First results from CRESST-II Phase 2

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The CRESST-II (Cryogenic Rare Event Search with Superconducting Thermometers) experiment, currently in its second phase, aims at the direct detection of WIMPs. Compared to previous runs the intrinsic radiopurity of $CaWO_4$ crystals and the capability to reject recoil events from alpha-surface contamination were significantly improved. Data from 29 kg-days of exposure acquired by a single $\sim 250\,g$ $CaWO_4$ detector provide competitive limits on the spin-independent WIMP-nucleon cross section, particularly for low-mass WIMPs, and probe a new region of parameter space for WIMP masses below $3\,\mathrm{GeV/c^2}$.

1 Introduction

Direct searches for dark matter in form of Weakly Interacting Massive Particles (WIMPs) have significantly improved the sensitivity to spin-independent WIMP-nucleon scattering within the last two decades. Possible hints for low-mass WIMPs with masses of $\mathcal{O}(10\,\mathrm{GeV/c^2})$ which recently arose [1, 2, 3, 4] are, however, clearly excluded by a variety of experiments [5, 6, 7, 8, 9, 10]. During the last years, these non-conclusive experimental results and theoretical dark matter models (see e.g. [11]) drew the attention to WIMPs with masses of $\lesssim 10\,\mathrm{GeV/c^2}$.

2 Results of the detector module TUM40

The CRESST-II (Cryogenic Rare Event Search with Superconducting Thermometers) experiment uses scintillating $CaWO_4$ crystals as target material for dark matter particles [1]. The modular detectors of 200-300 g each are based on a two-channel detector readout: 1) The target crystal itself is operated as a cryogenic detector at mK temperatures to measure the total deposited energy of particle interactions. This phonon channel is read-out by transition edge sensors (TES) realized by thin W-films. 2) A separate light detector (silicon-on-sapphire disc), also equipped with a TES, measures the scintillation light output induced by particles. Due to light quenching [12] this additional information provides identification of the type of particle interaction. Thus, beta/gamma background events can be discriminated from possible WIMP-induced nuclear-recoil events which, to a certain extent, can further be tagged as O, Ca and W recoils [13].

CRESST-II Phase 2 has started in July 2013 with a total target mass of $\sim 5\,kg$ using 18 detector modules of four different detector designs [15]. In this paper, one single detector module (called TUM40) of a new design, with the best performance among the detectors installed in CRESST-II Phase 2, is described. A block-shaped $CaWO_4$ crystal with a mass of 249 g is held by sticks made of $CaWO_4$, for details see [14]. Together with a polymeric foil the sticks provide a

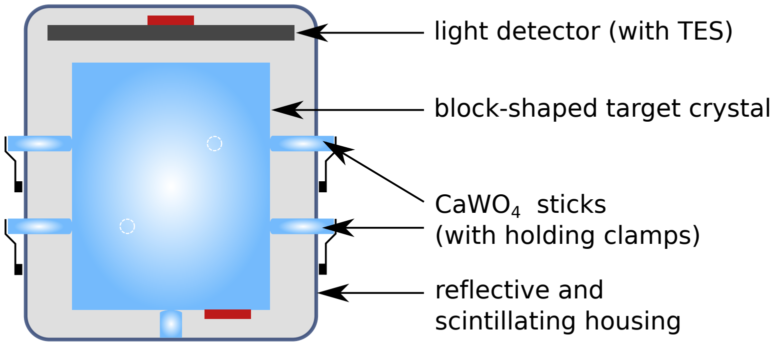

Figure 1: Scheme of the new detector module based on $CaWO_4$ sticks fed through the scintillating housing (polymeric foil). Inside the housing only scintillating material is present in order to reject surface-alpha background, see [14]. Unlike in the conventional design the bronze clamp are located outside.

