** 132.
[7] N. J. T. Smith *et al* submitted to *Phys. Lett. B.*
[8] Alessandro *et al Nucl. Phys. B (proc. supp.) (1999)* **10** 96.