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Measurement of nuclear recoil responses of NaI(Tl) crystal for dark matter search

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In direct detection of WIMP dark matter particles, scintillation crystals such as NaI(Tl) are commonly used as targets/detectors. Interactions between WIMP and the crystal are expected to produce nuclear recoils, while energy calibrations for the crystal are done with gamma sources that produce electron recoils. Since the light yields from electron and nuclear recoils of the same energy are different due to their different fraction of energy transferred to electrons, measurements of these light yield ratios -the so-called quenching factors- are necessary to obtain recoil energies from the light yields from WIMP interactions.

On the other hand, nuclear recoil events and beta/gamma-induced events can be discriminated based on their differences in scintillation characteristics. By using a pulse shape discrimination(PSD) analysis, discrimination between WIMP-induced recoils and the background beta/gamma events can be achived.

In this measurement, the quenching factor of a NaI(Tl) crystal (2 cm x 2 cm x 1.5 cm) were measured from the responses of the crystal to nuclear recoils. The nuclear recoils are produced by 2.43 MeV mono-energetic neutrons from D-D fusion reactions in a neutron generator. Neutron-induced events were selected by the time coincidence of signals in BC501a liquid scintillator neutron detectors and the NaI crystal.

In measurements of the quenching factor for sodium and iodine recoils, energies of the recoiling ions range from 6 to 150 keVnr for sodium and 10 to 75 keVnr for iodine. In these ranges, the quenching factors for sodium are measured at 10 points and vary from 10% to 22% and for iodine are measured at 6 points and vary from 5~6%.

The PSD power of the NaI(Tl) crystal was characterized using quality factors and measured from 1 keVnr to 10 keVee. To measure the quality factor, the responses to nuclear recoils are compared to the response to electron recoils produced by Compton scattering of 662 keV gamma-rays from a 137Cs source.

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