Neutron Scattering Experiment for the CRESST Dark Matter Search

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The CRESST dark matter search experiment [1,2,3] recently has developed detectors capable of measuring the temperature signal in coicidence with scintillation light produced within the absorber crystal. Since the light output of $CaWO_4$ used as absorber is different for nuclear and electron recoils, one can discriminate Gamma and Beta background events from nuclear recoil scattering events. It is important to calibrate the light output for nuclear recoils on tungsten since tungsten in $CaWO_4$ will be dominant in the coherent scattering of dark matter candidates. For this purpose a neutron scattering facility has been set up in hall II of the Maier-Leibniz-Labor in Garching. Fast neutrons are necessary to provide an energy transfer that is comparable to what is expected from WIMP interaction. For the calibration it is important to distinguish nuclear recoils on Ca, O and W. This will be done by the different energy transfers while the neutron energy and scattering angle are fixed. The neutron energy is determined by the production reaction in combination with conventional time of flight measurement.

A suitable low background reaction for monoenergetic neutron production at 11 MeV was found to be $^{1}H(^{11}B,n)^{11}C$. The gaseous hydrogen target is contained in a cylindrical stainless steel cell with an entrance window of a 5 μm thick Mo foil; the beam stop is a 1.5 mm thick electrically insulated Au plate. Together with an electrically insulated Au aperture in front of the entrance window this assembly serves as a Faraday cup for easily threading the beam onto the target and reading the beam current during the experiment. The pressure of H_2 gas is 0.3 MPa absolute. ¿From the cesium sputter source, typically -1 μA of either BO^- or B^- is extracted. This beam is then chopped by a combination of both a 10 and 5 MHz low and high energy oscillator and bunched by an RF wave. The repetition rate of the beam is typically 312.5 kHz and cannot be increased due to the long lifetime of the intrinsic fluorescence level of the scintillator. For maximum time resolution a burst duration of about 5 ns could be established for B^--ions. The neutron source properties are measured for an incident ^{11}B beam of 61 MeV impinging on the hydrogen target. Neutrons are produced with high monochromaticity and collimate into a forward cone with a maximum opening angle $\theta_{max} = 39°$ according to the inverse kinematical condition.

Scattered neutrons are detected by an array of 40 NE213 scintillator detectors set at different angles and path lengths. These 5 cm thick NE213 scintillators are optically coupled to Philips XP3461B photomultiplier tubes and allow for pulse-shape n–γ-discrimination and Time-of-Flight measurement due to their fast pulse rise time.

The scintillation efficiency of nuclear recoils in $CaWO_4$ at room temperature is subject to recent measurements. The light output of a cylindrical crystal of 10 mm height and 10 mm diameter is caught by optically coupled Burle 8850 photomultipliers. Interaction of neutrons and gammas in the photocathode and the dynode structure as well as thermionic induced dark pulses give rise to unwanted random coincidences. This background is reduced by facing the crystal by photomultipliers on either side. The dynode signals after the 7th multiplier stage is used to generate a crossover trigger and is also digitized for offline analysis. A second signal after 12 multiplier stages is recorded to get a better information on energies below about 15 keV. The coincidence between the NE213 scintillators, the neutron bunch and the two PMs watching the CaWO4 is determined offline, as well as the energy deposited in the crystal. At low energy, the long lifetime of the CaWO4 intrinsic flourescence level allows for single photoelectron counting which is more accurate than pulse height determination. Single photoelectron triggering also serves for accurately attributing the accelerator bunch trigger to scintillation events within the crystal.

Multiple neutron and/or gamma interaction within the crystal adds to the beam correlated background. Randomly scattered neutrons in the environment of the detector will cause random coincidences between $CaWO_4$ and NE213 detectors. In order to understand and reduce these background contributions a Monte Carlo simulation using the GEANT4 software package is set up [4].

References

[1] Th. Jagemann for the CRESST Collaboration: "The CRESST Dark Matter Search", Paper contributed to the XI International School "Particles and Cosmology", April 18 – 24, 2001

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