Dark Matter Search with CRESST

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There is compelling evidence for the existence of large amounts of non-luminous matter in the Universe. About 85 % of this Dark Matter is non-baryonic and not composed of any type of particles known in the standard model of particle physics. Weakly Interacting Massive Particles (WIMPs) are among the best motivated candidates for Dark Matter. This hypothesis is also supported by the prediction of Supersymmetric extensions of the standard model of particle physics, where the lightest of the supersymmetric particles is neutral and stable and as such has the right properties to explain the cosmological and astrophysical observations of Dark Matter.

CRESST (Cryogenic Rare Event Search with Superconducting Thermometers) is an experiment to search for direct interactions of Dark Matter WIMPs with ordinary matter by means of scintillating cryogenic detectors capable of discriminating most of the radioactive background through the different ratio of the thermal and the scintillation signal for electron recoils (background) and nuclear recoils (as induced by WIMPs).

The experiment is placed in Hall A of the Gran Sasso Underground laboratory in Italy where the potential of the method was demonstrated in a first measurement campaign. In this measurement from early 2004 only two detectors were exposed and the sensitivity was limited by neutrons from radioactivity of the surrounding rock [1].

The experimental setup has been upgraded in several respects: first a 50 cm thick polyethylene neutron moderator was installed around the existing setup, which is expected to reduce the neutron flux from environmental radioactivity by more than three orders of magnitude. Thus muon induced neutrons produced in the lead shielding remain as the dominating background. To also reduce this background, a muon veto detector was installed, which consists of 20 plastic scintillator panels. With the background reduced in this way by several orders of magnitude, it makes sense to increase the target mass for a better sensitivity. Therefore also additional electronics has been installed to run up to 33 detector modules corresponding to a total mass of 10 kg at the same time. The setup is being complemented with a new detector holding system inside the cryostat which allows to install the 33 detector modules. The installations are almost finished and a restart of the system is planned for Summer 2006.

For a good understanding and a reliable interpretation of the experimental data it is necessary to thoroughly investigate the detector response. Of special importance is the scintillation efficiency from nuclear recoils. The different light output of oxygen and tungsten recoils in our $CaWO_4$ target crystal allows to partially also discriminate the neutron background events which produce a signal dominated by oxygen recoils, while WIMPs are expected to prefer tungsten as scattering partner. Measurements of the quenching (light reduction for nuclear recoils as compared to electron recoils) have been performed at room temperature with different methods. At the Max-Planck-Institut für Physik a Time-of-Flight mass spectrometer has been used to irradiate the target with ions of different mass, showing a decreasing light output with increasing mass of the ion. This method is relatively easy to apply, but it probes only the crystal surface and can not be performed at temperatures in the mK range. At the MLL-tandem accelerator a neutron scattering facility is operated to study the scintillation light output from recoils of the different nuclei [2]. This method is technically more difficult but allows to probe the bulk and can be performed also at very low temperatures. The installation of a cryostat at the beamline is foreseen for Summer 2006. In addition, a standard neutron source (AmBe) has been used for a first determination of the quenching for different nuclei at low temperature. The neutron signal is dominated by oxygen recoils for the given neutron spectrum of the source but there is a region around 300 keV recoil energy where calcium recoils have a considerable contribution of about 20 %. From the distribution of the scintillation efficiency ('Yield') of the nuclear recoil events in this region one can deduce quenching factors for oxygen and calcium of about 8 and 13, respectively (see Fig. 1). Also these measurements will be improved by reduction of the target size to reduce double scatter effects. We are also working on improving the light detection by application of the Neganov-Luke effect for phononic amplification [3].

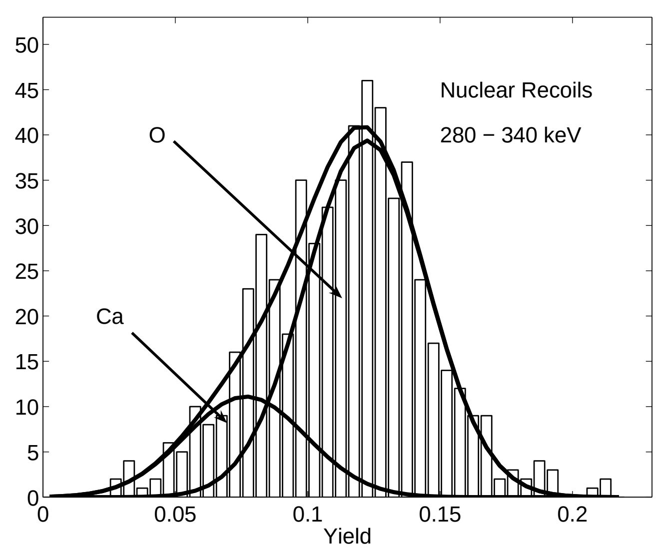

Fig. 1: Shown is the distribution of the light yield of nuclear recoils in $CaWO_4$ in the energy range from 280 to 340 keV. The asymmetric distribution can be fitted with two Gaussians, which represent the Ca (22 %) and the O (78 %) recoils. The deduced quenching factors are 13 and 8 respectively.

References

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