Development of a next-generation PSD type neutron detector, NiGIRI†

H. Matsuzawa,*1 S. Nishimura,*2 T. Isobe,*2 and K. Ieki*1

The azimuthal angle correlation of neutrons (n) and charged particles (p, d, t, ...) with respect to the reaction planes in heavy-ion collisions is a powerful approach for studying equation of state (EOS) in high density nuclear matter.

A next-generation neutron detector, NiGIRI (Neutron, ion, and Gamma-ray Identification for Radioactive Isotope beam), is designed to achieve (a) particle identification capability with pulse-shape discrimination (PSD), (b) high detection efficiency, and (c) high energy resolution. Feather, it is designed to be applicable for multiple particle detections.

NiGIRI is comprised of arrays of detectors, consisting of plastic scintillators (ELJEN EJ299-33, 35×35×60 mm^3), ultra-high quantum efficiency photomultiplier tubes (Hamamatsu H11265-200), and MPPCs (Multi-Pixel Photon Counter, Hamamatsu S10985-100C). The arrays are capable of particle discrimination and position sensibility. A newly developed plastic scintillator EJ299-33 with PSD capability is employed for identifying neutrons from gamma[1,2]. A novel concept followed by NiGIRI is that it reconstructs the particle interaction points in the scintillator by measuring the pulse height and the timing of the PMT and each MPPC attached on the side of the scintillator (Fig.1).

The performance of the PSD was investigated using a neutron source (^{252}Cf), where two charge-integrated QDCs with different gate widths were measured. One gate covers the whole signal and the other covers only the tail part of the signal. The duration of the two gates (total and tail) were 850 ns and 800 ns. Figure 2 shows the correlation plots between the tail and the total QDC values. The neutrons and gamma rays are separated.

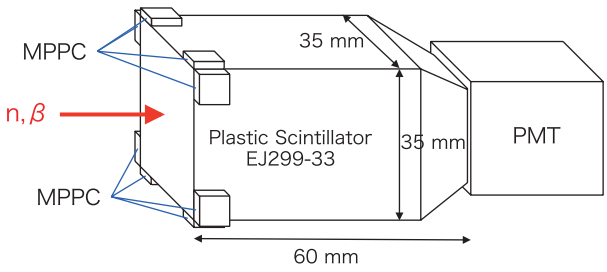

Fig. 1. The overview of the prototype NiGIRI detector.

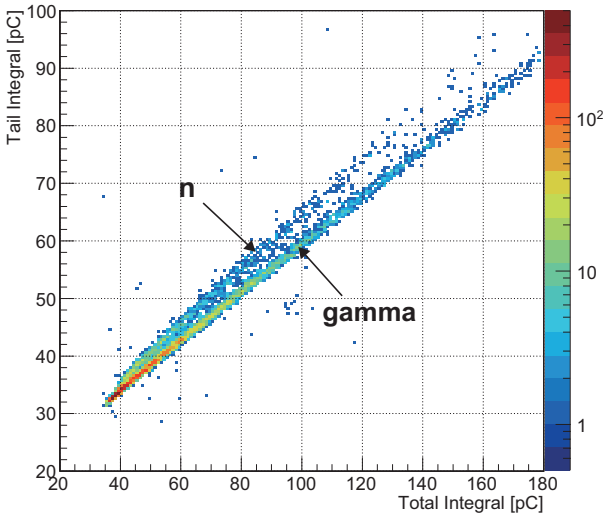

Fig. 2. Pulse shape discrimination between neutrons and gamma rays in EJ299-33.

Position reconstruction of the particles on the surface of the entrance window (35×35 mm^2) was estimated using β rays from ^{90}Sr source, where a 10 mm Al plate with a 1.5 mm diameter hole was used as a collimator. The time difference of signals between PMT and MPPCs was measured. The deviation of the interaction point with regard to depth was ignored in the position calibration owing to its relatively shorter range of β-ray relative to the length of the scintillator. We reconstructed the incident position from the time difference of the averaged two MPPCs between diagonal corners. The position resolution is estimated to be $\sigma_x = 5.8 \pm 0.2$ mm and $\sigma_y = 6.9 \pm 0.4$ mm after the position calibration. Improvement of the position resolution is anticipated by further correction.

Reconstruction of the interaction point in beam direction is under investigation. After the optimization of the prototype NiGIRI detector, mass production of the NiGIRI array will be initialed.

References

1) S.A. Pozzi et al.; Nucl. Instr. Meth. **A 723**, 19-23 (2013)
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† Supported by KAKENHI (25247045).
*1 Department of Physics, Rikkyo Univ.
*2 RIKEN Nishina Center