Ir/Au–Proximity Phase Transition Thermometers for the CRESST Dark Matter Search

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The CRESST dark matter search experiment [1,2,3] presently is using sapphire absorbers with tungsten superconducting phase transition thermometers evaporated onto their surface. For both, the investigation of possible backgrounds and for the elucidation of the nature of a Dark Matter candidate in case of a positive signal, it would be desirable to vary the absorber material. CRESST recently has developed detectors, capable of simultaneously measuring a temperature signal and scintillation light produced in the absorber crystal. Since the light output is different for nuclear recoils and electron recoils, one can distinguish Gamma- and Beta-background from nuclear recoils scattering events. The sensitivity in the search of particle Dark Matter candidates is increased by orders of magnitude. The scintillating crystal used as absorber is $CaWO_4$.

As soon as large CaWO4 detectors are available, the efficiency of light production of nuclear recoils can be measured and calibrated. Since the tungsten in CaWO4 will be dominant in the coherent scattering of dark matter candidates, it is very important to calibrate the light output for nuclear recoils on tungsten. During the measurement with neutrons, thus scattering on Ca, O and W have to be distinguished. This will be done by the different energy transfers, if the neutron energy and the scattering angle are fixed. The neutron energy will be fixed by the production reaction and by time of flight measurement.

A suitable low background reaction for monoenergetic neutron production at 11 MeV was found to be $^1H(^{11}B,n)^{11}C$. In order to investigate reaction properties, a hydrogen gas cell target was designed and installed in hall II of the accelerator laboratory. The hydrogen gas was contained in a cylindrical stainless steel cell with an entrance window of a 5 μm thick Mo foil, and the beam stopper was a 1.5 mm thick electrically isolated Au plate. Together with an electrically isolated Au aperture in front of the entrance window, this assembly served as a Faraday cup to easily threading the beam onto the target and reading the beam current during the experiment. The pressure of H_2 gas was 0.3 MPa absolute. From the cesium sputtering source, typically –1 μA of either BO^- or B^- was extracted. This beam was then chopped by a combination of both a 5 MHz low and high energy oscillator and bunched by a rf wave. The repetition rate of the beam was 1.25 MHz with a burst duration of about 1 ns.

The neutrons were detected by a 5 cm thick NE213 scintillator optically coupled to a Philips XP3461B photomultiplier tube set at several angles. Conventional time of flight technique with a pulse-shape n–γ discrimination was used. The neutron source properties were measured for an incident ^{11}B beam of 61 MeV hitting the hydrogen target.

Neutrons were produced with high monochromaticity and collimate into a forward cone with a maximal opening angle $\theta_{max} = 39$ according to the inverse kinematical condition.

For the final calibration of the cryogenic detectors, the neutron pulse repetition rate has to be much lower, such as 5kHz. Since the rate of events, coincident in the cryogenic detector and the neutron detectors will be very low, the background of randomly scattered neutrons will pose the main problem. During this year we plan beam times to optimize all parameters with respect to the background.

To increase the rate of 'good' coincidences, we tested 40 neutron detectors. These detectors were arranged in two ring-shaped arrays of 2 and 4 m diameter holding 10 and 30 of them, respectively. Data acquisition was established so that all 40 detectors could be read out at once. The rings were kept adjustable along the direction of the beamline in order to allow the investigation of different scattering angles. Several scattering experiments to test the trigger electronics and data acquisition of the setup using NE213 and NaJ at room temperature were carried out succesfully.

To run the cryogenic detectors, we set up an Oxford AST50 dilution refrigerator controlled by Kelvinox thermometry in hall II. Additionally, an adjustable platform to support the cryostat was installed and isolated against vibrations by means of pneumatic shock absorption and a 15 cm thick wooden plate. This year we plan to finish the additional temperature stabilization and the installation of two Jena SQUID channels required for the coincident phonon and scintillation light measurement. In april 2002, a scattering experiment is prepared for the measurement of the scintillation efficiency of nuclear recoils in $CaWO_4$ at room temperature.

Additionally a simulation of the experiment setup is discussed by Monte Carlo methods. A Monte Carlo simulation appears to be the most promising method to discriminate the coincidence of processes caused by two neutrons. For example a neutron scattered by the housing of the photomultiplier or the shielding, hitting a NE213 szintillator, and a second neutron scattered by the $CaWO_4$. Understanding this requires to calculate the sequence of all interactions from origin of the neutron to the energy deposition in the $CaWO_4$ or the NE213 szintillators. The need of tracking single particles and interactions resulted in using the geant4 [4] software package.

References

[1] J.Schnagl, J.Jochum *et al.*, "Development of Detectors with Ir/Au Thermometers", in Proceedings of 8th International Workshop on Low Temperature Detectors, Dalfsen, Netherland, Aug 16-20, 1999, to appear in Nucl. Instr. Methods

[2] J.Jochum for the CRESST Collaboration, "The CRESST Dark Matter Search", in Proceedings on Conference on Topics of Astro-Particle and Underground Physics, TAUP 99, Paris, France, Sep 6-10, 1999

[3] J.Jochum for the CRESST Collaboration, "The CRESST Dark Matter Search", in Proceedings of 4th UCLA Symposium on Dark Matter and Dark Energy DM2000, Marina del Rey, CA, USA, Feb 23-25, 2000 and hep-ex 0005003

[4] http://wwwinfo.cern.ch/asd/geant4/geant4.html
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