

The CRESST Dark Matter Search

W Seidel¹, G Angloher¹, M Bauer⁵, I Bavykina¹, A Bento¹, A Brown², C Bucci³,
C Ciemniak⁴, C Coppi⁴, G Deuter⁵, Fv Feilitzsch⁴, D Hauff¹, S Henry², P Huff¹,
J Imber², S Ingleby², C Isaila⁴, J Jochum⁵, M Kiefer¹, M Kimmerle⁵, H Kraus²,
J-C Lanfranchi⁴, R Lang¹, M Malek², R McGowan², V Mikhailik², E Pantic¹,
F Petricca¹, S Pfister⁴, W Potzel⁴, F Pröbst¹, S Roth⁴, K Rottler⁵, C Sailer⁵,
K Schäffner¹, J Schmalzer¹, S Scholl⁵, L Stodolsky¹, B Tolhurst²,
I Usherow-Marshak⁵ and W Westphal⁴

¹ Max-Planck-Institut für Physik, Föhringer Ring 6, 80805 München, Germany

² University of Oxford, Keble Road, Oxford, OX1 3RH, UK

³ Laboratori Nazionali del Gran Sasso, Assergi, Italy

⁴ Technische Universität München, James-Franck-Straße, 85748 Garching, Germany

⁵ Eberhard Karls Universität Tübingen, Auf der Morgenstelle 14, 72076 Tübingen, Germany

e-mail: Seidel@mppmu.mpg.de

Abstract. CRESST is a WIMP dark matter search using scintillating CaWO₄ cryogenic detectors with active background suppression. First results obtained in the commissioning run are presented.

1. Introduction

Despite persuasive indirect evidence for the existence of dark matter in the universe and in galaxies, the direct detection of dark matter remains one of the outstanding experimental challenges of present-day physics and cosmology.

A plausible candidate for the dark matter is the Weakly Interacting Massive Particle (WIMP) and it is possible that it can be detected by laboratory experiments, particularly using cryogenic methods, which are well adapted to the small energy deposit anticipated [1]. Supersymmetry provides a well motivated WIMP candidate in the form of the lightest supersymmetric particle. WIMPs [2] are expected to be gravitationally bound in a roughly isothermal halo around the visible part of our galaxy with a density of about $0.3\text{GeV}/\text{cm}^3$ at the position of the Earth [3].

Interaction with ordinary matter is expected via elastic scattering off nuclei. The elastic nuclear scattering can occur via coherent ("spin independent") or spin-dependent interactions. For the coherent case, a factor A^2 is expected in the cross section, favoring heavy nuclei. We present our WIMP limits in terms of this possibility.

In the CRESST experiment we attempt to detect the WIMP-nucleus scattering using cryogenic methods. For the second phase [4], CRESST-II, we have developed cryogenic detectors based on

scintillating CaWO_4 crystals [5]. When supplemented with a light detector these provide very efficient discrimination of nuclear recoils from radioactive γ and β backgrounds, down to recoil energies of about 10keV. The heaviest nucleus in our crystal is tungsten, for which the recoil energy due to WIMPs is expected to reach up to about 40keV, with rates below 1 event/(kg day). The mass of each crystal is about 300g.

Passive background suppression is achieved with a low background installation and the deep underground location. The overburden of 3500 meter water equivalent at the LNGS leads to a reduction of the surface muon flux by 10^6 to about $1/(\text{m}^2 \text{ h})$, while the detectors themselves are shielded against ambient radioactivity by thicknesses of 14 cm of low background copper and 20 cm of low background lead. A neutron shield consisting of 40cm of Polyethylene and a muon veto, were additionally installed since the last run.

2. Detectors

A single detector module consists of a scintillating CaWO_4 "target" crystal, operated as a cryogenic calorimeter (the "phonon channel"), and a nearby but separate cryogenic detector optimized for the detection of scintillation photons (the "light channel"). A schematic representation of a detector module is shown in figure 1.

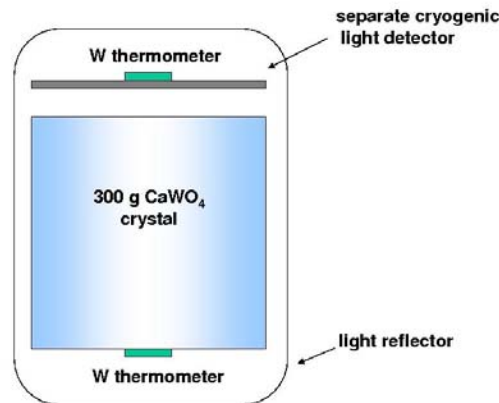


Fig.1 Schematic representation of the detector for coincident phonon light measurements. It consists of two cryogenic detectors enclosed in a highly reflective housing, read out by two tungsten superconducting phase transition thermometers

The phonon channel is designed to measure the energy transfer to a nucleus of the CaWO_4 crystal in a WIMP-nucleus elastic scattering. Since a nucleus and an electron or gamma of the same recoil energy differ substantially in the yield of scintillation light, an effective background discrimination against gammas and electrons is obtained by a simultaneous measurement of the phonon and light signals. Among different scintillating crystals, CaWO_4 was selected because of its high light yield at low temperatures and the absence of a noticeable degradation of the light yield for events near the crystal surface [6]. Such a degradation, often found in coincident phonon-charge measurements and some scintillators, can cause difficulties as it may lead to a misidentification of electron/photon surface events as nuclear recoils. In addition, the large atomic mass ($A=183.86$) of tungsten makes CaWO_4 a very favorable target for WIMPs with coherent interactions. A more detailed description of the detectors and their operation can be found elsewhere [5].

