Dark Matter Search with CRESST

W. Rau , C. Coppi , F. v. Feilitzsch , Th. Jagemann , J. Jochum , J. König , W. Potzel , M. Razeti , M. Stark , W. Westphal , and H. Wulandari

CRESST (Cryogenic Rare Event Search with Superconducting Thermometers) employs scintillating cryogenic detectors for the search for Weakly Interacting Massive Particles (WIMPs), that are proposed as Dark Matter particles constituting about 85 % of the matter in the universe. The main challenges of such an experiment are the low expected energy transfer in a nuclear recoil and the extremely low rate of interactions. Detectors sensitive to nuclear recoils as expected from WIMP interactions are as well sensitive to other kinds of radiation. Therefore CRESST is placed in the Gran Sasso underground laboratory in Italy for shielding against cosmic radiation. The environmental radioactivity is heavily suppressed by a 30 t lead and copper shielding directly surrounding the experiment. In addition the detector concept used in CRESST allows an active background suppression: electron recoils as induced e.g. by γ- or β-radiation produce much more light than nuclear recoils as expected from WIMPs or neutrons.

The detector response to nuclear recoils is calibrated with neutrons. However, using a standard neutron source (e.g. AmBe), the main signal will be from recoiling oxygen nuclei in our $CaWO_4$ target, whereas WIMPs are expected to preferably interact with tungsten, since for a coherent interaction the cross section is proportional to A^2, where A is the number of nucleons in the nucleus.

Therefore an experiment has been setup at the MLL-tandem accelerator to separately measure the response to the different recoiling nuclei. A monoenergetic pulsed neutron beam, produced via the reaction $p(^{11}B,n)^{11}C$, is directed onto the $CaWO_4$ target while the energy of the scattered neutrons is measured via their time-of-flight under a given angle. Thus the kinematics of the reaction is fully determined which allows to separate tungsten from oxygen or calcium recoils. A first set of measurements has been performed at room temperature. The quenching factors (that is the ratio of the light output from an electron recoil to that of a nuclear recoil of the same energy), found in this way are 12.8 ± 0.5 for oxygen, 16 ± 4 for calcium and >33 (2σ) for tungsten.

The next step is the presently performed installation of a cryostat. This will allow to measure the quenching factors under more realistic conditions, that is at temperatures in the milli-Kelvin range as used in the Dark Matter search in Gran Sasso.

A second measurement of the quenching factors at room temperature was performed with a different technique at the Max-Planck-Institut für Physik (München). Here beams of ions with different masses are directed onto the target and the light output is measured. This measurement also yields a dependence of the quenching factor from the mass of the nucleus. The result for tungsten here is 40 ± 5.

The large difference between the quenching factors for oxygen and tungsten allows in addition to the discrimination of electron recoils also a partial discrimination of the neutron background.

In spring 2004 a first long-term test of this new detection concept was carried out. Two detector modules have been running for about two months resulting in a total exposure of ~ 20 kg-days. The results are published in [1]. The measured rate of nuclear recoils is about 0.9 events/kg/day consistent with the expected rate of neutrons from radioactivity in the surrounding rock. One of the two modules has a sufficient energy resolution in the light channel to discriminate between oxygen and tungsten recoils down to a reasonably low energy (given, the quenching factor for tungsten is 40 also at low temperatures). Under this assumption a very good upper bound on the WIMP-nucleon cross section of 1.6×10^{-6} pb for 60 GeV WIMPs can be deduced.

As a side result, the decay of ^{180}W has for the first time been observed unambiguously with a half-live time of $T_{1/2} = (1.8 \pm 0.2) \times 10^{18}$ years [2].

Presently the CRESST setup is being upgraded by adding a neutron moderator and a muon veto and increasing the number of electronic channels to allow operation of a total target mass of up to 10 kg.

References

[1] CRESST collaboration, G. Angloher *et al.*, in press in Astropart.Phys.

[2] CRESST collaboration, C. Cozzini *et al.*, Phys.Rev. **C70** (2004) 064606