Development of a new low-energy neutron detector with pulse shape discrimination properties for (p,n) experiments

L. Stuhl,*1 M. Sasano,*1 K. Yako,*2 J. Yasuda,*3 and T. Uesaka*1

We are planning to investigate the spin-isospin responses of light nuclei near the neutron drip line[1] using a new experimental technique[2] to measure the (p,n) reaction in inverse kinematics. This method has already been successfully applied to ^{132}Sn isotope[3] at RIKEN. In these inverse kinematical reactions, the detection of recoil neutrons is crucial for missing mass reconstruction, but it is affected by the high gamma-ray background (∼1 kHz). Therefore, reducing the background event rate is of high priority. To achieve a higher signal-to-noise ratio in neutron detection, the possibility of online separation of neutrons and gammas is a key challenge.[4] One must ensure that only useful (p,n) events are tagged during the experiment. This helps in conducting experiments with higher intensity and efficiency at the same time.

We are designing a neutron detector system (as an upgrade for WINDS[5] (Wide-angle Inverse-kinematics Neutron Detector for SHARAQ)) using new advantages of the plastic scintillator composition.[6] From the very beginning of neutron detection, pulse shape discrimination (PSD) between neutrons and gamma rays in plastic scintillators has been an unsolved problem. The new EJ-299-34 type plastic scintillator[7,8] by Eljen Technology can perform neutron and gamma-ray discrimination neutron pulses contain more light in their tail region than gamma-ray pulses. The first prototype of large volume ($30 \times 5 \times 2.5$ cm^3) plastic scintillator detector bars has already been designed and constructed. It is wrapped with mylar foil and coupled to two Hamamatsu H7195 photomultiplier tubes (PMTs) at each end.

PSD measurements were performed by irradiating the scintillator with an unshielded ^{252}Cf source, which was placed on the surface of the scintillator. The charge integration method[9] with analog electronics was applied to perform PSD. The parameters of discrimination were empirically optimised. To quantify the efficiency of the neutron and gamma peak separation of our scintillator bar, the Figure of Merit (FoM) was obtained while projecting the bidimensional discrimination spectrum at a given energy. The FoM values were calculated in a manner similar to that described in Blanc et al.[9]

The obtained PSD spectrum for the prototype detector is presented in Fig 1. FoM values of 0.77 at 300 keVee and 0.81 at 500 keVee energies were obtained for our large volume detector. A similar type of detector with significantly smaller size (2"× 2" (in diam.)) and shape (circular cylinder) was investigated in Cester et al.[7], where FoM values of 0.92 at 300 keVee and 1.05 at 500 keVee were deduced. In this study a digital read out module (CAEN V1720) was used, which could also increase the efficiency of PSD. We believe that the lower FoM values obtained in our measurements are essentially due to the larger scintillator volume of our detector that probably blurs light collection.

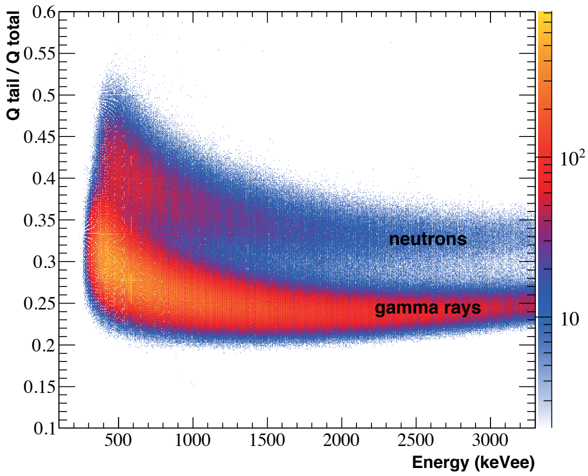

Fig. 1. Neutron/gamma discrimination spectra from prototype detector when exposed to a ^{252}Cf neutron source.

The position sensitivity of the PSD along the scintillator bar was also tested. We conclude that the PSD capability decreases by only less than 15% when the distance between the source and the PMT along the detector bar changes from 5 cm to 25 cm.

Henceforth, the CAENs V1730D module will be used in the construction of digital readout systems. We are planning to complete the development and further optimize the PSD, while increasing the FoM and decreasing the separation threshold. Construction of all detector bars and study of the properties of the upgraded spectrometer in experimental conditions are also scheduled.

*1 RIKEN Nishina Center
*2 CNS, University of Tokyo
*3 Department of Physics, Kyushu University

References
1) L. Stuhl et al.: RIKEN Accel. Pr. Rep. **48**, 54 (2015).
2) M. Sasano et al., Phys. Rev. Lett. **107**, 202501 (2011).
3) M. Sasano et al.: RIKEN Accel. Pr. Rep. **48**, 51 (2015).
4) M. Sasano et al.: In this report.
5) J. Yasuda et al.: RIKEN Accel. Pr. Rep. **48**, 203 (2015).
6) N. Zaitseva et al., Nucl. Instr. Meth. A **668**, 88 (2012).
7) D. Cester et al., Nucl. Instr. Meth. A **735**, 202 (2014).
8) S.A. Pozzi et al., Nucl. Instr. Meth. A **723**, 19 (2013).
9) P. Blanc et al., Nucl. Instr. Meth. A **750**, 1 (2014).