PROCEEDINGS OF SCIENCE

Measurement of quenching factor for NaI(Tl) scintillation crystal

Hanwool Ju[1]
Seoul National university (SNU)
1 Gwanak-ro, Gwanak-gu, Seoul 08826, Republic of Korea
E-mail: `hwjoo1240@gmail.com`

Hyeonseo Park
Korea Research Institute of Standards and Science (KRISS)
267 Gajeong-ro, Yuseong-gu, Daejeon 34113, Republic of Korea
E-mail: `hyeonseo.park@gmail.com`

Measurements of the quenching factor for sodium and iodine recoils in a small (2 cm x 2 cm x 1.5 cm) NaI(Tl) crystal have been performed with 2.48 MeV mono-energetic neutrons generated from D-D fusion. The crystal was made from the same Alpha Spectra-grown ingot as a large crystal used for KIMS-NaI experiment. BC501a liquid scintillators are installed in various angles to tag neutrons that scatter off sodium or iodine nuclei. Depending on the scattering angle of the neutron, energies of recoiled ions range from 10 to 100 keVnr for sodium and 10 to 75 keVnr for iodine. Quenching factors of sodium are measured at 4 points and those range from 14% to 20% and those of iodine are measured at 5 points and those range from 5~7%. Additional measurement in lower recoil energy regions for sodium is planned.

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[1]Speaker

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1. Introduction

The Korea Invisible Mass Search (KIMS) collaboration has developed low-background NaI(Tl) crystals that are suitable for the direct detection of WIMP dark matter. In scintillation crystals like NaI(Tl), the light yields from electron and nuclear recoils of the same energy are different. Since calibrations of the crystals are done with gamma sources that produce electron recoils while WIMP interactions are expected to produce nuclear recoils, measurements of these light yield ratios - the so-called quenching factors (QF) - are necessary.

$$\text{Q.F.} = \frac{\text{Light yield from nuclear recoils}}{\text{Light yield from electron recoils}} = \frac{\text{Measured energy of nuclear recoils}}{\text{Recoil energy from nuclear recoils}}$$

2. Experimental setup

2.1 Neutron generator

Neutron is generated by D-D nuclear fusion reaction. About 10^8 neutrons are generated per 1 second and in every direction. The neutrons are collimated with a small hole of 2.5 cm diameter in polyethylene shielding material and the collimated neutrons has ~2.43 MeV kinetic energy.

2.2 NaI(Tl) crystal

A small 2x2x1.5 cm3 NaI(Tl) crystal made from the Alpha Spectra-grown ingot was used as a target. To minimize the probability of neutron multiple scattering in the crystal and uncertainty in energy of neutrons that come into the crystal, a small dimension of the crystal was used. The NaI(Tl) crystal was placed 145 cm from the center of deuterium target in the neutron generator. The distance was chosen in order to prevent pileups in the NaI scintillation time window because of too high neutron rate and make enough space for installation of neutron detectors to detector neutrons scattered in backward directions.

2.3 Neutron Detectors

To identify neutrons that elastically scatter in the crystal, neutron-tagging detectors consisted of 3 inch BC501a liquid scintillator and PMT was used. Distance between the crystal and the detectors were 30~40 cm and chosen in order to obtain enough event rates and reduce uncertainty in recoil energy due to finite detector size.

3. Data Analysis

Data acquisition was done with 400 MHz flash ADC with coincidence between NaI signal and neutron detector signals. In offline analysis, some event selection cuts to reject PMT noses and pick out nuclear recoil events are applied. Quenching factor was evaluated by comparison between the simulated and observed recoil energies.

4.Preliminary result

Quenching factors of sodium are measured at 7 points and range from 14% to 20%. Those of iodine are measured at 5 points and range from 5~7%. But some events with low energies were lost by our trigger conditions so quenching factors of those events might be overestimated, but effects of those are not considered yet.

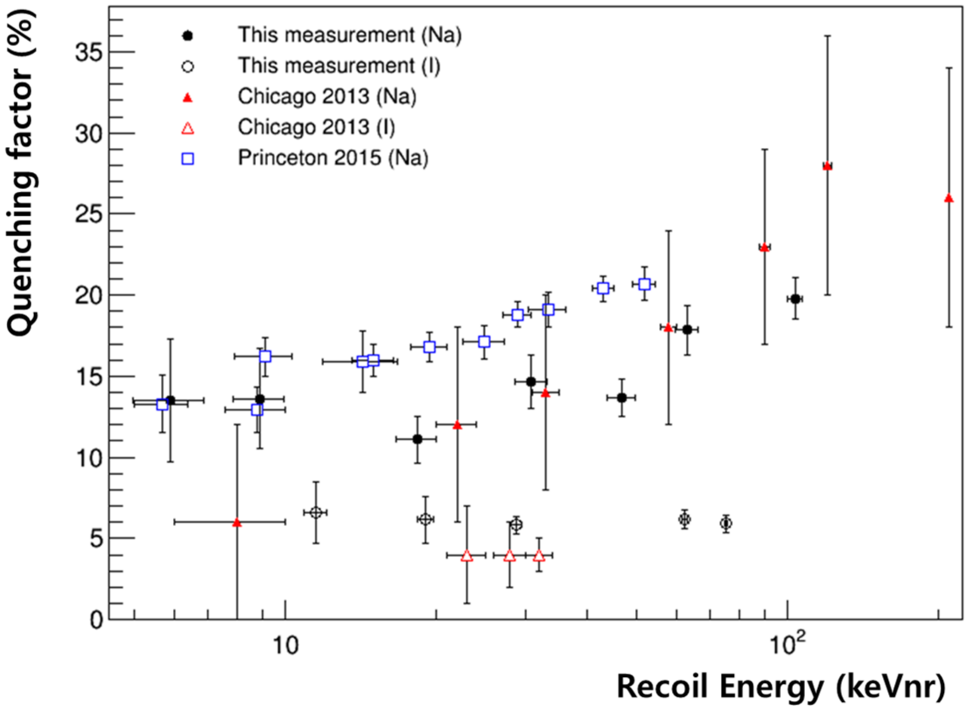

Figure 1 : 2D histogram of quenching factor vs. simulated nuclear recoil energy

5.Preliminary result

Quenching factors were measured for sodium and iodine at 7 and 5 points, respectively. In case of iodine recoils, quenching factor were measured with wider recoil energy range than Chicago group`s.

Correction for trigger efficiency at low energies is needed and measurement of quenching factor for other crystals (with different dopant, from different ingot, etc) is planned.