PANDORA, a large volume low-energy neutron detector with real-time neutron-gamma discrimination[†]

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Recent nuclear physics studies are increasingly focused on the region far from the valley of stability. The increase in the intensity of available exotic isotopes enables the investigation of phenomena with low cross-sections, such as inelastic scattering and charge-exchange (CE) reactions. Because the cross-sections of the CE reactions are very low, it is crucial to efficiently tag these reaction channels and minimize the contaminant events from other reaction channels with larger cross-sections (*e.g.*, elastic scattering, knockout reactions). The (p, n) CE reactions at intermediate energies (150–300 MeV/nucleon) are a powerful tool to study the spin-isospin excitations in nuclei. The inverse kinematics[1,2] enables the (p, n) reactions on exotic nuclei with a high luminosity. In this technique, neutron detectors are used to measure the time-of-flight (ToF) of low-energy recoil neutrons from a few hundred keV to a few MeV produced from the (p, n) reaction. This methodology has been successfully applied to study the Gamow-Teller strength distribution from ^{56}Ni[2] and ^{132}Sn[3] isotopes. We also started a program at RIBF aiming to study the spin-isospin responses of ^{11}Li and ^{14}Be light drip line nuclei.

The first generation of neutron detectors designed for these measurements, such as LENDA,[4] WINDS,[5] and ELENS[6] cannot distinguish between neutrons and gamma rays. The random gamma background, which mainly arises from the environment, cannot be removed from the neutron spectra. We developed the PANDORA (Particle Analyzer Neutron Detector Of Real-time Acquisition) system as an upgrade of the WINDS detector. PANDORA is based on a plastic scintillator, sensitive to the differences between neutrons and gamma rays. Neutrons and gamma rays can be distinguished by their pulse shapes because their signals in the tail region differ (larger tail for neutrons). PANDORA employs a digital data acquisition system. The signals are read-out with CAEN V1730 digitizer.

We presented the first results on the pulse shape discrimination capabilities of the new large volume plastic scintillator EJ-299-34-based device PANDORA coupled to a digital data acquisition system. The PSD performance was compared to that of the well-established EJ-299-33 scintillator.[7] We introduced the $\mathrm{PSD_{mean}}$ offline value as the arithmetic mean of online PSD values of two single-end read-outs ($\mathrm{PSD_{left}}$ and $\mathrm{PSD_{right}}$). The ToF distributions acquired using a ^{252}Cf fission source

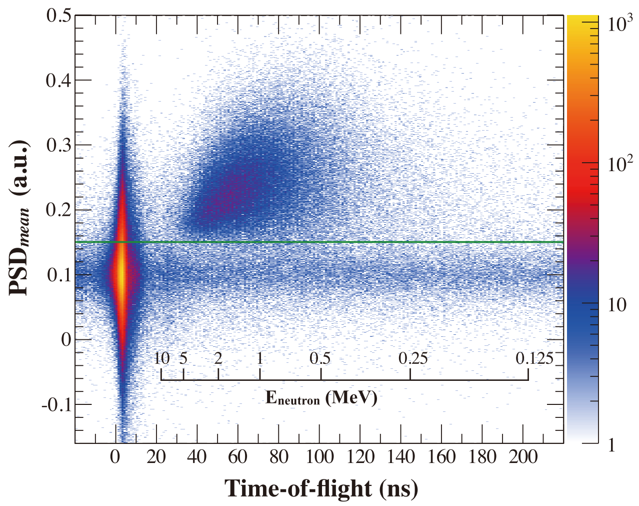

Fig. 1. $\mathrm{PSD_{mean}}$ vs. ToF spectrum shows a good separation of neutron and gamma-like events. The sharp peak below 10 ns corresponds to events identified as gamma rays, while the distribution in the higher ToF region and $\mathrm{PSD_{mean}} > 0.15$ represents neutron-like events. The inner scale corresponds to the kinetic energy of the detected neutrons obtained using the ToF method. A large random gamma background can also be observed.

show that with PANDORA, 91±1% of all detected neutrons can be identified online and 91±1% of the detected gamma rays can be excluded. This online gamma rejection (individual threshold conditions on the left and right PSDs) reduces the background by one order of magnitude.

Our goal of particle-based real-time triggering was successfully attained. This development allows (p, n) reactions on exotic nuclei to be measured with a secondary beam intensity up to 10^6 particle/sec. Furthermore, this new setup provides opportunity for reaction studies that involve emission of low-energy neutrons. The PANDORA system is capable to provide a filtered data package of energy, timing, PSD information, and digitized pulse shape, which can be used for further improvements offline.

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