Searching for dark matter with CRESST

H. Kraus[1], *G. Angloher*[2], *M. Bauer*[3], *I. Bavykina*[2], *A. Bento*[2,4], *A. Brown*[1], *C. Bucci*[5], *C. Ciemniak*[6], *C. Coppi*[6], *G. Deuter*[3], *F. von Feilitzsch*[6], *D. Hauff*[2], *S. Henry*[1], *P. Huff*[2], *J. Imber*[1], *S. Ingleby*[1], *C. Isaila*[6], *J. Jochum*[3], *M. Kiefer*[2], *M. Kimmerle*[3], *J.-C. Lanfranchi*[6], *R. F. Lang*[2], *B. Majorovits*[1,7], *M. Malek*[1], *R. McGowan*[1], *V. B. Mikhailik*[1], *E. Pantic*[2], *F. Petricca*[2], *S. Pfister*[6], *W. Potzel*[6], *F. Pröbst*[2], *S. Roth*[6], *K. Rottler*[3], *C. Sailer*[3], *K. Schäffner*[2], *J. Schmaler*[2], *S. Scholl*[3], *W. Seidel*[2], *M. von Sivers*[6], *L. Stodolsky*[2], *Ch. Strandhagen*[3], *R. Strauss*[6], *A. J. B. Tolhurst*[1], *I. Usherov*[3] and *W. Westphal*[6,†]

[1]Department of Physics, University of Oxford, Oxford OX1 3RH, United Kingdom
[2]Max-Planck-Institut für Physik, Föhringer Ring 6, D-80805 München, Germany
[3]Eberhard-Karls-Universität Tübingen, D-72076 Tübingen, Germany
[4]on leave from: Departamento de Fisica, Universidade de Coimbra, P3004 516 Coimbra, Portugal
[5]INFN, Laboratori Nazionali del Gran Sasso, I-67010 Assergi, Italy
[6]Physik-Department E15, Technische Universität München, D-85747 Garching, Germany
[7]now at: Max-Planck-Institut für Physik, Föhringer Ring 6, D-80805 München, Germany
[†] Deceased

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The CRESST II experiment is a dark matter search using cryogenic phonon-scintillation detectors, aiming to detect WIMP dark matter particle interactions. The detector consists of individual, modular and scintillating ($CaWO_4$ or $ZnWO_4$) target crystals, each equipped with a phonon sensor for precise determination of the energy deposited in the crystals. Each module is further equipped with a separate cryogenic scintillation light detector, allowing event-by-event background discrimination. An extended commissioning run during 2007 has set an upper limit on the WIMP-nucleon scattering cross section. Attention is currently focussed on the interpretation of a few remaining nuclear recoils candidate events.

1 Introduction

CRESST (Cryogenic Rare Event Search with Superconducting Thermometers) is a dark matter search experiment located in the Gran Sasso underground laboratory, Italy. The collaboration has developed sensitive cryogenic phonon-scintillation detectors. A particle interaction in the absorber will deposit most of its energy as phonons; these thermalise in a superconducting phase transition (SPT) sensor on the crystal surface, creating a large change in sensor resistance, which is measured using a SQUID. This technique of using SPT sensors to measure the phonon signal can achieve a very low energy threshold and excellent near-threshold energy resolution ($\sim$300eV). The low threshold is especially useful for a dark matter search as the expected event rate from WIMP interactions is highest at low energies. A small improvement in the energy threshold can lead to a significant improvement in the sensitivity of the experiment. The energy resolution is less important as the dark matter spectrum is featureless; however it allows