3. Commissioning run and results

During the last years the CRESST set-up has been upgraded with a neutron shield, a 66 channel SQUID system, new wiring, new bias electronics, a muon veto and a new DAQ. It is now capable to house up to 33 detector modules. After the upgrade a commissioning run was started to optimize the overall performance of the system. This run was also used for a short physics run in which in total 49,8 kg days of data were collected.

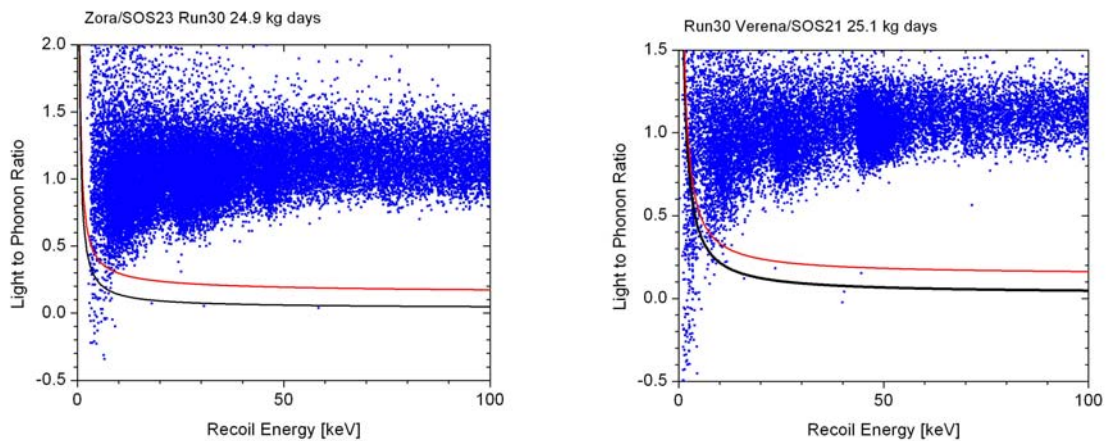


Figure 2. Low energy event distributions for the two modules Zora/SOS23 and Verena/SOS21. The vertical axis represents the light yield expressed as the ratio (energy in the light channel/energy in the phonon channel), and the horizontal axis the energy in the phonon channel. The region below the upper line contains 90% of all recoils while the region below the lower line contains 90% of the tungsten recoils.

Data of two detectors obtained in this run are shown in figure 2. The limits which are obtained from the data in a similar way as described in reference [5] combined with the data of reference [5] are shown in figure 3.

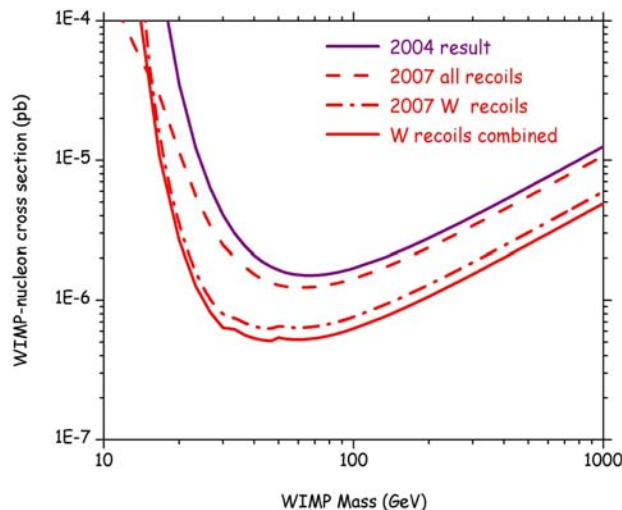


Figure 3. Preliminary limits of the 2007 commissioning run

Since a neutron calibration is still missing these limits should be considered as preliminary. They will be finalized after the neutron calibration in November 2007 and will be published elsewhere.

4. Acknowledgements

This work was partially supported by the DFG SFB 375 “Teilchen-Astrophysik”, Transregio27 “neutrinos and Beyond”, the Munich cluster of Excellence (“Origin and Structure of the Universe”), the EU Network “Cryogenic Detectors” (contract ERBFMRXCT980167), the EU Network HPRN-CT-2002-00322 “Applied Cryodetectors”, The Maier-Leibnitz-Laboratorium (Garching), BMBF, PPARC, two EU Marie Curie Fellowships and the network on direct dark matter detection of the ILIAS integrating activity (R113-CT-2003-506222)

References

- [1] M.W.Goodman and E. Witten, Phys. Rev. **D31** (1985) 3059
- [2] A general review, including matters related to direct detection, may be found in G.Jungman, M.Kamionkowski, and K.Griest, Phys. Rep. **267** (1996) 195.
- [3] J. A. R.Caldwell and J. P.Ostriker, Ap. J. **251** (1981) 61. For a more recent discussion with a wider range of values see E. I.Gates, G.Gyuk, and M. S.Turner, Ap. J. **449** (1995) L123.
- [4] Update of the proposal to the LNGS for a second phase of the CRESST dark matter search, MPI-PhE/2001-02.
- [5] G. Angloher et al. Astroparticle Physics **23** (2005) 325-339
- [6] P.Meunier, M.Bravin, M.Bruckmayer, S.Giordano, M.Loidl, O.Meier, F.Pröbst W.Seidel, M.Sisti, L.Stodolsky, S.Uchaikin and L.Zerle, Appl. Phys. Lett. **75** (1999) 1335.