CO12-1 Development of the CCD-Based UCN Detector with Fine Spatial Resolution

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INTRODUCTION: Quantum mechanics says that gravitational interactions can bind particles in the quantized energy levels as well as electromagnetic and strong interactions. However, a few of experiments to observe such levels were carried and the conclusive result have not been derived yet. Ultra-cold neutrons (UCNs) have lower kinetic energy than Fermi potentials of general materials. Therefore they can be bound by the earth's gravitational field and the bottom mirror. Their vertical distributions have modulations of about 6 microns. A series of experiments [1, 2] to observe such quantum levels were carried out at the Institut Laue-Langevin (ILL). In that experiment, the neutron height distribution was measured by the uranium-coated plastic nuclear detector (CR 39). We have proposed a more precise experiment with a pixel detector with a magnification system for the neutron vertical distribution [3].

DETECTOR DESIGN: We have developed a CCD-based position sensitive detector with a ^{10}B layer. The ^{10}B layer converts neutrons into charged particles by the nuclear reaction, ^{10}B(n, alpha)^{7}Li. A back-thinned type CCD (S7170-0909, Hamamatsu Photonics K. K.) was used to reduce energy loss of converted particles from passing through the insensitive layer. The active region of the CCD has 512 x 512 pixels of 24 x 24 microns. In order to keep the spatial resolution better, the converter was directly formed on the sensitive area by the vacuum evaporation using the Neutron Mirror Fabrication System at the KURRI. For the purpose of protect ^{10}B layer from changes in quality, the converter has three layer structure (Ti 20nm- ^{10}B 200nm- Ti 20nm). The thickness is designed to keep both the spatial resolution and the detection efficiency for UCN. The pressure inside the chamber during the evaporation process was 10^{-5} Torr and the production rate was 0.1 nm/s.

The incident charged particles create electron-hole pairs inside Si substance in CCD and the electrons are detected as a widely spread cluster. The total energy deposit is measured by the sum of charges in a cluster. The incident position is approximated by the barycenter. The energy spectrum of charged particles is shown (Fig. 1).

DETECTOR PERFORMANCE: The detection efficiency was measured by comparing the count rate of the pixel detector and ^{3}He detector (its detection efficiency is known) for neutrons of various energy regions. The detection performance for cold neutrons are measured at Japan Atomic Energy Agency (JAEA) MINE-2, very-cold and ultra-cold neutrons at ILL PF2. The detection efficiencies are derived to be 2.25±0.01 % (for CN 450 m/s), 5.00±0.08±0.47 % (for VCN 97.0 m/s), and 39.7±0.6±3.7 % (for UCN 7.2 m/s). The first error is statistical and the second is systematic. The systematic error is evaluated to small enough compared to the statistics for CN, therefore, only the statistic error is shown.

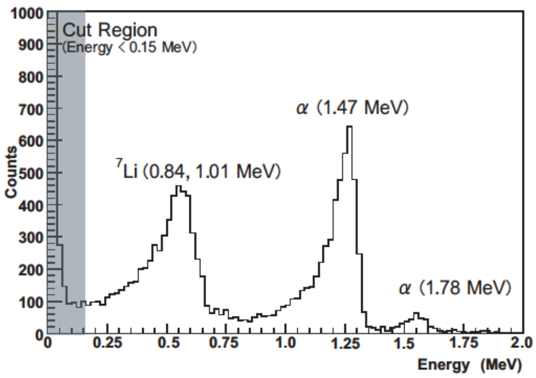

Fig. 1. Energy distribution of signals. Each peak corresponds to the energy deposit of converted particles with a correction of the energy loss in the converter. Low energy cut is applied to reject pedestal events.

CONCLUSION: We have developed a pixel detector for UCN using the Neutron Mirror Fabrication System at KURRI. The detection efficiency for UCN was measured to be 40 %. The spatial resolution has been investigated to be 3 microns. The UCN detector with high efficiency and micron spatial resolution is essential for our proposed experiment.

REFERENCES:

[1] V. V. Nesvizhevsky *et al.*, Nature, **415** (2002) 297-299.
[2] V. V. Nesvizhevsky *et al.*, Eur. Phys. J., **C40** (2005) 479-491.
[3] T. Sanuki *et al.*, Nucl. Instrum. Methods Phys. Res. A ,**600** (2009) 657-660.

採択課題番号 21016 CCD を用いた高位置分解能超冷中性子検出器の開発 共同通常
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