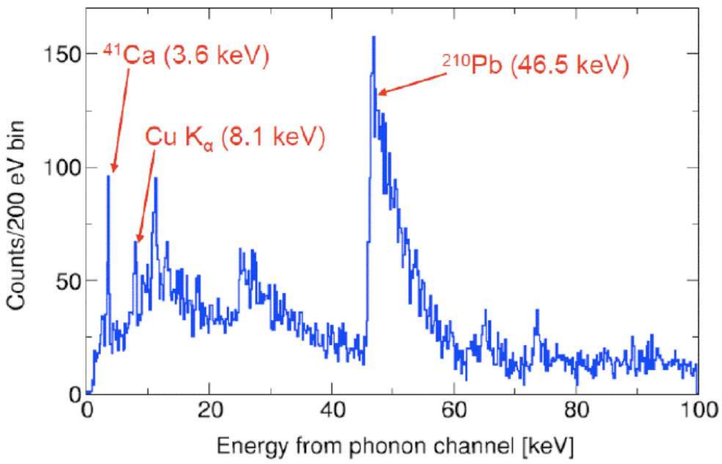

Figure 1: A background spectrum recorded by a CRESST detector.

the accurate identification of impurities in the absorber crystals from spectral lines. This is illustrated in Figure 1; further detail about backgrounds in CRESST is published elsewhere [1]. We expect that this information will be very valuable to allow sourcing radiopure scintillator crystals for EURECA.

The scintillation light produced by a particle interaction is detected by a second cryodetector consisting of a separate silicon absorber, equipped with a tungsten SPT sensor. Comparing the scintillation signal with the phonon signal allows us to identify each event as either being caused by a nuclear recoil or an electron recoil. The scintillating crystals are surrounded by a reflecting foil, which also acts as a scintillator, so any alpha decays on the surface of the dark matter target crystal (where the alpha particle recoils away from the target crystal) also produce a scintillation signal.

This combination of excellent energy resolution and threshold, with powerful event-by-event background discrimination make these detectors ideal for a dark matter search experiment.

2 Setup at Gran Sasso

The CRESST II upgrade was designed to allow us to run up to 33 detector modules [2]. The detector modules are cooled to $\sim$ 10mK temperature using a dilution refrigerator. The detector support structure is surrounded by shielding made from radiopure copper and lead. As shown in Fig. 2, this volume immediately around the coldbox of the cryostat (containing the detectors modules) and copper and lead shielding is enclosed, and continuously flushed with nitrogen gas to remove radon. Outside this volume, a muon-veto composed of individual scintillator panels is installed. Further, a polyethylene shield is used to moderate the energies of neutrons to below detection threshold.

The detector signals are read out using a 66-channel SQUID system [3]. The SQUID sensors are installed at the bottom of the main helium cryostat (see Fig. 2), and connected to the detectors, and to the room temperature electronics using specially designed woven cables. The

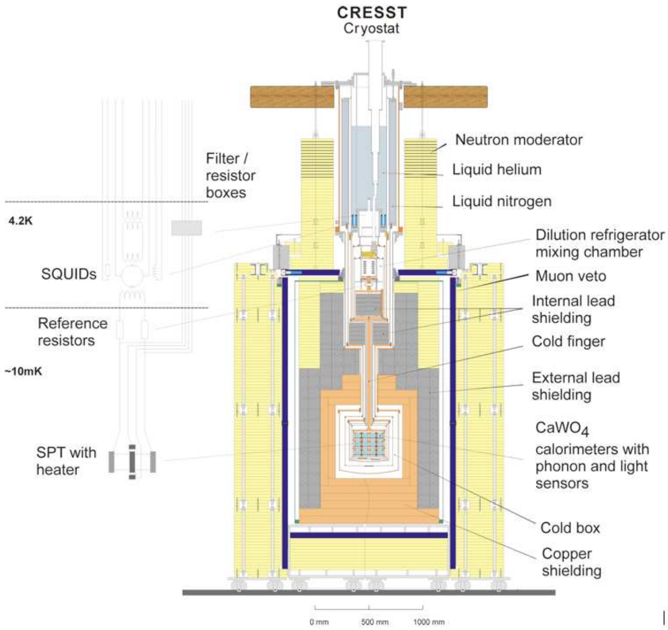

Figure 2: The CRESST cryostat at the Gran Sasso laboratory and the detector readout circuit connecting to an SPT of a detector and a heater on the same detector, used for operation and calibration.

electronics is designed to minimise electromagnetic noise, which could be picked-up by the detectors; and can be controlled remotely from outside the laboratory.

