The CRESST Dark Matter Search ◇

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The goal of the CRESST at Gran Sasso is the direct detection of particle Dark Matter. The search for Dark Matter remains one of the central problems in cosmology. There is strong evidence for it. The history of the universe is difficult to reconstruct without it, be it big bang nucleosynthesis [1] or the formation of structure [2].

Particle physics provides a candidate for Dark Matter with the lightest supersymmetric particle, the 'neutralino'. Generically, such particles are called WIMPS (Weakly Interacting Massive Particles). WIMPS are expected to interact with ordinary matter by elastic scattering on nuclei. Conventional methods for direct detection rely on the ionisation caused by the recoiling nucleus with low efficiency. Cryogenic detectors as used by CRESST rely on the principal physical effect of a WIMP nuclear recoil, the generation of phonons. The detectors developed by the CRESST collaboration consist of a dielectric crystal (absorber) with a small superconducting film evaporated onto the surface. When this film is held at the temperature of the superconducting phase transition, it functions as a highly sensitive thermometer. The present detectors use tungsten films and sapphire absorbers.

The central part of the CRESST low background facilitity is the cryostat. The cold box is constructed entirely of low background materials. During 1998 the installation was completed and showed stable operation for a period of months. At present four 262 g detectors are running. First results have shown that at energies above 30 keV, the counting rate is on the order of a few counts/ (kg keV day) and above 100 keV below 1 count/(kg keV day)

An advantage of cryogenic detectors is that they allow to use a wide variety of target materials. However, the choice is limited in practice due to restrictions by the fabrication process. Tungsten films, for example grow in proper structure almost exclusively on sapphire and the materials have to stand high temperatures during evaporation. One project at TUM focuses on the development of another thermometer type, the iridium-gold proximity sandwich, which can be used on a wide choice of absorber materials. A germanium detector with a mass of 342 g is in preparation.

Passive techniques of background reduction – radiopure materials and a low background environment – are of course imperative. However, the remaining background is dominated by β and γ emissions from nearby radioactive contaminants. These produce exclusively electron recoils in the detector. In contrast WIMPs, and of course also neutrons, lead to nuclear recoils. Therefore, dramatic improvements in sensitivity are to be expected if the detector itself is capable of distinguishing electrons from nuclear recoils.

We have recently developed a system, using $CaWO_4$ crystals, where a measurement of scintillation light is carried out in parallel to the phonon detection [3]. We find that these devices clearly discriminate nuclear recoils from electron recoils by a different ratio of light- to phonon-signal. The system consists of two independent detectors: A scintillating absorber with a superconducting phase transition thermometer on it, and a similar but smaller detector placed next to it to detect the scintillation light from the first detector. Irradiations with electrons, photons and neutrons show, that the rejection factor for electron recoils is 98% in the energy range between 10 keV and 20 keV, 99.7% in the range between 15 keV and 25 keV and better than 99.9% above 20 keV. The opportunity to employ different scintillators with different target nuclei, which is possible with CRESST technology, gives an unique handle for understanding and reducing backgrounds. Even the neutron background, always considered to be the ultimate limitation for such systems, could be understood by varying the target nuclei.

The intrinsic background in our $CaWO_4$ crystals is now being measured in the new Munich low background laboratory. No contamination was found as of this writing. For testing the detectors in Munich, the TUM group set up a mobile and compact cryostat system. It is based on a Helium-4 cryostat in combination with an adiabatic demagnetization stage. This cryostat allows much faster and more flexible tests than possible with the dilution fridge, which was the only available test site so far.

The present sapphire detectors, with their extremely low energy thresholds and a low mass target nucleus, are presently the only detectors able to explore the low WIMP mass range from 1 GeV to 10 GeV effectively. The new $CAWO_4$ light-phonon-detectors will improve the sensitivity for high mass WIMPSs (above 50GeV) by some orders of magnitude. With a 100 kg $CaW0_4$ detector and one year of measuring time one can probe relevant parts of the minimal supersymetric models (MSSM) parameter space for neutralino dark matter.

The unique large volume cryogenic radiopure set up at Gran Sasso and the combination of detectors, CRESST is one of the most promising experiments for the direct particle dark matter search.

References

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