NiGIRI: Identification of n, p, d, t, ^{3,4}He, ^{6,7}Li, and γ-rays†

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The azimuthal angle correlation of neutrons and charged particles with respect to the reaction plane in heavy-ion collisions is expected to provide essential information on the equation of state (EOS) of high density nuclear matter in supernovae and neutron star. A new scintillation detector NiGIRI (Neutron, ion, and γ-ray Identification for Radioactive Isotope beam), comprises two types of PMTs (Hamamatsu H11265-200, R8520-20-12) attached on both sides of a plastic scintillator EJ299-33 ($30 \times 55 \times 127$ mm^3), is designed to measure the positions and energies of neutrons (≥ 100 keV) and charged particles ($\pi^{\pm}$, p, d, t, ^{3,4}He, ^{6,7}Li, ..) with pulse-shape discrimination (PSD) capability[1-3].

A feasiblity study of the NiGIRI detectors was performed using ^{132}Xe + CsI collisions at energies of 400 AMeV at HIMAC. The energies and positions of charged particles were reconstructed and identified using the correlations of energy losses (ΔE), timings, and PSDs among the different layers of NiGIRI detectors. Sixty four signals (32 NiGIRI detectors x 2 PMTs), recorded with a synchronized wave-dump mode of four flash ADC modules (CAEN V1730B; 500 MHz with 14 bits), were analyzed to deduce the integrated charge, timing, and PSD offline.

Figure 1 demonstrates the particle identification of low energy p, d, t, ^{3,4}He, and ^{6,7}Li in the energy correlation of the 1st layer of NiGIRI (E) and a charged-particle veto plastic scintillator (CPV: 2 mm^t; ΔE). The punch-through charged particles with higher energy were identified using up to 8 layers of NiGIRI detectors.

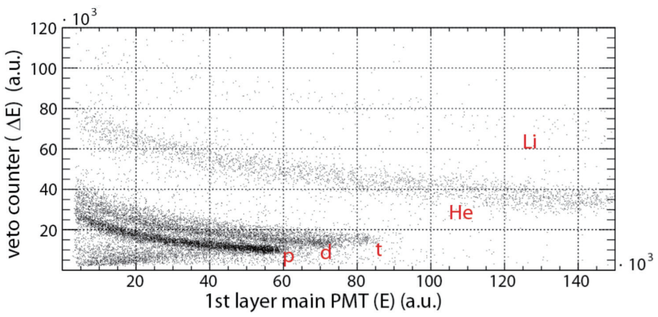

Fig. 1. Correlation between the veto counter (ΔE) and 1st layer (E).

Particle identification of neutrons was tested using the PSD, which is the ratio of the total charge-integral (gate width = 385 ns) and tail charge-integral (gate width = 360 ns; delay = 24 ns) of each PMT signal. The energy dependences of the PSD for charged-particles (Fig. 2a: events with CPV signal) and neutral particles (Fig. 2b: events with no CPV signal) show separation of particles among (p-d-t)-(He)-(Li) and (γ)-(n), respectively. The energies of these ions can be deduced using the time-of-flight (TOF) between the CsI target and the NiGIRI detectors, which is also useful for the consistency check with the energy losses in the NiGIRI detectors. $\pi^{\pm}$ production can also be studied by tagging stopped π decays in wave-dump signals of the last NiGIRI detector.

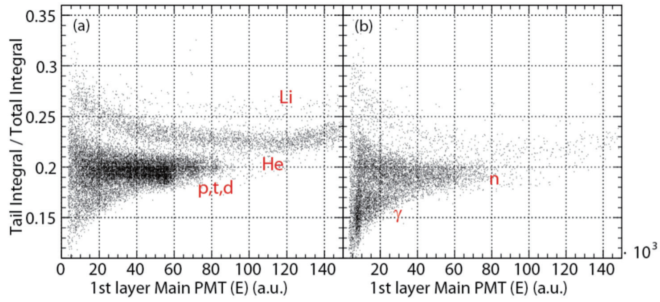

Fig. 2. PSD of the 1st layer main PMT of charged particles (a) and neutrons and γ-rays (b). Charged particle after CP veto in (b) is simply due to insufficient coverage of the NiGIRI detector.

Figure 3 shows the proto-type NiGIRI arrays arranged with full azimuthal coverage. Upgraded NiGIR detectors will be applied at RIBF to study the neutron-proton differencial flow at target rapidity in neutron-rich nucleus collisions, where reaction plane will be determined by measuring the squeeze-out out-of-plane flow in mid-rapidity region.

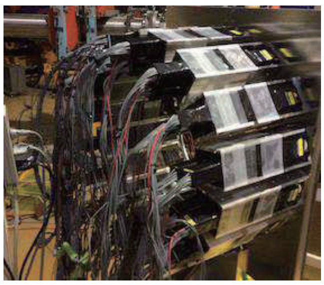

Fig. 3. Thirty two NiGIRI detectors (16 arrays x 2 layers) arranged at target rapidity for multiplicity measurement.

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