3 Results

An extended commissioning run of the upgraded CRESST II setup was undertaken in 2007. This demonstrated that the detectors could run in a stable fashion for an extended period. Two detector modules produced $\sim$ 48kg days of data, which was used to set an improved upper limit on WIMP-nucleon elastic scattering [1]. The background discrimination worked well; however, three events were present in the tungsten nuclear recoil band.

The most likely cause of these events was then believed to be either neutrons, or recoiling nuclei from an alpha decay on the surface of the crystal; although any alpha particles hitting the foil surrounding the crystal produced a scintillation signal, the clamps supporting the crystal were not completely covered with this foil. With the aim of reducing the number of these events, the neutron shielding around the cryostat was improved, and the clamps were covered with a scintillating epoxy.

A background run with these improvements, and a total of 9 modules was undertaken between August and December 2008. Some modules saw a small number of events in which no scintillation light signal was recorded. These were believed to be not due to particles, but due to a phonon signal produced by cracks in crystals which were clamped to hard.

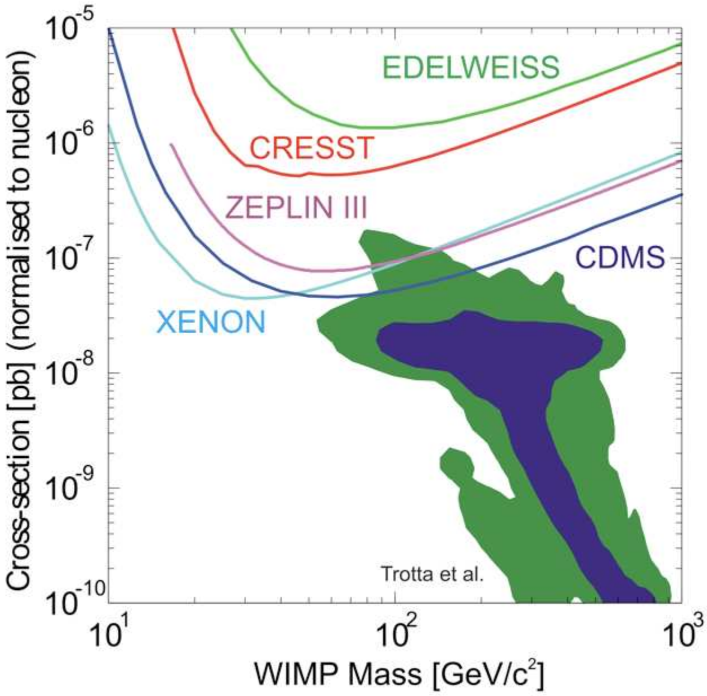

Figure 3: Dark matter limits set by CRESST and selected other experiments [4], and the region predicted by SUSY models [5].

In 2009 all the crystal holders were replaced with new clamps to hold the detectors with less pressure. The cryostat is currently cold and taking data is in progress with this setup; further results are expected shortly.

4 Scintillator research

Until 2008, all CRESST-II detector modules used $CaWO_4$ absorber crystals. We have an ongoing research programme to develop further scintillator materials [6]. This has led to the installation of $ZnWO_4$ crystals into the CRESST cryostat. $ZnWO_4$ is a very promising material with a lower intrinsic radioactivity and potentially higher light yield than $CaWO_4$. We are currently investigating further materials including $CaMoO_4$ and Al_2O_3-Ti. A wide range of detector materials will be particularly useful when we find an indication for a dark matter signal. To claim a discovery of dark matter, verification of the event rate scaling with different target nuclei should be performed. A range of scintillating target materials is especially useful as they can all be operated in the same cryogenic setup, thereby reducing systematic effects.

5 EURECA

CRESST, together with the EDELWEISS experiment [7] and other expert groups, is part of the EURECA [8] (European Underground Rare Event Calorimeter Array) project. This is planned to be a tonne-scale experiment using cryogenic techniques, pioneered by CRESST and EDELWEISS, in order to search for dark matter interactions with a cross section down to 10^{-10} pb. EURECA will be built in the Laboratoire Souterrain de Modane.

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