detector housing with fully-scintillating inner surface (see Fig. 1). Using this design, previously observed backgrounds from surface-alpha decays are rejected with high efficiency [14]. For the first time, $CaWO_4$ crystals from in-house production at the Technische Universität München [16] are operated in the CRESST-II setup. Using one of these crystals, the intrinsic background level could be reduced significantly to an average beta/gamma rate of 3.44/[kg keV day] in the region of interest at 1-40 keV [17, 18]. An energy threshold of $\sim$ 600 eV and a resolution of σ_{ph}=(0.090±0.010) keV (at 2.60 keV) were reached with TUM40. With the silicon-on-sapphire light detectors (diameter: 40 mm, thickness: 500 μm) used, a baseline resolution of $\sigma_l \sim 5$ eV is achieved.
In the first TUM40 data with 29 kg-days of exposure, all events observed in the region-of-interest for dark matter search are compatible with leakage of beta/gamma background. No indications for additional events above this background are observed. Therefore, a limit on the spin-independent WIMP-nucleon scattering cross section is derived (see Fig. 2) [17]. A new region of parameter space for WIMP masses below 3 GeV/c^2 is probed. An excess signal as observed by the previous results of CRESST-II [1] is not confirmed.

3 Conclusion and Outlook

The results of CRESST-II Phase 2 [17] demonstrate the potential of phonon-light detectors using scintillating crystals, in particular, for low-mass WIMP search. A new detector concept which provides an efficient veto against surface-alpha backgrounds has been successfully operated in the CRESST setup. The first data of CRESST-II Phase 2 with a moderate exposure of 29 kg-days acquired by a single detector module set a new limit on spin-independent WIMP-nucleon scattering cross section. A new region of parameter space is probed for WIMP masses below 3 GeV/c^2.
Concerning the search for higher WIMP masses ($\gtrsim$ 10 GeV/c^2), the discrimination capability of the present detector performance is sufficient. Above an energy of $\sim$ 12 keV, no leakage of beta/gamma events is expected in CRESST-II detectors of this new design, even for a possible ton-scale experiment ($< 10^{-4}$ events per detector and year [18]) as far as no other backgrounds

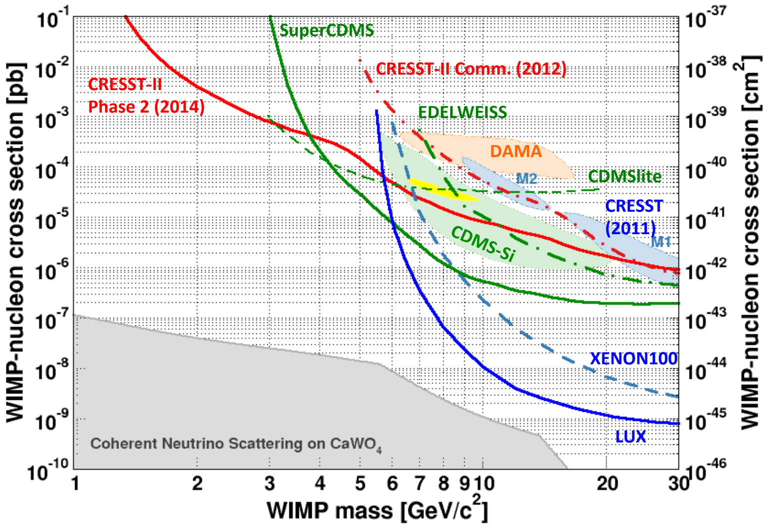

Figure 2: Spin-independent WIMP-nucleon cross section plotted against the WIMP mass with selected experimental results from direct dark matter searches [1, 2, 4, 5, 6, 7, 8, 9, 10]. The results of CRESST-II Phase 2 [17] (red full line) give the presently best limit below WIMP masses of ~3 GeV/c^2. It disfavours a WIMP-interpretation of the previous results of CRESST-II [1].

appear.
To increase the sensitivity to low-mass WIMPs (masses below 10 GeV/c^2) the performance of the detectors must be further improved. In particular, efforts to reduce the energy threshold, to improve the optical quality of the $CaWO_4$ crystals and to lower the background level are ongoing. There is a high potential to further investigate the low-mass WIMP region with future CRESST detectors and, for the first time, sensitivities to detect coherent neutrino-nucleus scattering might be in reach with exposures of $\sim$ 300 kg-years [19].

Acknowledgments

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